Validation methods for development of coastal ocean-color algorithm coupled atmosphere-ocean system

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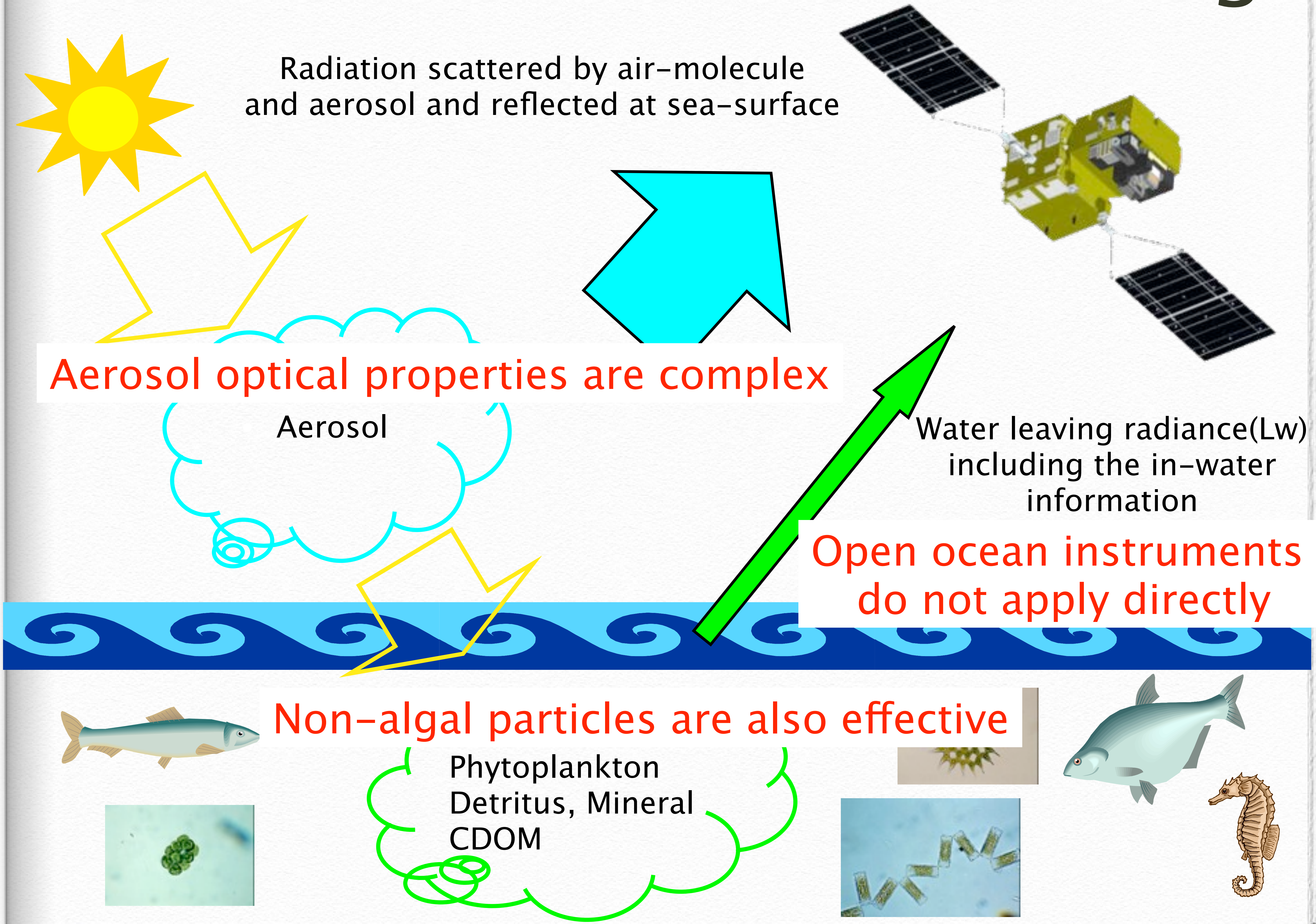
Ocean color remote sensing



Topics

- Validation of coastal ocean color remote sensing requires optical information of atmospheric aerosol particles, in-water materials, and water-leaving radiance simultaneously
- Aerosol measurement
  - Result of Shipboard-Skyradiometer
  - Development of shipboard-scanning sunphotometer
- Lw measurement
  - Development of Lw measuring buoy
- Optical properties of in-water materials measurement
  - In situ measurement
  - Result of backscattering coefficient of suspended matter

Shipboard-Skyradiometer

- Prede, POM-01mk2
- It was on board previous R/V Shirase (2000-2007)
- There were not enough good data due to sun-pointing error

POM-01 mk2

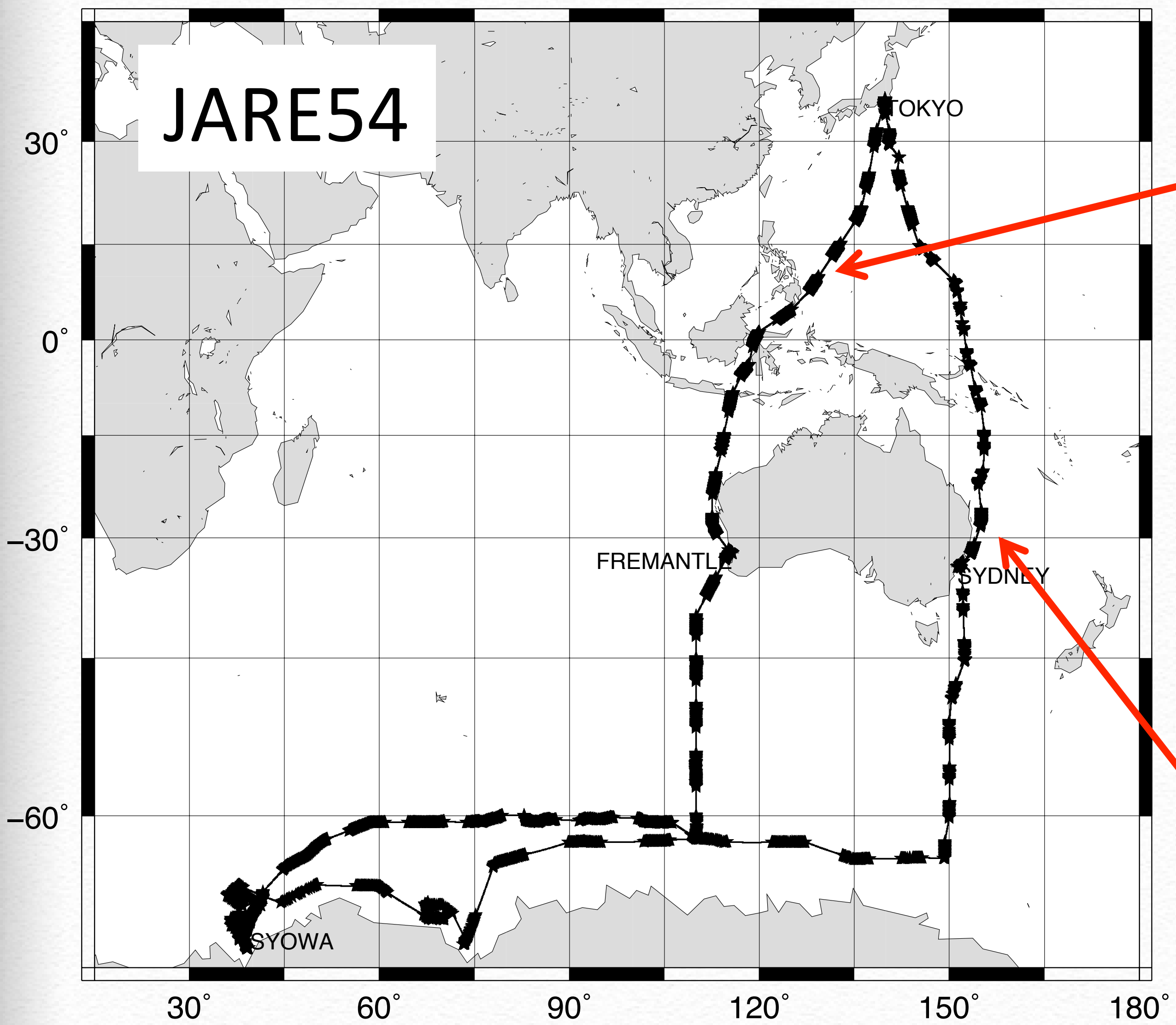
Improved-Skyradiometer

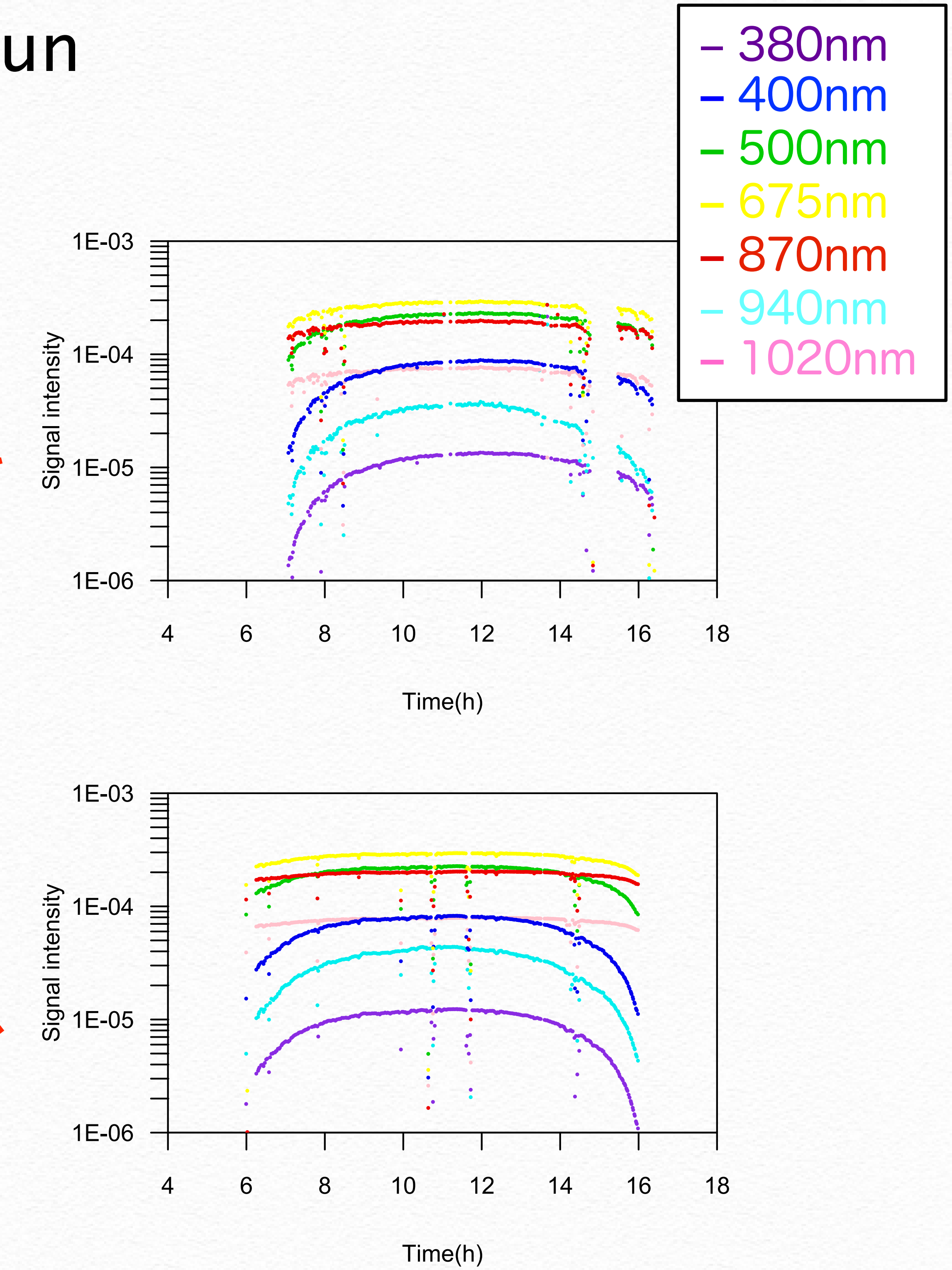
- Prede, POM-01mk3
- It is on board present R/V Shirase (2009-)
- Improvement
  - Drive system
  - Widening of radiometer's FOV

