Report on Himawari-8 from JMA

Japan Meteorological Agency

Toshiyuki SAKURAI*, Mika KIMURA, Akiko SHOJI (Marine Prediction Office),
Daisaku UESAWA, Ryo YOSHIDA, Arata OKUYAMA, Masaya TAKAHASHI
(Meteorological Satellite Center)

*e-mail: tsakurai@met.kishou.go.jp

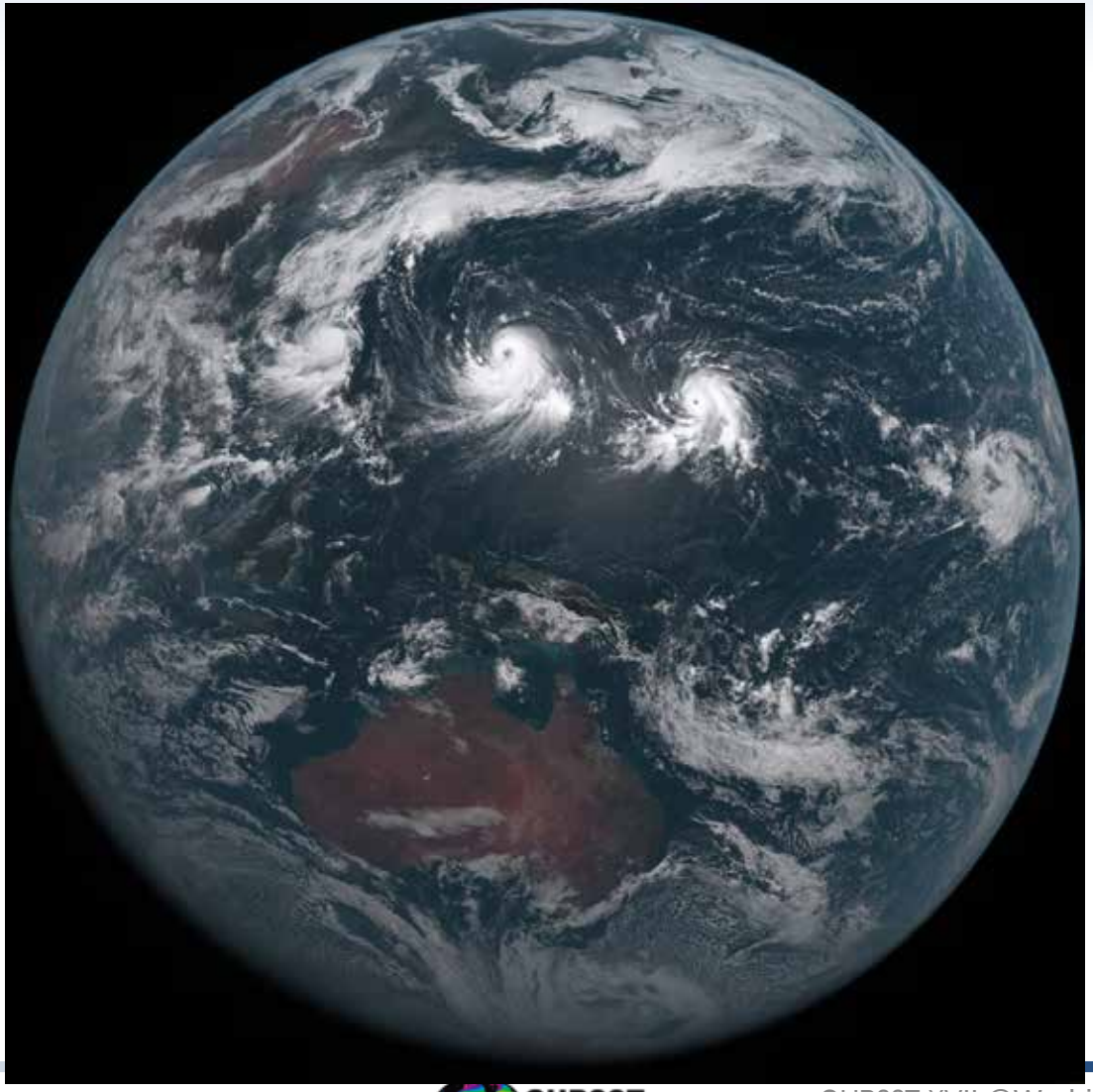
Contents

- **Introduction to Himawari-8**
- **Calibration and Validation for IR Bands**
- **Image Navigation and Registration (INR)**
  - **Ground processing system updates of 9 March 2016**
- **L3 SST and Cloud Mask**

Contents

- **Introduction to Himawari-8**
- Calibration and Validation for IR Bands
- Image Navigation and Registration (INR)
  - Ground processing system updates of 9 March 2016
- L3 SST and Cloud Mask

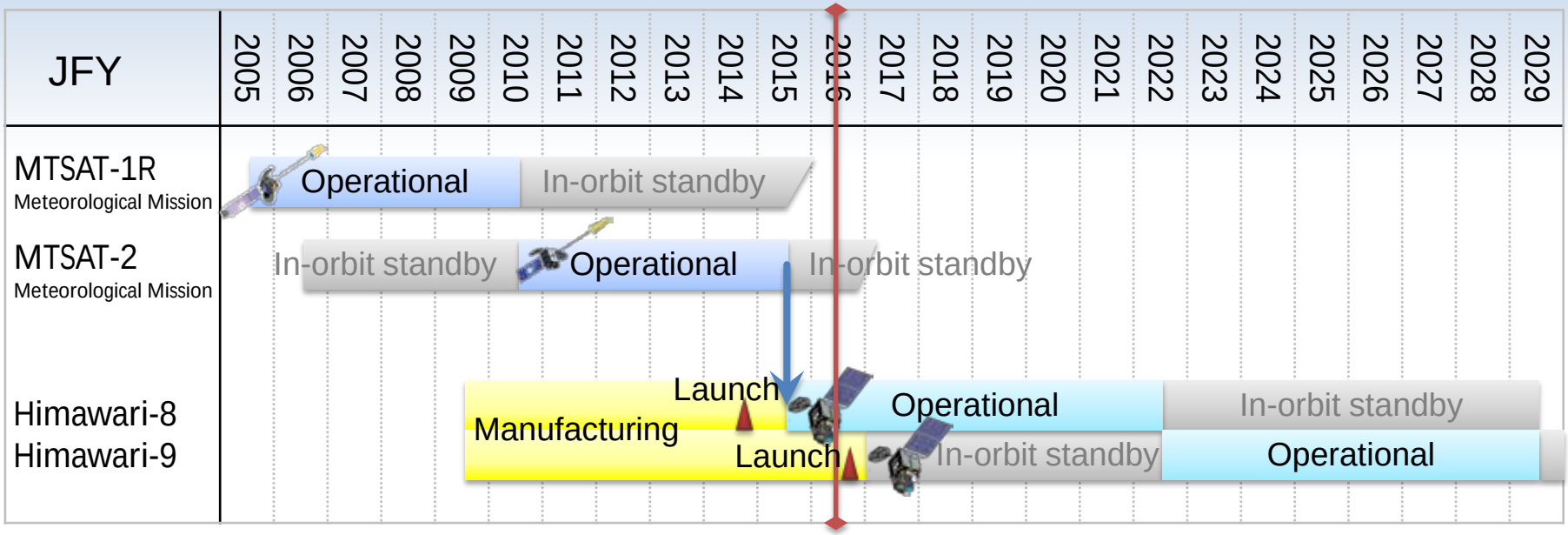
Himawari-8 started operation at 02 UTC on 7 July 2015.



True-Color Composite
R: Band 3 (0.64um)
G: Band 2 (0.51um)
B: Band 1 (0.47um)

02:00 UTC on 7 July 2015

Himawari-8/9 timeline



- **Himawari-8** was launched on 7 October 2014.
- **Himawari-8** started operation on 7 July 2015, replacing **MTSAT-2**.
- **MTSAT -2** observation parallel to **Himawari-8** operation terminated at 00 UTC on 24 March 2016.
- **Himawari-9** is scheduled for launch in 2016.

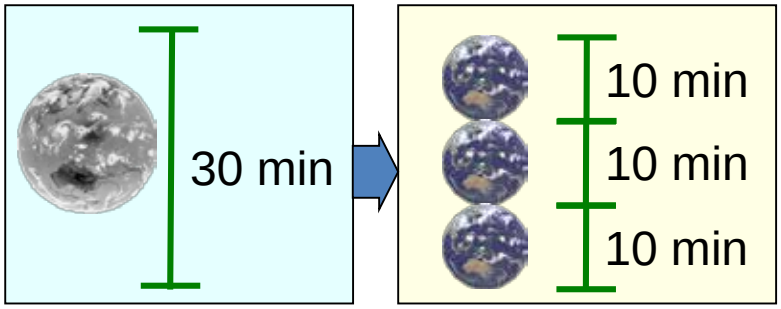
AHI (Advanced Himawari Imager)

Himawari-8 multispectral observation with higher spatial/temporal resolution provides more information on atmosphere/ocean/land than MTSAT.

