Variability in control and transient simulations with CSIRO Mk3.5 model

Siobhan O'Farrell

Antarctic Climate and Ecosystems CRC, CSIRO Marine and Atmospheric Research

Introduction and methods

Sea level has been calculated from 420 years of the CSIRO Mk3.5 model control simulation to investigate how well the model captures the natural modes of variability. The model has minimal drift in surface SST, but a slight drift in total heat content so this has been linearly detrended before EOF analysis has occurred. The analysis concentrates on annual data, seasonal data showed little difference in the major modes of variability. The first mode of the global pattern is shown in Figure 1, it shows a large scale ENSO-like pattern in the Pacific Ocean, with strong responses in the Indian Ocean and Amundsen Seas. The Atlantic sector also has strong dipoles in both North and South basins. The first 6 EOFs have been examined with most of the variability in the first 4 modes, modes 5 and 6 have been included as they sometimes contain weaker modes of low frequency variability. Details of the variance in each mode are outline in Table 1 and the frequency of the spectral peaks in the time series associated with each pattern of variability are shown in Table 2. There is low confidence in frequencies longer than 100 years which often appear as harmonics of the 420 year time series. Additional data is now being computed which will allow us to resolve further at the lower frequencies.

In order to examine the sources of the variability in each of these modes, the data has been broken down into regional EOFs (Figures 2-5). This has allowed us to define the source of some of long period modes in the data as the Southern ocean, whilst shorter ENSO and decadal North Pacific modes are seen in the other basins. The long period Southern ocean modes has an influence in South Pacific, South Atlantic and South Indian oceans (Figure 5). Correlations between the time series for each of modes and major indices of climate variability have been calculated, including indices of North Atlantic and Southern Ocean overturning. Table 1 is colour coded with the response of each mode, with the colour representing the strongest response, 'starred' colours show weaker responses to other indices for the same EOF mode. The strongest responses are to Nino3-4, North Pacific Index (NPI), and Southern ocean overturning.
Weaker regional responses are seen to the NAO, SAM and North Atlantic overturning indices.

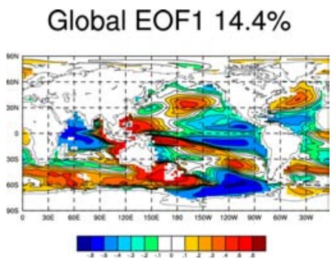

Figure 1. Pattern of EOF1 of sea level calculated in 420 year control simulation.

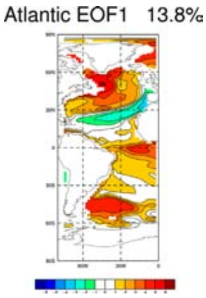

Figure 2. Pattern of regional EOF1 in the Atlantic Ocean.

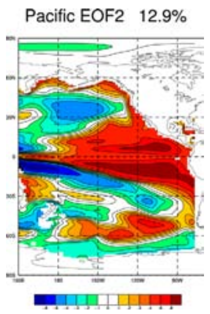

Figure 3. Pattern of regional EOF2 in the Pacific Ocean.

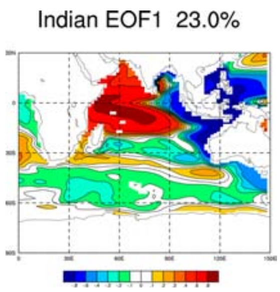

Figure 4. Pattern of regional EOF1 in the Indian Ocean.

Transient case and Reconstructed data.

The sea level change in Mk3.5 under SRESAIB scenario is shown in Figure 6. The regional pattern is in common with many models, with less warming in the Southern Ocean and North Atlantic and greater warming in the mid-latitudes. The data from the 1871-2000 transient run has been detrended with a 30 year running average, and a similar EOF analysis has undertaken (Figure 7). The 30 year running average acts a a low pass filter so lower frequencies are not present. This will be remedied by employing a polynomial fit at each grid point in the future. However it may not make a major difference as the principle source of the low frequency variability that has been identified is the meridional overturning in the Southern ocean which declines in strength as the transient run progresses. One major result is that the sea level shows that the ENSO period has shifted during the 21st century from a range of 4.4-6.7 years in the control run to 3.4-5.5 years in 21st Century. The 20th Century part of the transient run only has spectral peaks above 4 years.

Figure 8 shows EOF1 of the 1870-2001 reconstructed time series of Church *et al* (2004), again ENSO dominates the signal and the spectra shows similar results to the observed SOI with significant peaks at 3.6 years and a non-significant peak at 13 years. The 13 year frequency is also close to the 14 year period in the observed NPI. EOF4 has a 15 year frequency and is again correlated with the NPI. EOF5 of the reconstructed time series is correlated with the NAO and has a significant 8.6 Figure 7. Pattern of EOF1 in transient climate change run. year where the observed spectrum has an 8 year frequency. Again the data analysis used a running average to detrend the reconstructed time series, and the low frequency part of the spectrum is absent. However as these longer periods are driven by the thermohaline circulation it is less likely they would appear in the tidal record collected at coasts that were used in the reconstruction, so the reconstructed data would be dominated by the low frequencies in the atmospheric modes.

