Japan Geoscience Union Meeting 2015
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MIS22-01 Room:106 Time:May 27 09:00-09:15

An axisymmetric flow in a cylindrical tank with a rotating bottom: a confirmation of theory by experimental data

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As a model for non-axisymmetric flows in the terrestrial and planetary atmospheres under axisymmetric circumstances, symmetric breaking of flows are realized by a very simple laboratory experiment where a cylindrical container is filled with water and the disk at the bottom is rotated rapidly. We have been reported on the analytical solution of the axisymmetric flow obtained using boundary layer theories, which is necessary as a basic flow for the analysis of the symmetric breaking processes. This theory can predict the parameters of the basic circular flows.

Similar theory was proposed by Tophøj et al. (2013), where they decide the basic axisymmetric flow under the condition that the angular momentum given from the rotating bottom disk should be balanced with that lost at the lateral boundary.

They estimated the momentum exchange with boundaries based on the assumption that it is proportional to the square of the relative velocity of the internal flow to the boundary.

We examined the data of the rotation rate of the regime transition and the change of the water depth which are obtained by the laboratory experiments, and compared them with the present theory and that by Tophøj et al. (2013).

The comparison shows that present theory well predict the experimental results.

The assumption that the momentum exchange is proportional to the square of the velocity difference is considered to underestimate the momentum exchange at the lateral boundary and consequently to overestimate the flow speed of the rotating water.

Keywords: rotating flow, boundary layer, axisymmetric flow, laboratory experiment

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MIS22-02 Room:106 Time:May 27 09:15-09:30

Spontaneous rotation of a block ice melting on metal surface

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We have discovered that a block ice placed on a flat surface of a warm brass column rotates without any external driving torque. Air bubbles supplied to the ice-metal interface as ice melts are found to be essential to the spontaneous rotation. According to our observation, while the ice rotates, air bubbles almost remain stationary on the metal surface. Heat supplied at the bottom of the ice block is also essential. The ice block cannot rotate when the temperature of metal column is low enough.

We carried out the experiments to examine the dependences of the rotation rate on several parameters, which are the heat flux, the supply of air bubbles, the weight of ice, and the size of ice, under the setup with which the stability and the reproducibility are established.

It is found that the angular velocity of the rotation is proportional to the 0.51th power of the temperature gradient in the brass column and the minus 0.56th power of the size of the ice block. On the other hand, the air supply and the weight of the ice had little effect on the angular velocity.

We have developed a scaling theory for the angular velocity assuming that the rotation is driven by the excess pressure of the air bubbles in the water layer. Due to the difference between the thermal conductivities of water and air, the melting of ice just above air bubbles is retarded, resulting in the growth of inverted ridges of ice. The pressure in the air bubble is higher than it in the water layer because of the surface tension. The excess pressure pushes the ridges, and the ice block rotates. The scaling formula of the angular velocity, which is derived from the balance between the driving force and the viscous force on water ice interface can explain many of the experimental results quantitatively.

Keywords: phase change, surface tension, heat conduction, self-propelled motion, bubble

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MIS22-03 Room:106 Time:May 27 09:30-09:45

Flow reversals under a magnetic field induced by horizontal circulation

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Coherent flow structures in the outer core are controlled by the magnetic field and rotation of the Earth. It is important to know the basic behavior of flow in relation to the magnetic field, for understanding the flow patterns observed in the real Earth and core dynamo simulations. On the other hand, spontaneous flow reversals generally observed in high Rayleigh number thermal convections may provide clue to the mechanism of random geomagnetic field reversals. As the most basic setting to observe the nature of flow structures with their time variations, we performed numerical simulations of Rayleigh-Benard convection in a three-dimensional square vessel by an electrically conductive low Prandtl number fluid, under a uniform horizontal magnetic field. Computed behaviors are consistent with the result of laboratory experiment (Yanagisawa et al., 2013) that shows flow reversals, and detailed process of reversals is clarified. The key mechanism is the emergence of a global circulation in the horizontal plane and following reconnection between rolls. An increase of global circulation induces bend and reconnection of convection rolls. It establishes a reversed flow state through roll number transitions. The horizontal circulation is related to the skewed-varicose instability of two-dimensional roll structure aligned in the direction of the magnetic field. This is a newly identified mechanism of flow reversal that works in large-scale three-dimensional geometry.

