Seamless system to forecast climate extremes on multi annual to seasonal timescales

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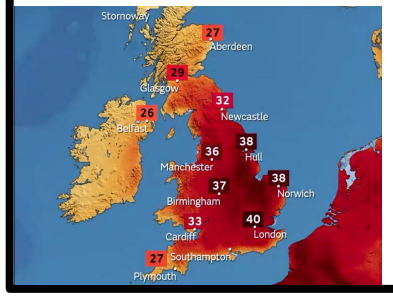
Climate Extremes in Changing change

ASPECT
FACILITATING SEAMLESS CLIMATE ADAPTATION

Heatwaves



UK Heatwave

Source: WMO

Hurricanes and floods

Air pollution

SMOG

South Asia including Pakistan

Source: BBC

Frost Risk

Frost Risk for vineyards

Source: Decanter.com

Climate sensitive diseases

Infectious diseases

Source: Carbon brief

Water, Agriculture, Biodiversity

Source: UN water

Source: Arctic Youth Network

Climate refugees and migration

Somali refugees flee flooding in Dabaab, Kenya (UNHCR)

Finance

e.g. Insurance, Pensions

Source: ortec finance

Forest fires

California fires

Source: Columbia magazine

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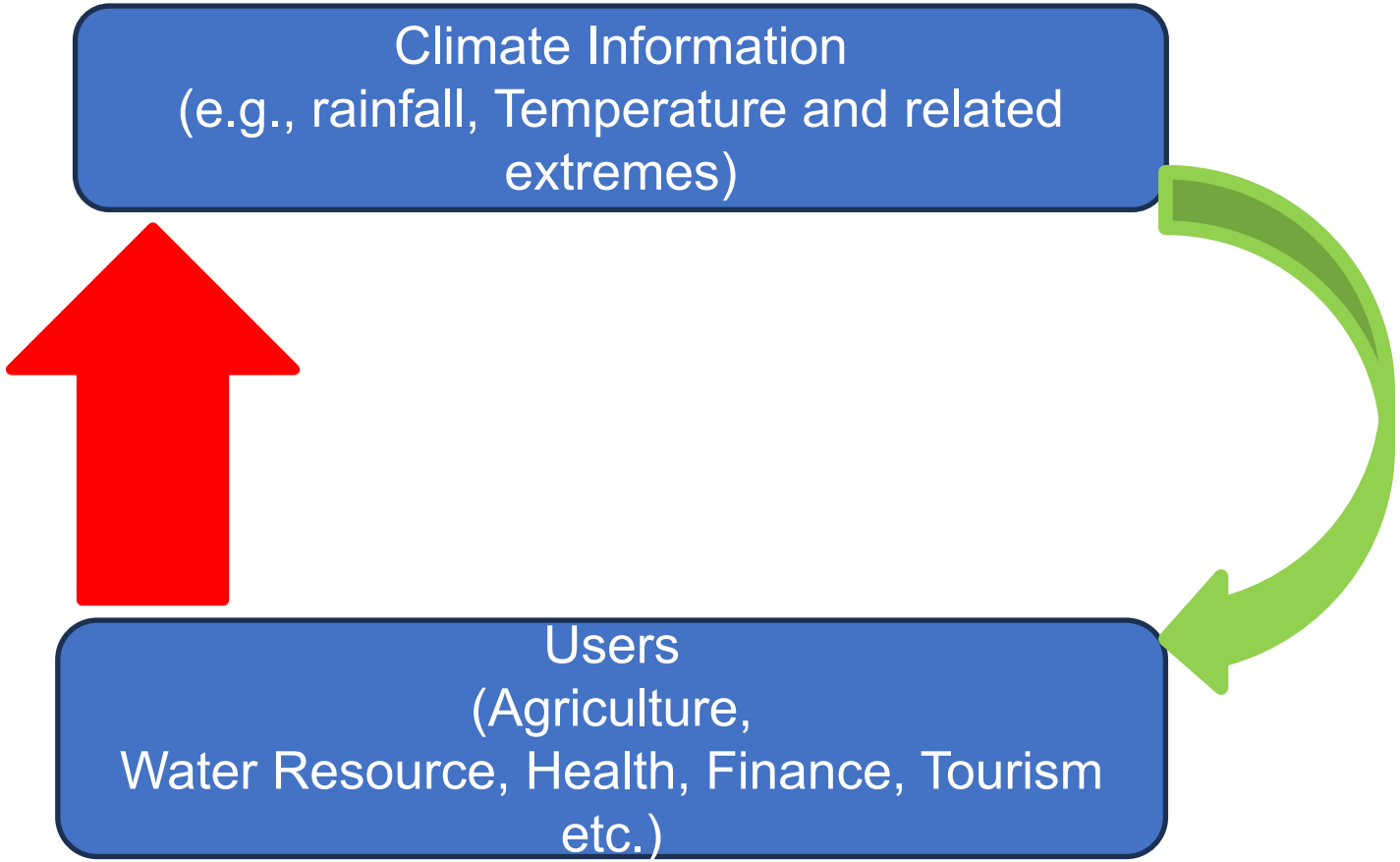
Co-production Framework for climate information



