Progress report in 2013FY

Estimation of net primary productivity (NPP) and discrimination of phytoplankton functional types (PFTs) (GCOM-C1 RA4 No.304)

PI: Toru Hirawake, Hokkaido Univ.

CI: Sei-Ichi Saitoh, Hokkaido Univ.

Amane Fujiwara, NIPR

Tasks in 2013FY

1. Reconstruction and validation of NPP and PFT algorithms
2. Collection of new data
3. Construction of database for in-situ data
4. Writing of protocols for in-situ measurements

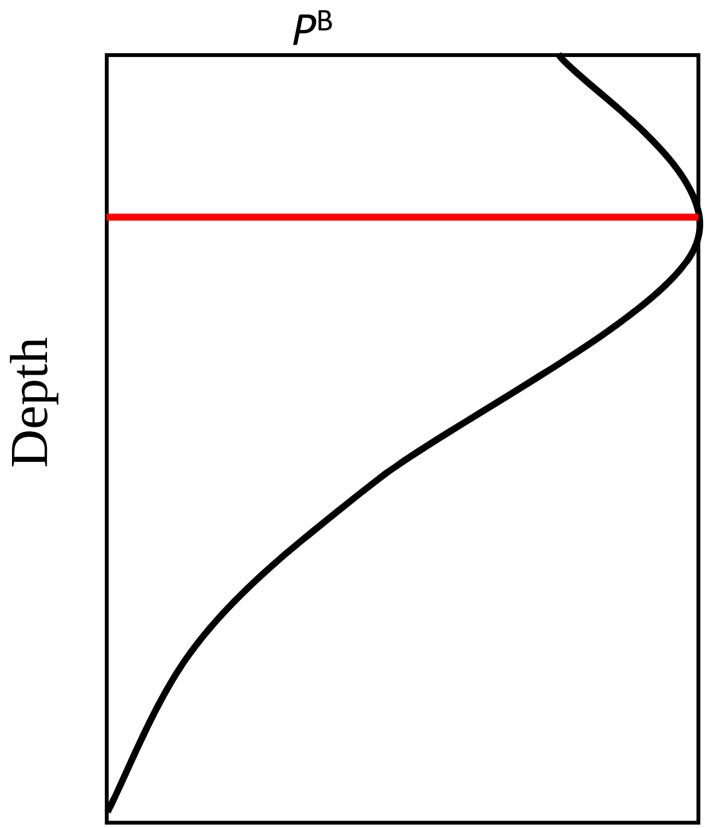
Ocean Net Primary Productivity algorithm

Absorption Based Primary Productivity Model (ABPM)

Absorption based primary productivity model (ABPM)

$$PP_{eu} = f\,[\tilde{a}_{\mathrm{ph}}(0\text{-})] \times Z_{eu} \times \frac{0.66125 \times E_0}{E_0 + 4.1} \times DL$$

VGPM (Behrenfeld & Falkowski, 1997)



Function of SST in VGPM

Assuming chl.a is homogeneous within water column

$$P^{B}_{opt} \times Chl_{surf} = Popt$$

Chl *a* and SST were not used.

$\tilde{a}_{\mathrm{ph}}(0\text{-})$

Absorption coefficient at the sea surface

Hirawake et al. 2011 Polar Biology

Reconstruction of Algorithm

Prototype

(Hirawake et al., 2011; Hirawake et al., 2012)

