S2S4E
Climate Services for Clean Energy

Understanding and forecasting the subseasonal meteorological drivers of the European electricity system in winter

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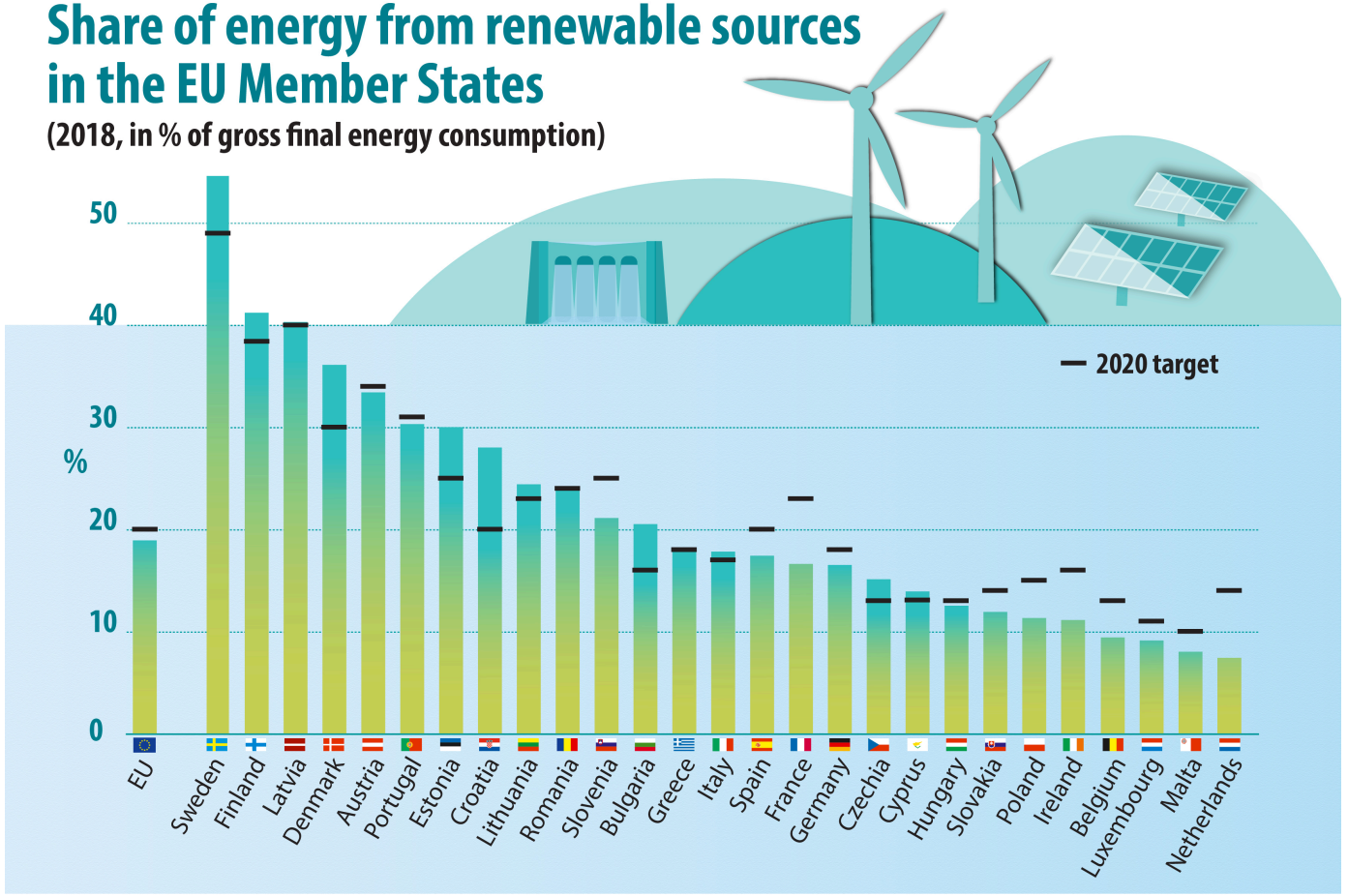
Motivation

- Renewable electricity is a key enabling step to decarbonising the energy sector.
- Europe is at the forefront of renewable deployment.
- More renewable energy generation means that the power systems are becoming increasingly sensitive to weather.
- It is becoming increasingly important to understand the meteorological drivers of energy system behaviour.
- There is therefore an increasing need for accurate weather forecasts within the energy sector.



