Regional sea level rise around the Australian coastline

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The impact of sea level rise on the Australian coasts and coastal infrastructure needs a number of scientific disciplines to collaborate. Contributions to global sea level rise as seen arise from ocean thermal expansion and melting glaciers, ice caps and ice sheets. The best current estimate for the global sea level rise is 18-59 cm given by Meehl et al (2007). In the final analysis of sea level projections issued by IPCC AR4, they increased the upper limit for projected sea level rise by 10 to 20 cm to cover uncertainty on ice sheet discharge based on recent evidence of acceleration in Greenland and Antarctica. Hunter (2008) has drawn up tables of the AR4 and TAR estimates of 21st century global sea level rise for the IPCC SRES scenarios.

Regional sea level rise at the Australian coast also include local effects that differ for each coastline. There is local thermal expansion in the ocean from changes in ocean currents and positions of frontal regimes, driven by changes in regional wind forcing and atmospheric fluxes. The sea level at the coast is also impacted by short term extreme events such as storm surges and wave regimes which reflect distant storminess, both are predicted to increase in severity under climate change. The final regional component of the coastal impact is the local geology, with different effects on sandy and rocky shorelines, and the longer term geological response of the earths crust to reduced ice sheet loading (post-glacial rebound), vertical shifts in land following earthquakes and ground water extraction which can cause different parts of the coastline to rise or fall.

The focus of this presentation is on the regional sea level rise from the thermal expansion derived from 17 IPCC AR4 climate models where sea level data has been made available through the PCMDI CMIP3 archive. The analysis has centred on the SRESA1b scenario a mid level scenario that reaches 720 ppm CO2 equivalent by 2100. The data for each model has been processed into decadal averages and the values for the control run simulation for the same decade subtracted to remove the drift. The models global mean sea level for each decade has been subtracted to provide regional anomalies and 20 year averages focussed on 2030, 2070 and 2100 extracted. Figure 1 shows the results for 2030 for the 17 models along with a mean field which was calculated by re-gridding all the models to a 1 degree x 1 degree grid and infilling to the coast from the nearest neighbour for models that had less detailed coastal geometry.

The results for 2030 show that greater than 70% of the models (BCCR, CSIRO Mk3.0, CSIRO Mk3.5, ECHO-G, GFDL2.0, GFDl2.1, GISS E-H, IPSL, Miroc-HIRES, MPI, MRI) have established the strongest aspect of pattern of sea level change seen in later decades, with a noticeable maximum of regional sea level rise on the East Coast of Australia and in particular in the Tasman Sea. This location of the maximum differs from what has been observed in the last couple of decades by the tide gauges of the National Tidal Centre and in the Topex/Poseidon and Jason satellite altimeter data set which showed maximum regional increase in Northern Australia. However, these observational time series were relatively short and have been biased by the tendency for ENSO conditions since the early 1990s.

The Tasman sea level rise signal (0-20cm) is linked to changes in East Australian current and the mirrors the increase seen in current flow and temperature observed along the NSW and Tasmanian coasts (Sutton et al, 2005, Ridgway et al, 2008). The change in the East Australian current is caused by the southward shift in winds and wind stress curl. The slightly different locations of the sea level maximum, in some of the models is due to the different position of the strongest gradient in the frontal systems, the structure of the currents which is model resolution dependent and the latitude of the strongest wind changes.

To the south of Australia, the sea level rise signal (0-10cm) is below the global average in nearly all the models. Earlier observational and modelling studies have shown that there is cooling in the ocean at mid depth 500-100m extending across the Indian ocean to south of Australia due to reduced ventilation. It is likely that this cooling is contributing to the reduced heat content changes over the water column but this needs further investigation.

To the west and north of the continent the models show a mixed picture but on average lower sea level rise than the global average. Several models show increased sea level rise in the Gulf of Carpentaria with one model having a very strong maximum. Detailed investigation of the oceanographic causes of this regional signal in these locations needs to be undertaken.

The model average created for Figure 1 has included all the models, and whilst it reflects the main features seen across the models, a more appropriate approach would be to form a weighted ensemble average. Criterion that would be prioritized in such a weighting would be realistic currents and salinity/temperature and density of water masses in the Austalian region in the control and 20th Century simulations, and the ability of the models to represent the present trends in heat content in the late 20th and early 21st century.

