EFFECTS OF SPRING-NEAP TIDES ON THE SEA SURFACE CHLOROPHYLL-A IN RELATION TO THE KUROSHIO PATH MODULATION DURING 2006-2021

TUMSAT

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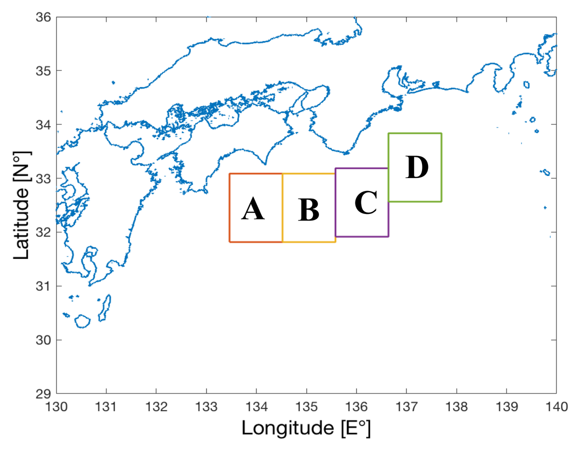
1. INTRODUCTION

Tides are one of the most important hydrodynamic processes and have proved their substantial effect not only on the sea surface but also in the ocean interior. A previous study using satellite data has suggested that the spring-neap tide results in variations of primary production with a fortnightly period in different areas, suggesting that the tidal mixing induced nutrient supply stimulates the phytoplankton increase. However, it remains unclear whether the fortnight chlorophyll-a (Chl-a) modulations can also be seen in the south coast of Japan, where the Kuroshio nutrient stream transports vital nutrients for phytoplankton in the dark subsurface layers. Lizarbe et al. (2021) showed enhanced Chl-a during the Kuroshio Large Meander (KLM) on the western side of the meander. However, the mechanism of increased Chl-a is still unknown. In this study, we analyze the temporal variabilities of Chl-a to investigate the influence of fortnightly modulating tide that could induce tidal mixing, injecting the nutrients of the Kuroshio nutrient stream to sunlit layers.

Objective: To elucidate the fortnightly tidal effects on Chl-a and their spatiotemporal variations associated with the Kuroshio path modulations.

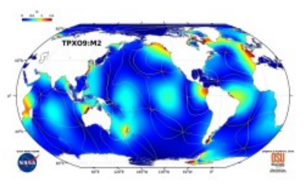
2. DATA AND METHODS

Study Areas



Study Periods:
- No Large Meander (NLM) 2006 - 2016
- Large Meander (LM) 2017 - 2021

Copernicus Marine Service

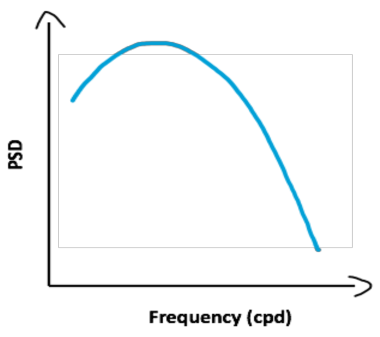


Data sets

- Sea Surface Chlorophyll-a (Chl-a): Ocean Color reprocessed L4 observations CMEMS
- Sea Surface Height (SSH): Global Ocean Physics Reanalysis L4 CMEMS (2006-2019) and Global Ocean Physics Analysis and Forecast (2020-2021)
- Tidal Amplitude (TA): TPXO9 Global Tidal Models (Egbert and Svetlana, 2002)

Methods

1. Chlorophyll-a Power spectral density
2. Hovmoller Plot of Chl-a power spectra
3. Coherence square between Chl-a and TA
4. Phase spectrum between Chl-a and TA
5. Spectral variance of Chl-a between 1/14 cpd
6. Ratio of tidal (1/20-1/10 cpd) variance to total variance of chlorophyll-a

