Iterative atmospheric correction algorithm for turbid case 2 Asian waters

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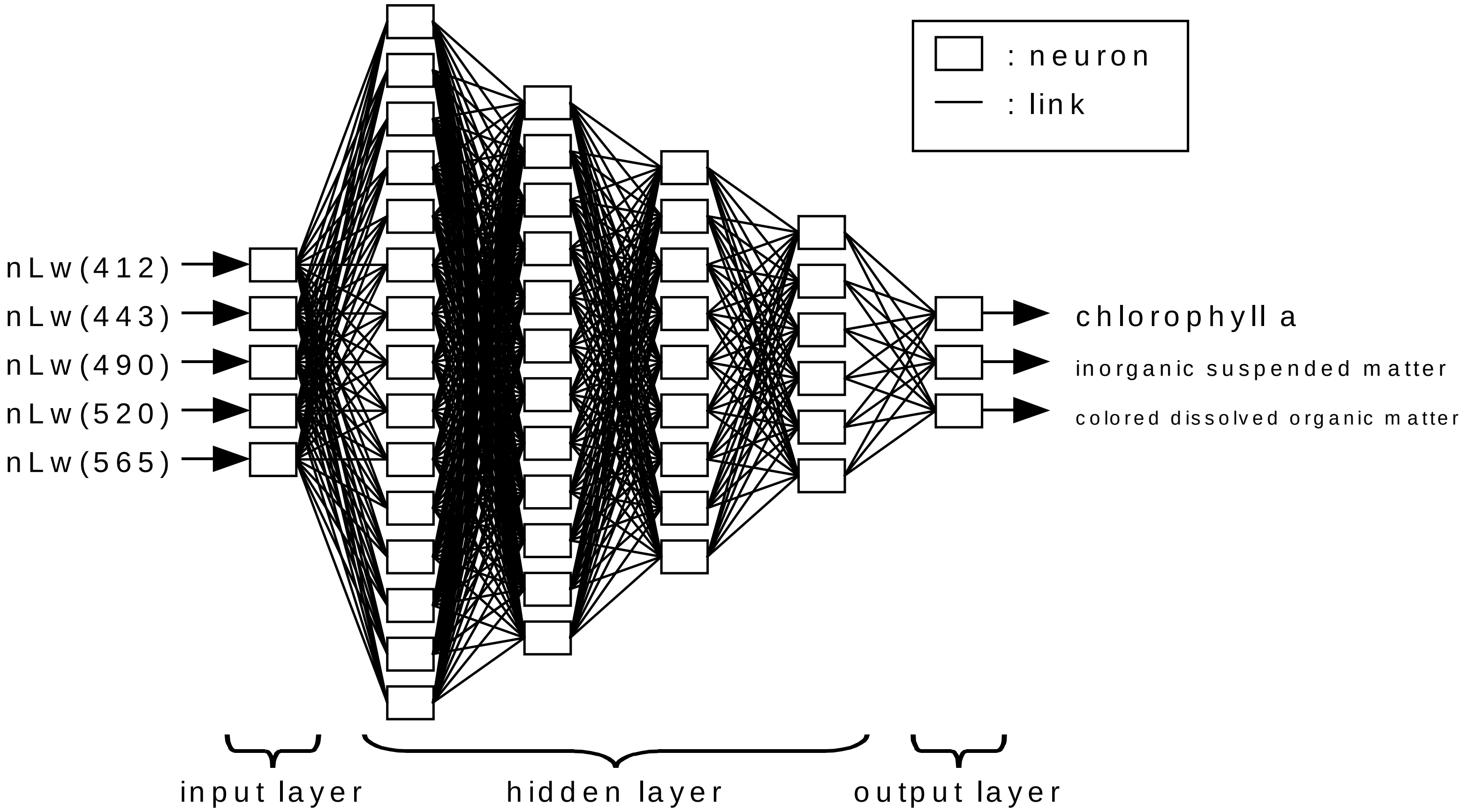
New atmospheric correction

- Based on Siegel's approach (Siegel et al.,2000)
  - Iterative atmospheric correction
    - To avoid black pixel assumption
  - Siegel's approach hardly causes negative Lw in Case 1 water.
  - But it isn't applicable in Case 2 water, because suspended matter isn't considered.
- We are making a new atmospheric correction algorithm to apply to case 2 water.

