Japan Geoscience Union Meeting 2012
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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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MIS22-P06 Room:Convention Hall Time:May 23 13:45-15:15

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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MIS22-P07 Room:Convention Hall Time:May 23 13:45-15:15

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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MIS22-P08 Room:Convention Hall Time:May 23 13:45-15:15

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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MIS22-P09 Room:Convention Hall Time:May 23 13:45-15:15

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).

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

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MIS22-P10 Room:Convention Hall Time:May 23 13:45-15:15

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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MIS22-P11 Room:Convention Hall Time:May 23 13:45-15:15

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