$a_{ph}(443, 0\text{-})$ or $\bar{a}_{ph}(0\text{-})$

$P_{opt} = P^{B}_{opt} \times C_{surf}$

New version

$a_{ph}(443, 0\text{-}) \text{ x } E_0 \,/\, DL$

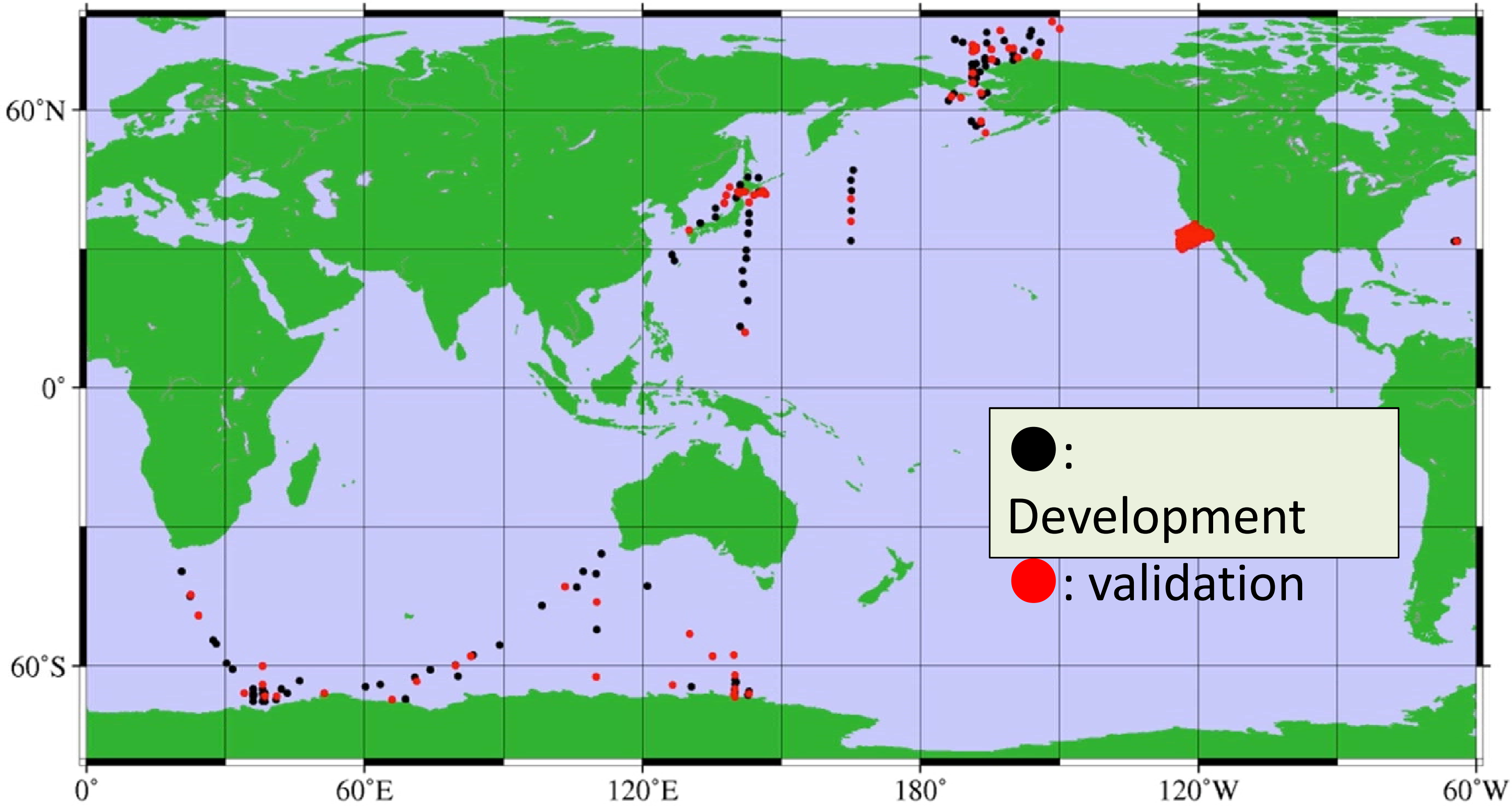
or

$\bar{a}_{ph}(0\text{-}) \text{ x } E_0 \,/\, DL$

(mol photons m^{-3} h^{-1})

