15th PICES/Workshop 8
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Temporal and Spatial Variability of Primary Production in the Sub-arctic North Pacific using Satellite Multi Sensor Remote Sensing

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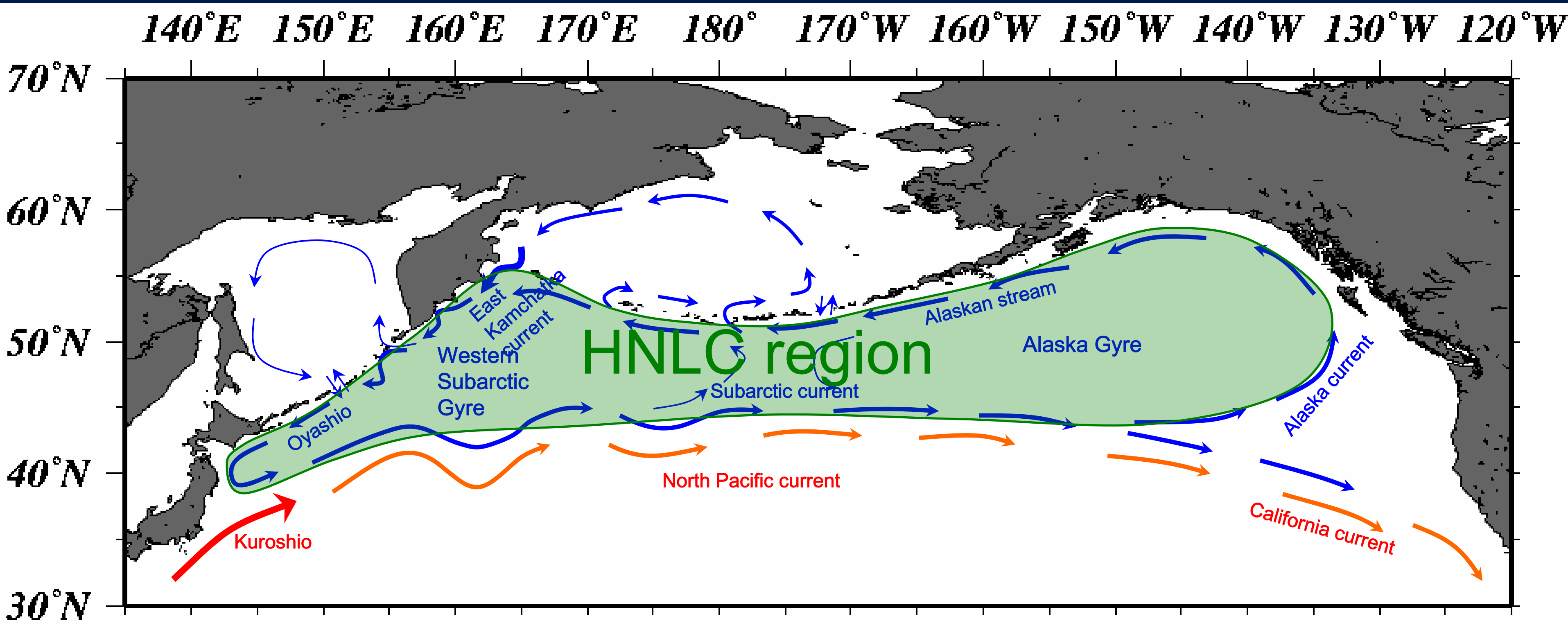
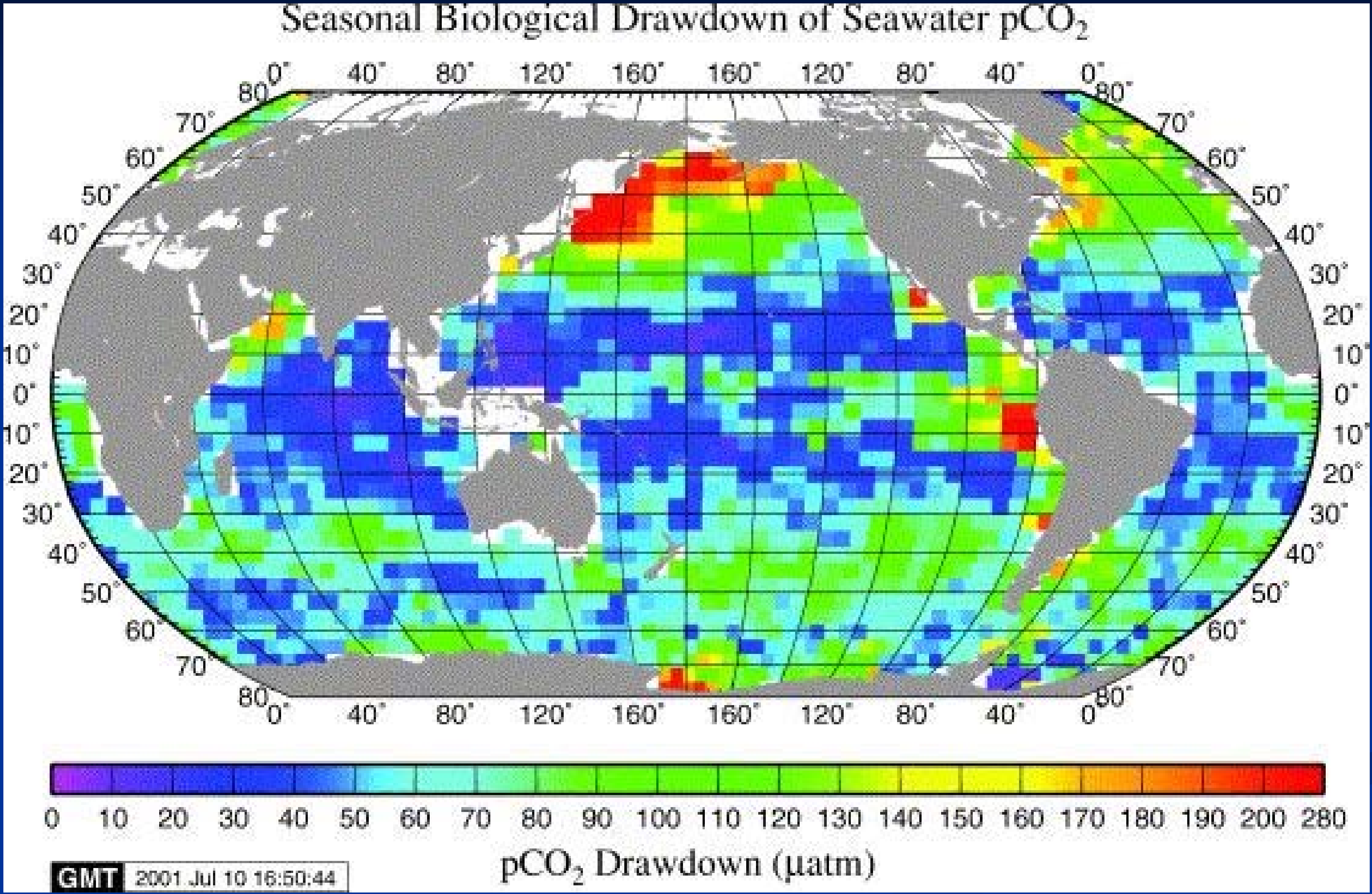
Outline

- Background
- Satellite Data and Methods
- East-West Comparison in two gyre
- Concluding remarks
- Future Work