ASPECT: **Adaptation-oriented Seamless Predictions of European Climate**

ASPECT
FACILITATING SEAMLESS CLIMATE ADAPTATION

CASE STUDIES: SEAMLESS DECISION MAKING

	Spatial scale	Climate predictions: Seasonal (1 to 12 months)	Climate predictions: Decadal (Longer than 1 year)	Climate change projections (20 to 30 years)
	Vineyard to region	Management decisions during the growing season (Apr-Sep) to maximise the harvest	Long-term planning and investment decisions	
	Asset level to national scale	Near term investment decision making	Understanding climate risks from climate extremes for mandatory disclosures	Horizon scanning, estimating future pension liabilities, Net Zero ambitions
Governance (EU Mission on Climate Adaptation)	Local to regional	Advancing existing climate services (e.g. irrigation demand forecasts, forecast based impact assessment)	Enhanced climate risk assessment for strategic and operational adaptation planning	
Disaster response during extreme events	Local to national	Seasonal extremes for locating emergency response (e.g. cold waves, storms and wildfire)	Response planning to more frequent weather related disasters	Modelling future operations under climate change
Humanitarian (health & migration)	Regional to international	Predictions of how childhood health impacted by nutrition, water and infection	Supporting health of moving populations	

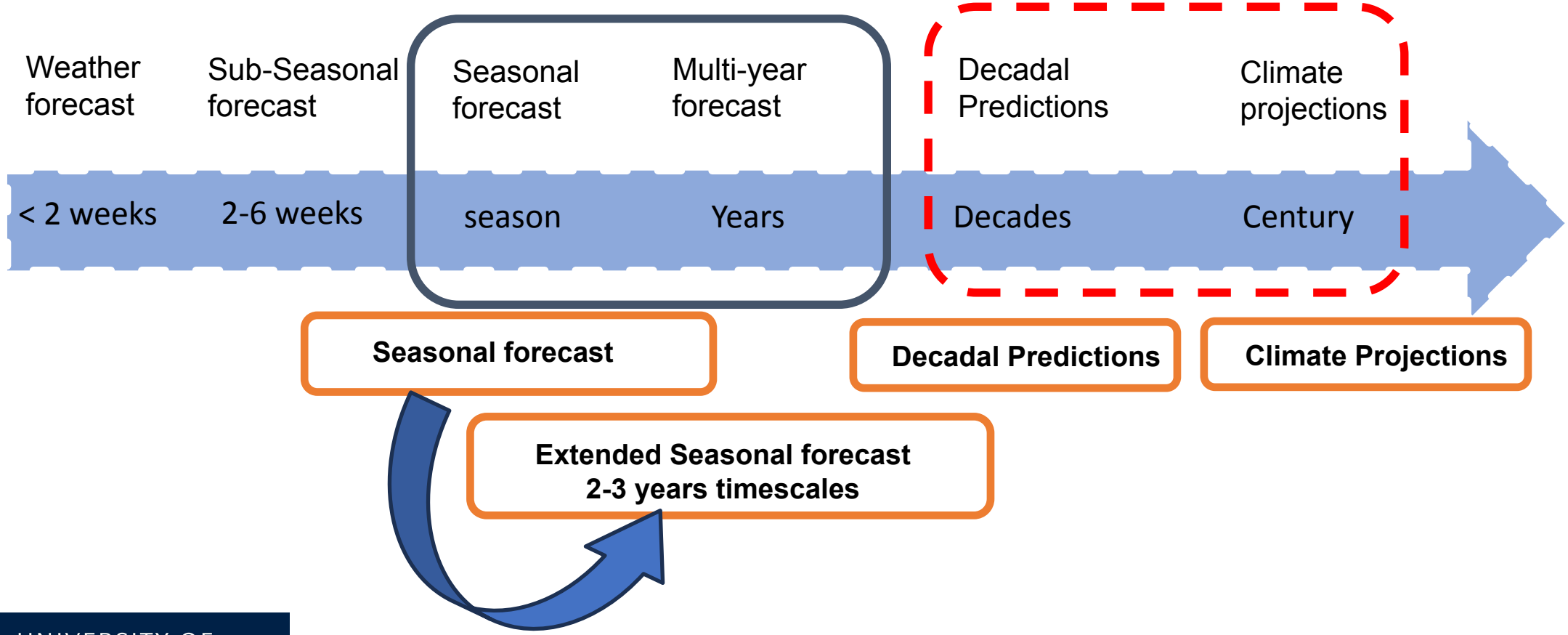
Time scale →

Funded by the European Union

Climate Information on different timescales

Climate forecast on different timescales are available with different modeling system.

Constraining and shadowing methods
e.g., Befort et al. (2020); Mehmood et al. (2021)



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Temporal Merging: Pooling Ensembles

- A new temporal merging method has been proposed for a seamless climate information from a month to 22-month lead times.

Ensembles across from all start dates are pooled together with equal weights.

$$Pooling\ Ensemble = \sum_{i=1}^{K} W_i F_i(m, x, y)$$

Where "i" represents each forecast start date, "K" total start dates, W is the weighting function and F represents forecast.