New approach for Case 2 water

- Estimation of water-leaving reflectance at near infrared band
  - Previous：It was assumed zero.
  - Siegel：function of chlorophyll-a concentration
  - This study：function of chlorophyll-a(chl), inorganic suspended matter(SS) and yellow substance(CDOM)
- Estimation of Chl、SS and CDOM
  - We use neural network in-water algorithm. (Tanaka et al., 1998)

Neural network algorithm



In-water model(1)

- water-leaving reflectance at near infrared bands

$$[\rho_W(\lambda)]_N = \pi \cdot R_{rs}(\lambda)$$

$[\rho_w]_N$: normalized water-leaving reflectance
R_{rs} : remote sensing refrectance

$$R_{rs}(\lambda) = 0.533 R(\lambda) / Q$$

Q=4.5

R : reflectance just below surface
(Lee et al., 1994)

In-Water model(2)

$$R(\lambda) = \frac{1}{3}\frac{b_b(\lambda)}{a(\lambda) + b_b(\lambda)}$$

a : absorption coefficient

b_b : backward scattering coefficient

$$a(\lambda) = a_w(\lambda) + a_c(\lambda, chl) + a_s(\lambda, SS) + a_y(\lambda, a_y(440))$$

$$b_b(\lambda) = b_{bw}(\lambda) + b_{bc}(\lambda, chl) + b_{bs}(\lambda, SS) + b_{by}(\lambda, a_y(440))$$

w : water, c : chlorophyll-a,

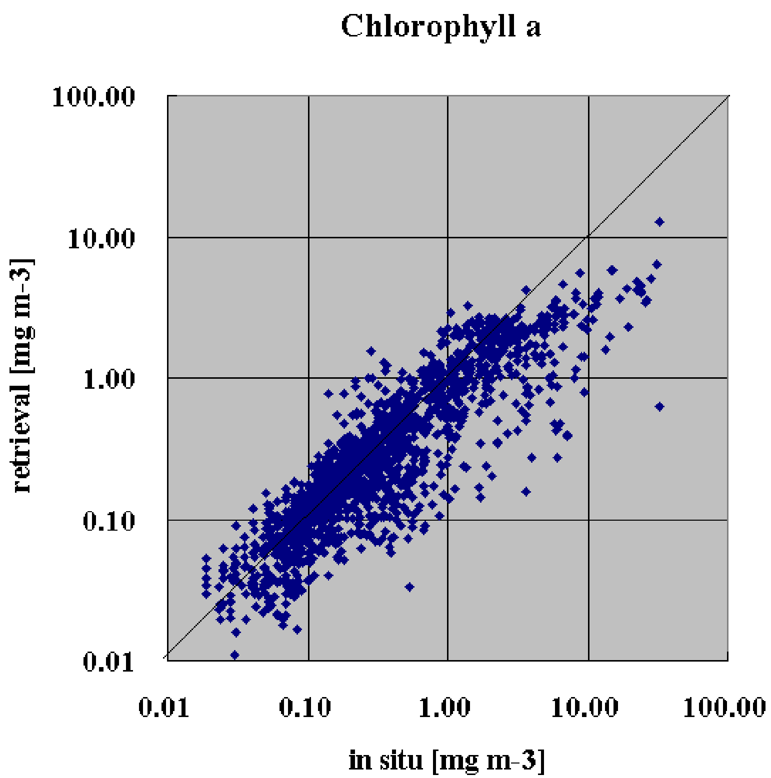
s : inorganic suspended matter,

y : yellow substance(CDOM)

Equations and References

coefficients	equations	references
a_w	$a_w(765)=2.7722$, $a_w(865)=5.1014$	Pope and Fry(1997)
a_c	$a_c(765)=0$, $a_c(865)=0$	Kishino(personal comm.)
a_y	$a_y(\lambda)=a_y(440)\cdot\exp\{-0.014\cdot(\lambda-440)\}$	Bricaud et al.(1981)
b_{bw}	$b_{bw}(765)=0.000229$,$b_{bw}(865)=0.000135$	Smith and Baker(1981)
b_{bc}	$b_{bc}(\lambda)=0.0087\times b_c(\lambda)$ $b_c(\lambda)=0.27\times chl^{0.698}\left(\frac{550}{\lambda}\right)^{-0.2983}$	Takahashi et al.(2000) Kishino(1988)
b_{bs}	$b_{bs}(\lambda)=b_s(\lambda)\cdot 0.01478$ $b_s(\lambda)=0.125\cdot SS\cdot\left(\frac{\lambda}{550}\right)^{-0.812}$	Babin and Doerffer (1996), Kronfeld (1988)

