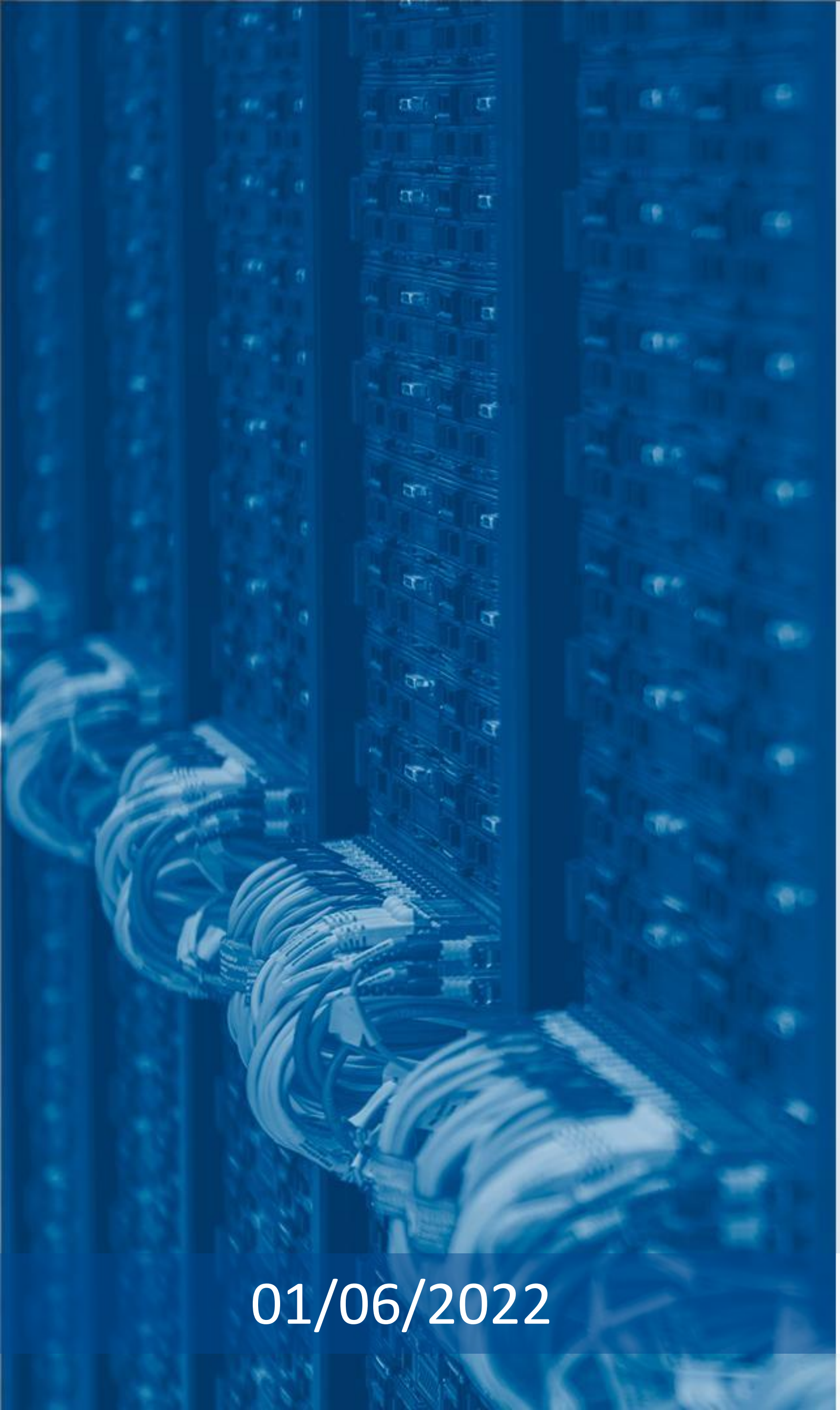

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Climate services prototypes for the renewable energy sector

Albert Soret, Lluís Palma, Jaume Ramon
Barcelona Supercomputing Center

01/06/2022

Mediterranean Climate Outlook Forum

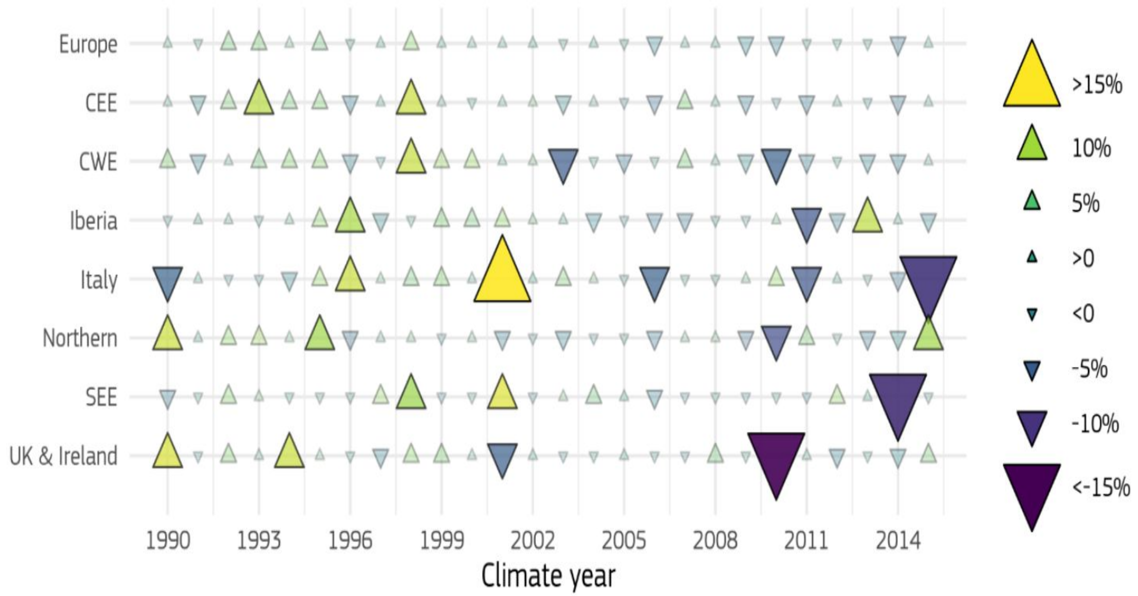
Outline

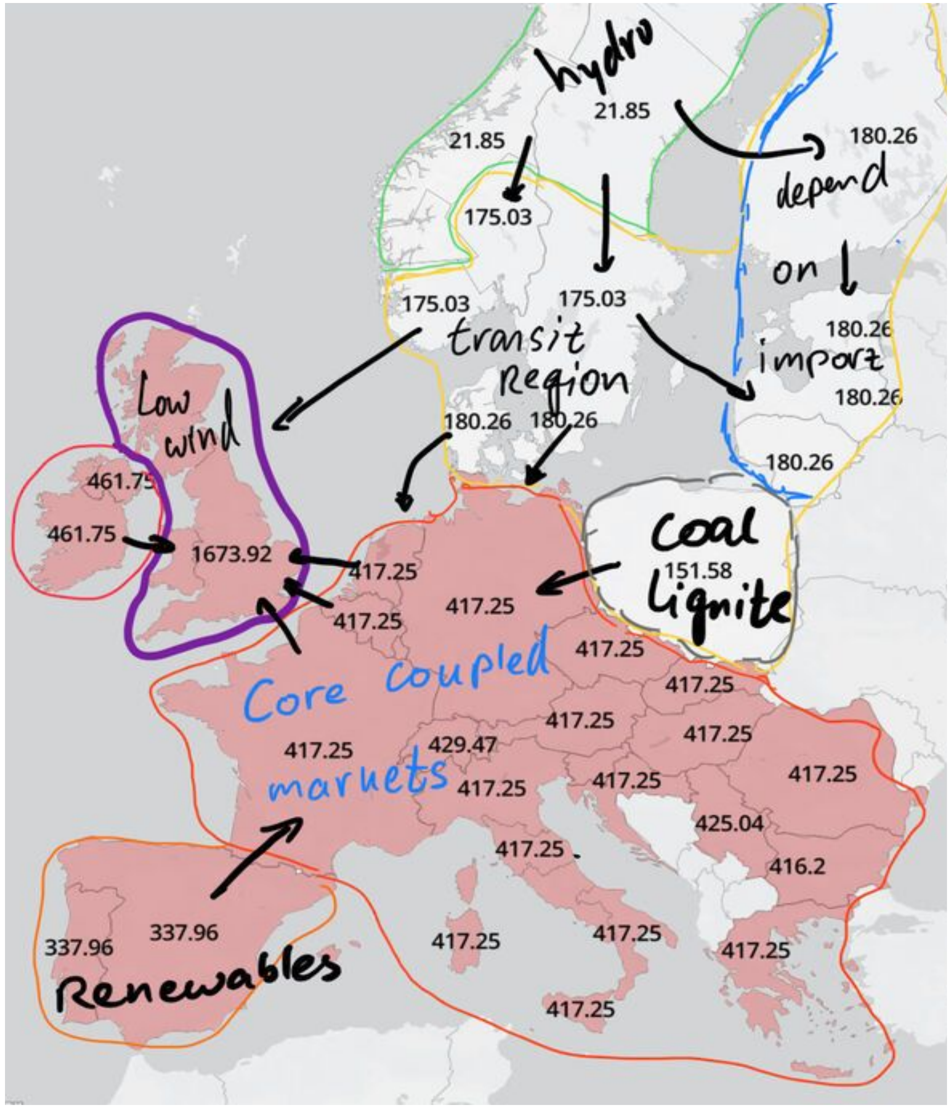
- Introduction to climate services and energy
- Challenges and opportunities
- Climate research, tailored for the wind energy sector
- Introduction to the DST of S2S4E
- Lessons learned from the implementation
- Case study. Filomena event.
- Next steps

Renewable energy and climate

- EU Green Deal: EU is required to fulfil at least 40% of its total energy generation with renewables by 2030.

- Both energy supply and demand are strongly influenced by atmospheric conditions and their evolution over time in terms of climate variability and climate change.





(Left) Annual variability (percentage of deviation from the average) on onshore wind resources in the 26 climate years for the considered regions (source: JRC 2020).
(Right) Day ahead prices for 16/12/2021. Large differences across the continent, with a core region around €420. UK prices are the highest in Europe due to low wind energy production, while Iberian system prices are the lowest due to high wind resources (source: EnAppSys).

European Union

EU plans 'massive' increase in green energy to help end reliance on Russia

European Commission says extra €210bn needed over next five years to pay for phasing out of Russian fossil fuels

Jennifer Rankin *in Brussels*
Wed 18 May 2022 14.24 BST

The European Commission said 45% of the EU's energy mix should come from renewables by 2030. Photograph: Pascal Rossignol/Reuters

Context and motivation

- The energy sector routinely uses weather forecast up to several days.
- But beyond this time horizon, past climatological records are used to estimate risks.

Met mast on Gwynt y Môr offshore wind farm (source: solar wheel)

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Climate services. Applications

Weather forecast	Climate predictions: Sub-seasonal	Climate predictions: Seasonal	Decadal	Climate projections or multidecadal
1-15 days	10 d-1 month	1-6 months	1-30 years	20-100 years

Time

Applications for wind/solar/hydro generation

Post-construction decisions

Energy producers: commit energy sales for next day

Grid operators: Market prices and grid balance

Energy traders: Anticipate energy prices

Plant operators: planning for cleaning and maintenance

Post-construction decisions

Energy producers: Resource management strategies

Energy traders: Resource effects on markets

Plant operators: Planning for maintenance works, especially offshore wind O&M

Plant investors: anticipate cash flow, optimize return on investments

Pre-construction decisions

Power plant developers: Site selection. Future risks assessment.

Investors: Evaluate return on investments

Policy-makers: Asses changes to energy mix

River-basin managers: understand changes to better manage the river flow

Applications for demand

Daily operation decisions

Grid operators:

Anticipate hot/cold days. Schedule power plants to reinforce supply.

Energy traders: Anticipate energy prices.

Mid-term planning

Grid operators:

Anticipate hotter/colder seasons Schedule power plants to reinforce supply.

Energy traders:

Anticipate energy prices.

Long-term planning

Grid operators:

Anticipate addition of more capacity. Adaptation of transmission lines

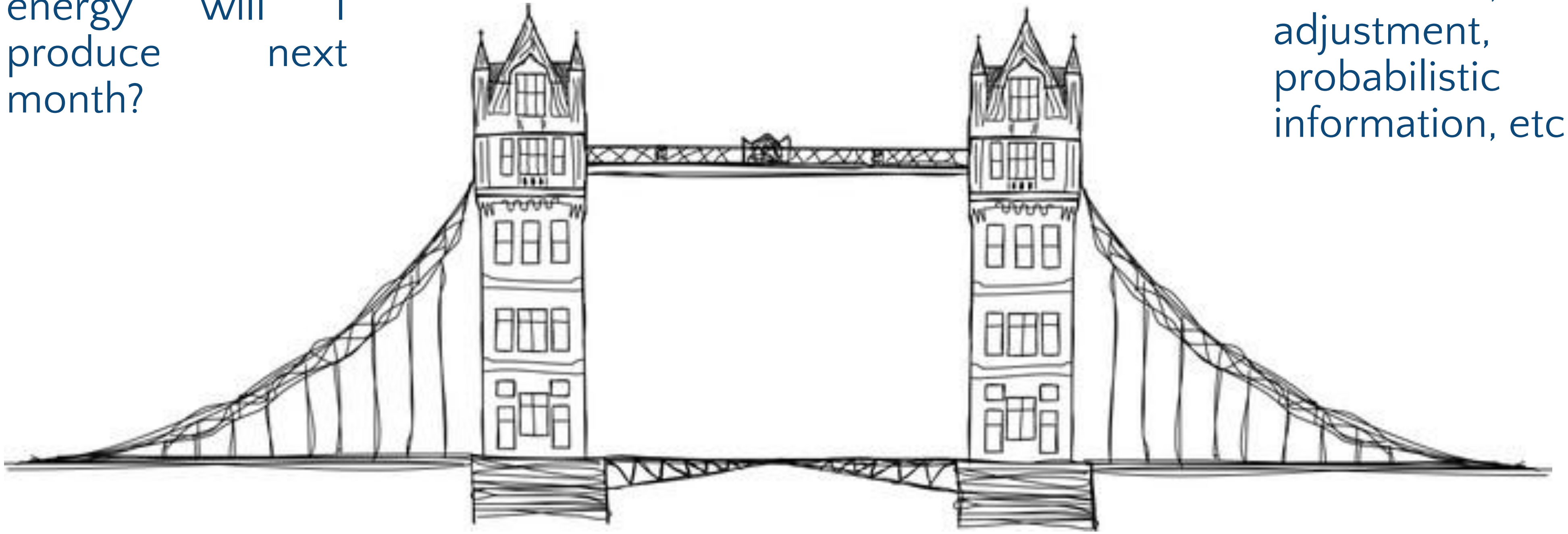
Policy-makers:

Plan addition of more capacity. Understand changes to energy mix

Challenges and opportunities

Climate services

- User: How much energy will I produce next month?



