Validation of JCOPE-T 1ks Water Quality Estimation Accuracy in Coastal Areas

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The JCOPE-T 1ks, a higher-resolution version of JCOPE-T DA, directly reflects the characteristics of the numerical physical model in coastal areas shallower than 200 meters without being constrained by JCOPE-T DA, which assimilates satellite observations and other data. Consequently, the water temperature and salinity estimated by JCOPE-T 1ks may not always accurately reproduce real-world conditions in coastal areas. To evaluate its accuracy, this study focuses on large-scale river discharge events, which are particularly challenging to simulate. The precision of JCOPE-T 1ks in coastal areas was assessed through: (1) a comparison of the spatial distribution of water temperature and salinity using GCOM-C/SGLI ocean standard products, and (2) a time-series comparison with water quality monitoring data from the Tokyo Bay Monitoring Post.

1. Comparison of the Spatial Distribution of Water Temperature and Salinity in Coastal Areas of Japan Using SGLI Ocean Standard Products

This study evaluates the spatial distribution of sea surface temperature (SST) and sea surface salinity (SSS) estimated by JCOPE-T 1ks in comparison with SGLI ocean standard products focusing on two large-scale river discharge events.

For SST, since SGLI has thermal infrared bands capable of direct SST observation [1], validation was conducted by directly comparing the SST estimates from JCOPE-T 1ks with SGLI observations. In contrast, SSS cannot be directly measured by SGLI. Therefore, validation was performed by comparing the SSS estimates from JCOPE-T 1ks with the absorption coefficient of colored dissolved organic matter at 412 nm (a_{CDOM}(412nm)), an ocean standard product of SGLI.

a_{CDOM}(412nm) represents the light absorption coefficient at a wavelength of 412 nm for Colored Dissolved Organic Matter (CDOM), which has the characteristic of absorbing light in the short visible wavelength range. This parameter can be observed using ocean color sensors, including SGLI [2]. In coastal areas, CDOM is predominantly of terrestrial origin, introduced through river discharge. Due to its recalcitrant nature and conservative behavior, it exhibits a strong negative correlation with salinity, making a_{CDOM} a widely used tracer for freshwater inflow [3][4].

Case 1: Heavy Rainfall Event in the Kanto-Tohoku Region Induced by Typhoon No. 13 from September 7 to September 9, 2023

ｉ)Sea Surface Temperature

Figure 1 illustrates the spatial distribution of SST observed by SGLI and the SST estimated by JCOPE-T 1ks off the coast of the Tohoku region on September 10, 2023, immediately following the passage of Typhoon No. 13. Within approximately 3 km from the coast, where river discharge has a significant influence, JCOPE-T 1ks exhibits a tendency to underestimate SST. This underestimation is likely due to the lower-than-actual river water temperature used as a boundary condition in JCOPE-T 1ks.Furthermore, the SST frequency distribution for individual grid points shown in Figure 2 confirms an overall underestimation of approximately 1° C. In JCOPE-T 1ks, river water temperature is set based on near-surface air temperature values from the NCEP-GFS. Moving forward, the JCOPE research group plans to further investigate this issue and consider modifications such as incorporating land water temperature data or adjusting the sea surface temperature of grid points in front of river mouths.