Neural network algorithm

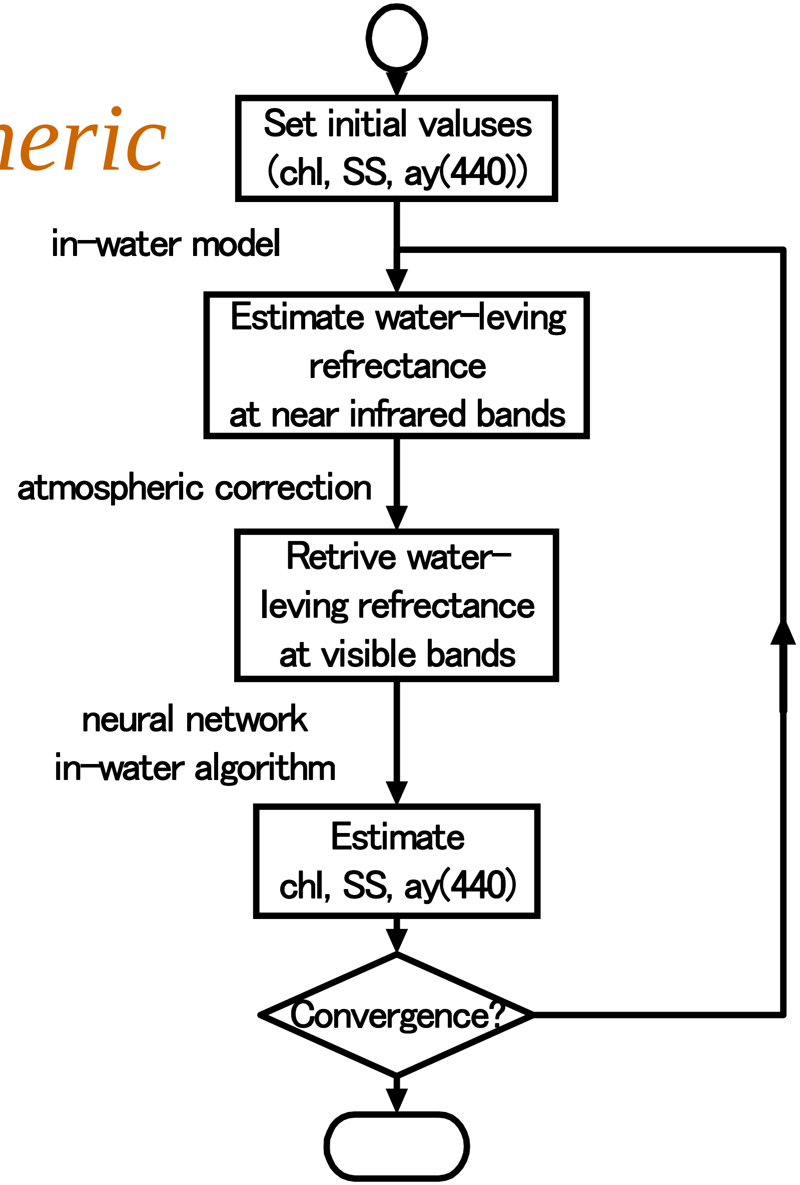


(Provided by Tanaka)

- Neural Network
  - This algorithm has good performance under $3mg/m^3$ although data are almost case 1 water.
- From SeaBAM data set

Flowchart of atmospheric correction for case 2 water

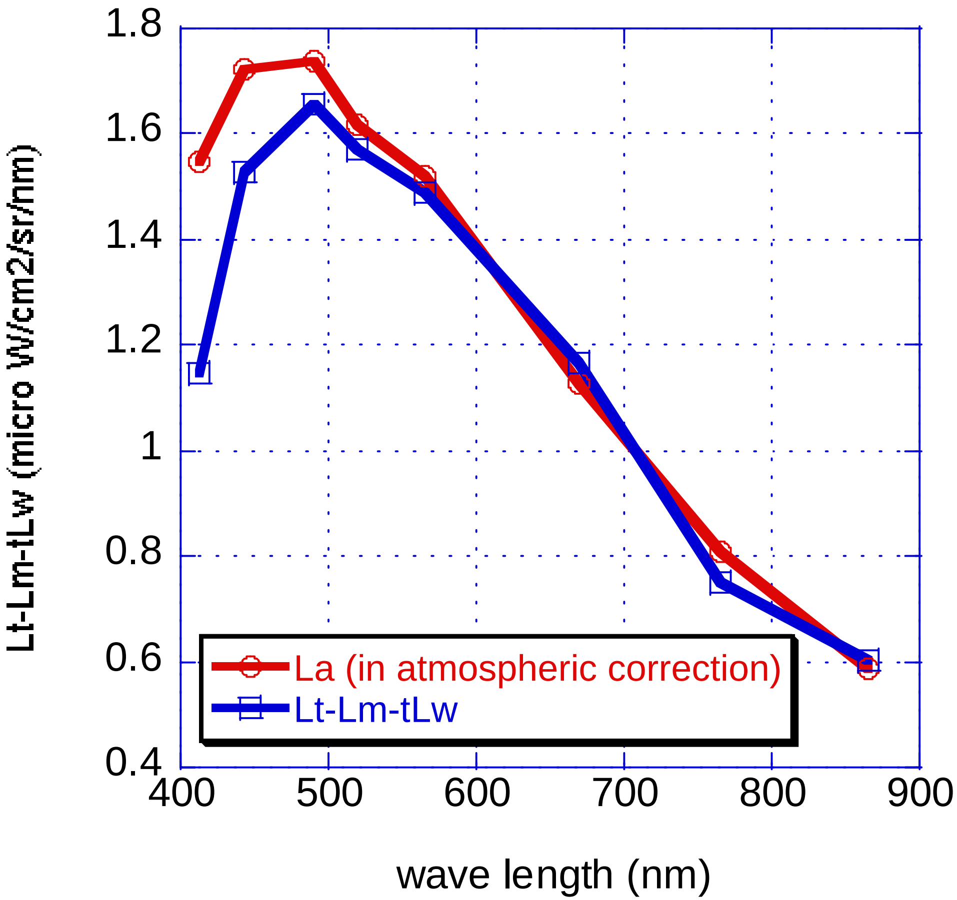
- The iterations will be terminated.
  - final Chl, SS and $a_y(440)$ are within 1% of the values obtained at the last iteration
  - ten times.



