Climate Digital Twin (DE340)

Energy Onshore

A DestinE use case in the ClimateDT

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INTRODUCTION

As the need of the **global energy system** for **decarbonisation** intensifies, renewable energies have become one of our most promising assets to achieve **net zero emissions**. Yet, unlike their fossil fuel counterparts, renewables are more vulnerable to **a changing climate** and **extreme weather events**. Wind energy is particularly exposed, emphasizing the crucial need for accurate representations of wind speed distributions; both in terms **of future output from current wind farms** and in decision making related to the **viability of a new wind farm** location [1].

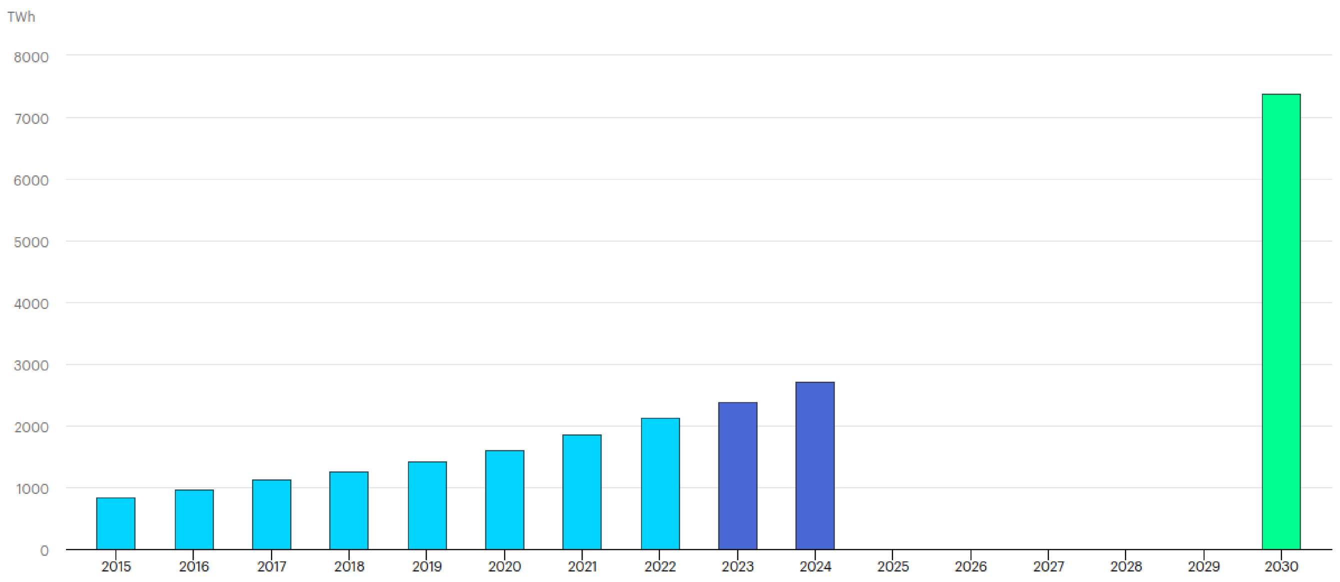

Figure 1: Global wind power generation (onshore and offshore) for the period 2015-2022 in light blue, forecasted for 2023-2024 in blue, and required to achieve net zero emissions by 2050 (NZE Scenario) in light green [2].
Source: International Energy Agency (IEA) 2023; "Wind power generation in the Net Zero Scenario, 2015-2030", License: CC BY 4.0

The overall goal of the Energy use case is to **provide estimates of the changes in wind resources** under future climate conditions.

USERS & STAKEHOLDERS

Current key user:

- **Joint Research Centre (JRC)**

Invited as the primary key user for the Energy Onshore use case of the ClimateDT, the JRC supplies policymakers with evidence-based facts to push European energy objectives forward. The JRC is a leading science-based institution that collaborates with the private and public sectors to develop open-access energy databases and innovative tools to model energy systems.

Potential key users

Other users from the private sector and scientific community have been envisioned as beneficiaries of the climate information produced by the ClimateDT. Among them are wind farm owners, power grid operators, technical consultancy groups and R&D university departments focused on renewable energies.

