The relative roles of wave and zonal mean processes in the downward coupling of the stratosphere and troposphere.

Nili Harnik

Lamont-Doherty Earth Observatory
Columbia University

Judith Perlwitz
NASA-GISS/Columbia University

Talk outline:

1. The observed relation between reflection and the strength of the vortex in the low/mid stratosphere.

   - Compare composites using U_{2-10} and U at 30 hPa

2. Why is reflection coincident with a stronger lower stratospheric vortex on the seasonal time scale?

   - Discuss 3 possibilities

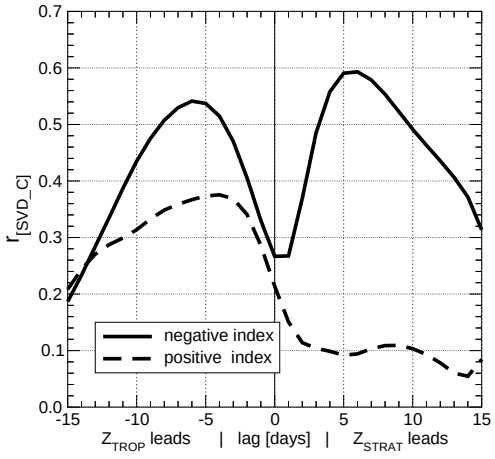
   → Two dynamical balances in the winter stratosphere: strong-reflective vortex and weak-absorptive vortex

3. How does downward coupling by wave reflection relate to the zonal mean coupling?

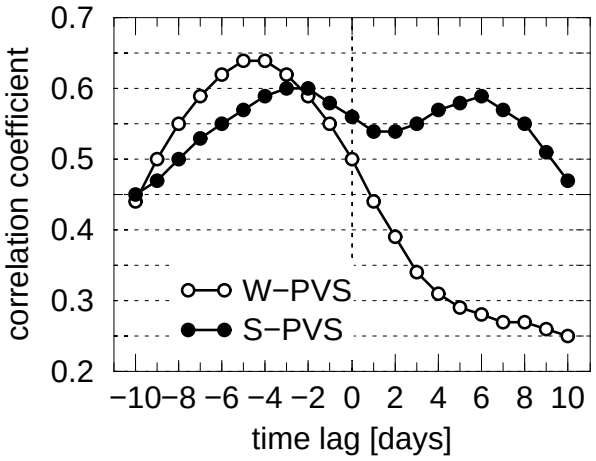
   The two dynamical balances are associated with different downward coupling mechanisms.

4. Implications for the troposphere.

Positive and negative U_{2-10}
(Perlwitz and Harnik, 2003)

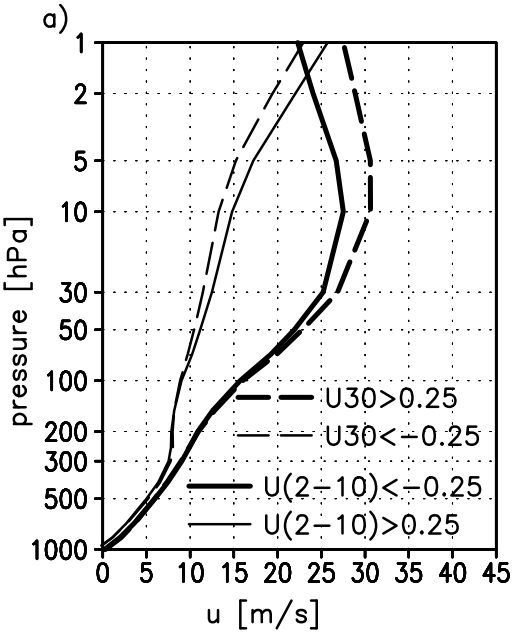


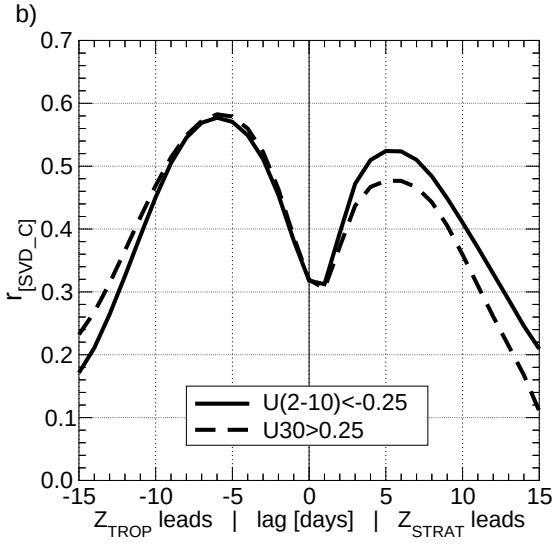
Strong and weak 50 hPa vortex
(Perlwitz and Graf, 2001)

