Current status of GK-2A AMV algorithm in NMSC/KMA

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NMSC/KMA

National Meteorological Satellite Center
Contents

- Status of COMS AMV
- Geo-KOMPSAT-2A(GK-2A) Programs
  - GK-2A AMV algorithm
    - Target selection
    - Target tracking
    - Height assignment
    - Quality control
- Results
- Summary
- AMV’s are **produced every 1 hour** (but not regularly)
- using 3 consecutive 15 min interval
- ENH observations
- disseminate by GTS
Status of COMS AMV

- AMV T24 (Operation)
  - Target size: 24x24 (96 X 96km)
  - Target selection: Regular (REG)
  - Target interval: 12 pixels

- AMV T16 (Tested)
  - Target size: 16x16 (56 X 56km)
  - Target selection: Optimal target selection
  - Target interval: 8 pixels
Status of COMS AMV

Accuracy of COMS AMV (April 1 - 24, 2016)

<table>
<thead>
<tr>
<th>Sonde(IR)</th>
<th>All level</th>
<th>High level</th>
<th>Middle level</th>
<th>Low level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T24</td>
<td>T24</td>
<td>T24</td>
<td>T24</td>
</tr>
<tr>
<td>Number</td>
<td>37940</td>
<td><strong>76507</strong></td>
<td>33601</td>
<td><strong>67665</strong></td>
</tr>
<tr>
<td>MVD</td>
<td>5.62</td>
<td>5.75</td>
<td>5.80</td>
<td><strong>5.57</strong></td>
</tr>
<tr>
<td>RMSVD</td>
<td>6.73</td>
<td><strong>6.69</strong></td>
<td>6.91</td>
<td><strong>6.86</strong></td>
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<tr>
<td>BIAS</td>
<td>-1.74</td>
<td><strong>-1.23</strong></td>
<td>-1.88</td>
<td><strong>-1.34</strong></td>
</tr>
<tr>
<td>RMSE</td>
<td>5.27</td>
<td><strong>5.14</strong></td>
<td>5.41</td>
<td><strong>5.27</strong></td>
</tr>
</tbody>
</table>

- Assimilate(24x24, VIS, IR, WV) in KMA global system since Dec. 2011. Positive impact especially in East Asia [NWP Center]

FSO of Satwind data in East Asia

<September~ October in 2011>

<Winter & Summer in 2013>
KMA plans to launch the next Korean geostationary meteorological satellite GEO-KOMPSAT-2A (GK-2A) in Nov. 2018
- GK-2A for the next generation Meteorological Imager and SWx monitoring
- GK-2B for the Ocean Color (GOCI2) and Atmospheric Trace Gas (GEMS) monitoring

**Geo-KOMPSAT-2A Programs**

- Meteorological Sensor
- Space weather Sensor

**2012 ~ 2018**
(7 years development)
### AMI (Advanced Meteorological Imager)

<table>
<thead>
<tr>
<th>Center wavelength (μm)</th>
<th>AMI (Resolution)</th>
<th>ABI</th>
<th>AHI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 blue</td>
<td>0.47 (1km)</td>
<td>0.47</td>
<td>0.46</td>
</tr>
<tr>
<td>2 green</td>
<td>0.511 (1km)</td>
<td>0.51</td>
<td></td>
</tr>
<tr>
<td>3 red</td>
<td>0.64 (0.5km)</td>
<td>0.64</td>
<td>0.64</td>
</tr>
<tr>
<td>4</td>
<td>0.856 (1km)</td>
<td>0.865</td>
<td>0.86</td>
</tr>
<tr>
<td>5</td>
<td>1.38 (2km)</td>
<td>1.378</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>1.61 (2km)</td>
<td>1.61</td>
<td>1.6</td>
</tr>
<tr>
<td>7</td>
<td>3.830 (2km)</td>
<td>3.90</td>
<td>3.9</td>
</tr>
<tr>
<td>8</td>
<td>6.241 (2km)</td>
<td>6.185</td>
<td>6.2</td>
</tr>
<tr>
<td>9</td>
<td>6.952 (2km)</td>
<td>6.95</td>
<td>7.0</td>
</tr>
<tr>
<td>10</td>
<td>7.344 (2km)</td>
<td>7.34</td>
<td>7.3</td>
</tr>
<tr>
<td>11</td>
<td>8.592 (2km)</td>
<td>8.50</td>
<td>8.6</td>
</tr>
<tr>
<td>12</td>
<td>9.625 (2km)</td>
<td>9.61</td>
<td>9.6</td>
</tr>
<tr>
<td>13</td>
<td>10.403 (2km)</td>
<td>10.35</td>
<td>10.4</td>
</tr>
<tr>
<td>14</td>
<td>11.212 (2km)</td>
<td>11.2</td>
<td>11.2</td>
</tr>
<tr>
<td>15</td>
<td>12.364 (2km)</td>
<td>12.3</td>
<td>12.3</td>
</tr>
<tr>
<td>16</td>
<td>13.31 (2km)</td>
<td>13.3</td>
<td>13.3</td>
</tr>
</tbody>
</table>

