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Bio-optical properties and in-water algorithm validation for ocean color remote sensing in the sub-arctic North Pacific

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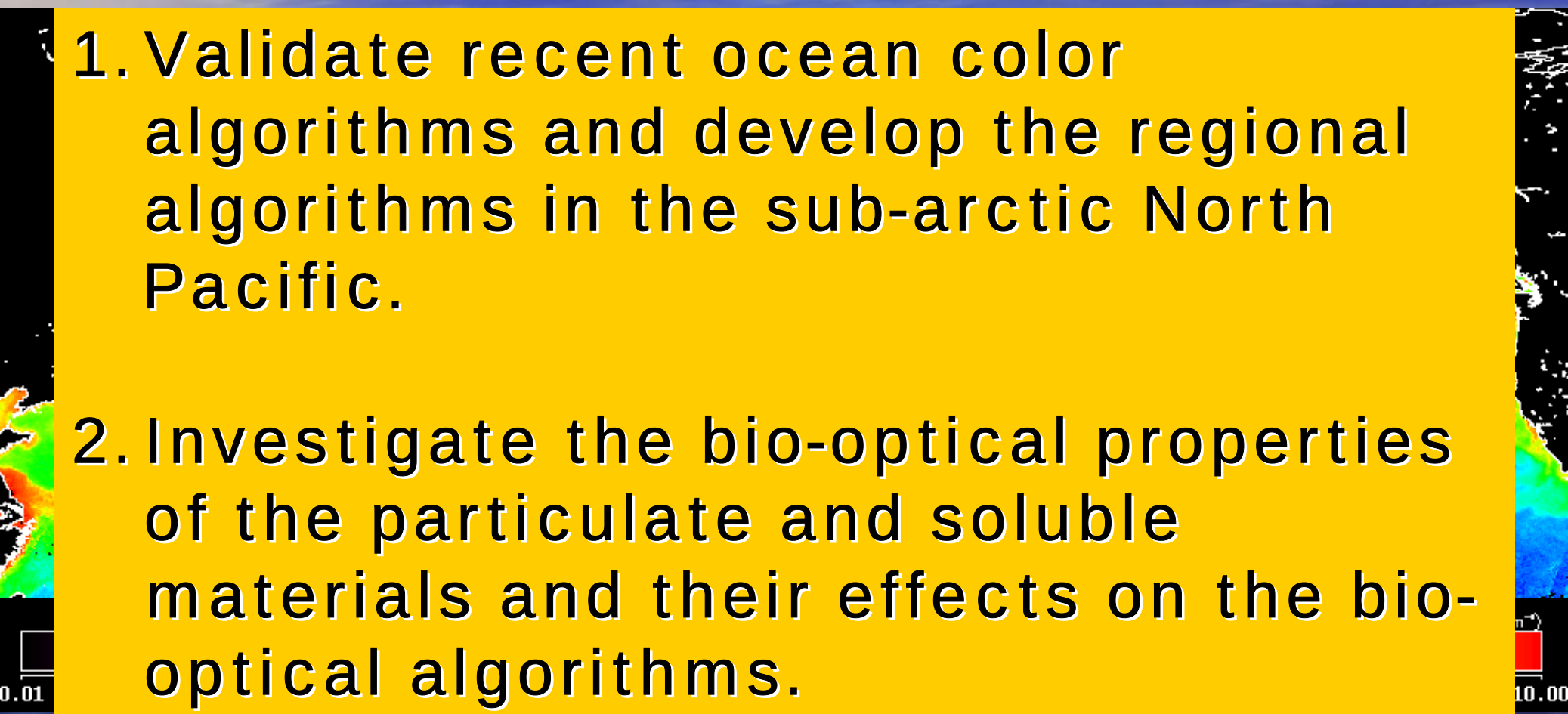
Objectives

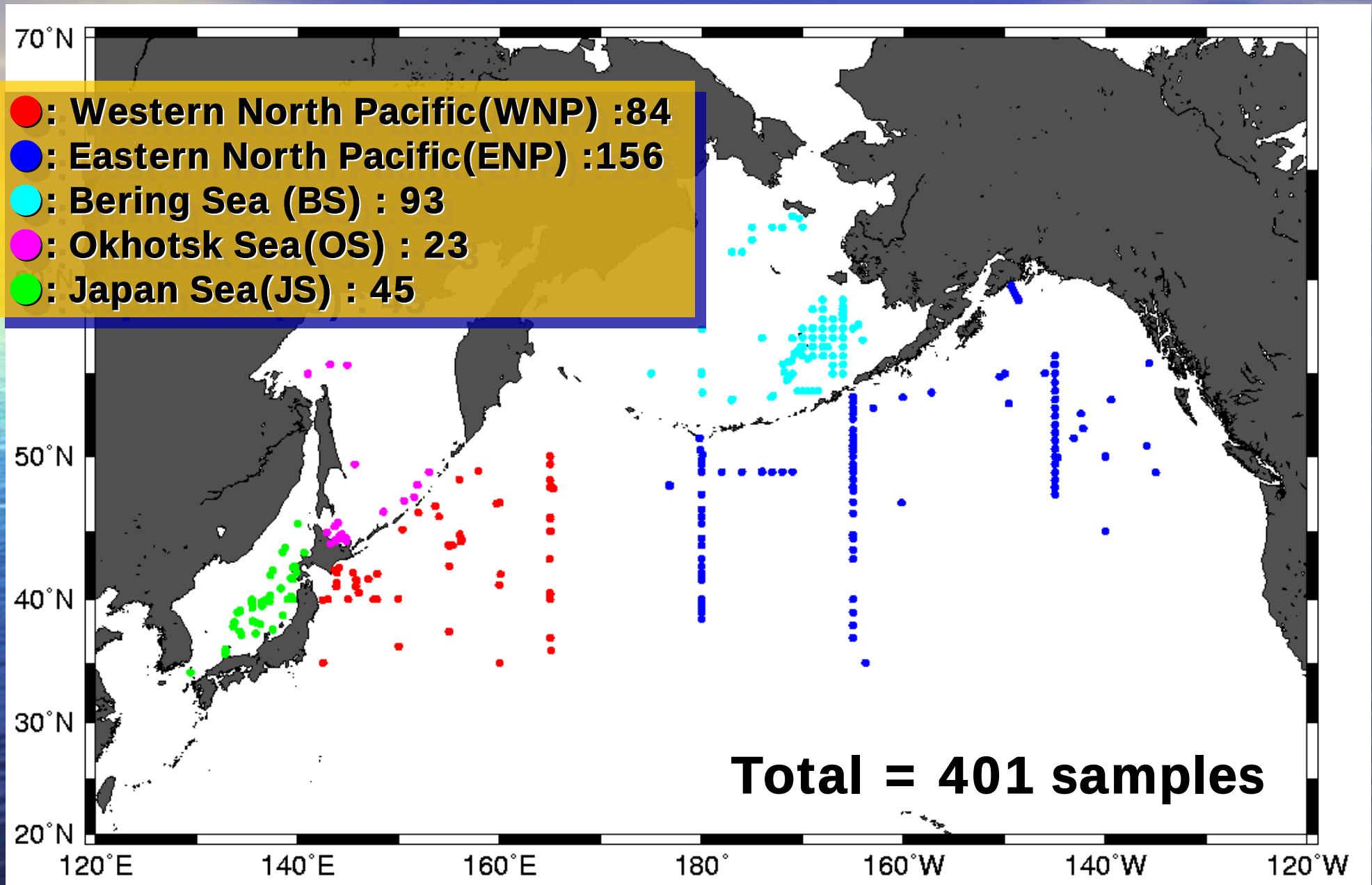
1. Validate recent ocean color algorithms and develop the regional algorithms in the sub-arctic North Pacific.

2. Investigate the bio-optical properties of the particulate and soluble materials and their effects on the bio-optical algorithms.