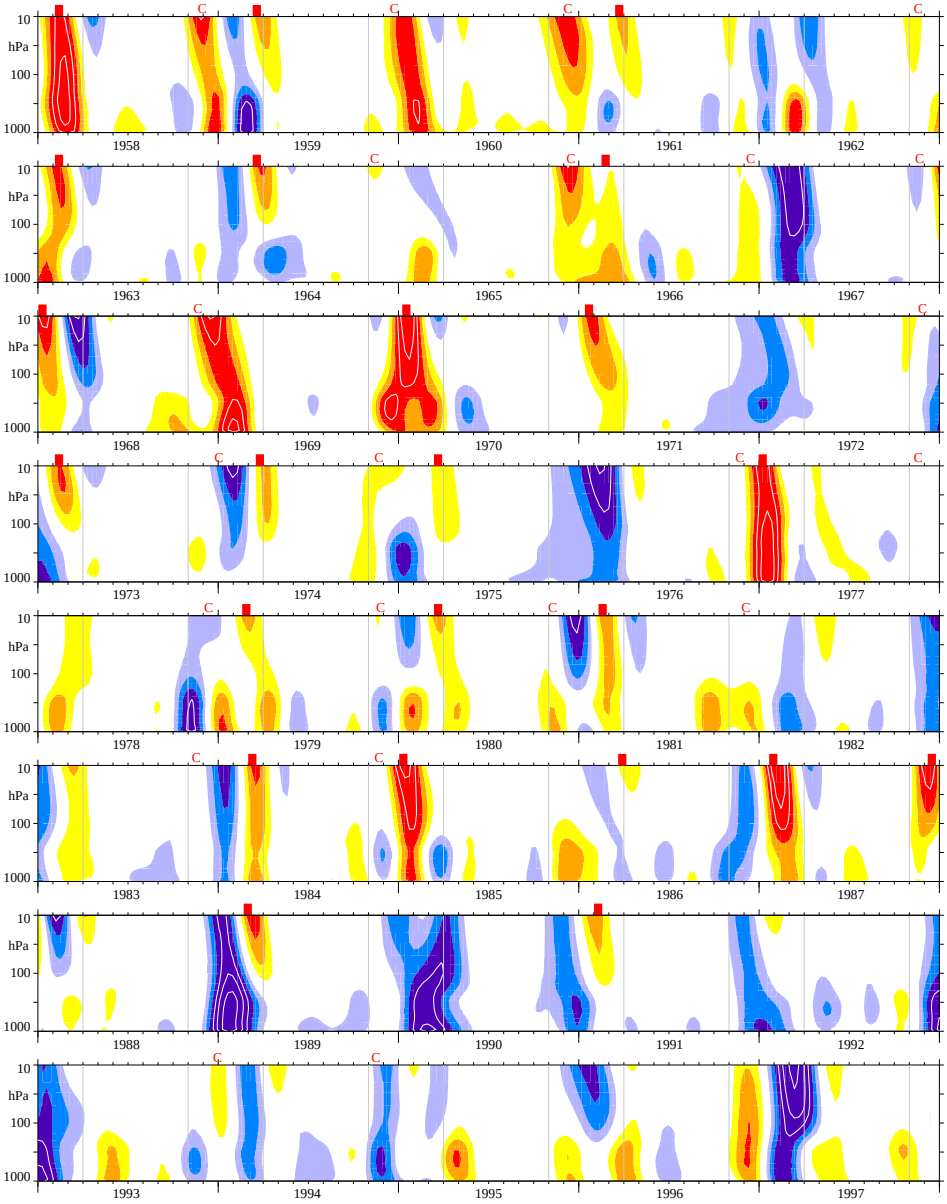


How do we explain the dependence of a reflective signal on vortex strength?

