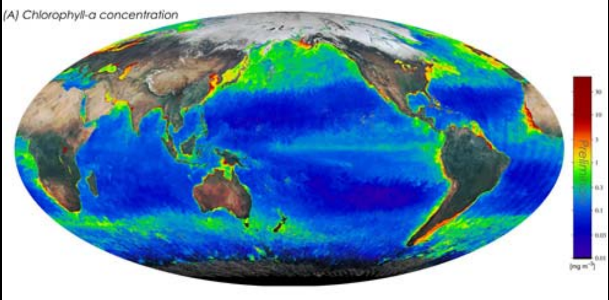
Methods of Sea Truth Measurements



Outline

- In-water Radiance
- Above-water Radiance
- Chlorophyll a
- Suspended Matter
- CDOM
- References

NASA Technical Memorandum

http://ntrs.nasa.gov/search.jsp

SeaWiFS technical report series. Volume 5 Ocean optics protocols for SeaWiFS validation: Mueller, J. L. and R.W. Austin, Eds., (1992)

SeaWiFS technical report series. Volume 25 Ocean optics protocols for SeaWiFS validation, revision 1: Mueller, J. L. and R.W. Austin, Eds. (1992)

Ocean Optics Protocols for Satellite Ocean Color Sensor Validation, Revision 2: Fargion, G.S. and J.L. Mueller, Eds. (2000)

Ocean Optics Protocols for Satellite Ocean Color Sensor Validation, Revision 3, Vol. 1&2: Mueller, J.L. and Fargion, G.S., Eds. (2002)

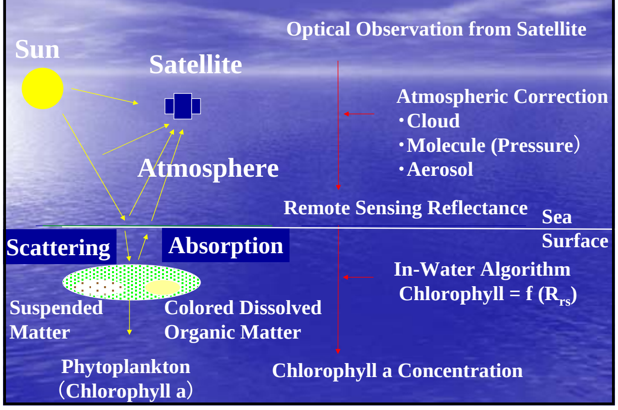
Ocean Optics Protocols for Satellite Ocean Color Sensor Validation, Revision 4, Vol. I-VI: Muller, J.L. et al., Ed.(2003)

Ocean Optics Protocols for Satellite Ocean Color Sensor Validation, Revision 5, Vol. V-VI: Muller, J.L. et al., Ed. (2003, 04)

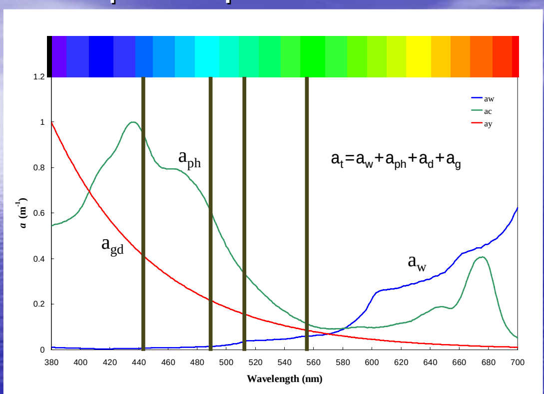
Ocean Optics Protocols for Satellite Ocean Color Sensor Validation, Revision 4 &5

- Vol. I: Intruduction, Background and Conventions
- Vol. II: Instrument Specifications, Characterization and Calibrtion
- Vol. III: Radiometric Measuremtns and Data Analysis Methods
- Vol. IV: Inherent Optical Properties: Instruments, Characterization, Field Measurements and Data Analysis Protocols
- Vol. V: Biogeochemical and Bio-Optical Measurements and Data Analysis Methods (Rev. 5)
- Vol. VI: Special Topics in Ocean Optics Protocols
- Vol. VI: Special Topics in Ocean Optics Protocols, Part II (Rev. 5)

