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Toward a European Climate Prediction System

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Information on the future climate is an essential basis for managing the risks, as well as potential opportunities, arising from a changing climate. Typically, this information comes from state-of-the-art numerical simulations of the climate in the form of *climate predictions* and *climate projections*. Climate predictions are based on simulations that are initiated from the present-day state of the climate and can extend out to several years in the future (typically a decade or less). Climate projections simulate the longer-term (decades) response to a scenario of changes in greenhouse gases and other radiative forcings, and are often initiated from a preindustrial climate.

For many decision-makers and policymakers the information available from climate simulations is not at the appropriate spatial and temporal scales they need to form the basis for their climate-related risk assessments or for climate action plans such as national climate adaptation programs. In addition, there are a range of methods and products that provide information on future climatic conditions. As a result, multiple lines of sometimes conflicting evidence often complicate adaptation planning and risk assessments. For example, there are several well-established but different national approaches to producing projections of climate change and informing national adaptation plans. Also, some decision-makers require information that spans a range of time scales from a few months or a year ahead to decades into the future. The scientific community has not yet managed to respond by providing usable climate information over this range of time scales in a transparent and robust way for many of the decision-makers.

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FROM GLOBAL SCALE TO THE CASE FOR EUROPE. At the global scale, the phase 5 of the Coupled Model Intercomparison Project (CMIP5; Taylor et al. 2012) provides a basis for coordinated and consistent global climate simulations, and is the underlying basis for the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2013). Other projects have also provided some consolidation of information, producing simulations of global and regional climate changes that provide common data that underpins projections in a number of member countries [e.g., the Ensemble-Based Predictions of Climate Changes and Their Impacts (ENSEMBLES) project in Europe, Hewitt and Griggs (2004)] but, as noted above, such global-level studies often lack the detailed focus and robustness that decision-makers and policymakers need on a regional and national scale.

For climate change impact and risk assessments at the national scale (where they exist), most countries draw on their own individual national climate projections of one form or another, often making some use of existing coarse-scale global scenarios. However, current national climate projections differ markedly in at least the following four ways:

1) There are large differences between those national climate projections that are officially recommended or mandated and those countries where national climate projections have no official recognition.
2) Uncertainties are inherent in climate simulations. The uncertainties represent limitations of knowledge, fundamental uncertainties when dealing with any complex system, differing socioeconomic scenarios, and uncertainties due to natural variations of the climate system. The treatment of these uncertainties in climate projections varies between those that explicitly quantify the impact of uncertainty on projected changes and those that acknowledge and discuss the sources of known uncertainties but provide little guidance as to how decisions can include it. There is little consistency between countries in

the data they draw on or their presentation. At their most comprehensive, climate projections quantify and account for the relative plausibility of various climate model simulations relative to the observed climate and present the information within a probabilistic context.

3) The different spatial and temporal scales of projections range from a few key variables presented for large regional and multidecadal averages to high-resolution regional data (e.g., 25-km or river basin resolution).
4) The presentation and availability of data can range from regional average changes to maps of changes; may be based on single models, multiple models, or estimates of the probability distributions; and can feature few variables or multivariate, multiscale changes. Large differences exist between whether the underlying climate model data are available to end users, and how accessible the data may be. For example, it is possible to access much of the underlying climate data that underpinned the U.K. Climate Projections (UKCP09) but it is only highly skilled users who are able to properly utilize it. Most users are presented some form of higher-level climate projection information.

These challenges can be illustrated by considering three of the best-resourced approaches for providing national climate projections, in the Netherlands (Van den Hurk et al. 2014), Switzerland (Appenzeller et al. 2011), and the United Kingdom (UKCP09; Jenkins et al. 2009). These three approaches differed in several ways, reflecting different internal drivers (Skelton et al. 2017) and targeting different end users. The main differences in approach featured different ways of generating the climate change data (different model resolutions and different complexities, with all using a multimodel approach but the U.K. scenarios additionally perturbing the physics of the model to generate an ensemble to more fully capture the model uncertainties), which in turn led to different treatments of uncertainties, different communication strategies of uncertainties (the British provided PDFs; the Swiss provided lower, medium, and upper values; and the Dutch provided single figures for each of four story lines), the actors involved (in the Netherlands the modeling and user engagement is done within one organization, while in the United Kingdom and Switzerland there are several organizations involved with well-defined responsibilities), and access to the climate data (the British made available all the output data and guidance on its limitations, while the Swiss and Dutch provided a more restricted set of information). Engagement with users during development and deployment of the climate projections also differed.

