Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

MIS021-09 Room:202 Time:May 22 11:15-11:30

Numerical experiments of large-scale vortices in Jupiter's atmosphere: The generation mechanism of large-scale vortices

Ryohei Kato[1*], Ko-ichiro SUGIYAMA[2], Kensuke Nakajima[3]

[1]Graduate School of Sciences, Kyushu Univ, [2]Inst. of Low Temp. Sci., Hokkaido Univ., [3]Faculty of Sciences, Kyushu Univ

1. Introduction

The Great Red Spot is a large-scale vortex in Jupiter's atmosphere larger than 20000 km in diameter and exists for more than a century. Williams(1996; here after W96) reproduced large-scale vortices resembling the Great Red Spot in size by using a three-dimensional numerical model. However, the strength of the jets (zonal mean zonal velocity) and vortices became weaker after long-time integration. If the strength of the jets is maintained, behavior of vortices is expected to change. Therefore, we try to maintain the strength of the jets by introducing forcings that maintain zonal mean state and examine how the behavior of vortices depends on the intensity of the forcings.

2. Model and Setup

We perform numerical experiments by using a three dimensional model on a sphere based on the primitive equation of the Boussinesq fluid with parameters in Jupiter's atmosphere. Experimental setup is almost the same as the case A4 of W96, in which stable "weather layer" and alternating jets are confined to the upper region of the vertical domain. However, in this study, we introduce forcings that maintain zonal mean state so as to maintain the jets. We conduct 19 experiments with four types of forcings: (1) no forcing, (2) momentum forcing that damps zonal mean zonal winds to the initial zonal wind, (3) thermal forcing that damps zonal mean temperature to the initial temperature, (4) both (2) and (3) with the same damping time. Six values of damping time, 30, 100, 300, 1000, 2000, and 4000 days, are used for both the thermal and momentum forcing terms. Each numerical experiment is continued for 10000 - 70000 days.

3. Results

Only in the four cases of both thermal and momentum forcings with damping time 100, 300, 1000, 2000 days, zonal mean fields and wave fields reach statistically steady states. In these cases, behavior of disturbances depends on the strength of the damping and can be classified into two groups.

In the cases of the strong forcings (damping time are 100 and 300 days), many large-scale vortices are generated continuously at 500 -1000 days intervals but their lifetime are short (500 -1000 days) (size is about 90000 km in longitude and 10000 km in latitude). The large-scale vortices exist across the latitude Phi_0 where the meridional gradient of zonal mean potential vorticity change sign horizontally. The disturbances with the scale of the large-scale vortices have an ability to transport westerly momentum latitudinally. As for the energy conversion property from zonal mean to wave field, barotropic conversion is positive for the disturbances.

In the cases of weak forcings (damping time are 1000 and 2000 days) , no large-scale vortices appear and waves exist on the north and south of Phi_0 with different scale. On the north (south) of Phi_0, small (large) scale wave exists and baroclinic (barotropic) conversion is positive.

We conduct a linear stability analysis for the time and zonal mean fields in the cases with strong and weak forcing. In the analysis, linear instability modes are found, whose zonal wave lengths, phase structures, and energy conversion properties are similar to those of the disturbances in nonlinear calculation shown above. For this reason, it is suggested that the disturbances in nonlinear calculation are generated by linear instabilities of the basic states. In addition, it is also suggested that the generation mechanism of the large-scale vortices in the case of strong forcing is not upward-cascade by small scale vortices but barotropic instability.

Keywords: Jupiter's Atmosphere, large-scale vorticies, The Great Red Spot, numerical experiment, barotropic instability, linear stability analisis