

Revisiting Variability of Atmospheric Predictability

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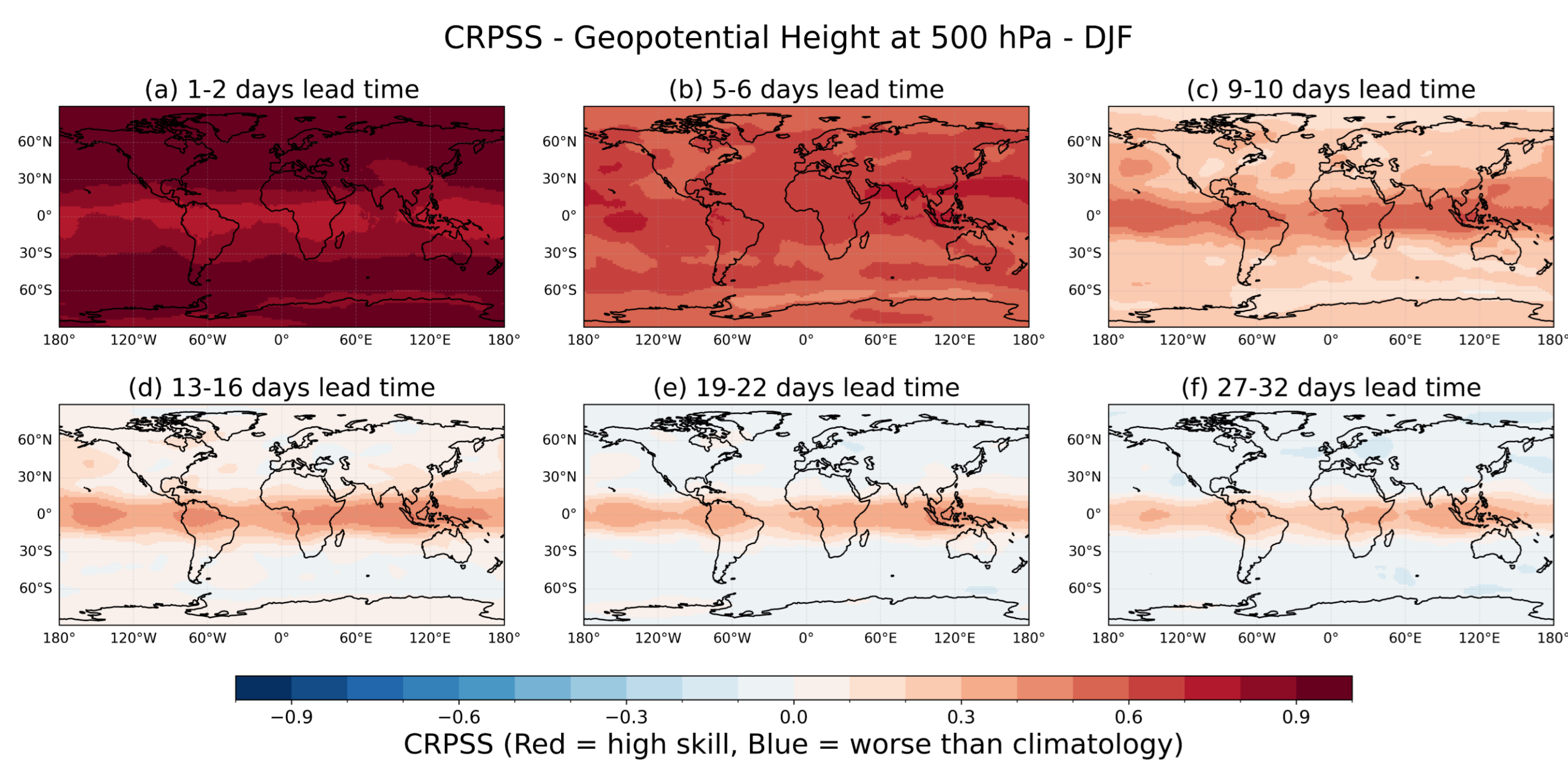
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Motivation

Predictability limits are commonly estimated at ~two weeks, and typically assessed using global- or extratropical-mean error in geopotential height, yet **relatively little is known regarding spatial and seasonal variation** and sensitivity to variable and metric. Moreover, some events within a given region are highly unpredictable, whereas others retain a prolonged influence from initial state.

We revisit the variability of atmospheric predictability, on medium-range to sub-seasonal timescales, and characterize atmospheric memory across the full distribution.

