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学　位　論　文　要　旨
Dissertation Summary

氏　　　名　(Name) 董孟洪

論　文　名：　Intra-tidal and inter tidal characteristics of a tidal front in the Seto Inland Sea
(Dissertation Title)

An arc-like tidal front near a strait in the Bungo Channel of the Seto Inland Sea is located between the mixed water on the northern side near the strait and the stratified water on the southern side in the channel. The intra-tidal and inter tidal variations of the tidal front were analyzed using five-year satellite sea surface temperature (SST) data, two field observations, and a numerical model.

The satellite SST data were obtained from the geostationary meteorological satellite Himawari-8 from April 2016 to August 2020, and have a spatial resolution of 2 km and a temporal interval of 1 h. A gradient-based front detection method was utilized to define the position and intensity of the front. After knowing the basic features of intra-tidal variations of the front, the distance of a virtual particle that moves with the tidal current synthesized from the harmonic constants of four major tidal constituents at the strait, was calculated to examine the relationship between the tidal current and the movement of the front. To test a hypothesis that the intra-tidal movement of the front depends on the background residual current, which changes with months and with the spring-neap tidal cycle, a composite satellite SST dataset that consisted of data at the same tidal phase was utilized to study the spring-neap tidal cycle variations of the tidal front and whether these variations change with months.

In July 2021, two field observations were conducted in the Bungo Channel during the spring and neap tide respectively to clarify the change in the vertical structure of the tidal front within a tidal cycle and the spring-neap tidal cycle using a new type of Conductivity-Temperature-Depth (CTD) system. We obtained four vertical sections of water temperature and salinity, and an SST dataset in four-second intervals along the sections during the observation period. The numerical model study was conducted utilizing the Massachusetts Institute of Technology general circulation model (MITgcm). The nonlinear

Smagorinsky viscosity scheme and nonlocal K-Profile Parameterization (KPP) scheme were used to parameterize horizontal and vertical sub-grid-scale mixing. Various sensitive simulations were performed to determine the key parameters used in the model for the parameterization schemes.

First, hourly satellite SST data and numerical simulations confirmed the theoretical intra-tidal movement of the tidal front, which is mainly controlled by tidal current advection. During a semidiurnal tidal cycle, the movement of the front corresponds with the ebb and flood currents. Notably, the intensity of the front increases as the front becomes steeper in the vertical direction during the ebb current phase, which carries the front toward the stratified area; however, it decreases when the front becomes flattened in the vertical direction during the flood current phase, which drives the front in the opposite direction. We found that the tidal current convergence (divergence) in the direction across the tidal front is likely to cause front intensification (weakening) during the ebb (flood) current phase; the tidal front structure changes in the vertical direction mainly occur due to the effect of tidal straining, which drives convective mixing when the heavy water from the mixed area is brought over the light water in the stratified area during the ebb current phase, and suppresses the vertical mixing when the light water is sheared from the stratified area to the mixed area during the flood current phase.

Second, the intra-tidal variations of the tidal front appear in a spring-neap tidal cycle. The larger intra-tidal variation in the intensity of the front during spring tide compared to that during neap tide can likely be attributed to the larger spatial variations of the tidal current (i.e., a larger convergence and divergence) during the spring tide than during the neap tide.

Finally, the spring-neap tidal cycle variations of the tidal front are dependent on the month when changes in the background stratification and residual current occur. The residual current in the Seto Inland Sea has a two-layer structure during summer. In April, the residual current is weak and exhibits a northward flow in the surface layer and a southward flow in the bottom layer. Due to the weak residual current, the change in the tidal front position during the spring–neap tidal cycle is mainly controlled by the stirring power produced by tidal currents. Consequently, the area of the mixed water is larger and the front is farther from the strait during the spring tide than during the neap tide. From May through August, due to increased stratification and river water input, the residual current gradually changes to southward in the surface layer and northward in the bottom layer. During this period, particularly after a heavy rain period around the end of June, the two-layer current and stratification are intensified. The enhanced stratification in July limits the spreading of the tidal front during the spring tide, consequently reducing the movement range of the front between the spring and neap tides. The background residual current also has a spring-neap tidal cycle that is stronger during the neap tide than during the spring tide. Consequently, the tidal front moves farther south during the neap tide than during the spring tide in July.