CEREs Science Team Meeting, NASA GISS, October 17–19th, 2023

CERES Cloud Radiative Swath (CRS) Update

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Collaboration with:

SARB group: David Rutan, and Emily Monroe (Surface validation)

David Fillmore and Antonio Viudez-Mora (MATCH/CAM6 aerosol)

TISA Group: Joshua C. Wilkins, David Doelling and Pamela Mlynczak (TISA gridding for CRS1deg product)

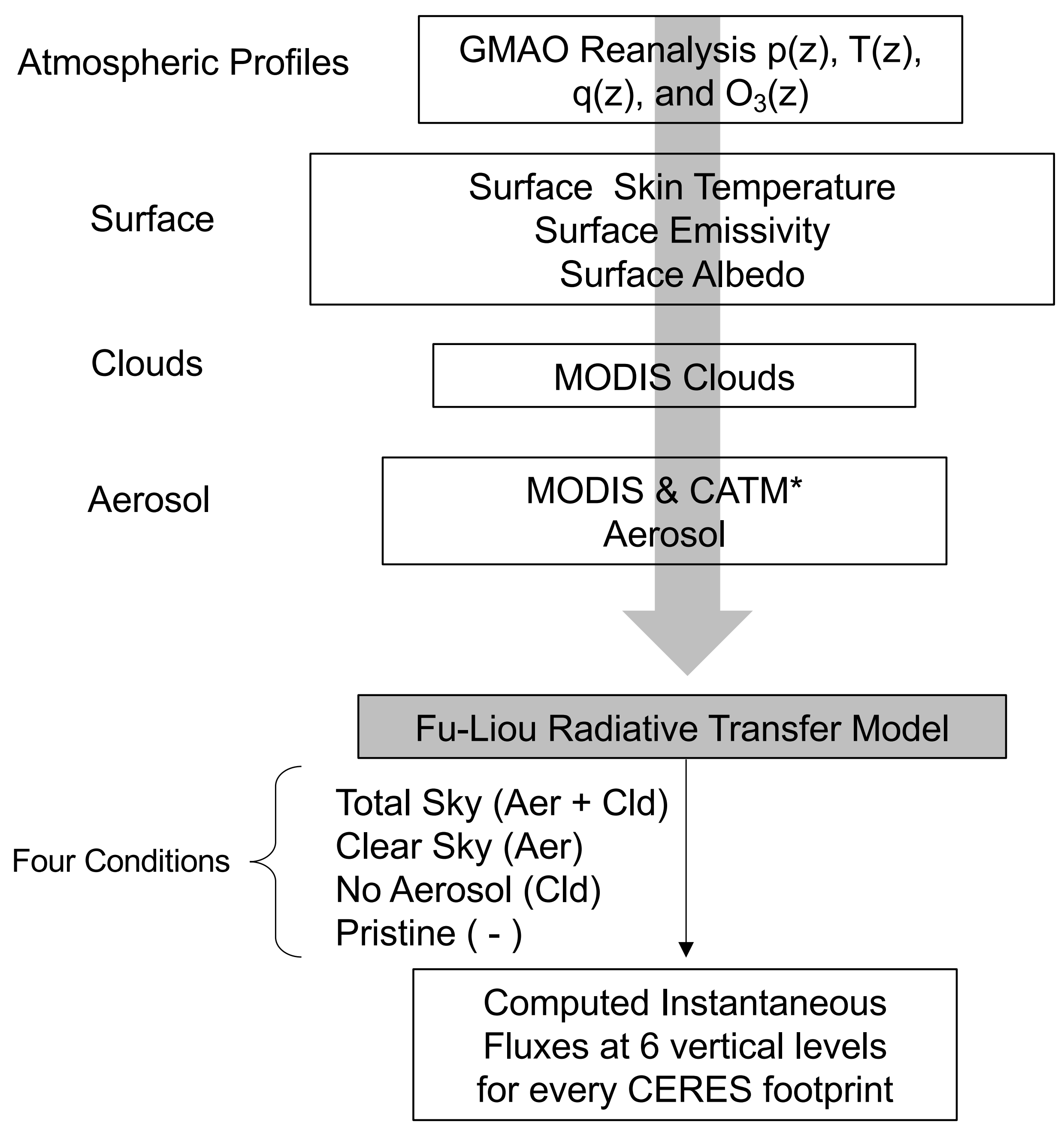
Data Management: Walter Miller, Victor Sothcott, and Kathleen Dejwakh

ADM Group: Wenying Su (TOA fluxes)

Cloud group: Bill Smith Jr, Sunny Sun-Mack, and Ben Scarino (Cloud and skin temperature retrievals)

FLASHFLUX group: Paul Stackhouse (Parameterized surface fluxes in FLASHFLUX)

CRS Flux Algorithm



Inputs

Atmospheric Profiles: GMAO Reanalysis p(z), T(z), q(z), and O_3(z)

