Wind-driven Ocean Circulations on Exoplanets. Weiwen Ji[1], Ru Chen[2], and Jun Yang[1],
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[Abstract] Over 3500 extrasolar planets have been discovered recently, and the critical question is which types of these exoplanets are potentially habitable. A variety of previous work concentrated on atmospheric dynamics and its effects on planetary climates. In this study, we expand the research by examining ocean dynamical regimes on exoplanets. As the first step of the project, using a one-layer shallow-water ocean model, we examine how planetary rotation rate, wind stress, fluid viscosity, ocean depth, ocean basin structure (closed or open in zonal direction) and surface gravity affect the pattern and strength of wind-driven ocean circulations on exoplanets. Our simulations demonstrate that in closed basins, planetary rotation rate and its variation in meridional direction (i.e., the beta effect) fundamentally determine the westward intensification and ocean pattern, and changes of other factors mainly contribute to enhancing or weakening it. For open ocean basins (with no west and east barriers, like the Antarctic Circumpolar Current region on our Earth), the ocean pattern is characterized by laminar flow and is more stable and hardly changes. We also compare the numerical results with analytic solutions for which the nonlinear advection terms are assumed to relatively small than other parts of the momentum equations. This work will improve our understanding of exoplanetary oceanography and provide important implications for studying the climates and habitability of exoplanets with oceans.

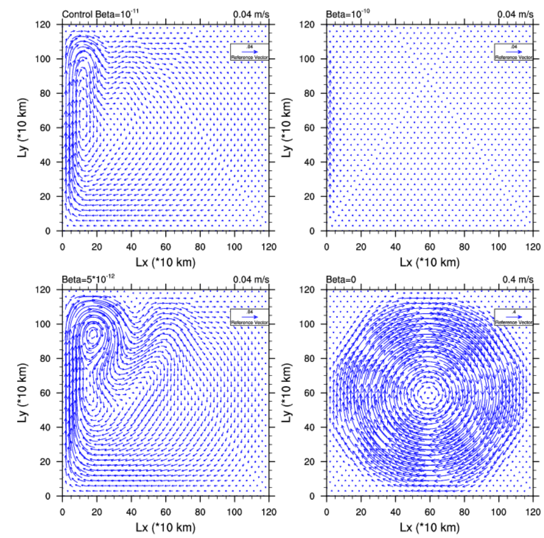

Figure 1. ocean circulation pattern and strength change with different β (assume the β plane approximation, $f = f_0 + \beta y$). Planets which rotate faster (i.e., larger β) show a more remarkable westward intensification and a slower flow rate. While on planets with faster rotation (i.e., smaller β), the flow rate increases and the advection will enhance, leading to the appearance of turbulence.