Status of the GeoKompsat-2A AMI rainfall rate algorithm

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**Algorithm Strategy**

*Well-known assumption in IR-based algorithms*

*Cloud top temperatures* are assumed to be associated with the surface rainfalls.

This assumption usually works for tall clouds with cold cloud top temperatures, but **NOT** for warm clouds, shallow clouds, and some tall clouds.

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**Separation of cloud types**
- Warm/Cold
- Shallow/Not-Shallow

**Various a-priori info**
- Static databases
- Dynamic databases

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**Acquire data representativeness and add recent and then close info to the target scene**

**Emissivity differences of IR channels for different cloud thicknesses**
Channels used for GeoKompsat-2A (GK-2A) AMI algorithm

<table>
<thead>
<tr>
<th>channel</th>
<th>Center wavelength (μm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AMI</td>
</tr>
<tr>
<td>1(VIS) blue</td>
<td>0.470</td>
</tr>
<tr>
<td>2(VIS) green</td>
<td>0.511</td>
</tr>
<tr>
<td>3(VIS) red</td>
<td>0.640</td>
</tr>
<tr>
<td>4(VIS)</td>
<td>0.856</td>
</tr>
<tr>
<td>5(NIR)</td>
<td>1.380</td>
</tr>
<tr>
<td>6(NIR) 1.610(2)</td>
<td>1.610(1)</td>
</tr>
<tr>
<td>NIR</td>
<td>2.250</td>
</tr>
<tr>
<td>7(IR)</td>
<td>3.830</td>
</tr>
<tr>
<td>8(WV)</td>
<td>6.241</td>
</tr>
<tr>
<td>9(WV)</td>
<td>6.952</td>
</tr>
<tr>
<td>10(WV)</td>
<td>7.344</td>
</tr>
<tr>
<td>11(IR)</td>
<td>8.592</td>
</tr>
<tr>
<td>12(IR)</td>
<td>9.625</td>
</tr>
<tr>
<td>13(IR)</td>
<td>10.403</td>
</tr>
<tr>
<td>14(IR)</td>
<td>11.212</td>
</tr>
<tr>
<td>15(IR)</td>
<td>12.364</td>
</tr>
<tr>
<td>16(IR)</td>
<td>13.31</td>
</tr>
</tbody>
</table>

**Channel comparisons**

ABI : Advanced Baseline Imager(GOES-R)
AHI : Advanced Himawari Imager(Himawari-8/9)
AMI: Advanced Meteorological Imager(GeoKompsat-2A)
MI: Meteorological Imager(COMS)
Flowchart of Rainfall Rate (RR) Algorithm

**Static DBs**
- IR/PMW observations
  - Construction of static DBs
  - Two types of a-priori DBs: Static
    - Shallow DBs: IR TBs, MW RR
    - Not-Shallow DBs: IR TBs, MW RR

**Main/Inversion**
- IR observations
  - Selection of DBs (BTD1 and BTD2 based)
    - Bayesian inversion
      - CDF-based scaling
  - Surface rain rates (RR)

**Dynamic DBs**
- IR/PMW observations
  - Construction of dynamic DBs
  - Recent scene-based a-priori DBs: Dynamics
    - Scene-based DBs: IR TBs, MW RR
  - Updating Static DBs

- Near real time
- On line
- Off line
Construction/Classification of a-priori Databases

IR sensor data (SEVIRI/AHI) → MW observations (GPROF/GMI) → Selection of rain scene → Collocation at retrieval resol. RR, IR TBs → Calculation of BTDs: BTD1:7.3-10.8µm, BTD2:8.7-10.8µm → Shallow flag BTD1 ≤ x1 & BTD2 ≤ x2 → Yes: Shallow DBs IR TBs, RR; No: Not-Shallow DBs IR TBs, RR

Shallow DBs IR TBs, RR → Calculation of BTDs: BTD1:7.3-10.8µm, BTD2:8.7-10.8µm → Shallow flag BTD1 ≤ x1 & BTD2 ≤ x2 → Yes: Shallow DBs IR TBs, RR; No: Not-Shallow DBs IR TBs, RR

DB Classification (For SEVIRI)

<table>
<thead>
<tr>
<th>#</th>
<th>Latitude</th>
<th>Cloud types</th>
<th>BTD1, BTD2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>60°S ~ 30°S</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>30°S ~ EQ</td>
<td>Shallow</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>EQ ~ 30°N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>30°N ~ 60°N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>60°S ~ 30°S</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>30°S ~ EQ</td>
<td>Not-Shallow</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>EQ ~ 30°N</td>
<td>Shallow</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>30°N ~ 60°N</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

x1= N1, x2=N2

(e.g.)

