TITLE: Numerical Studies of Baroclinic Instability at Small Richardson Number

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SIGNIFICANT ACCOMPLISHMENTS FOR FY-84:

Although the large-scale Richardson number in the earth's atmosphere is generally large, on the mesoscale it may not be large. Hence, modes of instability (of a thermal wind) whose horizontal length is of mesoscale size may be important in organizing convection in certain situations. This has been discussed by numerous authors. Furthermore, baroclinic instability ot small Ri may be important in atmospheres of planets with interior heating combined with differential solar heating, and in particular, it must be considered a plausible explanation for the existence of the banded structure of Jupiter's and Saturn's cloud patterns.

Baroclinic instability at small Ri consists of competition between symmetric (Solberg) modes, zonal (Eady) modes, and possibly other modes whose orientation is neither symmetric nor zonal. There have heretofore been huge gaps in our knowledge of the physics of the first two modes except for special cases. There have been no investigations of the possibility of the third case, except for modes that are nearly symmetric. Finally, until our work there have been no investigations of the fully nonlinear development and equilibration of any of these modes.

In FY-84 three steps have been taken to correct these deficiencies in our knowledge. First, a study of the fully nonlinear development and energetics of the symmetric modes was completed. The nonlinear effects were quite strong and, in some senses, surprising. A journal article on this work has been accepted for publication. Secondly, a study of the dependency of the energetics of the symmetric modes upon the physical parameters has been completed. A paper describing this work is in the final edit stage and will soon be submitted for publication.

FOCUS OF CURRENT RESEARCH ACTIVITIES:

Thirdly, a linear study of the fully three-dimensional possibilities and of the small Ri Eady modes is underway. This includes an analysis of the energetics. The results thus far have shown many surprises and indicate that this system is a rich one indeed.

PLANS FOR FY-85:

The three-dimensional linear study will be completed, which will include an analysis of the energetics of the fastest growing modes. Work will begin on developing a fully nonlinear three-dimensional model.

RECOMMENDATIONS FOR NEW RESEARCH:

Although the energetic analysis of the three-dimensional linear model will give some indication of the results of competition between various modes, a fully nonlinear three-dimensional model is required to determine the conditions under which (for example) the symmetric modes are dominant. The development of such a model should be supported. In conjunction with three-dimensional calculations to determine the preferred modes, the current two-dimensional model should be modified to include the zonal modes and used to investigate highly nonlinear flows, including transition to chaos.

Analysis of satellite and rawinsonde data of mesoscale systems should investigate possible effects of the symmetric modes in earth's troposphere. Analysis of meteorological data of planetary atmospheres (Jupiter and Saturn in particular) should include such investigations as well.

Laboratory investigations of small Ri baroclinic flows should be further pursued, using the apparatus currently operating. (See the report by Miller and Fowlis herein.)

PUBLICATIONS SINCE JUNE 1983:

T. L. Miller: The Structures and Energetics of Fully Nonlinear Symmetric Baroclinic Waves. J. Fluid Mech., in press (1984).

T. L. Miller: On the Energetics and Non-hydrostatic Aspects of Symmetric Baroclinic Instability. To be submitted to J. Atmos. Sci.