Impacts and Predictability of Southern Hemisphere Stratosphere-Troposphere Coupling

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Stratosphere-troposphere (S-T) coupling in the Southern Hemisphere (SH) polar region is an important dynamical process that provides predictability of the Southern Annular Mode (SAM) and associated SH surface climate. In this study S-T coupling is identified by height-time domain EOF analysis applied to monthly zonal mean zonal winds averaged over the circumpolar region (55-65˚S) from the surface to the 1 hPa level from April through March for the period 1979-2017. The leading EOF pattern (dimensioned 37 vertical levels by 12 months) is characterized by the subpolar upper stratospheric zonal mean zonal wind anomalies changing the sign from austral winter to spring, peaking in amplitude in the upper-middle stratosphere in October to November and extending downward to the surface from October through January. This S-T coupled mode accounts for 42% of the vertical-temporal variance of the Antarctic circumpolar zonal mean zonal winds.

SH S-T coupling is preconditioned by a meridional shift of the upper stratospheric jet in the midlatitudes and anomalous vertically propagating planetary wave activity in austral early winter. Interannual variability of the S-T coupled mode is highly correlated with the polar ozone concentration, tropospheric SAM, and Antarctic sea-ice concentration in the South Pacific and the Weddell Sea during late spring-early summer. This strong relationship between the SH surface climate and S-T coupling implies a long lead predictability of the spring-early summer surface climate, which can originate from the midlatitude upper stratosphere as early as in June.

Predictions from the Australian Bureau of Meteorology's two dynamical seasonal forecast systems, POAMA (low-top) and ACCESS-S1 (high-top), demonstrate good skill in predicting the S-T coupled mode for spring-summer at up to 3 month lead time. The high-top model ACCESS-S1 is skillful in simulating the upper stratosphere polar vortex variability in austral spring, but its linkage to the troposphere is weak at lead times beyond a month. In contrast, the low-top model POAMA simulates weaker polar vortex even at the shortest lead time, compared to ACCESS-S1. However, POAMA skillfully maintains tropospheric circulation anomalies associated with changes in the stratospheric polar vortex throughout austral spring to summer seasons at lead times up to 3 months. We find the current level of model skill to predict the S-T coupled mode encouraging, having considered that the skill is achieved without realistic ozone variation, which means a large scope for further improvement in forecast skill.

Key words: stratosphere-troposphere coupling, preconditioning, impacts, predictability