Surface: Surface Skin Temperature, Surface Emissivity, Surface Albedo

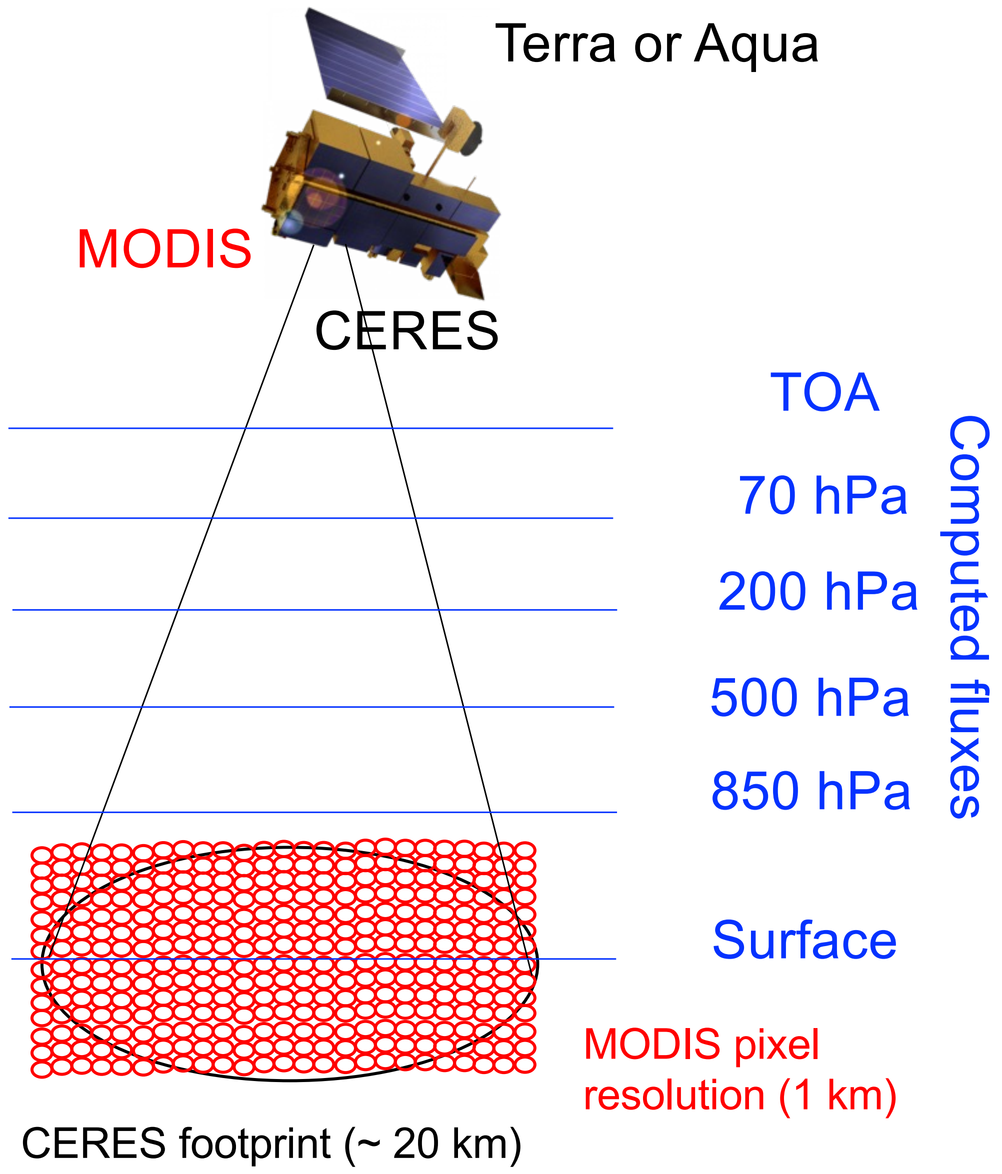
Clouds: MODIS Clouds

Aerosol: MODIS & CATM* Aerosol

Fu-Liou Radiative Transfer Model

Four Conditions
- Total Sky (Aer + Cld)
- Clear Sky (Aer)
- No Aerosol (Cld)
- Pristine (-)

Computed Instantaneous Fluxes at 6 vertical levels for every CERES footprint



CATM : CERES Atmospheric Transport Model produced by CERES SARB group

CRS Version History

	Ed2B (MOD C4 radiances)	Terra CERES-FM1 or FM2 Aqua CERES-FM3 or FM4	Mar 2000 – June 2006 July 2002 – May 2006
	Ed2C (MOD C5 radiances)	Aqua CERES-FM3	May 2006 – Dec 2007
Released in May 2023 (Last CERES STM)	Ed4 (MOD C6 radiances)	Terra CERES-FM1 Aqua CERES-FM3	2018-2022 2018-2022 ”5 years”

Ongoing Development

Ed5 Alpha	Terra CERES-FM1 Aqua CERES-FM3	TBD

Fu-Liou Model Inputs for CRS Flux Simulations

	Ed4 **(Released in May 2023)**	**Ed5 (Ongoing Development)** **(Target release date: 2025-2026)**
$T(z)/q(z)/O_3(z)$ profiles & wind speed	MOA-GEOS-5.4.1 (1° grid)	🟩 MOA-GEOS-IT (0.5° grid)
Skin Temperature	• MODIS 11 µm-derived T_{skin} for clear skies • GEOS-5.4.1 T_{skin}	🟨 • MODIS 11 µm-derived T_{skin} for clear skies (Affected by cloud detection algorithm change) • GEOS-IT T_{skin}
Surface Albedo	▪ Parameterized albedo model from Jin (2004) ▪ MODIS BRDF Spectral albedo ▪ Surface albedo history (SAH) Ed4 map derived from clear-sky CERES measurements	🟧 ▪ Theoretical albedo model from Jin (2004) ▪ MODIS BRDF Spectral albedo ▪ Surface albedo history (SAH) Ed5 map derived from clear-sky CERES measurements
Surface Emissivity	▪ CERES Emissivity for 11-12 µm bands ▪ Climatological emissivity based on IGBP	🟩 ▪ ADM Group-generated merged LW emissivity maps: Derived from far IR (Huang et al. 2016) and IASI-derived LW (Zhou et al. 2013) emissivity models.
Cloud properties	MODIS clouds from Ed4 Cloud Algorithm	🟨 MODIS clouds from Ed5 Cloud Algorithm
Aerosol Properties	• Ed4 Hourly CERES Atmospheric Transport Model (CATM) (Fillmore et al., 2022) • MODIS C6 multi-channel aerosol optical depths	🟧 • Ed5 Hourly CATM: MODIS/VIIRS aerosol with CAM6 aerosol scheme (Seiji's talk during CERES STM) • MODIS C7 multi-channel aerosol optical depths
RTM	Langley Fu-Liou model	🟧 Langley Fu-Liou model with updated correlated k gas absorption features

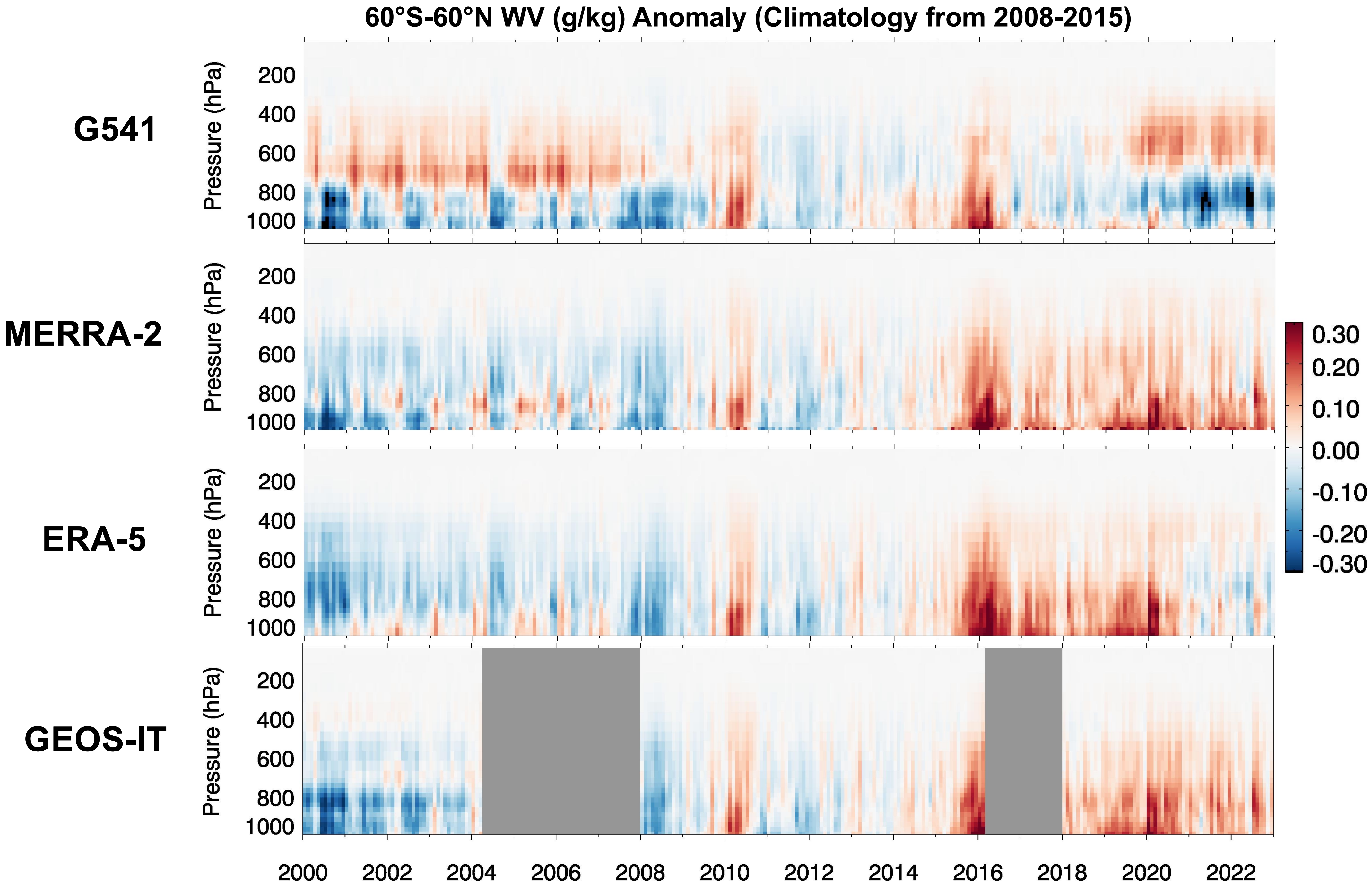
🟧 In Progress 🟨 Algorithm being tested 🟩 Completed