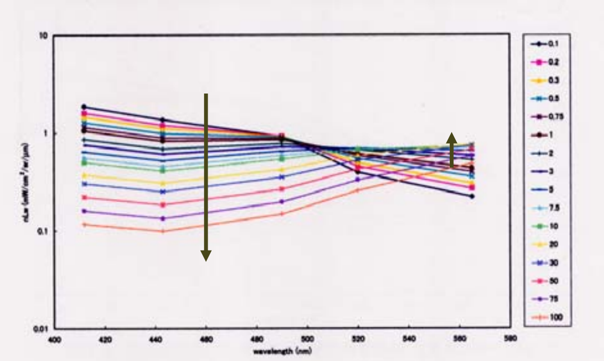
What is Ocean Color Remote Sensing



Absorption Spectra



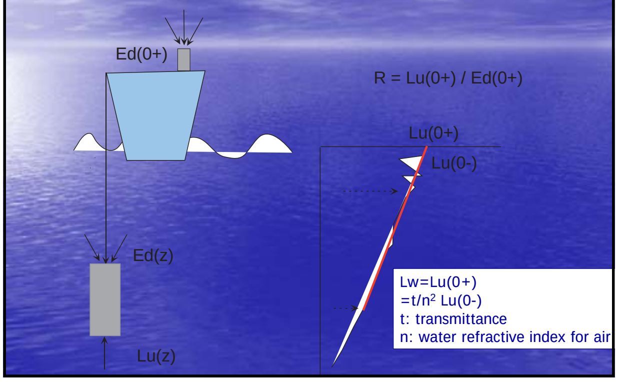
Change of Rrs with Chl.a (0.01-100mg mg^{-3})



Biospherical PRR-800/810

Satlantic HyperTSRB Profiler-II

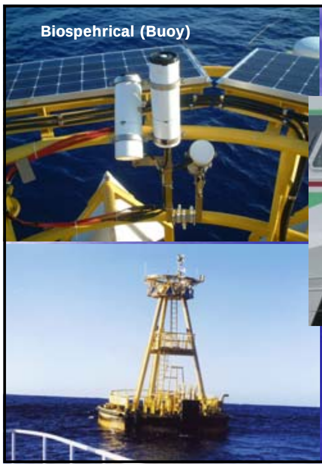
Estimation of Water Leaving Radiance from Under Water Radiometer Data

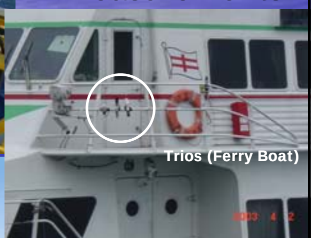


For underwater spectroradiometer

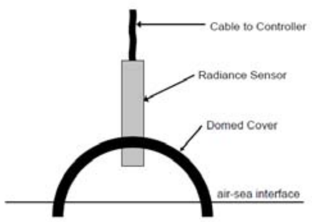
- Frequent calibration of equipment – at least once a year
- Avoid dirty and scratch of sensors
- Avoid ship shadow or reflectance – keep distance from ship
- Avoid tilting of the sensor
- Take into account the sensor length
- Check vertical profile carefully to decide the depth of extrapolation of data

Above-water Measurements





New Method of Above Water Measurement (Tanaka et al., 2006)



Measurements of Chlorophyll-a

- Spectrophotometer
  - Absorption of 2-3 wavelength
  - Low sensitivity (required >1L filteration)
- Fluorometer (blue excitation, red emission)
  - In vivo fluorescence
    - Fluorescence from living cells (approximation)
  - Extracted fluorescence
    - Sensitive (require filtration of ~100ml)
    - Acid Method
    - Calibration with spectrophotometer is required.

