Twentieth century behaviour of the Southern Annular Mode

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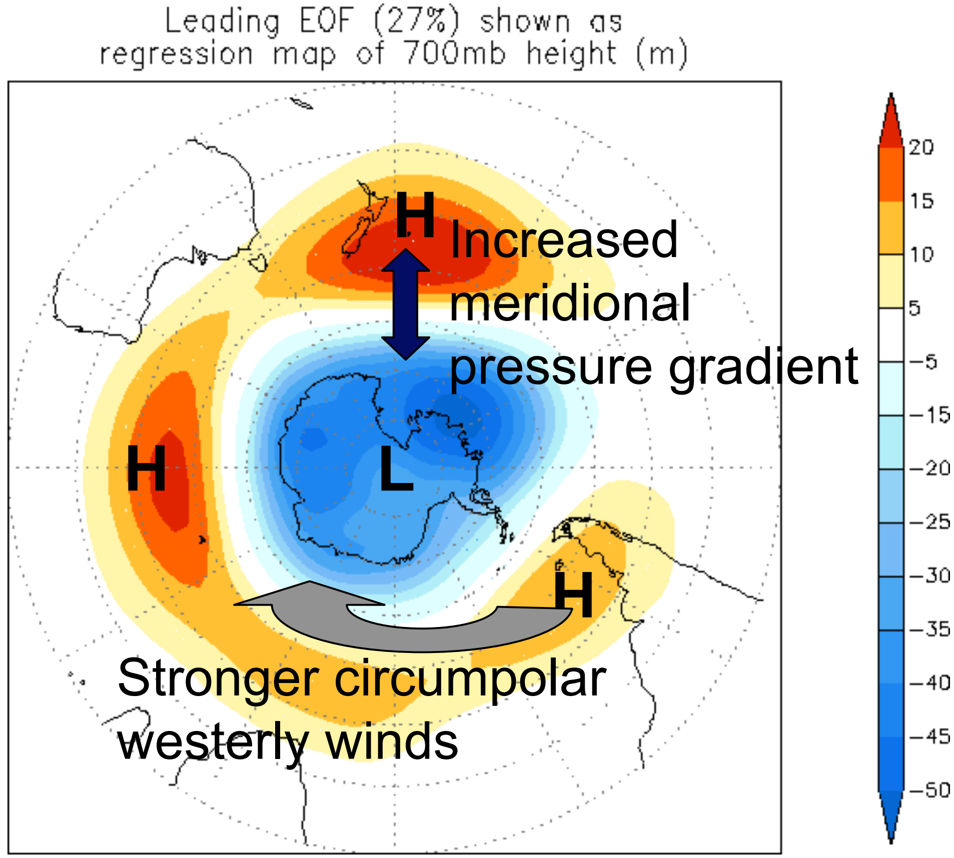
Twentieth century behaviour of the Southern Annular Mode

- Introduction to the Southern Annular Mode (SAM), recent trends, and data sources
- SAM reconstructions for the past century using station SLP data
- Use of these reconstructions to evaluate the SAM in IPCC AR4 model simulations

The SAM (also known as the Antarctic Oscillation)

Picture: Ryan Fogt



SAM positive phase

stronger, more poleward jet and storm tracks

Pattern: commonly defined as first EOF (Empirical Orthogonal Function) of extratropical sea level pressure (SLP) or geopotential height (GPH)

Timeseries: commonly defined as principal component (timeseries) of the EOF *or* normalised zonal mean SLP difference between 40°S and 65°S (Gong and Wang

Available (non-proxy) SAM reconstructions/ data from which SAM can be reconstructed

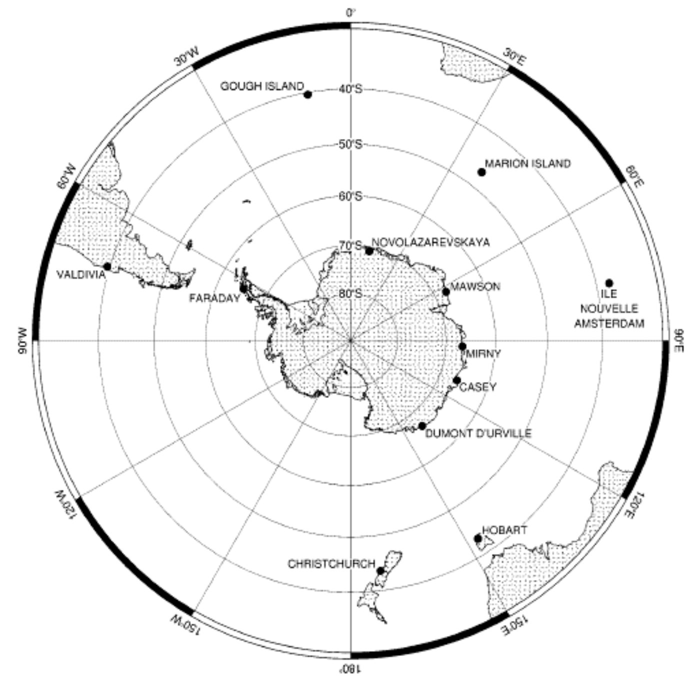
NCEP/NCAR and ERA40 reanalysis back to 1948 and 1958 respectively, but uncertainties at high latitudes prior to assimilation of satellite data (1979-) (e.g. Bromwich and Fogt 2004)

Marshall (2003) index, 1957-present, using six stations at mid- and high-latitudes

