Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

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Movie Moire Method, applied to Internal Gravity Wave.

Naohito Otobe[1*]

[1]Fukuoka Univ. Faculty of Science

In laboratory experiment, an internal gravity wave is propagating in stratified transparent fluid. When the wave id visualized, using a large-scale optical system , such as shuri-ren . But it can easily apply to rectangular tank, but it is need to rearrange the optical system to suit to certain shape of tank.

There is an other method , called moire method. It has not such issue, but it require strict setting of two stripes, combination of wave length of two stripes , and position of a camera .

Years before, we carried out visualization of internal gravity wave of QBO experiment, double exposure of distortion of one stripe, and digital processing makes moire pattern.A short of picture resolution and processing throughput does not make possible to real time visualization.

This time, We use digital Video camera and PC,and real time visualization is carried out.

Keywords: Moire, Experiment

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Experimental study of liquefaction and fluid transport

Nao Yasuda[1*], Ikuro Sumita[1]

[1]Kanazawa University

Liquefaction is a phenomenon in which the inter-particle contact of a liquid-saturated granular matter is loosened by vibration and as a result, the bulk behaves like a fluid. It is widely known that earthquakes can cause soil liquefaction which can manifest in the form of sand boils and mud volcanoes. Liquefaction can also occur in a more viscous fluid (e.g, Sumita and Manga, 2008, EPSL), one example of which is a magma chamber. Magmatic liquefaction may also be caused by earthquakes, and may even trigger a volcanic eruption. Moreover, on Mars, there are topographic features which seem to have formed from the eruption of fluid. There have been a number of experimental studies using water saturated soil and sand in the field of soil mechanics or civil engineering. However the details of the critical condition to cause the liquefaction, and how the consequences of the liquefaction differ with the changeable parameters, are still insufficiently known. Here we conduct an experimental study of liquefaction under a vertical vibration to understand the elementary process of liquefaction and fluid transport. We aim to explore the variety of phenomena which may occur, and to better constrain the conditions which cause these results.

An experimental cell (cross section 22.0mm x 99.4mm, height 107.6mm) is filled with a granular matter and liquid (water or glycerin solution). The lower 33.7mm is a two-layered granular medium; the upper layer and lower layer consist of packed glass beads with a size of 0.05 and 0.2 mm, respectively, such that the upper layer becomes a low-permeability layer. The cell is placed on a vertical shaker which vibrates sinusoidally with an acceleration of 2.0-41.1m/s^2 and a frequency of 10-40 Hz.

Here we describe the results for a water-saturated case. From a series of experiments, we find that as we increase the acceleration there are 4 styles of pore water discharge; No-change, Percolation, Transitional, and Flame (i.e., Rayleigh-Taylor type instability). Under a small acceleration, there is no apparent change in the thickness of the granular medium and the two-layer boundary (No-change). As we increase the acceleration, the two-layered granular medium compacts by expelling the pore-water. First there is no apparent change in the form of the two-layer boundary (Percolation), but as the acceleration increases, an instability appears (Transition) whose amplitude grows and a flame structure forms (Flame).

In a two-layered water-saturated granular medium, we find that the pore water which originated from the bottom layer temporary accumulates at the interface of the two layers, and then ascend through the upper layer in the form of vertical channels. We find that the critical acceleration for the formation of the flame structure is of the order of ((the particle-water density difference)/(the particle density))g, where g is the gravitational acceleration.

Keywords: low-permeability layer, Rayleigh-Taylor type instability, Flame structure

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Grain shape dependence of the convective structure in a vertically vibrate granular bed

Tomoya Yamada[1*], Hiroaki Katsuragi[1]

[1]Graduate Schools of Environmental Studies, Nagoya University

Miyamoto et al. reported that the migrations and sorting of regolith could result from gravel fluidization induced by vibration caused by an impact on surface of asteroid Itokawa [1]. In order to understand the detailed mechanism of such phenomena, fundamental physics of vibrated granular matter must be revealed. When granular materials such as regolith are shaken, we can see various phenomena, e.g. convection, segregation, and so on. In this study, we study the granular convection by the experiment. Although many literatures have reported on both experimental and numerical studies of granular convection [2-5], most of them have used spherical grains as constituents. In general, geophysically relevant sand grains are not spherical. Thus, we use rough shaped sand (JIS standard sand) as well as spherical glass beads, to examine the influence of grains shape to the granular convection. In the experiment, we investigate the global structure of granular convection and measure the convective velocity.