GLI Chl-a monthly mean image in May, 2003

Study area and ship observations(1996-2003)



Measurements

- **Optical measurements**

  Vertical profiles of the downward spectral irradiance and the upward spectral radiance **(nLw and Rrs)**

- **Sea-water sampling**

  Chlorophyll a concentrations **(Chl-a)**
  Absorption coefficients of particulate matter, phytoplankton, detritus and CDOM (Colored Dissolved Organic Matter)
  (a_p, a_{ph}, a_d, a_{CDOM})

Equation for in-water algorithms of ocean color sensor

Algorithm	Equation, Coefficients (a), Band Ratio (R)
OC2-V4	$CHLA = 10^{(a0 + a1*R + a2*R^2 + a3*R^3) + a4}$ a=[0.319, −2.336, 0.879, −0.135, −0.071] R=log10(Rrs(490)/Rrs(555))
OC4-V4	$CHLA = 10^{(a0 + a1*R + a2*R^2 + a3*R^3 + a4*R^4)}$ a=[0.336, −3.067, 1.930, 0.649, −1.532] R=log10(Rrs(443)>Rrs(490)>Rrs(510)/Rrs(555))
OC4-GLIV3	$CHLA = 10^{(a0 + a1*R + a2*R^2 + a3*R^3) + a4)}$ a=[0.531, −3.559, 4.488, −2.169, −0.230] R = log10(nLw443 > nLw460 > nLw520) / nLw545)

Evaluation of Error

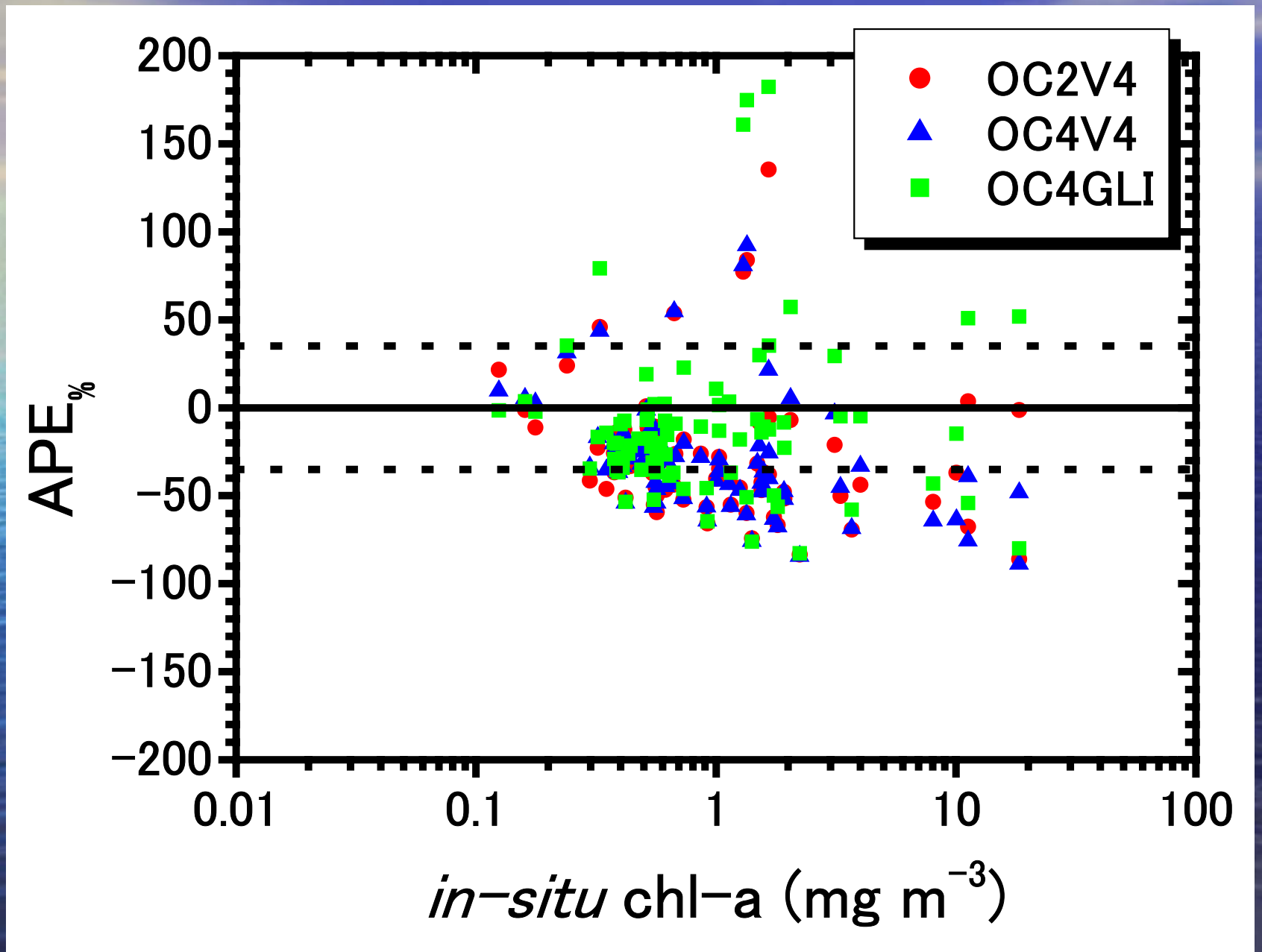
Average Percent of Error

$$APE = \frac{\sum \left(\frac{Model - InSitu}{InSitu} \right)}{N} * 100$$

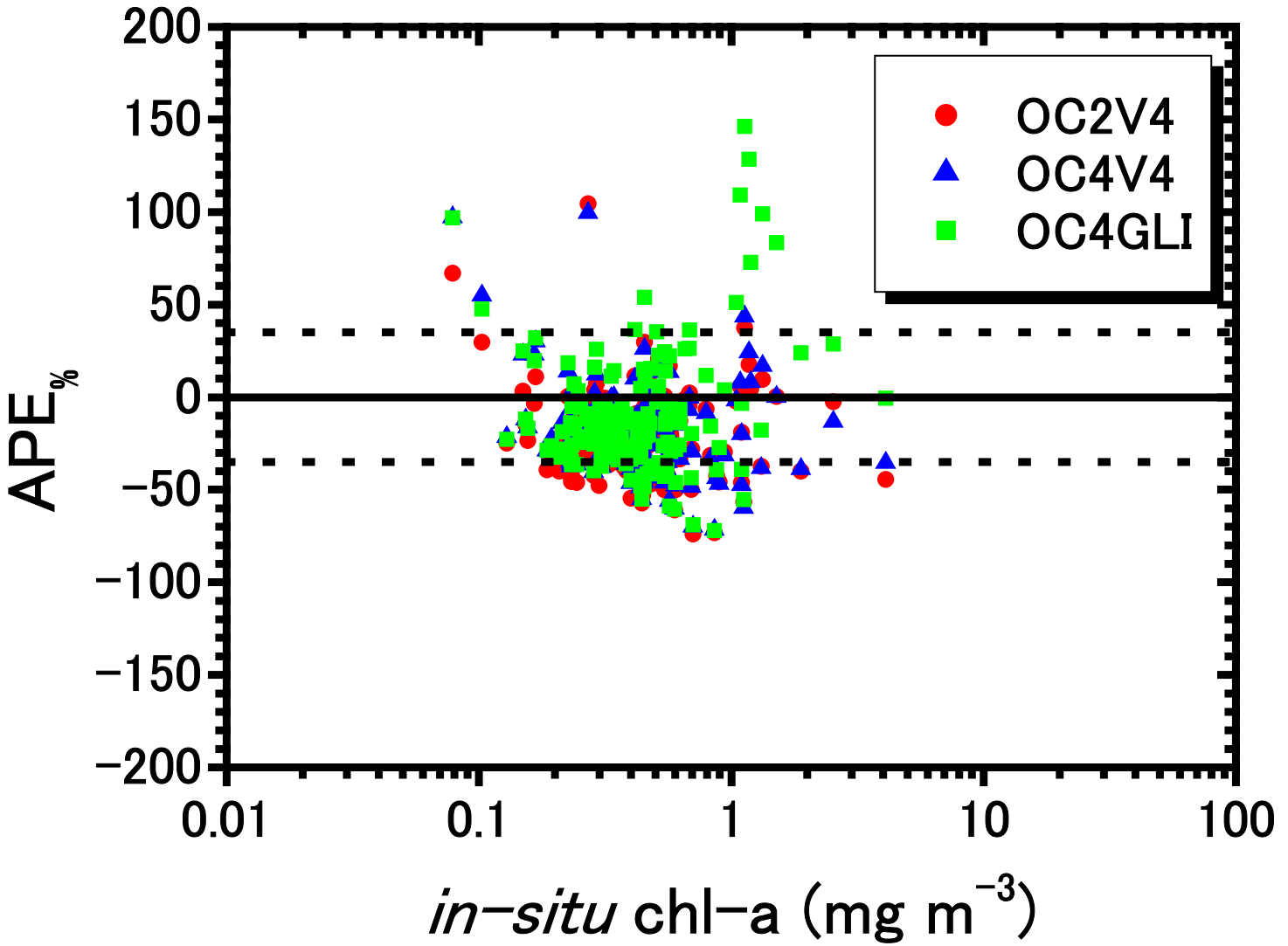
Root-Mean-Square Error in $\log_{10}$ scale

