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Title: USE OF SATELLITE DATA AND MODELING TO ASSESS THE INFLUENCE OF STRATOSPHERIC PROCESSES ON THE TROPOSPHERE

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Our research is comprised of the following tasks:

1) use simple analytical and numerical models of a coupled troposphere - stratosphere system to examine the effects of radiation and ozone on planetary wave dynamics and the tropospheric circulation;
2) use satellite data obtained from the Nimbus 7 Limb Infrared Monitor of the Stratosphere (LIMS) instrument and Solar Backscattered Ultraviolet (SBUV) experiment, in conjunction with National Meteorological Center (NMC) data, to determine the planetary wave vertical structures, dominant wave spectra, ozone spectra, and time variations in diabatic heating rate;
3) synthesize the modeling and observational results to provide a better understanding of the effects that stratospheric processes have on tropospheric dynamics.

Below we summarize our research carried out during the period 1 August 1987 to 15 June 1988, describe the research currently in progress, and outline our research plans for the period 1 August 1988 - 31 July 1989.

SIGNIFICANT ACCOMPLISHMENTS: 1 August 1987 - 15 June 1988

Our research during the past eleven months has focused on the following:

* **Examination of the barotropic stability of realistic stratospheric jets on a sphere in which the jet profiles are taken from observational data.**

Results show that approximately nondispersive modes are associated with a region of negative basic state absolute vorticity gradient on the poleward side of the jet. In particular, broader jets and those which peak at higher latitudes produce poleward modes that are less dispersive. The jet profiles were derived from observational data at 10, 5 and 2 mb for three Southern Hemisphere months, and the stability characteristics of these profiles were compared with quasi-nondispersive features which have been observed in satellite data in the Southern Hemisphere winter stratosphere. Characteristics of the barotropically unstable modes compare remarkably well with those of the observed modes. The barotropic model results for a month in which these features were not observed indicate the presence of equatorward modes at zonal wavenumbers 3 and 4 which grow considerable faster than the quasi-nondispersive poleward modes. Also identified are westward moving modes in the summer hemisphere during June, and in analytical jet profiles with a realistic global structure (details concerning this work are described in Mannney, Nathan and Stanford, 1988a).

This work serves as a basis from which we can now examine whether realistic vertically and horizontally sheared stratospheric jet structures in a baroclinic atmosphere can significantly alter the reflection and transmission properties of the planetary waves, and thus affect the tropospheric circulation.

* **Examination of the role of dissipation in the finite amplitude interactions between forced and free baroclinic waves.**

The effects of dissipation on the weakly nonlinear interactions between a marginally unstable wave and a resonant topographic wave were examined using multiple time scales in a quasigeostrophic, two-layer model on a midlatitude beta-plane channel. The lower boundary is characterized by sinusoidal bottom topography. The dissipation was chosen as one or a combination of the following forms: Ekman dissipation at the lower and upper boundaries, interfacial Ekman dissipation, thickness damping, and potential vorticity damping (PVD).

In the absence of topography the baroclinic wave always equilibrates irrespective of the form of the dissipation. If the dissipation is sufficiently weak and due solely to PVD, the baroclinic wave exhibits a damped vacillation symmetric about its steady value. If the form of the dissipation is different from PVD, the baroclinic wave evolves through three distinct stages: initial exponential growth, a damped vacillation in which the overall envelope of the vacillation increases on an intermediate time scale and, finally, an asymptotic approach towards equilibration.

In the presence of topography, numerical integrations of the asymptotically derived wave and mean flow evolution equations were carried out for the case where the topographic wave is taken zero initially. It is shown that depending on the form and/or the strength of the dissipation, the asymptotic state of the system is characterized by either a single (stationary) topographic wave state or a mixed wave state. Weak PVD favors the single wave states while, in sharp contrast, other dissipation forms, provided they are sufficiently weak, favor the mixed wave states. Perpetual vacillation was not obtained (details concerning this work can be found in Nathan, 1988b).

The degree to which these results are changed with the explicit incorporation of diabatic heating/cooling due to oxygen only photochemistry in a continuous model of the atmosphere is currently under study. Preliminary results indicate that such explicit photochemical coupling to the dynamics may have important implications regarding the stability of planetary waves and the coupling between the stratosphere and troposphere.

* **Examination of the influence of short-term variations of solar ultraviolet radiation on stratospheric ozone and temperature.**

This work examines the influence of variations in solar UV radiation flux on ozone and temperature in the middle to upper stratosphere for the time scale of the solar rotation period. The problem is formulated within the context of a coupled, one dimensional radiative-photochemical model. Negative ozone phases relative to the UV flux are predicted for the upper stratosphere in accord with recent observational and theoretical results. The increase in temperature phase with decreasing height results from a shift from direct forcing by solar flux variations at 1 mb to indirect forcing by sun induced ozone perturbations at 10 mb. The strength of damping strongly affects the response of the system to changes in the solar forcing period. (Results of this work are described in White and Yarger, 1988)

CURRENT RESEARCH ACTIVITIES

* **Examination of satellite-derived ozone and temperature field data.**

A reconstruction of synoptic ozone fields from asynoptic satellite ozone data is currently under study. The method of Salby (1982a,b; JAS), as applied to observational data by Lait and Stanford (1988; JAS), has been adopted. The Salby method was modified for use with only one scantrack and only ascending nodes, such as the backscattered ultraviolet ozone data of the Nimbus 4 BUV or Nimbus 7 SBUV experiments. Preliminary analyses of BUV ozone data have been carried out to obtain daily maps of ozone mixing ratio north of 30^{o} at 1 mb for April through October 1970. SBUV ozone data have been obtained for analysis by this technique. The reconstructed ozone fields and temperature fields will be used for comparison with our numerical model results. These reconstructed ozone fields will also be analyzed to better understand the time dependent behavior of stratospheric ozone over the period of satellite observations.

