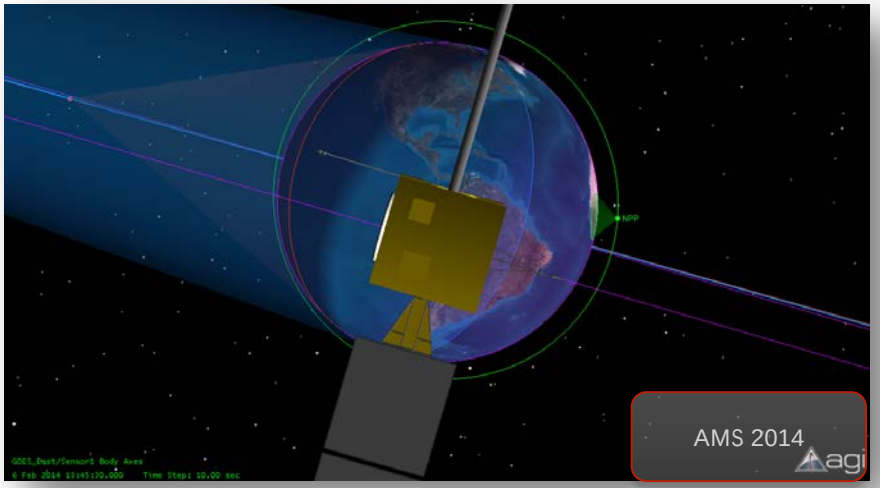
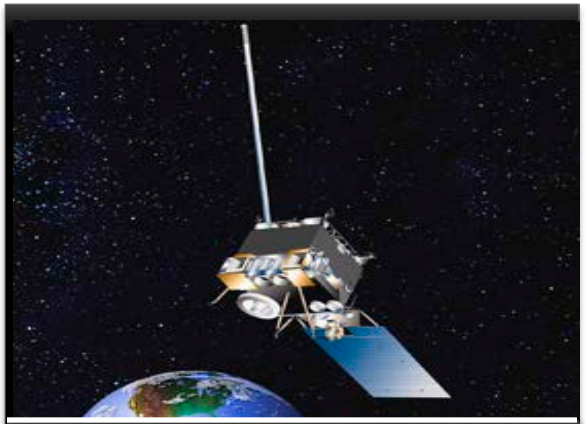


Using S-NPP VIIRS as a Transfer Radiometer to Inter-compare GOES-R ABI and Himawari-8 AHI

Francis Padula & Changyong Cao

NOAA/NESDIS/STAR

Heritage Environmental Satellites



NOAA: GOES

5 Band Imager	
Channels	Spatial Res.
1 Visible	1 km
4 Infrared	4 km

JMA: MTSAT

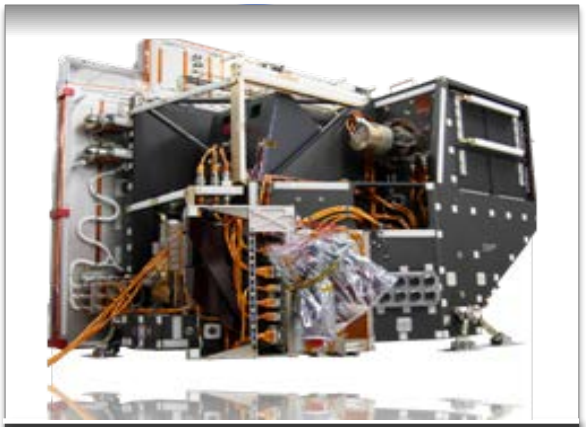
5 Band Imager	
Channels	Spatial Res.
1 Visible	1.25 km
4 Infrared	5 km

NOAA: POES

6 Band Imager	
Channels	Spatial Res.
1 Visible	1 km
2 NIR/SWIR	1 km
3 Infrared	1 km

Heritage instruments did not have on-board calibration sources in the Reflective Solar Bands (RSB)

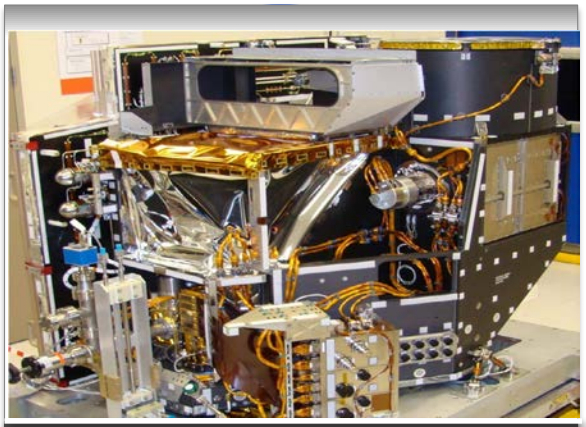
Next Generation of Environmental Satellites



NOAA: GOES-R ABI

16 Band Imager

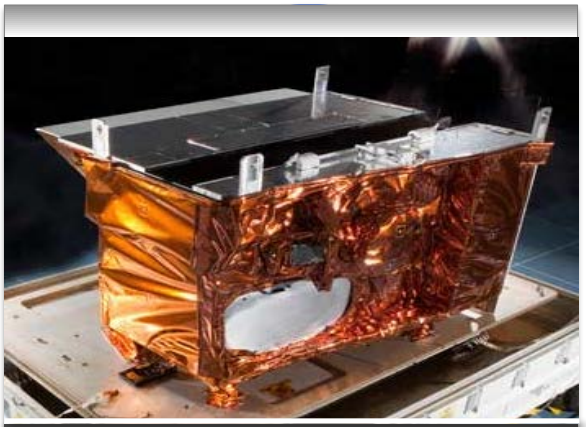
Spectral Region	Spatial Resolution
6 VNIR/SWIR	0.5,1 & 2 km
10 Infrared	2 km



JMA: Himawari 8 AHI

16 Band Imager

Spectral Region	Spatial Resolution
6 VNIR/SWIR	0.5,1 & 2 km
10 Infrared	2 km



NOAA: NPP VIIRS

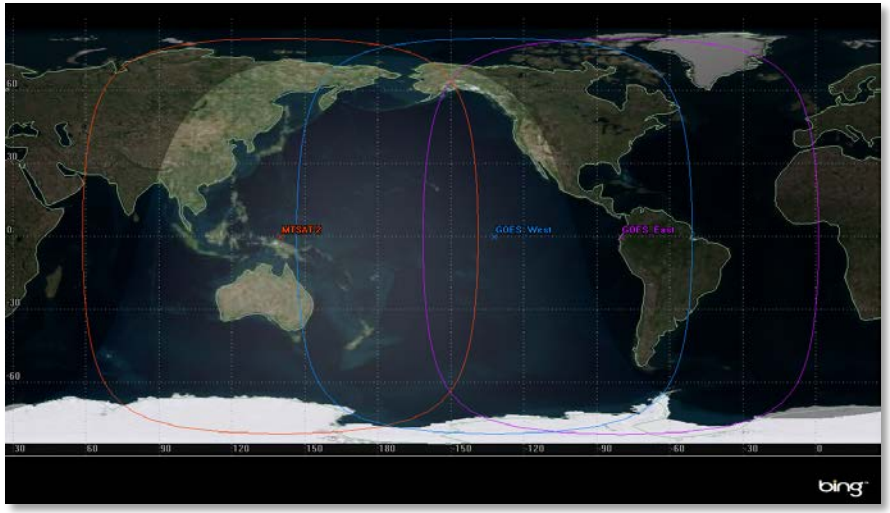
22 Band Imager

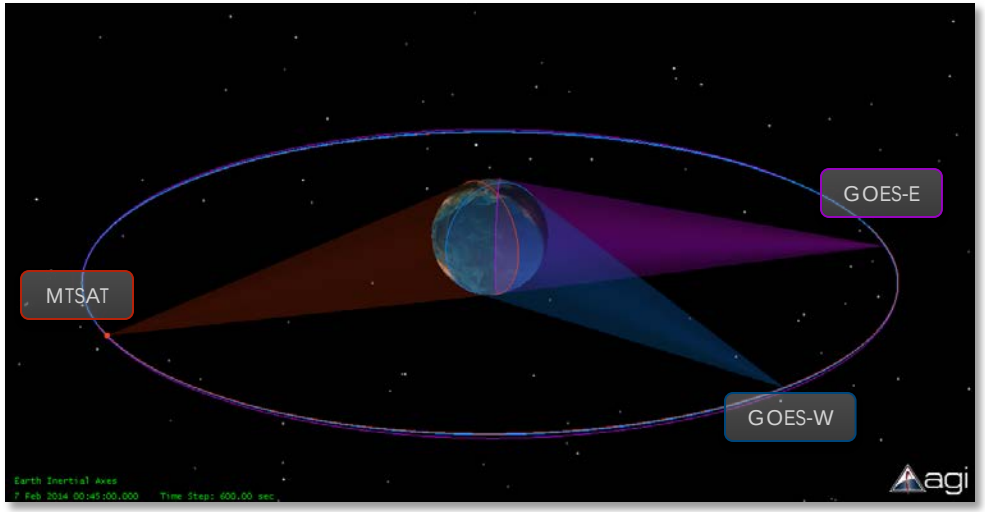
Spectral Region	Spatial Resolution
6 Visible	0.375/0.75 km
8 NIR/SWIR	0.375/0.75 km
DNB	0.75 km
7 Infrared	0.375/0.75 km

Significant enhancements in the Reflective Solar Bands (RSB) region, each instrument will have an on-board calibration source in the RSB

