

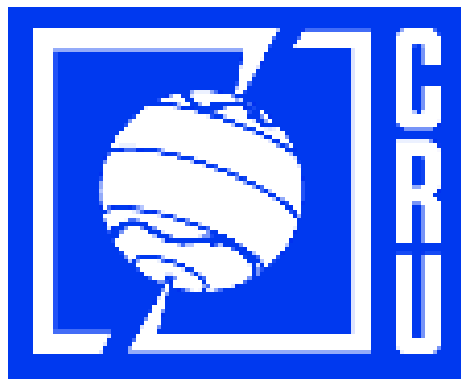
The role of eddies in determining the Southern Ocean response to the Southern Annular Mode

J. Screen (1), N. Gillett (1), D. Stevens (2), G. Marshall (3) and H. Roscoe (3)

(1) Climatic Research Unit, School of Environmental Sciences, University of East Anglia, Norwich, UK

(2) School of Mathematics, University of East Anglia, Norwich, UK

(3) British Antarctic Survey, Cambridge, UK



British Antarctic Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Corresponding author: James Screen, j.screen@uea.ac.uk/ Phone +44-1603-593808

Thanks to the members of the OCCAM team at the National Oceanography Centre, Southampton, for providing the model data used in this study.

1. Background

The Southern Ocean shows a clear response to the Southern Annular Mode (SAM). A positive shift in the SAM is associated with cold sea surface temperature (SST) anomalies centred at 60°S and warm SST anomalies centred at 40°S (Fig. 1). Transport of the Antarctic Circumpolar Current (ACC) has also been shown to increase during the positive phase of the SAM^a. The ACC transport increases due to a strengthening of the atmospheric westerlies. The SST response results from a combination of anomalous atmosphere-ocean heat fluxes and enhanced northward (southward) Ekman transport of cold (warm) water between 50-70°S (30-50°S). The modelled response is stronger and more zonal in structure than the observed response^b (Fig.1).

