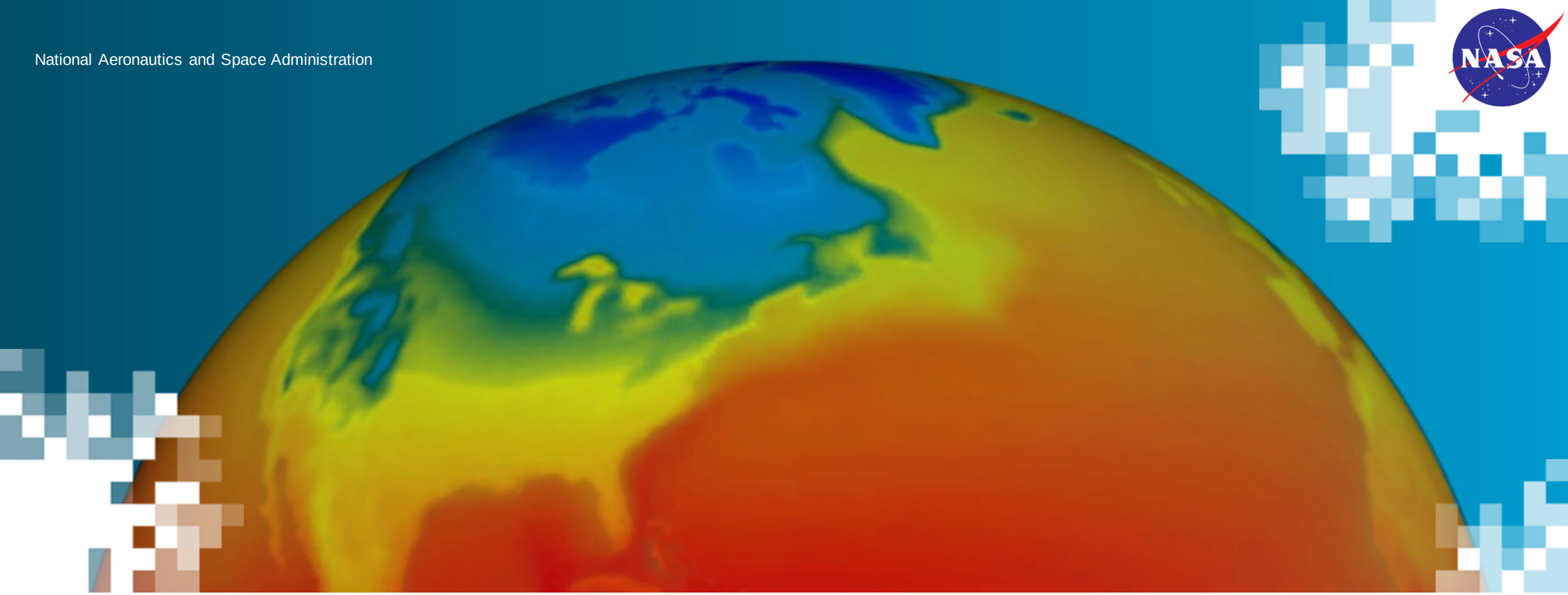
National Aeronautics and Space Administration



Introduction to the POWER Project

NASA Applied Science Week 2021

August 10th, 2021

POWER
Prediction Of Worldwide Energy Resources

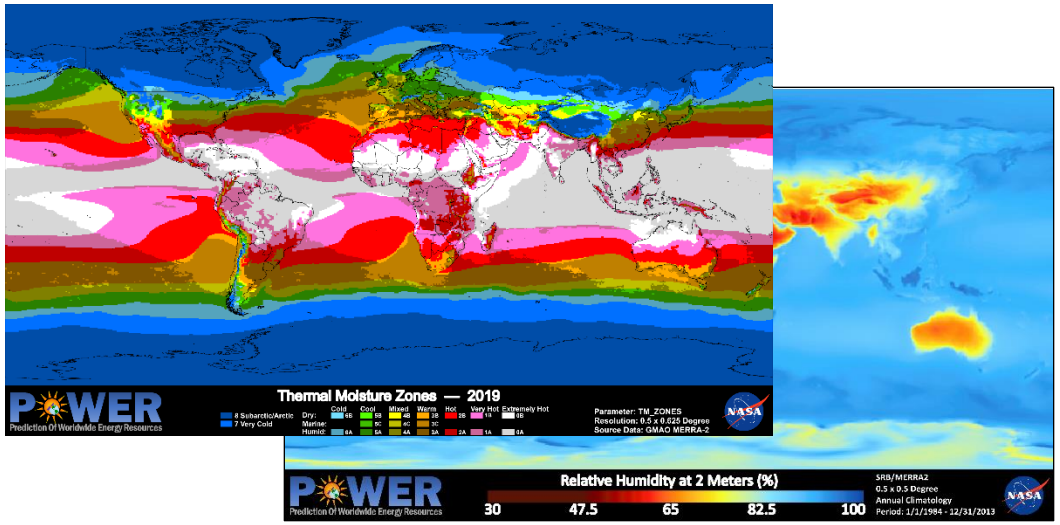
Prediction Of Worldwide Energy Resource (POWER)

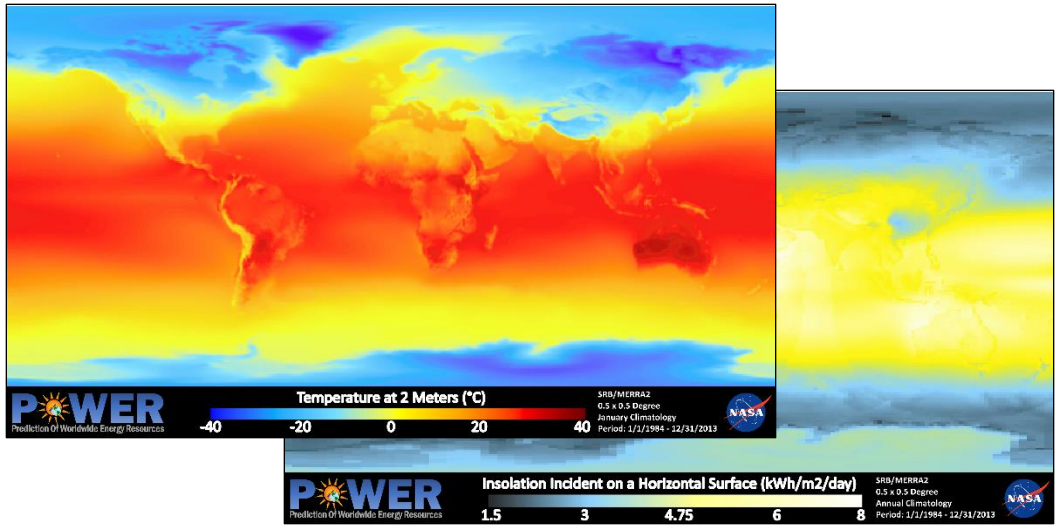
Aiming to improve the nation's public/private capability for integrating environmental data from NASA Earth observations, analysis and modeling, particularly information related to surface solar irradiance, to support increased **renewable energy development, building energy efficiency,** and **agroclimatology applications**.

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

Principal Investigator: Dr. Paul W. Stackhouse, Jr. – National Aeronautics and Space Administration (NASA)
Co-Investigators:

- Bradley Macpherson, Madison Broddle, Chequel McNeil, & A. Jason Barnett – Booz Allen Hamilton (BAH)
- Colleen Mikovitz & Taiping Zhang – Science Systems and Applications, Inc. (SSAI)





What Questions can be Answered with Earth Observations?

How can we help farmers in remote locations more effectively plan and grow crops?

How can we understand the variability of building environment climate parameters needed to determine current and future building standards? What about remove areas with poor ground measurements?

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 principles and effectiveness of implementing solar technologies anywhere around the world?

What are POWER's Impacts on the Community?

Renewable Energy

A West African Community used POWER data to evaluate a solar panel insulation; it was determined that the insulation's underperformance was caused by cloud patterns. This data then used to modify the system to better support the community.

