

## ***Interactive comment on “Systematic attribution of observed southern hemispheric circulation trends to external forcing and internal variability” by C. L. E. Franzke et al.***

### **Anonymous Referee #1**

Received and published: 1 June 2015

#### General comments

In this interesting paper, the authors analyze the drivers of the secular trends in the Southern Annular Mode (SAM) and blocking for all seasons. For this purpose, they use a non-stationary clustering, based on the finite element method, that can infer causation and thus, a systematic attribution of the causes of the circulation trends can be achieved. The aim of the paper is to complement model-based results and to try to separate natural variability from the forced response. The authors found strong observational evidence that anthropogenic greenhouse gas concentrations has caused the secular trends and that ozone depletion has played a minor role outside the austral summer season. Overall, I think the paper is original, well written and fits into the scope

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of the journal. I recommend publication, as this paper contributes to evaluate and improve climate models, and to better understand and predict the future climate change in the Southern Hemisphere. Consequently, it will be of great interest for the scientific community. However, I enumerate below some points that must be considered by the authors.

#### Specific comments

1) First paragraph, page 691, lines 8-9: “. . .employing a data-driven methodology that can infer causation. . .”. Do you think that the results are sensitive to the reanalysis used? Though this paper covers a more reliable period, some studies found that, even after 1979, large differences still exist between the reanalyses in the circulation, precipitation and SAM trends (e.g. Bromwich et al., 2007; Bromwich and Fogt, 2004).

2) There need to be more discussion of the Figure 3, especially in terms of time of residence in the summer season, which presents the most distinct pattern in relation to other seasons and annual: the regime transition have not occurred around 1980 and the frequency and persistence of the positive SAM and wave 3 are almost the same from 2000-2007.

3) Zonally asymmetric fields are used in the statistical analysis and not just mean zonal indices. This is important, as Ho et al. (2012) and others demonstrated that there is sensitivity associated with the index chosen to represent SAM and thus, it is necessary to consider the impact that the choice of SAM index has on the outcomes of any SAM attribution study. I suggest the inclusion of this reference in the Introduction section at the end of last but one paragraph.

#### Technical corrections

1) Section 3.2, line 27 introduces the acronym OMD, which is not defined previously. Is it the acronym for ozone mass deficit? This needs to be specified.

2) Missing units for geopotential height and surface air temperature in Figure 2.

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3) Missing the statistical significance in Figures 2 and 4.

#### References

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Bromwich, D. H., and R. L. Fogt (2004), Strong trends in the skill of the ERA-40 and NCEP–NCAR Reanalyses in the high and midlatitudes of the Southern Hemisphere 1958–2001, *J. Clim.*, 17(23), 4603–4619, doi:10.1175/3241.1.

Ho, M., A. S. Kiem, D. C. Verdon-Kidd (2012), The Southern Annular Mode: A comparison of indices, *Hydrology & Earth. System Sciences*, 16, 967–982, doi:10.5194/hess-16-967-2012.

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