

Providing Long-term Solar and Meteorological Resource Information from NASA Research through the GIS-Enabled POWER Web Services Portal

Paul W. Stackhouse Jr., NASA Langley Research Center

Co-authors:

Bradley Macpherson, Booz Allen Hamilton,
J. Colleen Mikovitz and Dr. Taiping Zhang, SSAI

Special contribution: NASA's LaRC Atmospheric Science Data Center (ASDC) and Brad Friesen, Friesen Energy

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NASA's POWER Project

Prediction Of Worldwide Energy Resources (POWER)

Integrate environmental data, analysis and modeling from NASA research and provide accessibility for enhanced energy related and agricultural applications.

Geospatially Enabling NASA ES Data For:

- Renewable Energy Applications
- Energy-Efficient Building Design
- Agricultural Crop Modeling Applications



<https://power.larc.nasa.gov>



POWER User Metrics and History

POWER Web Services Portal collects a variety of metric information to understand data requests and changes of the user base (**but access is free and anonymous**).

- *Derived from server logs are unique IP addresses (a proxy for users), data request volume, and API request attributes to subset requests by data sources, access methods, and more.*
- *Also, usage tracking as a function of time of the web site and data services by IP geolocation to map the requested data location and the location of user.*

After Geospatial Services

2018/05/01 – 2020/11/30

Requests > 139 Million

Unique Users ~283,500

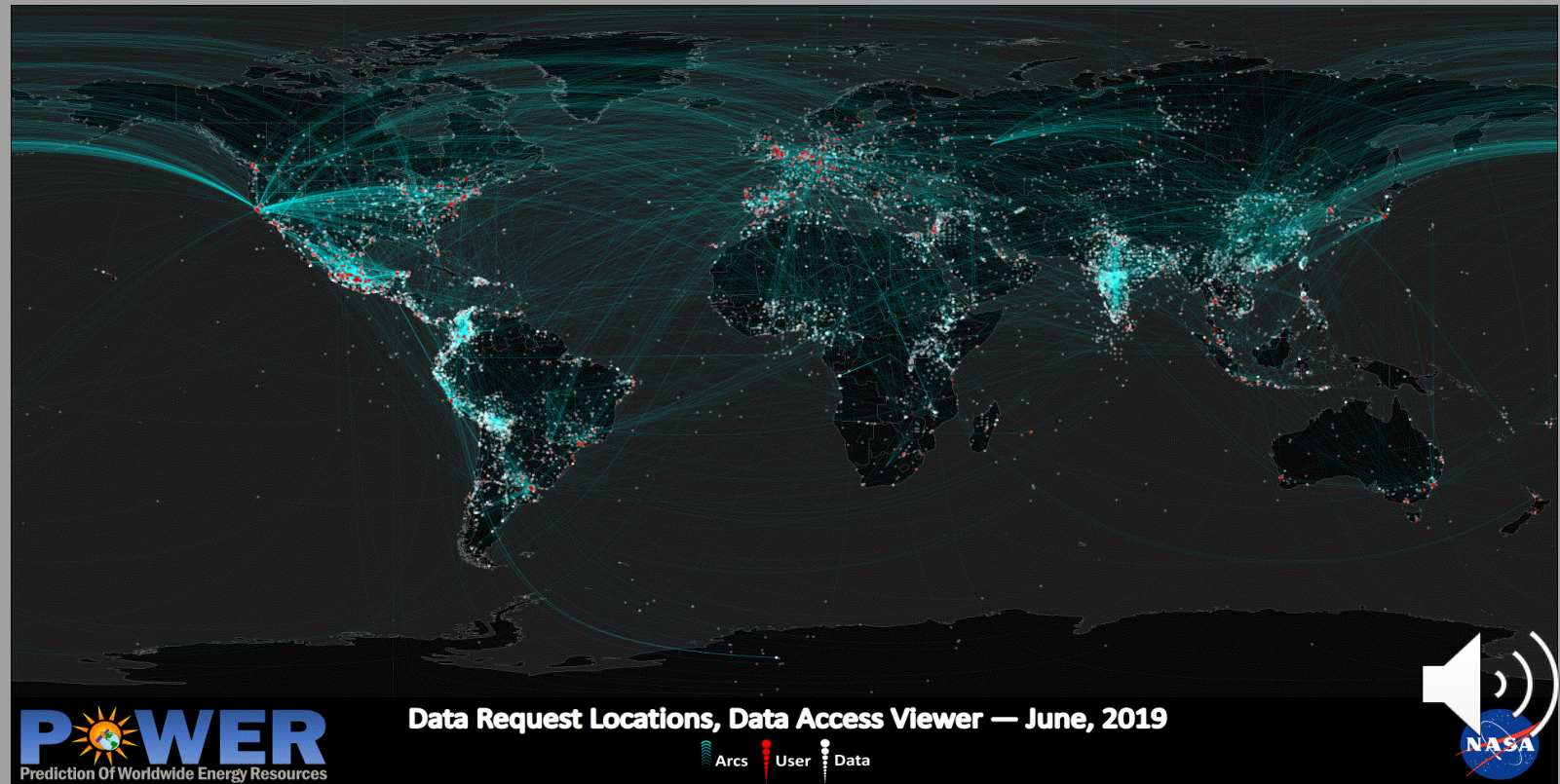
Data Volume ~12.8 TB

Before Geospatial Services

1999/06/01 – 2018/04/30

Requests ~36 Million

Data Volume 3.5 TB





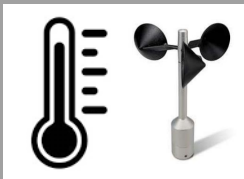
Current POWER Data Sources

The POWER Data Archive uses NASA research and modeling data products.



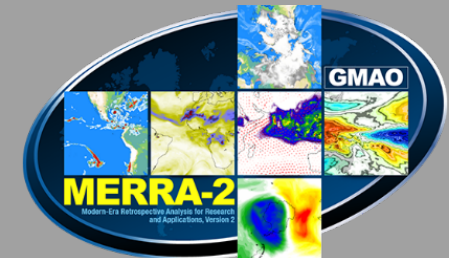
Clouds and Solar

Source	Temporal Coverage		Description
<u>GEWEX/SRB 3.0</u>	July 1, 1983	Dec. 31, 2007	Satellite analysis from global cloud imagers (from GEO and Polar orbiters)
<u>CERES FLASHFlux</u>	Jan. 1, 2008	Near Real Time	Satellite analysis of CERES (reflected solar) and MODIS (cloud imager) measurements (on Terra and Aqua satellites)



Meteorology

Source	Temporal Coverage		Description
<u>MERRA-2</u>	Jan. 1, 1981	End of MERRA2	Atmospheric reanalysis with assimilated observations (1-2 months behind real time)
<u>GMAO FP-IT (GEOS 5.12.4)</u>	End of MERRA2	Near Real Time	Same with less observations





POWER Data: What Parameters are Provided?

