Onset of circulation anomalies during stratospheric vortex weakening events: the role of planetary-scale waves

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1 Motivation

Events of strong stratospheric vortex variability, such as Stratospheric Sudden Warming events, are known to be coupled with the tropospheric circulation. However, the dynamical mechanisms responsible for the coupling remain uncertain.

In this work, we investigate Stratospheric Vortex Weakening (SVW) events in the Northern Hemisphere. SVW events are defined as events of strong zonal wind deceleration in the stratosphere. No threshold is imposed on zonal wind: SVW events occur under both strong and weak stratospheric vortex conditions.

We wish to clarify wave-mean flow interactions in SVW events and their role in the vertical coupling. We investigate the onset of SVW events, when planetary-scale wave activity is known to have a large effect on the zonal winds (Limpasuvan et. al. 2004, McDaniel and Black 2005, Nakagawa and Yamazaki 2006, Martineau and Son 2013). Especially, we wish to better characterize the evolution and the role of wave activity in the vertical coupling.

2 SVW definition

SVW events are detected using the time-derivative of the Northern Annular Mode (NAM) index at 50 hPa. A decrease of 1 standard deviation in 5 days is required. A total of 33 events are obtained from ERA-Interim and used in our composites. Events are also classified into +NAM (NAM>1) and –NAM (NAM<-1) events in order to evaluate the sensitivity of SVW events to the stratospheric background flow.

2 Diagnostic of wave-mean flow interaction

Wave-mean flow interaction is evaluated using the TEM momentum equation

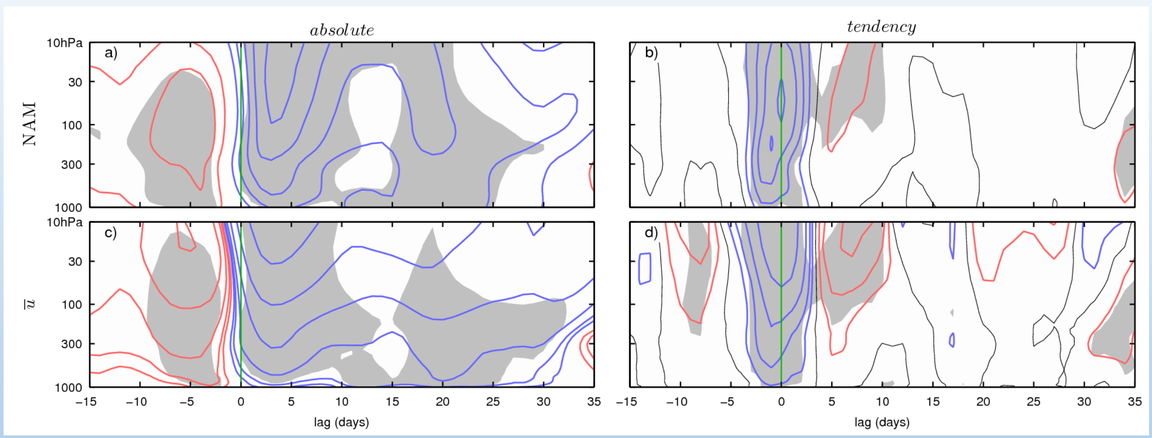
$$\frac{\partial \overline{u}}{\partial t} = f\overline{v}^* + \frac{1}{a\cos\phi}\vec{\nabla}\cdot\vec{F} + \overline{R} \qquad \{F_\phi, F_p\} = a\cos\phi\left\{-\overline{u'v'}, \frac{\overline{v'\theta'}}{\partial\overline{\theta}/\partial p} f\right\}$$

The relationship between wave activity and zonal wind is evaluated using Finite Amplitude Wave Activity (FAWA) combined with the TEM:

$$A_{FA}(\phi_e, p, t) = \frac{\left(\int_{\substack{q\geq Q(\phi_e)\\ 0.5\pi\geq\phi}} qdS - \int_{0.5\pi\geq\phi\geq\phi_e} qdS\right)}{2\pi a\cos\phi_e} \qquad \frac{\partial A_{FA}}{\partial t} = -\frac{1}{a\cos\phi}\nabla\cdot\vec{F} + S \qquad \frac{\partial \overline{u}}{\partial t} = f\overline{v}^* - \frac{\partial A_{FA}}{\partial t} + S + \overline{R}$$