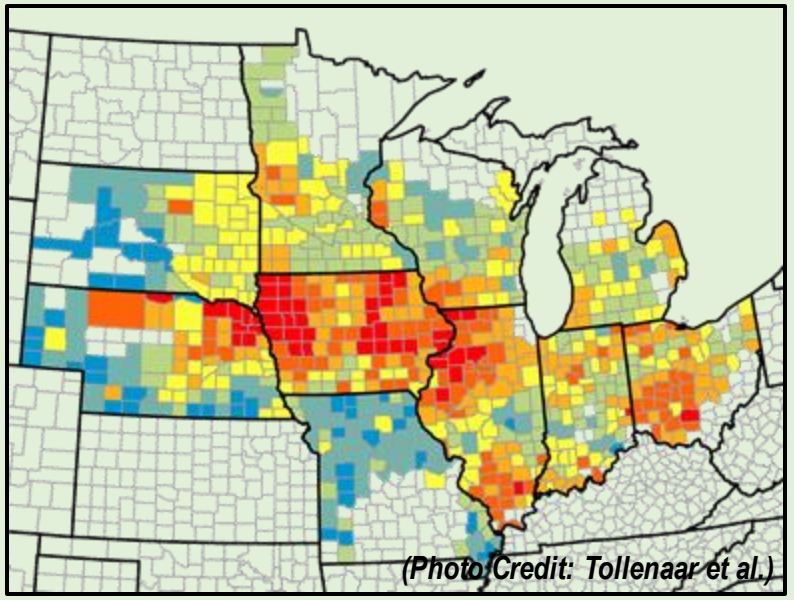
Climatological Information

Sustainable Buildings

Wicked Joe Coffee utilized RETScreen™ and POWER data to determined that a glazed solar wall would capture 40% more heat savings of approximately $10,000 per year.

Climatological and NRT time-series:
See more at NASA's Space for US

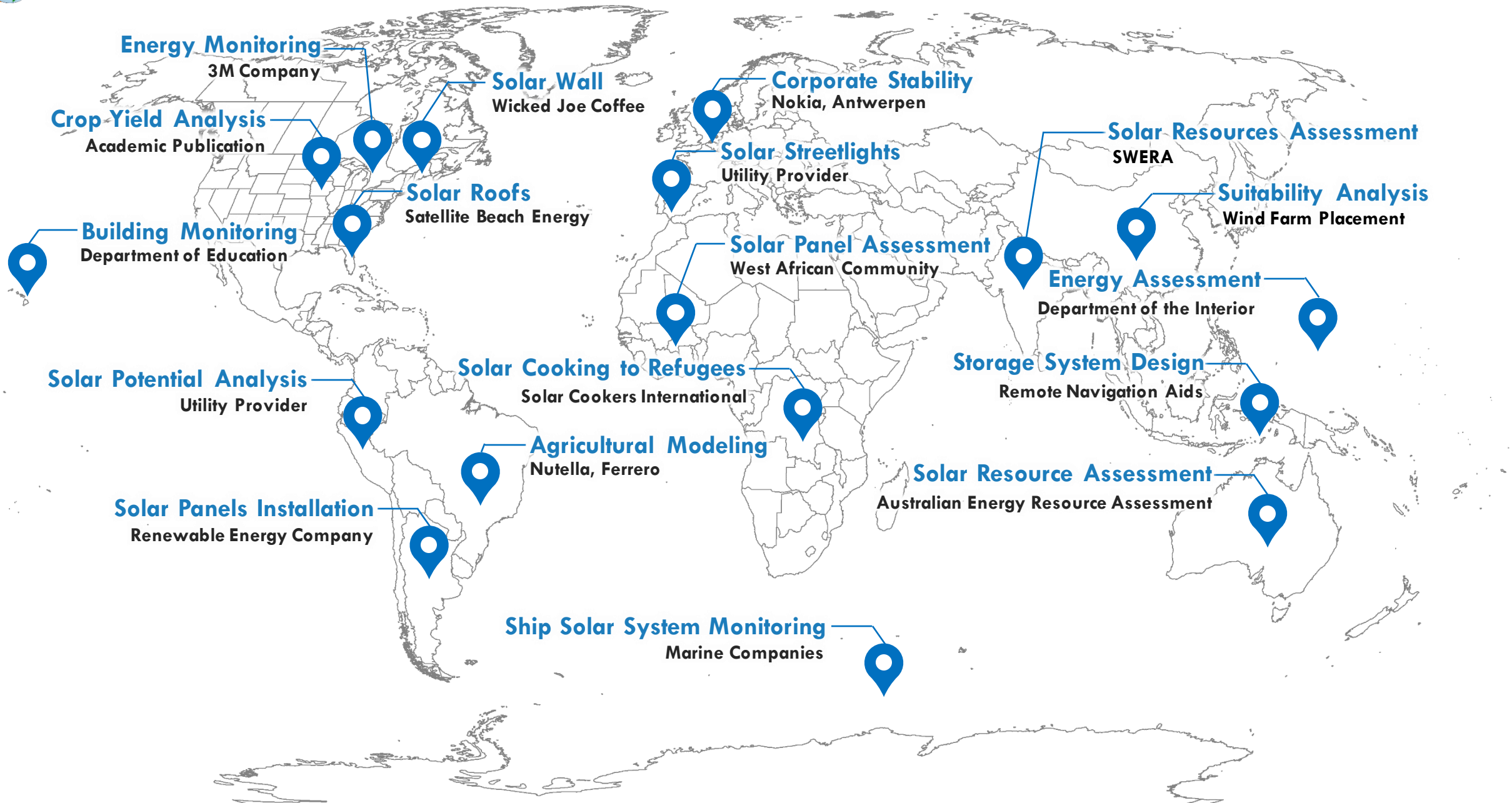
Agroclimatology



In the article 'The contribution of solar brightening to the user maize yield trend' POWER Data was used to help explain a 25% productivity increase in US corn-belt states!

Time-series Information

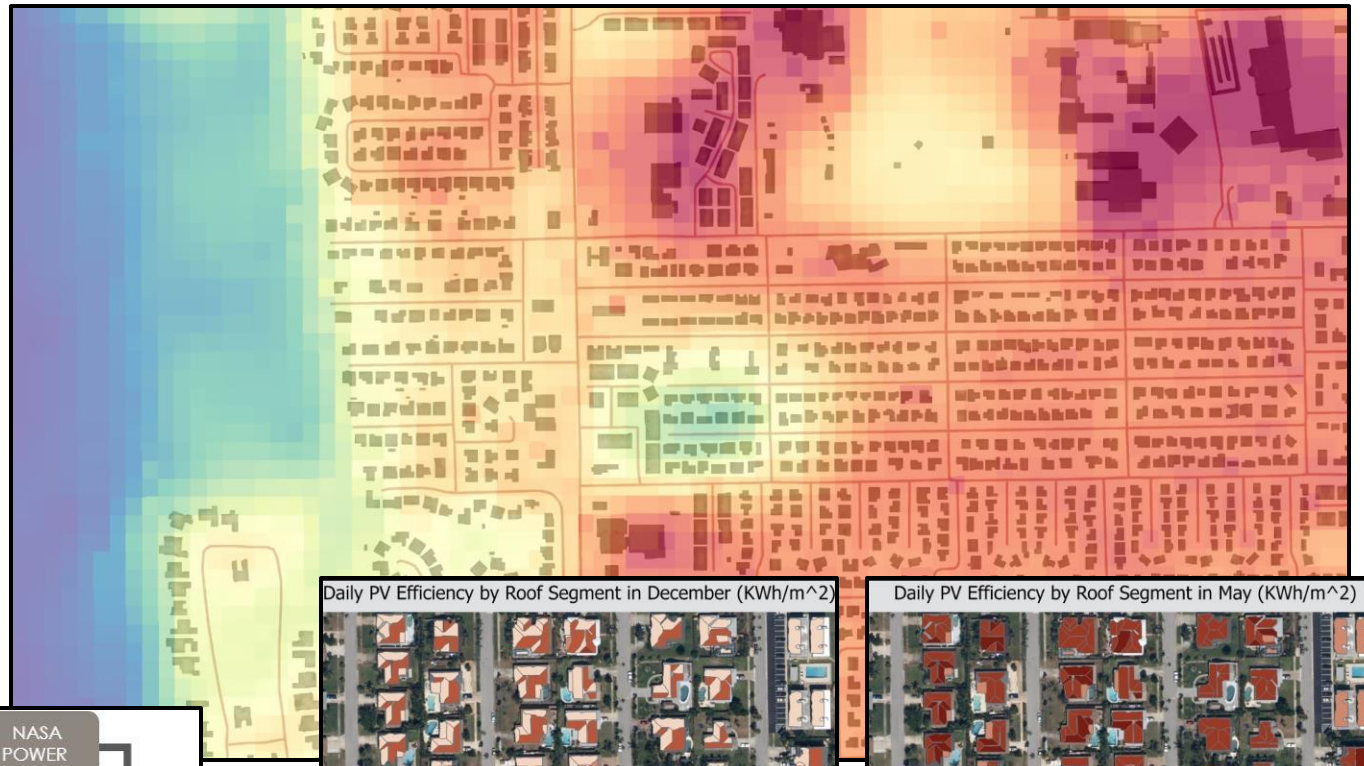
What are POWER's Impacts on the Community?