Base and Derived Parameters for POWER GIS v1

All parameters are available globally on a 0.5° latitude/longitude grids.

Source Base Data	Additional Daily & Monthly/Annual Averaged Parameters	Additional Long-term Averaged Parameters (Climatological)
<ul style="list-style-type: none"> • All-Sky & Clear-Sky Surface Solar Insolation on Horizontal Surface • Surface Reflected Solar Flux • All Sky Downward Longwave Radiative Flux; • Top-of-atmosphere Insolation • Average Air Temperature at 2 m, 10 m • Specific Humidity at 2 m, 10 m • Surface dewpoint at 2 m • Surface pressure • Surface skin temperature • U, V Wind Speed at 2 m, 10 m, and 50 m • Precipitation 	Clear & Cloudy Clearness Indexes	Solar geometry, Surface albedo, Direct Normal, Diffuse, Tilted surface solar parameters
	Tmin, Tmax, Trange at 2 m, Wet Bulb Temperature at 2 m, Temp Frost point at 2 m, Relative Humidity at 2 m	3-hourly solar fluxes and cloud parameters, No-sun Days, min insolation over day periods
	Wind speed and Direction at 10m, 50 m Max/Min Wind Speed	Heating/Cooling Degree Days (for 0° C, 10° C, 18.3° C standards), Skin Temperature max/min/range, Frost Days, Total Column Precipitable Water
		ASHRAE® Building Climate Thermal & Moisture zones

Notes:

1. GEWEX SRB 3.0 → NASA's Global Energy and Water Exchange Project /Surface Radiation Budget (<https://gewex-srb.larc.nasa.gov/> & <https://asdc.larc.nasa.gov/project/SRB>)
2. FLASHFlux → NASA's Fast Longwave And Shortwave Radiative Fluxes (<https://ceres.larc.nasa.gov/data/#fast-longwave-and-shortwave-flux-flashflux>)
3. MERRA-2 → NASA's Modern Era Retro-analysis for Research and Applications –assimilation model (<https://gmao.gsfc.nasa.gov/reanalysis/MERRA2/>)
4. FP-IT (GEOS 5.12.4) → Forward Processing – Instrument Team (https://gmao.gsfc.nasa.gov/news/geos_system_news/2016/FP-IT_NRT_G5.12.4.php)
5. ASHRAE®: "ASHRAE" is a registered trademark of the American Society of Heating, Refrigeration and Air Conditioning Engineers





POWER Data Validation of Parameters

Uses SRB & CERES satellite analysis for solar irradiance estimates

- All-sky, clear-sky fluxes total, direct, diffuse flux estimates compared against well-calibration instrument networks

FP-IT/MERRA-2 atmospheric reanalysis

- Validation against global NOAA database of surface observations

More detailed statistics availability in "Methodology" documentation pages

Daily mean comparisons between GEWEX SRB and CERES FLASHflux all-sky and clear-sky solar irradiance at the surface of the Earth.

