

The Characteristics and Uncertainties of Sea Level Change due to Ocean Climate Change

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In the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 30-50% of the projected global-mean sea-level rise by 2100 is due to expansion of sea water as the ocean takes up heat. The range of this thermosteric contribution represents a substantial uncertainty in projections of GMSLR. It arises partly from differences among models in climate sensitivity, determined by surface and atmospheric responses to radiative forcing, and partly from differences in the ocean processes which transport heat from the surface and redistribute it in the interior of the ocean. Changes in ocean circulation, temperature and salinity (and hence density) also alter regional dynamic sea level with non-uniform patterns of change that show a substantial spread among AOGCMs; for instance in the North Atlantic the inter-model standard deviation of dynamic sea level change is larger than the global-mean model-mean thermal expansion.

To investigate these long-standing systematic uncertainties in projections, the Flux-Anomaly-Forced Model Intercomparison Project (FAFMIP) has begun, as a component of the Coupled Model Intercomparison Project Phase 6 (CMIP6). The project depends on experiments of a novel design, in which prescribed surface flux perturbations of momentum, heat and freshwater are applied to the ocean in separate AOGCM simulations. The prescribed fields are typical of pattern and magnitude of changes in these fluxes projected by AOGCMs for doubled CO₂ concentration. Five groups have tested the experimental design with pre-CMIP6 AOGCMs. These preliminary results show that heat and water flux perturbation cause the dipole in sea-level change in the North Atlantic, while momentum and heat flux perturbation cause the gradient across the Antarctic Circumpolar Current. The Atlantic Meridional Overturning Circulation (AMOC) declines in response to the heat flux perturbation, but is little affected by freshwater or momentum. Heat is taken up largely as a passive tracer in the Southern Ocean, which is the region of greatest heat input.

Future analysis of these and other phenomena with the wider range of CMIP6 FAFMIP AOGCMs will benefit from new diagnostics of temperature and salinity tendencies, which will enable investigation of the model spread in behaviour in terms of physical processes as formulated in the models. The results so far encourage our hope that FAFMIP will offer new insight into the reasons for model spread in the ocean response, without the confounding influence of diversity in atmospheric response, and thus help towards narrowing uncertainties.

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