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

Japan Geoscience Union Meeting 2012
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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 $5R_c$ - $6R_c$.

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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

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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

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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

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MIS22-P01 Room:Convention Hall Time:May 23 13:45-15:15

Rainfall interception under a fractal sunshade

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Rainfall interception is a process that redistributes gross rainwater falling onto a canopy of vegetation. It is said that the amount of evaporation by rainfall interception occupy about 10 % to 50 % of annual precipitation, and the evaporation gives a significant impact on air transportation of latent heat. It is necessary to keep observing the amount of rain under trees because how to transport a water vapor and a latent heat to an atmosphere by rainfall interception is unclear yet. However, it is difficult to evaluate the amount of rainfall that evaporate, drips, and runs down through the canopy, because the distribution of trees, leaves, and stems is not spatially uniform. Therefore I observed how much rainfall interception really occurs under an artificial environment to compare the amount of rainfall under a fractal sunshade with unimpeded, regarding a fractal sunshade whose leaf area index is 1 as a simplified canopy. As a result, the interception rate under a fractal sunshade during all raining periods of the observational date is approximately 1% to 9%. It is proved that whenever it rains, a rainfall is intercepted by a fractal sunshade and some intercepted rain evaporate over or through the fractal sunshade, because the rain is always intercepted and the amount of a total rainfall is more than under that of a fractal sunshade, or the interception rate is always over 0%.

Last year, I presented that a bulk formulation is often used for a calculation of sensible heat, and suggested that a bulk exchange coefficient of sensible heat expresses not a turbulent diffusion but a rate of heat transport by heat conduction. Actually, a calculation of latent heat uses also a bulk formulation. To determine the amount of latent heat transportation from this study is also related a bulk exchange coefficient.

Keywords: rainfall interception, latent heat, bulk formulation

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MIS22-P02 Room:Convention Hall Time:May 23 13:45-15:15

Estimation of horizontal eddy diffusion coefficients in convective mixed layers

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Numerical models for geophysical fluids require parameterization of sub-grid scale turbulence. This study estimates the horizontal turbulent diffusion coefficient to prescribe the flux of the sub-grid scale horizontal turbulence in the daytime atmospheric convective mixed layer.

In contrast to the recent advances in parameterizations of vertical turbulent fluxes that have been validated by both observations and Large Eddy Simulation (LES) (e.g. Nakanishi and Niino 2009), those of horizontal turbulent fluxes are studied little; even physical mechanism of them is poorly understood. Horizontal fluxes in numerical models have often been tailored for damping unphysical oscillations in high frequency. However, we need a precise model that is based on a deep understanding of horizontal turbulence fluxes for the state-of-art high-resolution numerical models.

In this study, we carried out LES (Nakanishi 2000; Ito et al. 2010) with the grid size of 50 m for all (x-, y-, z-) directions; the size of domain is 36 km for the horizontal directions whereas 5 km for the vertical direction; the lateral boundaries are doubly periodic; no wind with a uniform stable stratification (4.0 K/km) is imposed; sensible heat flux Q of 0.2 K m/s is introduced from the bottom surface horizontally uniformly. The convective mixed layer gradually develops from the bottom in the LES.

To estimate the horizontal turbulent diffusion coefficient K_h of a passive scalar c, a uniform slope of the passive scalar is imposed at a time step t=0, and a prognostic equation of deviation c' from the initially assumed c is integrated in the LES. A horizontal average of the horizontal turbulent flux in LES divided by the slope of the initial c gives K_h at each height.

The passive scalar is stared at time when convective mixed layers are well developed (i.e. several hours after the initiation at least). Soon after the introduction, estimated K_h increases in proportional to t due to autocorrelation of the turbulent velocity. During a turnover time of an eddy, it gradually approaches to a constant K_h, which shows the eddy diffusion by the convective motion comes to realize. K_h turns out to be of the order of 100 m^2/s when it reaches a quasi-steady state and apparently has a different trend when compared with the vertical turbulent diffusion coefficient: K_h has local maxima at the lowest layer and top of the convective mixed layer.