Improved spatial resolution

MTSAT-1R/2	Himawari-8/9
VIS 1 km IR 4 km	VIS 0.5/1 km IR 2 km

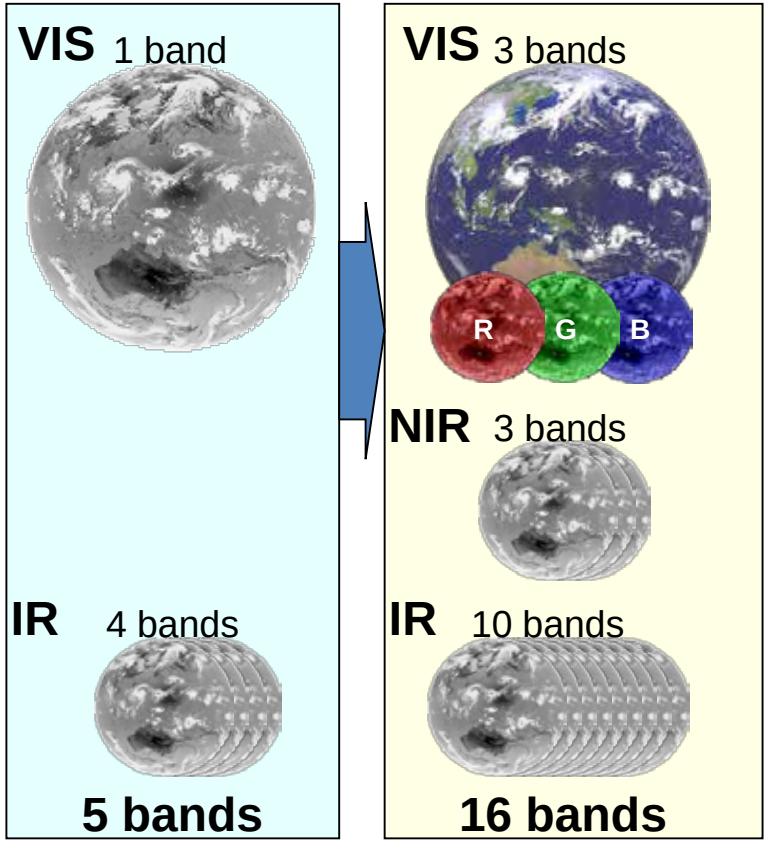
More frequent observation



More flexible regional observation

Special observation	Target area obs. every 2.5 minutes

More spectral bands



Contents

- Introduction to Himawari-8
- **Calibration and Validation for IR Bands**
- Image Navigation and Registration (INR)
  - Ground processing system updates of 9 March 2016
- L3 SST and Cloud Mask

Calibration and Validation for IR Bands

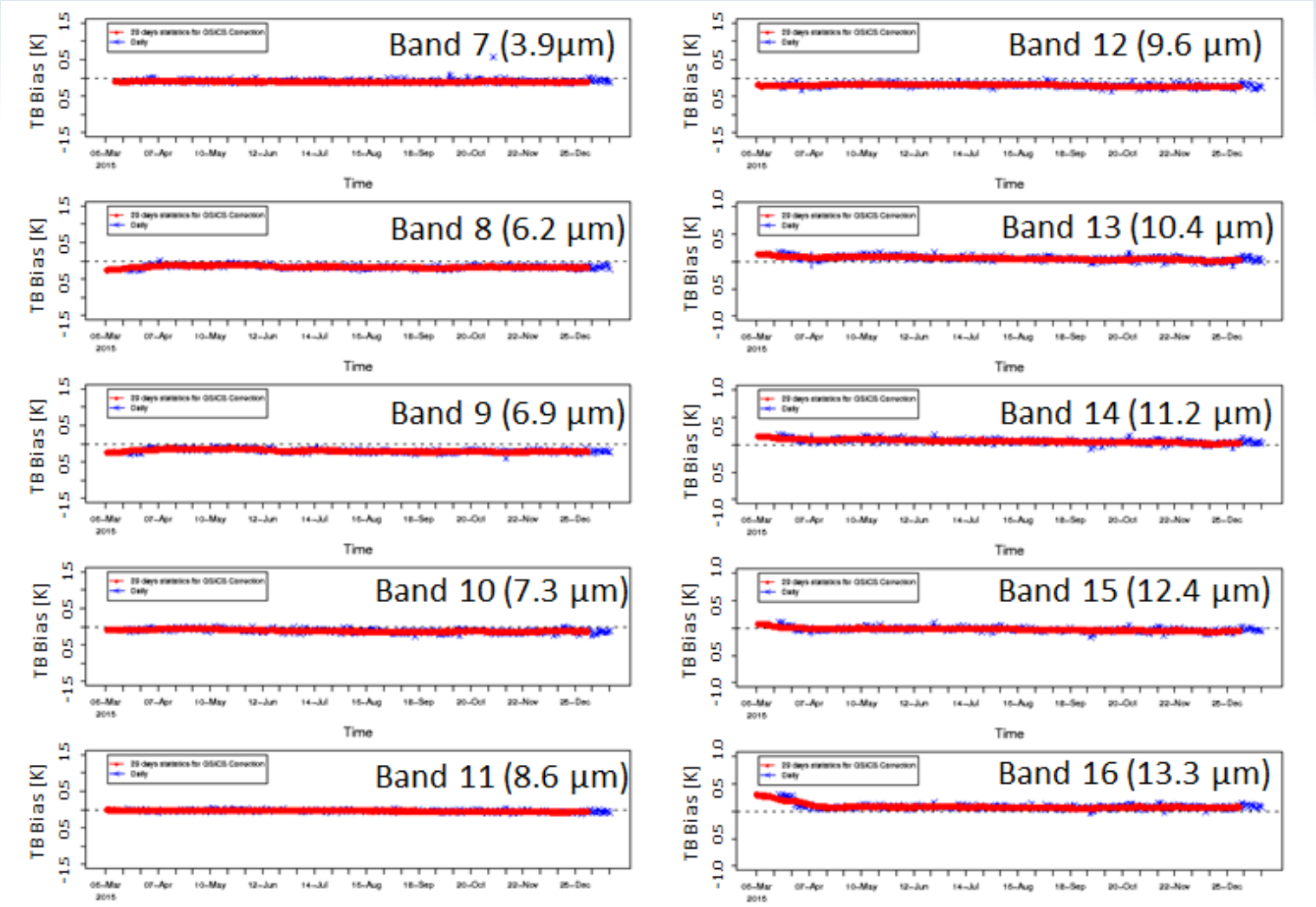
- On-board calibration
  - Ø A black body is provided as an on-board calibration source.

    Hot reference: Black body observation is performed every 10 minutes.
    Cold reference: Deep space viewing is conducted for every swath of full-disk observation.

- Inter-calibration for IR Bands
  - Ø JMA has developed an infrared calibration method under the GSICS (Global Space-based Inter-Calibration System) framework.
  - Ø AHI data are compared with data from hyper-spectral infrared sounders such as IASI/Metop and AIRS/Aqua.
  - Ø Statistical parameters derived from GSICS inter-calibration work are available on MSC's GSICS calibration monitoring website.

    (http://www.data.jma.go.jp/mscweb/data/monitoring/calibration.html)

TB biases for IR bands: very stable – less than 0.2K for standard scenes

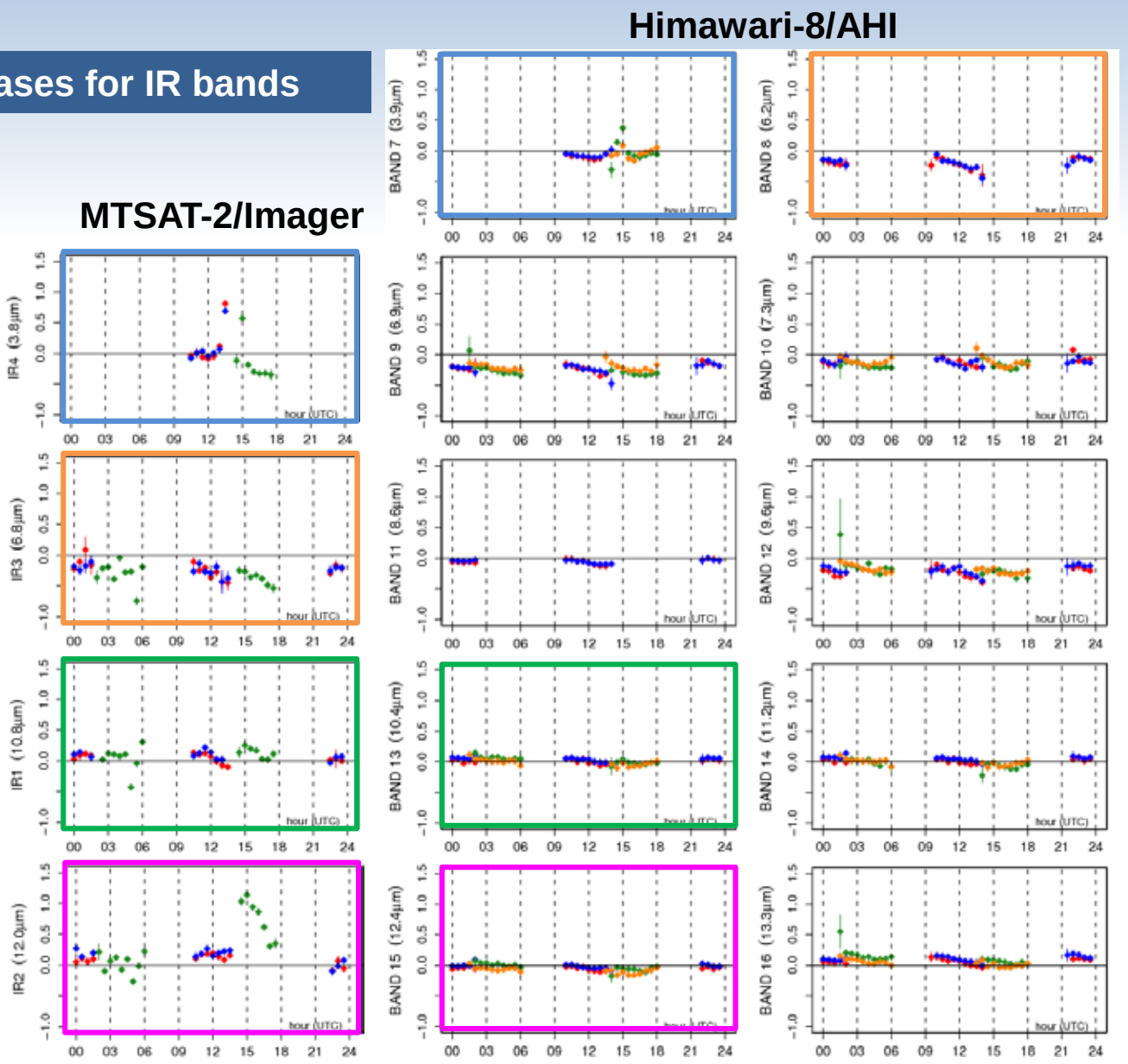


×Daily value × 29 days of statistics

Time dependence of TB biases for IR bands

- Monthly statistics for February 2016
- No significant diurnal variation in Himawari-8
- Root cause of small variations in Himawari-8 is under investigation

Reference sensors:
Metop-A/IASI
Metop-B/IASI
Aqua/AIRS
S-NPP/CrIS



Contents

- Introduction to Himawari-8
- Calibration and Validation for IR Bands
- **Image Navigation and Registration (INR)**
  - **Ground processing system updates of 9 March 2016**
- L3 SST and Cloud Mask

Himawari-8 Ground Processing System
Updates of 9 March 2016

1. Improvement of the band-to-band co-registration process for IR bands

   relative misalignment between sensor bands

2. Improvement of the resampling process
3. Implementation of a coherent noise reduction process
4. Bug fix for HSD header information

The updates significantly improved Himawari-8 image quality

Ground Processing System Update – Band-to-band Co-registration Process for IR Bands

- **Old process for estimation of co-registration correction:**
  - ü Based on co-registration errors from pattern matching during **in-orbit testing**
  - ü VNIR and Band 7 (3.9μm): optimized using AHI temperature data
  - ü IR except Band 7: constant
- **New process applied to IR bands 7, 8, 9, 10, 11, 12 and 15:**
  - ü Based on co-registration errors of previous full-disk observing cycle w/o optimization
  - ü Change of pattern matching method and bug fix for domain determination.
  - ü Significant error reduction (e.g., ~0.2km -> ~0.02km for band 15)
    - The new process would also be applied to other bands in the future.