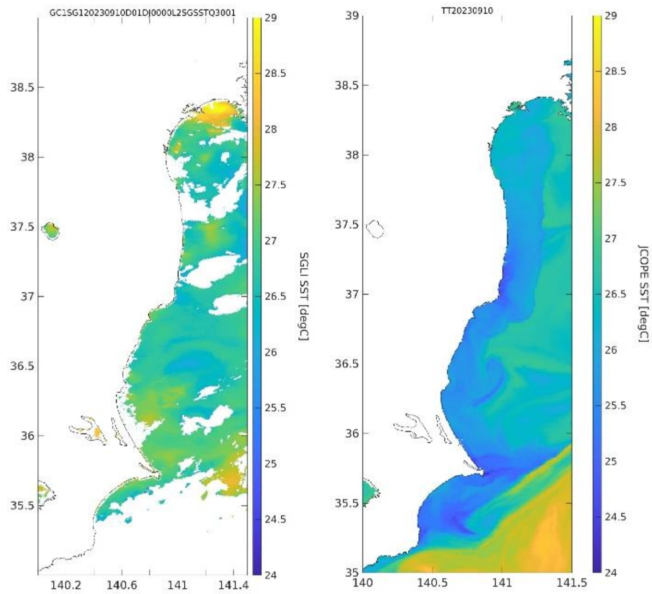

Figure 1: Spatial distribution of Sea Surface Temperature (SST) off the Tohoku region on September 10, 2023 (Left: SGLI observations, Right: JCOPE-T 1ks estimates)

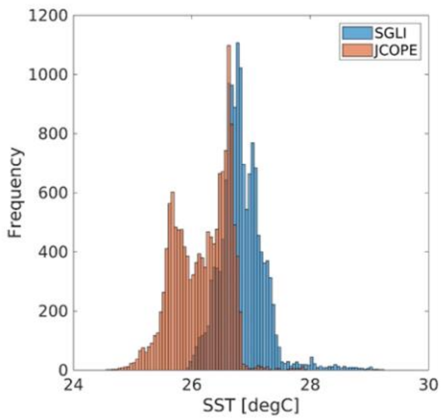

Figure 2: Frequency distribution of Sea Surface Temperature (SST) off the Tohoku region on September 10, 2023 (Red: SGLI observations, Blue: JCOPE-T 1ks estimates)

ii)Sea Surfae Salinity

Figure 3 presents the spatial distribution of a_{CDOM}(412nm) observed by SGLI and SSS estimated by JCOPE-T 1ks off the coast of the Tohoku region on September 10, 2023. The river plume front shows good agreement between the two datasets. In particular, in areas where a_{CDOM}(412nm) values are high, such as off the coast of Sendai and near the mouth of the Tone River, the SSS estimated by JCOPE-T 1ks falls below 30 PSU, indicating that the model appropriately captures the spatial distribution of salinity.

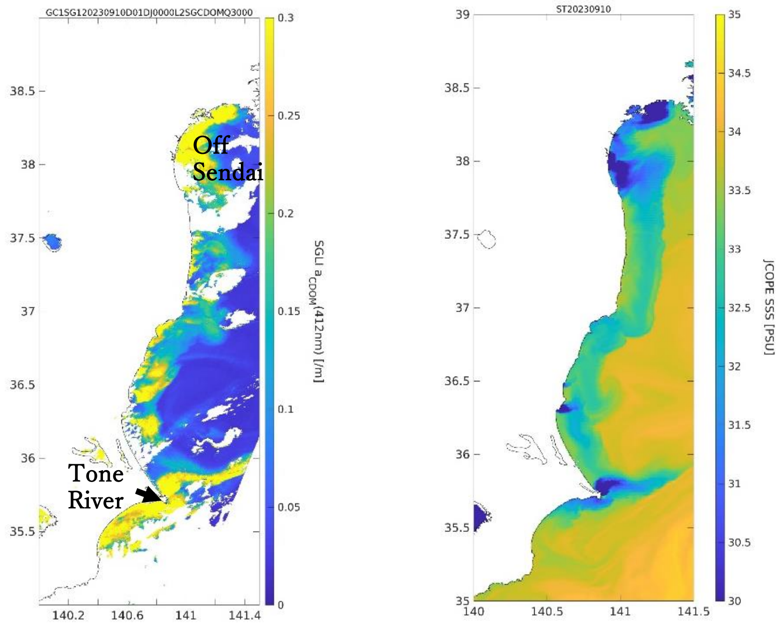

Figure 3: Spatial distribution off the Tohoku region on September 10, 2023 — SGLI-derived a_{CDOM}(412 nm) observations (Left) and JCOPE-T 1ks-estimated SSS (Right)

