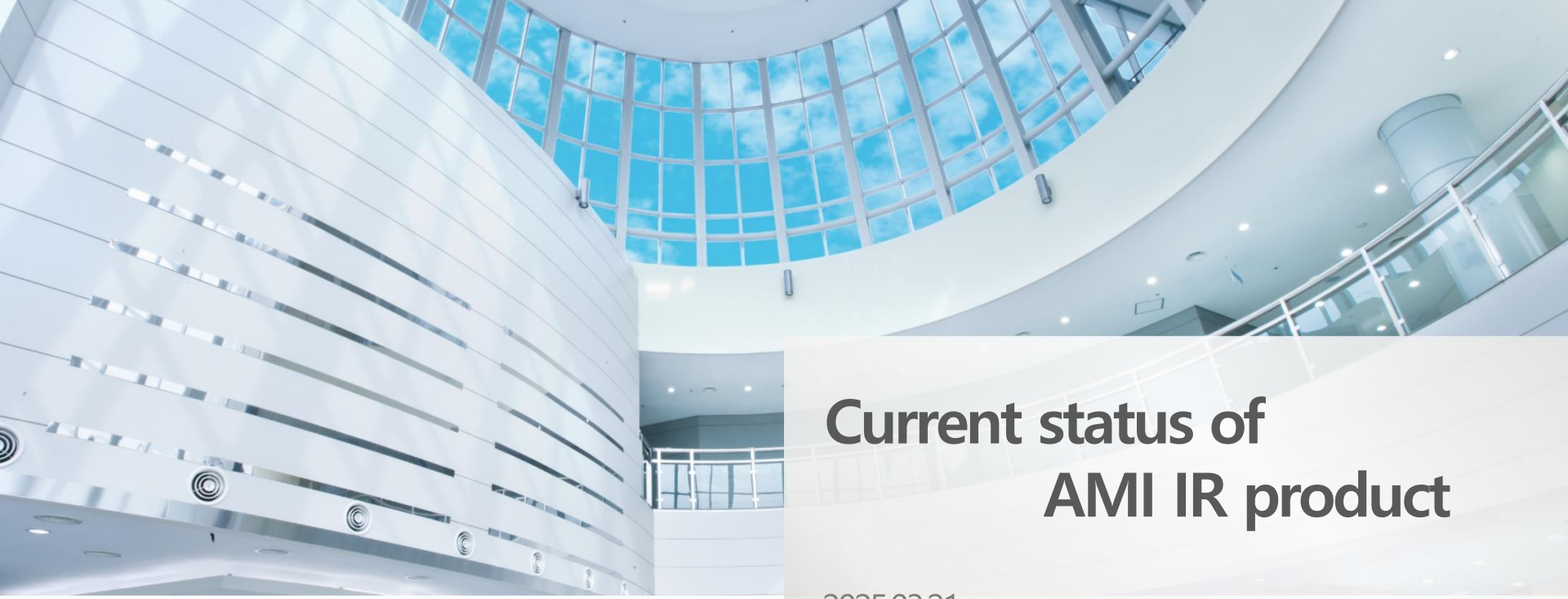
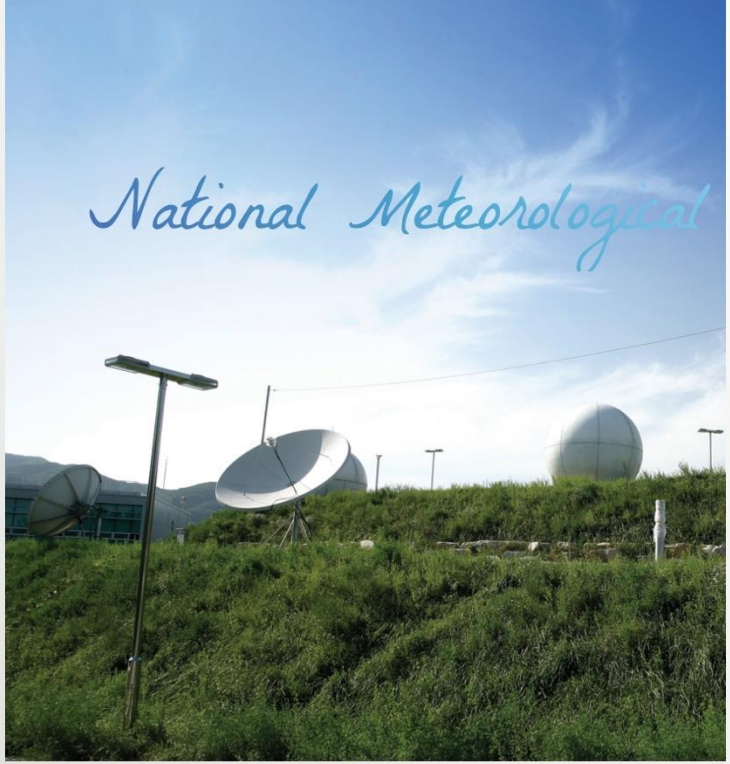


Current status of AMI IR product

2025.03.21.