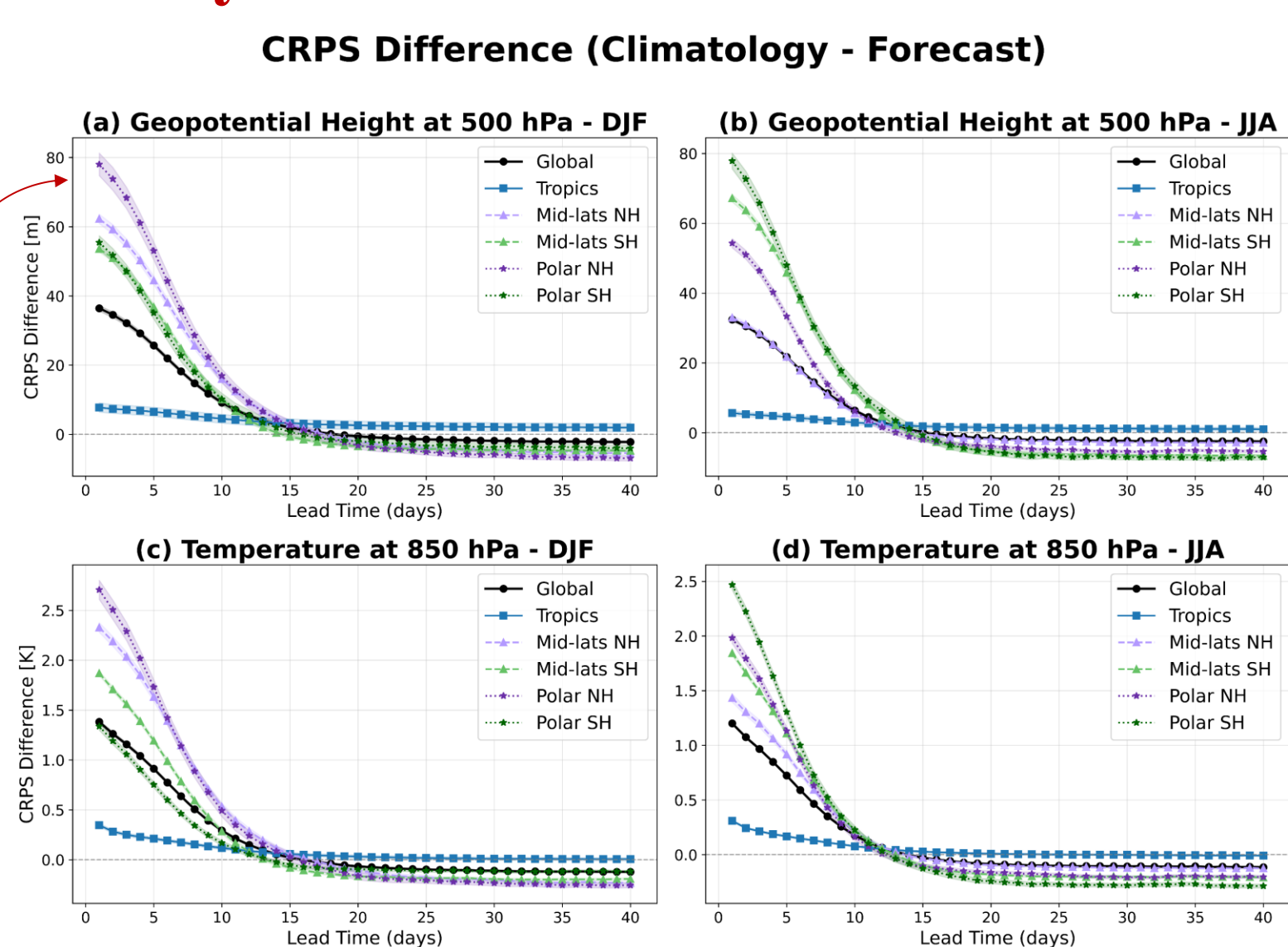
1. Spatial pattern of forecast skill



- ❖ Extra-tropical skill initially higher; **tropics remain predictable for longer.**
- ❖ Significant longitudinal variations: longer DJF predictability over North Pacific vs North Atlantic; Maritime Continents tropical hot spot.
- ❖ Lower and shorter skill in the poles vs mid-latitudes.