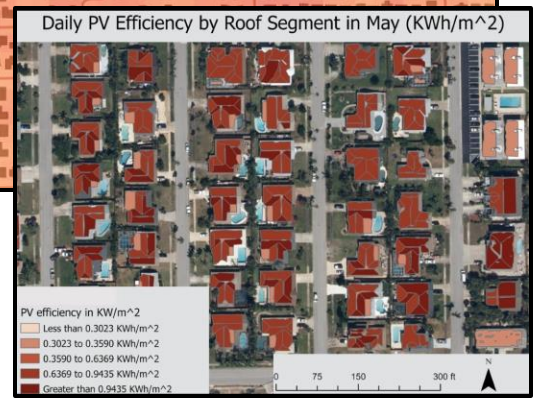


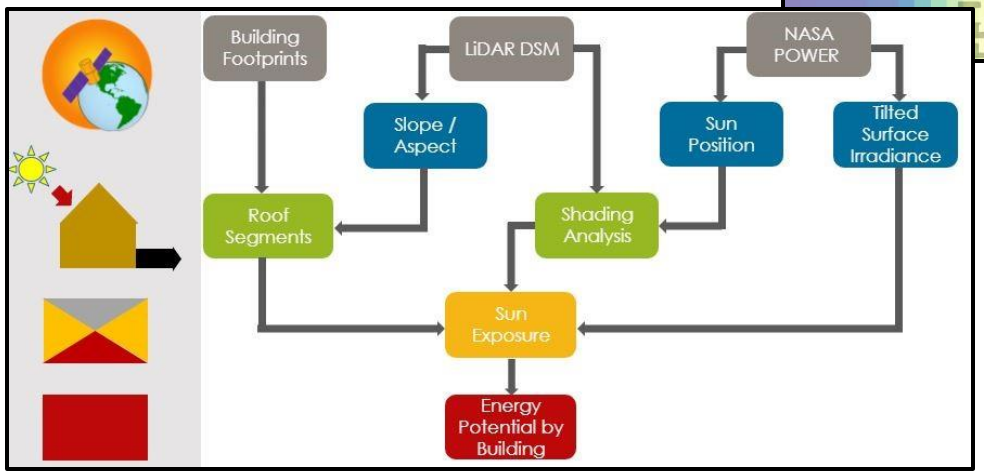
How can Solar Irradiance Parameters be Used? DEVELOP Project

Summer 2020: Satellite Beach Energy

- The City of Satellite Beach, FL, has committed to supplying 100% of its energy use from renewable energy, primarily solar, by the year 2050.
- The team estimated rooftop solar power potential using a high-resolution Light Detection and Ranging (LiDAR) dataset and the NASA Prediction of Worldwide Energy Resources (POWER) dataset to assist Satellite Beach in reaching their solar renewable energy goals.



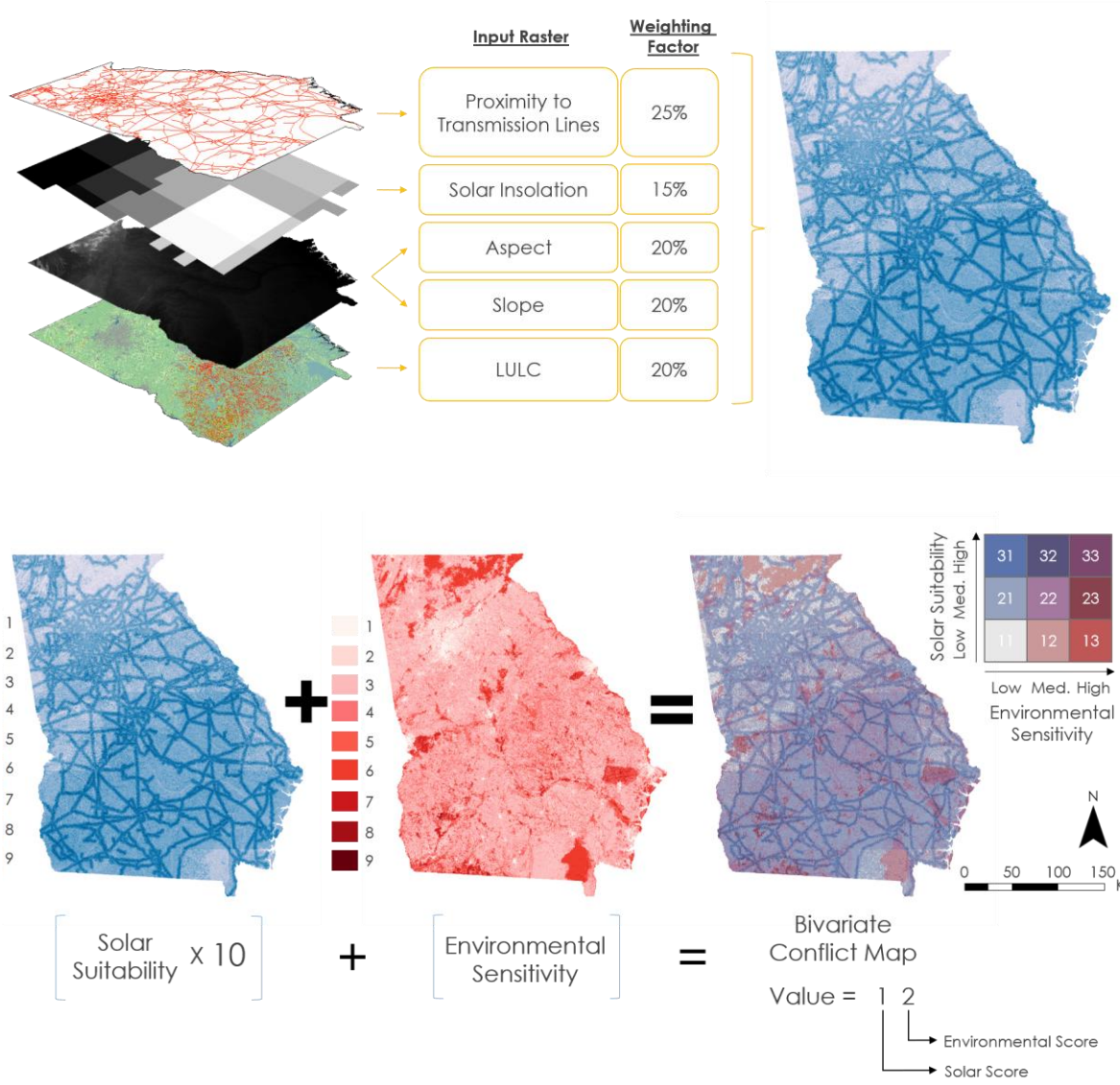




How can Solar Insolation Parameters be Used? DEVELOP Project

Summer 2020: Georgia Energy III

- The rapid expansion of the solar industry across the state of Georgia has a detrimental effect on the habitats of keystone and threatened species, such as the gopher tortoise and the American black bear.
- NASA DEVELOP collaborated with the Georgia Chapter of The Nature Conservancy (TNC) to assess the conflict between solar suitability and environmentally sensitive areas with the Land-Use Conflict Identification Strategy (LUCIS). The project utilized NASA Earth Observation and POWER Solar Insolation data to conduct and compare a general statewide LUCIS analysis from 2017 to 2019 and to complete an in-depth LUCIS analysis of Georgia's fastest-growing solar counties.



What NASA EO Can Provide These Data Parameters?