Band-to-band co-registration errors w.r.t. band 13 (10.4 μm) observation

BAND	01	02	03	04	05	06
BEFORE	0.1977	0.1996	0.3144	0.2074	0.4048	0.1979
AFTER	0.2171	0.2157	0.3408	0.2297	0.4044	0.1925

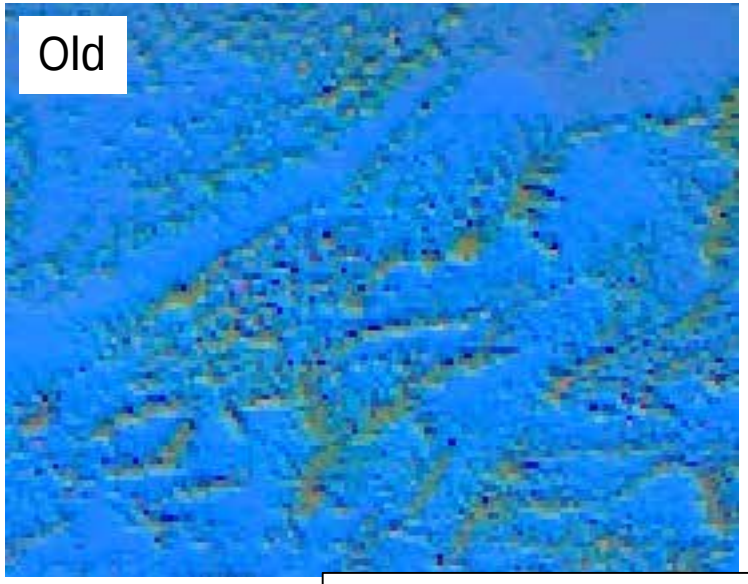
Units in IR pixel size
(1pixel = 2km at SSP)

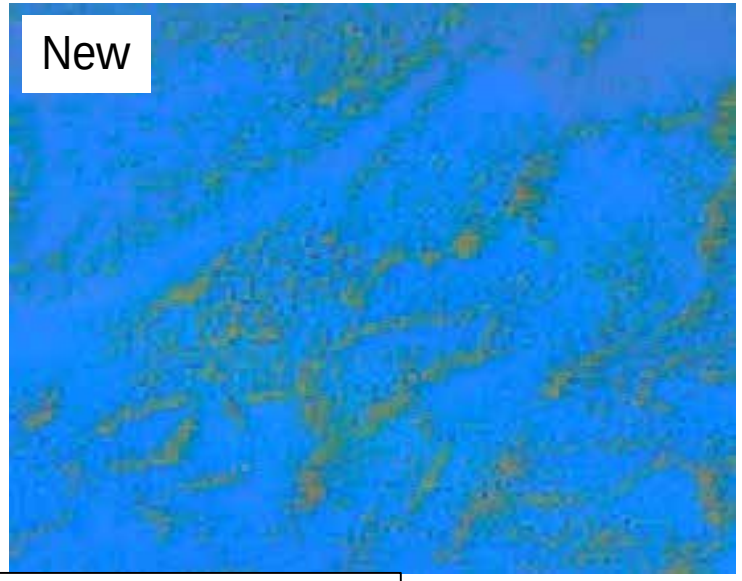
BAND	07	08	09	10	11	12	13	14	15	16
BEFORE	0.1162	0.1284	0.2159	0.2256	0.2756	0.1803	-	0.1168	0.1130	0.0159
AFTER	0.0134	0.0084	0.0091	0.0104	0.0115	0.0098	-	0.1194	0.0081	0.0159

- BEFORE and AFTER: averages of all full-disk data for 4-8 and 10-14 March 2016
- VIS/NIR bands: daytime averages (21:00-08:50 UTC)

Ground Processing System Update – Resampling Process

- **Old process**
  - ü Unnatural spotted pixels in band-to-band differential imagery at the edge of clouds
  - ü Caused by inadequate resampling and large band-to-band co-registration errors
- **New process (refined resampling parameters)**
  - ü Band-to-band radiance inconsistency significantly reduced.
  - ü New band-to-band co-registration process also contributes to this improvement





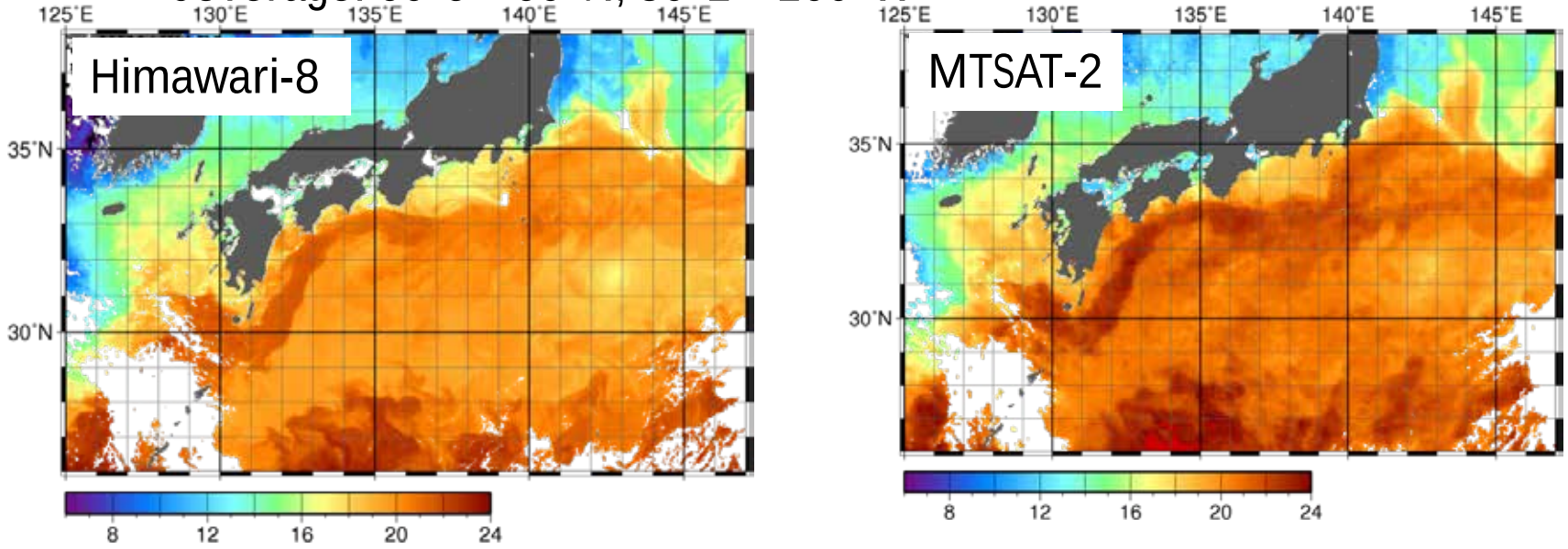
Dust RGB image at 00:10 UTC on 9 December 2015
Color composite: 12.4-10.4μm, 10.4-8.6μm, 10.4μm

Contents

- Introduction to Himawari-8
- Calibration and Validation for IR Bands
- Image Navigation and Registration (INR)
  - ground processing system updates of 9 March 2016
- **L3 SST and Cloud Mask**

Himawari-8 L3 SST

- JMA's Meteorological Satellite Center produces Himawari-8 L3 SST data
- Same SST retrieval algorithm as used by JAXA based on a quasi-physical algorithm (Kurihara et al. 2016)
- Band 11 (8.6μm), Band 13 (10.4μm) and Band 14 (11.2μm)
- Cloud mask based on JMA's Fundamental Cloud Product for Himawari-8
- Hourly, 0.02° horizontal resolution (0.04° for MTSAT-2)
- Coverage: 60°S – 60°N, 80°E – 160°W



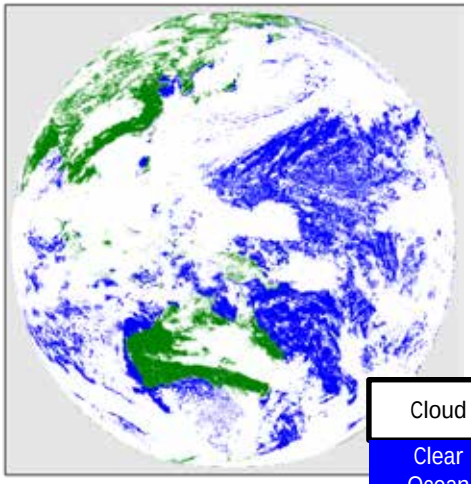
SST composite images for daytime on 17 Mar. 2016

Fundamental Cloud Product (FCP)

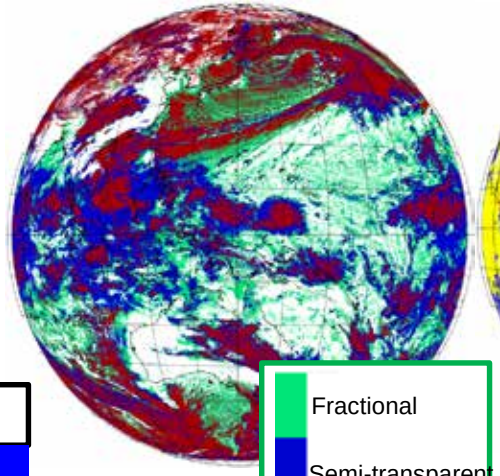
- Parameters: Cloud Mask, Type, Phase, and Top Height
- FCP is used for retrieval of other products within JMA/MSC
- Algorithm is based on NWC-SAF and NOAA/NESDIS
- HSD-pixel basis (2km)
- Algorithm documents published in March 2016

