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Climate Action in support of the Paris Agreement is the title of the Fifth Annual Conference of the Italian Society for Climate Sciences (SISC), that took place on October 26-27, 2017 at the CNR Conference Center in the Bologna Research Area, Italy.

The Conference aims to involve scientists, researchers and policy makers, whose activities are focused on different aspects of climate change, its impacts and related policies. The SISC Fifth Annual Conference was an important interdisciplinary platform for the presentation of new advances and research results in the fields of science and management of climate change. The Conference brings together leading scientists who are active at the frontiers of these diverse and multidisciplinary fields.

The main themes covered by this year’s Conference were:

- WATER FOR OUR ENVIRONMENT, ECONOMY AND SOCIETY - Tools and strategies to support water resources management and governance
- WATER FOR OUR ENVIRONMENT, ECONOMY AND SOCIETY - Characterizing hydrological extremes and cc impacts on water resources
- ADAPTATION AND CLIMATE SERVICES - Driving adaptive responses for risk assessment and reduction
- ADAPTATION AND CLIMATE SERVICES - Building a market: user needs, businesses models, cases study
- IMPROVING THE UNDERSTANDING OF KEY CLIMATE PROCESSES FOR REDUCING UNCERTAINTY IN CLIMATE PROJECTIONS
- CRYOSPHERE AND TIPPING POINTS
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- DECARBONISATION - Climate mitigation benefits, costs and technologies
- CONNECTING ECONOMIC AND ENVIRONMENTAL GAINS – THE CIRCULAR ECONOMY
- CLIMATE IMPACTS IN EUROPE
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ORAL SESSIONS
**Water for our environment, economy and society** - Tools and strategies to support water resources management and governance

**Chair: Antonello Pasini**

- Ciot M., Corpi Civili di Pace FOCSIV – *Ecuador, A little revolution in the Brazilian Semiarid*
- Oviedo P., The New School of Public Engagement, *The New Water War: the effects of poor management and extractive industries on water provision in La Paz, Bolivia; solutions through community-based and decentralized models*
- Standardi G., FEEM, *Economy-wide repercussions of agricultural water buyback in the Murcia region*
- Montebagnoli M.F., University of São Paulo, *Connecting National and Global Indicators: the Case of the Sustainable Development Goal on Water*
Abstract

This is happening in Brasil, in an ecosystem called Semiarid (or Caatinga, in Pati- Guaraní dialect). This ecosystem is a semi-desert area that covers 9 Brazilian States: Maranhão, Piauí, Ceará, Rio Grande do Norte, Paraíba, Pernambuco, Alagoas, Sergipe and Bahia. Usually, in this area, it rains between 200mm and 800mm annually, but in the last 10 years Semiarid citizens are living what they call “grande seca” (the huge drought). In some rural places it did not rains for several months. This drought, made more severe by climate change, create high migration rates from rural areas to the closest capital (Fortaleza, in Ceará State). Heater temperature are changing cloud paths. This phenomena has a lot of environmental, social and economic consequences in the nominated area. The first consequence is that, without water, rural communities are suffering and are becoming poorer. Water is THE resource. Without it, people cannot grow food, cannot raise farm animals. So finally they cannot sell the surplus, or even worst, what they grow is not enough for the family subsistence. Another consequence is the compulsory youth migration. A lot of youth, destroyed the opportunities of a rural life because of the lack of water, choose to move to the big city. Often this choice only made favelas becoming bigger, and increase problems like drug and alcohol abuse among youth. I worked in Crateús – CE, between September 2015 and August 2016. One of the project I worked for was called “Bioágua familiar”. A little but revolutionary project that aims to recycle rain water collected into big tanks (usually capable of 16000 liters storage or more). This water is used for cooking, and personal hygiene. But why use this water only once? This was one of the fundamental questions that gave life to the Bioágua familiar’s project. The idea it’s to build two big concrete tanks: one used as a bio-filter, the other used to collect the purified water. The second one is connected to a little engine, to irrigate fields with a drop by drop system. How does it works. Gray waters coming
from the shower and from the kitchen sink, goes into a little box where the biggest organic residues were filtered for the first time. Then the water continues its trip to the bio-filter. It gets on the filter by a punched pipe, so it falls on the first layer dropping like rain. The first layer is also the most important one because in it lives a kind of worms that eat biological leftovers. Here start the real water purification process that continues between the other layers made of sawdust, sand, little and big rocks at the bottom. When the water passes through all this layers, is ready to be used on fields and on fields only. The all system have a diary capacity of maximum 500 liters. This work began in December 2015. When finally we went back to the communities we helped, in June 2016, the panorama we faced was incredible: where before there was only a dry ground, now there are vegetables and fruits tree! It’s a little project that give hope to a lot of people. It’s the opportunity to continue the life in the Semiarid. The opportunity to keep youth people there, learning how to live with the Semiarid and not to fight against it. When I left the project, the system was built into twelve houses. When I left Brazil, in September 2016, the project won other funds for more systems to be built. So the adventure continues. This little experience could be very useful in many other regions of the World, because of the increasing average Earth temperature due to anthropic climate change.

Keywords: Water, Climate Change, Semiarid, Climate Migration, Brazil

REFERENCES

The New Water War: the effects of poor management and extractive industries on water provision in La Paz, Bolivia; solutions through community-based and decentralized models

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Abstract

“.. Bolivia’s people go thirsty, believing it is due to their failed autonomy, while their land is continuously stripped in order to fuel the same system that gives them that same failed autonomy.” - (Webber, 2016).

This paper examines the social and political repercussions of Bolivia’s worst ‘water crisis’ in one of the main urban centers: La Paz. Relevant information and data was collected through in a depth review of articles and reports. For more recent information a series of semi-structured interviews with experts working in this issue were carried out during a 5-month period. Based on this methodology the paper provides an overview of the historical background of water supply management in the country to display the political and regulatory trends that still prevail and continue to affect people’s right to water. The paper examines the factors that influenced the water crisis to depict how the population, -specifically low-income households- were affected. In contrast to approaches that center climate change and poor infrastructure as the root of the issue, the objective of this paper was to foreground the impact of extractive industries, low investments in infrastructure, and lack of institutional transparency on the accelerated rate of water resource depletion; explaining why the country’s political and economic context generates barriers to solve these issues. Drawing away from solely exploring the causes of the water crisis, the final parts of the paper provide examples of alternative models of water management currently being explored by peri-urban and urban
communities in La Paz and Cochabamba. These new models favor community-led and decentralized water treatment systems. They represent an alternative to current public and private management models as they favor democratic, transparent, and horizontal structures. Finally, the paper studies how these systems have tackled certain political and economic barriers through optimal practices.
Economy-wide repercussions of agricultural water buyback in the Murcia region

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Abstract

Ensuring hydrological regimes that are consistent with environmental objectives and climate change trends entails thorough, forward-looking reform of water allocation across economic sectors and users [1]. Yet, allocation regimes have proven hard to adjust. Binding impacting withdrawals can meet strong resistance from users, particularly in overexploited basins with inelastic supply, where the economic value of water is higher [2] [3]. Recent evidence from Australia, Spain and the US suggests that the buyback of water rights from irrigators can help unblock the transition [4] [5] [6] [7]. Water buyback is implemented through a market exchange, in which the restoration of natural assets for the society comes at the expense of compensations to agricultural water users (beneficiary pays principle). An expanding research analyzes the interaction between user-level choices and market mechanisms to limit information rents and agency costs in water purchase tenders [8] [9] [10] [11] [12]. Less is known, however, about the economy-wide implications of buyback, which include feedbacks on the output of economic sectors at a regional and even national scale.

Limited research available on the topic relies on theoretical models [13] and Computable General Equilibrium (CGE) models applied to the Australian case [14] [15]. The Australian studies use a dynamic CGE model containing water accounts to assess the economy-wide repercussions of water buyback in the Southern Murray-Darling Basin. The adjustment dynamics of the model relies on the existence of full-fledged water markets, a prerequisite that holds in Australia, Chile and the semi-arid states of Western US. Yet, in most regions and countries today, water markets do not
exist or are still in an early development stage. Buyback programmes implemented in this environment may lead to different repercussions at a regional and national scale that are yet to be explored.

Our research contributes to bridge this gap. This paper couples a bottom-up multiattribute Revealed Preference Model (RPM) with a top-down CGE model to assess the micro- and macroeconomic repercussions of water buyback programmes. RPM calibrates agents’ objective function (utility function) subject to a set of constraints, including water availability, charges and allocation rules. RPM are resolved at a farm, irrigation community or agricultural district scale (the agents). This paper uses the Intertemporal Computable Equilibrium System (ICES), a global CGE model that was recently calibrated at a regional (NUTS2) level for EU Mediterranean countries [16]. This bridges the scale gap and makes feasible the coupling between both models, which is resolved in two steps. In a first step, the water constraint is progressively strengthened in the RPM to assess agents’ responses to buyback and reveal: i) the foregone income; and ii) the compensating variation that addresses the foregone utility. In a second step, the foregone income and compensating variation obtained for every agent are aggregated at a regional level and reproduced in a macroeconomic context through two shocks in the CGE: i) a shock on agricultural production based on the foregone income; and ii) a shock on the regional income of the representative agent in Murcia resulting from the water sales—a function of the compensating variation. The economy-wide repercussions of water buyback are estimated as the difference between the Gross Value Added (GVA) of the economic sectors and regions under a given water reacquisition target and that of the baseline without water buyback.

Methods are illustrated with an application to the absolute water scarce Region of Murcia in southeastern Spain. The Region of Murcia is located in southeastern Spain, within the boundaries of the Segura River Basin. The Region of Murcia has a surface of 11,313 km², a population of 1.5 million inhabitants and a GDP per capita of EUR 19,089 [17]. Historically located along the middle stretches of the Segura River (Huerta Murciana), Murcia’s irrigated agriculture sprawled towards coastal areas from the 50s. This resulted in an increasing number of Agricultural Water Demand Units (AWDUs, the agent in the RPM model), which now total 55, and water use [18].
Results show that the economy-wide repercussions of water buyback in the agriculture for the most ambitious water reacquisition targets are relevant and can represent up to 33% production decrease in the Murcia region as compared to the income loss estimates of the microeconomic model (around 20%). This amplification effect is captured by the macro-economic model and is due to the re-allocation of capital and labor in the rest of Spain. Despite the compensations paid to farmers Murcia’s economy shows a GDP net loss and a supply contraction in the agricultural and related economic sectors. The remaining Spanish regions partially fill in the supply gap and experience a GDP net benefit through a substitution effect. Welfare effects are always negative for the overall Spain and negative even in Murcia for most scenarios except those where a high income transfer from the rest of Spain is established.

The comparison with other studies suggests that trade of water rights could play a key role in this policy and decrease the overall economic costs. Coupling the Computable General Equilibrium model with a bottom-up tool and increasing the spatial scales of the CGE appear desirable in order to get a more accurate estimate of the productivity impacts.

Even if the focus of this work is on the Murcia region the assessment can be replicated also for other European Mediterranean regions. This is important because climate change will very likely result in more frequent droughts and increased water stress in the Mediterranean environment. All this needs a demand management approach to achieve a sustainable use of water at the least economic cost.

While the results above provide a benchmark to inform the design of water purchase tenders, the performance of this policy in offsetting overallocation problems should be measured against that of existing alternatives, such as caps and charges.

**Keywords:** Mathematical programming, CGE, water buyback, water abstraction license
REFERENCES


Connecting national and global Indicators: 
the case of the Sustainable Development Goal on water

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Abstract

In September 2015 the United Nations General Assembly approved the Sustainable Development Goals (SDG) as a step towards the 2030 Agenda for Sustainable Development. This historic shift has brought along three main differences from the previous Millennium Development Goals set up in 2000: 1) Global Environmental Governance moves to a goal-setting strategy where specific targets to each goal will be available in a more coherent and transformative 2030 agenda; 2) The goals are more interlinked than ever before with seventeen goals integrating poverty, hunger, health and welfare, gender equality, energy, decent labor and full employment. In the case of environmental issues, the interdependence among them becomes a huge challenge. Water and sanitation to all depends on climate change and biodiversity, which in turn depends on oceans and the preservation of marine resources, which in turn depends on the sustainable management of forests, which in turn depends on water, etc.; 3) For the first time ever, Parts and International Organizations are not the ones to provide information in the form of metrics, indicators, indexes or any other dataset alone. Major sources of data will come from the public and private and third sectors in different parts of the world from local, subnational to national and regional levels as combating climate change, requires direct actions from non-state and substate actors. The concept of “hybrid multilateralism” is advanced as a heuristic to capture the intensified interplay between state and non-state actors in the new landscape of global climate governance [1] [2].

As indicated by Christiana Figueres, the former Executive Secretary of the United Nations Framework of Climate Change Convention (UNFCCC): “The recognition of actions by businesses, investors, cities and
regions is one of the key outcomes of COP 21.” Indeed, our world has experienced a remarkable groundswell of climate actions by non-state actors – according to the portal of Non-State Actor Zone for Climate Action (NAZCA), more than 4000 subnational governments, companies and investors have committed to set emission reduction goals, and they also form networks across national borders, coordinate and collaborate with their actions.

The Voluntary National Review on Sustainable Development Goals (VNRSDG), an official document that has been presented by Brazilian government this month (July 2017), during the High-Level Political Forum on Sustainable Development, provide some useful insights about the steps already taken by the country and the future strategies towards the internalization and localization of the 2030 Agenda. While the creation of the National Commission for the Sustainable Development Goals in October 2016 has been considered the main institutional mechanism for the implementation of the 2030 Agenda, a series of initiatives involving civil society organizations and subnational governments have already taken place. There is also a government effort to integrate the SDG targets and indicators to the targets and attributes existing in the national development strategies of the Multi-Year Plan (PPA, in Portuguese). According to the Report, 14% of SDG targets and 22% of the SDG indicators are still not convergent with the attributes of the current PPA. At the same time the Voluntary National Review on Sustainable Development Goals highlights the local governments in the provision of indicators and adaptation of the national targets with the creation of ‘local governance structures’. However, the Brazilian document mentions the data from ‘Atlas Brasil’ based on traditional concepts of GNP and GNP per capita in the context of HDI (UN). We already know it is not an adequate metric for sustainable development. Besides that, most ‘environmental-like’ SDGs as energy (7), Water (6), Climate Change (13), Oceans (14) and Forests and Loss of Biodiversity are the less convergent with attribute of the PPA. That means we will need more innovative and integrated indicators interlinking social and environmental drivers. The VNRSDG point out the necessity of engagement of the private sector but only IBGE and IPEA (Official Bodies) are mentioned as providers of data and information. IBGE is the only Brazilian body presented at United Nations Statistical Commission (UNSC) in charge of building up global indicators for the 2030 agenda.
In order to explore these inconsistencies between the Brazilian document and the Paris Agreement and the 2030 agenda we have chosen the SDG 6 on water as the case study for the ‘multilevel participatory model’ for the 2030 agenda as follows below:

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<td><strong>LEVELS</strong></td>
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<td>Local - municipality</td>
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<tr>
<td>National</td>
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We believe in the real public-private and third sector (NGOs) partnership in the provision of new, transparent and legitimate indicators for the 2030 agenda. In the last 15 years, Brazil has demonstrated expertise in some SDGs as food security and poverty eradication. But to go further in environmental issues we will need more bottom-up cooperation among different stakeholders as the Paris Agreement envisions. Water is one of the best pivotal cases studies as almost all SDGs are connected and dependent on water supply. Answering the questions above is the first step to evaluate and assess whether the ‘multilevel participatory model’ for the ‘multidisciplinary 2030 agenda’ will work properly.

**Keywords:** SDGs, water, non-state actors, data.

**REFERENCES**


Adaptation and climate services - Driving adaptive responses for risk assessment and reduction

Chair: Donatella Spano

- Mysiak J., CMCC, *Climate change adaptation and disaster risk reduction in Europe - Enhancing coherence of the knowledge base and policies*
- Aguinaldo M.E., Scuola Superiore Sant’Anna, *Risk Assessment and Climate Change Adaptation by Organizations: Determinants, Methods and Outcomes*
- Ferrise R., University of Florence, *Using Adaptation Response Surfaces and Probabilistic Projections for assessing Adaptation*
- Von Hardenberg J., ISAC-CNR, *Metrics and Indices for Data Analysis of Climate Models: C3S-MAGIC*
- Singletary L., University of Nevada, Reno, *Adapting to Earlier Snowmelt through Reservoir Reoperation*
Climate change adaptation and disaster risk reduction in Europe – Enhancing coherence of the knowledge base and policies

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Abstract

The impacts of weather- and climate-related hazards on societal sectors, human health and ecosystems are affected by socio-economic change (e.g. demographic development, land use change) and environmental change (e.g. climate change). Efforts to reduce disaster risk and at the same time adapt to a changing climate have become a global and European and national priority. Climate change adaptation (CCA) and disaster risk reduction (DRR) provide a range of complementary approaches for managing climate risks in order to build resilient and sustainable societies. Both are cross-cutting and have similarities and differences, e.g. CCA addresses mainly weather- and climate-related hazards and focuses on the future by addressing uncertainty and new risks, while DRR focuses on the present by addressing existing risks from all hazards (e.g. weather- and climate-related hazards, geophysical hazards, industrial hazards). On the other hand, CCA and DRR face similar challenges, such as incomplete and uncertain knowledge bases, involvement of multiple actors and limited financial and institutional resources. Enhancing coherence between CCA and DRR policies and practices is needed and requires creating awareness, mobilising resources, and action by public and private stakeholders, preferably in partnership.

attention to DRR and the links to CCA.

In October 2017 the European Environment Agency (EEA) publishes a report on “Climate change adaptation and disaster risk reduction in Europe - Enhancing coherence of the knowledge base and policies” [3]. This report explores how public policies and risk management practices can foster coherence, and to what extent transfer of knowledge and experience from domain-specific methods and tools can drive mutually beneficial learning and capacity building. It builds upon a review of available documents, knowledge elicitation and interaction with a large number of experts and country representatives from both policy domains. A survey sent to the EEA member countries in early 2016 and an expert workshop in April 2016 provided background information for preparing the report. The report also includes a review of past trends and future projections of ten selected weather and climate-related hazards, including their economic, social and environmental impacts. A better coherence between CCA and DRR can be fostered by development of a high-level strategic vision and local-level engagement of key actors, supported by adequate funding. The report presents six selected cases from various European countries in which effective coherence between CCA and DRR has been achieved, in various ways and to various degrees. The selection is based on criteria that define ‘good practice’: coherence is deliberately planned rather than an accidental outcome; improved coherence pays off in both policy areas; and uncertainty and multiple possible futures are explicitly accounted for in risk prevention efforts, from both short- and long-term perspectives. Six examples are explored in terms of governance, financing, policies and measures, data and knowledge, methods and tools, and monitoring and evaluation. The six cases are (1) development of a long-term planning vision in the Netherlands; (2) insurance and risk financing based on public–private partnerships in Spain, France and the United Kingdom; (3) local risk governance in Switzerland; (4) national risk assessments serving both CCA and DRR purposes; (5) city networking for improved urban resilience; and (6) financing nature-based solutions for CCA and DRR.

The report provides as well an overview of opportunities on how to better enhance the coherence between CCA and DRR in policy and practice. For example, both CCA and DDR communities use the concept of ‘resilience’ and this provides common ground upon which more coherent policies and actions might be built. At a strategic level, CCA and DRR can be better integrated through the development of long-term national programmes and could be supported by more innovative risk financing instruments. For CCA at the beginning of 2017, 26 European countries (23 EU Member States and 3 EEA member countries) have adopted a
national adaptation strategy (NAS) and 15 (13 EU Member States and 2 EEA member countries) have developed a national adaptation plan. For DRR, EU Member States (MS) have conducted national risk assessments and have established national DRR plans and national and local multi-stakeholder platforms (a forthcoming report of DG ECHO of European Commission will provide an overview of the EU MS efforts in DRR). As with CCA, the DRR communities are seeking to build actions using an ‘all-society’ engagement process informed by multiple perspectives from both public and private sectors. The target audience of the report are decision-makers in EU institutions and in EEA member countries, both at national and subnational levels, who are involved in the development and implementation of DRR and/or CCA policies. In addition the report can be useful to policy advisers and scientific/technical experts. The report is meant also as a contribution to the evaluation of the EU climate change adaptation strategy [4], being performed by the European Commission in 2017-2018.

The report has been prepared by EEA together with experts of its Topic Centre on Climate Change impacts, vulnerability and adaptation (ETC/CCA) and of its Topic Centre on Inland, Coastal and Marine waters (ETC/ICM). It received contributions from DG JRC and PLACARD H2020 project and international organizations. During the consultation process representatives from the EEA member countries and other experts provided valuable comments.

**Keywords:** adaptation, disaster risk reduction
REFERENCES


Risk assessment and climate change adaptation by organizations: determinants, methods and outcomes

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Abstract

Background – Climate change is an alarming phenomenon as it poses increasingly severe risks across environmental and socio-economic systems. The risks associated to climate change, if not properly identified and assessed, are constant threats to the production capacities and planned investments of companies, particularly those of small-scale producers. Hence, organizations adopting a systematic way to assess the extent to which climate change risks are impacting their business operations are more prepared to plan and implement appropriate adaptation measures in a timely manner.

Purpose – This paper therefore seeks to present empirical evidence on how to enable and support enterprises, particularly Small and Medium Enterprises (SMEs) located in industrial areas, in building and/or improving their resilience to climate change.

Design/methodology/approach – Within the Life IRIS project (Improve Resilience of Industry Sector), a risk assessment methodology has been designed, implemented and tested, with business clusters or groups of companies in same industrial areas, as case in point. In aid of reviewing the suitability and efficacy of the application of the risk assessment methodology, a semi-structured interview was the chosen method to complement the data collection. This, in turn, brings about insights to better communicate the issues and challenges of the application and efficacy of the risk assessment methodology at industrial areas.

Findings – The existing literature deals with corporate responses to climate change as well as the motivating factors affecting organizations’ decision to engage in adaptation behaviors and actions, with emphasis however remaining on firm-level empirical analyses. Research and insights are likewise lacking on how collective action among organizations can be
organized and enabled in managing the impacts of climate change through the proper identification and assessment of risks. In conclusion, the success of the application of the risk assessment methodology can be known and revealed with the consideration of several indicators, such as risk management plans prepared and implemented, adaptation strategies vis-à-vis occurrences of extreme weather or climate events, and stakeholder analysis to assess stakeholder engagement.

**Originality/value** – This paper offers a structured and innovative approach on how a risk assessment methodology on climate change risks can be implemented by business clusters in industrial areas.

**Keywords**: climate change adaptation, climate risks, risk assessment, cluster approach, industrial areas

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Risk Analysis, No. 30(6), pp. 881-886.


Abstract
Projected climate change may threaten future food and nutrition security due to the likely negative effect they may have on agricultural crop production. To alleviate the harmful effects of a global warming, suitable adaptation options must be identified. To this, crop models coupled with climate models represent a useful tool for assessing the impact of climate change and identify possible adaptation strategies to cope with. However, these kind of studies are usually affected by multiple sources of uncertainty related to both crop and climate and how they are modelled. This, in turn, may increase the complexity of addressing adaptations and evaluating risks at regional level, especially for rainfed cropping systems, for which even small discrepancies in precipitation projections can result in different impacts and therefore adaptation recommendations [1].
Decision makers need probability estimates to assess the seriousness of the implied impacts [2]. Accordingly, approaches are required for effectively quantifying climate impacts and the effect of adaptation options, managing inherent uncertainties and communicating the results.

In this study, a probabilistic framework developed within the MACSUR and MACSUR2 projects was applied for evaluating the effect of some adaptation strategies for winter wheat in northern Spain under two future time periods. The framework is based on coupling adaptation response surfaces (ARSs) and probabilistic projections (PP) of climate change to estimate the intensity and the probability of a selected adaptation option. As an extension of the impact response surfaces concept developed in [3], ARSs are bi-dimensional surfaces in which the effect of an adaptation option (e.g. changes in crop yield compared to the standard management) is plotted against two explanatory variables (e.g. changes in temperature and precipitation). The likelihood of the effect of adaptations was estimated using PP of climate change. These are joint probabilities of changes in the same explanatory variables used for calculating the ARSs. Therefore, ARSs were constructed and climate PP superimposed. This permit to estimate the distribution of the effect of the adaptation options and compute the probability of exceeding specific thresholds.

An ensemble of 17 models was used for creating ARSs for wheat crop under changed precipitation (P), temperature (T) and CO2 air concentrations. The models were calibrated using observed phenological, above ground biomass and yield data and were applied to simulate crop performance under standard management and 35 different combinations of adaptation options. The standard management was defined as rainfed winter wheat with medium crop cycle sown on 29 October. The adaptation strategies tested were from the combination of the following single options: 1) removing vernalization requirements, 2) changing the duration of phenological phases (from -10% to +10%, 3) considering a moderate advance of the sowing date by -15 days as well as a delay of the sowing by 30 days, and 4) application of 40 mm of supplemental irrigation at flowering. All the simulations were performed under non-nutrient limiting conditions.

The likelihood of having a positive response of the adaptations (i.e. increase in yield with respect to the standard management) was estimated. Further, the magnitude and the likelihood of having a positive recovery response (defined as the ability of an adaptation option to maintain yield at the same level as with standard management under present
climate conditions) was calculated. Results indicated that a wide scope for adaptation exists when considering combined options. The most promising adaptation strategies were based on a combination of spring wheat, longer growing cycle, advanced sowing date and supplementary irrigation. This provided a virtually certain (likelihood >99%) positive adaptation response (i.e. increase in yield compared to the standard management), with a median yield increase up to 37%. Other feasible strategies were also found for winter wheat with supplementary irrigation (extremely likely positive response, i.e. >95%; median of adaptation response up to 22%) and for spring wheat under rainfed conditions (extremely likely positive response; median up to 20%).

**Keywords:** Wheat, Mediterranean Basin, Adaptation options, Probabilistic projections, Ensemble of models.

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Metrics and indices for data analysis of climate models: C3S-MAGIC

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Abstract

In order to facilitate the use of climate model projection data for studies and applications in a wide range of sectors, it is crucial to provide tools to allow easy access to model data and to provide tools for the evaluation of the performance of the models compared to available measurements and observations. To this end a wide range of software solutions to access, visualize and manipulate the large data sets that are produced by climate models and which will be stored in the Copernicus Climate Data Store are being developed in the framework of Copernicus Climate Change, in particular by the C3S-Magic consortium. The software which is being developed contains modules to calculate standardized metrics and indices for each model to assess model performance for specific applications and quantifying the ability of climate models to represent the observed mean state and variability. In particular the project is using the ESMValTool diagnostic package as the main instrument to provide access to different metrics and diagnostics in a coherent and unified framework. The suite of tools developed by the authors includes also extratropical atmospheric large scale circulation indicators, which can be directly associated with more/less persistent weather conditions in different regions such as for example (mono and bi-dimensional) blocking indices and a computationally efficient metric for estimating the stratosphere-troposphere coupling and to identify patterns that are the most connected with stratospheric variability. Metrics and indices to assess extreme events, such as precipitation extremes and droughts, are being included, together with indices of the intensity of the hydrological cycle. A method for the selection of a sub-ensemble of models and members for present
climate and future scenarios according to user-needs is being developed, based on k-means clustering technique. On top of the selected members, the tool provides information about the statistics of the classification/clustering method: spread of the members in a group, distance between the groups, the frequency of occurrence of each group, to which group pertain each member. Examples of ensemble member selection over the EuroCORDEX region based on quantile of precipitation and surface temperature will be presented.

The project is also developing tailored solutions to assure that specific needs of envisaged end users in selected economic sectors (energy, insurance, water/hydrology and coastal areas) are addressed. In addition to presenting some of the tools that are being developed we will discuss examples of their application and present in particular some results related to precipitation extremes and North-Atlantic blocking.

**Keywords:** climate projections, metrics, indices, timeseries
Adapting to earlier snowmelt through reservoir reoperation

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Abstract

The Truckee River supplies water to the high desert communities of northwestern Nevada, USA through spring snowmelt originating as winter snowpack in the Sierra Nevada. Springtime snowmelt affects the timing and magnitude of runoff [1-2] and influences the release of upstream reservoir flows that are operated for flood control and water supply for municipalities, irrigated agriculture, and environmental habitat [3-4]. Climate-induced changes to mountain snowpack present challenges to water management [5] - especially practices historically designed and operated under an assumption of stationarity [6]. A collaborative research design is necessary to identify and examine potential adaptation strategies that address the diverse and competing water uses in the Truckee River Basin (7,925 square-kilometers), one of the most highly regulated basins in the USA [7-9]. Harnessing local stakeholder knowledge and perspectives and then using that information to simulate plausible hydrologic and operational change to the river not only demonstrates stakeholder participation in modeling but produces information critical to effective climate adaptation [10].

Consecutive years of warmer temperatures and drought recently observed (water years 2012-2016) in the region facilitate efforts to examine local water supply challenges [9]. A survey of 66 local water managers administered in 2015 reveals that 89% are concerned with climate change impacts. Eighty-three percent report that warming temperatures observed in the region impact their daily operations. Water
Managers note that a future ‘warmer’ climate would require water supply enhancement and innovative adaptation strategies. Thus, we simulate reservoir reoperation, by altering the rules that control storage and release, as an adaptation strategy that researchers and local managers collaboratively identify as feasible. Specifically, we simulate the effects of storing snowmelt in reservoirs earlier in the year as compared with historical management practices affixed to specific calendar dates.

The goal of this presentation is two-fold. First, we describe how primary data collected from local water managers identify a key adaptation strategy to be simulated using a suite of hydrologic and operations models. Second, we report the simulation results, highlighting the hydrologic and operational benefits and consequences at the basin scale. Our findings suggest that under a warmer climate and earlier runoff, operating the Truckee River upstream reservoirs ‘as is’ leads to storing less water in reservoirs. The peak streamflow timing change to 45 days earlier (March 17 versus May 2) causes Prosser Creek reservoir, for example, to fill only to 46% of capacity (13,800 acre-feet) versus the historical average of 76% of capacity (22,500 acre-feet). Reservoir reoperation scenarios simulated under a warmer climate scenario absorb this shift in snowmelt timing by increasing average storage to 64-76% of capacity (19,200-22,500 acre-feet). Allowing storage in the headwaters earlier in the year as opposed to current operations enhances water supply in the basin while also improving the flow regime distribution for fish at the river’s terminus. Local water managers validated these results in a workshop setting.

Our findings suggest that the utility of these hydrologic and operations models is greatly enhanced when adaptation strategies are identified through collaborative research that embeds stakeholder knowledge into model simulations. Ultimately, the collaborative modeling research design and results presented should be useful to others investigating adaptation in response to climate-induced water supply variability under existing water management institutions.

**Keywords:** reservoir reoperation, snowmelt, adaptation, drought, collaborative modeling
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Improving the understanding of key climate processes for reducing uncertainty in climate projections

Chair: Barbara Stenni

• Facchini M.C., CNR-ISAC, Air quality and climate: two sides of the same coin
• Davini P., CNR-ISAC / LMD-ENS, Coherent Structures in Stratocumulus Topped Boundary Layer: Towards a New Parametrization of Stratocumulus Convection in Global Climate Models
• Cagnazzo C., CNR-ISAC, Stratosphere---resolving CMIP5 models simulate different changes in the Southern Hemisphere
• Mercogliano P., CMCC, High-resolution COSMO-CLM climate projections over Israel
Air quality and climate: two sides of the same coin

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Abstract

Anthropogenic activities are responsible for the emission of gaseous and particulate pollutants that modify atmospheric composition. Such changes are, in turn, responsible for the degradation of air quality at the regional/local scale as well as for climate change. Air pollution and climate change are therefore two intimately connected environmental issues. However, these two environmental challenges are still viewed as separate issues, which are dealt with by different science communities and within different policy frameworks. Indeed, many mitigation options offer the possibility to both improve air quality and mitigate climate change but, at the same time, mitigation options that may provide benefits to one aspect, are worsening the situation in the other. Therefore, coordinated actions taking into account the air quality-climate linkages are required, and these actions need to be based on strong scientific grounds.

