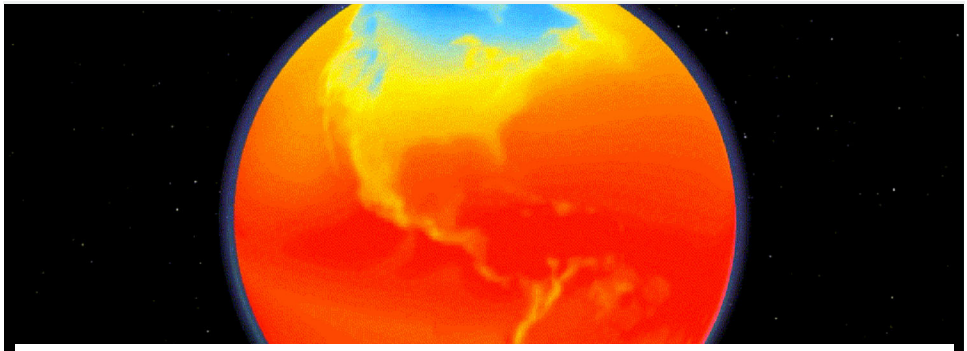
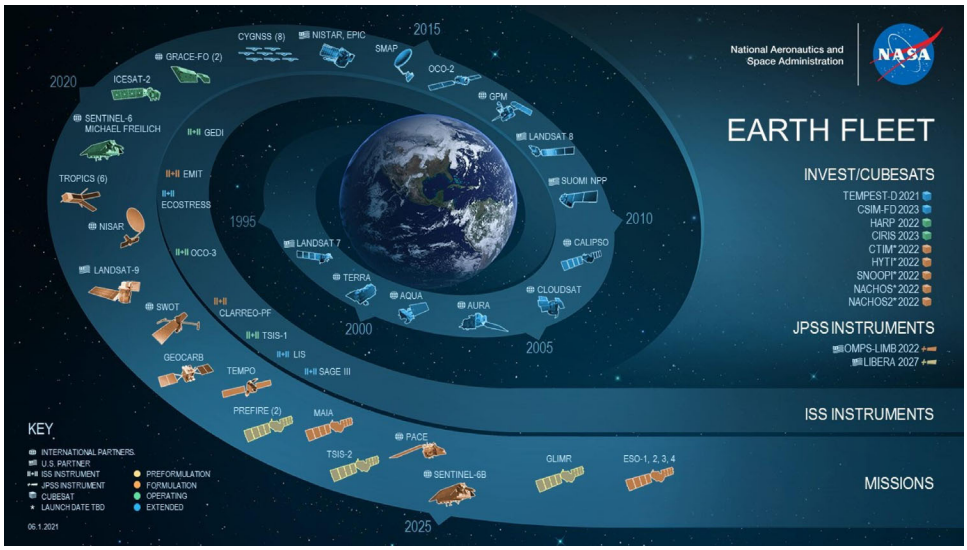


The Prediction of Worldwide Energy Resources (POWER) Project

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

The NASA POWER Team @ NASA Langley Research Center

Introduction to the POWER Project



NASA's Purpose

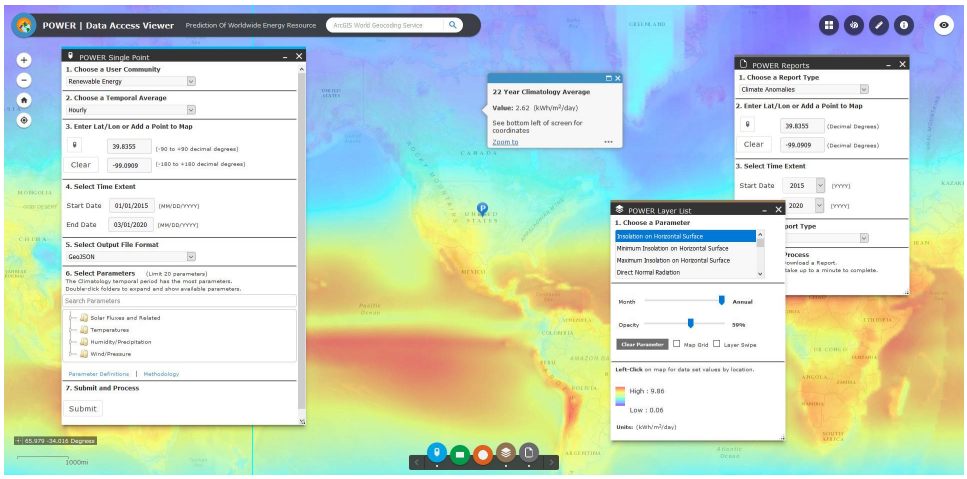
NASA through its Earth Science research programs, has long supported satellite systems and research providing data important to the study of climate and climate processes to the public and researchers. NASA's goal in Earth science is to observe, understand, and model the Earth system to discover how it is changing, to better predict changes, and to understand the consequences for life on Earth. The Applied Sciences Program serves NASA and Society by expanding and accelerating the realization of societal and economic benefits from Earth science, information, and technology research and development.

