Physical oceanography

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Drivers of Southern Ocean cooling

Southern Ocean sea surface temperatures (SST) cooled by ~−0.1 °C dec^{-1} from 1980 to 2010, with ecological and climatic impacts. This cooling tendency has often been linked to a greenhouse gas- and stratospheric ozone depletion-induced positive trend in the Southern Annular Mode (SAM), a corresponding strengthening of the mid-latitude westerlies and resulting northward Ekman transport. While there is clear support for such relationships at seasonal timescales, evidence of these dynamics driving Southern Ocean cooling over multi-decadal timescales is contradictory.

Yue Dong from Lamont–Doherty Earth Observatory, USA, and colleagues, investigate the extent to which (SAM-driven) changes in westerly winds contribute to the observed multi-decadal cooling trend using low-frequency component analysis (LFCA) — a statistical technique that extracts physically based climate modes in spatiotemporal signals, isolating modes of low-frequency variability. The leading modes of wind variability reproduce observed patterns of westerly strengthening. However, the magnitude of the wind-associated cooling trend is substantially weaker than observed. During December–February, for example, the first 3 modes combined produce cooling of ~−0.04 °C dec^{-1} in the Pacific sector over 1979–2022 versus ~−0.10 °C dec^{-1} in observations; differences in the annual mean are even larger (~−0.02 °C dec^{-1} versus ~−0.10 °C dec^{-1}). Simple linear extrapolation of SAM-regressions also suggests a limited role in long-term cooling. Accordingly, SAM-induced strengthening of the westerly winds is unlikely to be the key driver of the observed multi-decadal cooling in the Southern Ocean.

Other drivers must, therefore, be important contributors to this cooling trend. Possible contenders include freshwater input from ice melt, natural variability, northward sea-ice transport, or remote teleconnections. Ascertaining these drivers is integral to better projecting changes in the Southern Ocean under ongoing anthropogenic forcing.

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