Aerosol retrieval using Himawari-8 visible data

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Developing advanced Aerosol retrieval using AHI-08 VIS/NIR data

1. **2-channel method**
   B3 & B4 (Ocean)
   B1 & B4 (Land)
   → AOT, AE

Himawari-8 VIR bands & 0.86
From JMA HP

WL (μm)	Himawari8.9		Himawari6.7	
0.47	●	1		
0.51	●	1		
0.64	●	0.5	●	1
0.86	●	1		

2. **MWP method**
   → AOT(fine, coarse), AE, SSA, …
   → Ocean retrieval

3. Combination of 2-ch and MWP
   Future work…

2-ch method (REAP) (Higurashi and Nakajima, 1999)

Retrieval of Aerosol optical Properties

Satellite data
- VIS
- NIR

→

Products
- Aerosol optical thickness
- Ångström exponent

(over the ocean)

Observation

Year, Month, Day
θ, θ_0, ϕ

Band3 Band4
$R_{\lambda=0.64}$, $R_{\lambda=0.83}$

Compare

Retrieval
τ, α
(c_2/c_1)

water vapor amount (NCEP)

ozone amount (TOMS)

surface wind velocity (NCEP)

aerosol model

$$\frac{dv}{d\ln r} = \sum_{n=1}^{2} c_n \exp\left[-\frac{(\ln r - \ln r_{m,n})^2}{2\sigma_n^2}\right]$$

$r_{m,1} = 0.17\,\mu m, \quad r_{m,2} = 3.44\,\mu m$

$\sigma_1 = 1.96, \quad \sigma_2 = 2.37$

$\tilde{m} = 1.5 - 0.005i$

Composition

$$R(\mu,\mu_0,\phi) = T_{o_3} T_w (R_s + R_{mol,m} + R_{aer,m} + R_g)$$

Single scattering compornent

$$R_s(\mu,\mu_0,\phi) = \frac{1-e^{-\tau(1/\mu+1/\mu_0)}}{1/\mu+1/\mu_0}\frac{\pi\omega P}{\mu\mu_0}$$

Multiple scattering compornent

$$R_{mol,m} = \sum_{m=0}^{2} R_{mol,m}^{(m)} \cos m\phi$$

$$R_{aer,m} = \frac{1}{\mu\mu_0}\left\{\sum_{n=1}^{4} \chi_n \tau_a^n + \chi_5\left[1-e^{\tau_a(1/\mu+1/\mu_0)}\right]\right\}$$

Surface reflectance compornent

$$R_g(\mu,\mu_0,\phi) = r_s(\mu,\mu_0,\phi,v)e^{-\tau(\frac{1}{\mu}+\frac{1}{\mu_0})}$$

Correction of ozone absorption

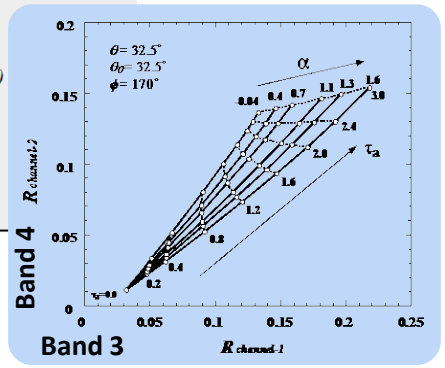
$$T_{o_3} = e^{-\tau_{o3}(1/\mu+1/\mu_0)}$$

Tables

Phase function : P
single scattering albedo : ω

coefficient of aerosol multiple scattering : X_n, $R_{mol,m}^{(m)}$

correction factor of water vapor absorption : T_w



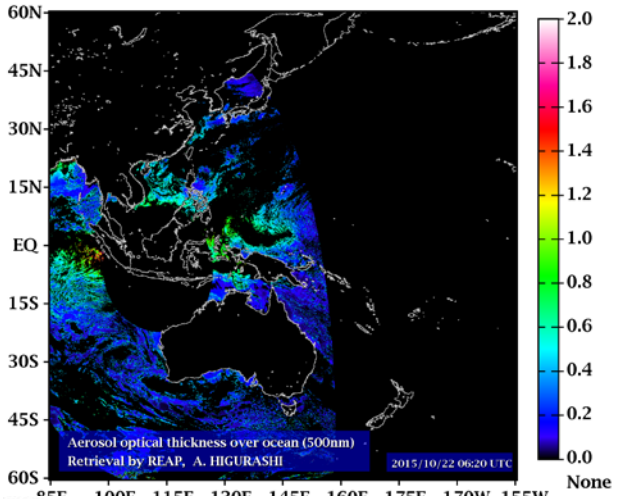
(by A. Higurashi)

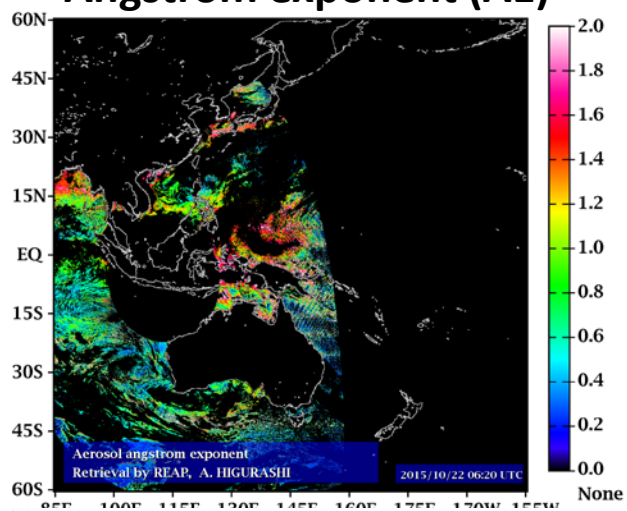
AHI-08 Aerosol Retrieval over ocean
- 2 channel method -