Euidong Hwang, KMA/NMSC

National Meteorological Satellite Center



Contents

- Uncertainty evaluation for AMI – IASI product
- Review of AMI IR products

Uncertainty evaluation for AMI-IASI product

Introduction

- Uncertainty Evaluation methods for AMI-IASI based on Hewison (2013)
- Analyzing the components of uncertainty: Systematic error and Random error
  - Systematic errors (4) : Temporal, Latitudinal, Longitudinal and Geometric mismatches
    - ✓ Spectral mismatch is excluded from this analysis (IASI covers all spectra of AMI)
  - Random errors (6) : Temporal, Latitudinal, Longitudinal and Geometric variabilities and Radiometric noise(2)

❖ Reference

Tim J. Hewison, 2013, “An Evaluation of the Uncertainty of the GSICS SEVIRI-IASI Intercalibration Products”, IEEE TGRS, VOL. 51, NO. 3, 1171-1181

- **Systematic errors [S]**

  To calculate the uncertainty caused by systematic components in the matching, the typical differences (Δx) and their sensitivities($\frac{\partial L}{\partial x}$) are used

$$u_j^s(L_i) = \Delta x_j^s (\frac{\partial \mathrm{L}}{\partial x^s})_\mathrm{j}$$

- **Random errors [R]**

  To calculate the uncertainty caused by random components in the matching, the random differences (zΔx) associated with the matching criteria and their sensitivities($\frac{\partial L}{\partial x}$) are used

$$u_j^r(L_i) = z_i \Delta x_{i,j}^r (\frac{\partial \mathrm{L}}{\partial x^r})_\mathrm{j}$$

Methods

where,
t_{max} : Time criteria
x_{max} : Median distance between adjacent pixel

- **Temporal mismatch/variability [S, R]**

  Δx : Typical differences in temporal distribution

  $\left(\frac{\partial L}{\partial x^s}\right)$: Change in radiance when only the time changes for the same pixel

$= \frac{2\Delta t_{max}}{\sqrt{3n}}$ OR t_{max} [S OR R]

$$= \begin{cases} \frac{1}{n_i n_j n_k} \sum_{i,j,k} \left[L(x_i, y_j, t_k + \Delta t) - L(x_i, y_j, t_k) \right] & \text{[S]} \\ \text{OR} & \\ \sqrt{\frac{1}{n} \sum \left(L(x_i, y_j, t_k + \Delta t) - L(x_i, y_j, t_k) \right)^2} & \text{[R]} \end{cases}$$

- **Spatial mismatch/variability [S, R]**

  Δx : Typical differences in spatial distribution caused by the geolocation accuracy of AMI and IASI

  $\left(\frac{\partial L}{\partial x^s}\right)$: Change in radiance when only the pixel changes

$= \left(\frac{GEO\ nav. + LEO\ acc.}{\sqrt{2}}\right) * \frac{1}{\sqrt{3}}$ OR x_{max} [S OR R]

$$= \begin{cases} \frac{1}{n_i n_j n_k} \sum_{i,j,k} \left[L(x_i + \Delta x, y_j, t_k) - L(x_i, y_j, t_k) \right] & \text{[S]} \\ \text{OR} & \\ \sqrt{\frac{1}{n} \sum \left(L(x_i + \Delta x, y_j, t_k) - L(x_i, y_j, t_k) \right)^2} & \text{[R]} \end{cases}$$

Methods

- **Geometric mismatch/variability [S, R]**

  Δx : Mean differences in geometric distribution of collocated data

  $\left(\frac{\partial L}{\partial x^s}\right)$: Change in radiance when only Sat_{zen} varies under the same observation conditions

$$= \text{mean}\left(\left|\frac{\cos(leo_{zen})}{\cos(geo_{zen})} - 1\right|\right) \text{ OR } 1 \text{ [S OR R]}$$

$$= \frac{1}{n}\sum[L_{RTM} - L_{zen\pm1^\circ}] \quad \text{[S, R]}$$

L_{RTM} : simulate AMI`s observation data*

* KMA is generating RTM simulated data based on the actual measurements from AMI

- **Radiometric noise [R]**

  Δx : 1

  $\left(\frac{\partial L}{\partial x^s}\right)$: Noise associated with actual channels/pixels used in spectral matching (= effective noise)