How can the initiative help to improve the state of the art methods in this sector?

For this we can identify the user needs and requirements that the ClimateDT will be able to address:

Needs	Requirements
Ensure security of energy supply, price and power grid stability of the European energy system while improving data access and availability.	Provide climate information that shows how future climate will affect on-shore wind distribution and hence available wind energy resources on a global scale until 2050.
Obtain reliable data on how energy systems and turbine structural integrity can cope with the effects of extreme events.	Determine how changes in the multi-decadal 50-year return period of extreme winds and (compound) extreme events impact the renewable wind energy system.
Insight into future changes in climate variability to plan and manage the design of energy systems and the impact on energy demands and prices.	Provide information on the changes in heating and cooling degree days that are strongly linked to electricity demands and are valuable as input for energy models.

TECHNICAL DESIGN

The Energy Onshore application is being developed as a Python library (current version: 0.3.0), with a main script containing a set of indicators and supporting scripts containing auxiliary functions for data pre- and post-processing [3][4].

Feature	State-of-the-art	ClimateDT
Climate variable	10m wind components (u10, v10) Requires interpolation	**100m wind** components (u100, v100)
Temporal resolution	3 to 6 hourly	**1 hourly** to sub-hourly
Spatial resolution	100 km (CMIP) 12.5 - 50 km (CORDEX)	**2.5 - 5 km**
Location	RCMs / downscaling required for regional climate information	**Regional climate information** available **globally**

Table 1: Summary of novel features introduced by the ClimateDT in GCMs.

The application will be capable of producing a set of indicators in a streaming configuration, using ClimateDT data as input, including:

- Wind speed distributions
- Capacity factors
- Energy demand (CDDs, HDDs)
- Wind speed anomalies

The data used by the application, simulated by the IFS-NEMO/FESOM and ICON models and then standardized into a Generic State Vector (GSV), consists of several climate fields, including but not limited to:

- 100m u/v wind components
- 2m temperature

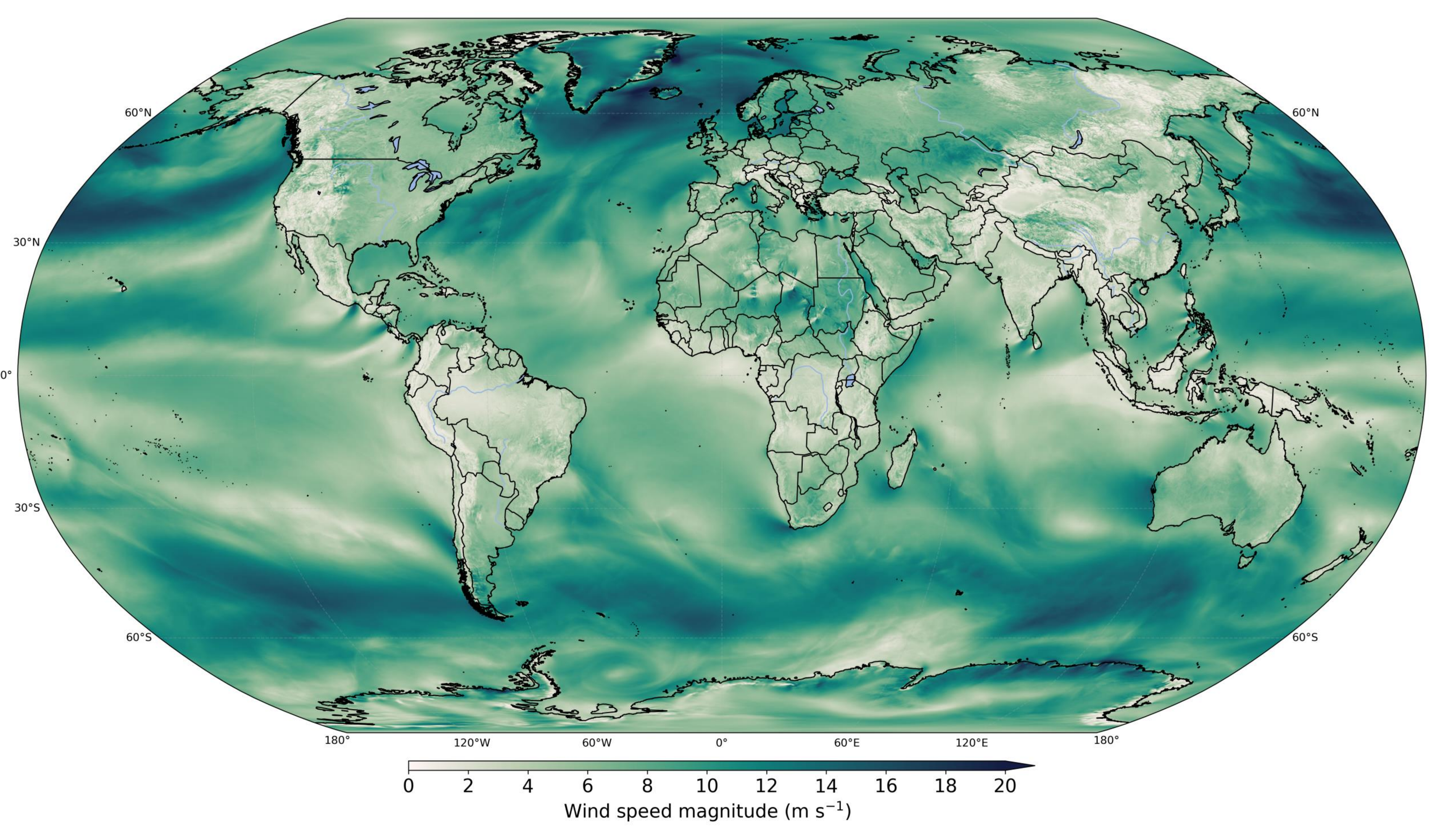

Figure 2: Wind speed at 100m averaged over one week in January 1950 from 1-hourly wind components (100u, 100v). Data was obtained from the ClimateDT IFS-NEMO control simulation.

