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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: 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

GMAO Reanalysis p(z), T(z), q(z), and O_3(z)

Surface Skin Temperature
Surface Emissivity
Surface Albedo

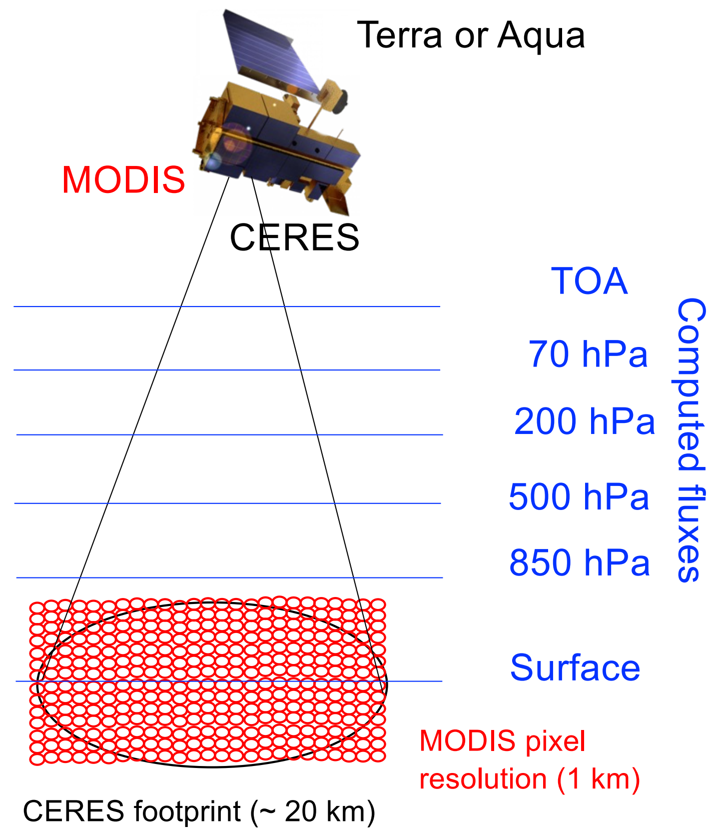
MODIS Clouds

MODIS & MATCH 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



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

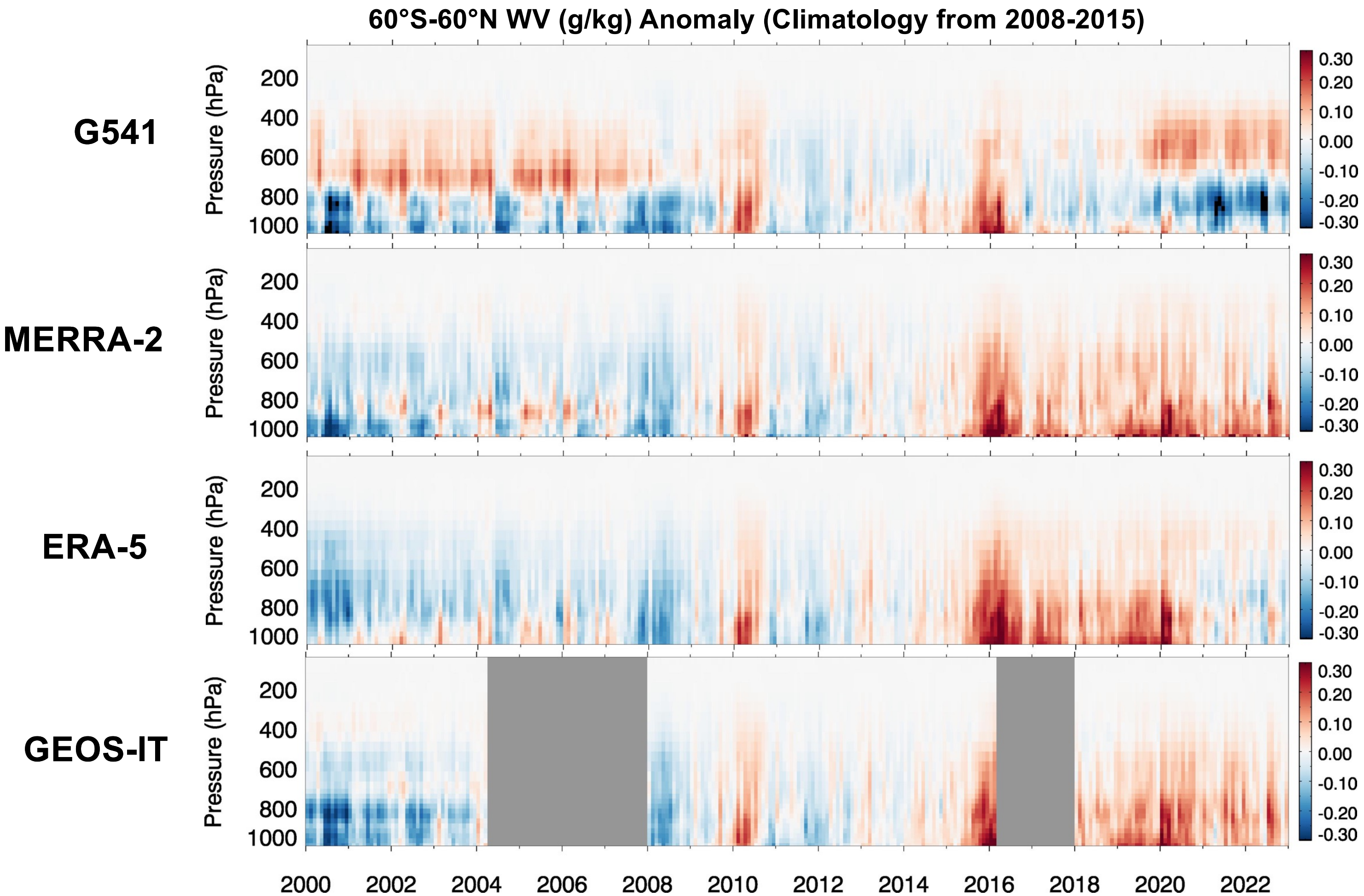
	Ed4 (Released in May 2023)	⇨ Ed5 (Ongoing Development) (Target release date: 2025-2026)
$T(z)/q(z)/O_3(z)$ profiles & wind speed	MOA-GEOS-5.4.1 (1° grid)	MOA-GEOS-IT (0.5° grid)
Skin Temperature	• MODIS 11 µm-derived T_{skin} for clear skies • GEOS-5.4.1 T_{skin}	• MODIS 11 µm-derived T_{skin} for clear skies • 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 MATCH (Fillmore et al., 2022) • MODIS C6 multi-channel aerosol optical depths	• Ed5 Hourly MATCH: MODIS/VIIRS aerosol with CAM6 aerosol scheme (David Fillmore'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)
- Inclusion of LW surface reflected component
- A better surface emissivity model with more realistic far-IR emissivity values
- 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.