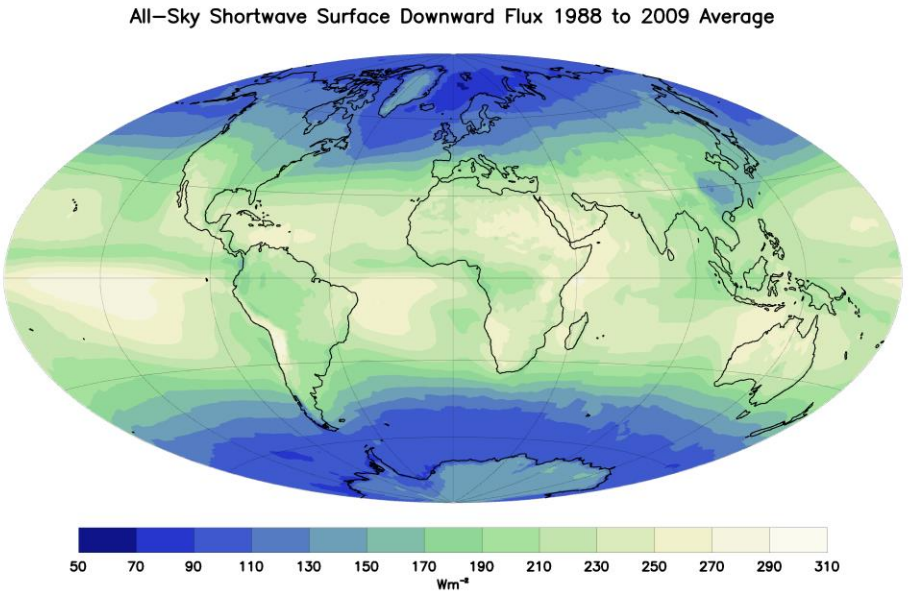
The POWER Data Archive uses NASA research and modeling data products plus value added data processing and services to customize parameters for community use.

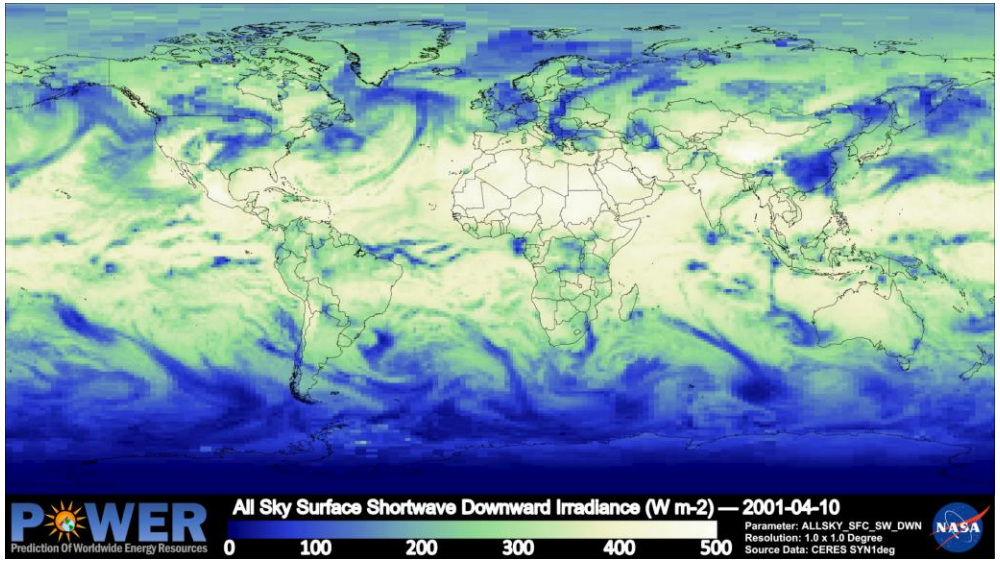
Source	Temporal Span		Temporal Average		Description
	Start	End	Input	Output	
GEWEX SRB 4.0	July 1, 1983	Dec. 31, 2000	Daily	Daily, Monthly, Annual, Multi-year	Satellite analysis from global cloud imagers (from geosynchronous and polar orbiters satellites) using radiative transfer lookup tables
CERES 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)
GMAO FP-IT (GEOS 5.12.4)	End of MERRA-2	Near Real Time	Hourly	Hourly, Daily, Monthly, Annual, Multi-year	Atmospheric reanalysis with assimilated observations with less assimilated observations, available within 2 days of real-time

What Sorts of Data Help Enhance POWER's Utility?

Time Averaged vs. Time Series

- Some users require statistics from long-term averaged data parameters
  - Useful for feasibility and engineering studies for large numbers of renewable energy projects
  - POWER beta now allows users to choose years for long-term averages
- Some users require time series data products
  - Useful for modeling energy systems with observed variability
  - Useful for monitoring building energy efficiency performance
  - POWER beta now allows up to hourly averaged data products but also features daily, monthly, annual time series statistics

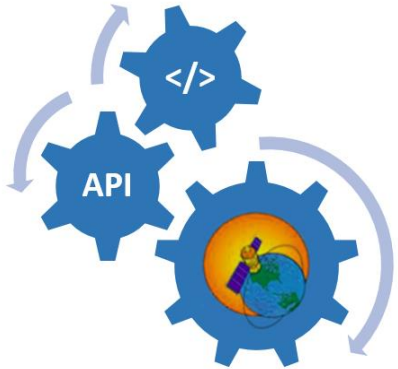




How do you Access POWER Data?

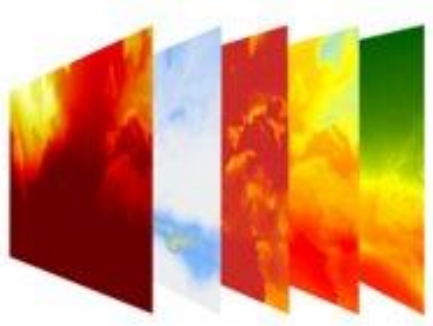
- POWER provides an integrated services suite to efficiently access environmental data, pre-computed analysis reports for management of energy production, and monitoring energy efficiently systems, as source data for modeling software.
- POWER enhances data discovery, access, and distribution as Analysis 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:
  - Application Programming Interface (API)
  - Data Access Viewer (DAV)
  - Geospatial Services

APIs



Data Access Viewer

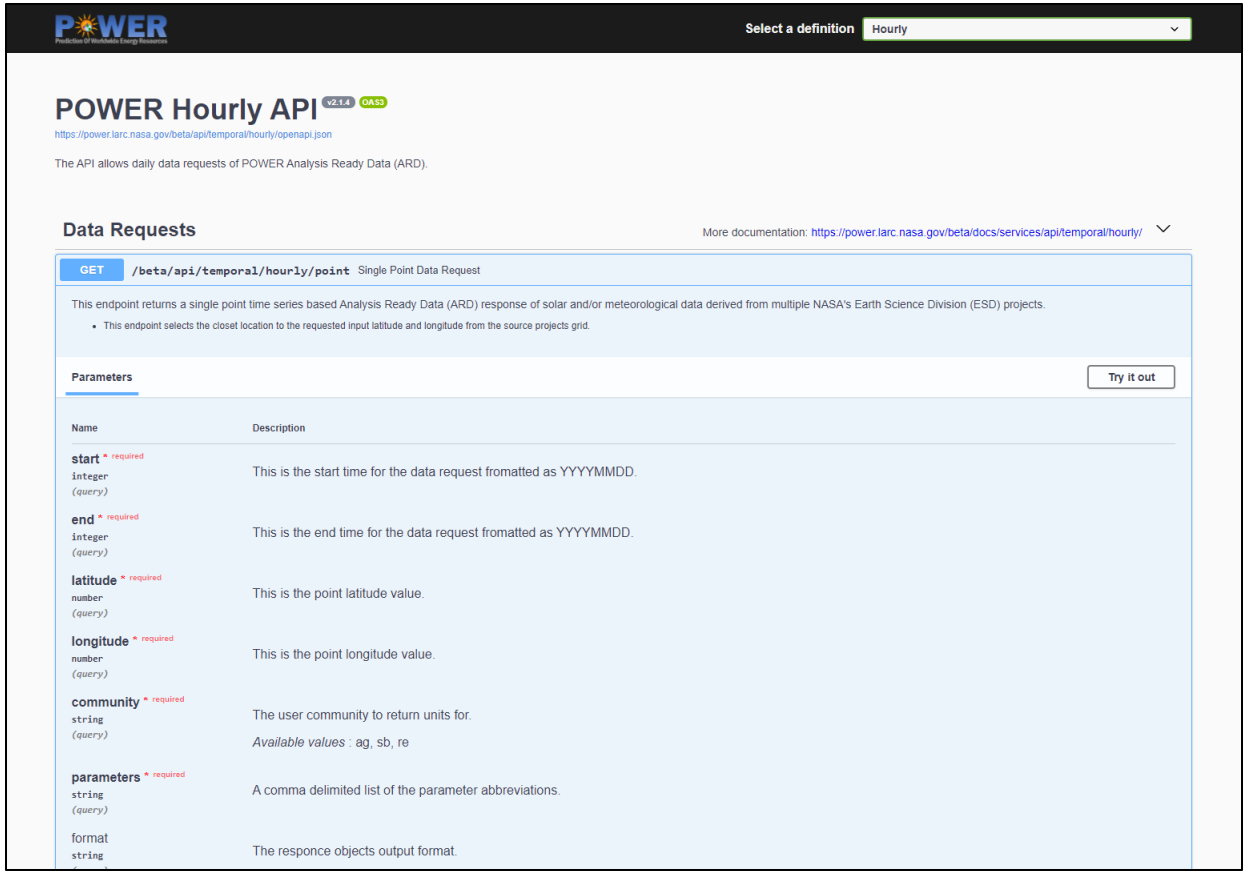
Geospatial Services



What Does the POWER API Do?