Keywords: climate change, air quality
The role of forcings in the 20th century
North Atlantic multi-decadal variability:
the 1940-1975 North Atlantic cooling case study

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Abstract

Results from a study inspecting the origins of multi-decadal variability in the North Atlantic sea-surface temperature (NASST), are presented. We target in particular the 1940-1975 “warm-to-cold” transition, an event that is generally framed in the context of the longer-term Atlantic Multi-decadal Variability (AMV) cycle, in turn associated with the Atlantic Meridional Overturning Circulation (AMOC) internal variability. Here we examine the ability of uninitialized, historical integrations from the 5th Coupled Model Inter-comparison Project (CMIP5) archive to retrospectively reproduce this specific episode of the 20th century climatic history, under a hierarchy of forcing conditions. For this purpose, both standard and so-called “historical Misc” CMIP5 simulations of the historical climate (combining selected natural and anthropogenic forcings) are exploited. Based on this multi-model analysis we find evidence for a significant influence of anthropogenic agents on multi-decadal sea surface temperature (SST) fluctuations across the Atlantic sector, and suggest that anthropogenic aerosols and greenhouse gases might have played a key role in the 1940-1975 North Atlantic cooling. However, the diagnosed forced response in CMIP5 models appears to be affected by a large uncertainty, with only a limited sub-set of models displaying significant skill in reproducing the mid-20th century NASST cooling. Such uncertainty originates from the existence of well-defined behavioral clusters within the analyzed CMIP5 ensembles, with the bulk of the models splitting into two main clusters. Such a strong polarization calls for some caution when using multi-model ensemble mean in climate model analyses, as averaging across fairly distinct model populations may result, through mutual cancellation, in a rather artificial description of the actual multi-model ensemble behavior. A potentially important role for both anthropogenic aerosols and greenhouse gases on the
observed North Atlantic multi-decadal variability has clear implications for decadal predictability and predictions. The uncertainty associated with alternative aerosol and greenhouse gas emission scenarios should be duly accounted for, in designing a common protocol for coordinated decadal forecast experiments.

**Keywords:** Atlantic Multi-decadal Variability, Anthropogenic Aerosols, Model uncertainty, Climate predictability, Decadal prediction
Coherent structures in stratocumulus topped boundary layer: towards a new parametrization of stratocumulus convection in Global Climate Models

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Abstract

The representation of stratocumulus clouds in Global Climate Models is still one of the main concerns for the climate modelling community [1,2]. This is mainly due to the limitations of current convective parametrizations, which are often unable to simulate the full set of phenomena that governs the Stratocumulus Topped Boundary Layer (STBL) [3,4]. Most of these parametrizations relies on the Eddy Diffusivity/Mass Flux (EDMF) approach, where an eddy-diffusion scheme is used in combination with a non-local mass-flux component aimed at characterizing an ensemble of updrafts [5,6]. However, EDMF schemes are based on the assumption that only a small areal fraction is covered by the updrafts and they do not include an explicit term to account for boundary layer entrainment: two assumptions clearly not true in the STBL [3].

Here we show that the main convective coherent structures, namely updrafts, downdrafts and entrainment, are equally important to describe the STBL dynamics. Furthermore, the sensitivity of each convective structure to different external large scale forcing can be considerably different, making EDMF approach ineffective in many instances.

This is done with a novel approach – based on a series of high-resolution large eddy simulations (LES) in a typical non-precipitating marine nighttime STBL, the Dycoms-II RF01 case study [7] – for which we are able to detect and track coherent structures in the STBL. We make use of a new classification method based on octant analysis - using vertical velocity
Coherent structures in stratocumulus topped boundary layer: towards a new parametrization of stratocumulus convection in Global Climate Models

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Abstract
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Here we show that the main convective coherent structures, namely updrafts, downdrafts and entrainment, are equally important to describe the STBL dynamics. Furthermore, the sensitivity of each convective structure to different external large scale forcing can be considerably different, making EDMF approach ineffective in many instances. This is done with a novel approach – based on a series of high-resolution large eddy simulations (LES) in a typical non-precipitating marine nighttime STBL, the Dycoms -II RF01 case study [7] – for which we are able to detect and track coherent structures in the STBL. We make use of a new classification method based on octant analysis - using vertical velocity and two passive scalars – which defines the structures also in cloud-free regions [8]. We are thus able to quantify the geometrical and thermodynamic characteristics (e.g. areal fraction, temperature, liquid and total water mixing ratio, buoyancy, etc.) of those structures, highlighting the single contributions to the turbulent transport of mass, heat and moisture. It is thus possible to estimate the sensitivity of the turbulent fluxes to the intensity of the cloud-top radiative or evaporative cooling, to the surface latent and sensible fluxes or the strength of the wind shear, comparing them to EDMF schemes.

This analysis lays thus the foundation for a new parametrization of stratocumulus- topped boundary layer for global climate models which accounts also for downdrafts and entrainment.

Keywords: stratocumulus clouds, STBL, Global Climate Models, coherent structures
REFERENCES


Stratosphere-resolving CMIP5 models simulate different changes in the Southern Hemisphere

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Abstract
This work documents long-term changes in the Southern Hemisphere circulation in the austral spring-summer season in the Coupled Intercomparison Project Phase 5 (CMIP5) models, showing that those changes are larger in magnitude and closer to ERA-Interim and other reanalysis if models include a dynamical representation of the stratosphere. Specifically, models with a high-top and included dynamical and in some cases chemical feedbacks within the stratosphere better simulate the lower stratospheric cooling observed since 1979 to 2001 and strongly driven by ozone depletion, when compared to the other models. This occurs because high-top models can fully capture the stratospheric large scale circulation response to the ozone-induced cooling. Interestingly, this difference is also found at the surface for the Southern Annular Mode (SAM) changes, even though all model categories tend to underestimate SAM trends over those decades. In this analysis, models including a proper dynamical stratosphere are more sensitive to lower stratospheric cooling in their tropospheric circulation response. After a brief discussion of two RCP scenarios, our study confirms that at least for large changes in the extratropical regions, stratospheric changes induced by external forcing have to be properly simulated, as they are important drivers of tropospheric climate variations.
High-resolution COSMO-CLM climate projections over Israel

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Abstract

Israel is found in an area characterized by transition from the Mediterranean climate in the north, to extreme desert climate conditions in the south. The climate conditions here are characterized by moderate air temperatures, changeable rainy weather during the cooler winter season and dry and stable hot weather during the summer. Most of the annual precipitation takes place during a limited number of rainy days typically associated with the formation of mesoscale synoptic systems occasionally associated with extreme weather events.

Topographical and coastal characteristics (with windward effects, gap winds, land- sea breezes, etc.) also affect the spatial distribution of climate characteristics in the region. Significant parts of the area of Israel are densely populated and are characterized by highly technologically developed advanced society quite vulnerable to the climate and its changes. These climatological aspects present the widely recognized need for accurate high-resolution climate projections for the 21\textsuperscript{st} century in a region already suffering from political unrest partly related to water availability.

In a previous work [1], two simulations were performed over the CORDEX-MENA domain at a spatial resolution of 0.44° (MNA44) and 0.22° (MNA22), driven by ERA-Interim reanalysis for 1979-2011. Then, simulations at the same spatial resolutions [2] were performed under Representative Concentration Pathways 4.5 (RCP4.5) scenario for the 21\textsuperscript{st} century, driven by
the Global Circulation Model (GCM) CMCC-CM participating in the Coupled Model Intercomparison Project Phase 5 (CMIP5) [6]. Successively, an evaluation of CMCC-CM runs was performed over the Middle East and Israel [5] and a very high resolution simulation over Israel (domain 28.01E – 39.45E, 24.01N - 35.45N) at 0.0715° (about 8 km) nested into MNA22 (driven by ERA-Interim) has been carried out (1979-2011) and evaluated in [3]. The model configuration was optimized by means of a sensitivity analysis over the period 1979-1984. It includes the parameterization of albedo derived from MODIS data [4] and the NASA-GISS AOD distribution [7]. Model results were evaluated against a combination of available ground observations and gridded datasets. It was shown that increased spatial resolution, from 50km to 8km, improves the simulation of precipitation and temperature, due to better representation of topography and the location of land and sea in the model. The considered variables are generally in good agreement with observations, confirming that the albedo and aerosol parameterizations adopted lead to a remarkable improvement in model performances. Furthermore, the results displayed substantial improvement from earlier RCM studies in the region.

The main aim of the current work is to provide a detailed picture of future climate conditions expected over Israel, as projected by COSMO-CLM under RCP4.5 scenario. The high-resolution simulation was performed at 0.0715° resolution considering a domain with 161 x 161 grid points encompassing the Israeli territory, nested into MNA22 driven by CMCC-CM, covering the period 1980-2070. Model response has been analyzed in terms of 2-meter temperature and precipitation. A preliminary analysis executed considering the average value over the whole domain shows a warming trend of about 0.03°C per year, leading to an increase of about 2.8°C from 1980 to 2070. Concerning precipitation, while the average value simulated by the model over 1980-2010 is about 216 mm/year, projections averaged over the whole area highlight a decreasing trend of about -0.08% per year. Detailed analyses, performed over subdomains, will be discussed.

A comparison with climate projections provided by a different COSMO-CLM run over MENA domain at 0.44° (employing another physical set-up) is also performed. The consistency of these projections with literature data has been verified and discussed.

The CMIP5 models tend to agree that in the 21st century the eastern Mediterranean is expected to experience decreases in precipitation and increases in 2m temperature [5]. It should be noted that these projections, thanks to their features, could be used as input data
for impact models, for example to evaluate effects of climate change on several hydrogeological hazards (e.g., floods, droughts, and landslides).

**Keywords:** Climate projections, Israel, High resolution.

**REFERENCES**


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Keywords: Climate projections, Israel, High resolution.

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Water for our environment, economy and society - Characterizing hydrological extremes and CC impacts on water resources

Chair: Silvio Gualdi

- Torresan S., CMCC, A multi-hazard Bayesian Network approach for the assessment of climate change and anthropic impacts on water quality
- Santini M., CMCC, Hydrological drought indices as support to water management under climate change: the case of Ofanto river (Italy)
- Pohll G., Desert Research Institute, Assessing the Impacts of Climate Change on a Groundwater System in a Snow-Dominated Watershed
- Garner C., Desert Research Institute, Assessing the Impacts of Climate Change on a Highly Managed Terminal Lake Basin
A multi-hazard Bayesian Network approach for the assessment of climate change and anthropic impacts on water quality

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Abstract

Climate change and land use represent two of the main threats to water quality and availability, but very few studies have considered the impact of these factors together \cite{1}-\cite{2}. Risk assessment procedures, in fact, typically analyse stressors in isolation neglecting cumulative or cascading effects. Understanding the relative role played by each of these pressures and predicting their combined impacts is necessary to support the implementation of efficient and well targeted adaptation strategies in synergies with sectorial policies and legislations (i.e. 2000/60/UE Directive).

A key research challenge is, therefore, the adoption of a multi-risk perspective enabling to account and model in a harmonic way multiple drivers’ interactions and assessment endpoints. The paper discusses the development of a multi-risk model, implementing Bayesian Network analysis, to determine the probability of water quality alterations over future scenarios and support the identification of appropriate management strategies.

Specifically, Bayesian Networks are used as a meta-modelling tool for structuring and combining the information coming from existing hydrological model’s simulations, climate change and land use scenarios, historical observations and expert opinion. The network has been applied in the Dese-Zero river estuary, one of the main tributaries of the Venice Lagoon in Northern Italy, to characterize the interlacing between climate (i.e. drought, extreme events) and land use changes (i.e. crop patterns, urbanization) and assess their cascading impacts.
on water quality parameters (i.e. nutrients loadings and concentrations). The Bayesian Network, after being validated with historical observations and comparable results from model simulations (i.e. SWAT), has been used to perform scenario analysis exploring trade-offs between different water and fertilizer management strategies and identifying optimal solutions for adaptation of water systems under changing conditions. Some results, including the application of the model at the case study level and examples of preliminary outcomes, will be here presented and discussed.

**Keywords**: multi-hazard, climate change impacts, water quality, land use, Bayesian Networks.

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Hydrological drought indices as support to water management under climate change: the case of Ofanto river (Italy)

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Abstract

Consensus that the Mediterranean Basin is a climate change hotspot was reached in several studies that used different models to project the future climate for the region [1]. Although the still large uncertainty for precipitation, in the published literature there are indications for a future decrease of annual rainfall amount and increase of inter-annual variability in terms of intensity and frequency of hydro-meteorological opposite extremes (excess and lack of rain, leading to floods and droughts, respectively) [2]. Puglia region, located in the southeastern part of Italy, reflects these climatic settings, being highly affected by arid conditions and water scarcity, and with expected worsening conditions under climate change [3]. The northern area of Puglia is extensively devoted to agricultural production, making its plains the second productive area of Italy, with strong application of irrigation. Water in Puglia is in fact mainly used for irrigation (54%), domestic supply (36%), and the remaining for energy and industrial purposes; all these sectors compete strongly internally for the resource especially during the touristic season in summer. In addition, Puglia is highly dependent on the neighboring regions (Molise, Campania, Basilicata) for 50% of its water resources (75% if considering only the domestic use) [4]. However, also the surrounding regions revealed to have vulnerable water resources, as in the case of springs in Campania region providing water to the Aqueduct in Puglia [5]. For this reason, one of the major vulnerability of Puglia under climate change
regards the availability of water and the sustainability of its use in the future. Among the main sources of water, the Ofanto river covers 75% of the internal supply for irrigation Consortia, through three main schemes: two reservoirs (Marana Capacciotti and Locone) and one diversion dam (Traversa Santa Venere) [6].

In the context of OrientGate project (http://www.orientgateproject.org), hydrological studies in view of climate change have been initiated for Ofanto river based on a semi-distributed model [6]. The climate simulated by regional model COSMO-CLM at high resolution (≈8 km) [7], under two IPCC scenarios of radiative forcing (intermediate and high), was used for projections of the hydrological cycle in the catchment up to 2070. Simulated data have been used after adopting scientifically sound procedures for model calibration and evaluation under the historical period, thanks to the long series of discharge data available for the most downstream station at San Samuele di Cafiero. As recommended for hydrological impact studies, daily data have been bias corrected for the two main variables affecting the water cycle, i.e. precipitation and temperature, relying on existing methods [8].

Besides analyzing changes in the annual discharge amount, monthly time series of streamflow have been synthetized into two well assessed indices useful to quantify several attributes of hydrological drought episodes, i.e. frequency, magnitude, timing and duration. The first is the Streamflow Drought Index (SDI) [9], expressing the frequency of occurrence for different classes of drought, from mild to moderate, severe, extreme, and considering different duration periods (3, 6, 9, 12 months) and starting months, so to capture likely re-phasing of the seasonal cycle in the future. The second indicator is the area under the storage yield curve, based on the Sequent Peak Algorithm (SPA) [10], which allows to calculate, given the known storage capacity of existing reservoirs, likely changes in the reliability of water yield under modified climate variability according to cumulated deficit periods, in terms of difference between water demand and inflow to the reservoir. Results show how climate change could led to new conditions that will pose serious risks to the reliability of water yield for Puglia region. This could help in finding alternative solutions when planning operation of the reservoirs to store more water towards a modified drought regime, or when diversification of sources is an option.

**Keywords**: Climate change, hydrological model, drought, reservoir, Ofanto
regards the availability of water and the sustainability of its use in the future. Among the main sources of water, the Ofanto river covers 75% of the internal supply for irrigation Consortia, through three main schemes: two reservoirs (Marana Capacciotti and Locone) and one diversion dam (Traversa Santa Venere) [6].

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Keywords: Climate change, hydrological model, drought, reservoir, Ofanto

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Assessing the impacts of climate change on a groundwater system in a snow-dominated watershed

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Abstract

The study of potential effects of climate change to groundwater systems have lagged behind research on surface waters. The IPCC [1] stated that a lack of necessary data has made it impossible to determine the magnitude and direction of groundwater change due solely to climate change [2]. IPCC projections show significant temperature increases and alterations in the frequency and amount of precipitation. These changes will ultimately affect the hydrologic cycle, altering surface water and groundwater recharge to aquifers [3].

Although there are large uncertainties in the alterations to the amount of precipitation due to climate change, many studies suggest that mountain system recharge is expected to decline across much of the region due to decreased snowpack [4]. Factors contributing the greatest uncertainty in the estimates include: (1) limited studies quantitatively coupling climate projections to recharge estimation methods using detailed, process-based numerical models; (2) a generally poor understanding of hydrologic flowpaths and processes in mountain systems; (3) difficulty predicting the response of focused recharge to potential changes in the frequency and intensity of extreme precipitation events; and (4) unconstrained feedbacks between climate, irrigation practices, and recharge in highly developed aquifer systems [4].

This study investigates the impacts of climate change on a groundwater system in a snow-dominated watershed in Lake Tahoe, California. The analysis relies on a fully-coupled surface and groundwater model to simulate the complex feedbacks between temperature, precipitation, evapotranspiration, and groundwater recharge.
Rather than simulating climate forcings from hundreds of global climate model (GCM) results we focus on a subset that are representative for California [5]. In addition, the climate scenarios are further explored to capture the full variability in both temperature and precipitation. Specifically, we group the climate responses to create five climate scenarios named Q1 to Q5. The climate scenarios represent a range of likely outcomes, Q1 – Drier with less warming; Q2 – Drier with more warming; Q3 – Wetter with more warming; Q4 – Wetter with less warming; and Q5 – Warming only with no change in future precipitation. A sixth scenario was developed which represents a plausible drought condition based on historical precipitation, but with increased warming.

The climate scenarios are then simulated with the coupled hydrologic model to investigate changes in groundwater recharge and groundwater levels. This information is being used by water managers to effectively plan for future changes in groundwater supplies.

**Keywords:** groundwater, climate change, water resources, recharge

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Assessing the impacts of climate change on a highly managed terminal Lake Basin

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Abstract

Climate change is considered to be one of the most severe threats to ecosystems around the globe [1]. Terminal lakes can be especially sensitive to climate variations [2] and make up about 50 percent of the world’s lakes. As demands on water supply increase, the long-term health and viability of these lakes may be threatened.

This research investigates the impact of climate change on Walker Lake, a terminal lake located in west-central Nevada, USA. Over the past century, natural flows along the Walker River, which drains into Walker Lake, were diverted to support hay, pasture, and other irrigated crops. As a result, lake levels have declined nearly 150 feet and dissolved solids have been concentrated to the point that the native Lahontan cutthroat trout can no longer survive. Recent conservation efforts have provided resources to purchase agricultural water rights to benefit Walker Lake. Changes in future climate could play an important role in the program’s effort to return lake levels to pre-development conditions.

The objective of this research is to assess the impact of climate change on future lake levels and associated salinity. An integrated hydrologic modeling framework [3] is used to simulate the hydrologic processes within the basin including partitioning of precipitation into frozen and liquid components, snowpack accumulation and melting, soil water storage, evapotranspiration, runoff, reservoir storage operations, agricultural diversions and demands, stream gains and losses, groundwater pumping, and lake evaporation.
Two climate scenarios were simulated to assess the impact of a warming climate on Walker Lake. The first scenario is a baseline simulation that establishes historical conditions over the period 1971 - 2000. The second scenario was developed to represent precipitation and temperature changes from 2031 - 2060 climate projections. A simple delta change method was used to estimate monthly changes in precipitation and temperature for the entire watershed. The historical precipitation and temperature data is from the 800-meter horizontal resolution PRISM dataset [4] and the future climate predictions are from the NCAR Community Climate System Model Version 4 (CCSM4) – IPCC Scenario 20C3M + RCP 8.5. The CCSM4 climate model was chosen because it accurately simulates climate conditions in the Walker Basin. The RCP 8.5 is a high emissions scenario that is consistent with a future of no policy changes to reduce emissions. It was developed by the International Institute for Applied System Analysis in Austria [5] and is characterized by increasing greenhouse gas emissions that lead to high greenhouse gas concentrations over time.

Results from the scenarios show the relative sensitivity of lake levels to increased lake evaporation and earlier runoff. Increased temperatures produce more lake evaporation which leads to declines in lake levels. Earlier runoff limits the effectiveness of upstream storage for agricultural diversions, thereby increasing natural flows to Walker Lake.

**Keywords:** terminal lakes, climate change, agriculture

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Adaptation and climate services - Building a market: user needs, businesses models, cases study

Chair: Sergio Castellari

• Tart Maurice S., LGI Consulting, *What european climate service users really want: A characterisation of their needs*
• Larosa S., CMCC, *Towards an efficient market for Climate Services: the role of business models*
• Kielmanowicz D., LGI Consulting, *MARCO Project: Case study on climate services in the Water and sanitation sector in Catalonia*
• Marletto V., ARPAE, *Climate services for irrigated agriculture: structure and results from the MOSES DSS*
What european climate service users really want: A characterisation of their needs

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Abstract

Climate services are an integral part of many adaptation plans, for both the public and private sectors alike. The global market for climate services is estimated to have grown at a steady pace between 6% - 8% each year since 2010/11 [1], and it is expected to grow around 9% in the near future [2]. Even with this strong growth, however, the market is failing to reach its full potential. Despite 90% of companies reportedly being impacted by climate-related events within the past three years, only 30% have responded to those threats [3].

Who makes up this 30%, and why are the other 70% not doing anything? Currently, market gaps exist between the users and suppliers of climate services, as the information that gets provided often does not match the users’ needs [4]. These gaps pose a critical challenge to the expansion of the climate services market in Europe, not to mention impede the creation of both jobs and wealth for the European economy [5]. Bridging these gaps will require a more thorough understanding of the demands of climate service users. As such, the EU-funded Horizon 2020 project MARCO (MArket Research for a Climate Services Observatory) aims to provide a 360-degree view of the climate services market, giving special attention to the users.

This paper will present both primary and secondary research conducted for the MARCO project regarding the demand for climate services across 24 different economic sectors. These sectors include those that are more traditional users of climate services, such as the mining, tourism and agriculture sectors; they also include sectors that exhibit a high potential to gain by employing climate services, yet
that have been less explored in recent climate service studies, such as the pharmaceutical and food and drink sectors.

Research methods for the paper focused on climate service users throughout the entire value chain, attempting to grasp in more detail where the market is headed. Data was collected via an online survey targeting both users and potential users of climate services around the world. The survey was accompanied by face-to-face interviews with high-level sustainability managers of private companies, industry analysts and R&D scientists, among others.

Results indicate that many climate service users have a greater need for either past climate data or data analysis for the next year, meaning they are less interested in long-term data with higher uncertainties. While their sources of data vary, many users note that they often rely on general providers of climate services, such as a national meteorological office. Furthermore, they tend to search for products and tools across multiple economic sectors, rather than just one.

In brief, the research has unveiled a more thorough understanding of how climate services are being applied across Europe’s economy. By exploring the decision-making processes that trigger a shift to the consumption of climate services, the research has broken down how users perceive the benefits of climate services, what the shortcomings and barriers are, and where opportunities for improvement lie.

**Keywords:** climate services, market, demand, gap
REFERENCES


Towards an efficient market for Climate Services: the role of business models

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Abstract

Climate services are means to support mitigation and adaptation to climate change and to boost a science-based and climate-informed policy environment. A well-functioning market is crucial to support further widespread uptake of climate services and represents a useful instrument to support international agreements. The diffusion of these innovations is highly dependent on the business model used, meant as the set of firms’ strategic choices to create, capture and share value within a certain network. Business model innovation, rather than product innovation itself, has been proved to be able to counter serious bottlenecks with the development and diffusion of sustainable technologies. Finally, business models may work as market devices and serve as signals within a certain environment. Despite their value, up to date only few studies have tackled this issue within the context of climate services. The aim of this paper is to shed a light on the role of business models in driving the market and to detect if an actual optimal business model exists. We collected qualitative information through semi-structured interviews with key stakeholders and we analysed data using thematic codes. The process was conducted on three sub-samples separately: publicly-funded projects, private companies and co-production partnerships. The analysis identified the critical issues, the main gaps and the most pressing limitations to an efficient market development for climate services. Results prove that the collaboration between public and private actors is able to boost innovation and to overcome technologic, economic and social barriers. Co-production partnerships are able to achieve this goal. Inputs from this work were collected in the context of EU-MACS (European Market for Climate Services), a Horizon2020 project.
aimed at studying the state of the art of potential opportunities of the existing market for Climate Services.

**Keywords:** climate services, business models, innovation

**REFERENCES**

Number all bibliographical references in the manuscript in brackets [ ] and list them in this section in 12-point Arial font. For example:


MARCO Project: case study on climate services in the water and sanitation sector in Catalonia

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Abstract

Climate-related tools, products, data and services may greatly contribute to climate change mitigation and adaptation by providing the necessary information for choosing the best action plan. However, current strategies face knowledge gaps, lack of visibility of climate services, and low awareness of the economic benefits associated to them. This reality triggers the need and potential for developing a global market for climate services.

Within this context, the ‘MARket Research for a Climate services Observatory’ (MARCO), an EU-funded Horizon 2020 collaborative project, aims to assess the climate services market in Europe, to forecast market growth and future trends, and to understand climate services user needs. To analyze in more details the demand and supply of climate services in Europe, MARCO will carry out nine case studies, including a case study on the use of climate services in the water and sanitation sector in Catalonia, Spain. This session highlights the findings of Catalonia’s case study, while making use of MARCO’s project discoveries to illustrate the overall reality of the climate service market in Europe.

As Southern Europe is facing ever more intense climatic events such as hydric stress and flooding from heavy storms [1], it is crucial to assess how the climate services market can support the long-term resilience of water and sanitation operators. In Catalonia, climate change impacts are increasingly the subject of special attention for various key sectors (agriculture, tourism, and health, among others) [2].

Within this context, the potential of climate services to support both operations and investment in the water and sanitation sector of Catalunya have been assessed. As
illustration, the use of climate data to manage climate risks associated with water supply and wastewater facilities was explored.

Both qualitative and quantitative research was conducted on the existing and future climate services demand in Catalonia. This research included semi-structured interviews with key stakeholders from the water and sanitation value chain, such as the Catalan Water Partnership, the Catalan Office for Climate Change, and others. Interviewees were also asked to participate in an exercise that helped to identify how climate services are being applied in the sector.

The study focuses on the demand-side requirements of the sector, but supply-side aspects were also investigated to provide additional context. The case study reveals that currently, climate data is more accessible than years ago, and is increasingly being used for the development of adaptation strategies in the water sector. Results show that the main water and sanitation actors in Catalonia are aware of climate change impacts, and they are starting to develop their own adaptation strategies. Overall, the analysis indicates that Catalonia’s water sector is keeping with the tradition of being ahead of its own time in water resources management and planning, and it is trying to turn challenges into new opportunities for technology advancement.

This case study will provide transferable lessons for other water-dependent industries, particularly in Southern Europe. As water is a scarce resource, understanding how to apply climate services for adaptation purposes will be critical in the future.

**Keywords:** climate services, market, water, sanitation, Catalonia

**REFERENCES**


Climate services for irrigated agriculture: structure and results from the MOSES DSS

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Abstract

MOSES is an Horizon 2020 innovation action (2015-2018) aiming at the development of climate services for adaptation of agriculture to climate change, in the form of an integrated decision support system (DSS) devoted to irrigation water agencies and consortia, with the objectives of managing and reducing the risks of droughts, saving irrigation water, improving services to farmers, reducing financial and energy costs.

The MOSES consortium includes universities, national and regional technical agencies, irrigation consortia and specialized SMEs, and is led by ESRI, an Italian GIS company. MOSES DSS builds on former experiences of partners like the Italian iCOLT system for regional irrigation seasonal prediction [1], and it includes early crop mapping from space, seasonal prediction of irrigation water demand, in season evapotranspiration and crop water status monitoring from space, mid-term irrigation numerical forecasting, all integrated in a geographical web portal (www.moses-project.eu).

After a preliminary alpha version tested in Italy in summer 2016, during year 2017 the preoperational (beta) version of the DSS system was activated in the four MOSES demonstration areas (DAs) located in Italy, Romania, Spain and Morocco. We present here the structure and the products of the preoperational beta version of the MOSES DSS.

Early crop mapping

Early Crop Mapping of current irrigated crops provides location and extent of irrigated fields in the area of interest for each DA; it applies mainly to herbaceous crops, as...
orchards and vineyards, showing a relatively stable coverage, are usually documented by available geographical cadastre and similar tools. A crop classification decision tree, derived by agriculture schemes [2], specific of a given area, has been applied to satellite based NDVI values computed at few given time windows, to map aggregated irrigated crop before the start of the irrigation season; the stemming semi-automatic classification procedure, requires the intervention of an operator only for the best image selection through a dedicated back-end web application for image visualization and choice developed by ESRI Italia.

Probabilistic seasonal forecast

The seasonal products include default probabilistic irrigation seasonal predictions and customized probabilistic irrigation seasonal predictions for each DA. All these products require as meteorological forcing an ensemble of daily minimum and maximum temperature and cumulated precipitation over the coming season produced by a seasonal prediction module. The default seasonal prediction module uses as input the EUROSIP multi-model probabilistic seasonal predictions produced at ECMWF. The default calibration methods is implemented in three steps. First seasonal climate indices are computed for the next season reforecast (1991 to 2014) and forecasts for each model of the EUROSIP system. The forecast values of each index are debiassed by means of a quantile mapping method, using as input the e-obs gridded observed indices for the same period of the reforecasts. Finally, the calibrated indices for each ensemble member of the forecasts are used as input of a local weather generator producing daily values of minimum and maximum temperature and cumulated precipitation for the next season.

Irrigation seasonal forecast

This products derives from the former and consists in 3-months probabilistic forecasts of total irrigation needs, computed by the MOSES Soil Water Balance processor for each computational unit (defined by the combination of crop, soil and meteo maps). Outputs are provided as statistical distributions of total irrigations (mm) expressed as percentiles (5, 10, 25, 50, 75, 90 and 95) for each unit map, and also as anomalies from the seasonal irrigation computed on observed climate data.
In season daily irrigation forecasts

This product provides a daily overview of the current situation in the field, together with a 7-day forecast of crop irrigation needs, for each computational unit, based on current computed crop water availability, and numerical 7-day forecast of rainfall and temperature. Outputs include computed cumulated previous irrigation volume and can be space aggregated according to user needs (e.g. over irrigation districts).

In season monitoring

The MOSES in-season monitoring module consists in a fully automated procedure relying on the integration of Sentinel 2A and Landsat 8 multispectral satellite observations, at high spatial and temporal resolution, in combination with meteorological data, including short-term meteorological forecasts.

Its main functionalities include the monitoring of crop phenological variables and crop water demand at 7-days temporal resolution or higher, depending on the availability of multispectral remote sensing observations. The crop output variables provided by the module are Normalized Difference Vegetation Index (NDVI) and Leaf Area Index (LAI). The module provides also estimates of variables related to irrigation demand: Crop coefficients (Kc), Crop water demand (CWD) and Gross Irrigation water requirements (GIWR). The latter variables are estimated using two different methodology: empirical and analytical [3].

Measurements and evaluation

Consistency between satellite remote sensing borne information and the measured ground truth is being tested in the DA-IT. MOSES services robustness and added value is also being evaluated through a cost benefit analysis, and impact and performances assessment, and finally by benchmarking the results obtained applying MOSES services.

The MOSES portal

The MOSES DSS relies on a portal framework allowing to collect, organize and share profiled information from the MOSES platform. In the beta version of the DSS, dissemination to the final user is performed through specific web maps and applications, serving the output products as information layer with optimized symbolization and analysis tools. Final users validated the beta version of DSS and
recommended some features and enhancements to be implemented in the Release Candidate version.

**Keywords:** climate services, irrigation, seasonal predictions, Copernicus, remote sensing

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Cryosphere and tipping points

Chair: Susanna Corti

- Stenni B., Ca’ Foscari University of Venice, *Antarctic climate variability at regional and continental scale over the last 2000 years*
- Scoto F., Ca’ Foscari University of Venice, *Defining the Paleo Sea-Ice evolution during abrupt climate change as a way to better understand modern retreat: a multidisciplinary approach*
- Colleoni F., CMCC, What does +2°C mean for the Antarctic ice sheet?
- Terzago S., ISAC-CNR, The representation of snowpack in climate models: the impact of the horizontal resolution
Antarctic climate variability at regional and continental scale over the last 2000 years


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Abstract

Climate trends in the Antarctic region remain poorly characterised, owing to the brevity and scarcity of direct climate observations and the large magnitude of interannual to decadal-scale climate variability. Paleotemperature reconstructions from Antarctica mainly rely on water stable isotope records from ice cores. The key factor controlling this proxy has been mainly related to temperature variations; however, this is not always straightforward and other processes acting on different spatial and temporal scales may influence the calibration between water stable isotopes and temperature. These processes can include precipitation-weighting of recorded air temperature, post-depositional movement and loss of snow, and ice flow...
and elevation effects. Early efforts to reconstruct the continental-scale temperature history of Antarctica over the past 2000 years indicated that at the continent-scale Antarctica is the only land region where the long-term cooling trend of the last 2000 years has not yet been reversed by recent significant warming [1]. However, this Antarctic temperature reconstruction has large uncertainties and masks important regional-scale features of Antarctica’s climate evolution over the last 2000 years. Here, within the framework of the PAGES Antarctica 2k working group, we present a greatly expanded paleoclimate database including ice core isotope records over 7 distinct climatic regions: the Antarctic Peninsula, the West Antarctic Ice Sheet, the East Antarctic Plateau, and four coastal domains of East Antarctica. We produce both unweighted and weighted isotopic ($\delta^{18}O$) composites and temperature reconstructions since 0 CE, binned at 5 and 10-year resolution, for these regions. We also produce composites and reconstructions for the broader regions of East Antarctica, West Antarctica, and the whole continent. We use three methods for our temperature reconstructions: i) a temperature scaling based on the $\delta^{18}O$-temperature relationship output from an ECHAM5-wiso model simulation nudged to ERA-interim atmospheric reanalysis data from 1979 to 2013, and adjusted for the West Antarctic Ice Sheet region to borehole temperature data; ii) a temperature scaling of the isotopic normalized anomalies to the variance of the regional reanalysis temperature and iii) a composite-plus-scaling approach used in a previous continental scale reconstruction of Antarctic temperature since 1 CE [1] but applied to the new Antarctic ice core database. The first long-term quantification of regional climate in Antarctica presented herein is a basis for data-model comparison and assessments of past, present and future driving factors of Antarctic climate.