Merging

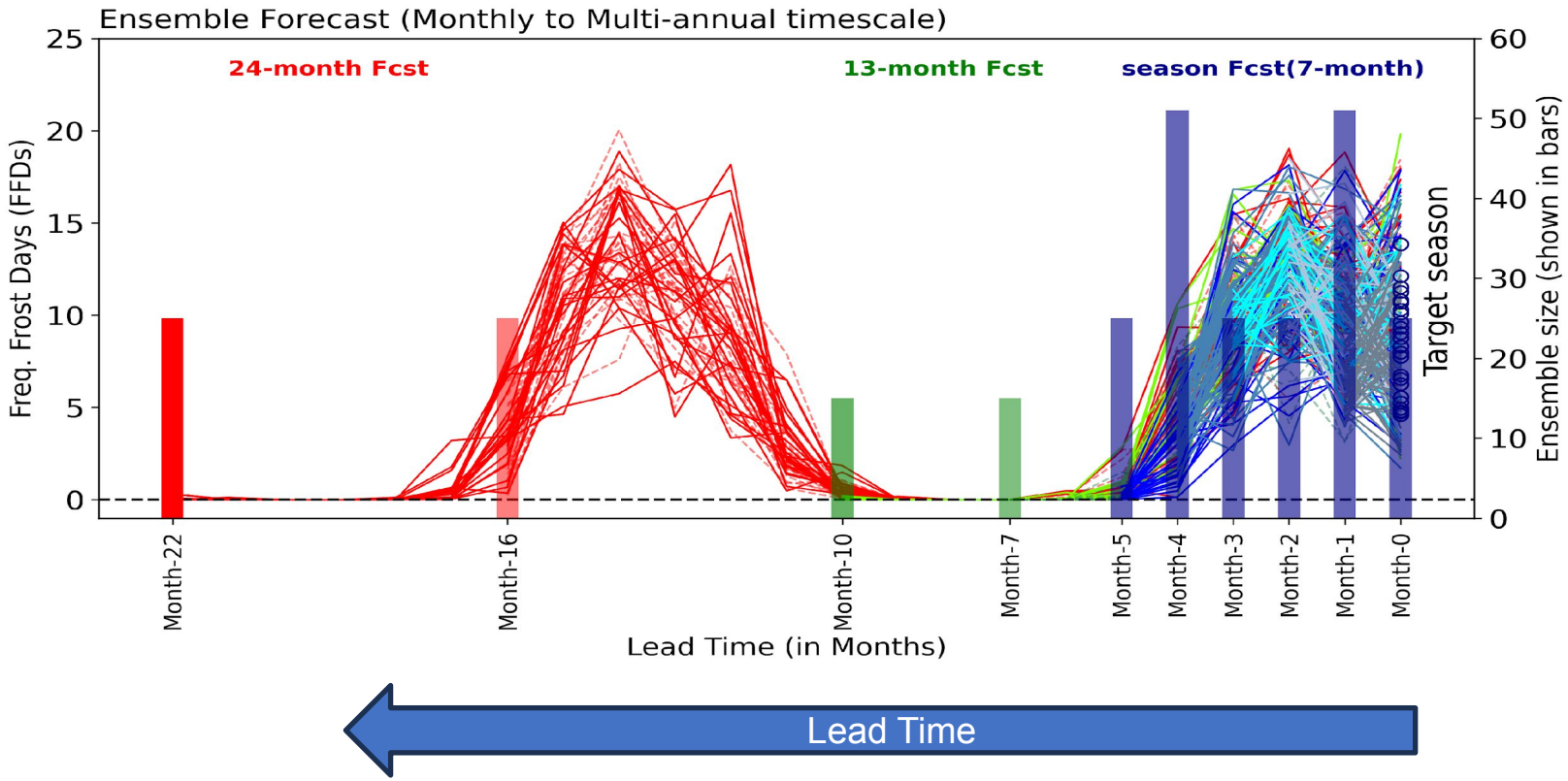
Source: Abid et al. 2025 in preparation

Temporal merging: Monthly to multi-year timescales

Seamless climate information on monthly to 22-month lead timescale for tailored climate extremes.

Example:

Forecast Frequency of Frost days (FFDs)



Source: Abid et al. 2025 in preparation

Main Advantages of the Temporal Merging

- Three main advantages of temporal merging

Seamless Forecast

- Connects different timescales into a single system.

Large Ensemble size

- Reduce Errors.
- Stable and persistence in forecast.