Ongoing Improvement/Development for Ed5

- Switching GMAO reanalysis dataset from GEOS-5.4.1 to GEOS-IT for T(z) and q(z)
- A better surface emissivity map with more realistic far-IR emissivity values
- Inclusion of LW surface reflected component
- Code interface for NetCDF ancillary datasets
- Minor code fix: Occasional failures of Fu-Liou Model runs when cloud layer was below the lowest model layer, MATCH AOT was stored in negative value when AOT > 3.27 during the data type conversion.
- New clouds, skin temperature, and aerosol properties are under development by Cloud and SARB groups, and these will be implemented in Ed5.

Issues in GEOS-5.4.1 (G541): Discontinuities in WV Time Series

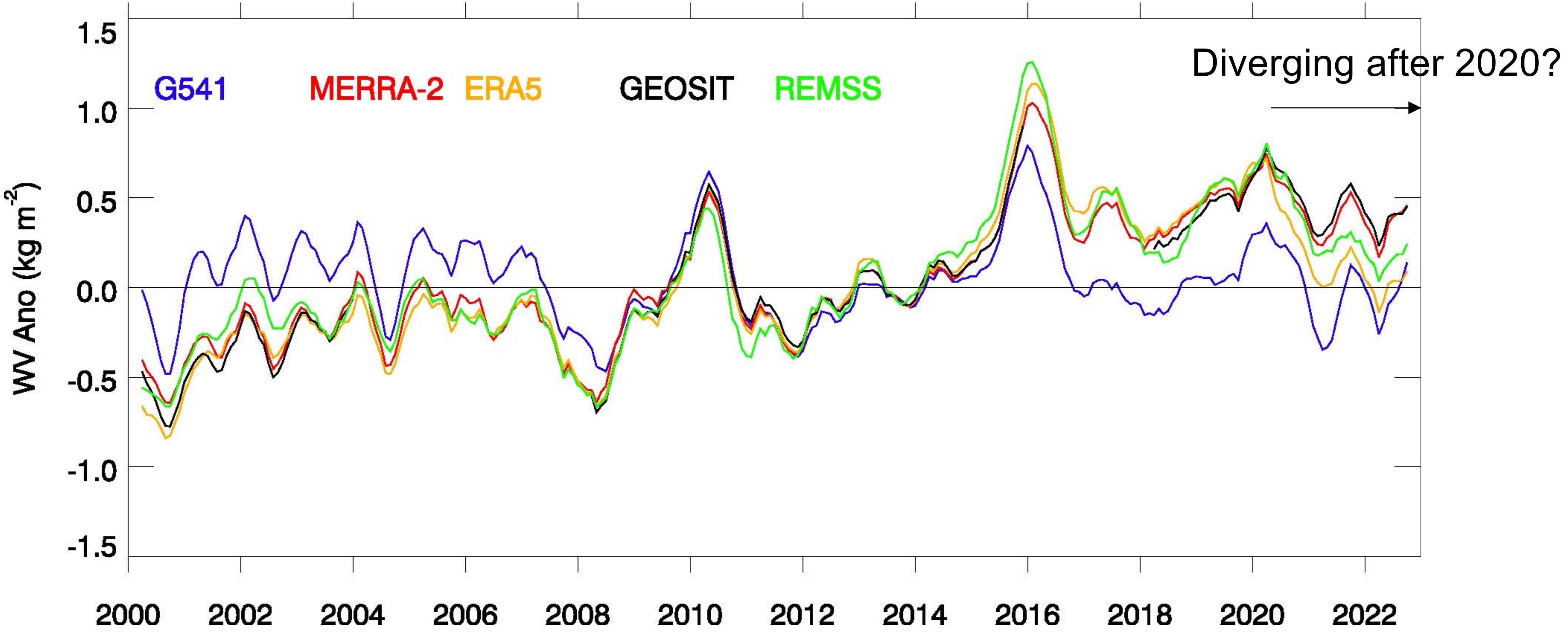
GEOS-IT is running in three different streams:
stream #1: 1998-2007
stream #2: 2008-2017
stream #3: 2018-present



- Discontinuities were found in GEOS-5.4.1 WV anomaly time series, which was used for Ed4 CRS processing.
- GEOS-IT WV time series is more consistent with MERRA-2 and ERA-5, not showing any discontinuities.
- However, after 2020, it seems that MERRA-2, ERA-5, and GEOS-IT are starts to diverge.