**Keywords:** Ice cores, Antarctica, last 2000 years, stable water isotopes

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Defining the Paleo Sea-Ice evolution during abrupt climate change as a way to better understand modern retreat: 
A multidisciplinary approach

Scoto F.1*, Spolaor A.1,2, Vallelonga P.3, Turetta C.2, Maffezzoli N.3, Cozzi G.2, Gabrieli J.2, Barbante C.1,2, Dahl-Jensen D.3

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Abstract
In the last four decades, Arctic sea ice is melting at a notably faster rate than projected by the most advanced numerical models, thus, a better comprehension of the mechanisms controlling the arctic sea ice dynamics as well its response to a past rapid warming become essential to better define and predict its future.

A precious archive of the past climate condition and fluctuation in Greenland and in the Arctic comes from the NEEM (North Greenland Eemian Ice Drilling Project) ice core which go back to the Eemian. δ18O variation in this period shows at least 24 rapid warming episodes (known as Dansgaard-Oeschger events) which occurred typically in a matter of centuries, so with a time scale reasonably comparable with global warming we are facing in recent time. Additionally, bromine concentration detected in NEEM ice core, can be used as a proxy to reconstruct paleo sea ice conditions. Its chemistry in fact, is extremely active at the polar sea ice margins with enhanced concentrations of BrO in the air column compared to the ocean surface or snow-covered land. So-called "Bromine explosions" occur principally in first-year sea ice close to the sea ice edge and are the major source of reactive bromine in the polar atmosphere. The net effect is the enrichment in Br− compared to the seawater Br/Na ratio in snow deposition, resulting in bromine enrichment (Br_{enr}).

Based on the high resolution (1-2 cm) NEEM bromine measurements from ultra-trace
Defining the Paleo Sea-Ice Evolution during a Rapid Climate Change as a Way to Better Understand Modern Retreat: A Multidisciplinary Approach

Scoto F. 1*, Spolaor A. 1,2, Vallelonga P. 3, Turetta C. 2, Maffezzoli N. 3, Cozzi G. 2, Gabrieli J. 2, Barbante C. 1,2, Dahl-Jensen D. 3

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A precious archive of the past climate condition and fluctuation in Greenland and in the Arctic comes from the NEEM (North Greenland Eemian Ice Drilling Project) ice core which go back to the Eemian. δ¹⁸O variation in this period shows at least 24 rapid warming episodes (known as Dansgaard-Oeschger events) which occurred typically in a matter of centuries, so with a time scale reasonably comparable with global warming we are facing in recent time. Additionally, bromine concentration detected in NEEM ice core, can be used as a proxy to reconstruct paleo sea ice conditions. Its chemistry in fact, is extremely active at the polar sea ice margins with enhanced concentrations of BrO in the air column compared to the ocean surface or snow-covered land. So-called ”Bromine explosions” occur principally in first-year sea ice close to the sea ice edge and are the major source of reactive bromine in the polar atmosphere. The net effect is the enrichment in Br⁻ compared to the seawater Br/Na ratio in snow deposition, resulting in bromine enrichment (Br enr).

Based on the high resolution (1-2 cm) NEEM bromine measurements from ultra-trace analysis of selected DO events by pursuing a multidisciplinary approach (including analytical techniques, numerical modelling and comparison with other climate archives) the goal of this study is to implement a paleo sea-ice extent numerical model in order to observe the sea ice changes and its time response to a rapid climate fluctuation.

Keywords: Arctic Sea Ice, NEEM, Ice Cores Analysis, Sea Ice modelling, Abrupt Climate Change

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What does +2°C mean for the Antarctic ice sheet?

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Abstract

The COP21 Paris agreement defined +2°C in global mean annual temperature, relatively to pre-industrial temperature, as the maximum targeted climate change for the next decades. How +2°C translate in terms of changes for cryosphere? The recent synthesis of the ISMASS group (SCAR)[1] shows that +2°C seems to be a tipping point of both Greenland and Antarctica [2,3,4]. They also suggest that RCP2.6 emission scenario might be the one mitigating the impact of climate change on the cryosphere, while the other scenarios lead to irreversible changes. As part of the glaciological community focuses on the projections of Greenland, Antarctica and mountain glaciers evolution until 2100 and up to 2500, little is known about their past responses to similar temperature fluctuations. In the case of Antarctica, several gaps have been highlighted: (1) the impact of basal meting under the ice shelves and marine terminating glaciers in response to ocean warming; (2) the various dynamical mechanisms involving the ice shelves mass balance and their importance in triggering a fast retreat of the grounding line and fast collapse of the main drainage basins; (3) the impact of the long-term thermodynamics of the ice sheet itself.

The most recent Antarctic projections [2] yield a contribution of +15.6 m, in the worst case, by the end of 2500 ([5] obtain half this number). Those projections, however, are based on initial conditions tuned to reach Mid-Pliocene (~3.3 Million years ago) and Last Interglacial (~125 kiloyears ago) sea level (both higher than today). Those two past periods are characterised by climate conditions warmer than today and their main driver is their orbital configuration: high eccentricity, high obliquity and high precession, putting the Earth at perihelion during
summer time. What is the impact of using those paleoclimates as initial conditions for projections?

The international paleoclimate efforts to understand the past evolution of Antarctica under those high atmospheric CO2 concentrations or under extreme climates conditions have been crystallized in the Past Antarctic Ice Sheet group (SCAR, PAIS). The work conducted by this group over the last years provided sound evidence of West and East Antarctic ice sheet repeated collapses over the last 5 Million of years [6,7] and probably before. However, ice sheet models still disagree on the mechanisms that triggered those collapses and do not converge on how much mass was lost or accumulated [e.g., 8,9,10]. The mechanisms involved in those past collapses are the same than the ones identified by the ISMASS group as the major sources of uncertainties for the projection of Antarctic evolution over the next centuries. This is where the future meets the past. A stronger synergy between both communities and a major reflexion on how to use paleoclimates evidence and modelling to refresh our point of view on Antarctica tipping point is necessary.

Keywords: ISMASS, PAIS, Antarctica, paleoclimate, projections
REFERENCES


The representation of snowpack in climate models: the impact of the horizontal resolution

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Abstract

The representation of the mountain cryosphere in climate models is critical owing to the scale mismatch between the snow-related processes, occurring at scales considerably smaller than 1 km, and the coarse grid of climate models (in a range between hundreds and few km). For instance, elevation gradients affect locally the air temperature which in turn controls the partition between solid and liquid precipitation, snowpack internal processes and snow melt at local scale. An adequate representation of the drivers of snow processes (e.g., temperature, snowfall), therefore, calls for high-resolution simulations. Moreover, a quantification of the uncertainty on snowpack estimates related to the coarse model resolution is of prime importance to correctly interpret the snow outputs of global and regional large-scale models, e.g. those included in the 5th Coupled Model Intercomparison Project (CMIP5, [1]) and in the the Coordinated Regional Climate Downscaling Experiment over the European domain (EURO-CORDEX, [2]), respectively.

The aim of the present study is threefold: First, we review the available snow water equivalent (SNW) datasets and quantitatively assess the uncertainties in the estimation of the snow water equivalent in the Alpine environment. We consider global SNW gridded datasets obtained from satellite and reanalysis data and we explore how they represent the snow climatology over the Greater Alpine Region (GAR, 4–19°E, 43–49°N). Based on this analysis, we discuss the performances of state-of-the-art SNW products in this orographically complex area and we provide an estimate of the inter-dataset spread in the Alps.

Second, these results are used as a reference for evaluating the state-of-the-art climate
models participating in the two major coordinated experiments: CMIP5, providing global simulations at average spatial resolution on the order of 100 km, and EURO-CORDEX providing regional simulations up to 12 km spatial resolution over the European domain. For each of the 36 GCMs and 5 RCMs considered we assess the ability to represent (i) the main drivers of snow processes, i.e. surface air temperature and precipitation, compared to the observational dataset EOBS [3], and (ii) the snow water equivalent climatology compared to the ensemble mean of the reference satellite and reanalysis datasets.

Third, we quantify the impact of horizontal resolution on the simulation of snow water equivalent. We exploit a set of 5 simulations performed with the global climate model EC-Earth [4] run at increasing spatial resolutions, from ~125 to ~16 km, and we assess the differences in the climatologies of (i) the drivers of snow processes (air temperature, total precipitation) and (ii) the snow water equivalent distribution, across the various model resolutions.

The results of the analysis show that the time-averaged spatial distribution and amplitude of the snow water equivalent annual cycle are reproduced quite differently by the different remote sensing and reanalysis datasets, which in fact exhibit a large spread around the ensemble mean. GCMs with spatial resolutions finer than 1.25° longitude (hereafter defined as “high resolution GCMs”) are in closer agreement with the ensemble mean of satellite and reanalysis products in terms of root mean square error and standard deviation than lower resolution GCMs. Still, one should take into account that all GCMs have evident limitations in representing the distribution of altitudes in the greater Alpine region, with the most resolved models underestimating the 95th percentile of the distribution by 500-800 meters. GCMs do not take into proper account elevations above 1500-2000 m a.s.l. which are simply non-represented in most models.

The EURO-CORDEX snow water equivalent simulations at 0.11° (~12 km) show a much thicker average snowpack over the alpine ridge and shallower snowpack at low elevations with respect to the ensemble mean of the reference datasets. This behavior, related to the RCM finer resolution, is sometimes smoothed out when snow water equivalent is spatially averaged over the Alpine domain. At regional scale, the annual cycle represented by ERA-Interim-driven RCMs results comparable to those found in the reference datasets and in GCMs. Important deviations from the reference datasets arise in GCM-driven RCM simulations. GCM-driven RCMs present stronger negative temperature
bias and/or stronger positive precipitation biases, resulting in thicker snow water equivalent with respect to the ERA-Interim driven runs. Overall, GCM-driven RCM simulations tend to suffer the biases already present in the driver GCM and to reflect them in SNW fields [5]. The analysis of EC-Earth simulations performed at different resolutions shows that when moving from the coarsest (125 km) to the finest (16 km) grid temperature and precipitation biases over the Alpine ridge decrease and the climatologies become closer to the EOBS reference. As expected, finer resolution simulations present a colder and wetter climate over the Alpine ridge with respect to the lower resolution simulations. Such conditions are reflected in significantly thicker snow packs in the most resolved runs and in a remarkable spread in the EC-Earth annual cycle. EURO-CORDEX RCMs future projections by mid 21st century in the RCP8.5 scenario show weaker snow reductions with respect to the coarser scale higher-resolution CMIP5 GCMs, especially in the spring season. Higher-resolution EC-Earth simulations (25 and 16 km) are in overall agreement with the considered EURO-CORDEX runs, suggesting the added value of higher resolution runs also for GCMs. While few regional models can have limited representativeness of the whole EURO-CORDEX ensemble and a larger set of simulations has to be considered as soon as they become available, this analysis highlights the large discrepancy among the considered datasets over the historical period and stresses the need of a reference observation-based product that could reliably represent the ground truth over the last decades.

**Keywords:** snow water equivalent, CMIP5 climate models, CORDEX, spatial resolution, mountains
REFERENCES


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Knowledge gaps in climate science, in support of IPCC reports

Chair: Mita Lapi

- Nicoli D., CMCC, *Global Climate Impacts of the Atlantic Multidecadal Variability: a model--based approach*
- Maione M., Università di Urbino-CNR, *Atmospheric Monitoring and Inverse Modelling for Verification of Halogenated Greenhouse Gas Inventories*
- Cristofanelli P., CNR, *Long-term trends of climate-altering species at the Mt. Cimone WMO/GAW Global Station (Italy, 2165 m a.s.l.)*
- Pavan V., ARPAE, *The ARCIS daily precipitation observational analysis for North- Central Italy from 1961 to 2015*
Global Climate Impacts of the Atlantic Multidecadal Variability: 
a model-based approach

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Abstract

The Atlantic Multidecadal Variability (AMV) is a low-frequency mode of variability, characterized by a coherent pattern of oscillatory variations in North Atlantic Sea Surface Temperature (SST) as reported in many studies [1]. Understanding low-frequency physical processes, as the AMV, that control predictability of the climate system is fundamental for improving decadal predictions and gaining further confidence in forecasts.

The aim of this study is to assess the climate impacts of SST anomalies associated to the AMV and to study the related physical processes, using a fully-coupled model framework. The project is intended to find out how the climate system responds to slowly evolving (decadal-scale) changes in the SST, focusing on the global response of both the atmospheric and oceanic sea ice sub-systems and the role of the North Atlantic Ocean in driving regional climate anomalies. The North Atlantic SST anomalies that define the AMV, also known as Atlantic Multidecadal Oscillation (AMO), are uniform in sign but show a maximum loading over the subpolar gyre region extending to the subtropics through the eastern side of the basin [2-4]. Furthermore, the SST variations persist throughout the year. The historical record (1870-2013) show two cold periods (1900-1920 and 1970-1990) and three warm period: one at the start of the record, another in the middle of the last century (1930-1960), and an ongoing one that began around 1990. During a positive (negative) phase of AMV, an enhanced (reduced) large-scale warming could be observed, in addition to the anthropogenic induced warming. Variations of North Atlantic SST have been linked to European and North American summer climate [5-8], Atlantic hurricane activity [2, 3, 9] and Arctic Sea Ice [10, 11]. This highlight the importance of better understanding and predicting...
the AMV and, in this context, climate models assume an important role for detecting and investigating AMV teleconnections because of a short observational record.

This study follows the experimental framework outlined in the CMIP6 Decadal Climate Predictions Project (DCPP) protocol [12] and tested by several authors [8, 13, 14]. Using the Earth System model CMCC U CM2 [15], the model North Atlantic SSTs are restored to fixed anomalies corresponding to an estimate of the internally driven component of the observed AMV [4], allowing the model to freely evolve outside of the target region. All external forcings (such as Greenhouse Gases, solar radiation and tropospheric aerosols) are set at the pre-industrial values (constant at 1850’s levels) to get just the internal variability effects, neglecting the anthropogenic and external contributions. In order to capture the linear climate response to AMV, this study focuses on the differences between the positive and negative phases. Two sets of idealized AMV SST perturbation experiments are performed:

1. AMV+ experiments: North Atlantic (10°N – 65°N) SSTs are restored to positive time-independent AMV anomaly (i.e. +1 standard deviation of the AMV index, which is estimated as the residual of the observed North Atlantic basin-wide averaged SST after subtracting the forced component) superimposed on 12 month model climatology. According to the framework protocol, an 8 degree wide buffer zone is opportunistically designed at the edge of the restored zone to minimize shocks and to avoid instabilities in no restores region. No restoring is performed where the sea ice is greater than 15% (Sea Ice Extent definition).

2. AMV- experiments: they are analogous to AMV+ experiments, but it is considered the negative AMV anomaly (i.e. -1 standard deviation of the AMV index). All the experiments include 10 ensemble members, generated from different oceanic initial states [16] of a multi-century pre-industrial run to isolate the internal unforced variability. The integration time of each simulation is 10 years, allowing a full climate response.

Keywords: Atlantic Multidecadal Variability, Climate Impacts, Teleconnections, Coupled Models
REFERENCES


Atmospheric monitoring and inverse modelling for verification of halogenated greenhouse gas inventories

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Abstract

HFCs are powerful GHGs developed as alternative of ozone depleting CFCs. The climate benefit of reducing the emissions of HFCs has been widely recognised, leading to an amendment of the Montreal Protocol calling for their phase down. Emission estimates based on atmospheric measurements can be used in support to the National Inventory Reports (NIRs) submitted every year to UNFCCC. We used atmospheric data from four European sites combined with FLEXPART dispersion model and a Bayesian inversion to derive emissions of 9 HFCs from the whole Europe and from 12 regions within it, and then compared our results with annual NIRs and EDGAR database. Despite several discrepancies when considering the specific compounds and at the country level, an overall agreement is found when comparing European aggregated data, which between 2008 and 2014 are 84.2±28 Tg-CO\textsubscript{2}-eq·yr\textsuperscript{−1} against the 95.1 Tg-CO\textsubscript{2}-eq·yr\textsuperscript{−1} reported by UNFCCC in the same period. Thus, in agreement with other studies [1] the gap on the global level between reported estimates (Annex I countries) and total global top-down emissions should be essentially due to emissions from non-reporting countries (non-Annex I).

Keywords: Hydrofluorocarbons, Kyoto gases, NIRs, Inverse modelling
REFERENCES

Abstract

The Mediterranean basin represents a global hot-spot for climate change, air quality and anthropogenic contributions to these issues. Since the early ’90s of the last Century, continuous observations of atmospheric composition have been carried out in Italy at the “O. Vittori” atmospheric observatory managed by the National Research Council of Italy (CNR), hosted by the Italian Air Force and part of the WMO/GAW global station “Mt. Cimone” (GAW id: CMN; 44°12’ N, 10°42’ E, 2165 m a.s.l.). Due to the completely free horizon, high altitude and great distance from major pollution sources, CMN represents a strategic platform to study the chemical-physical characteristics and climatology of the free troposphere in the South Europe and Mediterranean basin. At this observatory, continuous monitoring of climate-altering compounds (trace gases and aerosol), solar radiation as well as meteorological parameters are carried out. The Mt. Cimone long-term observations, carried out in the framework of international reference programme (i.e. Global Atmosphere Watch by WMO, AGAGE - Advanced Global Atmospheric Gases Experiment, ACTRIS- Aerosols, Clouds, and Trace gases Research InfraStructure Network, ICOS - Integrated Carbon Observation Cycle) can be used to assess the variability of anthropogenic and natural emissions of climate-altering and pollutant species in supporting national agencies or governments for the verification of emission inventories or for assessing the efficiency of mitigation measures, thus potentially representing a powerful support for the achievement of the Paris Agreement goals.

CH4 measurements at CMN started in 2008, with an average concentration over 2008-2016 of 1881.5 ppb and an increasing trend of 9.3 ppb yr-1. N2O is measured at CMN since 2008. Average concentrations during 2008-2016 are 326.5 ppb, with an increasing trend of 0.8 ppb yr-1, that the same growth rate given for the global scale [1].
Four CFCs are monitored at CMN: the average atmospheric mixing ratios updated to 2016 are 529.1 ppt for CFC-12, 245.7 ppt for CFC-11, 16.5 for CFC-114, and 8.4 ppt of CFC-115. Effects of their complete phase out under Montreal Protocol (MP) in 1996 in non-Article 5 (non-A5) and in 2010 in Article 5 (A5) countries, are evident in the decline of their background atmospheric mixing ratios of −0.9, −0.5, −0.3% yr−1, for CFC-11, CFC-12, CFC-114, respectively over the periods for which measurements at CMN are available (2008-2016). For CFC-115, the longest living among the CFCs considered, a still positive trend of 0.2% is observed but with no acceleration.

Updated “Halons” H-1211 and H-1301 average mixing ratios measured at CMN during 2002-2016 are 4.3 and 3.3 ppt, respectively. In agreement with global average concentrations, H-1211 seems to have started a steady decline around 2005, and currently its atmospheric trend is -1.5% yr-1. H-1301 shows an overall trend of 0.7% yr−1 but with no acceleration since 2010. Although halons have been banned in Europe since 1994, still occurring elevations above the baselines at CMN suggest the presence of some fresh emissions within the station domain, even if the pollution episodes have declined in the last few years.

The complete phase-out date of these second generation chlorofluorocarbons (HCFCs) has not yet been reached in A-5 parties and their background concentrations are still increasing. Average concentrations at CMN are 209.1, 25.6 and 23.0 ppt for HCFC-22 (2002-2016), 141b (2012-2016) and 142b (2008-2016) with trends of +2.8, +1.8 and +1.5% ppt yr−1, respectively. Methyl chloroform (MCF) is a man-made chlorinated solvent controlled under the MP that called for its phase-out in 1996 in developed countries and 2015 in developing countries. Updated average atmospheric mixing ratios at CMN are 12.6 ppt, with a decreasing trend since 2002 of 15.8% yr-1.

CCl4 is a near exclusively anthropogenic compound used as solvent, feedstock for chlorinated chemicals production, fire extinguisher, fumigant, rodenticide. CCl4 is measured at CMN since 2006, and average background concentration is 86.7 ppt with an atmospheric trend of -1.2% yr-1 over the measurement period.

CH3B average background concentration is 8.2 ppt and the trend is -1.4% yr-1. As a consequence of the MP a decrease of pollution episodes is observed at CMN in the period 2008–2009, whilst a renewed increase of such episodes occurred in 2010–2011, i.e. after the complete phase out and also after the cessation of allowed exemptions [2]. The increase of fresh emissions can be probably ascribed to massive and unreported use of stocks.
HFC-134a is the most abundant HFC in the global atmosphere. Main uses are as replacement refrigerant for CFC-12 in mobile air conditioners, stationary refrigeration, as well as in foam-blowing applications, in aerosol inhalers, and for dry etching. Average HFC-134a background concentration at CMN since 2002 is 61.5 ppt with an increasing trend of 7.6%. HFC-32, HFC-125 and HFC-143a are used in blend for stationary air conditioners and for minor applications (e.g., for fire suppression) as replacement of HCFC-22 and CFC-115. Their background concentrations at CMN are 8.6, 10.2 and 13.6 ppt for HFC-32, HFC-125 and HFC-143a, respectively, over the periods 2002 - 2016. Reflecting the global situation, these three HFCs show the highest increasing trend of all F-gases (17%, 13.6% and 9.5%, respectively), showing the importance of these refrigeration blends as replacement of HCFCs and CFCs. HFC-152a is used mainly as foam-blowing agent an aerosol propellant, its average background concentration at CMN is 8.5 ppt with an increasing trend of 6.3% from 2002 to 2016.

Together with CH4, HFCs and black carbon, O3 is considered a “short-lived climate forcers" (SLCF). The potential climate benefits of reducing SLCF emissions has been recognised by the United Nation Environmental Programme - Climate and Clean Air Coalition (UNEP-CCAC), an international initiative aiming at catalysing rapid reductions in SLCPs, based on the assumption that their timely reduction can slow the rate of climate change within the first half of this century, i.e. before the long lived CO2 reduction measures will take effect [3].

With the aim of investigating the long-term O3 trend over the period 1996 - 2013, we adopted the Theil-Sen method to the deseasonalised monthly values of O3. For CMN, over the whole measurement period, a negative trend (significant at the 99% confidence level) of -0.18 ± 0.7 ppb yr-1 was obtained. The same methodology was adopted for investigating the trend of black carbon, which is continuously measured at CMN since 2005. We find out (over the period 2005-2013) a statistically significant negative trend of -0.17 mg m-3 yr-1.

**Keywords:** Mediterranean basin, greenhouse gases, black carbon, long-term trends
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The ARCIS daily precipitation observational analysis for North-Central Italy from 1961 to 2015


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Abstract

A gridded daily precipitation observational analysis has been produced within the project ARCIS, which has the aim of producing a climatological analysis of surface parameters over the territory covered by the administrations who subscribed the convention. At present the dataset extends to North-Central Italy over the period 1961-2015. The dataset accepts as input only time series of observational daily data, made by one or more non overlapping stations, covering at least 80% of the full period (consistency check). Data are first checked for quality, eliminating all spurious persistences of null data, not consistent with the data in the surrounding stations. All times series are checked for homogeneity on annual totals using the SNHT test, supported by the Craddock test. Time series not passing the homogeneity test are not used in the analysis. Finally all time series are checked for synchronicity by comparing yearly values of not lagged or lagged correlation values with the surrounding series so as to reduce errors in observational time attributions. At the end of all preliminary operations, the number of time series used as input of the analysis is about 1000 stations, including those
kindly provided by MeteoSwiss, Meteo France, ZAMG, and the Meteorological Service of Slovenia, who provided the data along the Italian border so as to reduce interpolation errors in these areas. Although a threshold on time series consistency has been imposed, there is still a reduction in the number of station of about 10% in the last decades, starting from 2000, when the climatological monitoring network was redesigned and renewed; this is partly due to the fact that some stations were not immediately relocated close to the historical station, partly to economical problems and budget cuts on most Italian public offices. Daily data are interpolated using a modified Shepard algorithm, based on an inverse distance and direction weighting scheme. One of its advantages is the directional dependence of weights, allowing isolated stations to be overweighted with respect to clusters of stations. The Shepard scheme has been modified by generalizing the Cartesian distance between points to a topographic distance, so as to partly account for orographic effects. Results are presented for a group of yearly and seasonal indices showing mean values and trends. Indices include total cumulated precipitation, 90\textsuperscript{th} percentile of daily precipitation, number of wet days and maximum consecutive number of dry days. The results are compared with those presented by previous study covering the area.

Summer precipitation is significantly decreasing in several areas of North-Central Italy, and the maximum number of continuous dry days increases over several areas close to the Adriatic coast, of the central Po Valley and of Central pre-Alps, but increasing close to the northern Italian border over the Alps. On the contrary the 90\textsuperscript{th} percentile of daily summer precipitation is significantly increasing over large areas of the Po river and over the Alps, and locally over the Central Apennines, but is significantly decreases over local areas of Emilia Romagna and in general the regions close to the Adriatic coast. In autumn, the analysis indicates an increase of total precipitation over Northern Italy, which is barely significant on limited areas of the north-eastern regions, but a decrease in central Italy. In this season, the 90\textsuperscript{th} percentile of daily precipitation presents a significant positive trend over large areas of the north, but a significant negative trend in the center. At the same time, in this season, large areas of North Central Italy present a significant reduction in the maximum number of continuous dry day, which is opposite with respect to the other seasons. The summer and autumn results seem to indicate a shift in the distribution of daily precipitation in these seasons towards more intense daily values, confirmed also by extended areas of negative significant trends in the number of summer wet days and very reduced extension of the areas
presenting significant trends in the same index for autumn. The analysis indicates the presence of no significant change in total winter precipitation over the period considered, although it also indicates a significant increase in the 90th percentile of daily precipitation over the central and eastern pre-Alps, but a significant decrease over Piedmont, Emilia-Romagna and locally in central Italy. Moreover the maximum number of continuous dry days is significantly increasing in large areas of central Italy. It is finally interesting to notice that in spring total precipitation is decreasing over most areas, with significant trends only in eastern Liguria and Northern Apennine, but the 90th percentile of daily precipitation presents significant increases in the area around the Adriatic coast, in Umbria, over the pre-Alps and North-western Alps, but significant decreases over central Alps and Tyrrhenian slope of Northern Apennines. Some analysis of these results will be presented correlating the changes in precipitation with changes of large scale circulation indices.
Inter-relations between climate change, biodiversity and ecosystems

Chair: Dario Battistel

• Butenschön M., CMCC, *Can Global Climate Model projections inform on climate change impacts on the marine ecosystem services at regional scales relevant to marine policy?*

• De Oliveira Silva R., SRUC, *The role of agricultural intensification in Brazil’s Nationally Determined Contribution on emissions mitigation*

• Marcomini., CMCC, *Integrated modelling of climate change impacts on nutrient loadings and coastal aquatic ecosystems*

• D’Onofrio D., CNR, *Vegetation-fire-climate interactions in tropical Africa: learning from observations and dynamic global vegetation models*

• Cassardo C., University of Turin, *Climatology of micrometeorological and physiological parameters in the regional vineyard ecosystem*
Can Global Climate Model projections inform on climate change impacts on the marine ecosystem services at regional scales relevant to marine policy?

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Abstract

Over recent years, substantial research has been dedicated to investigate climate change in the ocean at global scale with particular attention to the issues of global warming, sea-level rise and carbon sequestration (IPCC, 2014). Less focus was given so far to other marine ecosystem services that nevertheless are highly relevant to marine policy such as provision of food and other biological resources, tourism, erosion and disturbance prevention, etc. There is substantial doubt in the scientific community if the currently available projections through the CMIP initiative are adequate to inform on these issues, which are mostly limited to the coastal ocean and may require downscaled, highly resolved simulations (Holt et al. 2016, Stock et al 2011).

Here we investigate a sub-set of simulations from the CMIP5-archive (Taylor et al. 2011) to assess their capability to provide projections of climate change impacts on the marine ecosystem at the scale most relevant to marine policy beyond the full global scale, i.e. Exclusive Economic Zones (EEZs). We provide quantified estimates on major climate change impact indicators, such as primary and secondary producer biomass taking into consideration the structural and scenario uncertainty in the simulations along with estimates on the performances of the simulations with respect to global reference data sets. The consequences of these changes to marine ecosystem services are illustrated on the example of fisheries by projected changes on total fish biomass via a size spectrum modelling approach underpinning the relevance of this work to marine policy.
Keywords: climate change impacts, marine ecosystem services, uncertainty

REFERENCES


The role of agricultural intensification in Brazil’s Nationally Determined Contribution on emissions mitigation

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Abstract

Brazil has become the first developing country to provide an absolute emissions cut as its Nationally Determined Contributions (NDC)1, which seeks to reduce total greenhouse gas (GHG) emissions by between 37% and 43% below 2005 levels by 2025 and 2030 respectively. The majority of the NDC mitigation potential is targeted on agriculture and land use change and methods of livestock production. The restoration of 20 Million ha of degraded pastures from 2020-2030 aims to contribute to direct and indirect emissions control, the latter via land sparing and the prevention of deforestation. The NDC also states an ambition to achieve zero net deforestation in the Amazon by 2030. The NDC ambition on emissions and deforestation are being set as the country seeks to meet an increasing demand for livestock production. This study was requested by the Brazilian Ministry of Agriculture through the Brazilian Agricultural Research Corporation (Embrapa) and derives the livestock sector contribution to the NDC in terms of the area of degraded pastureland required to be cost-effectively restored over 2020-30 assuming pasture contraction due to targets of reduction in deforestation, the livestock and agriculture competition for land and livestock product demand scenarios. We evaluated the restoration area requirement using two bio-economic models and demonstrate the extent of cost-effective mitigation that could be delivered by this measure, and to show a result that underpins the target of zero deforestation in all Brazilian biomes. The Demand Constrained Restored Area (DCRA) is a simplified one-equation model that considers two types of grasslands (degraded and not degraded), and the EAGGLE model2, a bottom-up multi-period linear programming model that simulates beef production
systems in Brazil subject to demand and pasture area, and estimates the greenhouse gases—including changes in soil carbon stocks. Using both models, we conclude that the required restored pasture to meet baseline demand while accomplishing deforestation targets ranges from 15-18.2 M ha. Estimated average costs of direct restoration of degraded pastures, i.e., costs associated with restoration practices (use of inputs and farm operations) are €12.48/ha/yr, €13.87/ha/yr and €12.36 ha/yr, respectively for the Cerrado, Amazon and Atlantic Forest biomes. The total mitigation potential of ZNDT, combined with agricultural intensification through pasture restoration is around 630 million tonnes of CO$_2$-e relative to the reference scenario, i.e., assuming baseline demand and no accomplishment of the NDC. The results are essentially a case study of sustainable agricultural intensification at scale.

**Keywords:** Agriculture; mitigation, sustainable intensification; deforestation

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Integrated modelling of climate change impacts on nutrient loadings and coastal aquatic ecosystems

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Abstract

It has been recognized that the increase of atmospheric greenhouse gases (GHGs) due to anthropogenic activities is causing changes in Earth’s climate [1]. Coastal waterbodies such as estuaries, bays and lagoons, together with the ecological and socio-economic services they provide, could be among those most affected by the ongoing changes on climate [2]. Particularly, climate change is expected to alter phytoplankton communities by changing climate and environmental drivers such as temperature, precipitation, nutrient loadings and concentrations, and to exacerbate the symptoms of eutrophication [3]. A better understanding of the links between environmental drivers and phytoplankton communities is therefore necessary for predicting climate change impacts on aquatic ecosystems. In this context, the integration of climate scenarios and environmental models can become a valuable tool for the investigation and prediction of phytoplankton ecosystem dynamics under climate change conditions.

