IEA Wind Task 36 – Forecasting Recommendations

Gregor Giebel, DTU Wind Energy

W. Shaw, H. Frank, C. Möhrlen, C. Draxl, J. Zack, P. Pinson, G. Kariniotakis, R. Bessa

ESIG Meteorology & Market Design for Grid Services Workshop, 2021

Technology Collaboration Programme
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News

- Overview
- IEC TR 63043
- Information portal
- **NWP benchmark**
- Update on IEA Recommended Practice
- Uncertainty propagation
- **Forecast games**
- Next phase

Task Objectives & Expected Results

Task Objective is to encourage improvements in:
1) weather prediction
2) power conversion
3) use of forecasts

Task Organisation is to encourage international collaboration between:
- → Research organisations and projects
- → Forecast providers
- → End-users and stakeholders

Task Work is divided into 3 work packages:
WP1: Weather Prediction Improvements
WP2: Power and Uncertainty Forecasting
WP3: Optimal Use of Forecasting Solutions

Current Term: 2019-2021 (First term 2016-2018)

IEC TR 63043 ED1: Renewable Energy Power Forecasting Technology

For a good, comprehensive and recent (Nov 2020) text on the state of the art in forecasting, please see this Technical Report from IEC Sub-Committee 8A Grid Integration of Renewable Energy Generation, Working Group 2 Renewable energy power prediction.

https://webstore.iec.ch/publication/26529

IEC TR 63043

Edition 1.0 2020-11

TECHNICAL REPORT

colour inside

Renewable energy power forecasting technology

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 29.020

ISBN 978-2-8322-9079-8

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IEA Wind TCP | Task 36 | Information Portal | Work Packages | Partners | Publications

The Task 36 Information Portal aims to be a useful resource for people in forecasting, especially providing links to publically available data for model development.

https://iea-wind.org/task-36/t36-information-portal/

Information Portal

The Task members identified several issues which might be useful in an information portal for wind power forecasting. Those are:

- A list of meteorology masts with online data over 100m height, useful for verification of wind speed predictions
- A list of meteorological experiments going on currently or recently, either to participate or to verify a flow model against
- A list of publicly available wind power forecasting benchmarks, to test your model against
- A list of current or finished research projects in the field of wind power forecasting
- A list of future research issues
- A list of open weather data

For all of those, we would be happy to accept input, so head over to the site and see where you can help, or what you can use!

Please find the full text of the task description here.

The task is led by Gregor Giebel from DTU Wind Energy.

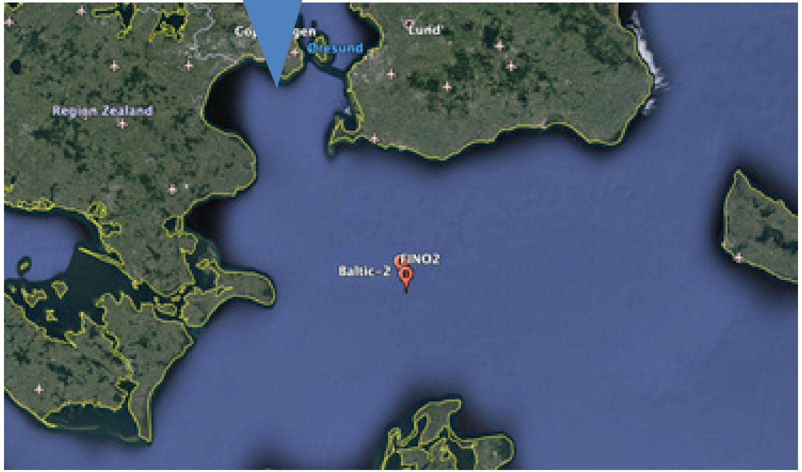
NWP Benchmark cases

Started: June 2021

U.S. case

- 1 day in September 2016
- mountain waves observed
- observations and model meteorological data available, at 10/5 min resolution
- well documented in the literature, a wealth of information available about the region
- wind farms in the area (but data under an NDA)

European case



- 1 week in October 2020
- power output available every 15 min, with 100% turbine availability
- corrected nacelle wind measurements averaged over the farm every 15 min
- FINO2 is about 4 km NW of Baltic-2

Slide from Caroline Draxl, NREL – please contact IEA.Forecasting.Benchmark@groups.nrel.gov *for participation*

The benchmarking tool

i-validate on GitHub:
https://github.com/joejoeyjoseph/i-validate/

Demo Jupyter Notebook (U.S. Mountain Wave case):
https://nbviewer.jupyter.org/github/joejoeyjoseph/i-validate/blob/main/notebooks/demo_notebook.ipynb

Existing metrics: RMSE, cRMSE, mean bias, mean absolute error
Existing plots: time series, histogram, scatter plot

Slide from Caroline Draxl, NREL

WP2 IEA Recommended Practice on Forecast Solution Selection

- Received feedback from industry, use of some concepts starts to appear in tenders
- Version Update (2021):
  - More input from industry
  - Filling in found omissions
  - More examples
  - Collaboration with IEA Solar Task
  - New Part 4 on meteorological measurements in grid codes (see next slide)

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EXPERT GROUP REPORT

ON

RECOMMENDED PRACTICES FOR SELECTING RENEWABLE POWER FORECASTING SOLUTIONS

Part 1: FORECAST SOLUTION SELECTION PROCESS

1. EDITION 2019

Submitted to the
Executive Committee of the
International Energy Agency Implementing Agreement
on 13th August 2019

