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Nonlinear mechanisms of interdecadal climate modes

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Our climate may vary due to forces outside the Earth's fluid envelope, or due to competing instabilities within the ocean–atmosphere system itself. Climate variability of the latter type in the Northern Hemisphere's mid-latitudes has been attributed to purely atmospheric, purely oceanic, or coupled ocean–atmosphere processes. The relative contribution of each type of process is still unknown. Here we show that the observed zonally averaged jet in the Northern Hemisphere atmosphere exhibits two spatial patterns with broadband variability in the decadal (10–15 years) and interdecadal (25–30 years) range; these patterns are reflected in atmospheric and oceanic fields that are consistent with an important role of local, mid-latitude ocean–atmosphere coupling.

Both observed modes of variability, decadal and interdecadal, have been found in our intermediate climate models. One mode has largely to do with buoyancy-related aspects of the ocean circulation and resembles tripolar patterns described elsewhere. The other mode is novel and has been predicted by coupled ocean—atmosphere modeling of climate processes; its key aspects include interaction of oceanic turbulence with the large-scale oceanic flow.

These results provide support for a more active oceanic role in mid-latitude climate variability than previously contemplated. A key aspect of this behavior is nonlinear sensitivity of the atmospheric jet's latitudinal position, which enables relatively small sea-surface temperature anomalies associated with ocean processes to affect the occupation frequency of two distinct atmospheric wind regimes. The associated long-term wind anomalies induce, in turn, complex three-dimensional anomalies in the ocean's main thermocline; in particular, they may be responsible for interdecadal variability in the observed upper-ocean heat content.