

AN ASSESSMENT OF AND ACCESS TO NASA CERES HOURLY SOLAR IRRADIANCE DATA PRODUCTS USING POWER WEB SERVICES

Solar World Congress 2021

Oct 25-29, 2021

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CERES Top-of-Atmosphere Measurements



Clouds and Earth's Radiant Energy System (CERES)

- CERES measures reflected solar and emitted thermal infrared energy at the top-of-atmosphere to:
 - Monitor balance of energy
 - Determine effects of clouds on climate
 - High accuracy and stability
- CERES flies on polar orbiting satellites with spectral imagers used to produce cloud properties within each footprint
 - Terra (AM overpass): MODIS*
 - Aqua (PM overpass): MODIS*
 - NPP (PM overpass): VIIRS**
 - NOAA-20 (PM overpass): VIIRS

*MODIS = MODerate resolution Imaging Spectrometer **VIIRS = Visible Infrared Imaging Spectrometer





CERES Surface Solar Irradiance: SYN1Deg Data Products

- CERES SYN1Deg (synoptic 1°x1°) products incorporate:
 - Terra/Aqua using CERES instruments with fused MODIS
 - GEO properties cross-calibrated to MODIS supplement
- Other key inputs include TSI, NSIDC Ice/Snow, surface types, NASA atmospheric reanalysis properties (3D temperature, humidity, ozone), aerosol optical properties, and surface albedo
- Computed fluxes from SYN1deg are produced using a radiative transfer model with retrieved cloud and other inputs.
 - Initial fluxes use original cloud and meteorological properties in CERES radiative transfer model
 - "Adjusted" fluxes use an adjustment algorithm that adjusts key atmospheric properties within uncertainties to agree with TOA fluxes (Rose *et al.*, 2015)
- SYN1Deg provides hourly surface solar irradiance from March 2000 to within a few months of present



CERES SYN1Deg Surface Solar Irradiance Average



CERES SYN1Deg Available Data Products

Rutan et al., 2015 (previous version)

CERES SYN1Deg:

- contains multiple parameters including the radiative fluxes, atmosphere, clouds and aerosols
- Available at multiple temporal resolutions

https://ceres.larc.nasa.gov/data/#syn1deg-level-3

Temporal Resolutions	Regional grid (1°x1° latitude by longitude)	
Monthly	SYN1deg-Month	
Monthly Hourly	SYN1deg-MHour	
Daily	SYN1deg-Day	
3-Hourly	SYN1deg-3Hour	
Hourly ^{10/9/21}	SYN1deg-1Hour Solar World C	ongress 20

	Parameter	Options
	TOA Fluxes (observed)	 Shortwave Flux Longwave Flux Window-region Flux (8-12µm) Downwelling UVA & UVB Fluxes (computed only) Downwelling PAR Flux (computed only)
	Surface Fluxes (computed)	 Shortwave Flux – Up Longwave Flux – Up Window-region Flux – Up Shortwave Flux – Down Longwave Flux – Down Window-region Flux – Down Surface Albedo Shortwave Direct/Diffuse Fluxes UVA & UVB Fluxes PAR Direct/Diffuse Fluxes
	In-Atmospheric Fluxes (computed)	 Shortwave Flux – Up Longwave Flux – Up Window-region Flux – Up Shortwave Flux – Down Longwave Flux – Down Window-region Flux – Down
	Cloud Properties (MODIS and GEO) [Diurnally Complete]	 Cloud Area Fraction Cloud Effective Pressure Cloud Effective Temperature Cloud Effective Height Cloud Top Pressure Cloud Base Pressure Cloud Particle Phase Liquid Water Path Ice Water Path Water Particle Radius Ice Particle Effective Diameter Cloud Visible Optical Depth
	Aerosols (MODIS & MATCH)	 MATCH Total Aerosol Optical Depth @ 0.55µm MODIS Aerosol Optical Depths over Land & Ocean
21	Auxiliary Data (GMAO GEOS)	 Surface Type Percent Coverage Skin Temperature Total Column Precipitable Water Upper-Tropospheric Precipitable Water Column Ozone