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EXPERT GROUP REPORT

ON

RECOMMENDED PRACTICES FOR SELECTING RENEWABLE POWER FORECASTING SOLUTIONS

Part 2: DESIGNING AND EXECUTING FORECASTING BENCHMARKS AND TRIALS

1. EDITION 2018

Submitted to the Executive Committee of the International Energy Agency Implementing Agreement
on 13th August 2018

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EXPERT GROUP REPORT

ON

RECOMMENDED PRACTICES FOR SELECTING RENEWABLE POWER FORECASTING SOLUTIONS

Part 3: Evaluation of Forecasts and Forecast Solutions

1. EDITION 2018

To be Submitted to the
Executive Committee of the
International Energy Agency Implementing Agreement
on 1st March 2019

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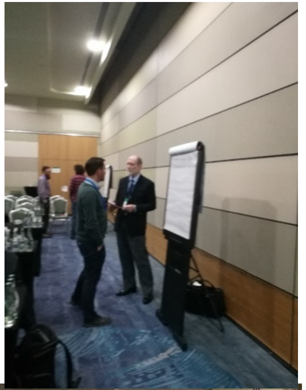
WP3.3: Meteorological Measurements and Instrumentation Standardization for Integration into Grid Codes

Results from 2 Workshops: ICEM 2019 & WIW 2019

- **General Agreement that Standards/RPs are Needed**
    - Grid codes vary from region to region
    - Concern about adopting WMO or similar standards, which may be expensive overkill for grid code purposes
    - Should reference traceability to standards but be instrument agnostic
    - Could suggest required measurements by IPPs at time of commissioning
    - Need education on importance of data quality
    - Need to address site selection for instrumentation
    - Need to tailor reporting interval to forecast model input needs



Uncertainty propagation

- Paper submitted
- Uncertainty sources, quantification and uses
- Aleatoric vs epistemic uncertainty
- In planning, operation and market phases

Broader paper on uncertainty forecasting

Prediction Models Designed to Prevent Significant Errors

By Jan Dobschinski, Ricardo Bessa, Pengwei Du, Kenneth Geisler, Sue Ellen Haupt, Matthias Lange, Corinna Möhrlen, Dora Nakafuji, and Miguel de la Torre Rodriguez

Uncertainty Forecasting in a Nutshell

DOI: *10.1109/MPE.2017.2729100*

Digital Object Identifier 10.1109/MPE.2017.2729100
Date of publication: 18 October 2017

IT IS IN THE NATURE OF CHAOTIC ATMOspheric processes that weather forecasts will never be perfectly accurate. This natural fact poses challenges not only for private life, public safety, and traffic but also for electrical power systems with high shares of weather-dependent wind and solar power production.

To facilitate a secure and economic grid and market integration of renewable energy sources (RES), grid operators and electricity traders must know how much power RES within their systems will produce over the next hours and days. This is why RES forecast models have grown over the past decade to become indispensable tools for many stakeholders in the energy economy. Driven by increased grid stability requirements and market forces, forecast systems have become tailored to the end user's application and already perform reliably over long periods. Apart from a residually moderate forecast error, there are single extreme-error events that greatly affect grid operators.

Nevertheless, there are also forecast systems that provide additional information about the expected forecast uncertainty and estimations of both moderate and extreme errors in addition to the "best" single forecast. Such uncertainty forecasts warn the grid operator to prepare to take special actions to ensure grid stability.

The State of the Art in Forecast Generation

Today, some forecast systems have been developed specifically to predict the power production of single wind and solar units, differently sized portfolios, local transformer stations and subgrids, distribution and transmission grids, and entire countries. Nearly all forecast systems have one thing in common: they rely on numerical weather predictions (NWPs) to calculate the expected RES power production. The way to transform weather predictions into power forecasts depends crucially on the end user's application and the available plant configuration and measurement data. If historical measurements are available, forecast model developers often use statistical and machine-learning techniques to automatically find a relation between historical weather forecasts and simultaneously observed power measurements. If no historical measurement data are available, e.g., for new installations of RES units, the transformation of weather to power is often accomplished by physically based models that consider the unit's parameters to map the internal physical processes.

Use of probabilistic forecasting

Open Access journal paper

48 pages on the use of uncertainty forecasts in the power industry

Definition – Methods – Communication of Uncertainty – End User Cases – Pitfalls - Recommendations

Source: http://www.mdpi.com/1996-1073/10/9/1402/

energies MDPI

Review

Towards Improved Understanding of the Applicability of Uncertainty Forecasts in the Electric Power Industry

Ricardo J. Bessa [1,*], Corinna Möhrlen [2], Vanessa Fundel [3], Malte Siefert [4], Jethro Browell [5], Sebastian Haglund El Gaidi [6], Bri-Mathias Hodge [7], Umit Cali [8] and George Kariniotakis [9]

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9 MINES ParisTech, PSL Research University, Centre for Processes, Renewable Energies and Energy Systems (PERSEE), 06904 Sophia Antipolis Cedex, France; georges.kariniotakis@mines-paristech.fr
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Academic Editor: David Wood
Received: 18 August 2017; Accepted: 8 September 2017; Published: 14 September 2017

Abstract: Around the world wind energy is starting to become a major energy provider in electricity markets, as well as participating in ancillary services markets to help maintain grid stability. The reliability of system operations and smooth integration of wind energy into electricity markets has been strongly supported by years of improvement in weather and wind power forecasting systems. Deterministic forecasts are still predominant in utility practice although truly optimal decisions and risk hedging are only possible with the adoption of uncertainty forecasts. One of the main barriers for the industrial adoption of uncertainty forecasts is the lack of understanding of its information content (e.g., its physical and statistical modeling) and standardization of uncertainty forecast products, which frequently leads to mistrust towards uncertainty forecasts and their applicability in practice. This paper aims at improving this understanding by establishing a common terminology and reviewing the methods to determine, estimate, and communicate the uncertainty in weather and wind power forecasts. This conceptual analysis of the state of the art highlights that: (i) end-users should start to look at the forecast's properties in order to map different uncertainty representations to specific wind energy-related user requirements; (ii) a multidisciplinary team is required to foster the integration of stochastic methods in the industry sector. A set of recommendations for standardization and improved training of operators are provided along with examples of best practices.

