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6. AUTHOR(S)
DAVID C FRITTS

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
LABORATORY FOR ATMOSPHERIC AND SPACE PHYSICS
UNIVERSITY OF COLORADO
BOULDER, CO 80309-0392

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FINAL TECHNICAL REPORT - FY96

1. Title: Modeling of Wave and Instability Processes in the Atmosphere

Agency: Air Force Office of Scientific Research

Grant Number: F49620-93-1-0577

Principal Investigator: David C. Fritts
Laboratory for Atmospheric and Space Physics
University of Colorado
Boulder, CO 80309-0392

Program Manager: Major James T. Kroll

2. Research Objectives

The goals of this research were to examine the dynamics of internal gravity waves accompanying wave breaking and shear flow instability processes using spectral collocation techniques. Important aspects of these flows are the development of instabilities within the flow field which drive the cascade of energy and enstrophy toward turbulence. We also anticipated that these processes would be sensitive to the environment in which they occurred. Our numerical results described below showed this to be true.

3. Research Results

This project led to several new scientific results which we believe comprise significant advances in the field of atmospheric dynamics and flow instability. Partial support for two graduate students, Teresa Palmer and Jim Garten, generated four papers that have either appeared or are now in press. An initial paper (Palmer et al., 1994) was the first to report the simulation of secondary convective instabilities within Kelvin-Helmholtz billows, which are apparently the precursor to turbulence in stratified shear flows. A second paper (Fritts et al., 1996a) on wave breaking and the energetics of the transition to turbulence in flows with parallel and skew shear flows was based on the analysis efforts of Jim Garten. Two additional papers (Fritts et al., 1996b; and Palmer et al., 1996) discussing the initial secondary convective instability of Kelvin-Helmholtz (KH) billows at low and intermediate Reynolds numbers in greater detail are based on simulation studies performed by Teresa Palmer.

These efforts have delineated the transition to three-dimensional (3D) flow and the role of secondary convective instability in the restratification of the shear layer following instability at low and intermediate Reynolds numbers. A further effort by Jim Garten considered the dynamics of counter-rotating vortices in stratified and sheared flows and defined the dominant features of the evolution and the instability processes that occur. A 3D extension of this effort is continuing to examine the influences of stratification and shear on the various modes of 3D instability as well.

Additional studies by Teresa Palmer currently underway are focussing on the extension of the KH modeling to higher Reynolds numbers for which we have seen secondary dynamical instabilities in two-dimensional (2D) and 3D simulations. Because the orientation of these secondary KH instabilities is approximately orthogonal to that of the initial streamwise convective instabilities also present at lower Re, we anticipate that the presence of the two processes together in high-resolution three-dimensional (3D) simulations will lead to a more rapid and more vigorous transition to smaller scales and turbulence. These results will be completed and written up with ongoing AFOSR support.

4. Publications Citing this AFOSR Support (since September 1994)

Palmer, T. L., D. C. Fritts, O. Andreassen, and I. Lie, 1994: Three-dimensional evolution of Kelvin-Helmholtz billows in stratified compressible flow, *Geophys. Res. Lett.*, 21, 2287–2290.

Fritts, D. C., J. F. Garten, and O. Andreassen, 1996a: Wave breaking and transition to turbulence in stratified shear flows, *J. Atmos. Sci.*, 1057–1085.

Fritts, D. C., Palmer, T. L., O. Andreassen, and I. Lie, 1996b: Evolution and breakdown of Kelvin-Helmholtz billows in stratified compressible flows, I: Comparison of two- and three-dimensional flows, *J. Atmos. Sci.*, in press.

Palmer, T. L., D. C. Fritts, and O. Andreassen, 1996: Evolution and breakdown of Kelvin-Helmholtz billows in stratified compressible flows, II: Instability structure, evolution, and energetics, *J. Atmos. Sci.*, in press.

Garten, J. F., D. C. Fritts, S. Arendt, and Ø. Andreassen, 1996: Dynamics of counter-rotating vortex pairs in stratified and sheared environments, *J. Fluid Mech.*, submitted.