FLASHFlux Working Group Status: Progress toward NN/ML SSF and GCC TISA

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POWER Team: ***Christopher Higham, Bradley MacPherson, Amanda Merritt, Zoe Waring and A. Jason Barnett (Booz-Allen-Hamilton)***

CERES FLASHFlux Overview

- ***FLASHFlux Overview***
  - Uses CERES based production system through inversion (w/ quarterly calibration updates projected forward)
  - Running 3-day TISA utilizing afternoon orbiter (NOAA-20 only)
- ***FLASHFlux Latency Objectives***
  - SSF products within 3-4 days
  - Global 1x1 daily averages from FF TISA; goal: 5-7 days latency
- ***FLASHFlux Uses***
  - Primarily used for applied science and education (i.e., POWER and Globe Clouds)
  - Supports also QC for selected missions (e.g., NOAA NESDIS, EarthCare)
  - TOA gridded fluxes; normalized to TOA EBAF for annual “State of the Climate” assessments.

FLASHFlux Operational Status

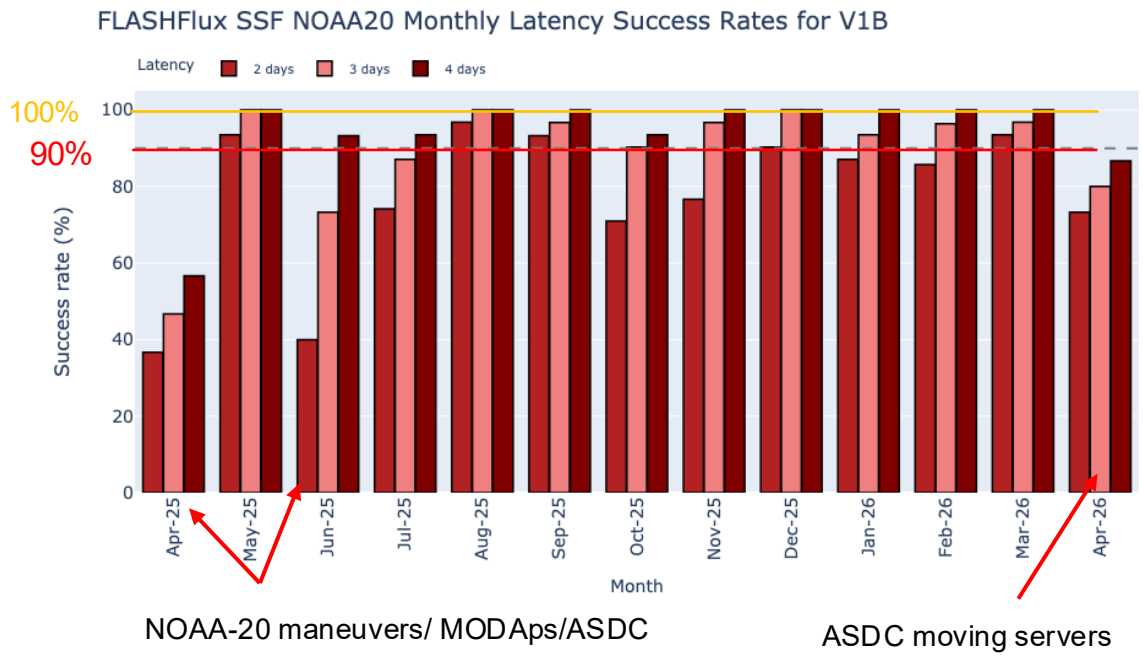
- ***FF Production status:***
  - Current Status:
    - SSF NOAA-20 (V1B): 5/10/26
    - TISA: NOAA-20-only v1A: 5/8/26
  - Updated calibration coefficients received & promoted as cc change effective 1/1/26 (next update scheduled for 7/1/26)
- ***Important Activities since last CERES Meetings:***
  - Maintained production and updated validation for old and new versions
  - Integrated NN/ML-derived weights into the production codebase for the footprint flux algorithms.
  - Generate global hourly TOA and surface radiative fluxes using SatCORPS GEO data within the Univa Grid Engine testing environment.

FLASHFlux SSF Latency Assessment

Success rate (%) of time data archived within 2, 3, or 4 days of observation

Lags are sometimes due to maneuvers/satellite issues, ASDC updates/outages, ASDC Dropbox/Darkhorse, GSFC LAADS and/or SIPS

Latency for March 2026:
95% of products archived at 3 days,
100% by 4 days
Latency for Apr 2026:
80% of products archived at 3 days,
87% by 4 days

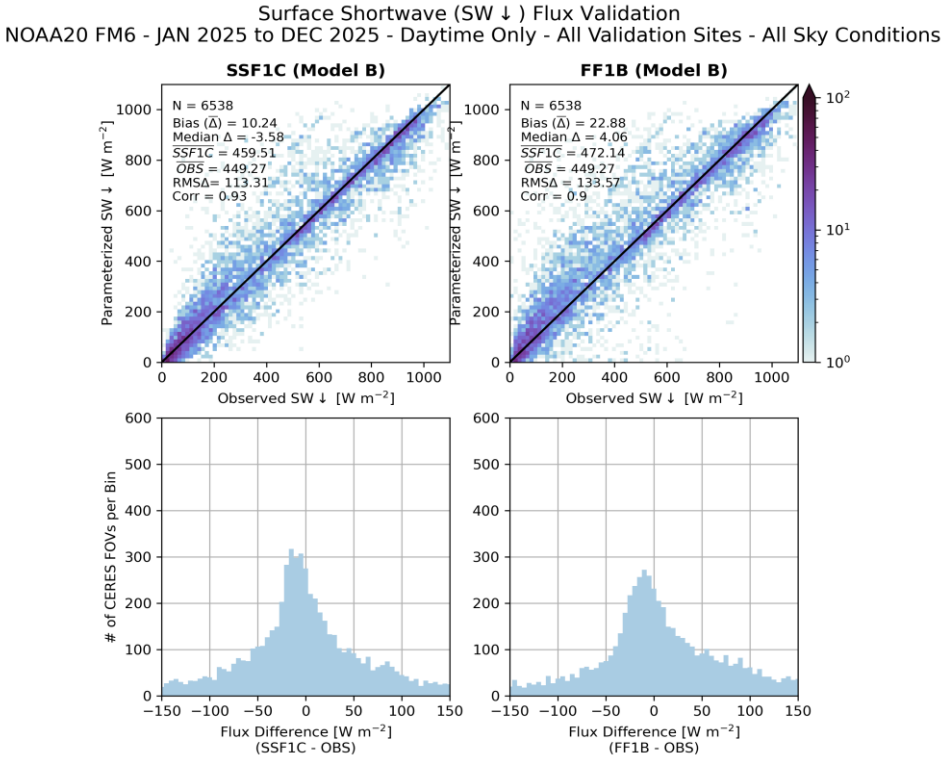


NOAA-20 SSF SW Flux Validation: 1/2025-12/2025

Overpass NOAA-20 SW daytime flux validation with BSRN measurements:

- Left: CERES SSF Ed1C (with G5-CERES): ~2.3% bias, ~ 25.2% RMS
- Right: FLASHFlux SSF V1B (with GEOS-IT): ~5.1% bias, ~29.7% RMS

