NASA Surface Radiation Budget Project: A Look Back and A Look Forward

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NASA/GEWEX SRB Rel4-Integrated Product Overview

The NASA/GEWEX (Global Energy and Water Exchanges project) Surface Radiation Budget (SRB) project produces longwave and shortwave radiative fluxes for the surface and top-of-atmosphere (TOA) (see, Kummerow et al., 2019, Stackhouse et al., 2022). The primary inputs of cloud and meteorology data have been undergoing improvements in quality and spatial and temporal resolution.

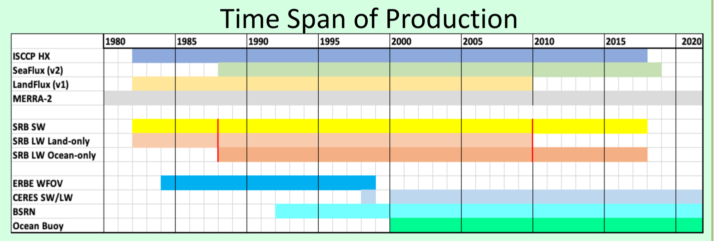
Key changes in the inputs and algorithm were:

- Reformulated with Look-up-tables using CERES Fu/Liou code (Rose et al. 2006). Ice cloud radiative properties added.
- Variable aerosol optical properties added (Max Planck v1 aerosol, Kinne et al. 2013).
- Cloud properties (for ice and water) and atmosphere uses ISCCP HXS and nnHIRS respectively (Young et al., 2017).
- Updated ozone profile with ISCCP ozone and MEaSUREs GOZCARDS.
- Updated maps of surface topography, vegetation type, and snow/ice by ISCCP
- Ocean and snow/ice albedo treatment updated (Jin, 2004); surface emissivity updated based upon surface/veg type
- Land skin temperature/Sea Surface Temperature from GEWEX LandFlux and Sea SeaFlux (v2).
- Total Solar Irradiance is now daily and averages to 1361 W m^{-2} (Coddington *et al.*, 2016).

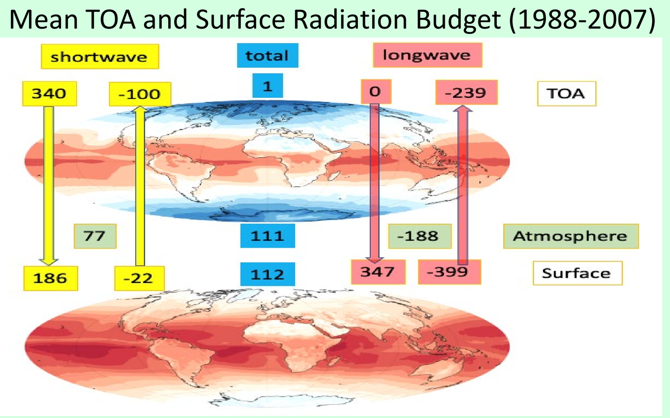
SRB Rel4-IP Data Parameters

Data Types	Model Name	Temporal Resolution	Parameters
SW	GEWEX SW (Pinker/Laszlo) (v4.0)	3-hourly, Monthly Averaged 3-hourly, Daily and Monthly Averaged (UTC and local sun time)	All-sky: Surface down, up, down direct and diffuse, PAR down, direct, diffuse; TOA Down, Up
			Clear-Sky: Surface Down, Up; PAR down; TOA Up
			Pristine-sky: Surface down, up; TOA up
LW	GEWEX LW (Fu/Liou/ Stackhouse) (v4.0)	3-hourly, Monthly Averaged 3-hourly, Daily and Monthly Averaged	All-sky: Surface Up and Down; TOA up
			Clear-sky: Surface Up and Down; TOA up
			Pristine-sky: Surface Up and Down; TOA up
Input Properties	Cloud, Aerosol and Surface Properties	3-Hourly	Surface emissivity, skin temperature, atmospheric profile; cloud phase, fraction, optical depth and LWC

Time Span of Production



Mean TOA and Surface Radiation Budget (1988-2007)