Two Gyre system and HNLC region

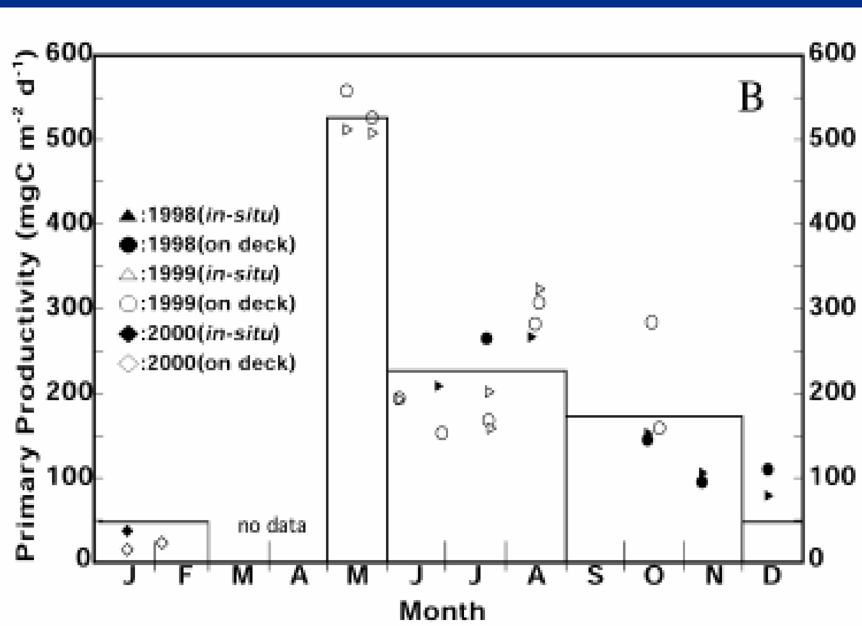


CO_2

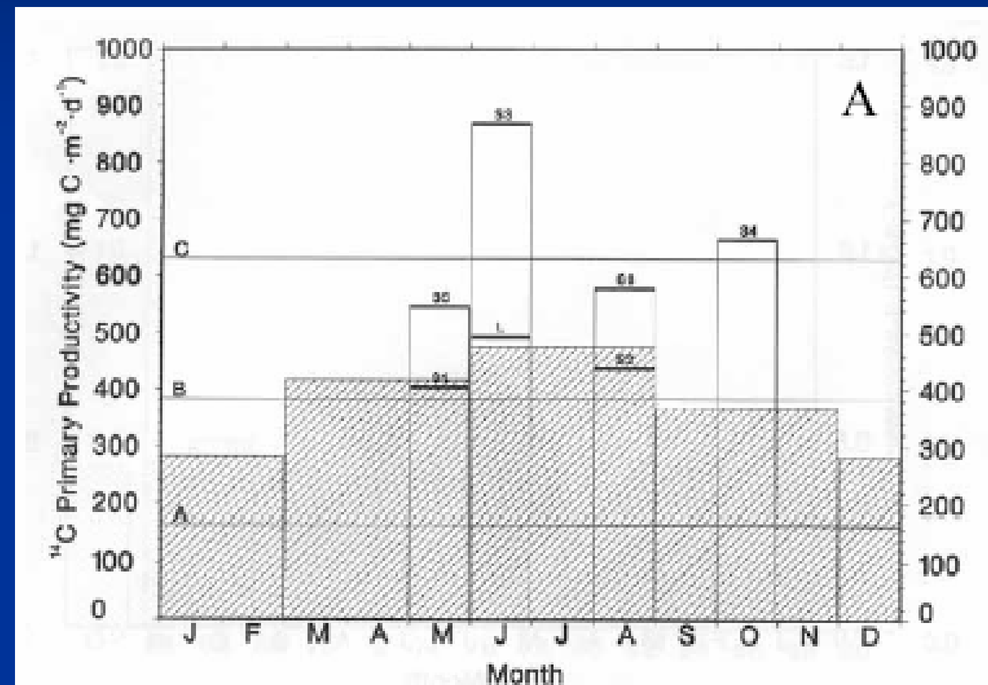


- Major sink of CO_2 (Takahashi *et al.*, 2002)

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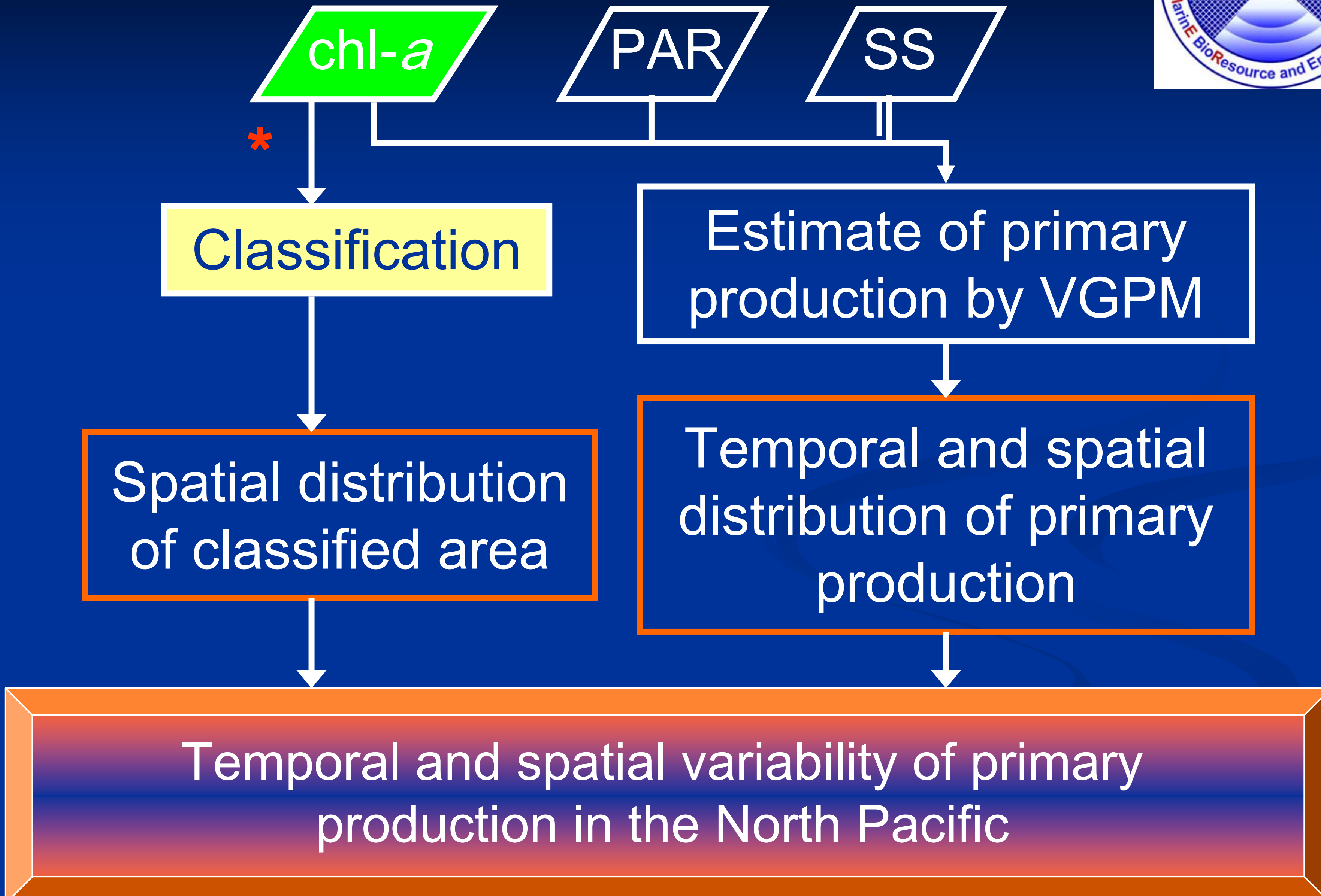
- To examine spatial pattern of ecological provinces using seasonal change of satellite estimated chl-a

- To describe recent variability of PP in the North Pacific from 1998 to 2004 using satellite data sets

Overview of data analysis



Modeling of primary production

VGPM Model (Behrenfeld and Falkowski, 1997

Satellite data : SST PAR Chl-a

$$PP_{eu}=0.66125*PB_{opt}*[Eo/Eo+4.1]*Zeu*Csat*Dirr$$

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

$$PB_{opt} =a*T^7+bT^6+cT^5+dT^4+eT^3+fT^2+gT+h$$

T: Sea Surface Temperature

Modeling of primary production
(Kameda and Ishizaka Model, 2005)

- VGPM model

(Behrenfeld and Falkowski, 1997)

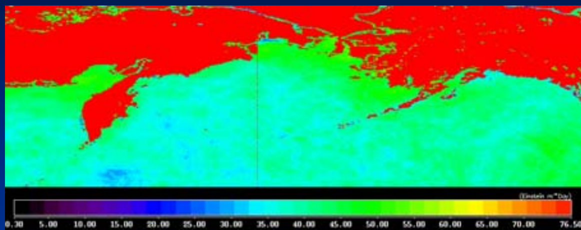
PP_{eu}=0.66125*PB_{opt}*[Eo/Eo+4.1]*Zeu*Csat*Dirr

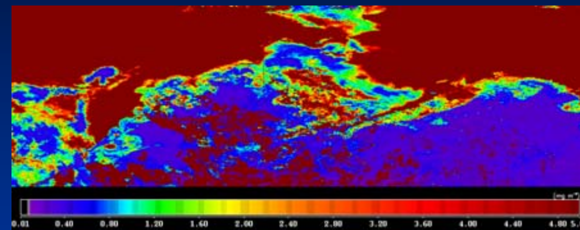
PB_{opt}

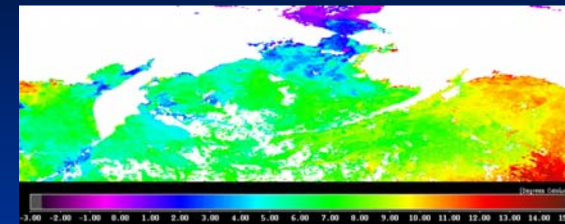
$= (0.071 \times T - 3.2\times10^{-3} \times T^2 + 3.0 \times 10^{-5} \times T^3) / C_{sat}$

$+ \quad (1.0 + 0.17 * T - 2.5 \times 10^{-3} * T^2 - 8.0 \times 10^{-5} \times T^3)$

