Inter-comparisons of Geostationary Infrared Observations using Simulated Radiances from two Numerical Weather Prediction models

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Table of Contents

- Satellite Sensors / NWP models / RTM
- Channel characteristics of the sensors
- Overall comparison results (Observation minus Simulation)
- Benefits of using NWP+RTM for GEO intercalibration

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Satellite Sensors / NWP models / RTM

- **4 Geostationary (GEO) Imagers**
  - ✓ **AMI** /Geo-KOMPSAT-2A (4 Dec. 2018)
  - ✓ **AHI** / Himawari-8 (7 Oct. 2014)
  - ✓ **ABI** / GOES-16 (19 Nov. 2016)
  - ✓ **SEVIRI** / Meteosat-11 (15 Jul. 2015)

Advanced imagers (16 channels) [AMI, AHI, ABI]

- **2 NWP model fields** (6-hourly)
  - ✓ **ERA5**
  - ✓ **UM** Analysis (Unified Model employed at KMA)

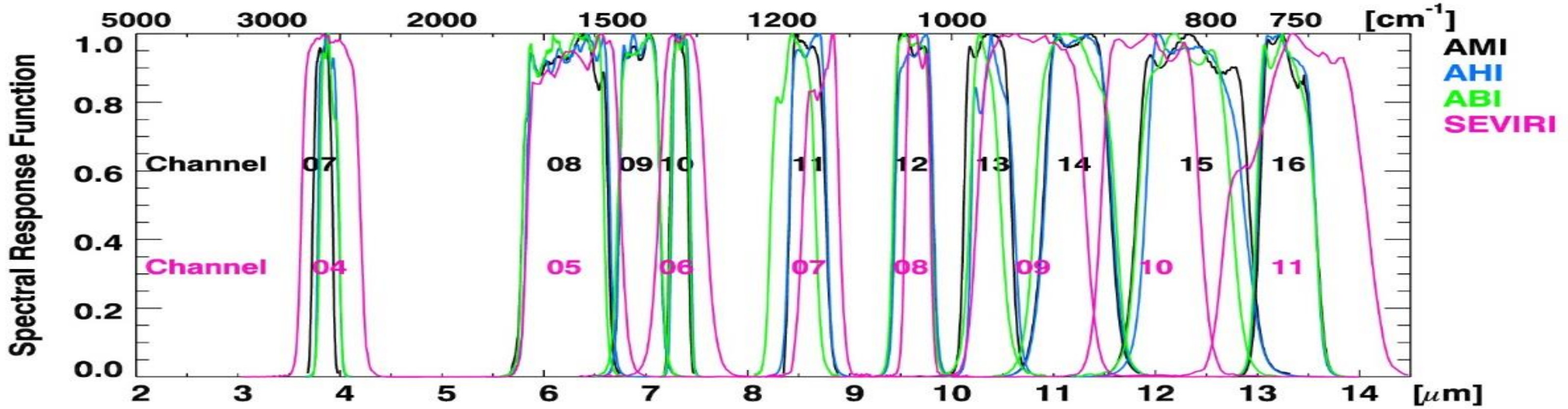
	ERA5	**UM N1280**
Horizontal resolution	0.25°	0.09375° (E-W), 0.140625° (N-S)
Vertical resolution	37 levels (1000~1hPa)	70 levels (1000~0.4 hPa)

- **Radiative Transfer Model (RTM)**
  - ✓ Fast forward model **RTTOV 12.3** (Saunders et al., 2018)

Channel characteristics of the 4 GEO imagers

Channels		AMI GK2A	AHI Himawari-8	ABI GOES-16	SEVIRI Meteosat-11	
SW38	Ch 07	3.83	3.89	3.89	Ch 04	3.91
WV1	Ch 08	6.18	6.24	6.185	Ch 05	6.27
WV2	Ch 09	6.94	6.94	6.95		
WV3	Ch 10	7.32	7.35	7.34	Ch 06	7.34
IR8	Ch 11	8.58	8.59	8.5	Ch 07	8.72
O3	Ch 12	9.62	9.64	9.61	Ch 08	9.66
IR10	Ch 13	10.35	10.41	10.35		
IR11	Ch 14	11.21	11.24	11.2	Ch 09	10.74
IR12	Ch 15	12.34	12.38	12.3	Ch 10	11.92
CO2	Ch 16	13.28	13.28	13.3	Ch 11	13.36
Spatial resolution		2 km	2 km	2 km		3 km
nadir		128.2°E	140.7°E	75.2°W		0°

