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Centro Nacional de Supercomputación

ASPECT
FACILITATING SEAMLESS CLIMATE ADAPTATION

BOREAS

Seamless seasonal-to-decadal predictions to support the renewable energy sector

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IEA Wind Task 51 Workshop
Forecasting Extremes in the Power System
iea wind

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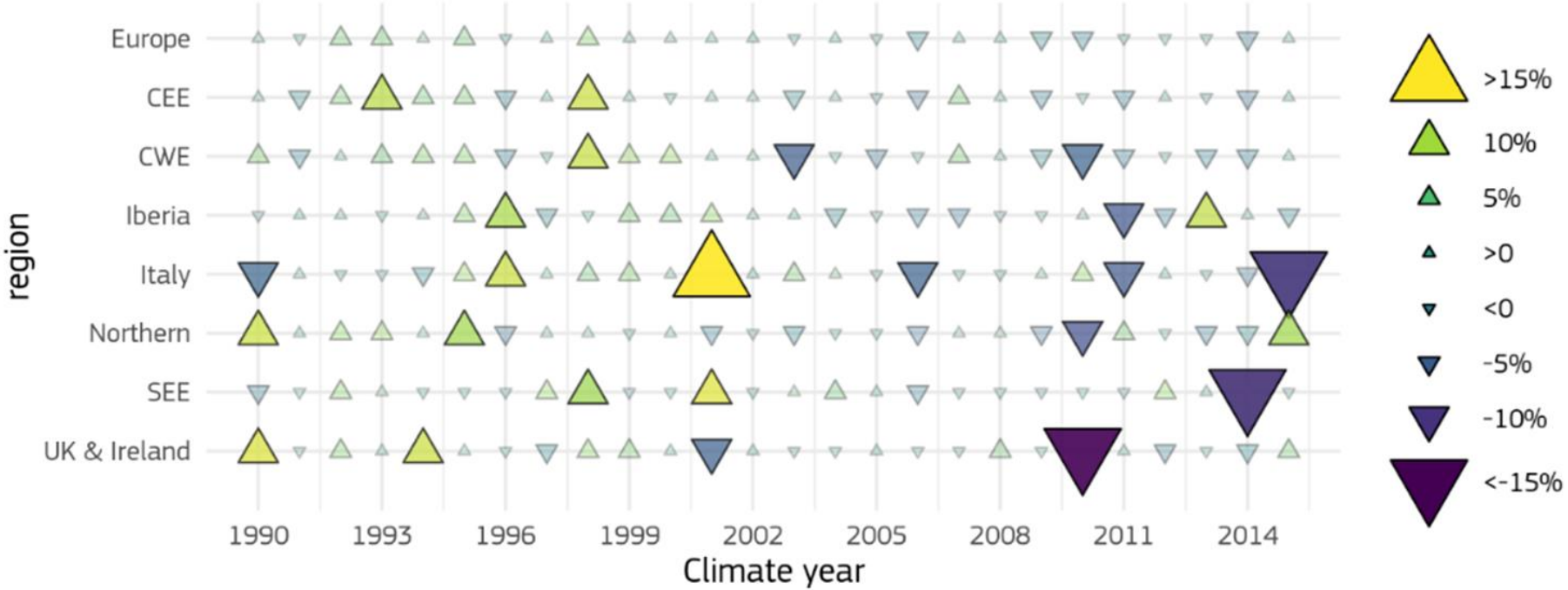
Climate variability



Annual variability (percentage deviation from the average) of onshore wind resources in the 26 climate years for the considered regions. Source: JRC, 2020

Impact and applications

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

Time

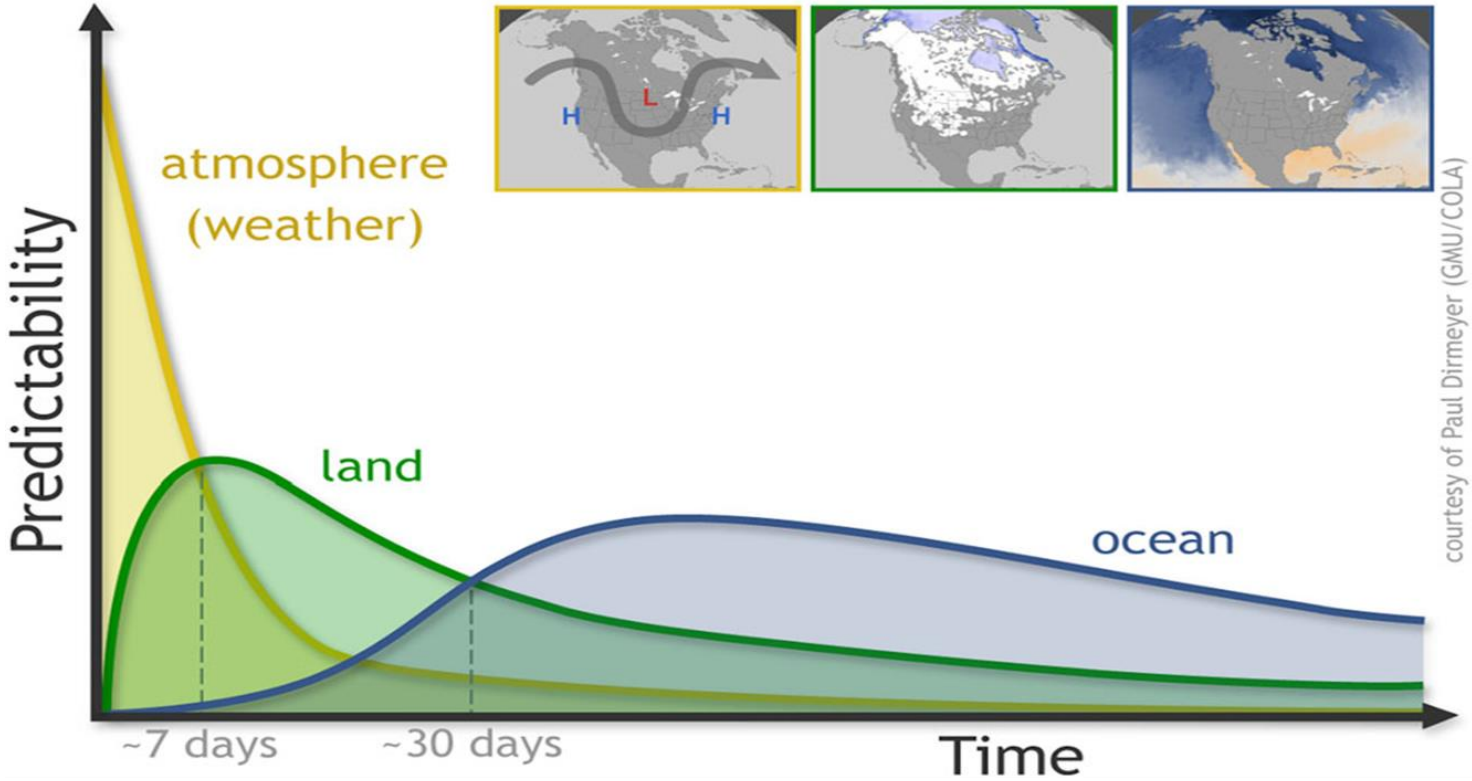
Applications for wind/solar/hydro generation

Post-construction decisions	Post-construction decisions	Pre-construction decisions
Energy producers: commit energy sales for next day **Grid operators:** market prices and grid balance **Energy traders:** anticipate energy prices **Plant operators:** plan cleaning and O&M	**Energy producers:** resource management strategies **Energy traders:** resource effects on markets **Plant operators:** O&M, especially offshore wind **Plant investors:** anticipate cash flow, optimize investments	**Power plant developers:** Site selection. Future risks assessment. **Investors:** Evaluate return on investments **Policy-makers:** Assess changes to energy mix **River-basin managers:** manage the river flow