$P_{opt} = P^{B}_{opt} \times C_{surf}$

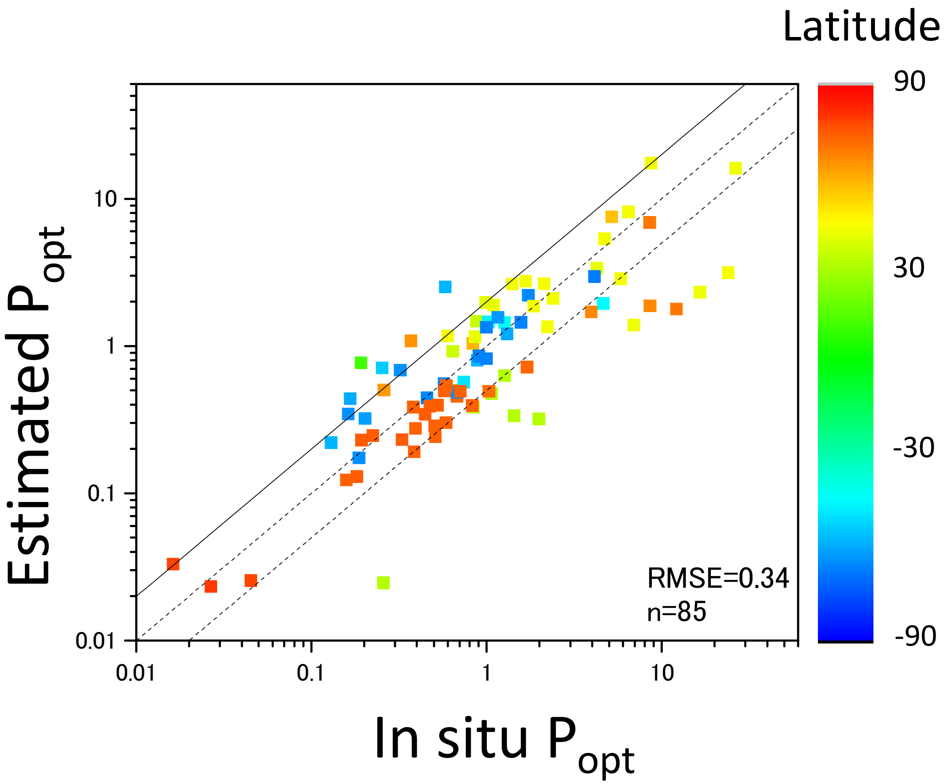
Map of sampling stations for NPP



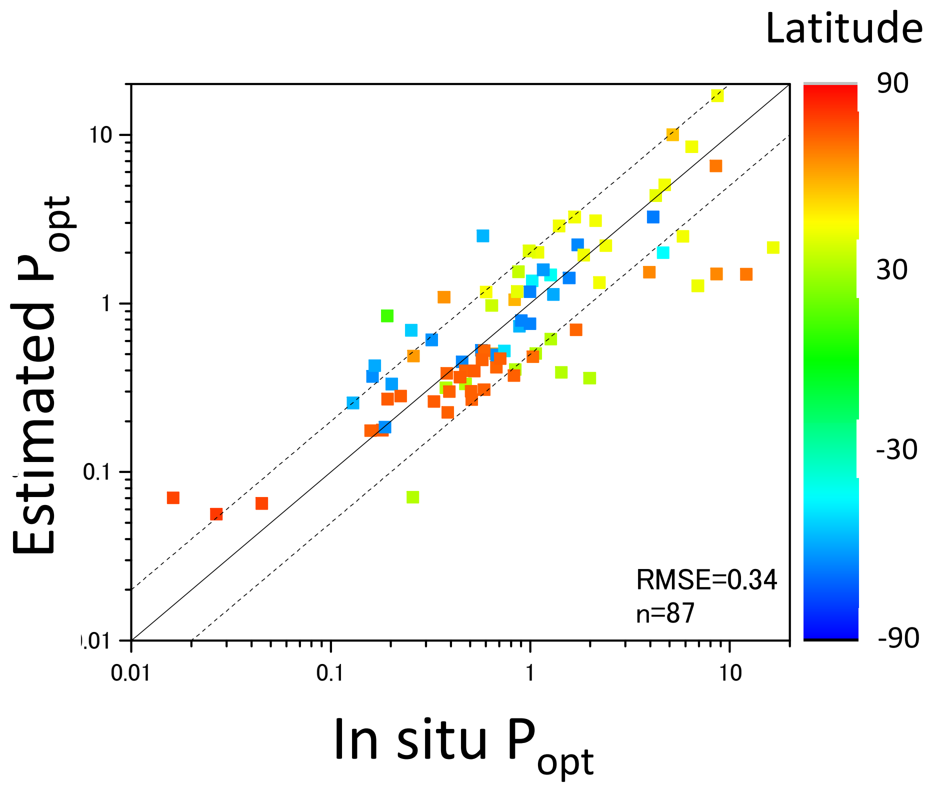
Dataset for NPP

Cruise	Year	Number of Stns.	For development	For validation	Methods	Region
OS180	2007	15	11	4	^{13}C	Arctic
OS190	2008	12	10	12	^{13}C	Bering Sea
OS216	2010	15	14	1	^{13}C	North Pacific
OS229	2011	13	9	4	^{13}C	Around Japan
US260	2012	3	-	3	^{13}C	Off Muroran
US263	2012	4	-	4	^{13}C	Off Muroran
MR0903	2009	15	8	7	^{13}C	Arcitc
MR12-E03	2012	10	8	2	^{13}C	Arcitc
MR1306	2013	18	-	18	^{13}C	Arcitc
UM0203	2003	17	9	8	^{13}C	Southern Ocean
UM0405	2005	13	12	1	^{13}C	Southern Ocean
UM0506	2006	10	7	3	^{13}C	Southern Ocean
UM0708	2008	22	13	9	^{13}C	Southern Ocean
UM0809	2009	10	7	3	^{13}C	Southern Ocean
OECOS	2007	10	5	5	^{13}C	Off Kushiro
BLOSSOM	2007	16	10	6	^{13}C	Off Kushiro
KT11-０７	2011	2	1	1	^{13}C	Off Kushiro
BATS	1998-2006	33	24	9	^{14}C	Off Bermuda
CALCOFI	2003-2004	69	-	69	^{14}C	Off California
		307	148	169		