- Scientist: Skill assessment, bias adjustment, probabilistic information, etc.

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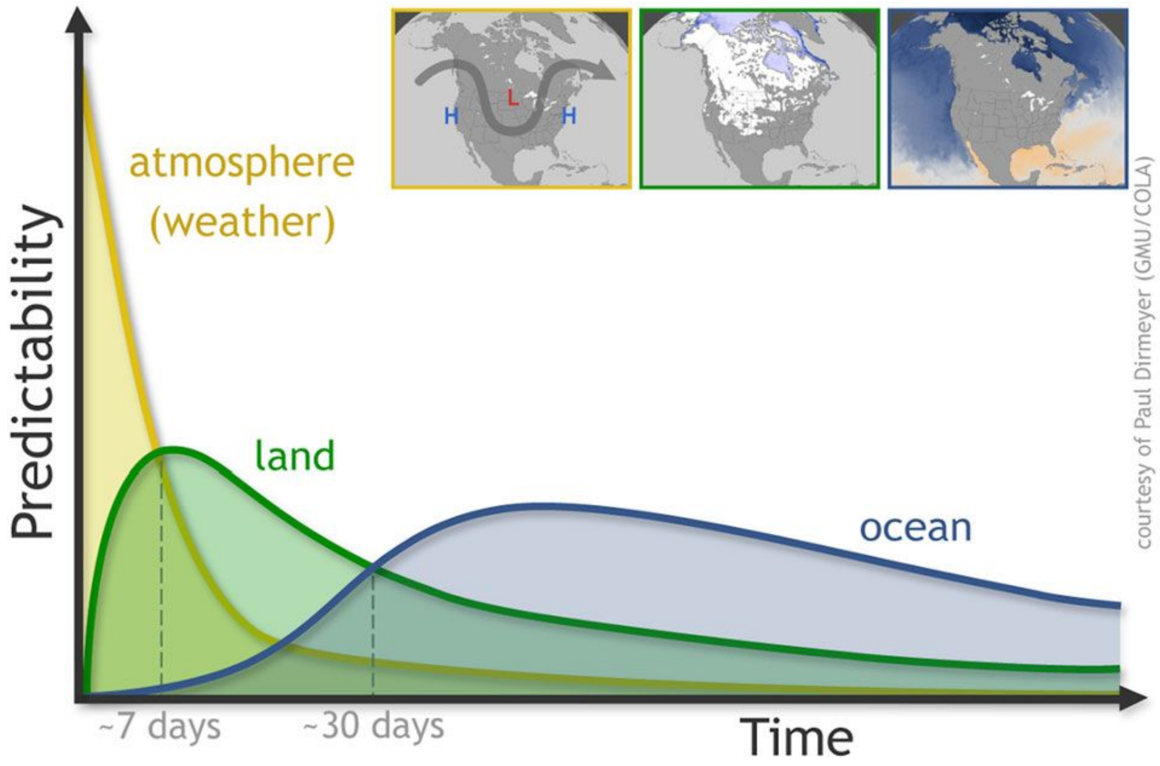
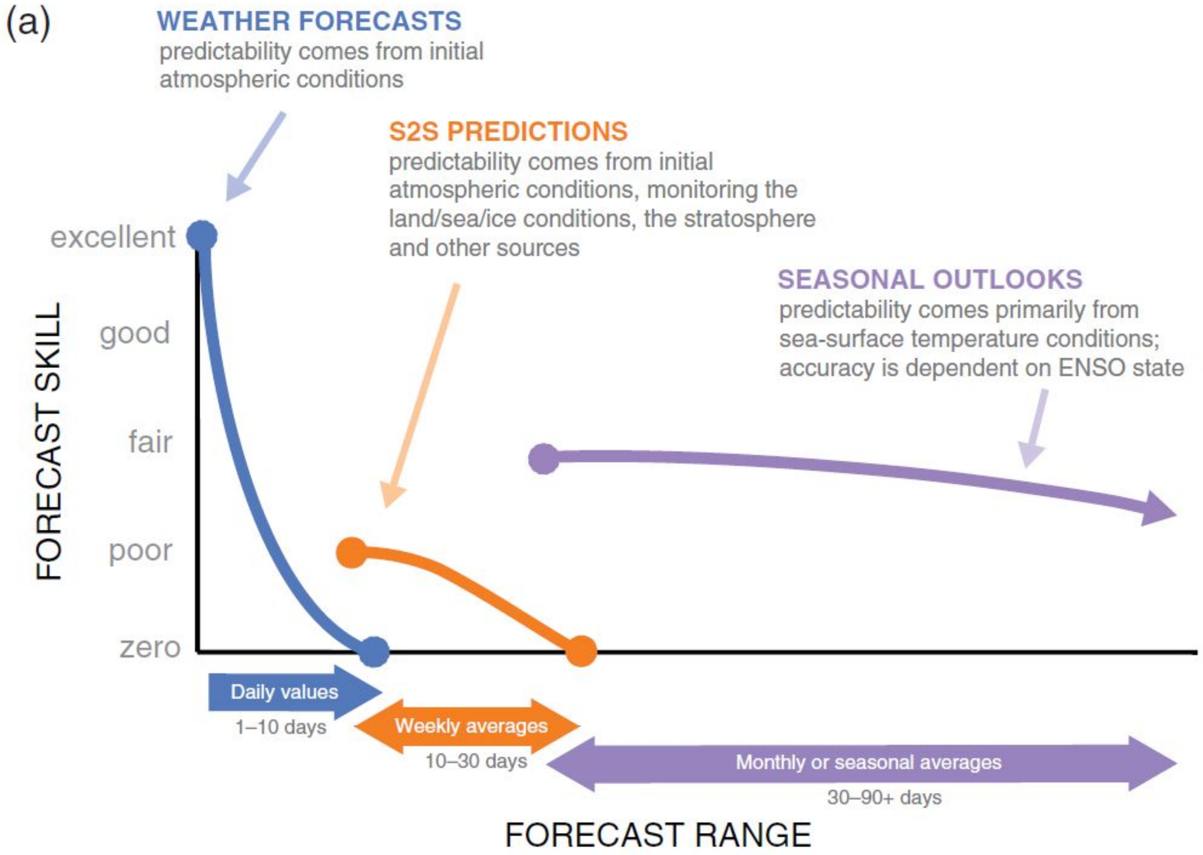
S2S forecasts ranges and skill

- Predictability sources:



(Source: Mariotti et al. 2018)

- Skill estimates:



(Source: White et al., 2017)

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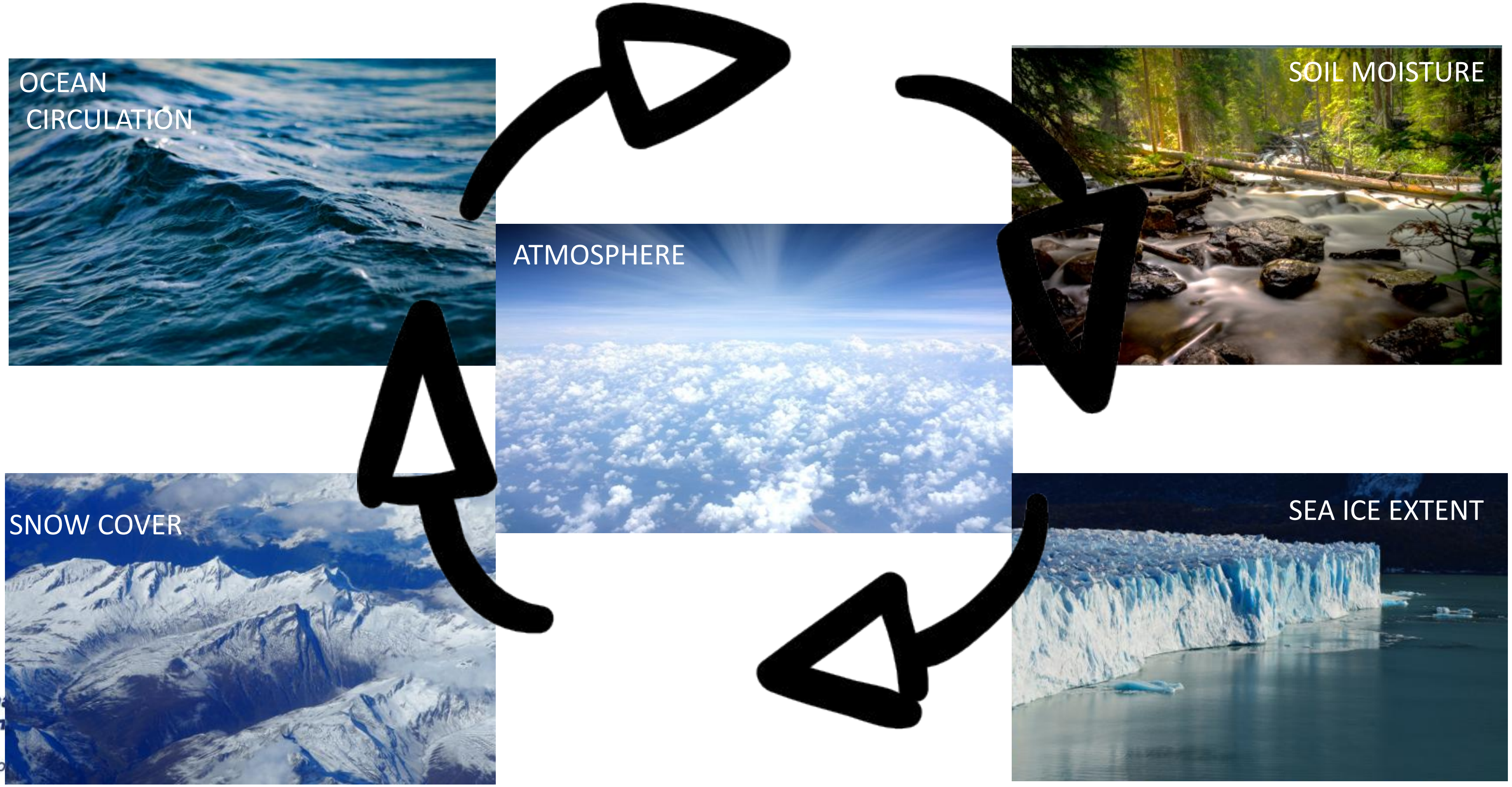
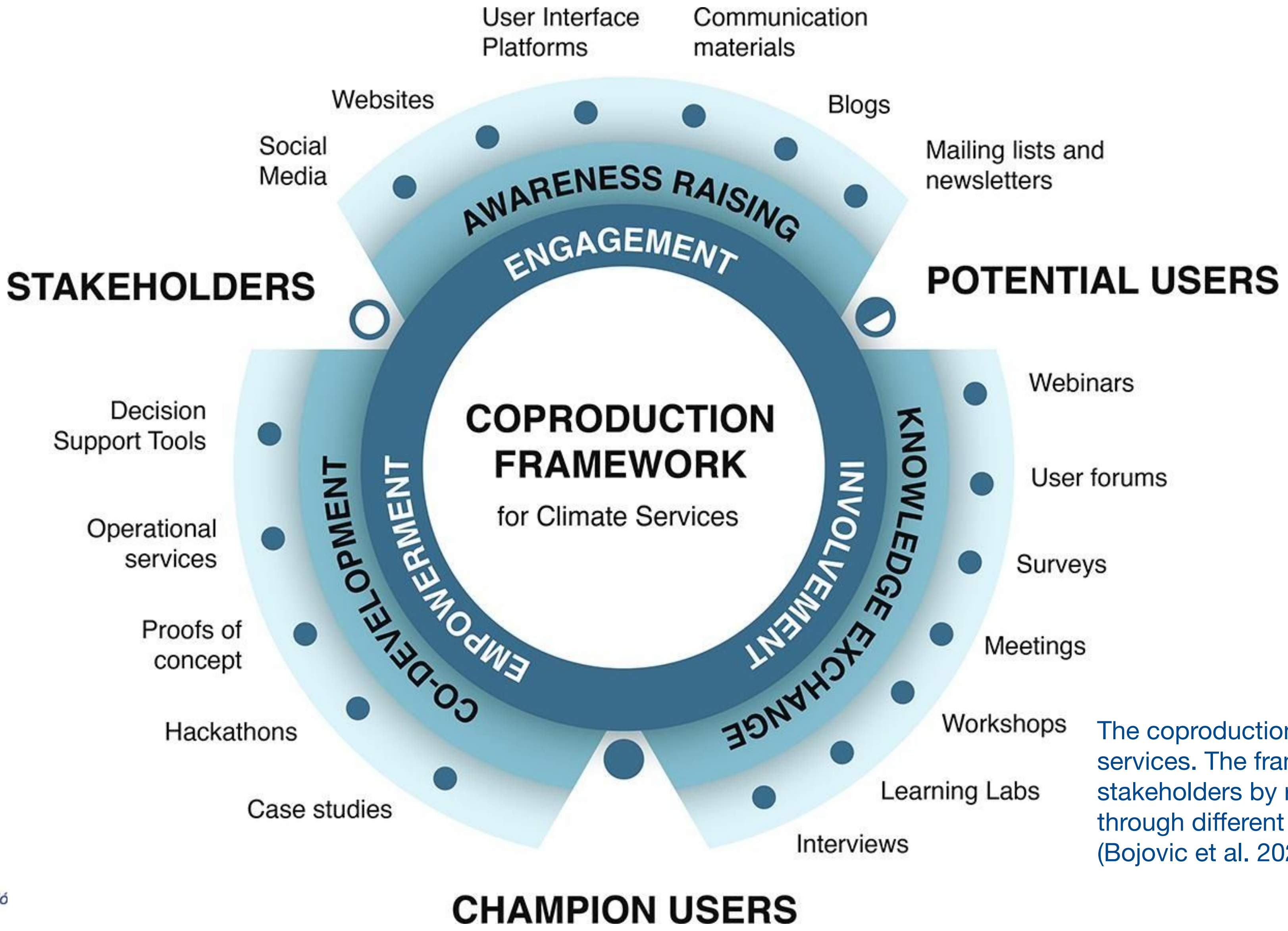
Predictability. Skill

- How can we predict climate for the coming season if we cannot predict the weather next week? Slow components (sea surface temperature, soil moisture, etc.) force the atmosphere.

