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FORECASTING POWER SYSTEM RELEVANT WEATHER EVENTS

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with thanks to: David Brayshaw, Andrew Charlton Perez, Dan Drew, Paula Gonzalez, Phil Coker, Hazel Thornton,

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- Group Leader: David Brayshaw
- Aim is to understand the impact of weather and climate on the energy sector, and to develop new ways to exploit weather and climate information for energy risk management.

- Address a range of energy sector issues, including:
  - Wind farm modelling
  - Resource characterisation
  - Extreme events and insurance
  - Forecasting and energy trading
  - System integration
  - Impacts of future climate change







The use of weather data in power systems

Operational seconds – days	Grid management, plant scheduling Anticipating extreme weather
Trading days – 1 year	Maintenance/resource planning Longer-term wholesale energy contracts
Strategic year – year climate variability	Characterising demand and supply Impacts of inter-annual variability
Planning climate change	Impacts of climate change Trade-off between climate change and energy system change
Extremes disrupting weather	Risk and impact of extreme disruptive weather local vs. far afield impacts

The use of weather data in power systems

Operational seconds – days	Grid management, plant scheduling Anticipating extreme weather	Nowcasting & short range
Trading days – 1 year	Maintenance/resource planning Longer-term wholesale energy contracts	Extended range & seasonal
Strategic year – year climate variability	Characterising demand and supply Impacts of inter-annual variability	Reanalysis & control runs
Planning climate change	Impacts of climate change Trade-off between climate change and energy system change	Climate models
Extremes disrupting weather	Risk and impact of extreme disruptive weather local vs. far afield impacts	All of the above!

The weather that matters

- Quantification of extremes with observed power system data is difficult as the data is inhomogeneous due to rapid growth of renewable generation

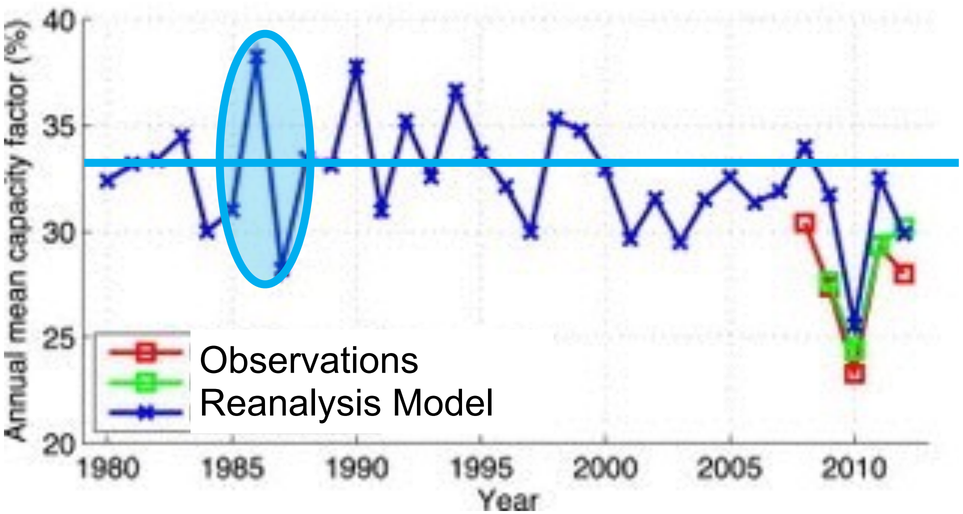
- UK currently has 21GW wind power, 13 GW solar power

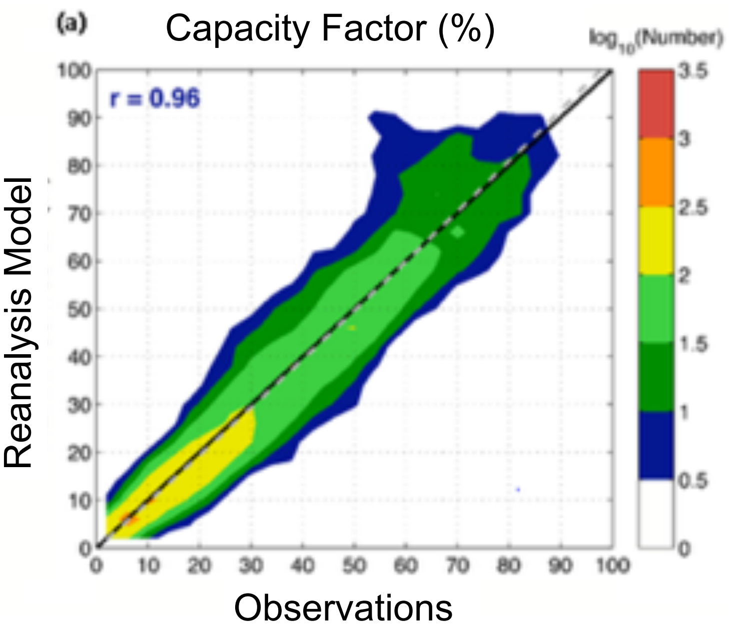
- How can we forecast:
  - Wind power ramps
  - Peak Load
  - Peak renewable days

First we need to know what we're looking for…

The weather that matters: using reanalysis

- Reanalysis based climatologies provide a good way of assessing extreme weather in power systems
- ~40 year reconstruction of atmospheric circulation => feed through wind turbine model
- Result: consistent reproduction of country-aggregate wind power generation (or solar or demand) with a fixed system setup