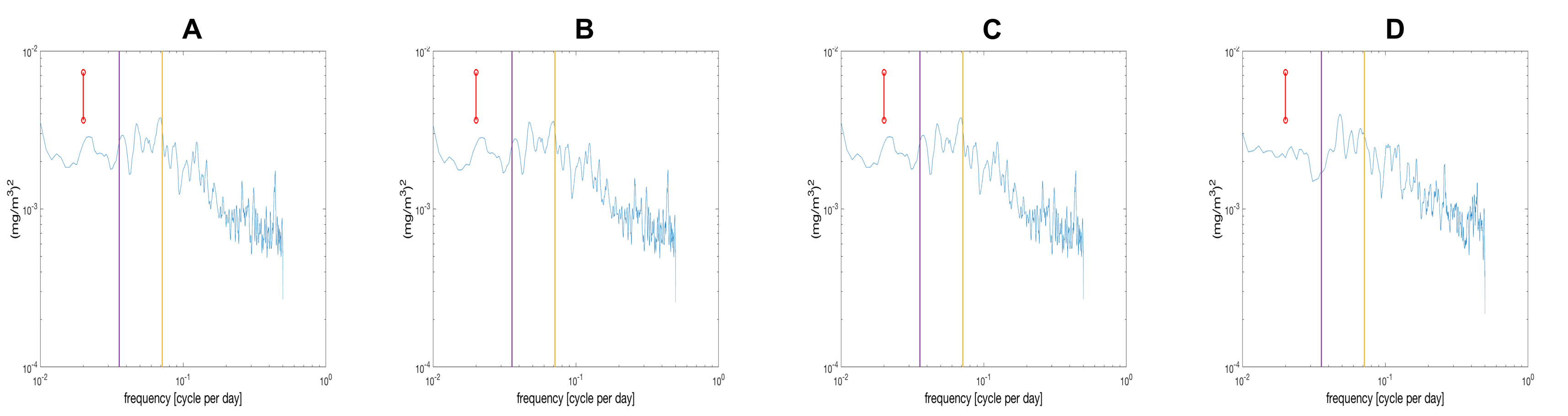


$$C_{xy}(f) = \frac{|P_{xy}(f)|^2}{P_{xx}(f)P_{yy}(f)}$$

3. RESULTS

Mf: Lunar fortnightly constituent — 14 days
Mm: Lunar monthly constituent — 28 days
Confidence Interval (95%)

