

Form drag and the zonal mean velocity in a barotropic beta channel with a bottom topography

Keisuke Uchimoto[1]; Atsushi Kubokawa[1]

[1] Environmental Earth Sci., Hokkaido Univ

It is well known that form stress is exerted on fluid when fluid flows over the uneven bottom. It is thought that the form drag is the dominant momentum sink in the Antarctic Circumpolar Current. As form drag is apparently independent of the transport of the flow, the relationship between the transport and the form drag in equilibrium remains to be solved.

When the fluid over the uneven bottom in a channel ocean is accelerated by the surface wind stress, does the acceleration stop, and, if it stops, how much is the transport? In the present study we investigate this problem in one of the simplest system by numerical calculations. Since our focus is on the form drag, a barotropic quasigeostrophic beta channel with a sinusoidal bottom topography in which only form drag is the zonal momentum sink is used. The wind stress is spatially and temporally constant. As the transport is proportional to the zonal mean velocity in this system, we discuss the zonal mean velocity, U , instead of the transport.

The present study consists of two part. One is the numerical calculation in which the steady solution of the system is sought by the Levenberg-Marquardt-Morrison method (LMM). Since U is constant, we treat it as a parameter. The other is the numerical experiments in which the quiescent fluid is accelerated by the wind stress.

The LMM necessitates an initial guess, on which the obtained steady solution depends. First, the quasi-linear solution is calculated by using the inviscid exact solution as the initial guess. A critical U is found; the stable quasi-linear solution is not obtained for larger U than it. The critical U coincide with the phase speed (the absolute value of the phase velocity) of a wave whose wavenumber is larger than that of the bottom topography. This is possibly due to the resonance of the wave.

Two other kinds of steady solutions are found for larger U than the critical one by performing the numerical integration starting from the unsteady quasi-linear solution. One consists of symmetry modes and is unstable to asymmetry modes. The other consists of both symmetry and asymmetry modes and is stable. The latter includes two solutions whose symmetry modes are same but whose asymmetry modes are reverse in the sign. These two kinds of steady solutions results from one solution by the pitchfork bifurcation. These steady solutions are investigated for wide range of parameters (U , the coefficient of diffusion, the amplitude of the bottom topography). As the amplitude of the bottom topography is larger, the critical U moves to the phase speed of a higher mode. That is, the range of U where the stable quasi-linear solution exists is small. In any case, the branch of the solution is similar; the stable quasi-linear solution exists for smaller U than the critical one and two kinds of steady solution whose form drag is large exist for larger U . The resonant velocity with the bottom topography does not play an important role.

Next, the numerical experiments is performed. When the applied wind is small enough that the stable quasi-linear solution exists for the wind, the solution converges into the quasi-linear solution. In this case, the U of the solution becomes large as the applied wind increases. When the wind is large enough that no stable steady solution is found for the wind, the acceleration does not stop. When the wind is intermediate, the U of the solution is almost constant in many cases independent of the magnitude of the wind: near the critical U discussed in the part of the steady solution.

In conclusion, the zonal mean velocity of the channel ocean like the present one depends on the amplitude of the bottom topography and the coefficient of the diffusion rather than the wind stress, and is near one of the phase speeds of waves of higher modes for wide range of the wind. It is thought that the resonance of that wave makes large form drag.