Validation of P_{opt}=P^{B}_{opt} × C_{surf} using in situ data

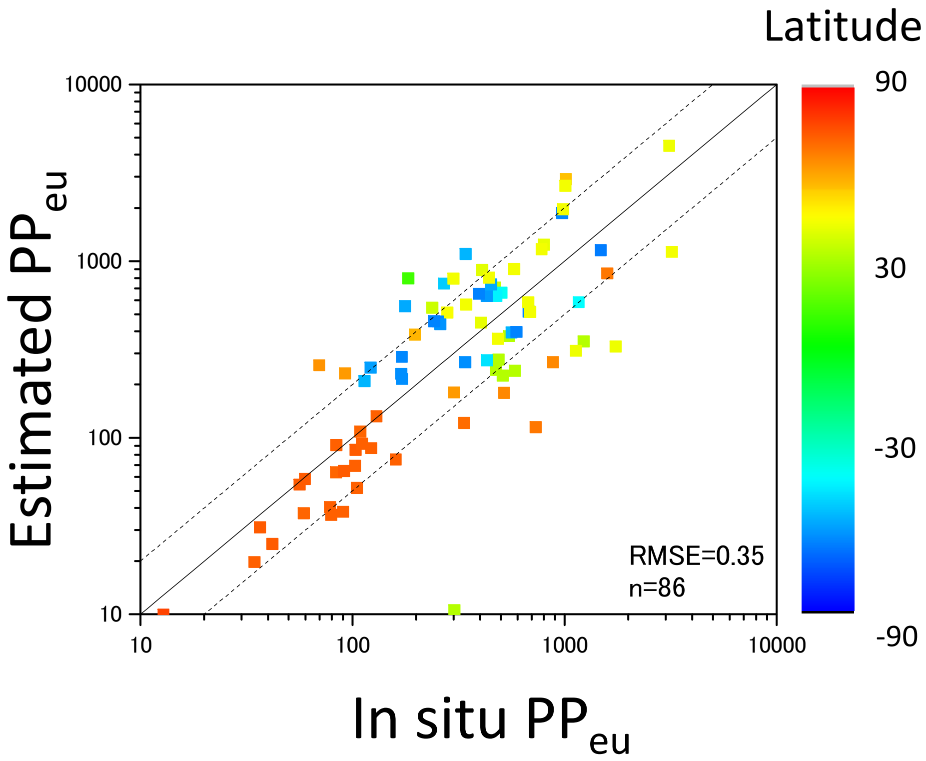


$\bar{a}_{ph}(0\text{-}) \times E_0 / DL$

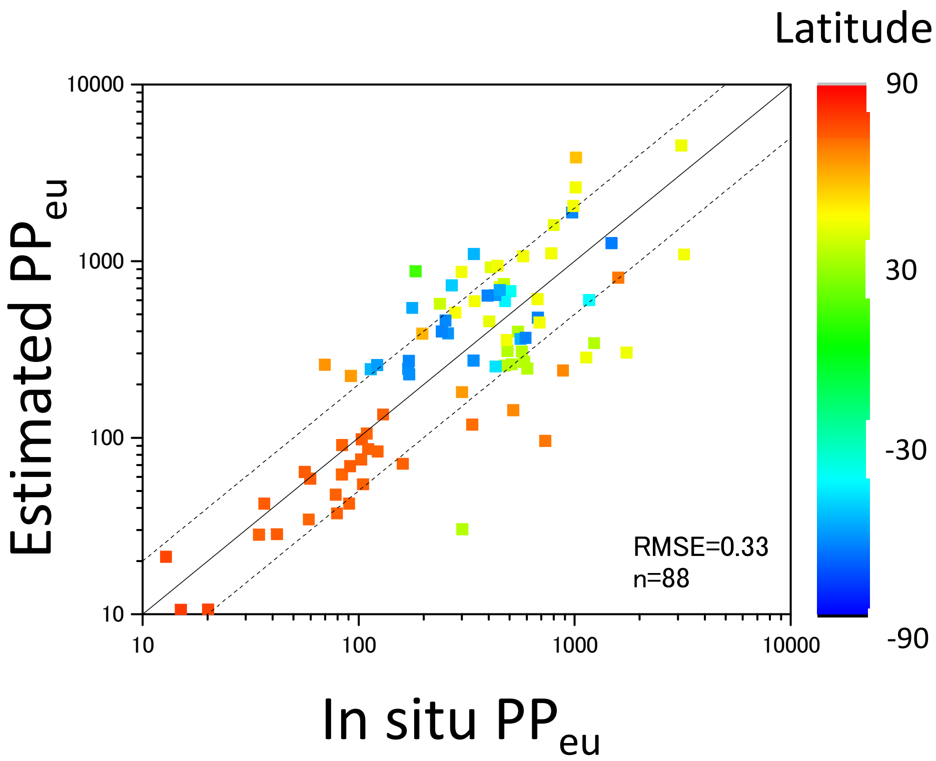


$a_{ph}(443, 0\text{-}) \times E_0 / DL$

Validation of NPP (PP_{eu}) using in situ data

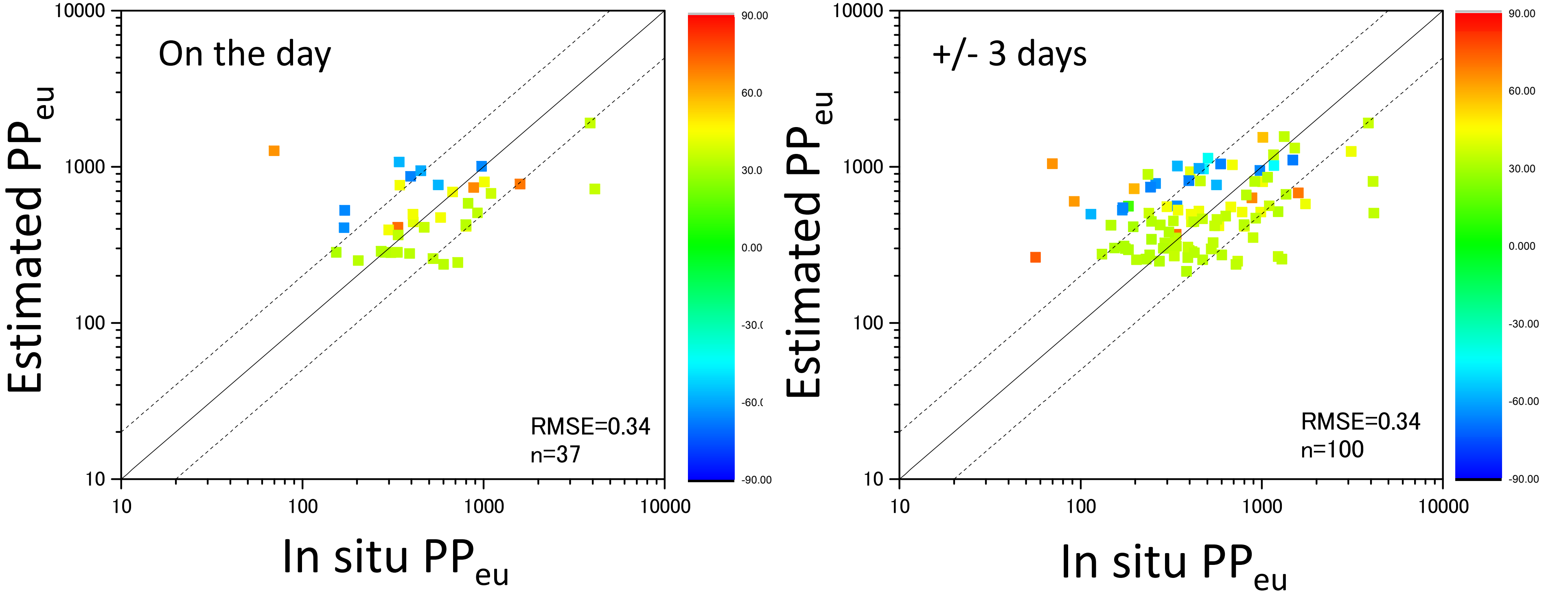


$\bar{a}_{ph}(0\text{-}) \times E_0 / DL$



$a_{ph}(443, 0\text{-}) \times E_0 / DL$

Validation of NPP (PP_{eu}) using MODIS data



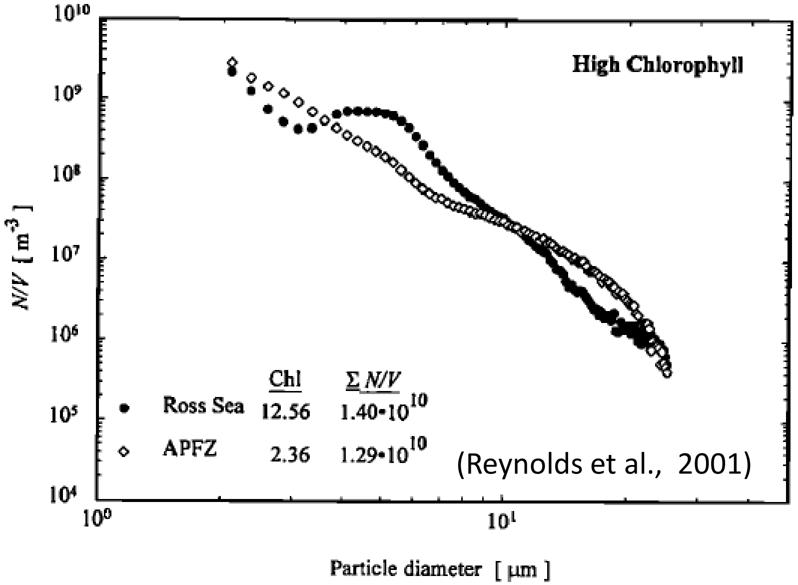
MODIS $a_{ph}(443, 0\text{-}) \times E_0 / DL$

Phytoplankton Functional Types (PFTs)

- Phytoplankton groups categorized by biogeochemical and ecological function

- Phytoplankton taxonomy
- **<u>Phytoplankton size class (this study)</u>**
  ---determines number of trophic levels in food web

Particle size distribution (PSD)



$$N/V(D) = N_0/V\,(D/D_0)^{-\xi}$$

- Particle number concentration at diameter D (N/V(D)) is a power law function of Junge-Slope ξ

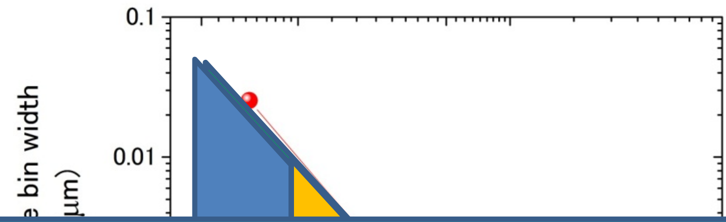
(Junge, 1963)

- Advantage

  Deriving the Junge-slope（ξ）and N_0/V make it possible to estimate particle number at any diameter
- Disadvantage

  It derives “particle“ number, not phytoplankton directly

Calculation of the fraction of phytoplankton size classes



$$\mathrm{Chl}a = \int_{D_{min}}^{D_{max}} \mathrm{nChla}(D_0)\left(\frac{D}{D_0}\right)^{\eta} dD \quad (\mathrm{mg\ m^{-3}}),$$