POM-01 mk3

Results of direct sun

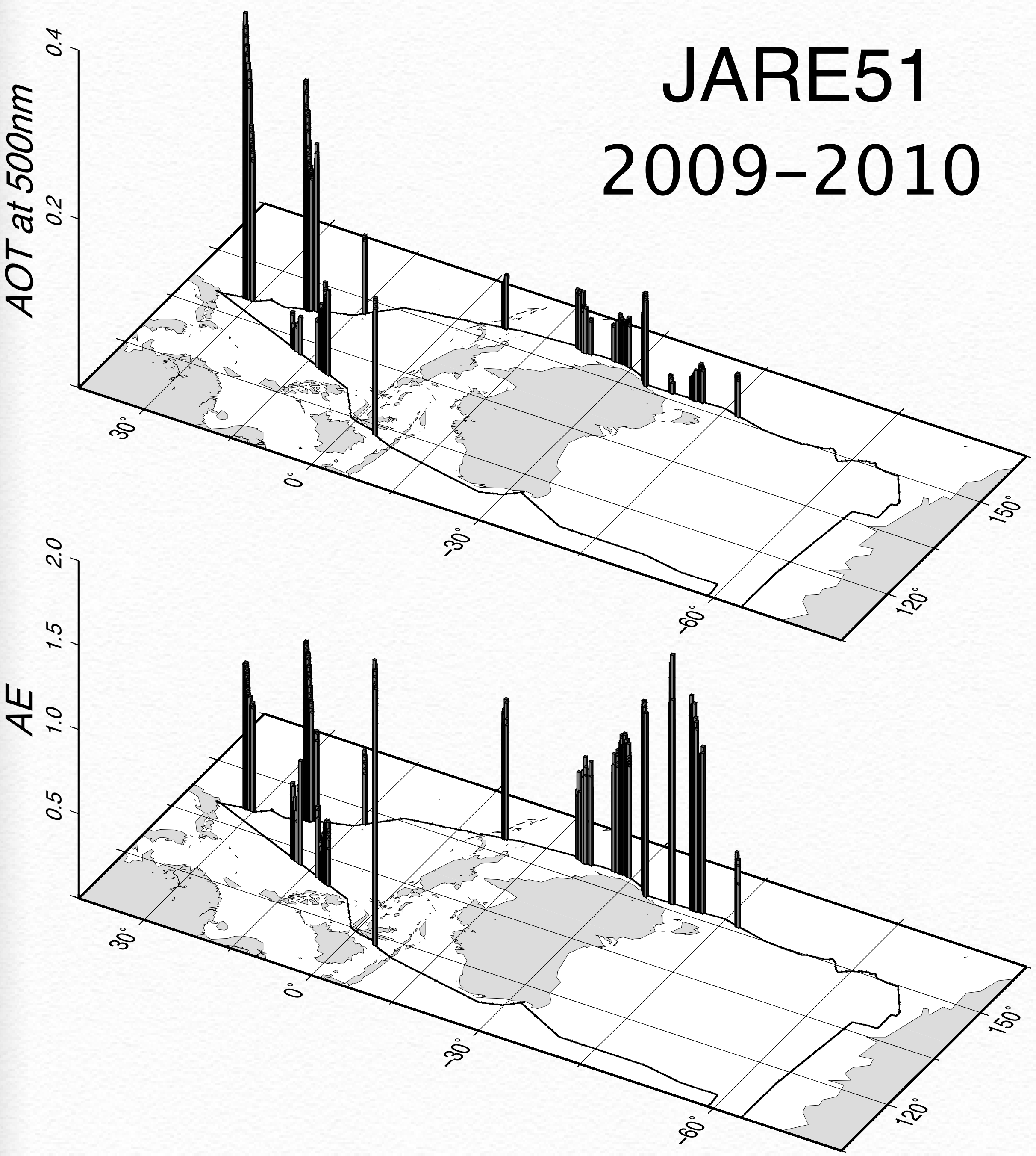
- POM-01mk3 could track the sun



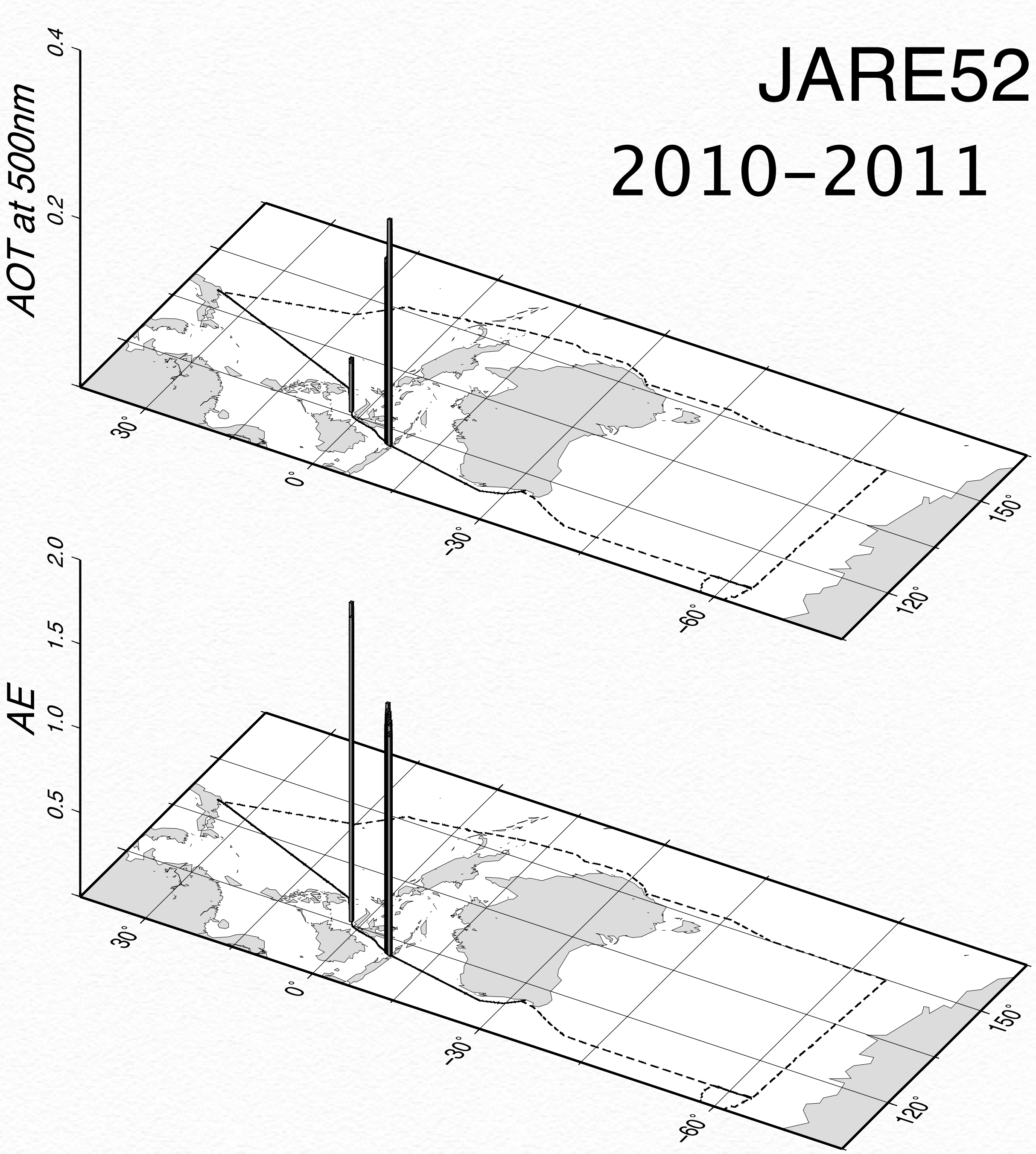


AOT at 500nm and AE

JARE51
2009-2010

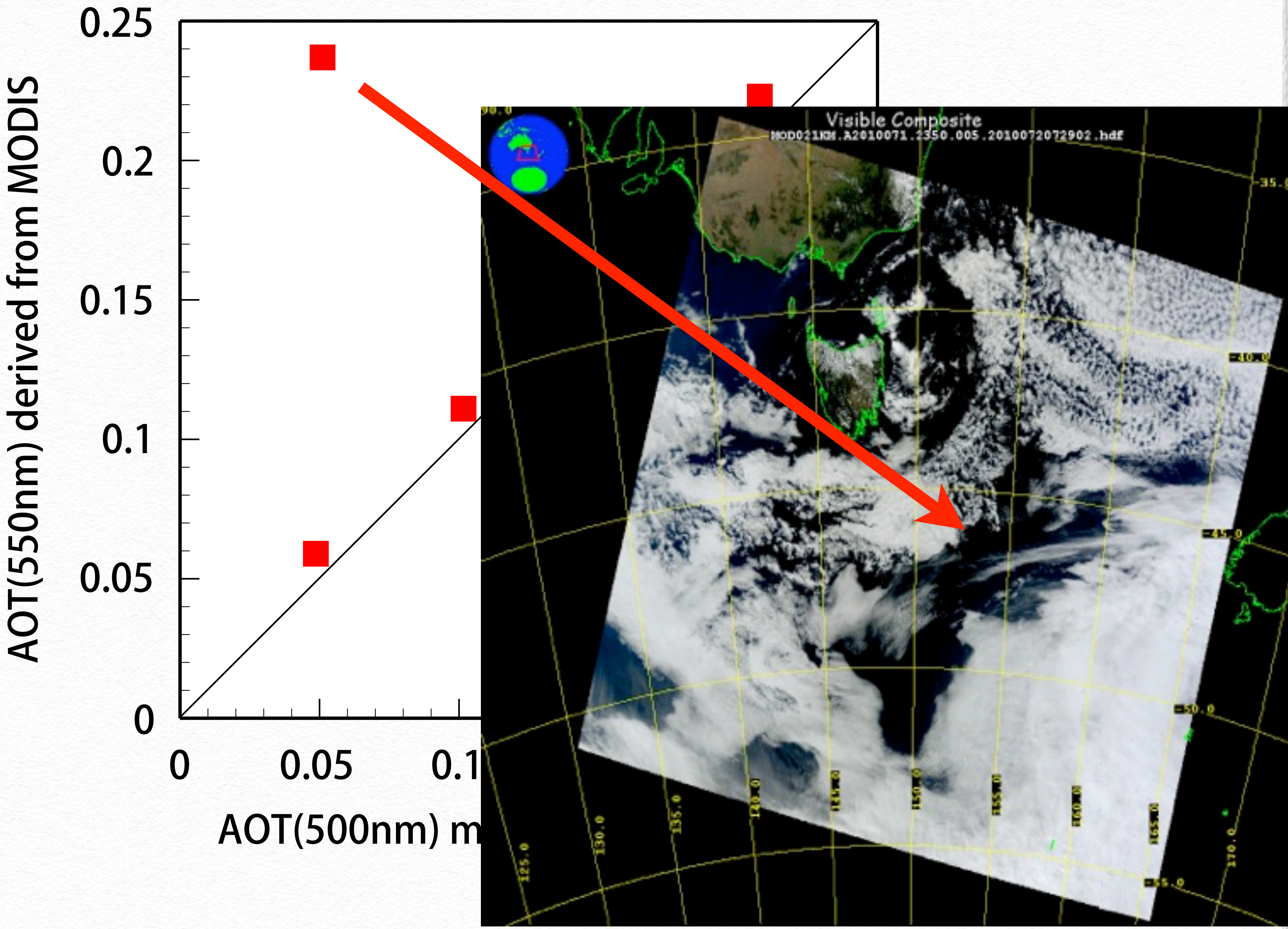


JARE52
2010-2011



Comparison with MODIS

- Good correlation

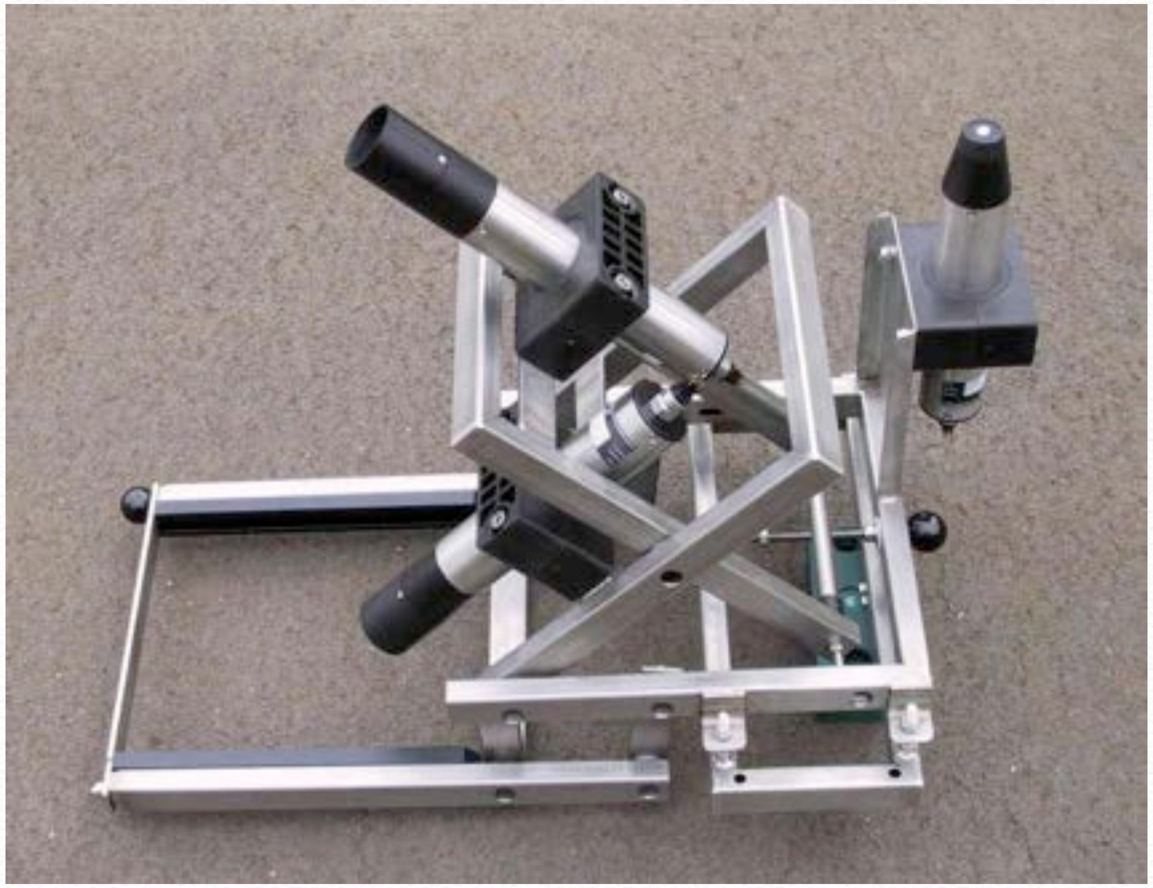


New scanning sunphotometer

- Some issue are remained on POM-01mk3
  - Stop sun-tracking during sky brightness measurement
    - Size distribution and optical properties are could not derived
  - Sun-tracking is based on on-off control
    - Tracking control rarely becomes unstable state
- Development of new shipboard scanning sunphotometer
  - Sun-tracking is based on PID or PD control