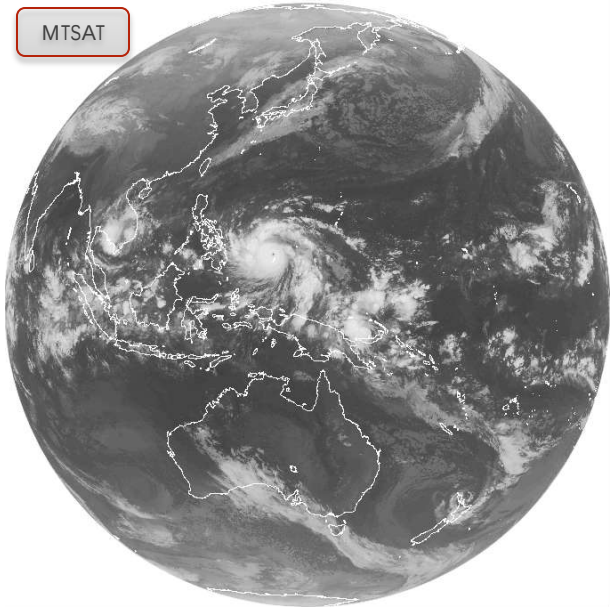
System Field of View

IR Data from (www.goes.noaa.gov): November 6, 2013 ~17:30 UTC

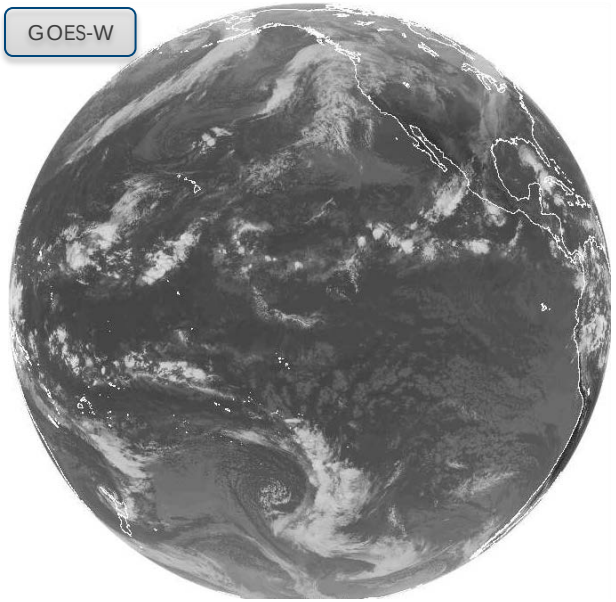




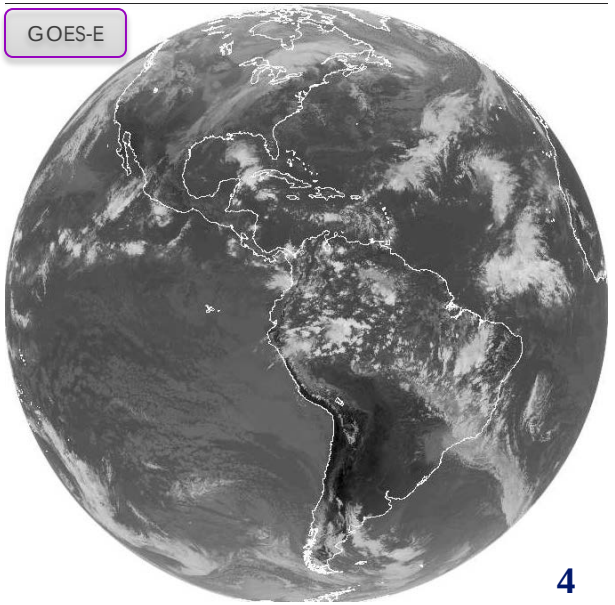
MTSAT



GOES-W

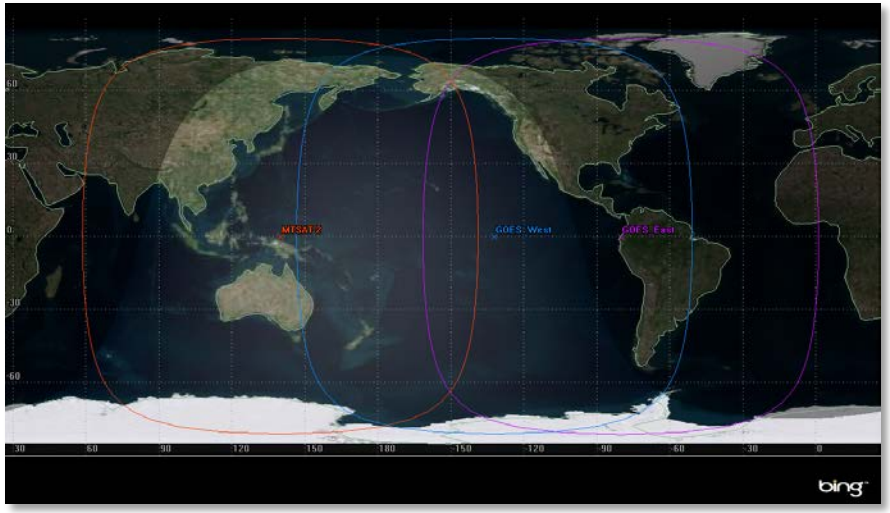


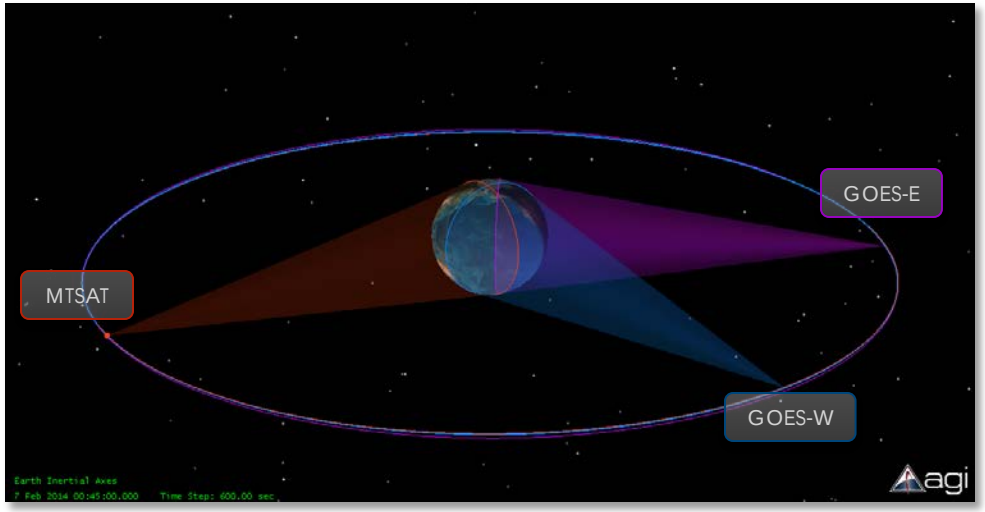
GOES-E

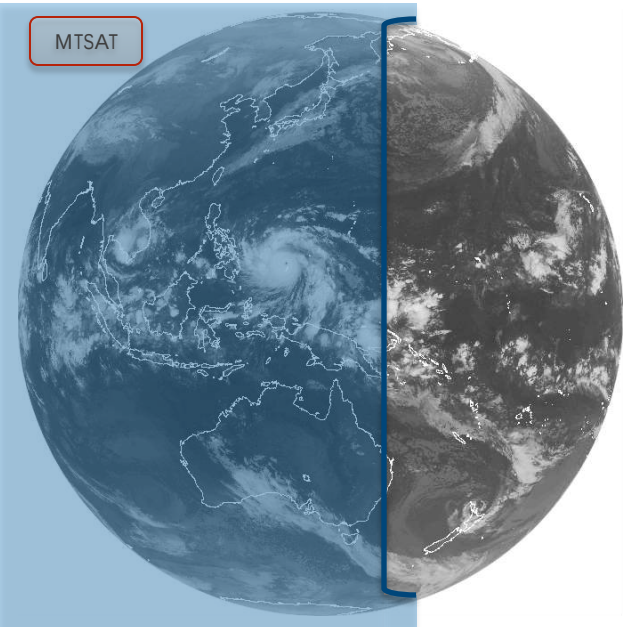


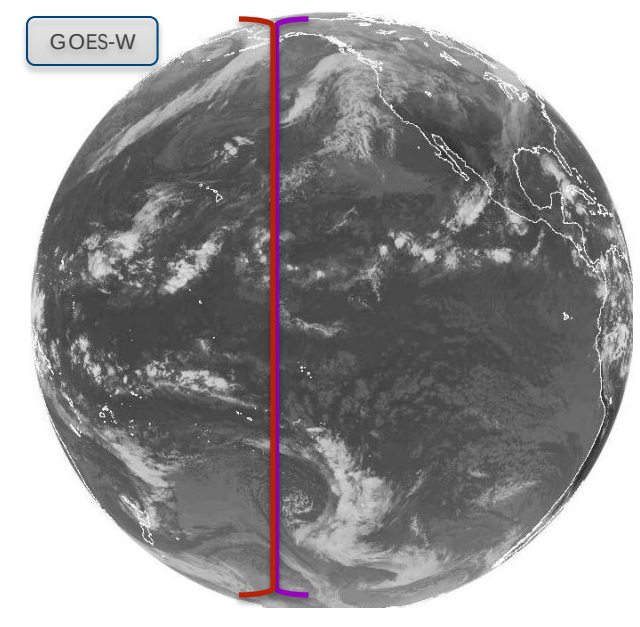
Overview of System Coverage

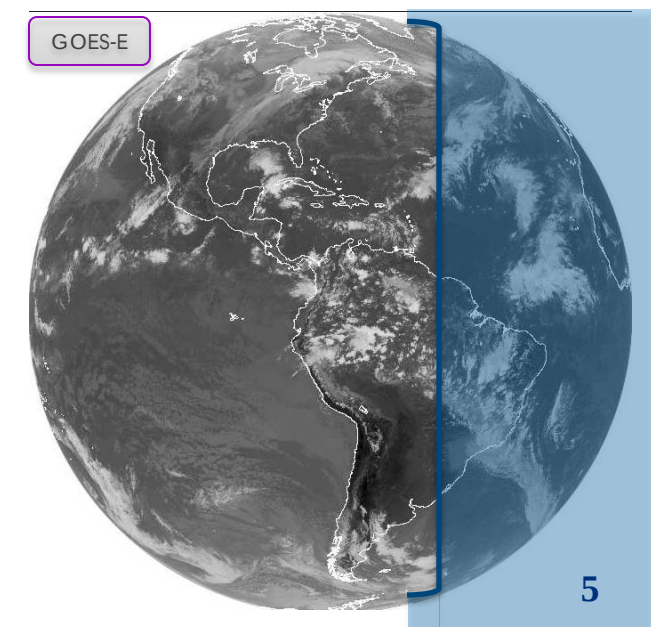
IR Data from (www.goes.noaa.gov): November 6, 2013 ~17:30 UTC



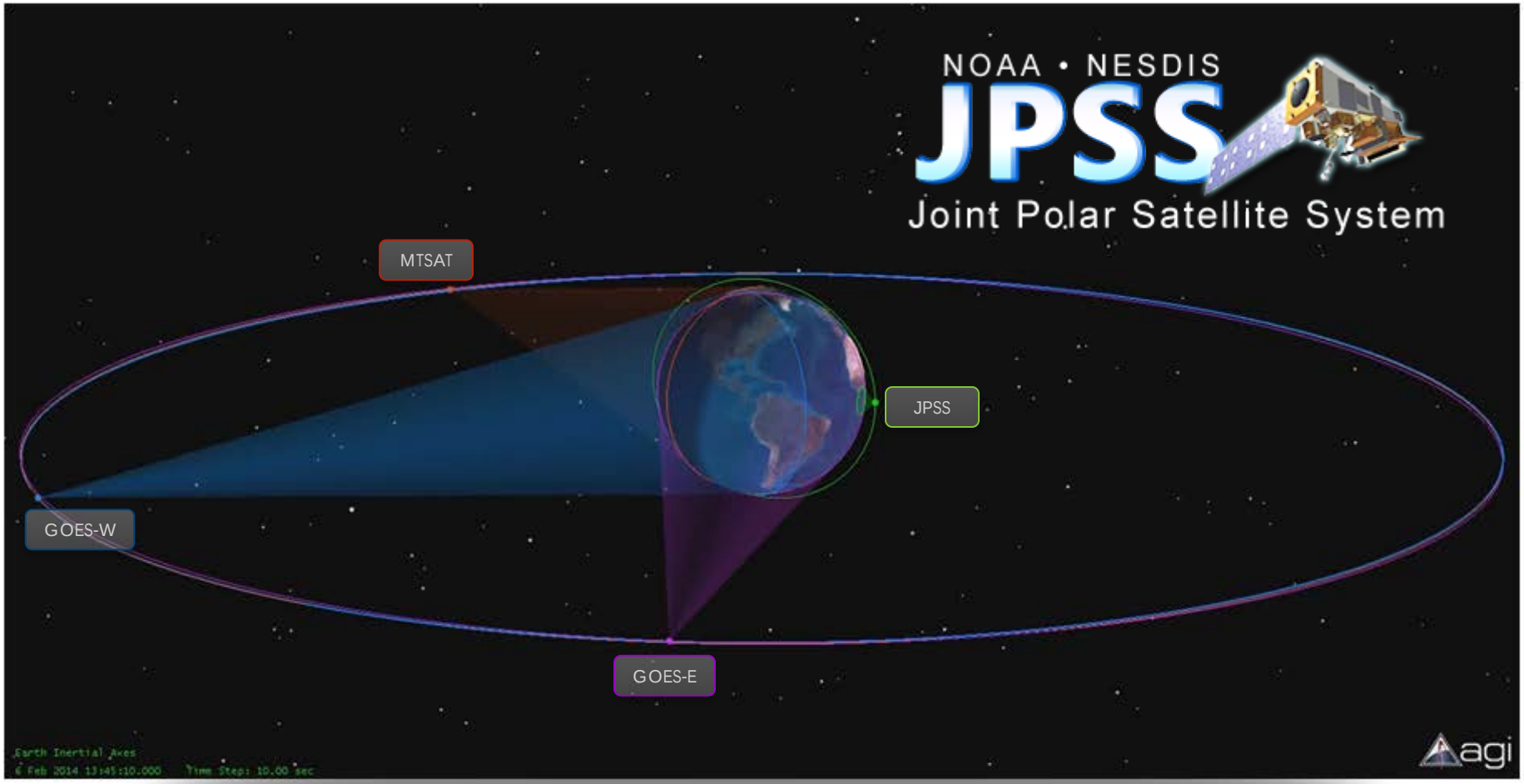




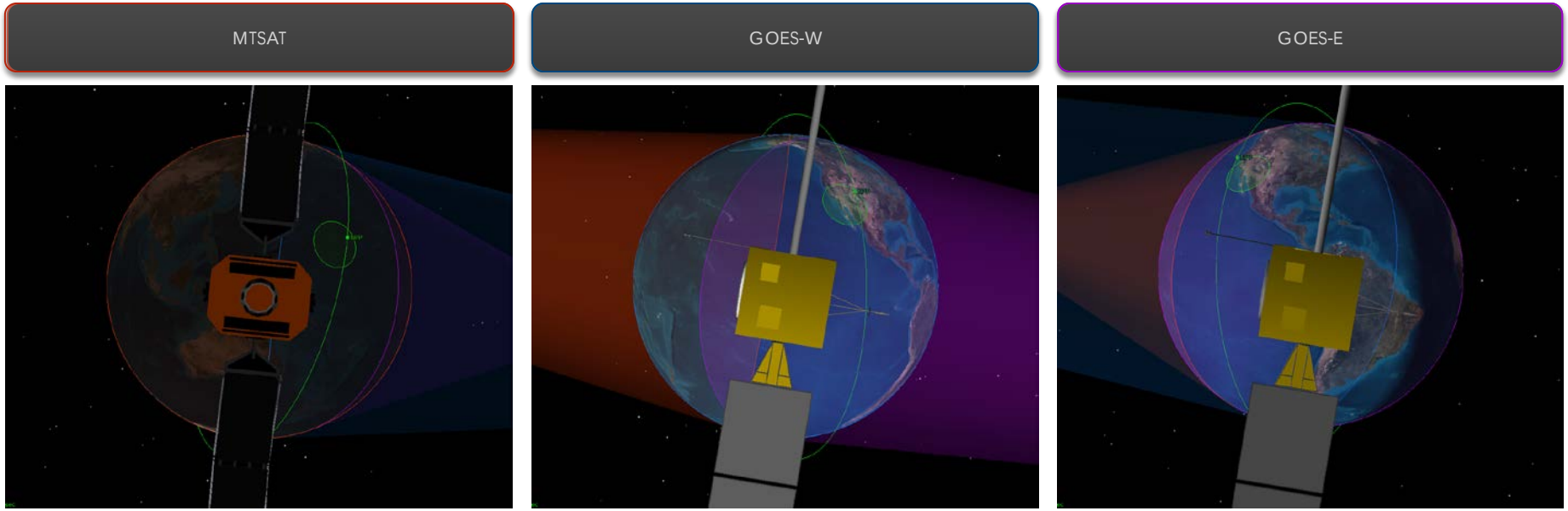




Bridging the Gap



Using Suomi NPP VIIRS as a Transfer Radiometer



- **Suomi NPP VIIRS has demonstrated to be a well calibrated radiometer:**
  - » Achieved Calibrated/Validated maturity status
  - » Absolute Radiometric Accuracy Requirements:
    - RSB: 2% absolute radiometric accuracy → GOES-R: 3-5 %
    - TEB: 0.13 K to 1.5 K (dependent upon channel) → GOES-R: 1 K
- **Suomi NPP VIIRS will be used as transfer radiometer to inter-compare GOES-R ABI and Himawari-8 AHI using Land, Ocean, and Cloud scenes**