AOT@500nm

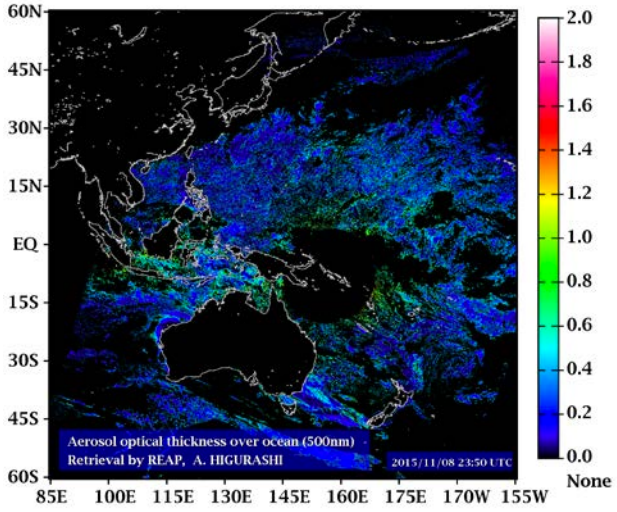
Angstrom exponent (AE)

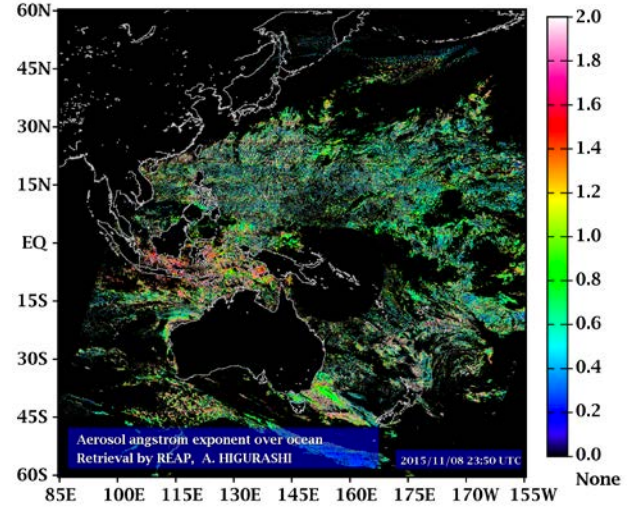
2015/10/22





2015/11/08





Around coast : AOT large, AE is large (=small size aerosol is dominant)

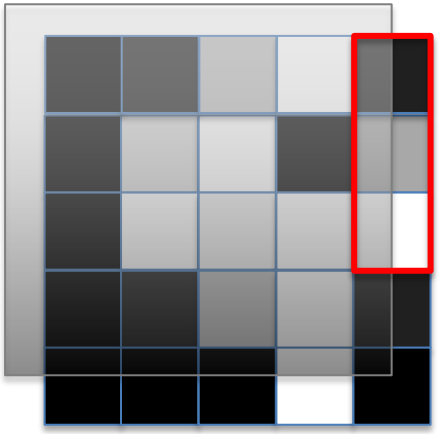
（by A. Higurashi and H. Takenaka）

Aerosol retrieval algorithm (MWP)

- **MWP = Multi-wavelength and multi-pixel method**

Kaufman neutral method : Kaufman (1987), MWP method : Hashimoto (PhD,2014)

- Using several wavelengths & pixels data of satellite observation at one retrieval



$$R = R_a + R_g \approx A_g + \tau \cdot [c_1 \cdot \omega P(\Theta) - c_2 \cdot A_g]$$

=0 (Independent of AOT*)

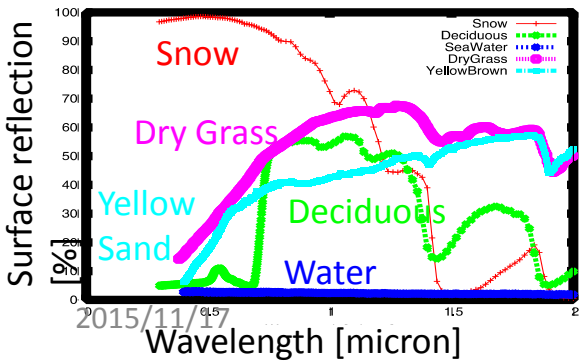
$$\rightarrow R = f(u) + e$$

(R: Reflectance, τ_λ: AOT, ω_λ: SSA, $P_\lambda(\Theta)$: Phase function)

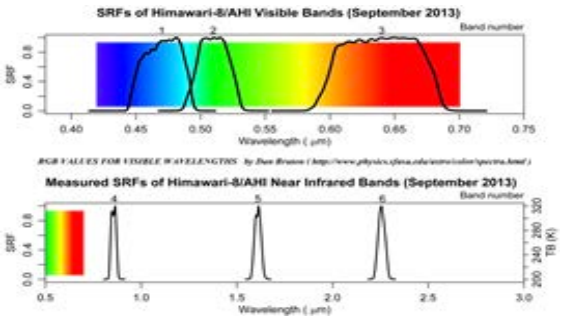
$$u = \{\tau_{550,fine}, \tau_{550,coarse}, \omega, \{A_g\}_\lambda\}_x$$

$$\lambda = \{\lambda_i, i = 1, N_{band}\}$$

Surface albedo spectral



Himawari8 VIS&NIR bands

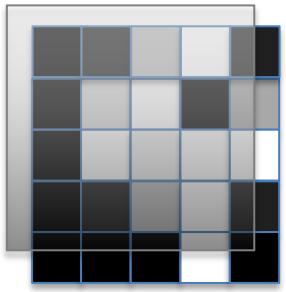


From JMA HP

→ Aerosol is smoothly distributed (Assumption)
→ Simultaneous retrieval of aerosol properties at several pixels (AOT, SSA, Ag…)