Parameter	Data:	Bias (%)	RMSE (%)
Solar All Sky Insolation	SRB	-1.72	20.47
Solar Clear Sky Insolation	SRB	-0.84	7.04
Solar All Sky SW Insolation	FLASHFlux	-1.18	17.06
Solar Clear-Sky SW Insolation	FLASHFlux	-3.25	5.07

Parameter	MBE	RMSE	Slope	Intercept	Rsqud
Average Temperature (°C)	-0.52	2.29	1.00	-0.48	0.96
Minimum Temperature (°C)	0.50	3.05	0.97	0.73	0.93
Maximum Temperature (°C)	-1.38	3.16	0.98	-1.01	0.95
Relative Humidity (%)	4.44	12.06	0.78	19.88	0.61
Dew Point Temperature (°C)	0.37	2.53	0.95	0.69	0.95
Precipitation (mm/day)	0.46	6.81	0.36	1.71	0.23
Specific Humidity (g/kg)	0.01	1.05	0.93	0.49	0.95
Uncorrected Atmospheric Pressure (mb)	-8.59	24.40	0.95	40.97	0.81
Elevation Corrected Atmospheric Pressure (mb)	0.03	2.82	1.00	1.08	1.00
Wind Speed (m/s)	0.37	1.65	0.73	1.36	0.55





POWER Data Access Methods: API

POWER enhances data discovery, access, and distribution as **Analysis Ready Data (ARD)** for direct application of inputs to decision to support tools, modeling and forecasting packages, and as inputs to scientific research is provided via three basic services:

API: *The RESTful Application Programming Interfaces (API) supports ARD distribution through a single endpoint (i.e., formatted URL string) that retrieves, subsets, and converts the data into user community specific formats like ASCII, ICASA, CSV, GeoJSON, NetCDF, and more.*

- Utilizes the **Open-source Project for a Network Data Access Protocol (OPeNDAP®)** and/or optimized file formats to support ARD distribution from POWER's multi-parameter and temporal data (i.e., daily, monthly, annual, climatological).
- Accessible via web browsers, custom applications integration, and many more.

Example request for 2020 daily data for Denver, Colorado

```
https://power.larc.nasa.gov/cgi-bin/v1/DataAccess.py?&request=execute&identifier=SinglePoint&parameters=RH2M,T2M,ALLSKY_SFC_SW_DWN&startDate=2020101&endDate=20201230&userCommunity=SSE&tempAverage=DAILY&outputList=ASCII&lat=39.6503&lon=-104.9773
```

JSON	Raw Data	Headers
Save	Copy	Collapse All Expand All Filter JSON
▼ features:		
▼ 0:		
▼ geometry:		
▼ coordinates:		
0:	-104.97729	
1:	39.65031	
2:	1826.36	
type:	"Point"	
▼ properties:		
▼ parameter:		
▼ ALLSKY_SFC_SW_DWN:		
20200101:	1.34	
20200102:	2.84	
20200103:	2.83	
20200104:	2.74	
20200105:	2.91	
20200106:	2.97	
20200107:	2.93	
20200108:	2.79	