While individual nations are at liberty to continue to develop different approaches for their own national adaptation plans, the situation becomes confusing for those interested in multinational or transboundary issues. The diversity of approaches may also lead to confusion among the intended beneficiaries of the climate information and those striving to provide the most reliable and authoritative climate information. In addition, multiple approaches may prove inefficient through the undertaking of expensive bespoke climate simulations and hinder the achievability of a consistent set of climate simulations that could be considered as authoritative. A fresh approach is required, which will be potentially of use in other nations and regions.

EUROPEAN CLIMATE PREDICTION SYSTEM. The European Commission, a significant funder of research and innovation for climate action, is investing in a major four-year research and development project, European Climate Prediction (EUCP), starting in December 2017, to develop a regional climate prediction and projection system based on high-resolution climate models for Europe by November 2021, to support climate adaptation and mitigation decisions for the coming decades across all the nations of Europe. Where the term "climate prediction system" is used hereafter, it covers both predictions and projections, and the EUCP project will develop methods to blend the outputs seamlessly across a range of time scales. The climate prediction system is intended to produce consistent, authoritative, and actionable climate information. Such climate information constitutes the robust foundation upon which a range of other climate service activities and investments can be built and can support national climate service developments in all European countries that are interested.

The EUCP project will also undertake research to improve methods for characterizing uncertainty in climate predictions and projections, undertake regional downscaling, and evaluate the climate prediction system against observations. The project will support innovation through access to the state-of-the-art climate simulations of the present and future, allowing a number of market sectors to improve their longer-term planning and growth strategies. EUCP will be of significant benefit to a wide range of users

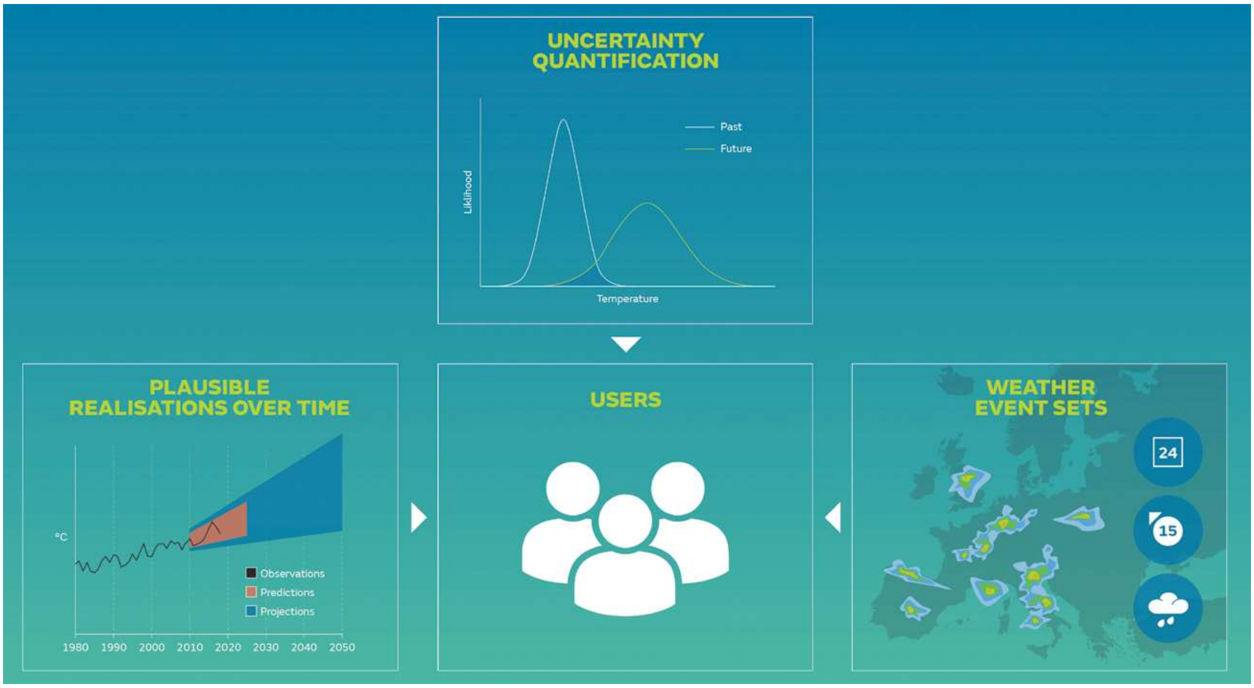

Fig. 1. Schematic of information that will be available to users from the EUCP project, including information about plausible realizations of climate, quantification of uncertainty, and extreme weather events under a changing climate.

and markets, including government policymakers, decision-makers in commercial organizations, and providers of climate services, such as national meteorological and hydrological services and climate service centers.

