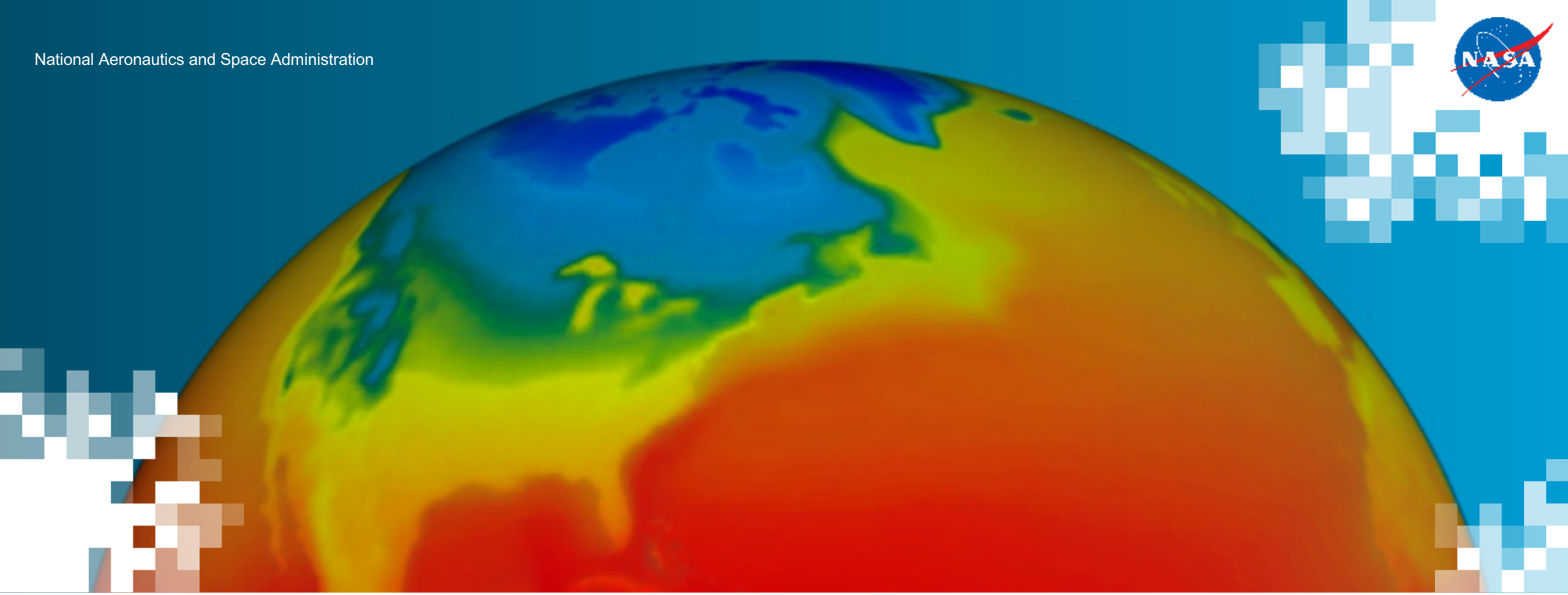
National Aeronautics and Space Administration



Entender y Obtener Productos de Datos de la NASA a través de POWER

Colaboración entre NASA POWER y NASA ARSET

15 de junio de 2021

POWER
Prediction Of Worldwide Energy Resources

¿Qué es POWER?

¿Cuál es el propósito de POWER?

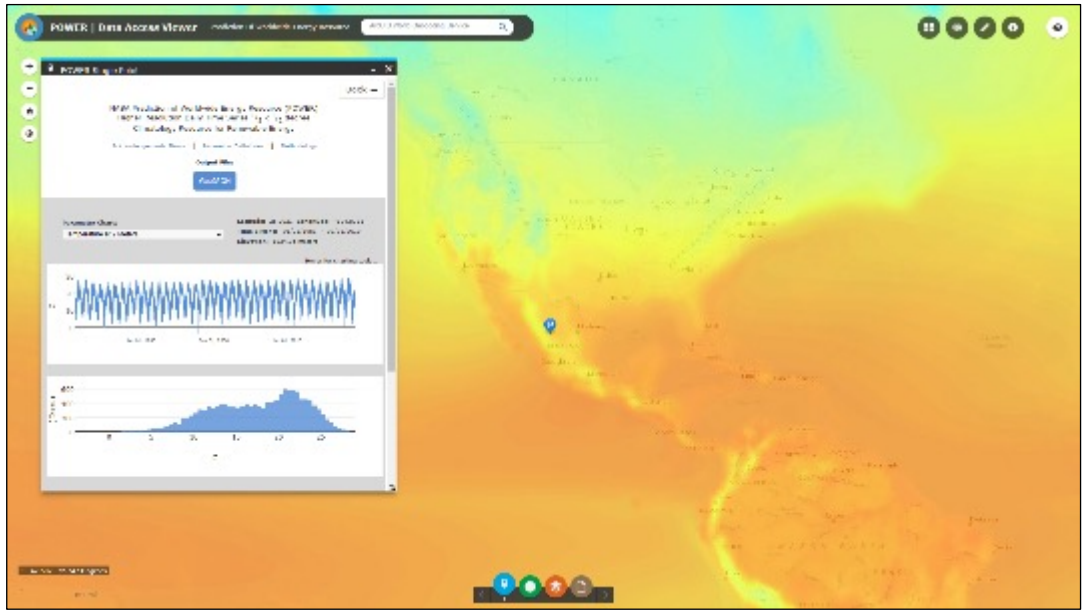
- POWER son las siglas de "Prediction of Worldwide Energy Resources" (Predicción de Recursos Energéticos a Nivel Mundial)- un proyecto financiado por la NASA para ayudar a facilitar el uso de observaciones de la tierra, análisis y modelos de la NASA para tratar cuestiones claves para la sociedad.
- POWER procura mejorar la capacidad pública/privada de la nación para integrar datos ambientales de las observaciones de la Tierra e investigaciones d la NASA, *particularlmente, irradiancia superficial solar,* para apoyar un aumento de:
  - desarrollo de energía renovable,
  - eficiencia y sostenibilidad energética y,
  - aplicaciones agroclimatológicas.

Photo Credits: nrdc.org, solvay.com, harvestreturns.com

¿Cuál es el papel de POWER's en la comunidad?

POWER apoya a la comunidad a través de:

- El acceso eficiente, abierto al púglico y la distrubición conveniente de datos de las observaciones de la Tierra de la NASA mediante un? suite de servicios integrado.
- Societal benefit area-specific content guided by interaction with and feedback from professional community members and organizations.
- Key partnerships with scientific data providers and user groups providing actionable and community feedback for improved future data products.



What questions can be answered with Earth Observations made available through POWER Web Services?

- What is typical variability of the sunlight, temperature, and winds over the past 25-30 years in a region?
- What is the anticipated level of production for an installed photovoltaic (PV) field? Is there an optimal tilt angle that considers cloud patterns?
- Is this regional area potentially suitable for wind power generation?
- How can we understand the variability of building environment climate parameters needed to determine current and future building standards?

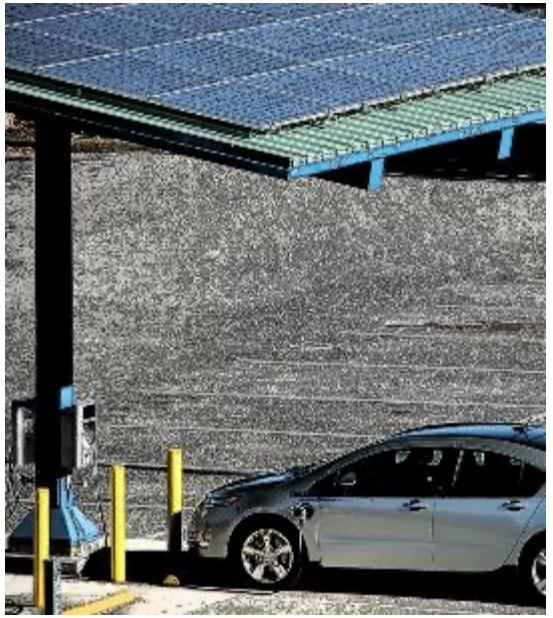


Photo Credit: NASA Technology Transfer Program

Photo Credit: NASA CERES

What questions can be answered with Earth Observations made available through POWER Web Services?

- How can we determine if incorporating renewable technologies makes sense from an environmental and economic perspective?
- Can I monitor the performance of my building and see if retrofitting renewable technologies is feasible and afterwards effective?
- How can I introduce a class to the principles and effectiveness of implementing solar technologies anywhere in the world?

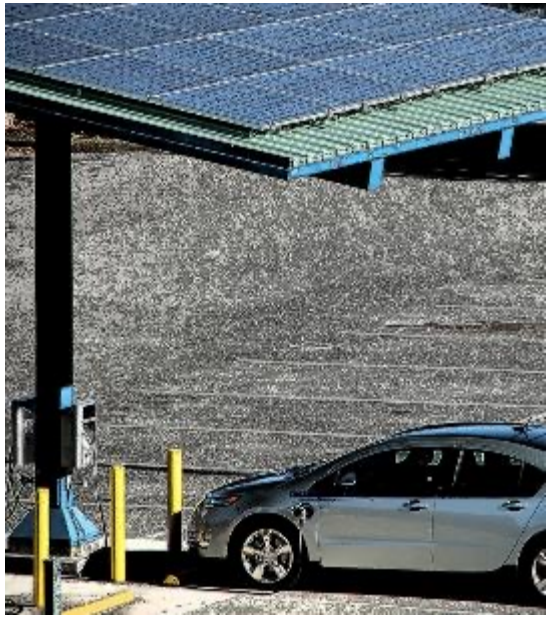


Photo Credit: NASA Technology Transfer Program

Photo Credit: NASA CERES

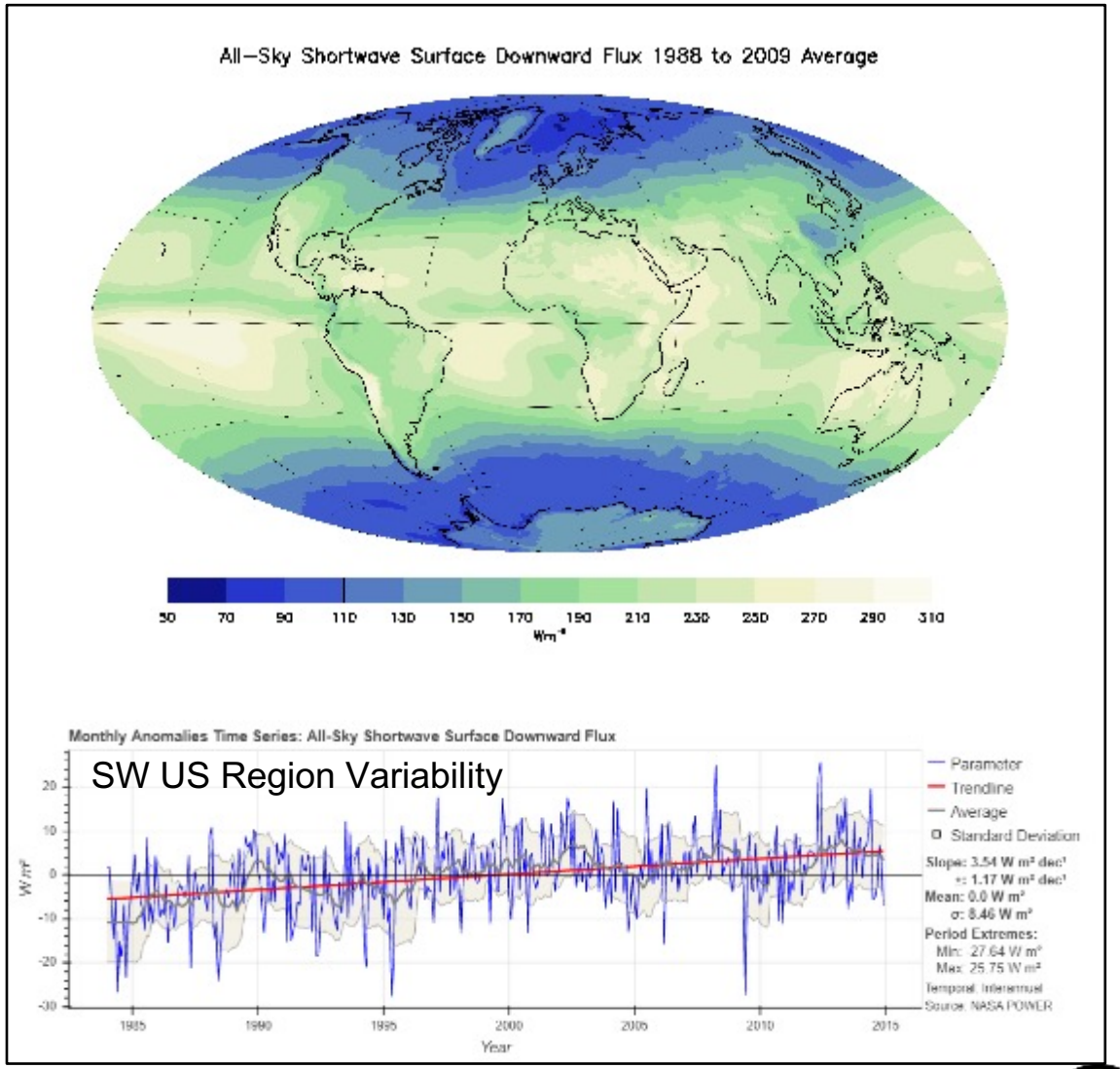
What information does the community need to answer those and other questions?

Among the most widely needed data are long records to near real-time of:

- Sunlight Information: Solar irradiance and related components (i.e., direct, diffuse, solar angles, surface albedo)
- Surface Temperature and Humidity (max and min T, dewpoint, RH, etc.)
- Wind Speed and Direction
- Cloud Coverage, Thickness, and Type

Time series of parameters are needed including:

- Hourly, Daily, Monthly, Annual
- Long-Term Averages

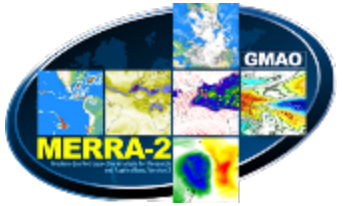


What NASA EOs can provide these data parameters?

The POWER Data Archive uses NASA research and modeling data products plus value added data processing and services to customize parameters for community use.

Current POWER version at: ***https://power.larc.nasa.gov***

Source	Temporal Span		Temporal Average		Description
	Start	End	Input	Output	
GEWEX SRB 3.0	July 1, 1983	Dec. 31, 2007	Daily	Daily, Monthly, Annual, Multi-Year	Satellite analysis from global cloud imagers (from geosynchronous and polar orbiting satellites) using radiative transfer lookup tables
CERES FLASHFlux	End of SRB Rel 3	Near Real-Time	Daily	Daily, Monthly, Annual , Multi-Year	Satellite analysis of CERES (reflected solar) and MODIS (cloud imager) measurements (on Terra and Aqua satellites)
MERRA-2	Jan. 1, 1981	End of MERRA-2 (current)	Hourly	Daily, Monthly, Annual, Multi-Year	Atmospheric reanalysis with assimilated observations (1-2 months behind real-time)
GMAO FP-IT (GEOS 5.12.4)	End of MERRA-2	Near Real-Time	Hourly	Daily, Monthly, Annual, Multi-Year	Atmospheric reanalysis with less assimilated observations, available within 2 days of real-time



What NASA EOs can provide these data parameters?

