(GRANT AGREEMENT 776613)

European Climate Prediction system (EUCP)

Deliverable D1.1

Compilation and combination of multiple initialised climate predictions and delivery of real time climate predictions in collaboration with WMO

Deliverable Title	*Compilation and combination of multiple initialised climate predictions and delivery of real time climate predictions*	
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		PP - Restricted to other programme participants, including the Commission services
		RE - Restricted to a group specified by the consortium, including the Commission services
		CO - Confidential, only for members of the consortium, including the Commission services

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1. Executive Summary

- *The report describes the current set up and the ongoing work in support of the WMO Lead Centre for Annual to Decadal Climate Predictions and its role in delivering information from decadal climate predictions in a consistent way, based on robust scientific methodology, and in a format accessible to a variety of users and audiences.*
- *Decadal climate predictions have been produced and collected together every year since 2010. This was originally an ad hoc activity but was recently formalised by the WMO who designated a Lead Centre for Annual to Decadal Climate Prediction in 2017 and four Global Producing Centres in 2018.*
- *All of the forecasts, along with verifying observations where available, are shown on the Lead Centre website (www.wmolc-adcp.org).*
- *An Annual to Decadal Climate Update has been developed that summarises the most recent forecast as maps and selected indices, along with assessments of forecast quality. This is currently in a trial phase, but will be distributed more widely to users in 2020.*

2. Project Objectives

With this deliverable, EUCP has contributed to the achievement of the following objectives (Description of Action, Section 1.1):

No.	Objective	Yes	No
1	Develop an ensembles climate prediction system based on high-resolution climate models for the European region for the near-term (~1-40 years)	Yes	
2	Use the climate prediction system to produce consistent, authoritative and actionable climate information	Yes	
3	Demonstrate the value of this climate prediction system through high impact extreme weather events in the near past and near future		No
4	Develop, and publish, methodologies, good practice and guidance for producing and using EUCP's authoritative climate predictions for 1-40-year timescales	Yes	

3. Detailed Report

Climate forecast systems predict the future evolution of climate, taking into account internal and external sources of variability, over timescales that range from a month to a few decades. Predictions are started from an accurate estimate of the contemporaneous state of the climate system, based on observations,

and are run for a number of years into the future - typically up to a decade. Predictions are performed using ensembles of simulations, to account for a variety of sources of uncertainties in the inputs and to allow quantification of their effect on the outputs. The predictions require sets of hindcasts (forecasts for the past performed with the same forecast system) to describe the climatology of the model - and thus identify systematic errors (i.e. biases) and estimate their magnitude - as well as the performance of the forecast system, from a variety of perspectives.

Climate forecasting is quickly becoming an operational activity around the world; at present, roles and responsibilities for coordination of operational activities reside with the WMO Lead Centres for long-range forecasts. In 2017, WMO designated a Lead Centre for Annual to Decadal Climate Prediction (LC-ADCP, www.wmolc-adcp.org) based at the Met Office in the UK; four Global Producing Centres for decadal predictions (GPC-ADCP) were also designated: Barcelona Supercomputing Center (BSC), Deutscher Wetterdienst (DWD), the Canadian Centre for Climate Modelling and Analysis (CCCMA), and the UK's Met Office Hadley Centre, (MOHC). Standards and protocols regarding the provision of decadal prediction by GPCs-ADCP and LC-ADCP have also been developed and included in the 2017 Edition of WMO's Manual on the Global Data Processing and Forecasting System. These define a clear process for the contributing centres seeking WMO accreditation as GPC-ADCP, requiring commitment to the WMO-specified products and fixed production cycles, as well as to prediction verification.