Multi-wavelength and -pixel method(MWP)

- **Optimal method (MAP) + Smoothing constraint**
  - Solve the problem so that PDF of state vector → Max.
  - Constraint condition by a priori information



$$\boldsymbol{R} = \boldsymbol{f}(\boldsymbol{u}) + \boldsymbol{e}$$

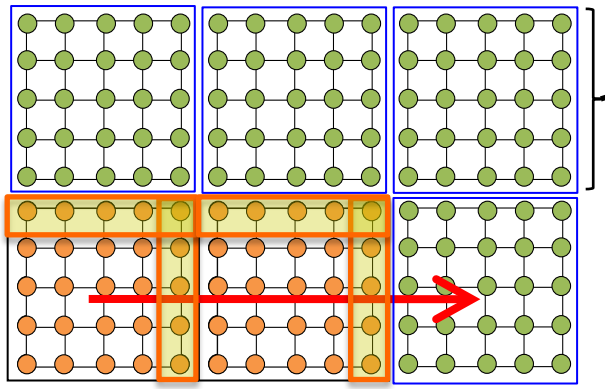
Combined RTE system composed of multi-wavelength and -pixel is solved to retrieve AOT and SSA:

$$\boldsymbol{R} = \{\{R\}_{\lambda}\}_{x}$$

$$\boldsymbol{u} = \{\tau_{fine}, \tau_{coarse}, \omega, \{A_g\}_{\lambda}\}_{x}$$

$$\lambda = \{\lambda_i, i = 1, N_{Band}\} \quad \boldsymbol{x} = \{x_i, y_j, i = 1, N_{domain}; j = 1, N_{domain}\}$$

5x5 pixels (=sub-domain) scanning with smoothing constraint



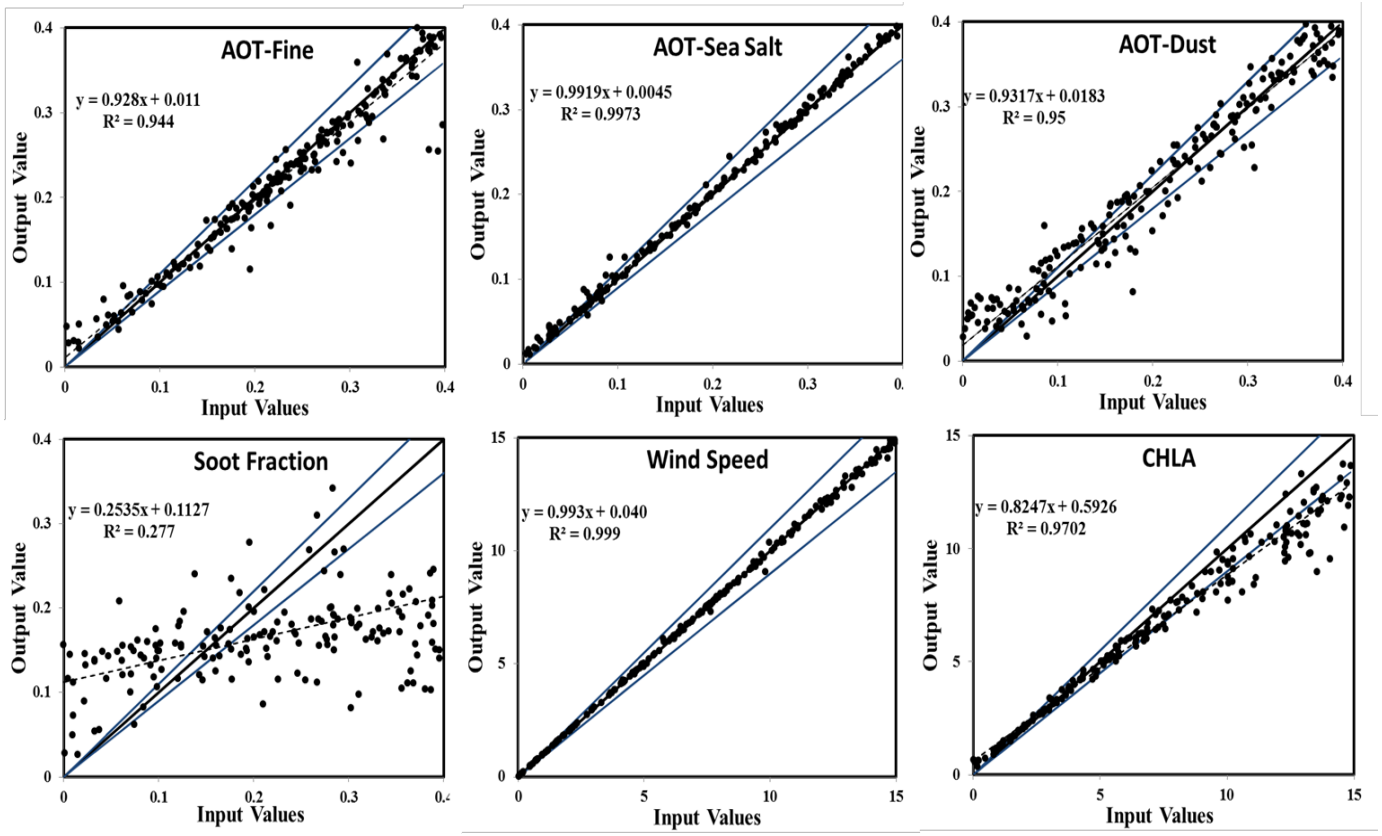
Cost function ( ) : **Optimal method: Bayes' theorem**