Forecast games to motivate probabilistic forecasting

- Probabilistic renewable power forecasts existed since ~2005
- Some superficial interest from end users, but little adoption
- Now: trying to ”gameify” the interest, and make the difference between deterministic forecasts and probabilistic clearer
- Collaboration with Nadine Fleischhut, researcher in decision making under uncertainty and communication of uncertainty at Max Planck Institute for Human Development

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WP3 Forecast Games and Experiments:
Game 1: Offshore wind power decision making in extreme events

Conducted by Dr. Corinna Möhrlen, WEPROG in collaboration with Dr. Nadine Fleischhut, MPI for Human Development, Berlin

3 Postulates formed the basis for the experiment design:

(1) Success in the trading is highly dependent on the costs of the balancing power needed due to forecast errors
(2) 5% of the cases, where there are large forecast errors are responsible for 95% of the costs in a month or year
(3) Reducing these costs is more important than improving the general forecasts by ~1%

The Experiment:

Decide in 12 cases whether to trade 50% or 100% of the generating power of an offshore wind park according to an available forecast given the possibility of a high-speed shutdown, where the wind park stops generating due to excessive wind conditions.

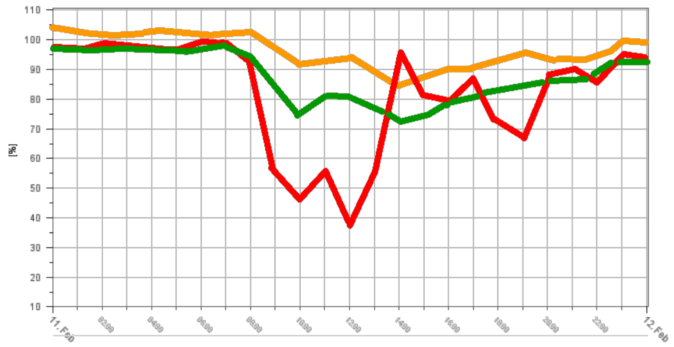
Definition of a "high-speed shutdown" (HSSD) or "cut-off wind" event :

A high-speed shutdown event occurs typically in the wind range above 21-27m/s, mostly known as the cut-off wind threshold of 25 m/s. Note that wind turbines use both wind gusts and the mean wind to determine, whether or not they turn into high-speed shutdown (HSSD).

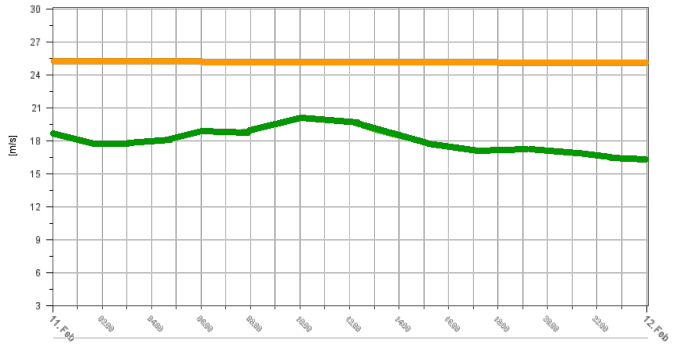
Forecast Game 1:
Offshore wind power decision making in extreme events

Type of forecasts used in the experiment:

In the experiement are determinisitic and probabilistic forecasts for the **day-ahead horizon**. All forecasts are generated with input from NWP (numerical weather prediction) forecasts from the 00UTC cycle the day before.