PAR image | **Chlorophyll a image** | **SST image**



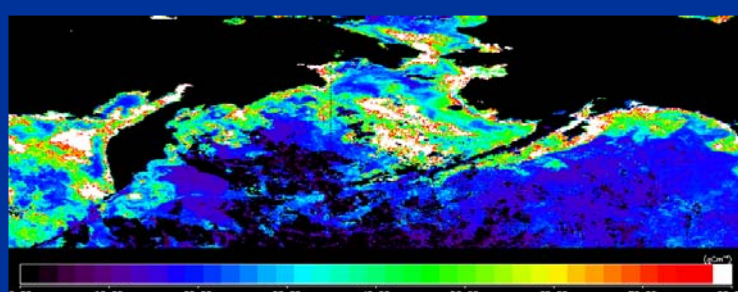




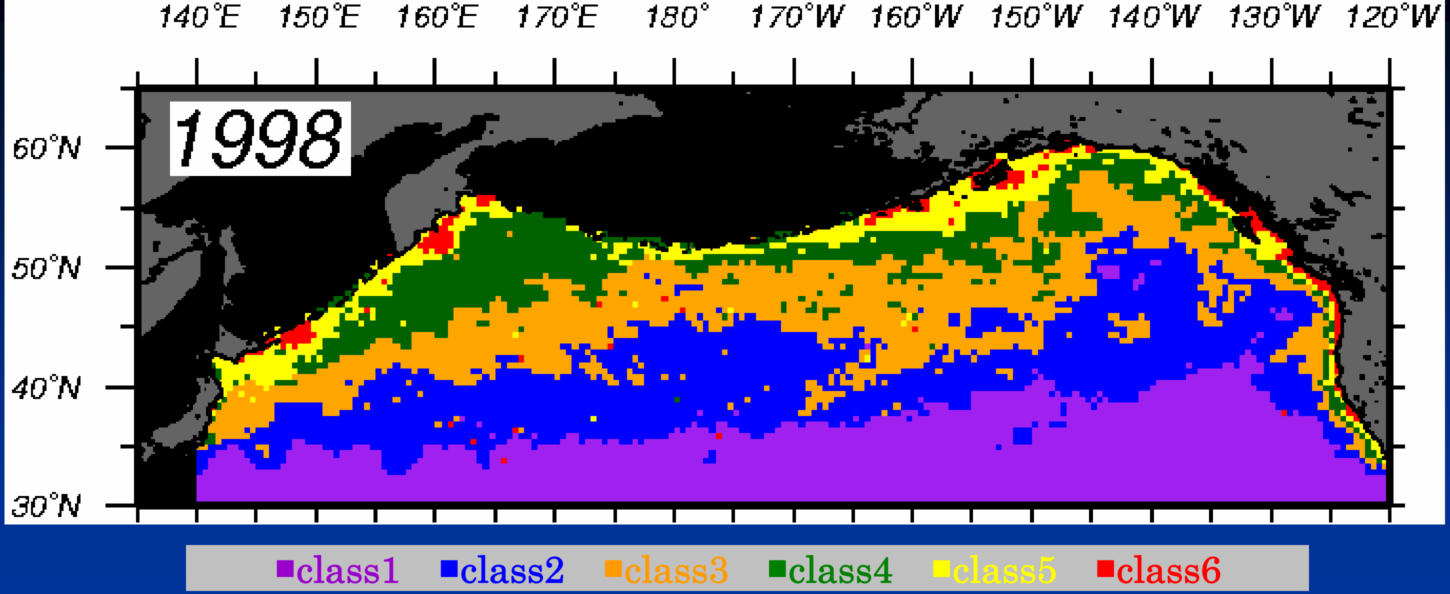
SeaWiFS → **Eo: PAR**

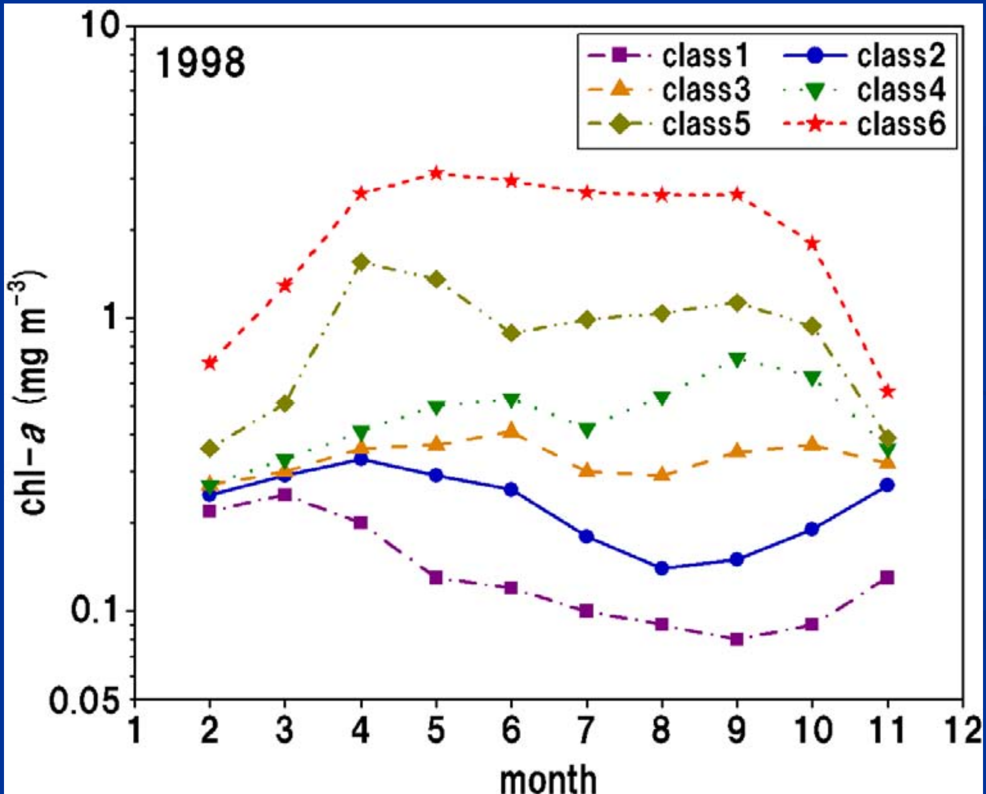
SeaWiFS → **Z_{eu}**

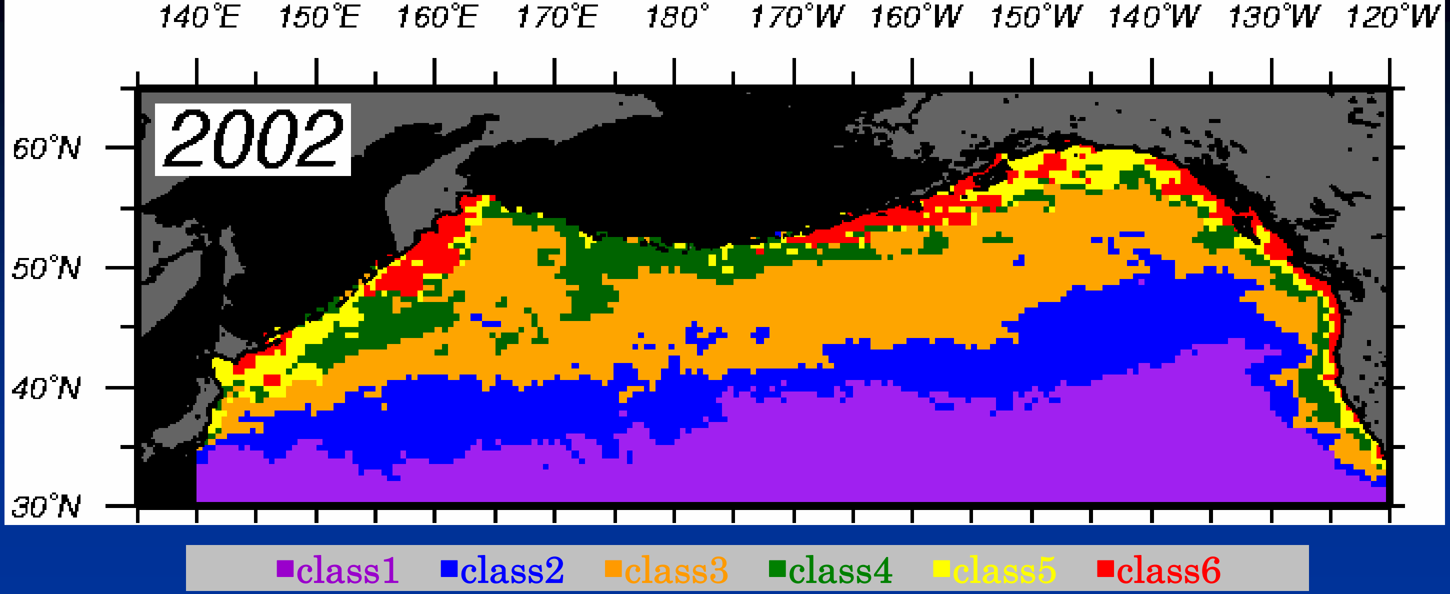
AVHRR → **PB_{opt}**

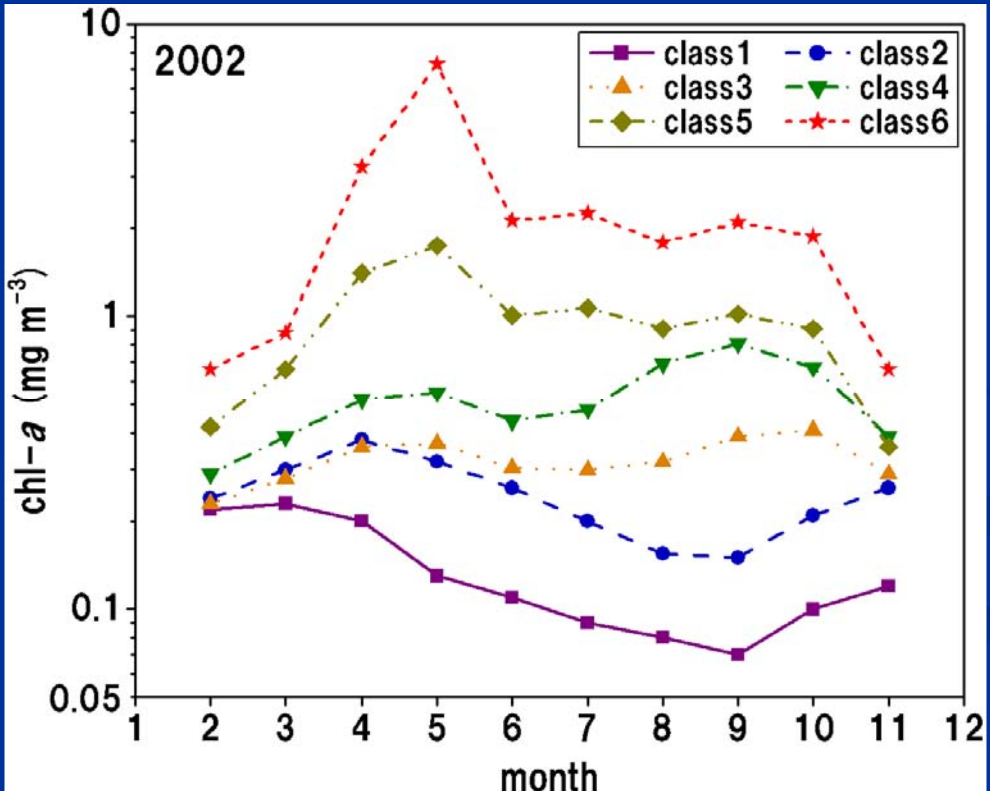


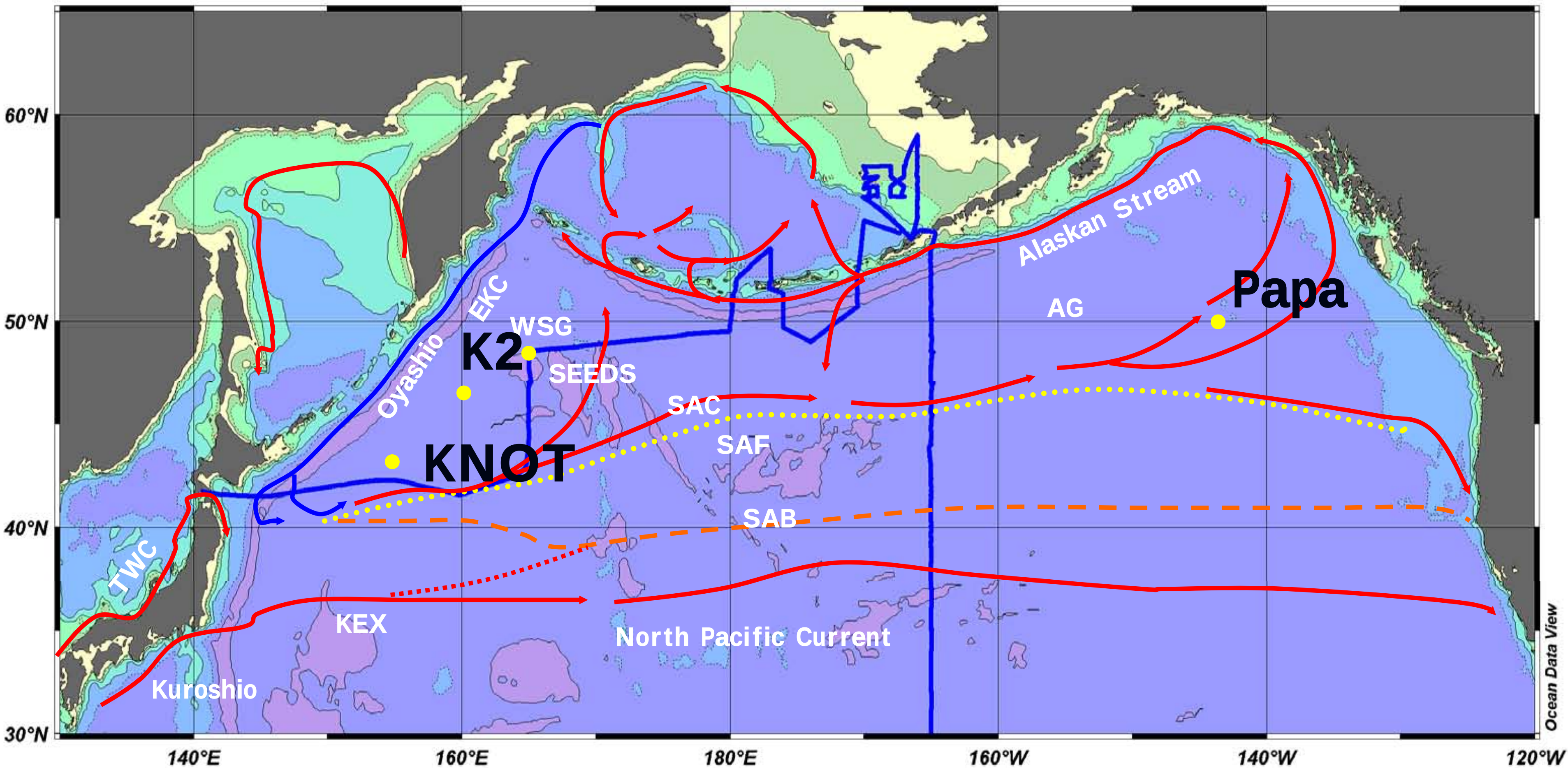
Primary Production Map (PPeu)


140°E
150°E