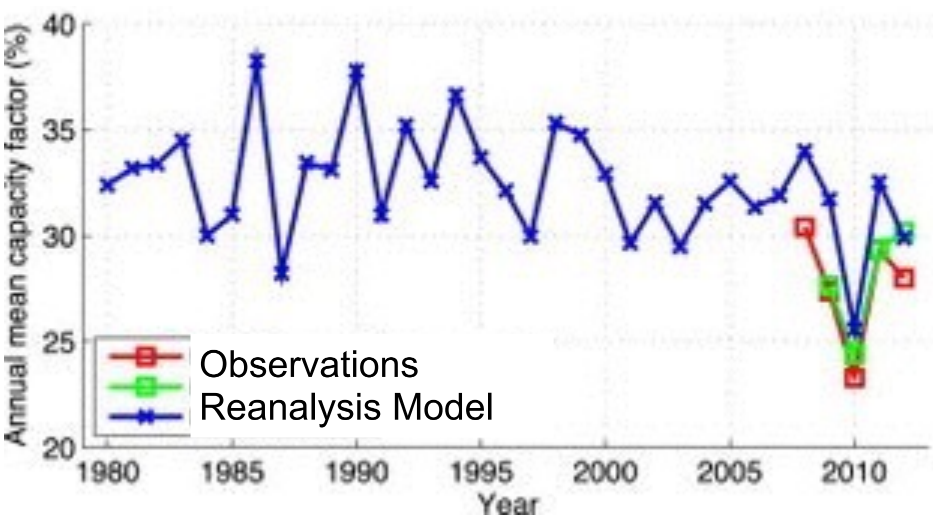
Model and data freely available:
www.met.reading.ac.uk/~energymet

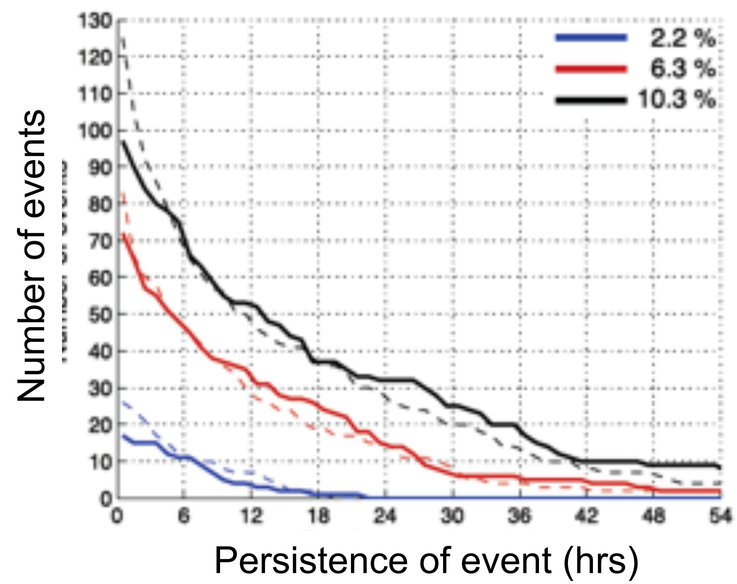
Cannon et al., (2015)

The weather that matters: wind power ramps

- Rapid growth of wind power capacity in UK (~1GW in 2009, 13GW in 2015, up to ~50GW in 2030?)
- Quantification of extremes with observed power system data is difficult as the data is inhomogeneous:
  - 2012 extreme: CF<6% for 3 days
  - Was this a bad, good or indifferent year?

To estimate system extremes you need a good climatology to distinguish the probable from the possible