$$RMSE = \sqrt{\frac{\sum \left[\log_{10}(Model) - \log_{10}(InSitu) \right]^2}{N}}$$

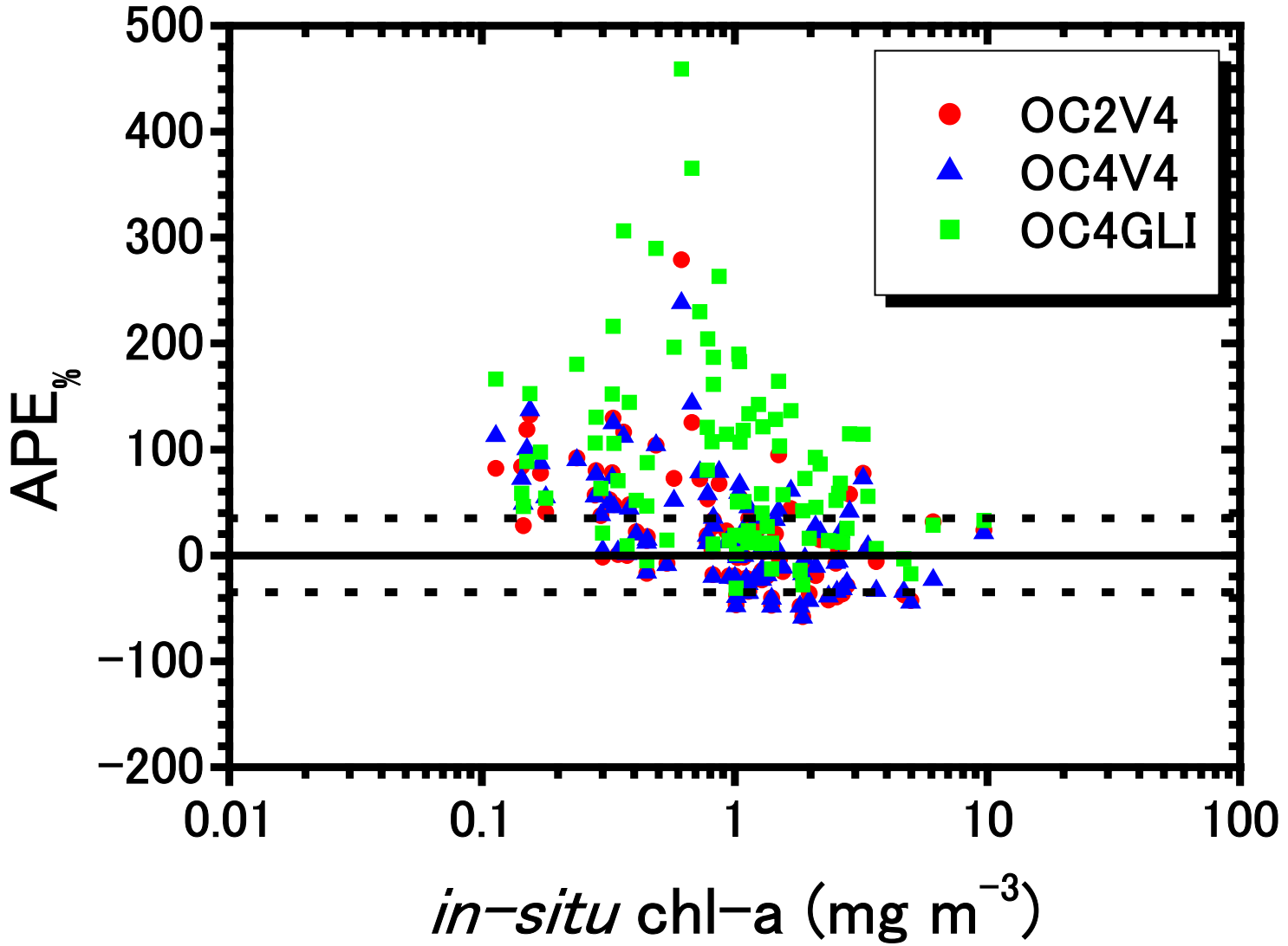
WNP(Western North Pacific)



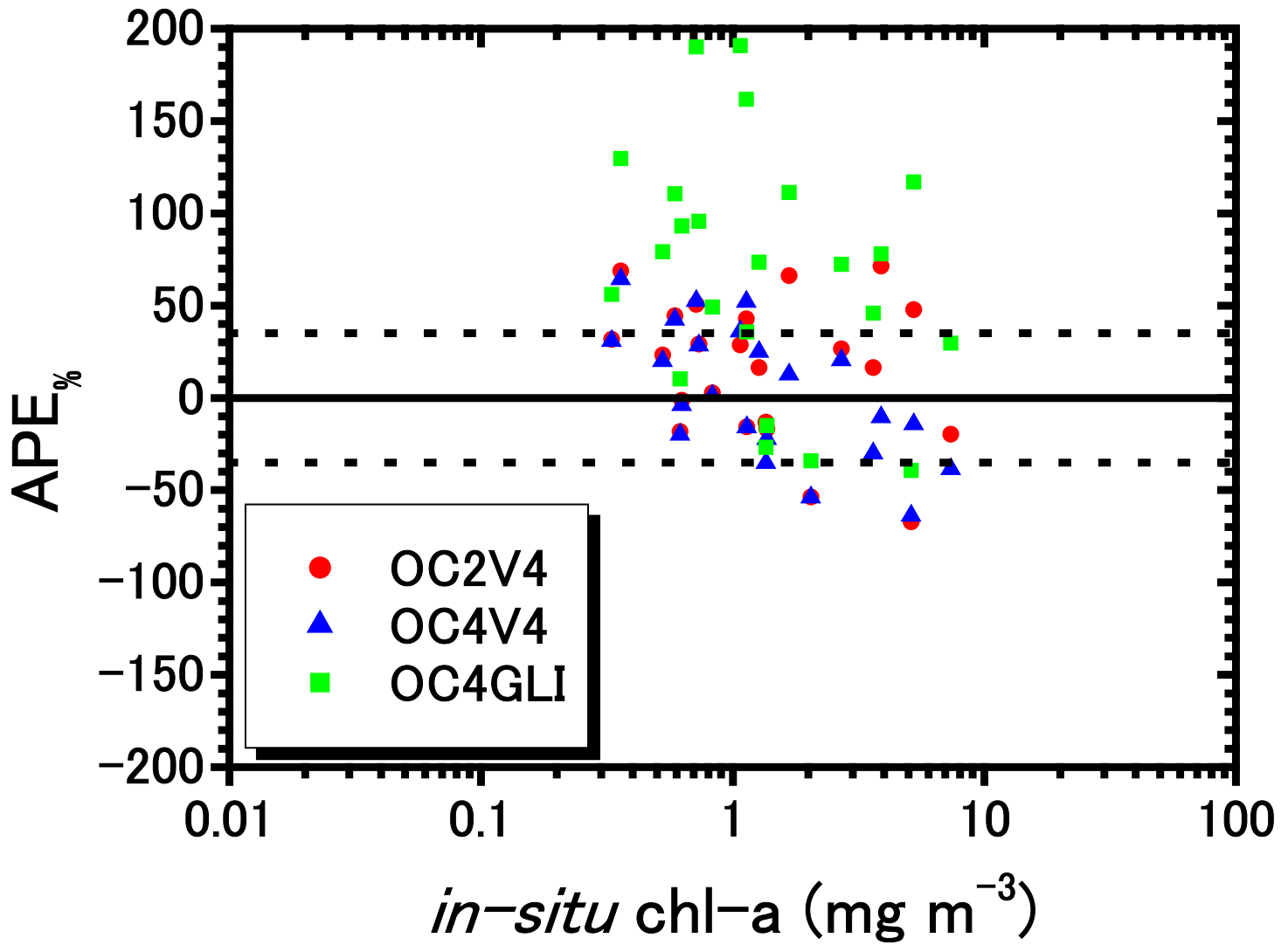
ENP (Eastern North Pacific)