Applications for demand

Daily operation decisions	Mid-term planning	Long-term planning
Grid operators: Anticipate hot/cold days. Schedule power plants to reinforce supply. **Energy traders:** Anticipate energy prices.	**Grid operators:** Anticipate hotter/colder seasons. Schedule power. **Energy traders:** Anticipate energy prices.	**Grid operators:** Anticipate addition of more capacity. Adaptation of transmission lines **Policy-makers:** Plan addition of more capacity. Understand changes to energy mix

Forecast range and skill



(Source: Mariotti et al. 2018)

Seamless S2D predictions

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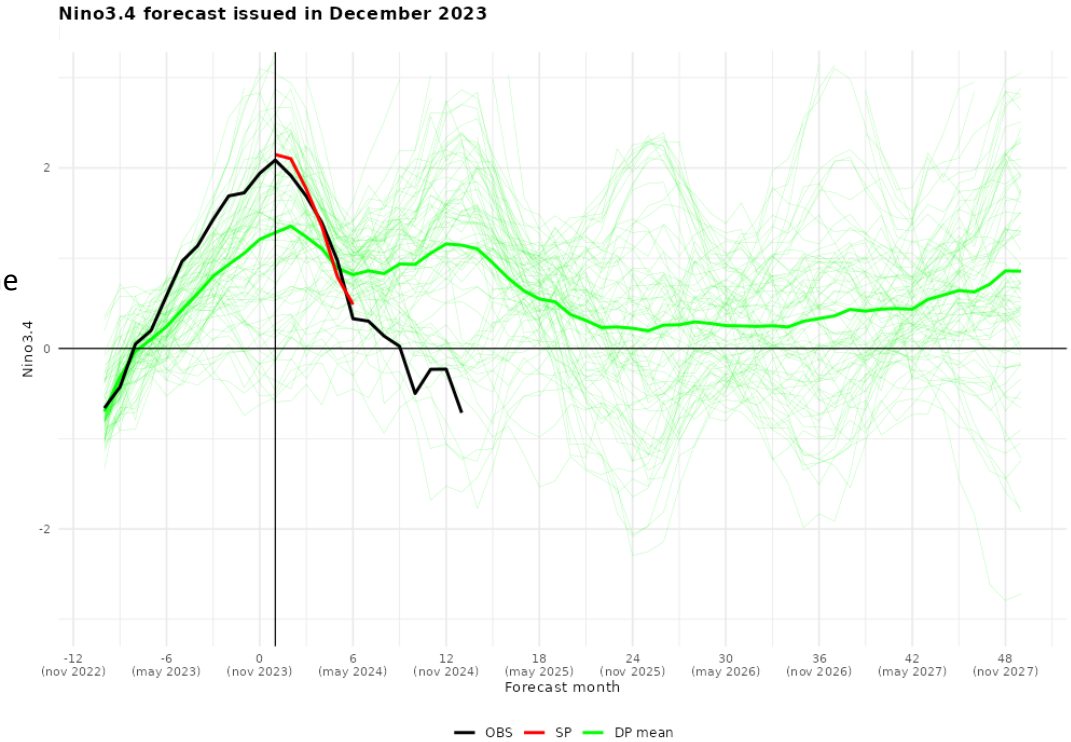
Motivation

- Increase **forecast quality** (by transferring short-term predictability into longer time scales)
- Improve **forecast coherence** at seasonal and decadal timescales (by avoiding “jumps” when switching from one horizon to the other)



Member selection approach

- Selection of the **best 30 members** from
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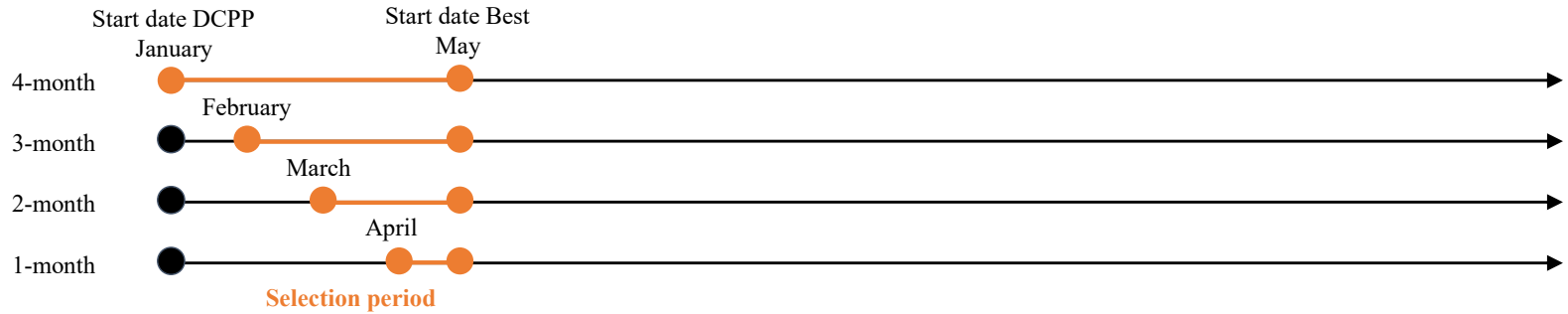

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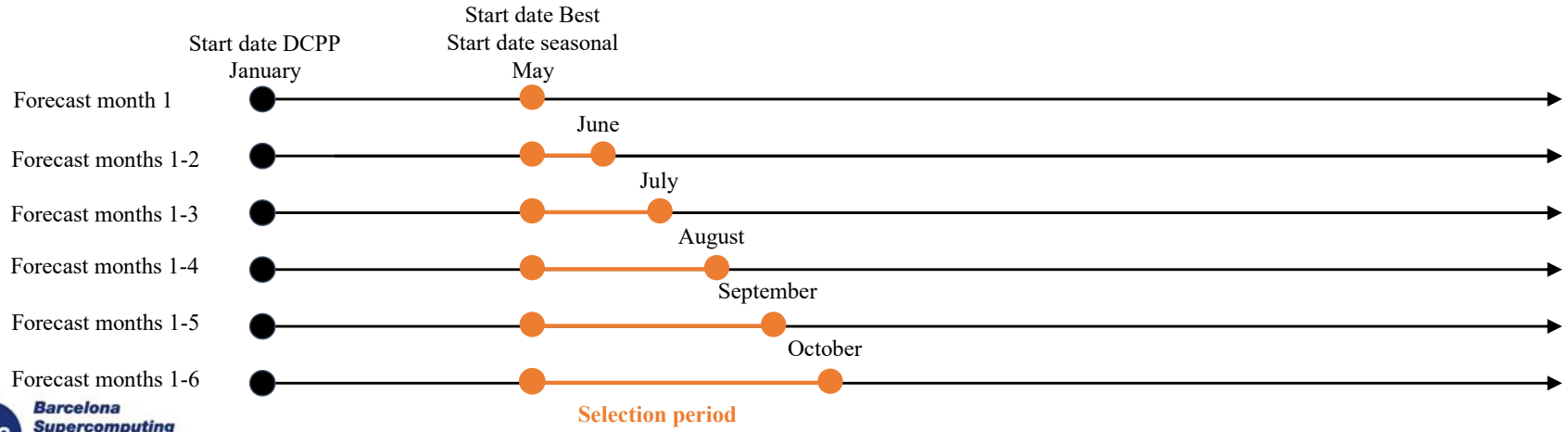

