Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

MIS22-01 Room:203 Time:May 23 09:00-09:15

Stability and the temporal variation of zonal flows under the influence of turbulence on a beta plane

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It has been well known that, in forced two-dimensional barotropic incompressible flows on a rotating sphere, a structure with many alternating eastward and westward jets emerges in the course of time development (Nozawa and Yoden [1]). The multiple zonal jets then experience gradual mergers/disappearances, and structure with two or three alternating large zonal jets is realised asymptotically (Huang *et al.* [2], Obuse *et al.* [3]).

One of the possible interpretations of such mergers/disappearances of zonal jets is that the state with multiple zonal jets may be dynamically unstable, and transitions to a stable state with wider and fewer zonal jets occur. It is accordingly tempted to examine the stability of zonal jets driven and maintained by a small-scale forcing and background small-scale turbulent motions. However, it is difficult to investigate the properties of zonal flows induced by a small-scale stochastic forcing, because it is hard to construct an analytically tractable and reasonable physical configuration.

Zonal jets having a deterministic transverse sinusoidal background flow on a beta plane is one of the models used to investigate the effect of the turbulence to zonal jets and the mechanism of mergers/disappearances of the jets described above. This one-dimensional model was originally introduced and numerically investigated by Manfroi and Young [4] and is known to show a structure with many zonal jets that slowly disappear one by one. Later, Obuse *et al.* [5] have derived steady isolated zonal jet solutions of the model and studied its linear stability, clarifying that all the steady isolated zonal jet solutions are linearly unstable because of the effect of the nonzonal background flow, and deform to be a uniform flow in the end.

The Manfroi-Young model [4] above, however, only considers the situation that the zonal flow is governed by one-dimensional equation, whilst the real zonal jets observed in two-dimensional turbulence has its two-dimensional governing equation. Therefore in our study, we first modify the Manfroi-Young model [4] by taking account of spatial variation of the disturbance in the zonal direction. Then to make the model a little more realistic, we also add the surface variation of the fluid layer to the model by introducing the Rossby deformation radius .

References:
[1] T. Nozawa and S. Yoden, Physics of Fluids, **9**, pp.2081-2093, 1997.
[2] H-P. Huang, B. Galoerin, and S. Sukoriansky, Physics of Fluids, **13**, pp.225-240, 2001.
[3]K. Obuse, S. Takehiro, and M. Yamada, Physics of Fluids, **22**, 156601, 2010.
[4] A. J. Manfroi and W. R. Young, Journal of the Atmospheric Sciences, **56**, pp.784-800, 1999.
[5] K. Obuse, S. Takehiro, and M. Yamada, Physica D, **240**, pp.1825-1834, 2011.

Keywords: rotating fluid, two-dimensional flow, turbulent flow, zonal jets, beta effect

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MIS22-02 Room:203 Time:May 23 09:15-09:30

Triaxial rotation of the inner and outer spheres driven by Boussinesq thermal convection in a rotating spherical shell

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The problem of Boussinesq thermal convection in a rotating spherical shell has been investigated in reference to the global thermal convection in astronomical bodies. While there are some MHD dynamo models allowing the inner sphere rotation, studies of thermal convection performed so far have assumed that both inner and outer spheres rotate with the same constant angular velocity (co-rotation). However, the spheres do not necessary co-rotate in the actual astronomical bodies, and it is a more natural situation that both the spheres rotate freely. Actually, recent seismological researches suggest that the inner core of the Earth rotates differentially against the mantle. In the present study, therefore, we construct a Boussinesq thermal convection model allowing triaxial rotation of both spheres due to the viscous torques of fluid. We compare the convection flow with those of the co-rotating system[1], and discuss characteristics of rotation of both spheres.

First, we consider the case where the inner sphere rotates due to the torque while the angular velocity of the outer sphere is fixed. We seek for the finite-amplitude solutions which bifurcate supercritically at the critical point with the Newton method. The ratio of the radii of the inner and outer spheres and the Prandtl number are fixed to 0.4 and 1, respectively, while the Taylor number is varied from 52^2 to 500^2. No-slip and fixed temperature boundary conditions are given on both spheres. The obtained solutions propagate in the azimuthal direction and have four-fold symmetry around the rotation axis. When the Taylor number is less than 100^2, the inner sphere rotates in the prograde direction with respect to the outer sphere. However, when the Taylor number is between 200^2 and 300^2, both spheres rotate with about same angular velocity, and when the Taylor number is larger than 400^2, the inner sphere rotates in the retrograde direction. The stable region of TW4s differs from that of the co-rotating system at most by one percent, and the pattern of TW4s is qualitatively the same.