Objectives

1. **Conduct a spectral comparison of GOES-R ABI and JMA Himawari 8 AHI:**
   - » Identify suitable channels for radiometric comparison between the two instruments (Qualitative and Quantitative)
   - » Characterize radiometric differences in identified channels

2. **Conduct a spectral comparison of Suomi NPP VIIRS, GOES-R ABI and JMA Himawari 8 AHI:**
   - » Identify suitable channels for radiometric comparison between each instrument (Qualitative and Quantitative)
   - » Identify bands best suited for on-orbit inter-comparisons with VIIRS to be used as a transfer radiometer

3. **Provide recommendations for post-launch Cal/Val risk mitigation and readiness using Suomi NPP as a transfer radiometer for the Geostationary missions**

Methodology

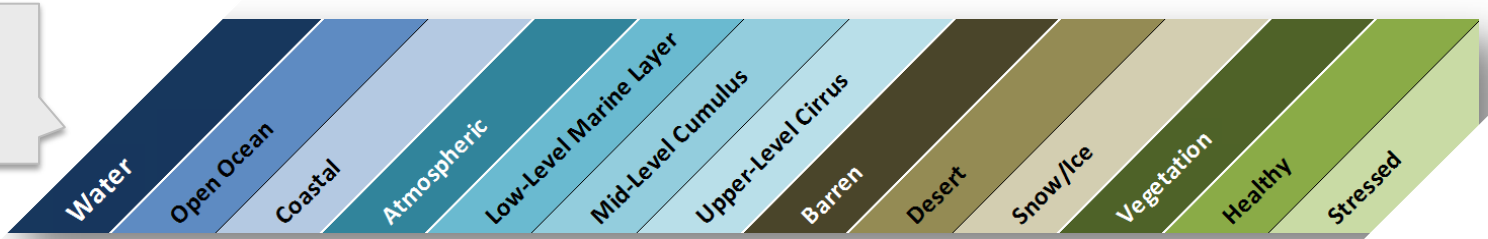
System SRFs:

- ABI version 2
  - https://cs.star.nesdis.noaa.gov/GOESRCWG/ABISRF
- AHI (released June 2012)
  - http://mscweb.kishou.go.jp/himawari89/space_segment/spsg_ahi.html
- VIIRS (IDPS version)
  - https://cs.star.nesdis.noaa.gov/NCC/SpectralResponseVIIRS

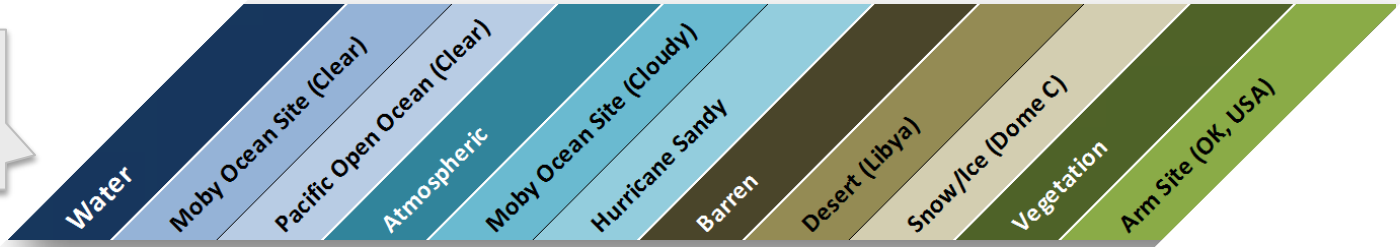
Typical Earth Target Hyperspectral Observations:

- **RSB:** Airborne Visible/Infrared Imaging Spectrometer (AVIRIS)
  - http://aviris.jpl.nasa.gov/alt_locator/
  - Data converted to “Top Of Atmosphere” Reflectance
- **TEB:** Infrared Atmospheric Sounding Interferometer (IASI)
  - http://www.class.ngdc.noaa.gov/saa/products/welcome

9 AVIRIS Targets Identified



7 IASI Targets Identified



Methodology

System SRFs:

- ABI version 2
  - https://cs.star.nesdis.noaa.gov/GOESRCWG/ABISRF
- AHI (released June 2012)
  - http://mscweb.kishou.go.jp/himawari89/space_segment/spsg_ahi.html
- VIIRS (provided by Northrop Grumman)
  - https://cs.star.nesdis.noaa.gov/NCC/SpectralResponseVIIRS

Typical Earth Target Hyperspectral Observations:

- **RSB:** Airborne Visible/Infrared Imaging Spectrometer (AVIRIS)
  - http://aviris.jpl.nasa.gov/alt_locator/
  - Data converted to "Top Of Atmosphere" Reflectance
- **TEB:** Infrared Atmospheric Sounding Interferometer (IASI)
  - http://www.class.ngdc.noaa.gov/saa/products/welcome

Data Processing:

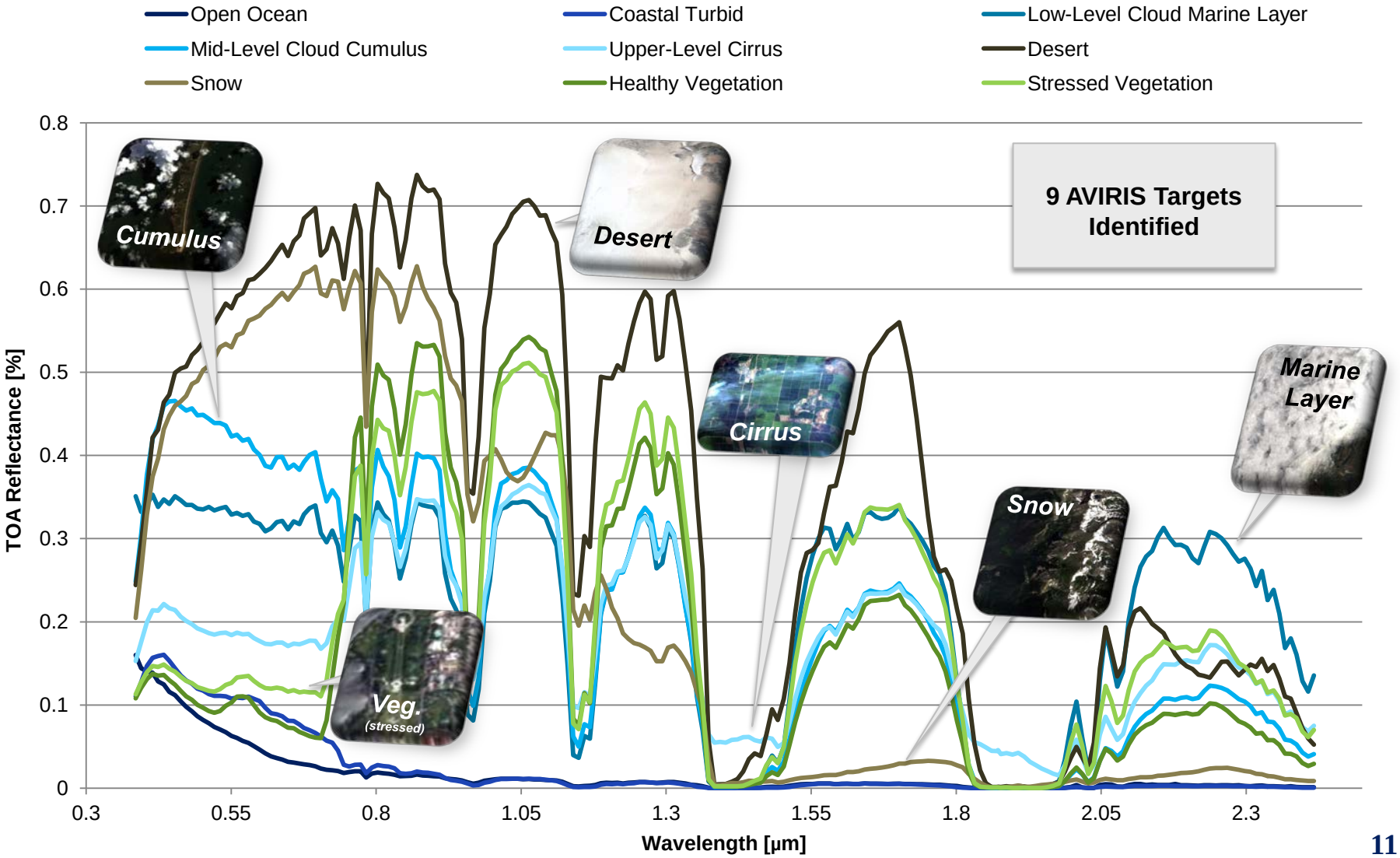
- Simulated channel effective spectral radiance (L_{eff}) was produced for each system:
  - Using the SRF data for each system and the corresponding typical earth targets [Eq 1]
- Simulated radiance for each system was analyzed:
  - **RSB:** percent difference in TOA Reflectance [%] used as metric of comparison
  - **TEB:** difference in effective temperature [K] used as metric of comparison

L sensor reaching radiance *Typical Earth Targets*

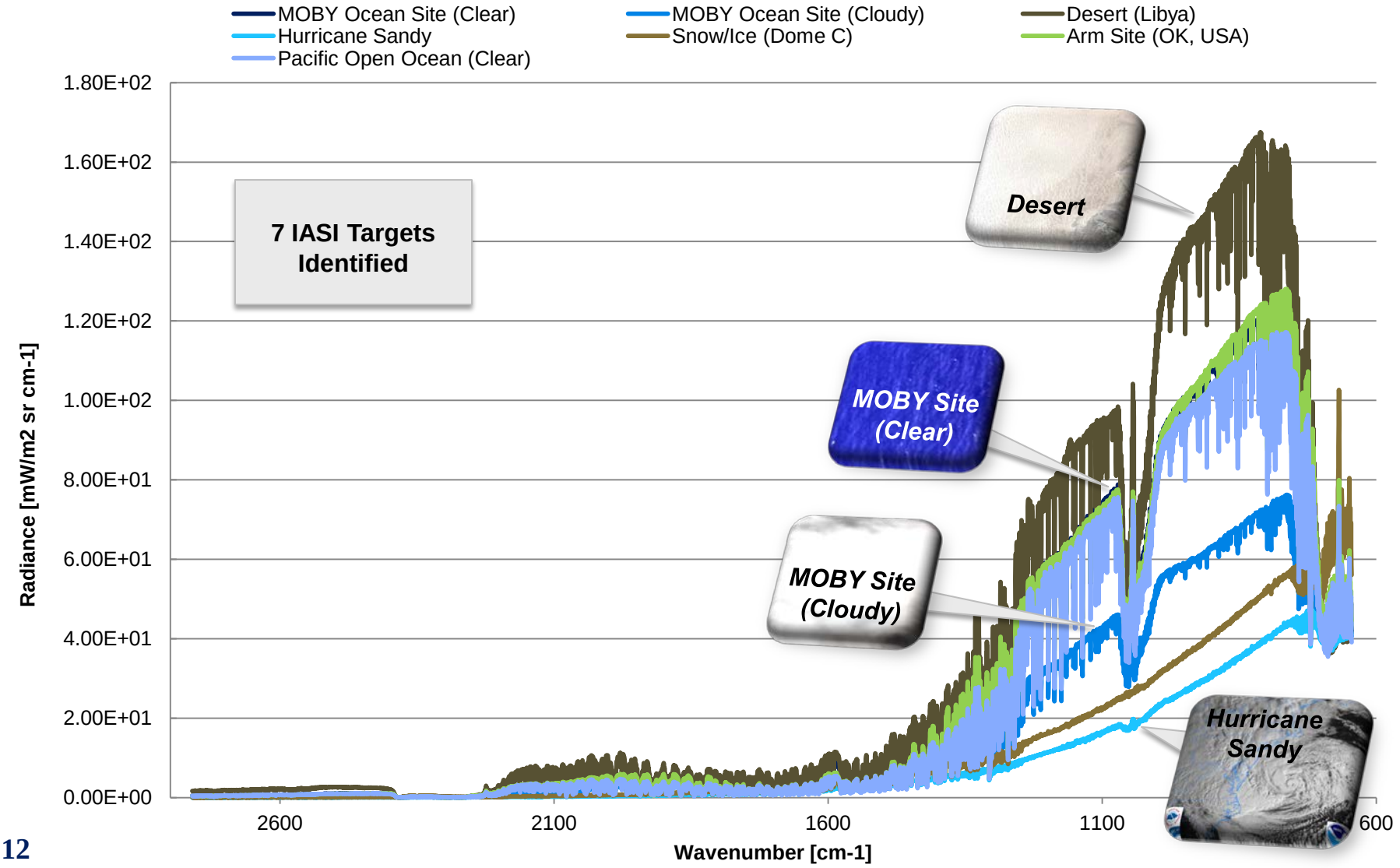
$$L_{eff} = \frac{\int_{\lambda_1}^{\lambda_2} L\, R_\lambda^{'}\, d\lambda}{\int_{\lambda_1}^{\lambda_2} R_\lambda^{'}\, d\lambda} \qquad \text{Eq. 1}$$

