Seasonal and Interannual Variability of Chlorophyll \(a\) and Primary Productivity in the Subarctic North Pacific during 1997-2000 using Multi-Sensor Remote Sensing

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1. Introduction and objectives

The North Pacific can be viewed as a large estuary in which a strong halocline at 300-200 metres depth separates the surface from the deeper waters. Nutrient concentrations in deep waters are high in the shallow areas of the basin, but the term region for the estuarial formation. High primary productivity and strong air-sea interactions characterise the carbon cycle of this region. Known is that this region is one of the high nutrients, low chlorophyll areas. A preliminary observation by the CZCS revealed significant south-north gradient in the distribution of chlorophyll \(a\), and the blooms are spring apparent only in the western region of the subarctic North Pacific.

2. Satellite data sets

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sensor</th>
<th>Products</th>
<th>Temporal/Spatial resolution</th>
<th>Period</th>
</tr>
</thead>
</table>

3. Modeling primary production

Time series data of primary productivity on a monthly time scale were computed using the VGP model (Behrenfeld and Falkowski, 1997). The inputs to the VGP model are satellite-derived data of chlorophyll \(a\), sea surface temperature (SST), and PAR at the water surface. The monthly primary productivity (\(P_{pp}\)) was estimated from the satellite chlorophyll data and SST using the equations of Morel and Bricaud (1984). The model is described as follows:

\[
P_{pp} = 0.66125 * P_{o} \cdot \frac{[\text{chl}-a]_{\text{satellite}}}{[\text{chl}-a]_{\text{max}}} \cdot \text{Dirr}
\]

Monthly Primary productivity (gCm\(^{-2}\)Month\(^{-1}\))

4. Estimate of sea surface nitrates

To help understanding the regulatory mechanism of chlorophyll \(a\) and primary productivity distributions, calculation was made for sea surface nitrate using SST and chl-a data (Goess et al., 1999,2000). Goess et al. (1999) reported the accuracy of these satellite-derived estimates of nitrate to be about 2-25 \(\mu\)M.

\[\text{NOS} = 25.68 - 1.97(T) + 0.04(T)^{2} - 1.63(\text{chl}-a) + 0.012(\text{chl}-a)^{2}\]

Monthly sea surface nitrate (\(\mu\)M)

5. Study Region

Classification based on chlorophyll \(a\) concentration

6. Results and discussion

6.1 Monthly Classification map of the study region based on chl-a concentrations

- Low chl-a regions (0.2-1.0 mg m\(^{-3}\)): Area-1 (Red), Area-2 (Blue) show small variability of chlorophyll \(a\) and dominate most of the open ocean in this study area. Together with the nitrate data, the entire region is judged as under the HNLC condition.
- High chl-a regions (> 1.0 mg m\(^{-3}\)): Area-3, Green; Area-4; Orange) locate mostly along the Kuril and Aleuian Islands, the west coast of North America, the east coast of Kamchatka Peninsula and the Japan islands. Spring and fall blooms were clearly seen in these areas.
- Spatial variability is mostly related to seasonal variability. But see remarks \(\ast\) and **

6.2 Time series variability of monthly mean at each classification areas (Area1-4) derived from Multi-Sensor data sets

- Coastal regions (Area2,3): Low seasonal variability (0.3-0.6 mg m\(^{-3}\))
- Open sea regions (Area1,4): High seasonal variability (1.0-3.0 mg m\(^{-3}\))
- Primary productivity
  - Coastal regions (Area2,3): Lower in winter compared with that of chl-a
  - Open sea regions (Area1,4): Lowest in winter compared with that of chl-a

- Nitrate concentration
  - Coastal regions (Area2,3): Higher in winter compared with that of chl-a
  - Open sea regions (Area1,4): Lower in winter compared with that of chl-a

4.3.1.1 Monthly Classification map of the study region based on chl-a concentrations

- In 1998 (blue circle), the Western Subarctic Gyre was remarkably high (yellow circle) compared with those in the same season of the other years.

7. Conclusions

Seasonal variability

Magnitudes of chl-a seasonal variability was low in the open sea area (Area-2,3) and ranges of chl-a concentrations were about 0.3-1.6 mg m\(^{-3}\) throughout the year. No bloom was observed, and the regions are in HNLC condition. In the coastal area (Area-1,4), spring blooms was clearly seen. Chl-a concentrations in spring tend to be higher in the west compared to the east. We suggest that strong spring blooms in the western coastal region resulted from combination of 1) stronger wind in winter to spring, 2) enhanced water column stability due to weak wind and increased PAR in spring to summer, and 3) larger nutrients inputs in winter, 4) enhanced water column stability due to weak wind and increased PAR in spring to summer.

Interannual variability

A large interannual variability of chl-a and primary productivity coincided with the 1997/1998 El Nino and 1998/1999 La Nino events. The onset of the spring bloom in the coastal regions of the Western Subarctic Pacific (Area2) was 1 month earlier in 1998 compared with other years. In 1998 fall, chl-a around the Western Subarctic Gyre was remarkably high compared with those in the same season of the other years. In spring to summer 1998, primary productivity in the open ocean varies in both east and west regions compared with other years.