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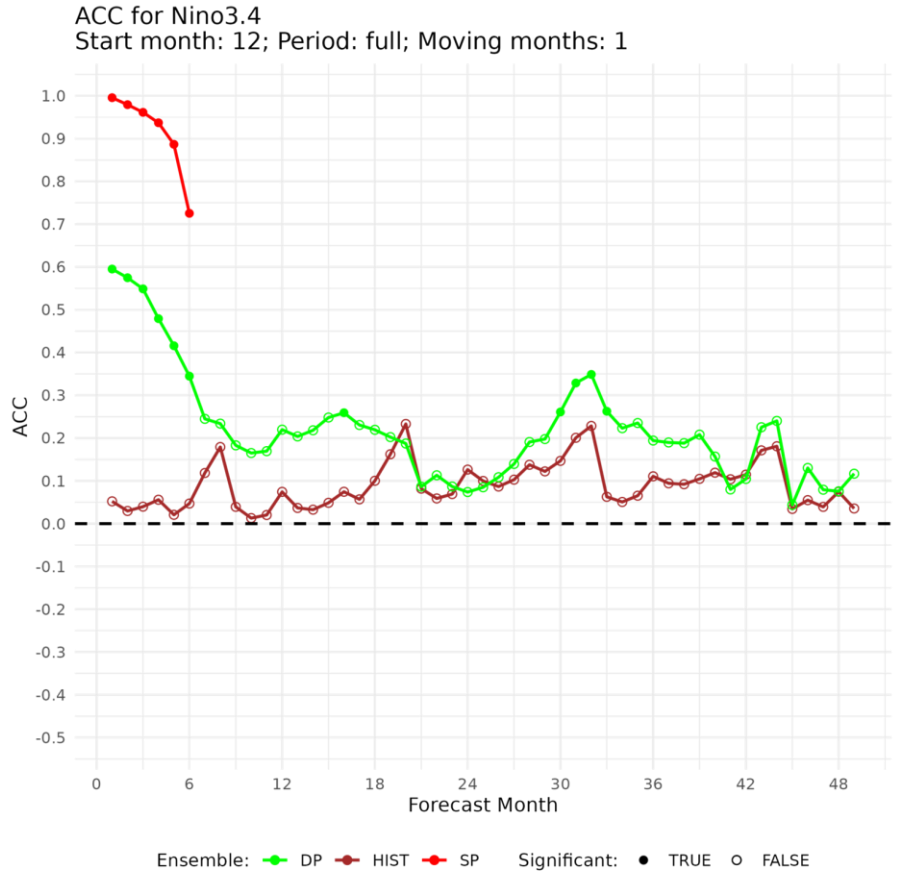
- **It can be updated at any time of the year** (with updated observations or seasonal predictions)

Improving forecast quality for ENSO



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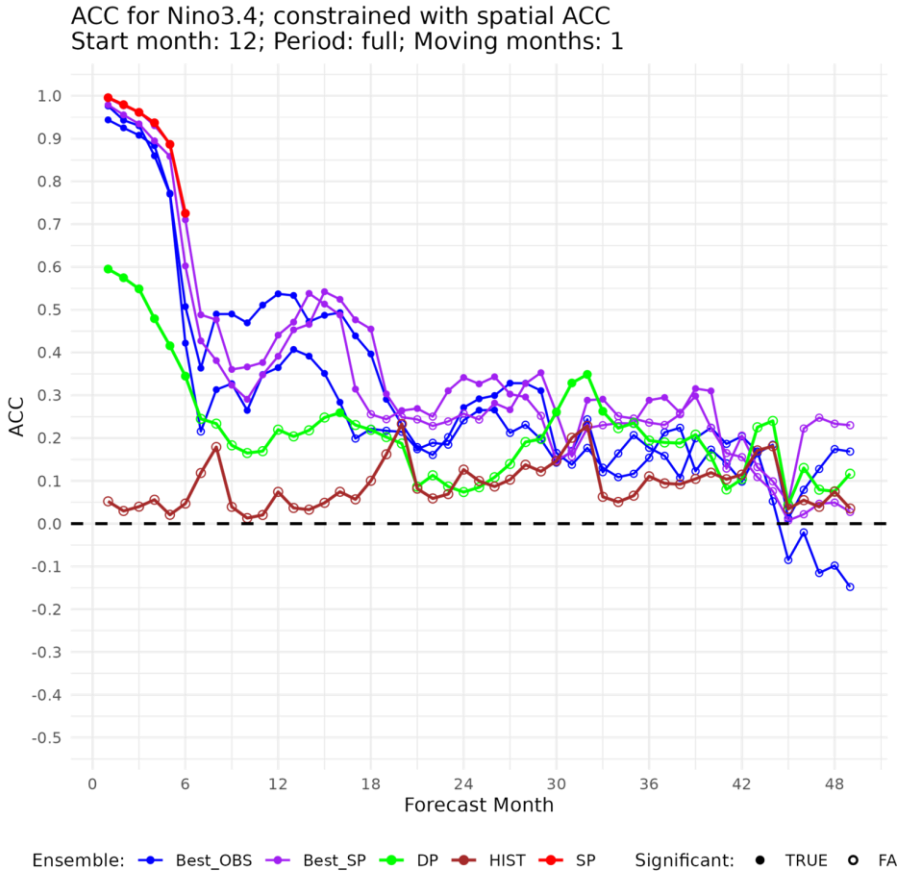
Improving forecast quality for ENSO



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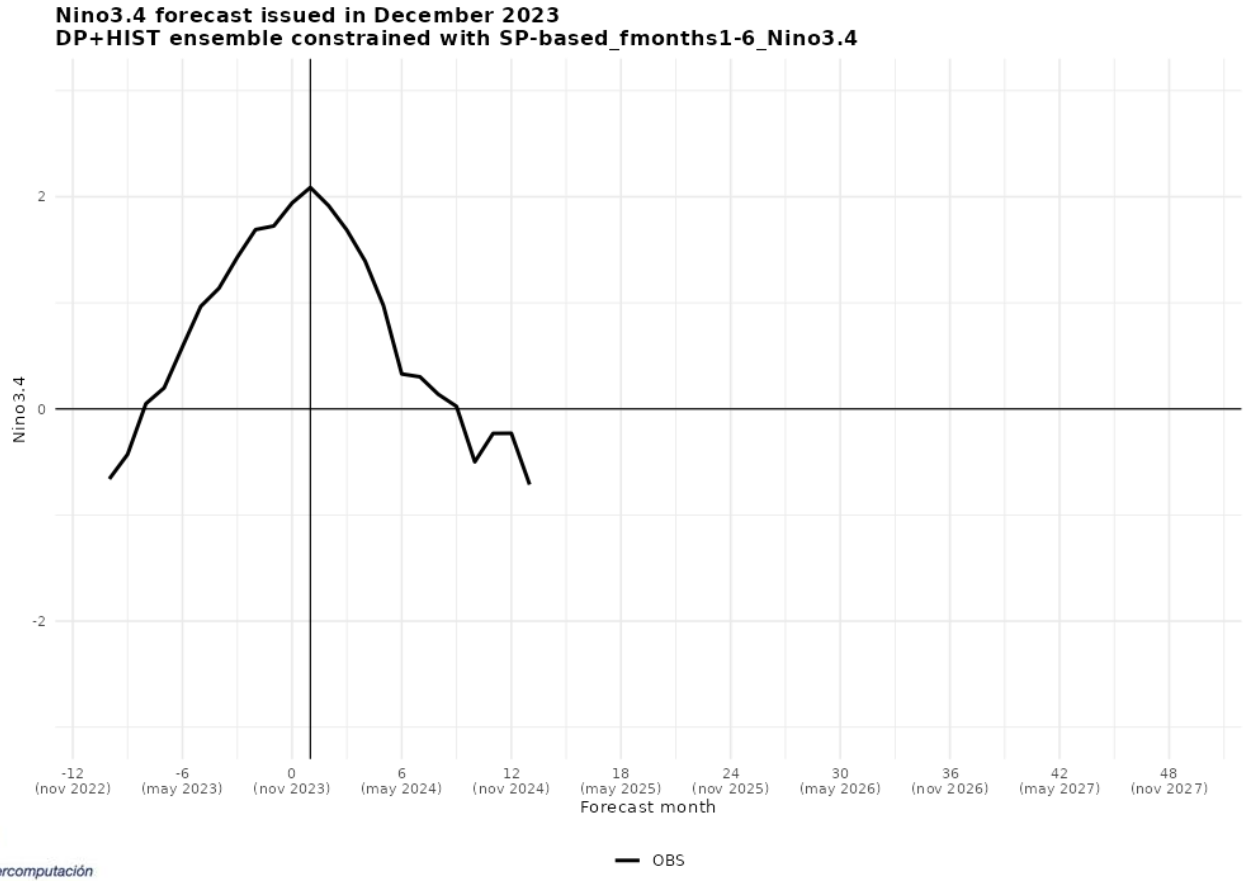
Improving forecast coherence for ENSO