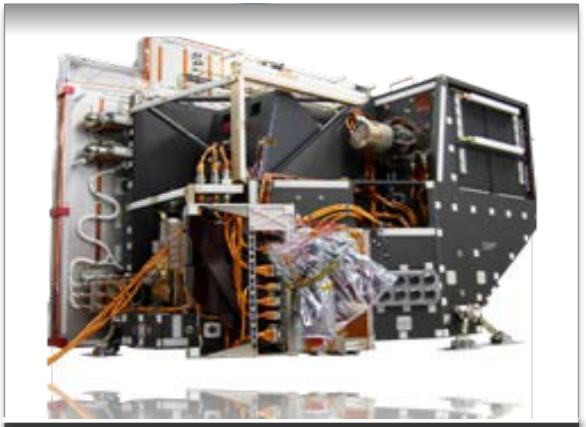
$R_\lambda^{'}$ peak normalized SRF for a given band

Reflective Solar Band Hyperspectral Observations

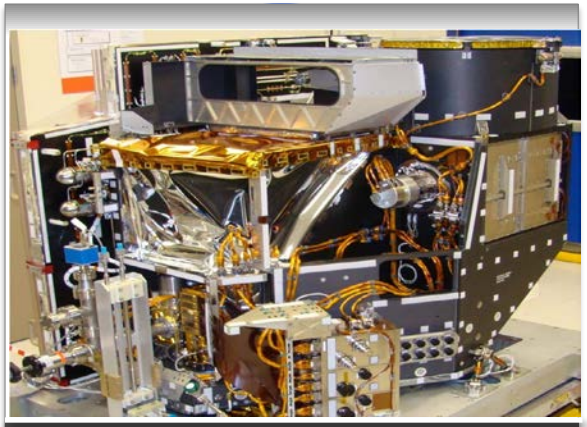


Thermal Emissive Band Hyperspectral Observations





NOAA: GOES-R ABI

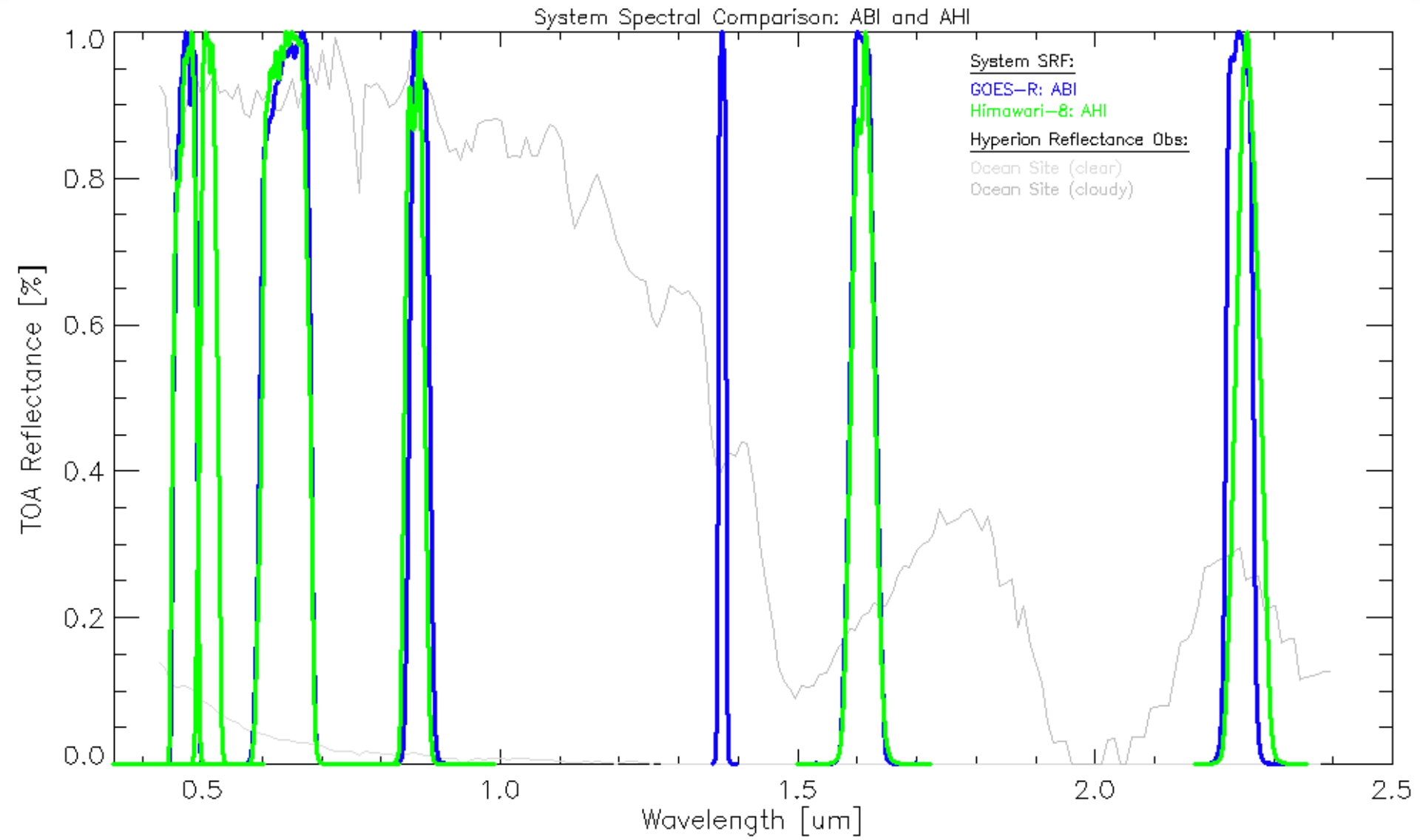


JMA: Himawari 8 AHI

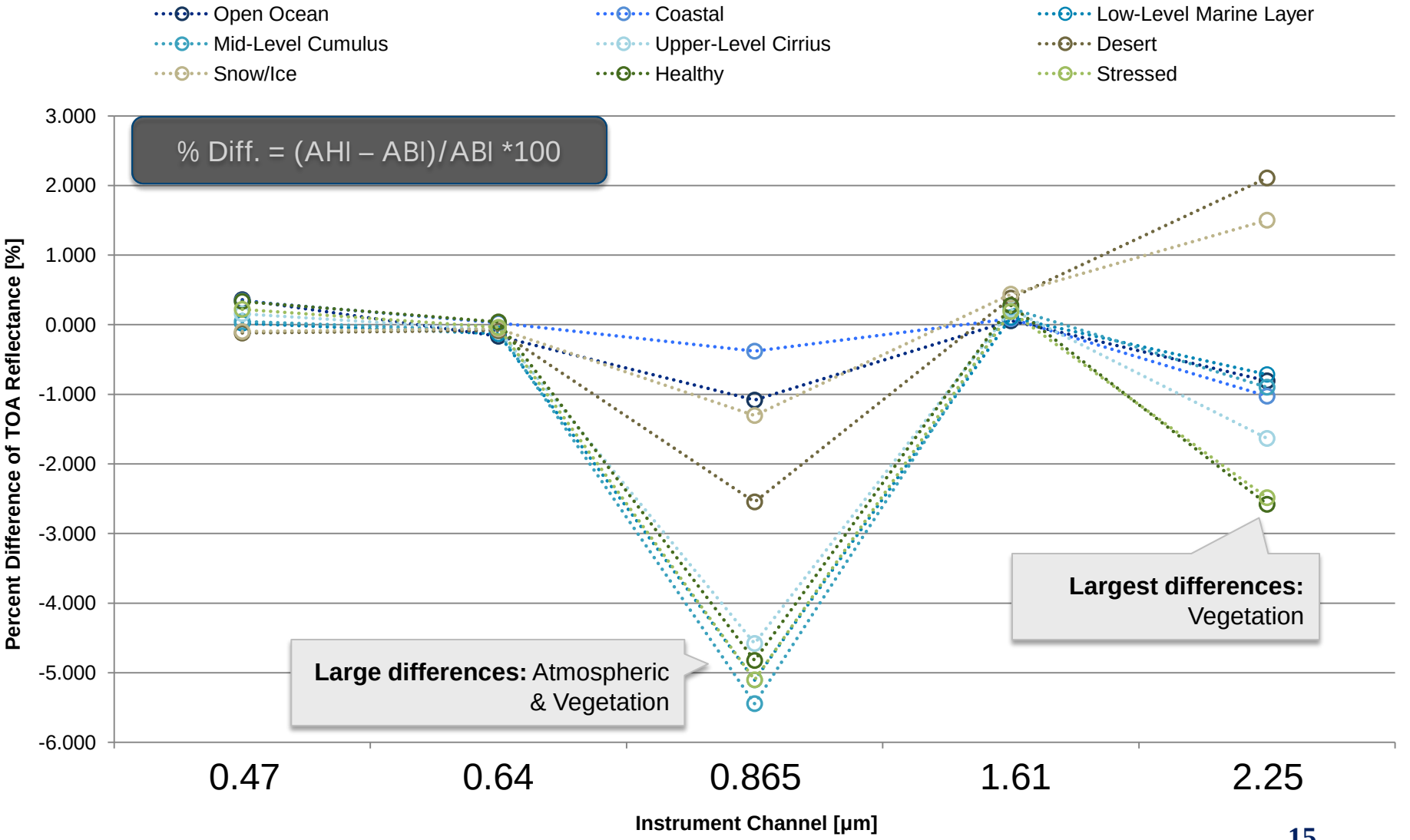
GOES-R ABI and Himarwari-8 AHI

SPECTRAL COMPARISON

ABI and AHI:
Reflective Solar Band Comparison



Reflective Solar Band: ABI & AHI Comparison
Percent Difference of TOA Reflectance [%]



Comparison Not applicable for: ABI - 1.38 µm and AHI - 0.51 µm

Reflective Solar Band: ABI & AHI Comparison
Percent Difference of TOA Reflectance [%]

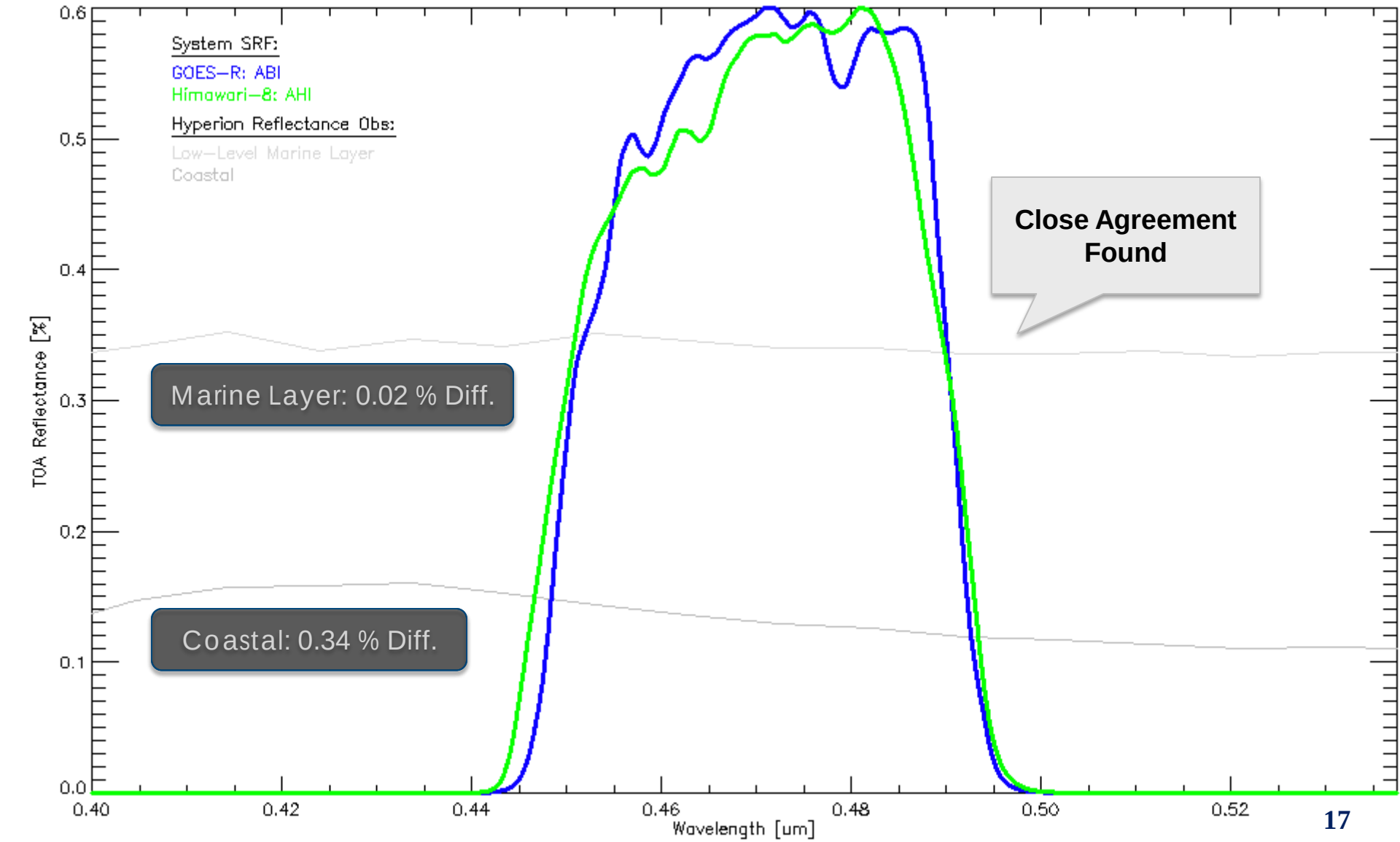
% Difference = (AHI – ABI)/ABI *100

Channel [µm]	Water	Open Ocean	Coastal	Atmospheric	Low-Level Marine Layer	Mid-Level Cumulus	Upper-Level Cirrus	Barren	Desert	Snow/Ice	Vegetation	Healthy	Stressed
0.47	0.360	0.341	0.018	0.047	0.159	-0.120	-0.098	0.335	0.221				
0.64	-0.165	0.027	-0.131	-0.086	-0.074	-0.084	-0.059	0.040	-0.039				
0.865	-1.083	-0.380	-5.105	-5.444	-4.580	-2.546	-1.304	-4.824	-5.102				
1.61	0.057	0.086	0.105	0.236	0.223	0.383	0.439	0.278	0.189				
2.25	-0.807	-1.026	-0.715	-0.897	-1.634	2.109	1.502	-2.580	-2.485				

