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Polar amplification of stratospheric variability

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At mid-to-high latitudes, the stratosphere contains >25% of the column of atmospheric mass. In Northern Hemisphere winter large-scale vertically-propagating waves drive a synchronised meridional circulation that moves mass into and out of the Arctic (>65ºN), modulating adiabatic warming of the stratospheric polar air column, and altering the strength of the stratospheric polar vortex (McIntyre and Palmer, 1983; 1984; Holton et al., 1995). These stratospheric changes are associated with substantial effects on surface weather and climate, especially on Northern Annular Mode (NAM, Thompson and Wallace, 1998; 2000) with associated long-lasting shifts in the jet streams, storm tracks, precipitation, and likelihood of blocking events (Baldwin and Dunkerton, 2001). Despite unambiguous observations of this phenomenon, as well as numerical simulations, a quantitative physical explanation of this downward coupling remains elusive. Here we show that amplification of the polar stratospheric pressure signal involves a positive dynamical feedback process within the troposphere. An initial Arctic tropospheric sea level pressure (SLP) signal (e.g., from a sudden stratospheric warming) reduces latitudinal pressure gradients and poleward heat transport within the troposphere, leading to increased cooling of the Arctic lower troposphere. This cooling induces higher pressure over the Arctic region (Hoskins et al. 1985), thus amplifying the original stratospheric signal. This positive dynamical feedback process appears to operate in both hemispheres, and is consistent with the observed lag in the tropospheric response to stratospheric signals (Baldwin and Dunkerton, 2001). The feedback process itself is not unique to stratospheric forcing, and may explain why the annular modes are easily forced, tend to self-amplify, and have relatively long time scales (Baldwin et al. 2003).