Given that this is a four-year research project, it is not possible for this system to be operational, but the methods being developed will be available to others worldwide—for example, through peer-reviewed publications—and can be used in other climate prediction systems, be they developmental or operational systems. As a tangible example, the European Union's Copernicus Climate Change Service (C3S) is developing quality-assured information about the past, current, and future states of the climate in Europe and worldwide. C3S is currently in transition from its development phase to an operational service, and in a few years' time the intent is to develop and provide an operational climate prediction and projection service. However, C3S will not undertake any underpinning research and instead will rely on other research activities. EUCP will therefore provide essential methodologies for a future operational C3S service. Close collaboration is being developed between C3S and EUCP, which offers the exciting opportunity to guide the EUCP climate research and development, and pull it through to an operational climate prediction system.

Coordinated European effort in EUCP through its 16 partners (listed in the acknowledgments) representing national meteorological services, research institutes, and climate service centers engaging closely with decision-makers, and wider engagement such as with C3S and many other activities and organizations, will draw on world-class expertise and more efficiently use resources than having multiple efforts, to create a groundbreaking set of climate products to support impact assessments and the developing landscape of European climate services. No single European member state can provide the resources (intellectual and financial) for such an endeavor, and the European Union is perhaps uniquely placed to do so. EUCP will also constitute a key and world-leading contribution from European science to the Global Framework for Climate Services (Hewitt et al. 2012).

EUCP PLANS AND OBJECTIVES. The primary objective of EUCP is to develop an ensemble climate prediction system based on high-resolution climate models for the European region for the near-term (1–40 years), including improved methods of characterizing uncertainty in climate predictions and projections, regional downscaling, and evaluation against observations. The climate prediction system will link current observed climate conditions, near-future predictions, and more distant future projections out to 40 years ahead. Such a climate prediction system and framework are currently lacking. The value of the climate prediction system will be demonstrated through applications focusing on high-impact extreme weather events in the near past and near future, drawing on convection-permitting regional climate models translated into risk information for, and more importantly with, targeted end users (Fig. 1).

EUCP will strive to provide climate information that will be consistent, authoritative, and actionable. The approach will be to develop and publish methodologies, good practice, and guidance for producing and using EUCP's climate predictions and projections. Progress will be monitored with targeted user engagement to test and refine the usefulness of the project outputs. Demonstration applications will be codesigned with the users.

EUCP will seek to improve the methods for quantifying uncertainty in future climate outcomes. One particular aspect will focus on how climate model output can be converted into more useful information by applying constraints derived from understanding weather and climate processes and observations of the way in which the real climate has evolved. This means that some model simulations will be given greater weight than others. Achieving this will add significant extra value to raw climate observations and model simulations. EUCP will produce possible realizations of future climate as pathways into the future selected from climate models and selected weather events. Results from climate models with spatial scales of 100 km or more will be downscaled across Europe to convective-permitting scales of less than 5 km, allowing an unprecedented ability to represent extreme weather events on climate time scales over Europe within a consistent framework (Fig. 1).

Currently, there are several barriers to providing seamless forecasts across a range of time scales, and EUCP will address many of these, such as the strong initialization shocks, the need for corrections to match observed variability and increase forecast reliability in the nearer term, and the use of constraints to bound uncertainty in the longer term. This will require the development of new forecast verification tools, and analyses and benchmarks for initialized near-term prediction systems. An immediate benefit will be new baseline information identifying where and when current systems have prediction skill over uninitialized simulations, including, for the first time, clarifying the relative strengths of different systems to be assessed (both regionally and temporally). This will reveal where the initialized predictions provide the skill required to make them decision ready. In doing so, EUCP will address the previously identified needs from decision-makers for climate information to be seamless across a range of time scales and actionable at the local scale [e.g., Bruno Soares and Dessai 2016 from the European Provision of Regional Impact Assessment on a Seasonal-to-Decadal Timescale (EUPORIAS) project; Hewitt et al. 2013]. This will allow users of climate information to look across different time scales without being concerned about the underlying modeling approach.