Negative U_{2-10} (solid) vs large U_{30} (dashed), JFM means



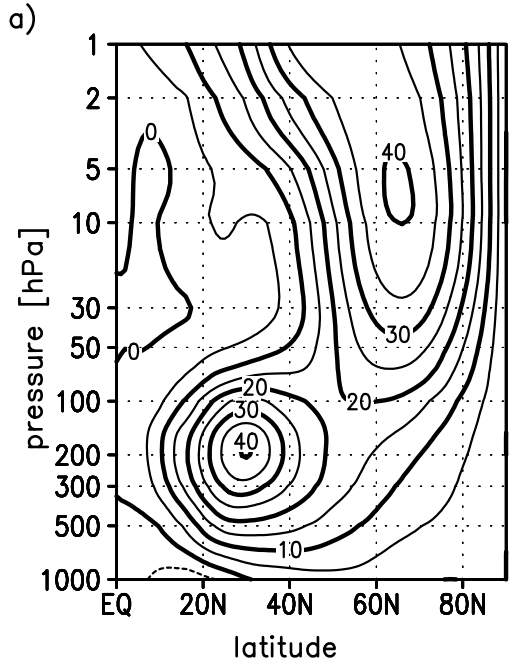


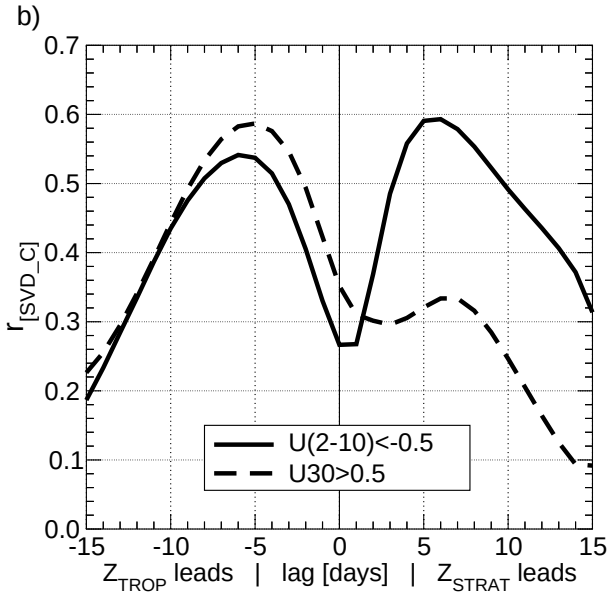


Baldwin and Dunkerton (1999)

Note: relation is not as good on monthly time scale.

U for large monthly $U_3{}^0$, and correlation vs negative U_{2-10}





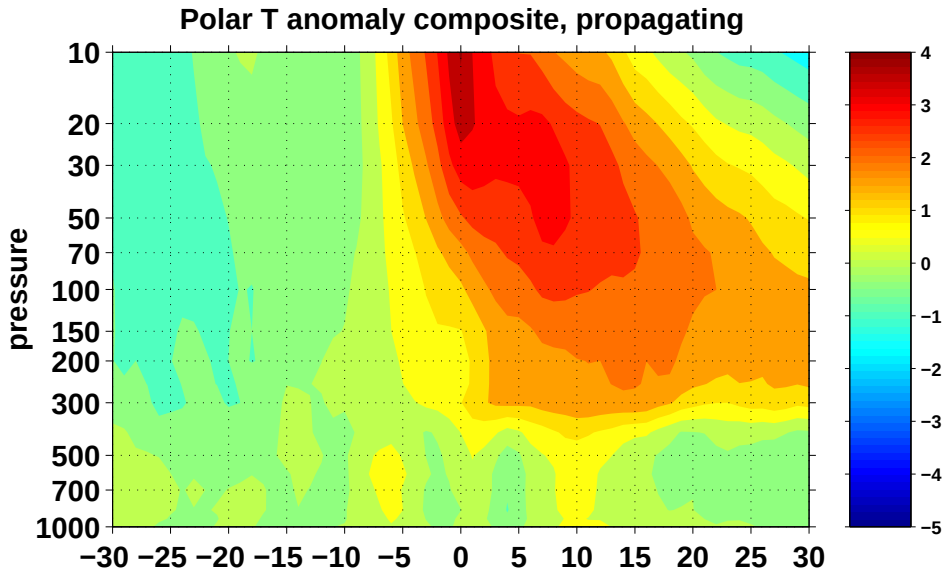
Why is a winter mean (JFM) reflective state coincident with a stronger vortex in the lower-mid stratosphere?