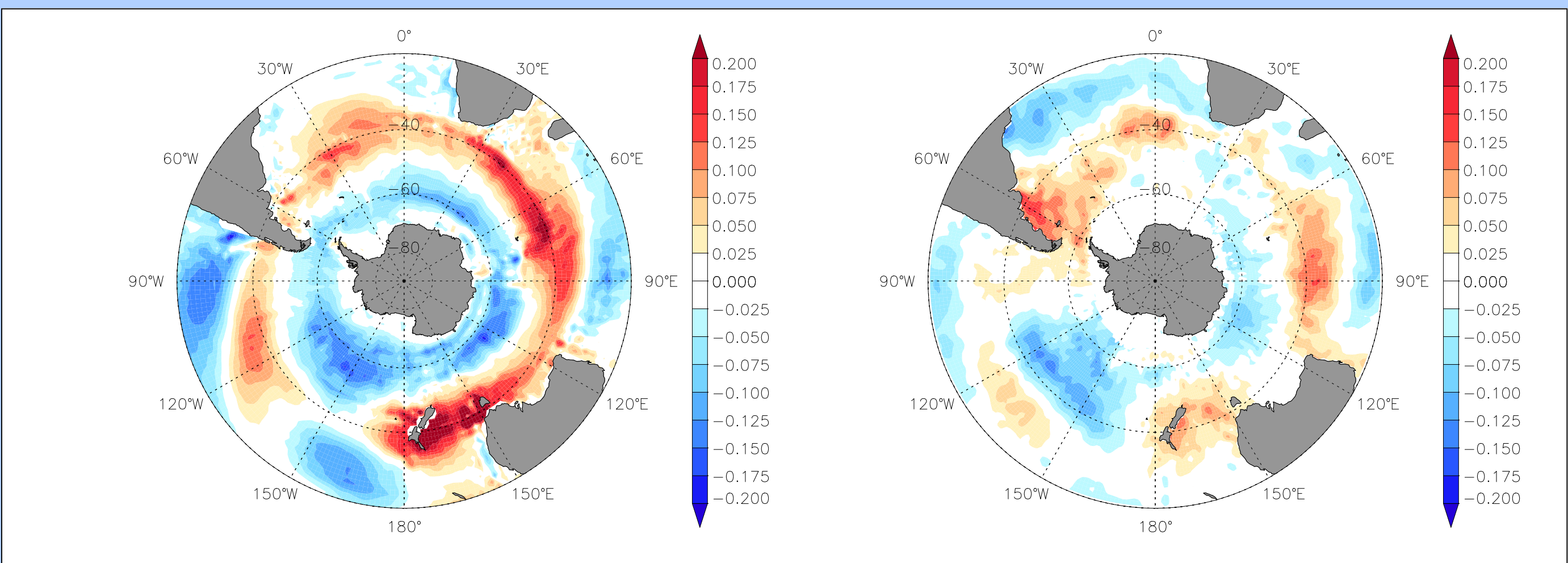


Fig. 1: Monthly mean SSTs regressed against the SAM Index in HadCM3 (1990-1999) (left) and HadISST (1982-2005) (right). Units are °C per 1 standard deviation increase in the SAM Index.

2. Hypothesis

The Southern Ocean mesoscale eddy field is responsible for a poleward heat flux that balances the heat lost to the atmosphere at high latitudes. Another key role played by the Southern Ocean eddy field concerns the balance of forces contributing to the ACC. It has been shown that Southern Ocean eddy activity increases when the SAM is in its positive phase^c. Eddies may act to reduce the SST response to the SAM by increasing southward heat transport, and reduce the ACC zonal transport response to the SAM by transferring momentum downwards in the water column. Consequently the Southern Ocean response to the SAM may be difficult to capture exactly with climate models that do not resolve eddies explicitly.

3. Data and Methods

Results are presented from the OCCAM ocean model which is run at 3 spatial resolutions - 1°, 1/4° and 1/12° - from coarse to eddy-permitting. Comparing coarse with fine resolutions indicates the effect of explicitly-resolved eddies on the Southern Ocean response to changes in the SAM. OCCAM is a primitive equation numerical model of the global ocean. The OCCAM model has been run with high resolution forcing using 6-hourly wind and heat fluxes from the NCEP reanalysis for the 1985-2000 period. SST observations are from the 1° HadISST dataset and are derived from in-situ measurements and satellite estimates. The SAM index is calculated by projecting monthly 850hPa geopotential height anomalies, from the NCEP reanalysis, onto the leading EOF mode. All time series were detrended and deseasonalised before calculating the regression coefficient.

