Observations of submesoscale surface Chlorophyll concentrations off the east coast of Korea

Jang Gon Yoo\(^1\) and Sung Yong Kim\(^1\)

\(^1\)Department of Mechanical Engineering
Korea Advanced Institute of Science and Technology (KAIST)
Republic of Korea
Oceanic processes in time and spatial scales

Submesoscale processes

- O(1) Rossby number \([\text{Ro} = \zeta/f]\)
- A horizontal scale smaller than the first baroclinic Rossby deformation radius; O(1-10) km
- Frequently observed as fronts, eddies, and filaments

(Courtesy of X. Capet and P. Klein)
Submesoscale processes

- O(1) Rossby number \([Ro = \zeta/f]\)
- A horizontal scale smaller than the first baroclinic Rossby deformation radius; O(1-10) km
- Frequently observed as fronts, eddies, and filaments
- Contribute to the vertical transport of oceanic tracers, mass, and buoyancy and rectify the mixed-layer structure and upper-ocean stratification
  - e.g., vertical frontal scale secondary circulation

(Williams and Follows, 2003)
Outline

• Basic data analysis
  • Probability density functions of CHL
  • Data availability in space and time
  • Diurnal variability
  • Spatial structure in nearshore and offshore regions
  • Wavenumber spectra
  • Concurrently observed surface currents and their energy spectra

• Summary
Study domain and data

- East/Japan Sea coastal region
- Hourly (during a day; approx. 8 samples a day) for five years (2011 to 2015)
- Flag options are available for end-users
Basic statistics of CHL off EJS

• Gaussian shape of CHL PDF under Flag 3
• Data analysis of Gaussian variable: Covariance, Correlation, and mean, standard deviation, etc...

Table 1: Flag parameters for GOCI data postprocessing. The data to satisfy the flag parameters are excluded in the optimally interpolated products. High order flag is a more strict QAQC procedure for scientific research.

<table>
<thead>
<tr>
<th>Flag tag</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flag 1</td>
<td>Cloud or ice, Land mask, Atmospheric algorithm failure, Wrong spectral shape of data</td>
</tr>
<tr>
<td>Flag 2</td>
<td>Iteration divergence, High solar zenith angle, Missing ancillary data, Negative Rayleigh corrected radiance, Cloud edge contamination, Existence of bright pixel, Unavailable pixel contamination, Missing slot information, Slot edge contamination, Non-calculable CHL, Statistically unreliable distribution of CHL</td>
</tr>
<tr>
<td>Flag 3</td>
<td>Extremely turbid water, High satellite zenith angle, Ancillary warning flag, High ozone concentration, High wind speed, Epsilon (869, 745) is less than 0.95, Negative water leaving irradiance, Low water leaving irradiance, Turbid water</td>
</tr>
<tr>
<td>Flag 4</td>
<td>High aerosol load, More than 300% aerosol reflectance at any bands</td>
</tr>
</tbody>
</table>
CHL data availability in space and time

- Flag 3 data
- 0 (no data) and 1 (full data)
Spatial correlations of CHL maps (Flag3)

- Hourly maps during a day for 5 years (2011 to 2015)
Cross-shore structures

- Correlated structure centered by reference locations
- E-folding scales of 10, 20, 30, and 40-km
- Longer decorrelation scale in the cross-shore direction

- Nearly constant decorrelation length scale in the along-shore direction
An example of diurnal CHL variability

- CHL concentration (log10 scale) in the cross-shore and time domain
- Less coverage due to more chance of cloud in summer
- Higher concentration of CHL in winter
- An example of CHL concentration becomes minimum of at noon and decreases offshore
An example of diurnal CHL variability

- Composite mean and standard deviation of CHL concentration in a cross-shore
- CHL has local maximum within 5 km from the coast and decreases offshore with nearly constant variability (STD);
- Diurnal variability and anomalous CHL at 07:00 (GMT; 16:00 Local time)
Energy spectra of CHL

- Energy spectra of passive tracers $[P(k); \text{CHL}]$
  - $k^{-1}$ forward cascade in 2D turbulence

$\text{Pr} = \frac{\nu}{\alpha} >> 1$  
[= momentum diffusivity/thermal diffusivity, sea water $\sim 7$]

Vallis, GFD 2000
Energy spectra of CHL

- Meridionally (red) and zonally (blue) averaged CHL energy spectra based on one year data (2013)
- $k^{-1}$ decay slope

**Figure 8:** (a) Wavenumber spectra of hourly CHL data for a period of one year (2013) sampled in the zonal (red) and meridional (blue) directions are averaged in the meridional and zonal directions, respectively. (b)
Seasonally averaged energy spectra of CHL

- Both have $k^{-1}$ decay slopes
- Summer > winter

and (c): Seasonally averaged wavenumber spectra. (b): Meridionally averaged wavenumber spectra (summer: red, winter: blue). (c): Zonally averaged wavenumber spectra (summer: red, winter: blue).
Concurrently observed submesoscale surface currents
Data availability

- Hourly surface current maps at a 1-km resolution grid obtained from two HF radars (WERA; phased-array system) for one year (2013)
- Effective spatial coverage and QAQC’ed region
- Intermittent missing data in time
- CTD profiles in Line 104 for seasonal stratification
Wavenumber-domain KE spectra

Radial velocity data for the entire year

Seasonal radial velocity data

Range direction

Power (cm$^2$ s$^{-2}$ km)

Wavenumber (km$^{-1}$)

(a) $k^3$

(b) $k^2$

Azimuthal direction

Power (cm$^2$ s$^{-2}$ cpgd$^{-1}$)

Wavenumber [cycles per degree (cpgd)]

(c) $k^3$

(d) $k^2$
Wavenumber-domain KE spectra
Summary

• Basic data analysis of chlorophyll concentration off the east coast of Korea is presented in terms of their PDFs, temporal and spatial data availability.

• Gaussian statistics of log10 CHL allow us to examine the CHL with typical data analysis tools.

• Spatial correlations and decorrelated structures can quantify the averaged variability of regional CHL. Particularly, the hourly and diurnal variability of CHL in the coastal region can be a good indicative of applications using GOCI data.