IMPLEMENTATION IN THE WORKFLOW

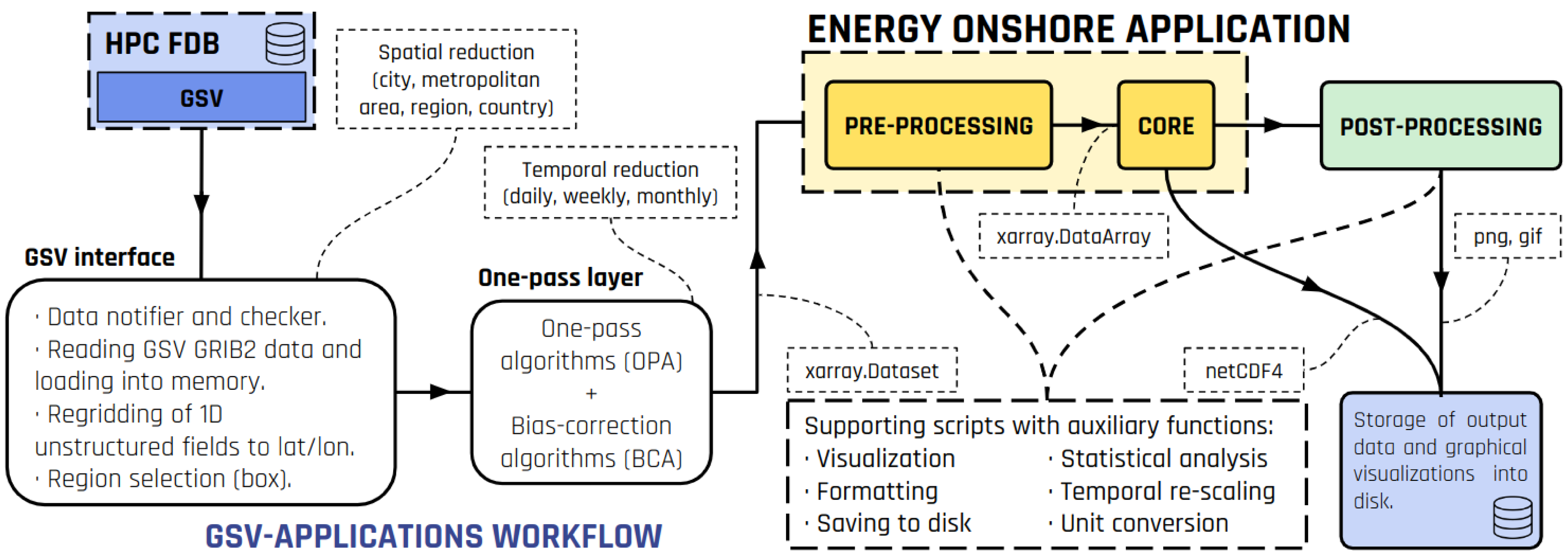

Figure 3: Architecture of the Energy Onshore application and its implementation in the DestinE workflow.

RESULTS

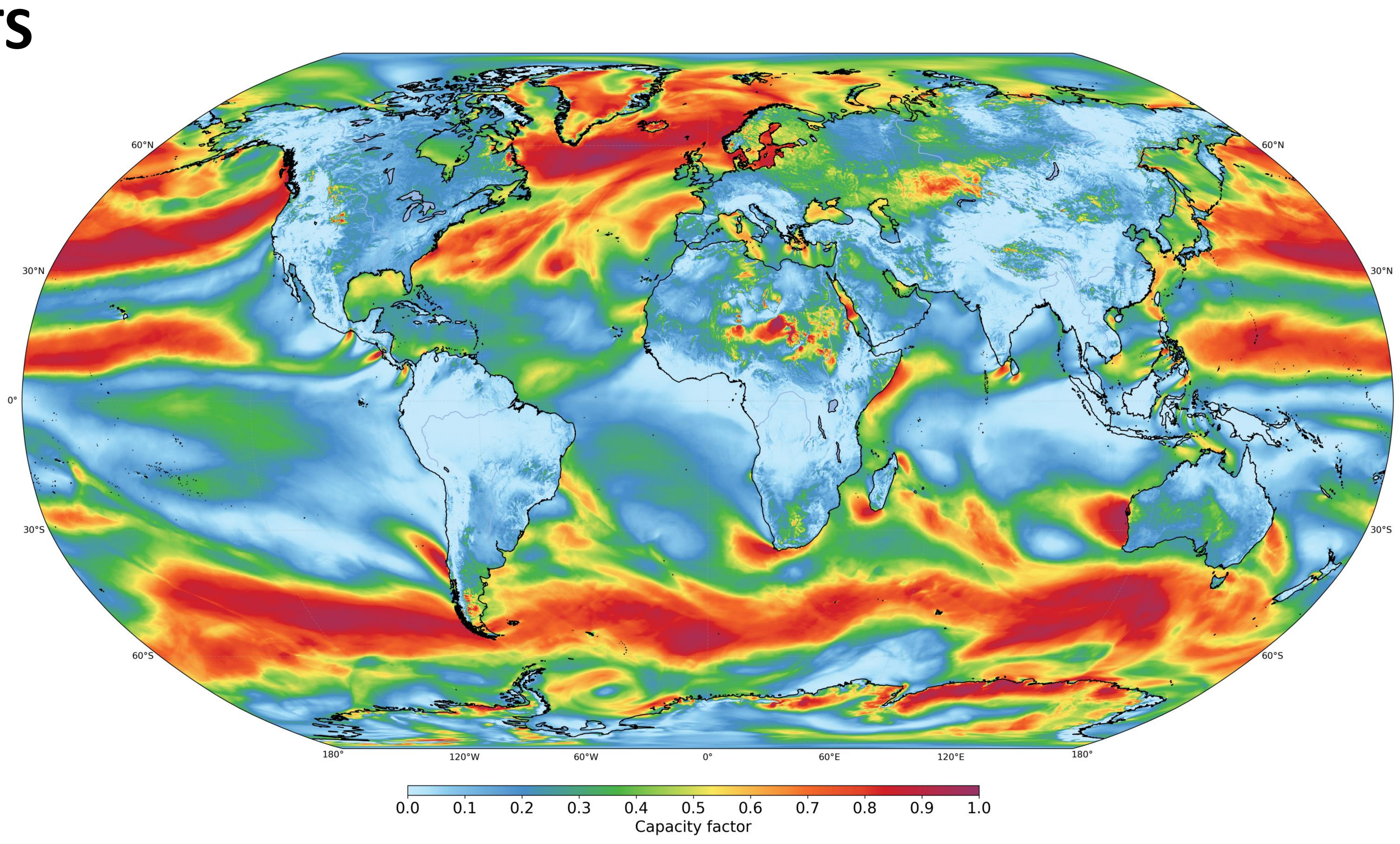

Figure 4: Capacity factor at 100m hub height for a class S Vestas V164 wind turbine, averaged over one week in January 1950 and computed from 1-hourly wind components (100u, 100v). Data was obtained from the ClimateDT IFS-NEMO control simulation.