CERES SW Down FF SW down

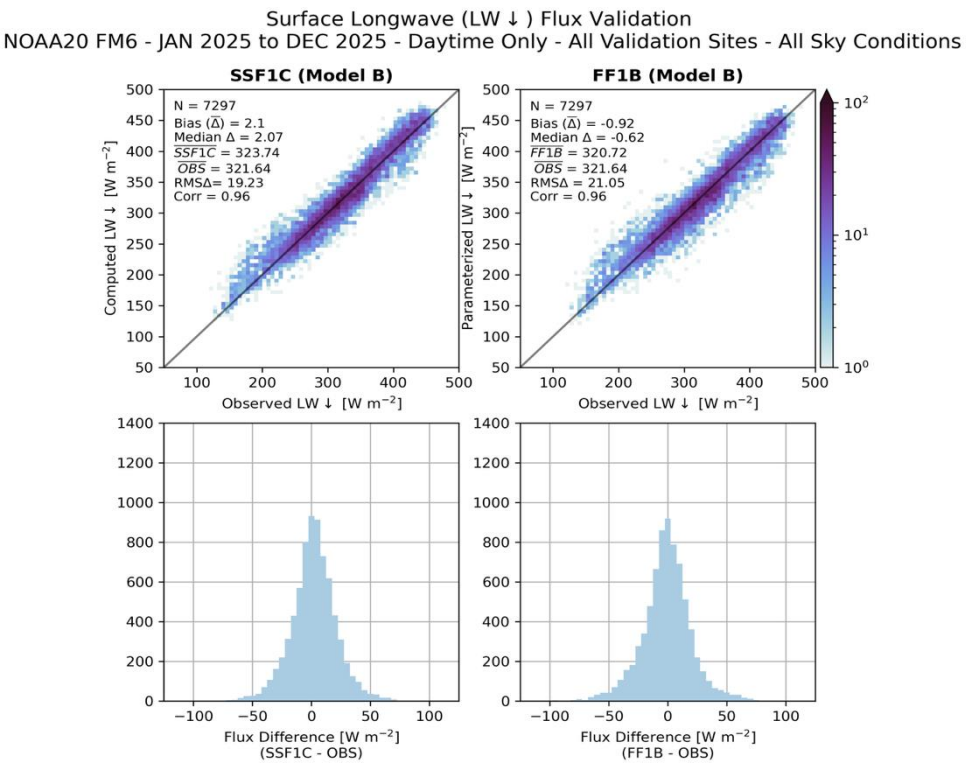


NOAA-20 SSF LW Flux Day Validation: 1/2025-12/2025

Overpass NOAA-20 LW daytime flux validation with BSRN measurements:

- Left: CERES SSF Ed1C (with G5-CERES): <1% bias, < 6% RMS
- Right: nighttime FLASHFlux SSF V1B (with GEOS-IT): <1% bias, ~6.5% RMS

CERES LW Down FF LW down

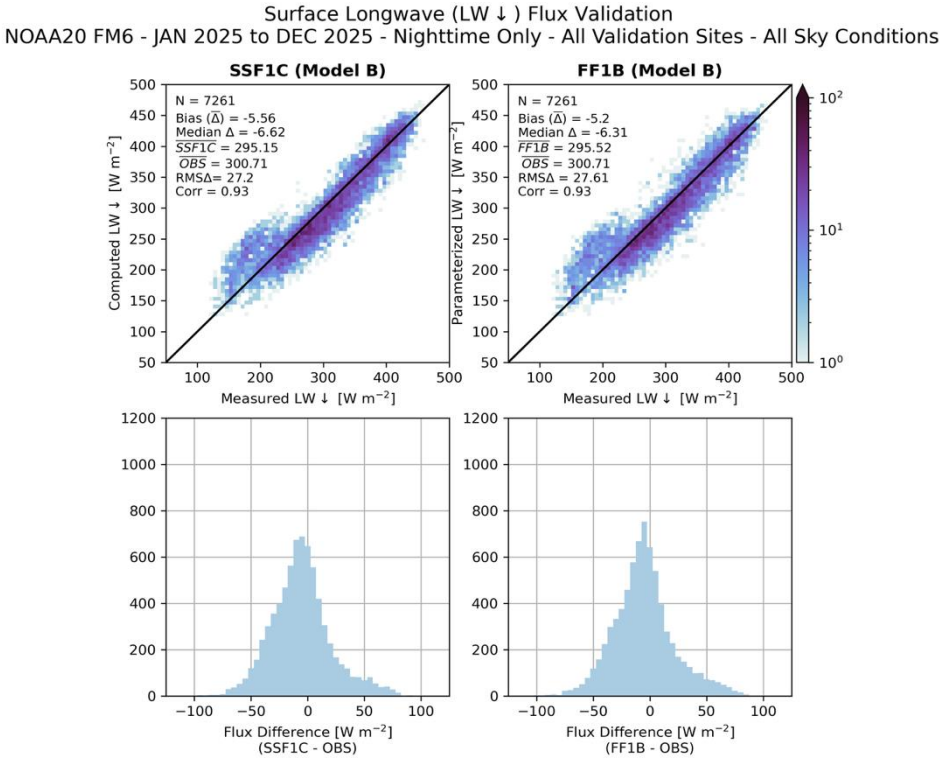


NOAA-20 SSF LW Flux Night Validation: 1/2025-12/2025

Overpass NOAA-20 LW nighttime flux validation with BSRN measurements:

- Left: CERES SSF Ed1C (with G5-CERES): <2% bias, ~ 9% RMS
- Right: nighttime FLASHFlux SSF V1B (with GEOS-IT): <2% bias, ~ 9% RMS

CERES LW Down FF LW down



SSF Flux Algorithm Updates: NN SW & LW

Justification:

- FF footprint fluxes have been used both scientifically and for applications
- Current LPSA/LPLA algorithms older methods, hard to update; separate from Fu/Liou

Objectives:

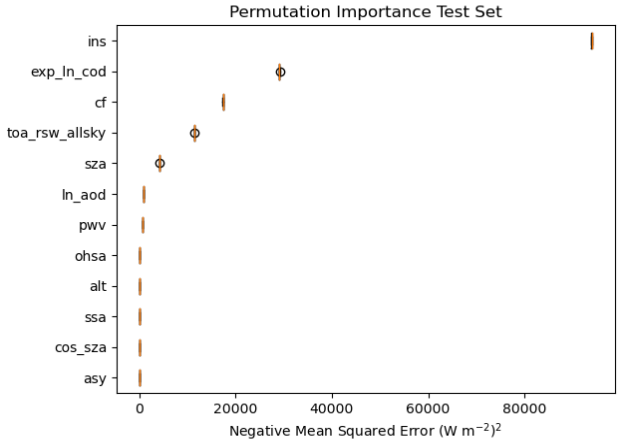
- Use NN/ML methods to devise algorithms that approximate surface fluxes for each footprint to replace old LPSA and LPLA estimates:
  - Produce SW, LW for all-sky, clear-sky ”clouds removed”; surface up, down and net
  - Use CRS Ed4 used for training since uses full Fu/Liou RT
  - Compare and assess relative to CRS outside of training period & surface measurements

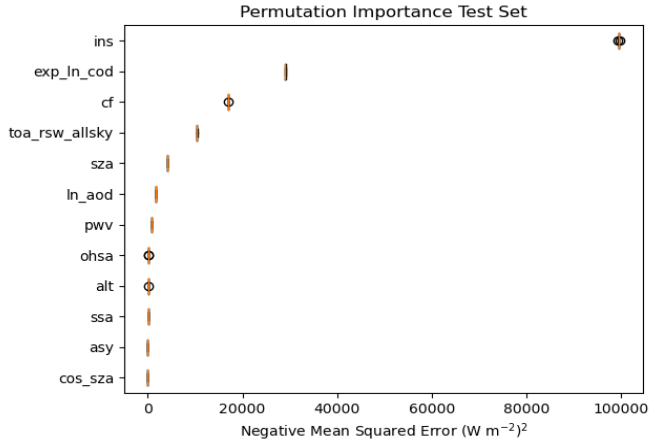
Progress since October 2025:

- *Refocused on SW fluxes only since LPSA is showing largest errors*
- Attempting to implement code with current coefficients into inversion
- Re-ran test simulations with CRS training data sets and parameters (Jan, July 2020) and compared CRS outputs to NN outputs for those months.
- Re-coded output coefficients in ASCII, so those can be read and utilized in inversion

Machine learning model training using CRS data

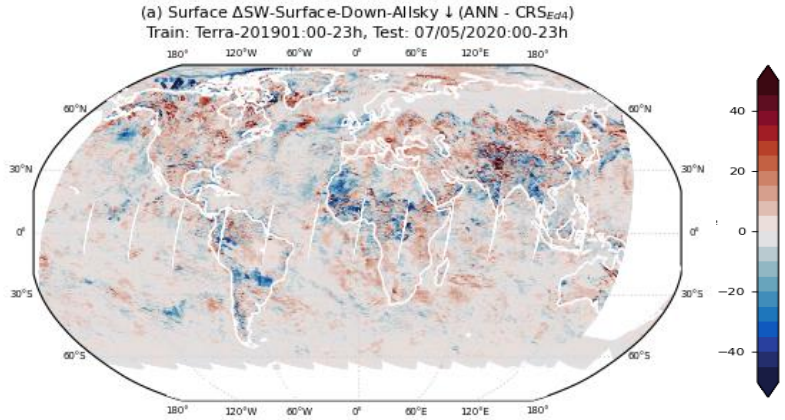
- Evaluating the impact of training-day selection in the ML framework (see next slide for results).
- Performing permutation importance tests: randomly shuffle each input variable; resulting degradation in model performance (e.g., change in mean square error or MSE) is quantified.
  - *Variables that produce the largest performance drop are interpreted as having the greatest influence on predictive skill (results for two representative days shown below).*
- Modifying/assessing input variables (e.g., using log(τ) and log(AOD) instead of τ and AOD), which reduces ANN–CRE differences in some regions; also testing various combinations using Cloud 1 properties.
- Testing different activation functions, particularly, in terms of mean bias errors (yields mixed results).