  - Sun-tracking conducts all-time including sky brightness scanning measurement
- Now
  - Development of sun-position sensor with high resolution as 0.1 degree

Lw measurement

- For open ocean, free-fall type submerged radiometer is usually used
  - However, it is not used for coastal waters due to shallow and optically dense waters (C-OPS is OK?!)
- Lw is directly measured above the sea-surface
  - It is contaminated by reflected sky brightness



Covered radiometer

- To avoid a contamination of sky radiance reflected on the surface, Tanaka et al.(2006) showed the Lw measurement with a covered radiometer
- However, it requires the shelf-shading correction

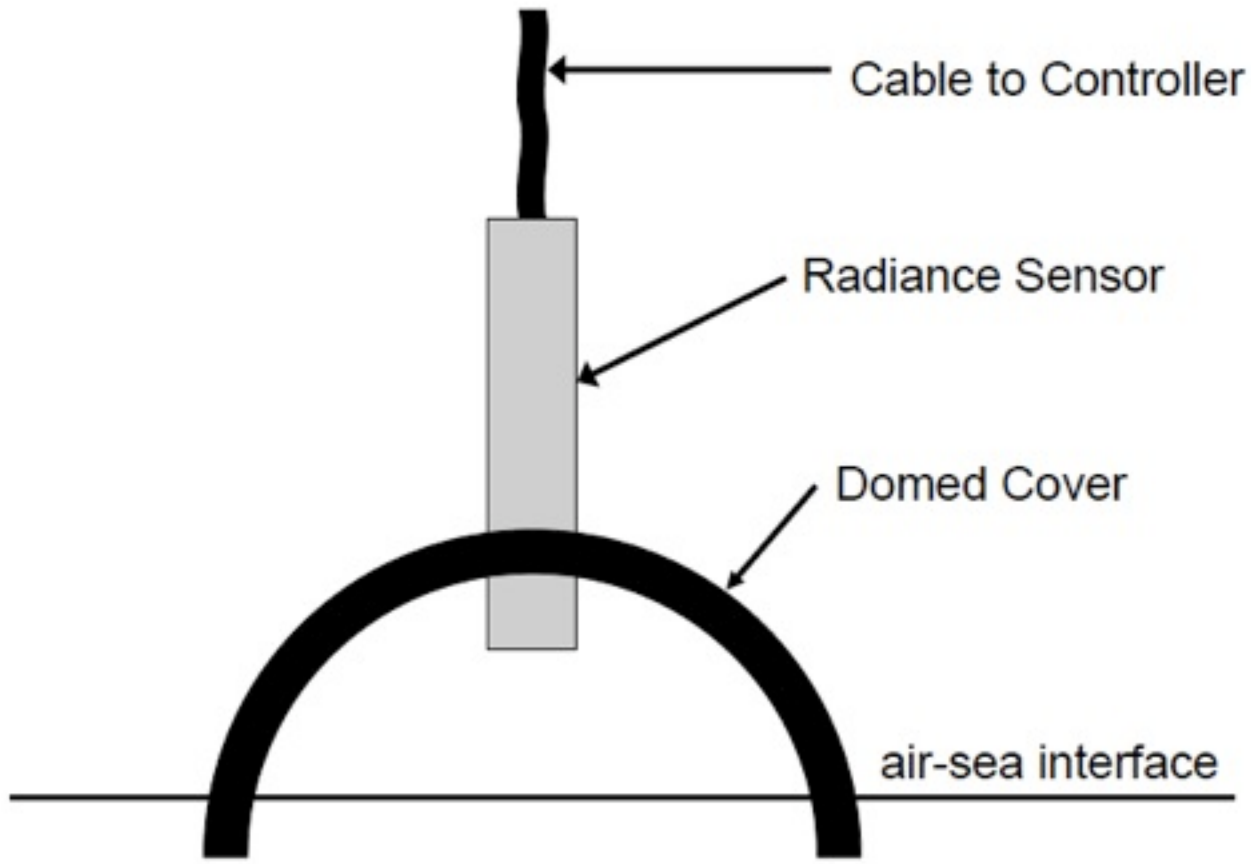


Fig. 1. Schematic diagram of the proposed domed-cover method.

