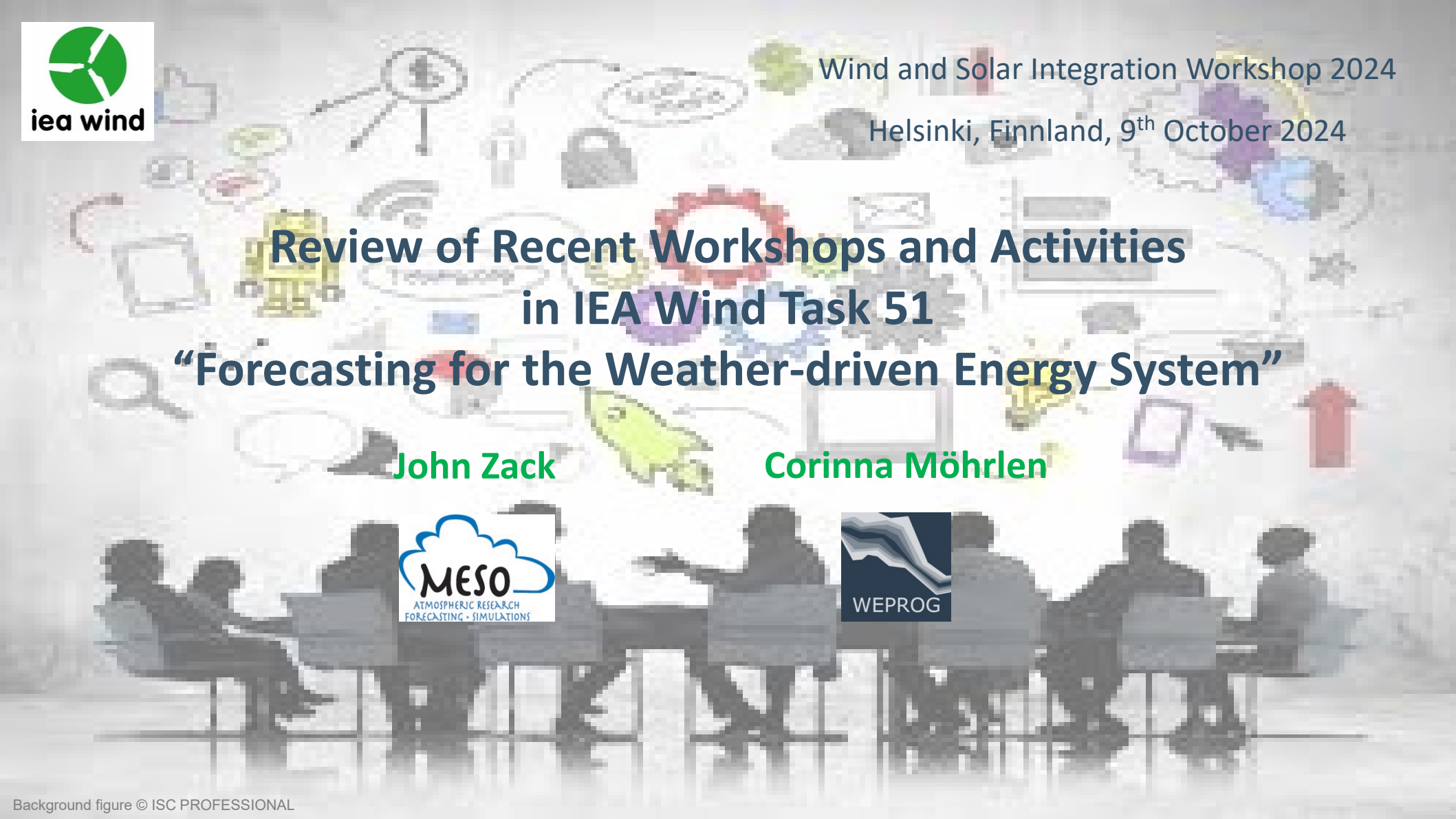
Wind and Solar Integration Workshop 2024

Helsinki, Finnland, 9th October 2024

Review of Recent Workshops and Activities in IEA Wind Task 51 "Forecasting for the Weather-driven Energy System"

