An algorithm for estimating aerosol optical depth from HIMAWARI-8 data over Ocean
(Sub title: Development of Aerosol retrieval algorithm for GK-2A satellite)

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2 Data & Methodology
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4 Validation
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1. Background

○ **GeoKOMPSAT-2A (GK-2A):**
  - Advanced Meteorological Imager (AMI)
  - 16 Bands, 0.5–2km spatial resolution, 52 operational products.

○ **Radiation/Aerosol Algorithm Development Team:**
  - Aerosol Detection (Ash/dust/smoke/etc),
    Aerosol Optical Depth, Angstrom exponent
    (by K.H. Lee & M.J. Jeong)
  - Radiative transfer model, Radiation products (by K.T. Lee)
## Official products

<table>
<thead>
<tr>
<th>Name</th>
<th>explanations</th>
<th>dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aerosol Detection Product (ADP)</strong></td>
<td>Pixel mask for Ash, dust, smoke, etc. type aerosols (separated algorithm for ocean &amp; land)</td>
<td>grid(lon, lat)</td>
</tr>
<tr>
<td></td>
<td>Ash &amp; Dust detection for day &amp; night</td>
<td></td>
</tr>
<tr>
<td><strong>Aerosol Optical Depth(AOD)</strong></td>
<td>wavelength: 550nm, range: 0.0 – 5.0 (day)</td>
<td>grid(lon, lat)</td>
</tr>
<tr>
<td><strong>Dust Aerosol Optical Depth(DAOD)</strong></td>
<td>wavelength: 11μm, range: 0.0 – 3.0 (day, night)</td>
<td>grid(lon, lat)</td>
</tr>
<tr>
<td><strong>volcanic ash product (VAP)</strong></td>
<td>Height, optical depth (11μm, range: 0.0 – 3.0; day &amp; night), effective radius, mass</td>
<td>List( lon, lat, attribute)</td>
</tr>
<tr>
<td><strong>Angstrom Exponent (AEP)</strong></td>
<td>Range: 0~3 (day)</td>
<td>grid( lon, lat)</td>
</tr>
</tbody>
</table>
# GK-2A mission requirements for Aerosol algorithm

<table>
<thead>
<tr>
<th>Year</th>
<th>Research Plan</th>
<th>Product accuracy</th>
</tr>
</thead>
</table>
| 2014 | • Algorithm development plan  
      • Design core algorithm | • Aerosol detection product (ADP):  
                                 Ocean: 50%, Land: 40%  
                                 • Aerosol optical depth (AOD):  
                                 Ocean: 0.25±0.45τ, Land: 0.30±0.50τ |
| 2015 | • Independent algorithms for main products  
      • Testbed with proxy data (MODIS) | • ADP: Ocean: 60%, Land: 50%  
                                 • AOD: Ocean: 0.20±0.40τ, Land: 0.25±0.45τ |
| 2016 | • Integration of algorithms  
      • Validation of products  
      • Transfer to the testbed (using AHI) | • ADP: Ocean: 65%, Land: 55%  
                                 • AOD: Ocean: 0.15±0.35τ, Land: 0.20±0.40τ |
| 2017 | • Revision & Improvement of the algorithm  
      • Provide the operational algorithm | • ADP: Ocean: 70%, Land: 60%  
                                 • AOD: Ocean: 0.10±0.30τ, Land: 0.15±0.35τ |
| 2018 | • GK-2A based operation support | • ADP: Ocean: 80%, Land: 70%  
                                 • AOD: Ocean: 0.05±0.20τ, Land: 0.10±0.30τ |
## 2. Data