You can learn more about NASA's Earth Science Satellite and Instrument Fleet by clicking here:

NASA Science Mission Directorate

NASA is developing the Earth System Observatory, the core of which is five satellite missions providing critical data on climate change, severe weather and other natural hazards, wildfires, and global food production. These observations will address the most pressing questions about...

https://science.nasa.gov/earth-science



POWER's Purpose

The POWER Project, a NASA Applied Sciences program, improves the accessibility and usage NASA Earth Observations (EO) data supporting community research in three focus areas: 1) renewable energy development, 2) building energy efficiency, and 3) agroclimatology applications. The POWER Project helps communities become resilient amid observed climate variability through the easy access of solar and meteorological data via a variety of access methods.

POWER's Website

POWER's Documentation

POWER's Data Access Viewer (DAV)

The image to the right shows the POWER Data Access Viewer (DAV) that is used to access the POWER Data.

POWER's History

The POWER project was initiated in 2003 as an outgrowth of the Surface meteorology and Solar Energy (SSE) project. The POWER project encompassed the SSE components and added new datasets with an added focus of architecture (e.g. Sustainable Buildings (SB)) and agricultural (e.g. Agroclimatology) industries, with the continuing improvements to and expansion of the parameters included in each section of POWER.

The project is funded by the Applied Science Program to foster use of NASA's data holdings. The POWER's data-delivery website was focused on providing easy access to parameters valued in the renewable energy industry (e.g. solar and wind energy) starting in 1997. In subsequent releases of POWER has continued to build upon an interactive dialog with potential customers resulting in updated parameters using the most recent NASA data as well as inclusion of new parameters that have been requested by the user community.

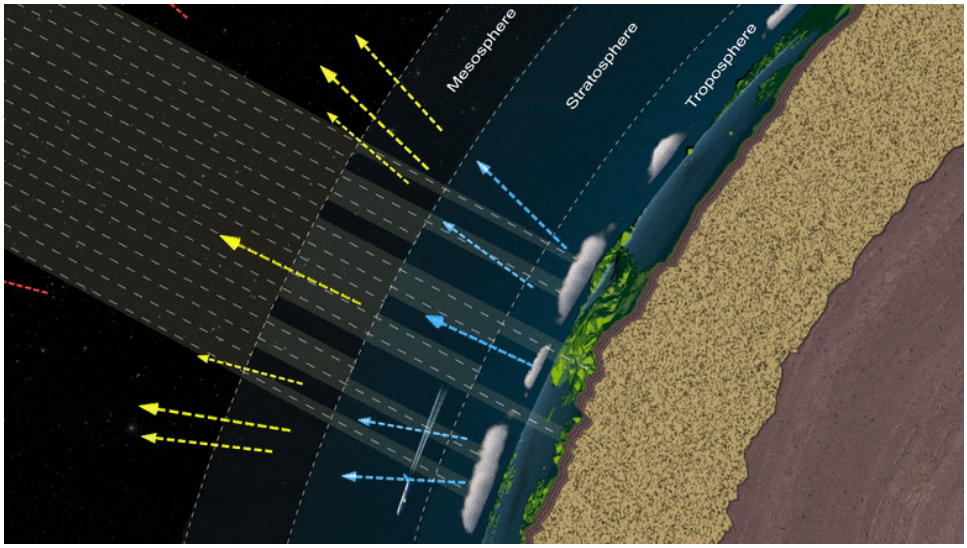
The timeline to the right shows the POWER Projects key improvements over time.

POWER's Data Sources

The latest POWER release builds upon the data portal established in previous version, but adds more recent data releases from NASA's Earth observation (EO) holdings. The new version improves the underling source data models and enhances traceability to source data models.

Specifically, the underling source data models for radiation-based parameters has changed. Like in previous versions, POWER continues to provide support for Near Real Time (NRT). For the enhanced traceability, POWER data includes improved parameter abbreviations and

definitions, in order to be more clear about what parameter is being used. The most prominent change is that POWER provides data at the underlying source data model's grid resolution while sill providing global data access.