2. Regional and seasonal variability

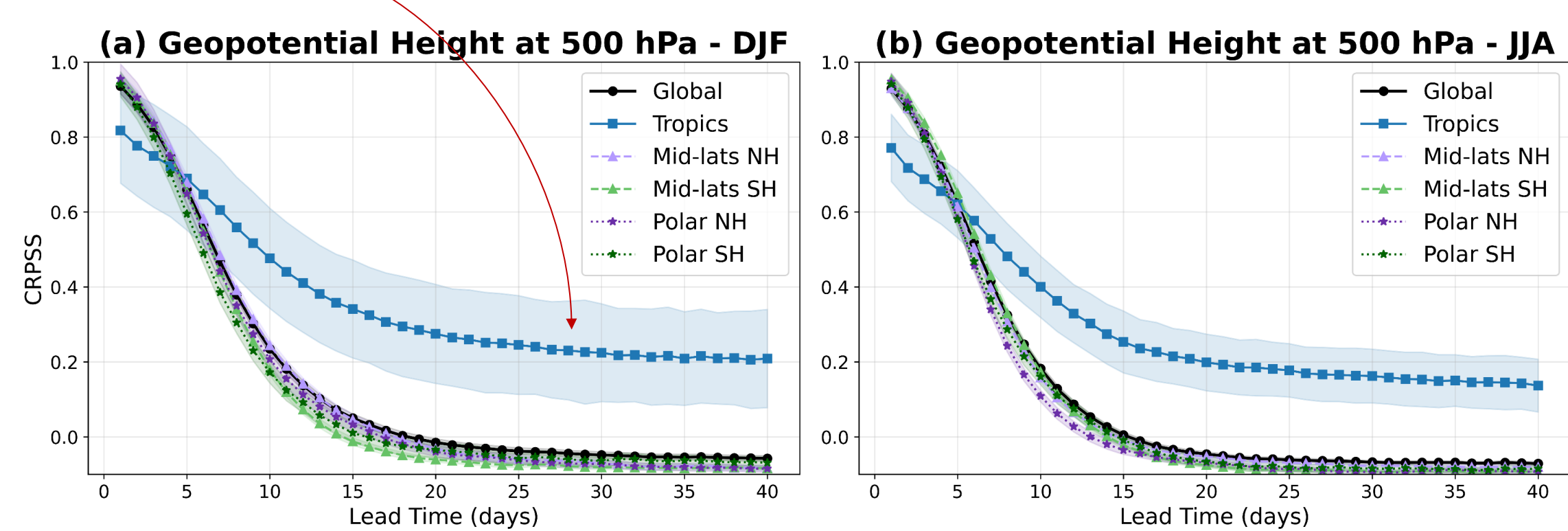
- ❖ Extra-tropical **predictability is longer in winter-hemispheres.**
- ❖ Longer Z500 skill than T850.
- ❖ Longer tropical predictability in DJF.
- ❖ **Tropical Z500 CRPSS does not reach zero at saturation.**



$$CRPS_{diff} = CRPS_{clim} - CRPS_{forecast}$$

$$CRPSS = 1 - \frac{CRPS_{forecast}}{CRPS_{clim}}$$

Regional CRPSS vs Lead Time



Methods

Data:

- Forecast: ECMWF IFS S2S ensemble hindcasts (cycle 49r1); 20 years (2005-2024); initialized every other day; 40 lead times; 10 ensemble members; resolution of ~30 km.
- Verification using ERA5 reanalysis.
- Reference: climatological ensemble - observations of a given day of year over 18 years, +- 15 days window = 558 ensemble members.
- Variables: geopotential height at 500 hPa and 200 hPa and temperature at 850 hPa.