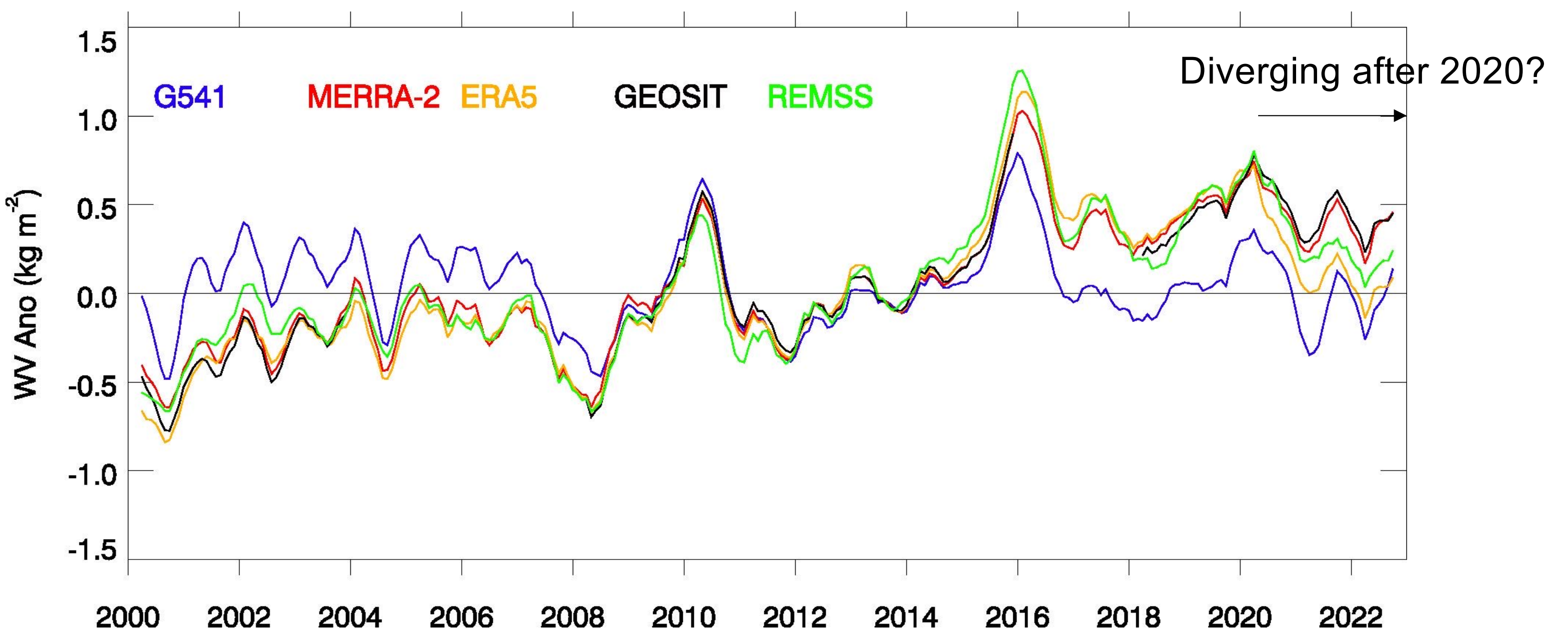
Issues in GEOS-5.4.1 (G541): Discontinuities in WV Time Series



- Discontinuities were found in GEOS-5.4.1 WV anomaly time series, which was used for Ed4 CRS proecssing.
- 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.

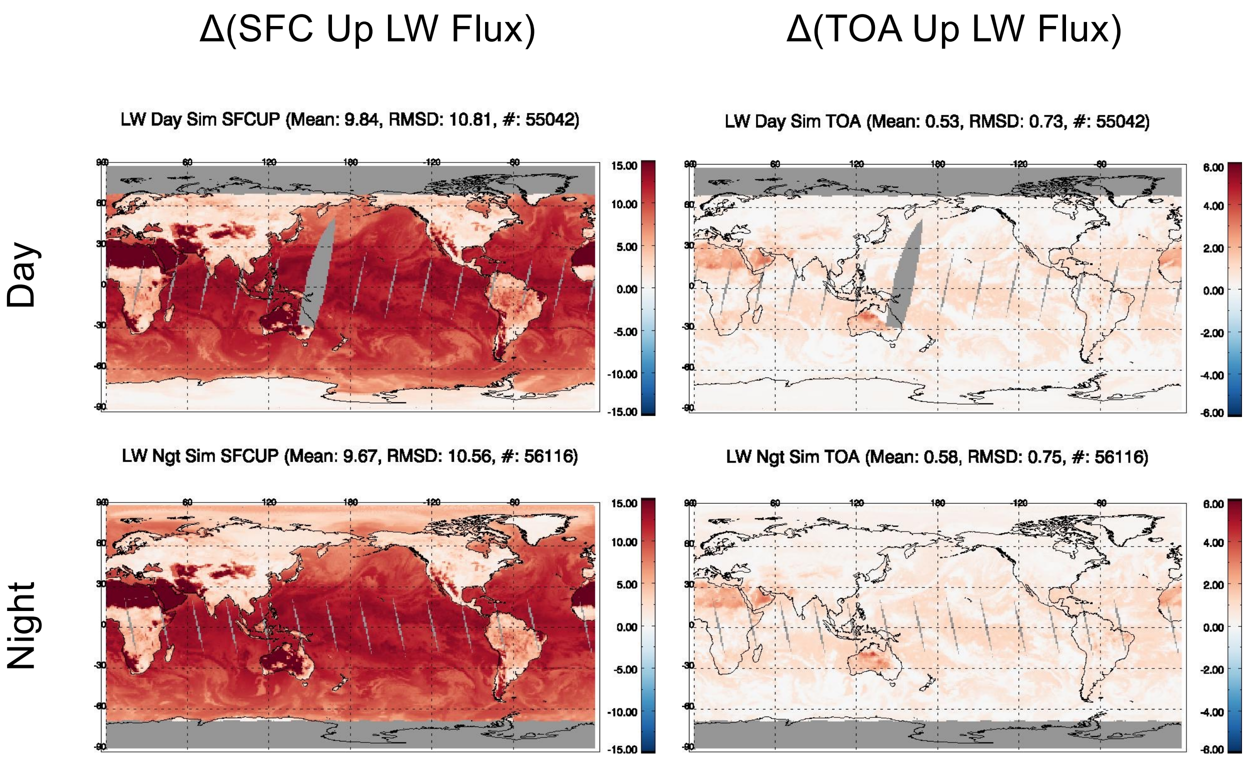
Trends (%) of Total Column Precipitable Water