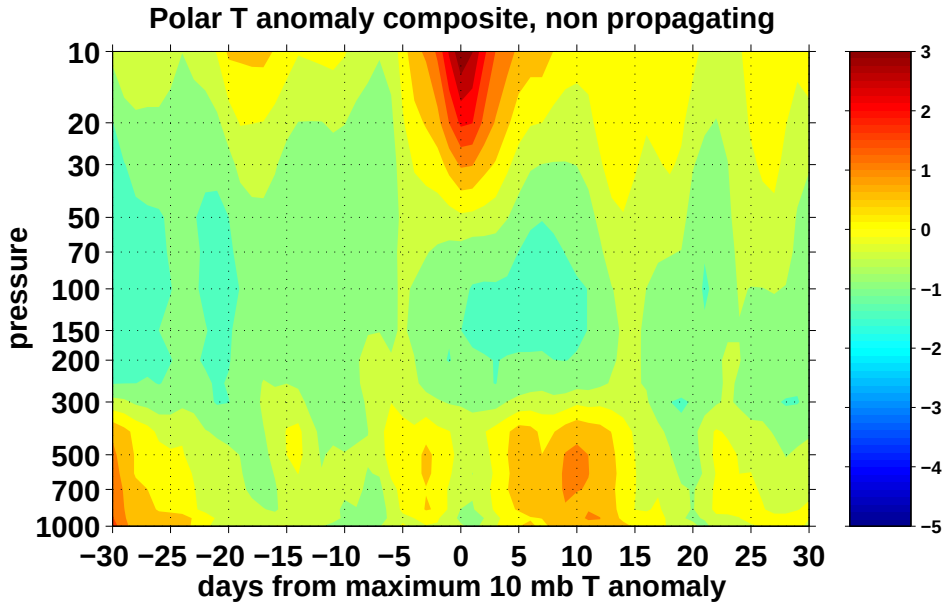
1. Reflection reduces absorption

- Wave mean flow interaction tends to shift downward with time.
  (Hines, 1974; Holton and Mass, 1976; Kodera et al, 1996)
- Reflection will reduce absorption, and subsequent downward propagation, leading to stronger vortex lower down.
- Seasonal time scale may come from the slow time scale for downward propagation (few weeks).
- Zhou et al (2002) divided observed warm polar temperature anomalies into downward propagating and non-propagating. The AO was seen more clearly for the propagating anomalies, which are associated with a downward migration of a critical surface.