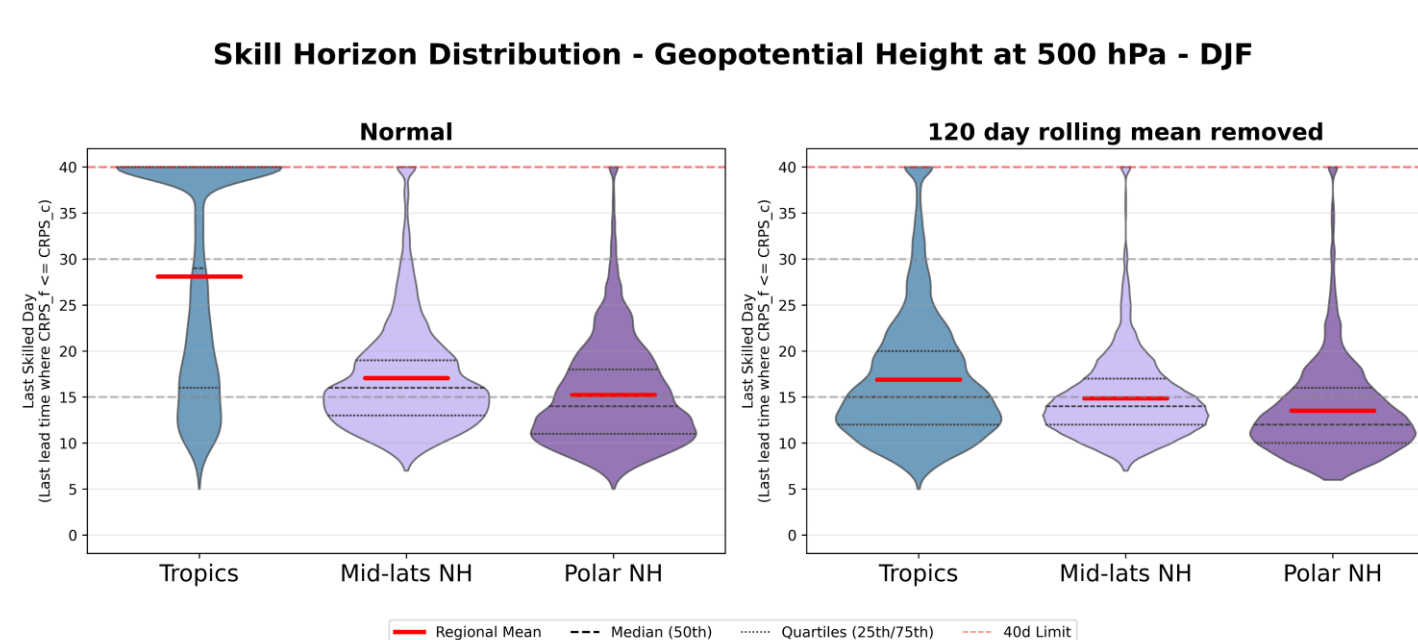
Metrics: continuous ranked probability score (CRPS) as a measure of practical predictability, and difference kinetic energy (DKE) as an estimate of ensemble coherence and intrinsic predictability (results not shown here).