Channels compared

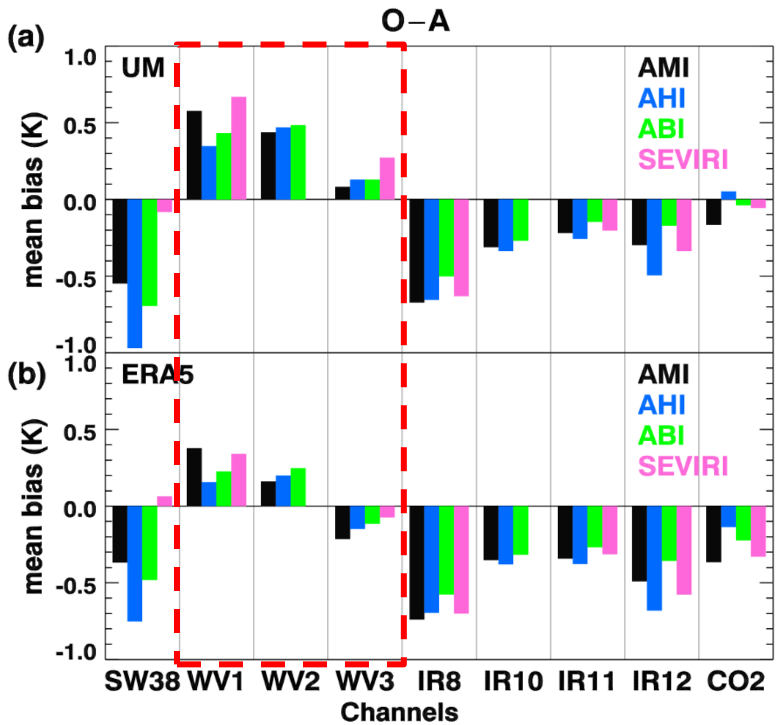


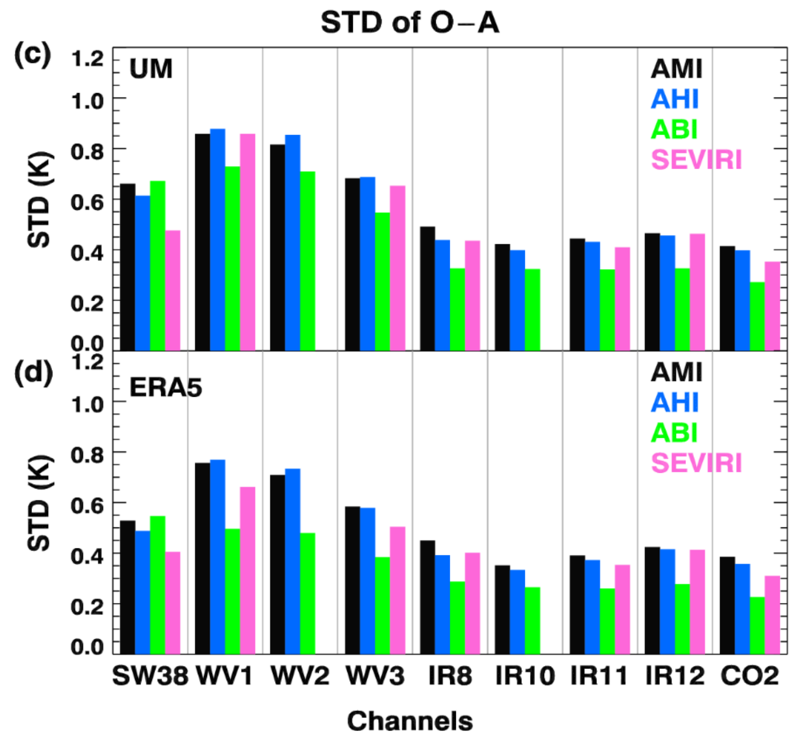
Spectral response function (SRF) of AMI, AHI, ABI, and SEVIRI

Overall Comparison Results

full-disk area,
clear-sky ocean,
in Aug. 2019

Observation minus simulation (monthly mean statistics)





* Number of matches analyzed: ~10^7(UM) ~10^6 (ERA5)

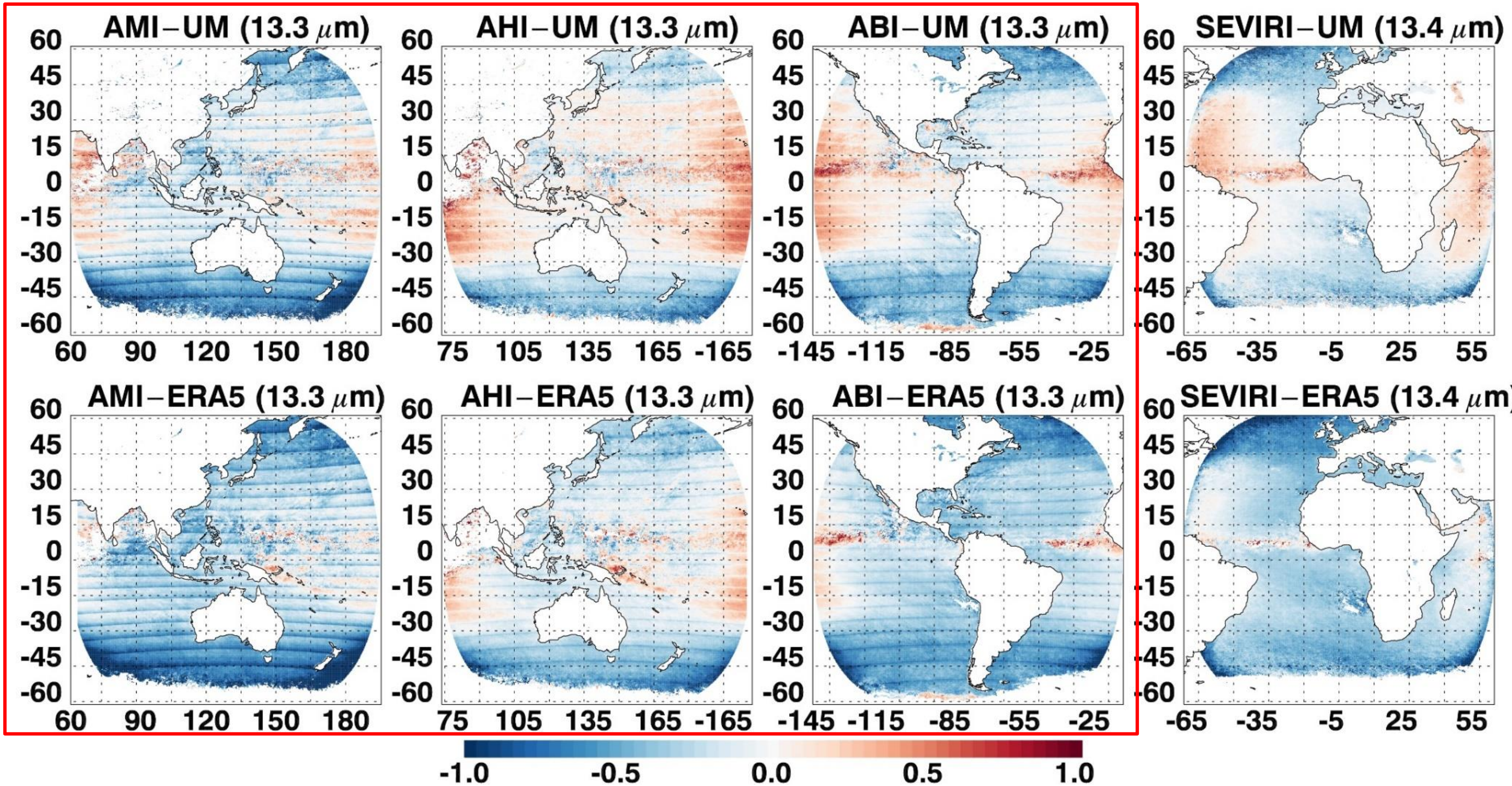
- ✓ Overall, mean O–A of the four instruments show **very similar patterns**
  - Negative difference for the SW and IR channels
  - Positive difference for the WV channels (except for ERA5 in WV3)