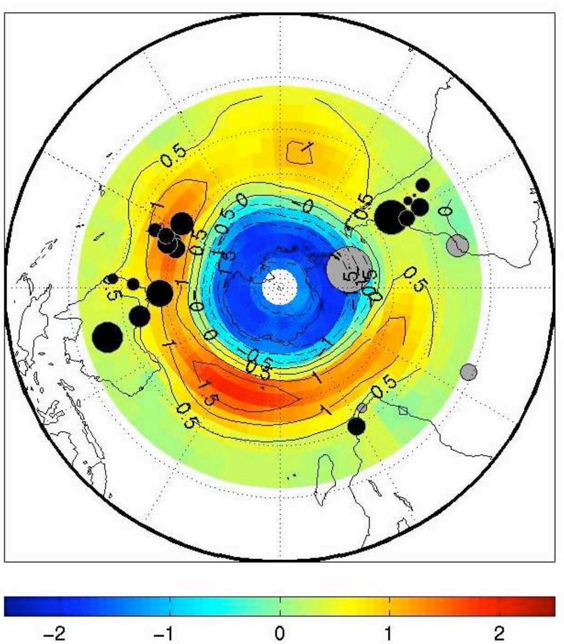
Reconstructions: using station SLP data (Jones and Widmann 2003,2004; Jones et al. 2009)

Twentieth Century Reanalysis (1871-2008)

HadSLP2 (1850-2005)



Century-length SAM reconstructions from station SLP



22 stations used in DJF 1905 reconstruction

Station SLP obtained from Phil Jones and Rob Allan

Determine at which stations SLP is significantly correlated with the SAM index

During period when have SAM index, fit statistical model (using principal component regression) between SLP from these stations and the SAM index (and validate this relationship using leave-one-out cross validation)

For period when only have station data, use the statistical relationship gained to reconstruct the SAM index

Jones and Widmann 2003, 2004; Jones et al. 2009

Seasonal Reconstructions 1865-2005

Jones and Widmann (JW)

Predictand: SAM index calculated from ERA40 reanalysis (PC-based)
1958-2001

Four networks – 1865 (DJF and MAM only)
- 1905
- 1951 (some island stations become available)
- 1958 (a number of Antarctic stations become available)

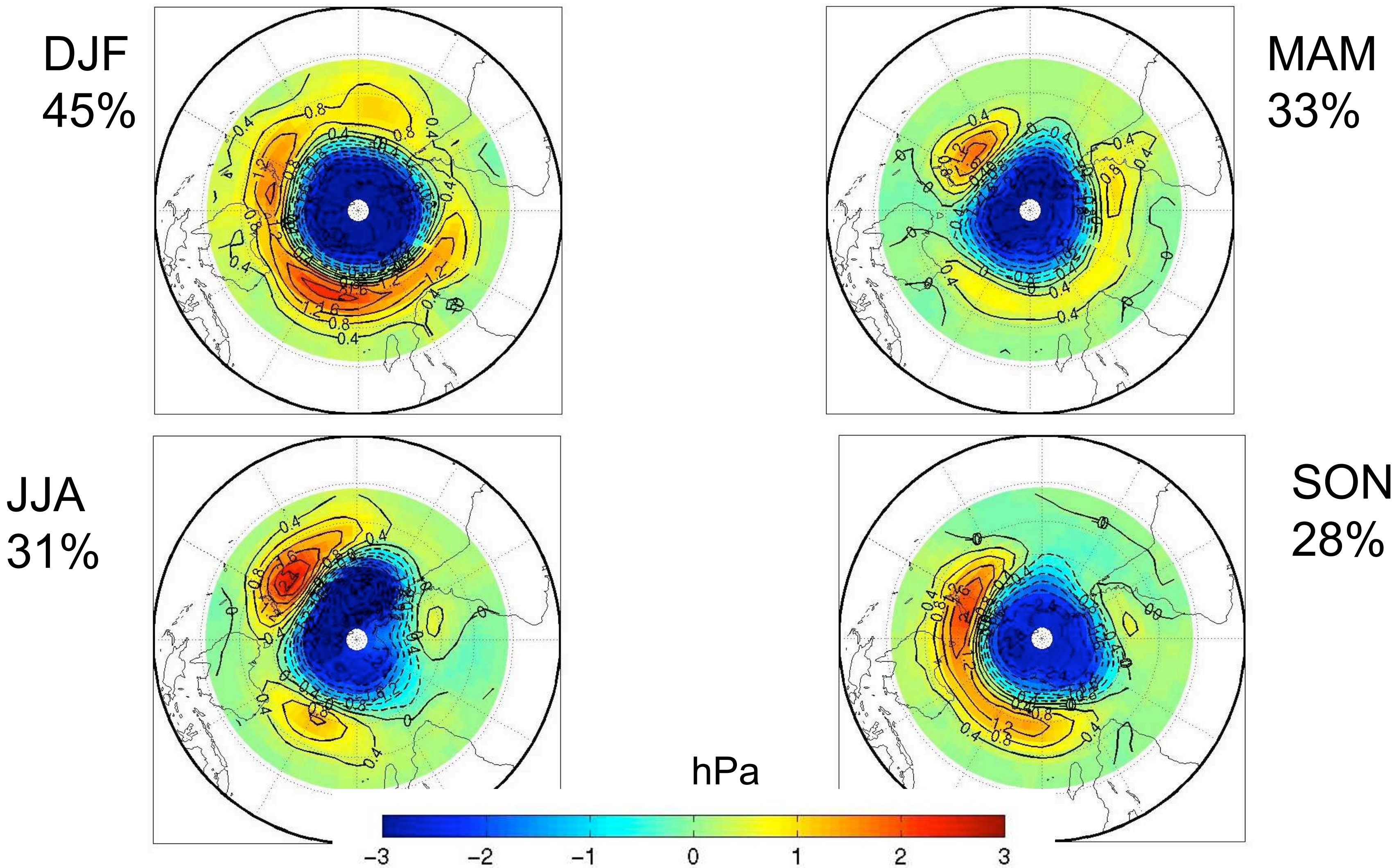
Fogt
Predictand: Marshall (2003) SAM index, 1957-2005

