Re-calibration for infrared channels of previous JMA GEO satellites

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1. Background

JMA has re-calibrated conventional infrared (IR; approx. 11 μm) and water vapor (WV; approx. 6 μm) channel data from the imagers on the GMS,-2,-3,-4,-5, GOES-9, MTSAT-1R and -2 satellites to support climate research conducted in collaboration with the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT). The work contributes to the Inter-calibration of passive imager observations from time-series of geo stationary satellites (IOGEO) project conducted under WMO's Sustained, Coordinated Processing of Environmental Satellite Data for Climate Monitoring (SCOPE-CM) initiative established in 2008. The project involves collaboration by space agencies and operators of environmental satellite systems in various countries to coordinate and facilitate international activities for the generation of Climate Data Records (CDRs) from multi-agency satellite data. IOGEO is intended to support the establishment of spatially and temporally homogeneous radiance data from all historical geostationary meteorological satellites.

2. Outline of the methodology

Pseudo geostationary imager radiances were computed using data from infrared sounding (Infrared Atmospheric Sounding Interferometer (IASI), Atmospheric Infrared Sounder (AIRS) and High-resolution Infrared Radiation Sounder/2 (HIRS/2) instruments) and regressed against radiance values from geostationary satellite observation. Recalibration factors were computed from these radiance pairs. The work was summarized by John et al. (2019) and Tabata et al. (2019).

3. Outcomes

- Daily correction parameters (slope and offset) for infrared channels of imagers on the GMS,-2,-3,-4,-5, GOES-9, MTSAT-1R and -2 satellites
- Spectral Band Difference Adjustment Factors (SBAF) to mitigate differences among GEO imagers

3.1. Notes

- One pair (slope and offset) of correction parameters is applied for each day and each channel.
- Correction parameters for some days have not been calculated due to missing data.
- Navigation error correction has not been applied.
- Uncertainties in correction for very cold brightness temperature data may be larger than those for warm data because collocation data between infrared sounding and geostationary imagers is insufficient for cold areas.
- Sensor Planck functions as proposed by Tahara (2008) are used in correction parameter application.
- Bréon et al. (1999) reported that the original Spectral Response Function (SRF) of the GMS-5/VISSR WV channel provided by the satellite sensor vendor had been contaminated by atmospheric absorption, and suggested SRF correction based on an atmospheric transmission model. Coefficients for the sensor Planck functions and SBAF for the SRF proposed by Bréon et al. (1999) were created.

4. Coefficient application tutorial

This section outlines the application of parameters for original data and a number of important related points. The Correction_Parameters.xlsx file contains the following tabs:

- Correction Parameters: Slopes and offsets for correction of radiance observation data for individual days, GEO satellites and channels
- Sensor Planck: Parameters for conversion between radiance and Tb values
- SBAF (Spectral Band Adjustment Factors): Parameters for homogenization (conversion) of sensor-based observation radiance data to data from other baseline sensors.

The terms “sensor-normalized” and “baseline sensor” in the following sections and the values of “slope_var,” “offset_var” and “slope_offset_cov” in the Excel file are described in Tabata et al. (2019).

Note: Corrected data for erroneous values in Table A5 in the original Tabata et al. paper (2019) are provided on the Sensor Planck tab.

4.1. Case 1: Application of coefficients to brightness temperature data

Scene: 1 Jun. 2012, MTSAT-2/IMAGER IR for original Tb = 280K

1. Convert from brightness temperature to radiance [mW/m2/sr/cm-1] using the sensor Planck function (see the Sensor Planck tab).

$$Te = TBeff2\_c0 + TBeff2\_c1 * T + TBeff2\_c2 * T^2$$
$$= 4.0368946.E\text{-}01 + 9.9811733.E\text{-}01 * 280 + 1.6749284.E\text{-}06 * 280^2$$
$$= 280.0078562$$

$$L = planck\_c1/(exp(planck\_c2/Te)-1)$$
$$= 9.4713340.E+03E+03/(exp(1.3329716.E+03E+03/280.0078562)-1)$$
$$= 81.7891112$$

2. Apply correction parameters (see the Correction Parameters tab).

$$L\_corr = slope * L + offset$$
$$= 1.0036080E+00 * 81.7891112 -3.8299280E\text{-}01$$
$$= 81.7012135$$

3. Convert from radiance to brightness temperature using the sensor Planck function (see sheet the Sensor Planck tab).

$$Te = planck\_c2/ln((planck\_c1/L\_corr)+1)$$
$$= 1.3329716.E+03/ln((9.4713340.E+03/81.7012135)+1)$$
$$= 279.9451652$$

$$T = TB2\_c0 + TB2\_c1 * Te + TB2\_c2 * Te^2$$
$$= -4.0439026.E\text{-}01 + 1.0018867.E+00 * 279.9451652 -1.6805293.E\text{-}06 * 279.9451652^2$$
$$= 279.9372456$$

