International Max Planck Research School on
EARTH SYSTEM MODELLING

Max-Planck-Institut für Meteorologie
Max Planck Institute for Meteorology

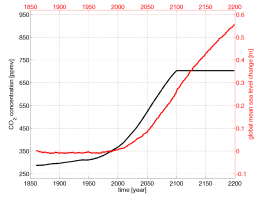
Regional Dynamic and Steric Sea Level Change
in an IPCC-A1B Scenario Simulation

Felix Landerer, Johann Jungclaus, Jochem Marotzke   **Contact: felix.landerer@zmaw.de**

We have analyzed regional sea level changes in a climate change simulation using the Max Planck Institute for Meteorology coupled Atmosphere Ocean General Circulation Model ECHAM5/MPI-OM. Compared to the unperturbed control climate, global sea level rises 0.26 m by 2100, and 0.56 m by 2199 through steric expansion; eustatic changes are not included in this simulation. The model's dynamic sea level evolves substantially different between ocean basins. Furthermore, the warming and circulation changes lead to secular bottom pressure anomalies, with strong signals across shallow areas. The horizontal and vertical contributions of temperature and salinity to steric changes vary strongly for different regions.

The Model and the Experiment

- ECHAM5 atmosphere model T63L31, coupled to MPI-OM ocean model with 1.5°x1.5 ° resolution and 40 levels
- 1860 - 2000: observed forcing (GHG)
- 2001 - 2099: IPCC-A1B scenario with increasing GHGs
- 2100 - 2199: constant GHGs
- concentration at 2099 level (703 ppmv)



1. Dynamic Sea Level Changes

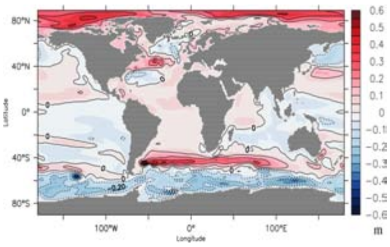


Figure 1: Regional sea level anomalies for the years 2090-2099 relative to the unperturbed climate. Sea level rise is strongest in the Arctic Ocean due to enhanced fresh water input from precipitation and continental run-off, and weakest in the Southern Ocean due to compensation of steric changes through dynamic sea surface height (SSH) adjustments. In the North Atlantic (NA), a complex tripole SSH pattern across the subtropical to subpolar gyre front evolves.

2. Temporal Evolution of Relative Sea Level Anomalies

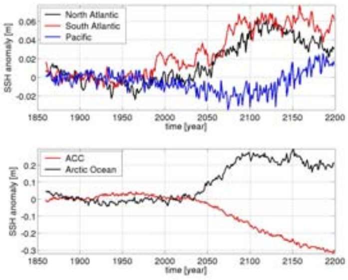


Figure 2: The temporal development of regional integrated relative sea level anomalies illustrates that the timescales of basin-integrated SSH adjustments are not uniform. Basin averaged SSHs in the North and South Atlantic exhibit a pronounced multidecadal variability, with maximum rates of change near 15 mm yr $^{-1}$. Towards 2120, relative SSH in the Atlantic basin has risen by 60 mm in both hemispheres, so that the South to North Atlantic SSH gradient remains largely unchanged. Note, however, that the variability of North and South Atlantic basin-integrated SSH is different.

3. Correlation of Sea Level Anomalies with MOC and Gyre Transport

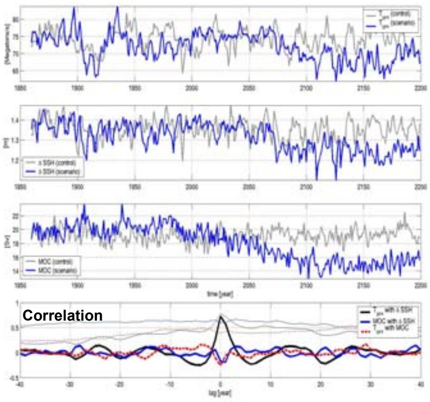


Figure 3: On interannual to decadal timescales, the sea level difference between Bermuda and the Labrador Sea correlates highly with the combined baroclinic gyre transport in the North Atlantic, but only weakly with the meridional overturning circulation (MOC), and thus does not allow for estimates of the MOC on these timescales (thick correlation lines: 21 year running mean removed).

