Session: C37 Poster: TH83A

Southern Ocean hydrography and circulation: Warming of global abyssal and deep Southern Ocean waters between the 1990s and 2000s

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We quantify abyssal global and deep Southern Ocean temperature trends between the 1990s and 2000s to assess the role of recent warming of these regions in global heat and sea level budgets. We compute warming rates with uncertainties along 28 full-depth, high-quality, hydrographic sections that have been occupied two or more times between 1980 and 2010. We divide the global ocean into 32 basins defined by the topography and climatological ocean bottom temperatures and estimate temperature trends in the 24 sampled basins. We also estimate bottom water transport variations consistent with heave rates below select isotherms. The three southernmost basins show a strong statistically significant abyssal warming trend, with that warming signal weakening to the north in the central Pacific, western Atlantic, and eastern Indian Oceans. Eastern Atlantic and western Indian Ocean basins show statistically insignificant abyssal cooling trends. Excepting the Arctic Ocean and Nordic seas, the rate of abyssal (below 4000 m) global ocean heat content change in the 1990s and 2000s is equivalent to a heat flux of 0.027 (±0.009) watts per square meter applied over the entire surface of the Earth. Deep (1000-4000 m) warming south of the Sub-Antarctic Front of the Antarctic Circumpolar Current adds 0.068 (±0.062) watts per square meter. The abyssal warming produces a 0.053 (±0.017) mm per year increase in global average sea level and the deep warming south of the Sub-Antarctic Front adds another 0.093 (±0.081) mm per year. Thus warming in these regions, ventilated primarily by Antarctic Bottom Water, accounts for a statistically significant fraction of the present global energy and sea level budgets.