Effects of Koshu Seamount on the Development of Baroclinic Instability Leading to the Kuroshio Large Meander

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It is well known that the Kuroshio south of Japan shows bimodal path fluctuations between the large meander (LM) path and the nonlarge meander (NLM) path. The transition from the NLM path to the LM path is triggered by a small meander which is generated off the southeastern coast of Kyushu and then propagates eastward to Cape Shiono-misaki while being amplified slowly through baroclinic interaction with a lower layer cyclone-anticyclone pair. This small meander thereafter amplifies rapidly over Koshu Seamount located about 200 km to the south of Cape Shiono-misaki, leading to the formation of the LM path. Although it is shown that the existence of Koshu Seamount is essential for the rapid amplification of the small meander, the underlying physical mechanism has not been fully understood yet.

In this study, the effects of Koshu Seamount on the development of baroclinic instability leading to the formation of the LM path of the Kuroshio are investigated using a two-layer quasi-geostrophic model taking into account the effect of bottom topography. Numerical experiments show that the transition processes from the NLM path to the LM path can be successfully reproduced only when the bottom topography mimicking Koshu Seamount is taken into account. In this case, the upper layer meander trough is amplified rapidly together with the lower layer cyclone-anticyclone pair during their passage over the seamount. This suggests that the transition from the NLM path to the LM path is caused by baroclinic instability enhanced over the seamount. A linear stability analysis with the bottom topography mimicking Koshu Seamount shows that baroclinic instability over the seamount is caused by a coupling between the upper layer Rossby wave propagating eastward in the background geostrophic flow and the lower layer topographically trapped wave propagating clockwise around the seamount. These two waves in the upper and lower layers propagate in the same direction with nearly the same speed so that they can resonantly interact with each other over the northern slope of the seamount. The spatial structure of the most unstable mode is shown to be close to that of the rapidly amplifying meander trough over the seamount reproduced in the numerical experiment.

Keywords: Large Meander of Kuroshio, Koshu Seamount, Baroclinic Instability, Topographically Trapped Wave, Two-Layer Quasi-Geostrophic Model, Linear Stability Analysis

Dynamics of the Atlantic meridional overturning circulation and Southern Ocean in an ocean model of intermediate complexity

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A steady-state, variable-density, 2-layer, ocean model (VLOM) is used to investigate basic dynamics of the Atlantic meridional overturning circulation and Southern Ocean. The domain consists of idealized (rectangular) representations of the Atlantic, Southern, and Pacific Oceans. The model equations represent the depth-averaged, layer-1 response.
A hierarchy of solutions is obtained in which forcings and processes are individually introduced. The complete solution set includes a wide variety of solution types: with sinking in the northern North Atlantic and with sinking near Antarctica; with and without wind forcing; with, without, and for two parameterizations of northern-boundary sinking that represent cooling external to and within the North Atlantic; for a wide range of mesoscale-eddy mixing strength and wind stress in the Antarctic Circumpolar region; and for different closures for mesoscale-eddy mixing. Novel aspects of the model and solutions include the following: use of VLOM, which allows buoyancy forcing to be introduced realistically; the aforementioned closure, which allows eddy-induced transport to be determined when layer 1 represents _both_ the surface mixed layer (h=h_m) and the depth of subsurface isopycnals (h>h_m); latitude where layer 1 outcrops in the Southern Ocean being _internally_ determined rather than externally specified; and a boundary layer, based on Gill's (1968) solution, that smoothly connects the Southern- and Atlantic-Ocean responses across the latitude of the southern tip of South America. Finally, some solutions in the set are comparable to solutions to idealized, ocean general circulation models (OGCMs); in these cases, our solutions provide insight into the underlying dynamics of the OGCM solutions, for example, pointing toward processes that may be involved in eddy saturation and compensation.

Keywords: Oceanic deep circulation, Layer model, Southern Ocean

Direct numerical simulation of deep-water waves in rotating frame

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The ratio of the periods of oceanic surface waves (wind waves and swells) and the inertial period is about 10^{-4}, and the earth's rotation does not greatly affect the orbital motion of fluid particles. Waves, however, do modify mean flow under the influence of Coriolis force. This is because the slight tilt of the orbital plane of fluid particle generates Reynolds stress. Hasselmann (1970) and Huang (1979) demonstrated that this Reynolds stress induced by waves can be expressed as the Coriolis force acting on the Stokes drift. The latter expression is called Coriolis-Stokes forcing. In ocean surface layer studies, Coriolis-Stokes forcing has been used as a standard formulation to incorporate the wave-stress effect. However, Coriolis-Stokes forcing is derived under several assumptions, and there has been no research that directly examined the appropriateness of the forcing.
Here we investigated the Coriolis-Stokes forcing, by performing direct numerical simulations of deep-water waves using a recently developed free-surface nonhydrostatic numerical model. The new scheme that this model adopts allows for the accurate simulation of the orbital motion and the dispersion relation of deep water waves, which could not be achieved by the conventional mode-splitting scheme.
Simulations were carried out under idealized conditions of x-z two dimensional domain with periodic horizontal boundaries. Waves were maintained by surface pressure perturbation. Reynolds stress was obtained from the velocity field, and the Coriolis-Stokes forcing was calculated using the Stokes drift, which we obtained from the on-line particle tracking.
Comparison of the two forces tells us that the Coriolis-Stokes forcing is nearly identical to the wave stress under the idealized condition. These forces induce a Eulerian response to the Stokes drift. In the existence of viscosity, this Eulerian flow generates the spiral current throughout the Ekman depth, even there is no net momentum input from the surface. By imposing a uniform stress on the surface, we also find that the mean current profile is described by Ekman-Stokes solution (Polton et al., 2005), which is obtained by considering Coriolis-Stokes forcing, rather than the classical Ekman solution. We will be presenting the results of further simulations under various conditions.

