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Regional bottom pressure changes from ocean thermal expansion in the 21st century and their effect on the degree-two Stokes coefficients

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Ocean thermal (or thermosteric) expansion occurs due to heat uptake by the ocean under global warming conditions. These steric sea level changes do not alter the global ocean mass, but a secular mass redistribution within the global ocean does occur due to the irregular geometry of ocean basins, changing ocean bottom pressures locally. Here, we present a simple conceptual model that explains why these bottom pressure changes must ensue due to ocean thermal expansion: the reason of the described effect can be explained with the decreasing ocean area with increasing depth, and ocean warming occurring at deeper layers. We diagnose these bottom pressure changes in a global warming simulation (following the IPCC-A1B scenario) with the coupled Atmosphere Ocean General Circulation Model ECHAM5/MPI-OM from Max Planck Institute for Meteorology. Globally, thermosteric sea level rises 0.26 m by 2100; eustatic changes are not included in this simulation. We find that shallow shelf areas experience relatively strong positive bottom pressure changes, while the deep ocean areas consistently show smaller negative bottom pressure anomalies. The strongest signal is on the Arctic shelves, where bottom pressures increase up to 0.45 m with a global mean sea level rise of 0.26 m and simultaneous ocean circulation changes. Since the shallow ocean areas are not distributed symmetrically across Earths surface, this pattern of anomalies leads to secular changes in the degree-two spherical harmonics of Earths gravity field, even at constant global ocean mass. Based on this mechanism, we estimate linear trends for the C20, C21 and S21 Stokes coefficients of -1.1964×10^{-12}, 9.6927×10^{-13} and 3.5043×10^{-13} per year, respectively, in the 21st century.