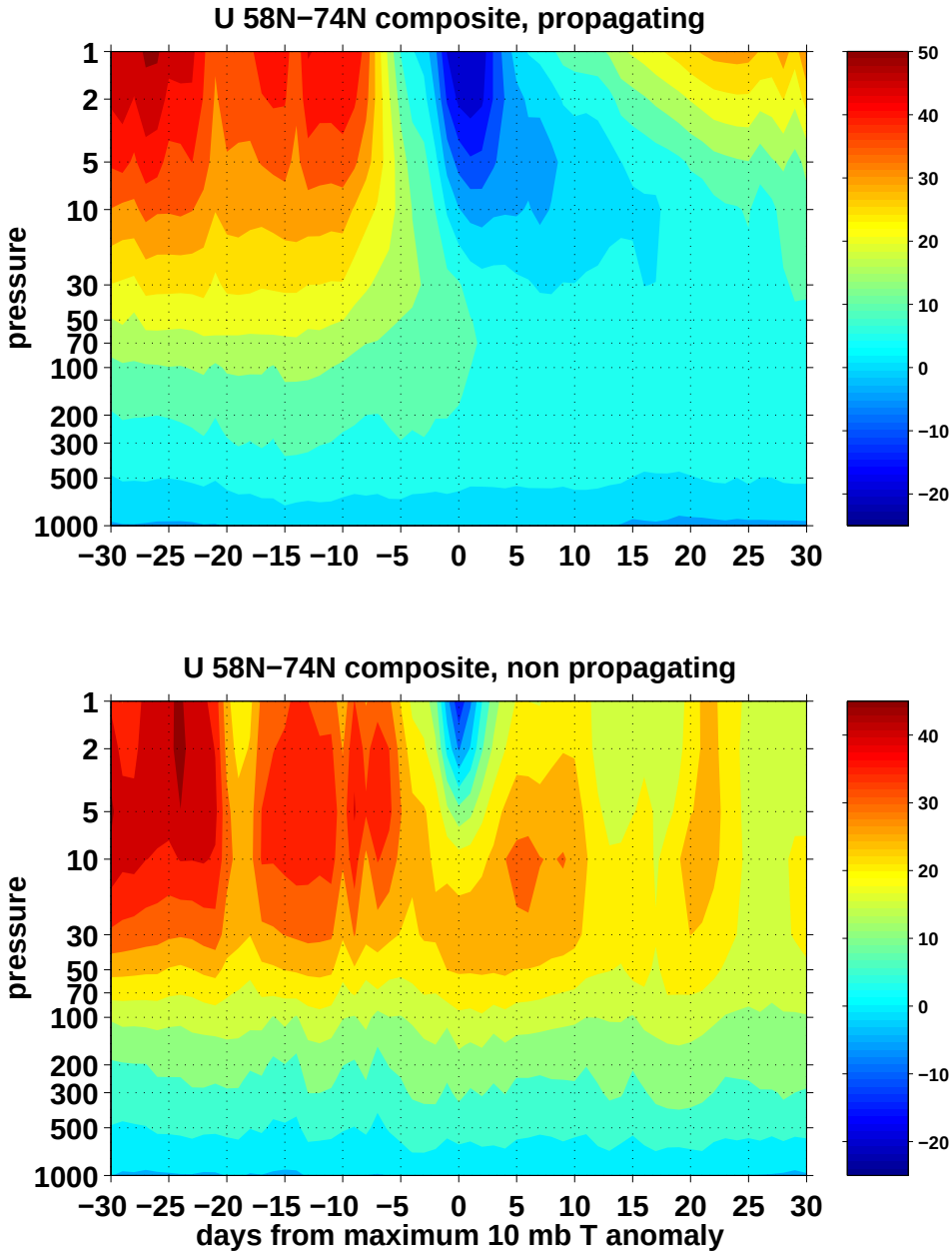
→ Are the non-propagating anomalies associated with reflection?

Polar T composites





$\langle U \rangle$ (58-74N) composites



2. Reflection forms preferably on a strong vortex, whereas a critical surface forms preferably on a weak vortex

Giannitsis (2001): What limits stratospheric wave amplitudes?
Giannitsis and Lindzen (2001a,b): ww.ldeo.columbia.edu/~nili/giannits.html

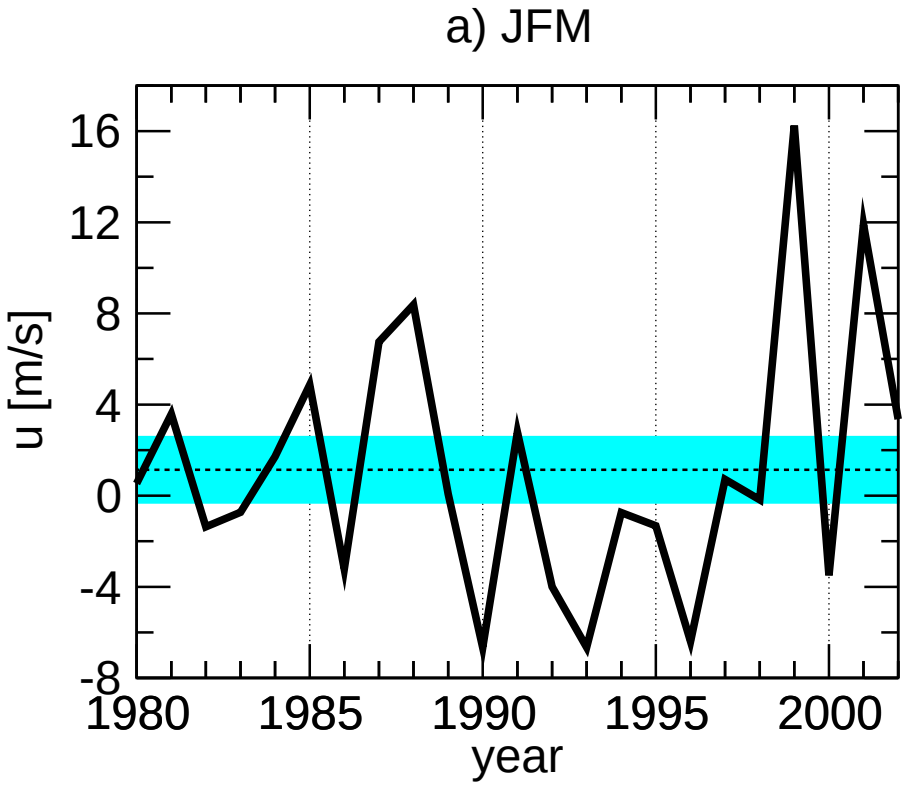
$U_o + \delta U_{WV}$ $(\delta U_{WV} < 0)$
$\rightarrow U = 0$ - a critical surface, wave absorption
$\rightarrow q_y < 0$ - a reflecting surface, reflection.