Spectrophotometric Method

- in DMF

  Chl.a（μg mL^{-1}） = (A(663)-A(750)) /0.08874
- in 90% Aceton

  Chl.a（μg mL^{-1}） = (A(663)-A(750)) /0.08767

HPLC

- Discriminate different pigments and degradation products.
- Chemotaxonomy
- Difficult to set up and handle.

TSM (SPM, SS, TSS)

- Nuclepore 0.2 µm
- Millipore HA 0.45 µm
- GF/F (~0.4 µm) required if ash be measured to distinguish organic to inorganic portion.
- Should be measured several times repeated drying to obtain stable data in low humidity room.

Estimation of Primary Production

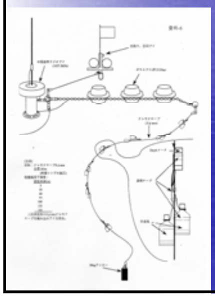
Biomass (Chlorophyll)

↓

Rate of Carbon Fixed

(C^{14} or C^{13} Incubation)

In situ Method



Simulated In Situ Method

Biomass and Production

- Biomass (Concentration)
  - Mass/Volume : μg-chl.a/L, = mg-chl.a/m^3
  - Mass/Area : mg/m^2
- Production (Rate)
  - Mass/Volume/Time : mgC/L/day
  - Mass/Area/Time : mgC/m^2/day, gC/m^2/year
- Production/Biomass (Activity) P^B
  - Mass/Mass/Time : mgC/mg-chl.a/day
  - Function of Temperature, Light, Nutrients, Species…

Photosynthesis

$6CO_2 + 12H_2O$ +Light Energy
→ $6CH_2O + 6H_2O + 6O_2$

Respiration
$6CH_2O + 6H_2O + 6O_2$
→ $6CO_2 + 12H_2O$ + Energy

Gross Primary Production (Photosynthesis)
Net Primary Production
(Photosynthesis - Respiration)

Estimation of Global Primary Production

Riley ('46)	126	DO method, several stations
Steemann Nielsen ('55)	15	^{14}C methods
Ryther ('69)	20	Ocean:Coast:Upwelling= 90:9.9:0.1
Koblentz-Mishke et al.('70)	23	7000 data
Lieth and Whittaker ('75)	18.6	Fleming ('57)
Platt and Sabbarao ('75)	31	Summaries areal data
Eppley and	19.1	Modified Koblentz-Mishke et al. ('70)
Peterson ('79)	23.7	Modified Platt and Subba Rao ('75)
Romankevich('84)	25	Modified Koblentz-Mishke et al. ('70)
Shushkina ('85)	56	130 stations ('68-'82)
Berger et al. ('87)	26.9	8000 stations (mostly '70-)
Martin et al. ('87)	51	Ryhter ('69) method + Clean Method
Longhurst et al. ('95)	45-51	Satellite data (CZCS) + biological provinces

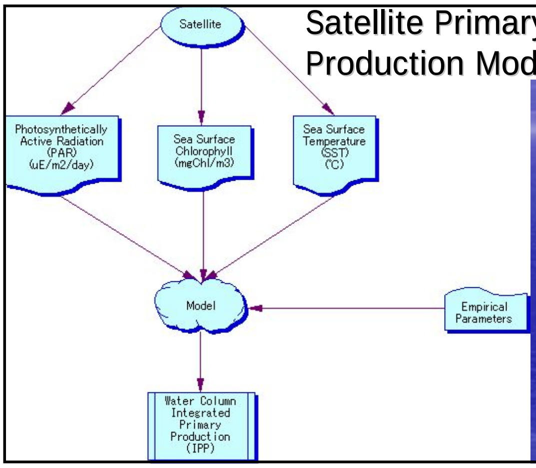
Sverdrup (1955) The Place of Physical Oceanography in the Oceanographic Research

Ryther, 1969 (Science)