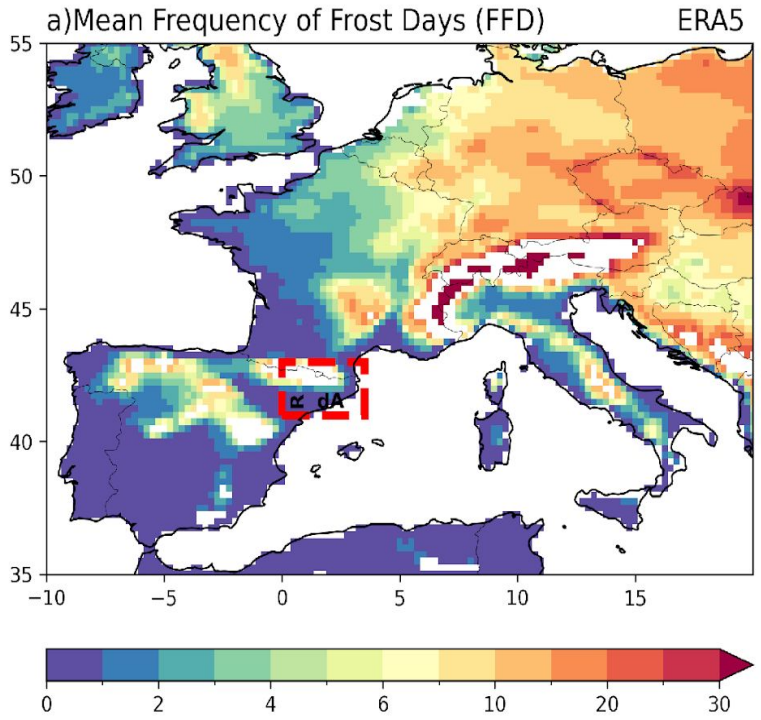
Additional information

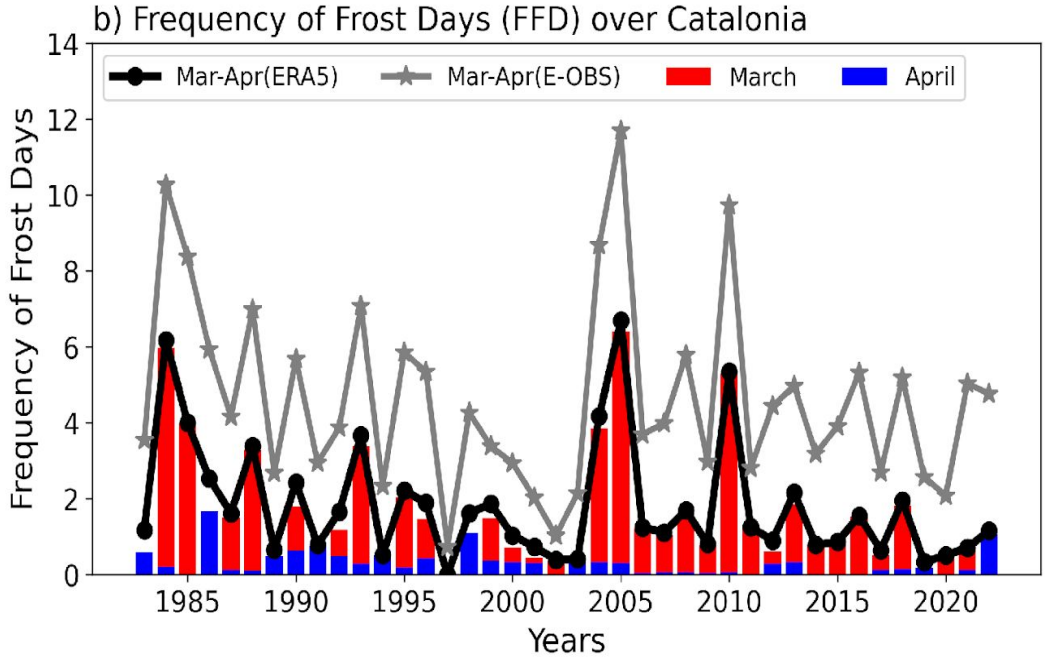
- Add useful information from different start dates without any additional cost to the system .

Source: Abid et al. 2025 in preparation

Observed Frequency of Frost days (FFD)

- Frequency of the Frost days (FFD) over Catalonia region is defined based on minimum temperature less than 0℃ for each grid point for the period 1983-2024.