Problem of this algorithm

- Negative water-leaving reflectance
  - Neural network algorithm doesn't work well.
  - Why is negative reflectance caused?
    - in-water model is insufficient?
      - Are coefficients different in turbid case 2 water?
      - We need to consider bi-directional effect?
    - Absorptive aerosol
      - Asian dust has absorption at short visible band
      - For example

Absorptive aerosol

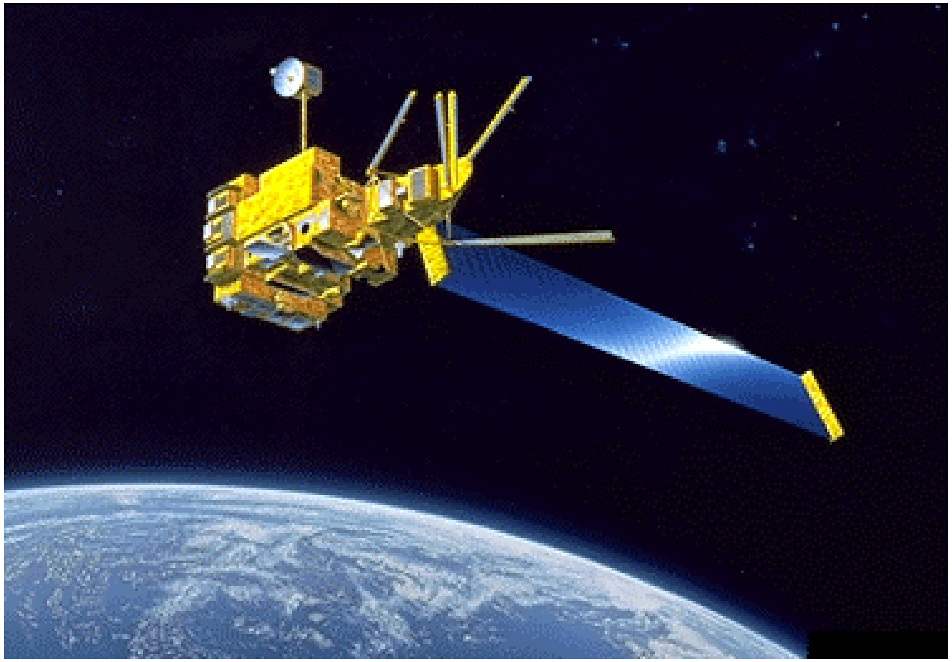


- La overestimates about 25% at 412nm.
- We should consider absorption aerosol.

For less water-leaving reflectance

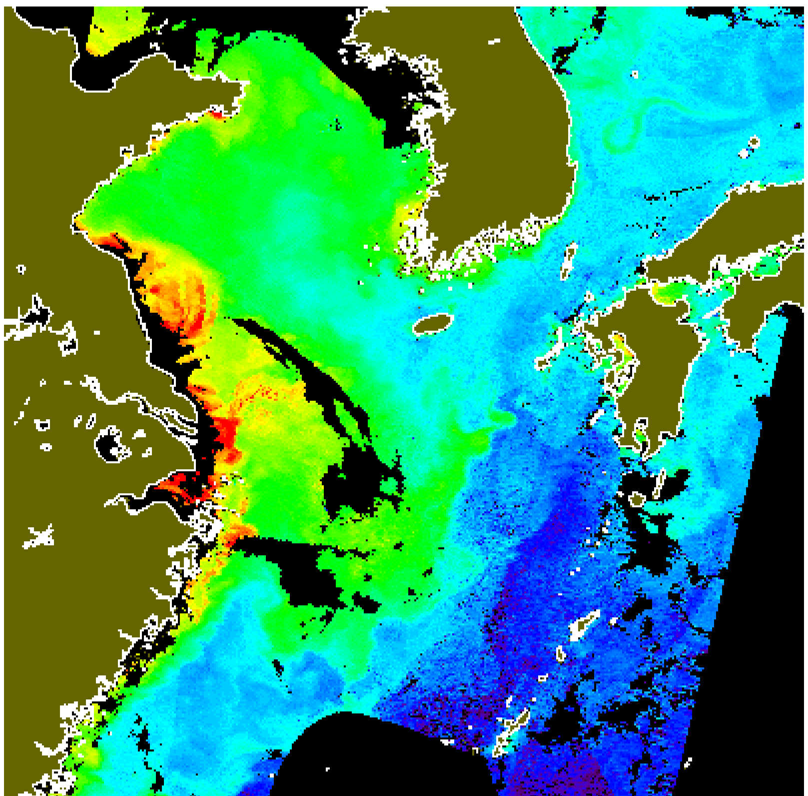
- If water-leaving reflectances at visible bands were less than minimum water-leaving reflectance, the value is replaced the minimum values temporary.