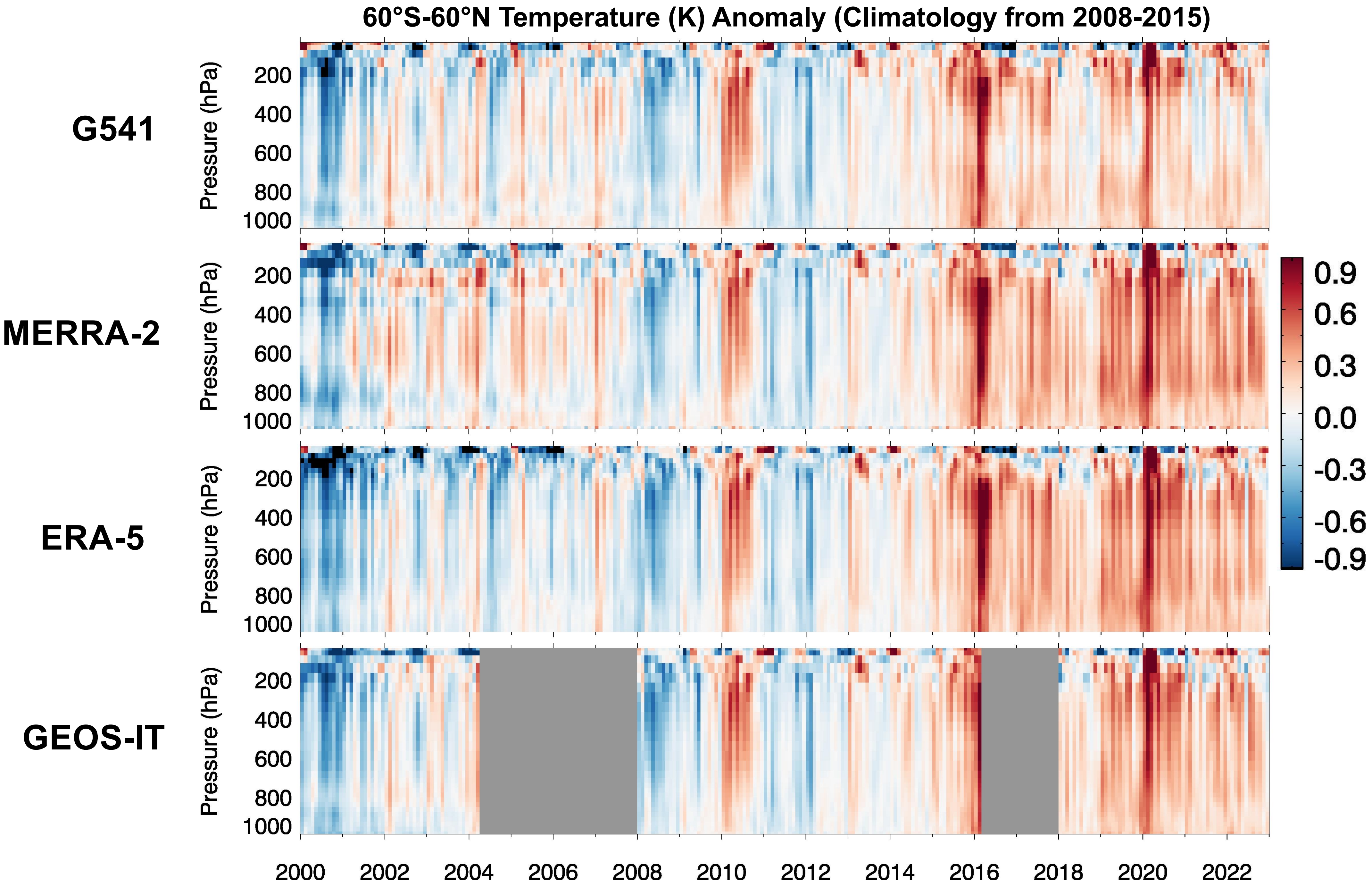
Anomalies of Total Column Water Vapor

- Anomaly from 2008-2015 climatology
- GEOS-IT is missing in some periods
- 6-month running means



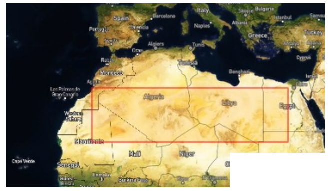
- ✓ G541 is an outlier from other datasets.
- ✓ MERRA-2, ERA-5, and GEOS-IT are similar each other, and they also follow microwave (RMESS) observations.
- ✓ Divergences across datasets appear after 2020, requiring further investigations.
- ✓ Different WV anomaly time series in GEOS-IT will improve trend of computed fluxes.

Consistent Temperature Anomalies Across Datasets



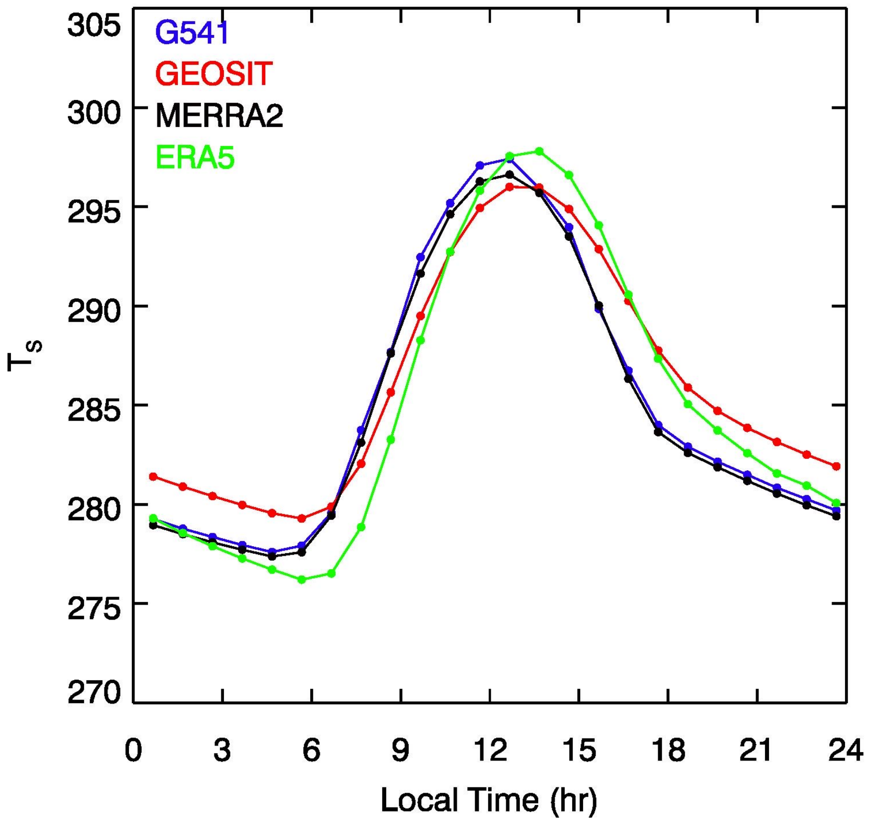
○ Temperature anomalies from G541, MERRA-2, ERA-5, and GEOS-IT generally well agree.

