2D.6 THE REPRESENTATION OF THE CIRCUMGLOBAL TELECONNECTION IN THE ECMWF SEASONAL FORECAST MODEL

Jonathan D. Beverley*, S. Woolnough, L. Baker, S. Johnson and A. Weisheimer

University of Reading, Reading, UK

1 INTRODUCTION

Recent research has led to improvements in European winter seasonal forecasts (e.g. Scaife et al., 2011; Dunstone et al., 2016) however there has been less of a focus on the summer season and so summer forecast skill remains relatively low. The European climate is affected by a large range of influences, including from tropical regions, and better understanding of the mechanisms behind these tropical-extratropical teleconnections can inform our evaluation of seasonal forecast systems and priorities for model development.

The teleconnection mechanism that we examine here is the circumglobal teleconnection (CGT). This was first identified by Ding and Wang (2005) as having a major role in modulating observed weather patterns in the Northern Hemisphere summer. Figure 1 shows the observed CGT correlations for August, as defined in Ding and Wang (2005) as the correlation between the 200hPa geopotential in west-central Asia (the box on Figure 1) and 200hPa geopotential height elsewhere. From this correlation pattern, they identified a wavenumber-5 structure where the pressure variations over the northeast Atlantic, east Asia, North Pacific and North America are all nearly in phase with the variations over west-central Asia. They also showed that the Indian summer monsoon (ISM) plays an important role in the maintenance of the CGT through a Gill-type response (Gill, 1980) to diabatic heating.

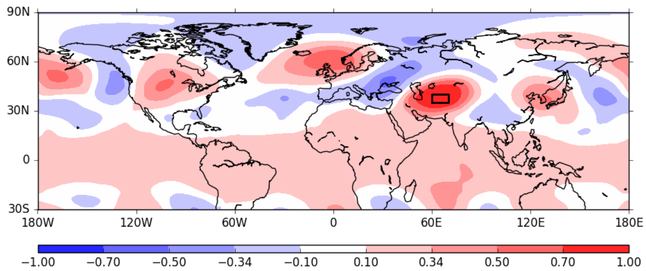

Figure 1: *One-point correlation between 200hPa geopotential at the base point (box, 35°-40° N, 60°-70° E) and 200hPa geopotential elsewhere in the ERA-Interim (1981-2014) reanalysis dataset for August. Correlation values of ± 0.34 are significant at the 5% level*

In this study we examine the model's representation of the CGT, and where differences exist examine possible causes for these through the use of several relaxation experiments.

2 MODEL

The model used for the hindcasts is version CY41R1 of the European Centre for Medium-Range Weather Forecasts (ECMWF)'s Integrated Forecasting System model (IFS), coupled to the Nucleus for European Modelling of the Ocean model (NEMO). The horizontal spectral resolution of the atmospheric model (T255) is similar to System 4 and corresponds to a grid length of approximately 80km with 91 vertical levels in the control run used for the analysis in section 3.1, with the model top at 0.01 hPa, while the ocean model has a resolution of approximately 1 degree with 42 vertical levels (Molteni et al., 2011; Weisheimer et al., 2016). The hindcasts were performed using the ECMWF ERA-Interim and Ocean (ORAS4) reanalyses for initialisation. Seasonal hindcasts over four months were initialised on 1st May for the period 1981–2014, therefore covering the boreal summer season of June–August (JJA) and much of the ISM season, and the analysis presented here uses monthly mean values for May–August from these hindcast runs. In order for the relaxation experiments to be carried out, the model was required to have 60 vertical levels (the same number as in ERA-Interim) therefore a second control experiment was also run with this number of levels to enable a fair comparison to be made. However, our analysis has found there to be little difference between the two control experiments.