  Imai and Yoshida (2016), http://www.data.jma.go.jp/mscweb/technotes/msctechrep61-1.pdf

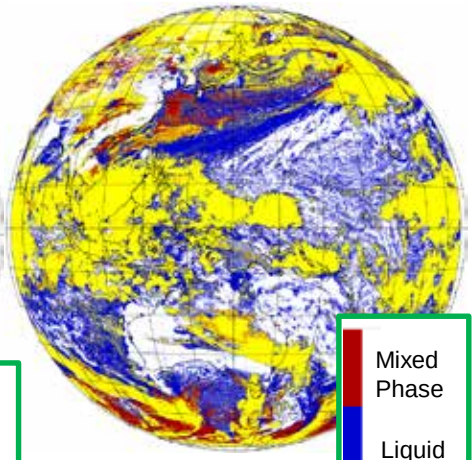
Cloud Mask



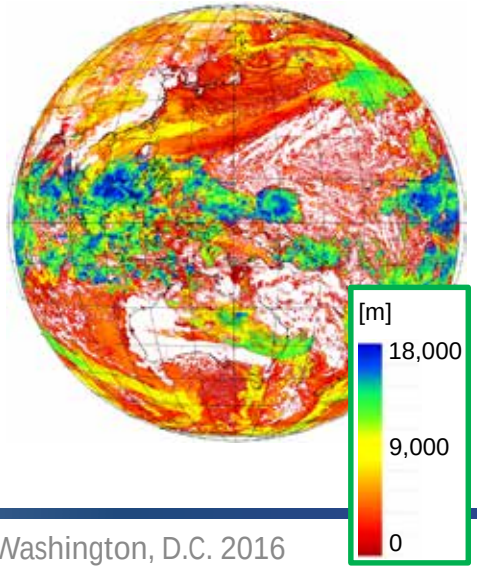
Type



Phase

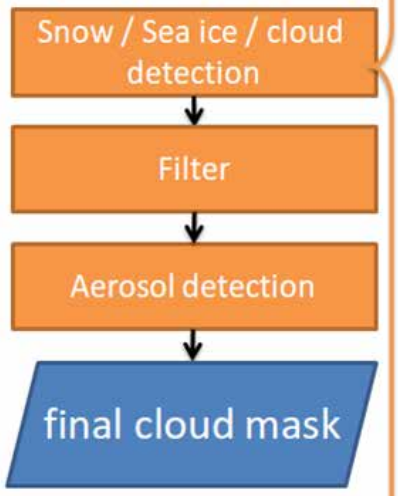


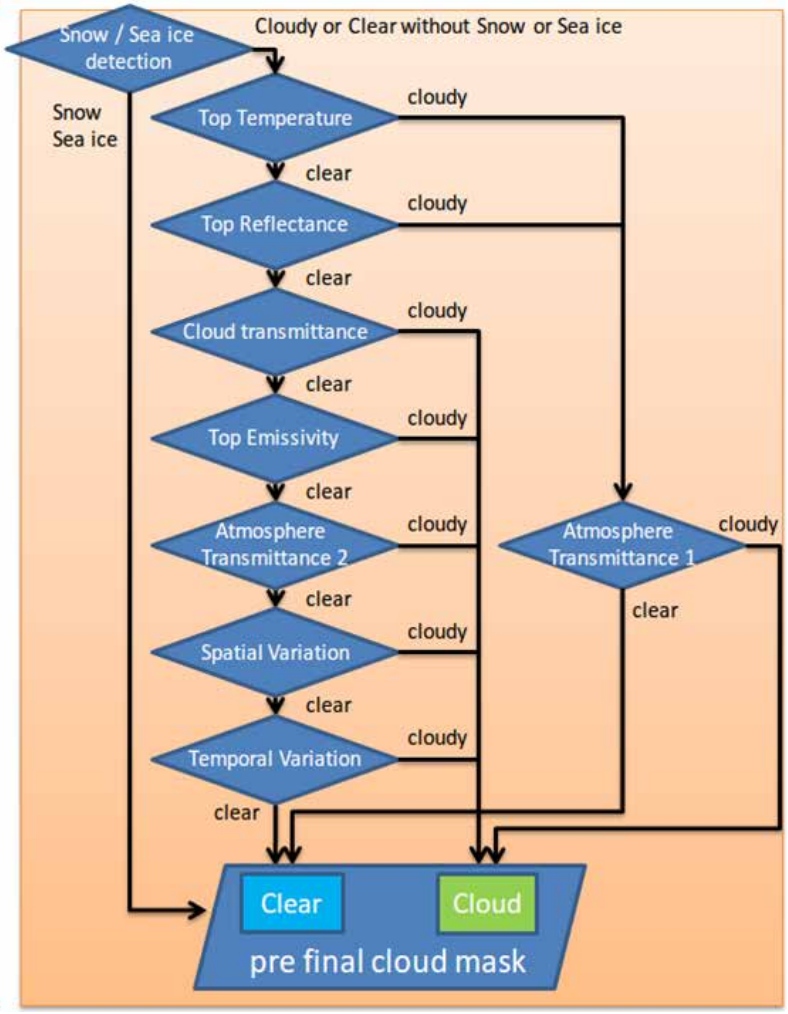
Cloud Top Height



Cloud Mask Algorithm

Clear/Cloudy status is determined from a variety of threshold tests.



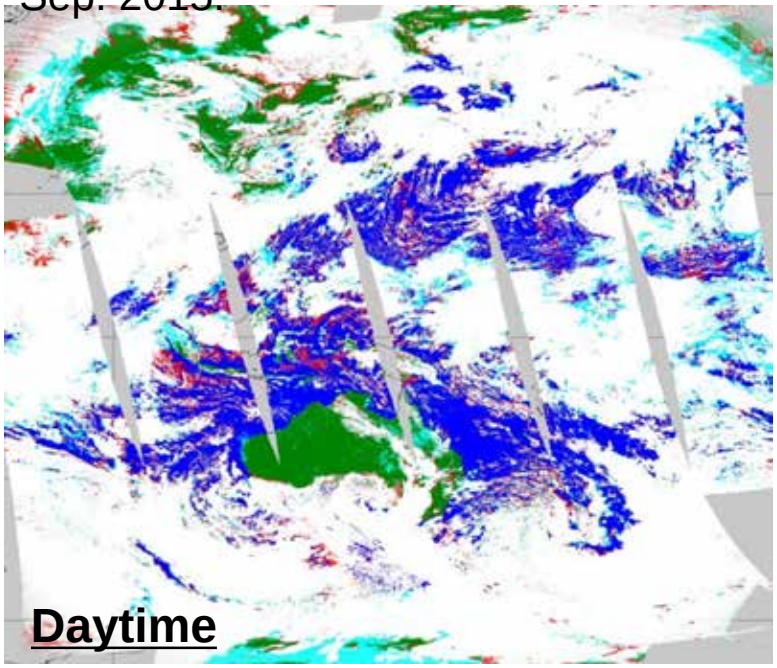


Thresholds are modified using offsets determined from comparison with a MODIS cloud mask product

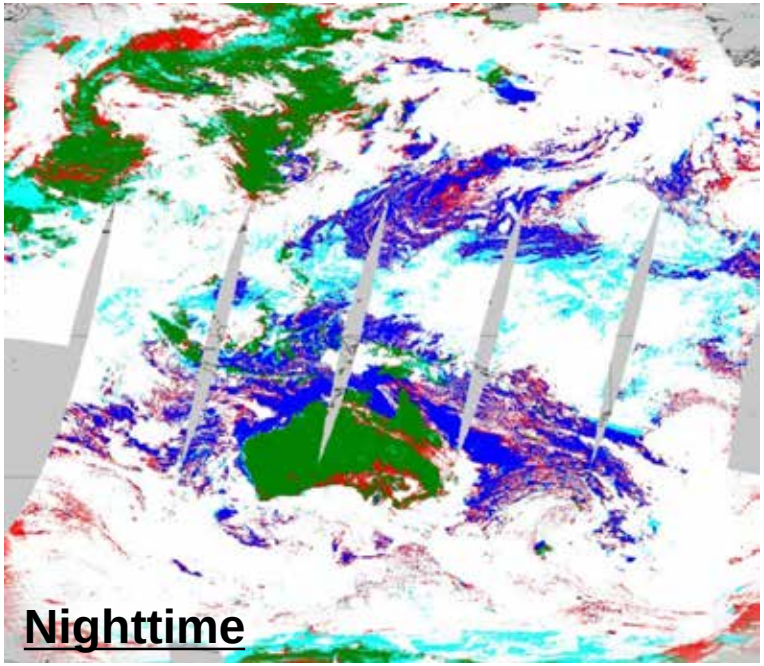
Cloud Mask Validation

Comparison with MODIS product

The FCP cloud mask hit rate compared with that of the MODIS product (MYD35_L2, C6) was about 85% for the two weeks leading up to 4 Sep. 2015. The daytime hit rate was slightly higher than the corresponding nighttime figure. Although false detections of cloud (cyan) was observed in the tropical region, this was corrected via offset adjustment on 6 Sep. 2015.