- 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.

Impact of Surface-Reflected Component in LW Computations



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

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

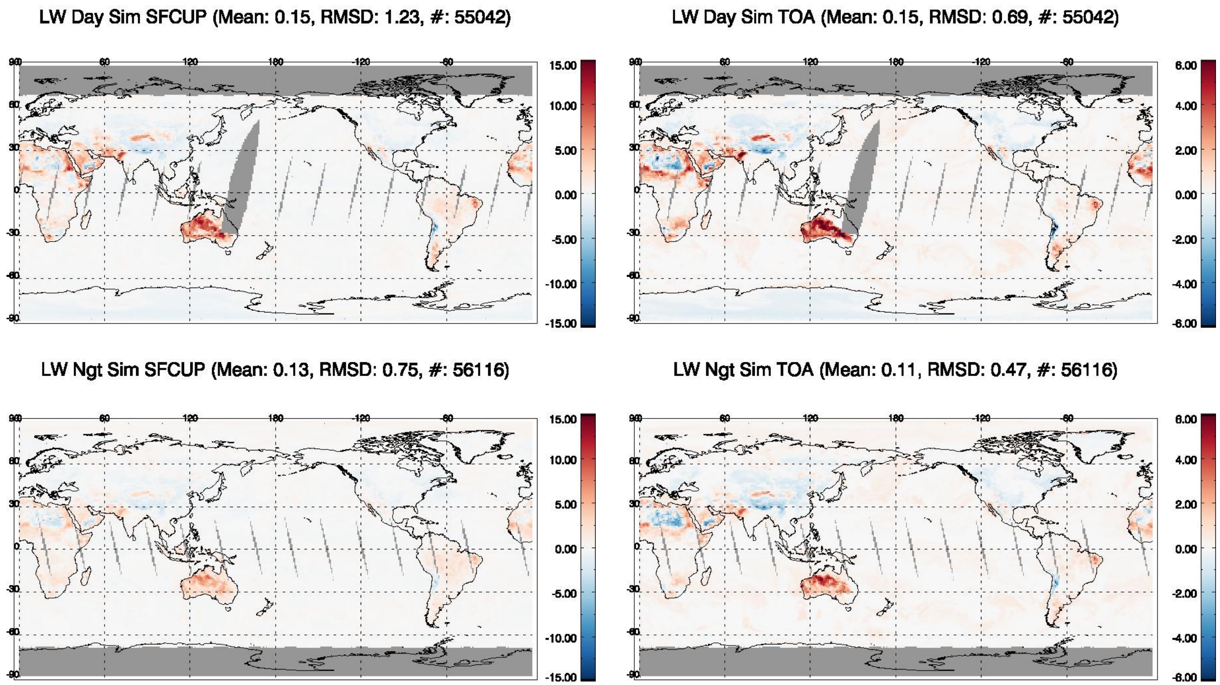
1st December 2019
Terra

Impact of Surface LW Emissivity Model

