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Final Report

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Computer Studies of Baroclinic Flow

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During the past year our work concerning the development of the computer programs necessary for the computation of the transition curve on the regime diagram for AGCE was completed. In fact the results have been written up and will appear in the Journal of Atmospheric Science. The significant results of that research were described in the NASA/MSFC FY-82 Atmospheric Processes Research review. However they will be briefly sketched here.

First the models were used to compute the regime diagram for the rotating annulus. This was accomplished for code written for the spherical configuration of AGCE by setting the radius of the sphere to a very large number and considering a small area near the pole.

The series of numerical calculations consisted of first computing the axisymmetric solution that would develop in the annulus in the absence of waves for a given thermal forcing and rotation rate. This flow was then tested for stability using a linear primitive equation model. If the flow was stable then the point on the regime diagram corresponding to the particular rotation rate and thermal forcing of the experiment was considered to be on the axisymmetric side of the regime diagram. If it was unstable then the point was assumed to be in the wave regime. In this way the transition curve (the line separating these two regimes) was constructed for the annulus. The results were that over a wide range of rotation rate and thermal forcing, the transition curve can be accurately predicted using these models. This result shows that the transition curve is given by the linear instability of the flow that would develop in the absence of eddies. That is, the linear theory explains the curve.

We also used the model to compute some axisymmetric flows for one possible configuration of AGCE. This work suggested that some design changes in the AGCE experiment may be desirable to provide more earth like flows within the apparatus. For this reason a detailed regime diagram was not constructed at this time. This work will be continued by Dr. Fowlis and others at the Marshall Space Flight Center.

Since we have essentially completed the work to develop numerical models for computing the transition curve for the annulus, we began during the winter to look at an important dynamical question suggested by the annulus experiments but which also is important in several other problems including AGCE, the general circulation of the atmosphere and tornadoes. This work will be the Ph.D. thesis of Jerry Steffens.

The purpose of this current research is to investigate the effect of geometrical constraints on the size of eddies developing from a basic state. In other words if we hypothesize that eddies like to be more or less round and that their dimension across the unstable region is given by the width of this region, then any geometrical constraint on the width of the unstable zone will ultimately limit the size of the eddies to wavelengths about equal to that width. For example in the annulus, this width and hence the wavelength would be determined by the width of the annulus. If one examines a regime diagram for the annulus, a preference for waves of a length about equal to that width is clearly displayed. In AGCE, the general circulation and tornadoes, this geometrical constraint will be the width of the shear zone or the baroclinic zone. This geometrical constraint has been shown to influence the most unstable wavelength in a number of barotropic and baroclinic flows. However, it must also play an important and perhaps different role when the waves are of large amplitude and highly non-linear. Our plan is to examine both barotropic and baroclinic flows, using linear and nonlinear models. We believe that the results will help explain the scale-selection mechanism of baroclinic eddies, in the atmosphere experimental models such as AGCE and the multiple-vortex phenomenon in tornadoes.

While the funding for the current NASA grant terminated in June 83 and this report is regarded as a final report, we expect that funding from NASA for this project will resume sometime in FY 84. Currently this work is being continued under other (NSF) grants.

RECENT PUBLICATIONS:

1. Thermally Driven Flow in a Rotating Spherical Shell: Axisymmetric States. T. L. Miller and R. L. Gall. J. Atmos. Sci., 40, xxx-xxx.

2. A Linear Analysis of the Transition Curve for the Baroclinic Annulus. T. Miller and R. Gall. Submitted to J. Atmos. Sci.