Daytime



Nighttime

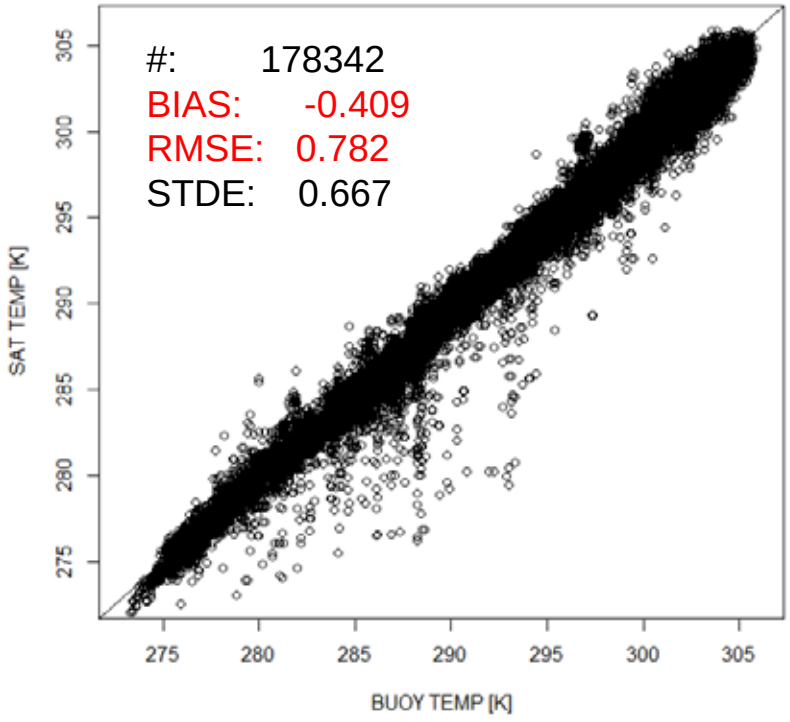
Clear(sea)	Clear(land)	AHI: Cloudy MODIS: Clear	AHI: Clear MODIS: Cloudy	Cloudy

Yoshida et al., An Introduction of Himawari-8 Cloud Products, Poster Presentation at the Sixth AOMSUC Conference, November 2015, Tokyo. [Available online at MSC website]

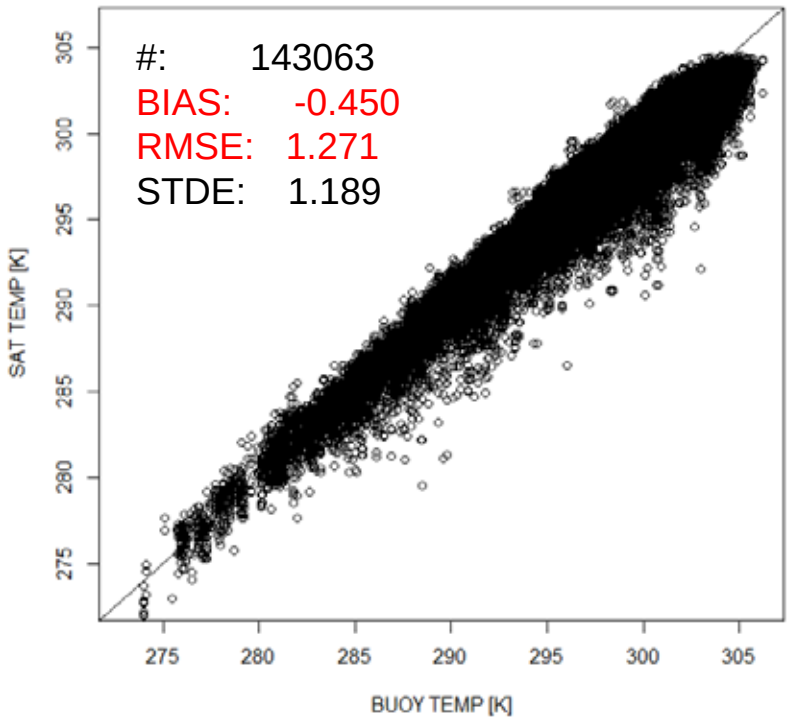
Himawari-8 SST Validation (March 2016)

- Match-up of satellite and buoy SSTs with time differences within 1.25 hours and spatial distances of less than 10km from March 1 to 31 (until March 24 for MTSAT-2).
- Himawari-8 SST data were superior to those of MTSAT-2.

Himawari-8



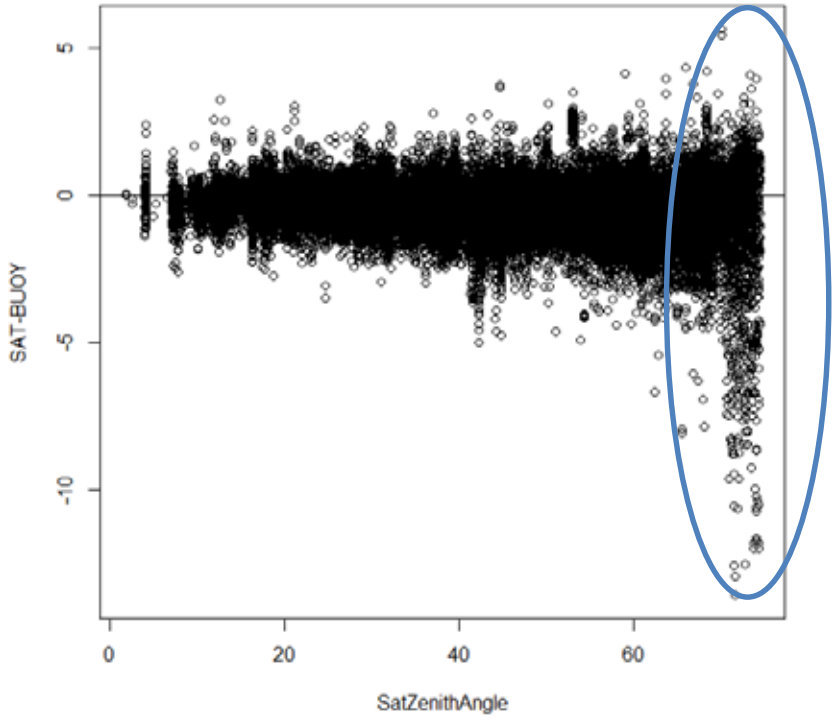
MTSAT-2



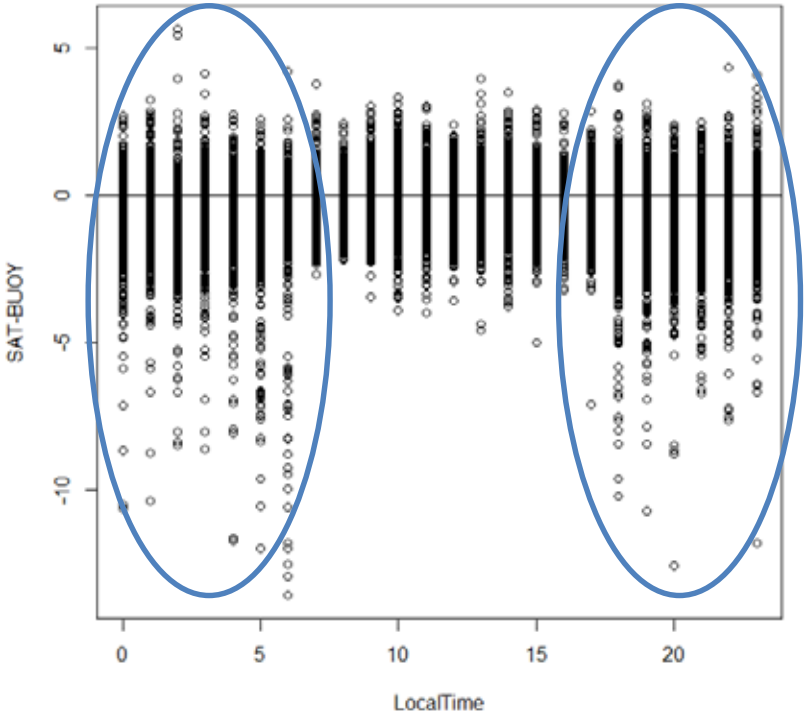
Himawari-8 SST Validation (March 2016)

Large negative bias for satellite zenith angles exceeding 70 degrees and for night time

Bias vs. satellite zenith angle

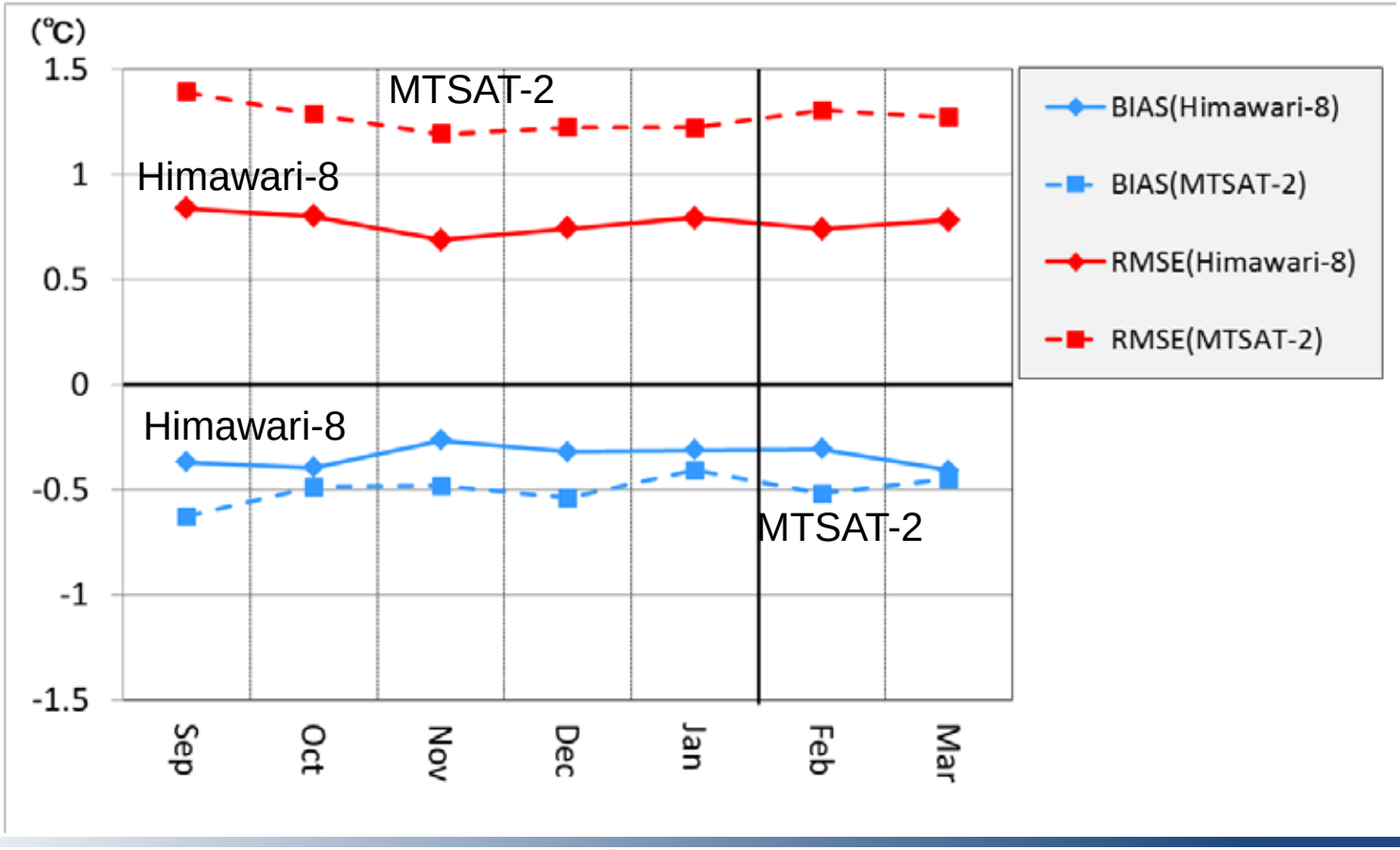


Bias vs. local time



Himawari-8 SST Validation (Monthly Statistics)