160°E
170°E
180°
170°W
160°W
150°W
140°W
130°W
120°W
60°N
50°N
40°N
30°N
1998
class1
class2
class3
class4
class5
class6

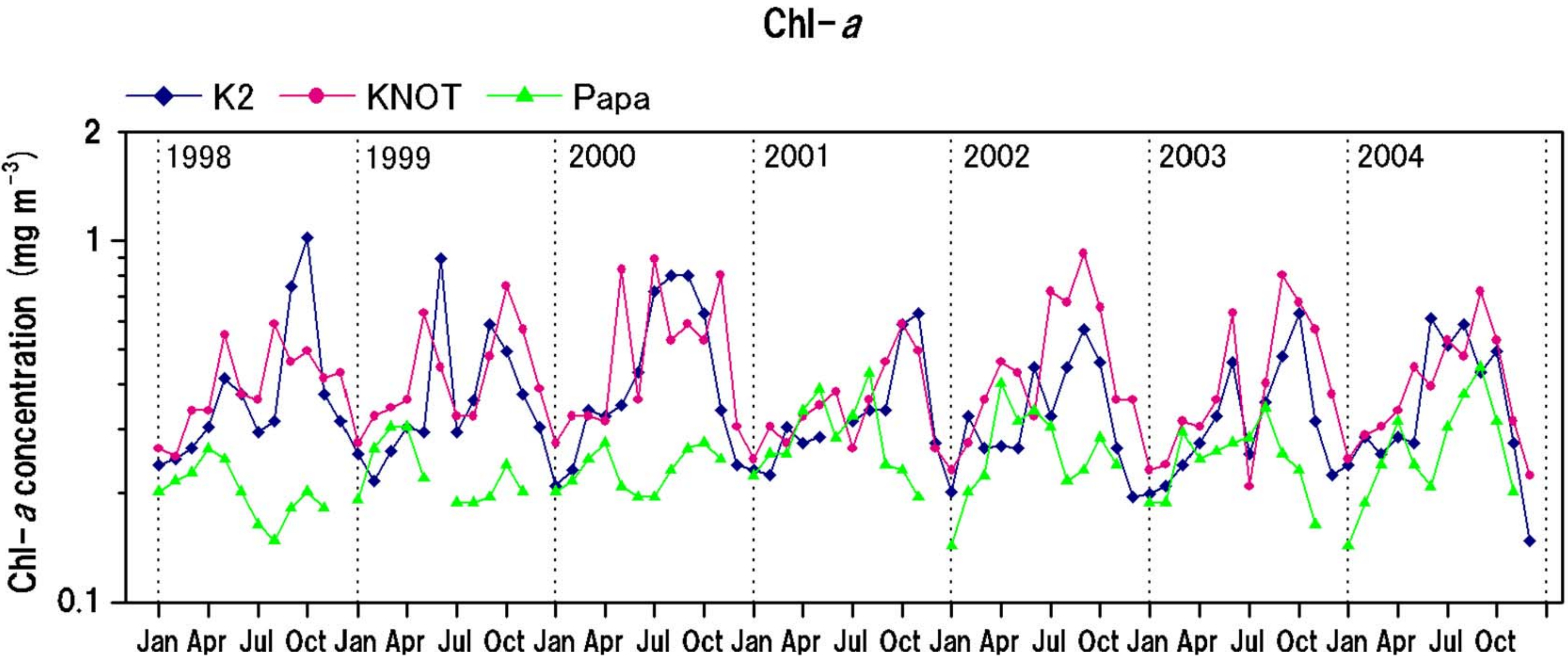

1998
class1
class2
class3
class4
class5
class6
chl-a (mg m⁻³)
10
1
0.1
0.05
1
2
3
4
5
6
7
8
9
10
11
12
month


140°E 150°E 160°E 170°E 180° 170°W 160°W 150°W 140°W 130°W 120°W
60°N
50°N
40°N
30°N
2002
■class1 ■class2 ■class3 ■class4 ■class5 ■class6