Re-trained ML – All-sky SW Surf Down Sample

Original Training



Stats relative to CRS (4 training days)

MAE: 6.85
MBE: 0.59
RMSE:13.18

Simulated CRS for 07/05/20

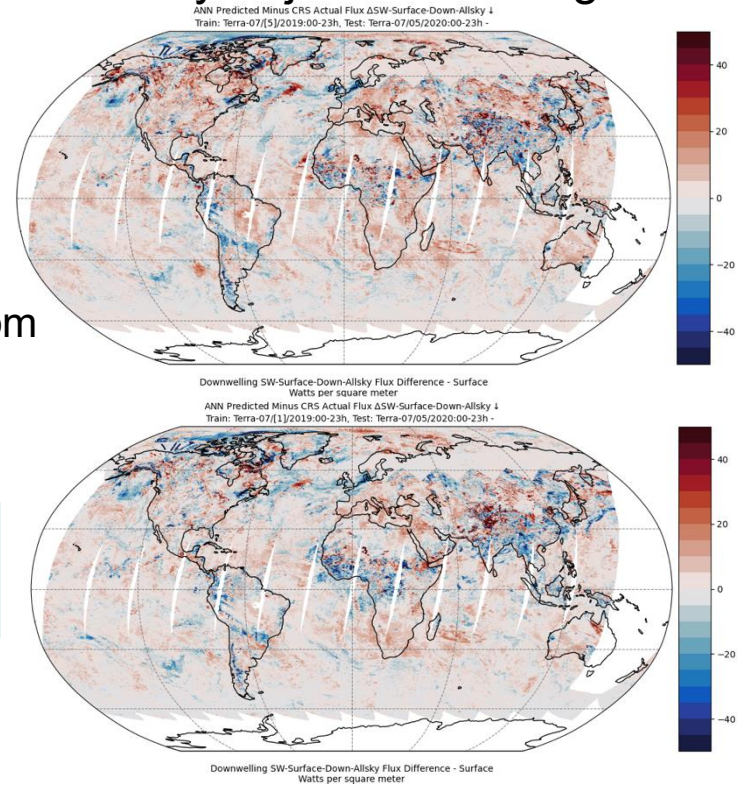
MAE: 7.13
MBE: 1.32
RMSE:13.23

(4 days; different from original)

MAE: 6.83
MBE: 0.04
RMSE:13.06

(7 days)

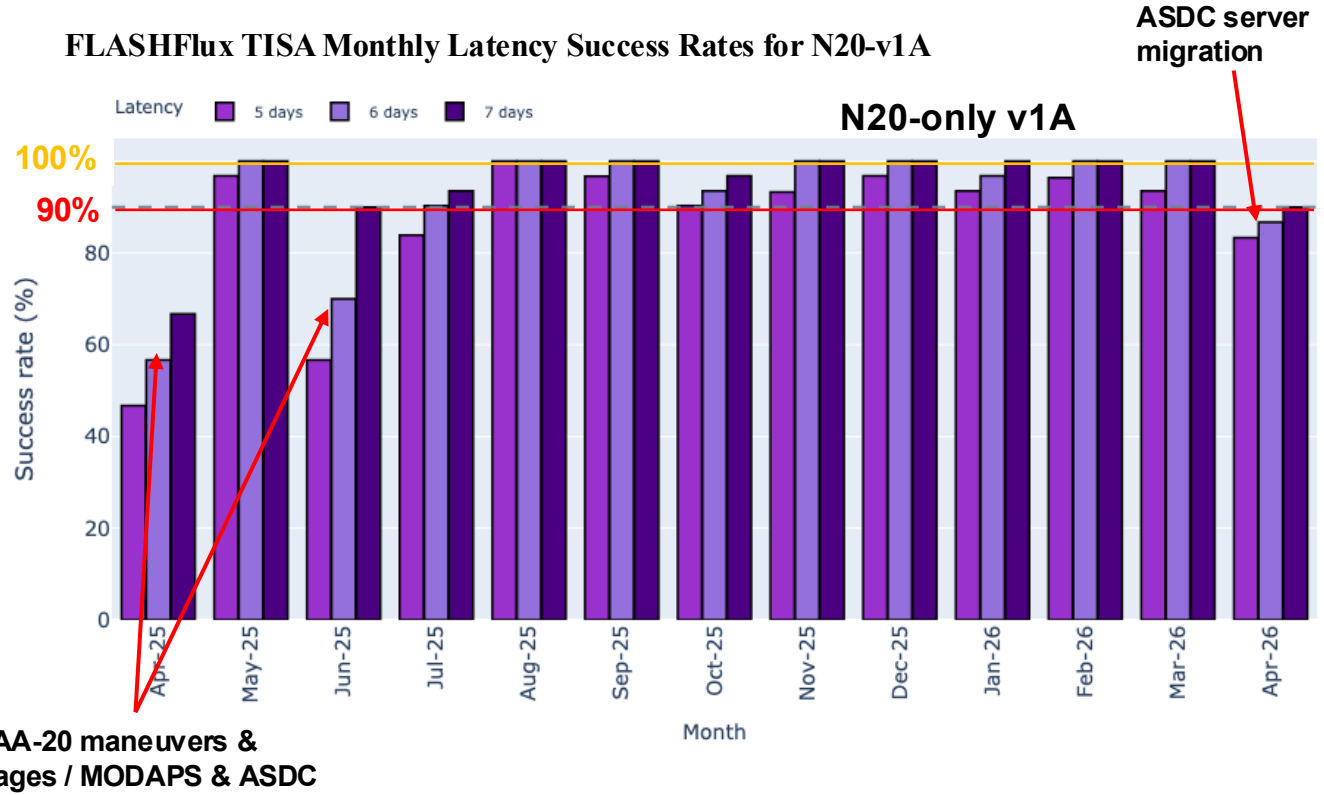
Newly Adjusted Training



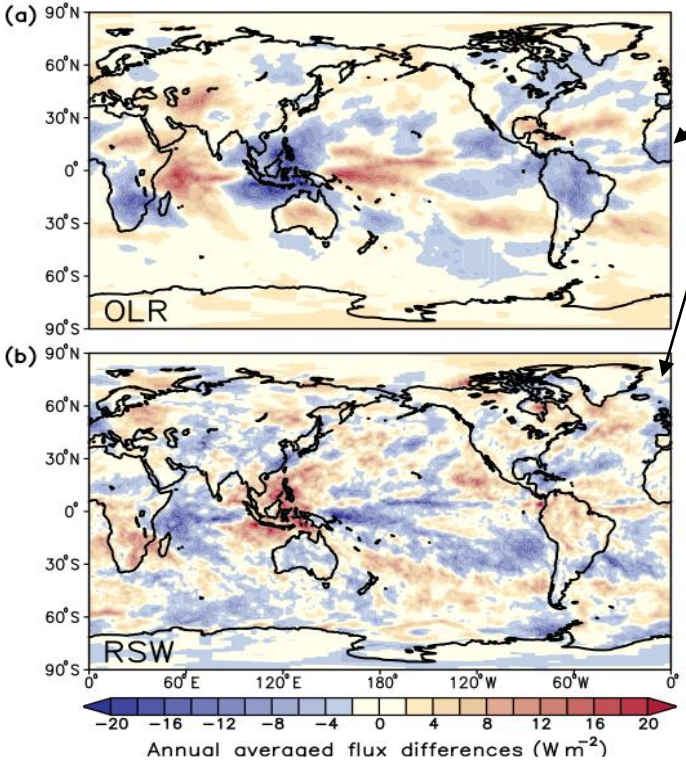
FLASHFlux TISA: Latency Statistics (N20v1A)

v4C/v1A success rates for TISA to be archived in 5, 6 or 7 days after observation

April 2026: 90% released by day 7 after obs (~ 80% by day 5); last 5 months 100% released by 7 days.