$$\phi = \phi_{\mathrm{MAP}} + \phi_{\mathrm{PT}}$$
$$= [\boldsymbol{R} - \boldsymbol{f}(\boldsymbol{u})]^{\mathrm{T}} \mathbf{S}_e^{-1} [\boldsymbol{R} - \boldsymbol{f}(\boldsymbol{u})] + (\boldsymbol{u} - \boldsymbol{u}_a)^{\mathrm{T}} \mathbf{S}_a^{-1} (\boldsymbol{u} - \boldsymbol{u}_a) + \sum_k \gamma \cdot (A_k + \mathbf{D}_k \boldsymbol{u})^2$$

$$\nabla\phi = 0, \quad \textbf{Gauss-Newton method etc..}$$

$$\boldsymbol{u}_{k+1} = \boldsymbol{u}_k + \left[(\mathbf{K}_k^{\mathrm{T}} \mathbf{S}_e^{-1} \mathbf{K}_k + \mathbf{S}_a^{-1}) + \sum_k \gamma_k \mathbf{H}_k\right]^{-1}$$
$$\times \left[\mathbf{K}_k^{\mathrm{T}} \mathbf{S}_e^{-1} (\boldsymbol{R} - \boldsymbol{f}(\boldsymbol{u})) - \mathbf{S}_a^{-1} (\boldsymbol{u} - \boldsymbol{u}_a) - \sum_k \gamma_k (\mathbf{H}_k \boldsymbol{u} + \mathbf{D}_k^{\mathrm{T}} \boldsymbol{u}_{\mathrm{b}})\right]$$

MWP method over ocean

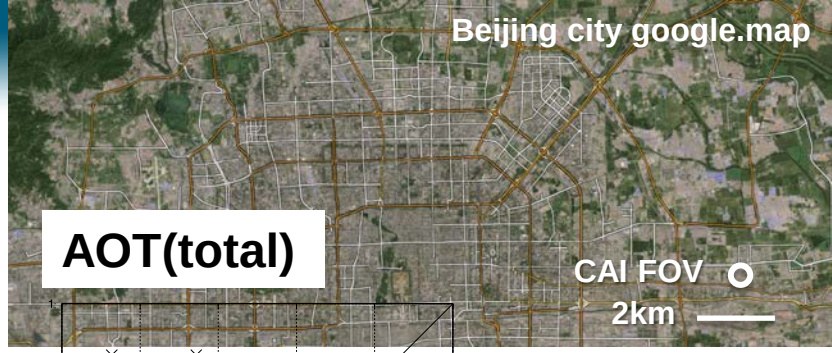


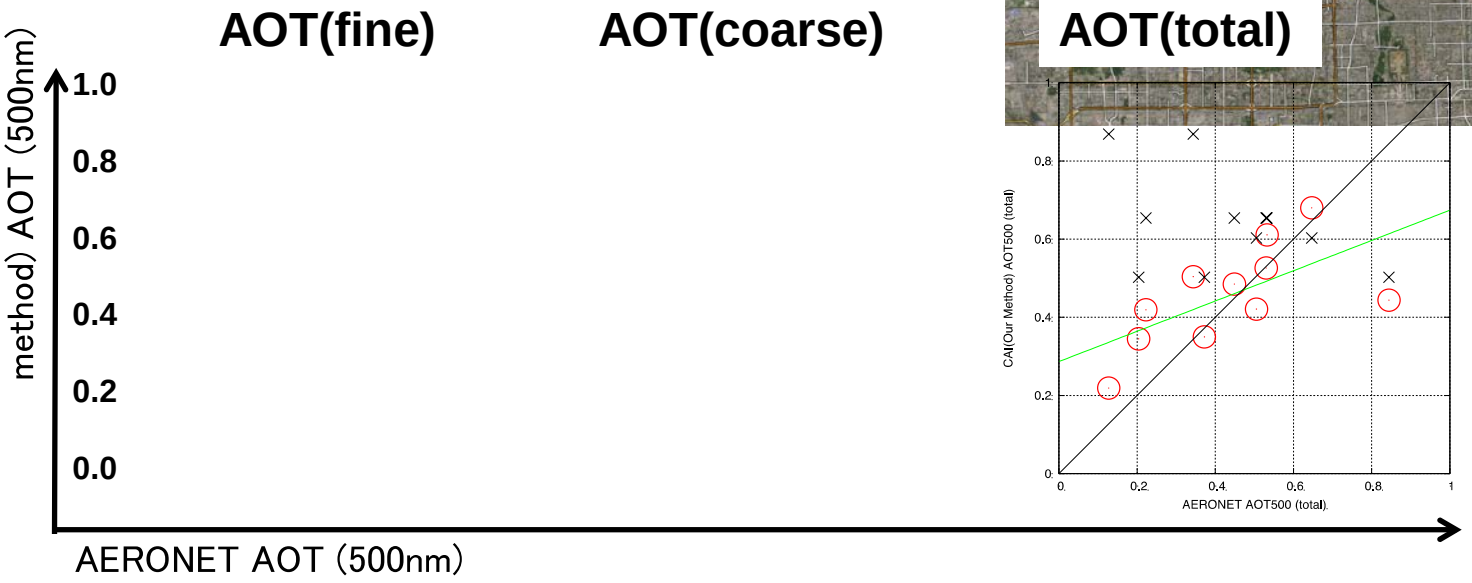
Simulation of simultaneous retrieval of atmosphere-ocean patameters using multi-wavelength radiance covering in and out-of sunglint.