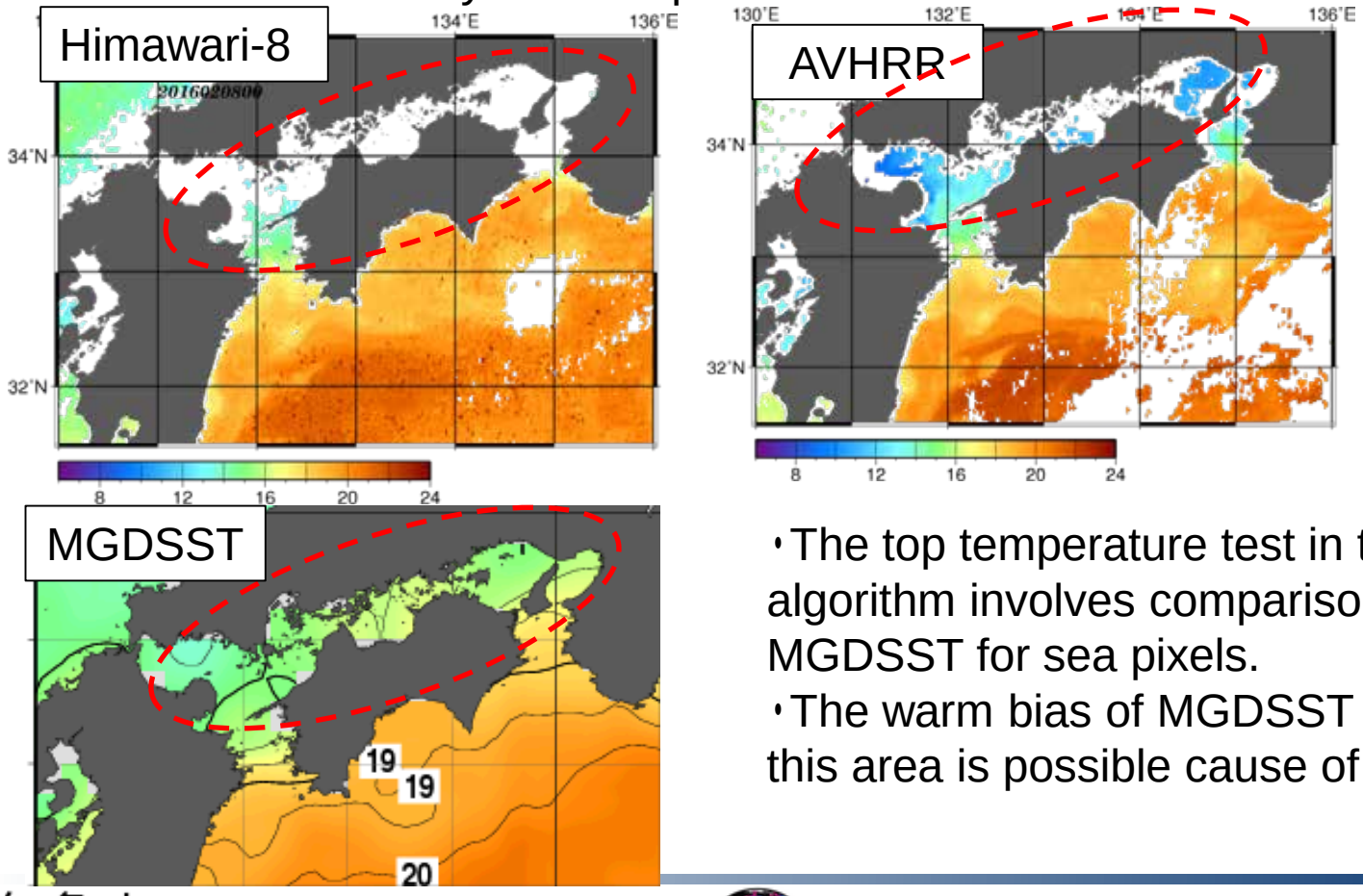
Bias：-0.3～-0.4℃, RMSE: 0.7～0.8℃ for Himawari-8
Bias: -0.4～-0.6℃, RMSE: 1.2～1.4℃ for MTSAT-2
The results show significant improvement over those from MTSAT-2.



Problems with Cloud Screening

・Cloud is often falsely detected over the Seto Inland Sea, especially in winter (see the figures below).
・Cloud is sometimes falsely detected in areas with large SST gradients.

daytime composite for 02/08/2016



・The top temperature test in the cloud mask algorithm involves comparison with MGDSST for sea pixels.
・The warm bias of MGDSST in winter for this area is possible cause of these issues.

Summary

- **Introduction**
  - **Himawari-8 started operation in July 2015**
  - **AHI: more spectral bands (16 bands), double the spatial resolution (4 ⇒ 2km for IR), more frequent observation**

- **Calibration and Validation for IR Bands**
  - **Brightness temperature biases: very stable – less than 0.2K for standard scenes, no significant diurnal variation**

- **Image Navigation and Registration (INR)**
  - **Ground processing system updates of 9 March 2016**
    - **significant improvement in image quality**

- **L3 SST and Cloud Mask**
  - **Same SST retrieval algorithm as used by JAXA; different cloud mask method (using JMA's Fundamental Cloud Product)**
  - **Hourly, 0.02° horizontal resolution**
  - **Himawari-8 SST vs. buoys: Bias: -0.3 – -0.4℃; RMSE: 0.7 – 0.8℃**

BACKUP

Introduction

- Himawari-8 started operation on 7 July 2015
- AHI (Advanced Himawari Imager) on Himawari-8: new generation GEO imager
  - ü 3 VIS, 3 NIR and 10 IR bands
  - ü Full disk observing cycle: 10 min., rapid scanning within 2.5 min. / 30 sec. intervals

Band	Himawari-8/AHI			GOES-R/ABI		MTSAT-2/IMAGER	
	Wave length	Spatial resolution	Bit depth	Wave length	Spatial resolution	Wave length	Spatial resolution
1	0.47 μm	1km	11	0.47 μm	1km		
2	0.51 μm	1km	11				
3	0.64 μm	0.5km	11	0.64 μm	0.5km	0.68 μm	1km
4	0.86 μm	1km	11	0.86 μm	1km		
				1.38 μm	2km		
5	1.6 μm	2km	11	1.61 μm	1km		
6	2.3 μm	2km	11	2.26 μm	2km		
7	3.9 μm	2km	14	3.90 μm	2km	3.7 μm	4km
8	6.2 μm	2km	11	6.15 μm	2km	6.8 μm	4km
9	6.9 μm	2km	11	7.00 μm	2km		
10	7.3 μm	2km	12	7.40 μm	2km		
11	8.6 μm	2km	12	8.50 μm	2km		
12	9.6 μm	2km	12	9.70 μm	2km		
13	10.4 μm	2km	12	10.3 μm	2km	10.8 μm	4km
14	11.2 μm	2km	12	11.2 μm	2km		
15	12.4 μm	2km	12	12.3 μm	2km	12.0 μm	4km
16	13.3 μm	2km	11	13.3 μm	2km		

Inter-calibration and Vicarious Calibration for VIS/NIR Bands

A) Ray-matching with reference to S-NPP/VIIRS

B) Comparison with simulated TOA radiance based on a radiative transfer model

C) Comparison with deep convective cloud measurements by Aqua/MODIS

D) Comparison with simulated lunar irradiance using GIRO (GSICS Implementation of the ROLO model)

C) and D) are under implementation

Validation of VNIR calibration slopes using RT simulation and Ray-matching approach

- Improvement of accuracy after updating calibration slopes based on SD observation
  - ü +6.1% bias for band 5, -4.3 % bias for band 6 based on ray-matching validation
  - ü Root cause is under investigation