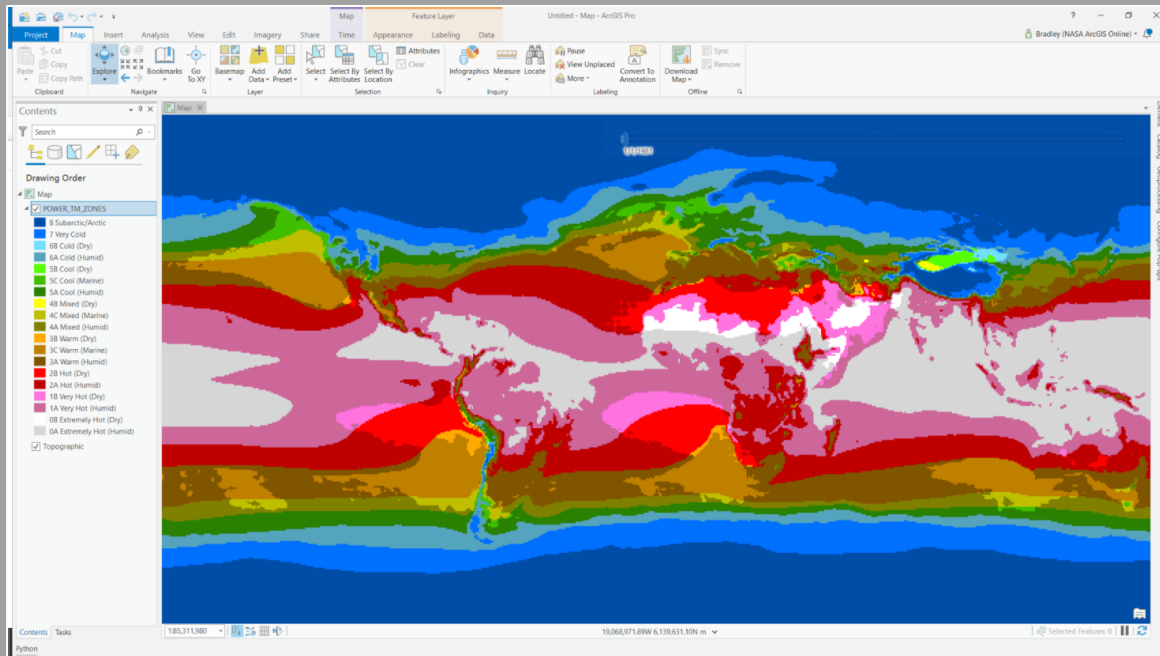


POWER Access Methods: ArcGIS Image and Feature Services

ArcGIS Image and Feature Services allow users to efficiently interact with the POWER data in GIS applications. The image services include global climatology based solar and meteorological parameters.

- Directly connect users to POWER climatology data in GIS applications.
- Services are available as Open Geospatial Consortium (OGC®) compliant services and multiple data portals including NASA ArcGIS Online, ASDC, and the Esri® Living Atlas.

Current feature services: global long-term ASHRAE® building climate thermal-moisture zones, 4-year rolling thermal zones, and period differences. In the future, a full selection of parameters service will be provided up to hourly and daily temporal averages.



Temperature at 2 Meters (30-Year Climatology)

Temperature at 2 Meters 30-year climatology from 1984-2013 for the POWER communities. This service provides global period and monthly climatologies in degrees Celsius (C).

[Open in Map Viewer](#)

Insolation Incident on a Horizontal Surface (30-Year Climatology)

Insolation Incident on a Horizontal Surface 30-year climatology from 1984-2013 for the POWER Agroclimatology (AG) community. This service provides global period and monthly climatologies in MJ/m²/day.

Imagery Layer by bmaspher_NASA

[Open in Map Viewer](#)

[Open in Scene Viewer](#)

Temperature at 2 Meters (T2)

The monthly average of the temperature from Dec. 2013.

Description

- The data is available on a 0.5 X 0.5 Degree
- Meteorological parameters are derived from NASA's GMAO MERRA-2 archive (Jan. 1, 1984 - Dec. 31, 2013).

Phenomenon Mapped: Temperature

Units: Degrees Celsius

Data Projection: GCS WGS84

Mosaic Projection: Web Mercator

Extent: Global

Source: NASA Prediction Of Worldwide Energy Resources (POWER)

Update Cycle: Sporadic

ArcGIS Server URL: <https://asdc.nasa.gov/arcgis/rest/services/POWER/T2/MapServer>

Four Year Rolling Thermal Moisture Zones

The Four Year Rolling Thermal Moisture Zones for 1984 to present.

Feature Layer by bmaspher_NASA

Created: Mar 17, 2020 Updated: Apr 7, 2020 View Count: 11

Description

The Prediction of Worldwide Energy Resource (POWER) Project is funded through the NASA Applied Sciences Program within the Earth Science Mission Directorate. POWER supports three user communities with solar and/or meteorological data.

Thermal Moisture Zones: This is a feature service that contains four year rolling Thermal Moisture Zones for all four year periods between 1984 to present. The Thermal Moisture Zones are derived from the POWER projects Thermal Zones version two Application Programming Interface (API) and are combined via a python framework.

Thermal Moisture Zones are regions of the earth that have the same general climate characteristics based upon climatologically averaged heating and cooling degree days and moisture. The thermal zone values range from 0 (hottest) to 8 (coldest). The moisture zones are based upon precipitation data and are characterized as marine, dry or humid with sub-zones designated as C, B, or A.

- The data is available on a 0.5° x 0.5° latitude and longitude global grid.
- Meteorological parameters are derived from NASA's GMAO MERRA-2 archive (Jan. 1, 1984 - Dec. 31, 2013).