(by Shi chon PhD, 2015)

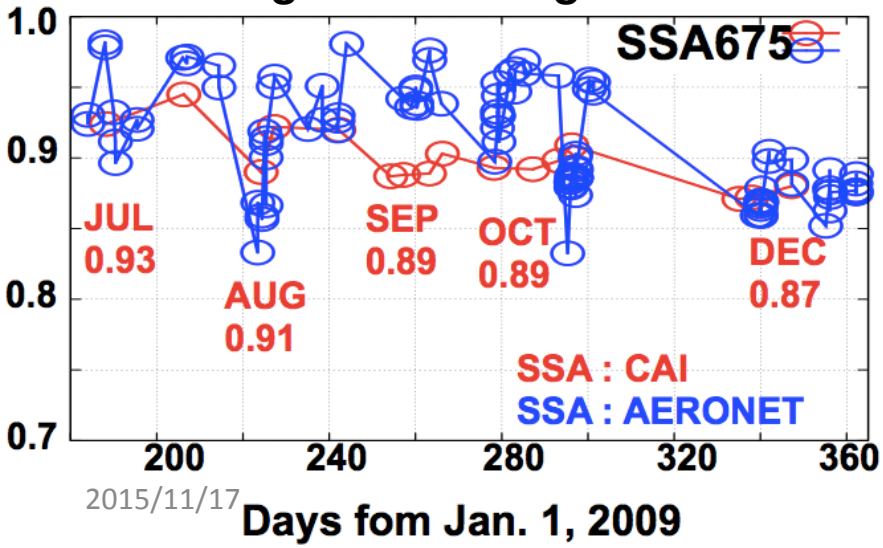
Beijing (Jul. ~ Dec. 2009)

Retrieval from GOSAT/CAI 4 bands



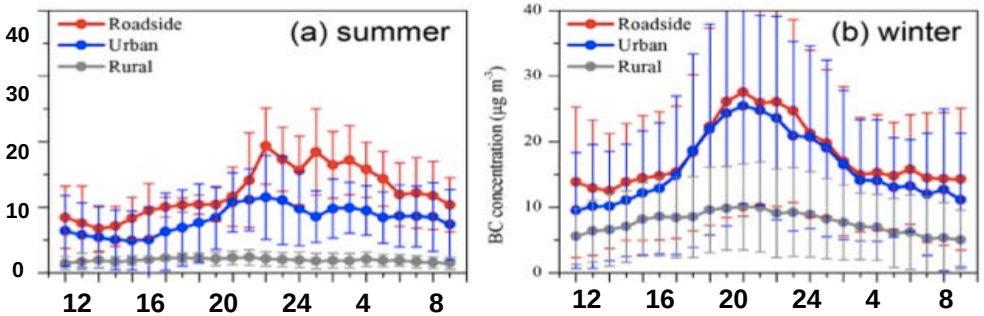


Single scattering albedo



In-situ measurement in 2009

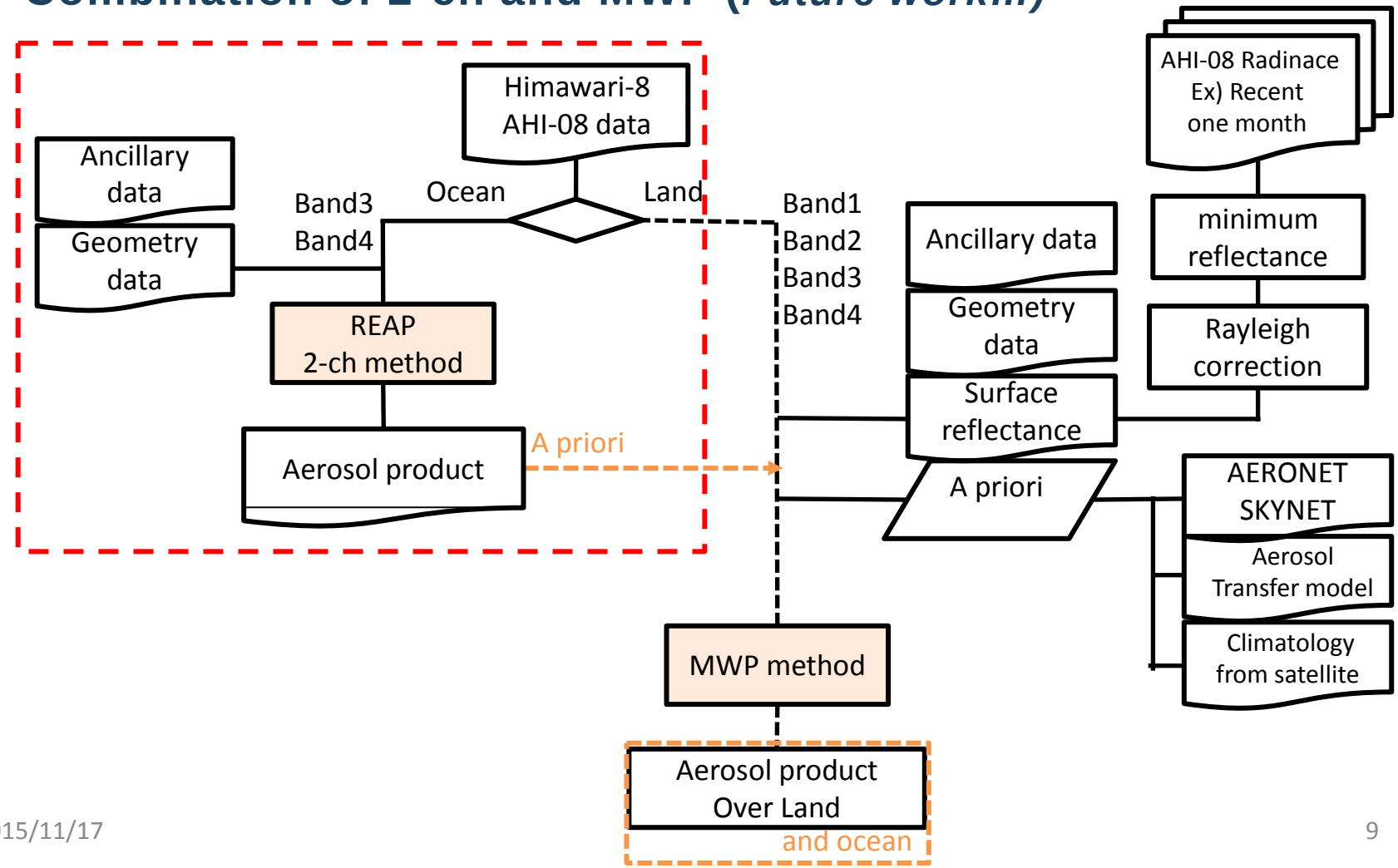
BC concentration[μgm^{-3}] (Song etal., 2013)



