ATMOSPHERIC GRAVITY WAVES IN CONSTITUENT DISTRIBUTIONS

By

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Abstract

This thesis has investigated the influence of atmospheric gravity waves on constituents, particularly ozone in the stratosphere and neutral sodium in the mesosphere. The study included theoretical, modeling, and observational approaches. The motivation for the work is presented first as previous studies are reviewed. A theoretical basis for gravity wave studies is then provided, leading into modeling, simulation studies, and data analysis.

A simple linear gravity wave simulation was developed and applied to the mesospheric neutral sodium layer. The simulation is particularly straightforward for the sodium layer due its approximate horizontal homogeneity and long chemical lifetime relative to gravity-wave timescales. This simulation was used to evaluate processing techniques presently applied to experimental sodium resonant lidar data to determine gravity wave characteristics. The processing of simulated data containing gravity wave fluctuations indicated that the stated limits and some results obtained from sodium lidar are unreliable. The use of simulated data provides a convenient framework within which to explore the sensitivity and selectivity of experimental techniques.

Stratospheric ozone was investigated as an important atmospheric constituent whose response to gravity-wave scale motions is complex and previously not well documented. Detailed observations of mesoscale ozone variation were obtained from two novel campaigns. A combination of quasi-simultaneous ozonesonde, radiosonde and ER-2 aircraft data from the 1994 Antarctic Southern Hemisphere Ozone Experiment (ASHOE), was used to provide a high-resolution picture of the vertical and horizontal variation of ozone, winds, and temperature.

A separate campaign consisting of simultaneous observations with an ozone differential absorption lidar (DIAL) and a Rayleigh–Mie Doppler wind lidar from the Observatoire de Haute Provence (OHP), France, provided high resolution information on the time evolution of ozone vertical structure including two ozone "laminae". The presence of a well-defined long-period inertia-gravity wave was detected in lidar horizontal winds at the same time and altitude as the two observed laminae. These observations provided an excellent case study through which to examine mesoscale ozone variability and test theoretical concepts of ozone response to wave fluctuations.

A two-dimensional Lagrangian mesoscale parcel advection model was developed in order to explore some of the features evident in the above observations more fully. In particular, the possible interaction between mesoscale fluctuations and synoptic-scale transport in generating observed ozone features was investigated. The impact of such interactions on the calculated ozone spectra was addressed. Aspects of the observed ozone variability from the case study of dual lidar observations were then re-examined from a modeling perspective.

As a detailed study of theory, modeling, and observations of mesoscale variability of constituents in the stratosphere and mesosphere, this thesis provides a useful coverage of constituent transport processes in the middle atmosphere.

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