<u>Case 2: Heavy Rainfall Event in the Kyushu-Kanto Region Induced by Typhoon No. 10 from August 27 to September 2, 2024</u>

i) Sea Surface Temperature

Figure 4 presents the spatial distribution of SST observed by SGLI and estimated by JCOPE-T 1ks in the Kanto-Chubu region on September 7, 2024. Similar to Case 1, JCOPE-T 1ks exhibits a tendency to underestimate SST in semi-enclosed bays such as Tokyo Bay and Ise Bay. However, overall, a high degree of spatial agreement is observed. In fact, the scatter plot and frequency distribution shown in Figures 5 and 6 confirm a strong correlation between the datasets.

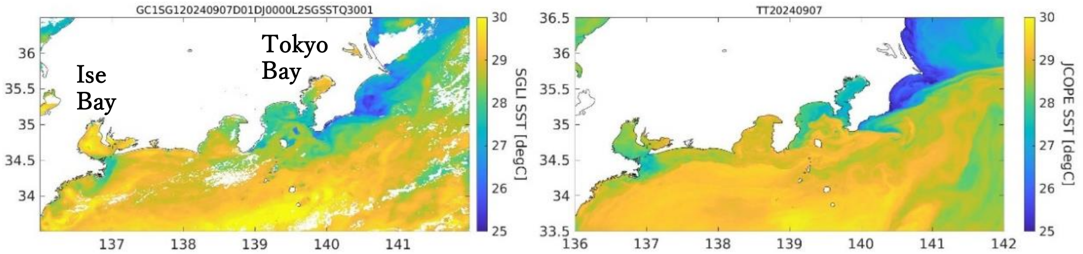

Figure 4: Spatial distribution of SST over the Kanto–Chubu region on September 7, 2024 (Left: SGLI observations, Right: JCOPE-T 1ks estimates)

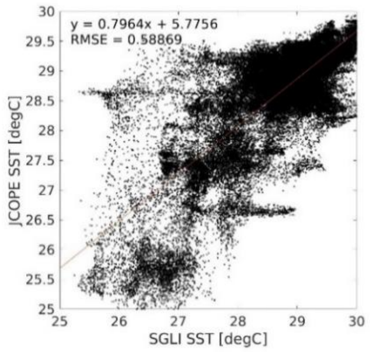

Figure 5: Scatter plot of SST over the Kanto–Chubu region on September 7, 2024

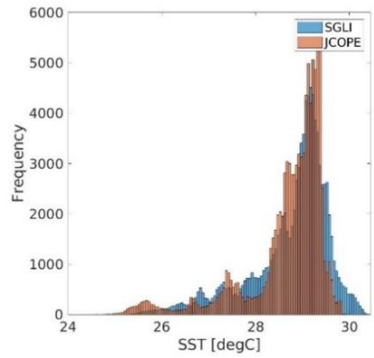

Figure 6: Frequency distribution of SST over the Kanto–Chubu region on September 7, 2024 (Blue: SGLI observations, Red: JCOPE-T 1ks estimates)

ii)Sea Surface Salinity

Figure 7 presents the spatial distribution of a_{CDOM}(412nm) observed by SGLI and the SSS estimated by JCOPE-T 1ks in the Kanto-Chubu region on September 7, 2024. Notably, in Tokyo Bay and Ise Bay, the concentration gradients of a_{CDOM}(412nm) and SSS exhibit a strong agreement. it indicates that JCOPE-T 1ks can successfully reproduce the detailed spatial distribution within small semi-enclosed bays.