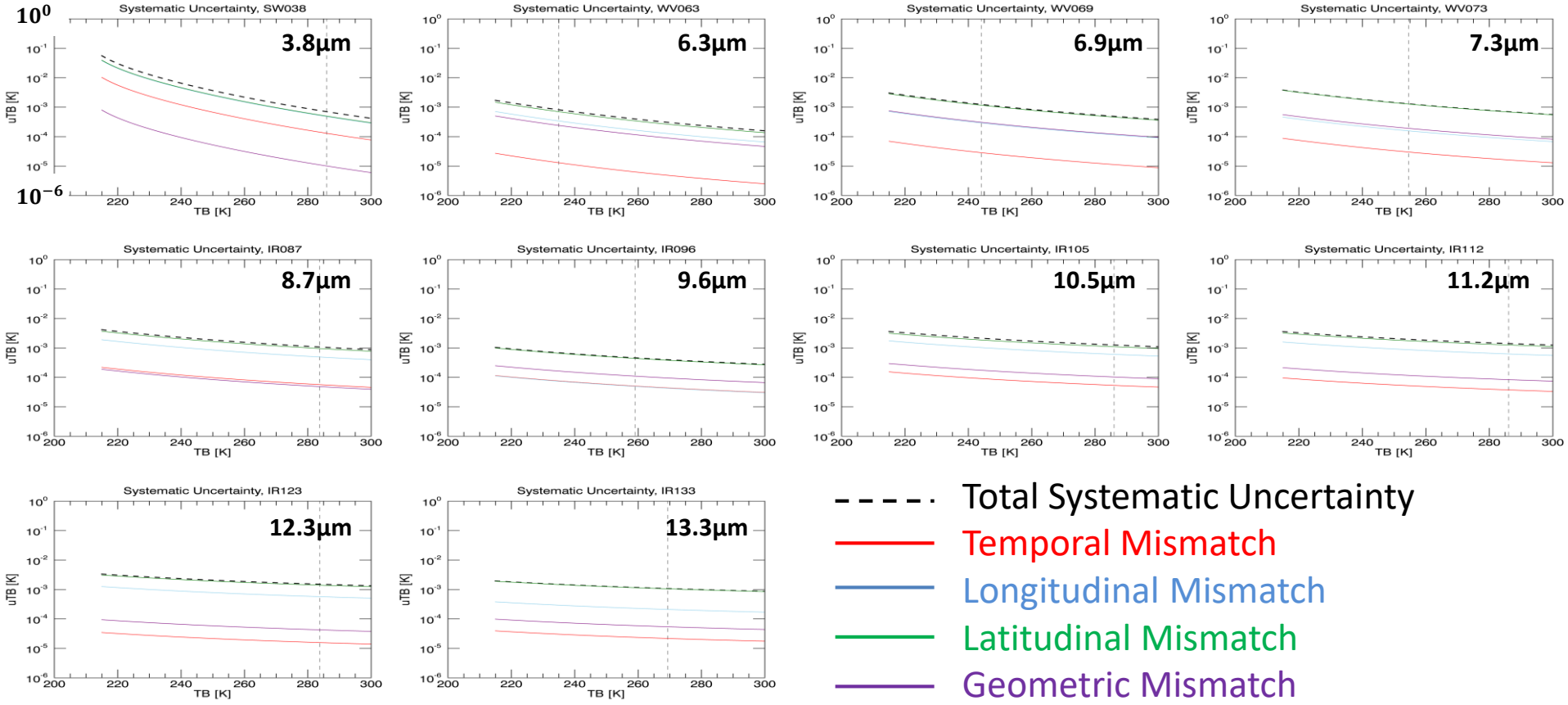
$$= \frac{NEdT}{\sqrt{effective\ \#\ of\ channels\ or\ pixels}} \quad \text{[R]}$$

(need to convert to rad.)

Summary of Uncertainty Evaluation for Systematic Error

- Uncertainties caused by temporal, longitudinal, latitudinal, and geometric mismatches are evaluated
  - Spectral mismatch was excluded because the spectra of IASI cover all channels of AMI
- Among the systematic errors, spatial mismatches are dominant. In particular, errors caused by latitudinal mismatch are the most significant
  - Latitudinal mismatch appears larger than longitudinal mismatch because the GEOS projection is more sensitive to curvature effects in the latitude direction.
- Total systematic error is largest in the 3.8μm channel at 0.1 K, while the other channels are below 0.01K

