Temperature trends in seasonal forecast models

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Introduction and global mean trends

We analyse temperature trends during DJF (initialised in November) and JJA (initialised in May) in seasonal prediction systems contributing to the Copernicus Climate Change Service (C3S) multi-model ensemble during the common hindcast period 1993-2016.

For global mean temperature, almost all seasonal prediction systems tend to warm significantly faster than reanalyses and observations already during the first forecast season (Fig 1).

Many of these prediction systems share the same ocean model and use the same data for initialisation.

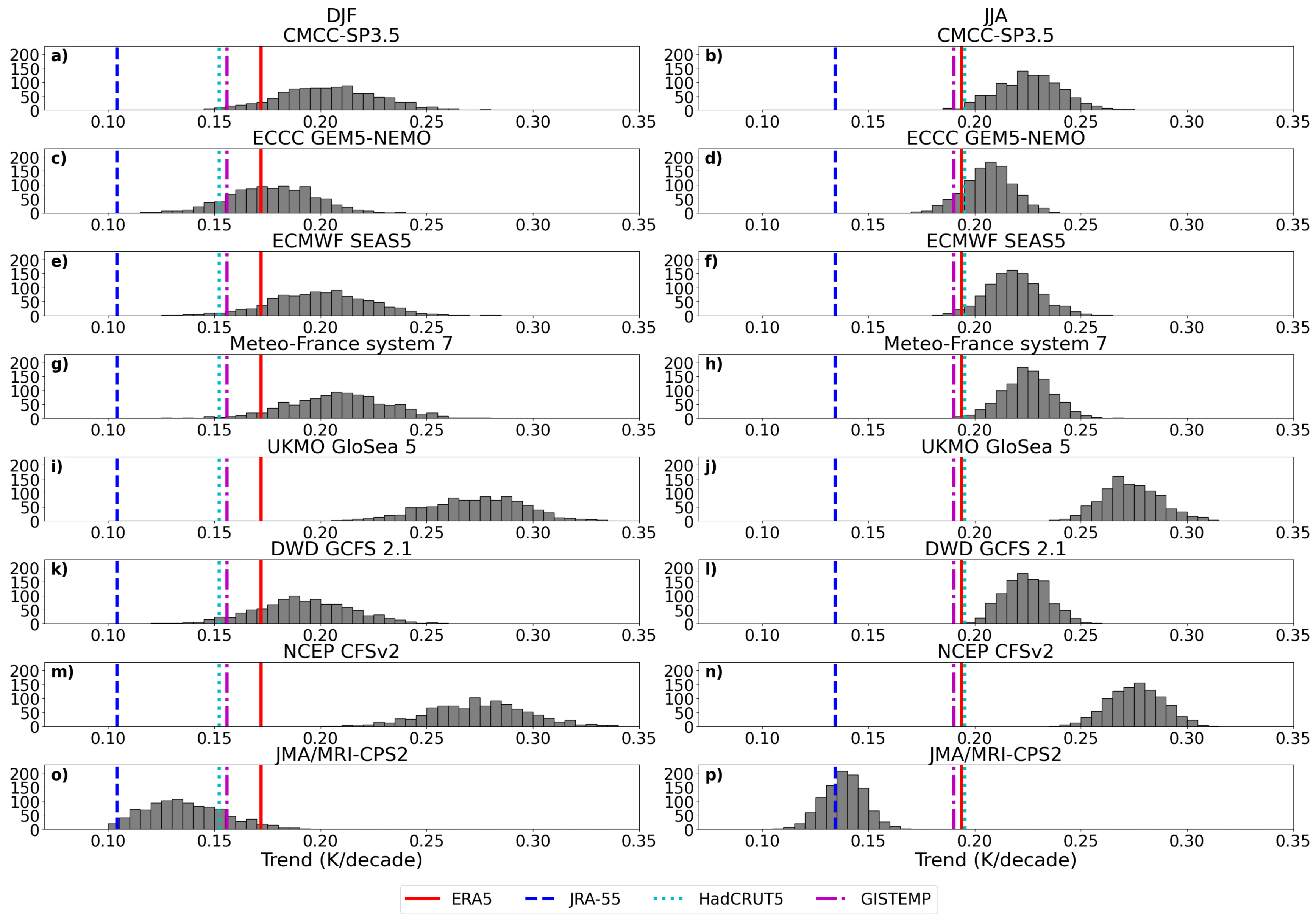


Fig 1: *Global mean T2m trends for predictions of the DJF (left) and JJA (right) one season ahead*