K_h increases in accordance with the development of the convective mixed layer, and it appears to be scaled by the product of the height of the convective mixed layer and the convective velocity $w*$. Nevertheless a bit deviation from this scaling is found. The deviation is believed to arise from insufficiency of the resolution of our numerical model: it is found that resolution of LES is enough for reproducing the horizontal convective motions is much higher than that for vertical motions. We will certify the above scaling for K_h by means of a finer resolution LES whose grid spacing is 25 m.

Keywords: turbulence diffusion coefficient, eddy diffusivity, horizontal sub-grid flux, convective mixed layer

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MIS22-P03 Room:Convention Hall Time:May 23 13:45-15:15

Propagation characteristics for vortex Rossby waves in the inner core region of an idealized tropical cyclone

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Tropical cyclone (TC) is a cyclonic vortex system having strong wind and heavy rain. In the mature stage, TC almost maintains in a quasi-steady state as an axisymmetric structure. To estimate the maximum intensity (i.e. maximum wind speed), the theoretical models have been developed in the assumption of two-dimensional axisymmetric structure for TC, which a TC tangentially has uniform structure. However, observations indicate that TCs have non-axisymmetric structures, such as polygonal eyewall and rainband, in the mature stage. Wang (2002) reported that a non-axisymmetric component contributes the TC's maximum intensity in the inner core in which TC has maximum wind speed in a three-dimensional model. A vortex Rossby wave is generated in the field with radial gradient of relative vorticity around the center in a large scale vortex, such as a TC. Wang (2002) showed that, in the inner core, non-axisymmetric component influence the TC's maximum intensity caused by redistribution of potential vorticity (PV) through the transport of PV by a vortex Rossby wave.

In this study, an identical experiment of a TC is performed utilizing with a three-dimensional non-hydrostatic model (CReSS) to quantitatively estimate radial and tangential propagating speed of non-axisymmetric component in the inner core region in a quasi-steady state. The estimated speed of the propagation in the model is compared with the theoretical speed of the propagation in the shallow water system.

This result indicates that non-axisymmetries of low wave number have rapid propagating speed, and the speed is close to the theoretical speed. We consider that the theoretical model for vortex Rossby wave in a shallow water system is helpful to understand the behavior of the waves in the three-dimensional core a TC in a stratified atmosphere.

Keywords: tropical cyclone, vortex, wave, non-axisymmetry

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MIS22-P04 Room:Convention Hall Time:May 23 13:45-15:15

Numerical simulation of tropical disturbances by using GCM-Cloud resolving coupled model

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In general, hydrostatic approximation is suitable for global atmosphere, however, vertical flow is not negligible in the regions occurring active convections such as Typhoons. We developed a new numerical model which coupled the general circulation model "AFES" (Shingu et al., 2001, 2002) and the regional cloud resolving model "CReSS" (Tsuboki and Sakakibara, 2009) for performing global atmospheric numerical simulations which have locally high resolution.

In this study, we simulated the Typhoon No.13 in 2006 by using the coupled model for investigating the effects of the active convections in tropical zone on the temperate zone. The resolutions of AFES is T213L48(T213: about 60km in horizontal on equator, L48: 48 layers in vertical) and CReSS is 1km in horizontal. The domain of CReSS is from 120 degree to 140 degree of east longitude, and from 20 degree to 30 degree of north latitude. Initial time is 00UTC on September 12, 2006, and initial data is Global Reanalysis data (GANAL) provided by Japan Meteorological Agency (JMA). We used mgdSST, which also provided by the JMA, for sea surface temperature, and GTOPO30 (http://edcwww.cr.usgs.gov/landdaac/gtopo30/gtopo30.html) for terrain data in both models.