  => indicating that the NWP model humidity fields are wetter than observations in the upper-mid tropospheric atmosphere (similar results are found in the previous studies (e.g., Xue et al. (2020))

- ✓ Instrument-specific features (refer to Lee&Ahn, 2012 for details)

Benefits of using NWP+RTM for GEO intercalibration

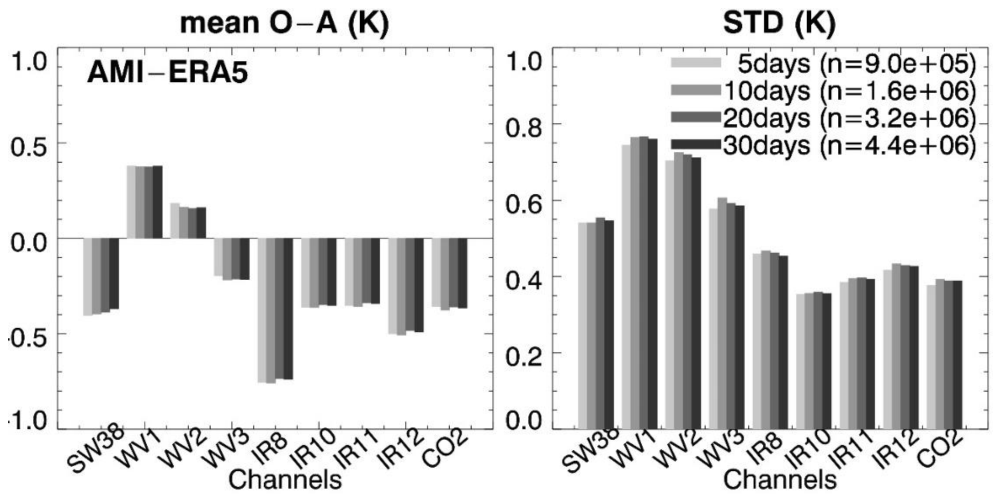
1. Capture Stripes in the CO2 channels of advanced imagers



- ✓ Stripes are evident in the CO2 channels of the three advanced imagers
- ✓ Stripes in the O-A map become clearer with sufficient amount of model data

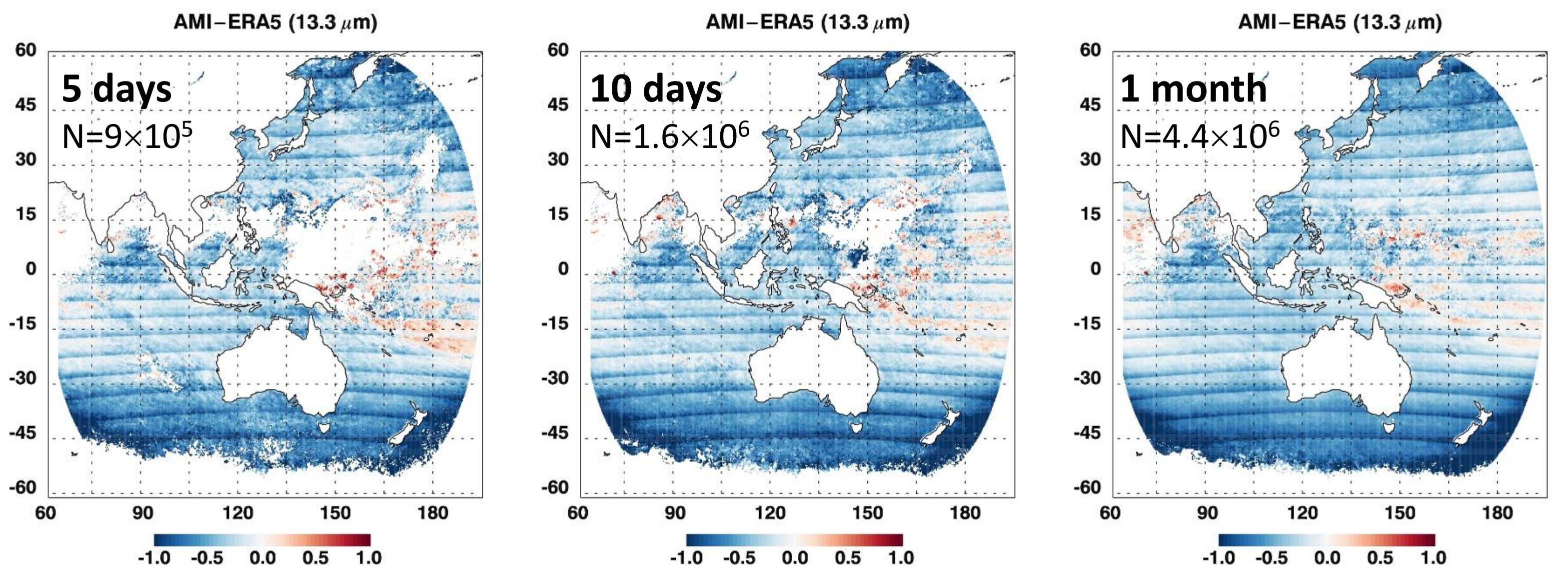
Benefits of using NWP+RTM for GEO intercalibration

