Summary of the UGROW subproject on tropospheric temperature bias during JJA over the northern hemisphere

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UGROW – Understanding systematic error GROWth

UGROW is an ECMWF cross-departmental project focused on Understanding systematic error GROWth from hours to seasons ahead. It aims to build on and strengthen existing efforts and constitutes an additional channel to bring together scientists from various teams across ECMWF who are interested in identifying ways to enhance predictive skill, in particular at sub-seasonal timescales (weeks 2-4). In 2021, three UGROW sub-topics were selected: Indian Ocean biases, northern hemisphere summer tropospheric temperature biases and the winter Pacific jet stream bias.

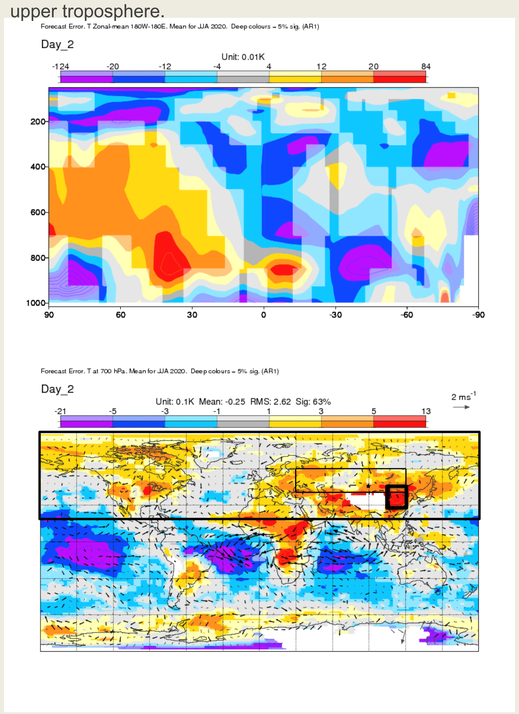
Here we present results about the summer tropospheric temperature bias. The Indian Ocean bias will be presented as an oral presentation and the winter Pacific jet stream bias in another poster.

Medium-range signature

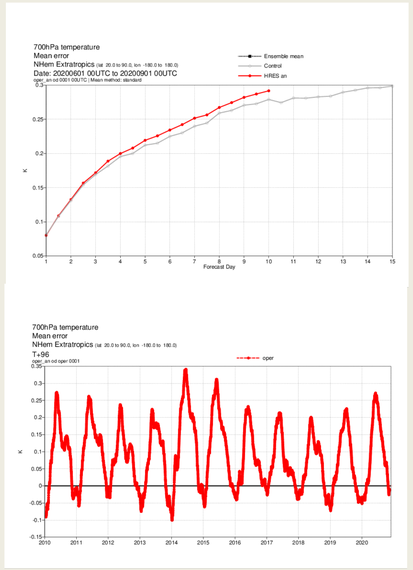
The vertical cross-section of the temperature bias on day 2 shows that all latitudes in the northern hemisphere outside the tropics exhibit a warm bias between 700 and 400 hPa. A strong warm bias also appears down to 850 hPa for 30°N-40°N. The **warm bias at 700 hPa** in 2-day forecasts is most **pronounced over most landmasses** of the northern hemisphere, with the **strongest bias found over north-eastern China**. At the same time, we see cold biases over large parts of the oceans for this level. The lead-time dependence of the bias over the northern hemisphere extra-tropics (N.Hem, 20°N-90°N) shows that the bias **grows fastest over the first four forecast days** and seems to further slow down after 10 days.

The T700 bias over the northern hemisphere shows a **strong seasonality** and the summertime bias has been **present for many years**.

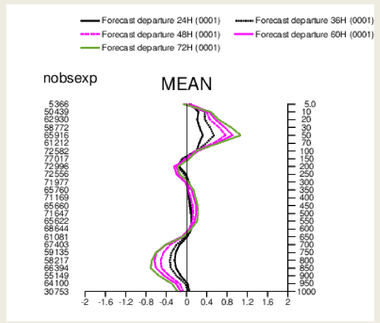
The forecast departures (observations minus forecasts) from radiosondes in a **region over China** (where the strongest bias is seen), shows a growth of the departures (forecast being warmer than observations) during the first days of the forecasts. **The growth of the warm bias is strongest between 900 and 700hPa** and there is a negative bias in the upper troposphere.



Vertical cross-section (top) and 700-hPa (bottom) temperature bias for 2-day forecasts for HRES from JJA 2020. Boxes in the right plot indicate regions used in this report. White areas are masked below orography.

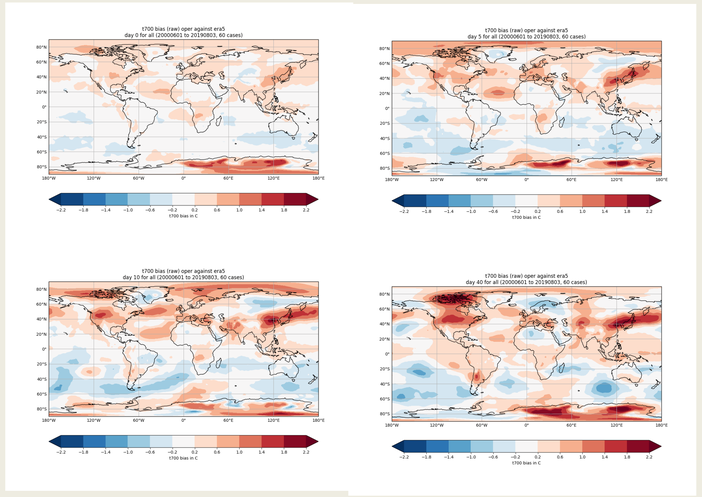


700-hPa temperature bias for N.Hem in HRES (red) and ENS control (grey) as function of lead-time (top) and time-series for 4-day HRES bias with 30-day running mean applied (bottom).