Secondly, numerical time integrations are performed in the case where both spheres freely rotate due to the viscous torque of the fluid. The radius ratio, the Prandtl number and the Taylor number are set to be 0.4, 1 and 500^2, respectively, with the Rayleigh number being 30,000 (= 4.7 R_c) and 50,000 (= 7.8 R_c) where R_c is the critical Rayleigh number. No-slip and fixed temperature boundary conditions are applied on both spheres. The inertial moment of the inner sphere is set to be 0.22, assuming that the density of the inner sphere is the same as that of fluid, while the inertial moment of the outer sphere is assumed to be 100, which is similar to the value of the mantle of the Earth. When the Rayleigh number is 30,000, the convection pattern has the equatorial symmetry and only the axial components of the angular velocity of the inner and outer spheres have significant values, although the behavior of convection pattern appears to be chaotic. When the Rayleigh number is 50,000, however, the equatorially asymmetric convection pattern emerges and all the three components of the angular velocity of both the spheres have significant values.

Finally, we examine the transition Rayleigh number where the equatorially asymmetric convection patterns emerge in the range of the Taylor number between 500^2 and 5000^2. We find that the equatorially asymmetric convection patterns appear when the Rayleigh number is larger than $5R_c$ - $6R_c$.

[1] K.Kimura, S.Takehiro and M.Yamada, Phys. Fluids, Vol.23, 074101 (2011)

Keywords: bifurcation, traveling wave, torque, differential rotation

Japan Geoscience Union Meeting 2012
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MIS22-03 Room:203 Time:May 23 09:30-09:45

Numerical investigations of effects of spatial variations in physical properties on the mantle convection patterns

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A series of numerical simulations is carried out on the onset of thermal convection of Boussinesq fluid of an infinite Prandtl number in a planar layer in the presence of spatial variation of physical properties such as viscosity, thermal conductivity and expansivity. The viscosity of the fluid is exponentially dependent on temperature, while thermal conductivity and expansivity are linearly dependent on pressure (or depth). Based on the linear stability analysis, velocity and temperature distributions are solved for infinitesimal perturbations for given horizontal wave number. We seek for the condition for the onset of convection by changing the horizontal wave number of perturbation as well as the amplitudes of spatial variations in physical properties (viscosity, thermal conductivity and thermal expansivity). Then, we examine influences on both the critical conditions and the dominant flow patterns of spatial variations in those physical properties. From the changes in flow patterns with increasing the amplitudes of temperature dependence of viscosity, we successfully identified the transition into the ”stagnant lid” (ST) regime, where the convection occurs only beneath a thick and stagnant lid of cold fluid at the top surface. We also found that the transition takes place regardless of the spatial variations in thermal conductivity and/or expansivity.

However, detailed analysis of the numerical results showed a quantitative difference in the critical condition for the onset of ST convection due to the presence of spatial variations in thermal conductivity and expansivity. First, the horizontal wave number of perturbation is decreased by the introduction of spatial variations in these properties. In particular, the variation in thermal conductivity can significantly reduce the wave number: the horizontal length scale of convection can be enlarged by up to 50% when viscosity is strongly dependent on temperature. Another difference can be found in threshold values of temperature dependence of viscosity for the transition into the ST regime: the spatial variations in thermal conductivity slightly decrease the threshold viscosity contrast, while those in thermal expansivity increase them. These two differences can be successfully reproduced by our analytical estimates, which consider the thickness of stagnant lid and convective vigor beneath it.

The results of present studies indicate that, under certain conditions, the convection of fluids with strongly temperature-dependent viscosity takes place which is characterized simultaneously by (i) large horizontal length scales of convective cells and (ii) thick stiff lid of highly viscous fluid above it. This is in a stark contrast with earlier numerical studies using constant thermal conductivity and expansivity where the convection beneath stagnant lids is always associated with cells with small horizontal length scales. Our findings therefore highlight the essential roles of the spatial variation of the thermal conductivity and thermal expansivity on the convection patterns in the mantle of terrestrial planets.

Keywords: mantle convection, linear stability analysis, temperature-dependent viscosity, pressure-dependent thermal conductivity, pressure-dependent thermal expansivity, stagnant-lid convection

Japan Geoscience Union Meeting 2012
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MIS22-04 Room:203 Time:May 23 09:45-10:00

Diurnal variation of a wind system by sea breeze invasions from different scale and influence by geographical feature on

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On the Nikawa plain located in northeastern Toyama , it is begun to blow a sea breeze from the northwest. This has invaded from a sea direction. However, in the afternoon, the wind direction is changing to northeast. At Uozu, the sea breeze blow in parallel with the coastline. This research clarifies diurnal variation of a wind system and influence of the geographical feature to the sea breeze which invades in parallel with the coastline.

The northwest wind serves as a wind direction which intersects perpendicularly with the coastline, and local circulation of the Nikawa plain scale has influenced. Circulation of the Toyama plain and the Hida high-ground scale has influenced the northeasterly wind. A northeast sea breeze pass to the coastline, a contour line, and parallel. A northeast sea breeze has a tendency near the seashore where an altitude is low in big influence.