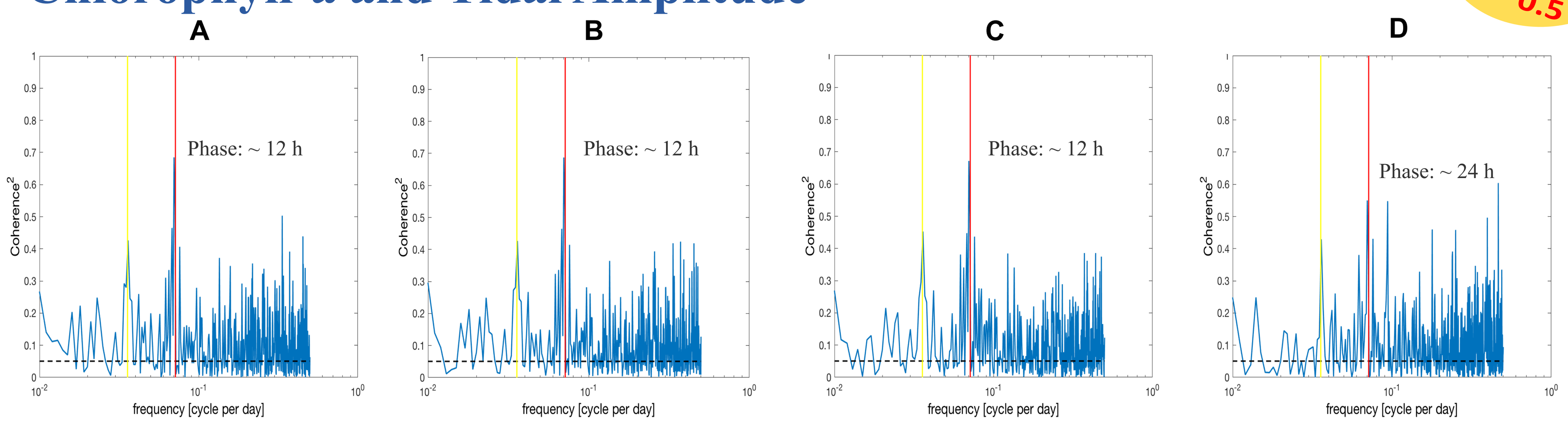
Chlorophyll-a Power Spectral Density



Coherence square between Chlorophyll-a and Tidal Amplitude

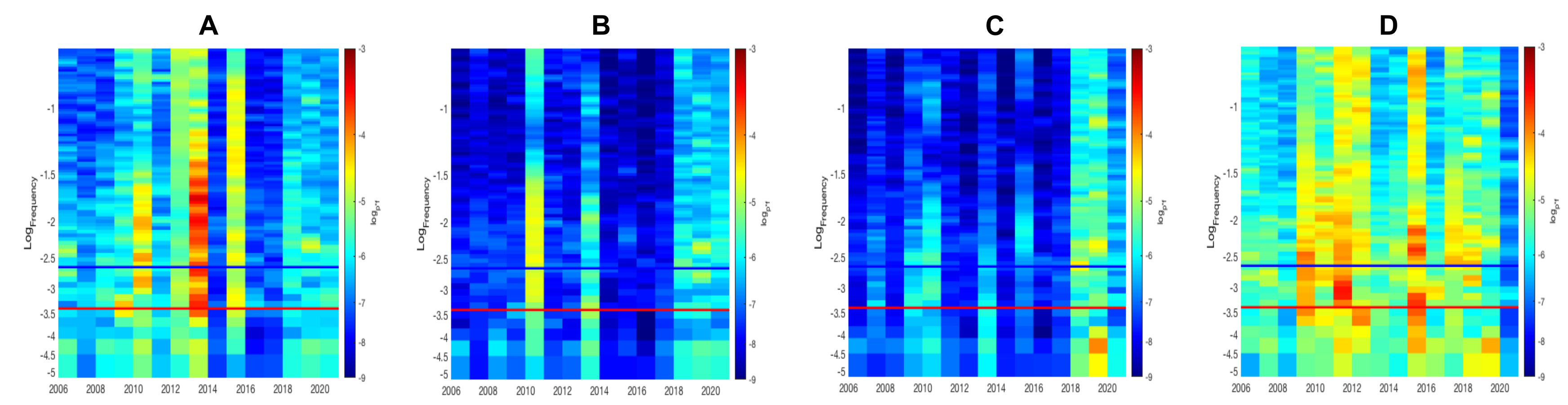
Confidence Interval (95%) ----

Significant Coherence² > 0.5



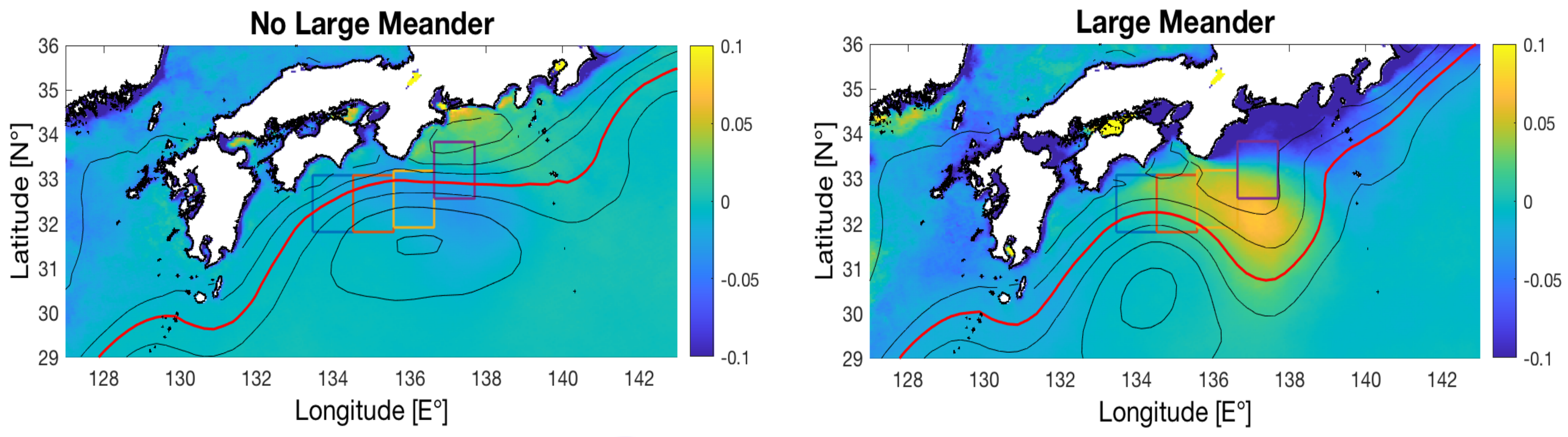
Interannual variability of frequency spectra