Covered radiometer

- Aas and Korsø (1997) showed a relationship between the correction factor and a value related a sensor radius
- It means using different shade size could correct the self-shading

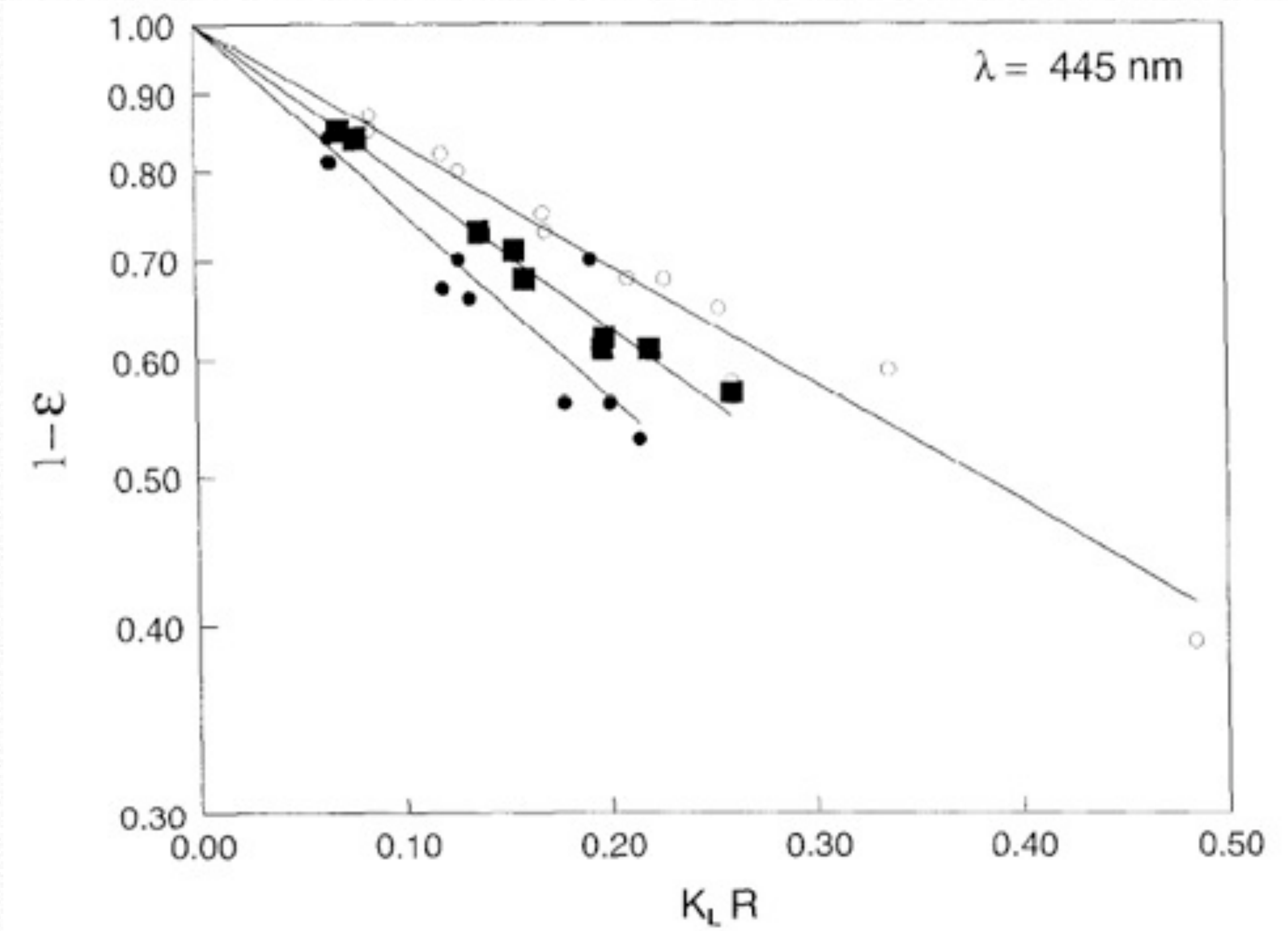


Fig. 1. Observed values of $1 - \epsilon$ for nadir radiance at 445 nm, as a function of $K_L R$. $\theta_0 = 40°$—●; $\theta_0 = 50°$—■; $\theta_0 = 60°$—○.

Covered radiometer

- Two radiometer with different cover sizes
- Self-shading error was estimated from these measurement

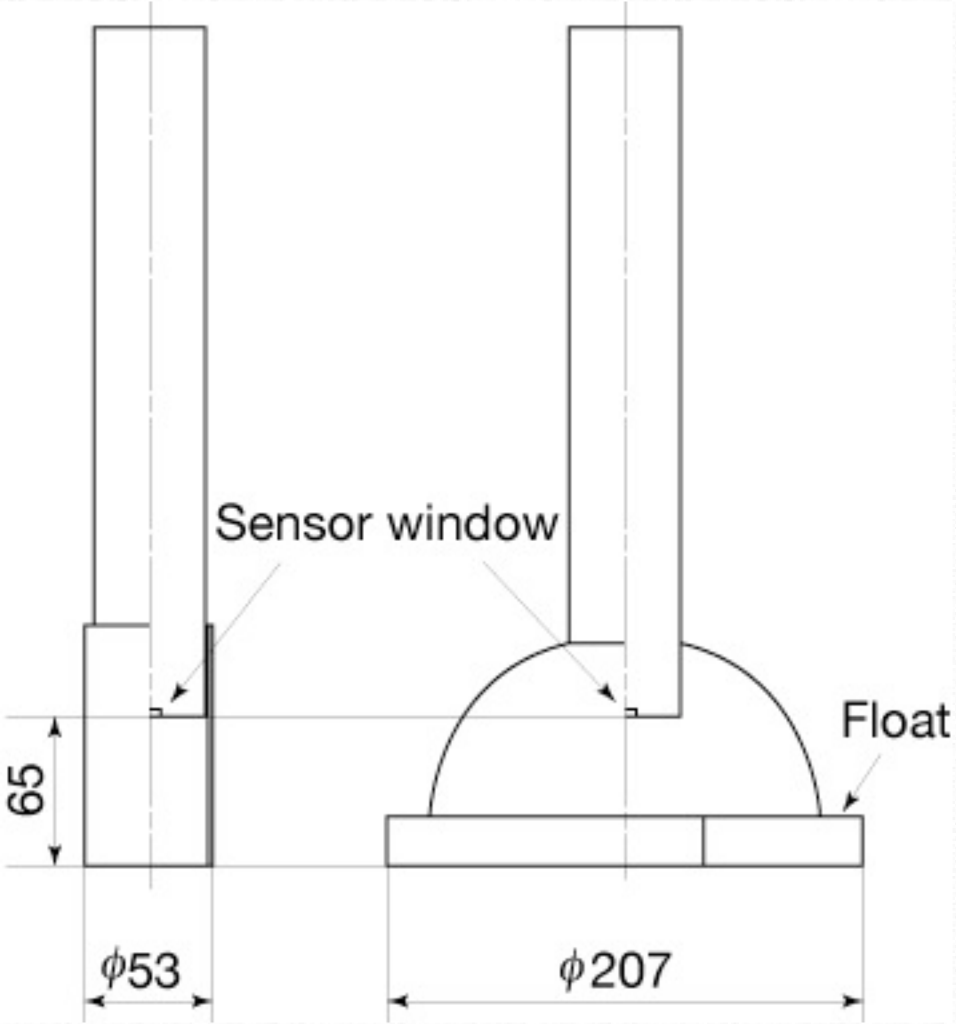
$Lu^{true} = Lu^{meas.}/(1-\varepsilon)$

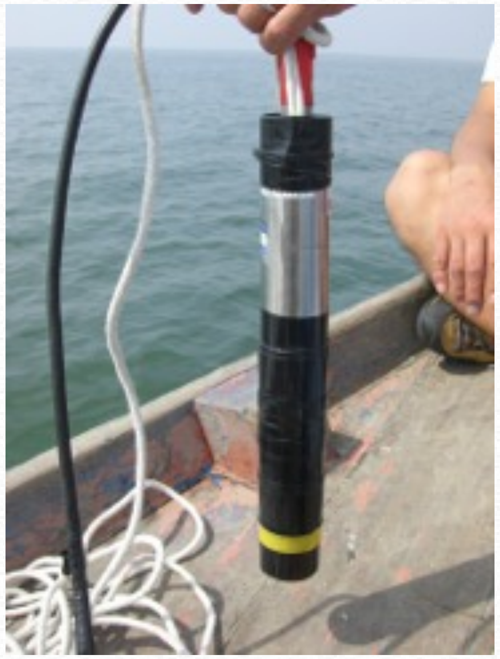
$\varepsilon = 1-\exp(-kaR)$ Gordon and Ding(1992)