<table>
<thead>
<tr>
<th>Channels</th>
<th>Center Wavelengths((\mu m))</th>
<th>AMI</th>
<th>ABI</th>
<th>AHI</th>
<th>MI</th>
<th>MODIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1(VIS) blue</td>
<td>0.470</td>
<td>0.470</td>
<td>0.46</td>
<td>0.466 (B03)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2(VIS) green</td>
<td>0.511</td>
<td>0.511</td>
<td>0.51</td>
<td>0.554 (B04)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3(VIS) red</td>
<td>0.640</td>
<td>0.640</td>
<td>0.64</td>
<td>0.675</td>
<td>0.647 (B01)</td>
<td></td>
</tr>
<tr>
<td>4(VIS)</td>
<td>0.856</td>
<td>0.865</td>
<td>0.86</td>
<td>0.857 (B02)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5(NIR)</td>
<td>1.380</td>
<td>1.378</td>
<td>1.382 (B26)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6(NIR)</td>
<td>1.610(2)</td>
<td>1.610(1)</td>
<td>1.6(2)</td>
<td>1.629 (B06)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NIR</td>
<td>2.250</td>
<td>2.3</td>
<td>2.114 (B07)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>7(IR)</td>
<td>3.830</td>
<td>3.90</td>
<td>3.9</td>
<td>3.75</td>
<td>3.788 (B20)</td>
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</tr>
<tr>
<td>8(WV)</td>
<td>6.241</td>
<td>6.185</td>
<td>6.2</td>
<td>6.765 (B27)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9(WV)</td>
<td>6.952</td>
<td>6.95</td>
<td>7.0</td>
<td>6.75</td>
<td>6.765 (B27)</td>
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</tr>
<tr>
<td>10(WV)</td>
<td>7.344</td>
<td>7.34</td>
<td>7.3</td>
<td>7.337 (B28)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11(IR)</td>
<td>8.592</td>
<td>8.50</td>
<td>8.6</td>
<td>8.529 (B29)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12(IR)</td>
<td>9.625</td>
<td>9.61</td>
<td>9.6</td>
<td>9.734 (B30)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13(IR)</td>
<td>10.403</td>
<td>10.35</td>
<td>10.4</td>
<td>10.8</td>
<td>B30+B31</td>
<td></td>
</tr>
<tr>
<td>14(IR)</td>
<td>11.212</td>
<td>11.20</td>
<td>11.2</td>
<td>11.019 (B31)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15(IR)</td>
<td>12.364</td>
<td>12.30</td>
<td>12.3</td>
<td>12.0</td>
<td>12.032 (B32)</td>
<td></td>
</tr>
<tr>
<td>16(IR)</td>
<td>13.31</td>
<td>13.30</td>
<td>13.3</td>
<td>13.365 (B33)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Band response functions

RSR vs. Wavelength [μm]

- Red line: AHI
- Black line: MODIS
New Generation Geostationary Satellites

**Current**
- COMS/MI, MTSAT
- 1 Visible: 1km, 30min
- 4 IR: 4km
- 5 bands

**Future**
- Himawari/AHI, GK-2A/AMI, GOES-R/ABI
- 3 Visible:
  - ~0.5km, 10min
- 3NIR:
  - 2km
- 10 IR: 2km
- 16 bands
MTSAT vs. AHI

MTSAT Dust

AHI Dust

MTSAT Ash

AHI Ash
Methodology

**Base Algorithm**

1) **Proxy data: MODIS**
   - 16 bands, geo-data
   - 10km resolution
   - LUTs based retrieval

2) **Code: IDL 8.x+Fortran 90**
   - independent
   - For research

3) **Aerosol algorithm**
   - Land/Ocean ADP
   - Land/Ocean AOD(day/visible)
   - Land/Ocean DOD(IR)
   - VAP(IR)

4) **Verification**
   - Case study based

**Core Algorithm**

1) **Proxy data: Himawari L1**
   - 16 bands, lon-lat data
   - 2km resolution
   - Calculate sun-sat geometry
   - Re-construction LUTs

2) **Code: Fortran 90**
   - Integration
   - standard protocol for testbed

3) **Aerosol algorithm**
   - Land/Ocean ADP
   - Land/Ocean AOD(day/visible)
   - Land/Ocean DOD(IR)
   - VAP(IR)

4) **Validation tools**
   - ADP
   - DOD
   - VAP
Design for satellite data processing

L1B data

Data quality check

Clear sky test:
Cloud, glint, snow/ice

Aerosol Type
(ash, dust, smoke, generic)

Visible channel AOD retrieval

Atmospheric correction
(Gas absorption
Rayleigh scattering)

BRDF correction
(glint, white foam, CDOM)

Size information
(Angstrom, FMF)

Ash retrieval
(height, effective radius, mass)

Dust retrieval
(height, effective radius, mass)

L2 data
(ADP, AOD, AEP, DOD, VAP)
ADP algorithm

L1b (Ref, BT)

Clear Sky

Glint, cloudy, sediment

No Proc.