The experimental setup consists of a cylinder made by plexiglass of 75 mm inner diameter and 150 mm height, which is mounted on an electromechanical vibration exciter (EMIC 513-B/A). The vibrator frequency f is varied from 10 to 300 Hz and the dimensionless accelerations from 2 to 6. The grains used are glass beads (0.8 mm in diameter) and JIS (Japan Industry Standard) standard sand (from 0.71 mm and 1.4 mm in diameter). The granular layer height is fixed to 50 mm. We use a high-speed camera (Photoron SA-5) with a macro lens to record the motion of grains at 1000 fps. PIV (Particle image velocimetry) method is used to obtain the convective velocities on the side wall of the container.

We find that global structure of convection shows a transition from single cycle roll state to doughnut like roll state when f increases. In the former, grains rise up on the one side wall and fall down on the other side wall. In the latter, grains rise up at the center of container and fall down on all over the wall. We also find that the measured convective velocity decreases rapidly in deep region of the bed. While this tendency is more or less similar to previous studies [2,3], the form of decreasing function is clearly different between glass beads and rough shaped sand. Moreover, the convective velocity field seems to have spatial and temporal inhomogeneities.

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Keywords: Grain shape dependence, Convection, Vertical vibration, Itokawa

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Numerical Experiments for Concentric Eyewalls of Typhoon Bolaven (2012)

Satoki Tsujino[1*], Kazuhisa Tsuboki[1]

[1]Hydrospheric Atmospheric Research Center, Nagoya University

Eyewall is a ring of convective clouds that encircles the eye of a tropical cyclone (TC) such as typhoon and hurricane. TC occasionally has some eyewalls which are called as concentric eyewalls. Striking concentric eyewalls of some hurricanes are studied by airborne radar observations and numerical simulations. These previous studies indicate that eyewall replacement often occurs once concentric eyewalls are formed. The eyewall replacement is a process that the inner eyewall gradually decays and the outer eyewall moves into the position of the inner (old) eyewall. In addition, the wind speed of TC rapidly varies during the replacement. It is important for prediction of TC's intensity to understand the process of the eyewall replacement. However, typhoon Bolaven, which passed in main Okinawa island in 2012, had stationary concentric eyewalls for very long time. And the replacement of Bolaven's concentric eyewalls did not occur. It is clear from observation by Doppler radars of Japan Meteorological Agency (JMA). It shows that the eyewall replacement does not always occur even if concentric eyewalls are formed. As seen above, the process of the eyewall replacement are not fully known.

In this study, we investigate that Bolaven's concentric eyewalls structure and their maintaining reason, using the Cloud Resolving Storm Simulator (CReSS) which is a three-dimensional, nonhydrostatic model. According to some previous studies for concentric eyewalls of hurricanes, concentric eyewalls has horizontal scale of about 10 km. In order to simulate the concentric eyewalls of Bolaven, it suggests that we conduct numerical experiment with horizontal resolution of about 1 km. First, we perform the experiment with 5 km horizontal resolution whose initial and boundary conditions are given by the initial data of the Global Spectral Model (GSM; 0.5 degree horizontal resolution) provided by JMA. Second, we perform the experiment with 2.5 km horizontal resolution based on the output data of 5 km horizontal resolution. Finally, we perform the experiment with 1 km horizontal resolution based on the output data of 2.5 km horizontal resolution.

We could simulate the striking concentric eyewalls which were located within about 100 km radius from Bolaven's center with 1 km horizontal resolution. Simulated concentric eyewalls are stationary for over one day. It substantially exceeds the time required for the eyewall replacement And, the simulated concentric eyewalls have the moat regions, which is very dry and weakly descending. These results almost agree with some observations.

The inner eyewall of a TC gradually decays when supply of vapor into the inner eyewall due to low level inflow from outside of TC is constrained by existence of moat region. This structure is characteristic when replacement of eyewall occurs in TC. Despite of these features, the inner eyewall of Bolaven is stationary. Thus, it suggests that vapor supplied from the periphery of the inner eyewall region is enough to maintain the inner eyewall, even if the moat regions suppress supply of vapor by inflow from outside of Bolaven.