14 days
month



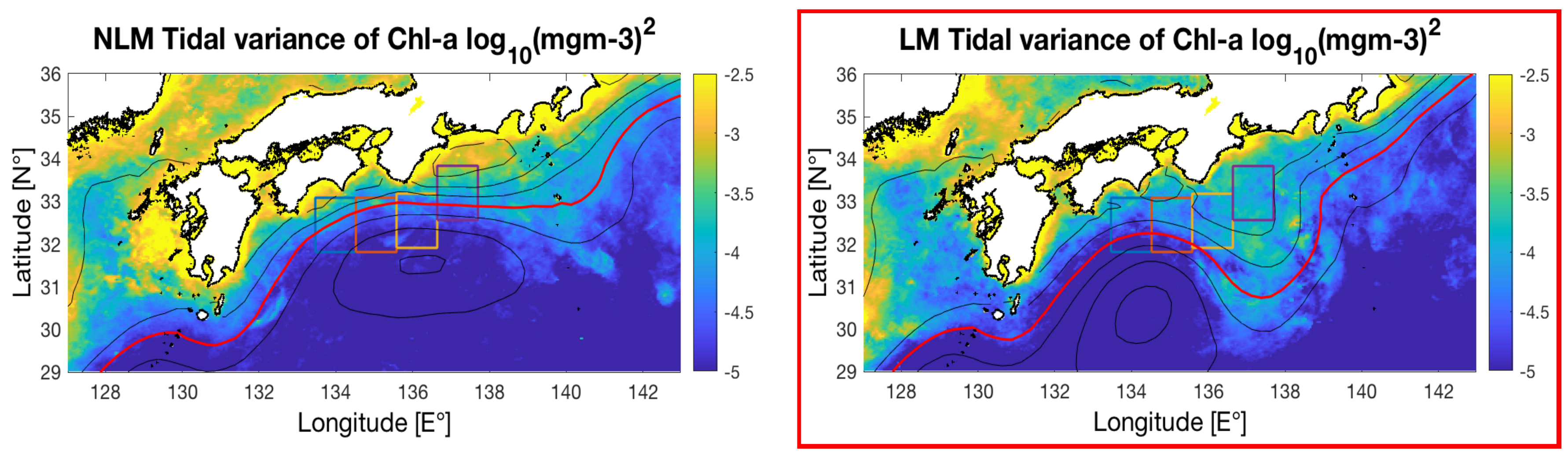
Mean of the Chlorophyll-a monthly anomaly