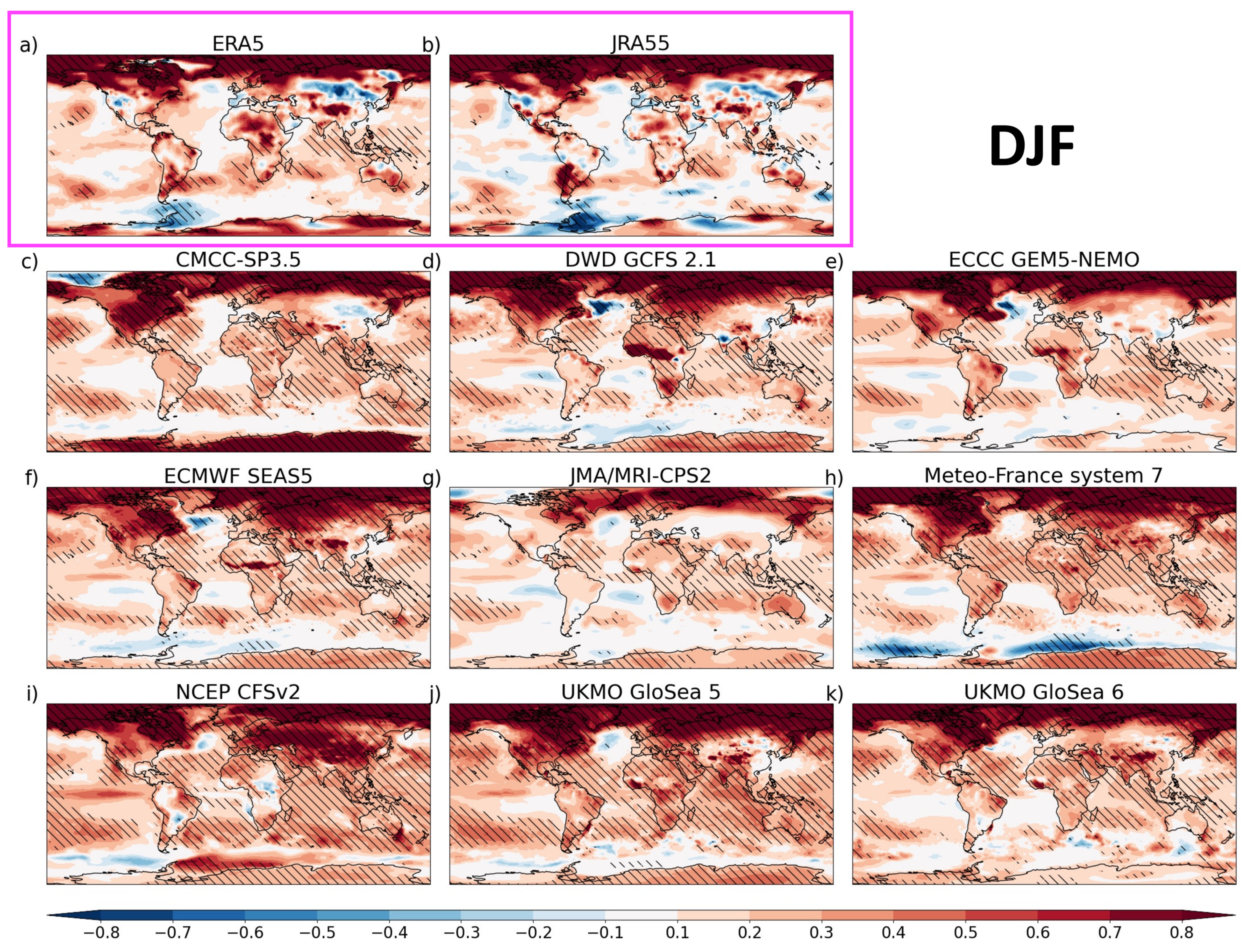


Fig 2: *DJF T2m trends in ERA5 & JRA55 and seasonal forecast models. Hatching indicates significant trends (p<0.05). In K/decade.*

Regional trends

- Strong warming trends in the tropics in many seasonal forecast models, particularly over the oceans (Fig 2 & 3)
- **El Niño-like warming trends are very noticeable already after 2-4 forecast months**