Tb_{7.3-10.8} ≤ -12.3

Tb_{8.7-10.8} ≤ 1.3
Proxy Data Sets

GEO IR sensor observations: **Meteosat9 SEVIRI**
- Satellite position: 9.5°E/36,000 km
- Spatial resolution: 3 km
- Temporal resolution: 15 min.
- Coverage: 80W-80E, 80S-80N
- Channels in use: IR 6.2, 7.3, 8.7, 10.8, 12.0 µm

LEO MW sensor estimated rainfall rate: **GPROF (Goddard profiling algorithm, 2010v2)**
- Orbital data mapped to 0.25° grid
- SSMIS (DMSP F16, F17, F18) rain rates
Proxy Data Sets

Before the launch of GK2A

GEO IR sensor observations: **Himawari AHI**
- Satellite position: 140°E/36,000 km
- Spatial resolution: 2 km
- Temporal resolution: 10 min.
- Coverage: 60E-220E, 80S-80N
- Channels in use: IR 6.2, 7.3, 8.6, 11.2, 12.4 µm

GPM (Global Precipitation Measurement) data: GMI, DPR
- GMI, DPR surface precipitation rate
- Orbital data (Level 2)
- 180°W-180°E, 65°S-65°N

After the launch of GK2A

GEO IR sensor observations: **GK-2A AMI**
- Satellite position: 128°E/36,000 km
- Spatial resolution: 2 km
- Temporal resolution: 10 min.
- Coverage: 60E-220E, 80S-80N
- Channels in use: IR 6.2, 7.3, 8.6, 11.2, 12.4 µm

GPM (Global Precipitation Measurement) data: GMI, DPR
- GMI, DPR surface precipitation rate
- Rain rate from the parametric Algorithm (Yonsei version) for MW rainfalls (possible).
- Orbital data (Level 2)
- 180°W-180°E, 65°S-65°N

We are in this stage...
Collocation of Proxy Data (for prototype)

- **Time collocation**
  - SEVIRI observes for 12 minutes
  - ex) 2010.7.1.16:45 UTC → 16:45~16:57 UTC
  - Find GPROF rain pixels matched with SEVIRI observation time and composite(average) the pixels.

- **Spatial collocation**
  - SSMIS - GPROF Data collocated at the SEVIRI pixels (3km)
Collocation of Proxy Data (for working on version)

- **Time collocation**
  - AHI observes for 10 minutes
  - Find GMI rain pixels matched with AHI observation time.

- **Spatial collocation**
  - AHI data collocated at the GMI pixels
Separation of Cloud Types

- The cloud emissivity can be different as a function of wavelength if cloud thickness is less than about 500m.
- The thick clouds (>500m) can have a similar emissivity (almost 1).

**Shallow and not-shallow clouds separation**

Based on brightness temperature differences (BTD)

<table>
<thead>
<tr>
<th>BTD1=TB7.3-TB10.8µm,</th>
<th>BTD2=TB8.7-TB10.8µm (SEVIRI/PR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BTD1=TB7.3-TB11.2µm,</td>
<td>BTD2=TB8.6-TB11.2µm (AHI/DPR)</td>
</tr>
</tbody>
</table>

- Shallow rain threshold values are obtained using TRMM PR / GPM DPR observations (Shallow rain flag).
- The threshold values are based on TRMM PR (2A23, 2A25)/ GPM DPR and TBs at SEVIRI(AHI)’s 5 channels for the period 2010.7.1~7.31/2015.8.1~8.15.
- PR/DPR defines shallow rain if the storm height is lower than the height of freezing level by 1km.
Shallow/Not-shallow Cloud Discrimination with SEVIRI & PR over Africa

- PDFs of BTD1, BTD2

- Threshold values optimized from Heidke Skill Score (HSS)

<table>
<thead>
<tr>
<th>Constraint</th>
<th>BTD1</th>
<th>BTD2</th>
<th>BTD1 &amp; BTD2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Threshold (K)</td>
<td>-12.3</td>
<td>-1.0</td>
<td>-12.3, 1.3</td>
</tr>
<tr>
<td>HSS</td>
<td>0.662</td>
<td>0.575</td>
<td>0.664</td>
</tr>
</tbody>
</table>

- BTD1 is a good separator.
- Adding BTD2 increases the skill score slightly.

binsize = 0.5 K
Shallow/Not-shallow Cloud Discrimination with SEVIRI & PR over Africa

Verification of the thresholds
Shallow/Not-shallow Cloud Discrimination with AHI & DPR over Asia

- PDFs of BTD1, BTD2

- Threshold values optimized from Heidke Skill Score (HSS)