Here we present the case study of the Zero river basin (ZRB) in Italy, one of the main contributors of freshwater and nutrients loadings to the salt-marsh Palude di Cona (PDC), a waterbody belonging to the lagoon of Venice. To predict the impacts of climate change on nitrogen (N) and phosphorus (P) loadings of the ZRB and the consequent effects on the coastal phytoplankton community of PDC, we applied a methodology integrating an ensemble of GCM-RCM climate projections, the hydrological model SWAT and the ecological model
AQUATOX. Climate scenarios for the area indicate an increase of precipitations in winter and a decrease in summer, while temperatures show a significant increase over the year. SWAT predicted changes in water discharge and nutrient loadings of the ZRB, pointing out an increase in the winter period and a reduction in summer. AQUATOX predicted changes in water temperature, nutrient concentrations and N:P ratios, and consequent variations in the biomass and composition of phytoplankton in PDC.

**Keywords:** climate change impacts, coastal areas, water quality, phytoplankton, environmental modelling

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Vegetation-fire-climate interactions in tropical Africa: learning from observations and dynamic global vegetation models

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Abstract

Tropical grassy biomes (TGB) comprise grassland and savanna and cover about one third of the African land surface. At the wetter end of their distribution range, TGB transition into tropical forests (TF), which are shaded environments with closed tree canopy, which cover about 11% of Africa [1]. These biomes are the most productive terrestrial ecosystems [1,2], and owing to their different biogeophysical and biogeochemical characteristics, future changes in their distributions could have also impacts on climate states [3]. In particular, possible biomes distribution changes due to expected increasing temperatures and CO2 concentrations, modified precipitation regimes, as well as increasing land-use intensity [4], could have large impacts on global biogeochemical cycles and precipitation, influencing the inter-relations between ecosystem and climate [5]. Dynamic Global Vegetation Models (DGVMs) are useful tools for simulating the distribution and structure of global vegetation in response to past, present and future climates [6]. Although DGVMs, including those incorporated into Earth System Models (ESMs), are able to realistically reproduce the distribution of the most worldwide biomes, they display high uncertainty in predicting the distribution of tropical biomes and the transitions between them in tropical areas [7]. This difficulty has been associated with the way they represent the ecological processes and feedbacks between biotic and abiotic conditions [7]. The inclusion of appropriate ecological mechanisms under present climatic conditions is essential for obtaining reliable future projections of vegetation and climate states. However, given the global application of DGVMs, the ecological parameterizations should be kept simple as
possible.
The dynamics of tropical biomes and their environmental limits are determined by complex and dynamic interactions between vegetation and biotic factors, such as climate (e.g. precipitation annual average and seasonality) and disturbance (e.g. fire) [8]. The ecology of these biomes has been studied for a long time, and the current theory postulates that in arid conditions grassy biomes are predominant because of water limitation to tree growth, and tree-grass competition [9]. Whereas, in conditions of high precipitation, although water is enough for the development of TF, TGB can occur as alternative stable state maintained by a positive feedback between grass and fire [10].

In this work we analyse observed relationships of tree and grass cover with climate and fire in sub-Saharan Africa, and use the current ecological understanding of the mechanisms driving the TGB-TF transition in Africa to evaluate the outcomes of current state-of-the–art DGVMs and to assess which ecological processes need to be included or improved within the models. Specifically, we analyse patterns of tree and grass cover and fire intervals from MODIS satellite observations, rainfall annual average and seasonality from TRMM satellite measurements and tree phenology information from the ESA global land cover map, comparing them with the outcomes of the LPJ-GUESS DGVM [11], also used by the EC-Earth global climate model.

This type of analysis could be useful for evaluating and comparing DGVMs in tropical areas, helping to understand the role of the different main ecological processes at work and to improve the simulations of tropical land-climate interactions.

**Keywords:** African tree and grass cover, DGVM, fire, precipitation, remote sensing data

**REFERENCES**


Climatology of micrometeorological and physiological parameters in the regional vineyard ecosystem

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Abstract

Several factors influence crop productivity, including soil fertility, management practices, climate and meteorology. This is also true for grapevine, because the wine is one of the most exported Italian products, in particular for Piemonte region, which produces several high-quality wines (DOCG and DOC). Among the above-mentioned factors, there is a need for a reliable assessment of the effects under a changing climate on yield and quality. In this respect, it is essential to primarily understand how and how much climate and meteorology affect grape productivity and quality. In this context, crop models are essential tools for investigating the effects of climate change on crop development and growth via the integration of existing knowledge of crop physiology relating to changing environmental conditions.

In the past recent years, several oenology and viticulture studies aimed to developing tools to manage vineyards and improve wine quality. Among these, we can mention the monitoring of physical and physiological processes related to environmental conditions that have influence on vine growth, yield and grape quality and the characterization of the vineyard microclimate and its variability within the vineyard itself. Also this work is inserted in this category. A tool of numerical models has been developed to study the complex system “vineyard”, simulating physical, physiological, and phenological processes and diagnosing microscale plant responses to environment.

In particular, two models have been used in this study. The land surface scheme UTOPIA (University of TOrino model of land Process Interaction with Atmosphere) has been run to
simulate micro-meteorological conditions within vineyards, and the meaningful components of hydrological and energy budget, as well as soil and canopy parameters, have been evaluated. UTOPIA is a diagnostic one-dimensional model [Cassardo, 2015], formerly named as Land Surface Process Model [LSPM; Cassardo et al., 1995; Cassardo, 2006] that can be used as a stand-alone basis or be coupled with an atmospheric circulation model or a regional climate model, serving as the lower boundary condition. The land surface processes in UTOPIA are described in terms of physical fluxes and hydrologic states of the land. The former includes radiation fluxes, momentum fluxes, sensible and latent energy fluxes and heat transfer in multi-layer soil, while the latter includes snow accumulation and melt, rainfall, interception, infiltration, runoff, and soil hydrology. All fluxes are computed using an electric analogue formulation, in which a flux is directly proportional to the gradients of the related scalars and inversely proportional to an adequate resistance. Since the UTOPIA is a diagnostic model, thus some observations in the atmospheric layer are required as boundary conditions, including air temperature, humidity, pressure, wind speed, cloud cover, long-wave and short-wave incoming radiation, and precipitation rate. Usually these observations are measured values, eventually with the reconstruction of some missing data using adequate interpolation techniques.

Subsequently, the crop model IVINE (Italian Vineyard Integrated Numerical model for Estimating physiological values) has been applied, fed by some UTOPIA outputs and other data. IVINE is a crop model created in 2016 by two of the authors (Andreoli V., Cassardo C.) to simulate physiological and phenological vineyard conditions. The required boundary conditions, to be provided during the simulation, data are: temperature, relative humidity, solar global radiation, photosynthetically active radiation, soil temperature, soil water content, wind speed and direction, rainfall, and leaf wetness. Other data are required as input: vineyard and soil characteristics, geographic informations (latitude, longitude, slope, height), plant density, variety characteristics (clusters/plants, berries/cluster,...), and vineyard management (trimming, severity of trimming). The main model outputs are: the predawn leaf water potential, the timing of the main phenological phases (dormancy break, budburst, ...), the leaf development, the yield, and the sugar concentration. The model requires some experimental parameters depending on the cultivar.

The output data of two models allow inferring micro-meteorological and physiological variables within the vineyards. To get information over a period of climatological relevance,
the boundary conditions have been extracted for sixty years. In this way, it could be studied, in a second phase of the study, which micro-climatic conditions could improve grape quality.

Since input data required by models are not always simple to be retrieved, in this work we have used data coming by worldwide-distributed databases. In particular, the data needed by models as boundary conditions have been extracted by the freely available global database GLDAS (Global Land Data Assimilation System: https://disc.gsfc.nasa.gov/gesNews/gldas_2_data_release).

The numerical experiments, in this moment in the phase of execution, are planned in this way: firstly the run of UTOPIA, and then IVINE, for each grid point. The eventual success of this methodology can indicate that it is suitable to employ numerical models to evaluate agronomic variables trends by means of gridded databases.

This experiment is ongoing, and its preliminary results will be presented during the conference. The results available in this moment (a preliminary simulation has been carried out for forty years in Piemonte) reveal that the model chain seems able to evaluate the most characteristic variables related to the vine, which may be used in order to guess the quality of the grape. A close look on the time trend during the 40-years period reveal clear trends for many variables, although statistically not significant, due to the large interannual variability.

The future perspective of this work is a deepening of the analysis, with more quantitative conclusions about data and variations. Also simulations for different cultivars will be performed with IVINE, that must be optimized for such cultivars. Finally, other parameters may be evaluated. Among these, we may mention: acids, alcohol content, etc.

**Keywords:** numerical models; grapevine; physiological processes; surface parameters; climate.
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REFERENCES
Decarbonisation - Climate mitigation benefits, costs and technologies

Chair: Cristina Sabbioni

- Piana V.C.L., Economics Web Institute, *With the new National Energy Strategy and the Roadmap for Sustainable Mobility, which role for transport in Italy’s decarbonisation in 1.5°C- consistent pathways under the Paris Agreement?*
- Mazziotti C., CNR-IIA, *Coal fired power plants in Italy from past to future*
- De Marchi M., University of Padua, *Where To Leave Fossil Fuels Underground? Multicriteria GIS Analysis To Assess Unburnable Carbon Areas In Bolivia And Italy*
- Drouet L., FEEM, *Heterogeneity in the national contributions to the Social Cost of Carbon*
- Aleluia Reis L., FEEM, *Global Air Quality Index under different socioeconomic and climate scenarios*
With the new National Energy Strategy and the Roadmap for Sustainable Mobility, which role for transport in Italy's decarbonisation in 1.5°C-consistent pathways under the Paris Agreement?

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Abstract

Introduction

The draft NES of Italy posits transport as the sector with the second deepest absolute cuts in energy consumption and the highest rise of renewable energy utilisation (three times more in 2030 than in 2015). Having been personally involved in the stakeholders' consultation on Italian 2030 Sustainable Mobility Roadmap, the author develops an original view of the overall role of transport in Italy's decarbonisation to match and overcome NES targets, keeping into account the national vital interest of limiting warming to 1.5 degrees. In particular, a simulation of the impacts of the advanced implementation of the consensus-based stakeholders recommendation is provided, enhanced by additional national and local measures.

Keywords:

Italy's National Energy Strategy, sustainable mobility, mitigation policies, 1.5 degrees of global warming, emission pathways

1. The new National Energy Strategy

In June 2017, the Ministry of Economic Development and the Ministry of Environment have submitted to public consultation a draft new Energy Strategy for Italy [1]. In the letter to stakeholders, they call for total decarbonisation, although no date or full trajectory is developed in the full text. In the synthesis of priority actions, the share of renewable sources in transport is set to triple, from 6.4% in 2015 to 17-19% in 2030. This proportion is higher than in the electricity sector and in the heat sector. The
current version tends to implement such goal by second-generation bio-fuels and a target of 5 millions electric vehicles, while stakeholders have suggested a role for biomethane for heavy duty trucks and public buses, as well as an increase of railway share.

In the “intermediate policy scenario”, transport is expected to deliver a CO$_2$ reduction of at least 22%, which would correspond to an absolute fall of 23.32 Mt, second to the 39.75 Mt expected from Industry (including energy production), but before the building sector (13.32 Mt), agriculture (0.64 Mt) and non-energy-related sources of emissions (5.53 Mt).

These targets, taken in a macroeconomic scenario of modest but steady GDP growth, stand out as opposing natural trends in transport, which testified a systematic increase of emissions for many years, with an increase of 25,62 Mt from 1990 to 2006. Transport was then hit by the economic crisis, with one-year fall in emission as high as 7.49 Mt in 2013, 6.94 Mt and 2009, and 5,58 Mt in 2010, with a cumulated fall of 25 Mt between 2008 and 2014. It shortly rebounded in 2015, followed by a minor fall in 2016 [2].

Comparing the targets and the history, the scale of foreseen fall is not particularly ambitious, since it requires some 13 years to achieve more or less the same reduction that actually occurred in 7. But as we cannot rely on deep and prolonged economic crisis to further reduce emissions, NES requires an active sectoral policy that generates de-coupling between GDP and transport emission in a very high degree [3].

Moreover, the ambition of the overall NES is insufficient to fairly contribute to the goals set in art. 2 of the Paris Agreement on climate, since it tries to align with the EU NDC without keeping into consideration the emission gap between the overall NDC ambition and what the science requires to remain in the least-cost trajectory for “well below” 2 degrees [4] and even more so in the more stringent requirements of the carbon budget for 1.5 degrees [5, 6, 7], which is crucially important for Mediterranean region and Italy [8].

In 2018 an upward revision of all NDC will be called upon during the Facilitative Dialogue taking place under the UNFCCC, to react to the new IPCC Special Report on 1.5 degrees of warming.
2. The Sustainable Mobility Roadmap and the consensus-based Recommendations of the stakeholders

Since June 2016, the Prime Minister Office has been coordinating a stakeholder consultation, including key ministries, to share scenarios and explore policy options for sustainable transport, partly in response to EU policy papers, partly to develop the national interest in identifying and supporting industries and employment, initially under the title of “Roadmap della mobilità sostenibile fino al 2030”.

The author of the present paper was involved in most meetings and paperwork of this process, within the delegation of Legambiente, the only environmental NGO participating. We produced a 1.5°C-consistent pathway for the sector, with a 86% emission reduction by 2030, by cutting in half of the number of vehicles (today standing at some 37 millions) and by their total substitution with zero emission fleets (both private and collective, including car-sharing, car-pooling and taxis), thanks to the implementation of 44 specific proposed measures.

The technical assistance of the process was supplied by RSE, through meetings, presentations and several successive drafts of the main document, collating the solicited contribution of the rising number of participants, which grew over time because of the perceived importance of the process, with a meeting in the Green Room in Palazzo Chigi having exhausted entry pass because of such high number.

The document was finally released under humbler title of “elements towards” the Sustainable Mobility Roadmap [8] and by separating policy recommendations [10] that, instead of being signed by ministries, was signed by a list of willing stakeholders, a sort of a new coalitions, all heated exchanges and differences notwithstanding.

The list includes many car producers, as Toyota, Renault and several others, with the notable exception of Fiat / FCA.

3. Preliminary estimation of potential mitigation in the transport sector

The policy recommendations, with only partially reflected ours, do constitute a landscape of proposal that fully implemented could well lead to some 40% reduction of emissions by 2030 in the sector.
With the radical implementation of our additional proposals, and a conducive international and technological environment, as generated by countries, financial institutions and firms committed to the Paris Agreement and the Marrakech Partnership for Global Climate Action, including the Paris Process on Mobility and Climate, the transport sector can give an extremely important contribution in avoiding to exhaust the 1.5°C carbon budget, as the broader numerical simulation analysis presented by the author to the Oxford conference "1.5 Degrees: Meeting the challenges of the Paris Agreement" demonstrates [11].

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Coal fired power plants in Italy from past to future

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Introduction

A relevant source of global emissions of CO₂ from human activities is due to the industrial processes, mainly related to conversion of natural resources, production of iron and steel, production of chemicals [1]. The burning of fossil fuels to generate energy, in particular the combustion of coal, is considered one of the largest responsible for the industrial emissions of greenhouse gases into the atmosphere [2]. Moreover, globally coal combustion contributes for approximately 46% of direct carbon dioxide (CO₂) emissions from the overall fossil-fuel combustion [3].

This paper focuses on Italian coal power plants and reviews IPPC permits adopted for the Italian coal fired power plants as regulated by the recent EU legislation on integrated pollution prevention and control (IPPC-IED). According to such a piece of legislation, IPPC permits should be based on Best Available Techniques (BAT) in order to reach an adequate level of environmental protection and should establish all the necessary measures including operating conditions, emission limit values for relevant polluting substances as well as monitoring requirements. Possible emissions to water, air, soil as well as energy efficiency, waste production, use of raw materials as well as recovering and recycling, prevention of accidents and restoration of the site upon closure are taken into account in IPPC permits.

Measures such as co-generation of heat and power (CHP operating condition) or co-combustion of waste or biomass might be considered an efficient mean of increasing the energy efficiency in terms of lower fuel utilization and re-use of materials.
Furthermore, according to article 36 of the IED, all plants with a rated electrical output of 300 MWe or more should assess feasibility of carbon capture and storage or, eventually, retrofittability to meet the necessary conditions for CO₂ capture.

**Methodology**

For the present analysis Large Combustion Plants (LCP) with a total rated thermal input equal or greater than 50 MWth, are taken into account. In particular, it is described the assessment of the IPPC permits released by the Italian Ministry for the Environment, Land and Sea according to the IPPC-IED Directive 2010/75/UE on industrial emissions (IPPC-IED), as transposed by Decree 46/2014 [4, 5].

In fact, IED establishes that each installation must have a specific permit identifying all the necessary conditions to ensure a proper environmental management of installation. Such measures should be adopted in accordance to relevant BAT Conclusions or to the Integrated Pollution Prevention and Control Reference Documents (BRef), that identify the applicability of BATs, the specific emission limit values, the monitoring requirements to be applied.

**Discussion**

IPPC permits for coal fired combustion plants released at national level set stringent emission limit values due to the presence of heavy metals and other trace elements in coal. On this purpose many IPPC permits already applies emission limit values lower than those in 2006 LCP BRef and comparable to forthcoming BAT Conclusions (Table 1) [6].

As a consequence of first IPPC permits release, some LCPs performed main revamping by installing up-to-date emission abatement systems to prevent NOx, SO₂ and dust emissions, while some other installations, especially the older one, shut-down (Table 2 and Figure 1).

Thus, many coal LCPs are having their units fitted with SCR and dry low NOx burners for the abatement of NOx emissions as well as with wet/dry desulphurization for the abatement of sulphur emissions. The use of high quality carbon (< 1 % S) is also usually requested in the IPPC permit [6].
Table 1. Emission limit values set in some Italian permits for coal fired large combustion plants compared to references values associated with the BRef or the BAT Conclusions for LCPs [6].

<table>
<thead>
<tr>
<th>Combustion Plant</th>
<th>Capacity (MWt)</th>
<th>Pollutant</th>
<th>BRef (July 2006) (mg/Nm³)</th>
<th>BAT Conclusions (2017) (mg/Nm³)</th>
<th>AIA Limit value (mg/Nm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combustion Plant n.1</td>
<td>4,260 as whole (3 units)</td>
<td>NOₓ</td>
<td>90 – 150 (d.a.)</td>
<td>&lt;85 – 200 (d.a.)</td>
<td>80 (d.a.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>65 – 150 (y.a.)</td>
<td>65 – 150 (y.a.)</td>
<td>100 (d.a.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SO₂</td>
<td>20 – 150 (d.a.)</td>
<td>25 – 205 (d.a.)</td>
<td>80 (d.a.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>10 – 130 (y.a.)</td>
<td>10 – 130 (y.a.)</td>
<td>100 (h.a.)</td>
</tr>
<tr>
<td>Combustion Plant n. 2</td>
<td>6,560 as whole (4 units of 1,640 each)</td>
<td>NOₓ</td>
<td>90 – 200 (d.a.)</td>
<td>&lt;85 – 200 (d.a.)</td>
<td>150 (m.a.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>65 – 150 (y.a.)</td>
<td>65 – 150 (y.a.)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SO₂</td>
<td>20 – 200 (d.a.)</td>
<td>25 – 205 (d.a.)</td>
<td>150 (m.a.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>10 – 130 (y.a.)</td>
<td>10 – 130 (y.a.)</td>
<td></td>
</tr>
<tr>
<td>Combustion Plant n. 3</td>
<td>Unit 1: 420</td>
<td>NOₓ</td>
<td>90 – 200 (d.a.)</td>
<td>&lt;85 – 200 (d.a.)</td>
<td>180 (d.a.)</td>
</tr>
<tr>
<td></td>
<td>Unit 2: 435</td>
<td></td>
<td>65 – 150 (y.a.)</td>
<td>65 – 150 (y.a.)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SO₂</td>
<td>20 – 200 (d.a.)</td>
<td>25 – 205 (d.a.)</td>
<td>200 (m.a.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>10 – 130 (y.a.)</td>
<td>10 – 130 (y.a.)</td>
<td>220 (48h a.)</td>
</tr>
<tr>
<td>Combustion Plant n. 4</td>
<td>Unit 1: 415</td>
<td>NOₓ</td>
<td>90 – 200 (d.a.)</td>
<td>&lt;85 – 200 (d.a.)</td>
<td>200 (m.a.)</td>
</tr>
<tr>
<td></td>
<td>Unit 2: 430</td>
<td></td>
<td>65 – 150 (y.a.)</td>
<td>65 – 150 (y.a.)</td>
<td>220 (48h a.)</td>
</tr>
<tr>
<td></td>
<td>Unit 3: 793</td>
<td>SO₂</td>
<td>20 – 200 (d.a.)</td>
<td>25 – 205 (d.a.)</td>
<td>200 (m.a.)</td>
</tr>
<tr>
<td></td>
<td>Unit 4: 793</td>
<td></td>
<td>10 – 130 (y.a.)</td>
<td>10 – 130 (y.a.)</td>
<td>220 (48h a.)</td>
</tr>
<tr>
<td>Combustion Plant n. 5</td>
<td>Unit 3 200</td>
<td>NOₓ</td>
<td>90 – 200 (d.a.)</td>
<td>155-210 (d.a.)</td>
<td>200 (d.a.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>100 – 180 (y.a.)</td>
<td>100 – 180 (y.a.)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SO₂</td>
<td>100 – 250 (d.a.)</td>
<td>135-220 (d.a.)</td>
<td>250 (d.a.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>95 – 200 (y.a.)</td>
<td>95 – 200 (y.a.)</td>
<td></td>
</tr>
</tbody>
</table>

h.a. = hourly average
d.a. = daily average
m.a. = monthly average
y.a. = yearly average
48 h a. = 48 hours average

It should be noted that the installation n. 1 in Table 1 has been recognized as a reference for its excellent environmental performances due to state of the art abatement systems as well as the advanced measures for preventing releases of dust from the storage and handling of coal, ashes, gypsum, limestone. In fact, coal stockpiles are stored in domes and moved using enclosed conveyors [3, 6].

On the other hand, there are other installations associating the production of electricity to co-generation of heat and power for district heating (n. 5 in Table 2) or co-combustion of peat, wood and coal (n. 10 and 11) [6].
Finally, in installation n. 4 in Table 2, located in north Italy, co-combustion has been applying waste/residues co-incineration for the reduction of resources use and minimization of waste disposal [6]. As a matter of fact, the co-incineration of biomass waste and other waste with lower specific CO2 emissions than the fuel is one option to reduce greenhouse gas emissions [3].

<table>
<thead>
<tr>
<th>Combustion plant</th>
<th>Condition</th>
<th>Year of start of activity</th>
<th>Year of the last revamping</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combustion Plant n.1</td>
<td>In exercise</td>
<td>2009-2010</td>
<td>2009-2010</td>
</tr>
<tr>
<td>Combustion Plant n.2</td>
<td>In exercise</td>
<td>1991-1993</td>
<td>1998</td>
</tr>
<tr>
<td>Combustion Plant n.3</td>
<td>In exercise</td>
<td>1965-1970</td>
<td>2016</td>
</tr>
<tr>
<td>Combustion Plant n.5</td>
<td>In exercise</td>
<td>1972</td>
<td>2013</td>
</tr>
<tr>
<td>Combustion Plant n.6</td>
<td>Shut-down</td>
<td>1952-1960</td>
<td></td>
</tr>
<tr>
<td>Combustion Plant n.7</td>
<td>Shut-down *</td>
<td>1989-1990</td>
<td></td>
</tr>
<tr>
<td>Combustion Plant n.8</td>
<td>In exercise</td>
<td>1969</td>
<td>2001</td>
</tr>
<tr>
<td>Combustion Plant n.9</td>
<td>Shut-down</td>
<td>1971</td>
<td></td>
</tr>
<tr>
<td>Combustion Plant n.10</td>
<td>In exercise</td>
<td>1986-2005</td>
<td>2002-2005</td>
</tr>
</tbody>
</table>

* In exercise only for eventual request for safety of the national grid

In Italy, in coherence with the European Union legislation and the global international framework of policies aimed to the reduction of CO2 emissions, some LCPs were shut down since they were not in line with the foreseen environmental performance, while other LCPs performed main revamping with advanced emission abatement systems. Thus, national coal fired power plants in exercise are already compliant with relevant LCP BAT Conclusions recently adopted by the European Commission [6 and 7].
Conclusions

This paper reviews IPPC permits released to coal power plants and low carbon technologies associated to the Italian IPPC licensing framework in order to achieve an adequate level of environmental protection and, as a result, a reduction of CO$_2$ emissions.

A synthesis of relevant emission limit values in IPPC permit releases to such installations is provided together with other information published on the AIA Portal [6].

Keywords: Decarbonisation, coal, Large combustion plants, IPPC.

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Where to leave fossil fuels underground?
Multicriteria GIS Analysis to assess unburnable carbon areas in Bolivia and Italy

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Abstract

Since the first Earth Summit on Climate Change of Rio in 1992, the social, political and scientific debate on relationships between global warming and the use of fossil fuels has been showing an exponential increase, highlighting how development policies should be strongly linked to environmental and energy sustainability.

The main reference point concerning climate change studies, policies and agreements is the United Nations Framework Convention on Climate Change (UNFCCC) and its Conference of the Parties (COP) [1]. In particular, the COP21 of 2015 with the Paris Agreements reaffirms the aim to reach a significant reduction in global greenhouse gases emissions from 2020, in order to maintain world temperature below 2°C above pre-industrial levels, to avoid or reduce the worst climate change impacts [2, 3]. Recent studies affirm that for the period between 2011 and 2050 cumulative CO2 emissions must remain between 870 and 1240 Gt to avoid exceeding the 2°C threshold [4].

International decarbonisation policies and strategies usually foresee actions to progressively increase the use of renewable energies and to promote energy efficiency, low-carbon lifestyle and the scientific research in carbon capture and storage technologies [5, 6]. Within these efforts emerge the lack of one open question of great importance, in our view, that is the need to establish policies and
actions aimed to leave part of fossil fuels underground, a concept that in literature is expressed with the term “unburnable carbon” or “unburnable fossil fuel”. In fact, in the article published by Nature in 2015, it is estimated that to keep the temperature from increasing by 2°C, more than 80% of coal, 50% of gas and 30% of oil reserves must remain in unburnable underground [4].

Globally, only one political experiment was carried out between 2007 and 2013 in Ecuador about the Yasuní National Park, which aimed to not extract hydrocarbons, with the simultaneous creation of an international compensation fund. Although the international initiative, called “Yasuní-ITT”, has been abandoned, the idea is still supported by the scientific community and civil society that have created the neologism “Yasunisation” [7]. At the state of the art, general fossil fuel underground targets have been set at national or regional level, but the definition of methodologies and geographical criteria to define where to leave fossil fuel untapped remains still unexplored.

In fact, it should be remembered that limiting hydrocarbon extraction does not only benefit for the avoided emissions of greenhouse gases, but that the different phases (exploration, production, refining, transportation) may cause various direct and indirect socio-environmental impacts, ranging from deforestation to noise pollution and water resources contamination, to socio-environmental conflicts [8].

On the basis of these premises, the University of Padova has started in 2016 a research project, which aims are: 1) to map, at a global scale, relationships and impacts between on-shore oil and gas activities and highly sensitive and diverse cultural and biological areas; 2) to define geographical criteria and methodologies to identify unburnable carbon areas or where these oil and gas activities should be carried out with best practices. To reach these ambitious aims, we are carrying out and testing different methodologies in different countries, following these successive and complementary steps: literature review concerning oil and gas activities, their economic benefits and their socio-environmental impacts; spatial and non spatial data mining about oil and gas activities (such as wells, pipelines, seismic, concessions), ecological and conservation features (such as protected areas and ecosystems), environmental and geographical layers (Digital Elevation Models, rivers, boundaries, etc.), anthropic and cultural dataset (indigenous territories, road network, land use land cover, etc.) from different national and international sources; the construction of an open source geodatabase in Geographic Information System (GIS)
environment, using the open source GIS software QGIS; different spatial analysis (overlay, spatial geometries calculation, etc.) to analyze the spatial relationships between the different dataset; and finally, different spatial Multiple Criteria Decision Analysis (spatial MCDA), methods that allow to compare different alternatives and choose the best one on the basis of different geographical criteria [9]. We carried out this process through the simulation of public debate and expert consultation processes to define the types and weights of the criteria to use, if they should be considered as costs or benefits and the GIS analysis with different tools, such as the QGIS Vector MCDA plugin. In this paper we present some results of the spatial MCDA carried out in two study cases that represent different realities from the opposite sides of the world: 1) Bolivia in South America, a developing country that is very rich in biodiversity and with more than 65% of its population represented by indigenous people, where oil & gas sector is considered strategic with many projects in development, mainly in the Amazon Region that occupy the 30% of its territory, causing different conflicts with indigenous communities; 2) and Italy, that is one of the most highly density populated and biodiverse country of Europe, with more than 25% of its territory under some form of conservation, and where oil & gas activities make it the 4th European producer, with Val d’Agri (Basilicata region) that is the main European on-shore oil field. In particular, we want to focus the attention and propose reflections about the spatial MCDA analysis process carried out to define which oil and gas blocks, i.e. the areas under concession, should be closed or developed with best practices or, on contrary the production may go on, on the basis of different spatial socio-environmental, economic and productive criteria. Preliminary results highlight that, closing the worst blocks according to the Spatial MCDA ranking, Bolivia could avoid possible oil and gas related impacts on the 30% of Indigenous territories and 11% of protected areas within blocks, while Italy on the 18% of its protected areas within blocks. This work reveals the complexity and usefulness of this kind of tool in decision-making process, opening questions about the involvement of the stakeholders, the availability and quality of spatial data used, the criteria and criteria weights selection and if they should be considered as costs or benefits. Keywords: unburnable carbon, unburnable fossil fuel, spatial MCDA, Yasunisation, GIS analysis.
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Heterogeneity in the national contributions to the Social Cost of Carbon

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Abstract

The current estimates of the social cost of carbon (SCC) do not take into account the heterogeneities of the climate impacts in space and in time. In this study, we compute the SCC at country level using recent developments in the computation of the marginal effect of emissions on temperature projections [1] and the estimation of the impacts of climate change [2].

The social cost of carbon can be a valuable tool to formulate climate policy, as it summarizes both the cost and the benefits from climate change, and provides value in dollar per ton of emitted carbon. At country-scale, the country-level SCC can be seen as the willingness to pay of the country for reducing its emissions. It represents the national contribution to the global SCC, which can then be simply obtained by summing up all the country-level SCCs.

Usually, the estimates of the SCC are computed using integrated assessment models which use a highly aggregate damage function. In July 2015, the U.S. Environmental Protection Agency (EPA) provided a revised version of their estimation of the SCC using three models: DICE, FUND and PAGE, varying emission projections and the discount rates. We would like to compare the two methodologies. Preliminary results show that our estimate of the SCC is higher than these current estimates in the literature.

The value of the SCC is highly sensitive to the projections of the future emissions. To span the socioeconomic uncertainty space (regarding mitigation and adaptation), we make use of the five Shared Socioeconomic Pathways (SSPs) [3]. The SSP scenarios
are narratives describing five rather different, but still likely futures regarding global and regional developments of technological progress, markets developments, convergence, and population dynamics. In this study, we use two socioeconomic drivers of the SSP, GDP and population, as they have been implemented and quantified by the OECD for GDP and by IIASA for the population.

The projections of the temperature increase are coming from CMIP5 (Taylor et al. 2012). The gridded surface air temperature generated by the general circulation models are converted into the population-weighted average. Country temperature projections are then obtained by combining the cells covering each country. To reflect the diversity of the SSPs, we use the temperature projections of three Representative Concentration Pathways (RCPs), RCP4.5, RCP6.0, and RCP8.5.

Using the outcomes from the CMIP5 ensemble, and using several carbon cycle models, it is possible to obtain the effect of an additional increase in emissions (1 GtCO$_2$) at a given period [1]. We obtain the gridded temperature under these new conditions, and we compute the same way the population-average temperature at each grid and for each country.

Last studies about the SCC used regional or global aggregate climate damages in integrated assessment models. Damages are expressed as a proportion of per capita GDP and are linked to the temperature increase with a convex damage function calibrated on highly aggregated estimates of the economic impacts of climate change. Here, we use a recently developed damage function which captures the nonlinear effect of local temperature on the annual economic productivity [2].

This function is calibrated on historical economic and weather data and is valid for the whole globe in which the average annual per capita GDP for each country is obtained by combining the country-specific SSP growth rate in the reference scenario and the additional effect of warming on growth (relative to the period 1960-2010 during which the function has been calibrated). We use a functional form that differentiates the rich and the poor countries in the temperature’s response.