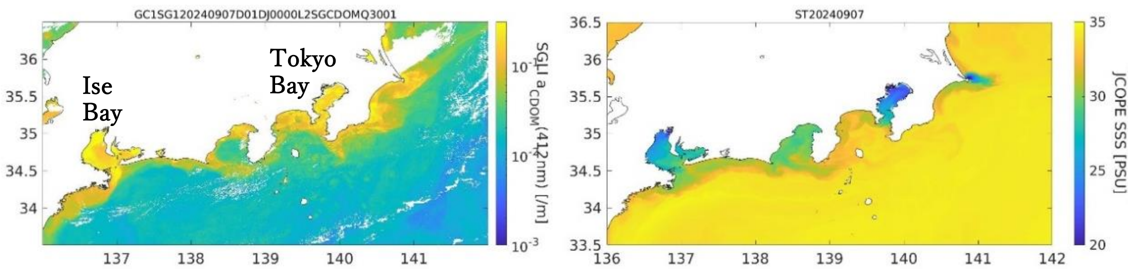

Figure 7: Spatial distribution over the Kanto–Chubu region on September 7, 2024 — SGLI-derived a_{CDOM}(412 nm) observations (Left) and JCOPE-T 1ks-estimated SSS (Right)

2. Time-Series Comparison of Water Temperature and Salinity Using Water Quality Observations from the Tokyo Bay Monitoring Post

Monitoring posts have been established at four locations in Tokyo Bay: (i) Kemigawa Offshore (35.61° N, 140.02° E), (ii) Chiba Port Entrance No.1 Light Beacon (35.54° N, 139.95° E), (iii) Kawasaki Artificial Island (35.49° N, 139.83° E), and (iv) Urayasu Offshore (35.64° N, 139.94° E) (Figure 8). These monitoring posts conduct continuous 24-hour observations of water quality, meteorological conditions, and current flow, with real-time observation data publicly available online (https://www.tbeic.go.jp/MonitoringPost/top).

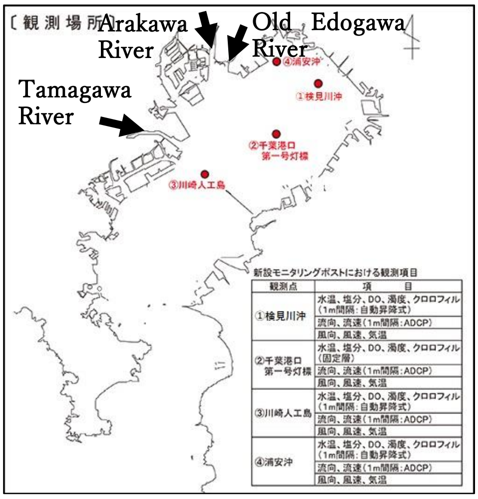

Figure 8: Monitoring post observation sites and major inflowing rivers in Tokyo Bay (https://www.pa.ktr.mlit.go.jp/wankou/overview/monitoring/index4.html)

In this section, time-series validation results for JCOPE-T 1ks water temperature, salinity, and current flow (east-west current velocity (U), north-south current velocity (V)) are presented, using water quality observations from the Tokyo Bay Monitoring Posts. The analysis focuses on the same river discharge event as in section1-Case 2.

Figure 9 illustrates a time-series comparison of river discharge from the inflowing rivers into Tokyo Bay (Arakawa, Edogawa, and Tamagawa), sea surface wind speed, water temperature, salinity, east-west current velocity, and north-south current velocity at each monitoring location from August 28 to September 11, 2024. It should be noted that the in-situ data from the monitoring posts represent measurements at a depth of approximately 1 m, whereas the JCOPE-T 1ks estimates correspond to surface values at 0 m.