Keywords: tropical cyclone, concentric eyewall, vortex dynamics, numerical modeling, nonhydrostatic cloud resolving model

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Dynamic and thermal processes of a surface low developed by a vortex aloft

Ibuki Seto[1*], Keita Iga[1]

[1]AORI, The University of Tokyo

Over high-latitude oceans in winter, polar lows sometimes develop, whose typical size is a few hundred kilometers. Upper level trough is considered to be one of the important factors for development of polar lows. In this study, this type of process of development is focused: dynamical and thermal processes by which a vortical disturbance aloft excites a surface low are investigated through numerical simulations in an idealized atmosphere.

Some numerical studies in an idealized atmosphere for polar lows caused by upper level vortical disturbances have been conducted. In many studies, not only a vortex aloft but also a disturbance on the surface are located in the initial state, but it is reported recently that surface disturbances could be excited only by vortical disturbances aloft and some sensitivity experiments for such situations are carried out. However, the height of tropopause and upper level vortices are often set at 5000m to 6500m which is lower than real cases. Moreover, excitement of surface disturbances by upper vorticies are mainly investigated through dynamical processes and effects of thermal processes such as convections raised by weak stratification beneath the cold air aloft are not considered enough in idealized simulations.

Therefore, simulations in a zonally uniform baroclinic channel with a higher tropopause level are carried out. As a result, a comma-shaped polar low was simulated even when the upper level vorticies and tropopause is located at 8000m height level. However, it is revealed that in an early stage, the low was developed due to convective processes which are caused by destabilization of stratification rather than dynamical processes which are frequently mentioned in early studies. In order to understand the mechanism of the early stage of the development, simulations with various combinations of tropopause height and the stratification of the background atmosphere. As a result, the mechanism of the disturbance excitement could be classified into some patterns. Dynamical processes tend to occur when the height of a vortex and tropopause is low, and the stratification of the background is weak. In other cases, the low was excited by convective processes and in some cases with high tropopause height and strong stratification, the low was not developed. The condition of dynamical excitement of disturbances resembles that of Eady instability. A low will be emerged by interaction between vorticies when it is under the condition of instability of Eady model, but otherwise surface disturbances are developed convectively. The height which convective vertical flows can reach was calculated by using emagram and compared with the results of numerical simulation. When stratification is weak, the height of convection explains the result of the simulations well. There is, however, discrepancy when stratification is strong; it may be because potential temperature anomalies associated with vorticies and heat fluxes from sea surface are not taken into account.

Keywords: polar low, vortex aloft, stratification, convection

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Boundary layers of an axisymmetric flow in a cylindrical tank with a rotating bottom

Keita Iga[1*]

[1]AORI, The University of Tokyo

In an image from the spacecraft Cassini, hexagonal flow pattern around Saturn's pole is observed. In typhoon images in meteorological sattetiles, we often find typhoon eyes with polygonal shapes. In the terrestrial and planetary atmospheres, non-axisymmetric flows are often formed in axisymmetric environments

Such a breaking of axisymmetry is realized in a simple laboratory experiment: water in a cylindrical tank is driven by a rapidly-rotating disk at the bottom. In this experiment, not only flows with polygonal patterns are observed but also hysteresis between axisymmetric circular flow and eliptical non-axisymmetric flow, and excitation of a large amplitude wave propagating along the side wall, on which we have been reported.

When we understand the mechanism of these phenomena, however, we must know the axisymmetric flow realized under this condition in spite that the phenomena themselves are not axisymmetric, since we should consider the mechanism based on the basic axisymmetric flows. Therefore, we tried to obtain analytically the axisymmetric flow in a cylindrical container with a bottom rotating in a constant angular velocity.

It is impossible to solve the exact solution of the flow, but we successfully obtained the approximate solution under the condition that the Ekman number is small with help of boundary layer theory. The flow is solved by dividing the flow in the cylindrical container into six regions with different balances: (i) inner region with rigid rotating flow, (ii) inner region with constant angular momentum, (iii) Stewrtson's 1/4-layer between two inner regions, (iv) Ekman layer near the rotationg bottom, (v) boundary layer near the side wall, and (vi) corner region where the side wall and the bottom disc meets.

In particular, we estimated the flow flux of the meridional circulation by integrating the flows obtained in each region, described the whole features of the axisymmetric flow.

Keywords: axisymmetric flow, rotating flow, boundary layer