Level	Flux Component	Wild et al (2015) SW	Wild et al (2015) LW	Level	Flux Component	Wild et al (2015) SW	Wild et al (2015) LW
Surface	Down	185 (179:189)	342 (338:348)	Top-of-Atmosphere	Down	340 (340:341)	0
	Up	25 (22:26)	398 (394:400)		Up	100 (96:100)	239 (236:242)
	Net	160 (154:166)	-56 (-46:-62)		Net	240 (240:245)	-239 (-236:-242)
				Whole Atmosphere	Net	80 (74 :91)	-183 (-174:-196)

Processed:

- SW: July 1983 – June 2017 (also extending)
- LW: Jan 1988 – Dec 2008 (limited by Skin Temp data products)

Files with Metadata delivered to ASDC: files available through DDD, OpenDap and EarthData

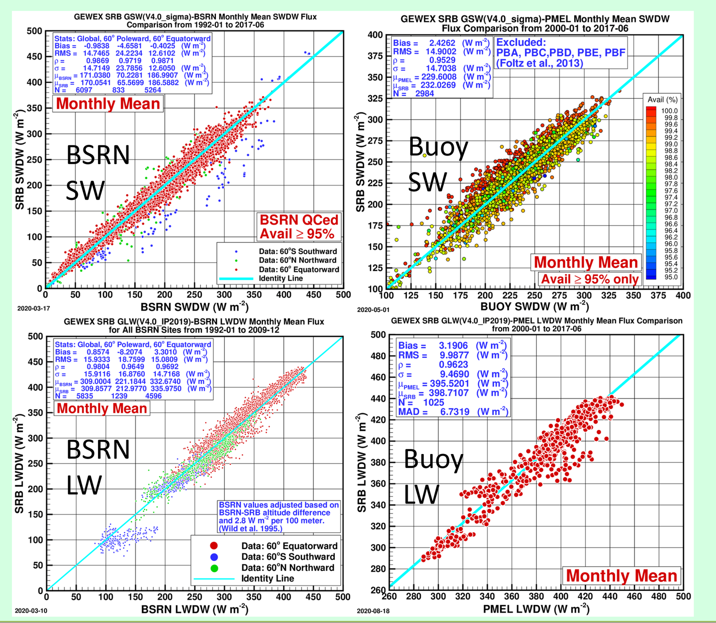
Surface Point Validation Statistics:

Surface downward fluxes assessed against surface measurements from BSRN:

- SW: ~-1 W m^{-2} bias, 14.7 RMS
- LW: ~+1 W m^{-2} bias, 15.9 RMS

Ocean Buoy (filtered Foltz et al)

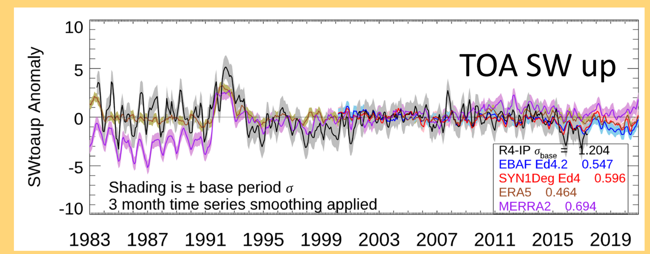
- SW: ~2.4 W m^{-2} bias, 14.9 RMS
- LW: ~3.2 W m^{-2} bias, 10.0 RMS

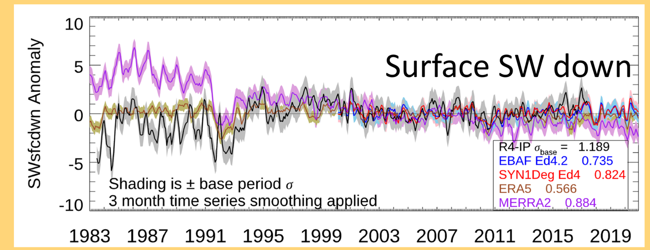


SW Long-term Global Annual Averaged Anomalies Comparisons to Featuring SRB and CERES EBAF Ed 4.2

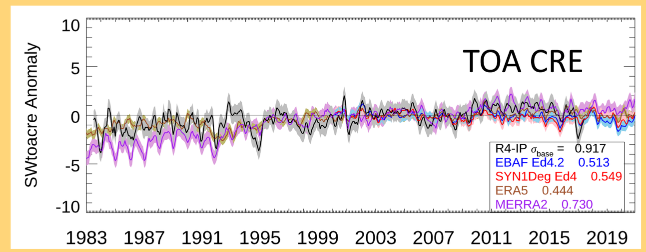
Global annual average anomalies for TOA SW flux up and Surface SW flux down are determined from the beginning of SRB through 2017. The base period is 2001 through 2008. Thus, the variability of longer data sets like SRB and the atmospheric reanalysis of ERA-5 and MERRA-2 can be compared to the shorter period of CERES. 3- month smoothing is applied to reduce noise. The standard deviations of each featured data product are given relative to the mean in the legend. The shaded area represents +/- 1 sigma.