	Area ($x10^6$ km^2)	Primary Production ($gC/m^2/y$)	Number of Trophic Level	Transfer Efficient (%)	Fish Production ($mgC/m^2/y$)	Global Fish Production ($x10^3$ t/y)
Open Ocean	322	50 (1)	5	10	0.5 (1)	150 (1)
Coastal	26.2	100 (2)	3	15	340 (680)	9000 (60)
Upwell-ing	0.4	300 (6)	1.5	20	36,000 (72,000)	14,400 (100)

Longhurst et al. (1995)

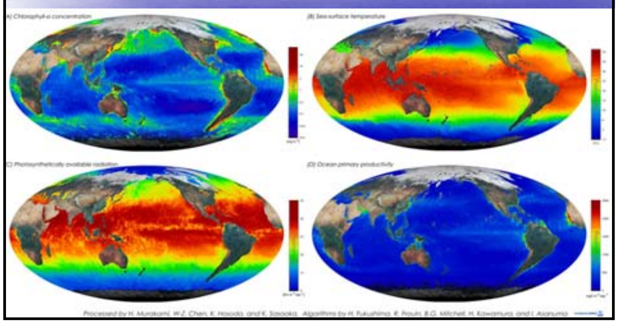
Satellite Primary Production Model



Controlling Factors

- Phytoplankton Biomass
- Light (Energy Source)
- Nutrients (Material Source)
  - Macro: NO_3, NO_2, NH_4, PO_4, SiO_2
  - Micro: Fe,,,
- Temperature (Chemical Reaction Speed)
- Phytoplankton Group

CHL, SST, PAR - SST



Different Type of Primary Production Models (Behrenfeld and Falkowski, 1997)

- Wavelength-Resolved Models (WRMs) -(WTDRM)

$$\sum PP = \int_{\lambda=400}^{700}\int_{Sunrise}^{Sunset}\int_{Z=0}^{Zeu}\Phi(\lambda,z)\cdot PAR(\lambda,t,z)\cdot a^{*}\cdot Chl(z)\,d\lambda dtdz$$

- Wavelength-Integrated Models (WIMs)-(TDRM)

$$\sum PP = \int_{Sunrise}^{Sunset}\int_{Z=0}^{Zeu}\Psi(z)\cdot PAR(t,z)\cdot Chl(z)\,dtdz$$

- Time Integrated Models (TIMs)-(DRM)

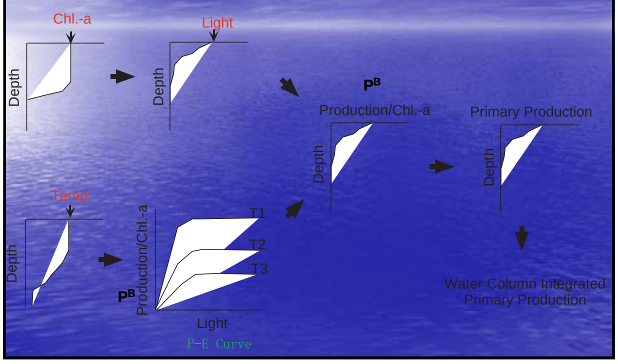
$$\sum PP = \int_{Z=0}^{Zeu}P^{B}(z)\cdot PAR(z)\cdot DL\cdot Chl(z)\,dz$$

- Depth-Integrated Models (DIMs)-(IM)

$$\sum PP = P^{B}_{opt}\cdot PAR(0)\cdot DL\cdot Chl(0)\cdot Zeu$$

Biogeochemical Provinces (Longhurst et al., 1995)