With the help of a baseline projection of temperature changes, it is possible to compute the economic impacts (costs and benefits) of climate change on the per capita GDP using the damage function defined earlier.
The social cost of carbon is the discounted extra cost induced by a minimal increase in emissions, i.e. the derivative of the economic impacts of climate change.

We consider that each country ignores the damages outside its territory. We also exclude the case when the impacts abroad would reduce its welfare as we are not able to quantify this effect. Regarding equity, this is a sovereignty policy position [4]. In our setup, the country-level SCC can be computed as 

$$SCC = \sum_{t} \frac{\delta Y_{t}}{\delta E_{0}} L_{t} (1 + \rho + \epsilon g_{t})^{-t},$$

where $E_{0}$ are the CO$_2$ emissions in the impulse year ($t = 0$), $L_{t}$ is the population, $\rho$ is the pure rate of time preference, $\epsilon$ represents the inequality aversion and $g_{t}$ is the average annual growth rate.

As results, for a discounting of 5% and the SSP2 scenario, the estimates of the SCC range from -11$/tCO_{2}$ for Russia to 35$/tCO_{2}$ for India. Brazil, Nigeria, and Indonesia have an SCC around 6$/tCO_{2}$ (see Figure 1). To summarize, tropical countries have positive SCC while the countries located have a positive SCC. These results reflect the climate projections, where the warming is largely dependent on the latitude. Other variations are coming from the size of the economy, the biggest economy under the tropical latitudes have the highest social cost of carbon.

Figure 1: Country-level estimates of the social cost of carbon for an SSP2 scenario at present value with a discounting rate of 5%
Table 1: World social cost of carbon across SSPs at present value discounted at 5%

The world SCC range from 51 to 122$/tCO₂ (Table 1). SSP2, which is the “middle of the road” scenario, lies in the midst of the range with 83$/tCO₂. This large range shows how much the SCC is sensitive to the socio-economic baseline assumptions.

By way of comparison, the revised social cost for the year 2020 at a discount rate of 5% is estimated at 12$ 2007/tCO₂ [5]. Our estimates are all higher, and this is plausibly due to the introduction of the heterogeneity in the climate damages. Our results also explore the various dimension of uncertainty: the climate uncertainty, the damage function specification and the utility preferences (time, inequality aversion and discount rate).

**Keywords**: Social cost of carbon, climate damages, national policy, heterogeneity.

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Global Air Quality Index under different socioeconomic and climate scenarios

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Abstract

We estimate a global air quality index (AQI) that is adaptable to the results produced by the global integrated assessment models and provides insight on regional and global future air quality. The aim of this work is to provide an AQI that is meaningful for global environmental action at the time and spatial scale of IAMs; and to study how it varies across several socioeconomic and climate assumptions.

We used the SSP-RCP (socioeconomic shared pathway - Representative Concentration Pathways) air pollutant's emission database and the model FASST(R) to compute the future concentration metrics for all the possible socioeconomic and climate policies scenario combination. This work builds on these concentration metrics to develop a global air quality index that can be used at the regional and temporal scales of the integrated assessment models, in order to provide a quantification of the impacts and to support the regional decision making process. The SSP-RCP set of scenarios are the most recent scenario exercise for the IPCC's next assessment report, they combine a set of regional air pollution control narratives and radiative forcing-climate goals.

We build on the YACAQI (Yearly Average Common Air Quality Index), which is based on yearly averages, proposed by the CITEAIR II project [1]: the YACAQI provides information that helps policy makers to orient and design their local air pollution policies to prevent the air quality levels to exceed the legal standards that are considered dangerous for human health. Although some information is lost on the calculation of the AQI, there is always a scientific base for the limits used in the calculation of the index that reflect the impacts on human health [2]. In this work we focus on the most relevant pollutants and on the annual mean concentrations from the IAM emissions pathways.
The air quality index provides insights on impacts and co-benefits of climate policies (through different RCPs) and different socioeconomic scenarios (SSPs) in terms of air quality. It aggregates information on public health that can be used in sustainable integrated policy decision process. The AQI construction entails a loss of information. Nevertheless it is very useful for many other reasons, such as general public information and awareness, civil society organizations, and policy making. As noted by [3], indices can be used not only to inform the public, but also to assist policy making either by evaluating air pollution measures or by supporting the policy optimization and ultimately to control legislative compliance. Additionally, the AQI can be used to represent the health dimension when considering a multi-criteria welfare analysis of different policies and scenarios of sustainable long-term integrated policies.

We explore different formulations of the Global Air Quality Index, in order to assess the impact of the different multi-pollutant aggregation methods.

A global yearly index, trends to smooth the ‘nasty’ impact outcomes, even if the spatial aggregation uses population weighting method in order to better capture the effect of population exposure. It does not provide information on how many people are actually exposed to poor air quality on an average yearly basis. At such regional aggregation level it is important to capture the local effects, such as the fraction of population that is exposed to annual concentrations above the limits and above very high levels such as the double of the thresholds. The fractions of population exposed to high pollution levels were calculated.

The results of the Global AQI are presented in Figure 1. The fine particles (PM2.5) are the most problematic pollutant, bringing the AQI values up especially in the Asian region.

Both the socioeconomic and the climate scenario assumptions (SSPs and RCPs) play a role on air quality improvement however, climate policies, the RCPs, are generally more relevant in reducing air pollution in the considered set of scenarios.
Fig. 1: The global AQI of all regions, across the SSP and RCPs. The shaded area represents the model range. The Total Radiative Forcing (TRF) for the reference scenario is presented for comparison with the climate policies.

Not surprisingly, SSP3 is the most problematic of the socioeconomic baseline in terms of air quality. On the other hand, SSP1 is the scenario where the greatest improvements on air quality are realized, even when compared with SSP5. In terms of regional detail, the Asian region faces the highest challenges as far as air quality compliance is concerned and OECD shows the highest improvements. Additionally, we provide an on-line tool (https://datashowb.shinyapps.io/AQIvis/) that is publicly available and allows to explore the future long-term air quality indicator, across the five SSPs and the climate policy dimension represented by the RCPs.

**Keywords:** Global AQI, Air pollution impacts, SSPs-RCPs
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Connecting economic and environmental gains – the circular economy

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- Van der Tak C.M., Nutawa Sagl, Switzerland, *Mitigation and carbon loans & bonds*
- Glynn P., Bond University, Queensland Australia, *Business, organized labour and climate policy. Forging a role at the negotiating table*
- Sanna L., CNR-IBIMET, *Eco-sustainable dairy sheep production: an LCA approach from Sardinia, Italy*
- Dasgupta S., FEEM - Ca’ Foscari University of Venice, *Climatic Exposure and Economic Activity – An Update*
Mitigation and carbon loans & bonds

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Abstract

Developing countries needs finance to meet their national climate change goals, as was recently again confirmed through a UNFCCC survey. Provision of finance is an obligation of developed countries under the UNFCCC and its Paris Agreement. A straightforward climate finance deal might seem possible, however, in practice climate finance has been slow in coming. A recent study [1] and policy brief [2] prepared by the ClimaSouth¹ project, an EU funded development cooperation project building climate change in North Africa (Algeria, Egypt, Libya, Morocco, Tunisia) and the Middle East (Israel, Jordan, Lebanon, Palestine) have proposed a new climate finance instrument, mitigation bonds & mitigation loans, to fill part of this gap. This paper formally analyzes the mitigation bonds and mitigation loans concept, and discusses several possible extensions.

Mitigation loans are zero- or very-low-interest loans invested in mitigation projects and programs in developing countries, which, instead of yielding interest, provide as a return on the investment a share in the mitigation results obtained, transferred to the investors as internationally transferred mitigation outcomes (ITMOs). Mitigation loan borrowers will typically be private sector entities, or in any case, non-sovereign borrowers. Mitigation bonds are zero- or very-low interest rate bonds, and the proceeds of their issue are invested in mitigation loans. Like mitigation loans, mitigation bonds provide as a return on the investment a share in the mitigation results obtained, transferred as ITMOs.

Simulations of these instruments projecting return on investment and return on equity as well as shifts in greenhouse gas mitigation cost curves show that these novel

¹ Formally named “Climate Change Mitigation and Adaptation in the ENPI South Region”. See http://www.climasouth.eu/.
climate finance instruments are attractive for both the provider of climate finance and the parties seeking climate finance, providing adequate returns and incentives to invest in mitigation projects and programs as well as revolving financing constraints for mitigation projects.

**Keywords:** Climate finance, mitigation bonds, carbon bonds

**REFERENCES**


Business, organized labour and climate policy: 
Forging a role at the negotiating table¹

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Abstract

Climate change policy has an impact across all levels and sections of society and not the least on the labour market, yet climate change policy rarely provides for labour market planning. Absent are the strategies necessary to ensure the workforce is available in the number and with the skills required to meet the demands of the new low carbon marketplace, and to provide a fair and just transition for those workers displaced by those policies. Employers organisations and trade unions are best placed to advise governments and to advocate in the interests of their membership, yet it appears to have been of little effect.

This paper examines the role of employers’ organisations and trade unions in the process of developing of climate change policy using case studies in 6 developed and 2 developing economies, and the European Union. The research finds that climate change was not generally a part of organisation policy and nor was it being prioritized, and neither do they have the capacity to take on this additional role.

The paper also provides a rationale for the selection of a theoretical framework for investigating policymaking processes and its validity for framing policy on climate change.

Objective: This research project questions of the role of employers’ organisations and trade unions in the development of climate change policy. It discusses whether labour market considerations should be an element of climate change policy, the role of civil society actors including employers’ organisations and trade unions, and how a theoretical framework can guide the consideration of these issues in the policy development process. The research tests the hypotheses:

- 1) The labour market is significantly impacted by climate change policy
- 2) Employers organisations and trade unions are important actors in the development and implementation of climate change policy
- 3) A theoretical framework can guide the policy development process
• 4) Employers organisations and trade unions are important actors in the theoretical framework of ecological modernisation

Methodology: The research is a qualitative study of employers’ organisations and trade unions using case studies in the European Union, UK, France and Germany, along with the non-EU countries of Australia, Canada, Singapore, India and Kenya. As well, a survey conducted across a broader community of stakeholders assessed the respective expectations of employers’ organisations and trade unions, their networks and influence, commitment and capacity. The case studies and survey were also used to help inform the analysis of the theoretical framework of ecological modernisation.

Key findings: The research establishes the effectiveness of public policy, and the role of stakeholders in structures and processes of climate change related policymaking. Research published in 2007 and 2008 was instrumental in creating awareness of the employment and workplace impacts of climate change policy. The Worldwatch Institute’s (2008)2 report for the ILO encapsulates the findings that are common across research on the subject: due to the impact of climate change on public policy and the economy, there will be a consequential impact on the labour market and some jobs will be lost, some jobs will be created and some jobs will change. On balance, there will be a modest net growth in employment and all sectors of industry will be affected. It is contended by the ILO that governments must have policy to manage these changes and that social protection systems need to be in place to afford workers a just transition. The 2012 research by the International Labour Organizations’ (ILO) International Institute of Labour Studies (ILO, 2012)3, updating the Worldwatch Institute (2008) Report reiterates the earlier findings, adding that outcomes for employment and incomes are largely determined by the policy instruments and the institutions (that is, the governance systems) that implement them, rather than being an inherent part of a shift to a greener economy.

Despite the earlier reports of the ILO and others, and the research for this project that finds domestic labour market planning is essential in responding to climate change, this project also finds that labour market and climate change policies are not linked. Second, although employers’ organizations and trade unions are influential as climate change activists within civil society, they are not effective advocates when it comes to substantively influencing climate change policy or attracting attention to the labour market impacts of climate change. The research for this project also highlights the importance of understanding the governance
Employers organisations and trade unions are important actors in the theoretical framework of ecological modernisation.

Methodology: The research is a qualitative study of employers' organisations and trade unions using case studies in the European Union, UK, France and Germany, along with the non-EU countries of Australia, Canada, Singapore, India and Kenya. As well, a survey conducted across a broader community of stakeholders assessed the respective expectations of employers' organisations and trade unions, their networks and influence, commitment and capacity. The case studies and survey were also used to help inform the analysis of the theoretical framework of ecological modernisation.

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The research for this project also highlights the importance of understanding the governance of climate change policy and its contribution to monitoring and evaluating the role of non-state actors such as business and labour in policymaking.

It was also found that although the theorists' contend the theoretical framework of ecological modernisation (EM) is shaping the discourse in environmental politics, the international, regional and national policies and policy development processes profiled are not guided by EM or any other theoretical framework. The research then considered the questions of whether and how EM could be extended as a practical guide to inform the policy development process and, if so, could EM be a tool to bridge the gap that exists between performance and the ambition of those policies? The findings are in the affirmative but within the constraint of the range of, in most cases, the multiple objectives of the policies and the commitments of the stakeholders.

Summary and conclusion: The research finds that climate change has and will have significant impacts on labour markets. Despite this, the consequential requirements for labour market planning are not always priorities for employers' organizations and trade unions. In addition, the policy development processes do not always benefit from the important contribution these organizations can bring to the table.

The research concludes that participation of civil society organisations in climate change-related deliberations, particularly around issues of inclusiveness, equality, transparency and resources, must be addressed both by ecological modernization theory and policymaking processes if business and labour are truly to have a seat at the negotiating table and make a productive contribution to the desired ecological outcome.

**Keywords:** Climate policy, employers organisations, trade unions, ecological modernisation
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Eco-sustainable dairy sheep production: an LCA approach from Sardinia, Italy

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Abstract

In December 2015 the first universal and legally binding worldwide climate agreement was adopted by 195 countries during the COP21 Paris Climate Conference. With this agreement, governments set out a comprehensive action plan in the context of sustainable development to bring the world back on track to avoid dangerous climate change by limiting the average global temperature rise well below 2 oC, as this would significantly mitigate the impacts of climate change [1]. Moreover, they recognize the fundamental priority of safeguarding food security and its particular vulnerability to the adverse effects of climate change.

In order to achieve the long-term temperature goal, one of the European Union financial instrument supporting climate change mitigation action is the LIFE programme [2]. It implements innovative solutions that help the greenhouse gas emissions reduction in different economic segments, also in non EU ETS sectors as agri-food production systems [3].

In this framework, in July 2016 the SheepToShip LIFE project was financed by the EU LIFE Programme Climate Action 2014-2020 with the aim to reduce the greenhouse gas emissions from the dairy sheep sector in Sardinia, an absolute leader on dairy sheep raising [4]. In particular, the main objective of the project is to reduce by 20% in 10 years GHG emissions (nitrous oxide, methane and carbon dioxide) from the Sardinian dairy sheep supply chain. The immediate goals of the project are to encourage the environmental improvements of production systems in the sheep sector and to demonstrate the environmental, economic and social benefits deriving from eco-innovation in the dairy industry and sheep farming sector. Additionally, its actions promote the implementation of environmental policies and rural development, guided by the Life Cycle Thinking approach, and aimed at enhancing the environmental quality of local sheep’s milk and cheese supply chains. Furthermore, one of the
project scopes is to increase the level of knowledge and awareness of stakeholders and the general public regarding the environmental sustainability of products made from sheep’s milk and their contribution to the mitigation of climate change.

With this approach, the project expects to achieve the development of a common methodology for analysing the life-cycle of sheep’s milk supply chains. This procedure will be used to determine the environmental impact of the sheep’s milk business in Sardinia, including the environmental hotspots of the life-cycle of Sardinian Protected Designation of Origin (PDO) sheep’s cheese, and will be tested in several cases study (sheep farms and sheep dairy businesses) through the introduction of low-input techniques compatible with maintaining quality standards of products.

During the first year, the organizational structure together with the management and operational tools were defined by the characterization of dairy sheep production systems in Sardinia. This provides an overview of Sardinian dairy sheep sector and the methodology to distinguish and discriminate the main dairy sheep production systems in this Island. This methodology is also implemented on a wide database to characterize the sheep farms within the main production systems and to evaluate the most frequent values of key indicators of farm size, intensification level and performance and their variability within each production system.

Through this preparatory phase, the analysis of the environmental implications of the sheep milk supply chain was compiled revising the state of the art on the climate impact of the sheep sector. LCA studies on sheep farm productions (meat, wool, milk and cheese, ecosystem services) and on post-farm emissions were reviewed focusing their methodological approach and main outcomes. Studies aiming at the most important biological and technical option for the reduction of methane emissions, nitrogen excreta and variation of soil carbon stock were also discussed. This effort allowed deducing important information for the planning of emission mitigation strategies to be applied in dairy sheep sector at territorial level in the European sheep farming systems.

Moreover, on the basis of this information, the guidelines for LCA application on Mediterranean dairy sheep supply chains were delivered. These guidelines are mainly addressed to key methodological issues of LCA studies in agri-food sector, which represent the main challenge for enabling the reliable environmental assessment of Mediterranean dairy sheep supply chains. The methodology illustrated is based on and conform to the European standards of the main LCA’s international guidelines. Also a LCA data collection handbook containing the practical guidelines and the methodological standards concerning on-field data collection for LCA studies carried out within the SheepToShip LIFE project was provided.

The next steps will be the release of the reports on good practices for sheep farming and
dairy businesses using sheep’s milk for the mitigation of the sector’s environmental impact. The optimal management policies needed to reduce environmental impacts will be also identified for each type of production system.

The strategy of the project includes the dissemination of results for exchanging best practices and transferring innovative methods and technologies. Besides, an important project aspect will be the engagement with stakeholders to drive eco-innovation and environmental improvement of sheep farming techniques and industrial cheese-making processes, finalized to the elaboration and implementation of an Environmental Action Plan for the Sardinian dairy sheep sector.

**Keywords:** agricultural method, dairy sheep productions, emission reduction, greenhouse gas, land use.

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Climatic exposure and economic activity – An update

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Introduction
This paper provides updated climatic tipping-points and optimal conditions [1, 2] to maximize economic activity using high-resolution spatial data. We also analyze if the optimal conditions have shifted over the last forty years (1980, 1990, 2000, and 2010). Using data at 1° × 1° resolution and robust econometric techniques, we argue that economic activity is a function of geographic factors rather than demographic factors. The high-resolution data allows us choice over the level of aggregation at which to conduct the analysis; this is useful as some types of measurement error could counterintuitively favor a more aggregated level of analysis.

We use gridded economic activity and population data from the Global Carbon Project’s (GCP) dataset (Murakami and Yamagata 2016). The dataset provides global population and GDP scenarios in grids of 0.5° by 0.5° by country between 1980 and 2100 for every ten years. Actual populations and GDPs by country were downscaled to estimate the high-resolution spatial data between 1980 and 2010. The climatic data, extracted from Global Land Data Assimilation System (GLDAS) version 2, a land surface mode providing data at 1° by 1° and 3-hourly resolution [3] (Rodell et al. 2004).

Methodology
We begin by estimating the following multivariate cross-section regression with the natural log of Gross Domestic Product (GDP) as the dependent variable and controlling for mean temperature, mean precipitation, their second-degree polynomials, the type of soil in each grid, and the elevation characteristic of each grid;

\[
\ln(y_{ij}) = \theta_j + \beta_1 T_{ij} + \beta_2 T_{ij}^2 + \beta_3 P_{ij} + \beta_4 P_{ij}^2 + \beta_5 S_{ij} + \beta_6 R_{ij} + \beta_7 R_{ij}^2 + \epsilon_{ij}
\]
where $i$ and $j$ represents the grids and the countries, respectively. The dependent variable $y_{itj}$ is the natural log of downscaled GDP at each grid, $\beta_{0j}$ represents country fixed-effects, while $T$ and $P$ are decadal mean temperature and precipitation (and their second-degree polynomials). $S$ is a categorical variable representing soil properties [4] (Zobler 1999), while $R$ (roughness and its second-degree polynomial) is the dispersion measured as the difference between the maximum and the minimum value of a grid elevation and its eight surrounding grids. We also control for the Terrain Ruggedness Index (TRI), the mean of the absolute differences between the value of a grid and the value of its eight surrounding grids.

**Results**

Our results suggest that the optimal temperature for the decade ending 1980 was 17.2°C. However, the optimal decadal mean precipitation is slightly higher at 1,534.6 mm. For the decade ending in 1990, the optimal decadal mean temperature was estimated at 17.8°C. The decadal optimal mean temperature remained steady at 17.6°C during the decade ending in 2000 and 2010 – 0.4°C higher than the first decade in our dataset (1971 – 1980). The optimal decadal mean precipitation for maximizing economic activity at the global level declined from the 1971 – 1980 level by around 60 mm during 1981 – 1990 but increased to the level of the first decade before increasing further by approximately 50 mm during the decade of 2001 – 2010.

**Figure 1: Global Decadal Temperature and Economic Activity: 1980 - 2010**

The main specification is a panel analysis using the four time periods with three fixed-effects; coordinate ($i$), country ($j$), and year ($t$). The results suggest lower optimums conditions (13.4°C) also but much narrower confidence intervals.
Spatial Econometrics

It is likely that the economic activity in the grids is spatially dependent on the values observed in the neighboring grids. It is critical that we utilize spatial regressions to investigate the relationship between climatic variables and economic activity, not only due to the likely spatial dependence of the data but also because this is a novel contribution to the literature [1]. Using Moran’s $I$ test for spatial autocorrelation, we can reject the null hypothesis of spatial independence for all the years. We utilize spatial regressions with several spatial weight matrices to control for spatial dependence among the grids and to compute robust optimal conditions to maximize economic activity.

A spatial lag model can be expressed as,

$$y_{ij} = \rho W y_{ij} + X r_{ij} + \epsilon_{ij} \quad (3)$$

where $\rho$ is a spatial autoregressive coefficient, $\epsilon_{ij}$ is a vector of error terms and $W$ is the spatial weight matrix, defined by the three methods above. The term $\rho W y_{ij}$ measures the potential spillover effect that occurs in economic activity if this outcome is influenced by the economic activity in other grids, where the location or distance to other observations is a factor determining the spillover effect. Thus, the neighbors for each observation have greater (or in some cases less) influence on the economic activity in a particular grids, independent of the explanatory variables (Baltagi 2003).
Results from the spatial regression suggest that the optimal temperature to maximize global economic activity has declined from 15.4°C in 1980 to 14.1°C in 2010. However, these optimal temperatures are still significantly higher than the 12°C and 13°C computed by [1, 2] but suggests a declining trend in optimal mean temperature. The optimal mean precipitation has increased in the last four decades (3.8 mm in 1980 to 5 mm in 2010).

**Projections**
We use the delta method to compute projections to investigate the impact of climate change on economic activity by the end of the 21st century. We find that under the RCP 8.5 scenario, there will be a 43.4% decline in economic activity.

**Conclusion**
This paper provides an update of the relationship between climatic and geographic variables using the highest resolution economic activity and climatic data available. The results confirm the highly non-linear relationship between climatic exposure and economic activity and that there is a threshold climatic level for maximizing economic activity. We find that the global daily mean optimal temperature between 1980 and 2010 is 13.4°C and as temperature increases beyond this threshold, there is a negative impact on economic activity. Finally, our results suggest that there will be a 43.4% decline in economic activity due to climate change by the end of the 21st century.

**Keywords:** climate change; economic activity; optimal conditions; tipping-points; spatial analysis
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Climate impacts in Europe

Chair: Carlo Barbante

- Bosello F., CMCC-FEEM, Soil erosion in the European Union: from direct costs to macro-economic effects
- Noce S., CMCC, Changes in Forest Species Suitability, Distribution and Diversity Under Future Climate: the Case of Southern Europe
- Scoccimarro E., CMCC, The role of humidity in determining perceived temperature extremes scenarios in Europe
- Giordano F., ISPRA, Selecting And Evaluating Climate Change Impact Indicators Towards a National Framework for Italy
- Pasini A., IIA-CNR, Institute of Atmospheric Pollution Research, Influence of climatic changes on migration fluxes from the Sahel countries to Italy in the period 1995-2009
Soil erosion in the European Union: from direct costs to macro-economic effects

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Abstract

Soil erosion is one of the major threat to soil because it removes organic matter and important nutrients, preventing vegetation growth and overall biodiversity. In particular, soil erosion changes the physical, chemical and biological characteristics of soil causing a drop in potential agricultural productivity and raising concerns about food security, especially in the context of growing world population [1] [2].

The consequences of soil erosion for the society deserve the attention of the policy maker. According to [3], erosion affects 115 million hectares (ha) in Europe which is around 12% of the total land area. The EU Thematic Strategy for Soil Protection calls for policies able to protect soil and to mitigate soil degradation including soil erosion as a key priority for action. Soil erosion is also perceived as potential threat to development: Land Degradation Neutrality (LDN) is included in the recent international policy agreements (UNCCD, UNFCCC). The Sustainable Development Goals (SDGs) mention its importance [4]. A recent study [5] stresses the need to estimate the costs of land degradation at global scale, promoting the Economics of Land Degradation (ELD) initiative aiming at developing science basis to assess the costs of land degradation. The new United Nations, System of Environmental and Economic Accounts (SEEA) introduced in 2014 integrate environmental data with economic measures such as national income, stock markets and gross domestic product (GDP). A letter to Nature [6] urges to integrate information on soil resources with other measures of natural capital and economic activity in the context of the SEEA.

Against this background, the main objective of this study is to propose a cost estimate of agricultural productivity loss due to soil erosion by water in the EU using direct cost evaluation approaches and macro-economic models. The direct cost evaluation approach considers mainly the cost of crop productivity loss (lost tonnes of crop commodities due to soil erosion). The macro-economic models evaluation quantifies the impact of soil erosion on the overall economic activity of the agricultural sector and on GDP of European Member
States using a Computable General Equilibrium (CGE) economic model. The direct cost evaluation approach estimates the crop productivity expressed as ton per hectare (t/ha) for 10 commodity crops, then identifies areas where severe erosion will occur and finally estimates the loss of crop productivity. Last, an annualised economic value of crop productivity loss was derived by multiplying the lost production by the average market price of the 10 crops.

The land productivity losses estimated in direct cost evaluation are key inputs for the evaluating the macro-economic impact of soil erosion in agricultural sector and GDP. The macroeconomic effects of soil erosion can be further evaluated by the CGE model. This implies going beyond the direct cost represented by the lost production, quantifying its impacts on the economic activity of the agricultural sector and of the overall capacity of a country to produce goods and services, namely its GDP. Among the different economic modelling approaches able to provide an aggregated and systemic representation of the economic activity, Computable General Equilibrium (CGE) models are hugely used and consolidated both within the academia and the policy environments [7]. It is worth noting that the macro-economic effects captured by the CGE models are those originating by the decisions of representative consumers, firms, and the public sector driven by changes in market prices. All these agents interact in the national and even international economy.

In the European Union, results show that the loss of agricultural productivity due to soil erosion by water is estimated to 0.43% annually based on the combined outputs of biophysical and agronomic models. The cost of agricultural productivity loss is estimated to around 1.25 billion Euros annually. The application of macro-economic models such as CGE estimates the cost of soil erosion to agricultural sector to be around 295 million Euros (reduction of 0.12%) and the GDP loss only 155 million Euros annually. CGE losses and GDP losses in particular should be considered just as the lower bound for the economic losses. The agricultural productivity loss is 4 times higher than the loss in agricultural sector and 8 times higher the GDP loss. This is due to endogenous adjustments or adaptations in the economic system through trading mechanisms (import/export flows, competitiveness, consumer preferences, re-allocation of labor and capital between sectors) that smooth initial losses and that a macro-economic models like CGE can take into account. Therefore the following points are worthy to be clarified: first of all GDP is a flow and not a stock measure. As such, for instance, the value of soil (or of land, houses etc.) is not part of GDP. GDP records just what the soil effectively produces in terms of goods and services in one year. Stock-property losses are thus only indirectly and partially captured by GDP. Moreover, the cost of land restoration, when undertaken, albeit compensating a loss, is a positive item in GDP accounting. Finally, it is worth noting that those “smaller” GDP losses can be attained only as long as perfectly flexible and competitive market conditions holds.

Another important characteristic of the CGE is the identification of a winner/looser dynamic between countries. In this experiment for example Slovenia, Italy, Spain and Greece are the
most negatively affected regions by soil erosion while other countries such as Denmark, Netherlands and Belgium even experience some economic benefits. This takes place because of the shift of the demand toward cheaper product. These Northern countries even if negatively impacted by soil erosion are less impacted than the European Mediterranean countries and can take advantage of this in the international trade market.

**Keywords:** SEEA, CGE, agricultural productivity, food security

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Changes in forest species suitability, distribution and diversity under future climate: the case of Southern Europe

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Abstract

Global Change poses a great challenge to the actors (policy makers and stakeholders) who deal with ecosystem protection and conservation strategies [1–3]. Therefore, in delineating these strategies and plans, the concepts of biogeography and expected shifts in species habitats, as well as the modification in species regional distribution and local diversity under climate projections, become critical [4–9]. Forest ecosystems are strategic for biodiversity conservation and carbon sequestration; they have evolved their resilience and adaptation capability to disturbances (e.g. droughts, fires, windstorms, pests, diseases, and invasive species), but under global change, with an altered intrinsic vulnerability due to modified average environmental conditions, they have to face an additional challenge: coping with a quickly increasing variability of extreme events and disturbances as well as novel perturbations. Such complex transformations are occurring too fast to be accompanied by both evolutionary adaptation [10–12] and migration processes. In this sense, we adopt, in this work, the Ensemble Forecasting-SDM approach to predict the possible impacts of climate change in terms of geographic range shifts, over medium- and long-term, for ten forest categories (groups of species). We focus our attention on southern Europe, and the Mediterranean Basin in particular, as they are among the world’s major areas for plant biodiversity and endemism [13–16]. In a nutshell, our work [17] aims to complement other similar recent studies [18,19] by merging/harmonizing two datasets of forest species presence [20], and exploiting the latest
projections under CMIP5, guaranteeing robustness in terms of model consensus in predicting future distribution of each forest category. We use the IPCC terminology on likelihood to treat the uncertainty on future outlooks [21]. The approach we adopt is what we call a cascade ensemble system, which concatenates the ensemble forecasting approach of SDMs to a sub-ensemble of CMIP5 climate projections. So, for each forest category and time horizon, ten maps of future distribution (5 GCMs by 2 RCPs) are thus combined in a single suitability map supplied with information about the “likelihood” adopting the IPCC terminology based on consensus among projections.

The potential distribution of the considered tree forest categories under climate change was projected through the “BIOMOD2” package v3.3-7 in a study area that spreads from 10°W to 30°E longitude and from 24° to 50°N latitude covering the territories of 18 countries of southern Europe: Albania, Andorra, Austria, Bosnia and Herzegovina, Bulgaria, Croatia, France, Greece, Italy, Republic of Macedonia, Montenegro, Portugal, Romania, San Marino, Serbia, Slovenia, Spain, and Switzerland. The surface is approximately 2.34 million square kilometres. Two categories of environmental predictors have been considered for the calibration and projection phases of SDMs. Nine (9) topographic predictors and nineteen bioclimatic predictors.

After producing maps of potential spatial distribution of each forest category under each GCMs and RPCs (i.e. cascade ensemble member CEM), the spread scenarios was addressed by adapting the approach and terminology to treat the uncertainty and communicate the “likelihood” of outcomes, as proposed by IPCC-AR5 [22]. If the suitability is predicted only by 1 CEM, the outcome is considered as extremely unlikely; if by 2 or 3 CEMs, as unlikely; if by 4 to 6 CEMs, as about as likely as not; if by 7 or 8 CEMs, as likely; and if by 9 or 10 CEMs, as extremely likely.

The findings of this work should be regarded as “habitat suitability” or simply “suitability”, referring to favourable habitats for the analysed forest categories rather than to their expected future spatial distribution under the impacts of climate change, because of some main points: first of all, the investigated forest categories represent a significant portion of species in Southern Europe but, obviously, they neither cover the totality of current forest diversity, nor are representative of other species in the adjacent regions that can migrate toward southern Europe. Thus, competitive dynamics (expressed here as higher or lower probability of occurrence among categories) should also consider other species not included in this study. Similarly, the other land uses/covers (agriculture, artificial surfaces, water bodies), well established in the domain, are not considered in our analysis, neither in their current locations, nor in the likely new areas of expansion.

Concluding briefly, results in terms of forest shift, regional composition and local diversity
confirmed how climate change is likely to lead to significant modifications in the future, affecting forests with different degrees of magnitude across species and with various levels of uncertainty within species also due to the spatial heterogeneity, the auto-ecological traits and the adaptation strategies.

While some forest categories will find more suitable conditions in previously unsuitable locations, for other categories the same new conditions will become less suited. A decrease of local species diversity is projected in most of the area, with Alpine region showing the potentiality to become a refuge for species migration.

**Keywords**: BIOMOD, Forests, Global Circulation Models, Likelihood, Forest diversity

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While some forest categories will find more suitable conditions in previously unsuitable locations, for other categories the same new conditions will become less suited. A decrease of local species diversity is projected in most of the area, with Alpine region showing the potentiality to become a refuge for species migration.