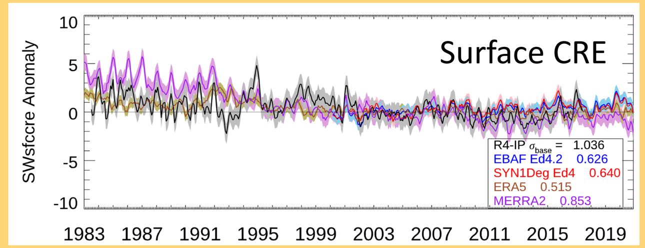
- SW TOA up and surface down are clearly complementary.
- SRB is more variable than the other data sets; analysis shows that this can be due to ISCCP sampling/calibration changes, but also constitute real variability.
- MERRA-2 radiative fluxes appear to show a much larger multi-decadal trend than any of the other data products.
- Cloud Radiative Effect between the TOA and surface does vary in a consistent way between the sets with an increase (decrease) in the TOA (surface) from the early 1980's through about 2012-2014 before peaking and decreasing (increasing) for TOA (surface).





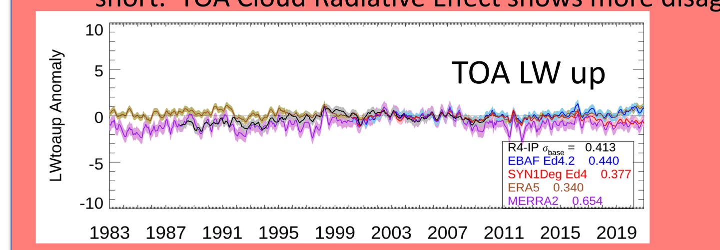
Cloud Radiative Effect Anomalies

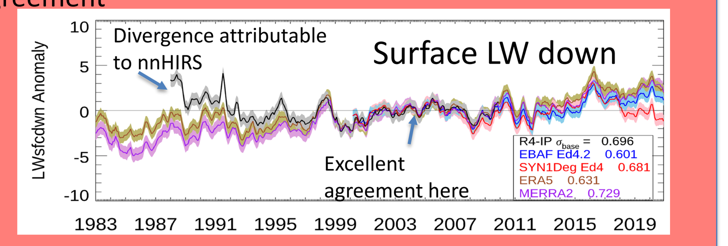


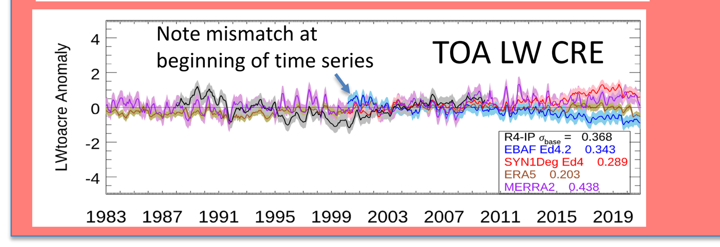


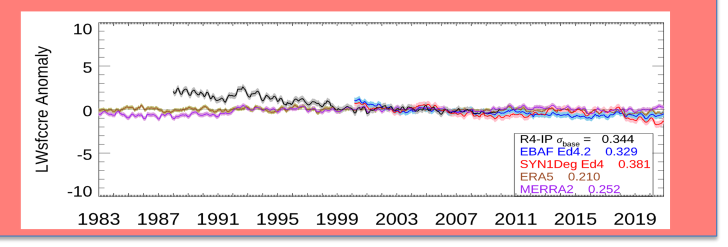
LW Long-term Global Annual Averaged Anomalies Comparisons to Featuring SRB and CERES EBAF Ed 4.2

Same as SW above but for TOA. TOA is stable within +/- 1 W m^{-2}. SRB agrees well with CERES but is short. TOA Cloud Radiative Effect shows more disagreement