Keywords: flow reversal, horizontal circulation, low Prandlt number, magnetic field

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MIS22-04 Room:106 Time:May 27 09:45-10:00

Hopf bifurcations on convection rolls toward flow reversals in a liquid metal layer with a horizontal magnetic field

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Spontaneous flow reversals of convection rolls that were recently observed in experiments using a liquid metal layer in a box under a horizontal magnetic field (Yanagisawa, *et al*., 2011) have collected attentions related to geomagnetic polarity reversals. If applying magnetic field is strong enough, convection disappears because of energy dissipation in Hartmann boundary layer on the side wall of box. On the other hand, the convection in liquid metal layers that have extremely small Prandtl number easily achieves thermal turbulence condition without applying magnetic field. In the intermediate cases of magnetic field, quasi-two dimensional rolls aligned parallel to the magnetic field are formed and instabilities occur toward losing two-dimensionality with decreasing the intensity of magnetic field. The flow reversals appear in this way to the thermal turbulence. Decreasing the intensity of magnetic field also produces decrease of the dominant number of convection rolls in the fluid layer. Yanagisawa, *et al*. (2013) explained that the flow reversals consist of competition between two modes having different number of rolls and relatively fast switching of flow direction is caused by Skewed-Varicose instability that was reported as one of instabilities on two-dimensional rolls in general Rayleigh-Benard convection in shallow fluid layers. Including the instability having O(1 s) time scale, there are three different time scales, oscillation of convection rolls with O(10 s) and the flow reversals with O(100 s). And we can assume that the flow reversals consist of three different mechanisms.

We performed detailed experimental investigations of process of transitions on convection rolls with decreasing the intensity of magnetic field from quasi-two dimensional rolls toward flow reversals. For rectangular box filled by liquid gallium with 200 mm $*$200 mm $*$40 mm in dimensions, ultrasonic velocity profiling (UVP) and thermistor probes were adopted to capture spatio-temporal velocity profiles and time fluctuation of temperature. These information provide the number of rolls, magnitude of velocity in the directions perpendicular or parallel to the magnetic field, dominant frequency of roll oscillation and intensity of temperature fluctuations. Summarizing the results elucidated that in the process of decreasing of magnetic field primary and secondary Hopf bifurcations occur. The first bifurcation keeps two-dimensionality on the rolls and the second one provides three-dimensional motion on the rolls. Fluid motions parallel to the magnetic field become considerable and corresponding flow velocity takes from 4 to 5 mm/s. Traveling time of fluid particles in the fluid layer with this velocity scale is in O(100 s). We can deduce that the development of three-dimensional motion provides large scale, long time scale motion in the fluid layer triggering SV instability for the flow reversals.

Keywords: Geomagnetic polarity reversals, Liquid metal flow, Thermal convection

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MIS22-05 Room:106 Time:May 27 10:00-10:15

A phenomenological model for convective cell size in a fluid layer with internal heat generation at low Rayleigh numbers

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The convective behavior of a fluid layer with internal heat generation at low Rayleigh number ($6 \leq$ RaI/RaIc ≤ 12) was experimentally investigated. The horizontal fluid layer of 0.5 wt% KCl water solution was internally heated by Joule heating using the electric current. We quantitatively measured 2-D temperature and velocity fields by seeding the micro-encapsulated thermo-chromic liquid crystals in the fluid layer. We experimentally obtained the fluid dynamic scaling on non-dimensional temperature and the maximum downwelling velocity as a function of the Rayleigh number, and also refined the experimental data obtained by the previous studies. The scaling relations were combined with a phenomenological model based on the stability of the top thermal boundary layer. This phenomenological model consistently explained the increase in convective wavelength with increasing the Rayleigh number.

Keywords: internal heat generation, natural convection, cell size, visualization, experiment, fluid mechanics

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MIS22-06 Room:106 Time:May 27 10:15-10:30

On solid state flow induced by Joule heating in the inner core of the Earth

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The elastic anisotropy of the earth's inner core as revealed by recent seismic observations is considered to originate from the alignment of texture formed along the solidification of the core or alignment of the preferred orientation of crystals by plastic deformation of fluid motions. The depth dependency of the anisotropy is difficult to explain by the solidification mechanism, whereas the various factors driving fluid flows in the inner core considered thus far do not appear to yield sufficiently strong stresses for generation of the elastic anisotropy. Takehiro (2011) proposed Joule heating of the magnetic field penetrating diffusively from the inner core boundary (ICB) as a possible source of inner core flows. His specific calculation in the case of toroidal magnetic field with the horizontal structure of spherical harmonics $Y_2{}^0$ showed that downward flow in the equatorial region and upward flows in the polar region are induced by the Joule heating. This flow field has non-zero radial velocity component at the ICB, causing mass exchange between the inner and the outer core. This feature is a result of the constant normal stress boundary condition at the ICB, and it is implicitly assumed that the phase change occurs instantaneously at the ICB. However, the actual speed of the phase change is finite. If the speed of the phase change is slow enough, the ICB would be deformed and the surface displacement is induced by the non-zero radial velocity at the ICB. This surface displacement may prevent inner core flows due to the buoyancy force originated from the density contrast between the inner and the outer cores. Therefore, in this study, we investigate influence of surface displacement on fluid motions induced by horizontally heterogeneous Joule heating in the inner core. We examine the extent of development of the surface displacement and modification of flow field of the inner core.