Solar Sources

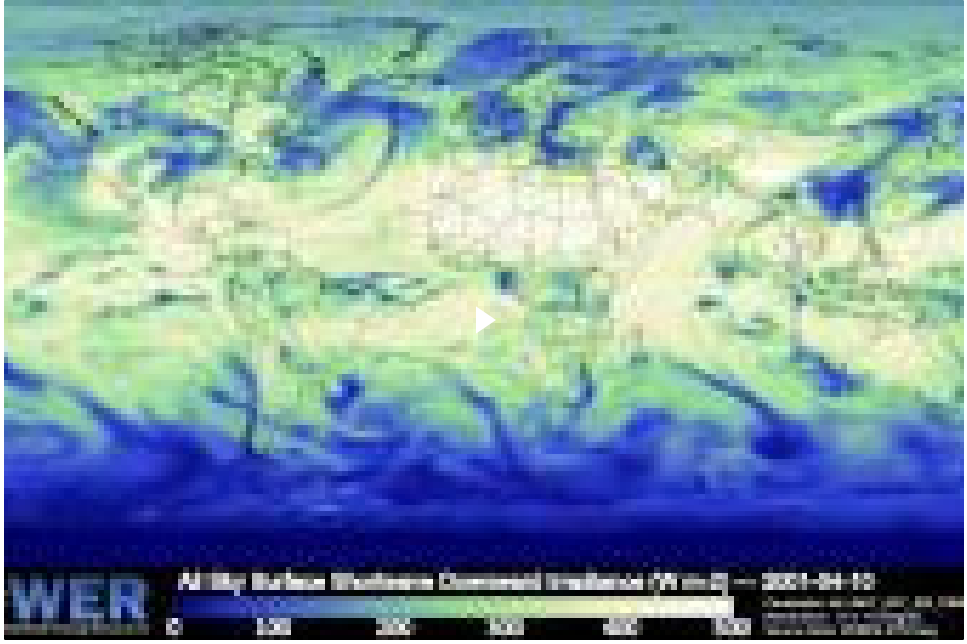
The solar based data/parameters in POWER are based upon satellite observations with subsequent inversion to surface solar insolation by NASA's Global Energy and Water Exchange Project (GEWEX) /Surface Radiation Budget (SRB) Release 4 for 1984 through 2000. From 2001, we now provide CERES SYN1deg until three months before present time. Like in previous versions, POWER continues to provide support for Near Real Time (NRT) availably with FLASHFlux. and NASA's CERES Fast Longwave And Shortwave Radiative project (FLASHFlux).

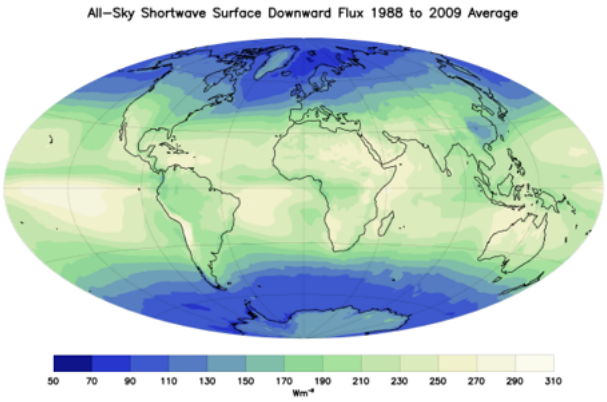
The animation to the right displays solar irradiance interacting with the atmosphere.

Meteorology Sources

The meteorological data/parameters in POWER are based upon the Goddard's Global Modeling and Assimilation Office (GMAO) Modern Era Retrospective-Analysis for Research and Applications (MERRA-2) assimilation model products and GMAO Forward Processing – Instrument Teams (FP-IT) GEOS 5.12.4 Near Real Time (NRT) products. The MERRA-2 data spans the time period from 1981 to within several months of real time; the GEOS 5.12.4 data span the time period from the end of the MERRA-2 data stream to within several days of real time. The MERRA-2 and GEOS 5.12.4 versions are essentially the same and thus discontinuities that are often apparent between different assimilation models are minimized.

The video to the right displays a all the types of observations that are assimilated over time to produce GEOS 5.12.4 and MERRA-2 data.





Time Averaged vs. Time Series

Some users require statistics from long-term averaged data parameters, like the image above:

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, as seen to the right:

- 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

Assessing POWER Data

Data Availability

POWER provides data at the underlying source data model's grid resolution while sill providing global data access.

The resolutions are 1.0° latitude by 1.0° longitude for the radiation data sets and ½° latitude by ⅝° longitude for the meteorological data sets.

The dashboard to the left displays a real-time overview of the Radiation and Meteorology data sources.

About POWER's Data Offerings: Hourly

The latest POWER versions include hourly-based source Analysis Ready Data (ARD). The hourly source data are from Clouds and the Earth's Radiant Energy System (CERES) and Global Modeling and Assimilation Office (GMAO), spanning 20 years from 2001. The hourly data will provide users the ARD needed to model the energy performance of building systems, providing information directly amenable to decision support tools introducing the industry standard EPW (EnergyPlus Weather file).