- Depends on U_o: Weak vortex $\rightarrow$ critical surface.

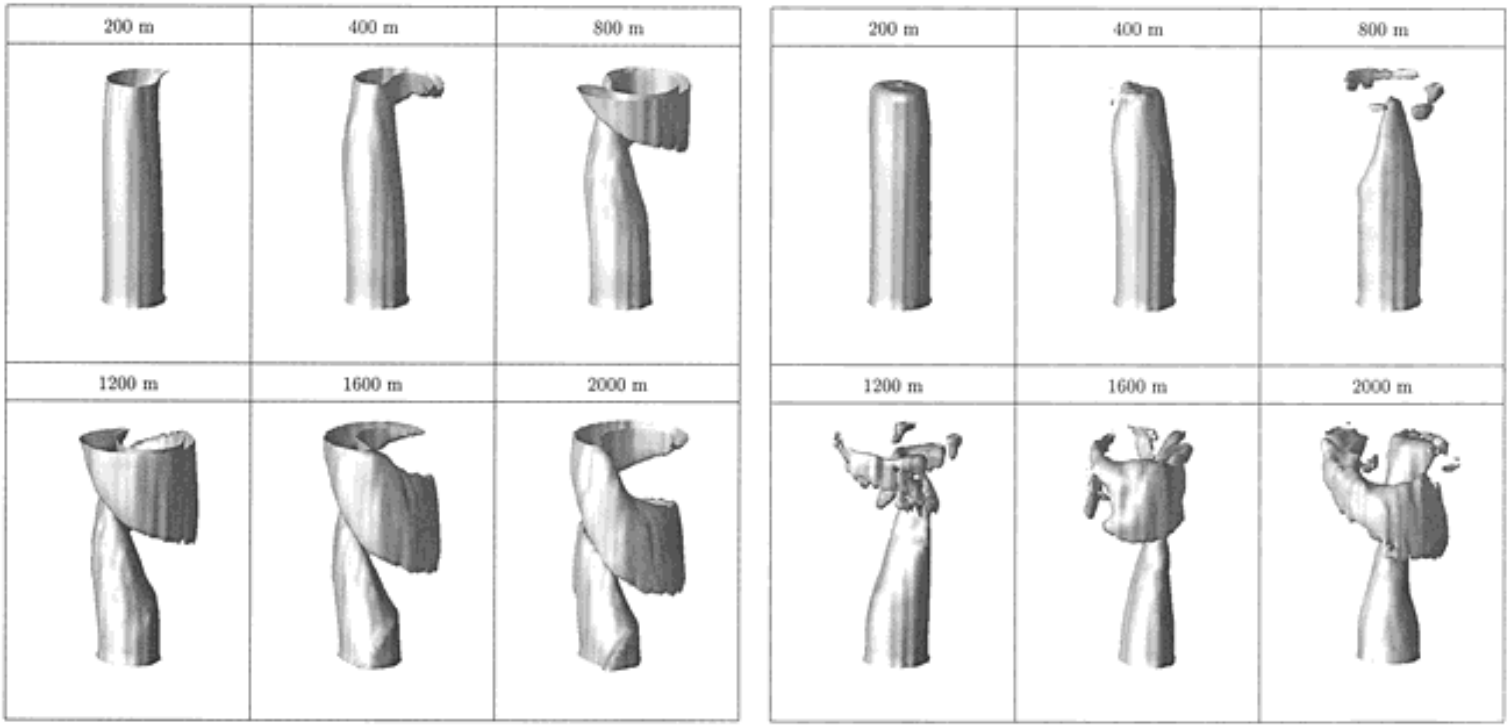
  Strong vortex $\rightarrow$ reflecting surface.

