DESTINATION EARTH

Post-processing for wind energy production: added value of hectometric NWP forecasts with NWP wind farm parameterization and targeted machine learning

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INTRODUCTION

The transition from a predominantly fossil-fuel and nuclear-based energy system to one driven largely by renewable sources necessitates highly accurate and detailed weather forecasts with fine temporal and spatial resolution. This shift also demands that power system operators and grid managers are equipped to handle production anomalies, extreme weather conditions affecting power generation, and threats to power infrastructure.

Extreme weather events, can have a significant impact on grid stability. Therefore, accurate and timely forecasts of power production under adverse weather conditions are essential for anticipating and mitigating extreme events in the power system—particularly as the integration of wind energy into the European grid continues to grow.

OUTLOOK

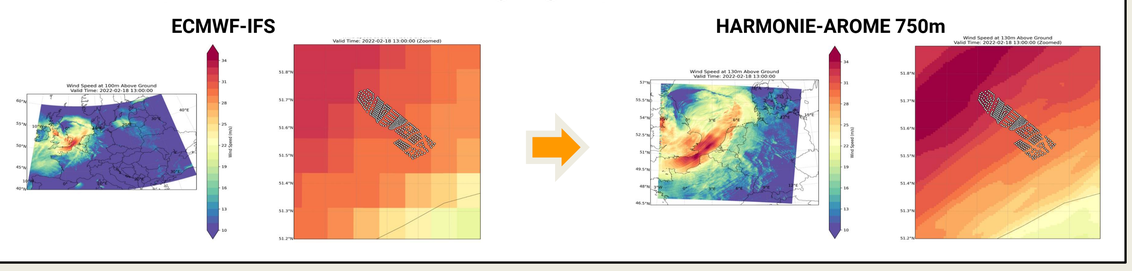
- Challenge 1: wake representation in hectometric ALARO model currently evaluated, pyWake in post-processing to be included end of 2024
- Challenge 2: a joint, quality controlled metadata set to be finished mid-October
- Challenge 3: multi-domain, multi-metadata training data set appr. Q2 2025
- Challenge 4: definition of events ongoing first iteration finished end November 2024. Discussions with users in multiple iterations until end of phase 2.

POST-PROCESSING ADRESSING CHALLENGES & HOW WE TACKLE THEM

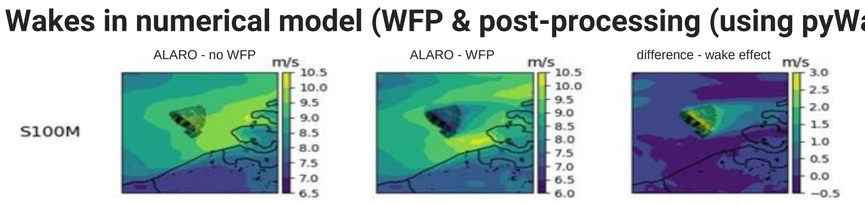
CHALLENGE 1 - Scale of wind energy production

- Wind energy production is very localised and depends on both local and synoptic scale events.
- High temporal fluctuation in production possible which needs high temporal resolution.
- Wakes of neighbouring wind farms can have a negative effect on the energy production

Impact of resolution – using high spatial and temporal NWP runs



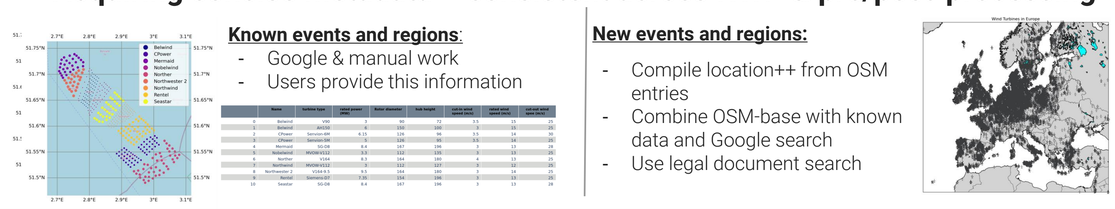
Wakes in numerical model (WFP & post-processing (using pyWake)



CHALLENGE 2 - Metadata and real, historic/near-realtime production data

- To represent wind farms in NWP models and wind farm parameterizations, metadata (location, type of turbine, rotor diameter) is needed.
- For post-processing/targeted forecast metadata is needed.
- For very localised forecasts per turbine, ideally real wind power production data, is needed (also to reproduce wakes). But we rarely get them to refine the post-processing.
- Can synthetic data help? Can we generate What-if? scenarios using that?

