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Large regional contributions of ocean heat content variability, freshwater content and steric height changes

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Recent studies revealing the changes in the climate system's energy budget have been linked to ocean temperature and the associated thermal expansion contribution to sea-level rise (Levitus et al., 2005; Bindoff et al., 2007). The penetration of water changes into the ocean subsurface layers is varying from region to region as air-sea heat and freshwater fluxes are unevenly distributed (Barnett et al., 2005). Here we present estimations of heat content variability and freshwater content as well as steric height for the upper 1500 m depth determined from various existing hydrological observations during 2004-2008, including the Argo network of profiling floats. We make use of adapted mathematical techniques to take into account the diverse spatial coverage of the data. While air-sea processes are yet largely unknown as their direct estimates are too sparse and inaccurate, here we show that the Southern Ocean between 30°S-60°S is the most sensitive basin relatively to such changes with heat content and freshwater volume both increasing and reaching deep into the ocean. In comparison, the tropical ocean (30°S-30°N) does not show enhanced 5-year trends, but interannual variability restricted to the upper ocean layers. The 30°-60° belt of the Northern Hemisphere does exhibit a 5-year trend, but smaller in amplitude than the Southern Hemisphere and primarly characterized by heat content changes. The related estimates of deep ocean (10-1500m depth) thermal expansion and halosteric contributions to sea level rise are major in the Southern Ocean. In the 30°S to 60°S latitude belt density changes between 700-1500m depth as well as halosteric effects for the 10-1500m depth layer affect the global budget by about 20% during the years 2004-2008. North of this latitude band, density changes below 700m depth as well as halosteric processes show a negligible small impact on the global steric rates during that time period. In the Southern Ocean, the sum contribution (thermosteric plus halosteric) from 2004-2008 is 2.2$\pm$0.9 mm/a, that represents 70% of the sea-level rise estimated from the satellite derived sea level height in the same region and over the same period of time.