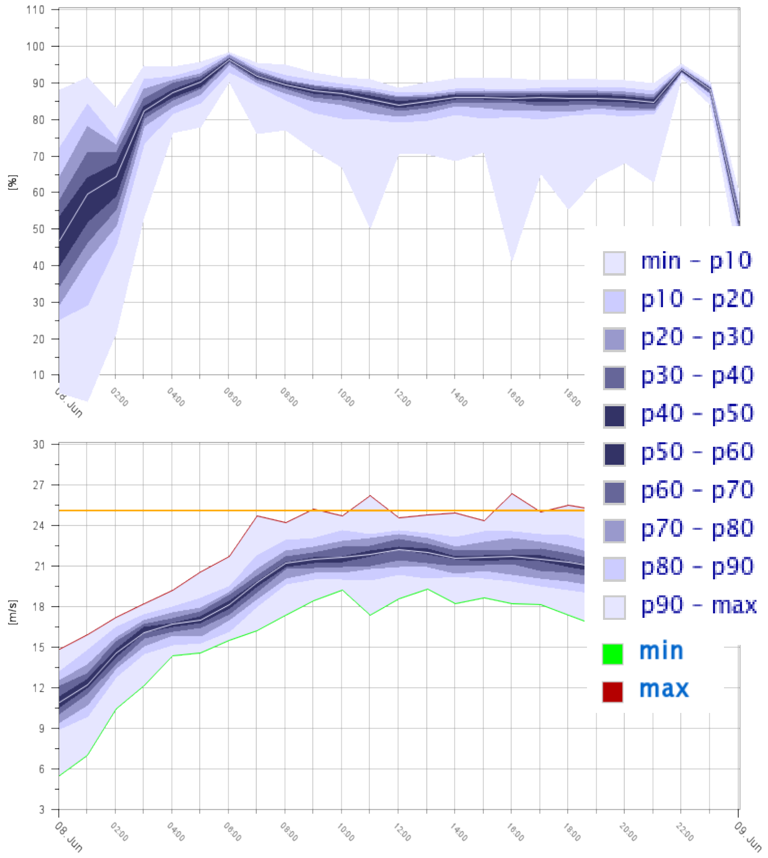


3 independent deterministic wind power forecasts in the unit [% of installed capacity] based on 3 different NWP (numerical weather prediction) models



1 wind speed forecast in the unit [m/s], which is a mean forecast from 75 ensemble members and smoother than a typical deterministic forecast. **Additionally, you see a reference line for the 25m/s threshold reference value** for high-speed shutdown or also sometimes called cut-off wind speed threshold.

Forecast Game 1: Offshore wind power decision making in extreme events



9 wind power percentiles (P10..P90) and a mean (white line) in the unit [% of installed capacity] generated from 75 NWP forecasts of a multi-scheme ensemble prediction system.

9 wind speed percentiles P10..P90 and a mean (white line) in the unit [% of installed capacity] generated from 75 NWP forecasts of a multi-scheme ensemble prediction system.

Note: The percentiles here are physically based uncertainty bands and provide an overview of the uncertainty of the forecast.

Definition: A percentile indicats the value below which a given percentage of foreasts from the 75 available forecasts falls. E.g., the 20th percentile is the value below which 20% of the forecasts are found.

Forecast Game 1: Offshore wind power decision making in extreme events

The cost profile

To reflect the costs of large and small errors we have defined a simplified cost function for the period, where high-speed shutdown (HSSD) can take place.

Definitions:

- the wind farm is 100MW and the spot market price is 50 Eur/Mwh.
- balance costs are equivalent to spot market prices
- The cost function will only consider your choice for the hours, where the actual generation is full load or no generation

Trading	HSSD*	No HSSD*
100%	-5.000	5.000
50%	0	2.500

* High-Speed Shutdown == cut-off winds

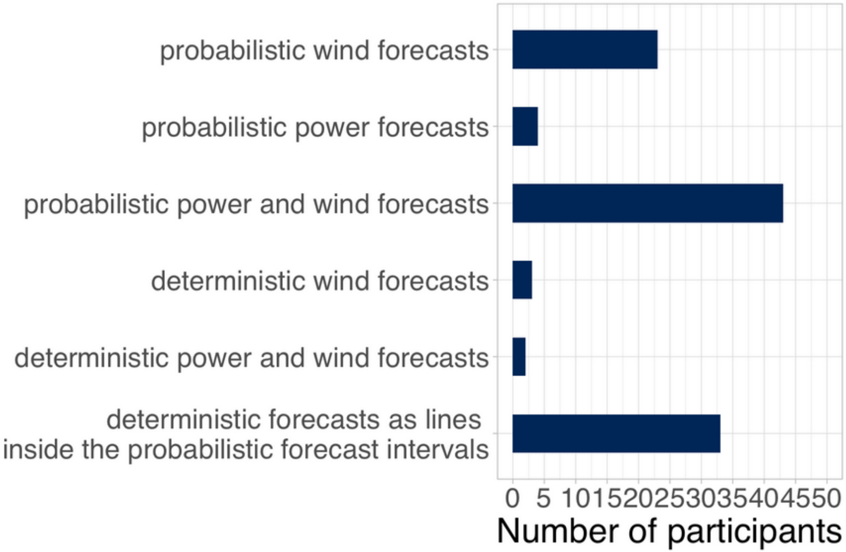
Note that trading **100% is a risky choice** that can both increase your income and loss.
The more conservative **50% trading strategy eliminates the risk of a loss**, because **balance costs are equal to spot market prices** and **you can curtail the wind farm to avoid balance costs.**

Forecast Game 1:
Offshore wind power decision making in extreme events

ANALYSIS of Questions – preferred information -

Histogram of participants' preferred information

No one preferred to make decisions based on deterministic power forecast alone.



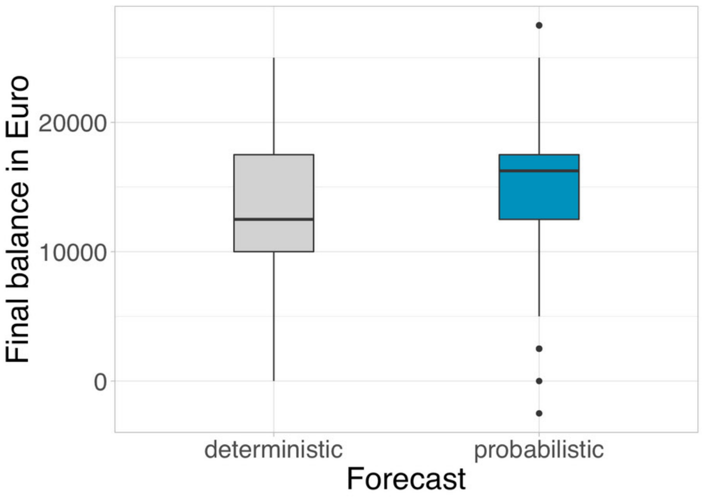
Forecast Game:
Offshore wind power decision making in extreme events