ec.europa.eu/eurostat

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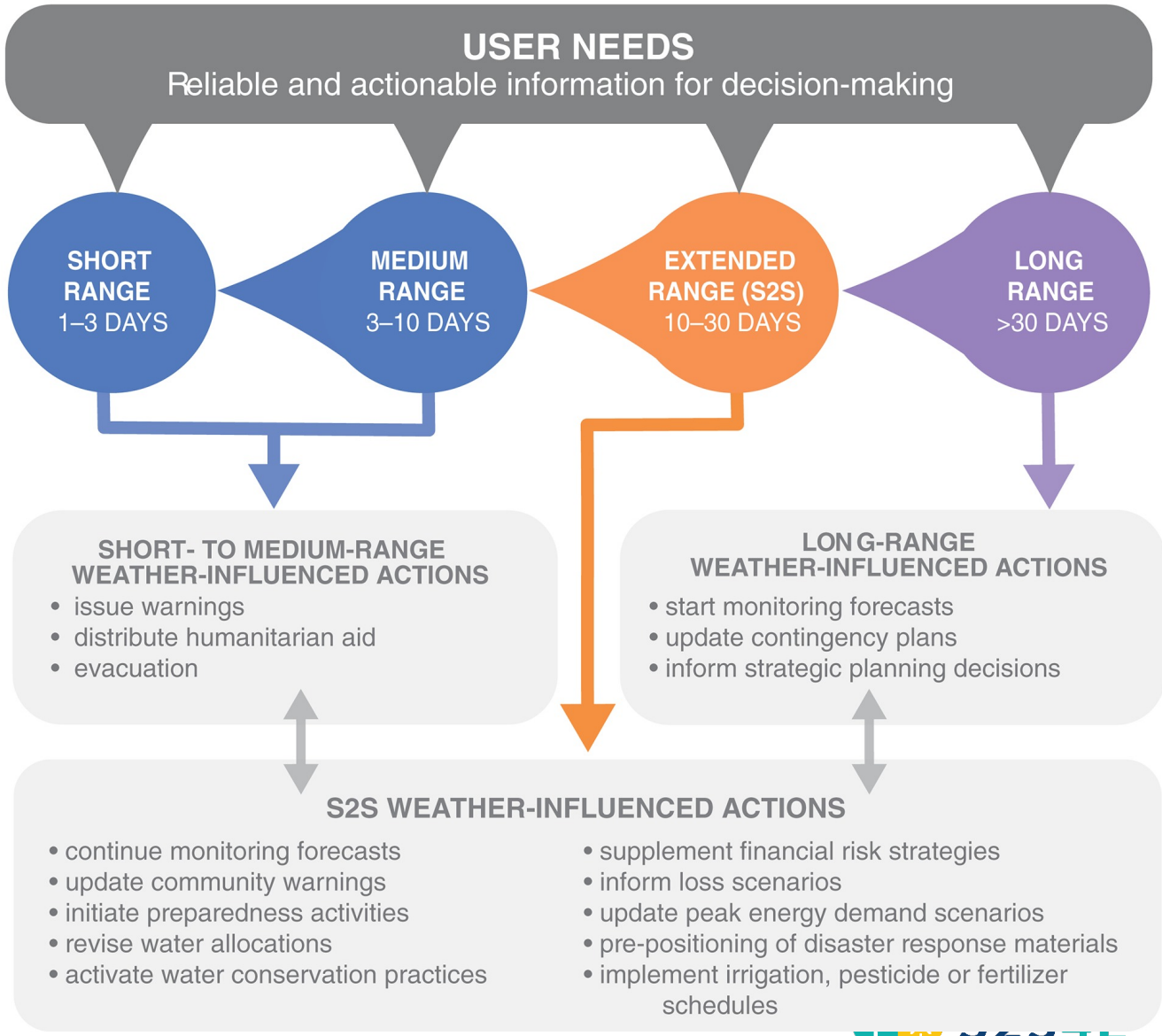
Source: https://ec.europa.eu/eurostat/statistics-explained/index.php/Renewable_energy_statistics

Motivation

- Climate information on sub-seasonal (S2S) timescales is needed for decision making.
- Grid point forecasts have limited skill at lead times greater than 1 week.
- Therefore in the energy industry sub-seasonal forecasts have had limited use.
- Using S2S forecasts within the energy sector could help address:
  - wind power intermittency
  - Hedging for peak demands
  - Grid operation optimisation of energy prices
  - Nuclear power maintenance schedules



White et al, (2017)

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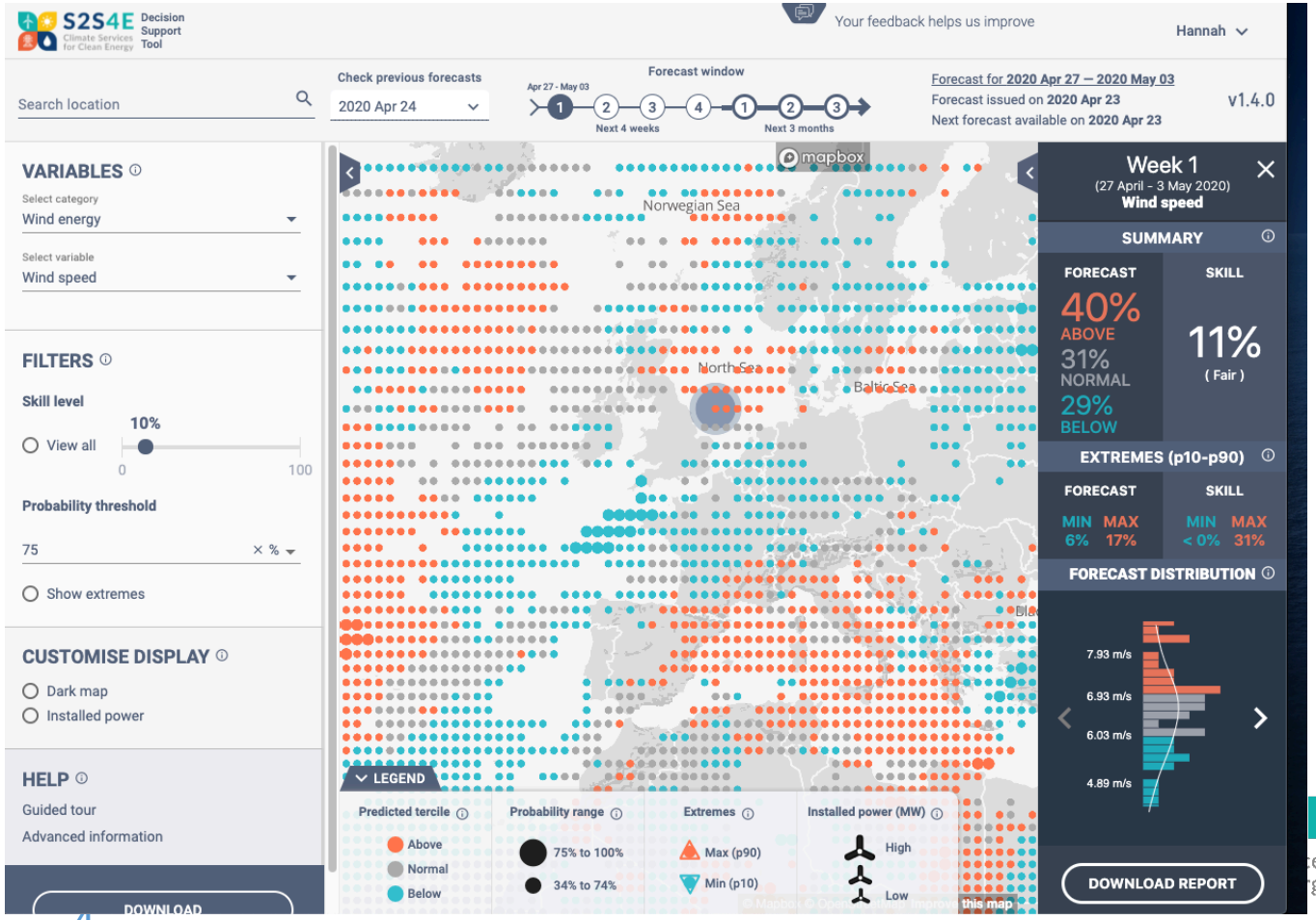
Motivation