Phenomenon Mapped: Thermal Moisture Zones Differences

Units: Differences

Time Interval: 1 Year

Cell Size: 0.5 X 0.5 Degree

Source Type: Integer

ArcGIS Server URL: <https://asdc.nasa.gov/arcgis/rest/services/POWER/ThermalMoistureZones/MapServer>

Details

Source: Feature Service

Data Last Updated: Mar 17, 2020, 3:54:36 PM

Size: 22 MB

Share

Owner: bmaspher

Tags: POWER, Thermal Moisture Zones, NASA Applied Sciences, Climatology, Prediction Of Worldwide Energy Resources (POWER), NASA

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POWER Access Methods: Data Access Viewer (DAV)

Custom user interface with a geospatial map and widgets for **Single Point** (all temporal levels), **Small Regions** (2.5x2.5 degree), **Global** (zones & climatology), **Layer List** (image and feature services), and in the future will prepare user community-specific reports (indicators, anomalies, & windrose)

Key Features:

- Responsive and scalable; built for mobile and desktop use
- Can submit a request from a widget to visualize and download the data
- Provide simple graphing capabilities for any temporal level (except hourly)

<https://power.larc.nasa.gov/data-access-viewer/>

The screenshot shows the 'POWER Data Access Viewer' interface. The main panel is titled 'POWER Single Point Data Access' and contains a multi-step workflow:

- 1. Choose a User Community:** A dropdown menu for 'All Communities'.
- 2. Choose a Temporal Average:** Radio buttons for 'Daily', 'Interannual', and 'Climatology'.
- 3. Enter Lat/Lon or Add a Point to Map:** Input fields for Latitude and Longitude, with a 'Clear' button and a 'Zoom to' button.
- 4. Select Time Extent:** 'Start Date' (01/01/2015) and 'End Date' (03/05/2015) fields.
- 5. Select Output File Formats:** Checkboxes for 'ASCII', 'CSV', 'GeoJSON', 'ICASA', and 'NetCDF'.
- 6. Select Parameters:** A list of parameters including 'Downward Longwave Radiative Flux', 'Insolation Incident on a Horizontal Surface', and 'Insolation Incident On A Horizontal Surface at 0'.

A secondary window displays '30 Year Climatology' for a point with a value of -17.47 (C). It includes a line graph of 'Insolation On A Horizontal Surface (kWh/m²/day)' and a bar chart of 'Insolation Incident On A Horizontal Surface (kWh/m²/day)'. A '30 Year Climatology' pop-up also shows a value of -17.47 (C) and a 'Zoom to' button.

The screenshot shows the 'POWER Data Access Viewer' interface with the 'Single Point' workflow:

- 5. Select Output File Format:** A dropdown menu set to 'GeoJSON'.
- 6. Select Parameters:** A search bar and a list of parameter categories: 'Meteorology (Moisture and Other)', 'Meteorology (Temperature)', 'Meteorology (Wind)', and 'Sizing and Pointing of Solar Panels and for Solar Thermal Applications'.

The screenshot shows the 'POWER Data Access Viewer' interface with the 'Global' workflow:

- 1. Choose a Parameter:** A dropdown menu for 'Insolation Incident On A Horizontal Surface'.
- 2. Choose a Temporal Average:** Radio buttons for 'Daily', 'Interannual', and 'Climatology'.
- 3. Enter Lat/Lon or Add a Point to Map:** Input fields for Latitude and Longitude.
- 4. Select Time Extent:** 'Start Date' and 'End Date' fields.
- 5. Select Output File Formats:** Checkboxes for 'ASCII', 'CSV', 'GeoJSON', 'ICASA', and 'NetCDF'.
- 6. Select Parameters:** A list of parameters.

The background shows a global map with a color-coded energy resource distribution. A secondary window displays a line graph of 'Insolation Incident On A Horizontal Surface (kWh/m²/day)'.





