Available online at www.sciencedirect.com
ScienceDirect
Journal of Hydrodynamics
2011,23(2):193-203
DOI: 10.1016/S1001-6058(10)60104-7
www.sciencedirect.com/science/journal/10016058

EFFECT OF INSTABILITIES OF FLOW ON MESOSCALE PREDICTABILITY OF WEATHER SYSTEMS*

LUO Yu, ZHANG Li-feng
Institute of Meteorology, PLA University of Science and Technology, Nanjing 211101,
E-mail: luoyu2489@163.com

(Received August 3, 2010, Revised November 2, 2010)

Abstract: The numerical solution of Boussinesq equations is worked out as an initial-value problem to study the effect of the instabilities of flow on the initial error growth and mesoscale predictability. The development of weather systems depends on different dynamic instability mechanisms according to the spatial scales of the system and the development of mesoscale systems is determined by symmetric instability. Since symmetric instability dominates among the three types of dynamic instability, it makes the prediction of the associated mesoscale systems more sensitive to initial uncertainties. This indicates that the stronger instability leads to faster initial error growth and thus limits the mesoscale predictability. Besides dynamic instability, the impact of thermodynamic instability is also explored. The evolvement of convective instability manifests as dramatic variation in small spatial scale and short temporal scale, and furthermore, it exhibits the upscale growth. Since these features determine the initial error growth, the mesoscale systems arising from convective instability are less predictable and the upscale error growth limits the predictability of larger scales. The latent heating is responsible for changing the stability of flow and subsequently influencing the error growth and the predictability.

Key words: instabilities of flow, mesoscale system, predictability, initial errors

Introduction

Since the development of weather systems mostly depends on the stability of atmospheric flows, it has been noted that the disastrous events like heavy rainfall and flood usually occur under the condition of unstable flow. Therefore, it is widely accepted that the study on instability of the flow is an important aspect in atmospheric dynamics. The investigation of instability aims at achieving further understanding on the genesis mechanism of mesoscale system and subsequently describing correctly this mechanism in sophisticated numerical model for fine prediction.

The development mechanisms of mesoscale systems are associated with both dynamic and thermodynamic instability. Three types of mesoscale dynamic instability based on previous works can be concluded as follows[1]. The first type is symmetric instability and it is characterized by the propagation of disturbance orthogonal to the basic flow. Some investigations indicated that symmetric instability could explain the formation of rainband along fronts and it plays an important role in organizing the mesoscale convections. The second type, defined as transverse instability, is characterized by the propagation of disturbance parallel to the basic flow. Different from the synoptic-scale instability, it is proved to be the mesoscale ageostrophic instability. The third type of instability actually depicts a generalized state in which a certain angle exists between the basic flow and the propagation of disturbance. It can be defined as heterotropic instability and it grows significantly in meso-α spectral band while the symmetric- and transverse-disturbances remain stable in this spectrum. Such instability is subsequently proved to be the instability of ageostrophic vortex wave[2].

The above dynamic instabilities are constrained under the stable stratification. However, the effect of unstable stratification is also thought to be crucial and

---

* Project supported by the National Natural Science Foundation of China (Grant No. 40975031), the National Science Foundation for Young Scientists of China (Grant No. 41005030).

Biography: LUO Yu (1984-), Male, Ph. D.