3 RESULTS & DISCUSSION

3.1 CONTROL EXPERIMENT

We first analyse a control experiment to determine the overall model skill and how well the model represents the CGT. Figure 2a is equivalent to Figure 1, but for the average of the correlation maps from all ensemble members. Although the model has centres of positive correlation in broadly the right location, the magnitude of these correlations is much too weak. We also see from Figure 2b that the model has several areas of no skill, including some with negative correlations, in 200hPa geopotential height. These include over Europe, and perhaps importantly over west-central Asia, in the region used for the base point of the CGT correlations. The similarity between the location of the positive correlation in Figure 1 and the areas of reduced model skill in geopotential height in Figure 2b is one of the main motivations for the relaxation experiments that have been performed.

*Department of Meteorology, University of Reading, Reading, UK; email: j.beverley@pgr.reading.ac.uk

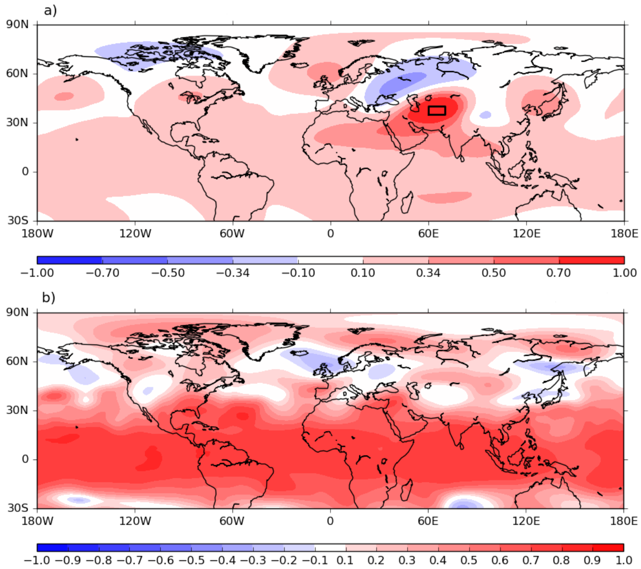

Figure 2: *(a) Same as Figure 1, except the average of 25 ensemble member correlations for the model hindcasts for August. (b) Model ensemble mean skill for 200hPa geopotential height as defined as the correlation between ERA-Interim and model ensemble mean for August*

The CGT mechanism relies on the generation and propagation of Rossby waves, which are governed by the Rossby wave source (RWS) term:

$$RWS = -\zeta D - \mathbf{v}_\chi \cdot \nabla\zeta \qquad (1)$$

where ζ is the absolute vorticity, D is the horizontal divergence and $\mathbf{v}_\chi$ is the divergent part of the wind field. Given the likely interaction between Rossby waves generated by the ISM and the CGT, we compare the RWS in the model to ERA-Interim to help understand the role of any errors in RWS in the representation of the CGT in the model.

The RWS in ERA-Interim and the model ensemble mean are shown in Figures 3a and 3b. All of the panels in Figure 3 are for July, which is representative of the patterns seen in both June and August.

The centre of positive RWS located at approximately 40°N, 60°E is broader and is located further to the north in the model than in ERA-Interim. This is associated with a northward displacement of the model jet stream by several degrees when compared to ERA-Interim. The variance of the RWS in ERA-Interim (Figure 3c) is also lower than in the model (Figure 3d). Much of the difference in the RWS variance can be attributed to the larger magnitude of the RWS in the model when compared to ERA-Interim. Generally, the model has greater magnitude of RWS in regions where there is either strong positive or negative RWS in ERA-Interim.

While the northward displacement of the jet is likely to be one reason for the error in the RWS seen in Figures 3a and 3b, an examination of the divergence field provides another. This is shown in Figures 3e (ERA-Interim) and 3f (model). The centre of negative divergence (convergence) located at approximately 40°N, 60°E (in the same location as the centre of large RWS in Figure 3a) is both larger in magnitude and located further to the north in the model than in ERA-Interim. The northward bias in the jet accounts for the displacement of the centre of convergence in this region, but the cause of the difference in magnitudes is likely to due to the difference in divergence seen over both the Arabian Sea and the Bay of Bengal. Here, the divergence is much greater in the model than in ERA-Interim, associated with too much precipitation in the model in these regions. The associated Gill response to this heating will therefore be stronger in the model than in ERA-Interim, and thus the convergence at 40°N, 60°E is of larger magnitude. The RWS term is dominated by the divergence component, and therefore the convergence in the model (which is both too strong and located in the wrong place) is likely to be an important factor in the errors in RWS in the model, and thus the errors in the CGT.