Two networks – 1865 (DJF and MAM)
- 1905 (JJA and SON)

Use different predictands: may influence similarity we can expect

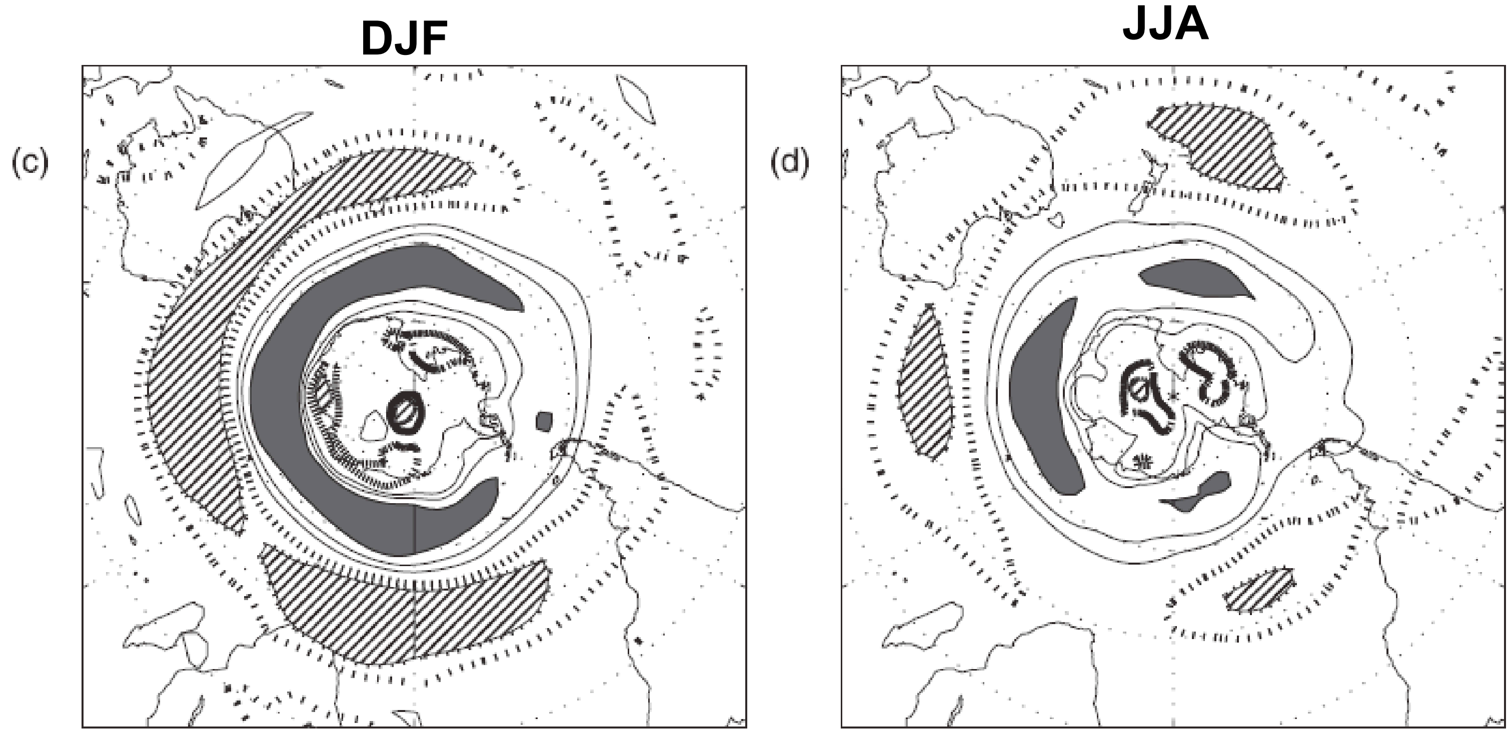
Jones, J. M., R. L. Fogt, M. Widmann, G. J. Marshall, P. D. Jones, and M. Visbeck, 2009. Historical Sam Variability. Part 1: Century length seasonal Reconstructions. *J. Climate*, **22**, 5319-5344.

SLP EOF1 (SAM) ERA40 1979-2001



- Structure of SAM varies seasonally
- areas of strong SAM signal away from continents in JJA and SON
  - fewer and less strongly correlated stations enter reconstruction in these seasons