Application to OCTS data

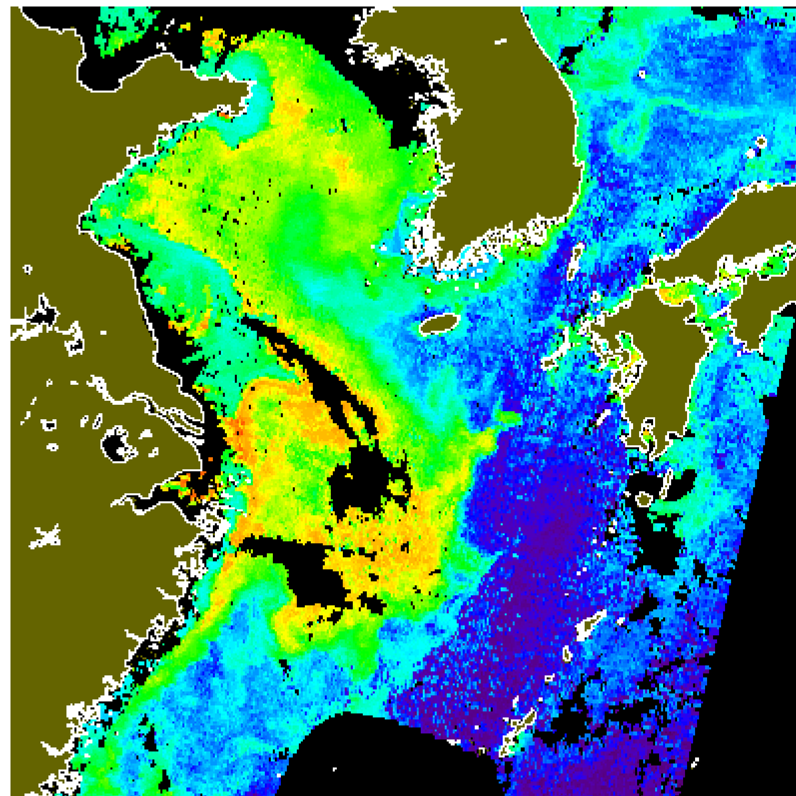


- OCTS data over East China Sea
  - 15 scenes
    - 1997/2/19, 1997/5/9, 1997/5/31…etc