POWER's Data Offerings: Daily

The latest POWER continues to provide daily-based Analysis Ready Data (ARD). The daily source data are from Surface Radiation Budget (SRB), Clouds and the Earth's Radiant Energy System (CERES), and Global Modeling and Assimilation Office (GMAO), spanning 40 years for meteorology available from 1981 and solar-based parameters start in 1984.

Evaluating Data Uncertainty

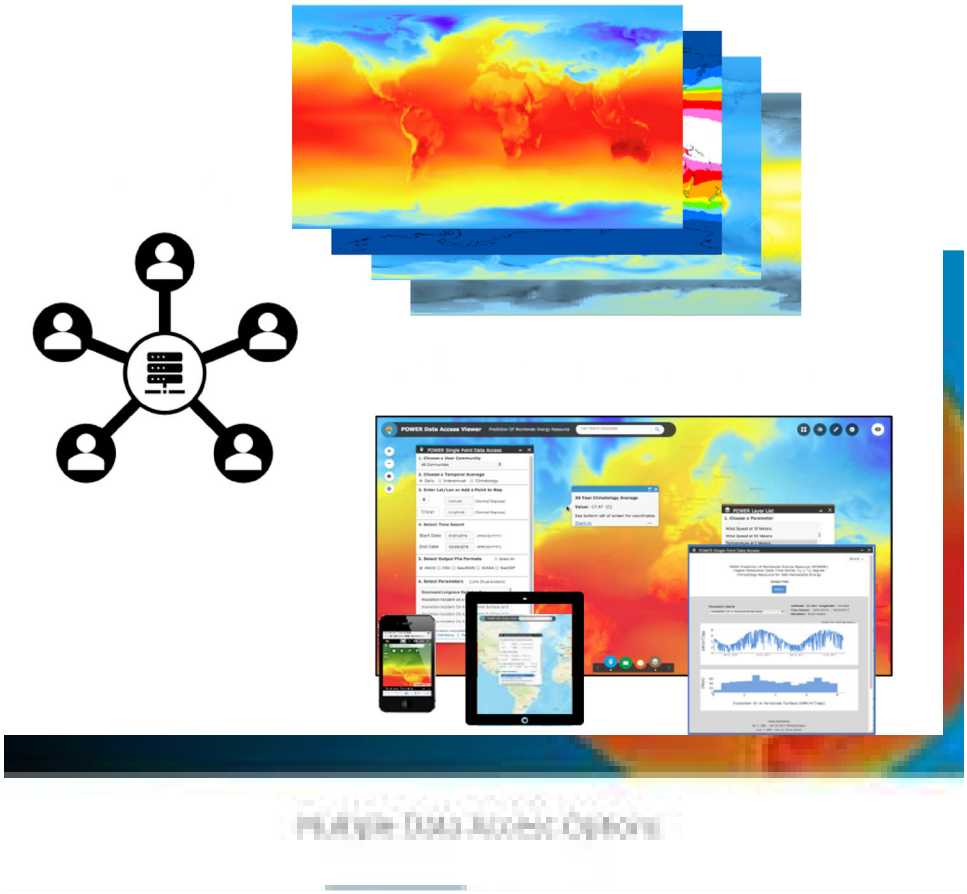
You can scroll through this Map Journal to learn more about how POWER evaluates biases in its data.

How Can 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



Multiple Data Access Options

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.