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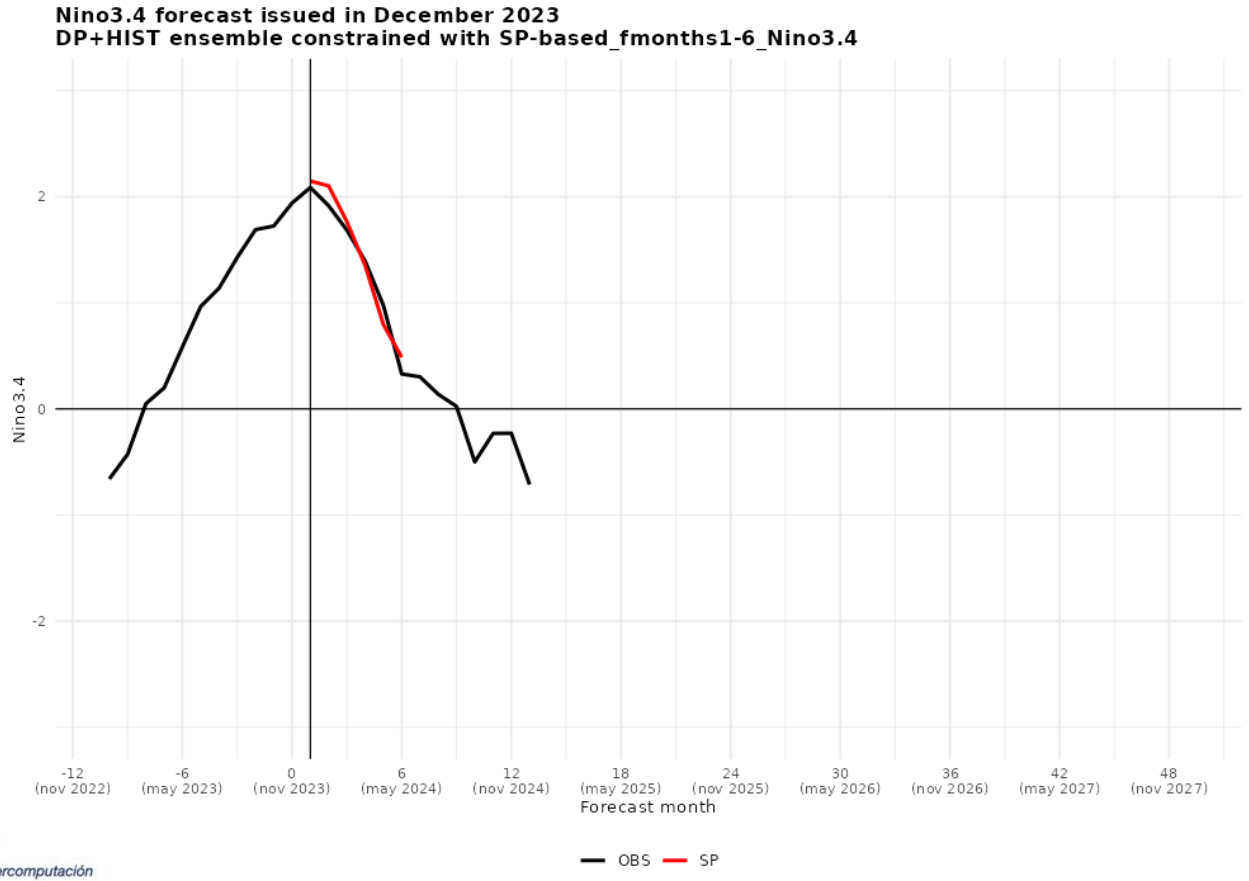