2. Can characterize features with data from short period of time



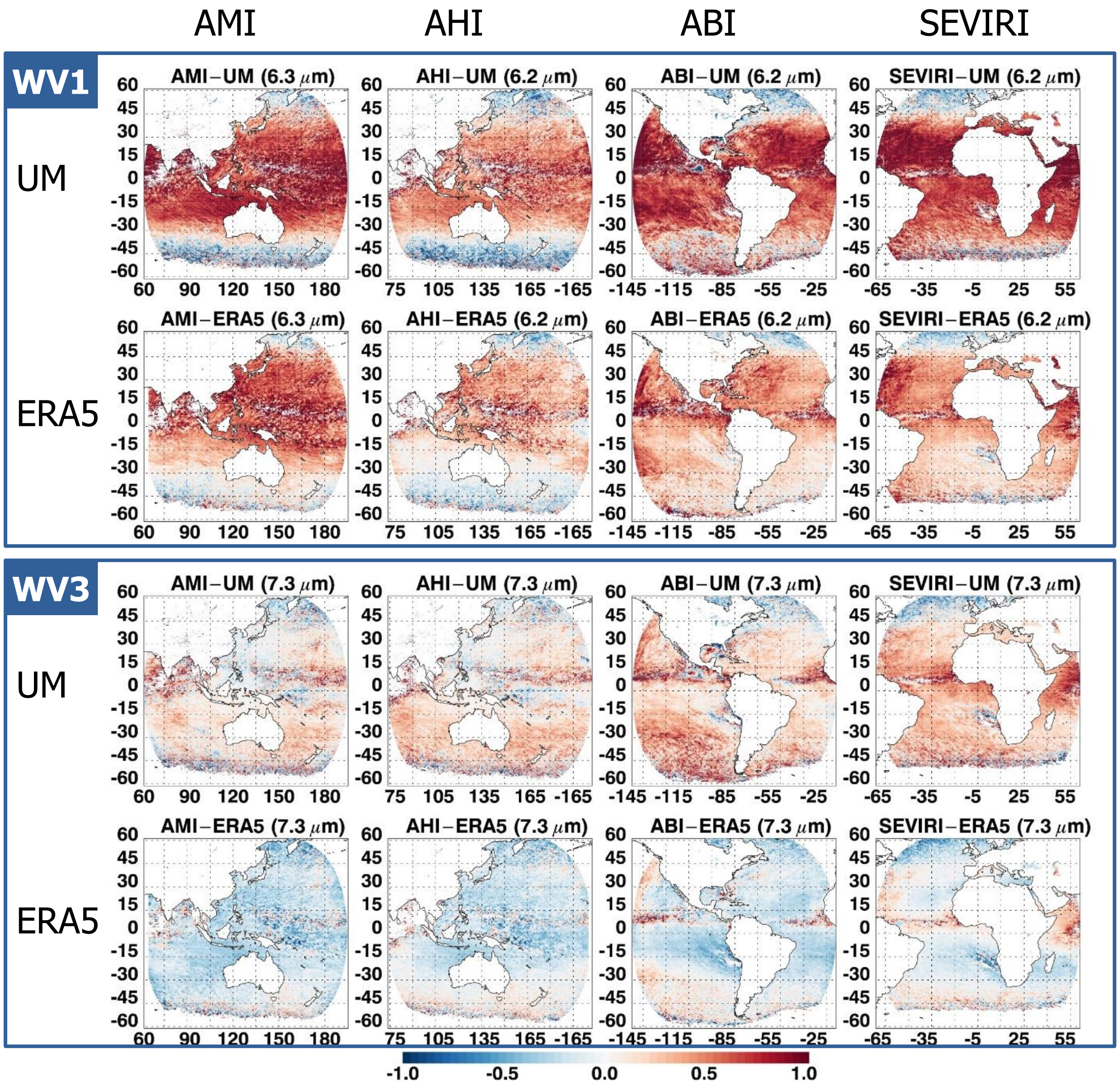
- ✓ statistics from 5 days are similar to the statistics from one month

- ✓ High spatial resolution of NWP models helps characterize features like striping issue



Benefits of using NWP+RTM for GEO intercalibration

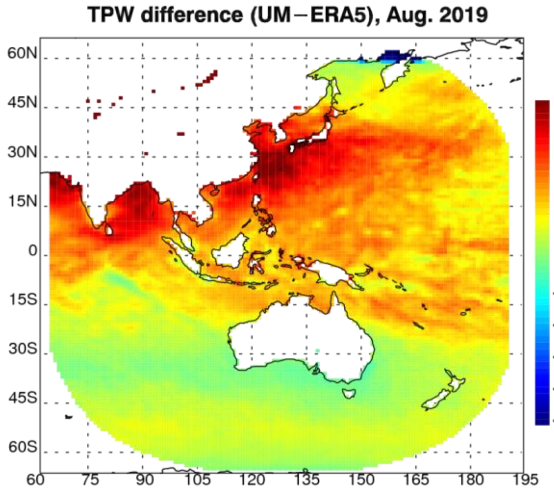
3. Reveals the characteristics of NWP models (if more than 1 NWP model is used)



- ✓ Near Tropics and low latitudes, both UM and ERA5 are wetter then the observation
- ✓ UM displays larger wet bias overall
- ✓ Similar feature is also found in the mid-troposphere (UM wetter than ERA5)