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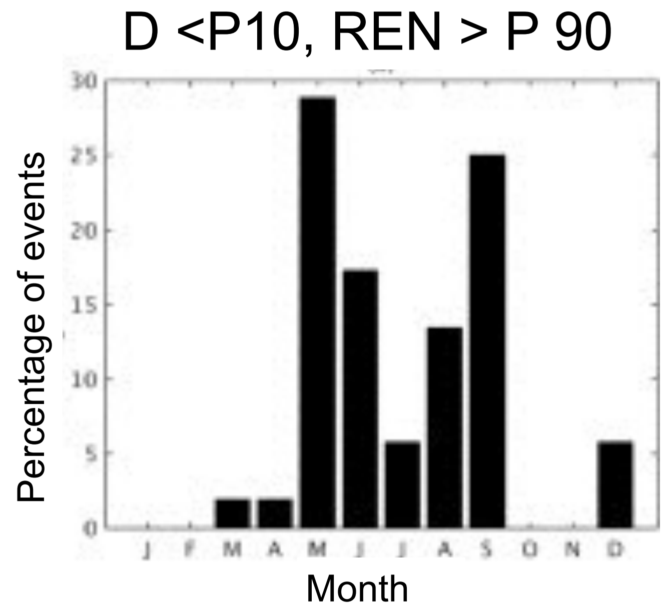
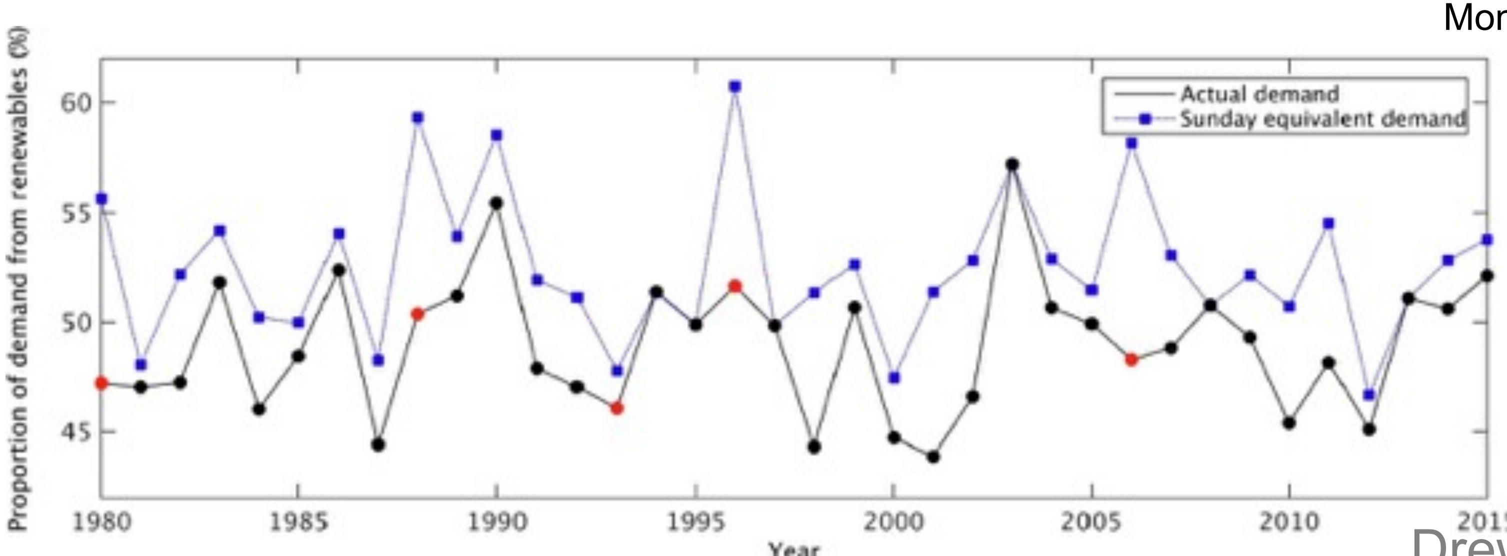
Cannon et al., (2015)

The weather that matters: Peak renewable days

- At present in the UK peak renewable day happens in either Spring or Autumn.
- 31 peak days occur on weekends when demand is low, but not exclusively (red dots)
- Reanalysis allows us to remove exogenous factors (e.g. weekday) from the modelling



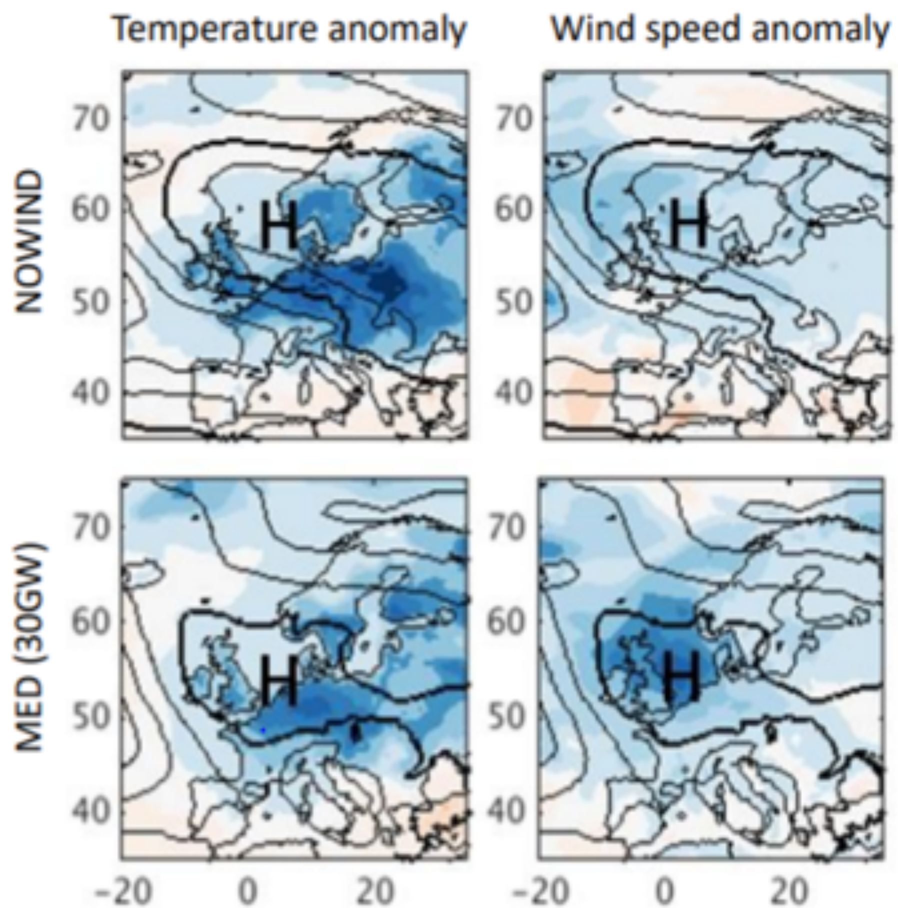


Drew et al., (2019)