4.2. Case 2: Application to GMS-5 WV channel data with Bréon's SRF

Scene: 8 Nov. 1996, GMS-5/VISSR WV for original Tb = 250K

1. Convert from brightness temperature to radiance using the sensor Planck function.
   (Use sensor Planck coefficients for the original SRF)

$$Te = TBeff2\_c0 + TBeff2\_c1 * T + TBeff2\_c2 * T^2$$
$$= 5.1377345.E-01 + 9.9854599.E-01 * 250 + 6.5603058.E-07 * 250^2$$
$$= 250.1912729$$

$$L = planck\_c1/(exp(planck\_c2/Te)-1)$$
$$= 3.5820476.E+04 / (exp(2.0767979.E+03/250.1912729)-1)$$
$$= 8.8967194$$

2. Apply correction parameters (as above).

$$L\_corr = slope * L + offset$$
$$= 1.0047330E+00 * 8.8967194 - 1.2251760E-02$$
$$= 8.9265758$$

3. Convert from radiance to brightness temperature using the sensor Planck function.
   (Use sensor Planck coefficients for the SRF suggested by Bréon)

$$Te = planck\_c2/ln((planck\_c1/L\_corr)+1)$$
$$= 2.0788468E+03/ln((3.5926602E+04/8.9265758)+1)$$
$$= 250.4499256$$

$$T = TB2\_c0 + TB2\_c1 * Te + TB2\_c2 * Te^2$$
$$= -5.5772771.E-01 + 1.0015964.E+00 * 250.4499256 - 7.5910270.E-07 * 250.4499256^2$$
$$= 250.2444013$$

4.3. Case 3: Homogenization for baseline sensor data

Scene: 8 Nov. 1996, GMS-5/VISSR WV for original Tb = 250 K, making sensor normalized radiance (baseline sensor: MTSAT-2/IMAGER)

1. Convert from brightness temperature to radiance using the sensor Planck function (as above).

Te = TBeff2_c0 + TBeff2_c1 * T + TBeff2_c2 * T^2
= 5.1377345.E-01 + 9.9854599.E-01 * 250 + 6.5603058.E-07 * 250^2
= 250.1912729
L = planck_c1/(exp(planck_c2/Te)-1)
= 3.5820476.E+04 / (exp(2.0767979.E+03/250.1912729)-1)
= 8.8967194

2. Apply correction parameters (as above).

L_corr = slope * L + offset
= 1.0047330E+00 * 8.8967194 - 1.2251760E-02
= 8.9265758

3. Apply SBAF for sensor normalization (see the SBAF tab. GMS-5/VISSR(Bréon) → MTSAT-2/IMAGER).

L_sbaf = slope * L_corr + offset
= 7.1350740E-01 * 8.9265758 + 1.9700611E-01
= 6.5661840

4. Convert from radiance to brightness temperature using the sensor Planck function. (Use sensor Planck coefficients for the SRF of baseline sensor (MTSAT-2/IMAGER))

Te = planck_c2/ln((planck_c1/L_sbaf)+1)
= 2.1246247.E+03E+03/ln((3.8352633.E+04/6.5661840)+1)
= 244.9751618
T = TB2_c0 + TB2_c1 * Te + TB2_c2 * Te^2
= -4.0112791.E-01 + 1.0011449.E+00 * 244.9751618 -5.7546785.E-07 * 244.9751618^2
= 244.8199705

5. References

- John, V.O.; Tabata, T.; Rüthrich, F.; Roebeling, R.; Hewison, T.; Stöckli, R.; Schulz, J.; "On the Methods for Recalibrating Geostationary Longwave Channels Using Polar Orbiting Infrared Sounders.", Remote Sens., 2019, 11, 1171.
- Tabata, T.; John, V.O.; Roebeling, R.A.; Hewison, T.; Schulz, J.; "Recalibration of over 35 Years of Infrared and Water Vapor Channel Radiances of the JMA Geostationary Satellites", Remote Sens., 2019, 11, 1189.
- Bréon, F.M.; Jackson, D.; "Evidence of Atmospheric Contamination on the Measurement of the Spectral Response of the GMS-5 Water Vapor Channel", J. Atmos. Oceanic. Technol., 1999, 16, 1851-1853.
- Tahara, Y.; "Central Wavelengths and Wavenumbers and Sensor Planck Functions of the GMS and MTSAT Infrared Channels", Meteorological Satellite Center Technical Note. 2008, 50, 51-59 (in Japanese).