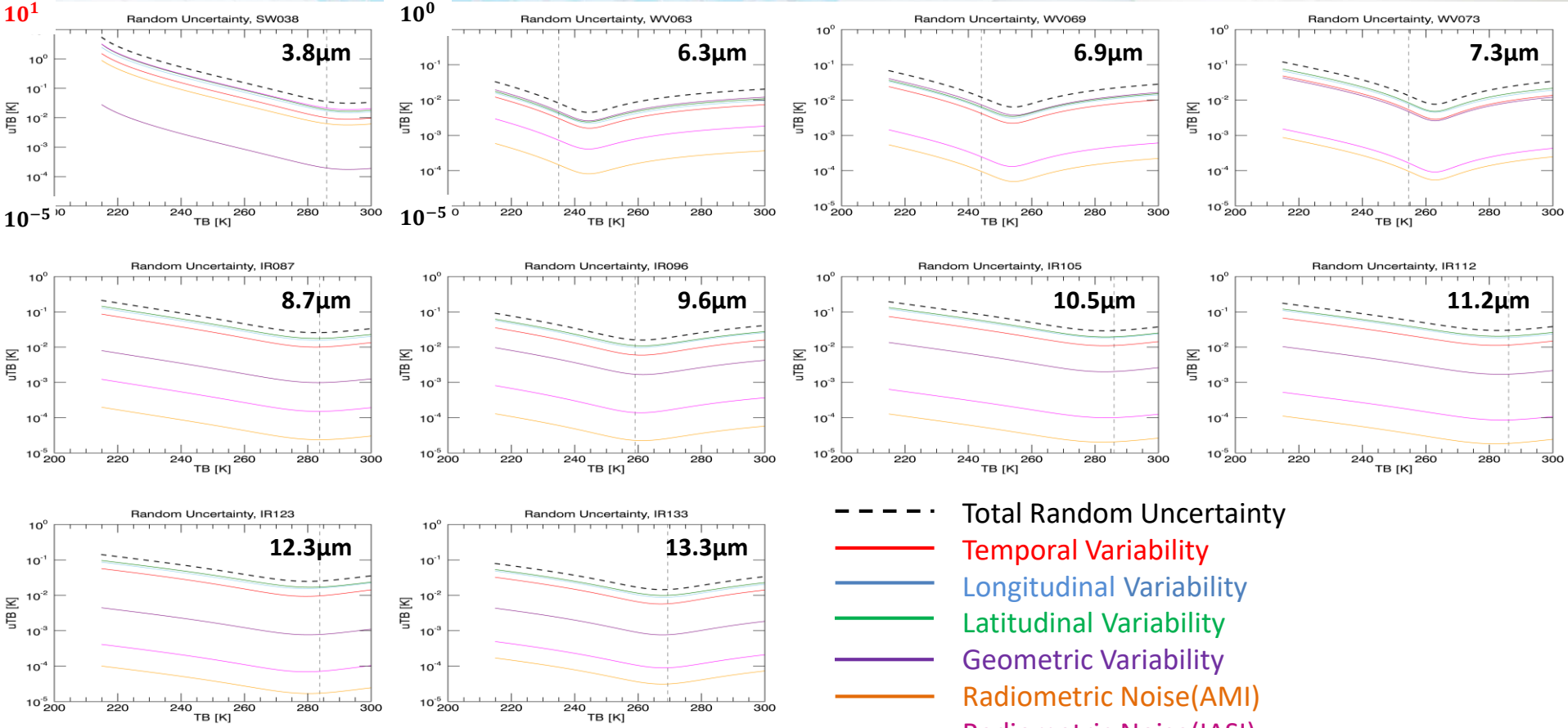
Contribution of Systematic Error



Summary of Uncertainty Evaluation for Random Error

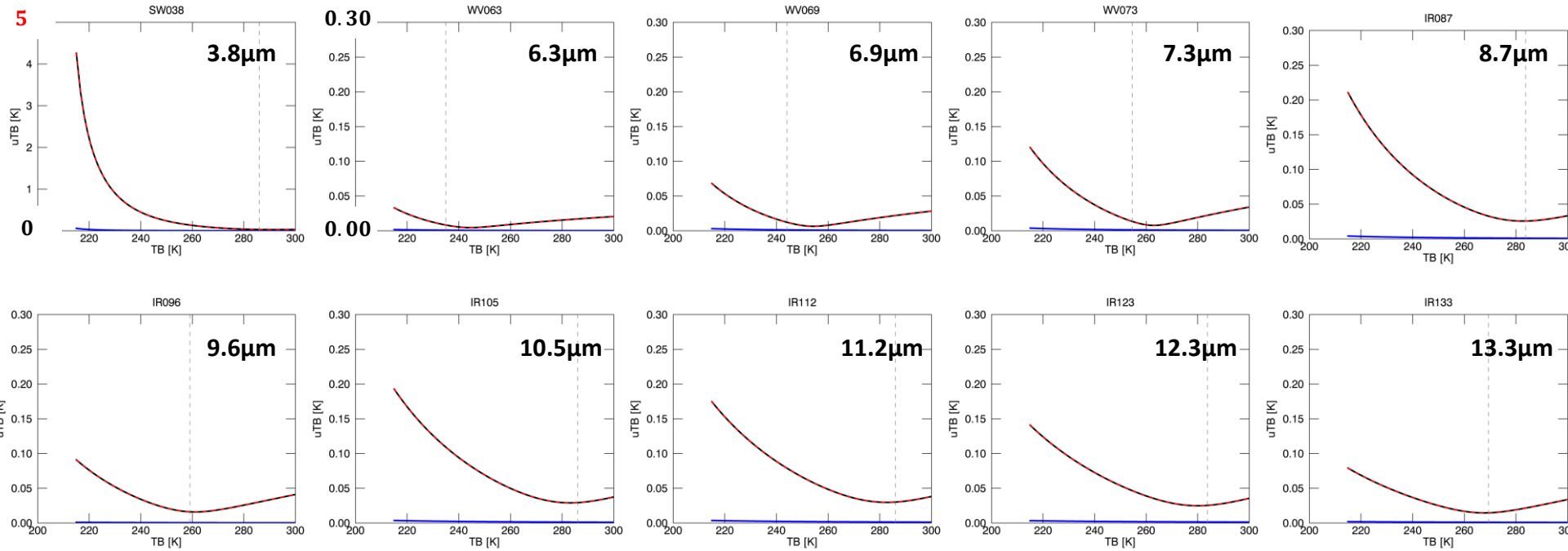
- Uncertainties caused by temporal, longitudinal, latitudinal, and geometric variabilities and Radiometric noise are evaluated
- Among the random errors, spatiotemporal variabilities are dominant in most channels
- Total random error is largest in the 3.8μm channel at approximately 4K, while the other channels are below 1K
- V-shape pattern
  - In the contribution plot of random error, a V-shape pattern is observed, with high errors in the low and high temperature regions and the smallest errors near the standard scene TB
    - ➢ This occurs because random error decreases with more data
    - ➢ The majority of the collocated data is concentrated near the standard scene TB, resulting in smaller errors

Contribution of Random Error



Contribution of Total Error

Total Combined Uncertainty
Total Systematic Uncertainty
Total Random Uncertainty



- Except for the 3.8μm channel, total errors were below 0.3 K, and all channels showed below 0.05K @ standard scene TB

