

## Eurasian Snow Cover Variability and Links with Stratosphere-Troposphere Coupling and their Potential Use in Seasonal to Decadal Climate Predictions

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Many tropospheric Arctic Oscillation (AO) events are preceded by stratospheric AO events and even earlier in time by anomalous upward energy flux associated with Rossby waves in the troposphere. However little is known about tropospheric variability that forces changes in upward tropospheric energy flux. Compositing analysis of stratospheric warming events identifies regional tropospheric precursors, which precedes stratospheric warmings. The tropospheric precursor is found to vary when compositing over polar vortex displacements and splits separately. We will also explore linkage between tropospheric precursors to boundary forcings such as Eurasian snow cover and ENSO. Identification of a unique tropospheric precursor to stratospheric warming and subsequently tropospheric AO events can be exploited for predicting large AO events weeks and even months in advance. Furthermore the observational evidence presented here can be compared with model simulations of winter climate variability and lead to potential model improvements.

We have operationally produced real-time winter forecasts for the extratropical Northern Hemisphere based on fall Eurasian snow cover and atmospheric anomalies for the past ten years. The operational forecasts continue to demonstrate skill, up through the most recent winter season. These snow-based forecasts appear to provide considerable additional information beyond the standard-ENSO based forecasts and even the most sophisticated dynamical models.

Furthermore, a warming trend in global surface temperatures over the last forty years has been well established, consistent with anthropogenic increases in greenhouse gases. Over the last two decades, this trend appears to have accelerated. In contrast to this general behavior, however, we show that trends during the boreal cold months in the recent period have developed a marked asymmetry, with vigorous warming in the fall followed by a reversal to a neutral/cold trend in the winter. This observed asymmetry in the cold half of the boreal year is linked to a two-way stratosphere-troposphere interaction and a negative trend in the NAM index, which is strongest in the Northern Hemisphere during winter and is related to variability in Eurasian land surface conditions during autumn. This link has been demonstrated for year- to-year variability and used to improve seasonal-timescale winter forecasts; however, this coupling is also shown to strongly modulate the warming trend, with implications for decadal-scale temperature projections.