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A WORLD TOP 100 UNIVERSITY

Past, present, and future of renewable energy forecasting

MetDesk Winter 2023/24 Forecast Symposium

10 October 2023

WORLD CHANGING GLASGOW

Dr Jethro Browell
Senior Lecturer
School of Mathematics and Statistics
University of Glasgow
jethro.browell@glasgow.ac.uk

THE TIMES THE SUNDAY TIMES GOOD UNIVERSITY GUIDE 2024 SCOTTISH UNIVERSITY OF THE YEAR

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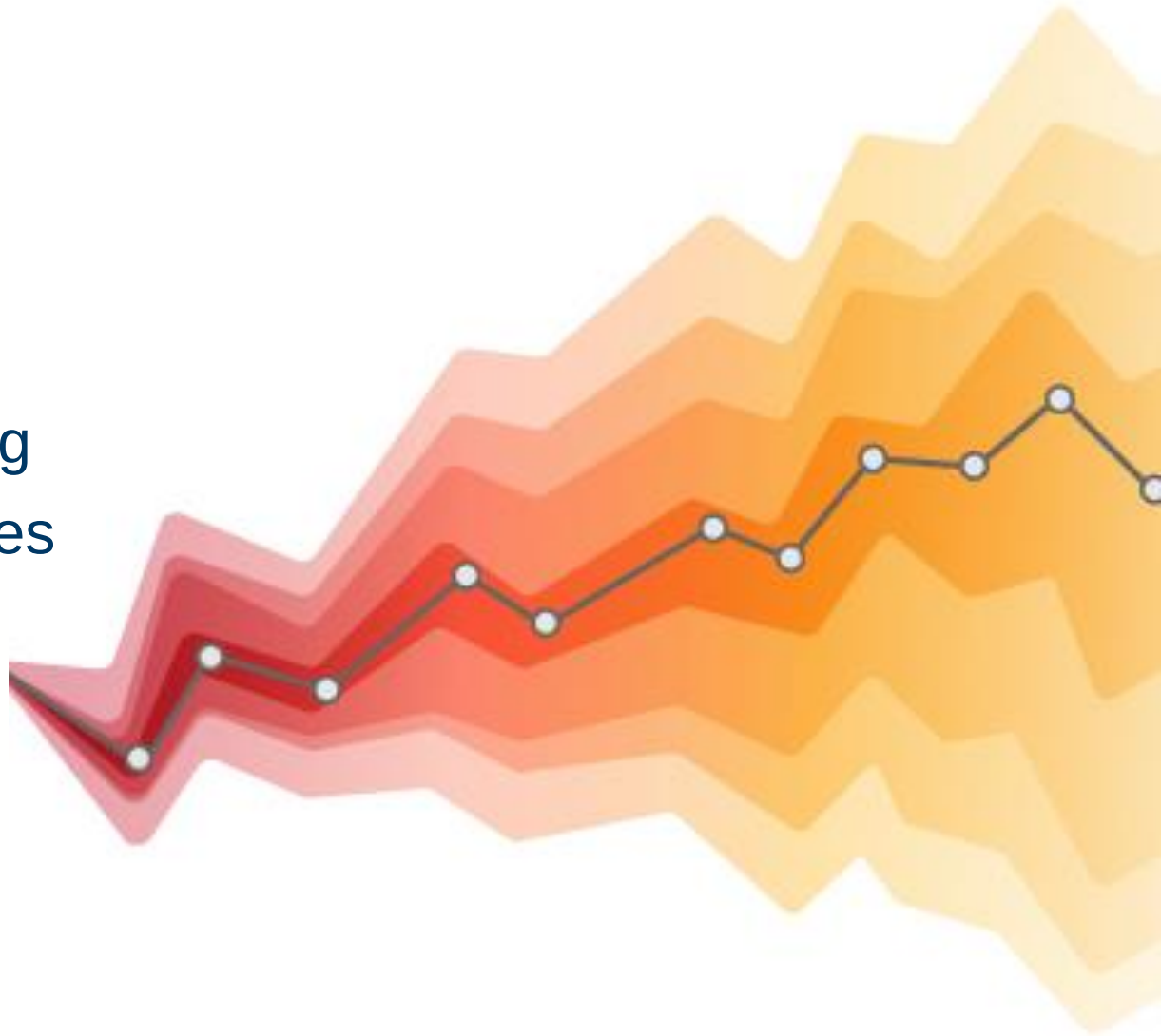
- A brief history of wind power forecasting
- Challenges, advances, and opportunities
- The future of energy forecasting



Thanks to my many collaborators!

Links and references at the end…

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A brief history of wind power forecasting