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Red indicates changes for POWER Beta web site: https://power.larc.nasa.gov/beta

Source	Temporal Span		Temporal Average		Description
	Start	End	Input	Output	
GEWEX SRB 4.0	July 1, 1983	Dec. 31, 2000	Daily	Daily, Monthly, Annual, Multi-Year	Satellite analysis from global cloud imagers (from geosynchronous and polar orbiting satellites) using radiative transfer lookup tables
CERES SYN1Deg (Ed 4A)	Jan 1, 2001	End of SYN1Deg (current)	Hourly	Hourly, Daily, Monthly, Annual, Multi-Year	Satellite analysis from CERES convolved with MODIS for scene and TOA fluxes, then uses radiative transfer with additional input from geosynchronous satellites and other inputs to produce surface fluxes
CERES FLASHFlux	End of SYN1deg (current)	Near Real Time	Daily	Daily, Monthly, Annual , Multi-Year	Satellite analysis of CERES (reflected solar) and MODIS (cloud imager) measurements (on Terra and Aqua satellites)
MERRA-2	Jan. 1, 1981	End of MERRA-2 (current)	Hourly	Hourly, Daily, Monthly, Annual, Multi-Year	Atmospheric reanalysis with assimilated observations (1-2 months behind real-time)
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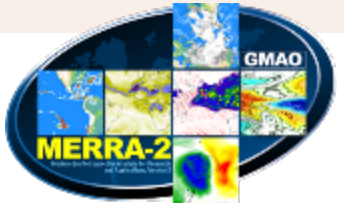
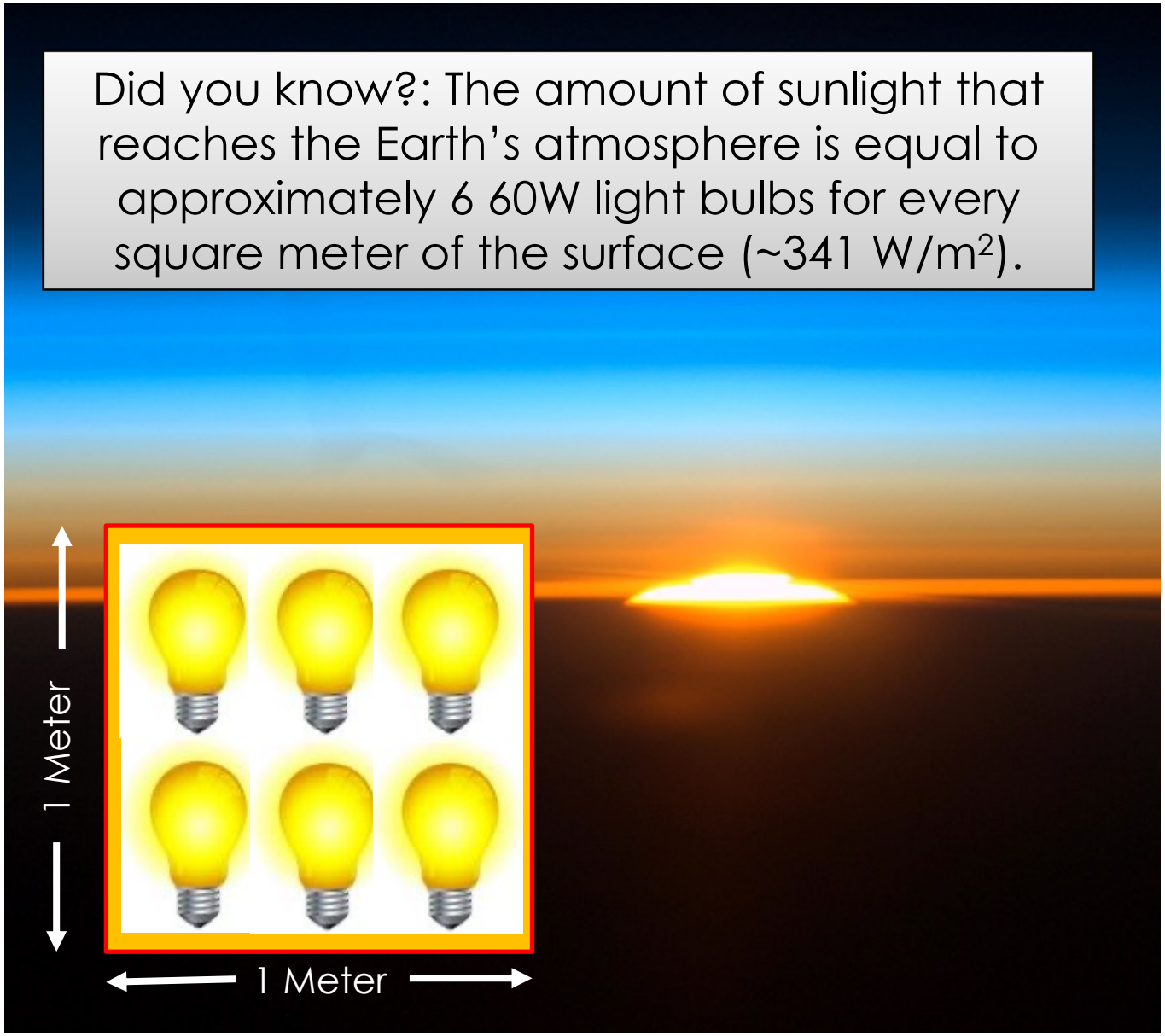


What is solar irradiance?

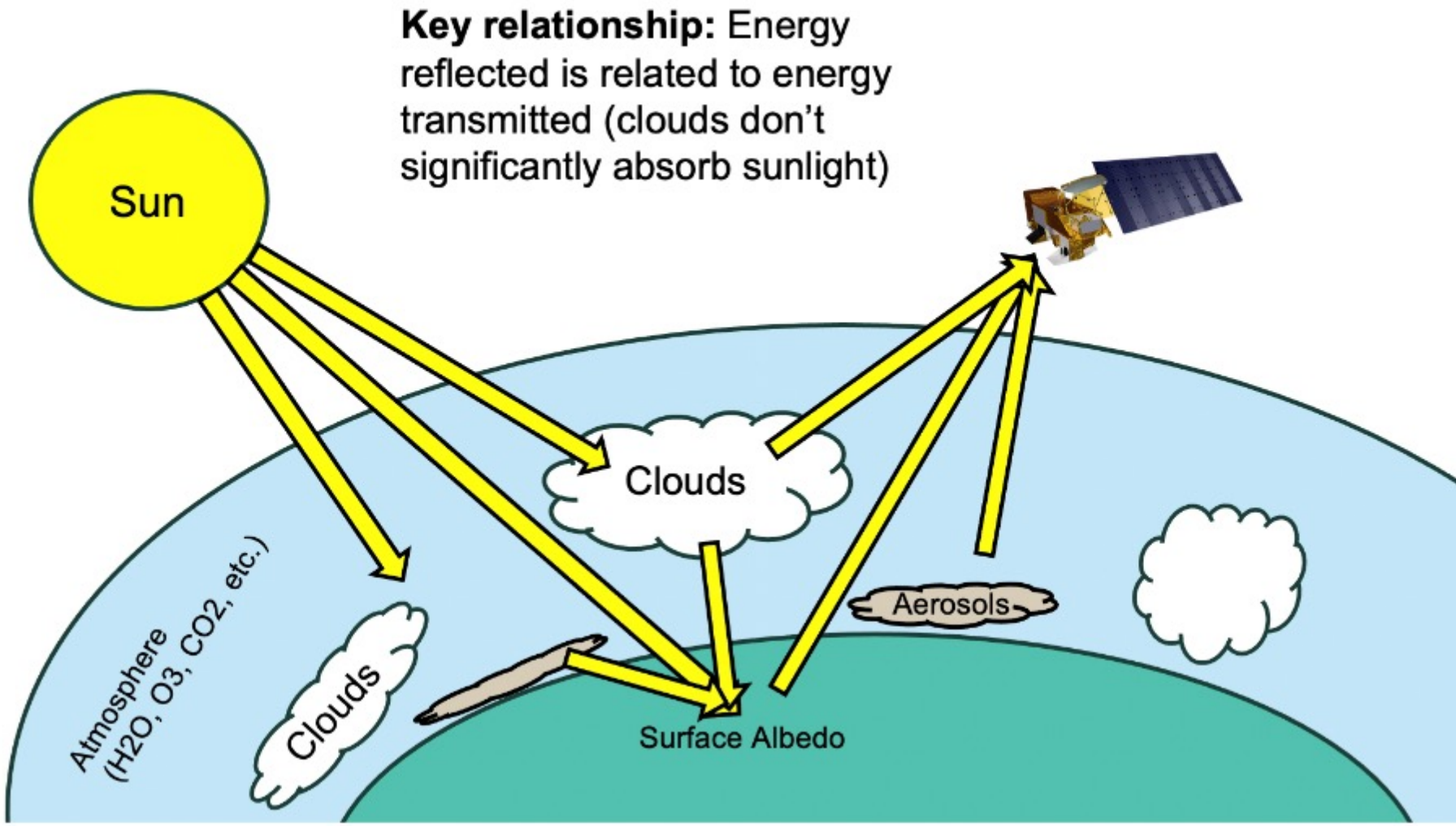
- Solar irradiance is the rate at which solar energy falls onto a surface, per unit area. The units are power per area: Watts per square meter, abbreviated as W/m^2.
- Solar irradiance is transmitted through the atmosphere and is vital for understanding climate variability and surface heating.
- Surface solar irradiance is an important factor in the sizing of both solar panels and battery backup systems, solar cooking applications, and building design.



How is surface solar irradiance calculated from Earth observations?

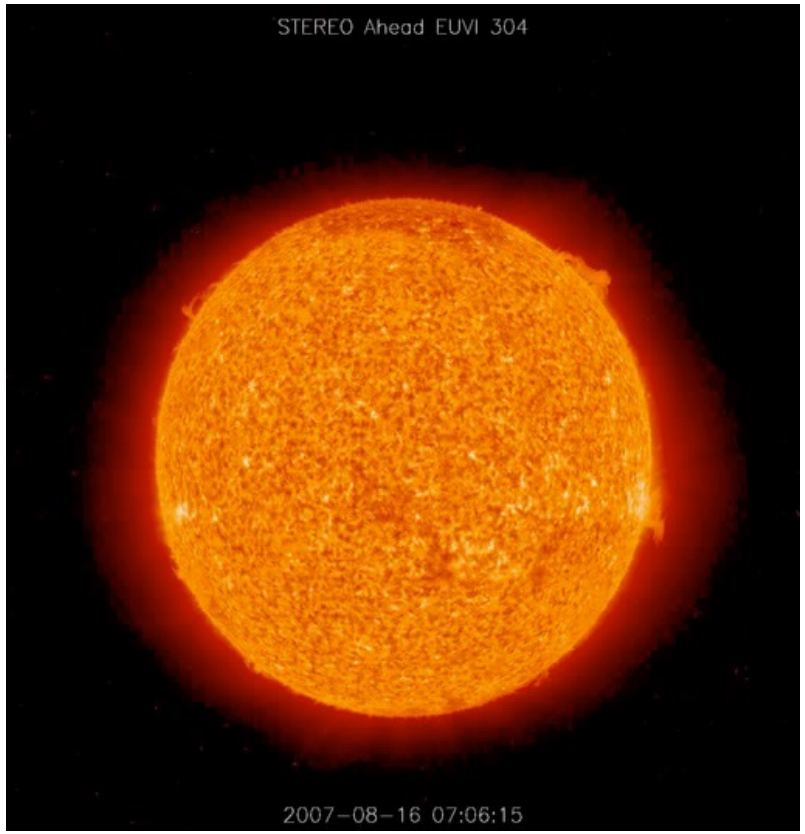
Need to know the:

- Amount energy that comes from the sun
- Total received energy for various satellite sensors
- Concentration of atmospheric gases that absorb and scatter light (H2O, O3, CO2, etc.)
- Amount, thickness, and type of clouds and aerosols that reflect, absorb and scatter light
- Reflective nature of the surface (i.e., albedo)

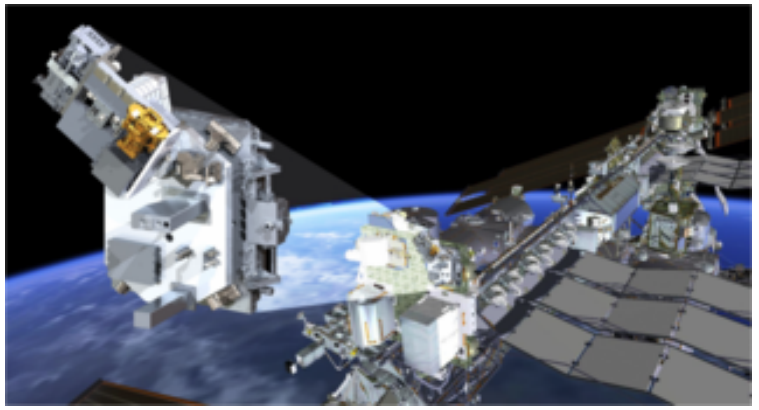


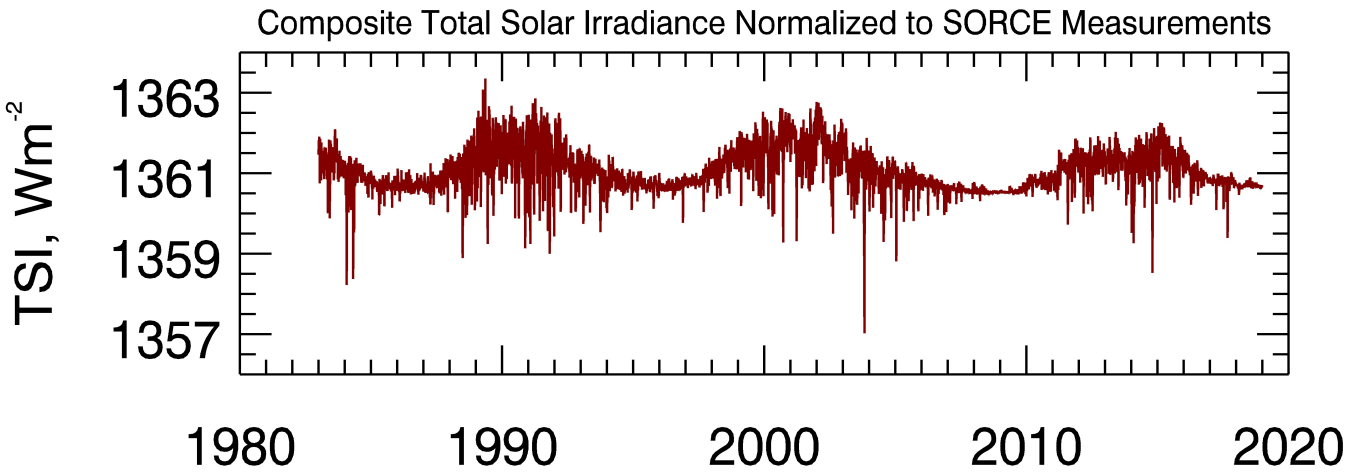
Estimating solar irradiance at the surface starts at the top!

First, measure the energy from the Sun received at the Top Of Atmosphere (TOA) Total Solar Irradiance (TSI).



NASA's SORCE Mission is now replaced by TSIS-1 on board the ISS.



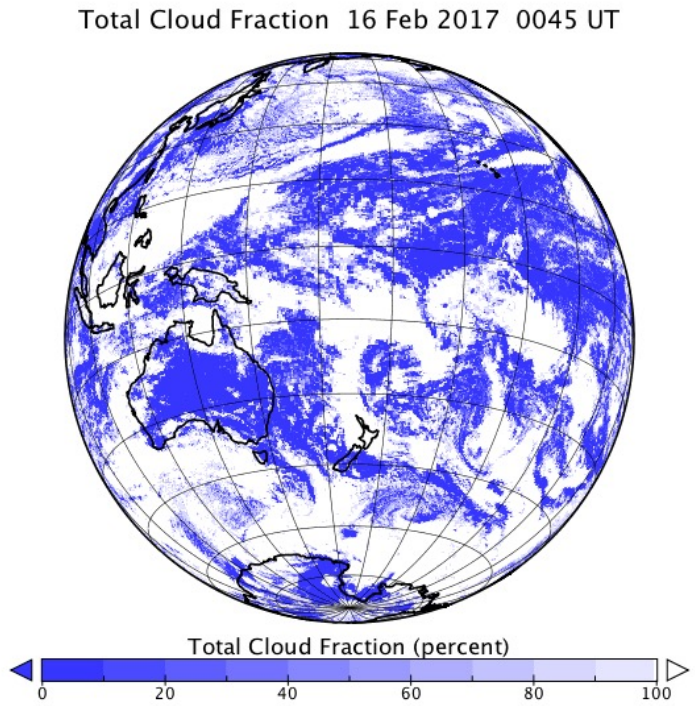


SORCE = SOlar Radiation Climate and Experiment; TSIS = Total and Spectral Solar Irradiance Sensor; ISS = International Space Station

GEWEX Surface Radiation Budget Project (SRB): Start with Clouds

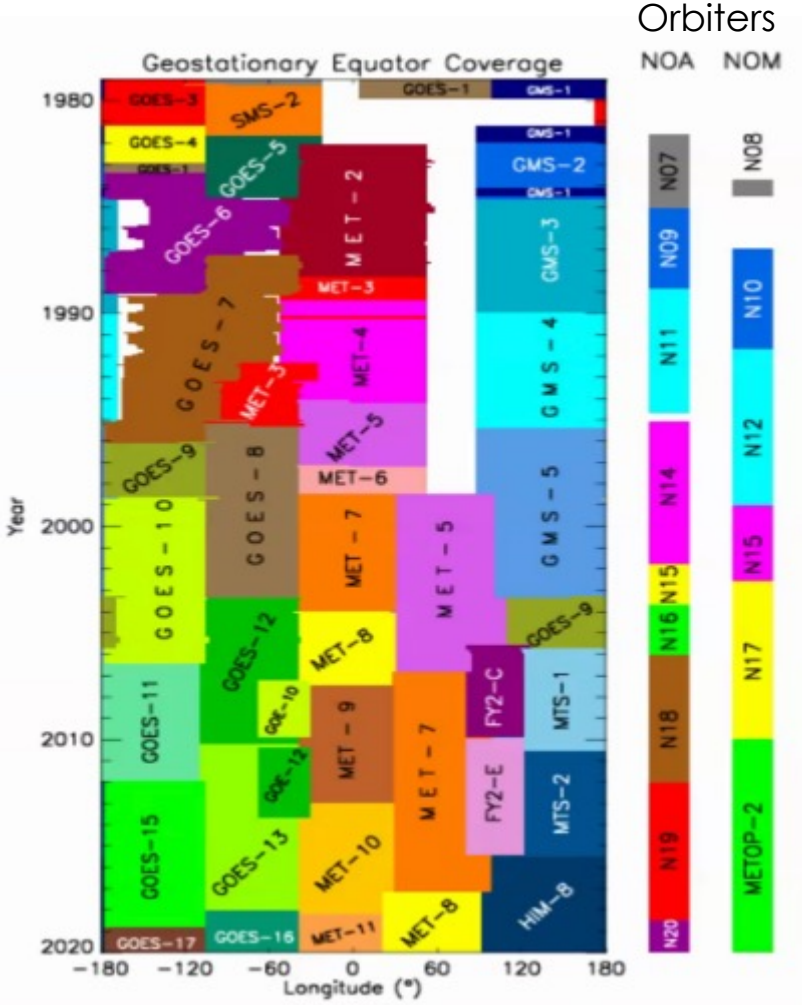
Obtain 3-hourly Global Cloud Properties from World's GEO and LEO Imagers

