climateurope
Linking science and society

POLICY BRIEF No. 1

European Earth System Modelling for Climate Services

The European landscape of climate services is very diverse. It includes a growing number of initiatives at the international and European level, from research networks of data providers, operational services, impact assessments, to coordination of government initiatives and provision of policy relevant recommendations; all provided on a wide range of timescales, from few years to decades and more, referring to the past, the present and the near to far future.

While many research projects are increasingly focusing on providing actionable results based on the scientific research on climate change, the “European Roadmap on Climate Services” stresses a need for stronger links between providers and users of climate change knowledge and information. The Coordinating Support Action Climateurope aims to respond to this demand by creating and managing a framework to coordinate, integrate and support Europe’s research and innovation activities in the fields of Earth System modelling, infrastructure and observations on one side, and climate services on the other side.

This policy brief provides an overview on the state of the art of Earth System Models (ESMs), which are an important element in the chain towards climate services. Based on Climateurope's "Report on European Earth System Modelling for Climate Services", this document synthesizes the analyses on the ESMs’ ability to perform long-term climate projections, and seasonal-to-decadal scale predictions in relation to uncertainties and opportunities for climate services. Stakeholder-oriented application often requires regionalization, also called downscaling, of the global climate change signal. The state of downscaling efforts is also addressed, as well as further refinement techniques (bias adjustment and selection techniques).

Finally, the link between ESMs and climate services is described, and some main challenges for the future are pointed out.

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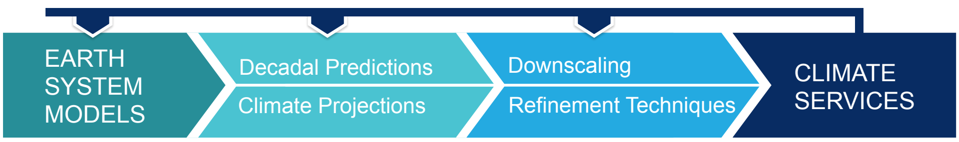
Earth System Modelling and Climate Services

Earth System Models (ESMs) are the most advanced and complex descriptions of the Earth system, providing gridded climate variables in geographical 3D space and in time.

They provide scientific support for informed adaptation and mitigation measures related to climate change, resulting in responses for human activities.

The more reliable and comprehensive ESMs are, the more accurate subsequent activities such as impact and adaptation modelling will be.



The various steps from ESMs to climate services. Information on users' requirements often influences the development of e.g. downscaling techniques, the way climate projections are analysed.

Earth System Models (ESMs) describe the global climate system and its development in time by a combination of coupled physical and biogeochemical cycles. ESMs are software codes running on the most capable available computers (HPC systems), with climate processes formulated as mathematical equations covering a geographical grid in the atmosphere, the ocean and on the land surfaces.

Earth System Modelling for Climate Projections

Earth System Models are built in basic physical principles, and they reproduce many important aspects of the observed climate. Climate projections of possible future climates need to be complemented by a quantification of results robustness, and uncertainty in order to provide relevant information for decision making.

To better understand climate change and assess model robustness, a concept based on multiple models has been initiated as Climate Model Intercomparison Project (CMIP) under the auspices of the World Climate Research Programme (WCRP). CMIP5 and the upcoming CMIP6, the latest versions of the standard experimental protocol, provide a community-based infrastructure in support of climate model diagnosis, validation, intercomparison, documentation and data access.

The quality of climate simulations for the past has increased since the mid 1990s. This brings growing confidence in climate models for quantitative future predictions and projections.

In order to assess possible future climate change, different emission scenarios are projected. New climate projections of possible future climates are to be carried out under the CMIP6 Scenario Model Intercomparison Project (Scenario-MIP) starting in 2017.

The greenhouse gas (GHG) emissions scenarios used in CMIP5 were based on Representative Concentration Pathways (RCPs) associated with different policy scenarios. For CMIP6 the concept is extended by new Shared Socio-economic Pathways (SSPs) which describe alternative evolutions of future society in the absence of climate change or climate policy. Those are combined with a range of mitigation levels and land use options, which span a matrix of possible optional pathways into the future, associated with alternatives for policy decisions.

Representative Concentration Pathways (RCPs). Scenarios that include time series of emissions and concentrations of the full suite of greenhouse gases (GHGs) and aerosols and chemically active gases, as well as land use/land cover. The word *representative* signifies that each RCP provides only one of many possible scenarios that would lead to the specific radiative forcing characteristics. The term *pathway* emphasises that not only the long-term concentration levels are of interest, but also the trajectory taken over time to reach that outcome.

Shared Socio-economic Pathways (SSPs). An SSP is one of a collection of "reference" pathways that describe alternative futures of socio-economic development in the absence of climate policy intervention. The combination of SSP-based socio-economic scenarios and Representative Concentration Pathway (RCP)-based climate projections should provide a useful integrative frame for climate impact and policy analysis. In CMIP6 RCPs and SSPs are combined to be used as input to ESMs.

