EUCP Policy Brief No 3

European Climate Prediction system

ADVANCES IN METHODS, APPROACHES AND TOOLS

for climate service providers generated by EUCP

Providing high quality, actionable climate information is a key part of the work of climate service providers; the information is needed to help policymakers, businesses and other stakeholders develop effective climate planning. The EUCP project has provided new scientific findings and various different climate service products to bring the very latest approaches to the hands of climate information users.

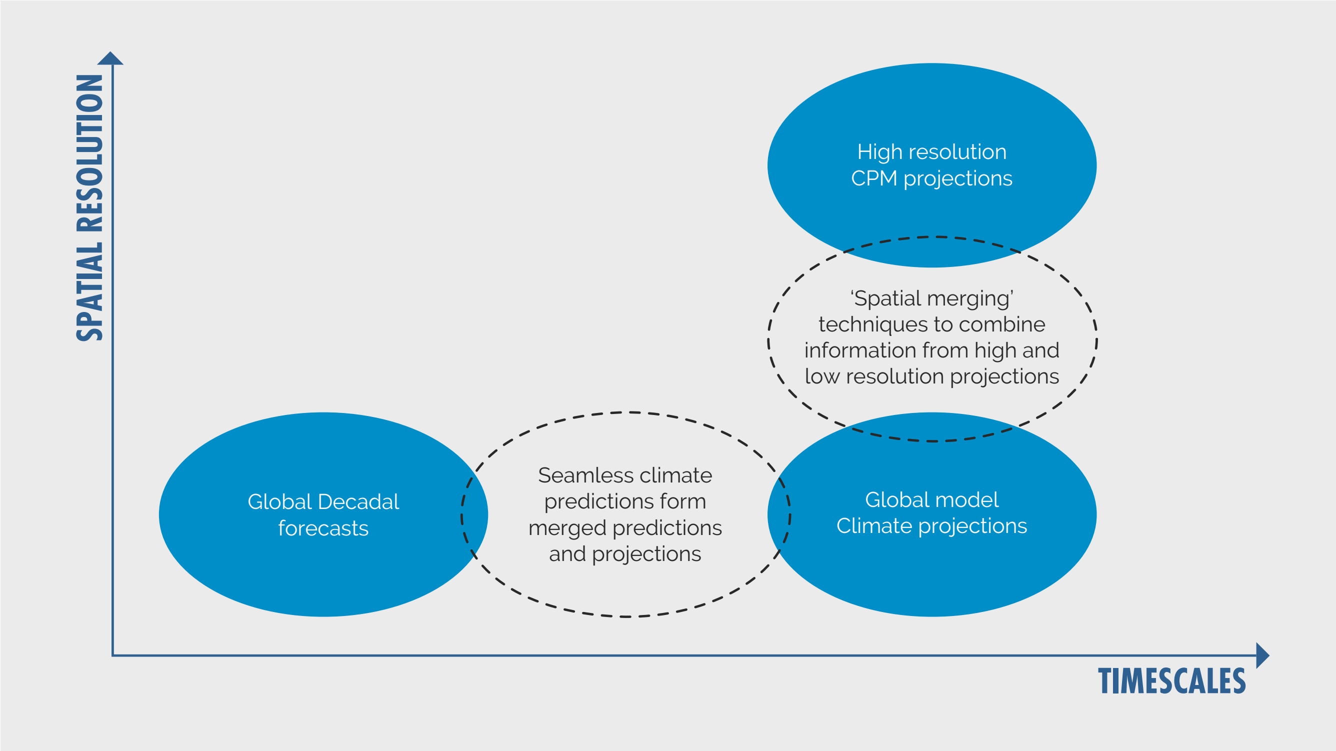
In addition, the project has developed various new methodological approaches to refine climate information products, integrate cutting-edge science and build tailored, user-focussed services.

In this brief, we present some of the key EUCP outputs, products and methodological advances. This is intended to highlight developments useful to climate service providers. They may be suitable for integrating into wider suites of climate service products or helping improve climate information offerings.