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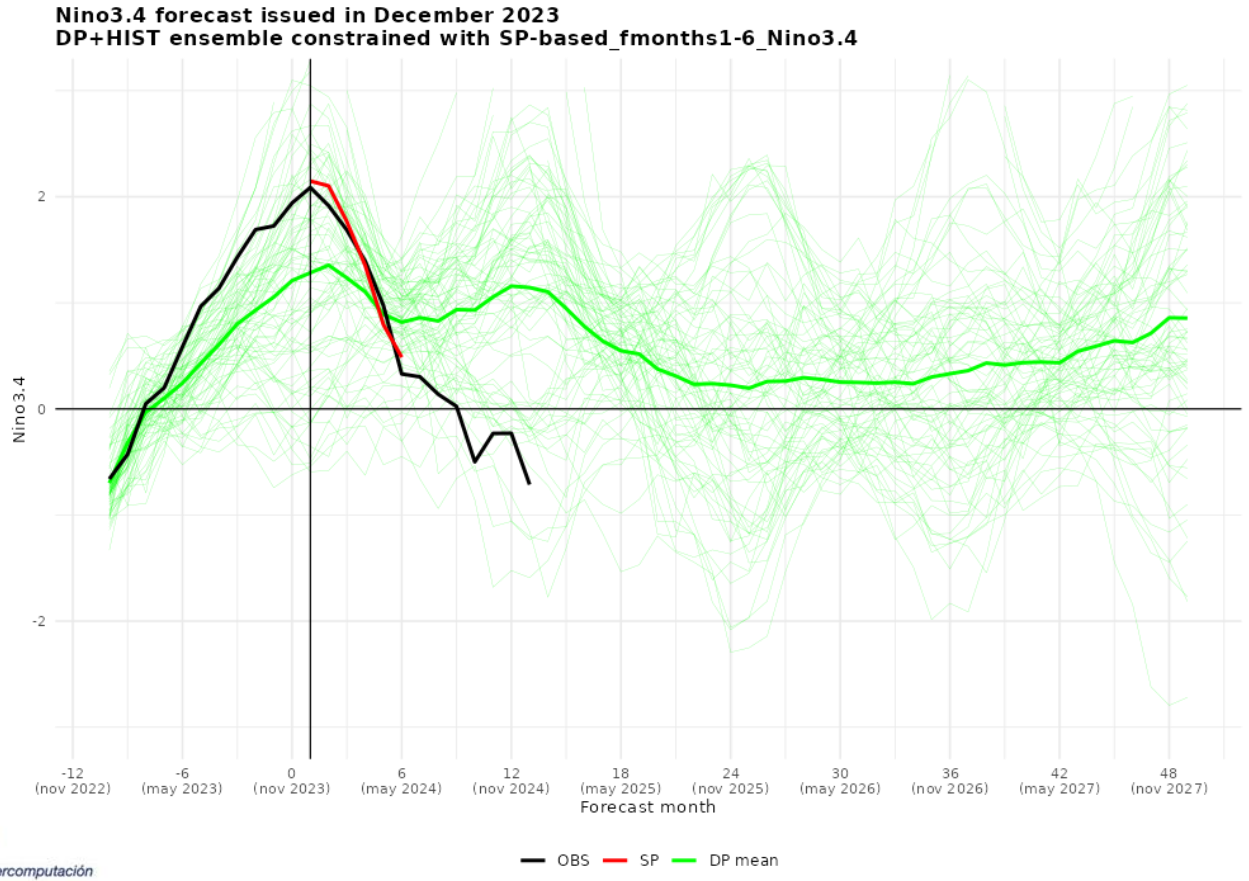
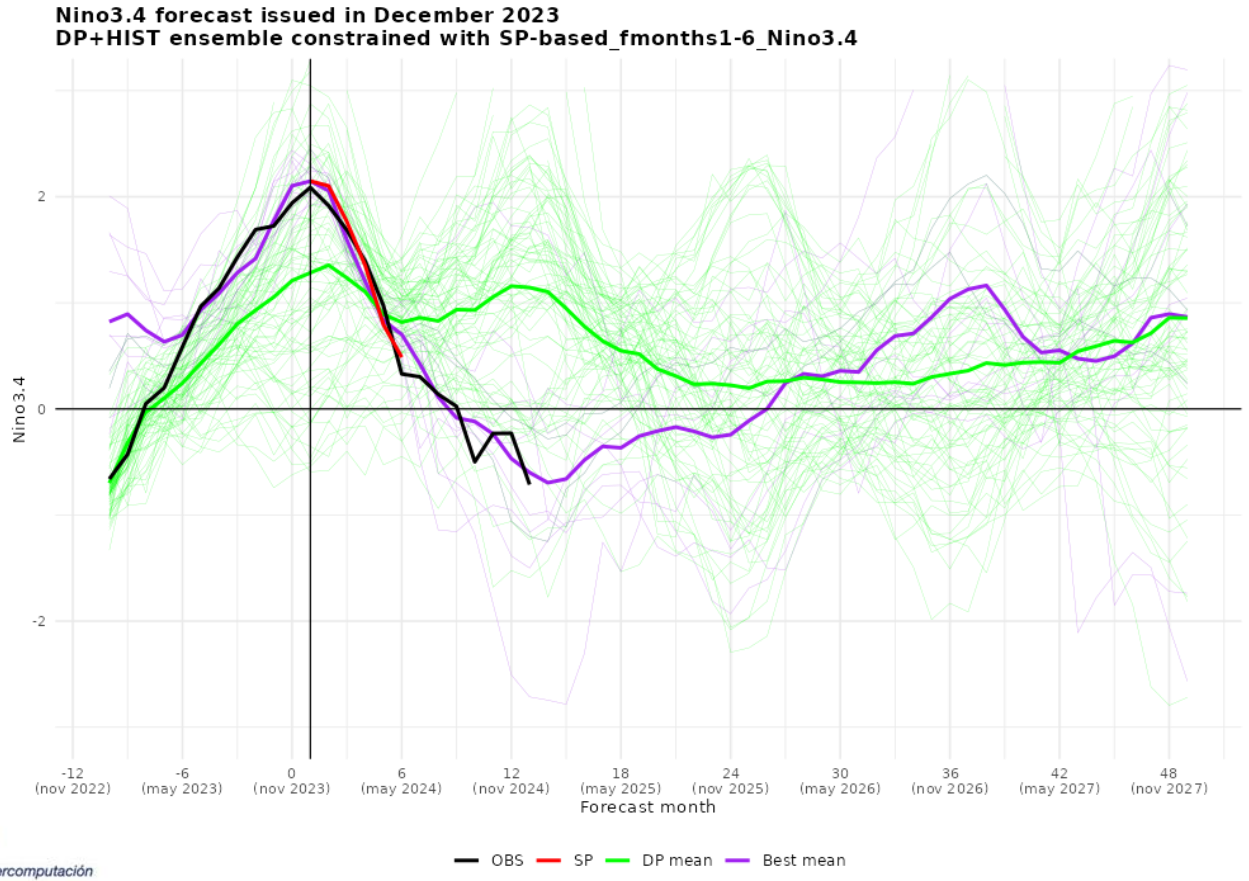


Improving forecast coherence for ENSO



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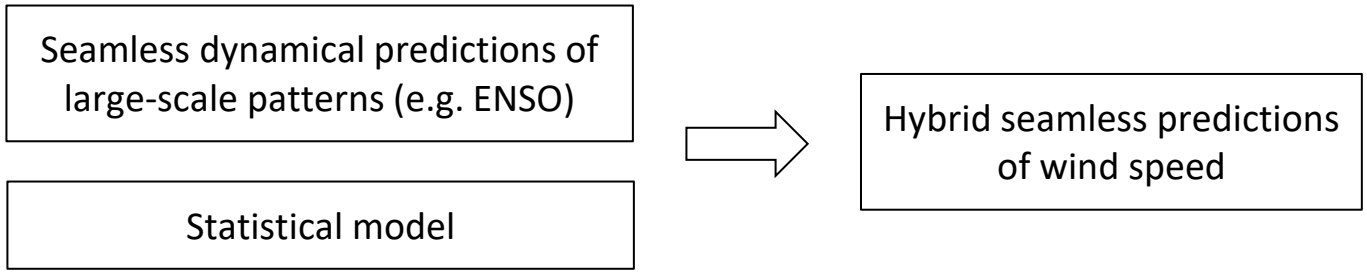
Application for wind speed

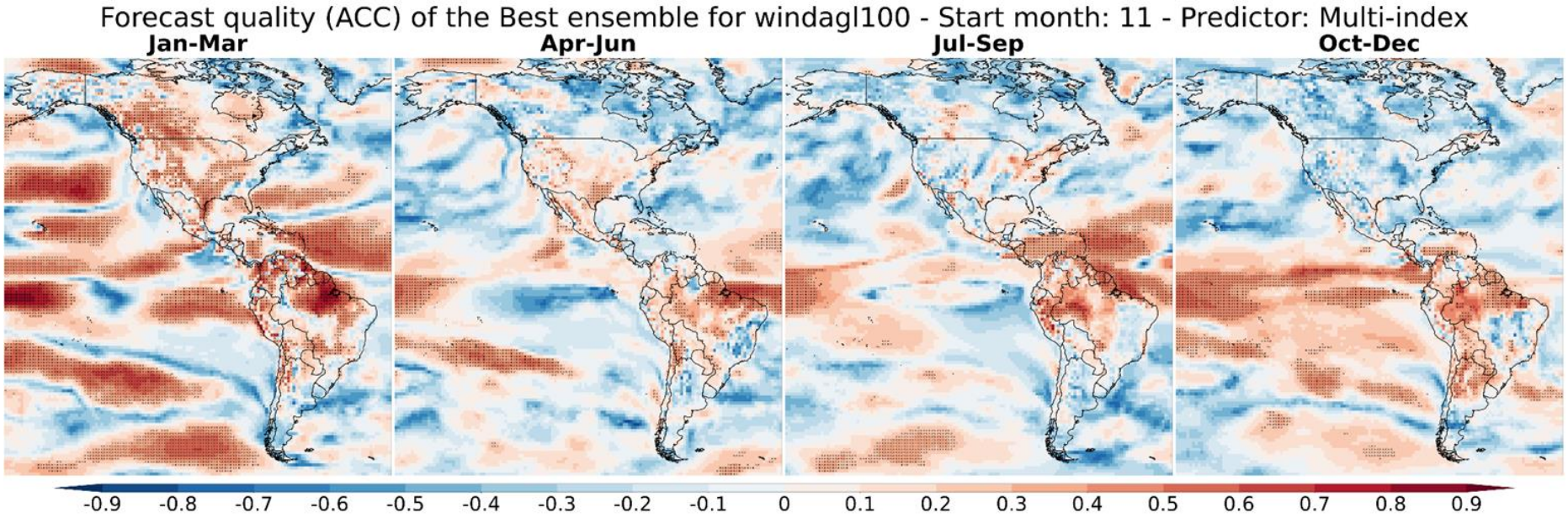
Hybrid (dynamical+statistical) model

- Dynamical forecasts of wind speed at multi-annual time scales have low skill
- Dynamical models are only run once per year
- The idea is **combine dynamical predictions with a statistical model** to predict wind speed
- Approach:
  - Produce seamless S2D predictions of large-scale patterns (ENSO, TAD, IOD, ATL3)
  - Train a statistical model based on large-scale predictors vs wind speed
  - Predict wind speed (both at surface and 100m)