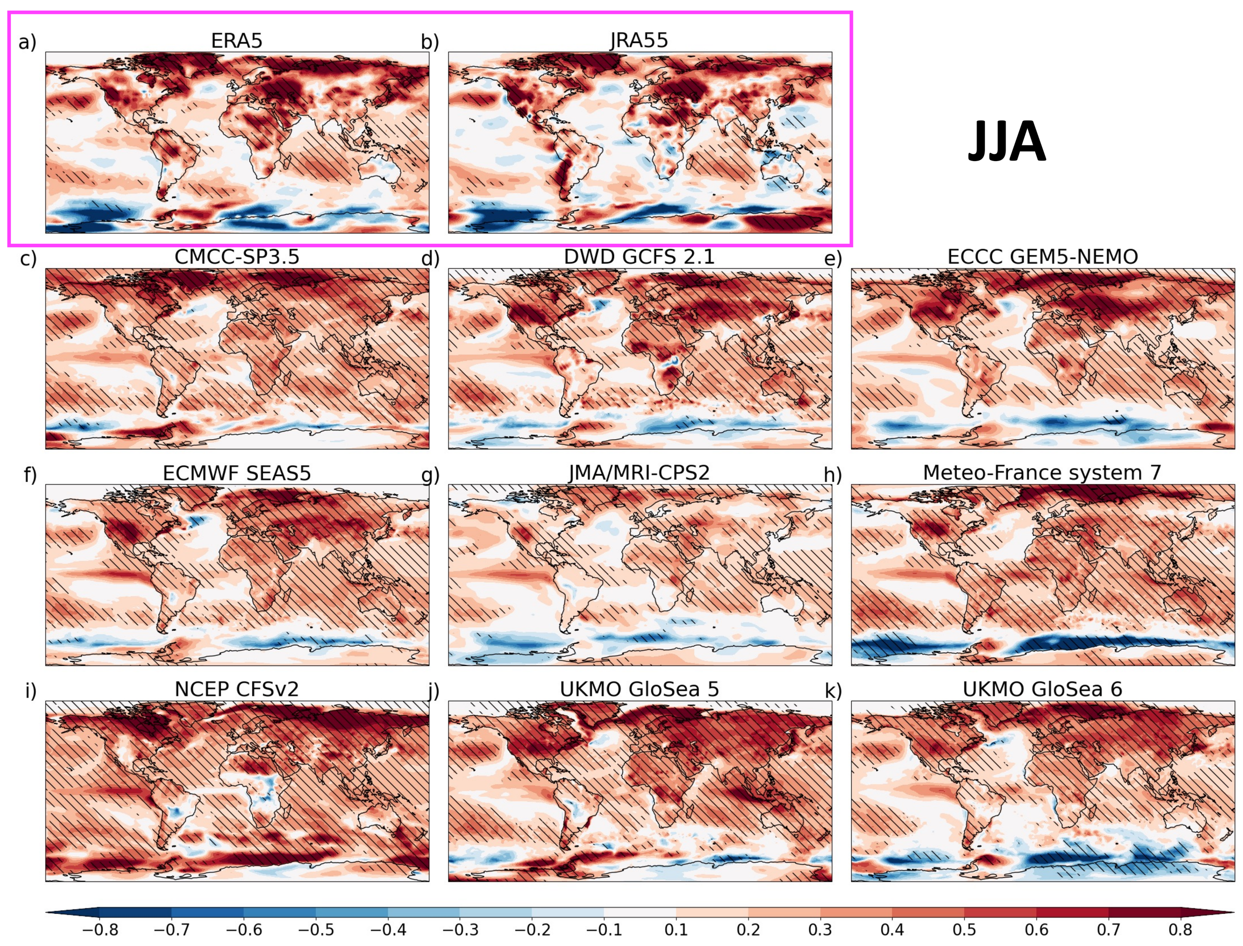


Fig 3: *As Fig. 2 but for JJA.*

The ECMWF model

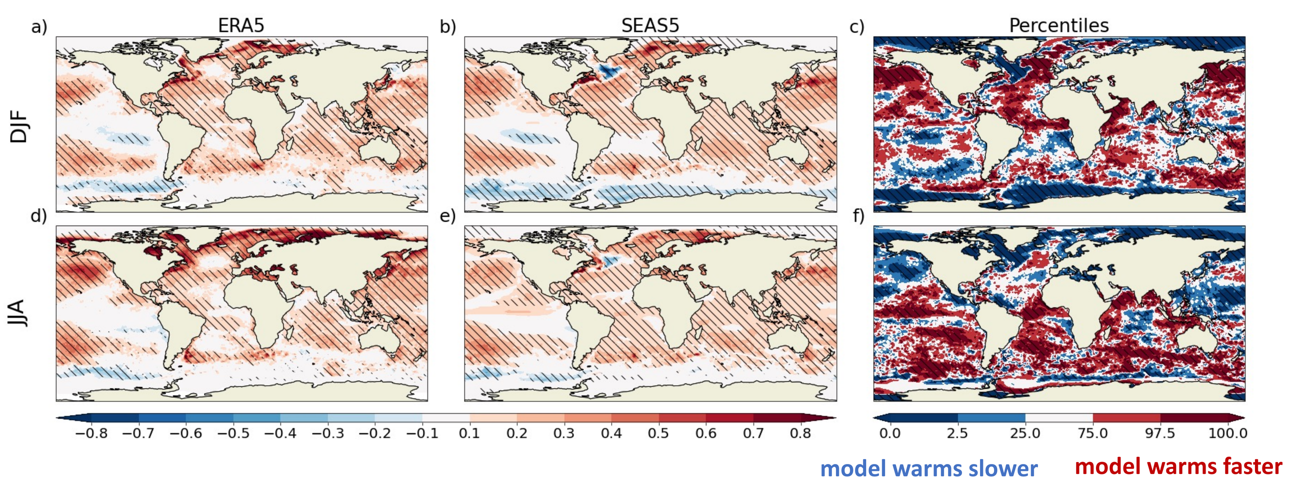


Fig 4: *SST trends in ERA5 (left), SEAS5 (middle) and inverse percentile of the SEAS5 trend distribution where the ERA5 trend lies at each grid-point. Hatching for ERA5 and SEAS5 indicates significant trends (p<0.05). Hatching for the