- International Satellite Cloud Climatology Project (ISCCP)



(A global cloud composite example, complements of LaRC SatCORPS for DSCOVR Satellite Mission)

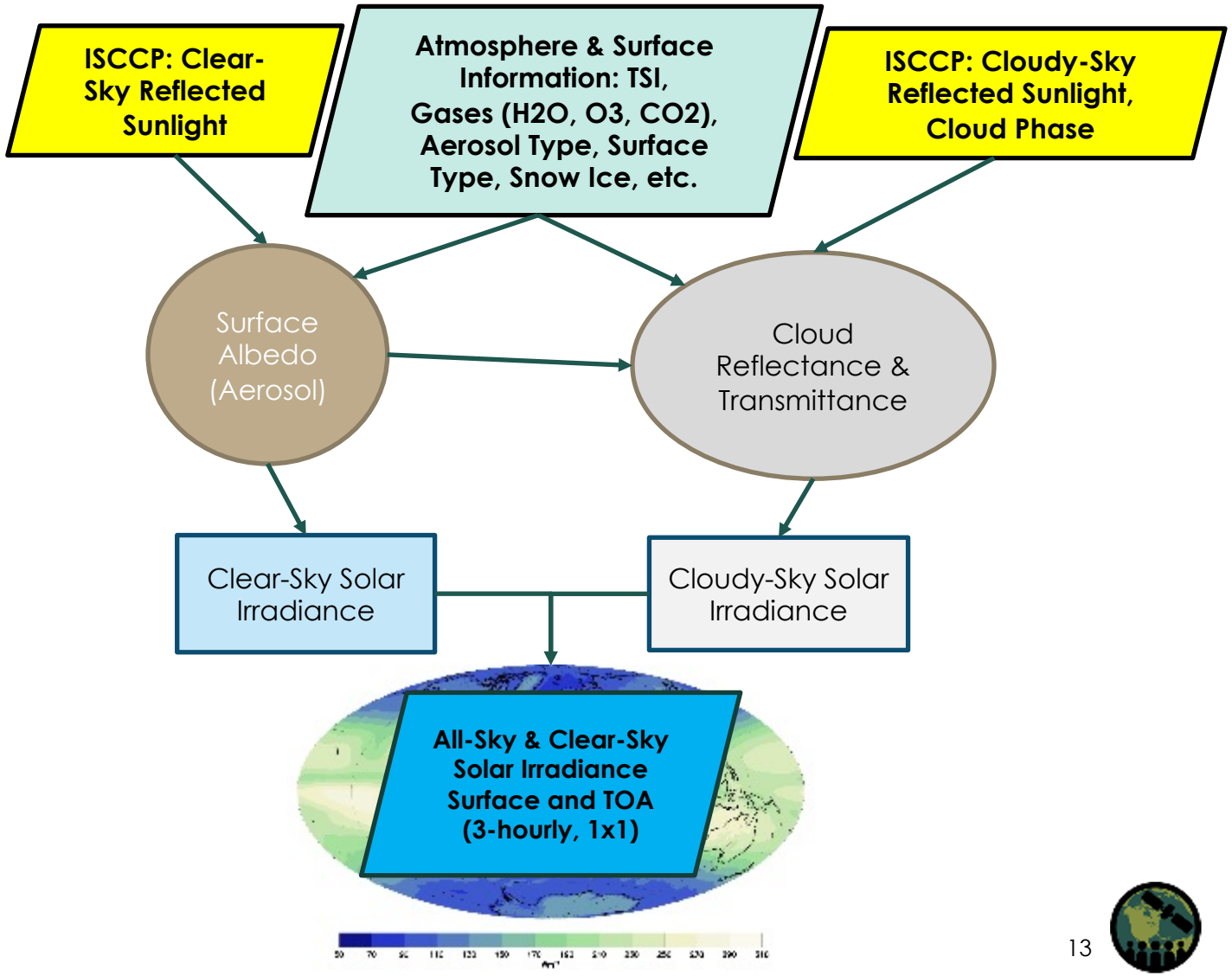
- Multi-satellite imager data cross-calibrated together from both geosynchronous (GEO) and low earth orbit (LEO)
- Satellite visible reflectance/thermal infrared emission, cloud and surface reflectance information output
- Processed globally every 3 hours from July 1984



Courtesy NOAA NCEI (K. Knapp)

GEWEX SRB: Compute the Surface Solar Irradiance

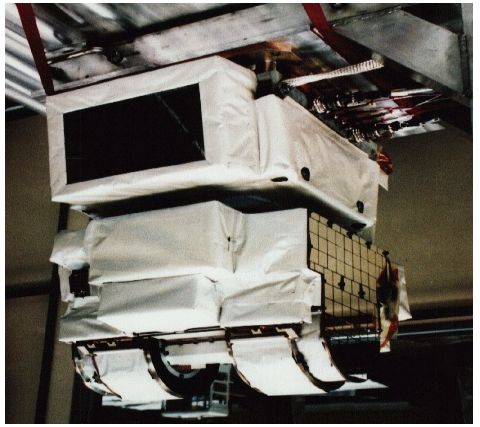
- ISCCP satellite products provide measured reflected sunlight for clear and cloudy skies: cloud detection and phase.
- Other ancillary information including TSI, gases, aerosols, surface types, etc. is input.
- The GEWEX shortwave (SW) model uses an iterative technique to infer the clear and cloudy sky solar irradiance.
  - Estimates albedo from clear-sky using aerosol information
  - Estimates cloud reflectance and transmission of sunlight
  - Computes fluxes given time and location

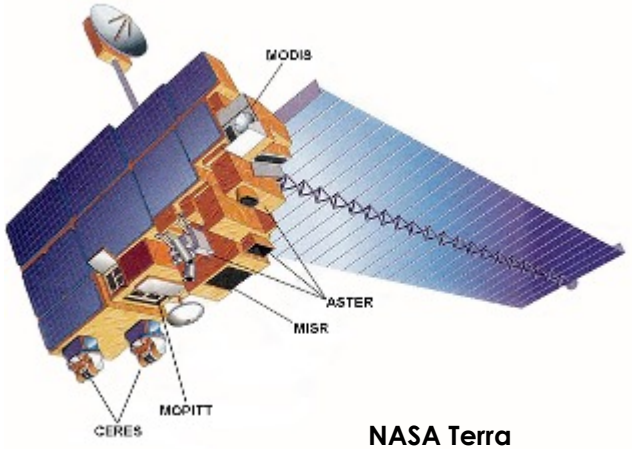


CERES Top-of-Atmosphere Measurements

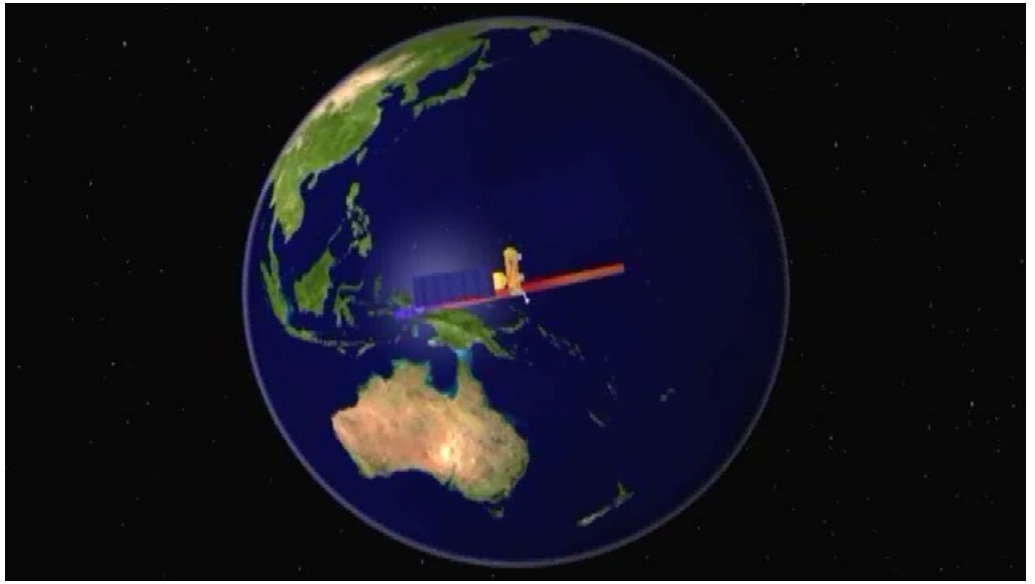
Clouds and Earth's Radiant Energy System (CERES) Starting in 2000

- 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
  - **Much higher accuracy and stability**
- CERES flies on satellites with imagers used to produce cloud properties (like ISCCP H) but has far better resolution and more spectral channels.
  - Terra (AM overpass): MODIS*
  - Aqua (PM overpass): MODIS
  - NPP (PM overpass): VIIRS**
  - NOAA-20 (PM overpass): VIIRS





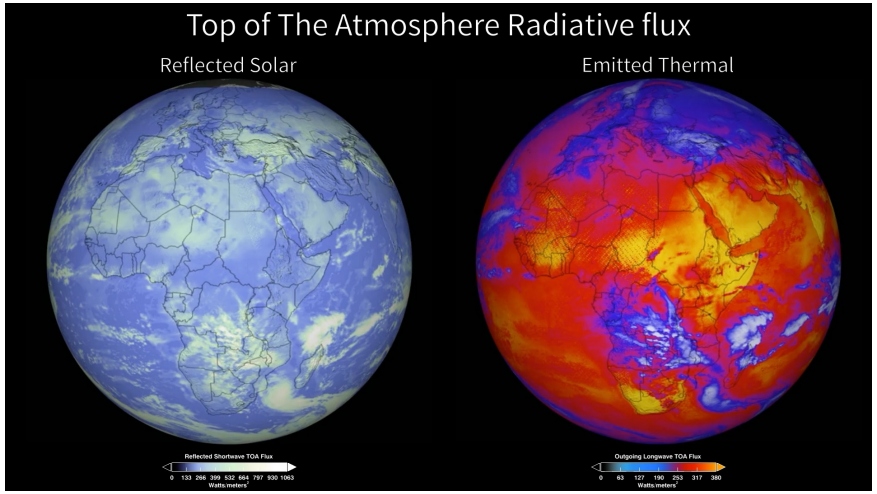
NASA Terra



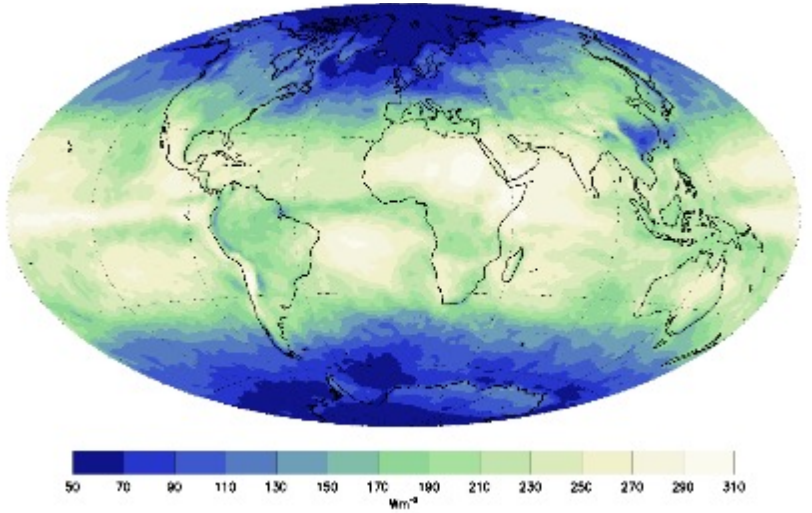
*MODIS = MODerate resolution Imaging Spectrometer
**VIIRS = Visible Infrared Imaging Spectrometer

CERES Surface Solar Irradiance: SYN1Deg Data Products

- Computed fluxes from CERES SYN1Deg (synoptic 1°x1°) are produced using a radiative transfer model with MODIS and geosynchronous satellite-derived cloud properties.
- SYN1Deg provides hourly surface solar irradiance from March 2000 to within a few months of present.
- SYN1Deg 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

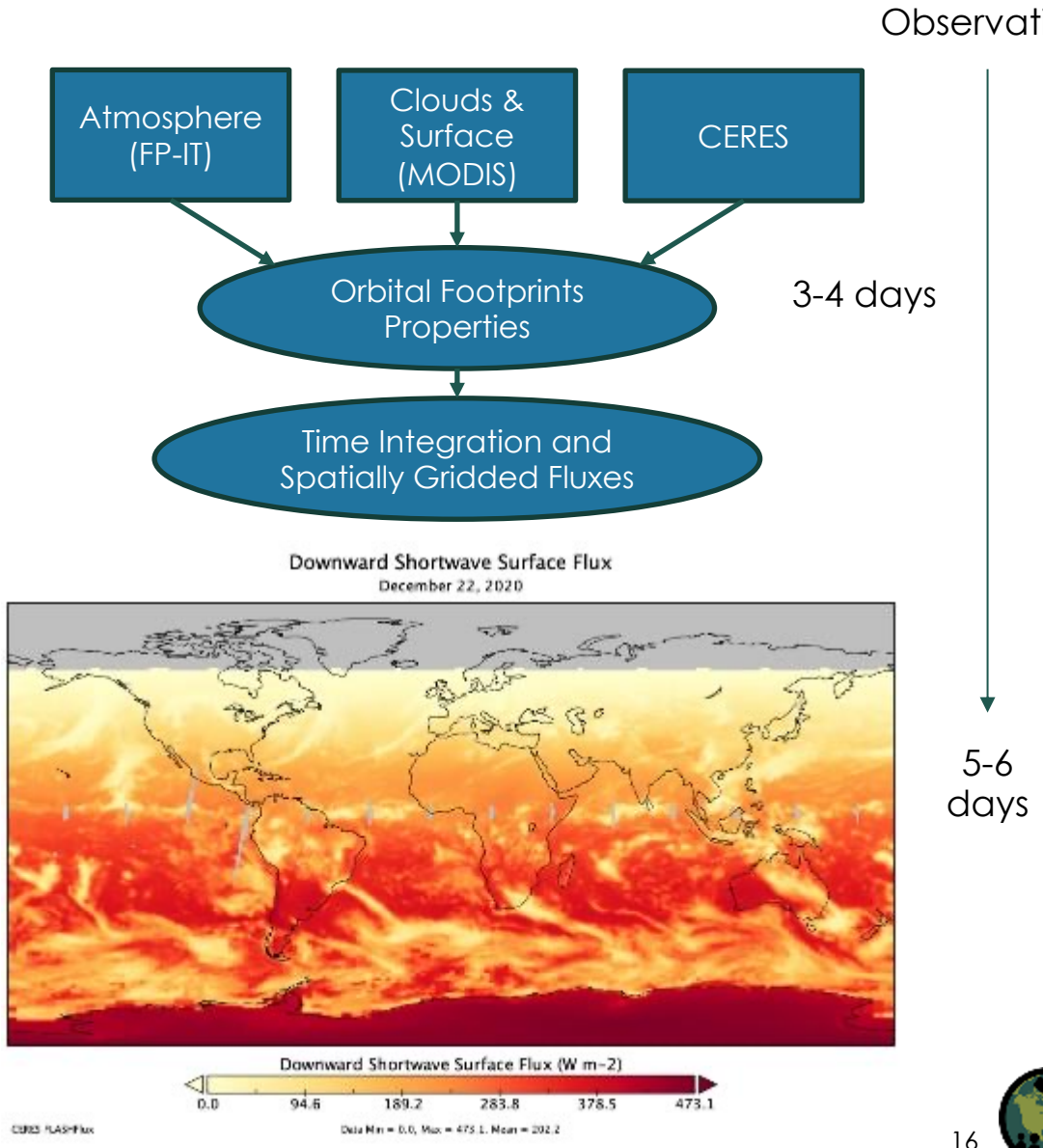


CERES SYN1Deg Surface Solar Irradiance Average



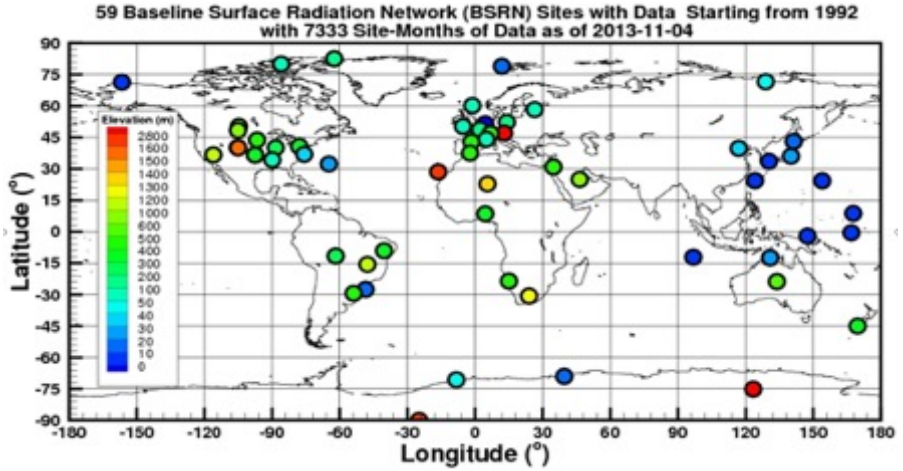
CERES Near-Real Time: FLASHFlux Data Products

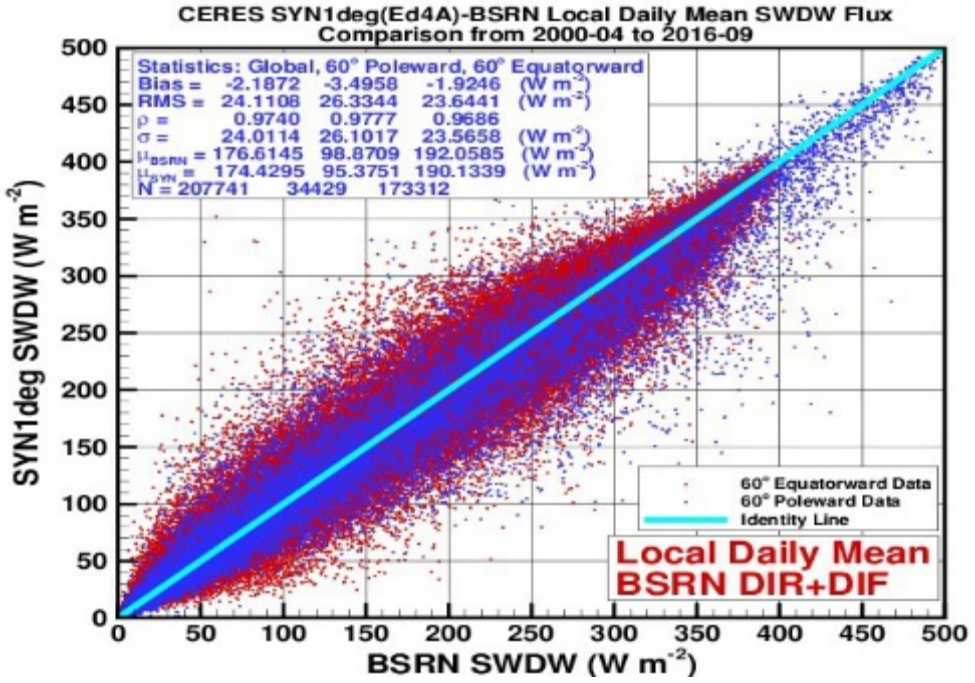
- Due to the needs of POWER data users for the most up-to-date solar irradiance data available, a second CERES Product, FLASHFlux, is utilized.
  - FLASHFlux uses the same inputs as SYN1deg but faster with a **target latency of 7 days.**
  - Data product quality is assessed independently for each source.
  - Day-to-day variability is sufficiently consistent for applications.
  - For the Beta, FLASHFlux data are overwritten with climate quality SYN1deg as soon as the data are available.