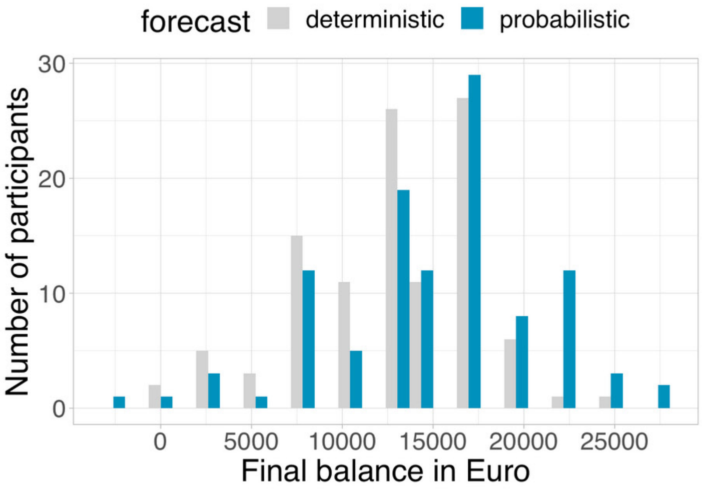
ANALYSIS – final balance -

Probabilistic forecasts lead to:
- higher income
- less spread in performance

108 participants:
Best score deterministic: 25.000 EUR
Best score probabilistic: 27.500 EUR

Histogram of participants' final balance based on deterministic vs. probabilistic forecasts



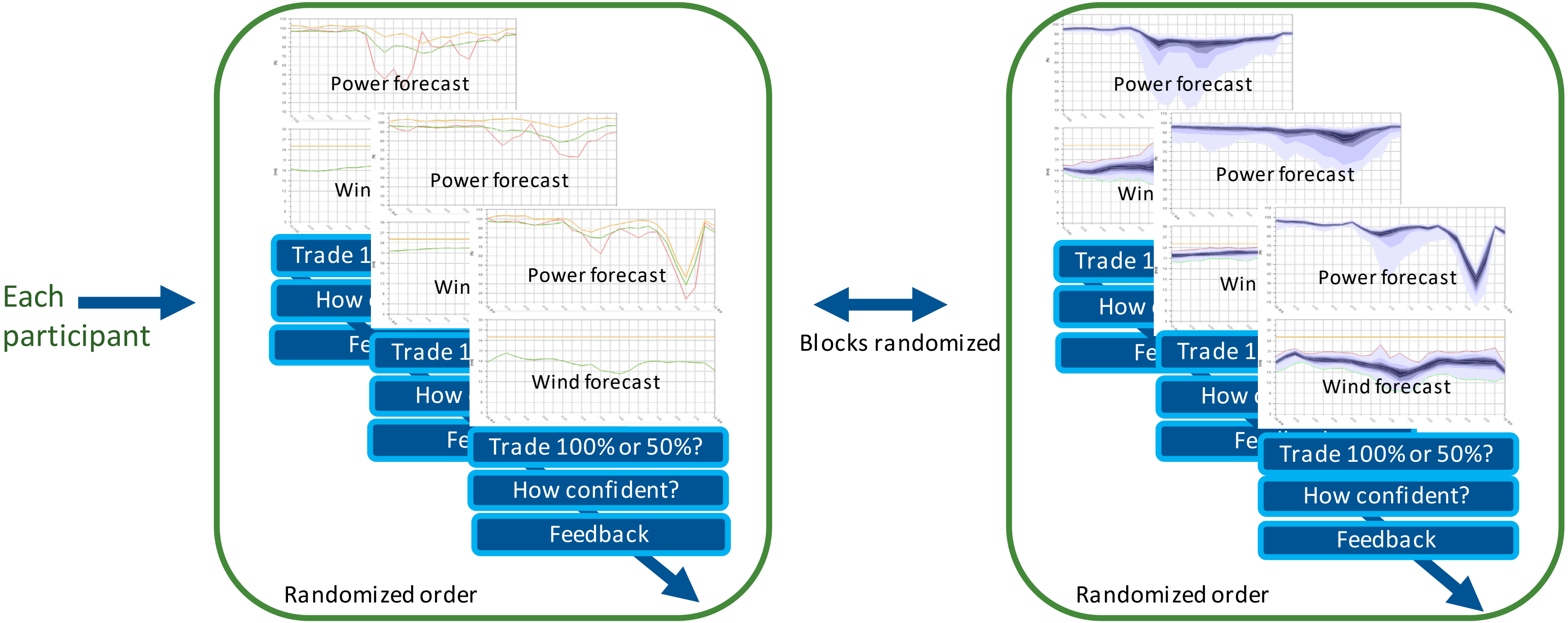


2nd edition: Value of probabilistic power forecasts

How do professionals decide based on probabilistic wind & power forecasts?

Corinna Möhrlen, Ricardo Bessa & Nadine Fleischhut

Trade 100% or only 50% wind energy – given the risk of high-speed shutdown?