Evolution of bias from radiosondes (observations minus forecast) in the region over eastern Asia (28°N-45°N, 105°E-120°E)

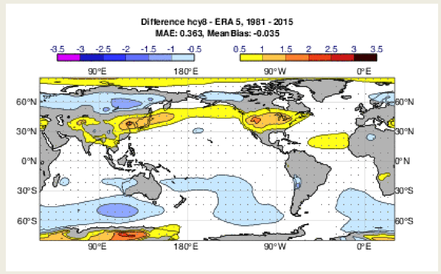
Extended-range and seasonal signature



700-hPa temperature bias in ECMWF reforecasts valid in JJA for day 0-4 (top-left), day 5-9 (top-right), day 10-14 (bottom-left) and day 40-44 (bottom-right).

On the sub-seasonal scale, the hotspot for the bias over eastern Asia continues to grow and the bias also extends to the east over the Pacific in the 2nd and 3rd pentad. The T700 bias also grows over North America in the lee of the Rockies and over northern Canada.

We have also evaluated the temperature bias in seasonal reforecasts initialised in May 1981-2015 and valid for JJA. On this time scale, the warm bias over China, the North Pacific and North America remains, while a cold bias develops further to the north (around 60°N) over Europe and Asia.



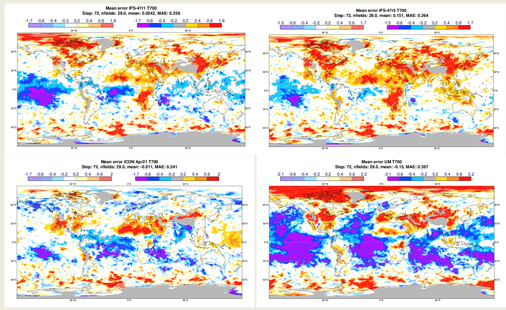
700-hPa temperature bias in ECMWF seasonal 47r1 reforecasts with resolution TCo199 initialised 1 May 1981-2015 valid in JJA.

Comparison with other models

The temperature bias has also been explored in forecasts from other modelling centres, using data from the model intercomparison project DIMOSIC (Magnusson et al., 2022, BAMS). The dataset consists of forecasts from different models initialised from the same (ECMWF) analyses.

The UKMO-UM shows a similar regional pattern in the warm bias over northern hemisphere continents but with a lower amplitude.

ICON does not show such a pattern but seems to be too warm over arid regions.



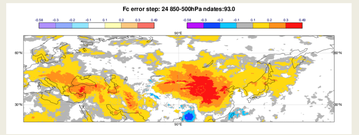
700 hPa temperature bias for 3-day forecasts from the DIMOSIC dataset (29 start dates in JJA2018) for IFS-47r1 (top-left), IFS-47r3 (top-right), DWD-ICON (bottom-left) and UKMO-UM (bottom-right). Areas below orography are masked in grey.

Short-range signature and link to processes

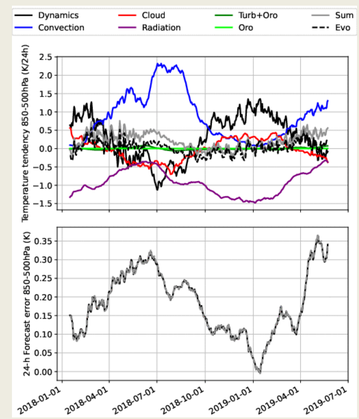
The forecast error and model tendencies have been explored in the box centred over China and averaged over the layer 850-500 hPa. For this region and levels, the bias is present for most times of the year during the evaluated 1.5-year Year of Polar Prediction (YOPP) dataset but is strongest during the spring and first part of the summer.

Looking at the phasing between the error and the different tendencies, one can first note that the error is lower during the peak of the boreal summer when the convection is strongest. On other hand the error seems to occur during the period when the negative tendency from the cloud scheme (due to evaporation) is largest.

It is therefore difficult to draw a conclusion about the process leading to the forecast bias.



Temperature bias at day 1 averaged between 850-500hPa for YOPP forecast (ENS CF) for JJA2018.



Time series of model tendencies for temperature averaged over the first 24 forecast hours (top) and 24-hour temperature forecast errors (bottom), averaged between 850 hPa and 500 hPa. The top panel also includes the evolution of the temperature over 24 hours. The bottom panel shows the forecast error calculated from the 24-hour forecast output (black) and from the sum of the tendencies minus the evolution (grey dashed). A 30-day running mean is applied to the time-series. All data are averaged inside a box between 28°N-45°N latitude and 105°E-120°E longitude.

Discussion

In this sub-topic of the UGROW project we have investigated biases in the lower to mid-tropospheric temperature during the northern hemisphere summers. The bias peaks around 700 hPa and grows fastest during the first days of the forecast. The bias mainly appears over land masses in early forecast ranges and has a maximum over eastern Asia. Despite being robust both in terms of day-to-day and year-to-year variability, the investigations so far have not pointed to a clear error source. It is plausible that the error is a result of several different errors adding up to the structure we see.

However, several future directions of investigation were discussed during the UGROW meetings:

- Links to precipitation biases over eastern Asia
- Possible lee effects of orography Tibetian Plateau
- Land-sea contrast in bias
- Aerosol effect (direct and cloud-effect)
- Regime-dependent evaluation

UGROW gave a great framework to discuss different evaluation metrics and time-scales. The results will serve as a base for future investigations

For more information, see:

ECMWF Technical Memorandum 891