Warming trends in seasonal forecast models are consistently larger than in observations

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Key points

We investigate the extent to which seasonal forecast models reproduce observed boreal winter temperature trends spanning **1993-2016**. We find that:

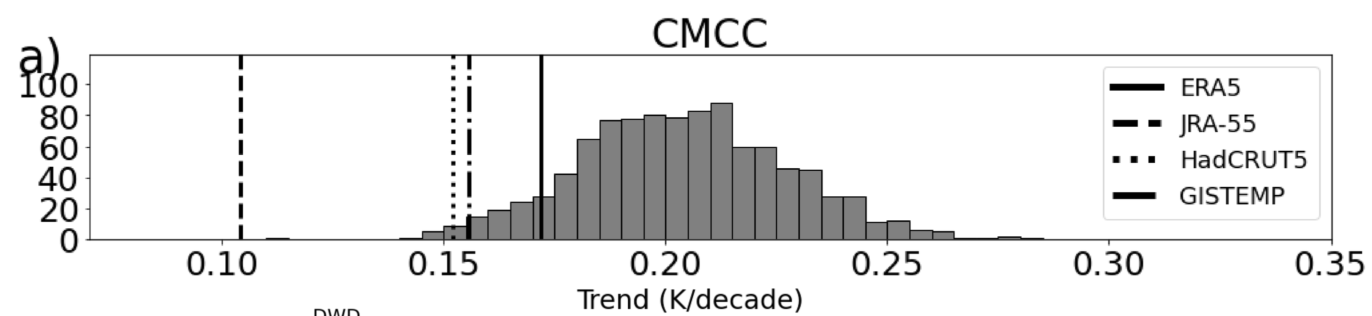
1. Seasonal forecasting systems tend to **warm faster** than observations
2. This is the particularly true in the tropics with **stronger warming** over the **tropical Indian** and **Pacific Oceans**.
3. The **trend difference** from observations varies as a function of **lead-time**.