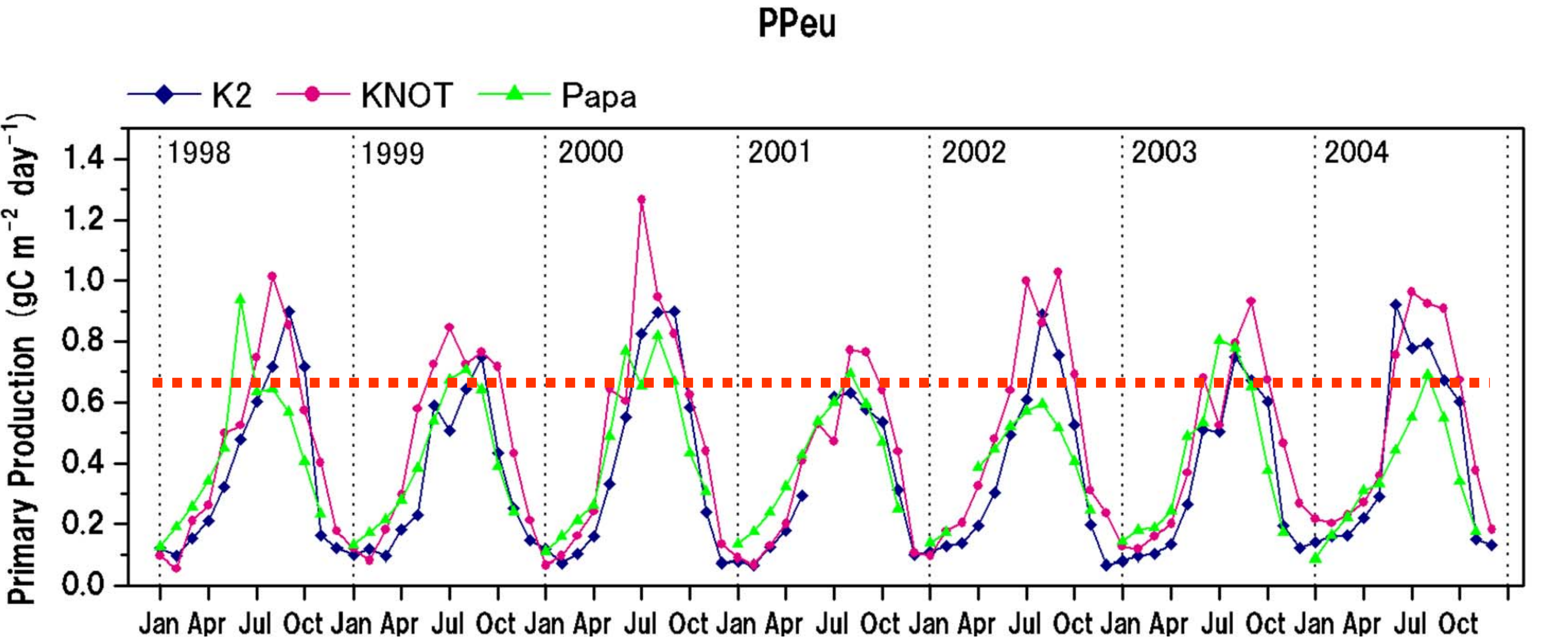

2002
class1
class2
class3
class4
class5
class6
chl-a (mg m⁻³)
10
1
0.1
0.05
1 2 3 4 5 6 7 8 9 10 11 12
month



60°N
50°N
40°N
30°N
140°E
160°E
180°E
160°W
140°W
120°W
Alaskan Stream
Papa
AG
K2
WSG
EKC
Oyashio
SEEDS
SAC
SAF
KNOT
SAB
TWC
KEX
North Pacific Current
Kuroshio
Ocean Data View



- K2 and KNOT : 0.2 – 1.0 mg m^{-3}
- Papa : 0.1 – 0.4 mg m^{-3}



KNOT > K2 = Papa

KNOT, K2 : High in 2000, 2002, 2004

Papa: High in 2000

Primary production in Summer/Fall season maintains total PP in both regions

Primary Production in summer

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

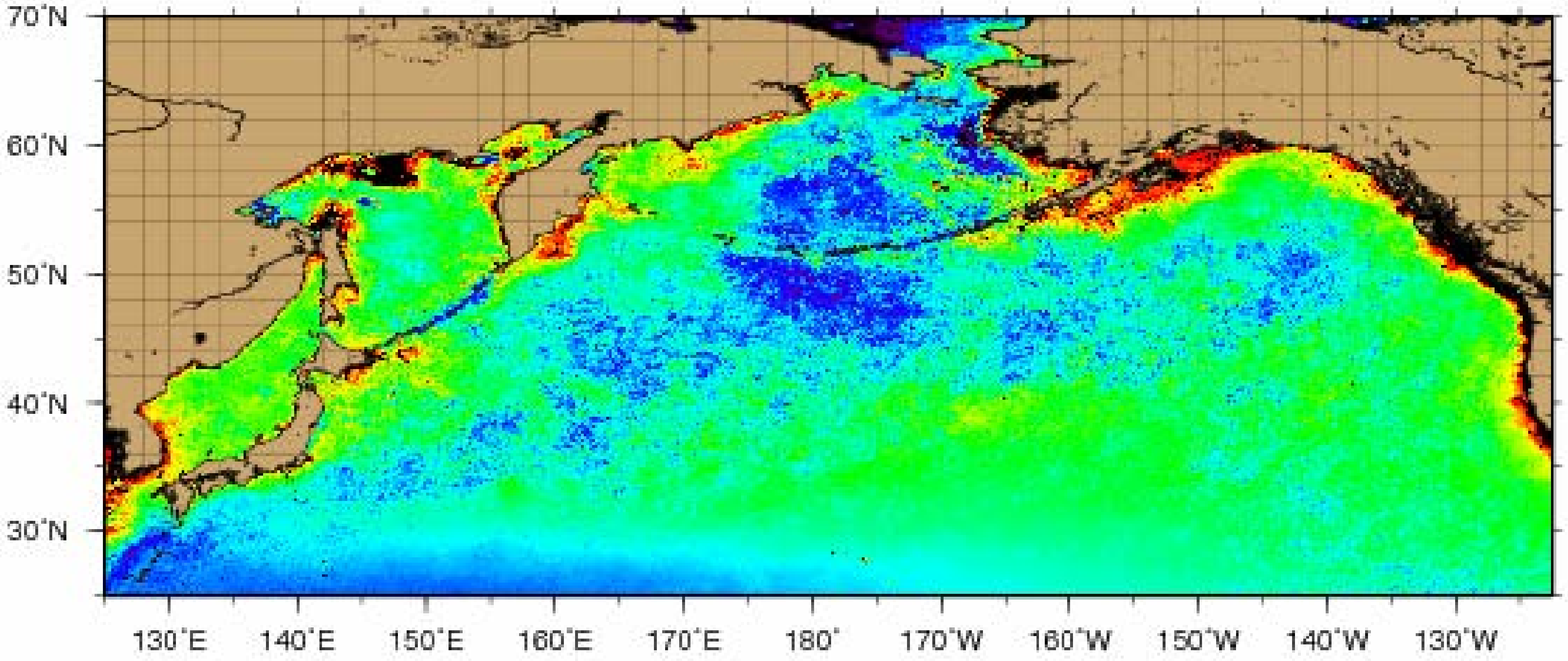
	WSG	AG
Primary production, mg C m^{-2} d^{-1}	663 ± 86 (range, 225–1198; *n* = 11)[a]	642 ± 55 (range, 290–1550; *n* = 19)[b]
	751 ± 94 (range 278–1397; *n* = 11)[c]	
Chl concentration, μg L^{-1}	1.03 ± 0.15 (*n* = 44)	~0.4[d]
	0.82 ± 0.05 (*n* = 40[e]	
Chl standing stock, mg m^{-2}	28.6 ± 2.9 (*n* = 11)[a]	22.9 ± 1.6 (*n* = 18)[f]
Surface primary productivity, μg C (μg chl)$^{-1}$ d^{-1}	33.4 ± 2.5 (range, 21–49; *n* = 11)	51.3 ± 5.6 (range, 15–94; *n* = 19)[f]
Temperature shallower than 50 m, °C	3.0–9.5	6–12[g]
Euphotic zone (1% light depth), m	24–49 (mean ± SE, 37 ± 3; *n* = 11)	57–82 (mean ± SE, 62 ± 1; *n* = 18)[f]
Extinction coefficient between 100 and 1% light depths, m^{-1}	0.105–0.114 (mean ± SE, 0.110 ± 0.0016; *n* = 6)	0.0565–0.0815 (mean ± SE; 0.0749 ± 0.0015; *n* = 18)[f]
Surface mixed layer, m	20–50	10–60[g]
Nitrite + nitrate concentration, μM	10.4–22.9	6–17[h]

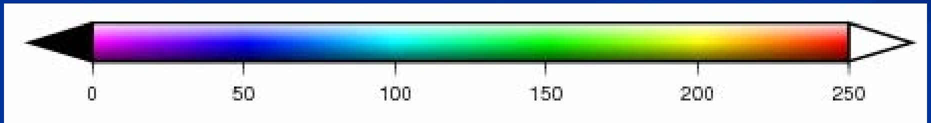
There is consistent between in situ observation and satellite observation

Shiomoto et al.(1998)