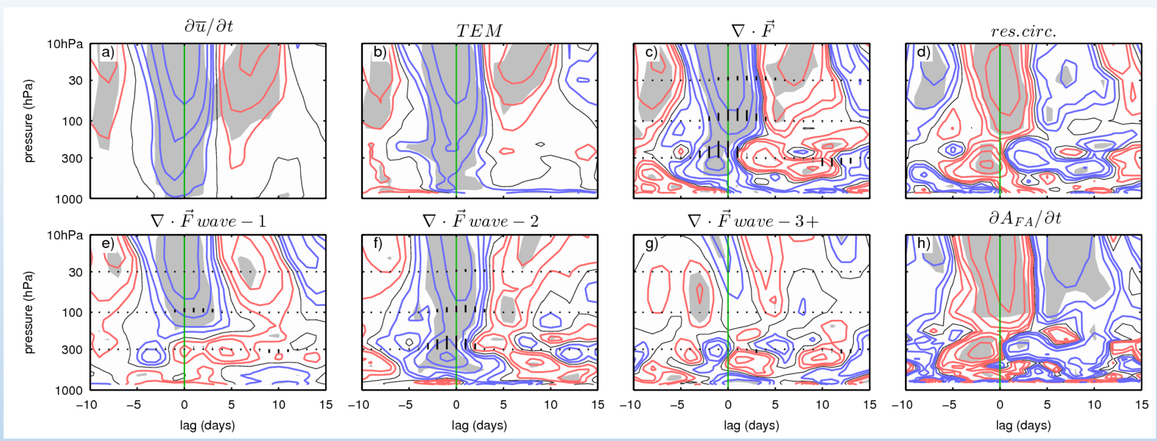
We can evaluate the relationship between wave activity and the zonal wind tendency, as well as estimating the role of wave sources/dissipation (S).

3 Evolution of SVW events



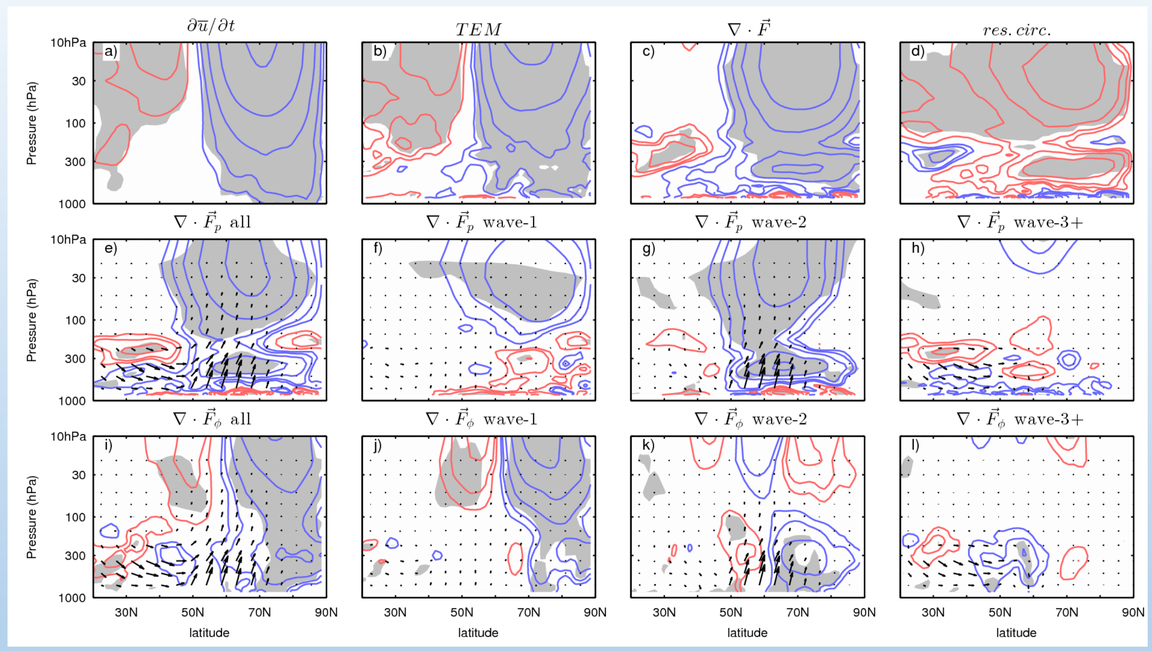
SVW events show near-instantaneous decrease of NAM index in the troposphere and the stratosphere. In fact, weakest tendency is observed about 2 days earlier in the troposphere compared to the stratospheric tendency.