Keywords: BIOMOD, Forests, Global Circulation Models, Likelihood, Forest diversity

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The role of humidity in determining perceived temperature extremes scenarios in Europe

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Abstract

An increase of 2-meter temperature over Europe is expected within the current century. In order to consider health impacts, it is important to evaluate the combined effect of temperature and humidity on the human body. To this aim, projections of a basic index – the humidex - representative of the perceived temperature, under different scenarios and periods, have been investigated. The simultaneous occurrence of observed extreme temperature events and extreme perceived temperature events is seldom found over the present climate, reinforcing the importance to investigate the combination of the two fields. A set of 10-km resolution regional climate simulations, provided within the EURO-CORDEX multi-model effort, demonstrates ability in representing moderate to extreme events of perceived temperature over the present climate and to be eligible as a tool for quantifying future changes in geographical patterns of exposed areas over Europe. Following the RCP8.5 emission scenario, an enlargement of the area subject to dangerous conditions is suggested since the middle of the current century, reaching 60 degrees North. The most significant increase of extreme perceived temperature conditions is found comparing the 2066-2095 projections to the 1976-2005 period: bearing in mind that changes in relative humidity may either amplify or offset the health effects of temperature, a less pronounced projected reduction of relative humidity in the north-eastern part of Europe, associated to extreme humidex events, makes northern Europe the most prone region to an increase of moderate to extreme values of perceived temperature. This is in agreement with a pronounced projected specific humidity increase.

Keywords: extreme events, perceived temperature, future scenarios, humidity.
Selecting And Evaluating Climate Change Impact Indicators Towards a National Framework for Italy

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Abstract

Climate change and its consequences already occurring in Italy, will likely give rise to new problems as well as exacerbate existing phenomena. The scientific community is therefore required to face new challenges, which will call for new knowledge tools and decision support systems. As a matter of fact, a good understanding of phenomena represents the first step for every action aimed at reducing vulnerability to climate change, thus ensuring that adaptation measures are implemented in the right way and in a proper time.

As the National Adaptation Strategy emphasizes there is an increasing need to develop and set up appropriate sets of climate change impacts indicators at national level in order to improve a suitable knowledge base as a primary starting point for the implementation of adaptation processes [Ministry for the Environment, Land and Sea, 2015].

In this context, the National System for Environmental Protection including both the Italian Institute for Environmental Protection and Research (ISPRA) and the Regional Environmental Protection Agencies (ARPA), launched in 2016 a national initiative aiming at the definition of a set of climate change impact indicators at national level based on two different steps: i. selection of a wide range of “potential” climate change impact indicators and ii. evaluation of the most suitable climate change impact indicators based on specific criteria.
The implementation of the first step started with the identification of the key potential impacts of climate change emerging from the National Adaptation Strategy (NAS) on the most sensitive environmental systems and socio-economic sectors in Italy, such as: i. water resources; ii. desertification and drought; iii. hydrogeological risk; iv. biodiversity and ecosystems; v. health; vi. forestry; vii. agriculture; viii. fisheries and aquaculture; ix. energy; x. coastal areas; xi. tourism; xii. urban settlements; xiii. cultural heritage; xiv. transport and infrastructure; xv. Industry and infrastructure, and two special cases such as mountain areas and Po river basin [Castellari et al., 2014].

Based on a review of scientific literature focusing on climate change impact indicators used at European and Member States level (i.e. Germany, Switzerland, France, Belgium, Spain, etc) and on the judgment of sectoral groups of experts within the National System of Environmental Protection, a list of about 150 “potential climate change impact indicators” was defined and clustered into the systems and sectors above mentioned. Together, a set of essential climatic indices was defined, in order to allow the correct impact indices evaluation and to address the change in the natural or socio-economic systems to climate.

In order to implement the second step of the process, a conceptual framework for the characterization of climate change impact indicators based on specific criteria was defined. Examples of key criteria identified are the following:

- relevance for climate change and its impacts: strong and clear cause/effect relationship between the indicator and what is expected to indicate (climate change and its impacts) and sensitivity towards change;

- clear, well founded and reproducible methodology for the elaboration of indicator (including uncertainty);

- public availability of relevant data (i.e. regular updating, adequate length of time series, adequate spatial resolution);

- capacity to support decision-making.

It is recognized that one of the most important criteria for the evaluation of an impact indicator is its relevance for climate change and its impacts: this means that a scientific documented strong and clear link must exist between the indicator and the climate change impact to be quantified. As a matter of fact, sometimes a solid theoretical relationship is established but poor evidence of a statistical relation is
found. In other cases, solid and agreed theoretic relationship linking indicator and impact, and a statistical relation is established. In addition, the indicator must be sensitive towards change thus being able to distinguish meaningful variations and differences in the trend of the impact. The analysis should highlight the indicator reliability in explaining the climate change impact, taking into account that also weak indicators at national level could be effective at local level and that statistically flimsy indicator could be the only chance to support strategic adaptation options.

Furthermore, a clear and well founded methodology for the elaboration of the impact indicator means that the way the indicator is produced is transparent and scientifically sound, so that it can be reproduced in other contexts. Also, uncertainties that may affect the interpretation of the indicator are identified and described.

The third key criteria is related to the public availability of relevant data, both in term of time series, spatial coverage, updating frequency. Of course, indicators based on publicly available data are more suitable than indicators that partially or fully depend on costly or limited data. Furthermore, short times series are not really sufficient to allow the attribution of the indicator to climate change. In addition, spatial resolution can be also heterogeneous, as it can range from point measurements (station data) to high spatial resolution deriving from satellite imagery.

Finally, as these indicators are supposed to provide the knowledge base to support the adaptation processes towards the development of adaptation strategies and plans, their ability to provide useful information for decision-making will be crucial [Costa et al, 2016]. To this aim an evaluation of the indicator representativeness both geographical (national, regional, local) and over time will be carried on as well as the best communication approaches to decision-makers.

Future activities for the further definition of the most suitable set of climate change impact indicators at national level will imply a check aimed at selecting which of the “potential indicators” identified will match those (and other) key evaluation criteria identified. The finalization of such set of climate change impact indicators and their quantitative evaluation will help enhance the knowledge base regarding the climate change impacts assessment in Italy as well as build a useful tool for a further monitoring, reporting and evaluation activity of adaptation actions at national level [EEA, 2017].
Keywords: climate change, impacts, adaptation, indicators, criteria.

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Influence of climatic changes on migration fluxes from the Sahel countries to Italy in the period 1995-2009

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Abstract

At present, migration is probably the problem at the top of the political agenda in Europe. Among European countries, Italy is the most impacted one due to its role of “bridge” between the African continent and Europe.

Many causes can be recognized as drivers for the observed migration fluxes. Among them, obviously, we may cite civil wars, such as the recent Syrian one, other kinds of conflicts, terrorism, difficulties in maintaining a subsistence agriculture, loss of yields, etc.. Recently, however, some evidences for a role of climatic changes in triggering or amplifying conflicts and/or migrations appeared in the scientific literature: see for instance, refs. [1-8].

Due to the fact that recent crises may have obscured the role of climate change as a driver of migrations (see, however, [4], where a specific causal role of drought has been recognized also in the devastating Syrian crisis), here we limit our analysis to migrations from the Sahelian belt to Italy in the 15 years before the Syrian crisis and the so called Arabian Spring. In doing so, even if local crises were of course present in the Sahelian countries also during these years (for instance, the Darfur conflict) and can be causes of migrations, we are confident that we mainly avoid big changes in causes which could overwhelm the direct role of climate change.

In this study, after the use of simple linear techniques, we apply fully non-linear neural network models (specifically developed for analyses of small data sets [9,10]) and an ensemble strategy, with the aim of modelling the influence of climatic drivers on the amount of yields in ten countries (Senegal, Gambia, Mauritania, Mali, Burkina
Fasu, Niger, Nigeria, Chad, Sudan, Eritrea) and on migration fluxes from these countries to Italy. Our analysis is based on data extracted from the more global dataset used in [5] (we acknowledge the authors of this paper for having supplied us with these data).

The results allow us to identify the major climatic drivers affecting these quantities and also highlight the capacity of the model to explain the majority of the variance found in the data.

In particular, the amounts of yields in the ten countries are quite well reconstructed when annual mean temperature, annual total precipitation and the total number of hours in which the plants are exposed to $T > 30^\circ$C during the growing season are considered as predictors in our model. The same variables (+ the amount of yields) are considered as predictors for reconstruction of the migration fluxes. In doing so, the explained variance in the data of migrations is 78%.

A pruning activity – excluding one input in turn from the neural networks – shows clearly that agriculture (the amount of yields) represents a link between climatic changes and migrations, which can enhance this latter phenomenon. However, the dominant role on migration fluxes appears to be due to the effect of temperature, indirectly on the yields, but also directly on the population. This confirm previous studies which show how the large observed increase in heat waves leads to exceed the threshold of thermal tolerance for animals and humans, especially in low-income countries such as the African ones [11].

In short, this study shows that climatic impacts in Italy not only come from climatic changes on the national territory, but also from changes in the climate of other countries which are origin of migration fluxes towards our nation. Besides mitigation and adaptation, this leads to consider also actions in those countries, in order to build a more resilient agriculture for their sustenance and development, and to prevent non-sustainable migration fluxes.

**Keywords:** migration, yields, Sahel, neural network modelling.
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Late Holocene human-environment interactions in New Zealand: a biomarker approach

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Abstract

The arrival of the first Polynesian colonizers in New Zealand’s South Island, estimated at c. AD 1280, marked an irreversible vegetation shift from the native forest, that used to cover more than 80% of the land, to widespread shrubland. Before the advent of humans, wildfires were very infrequent, and vegetation was not adapted to fire [1]. Despite the small number of individuals, humans were able to trigger an abrupt and permanent transition to an unprecedented state of the system, resulting from the loss of 40-50% of the native forest. Local vegetation small scale feedbacks are likely responsible for the incapability of the system to recover, as revealed by fire sensitivity studies [2]. The extensive use of fire to clear the landscape and its effect on the vegetation composition are widely documented in charcoal and pollen records, although to date no direct evidence of human presence was provided to estimate the level of anthropic pressure involved.

The introduction of specific human tracers to complement existing records is key to better understanding the dynamics that made such changes possible to the observed spatial and temporal extent. Here, we employ novel biomarkers directly related to the human presence, together with organic tracers of biomass burning and land use, to reconstruct the relationship between humans, fire and vegetation in the last millennium from lake sediments. Selected tracers include 26 different molecules among monosaccharide anhydrides (MAs), polycyclic aromatic hydrocarbons (PAHs) and fecal and plant sterols (FPS). MAs (levoglucosan and its
two isomers mannosan and galactosan) are specific tracers for the combustion of cellulose and hemicellulose [3], while PAHs are employed as generic markers of fire events, due to their persistence in the environment and the possibility to use different compounds in source apportionment studies. Two compounds of fecal origin (coprostanol and epi-coprostanol) are used as direct tracers of human presence [4] within the lake catchment, while other FPS are useful in the reconstruction of the redox conditions and of the terrigenous influx to the lake, consequent to deforestation and land use in general.

The sampling sites considered in this research are Lake Kirkpatrick and Lake Diamond, two alpine lakes located in the southwestern South Island (Otago region). These lakes are among the sites that present the highest charcoal fluxes following the arrival of people in the South Island [1]. The two cores were collected in 2009 with polycarbonate tubes and subsampled at 1 cm resolution. Chronology was obtained by AMS $^{14}$C dates and calibrated with BChron [5,6]. Dry samples were solvent extracted and underwent chromatographic clean-up and fractionation. Target compounds were analyzed through gas chromatography and ion chromatography coupled to mass spectrometry. Samples covered a ~800 yr time span (c. AD 1150-1960), encompassing both the Māori and European colonization waves. All tracers peak sharply and abruptly in a brief period centered at about AD 1350, corresponding to the first increase in fire activity and decline in arboreal species in the South Island and to a huge input of organic matter to the basin, coherent with intense deforestation. Values decrease to background after ~AD 1400, until the beginning of the 19th century, when a huge increase is registered in FPS after the European arrival, strongly correlated with population growth. Unexpectedly, no significant increase in fire activity is registered during the European period. The 15th century decline likely indicates decreased anthropic pressure following too intense land exploitation and the transition towards colder and wetter conditions as indicated by reconstructions of temperature [7] and main climate oscillations such as ENSO [8] and the Southern Annular Mode [9]. The combination of these factors probably made the area inhospitable to people within a few decades as a result of rapid resource consumption. Results are coherent with a short occupation of the two lakes watersheds, followed by land abandonment or to human presence reduced to occasional. Therefore, intensive early human activity in
the area was probably very limited in time, but the initial deforestation triggered a permanent change that is still visible today. The multi-proxy approach used in the present work allows a fine-scale reconstruction of the local influence of human activity since the first occupation, improving and complementing the understanding provided by paleoecological, archaeological and modeling approaches.

**Keywords:** Biomarkers, New Zealand, Fire, Human Impact, Lake sediments

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Adaptation system frames: a comparison of international and national climate policy frames and narratives

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Abstract

Adaptation system frames manifest at decision-making scales, bounding the range of framing options available to local actors developing political responses to the impacts of climate change. We critically analyse the adaptation policy frames of the five Intergovernmental Panel on Climate Change (IPCC) assessment reports, and the adaptation system frames from a sample of the world's most and least vulnerable countries to climate change. The IPCC's adaptation policy frames are reflected in the world's most vulnerable national adaptation agendas, but not the world's least vulnerable. The world's least vulnerable countries present a frame underpinned by a techno-scientific narrative, which may contribute to the observed slow progression toward successful adaptation outcomes at operational scales. The world's most vulnerable countries tie constraints to adaptation with perennial sustainable development issues. Yet, solutions also align with the techno-scientific narrative, and this may potentially constrain local communities to optimise outcomes from internationally funded adaptation projects.

Keywords:
Adaptation, IPCC, national policy, frames
Economic modeling of climate-smart agriculture in Iran

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Abstract
Global warming is the immediate consequence of increased greenhouse gas emissions, which can have different impacts on agriculture. Agriculture is a significant source in terms of greenhouse gas emissions and on the other hand, the main sector in terms of producing food. As global food demand grows, the share of agriculture in the total greenhouse gas emissions will rise too. Therefore, agriculture needs to cut the greenhouse gas emissions. A response to the two important issues today, i.e. achieving food security and reducing greenhouse gas emissions is climate-smart agriculture. According to the Paris Agreement, an international effort to reduce greenhouse gas emissions, Iran has to decrease 12 percent of its greenhouse gas emissions by 2050, which all sectors have to contribute. Since the pathway to define strategies, is to explore the challenges; in this study, a seemingly unrelated regression technique has been used to model the climate-smart agriculture in Iran. Three main sub-sectors of agriculture; i.e. crops, livestock, and aquatics production, have been considered in the model to find the role of them in improving food security and emitting greenhouse gasses. The findings show livestock and aquaculture sectors have had a positive significant impact in achieving food security. On the other hand, these sectors have had a positive significant effect on the emitting greenhouse gasses while the effect of livestock production is very stronger than aquatic production. Cropping system was not found to have a significant role in achieving food security and emitting greenhouse gasses in Iran although the expected signs (+) has been confirmed by the model. New technical and behavioral innovations have to be done in agriculture to be climate-friendly and sustainable. Appropriate solutions such as agroforestry, crossbreeding, and changes towards a more healthy diet with more vegetable and white meat and less red meat, where is possible, also can reduce emissions.

Keywords: Paris Agreement, Climate-Smart Agriculture, Seemingly Unrelated Regression, Iran
**The response of the atmosphere to local CO$_2$ asymmetries**

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**Abstract**

Due to its long residence time, CO$_2$ is distributed in the troposphere in a broadly homogeneous way. Nevertheless, observational data [1] reveal that carbon dioxide concentration is indeed characterized by some spatial variability. The observed pattern of CO$_2$ concentration reflects the distribution of surface sources and sinks, and the fundamental role of the main atmospheric transport pathways. One of the major features of the observed CO$_2$ concentration is the clear meridional gradient with the maximum in the mid latitude Northern Hemisphere, fostered by the natural biospheric fluxes and by the global asymmetric distribution of the main fossil fuel emitters [4, 5].

The aim of this study is to evaluate the atmospheric response linked to a localized and stationary CO$_2$ distribution forcing. In a “business as usual” scenario the spatial asymmetry in the carbon dioxide concentration arguably will be enhanced due to increased fossil fuel emissions and land-use changes, and hence less effective compensation feedbacks provided by the complex carbon exchange processes across the different Earth System components [2]. In this work we present a set of idealized experiments, performed with numerical models of different complexity, taking into account a stationary and localized carbon dioxide forcing. This approach has allowed us to detect how the state of the atmosphere is influenced by a stationary CO$_2$ forcing, and how sensible the system is to the location of the forcing itself. For this reason we have focused our attention over regions indeed characterized by strong carbon emissions (North America and South East Asia).
In an ensemble of forced simulations performed with the Community Earth System Model (CESM) [3], a spot of anomalous carbon dioxide concentration has been included over each chosen source region, and the mean stationary signal for the two cases has been analyzed. In both instances a statistically significant pattern extended from the originally forced area to the whole Northern Hemisphere sector has been obtained. In order to better assess the role of the forcing and the mechanisms in action, we have compared the full model response with the linear dynamical fingerprint due to CO₂-related heating.

In this framework a linear model has been proposed, which represents the linearization of the current version of the spectral Eulerian Dynamical Core of the Community Atmosphere Model (CAM) – the atmospheric model component of the CESM. This new linear model is a simple but powerful tool to investigate the features of the stationary state of the atmosphere and the response of the system to stationary external forcing. The combined use of the general circulation model and the linear model has allowed us to identify which source region is more sensitive to the localized forcing and the pattern of the local and remote response.

**Keywords:** Climate Change, Community Earth System Model, Atmospheric Modeling, Carbon Dioxide

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Impacts of wet snow events on the overhead power lines in the future climate change

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Abstract

The last heavy wet snowfall in the Abruzzo region (16-18 January 2017) caused serious problems for the safety and operation of the Italian Electric System. During this event, wet snow sleeves on overhead conductors reached 15 kg/m in areas where the design criteria did not exceed 5 kg/m.

As the frequency of these extreme phenomena on Italian territory has shown a strong increase in the last 15 years, there is an urgent need for a Climate Change Resilience Planning of the entire electrical system to cope with the increasing of extreme phenomena and to minimize potential power outages.

A wet snow load map, estimating the ice load of all the past wet snow events, may be an useful tool for evaluating the Italian electric grid vulnerability to the risks of these severe events, as well as designing overhead power lines in order to increase the robustness of the electric power infrastructures.

This map has been elaborated using MESAN reanalysis dataset [3] in the period 1979-2005 and has been derived by applying a wet snow accretion model (Makkonen model, [1],[2]) whose meteorological input consists of daily maximum, minimum and average 2m air temperature, daily precipitation and 6 hours wind intensity. Then a GEV (Generalized Extreme Value) analysis has been applied to the yearly maxima of wet snow loads over Italy to obtain the snow load map with different return periods for a typical conductor of the high voltage overhead power line.

To investigate the future trend of the climatic signal related to wet snow events, the same procedure, applied to MESAN dataset, has been adopted by using the daily
outputs of an ensemble of 12 bias corrected RCMs under the RCP 8.5 radiative forcing provided by Euro-CORDEX Project [4] in the baseline period (1979-2005) and in the near future (2021-2050).

Analyzing the average signal, a light decrease of wet snow load with 50 years return period has been obtained in short term, especially over the mountain regions, due to the increase of snow level related to the temperature increase. For the Italian regions faced to the Adriatic sea, the projections are more uncertain. Indeed, the persistence of some easterly circulation, typical of winter periods, may contain the effect of reduction of wet snow loads.

The wet snow load map together with the climatic analysis derived in this study may be an useful support to Transmission and Distribution System Operators for a renewal plan of power lines able to increase the robustness of the infrastructures to cope with the current and future climate change.

**Keywords:** wet-snow, resilience, regional climate model, reanalysis, wet snow load map

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The C3S Climate Data Store (CDS) Toolbox

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Abstract

The CDS Toolbox is the main interface of the Copernicus Climate Change Service (C3S) to the larger community of end-user interested in climate data by empowering developers to easily create applications that exploit the Climate Data Store (CDS) datasets and infrastructure. Copernicus is the European Programme for the establishment of a European capacity for Earth Observation it will provide data with unprecedented quality, coverage and frequency. Copernicus services promise to promote economic growth, spur innovation, and support the societal challenges Europe faces as identified in 2020 strategy.

The CDS Toolbox is designed to handle a wide typology of CDS data ranging from climate model outputs to local observational series. Data contains different variables, dimensions, spatial-temporal sampling; Climate relevant information is obtained through the application of specific diagnostics to the data such as statistical analysis tools and specific models to derive information for instance not yet explicitly contained in the data. CDS Toolbox configures as a highly innovative system that should contribute to boost the accessibility and a correct use of climatic information in both research and industry in strategic sectors.
Fire and vegetation changes during Holocene recorded in Tibetan lacustrine sediments

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Abstract

Increasing awareness of how land use changes have been influencing Holocene’s climate is a hotly debated topic which led to chemical and physical investigations of natural archives, such as sediments, peat bogs, ice cores. Lacustrine sedimentary cores provide continuous records of large-scale and local environmental modifications, intelligible thanks to specific biomarkers that accumulated in these archives during past millennia [1]. The Asiatic region is one of the centers of the advent of agriculture and pastoralism, and it is a strategic area to explore biomarker distributions. In order to study the interactions between human, environmental changes and fire during the Holocene in Asia, we selected a small moraine lake called Paru Co [2], located in the South-Eastern Tibetan Plateau. We extracted 72 Paru Co sediment samples by Accelerated Solvent Extraction and analysed different organic molecular proxies by GC-MS and IC-MS [3, 4]. Firstly we aimed to reconstruct past fire history using a group of molecules called monosaccharide anhydrides (MAs). Furthermore, we analysed polycyclic aromatic hydrocarbons (PAHs) as additional combustion proxies. To better understand the changes in vegetation and human presence at the lake shore we analysed n-alkanes and faecal sterols. The information obtained from these organic geochemical data needs to be complemented with archaeological findings, meteorological data and charcoal data. In this way we can contextualize in a regional setting the biomass burning events
occurred in the Tibetan Plateau. Moreover, the association of past climate fluctuations with vegetation changes and possible human disturbances is allowed. From the MAs results we can see that the very high intensity of biomass burning recorded in the Early Holocene samples is parallel with the drier climate of the same period, following the deglaciation occurred between Pleistocene and Holocene. The promptest results show that the local ecosystem and vegetation changes are climate driven and not human driven since there is an agreement with intensity’s variations in the Indian Summer Monsoon rainfall [2].

**Keywords:** lake sediments, biomarkers, biomass burning, Holocene, vegetation

**REFERENCES**


Fire and vegetation changes during Holocene recorded in Tibetan lacustrine sediments

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Abstract

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occurred in the Tibetan Plateau. Moreover, the association of past climate fluctuations with vegetation changes and possible human disturbances is allowed. From the MAs results we can see that the very high intensity of biomass burning recorded in the Early Holocene samples is parallel with the drier climate of the same period, following the deglaciation occurred between Pleistocene and Holocene. The promptest results show that the local ecosystem and vegetation changes are climate driven and not human driven since there is an agreement with intensity’s variations in the Indian Summer Monsoon rainfall [2].

**Keywords:** lake sediments, biomarkers, biomass burning, Holocene, vegetation

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Improving knowledge of land cover change impacts on climate: role of biophysical effects beyond carbon

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Abstract

Land Use and Land Cover Changes (LULCC) affect regional and global climate through biophysical variations of the surface energy budget mediated by albedo, evapotranspiration, and roughness. This may exacerbate or counteract biogeochemical greenhouse gas effects of LULCC, with a large body of emerging assessments being produced, sometimes apparently contradictory. We reviewed existing scientific literature with the objective to provide an overview of the state-of-the-knowledge of the biophysical LULCC climate effects, in support of the assessment of mitigation/adaptation land policies. Out of the published studies that were analyzed, 28 papers fulfilled the eligibility criteria, providing surface air temperature and/or precipitation change with respect to LULCC regionally and/or globally. We provide a synthesis of the signal, magnitude and uncertainty of temperature and precipitation changes in response to LULCC biophysical effects by climate region (boreal/temperate/tropical) and by key land cover transitions (e.g. deforestation, forestation). Results show that a modification of the biophysical processes at the land surface has a strong regional climate effect, and non-negligible global impact on temperature. On average, model-based experiments of regional large-scale deforestation reduces precipitation from -80 mm/yr
in boreal regions to -290 mm/yr in tropical regions, while surface temperature increases in Tropics (+0.6°C) and decreases in boreal regions (-2°C). Global deforestation tends to cause cooler and slightly drier global climate. Observed biophysical effects indicates warmer than simulated estimates of temperature change following deforestation in tropical and boreal regions, while contrasting results are found in temperate region. Biophysical effects of land use change cannot be ignored, on the other side science has still to provide effective tools for their measuring and monitoring at local and global level with the final aim to offer to policy makers a simple instrument for an overall evaluation of LULCC-climate impacts.

Keywords: land cover changes, deforestation, biophysical impacts, climate change, climate policies

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Rapid response to climate change in a marginal sea

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Abstract

The Mediterranean Sea is a mid-latitude marginal sea, particularly responsive to climate change as reported by recent studies. The Sicily Channel is a choke point separating the sea in two main basins, the Eastern Mediterranean Sea and the Western Mediterranean Sea. Here, we report and analyse a long-term record (1993-2016) of the thermohaline properties of the Intermediate Water that crosses the Sicily Channel, showing increasing temperature and salinity trends much stronger than those observed at intermediate depths in the global ocean. We investigate the causes of the observed trends and in particular determine the role of a changing climate over the Eastern Mediterranean, where the Intermediate Water is formed. The long-term Sicily record reveals how fast the response to climate change can be in a marginal sea like the Mediterranean Sea compared to the global ocean, and demonstrates the essential role of long time series in the ocean.
State and evolution of polar ice sheets and sea ice in the perspective of the Paris agreement target +2°C

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Abstract

The COP21 Paris agreement defined +2°C in global mean annual temperature, relatively to pre-industrial temperature, as the maximum targeted climate change for the next decades. How +2°C translate in terms of changes for cryosphere? The recent synthesis of the ISMASS group (SCAR) [1] shows that +2°C seems to be a tipping point of both Greenland and Antarctica [2,3,4]. They also suggest that RCP2.6 emission scenario might be the one mitigating the impact of climate change on the cryosphere, while the other scenarios lead to irreversible changes. In the case of Antarctica and Greenland, several gaps have been highlighted: (1) the impact of basal melting under the ice shelves and marine terminating glaciers in response to ocean warming; (2) the various dynamical mechanisms involving the ice shelves mass balance and their importance in triggering a fast retreat of the grounding line and fast collapse of the main drainage basins; (3) the impact of the long-term thermodynamics of the ice sheet itself, (4) the difficulty in assessing ice melting and runoff to ocean. All those mechanisms impact directly on the estimate of the contribution of both Greenland and Antarctica to ongoing and future sea level changes. The most recent Antarctic projections [2] yield a contribution of +15.6 m, in the worst case, by the end of 2500 (|5| obtain half this number). While for Greenland projections suggest a contribution from 9.2 [6] and 10.15 [7] cm of Sea Level Equivalent (SLE) to 20 [8] and 27 [9] cm SLE by the end of the 21st century under the worst emission scenario.

Warming temperatures largely affect sea ice variability. Changes in the amount of sea ice can disrupt normal ocean circulation, thereby leading to changes in global climate. The Earth has lost sea ice at an average rate of 35000 km² per year since
In the Arctic, temperature has increased at twice the rate as the rest of the globe, and could increase by another 8°C by the end of this century [11]. The warming atmosphere along with new weather pattern extremes is causing Arctic sea ice to melt at an alarming rate. September sea ice extent is decreasing at an average rate of 13% per decade [12]. Forecasts of an ice-free Arctic range from 20-30 years from now to much sooner. Antarctic sea ice has shown more erratic and controversial behavior. It had barely changed in the last decades as complex response to atmospheric and ice sheet variability. In 2016, the Antarctic ice extent peaked on August 31st [12] and the melt season started very early. By November, the ice reached daily record lows amid air temperatures that were 2 to 4°C above average, with an earlier patter of strong westerly winds helping disperse the sea ice pack [13]. However, this might just be an extreme case of pushing the envelope of year-to-year variability. We will need to have several more years of data to be able to say there has been a significant change in the trend. Sea ice loss is predicted to occur during the 21st century, toward an ice-free Arctic and less acute decline around Antarctica [14]. Until recently, climate models have done a poor job predicting the sea ice variability in both hemisphere, with a major limitation in the uncomplete representation of the physical processes that governs interactions between sea ice, the ocean and the atmosphere.

Here we review the state of the art of ice sheets and sea ice evolution over the past and next decades in the framework of the Paris agreement. We highlight the interactions between those two cryospheric components and the impact of this interplay on their future evolution.

**Keywords:** ISMASS, ice sheets, sea ice, reanalysis, freshwater

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Effects of sustainability on companies performance:

An evaluation in the Tuscan wineries

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Abstract

BACKGROUND - Current generations are paying the cost of exploiting, polluting and destroying ecosystems; climate change with its consequences is a proof. Social tissue erosion, over-consumption, lack of confidence in the institutions, inequality and unemployment complete the overview of the ills facing the planet today. Within this disconcerting picture, the business world has a prominent role in several aspects. Companies are co-responsible for this situation. In order to maximize profits, they have contributed to the uncontrolled production of goods and services without worrying about the consequences of their actions towards the environment and society. Because of that, the model and the rhythms of production have been considered unsustainable and the companies are not only required to review the pace of production but also to contribute to the creation of well-being [1]. In specialist literature this is reflected in the evolution of strategic thinking that has progressively expanded the boundaries of corporate responsibility to embrace the interests of all subjects potentially involved in the business. Sustainability should not be seen as independent and separate from the strategic problem, on the contrary "strategy" should build a sustainable competitive advantage in the long run through the synergistic generation of financial, environmental and social value [2]. That means to consider and incorporate the non-financial outcomes as part of the company’s performance. Companies that have revised their strategy have converted what was a necessity into opportunity and they did it by raising the strategic, environmental and social value they have been able to create.
GOAL - The purpose of this research is to evaluate the economic potential of sustainable strategies implemented in one of the sectors that express the excellence of "made in Italy": the wine industry. Sustainability of the wine industry refers to all phases of the production chain, including economic, environmental and social sustainability; innovations concern cultivation and production techniques, evaluation and certification, organization of the company and the workers, and relationships that the company has to deal with external subjects. In this regard, it is proposed a personal definition of such strategy in the core business, meant as integration of the concern of the environment, workplace safety, ergonomics and work-related stress. Companies in this sector are encouraged to adopt sustainable business models in response to consumer demand and the need to adapt the strategy to ongoing changes in the wine sector. Therefore, the purpose of the present study is to identify, by comparing the company profiles, the relationship between social and environmental prevention and business performance. At present, the analysis of the literature shows that previous studies have evaluated the company's performance, through the comparison of companies, focusing on just one dimension of sustainability such as environmental certifications [3], [4], [5], [6]. Performance evaluation based on all impacts is still an ignored but potential aspect. In light of this, this work intends to consider the company in its integrity and complexity.

METHODOLOGY – The empirical analysis consists of evaluating a sample of Tuscan wineries. The research compares companies that are similar for their economic and financial aspects and dissimilar for their social and environmental sustainability. Therefore, the differences in economic performance are related to its sustainability. The methodology used to create pairs of "similar" companies is based on the statistical data processing of the balance sheet data provided by the AIDA database (consulted in October 2016) of all Tuscan wineries. The inference of the data was aimed at comparing each sample company with the others on the basis of the balance sheet data. With the help of some statistical tests, have been termed "similar" those pairs of companies that have similar average values related to some budget indices. Likewise, "similar" couples respond to other criteria: they have the same company size in terms of number of employees, they belong to the same production sector and they belong to the same Region (Province of Siena or Florence). Through these steps, the number of companies has been considerably
reduced and, with the aim of choosing companies with different behaviors over the socio-environmental dimension, has come to a sample of six companies.

The Companies have been considered in a holistic approach that combines the environmental dimension, the social dimension and the economic dimension. The Company performance data has been extrapolated from the balance sheet data. Those related to the socio-environmental dimension were collected using two questionnaires at the corporate headquarters, in the months of January and February 2016: one addressed to the owner or business manager and one for the employees. The survey analysis conducted then allowed to process the data and analyze them through methodologies based on statistics. The six companies in the sample combined into three pairs were assessed by comparing, within each pair, socio-environmental and financial performance.

