MESOSCALE AGEOSTROPHIC CIRCULATIONS ASSOCIATED WITH BAROCLINIC JET STREAKS

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Significant Accomplishments

In our focus on studies of ageostrophic motion attending jet streaks and convection, various types of dynamical experiments have been carried out with the hybrid isentropic-sigma coordinate model during the past year. These involved examination of the effects of vorticity and static stability distributions on the intensity of secondary circulations forced by inertial accelerations as well as the superposition of an amplifying baroclinic wave on the jet streak structure.

In one series of experiments, the horizontal wind shear of the jet streak was increased relative to previous experiments (Fig. 1) while retaining the same maximum wind speed and alongstream variation in the wind. The result was an enhanced development of the direct and indirect circulations at the jet entrance and exit regions, respectively, as revealed by increased precipitation in the jet's left exit region. From quasi-geostrophic concepts, the increase in positive differential vorticity advection enhanced the vertical motion and increased the precipitation. The increase in positive vorticity advection was associated with the larger positive vorticity on the jet's cyclonic side. Another test was made in which the initial anticyclonic wind shear was increased only on the jet's anticyclonic side (reducing the absolute vorticity from 4×10^{-5} to 1.5×10^{-5} s^{-1}) but was not increased on the cyclonic side. In this case, the positive differential vorticity advection was not increased. Figure 2 shows that precipitation was still 50% greater under the jet's left exit region than for the original experiment. In this case, the increased ageostrophic response of the baroclinic jet streak must be explained using Eliassen's concepts in the sense that a decrease in the absolute vorticity results in an enhanced response of the indirect circulation at the jet exit. This in turn leads to greater upward motion on the cyclonic side and thus to increased precipitation.

Another experiment involved decreasing the static stability below the jet streak while maintaining essentially the same velocity structure. This was accomplished by increasing the ground temperature by 10 K along the center of the channel and increasing the lapse rate from 5×10^{-3} K/m to 6×10^{-3} K/m. Areas of precipitation formed under the right entrance and left exit regions with magnitudes three to four times larger than for the original experiment.

The third major experiment involved the superposition of an amplifying baroclinic wave on the jet streak. The maximum wind and alongstream variation of the jet streak at 340 K were nearly the same as in the zonal experiments. The small circular surface low pressure center (997 mb) was located downstream of the trough axis while the circular high pressure center (1003 mb) was located upstream. Figure 3A shows the surface pressure and temperature configurations at 36 hours. Note the apparent development of cold and warm frontal regions south and east of the low. The development of a relatively continuous band of precipitation along the baroclinic zone is shown in

Figure 3B. Areas of maximum rainfall tend to coincide with the areas of greatest positive thermal advection.

A comparison was made between experiments with similar pseudo-geostrophic and geostrophic initial wind distributions. Subsequent evolution of the ageostrophic wind may be assessed by decomposing the ageostrophic acceleration into terms describing centripetal acceleration, kinetic energy gradient, and non-steadiness. The latter effect is, of course, given by $\partial \tilde{U}/\partial t$. Figure 4 depicts this acceleration at 6 hours into the simulations for both the pseudo-geostrophic and geostrophic experiments. The general sense of the vector field in the pseudo-geostrophic case (towards higher pressure) is the same as that which occurs at later time periods in both runs after the imbalances of initialization have subsided. However, in the geostrophic case the acceleration downstream of the wind maximum at 6 hours is almost reversed in direction (towards lower pressure). The cross product of $\tilde{k}$ with $\partial \tilde{U}/\partial t$ gives the direction of the ageostrophic motion. In the geostrophic case at 6 hours, the ageostrophic motion in this area is almost entirely reversed from the field that ultimately develops. Pseudo-geostrophic initialization has eliminated the unrealistic adjustment of the geostrophic case.

Focus of Current Research

The current emphasis of effort is on consolidation of the experimental model results involving the attributes of pseudo-geostrophic initialization of baroclinic jets and several studies of the effects of horizontal wind shear, static stability, and amplifying baroclinic circulations on ageostrophic motion associated with jet streaks. The influence of viscosity and horizontal resolution is also being analyzed.

Recommendations for New Research

Future work should investigate the strengths and weaknesses of:

1) Determination of atmospheric structure from conventional and satellite observations using a time-dependent isentropic assimilation model.
2) Tests of numerical mesoscale prediction comparing different methods of data assimilation.
3) Isentropic models for numerical weather prediction.