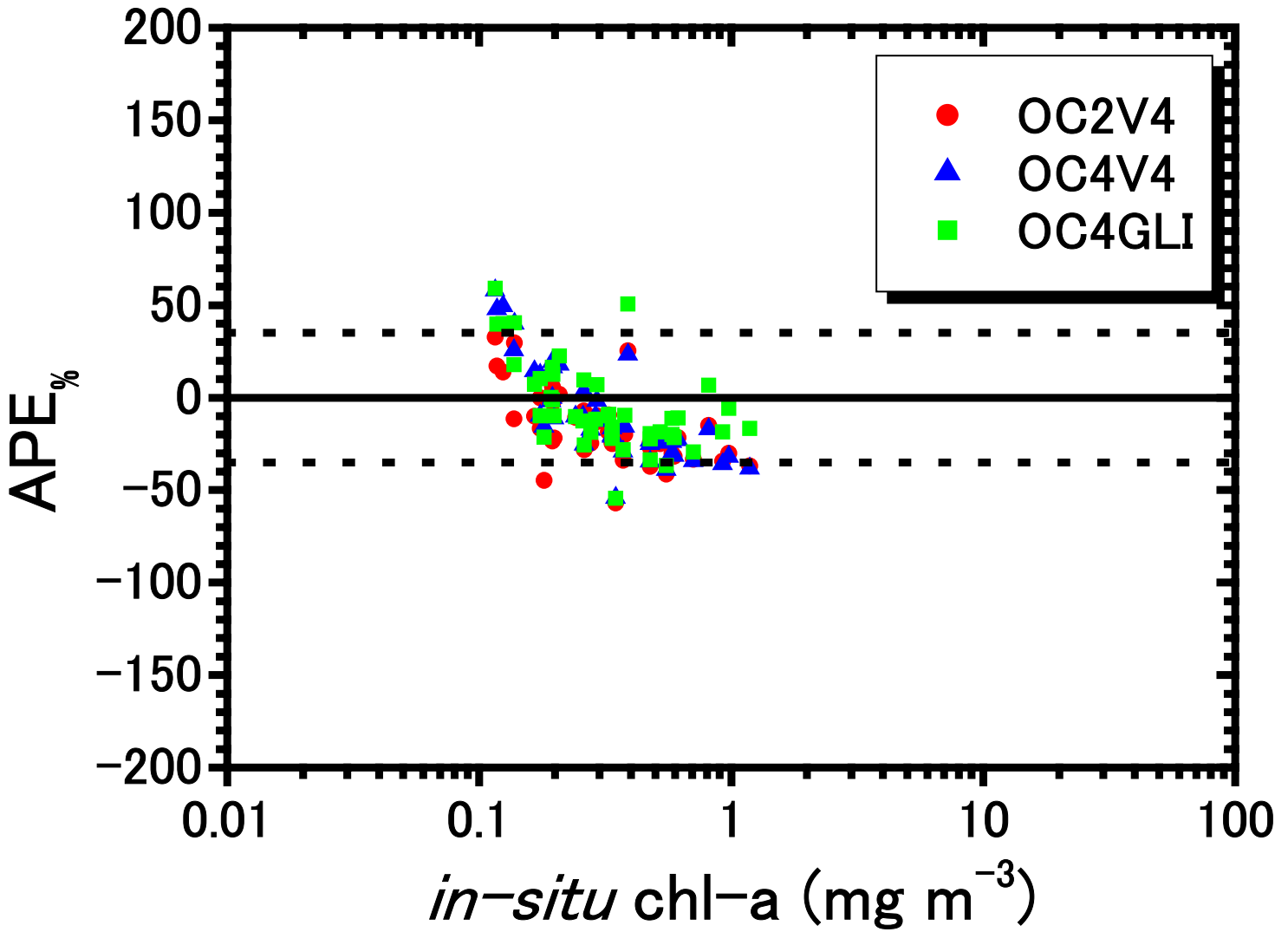
BS (Bering Sea)



OS (Okhotsk Sea)



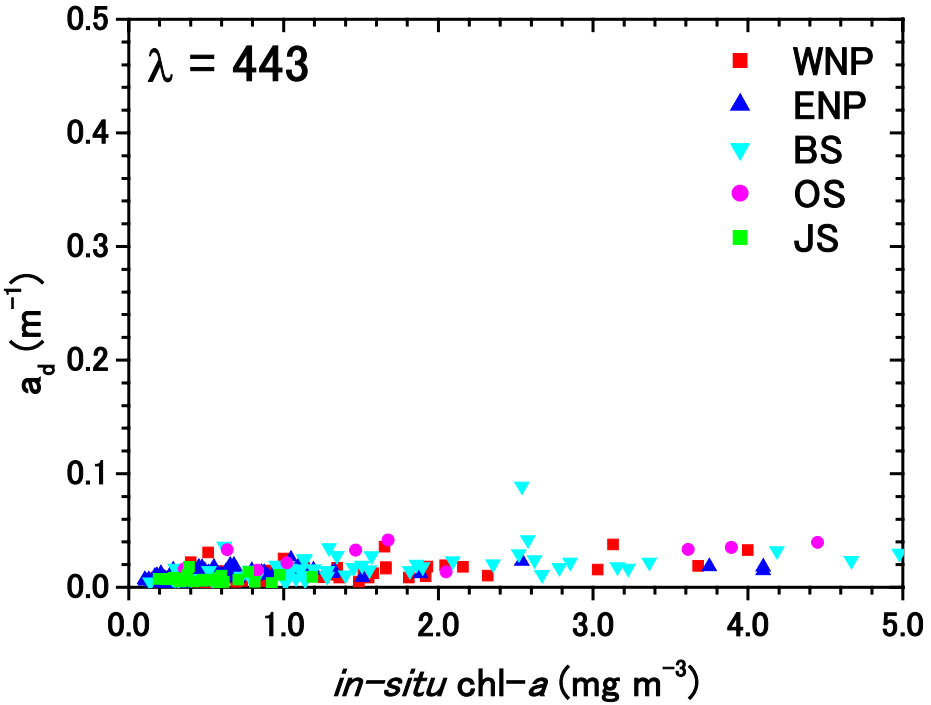
JS (Japan Sea)