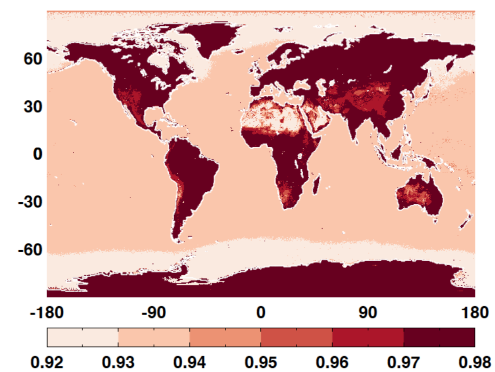
Δ(SFC Up LW Flux) Δ(TOA Up LW Flux)

Day

Night



New Emissivity (Jan)



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

- Overall impact of LW emissivity changes 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}.

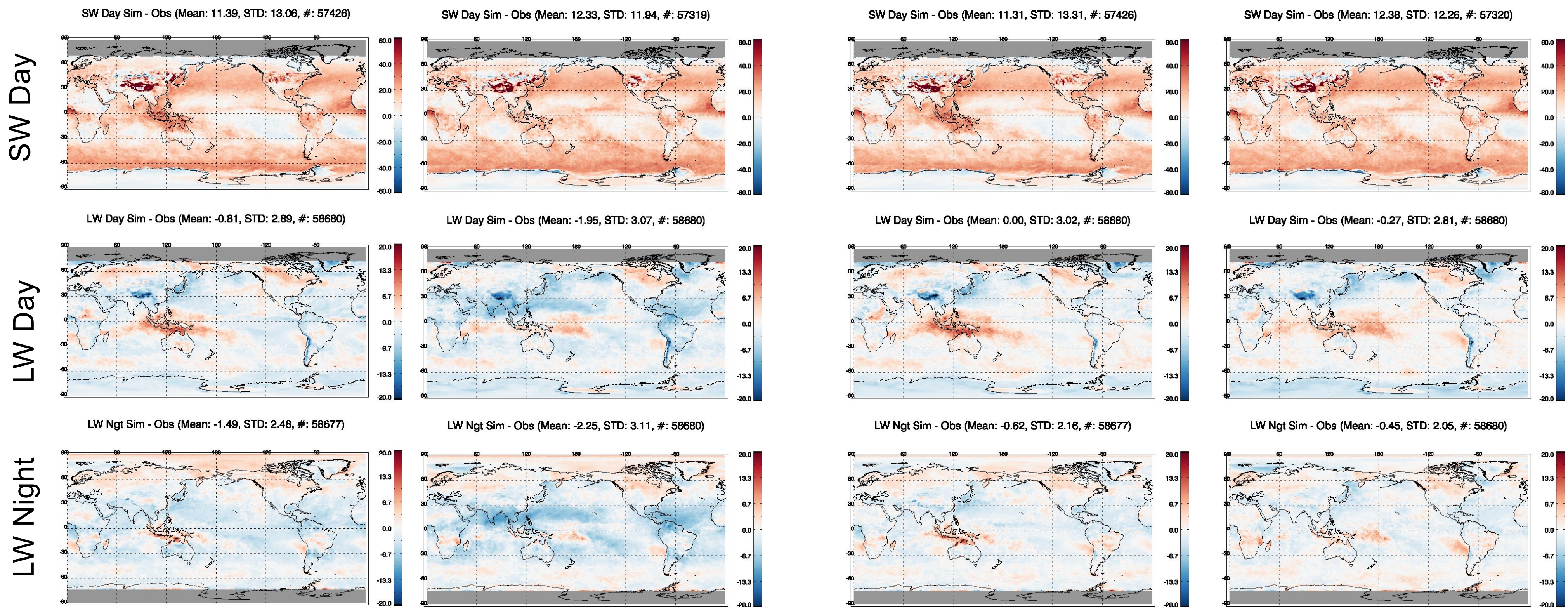
TOA Biases (Computed minus CERES-observed fluxes)