percentiles indicates where ERA5 is outside +/- 2σ of the SEAS5 distribution. Top row: DJF, bottom row: JJA. Forecasts initialised on 1st Nov and 1st May. Period: 1981-2022.*

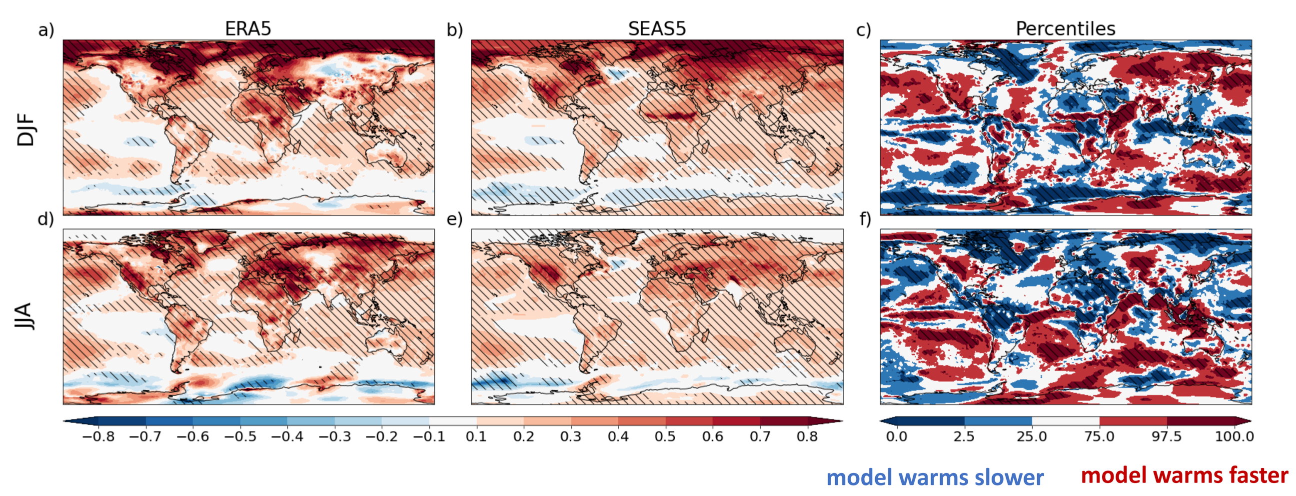


Fig 5: *similar to Fig 4 but for T2m.*

- SSTs in the **tropical basins and the winter hemisphere warm particularly fast** in ECMWF's SEAS5 (Fig 4)