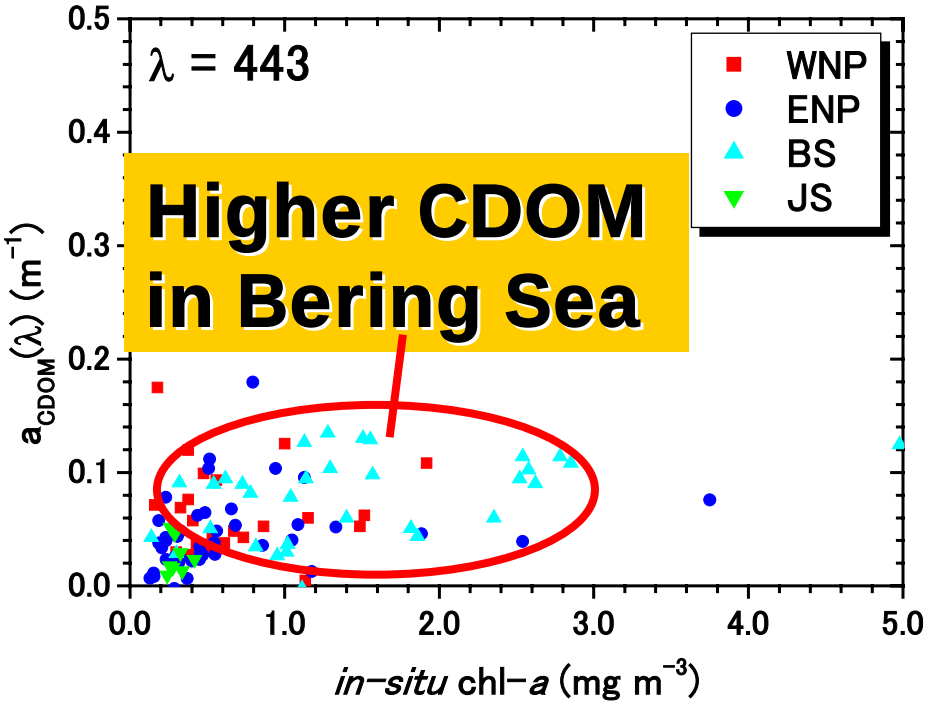

200
150
100
50
0
−50
−100
−150
−200
APE%
0.01
0.1
1
10
100
in-situ chl-a (mg m-3)
OC2V4
OC4V4
OC4GLI

Summery of $APE_{\%}$ and RMSE

Region	Sample num.	$APE_{\%}$			RMSE		
		OC2V4	OC4V4	OC4GLI	OC2V4	OC4V4	OC4GLI
WNP	84	-27.31	-29.90	-6.77	0.072	0.078	0.053
ENP	156	-21.92	-19.18	-8.46	0.032	0.028	0.029
BS	93	20.57	20.03	87.09	0.035	0.035	0.088
OS	23	15.72	3.33	70.20	0.031	0.028	0.074
JS	45	-16.23	-8.43	-4.76	0.017	0.016	0.012