RESULTS - The comparison between the three pairs of companies selected shows that: a sustainable approach has better financial performances (valid for 2 pairs out of 3); there is a link between environmental investments and the increasing financial performance (valid for 5 companies out of 6); sustainable companies suffered less the global market crisis (valid for 3 pairs out of 3); the difference in financial performance between sustainable and less sustainable companies is explained, in the sample, to 31.25% by the variable "environment."

Therefore, beyond the ethical motivations, the company derives economic benefits from the implementation of social and environmental prevention measures that justify their pursuit. So a new, globally sustainable business dimension could provide better performance.

**Keywords:** environmental and social prevention, sustainable performance, wine industry, evaluation of a sample of companies.

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Mitigating the impact of the food and farming sectors on climate change

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Abstract
The UN Food and Agriculture estimates that the livestock sector is responsible for greenhouse gas (GHG) emissions of 7.1 gigatonnes CO$_2$-e per annum, i.e. 14.5 percent of human-induced emissions [1]. Livestock supply chains emit 44 percent of anthropogenic methane (CH$_4$) emissions, 53 percent of anthropogenic nitrous oxide emissions (N$_2$O) and 5 percent of anthropogenic carbon dioxide (CO$_2$) emissions [1]. Directly and indirectly, the agricultural sector is responsible for around 22–24 percent of total anthropogenic GHG emissions [10]. To make up the shortfall between emission reductions pledged and the reductions needed to meet the Paris Climate Agreement’s targets, all sectors need to reduce their emissions. However, research shows that on a business-as-usual basis emissions from food and agriculture will increase substantially and could make it very difficult to reach the Paris Agreement’s targets [2].

Policy-makers tend to focus on technical mitigation measures and increased productivity in order to deliver a reduction in agriculture’s emissions. However, research indicates that such measures will be insufficient on their own to prevent an increase in farming’s GHG emissions, let alone achieve a reduction [3].

Action is needed in three areas if food and farming’s emissions are to be reduced: a switch to healthier diets with lower meat and dairy consumption, a reduction in food waste and losses, and an increase in soil carbon sequestration.

Livestock generally produce more emissions per unit of nutrition produced than plant-based foods [4]. Hilal Elver, the UN Special Rapporteur on the right to food says: “The world’s current consumption pattern of meat and dairy products is a major driver of climate change and climate change can only be effectively addressed if demand for these products is reduced” [5]. Bajželj et al (2013) conclude that emissions from
agriculture can only be reduced by a 50% decrease in food waste and a move to healthy diets which in many (but not all) parts of the world involves substantial reductions in meat and dairy consumption [2]. Transitioning toward more plant-based diets that are in line with standard dietary guidelines could reduce global food-related GHG emissions by 29–70 percent [6]. Halving the consumption of meat, dairy products and eggs in the EU would achieve a 19–42 percent reduction in GHG emissions from agriculture [7]. A person eating over 100g per day of meat is responsible for GHG emissions that are 88 percent higher than those of a vegetarian [8].

A reduction in meat and dairy consumption would not only reduce GHG emissions but would have important health and environmental co-benefits. The high levels of consumption of red and processed meat that are common in developed and newly industrialised countries contribute to heart disease, obesity, diabetes and certain cancers [18, 19]. High consumption levels of meat and dairy products have been made possible by intensive livestock production. However, the demand for large quantities of cereals and soy as feed for intensively reared animals has fuelled the intensification of crop production which, with its monocultures and use of agro-chemicals, has led to overuse and pollution of water, soil degradation and biodiversity loss [20, 21, 22].

The production of food that is lost or wasted involves the emission of greenhouse gases for no good purpose. Worldwide 25% of food calories are lost or wasted post harvest or at the distribution/retail and consumer levels [9]. Recent studies indicate that substantial losses also arise as a result of some people’s consumption being in excess of food nutritional requirements [10, 11]. One study found that over-eating is at least as large a contributor to food system losses as consumer food waste [10]. It calculates that GHG emissions associated with consumer food waste and over-eating may increase by 2050 to 1.9–2.5 Gt CO$_2$-e per annum.

Another form of food waste – with its associated unnecessary GHG emissions – arises from the use of human-edible cereals as animal feed. Animals convert cereals very inefficiently into meat and milk. For every 100 crop calories fed to animals, we receive just 17-30 calories as meat [13, 14]. 36 percent of the world’s crop calories are fed to animals but three-quarters of this - 27 percent of global crop calories - is wasted due to the low efficiency with which animals convert cereals to
meat and milk [12, 13, 14]. The effect of this is that the GHG emissions arising from 27% of global crop production are produced in vain as these crops add nothing to the total of food available for human consumption.

A substantial reduction in all the various forms of food loss and waste referred to above would lead to a decrease in overall food demand and lower GHG emissions.

The Paris Agreement requires the Parties to conserve and enhance sinks of greenhouse gases. Agricultural soils represent a major potential sink for atmospheric carbon [15]. Soil erosion control and soil restoration has an estimated carbon sequestration capacity of 5-15 percent of global emissions [16]. It must, however, be noted that the yearly amount of carbon sequestered will gradually level off as the soil reaches a new equilibrium [17]. Examples of soil carbon sequestration practices include the application of conservation tillage systems, the use of periodic green fallows, winter cover crops, crop rotations that utilize semi-perennial crops, rotational grazing and decreased grassland management intensity [17]. Increasing soil carbon sequestration would also have benefits for climate change adaptation. Soils with plentiful organic matter have enhanced resilience to changing weather patterns and extremes as they are able to retain water thereby mitigating droughts and preventing flooding. In addition, such soils are more fertile and are less susceptible to erosion.

In conclusion, more attention should be given by policy-makers to the role in climate change mitigation of reduced consumption of meat and dairy products, decreased food losses and waste and enhanced carbon sequestration in agricultural soils.

**Keywords:** Climate change, meat, food losses and waste, carbon sequestration

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Illustrating the pattern of the Lombardy Foundation for the Environment for mainstreaming climate change adaptation in the policy context of Lombardy region, Italy: from the analytical level to new opportunities for the implementation of planned actions.

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Abstract

The process of mainstreaming of climate change adaptation has been an issue of interest in the field of political sciences in the last years and an essential milestone for the planning and implementation of climate change measures. Apparently yet, there are many understandings of the concept of mainstreaming and how it should be developed in practice. The paper aims to report and elaborate on the experience developed along with the design of the Strategy (2014) and the Action Plan (2016) for Adaptation to Climate Change of Lombardy Region, for which the Lombardy Foundation for the Environment (FLA) has been the leading scientific advisor. Starting from these landmark policy documents, the paper moves forward to the appraisal of the firsts findings of two new international projects: Go Apply – Multidimensional Governance of Climate Change Adaptation in Policy making and Practice and Master Adapt - MAinSTreaming Experiences at Regional and local level for adaptation to climate change. The first one is an Interreg-Alpine Space project focused on the governance of adaptation at the institutional level, with the goal of defining a conceptual and operative framework valid on the transnational basis; whereas Master Adapt aims at the vertical and horizontal integration of different institutional levels in the implementation of concrete adaptation measures. The paper hence aims to contribute to the growing debate on the governance and the implementation of the climate change adaptation perspective, by elaborating on three specific themes: i) the application of an analytical framework for mainstreaming...
processes; ii) the challenges and opportunities that emerge from the analysis of the actual experience of mainstreaming in Lombardy iii) the transformation of planned intervention strategies into practices and realizations.
An indicator-based assessment of climate change vulnerability in the Marche Region

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Abstract

A large number of tools, guidance and methods for climate change impacts, vulnerability and risk assessment has been developed in the recent decades by many authoritative international scientific sources all over the world. However, there is no fixed rules suggesting which approaches and methods to consider when approaching a quantitative vulnerability assessment to climate change [EEA, 2017].

Among its objectives, the project LIFE Sec-ADAPT (Upgrading Sustainable Energy Communities in Mayor Adapt initiative by planning Climate Change Adaptation strategies) aims to support Italian (Marche region) and Croatian (Istria region) regional and local administrators in the development of an indicator-based vulnerability assessment, as a fundamental knowledge base for their climate change adaptation strategies and plans.

For this purpose, the following work chain framework has been defined as a preliminary process to the implementation of the Marche region indicator-based vulnerability assessment:

1. evaluation of past and current climate trends: based on the data availability of temperature (minimum and maximum) and precipitation for the period 1961-2015, both the mean and the extreme values were analyzed. Climate extremes were examined using a subset of indices, selected from the ETCCDI core set defined by the CCL/CLIVAR Working Group on Climate Change Detection of WMO and the ETSCI indices.
2. estimate of the future scenarios: four regional climate models (RCMs) taking part in MED-CORDEX were used for the estimate of the future climate projections over Marche region. In particular, the evolution of the main climate parameters (minimum, maximum and mean temperature, precipitation) over the region was examined with reference to the next decades of the 21st century. The model outputs follow two different socio-economic and greenhouse emissions scenarios which represent respectively an intermediate (RCP4.5) and a high emission scenario (RCP8.5).

3. identification of current and potential climate change impacts: the identification of climate change impacts started with a broad view, including a desktop review and a brainstorming process among the key regional experts and stakeholders. Key questions in identifying the potential impacts include: how have weather phenomena and extreme climate events impacted your system in the past? Have you observed any new trends or recent events (e.g. in the last decade)? [Fritzsche, 2014]. The results of the first and second steps provided the scientific support for answering these questions, thus identifying the following key sectors and impacts for the Marche Region:

- agriculture: water scarcity in agriculture, change in crop production, loss of agricultural soil;
- biodiversity: loss of biodiversity and ecosystems;
- hydrogeological risk: increase in flooding and landslide events and their consequences;
- infrastructure/energy: damages to infrastructure and networks;
- health: increase in mortality/morbidity due to heatwaves;
- tourism: change in touristic flows.

For the purpose of the vulnerability assessment, the definitions and approaches proposed by the Intergovernmental Panel on Climate Change in 2007 as well as the following vulnerability function has been adopted:

Vulnerability = f (Exposure, Sensitivity, Adaptive Capacity)

where

- vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of
climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity;

- **exposure** is the nature and degree to which a system is exposed to significant climatic variations where the exposure unit is an activity, group, region, or resource that is subjected to climatic stimuli;

- **sensitivity** is the degree to which a system or species is affected, either adversely or beneficially, by climate variability or change;

- **adaptive capacity** is the ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences [Parry et al, 2007].

Once identified the potential impacts and selected the more appropriate vulnerability assessment approach, further activities will be addressed to structure an impact chain for each potential impact in order to better understand, systemize and prioritise the factors that drive vulnerability in the systems under review.

Key indicators for exposure, sensitivity and adaptive capacity will be then identified and calculated for each impact selected, based on the availability of quantitative data from national and regional data sources. Values will be then normalized, weighted and aggregated into composite indicators for Exposure and Sensitivity, and then combined into a Potential Impact index, and Adaptive Capacity. Finally, a composite vulnerability index for each impact will be elaborated by combining together the Potential Impact with the Adaptive Capacity [Fritzsche, 2014].

**Keywords:** climate change impacts, vulnerability, exposure, sensitivity, adaptive capacity

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Antarctic sea ice response to climate change: a model study

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Abstract

While Arctic sea ice is melting at a record pace, observations show that sea ice surrounding Antarctica has been slowly expanding in the satellite era until spring 2016 [1]. Increased melt rates of the Antarctic ice sheet and changes in atmospheric dynamics and winds are both considered to be key drivers of sea ice trends.

We present a sensitivity study with an eddy-permitting global NEMO sea ice-ocean model (forced with ERA-Interim atmospheric reanalysis) that aims to investigate how modifications of regional climate conditions can affect Antarctic sea ice variability and in turn how these changes impact on-shelf water properties.

First, we performed a set of numerical simulations with additional fresh water supply at the Antarctic ocean surface. Our results confirm that enhanced freshwater inputs can increase the sea ice extent. However, a very strong freshwater discharge might eventually invert the trend. The freshwater spatial distribution plays a key role in our simulations. It affects sea ice dynamics and can strongly alter regional sea ice concentration and thickness. We find that additional coastal runoff generally leads to fresher and warmer dense shelf waters.

Then, we performed and compared numerical simulations where wind velocities in the ERA-Interim reanalysis data are simply manipulated. How idealized wind intensifications (in both zonal and meridional components) impact regional properties of sea ice is also shown.

Keywords: Antarctic sea ice, variability, climate changes, ocean-ice interaction
REFERENCES

Regional implementation of multilateral environmental agreements; necessity or waste of time? 
Case study of the Paris Agreement

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Abstract

The understanding, acknowledgement and acceptance of climate impacts across the globe [1] and the urgent need of a plan of action to maintain the world temperature below 2 degree Celsius [2] were able to bring forth the Paris Agreement of 2015 and its early ratification by States on 22 April 2016. Hence, with this, the world has its binding legal regime in its fight against climate change and along site, the assurance of the implementation of Goal 13 of the United Nations Sustainable Development Goal. Indeed, the ratification of the Paris Agreement in 2016, at the United Nations headquarters in New York was a great step ahead. However, a lot is still to be done for this global legal regime to be effective or to be rightfully implemented. The work of the UNFCCC’s COP 21 in 2015 enhances the fact that everyone is involved; no one is to be left behind. Climate Change is a global problem and it is a global solution that was founded in the Paris Agreement that was found; and thus, one could also say in line with many schools of thoughts that global action plans must also be sought in order to ensure the implementation of this legal instrument [2; 3]. It seems as though all must be done only at the level of the UN and its specialised agencies. States or the civil societies have to plan their climate actions towards the implementation of the Paris Agreement at the global level while dragging it down at the national level. In this regard, States were asked to present their Intended Nationally Determined Contributions (INDCs) at the COP 21 in Paris, and thus, the mechanisms of implementation of the Agreement. This leads to the understanding that the
implementation of global multilateral environmental agreements such as the Paris Agreement is best or can only be carried out globally or nationally. So then, any other way, in this case, the regionalisation of climate protection action plans, could only possibly be a waste of time or resources. Still, there are other schools of thoughts, which believe in the strategic role of regionalisation in the implementation process of any global agreement [12]. And the Paris Agreement would not be an exception to it. For these schools, the world is not made up of only the global and the national levels; it is a composite of several regions. Between the global and the national implementation process or action plans, there is a vacuum that must be filled. A bridge that should be built for a smoother implementation of the Paris Agreement [6]. The existence of the different regions of the planet makes one understand the degree of multiplicity in the geographical, cultural, social, economic or even political backgrounds of the different nations of the world [5]. This diversity leads to the need to associate and to belong with those likening to you. Hence, though climate change is a global problem, the understanding, the acceptance or the carrying out of implementing mechanisms will differ from country to country and subsequently region to region because the probability will be to find nations of the same region having the same or almost same action plans [7]. To this effect, a tailor-made and context-specific regional partnerships action plan for the implementation of the Paris Agreement through regional legal governance could prove useful [8]. Such partnerships could provide a platform for dialogue and exchanges on implementation challenges within a region, as well as create a mechanism through which countries and competent regional and global management organisations could cooperate towards a harmonised implementation of this global legal regime [4]. And this platform would not be only political [9], as it will certainly be involving and bringing together all stakeholders at the regional level, but it will multidiscipline [10; 11]. In fact, the regional implementation of the Paris Agreement can never be a waste of time because, it is not only a want but a need; as the global or national actions meant to support this Agreement would be more effectively enhanced through regional organisations/actions.

Keywords: climate change, regionalisation, necessity or waste of time, multilateral environmental agreements, implementation
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Sunshine duration and surface solar radiation variability and trends for Italy (1959-2013): agreements and disagreements and the role of atmospheric turbidity changes

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Abstract

Downward surface solar radiation ($E_{g\downarrow}$) is an essential part of the Global Energy Balance and the climate system and, consequently, the understanding of variations in $E_{g\downarrow}$ are of primary importance to improve the knowledge of the climate change issue. Despite its relevance, large uncertainties remain with respect to the response of it to clouds and aerosol changes limiting the interpretation and the estimation of the Earth’s changing energy budget [1]. Recently, two homogenized data sets of sunshine duration (SD – the most commonly used proxy variable for $E_{g\downarrow}$) [2] and $E_{g\downarrow}$ [3] have been established for the first time for the Italian territory for the periods 1936–2013 and 1959–2013, respectively. Over the common period, both variables show a decreasing tendency until the mid-1980s, known in literature as “global dimming” and a subsequent increase until the end of the series called “brightening period”. The agreement between the decadal variability and long-term trends of SD and $E_{g\downarrow}$ depends on the considered region, season, and period. Overall, under all-sky conditions, the SD records show a shorter and less intense decrease during the dimming period (considering the 1959-1980 period for the annual mean the decrease is not significant – $p > 0.1$ [3]) with respect to the $E_{g\downarrow}$ ones (considering the 1959-
1980 period for the annual mean the trend is about -3% per decade), while the agreement is better if the subsequent period is considered, where both variables show an increasing tendency (considering the 1985-2013 period for the annual mean the trend is about +4% per decade for E_g↓ and about +3% per decade for SD) [3]. Also under clear-sky conditions the obtained E_g↓ trends are stronger than the SD ones (considering the 1959-1980 period for the annual mean the trend is about -3% per decade for E_g↓ and about -1% per decade for SD while considering the 1985-2013 period the trend is about +4% per decade for E_g↓ and +2% per decade for SD) [4]. The reasons for which E_g↓ and SD present differences in the intensity of the trends (reported in literature also for other regions) for some periods are not completely clear especially due to the lack of long quality-checked series of variables like e.g. aerosols, relative humidity and cloudiness. Thus, in order to establish if the observed differences under clear-sky conditions could be due to a different sensitivity of these two variables to atmospheric turbidity changes, the E_g↓ and SD variations are simulated applying a model based both on Lambert-Beer’s law and on a simple estimation of diffuse radiation [4]. Results show that most of the differences observed in the trends of the clear-sky SD and E_g↓ records over the 1959-2013 period can be explained considering a realistic pattern (increase during the global dimming and decrease during the brightening period) of atmospheric turbidity (expressed by means of the turbidity Linke factor - T_L) and so that the differences in the observed SD and E_g↓ trends could be explained on the basis of their different response to T_L variations. The only exception concerns winter and autumn in northern Italy where the observed clear-sky SD does not decrease in the dimming period as much as it would be expected (modeled clear-sky SD) on the basis of the corresponding increase in atmospheric turbidity. One reason for this discrepancy could be the influence of other variables like relative humidity. A more detailed understanding of the observed E_g↓ and SD trends under all-sky and clear-sky conditions calls for further research including the study of other key variables such as relative humidity, visibility and cloudiness.

**Keywords:** Italy, sunshine duration, surface solar radiation, comparison, atmospheric turbidity
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Assessment of fire and drought vulnerability for Sardinia Region

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Abstract

Europe is one of the most vulnerable areas to climate change (CC) [1] and especially the Mediterranean basin will be the most affected area. Most of climate models predict that this area will be subjected to a temperature increase from 2.2°C to 5.1°C by the end of the century (depending on the different emission scenarios) and will also be affected by a diffuse water stress, involving more than 40% of Mediterranean population.

Sardinia Region (Italy) is located in the middle of the Mediterranean sea and climate projections show a warming tendency since the early '80s. An increase of the indices describing extremes of heat and a reduction of extremes of cold (number of tropical nights, summer days and warm nights) has been observed, as well as a slightly decrease in the mean annual amount of precipitation. Changes in climatic conditions could have an impact on key sectors for Sardinian economy: agricultural productivity could be altered, both in terms of quantity and quality of agricultural products, as well as water supply and the hydrological regime, with implications for water resources availability. Increases in irrigation requirements are then expected for the main crops cultivated in Sardinia because of climate change. Moreover, increases in water demand can derive from socio-economic changes, urbanization, population pressure on selected areas, and life style changes, causing a serious concern. Other climate
change-related pressures include changes in fire probability and severity, with a projected prolonged fire season and increased fire risk.

In order to deal with these climate impacts, and to help the Region in the development of Regional Adaptation Plan and in defining and developing adaptation strategies and policies, a vulnerability assessment of Sardinia Region to climate change was performed, in the framework of the LIFE Project “Master Adapt” (masteradapt.eu).

Based on the climate analysis and on the historical events that affected Sardinia Region, the vulnerability analysis focused on two main potential impacts that can be exacerbated by the changing climate: Fire and Drought.

Starting from the new concept of vulnerability based on the IPCC AR5 framework, where changes in both the climate system and socio-economic processes, including adaptation and mitigation, are drivers of hazards, exposure, and vulnerability, the methodological approach followed the steps presented in the Vulnerability Sourcebook [2]: per each identified potential impact, indicators related to the climate hazard, exposure, sensitivity, and adaptive capacity were collected and analyzed at municipality level.

The exposure assessment aimed to identify the main categories of assets and services exposed to fire and drought. They varied from people and animals, living in each municipality of the Sardinia Region, to the density of arable farms, as well as vegetation cover, industrial and residential areas. The sensitivity of the area to potential impact was estimated based on indicators related to vegetation characteristics, presence of irrigated farms, and percentage of elderly and young people. The level of education and economic resources available in the territory is considered an indication of its capacity to respond or manage an event, so such indicators have been used to estimate the adaptive capacity. In addition, the presence of administrative initiatives (projects, plans, etc.) that can reflect the ability to reduce the vulnerability to climate change impacts, has been considered.

All indicators were normalized and aggregated to obtain Global Exposure, Global Sensitivity, and Global Adaptive Capacity Indices, respectively. Then, the Vulnerability Index was elaborated as the combination result of the Global Sensitivity and Adaptive Capacity components per each municipality, and it was represented in
five classes. The class 1 represents the lower vulnerability level, while class 5 indicates the highest vulnerability level. Classes 2 and 4 represent the medium-low and medium-high level of vulnerability, while class 3 indicates a medium level.

Results showed that the Campidano plain is the area less sensitive to fire since it is the most agricultural area of the region, with a lot of irrigated farm land, while the most forested areas are at a medium level of sensitivity. Adaptive capacity is medium or medium-low in the island, and the global vulnerability index for fire is higher in the most natural and forested areas.

The global index for drought is actually at a medium level. However, most sensitive areas are the most natural, forested, and agricultural zones. A general medium-low adaptive capacity to drought is reported all over the island, except for the most urbanized areas (Cagliari and Sassari, Nuoro and Oristano) and the global vulnerability index ranged between class 2 (medium-low level) and 3 (medium level).

Since climate projections confirm the warming tendency of the extreme temperature indices and a slight increase in dry spells, higher level of vulnerability to both fire and drought is expected for the future (mainly under the RCP 8.5), especially in the areas already experiencing the higher sensitivity and vulnerability classes.

**Keywords:** climate change, adaptive capacity, indicators, IPCC, LIFE Master Adapt

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Impact of resolution and stochastic physics on Euro-Atlantic weather regimes’ representation

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Abstract

A set of 30-year (1979-2008) atmosphere-only ensemble simulations forced by observed SSTs is run with the EC-Earth 3.1 climate model [2] in order to investigate the ability of the model to represent the observed weather regimes over the Euro-Atlantic region [1]. Moreover, T255 resolution baseline experiment (10 ensemble members), T255 resolution experiment in which the stochastic physics parametrization [4] has been activated (10 ensemble members) and T511 resolution baseline experiments (6 ensemble members) are used in order to assess whether the representation improves increasing resolution and adding stochastic physics. Model results are compared with NCEP/NCAR reanalysis for the same period, and ERA-Interim reanalysis is also used as an additional reference. Weather regimes over the Euro-Atlantic region are computed via k-means clustering to DJF Z500 daily data for observations and simulations in the same way. The k-means algorithm [3] is applied to the first 4 Principal Components (PCs), which explain more than 50% of the variance. The standard 4 regimes are identified: NAO+, Blocking, Atlantic Ridge, NAO-. The EC-EARTH 3.1 model is able to represent the observed weather regimes over the Euro-Atlantic region. In general, the model underestimates NAO+ and Blocking frequency and overestimates Atlantic Ridge and NAO- frequency. For NAO+, Atlantic Ridge and especially for Blocking (nothing changes for NAO-) the stochastic physics improves the frequency of occurrence more than the increased
resolution. Significance of cluster partition increases of about 30% at T511 resolution and of about 12% when stochastic physics is applied.

**Keywords:** weather regimes, stochastic physics, NAO, Blocking.

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The integration of Climate Change issue in strategic Environmental Assessments (VAS): the case of heatwaves risk for the city of Prato

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Abstract

Despite many uncertainties, there is a widespread recognition that climate change will inevitably increase the susceptibility of urban societies if no effective adaptation takes place (IPCC, 2014).

The susceptibility of human communities to climate change is on the rise, and environmental transformations are seemingly happening at a previously unseen rate. As a result, assessing the effects of local changes (in temperature, for example) on the evolution and on the social, economic, institutional, and environmental resilience of communities is becoming more crucial. Community stakeholders and decision makers are responsible for protecting urban areas and their inhabitants from a wide variety of short-term and long-term risks. Determining the magnitude of such risks, which assets and communities are most vulnerable, and where limited resources would be better invested, could be a major challenge.

Current environmental baselines do not assess climate conditions as a primary factor of pressure on the environment and, consequently, on urban growth.

The purpose of this paper is to propose a quantitative, analytic framework for the identification, hierarchization, estimation, assessment and management of climate change-induced risks to human communities. The framework is intended to aid stakeholders and decision makers in the setting of priorities for the selection and implementation of resilience strategies to be integrated into urban planning. The
general process outlined herein can be extended to any type of risk, independent of its relation to climate change.

A distinctive feature of this novel approach is the mainstreaming of adaptation strategies into the development and appraisal of urban policies, plans and programmes.

The quantitative estimation, assessment and management of risks can assist in defining budgetary priorities, as well as pre-empting future hazardous events and taking specific actions aimed at local mitigation.

The development of this methodology reached an applicative stage in 2016, with the implementation of an integrated method for the estimation of the present-day and future risk to heat waves for the city of Prato (Italy).

The goal of this pilot project is the integration of climate change adaptation strategies into the ongoing development of urban plans, through the application of Strategic Environmental Assessment (SEA). Mainstreaming this new framework into assessment procedures such as SEA (now required by law) provides an effective tool for the seamless inclusion of climate change adaptation into local plan development from the earliest stage.

The proposed risk model is based on the estimation of risk as the product of three macro-factors; namely: hazard, vulnerability and exposure. In the context of climate change and its effects on urban communities, hazard refers to the likelihood of a threat (i.e., a hazardous weather event or natural disaster) occurring in a given reference period. Vulnerability describes the degree to which one or more physical or non-physical components of the community are susceptible to impacts and damages. Exposure parameterizes the degree of presence and/or magnitude of assets in places that could be adversely affected.

The Prato case study, thermal stress is the reference threat. “Vulnerability” refers to the susceptibility of the city’s senior population to such hazard, while “exposure” takes into account the distribution and density of these vulnerable citizens.

Operationally, the framework entails a stepwise modular calculation procedure coupled with a GIS. Such synergy allows seamless mapping of risk and its factors for
the case study area. The first step aims to identify the environmental conditions that lead to a high degree of thermal stress. The quantitative hazard assessment is based upon the use of the index known as Humidex describing the degree of thermal discomfort by combining the effects of heat and humidity. Heat waves are defined on the basis of quantitative values of such parameter. Quantitative hazard scenarios are compiled and mapped, illustrating the links between the intensity of a climate-related event and the discomfort experienced by a vulnerable population. Scenarios are built for the present-day situation using observed weather data, and for future scenarios using climate model projections returned by regional model COSMO_CLM in optimized configuration performed by Bucchignani et al. (2016) at the highest horizontal resolution currently available on Italian territory.

The second step focuses on the quantitative modelling of the vulnerability of senior citizens to heat waves. This step is pursued through back-calculation from available weather and health data.

The third step focuses on the compilation of an exposure scenario, detailing the distribution of vulnerable assets (elders) in each specific area of Prato consistently with available census data. This part of the evaluation process focuses on people and communities that may be more vulnerable, identifying which areas of the city stand to suffer more from a particular threat (the heat waves). The modelled scenario could be modified based on future demographic projections to adjust for urban growth.

The third step concerns the building of a risk map, detailing the quantitative estimation of thermal stress risk, and highlighting the spatial distribution of the impact of heat waves, thereby allowing the identification of the more vulnerable areas.

The results of the proposed risk estimation framework provide a quantitative example of how a community’s potential vulnerabilities can be estimated and modelled. These findings, as a part of the environmental baseline, could lead to a better oriented definition and implementation of local planning objectives and actions.

The output risk maps also serve as informative bases for the risk mitigation phase. The potential heat mitigation effects of green areas were investigated quantitatively through the modeling of the “cooling effect” index and the propagation distance of the effect itself. Quantitative mitigation scenarios, describing the decrease in hazard and
risk following the implementation of green solutions, can be prepared. This tool can be effectively adopted in the process of urban planning by stakeholders and decision-makers.

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**Keywords:** Heat waves, cooling effect, Strategic Environmental Assessment, urban heat island, risk mapping

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Antarctic sea-ice region as source of biogenic organic nitrogen in marine aerosol

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Abstract

Polar sea ice is one of the largest ecosystems on Earth, composed of a complex multiphase environment with a variety of organisms living in it and tolerating extreme conditions [1, 2]. Climate warming affects the development and distribution of sea ice, but at present the evidence of polar ecosystem feedbacks on climate through changes in the atmospheric composition is scarce. Polar marine aerosol is recognized as a key climate agent, affecting cloud properties and lifetime [3]. However, there is still a poor knowledge about the physical-chemical properties of primary (sea-spray) and secondary (atmospherically-formed) particles, especially over biologically active seawaters [4]. In the framework of the Spanish project PEGASO (Plankton-derived Emission of Gases and Aerosols in the Southern Ocean), observations of atmospheric aerosols and of surface ocean water composition were carried out during a 6 weeks long oceanographic cruise (2nd January 2015 - 11th February 2015) in the regions of Antarctic Peninsula, South
Orkney and South Georgia Islands. In this area of the ocean in the summer, large patches of productive waters (phytoplankton blooms) are observed close to sea-ice.

By means of a suite of atmospheric aerosol measurements including advanced spectroscopic techniques, we found an enhancement of secondary aerosol nitrogen compounds (especially low molecular weight alkyl-amines) in air masses travelling over the sea-ice region. Concomitant sulphur secondary species (methanesulphonic acid and non-sea-salt sulphate) and newly formed particles (1-3 nm in size) supported the dominance of gas-to-particle conversion mechanisms of aerosol formation. In addition, experiments focusing on aerosols generated by deliberate bubbling of melted sea ice showed an enrichment of organic nitrogen, suggesting sea-ice can provide an additional contribution to atmospheric aerosol nitrogen through water-ice floe-wind interactions.

Chemical and biological analyses of sea-ice and surrounding sea water confirmed the biological origin of both primary and secondary aerosol nitrogen components. The microbiota of sea ice and sea ice-influenced ocean, therefore, are a previously unknown significant source of atmospheric organic nitrogen.

**Keywords:** sea-ice microbiota, marine aerosol sources, organic nitrogen

**REFERENCES**


Non linear oscillations of mean annual sea level data in Genoa

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Abstract

In this paper we examined the tide gauge records of Genoa (44°25’ N, 08°54’ E) from 1928 to 2016 to investigate long period oscillations of mean annual sea level data. We found a significant oscillation with a period of 18.6 years associated with the period of the retrograde orbital motion of the Moon’s nodes through a complete cycle (Schureman, 1941). At the Thomson gauge of Genoa a permanent sea land reference mark is used to measure sea level changes (Lusetti, 1977). A statistical analysis on the mean annual data from 1928 to 2006 has produced a linear positive trend of about 1.1 mm per year (Demarte et al., 2007). In the present investigation the mean sea level from 2006 to 2016 has shown a positive rate of 10.2 cm compared to the 1937 to 1946 average value which is the standard reference mark for the Italian terrestrial topography. Although the tide gauge data of Genoa are limited the mean annual sea level rise can hypothetically be described in terms of harmonic and subharmonic oscillations of the 18.6 year tidal wave (Mandelstam and Papalexi, 1932). The harmonic and subharmonic oscillations of the 18.6 year tidal wave could be a powerful technique to predict sea level changes in Genoa over coming decades.
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Carbon budget of productive agroecosystems for forest regeneration

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Abstract
The regeneration of degraded lands in the Amazonian region is seen as a potential action to restore the ecosystem functions of natural forests, which have been lost through deforestation. Effective regeneration strategies should respect the local environment, be productive and economically viable to raise the interest of local communities and investors, provide a significant carbon stock to contribute to climate change mitigation, and reproduce the main characteristics of the virgin forest to attempt to replicate the main ecosystem processes. The regeneration of those lands is a (long) process that may last for years, and the planning behind substantially differs from classical agricultural plans, which are usually characterized by a scale of one or few years.