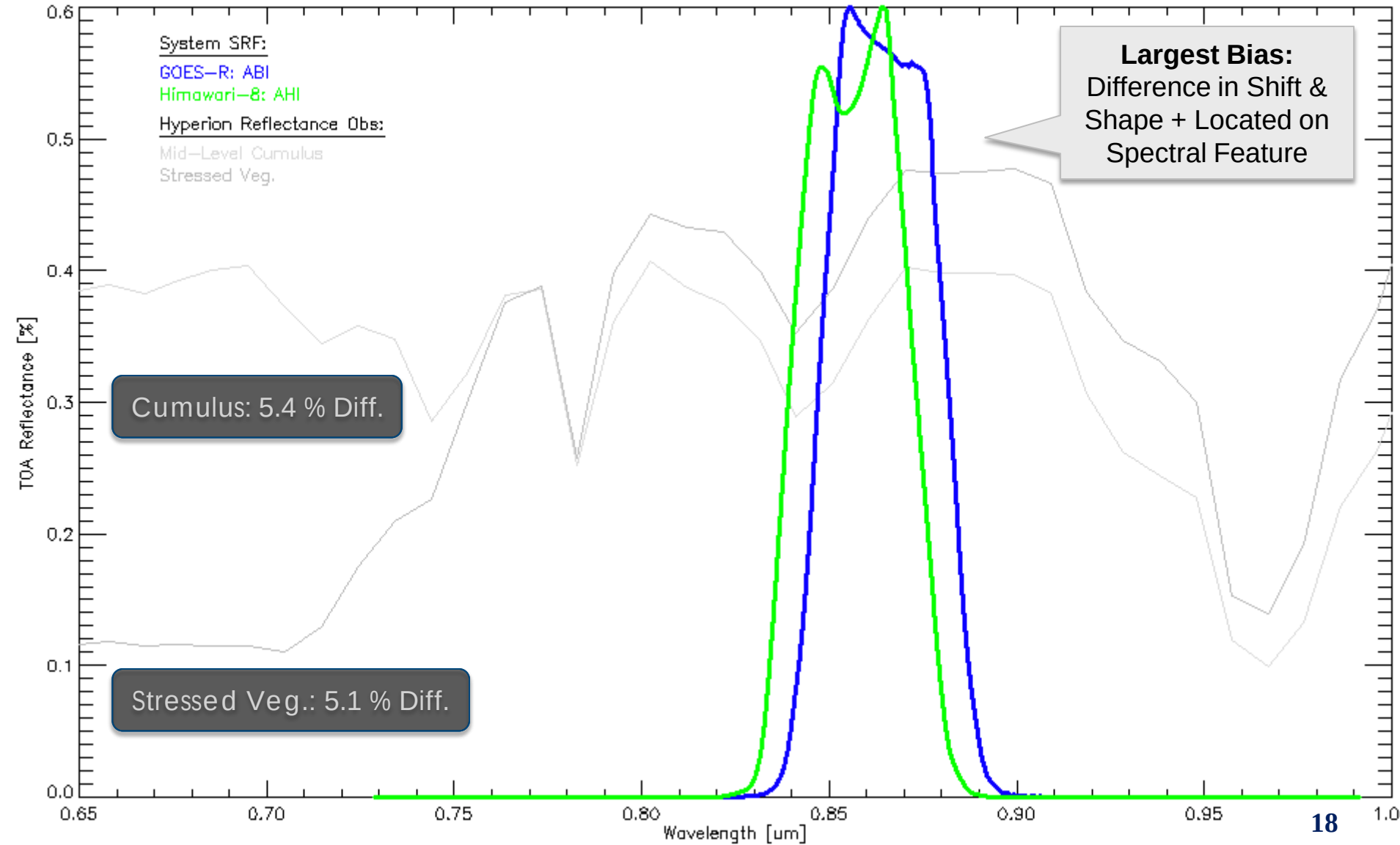
- Small differences >0.5% for channel's: 0.47 µm, 0.64 µm &1.61 µm
- Largest differences in 0.865 µm and 2.25 µm channels:
  - » 0.865 µm - impacts vegetation, aerosol over water, winds products
  - » 2.25 µm - impacts daytime land/cloud properties, participle size, snow products

Comparison Not applicable for: ABI - 1.38 µm and AHI - 0.51 µm

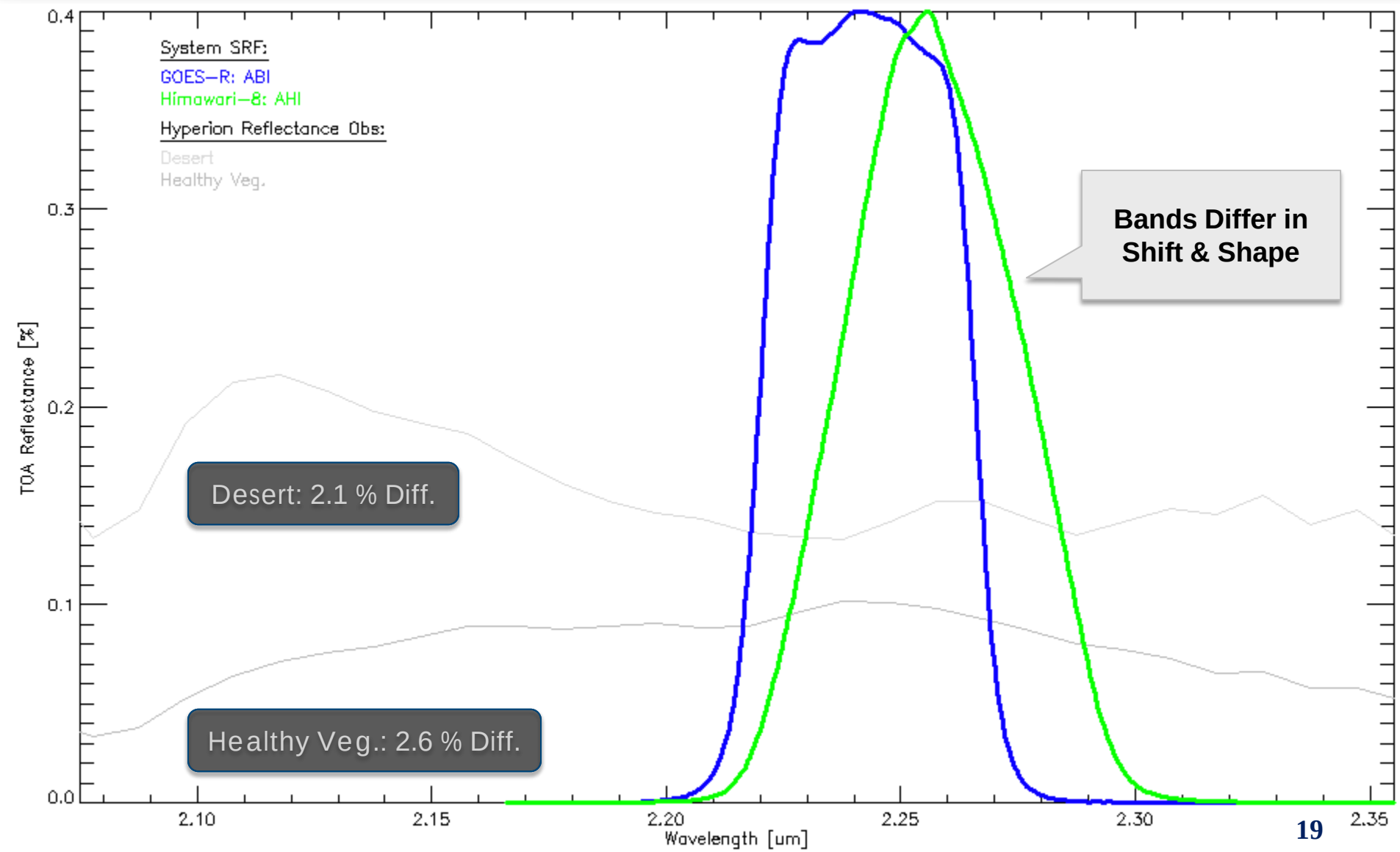
Reflective Solar Band: ABI & AHI Comparison 0.47 µm



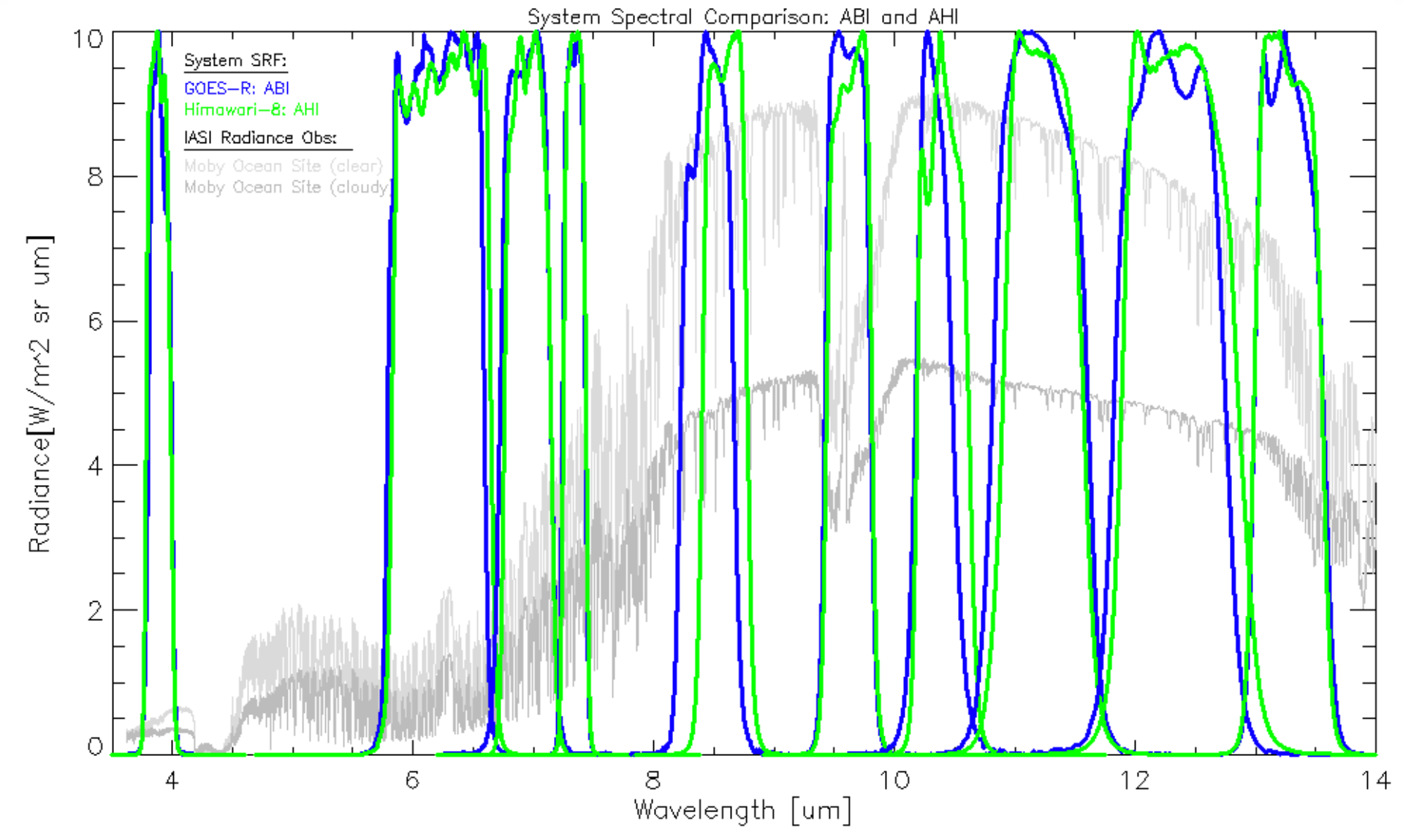
Reflective Solar Band: ABI & AHI Comparison 0.865 µm