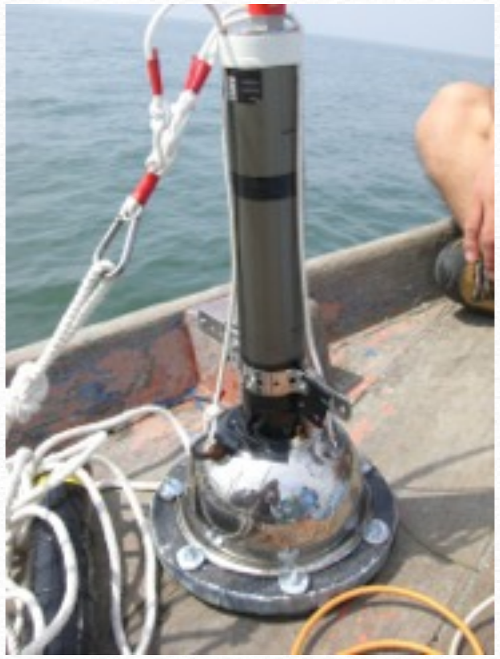
$k = 2/\tan\theta_{0W}$

$Lu^{true} = Lu^{small}/\exp(-kaR_S) = Lu^{large}/\exp(-kaR_L)$

$ka = \ln(Lu^{small}/\ Lu^{large})/(R_L-R_S)$





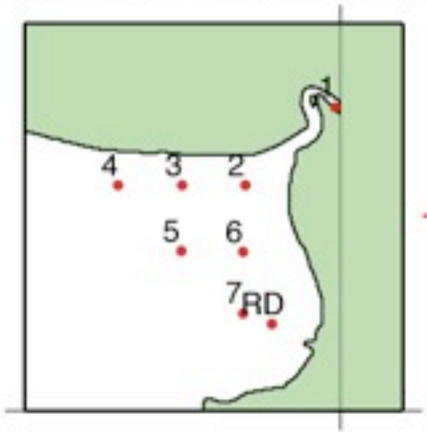


Observation areas

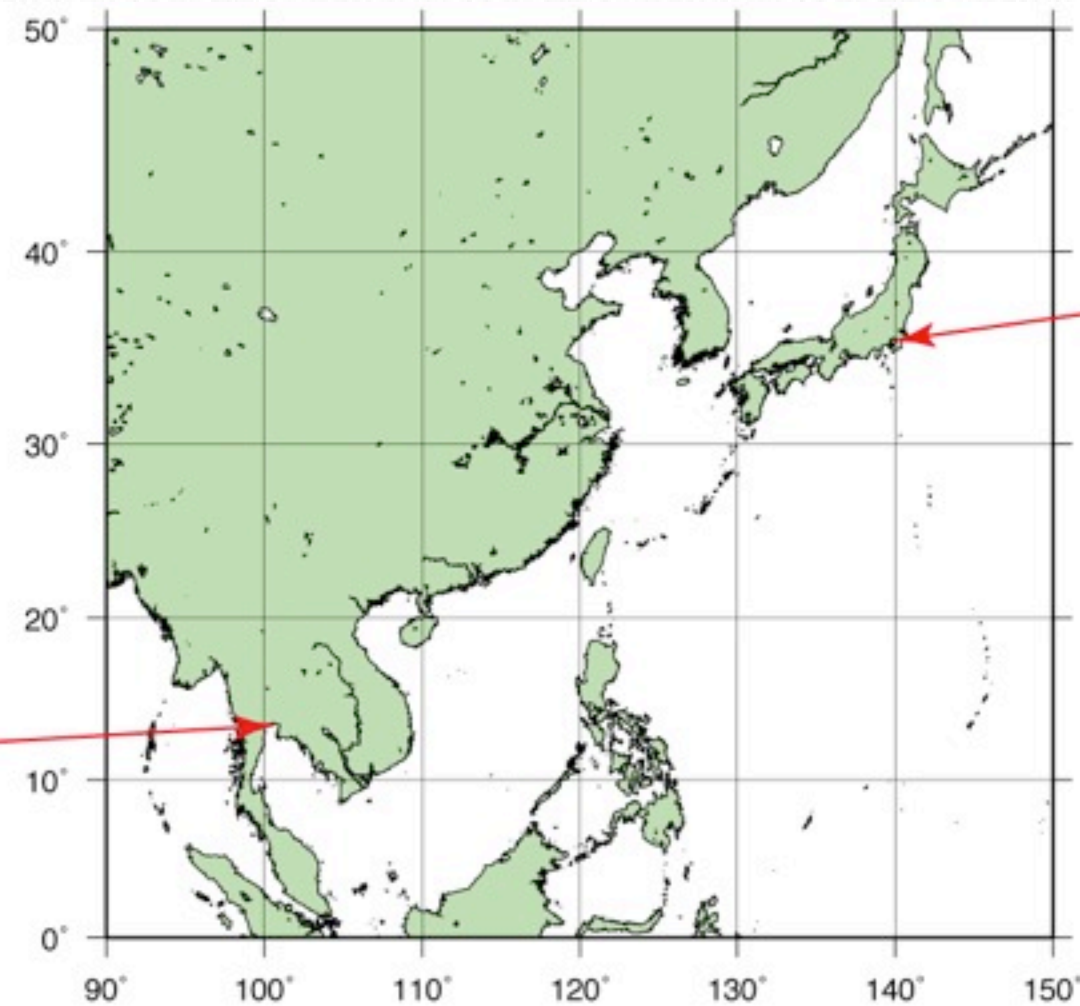
- Bangpakong river estuary around northeastern of the upper Gulf of Thailand (December in 2009-2011)
- Tokyo bay (May-October in 2010-2013)

	min.	mean	max.
Chl-a (mg m^{-3})	3.1	14.3	39.8
TSM (g m^{-3})	2.7	10.2	32.6
ISM (g m^{-3})	1.7	7.2	28.1
OSM (g m^{-3})	0.8	3.0	10.7

Bangpakong river estuary



Scattering water



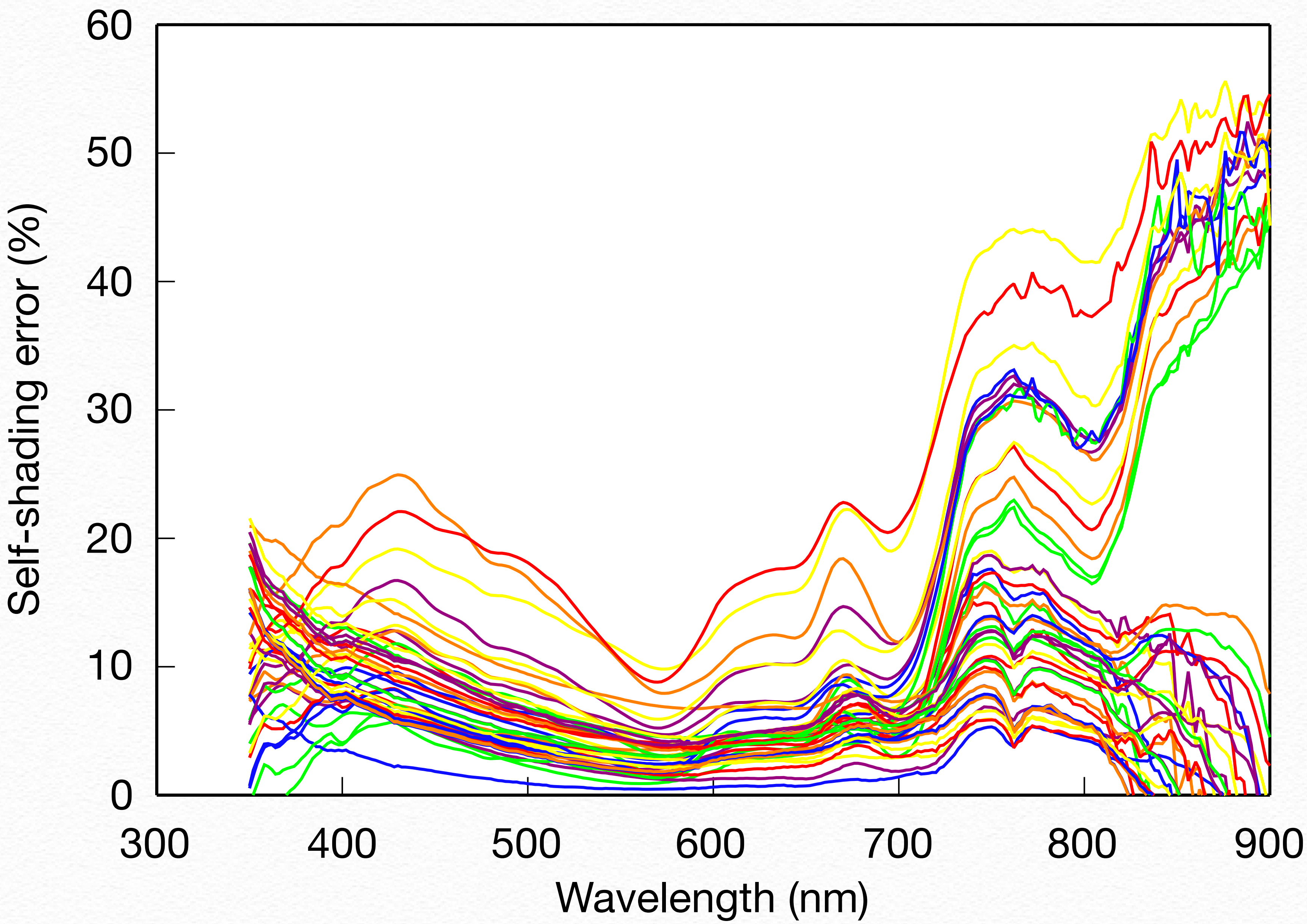
Tokyo bay

	min.	mean	max.
Chl-a (mg m^{-3})	3.2	25.1	69.0
TSM (g m^{-3})	2.5	7.6	12.4
ISM (g m^{-3})	0.0	2.6	7.5
OSM (g m^{-3})	2.5	5.0	7.8