Direct comparison of UM and ERA5 humidity fields

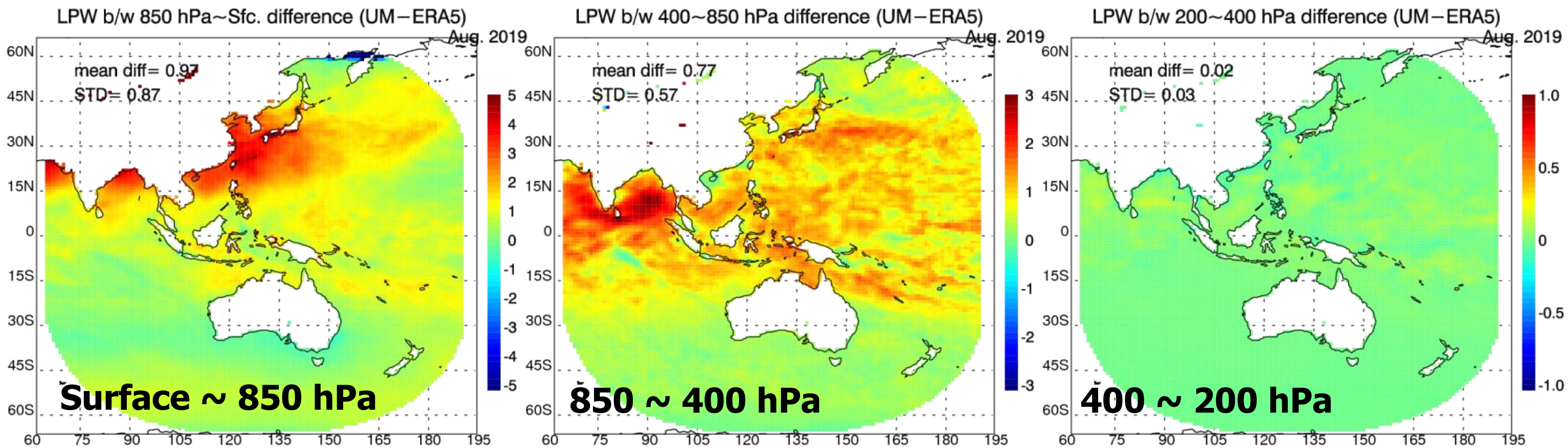
➢ Total Precipitable Water (TPW)



- ✓ UM TPW is larger than ERA5 TPW by 1.7 mm over the all-sky ocean (STD=1.3 mm) (averaged over the all-sky ocean of AMI coverage for Aug. 2019)

- ✓ UM LPW is larger than ERA5 over (sub)tropical and mid-latitude ocean by 1 mm, 0.8 mm, and 0.02 mm at the low, mid, and upper troposphere, respectively.

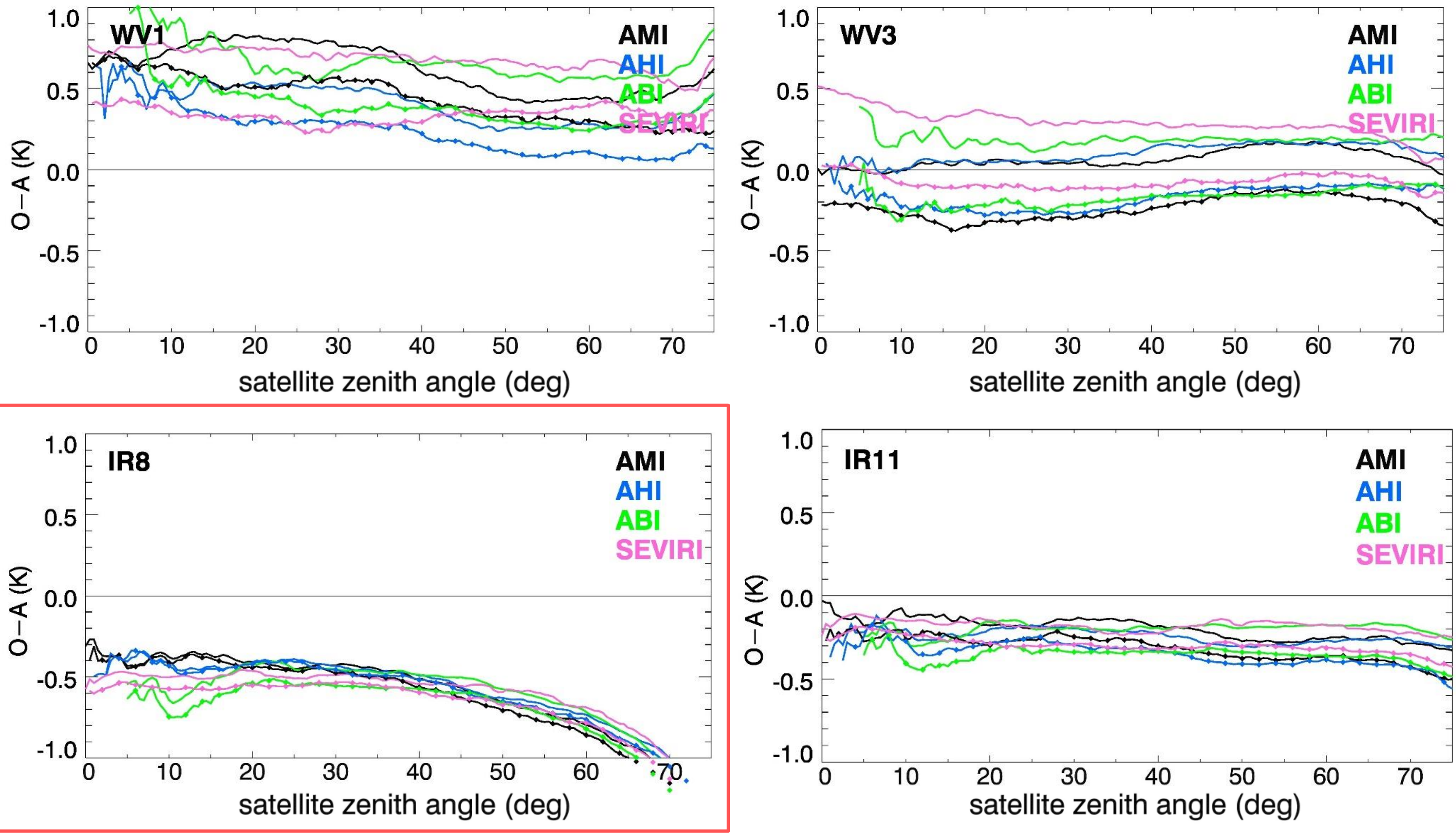
➢ Layer Precipitable Water (LPW)