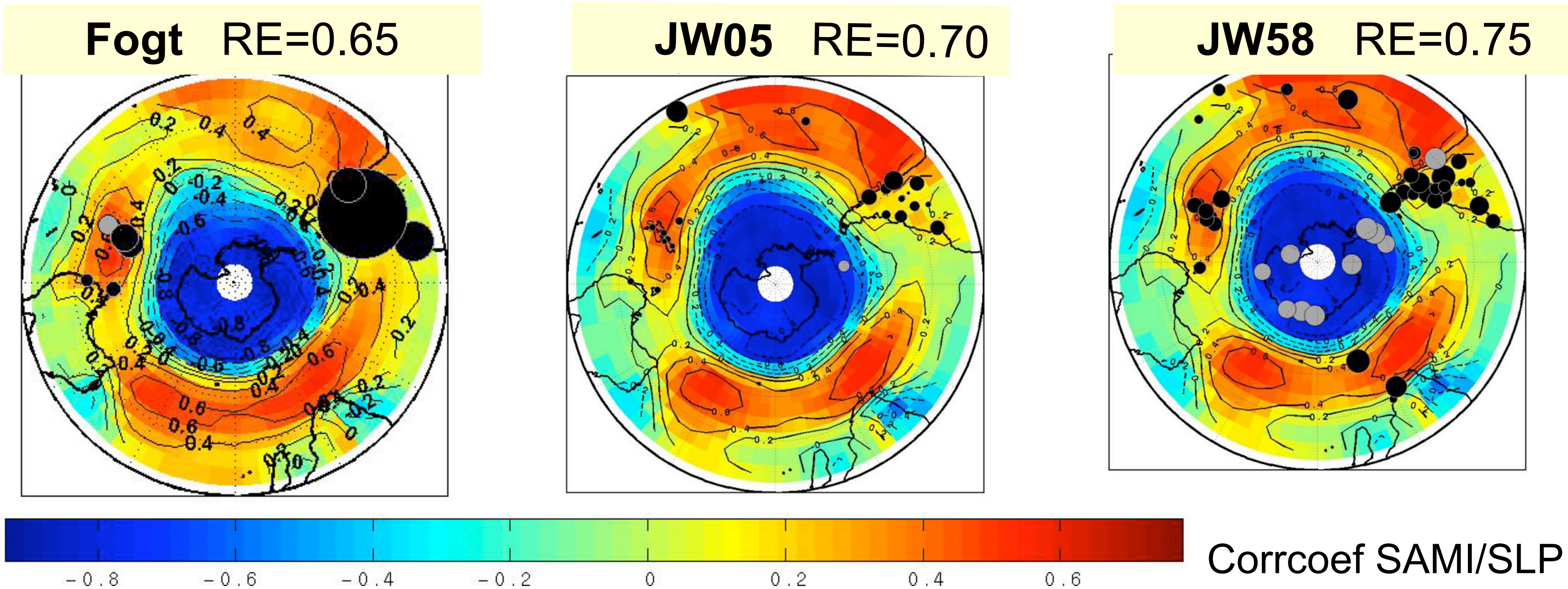
Correlation coefficient between SAM index and wind speed anomalies



contour omitted. The contours ±1 m s⁻¹ std⁻¹ are bold, and $-1.5 > R > 2$ m s^{-1} std^{-1} are hatched/shaded. Correlation coefficient (R) for the monthly mean wind speed anomalies at 500 hPa with the SAM during (c) summer and (d) winter. Contour interval is every 0.2, with the zero contour omitted; $-0.4 > R > 0.6$ are hatched/shaded.

Kidston and Renwick 2009

Reconstruction quality: DJF



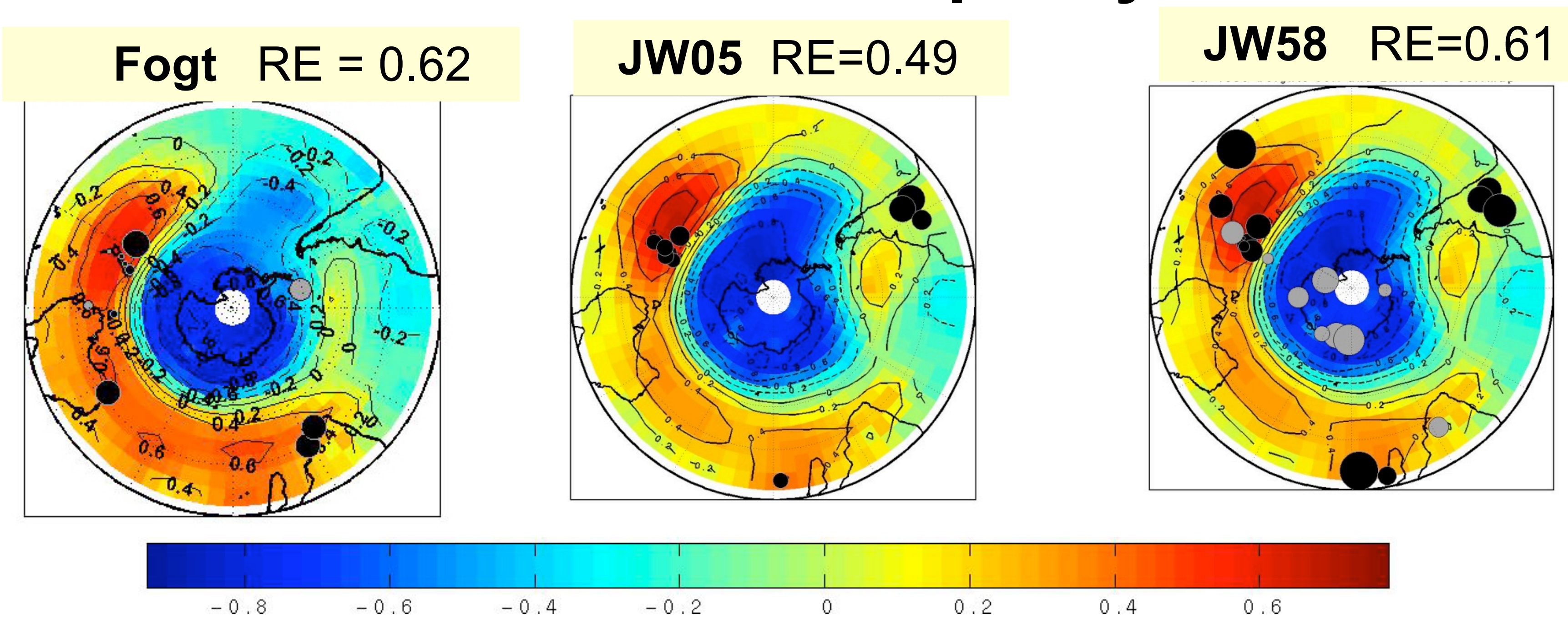
Reconstructions with high reduction of error (RE) can be obtained

Good agreement: $r_{Fogt/JW58}$= 0.82, $r_{Fogt/JW05}$=0.86

Strong agreement between Marshall index and ERA40 PC, so stations from similar locations selected

Similar results in MAM: Fogt RE= 0.50, JW05 = 0.63, JW58=0.78

Reconstruction quality: JJA



Poorest JW reconstructions in this season

$r_{Fogt/JW58}$= 0.72, $r_{Fogt/JW05}$=0.65;