Climatology: 1998-2019
Kuroshio axis SSH: 1.2 m



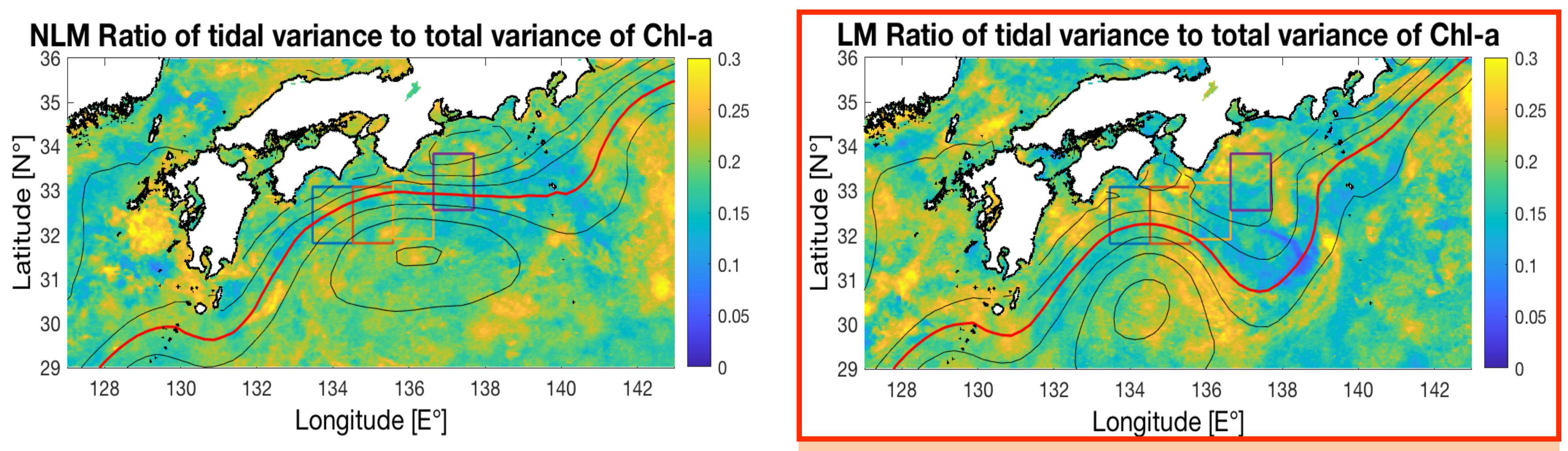
Spectral tidal variance

f=1/14 CPD



Ratio of tidal variance to total variance of chlorophyll-a

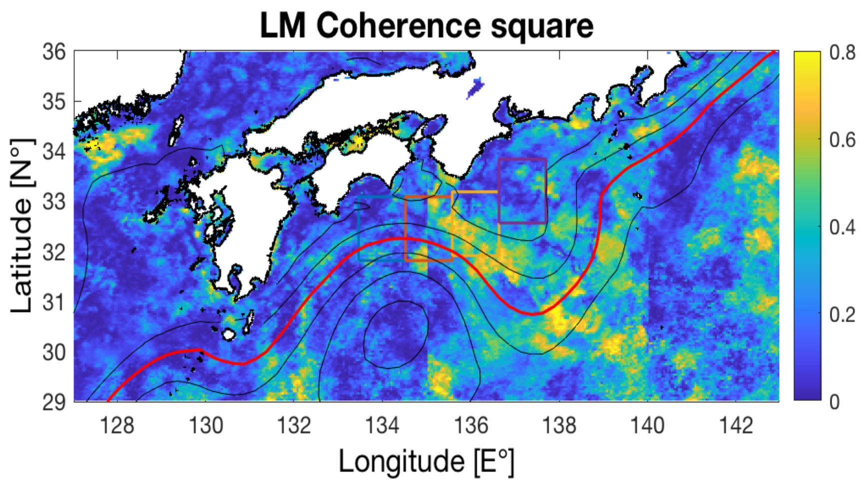
f=1/20 - 1/10 CPD



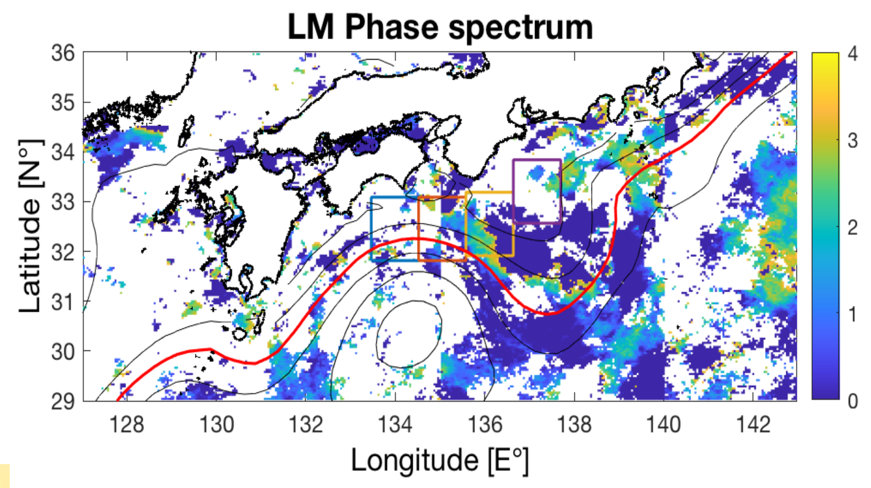
Variation with 10-20 days periods (including fortnightly tide) explains 30% of the total variance of enhanced Chl-a during the LM.

Coherence and Phase spectrum during Large Meander

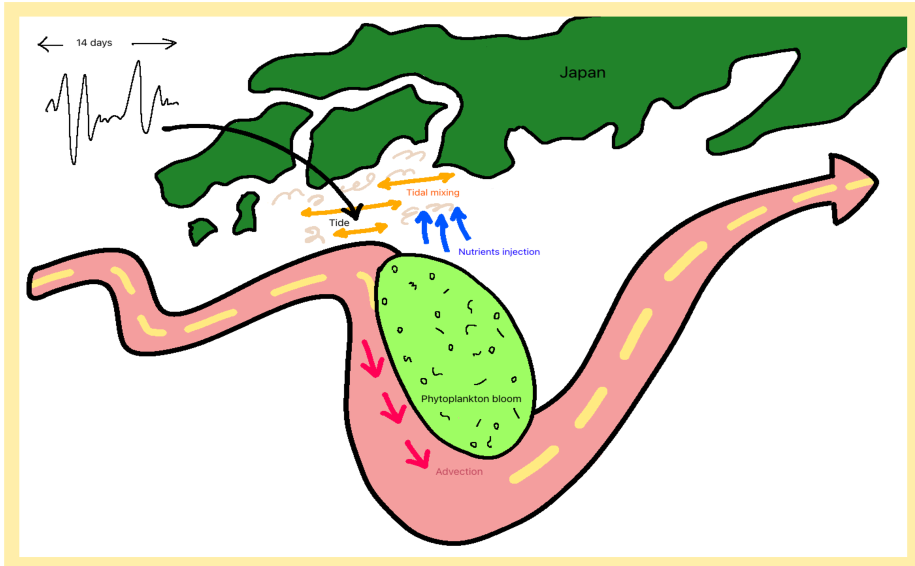
f=1/14 CPD



The high coherence² is found between tidal amplitude and Chl-a at a 14 day period, along the LM Kuroshio off Kii Peninsula.



To have an effect in the sea surface chlorophyll-a due to the fortnightly tide, it takes around 1 and 4 days along the LM.



Hypothesis Schematics

4. CONCLUSION

The enhanced Chl-a concentrations during the KLM (2017-2021) on the western side of the meander are contributed from the Chl-a variations with periods between 10-20 days, including fortnightly tide (and possibly submesoscale processes) that account for 30% of the total Chl-a variance. A band of high coherence square ~0.8 between tidal amplitude and Chl-a at 14-day period appears along the KLM up to the southernmost tip of the meander with time lags of 0-4 days, suggesting effects of fortnightly tide near the coast are advected to the downstream along the large meandering Kuroshio.

5. REFERENCES

1. Durán Gomez G. S., & Nagai, T. (2022). Elevated nutrient supply caused by the approaching Kuroshio to the southern coast of Japan. Frontiers in Marine Science.
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3. Xing, Q., Yu, H., Wang, H., Ito, S. I., & Yuan, C. (2021). Evaluating the spring-neap tidal effects on chlorophyll-a variations based on the geostationary satellite. Frontiers in Marine Science.

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