How do we determine solar irradiance data quality?

- Solar irradiance data quality can be evaluated through:
  - Validation by comparison to surface measurements from networks like BSRN, ARM, and GEBA.
  - Ensemble and time averaged statistics are calculated.
  - Comparisons to other datasets such as CERES compared to SRB and/or to other independent data sets.
- See "Methodology Documentation" pages for more information and statistics

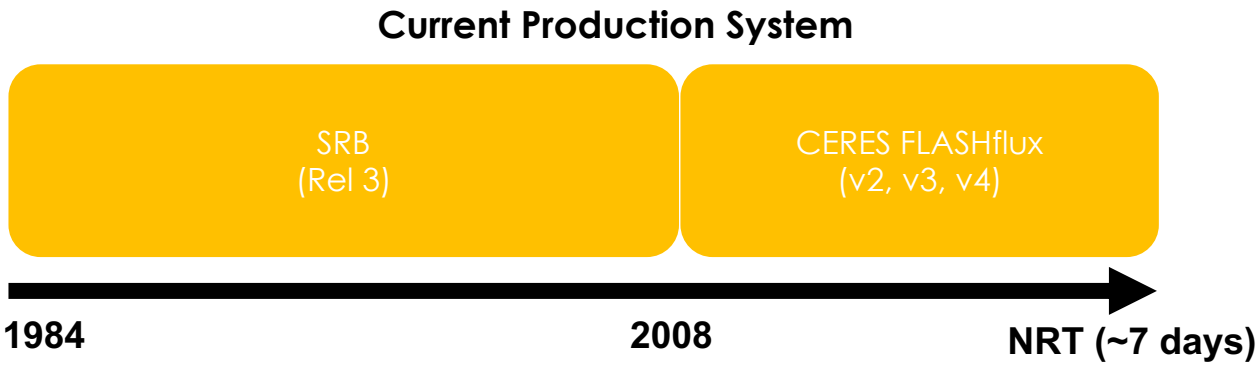




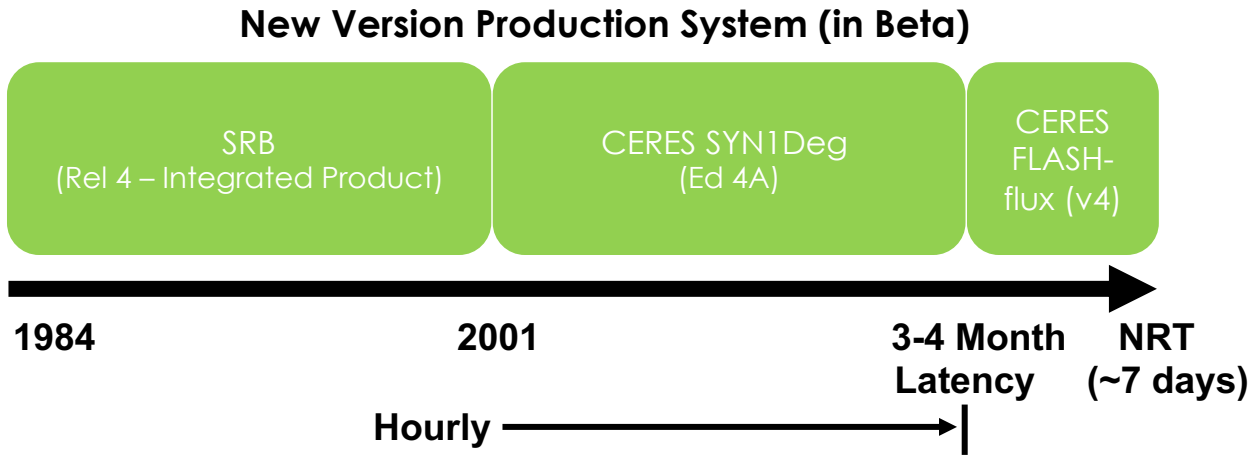
https://power.larc.nasa.gov/docs/methodology/solar/

Time Span of POWER Solar Data Products

- **Current Version:**
  - Daily solar data products from 1984 provided through 7 days of real-time
  - SRB Rel 3 to CERES FLASHFlux (v4A)
  - MERRA-2 to FP-IT

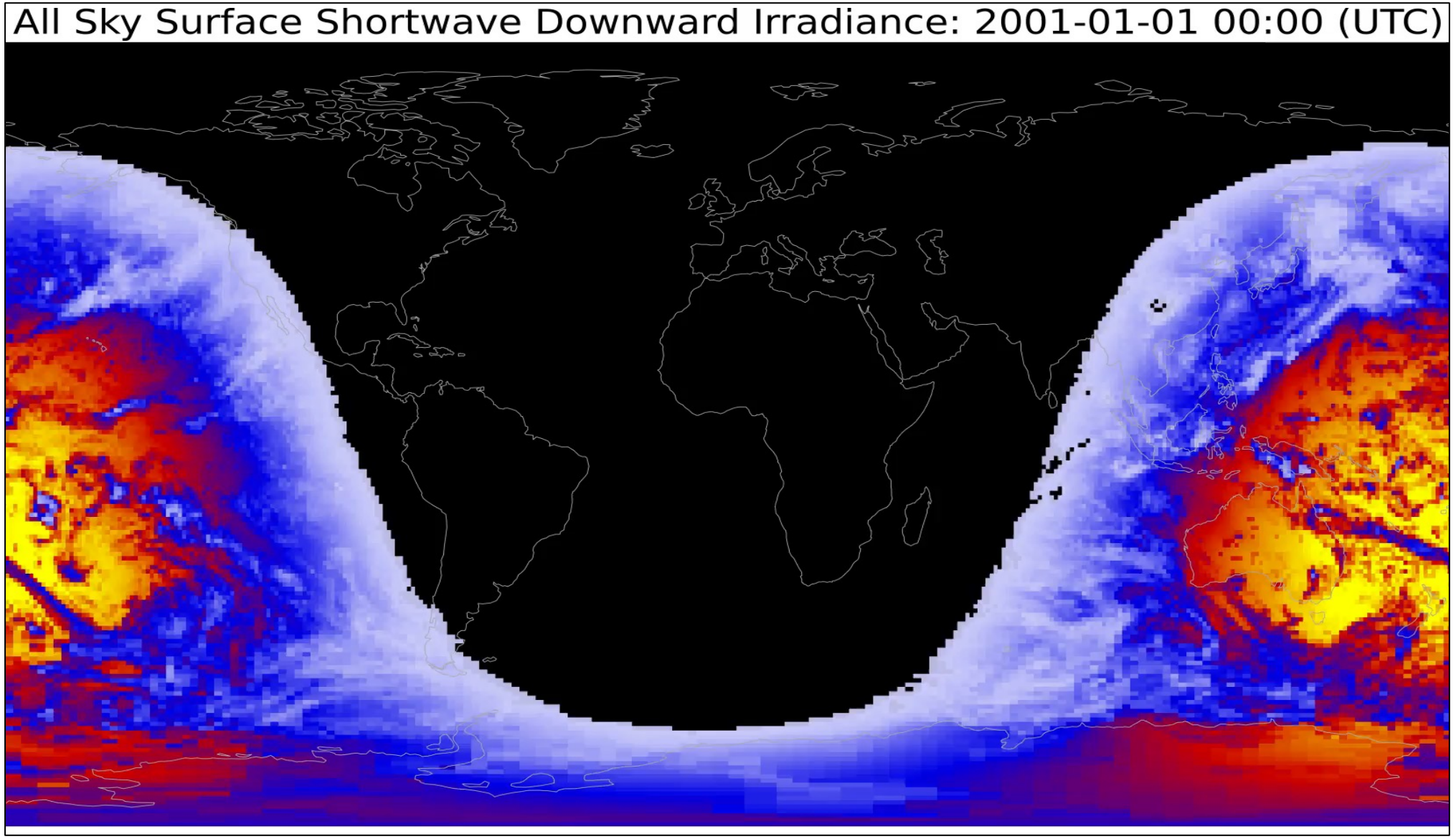


- **New Version Production System:**
  - Daily solar data products from 1984 provided through 7 days of real-time
  - SRB to CERES SYN1Deg, to FLASHFlux
  - Hourly from 2001 through 3-4 months of observation
  - MERRA-2 to FP-IT



Interpret long time series with caution due to concatenation of data products.

Daily Solar Irradiance – Hourly Video

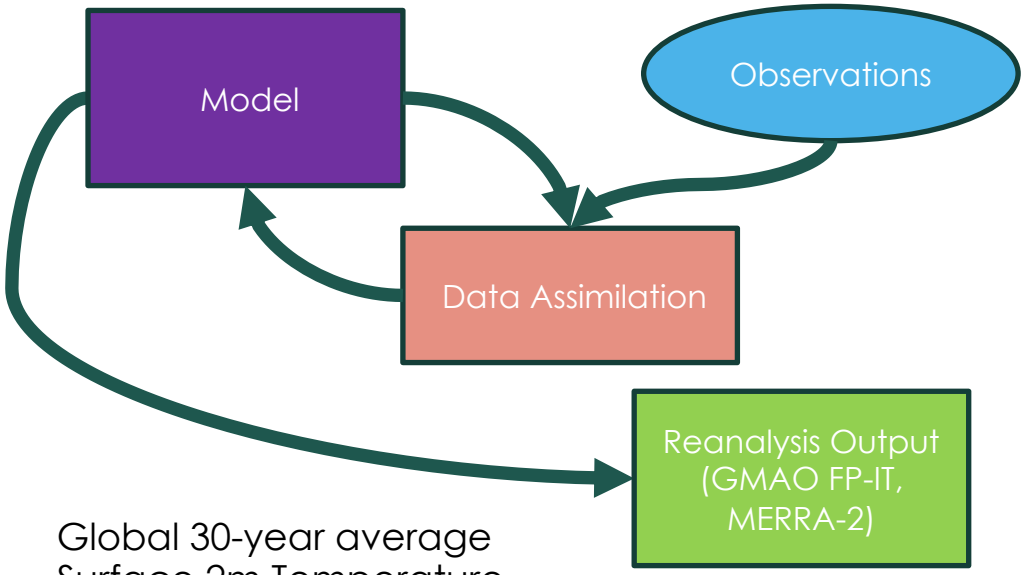


Where can we obtain surface meteorological parameters?

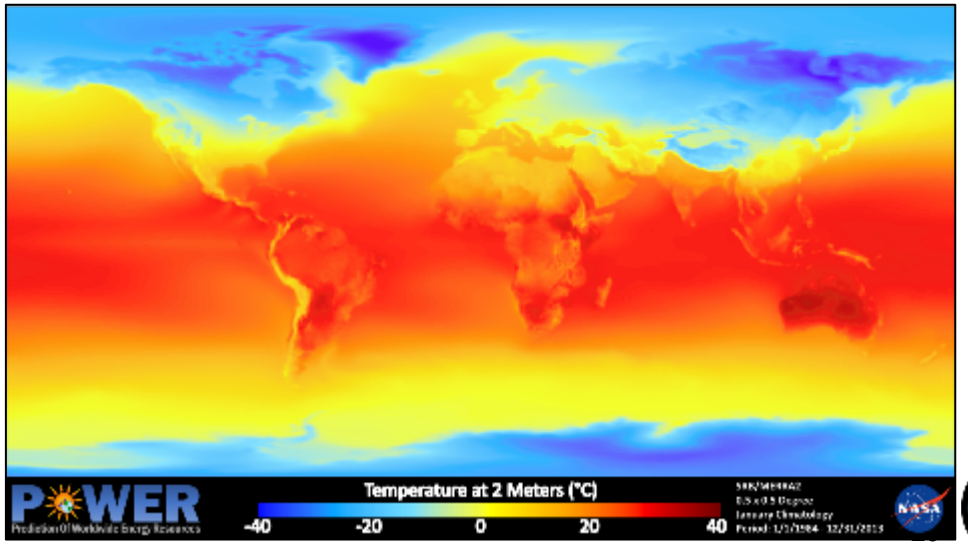
NASA's Global Modeling and Assimilation Office (GMAO) Data Products

What is an atmospheric data assimilation?

- Global atmospheric models run iteratively.
  - Model 6hr forecasts are adjusted within thresholds to observations
  - Model forecasts rerun to produce products
- GMAO produces:
  - Near real-time (FP-IT; 2 days)
  - Long-term MERRA-2 (Modern Era Retrospective analysis for Research and Applications)
- MERRA-2 has assimilated 50 Billion observations over 40 years.



Global 30-year average Surface 2m Temperature



What sorts of observations are assimilated?

- Surface measurements including:
  - Weather Stations and Buoys, Ships
- Airborne on radiosondes and commercial aircraft
- Satellites (large variety):
  - Spectral imagers
  - Microwave instruments
  - Atmospheric sounders
  - GPS occultation