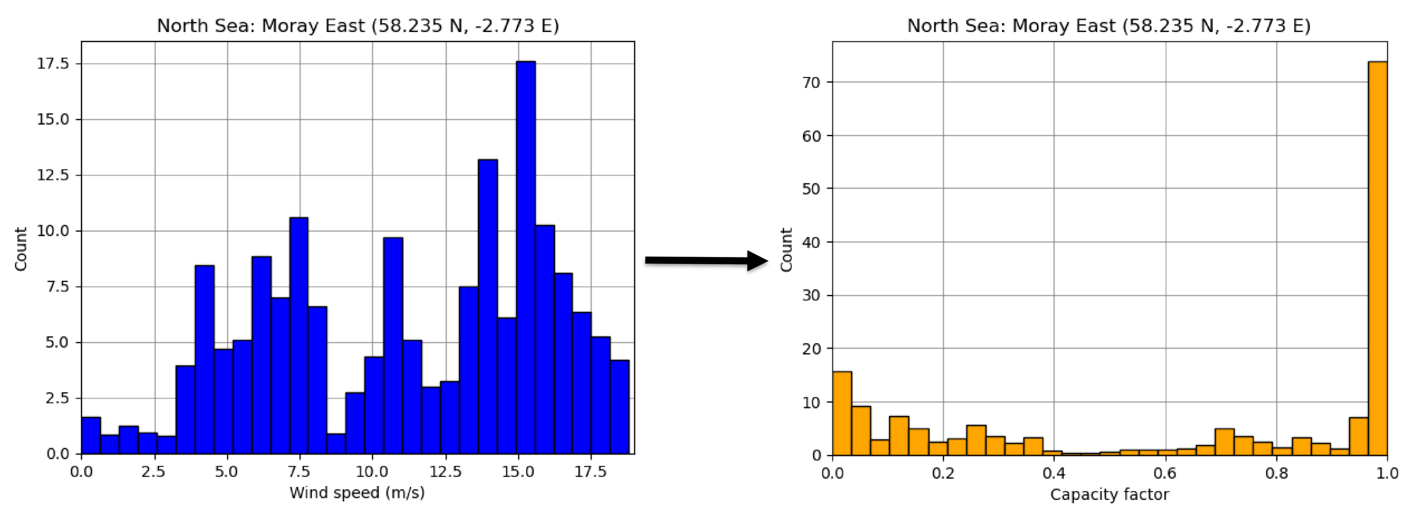

Figure 5: Wind speed (left) and capacity factor (right) distributions for a class S Vestas V164 wind turbine over one week in January 1950 and computed from 1-hourly wind components (100u, 100v). Data was obtained from the ClimateDT IFS-NEMO control simulation.

References

[1]: Lledó, L., Torralba, V., Soret, A., Ramon, J., & Doblas-Reyes, F. J. (2019). Seasonal forecasts of wind power generation. Renewable Energy, 143, 91–100. https://doi.org/10.1016/j.renene.2019.04.135

[2]: International Energy Agency (IEA), 2023, https://www.iea.org/energy-system/renewables/wind

[3]: Bett, P. E., & Thornton, H. E. (2016). The climatological relationships between wind and solar energy supply in Britain. Renewable Energy, 87, 96–110. https://doi.org/10.1016/j.renene.2015.10.006

[4]: Shi, H., Dong, Z., Xiao, N., & Huang, Q. (2021). Wind Speed Distributions Used in Wind Energy Assessment: A Review. Frontiers in Energy Research, 9(November), 1–14. https://doi.org/10.3389/fenrg.2021.769920

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