- Combined with point 1 this suggests a positive feedback, allowing two dynamical balances: strong-reflective and weak-absorptive vortex.

A given JFM season shows either reflection or a major warming

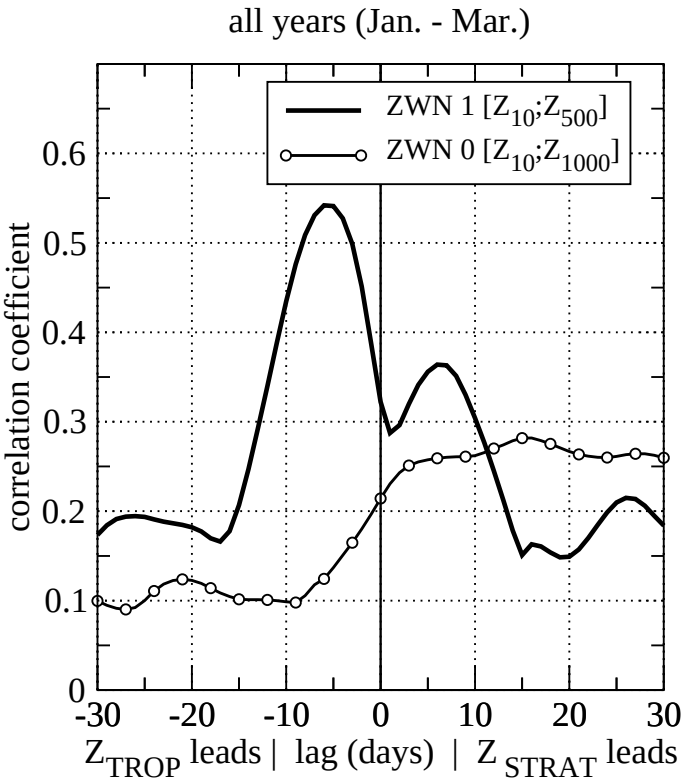


3. Depends on type of wave breaking

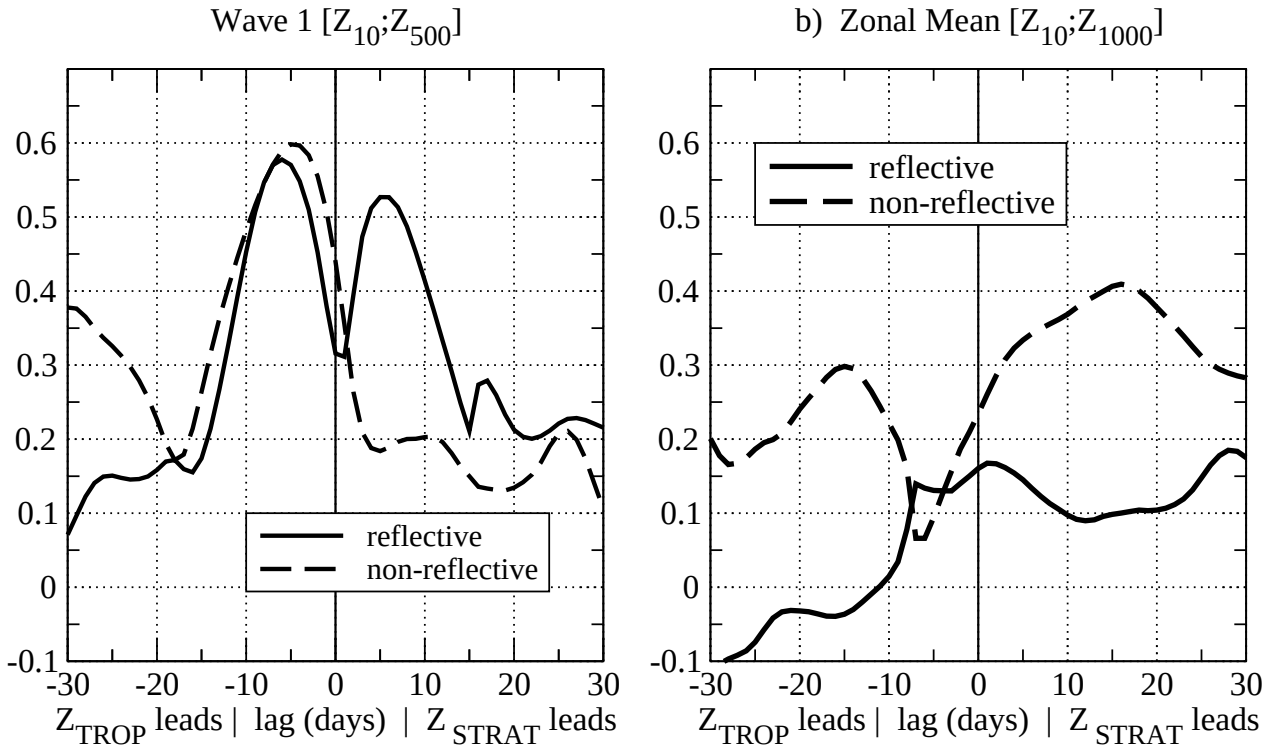


Polvani and Saravanan (2000)

How does reflection relate to the Annular Mode based coupling?



Separating based on the reflective index U_{2-10}.



Summary:

- Reflective state is associated with an anomalously strong vortex in the lower-mid stratosphere, on seasonal time scale

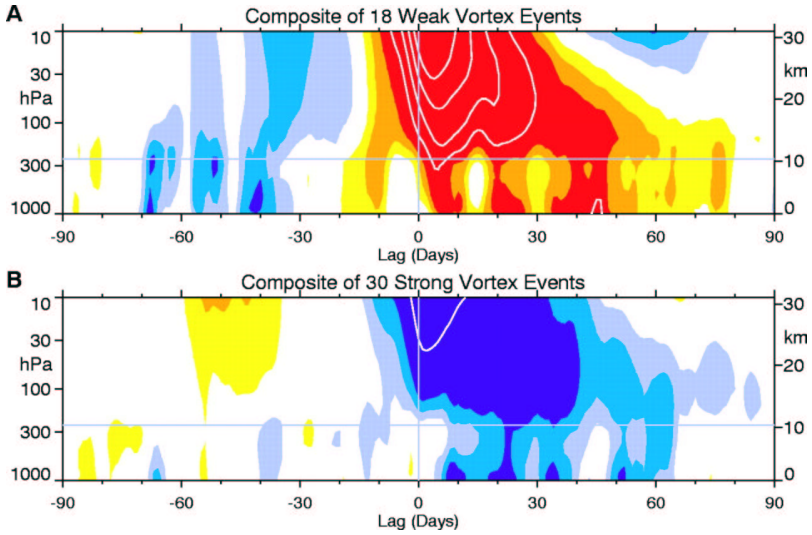
  Various possible reasons (reflection reduces absorption, strong vortex favors reflection, morphology of wave breaking).