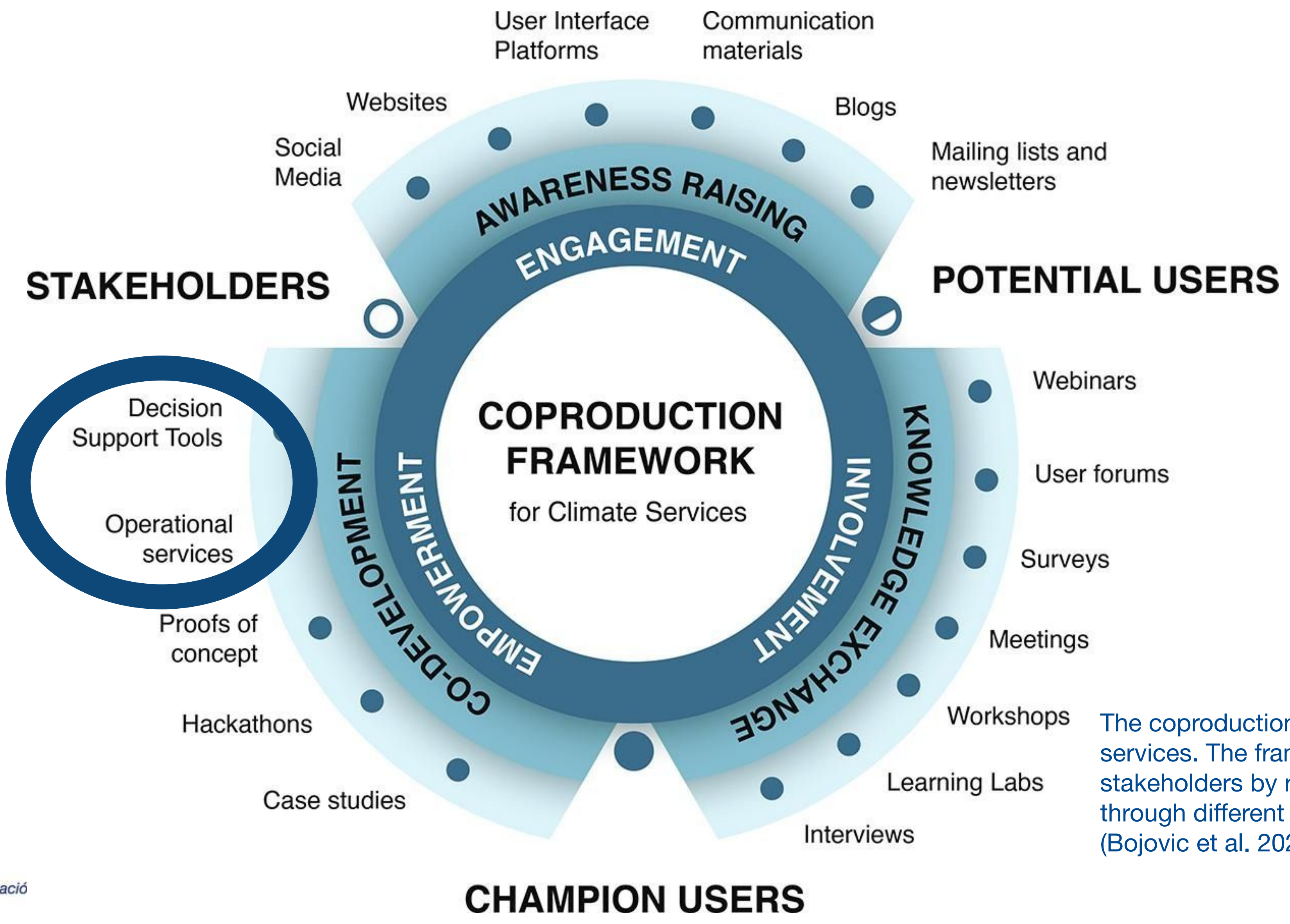


Co-production



The coproduction framework for climate services. The framework engages stakeholders by raising awareness through different communication tools. (Bojovic et al. 2021)

Co-production



The coproduction framework for climate services. The framework engages stakeholders by raising awareness through different communication tools. (Bojovic et al. 2021)

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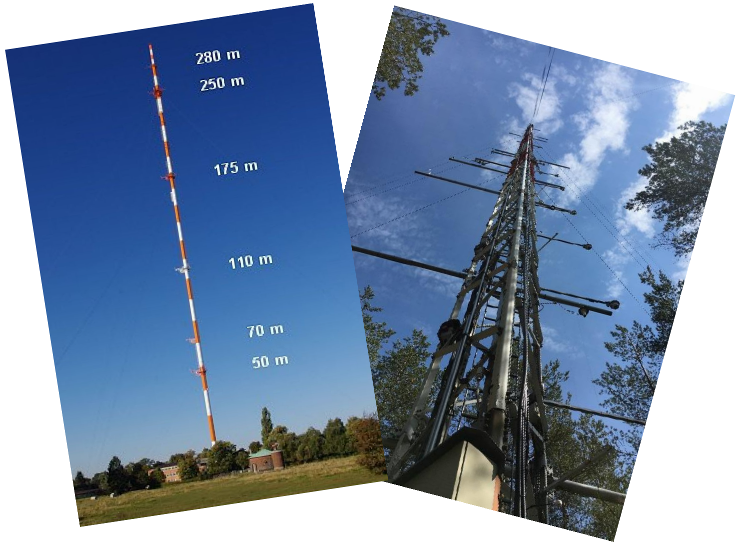
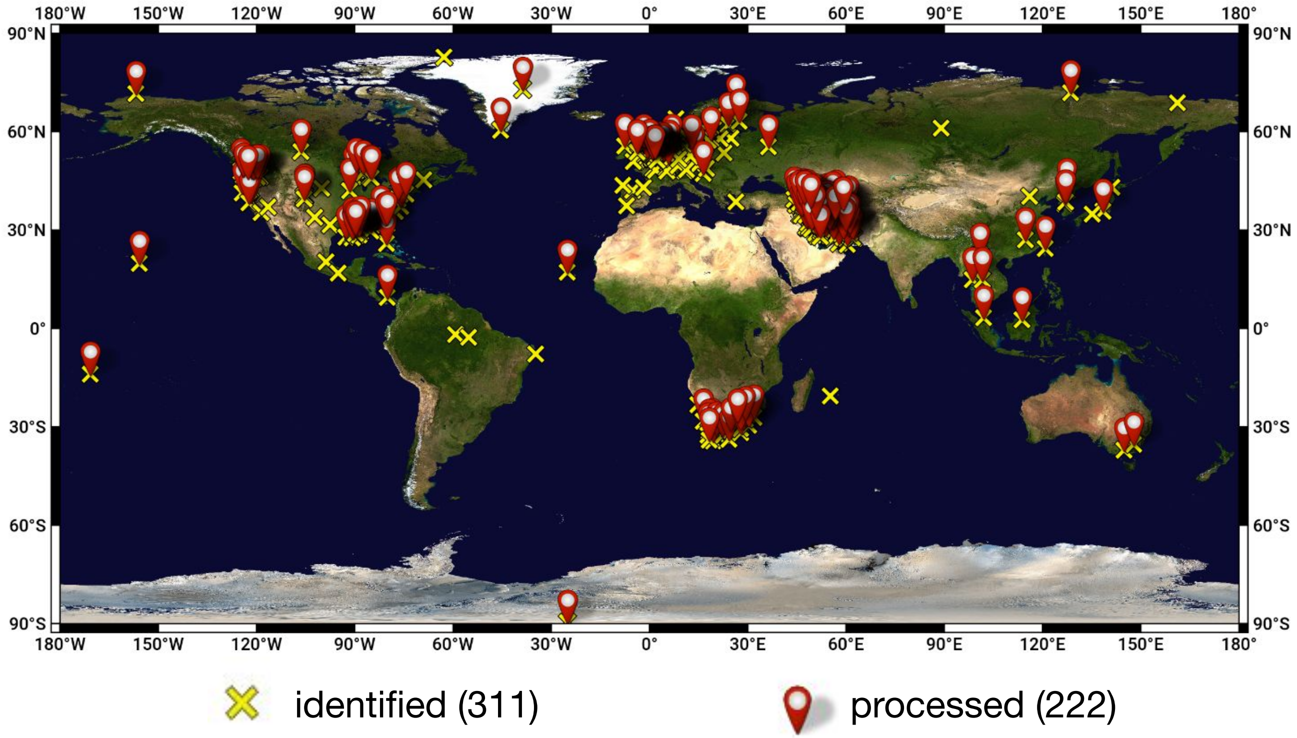
Climate research tailored for the renewable energy sector

Creation of a dataset

- Wind data from **tall towers** are a valuable source of information for many climatic analyses: e.g. climate data verification, wind resource assessment.
- These data has been traditionally **difficult** to **find** and **access**, i.e., stored in sparse datasets.

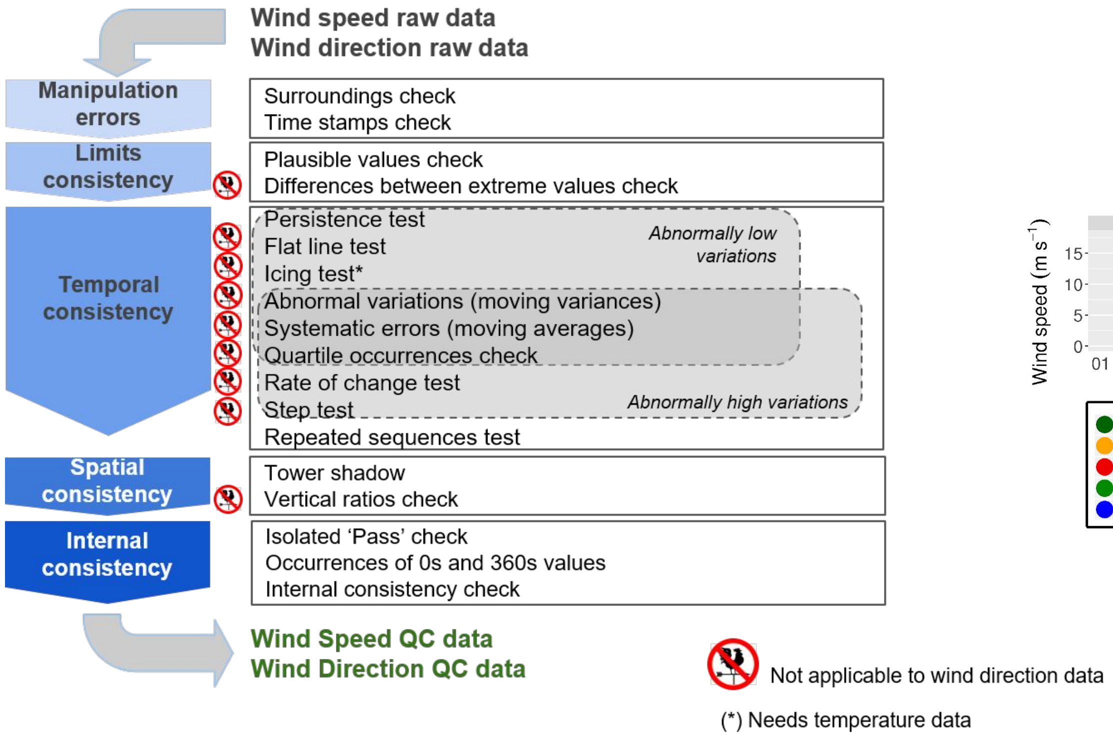


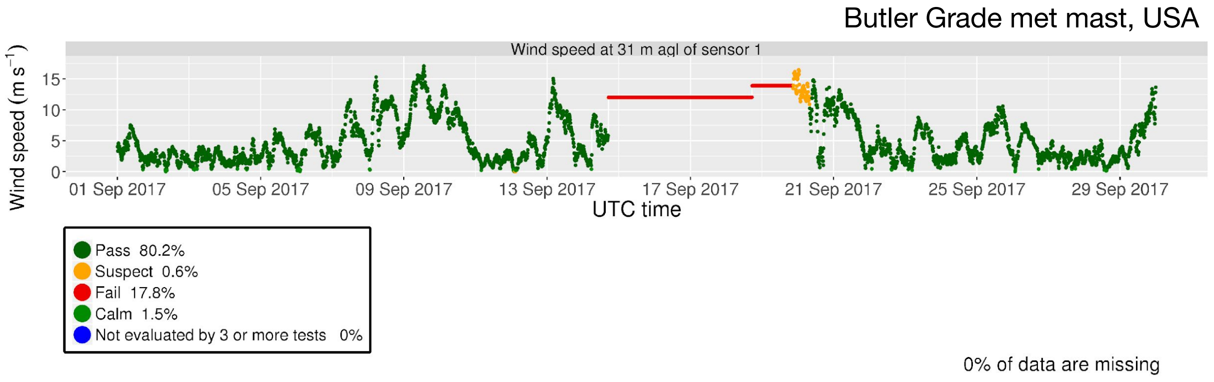


Credits: Jesús Yus-Díez

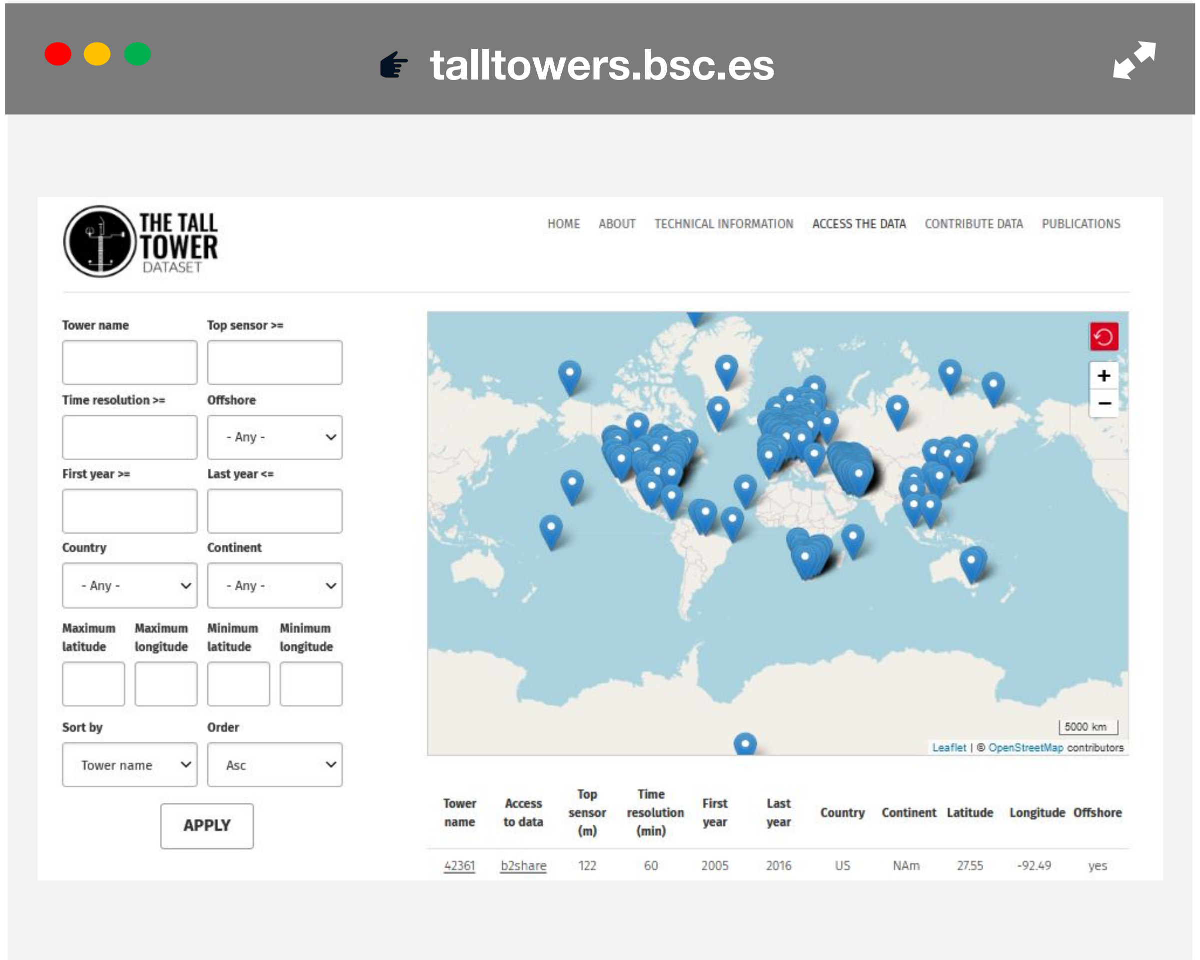
Providing Quality Controlled tall tower data