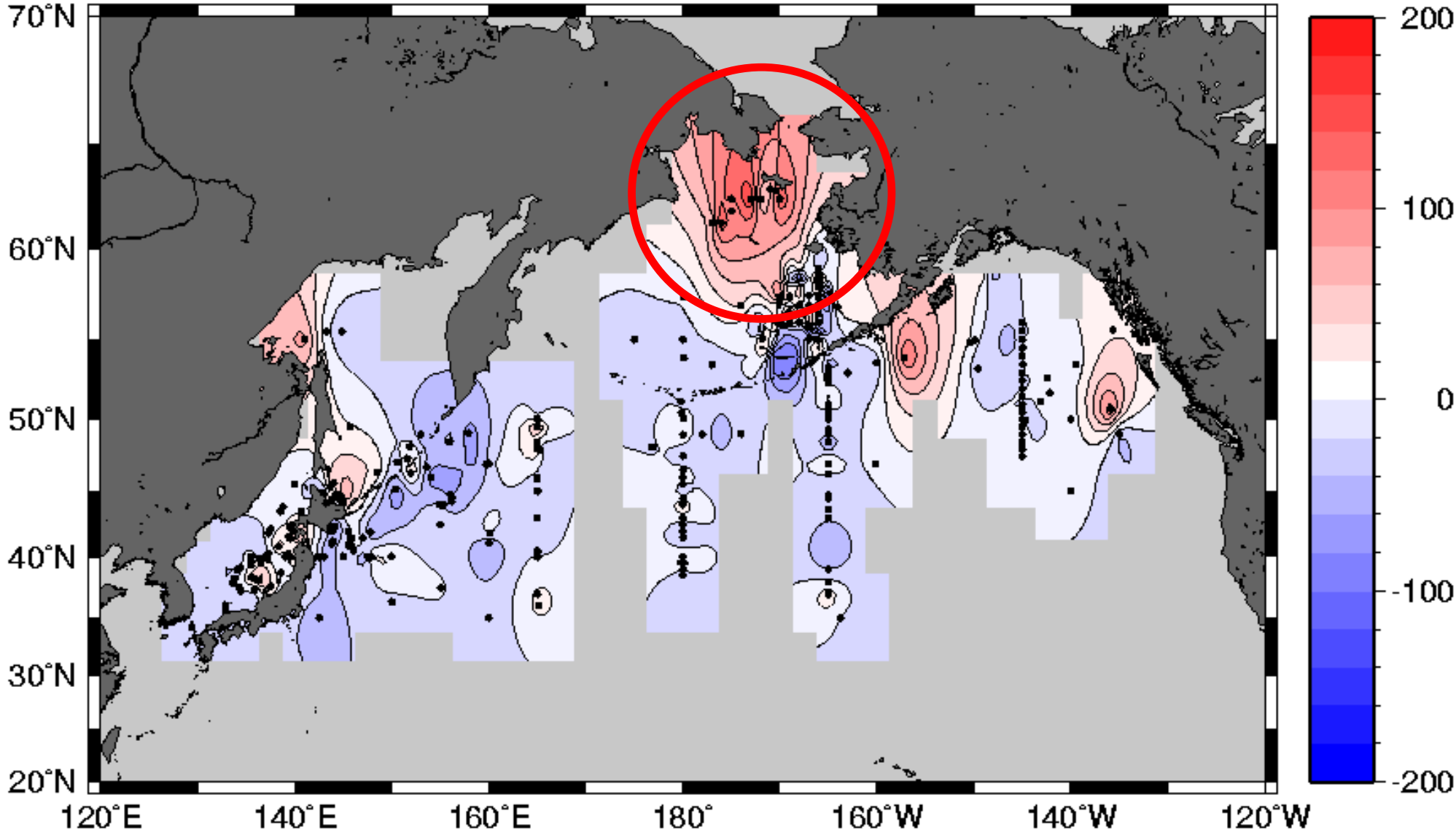
In-situ chl-a vs. a_d and a_{CDOM}



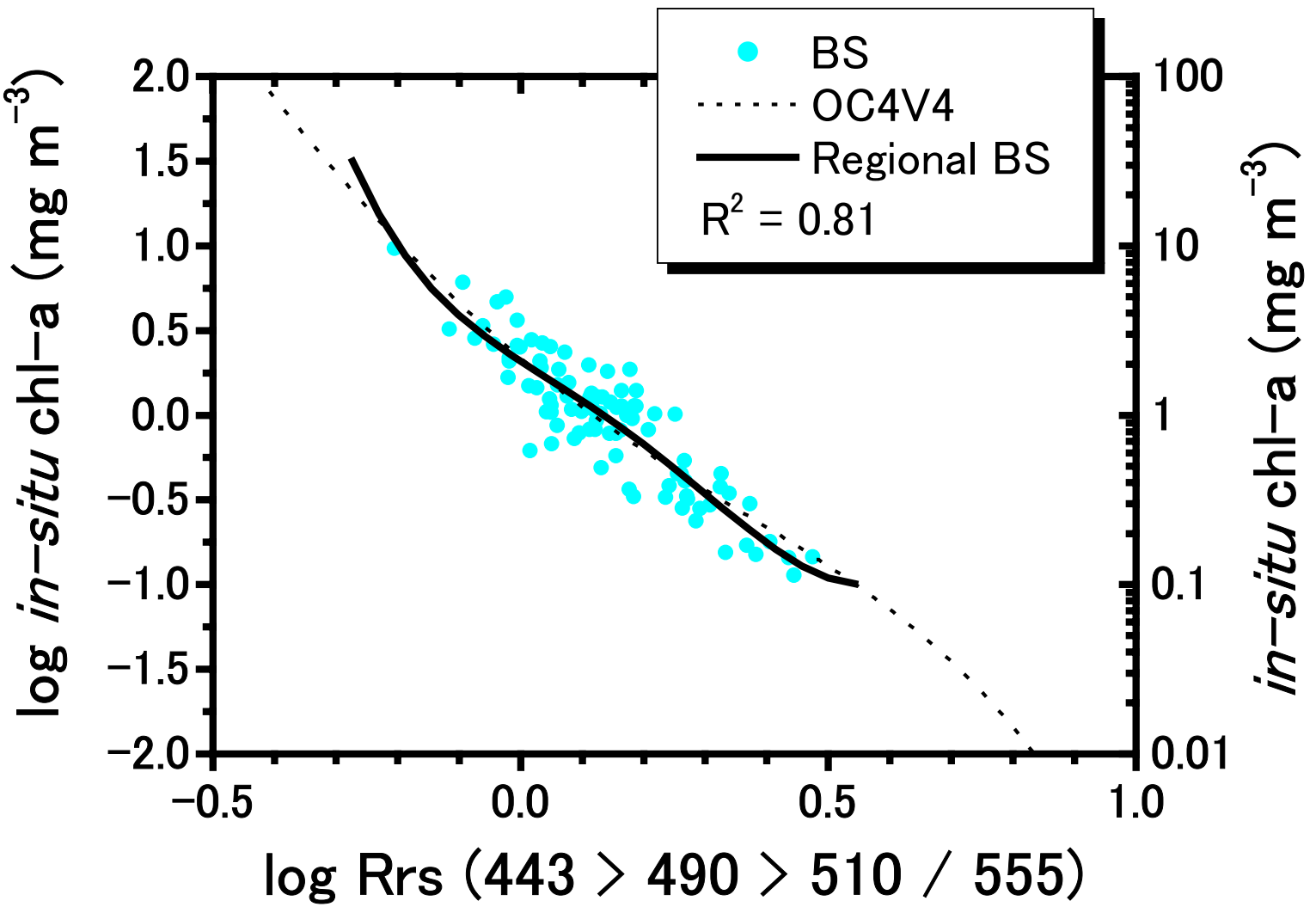


Geographical map of APE for OC4V4

$APE_{\%}$



Regional algorithm for Bering Sea



OC4V4 VS. Regional Bering Sea

$$Chl\text{-}a = 10^{(a0 + a1*R + a2*R^2 + a3*R^3 + a4*R^4)}$$
$$R=\log10(Rrs(443)>Rrs(490)>Rrs(510)/Rrs(555))$$

Algorithm	Coefficients (a)	$APE_{\%}$ at BS	RMSE at BS
OC4-V4	a=[0.336, −3.067, 1.930, 0.649, −1.532]	20.03	0.035
Regional_BS	a=[0.317, −2.376, 1.708, -14.33, 20.35]	8.30	0.029

Conclusions

- **Underestimate Chl-a in the WNP and ENP: OC2V4 and OC4V4(SeaWiFS type)**
- **High accuracy in the WNP and ENP: OC4GLI**
- **High accuracy in the OS: OC2V4 and OC4V4(SeaWiFS type)**
- **Highest accuracy in the JS: All algorithms**
- **Large overestimation of Chl-a in the Bering Sea: Higher CDOM absorption effects**
- **Regional algorithm for the BS: Improved APE from Over 20% to +8%**

Thank you !

Calculate remote sensing reflectance (Rrs)

$$E_d(\lambda,z) = E_d(\lambda,0-) * \exp[-K_d(\lambda) * z]$$

$$L_u(\lambda,z) = L_u(\lambda,0-) * \exp[-K_u(\lambda) * z]$$

$$L_w(\lambda) = (t/n_w^2) * L_u(\lambda,0-)$$

$$\mathbf{Rrs(\lambda) = L_w(\lambda) / E_{ds}(\lambda)}$$

E_d: Downwelling irradiance L_u: Upwelling radiance

K_d: Diffuse attenuation coefficient of downwelling irradiance

K_u: Diffuse attenuation coefficient of upwelling irradiance

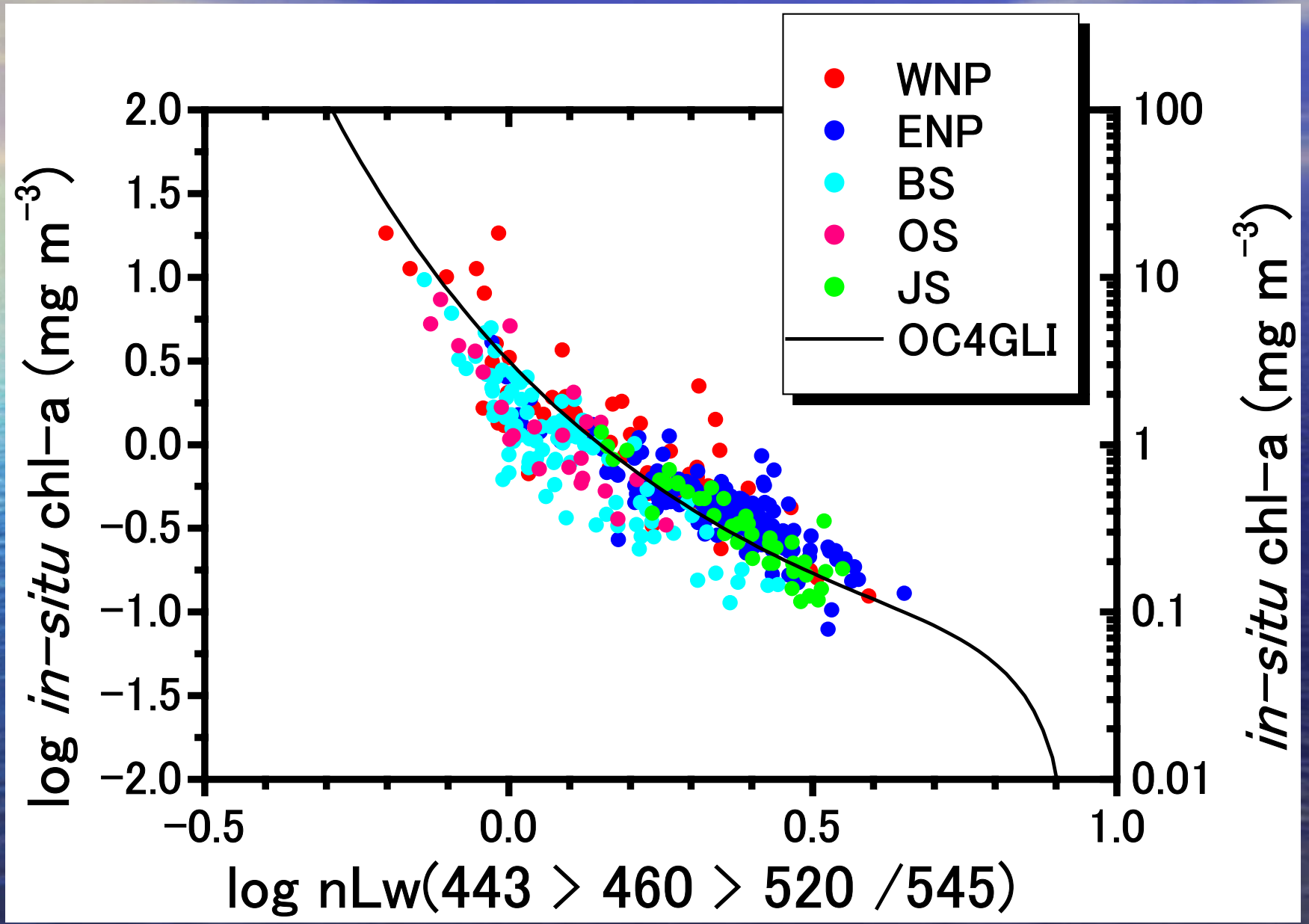
L_w: Water leaving radiance t: Transmittance of the air-sea interface