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

1998

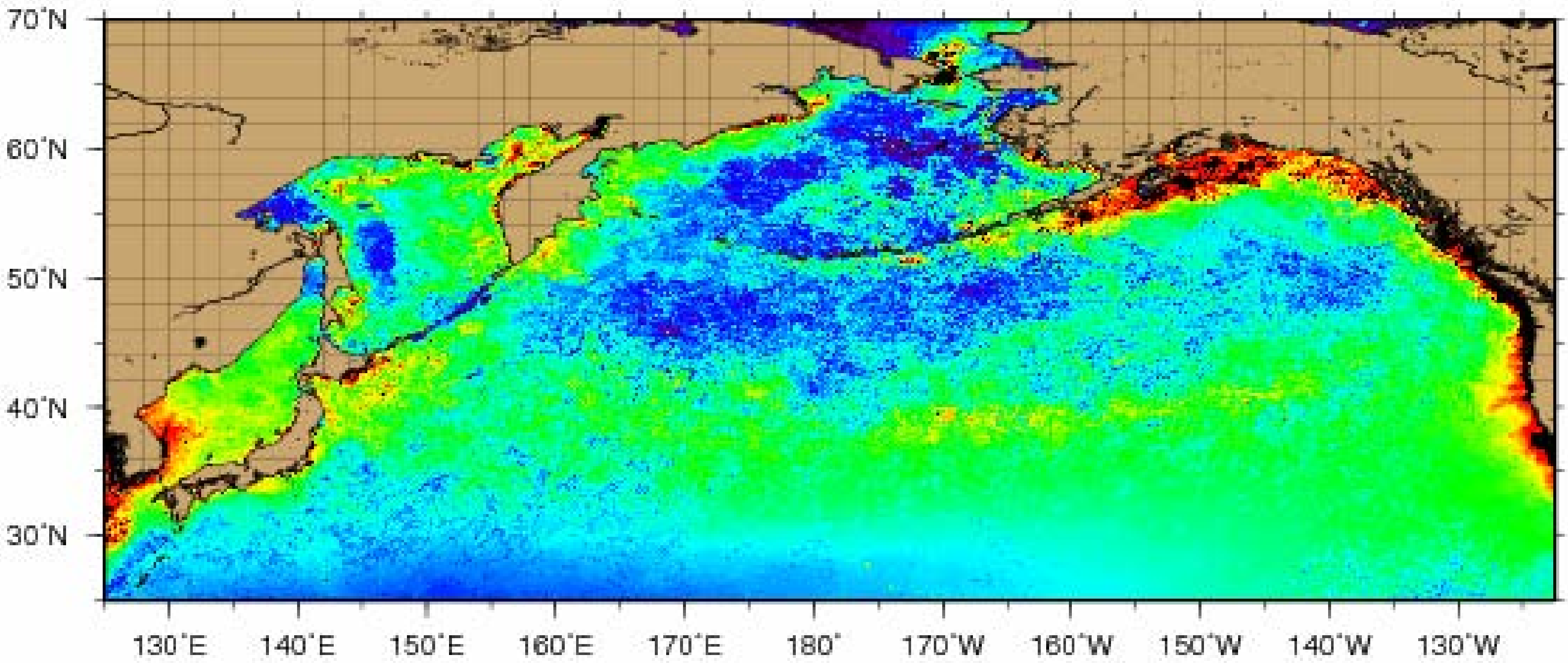


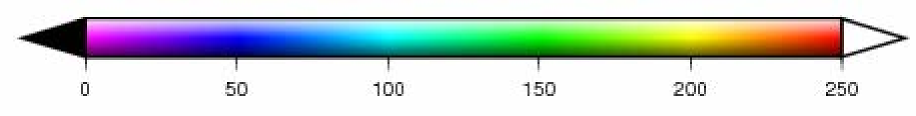


($gCm^{-2}year^{-1}$)

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

1999

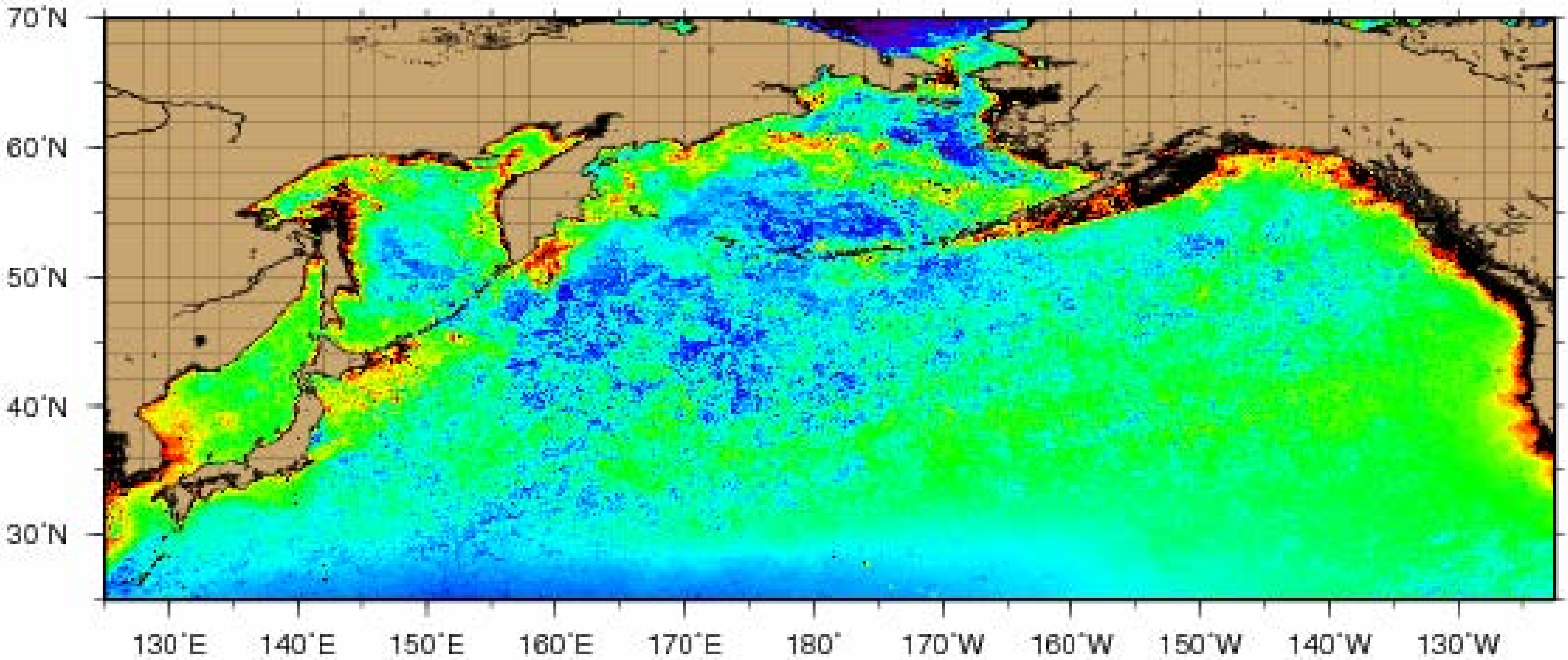


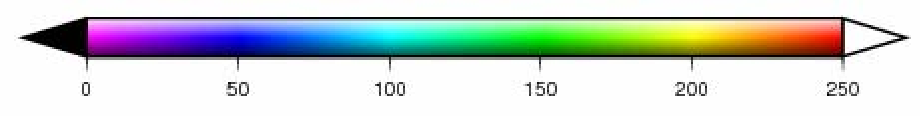


($gCm^{-2}year^{-1}$)

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

2000

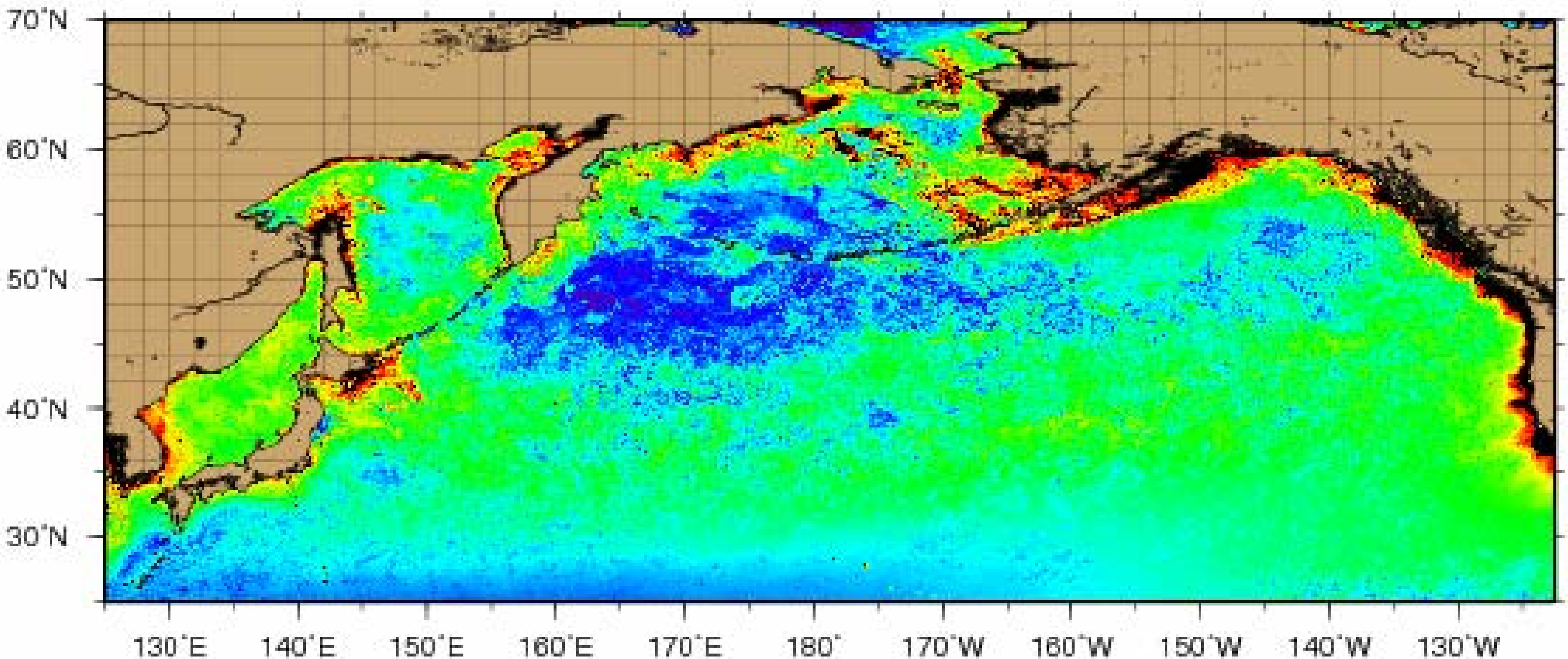


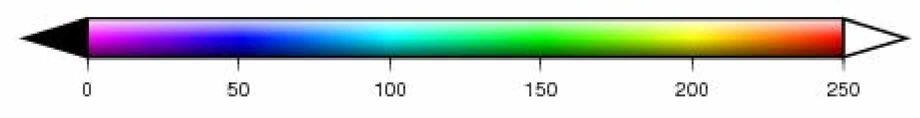


($gCm^{-2}year^{-1}$)