Bridging the gaps in prediction and projection information

The EUCP project has developed new approaches to producing and using climate predictions and projections. As well as offering new model simulations, new operational systems and new approaches to their application, EUCP has specifically addressed some of the gaps between the types of information required and the types of information currently available.

These include bridging the timescale gap between prediction and projection products to offer 'seamless' products for use across the timescales of a few years to 40+ years, and bridging the spatial scale gap using techniques to combine high-resolution information from small CPM ensembles with wider uncertainty information from larger ensembles of coarser global models.



IMPROVEMENTS IN DECADAL FORECASTS

Decadal climate predictions have improved considerably in recent years to the point where they are becoming a valuable source of climate information for users, and their production has moved from research to operational status. This is done by beginning the simulation so that it follows the recent past, observed, real-world climate variations, a process called initialisation, before it is run on into the future, typically for 5 or 10 years.

These predictions are computationally intensive, but despite this an effort supported by EUCP has been established to produce operational decadal forecasts for 5 years ahead. The WMO Lead Centre for Annual-to-Decadal Climate Prediction gathers forecasts from a number of contributing modelling centres and produces a new forecast every year including predictions of various indices such as temperature and rainfall. This new operational service will continue beyond the lifetime of EUCP.

These decadal predictions are skilful in several areas, such as sea level temperature and pressure. This leads on to skilful predictions of large-scale circulatory variables, including the North Atlantic Oscillation and Atlantic Multidecadal Variability. Global and regional forecasts are made for temperature, rainfall and other variables such as the chance of tropical cyclones.

The availability of new multi-model operational predictions has allowed the development of pioneering new prototype climate services. These cover many different industries, demonstrating the broad applicability of this kind of climate information:

- **Mitigation advice** – The forecast looks at the chance of seeing temperatures exceed 1.5 ˚C above pre-industrial levels, part of targets set under the Paris Agreement. Maps of these indices are provided as part of the product, as well as a verification of the previous forecast.
- **Wind power** – A team worked with partners in the wind energy industry, producing a forecast of global future wind speed. Even with a limited model ensemble due to the variable required, high skill was still seen in some areas, notably across North America.
- **Agriculture** – Two EUCP projects looked at different applications of these simulations in agriculture. Predictions of mean drought index and heat stress are particularly relevant to the wheat industry, and were found to be skilful in the forecasts. The wine industry is also likely to be affected by climate change, and a separate study looked at the impact of abrupt cooling in the North Atlantic Gyre, a possibility under climate change. The team found this could cool large areas of Europe by up to 3˚C, rendering some areas unsuitable for growing certain grape varieties.

Other projects such as the Copernicus-led C3S_34c project have applied these new forecasts in a number of other sectors:

- **Insurance** – 5-year predictions of hurricane energy and insured losses in the USA were made for a partner in the insurance industry. These had good hindcast skill, helping the partner organisation understand the challenges their business may face in the near future.
- **Water management** – The team also worked with a partner in the water management sector, looking at multi-year drought indices, supporting the partner's need for data with a high spatial resolution.
- **Hydropower** – This application involved decadal predictions of rainfall, a key factor in the effectiveness of hydropower installations. Direct forecasting by the model was not skilful but forecasting rainfall via predictions of the North Atlantic Oscillation gave much higher skill.

These examples show how useful operational decadal predictions can be to climate information users across different industries and applications, interested in different variables and different spatial and temporal scales. Climate service providers can now start to build on the examples from other users and start to build decadal forecast information into real-world applications.

NEW SEAMLESS INFORMATION FOR ADAPTATION ACROSS TIME-SCALES

Climate information is a key part of adapting to future climate changes. Climate model simulations might tell us how heatwaves could change a few years ahead out to 40+ years' time, helping us adapt public health measures. They may simulate worsening droughts, allowing us to adapt water management plans accordingly. EUCP is committed to providing methods for accurate, reliable and actionable climate information to enable effective decision making as the climate changes in the coming decades.