- The S2S4E project has developed a **decision support tool** to aid industry engagement with operational sub-seasonal forecasts. And demonstrate the country-level and grid point level skill present in weeks 1-4 and months 1-3
- The demonstrator focuses on displaying grid point forecast skill.
- However, there may be more energy-relevant skill available if **pattern-based methods** are used to relate skill in large-scale features to what is happening on the ground.



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A new method of understanding energy system variability

- This study presents a new and generally applicable approach: **Targeted Circulation Types** (TCTs).
- In contrast to standard meteorological circulation types (e.g. weather regimes), TCTs convolve the weather sensitivity of an impacted system (e.g. the power system) with atmospheric structures to identify the meteorological drivers.
- TCTs provide greater explanatory power for power system variability and extremes compared with standard meteorological typing such as weather regimes.
- To complete this work a new 38 year ERA5 reanalysis-based reconstruction of daily electricity demand, wind power and solar power generation across Europe is used to identify the winter large−scale circulation patterns of most interest to the European electricity grid.
- This dataset is freely available for use here: http://dx.doi.org/10.17864/1947.227

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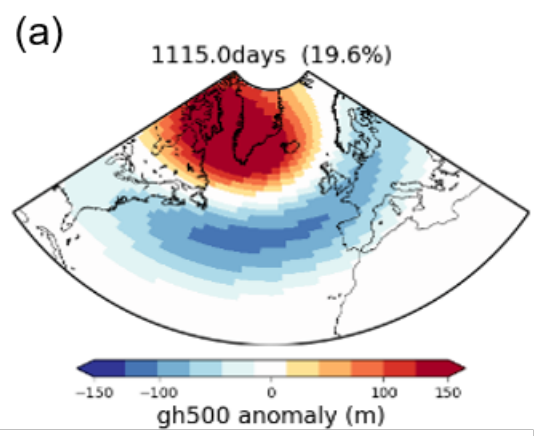
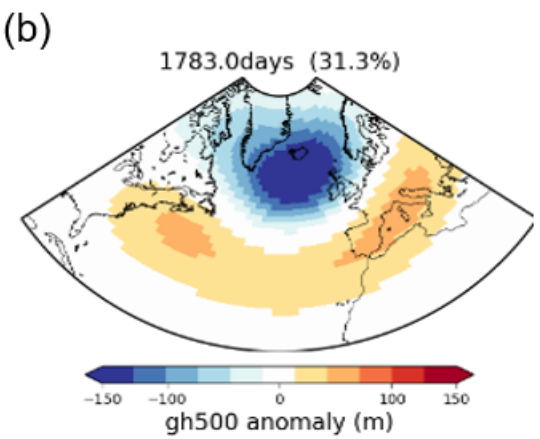
A recap of traditional weather regimes

- Weather regimes are used in this study as a comparison to TCT's.
- They are Large Scale recurrent, persistent circulation patterns.
- Defined by k-means clustering algorithm, which puts daily maps of a large scale field into a regime.
- Nov-Mar Euro-Atlantic variability can be described by four regimes:

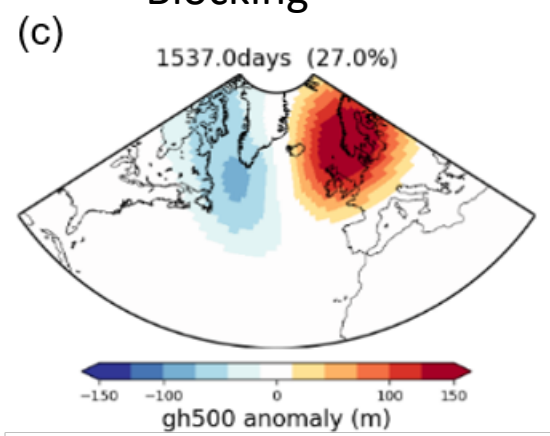
NAO-



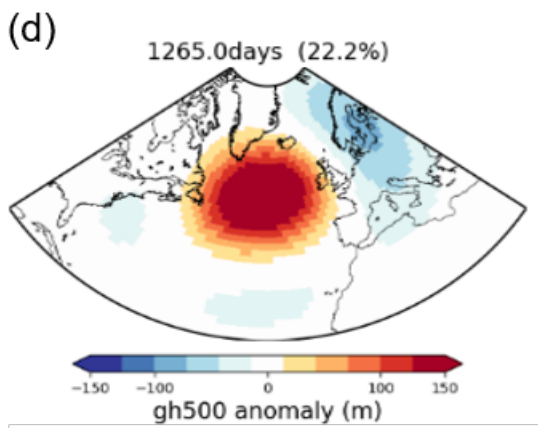
NAO+



Scandinavian Blocking



Atlantic Ridge



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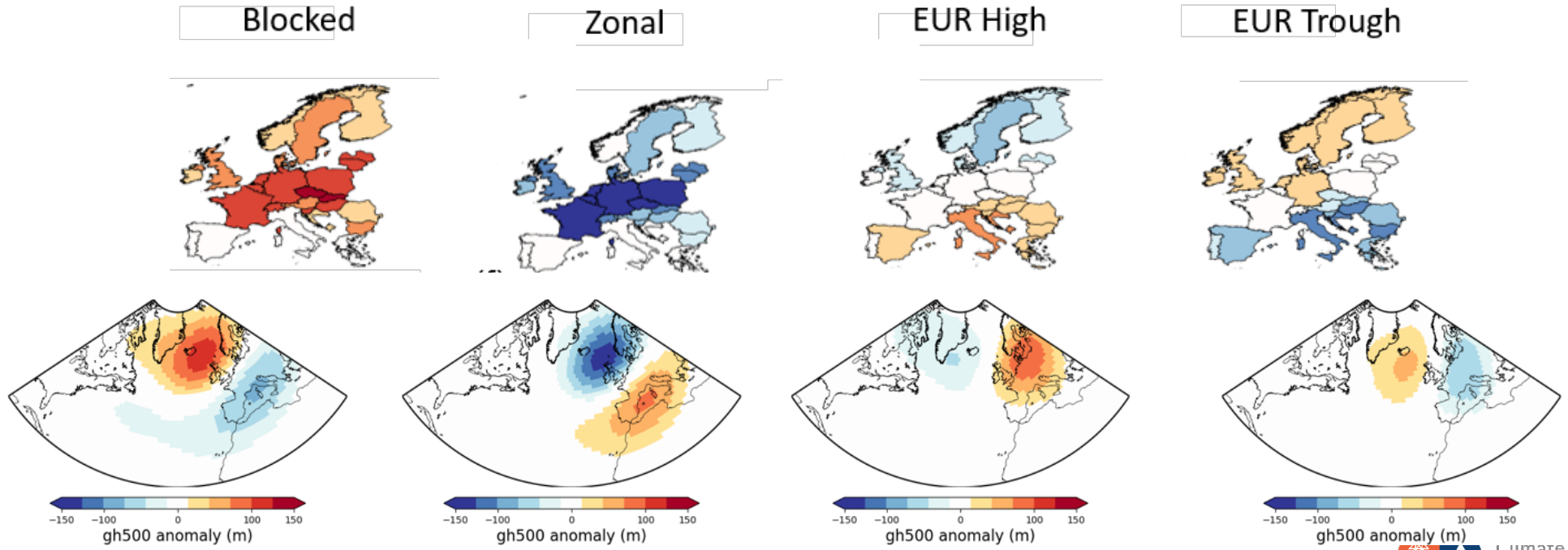
Generated using the method of Cassou (2008)

Targeted Circulation Types

- Rather than clustering on a large scale field, the TCTs cluster based on the normalised surface energy data (28 countries across Europe) to get a set of four recurring patterns. This could be demand, wind power generation, demand-net-renewables etc.
- To take advantage of the potentially increased skill in forecasting the large scale flow we find the mean 500hPa geopotential height anomalies during each of these patterns and use these when investigating the TCT pattern skill in later analysis.
- Defined for Nov-Mar using the ERA5 re-analysis (1980-2018)

ERA5 TCT patterns for demand

Mean Z500 anomaly during each TCT



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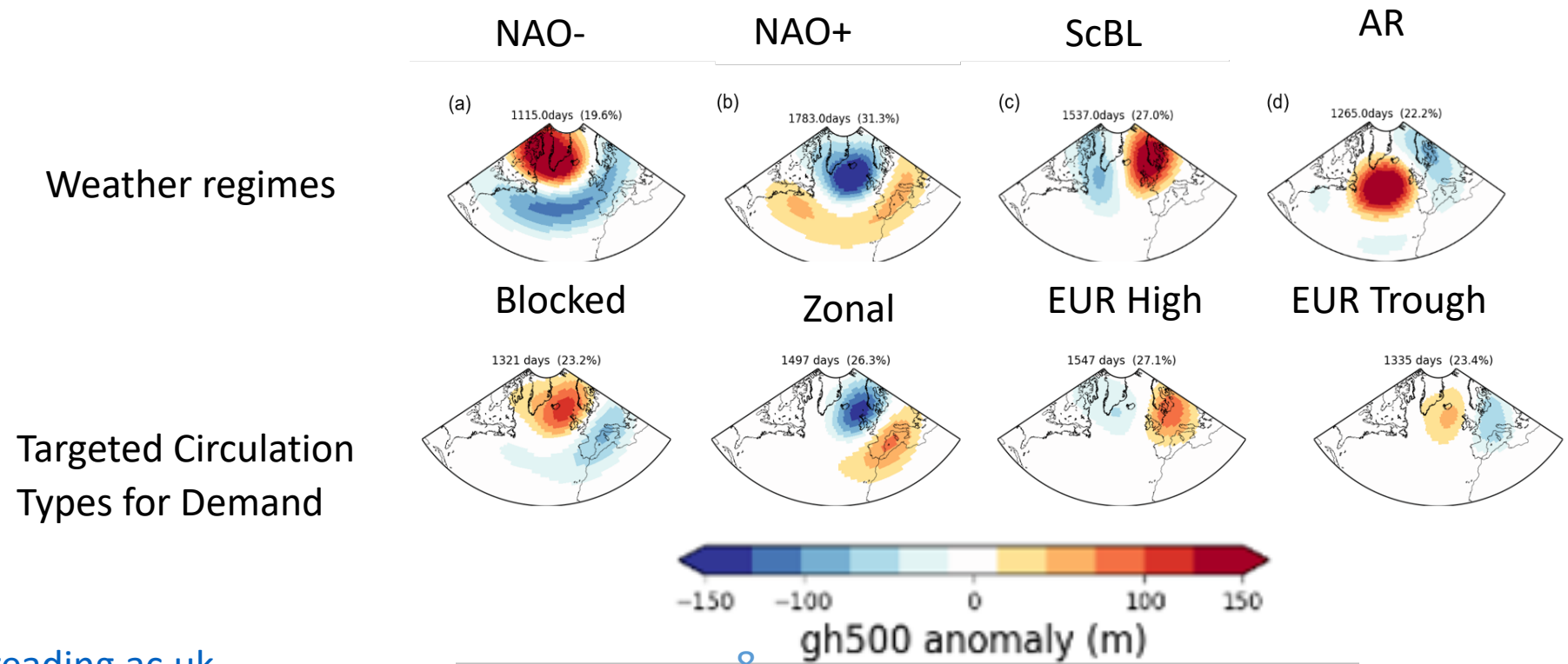
Bloomfield et al., 2020