**vs. AHI:**
- **1.38 μm (NIR):** favorable for cirrus cloud detection, cloud type and amount
- **2.3 μm:** favorable for Land/cloud Properties
## 52 Meteorological Products

### 23 Primary Products & 29 Secondary Products

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloud detection</td>
<td>Cloud Top Temperature</td>
<td>Aerosol Detection</td>
<td>Atmospheric Motion Vector</td>
</tr>
<tr>
<td>Snow Cover</td>
<td>Cloud Top Pressure</td>
<td>Aerosol Optical Depth</td>
<td>Vertical Temperature Profile</td>
</tr>
<tr>
<td>Sea Ice Cover</td>
<td>Cloud Top Height</td>
<td>Asian Dust Detection</td>
<td>Vertical Moisture Profile</td>
</tr>
<tr>
<td>Fog</td>
<td>Cloud Type</td>
<td>Asian Dust Optical Depth</td>
<td>Stability Index</td>
</tr>
<tr>
<td>Sea Surface Temperature</td>
<td>Cloud Phase</td>
<td>Aerosol Particle Size</td>
<td>Total Precipitable Water</td>
</tr>
<tr>
<td>Land Surface Temperature</td>
<td>Cloud Amount</td>
<td>Volcanic Ash Detection and Height</td>
<td>Tropopause Folding Turbulence</td>
</tr>
<tr>
<td>Surface Emissivity</td>
<td>Cloud Optical Depth</td>
<td>Visibility</td>
<td>Total Ozone</td>
</tr>
<tr>
<td>Surface Albedo</td>
<td>Cloud Effective Radius</td>
<td>Radiances</td>
<td>SO₂ Detection</td>
</tr>
<tr>
<td>Fire Detection</td>
<td>Cloud Liquid Water Path</td>
<td>Downward SW Radiation (SFC)</td>
<td>Convective Initiation</td>
</tr>
<tr>
<td>Vegetation Index</td>
<td>Cloud Ice Water Path</td>
<td>Reflected SW Radiation (TOA)</td>
<td>Overshooting Top Detection</td>
</tr>
<tr>
<td>Vegetation Green Fraction</td>
<td>Cloud Layer/Height</td>
<td>Absorbed SW Radiation (SFC)</td>
<td>Aircraft Icing</td>
</tr>
<tr>
<td>Snow Depth</td>
<td>Rainfall Rate</td>
<td>Upward LW Radiation (TOA)</td>
<td></td>
</tr>
<tr>
<td>Ocean Current</td>
<td>Rainfall Potential</td>
<td>Downward LW Radiation (SFC)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Probability of Rainfall</td>
<td>Upward LW Radiation (SFC)</td>
<td></td>
</tr>
</tbody>
</table>
### Specification and flow chart