POWER's Data Access Viewer

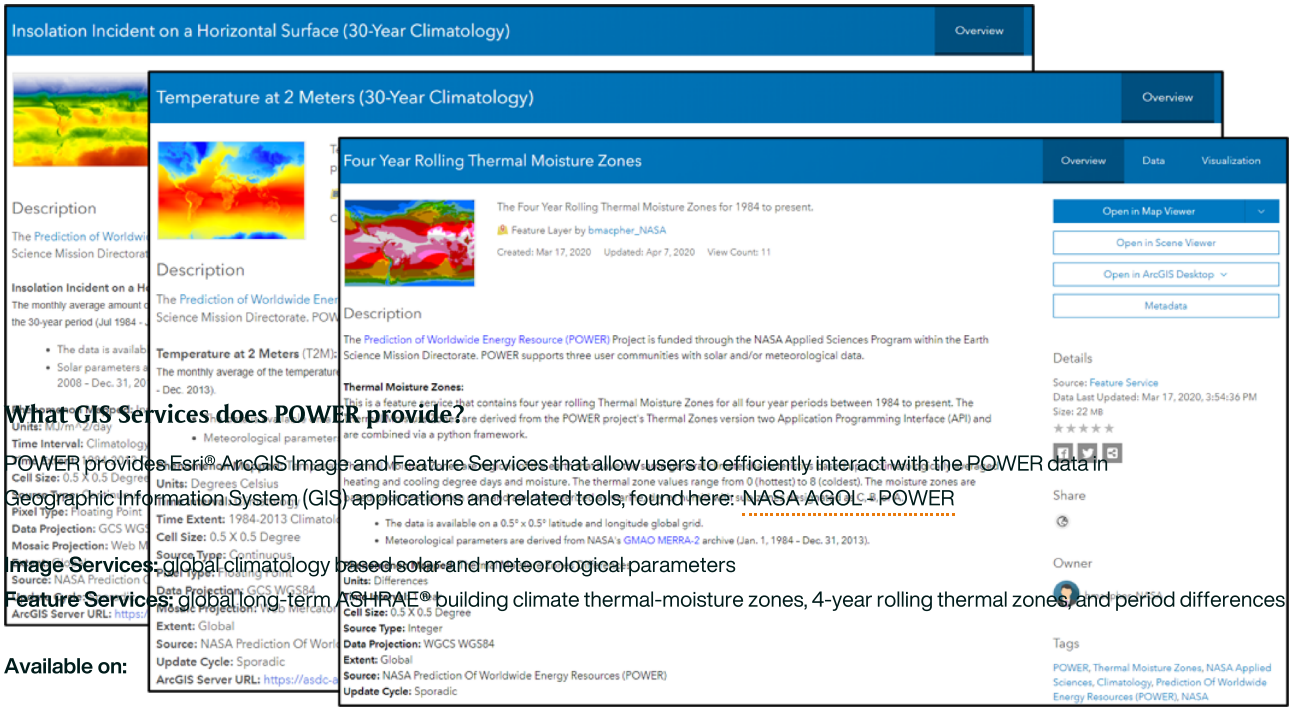
API

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!

If you'd like to explore the API further, please check out the Esri Jupyter Notebook below, created by the POWER Team to help users learn how to utilize POWER's API. You can download the resource and open it with your preferred Python application.

NASA POWER API Access Notebook



What GIS Services does POWER provide?

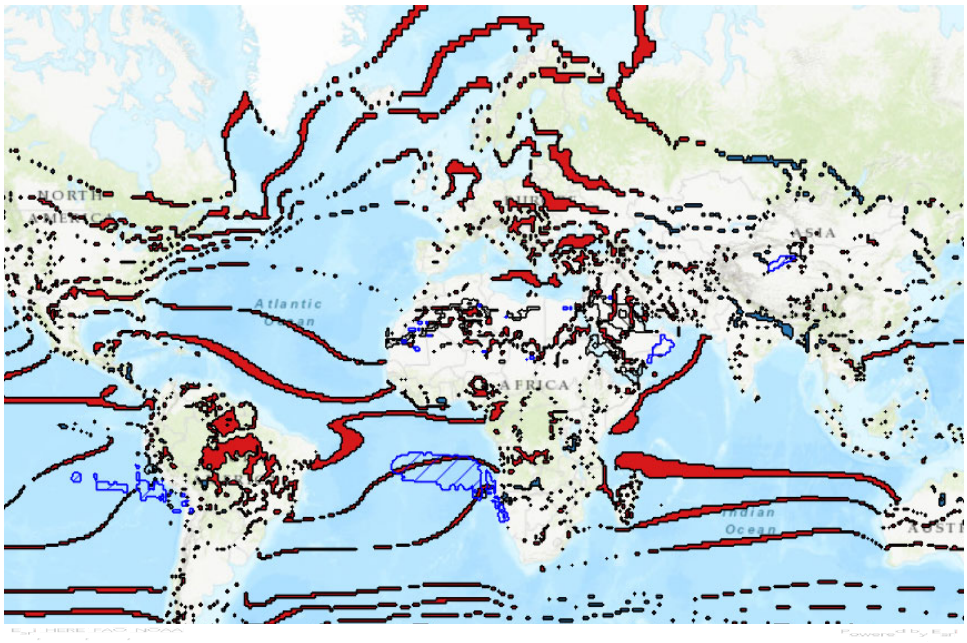
POWER provides Esri® ArcGIS Image and Feature Services that allow users to efficiently interact with the POWER data in Geographic Information System (GIS) applications and related tools, found here: NASA AGOL POWER

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:

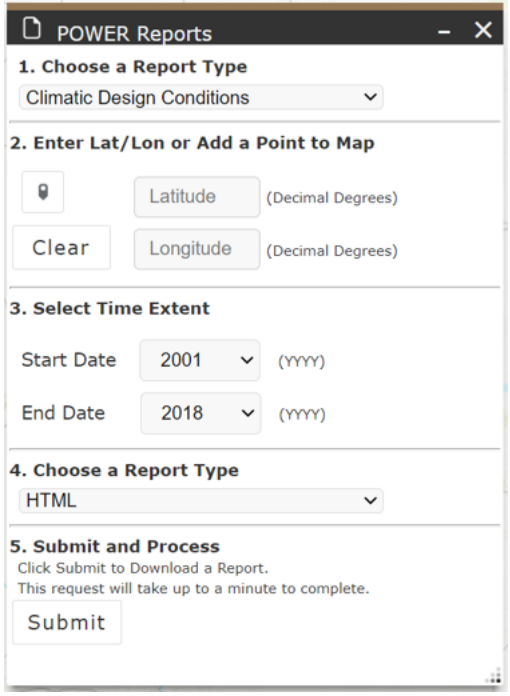
- NASA ArcGIS Online (AGOL)
- ASDC ArcGIS Online
- Esri Living Atlas