- ➢ The QC ensures the high quality of the dataset, and ensures the robustness of every result employing these data.
- ➢ The Tall Tower Dataset underwent a QC software of 18 tests.





The Tall Tower Dataset



Up to 311 tall tower locations

240,371,908 wind speed and wind direction records

Temperature, barometric pressure, and relative humidity also available

18 quality control checks

Up to 130 new web users accessed over the last 5 months

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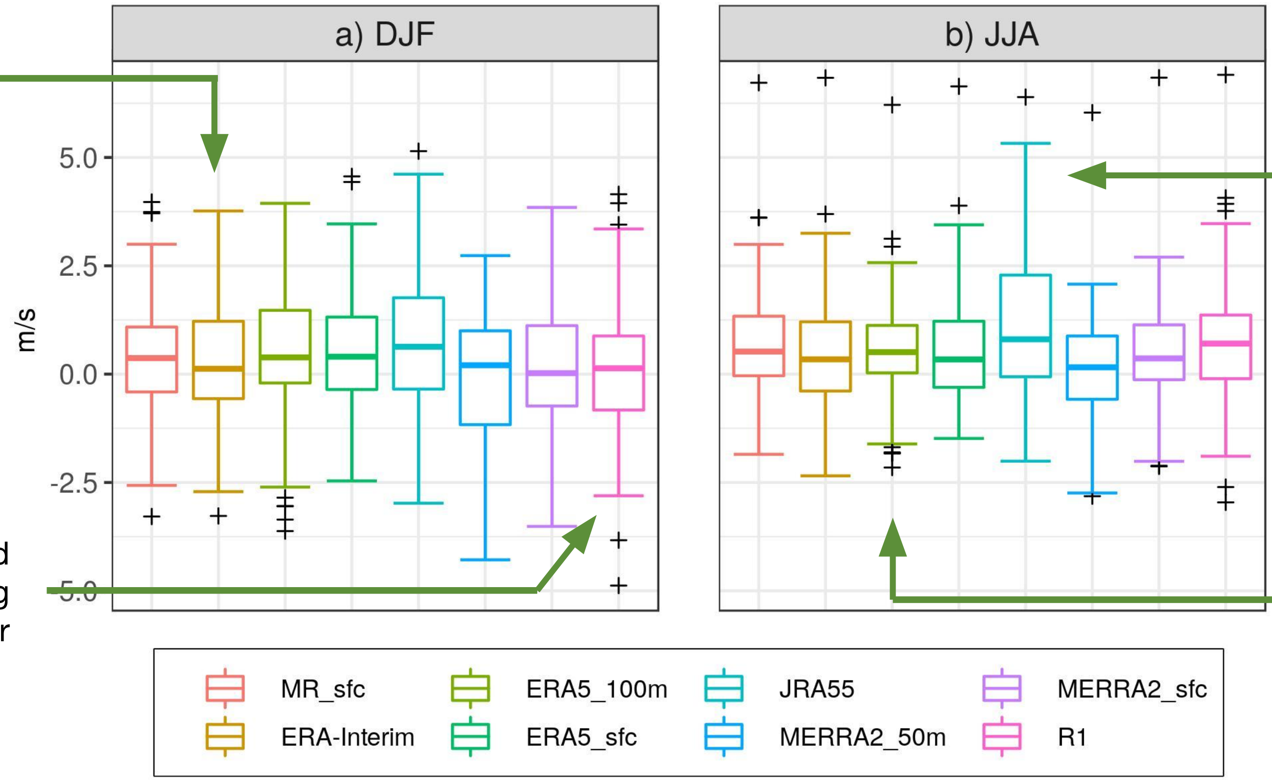
Use of tall tower data to verify reanalyses

- ➢ Five global reanalyses: ERA-Interim, ERA5, MERRA2, JRA55 and NCEP/NCAR R1

tall tower - reanalysis

The median is closest to zero, but also high differences

JRA55 displays the worst results



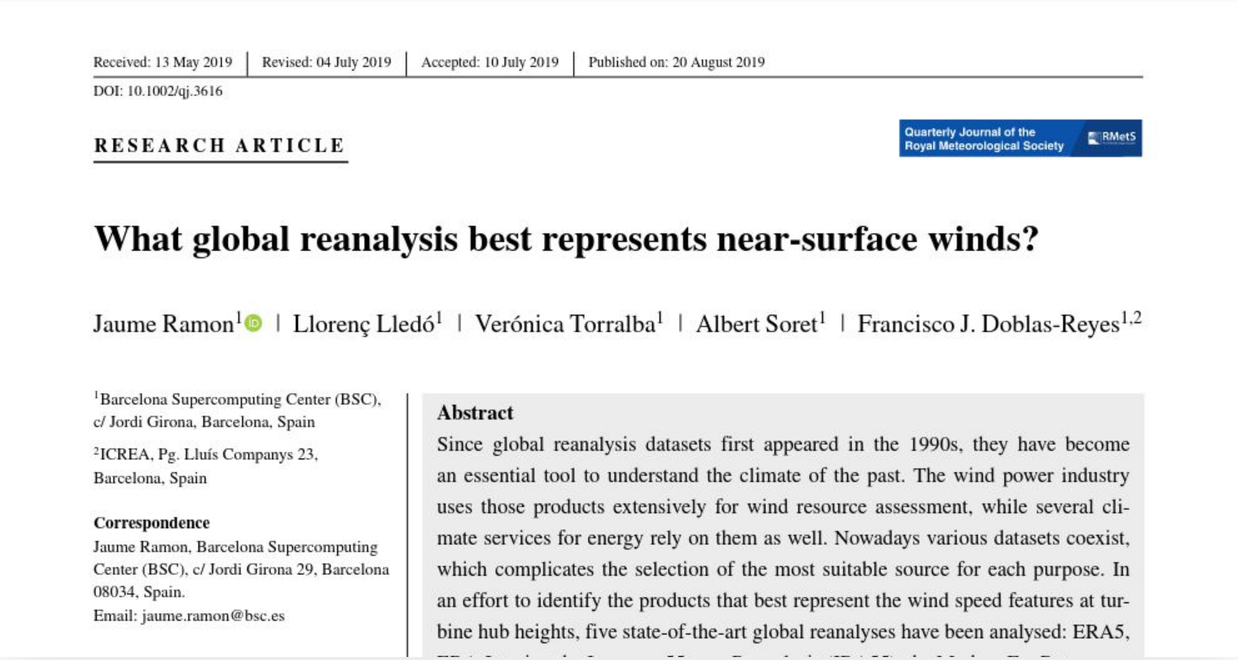
R1 shows a comparably good performance, despite being created much earlier

ERA5 100m winds are the closest to the real

Use of tall tower data to verify reanalyses

- We emphasise the perils of **choosing arbitrarily a reanalysis** dataset as a reference in climate analyses. Our work provides guidance on which is the **best product** to infer near-surface wind speeds.

- Having the best product, i.e. ERA5, will **minimise the uncertainty** in the reference data and thus of every derived analysis.



Received: 13 May 2019 | Revised: 04 July 2019 | Accepted: 10 July 2019 | Published on: 20 August 2019
DOI: 10.1002/qj.3616

RESEARCH ARTICLE

Quarterly Journal of the Royal Meteorological Society RMetS

What global reanalysis best represents near-surface winds?

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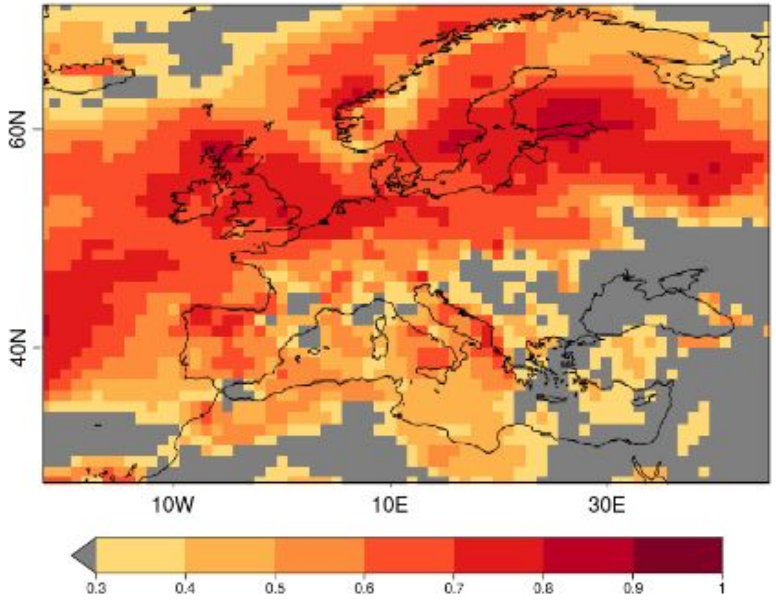
Abstract
Since global reanalysis datasets first appeared in the 1990s, they have become an essential tool to understand the climate of the past. The wind power industry uses those products extensively for wind resource assessment, while several climate services for energy rely on them as well. Nowadays various datasets coexist, which complicates the selection of the most suitable source for each purpose. In an effort to identify the products that best represent the wind speed features at turbine hub heights, five state-of-the-art global reanalyses have been analysed: ERA5,

Ramon, J., Lledó, Ll., Torralba, V., Soret, A., and Doblas-Reyes, F.J. (2019). What global reanalysis best represents near surface winds? *Quarterly Journal of the Royal Meteorological Society*, 145(274):3236-3251, doi:10.1002/qj.3616

Use of tall tower data to generate predictions

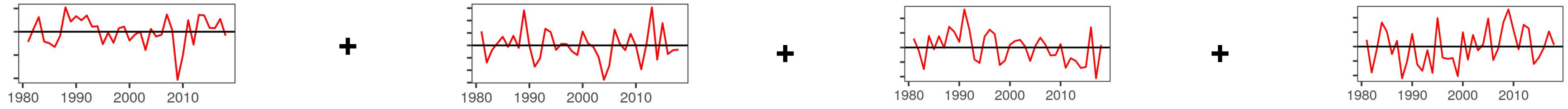
- The **variability** of surface wind speeds in Europe can be very much explained by the **Euro-Atlantic Teleconnections** (e.g. NAO, SCA …).

- Empirical predictions can be generated **fitting a linear model** with tall tower observations and the indices of the EATC.



$$w'(x,y,t) = a_0(x,y) + a_1(x,y) * NAO(t) + a_2(x,y) * EA(t) + a_3(x,y) * EAWR(t) + a_4(x,y) * SCA(t)$$