Changes in Temperature Diurnal Cycle from GEOS-5.4.1 to GEOS-IT



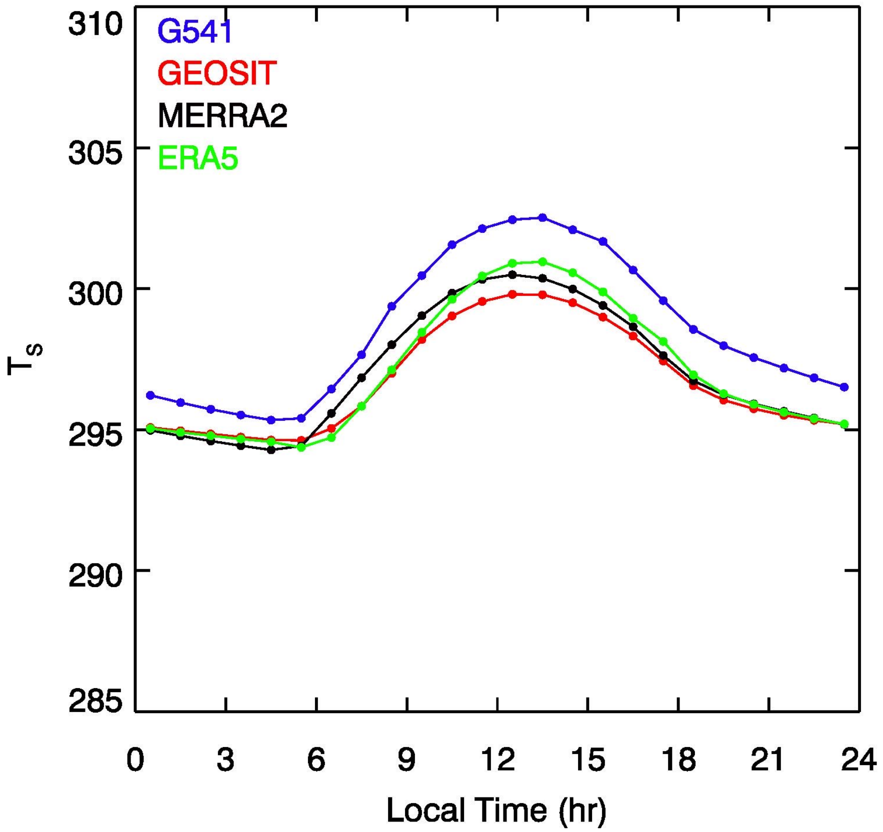
North Africa/Sahara Region
(10°W-30°E, 20-30°N)

200801



South America
(75°W–60°W, EQ–15°N)

200801



Comparison of Land Skin Temperature (LST) will be shown in Ben Scarino's Thursday talk

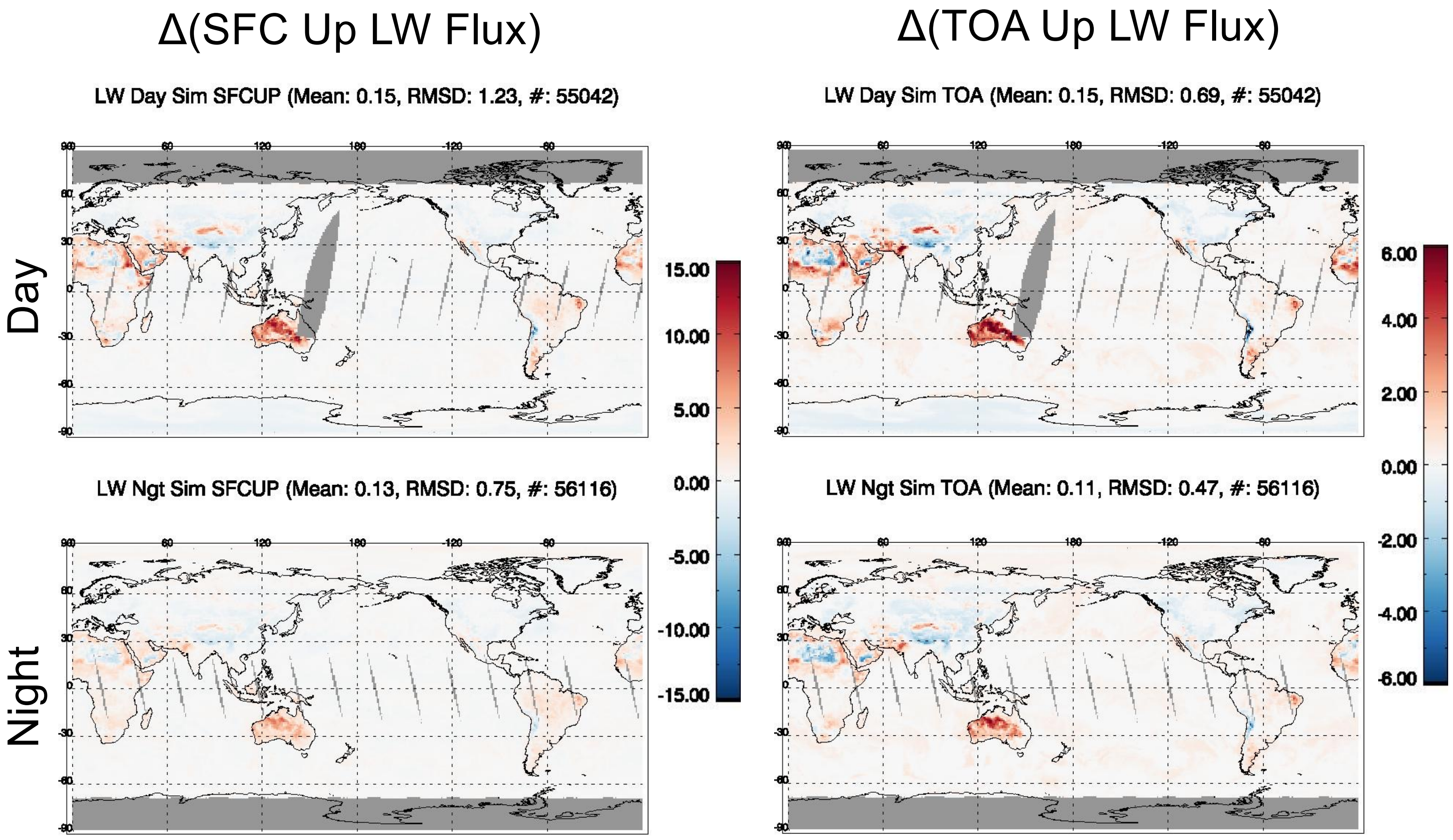
Skin temperature improvement in polar region will be discussed in David Rutan's Thursday talk

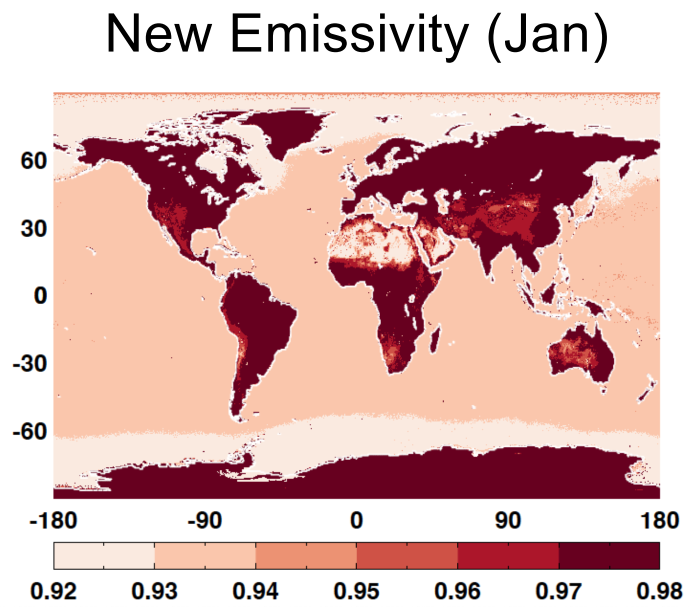
- ✓ Diurnal skin temperature (T_s) range of GEOS-IT is generally smaller than that of GEOS-IT.
- ✓ Daytime GEOS-IT skin temperature is smaller than other datasets.
- ✓ The 2-m air temperature (T2M) shows similar differences as in T_s.
- ✓ Changes in T2M will impacts on computed LW surface downward fluxes.
- ✓ Changes in Ts will impact on computed LW surface upward fluxes for overcast scenes.
- ✓ We found that improvement of polar region skin temperatures in GEOS-IT.

