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The Southern Annular Mode in the 21st Century: The Effect of Greenhouse Gas Emissions and Ozone Recovery

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The leading mode of Southern Hemisphere (SH) climatic variability, the Southern Annular Mode (SAM), has recently seen a shift towards positive phases; a product of stratospheric ozone depletion and increasing greenhouse gas (GHG) concentrations. Despite such contemporary changes being widely studied, few studies have examined how such factors will affect the SAM throughout the 21st Century (C21). This study has therefore investigated the evolution of the SAM (defined as the leading empirical orthogonal function, and corresponding principal component, of sea level pressure from 20º-85ºS) in the C21 for austral summer and winter.

A multi-model ensemble approach was adopted to obtain a higher signal to noise ratio; in total, 16 models of the Intergovernmental Panel on Climate Change Fourth Assessment Report were utilised. In order to assess the impact of stratospheric ozone recovery, models were divided into those that include, or exclude, stratospheric ozone forcing, producing the so-called ozone and non-ozone ensembles respectively. Furthermore, data was collected for three IPCC SRES (A2, A1B, and B1), allowing investigation into the effect future GHG emissions will have on the SAM.

Investigation into the effect of stratospheric ozone recovery was concentrated to the summer season when ozone exerts its strongest influence on the SAM. Whereas the non-ozone ensemble projects a continuation of contemporary positive trends during summer, the ozone ensemble does not. In contrast to some previous studies we find negative SAM index trends from 2000-2050 due to the effect of ozone recovery; however these trends are not large enough to return the SAM index to pre-ozone-hole levels. Following this, a threshold is reached whereby GHG-forcing dominates, re-establishing a positive SAM index trend. Further investigation revealed that these results are sensitive to model choice, explaining, in particular, the difference with previous studies.

The impact of GHG emissions on the future SAM was clear in both summer and winter. In both seasons, SRES scenario results were shown to be statistically distinguishable from one another. The strongest response is achieved under SRES A2, followed by SRES A1B and B1 respectively. This suggests that SAM-behaviour is strongly sensitive to GHG emissions. Due to the aforementioned effect of ozone recovery, sensitivity is weaker during summer.

In summary, this investigation has demonstrated the importance of both factors - stratospheric ozone recovery and future GHG emissions - in determining the evolutionary course of the SAM.