Analyses of the trends in heat content globally have been prepared by Antonov et al, 2002, and Levitus et al 2005, and a new regional analysis is currently underway by CSIRO colleagues in Hobart (Wijffels, Domingues) that will be used to select the most appropriate models for our region. However, when using this approach one needs to consider how the pattern of regional heat content change develops above the noise with many multi-decadal variability signals impinging on the region at different ocean depths and integrated up into the sea level signal. Many of the models show clear differences in the regional sea level pattern between 2030, 2070 and 2100. Examination of the ensemble members of the 20th century simulations in the CSIRO Mk3.0 and Mk3.5 models show different patterns evolve in the sub-surface temperature fields in the different members. The 20th century ensemble ocean results exist for most of the AR4 models included in Figure 1 and a subset of the AR4 models (CSIRO Mk3.5 GISS_AOM, GISS_E-R, GISS_E-H, FGOALS, MIROC_MED, MPI, MRI) have 21st century ensembles that could be used in the analysis to derive a realistic weighted average of regional sea level rise.

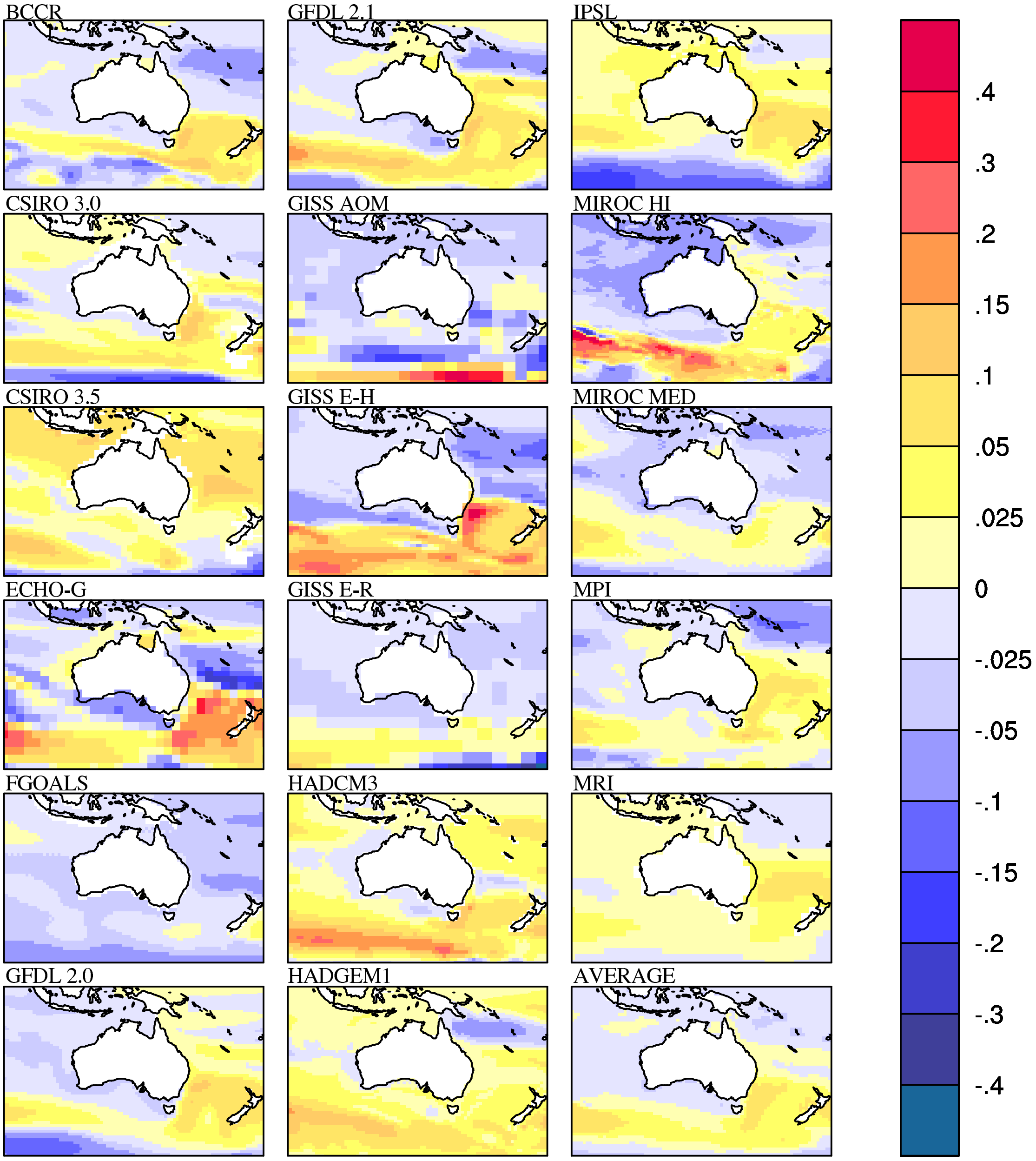

Figure 1. Regional sea level rise (in m) relative to global sea level rise for 17 AR4 models and an averaged field for a 20 year decadal average centred on 2030.

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