Applications of Satellite Ocean Color Products in HYCOM Model Simulations

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Introduction

- Solar radiation is an important factor for sea surface temperature (SST) variations and ocean mixed-layer dynamics. The penetration of the solar radiation in the upper oceans highly depends on the ocean turbidity. Currently, the Hybrid Coordinate Ocean Model (HYCOM) uses the climatology of the diffuse attenuation coefficient for the downwelling photosynthetically available radiation (PAR), K_d(PAR), to formulate the solar radiation heating in the upper ocean. However, the high-frequency and seasonal and inter-annual variability of ocean turbidity is generally significant due to biological activities and sediment transportation.
- In this study, K_d(PAR) derived from the Visible Infrared Imaging Radiometer Suite (VIIRS) on board the Suomi National Polar-orbiting Partnership (SNPP) are used to study the sensitivity of SST and ocean mixed-layer dynamics to K_d(PAR) variations in HYCOM simulations in the western Pacific Ocean.

K_d(PAR) and Mixed-Layer Depth Variations in the Western Pacific Ocean

- VIIRS-derived K_d(PAR) shows significant seasonal variations in 2013: very low K_d(PAR) is found in summer, and high in spring and winter. Spatially, K_d(PAR) and its variations are larger in coastal oceans than those in open oceans (Figs. 1 & 2).
- K_d(PAR) variations affect the SST by subsurface heating below the mixed-layer. Lower K_d(PAR) usually results in cooler SST, because less solar irradiance is absorbed within the mixed-layer. If the mixed-layer is too deep, K_d(PAR) has little effect on the SST. Fig. 3 shows the climatology mixed-layer depth of the area of study in January and July (from World Ocean Atlas 1994).

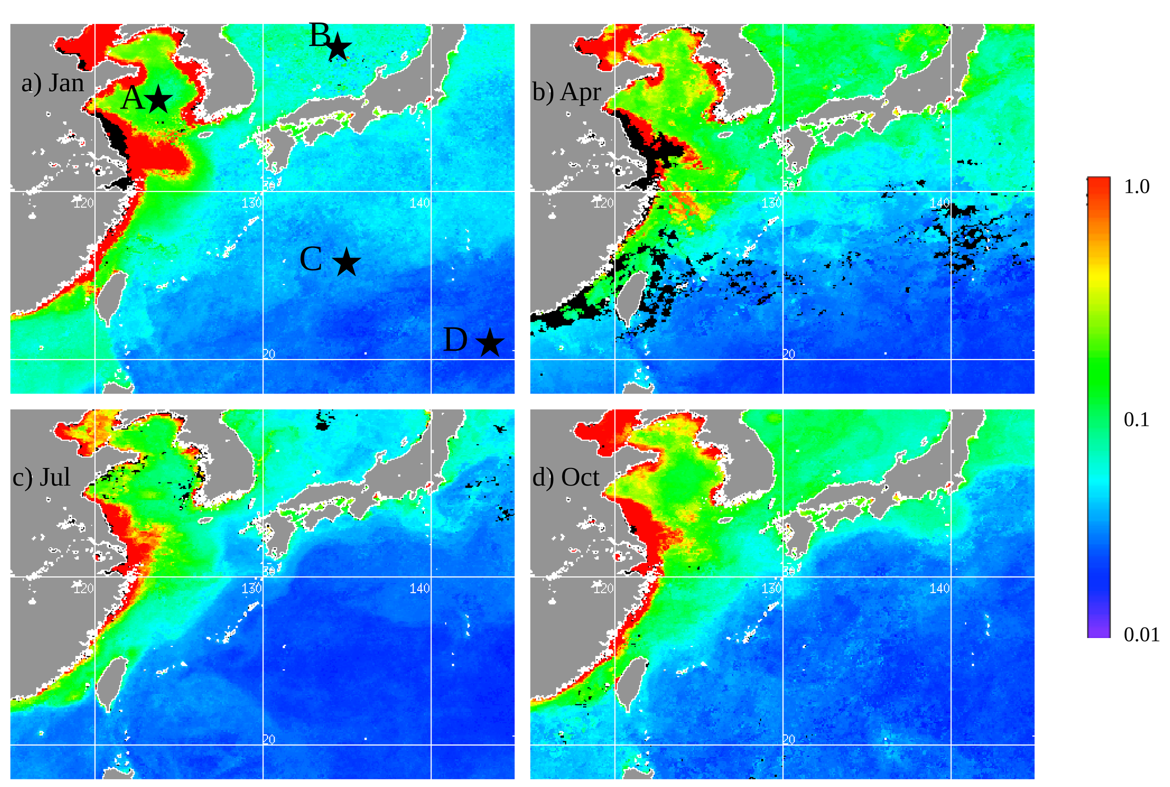

Figure 1. VIIRS-derived monthly-averaged K_d(PAR) in (a) January, (b) April, (c) July, and (d) October of 2013 in the western Pacific Ocean (unit: m^{-1}).