(Source: IPCC GLossary - http://www.ipcc-data.org/)

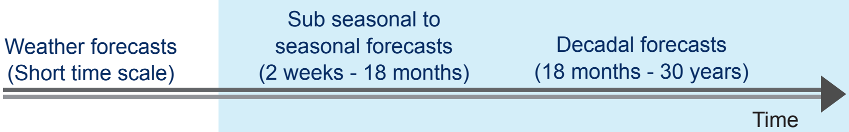
Climate Predictions and Future Challenges

Subseasonal-to-decadal (S2D) predictions, also known as climate predictions, have been a central research theme in climate science for the last thirty years. The reason behind the interest is twofold. On the one hand, a growing need has recently emerged from a suite of stakeholders. On the other hand, the scientific development behind S2D prediction benefits from progress in aspects involving both weather forecasting and long-term climate change assessment, covering a wide range of topics.

The recent developments in those two fields (increased resolution, inclusion of new components, better observations, etc.) have brought a leap forward in the quality of the climate information provided by the operational climate prediction systems.

Nevertheless, climate predictions are also expected to address a long list of challenges to produce climate information that responds to the expectations of both existing and future climate services. Three main obstacles are currently hindering the development of skilful and reliable S2D predictions:

- limited computational resources to carry out the predictions with the new systems,
- a lack of efficient communication between the scientific community and the community of users of climate information to identify the priorities for joint development, and
- the quality of the prediction system themselves to satisfy the increasing user demands.



Climate Predictions (S2D) aim at issuing statements about the actual future evolution of climate at time scales between sub seasonal and a few decades based on specific starting conditions. These statements are usally probabilistic in nature and are always made along esimates of the forecast uncertainty and quality.

From Weather Forecast to Climate Predictions

The Downscaling Effort: Climate Modelling Goes Regional

Global Climate Models (GCMs) and ESMs provide a large-scale picture of climate and climate change signals, as well as of the interactions between the various components of the global Earth system. In recent years, demands for more detailed climate information in support of climate impact assessments and of the development of regional to local-scale adaptation strategies have grown quickly. In particular, interest is high when dealing with small-scale extreme events such as local floods caused by short-term, heavy precipitation. In fact, regional and local scales are the realms of adaptation, where climate change impacts are felt and adaptation needs exist.

Regional Climate Models (RCMs) are one of the answers to those demands. By providing information with higher spatial resolution than global models can provide, regional downscaling is adding value to the underlying global climate projections and predictions. This downscaling is often needed for downstream development of climate services.

The downscaling community is focusing on further improving climate modelling, related processes and information integration methods, such as fine-scale process-level changes in the climate system and robust assessment of regional change, mainly via CORDEX. Those efforts are expected to further improve downstream climate services. EURO-CORDEX and Med-CORDEX are valuable expert communities working on both the benefits and limitations of regionally downscaled climate information. They provide guidance to user communities and are actively engaged in interdisciplinary efforts with distributors such as Copernicus Climate Change Services, and other downstream developers of climate services.

Downscaling is a method that derives local-to regional-scale (10-100 km) information from larger-scale models or data analyses. Two main methods exist: dynamical downscaling and empirical/statistical downscaling. The dynamical method uses the output of regional climate models, global models with variable spatial resolution or high-resolution global models. The empirical/statistical methods develop statistical relationships that link the large-scale atmospheric variables with local/regional climate variables. In all cases, the quality of the driving model remains an important limitation on the quality of the downscaled information.

(Source: Climate4Impact)

CORDEX. The World Climate Research Programme (WCRP) established in 2009 the Task Force for Regional Climate Downscaling (TFRCD), which created the CORDEX initiative to advance and coordinate the science and application of regional climate downscaling through global partnerships - *www.cordex.org*

EURO-CORDEX is the European branch of the CORDEX initiative - *www.euro-cordex.net*

Med-CORDEX is a coordinated contribution to CORDEX that has been proposed by the Mediterranean climate research community as a follow-up of previous and existing initiatives. MED-CORDEX takes advantage of new fully coupled Regional Climate System Models (RCSMs) - *www.medcordex.eu*

Refinement Techniques

The scientific community is committed to provide reliable data. Whether it is about climate predictions or projections, or it is about global or regional scale, the output of the models needs to be handled with care before being translated into services. The selection of a subset of models, as well as the choice of the emissions scenario(s), need to be the result of a thorough, strategic approach. Whatever selection method is applied, it is useful to provide information on the spread across the selected models and across the available models. This could help inform policy-makers about uncertainties of climate projections and their use, while also helping them consider a plausible range of projections.