FLASHFlux TISA Application: Updated Anomalies



Global map of annual mean (a) OLR and (b) RSW for 2025 minus 2024

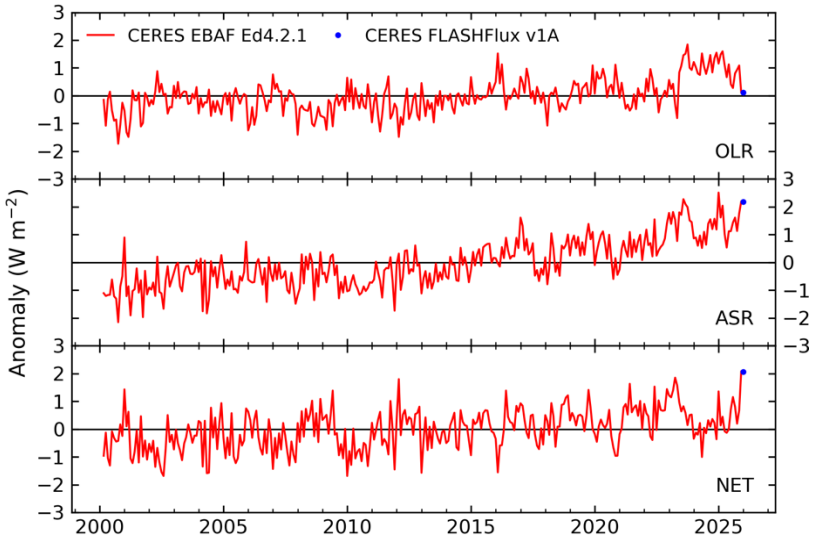
Global annual mean top-of-atmosphere (TOA) radiative flux means, changes, anomalies, and the 2-sigma interannual as shown. All flux values have been rounded to the nearest 0.05 W m^{-2} and only balance to that level of significance.

Global	One Year Change (2025 minus 2024) (W m^{-2})	2025 Anomaly (Relative to 2001–20) (W m^{-2})	Climatological Mean (2001–20) (W m^{-2})	Interannual Variability (2001–20) (W m^{-2})
OLR	-0.20	+1.00	240.35	±0.65
TSI	-0.05	+0.25	340.20	±0.15
RSW	-0.50	−1.50	99.05	±0.95
ASR	0.45	+1.75	241.10	±0.90
Net	+0.65	+0.75	0.80	±0.80

Stackhouse *et al.*, 2026, submitted to BAMS State of the Climate Special Issue

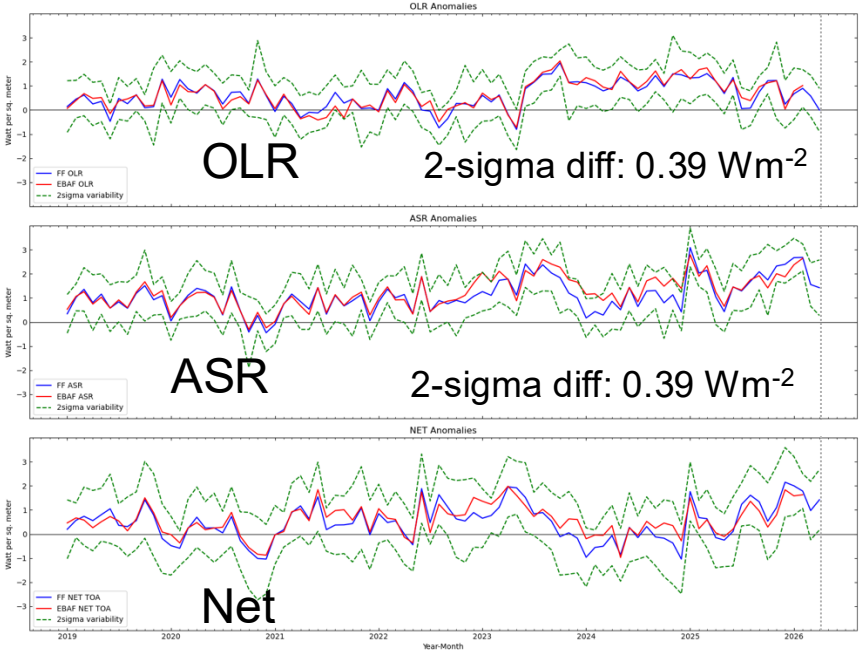
FLASHFlux TISA Application: Updated TOA Anomalies

TOA Flux Anomalies (through 2025)



Stackhouse *et al*., 2026, submitted BAMS SotC

TOA Flux Anomalies (updated through 4/26)

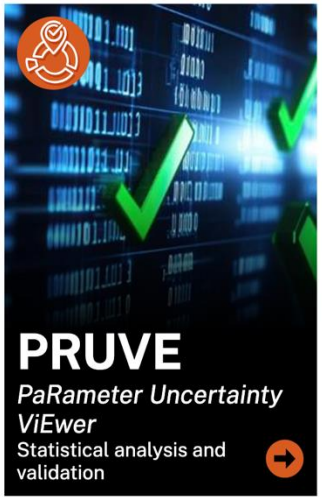


Includes TISA NOAA20 from 1/2024 transition; EBAF base period 01/2001 to 12/2020

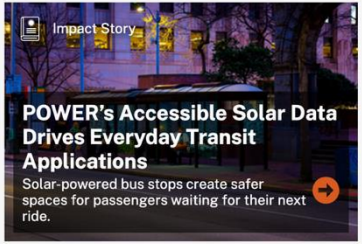
FLASHFlux (& SYN1Deg) Applications through POWER Web Services

POWER continually updates with CERES Data Products for Energy, Infrastructure and Agricultural Applications

Tools and Services



Featured Stories and Events



Data Accessible via Numerous Optional Pathways and Formats

https://power.larc.nasa.gov

National Aeronautics and Space Administration

Prediction of Worldwide Energy Resources (POWER) Project

Monitoring Performance for Community Solar Gardens Providing Energy in 360 Locations Across the United States

- **Xcel Energy** serves nearly 4 million electricity more than 2 million natural gas customers across eight Southwest and Midwest states (e.g., TX, CO, MN, and NM).
- **Xcel Energy** uses POWER solar (from CERES) and meteorological data (GMAO) to supplement when its in-situ sensors provide “bad reads” while monitoring the performance of 360 “community solar gardens” (photovoltaic array fields).
- POWER is exploring collaboration avenues to enable Xcel Energy's risk analysis, which will inform resilient energy decisions 10-30 years into the future.

EPRI (Electric Power Research Institute) cites POWER (and thus CERES & GMAO) as one of their key resource data products; solar + battery storage is a key to facing the electric power supply crisis due to Data Center development.

FLASHFlux TISA & SYN1Deg Usage via POWER Web Services Portal (2025/05/01 to 2026/04/30)

CERES Data Orders Delivered via POWER < 3 weeks latency (FLASHFlux Data)

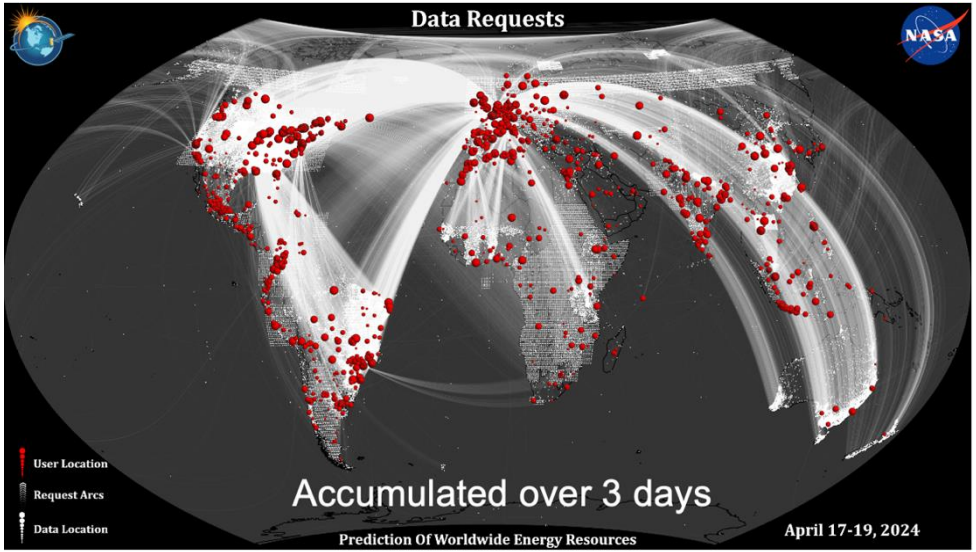
	Total	Monthly	Avg. Last 3 Months
Unique Users IPs	~148.8 K (21%)	~14.8 K (21%)	~16.6 K (18%)
Requests	~92.5 M (33%)	~7.7 M (33%)	~8.8 M (30%)