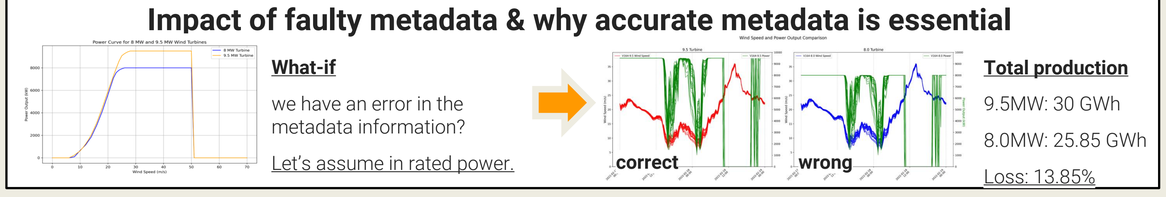
Acquiring concise metadata – consistent across NWP & pre/post-processing



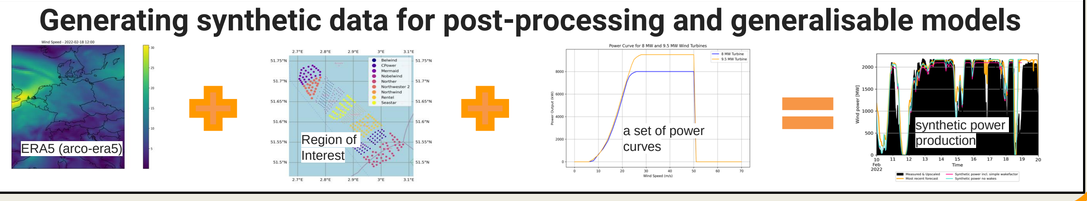
Known events and regions:
- Google & manual work
- Users provide this information

New events and regions:
- Compile location++ from OSM entries
- Combine OSM-base with known data and Google search
- Use legal document search

Impact of faulty metadata & why accurate metadata is essential



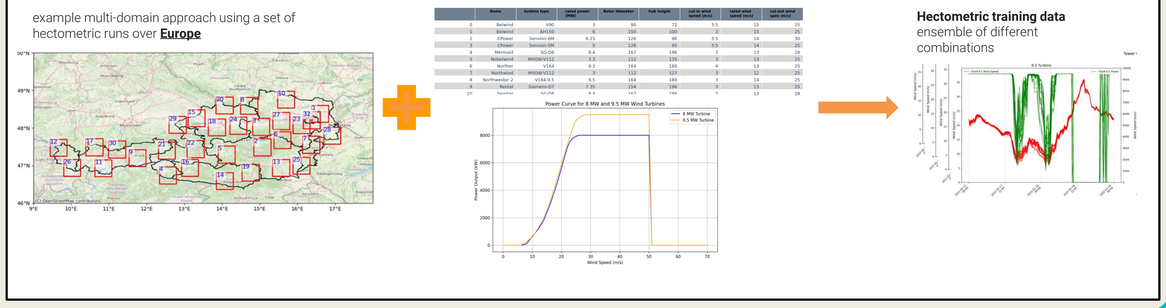
Generating synthetic data for post-processing and generalisable models



CHALLENGE 3 - Training data availability on the hectometric scale

- A comprehensive hectometric NWP training dataset, meeting the traditional standards for statistical and machine learning model training
- Include a decent number of wind farms needs to be compiled.

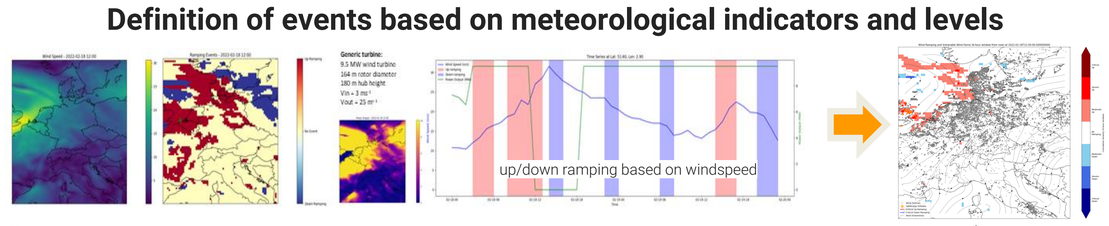
Multi-domain, multi-wind farm configuration training data set



CHALLENGE 4 - Non-clear defined definition of extremes in the industry & quantify uncertainty

- Extreme events in the renewables industry are not clearly defined, vary for turbine type, location, importance to operators, local and large scale aspects, etc.
- uncertainty quantification considering uncertainty along the workflow:
  - Metadata
  - synthetic vs. real data
  - Ensemble NWP information
  - Multi-model approach

Definition of events based on meteorological indicators and levels



Questionnaire and one-on-one meetings with industry/stakeholders on their events/needs and wishes (feeding als **What-if**) and find common denominator for meteorological levels and indicators.

Uncertainty quantification addressing all aspects