Reflective Solar Band: ABI & AHI Comparison 2.25 µm

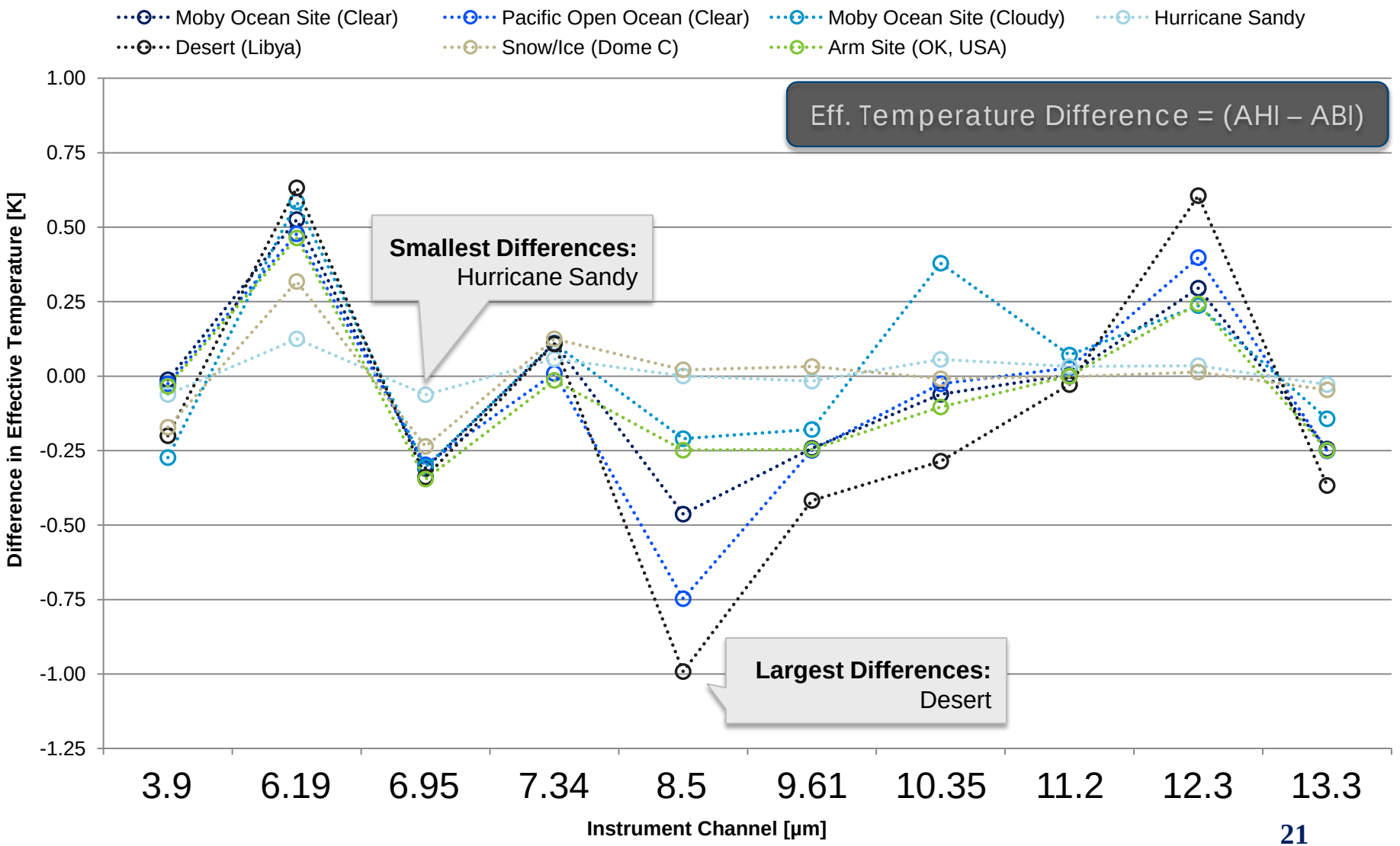


ABI and AHI:
Emissive Band Comparison



Emissive Band Comparison: ABI & AHI Comparison

Effective Temperature Difference [K]



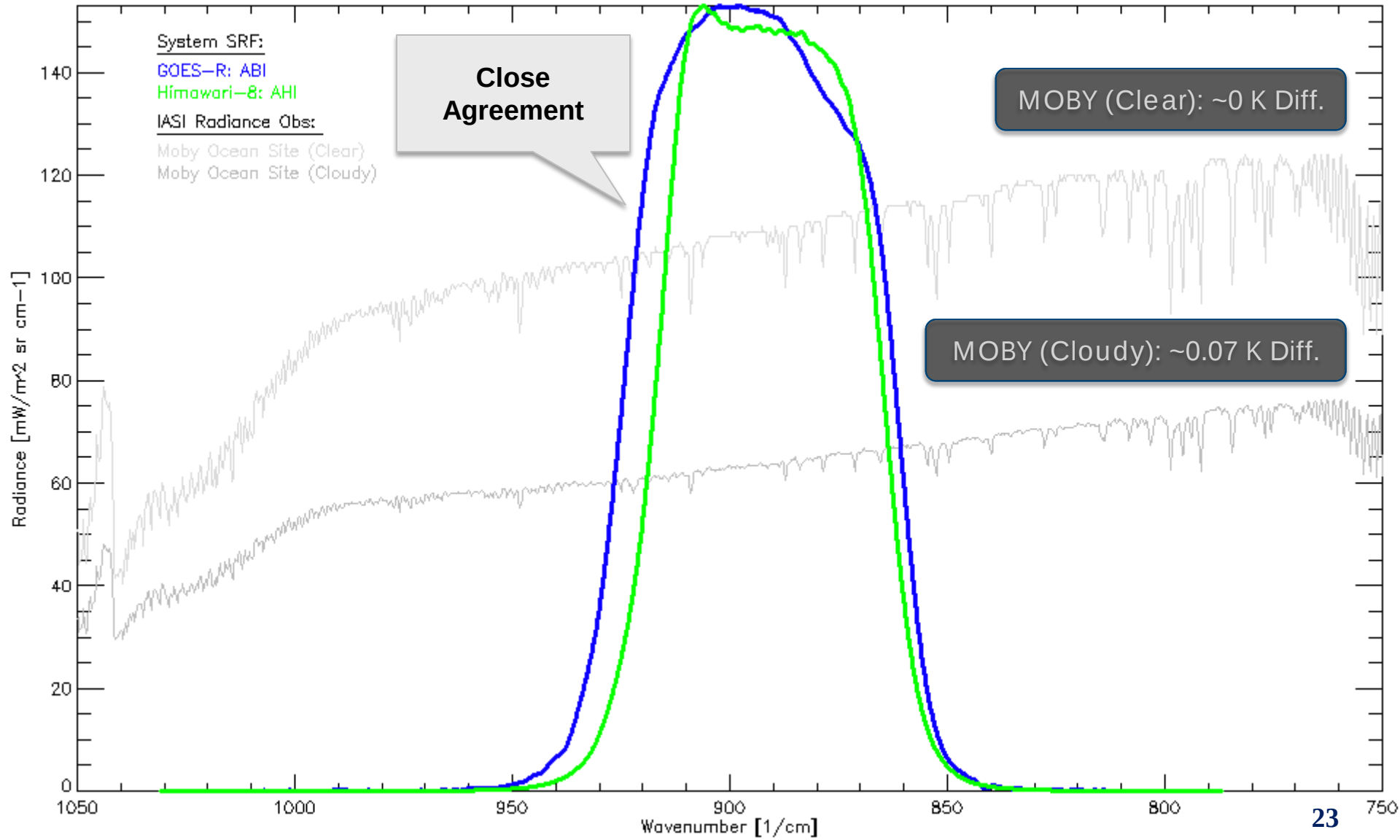
Emissive Band Comparison: ABI & AHI Comparison
Effective Temperature Difference [K]

Channel [µm]	Water	Moby Ocean Site (Clear)	Pacific Open Ocean (Clear)	Atmospheric	Moby Ocean Site (Cloudy)	Hurricane Sandy	Barren	Desert (Libya)	Snow/Ice (Dome C)	Vegetation	Arm Site (OK, USA)
3.9	-0.01	-0.03	-0.27	-0.06	-0.20	-0.17	-0.03				
6.19	0.53	0.48	0.59	0.12	0.63	0.32	0.46				
6.95	-0.31	-0.30	-0.30	-0.06	-0.34	-0.24	-0.35				
7.34	0.11	0.01	0.11	0.06	0.11	0.13	-0.01				
8.5	-0.46	-0.75	-0.21	0.00	-0.99	0.02	-0.25				
9.61	-0.24	-0.25	-0.18	-0.02	-0.42	0.03	-0.25				
10.35	-0.06	-0.03	0.38	0.06	-0.29	-0.01	-0.10				
11.2	0.00	0.03	0.07	0.03	-0.03	0.00	0.00				
12.3	0.30	0.40	0.24	0.04	0.61	0.01	0.24				
13.3	-0.24	-0.25	-0.14	-0.03	-0.37	-0.05	-0.25				

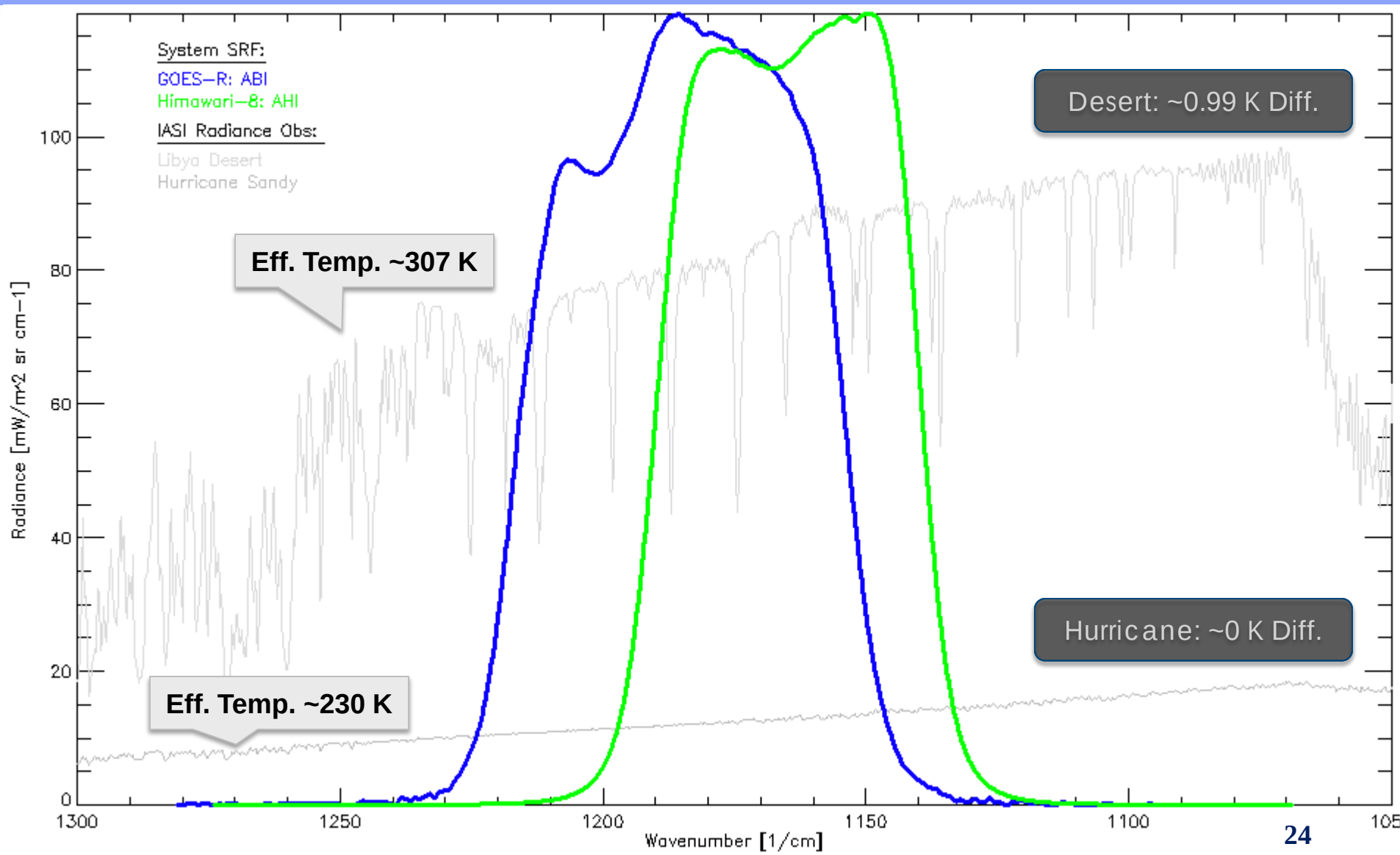
All differences in Eff. Temperature within 1 K

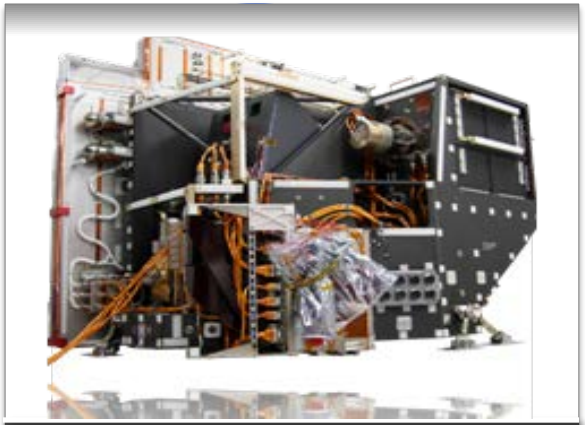
- Best Agreement (> ~0.1 K) in channels: 7.34 µm &11.2 µm
- Largest differences(> ~0.5 K) in channels: 6.19 µm & 8.5 µm
  - » 6.19 µm - impacts high-level atmospheric water vapor, winds, rainfall
  - » 8.5 µm - impacts total water for stability, cloud phase, dust, SO_2, rainfall