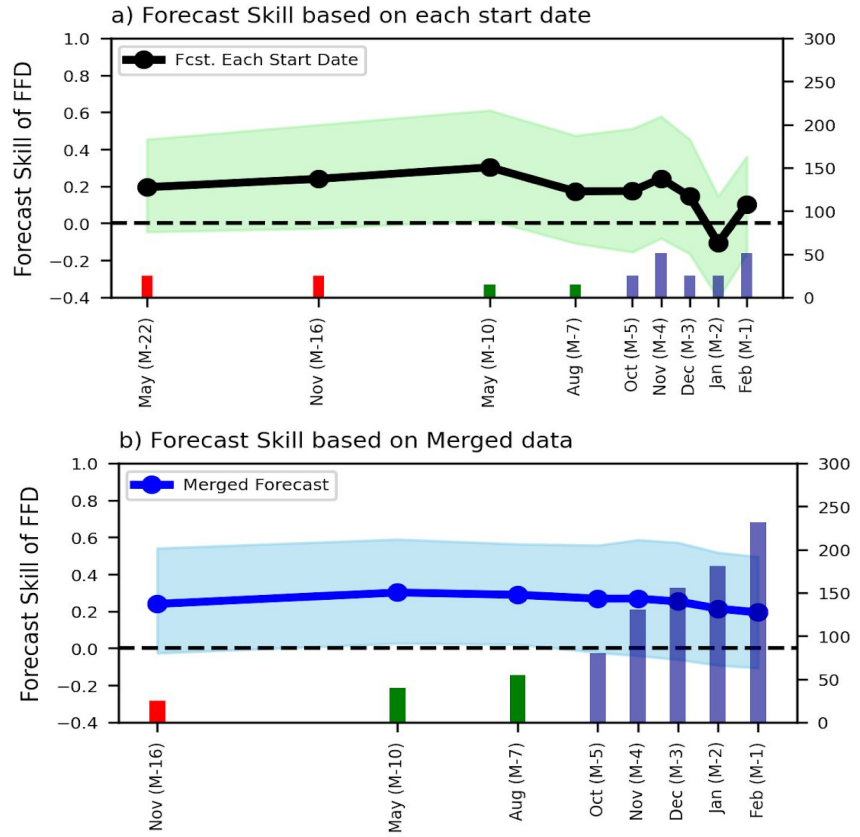




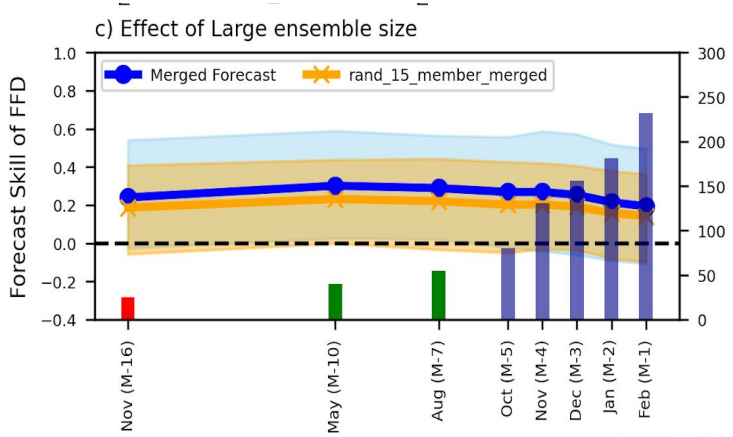
Source: Abid et al. 2025; in preparation

Forecast (Temporally Merged vs Each start date)

1- Seamless Forecast