Building Climate Thermal Moisture Zones Differences

This is a web-map that compares two periods of Thermal Moisture Building Climate Zones for two fifteen year periods 1984-1998 and 2004-2018.

- Building Climate 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.



POWER's Analytic Data Services

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

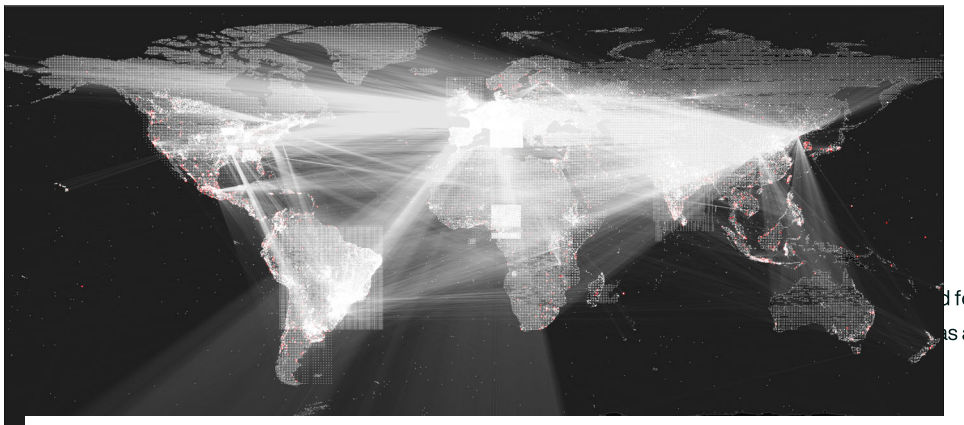
Windrose Report

- Average wind speeds reported in tables classified according to NREL using wind energy thresholds

POWER's Timeseries Anomaly

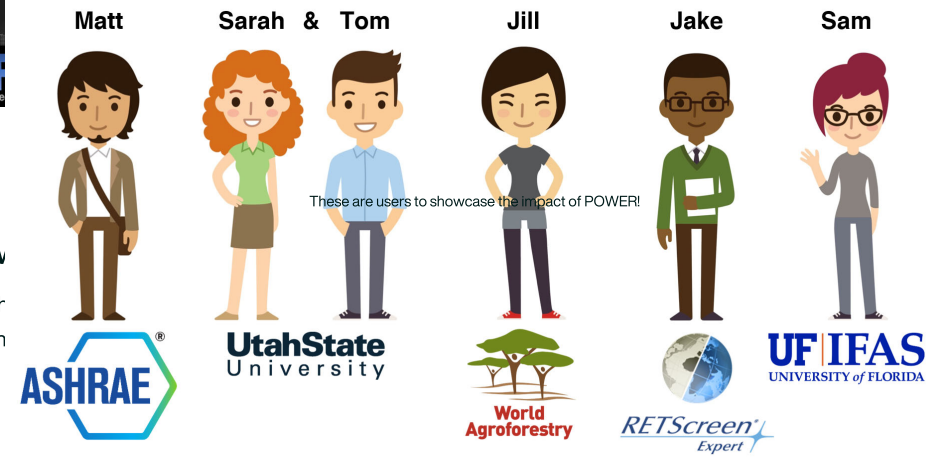
Here is another example of a POWER-generated report. This report is a way to visualize the trends of data over time.

POWER User Stories & Communities



Access to the POWER Web Services are free and anonymous; we collect a variety of service usage metric information to understand data requests and the changing needs of the base over time.

