The Application of Satellite Data to Study the Effects of Latent Heat Release on Cyclones

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Significant Accomplishments FY-84:

Our research has concentrated more and more on understanding mesoscale convective processes and how they affect and interact with mid-latitude cyclones.

The diagnostic study of the March 1978 storm using conventional and satellite-cloud data has progressed to the point where

i. the ageostrophic and associated vertical motion field have been calculated using a highly accurate iterative method of solving the semi-geostrophic omega equation. A M.S student had attempted to solve the equation in a transformed geostrophic coordinate, but the inevitable smoothing errors involved with the transformation lead to highly suspect and inaccurate solutions. The new method shows how important ageostrophic vorticity and thermal advection is in the dynamics of the system.

ii. the tendencies for convective destabilization in the 850-750 mb layer due to (a) differential geostrophic and ageostrophic advection and (b) differential moist adiabatic ascent, have been found. We are attempting to explain the observed presence of embedded convection in the area of large-scale warm frontal ascent.

Satellite and conventional data reveal the presence of organized rainbands in convectively stable regions where there is no background shear for the bands to feed upon. We have developed a wave-CISK model (Xu and Clark, 1984) which shows that such bands can develop because of the released latent heating provided a non-equilibrium cloud model is used where the clouds, after being triggered by low-level moisture convergence associated with a traveling internal gravity wave, actively grow and decay in a life-cycle controled by (a) the supply of buoyant potential energy in the boundary layer and (b) small scale eddy dissipative processes. The wavelength amplitude and phase speed of the resulting traveling disturbance agrees quite well with field observations.

Dr. Qin Xu, now a post-doc at The University of Oklahoma, completed a dissertation entitled "Conditional Symmertric Instability and Mesoscale Rainbands". It is a comprehensive study of conditional symmetric instability (CSI) in a sheared, conditionally unstable environment.

For a uniform basic flow in which the wind shear, dry and moist stratifications are constant, linear solutions are found for different CSI modes, e.g., isolated, periodic, and hybrid modes. Inviscid growth rates, spatial structures including the formulae for the width and slope angle of moist updraft, and stability critria are found and discussed. When a bulk viscosity is accounted for, the most rapidly growing CSI circulations bear a close resemblance to some observed rainbands. The stability criterion of viscous CSI also shows a better comparison with observational data than inviscid CSI.

When generalized energy considerations are made, some of the above results are extended to linear CSI with a nonuniform basic state in which the stratification and shear of the basic flow are functions of space. The

generalized energetics are also studied for nonlinear inviscid SI. The results indicate: (a) the linear theory fails to predict the stability in certain cases where the basic state is transitional between stability and instability; (b) the initial growth of the SI perturbations can be fairly well approximated by linear theory, but the long time nonlinear evolutions will be bounded energetically if the SI region is finite. However, a further extension of the energetics to CSI shows that the nonlinear evolution of CSI circulation will energetically depnd much more on the precipitation in a complicated way.

By treating the latent heat as a source which is implicitly related to the motion field, the existence, uniqueness and stability of steady viscous CSI circulations are studied. Viscous CSI circulations are proved to be unique and asymptotically stable when the heat souces are weak and less sensitive to the motion perturbations. By considering the fact that moist updrafts are narrow and using eddy viscosity of $O(10^3\ m^2/s)$, the stability criterion suggests that some frontal rainbands were probably dominated by the CSI mechanism even in their mature quasi-steady stage.

Focus of Current Research:

The diagnositc semi-geostrophic model is now being used to evaluate the tendencies to make

$$S \equiv \frac{f + \delta}{f} - \frac{1}{Ri}$$

negative and thus, anticipate regions of potential CSI in the March, 1978 storm. Ri is the Richardson number, δ vorticity, and f the Coriolis parameter.

Plans for FY-85:

Once we have developed criteria to predict areas of potential convective activity in mid-latitude synoptic systems, we plan to include a convective parameterization scheme (already developed) in our diagnostic model and re-evaluate the ageostrophic motions and tendency field for the March, 1978 storm with large-scale as well as convective latent heating accounted for. In that way we can make a reliable assessment of latent heating effects on the system.

Publications:

Accepted for Publication

Xu, Qin and J.H.E. Clark, 1984: Wave CISK and Mesoscale Convective Systems, J. Atmos. Sci.

Submitted

Xu, Qin, 1984: The Basic Nature of Symmetrc Instabilty and its Similarity to Convective and Inertial Instability, Quart. J. Roy. Meteor. Soc.

Xu, Qin, 1984: Conditional Symmetric Instability and Mesoscale Instability, J. Atmos. Sci.