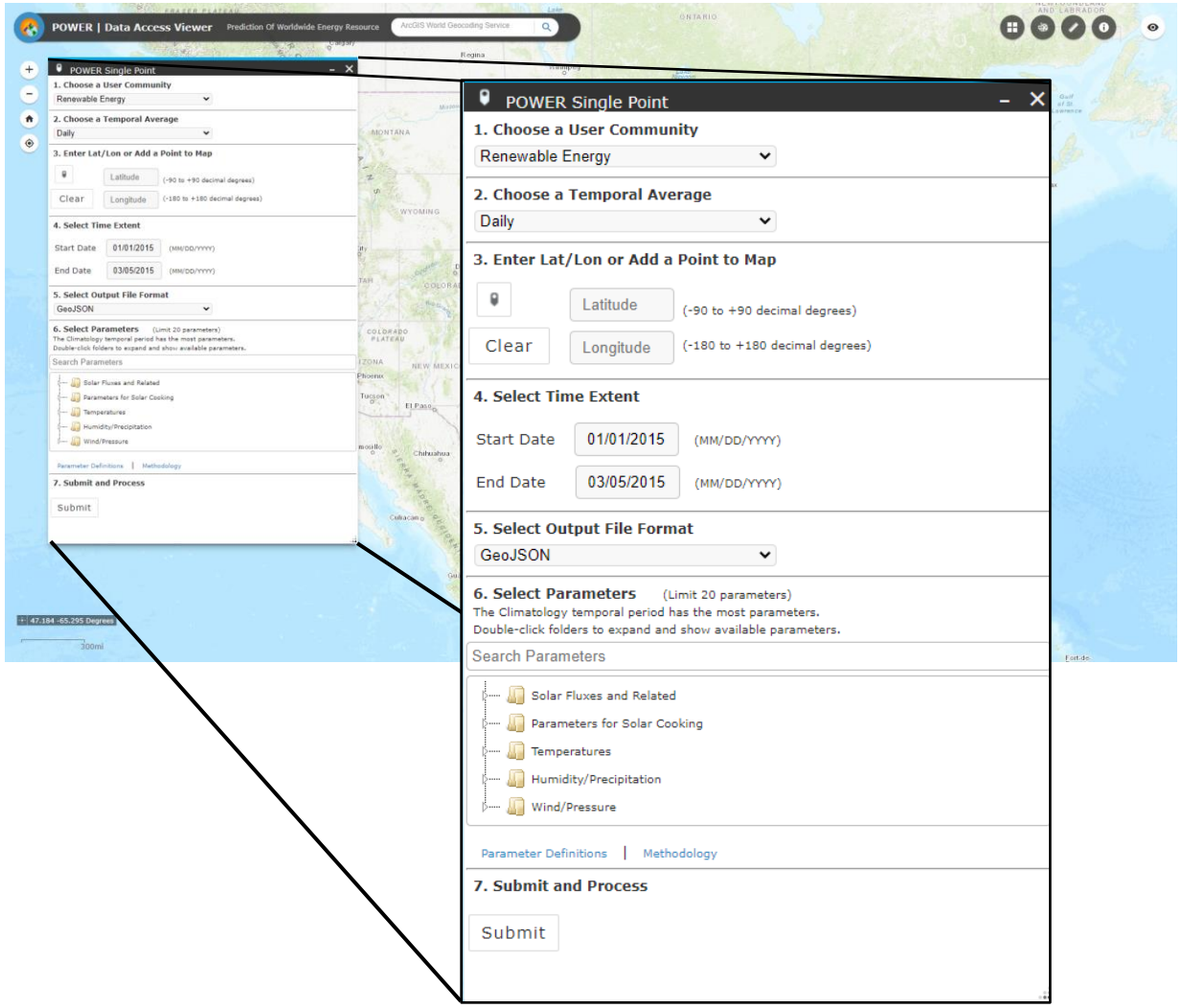
The POWER API delivers Analysis Ready Data (ARD) for inputs to decision to support tools, modeling and forecasting packages, and as inputs to scientific research by providing:

- Complete access to 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!

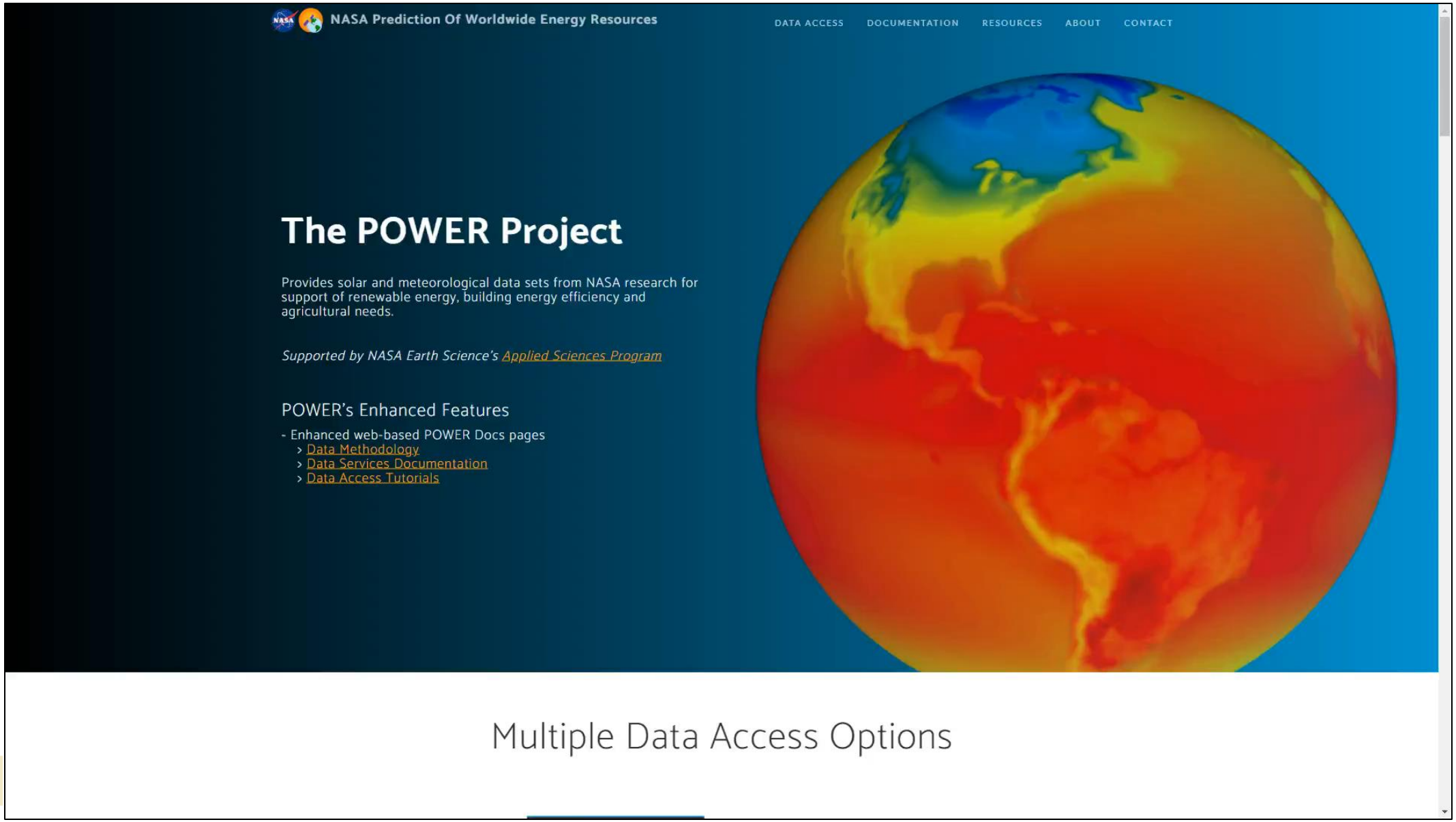


What is the POWER Data Access Viewer (DAV)?