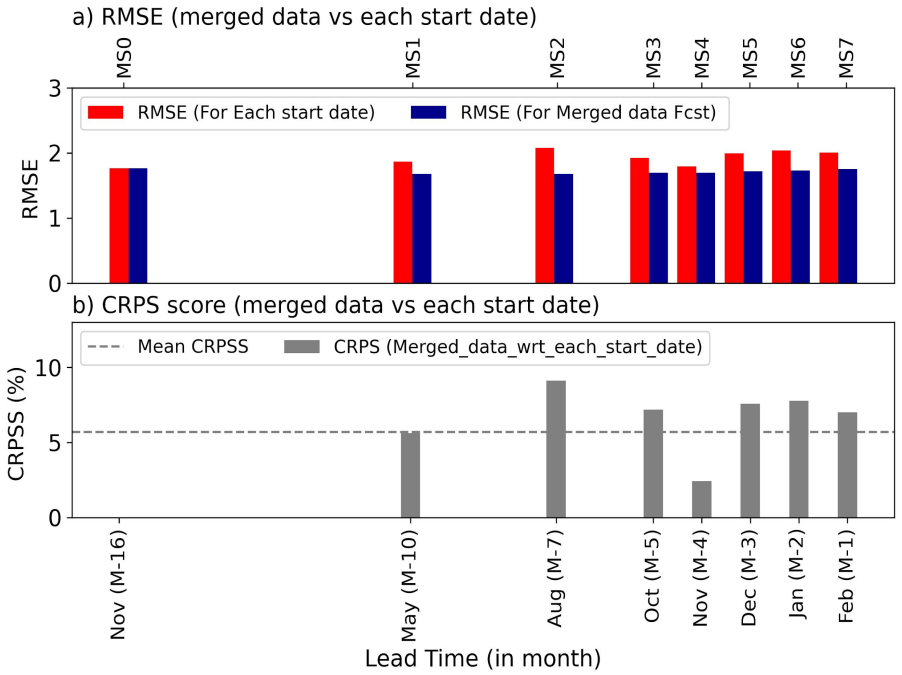


2- Large Ensemble size



- About 30% of the forecast skill is added to the Jan. Start date.
- About 5-10% forecast skill is attributed to the large ensembles.