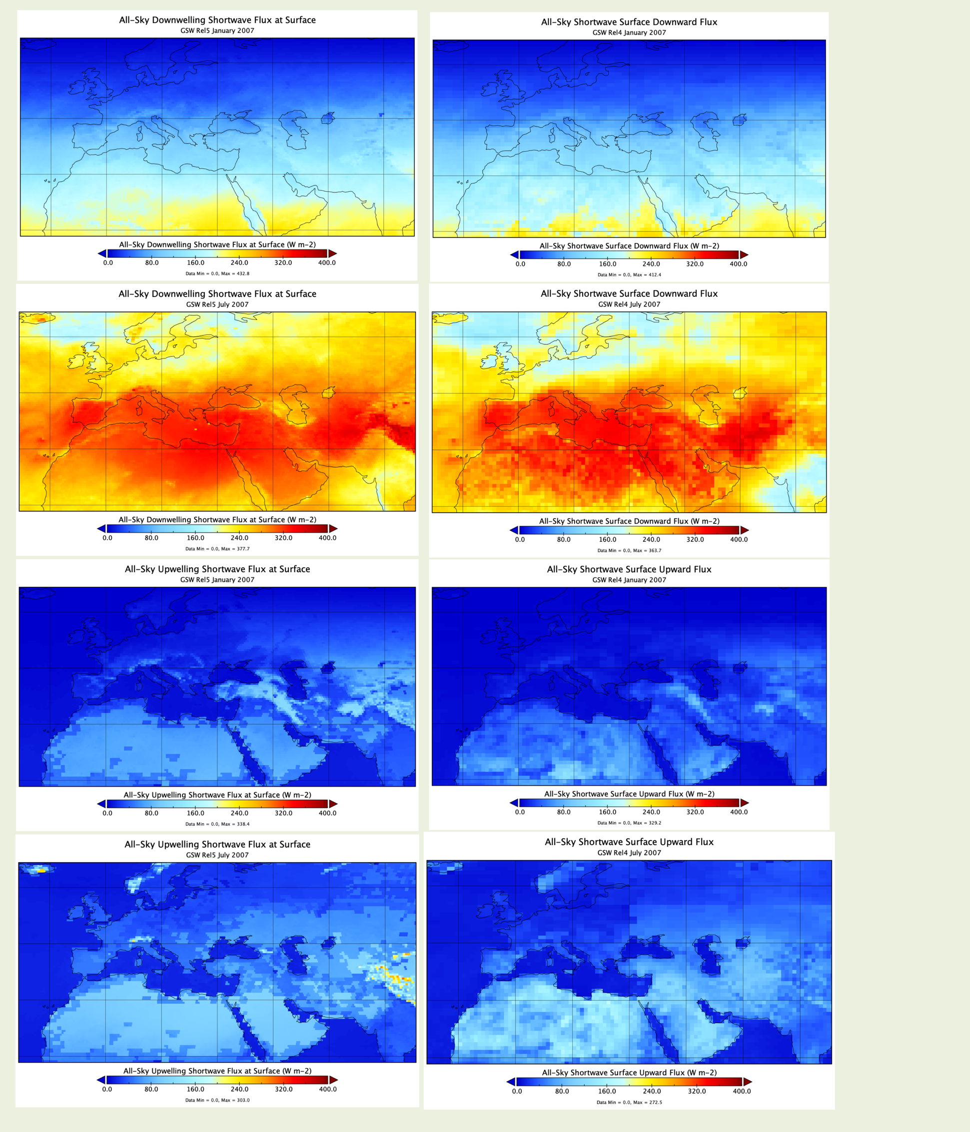


Moving Toward SRB Release 5

The SRB team is finalizing algorithm and input changes for a full release in 2025. Spatial resolution is increasing from 1°x1° to 0.5°x0.5°. Fluxes at intermediate layers of the atmosphere will be added to existing surface and TOA flux calculations. The shortwave algorithm will be changed from the Pinker-Laszlo approach, which attempted to derive surface albedo, aerosol and cloud information from ISCCP radiances, to a forward call of the Fu-Liou algorithm, bringing the SW and LW algorithms in line, and improving results in areas where Pinker-Laszlo struggled, such as snow/ice and bright deserts.