The difference of the governing equations from those of Takehiro (2011) is the boundary conditions at the ICB. Temperature disturbance at the ICB coincides with the melting temperature which varies depending on the surface displacement. The normal component of stress equates with buoyancy induced by the surface displacement. The toroidal magnetic field and surface displacement with the horizontal structure of $Y_2{}^0$ is given. The flow fields are calculated numerically for various amplitudes of the surface displacement with the expected values of the parameters of the cores.

The results show that, when the surface displacement is the order of 0.006–0.06m or less, the flow and stress fields are similar to those of Takehiro (2011), where the surface displacement vanishes. As the amplitude of the surface displacement is increased, counter flows from the polar to the equatorial regions come to emerge around the ICB, while the flow in the inner regions is directed from the equatorial to the polar regions in the inner region and non-zero radial component of velocity at the ICB still exists. When the surface displacement is about 0.018–1.8m, radial component of velocity at the ICB vanishes, the surface counter flows becomes stronger than the flow in the inner region, and the amplitude of the stress field near the ICB dominates that of the inner region, which might be inconsistent for the elastic anisotropy in the inner core. However, the mechanism proposed here might play a important role in the past, possibly because heat flux through the core-mantle boundary was larger, yielding stronger magnetic field in the outer core.

Reference: Takehiro, S., 2011: Phys. Earth Planet. Inter., 184, 134–142.

Keywords: anisotropy of the Earth's inner core, magnetic fields in the Earth's outer core, flows in the Earth's outer core, inner core boundary of the Earth, dynamo action in the Earth's outer core

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MIS22-07 Room:106 Time:May 27 10:30-10:45

Formation mechanism of the Moon and Earth's Deep Ocean-floor and plate edge cracks, with multi-impact hypo

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In Multi-Impact Hypothesis,we assume that Protoplanet CERRA(about Mars size),which was on the same revolution surface,deformed as potential energy universal at the near point side of Jupiter by perturbation of Jupiter.CERRA of asteroid Ceres position at a meeting cycle of approximately every 275 years,and after several million years elliptical orbit was flattened so as to intersect the Jupiter's orbit.The attraction of both Sun and Jupiter,CERRA is beyond its breaking strength just before collision,to tear into multiple pieces.Since orbit CERRA during tidal destruction intersects the earth orbit,mantle pieces (about a month size)is the collision time difference more than once.In the first collision (about 1.5 month size),the formation of the Pacific Ocean of impact craters and the moon has occurred.By isostasy, mantle is about 4700m depth of the Pacific Ocean more than half of the size of the deep ocean's floor was formed.Giant impact of mantle debris with Darwin raised,along with scattered melting and loss of crust and mantle, deformation and mantle,including the eccentricity of the core,to the Earth radius R_E:6400km, of depth:5km depth of the seabed surface area status quo rate of about 70 percent,to there can be no chance in the formation.**Mr. Wegener had raised issue,but the origin of the deeep ocean-floor problem had been forgotten.**

As a results of plate boundary cracks and formation as the formation of a concave depression and arc archipelago of plate,and as a result start of subduction of the plate due to boundary stress of convex plate,the correction of the power of the unbalance of rotation and inertia secondary moment(the minimum value) has pointed out as a driving force.Trajectory and the seamount due to the hot spot of the Pacific Ocean,Distance and residual magnetization direction conversion of even rapid 60 degrees to the moving direction is the same time due to the earth time pattern by from the mid-ocean ridge as the Ocean-floor spreading theory,Can not be explained by the driving force of mantle convection theory.Even if the plume tectonics,why to convection and plume occurs in that position,what has been formed in the way any boundary of the plate,what is now the driving force is generated in any way,there are many problems which can not be sufficiently explained.Collision(:formation of kimberlite pipe to Mirunui position is shown) of **the Drake Passage position** forming the Tethys(high latitudes) is generated the moment of tilting the earth's axis about 23.5 degrees and Moon's orbit radius as $60*R_E$.As a result of mantle missing of the Arctic Ocean position,Antarctica is not moving after fits to the rotation pole.But Deccan Plateau and Australia have moved actively.Indian Ocean is formed,when the Gondwana continent is divided, divided continent occurs large-scaale move to any direction.Not the time(about 4.6 billion years ago) of magma ocean by accumulation of planetesimals.But the flattening of the elliptical orbit of up to 40 million years ago and cooling,Mantle and core has been fully differentiated,It was tidal disruption.Part of the core-mantle CERRA loses energy and angular momentum,became Mercury by changing the orbit the sun direction.