3.2 RELAXATION EXPERIMENTS

We now use relaxation experiments to further understand the errors in the model representation of the CGT. Figure 4 shows the model 200hPa geopotential height skill and model CGT pattern in the new control experiment and Experiments 1 and 2. Firstly, we note that the geopotential height skill map from the new control is very similar to the one from the original control. There are some differences: the area of negative correlation over Europe is in a slightly more eastward location, and there is slightly more skill over the North Pacific, but the overall pattern of high and low correlations is very similar. The model CGT also has the same pattern as the original control, with correlations at the centres of action that are much too weak.

Experiment 1 relaxed a region centred over the D&W region to determine whether correcting the circulation here led to improvements in the skill over Europe. However, we see from Figure 4c that the skill over Europe is largely unchanged. Skill over Asia is generally improved, particularly in east Asia, but elsewhere there is not much change. There is also little change in the representation of the CGT (it is actually slightly worse) which suggests that the CGT is not directly forced from this region. However, the biases in the jet that are found in the control experiment are still present in this relaxation experiment (outside of the relaxation region) and so any waves forced in this region will not propagate in the correct manner, which may partly explain the lack of improvement in the CGT representation.

Experiment 2 relaxed a region over western Europe to determine whether the errors in west-central Asia propagate from Europe. From Figure 4e we can see that there is a large improvement in the geopotential height skill over most of Asia when compared to the control. This suggests that the errors in Asia propagate from Europe, and the skill over Asia in Experiments 1 and 2 is very similar. There is also some improvement in the CGT in this experiment (Figure 4f), although this is exclusively over Eurasia. The wave pattern in the correlations from Europe to Asia is much improved and closely resembles observations in this region.

4 CONCLUSIONS

From analysing seasonal hindcasts from the ECMWF model, we have shown that the model has large errors in 200hPa geopotential height and a northerly jet bias. Associated with this are errors in the RWS, and together these result in a poor representation of the CGT in the model. Through analysing relaxation experiments we have found that relaxing in west-central Asia results in no improvement in the model CGT or geopotential height skill in Europe, however a European relaxation region does help to improve the model's representation of the CGT.