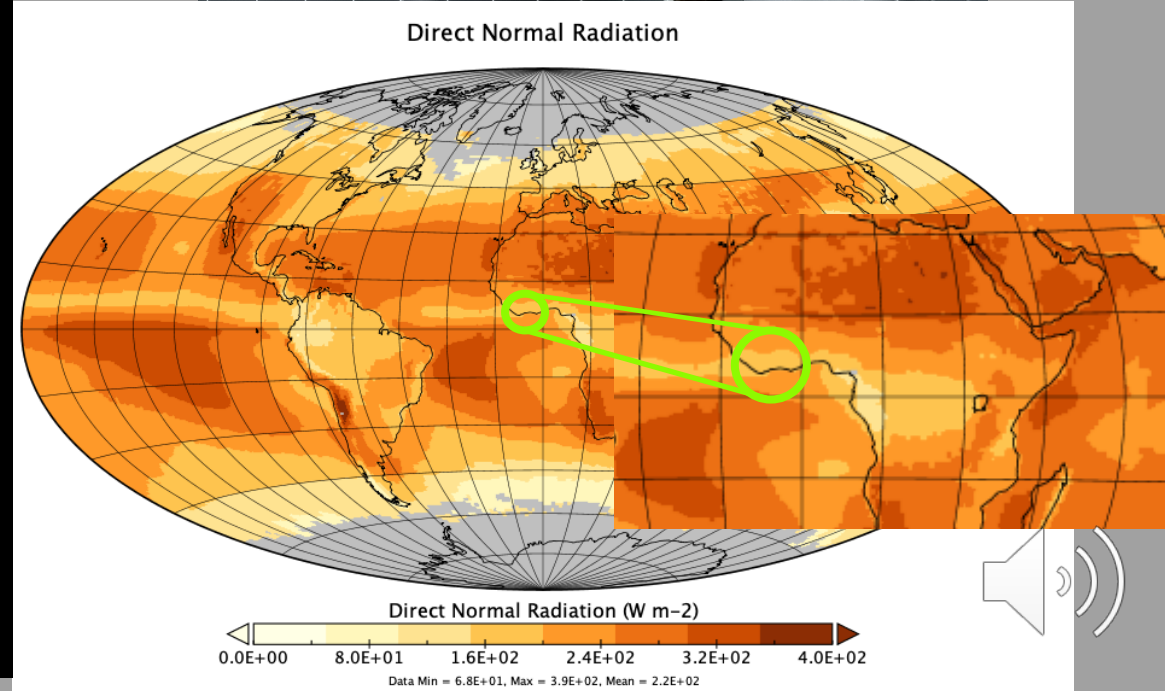
POWER Applications: Community Solar Evaluation

- A community solar power project in a remote village in West Africa appeared to be working poorly.
- A solar consultant investigated using insolation data from the “POWER Single Point Data Access” application on POWER’s “Data-Access-Viewer”. Sample data:



PARAMETER	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
DNR	6.13	5.88	5.04	4.29	4.12	3.54	2.97	2.84	3.35	4.09	4.65	5.67	4.37
DNR_MAX	7.53	7.42	5.7	4.78	4.68	4.3	4.04	3.56	3.99	4.7	5.05	7.13	5.24
DNR_MIN	4.97	4.81	4.42	3.85	3.47	2.76	2.3	2.27	2.59	3.57	3.88	4.51	3.62

- POWER provided data showed that cloud coverage that peaked at nearly 80% in August was the culprit.
- The community was able to verify their systems were working properly, but required management adjustments for the expected power output, system configuration and billing.