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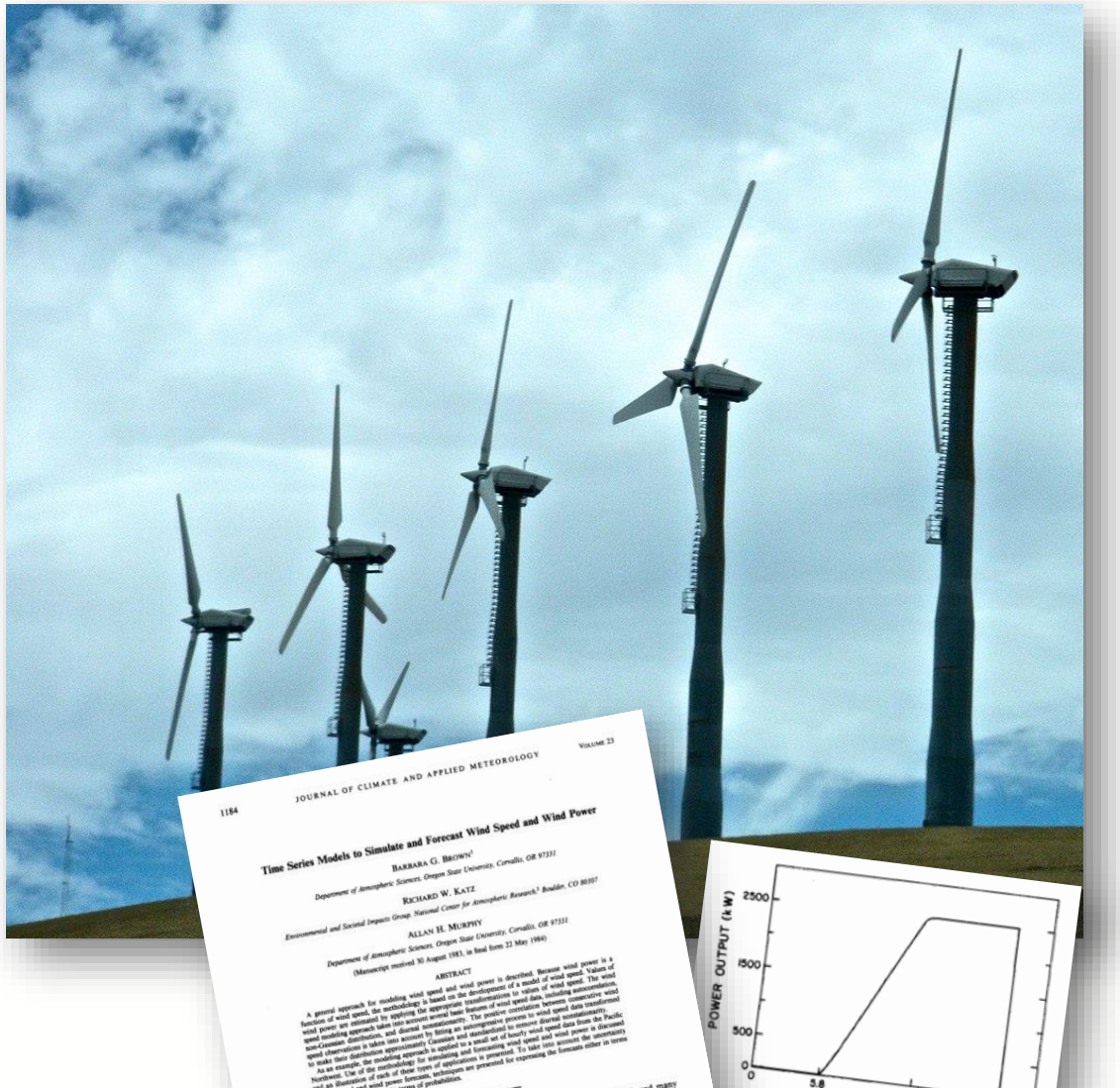
1980s

- First wind farms followed by the first research on wind power forecasting
- Predictive control for wind turbines

1990s

- Small island systems have immediate need for forecasting
- Combination of weather forecasts and wind farm models pioneered in Denmark



By Coastergeekperson04 at English Wikipedia, CC BY 3.0, https://commons.wikimedia.org/w/index.php?curid=7333747

2000s

- Ensemble weather forecasting
- First wind and solar power forecasting start-ups

2010s

- R&D consolidation though ANEMOS.plus, WFIP, Smart4RES…
- Maturing and consolidation of commercial energy forecasting services

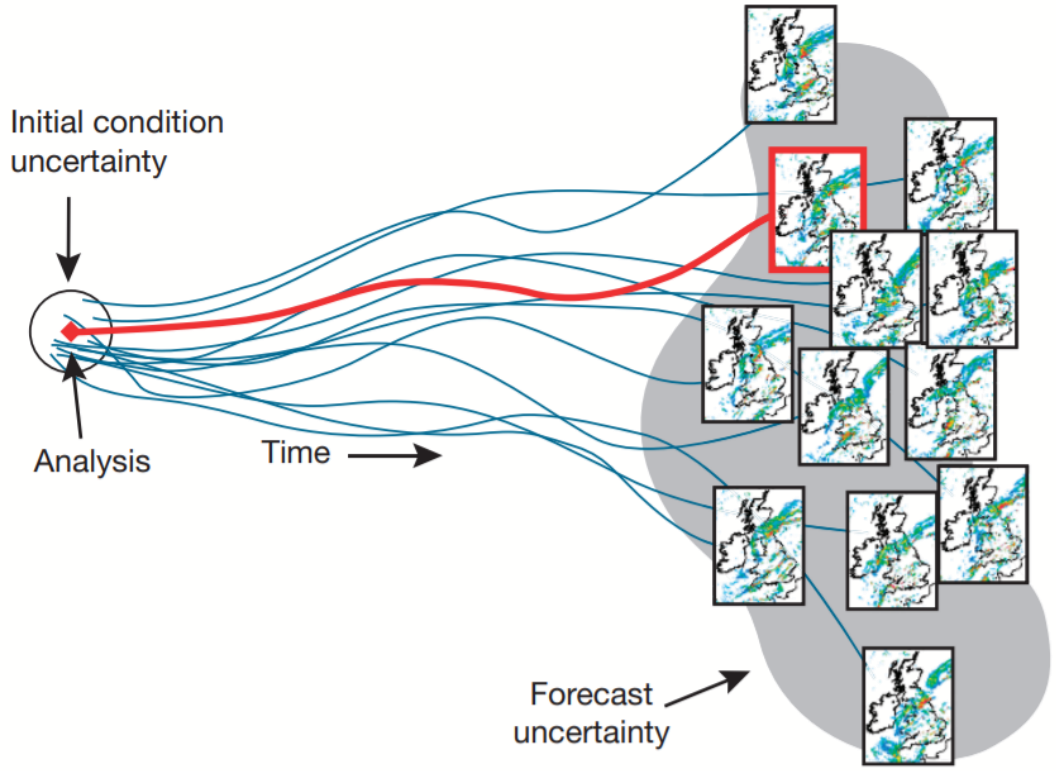


Figure source: Bauer, P., Thorpe, A. & Brunet, G. The quiet revolution of numerical weather prediction. *Nature* **525,** 47–55 (2015). https://doi.org/10.1038/nature14956