4. Results

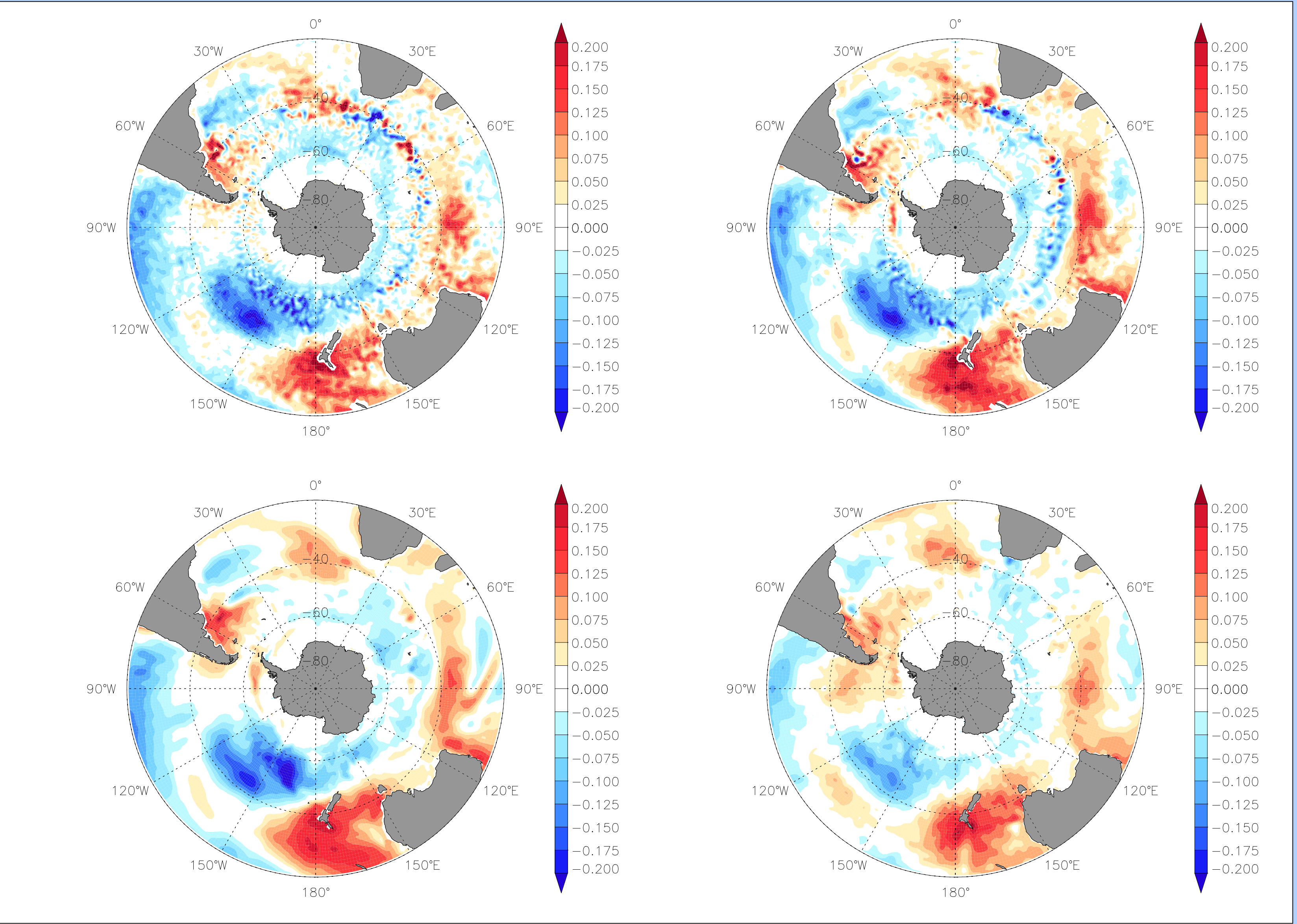


Fig. 2: Monthly mean SSTs regressed against the SAM Index, 1985-2000, using the 1/12° (upper right), 1/4° (upper left), 1° (lower left) resolutions of the OCCAM model, and HadISST observations (lower right). All values are regressions in °C resulting from a 1 standard deviation increase in the SAM index. The 1/12° and 1/4° plots have been regridded to 1° resolution.

Resolution (°)	Variance	Regression with SAM (Sv). 2 sigma error in brackets
1	8.44	1.64 (0.36)
1/4	7.74	1.06 (0.38)
1/12	9.27	1.22 (0.42)

Table 1: Variance in monthly mean ACC zonal transport through Drake Passage and the regression between transport and the SAM index in the different resolutions of the OCCAM model, 1988-2000. The first 3 years have been removed to allow the model to spin-up.

5. Conclusions

The observed SST response to the SAM is well represented by all resolutions of the model (Fig. 2). It appears that eddies play a minor role in determining the SST response to the SAM on monthly timescales.

The regressions between monthly Drake Passage transport anomalies and the SAM are not significantly different in the three model resolutions. Thus eddies do not dampen the response of the ACC to a change in wind stress forced by the SAM.

These results are encouraging for climate modellers as they suggest that low (1°) resolution models are able to capture the main features of the Southern Ocean response to the SAM on monthly timescales. However, preliminary results suggest that the response of the Southern Ocean eddy field to the SAM is lagged by 2-4 years. Eddy kinetic energy responds to the SAM on longer timescales than the SSTs and ACC transport. Consequently, over inter-annual timescales eddies may play a more important role. This is being examined in ongoing work.

References

- ^a Meredith, M.P., P.L. Woodworth, C.W. Hughes and V. Stepanov. Changes in the ocean transport through Drake Passage during the 1980s and 1990s, forced by changes in the Southern Annular Mode, *Geophysical Research Letters*, **31**(21), 2004.
^b Sen Gupta, A. and M. England. Coupled Ocean-Atmosphere-Ice response to variations in the Southern Annular Mode, *Journal of Climate*, **19**(18), 4457-4486, 2006
^c Meredith, M.P. and A.McC. Hogg. Circumpolar response of Southern Ocean eddy activity to changes in the Southern Annular Mode, *Geophysical Research Letters*, **33**(16), 2006.