Low-frequency variability and potential decadal predictability of the Southern Annular Mode

Supervisors:
Martin Widmann (Univ. Birmingham), Julie Jones (Univ. Sheffield) and Jeff Knight (UK Meteorological Office)

Abstract

The Southern hemisphere Annular Mode (SAM) is the dominant mode of extratropical atmospheric circulation in the southern hemisphere. Neither the magnitude of decadal and longer SAM variability nor the processes that cause this low-frequency variability are well understood. The instrumental pressure measurements are too short to comprehensively analyse SAM variability, but the analysis of long climate simulations provides a promising alternative.

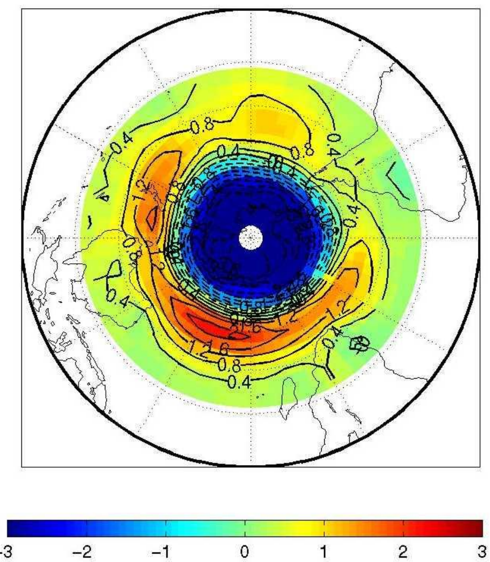
In this project General Circulation Model (GCM) simulations with lengths of 1000 years or more will be used to quantify decadal SAM variability, to improve process understanding and to assess potential SAM predictability. Many of these simulations only became available during the last few years and their potential for SAM studies has not been fully exploited yet. The predictability analysis will focus on statistical links between ocean states and SAM states at a later time. Ocean anomalies that appear to be linked to the SAM in the long GCM simulations will be tested for their practical relevance by using them as initial conditions in the UK Met Office decadal climate prediction model.

The PhD student will be part of an active climate and atmosphere research group at the School of Geography, Earth and Environmental Sciences at the University of Birmingham. The supervisory team has extensive experience in SAM reconstructions and analysis, climate modelling, weather forecasting and climate statistics. The project is linked to the UK Met Office through a CASE studentship and includes several short and one three-months visit to the UK Met Office.

Applicants should have a background in a related field such as meteorology, oceanography, climatology, geosciences, or physics. Sound mathematical and statistical skills, as well as programming experience are essential. For further details please contact M. Widmann (m.widmann@bham.ac.uk).

Introduction

The Southern hemisphere Annular Mode (SAM), also known as the Antarctic Oscillation, can be defined as the first principal component of sea level pressure (SLP) and is approximately zonally symmetric (Thompson and Wallace 2000, Jones et al. 2009). A positive (negative) index represents negative (positive) highlatitude and positive (negative) midlatitude pressure anomalies and hence stronger (weaker) westerly circumpolar flow. The SAM influences diverse aspects of SH climate, including Antarctic temperatures, precipitation in the SH midlatitudes, sea ice and ocean circulation.



Colour: SAM for Dec-Jan, defined as first principal component of seasonal sea level pressure (SLP) in the extratropical SH (in hPa/PC standard deviation). Isolines: correlation between SAM index and SLP.

The SAM has attracted much interest because of statistically significant positive trends in recent decades during austral summer and autumn. Related studies have mostly concentrated on anthropogenic causes, specifically stratospheric ozone depletion (e.g. Thompson and Solomon 2002). To put these trends in a larger perspective Jones and Widmann (2004) reconstructed the austral summer SAM index from 1878 onwards from a sparse network of instrumental SLP measurements, Jones et al. (2009) produced analogous reconstructions for all seasons, and Jones and Widmann (2003) used tree-ring records to estimate the SAM index back to 1743.