Depth Resolved Primary Production Model

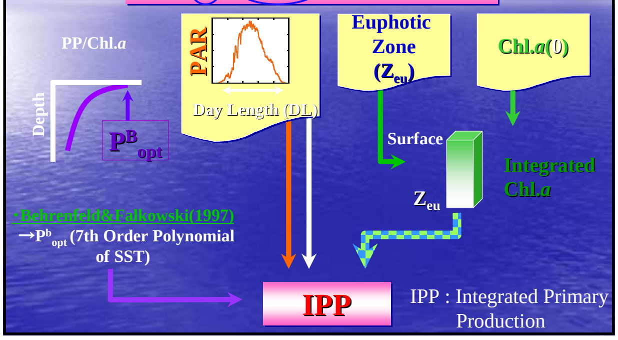


Wavelength,
Time,
Depth
Resolved
Primary
Production
Model
(Ishizaka
et al., 1998)

based on
(Morel, 1991)

VGPM (Vertically Generalized Production Model)
Behrenfeld & Falkowski (1997)

$$IPP = P^b_{opt} \times f[PAR(0)] \times DL \times Chl.a(0) \times Z_{eu}$$



Modified Behrenfeld and Falkowski (1997)
Two Phytoplankton Community Model of P^B_{opt}
(Kameda and Ishizaka, 2005)

IPP =

$$0.66125\ P^B_{opt}\ [E_0 / (E_0 + 4.1)]\ Z_{eu}\ C_{z0}\ D_{irr}$$

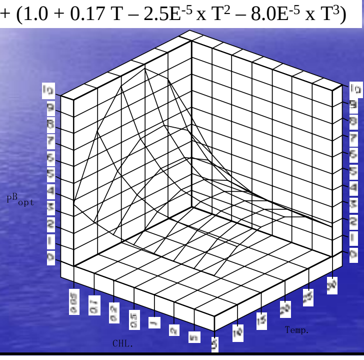
P^B_{opt} = f (SST) B&F 7th order polynomial
P^B_{opt} = f (SST, CHL) K&I

$CHL = CHL_S + CHL_L$
$Prod = Prod_S\ CHL_S + Prod_L CHL_L$

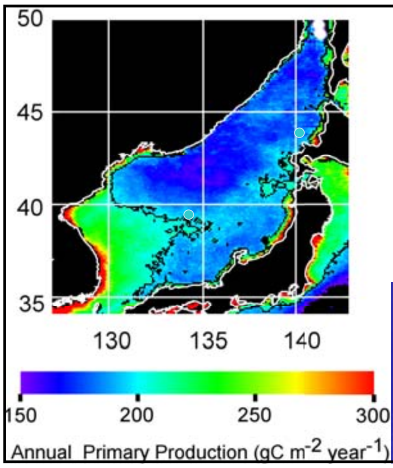
Temperature Dependence of P^B_{opt} (Behrenfeld and Falkowski, 1997)

Temperature-Chlorophyll Dependent Model of P^B_{opt} (Kameda & Ishizaka, 2005)

$$P^B_{opt} = (0.071\,T - 3.2E^{-3} \times T^2 + 3.0E^{-5} \times T^3)/Chl + (1.0 + 0.17\,T - 2.5E^{-5} \times T^2 - 8.0E^{-5} \times T^3)$$

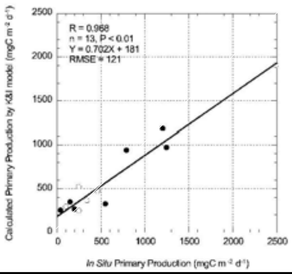


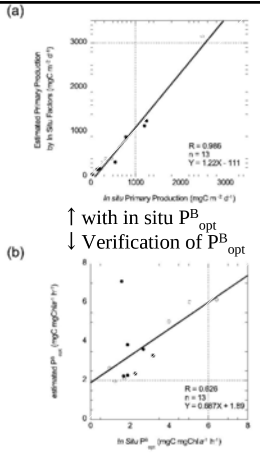
Primary Production in the Japan Sea by K&I Model (Yamada et al, 2005)