Absorptive water

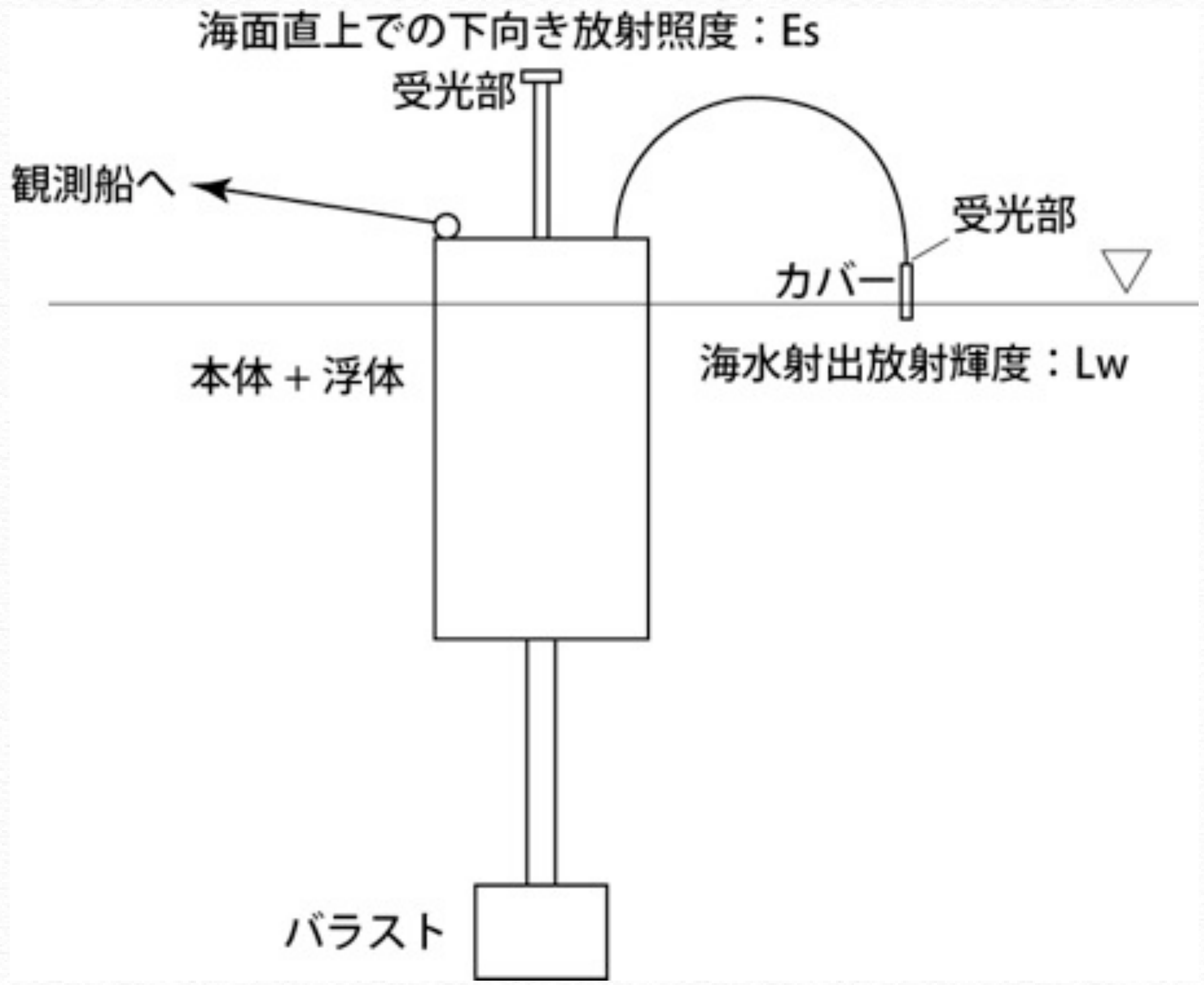
Self-shading error

- Results in the case of TriOS RAMSES (D=4.7cm)
- The result shows two groups, corresponding to absorptive or scattering waters



Lw measuring buoy

- Two radiometer method has some problems
  - It affected by bubbles, reflection and shade associated with boat
  - It is hard work
- Development new Lw measuring buoy



Self-shading error

- Tokyo bay Stn. 98 Chl-a concentration = $58.4 mg/m^3$

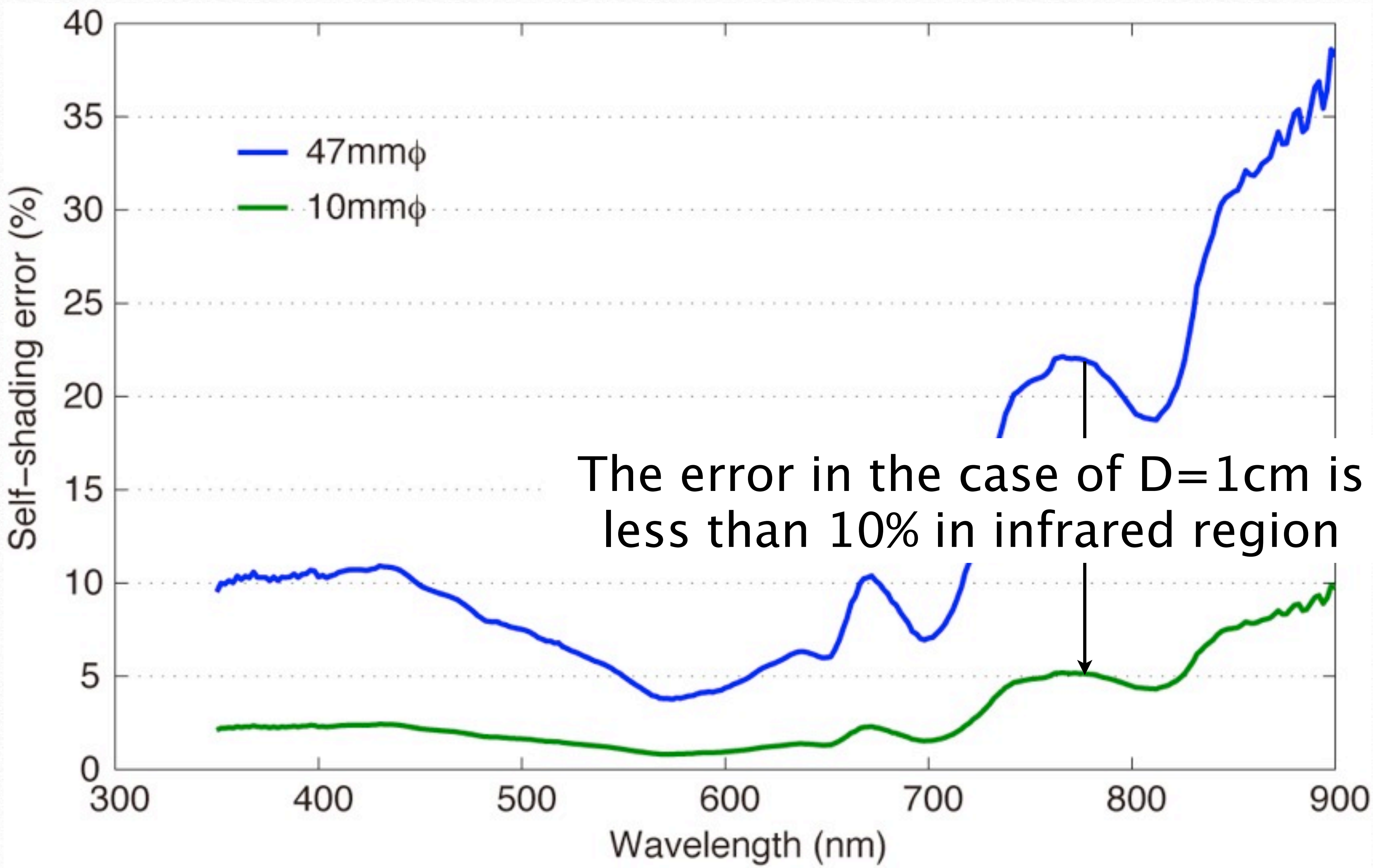
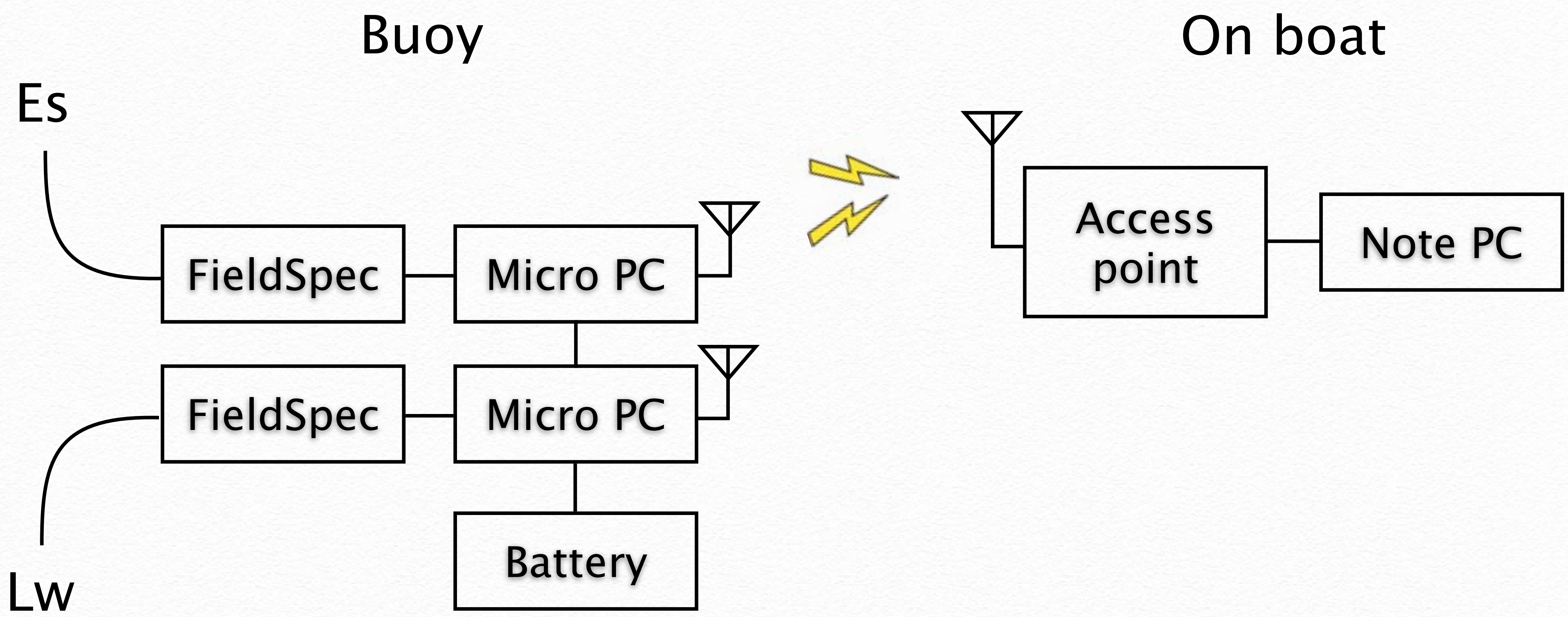


Diagram of buoy

- FieldSpec HH needs manual operation via PC
- FieldSpecs are operated from on boat PC via VNC



In-situ measurement

- Suspended matter is key player in coastal waters radiative transfer
  - Its optical property is required for an atmospheric correction
  - and in-water algorithm based on theoretical model
- We evaluate a relationship between backward-scattering coefficient of particulate matter and each suspended matter concentration.