Hybrid (dynamical+statistical) model

Quality of the hybrid forecast issued in November for the next year
Predictors: Niño3.4, TAD, IOD, ATL3



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Indicators


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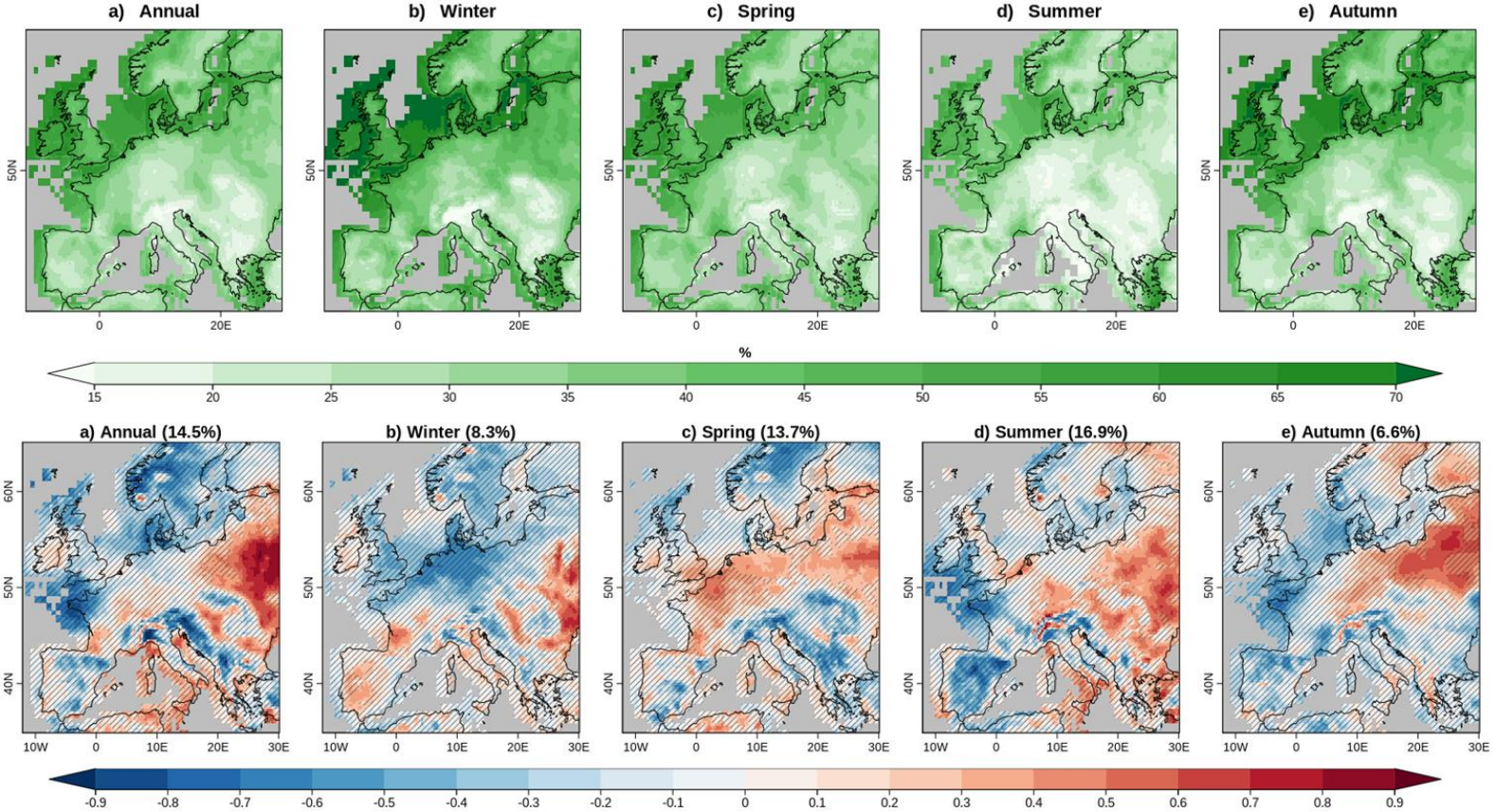
Capacity factor for decadal predictions

Wind CF

ACC (skill)



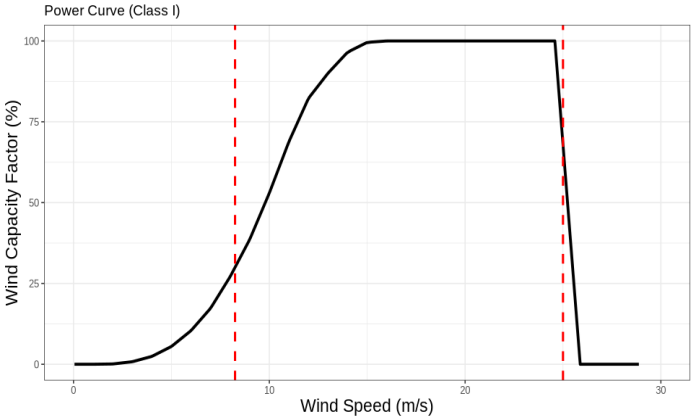
Wind CF: low seasonal variability and higher values offshore than onshore

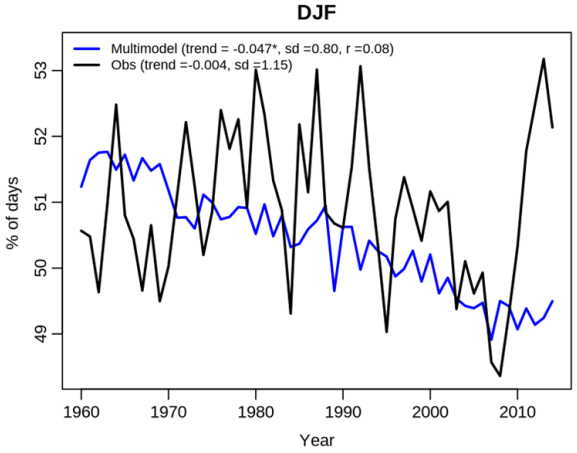
Predictive skill significantly positive only at some parts of central Europe and points of Italy

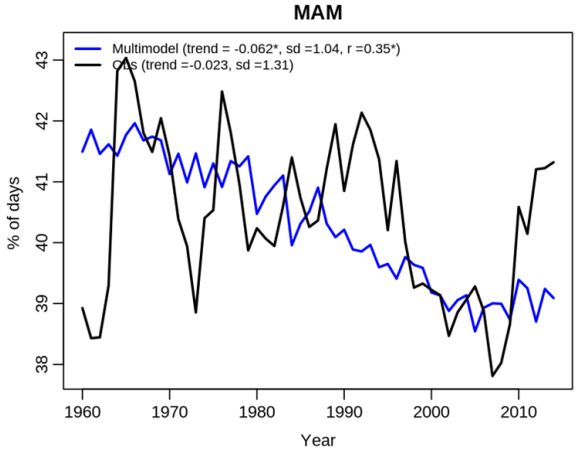
Effective days of wind energy production

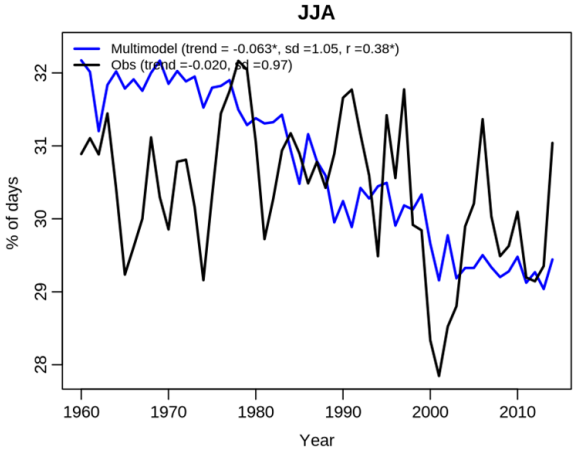
Count of days when wind speed falls between a lower and an upper threshold