CERES Data Orders Delivered via POWER including SYN1Deg and FLASHFlux data

	Total	Monthly	Avg. Last 3 Months
Unique Users IPs	~463.0 K (65%)	~44.9 K (64%)	~56.3 K (63%)
Requests	~ 170.0 M (61%)	~14.2 M (61%)	~16.5 M (61%)

(includes SYN1Deg from Sep 2001 through latest month released)

Dot density map showing locations of users (red) and data request locations (white). Brighter colors show larger frequency at that location.



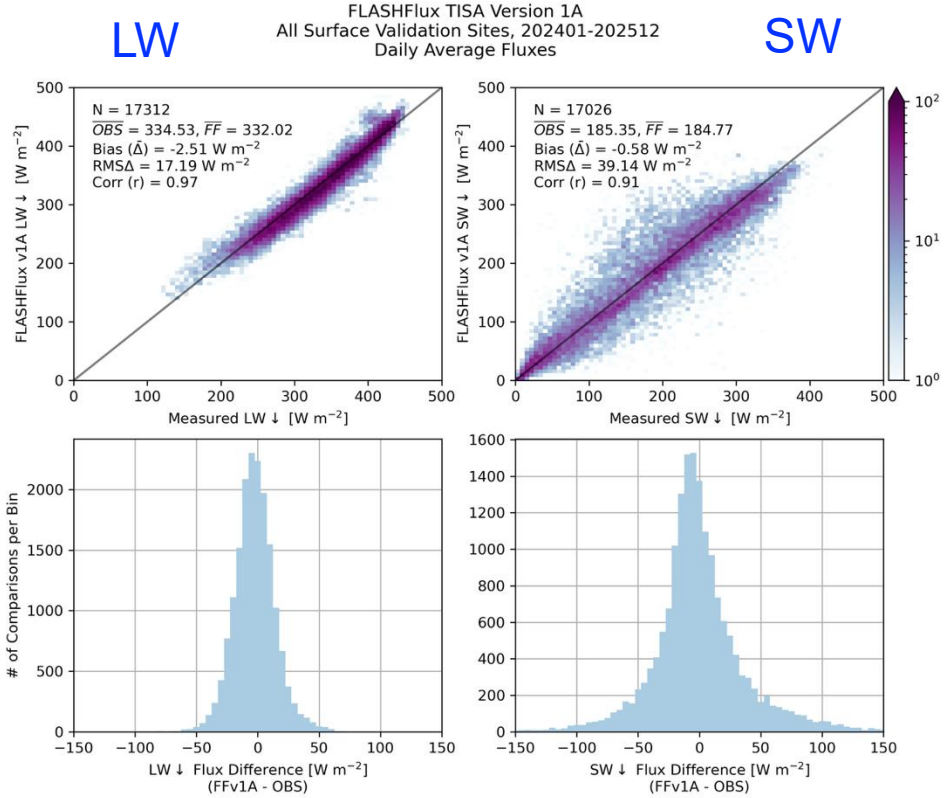
Most recent 12 month up by about **20% and 38% for FF only and FF+SYN1** respectively relative to previous 12 month period.

FLASHFlux TISA Validation: NOAA-20 TISA

- Ensemble FLASHFlux TISA NOAA20 only Daily Average Comparisons to Surface Measurements (1/2024-12/2025)

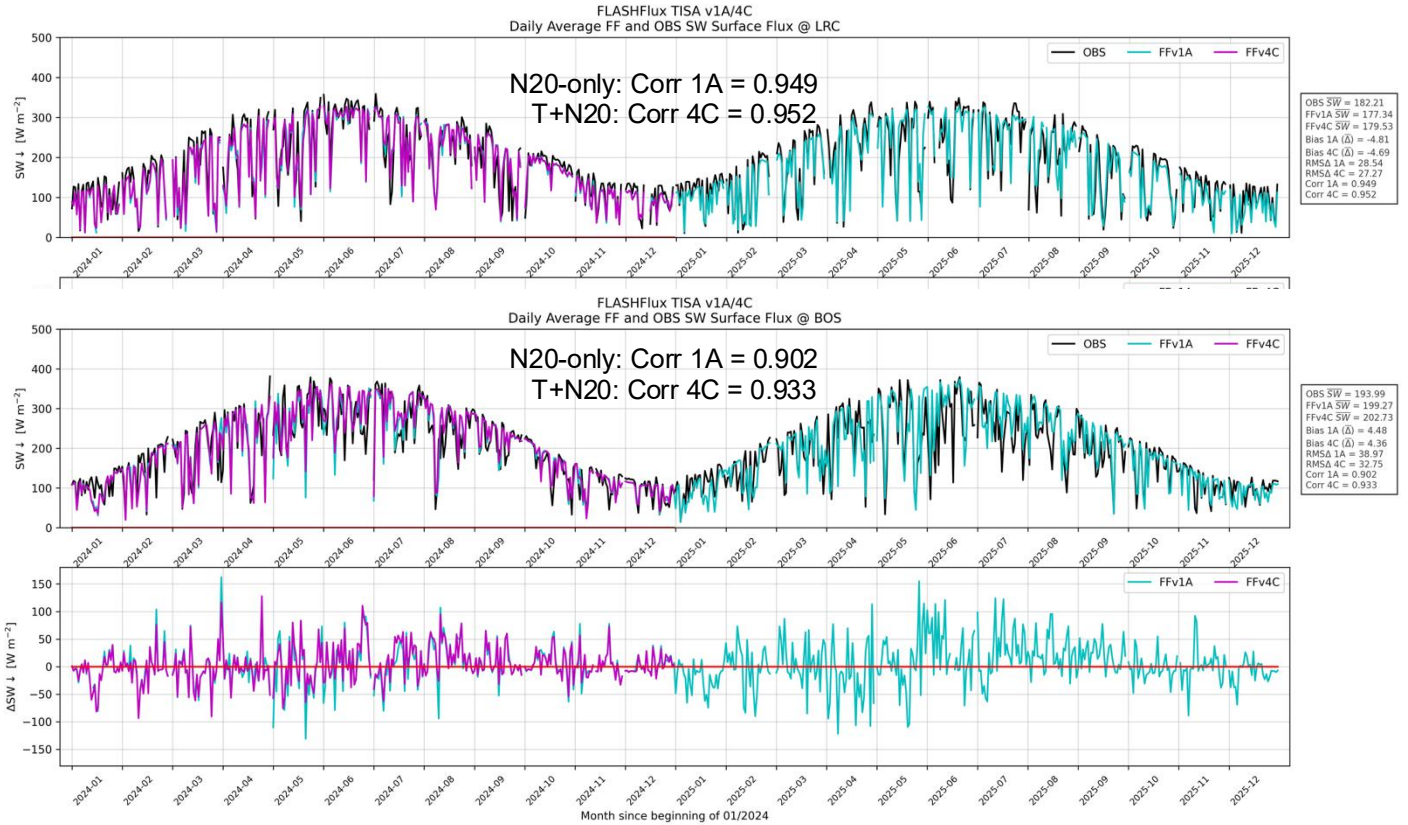
- LW fluxes show very consistent statistical quality relative to surface measurements:
  - Bias Diff: < -0.9%
  - RMS Diff: < 5.2%

- Histograms show peaked, relatively symmetric distributions, median bias is negative for LW; N20-only bias/RMS just slightly higher