d for data volume, and API request
s a function of time of the web site



W

Th ocieties, Government, Research, an

- g, Refrigerating and Air-
  ), the POWER project has implemented the, recently adopted, ASHRAE's Standard 169-2013 to produce Building Thermal Moisture Zones. Additionally, POWER is developing the building design conditions report as the indicators report.
- **Utah State University:** The POWER project works with universities and studies to help support research. In this case the students picked 15 locations and we provided hourly (T2M, RH2M, WS10M, and ALL_SFC_SW_DWN) data for student research in reenable energy.
- **World Agroforestry:** The POWER project supploys data to researchers at World Agroforestry Centre. They are using POWER data in R to test the climate resilience of different farming methods in Africa.
- **RETScreen:** The POWER project has worked with Natural Resources Canada (NRCan) to have the RETScreen Clean Energy Management Software (RETScreen Expert) embed POWER climatology data and direct Application Programing Interface (API) integration of POWER's daily and hourly time series data. This direct data integration allows every RETScreen user has access to POWER Data and start to use the software immediately. Additionally, POWER has entered into a Space Act Agreement for RETScreen Award process where POWER and RETScreen will nominate recipients for Awards in sustainable buildings.
- **UF-IFAS:** The POWER project maintains the ability to download International Consortium for Agricultural Systems Applications (ICASA) 1.0 format based on ongoing collaboration with Dr. Gerrit Hoogenboom at University of Florida, Institute of Sustainable Food Systems, Decision Support System for Agrotechnology Transfer (DSSAT) program. The DSSAT software can directly use POWER Data in the ICASA format to support Crop Simulation Modeling (CSM). Institute of Food and Agricultural Sciences (ifas.ufl.edu) is researching energy in Africa using that data standard.

POWER Communities

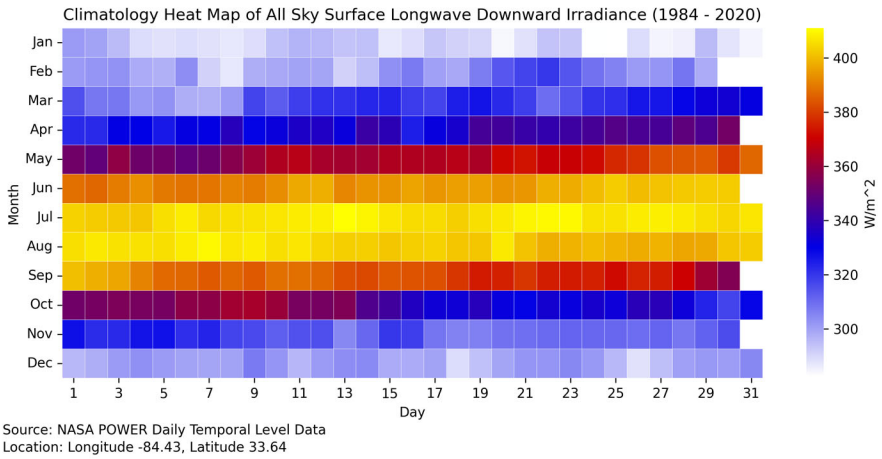
POWER Users Map

The POWER Project improves the accessibility and usage NASA Earth Observations (EO) supporting community research in three focus areas:

1. Renewable Energy
2. Sustainable Building
3. Agroclimatology

POWER supports communities with:

- Public open discovery, efficient access, and convenient distribution of NASA Earth Observations data through an integrated services suite.
- 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.

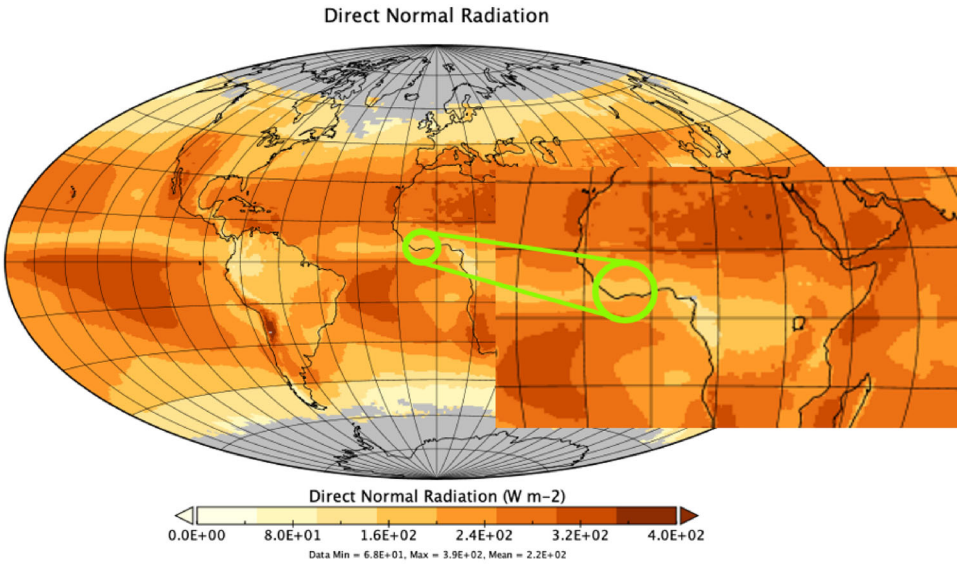


Renewable Energy Development

POWER's Renewable Energy Archive is designed to provide access to parameters specifically tailored to assist in the design of solar and wind powered renewable energy systems.