3. Is the high tropical skill at long leads real or an artifact of climatology design?

We remove the 120-day rolling mean from the climatological ensemble

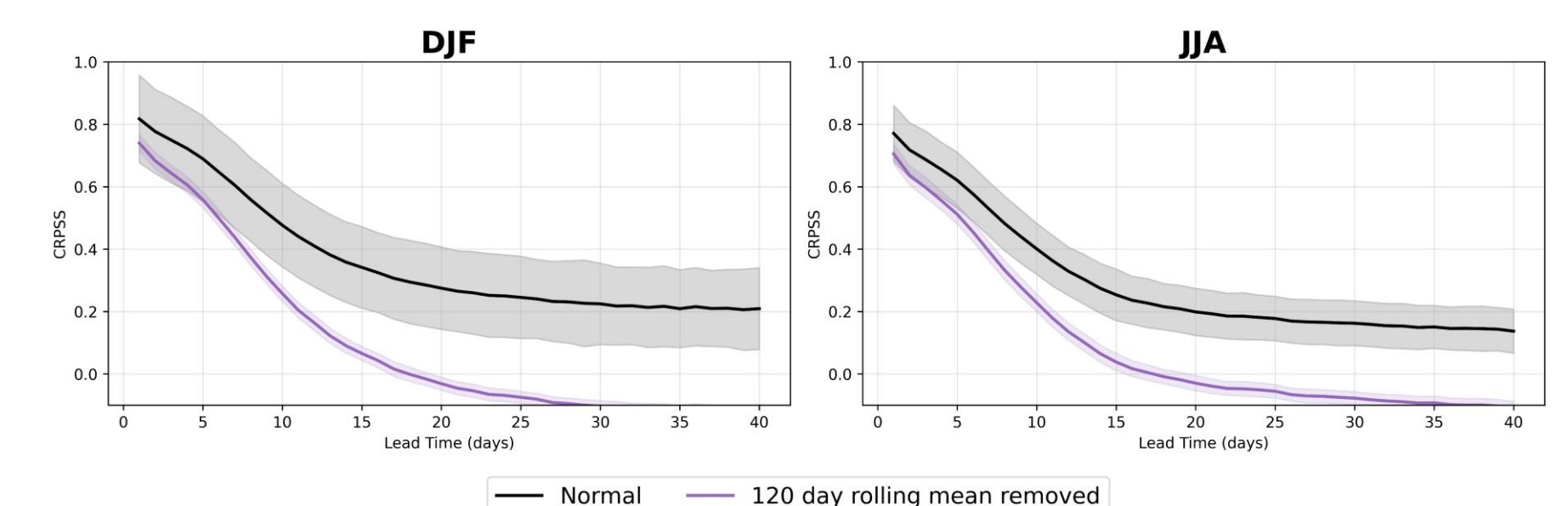
CRPS of climatology improves

Reduced tropical skill score



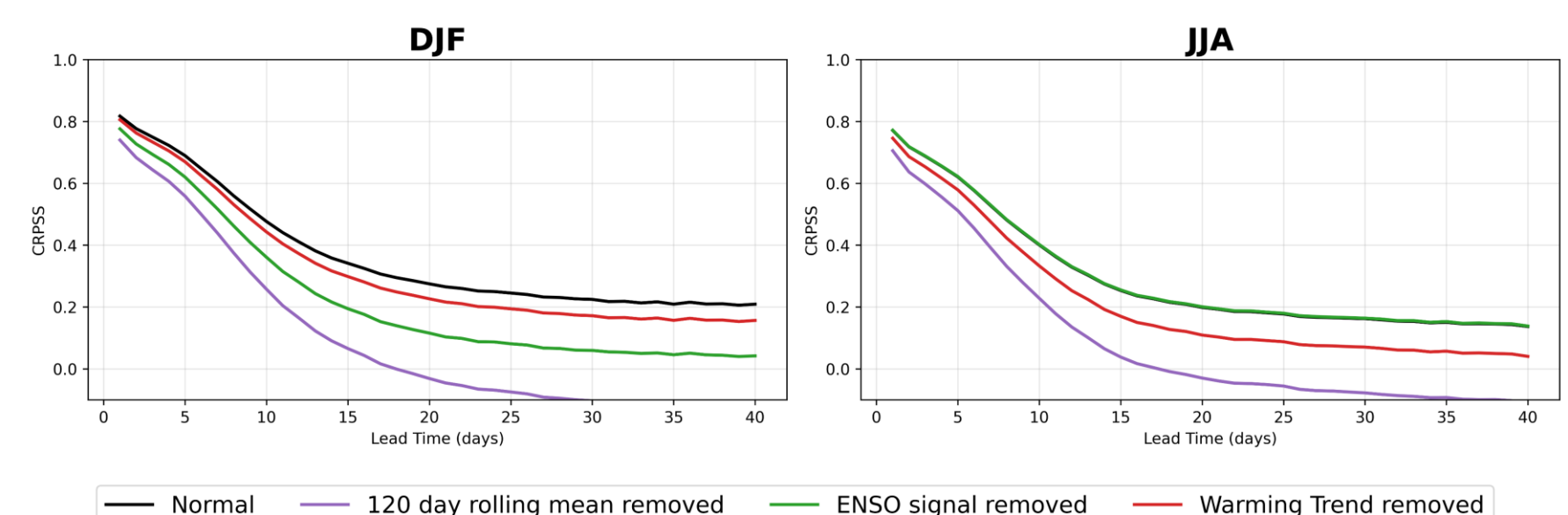
Removing the rolling mean reduces long-skill-horizon days in the tropics; shortens predictability limits also in the extra-tropics.

Regional CRPSS vs Lead Time - Geopotential Height at 500 hPa - Tropics



Rolling seasonal filtering of climatology removes long-lead plateauing; reduces skill score in all lead times; less uncertainty in the mean.