ｉ) Sea Surface Temperature:

At all locations, a maximum underestimation of 3° C was observed, similar to the validation results of section1-Case 2. This underestimation is likely attributed to the lower river water temperature prescribed as a boundary condition in JCOPE-T 1ks.

ii) Sea Surface Salinity (SSS):

At all locations, the decreasing trend in salinity due to river discharge was successfully reproduced; however, an overall overestimation tendency was observed. In particular, at Urayasu Offshore, located near the mouths of the Arakawa and Old Edogawa Rivers, and at Kawasaki Artificial Island, near the mouth of the Tamagawa River, discrepancies were noted

in the timing of salinity decrease. Additionally, due to the relatively low freshwater inflow from these rivers, the post-discharge salinity estimates were significantly overestimated.
On the other hand, at Kemigawa Offshore, located in the innermost part of the bay, an increase in salinity was observed on September 4, associated with coastal upwelling induced by northerly winds. Although there are still challenges in accurately estimating salinity variations due to river discharge, the general trend was reasonably well captured. These findings suggest that the high-resolution analysis provided by JCOPE-T 1ks enables the reproduction of small-scale oceanographic phenomena in coastal regions that were previously difficult to resolve.

ⅲ) Horizontal current components (U, V):

The analysis at three locations, Kemigawa Offshore, Chiba Port Entrance No.1 Light Beacon, and Urayasu Offshore, confirmed that relatively accurate estimations of both east-west and north-south current velocities are achievable, despite the presence of partial phase inversions in some cases. On the other hand, for the north-south current velocity (V) near the Kawasaki artificial island, an overestimation was observed during the period of southerly winds from August 27 to September 3, while an underestimation occurred during the northerly winds from September 3 to September 6. The maximum error observed reached approximately 0.5 m/s. One possible cause of this discrepancy is the overestimation of sea surface wind speeds in the NCEP-GFS data, which serve as boundary conditions for the JCOPE-T 1km.

