

## **Global overturning circulation: freshwater transports and down-gradient flow**

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The relation between the observed global overturning circulation, observed steric height distributions at all depths, and freshwater transports is examined. (1) The global circulation is down-gradient in terms of the largest spatial scales of steric height distributions, at all depths from the surface to the bottom, based on observational syntheses. Diapycnal upwelling in both the Southern Ocean and the Indian/Pacific Oceans is integral to the global overturn, in addition to downwelling in the well-known deepwater source regions. The Indian/Pacific upwelling to mid-depth forms the deep waters that return to the Southern Ocean (22 Sv total), upwell to the sea surface, and feed the northward surface flows that eventually return to the northern North Atlantic (NADW overturning cell of 18-20 Sv). The remainder of the Indian/Pacific Deep Waters join the upwelled North Atlantic Deep Water to form the large (34Sv) Antarctic Bottom Water overturning cell. (2) The distribution of diapycnal fluxes depends mainly on the small salinity differences between ocean basins that arise from the pattern of atmospheric water vapor transports. The equatorward freshwater transports from the high latitude southern and northern hemispheres are carried by the surface overturning cells in the south, and by North Atlantic Deep Water and North Pacific Intermediate Water formation in the north; the dynamical difference is due to the open Drake Passage in the south.