Sub-seasonal trends

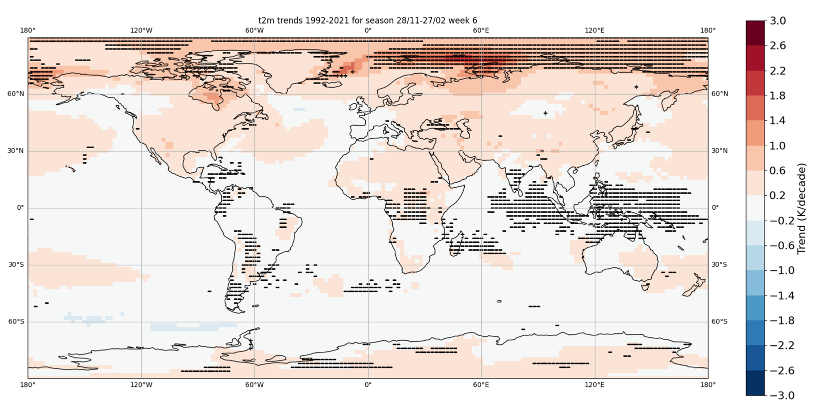
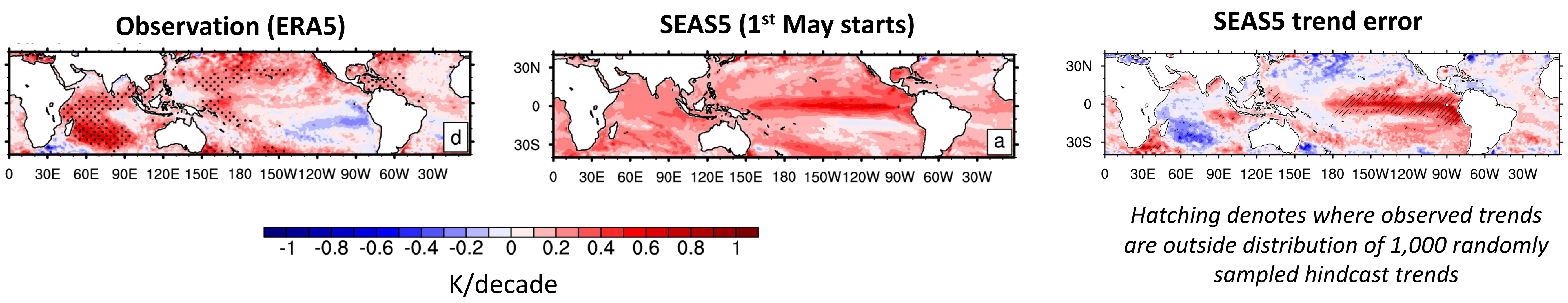


Fig 6: *T2m trends in latest ECMWF sub-seasonal forecasts for week 6 during DJF 1992-2021. "-" indicates trend is smaller than in ERA5, "+" indicates trend is larger than in ERA5.*

Tropical SST trends in the ECMWF model



Hatching denotes where observed trends are outside distribution of 1,000 randomly sampled hindcast trends

Fig 7: *SST trends in ERA5 (left), SEAS5 initialised on 1st May (middle) and trend error SEAS5 minus ERA5 (right) during the period 1993-2019.*

Trends of Niño3.4 in Nov

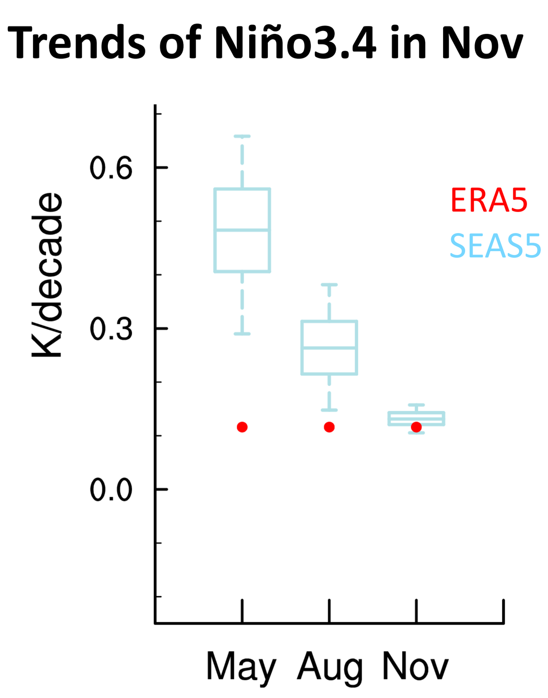


Fig 8: *SEAS5 Nino3.4 SST trend distribution for different start dates.*

- **Equatorial Pacific SSTs warm too fast in SEAS5** (Fig 7)
- SEAS5 **underestimates cooling trend in south-eastern tropical Pacific** (Fig 7)
- Observed Niño3.4 trends in November are inconsistent with forecasts from May or August (Fig 8)
- SST trends are associated with **underestimation of strengthening equatorial easterlies** and northward cross-equatorial winds in the Pacific (not shown). Wind trend errors also present in uncoupled runs with prescribed observed SSTs.