Keywords: wave-mean flow interaction, Coriolis-Stokes forcing, free-surface nonhydrostatic numerical model

A route to steady state of liquid fluidization

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When fluid is injected with low flux into the saturated packed bed of particles, fluid flows through interstitial spaces. This is known as a permeable flow. In this situation an empirical relationship, the Darcy law is known to exist in laminar flow, where the fluid flux is proportional to the applied pressure difference. When the applied pressure difference is increased and hence, the fluid flux is increased and both fluid and particles begin to flow together as a suspension. This gross flow called fluidization is important because it can drastically change efficiency of material transport. In the field of hydrology, for an example, this is related to an initiation of debris flow. In the field of volcanology, this process is related to the rejuvenation of a dormant magma chamber where the injection of new magma into the crystal mush causes the replenishment. In the field of chemical engineering, fluidization is well investigated for the engineering applications. The transition between a permeable flow and a gross flow is a kind of phase change; This critical superficial velocity is known as a minimum fluidization velocity (v_{mf}). The dynamics of the change from a permeable flow state to a gross flow state is more important in the initiation of such as debris flow and rejuvenation of magma chamber. The process of the initiation of fluidization is as follows; Water start to flow with high velocity enough to fluidize, both upper and fluidized front are lifted from top and bottom of particles bed, respectively(Slis et al. (1959)). Gibilaro et al. (1984) derived that upper front velocity has constant value until it reaches steady state and depends on water flux, and Thelen and Ramirez(1997) confirmed it experimentally. Upper front velocity is discussed like above, however, fluidized front velocity is not observed experimentally. In this presentation, we focus on the dynamics of the initiation process of the fluidization and present experimental approaches.

To observe the initiation process of the fluidization, we employed a vertical fluidizing bed. Transparent acrylic pipe (inside diameter:30 mm, length: 40~120 cm) is used, where particles are packed at the bottom of 12.5 cm. From water-saturated state, water is injected from the bottom at constant flux(the superficial velocity of 0.5~4.7 cm/s). The hydrostatic pressures are monitored at 3 different positions at 0,5,10 cm hight from bottom. Glass beads(diameter:0.8 mm, density:2.5 g/cm^3) and polystyrene beads(diameter:0.8 mm, density:1.03 g/cm^3) are used as particles. The all move of beads are filmed, and inside area of this pipe is divided into fixed, fluidized and no particle area by differential of particles density.

We found that top of the particle bed and the fluidization area propagates from bottom to upward when the injected velocity is above the critical value v_{mf}. Because fluidization front velocity is larger than upper front velocity, the thickness of fixed bed becomes gradually small, and after that all beads become fluidized. On checking pressure and movie of the same time, it is revealed that hydrostatic pressure gradient of fixed bed are larger than fluidized bed during rise. Propagation of fluidized bed is divided into two types by flux; In case injected velocity is slightly larger than v_{mf}, the propagation ends when both upper and fluidization front reach same hight. In case injected velocity is enough high compared with v_{mf}, rise lasts after a while that. Fluidized front velocity depends on injected flux when it is low, however, fluidized front velocity saturates when it is high. Porosity of propagating fluidized bed is kept nearly equal value to one of terminal fluidized bed.

We also compare the cases for soft gels are used as elastic particles and discuss the effect of modification of packing and particle shape during flow.

Keywords: Fluidization, Bed of particles, Substance transportation, Suspension, Laboratory experiment

Height structure of solar surface convective velocity from absorption line profile

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Convection phenomenon in the star is responsible for a energy carrier in the interior and its atmospheric activity. The internal structure of stars depends on how the energy created by nuclear fusion is transported toward outer space. The sun, the nearest star for us, is a good target in terms of understanding the convection phenomenon of the star. In the case of the sun, the energy created in the core part is carried by radiative effect. In the outer part of 30 % of the radius, energy transport mechanism changes to convective motion. The convective motion penetrates to the solar surface, which is seen with visible light. It is the important energy source of the upper atmospheric heating and its dynamics. The solar surface convection is considered as a energy carrier for the outer atmosphere, however we are still lack of understanding it. The solar surface, the photosphere, is covered with numerous bright ”granules”, which are separated dark ”intergranular lanes”. The granular regions show going upward materials coming from the interior, while the intergranular regions represent going downward gas. Some authors have been tested the phenomenon with their numerical simulations, while an actual process to decelerate the gas motion is still unclear observationally. It is important to derive the height structure of velocity field because the deceleration is being caused during ascending gas motion. Nevertheless we are lack of observational velocity field with enough time- and spatial-resolution for this analysis.In this study, we investigated the height structure of velocity field, using the spectral data for the analysis of absorption line shape acquired with the Spectro-Polarimeter (SP) of the Hinode / Solar Optical Tele- scope (SOT). It is possible to derive the velocity field for continuous height in the photosphere, calculating Doppler velocity for each intensity in the absorption line. This method is based on the fact that observed light at each intensity reflects different height. Hinode/SP is suited to this analysis because it provides high signal-to-noise data contributing to good accuracy for shape of absorption line with high spatial resolution. Our result, focusing on the height structure difference between on granules and intergranular lanes, shows that materials going upward accelerate with height until a certain level and decelerate in the higher layer, while submerging materials accelerate with depth. The latter accelerating process is cannot explained by the conventional 1-dimensional steady model. We are going to discuss some candidates to solve it in my talk.

Keywords: convection, the sun