Summary of Perturbations and Sensitivities (AMI)

Systematic Error Type	Δx	Sensitivity [mW/m2/sr/cm-1/dx]									
		SW038	WV063	WV069	WV073	IR087	IR096	IR105	IR112	IR123	IR133
Longitudinal mismatch(AMI)	0.920km	0.00001	-0.00004	-0.00008	-0.00007	0.00057	-0.00005	0.00094	0.00103	0.00096	0.00032
Latitudinal mismatch(AMI)	0.952km	0.00001	0.00008	0.00031	0.00055	0.00107	0.00043	0.00165	0.00201	0.00228	0.00155
Temporal mismatch(AMI)	0.0007111hr	-0.00349	0.00197	0.01012	0.01725	-0.08496	-0.06605	-0.10756	-0.08010	-0.03412	0.04266
Geometric mismatch(AMI)	0.000481	0.00191	0.01617	0.03820	0.06176	0.12513	0.25335	0.14352	0.15493	0.17347	0.24455
Spectral Calibration	2 ppm	-	-	-	-	-	-	-	-	-	-

Random Error Type	Δx	Sensitivity [mW/m2/sr/cm-1/dx]									
		SW038	WV063	WV069	WV073	IR087	IR096	IR105	IR112	IR123	IR133
Longitudinal variability(AMI)	2.105 km	0.01644	0.02158	0.06275	0.12441	0.84334	0.60393	1.26767	1.35550	1.30280	0.87614
Latitudinal variability(AMI)	2.173 km	0.01790	0.02319	0.06709	0.13360	0.89955	0.64798	1.34632	1.44343	1.38865	0.93158
Temporal variability(AMI)	5 min	0.00424	0.00691	0.01929	0.03630	0.22366	0.15685	0.32941	0.36093	0.35451	0.24298
Geometric variability(AMI)	1	0.00191	0.01617	0.03820	0.06176	0.12513	0.25335	0.14352	0.15493	0.17347	0.24455
Radiometric noise(AMI)	1	0.00042	0.00088	0.00176	0.00314	0.00359	0.00443	0.00497	0.00497	0.00559	0.01113
Radiometric noise(IASI)	1	0.00066	0.00311	0.00330	0.00373	0.01723	0.02134	0.01930	0.01987	0.01887	0.02779

Summary of Perturbations and Sensitivities (vs AHI)

Longitudinal components		Δx	Sensitivity [mW/m2/sr/cm-1/dx]									
			sw038	wv063	wv069	wv073	ir087	ir096	ir105	ir112	ir123	ir133
Systematic Error	GK2A/AMI	0.920 km	0.00001	-0.00004	-0.00008	-0.00007	0.00057	-0.00005	0.00094	0.00103	0.00096	0.00032
	Himawari-8/AHI	1.119 km	0.00001	-0.00013	-0.00035	-0.00048	-0.00026	0.00016	-0.00056	-0.00086	-0.00127	-0.00096
Random Error	GK2A/AMI	2.105 km	0.01644	0.02158	0.06275	0.12441	0.84334	0.60393	1.26767	1.35550	1.30280	0.87614
	Himawari-8/AHI	2.130km	0.01500	0.02900	0.08700	0.17400	0.84700	0.63900	1.23800	1.32300	1.28600	0.99000

Latitudinal components		Δx	Sensitivity [mW/m2/sr/cm-1/dx]									
			sw038	wv063	wv069	wv073	ir087	ir096	ir105	ir112	ir123	ir133
Systematic Error	GK2A/AMI	0.952 km	0.00001	0.00008	0.00031	0.00055	0.00107	0.00043	0.00165	0.00201	0.00228	0.00155
	Himawari-8/AHI	1.106 km	0.00001	-0.00003	-0.00009	-0.00018	-0.00075	0.00049	-0.00111	-0.00121	-0.00121	-0.00091
Random Error	GK2A/AMI	2.173 km	0.01790	0.02319	0.06709	0.13360	0.89955	0.64798	1.34632	1.44343	1.38865	0.93158
	Himawari-8/AHI	2.181km	0.01600	0.02900	0.08600	0.17000	0.86100	0.64900	1.24900	1.32600	1.28400	0.97500

* Arata Okuyama, "JMA GSICS IR Product Status“, GRWG/GDWG Annual Meeting, 19 Mar. 2020, Online meeting

Summary of Perturbations and Sensitivities (vs AHI)

Temporal components		Δx	Sensitivity [mW/m2/sr/cm-1/dx]									
			sw038	wv063	wv069	wv073	ir087	ir096	ir105	ir112	ir123	ir133
Systematic Error	GK2A/AMI	0.000711hr	-0.00349	0.00197	0.01012	0.01725	-0.08496	-0.06605	-0.10756	-0.08010	-0.03412	0.04266
	Himawari-8/AHI	0.000706hr	-0.00313	-0.00290	-0.00327	-0.00051	-0.06475	-0.05735	-0.07949	-0.07893	-0.05872	-0.00409
Random Error	GK2A/AMI	5 min	0.00424	0.00691	0.01929	0.03630	0.22366	0.15685	0.32941	0.36093	0.35451	0.24298
	Himawari-8/AHI	5 min	0.00410	0.00920	0.02700	0.05270	0.24460	0.18550	0.35930	0.38800	0.38240	0.29870

