The tropospheric response to stratospheric perturbations and its sensitivities to topographically - forced stationary waves in a simple GCM

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1. Motivation

From observations, Baldwin and Dunkerton (2001) have demonstrated that weak stratospheric vortex events precede an equatorward shift in the tropospheric jet.

Similarly, from a modeling study, Polvani and Kushner (2002) have shown an increase in the stratospheric polar vortex results in a poleward shift in the maximum surface winds, consistent with the work described above.

Fluctuation-dissipation theorem relates the linear response to an imposed forcing and its projection onto the system's natural modes of variability. While there is a strong understanding in the troposphere (the eddy feedback associated with the jet oscillation), what determines this structure when the variability extends into the stratosphere?

Is there a way to predict whether the stratosphere can influence the troposphere *a priori?*

2. Model Setup

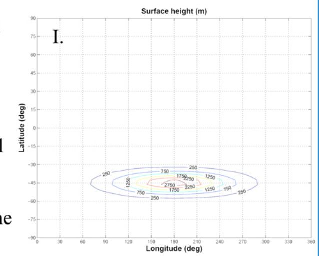
Dry, hydrostatic primitive equation model in sigma coordinates; T30 resolution with 3.75° in lat/lon grid points; 40 vertical levels equally spaced in log-pressure

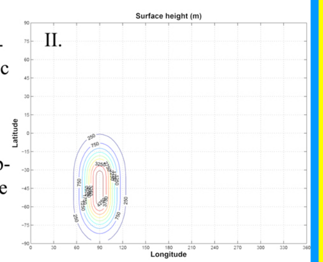
Tropospheric values are similar to that used by Held and Suarez (1994). We induce a perpetual winter and summer hemisphere by adding an additional term to the relaxation temperature profile equal to 10K multiplied by the sine of the latitude.

Setup is similar to Polvani and Kushner (2002); however, in the cases shown here, we add gaussian-shaped topography to represent more realistic planetary scale waves important to the stratospheric variability.

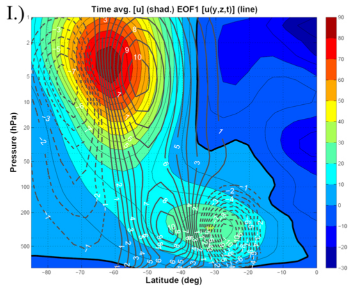
The two figures shown to the right show two separate topographical configurations. Although the central peak of both "mountains" are located at the same latitude, note the different latitudinal structure.

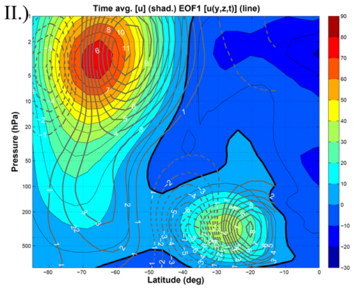
Two Experiments:





3. Variations in internal variability





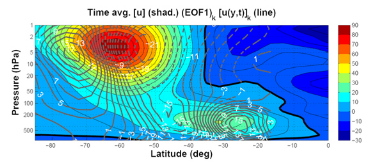
The leading mode for the zonal-mean zonal wind variability. The tropospheric component is largely associated with the oscillating jet, with the poleward modal structure connecting with the stratospheric variability.

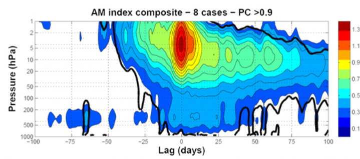
Here, a *weakening* of the stratospheric polar vortex is associated with an *equatorward* shift of the tropospheric jet.

In this experiment, the poleward modal structure (once again, associated with the tropospheric oscillating jet again) does *not* connect with the stratospheric variability.

Here, a *weakening* of the stratospheric polar vortex is associated with a ***poleward*** shift of the tropospheric jet. Such behavior has not been documented in observations.

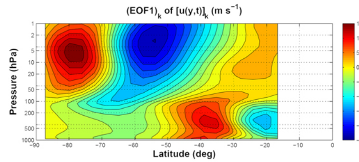
4. S / T coupling

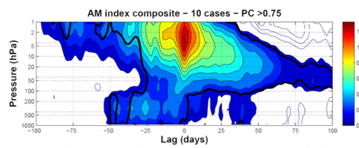




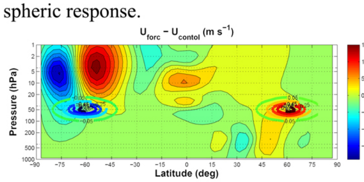
In experiment I, the composites of the AM index at each level from weak stratospheric vortex events show that the tropospheric AM index ***lags*** the weak stratospheric vortex events, suggesting a stratospheric influence onto the troposphere.

However, in experiment II, the opposite is true: the tropospheric AM index ***lead*** the weak stratospheric vortex events.

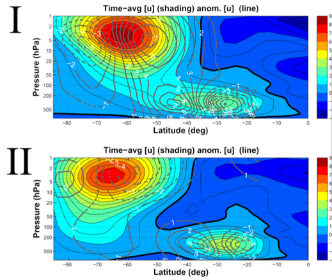




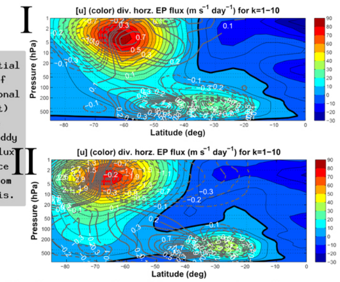
To test the second case further, we added a lower stratospheric momentum forcing. As indicated below, there is virtually no tropospheric response.



5. Discussion



Leading spatial pattern of anomalous zonal wind (left) with the anomalous eddy momentum flux convergence derived from SVD analysis.



Whether the tropospheric AM index *follows* or *precedes* the stratospheric weak vortex events appears to depend on the climatological jet structure.

Comparing both cases, the stratospheric and tropospheric jet correspond roughly to the same latitude. Also, the anomalous zonal wind activity in the two experiments mostly straddle the two jets.

However, in experiment II, the stratospheric jet extends slightly poleward towards the troposphere. As a result, the anomalous stratospheric activity does not "overlap" with the tropospheric eddy feedback (associated with the jet oscillation.)

Furthermore, the eddy momentum flux convergence corresponding to the zonal wind anomalies shown to the left are quite different in the two cases.

In experiment I, the *sign* of the horizontal EP flux divergence is largely *independent* of height. While in experiment II, this is not the case and therefore, when vertically-integrating the eddy momentum flux convergence, (largely due to cancellation) the surface may not respond to a stratospheric forcing.

6. Conclusion

The behavior of the coupling between the troposphere and stratosphere was dependent on the structure of the topography.

In the experiment with topography extending into the polar region, the same-signed tropospheric AM index *precede* weak stratospheric vortex events. In addition, in this case, the *weakening* of the stratospheric jet was related to a *poleward* shift of the tropospheric jet - the opposite behavior of our current observations. Under this setup, when a stratospheric forcing was applied, there was virtually no tropospheric response.

Preliminary results suggest that the lag-lead behavior of the AM index composite depends not only on the stratospheric eddy forcings, but on whether there is "overlap" with the same-signed eddy forcings in the troposphere. If they are vertically aligned, as in experiment I, then the vertically-integrated eddy momentum flux divergence will likely induce changes in the surface zonal flow, an idea similar to Thompson et. al. (2006).