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Estimation of freshwater discharge into the Northeast Pacific from the Alaskan mountains
and its effects on the subtropical and equatorial ventilated thermocline
(アラスカ山岳地帯から北東太平洋への淡水流出の推定
および亜熱帯と赤道の通気水温躍層への影響)

The freshwater discharge from catchments along the Gulf of Alaska, termed Alaska discharge, is characterized by significant quantity and variability. Owing to subarctic climate and mountainous topography, the Alaska discharge variations may deliver possible impacts beyond the local hydrology. While short-term and local discharge estimation has been frequently realized, a longer time span and a discussion on cascading impacts remain unexplored in this area. In the first part of this study, the Alaska discharge during 1982–2022 is estimated using the Soil and Water Assessment Tool (SWAT). The adequate balance between the model complexity and the functional efficiency of SWAT suits the objective well, and discharge simulation is successfully conducted after customization in melting calculations and careful calibrations. During 1982–2022, the Alaska discharge is estimated to be $14,396 \pm 819 \text{ m}^3 \cdot \text{s}^{-1} \cdot \text{yr}^{-1}$, with meltwater contributing approximately 53%. Regarding variation in the Alaska discharge, the interannual change is found to be negatively correlated with sea surface salinity (SSS) anomalies in the Alaska Stream, while the decadal change positively correlates with the North Pacific Gyre Oscillation, with reasonable time lags in both cases. These new findings provide insights into the relationship between local hydrology and regional climate in this area. More importantly, this study provides rare evidence that variation in freshwater discharge may affect properties beyond the local hydrology.

Such freshwater discharge from subpolar lands may influence the ocean circulation of the Pacific Ocean. The subpolar waters are transported to the subtropical gyre via surface Ekman flow. Subsequently, warm water from low latitudes subsequently mixes with this subpolar surface water along the northern boundary of the subtropical gyre, and then subducts to the thermocline layers. This subducted water flows toward the equator and upwells, affecting sea surface temperature (SST). Thus, variations in the thermocline depth and structure

significantly influence the SST pattern, and consequently influence biological cycles and atmospheric variability in the tropical Pacific. While wind forcing is the primary driver for the thermocline circulation, other factors, such as the above-mentioned thermohaline processes caused by river discharges as well as the evaporation minus precipitation over the ocean, may also provide crucial influences.

Therefore, in the second part of this study, I focus on investigating whether and how surface freshwater from high-latitudes, especially from the Northeast Pacific Ocean, affects the equatorial thermocline. The Massachusetts Institute of Technology General Circulation model (MITgcm) is used to conduct numerical experiments without and with freshwater forcing under various freshwater scenarios. These experiments examine the changes in temperature, salinity, and density distributions, and their effects on the equatorial thermocline. The control experiment, without freshwater, indicates that warm water in the northern subtropical gyre is cooled by heat release from the ocean to the atmosphere and subducts into the subsurface, where it flows along isopycnal surfaces toward the equator and upwells in the eastern equatorial Pacific, contributing to the formation of the cold tongue and an east-west slope in the thermocline. In the freshwater experiments, freshwater fluxes driven by evaporation minus precipitation and boundary freshwater discharge enhance the variability in SSS, with significant freshening in the subpolar gyres. These variations in salinity also affect subsurface thermal structures in the subtropical gyre, and consequently results in warming at depths of 200-400 m in the equatorial Pacific. Especially, in extreme freshwater scenarios, driven by the collapse of the Cordilleran Ice Sheet (CIS) into the northeast Pacific, substantial changes of salinity and temperature are observed in both hemispheres. In the North Pacific, low-salinity and cooled water is transported southward, primarily contributing to cooling in the upper layers of the western equatorial Pacific, while the relatively high temperature and salinity in the South Pacific contribute to a warming in the whole equatorial thermocline. Furthermore, the study reveals that increased freshwater input weakens the east-west SST gradient and deepens the equatorial thermocline, causing an El Nino-like state. Thus, these findings suggest that freshwater from the subpolar gyre has a potential to significantly affect the equatorial thermocline, which may influence both regional and global climate systems.

Overall, this study presents the reasonable estimation of freshwater discharge from the Alaska drainage basins using a hydrological model and explores the potential relationship between this discharge and atmospheric variability, and its effects on the SSS. Furthermore, with the help of an ocean circulation model, the findings highlight the effects of the freshwater from the subpolar lands on equatorial thermocline and the underlying mechanisms, especially in the case of an extremely large freshwater discharge due to an ice sheet collapse.