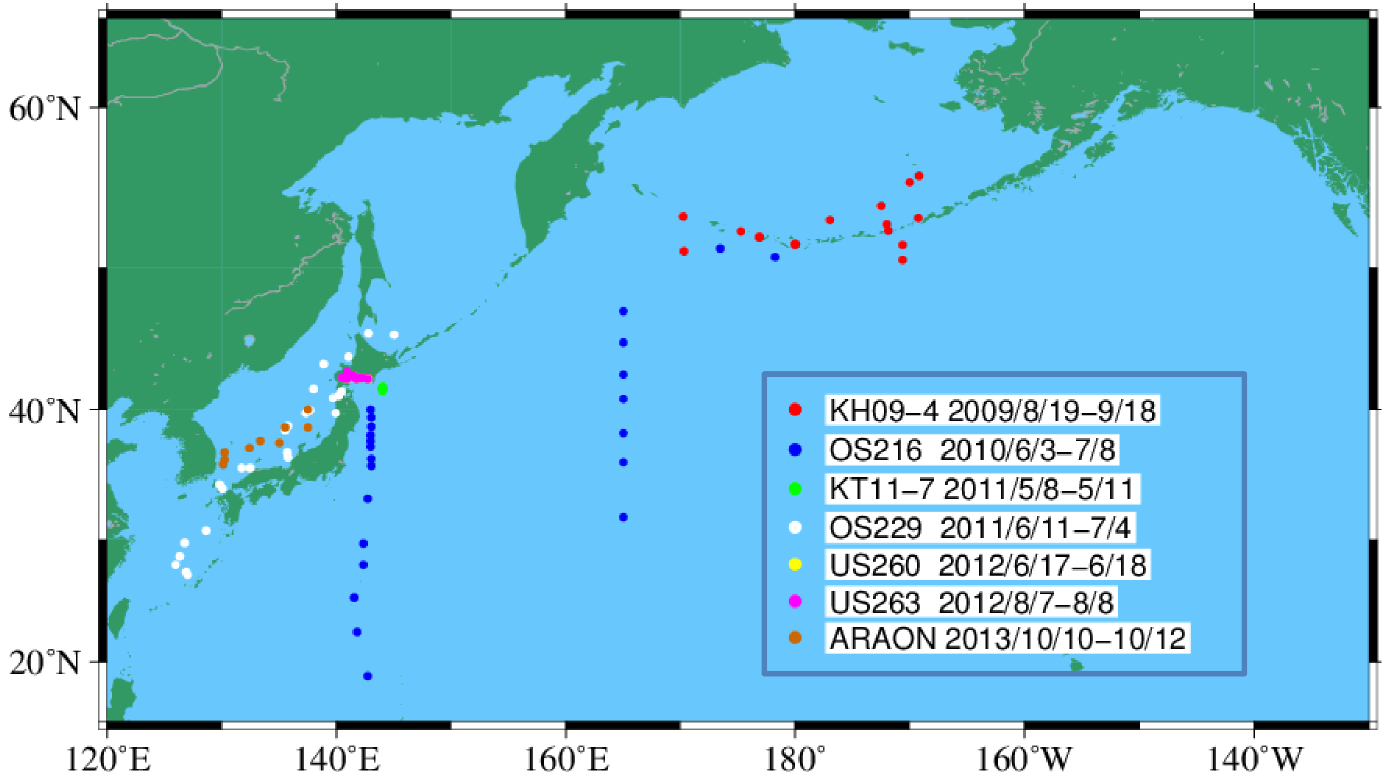
Chl*a*: Chlorophyll *a* concentration (mg m^{-3})

- **Size fraction could be calculated without deriving nChla(D_0), D_0. Only η is essential parameter.**
- **Size fraction at any size can be derived, by substituting Dmax and Dmin (e.g. ultraplankton < 5μm)**

We can calculate the size fraction using the following equation

$$F(\%) = \frac{\int_{D\min}^{D\max} \mathrm{nChl}\,a(D_0)\left(\frac{D}{D_0}\right)^{\eta}}{\int_{0.7\mu\mathrm{m}}^{200\mu\mathrm{m}} \mathrm{nChl}\,a(D_0)\left(\frac{D}{D_0}\right)^{\eta}} = \frac{(D\max^{\eta+1} - D\min^{\eta+1})}{(200^{\eta+1} - 0.7^{\eta+1})},$$

Dataset



In situ data at 106 stations

- Size fractionated Chl*a*
- Phytoplankton absorption coeff. (a_{ph})
- Particle backscattering coeff. (b_{bx})
- Remote sensing reflectance (R_{rs})

Development: 74 stations (70%)
Validation: 32 stations (30%)

Reconstruction of algorithm

In 2012 FY (RA2)

- Derived the slope η directly from phytoplankton absorption (a_{ph}) and particle backscattering coefficients (b_{bp}).
- Value of b_{bp} is very small and particle size distribution is sensitive to b_{bp}. Therefore, small change (error) in b_{bp} induce large error.

In 2013 FY (RA4)

- Derived the slope η through Fmicro from only aph.
- Roy et al. (2013) is almost same way but they used aph(676) which is difficult to estimate from satellite correctly. Therefore, shorter wavelengths were chosen.

Algorithm

$\eta = A_0 + A_1 \text{ x } F_{micro} + A_2 \text{ x } F_{micro}{}^2 + A_3 \text{ x } F_{micro}{}^3$

$A_0 = -2.53$, $A_1 = 9.22 \times 10^{-2}$, $A_2 = -1.71 \times 10^{-3}$, $A_3 = 1.12 \times 10^{-}$