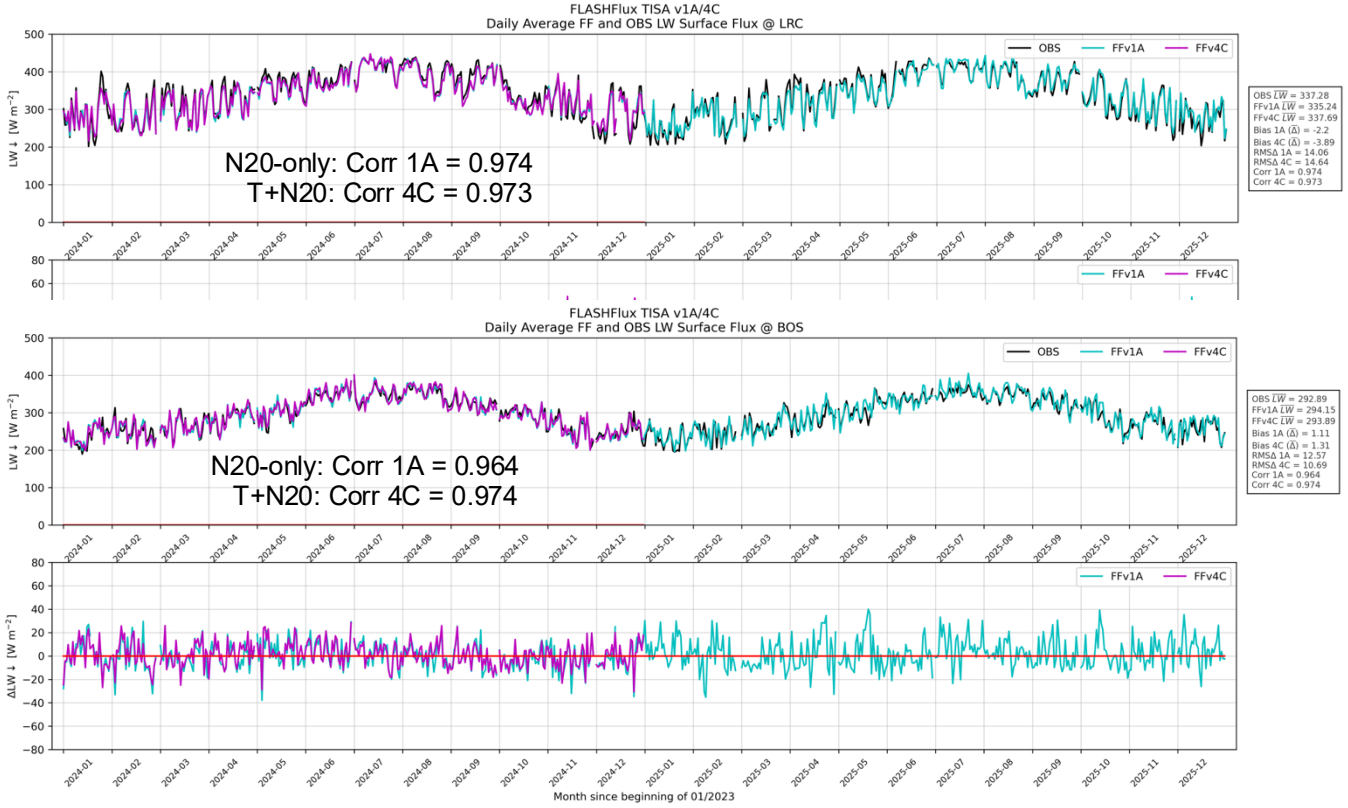
Time Series Validation: SW

- Example time series comparison against SW measurements from the LRC & BOS BSRN sites for:
  - FF T+N20 v4C
  - FF N20-only v1A
- Biases occur for periods but these vary site to site.
- However, RMS's (correlations) are increased (de-creased) at every site.
- No SW long-term drifts currently observed.

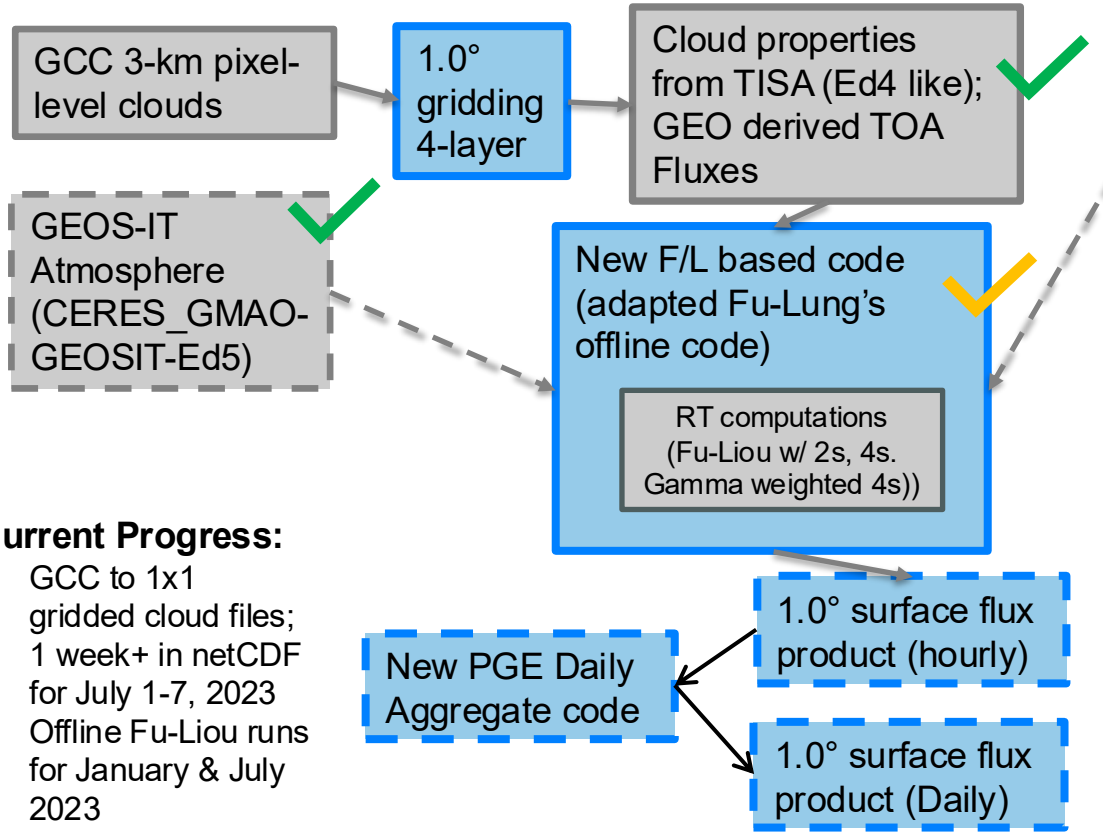


Time Series Validation: LW

- Example time series comparison against LW LRC and BOS BSRN sites
  - FF T+N20 v4C
  - FF N20-only v1A
- Although day-to-day variability is smaller, there still seems to be more noise in the N20-only version.
- RMS's (correlations) are increased (decreased), but to a lesser extent
- No LW drifts currently observed.