The weather that matters: Peak Load

- Not all weather/climate variations are equally important for power system operation
  - Peak Demand: dependent on high pressure centred NE of the UK
  - Peak Demand-net-wind: dependent on high pressure centred North of the UK

Weather conditions of interest depend on the system set-up and the property you are trying to forecast



Bloomfield et al., (2018)

Forecasting power system relevant events

- **Short range forecasts**: 12-72 hours ahead for operations, example of wind ramps
- **Extended-range/Long range forecasts**: probabilistic forecasting 3-10 days ahead/30+ days, an example of system stress indicators
- **Future system design**: robustness under a changing climate

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Planning climate change	Impacts of climate change Trade-off between climate change and energy system change

Short-range: UKV 1.5km model

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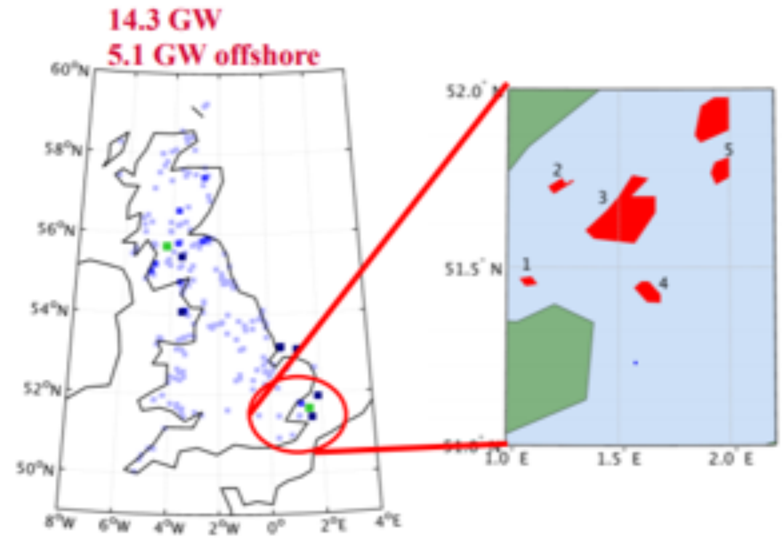
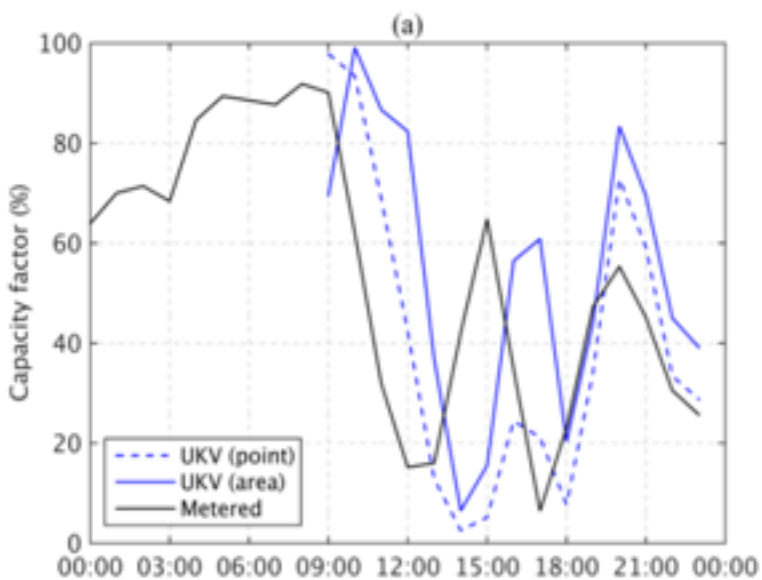
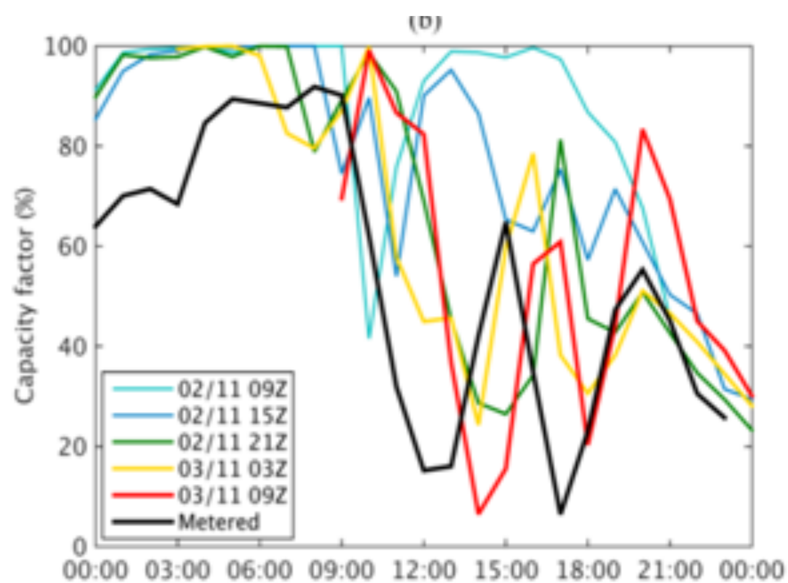
- Wind power ramp not captured clearly if precise turbine locations used.
- Improved by considering maximum wind speed within 10 km area around each turbine.
- Feature present 24 hours ahead.







