Aerosol retrieval using Himawari-8 visible data

*Makiko Hashimoto (JAXA), Akiko Higurashi (NIES), Hideaki Takenaka (JAXA), Teruyuki Nakajima (JAXA)
Developing advanced Aerosol retrieval using AHI-08 VIS/NIR data

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

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

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

Himawari-8 VIR bands & 0.86
From JMA HP

<table>
<thead>
<tr>
<th>WL (μm)</th>
<th>Himawari8.9</th>
<th>Himawari6.7</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.47</td>
<td>●</td>
<td>1</td>
</tr>
<tr>
<td>0.51</td>
<td>●</td>
<td>1</td>
</tr>
<tr>
<td>0.64</td>
<td>●</td>
<td>0.5</td>
</tr>
<tr>
<td>0.86</td>
<td>●</td>
<td>1</td>
</tr>
</tbody>
</table>
2-ch method (REAP) (Higurashi and Nakajima, 1999)

Retrieval of Aerosol optical Properties

Satellite data
- VIS
- NIR

Products
- Aerosol optical thickness (over the ocean)
- Ångström exponent

Observation

Year, Month, Day
θ, θ₀, φ

Band 3
Band 4

Comparison

Retrieval
τ, α
(c₂ / c₁)

Composition

\[ R(\mu, \mu₀, \phi) = T_{o₁} T_{w_1} (R_s + R_{mol,m} + R_{aer,m} + R_g) \]

Single scattering component
\[ R_s(\mu, \mu₀, \phi) = \frac{1 - e^{-(1/\mu + 1/\mu₀)}}{1/\mu + 1/\mu₀} \]

Multiple scattering component
\[ R_{mol,m} = \sum_{m=0}^{2} R_{mol,m} \cos m\phi \]
\[ R_{aer,m} = \frac{1}{\mu\mu₀} \left( \sum_{n=1}^{4} \chi_n \tau_0^n + \chi_5 \left[ 1 - e^{-\tau_0 (1/\mu + 1/\mu₀)} \right] \right) \]

Surface reflectance component
\[ R_g(\mu, \mu₀, \phi) = r_g(\mu, \mu₀, \phi, \nu) e^{-\tau_0 (1/\mu + 1/\mu₀)} \]

Correction of ozone absorption
\[ T_{o₁} = e^{-\tau_0 (1/\mu + 1/\mu₀)} \]

Tables

Phase function: \( P \)
single scattering albedo: \( \omega \)
correction factor of water vapor absorption: \( T_{w_1} \)

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

2015/11/17

(by A. Higurashi)
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**
  - Using several wavelengths & pixels data of satellite observation at one retrieval

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

\[ R = f(u) + e \]

- R: Reflectance, \( \tau \): AOT, \( \omega \): SSA, \( P(\Theta) \): Phase function
- \( u = \{\tau_{550, \text{fine}}, \tau_{550, \text{coarse}}, \omega, \{A_g\}_\lambda\}_x \)
  - \( \lambda = \{\lambda_i, i = 1, N_{\text{band}}\} \)

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

Surface albedo spectral

Himawari8 VIS&NIR bands

From JMA HP
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

\[ R = f(u) + e \]

\[ R = \{ \{ R \}_\lambda \}_x \]

\[ u = \{ \tau_{\text{fine}}, \tau_{\text{coarse}}, \omega, \{ A_\lambda \}_\lambda \}_x \]

\[ \lambda = \{ \lambda_i, i = 1, N_{\text{Band}} \} \quad x = \{ x_i, y_j, i = 1, N_{\text{domain}}, j = 1, N_{\text{domain}} \} \]

Cost function \((\cdot)\):
- Optimal method: Bayes’ theorem

\[ \phi = \phi_{\text{MAP}} + \phi_{\text{PT}} \]

\[ = [R - f(u)]^T S_e^{-1} [R - f(u)] + (u - u_a)^T S_a^{-1}(u - u_a) + \sum_k \gamma_k (A_k + D_k u)^2 \]

\[ \nabla \phi = 0, \quad \text{Gauss-Newton method etc..} \]

\[ u_{k+1} = u_k + [(K_k^T S_e^{-1} K_k + S_a^{-1}) + \sum_k \gamma_k H_k]^{-1} \]

\[ \times [K_k^T S_e^{-1}(R - f(u)) - S_a^{-1}(u - u_a) - \sum_k \gamma_k (H_k u + D_k^T u)] \]
MWP method over ocean

Simulation of simultaneous retrieval of atmosphere-ocean parameters 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

AOT(fine)  AOT(coarse)  AOT(total)

1.0  0.8  0.6  0.4  0.2  0.0

Retrieval from GOSAT/CAI 4 bands

Local Time

BC concentration [µg m⁻³] (Song et al., 2013)

In-situ measurement in 2009

Single scattering albedo

SSA675

JUL 0.93  AUG 0.91  SEP 0.89  OCT 0.89  DEC 0.87

Days from Jan. 1, 2009

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...)

- Ancillary data
- Geometry data
- REAP 2-ch method
- Aerosol product
- Himawari-8 AHI-08 data
- Band 3
- Band 4
- Ocean
- Land
- A priori
- Band 1
- Band 2
- Band 3
- Band 4
- Ancillary data
- Geometry data
- Surface reflectance
- A priori
- AHI-08 Radiance
- AERONET
- SKYNET
- Aerosol Transfer model
- Climatology from satellite
- Minimum reflectance
- Rayleigh correction
- 2015/11/17
JAXA Himawari Monitor

- 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

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

Prior Assimilated
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!