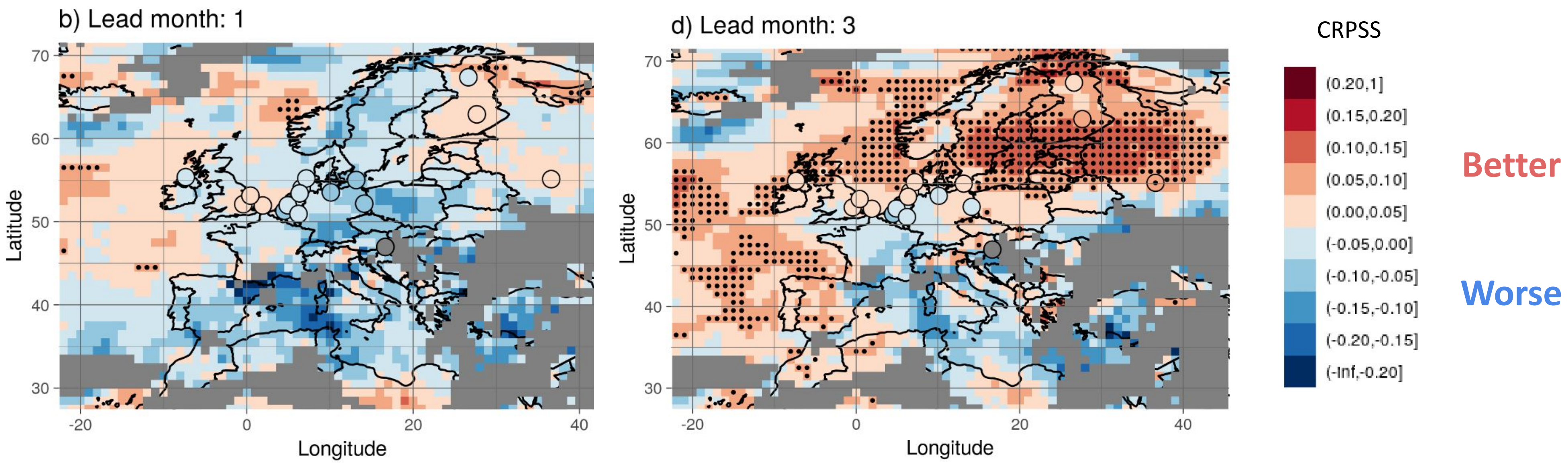
~



Use of tall tower data to generate predictions

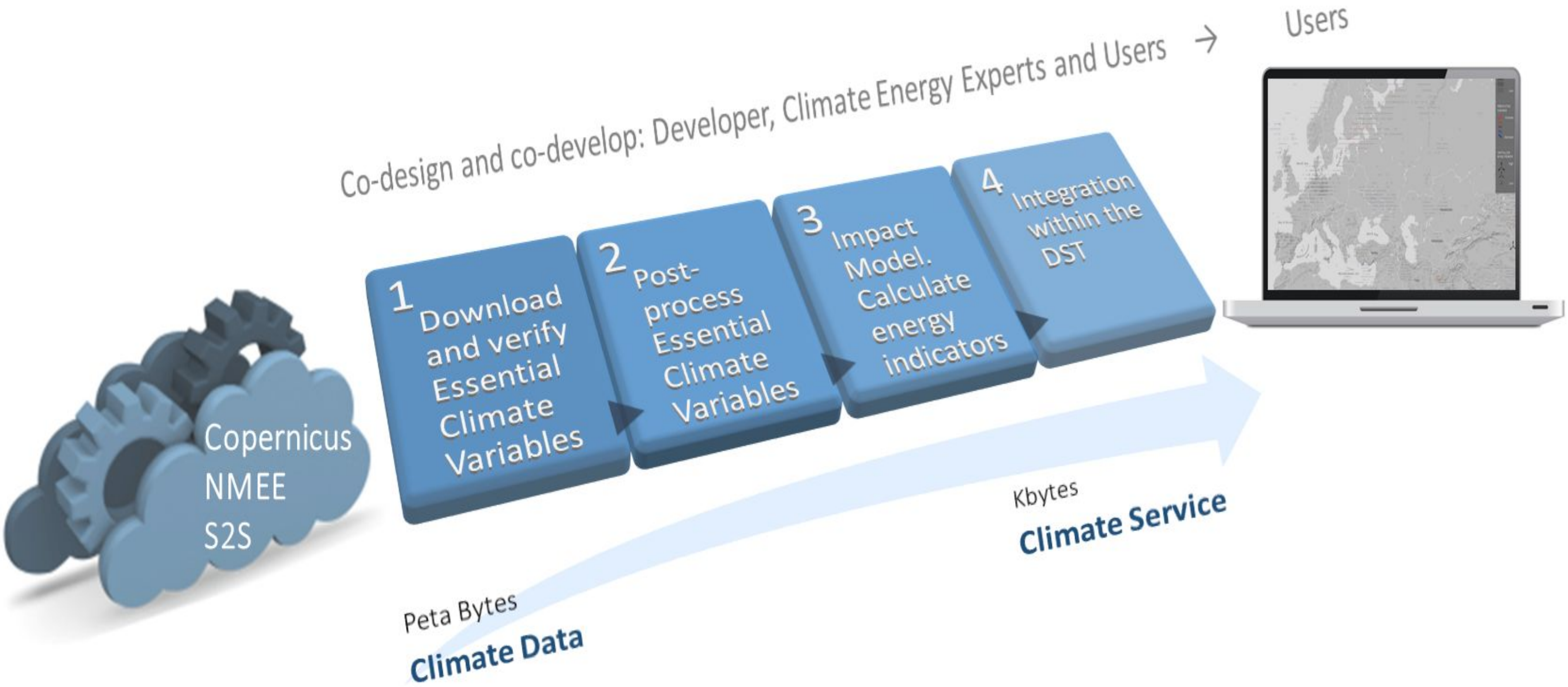
- We **compare** the our approach for **empirical** predictions with the purely **dynamical** predictions of surface wind speeds .

- The empirical predictions **improve** (reds) the dynamical for the **longest lead times** and over **northern Europe**. Empirical predictions also outperform the dynamical at the **tall tower locations** (filled points).



DST of S2S4E

From climate data to climate services



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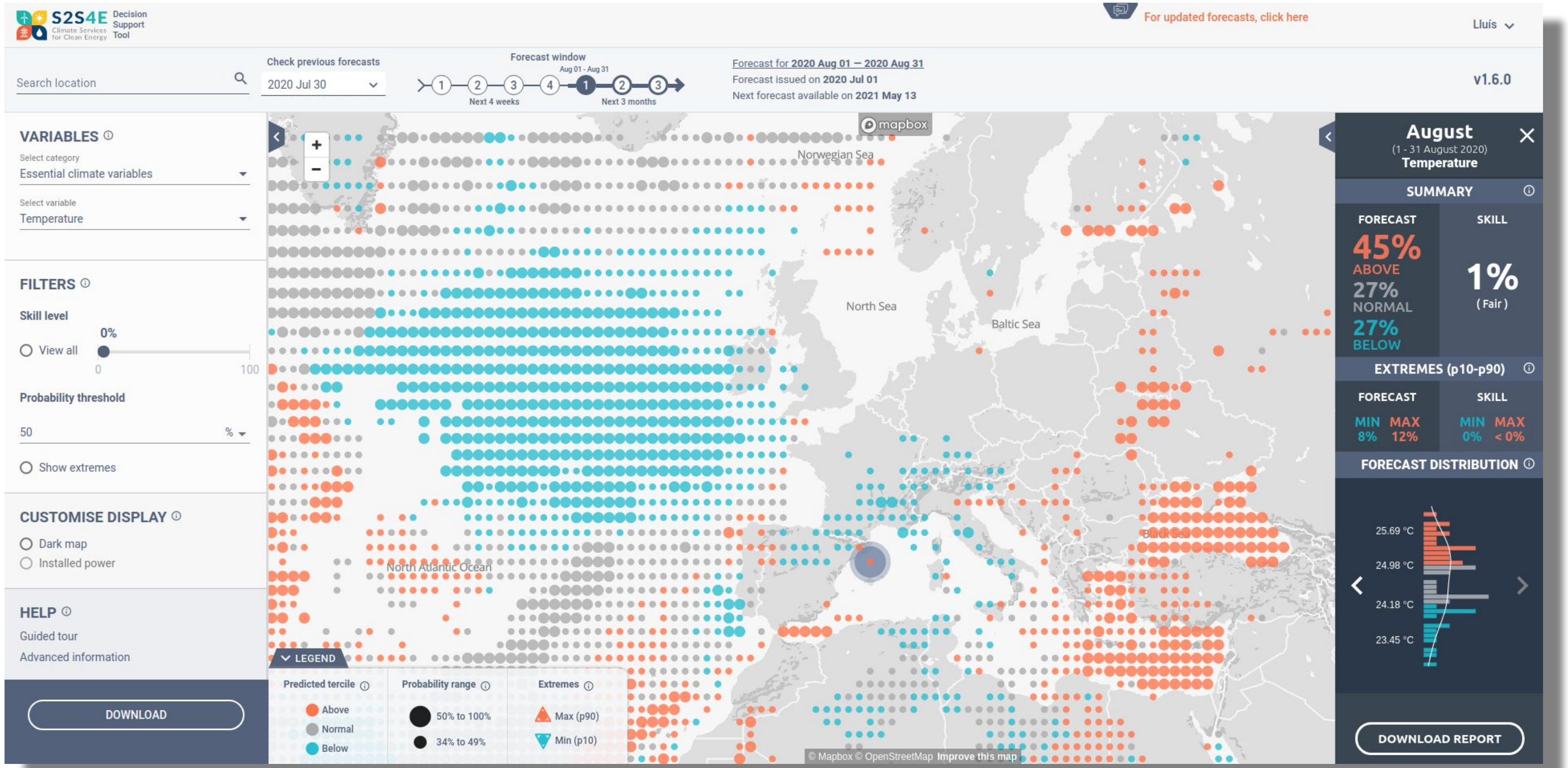
Decision Support Tool (DST)

➢ Integration for the first time of sub-seasonal to seasonal (S2S) climate predictions with RE production and electricity demand.



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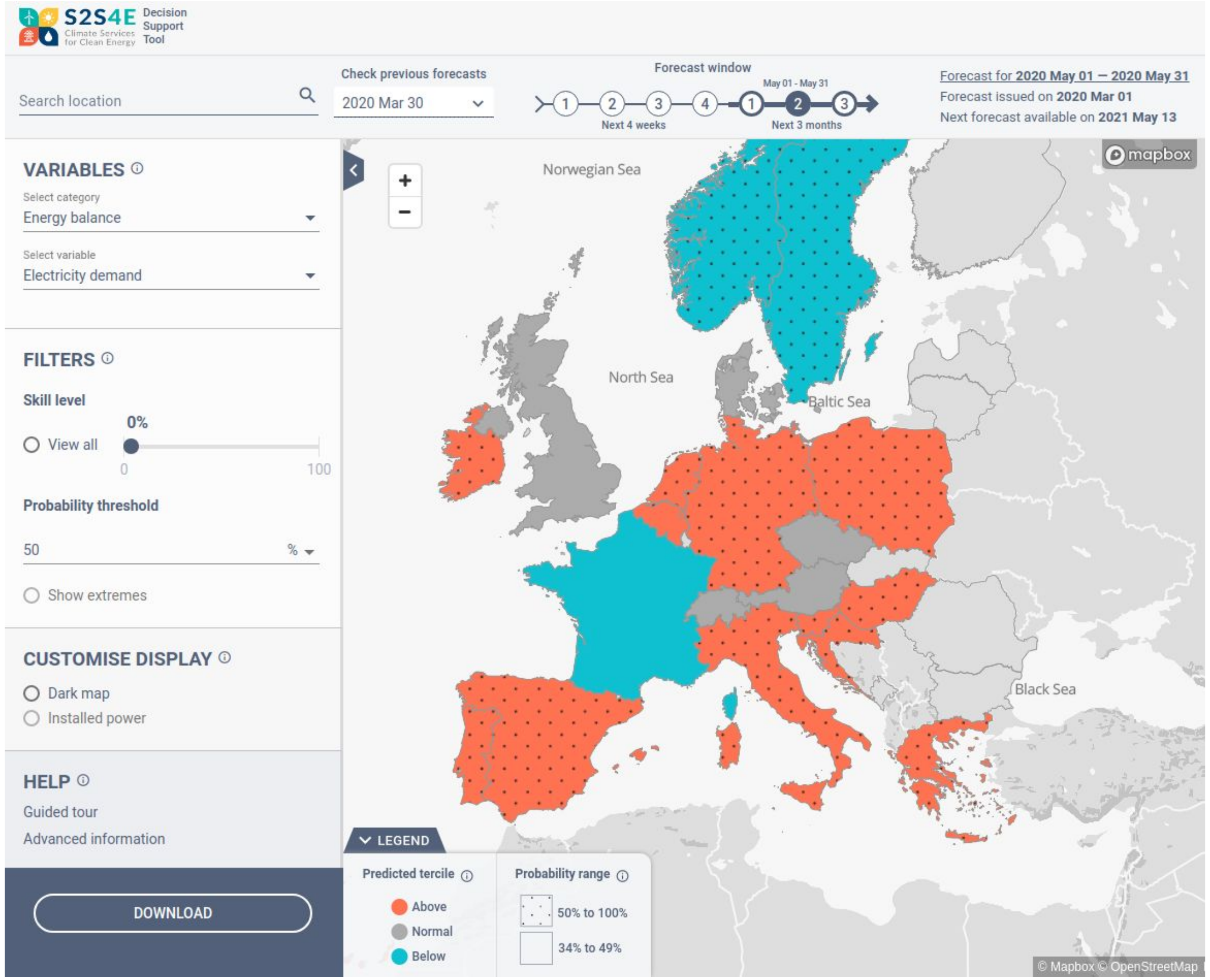
https://s2s4e.eu/dst

S2S4E Climate Services for Clean Energy

Variables in the DST

- **Essential climate variables:**
  - Wind speed
  - Temperature (mean, max & min)
  - Solar radiation
  - Precipitation
  - Mean sea level pressure

- **Energy Indicators:**
  - Wind capacity factor
  - Solar capacity factor
  - Electricity demand at country level
  - Hydro power (inflow/ annual snow max anomaly)



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S2S4E Climate Services for Clean Energy

Prediction systems used in the DST

- **PREDICTION SYSTEMS:**
  - **Seasonal:**
    - SEAS5
    - Multi-model: ECMWF, MF, DWD, CMCC & GLOSEA
  - **Subseasonal:**
    - NCEP CFSv2
    - ECMWF-Ext-ENS