https://svs.gsfc.nasa.gov/search/?search=mccarty

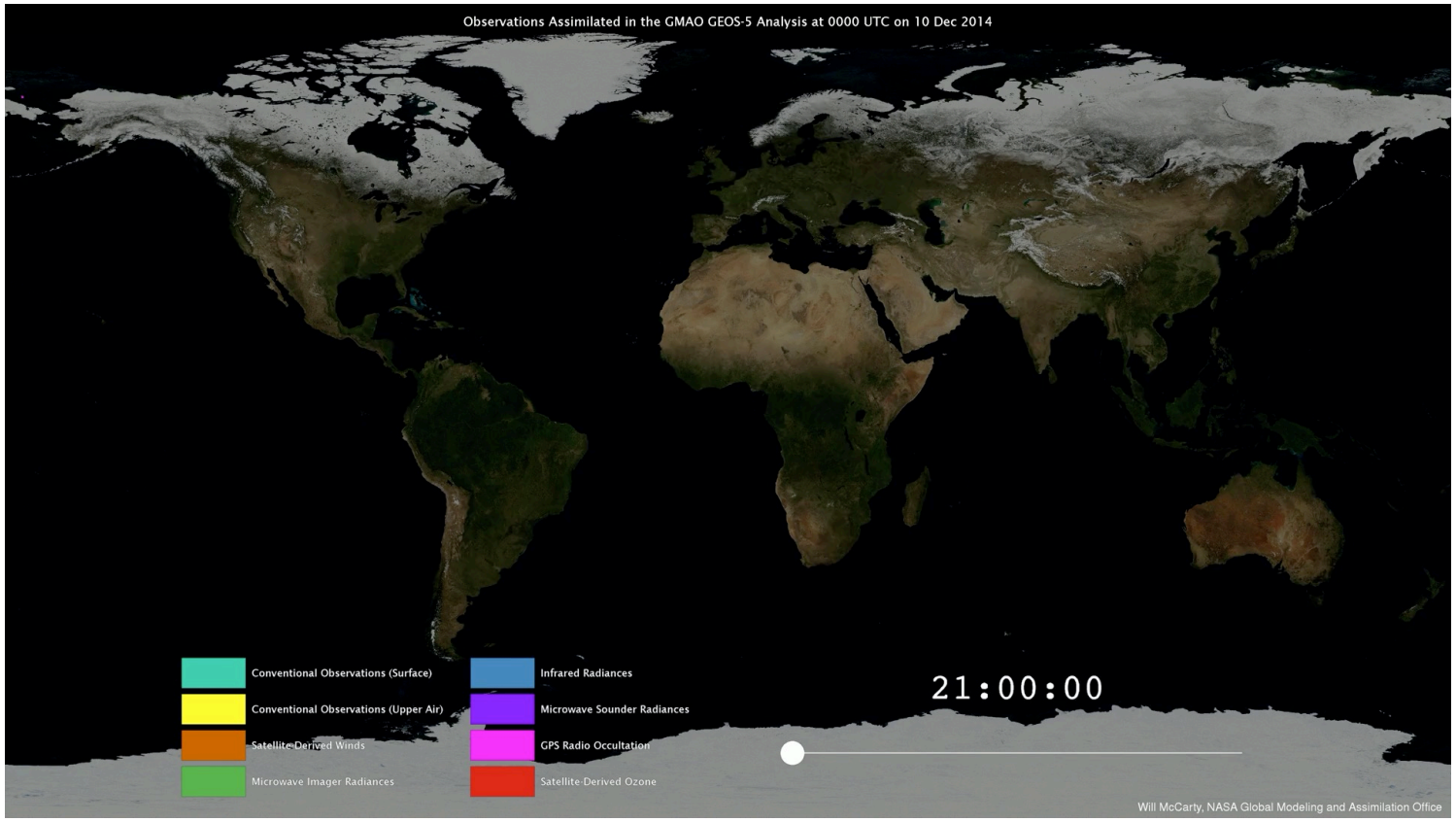


Photo Credit: NOAA PMEL

Photo Credit: wiki commons by Famartin

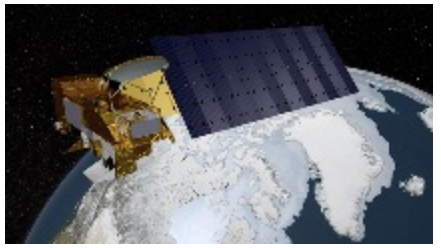
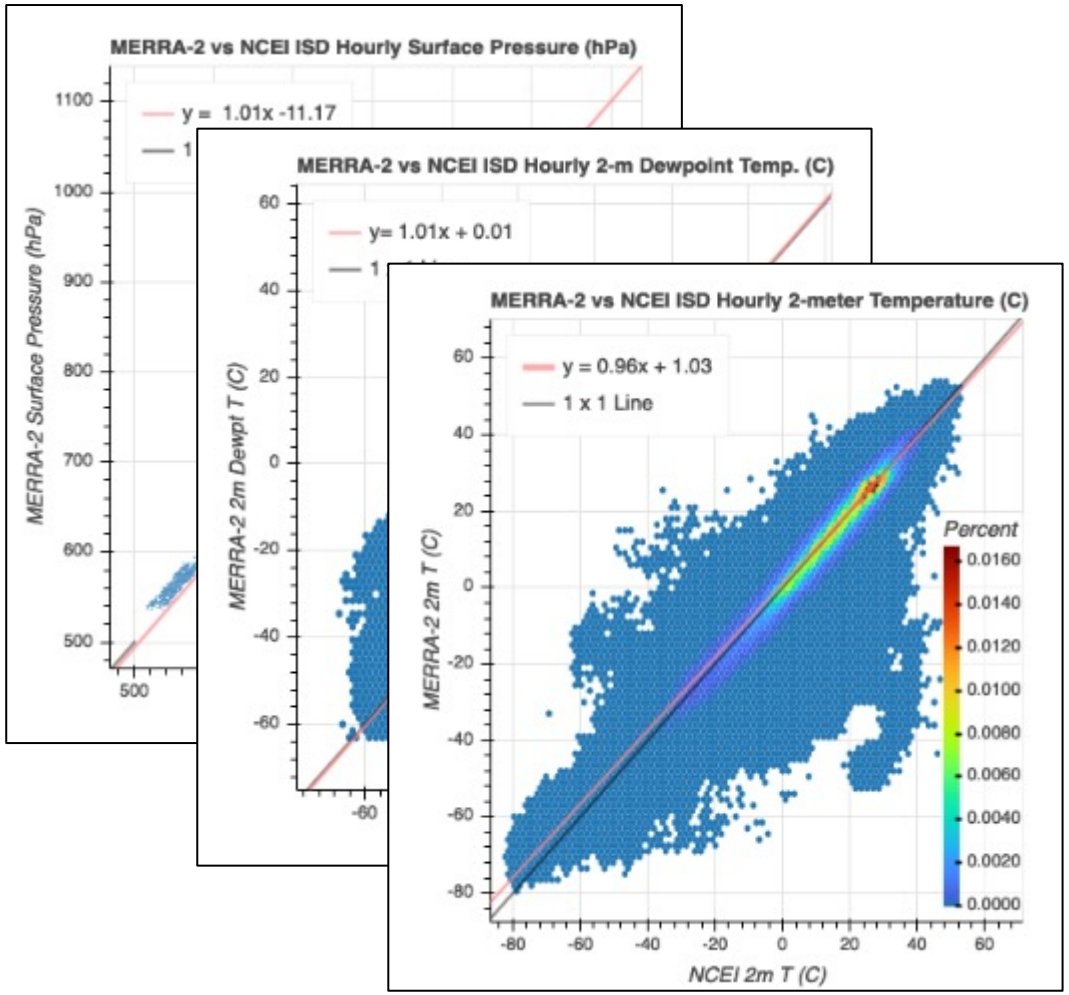


Photo Credit: NASA Aqua

How do we determine MERRA-2 data quality?

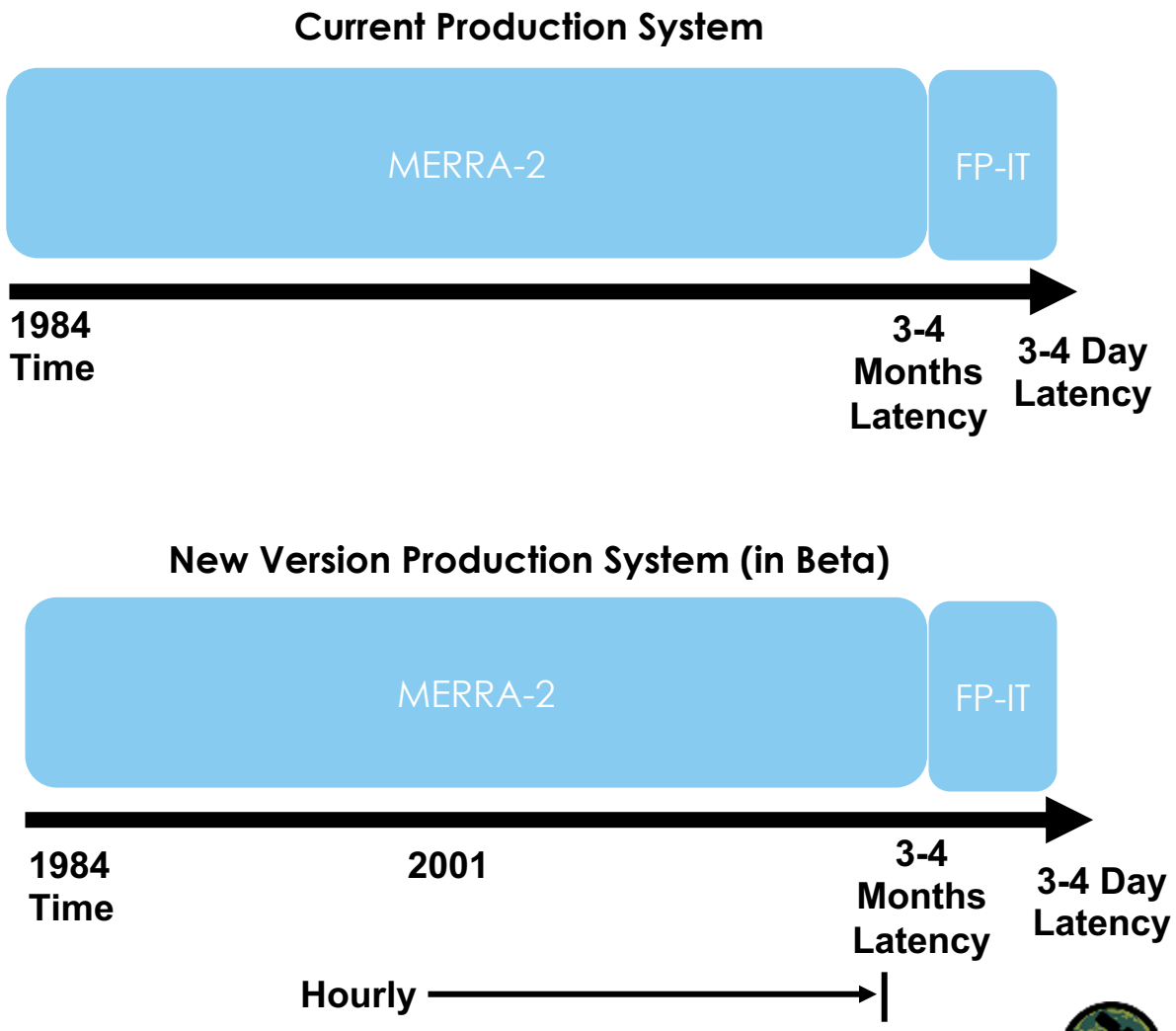
- The POWER Project conducts additional parameter data validation for basic parameters with the National Oceanic and Atmospheric Administration (NOAA) National Center for Environmental Information (NCEI) surface measurements:
  - Global Summary of the Day (GSOD) for daily validation
  - Integrated Surface Database (ISD) for hourly validation
- Producing histograms and scatterplots conducted by month and surface type produced in 4-year blocks and both aggregated and site-specific static reports/histograms



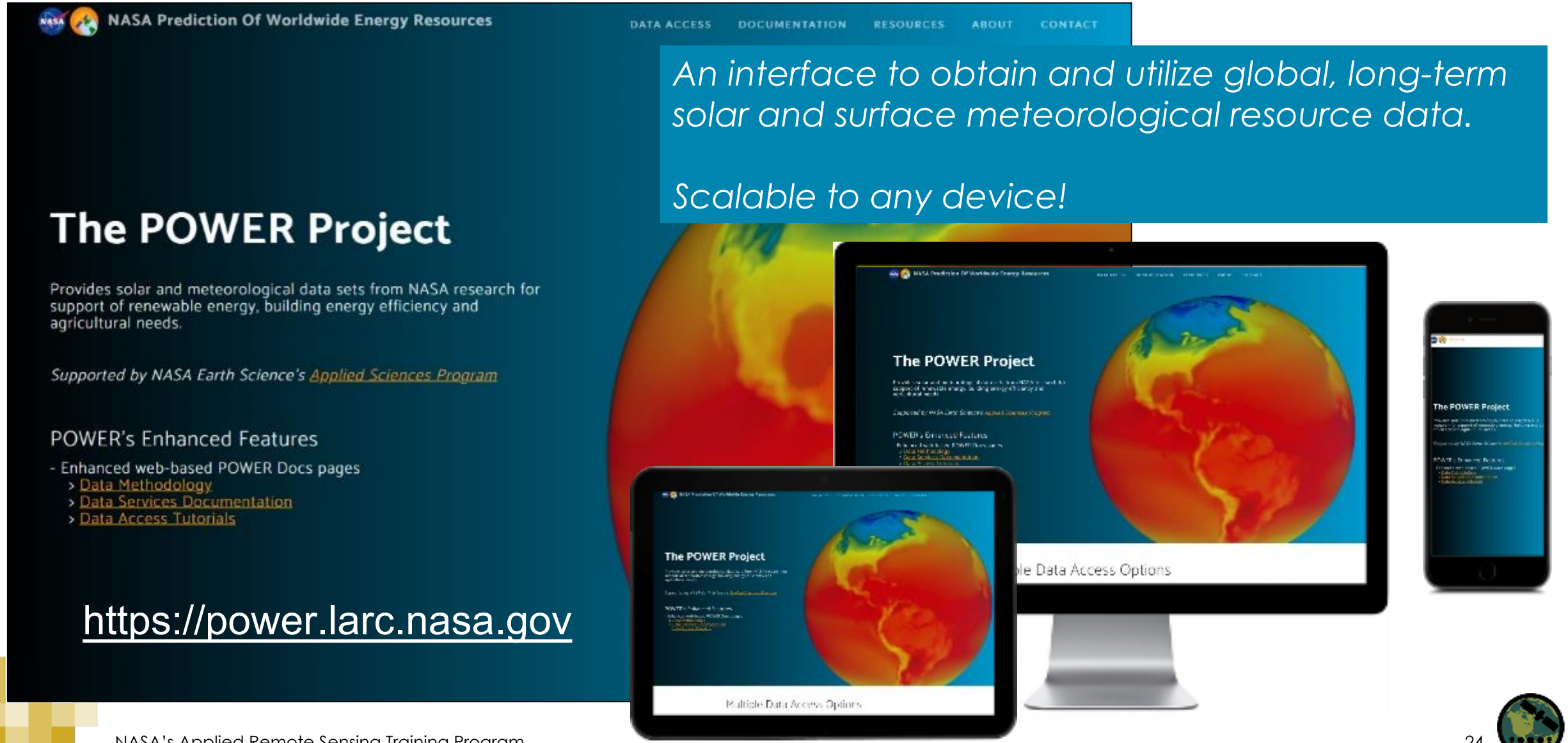
https://power.larc.nasa.gov/docs/methodology/meteorology/

Time Span of POWER Surface Meteorological Data Products

- **Current Production System:**
  - Meteorological products from MERRA-2 begin Jan 1984 (with solar) to 3-4 months of real-time
  - Near real-time is from a separate assimilation called FP-IT (Forward Processing-Instrument Team)
    - Subset of the parameters for optimization
    - No precipitation adjustments implemented like MERRA-2
    - Available via POWER at 3-4 days latency
- **New Version Production System (Now Beta):**
  - Same as above except:
    - Hourly from Jan 2001 through Long-Term data replaces FP-IT with MERRA-2
    - FP-IT to be replaced by new version within the next year; MERRA-2 within 3-4 years



Introduction POWER Web Services Portal



POWER Data Access Methods

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:

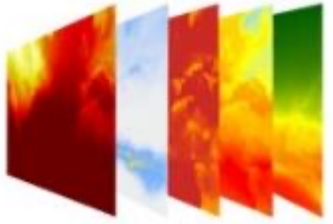
APIs

API: *The RESTful Application Programming Interfaces (API) through a single endpoint (i.e., formatted URL string); delivery directly though user browser and/or application.*

Data Access Viewer

Data Access Viewer (DAV): *The DAV provides a web map with a simple user interface via widgets that allow users to select community specific parameters, units, time periods, and the output formats (invokes the API).*

Geospatial Services

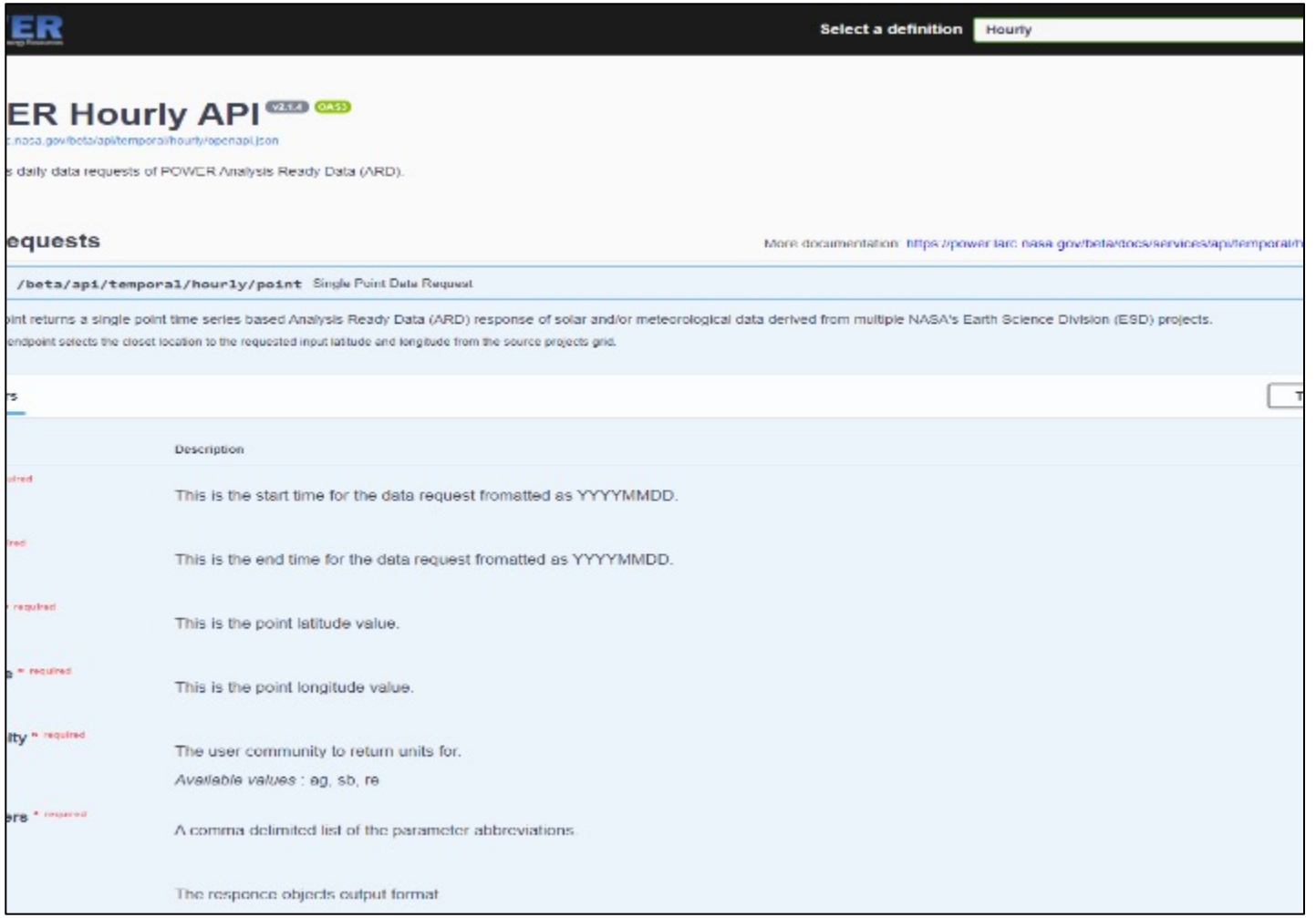


ArcGIS: *The RESTful Esri® ArcGIS® Image and Feature Services that support geospatially-enabled data distribution for direct use in Geographic Information System (GIS) and related tools.*

What does the POWER Application Programming Interface (API) do?

