Stable and Unstable Planetary Waves[1]

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Abstract

Originally, the author intended to attack the problem of dynamic effects of the Tibet Plateau on the general circulation of the atmosphere. As the work was progressing, it appeared that the concept of assimilation of space and time had to be introduced. The result was a more general conclusion about the extent of the existence of planetary waves, the coupling of high- and low-level disturbances, and the criteria of space and time baroclinic instability. The classical theory of the baroclinic instability was revised and generalized.

The concept of "space baroclinic instability" is introduced, which means that perturbation amplitudes can vary exponentially with latitudinal distance, as well as sinusoidally. Using this idea, one can distinguish three different cases: space stable, marginally space stable, and space unstable.

In the classical theory of baroclinic instability (e.g., Holton, 1972), the dispersion relation of a two-level model yields a complex phase speed

$$c = c_r + ic_i = c_2 \pm \delta^{1/2},$$

where c_2 depends on the vertically averaged zonal mean flow and the beta effect, and δ depends on the thermal wind component of the zonal mean flow and beta.

By considering all three cases, one arrives at the following conclusion: The criterion of time baroclinic instability is not $\delta < 0$, but $c_r = c_2$. The classical theory of baroclinic instability deals only with the marginally space stable case and gives plausible results.

The physical interpretation of the point of singularity at which c may become imaginary can be stated as follows: The frequency of the existing planetary wave is kc, while the characteristic frequency of the planetary wave in the existing baroclinic atmosphere is kc_2, the frequency of the marginally stable baroclinic Rossby wave. When $c = c_2$, a phenomenon resembling resonance occurs, and c becomes imaginary, $c = c_r + ic_i$, $c_r = c_2$, and c_i equals some value depending on the vertical stratification and on the configuration of the existing flow patterns. The results support the idea that the large-scale atmospheric motion should be considered as quasi- or semiturbulent (Xie, 1980).

The theory in its present form suggests that the effects of any highland, such as the Tibet Plateau, the Rocky Mountains, or any other forcing source, on the general circulation might be different for different vertical stratifications and flow patterns. Prof. Chen Shou-jen, head of the numerical modeling group, Department of Geophysics, Beijing University, is presently conducting numerical experiments to test this hypothesis. Preliminary results from his study are encouraging.

[1]This is an abbreviated version of a paper submitted to the *Journal of Meteorology,* Chinese Meteorological Society, on 23 April 1980.

[2]Prof. Xie Yibing studied at the University of Chicago after World War II and received a Ph.D. degree from that university. To his American colleagues and friends he is better known under the old spelling of his name: Yi-Ping Hsieh. He is Head of the Department of Geophysics and Astronomy of Beijing (Peking) University, Vice-President of the Chinese Meteorological Society, chief editor of *Acta Meteorologica Sinica,* and Vice-Chairman of the Working Group of Atmospheric Science in the Committee of Science and Technology (President of that committee is Vice-Premier Feng Yi). (Comments by E. R. Reiter.)

References

Holton, J. R., 1972: *An Introduction to Dynamic Meteorology.* Academic Press, New York and London, pp. 186–192.

Xie, Yibing (Yi-Ping Hsieh), 1980: The oscillation of certain zonal mean characteristics of atmospheric motion. *J. Meteorol.,* Chinese Meteorological Society, **38,** 111–121.

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New energy fact sheet

The Clearinghouse for Science, Mathematics, and Environmental Education of ERIC (Educational Resources Information Center) recently began publication of the *Energy Conservation/Education Fact Sheet* series, which will focus on topics of interest and utility to people involved in energy education. The first issue of the *Fact Sheet* deals with films useful for energy education and the second issue targets energy conservation tips for the home. To be added to the mailing list write: SMEAC Information Reference Center, Ohio State University, 1200 Chambers Rd., Room 310, Columbus, Ohio 43212.

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