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MIS22-05 Room:203 Time:May 23 10:00-10:15

Numerical analysis of the development process of meso-scale vortical disturbances causing a severe snowstorm

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Meso-beta-scale vortical disturbances (hereafter MBSDs) which are formed and develop over the Japan Sea in winter often cause a severe snowstorm in the coastal region of the Hokuriku District. A snowstorm caused by the passage of developed MBSDs brought about several power failures and traffic accidents in the Niigata prefecture on 13th January 2010. Previous studies revealed that the MBSD causing a severe snowstorm had a warm core structure, and suggested that the CISK and the WISHE instability mechanism were important in the development process of the MBSD (Araki et al., 2011, JpGU Meeting MIS021-02). In this study, in order to more quantitatively examine the development process of the MBSD and to investigate the effect of the lower boundary condition, we performed numerical simulations using the JMA-nonhydrostatic model (JMA-NHM) with a horizontal resolution of 2km (2km-NHM). The 2km-NHM well reproduced MBSDs that had features both spatially and temporally similar to those of the observed MBSDs.

Firstly, results of sensitivity experiments without the condensational heating showed that the condensational heating directly contributed to the development process of the MBSD. In addition, results of sensitivity experiments without heat fluxes from the sea surface suggested that heat fluxes eventually had an effect to modify the environment of the vortex. In fact, in any experiment without the sensible heat flux, the environmental surface potential temperature was lower than that with the sensible heat flux and the lower atmosphere was stably stratified. In other words, heat fluxes are considered to indirectly contribute to the development of the MBSD with maintaining the unstable stratification of the environment. These are consistent with the results of Yanase et al. (2004) dealing with the Polar Low over the Japan Sea.

Secondly, sensitivity experiments which changed the sea surface temperature (SST) of the Japan Sea were performed. Results of experiments with SST constant in time showed that heat fluxes from the sea surface was more enhanced in experiments with the higher SST resulting in MBSDs with deeper convection. Experiments with a north-south gradient in SST showed that the north-south distribution of SST affected the development of MBSD through the baroclinicity. In addition, MBSDs simulated in these experiments moved more southward than the others. This suggests that an anticyclone vortex formed by relatively cold air advection at the rear of the MBSD in these experiments with a north-south gradient in SST, which forms a vortex pair (Ito and Iga, 2011, JpGU Meeting MIS021-01), causes the southward displacement of the MBSD. As a result of experiments changing the SST in the region containing the MBSD only for three hours from the start of calculation, it was suggested that the distribution of the SST in the area where MBSD located in the early stages of evolution, was important to the development of MBSD causing the severe snowstorm.

Keywords: Vortical Disturbances, NHM, severe snowstorm

Japan Geoscience Union Meeting 2012
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MIS22-06 Room:203 Time:May 23 10:15-10:30

Irregular motions of a typhoon near steep mountainous lands

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It has been known that typhoons move irregularly on around steep mountainous islands such as Luzon, Taiwan, Kyushu, Shikoku and Honshu, in particular inside Pacific subtropical high where background flows are weak. Even over oceans, when two typhoons exist, they may move cyclonically and often irregularly by Fujiwara effect (Fujiwara, 1921). An isolated typhoon may take trochoidal (cycloidal) motions as a secondary effect of vortex motions (e.g. Syono, 1955; Muramatsu, 1986), and they are related to their losing axi-symmetric structures (e.g. Abe, 1987; Itano and Ishikawa, 2010).

Typhoon Ma-on (T2011) took an irregular motion near the southern coast of Shikoku and Honshu. It changed suddenly from northward to southward at the southeast edge of Shikoku on July 19, 2011. We analyzed a local trough on Shikoku, which seems similar to a local orographic low found by Higashi et al. (2010) near the Baiu-frontal medium-scale cyclone. We examined meandering typhoon motion, background wind change, and typhoon transformation. The last one includes Fujiwara effect between the typhoon and a local low.

Keywords: typhoon, irregular motion, orographic low

Japan Geoscience Union Meeting 2012
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MIS22-07 Room:203 Time:May 23 10:45-11:00

Numerical simulations of atmospheric pressure perturbations and ionospheric oscillations following the Tohoku earthquake

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Following the M9.0 Tohoku earthquake on March 11, 2011, oscillations of total electric content (TEC) was observed in the ionosphere. The oscillations had dominant periods of about 4 min in the vicinity of the epicenter [Saito et al., 2011] and tens of minutes in the distance from the epicenter [Tsugawa et al., 2011]. The maximum amplitudes of these oscillations were almost the same. Atmospheric pressure perturbations caused by Lamb waves were also observed at the ground level [Arai et al., 2011]. The source of the ionospheric TEC and the atmospheric pressure variations were assumed to be the oceanic surface displacement. The aim of this study is to simulate these variations numerically and to estimate the temporal and spatial scales of the oceanic surface displacement.