$r^2 = 0.99$

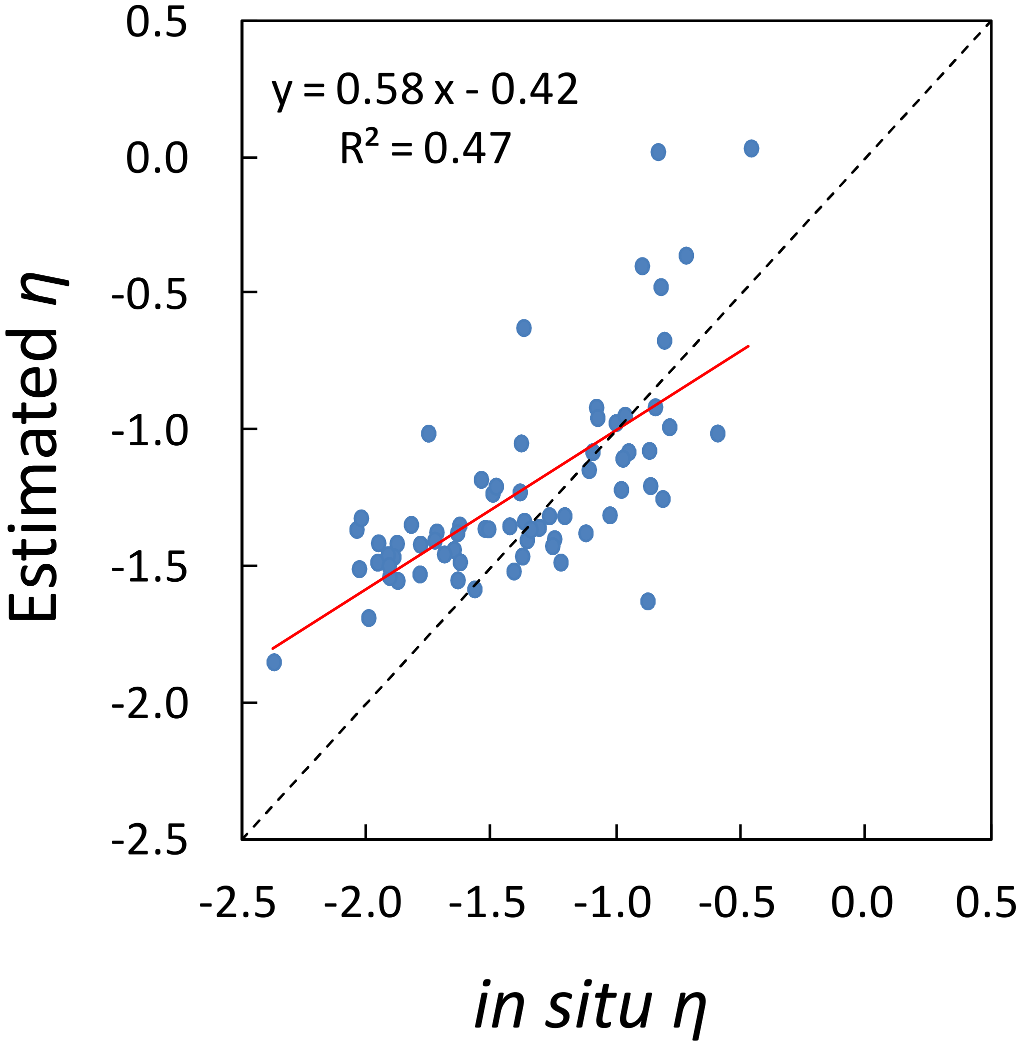
$F_{micro} = 1/[1+\exp(B_0 \text{x} a_{ph}(412) + B_1 \text{x} a_{ph}(443) + B_2 \text{x} a_{ph}(510))] \text{x} 100$

$B_0 = 80.402$, $B_1 = -150.936$, $B_2 = 203.045$, $B_3 = -0.909$

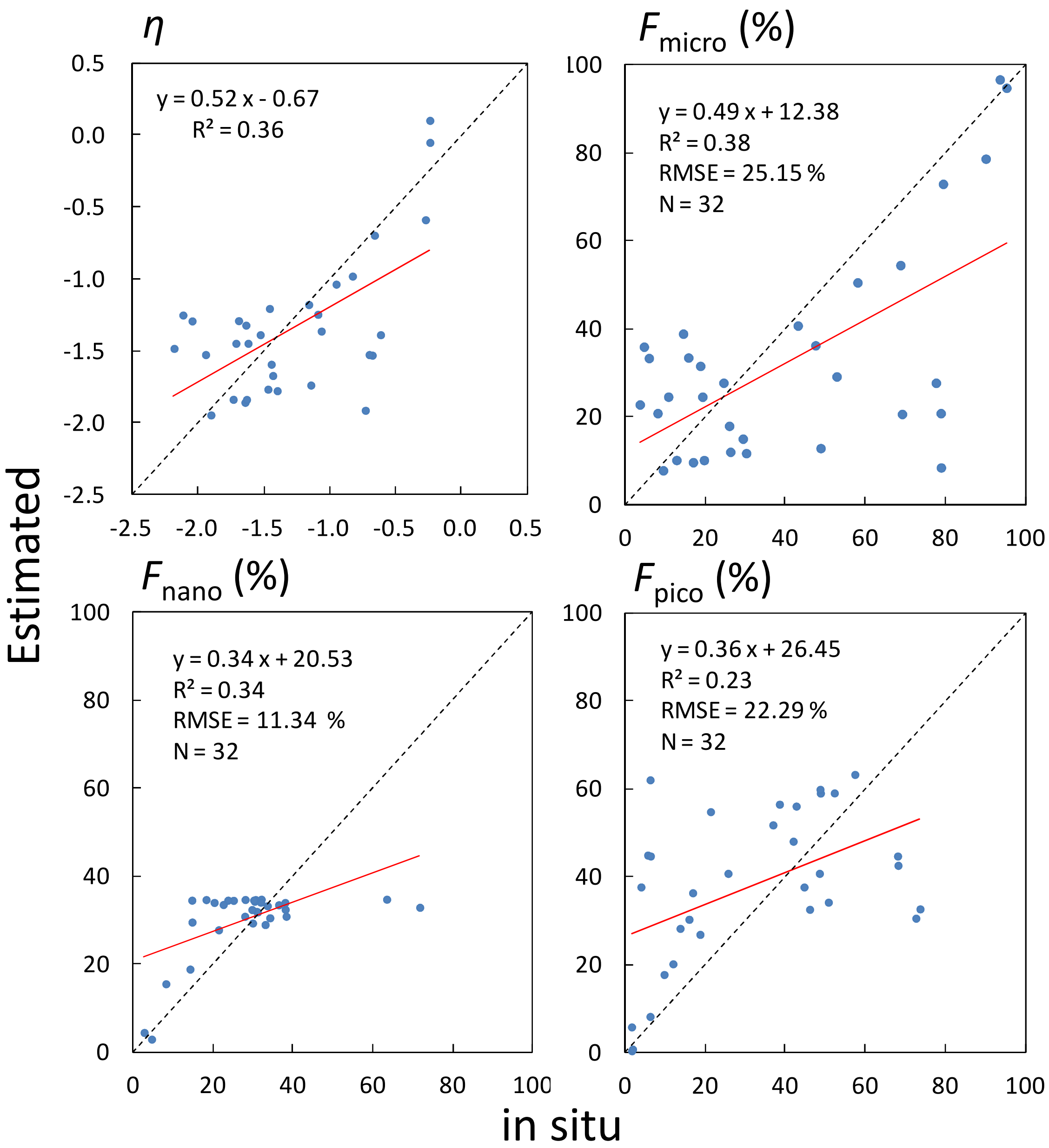
$$F(\%) = \frac{\int_{D\min}^{D\max} n\mathrm{Chl}\, a(D_0)\left(\frac{D}{D_0}\right)^{\eta}}{\int_{0.7\mu m}^{200\mu m} n\mathrm{Chl}\, a(D_0)\left(\frac{D}{D_0}\right)^{\eta}} = \frac{(D\max^{\eta+1} - D\min^{\eta+1})}{(200^{\eta+1} - 0.7^{\eta+1})},$$