Validation Using BSRN Measurements



Uses Zhang et al., (2013) to process and quality control measurements

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Monthly and Daily Mean Validation of SYN1Deg GHI



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Validation of CERES SYN1Deg Hourly Global **Horizontal Irradiance (GHI)**



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CERES SYN1Deg Diffuse Horizontal Validation

- Note significant
 positive bias
- Note also the dependence of the bias on the solar zenith angle



CERES SYN1Deg Direct Horizontal Validation

- Note significant negative bias
- Note also the dependence of the bias on the solar zenith angle



CERES SYN1deg(Ed4.1)-BSRN Hourly Summary and "Adjustment" Procedure

CERES SYN1deg(ED4.1)-BSRN hourly all-sky GHI, DHI, DirHI and DNI comparison statistics from 2000-03 to 2020-07.

All-Sky Hourly	Bias	RMS	ρ	σ	μ_{DATA}	N
Original CERES SYN1deg(Ed4.1)						
GHI	-2.91	83.49	0.9566	83.44	341.63	3,331,148
DHI	30.58	85.86	0.8306	80.23	168.33	3,450,473
DirHI	-37.09	122.24	0.8881	116.48	192.60	3,009,959
DNI, or DirHI/cos(Z)	-54.32	203.73	0.8224	196.35	342.79	3,009,963

1. Initial bias correction using the dependence of the solar zenith angle to correct the various components.

- Implemented correction for diffuse and direct horizontal by solar zenith angle bin using a ratio correction expression and then used to recompute the Direct Normal
- Relatively robust when cloud fraction at surface site is within a 15% threshold of the area averaged cloud fraction

2. Also, implemented a correction for the large solar zenith angles towards sunrise and sunset when normal CERES calculations with cloud properties are truncated. The form is:

If $SZA \leq 75^\circ$, then $\mu_{eff} = \mu$; if $SZA > 75^\circ$, then $\mu_{eff} = \mu^k$, where $k = (\frac{\mu}{\mu_{75d}})^{0.13}$, where $\mu_{75d} = \cos 75^\circ$ where $\mu = \cos(SZA)$,

DHI and DNI — After Bias Correction

DHI

DNI [(GHI-DHI) /cos(SZA)]

Cos(SZA) modified when SZA>75°





Distribution of Bias/RMS Differences by site for Corrected DHI and DNI



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CERES SYN1deg(Ed4.1) Post Correction Hourly DHI, DirHI and DNI Validation

CERES SYN1deg(ED4.1)-BSRN hourly all-sky GHI, DHI, DirHI and DNI comparison statistics from 2000-03 to 2020-07 before and after the correction. The DNI from the DirIndex model in the last line for comparison.

All-Sky Hourly	Bias	RMS	ρ	σ	μ_{DATA}	Ν
Original CERES SYN1deg(Ed4.1)						
GHI	-2.91	83.49	0.9566	83.44	341.63	3,331,148
DHI	30.58	85.86	0.8306	80.23	168.33	3,450,473
DirHl	-37.09	122.24	0.8881	116.48	192.60	3,009,959
DNI, or DirHI/cos(Z)	-54.32	203.73	0.8224	196.35	342.79	3,009,963
	After Correction					
DHI	0.01	65.70	0.8300	65.70 (48%)	137.88	3,450,473
DirHl, or GHI-DHI	-0.02	106.45	0.9058	106.45 (48%)	222.64	3,107,945
DNI, or DirHI/cos(Z)	0.72	182.15	0.8509	182.15 (47%)	386.06	3,107,969
DNI from the DirIndex Model						
DNI from DirIndex Model ^{*1}	8.54	228.81	0.7580	228.65 (51%)	444.91	2,195,000

POWER Web Services Suite Provides Access

🔥 NASA Prediction Of Worldwide Energy Resources

The POWER Project

Provides solar and meteorological data sets from NASA research for support of renewable energy, building energy efficiency and agricultural needs.