A three-dimensional non-hydrostatic atmosphere and ionosphere model is used for simulations. The source has a certain area and the center lies on the epicenter. The vertical wind velocity in the form of a damped oscillation is input in the source region. Simulations are performed for some source areas and periods. They show that Lamb waves with half wavelengths close to the source widths and ones with periods close to the source periods are excited near the ground level. The observed atmospheric pressure perturbations are well reproduced for the source with the period of 200 sec, and the width of 150 km along the trench and 100 km across the trench. In the ionosphere, the ratio of the amplitude of 4-min TEC oscillation to that of tens of minutes varies with the source area and period. The amplitude of the 4-min oscillation is larger by two orders for the above setting. It is necessary for the reproduction of the amplitude ratio to add propagating sources such as tsunamis.

Keywords: earthquake, TEC, acoustic wave, gravity wave, Lamb wave, tsunami

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MIS22-08 Room:203 Time:May 23 11:00-11:15

Modeling of Atmospheric and Ionospheric Perturbations Excited by Large Earthquakes

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Evidence of the 2008 Iwate-Miyagi Nairiku Earthquake, of which moment magnitude is 6.9 and focal depth is only 6km or less, was recorded in non-seismic observations such as atmospheric and electromagnetic observations. A CTBT infrasound monitoring station at Isumi, Japan at an epicentral distance of 417km recorded air pressure variations excited by this earthquake. Clear two large wave packets having amplitudes of several pascals appeared in 1 minute and 20 minutes after the origin time. The earlier arriving packet was the Rayleigh wave coming together with the ground motion whereas the later one was the acoustic waves that had propagated in the atmosphere directly from the rupture zone.

A normal mode summation technique synthesizes this observational evidence based on a given realistic source mechanism in a one-dimensional joint model that consists of the solid Earth and the atmosphere extending from the center of the Earth to the altitude of 1000 km. The simulation model parameters, e.g., the rupture velocity and the moment magnitude of each subevent hypothetically placed along the fault, are determined through the framework of data assimilation, which is capable to provide not only an optimum value but also a probability distribution function for each model parameter. The obtained synthetic waveforms successfully account for the observed ones in the period range $>$30 seconds assuming a focal depth of 3-4km, which is shallower than in the previously proposed models. Since the amplitude of such seismoacoustic wave is more sensitive to the focal depth than seismic wave, a joint analysis with seismograms could give strong constraints on seismic mechanisms especially in the cases of shallow earthquakes.

On the other hand, an electromagnetic observation using the HF-Doppler radar, which monitors ionospheric activities at the same epicentral distance with the Isumi observatory, recorded the Rayleigh wave traveling in the ionosphere at an altitude of 250km. Our procedure also successfully reproduces this waveform with the optimum model parameters determined by the inversion of the infrasound phenomenon mentioned above, although the assumed reflecting altitude is slightly lower than the observation.

Keywords: infrasound, CTBT, Iwate-Miyagi Nairiku Earthquake, Great Japan East Earthquake, normal mode, data assimilation

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MIS22-09 Room:203 Time:May 23 11:15-11:30

Transient property of the atmospheric radiation and effective radiation distance

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The transient property of the atmospheric radiation is discussed. For a given disturbance in the atmospheric temperature, the relaxation time of disturbances is obtained. The results shows that there is a optimal scale for a given absorption rate and the radiation is less effective for other scales.

This indicates that the thermal radiation in the band longer than the atmospheric window is very effective for the thermal balance in the atmospheric boundary layer.

Keywords: Atmospheric boundary layer, Atmospheric radiation

Japan Geoscience Union Meeting 2012
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MIS22-10 Room:203 Time:May 23 11:30-11:45

The atmosphere is cooled from the top, indeed

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In general, the atmosphere near the ground is considered to be cooled by the ground surface, and therefore, it is stratified from the bottom of the atmosphere. However, according to the air temperature that we observed, stratification starts from the top of the boundary layer contrary to the general assumption. This indicates that the atmosphere in the ABL is mainly cooled by radiation. To confirm this nocturnal cooling process in the atmospheric boundary layer (ABL), we performed computations using a one-dimensional radiation model. The infrared cooling rate is computed as 2 K/day by Rowe and Liou (1978).However, the cooling process in the ABL is different from that described in previous studies. This is considered to be because in previous studies, radiative equilibrium in the atmosphere is studied. On the other hand, our study focuses on the ABL and daily variation. Therefore, we verified the data via calculations concerning the gray atmosphere in the ABL, which has transient properties. The results of the computations show that the atmosphere starts cooling from the top of the ABL.

Keywords: the atmospheric boundary layer, radiation, stratification