How do the two sets of patterns compare?

- The Blocked and Zonal patterns resemble the meridional dipole structure of the NAO, but shifted eastward into Europe, while the second pair is weaker and corresponds to surface pressure anomalies over Central Southern and Eastern Europe.
- When the patterns are assigned there are sets of patterns that are comparable (the NAO-WR and Blocked TCT) but some patterns are very different (e.g. no TCT resembles the Atlantic Ridge.



Bloomfield et al., 20

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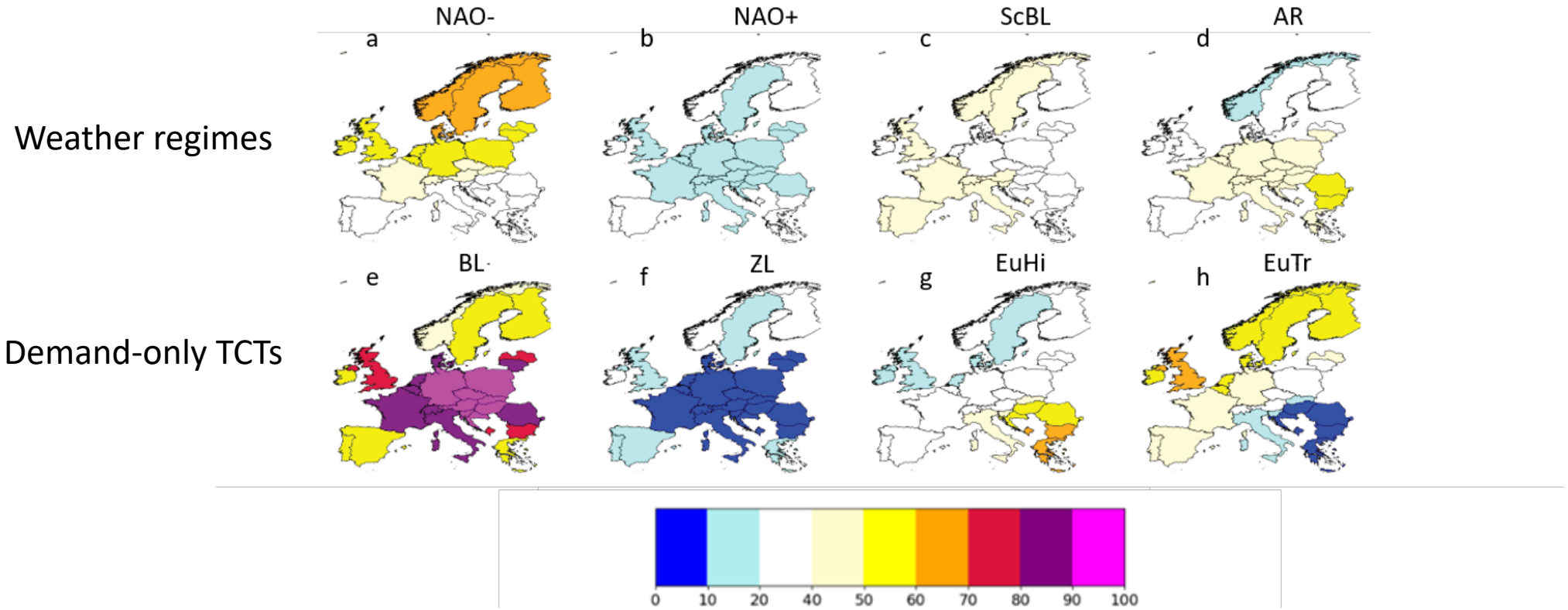
Why Might TCT's be more useful for energy users?

- The detailed structure of the TCT is strongly impacted by the location of installed renewables or level of demand used to construct the patterns.
- If the TCT's could be perfectly predicted they would be useful as they have much stronger surface signatures with the country level energy data than the traditional weather regimes.



Probability of Demand being in the upper tercile during each pattern

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Bloomfield et al., 2020

But are the TCT patterns predictable?