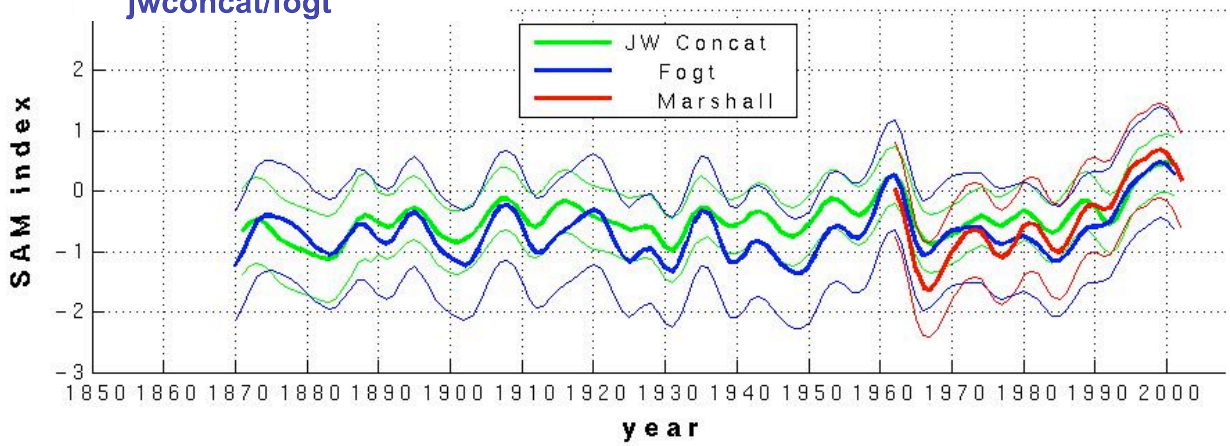
Weaker SAM SLP signal over mid-lat land areas – less stations, with weaker relationship to SAM, included

Marshall SAM SLP signal stronger over Australia, Indian Ocean and Southern Africa than ERA40, so more stations included

Similar results in SON: Fogt RE = 0.67, JW05 = 0.52, JW58 = 0.65

Reconstructed past SAM variability

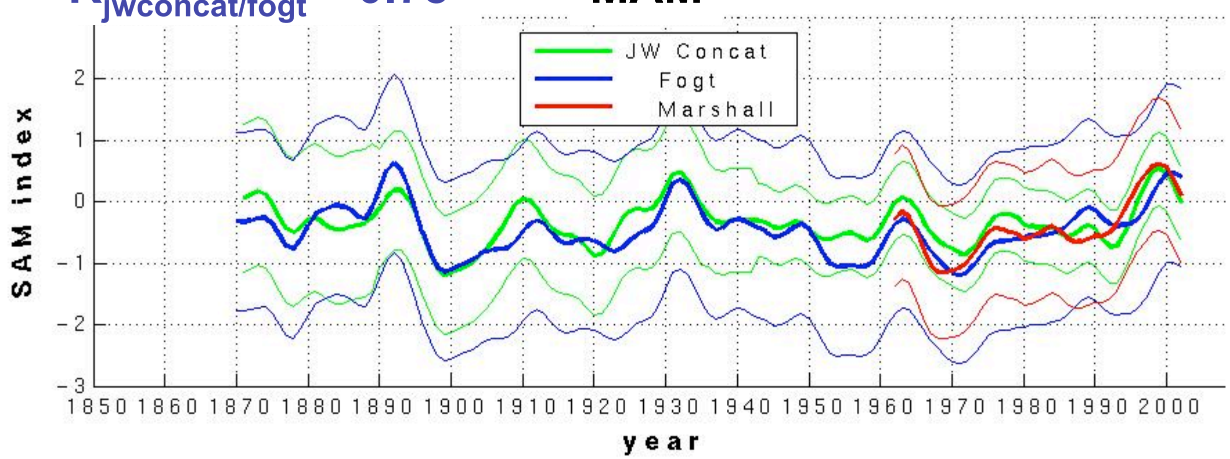
$R_{jwconcat/fogt} = 0.79$ **DJF**



9-year hamming filter applied to series, thin lines 95% conf int

- Decadal-scale variability throughout
- Recent positive trend largest in series
- Correlation good throughout, although difference in means

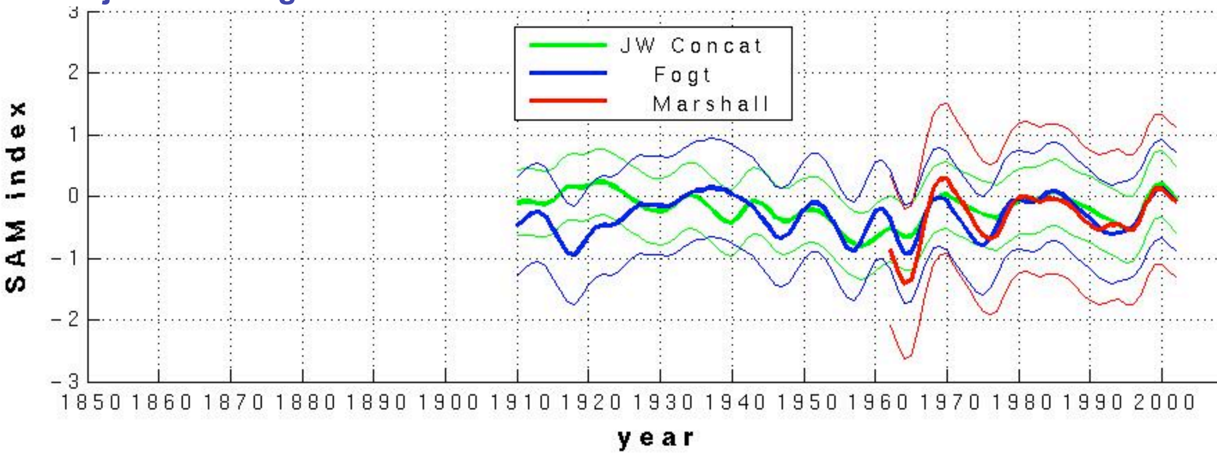
$R_{jwconcat/fogt} = 0.78$ **MAM**



- Considerable decadal variability
- Peaks in 1890, 1930 and present
- 1930's peak hemispheric