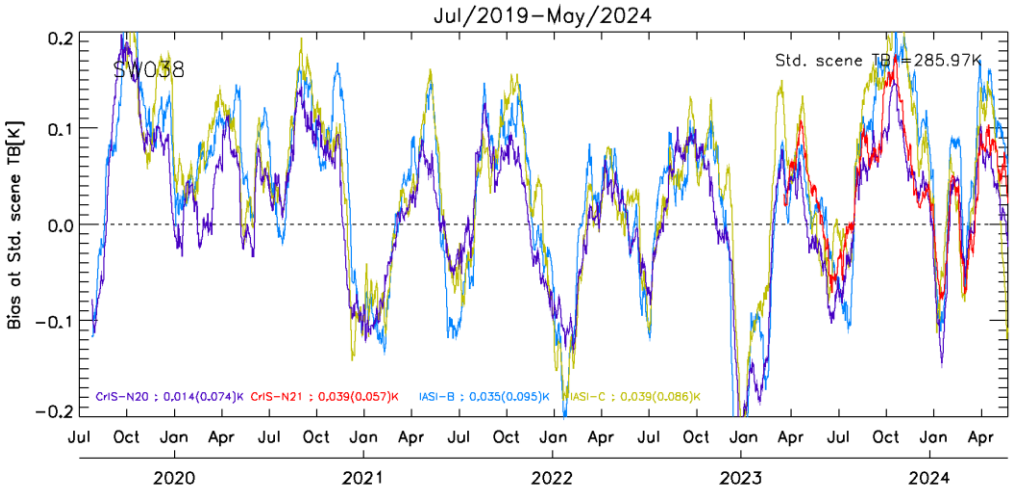
Geometric components		Δx	Sensitivity [mW/m2/sr/cm-1/dx]									
			sw038	wv063	wv069	wv073	ir087	ir096	ir105	ir112	ir123	ir133
Systematic Error	GK2A/AMI	0.000481	0.00191	0.01617	0.03820	0.06176	0.12513	0.25335	0.14352	0.15493	0.17347	0.24455
	Himawari-8/AHI	0.000506	0.02540	0.02551	0.02551	0.02551	0.02543	0.02543	0.02544	0.02544	0.02544	0.02545
Random Error	GK2A/AMI	1	0.00191	0.01617	0.03820	0.06176	0.12513	0.25335	0.14352	0.15493	0.17347	0.24455
	Himawari-8/AHI	1	0.02500	0.02600	0.02600	0.02600	0.02500	0.02500	0.02500	0.02500	0.02500	0.02500

Review of AMI IR products

Background

- ✓ GK2A/AMI has been performing meteorological observations since July 2019 and has been operational for approximately 5 years
- ✓ At this midpoint of AMI's mission duration, we are conducting a detailed analysis of the calibration status of AMI
- ✓ Additionally, we are reviewing the GSICS inter-calibration process:
  - Regression (ODR vs WLR, IR algorithm ver. 2)
  - Plotting script (for research)
  - GSICS products (NRTC, RAC)

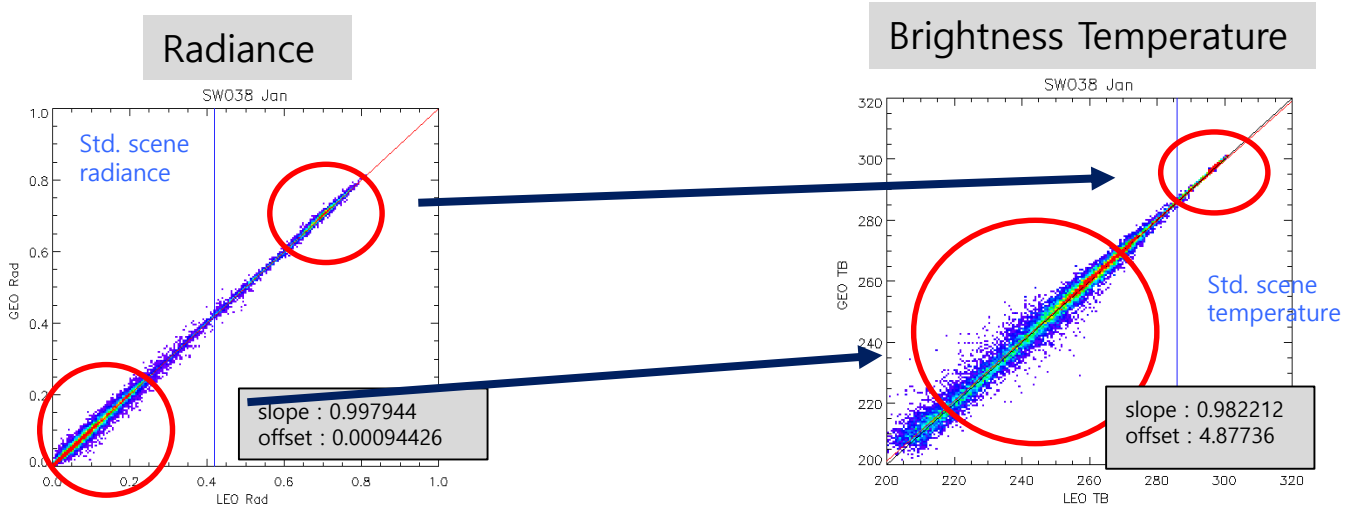
Review of plotting script (for Research)