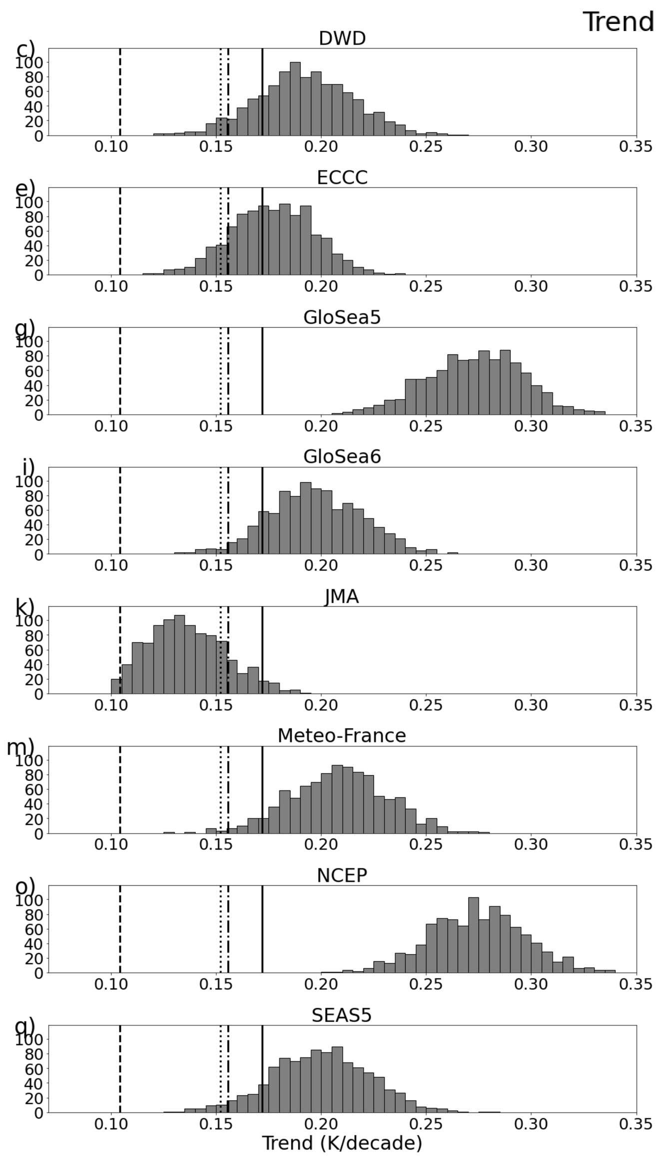
Seasonal forecast models

Centre	System	Ocean model	Resolution (atm.)	Resolution (ocean)	Time-varying GHG forcing	Time-varying aerosol forcing
CMCC	CMCC-SPS3.5	NEMO v3.4	0.5°x0.5° / L46	0.25°x0.25°	✓	
DWD	GCFS 2.1	MPIOM 1.6.3	T127 / L95	TP04 (0.4°)	✓	✓
ECCC	GEM5-NEMO	NEMO v3.6	110km / L85	1°x1°	✓	
ECMWF	SEAS5	NEMO v3.4	36km / L91	ORCA 0.25	✓	✓
JMA	JMA/MRI-CPS2	MRI.COM v3	TL319 / L100	0.25°x0.25°	✓	
Meteo-France	System 7	NEMO v3.6	TL359 / L137	ORCA 0.25	✓	
NCEP	CFSv2	GFDL MOM4	T128 / L64	0.5°x0.5°	✓	
UKMO	GloSea5	NEMO v3.4	N216 / L85	ORCA 0.25	✓	
UKMO	GloSea6	NEM0 v3.6	N216 / L85	ORCA 0.25	✓	

We examine trends in the seasonal forecast models in the Copernicus Climate Change Service (C3S) archive for the common hindcast period, 1993-2016. For this poster all figures show boreal winter (DJF) for runs initialised in November, but **results are similar for boreal summer.**

1. Global-mean trends





Almost all models warm faster than observations in the global-mean with the sole exception being the JMA system. UKMO GloSea5 and NCEP CFSv2 show the largest trends overall.

Figure 1: Histograms of DJF global-mean 2m temperature trends for each model constructed by taking a random ensemble member from each year and calculating the trend, repeating this many times. Vertical lines show trends in reanalysis and observations over the same period.

2. Trend maps

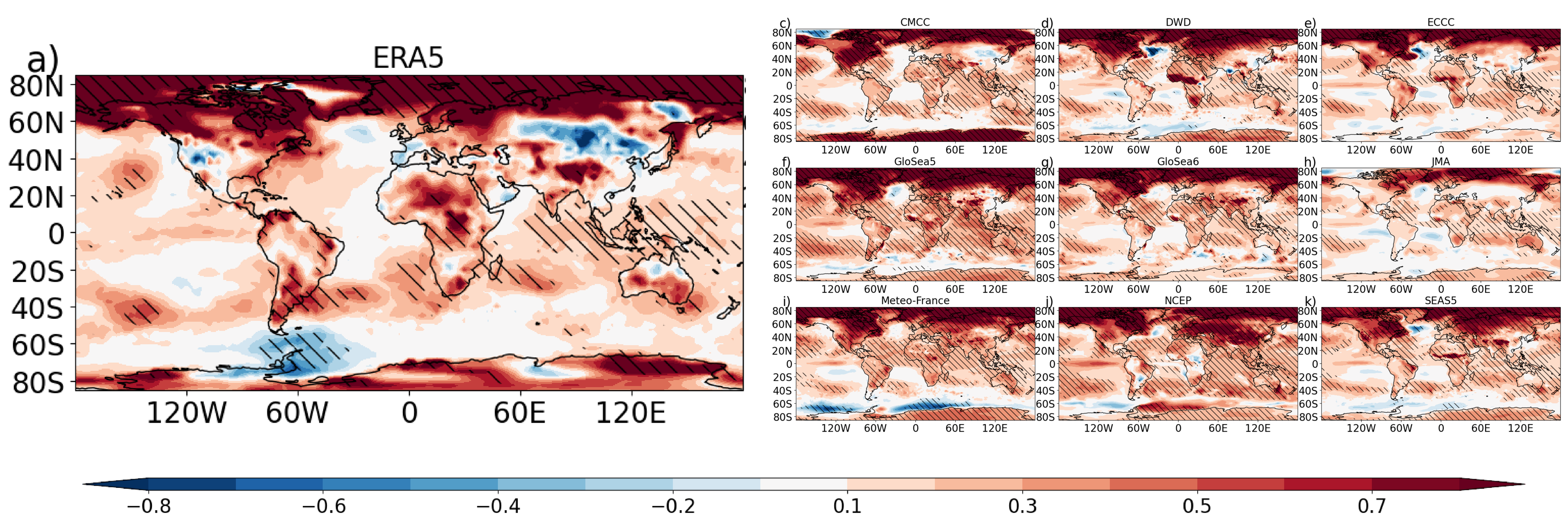


*Figure 2: Spatial maps of DJF 2m temperature trends for ERA5 and seasonal forecast models. For forecast models the trend is the ensemble-mean trend. Units of **K/decade**. Hatching indicates statistically significant trends, p<0.05.*

Examination of spatial maps indicates that 2m temperature tends to warm faster in models than ERA5 particularly over the ocean (especially the **tropical Pacific, Atlantic** and **Indian Oceans,** see boxes in figure 3).