- **REANALYSIS (Skill assesment + bias adjustment)**
  - ERA5

Climate Change Service
climate.copernicus.eu

Subseasonal-to-Seasonal S2S Prediction Project

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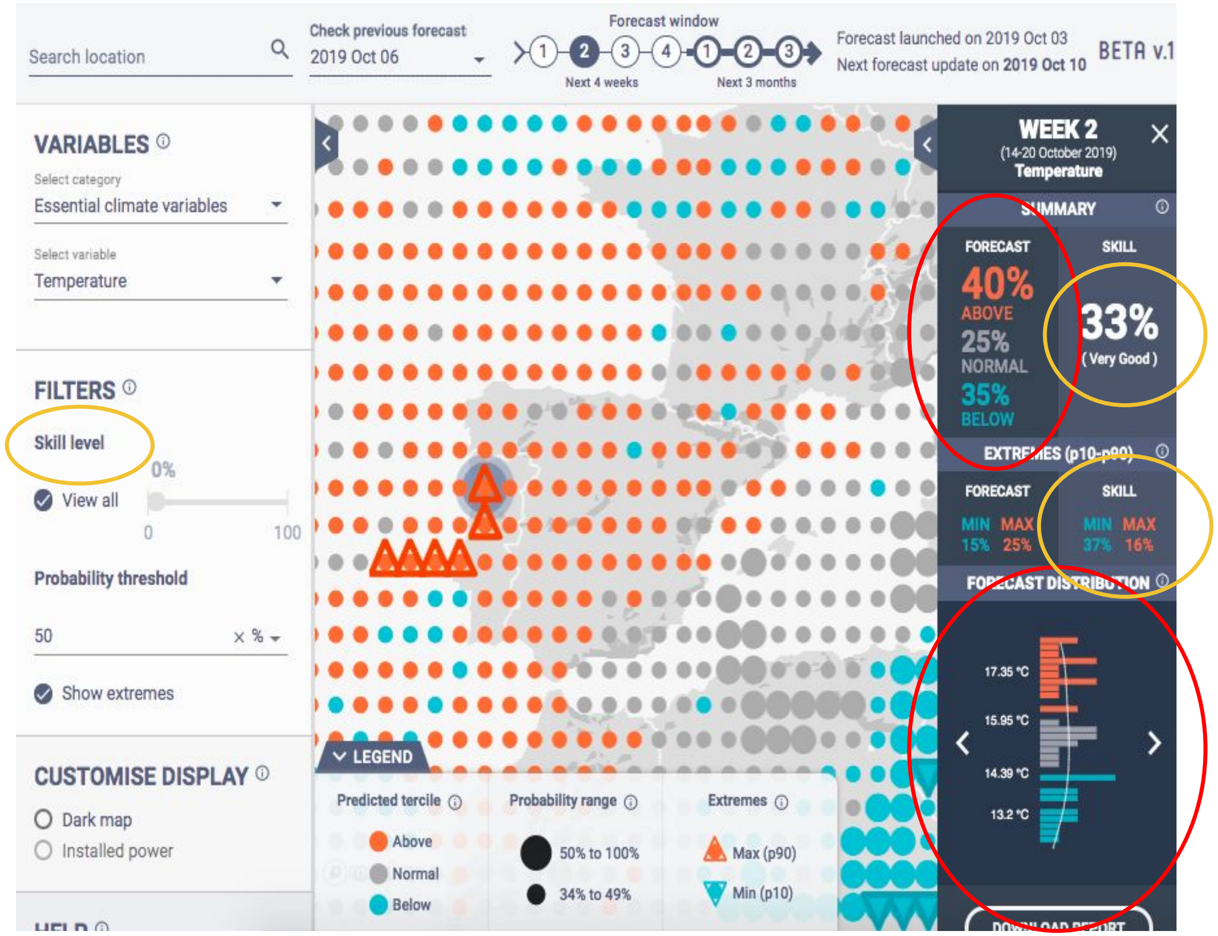
S2S4E Climate Services for Clean Energy

Products and verification metrics

- **Tercile probabilities:** Probability (number of members) of being in the lower, middle or upper tercile of the system's climatology.
  - Fair Ranked probability skill score (fair RPSS)
- **Probability of extremes**: Probability of exceeding the system's climatological 10th/90th percentile. The triangles are shown when the probability is larger than 25%
  - Fair Brier Skill Score (fair BSS)



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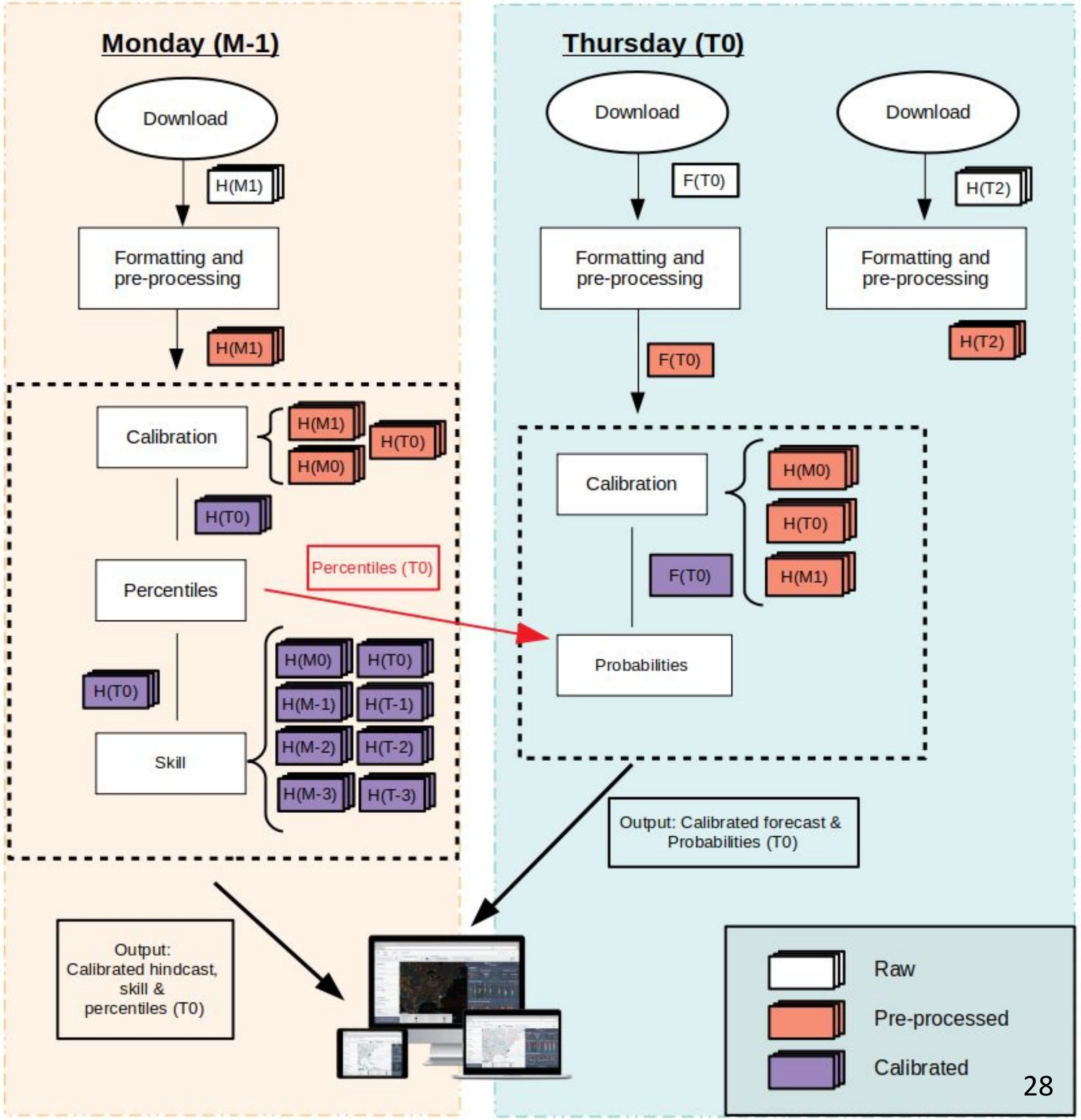
S2S4E
Climate Services for Clean Energy

Lessons learned from the implementation

1. “Timing” your workflow

- **Data availability** can limit your methodology. In some cases, changes will be needed to ensure that you can issue the forecast on time with the available data.

- Implementing the workflow for retrieving and post-processing the data on time implies extra developments and discussions with domain scientists.



H: Hindcast
F: Forecast

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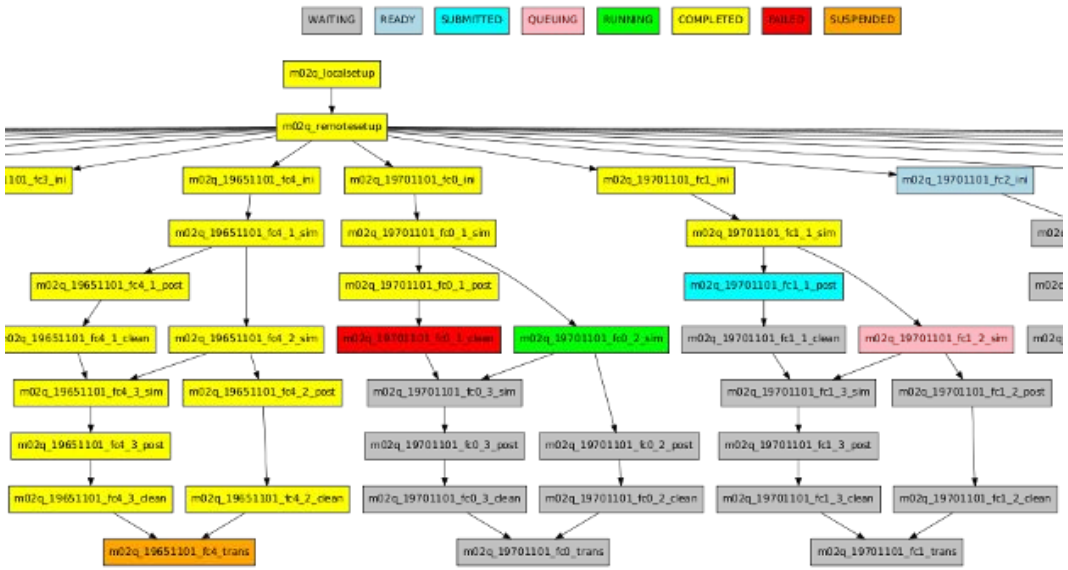
Manrique-Suñén et al., (in-prep)

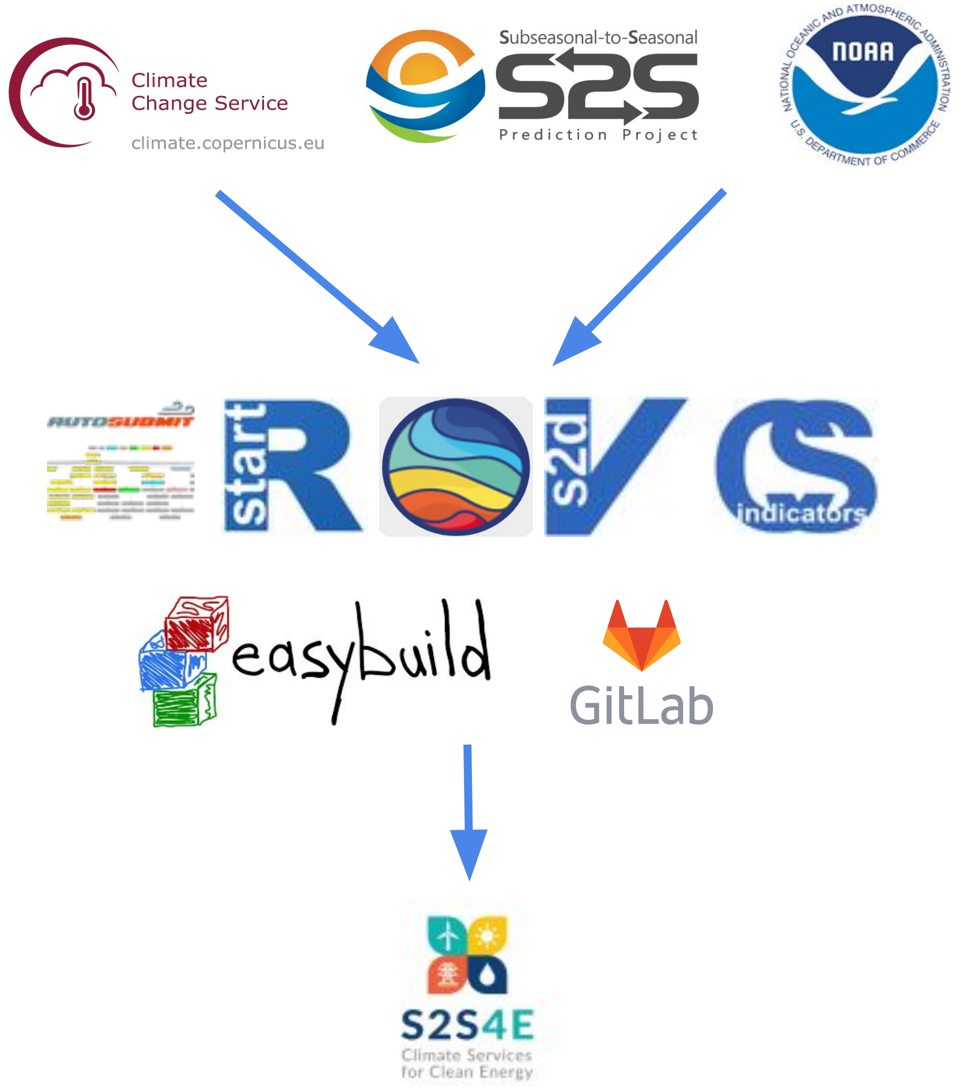
2. Automatization using workflow managers

- Operational services need to handle **incidences** like **delays** in the publication of the forecast or **corruption** of the data originated in the source or during the transfer.
- **Workflow managers** are a great asset, as they can handle fails and retrials, in addition to dependencies between jobs and different machines.
  - In S2S4E, **Autosubmit**, a python-based workflow manager was used for the service implementation.



3. Managing your software

- Clean documentation/code, version control, and quality checks over new versions ensures the proper functioning of the service.
- **Version control:** Tools like **Easybuild and Git** will allow managing different software versions in production and reverse to past versions in case of failure.
- Collaborating with domain scientist through **package development** ensures fluent knowledge transfer between the two.
    - In S2S4E, several R packages, like **StartR** or **CSTools**, were co-developed.



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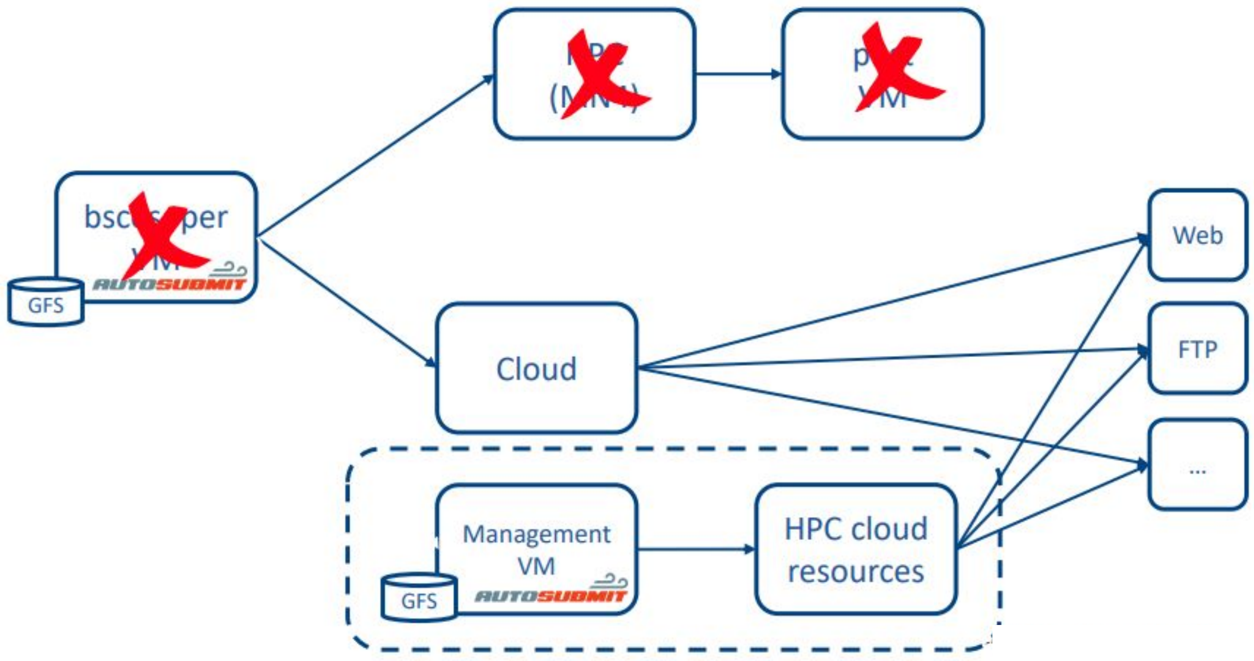
4. Building resilience around your service: Oracle's cloud usecase

- We conducted a test in collobaration with **Oracle and HPC now!**.
- Working with a workflow manager like **Autosubmit** and **easybuild** to manage the software stack, allowed us to port our data pipeline to the cloud easily.
- Cloud resources demonstrated to be a feasible solution replacing usual HPC premises as a **backup solution**.