In 2010 an informal exchange of near real-time decadal forecasts started as a research collaboration among several institutions around the world. In the first few years 8-10 centres participated, all participants provided surface air temperature, while few (only three centres in the first two years) also provided precipitation and mean sea level pressure. In 2013 data describing the Atlantic Meridional Overturning Circulation (AMOC) also became part of the exchange. The exchange was set on a more robust footing, with the designation of Global Producing Centres and the Lead Centre, which secured the commitment of these centres to approaching decadal prediction as an operational activity. The beginning of the EUCP project also allowed a better interface to users to be created, as well as offering support to more in-depth analysis of the data.

Data from the decadal prediction exchange is hosted at the LC-ADCP, as is a website open to public access where graphical products derived from the data are displayed (see www.wmolc-adcp.org). The average of all ensemble members from each model is shown, for the annual mean of year 1 in the forecast and for the mean over years 1-5. The average of the grand (i.e. all-models) ensemble is also calculated and displayed. The whole archive of prediction performed in real time is displayed; when available, corresponding observations are added alongside past forecasts, for comparison.

All participating centres produce initialised real-time forecasts once a year, with the date of initial conditions between 1 November and 1 January, depending on the system. The graphical plots and the data and graphical products are published in the 2-3 months following the initial conditions.

The example below (*Figure 1*) (publicly available from www.wmolc-adcp.org) shows the ensemble mean of predicted anomalies (relative to 1971-2000) for each of the participating centres, as well the average over the whole ensemble computed as the average of the single-forecast system ensemble mean, for surface air temperature in the first whole year from the beginning of the forecast (in this case, 2018), alongside the corresponding observations. In this case, ten centres provided data: BCCR (the Bjerknes Centre for Climate Research, from Norway), BSC (Barcelona Supercomputing Center, from Spain), CCCMA (Canadian Centre for Climate Modelling and Analysis), GFDL (the Geophysical Fluid Dynamics Laboratory, from the USA), LASG (State Key Laboratory of Numerical Modeling for Atmospheric Sciences and Geophysical Fluid Dynamics, from China), MIROC (a group of research institutes from Japan, including the Japan Agency for Marine-Earth Science and Technology, Yokohama), MOHC (the Met Office Hadley Centre, from UK), MPI (Max-

Plank Institute-DWD, from Germany), MRI (the Meteorological Research Institute, Tsukuba, Japan) and NRL (the US Naval Research Laboratory).