Reconstructed past SAM variability

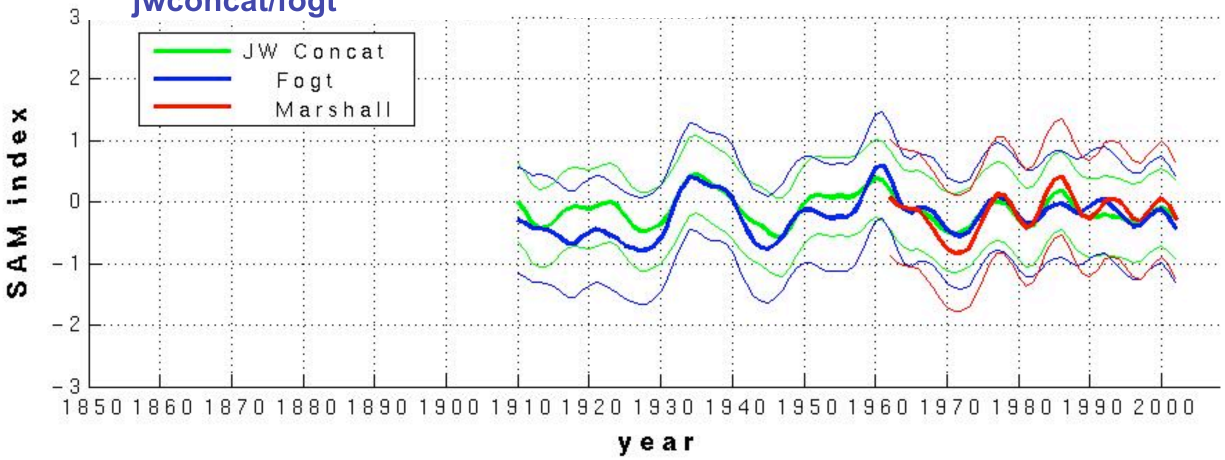
$R_{jwconcat/fogt} = 0.40$ JJA



- Low decadal variability prior to 1960
- Early disagreement between reconstructions (Fogt has better validation statistics)

9-year hamming filter applied to series, thin lines 95% conf int

$R_{jwconcat/fogt} = 0.82$ SON

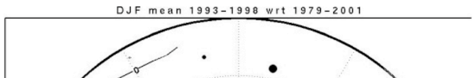


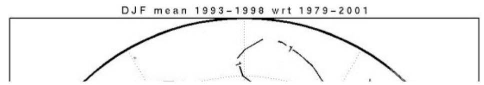
- No positive recent trend
- Higher decadal variability in early C20
- Disagreement at beginning (Fogt better validation..)

But not all SAM periods are ‘SAM-like’

stations **ERA40**

DJF SLP anomalies 1993-1998 wrt 1979-2001





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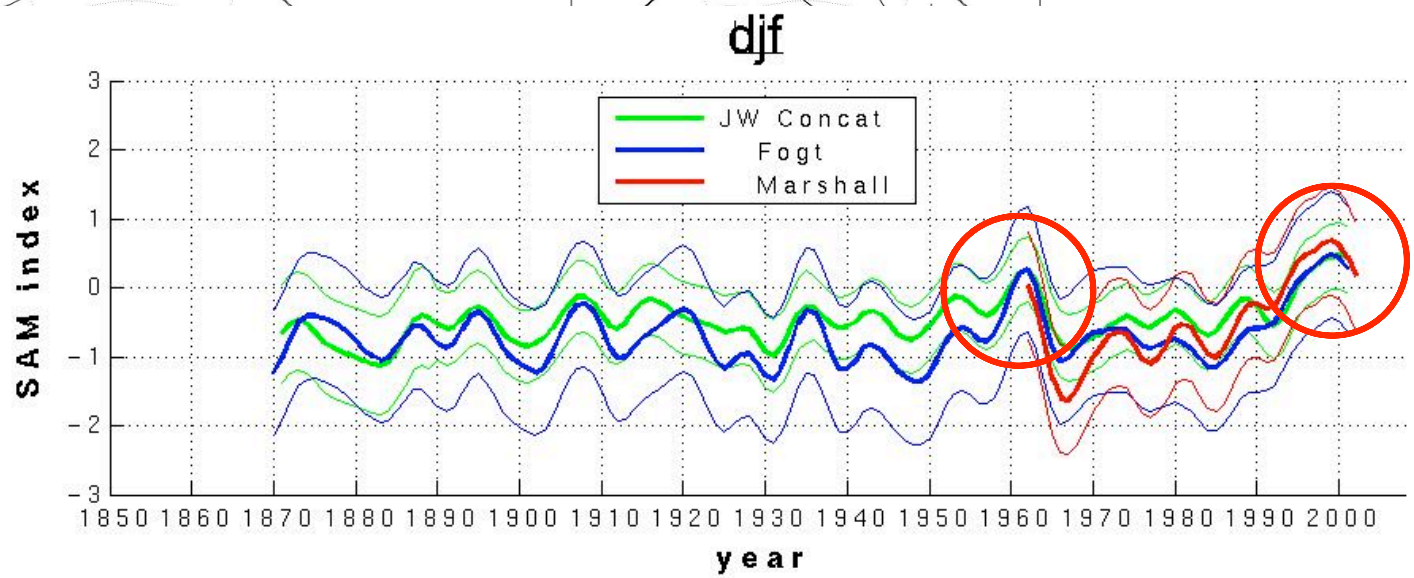