Many strategic decisions require climate information that spans the next few decades. This information can come from two distinct types of climate simulation. Decadal predictions, which integrate observational data to refine their simulations, typically run for 5 or 10 years into the future. Climate projections run much further into the future (several decades or longer) and capture long-term responses to forcings like greenhouse gas emissions but don't typically capture the phase of important real-world modes of natural climate variations, such as the state of the North Atlantic Oscillation. This means that two different systems are used to provide information.

EUCP has developed pioneering new methods to combine the information from these two types of simulation, in order to capture the benefits of both predictions and projections and provide a single, seamless product for applications which span these timescales. One such approach uses the information from the decadal predictions to constrain the longer-term projections. By sampling projections with the highest agreement with the decadal predictions over their first 10 years, EUCP has found that the selected subset shows improved skill out to around 20 years in the future. This can therefore be used to provide climate information across the timescales. An alternative approach is to 'stitch' together information from prediction and projection ensembles. EUCP has pioneered this stitching approach using prediction and projection data from 8 climate modelling systems, exploring how observational constraints could be used to minimise inconsistencies at the merging point.

Ongoing research is taking place on these techniques, which could become a valuable part of the future climate projection toolkit. Currently, the technical readiness of this information is lower than for other decadal forecast information, but we hope that climate service providers can help to shape these products and look towards operationalising seamless climate predictions. They can do this through projects such as climateurope2 and other new projects due to commence in the next round of funded Horizon Europe research such as ASPECT.

[1] The North Atlantic Oscillation (NAO) is a large-scale atmospheric pressure see-saw in the North Atlantic region which strongly influences more local European weather patterns such as temperature, rainfall and wind strength/direction. Predicting the phase of the NAO several months or years ahead offers important opportunities to prepare for increased or decreased likelihood of associated weather events such as damaging winter storms, high near surface wind-speeds and extreme temperatures.

IMPROVED INFORMATION ON EXTREME WEATHER IN THE CLIMATE OF THE FUTURE

Convection-permitting regional climate models (CPMs, or CP-RCMS) are very high-resolution models of the Earth's climate that have a grid spacing of less than 5km. This enables them to represent small-scale processes in the atmosphere such as convection. Convective storms can cause some of the most extreme and sometimes damaging weather in the form of extreme rainfall, hail, lightning, and severe wind gusts. Research from EUCP has provided high-resolution climate simulations for Europe for the coming decades that can be used for risk-based planning. CPMs can provide robust projections of future changes in short-duration precipitation extremes, particularly useful in flood risk planning.

EUCP has produced a set of new high-resolution CPM projections for domains that capture mainland Europe. For each domain, these high-resolution projections have been made using at least 2 CPMs developed by different climate modelling centres. These multi-model CPM projections allow us for the first time to assess the uncertainty in future changes in high-impact weather that occurs due to convection, such as high-intensity, short duration rainfall.

EUCP contributed to a study using 12 different CPM models for a single common region over the Alps, an area often affected by short duration extreme rainfall which can result in flash flooding. This model comparison has shown that CPMs show consistent improvements over coarser models in representing the occurrence of rainfall and the intensity of high-impact extreme events. Multi-model CPM ensembles have also helped to reduce uncertainty in future rainfall projections – results from 12 models showed consistent future increases in the intensity of summer and autumn downpours over the Alpine region. These high-resolution simulations have been applied to hydrological impact studies for the Alps to provide new information about the future frequency and severity of flash floods.

The EUCP projections provide information at an unprecedented scale for understanding uncertainty in future change in high impact weather events, including flash flooding, droughts and heatwaves. Other important areas include climate change impacts on electricity generation such as wind for renewables and transmission, including hail and lightning impacts on electricity infrastructure and on urban heat and human health.

There are still come challenges to overcome; CPMs still require too much computing capacity to run large enough ensembles to fully represent uncertainty for all parts of Europe. EUCP has explored and compared a number of approaches for combining the high-resolution information from a small number of CPM simulations with the wider uncertainties captured by lager ensembles of coarser global models ('spatial merging').

Climate service providers can now start to use CPM data in their products. However, as the CPM data is still limited, they should use it alongside other regional climate projection products.