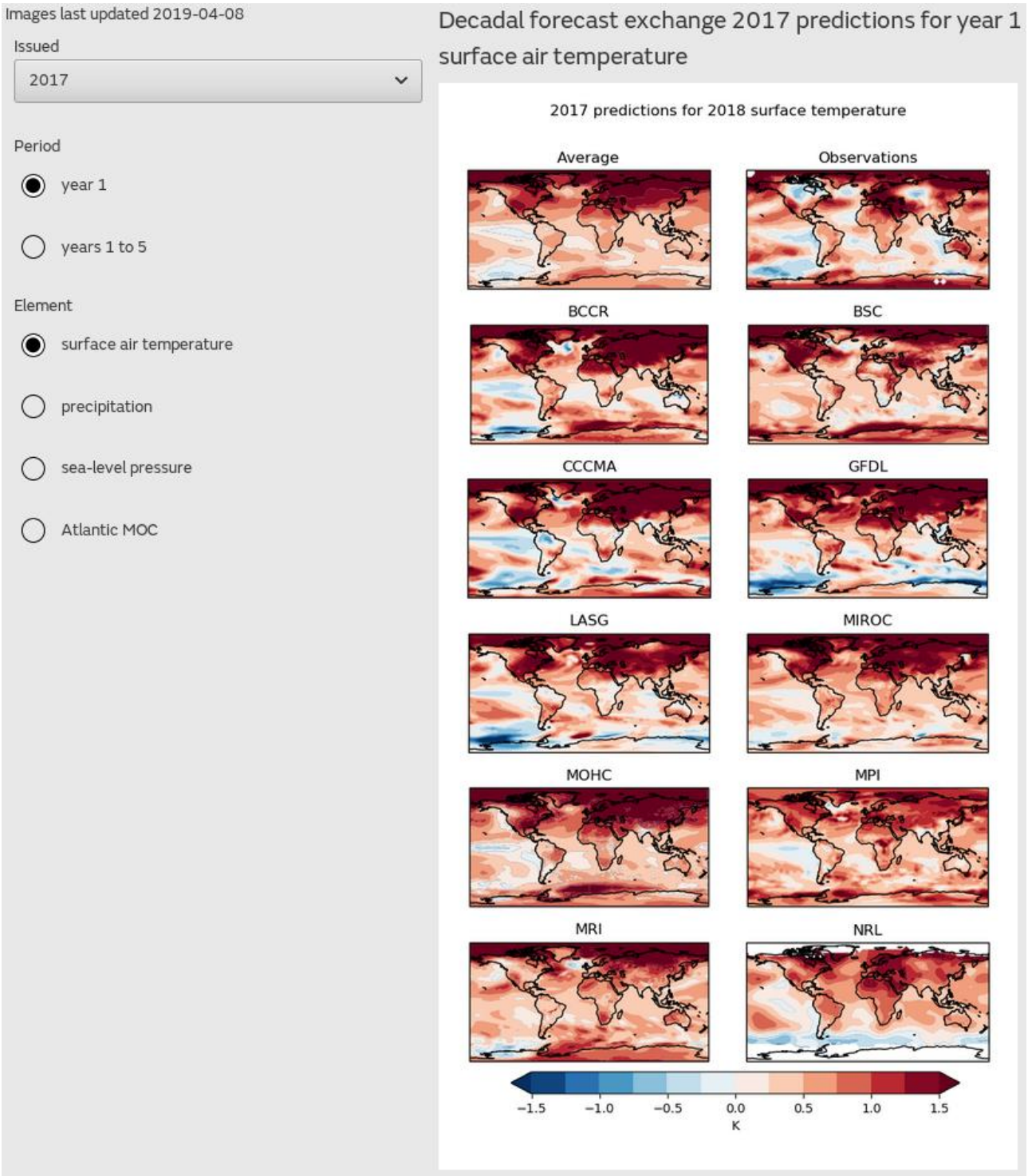

Figure 1: Example of ensemble mean of predicted anomalies (relative to 1971-2000) for surface air temperature, for each of the centres participating in the decadal prediction exchange

In the case of the Atlantic MOC (example below [*Figure 2*], showing a set of diagnostics similar to that for surface air temperature) only data from a subset of the contributors is available. Predicting the AMOC is a

key focus of decadal predictions because of its influence on European climate. However, a comparison of the predictions with observations is not provided, due to the lack of suitable observations-based products suitable for the purpose.

