Geophysical Research Abstracts
Vol. 16, EGU2014-9601-1, 2014
EGU General Assembly 2014

Model derived uncertainty in observed deep ocean heat content trends

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We subsample a high-resolution ocean-only model to estimate uncertainty associated with observational estimates of deep ocean heat content. The deep ocean is a potentially vast reservoir for heat uptake, but the slowdown of surface air temperature warming in the early twenty-first century suggests that heat uptake is variable. It is therefore necessary to quantify entire ocean heat content changes to reduce uncertainty in climate projections and sea level rise estimates. While the Argo network effectively samples the 0-2000m layer, deep ocean observations are spatially and temporally limited, with our best estimates of heat content change relying on repeat hydrographic sections. Here we estimate the uncertainty associated with heat content changes from repeat hydrographic sections.

We use a historical 1/12° simulation of the eddy permitting ocean model NEMO between 1980 and 2010, with a focus on the North-East Atlantic. Two types of uncertainty are considered to address the representativeness of large-scale heat content estimates generated from observations:

* There are typically 5-year intervals between repeat hydrographic sections, so temporal uncertainty is concerned with how well observations reflect the true variability or whether a strongly aliased signal is measured.

* Spatial uncertainty exists because two or three repeated sections in a basin may not be representative of the heat content variability of the whole basin.

We find that in the sub-2000m North-East Atlantic temperature trends on hydrographic sections are captured well by typically pentadal sampling. Spatial uncertainty results in a systematic difference between trends from whole-basin sampling of the model and those determined from subsampling the hydrographic sections. Warming between 2000-2500m is overestimated by 10%. Between 3000-5000m, on average 67% of a cooling trend across the basin is captured on subsampled sections, increasing with depth to 5000m where the sub-sampled and whole-basin estimates agree. In this analysis we use basin average temperatures from 1990 to reduce the influence of model spin-up.

This analysis implies that repeated hydrographic sections in the North-East Atlantic capture the sense of trends in deep ocean heat content well, but where a significant trend is present they systematically over- or under-estimate the trend by up to 100% depending on the depth. Our model analysis suggests that, in total, subsampling repeat hydrographic sections underestimates cooling beneath 2000m by 8% between 1990 and 2010 in the North-East Atlantic.