Updates of LW Surface Emissivity Model for Ed 5 CRS Flux Computations

1st July 2019
Terra

Impact of Surface LW Emissivity Map





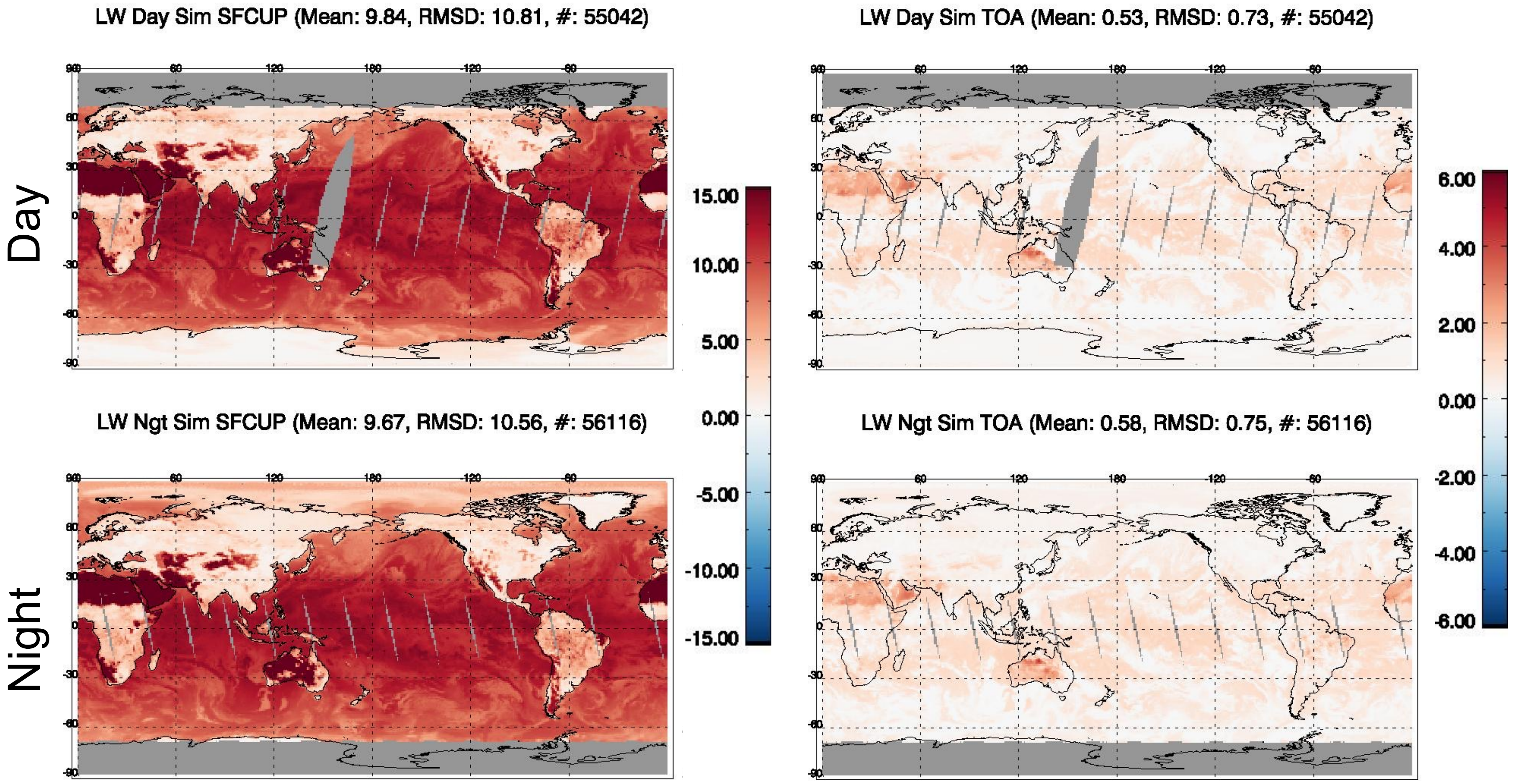
Zachary A. Eitzen, Wenying Su, Lusheng Liang, and Sergio Sejas 2023: A New Emissivity Dataset for CERES, Technical Report

- Overall impact of the LW emissivity model on LW computations is small.
- Surface LW upward changes by 0.15 W m^{-2}, and TOA LW surface upward changes up to 0.15 W m^{-2}.

Impact of Surface-Reflected Component in LW Computations

Δ(SFC Up LW Flux)

Δ(TOA Up LW Flux)



LW Day Sim SFCUP (Mean: 9.84, RMSD: 10.81, #: 55042)

LW Ngt Sim SFCUP (Mean: 9.67, RMSD: 10.56, #: 56116)

LW Day Sim TOA (Mean: 0.53, RMSD: 0.73, #: 55042)

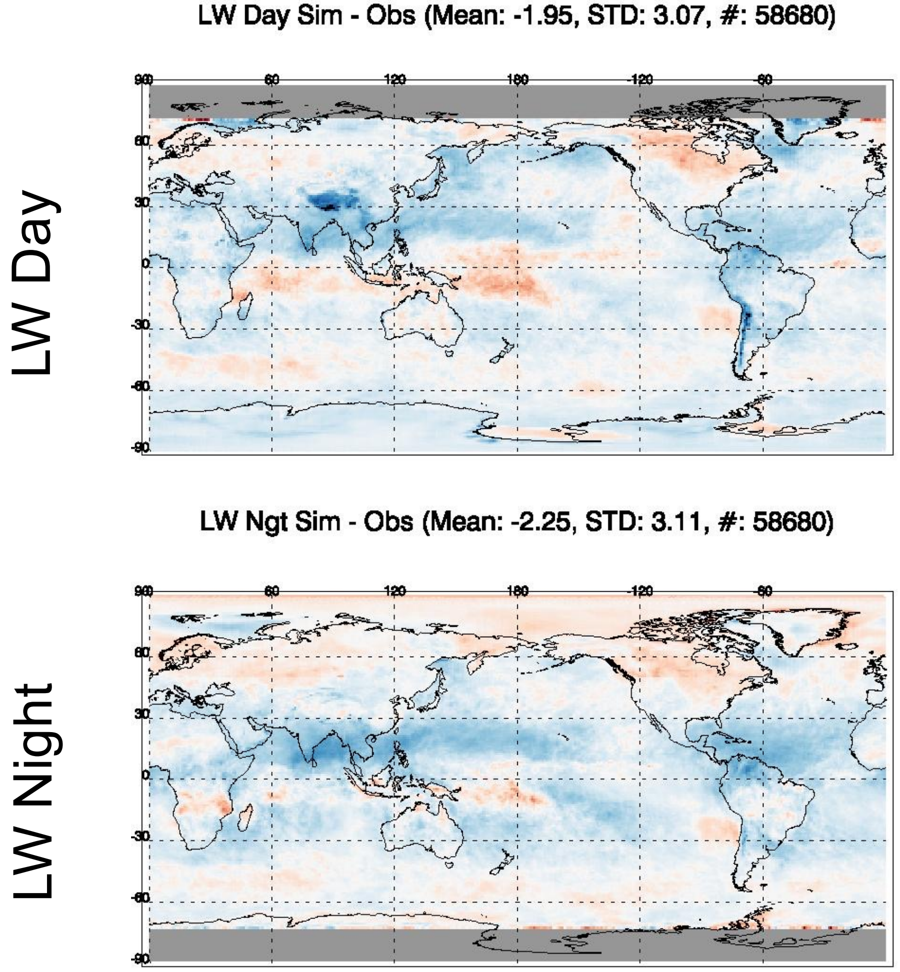
LW Ngt Sim TOA (Mean: 0.58, RMSD: 0.75, #: 56116)