- 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 and 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)?

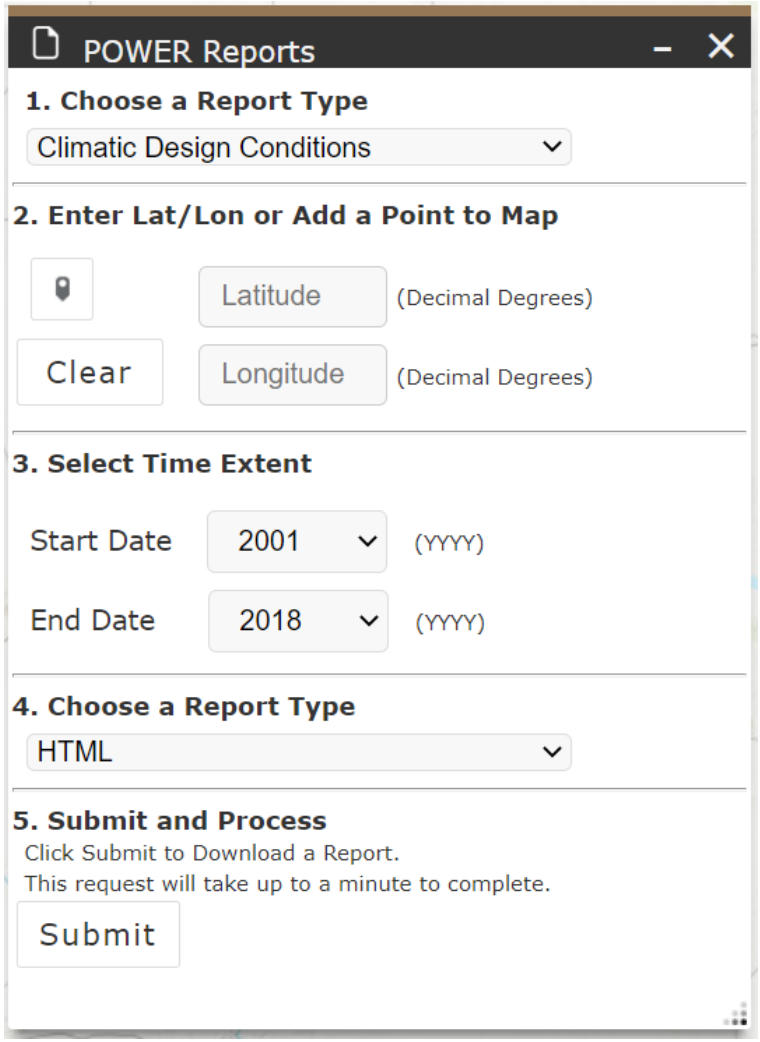


What are POWER's Analytic Data Services?

New now in power/beta …

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

- **Anomaly Report**
  - Timeseries 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