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Challenges, advances, and opportunities

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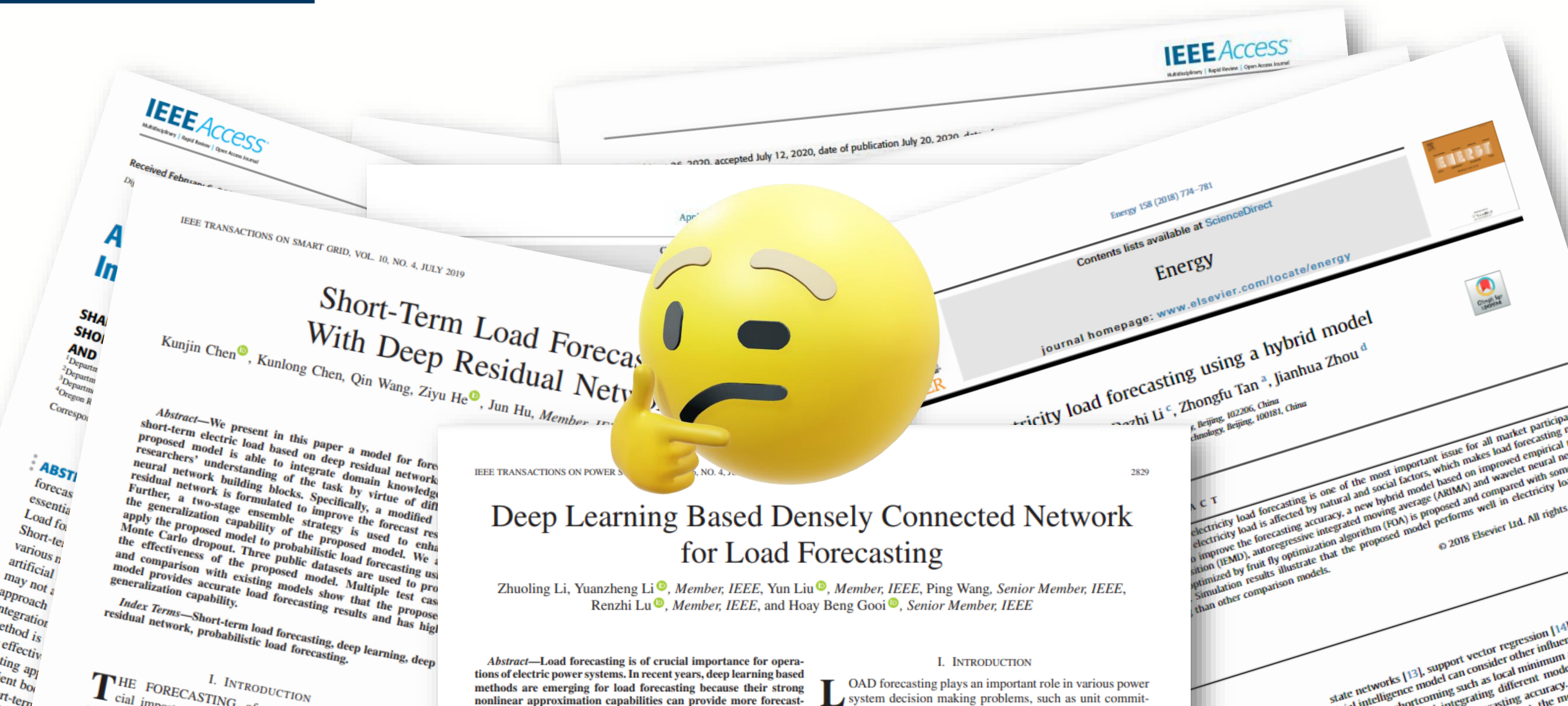
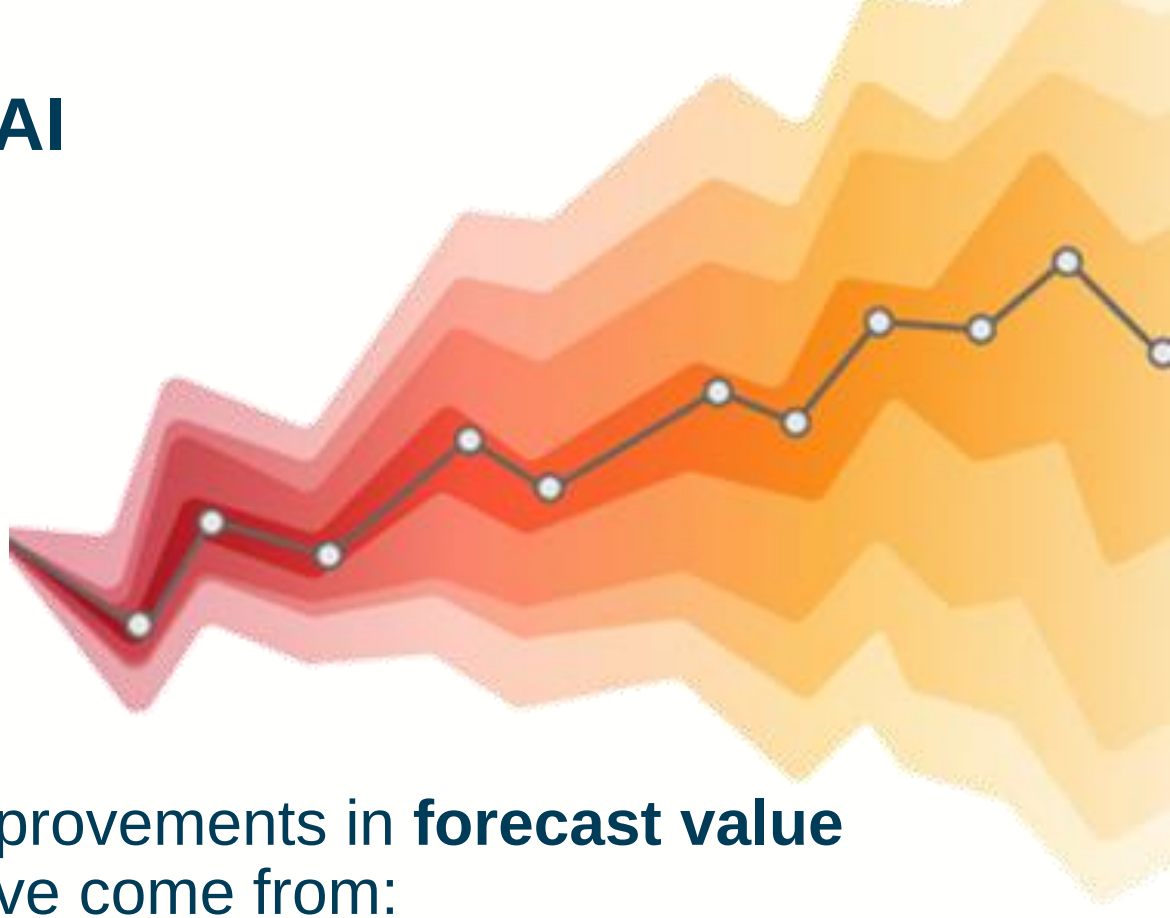
Machine learning and AI