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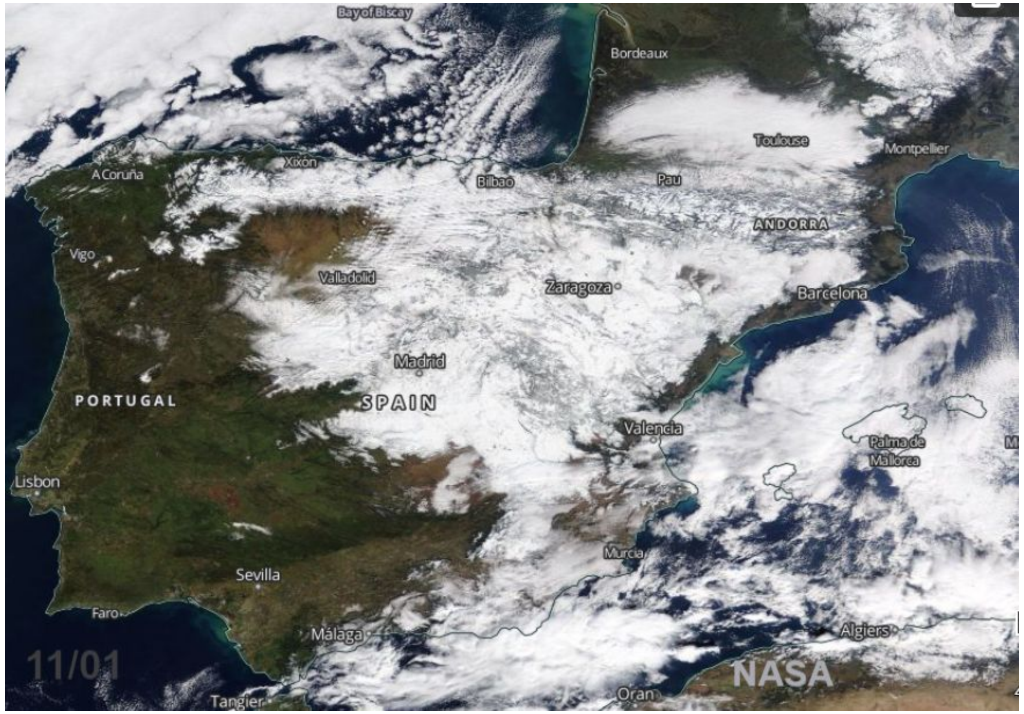
Case study. Filomena event. Unusual cold spell and snow storm in the Iberian Peninsula

Filomena. January 2021



Clearing skies after Storm Filomena with dendritic patterns of lying snow over mainland Spain visible, some cloud cover too.

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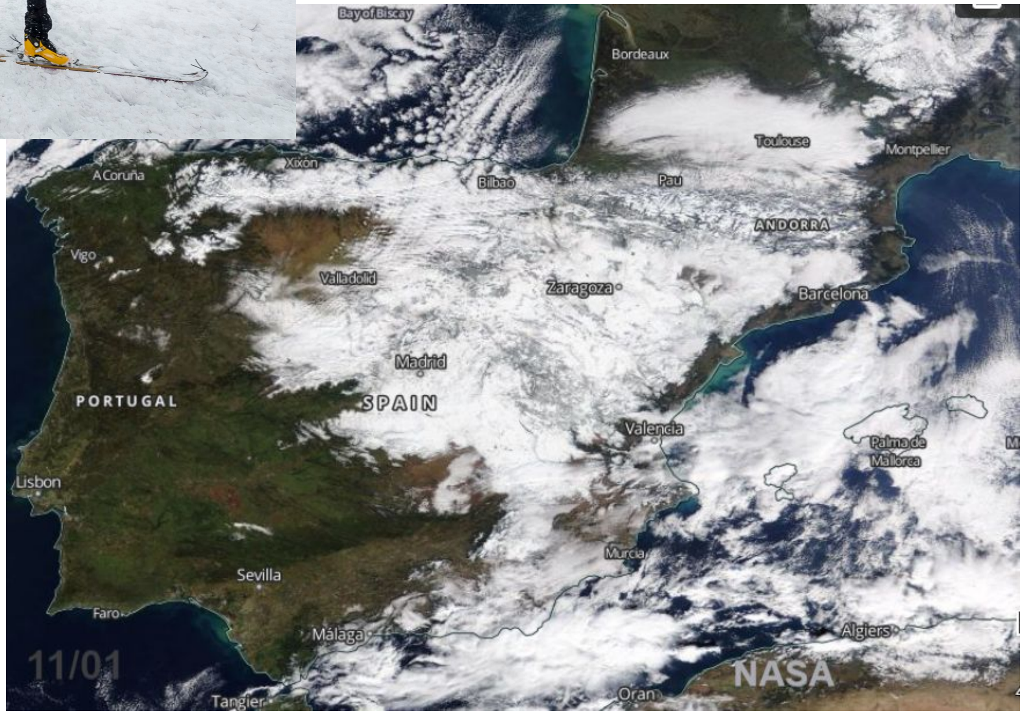
Filomena. January 2021



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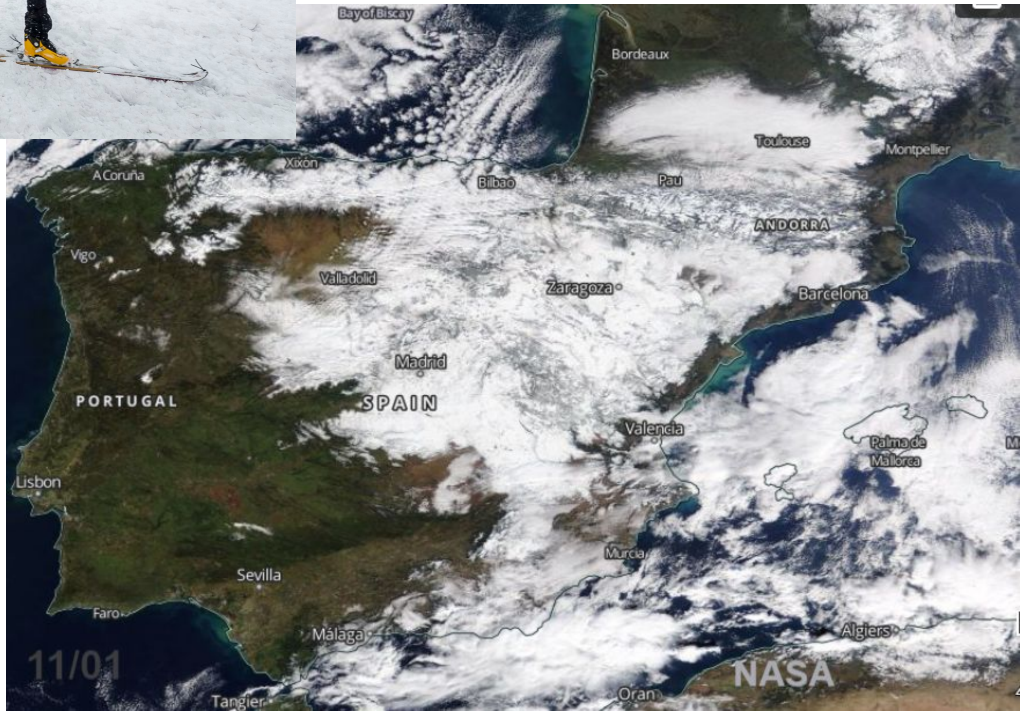
Filomena. January 2021



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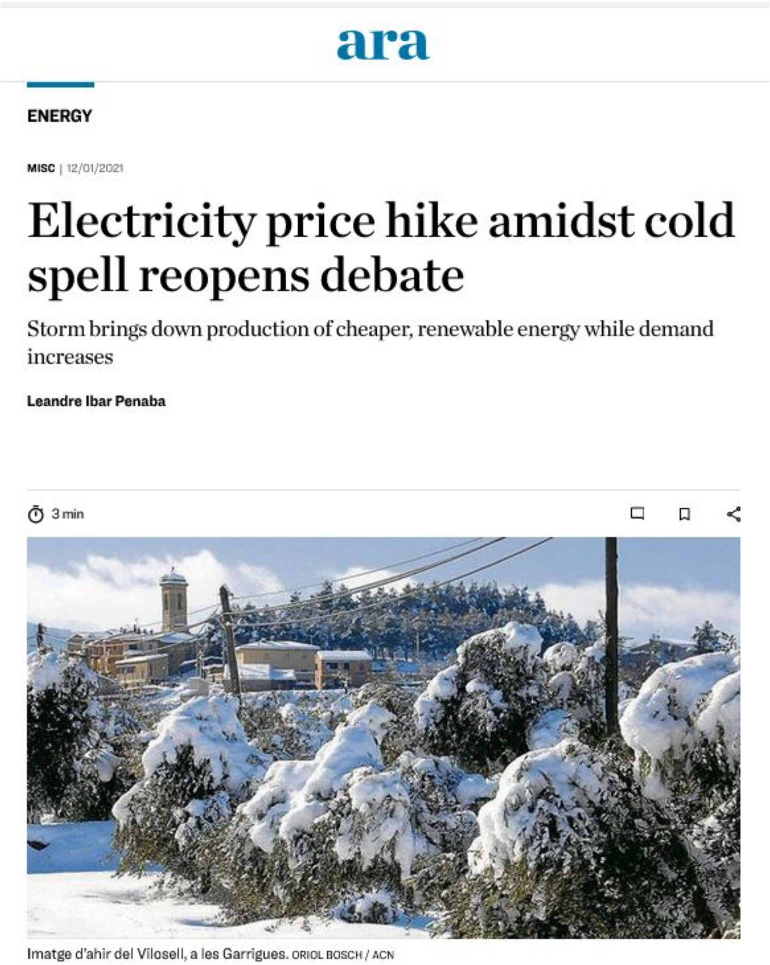

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ENERGY

MISC | 12/01/2021

Electricity price hike amidst cold spell reopens debate

Storm brings down production of cheaper, renewable energy while demand increases

Leandre Ibar Penaba

3 min

Imatge d'ahir del Vilosell, a les Garrigues. ORIOL BOSCH / ACN

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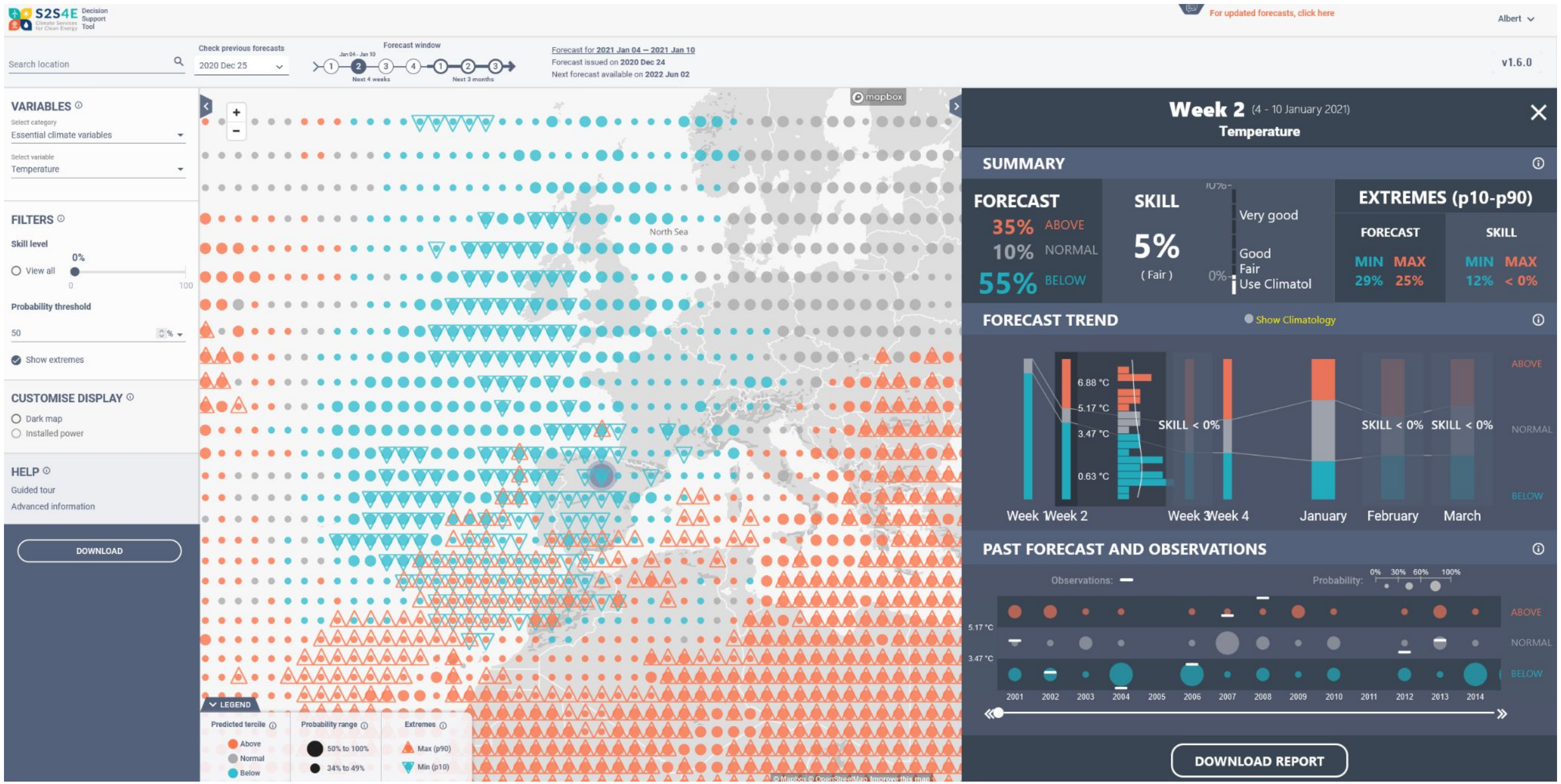
Filomena. January 2021