n_w: Refractive index of sea surface

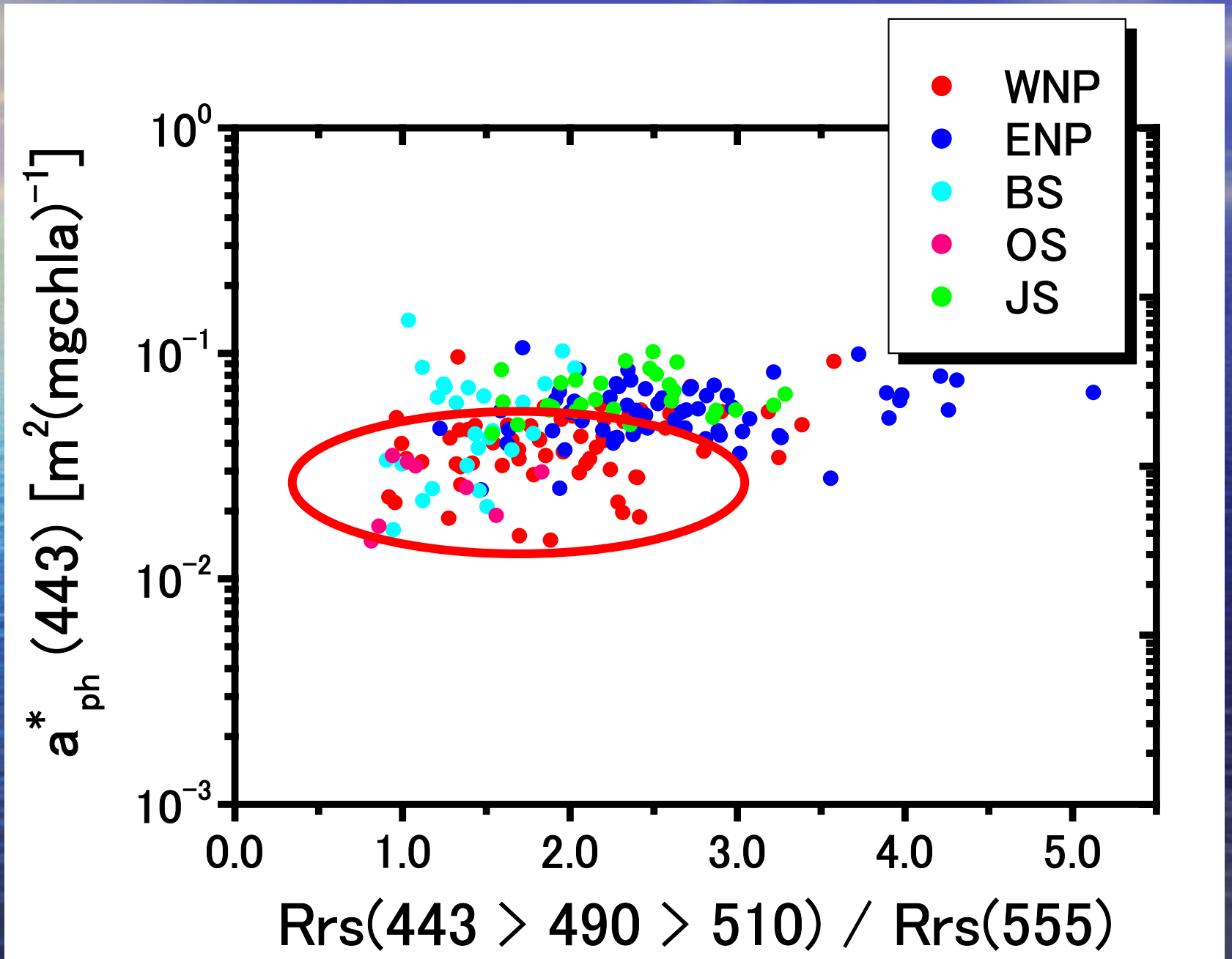
Rrs: Remote sensing reflectance

E_{ds}: Downwelling irradiance ant just below the sea surface

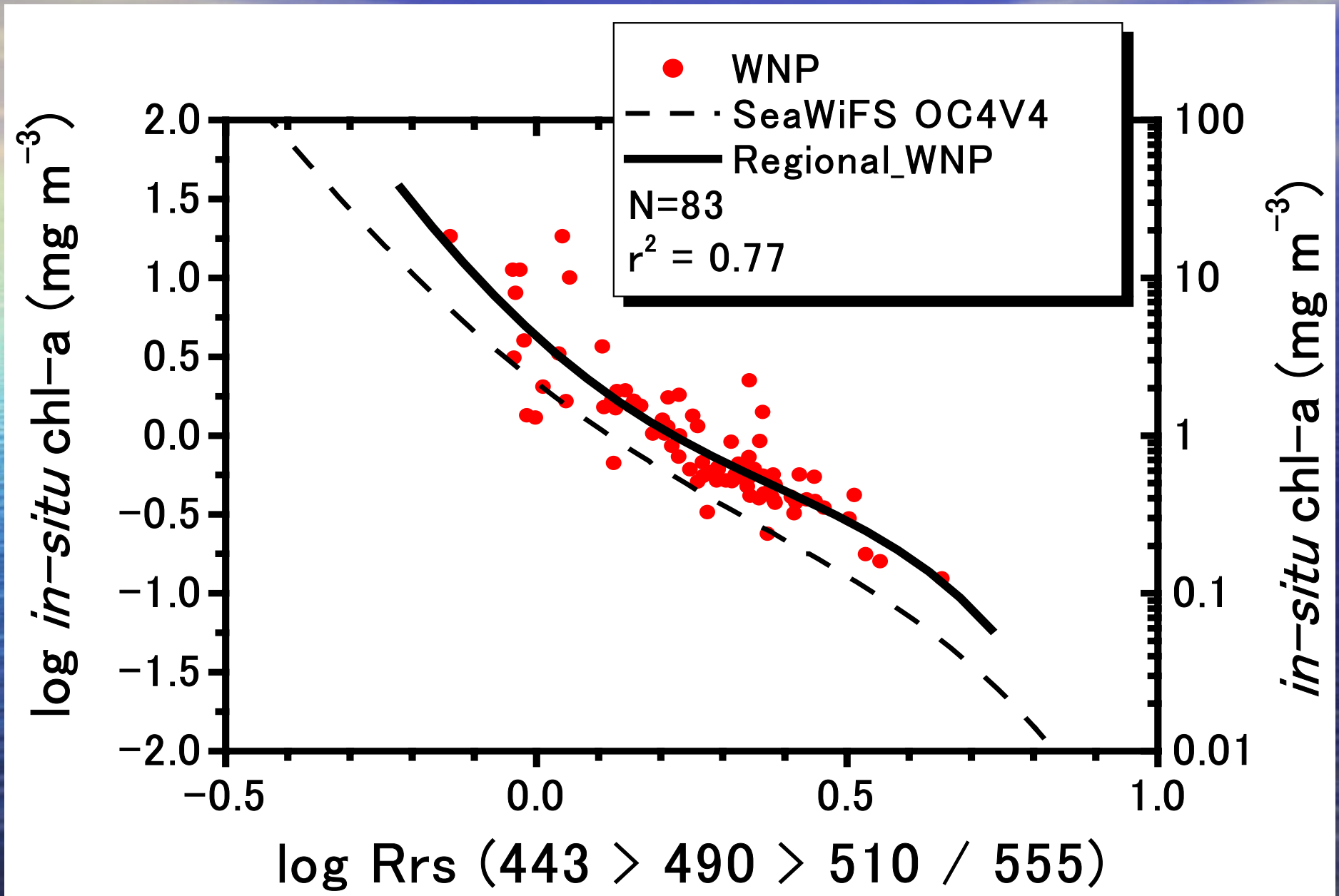
OC4GLI (GLI)


WNP
ENP
BS
OS
JS
OC4GLI
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
log in-situ chl-a (mg m^{-3})
100
10
1
0.1
0.01
in-situ chl-a (mg m^{-3})
−0.5
0.0
0.5
1.0
log nLw(443 > 460 > 520 /545)

Packaging Effect in the NW North Pacific



Regional_WNP (OC4V4)



