On the Role of Radiative Processes in Stratosphere-Troposphere Coupling

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BACKGROUND

Variability in the extratropical stratosphere is associated with circulation changes at both stratospheric and tropospheric levels. Such stratosphere-troposphere coupling has been documented in the cases of 1) recent Southern Hemisphere (SH) climate trends (e.g., Thompson and Solomon 2002) and 2) intraseasonal dynamic variability in the Northern Hemisphere (NH) stratospheric polar vortex (e.g., Baldwin and Dunkerton 2001). Most mechanisms hypothesized to explain stratosphere-troposphere coupling focus solely on atmospheric dynamics, and little consensus has been reached from these studies.

GOAL

To quantify the importance of radiative processes in driving the polar tropospheric temperature anomalies observed in association with stratosphere-troposphere coupling.

DATA

	Temperature	Ozone
SH Trends	(65°S - 90°S) (1997-2001) – (1979-1983) NCEP-NCAR Reanalysis (Kalnay et al. 1996)	(1997-2001) – (1979-1983) EESC-Fitted Syowa Ozonesonde (Randel and Wu 2007)
NH Dynamic Variability	(60°N - 90°N) 1979-2007 November-April NCEP-NCAR Reanalysis	1979-2003 November-April Resolute Ozonesonde

METHODOLOGY

1. Prescribe the stratospheric temperature and ozone values as per the observations.
   - a.) Climatological temperature and ozone
   - b.) Perturbed temperature and climatological ozone ("temperature effect")
   - c.) Climatological temperature and perturbed ozone ("emissivity/transmissivity effect")

2. Radiative calculations using the Reading Narrowband Model (e.g., Forster and Shine 1997; Forster and Shine 2002) fix the dynamical heating to climatological values and allow tropospheric temperatures to adjust to the radiative heating rates calculated for the prescribed stratospheric temperature and ozone values. The adjustment procedure is analogous to fixed dynamical heating (e.g., Ramanathan and Dickinson 1979; Fels et al. 1980) for the SH trends case and to seasonally evolving fixed dynamical heating (Forster et al. 1997) for the NH dynamic variability case, except that the temperatures are adjusted at tropospheric levels.

RESULTS

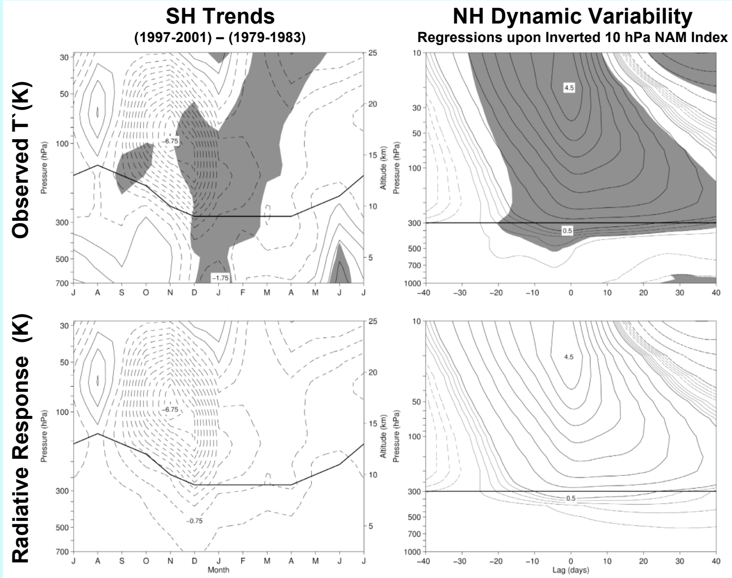
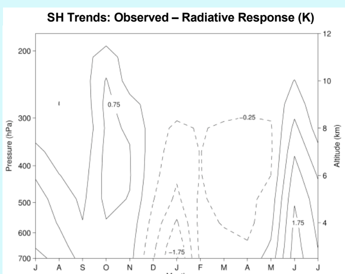


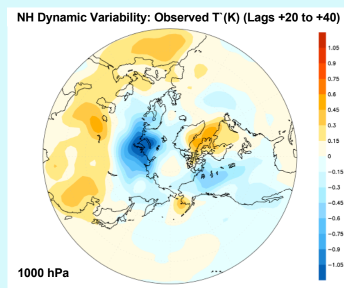
Figure Details: -Radiative response = "Temperature effect" calculations – climatology calculations
-Shading (top panels) indicates 95% significance.
-Solid black line represents tropopause.

The differences between the observed and radiative responses reflect those processes explicitly neglected by the radiative calculations:

- Tropospheric dynamics (e.g., heat transport by baroclinic eddies)
- Radiative absorption at the surface
- Convective adjustment



Observed near-surface cooling during December and January is likely attributable to changes in surface radiative absorption and tropospheric dynamics.



Observed surface cooling over high-latitude continents at large positive lags results from reduced zonal flow and temperature advection (e.g., Thompson et al. 2002).

CONCLUSIONS

- Radiative processes clearly play a role in stratosphere-troposphere coupling, particularly in the SH trends case.
- The bulk of the net radiative response is attributable to the anomalous longwave radiation associated with stratospheric temperature changes. The "emissivity/transmissivity effect" of stratospheric ozone changes is negligible.
- For the SH trends case, both the amplitude and seasonality of the middle and upper tropospheric radiative response compare well with the observations.
- For the NH dynamic variability case, the radiative response extends deeper into the troposphere and persists longer than in the observations.
- Differences between the observed and radiative responses can likely be explained by tropospheric dynamics and surface radiative absorption.
- Radiatively induced temperature anomalies alter the meridional temperature gradient in the upper troposphere and could therefore trigger the changes in tropospheric dynamics observed in association with stratosphere-troposphere coupling.

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