John Zack

Corinna Möhrlen



Recent IEA Wind Task 51 Events

- **Seasonal Forecasting for the Weather Driven Energy System**
  - 17-19 May 2023 - Reading, UK (University of Reading)
    On YouTube: Day 1: https://youtu.be/OqirPIAqtWY & Day 2: https://youtu.be/kRJ0J0G7ruU
- **Minute-Scale Forecasting for the weather-driven Energy System**
  - 9-11 April 2024 - Risoe, Denmark (DTU-Risoe)
- **Topical Expert Meeting (TEM) #111: Reanalysis Datasets**
  - 25-26 April 2024 - Lyngby, Denmark (DTU-Lyngby)
- **Webinar: Deep Learning for Weather-Based Power Prediction**
  - 11 January 2024 - On YouTube: https://youtu.be/t6H7diavQdg

Objectives

- to facilitate the dissemination of information to members of the energy community
- to gather information about methods, state-of-the-art skill, value, uses and unmet needs

IEA S2S Forecasting Workshop: Agenda

Session	Title
Keynote	History, Current Status and Challenges of S2S Forecasting
1	Forecasting Techniques
2	Forecast Evaluation
3	Public Forecast Providers and Products
4	Commercial Forecast Providers and Products
5	Forecast User Experiences
6	Open-space Discussion
7	Research Issues and Projects: Current and Envisioned

IEA S2S Forecasting Workshop: Key Points

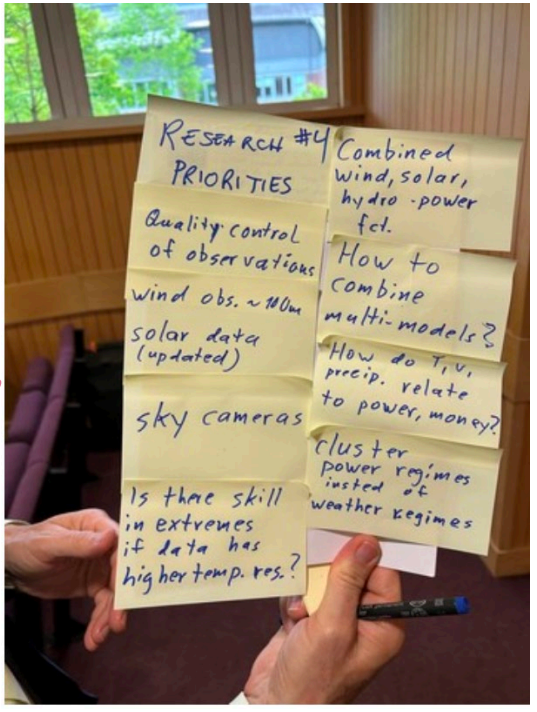
- **Objectives/Focus**
  - Predictions typically focus on anomalies vs “climatology”
  - Usually expressed as a probability of an anomaly
- **Current Techniques**
  - Ensemble of long-term (weeks to months ahead) NWP runs
  - Statistical teleconnections to atmospheric circulation indices (e.g. ENSO) and “slow-changing” ocean (e.g. SST anomalies)/earth’s surface (e.g. snow cover) variables
- **Evaluation**
  - Anomaly prediction has considerable skill vs climatology from 3 weeks to multi-seasons ahead
  - **Skill is strongly episodic** – i.e. when strong signals are detected (e.g. ENSO)
- **Products**
  - Forecasts of temperature and precipitation are most widely available – especially from public sources
  - **Wind & solar forecasts have much more limited availability** – mostly private sources

IEA S2S Forecasting Workshop: Thoughts from the **OpenSpace** Discussion

- **Evaluation and Performance**
  - Evaluation needs to be tailored to the user's application
  - Performance metrics should be stratified by S2S state (e.g. positive ENSO etc.)
  - Great interest in performance for large-amplitude rare events
- **Services and Products**
  - Ease of use
    - Standardization to facilitate comparisons
    - Availability of scenarios in addition to probability anomalies
  - Desire for customized/targeted content/format
    - Maps of forecast error a range of timescales
    - Hourly time series: wind/solar/hydro from 14 days to 3 months
    - Identification of factors that modulate predictability/uncertainty
    - Prediction of statistics of time series
  - Requests from users are often not scientifically possible