Drew et al., (2017)

Short-range: 2.2km 11 member

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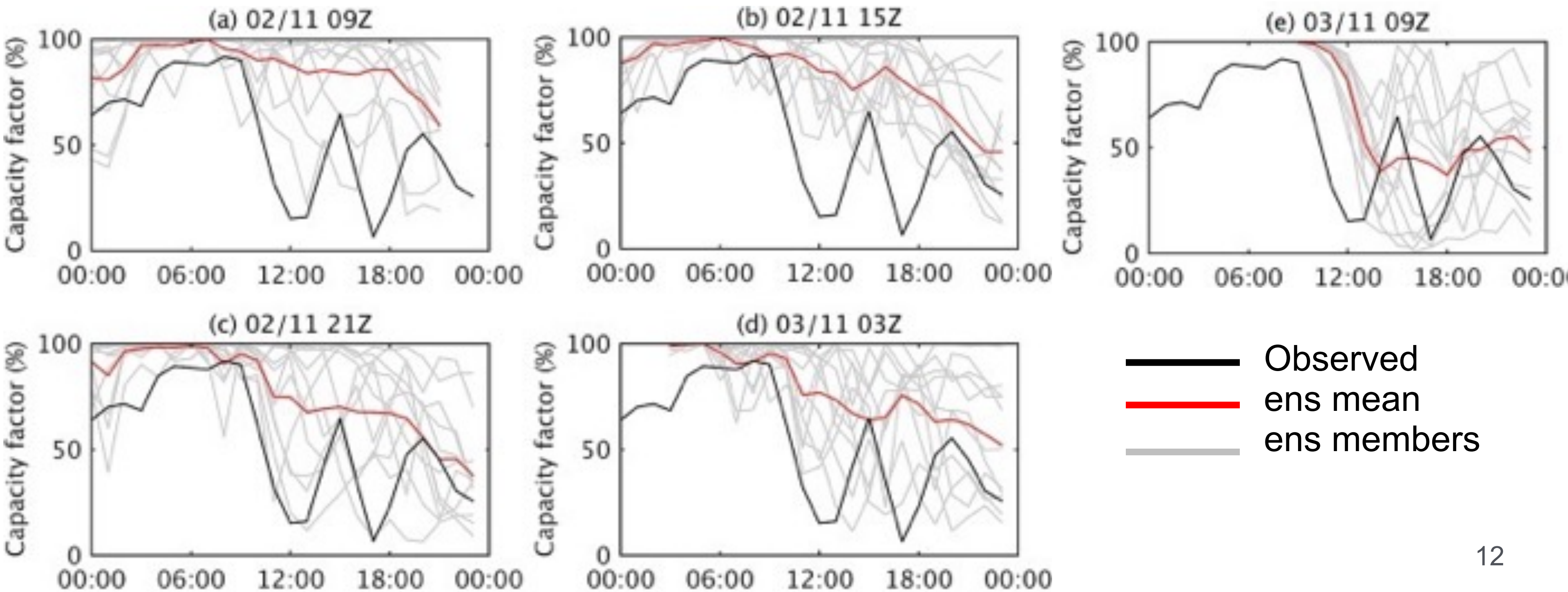
nationalgrid

- 4 hr ramping – caused by frontal features associated with low pressure systems
- Small scale phenomena need to be captured by forecast models
- Feature not captured when forecast uses ensemble mean wind speed.
- **Need the information of the ensemble members**

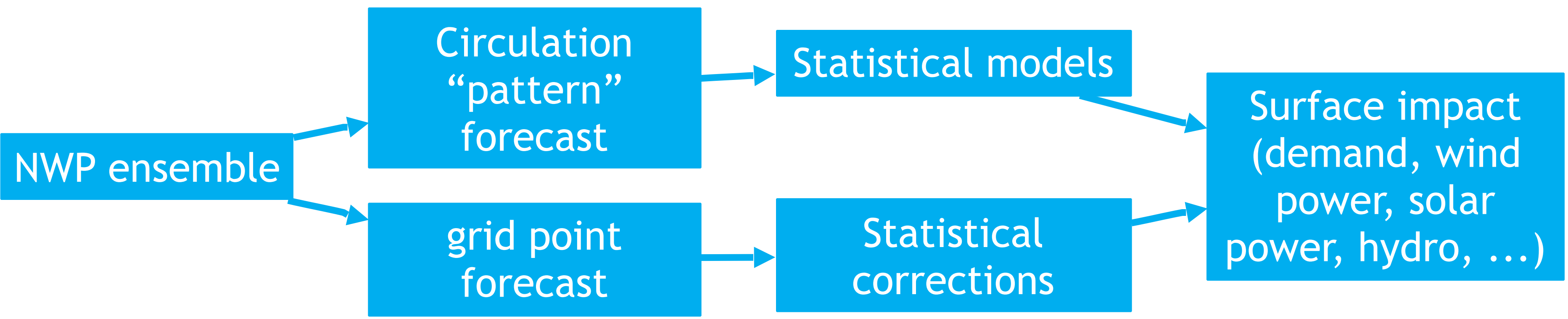


Drew et al., (2017)