1 mm (STD: 0.9 mm) | 0.8 mm (STD: 0.6 mm) | 0.02 mm (STD: 0.03 mm)

Benefits of using NWP+RTM for GEO intercalibration

4. Reveal uncertainties in RTM



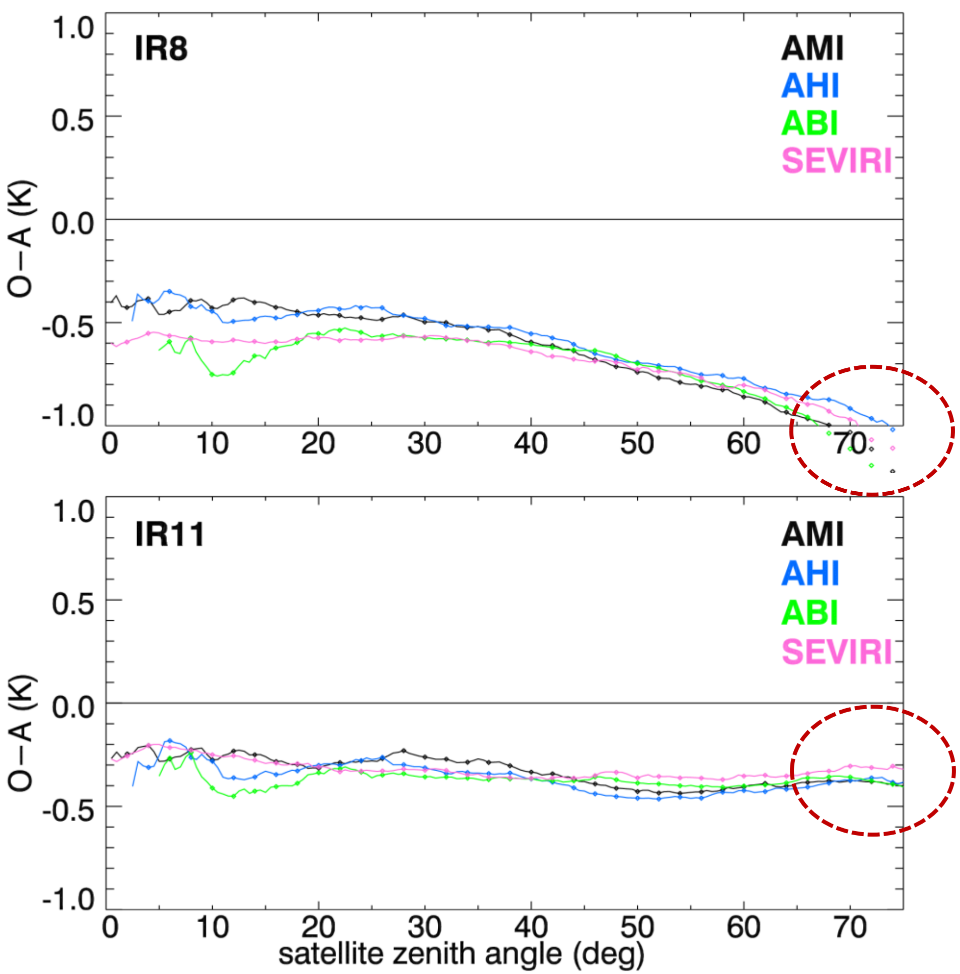
- ✓ Satellite zenith angle dependence is not significant except for IR8, where negative biases increase with increasing zenith angles for all instruments and both NWP models

Benefits of using NWP+RTM for GEO intercalibration

4. Reveal uncertainties in RTM

- ✓ **Sea surface emissivity model** used in RTM can affect the simulated radiance

ISEM, V7 Predictors (old model)



- ✓ **IREMIS** (new model)
  Uses wind speed, skin temperature, and zenith angle for the parameterization of emissivity
- ✓ **ISEM** (old model)
  Use satellite zenith angle only