Publications Since June 1983

Black, T. L., 1984: An investigation of ageostrophic circulations of jet streaks using a hybrid isentropic-sigma coordinate numerical model. Ph.D. thesis, University of Wisconsin.

Johnson, D. R., 1984: The inducement of planetary boundary layer mass convergence associated with varying vorticity beneath tropospheric wind maximum. Proc. 2nd Int. Symp. on Nowcasting, Norrkoping, Sweden (to be available from Eur. Space Agency, Sci. and Tech. Publ. Branch).

Keyser, D. A. and D. R. Johnson, 1984: Effects of diabatic heating on the ageostrophic circulation of an upper tropospheric jet streak. Conditionally accepted for publication in *Mon. Wea. Rev.*

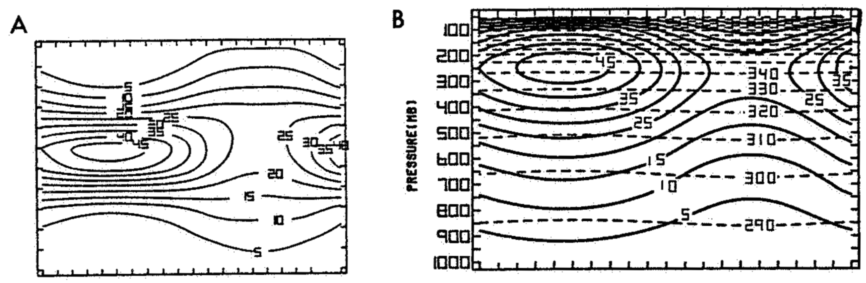

Figure 1. Initial pseudo-geostrophic wind field for zonal jet; solid lines are isotachs (m/s). (A) Horizontal cross section at 340 K; (B) vertical west-east cross section through center of domain; dashed lines are isentropes (K).

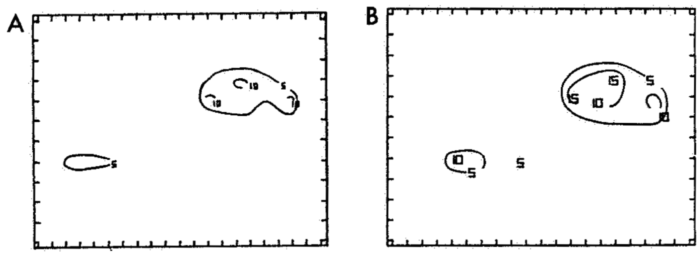

Figure 2. Total precipitation (10^{-1} mm) for run with zonal jet. Initial minimum absolute vorticity south of jet is (A) 4×10^{-5} s^{-1}, (B) 1.5×10^{-5} s^{-1}.

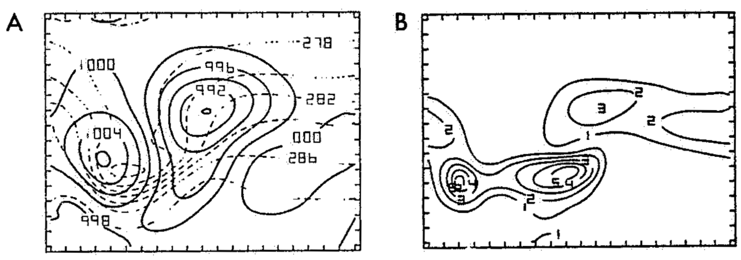

Figure 3. Surface conditions at 36 hours for run initialized with wave structure and circular pressure centers. (A) Solid lines are isobars (mb) and dashed lines are temperature (K), (B) total precipitation (mm).

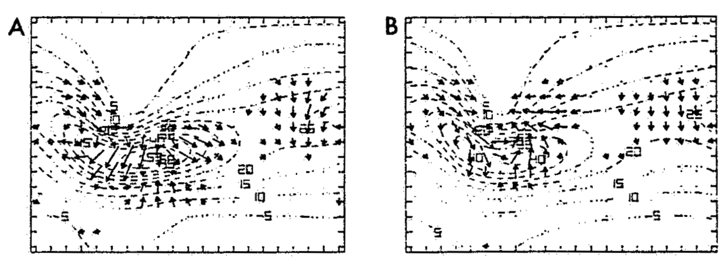

Figure 4. Vectors describing direction and relative magnitude of $\partial \underset{\sim}{U}/\partial t$ at 6 hours at 340 K. Dashed lines are isotachs (m/s). (A) Pseudo-geostrophic initialization, (B) geostrophic initialization.