20 decision situations with deterministic forecasts

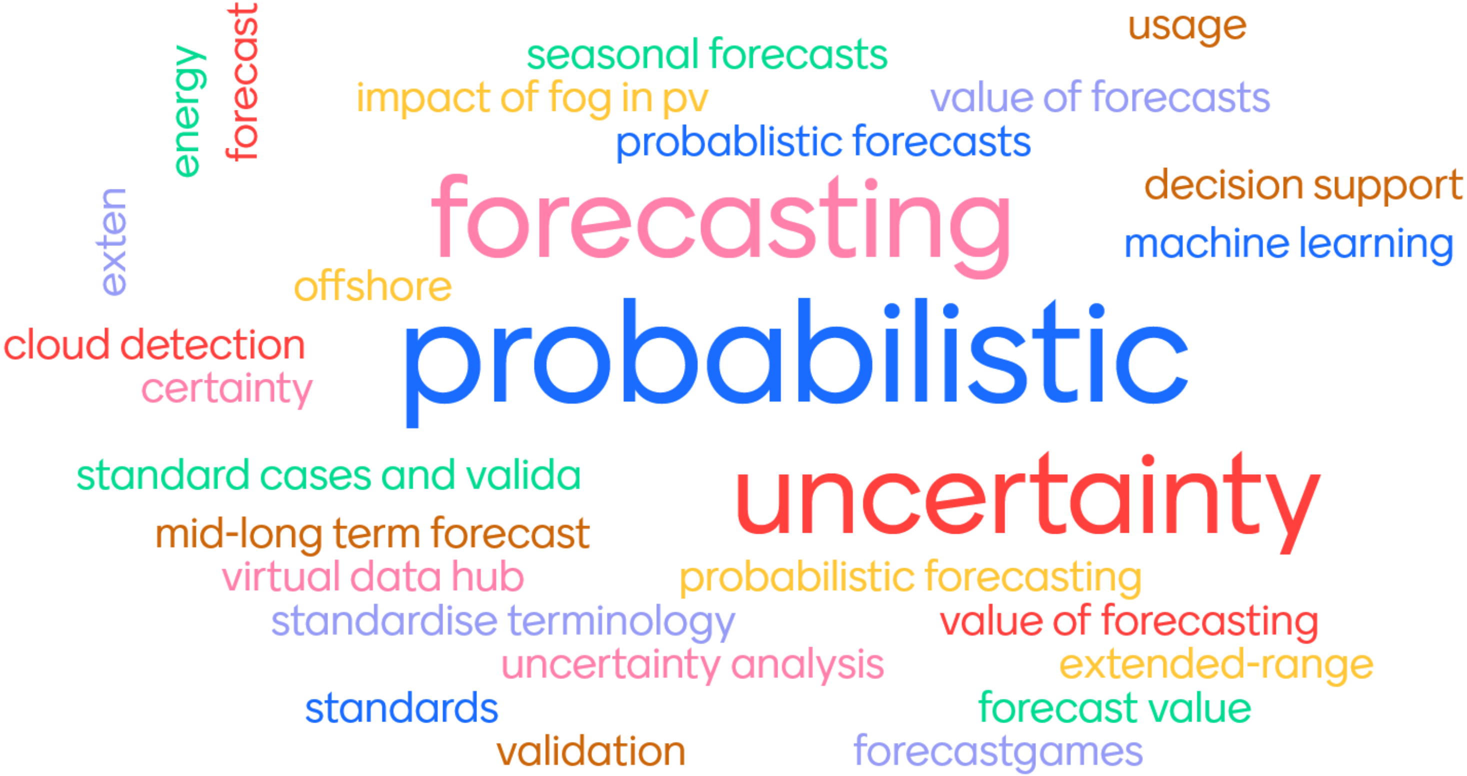
20 decision situations with probabilistic forecasts

IEA Wind Task 36 - Phase III

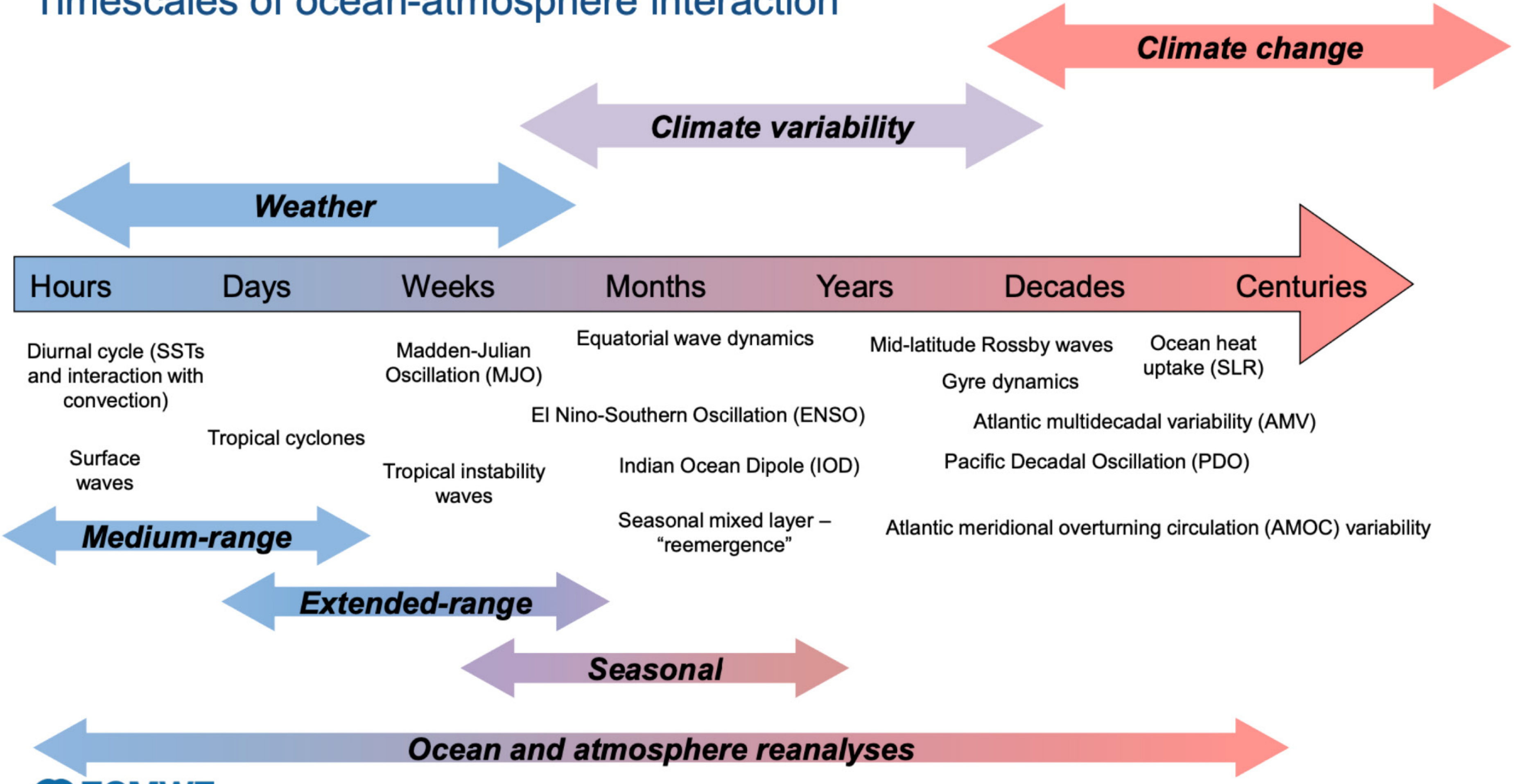
Preparations for Phase III of Task 36 are ongoing. A recent Task meeting yielded this word cloud.