The POWER API delivers Analysis Ready Data (ARD) for inputs to decision support tools, modeling and forecasting packages, and as inputs to scientific research by providing:

- Complete access to the entire database without any other services.
- Direct integration into external applications; users can submit a request and a response will be returned without leaving their application!
- User specified subsets converted into user community specific units and provides formats like ASCII, ICASA, CSV, GeoJSON, NetCDF, and more!



What is the POWER Application Programming Interface (API)?

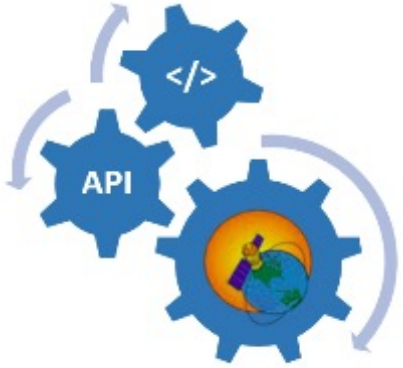
Example Temporal API Requests

Hourly Point API Request URL

Daily Point API Request URL

Monthly Point API Request URL

Climatology Point API Request URL

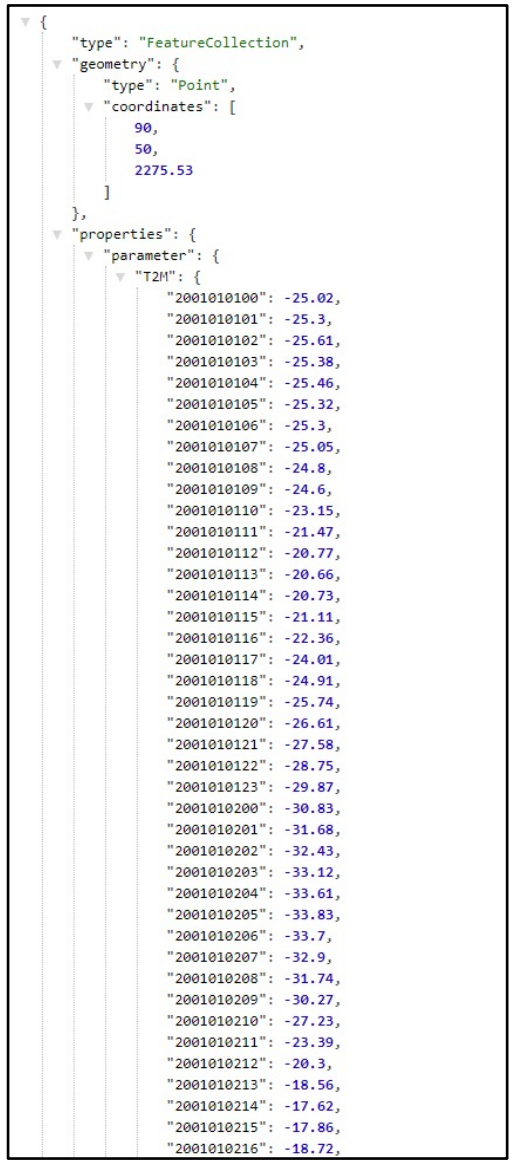


Example for Daily API

Uniform Resource Locator (URL):
https://power.larc.nasa.gov/beta/api/temporal/daily/point

Uniform Resource Identifier (URI):
?start=20010101&end=20011231&latitude=50&longitude=50&community=sb&parameters= T2M,ALLSKY_SFC_SW_DWN

https://power.larc.nasa.gov/beta/api/temporal/daily/point?start=20010101&end=20011231&latitude=50&longitude=50&community=sb&parameters=T2M,ALLSKY_SFC_SW_DWN