Extended/Long-range

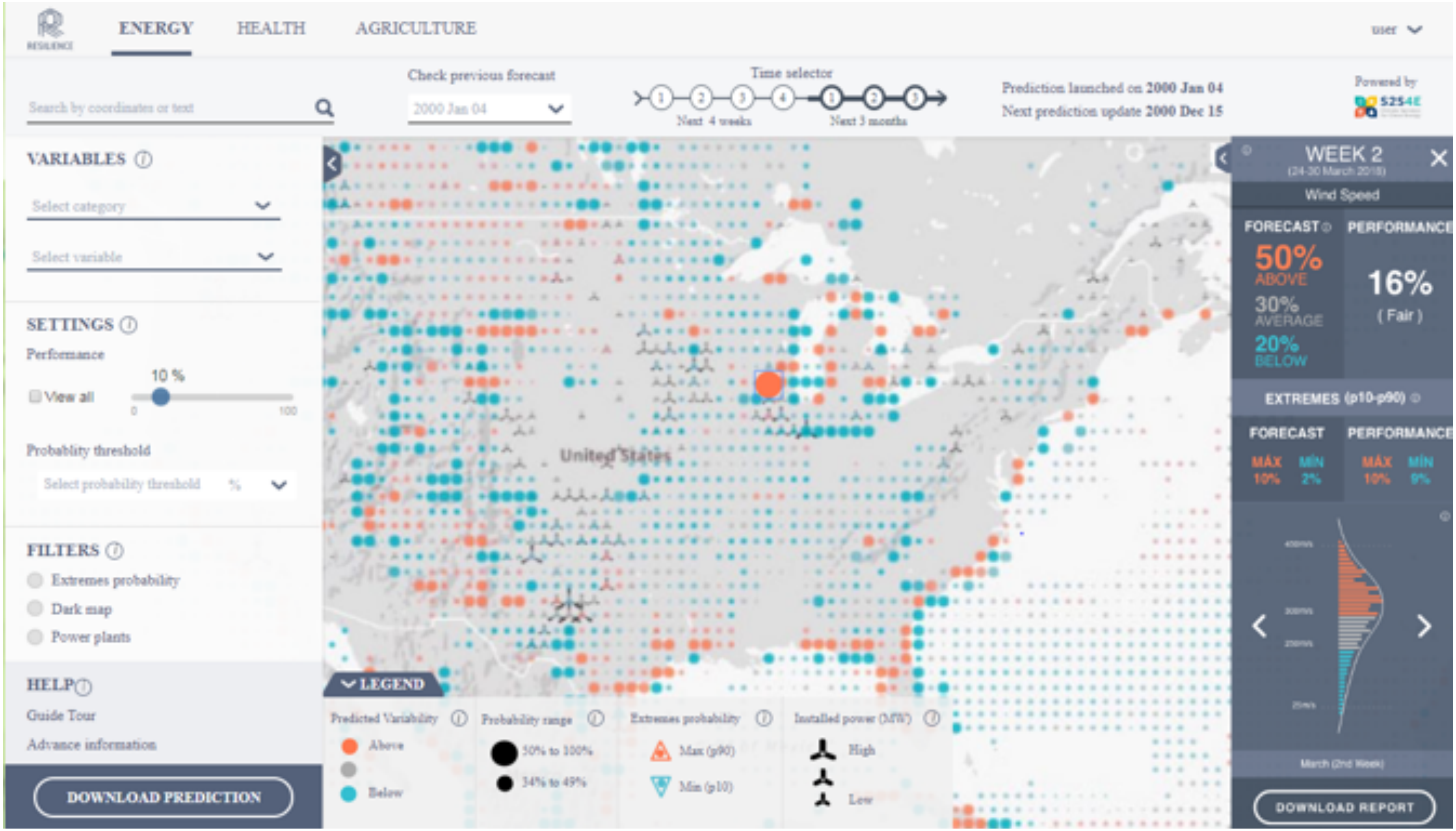
- Energy is a major target sector for climate service development
  - ECEM and CLIM4POWER (EU Copernicus); e.g.: http://ecem.wemcouncil.org
  - S2S4E, SECLIFIRM, CLIM4RES (EU H2020); e.g.: https://s2s4e.eu

- There is skill in forecasting weekly-/monthly-/seasonal- demand, wind,



See, e.g., Lynch et al 2014; Scaife et al, 2014; Clark et al 2017; Thornton et al 2018

