Temporal and Spatial Variability of Primary Production in the Sub-arctic North Pacific using Satellite Multi Sensor Remote Sensing

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Outline

- Background
- Satellite Data and Methods
- East-West Comparison in two gyre
- Concluding remarks
- Future Work
Two Gyre system and HNLC region

- Kuroshio
- North Pacific current
- California current
- Alaskan stream
- Subarctic current
- Subarctic Gyre
- East Kamchatka current
- Western Subarctic Gyre
- Oyashio
- HNLC region
- Alaska Gyre
- Alaskan stream
- North Pacific current
- California current
Major sink of CO$_2$ (Takahashi et al., 2002)
Annual cycle of primary production

Stn. KNOT

Stn. Papa

Harrison et al. (2004)
Objectives

• To examine spatial pattern of ecological provinces using seasonal change of satellite estimated chl-a
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• To examine spatial pattern of ecological provinces using seasonal change of satellite estimated chl-a

• To describe recent variability of PP in the North Pacific from 1998 to 2004 using satellite data sets
Spatial distribution of classified area

Classification

Temporal and spatial distribution of primary production

Estimate of primary production by VGPM

Temporal and spatial variability of primary production in the North Pacific
Modeling of primary production

VGPM Model (Behrenfeld and Falkowski, 1997)

Satellite data:
- SST
- PAR
- Chl-a

\[ PP_{eu} = 0.66125 \times P_{B_{opt}} \times \left[ \frac{E_o}{E_o + 4.1} \right] \times Z_{eu} \times C_{sat} \times D_{irr} \]

\( PP_{eu} \): Daily C fixation integrated from the surface to \( Z_{eu} \) (mgCm\(^{-2}\))  
\( P_{B_{opt}} \): Maximum C fixation rate within a water column (mgC(mgChl\(^{-1}\))h\(^{-1}\))  
\( E_o \): Sea surface daily PAR (Photosynthetically Available irradiance) mol quanta m\(^{-2}\)  
\( Z_{eu} \): Physical depth receiving 1% of \( E_o \) (m)  
\( C_{sat} \): Surface Chl-a concentration derived by satellite mgm\(^{-3}\)  
\( D_{irr} \): Photoperiod, decimal hours

\( P_{B_{opt}} = a \times T^7 + b \times T^6 + c \times T^5 + d \times T^4 + e \times T^3 + f \times T^2 + g \times T + h \)

\( T \): Sea Surface Temperature
VGPM model
(Behrenfeld and Falkowski, 1997)

\[ PP_{eu} = 0.66125 \times PB_{opt} \times \left[ \frac{Eo}{Eo+4.1} \right] \times Zeu \times C_{sat} \times \text{Dirr} \]

\[ PB_{opt} = \frac{0.071 \times T - 3.2 \times 10^{-3} \times T^2 + 3.0 \times 10^{-5} \times T^3}{C_{sat}} + (1.0 + 0.17 \times T - 2.5 \times 10^{-3} \times T^2 - 8.0 \times 10^{-5} \times T^3) \]
Chlorophyll a image

SeaWiFS

Eo: PAR

SeaWiFS

Z_{eu}

AVHRR

P_{Bopt}

Primary Production Map (PPeu)
• **K2 and KNOT**: 0.2 – 1.0 mg m\(^{-3}\)

• **Papa**: 0.1 – 0.4 mg m\(^{-3}\)
KNOT > K2 = Papa
Papa: High in 2000
Primary production in Summer/Fall season maintains total PP in both regions
Primary Production in summer

Shiomoto et al. (1998)

Table 2. Comparison of Primary Production and Phytoplankton Biomass, and Physical and Chemical Environmental Factors Between the Western Subarctic Gyre (WSG) and Alaskan Gyre (AG) in Summer

<table>
<thead>
<tr>
<th></th>
<th>WSG</th>
<th>AG</th>
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<tbody>
<tr>
<td>Primary production, mg C m(^{-2}) d(^{-1})</td>
<td>663 ± 86 (range, 225–1198; n = 11)(^a)</td>
<td>642 ± 55 (range, 290–1550; n = 19)(^b)</td>
</tr>
<tr>
<td>Chl concentration, µg L(^{-1})</td>
<td>751 ± 94 (range 278–1397; n = 11)(^b)</td>
<td>~0.4(^d)</td>
</tr>
<tr>
<td>Chl standing stock, mg m(^{-2})</td>
<td>1.03 ± 0.15 (n = 44)</td>
<td></td>
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<tr>
<td>Surface primary productivity, µg C (µg chl)(^{-1}) d(^{-1})</td>
<td>0.82 ± 0.05 (n = 40)(^e)</td>
<td></td>
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<tr>
<td>Temperature shallower than 50 m, °C</td>
<td>28.6 ± 2.9 (n = 11)(^a)</td>
<td>22.9 ± 1.6 (n = 18)(^f)</td>
</tr>
<tr>
<td>Euphotic zone (1% light depth), m</td>
<td>33.4 ± 2.5 (range, 21–49; n = 11)</td>
<td>51.3 ± 5.6 (range, 15–94; n = 19)(^f)</td>
</tr>
<tr>
<td>Extinction coefficient between 100 and 1% light depths, m(^{-1})</td>
<td>3.0–9.5</td>
<td>6–12(^g)</td>
</tr>
<tr>
<td>Surface mixed layer, m</td>
<td>24–49 (mean ± SE, 37 ± 3; n = 11)</td>
<td>57–82 (mean ± SE, 62 ± 1; n = 18)(^f)</td>
</tr>
<tr>
<td>Nitrite + nitrate concentration, µM</td>
<td>0.105–0.114 (mean ± SE, 0.110 ± 0.0016; n = 6)</td>
<td>0.0565–0.0815 (mean ± SE; 0.0749 ± 0.0015; n = 18)(^f)</td>
</tr>
</tbody>
</table>

There is consistent between in situ observation and satellite observation

Shiomoto et al. (1998)
Annual Primary Production (gCm\(^{-2}\)year\(^{-1}\))

1998

(gCm\(^{-2}\)year\(^{-1}\))
Annual Primary Production (gCm$^{-2}$year$^{-1}$)

1999
Annual Primary Production ($g\text{Cm}^{-2}\text{year}^{-1}$)

2000

(g\text{Cm}^{-2}\text{year}^{-1})
Annual Primary Production \( (g\text{Cm}^{-2}\text{year}^{-1}) \)

2001
Annual Primary Production ($gCm^{-2}year^{-1}$)

2002
Annual Primary Production (gCm\(^{-2}\)year\(^{-1}\))

2003
Annual Primary Production ($gCm^{-2}year^{-1}$)

2004

(gCm$^{-2}year^{-1}$)
Concluding Remarks

K2 and KNOT
Minimum year of total primary production is 2001 and relatively high year are 2000, 2002, 2004. Interannual variation is larger than Papa.

Papa
Primary production is relatively stable with decreasing tendency.

Summer/Fall PP contributes to yearly PP both in the two gyre regions.
SPEEDS:
Summer 2008
Subarctic Pacific Experiment for Ecosystem Dynamics Study

BLOCKS:
Spring 2007
Bloom Caused by Kosa Study

SNIFFS I & II:
Summer 2006 & 2009
Subtropical Nitrogen Fixation Flux Study
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Did Sea Lion know climate change?

Thank you!

Photo by Sei-ichi Saitoh
Baby Island, Aleutian Islands
in Summer, 1975