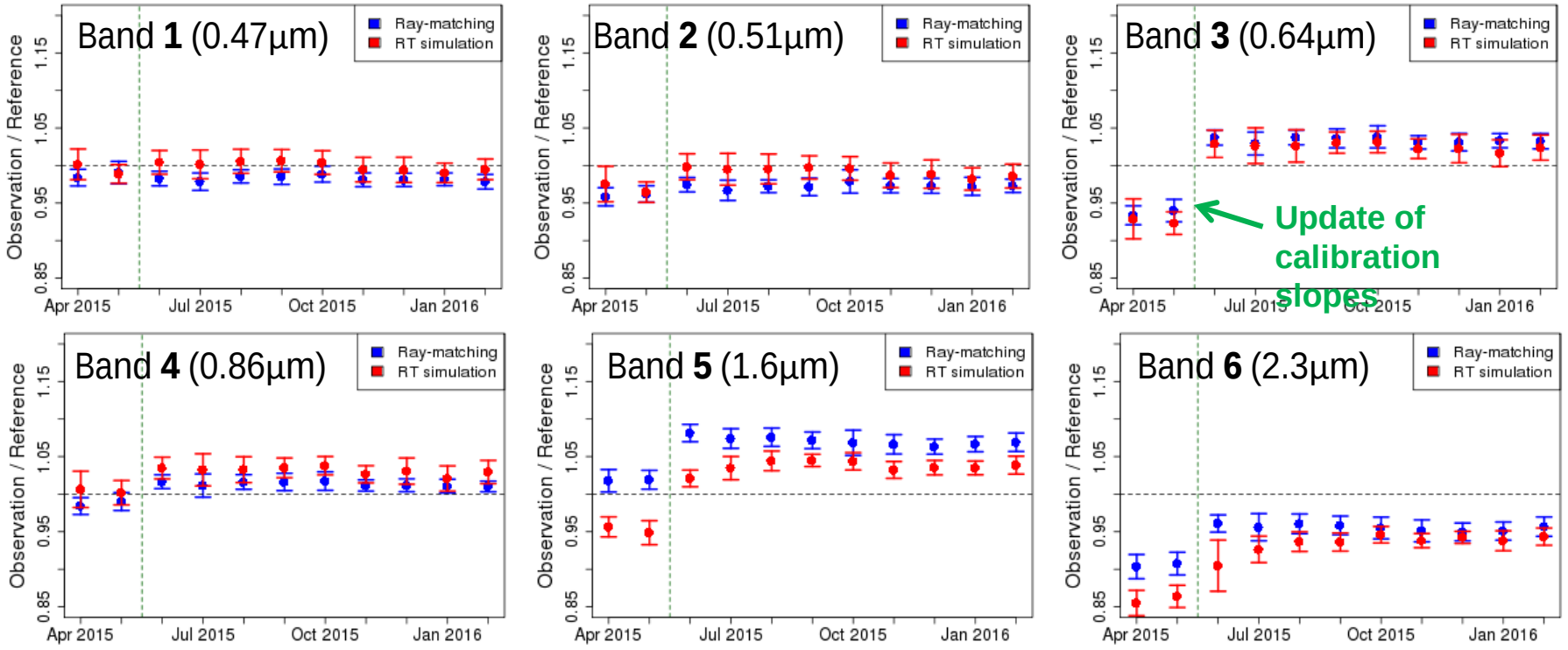


Image Navigation and Registration (INR)

- Orbit determination: based on ranging data
- Satellite attitude determination involves the use of star trackers and gyros
  - ü Refined using landmark analysis based on pattern matching for coastlines
- Residual image navigation error in Himawari Standard Data (L1B equiv. data) is validated using landmark analysis

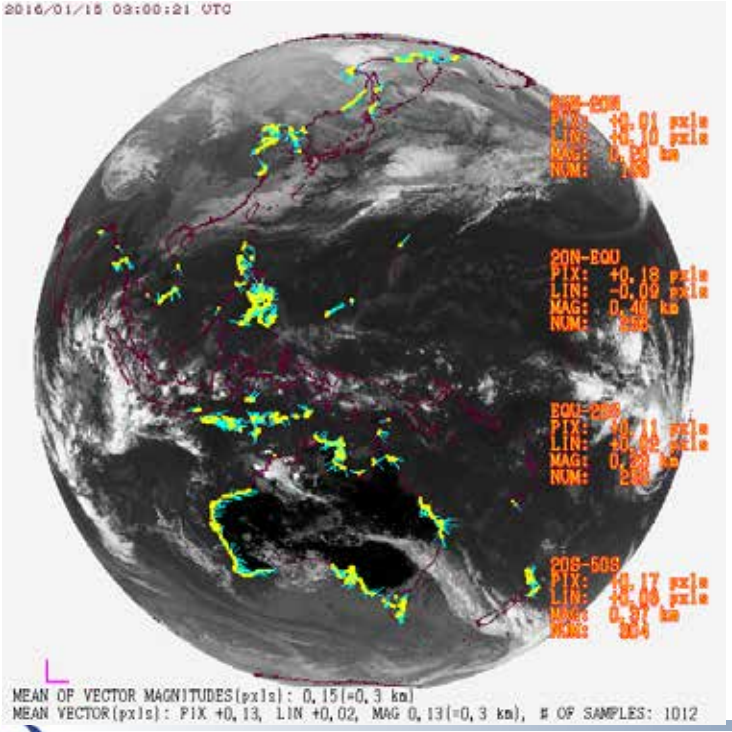


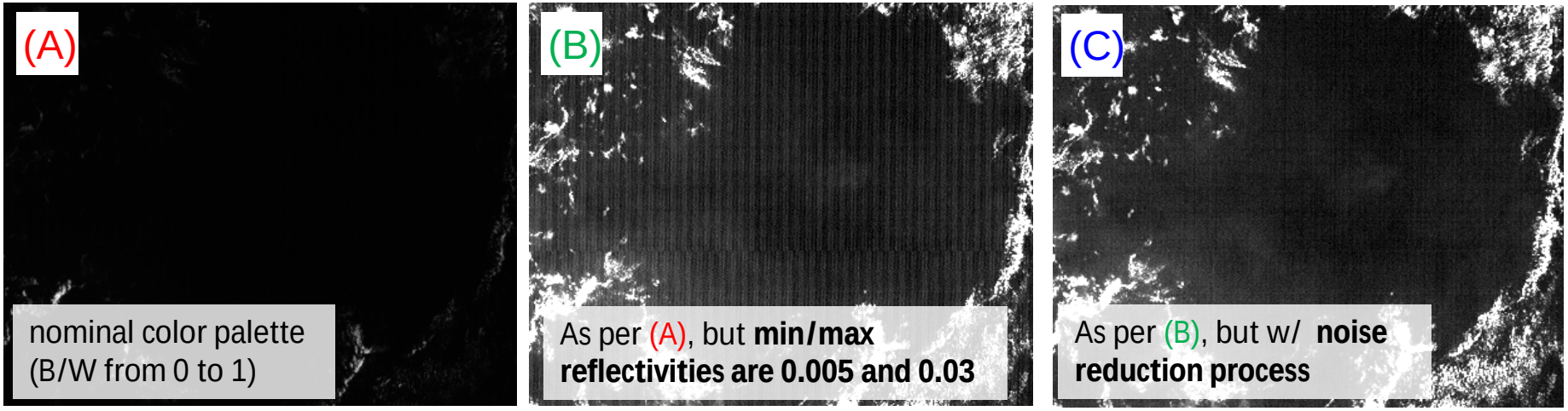
Image navigation error

- Usually less than 0.5 IR pixels (approx. 1 km at SSP)
- The error occasionally/provisionally becomes larger in the next full-disk observing cycle after station keeping maneuver and the timing of satellite eclipse
- Root cause: under-investigation

Ground Processing System Update – Coherent Noise Reduction Process

- **AHI sensor configuration creates coherent noise:**
  - ü Stripes perpendicular to the scan direction over low-radiance areas
  - ü E.g. cloud-free ocean in VIS/NIR, deep convective cloud in IR and deep space in all bands
- **Noise reduction module was applied to bands 1, 2, 4, 5, 6, 10, 11, 12, 13, 14 and 15**
  - ü Noise reduction parameters: based on deep-space observation and the Fourier transform
  - ü significant reduction of striping
  - ü The module was applied for band 7 on 18 June 2015

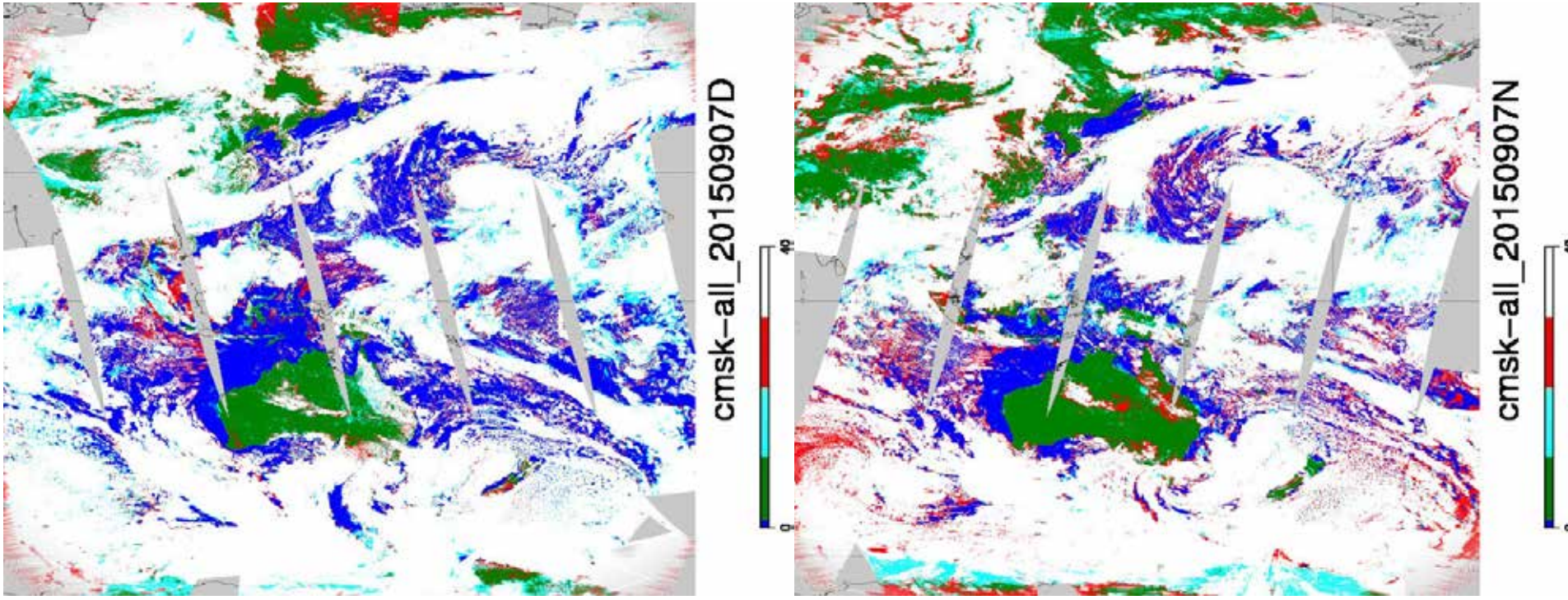
Band 4 (0.86 μm) reflectivity at 00:20 UTC on 25 November 2015