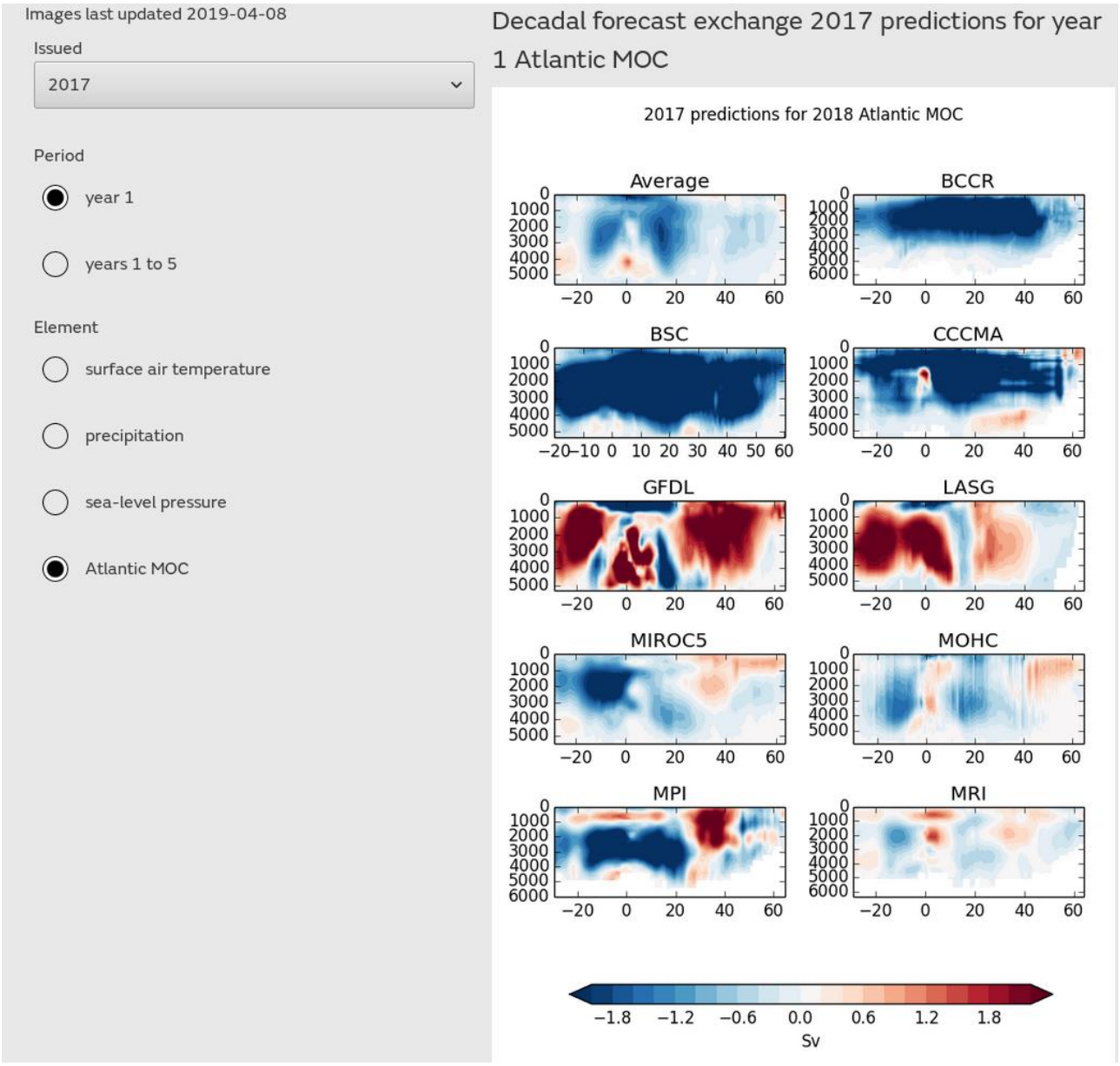

Figure 2: Example of ensemble mean of predicted anomalies (relative to 1971-2000) for Atlantic MOC

At present the data submitted by the contributing centres is restricted to anomalies for all ensemble members, post-processed by each centre according to its own methods. Hindcasts are not made available, which means that the options for different post-processing or for evaluation of the forecast products, at the Lead Centre, are restricted. Since the beginning of EUCP and the WMO support for standardisation and operationalisation, the protocol has been updated, with the aim to implement this update in the new generation forecast systems set up to contribute to IPCC's 6th Assessment Report (AR6). There, component A of the Decadal Climate Prediction Project will provide publicly-available hindcast data to complement the

real-time forecasts delivered in component B (and, separately, to the WMO-LC). The delay to implementation is unavoidable, given the need to re-run all hindcast sets with the forcing data relevant to CMIP6. This new, richer data set will allow uniform post-processing, better derivation of multi-model products as well as extensive evaluation of the attributes (skill, association, reliability) of the forecast products.

The Lead Centre website is currently being developed to allow data to be downloaded. Details on how to access this data in the pre-release phase can be obtained on request from the contact point at the Lead Centre (wmolc-adcp@metoffice.gov.uk).