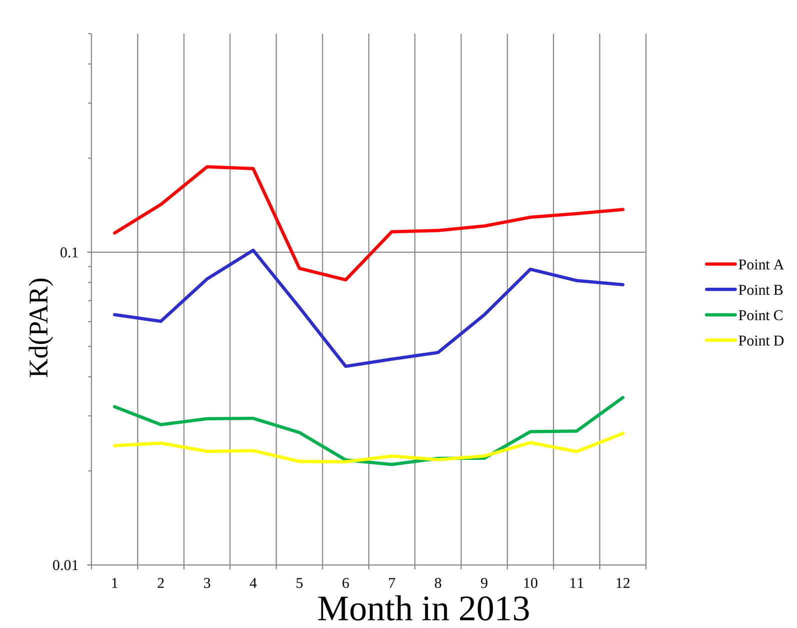

Figure 2. Time series of monthly K_d(PAR) of 2013 for the four locations marked as A, B, C and D in Figure 1(a). While seasonal variations are significant in all four points, variations at points A and B are larger than points C and D.

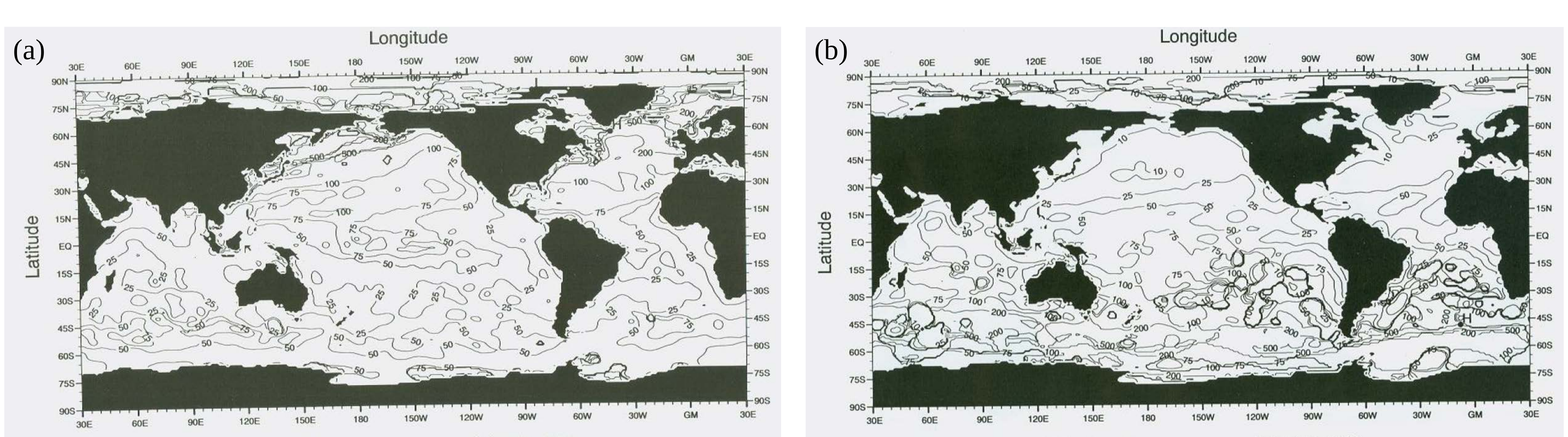

Figure 3. Climatology mixed-layer depth in (a) January and (b) July from the World Ocean Atlas (Monterey and Levitus, 1997). Since the mixed-layer is shallow (~10 m), and K_d(PAR) is low in summer, significant subsurface heating are anticipated in the western Pacific Ocean.

HYCOM Simulations

- VIIRS climatology and 2013 monthly-averaged K_d(PAR) are used to drive HYCOM in two simulations, A and B, respectively, while all other model settings are kept the same.