* **Examination of the effects of radiation and ozone on the linear stability properties of external Rossby waves in a continuously stratified model of the atmosphere.**

The role of ozone in the linear stability of Rossby normal modes was examined in a continuously stratified, extratropical baroclinic atmosphere. The flow is described by coupled equations for the quasigeostrophic potential vorticity and ozone volume mixing ratio. A perturbation analysis has been carried out under the assumption of weak diabatic heating, which is generated by Newtonian cooling and dynamics-ozone interaction. An expression for the propagation and growth characteristics was obtained analytically in terms of the vertically averaged wave activity, which depends on the wave spatial structure, photochemistry, and basic state distributions of wind, temperature and ozone volume mixing ratio. A qualitative analysis of the results suggests that coupling of the dynamics with ozone has a destabilizing influence on external Rossby waves (results of this study can be found in Nathan, 1988c).

The possible effects of chlorofluorocarbons (CFCs) on the stability of traveling normal modes, and implications for the tropospheric circulation, are currently under investigation.

* **Examination of the effects of radiation, ozone advection, and ozone photochemistry on the linear stability properties of transient normal modes in a multilevel, quasigeostrophic, midlatitude beta plane channel model.**

We are currently investigating to what extent diabatic heating induced by the advection of ozone and ozone photochemistry can alter the vertical structure, propagation characteristics and growth rates of transient planetary waves based on realistic basic state distributions of zonal wind, temperature and ozone. Variable opacity and temperature dependent ozone absorption have also been incorporated into the model. Standard reference profiles of ozone and temperature have been obtained for calculation of the photochemical variables. The numerical code for determining the structure and stability properties of the transient planetary waves is currently being developed.

RESEARCH PLANS: 1 August 1988 - 31 July 1989

Our research plans for the next year are:

* Determine analytically the effects of radiation and photochemistry on the linear stability properties of internal Rossby waves and compare with our results obtained for the external Rossby waves.
* Develop analytically the wave - mean flow interaction equations for travelling normal modes in the presence of radiation and ozone photochemistry.
* Complete development of the numerical code for the multi-level, linearized quasigeostrophic model which incorporates radiation and ozone photochemistry. The model will be used to confirm our analytically derived results and to consider more realistic basic state flow structures.
* Continue to analyze satellite derived ozone and temperature fields, and compare our observational results with our analytical and numerical model results.
* Begin an extensive description of stratospheric ozone characteristics based on satellite observations.

PUBLICATIONS/PRESENTATIONS: 1 August 1987 - 15 June 1988

a) **Refereed Publications**

1) Nathan, T. R., 1988a: "Finite amplitude interactions between unstable baroclinic waves and resonant topographic waves." J. Atmos. Sci., 45, 1052-1071.
2) Manney, G., T. R. Nathan, and J. Stanford, 1988a: "Barotropic stability of realistic stratospheric jets." J. Atmos. Sci. (in press).
3) Nathan, T. R., 1988b: "On the role of dissipation in the finite amplitude interactions between forced and free baroclinic waves." Geophys. Astro. Fluid Dyn. (in press)
4) White, R., and D. Y. Yarger, 1988: "Influence of short term variations of solar UV radiation on stratospheric ozone and temperature." (submitted to Pure and Applied Geophysics)
5) Manney, G., T. R. Nathan, and J. Stanford, 1988b: "Barotropic instability of basic states with a realistic jet and a wave. J. Atmos. Sci. (in revision)
6) Nathan, T. R., 1988c: "On the role of ozone in the stability of Rossby Normal modes." (submitted to J. Atmos. Sci.)

b) **Refereed Abstracts/Conference Presentations**

1) Nathan, T. R., 1987: "Interactions between unstable baroclinic waves and quasistationary waves in the presence of topography and periodic forcing." Sixth Conference on Atmospheric and Oceanic Waves and Stability, Seattle, Washington.
2) Barcilon, A., and T. R. Nathan, 1987: "Dynamics of Forced and Free Finite Amplitude Baroclinic Waves." Sixth Conference on Atmospheric and Oceanic Waves and Stability, Seattle, Washington.
3) Nathan, T. R., 1988: "Chaos in Physical Systems." Physics Section, 100th Session of the Iowa Academy of Sciences."
4) Manney, G. L., T. R. Nathan, and J. Stanford, 1988: "Stability of stratospheric zonally varying flow." Southeast Geophysical Fluid Dynamics Conference, Huntsville, Alabama.
5) Nathan, T. R., 1988: "Seasonal forcing of finite amplitude baroclinic waves." Southeast Geophysical Fluid Dynamics Conference, Huntsville, Alabama.