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

2001

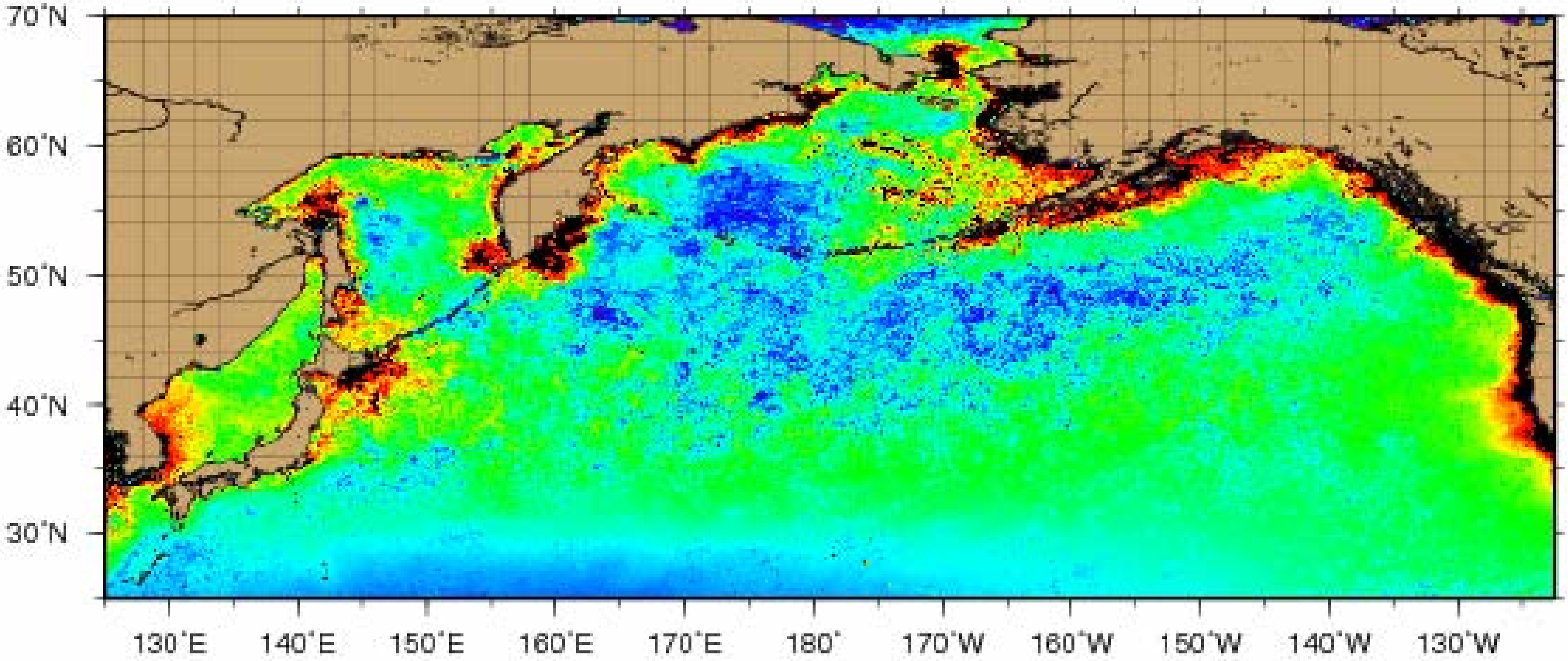


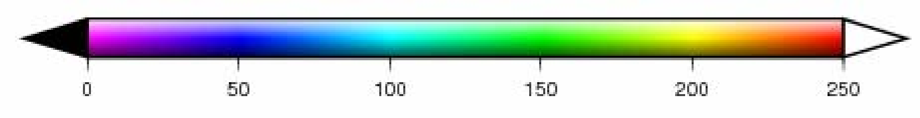


($gCm^{-2}year^{-1}$)

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

2002

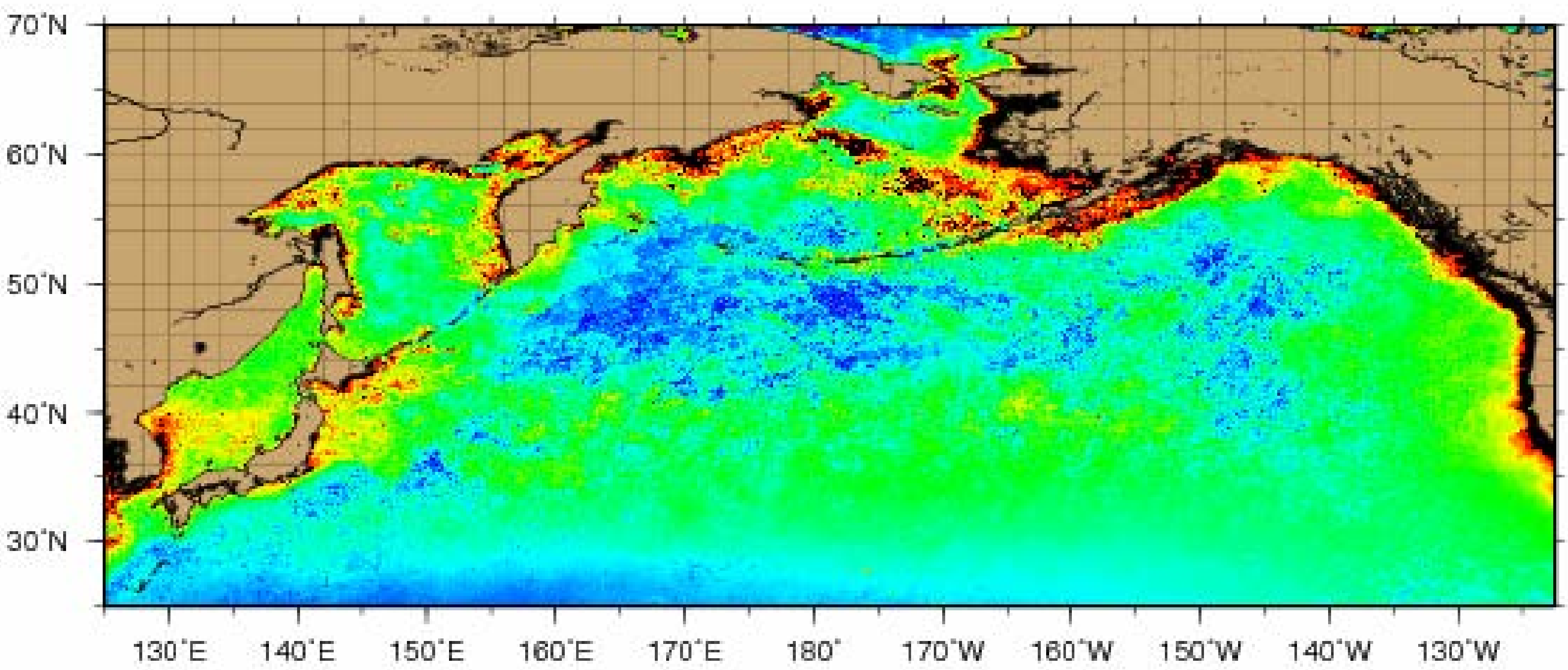




($gCm^{-2}year^{-1}$)