Ash test (BTD, TVAP)

Ash

Dust test (BTD, Tvis, D*,...)

Dust

Glint, Clear

Smoke Test (Tvis, TIR)

Smoke

Etc.

BTD_{11-12} < -0.5
TVAP > 70
ρ_{3.9}/ρ_{0.66} > 0.6

BTD_{11-12} < -0.5
D* > 0.97
R_{BR} > Thr
ρ_{vis} > Thr

R_{BR} > Thr
ρ_{vis} > Thr

Y

N

Y

N

Y

N

Detail information on ash detection is found from Lee et al (RSE, 2016)
on D* for dust detection is from Hansell et al (GRL, 2007)
3. Case study (Volcanic ash)

Mt. Shinmoedake eruption, Japan (26 Jan 2011)

MODIS
Case study (Volcanic ash)

Mt. Shinmoedake eruption, Japan (26 Jan 2011)
COMS MI
Comparisons with other satellite products

00:54 UTC
1x1.25deg

01:24 UTC
30km X 60km

GOME2 AAI 01/27/2011

SCIAMACHY AAI 01/27/2011

2011-01-27 01:15 UTC

Lee et al (RSE, 2016)
Comparisons with other satellite products
3. Case study (Smoke)

ADP
Hazy aerosols
AOD

White cloud
Glint
3. Case study (Smoke)

Asian Dust plume over Yellow Sea (1 May 2011)
3. Case study (Smoke and Dust over Land)
3. Case study (Smoke and Dust over Land)
Improvement: Land surface estimation

**Proposed Method:**

\[ R_{sfc}(VIS) = R_{toa}(NIR) \times (a \times NDVI + b) + c \]

This Study – MODIS DT as function of AOT

This Study – MODIS DT as function of Scattering Angle
New era for Aerosol detection using AHI

- HIMAWARI-8 L1B (2km) RGB and ADP products
- Asian dust storm has been well detected during Mar 5, 2016.
- Nighttime detection using two IR bands has noisy pixels.
New era for Aerosol retrieval using AHI

No detection over Glint, cloudy pixels

Smoke plume!!
Aerosol products from AHI

- RGB (Atm. Corr.)
- Cloud Mask
- ADP
- AOD at 550nm

2015/08/23 05:00Z
✓ HIMAWARI-8 (2km) (Modify threshold values and Surface reflectance)
Aerosol products from AHI

RGB (Atm. Corr.)

Cloud Mask

Aerosol Mask

AOD at 550nm

2015/10/15
0500Z
4. Validation plan

◆ **Area:** Full Disk

◆ **Period:** 2015.8 ~ present

◆ **Datasets**

  ➢ **AERONET, Microtops II**
    ✓ Ground-based AOD,
    ✓ Angstrom exponent

  ➢ **Lidar Network**
    ✓ AD-net, KALION

  ➢ **MODIS, VIIRS, OMI**
    ✓ Satellite-based AOD
    ✓ Angstrom exponent

  ➢ **CALIPSO**
    ✓ VFM(Aerosol type)
    ✓ AOD
Korea Aerosol Lidar Observation Network (KALION)
4. Compare different satellite products

Dust case
4. Validation

**GK-2A v.s. MODIS**

Comparison of MODIS AOD at 550nm with GK-2A Alg.

- $Y = 0.74x + 0.15$
- $R = 0.88$
- Bias = 0.01
- RMSD = 0.02

**Mar-May 2012, East Asian Region**

**GK-2A v.s. AERONET**

GK-2A Alg. v.s. AERONET AOT

- $Y = 0.72(x) + 0.19$
- $N = 290$
- $R = 0.88$
- RMSD = 0.20

**GK2A AOD vs MODIS L2 AOD**

- $Y = 0.99x + 0.07$
- $n = 2018$, $R = 0.83$
5. Summary

- Integrated aerosol retrieval algorithm for the new generation geostationary satellite (Himawari-8, GK-2A) data has been developed.

- The results showed that the derived aerosol detection and optical depth can effectively produce aerosol products by using the proxy data.

- Time-and-space distribution of the aerosol pixels is in good agreement with the data pertaining to operational aerosol products.

- This algorithm is expected to provide a fine spatial and temporal resolution of aerosol products from GK-2A satellite observation data.
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