**10.3** STRATOSPHERIC-TROPOSPHERE COUPLING DURING INTRASEASONAL VARIATIONS IN THE ARCTIC OSCILLATION

Brent A. McDaniel*
Robert X. Black
Georgia Institute of Technology
Atlanta, Georgia

## 1. INTRODUCTION

The long-held view of at mospheric dynamicists is that the troposphere, with its abundance of mass and momentum, dominates global atmospheric dynamical processes whereas the stratosphere is a more passive component, contributing little downward influence to the troposphere. In light of recent observational and modeling studies, this view is beginning to change as the stratosphere has been found to contribute both directly and indirectly to the tropospheric circulation. In particular, the mid- to high-latitude troposphere is sensitive to variations in the stratospheric polar vortex related to the Arctic Oscillation (AO). In fact, recent observational studies suggest that, on intraseasonal time scales, there are likely stratospheric dynamical triggers for the AO (Baldwin and Dunkerton 1999 hereafter BD). We study this dynamic interaction to deduce the role of potential coupling mechanisms between the troposphere and stratosphere in mid- to high-latitudes.

Our focus is on how transient stratospheric flow anomalies influence the tropospheric circulation. This is approached by first determining the synoptic and dynamic structures typically associated with AO events using lag regression techniques. Transformed Eulerian mean (TEM) and potential vorticity (PV) analyses are then used as a basis to diagnose the two-way dynamic interaction between the troposphere and stratosphere during the time evolution of intraseasonal variations in the AO. TEM analyses examine the dynamics of the zonal-mean flow and provide input for 2-D diagnostic models. The 3-D dynamic evolution is studied using Rossby wave activity flux analyses and PV inversions. In particular, 3-D circulation anomalies are decomposed into separate parts related to distinct PV anomaly features, permitting a diagnosis of far-field circulations due to local PV structures. The dynamic interaction among separate anomaly features can then be assessed. Our results show that zonal stratospheric PV anomalies likely act to initiate certain tropospheric AO events.

* *Corresponding author address:* Brent A. McDaniel, School of Earth and Atmospheric Sciences, Georgia Institute of Technology, Atlanta, GA, 30332-0340; e-mail: brent.mcdaniel@eas.gatech.edu.

## 2. METHODS

The three-dimensional flow anomaly evolution is ascertained using lag-regressions based upon high temporal resolution AO indices (e.g., BD). Using daily NCEP/NCAR reanalyses, we isolate the structural time evolution of wind, height, and temperature anomalies. These are used to assess higher order flow measures such as potential vorticity and as a basis for performing subsequent diagnostic analyses. We also determine the evolution of fundamental wave measures such as power spectra, heat and momentum fluxes, PV, and Eliassen-Palm fluxes. We focus on the winter period December through February, for which stratosphere-troposphere coupling of the AO appears most prominent. To facilitate comparisons with existing studies (e.g., BD), we analyze unfiltered and time filtered data.

The intraseasonal AO evolution is divided into 4 idealized stages:

1) Formation of mid-stratospheric vortex anomalies
2) Descent of polar vortex anomalies from the mid to lower stratosphere
3) Initial descent of zonal anomalies into troposphere
4) Subsequent adjustment of tropospheric flow

This observational characterization provides input for the diagnostic analyses and guidance for future mechanistic model experiments. We employ daily-averaged NCEP/NCAR pressure coordinate output archived at NOAA's Climate Diagnostics Center for years 1958 to the present day. These data are on a 2.5$^{o}$ latitude by 2.5$^{o}$ longitude global horizontal grid for 17 pressure levels extending up to 10 hPa.

Our approach is to use the lag-regressed fields to perform PV-based as well as conventional dynamical diagnostic analyses of the AO evolution. These can be contrasted with existing parallel analyses of the dynamical balances sustaining quasi-steady AO anomalies. We first consider the zonal-mean dynamics, for which relevant diagnostic measures include E-P fluxes and their divergences. E-P fluxes provide a measure of Rossby-wave propagation in the meridional plane (Edmon et al. 1980) and the E-P flux divergence represents the net eddy-forcing of the zonal-mean flow (Andrews et al. 1987). TEM analyses of [u] tendency are performed to determine specific sources of zonal acceleration. E-P flux divergences related to eddies having different scales are also diagnosed. This 2-D wave-mean flow perspective is particularly useful in the stratosphere, where the flow can be characterized by its zonal mean and a small number of planetary waves and is approximately conservative on the time scales being considered. The two-dimensional analyses provide information on how the troposphere influences the stratosphere and on the potential indirect influence of the stratosphere upon the troposphere. The TEM analyses also provide relevant input for 2-D diagnostic modeling calculations.

There are important zonal asymmetries for the AO, however, especially in the mid- and lower troposphere (Thompson and Wallace 1998). In three dimensional flows, wave propagation characteristics and wave-mean flow interaction can be diagnosed using wave activity fluxes (Plumb 1985, Black 1997). We apply these to deduce regional sources and sinks of wave activity in the troposphere.

For each phase of AO development we use a PV dynamical framework to deduce the flow anomalies induced by PV anomalies in different atmospheric regions. This is pursued using PV inversions (e.g., Hartley et al. 1998) which provide snapshots of flow attribution. To disentangle cause and effect, however, it will ultimately be necessary to assess the proximate sources for the important regional PV anomalies. This problem will be addressed in future work by applying potential vorticity tendency and piecewise tendency analyses (Nielsen-Gammon and Lefevre 1996) in which local tendencies in geopotential height are linked to specific regional dynamical and physical processes within a PV dynamical framework. At the conference we will present analyses indicating that, on short time scales, zonal stratospheric anomalies likely act to initiate certain tropospheric AO events.

.

*Acknowledgments.* This work is supported by the NSF Climate Dynamics Program under Grant ATM-0001346.

REFERENCES

Andrews, D. G., J. R. Holton, and C. B. Leovy, 1987: *Middle atmosphere dynamics*. Academic Press, 489 pp.

Baldwin, M.P., and T.J. Dunkerton, 1999: Propagation of the Arctic Oscillation from the stratosphere to the troposphere. *J. Geophys. Res.*, **104,** 30937-30946.

Black, R. X., 1997: Deducing anomalous wave source regions during the life cycles of persistent flow anomalies. *J. Atmos. Sci.*, **54,** 895-907.

Edmon, H. J., B. J. Hoskins, and M. E. McIntyre, 1980: Eliassen-Palm cross sections for the troposphere. *J. Atmos. Sci.*, **37,** 2600-2616.

Hartley, D.E., J. Villarin, R.X. Black, and C.A. Davis, 1998: A new perspective on the dynamical link between the stratosphere and troposphere. *Nature*, **391,** 471-474.

Nielsen-Gammon, J.W., and R.J. Lefevre, 1996: Piecewise tendency diagnosis of dynamical processes governing the development of an upper-tropospheric mobile trough. *J. Atmos. Sci.*, **53**, 3120-3142

Plumb, R.A., 1985: On the three-dimensional propagation of stationary waves. *J. Atmos. Sci.*, **42,** 217-229.

Thompson, W. J., and J. M. Wallace, 1998: The Arctic Oscillation signature in the wintertime geopotential height and temperature fields. *Geophys. Res. Lett.*, **25,** 1297-1300.