Adding GEO to FF TISA: SatCORPS GCC into FLASHFlux



Current Progress:

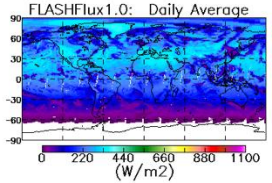
1. GCC to 1x1 gridded cloud files; 1 week+ in netCDF for July 1-7, 2023
2. Offline Fu-Liou runs for January & July 2023

Progress:

1. Completed cloud gridding code – targeting Ed4 clouds (4 layers) since code exists. **Done**
2. Align all inputs to correct data structures global by time: **Ongoing**
3. Create PCF structure to process global-hourly maps. **Done**
4. Implementing improvements
5. Offline F/L code used for testing improvements to algorithms/inputs. **Completed numerous test runs with various inputs**

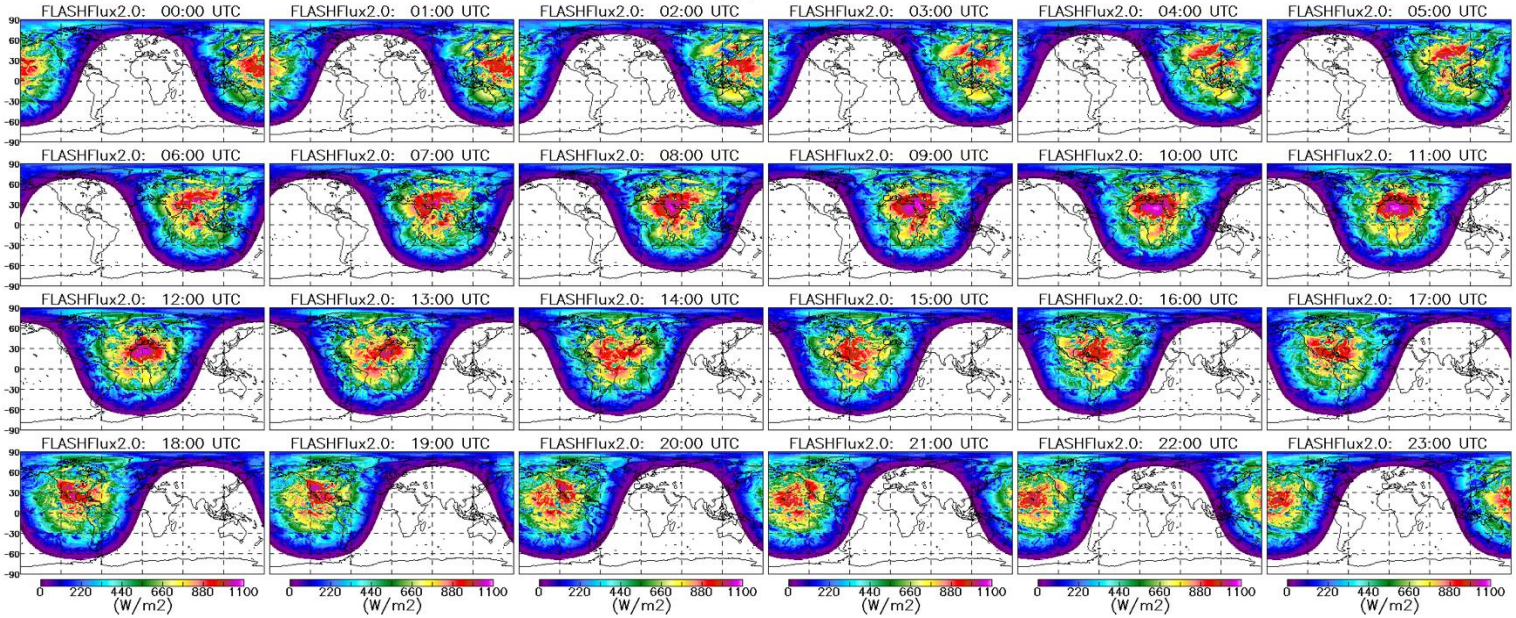
Preliminary GEO to FF TISA Fluxes

All-Sky Downward Surface SW fluxes on July 14, 2023.



Current Daily Average Only

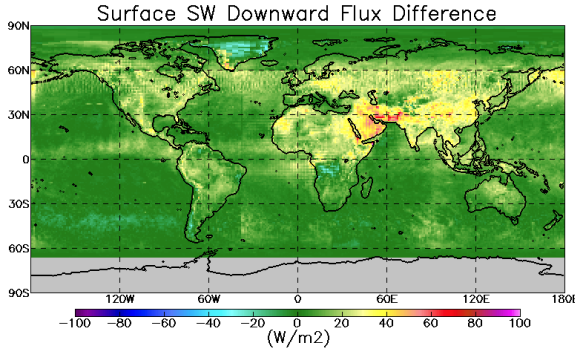
Sample GCC HOURLY SW fluxes.

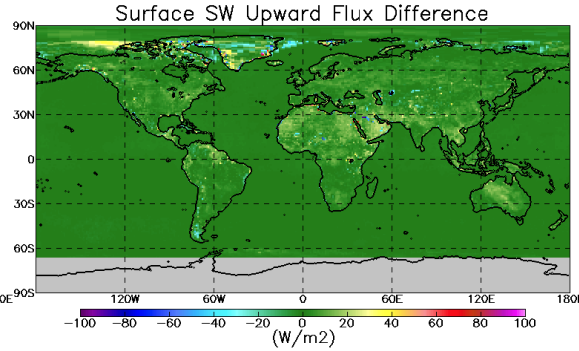


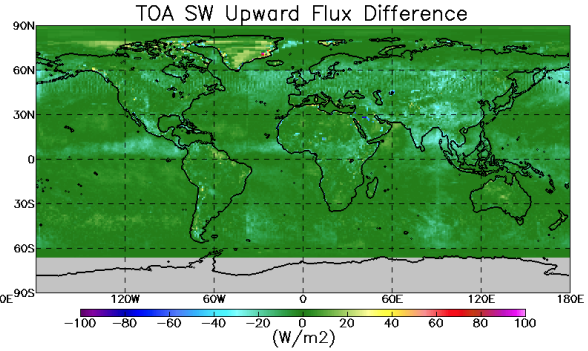
Preliminary GEO to FF TISA: Difference with SYN1Deg