Hashimoto et al. (preparing)

Aerosol retrieval using AHI-08

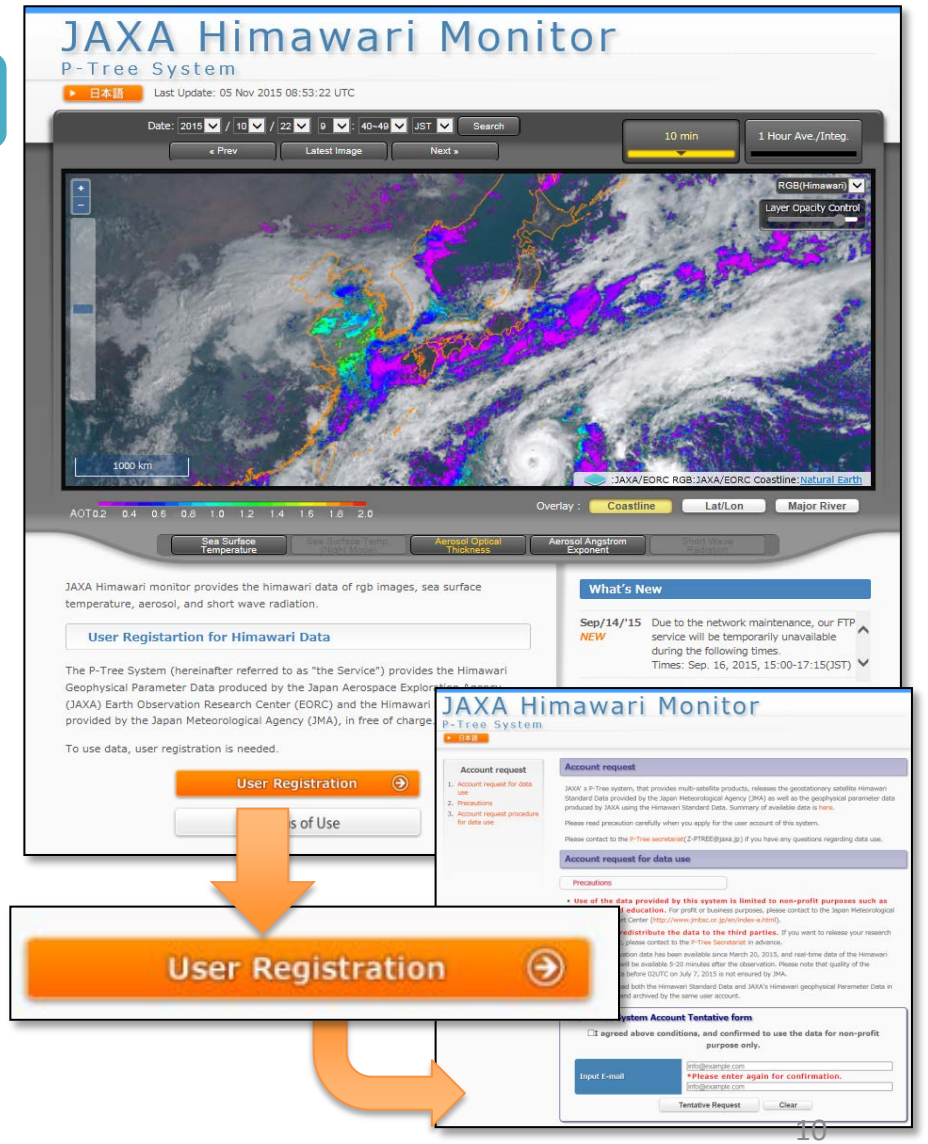
1. **2-channel method → AOT, AE**
2. **MWP method → AOT(fine, coarse), AE, SSA, …**
3. **Combination of 2-ch and MWP (*Future work…*)**



JAXA Himawari Monitor

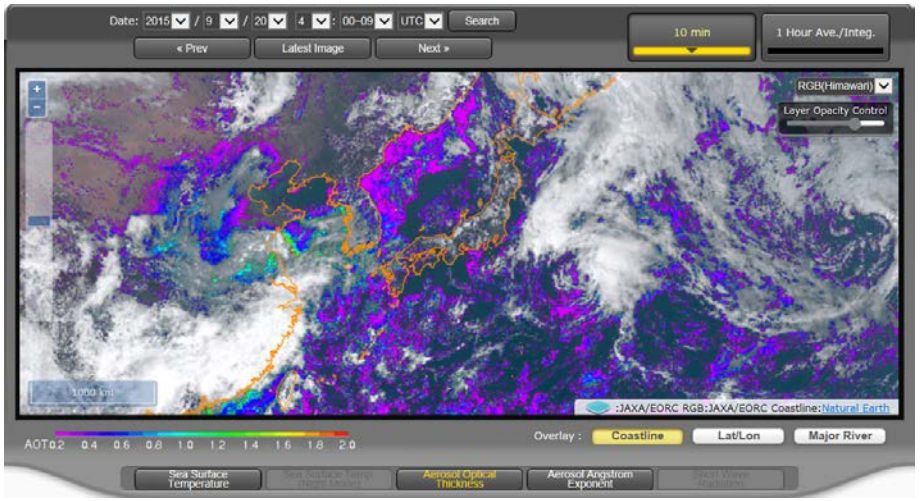
http://www.eorc.jaxa.jp/ptree/index_j.html