From the intersection of Earth orbit and the elliptical orbit,**the relative speed** at the time of collision is **12.4km/s and impact angle is about 34.6 degrees** and the moon's orbit radius was calculated to be $60*R_E$.Second-order space velocity of the Earth is a 11.2km/s, first-order space velocity is 7.9km/s.When describes the radius of the earth as R_M,***in Multi-Impact Hypothesis, Moon is formed substantially of current position(about 60$*R_M$).*** **In Giant impact hypothesis,Moon is formed at a distance of 3$*R_M$,it is a 1/20 position energy of the current moon.**But there is no consideration of fee-dengue zone of impactor of Mars size,that impact velocity and direction of the realization probability is too good to be accidentally.

I propose ***The unified formation mechanism.***

Keywords: Formation mechanism of moon and Earth's Deep Seafloor, The plate edge crack formation, Multi-impact hypothesis, Driving force of plate move, Large extinction of over and over again of organism species, Frequency curve showing a two-peak

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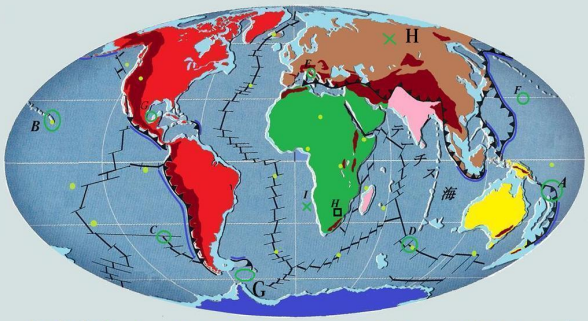
MIS22-07 Room:106 Time:May 27 10:30-10:45

マルチ-インパクトの衝突痕跡とプレートテクトニクス境界亀裂分布



衝突痕跡：A～G G:Drake passage プレート境界と山脈
海嶺と海溝、大陸と海洋、ホットスポット分布と海山列

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MIS22-08 Room:106 Time:May 27 11:00-11:15

A divergence-form wave-induced pressure for extending the Eliassen-Palm theory to all waves at all latitudes

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Classical theory concerning the Eliassen-Palm relation is extended in this study to allow for a unified treatment of mid-latitude inertia-gravity waves (MIGWs), mid-latitude Rossby waves (MRWs), and equatorial waves (EQWs). A conservation equation for (what the authors call) the impulse-bolus (IB) pseudomomentum is useful because it is applicable to ageostrophic waves and the associated three-dimensional flux is parallel to the direction of the group velocity of MRWs. The equation has previously been derived in an isentropic coordinate system or a shallow water model. The authors make an explicit comparison of prognostic equations for the IB pseudomomentum vector and the classical energy-based (CE) pseudomomentum vector, assuming inviscid linear waves in a sufficiently- weak mean flow, to provide a basis for the former quantity to be used in an Eulerian time-mean (EM) framework. The authors investigate what makes the three-dimensional fluxes in the IB and CE pseudomomentum equations look in different directions. It is found that the two fluxes are linked by a gauge transformation, previously unmentioned, associated with a divergence-form wave-induced pressure (symbolized as Λ in the present study). The quantity Λ vanishes for MIGWs and becomes nonzero for MRWs and EQWs, and may be estimated using the virial theorem. Concerning the effect of waves on the mean flow, the quantity Λ represents an additional effect in the pressure gradient term of both (the three-dimensional versions of) the transformed EM momentum equations and the merged form of the EM momentum equations (the latter of which is associated with the nonacceleration theorem).