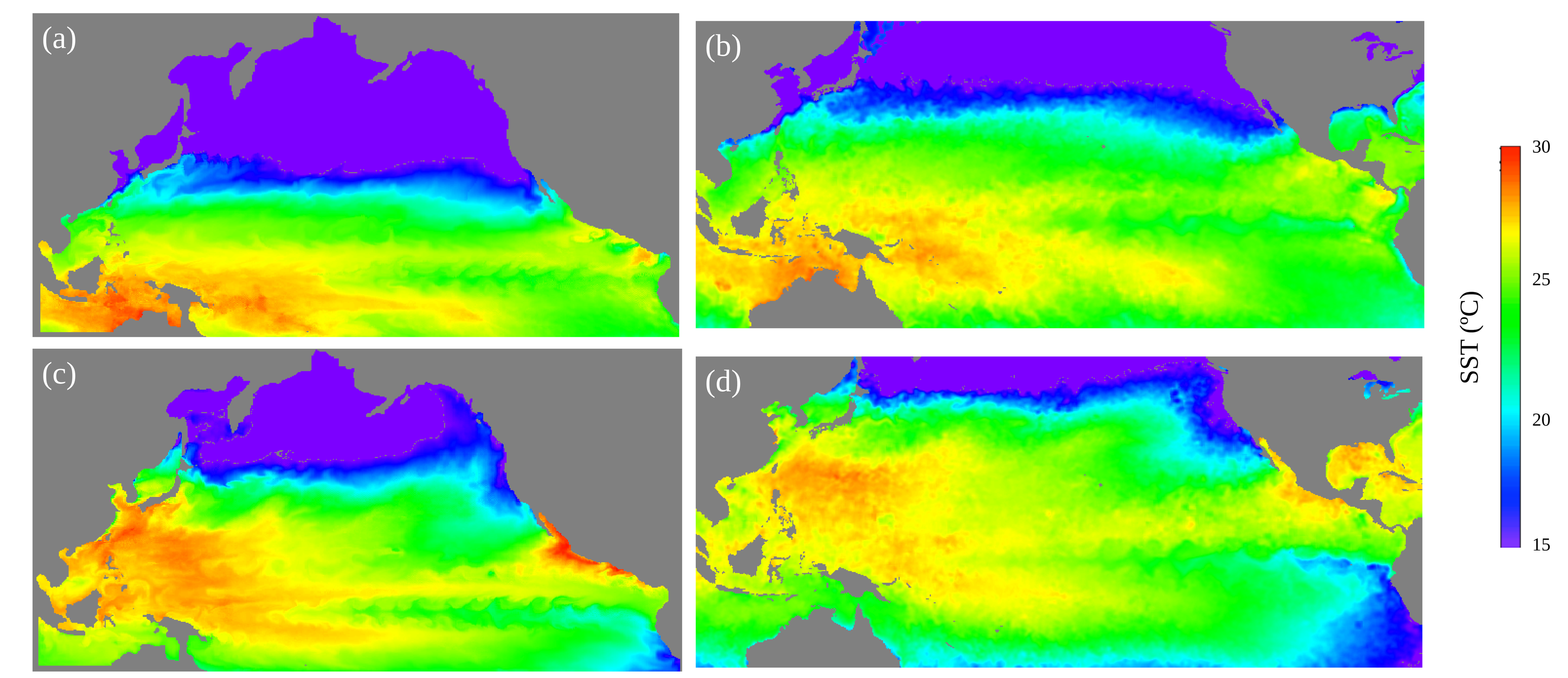

Figure 4. Comparison of model SST (a & c) and Reynolds SST (b & d) in January (a & b) and July (c & d) of 2013. SST is overestimated in model simulations in summer in the tropical western and tropical Pacific ocean.