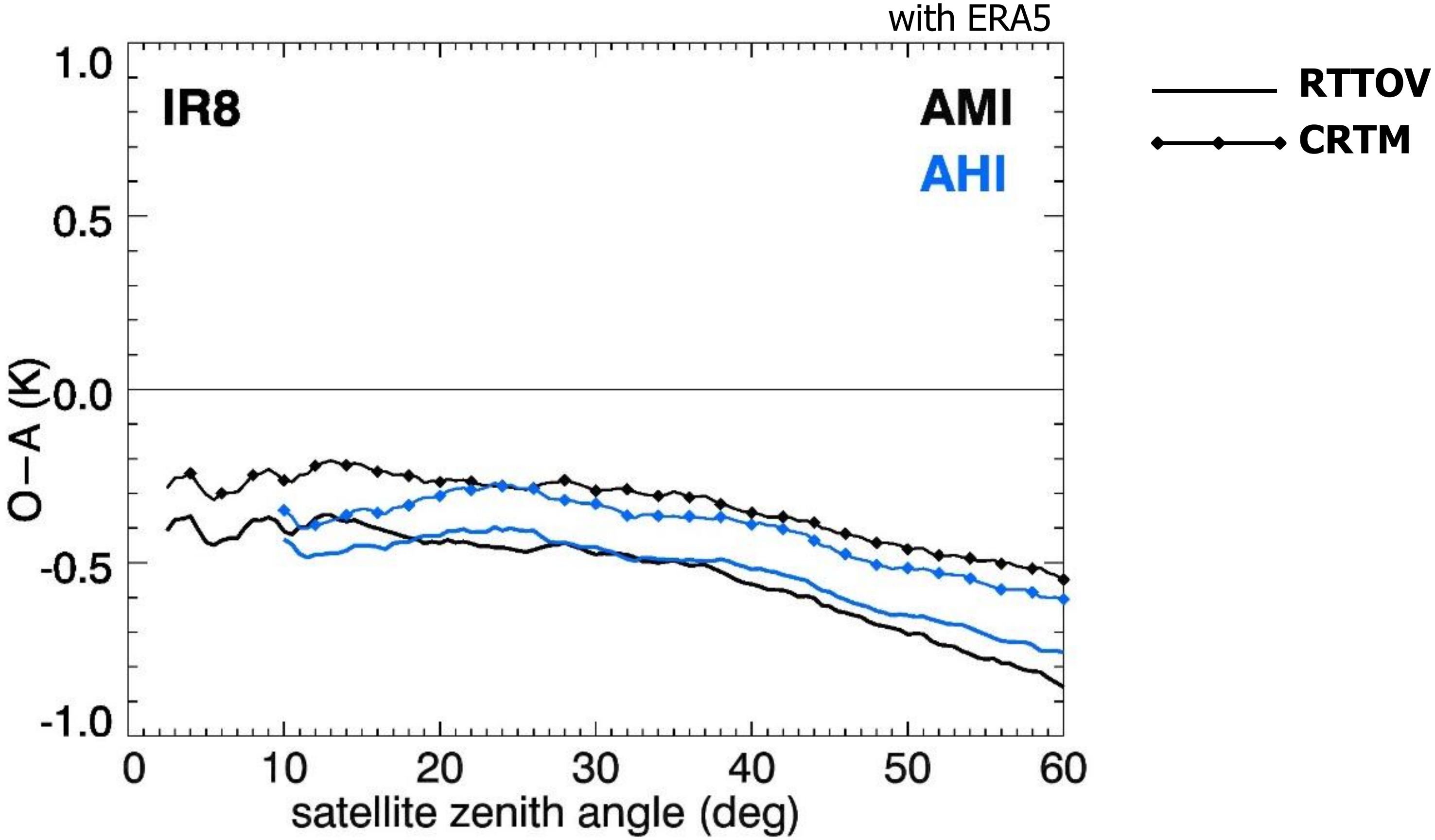
[*RTTOV-12 science and validation report*]

Benefits of using NWP+RTM for GEO intercalibration

4. Reveal uncertainties in RTM

- ✓ Using more than one RTM helps to identify the error source.