Thermal Emissive Band: ABI & AHI Comparison 11.2 µm

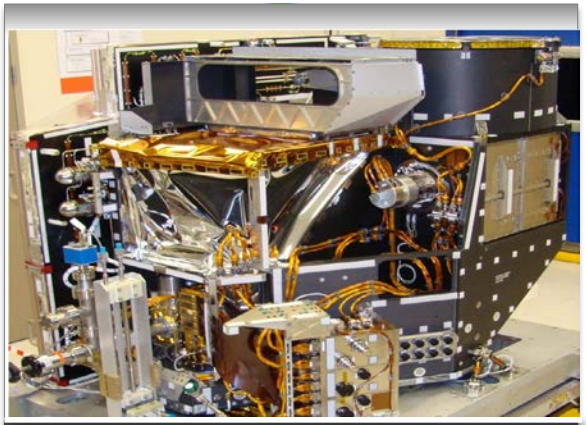


Thermal Emissive Band: ABI & AHI Comparison 8.5 µm

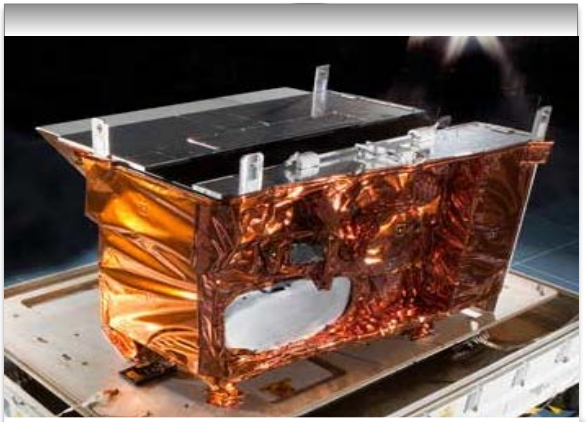




NOAA: GOES-R ABI



JMA: Himawari 8 AHI

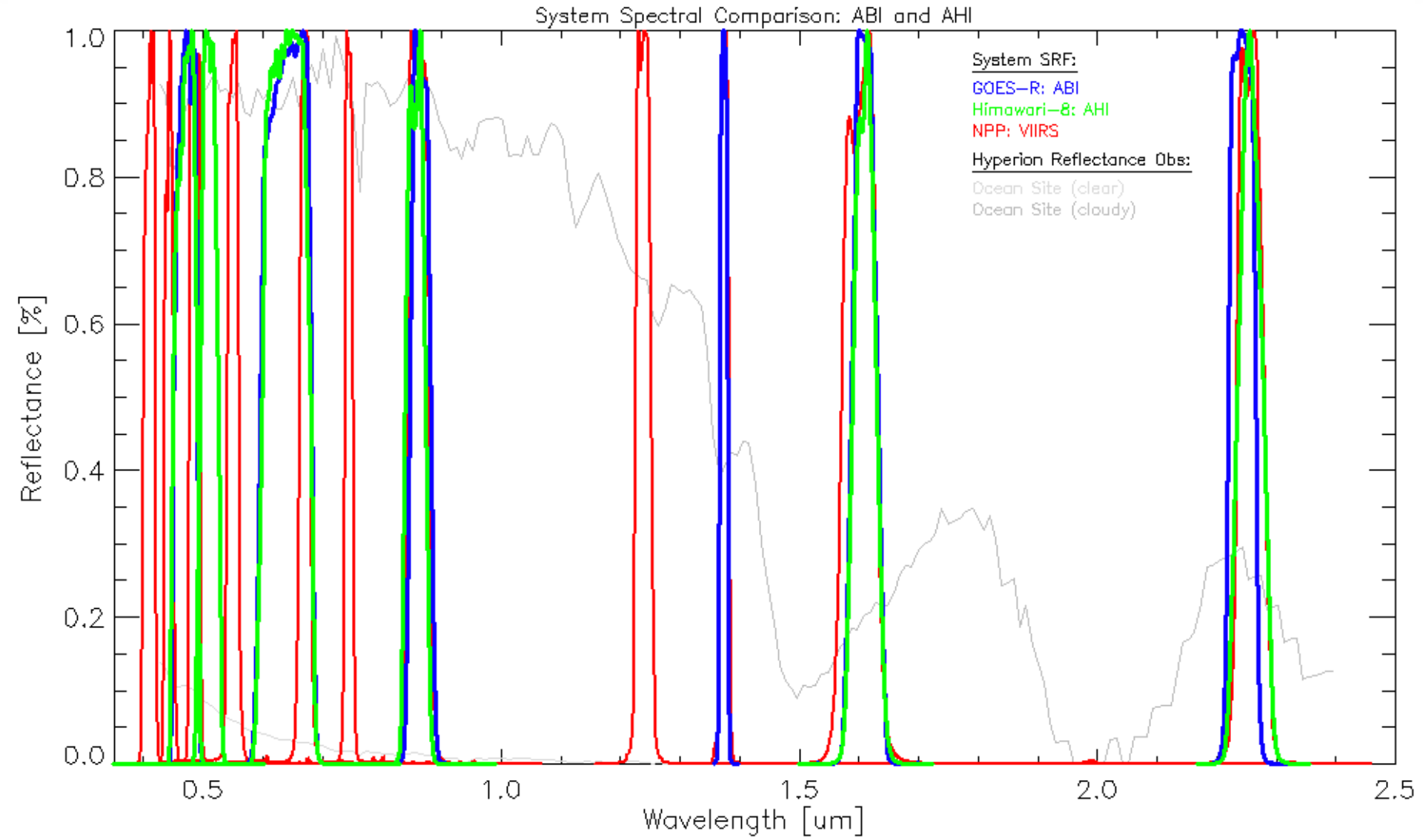


NOAA: NPP VIIRS

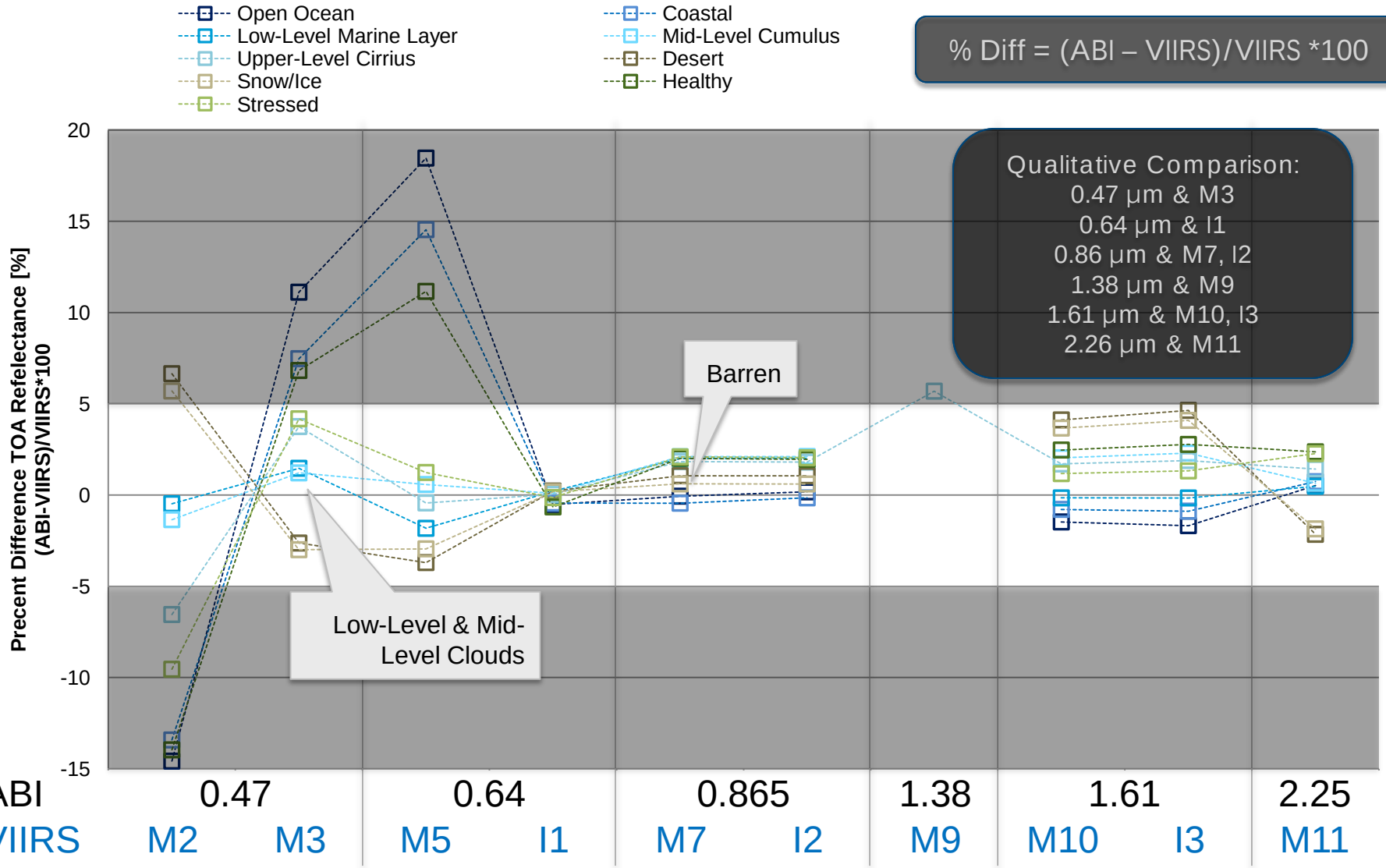
GOES-R ABI, Himarwari-8 AHI and NPP VIIRS

SPECTRAL COMPARISON

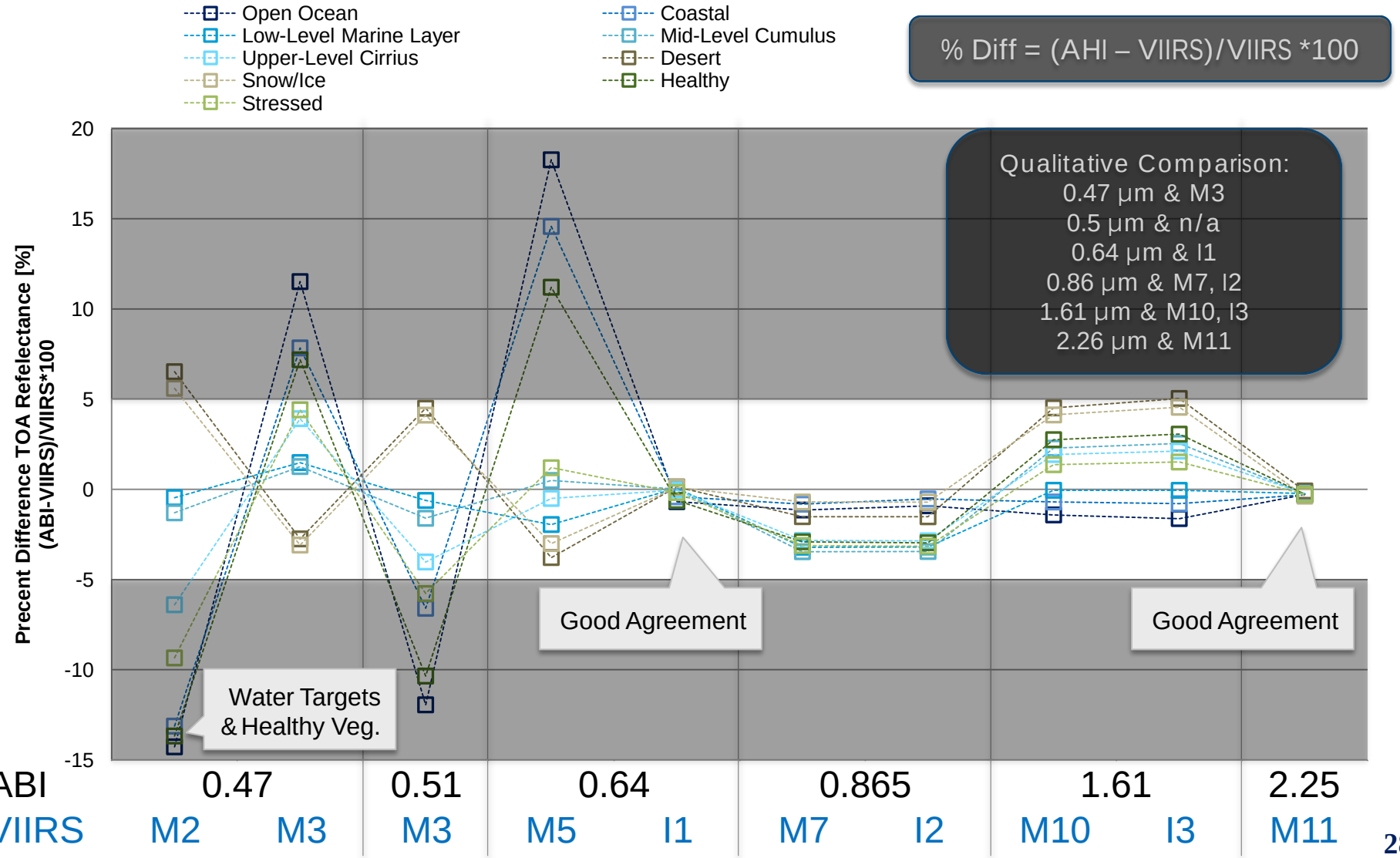
ABI, AHI & VIIRS:
Reflective Solar Band Comparison