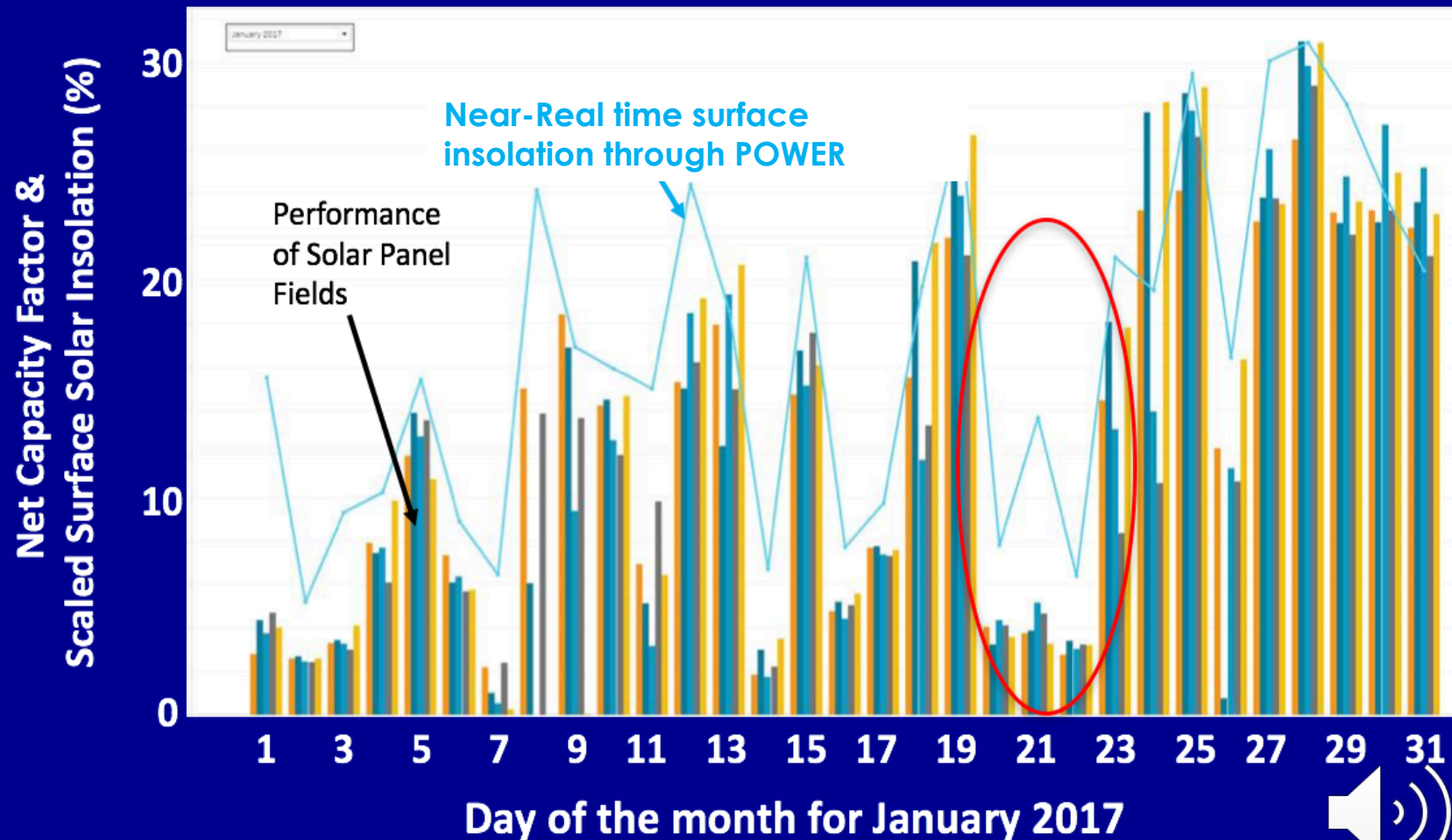




POWER API Usage: Solar Panel Performance Monitoring

- Using an URL command, solar consultants obtain daily data to help monitor solar field performance (First Customers Renewables) remotely.
- Five solar array fields monitored in North Carolina, US.
- Consultant collects daily averaged solar irradiance data from POWER (from CERES FLASHFlux) and creates a “value added” scaling factor on a daily basis within 1 week of actual time.
- Variability of solar field output is compared to irradiance values to assess performance and identify potential system problems.

Solar POWER Produced vs Solar Energy Available

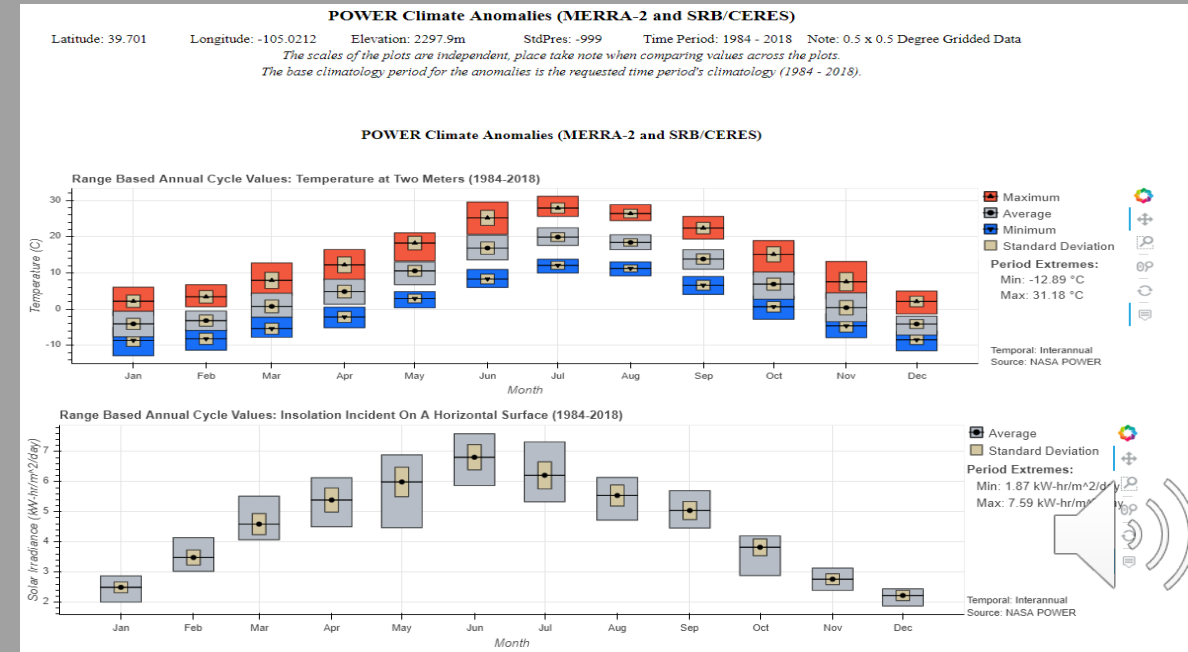




POWER-GIS v2 Beta Release!