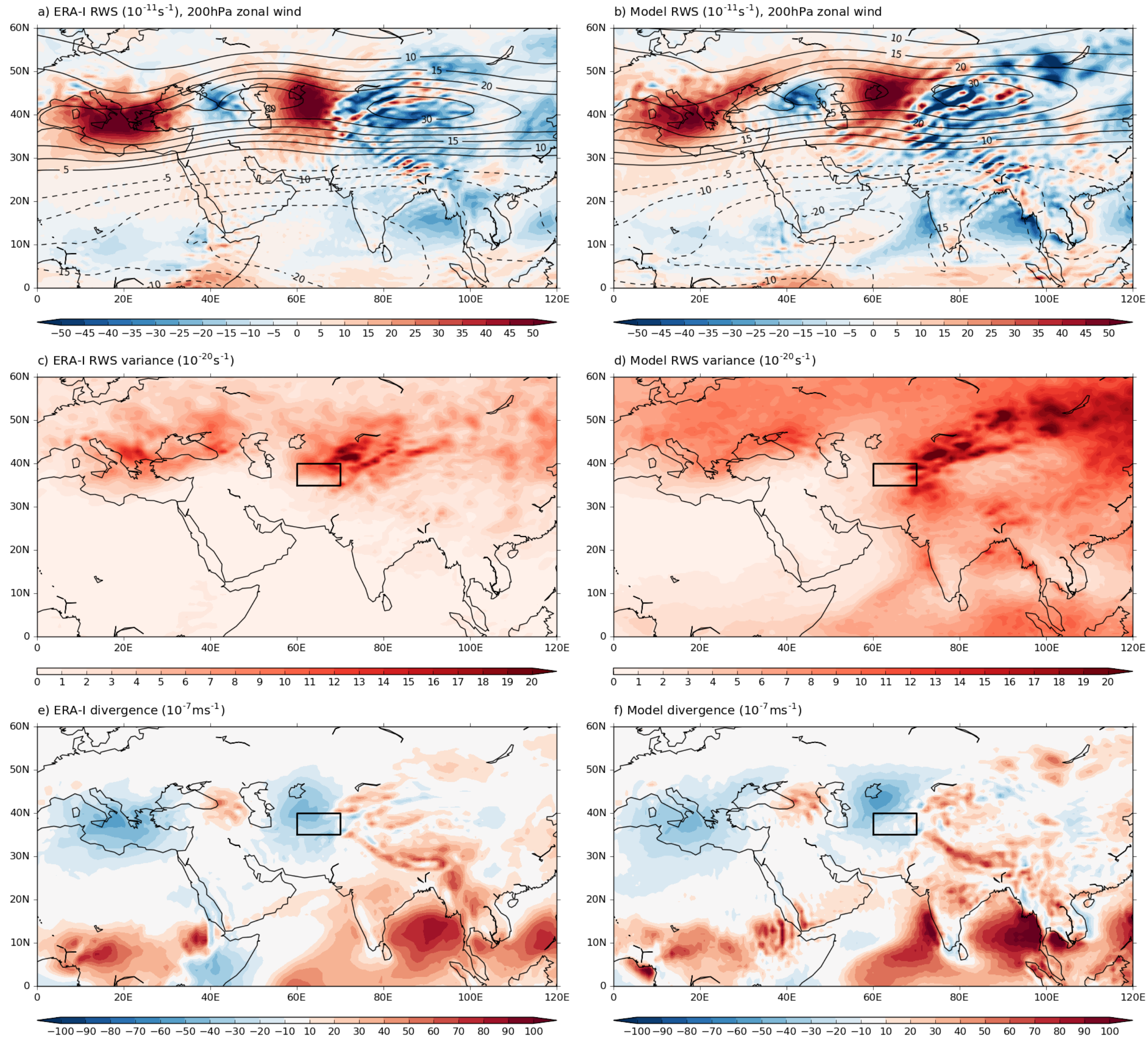

Figure 3: *(a) ERA-Interim and (b) model ensemble mean RWS term (filled contours) and 200hPa zonal wind (black contours). (c) ERA-Interim and (d) model variance of the RWS term. The model variance is for all members concatenated together. (e) ERA-Interim and (f) model ensemble mean divergence. All panels are for July, and the D&W region is marked as a box.*