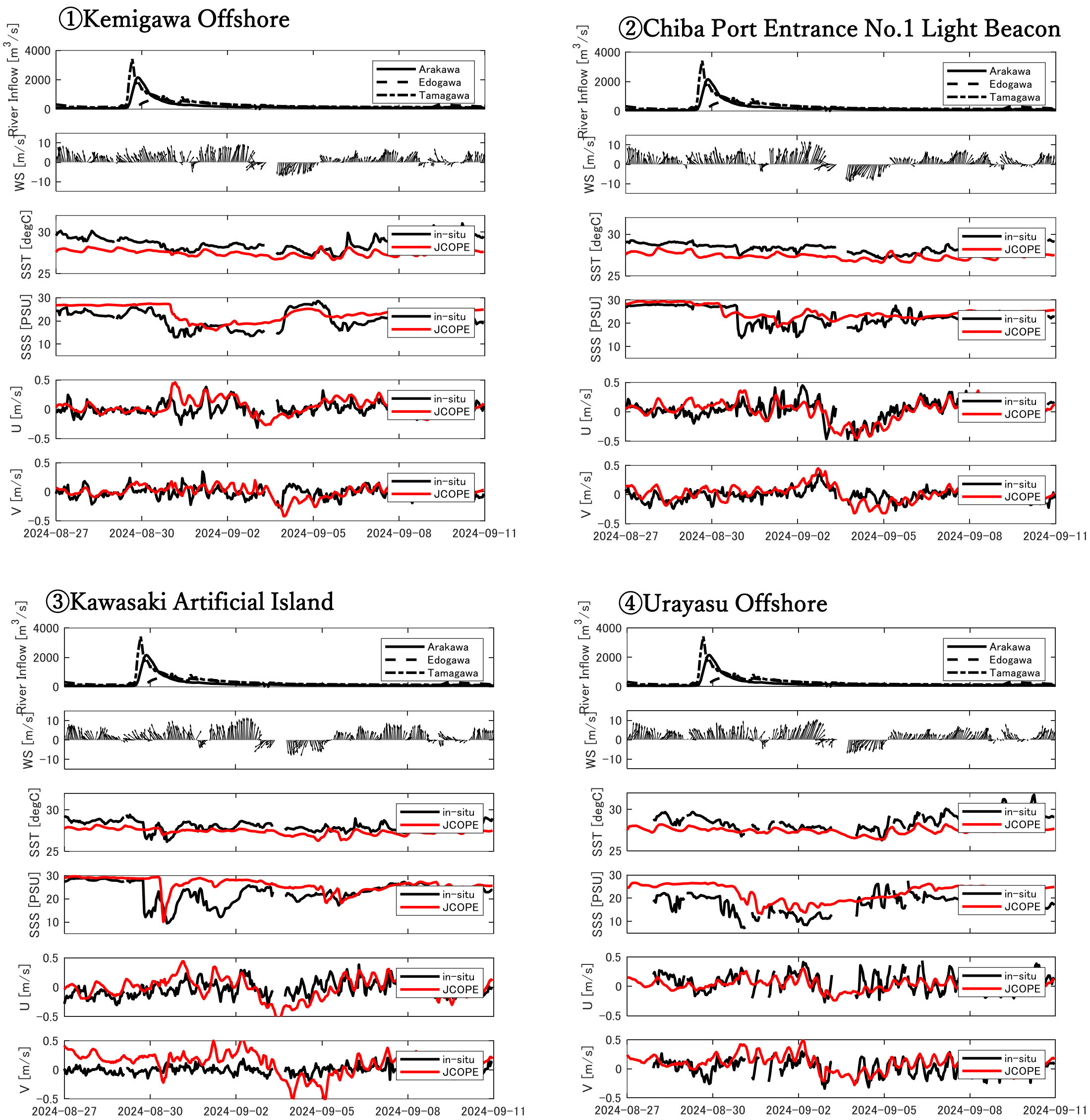

Figure 9: Time series comparison from August 28 to September 11, 2024, of river discharge into Tokyo Bay and wind speed, water temperature, salinity, eastward velocity, and northward velocity at each monitoring post (①: Kemigawa Offshore, ②: Chiba Port Entrance No.1 Light Beacon, ③: Kawasaki Artificial Island, ④: Urayasu Offshore) (Black: in-situ, Red: JCOPE-T 1ks estimates)

Conclusion

The estimation of SSS using JCOPE-T 1ks successfully reproduced the salinity reduction trends induced by river discharges in both spatial and temporal distributions. In particular, in semi-enclosed bays such as Tokyo Bay and Ise Bay, the model was able to capture detailed horizontal gradients and upwelling phenomena in the inner bay regions, which were difficult to resolve with conventional model resolutions. These high-resolution analysis results provided by JCOPE-T 1ks are expected to be utilized as a valuable tool for delivering ocean condition information to coastal environmental conservation and to the fisheries sector.

However, the prediction accuracy remains insufficient. Notable issues include underestimation of SST, overestimation of SSS, and overestimation of surface current velocities, all of which are attributed to errors in the boundary conditions. Moving forward, the JAXA-JAMSTEC JCOPE group will continue research and development aimed at improving the water quality forecasting performance of JCOPE-T 1ks, including a reassessment of the boundary conditions.

Reference

[1] Kurihara, Yukio, et al. "A quasi-physical sea surface temperature method for the split-window data from the Second-generation Global Imager (SGLI) onboard the Global Change Observation Mission-Climate (GCOM-C) satellite." *Remote Sensing of Environment* 257 (2021): 112347.

[2] Takafumi, Hirata and Yohei, Yamashita "Derivation of the absorption coefficient of Colourd Dissolved Organic Matter (CDOM)" *SGLI Algorithm Technical Background Document* (2020).

[3] Keith, Darryl J., Ross S. Lunetta, and Blake A. Schaeffer. "Optical models for remote sensing of colored dissolved organic matter absorption and salinity in New England, Middle Atlantic and gulf coast Estuaries USA." *Remote Sensing* 8.4 (2016): 283.

[4] Hiroto, Higa, et al. "ESTIMATION OF SALINITY DISTRIBUTIONS BASED ON THE OPTICAL PROPERTY OF COLOR DISSOLVED ORGANIC MATTER BY THE GEOSTATIONARY OCEAN CLOLOR SATELLITE IN TOKYO BAY" J.JSCE, Ser.B2, Coastal engineering 73.2 (2017): I_1237-I_1242.