Medium-range: grid point

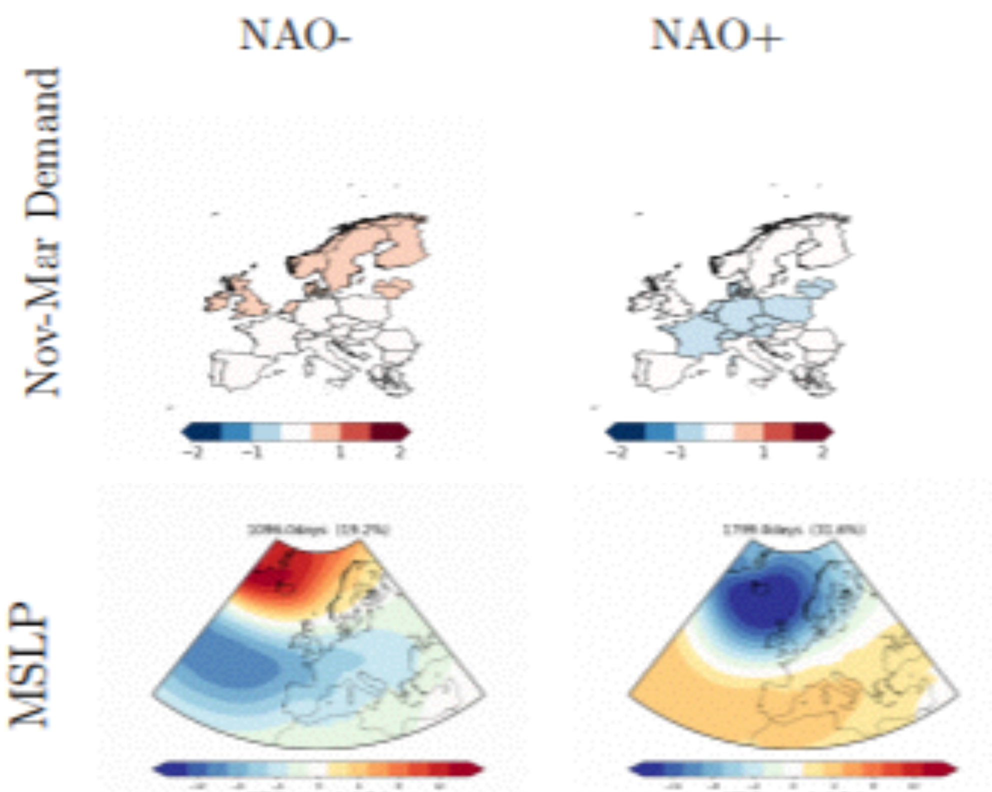


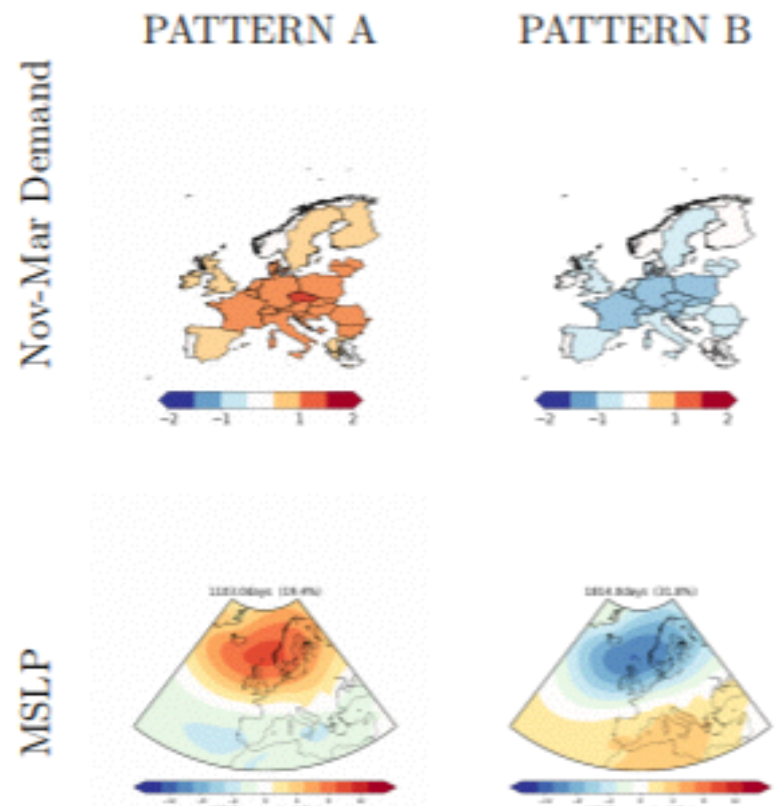
https://s2s4e.eu/ for more info

Medium-range: Patterns

Weather patterns: predictable but weak link to surface weather & demand *over regions of interest*

Impact Patterns: unknown predictability (work in progress) but good links to surface weather & impacts





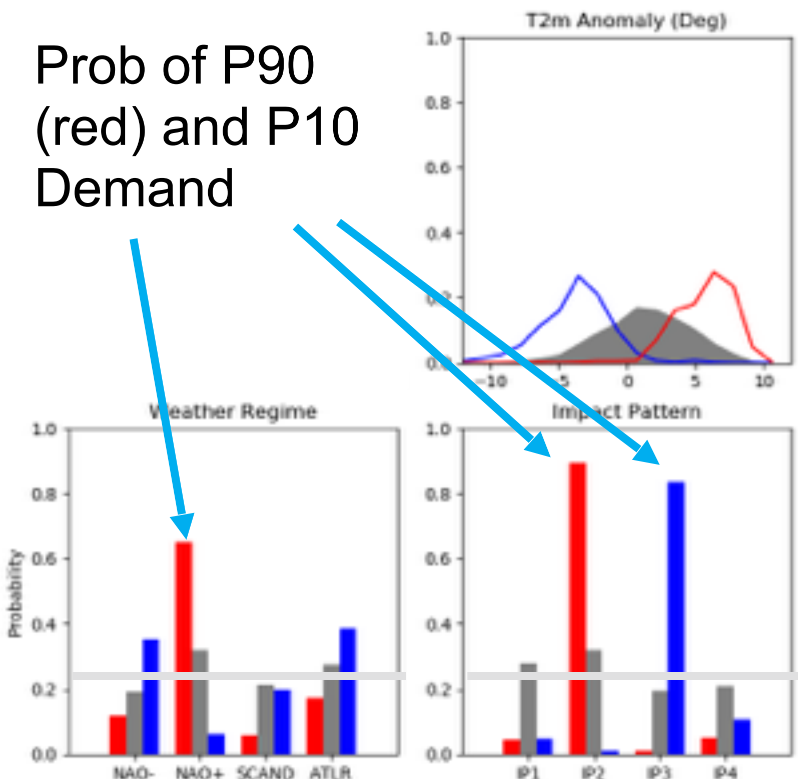
Bloomfield et al., (in prep)