	Global	Atlantic	Pacific	Indian	Southern Ocean	Transient	Reconstructed
EOF1	14.4%**	13.8%	22.4%	23.0%	35.9%	19.9%***	64.0%*
EOF2	11.7%**	10.5%	12.9%*	10.5%	17.8%	9.3%**	15.1%
EOF3	6.8%	9.0%*	8.9%	7.1%	8.6%	4.7%	11.0%
EOF4	5.2%	8.0%	6.3%	6.0%	5.2%	3.8%	5.0%
EOF5	4.3%	5.1%	4.0%	4.2%	4.2%	3.6%	2.8%
EOF6	3.7%*	4.6%	3.5%	3.6%	3.1%	3.1%	2.1%

Key: NINO3-4, NAO, NPI, SAM, NA overturning, SO overturning *=multi-mode

Table 1. Percentage of variance in the major EOF modes for global and regional cases and correlations with major climate indices.

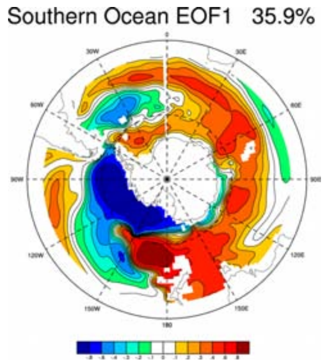

Figure 5. Pattern of regional EOF1 in the Southern Ocean.

	Global	Atlantic	Pacific	Indian	Southern Ocean	Transient	Reconstructed
EOF1	64	210	70	6.8,5.6, 4.8,4.4	105	5.5,4.3. 3.9,3.4	13,9.2, 5.4,3.6
EOF2	6.7,5.6, 4.7,4.3	210, 52.4	6.7,5.6 5.1,4.4	70	105	5.4,4.3, 3.7,3.4	12,4.4, 3.6,2.8
EOF3	64	70	60	70,5.6, 4.4,3.7	105	33,18, 9.2	20,10, 5
EOF4	64,5.5, 4.7,4.3	210,16,6	6.7,5.2, 4.8,4.4	210,60	84	19	15,9.2, 3.7
EOF5	64	210	140	210,60	140	19,8.8 ,6.6	8.6,6.3
EOF6	64	70,6, 5.1	210	105,20	140	29,7.7, 6.4	12,6.7

Results are shown in red are significant at the 95% confidence level

Table 2. Spectral frequencies in the major EOF modes for global and regional cases.

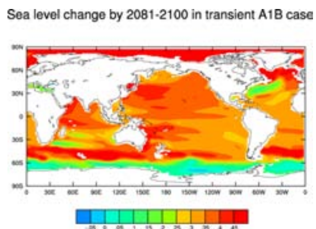

Figure 6. Pattern of sea level change in SRESA1B scenario 1871-2000.

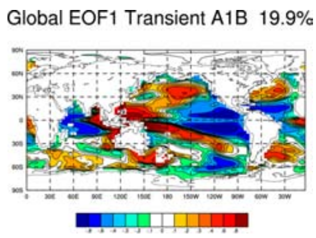

Figure 7. Pattern of EOF1 in transient climate change run

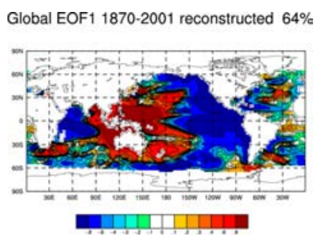

Figure 8. Pattern of EOF1 in 1870-2001 reconstructed time series.

Conclusions

The model and reconstructed data display signatures of the main modes of atmospheric, oceanic and coupled variability in both control and transient simulations. There are some insights in to how the modes of variability may shift in the 21st Century by examining the changes to total heat content of the ocean. The longest modes of variability are driven by the ocean thermohaline circulation, with periods of 20-70 years, so it will take considerably more observations before the satellite data can capture the full range of variability that needs to be considered alongside the thermal warming signal that will impact on regional sea levels.

Acknowledgements
I wish to thank Ian Smith for access to his EOF and spectral packages and for frequent advice on this study. Also thanks to Neil White for making available the 1870-2001 reconstructed sea level time series.

References

Church. J.A., N.J. White, R. Coleman, K. Lambeck and J.X. Mitrovica, 2004, Estimates of the Regional Distribution of Sea Level Rise over the 1950-2000 period. *J.Climate* 17(13) 2609-2625.