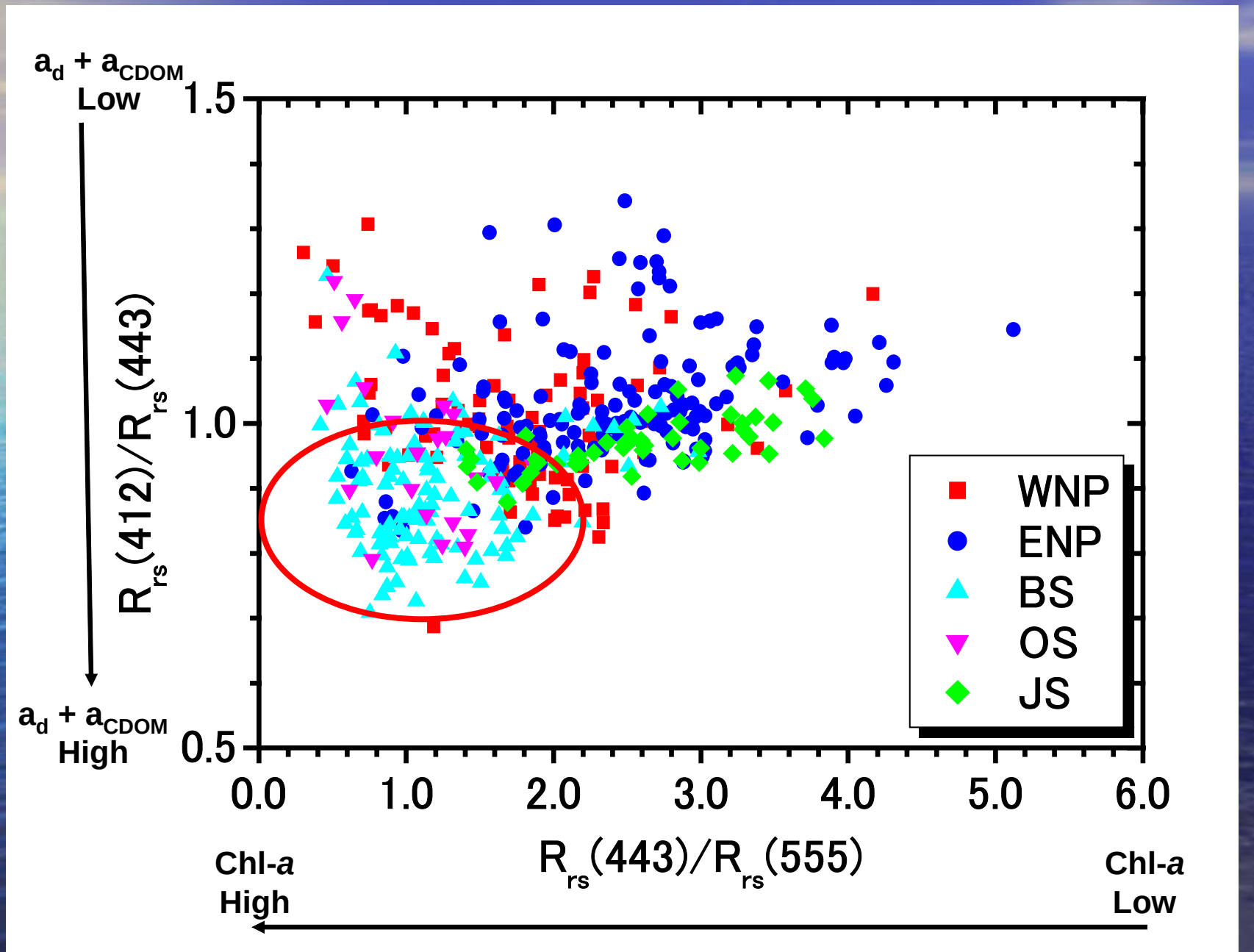
OC4V4 VS. Regional_WNP

$$CHLA = 10^{(a0 + a1*R + a2*R^2 + a3*R^3 + a4*R^4)}$$

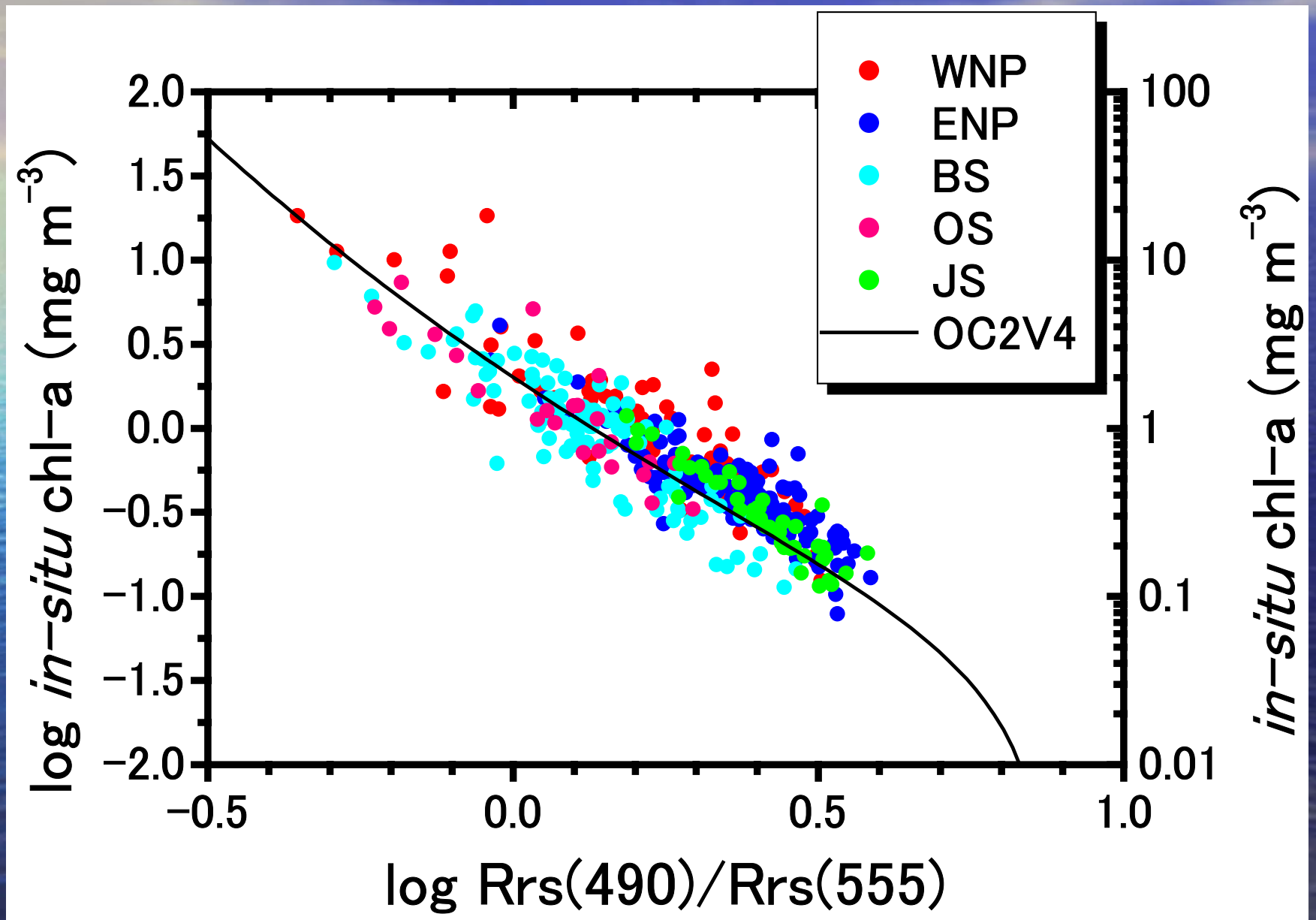
$$R = \log10(Rrs(443) > Rrs(490) > Rrs(510)/Rrs(555))$$

Algorithm	Coefficients (a)	$APE_{\%}$ at WNP	RMSE at WSG
OC4-V4	a=[0.336, −3.067, 1.930, 0.649, −1.532]	-31.65	0.091
Regional_WNP	a=[0.630, −3.574, 3.474, -0.265, −3.483]	11.74	0.044

Particulate and soluble materials effects



OC2V4 (Old SeaWiFS)



OC4V4 (Current SeaWiFS)