Introduction and Motivation

On seasonal time-scales, coupling between the Northern hemisphere stratosphere and troposphere is most pronounced following major sudden stratospheric warmings [1]. The extended dynamical timescales found in the lower stratosphere [2] are a potential source of skill in seasonal forecasts [3]. We show here, using a novel tool for the visualization of the variability of the polar-night jet, that the extended timescale recovery of the Arctic polar-night jet is most pronounced following only a subset of major warmings. Following [4], we term these extended time-scale recoveries Polar-night Jet Oscillation (PJO) events. We make use of several reanalyses (ERA40, ERA Interim, MMRA, satellite observations (MSL) and the ensemble of three REPS runs of the Canadian Middle Atmosphere Model (CMAM) from CMAMv1. These PJO events are characterized by large amplitude temperature anomalies in the Arctic middle-atmosphere. Their long timescales are a result of both the long radiative timescales in the lower stratosphere, and the suppression of further dynamical perturbations from upwelling planetary waves. The persistent lower-stratospheric temperature anomaly leads to a more persistent, stronger tropospheric response during PJO events as opposed to non-PJO warmings. In the upper stratosphere following the initial warming, the jet overshoots its climatological state, leading to a high, strong jet. This changes the filtering of gravity waves, leading to a high and descending stratosphere. Finally, we point out that the large amplitudes and long timescales of PJO events can easily mask standard statistical tests for significance.

Abacus plots and the PJO

Arctic pole-cap temperature anomalies are well-described by their first two EOFs. The corresponding PC time series define a trajectory in 2D phase space, which can be used to visualize the variability in a compact manner. The 2008 and 2009 major warmings are shown here as examples; the latter was followed by an archetypical PJO event.

Planetary wave suppression

Composites of weeks following PJO events vs. those not followed by PJO events show that the upward Eliassen-Palm flux (shading) into the vortex (50-70°N) is strongly suppressed for 60 days following the warming. The model results suggest that this suppression extends down to the surface. This coincides with the period of weak westerly zonal winds (contours) in the lower stratosphere.

Tropospheric impact

Composites of the annual mode indices during weak-vortex events followed by PJO events vs. those not followed by PJO events show that the more persistent, larger amplitude events in the stratosphere also have a stronger and more persistent impact on the troposphere. PJO events are best predicted by the depth to which the warming descends in the stratosphere. They are more likely following the largest amplitude weak-vortex events, but they cannot be defined by a particular threshold.

Decadal variability

The occurrence of PJO events in the ensemble of three CMAMv1 REF2 integrations of CMAM are well described, statistically, by assuming that one will occur each winter with probability $p = 43\%$. The ensemble-averaged frequency of events shows no evidence of a trend; nor does their mean duration. Nonetheless, their large amplitude and serial correlation are each tied to highly structured polar-cap temperature anomalies of up to 10 K between 30-year climatologies, which appear highly (but erroneously) significant by standard statistical tests (coloured shading).

Conclusions

We show here that highly coherent, large amplitude, and long-timescale recoveries occur following roughly half of all major stratospheric sudden warmings. These PJO events are well simulated by the CMAM. We present a new tool for the visualization of the variability of the Arctic polar-night jet, which is useful for understanding the relationship between these events and other commonly used indices of Arctic variability. The robustness of the circulation anomalies during PJO events and the dominance of radiative processes during the recovery phase suggests that they are highly predictable, and their impact on the troposphere suggests this may in turn be a source of skill in seasonal forecasting. Their large amplitude and strong serial correlations, however, present challenges for the detection and attribution of externally-forced changes in the Arctic stratosphere.