In the simulation results, there is substantial improvement in forecast accuracy by using the coupled model. For example, the center pressure value of T0613 became lower than the result which provided by AFES simulation. After 09UTC on September 16, 2006, improvements of distributions of rain fall amounts appeared not only the region covered with CReSS but also the outside region which calculated by AFES. If we coupled CReSS and AFES, we can simulate the precipitations and convection associated with Typhoon under using AFES having low resolution for simulations of meso scale phenomena.

In presentation, we will also introduce the contents and flow chart of the coupled model.

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MIS22-P05 Room:Convention Hall Time:May 23 13:45-15:15

Resolution dependence on tropical intra-seasonal oscillation in an aqua-planet global non-hydrostatic model

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We conducted an aqua-planet experiment with a time-independent zonally asymmetric Sea surface temperature (SST) of zonal wave number 1 component by the global non-hydrostatic model, NICAM in order to understand tropical intra-seasonal oscillation and their associated nonlinear multi-scale interactions of organized tropical convection.

The integration time of each experiment is 1-year. A preliminary result for low-resolution (224-km, 112-km, 56-km, and 28-km) experiment with Arakawa-Schubert cumulus parameterization scheme shows that an westerly component of low-level wind appears over the center of convection area (the warmest SST area) in climatology more clearly for the case with higher resolution.

A comparison to zonally symmetric SST case with 224-km resolution reveals that there exists less eastward propagation of convection over the lower SST area. A detail of resolution dependence of convection on the other cumulus parameterization schemes (Tiedtke scheme and Chikira scheme) will be shown on the presentation.

Keywords: Tropical intra-seasonal oscillation, Global non-hydrostatic atmospheric model, Cumulus parameterization

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Development of a general circulation model for planetary atmospheres : Simulation of the Earth's atmosphere

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In the solar system, there are several planets which have atmospheres. Those planets show a various surface environments and general circulation structures. Recently, a lot of exoplanets have been discovered so far, and many of those exoplanets would have atmospheres and surface environment on such planets may be very different from those on planets in the solar system. We have been developing a general circulation model (GCM) for planetary atmospheres to investigate a variety of surface environment and general circulation structures. In this presentation, current status of model development is presented, and some results of simulations of Earth's atmosphere are shown. In addition, some results of experiments with several values of obliquity will be reported.

A planetary atmosphere GCM, dcpam (http://www.gfd-dennou.org/library/dcpam/index.htm.en), is developed with the basis of the Geophysical Fluid Dynamics (GFD) Dennou Club atmospheric GCM (http://www.gfd-dennou.org/library/agcm5/index.htm.en). Dynamical core of dcpam solves the primitive equation system by using spectral transform method with the finite difference method in vertical direction. As physical processes, following processes/schemes are included: radiation processes for Earth's atmosphere and Martian atmosphere, turbulent mixing process, cumulus convection parameterization, and large scale condensation process. Amount of cloud liquid water is calculated by solving a prognostic equation with considering turbulent mixing, production by cumulus convection and large scale condensation, and a simple loss process with a constant life time. In the current model, cloud fraction in each grid box is assumed to be one. Surface temperature is calculated by solving a surface heat budget equation and heat diffusion equation in a soil. In our model, a budget model is included to calculate soil moisture. Sea surface temperature can be prescribed with input data or can be calculated with an assumption of a slab ocean.

By the use of this model, simulations are performed with several values of cloud liquid water life time to tune the model to the Earth. In these simulations, climatological distributions of sea surface temperature and ozone are prescribed. Those simulations are performed with a resolution of T42L22, which corresponds to about 2.8 degrees longitude-latitude grid and includes 22 vertical layers. By examining a global mean radiative flux budget at top of the atmosphere, an optimum liquid water life time, which produces minimum net flux at top of the atmosphere, is chosen. A result of simulation with the optimum liquid water life time is compared with observations. A comparison shows that difference in global mean longwave radiation flux, shortwave radiation flux, latent heat flux, and sensible heat flux between the model and observation is less than about 5 W m^{-2}, except for the surface shortwave radiation flux. Global mean surface shortwave radiation flux by the model is different from that by observation by about 12 W m^{-2}. On the other hand, the comparison in the zonal mean circulation between the model and observation shows that the model roughly reproduces characteristic features of zonal mean circulation and its seasonal variation in a real Earth's atmosphere. However, large differences are observed in intensity of meridional circulation, and distributions of zonal wind and temperature in stratosphere.