- This plot monitors the calibration status of AMI (time series of standard scene bias)
  - The calibration coefficients used to calculate bias are derived from TB regression
  - It shows peaks in specific months and may appear to indicate seasonal variation

Review of plotting script (for Research)

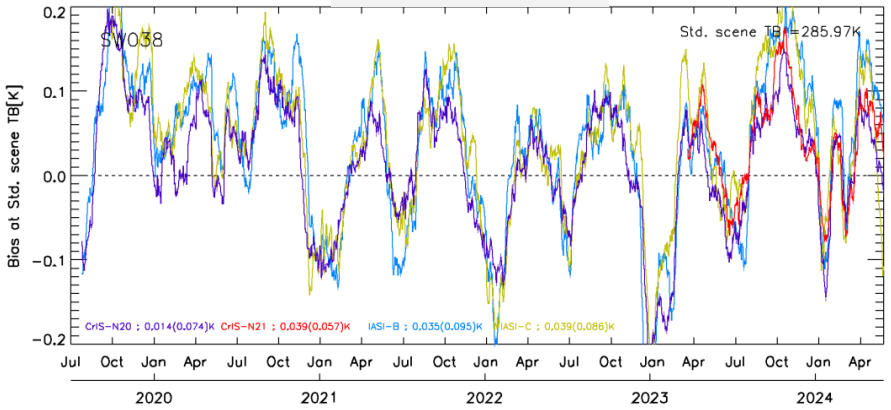
- Radiance and Brightness Temperature(TB) are non-linear
  - In the low-temperature range, the distribution is sparse, while in the high-temperature range, it is dense (i.e., the distribution per DN differs)
  - For this reason, when data from the low-temperature range is converted to TB, it results in larger uncertainty compared to the high-temperature range



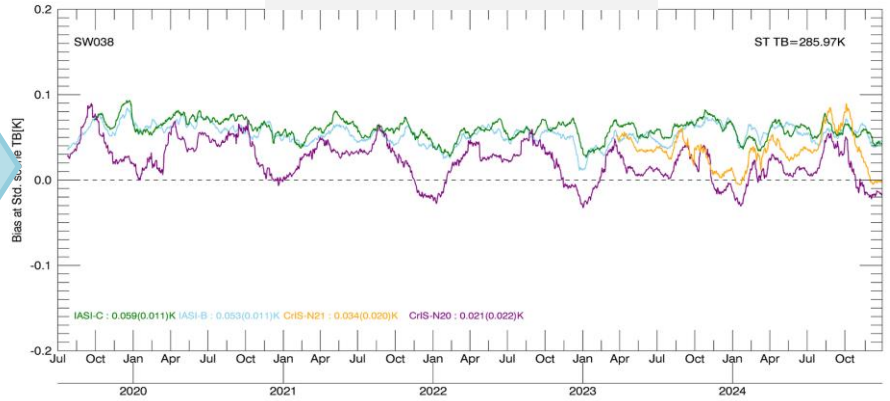
Review of plotting script (for Research)

- The research plotting script was performing regression on TB (Not operational)
  - TB regress also indicates the trend of bias, but it includes uncertainty (particularly in 3.8μm)

TB regression



Radiance regression

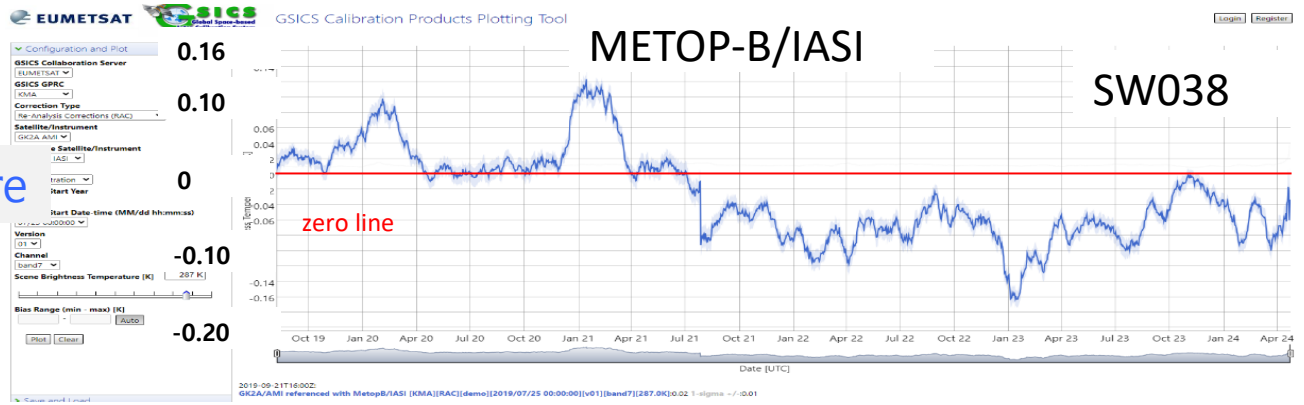


➢ We plan to utilize the improved process to analyze the long-term calibration status of AMI