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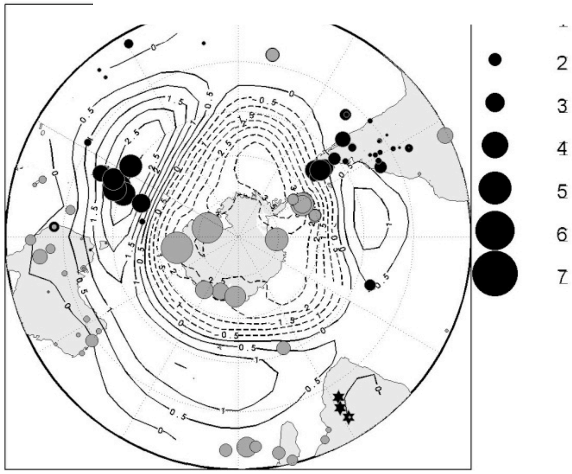
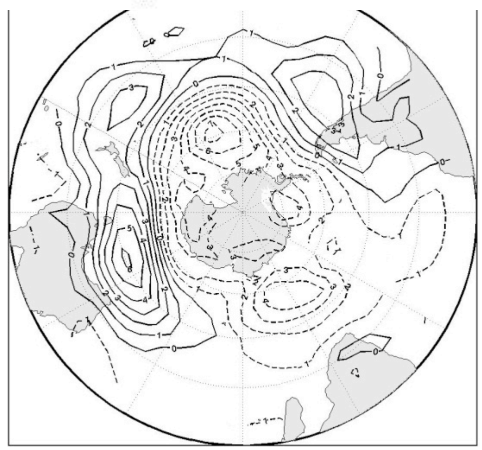
DJF 196





Less zonal: so SAM peak less pronounced in ERA40 PC than reconstructions

Use of reconstructions for model evaluation

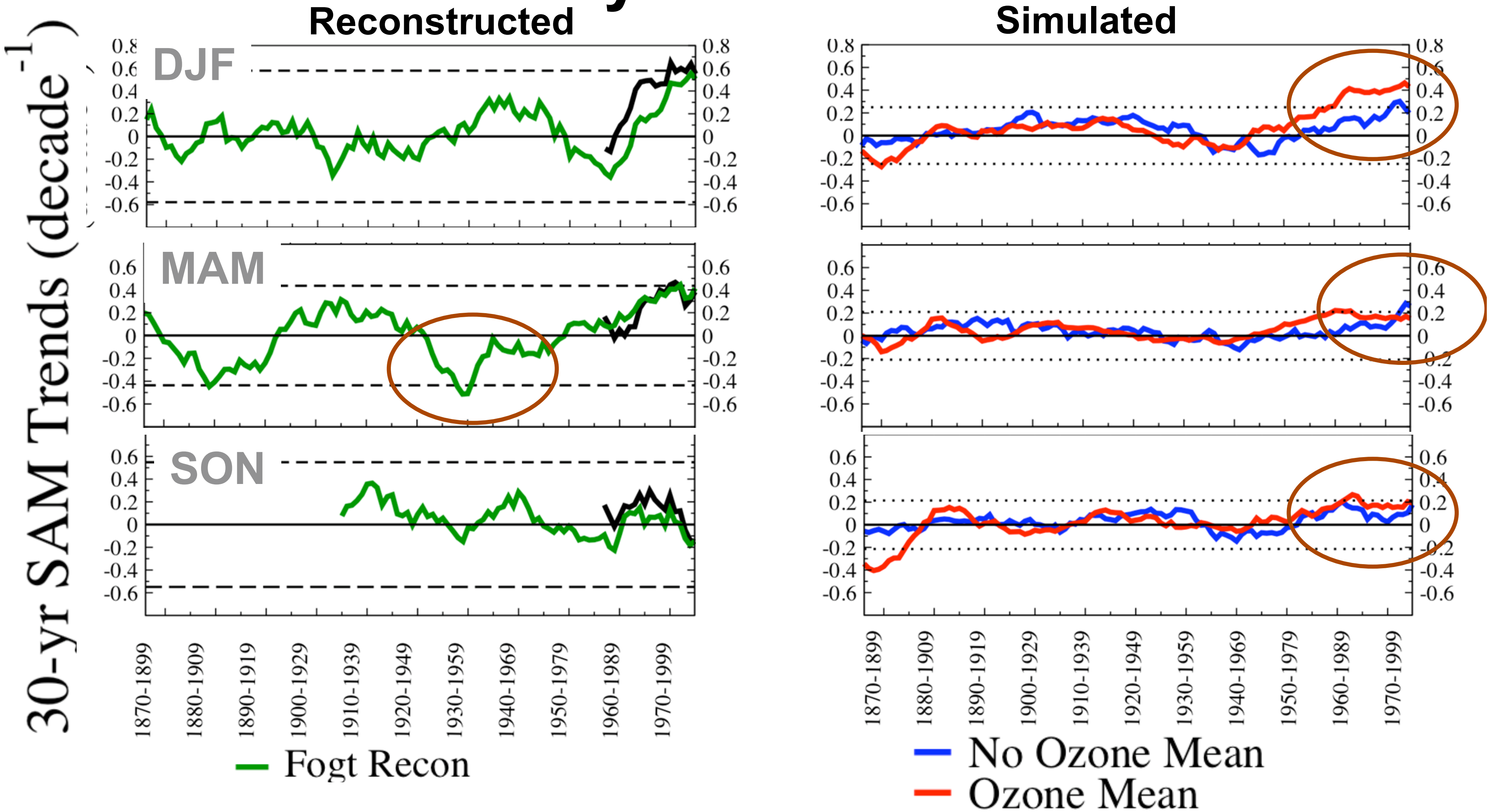
IPCC 4th Assessment Report (AR4) simulations