Estimation of F_{micro}, F_{nano}, F_{pico}

Estimation of η



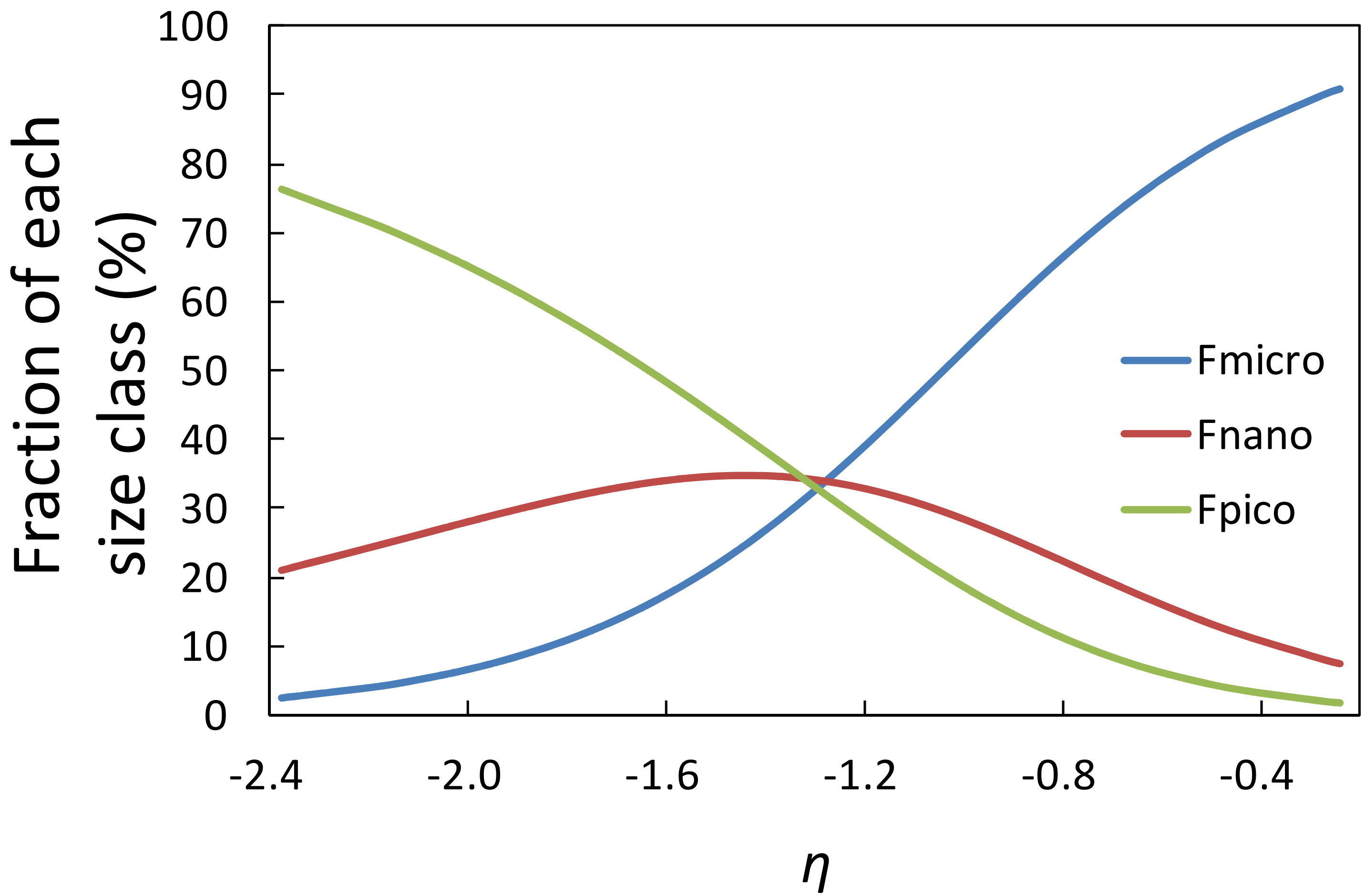
Validation using *in situ* R_{rs}



RMSE (FY2012 → FY2013)

- F_{micro}
  35.94% → 25.15%
- F_{nano}
  14.81% → 11.34%
- F_{pico}
  26.31% → 22.29%