IEA S2S Forecasting Workshop: Thoughts from the **OpenSpace** Discussion

- **Current and Potential Applications**
  - Power Trading: demand, supply & price forecasting
  - Reserve estimation: hydro, wind, solar etc.
  - Prediction of likelihood of extreme grid stress events
    - Correlated wind/solar/hydro drought & high demand events
    - Weather damage to wind/solar gen facilities
  - Customized forecasts for each energy sector
- **Research Issues/Priorities**
  - Improve energy-weather-related observations for ML applications
    - Data quality control is essential!
    - Wind data near current hub heights (~100 m and higher)
    - Sky cameras for solar
  - Assess & improve skill in prediction of energy-impacting weather extremes
  - Combined wind/solar/hydro forecasting
  - Diagnose (e.g. clustering) power regimes instead of weather regimes



Forecasts of wind and clouds are important inputs for the control and value of renewable power plants. The forecasts on a time resolution of minutes or seconds are typically data driven, looking at upstream plants, all-sky images of clouds or direct measurements of wind by lidars. Therefore, to facilitate the dissemination of information about minute scale forecasting products, skill, applications, issues, and best practices to members of the electric energy community, we invite you to a Minute Scale Forecasting workshop with the goal of gathering information about methods used to produce the forecasts, the current state-of-the-art skill and uncertainty in forecasting for variables on high temporal resolution, current and planned research activities intended to improve the current level of skill, types of public and private sector operational forecasting products, the range of minute scale applications in the energy community and the quantified or perceived value obtained from those applications, the sensitivity of user's application performance to variations in forecast skill, and the unmet minute-scale forecasting-related needs or desires of the energy user community.

The workshop takes place as the collaboration of the International Energy Agency's (IEA) Wind Task 51, entitled "Forecasting for the Weather Driven Energy System", IEA Wind Task 52 Lidars, IEA Wind Task 50 Hybrid Power Plants, IEA Wind Task 44 Wind Farm Flow Control and IEA Photovoltaic Power Systems Programme (PVPS) Task 16 Solar Resource.

The venue is Risø, Denmark, on the campus of the Technical University of Denmark (https://www.dtu.dk/om-dtu/kontakt-og-besoeg/find-vej/dtu_risoe_campus).

- Venue: Risø, Denmark.
- Attendence: 70+ in-person, 20 online.
- Collaboration of multiple IEA tasks:
  - IEA Wind Task 51 "Forecasting for the Weather-driven Energy System"
  - IEA Wind Task 52 Lidars
  - IEA Wind Task 50 Hybrid Power Plants
  - IEA Wind Task 44 Wind Farm Flow Control
  - IEA Photovoltaic Power Systems Task 16 Solar Resource.

See talks at iea-wind.org/task51 →Workstreams → Minute Scale Forecasting
& videos at our YouTube Chanell "IEAWind Forecasting"

State-of-the-art:

- Forecasts of wind and clouds are important inputs for the control and value of renewable power plants.
- The forecasts on a time resolution of minutes or seconds are typically data driven, looking at upstream plants, all-sky images of clouds or direct measurements of wind by lidars or sodars.

IEA Minute-Scale Forecasting Workshop

Two aspects of Minute-scale

1) **Forecasts for the minutes-ahead (i.e. 0-1 hour look-ahead time)**
Applications use data-driven or hybrid algorithms such as:

Data-driven algorithms: Machine Learning, dynamic graph ML, neural networks such as GNN, feature engineering, generator models, graph convolutional long-short-term memory models etc.