- Although the TCT patterns provide a more direct comparison to European power system operation, this does not necessarily mean these patterns are as predictable as those derived from more traditional meteorological techniques (e.g., weather regimes).
- The predictability of the TCT patterns is assessed using the ECMWF (1996-2016) and NCEP (1999-2010) extended range hindcasts from the S2S database. This is compared to the weather regimes, and grid point forecast skill.
- The dataset of country-level demand and wind power generation created from these hindcasts is available upon request (and soon to be published!)

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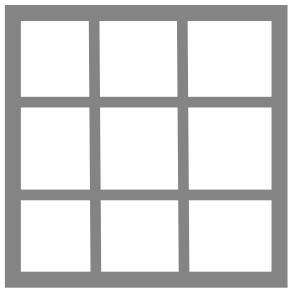
Three methods of forecasting demand

Grid point forecasts

Gridded daily T2m ens member

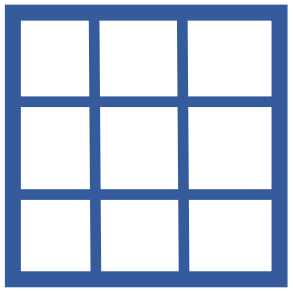


Demand model

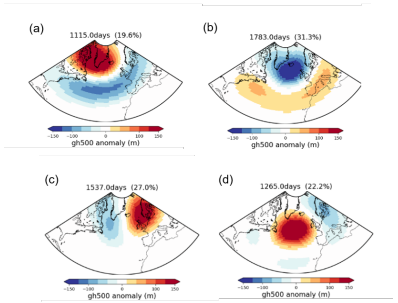
Country scale demand

Weather Regimes

Gridded daily Z500 ens member



Assign PC's of Z500 to a weather regime

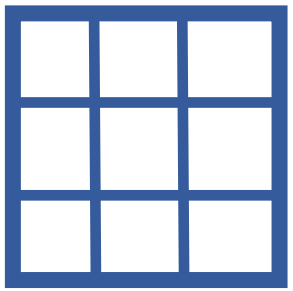


The mean demand from the chosen regime (defined in ERA5) is the daily forecast for that ens member

Country scale demand

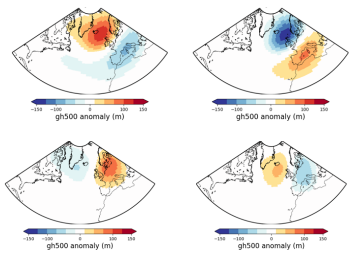
Targeted Circulation Types

Gridded daily Z500 ens member

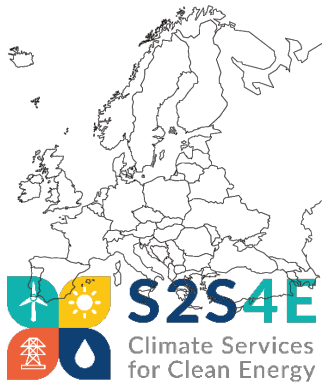


Assign PC's of Z500 to a TCT pattern

Z500 used to make use of large scale predictability



The mean demand from the chosen TCT (defined in ERA5) is the daily forecast for that ens member



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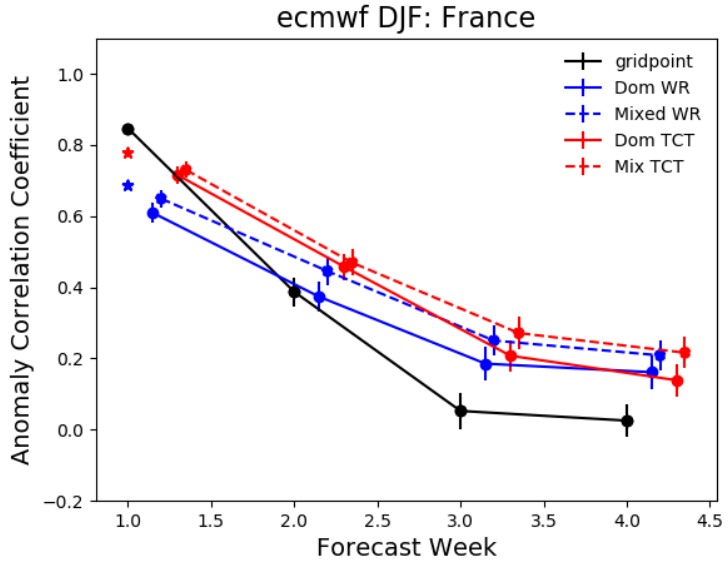
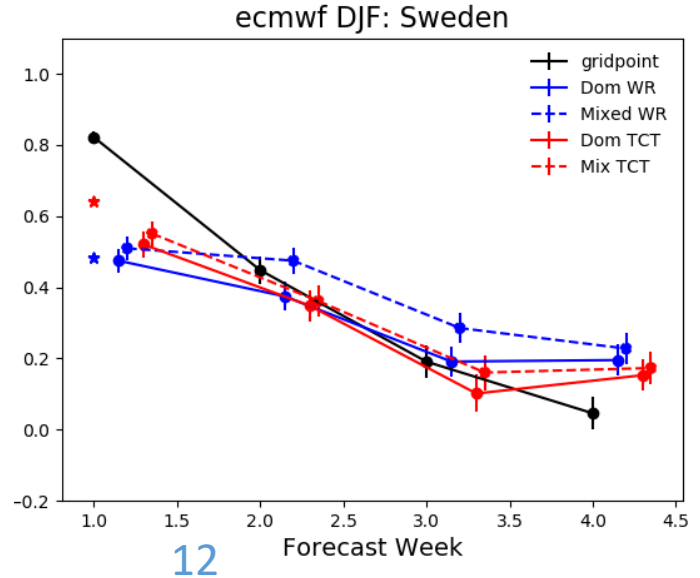
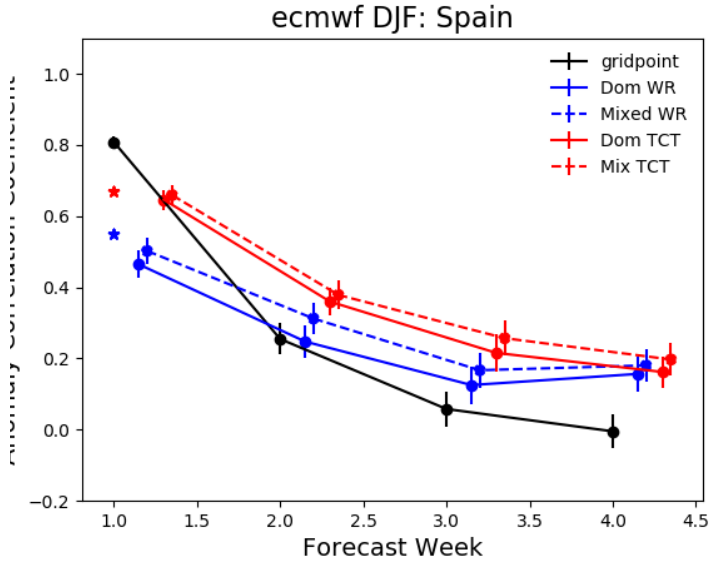
Sub-seasonal predictability of Country-level demand