<table>
<thead>
<tr>
<th>Constrains</th>
<th>BTD1</th>
<th>BTD2</th>
<th>BTD1 &amp; BTD2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Threshold (K)</td>
<td>-17.4</td>
<td>-1.6</td>
<td>-20.5, 7.5</td>
</tr>
<tr>
<td>HSS</td>
<td>0.583</td>
<td>0.187</td>
<td>0.514</td>
</tr>
</tbody>
</table>

- Using BTD1 is enough

binsize = 0.5 K
Shallow/Not-shallow Cloud Discrimination with AHI & DPR over Asia

Verification of the thresholds

Shallow

Not shallow

Occurrence

Storm height

Near surface rain
Characteristics of the Static Databases (with SEVIRI & PR over Africa)

R-Tb (10.8μm) relationships for cloud types and latitudinal bands

Not Shallow

Shallow

60°S~30°S  30°S~EQ  EQ~30°N  30°N~60°N
Characteristics of the Static Databases
(with AHI & DPR over Asia)

R-Tb (11.2µm) relationships for cloud types and latitudinal bands

R-Tb relationships are not as clear as those obtained for Arica

70°S~30°S
30°S~EQ
EQ~30°N
30°N~70°N
Inversion: Bayesian Approach

The posterior probability, Probability to get $h$ given $b$:

$$P(h | b) \propto P(b | h) P(h)$$

The conditional probability, a probability to get $b$ given $h$, (Rodgers, 2000),

$$P(b | h) = \frac{1}{(2\pi)^{P/2}|C_b|^{1/2}} \exp\left\{ -\frac{1}{2} [b - b_m(h)]^T C_b^{-1} [b - b_m(h)] \right\},$$

For our case based on the observation, $P(h) = 1/N$ : the probability to have $h$

$$P(b | h) P(h) =$$

$$\frac{1}{(2\pi)^{P/2}|C_b|^{1/2}} \exp\left\{ -\frac{1}{2} [b - b_m(h)]^T C_b^{-1} [b - b_m(h)] \right\} \cdot \frac{1}{N}$$

The retrieval is to evaluate the expectation for $h$ as given by

$$E(h) = \frac{\int h P(h | b) dh}{\int P(h | b) dh}.$$
Scaling Rainfall Range

- The AMI rainfall algorithm tends to estimate rain rates lower than those from the PMW algorithm. It is because the rain rates in the a-priori databases are originated from the microwave sensor with lower spatial resolutions, equivalently larger footprints.

- Assume cumulative distribution functions of the retrieved rain rates and GPROF rain rates are equal.

\[
\int_0^{R_S} P(R_S) dR_S = \int_0^{R_O} P(R_O) dR_O
\]

\(R_s\) : Retrieved rain rate
\(R_o\) : GPROF rain rate

- LUTs are prepared at every 10° latitude bands.
Retrieval Examples
Validation Statistics for the examples

<table>
<thead>
<tr>
<th>Method Scene</th>
<th>Scalar Accuracy Measures</th>
<th>Categorical Accuracy Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Corr</td>
<td>Bias</td>
</tr>
<tr>
<td>2012.07.19.15:45</td>
<td>0.587</td>
<td>-0.008</td>
</tr>
<tr>
<td>2012.07.19.16:00</td>
<td>0.673</td>
<td>0.091</td>
</tr>
</tbody>
</table>

### Diagrams

- **201207191545**
  - Corr: 0.587
  - Bias: -0.008
  - RMSE: 0.938
  - \( y = 0.05 + 0.53 \times \)

- **201207191600**
  - Corr: 0.673
  - Bias: 0.091
  - RMSE: 1.734
  - \( y = 0.06 + 1.26 \times \)
Preliminary Results with Dynamic Database

Correlation: 0.643

Correlation: 0.635

Static DBs + Dynamic DBs (-1 and -2 days)

Static DBs + Dynamic DBs (-2, -3 days)
Preliminary Retrieval Results for AHI

(without scaling process)
Ongoing Works

Current status summary:
- Theoretical basis and the algorithm frame including construction of a-priori DBs and inversion are developed.
- Retrievals with limited databases produce rain fields as a prototype

Ongoing works
- Working with the proxy datasets for longer periods (more than 6 months)
  - Thresholds of BTD1 and BTD2
  - Re-defining the latitudinal bands for database classification
  - Adjustments AHI data to AMI
- Enhancement of the dynamic databases
  - Retrieval of rainfall rates using static and dynamic databases
  - Updating the static database using the dynamic database
- Improvement of the scaling method
- Validation of the Algorithm: GPM GMI, DPR
Retrieval Examples