Regional CRPSS vs Lead Time - Geopotential Height at 500 hPa - Tropics

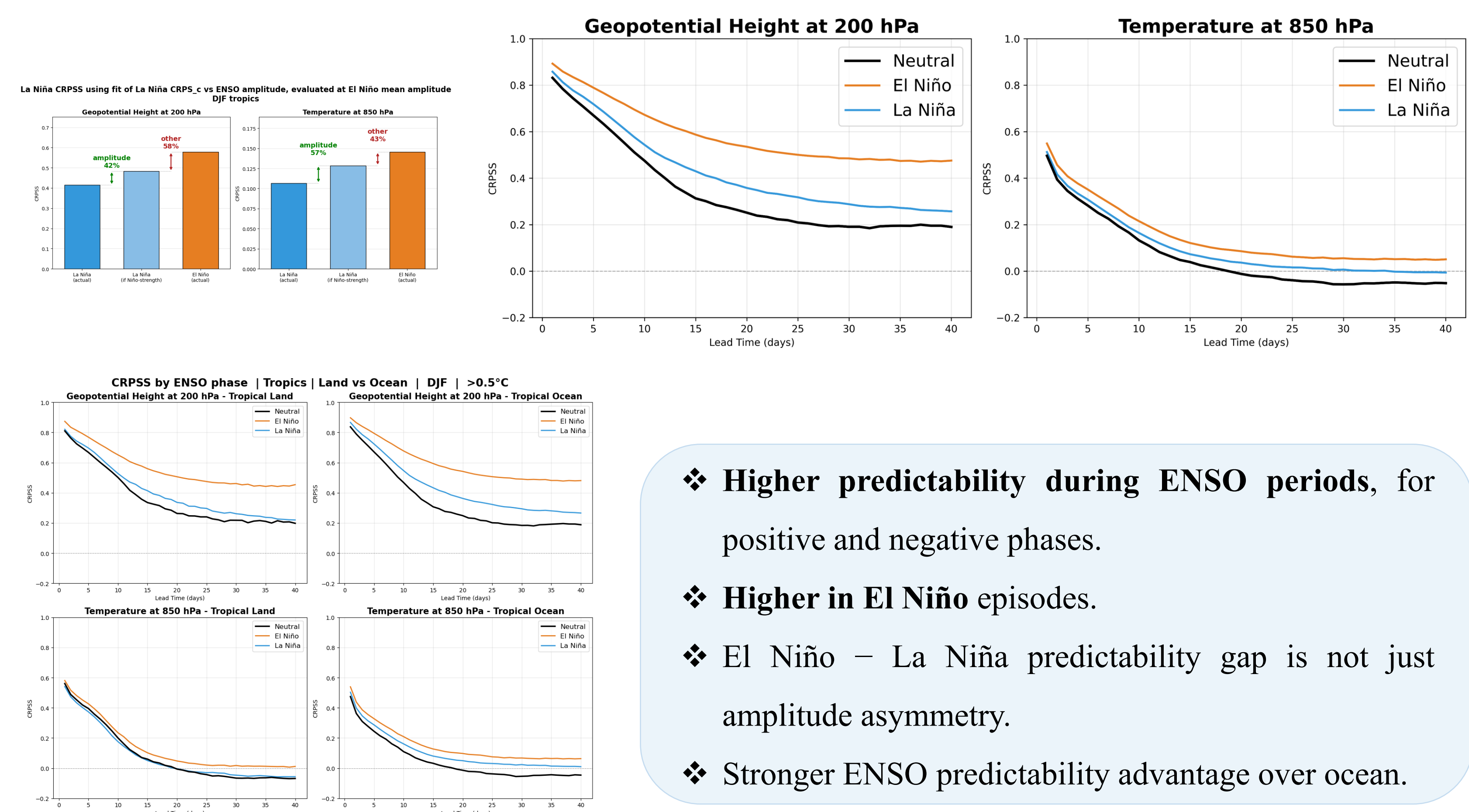


In DJF: rolling seasonal filtering effect is partially realized by removing ENSO signal; in JJA: partially realized by removing the warming trend.

4. ENSO composites

CRPSS by ENSO phase - Tropics - DJF

Neutral: 150 d | El Niño: 294 d (>0.5°C) | La Niña: 430 d (<-0.5°C)



- ❖ **Higher predictability during ENSO periods**, for positive and negative phases.
- ❖ **Higher in El Niño episodes.**
- ❖ El Niño – La Niña predictability gap is not just amplitude asymmetry.
- ❖ Stronger ENSO predictability advantage over ocean.

Key Findings so far:

- The tropics have longer predictability limits than the mid-latitudes (in agreement with previous studies).
- Extra-tropical predictability peaks in winter; tropics show maximum skill in DJF.
- Tropical predictability is sensitive to inter-annual variability of the climatological ensemble.
- Removing the rolling seasonal mean from the climatological ensemble reduces predictability (both skill and limits), particularly in the tropics.
- ENSO activity enhances tropical predictability, especially during El Niño.
- Oceanic predictability benefits more from ENSO modulation than continental regions.

¹Judt, F. (2019). Atmospheric predictability of the tropics, middle latitudes, and polar regions explored through global storm-resolving simulations.²Buizza, R., & Leutbecher, M. (2015). The forecast skill horizon.