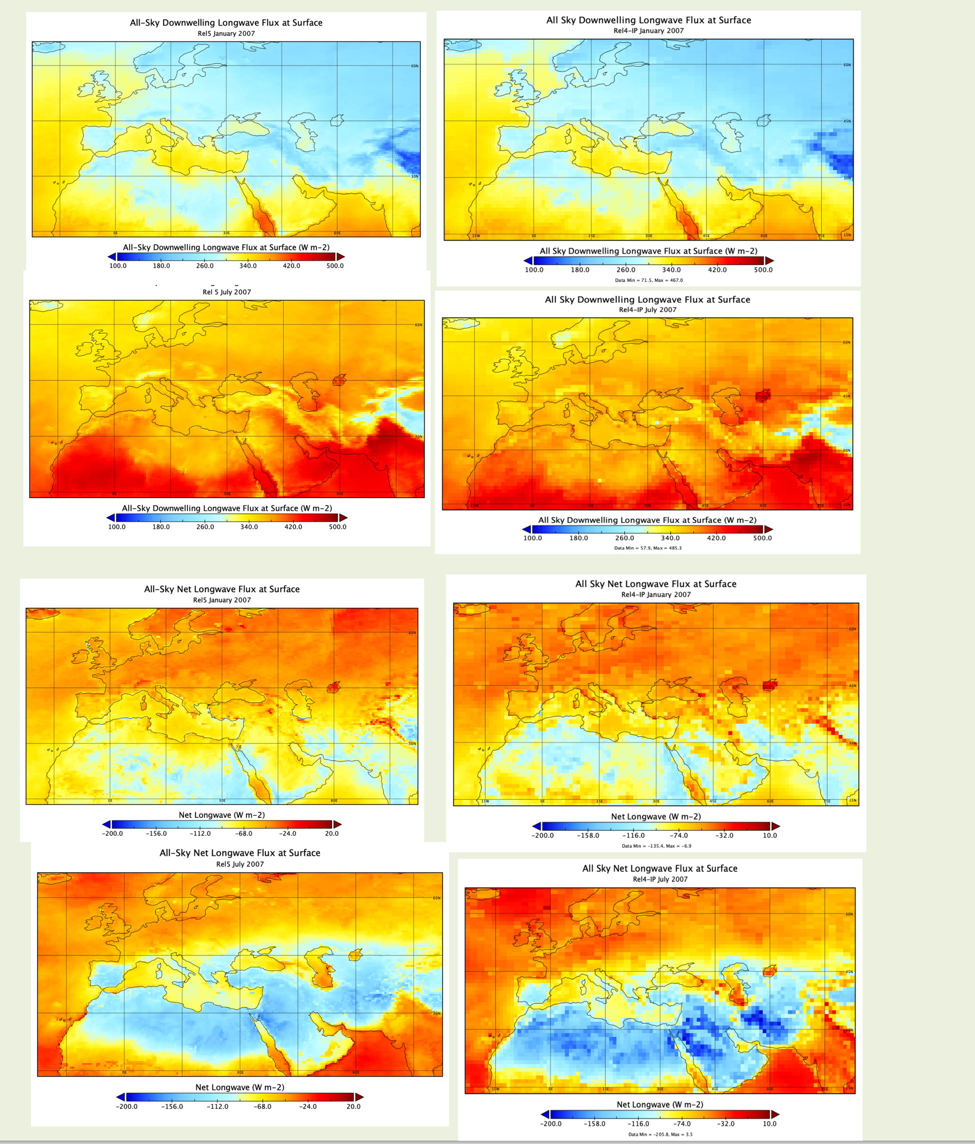
SW Input and Code Changes, Results Below