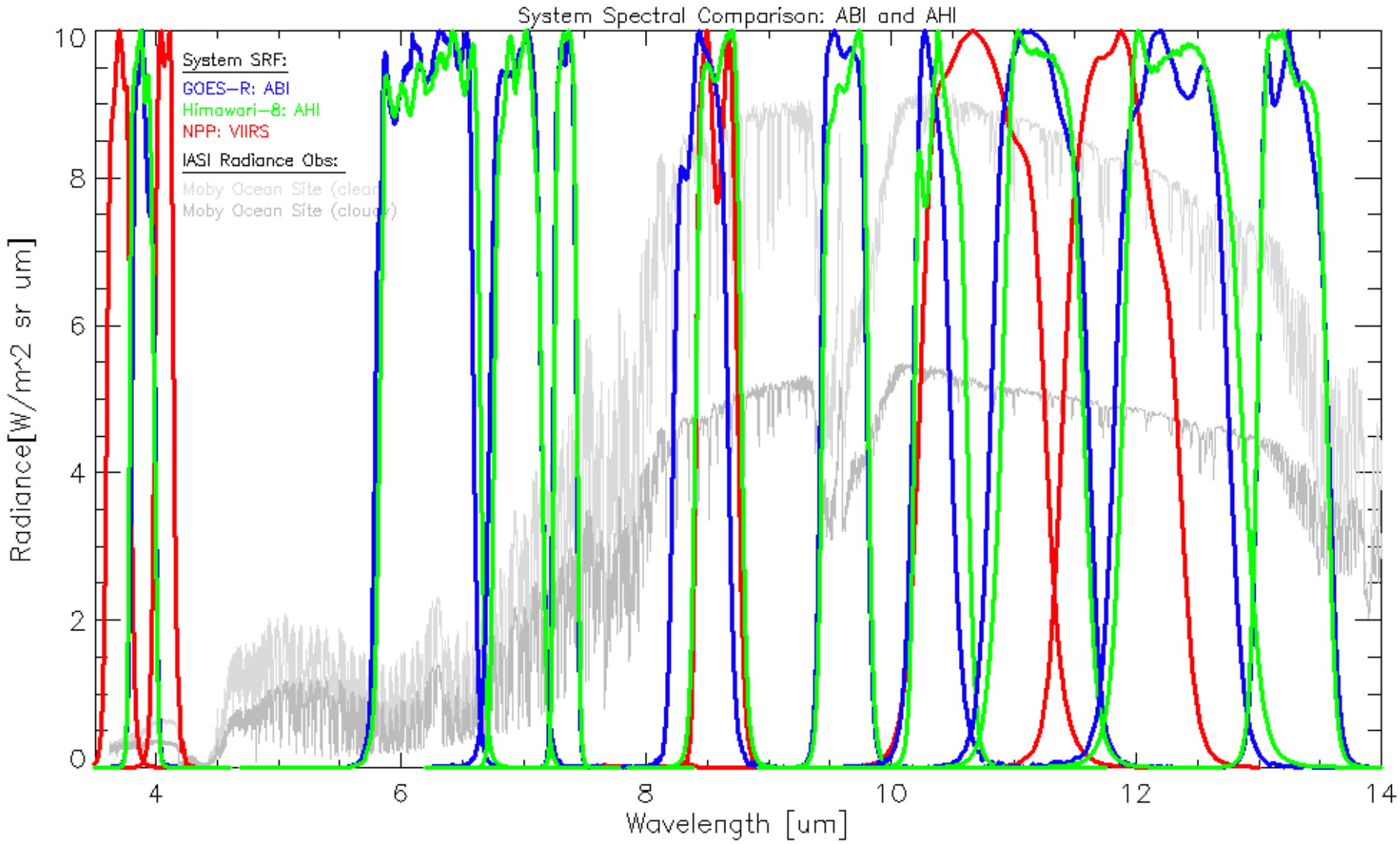
Reflective Solar Band: ABI & VIIRS Comparison
Percent Difference of TOA Reflectance [%]



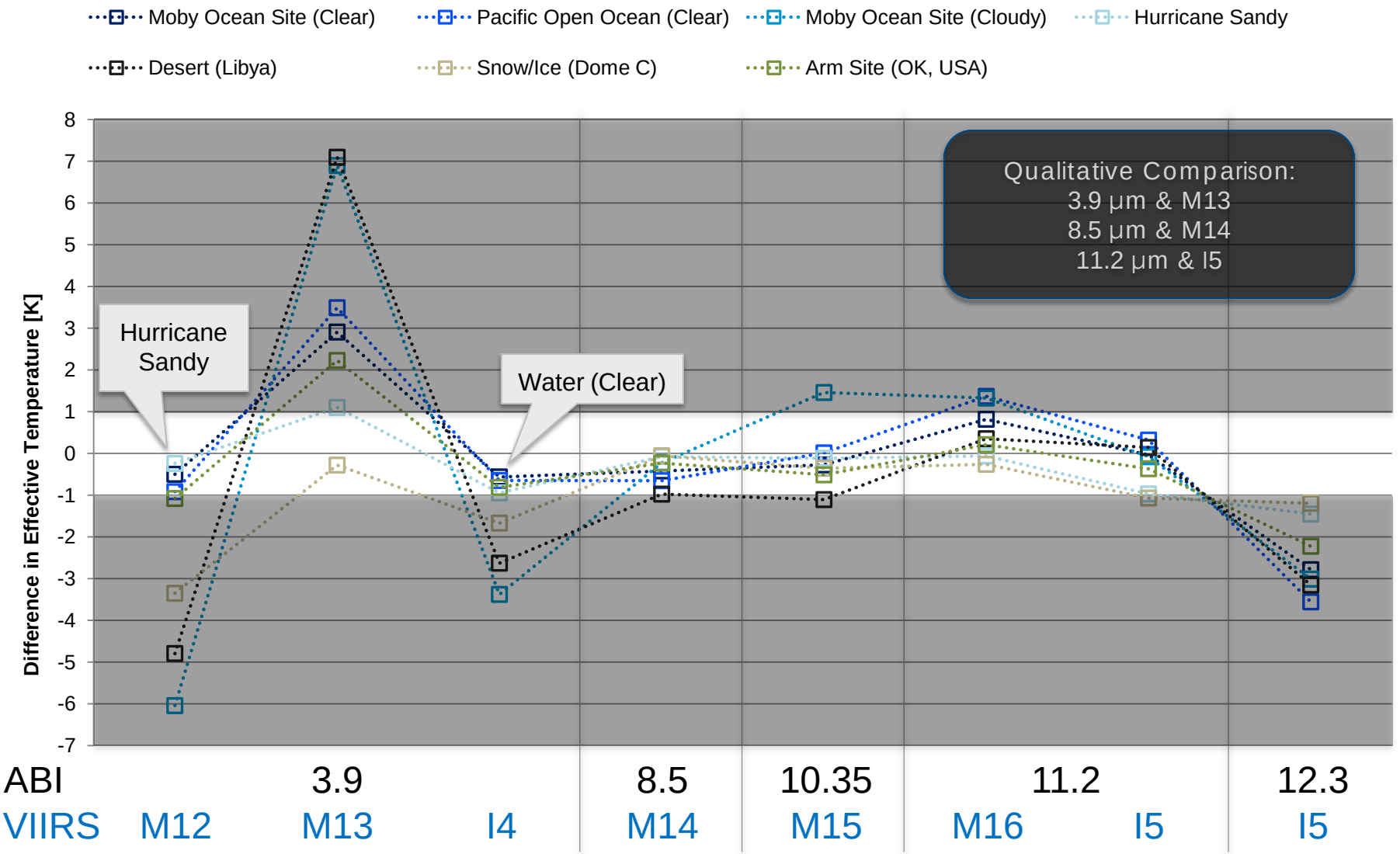
Reflective Solar Band: AHI & VIIRS Comparison
Percent Difference of TOA Reflectance [%]



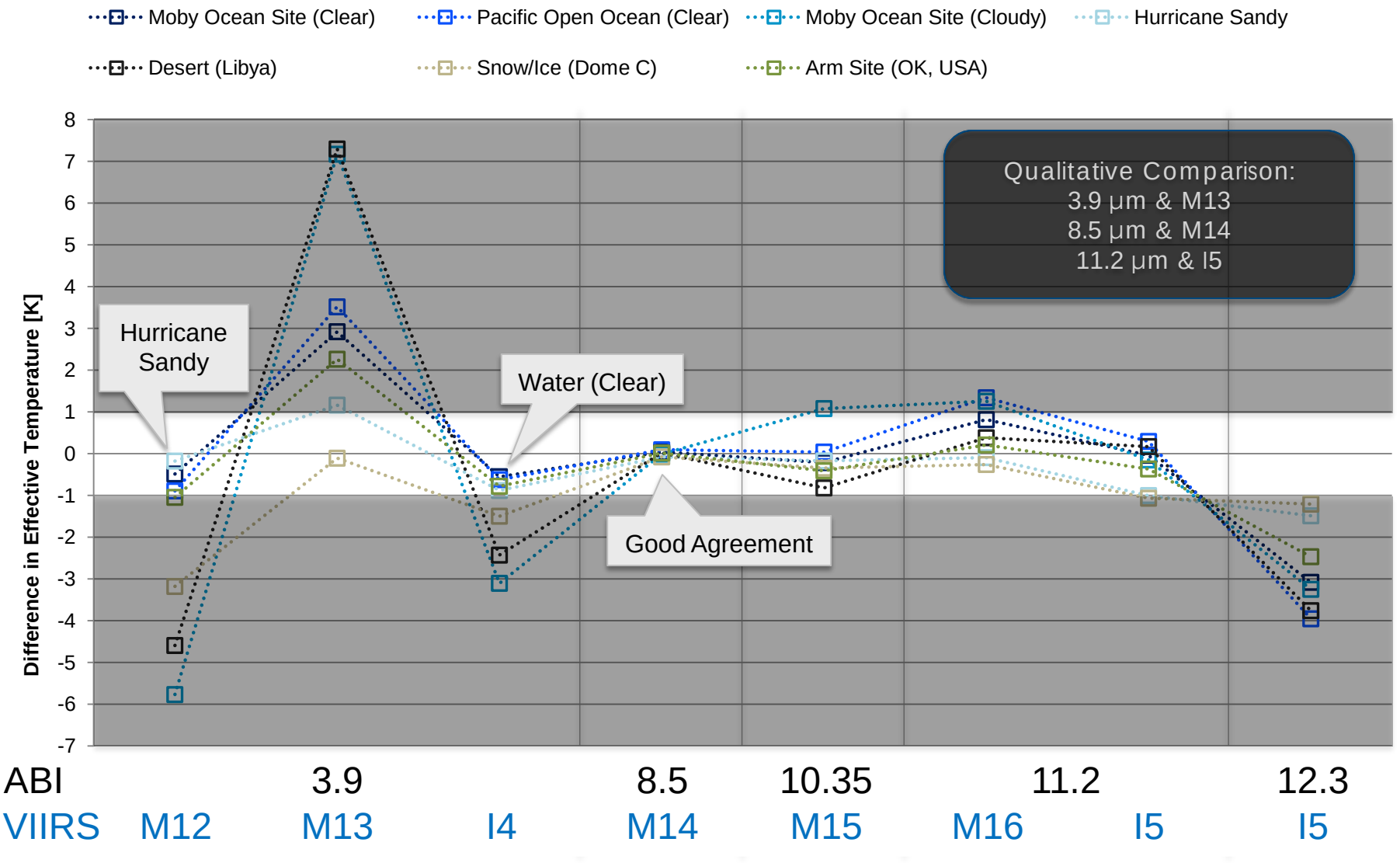
ABI, AHI & VIIRS:
Emissive Band Comparison



Thermal Emissive Band: ABI & VIIRS Comparison Effective Temperature Difference [K]



Thermal Emissive Band: AHI & VIIRS Comparison Effective Temperature Difference [K]



Recommendations:
Post-Launch Cal/Val Risk Mitigation & Readiness

Using Suomi NPP VIIRS as a transfer radiometer for the next generation of geostationary operational environmental satellites

Spectral Region	Center Wavelength [μm]	ABI	AHI	VIIRS	Recommended Target
Reflective Solar	0.47	Ch 1	Ch 1	M3	**Clouds**
Reflective Solar	0.51		Ch 2	M3	Barren & Clouds
Reflective Solar	0.64	Ch 2	Ch 3	**I1**, M5	**All**
Reflective Solar	0.86	Ch 3	Ch 4	**M7, I2**	**All**
Reflective Solar	1.38	Ch 4		**M9**	**Clouds (DCC)**
Reflective Solar	1.61	Ch 5	Ch 5	**M10, I3**	**All**
Reflective Solar	2.26	Ch 6	Ch 6	**M11**	**All**
Thermal Emissive	3.9	Ch 7	Ch 7	I4, M12*	Ocean
Thermal Emissive	8.6	Ch 11	Ch 11	**M14**	**Clouds**
Thermal Emissive	10.35	Ch 13	Ch 13	**M15**	**Ocean, DCC, Snow**
Thermal Emissive	11.2	Ch 14	Ch 14	I5	Ocean, Clouds
Thermal Emissive	12.3	Ch 15	Ch 15	I5	-

*IASI spectral range did not completely cover M12, and I4 spectral range

JMA Collaboration

- Leverage early Himawari-8 AHI on-orbit data for GOES-R Cal/Val risk mitigation and post-launch readiness
  - » AHI and VIIRS are assets to be utilized during Post Launch Tests and throughout mission life
    - – ***Himawari-8*** scheduled to launch Fall of 2014
    - – ***GOES-R*** scheduled to launch in Fall 2015/early 2016
- NOAA MOU between NESDIS and JMA:
  - » NOAA will host JMA visiting scientist (see Steve Goodman, GOES-R Program Scientist)

Summary

- **ABI & AHI Comparison:**
  - » **RSB:** Overall good agreement in most channels (>0.5% Diff.)
    - – Largest differences in 0.865 µm & 2.25 µm channels
  - » **TEB:** All differences in Eff. Temperature within 1 K
    - – Largest differences in 6.19 µm & 8.5 µm channels
- **S-NPP VIIRS as a Transfer Radiometer:**
  - » All ABI & AHI RSB channels are suitable for inter-comparisons
  - » Only ABI & AHI TEB channels: 7, 11, 13, & 14 are suitable for inter-comparisons
- This effort supports GOES-R post-launch Cal/Val risk mitigation & readiness, as well as an opportunity to collaborate with the JMA
- Establishes a baseline for future comparisons between these systems

Using Suomi NPP VIIRS as a transfer radiometer for the next generation of geostationary operational environmental satellites