http://dx.doi.org/10.1175/JAS-D-14-0172.1

Keywords: inertia-gravity waves, mid-latitude Rossby waves, equatorial waves

Figure 1

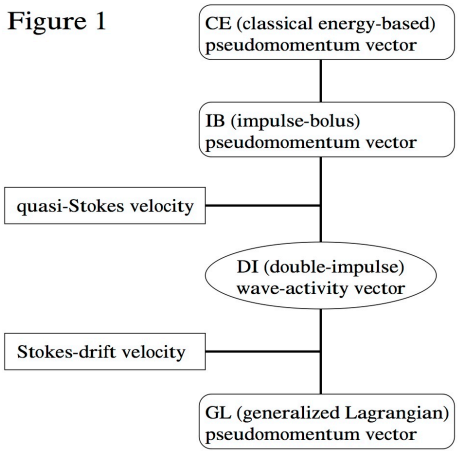
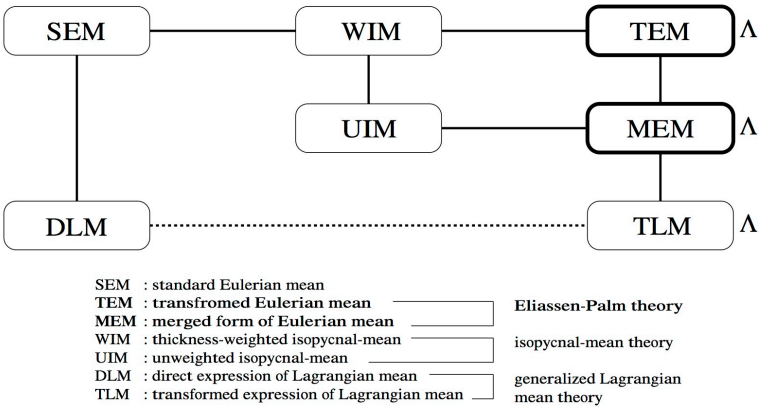


Figure 2



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MIS22-09 Room:106 Time:May 27 11:15-11:30

Atlantic meridional overturning circulation in a variable-density, two-layer model: interaction with the Southern Ocean

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The flow of the North Atlantic Deep Water (NADW) forms a global overturning circulation, in which the water sinks in the northern North Atlantic to deep ocean, upwells in the Southern Ocean and elsewhere to the upper ocean, and returns to the North Atlantic within the upper layer. This circulation can be described by a 1.5-layer model with the branch of the circulation after the upwelling and before the sinking contained in the upper layer of the model. Because the connection between the Southern Ocean and each ocean basin is not well understood, however, the description of the circulation by a 1.5-layer model is not complete.

In this study, we examine the boundary layer between the Southern Ocean (where the domain is zonally cyclic) and an ocean basin representing the Atlantic (where the Sverdrup dynamics determines the flow) in detail to derive the matching condition between the two regions, thereby completing the 1.5-layer description of the NADW circulation. This enables us, for example, to theoretically predict the dependence of the strength of the NADW circulation on winds in the Southern Ocean and on the mesoscale-eddy-mixing coefficient.

The governing equations are

$$-f V = -P_x - \nu U + \tau^x,$$
$$f U = -P_y - \nu V,$$
$$U_x + V_y = w_e + w_m.$$

where $(U,V) = (hu,hv)$ is the "residual" transport vector in the upper layer, $P = g' h^2/2$ is the integrated pressure, h is the upper-layer thickness, $g' = g(\rho_2 - \rho_1)/\rho_2$ is the reduced gravity, τ^x is a zonal wind stress, and interior upwelling due to vertical diffusion w_m is prescribed. "Vertical viscosity" ν is actually an expression of horizontal mass transport due to parameterized mesoscale eddies and can be written as $\nu = \kappa_{GM} f^2/(g'/h)$, using the GM thickness diffusivity. Traditionally, κ_{GM} is often assumed constant, but we assume ν to be constant for simplicity.

It is easy to obtain the interior solution within each of the Atlantic basin and the Southern Ocean (not shown), but these solutions do not match, requiring a zonal boundary layer. It can be shown that the boundary layer solution (total solution minus interior solution) approximately obeys (ignoring the western boundary layer)

$$-P''_x = r P''_{yy},$$

where $r = \nu/\beta$. This is a "diffusion equation" where $-x$ is analogous to time. In physical terms, this equation describes how pressure anomaly associated with Rossby waves is spread meridionally by viscosity. This equation can be solved under the cyclicity condition $P''(x=0, y) = P''(x=-L, y)$ for $y > y_a$ and the eastern boundary condition $P''(x=0, y) = P_e$ = const. for $y < y_a$, and the matching condition that the total pressure and its y derivative must be continuous across $y = y_a$, where y_a is the latitude of the southern tip of South America. The solution (not shown) determines one of the unknown constants of integration of the interior solutions, thereby closing the problem.