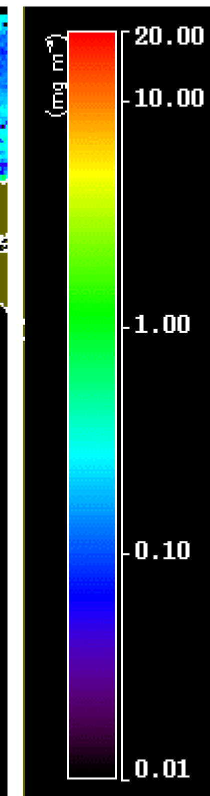
Comparison with Siegel's approach



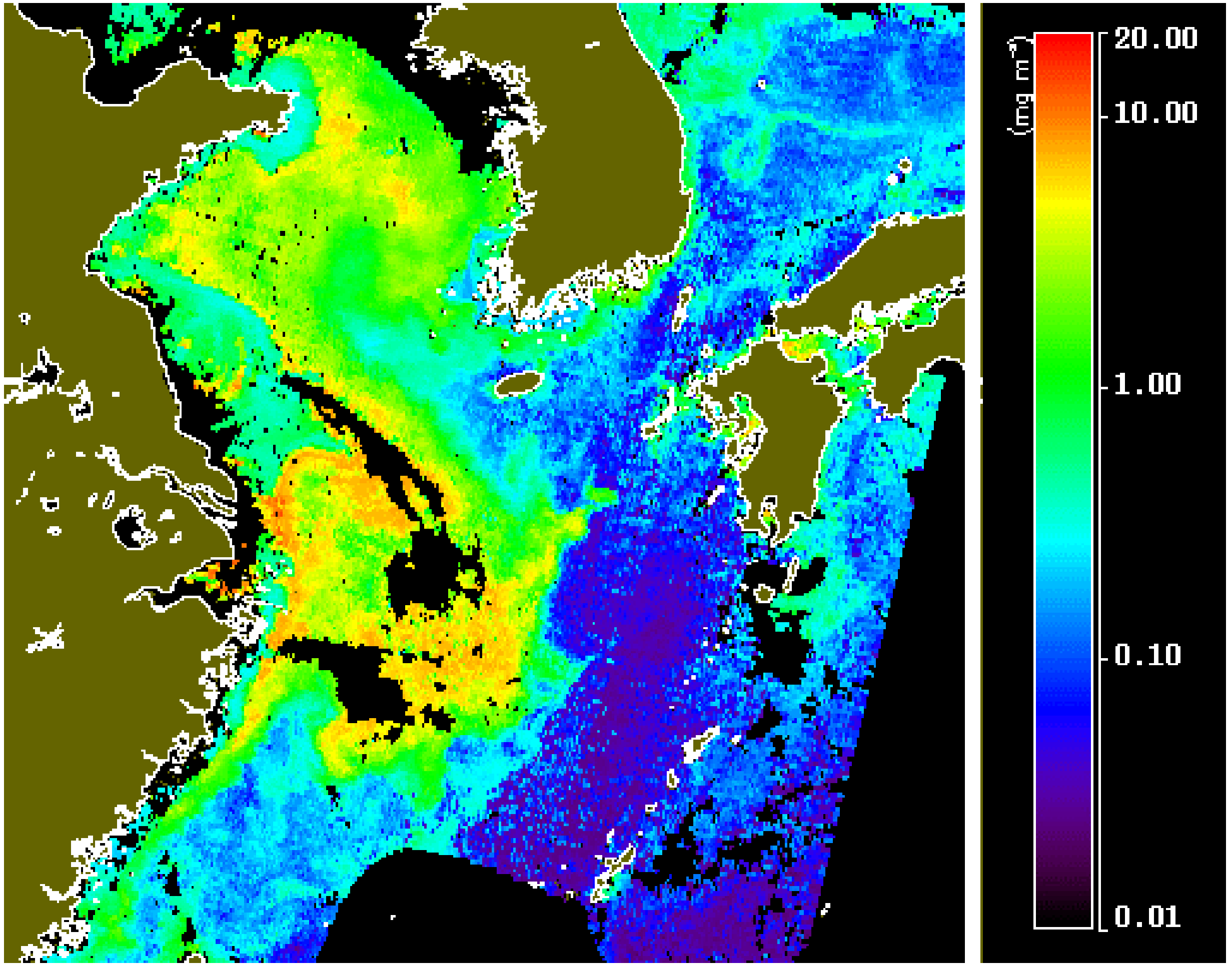
Siegel's approach



This study



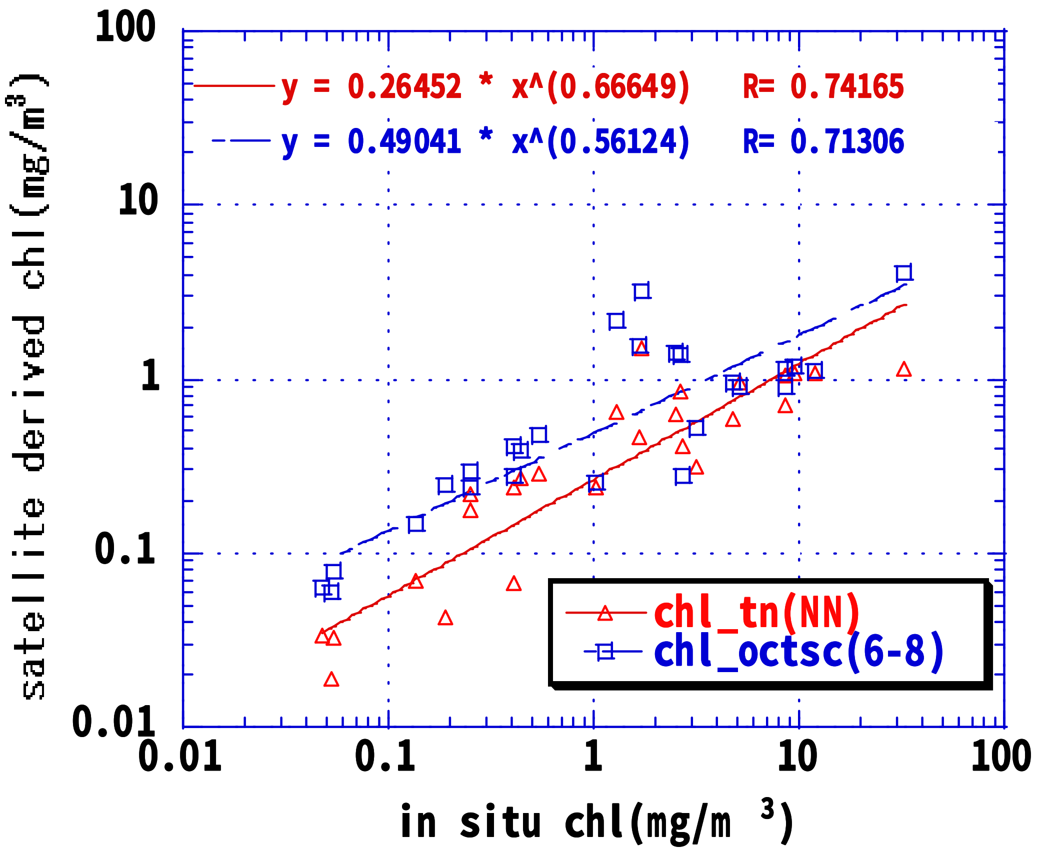
Chlorophyll-a concentration



Satellite(1997/5/31)
0.5-3.0 mg/m^3
(Yellow Sea)
2-5mg/m^3
(mouth of Chengjieng

Tang et al(1998)
0.5-1.7mg/m3
(Yellow Sea)
2.0-4.6mg/m^3
(mouth of the river)