- ○ In Ed4 CRS computations, surface-reflected component was not included for LW computations. In Ed5, when the surface emissivity (ε_s) < 1 (e.g., 0.95), surface reflectivity of 1 – ε_s(e.g., 0.05) will be included in the computations.
- ○ By including LW surface reflected component, surface LW upward flux is increased by 10 W m^{-2}, and TOA LW upward flux is increased by 0.6 W m^{-2}.

TOA Biases (Computed minus CERES-observed TOA Upward Fluxes)

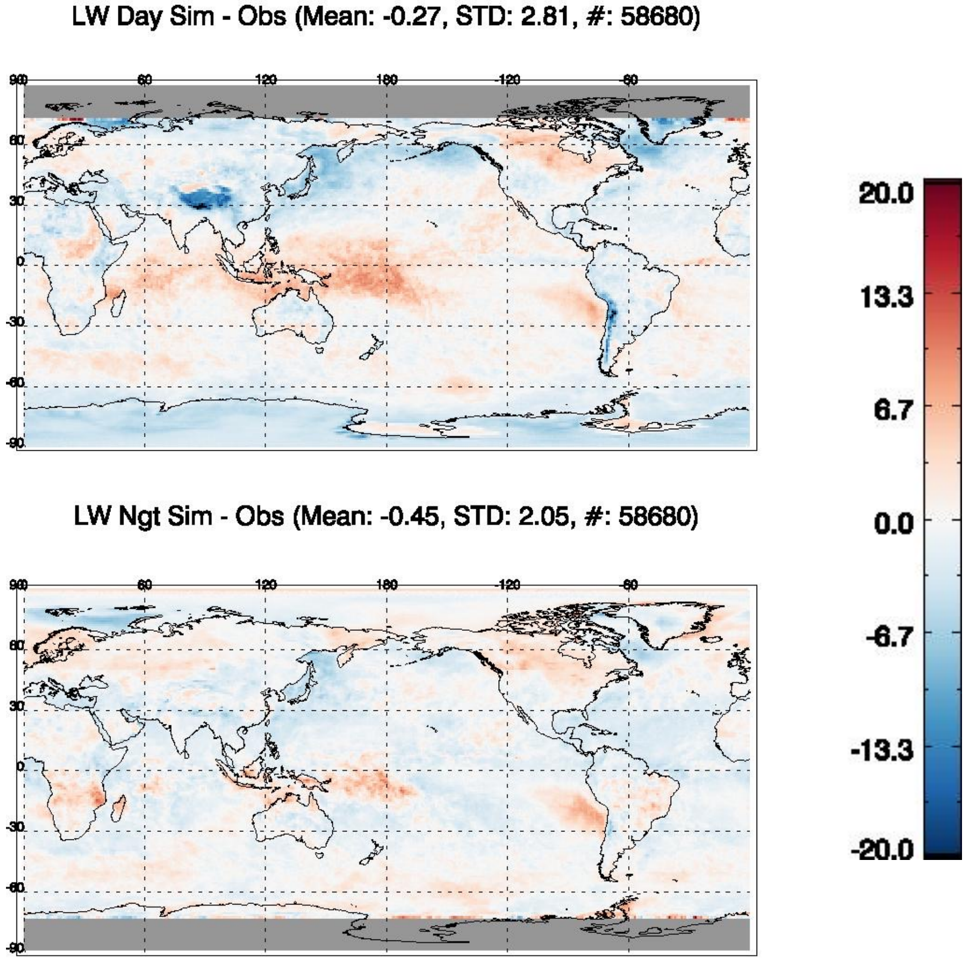
All cases
Jan2020

TOA Flux Biases in CRS Ed4
(GEOS-5.4.1+Ed4 LW ε_s + No LW surface reflection)


LW Day Sim - Obs (Mean: -1.95, STD: 3.07, #: 58680)

LW Ngt Sim - Obs (Mean: -2.25, STD: 3.11, #: 58680)

TOA Flux Biases in CRS Ed5-Alpha-Test
(GEOS-IT + Ed5 LW ε_s + LW surface reflection)

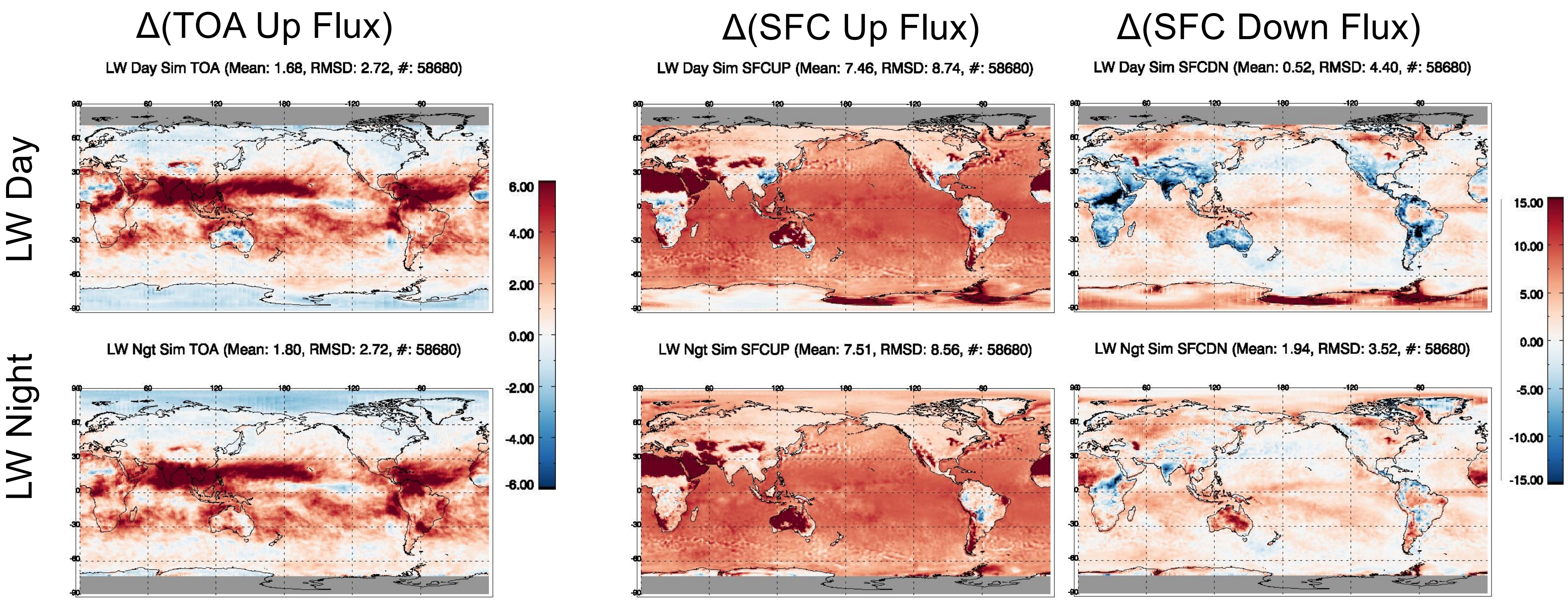

LW Day Sim - Obs (Mean: -0.27, STD: 2.81, #: 58680)