4 Explaining zonal wind tendency



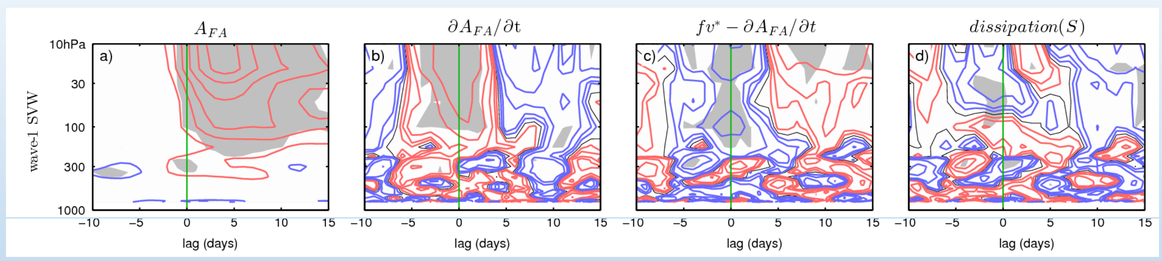
- The deceleration in both the stratosphere and troposphere is largely explained by EP flux convergence and increase of wave activity, mainly at wave-1 and wave-2 scales.
- The residual circulation is heavily but not completely opposed to wave forcing, resulting in a net deceleration in both the stratosphere and troposphere.

5 Onset by anomalous wave propagation



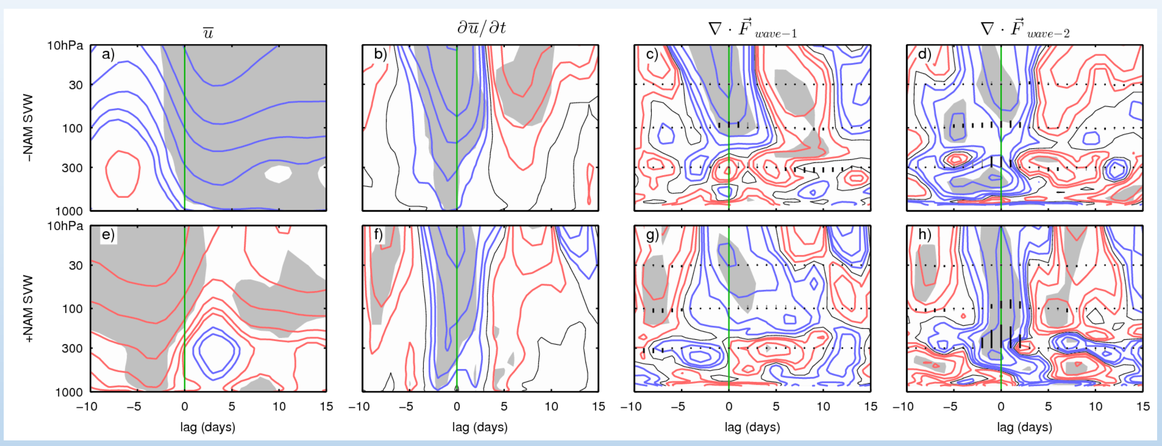
- Both the stratosphere and troposphere experience deceleration north of 50N
- Poleward and upward fluxes by wave-2 act as the main forcing for zonal wind deceleration (Nakagawa and Yamazaki 2006).

6 Wave activity growth vs dissipation



- The deceleration is explained largely by an increase in wave activity in both the troposphere and stratosphere. Wave dissipation is small.
- The residual circulation is opposed, but not completely to the growth of wave activity, which produces a net deceleration.

6 Sensitivity to background flow



- The evolution of SVW events is not sensitive to the stratospheric background flow : both show qualitatively similar forcing by wave-1 and wave-2.
- Although the background flow is very different, both categories show a weakening of wind in the troposphere and stratosphere with lasting effect.

7 Summary

- The onset of SVW events is explained by upward and poleward fluxes of planetary-scale wave activity (mainly wave-2).
- Deceleration of zonal wind results primarily from an increase in wave activity rather than wave dissipation.
- The results are largely insensitive to stratospheric background flow. Robust coupling is observed in both –NAM and +NAM cases.
- Although dissipative processes are small in comparison to wave transience, transfer across scales of wave activity (wave-breaking) is not excluded. Decomposition of wave activity according to the scale of disturbances is the topic of future work.

References

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