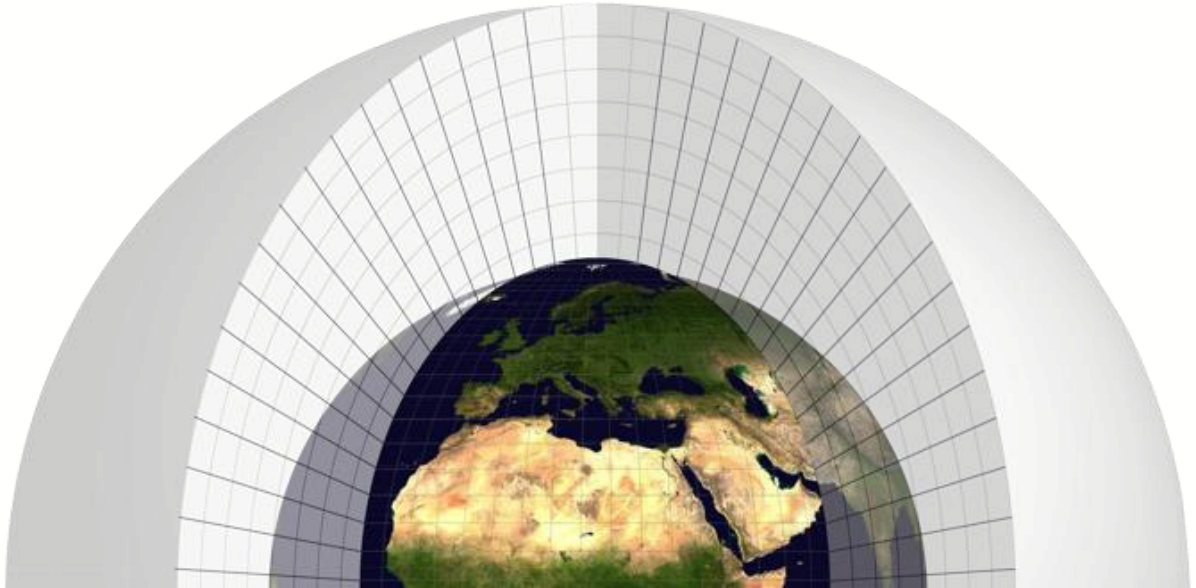


Machine Learning and AI



Improvements in **forecast skill** have come from:

1. New sources of predictability (and access to data)
2. ML, particularly tree methods and physics-informed implementation

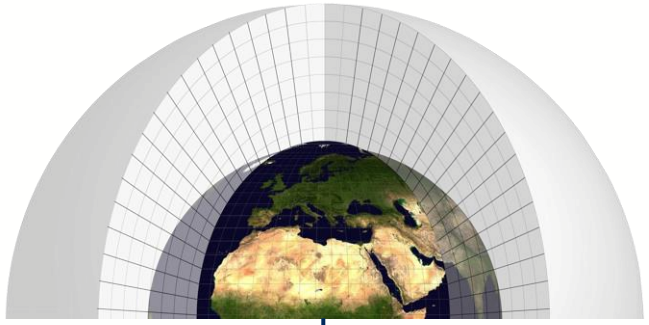


Improvements in **forecast value** have come from:

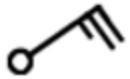
1. Making use of uncertainty quantification
2. Decision-support and automation
3. Closer collaboration between forecasters and forecast users