Hybrid algorithms: can include heterogenous data sources from satellite or NWP images improve predictions, use cloud-scale dependent auto-regressive advection or deep learning radiative transfer emulators, Kalman filters

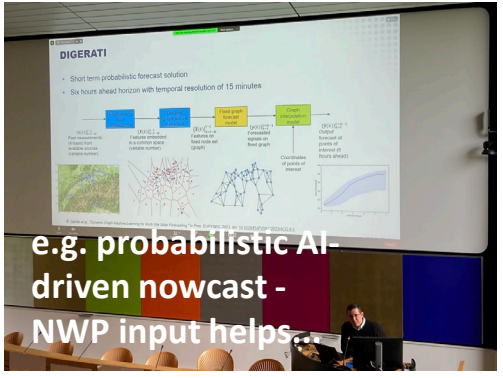
2) Longer term (hours or longer) forecasting in **time-scales of minutes**
e.g. High-time resolution NWP, Interpolation algorithms using AI methods

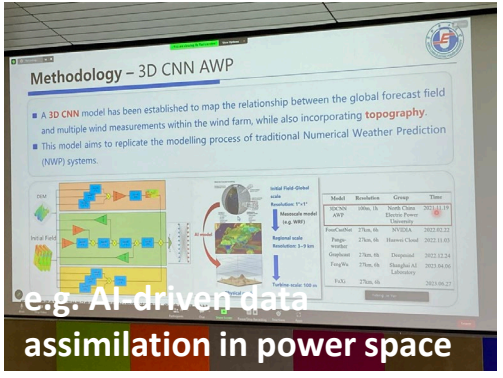
Observational data sources:

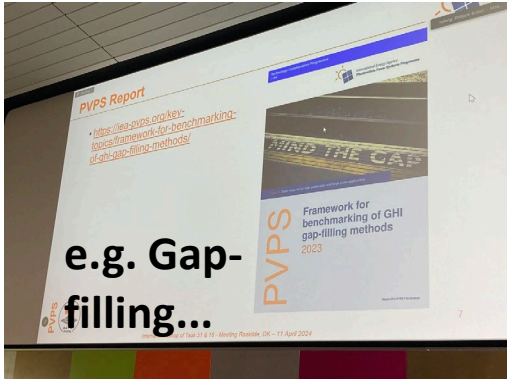
- WIND: scanning LIDARs with scanning heads, sonic anemometers, sodars for wind applications
- SOLAR: ASI (all sky imaging, fish-eye cameras pointed at the sky) and satellite observations

IEA Minute-Scale Forecasting Workshop

- ***Key points from Research & Development presentations:***
  - Feature engineering methods need "engineering" in the sense of knowing the atmosphere and its development to be useful
  - High-resolution NWP with high-time resolution of the order 5-10min are enabling NWP models to be used for minute-scale forecasting
  - AI weather forecasting system 3D-CNN is mapping relationship between global analysis and local measurements and aims to replace the modelling process of NWP with local measurements
  - The need for remote sensing is driving the development of instruments to solve current short-comings







Topical Expert Meeting #111

Reanalyses for Wind Energy

Practical information prior to your visit

Meeting Dates

April 25th and 26th, 2024
Day 1 (Thursday) | 09:00 – 17:30 CET
Day 2 (Friday) | 09:00 – 13:00 CET

Meeting Location

Technical University of Denmark
Anker Engelunds Vej 101
2800 Kongens Lyngby

Summary of IEA Wind TEM on Reanalysis Data

- Better inter-diciplinary cooperation between energy and meteorology community is needed ...
  "energy is not meteorology and engineers are different than scientists"
  - To bridge this gab, we need:
    - industry guidelines, e.g. a IEA Wind Recommended Practice (reanalysis, downscaling, validation)
    - Future compatible simulation and measurement data is required at altitudes of up to 1000m

- Data availability and quality is key for good reanalysis data -- just as for real-time analysis -- and that there is no international agreement on quality for energy related data.
  - To bridge this gap, we need
    - an international agreement on quality and availability
    - data sharing policy acts in some way are needed for the next generation of wind turbines (ca. 450m) and airborne wind turbines up to 1000m

Importance of input data & validation received the highest attention & was discussed most

Summary of IEA Wind Technical Expert Meeting on Reanalysis Data

Validation of data

- data quality of observations ==> quality of the reanalysis
- Uncertainties of reanalysis data !?
- Lack of measurements
- Use cases of reanalysis data for wind energy missing

Coupling strategies

- Coupling from macro-scale -> meso-scale -> micro-scale
- Metocean coupling ?