Observation items

- Radiative quantities
  - Water-leaving radiance Lw
  - Downward irradiance on the surface Es
- Optical properties
  - aCDOM
  - aph, ad
  - bbp with HYDROSCAT-6P
- Substance quantities
  - Chlorophyll-a
  - Total suspended matter(TSM)
    - Using Nuclepore (pore size 0.4 μm)
  - Organic and inorganic suspended matter(OSM, ISM)
    - Using GF/F
    - Heating at 550°C for three hours

Estimation of b_{bp}

- Backward-scattering coefficient of particulate matter b_{bp} was derived from Rrs and sum of each measured absorption coefficient (Lee et al., 2002)

$$r_{rs} = \frac{R_{rs}}{0.52 + 1.7 R_{rs}}$$

$$u = \frac{-g_0 + [g_0^2 + 4 g_1 r_{rs}]^{1/2}}{2 g_1}$$

$$g_0 = 0.0895, g_1 = 0.1247$$

$$b_b = \frac{ua}{1-u} - b_{bw}$$

Model of bbp

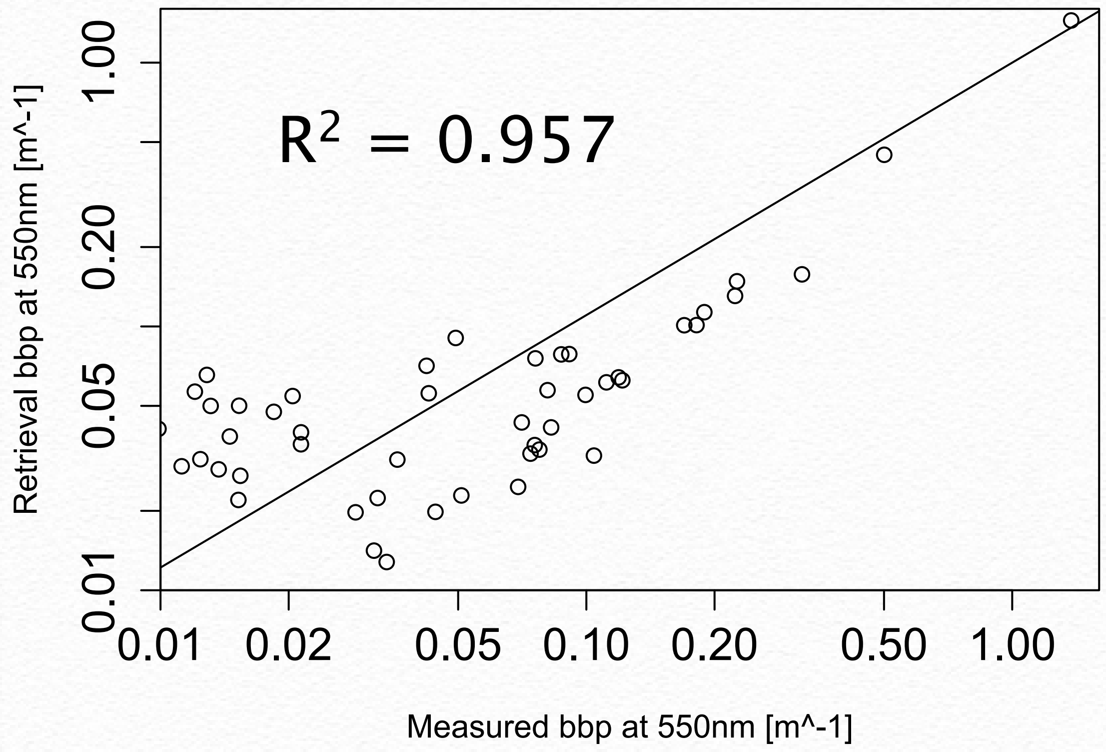
- Relationship between bbp with a combination of each particulate matter concentration derived using with general linear model
- It assumed that the backward-scattering coefficient was proportional to each concentration
  - Model 1: bbp = c1*Chl-a + c2*TSM
  - Model 2: bbp = c1*Chl-a + c2*ISM
  - Model 3: bbp = c1*Chl-a + c2*ISM + c3*OSM
  - Model 4: bbp = c1*ISM + c2*OSM