The Global Annual to Decadal Climate Update

In an important development, at the inception of WMO's LC-ADCP, an initiative was launched to develop a document summarising the information from decadal prediction systems, similar to that produced by WMO's Lead Centre for long-range predictions for seasonal time scales, routinely, over the last six years. The content of this summary - known as the Global Annual to Decadal Climate Update, or A2DCU - has been aligned with the objectives of EUCP and is now produced each year. The Update is available only to the participants in the decadal prediction exchange and selected, registered users, during the trial period currently underway. From 2020 onwards it is planned to be distributed more widely throughout the WMO, including regional climate centres to help plan for predicted changes in climate.

The Update opens with an executive summary describing salient results from the forecasts, including the probability of exceeding 1.5 degrees C over the next five years, which is of great interest to scientists and policy makers. Then follows a section briefly describing the current state of the climate, from the perspective of inter-annual/decadal variability. Observations for the most recent 1-year and 5-year periods for temperature, sea-level pressure and precipitation are presented as map (anomalies are calculated for the same climate reference as used in the predictions: 1971-2000). Large scale indices are also presented in time series spanning the period 1960 to present day; these include the global-average (air surface) temperature and the sea surface temperature-based Atlantic Multidecadal Variability (AMV) index and Nino 3.4 index.

A prediction section follows, which include deterministic and probabilistic predictions, the former based on ensemble means, the latter describing the probability of anomalies being positive. These predictions are based on data from the Lead Centre, and they cover temperature, mean sea level pressure and precipitation at regional level (maps based on gridded data), as well as timeseries for indices indicative of large-scale variability (global-average temperature, AMV, and Nino3.4), presented in the context of past observations and predictions.

In an extension to the information currently available on the LC website, information on skill accompanies the prediction products provided. The metrics used are Pearson correlation and contingency tables (for deterministic forecast products) and ROC area for the probabilistic prediction of the 'above-average' category. This skill assessment is based on data from versions of the forecast system somewhat different from those used in the real-time prediction products (in some cases, post-dating CMIP5), used in research mode; this is not, however, thought to affect the conclusions significantly. Once the predictions for CMIP6 are in place, the products and skill assessment will be brought into line. To complete the picture, a comparison of the most recent forecasts with corresponding observations is also provided.

The Update closes with an appendix showing predictions for a few more indices, not available in the opening monitoring sections: the Atlantic MOC, the SST-based Pacific Decadal Variability (PDV) index and the mean-sea level-based Arctic- and Antarctic-Oscillation indices (AO and AAO, respectively). The diagnostics used in each case are the same as those used in the main body of the Update.

4. Lessons Learnt and links Built

We learnt that it is difficult to get voluntary, unfunded contributions in a timely manner. As is easy to see on the WMO Lead Centre website (www.wmolc-adcp.org), contributors come and go through the years, depending on funding and interest.

This work has benefitted from a strong link to the WCRP Grand Challenge on Near Term Climate Prediction (www.wcrp-climate.org/gc-near-term-climate-prediction) who have contributed ideas and reviewed the Annual to Decadal Climate Update document.

5. References

Boer, G. J., Smith, D. M., Cassou, C., Doblas-Reyes, F., Danabasoglu, G., Kirtman, B., Kushnir, Y., Kimoto, M., Meehl, G. A., Msadek, R., Mueller, W. A., Taylor, K. E., Zwiers, F., Rixen, M., Ruprich-Robert, Y., and Eade, R.: The Decadal Climate Prediction Project (DCPP) contribution to CMIP6, Geosci. Model Dev., 9, 3751-3777, https://doi.org/10.5194/gmd-9-3751-2016

Smith, D.M., Scaife, A.A., Boer, G.J. et al., Real-time multi-model decadal climate predictions, Clim Dyn (2013) 41: 2875. https://doi.org/10.1007/s00382-012-1600-0