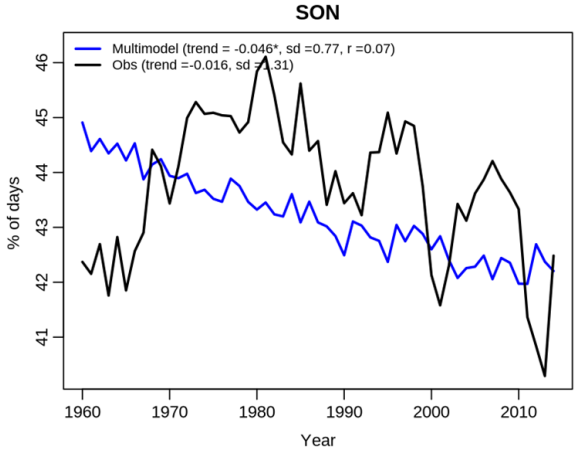
- **Upper threshold (cut-out speed):** Maximum wind speed turbines can safely operate at.
- **Lower threshold:** Wind speed corresponding to the chosen capacity-factor threshold (e.g., CF ≥ 30%).











Driver identification

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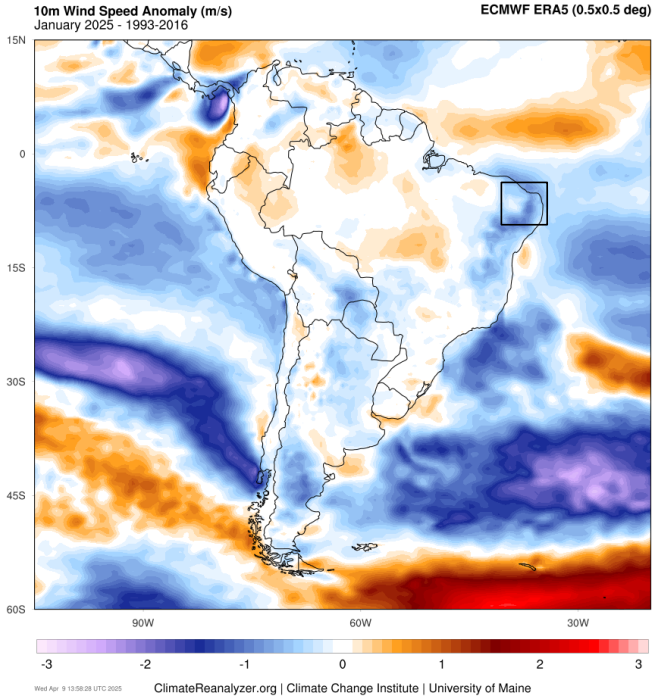
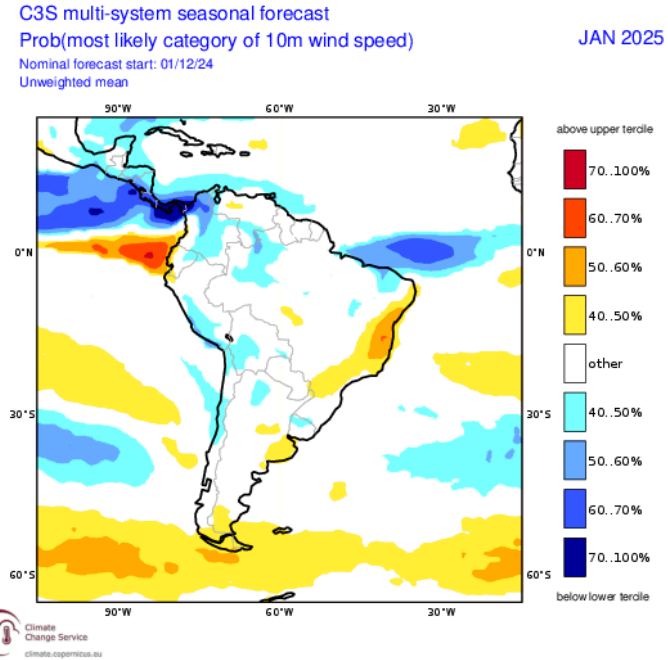
Identification of dynamic drivers

- During January 2025, the Rio Grande do Norte (RGN) region in Northeast Brazil experienced below normal winds which were not anticipated by most seasonal forecasting systems.

➢ What did happen (based on ERA5 data)?



➢ What was forecasted (lead time 1)?

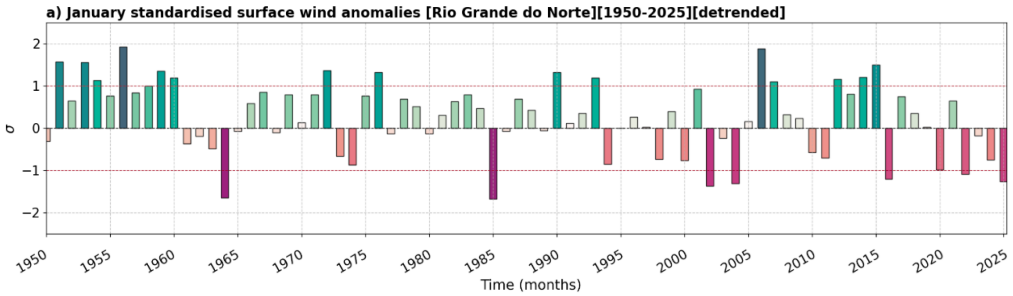


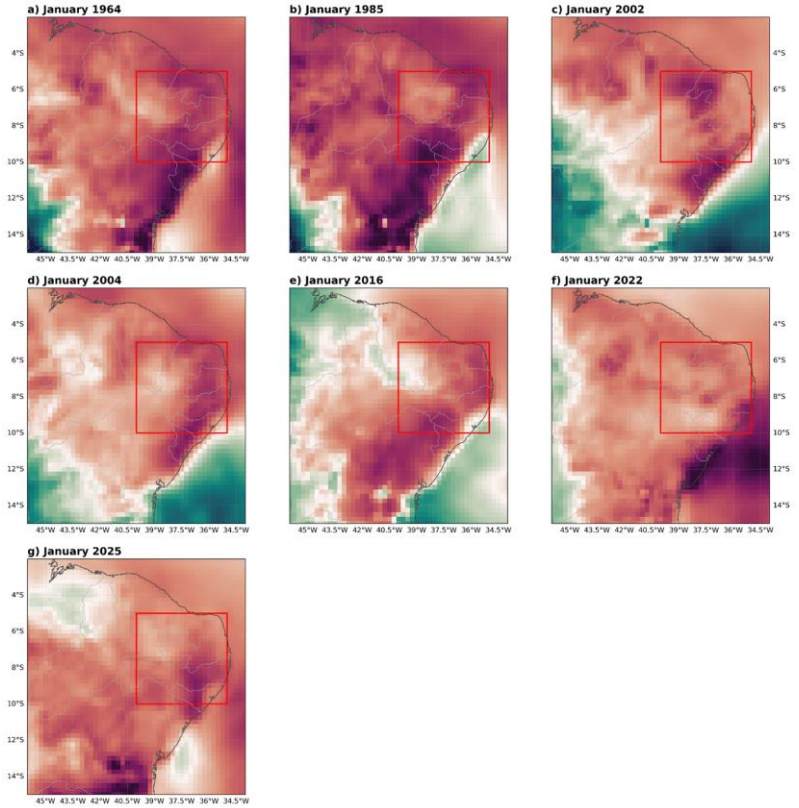
➢ From a total of 8 forecasting systems, only 3 (SEAS5, System8, CPS3) were able to predict the observed climate response, while the rest displayed the complete opposite signal or just normal conditions.

