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Red Sea deep circulation driven by remote volcanic eruptions

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The Red Sea is the source region of the Red Sea Overflow Water (RSOW), which is manifested as an intermediate-depth salinity maximum in the Indian Ocean. The formation processes of the RSOW involve a two-cell vertical overturning circulation system in the Red Sea: A shallow overturning cell, consisting of an annual mean northward surface inflow and a southward intermediate out- flow, lies above the sill depth in the south and deepens to about 300 m in the north; a deep overturning cell suggested by the gradients in the distributions of geochemical tracers and dissolved oxygen lies below 300 m to depths over 2000 m. While the circulation patterns and forcing mechanisms for the shallow overturning cell are fairly clear, the deep circulation in the Red Sea remains largely unexplored. We use historical in situ hydrographic observations and simulations of an ocean general circulation model with realistic atmospheric forcing to show that large volumes of dense water were formed through open ocean deep convections in the northern Red Sea in the winters following the 1982 El Chichón eruption in Mexico and the 1991 Mount Pinatubo eruption in the Philippines. These remote volcanic eruptions conveyed their effects to the Middle East through the atmospheric circulations and created exceptionally favorable conditions for deep convections in the northern Red Sea. Ensuing spreading of the newly formed dense water induced a southward bottom flow and a northward intermediate returning flow, forming an enclosed deep overturning cell same in direction to the shallow overturning cell.