In the presentation, the details of comparison results will be shown. Further, the results of experiments with different obliquities will also be reported.

Keywords: planetary atmosphere, general circulation model, Earth

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On the Spectrum of Normal Vibrations of Viscous Compressible Stratified Fluid in the Atmosphere and the Ocean

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The exponentially stratified fluid can be considered as describing the density of the Atmosphere or the Ocean in the homogeneous gravitational field of the Earth.

For the model of viscous compressible barotropic exponentially stratified three-dimensional fluid, we investigate the structure and localization of the spectrum for the problems of the normal oscillations. We find a sector of the complex plane to which all the eigenvalues belong. We consider both the cases of geophysical viscous fluid and the geophysical inviscid fluid.

Keywords: stratified fluid, internal waves in the Atmosphere and the Ocean, viscous barotropic fluid, normal oscillations, eigenvalues, spectrum, mathematical fluid dynamics

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Impact of arithmetic asymmetries on simulated thermodynamical ice-sheet evolution

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Numerical ice sheet model experiments sometimes exhibit asymmetries in the solutions despite the symmetric conditions imposed. Identifying the arithmetic asymmetry in the models as one of the reasons for symmetry breaking through loss of trailing digits, this paper presents a numerical procedure to preserve the symmetries by restructuring of the order of the floating-point evaluation of the equations in the numerical ice sheet model. Reexamination of the series of experiments in the HEINO topic of the ISMIP demonstrates that small perturbations triggered by arithmetic asymmetries significantly amplify to cause qualitative differences in the simulated ice-sheet evolutions. It is imperative to apply a symmetric scheme to maintain overall symmetries for the simulation of ice-sheet evolution, at least under such highly idealized configuration.

Keywords: Numerical model, Ice sheet, Asymmetry

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Dynamic role of the weak continental margin on the stability of continental lithosphere: A 3D mantle convection model

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It is still difficult to find the conditions which allow both stable cratonic lithosphere and plate tectonics in the numerical modeling of mantle convection (e.g., Yoshida, 2010, Yoshida and Santosh, 2011). A three-dimensional (3D) numerical model presented herein makes it possible to model the cratonic lithosphere that survives for a geologically long period of time, i.e., over ten billion years (Yoshida, 2012). In the present model, the lateral side of the highly viscous cratonic lithosphere (CL) is surrounded by the weak (low-viscosity) continental margin (WCM), such as the tectonically mobile (orogenic) regions.

Numerical results show that an important factor in the longevity of cratonic lithosphere is the localized rheological (viscosity) contrast between the cratonic and oceanic lithospheres, i.e., the presence of the WCM. The WCM protects the cratonic lithosphere from being stretched by the surrounding convection force. In addition to the presence of the WCM, the higher viscosity of the cratonic lithosphere itself effectively contributes to the stability of the cratonic lithosphere, as suggested by the previous numerical modeling. However, the results of the present study suggest that the WCM plays a primary role in the longevity of cratonic lithosphere, even if the viscosity contrast between the cratonic and oceanic lithospheres is quite high, 10^3, and the high-viscosity of cratonic lithosphere may play a secondary role in the longevity of cratonic lithosphere. The combination of the presence of a WCM and the high-viscosity of cratonic lithosphere may realize the longevity of cratonic lithosphere that survives for over two billion years.