<table>
<thead>
<tr>
<th>Channel</th>
<th>VIS(03), SWIR(07), IR(13, 14), WV(08, 09, 10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input L1b Images</td>
<td>3 images (proxy: Himawari8/AHI)</td>
</tr>
<tr>
<td>Time interval</td>
<td>Normal scan (FD) 10 minute, Rapid scan 2 minute</td>
</tr>
<tr>
<td>Model / RTM</td>
<td>UM N768/rttov 11.2</td>
</tr>
</tbody>
</table>
| Target box size | **Cloudy target**
VIS : 32by32, SWIR : 16by16, IR : 16by16, WV : 16by16

**Clear-air target**
WV : 16by16 |

| Target selection | Optimal (Statistic) |
| Grid step size | Same with target box size |

**Search box size**

| Cloudy target | VIS : 185by185, SWIR : 54by54, IR : 54by54, WV : 54by54 |
| Clear-air target | WV : 54by54 |

| Center of search area | Regular |
| Target tracking | CC |
| Height assignment | **Cloudy target**
1. CCC
2. EBBT(CBC) & IR/WV
3. EBBT(CBC)
4. IR/WV
5. CO2 slicing (+Inversion layer correction)

Clear-air target
1. NTC & NTCC
2. NTC
3. NTCC |

| Quality control | QI, EE |

**Target selection (Optimal method)**

**Cloudy target HA**
1. CCC
2. EBBT(CBC) & IR/WV
3. EBBT(CBC)
4. IR/WV
5. CO2 slicing

**Clear-air target HA**
1. NTC & NTCC
2. NTC
3. NTCC

**Inversion layer correction**

**Tracking (Cross correlation coefficient)**

**Quality Control**
1. Quality indicator
2. Expected error

**Final output**
Step 1: Target selection

- Optimal target selection
  - Cloud Target: 03, 07, 08, 09, 10, 13, 14 (Using cloud mask)
  - Clear Target: 08, 09, 10

\[
STD_{m,n} = \sqrt{\frac{1}{9} \sum_{i=-1}^{1} \sum_{j=-1}^{1} (BT_{m+i,n+j} - \overline{BT}_{m,n})^2}
\]
Step 1: Target (search) size and temporal gap

- **Preliminary Results for GK-2A**

<table>
<thead>
<tr>
<th>Periods</th>
<th>2016.07.21. 00:00 ~ 23:00 (UTC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel</td>
<td>Ch. 13 cloudy target, Ch. 08 clear target</td>
</tr>
<tr>
<td>Time interval</td>
<td>10 minute</td>
</tr>
<tr>
<td>Target (Search) box size</td>
<td>8(46), 16(54), 24(62), 32(70), 40(78), 48(86)</td>
</tr>
</tbody>
</table>

- **[P10: Sensitivity Tests]**

Graphs for Ch13 cloudy and Ch08 clear with NWP.
Step2: Target tracking

Cross Correlation Coefficient

\[ CC_{m,n} = \frac{1}{N_x N_y} \sum_{i=1}^{N_x} \sum_{j=1}^{N_y} \left( \frac{a_{m+i,n+j} - \bar{a}_{m,n}}{(\sigma_a)_{m,n}} \frac{b_{i,j} - \bar{b}}{\sigma_b} \right) \]

\( a_{i,j} \) : BT value in ith row and jth column of \( N_x \) by \( N_y \) target box in search area at time \( t_0 + \Delta t \).
\( \bar{a} \) : Average of \( a_{i,j} \).
\( \sigma_a \) : Standard deviation of \( a_{i,j} \).
\( b_{i,j} \) : BT value in ith row and jth column of \( N_x \) by \( N_y \) target at time \( t_0 \).
\( \bar{b} \) : Average of \( b_{i,j} \).
\( \sigma_b \) : Standard deviation of \( b_{i,j} \).
\( N_x, N_y \) : Size of target box.