Comparison with match-up data

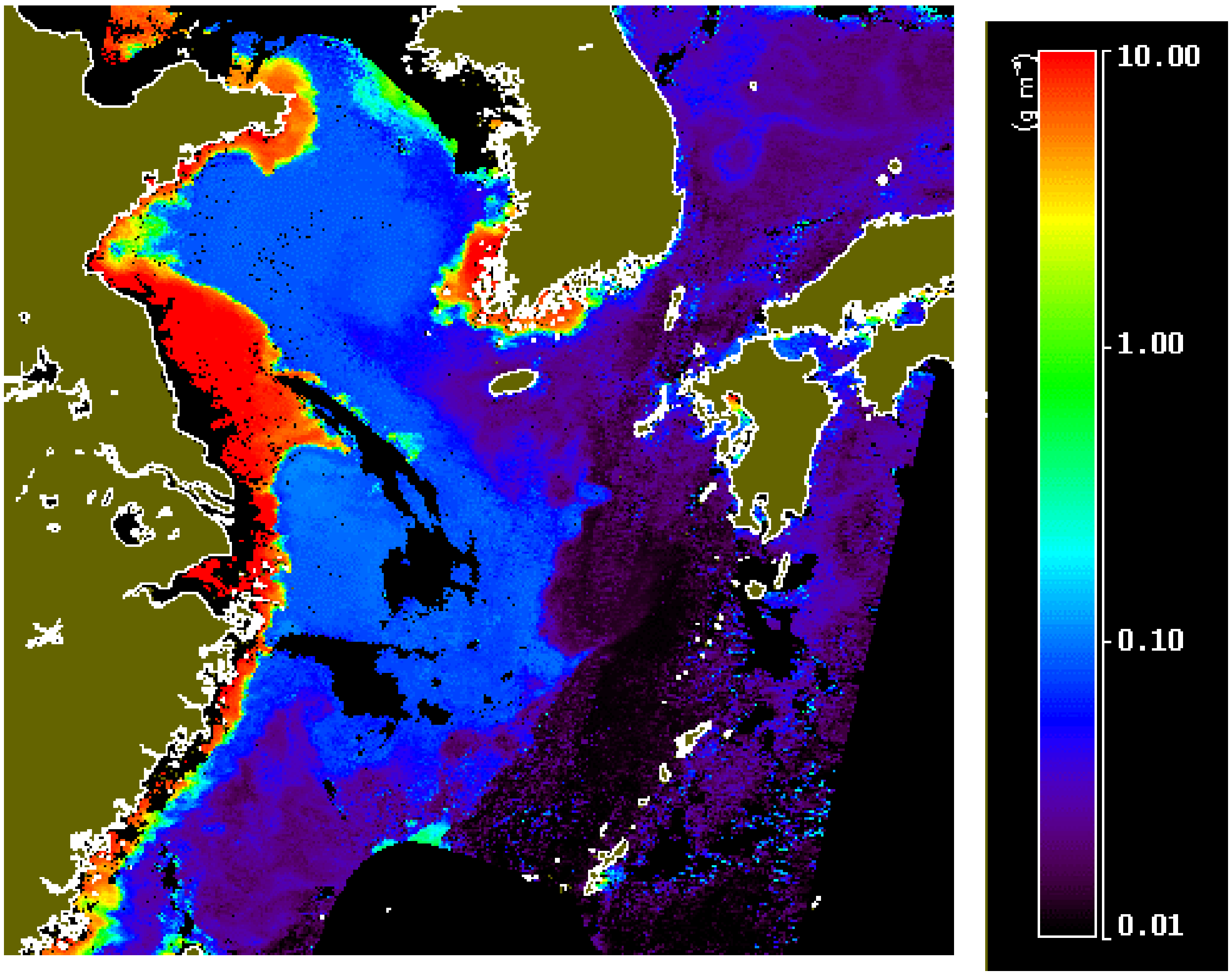


Chlorophyll-a concentration was underestimated.

Correlation is better than previous algorithm.