Reanalysis need to be complementary to other scales & areas

- global, high-frequency, high time resolution, relevant levels also for underserved areas
- Multi-variate and multi-decadal datasets
- Ensemble data and coupled scales

Summary of IEA Wind TEM on Reanalysis Data

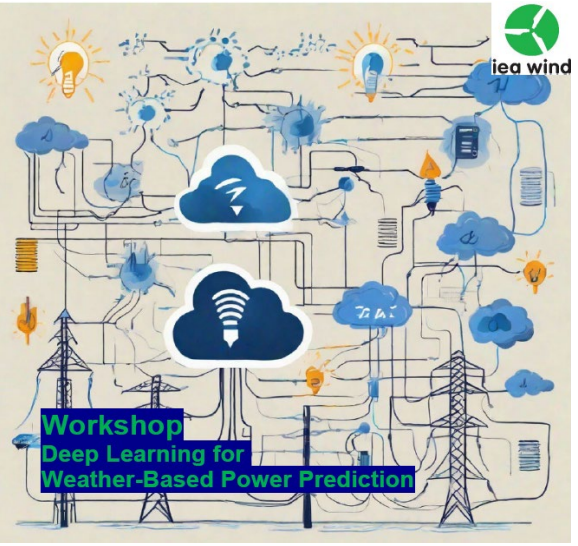
- **Reanalysis datasets that were discussed**
  - BARRA-R2/RE2 (1979 - present) – 12km
  - BARRA-C2 downscaled BARRA in 4.4km
  - ERA5, ERA6
  - GEOS Digital Replicas of the Physical System
  - MERRA-2 will be discontinued
  - NASA Earth Action Strategy
- **Applications for reanalysis data that were identified and discussed**
  - Fire weather applications
  - Ocean hazard modelling with coupled hydrodynamic/wave model
  - Resource analysis for offshore wind development
  - Site selection and design for wind and solar facilities (mostly ERA5)
  - Design conditions & metocean landscape for storm surge at offshore wind farms

No reanalysis data set is today focusing on Met-ocean or Wind + Solar

Webinar: Deep Learning for Weather-Based Power Prediction

Objectives:

- **Issue:** Energy-community stakeholders have expressed concerns about the impacts of increasingly incorporating AI and Machine Learning into weather and power prediction models
- **Approach:** IEA Task 51 organized a webinar on Deep Learning for Weather-Based Power Prediction brings together the **Energy Meteorology and Machine Learning / Deep Learning (ML/DL) communities** to showcase the latest advancements in ML/DL for weather prediction.



Webinar available in our YouTube channel

https://youtu.be/t6H7diavQdg

iea wind

Summary and Lessons learned in the AI Webinar

Positive developments:

- The models start to show skill
- The models suggest a new approach to meteorological questions
- Fast hypothesis testing and scope narrowing for simulations with physics models
- The models develop fast due to large resources put into new features
- Ensembles and probabilistic forecasts are on the horizon
- There is work underway to start the AI models from measurements alone

Challenges to be addressed:

- Quality control of input data is not yet handled especially for outliers, missing or corrupt data
- High complexity and variety of data to train models is a challenge
- Feature engineering needs features – without physics this will be difficult
- Data-driven models require new look upon data sharing, which has been a challenge until now

General Conclusions from Meetings

Observational data & data quality control is key for all future development in weather and energy forecasting

Data-driven algorithms are penetrating all aspects and the entire chain of stages of wind and solar integration

Increased collaboration with other IEA Tasks, groups, authorities and broader energy community is needed...

More collaborative sessions at conferences, workshops and meetings to enhance exchange and cross-sector communication

THANK YOU for your attention...

Questions

Follow us:

Project webpage: http://www.iea-wind.org/task51

Publications: https://iea-wind.org/task51/task51-publications/

YouTube Channel: https://www.youtube.com/channel/UCsP1rLoutSXP0ECZKicczXg

Sign up for our Newsletter by contacting Gregor Giebel (grgi@dtu.dk)

Presenter:

Dr. John W. Zack
WP2 Leader
MESO, Inc, USA
jzack@meso.com

Dr. Corinna Möhrlen
TM & WP3 Lead
WEPROG, Denmark
com@weprog.com