Numerical modelling of Jovian atmospheric largescale vortices.

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1. Introduction

In Jupiter's atmosphere, there are many large scale vortices, such as the Great Red Spot and White Ovals. Williams(1996) numerically examined the genesis and stability of large scale vortices like the Great Red Spot using a three dimensional model based on the primitive equation of the Boussinesq fluid. In many of his experiments, the emergence of small scale waves due to the instability of an unstable easterly jet and gradual development into a coherent vortex resembling the Great Red Spot were reproduced. However, wind speed and temperature anomaly of the large scale vortex became weaker after a long time integration. The decay of the vortex might be caused by the variations of the zonal mean field from that of the initial condition. Therefore, we introduce forcing to maintain zonal mean fields, and examine possible sensitivities of the behavior of simulated vortices in the statistically steady state to the type and the intensity of the forcing.

2. Model and Setup

We develop a three dimensional model based on the primitive equation model of the Boussinesq fluid. The computational domain covers 180 degrees in longitude with periodic boundary condition, from equator to -40 degrees in latitude, and 10000km vertically. Governing equations are discretized employing the grid point method. The number of grid points are 100, 40, and 20 in the longitude, latitude, and height directions, respectively. The vertical grid spacing varies exponentially so as to enhance the resolution in the upper active layer. The model atmosphere consists of a stably stratified 'weather' layer with 500km thickness and a deep neutral layer with 9500km thickness.

We assume that the initial alternating jets are confined to the weather layer. We assume that the jets are weak at the upper boundary and become stronger downward near the surface; the the jets are set to have the hyperbolicsecant profile with the maxima at z=-100km, being zero at z=0 and -500km. The latitudinal structure of the temperature field is determined by assuming the thermal wind balance.

These setups described so far follow those of the case A4 of Williams(1996). However, in this study, we introduce forcing to maintain the zonal mean field. We conduct four types of experiments as to the types of forcing: 1.no forcing, 2.momentum forcing to damp the zonal mean winds to the initial the zonal winds, 3.thermal forcing to damp the zonal mean temperature to the initial temperature. Four values of damping time, which are 30,100,300, and 1000days, are used. Each numerical experiment is continued for 6000 days.

3. Results

We find that the behavior of simulated vortices depend on the type and the damping time of forcing. In every case with forcing terms with 1000days damping time, a large scale vortex coherence and longevity are maintained. On the other hand, in all cases with forcing terms with short damping time, coherent vortices are not maintained. Depending on the types of forcing employed, two types of behavior of vortices are simulated: 1. numerous large scale vortices are developed but these longevity is short(in cases of the momentum forcing with 30-300 days damping time, except the case of momentum forcing alone with 300 days damping time), 2. These vortices can't develop into a large scale coherent vortex after a long time integration.

As regards to zonal mean fields, in case of both(momentum and thermal) forcing with short damping time, the structure of jets and temperature field are well maintained. However, in cases of momentum forcing alone with short damping time, the structure of temperature field change significantly. On the other hand, in cases of thermal forcing alone with short damping time, the structure of jets change significantly, esspecially barotropic component of jets are generated. These differences of zonal mean field in a steady state might cause the observed variety in the behavior of vortices.