We construct ensembles of warming trends for each grid-point by taking one random ensemble member for each year and calculating the trend, doing this many times.

In general, ERA5 lies near the lower bound of the model trend ensembles in the tropics.

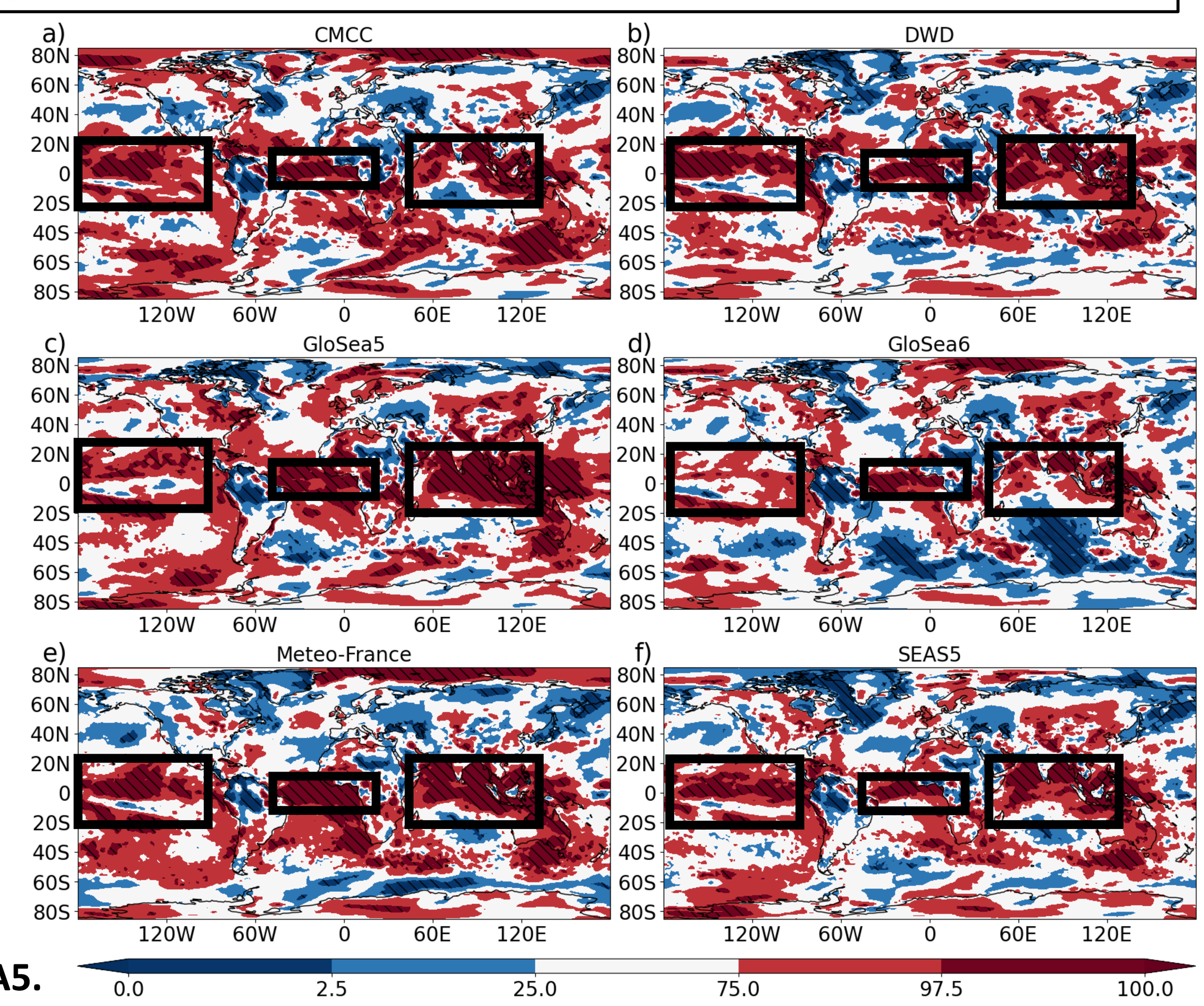


Figure 3: The percentile that ERA5 trends in DJF 2m temperature are found at in comparison to ensembles of model trends. Hatching / dark red indicates that ERA5 lies outside the 95% confidence interval of the model ensemble.

Red = models warm faster than ERA5
Blue = models warm more slowly than ERA5.

3. Lead-time dependence

Equatorial Pacific SSTs trends **become more pronounced at longer lead-time.** These SST trends also affect circulation patterns and may become a considerable source of forecast error at longer lead-times.