Comparison with 17 coupled atmosphere-ocean GCM simulations, 11 of which employ time-varying ozone forcing

Expands on previous studies which were for the recent reanalysis period and for annual values (Miller et al. 2006) or DJF (Cai and Cowan 2007)

Fogt, R. L., J. Perlwitz., A. J. Monoghan, D. H. Bromwich, J. M. Jones and G. J. Marshall, 2009: Historical SAM variability. Part II: Twentieth-century variability and trends from reconstructions, Observations, and the IPCC AR4 models. *J. Climate,* ***22****, 5356-5365.*

30-yr SAM Trends

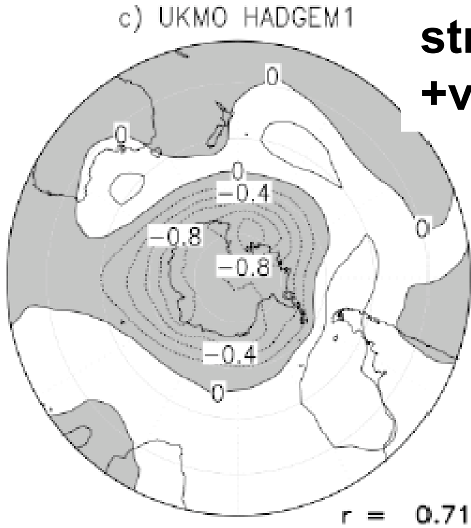


DJF: Recon. and simulated recent trends outside internal variability

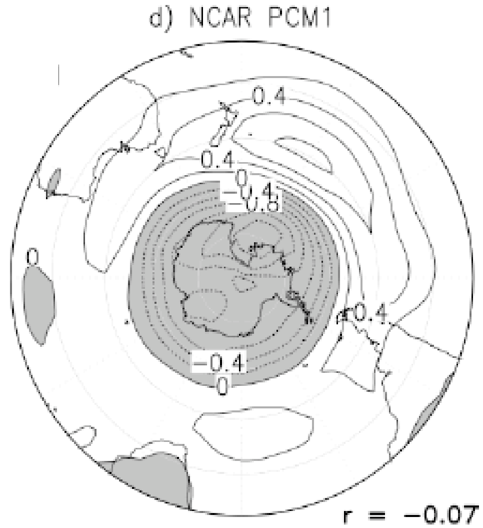
MAM: sig. -ve reconstructed trends (from 30s peak down), stronger than recent +ve trend (also sig), recent simulated trends just outside confidence intervals, weaker

SON: recons show weak variability, no sig. trends, most ozone models and >1/2 non-ozone models show significant recent trends (**JJA** not sig in recon or models)

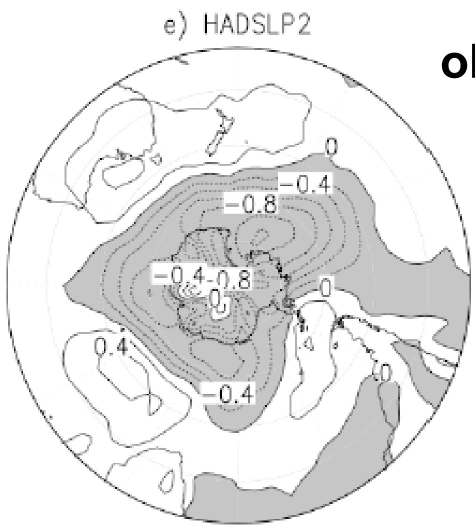
Model spatial SLP trends 1958-2005



Model with strongest +ve trend

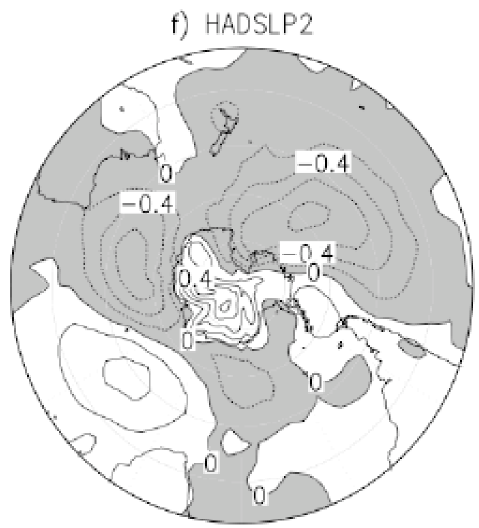


MAM: observed and simulated trend pattern annular, model amplitude too low



MAM

observed



SON

SON: simulated trend pattern too annular, missing observed negative trends in SE Pacific
– an area of strong ENSO influence in this season

Conclusions

- **Seasonality important both for SAM pattern (and hence climate impacts), variability and trends over past century, ability of models to capture SAM variability depends on season**
- Reconstructed DJF recent trend largest in series
- Low-frequency variability in DJF and SON and ***particularly MAM*** early in reconstructions (prior to strong greenhouse and ozone forcing)
- Only in DJF is there a clear simulated anthropogenically forced component in the SAM trend (ozone + GHG)
- MAM trends ***may*** have a forced component, but there are peaks and stronger trends earlier in the reconstruction, peaks of these magnitude not simulated by models
- JJA (not shown) both models and reconstructions show no significant trends
- The models simulate forced trends in SON (which Arblaster and Meehl 2006 find is response to GHG forcing), while observations do not: caution in interpreting model results in this season

MAM and SON results indicate perhaps that tropical-extratropical interactions, and/or trop-strat coupling not well resolved by models (indication of which components of climate system important to improve)