Given that there already exists a large number of highly useful climate simulations (as noted above), rather than undertake another large climate modeling exercise, EUCP will reuse and add value to the existing climate simulations where possible by developing and applying the methodologies introduced above to provide usable climate information. It will harvest from the wealth of existing and planned predictions and projections at the global and regional scales and create tools to combine the information derived from these components into impact-relevant analyses. However, where suitable model simulations do not exist, EUCP will produce some new model runs, such as the new convective-permitting regional simulations over Europe.

The range and quantity of climate data (observations, climate projections, and seasonal-to-decadal predictions) continue to increase. While this increase offers many benefits, inherent uncertainties, disparate and sometimes contradictory data sources, and complexity represent real barriers for use in most decision-making. As newer experiments with climate models become available, they can be included in the project, and the evolving experience with the tailoring of climate information will mean the needs of users can be better served.

In summary, EUCP will address the large differences in countries' capabilities when it comes to synthesizing climate prediction and projection information. This offers the opportunity to remove the inequality and heterogeneity that underpin the current differences in country-to-country adaptation capability and will ensure that European decision-makers will have access to consistent information, regardless of geographical location. EUCP will create the capability to produce actionable climate information, stimulate a market for climate services, and ultimately improve the social and economic well-being of Europe and its citizens. While EUCP will not provide an operational service, it will provide a framework, datasets, and demonstration services that can form the bedrock of future operational climate services for Europe.

Communication is at the heart of the EUCP project, and we will have a number of channels for disseminating the findings to researcher and practitioner communities. We invite all readers who are interested in collaborating or engaging with us to contact us so that we may involve you in this exciting project.

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FOR FURTHER READING

Appenzeller, C., I. Bey, M. Croci-Maspoli, J. Fuhrer, R. Knutti, C. Kull, and C. Schär, Eds., 2011: Swiss climate change scenarios CH2011. C2SM–MeteoSwiss–ETH–NCCR Climate–OcCC, 88 pp., www.ch2011.ch/pdf/CH2011reportLOW.pdf.

Bruno Soares, M., and S. Dessai, 2016: Barriers and enablers to the use of seasonal climate forecasts amongst organisations in Europe. *Climatic Change,* **137,** 89–103, https://doi.org/10.1007/s10584-016-1671-8.

Hewitt, C. D., and D. J. Griggs, 2004: Ensembles-based predictions of climate changes and their impacts. *Eos, Trans. Amer. Geophys. Union,* **85,** 566, https://doi.org/10.1029/2004EO520005.

——, S. Mason, and D. Walland, 2012: The global framework for climate services. *Nat. Climate Change,* **2,** 831–832, https://doi.org/10.1038/nclimate1745.

——, C. Buontempo, and P. C. Newton, 2013: Using climate predictions to better serve society's needs. *Eos, Trans. Amer. Geophys. Union,* **94,** 105–107, https://doi.org/10.1002/2013EO110002.

IPCC, 2013: *Climate Change 2013: The Physical Science Basis.* Cambridge University Press, 1535 pp., https://doi.org/10.1017/CBO9781107415324.

Jenkins, G., J. Murphy, D. Sexton, and J. A. Lowe, 2009: UK Climate Projections: Briefing report. Met Office Hadley Centre, http://ukclimateprojections.metoffice.gov.uk.

Skelton, M., J. J. Porter, S. Dessai, D. N. Bresch, and R. Knutti, 2017: The social and scientific values that shape national climate scenarios: A comparison of the Netherlands, Switzerland and the UK. *Reg. Environ. Change,* **17,** 2325–2338, https://doi.org/10.1007/s10113-017-1155-z.

Taylor, K. E., R. J. Stouffer, and G. A. Meehl, 2012: An overview of CMIP5 and the experiment design. *Bull. Amer. Meteor. Soc.,* **93,** 485–498, https://doi.org/10.1175/BAMS-D-11-00094.1.

Van den Hurk, B., P. Siegmund, and A. Klein Tank, Eds., 2014: KNMI'14: Climate change scenarios for the 21st century—A Netherlands perspective. KNMI Scientific Rep. WR2014-01, 98 pp. + appendixes, http://bibliotheek.knmi.nl/knmipubWR/WR2014-01.pdf.