Daytime All-Sky flux differences with SYN1Deg (Ed4.2) on July 14, 2023

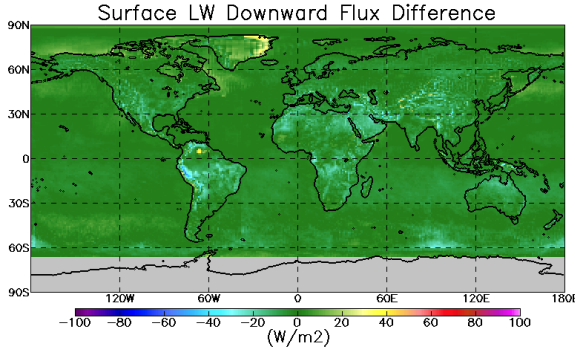
SW

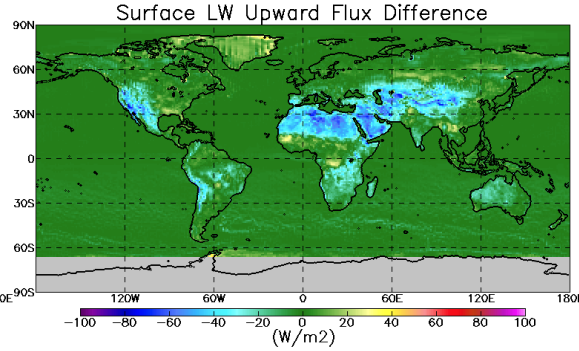


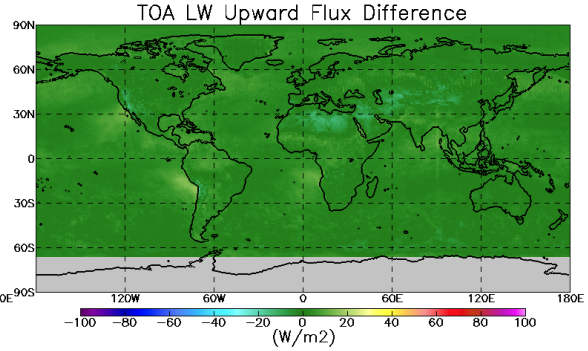




LW



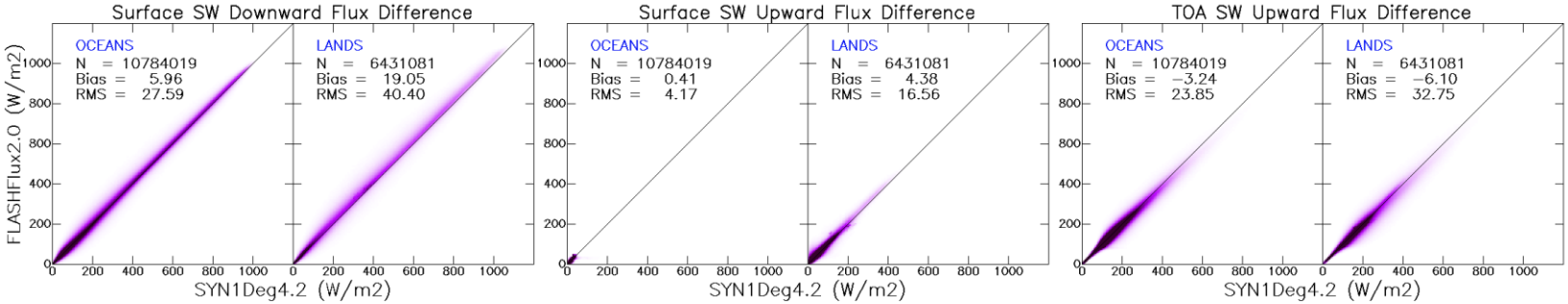




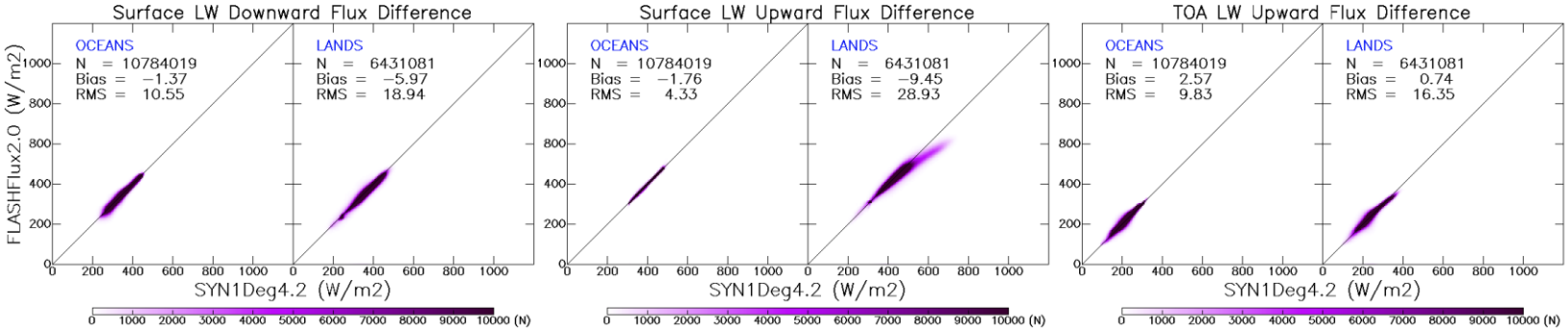
Preliminary GEO to FF TISA: Difference with SYN1Deg

Daytime All-Sky flux differences with SYN1Deg (Ed4.2) on July 14, 2023

SW

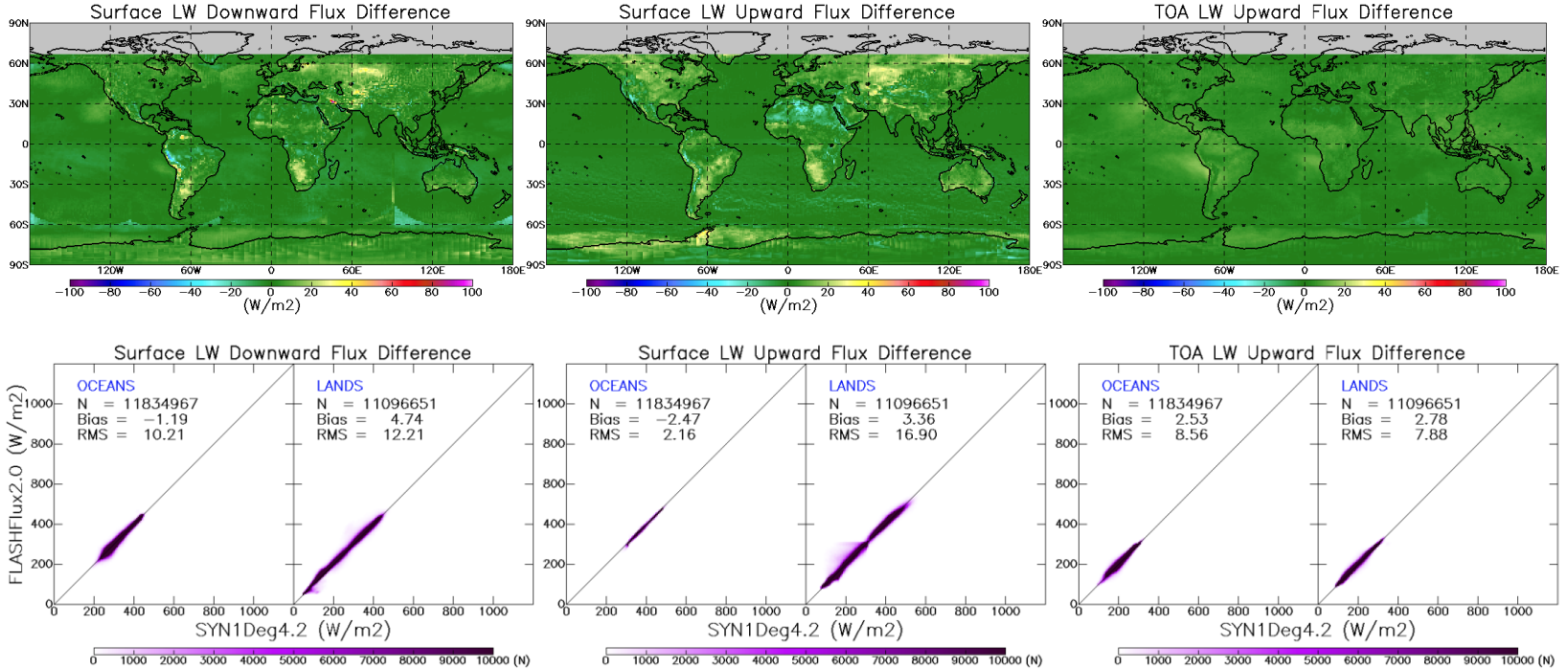


LW



Preliminary GEO to FF TISA: Difference with SYN1Deg

Nighttime All-Sky flux differences with SYN1Deg (Ed4.2) on July 14, 2023



GEO to FLASHFlux Next Steps

- **Complete the production consistent version of FF GEO TISA v0.1 to enable longer test periods (new versions):**
  - Implement time/space weighted SZA consistent with Ed5
  - Potential additional improvements:
    - Improve aerosol optical properties; perhaps a MATCH or GEOS-IT climatology to better estimate land aerosol optical properties
    - Improve surface albedo representation by incorporating running "Surface Albedo History" maps (reconfigured for NRT)
- **Complete longer runs for evaluation and testing**
  - Move production/testing to 2025 to get a more recent GCC version
  - At least 4 mid-seasonal months comparison to SYN1Deg (may have to move to 2024 to allow comparison to current FF TISA products)
  - Assess fluxes with surface validation
- **Operationalize into CATALYST (Fall 2026)**
  - Promote to operations (limit period of dual processing
  - Final version promotion

FLASHFlux Summary

- ***Production with SSF for NOAA-20 only (1b) and TISA (v1A) Continues***
  - FF NOAA-20 V1B SSF (5/10/26) and Terra V4B (2/13/25 - end) with GEOS-IT
  - TISA NOAA-20-only V1A through 5/8/26
  - New FF Gain+Spectral coefficients beginning Jan1st, 2026.
- ***Validation and Assessment Relative to BSRN/Buoy***
  - FLASHFlux NOAA-20 SSF V1B through March 2025; SW biases larger
  - TISA Terra+NOAA-20 V4C compared to NOAA-20-only V1A daily averages from Jan-Dec 2024 (12 months); biases slightly worse for SW/LW; RMS's higher and correlation lower for N20-only
- ***FLASHFlux Modernization and Updates***
  - ML based algorithms for future FF SSF data products: Goal Operational Fall 2026
  - Migrate configuration to NOAA-20 + GCC GEO & F/L Fluxes: Goal Operational Fall 2026
- ***FLASHFlux Information & Data Provision Through ...***
  - CERES web site and subsetter both SSF and TISA, ASDC (via EarthData) and POWER
    - FF+Syn1 POWER Distribution in last year: ~463K unique IPs; ~ 170M orders; orders >30% FF
  - 2025 BAMS State of the Climate TOA Flux reports submitted

FLASHFlux Web Sites & Acknowledgments

https://ceres.larc.nasa.gov/data/#fast-longwave-and-shortwave-flux-flashflux

Data also served through
https://power.larc.nasa.gov

Extras