Verification of K&I Model in the Japan Sea

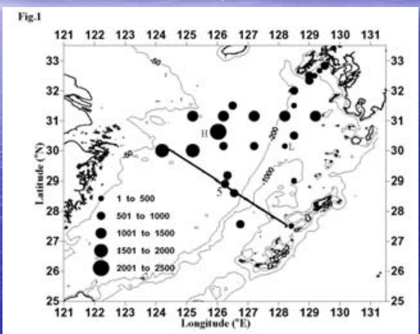
(Yamada et al, JO-2005)





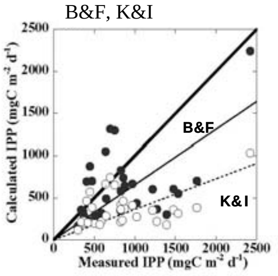
Primary Production Measurements in the East China Sea

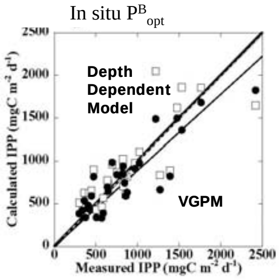
(Siswanto et al., 2006-JO)

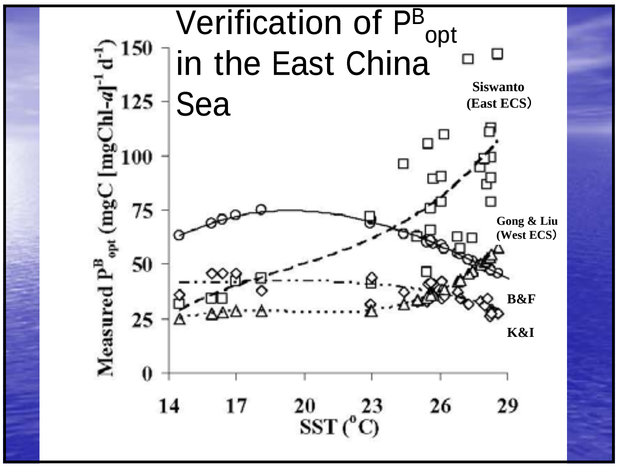


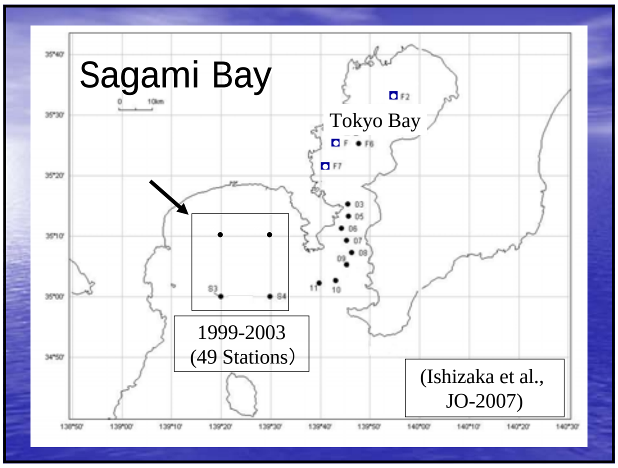
Verification of VGPM in the East China Sea

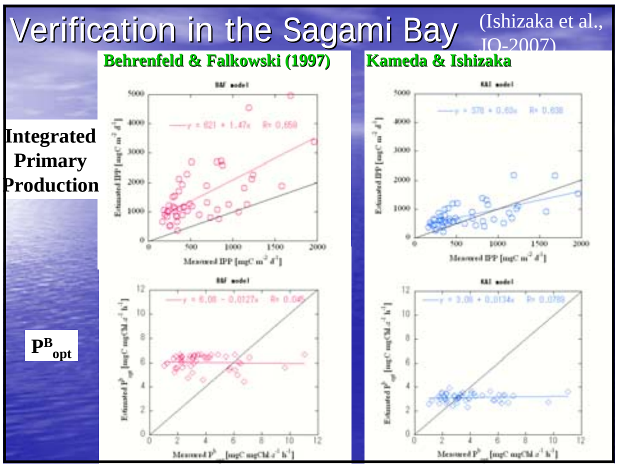
(Siswanto et al., 2006-JO)