Probably will include hydrogen as use case.

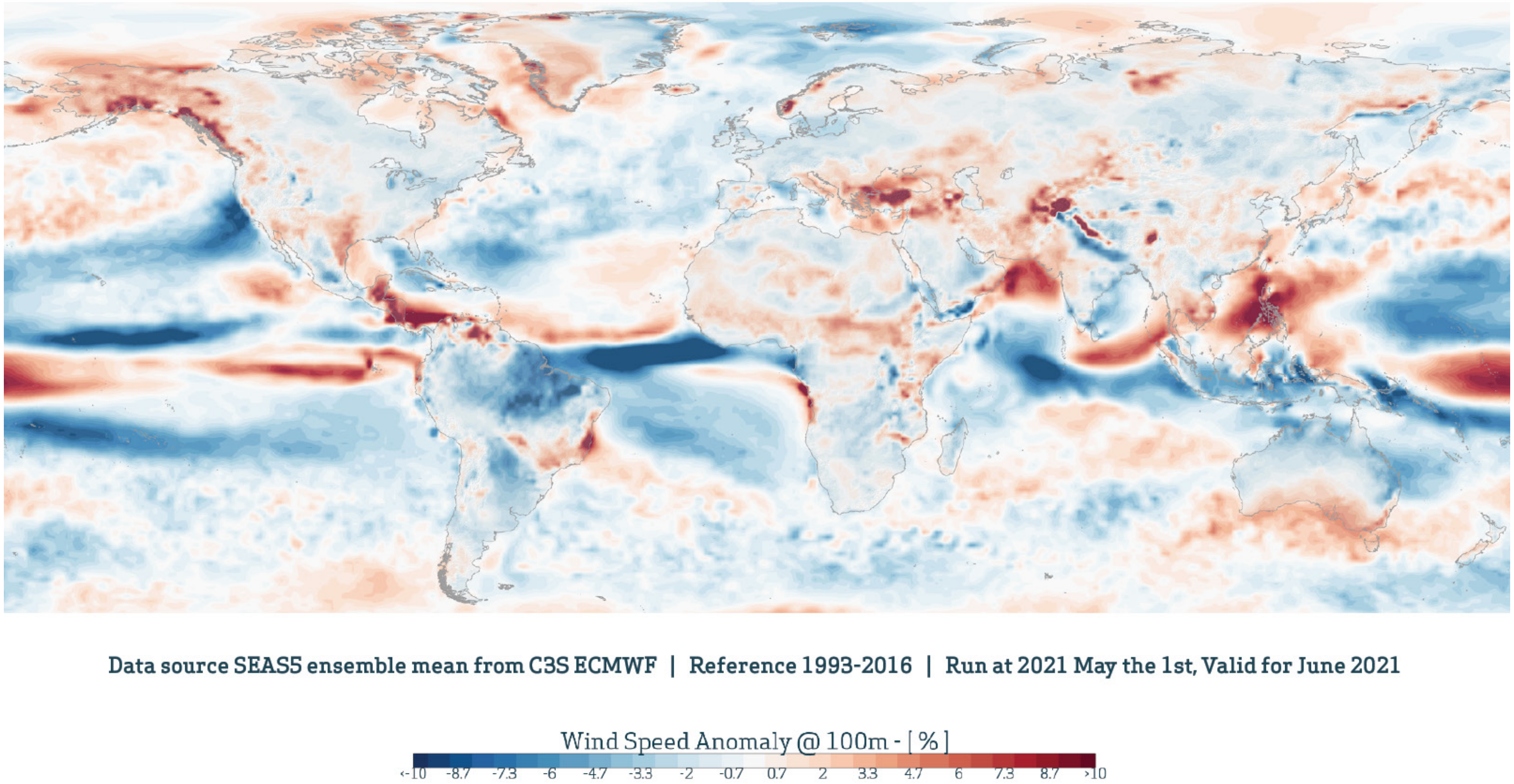
To start 2022.