RTTOV 12.3 vs. CRTM 2.4.0

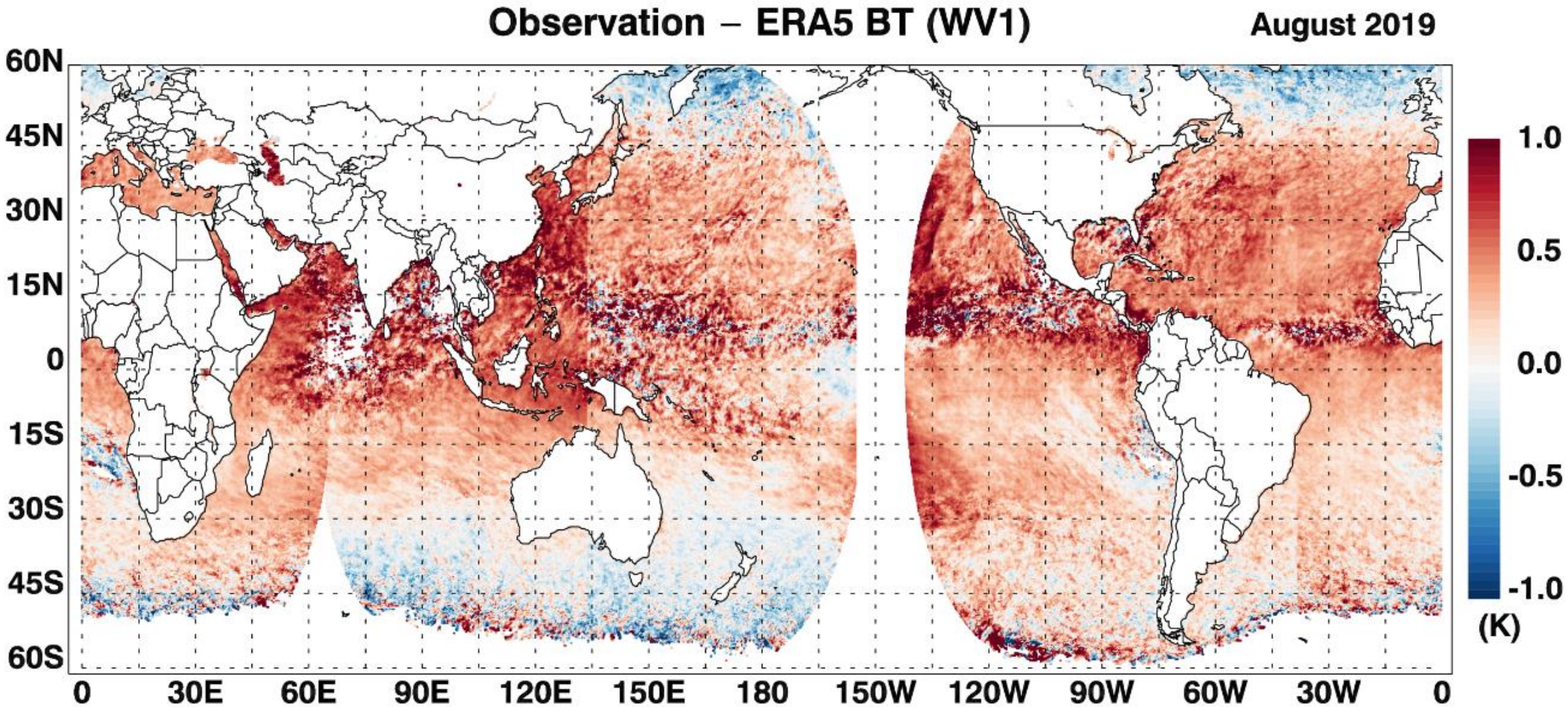


Benefits of using NWP+RTM for GEO intercalibration

5. Global monitoring

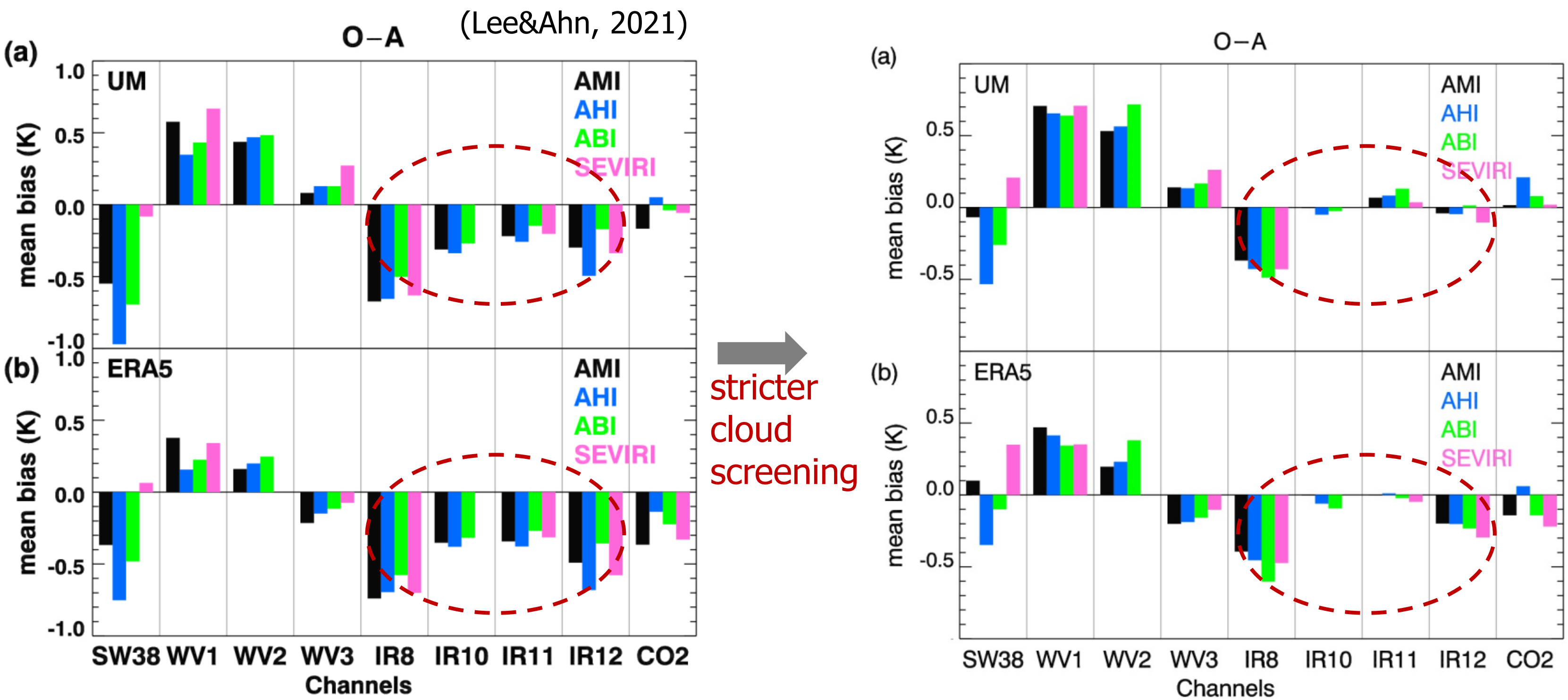
- ✓ Enables to build global monitoring system for GEO calibration and other applications

Global composite map of O–A with ERA5 for WV1



Challenges of using NWP+RTM method

- **Cloud screening**
  - ✓ Need decent cloud screening that can be applied for the multiple satellites.



- **Various error sources**
  - ✓ Errors in NWP models and RTM uncertainties can add ambiguity to the estimation and interpretation of the calibration results ➔ using two different NWP models and/or two different RTMs, and analyzing double difference of the biases can help locating the root cause of a specific feature (e.g., angle dependence of O-A in IR8)

Summary

- **Infrared observations from AMI, AHI, ABI, and SEVIRI are inter-compared using the NWP+RTM method**
- **The monthly mean O-A of the four imagers show overall similar statistics**
- **Using the NWP+RTM method can benefit the GEO intercalibration by**
  - ✓ Capturing instrument features like stripes shown in the CO2 channels of the advanced imagers
  - ✓ Characterizing features with data from short period of time (e.g. 5-days data produce similar results to statistics with 1-month data)
  - ✓ Revealing the characteristics of NWP models (e.g. wetness in the moisture field)
  - ✓ Revealing the uncertainties in RTM
  - ✓ Building a global monitoring system for GEO satellite calibration

Thank you