IMPROVED REGIONAL CLIMATE INFORMATION FROM GLOBAL MODEL PROJECTION ENSEMBLES

Climate model ensembles offer the basis for our uncertainty estimates of future long-term climate, but simple interpretation of the ensemble might not lead to the most useful information. EUCP has explored a number of avenues for treating models that help us to offer improved regional information from the data contained in those ensembles.

Using observations to constrain climate projections:

EUCP has applied and evaluated a number of different methods for constraining, calibrating and weighting model projections for Europe. This is the first time that such skill has been systematically evaluated for a range of methodologies, and the study has provided clear evidence that constraining climate projections against observed changes adds value over using raw climate projections.

- Evaluation has shown clear benefits for projections of temperature changes (or closely related variables). These benefits are evident for all methodologies explored, though some clearly do better than others (in metrics, or either forecast skill or mitigating over-confidence). This work makes a strong case that constraining with observations is likely to lead to more reliable regional climate projections.

- In contrast, there are no obvious benefits for rainfall projections in terms of narrowing uncertainty range or mitigating over confidence. Observational constraints do not obviously degrade skill either and may still represent an appropriate approach when exploring constraints on joint distribution of variables.

- Choice of methodology (amongst those evaluated in EUCP) for a particular application will depend on the demands. EUCP provides an evidence basis for the added skill, which can help inform choices, alongside other factors such as whether spatial and physical coherence is needed across variables.

- Maps of pre-processed observationally constrained data have been made available via the EUCP European Atlas (tinyurl.com/EUCPatlas) for all methods, alongside source code and public code implementations for a number of the methods, as well as user guidance.

Providing context for climate impact case studies over Europe:

Observationally constrained European projections can be used to provide context for individual realisations or subset of models. For example, impact models often rely on inputs from smaller samples of higher resolution regional climate models. By placing the large-scale response of these models within the constrained ranges, it provides a context how these subsets of individual realisations span the wider plausible ranges – indicating, for example whether they sample the higher or lower end of potential temperature changes or whether they sample drying or moistening ends of the rainfall distributions.

Selecting appropriate ensemble members for European climate impact studies:

Approaches have been developed in EUCP that either assess the latest projections from CMIP6 in terms of their performance in simulating large-scale characteristics of European climate, or other ways to weight or constrain projections, and identify a set of well performing models for the region that are suitable for a wide range of applications. EUCP has worked to screen out CMIP6/5 simulations that fail to capture key European climate processes (e.g., storm tracks, blocking) – helping to avoid climate projections based on poor climate models. This screening of current models helps users of this data access the more plausible future projections and reduce ensemble size.

Storylines approaches for Europe:

Storylines, or narrative approaches to constructing and communicating climate information, are a growing area within climate science and services. EUCP has explored this in the contexts of
(a) storylines as part of the scientific and data production process, and
(b) storylines as a climate service.

EUCP has developed and demonstrated a number of the scientific 'building blocks' of storylines including hazard events and variability, as well as clustering methods. A key part of the storyline construction process is the co-production of knowledge around climate forecasts and projections. EUCP has demonstrated two co-production case studies for the heritage and water supply management sectors, finding that there is an appetite for storylines across these very different users. We have also shown how storylines can be used as a communication tool by simplifying the often-overwhelming volume of climate data, as well as a tool for better understanding of the characteristics of a climate model ensemble for a climate hazard of interest.

Climate service providers should now consider moving beyond giving equal weight to all climate projection ensemble members but should do so with caution, noting the differences between methods. Additionally, the use of storyline approaches might be appropriate in many circumstances, but ideally is used together with information on the likelihood of particular climate outcomes from multiple lines of evidence.

MORE INFORMATION

1. EUCP data catalogue:
   tinyurl.com/EUCPdata

2. Atlas of Constrained projections for Europe:
   tinyurl.com/EUCPatlas

3. Storyboards:
   tinyurl.com/EUCPstory

4. Carbon Brief article on new high-resolution projections for Europe:
   tinyurl.com/EUCPhi-res

EUCP has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 776613