Timescales of ocean-atmosphere interaction

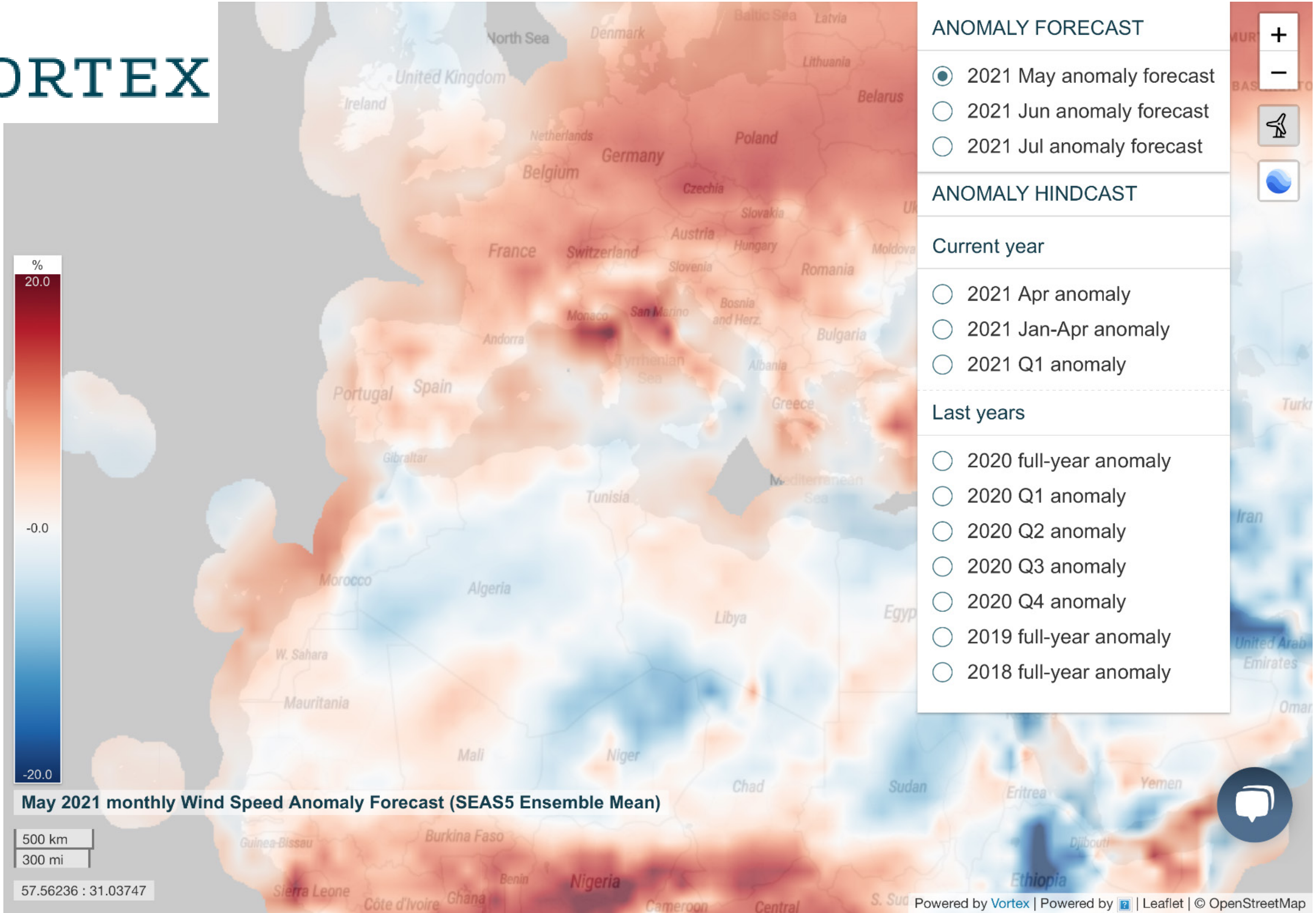


Monthly Wind Speed Anomaly Forecast for: **June 2021**



Data source SEAS5 ensemble mean from C3S ECMWF | Reference 1993-2016 | Run at 2021 May the 1st, Valid for June 2021

VORTEX


ANOMALY FORECAST
2021 May anomaly forecast
2021 Jun anomaly forecast
2021 Jul anomaly forecast
ANOMALY HINDCAST
Current year
2021 Apr anomaly
2021 Jan-Apr anomaly
2021 Q1 anomaly
Last years
2020 full-year anomaly
2020 Q1 anomaly
2020 Q2 anomaly
2020 Q3 anomaly
2020 Q4 anomaly
2019 full-year anomaly
2018 full-year anomaly
%
20.0
-0.0
-20.0
May 2021 monthly Wind Speed Anomaly Forecast (SEAS5 Ensemble Mean)
500 km
300 mi
57.56236 : 31.03747
Powered by Vortex | Powered by | Leaflet | © OpenStreetMap

www.IEAWindForecasting.dk

For more detailed information, see also the Annex of last year’s presentation :
https://meetingorganizer.copernicus.org/EGU2020/EGU2020-14253.html

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Next meeting: June 16-18, 1330-1630 UTC (0630 Seattle, 2130 Beijing), contact me for participation