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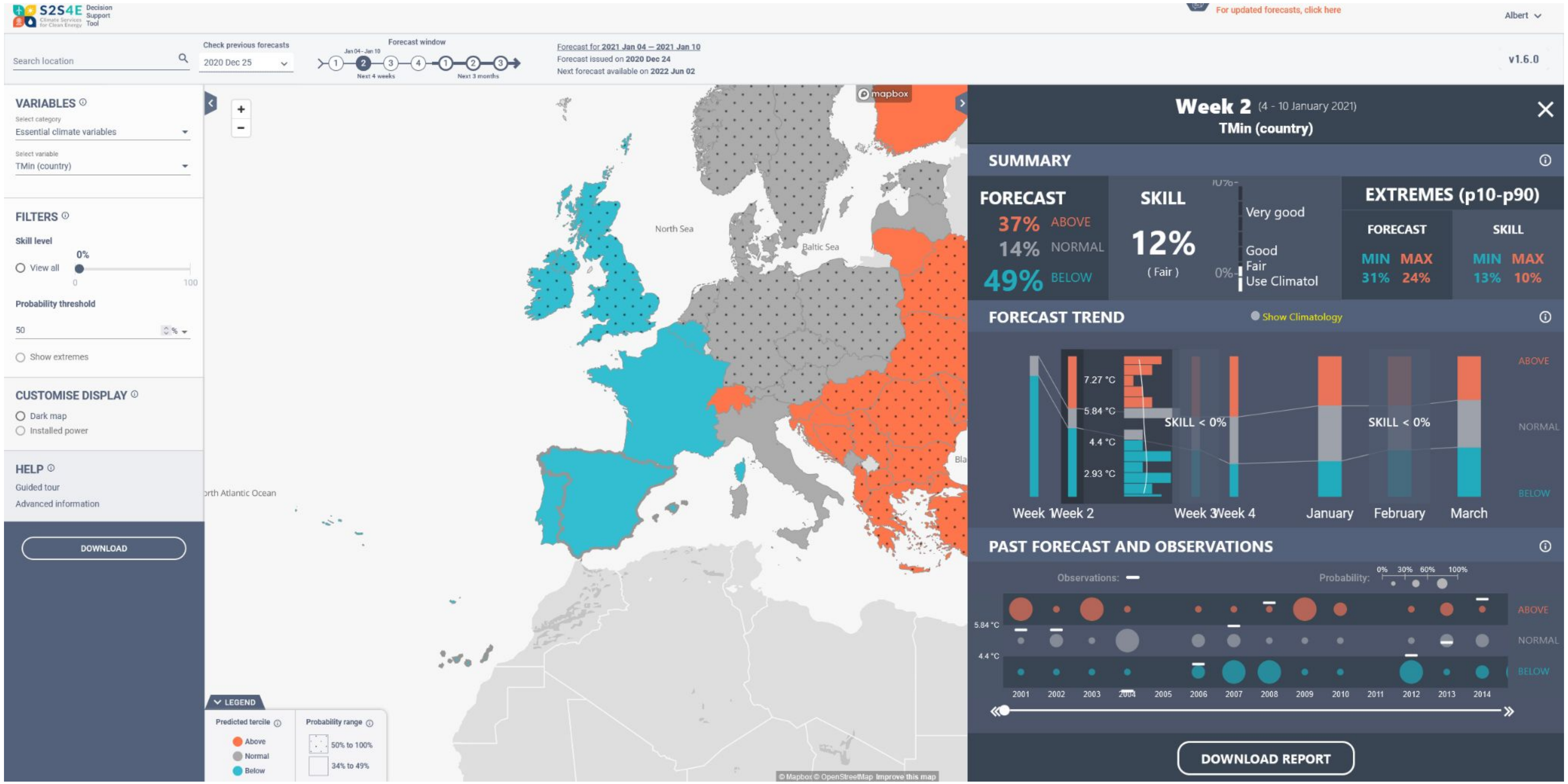

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Clearing skies after Storm Filomena with dendritic patterns of lying snow over mainland Spain visible, some cloud cover too.

Economic assessment

DST Influence on Hedging and Trading Decisions

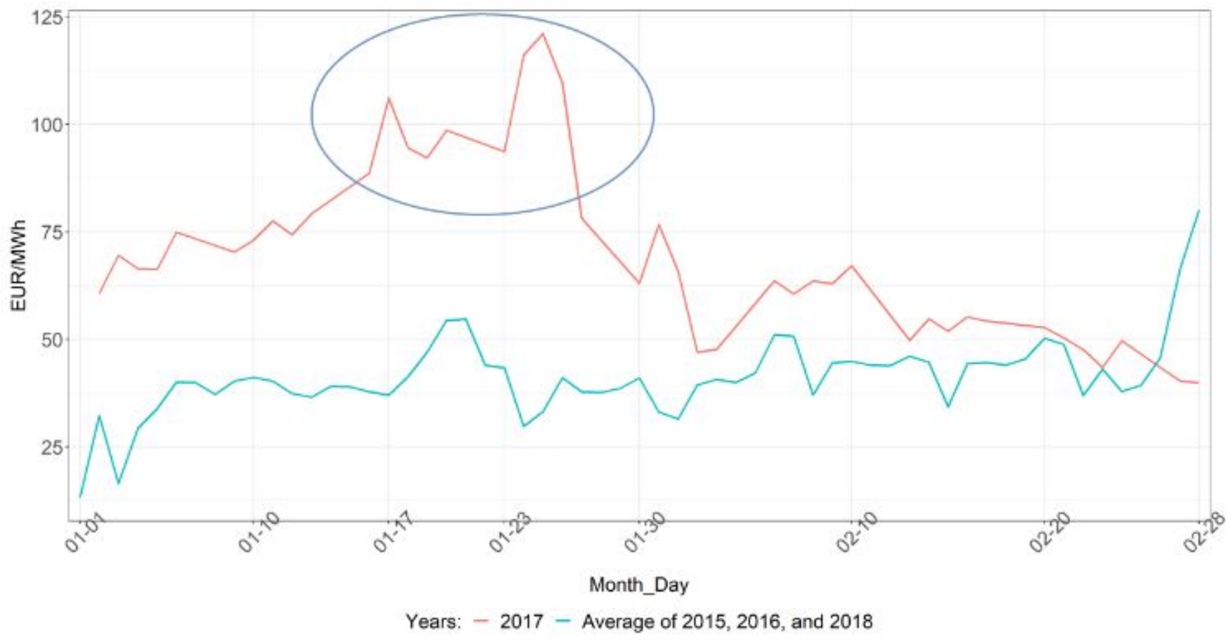

Figure 4: Day-ahead electricity prices in France in January-February 2017. Only weekdays are shown. Source: ENTSO-E

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Next steps

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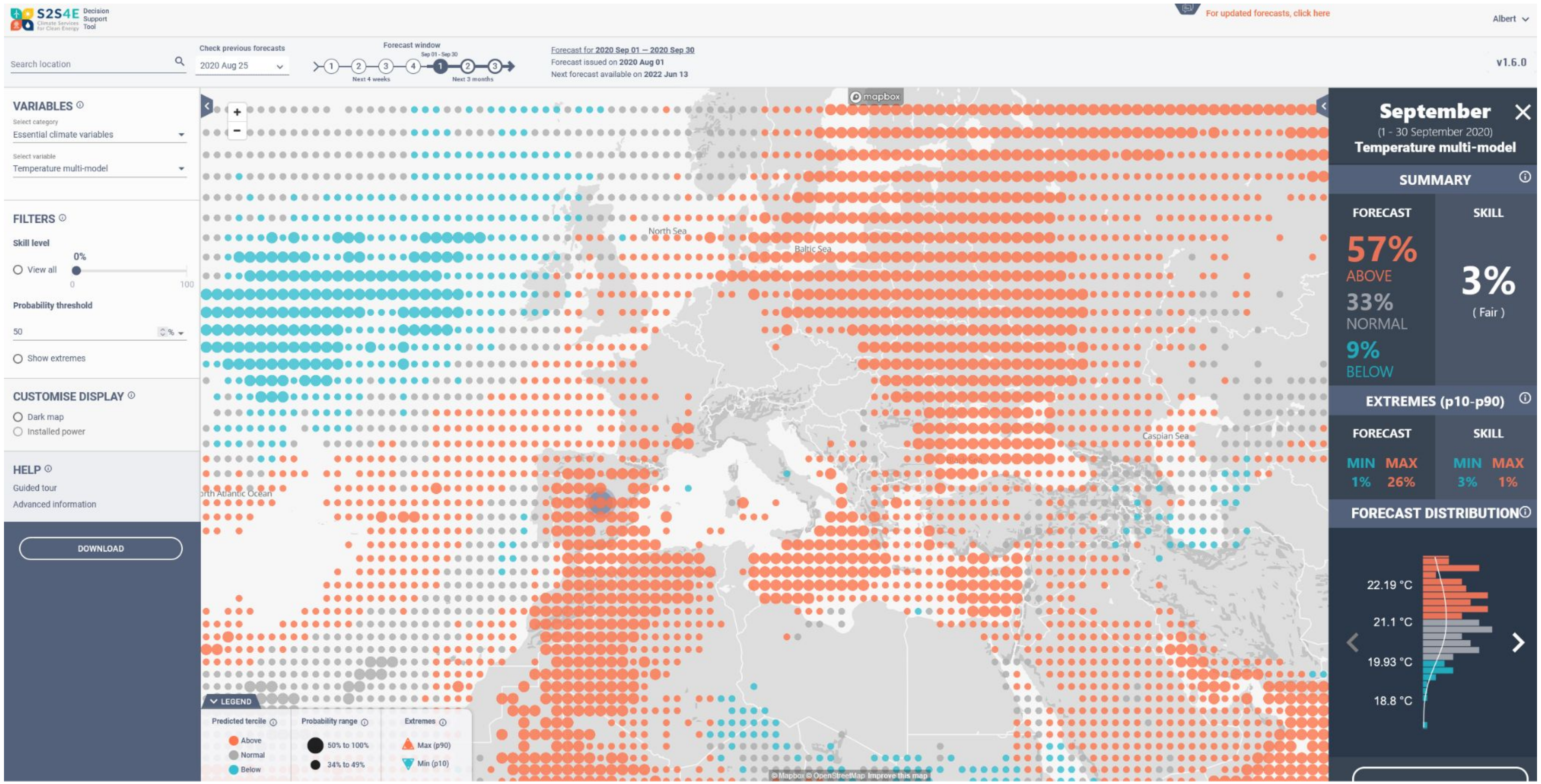
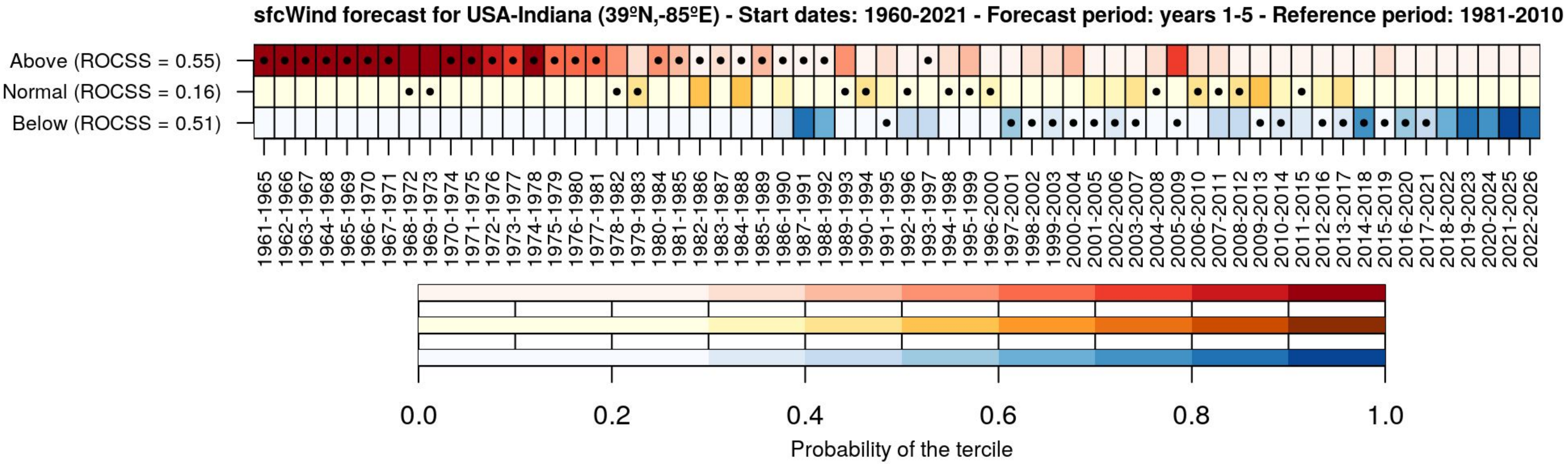
Multi model



S2S4E Decision Support Tool
For updated forecasts, click here
Albert
Search location
Check previous forecasts
2020 Aug 25
Forecast window
Next 4 weeks
Next 3 months
Forecast for 2020 Sep 01 – 2020 Sep 30
Forecast issued on 2020 Aug 01
Next forecast available on 2022 Jun 13
v1.6.0
VARIABLES
Select category
Essential climate variables
Select variable
Temperature multi-model
FILTERS
Skill level
0%
View all
Probability threshold
50
Show extremes
CUSTOMISE DISPLAY
Dark map
Installed power
HELP
Guided tour
Advanced information
DOWNLOAD
North Sea
Baltic Sea
Caspian Sea
North Atlantic Ocean
LEGEND
Predicted tercile
Above
Normal
Below
Probability range
50% to 100%
34% to 49%
Extremes
Max (p90)
Min (p10)
September
(1 - 30 September 2020)
Temperature multi-model
SUMMARY
FORECAST
SKILL
57%
ABOVE
33%
NORMAL
9%
BELOW
3%
(Fair)
EXTREMES (p10-p90)
MIN MAX
1% 26%
3% 1%
FORECAST DISTRIBUTION
22.19 °C
21.1 °C
19.93 °C
18.8 °C

Decadal predictions



EC-Earth3-i4 forecast of the surface wind speed for the forecast years 1-5 over Indiana, USA.

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Thank you

https://s2s4e.eu/dst

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