- POWER-GIS v2 Beta is fully cloud optimized services and data processing
 - Updated GEWEX SRB (Release 4-Integrated Product, AMS Paper 6.7), FLASHFlux (v4A) and introducing CERES SYN1Deg Edition 4.1 global flux data products
 - Multiple additional parameters for both solar related and meteorological parameters
 - Temporal resolution now up to **hourly** from Jan 1, 2001 through 2019
 - New data format to support **hourly** energy analysis for buildings (EPW format compatible with EnergyPlus and numerous decision support tools)
 - New applications that include reports: Climate Design Conditions, Long-term statistics

POWER Climatic Design Conditions (MERRA-2 and SRB/CERES)															
Latitude:		Longitude:		Elevation: 60.8		StdPres: 14.66		Time Period: -		Note: Gridded Data					
Annual Heating and Humidification Design Conditions															
Coldest Month	Heating DB		Humidification DP/MCDB and HR						Coldest month WS/MCDB			MCWS/PCWD to 99.6% DB			
	99.6%	99%	99.6%		99%		0.4%		1%						
1	-9.0	-6.7	DP	HR	MCDB	DP	HR	MCDB	WS	MCDB	WS	MCDB	MCWS	PCWD	
			-13.6	1221.8		-11.9	1442.1		2.7		2.7				
Annual Cooling, Dehumidification, and Enthalpy Design Conditions															
Hottest Month	Hottest Month DB Range	Cooling DB/MCWB				Evaporation WB/MCDB				MCWS/PCWD to 0.4% DB					
		0.4%		1%		2%		0.4%		1%		2%			
7	12.7	DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	WB	MCDB	MCWS	PCWD
		36.6		35.0		33.6		27.9		27.2		26.5			
Dehumidification DP/MCDB and HR															
0.4%		1%		2%		0.4%		1%		2%		Extreme Max WB			
DP	HR	MCDB	DP	HR	MCDB	DP	HR	MCDB	Enth	MCDB	Enth	MCDB	Enth	MCDB	30.4
36.6	18740.0		23.5	18130.0		23.0	17520.0								
Extreme Annual Design Conditions															
Extreme Annual WS			Extreme Annual Temperature				n-Year Return Period Values of Extreme Temperature								
			Mean		Standard deviation		n=5 years		n=10 years		n=20 years		n=50 years		
1%	2.5%	5%	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	
6.1	5.3	4.6	DB	-11.9	38.2	3.2	2.0	-14.2	39.7	-16.0	40.9	-17.8	42.0	-20.1	43.5
			WB	-13.2	29.1	3.0	0.7	-15.3	29.6	-17.1	30.0	-18.7	30.4	-20.9	31.0
Monthly Climatic Design Conditions															
Temperatures, Degree-Days and Degree-Hours	Annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
	DBAvg	14.4	1.7	3.3	7.7	13.9	19.1	24.3	26.5	25.7	21.9	15.2	8.8	4.3	
	DBStd	0.6	2.0	2.7	2.2	1.3	1.5	1.2	1.3	1.3	1.5	1.6	2.6		
	HDD10.0	768	240	180	96	13	0	0	0	0	7	62	169		
	HDD18.3	2150	489	402	307	134	35	1	0	7	105	259	409		
	CDD10.0	2584	8	12	47	143	292	433	519	500	371	188	53	17	
	CDD18.3	834	0	0	1	15	70	185	262	243	178	70	1	0	





Conclusions

POWER has successfully provided parameters from NASA Earth observations and analysis to enable a wide variety of applications including solar energy

- 35+ year time series of solar and meteorological parameters (up to a few days or real-time); numerous data formats
- Continually updated and documented new data parameters for usage

POWER GIS-enabled is serving customers in government and industry using advanced GIS enabled capabilities and data analysis tools

- Since release, nearly 140 million data requests and over 280,000 unique users
- Data accessible by: DAV, Image Services and directly through API
- Improved user metrics for better data collection of statistics and stories

POWER GIS-enabled cloud enabled core system is poised is ready for evaluation

- Applicable to new data sets from other missions and research (i.e., CERES, fires, etc.)
- Adaptable to higher spatial/temporal resolution parameters (i.e., hourly)
- Contact me for access to the new Beta: paul.w.stackhouse@nasa.gov
- Public beta available in February 2021 for trial period (maintain current)
- Fully operational transition June 2021

POWER GIS v1 at: <https://power.larc.nasa.gov>