- Opened the Webpage on 31st August
- Registration: 122 people (at 18th Oct)
- Shows images in the Webpage
- Disseminates Himawari Standard Data and Geophysical data via FTP
- Data can be achieved with simple user registration

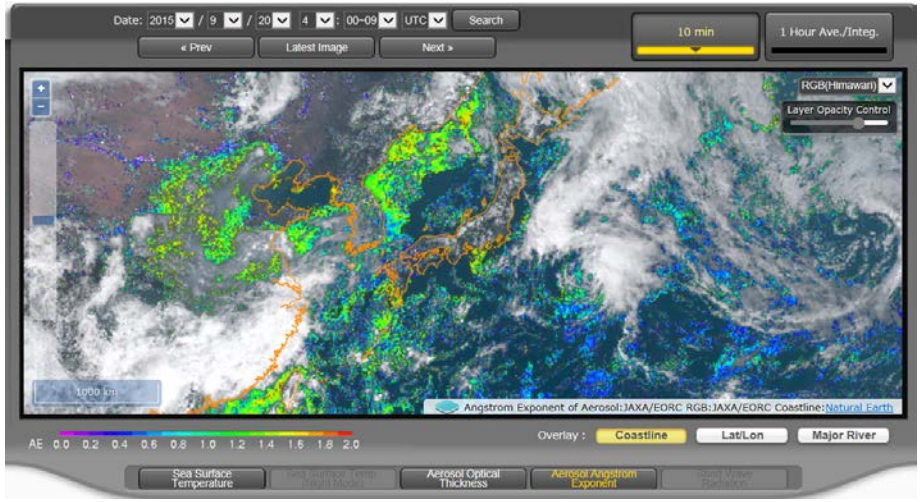


Example of JAXA Himawari Products

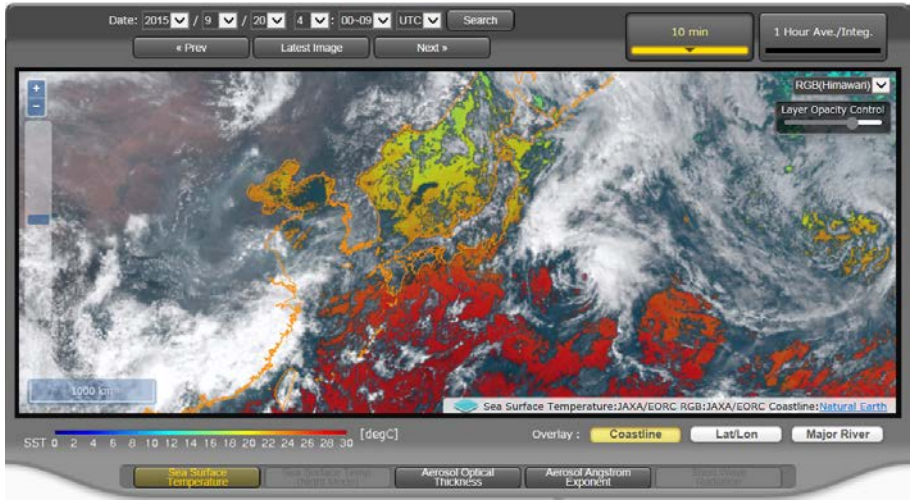
Aerosol Optical Thickness at 04:00Z Sep. 20



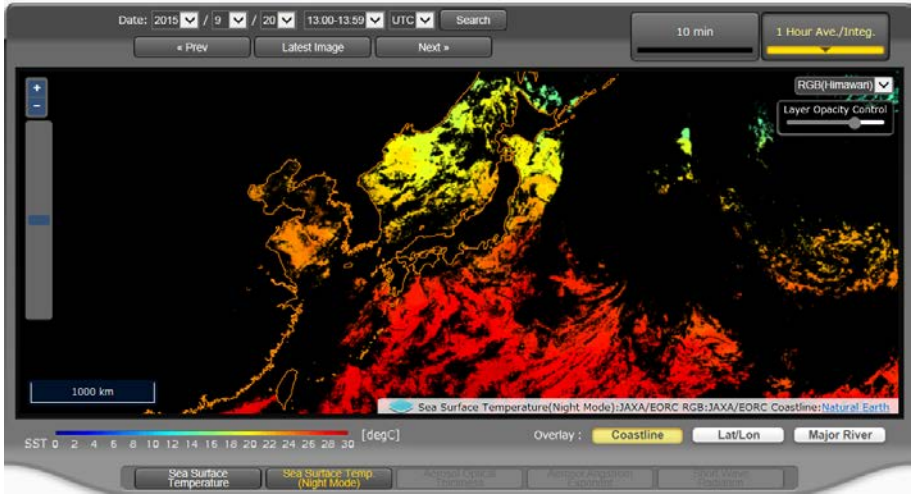
Aerosol Angstrom Exponent at 04:00Z Sep. 20



SST at 04:00Z Sep. 20



Nighttime SST at 13Z Sep. 20



Aerosol products are retrieved by 2-ch method (Higurashi and Nakajima, 1999)