Improvements in forecast skill

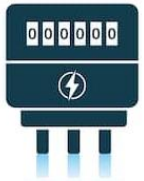
4D Grid of Weather Predictions



“Site Specific” Weather Forecast

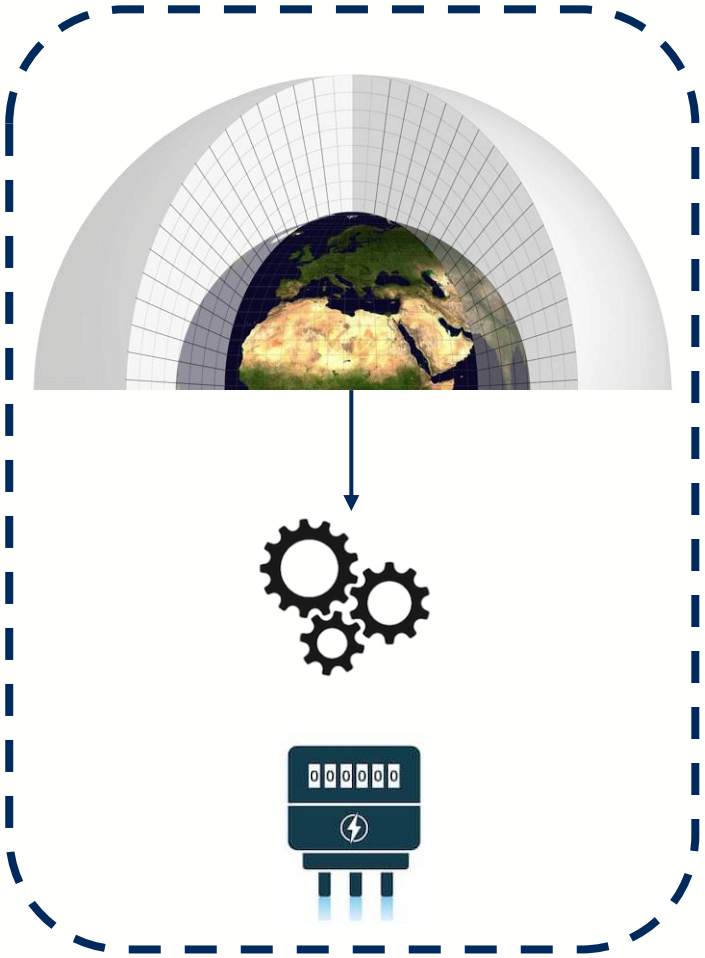


Export Meter



Simple weather-to-power relationship

Improvements in forecast skill

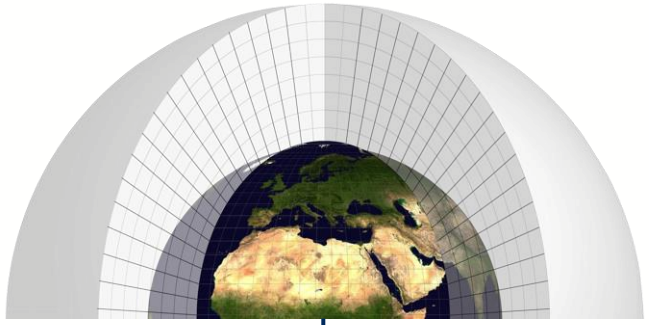


Data-driven weather-to-power relationship

Proposed by Andrade & Bessa (2017), doi:10.1109/TSTE.2017.2694340

Improvements in forecast skill

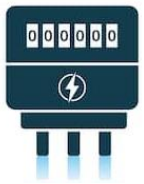
4D Grid of Weather Predictions



Feature Engineering

SCADA
(Wind or Solar)

Export Meter



Data-driven weather-to-power relationship

Proposed by Gilbert, Browell & McMillan (2019), doi:10.1109/TSTE.2019.2920085

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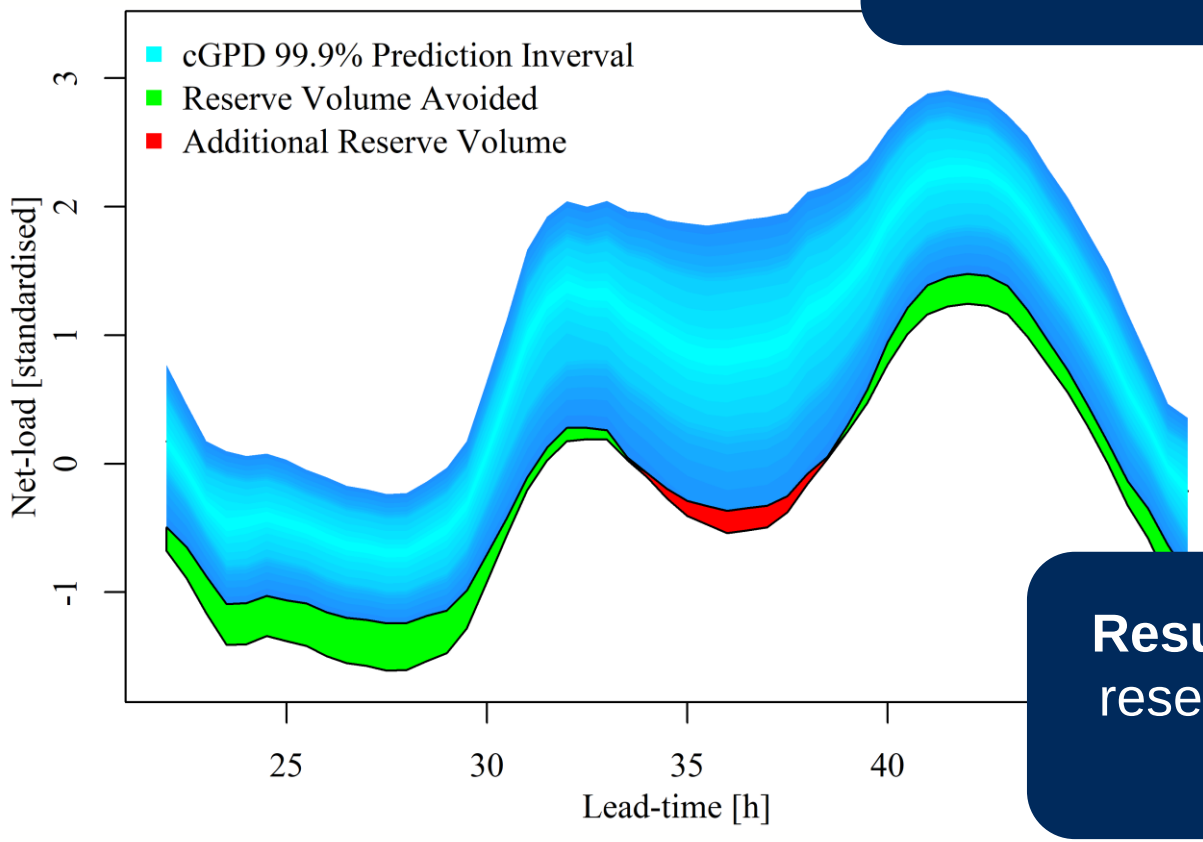
Improvement in forecast value