SW Updates	Release 4.0 IP (GSW with HXS v1)	Release 5.0 (GSW with HXS v2)
Radiative bands	18 (from CERES LFL05 model; Fu/Liou based)	No LUT; Full 18 (from CERES LFL05 model; Fu/Liou based)
Spectral Albedo	New expanded albedo from MODIS and ASTER, Jin (2004) ocean, ice, and snow albedos	Neural Net trained on CERES SYN1deg spectral albedo will provide better albedos back through 1983 (see below)
Aerosol Radiative Properties	Variable asymmetry parameter and single scatter albedo permitted with expanded LUT	Full RT aerosol properties specified; evaluating Max Planck Aerosol Climatology v3; comparing to MERRA-2
Input aerosol	Max-Planck Aerosol Climatology, with variable optical depth and composition through product time period (1983-present)	Max Planck Aerosol monthly climatology; assessing utilizing MERRA-2 daily variability.
Clouds	ISCCP HXS; Liquid and ice clouds supported, use Water/Ice temperature threshold.	ISCCP HXS; Liquid and ice clouds supported, use Water/Ice temperature threshold. Cloud properties assigned w/ overlap
TSI	Coddington et al., (2016)	Community TSI (Kopp et al)
Data Product Changes	TOA, Surface only; SW total, direct, diffuse, PAR	TOA, Surface only; SW total, direct, diffuse, PAR, UV, VIS, NIR; atmospheric levels
Run Period	July 1983 – June 2017	July 1983 – June 2020+



LW Input and Code Changes, Results Below

LW Updates	Rel. 4.0-IP	Rel. 5.0
Aerosol Inputs	MAC v1 Aerosols (Kinne et al., 2013)	Evaluating MAC v3 Aerosols (Kinne et al., 2013)
Ice Cloud Properties	Updated ice cloud radiative properties (Rose et al. 2015); scaled to ISCCP Tau VIS/IR	Updated ice cloud radiative properties (Rose et al. 2015); scaled to ISCCP Tau VIS/IR
Water Cloud Properties	Add high water cloud; modified cloud overlap to treat high water clouds; scaled to ISCCP Tau VIS/IR	Add high water cloud; modified cloud overlap to treat high water clouds; scaled to ISCCP Tau VIS/IR
T, q profile	ISCCP nnHIRS (Shi et al); MERRA-2 based oceanic inversion layer correction	MERRA-2 based T, q with oceanic inversion layer correction; snow/ice inversion correction; UTH correction
Tskin	Blend SeaFlux SST (CDR R2) / LandFlux Ts (Coccia et al) /ISCCP HX Ts; emissivity correction to desert/sparsely vegetated surface types	Blend SeaFlux SST (CDR R3) / LST from MERRA (testing NN retrieval adjustment algorithm) / ISCCP HX Ts; emissivity correction to desert/sparsely vegetated surface types
Data Product Changes	Pristine-sky (no aerosols), local time, atmospheric levels.	Pristine-sky (no aerosols), local time, atmospheric levels, broad spectral bands (NIR, window, far-ir); atmospheric levels
Years Run	1998 - 2009	1983 – 2020+



Neural Net for Surface Albedo Prediction

SRB Rel4 and earlier releases derived surface albedo by first calculating a broadband albedo from the ISCCP clear sky radiance, and then choosing a surface albedo value which, with an assumed background aerosol, and the elevation, column water vapor, and column ozone, would produce an outgoing TOA flux equal to that implied by the broadband TOA albedo. This produced acceptable results, but was dependent on the assumed Angular Distribution Models, and the accuracy of the background aerosol.

CERES SYN1deg has a 24+ year history of surface albedos beginning in 2000. (Methodology described in Rutan et al., 2015.). This provides a potential training data set for a neural net, which when complete and trained allows more accurate predictions of albedo prior to the CERES era.

A six layer neural net has been created for each of 18 IGBP surface types and 2 snow/ice conditions (present or not), for 36 models in all, with the following inputs:

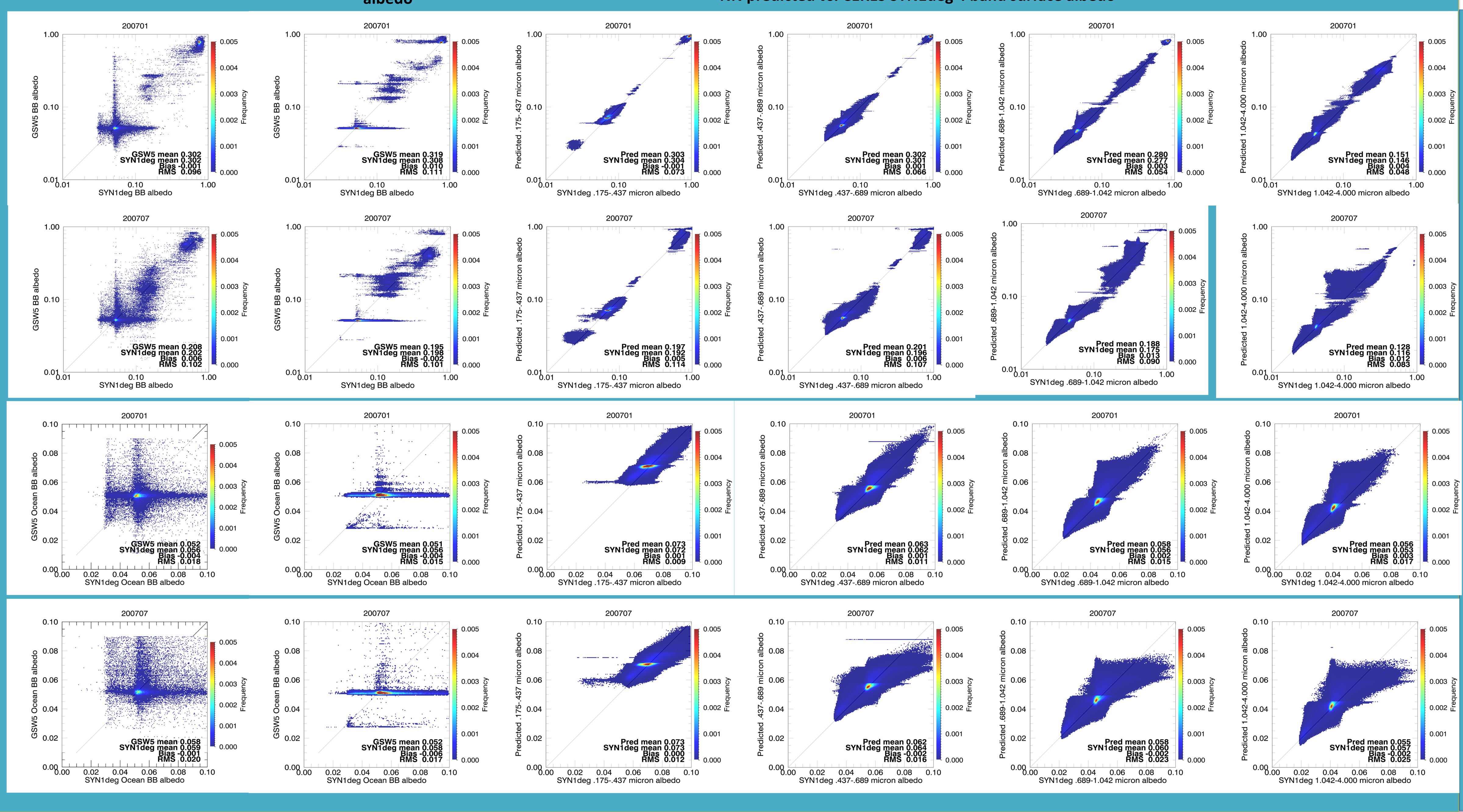
Day; lon; lat; monthly MODIS chlorophyll climatology;ISCCP satellite view angle, solar zenith angle, azimuth angle, cloud properties, rdadiances, snow/ice fraction; MAC aerosol optical properties; NDVI. The model is trained on SYN1deg surface albedo.

Preliminary results indicate that the model provides much improved surface albedos relative to SRB Rel4-IP and the direct diagnostic approach in the Fu-Liou algorithm.

SRB Rel4-IP vs SYN1deg broadband albedo

Fu-Liou diagnostic vs SYN1deg broadband albedo

NN predicted vs. CERES SYN1deg 4 band surface albedo



Jan 2007, all

Jul 2007, all

Jan 2007, ice-free ocean

Jul 2007, ice-free ocean

Conclusions

NASA/GEWEX Surface Radiation Budget (SRB) Rel4-IP may be accessed from science.larc.nasa.gov/gewex-srb/. Fluxes are provided at 1°, 3-hourly and above temporal resolutions.

SRB R4-IP agrees well with surface measurements and the new CERES EBAF Ed4.2, but some variability exists due to issues with sampling and calibration from ISCCP. Long-term variability is consistent except possibly for LW Cloud Radiative Effect. SRB LW R4-IP is limited due to the shorter land surface and sea surface skin temperatures.

SRB efforts are focusing on the higher resolution, 0.5° by 0.5° equal area grid. First cut sample regional plots show that the code is now operational for the radiative transfer. Production and release are planned for 2025.

Acknowledgments

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