- The predictability of the weekly-mean grid point forecast (black) is compared with weekly-mean forecasts created using weather regimes (blue) or TCTs (red).
- Two methods of pattern forecast are used: Dominant (when the modal regime each week is chosen) and Mixed (when the weighted average of all days patterns are used).
- The pattern based methods show the potential to provide more skill than the grid point forecasts in weeks 2-4.
- The focus here is energy demand, similar results are seen for other energy variables (e.g. demand-net-wind)







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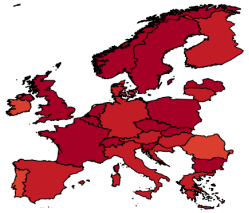
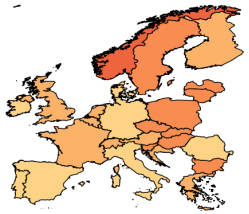
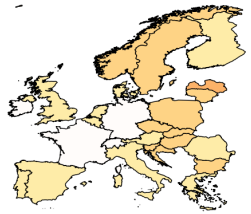
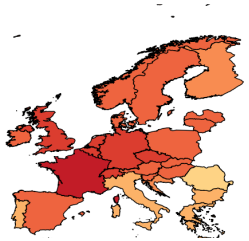
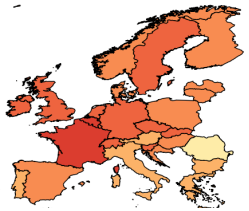
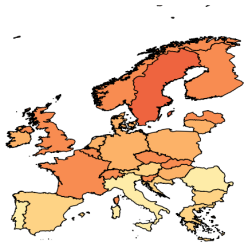
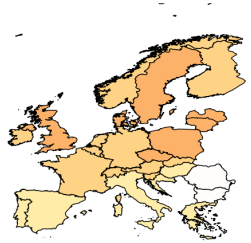
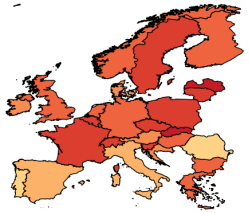
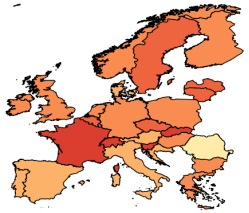
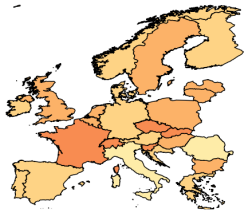
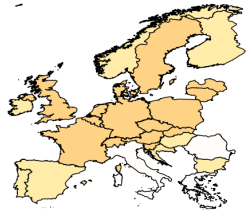
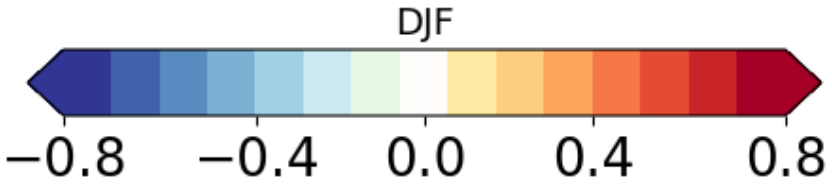
Sub-seasonal predictability of Country-level demand

	Perfect forecast (use ERA5 pattern)	ECMWF Week 1 (days 5-11)	ECMWF Week 2 (days 12-18)	ECMWF Week 3 (days 19-25)
Grid point forecast				
Weather regime based forecast				
Similar				
TCT based forecast				



- Pattern based skill in week 1 is close to “perfect” forecast skill
- This is however still much less than grid point skill, so methods need refining.
- Northern and Eastern Europe have highest forecast skill
- Similar results are seen for NCEP (not shown)

