REVIEW: Atmospheric blocking: The impact of topography in an idealised general circulation model by Narinesingh et al.

Summary:

Scientific significance: Fair
Scientific quality: Fair
Presentation quality: Fair

This paper uses an idealized aquaplanet model to compare statistics of atmospheric blocking between configurations with zonally symmetric and asymmetric surface boundary conditions. Zonally asymmetric boundary conditions change the spatial location, frequency and duration of blocking in comparison to the zonally symmetric configuration, consistent with changes in climatological storm tracks and stationary waves. The results suggest zonally asymmetric surface boundary conditions control the spatial distribution of blocking in the real atmosphere to first order.

I think this paper is interesting and the results are relevant to this journal. However, I think the paper 1) does not provide sufficient explanations for the questions posed, 2) needs to focus more on the key results and 3) does not consider a key implication of the experiments which was proposed in previous work. Therefore it is for these reasons, which are summarised in more detail below, which I recommend major revisions before this paper can be published.

General comments:

1. I don't think the paper provides sufficient explanations for the questions posed (e.g. lines 344-346 and 483-487). Specifically, the explanations are generally qualitative and show consistency between different fields (e.g. storm tracks, stationary waves and blocking) and the authors often state that future work is required to understand the causal mechanisms (e.g. lines 443-445, 457-458, 492-493, 556-558). While it is clear that the surface boundary conditions cause the changes in blocking, it is difficult to establish the exact mechanisms because everything is changing at once. Therefore, I'm not sure the authors can answer the questions posed with these simulations only. It likely requires more detailed analysis with regards to the theories discussed in the Introduction or more experiments with simpler models.

2. I think the paper would benefit from focusing more on the key results. For example, I'm not sure how the analysis of high-latitude versus low-latitude blocking relates to the experiments because the authors state that the results are similar in all simulations and reanalysis (lines 296-299) and blocking is much less frequent in high-latitudes (Fig. 4a). The authors devote a significant portion of the results to discussing the reanalysis and model climatological stationary waves, storm tracks and jets (lines 306-404) which could be summarised in a few sentences since these features are well known and the responses are well understood. Finally, the subsampling analysis in Fig. 7 could also be discussed in words only and the case study in Fig. 1 could be omitted altogether since similar results are presented in Fig. 2.

3. I think the paper does not consider a key implication of their results which was proposed by

Hu et al. (2008). Viewed from their perspective, the results presented here demonstrate that zonally symmetric models capture the key features of blocking. To be clear, the results show that the surface boundary condition controls the spatial distribution of blocking. However, I was surprised to see that many of the hemispheric statistics listed in Tables 2-4 show modest changes on the order of 10-30% when topography is included. Moreover, the composite analyses in Figs. 3 and 9 suggest the dynamics of individual blocks are similar with and without topography. I think this would be an interesting point given recent work has focused on the role of orographic drag in improving the simulation of blocking (Pithan et al. 2016 GRL) and zonally asymmetric boundary conditions have been hypothesised to be critical for blocking formation (e.g., Tung and Lindzen 1979). Moreover, the results suggest that the poor simulation of blocking in climate models for the past several decades (e.g., Davini and D'Andrea 2016 JCLIM) could be better understood by understanding blocking dynamics in more simple aquaplanet models.

Given this different perspective and the issues discussed in general comment 1, a suggestion to improve the paper would be to focus on the following questions: 1) Are the characteristics of individual blocking events different with zonally symmetric versus asymmetric boundary conditions? 2) do zonally asymmetric boundary conditions control the spatial statistics of blocking? and 3) Are the hemispherically integrated statistics of blocking different for zonally symmetric versus asymmetric boundary conditions ?

Specific comments:

1. Lines 18-19: This suggests high-latitude blocking is different from reanalysis in the model however the text says the opposite.

2. Lines 42-43: Is this true if you integrate blocking statistics over the entire NH versus SH? How different are the statistics quantitatively?

3. Line 46: I think a better topic sentence for this paragraph is that the dynamics of blocking are unclear. Also I suggest to cite Nakamura et al. (2018) Science. Their work provides a simple theory for which can be used to explain why stationary waves preferentially localise blocking in certain longitudes, e.g., they slow the 'speed limit' and modify the source of zonal wave activity flux.

4. Lines 72-74: Suggest adding 'in order to relate the idealized results to the real atmosphere, e.g. NH vs SH and NH PAC vs NH ATL'.

5. Line 94: Does the omission of these processes influence blocking in the model compared to the real world ? e.g. diabatic effects shown by Pfahl et al. (2015) nature.

6. Line 96: The experiments include both topography and land-sea contrast yet the title only mentioned topography. What is more important for the results, topography or land-sea contrast?

7. Line 99: Suggest mentioning again why this specific configuration is used: to relate results to the real atmosphere.

8. Lines 100-106: Have the authors confirmed how their results are sensitive to the mountain amplitude?

9. Section 2.3: Could the anomaly normalisation or the spatial area threshold used to identify events be responsible for the different blocking events in mid versus high latitudes? Longitude lines converge poleward and the thresholds were likely tuned for midlatitudes. Have the authors checked the sensitivity of their results do different thresholds? Or a different blocking index? I suggest confirming the results with a simpler index involving only geopotential height anomalies or the reversal of the geopotential.

10. Sections 2.4.1-2.4.2: I suggest mentioning this in words in the results instead.

11. Section 2.4.3: Isn't a simple lanczos filter more commonly used (e.g. Shaw et al. 2016 nature)?

12. Section 2.4.5: I'm confused about the wave activity flux vectors. Shouldn't these be calculated for high-frequency eddies only since they characterize their influence on low-frequency blocking ? e.g., Hoskins et al. 1983 JAS Fig. 15. Here the quantities used to calculate the fluxes are low pass filtered.

13. Lines 247-248: I suspect that the lower statistical significance threshold was used because the blocking statistics are not that different between the zonally symmetric versus asymmetric experiments. This supports general comment 3 above.

14. Lines 290-291: I disagree. The contours differ by 25m, e.g. 275 versus 300.

15. Lines 505-506: I believe Hassanzadeh et al. 2014 used a dry-dynamical core not an aquaplanet model.

16. Lines 537 and 545: Resonance has a very specific meaning, e.g., multiple reflection of waves on turning points following linear theory. I don't think it is what is implied here.

17. Figs 2,3,4 and 9 and related analysis: I suggest the authors interpret the wave activity fluxes with regards to flux convergence not the flux itself since this is the key dynamical quantity for blocking (Hoskins et al. 1983 JAS, Nakamura et al. 2018 science).

18. Figs. 3 and related analysis: I suggest the authors compare the zonally-symmetric and asymmetric model simulations with reanalysis explicitly rather than reference previous work. Specifically, I suggest replacing Fig. 3 with a 3 x 3 panelled figure showing midlatitude blocking for reanalysis (top), zonally symmetric model (middle) and one zonally asymmetric model simulation for all 3 lifecycle stages (left, middle, right). This would also show that the two model configuration show similar results.