Notice: almost case 1 water

Inorganic suspended matter



Satellite(1997/5/31)

1.5-6g/m^3

(mouth of Chengjieng)

Matsuike et al.(1983)

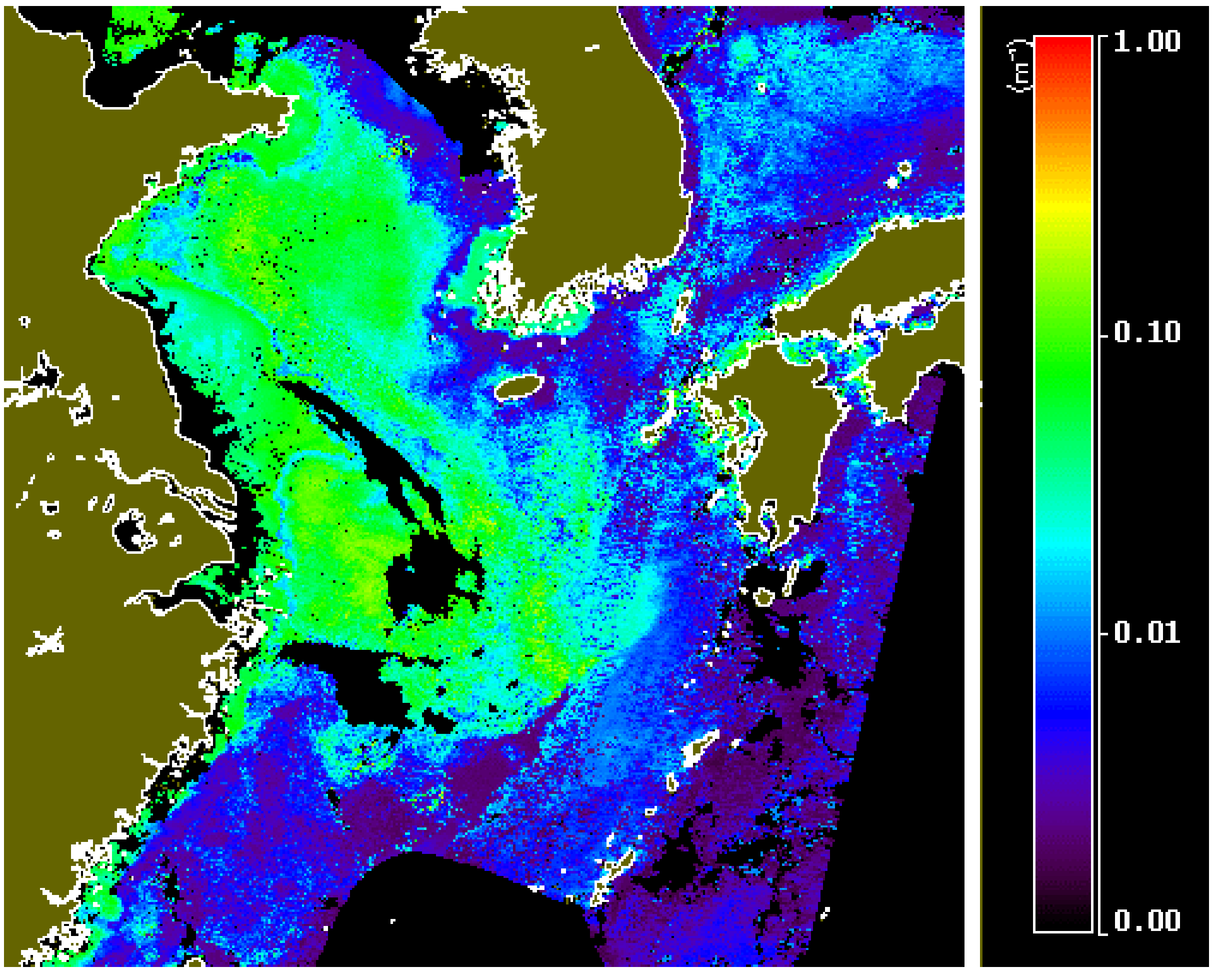
0.7～3.1g/m^3

Sep. in 1981

Problem:

High SS is caused around cloud because of contamination of multi-scattered light from cloud.

Absorption coefficient of CDOM at 440nm



Satellite(1997/5/31)

$0.7\text{-}0.2m^{-1}$

(mouth of Chengjieng)

Matsuike et al.1983

$Ay(440)=0.5\text{-}3\ m^{-1}$

Sep. in 1981

Conclusion

- This scheme simultaneously estimates

  Chlorophyll-a concentration

  inorganic suspended matter concentration

  absorption coefficient of yellow substance at 440nm.
- We evaluated the applicability of the iterative atmospheric correction procedure.
  - The range of satellite-derived these values approximately coincides with the ship measurement although the in-situ data was not synchronized with the satellite data.
- Number of iterations is typically three to four iterations, not so many overheads.

Conclusion (cont.)

- This scheme has better performance than Siegel's approach in Case 2 water.
- We need to improve in-water model.
  - Coefficients
  - Bi-directional effect
- We need to consider absorptive aerosol, as such as Asian dust.
- The contemporaneous in-situ measurements are importance for further algorithm development and validation.