All cases

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

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

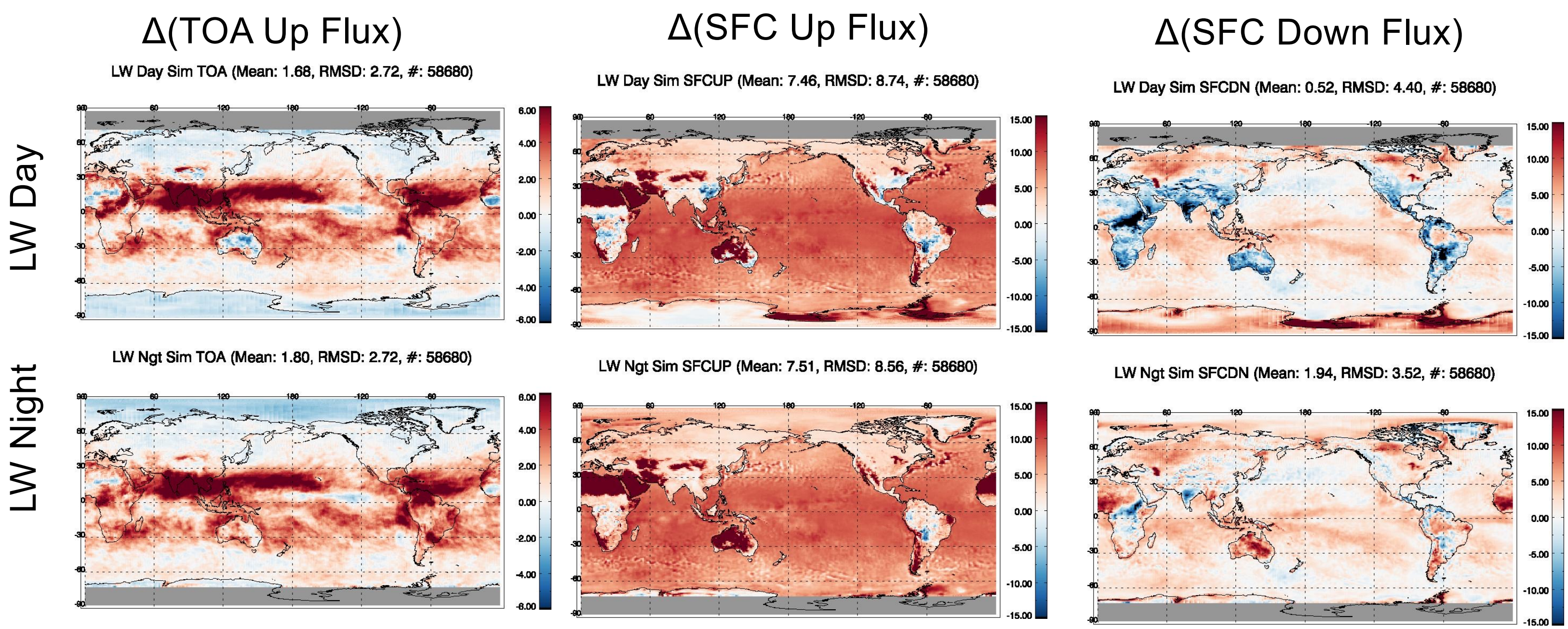
January 2018 | January 2020 | January 2018 | January 2020



- Computed LW fluxes using GEOS-IT are better agreed with CERES observations, compared to those using GEOS-5.4.1.
- The same Ed4 clouds are used in both computations, and further examination is required for positive SW biases.

Changes in Computed Fluxes by 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.

Summary

- CRS Ed5 development is ongoing.
- 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.
- 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 surface reflected component in LW calculations was not included in Ed4, and inclusion of this component will bring a larger changes, 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.

Future Plans

- Surface validation using ground observations can be used to verify if the CRS flux algorithm is improved or not (See talk David Rutan's Thursday talk).
- The results shown in this talk only includes for a short-term period. A longer record will give more idea whether the timeseries of flux biases are not affected by artifacts in input parameters (such as WV anomalies).
- Clouds and aerosol are main drivers to determine radiative fluxes. The new version of these parameters will be tested for the CRS algorithm.

Thank you for your attention!

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