Supported by NASA Earth Science's Applied Sciences Program

POWER's Enhanced Features

- Enhanced web-based POWER Docs pages
 Data Methodology
- > Data Methodology
- > Data Services Documentation
- > Data Access Tutorials

https://power.larc.nasa.gov

DATA ACCESS DOCUMENTATION RESOURCES ABOUT CONTACT

An interface to obtain and utilize global, long-term solar and surface meteorological resource data

Now provides access to scaled CERES SYN1Deg



Access to the Hourly Parameters is Supported

Category	Parameters	Source
	Top-Of-Atmosphere Shortwave Downward Irradiance	CERES (SORCE, TSIS)
	Top-Of-Atmosphere Shortwave Direct Normal Radiation	CERES (SORCE, TSIS)
	All Sky Surface Shortwave Downward Irradiance (horizontal), Diffuse Horizontal*, Direct horizontal*,	CERES SYN1Deg Ed4
	Direct Normal Irradiances* (* refers to the bias corrected all-sky fluxes)	
Solar Parameters	Clear Sky Surface Shortwave Downward Irradiance (horizontal), Diffuse Horizontal, Direct horizontal, Direct Normal Irradiances	CERES SYN1Deg Ed4
	All Sky and Clear sky Spectral Fluxes: PAR, UVA, UVB and an UV Index	CERES SYN1Deg Ed4
	Insolation Clearness Index, Clear-sky clearness index, and normalized clearness index	CERES SYN1Deg Ed4
	Surface Albedo	CERES SYN1Deg Ed4
	Solar Zenith Angle	CERES SYN1Deg Ed4
Thermal Infared Irradiance	All Sky and Clear-sky Surface Longwave Downward Irradiance	CERES SYN1Deg Ed4
Cloud	Cloud fraction, optical depth, cloud top and base heights	CERES SYN1Deg Ed4
Aerosol	Aerosol optical depth at 0.55 and 0.85 micrometers	CERES SYN1Deg Ed4
	Surface pressure, temperature (2, 10 m), surface air density (2m), specific humidity (2, 10m), relative	
Surface Meteorology	humidity (2, 10m), dew/frost point temperatures (2m), wet bulb temperature (2, 10m)	MERRA-2
	Earth Skin temperature	MERRA-2
	Wind Components (at 2, 10, 50 Meters)	MERRA-2
	Precipitation, Precipitation Corrected	MERRA-2
Meteorology	Total Column Precipitable Water, Total Column Ozone, Planetary Boundary Layer Top Pressure	MERRA-2
	Ice Covered Fraction, Land Snowcover Fraction, Snow Depth, Zero Plane Displacement Height, Surface	MERRA-2
Surface Properties	Roughness	1
	Surface Soil Wetness, Soil Temperatures (5 Layers)	MERRA-2
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Summary and Conclusions

- CERES SYN1Deg Data is an excellent resource for GHI at multiple temporal resolutions from hourly to monthly
 - However, direct and diffuse are biased in complementary ways
 - Analysis showed that the current algorithm leads to biases that are functions of solar zenith angle
 - A correction based on solar zenith was implemented and based upon the ensemble analysis of BSRN site measurements.
 - The correction proves help mitigate the overall bias, but clearly will vary from site to site but appears to be good enough for solar related applications

POWER Web Services Suite Provides Access to "Corrected" Flux components

- Fully implementation into cloud based architecture to improve performance for delivering of up to hourly data products starting in Jan 2001
- Finalizing validation and documentation

• Future Work

- Continue to assess the "correction" algorithm under all conditions and validate
- CERES team plans their own correction to clouds at very low sun angles that may reduce some of the noise found at those solar zenith angles.
- Work with CERES Science team to revise radiative transfer algorithm for solar flux components

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