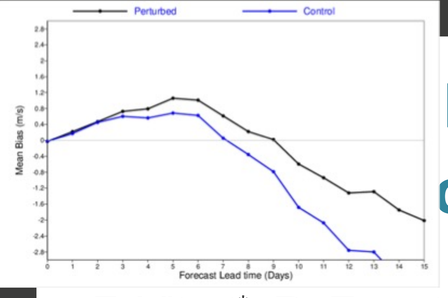

Investigating biases in the representation of the opical jet stream in the ECMWF forecasts

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Motivation

UGROW-JET focusses on biases in the representation of the Pacific sub-tropical jet stream. A main reason for this focus is that the Pacific sub-tropical jet stream is a wave guide for Rossby wave propagation, including those originating from the Madden Julian Oscillation (MJO). Therefore, the Pacific sub-tropical jet stream plays a key role in the representation of MJO teleconnections, a dominant source of predictability at the sub-seasonal time scale.

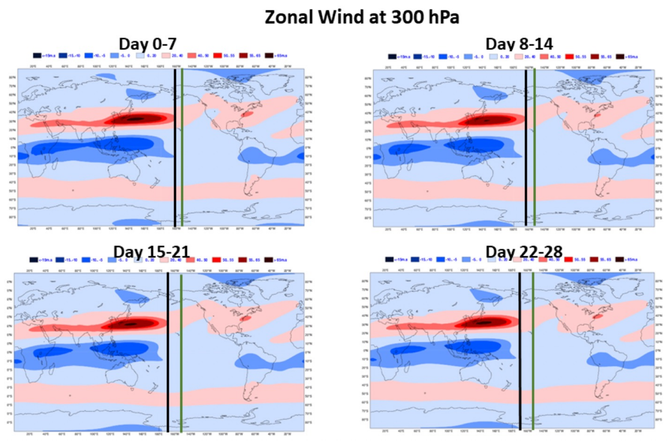
Lee, R. W., Woolnough, S. J., Charlton-Perez, A. J., & Vitart, F. (2019). ENSO modulation of MJO teleconnections to the North Atlantic and Europe. *Geophysical Research Letters*, 46, 13535– 13545. https://doi.org/10.1029/2019GL084683

For instance, Lee et al. (2020) showed that the impact of the MJO on Euro-Atlantic weather regimes is much stronger during El-Niño years than during La-Niña years They suggested that this was due to the impact of ENSO on the Pacific sub-tropical jet stream which retreats to the west during La-Niña years and extends more to the east during El-Niño years. Zhou et al. (2020) also found that the eastward shift in the exit region of the subtropical jet caused by the anthropogenic global warming has a stronger impact on MJO teleconnections than the eastward shift of the MJO also caused by global warming.

Zhou, W., Yang, D., Xie, S.-P., & Ma, J. (2020). Amplified Madden–Julian oscillation impacts in the Pacific–North America region. *Nature Climate Change*, **10**, 654– 660.

Errors in the position of the Pacific jet

The Pacific sub-tropical jet bias was diagnosed from the operational ECMWF reforecasts (20 years and 11 ensemble members) produced with IFS cycle 46R1 (operational from June 2019 to June 2020).

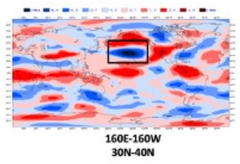


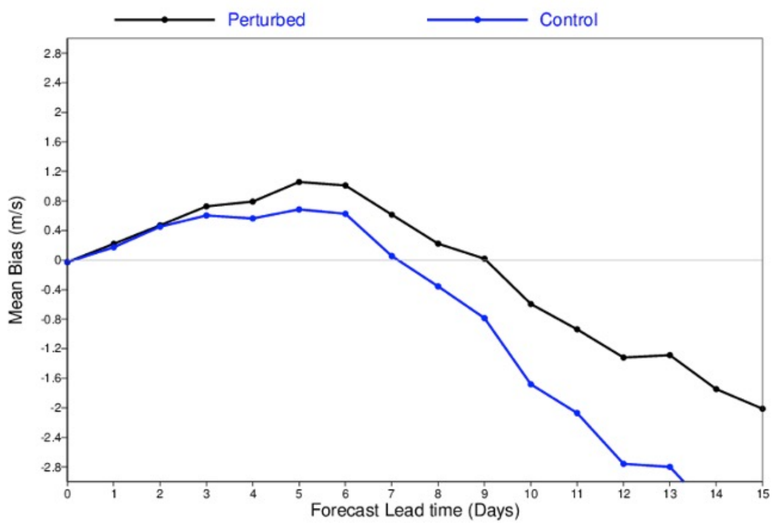
U300 climatology computed from the 46R1 operational 20-year re-forecasts and verifying in January for 4 different lead times. The green vertical line represents this location in the ERA5 reanalysis.

In the extended-range forecast, the climatological position of the jet stream is moving westward with lead time

- The jet stream extension bias at 300 hPa is seasonal and strongest in January
- The bias is modulated by ENSO (stronger in El-Niño years than in La-Niña years).
- The bias is stronger in control forecast than perturbed forecasts.
- This bias is common to most S2S models

Daily evolution of the Bias



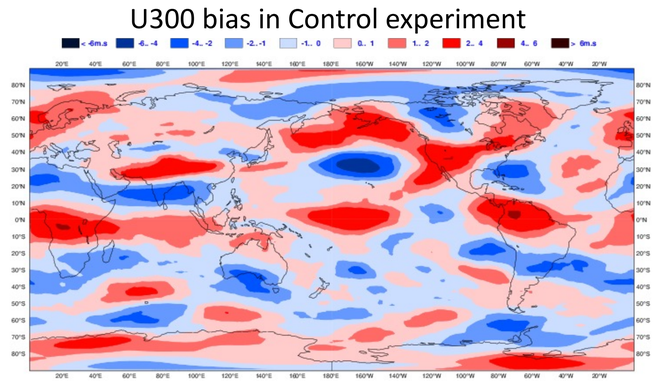


Daily evolution of the U300 bias, averaged over the area 160E-140W, 20N-40N, up to day 15 for the perturbed forecasts (black line) and the control forecast (blue line). This figure shows that the bias changes sign with lead time and that the amplitude of the bias is significantly larger in the control forecasts after 7 days.