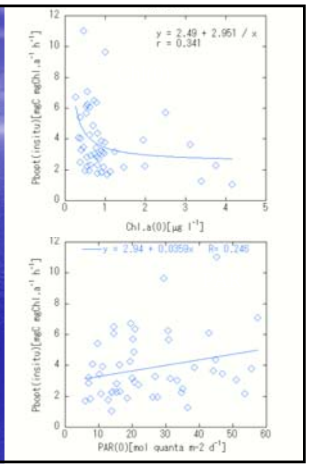

Verification of P^B_{opt} in the East China Sea
Siswanto (East ECS)
Gong & Liu (West ECS)
B&F
K&I
Measured P^B_{opt} (mgC [mgChl-a]$^{-1}$ d^{-1})
SST (^{o}C)
0
25
50
75
100
125
150
14
17
20
23
26
29

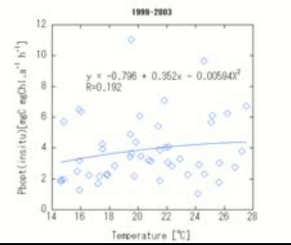

Sagami Bay
Tokyo Bay
1999-2003
(49 Stations)
(Ishizaka et al., JO-2007)


Verification in the Sagami Bay
(Ishizaka et al., JO-2007)
Behrenfeld & Falkowski (1997)
Kameda & Ishizaka
Integrated Primary Production
P^B_{opt}

P^B_{opt} and SST, Chl(0), PAR

(Ishizaka et al., JO-2007)

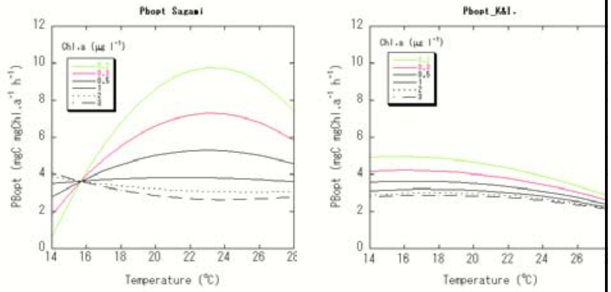




P^B_{opt} Model in the Sagami Bay

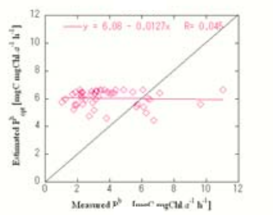
P^B_{opt} =
$(-12.2+1.17\,T - 0.025\,T^2)/\mathrm{Chl}$
$+ (13.3 + 0.916\,T - 0.0191\,T^2)$

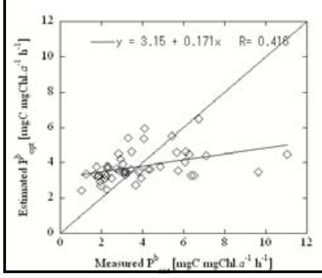
P^B_{opt} =
$(0.071\,T - 3.2E^{-3} + 3.0E^{-5}\,T^3)/\mathrm{Chl}$
$+ (1.0 + 0.17\,T - 2.5E^{-5}\,T^2 - 8.0E^{-5}\,T^3)$



(Ishizaka et al., JO-2007)

Predicted P^B_{opt}





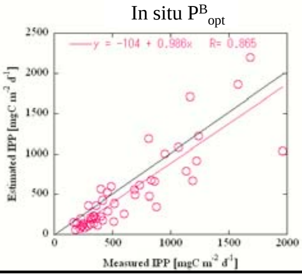
Parameter Adjustment of VGPM

IPP=

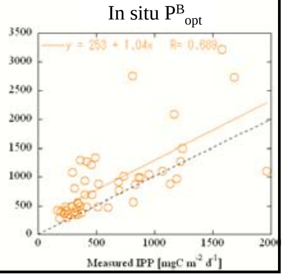
(best fit) $4.19\ P^B_{opt}\ PAR/(PAR+336) DL\ Chl(0)\ Zeu$