Problem in F_{nano}

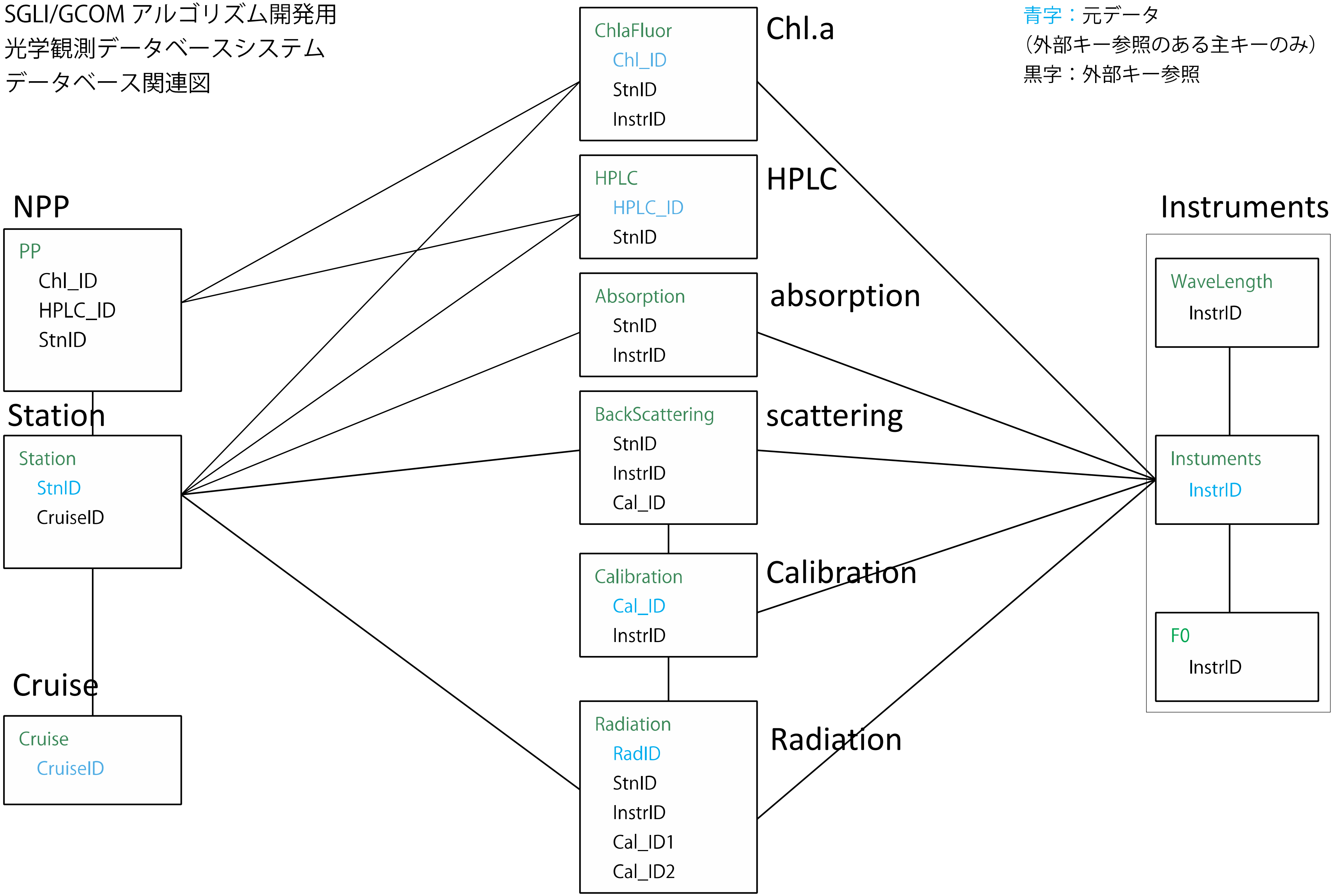


Database for in-situ data

- Dataset
  Spectral radiation, pigments, absorption, backscattering, PAR, NPP, etc...
- Interface
  Web-based interface (upload, search and download)
- Output
  Surface data as a table and profile/spectrum data as files (excel, csv, hdf, etc.)

SGLI/GCOM アルゴリズム開発用
光学観測データベースシステム
データベース関連図

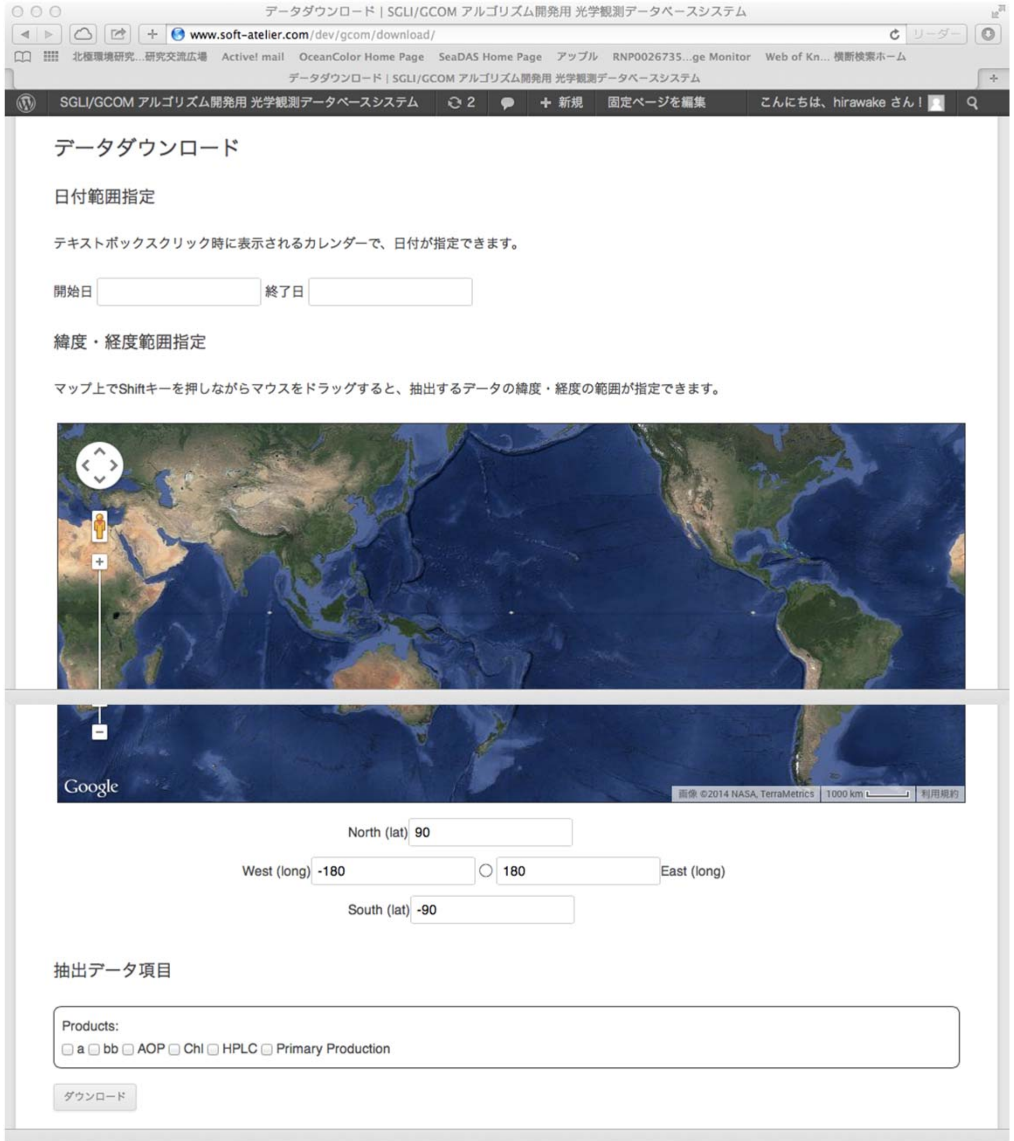
青字：元データ
(外部キー参照のある主キーのみ)
黒字：外部キー参照



Interface （Data upload）

Just put formatted Excel files on this window.

Interface



1. Search the data based on date, region of interest, and parameters.
2. Push Download
3. CSV formatted data file is created and automatically downloaded on local PC.

Summary: Progress in 2013FY

- Collected new data (> 50 stations) from the Bering, Chukchi and Japan Seas
- NPP and PFT algorithms were reconstructed and validated using new data. Some improvements are required (nanoplankton for PFT, vertical distribution for NPP
- Prototype of database for *in-situ* data was created