Example: Reserve procurement

Sometimes (~25%) **more** reserve than benchmark needed to satisfy risk appetite



Most of the time, **less** reserve can be held than the benchmark

Result: overall reduction in reserve cost and improved risk profile

With a reserve cost of £50/MWh, this represents a saving of approximately £75m per year!

Control REACT

NIA project with

nationalgridESO

tnei

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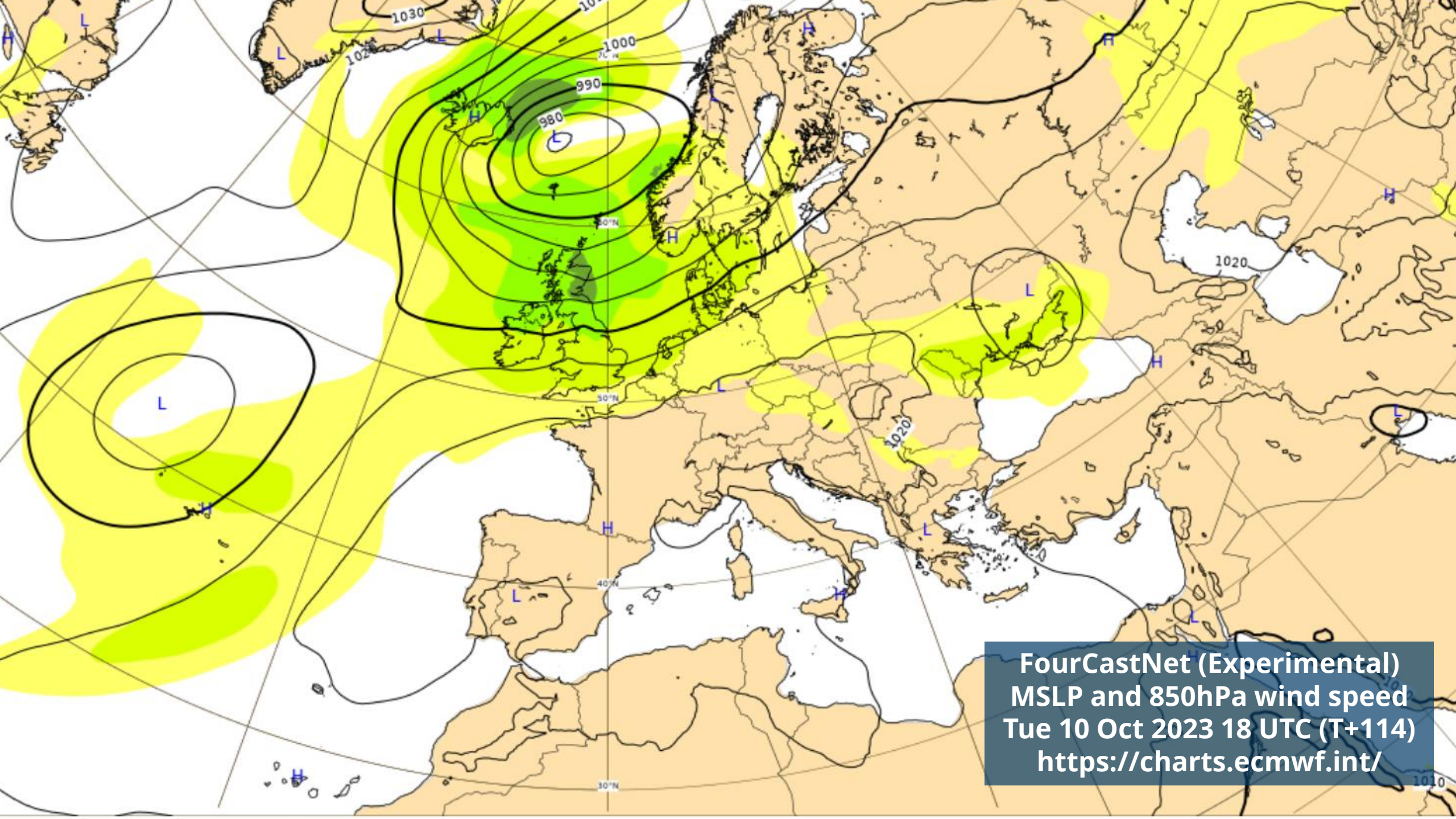
The future of energy forecasting


