D1.1 Deliver seasonal-to-decadal pre-operational datasets

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* **R**=Document, report; **DEM**=Demonstrator, pilot, prototype; **DEC**=website, patent fillings, videos, etc.; **OTHER**=other
** **PU**=Public, **CO**=Confidential, only for members of the consortium (including the Commission Services), **CI**=Classified

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Executive Summary

This Deliverable documents the seasonal to (multi-) decadal datasets that have been produced within ASPECT. In particular, ASPECT enhanced seasonal and decadal predictions through model improvements and increasing forecast ensemble sizes. In addition, ASPECT has performed new coordinated experimental predictions targeting multi-annual and multi-decadal time scales. These datasets are available for further research and exploration of their use for climate service applications.

About ASPECT

ASPECT aims to set up and demonstrate a seamless climate information (SCI) system with a time horizon up to 30 years and accompanied with underlying research and using climate information for sectoral applications. The project's goal is to improve existing climate prediction systems and to merge their outputs across timescales together with climate projections to unify a SCI as a standard for sectoral decision-making.

The project focus will be on European climate information, but we will also look where there is a wider policy interest (e.g., disaster preparedness) and in regions of European interest. We will maintain a strong link with the WCRP lighthouse activities to exploit learning for explaining and predicting earth system change. To provide a bandwidth diversity of information, the SCI system will be based on multi-model climate forecasts and will build on learning from projects such as EUCP. It will align with new activities on Digital Twins within Europe, including DestinE. The SCI will combine physical science aspects with those from other disciplines to ensure the information is robust, reliable, and relevant for a range of user-driven decision cases. The information package will incorporate baseline forecasts and projections (plus uncertainty), and will explore new frontiers (e.g., extremes which are of socioeconomic high-level interest).

To ensure success, the research will encompass: an understanding and attribution of various processes along timescales (such as exploring signal-to-noise ratio) and their impact on predictability, new ways of initialisation of the prediction systems, merging predictions with projections, provision of regional SCI for Europe by downscaling (statistical methods, AI) and HighRes models (including convection-permitting models) and innovative post-processing method enhancing the skill and robustness of the climate forecasts.

1 Introduction

The WP1 of ASPECT enhances seasonal to (multi-) decadal predictions by improving prediction systems, enhancing ensemble sizes, and developing new climate predictions that bridge specific traditional prediction time scales towards developing seamless climate predictions. By the start of ASPECT, climate predictions were operationally provided for sub-seasonal, seasonal and decadal time scales. In addition, long-term climate projections were (and still are) produced in synchronisation with the IPCC Report cycles. In addition to enhancing the existing prediction products, ASPECT WP1 is developing prototypes for novel prediction products targeting multi-annual and multi-decadal prediction time scales. The multi-annual predictions bridge the traditional seasonal and decadal predictions, by extending the seasonal predictions to run for 24 to 26 months (initialised at least twice per year). The multi-decadal predictions bridge the traditional decadal predictions and longer-term projections, by extending the decadal predictions for 20 to 30 years after initialisation.

2 Overview of seasonal to decadal climate prediction simulations within ASPECT

Several seasonal to (multi-) decadal climate prediction datasets have been completed and delivered, and can now be analysed and exploited for user applications and further evaluation studies. In this documentation we provide only a brief overview of the different datasets produced within ASPECT. More detailed information about these datasets, and how to access them, can be found in the Deliverable D6.1 "Catalogue with a clear access point to data" and on the dedicated website of ASPECT datasets (https://www.aspect-project.eu/dataset/). Please note that this website will also be continuously updated as new datasets become available.

2.1 Seasonal prediction datasets

CMCC, ECMWF and UKMO are producing seasonal predictions, which are operationally delivered to the Copernicus Climate Change Service (C3S), and accessible at the Copernicus Data Store (CDS). These seasonal predictions are initialised every month and provide prediction data for the next 6 months after initialisation. Please refer to D6.1 Section 3.1 for more details about these datasets.

2.2 Multi-annual predictions

A new development within ASPECT are the multi-annual predictions, to which ECMWF, BSC, CMCC and UKMO have contributed. For a common protocol, these hindcasts are initialised at least twice per year (May and November, although some partners also initialise four time per year) and integrated for at least 24 months after initialisation (BSC runs the predictions up to 36 months). Evaluation of these novel multi-annual predictions is currently underway.
The multi-annual prediction data by ECMWF are stored, and can be accessed, at MARS, and BSC and CMCC have shared their multi-annual predictions via ESGF. Please refer to D6.1 Section 3.2 for more details about these datasets.

2.3 Decadal predictions

BSC, CMCC, MPI and UKMO are producing decadal predictions. Within ASPECT, all partners have enhanced their decadal predictions by increasing the ensemble sizes of the forecasts. These decadal hindcasts and predictions are initialised once per year (typically between 1st of November and 1st of January), and run for 10 years after initialisation. The decadal prediction data are all made available at ESGF (contributing to the *dcppA* and *dcppB* experiments). Decadal data from MPI are also stored at the World Data Center for Climate (WDCC). Please refer to D6.1 Section 3.3 for more details about these datasets.

2.4 Multi-decadal predictions

A new development within ASPECT are the multi-decadal predictions, to which BSC, CMCC and MPI have contributed. These multi-annual predictions extend the decadal predictions out

to at least 20 years. A common protocol has been defined, based on which hindcasts are initialised every 5 years (1960, 1965, 1970, etc.), and then run for at least 20 years after initialisation. MPI provided the 20-year hindcasts with annual initialisation, and BSC extended the multi-decadal predictions out to 30 years after initialisation.

In addition, ECMWF has produced initialised 30-year climate outlooks, however without producing a corresponding hindcast set for forecast quality evaluation and drift correction.

The multi-decadal hindcasts by MPI and BSC are already documented in peer-reviewed publications (Düsterhus and Brune, 2024; Mahmood et al. 2025), and a multi-model evaluation is forthcoming, led by CMCC.

BSC and CMCC made their multi-decadal predictions data available at ESGF, the 20-year hindcasts by MPI are stored at the World Data Center for Climate (WDCC), and ECMWF's 30-year climate outlook is stored at MARS. Please refer to D6.1 Sections 3.3 and 3.4 for more details about these datasets, and how to access them.

3 Conclusion

A range of seasonal to (multi-) decadal datasets has been produced within ASPECT WP1, and the datasets have been made available for further analysis and exploitation within the project and beyond. Apart from enhancing existing seasonal and decadal predictions, ASPECT has produced novel pre-operational datasets that provide multi-annual and multi-decadal predictions, as a step towards developing seamless climate prediction information across a range of time scales.
Ongoing research explores the benefits of these novel predictions for both scientific applications and development of climate services.

References

Düsterhus, A. and Brune, S., (2024) The effect of initialisation on 20 year multi-decadal climate predictions, *Clim. Dynam.*, 62, 831–840, https://doi.org/10.1007/s00382-023-06941-1.

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