Calulated vector: \( \hat{v} = \frac{\vec{r}}{\Delta t} \)
Step 3: Height assignment (Cloud Target)

- **Cloud Target: 4 methods + 2 combinations**

  **EBBT**
  - Equivalent Blackbody Temperature
  - Opaque Clouds
  - NWP Temp. Profile + RTM simulation
  - Coldest 15% temp.: Dominant motion level of targets

  ![EBBT Diagram]

  \[
  \frac{R_{\text{clt}}(CO_2) - R_{\text{clt}}(CO_2)}{R_{\text{clt}}(IR_\lambda) - R_{\text{clt}}(IR_\lambda)} = \frac{\epsilon(CO_2)}{\epsilon(IR_\lambda)} \frac{[R_{\text{sfc}}(CO_2) - R_{\text{bkd}}(CO_2, P_{\text{clt}})]}{[R_{\text{sfc}}(IR_\lambda) - R_{\text{bkd}}(IR_\lambda, P_{\text{clt}})]}
  \]
  
  - \(R_{\text{clt}}\): Measured cloudy radiance
  - \(R_{\text{sfc}}\): Measured cloud free radiance
  - \(R_{\text{bkd}}\): Calculated Planck blackbody radiance for a cloud at level \(P_{\text{clt}}\)

  **IR/WV Intercept**
  - Semi-transparent Clouds Optically Thin Clouds (e.g., cirrus)

  \[
  \frac{R_{\text{clt}}(WV) - R_{\text{clt}}(IR_\lambda)}{R_{\text{clt}}(IR_\lambda) - R_{\text{clt}}(IR_\lambda)} = \frac{\epsilon(WV)}{\epsilon(IR_\lambda)} \left[ R_{\text{bkd}}(WV, P_{\text{clt}}) - R_{\text{sfc}}(WV) \right] \]

  - \(R_{\text{clt}}\): Measured cloudy radiance
  - \(R_{\text{bkd}}\): Calculated Planck blackbody radiance for a cloud at level \(P_{\text{clt}}\)
  - \(R_{\text{sfc}}\): Calculated clear air radiance

  **CO₂ Slicing Method**
  - Similar to IR/WV intercept, but use CO₂ channel

  \[
  \frac{R_{\text{ctr}}(CO_2) - R_{\text{clt}}(CO_2)}{R_{\text{ctr}}(IR_\lambda) - R_{\text{clt}}(IR_\lambda)} = \frac{\epsilon(CO_2)}{\epsilon(IR_\lambda)} \frac{[R_{\text{sfc}}(CO_2) - R_{\text{bkd}}(CO_2, P_{\text{clt}})]}{[R_{\text{sfc}}(IR_\lambda) - R_{\text{bkd}}(IR_\lambda, P_{\text{clt}})]}
  \]

  - \(R_{\text{ctr}}\): Measured cloudy radiance
  - \(R_{\text{sfc}}\): Measured cloud free radiance
  - \(R_{\text{bkd}}\): Calculated clear air radiance

  **CCC**
  - Cross-Correlation Contribution
  - Every Cloud
  - Depends on CTP

  \[
  P = \frac{\sum C_{i,j} CTP_{i,j}}{\sum c_{i,j} > c_{i,j} \text{thres}}
  \]

  - \(P\): Probability
  - \(c_{i,j}\): Individual pixel contribution (CO₂)
  - \(C_{i,j}\): Cloud index
  - \(CTP_{i,j}\): Cloud Top Pressure
  - \(c_{i,j} \text{thres}\): Threshold
Step 3: Height assignment (Clear Target)

- Clear Target: 2 methods → chose higher one
  - NTC & NTCC methods. (Transmittance profile by channel.)

*NTC: Normalized total contribution
*NTCC: Normalized total cumulative contribution
Step 4: Quality Control

- **Quality Indicator (QI)**
  - **Calculation Procedure:** Calculated using weighted averaged of 5 consistencies
    1. Temporal **Direction** Consistency
    2. Temporal **Speed** Consistency
    3. Temporal **Vector** Consistency
    4. **Forecast** Consistency
    5. **Local Vector** Consistency

- **Direction Test**
  \[
  \Phi_{dir.} = 1 - \left[ \tanh \left( \frac{\text{Diff.}(\text{Dir.})}{\text{coeff.}A \cdot \exp \left( \frac{-\text{Spd.avg}}{\text{coeff.B}} \right) + \text{coeff.C} \cdot \text{Spd.avg} + \text{coeff.D} \right) \right]^{\text{coeff.E}}
  \]