FourCastNet (Experimental)
MSLP and 850hPa wind speed
Tue 10 Oct 2023 18 UTC (T+114)
https://charts.ecmwf.int/

Machine Learning and AI

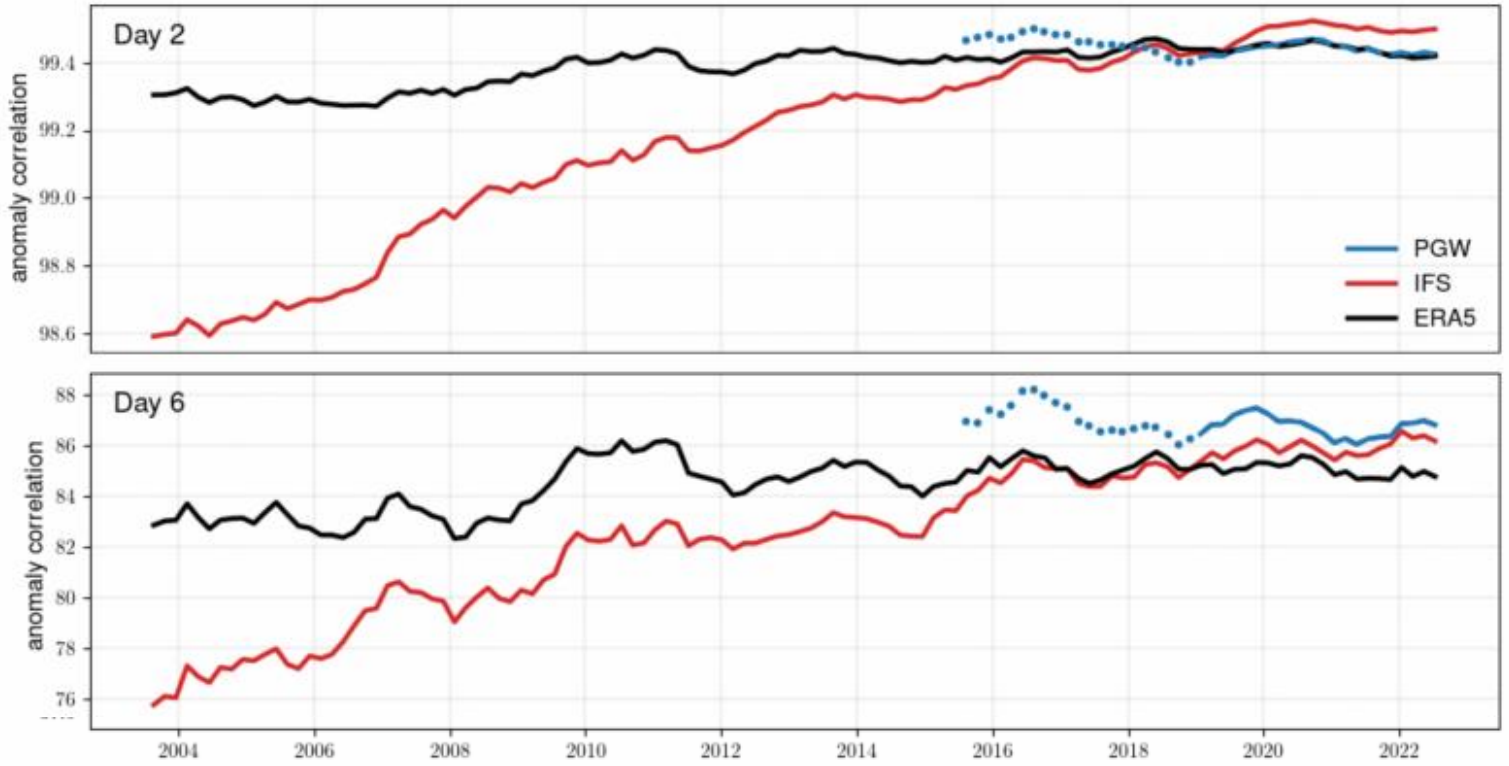
Data-driven weather forecasts

- Huawei, NVIDIA, DeepMind
- Super-fast!
- Competitive performance

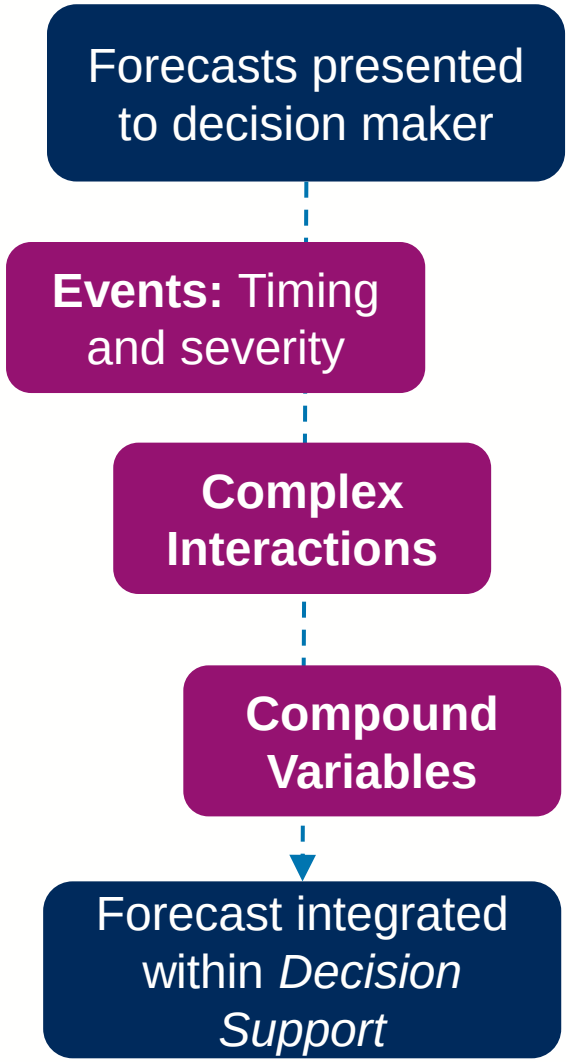
Huawei's Pangu-Weather performing very well!