Validation of Cloud Mask

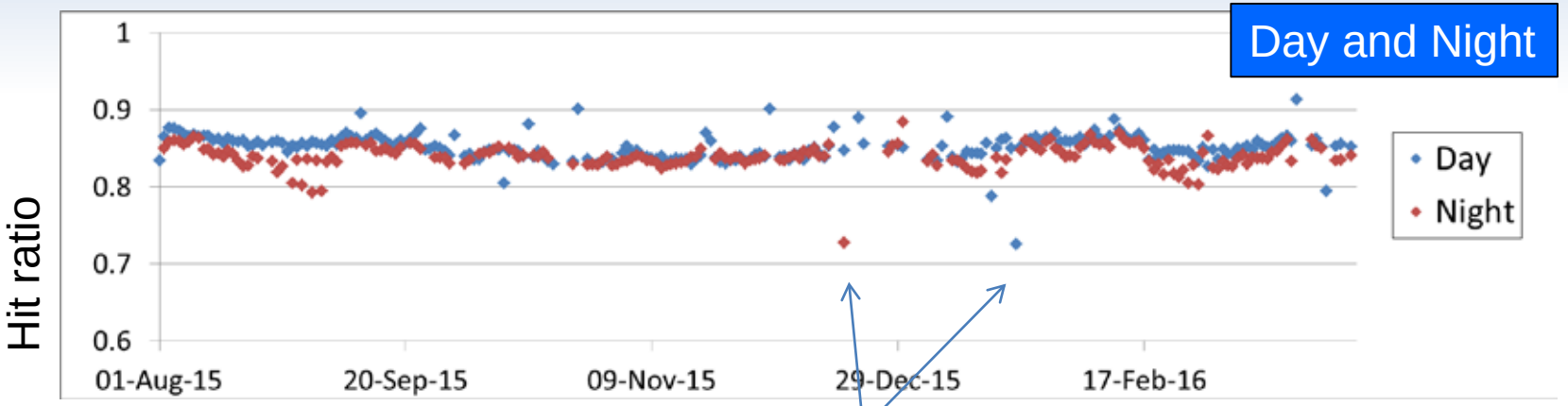
Comparison with MODIS product

7 Sep. 2015

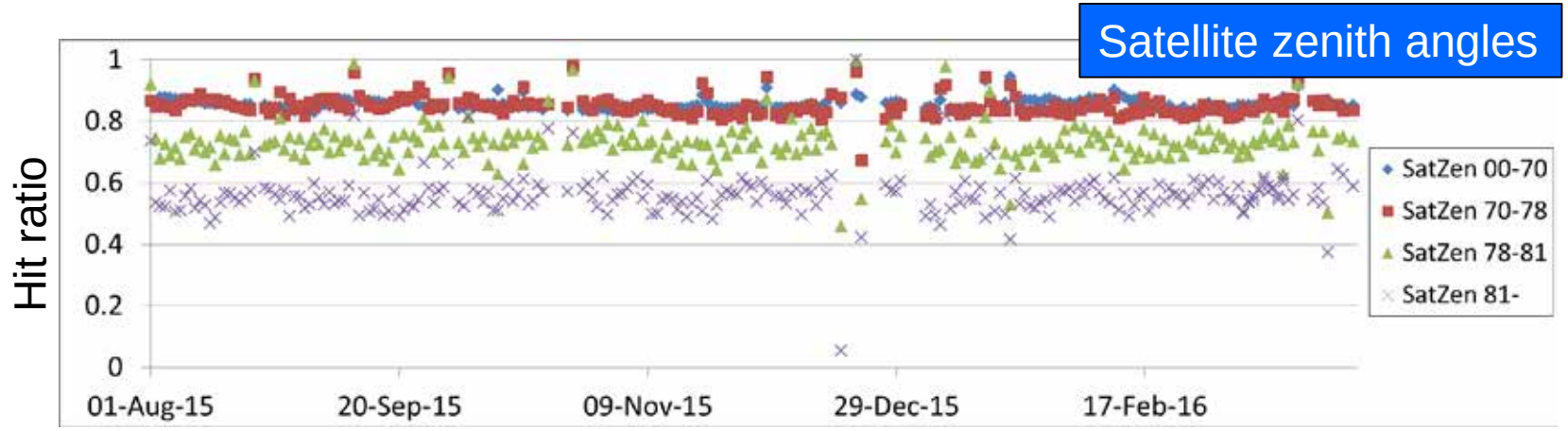


Cloud Mask comparison with MODIS

The FCP Cloud Mask has been compared with the MODIS cloud product (MYD03, C6)



Spike-shaped degradations are due to insufficient MODIS data at the time.



- ü Some 85%, slightly better for the daytime than the nighttime
- ü Degraded in the high satellite zenith angle area (> 78deg)

Hit Ratio Definition

		Actual cloud mask	
		Clear	Cloudy
CMP	Clear	A	B
	Cloudy	C	D

Hit ratio = (A + D) / (A + B + C+ D)

Clear hit ratio = A / (A + B)

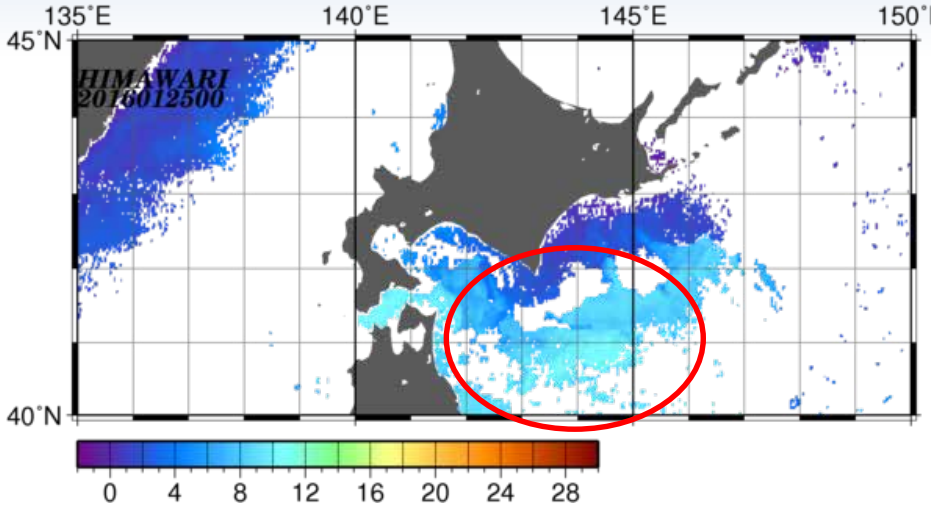
Cloudy hit ratio D / (C + D)

Table 9 Hit ratios of the CMP algorithm for MSG/SEVIRI data compared with those of the Aqua/MODIS product for each season (winter: 28 December 2011 – 10 January 2012; spring: 28 March – 10 April 2012; summer: 27 June – 10 July 2012; autumn: 27 September – 10 October 2012)

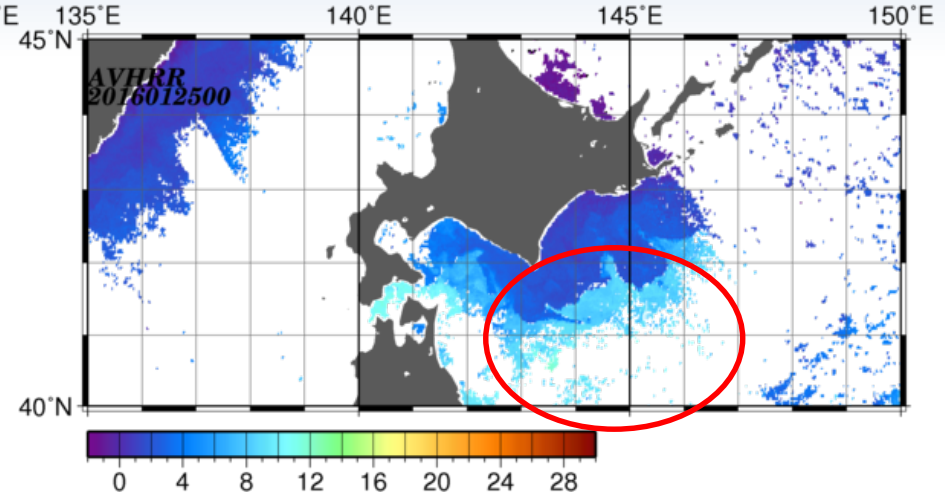
	Winter	Spring	Summer	Autumn	All
All region	0.86	0.85	0.85	0.85	0.85
Sea	0.86	0.85	0.85	0.86	0.85
Snow/Ice	0.86	0.81	0.72	0.86	0.81
Sand	0.87	0.86	0.86	0.89	0.87
Vegetation	0.86	0.84	0.83	0.83	0.84
Others	0.80	0.82	0.86	0.84	0.84

Problems with cloud-screening for SST

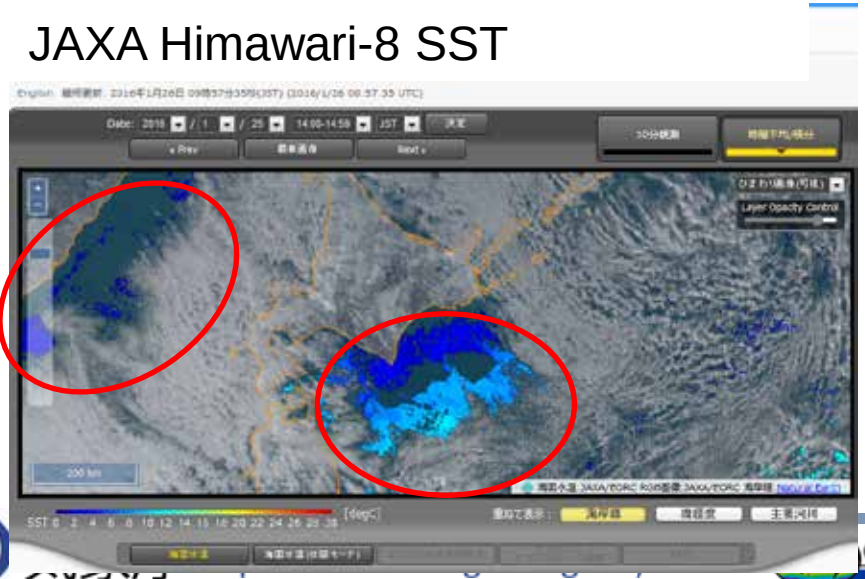
Himawari-8



AVHRR/NOAA19



JAXA Himawari-8 SST



issue of unnatural spotted pixels
-A case of SST -

- Unnatural spotted pixels are seen in the maximum-value composite image for HIMAWARI SST.
- New resampling and band-to-band co-registration process may reduce these unnatural spotted pixels.

daytime composite in 2016/02/08