When designing and planning (agro)ecosystems aimed to regeneration of degraded lands we thus should take into account both the economic, the environmental and the social dimensions. Moreover, to maximize revenues, agrobiodiversity and carbon stock, we should consider a mid-long term planning horizon and derive only average values along this horizon [6].

In this study, we attempt to tackle these issues by analyzing and comparing alternative agroecosystems and planting strategies, starting from the traditional intensive agriculture of a single, most productive crop, to an analog forest including several productive species maturing at different times with quite different biomass. In particular, we focus on the estimate of possible climate regulating services in terms of carbon stock of different regenerative agroecosystems suitable for typical conditions of the Peruvian Amazon, in a region located 800 km from the capital Lima.
We model both the average annual carbon budget (Mg C ha$^{-1}$ year$^{-1}$) and the evolution of this budget along the first 15 years from the initialization of plantation.

The starting point of our analysis is a plant species database, containing 30 autochthonous cultivars particularly suited for agroforestry in the Peruvian Amazon [6]. Then, through data about trunk diameter, height, and wood density (g cm$^{-3}$), we feed allometric equations [4, 5, 7] developed to convert these morphometric characteristics (i.e., trunk diameter of height) into dry wooden biomass (kg). To assess the climate regulating services capacity of each species, we then transform the biomass into carbon through the use of well-known coefficients ranging from 0.46 to 0.49, depending on the species [1, 3], and we use this value within the equation describing its dynamics in time [9].

Finally, we move from the species to the field scale, by considering different possible agroecosystems. We first selected the monoculture of a regional hot pepper (i.e., Ojito de pescado) on which different rotation policies are implemented, a first one in which all plants are uprooted together and a second in which plants are uprooted gradually (i.e., the field never remains empty). Secondly, we examine three different configurations of analog forests corresponding to the solutions of different optimization problems: the maximization of the economic income, that of agrobiodiversity, and the third representing a trade-off between these two criteria. We thus compare the potential climate regulating services in terms of carbon storage with the traditional agricultural provisioning ones, expressed in terms of economic income.

The 30 considered species range from lower bushes characterized by short life cycle but quick productivity (e.g., hot pepper) to higher trees with long life cycles (e.g., Brazilian nut). This diversity is reflected also in the carbon stock performances. When we analyze the whole agroecosystems, the average carbon annually stored in one hectare ranges from 28 to 178 Mg C ha$^{-1}$ yr$^{-1}$, with carbon stocked by agroforestry being from 4.2 to 6.3 times higher than monoculture, depending on the specific alternatives considered. Moreover, according to the data we have, the agroforestry configurations achieve the plateau value of C stocked within 10 years, being comparable, at least in terms of C stocked, to the virgin rainforest [2].

On the other side, a definite conflict emerges between climate regulating and provisioning services: the monocultures have, indeed, from 1.1 to 2.8 times higher average annual economic income than agroforestry. Nevertheless, if we compare the
average performance of monoculture and the *trade-off* configuration of analog forest (i.e., compromise between maximization of income and of agrobiodiversity), it results that with an income loss of 23% we can increase fivefold the carbon storage. The agroforestry or analog forestry thus emerged as an effective solution to restore the climate regulating services lost through deforestation in the Amazon region. Moreover, the contribution to climate change mitigation of analog forestry can be even more positive since it can improve carbon stocking in the soil, and, if properly designed, it requires less chemical and energy inputs and thus reduces the GHGs emissions along the whole life cycle of the considered agricultural practices [8]. In addition, the consequent avoided input costs together with introduction of environmental incentives or compensation mechanisms could improve the short-term economic performance of those agricultural approaches and reduce the existing gap with traditional monoculture. Of course, other aspects, like nutrients balance and resilience to variable climatic conditions, should be taken into account in this comparison, and field measurements are required to assess the effective performance of real agroecosystems.

**Keywords:** Carbon stock; agroecosystems; allometric equations; deforestation; Amazon

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Isotopic signature of cave-air carbon dioxide in a semi-arid karst region

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Abstract

Planning climate adaptation and mitigation strategies requires the identification of many key aspects of the climate system and includes the development of future predictions of the effects of the current anthropogenic global warming. The main limitation of future climate projections arises from the uncertainties of scenarios built on short-term observational data based on direct physical and biogeochemical measurements, and remote sensing records. To reduce uncertainty on future projections, paleoclimate researches offer a range of tools that provides a comprehensive view of the long-term changes. Using chemical, biological and physical proxies that respond to environmental conditions, it is possible to reconstruct the climate system in periods prior to instrumental record. Past climate information also documents the behaviour of slow components of the climate system including the carbon cycle [1]. Among the different proxies, carbonate speleothems (cave mineral deposits) are excellent tools for paleoclimate reconstructions [2]. Indeed, cave environment is related to the external atmosphere and also reflects changes of global climate that can be recorded in cave deposits [3]. Thanks to their extremely high temporal resolution in stable isotopes (δ¹⁸O, δ¹³C), speleothems provide a unique opportunity for assessing changes on various spatial and temporal scales in the hydrological cycle as well as in atmospheric composition. In fact, carbonate precipitation is triggered by degassing of CO₂-rich waters that leaved the overlying soils seeping through the rock into the cave atmosphere. In turn, the abundance of CO₂ in soils is related to climate-driven vegetation activity, with warm and wet periods promoting higher concentrations. Moreover, for carbonate speleothems formed in gypsum caves, the biogenic CO₂ plays a key role in their precipitation due
to the limited contribution of the bedrock [4]. In such caves, carbonate speleothems have recently been used as paleoclimate records and their deposition has been found to be sensitive to the main climate pulsations over the last 250,000 years in Western Mediterranean [5]. However, the understanding of the connection between climate and carbonate speleothems from gypsum karst needs to be better calibrated in order to set the background for their application in future projections.

For this purpose, the $\delta^{13}$C signature of cave-air CO$_2$ has been investigated in Covadura Cave in the gypsum karst of Sorbas (Almeria, South-East Spain), a semi-arid Mediterranean region characterized by very-dry climate (less than 300 mm of annual precipitation) and by sparse maquis/matorral vegetation over a thin soil cover [6]. The 4.5 km long network of underground cave passages develops within Messinian gypsum strata (5.5 Ma), with up to 7 levels of passages connected by shafts that reach a maximum depth of 120 metres. This cave system has several entrances that connect underground and external atmospheres, thus enabling a strong air flow [7]. Air sampling campaign was carried out at different cave levels in order to obtain representative air samples at different depths and distances from the main cave entrances. The external atmosphere was also collected for comparison. Sampling was carried out by drawing cave air in a sterile syringe and injecting it into 10 mL vials with rubber septum to which the vacuum has been previously made. Air samples were analyzed in the stable isotope laboratory of Boston University using an IRMS Delta V instrument in dual inlet mode. This instrument allows the simultaneous analysis of carbon ($\delta^{13}$C) isotopic deviation to an accuracy of 0.1‰ with respect to the international standard V-PDB. Also the CO$_2$ concentration in each sample was measured.

The $\delta^{13}$C values of CO$_2$ in Covadura Cave atmosphere range from -10.56‰ to -13.78‰, with a mean signature of -12.07‰. The carbon dioxide from the air outside the cave was -12.23‰. Preliminary data indicate a significant negative correlation between CO$_2$ concentration and $\delta^{13}$C. This fact is undoubtedly indicative of the contributions of CO$_2$ from vegetation cover, which typically presents isotopically more depleted values than atmospheric CO$_2$, depending on the type of vegetation (C$_3$ or C$_4$). Indeed, the isotopic CO$_2$ signal that plants bring to the soil varies according to their metabolism, which is around -26‰ for plants with metabolism C$_3$ and close to -13‰ for those with C$_4$ photosynthesis [8]. However, due to CO$_2$ diffusion processes
in the soil, $\delta^{13}C$ is enriched approximately of 4‰, so the final isotopic signal of the vegetation in speleothems ranges around -23‰ and -9‰ for C$_3$ and C$_4$ plants, respectively [9].

These results show that although the cave atmosphere receives contributions of CO$_2$ coming from the soil by seeping water, external atmosphere influences the isotopic signature of cave-air CO$_2$. This point validates the importance of the dynamics of air circulation in cave and supports the use of carbonate speleothems from gypsum caves as paleoclimate proxy. Further researches on the carbon dioxide in gypsum cave should be carried out in order to establish transfer functions between the CO$_2$ contribution of the soil and atmosphere, and the response of the cave air to these inputs, then recorded in speleothems.

**Keywords:** Stable carbon isotope, cave atmosphere, carbon dioxide, speleothems, paleoclimate.

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Evaluation of CMIP5 simulations in reproducing freshwater flow from rivers to the sea: the case of Congo basin

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Abstract

Although water resources are fundamental for many sectors especially in the context of climate change, and projections on their expected availability have the potential to robustly support a more appropriate management, it remains still difficult to correctly simulate the freshwater cycle over the land via General Circulation and Earth System Models (GCMs and ESMs). Existing efforts from the Climate Model Intercomparison Project 5 (CMIP5 [1]) were mainly devoted to the validation of atmospheric variables like temperature and precipitation. The hydrological cycle, due to the lack in spatially explicit datasets on observed runoff, was mainly evaluated converting the simulated runoff into discharge through approaches ranging from simple averaging at catchment scale to offline flow routing algorithms.

To investigate the present-day performances of GCMs and ESMs participating to CMIP5 in simulating the discharge of large rivers into the sea, we considered the output variable “Water Flux into Sea Water From Rivers” for 20 CMIP5 models and related runs (in total 71) under historical forcing (reflecting atmospheric composition changes due to both anthropogenic and natural sources and, for the first time, including reconstructed evolution of land cover). The selected case study was the river Congo thanks to: i) the long-term availability of discharge data for the Kinshasa hydrological station taken as representative of more than 95% of the water accumulated in the whole catchment [2]; and ii) its still low influence by human
intervention, which enables comparison with the (mostly) natural streamflow simulated within CMIP5.

Our findings suggest that many advancements are still required in global modelling to satisfactorily reproduce the discharge at least for Congo river, since most of models appear overestimating the streamflow in terms of seasonal cycle, especially in the late winter and spring, when the secondary peak of discharge is well above that in observations, while overestimation and variability across models are lower in late summer. Besides standard ensemble mean and median, Weighted Ensemble Means (WEMs) were also calculated based on simulations’ performances according to several metrics, showing some skills in improving the overall results.

Concerning the reproduction of discharge variability, simulated inter-monthly and inter-annual percent anomalies do not appear significantly different from those in observed data. However, when translated into well consolidated indicators of drought attributes (frequency, magnitude, timing, duration), usually adopted for more immediate communication to stakeholders and decision makers, such anomalies can be misleading. On average, the frequency for moderate, severe to extreme drought appears underestimated, and the intra-year timing not well detected, by models. At the same time, the duration of water deficit periods with respect to a reasonable water demand, i.e. assumed sustainable if looking at monthly streamflow averaged over the long-term, seem overestimated by models. These inconsistencies produce incorrect assessments towards water management planning and infrastructures (e.g. dams or areas to be irrigated), especially if models are used instead of measurements, as in case of ungauged basins or for basins with insufficient data, as well as when relying on models for future estimates without a preliminary quantification of model biases.

**Keywords:** discharge, climate models, CMIP5, drought indicators, Congo river

**REFERENCES**

Impact of reduced sea ice in the Barents/Kara Seas on NH winter atmospheric circulation in a Seasonal Prediction System

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Abstract

The sea ice cover in the Arctic Ocean has experienced an ongoing loss in both thickness and extent in the last decades, with consequences for northern hemisphere winter atmospheric circulation (Bader et al., 2011). Sea ice is an important player in the global climate system owing to its properties: 1) It acts as an insulator between ocean and atmosphere, therefore hindering fluxes of energy, mass and momentum, 2) it is an efficient reflector of incoming shortwave radiation and 3) phase changes related to freezing and melting processes alter the vertical stability characteristics of the water column and therefore ocean circulation. While a lot of attention has been paid to the mechanisms that have been driving the accelerated decline in sea ice extent in the last decades, it has also become clear that reduced sea ice conditions during summer and autumn effect the local and large-scale in the atmosphere in the following winter. On the seasonal time scale, autumn Arctic sea ice concentrations (SIC) have shown to be a source of predictability for winter Euro-Atlantic climate in observational data (García-Serrano et al., 2015). The present study aims at investigating this aspect further by forcing a seasonal prediction system with reduced sea ice cover in the B/K Seas to study the timing and character of the atmospheric response in the following winter season.

The largest sea ice loss in the Arctic Ocean during the observational period since the late 1980s has been occurring in the Barents/Kara Seas (B/K seas), which has been associated with the warming and strengthening influence of Atlantic inflow (Årthun and Eldevik, 2012). Areas of sea ice loss are characterized by an increase in near-surface temperature, increased
latent and sensible heat fluxes from the ocean to the atmosphere, reduced atmospheric vertical stability and a decreased meridional temperature gradient to lower latitudes and consequently a weaker westerly flow. In most modelling studies an SLP pattern emerges that resembles the negative phase of the NAO (e.g. Deser et al., 2007). It has further been demonstrated that the timing of sea ice perturbation sets the robustness, significance and timing of the atmospheric response in winter (DJF). Re-analysis studies have shown that only November sea ice anomalies had a significant impact on later winter SLP, surface air temperature, and precipitation anomalies over the Euro-Atlantic sector, involving a coupled response with the stratospheric polar vortex (García-Serano et al. 2015). Here, the transient character of the atmospheric response to reduced sea ice conditions in November and beyond is studied in an ensemble of simulations using the CMCC seasonal prediction modelling system (SPS). The winter of 2016/17, which was characterized by strong negative sea ice conditions in the B/K seas region, serves as a benchmark year for studying the transient winter atmospheric response to both realistic and reduced autumn sea ice conditions in the B/K Seas. Analyzed fields include Arctic surface energy fluxes and lower tropospheric circulation, as well as aspects of large-scale circulation beyond the Arctic.

**Keywords:** Arctic sea ice, Arctic-mid latitude teleconnections, seasonal prediction
REFERENCES


Soil organic carbon in Italian forestry and tree crop soils: actual stock and future projections under climate change conditions

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Abstract

Soil organic carbon (SOC) represents the largest carbon pool in the terrestrial biosphere, containing twice as much carbon as the atmosphere and three times that in global vegetation[1]. The soil can act both as a carbon sink (taking CO₂ from the atmosphere) and as a carbon source (releasing CO₂ into the atmosphere) according to a direct relationship: an increase of 1 Pg of SOC corresponds to a decrease of 0.47 ppm of atmospheric CO₂ and vice versa[2]. Soil carbon sequestration should be evaluated as a strategy for climate change mitigation by reducing the atmospheric Greenhouse Gases (GHGs) concentration over the next century[3]. Therefore, it is crucial to improve our knowledge on Soil Organic Matter (SOM) dynamics in order to understand the potential of soils to accumulate carbon and to estimate the actual SOC stock and future changes at global level. Regional studies are necessary to improve the accuracy and precision of global SOC estimates, mainly at country scale[4]. A literature survey carried out in the Euro-Mediterranean area showed a data shortage related to the carbon stored in forested and tree crop soils[5]. Furthermore, few works evaluated the climate change impacts on the SOC stock. Models of SOC dynamics, as CENTURY ecosystem model[6], represent a powerful tool to assess both the actual SOC stock and future changes on terrestrial ecosystems.
CENTURY, enclosed the last available version (v.5), works at local scale (single points) and has been validated for many agricultural and forest ecosystems.

The main objectives of this work were: (i) to develop a methodology for allowing the use of CENTURY 5 at regional scale and (ii) to assess the current SOC stock and the climate change impacts at national (Italy) scale for forestry and tree crop surfaces.

In the first part of this work, a spatial modeling platform was developed in a GIS environment. Using ArcMap 10.1©, the soil (HWSD 1.2)[7], climate (EURO-CORDEX Project), and land cover (IUTI)[8] layers were overlaid.

Considering all land cover classes, the actual SOC stock values ranged from 51.40 to 129.50 Mg ha\(^{-1}\). The minimum value was observed for the orchard category (51.30±1.20 Mg ha\(^{-1}\)), followed by vineyards (51.50±1.40 Mg ha\(^{-1}\)), and olive groves (51.60±1.60 Mg ha\(^{-1}\)). The highest value was found in coniferous forests (129.50±201.10 Mg ha\(^{-1}\)). High SOC stock values correspond also to Mediterranean maquis, ranging between 86.90±95.40 and 81.30±35.80 Mg ha\(^{-1}\), and to broad-leaved forests (80.30±1.30 Mg ha\(^{-1}\)). The SOC stock values simulated for the natural grassland ranged from 52.80±3.30 to 52.60±3.50 Mg ha\(^{-1}\).

Considering the 3 different GCMs used in this study, the total SOC stock in Italian forestry and tree crop soils ranges from 1320.10 to 1425.10 Tg. The largest contribution to the total SOC stock was found in the broad-leaved forests (701 Tg), followed by coniferous forests (from 295 to 399 Tg). Mediterranean maquis systems provided a small contribution to the total SOC stock (from 43.40 to 46.50 Tg).

CENTURY 5 simulated very low SOC decreases from the year 2005 to 2095, greater for the extreme scenario (RCP 8.5) compared to the moderate one (RCP 4.5).

The future projections obtained in this work were compared with those reported by other authors that simulated future changes of total SOC stock, mainly for other land cover classes.

The total SOC decrease observed was lower compared to those reported by other authors. These trends confirmed that forestry and tree crop soils, compared to other land cover classes, could represent an important tool for the climate change mitigation. These results would represent a contribution for improving our knowledge on the role of Italian forestry surfaces both for scientific purposes and the development of policies related to climate change mitigation.
Keywords: Soil Organic Carbon, CENTURY model, carbon stock, climate change, Italian forests, tree crops

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The Influence of Causal Knowledge on the Willingness to Change Attitude toward Climate Change: Results from an Empirical Study

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Abstract

Climate change is one of the most important global challenges currently facing the world today. The global climate is warming and significant changes are expected in the future, with many people at high risk. Political reaction to this global threat has been slow and uncertain so far, and the reaction of the general public seems to be similarly sluggish. Many surveys were run in the past few years about people’s perception of, and reaction to, climate change. Thanks to the reliable work of organizations such as the Intergovernmental Panel on Climate Change (IPCC), belief in the existence of anthropogenic climate change and its seriousness has been consolidating in recent years, at least across Europe and the United States, while unfortunately the behavioural response is still limited, with few people taking relevant action [1][2].

Far fewer surveys have focused on the reason for this lack of behavioural response. A 2008 Eurobarometer [3] directly asked interviewees why they have not taken action on climate change, and it emerged that 42% think “it is governments, companies and industries that have to change their behaviour, not citizens”; 34% “would like to take action but do not know what you could do to fight climate change”; and 26% “think [that] changing behaviour will not have a real impact on climate change”. Lack of knowledge has often been considered as a minor factor in influencing behaviour towards the environment [4][5][6]. Furthermore, surveys have reported a widespread awareness (and even a certain degree of self-reported knowledge) of climate
change, but still insufficient behavioural response [1][2]. However, surveys that went more in depth in the investigation of people’s knowledge about climate change revealed a relatively poor understanding of some basic climate dynamics. Interviewees did not have a clear idea in their minds as to what CO2 is exactly [7]; they believed that the ozone hole is a significant contribution to climate change and the greenhouse effect, and that greenhouse gases in the atmosphere do not affect the average global temperature of the Earth [8].

By analyzing the survey results, we can advance a first hypothesis: people are aware of climate change, but they lack knowledge of causal relations within climate dynamics, and, specifically, they are not aware of their role as “causal agents” within climate problems: individuals do not know what causes climate change and do not grasp their interaction with it, and consequently do not perceive the effect of their actions on the environment. [9] This implies also a lack in the sense of moral responsibility. [10]

In this study, we make the hypothesis that there is a kind of knowledge that can positively influence willingness to adopt pro-environmental behaviour - a scientific knowledge focused on clarifying climate dynamics, which can make people understand the existence of a complex interaction between man and nature, through modelling climate phenomena like greenhouse effect and global warming, and recognize their role as causal agent in such a complex dynamic. We argue that willingness to adopt pro-environmental behaviours presupposes a kind of knowledge where individual causality is clear and explicit, and that acquiring some practical knowledge on the impact of daily actions on the environment may allow people to help prevent climate change.

In order to test our hypothesis, we designed proper teaching material [11] for Italian secondary-school students (grades 11-13) and implemented it in a multidimensional laboratory course (15 hours).

The teaching experiences consisted of after-school laboratory-courses held in science-oriented secondary schools in 2012-2013-2014. The teaching materials implemented in the laboratory-courses were designed in light of the multi-dimensional nature of the problem and is intended to mirror the complexity of the issue.
During the course, data were collected. In order to investigate the level of students’ involvement in climate change and the quality of their knowledge we designed a pre-questionnaire (Q1) and a post-questionnaire (Q2), given before and after the course. Students’ answers were analysed through a bottom-up iterative process, aimed at discovering ways to reveal whether and how their level of knowledge and behavioural attitudes evolved.

Operatively, the analysis allowed us to identify some operative markers which could reveal whether and how students i) enriched and refined their level of knowledge, ii) improved their behavioural habits; iii) and if there are any correlations between level of knowledge and behavioural habits. The markers concern two kinds of patterns - of knowledge and of behaviour, which have been identified through a process of triangulation among the researchers. The identification of them allowed us to track the evolution of the whole group of students along the two dimensions investigated.

This work was the subject of a recent publication of the authors [12].

In this presentation, we will describe the teaching experience we ran in order to investigate the relationship between knowledge and willingness to adopt pro-environmental behaviour, we will discuss the data collected and propose a possible interpretation.

**Keywords:** causal knowledge; behavioural change; science education.

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Climate downscaling for assessing the impact of changes in precipitation extremes

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Abstract

The horizontal resolution of climate models, currently ranging from hundreds to tens of km, is generally not adequate for studying the impacts of climate change at local scales, for example on ecosystem functions and processes for which resolutions of 1 km or finer would be required. Downscaling techniques are commonly applied to increase the spatial resolution and refine the spatial detail provided by the climate models. In this study we focus on the downscaling of precipitation and we propose a modification to an existing stochastic downscaling procedure, RainFARM [1, 2], to take into account the additional complexity in case of mountain topography.

Orographic precipitation mechanisms play an important role in determining patterns of small-scale precipitation in areas with complex orography, but several current stochastic precipitation downscaling procedures cannot take into account orographic effects at scales smaller than those resolved by the original precipitation field to downscale. As a result, the long-term climatology at individual grid points may differ significantly from observations.

We introduce a simple method to take fine-scale orography into account when the stochastic method Rain-FARM is applied to downscale precipitation from climate simulations. The method is based on the availability of a reference fine-scale climatology, such as gridded observations from a dense network or high-resolution dynamical simulations. This reference climatology allows to derive corrective weights which are applied to the realizations of stochastic fields generated by RainFARM, allowing to reproduce a more realistic long-term precipitation climatology at fine scales.
We first demonstrate the method in a perfect model example: large-scale (64km) precipitation fields, obtained by spatially aggregating high-resolution precipitation fields (4km) from WRF simulations over the Swiss Alps in the period 1980-2008, are downscaled back to the original fine resolution. We compare the resulting probability distribution of precipitation extremes with that represented by the original fine-scale data. In this case, a perfect knowledge of the desired precipitation climatology is assumed, and the climatology resulting from the fine-scale WRF data is used.

Further, we demonstrate the method in a more realistic setup, in which we downscale E-OBS precipitation data (25km to 1km) over the Swiss Alps and compare the resulting fields with high-quality in-situ observations from MeteoSWISS, in the period 1981-2010. We compare the impact of using different data sources for the weights and we show that a high-resolution climatology derived from regional model simulations, even if affected by important biases, can provide useful weights, comparable to those which can be obtained from dense observation networks. This would allow to apply this method, without any calibration, also in areas where a high-resolution precipitation climatology from observations is not available or reliable. This method has been applied to derive fine-scale precipitation scenarios for a set of internationally recognized Protected Areas in Europe in the framework of the H2020 ECOPOTENTIAL project.

**Keywords**: precipitation, stochastic downscaling, RainFARM, mountains, ecosystems

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Projected mean and extreme precipitation through statistical downscaling method in Life-PRIMES project

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Abstract

Extreme climate and related impacts are becoming more frequent during the last decades. Intensification of the hydrological cycle is expected to coexist with a warming climate. Changes in precipitation may differ between regions, seasons and aspects, such as totals or extremes. An increase in extreme precipitation may not always lead to an increase in total precipitation over a season or over the year. Deep knowledge on this topic, over present and future period, could help to reduce risks and exposure and tackle the emergencies. The Life PRIMES (01/10/2016-31/07/2018) -Preventing flooding risk by making resilient communities- is project funded by the EU Life Program focused on the issue of adaptation to climate change, and aims to build resilient communities over three Adriatic regions: Emilia-Romagna, Marche and Abruzzo (ER-MA-AB). The first step of the project is to construct a climate profile over the three regions, with focus on precipitation. To this aim, a set of climatic indices focused on mean and extreme precipitation has been selected and changes during 1961-2015 (present) and 2021-2050 (future) are evaluated and presented in the present work.

Daily precipitation from stations that belong to the three regions ER-MA-AB have been collected for the 1961-2015 period, analyzed and selected from homogeneity and quality point of view. Finally, around 280 stations from the three regions contribute to a definition of a gridded daily analysis at 5x5km resolution (Antolini et
al., 2015), that represents the common data set of Primes project. Trends and changes at annual and seasonal level of total amount of precipitation, frequency of extreme precipitation, consecutive number of dry days, have been analyzed over 1961-2014 period. The results stresses a slightly negative trend in the amount of precipitation during winter and summer and a slightly positive trend during spring and autumn, over 1961-2014 period. Also, the maximum number of consecutive dry days presents positive trends during summer while autumn registered a decrease of dry days. In addition, positive trends in the number of days with precipitation greater than 95th percentile (extreme precipitation) has been detected especially during autumn season. The future scenarios of these indices have been obtained through statistical downscaling technique based on canonical correlation analysis (Tomozeiu et al., 2014) applied to CMCC-CM global climate simulations (Scoccimarro et al., 2011). The local scenarios are constructed in the framework of RCP4.5 and RCP8.5-Representative Concentration Pathways, and are referred to 2021-2050 with respect to 1971-2000. The projections of precipitation highlight a future decrease especially during spring and summer (around -15%) and an increase during winter (slightly) and autumn (around 15%). Autumn is the season with more intense signal of changes, characterized by an increase of amount of precipitation, followed by a decrease of consecutive number of dry days and an increase of the frequency of extreme precipitation.

**Keywords:** extreme precipitation, climate profile, scenarios, statistical downscaling

**REFERENCES**


Projections of tropical nights over Bologna as a resilient city

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Abstract

Urban SIS-Climate Information for European Cities is a project, running from November 2015 to December 2017, funded by the European Earth observation programme Copernicus. The project coordinated by the Swedish Meteorological and Hydrological Institute involves as partners University of Reading, University of Umea, ARPA-SIMC Emilia Romagna, University of Bologna and Veryday from Stockholm.

The goal of the project is to provide a proof-of-concept of a climate service offering essential climate variables and impact indicators based on temperature and other climatic variables peculiar for the urban environment. Bologna, Stockholm and Amsterdam-Rotterdam are selected as case studies of the project.

As contributing to the description of the local climate carried out by the project a study on a complete framework of the variability of present and future climatological indicators derived from minimum and maximum temperature with impact on human health over the city of Bologna has been run. Seasonal minimum and maximum temperature as well as tropical nights are the main analyzed indices. To this aim the gridded daily analysis of temperature with a resolution of 5x5km (Antolini et al., 2015) has been used in order to compute seasonal indices over 1961-2016 period. Trends and change points in the time series have been analysed. Future climate scenarios of these indices are constructed at local level, over the period 2021-2050 and 2051-2080 with respect to 1971-2000 through a statistical downscaling model based on multivariate regression (Tomozeiu et al., 2014), applied to CMCC-CM global climate simulation, in the framework of RCP4.5 and RCP8.5 radiative concentration pathways. As large fields, Z500, T850 and MSLP derived from ERA40 and Era-
interim re-analysis, over 1957-2010 has been used in the setup of statistical downscaling model (http://www.ecmwf.int/products/) as well Z500, T850 and MSLP derived from CMCC-CM model (CMIP5 runs) at resolution of 0.75°x0.75° from 1971-2000 and 2021-2050, 2051-2080 periods have been used for future scenarios (Scoccimaro et al. 2011).

The observed climate profile reveals significant positive trends in seasonal minimum and maximum temperature accompanied by an increase in tropical nights, especially during summer. These signals became more intense after 1990, when strong and positive anomalies in minimum and maximum temperature had been recorded over 1961-2016. Future scenarios project an increase in minimum and maximum temperature over Bologna metropolitan area during all seasons between 1-2.5°C, for 2021-2050 with respect to 1971-2000. Small differences between the climate projections of RCP4.5 and RCP8.5 during 2021-2050. The increase is more pronounced to the end of the century and during summer, when the anomalies could reach 5.5-6°C respect present climate. An intensification of the tropical is projected, more intense to the to 2051-2080 period.

**Keywords:** tropical nights, projections, statistical downscaling

**REFERENCES**


Effect of climate change on non-communicable diseases:
A data analysis using an econometric estimation

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Abstract
Several effects of climate change are widely recognized to entail serious consequences for human health. The World Health Organization estimates that the warming and precipitation trends due to anthropogenic climate change of the past 30 years already determines 150,000 deaths annually. Many prevalent human diseases are linked to climate fluctuations, from cardiovascular mortality and respiratory illnesses due to heatwaves [1]. Concurrently with the continuous growth in the global population, an increased atmospheric concentrations of greenhouse gases (GHGs), particularly CO2, methane, and nitrogen oxide, and to climate change has been registered. This paper analyses the impact of emission on non-communicable diseases (NCD) incidence and mortality rates in twenty-seven European countries. The data have been gathered from EDGAR dataset for the GHG emissions and from WHO for the epidemiology of NCDs. The changing climate has modified weather patterns, which in turn have influenced the levels and location of outdoor air pollutants, such as SO2, NOx CH4, CO, NH2, and mass particle. Literature studies has shown the impact of air quality on human health including eye irritation, Ashman, chronic obstructive pulmonary disease (COPD), heart attacks, lung cancer diabetes, premature death and damage to the body’s immune neurological and reproductive system [2].

Exposure to air pollutants may increase due to climate change because of its effect on weather and thereby pollution concentrations, anthropogenic emissions, natural sources of air pollutants, and the distribution and types of airborne allergens. For example, carbon dioxide (CO2) levels also promote the growth of plants that release airborne allergens. Summarizing, augmented GHG emissions and correlated effects, contributes to the increase in NCDs [3]. Non-communicable diseases, also known as chronic diseases, tend to be of long duration and are the result of a
combination of genetic, physiological, environmental and behaviors factors. The main types of NCDs are; cardiovascular diseases, cancers, chronic respiratory diseases (such as chronic obstructive pulmonary disease and asthma), and diabetes. In 2004, NCDs lead to 58 million global annual deaths [4]. Of the six WHO regions, the European Region is the most affected by NCD: the European office of WHO, estimated that the mortality from these diseases will increase to 8.6 million deaths per year by 2015 and this trend is worsen by the aging European population and limited public resources [5]. In order to investigate the impact of pollution on NCD mortality in Europe, we utilize a panel regression with both location and time fixed-effects to control for unobserved heterogeneity and inter-temporal trends that are uniform across countries. Our dependent variable is the incidence rate of NCDs in a particular European country in a given year, while our major explanatory variables are air pollutants, such as SO2, NOx CH4, CO, NH2s and mass particle (included individually). Furthermore, we will utilize emissions projections data under various scenarios from OECD to forecast future NCD related mortality. Our analysis shows that increases in PM and GHG levels NCDs mortality increase, coherently with several other studies that, explored potential biological mechanisms or pathophysiological pathways that link PM and GHG exposure and NCDs. Particularly, literature shows that PM acute exposure exacerbates existing pulmonary diseases, long-term exposures instead determines rapid progressions of COPD, asthma. [7]. Indeed short-term exposures have been associated with cardiovascular mortality and hospital admissions, stroke mortality. The trend is strengthen considering RCP 4.5 and RCP 8.5. The study offers an overview of the effect of climate change has an impact on the onset of NCDs suggesting how GHG emissions and air pollution represent a leading cause of both NCDs and climate change. This analysis offers also, supports on policy and actions [7] to address anthropogenic emission reduction at different areas of intervention, as air pollution, energy transition from fossil fuels to renewable, transport, forestry and food systems - that could provide benefits to NCDs and related behavioral risks[7] having positive effects on both human and planetary health.

**Keywords:** climate change, pollution, health, NCD, effects
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