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

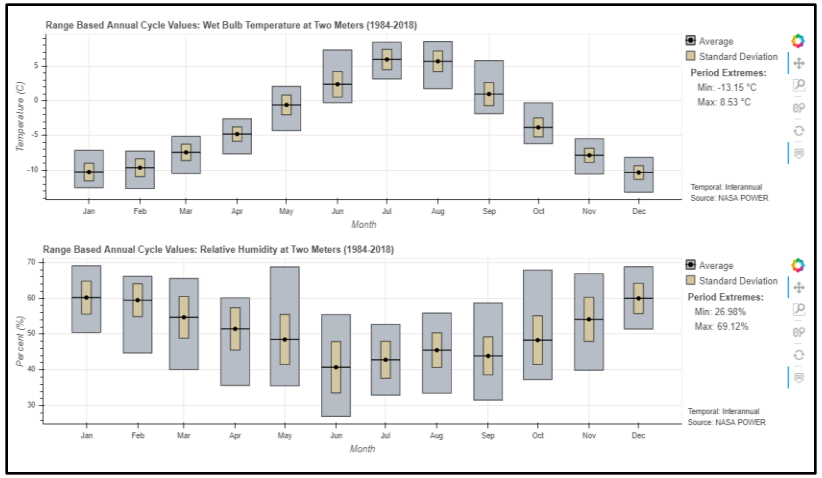
Extreme Annual Design Conditions

Extreme Annual WS 1%	2.5%	5%	Extreme Annual Temperature Mean	Min	Max	Standard deviation Min	Max	n-Year Return Period Values of Extreme Temperature n=5 years Min	Max	n=10 years Min	Max	n=20 years Min	Max	n=50 years Min	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	19.2	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	5% DB 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													
	5% WB MCDBR													
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
```

What GIS Services does POWER provide?

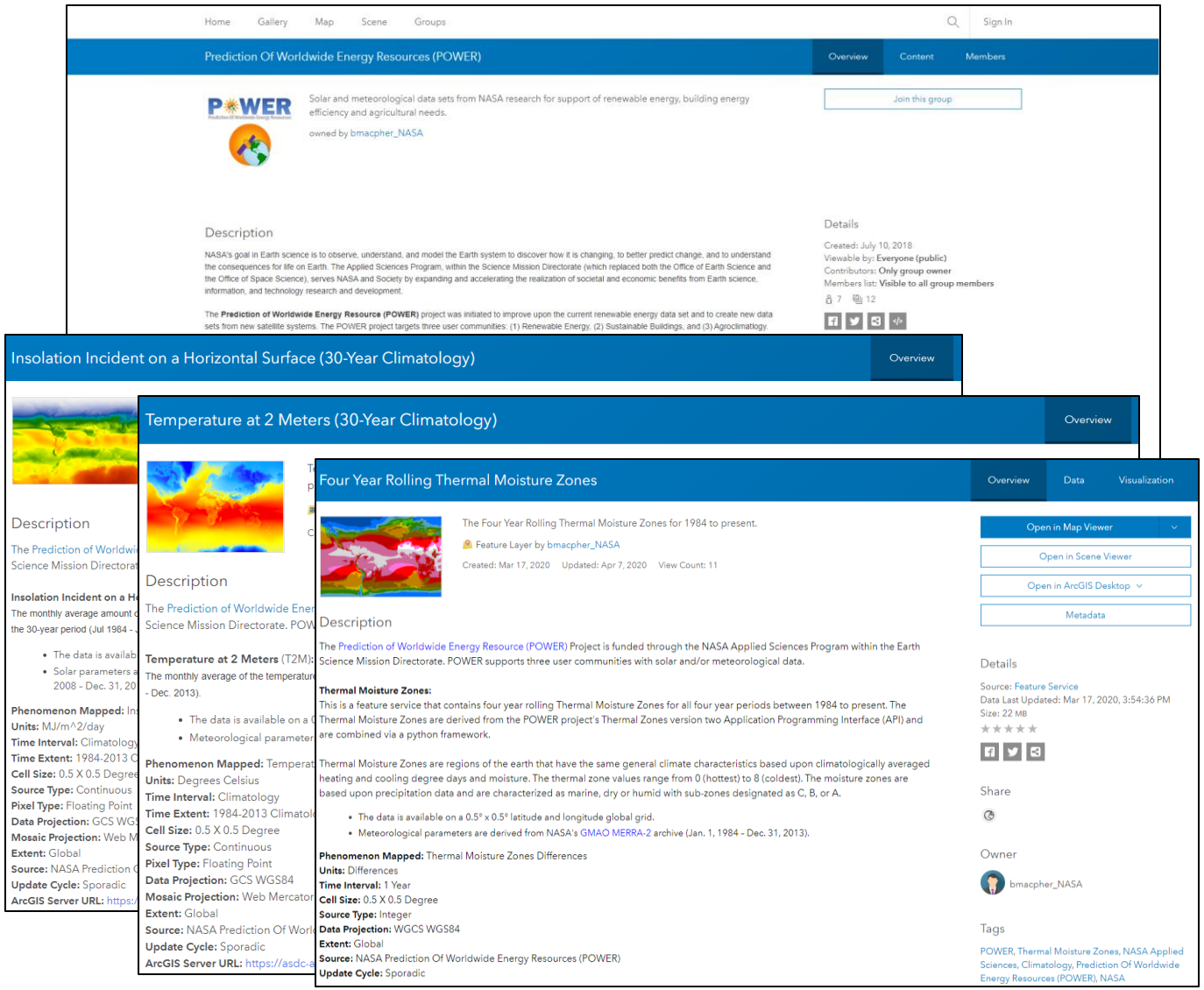
POWER provides Esri® ArcGIS Image and Feature Services that allow users to efficiently interact with the POWER data in Geographic Information System (GIS) applications and related tools.

- **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

Hyperlink: [NASA AGOL - POWER]



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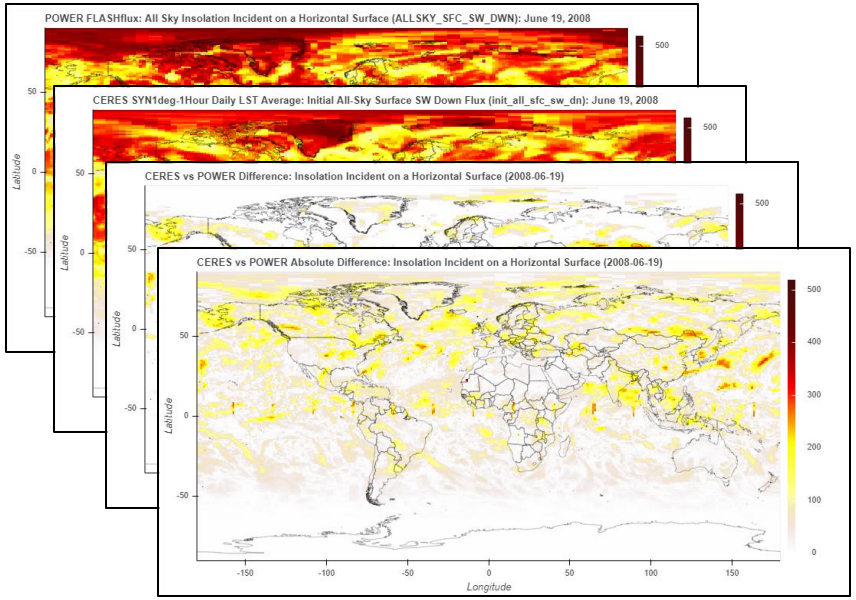
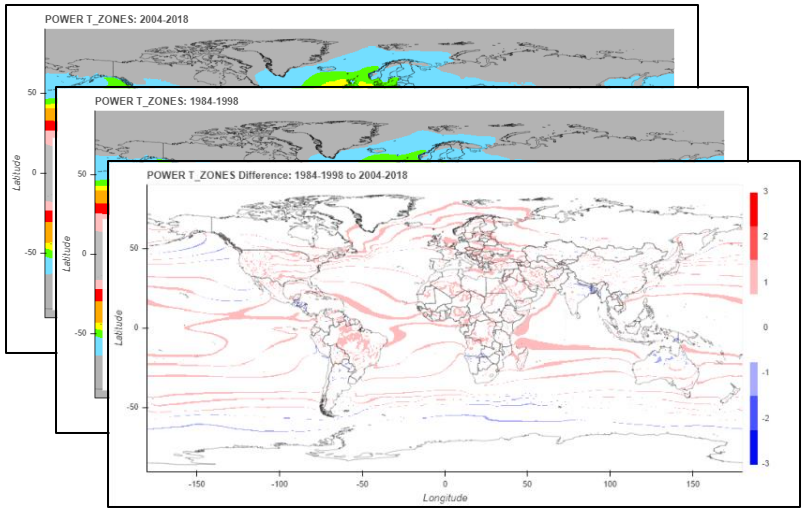
Analysis – Data Analytics

POWER uses Jupyter ® Notebooks in conjunction with the POWER Services Catalog to improve understanding of Data Analytics by using notebooks to validate, review, provide tutorials, and complete development work. The Jupyter ® Notebooks allow POWER to show workflows across the team and to the user community by documenting a script's workflow, inputs, and outputs allowing everyone to be on the same page and add work effectively.

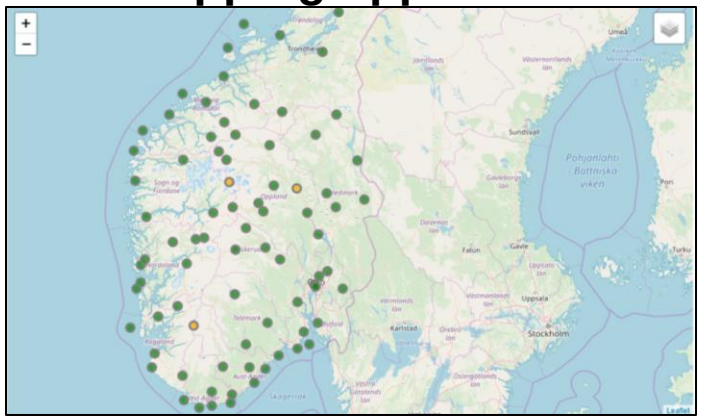
Solar Irradiance Differences