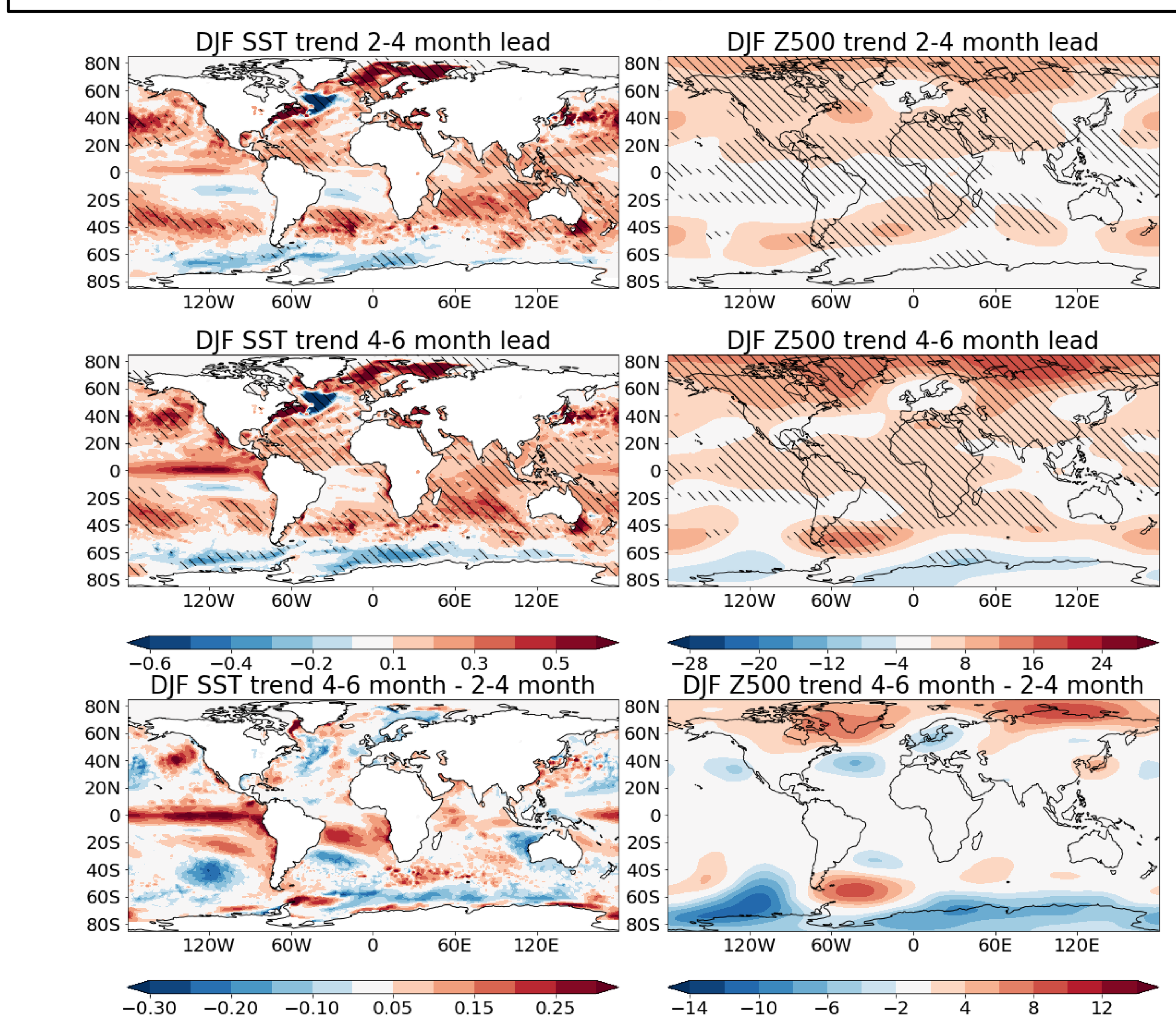


Figure 4: Trend in ECMWF's SEAS5 model for DJF (left) SSTs and (right) Z500 for runs initialised in (top) November (2-4 month lead) and (middle) September (4-6 month lead). The difference, September – November initialisation, is shown in the bottom panels.

Discussion

- The representation of temperature trends presents a test for seasonal forecasting models.
- The finding that almost all models considerably overestimate warming trends could be a **source of forecast error**.
- The causes (and impacts) of the overestimation are not yet understood and require further work. Some potential explanations are:
  - Poor **representation of external forcing**
  - **Mean-state ocean biases**
  - Incorrect **initialisation**

For further information on the role of externally forced trends in 2m temperature skill in seasonal forecast models, also see

Patterson et al (2022) "The strong role of external forcing in seasonal forecasts of European summer temperature." Environmental Research Letters, vol. 17, number 10.