Medium-range: Patterns

Impact Patterns: Potential predictability is good due to their construction based on the impacted system. Next steps is checking in the forecasts…

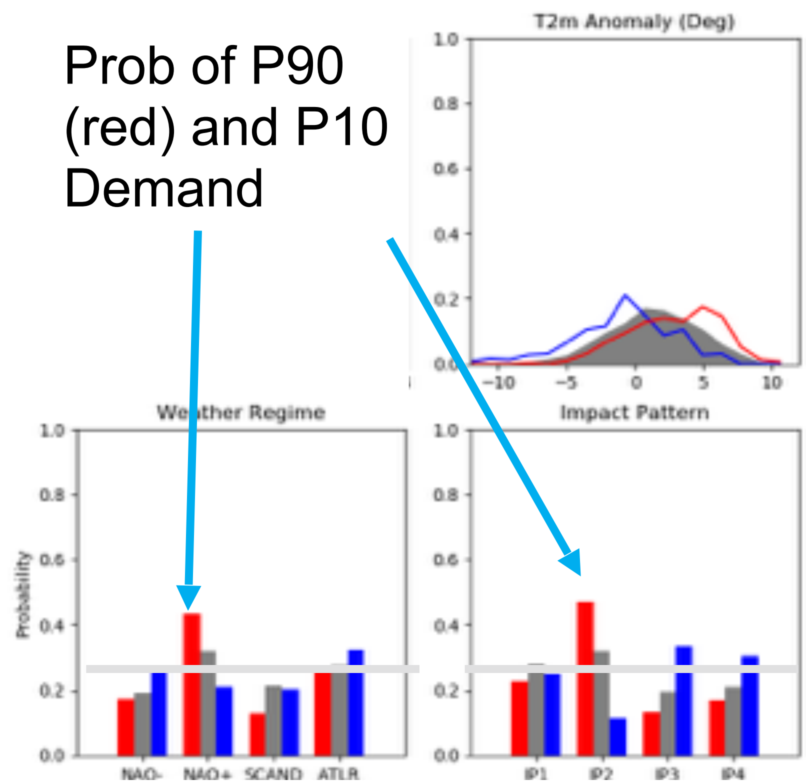
Day ahead

Prob of P90 (red) and P10 Demand



8 days ahead

Prob of P90 (red) and P10 Demand



Bloomfield et al., (in prep)

Future system design

Climate is global, not local

- Climate impacts on power system design poorly understood and typically rely on relatively coarse-resolution global climate models
- Fundamental questions as to whether climate processes affecting energy are well-understood and represented (e.g., hydrological cycle, Roberts et al 2018; surface winds, Gonzalez et al 2019)

PRIMAVERA: a flagship EU research programme (€15m over 5 years)

- Next-generation, multi-model, climate simulations
- Unprecedented high *global* resolution (~20-50 km at 50^{o}N)
  - Improved representation of underlying processes driving the climate
- Tailored high resolution, high frequency dataset designed for energy modelling
  - Sub-daily wind, temperature, solar, precipitation
- Engaging with energy users – if interested, please contact d.j.brayshaw@reading.ac.uk
- Website - https://uip.primavera-h2020.eu

Concluding remarks

- To estimate system extremes you need a good climatology to distinguish the probable range of possible events
- Weather conditions at impact extremes depend on the system set-up and the property you are trying to forecast
- Physically-based forecasts can be a powerful tool from days-seasons ahead
- Statistical forecasting methods and significant amounts of model calibration can increase the value of forecasts at longer lead-times.
- **Challenges:**
  - Impact chain – from climate data, to specific meteorological drivers of system behaviour, to impacts in complex power system models
  - Modelling hierarchy – to understand the full impact chain both simple and complex models are required
  - Incorporating large climate datasets into power system models
  - How to integrate forecasting into effective decision making?

Contact us:

For more information contact me: h.c.bloomfield@reading.ac.uk

and see:

- S2S4E https://s2s4e.eu/
- PRIMAVERA https://uip.primavera-h2020.eu
- Energy-met@Reading https://research.reading.ac.uk/met-energy/

Selected citations:

- Cannon, et al (2015) Using reanalysis data to quantify extreme wind power generation statistics : a 33 year case study in Great Britain. Renewable Energy, 75. pp. 767-778.
- Drew et al., (2019) Sunny Windy Sundays *Renewable Energy* 138, 870-875
- Bloomfield et al., (2018). The changing sensitivity of power systems to meteorological drivers: a case study of Great Britain. *Environmental Research Letters*, *13*(5), 054028.
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- Drew et al., (2017) The importance of forecasting regional wind power ramping: A case study for the UK *Renewable energy* 114, 1201-1208