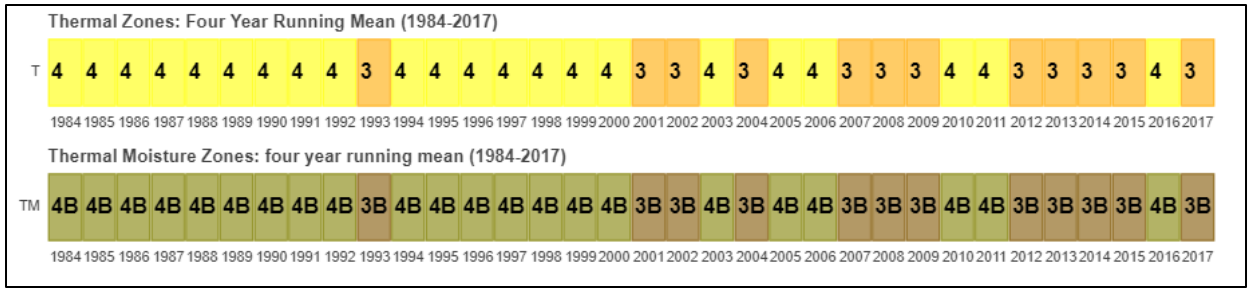
Thermal Zones Differences



Bias Mapping Application



Four-year Rolling Thermal & Thermal Moisture Zones Changes



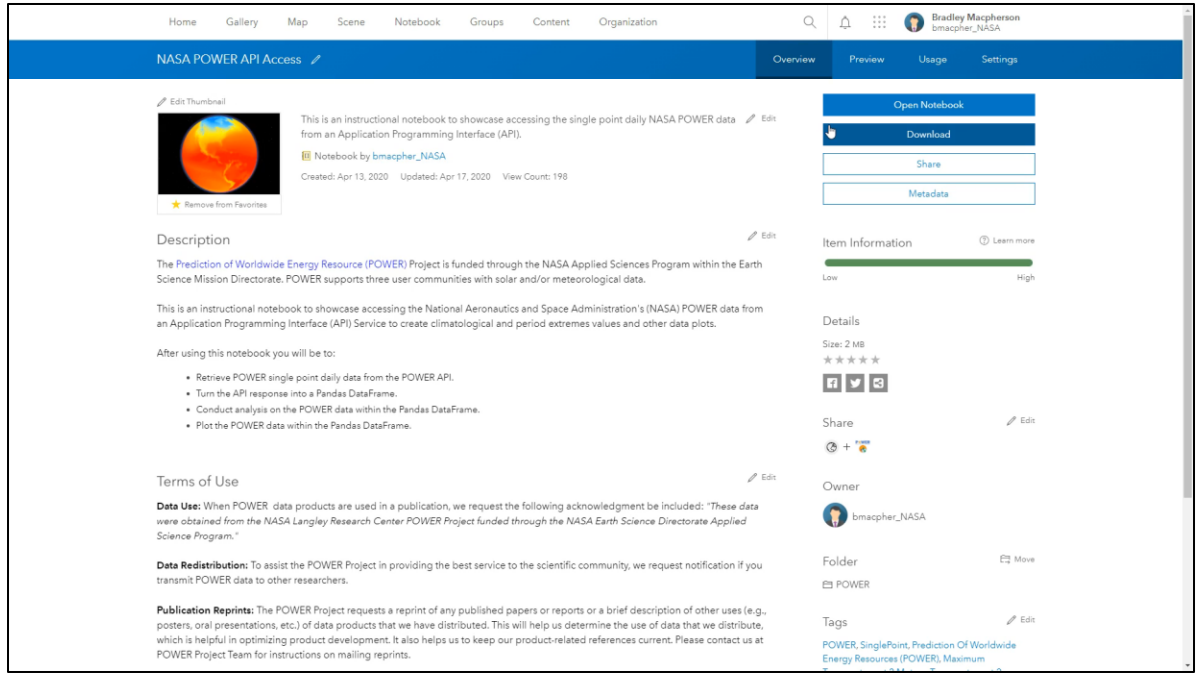
Analytics with Jupyter Noteboks

Key Features:

- The POWER project has some Jupyter® notebooks currently available to conduct climate anomalies detection
- Allow users to interact with the POWER API in a Jupyter® Notebook without the need for additional software.
- Provides step by step instructions on how to use the new data services and tools

Presented at the ASDC Data Presentation for 2020 DEVELOP Fellow Class on April 22nd, 2020

Hyperlink: [NASA POWER API Access]

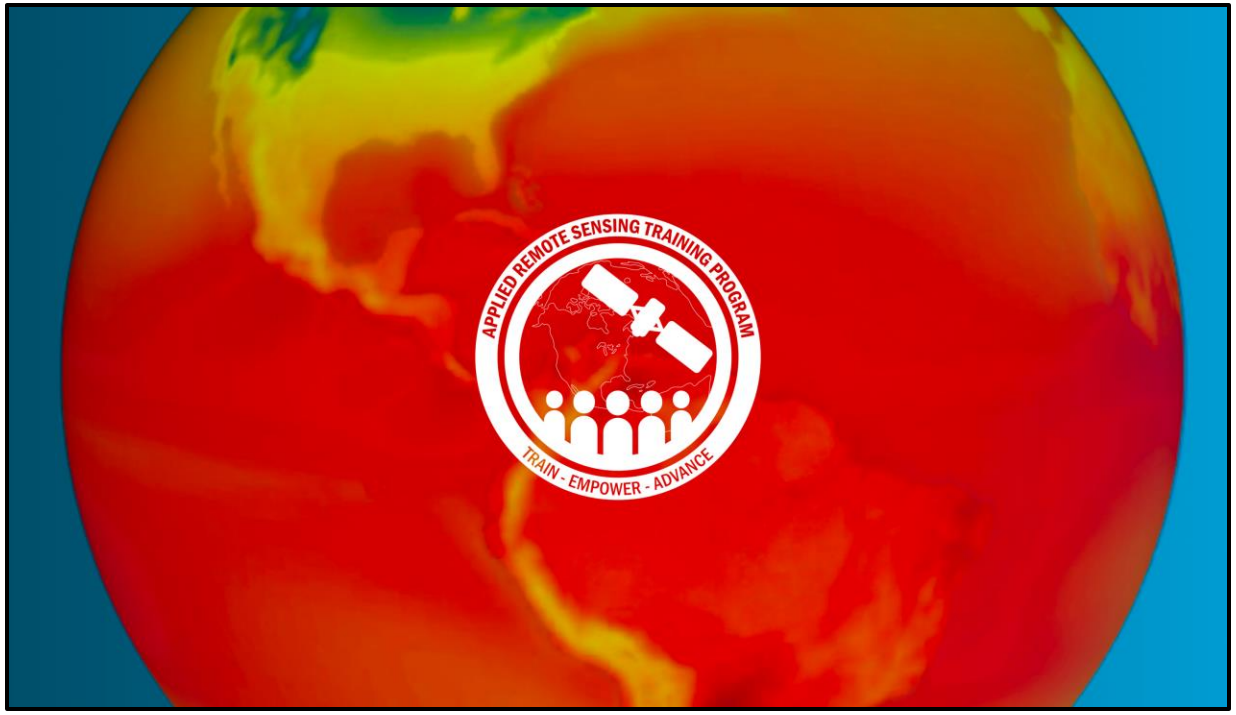


Want to Learn More? Check out the ARSET Webinars

The POWER Team gave a series of ARSET webinars this past June. You can access the webinars on the Energy Management section of ARSET's website and learn about the following topics:

- Part 1: Introduction to Earth Observations (EOs) for Energy Management
- Part 2: Using NASA Products for a More Climate Resilient Energy Sector
- Part 3: NASA Resources for Renewable Energy and Building Energy Efficiency Applications
- Part 4: Data Access: Utilizing the NASA POWER Web Services for Energy Related Applications

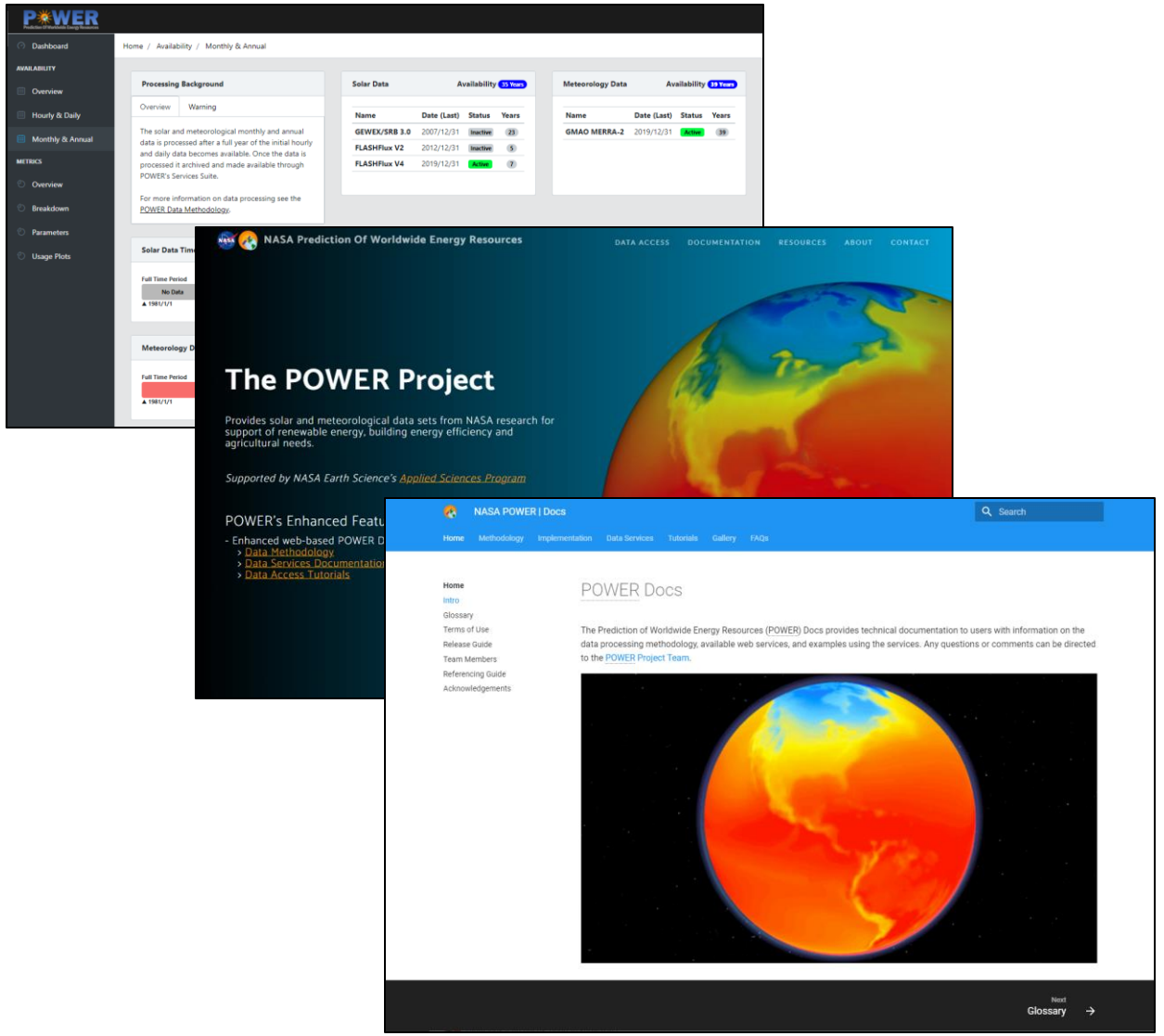
EARTH SCIENCE
APPLIED SCIENCES



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 web pages 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 projects documentation and methodology providing accurate and detailed information to users.



Thank you!

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