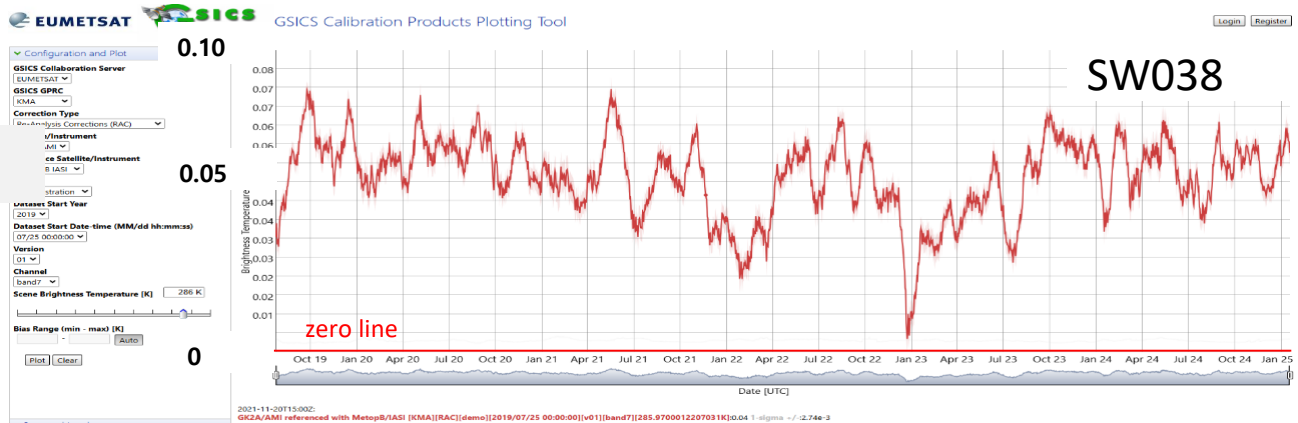
Review of GSICS products

- Fixing the bug in the product generation process for 3.8μm channel`s RAC products

Before



After



Now available!

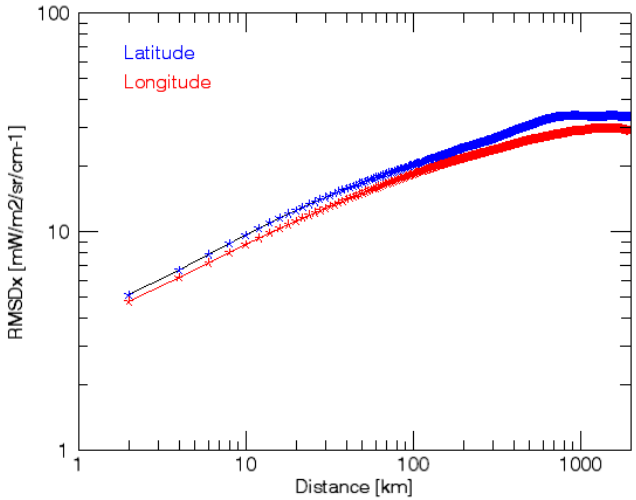
Summary

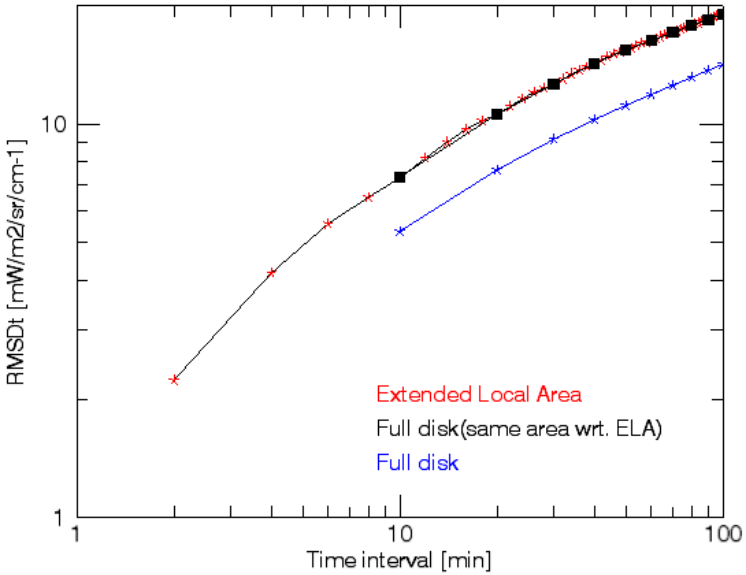
- Uncertainty evaluation for AMI-IASI products is performed
  - **In systematic error,** spatial mismatch is dominant. In particular, the larger latitudinal error seems to be due to the GEOS projection
  - **In random error,** spatiotemporal components are dominant in most channels, and more data means less random error
  - Total error is below 0.05K in all channels (@ std. scene TB)
  - The analysis results, excluding the geometric components, are similar to Himawari-8.
- Modifying the GSICS process to analysis the long-term performance of the GK2A/AMI infrared channel
  - Enhanced the plotting script for research
  - Fixed bug in the 3.8μm RAC products, and they are currently being reproduced and distributed

Thank you

National Meteorological Satellite Center

[Appendix] Spatial/Temporal Variogram





- ✓ Confirmed the homogeneity of the spatial distribution through the linearity

- ✓ Confirmed the homogeneity of the temporal distribution through the linearity

[Appendix] Long-term IR calibration of AMI

National Meteorological Satellite Center