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{
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        "2001010214": -17.62,
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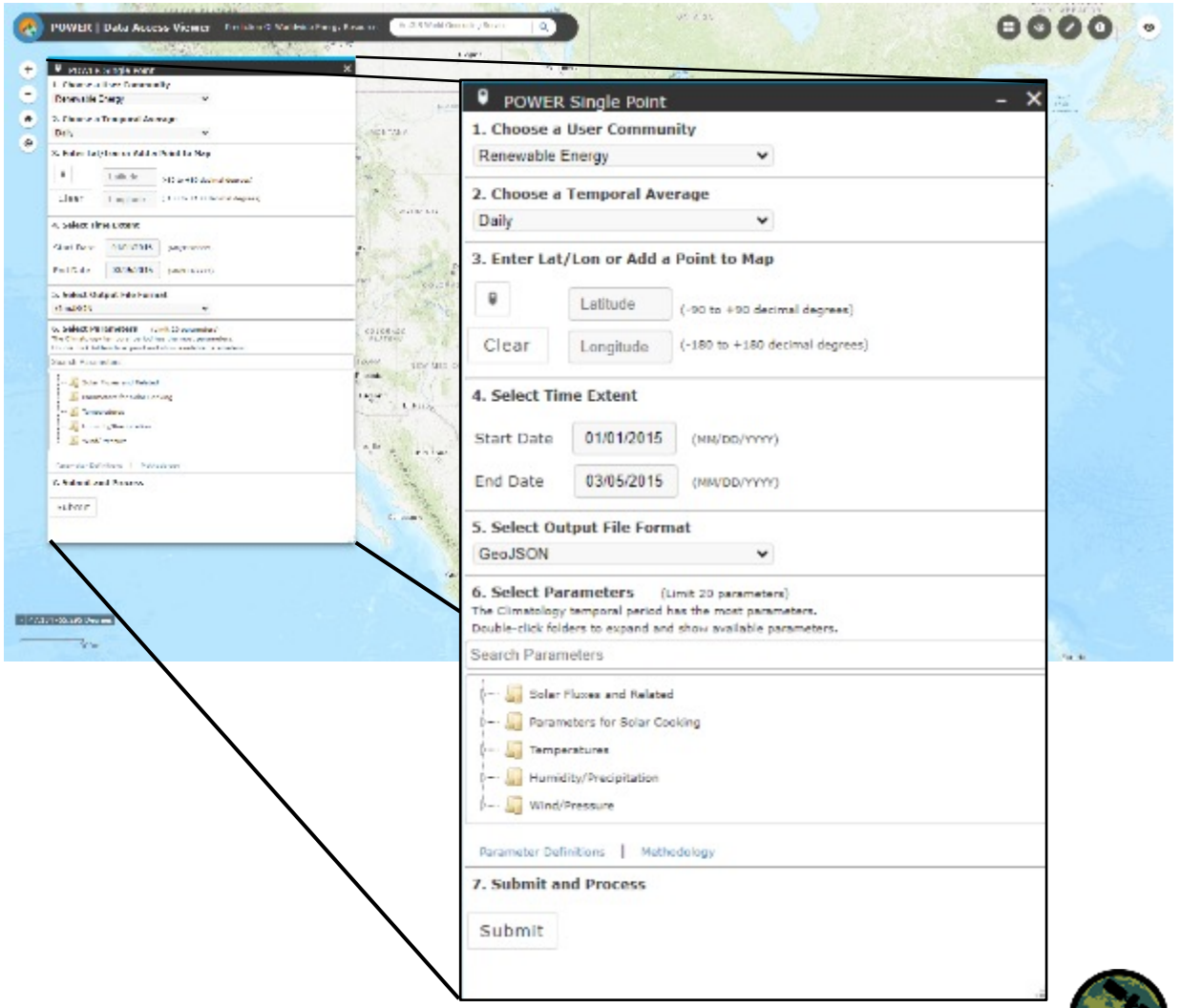
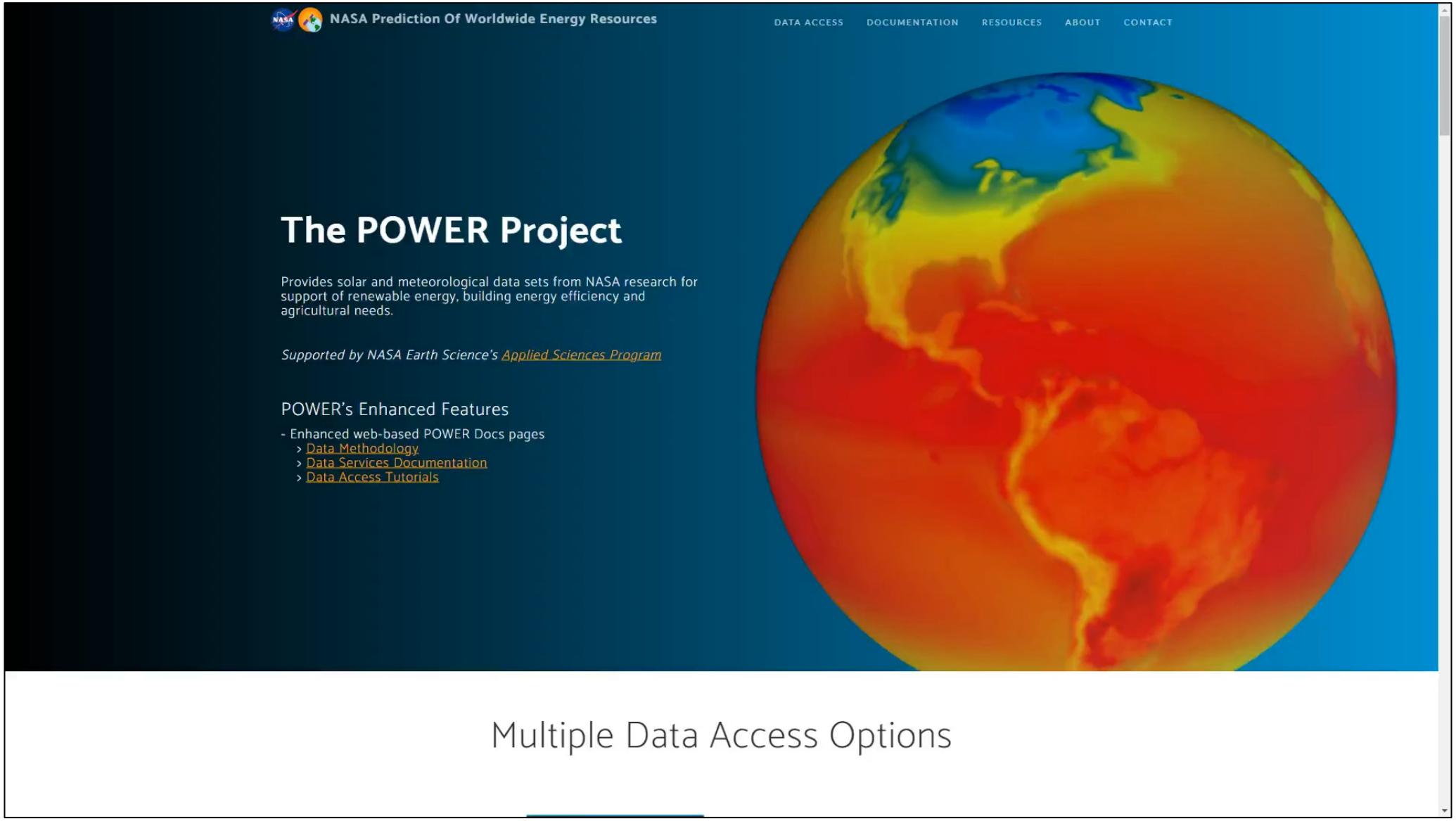
        "2001010216": -18.72,
```

What is the POWER Data Access Viewer (DAV)?

- Provides a front-end web map with a simple user interface via integrated widgets that is responsive and built for mobile and desktop use
- Allows users to select community specific parameters, units, time periods, and the output formats to efficiently retrieve data from the Application Programing Interface (API)
- Enables users to follow a set of questions (without programming knowledge), to create the API request URL and download the requested data
- Displays global ArcGIS Image and Feature Services of data parameters and provides simple graphing capabilities



How do you use the POWER Data Access Viewer (DAV)?

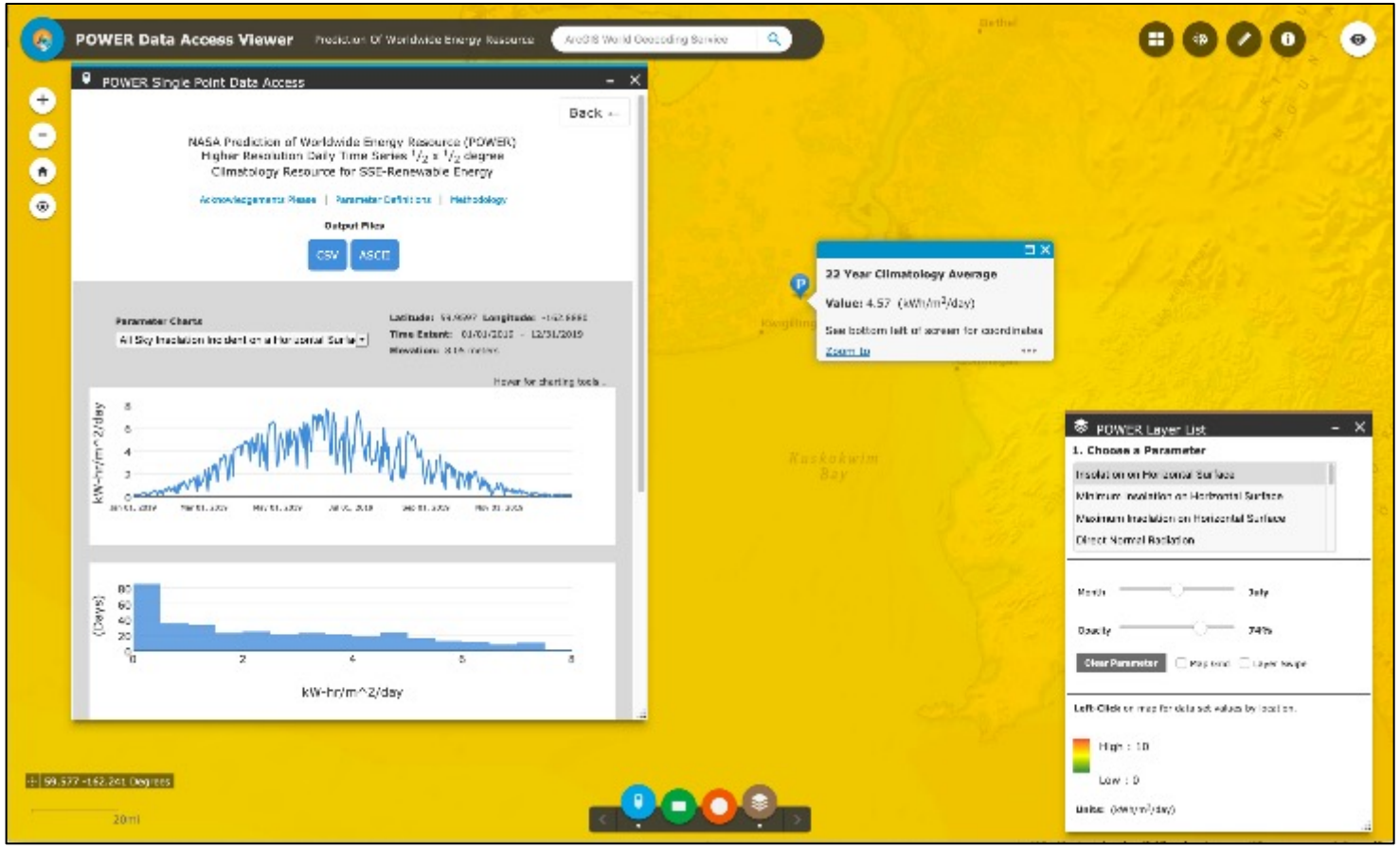


How do you use the POWER Data Access Viewer (DAV)?

Layer List Image Services:

- Climatological average maps services for 20+ key variables
- Monthly and annual averages available
- Interactive values displayed for any location when clicked
- Integrated opacity control to view terrain below

Solar Irradiance for July in Kongiganak, Alaska, US



What GIS Services does POWER provide?

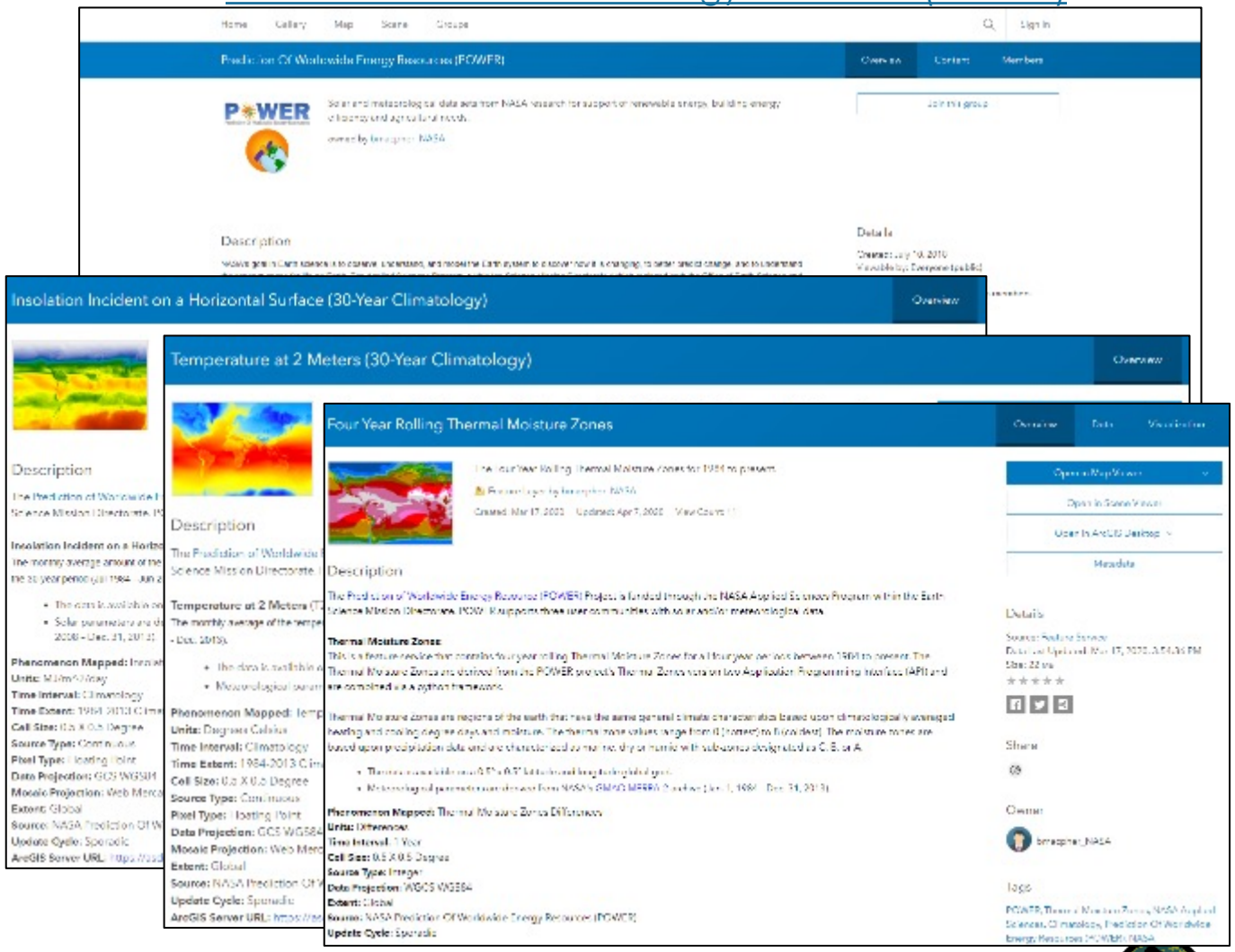
POWER provides Esri® ArcGIS Image and Feature Services that allow users to efficiently interact with the POWER data in Geographic Information System (GIS) applications and related tools.

- **Image Services:** Global climatology-based solar and meteorological parameters
- **Feature Services:** Global long-term ASHRAE® building climate thermal-moisture zones, 4-year rolling thermal zones, and period differences

Available on:

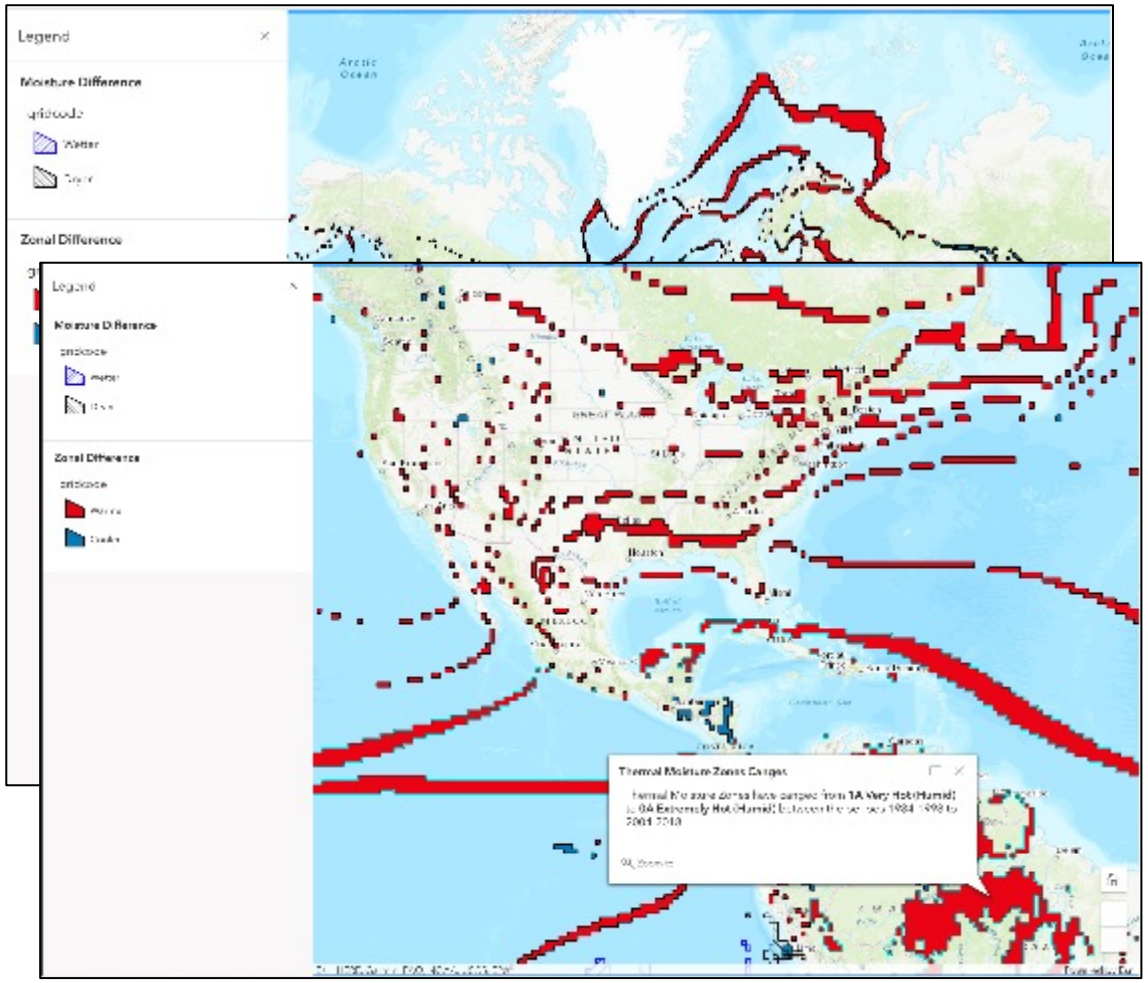
- NASA ArcGIS Online (AGOL)
- ASDC ArcGIS Online
- Esri Living Atlas

Prediction Of Worldwide Energy Resources (POWER)



What GIS services does POWER provide?

- The Web maps and StoryMaps® allow users to more efficiently explore, modify, and interact with the POWER Data without need for additional software
- Responsive and scalable; built for mobile and desktop use
- Examples:
  - Reviewing regional data quality by comparing to surface measurements
  - Long-term differences in ASHRAE® building climate zones

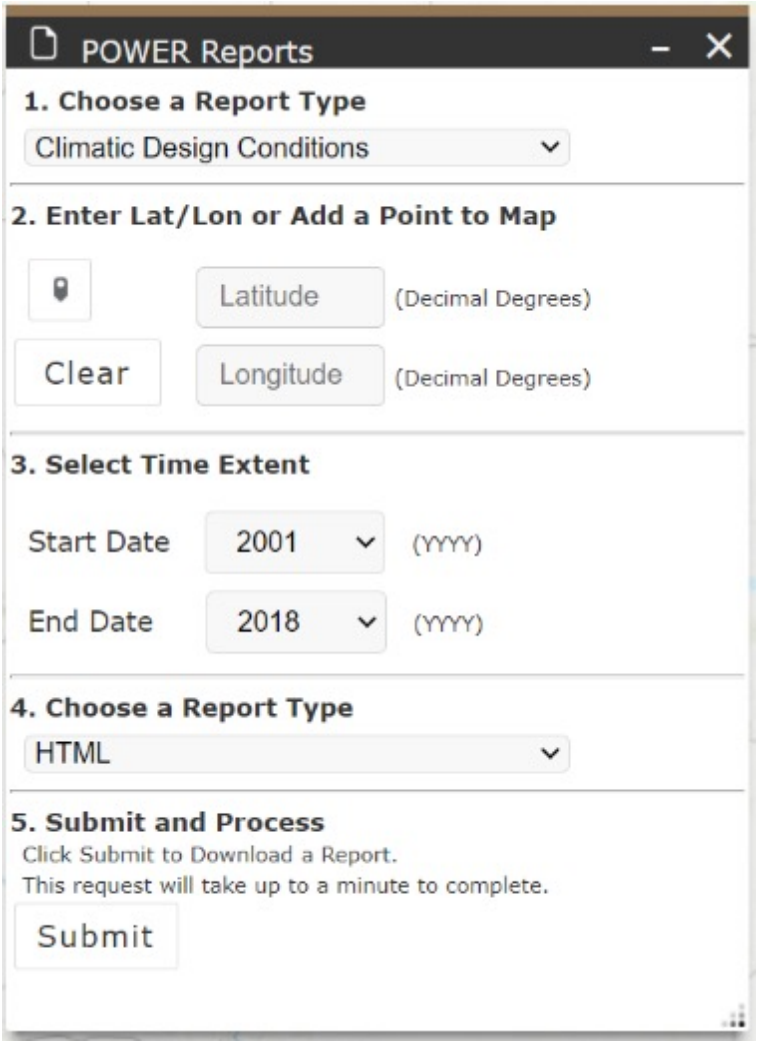


What are POWER's analytic data services?

New in power/beta …

POWER provides single location, user specified time period reports to assess long-term variability:

- **Anomaly Report**
  - Time series plots and climatological assessments
  - ASHRAE® building climate zone indicators change plots for climate monitoring
- **Building Climate Design Conditions Report**
  - Developed with ASHRAE® from the Design Condition report
- **Windrose Report**
  - Average wind speeds reported in tables classified according to NREL using wind energy thresholds



ASHRAE®: is a registered trademark of the American Society of Heating, Refrigerating and Air-Conditioning Engineers

Analytic Data Services – Report Outputs

Building Climatic Design Conditions

POWER Climatic Design Conditions (MERRA-2 and SRB/CERES)

Latitude: 29.6106 | Longitude: -82.2603 | Elevation: 28.3 | StdPres: 14.68 | Time Period: 2014 - 2019 | Note: 0.5 x 0.5 Degree Gridded Data

Annual Heating and Humidification Design Conditions

Coldest Month	Heating DB 99.6%	Heating DB 99%	Humidification DP/MCDB and HR 99.6% DP	HR	MCDB	Humidification DP/MCDB and HR 99% DP	HR	MCDB	Coldest month WS/MCDB 0.4% WS	MCDB	Coldest month WS/MCDB 1% WS	MCDB	MCWS/PCWD to 99.6% DB MCWS	PCWD
1	-0.2	1.8	-5.6	0.0		-3.2	0.0		2.7		2.7			

Annual Cooling, Dehumidification, and Enthalpy Design Conditions

Hottest Month	Hottest Month DB Range	Cooling DB/MCWB 0.4% DB	MCWB	1% DB	MCWB	2% DB	MCWB	Evaporation WB/MCDB 0.4% WB	MCDB	1% WB	MCDB	2% WB	MCDB	MCWS/PCWD to 0.4% DB MCWS	PCWD
7	12.5	35.8		34.7		33.6		28.4		28.1		27.8			

Dehumidification DP/MCDB and HR 0.4% DP	HR	MCDB	1% DP	HR	MCDB	2% DP	HR	MCDB	Enthalpy/MCDB 0.4% Enth	MCDB	1% Enth	MCDB	2% Enth	MCDB	Extreme Max WB
35.8	20.0		25.3	20.0		25.0	20.0								29.6

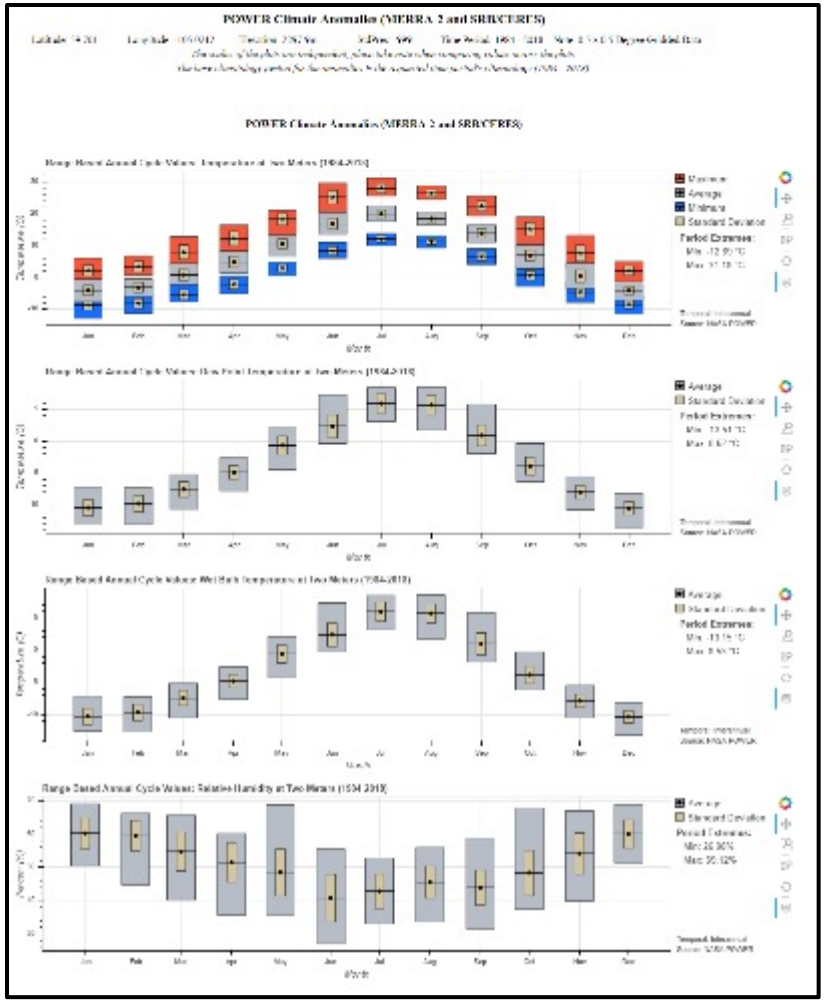
Extreme Annual Design Conditions

Extreme Annual WS 1%	2.5%	5%		Extreme Annual Temperature Mean Min	Mean Max	Standard deviation Min	Standard deviation Max	n-Year Return Period Values of Extreme Temperature n=5 years Min	n=5 years Max	n=10 years Min	n=10 years Max	n=20 years Min	n=20 years Max	n=50 years Min	n=50 years Max
6.0	5.2	4.5	DB	-3.6	37.4	1.8	1.6	-4.9	38.6	-6.0	39.6	-7.0	40.5	-8.3	41.7
			WB	-5.4	29.2	2.9	0.4	-7.5	29.5	-9.2	29.7	-10.8	29.9	-12.9	30.1

Monthly Climatic Design Conditions

		Annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperatures, Degree-Days and Degree-Hours	DBAvg	21.2	11.5	15.3	17.3	21.3	25.1	27.1	27.9	27.5	26.0	22.3	17.2	15.6
	DBStd	0.7	2.2	3.0	1.8	1.3	1.1	0.9	0.8	0.4	0.8	1.4	2.1	2.1
	HDD10.0	59	40	8	2	0	0	0	0	0	0	0	3	6
	HDD18.3	535	204	95	63	8	0	0	0	0	0	8	61	95
	CDD10.0	4302	100	168	240	350	475	524	563	555	495	397	235	199
	CDD18.3	1747	7	20	45	109	218	275	306	298	246	148	44	31
	CDH23.3													
	CDH26.7													
Wind	WSAvg	2.3	2.7	2.6	2.6	2.6	2.3	2.0	1.7	1.9	2.1	2.6	2.4	2.5
Precipitation	PrecAvg	811	53	44	45	41	45	86	77	145	173	38	44	31
	PrecMax	1383	125	94	146	99	108	202	156	268	394	92	101	80
	PrecMin	3	3	2	1	2	1	3	5	3	1	2	2	5
	PrecStd	637	48	39	53	41	40	76	68	123	155	37	46	27
Monthly Design Dry Bulb and Mean Coincident Wet Bulb Temperatures	0.4% DB		15.2	18.2	19.3	22.9	26.8	28.1	29.4	28.1	27.1	24.3	20.2	19.1
	0.4% MCWB		11.2	16.0	15.2	18.4	19.4	23.0	23.8	24.2	23.4	20.1	17.7	16.3
	2% DB		15.0	18.1	19.2	22.9	26.7	28.1	29.3	28.1	27.1	24.3	20.1	18.9
	2% MCWB		11.0	15.9	15.2	18.4	19.4	23.0	23.8	24.2	23.4	20.0	17.5	16.0
	5% DB		14.4	18.1	19.2	22.9	26.5	28.1	29.1	28.0	27.0	24.2	19.7	18.5
	5% MCWB		10.7	15.8	15.1	18.3	19.4	23.0	23.8	24.2	23.3	19.8	17.1	15.5
	10% DB		13.6	17.9	15.2	22.8	26.2	28.1	28.7	27.9	26.9	24.0	19.1	17.9
	10% MCWB		10.1	15.7	15.0	18.1	19.4	23.0	23.8	24.2	23.1	19.5	16.5	14.6
Monthly Design Wet Bulb and Mean Coincident Dry Bulb Temperatures	0.4% WB		11.2	16.0	15.2	18.4	19.4	23.0	23.8	24.2	23.4	20.1	17.7	16.3
	0.4% MCDB		15.2	18.2	19.3	22.9	24.1	26.5	27.9	27.7	27.1	24.3	20.2	19.1
	2% WB		11.0	15.9	15.2	18.3	19.3	23.0	23.8	24.2	23.4	20.0	17.4	16.0
	2% MCDB		15.0	18.1	19.3	22.8	24.1	26.5	27.9	27.7	27.1	24.1	20.1	18.9
	5% WB		10.7	15.8	15.1	18.0	19.2	23.0	23.8	24.2	23.3	19.8	17.0	15.5
	5% MCDB		14.4	18.1	19.2	22.6	24.1	26.5	27.9	27.7	27.0	23.8	19.7	18.5
	10% WB		10.1	15.6	14.9	17.5	19.0	22.9	23.8	24.2	23.1	19.4	16.2	14.6
	10% MCDB		13.6	18.0	19.2	22.4	24.1	26.5	27.8	27.6	26.9	23.3	19.1	17.9
Mean Daily Temperature Range	MDBR		11.5	11.8	12.5	12.3	12.1	9.5	9.0	8.4	8.4	10.2	11.6	10.7
	5% DB MCDBR													
	5% WB MCWBR													
	MCDBR													
	MCWBR													
Clear Sky Solar Irradiance	taub													
	taud													
	Ebn,noon													
	Edn,noon													
All-Sky Solar Radiation	RadAvg	3.2	3.94	5.02	5.97	6.45	5.84	5.43	5.38	4.79	4.48	3.53	2.95	
	RadStd	1.12	1.42	1.53	1.64	1.6	1.72	1.65	1.44	1.44	0.99	1.05	0.94	

Climate Variability and Anomalies Report



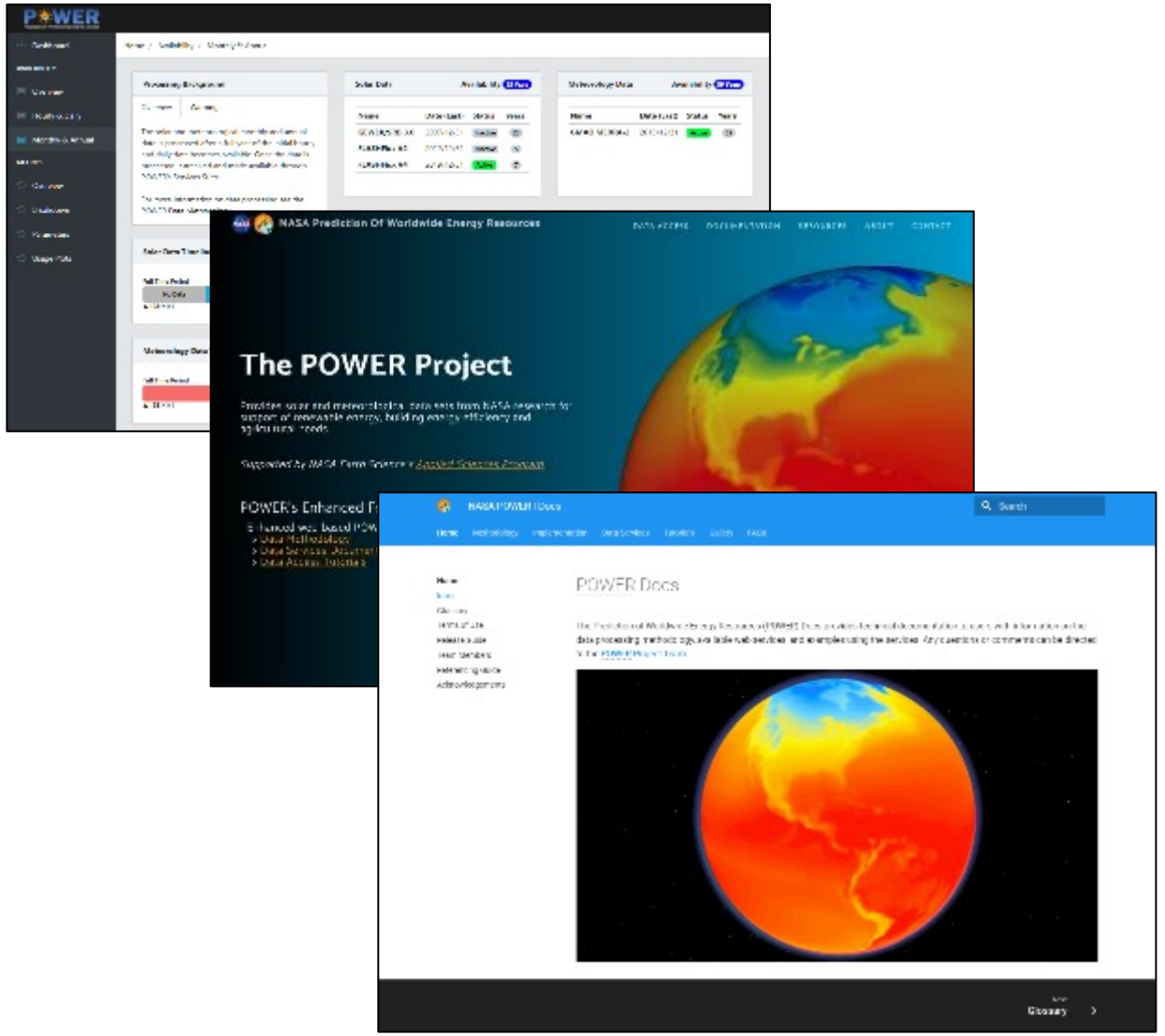
Windrose Report Table by NREL Classes