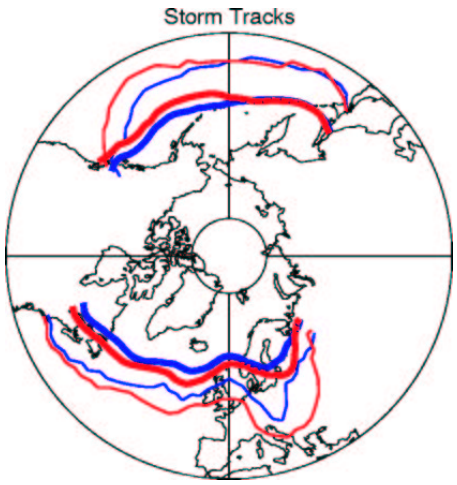
- Two dynamical balances in the winter stratosphere:
  strong-reflective or weak-absorptive vortex.
  Different from Holton and Mass (1976) in type of reflection.

- Wave-wave downward coupling (reflection) dominates during reflective years, downward zonal mean coupling (wave-mean flow interaction) dominates during non-reflective years.

- Downward reflection of waves can't be ignored as a dynamic process by which the stratosphere may affect the troposphere.

Baldwin and Dunkerton, 2001





Is some of the difference related to having a different coupling process during strong and weak stratospheric NAM?

How does reflection affect the troposphere?