3- Additional information



Source: Abid et al. 2025 in preparation

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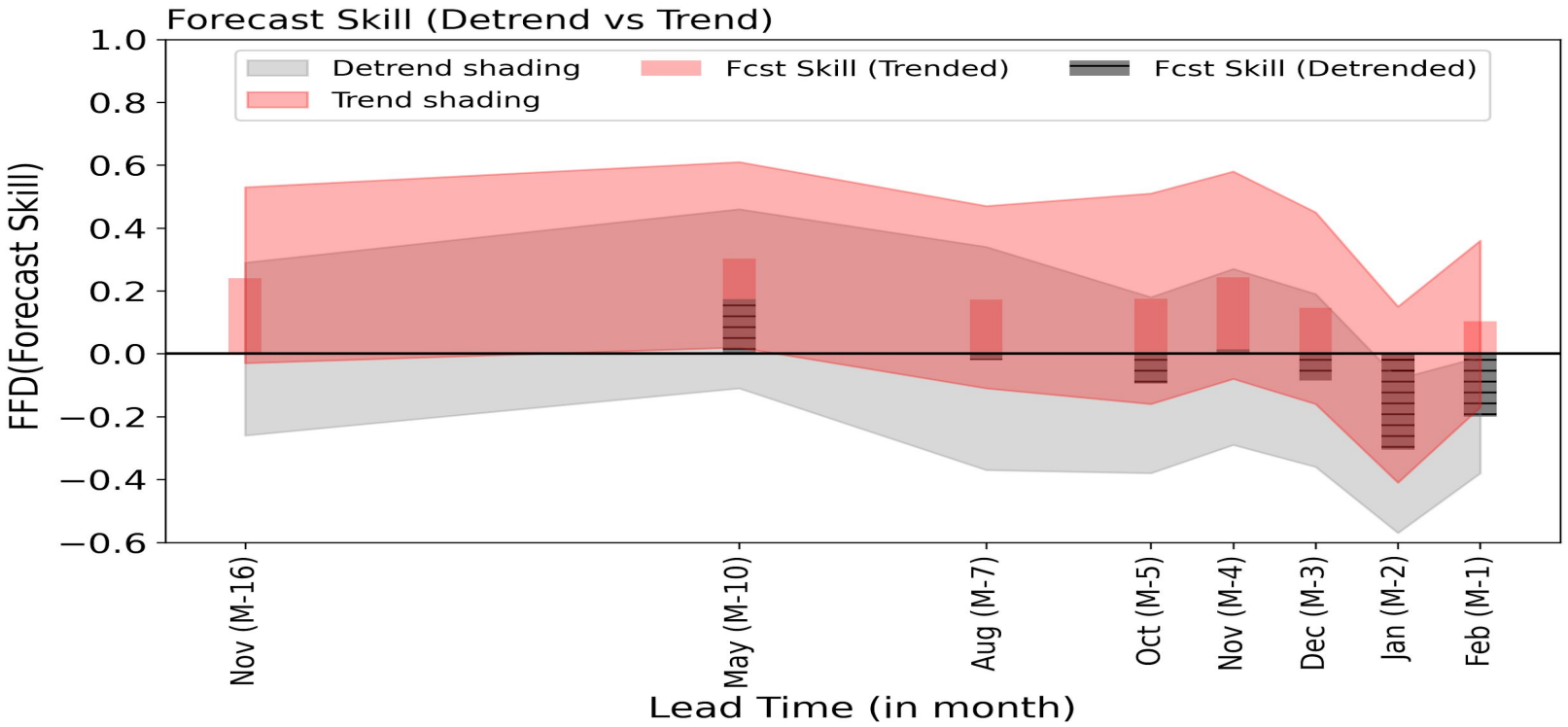
Forecast Skill (Trends vs variability)



- Most of the forecast skill is related to the long term trends.
- For May (M-10) the forecast skill of FFDs are 60% explained by the internal variability.

Source: Abid et al. 2025; in preparation

Framework for Actionable measures

Long lead time forecast, risk indicated to users.

Start preparing for potential hazards, training people etc.,

Keep on monitoring forecast as new forecast come is..

Persistent Forecast indication, helps to alarm the community.

At short lead, in conjunction to seamless forecast, sub-seasonal and weather forecast will also be helpful.

Combining weather and climate information helps to take final measures that minimize losses expected due to climate extremes.

Source: Abid et al. 2025; in preparation

Summary

- Seamless forecast system is proposed to forecast climate extremes on multi-year to monthly lead timescales.
- Ensemble members are pooled together from lead time (M-16 to M-1), provides large ensemble members, that reduce errors and provide stable forecast.
- In merged forecast ensemble members from prior start dates carry useful information, without any additional cost, add value of about 5 to 30% forecast skill, with maxima noted for January start date.
- For most of the start dates, FFD's forecast skill is modulated by long term trends except of May (M-10).
- ***Ready-Steady-Go*** framework is proposed to the users, where they can monitor the forecast and take actions.

Source: Abid et al. 2025 in preparation