Keywords: analytic model, viscosity, eddy induced transport, wind stress, Ekman transport

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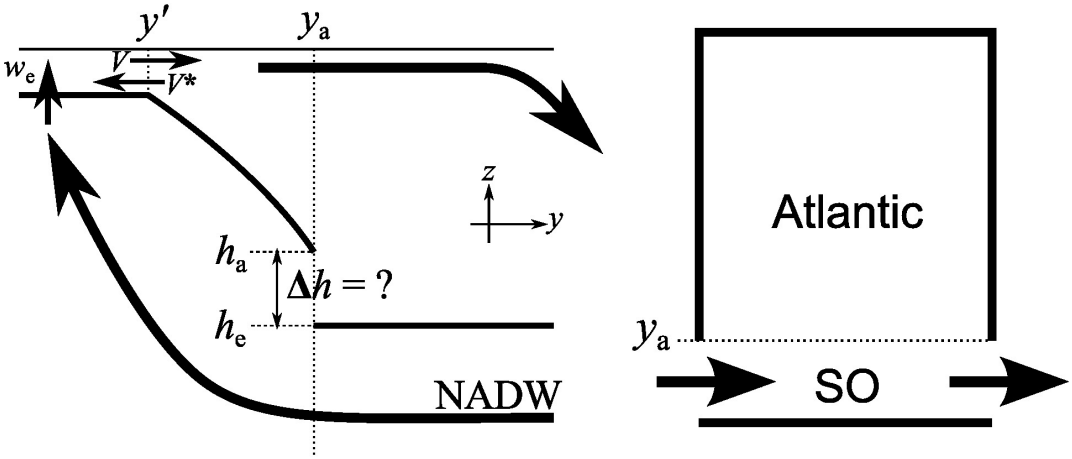

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MIS22-10 Room:106 Time:May 27 11:30-11:45

Snowfall on the South Kanto region under winter pressure pattern, and by south-coast cyclones

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Snowfall on the south Kanto is generally caused by synoptic-scale extratropical cyclones which pass along the southern coast of Honshu Island (so-called south-coast cyclones). However, the south Kanto on Jan. 23, 2012 experienced a heavy snowfall without such type of cyclones, under a synoptic-scale circumstance regarded as the winter pressure pattern (Hara, 2012). With regard to such winter pressure pattern snowfall on the south Kanto, Yamamoto (1984) reported a case in Feb. 8, 1984 and implied that it might have been associated with the lower layer convergence line caused by winter monsoon which bypasses the mountains of central Honshu.

In this study, the heavy snowfall on Jan. 23, 2012 was analyzed using the data of JMA Meso-scale Analysis. According to the analysis, in the synoptic scale, JPCZ (Japan sea Polar air mass Convergence Zone) was formed in the western Japan sea, and another convergence zone in the Pacific side of Honshu Island. In the latter convergence zone, a meso-scale convergence line extending to the southeast from the vicinity of the Suruga Bay located on the southwest side of the Kanto was remarkable. Environmental profile near the convergence line was unstable due to the cold air in the upper layer and the warm moist air flowing into the line so that relatively deep convections easily occur. In the vicinity of Kanto, northeast wind in the lower layer toward the convergence line and southwest wind in the middle upper layer in front of the trough were blowing, which made notable vertical shear of horizontal wind. It is believed that convections which occurred along the convergence line were advected by southwest wind in the middle upper layer toward the south Kanto located downwind, and brought snowfall there.

The vertical structure of the equivalent potential temperature in the vicinity of the Kanto were compared between the heavy snowfall on Jan. 23, 2012 and a typical case of the south-coast cyclones on Feb. 8, 2014. The equivalent potential temperature difference in the vertical direction was small (weak stratification) on Jan. 23, and large (strong stratification) on Feb. 8. Based on this result, 46 heavy snowfall events in Tokyo or Yokohama in the past 30 years were analyzed in respect to the vertical structure of the equivalent potential temperature in the vicinity of Kanto using the data of JRA-55, and as a result, 4 out of 46 (8.7%) were extracted as the cases whose stratification were as weak or weaker than that of Jan. 23, 2012, and 42 out of 46 (91.3%) as the cases of stronger stratification. 86 snowfall days (no distinction between heavy and light) in Tokyo in the past 10 years were analyzed using the same technique, and as a result, 29 out of 86 (33.7%) were extracted as the cases of the “weak” stratification, and 57 out of 86 (66.3%) as the cases of “strong” . In comparison with the contribution in the heavy snow cases, the contribution of “weak” stratification is relatively large in the snowfall days. Although only the information of precipitation and equivalent potential temperature were used in the classification, the features of the composites of the cases classified as “weak stratification” show the winter pressure pattern which resembles that of the case of heavy snowfall on Jan. 23, 2012, and those as “strong” show the south-coast cyclone pressure pattern which brings heavy snowfall on the south Kanto; it shows the validity of the classification. Through this analysis south-coast cyclones are confirmed to be the major factor in the south Kanto snowfall, while it is elucidated that the event on Jan. 23, 2012 was not the sole case of heavy snowfall under winter pressure pattern.