Future studies based on numerical modeling must address the geodynamic mechanisms of (1) the origin and growth of the continental crust, (2) the episodic growth of continental crust, and (3) the creation and destruction of continental crust related to subduction zone processes. In particular, the mechanism of crust production and growth should be incorporated in a future numerical model in order to investigate the hypothesis that plate tectonics creates and destroys continental crust over time. Such a study would test whether the geologically suggested episodic emergence of supercontinents are realized in the numerical model (e.g., Yoshida and Santosh, 2011).

References:
Yoshida, M., Earth Planet. Sci. Let., 295(1-2), 205-218, 2010.
Yoshida, M., Tectonophys., 2012, in press.
Yoshida, M and M. Santosh, Earth-Sci. Rev., 105(1-2), 1-24, 2011

Keywords: continental lithosphere, continental margin, craton, viscosity, mantle convection, numerical simulation

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Rotating convection of a liquid metal by laboratory experiments and numerical simulations

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We performed laboratory experiments of Rayleigh-Benard convection on a rotating table by using liquid gallium, to see the effect of Coriolis force on the flow pattern in low Prandtl number (Pr) fluids. The vessel we used has a square geometry with aspect ratio five; convection is driven by bottom heating and top cooling. The range of Rayleigh number (Ra) is from 10^3 to 10^5, and the Pr of liquid gallium is 0.025. The range of Taylor number (Ta), which is proportional to the square of the rotating speed, is from 0 to 10^7. Flow patterns were visualized by ultrasonic velocity profiling method, and convective flow structures with time variation were clearly observed. We compared the results with the experiments using water (Pr=6) in the same geometry.

We also made up codes for numerical simulation of thermal convection with Coriolis force, to compare with the results obtained by these laboratory experiments. Theoretical studies for the onset of instability indicates that the critical Ra is proportional to $Ta^{2/3}$ in an asymptotic form, and the state of overstability occurs for $Pr < 0.6$. Our numerical result reproduced the relation of critical Ra on Ta, depending on Pr. Convection patterns above the critical Ra are consistent with that observed in the laboratory experiments. We analyzed the global structure and its time variations.

Keywords: rotating convection, liquid metal, Coriolis force, laboratory experiment, numerical simulation

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Oscillation on surface of water over rotating disc

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In the terrestrial and planetary atmospheres, the axisymmetry of a vortex occasionally breaks and vortices with various structures are observed. For example, polygonal eyes of tropical cyclones are sometimes observed, and polar stream of Saturn has a hexagonal pattern. Moreover, such non-axisymmetric phenomena are not always steady: polar jet of the earth occasionally meanders but also takes relatively straight path.

Similar phenomena are observed on water surface in laboratory experiments in which water layer in a right cylindrical tank is driven by a rapidly-rotating bottom plate: the shape of the water surface near the rotation center is modified to be a polygon under a certain condition of rotation rate, and it oscillates greatly and becomes calm alternately in another case.

In this study, we focused on the cases of rotation rate of the bottom plate less than that of the polygonal patterns: in certain ranges of this slow rotation rate, the water surface oscillates with a large amplitude. We investigated the features of the flow in vacillation. We can summarize the characteristics of the vacillation as follows: as the initial water depth becomes deeper and as the rotation rate of the plate becomes faster, the vacillation interval becomes shorter and the amplitude of the water surface oscillation becomes smaller. Furthermore, we found small and steady oscillation in other rotation rate range.

We also examined the condition of initial water depth and rotation rate of the plate that the vacillation occurs from the view point of resonance between waves. The fundamental flow of water is rigid body rotation with approximately the same rotation rate of the plate near the center of the tank, though it is slower in the outer region. Moreover, the depth of water becomes shallower near the center of the tank: owing to the gradient of the water layer thickness, there exist topographic Rossby waves. Thus, the coincidence of the phase velocity of a gravity wave travelling along the outer wall in the same direction of rotation of the plate and that of topographic Rossby wave near the center on the flow, which itself travels in the opposite direction of rotation of the plate, leads an instability which might cause these vacillation or oscillation phenomena.

Keywords: rotating fluid, laboratory experiment, oscillation