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

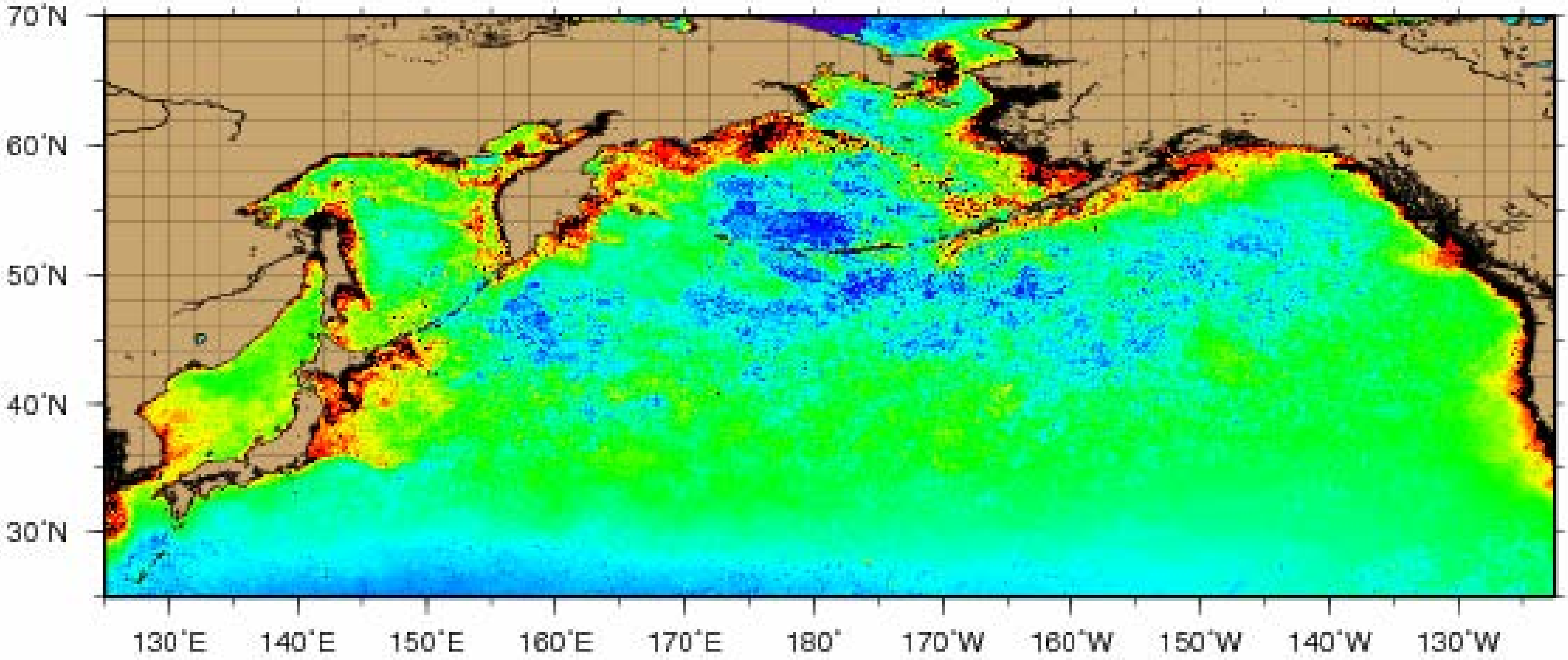
2003

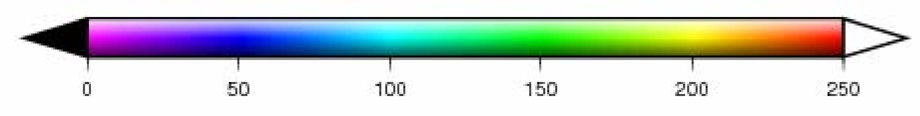


($gCm^{-2}year^{-1}$)

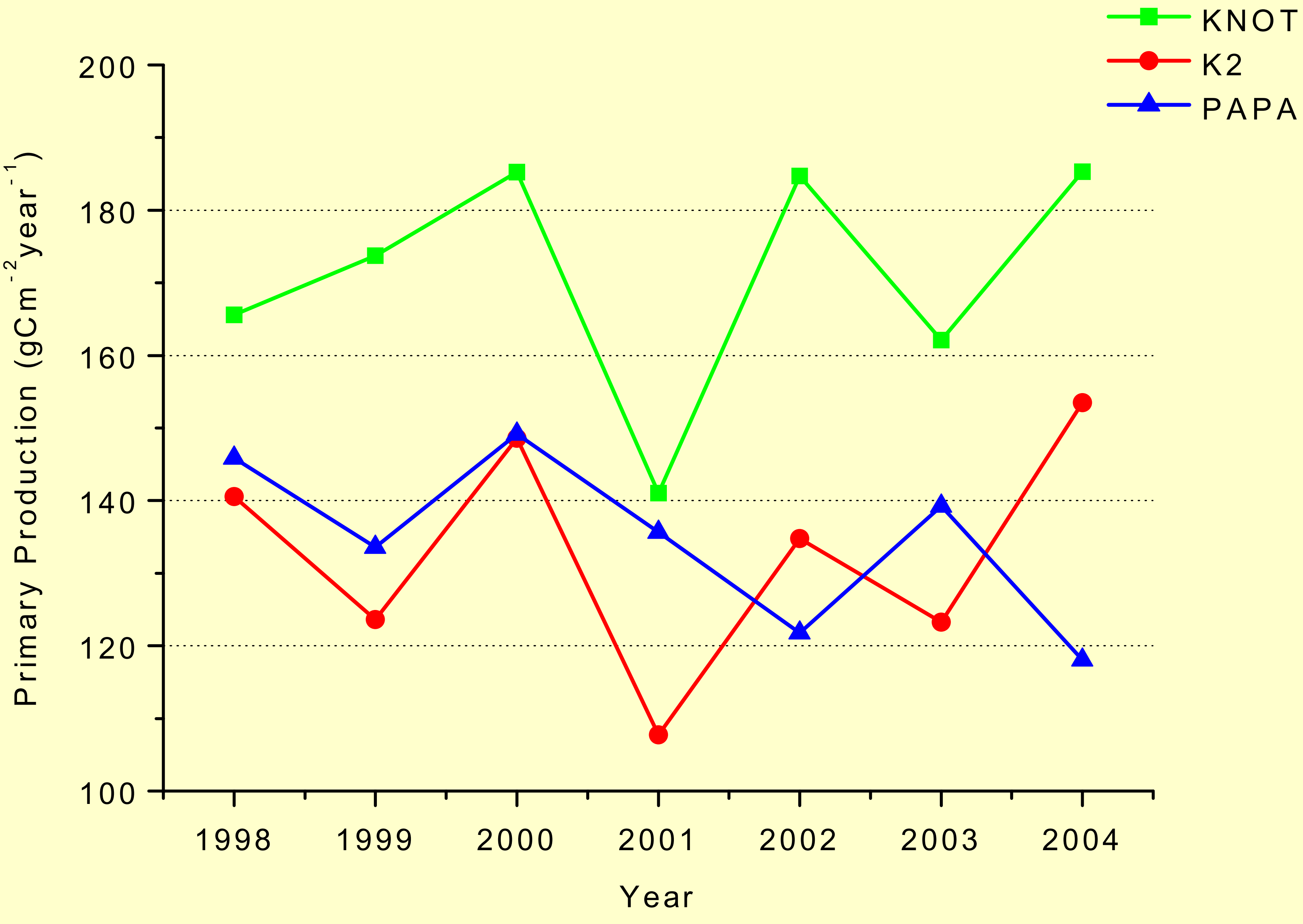
Annual Primary Production ($gCm^{-2}year^{-1}$)

2004





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



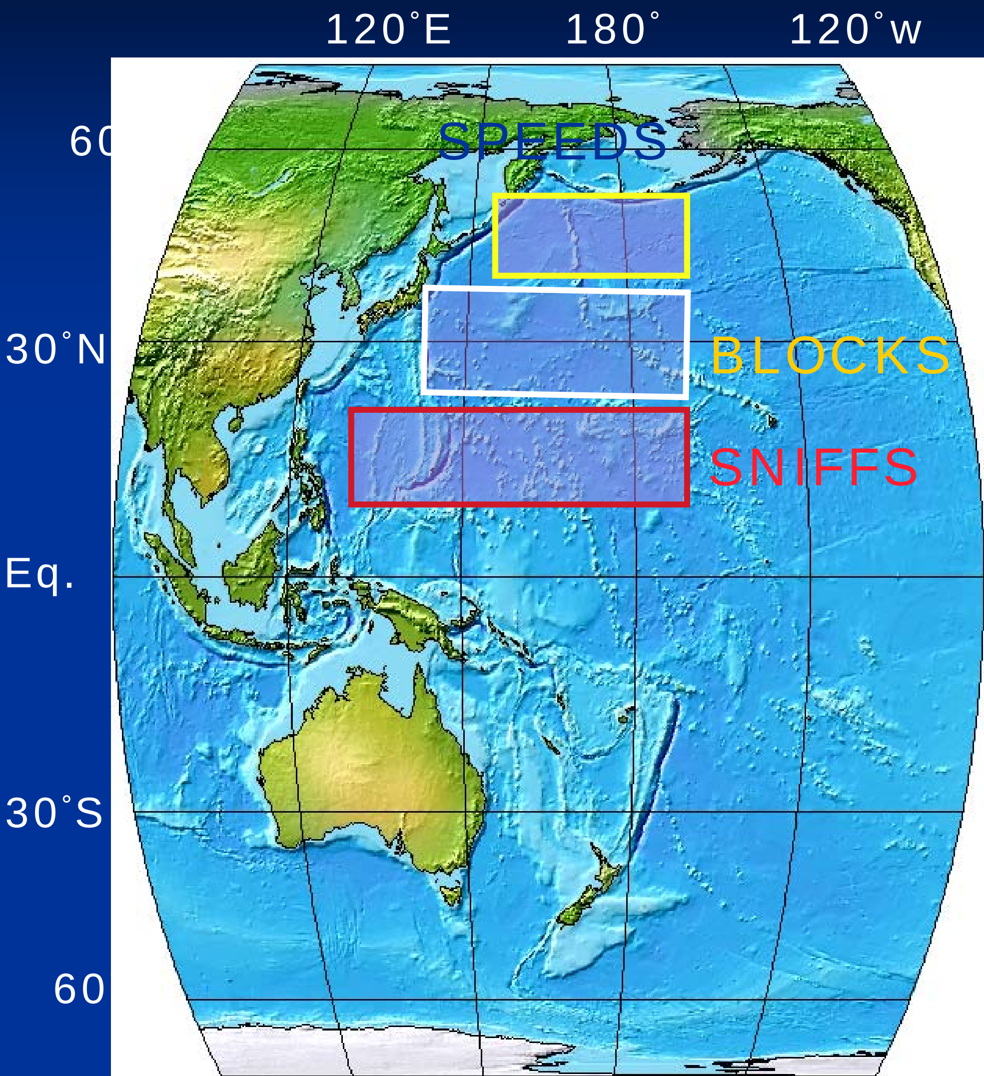
KNOT
K2
PAPA
200
180
160
140
120
100
Primary Production (gCm^{-2} year^{-1})
1998
1999
2000
2001
2002
2003
2004
Year

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

- Acknowledgement -

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using IARC (International Arctic Research Center)-JAXA
Information System (INIS).

Did Sea Lion know climate change?

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