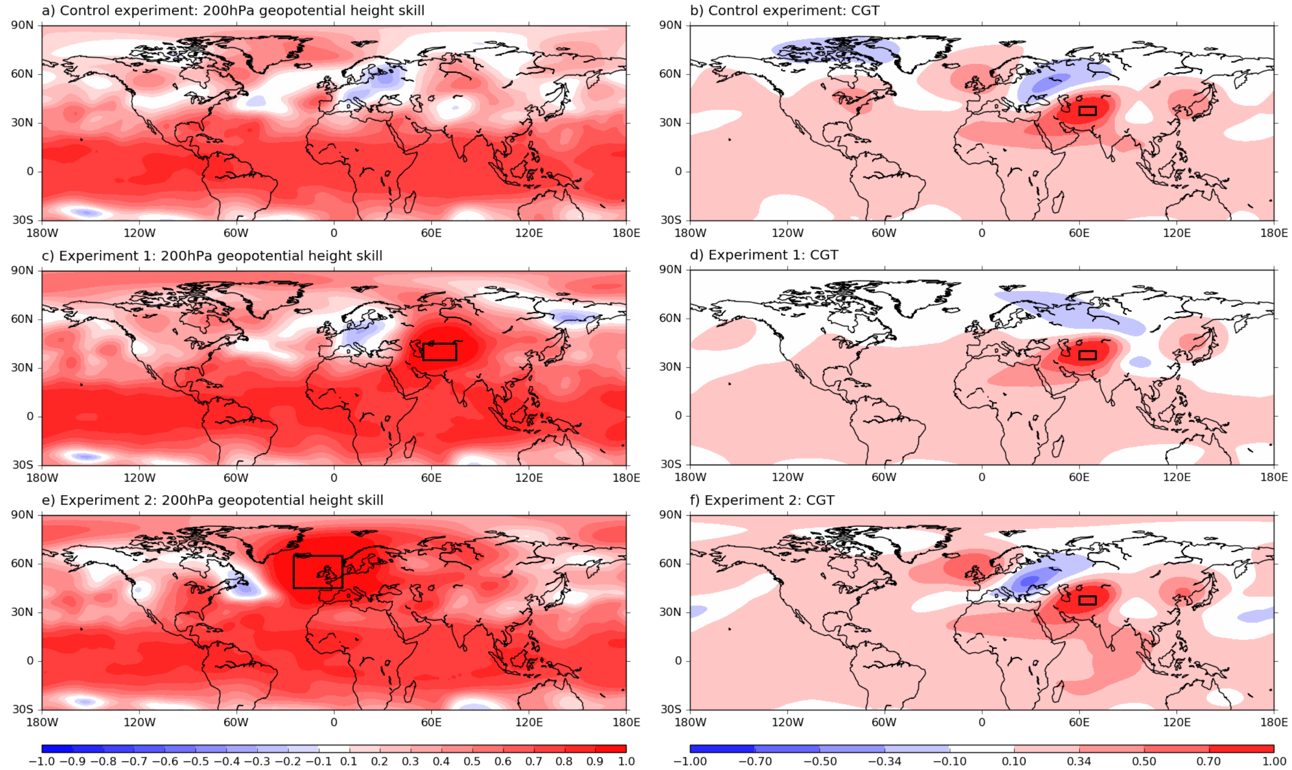

Figure 4: *200hPa geopotential height skill for August in (a) the new control experiment (with 60 vertical levels) (c) Experiment 1 (D&W region relaxation) and (e) Experiment 2 (northwest Europe relaxation). August CGT pattern (as defined in Ding and Wang (2005)) in (b) the new control experiment (d) Experiment 1 and (f) Experiment 2. The boxes marked on c and e are the relaxation regions, and on b, d and f are the base point used for the CGT correlations (the D&W region). All plots use data filtered to remove the long term trend and decadal variations with a period of longer than 8.5 years.*

REFERENCES

Ding, Q. and B. Wang, 2005: Circumglobal Teleconnection in the Northern Hemisphere Summer. *J. Climate*, **18**, 3483–3505, doi:10.1175/JCLI3473.1.

Dunstone, N., D. Smith, A. Scaife, L. Hermanson, R. Eade, N. Robinson, M. Andrews, and J. Knight, 2016: Skilful predictions of the winter North Atlantic Oscillation one year ahead. *Nat. Geosci.*, **9**, 809–814.

Gill, A., 1980: Some simple solutions for heat-induced tropical circulation. *Quart. J. Roy. Meteorol. Soc.*, **106**, 447–462.

Molteni, F., T. Stockdale, M. Balmaseda, G. Balsamo, R. Buizza, L. Ferranti, L. Magnusson, K. Mogensen, T. Palmer, and F. Vitart, 2011: *The new ECMWF seasonal forecast system (System 4)*. European Centre for Medium-Range Weather Forecasts.

Scaife, A. A., D. Copsey, C. Gordon, C. Harris, T. Hinton, S. Keeley, A. O'Neill, M. Roberts, and K. Williams, 2011: Improved Atlantic winter blocking in a climate model. *Geophys. Res. Lett.*, **38**.

Weisheimer, A., N. Schaller, C. O'Reilly, D. A. MacLeod, and T. Palmer, 2016: Atmospheric seasonal forecasts of the twentieth century: multi-decadal variability in predictive skill of the winter North Atlantic Oscillation (NAO) and their potential value for extreme event attribution. *Quart. J. Roy. Meteorol. Soc.*.