- **Others**
  \[
  \Phi_{other} = 1 - \left[ \tanh \left( \frac{\text{Diff.}}{\text{MAX}(\text{coeff.A} \cdot \text{Spd.avg}, \text{coeff.B}) + \text{coeff.C}} \right) \right]^{\text{coeff.D}}
  \]

\[
QI = \sum_{i=1}^{5} W_i \Phi_i
\]
Results: Cloudy target for 10.4μm

- **Validation: 4 HA methods + 2 combinations**
  - 2016.7.1. ~ 7.7. (All level(1000~100 hPa))

<table>
<thead>
<tr>
<th>Ch13 (10.4)</th>
<th>GK-2A (Himawari-8)</th>
<th>Goes-R (Meteosat-8)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Period</strong></td>
<td>2016.7.1.~7.7.</td>
<td>Aug 2006</td>
</tr>
<tr>
<td><strong>HA method</strong></td>
<td>EBBT &amp; IR/WV</td>
<td>EBBT &amp; CO2</td>
</tr>
<tr>
<td><strong>Count</strong></td>
<td>17702</td>
<td>17345</td>
</tr>
<tr>
<td><strong>MVD</strong></td>
<td>4.71</td>
<td>5.05</td>
</tr>
<tr>
<td><strong>RMSVD</strong></td>
<td>5.71</td>
<td>6.14</td>
</tr>
<tr>
<td><strong>Bias</strong></td>
<td>-0.67</td>
<td>-1.09</td>
</tr>
<tr>
<td><strong>RMSE</strong></td>
<td>4.35</td>
<td>4.64</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ch13 (10.4)</th>
<th>GK-2A</th>
<th>MTG</th>
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<tbody>
<tr>
<td><strong>QI&gt;80</strong></td>
<td>&gt; 80</td>
<td>&gt; 80</td>
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<td><strong>Reference</strong></td>
<td>NWP</td>
<td>Sonde</td>
</tr>
<tr>
<td><strong>Count</strong></td>
<td>44145</td>
<td>1028</td>
</tr>
<tr>
<td><strong>Bias</strong></td>
<td>-0.34</td>
<td>-1.32</td>
</tr>
<tr>
<td><strong>RMSE</strong></td>
<td>4.74</td>
<td>5.92</td>
</tr>
<tr>
<td><strong>NBias</strong></td>
<td>-0.023</td>
<td>-0.071</td>
</tr>
<tr>
<td><strong>NRMSE</strong></td>
<td>0.316</td>
<td>0.316</td>
</tr>
</tbody>
</table>

[Jaime Daniels, et al., GOES-R ATBD(2012)]

- **Inter-comparison with MTG algorithm** [P9: Inter-comparison results]
AMV height assignment methods

- Optically THICK LOW cloud case

**EBBT + IR/WV Intercept**

**EBBT + CO2 Slicing**
Optically THICK LOW cloud case
AMV height assignment methods

- Optically THIN HIGH cloud case

**EBBT + IR/WV Intercept**

**EBBT + CO2 Slicing**

CALIOP CTH

AMV Height
AMV height assignment methods

- Optically THIN HIGH cloud case

![Diagram showing AMV height assignment methods with CCC Method and CALIOP CTH](image)
Summary

- We have developed Atmosphere Motion Vector for GK-2A/AMI using Himawari8/AHI as proxy data.
  - Target size (Search size) : 16 X 16 (54 X 54)
  - Height Assignment : EBBT+IR/WV intercept
  - The result is comparable with other institute
  - The accuracy is better than COMS one
  - Need to validate with long term data

- Related Posters
  - P7: Quality Control (Quality Index and Expect Error)
  - P9: AMV Inter-comparison with EUMETSAT
  - P10: Sensitivity Tests for target size and HA methods
  - P11: Impact assessment
Thank you!!!