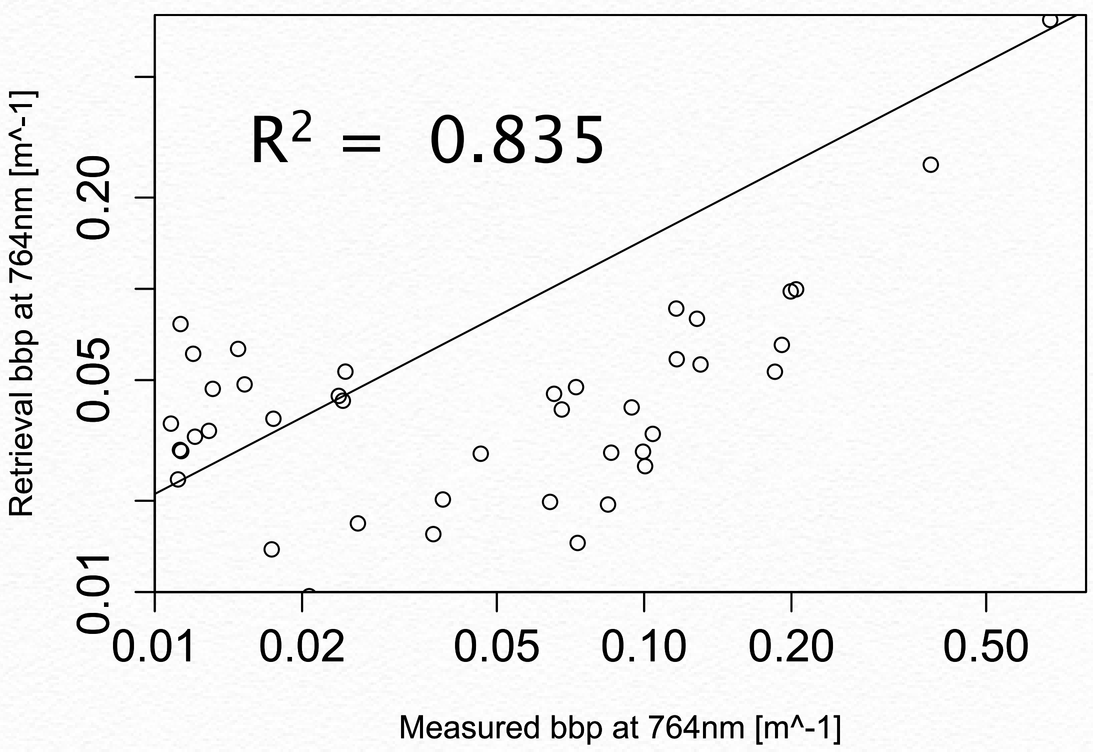
General b_{bp} model

- Model estimates the measured bbp well

$$b_{bp}(550) = 0.00049*\text{Chl-a} + 0.00370*\text{ISM} + 0.00501*\text{OSM}$$

$$b_{bp}(764) = 0.00032*\text{Chl-a} + 0.00117*\text{ISM} + 0.00672*\text{OSM}$$



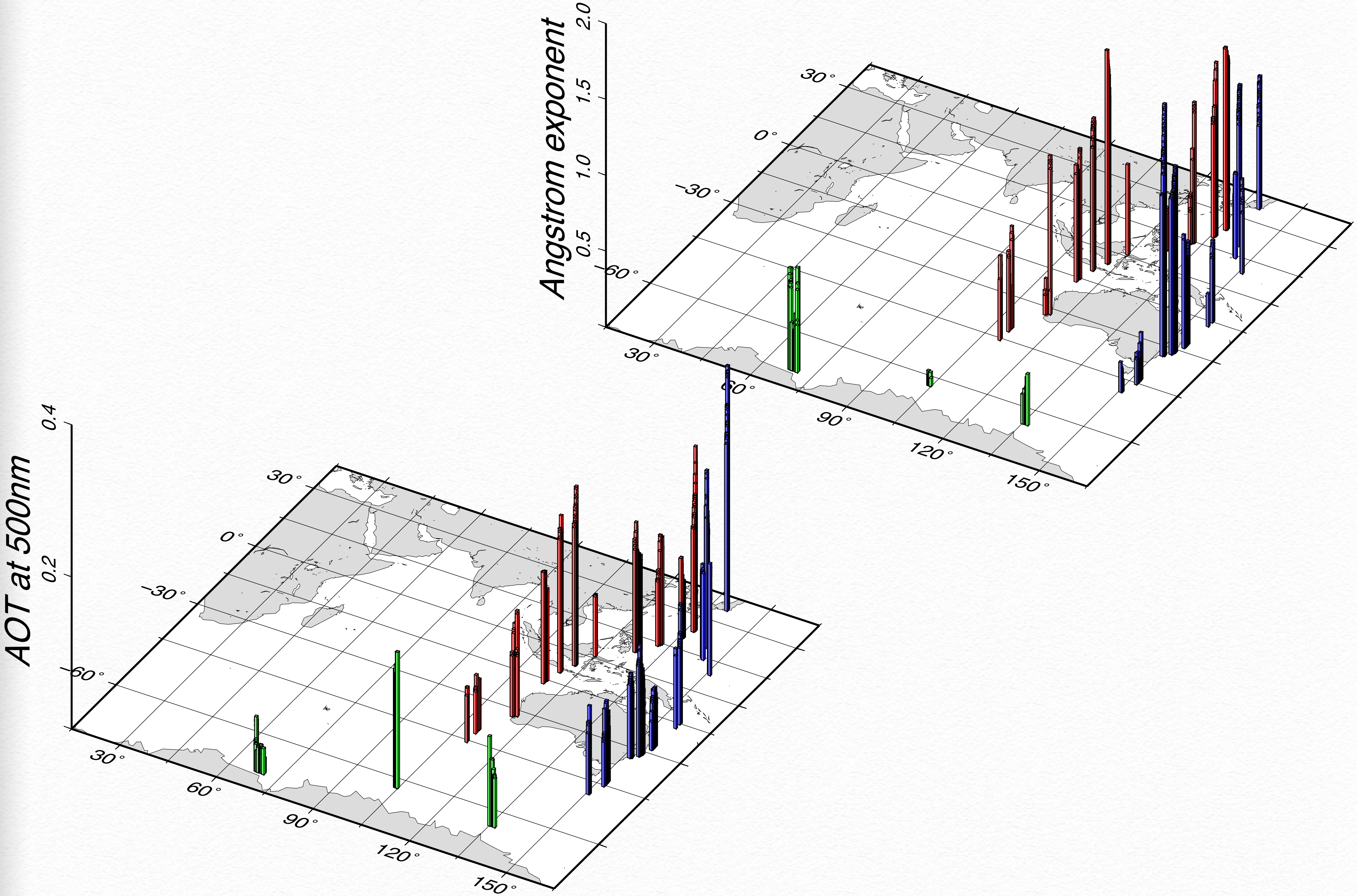


Summary

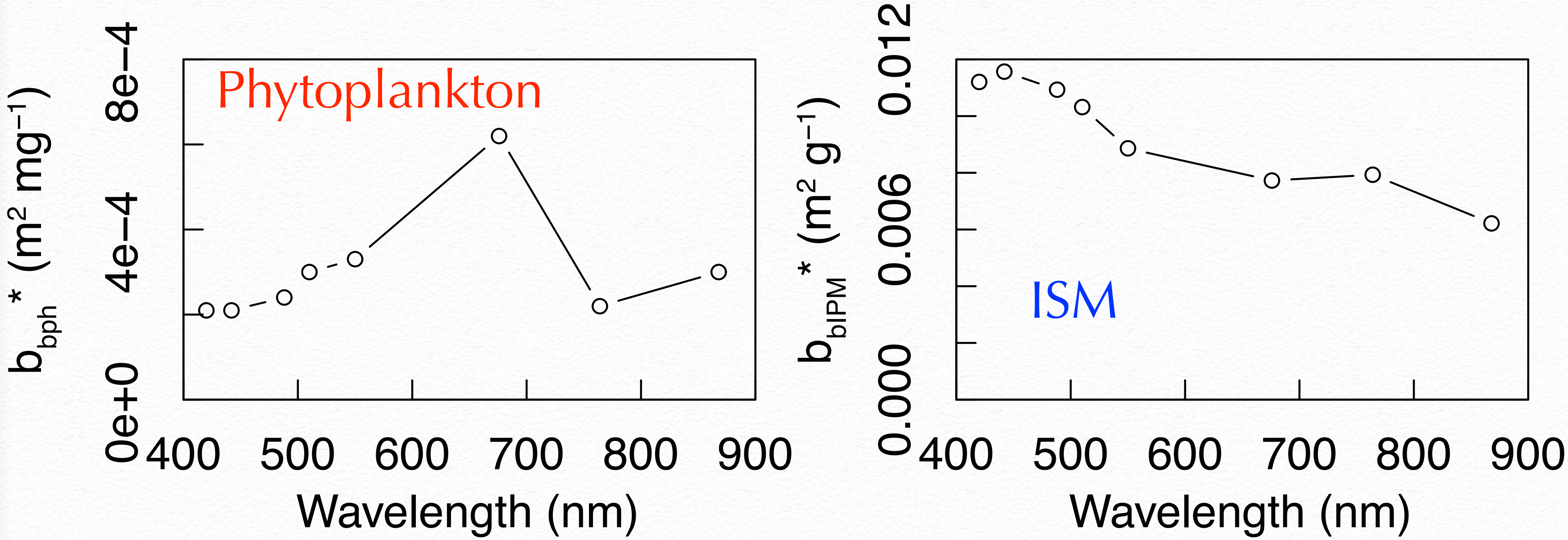
- New scanning sunphotometer will be on board R/V Shirase next cruise, departure on November
- Buoy's balance test will conduct on next march or next FY at wave-making tank of Hiroshima University
- Lw measuring buoy will test on board at Tokyo bay in next FY
- Good relationship between bbp with a combination of each particulate matter concentration was derived using with general linear model

Thank you very much

AOT at 500nm and AE

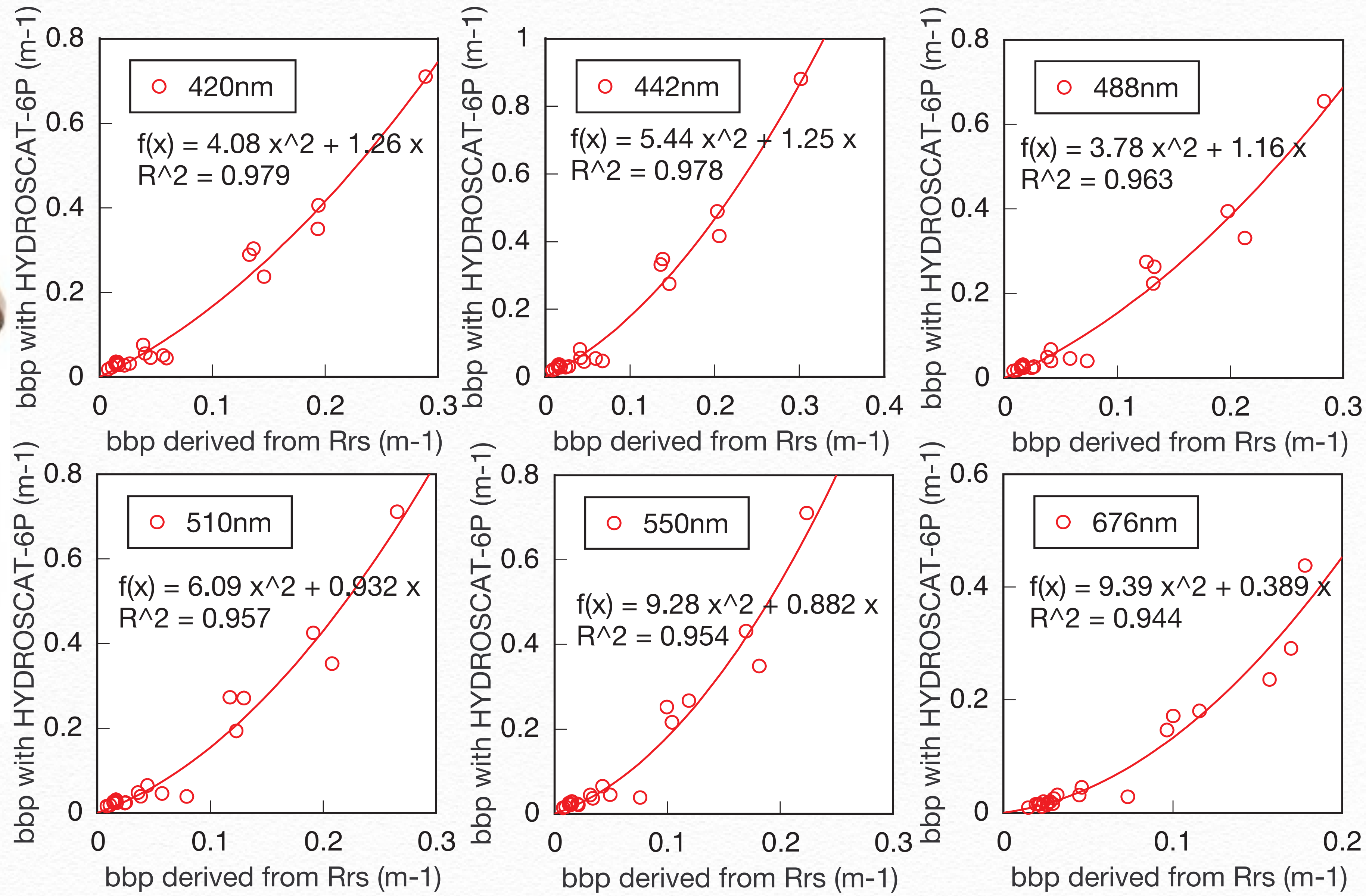


Mass-specific b_{bp}



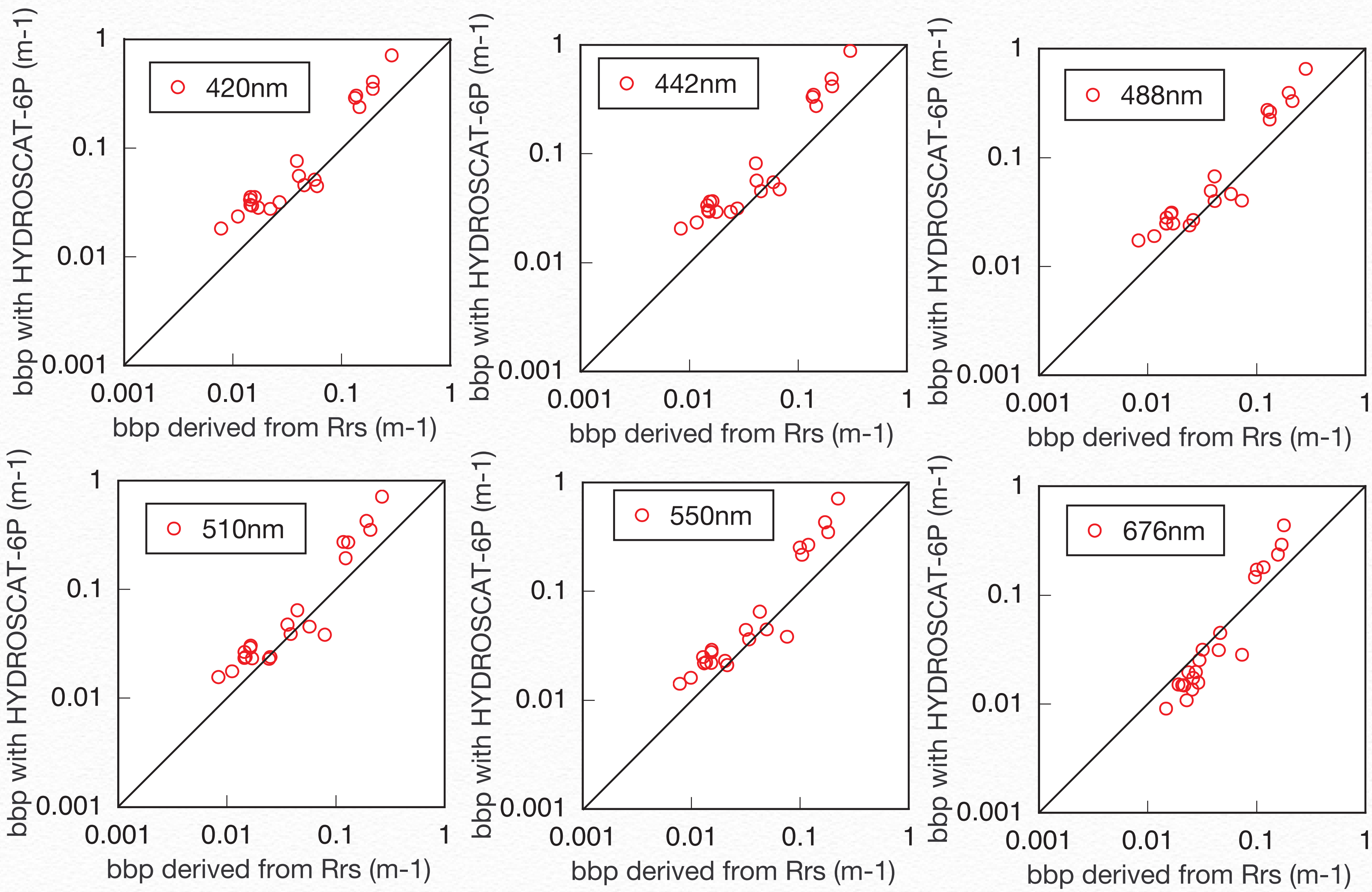
- Reasonable values were estimated despite only statistics analysis not optical theory
- The b_{bph} includes fluorescence, therefore, the use of this value could represent fluorescence peak on Rrs spectrum

Comparison of b_{bp}



- The bbp measured with HYDROSCAT-6P was overestimated and the relationship was not linear

Comparison of b_{bp}



- The slopes were steeper than 1:1 line