```
-BEGIN HEADER-
NASA/POWER Wind Rose MERRA2/GEOS 5.12.4 (FP-IT) 0.5 x 0.5 Degree Daily Averaged Data
Dates (month/day/year): 01/01/1984 through 12/31/2018
Single Point Total
Location: Latitude  38.9531   Longitude -77.028
Elevation from MERRA-2: Average for 1/2x1/2 degree lat/lon region = 83.32 meters   Site = na
Value for missing model data; cannot be computed or out of model availability range: -999
Parameter(s):
    WR10M     Wind Rose at 10 meters (percent)
                  CLASS_1: 0-1.5 m/s
                  CLASS_2: 1.5-3.0 m/s
                  CLASS_3: 3.0-4.4 m/s
                  CLASS_4: 4.4-5.1 m/s
                  CLASS_5: 5.1-5.6 m/s
                  CLASS_6: 5.6-6.0 m/s
                  CLASS_7: 6.0-6.4 m/s
                  CLASS_8: 6.4-7.0 m/s
                  CLASS_9: 7.0-9.4 m/s
                  CLASS_10: 9.4+ m/s
    WR50M     Wind Rose at 50 meters (percent)
                  CLASS_1: 0-1.5 m/s
                  CLASS_2: 1.5-3.0 m/s
                  CLASS_3: 3.0-5.6 m/s
                  CLASS_4: 5.6-6.4 m/s
                  CLASS_5: 6.4-7.0 m/s
                  CLASS_6: 7.0-7.5 m/s
                  CLASS_7: 7.5-8.0 m/s
                  CLASS_8: 8.0-8.8 m/s
                  CLASS_9: 8.8-11.9 m/s
                  CLASS_10: 11.9+ m/s
    WD_PCT    Wind Direction Percent (percent)
    WD_AVG    Wind Direction Average Wind Speed (m/s)
DIRECTION     This consists of 16 22.5 degree swaths; the center point being defined. (degrees)
CLASS         The NREL Wind Classifications with enhanced low-end wind levels that have different cutoffs for 10m and 50m Heights.
PARAMETER DIRECTION  CLASS_1  CLASS_2  CLASS_3  CLASS_4  CLASS_5  CLASS_6  CLASS_7  CLASS_8  CLASS_9  CLASS_10  WD_PCT  WD_AVG
-END HEADER-
    WR10M      000.0     1.59     4.03     1.60     0.33     0.16     0.03     0.05     0.02     0.03     0.00    7.83    2.50
    WR10M      022.5     1.73     3.86     0.94     0.10     0.00     0.02     0.00     0.01     0.00     0.00    6.66    2.15
    WR10M      045.0     1.42     4.07     1.27     0.09     0.02     0.01     0.00     0.00     0.00     0.00    6.87    2.28
    WR10M      067.5     1.53     4.69     2.89     0.41     0.10     0.04     0.02     0.01     0.00     0.00    9.68    2.64
    WR10M      090.0     1.44     3.77     1.69     0.16     0.06     0.02     0.01     0.01     0.00     0.00    7.15    2.42
    WR10M      112.5     1.33     2.56     0.77     0.09     0.03     0.01     0.01     0.00     0.00     0.00    4.80    2.15
    WR10M      135.0     1.01     1.71     0.41     0.11     0.00     0.01     0.00     0.00     0.00     0.00    3.25    2.06
    WR10M      157.5     1.15     1.76     0.39     0.03     0.00     0.00     0.01     0.01     0.01     0.00    3.36    1.95
    WR10M      180.0     1.00     1.64     0.51     0.09     0.02     0.02     0.02     0.00     0.00     0.00    3.29    2.14
    WR10M      202.5     1.06     2.07     0.63     0.09     0.02     0.02     0.01     0.00     0.01     0.00    3.91    2.18
    WR10M      225.0     1.17     1.99     0.79     0.09     0.08     0.02     0.02     0.02     0.04     0.00    4.22    2.31
    WR10M      247.5     1.19     1.94     0.80     0.13     0.03     0.02     0.02     0.02     0.03     0.00    4.18    2.33
    WR10M      270.0     1.13     2.64     1.34     0.13     0.08     0.04     0.03     0.02     0.02     0.00    5.42    2.48
    WR10M      292.5     1.23     3.30     2.03     0.41     0.23     0.09     0.08     0.03     0.09     0.00    7.49    2.82
    WR10M      315.0     1.60     3.56     3.49     0.95     0.48     0.24     0.26     0.21     0.25     0.02   11.05    3.28
    WR10M      337.5     1.51     4.01     3.13     1.02     0.45     0.27     0.17     0.10     0.20     0.01   10.86    3.14
    WR10M        ALL    21.09    47.60    22.68     4.23     1.76     0.86     0.71     0.46     0.68     0.03  100.02
    WR50M      000.0     0.63     1.85     3.79     0.59     0.41     0.16     0.23     0.15     0.13     0.01    7.95    4.12
    WR50M      022.5     0.46     1.73     3.75     0.53     0.16     0.11     0.03     0.02     0.01     0.00    6.80    3.77
    WR50M      045.0     0.54     1.63     4.06     0.65     0.21     0.09     0.07     0.02     0.01     0.00    7.27    3.87
    WR50M      067.5     0.41     1.66     5.24     1.18     0.61     0.34     0.23     0.13     0.13     0.00    9.93    4.51
    WR50M      090.0     0.52     1.48     3.81     0.56     0.20     0.15     0.09     0.06     0.04     0.00    6.90    4.00
    WR50M      112.5     0.37     1.45     2.44     0.24     0.06     0.05     0.04     0.05     0.02     0.00    4.72    3.57
    WR50M      135.0     0.39     1.08     1.45     0.13     0.07     0.06     0.02     0.00     0.00     0.00    3.21    3.33
    WR50M      157.5     0.47     1.18     1.44     0.06     0.04     0.01     0.00     0.01     0.03     0.00    3.24    3.10
    WR50M      180.0     0.46     1.09     1.49     0.15     0.07     0.02     0.02     0.01     0.02     0.00    3.32    3.24
    WR50M      202.5     0.43     1.18     1.81     0.17     0.10     0.04     0.02     0.01     0.03     0.01    3.80    3.49
    WR50M      225.0     0.47     1.31     2.01     0.17     0.12     0.07     0.02     0.05     0.05     0.01    4.28    3.57
    WR50M      247.5     0.42     1.20     1.83     0.27     0.12     0.05     0.02     0.02     0.07     0.00    4.01    3.64
    WR50M      270.0     0.55     1.31     2.63     0.45     0.16     0.07     0.05     0.10     0.04     0.01    5.37    3.87
    WR50M      292.5     0.58     1.35     3.39     0.74     0.35     0.31     0.22     0.18     0.24     0.02    7.38    4.52
    WR50M      315.0     0.62     1.53     4.21     1.30     0.86     0.62     0.56     0.58     0.70     0.07   11.04    5.23
    WR50M      337.5     0.54     1.71     4.32     1.06     0.81     0.58     0.53     0.61     0.59     0.05   10.80    5.07
    WR50M        ALL     7.86    22.74    47.67     8.25     4.35     2.73     2.15     2.00     2.11     0.18  100.02
```

Where is the POWER documentation?

The POWER Documentation consists of four main sites that are built for both mobile and desktop use:

- **Homepage:** The project overview with links to all POWER resources.
- **Dashboard:** A series of dynamic webpages that provide real-time status information on data processing.
- **Pages:** The API landing pages that use the OpenAPI specification to create interactive pages for the API endpoints.
- **Docs:** The project's documentation and methodology providing accurate and detailed information to users.



What Have We Learned?

NASA Earth Observations (EO) data products are customized through POWER to address energy related data needs.

- Global solar irradiance estimates are made using specialized measurements:
  - Of the sun from SORCE/TSIS
  - Calculated using information from a combination of NASA CERES instruments and satellite imagers
  - Estimates are made within a week of observation
- Surface meteorological parameters are made available from atmospheric reanalysis from NASA's MERRA-2
  - Estimates of these quantities are available within a few days

- The POWER Web Services Portal:
  - Uses NASA's EO and modeling to customize datasets for energy related applications
  - Spans from 1984 to within a few days of the current time
  - Daily, Monthly, Annual, and Climatological averages provided
  - Data is made available through:
    - API for direct usage
    - DAV for interactive selection
    - Web image and feature services
  - New version features hourly data since Jan. 2001

Thank You!

Find us at: https://power.larc.nasa.gov/
Email us at: larc-power-project@mail.nasa.gov

ACRONYMS

3D	Three Dimensional
API	Application Programming Interface
ARD	Analysis Ready Data
ARM	Atmospheric Radiation Measurement
ASCII	American Standard Code for Information Interchange
BSRN	Baseline Surface Radiation Network
CERES	Clouds and the Earth's Radiant Energy System
CSV	Comma Separated Values
DAV	Data Access Viewer
DSCOVR	Deep Space Climate Observatory
EO	Earth Observation
FLASHFlux	Fast Longwave and Shortwave Flux
FP-IT	Forward Processing-Investigator Team
GEBA	Global Energy Balance Archive
GEOS	Geostationary Operational Environmental Satellite
GEWEX	Global Energy and Water Exchanges Project
GIS	Geographic Information System
GMAO	Global Modeling and Assimilation Office
GSOD	Global Summary of the Day
ISCCP	International Satellite Cloud Climatology Project
ISD	Integrated Surface Database
ISS	International Space Station
LaRC	Langley Research Center
MAC	Max-Planck Aerosol Climatology

MERRA-2	Modern-Era Retrospective analysis for Research and Applications, Version 2
MODIS	MODerate resolution Imaging Spectrometer
NASA	National Aeronautics and Space Administration
NCEI	National Center for Environmental Information
NetCDF	Network Common Data Form
NOAA	National Oceanic and Atmospheric Administration
NREL	National Renewable Energy Laboratory
NSIDC	National Snow and Ice Data Center
PAR	Photosynthetically Active Radiation
POWER	Prediction of Worldwide Energy Resources
PV	Photovoltaic
SatCORPS	Satellite ClOud and Radiation Property retrieval System
SORCE	SOlar Radiation Climate and Experiment
SRB	Surface Radiation Budget Project
TOA	Top Of Atmosphere
TSI	Total Solar Irradiance
TSIS	Total and Spectral Solar Irradiance Sensor
URI	Uniform Resource Identifier
URL	Uniform Resource Locator
VIIRS	Visible Infrared Imaging Spectrometer

POWER Data: What Parameters are Provided?

Base and Derived Parameters for POWER GIS v2 (Beta)

All parameters are available globally at the source data resolution.

Source Data (Hourly)

- All-Sky & Clear-Sky Surface Solar Insolation on Horizontal Surface
- Surface Reflected Solar Flux
- All Sky Downward Longwave Radiative Flux
- Top-Of-Atmosphere Insolation

- 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, & Wind Direction at 2 m, 10 m, and 50 m
- Precipitation

Daily, Monthly, & Annual

- Clear & Cloudy Clearness Indexes

- Air Temperature Average, Min, Max, Range at 2 m, Wet Bulb
- Temp Frost point at 2 m
- Relative Humidity at 2 m
- Wind speed and Direction at 10m, 50 m
- Max/Min Wind Speed

Climatological

- Solar geometry, Surface albedo, Direct Normal, Diffuse, Tilted surface solar parameters
- 3-hourly solar fluxes and cloud parameters,
- No-sun Days, min insolation over day periods

- 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

Source Data:

- Global Energy and Water Exchange Project (GEWEX) Surface Radiation Budget (SRB)
- Fast Longwave And SHortwave Radiative Fluxes (FLASHFlux)
- Modern Era Retro-analysis for Research and Applications (MERRA-2)
- Forward Processing – Instrument Team FP-IT (GEOS 5.12.4)