Figure 1 from Ben-Bouallegxue *et al* "The rise of data-driven weather forecasting", 2023, arXiv:2307.10128

Forecast skill (the larger the better) over the Northern Hemisphere at day+2 and day+6. Skill is measured as the correlation between the forecasts and the verifying analysis (operational IFS) for the geopotential height at 500hPa.

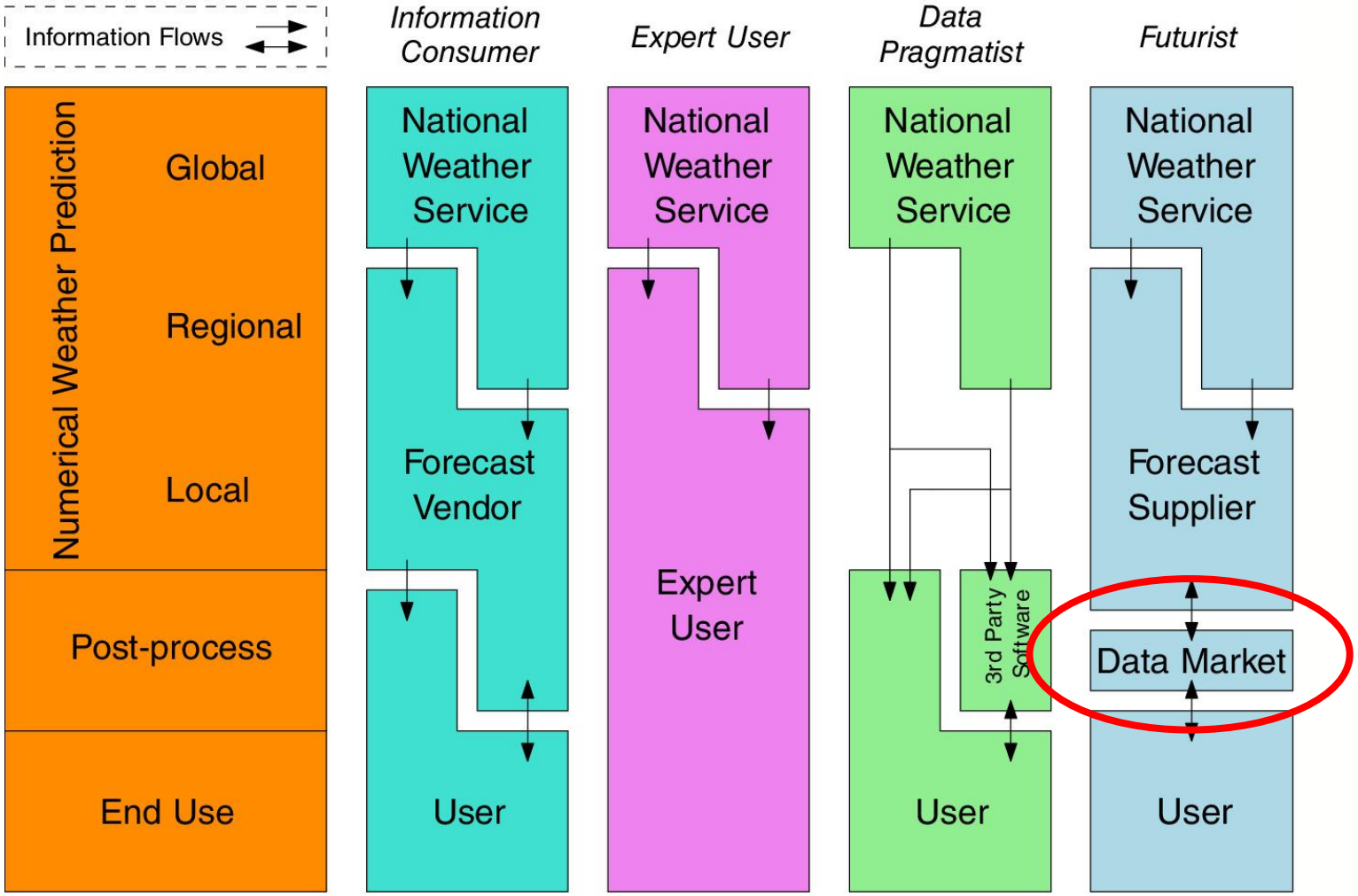


What do we want to predict anyway?



- **Energy:** Blocks of energy for trading and generator scheduling, risk/reserve requirements
- **Power:** ramps for balancing; instantaneous power for ancillary services, reactive power
- **Interdependency with markets:** risk management, algorithmic trading, embedded flexibility
- **Network flows/constraints:** probability of constraint, regional balancing, TSO/DSO flow

The future of energy forecasting?



- Sharing observations, forecasts, and models
- Incentivised though performance gain and financial remuneration
- Privacy-preserving to protect commercial interests and personal data

Figure source: Sweeney, Browell *et al* (2020)

References and links

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- Z. Ben-Bouallegxue *et al* “The rise of data-driven weather forecasting”, 2023, arXiv:2307.10128
- AI Weather Forecasting at ECMWF: https://www.ecmwf.int/en/forecasts/dataset/machine-learning-model-data
- Smart4RES Horizon Project 2019-2023: https://www.smart4res.eu/

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www.jethrobrowell.com
@jethrobrowell