N92-14552

1. Title of Research Task

Analysis of Troposphere-Stratosphere Exchange

2. Investigators and Institutions

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3. Abstract of Research Objectives

The overall goal of this work is to improve our understanding of stratosphere-troposphere exchange processes in the tropics and midlatitudes. Specifically, we will do modeling and analysis using the aircraft, radiosonde, and satellite data from the 1980 and 1987 NASA tropical field experiments in Panama and Australia, respectively, and the 1986 NASA jet stream field experiment in California. The objectives are to: (1) examine the structure of ozone, temperature, horizontal winds, tropospheric tracers, water and ice particles, and water vapor within, around, and above cumulus anvils in the tropics and jet streams in midlatitudes; (2) establish the presence, during each of the experimental periods, of various potential mechanisms of exchange, such as direct injection by cumulus, gravity wave fluxes, turbulent fluxes, and radiative heating; and (3) evaluate quantitatively, if possible, the mass of air transferred by these mechanisms during specific transport events.

4. Summary of Progress and Results

Our analysis of the 1980 Panama measurements have been devoted to the generation of gravity waves by convection. It is obvious that mesoscale convective systems generate disturbances in the overlying stratosphere. Analysis of the 1980 Panama measurements indicates that these stratospheric disturbances have scales ranging from those of underlying convective plumes (~1 km) to entire anvil systems (~100 km). Using a simple gravity wave model, we have shown that mesoscale convective systems during the experimental period can generate gravity waves in the stratosphere that propagate to stratopause levels, where they break and impart westerly momentum to the flow. Our calculations indicate that they make a significant contribution to the momentum budget of the semiannual wind oscillation.

In addition to continuing our investigation of convectively generated gravity waves using the 1987 Australia data, we have looked into other transport mechanisms with this superior dataset. Our major results to date are: (1) clearly establishing (using wind measurements not available in Panama) that the anvil scale disturbances over convection within the lower stratosphere are gravity waves; (2) documenting an example of shear instability, with subsequent mixing, within an anvil scale gravity wave; (3) establishing that turbulence occurring over a horizontal extent of ~100 km at the top of an anvil can transport tracers perhaps 1 km or more into the stratosphere; (4) documenting a case of hydration of the lower stratosphere over a convective region by upward mixing of ice particles through the "cold trap" region near the tropopause; (5) discovery of short (5 km length scale) trapped gravity waves in the lower stratosphere, in both convective and clear conditions.

Examination of the 1986 STEP midlatitude dataset has just begun. The most important finding so far is the discovery of a strongly layered structure in the tracers above the midlatitude jet stream, similar to structures found in the 1984 STEP field program. These quasi-isentropic layers are about 1 km thick, and represent undulations of the strong mean gradient of tracers that occurs over the jet stream. There is preliminary evidence (in the form of enhanced small scale variation) that suggests mixing between these layers.

5. Publications

Pfister L., H. B. Selkirk, K. R. Chan, B. Gary, K. Kelly, M. Proffitt, J. Wilson, and R. Knollenberg, 1989: Characteristics of the stratosphere-troposphere interface above a tropical cyclone during STEP Australia. Proceedings of the 18th Conference on Hurricanes and tropical meteorology, American Meteorological Society, San Diego, CA.

Pfister, L., S. Scott, S. Bowen, and M. Legg, 1989: Amplitudes and scales of gravity waves generated by tropical convection. to be submitted to Journal of the Atmospheric Sciences.

A. An Investigation of Mesoscale Variability Using GASP Aircraft Data

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C. Abstract of Research Objectives

The purpose of this research effort was to examine, using the GASP aircraft data set, the geographic variability of mesoscale fluctuations of wind and temperature. Of particular interest was an apparent enhancement, based on a pilot study, of the mesoscale motion spectrum at horizontal scales of 4 to 80 km over mountainous terrain. This suggested that gravity waves excited by high terrain may play a key role in the local forcing of the large-scale atmospheric circulation. It was our intent to extend this analysis to the global GASP data set and to seek evidence of variance enhancements due to other potentially significant sources of mesoscale motions as well. Such information is important in assessing the impact of gravity wave forcing of the lower and middle atmosphere and in determining where observations should be made in order to be most representative of the various wave forcing environments.

D. Summary of Progress and Results

During the first year of this grant, the pilot study conducted with data collected over the continental US and eastern Pacific was extended to the global GASP data set and was stratified further by two measures of terrain roughness. This work showed the same trends as the pilot study (a ~ 3x enhancement of variance over rough terrain), with high terrain leading to even larger enhancements (~ 10x). The implications of these results are that high terrain, in particular, plays a disproportionately large role in the excitation of mesoscale (primarily gravity wave) motions and likely thus contributes appreciably to the global energy density and energy flux at these scales. The energy flux by such motions is especially important as it represents, on theoretical grounds, the majority of the energy flux at all scales in the atmospheric fluctuation spectrum. This study is now in press in J. Atmos. Sci.

Additional efforts during 1988 and 1989 have focussed on other potentially important sources of mesoscale activity and geographic variability. Two such sources were judged to warrant additional effort. These are frontal zones, which appear to cause large local enhancements of the velocity and temperature variance at scales less than 64 km, and tropical convection, which causes enhancements over greater areas, but which is less closely coupled with identifiable, discrete sources. In each case, the inferred velocity and temperature variance was computed in 64 km segments along flight paths that crossed zones of convection or frontal activity. The variance estimates were then correlated with evidence of frontal or convective activity obtained from conjunctive satellite imagery. Like the variance enhancements due to high terrain, these sources appear to lead to large, local enhancements of velocity and temperature fluctuations and are likely to represent strong, local forcings of the atmosphere that are highly time dependent. These efforts are continuing and will likely lead to two publications presenting selected case studies and the statistics of variance enhancements due to convection.

Finally, this grant contributed during this period to an assessment of the relative importance and role of gravity waves in forcing the large-scale circulation in the northern and southern hemispheres using evidence collected from a variety of instrument systems. The conclusions of this effort suggest that gravity waves are less prevalent in the southern hemisphere due to the lack of major topography at middle latitudes, but that other sources are necessarily more significant and contribute to lower and middle atmosphere forcing at those locations. This work is in press in a NATO Advanced Studies volume entitled Dynamics, Transport and Photochemistry in the Middle Atmosphere of the Southern Hemisphere.

E. Publications

Jasperson, W.H., G.D. Nastrom, and D.C. Fritts, Futher study of terrain effects on the mesoscale spectrum of atmospheric motions, J. Atmos. Sci., in press.

Fritts, D.C., Gravity waves in the middle atmosphere of the southern hemisphere, Dynamics, Transport and Photochemistry in the Middle Atmosphere of the Southern Hemisphere, A. O'Neill and C.R. Mechoso, Eds., in press.

Fritts, D.C., G.D. Nastrom, and W.H. Jasperson, Case studies of mesoscale variance enhancements due to localized gravity wave sources, in preparation.

Nastrom, G.D., and D.C. Fritts, The mesoscale motion spectrum due to frontal and convective excitation, in press.