# Energetics of ocean circulation with particular emphasis on the role of bottom relief

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In order to explain some oceanic phenomena, such as seasonal transport variations of the western boundary current, we must take into account the effect of bottom topography, such as continental slopes and ridges. Topographic effects on a rotating stratified ocean can be formulated in terms of joint effect of baroclinicity and bottom relief (JEBAR). In the vorticity equation for ocean circulation, the JEBAR term plays a part in extracting torques from the rotating solid earth, leading to interchanges between barotropic and baroclinic motions in the ocean. Since the vorticity form of JEBAR dose not seem to appeal to physical oceanographers, we have recently formulated the energetics of JEBAR and applied it to a wind-driven subtropical gyre.

The Kuroshio is produced by the planetary beta effect and closes the broad subtropical gyre in the North Pacific. If the gyre is driven only by the wind stress and the bottom is flat, the seasonal variation of the Kuroshio transport must be more than 50 Sv (1 Sv = 1 million cubic meter per second). However, observational results show an annual range of at most 10 Sv. This discrepancy was resolved by considering JEBAR. In this study, we reinterpret this result using our energetics. From numerical experiments using a simple two-layer model, we find that the energy conversion from potential energy to barotropic kinetic energy is very active over the bottom slope (modelling the Izu Ridge), and that the direction of conversion in winter is opposite to that in summer. In winter, when the wind is strong, barotropic kinetic energy is converted into potential energy, resulting in the reduction of the winter transport. On the other hand, in summer, when the wind is weak, this accumulated potential energy is released in the form of barotropic kinetic energy, so that the summer transport is maintained. As a consequence, the amplitude of the seasonal transport variation is decreased. We also confirm that the seasonal reversal of energy conversion and the resulting reduction of seasonal transport variation are not very dependent on the details of topography.

We may associate this conversion process with the process at the liquid-solid boundary, namely, the work done by the pressure gradient force at the bottom. Other forms of energy, such as mechanical energy of ocean earthquakes and geothermal heating, might also contribute to the oceanic motions, and easily included in the present energetics. Conversely, it is expected that a good deal of information on the dynamics at the ocean floor might be obtained by examining energy budgets of ocean circulation.