Climate models are simplifications, and therefore contain deviations (biases) from reality. Most climate services need to reduce or remove these biases before the climate model results can be used. A number of bias adjustment techniques are being developed, ranging from simple scaling to multidimensional approaches. They are now an integral part of pre-processing of climate simulations results for use in impact modelling studies. Bias adjustment as a statistical approach introduces a new and unexplored level of uncertainty to the chain of uncertainties. Bias adjustment should then be applied with caution, and only with an understanding how the adjustment relates to the bias causes. Despite its imperfections, together with efforts devoted towards the development of better models, the current consensus is that there are no realistic alternative to bias adjustment for improving climate simulations. In order to explore that level, a Bias Correction Intercomparison Project (BCIP) has been recently established, and it can be expected that future climate services benefit from that effort.

The **Bias Correction Intercomparison Project (BCIP)** addresses the following topics:

- to quantify what level of uncertainty bias adjustment introduces to the workflow of climate information;
- to advance bias-adjustment techniques;
- to provide the best practices on use of bias-adjusted climate simulations;
- to make bias-adjusted simulations available on the Earth System Grid Federation (ESGF).

The **Earth System Grid Federation (ESGF)** is a collaboration that develops, deploys and maintains software infrastructure for the management, dissemination, and analysis of model output and observational data. ESGF's primary goal is to facilitate advancements in Earth System Science.

This Policy Brief is based on and refers to the ***Report on European Earth System Modelling for Climate Services****.*

Lead Author: Ralf Döscher (SMHI)

Contributors: Janette Bessembinder (KNMI), Francisco J. Doblas- Reyes (BSC), Helena Martins (SMHI), Laurent Brodeau (BSC), Vladimir Djurdjevic (RHMSS), Florian Gallo (UK Met Office), Natalie Garret (UK Met Office), Silvio Gualdi (CMCC), Daniela Jacob (GERICS), Lola Kotova (GERICS), François Massonnet (BSC), Claas Teichmann (GERICS).

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Climateurope is:

- The Europe-wide network for researchers, suppliers and users of climate information;
- A place to share best practices, gaps and recommendations and discover the state of the art about climate observations, climate modelling and climate services;
- An opportunity to actively interact with users and suppliers of climate information.

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Climateurope Partners

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www.climateurope.eu
info@climateurope.eu

From science to society

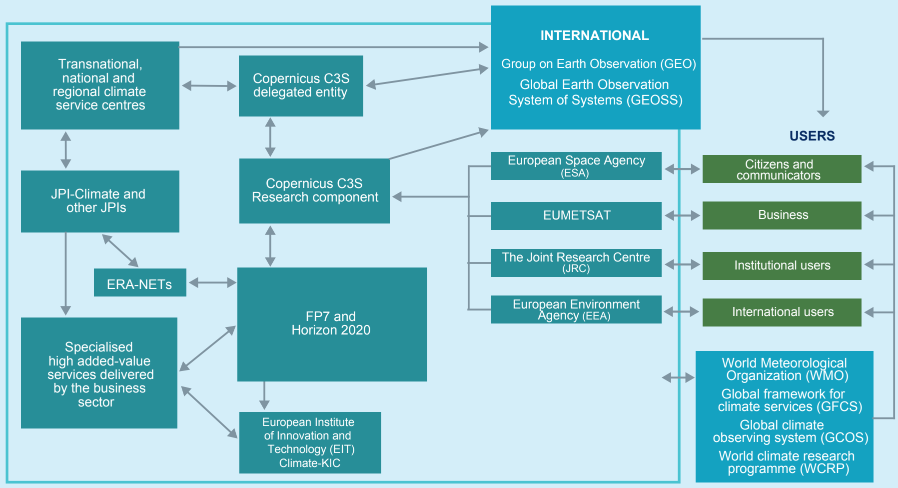
Although climate services have existed for more than a century, the term itself has only been used for the last two decades. There are several definitions of "climate services" and they are all very broad. This could be confusing for potential users and decision makers. Many of them are not aware of the kind of climate services that are available, where to find them, how to use them. In order to avoid this confusion, further development of the research-provider–user partnership will be essential to create useful climate services, and to stimulate their broader use.

The European landscape of climate services is made of a wealth of projects and initiatives. It is challenging to keep an overview, but this would enhance the integration of results and the identification of lessons learned.

Climate services users often require information that is based on various disciplines. The integration of disciplines should thus be extended and improved in order to produce added value to the services.

Quality is also an important point, but how to establish and measure the quality of climate services is still an open issue. To address this challenge a combination of excellent scientific quality of the basic data, and of combined products (integration of climate data with other relevant data), and relevance for the user ("fit for purpose", relevance for a sector or a question) should be made.

Improving exchange of experiences (papers, overviews, case studies and examples) will also help to promote an increasingly fruitful discussion on climate services and challenges.



Relationships within the European Climate Services landscape

Climate services: the transformation of climate-related data — together with other relevant information — into customized products such as projections, forecasts, information, trends, economic analysis, assessments (including technology assessment), counselling on best practices, development and evaluation of solutions, and any other service in relation to climate that may be of use for the society at large. As such, these services include data, information and knowledge that support adaptation, mitigation and Disaster Risk Management.

(Source: European Roadmap for Climate Services, 2015)

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