4. Bottom Pressure Changes

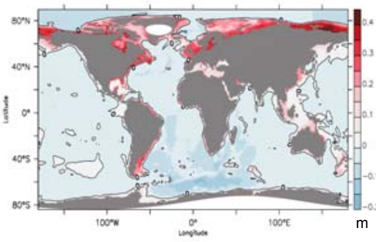


Figure 4: Bottom pressure changes for the period 2090-2099 relative to the control run. All bottom pressure changes occur solely due to mass redistribution within the global ocean. Most prominently, all shelf regions experience an additional mass loading of up to 0.45 m. Another salient feature is the pronounced negative bottom pressure anomaly of up to 0.2 m in the Atlantic section of the Southern Ocean, which we relate to the intensified gyre circulation.

5. Thermo- and Halosteric Changes

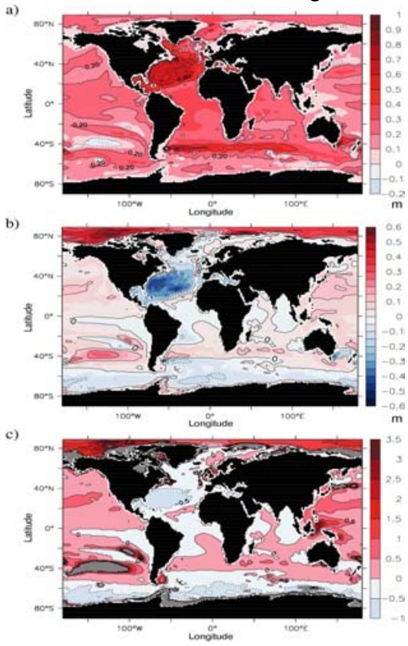


Figure 5: Steric anomalies (years 2090-2099) are influenced generally as much by salinity (b) variations as by changes in temperature (a). Maximum thermosteric expansion occurs in the subtropical North Atlantic, while negative halosteric anomalies in this region partly compensate the thermosteric sea level rise (c). Freshening in the Arctic Ocean, however, leads to an additional halosteric sea level rise, which can be partly explained by the increased atmospheric moisture transport from low to high latitudes.

6. Vertical Distribution of Steric Changes

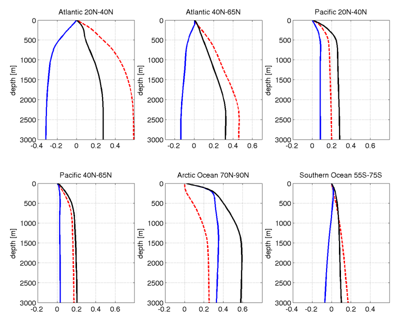


Figure 6: In the North Atlantic, the steric anomalies reach to depths of the North Atlantic Deep Water (2000 m), whereas steric anomalies in the entire Pacific Ocean occur mainly in the upper 500 m. In the Southern Ocean, steric anomalies occur throughout the entire water column (more than 3000 m). Anomalies are shown for years 2090-2099.

Conclusions

- Regional sea level changes vary up to ±100% from the global mean.
- Sea level anomalies in the North Atlantic correlate well with the baroclinic gyre transport, but overturning changes cannot be reliably inferred on timescales less than at least 21 years.
- Mass redistribution through thermal expansion and circulation changes causes secular bottom pressure anomalies (see also poster P69).
- Thermosteric and halosteric anomalies are equally important, and often partly cancel each other. The sign and magnitude of the vertical distribution of steric anomalies varies widely by ocean.

Reference: Landerer, F., Jungclaus, J. and Marotzke, J., 2006, Regional dynamic and steric sea level change in response to the IPCC-A1B scenario, JPO (accepted).