(original B&F) $0.66125\ P^B_{opt}\ PAR/(PAR+4.1)\ DL\ Chl(0)\ Zeu$

In situ P^B_{opt}

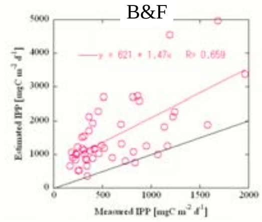


In situ P^B_{opt}

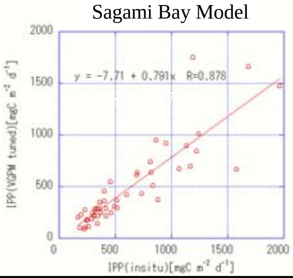


Results of Sagami Bay Model and Global Models

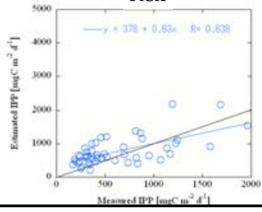
B&F



Sagami Bay Model



K&I



Summary

- Primary Production is important parameter for ecosystem dynamics.
- With Satellite, it is easy to calculate.
- Some models with different complexity are available.
- However, parameters are different regionally, and at present measurements and tuning of the model is necessary.

References and suggested readings

Ishizaka, J., E. Siswanto, T. Itoh, H. Murakami, Y. Yamaguchi, T. Ishimaru, S. Hashimoto and T. Saino (2007): Verification of Vertically Generalized Production Model and Estimation of Primary Production in the Sagami Bay, Japan. J. Oceanogr. 64, 517-524.

Siswanto, E., J. Ishizaka and K. Yokouchi (2006) Optimal primary production model and parameterization in the eastern East China Sea. J. Oceanogr. 62, 361-372.

Yamada, K., J. Ishizaka, H. Nagata (2005) Spatial and temporal variability of satellite estimated primary production in the Japan Sea from 1998 to 2002. J. Oceanogr. 61, 857-869.

Kameda, T. and J. Ishizaka (2005) Size-fractionated primary production estimated by a two-phytoplankton community model applicable to ocean color remote sensing. J. Oceanogr. 61, 663-672.

Carr, M. E., M.A.M. Fredrichs, M. Schmeltz, M.N. Aita, D. Antoine, K.R. Arrigo, I. Asanuma, O. Aumont, R. Barber, M. Behrefeld, R. Bidigare, E. Buitenhuis, J. Campbell, A. Ciotti, H. Dierssen, M. Dowell, J. Dunne, W. Esaias, B. Gentili, S. Groom, N. Hoepffner, J. Ishizaka, T. Kameda, C. LeQuere, S. Lohrenz, J. Marra, F. Melin, K. Moore, A. Morel, T. Reddy, J. Ryan, M. Scardi, T. Smyth, K. Turpie, G. Tilstone, K. Waters, Y. Yamanaka (2006): A comparison of global estimates of marine primary production from ocean color. Deep-Sea Res. II, 53, 741-770.

References and Suggested Readings

- Ishizaka, J. (1998): Spatial distribution of primary production off Sanriku, Northwestern Pacific, during spring estimated by Ocean Color and Temperature Scanner (OCTS). J. Oceanogr., 54, 553-564.
- Behrenfeld, M. J. and P. G. Falkowski (1997): A comumers guide to primary productivity models. Limnol. Oceanogr. 42: 1479-1491.
- Behrenfeld, M. J. and P. G. Falkowski (1997): Photosynthetic rates derived from satellite-based chlorophyll concentration. Limnol. Oceanogr. 42: 1-20.
- Longhurst, A., S. Sathyendranath, T. Platt and C. Caverhill (1995): An estimate of global primary production in the ocean from satellite radiometer data. J. Plankton Res. 17: 1245-1271.