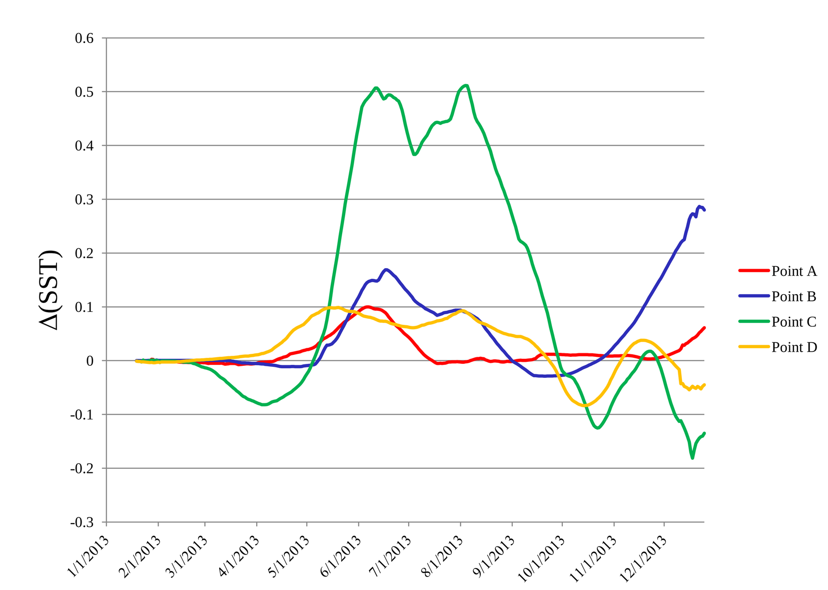

Figure 5. Difference of SST (simulation A – simulation B) at points A, B, C, and D. Monthly K_d(PAR) in 2013 produces cooler SST at all four points in summer, and the most significant effect is found near Point C (~0.5 ºC).

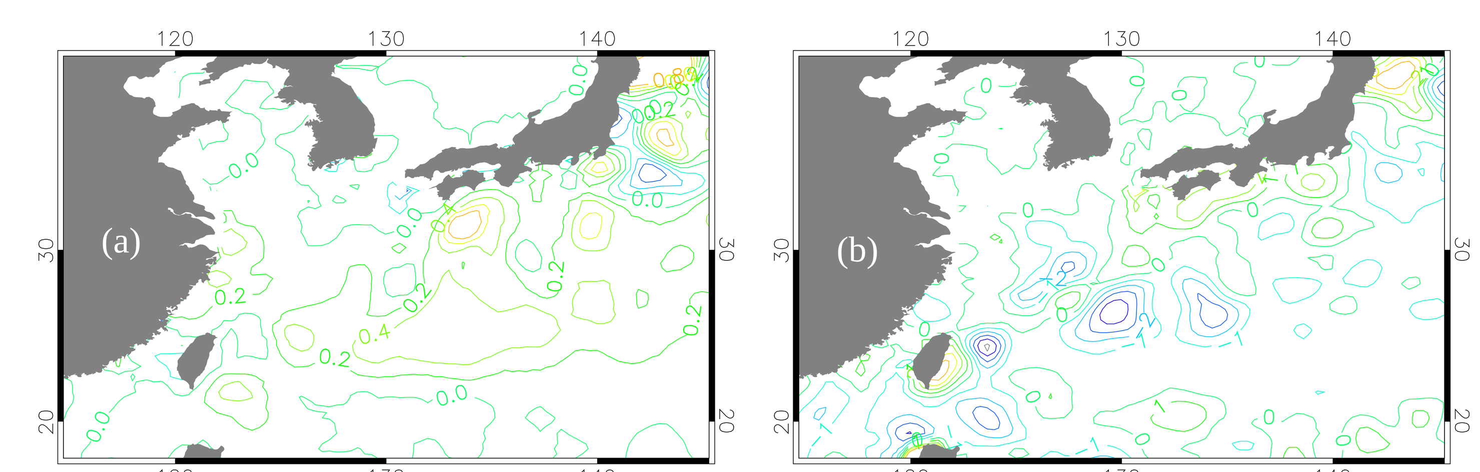

Figure 6. Difference of (a) SST and (b) mixed-layer depth (simulation A – simulation B) in July 2013. Using 2013 monthly-averaged K_d(PAR), HYCOM produced cooler (> 0.4 ºC) SST and deeper mixed-layer than using climatology K_d(PAR) in the region south of Japan. However, the effect is not significant in the marginal seas, such as Yellow Sea and Bohai Sea. This is because solar irradiance is almost completely absorbed within the mixed-layer in the marginal seas due to large K_d(PAR) values, and resulting very little subsurface heating.

Conclusions

- Monthly-averaged K_d(PAR) in 2013 shows significant seasonal variations in the western Pacific Ocean, and subsurface heating below mixed-layer occurs in summer when the mixed-layer is shallow (10–20 m) in the region south of Japan.
- Sensitivity tests in HYCOM using the climatology and 2013 monthly averaged K_d(PAR) show that 2013 monthly averaged K_d(PAR) produced significant cooler (~0.5 ºC) SST than that using climatology K_d(PAR) in the region south of Japan in summer of 2013. The effect is less significant in winter due to deep mixed-layer.
- Spatially, although K_d(PAR) varies significantly in the marginal seas, such as the Bohai Sea and Yellow Sea, it has little effect on the SST and mixed-layer depth. Because of large K_d(PAR) values in the marginal seas, solar irradiance is almost completely absorbed within mixed-layer, and very little subsurface heating occurs.
- The impact of high-frequency (weekly and daily) K_d(PAR) variations on the SST and mixed-layer needs to be further investigated.

Acknowledgements

HYCOM source code was downloaded from its website: https://hycom.org/, and Reynolds SST data were downloaded from http://www.ncdc.noaa.gov/sst/.