MRI Aerosol Assimilation

Himawari-8 retrieval

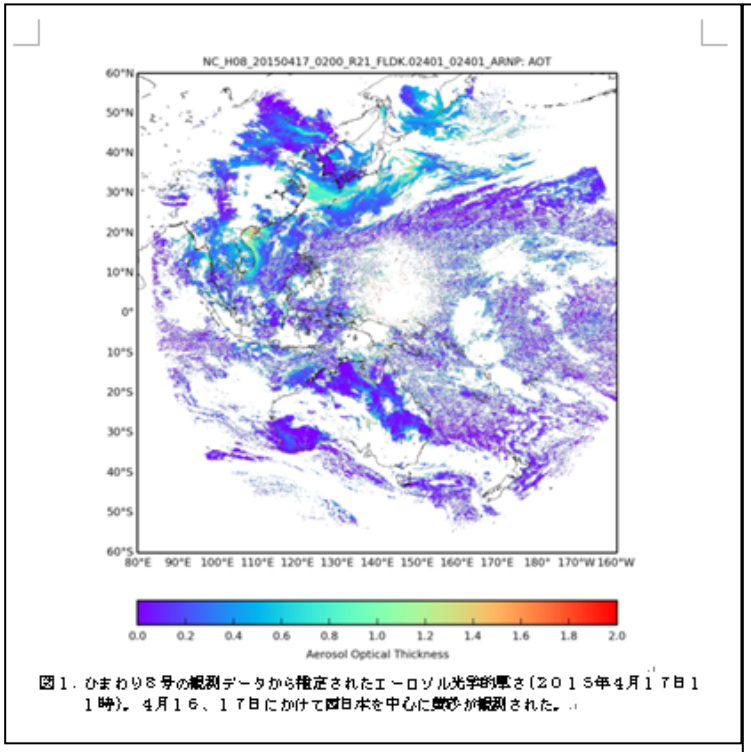


図１．ひまわり８号の観測データから推定されたエーロゾル光学的厚さ（２０１５年４月１７日１１時）。４月１６、１７日にかけて西日本を中心に黄砂が観測された。

Prior

Assimilated

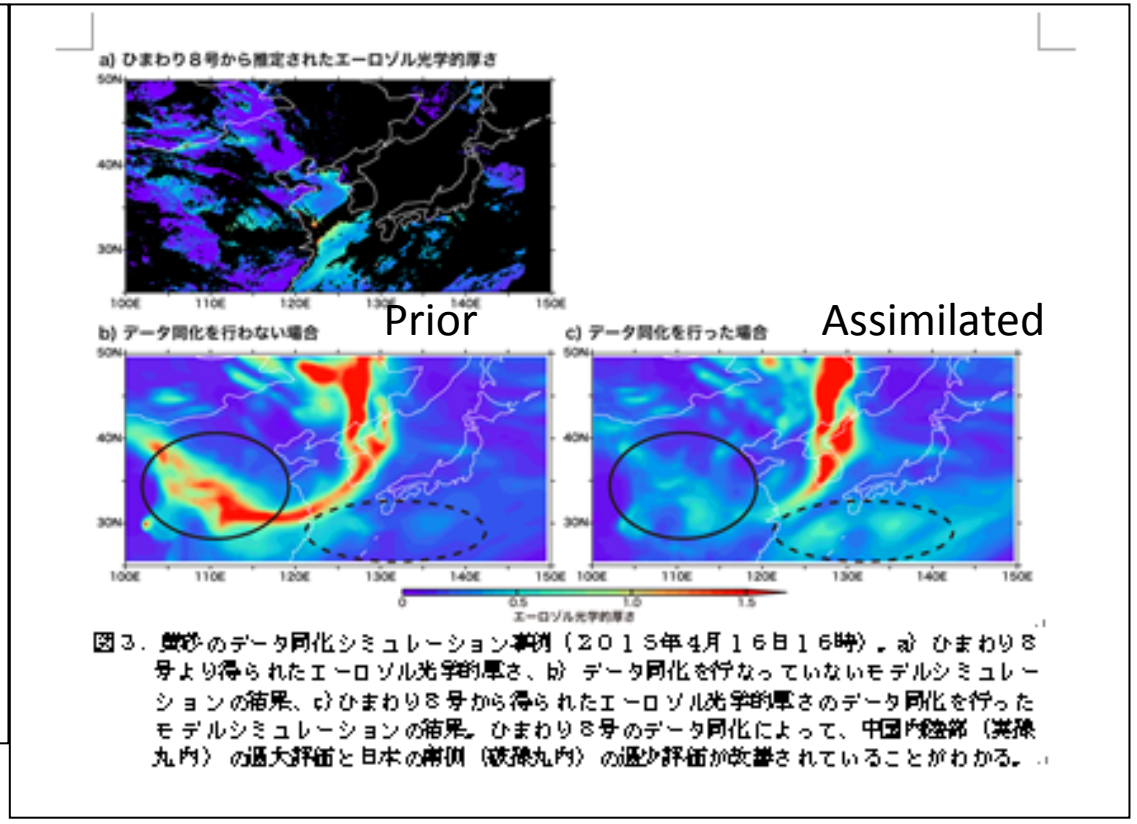


図３．黄砂のデータ同化シミュレーション事例（２０１５年４月１６日１６時）。a) ひまわり８号より得られたエーロゾル光学的厚さ、b) データ同化を行なっていないモデルシミュレーションの結果、c) ひまわり８号から得られたエーロゾル光学的厚さのデータ同化を行ったモデルシミュレーションの結果。ひまわり８号のデータ同化によって、中国内陸部（黄線丸内）の過大評価と日本の南側（破線丸内）の過少評価が改善されていることがわかる。

K. Yumimoto @ MRI

Summary

- Developing aerosol retrieval system using GCOM-C/SGLI algorithm for Himawari8 data AOT and AE from 2-ch method (semi-real time)

- Developing new approach to retrieve aerosol properties (MWP)
  → Example result using another satellite data

- Himawari monitor providing Retrieval results of SST, Cloud, aerosol etc.

- MRI Aerosol Assimilation on going


Thank you for your kind attention!