➢ Understanding which physical drivers were behind the anomalous event allows us to diagnose whether an inadequate representation of these dynamic processes in the models led to the failed forecasts (i.e., process-based evaluation).

Identification of dynamic drivers

- Similar event detection:
  - Find events in the reanalysis were the climate response over RGN is similar (based on what happened in January 2025).
  - Compute standardised anomalies and define a sigma threshold (σ = 1.0) to identify similar events which may share common driving mechanisms.

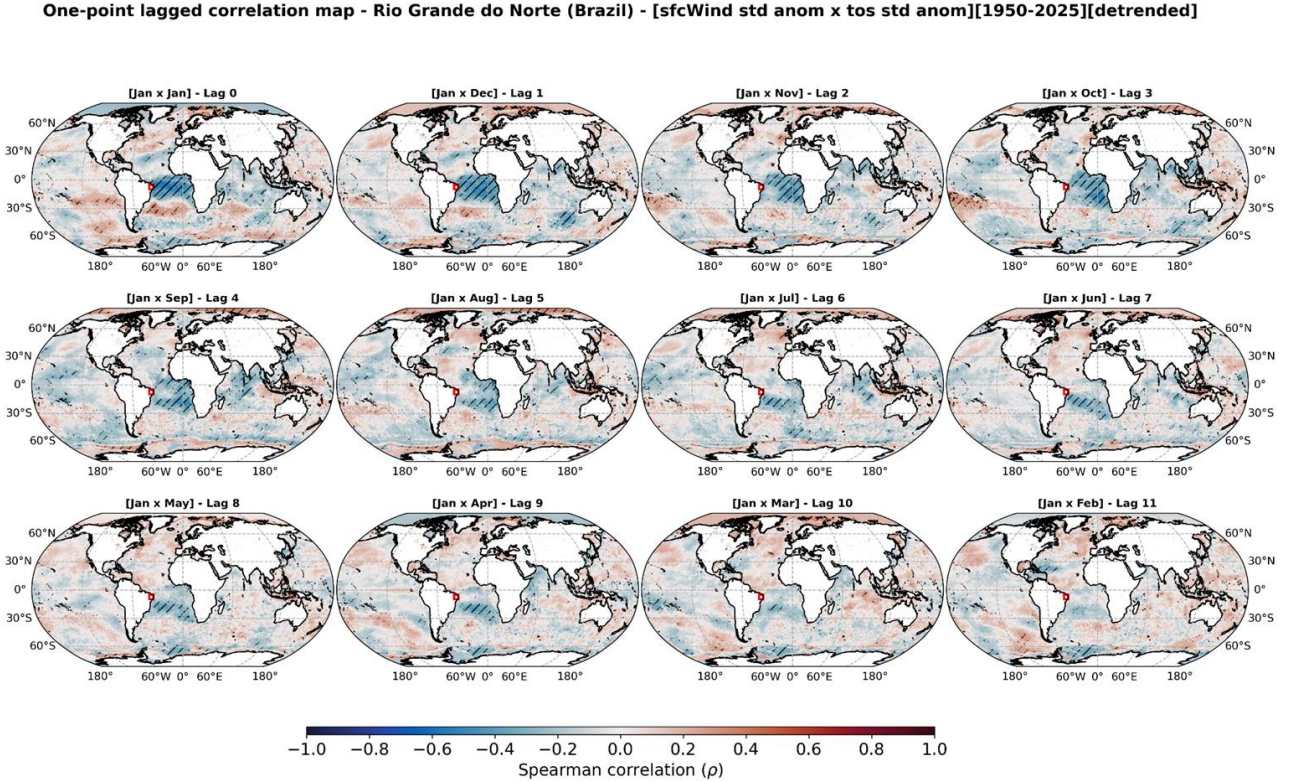




Identification of dynamic drivers

- One-point lagged correlation analysis:
  - Target month: January
  - Period: 1950 - 2025
  - Non-linear detrending by removing climate change signal.

- Surface wind in RGN during January displays strong anti-correlation with the Tropical South Atlantic (TSA) up to lag 5, suggesting a significant influence from the Tropical and Southern Atlantic Dipoles (TAD/SAD).



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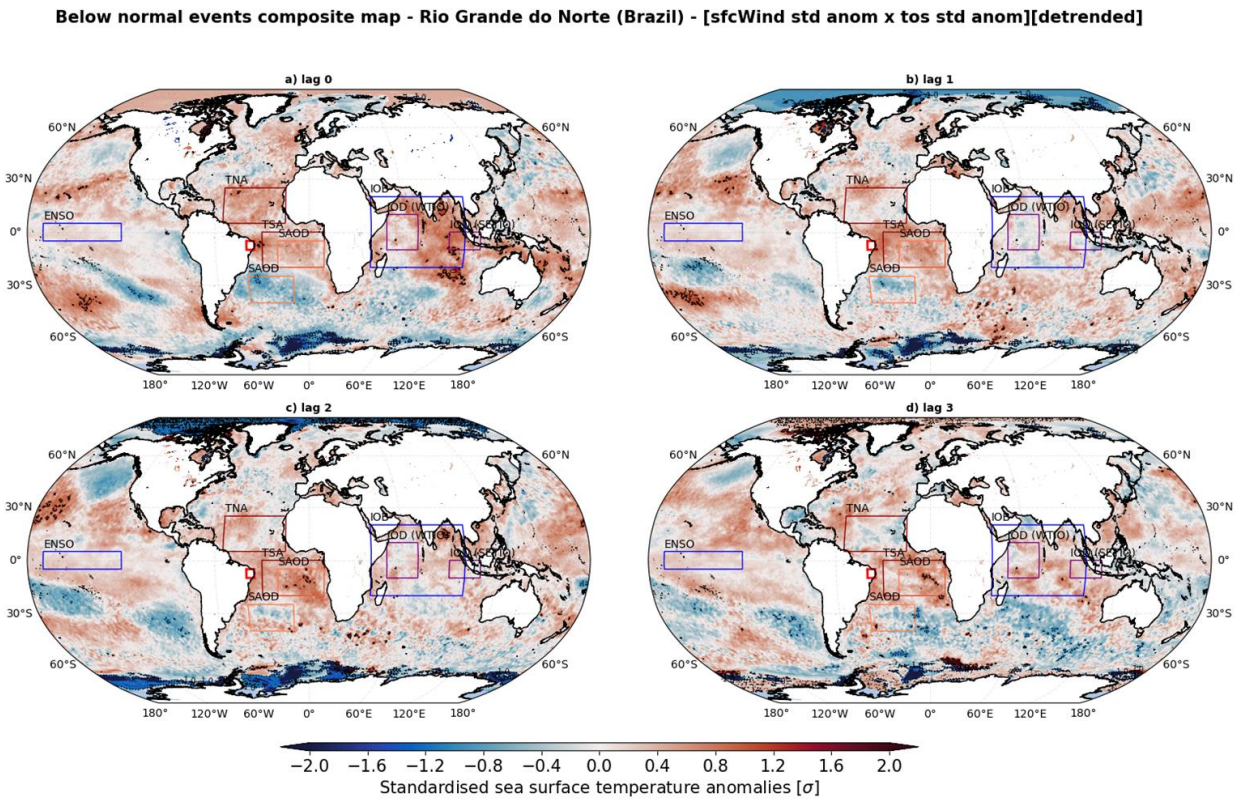
Identification of dynamic drivers

- Conditional compositing analysis:
  - Based on the similar event detection, we compute (lagged) composites of key variables (SST, SLP, geopotential) with the goal of detecting patterns that allow us to identify which dynamic processes (e.g., modes of climate variability) are driving the observed climate response.



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Thank you!

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