Keywords: snowfall on the South Kanto region, winter pressure pattern, south-coast cyclones, low level convergence, stratification

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MIS22-11 Room:106 Time:May 27 11:45-12:00

Dynamic energy efficiency of tropical cyclones with long-lived concentric eyewall in numerical simulation

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”Eyewall” is a ring of convective clouds that encircles the eye of a tropical cyclone (TC) such as typhoon and hurricane. Multiple eyewalls, named ”concentric eyewall”, are observed in some TCs, and ”eyewall replacement cycle” is also observed after the formation of concentric eyewall. In the process of an eyewall replacement, the inner eyewall gradually disappears while then the outer eyewall moves towards the TC center in closing to the previous inner eyewall. During the period of a replacement cycle, the TC intensity changes drastically. 24 percentages of TCs with concentric eyewalls maintained in a long time (over 20 hours) in satellite observations (Yang et al., 2013). The result suggests that a TC with concentric eyewall does not always undergo the replacement cycle. There are very few studies of long-lived concentric eyewall. Moreover the maintenance mechanism of long-lived concentric eyewall is also not clear.

To understand the maintaining mechanism of concentric eyewall, we employ dynamic energy efficiency in considering the change of kinetic energy (KE) and available potential energy (APE) due to the internal dynamics of a TC. We focus on a parameter of dynamic energy efficiency, which is proposed as an index of conversion efficiency of potential energy to KE. In this study, dynamic energy efficiency of idealized TCs with replaced and long-lived concentric eyewall, and then, real typhoon Bolaven (2012) with long-lived concentric eyewall was investigated, using numerical simulation results which were performed by Tsujino and Tsuboki (2013, 2014). TC simulation data in this study were supported by an atmospheric numerical model of a three-dimensional, non-hydrostatic and full-physics, which is called by CReSS (Cloud Resolving Storm Simulator; Tsuboki and Sakakibara, 2007).

The formula for the dynamic energy efficiency of heat and of momentum in balanced vortex, whose the primary circulation is gradient wind balance, and the secondary circulation is induced due to convective heating and surface friction, was derived by Kuo et al. (2013). The dynamic energy efficiency of heat and of momentum is determined by the solution of the Eliassen transverse circulation equation with the radial temperature gradient instead of the radial heating gradient. They showed that dynamic energy efficiency enables to explain intensity change of TC through diabatic heating and friction with analytical profile of idealized TCs. The dynamic energy efficiency of an idealized TC with replaced concentric eyewall was increasing drastically during the replacement cycle, and the value of dynamic energy efficiency had maximum when inner eyewall dissipated. Low (high) dynamic energy efficiency indicates that conversion of APE to KE is inefficient (efficient) for TC’s intensification. The tendency of dynamic energy efficiency of TC with replaced concentric eyewall was consistent with the TC’s intensity change during the replacement cycle. On the other hand, the dynamic energy efficiency of the idealized TC with long-lived concentric eyewall did not increase apparently after the outer eyewall formed. The result suggests that the conversion of APE to KE in the outer eyewall does not control much the TC intensity change. The tendency of dynamic energy efficiency resembled that of a typical TC with single eyewall which was shown by Kuo et al. (2013). Moreover, in typhoon Bolaven (2012), the tendency of dynamic energy efficiency also resembled that of the idealized TC with long-lived concentric eyewall. These results imply that the dynamic energy efficiency of TCs with long-lived concentric eyewall may describe one of the universal characters of a TC development process.

Keywords: Eliassen transverse circulation, concentric eyewall, tropical cyclone

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MIS22-12 Room:106 Time:May 27 12:00-12:15

Optimal excitation of asymmetric perturbations on an axisymmetric barotropic vortex with piecewise constant vorticity

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Regarding the hierarchal structure seen in natural and artificial vortices, where the multiple secondary vortices revolve around the core of their parent vortex, a linear singular value problem is formulated and solved analytically based on the axisymmetric barotropic vortex consisting of three piecewise constant vorticity regions: i.e. from the non-divergent barotropic vorticity equation linearized around the basic tangential flow with three regions of piecewise constant vorticity, the simultaneous ordinary differential equation on the vector, whose components are the amplitude of the Rossby waves evoked by the vorticity discontinuity of the basic flow. This equation is solved as an initial value problem, and the resultant resolvent matrix is applied to obtain the singular values and the corresponding forward and backward singular vectors under the L2 norm.