LW Ngt Sim - Obs (Mean: -0.45, STD: 2.05, #: 58680)

- SW changes are small and so these are not included.
- Computed LW fluxes using GEOS-IT are better agreed with CERES observations, compared to those using GEOS-5.4.1.
- More time-consistent LW biases when using GEOS-IT, compared to results using GEOS-5.4.1.

Changes in Computed Fluxes from Ed4 to Ed5-Alpha-Test (Switching GMAO dataset, Surface Emissivity, and Including Surface LW reflection)

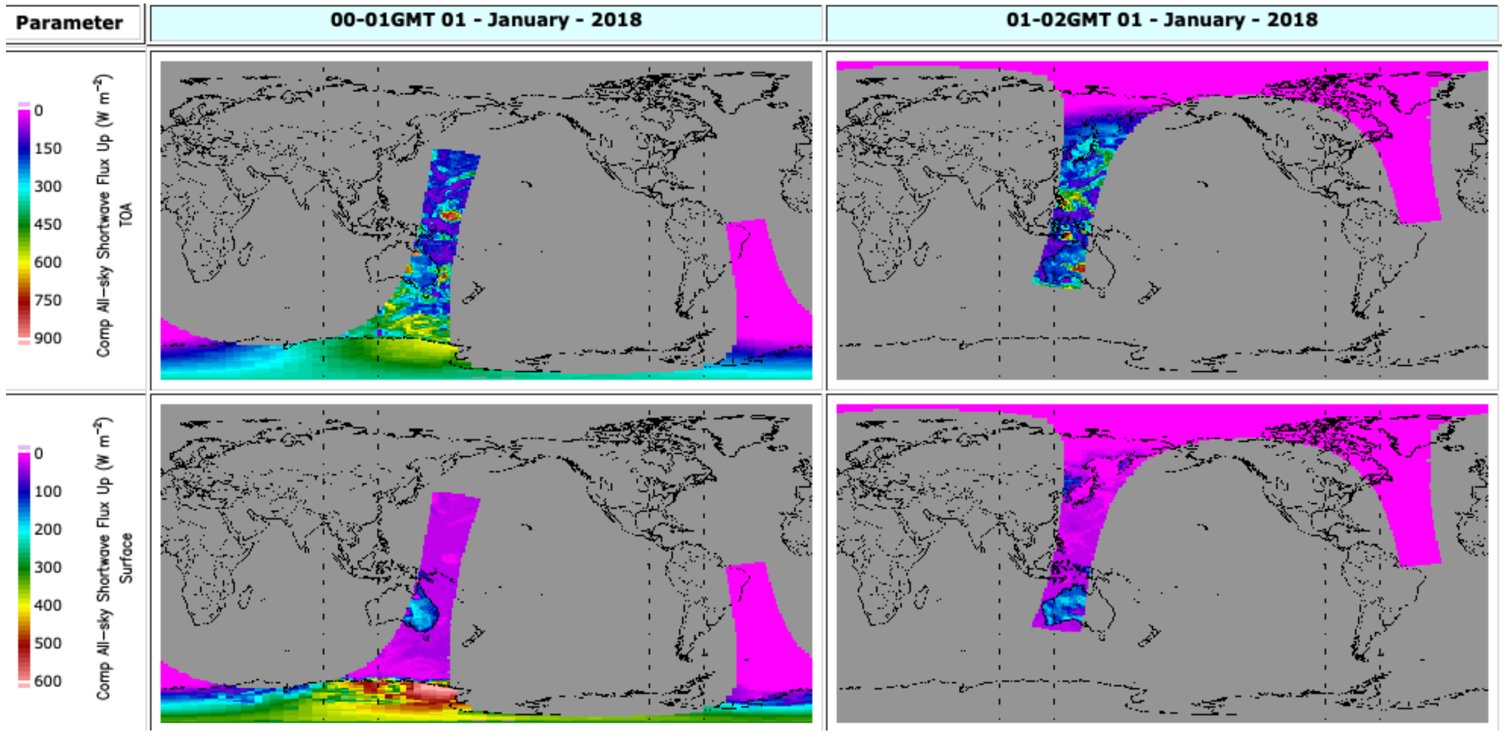
January 2020, Terra



- SW changes are small so not included in this plot.
- Changes in TOA LW upward fluxes are mostly related to WV changes from GEOS-5.4.1 to GEOS-IT.
- Changes in SFC LW upward fluxes are mainly caused by inclusion of surface-reflected component.
- Changes in SFC LW downward fluxes are related to near-surface temperature changes. GEOS-IT daytime land skin temperature is colder than GEOS-5.4.1 skin temperature.

CRS Ed4 1deg-Hour Product (In Progress with TISA group)

- Ed4 CRS1deg-Hour will be available soon.
- Level-3 hourly averaged gridded (1°) product of instantaneous computed and observed fluxes
- CRS1deg product are aligned with SSF1deg product. Both products contain the same number of CERES footprints.
- The relationship between cloud/aerosol with radiative fluxes can be examined on a grid scale.
- The L3 product can be more easily collocated with other satellite product (e.g., AIRS) and climate model results.
- Note that CRS1deg-Hour product is derived from a certain local time (10:30AM for Terra and 1:30PM for Aqua) and when comparing with other products, the time differences across datasets should be considered.



Summary

- Switching reanalysis dataset from GEOS-5.4.1 and GEOS-IT will impact on the trend of computed LW fluxes, mostly related to the different WV trends. Note that SYN Ed4 used GEOS-5.4.1 and EBAF Ed4 used MERRA-2.
- Daytime GEOS-IT skin temperatures are colder than GEOS-5.4.1, causing smaller LW surface downward fluxes when using GEOS-IT. The impact on LW surface upward fluxes will be relatively small since we use imager (MODIS)-derived skin temperature for Fu-Liou calculations, if available.
- The new LW emissivity model is slightly smaller than Ed4 emissivity for most regions. The impact of the new LW emissivity on TOA LW fluxes is around 0.15 W m^{-2}. The inclusion of this component will bring flux chages, up to 10 W m^{-2} for TOA LW up and 0.6 W m^{-2} surface LW up.
- Cloud and aerosol are main factors to determine in computing fluxes, and the impact of these parameters will be examined.

Thank you for your attention!

Please contact to seung-hee.ham@nasa.gov if you have any questions.