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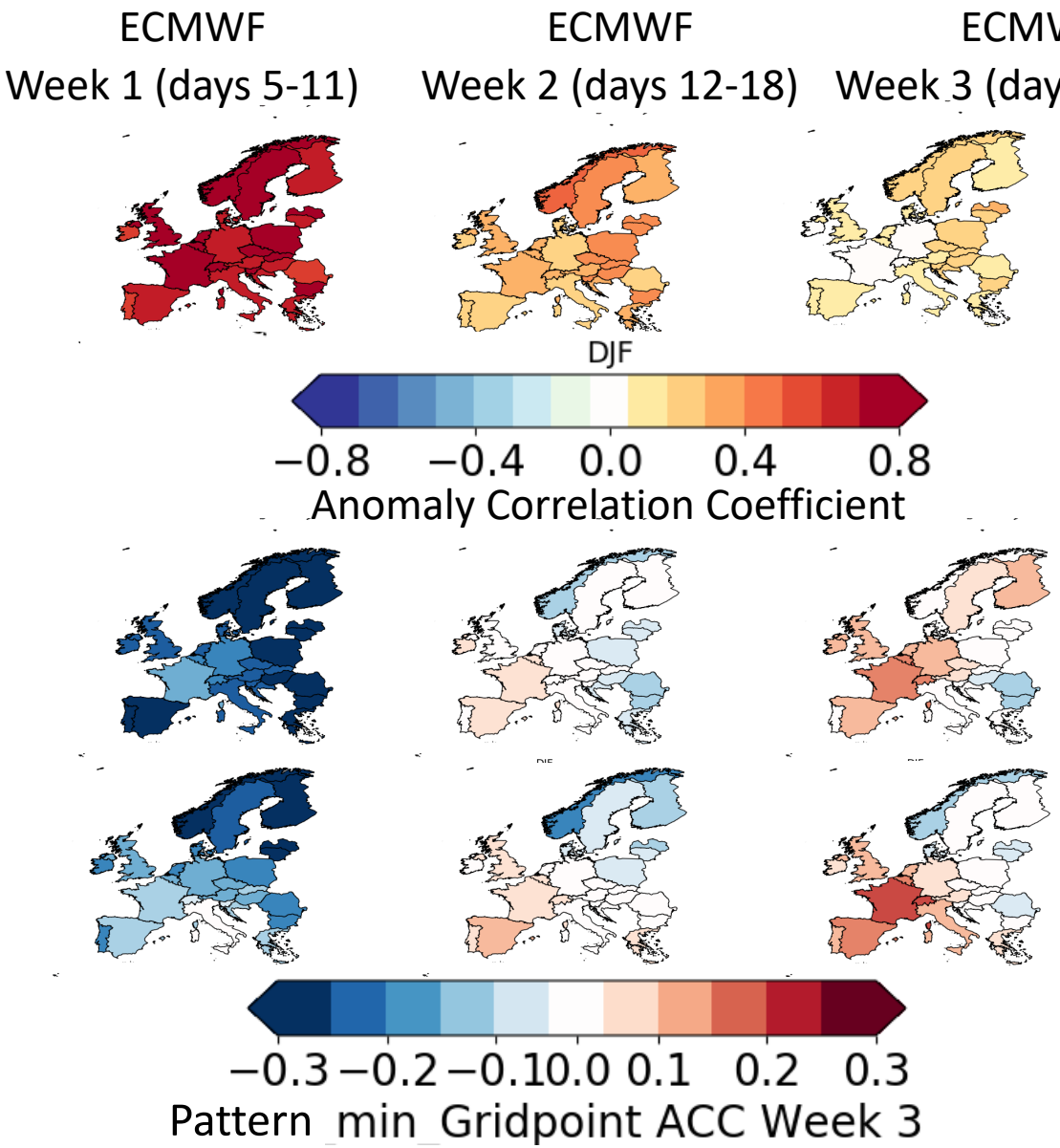
Sub-seasonal predictability of Country-level demand



- Red (blue) colours mean WR/TCT method is more (less) skilful than grid point forecast
- Notably more skill in grid point forecast in Northern and Eastern Europe.
- WR/TCT's perform best in SE Europe
- Similar results are seen for NCEP and demand-net-wind (not shown)

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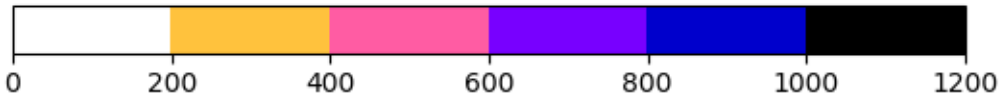
Ongoing Challenges

- The TCT patterns are defined based on **surface** energy data (e.g. 28 countries demand). However in the hindcasts we assign each day to a pattern based on the **500hPa geopotential height** data, in order to take advantage of the fields large scale predicability demonstrated in previous studies.
- This creates a problem, as the assignment at Z500 is not the same as at the surface (see hit rate table to right) within ERA5
- Ongoing work is looking at improving this hit rate using fields such as 850hPa temperature (~65% hit rate) 2m Temperature (~85% hit rate).
- However, this increased pattern assignment hit rate may lead to a trade off in predicability of the field.

TCTs classified from Z500 PC's

TCTs classified from surface energy data

	0	1	2	3
0	693	76	303	415
1	51	1009	290	199
2	337	223	810	323
3	240	189	144	398



53.0% success ratio

Needs improvement!

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Summary

- **Targeted Circulation Types** are a novel pattern based method that can be used to provide information about the meteorological drivers of energy system behaviour.
- **A 38 year dataset** of European country-level demand wind and solar generation from ERA5 has been published. A corresponding hindcast set is also available on request.
- **Grid-point sub seasonal forecasts** are able to provide a surprising amount of useful information for the energy sector out to 4 weeks lead time (see S2S4E website for more information)
- **Pattern based methods** have a modest amount of skill in week 1, with more skill seen in the grid point forecasts. At longer lead times then improvements in skill are seen compared to grid point forecasts.
- **Further improvements** in skill may be seen with refinement of the method (mainly associated with the pattern assignment)

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Thanks for taking the time to read this.
If you have any questions or suggestions please get in touch!

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