The results can be categorized into the two kinds based on the shape of the basic vortex. For Michalke & Timme's vortex characterized by a ring of high vorticity, the forward and backward singular vectors and the growing eigenvector are rather similar in shape with each other. On the contrary, for Syono's vortex incorporating a negative vorticity region surrounding the positive vorticity core, the shape of the forward singular vector is quite different from that of the backward singular vector and the growing eigenvector. Some results in the case adopting energy norm are also introduced.

Keywords: optimal excitation, singular value, singular vector, barotropic vortex, multiple vortex

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MIS22-13 Room:106 Time:May 27 12:15-12:30

Development of a general circulation model for planetary atmospheres: Single column model experiments

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We have been developing a general circulation model for planetary atmospheres, DCPAM (http://www.gfd-dennou.org/library/dcpam/), to investigate various structures of atmospheric general circulation and surface environments of planets in our solar system and exoplanets. In this talk, some single column model (SCM) experiments by use of the DCPAM are reported. These SCM experiments are useful to check implementation of the parameterizations and to investigate its nature. On the other hand, it is also useful to investigate how a parameterization based on the Earth's atmosphere observations behaves under planetary atmospheric conditions. This study is performed as a part of developing a common physical process library in partnership with groups in RIKEN AICS and Japan Meteorological Agency.

The DCPAM is a general circulation model for planetary atmospheres which some members of GFD Dennou Club have been developing. The model is composed of spectral dynamics based on primitive equation system and physical processes of radiation, turbulence, condensation, cloud process, and surface processes. Further, this model is designed to be used for axisymmetric two-dimensional and vertical one-dimensional experiments with almost no code modifications.

In this study, four kinds of SCM experiments to check parameterizations implemented in the DCPAM: (1) ICRCCM (InterComparison of Radiation Codes in Climate Models; Ellingson et al., 1991) experiment, (2) GABLS2 (GEWEX Atmospheric Boundary Layer Study 2; Svensson et al., 2011) experiment, (3) TWP-ICE (Tropical Warm Pool International Cloud Experiment) experiment (Davies et al., 2013), (4) Mars atmosphere boundary layer experiment. Below, experiments 3 and 4 are described briefly.

In TWP-ICE experiments, atmospheric structure formed by radiation, turbulence, and condensation under an observation-based forcing is investigated. In our TWP-ICE experiment, relaxed Arakawa-Schubert scheme (Moorthi and Suarez, 1992), non-convective condensation by Le Treut and Li (1991), and turbulence by Mellor and Yamada (1982) level 2.5 are used. Experimental results show that temporal variation of precipitation is roughly consistent with other SCM results (Davies et al., 2013). However, relative humidity in DCPAM is lower than those in other SCMs in lower troposphere. We will examine what causes this difference between our and other SCMs.

In Mars atmosphere boundary layer experiments, structure of Martian atmospheric boundary layer formed by radiation, turbulence, and surface processes under a prescribed large scale pressure gradient is investigated. We use turbulence scheme of Mellor and Yamada (1982) level 2.5 in this experiment. The boundary layer height and its diurnal variation represented by the model are roughly consistent with those of previous studies with two- or three- dimensional convection resolving model simulations (e.g., Odaka, 2001). For example, top of the boundary layer on Mars is located about 5 km with a typical atmospheric dust condition.

In future, we will use the SCM experiments as fundamental experiments for other planetary atmospheres.

Keywords: planetary atmosphere, general circulation model, Earth, Mars, Single column model

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MIS22-P01 Room:Convention Hall Time:May 27 18:15-19:30

On the solution of the system modelling non-linear stratified rotating fluid

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We consider non-linear motion of exponentially stratified fluid which is rotating over the vertical axis.
The model is used to describe the three-dimensional velocity camp of the flows of the Atmosphere and the Ocean.
Analytically, we prove the local existence and the uniqueness of the solution.
For the solution, we also prove the convergence of the numerical algorithm by using the Galerkin method.

Keywords: geophysical fluid dynamics, rotating fluid, stratified fluid in a homogeneous gravity field, dynamics of the Atmosphere and the Ocean, approximate solution by Galerkin method, mathematical qualitative properties of the solutions of PDE