These SAM reconstructions indicated that the trends in recent decades are not unprecedented, and thus natural climate forcings and internal variability can also strongly influence the SAM. However, the quantification and understanding of decadal and longer SAM variability is still in a very early stage and the reconstructions are too short to lead to conclusive results. A promising avenue for progress is the analysis of GCM simulations with lengths of thousand years or more, which have only recently become available.

In this project SAM variability in several long simulations from leading climate modelling centers such at the UK Hadley Center or the German Max Planck Institute for Meteorology will be analysed. The project will also address the question whether decadal SAM variability can be predicted from the state of the ocean by analysing statistical links in long GCM simulations and by using the UK Met Office DePreSys decadal forecasting system.

Aims

This project aims at quantifying and understanding decadal and longer SAM variability, as well as at exploring the potential for predicting SAM variability on decadal timescales. The specific objectives are

i. to quantify internally generated SAM variability in long GCM simulations;

ii. to investigate concurrent and lagged links between ocean states and SAM states in long GCM simulations;

iii. to investigate the SAM response to solar, volcanic and anthropogenic forcings;

iv. to investigate whether the ocean-SAM links found in long GCM simulations can be used for decadal SAM predictions with the DePreSys model.

Methods

Long equilibrium and forced simulations with ECHAM5/6-MPI-OM and HadCM3 will be analysed. Concurrent and lagged links between ocean and SAM states will be described by linear models, such as PC multiple linear regression or 1-dimensional maximum covariance analysis, including cross-validation. Non-linear links will be investigated through composite analysis. Ocean variables will include SST, upper-ocean heat content, downwelling and vertical heat transport.

Climate forcing signals will be investigated by comparing the SAM variability in equilibrium and in transient, forced simulation, and if possible by analysing linear and non-linear links between the forcings and the SAM index through correlation and composite analysis.

Ocean states found to be linked to SAM variability will be used to initialise the ocean in the DePreSys forecasting system and it will be investigated whether the links can be reproduced. Ocean anomalies from the past decades will be used to investigate to what extent SAM variability over the past decades has been influenced by the ocean.

Training

The supervisory team will provide training in all aspects of the project such as advanced statistics, climate analysis, climate modelling and the use of supercomputers. It also brings multiple national and international links to the project. M. Widmann has extensive expertise in climate modelling, climatology and statistics, J. Jones is one of the leading experts in SAM reconstructions, and J. Knight is an expert in climate modelling and numerical weather prediction.

The PhD student will be part of the Climate and Atmosphere Research Group in the School of Geography, Earth and Environmental Sciences. The project is linked to the UK Met Office through a CASE studentship and includes several short and one three-months visit to the UK Met Office, which will provide training in using the DePreSys decadal forecasting system.

Prerequisites

Applicants should have a MSc or equivalent degree in a related field such as meteorology, oceanography, climatology, geosciences or physics. Sound mathematical and statistical skills, as well as programming experience are essential. Some working experience with UNIX, FORTRAN, MATLAB and with climate modelling would be beneficial.

References

Jones, J. M. and M. Widmann, 2003: Instrument- and tree-ring-based estimates for the Antarctic Oscillation. *J. Climate*, 16(21), 3511-3524.

Jones, J.M. and M. Widmann, 2004: Early peak in Antarctic Oscillation Index. *Nature*, 432, 290-291.

Jones, J.M., R.L. Fogt, M. Widmann et al., 2009: Historical SAM Variability. Part I: Century Length Seasonal Reconstructions, *J. Climate,* **22**, 5319-5345.

Knight, J.R, 2009: The Atlantic Multidecadal Oscillation as inferred from the forced climate response in coupled general circulation models. *J. Climate*, 22, 1610-1625.

Thompson,D.W. J., and J. M. Wallace, 2000: Annular modes in the extratropical circulation. Part I: Month-to-month variability. *J. Climate*, 13, 1000–1016.

Thompson D.W.J. and S. Solomon, 2002: Interpretation of recent Southern Hemisphere climate change. *Science*, 296, 895–899.

Widmann, M., 2005: One dimensional CCA and SVD, and their relationship to regression maps. *J. Climate*, 18(14), 2785-2792.