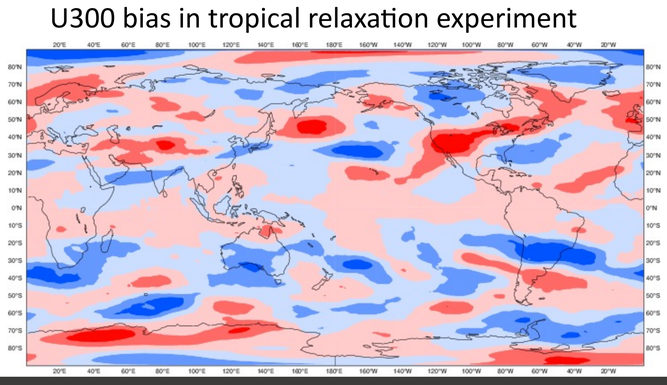
Investigating potential sources of error using relaxation experiments

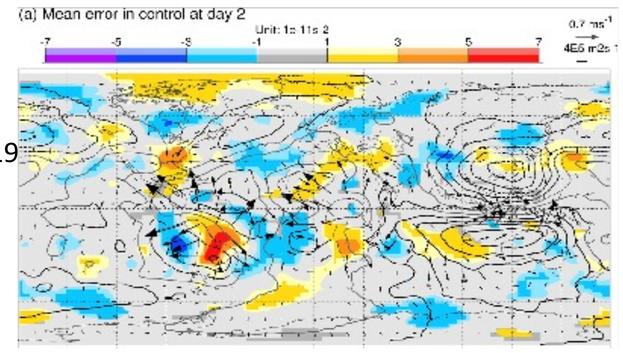
- Tropical relaxation: 10N-10S relaxed towards ERA5
- Resolution: Tco319 L137
- Cycle 47R1
- 11 ensemble members, 20 years of reforecasts
- Start dates: same as operational re-forecasts produced in 2019 2020: twice weekly during the period Dec/Jan 2019-2020,

U300 bias in Control experiment



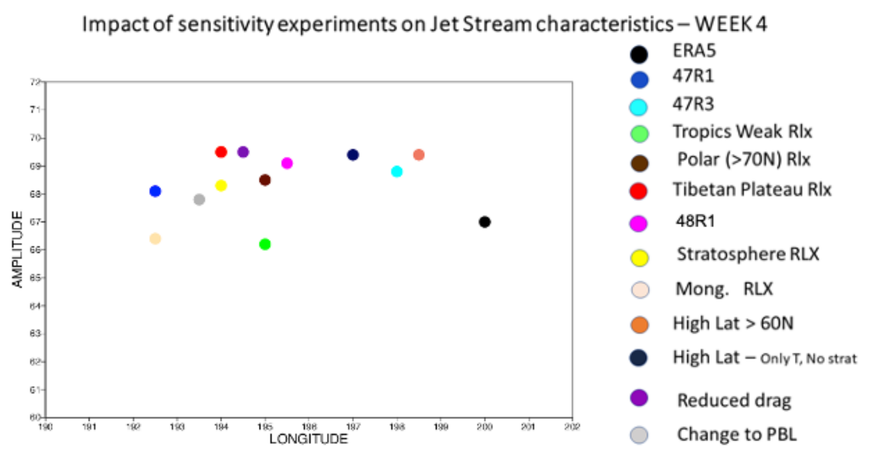
U300 bias in tropical relaxation experiment





The upper panel shows the mean error at day 2 in the control re-forecasts (2000-2016), with streamfunction (contoured), divergent wind (vectors) and the forcing of vorticity by the divergent winds (the 'Rossby Wave Source', shaded). The lower panel shows the difference (relaxation minus reference reforecast) at day 2. Black contours and vectors, and the more saturated colours in the colour bar key, indicate statistical significance at the 5% level.

Impact of sensitivity experiments on Jet Stream characteristics – WEEK 4



Pacific sub-tropical jet eastward extension (x-axis) and maximum amplitude (y-axis) in January in ERA 5 (black Circle) and at week 4 in the reference re-forecast experiment (Cycle 47r1, dark blue circle) and in several sensitivity experiments.

Summary

- Pacific sub-tropical jet eastern extension moves westward with lead time in the extended-range forecasts (weeks 1 to 4) and is only visible after week 1.
- A series of sensitivity experiments where part of the atmospheric circulation is nudged towards ERA5 suggests that there is not a unique source for this bias.
- Among the different relaxation experiments, the best jet stream position is obtained by relaxing the high latitudes
- The bias has been considerably reduced in cycle 47R3 but increased again in Cycle 48R1.

More information in Vitart et al. 2022, ECMWF Technical Memorandum, 889, 20pp

Points for discussion / outlook

- Continue search for origin of main model errors driving the Pacific jet stream bias.
- Diagnostics for this error are now applied to new ECMWF model versions
- Quantify impact of the jet stream bias on the representation of MJO teleconnections over the Euro-Atlantic sector.
- Impact of increased horizontal resolution will be investigated?