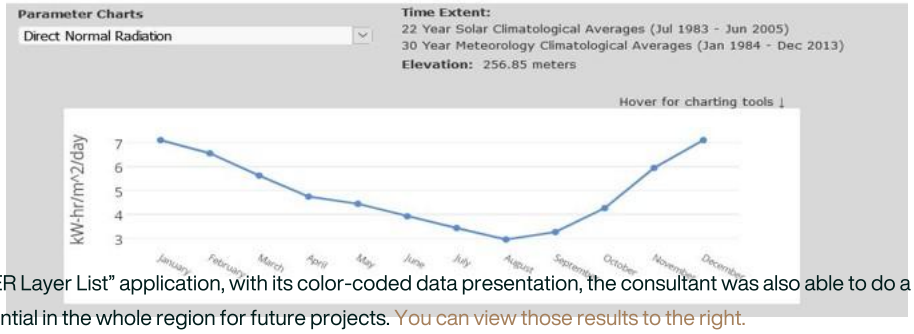
The Renewable Energy (RE) solar and meteorological parameters are available as climatologically and inter-annual (monthly and annual) averaged values, as well as in a daily time series format for user selected grids. All RE parameters are provided on the original resolution grid, which is dependent on the parameter. The climatologically averaged parameters are calculated to support applications such as solar cooking, sizing solar panels, and sizing battery backup systems. The monthly and annually averaged parameters are provided as monthly and annual averaged values by year for each of the base solar and meteorological data parameters. The daily and hourly time series include the basic solar and meteorology parameters as well as additional calculated parameters such as diffuse and direct normal radiation.

The image to the right shows a daily based climatology of longwave irradiance used to visualize climatic trends over time. This example is for Atlanta, Georgia, USA.



User Story: West African Community

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:

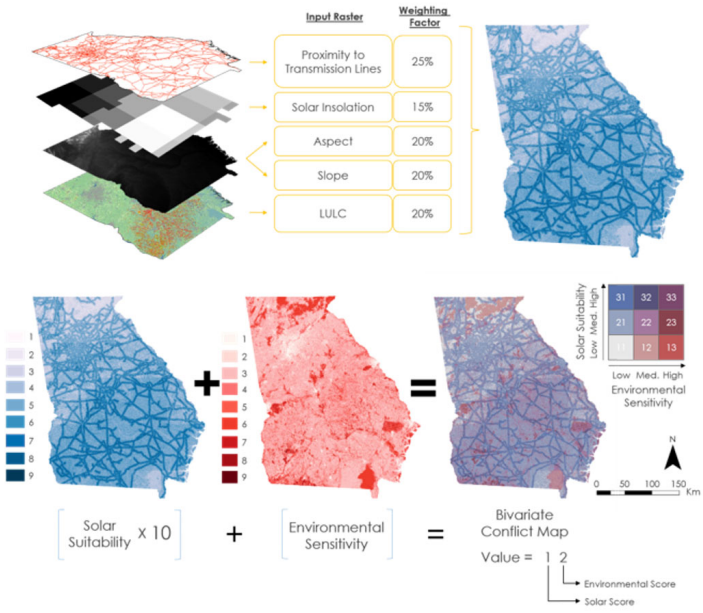


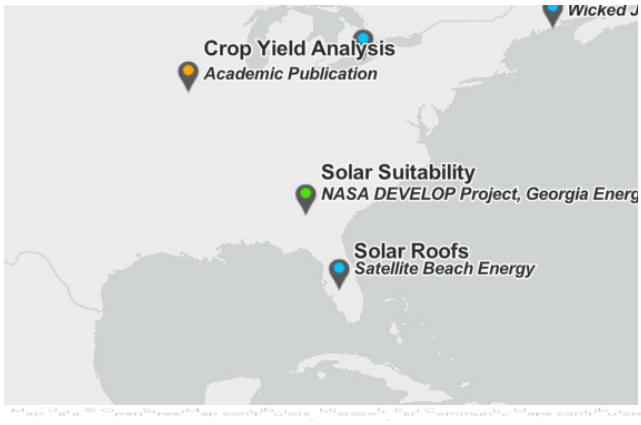
Going to the “POWER Layer List” application, with its color-coded data presentation, the consultant was also able to do a quick visual survey of solar energy potential in the whole region for future projects. You can view those results to the right.

The conclusion of the investigation was that, although the location had hot and humid tropical weather, frequent cloud cover significantly lowered the Direct Normal Radiation (DNR) which is needed for the efficient operation of photovoltaic modules. Annual average daytime cloud amount >60%; with 9 of 12 months > 50% .

NASA’s DNR data revealed that the solar array was actually performing up to specifications, though not up to expectations. Local management made the necessary adjustments to power usage and billing, and were able to move forward better informed.

Photo Credit: Friesen Energy





User Story: NASA DEVELOP Project, Georgia Energy III

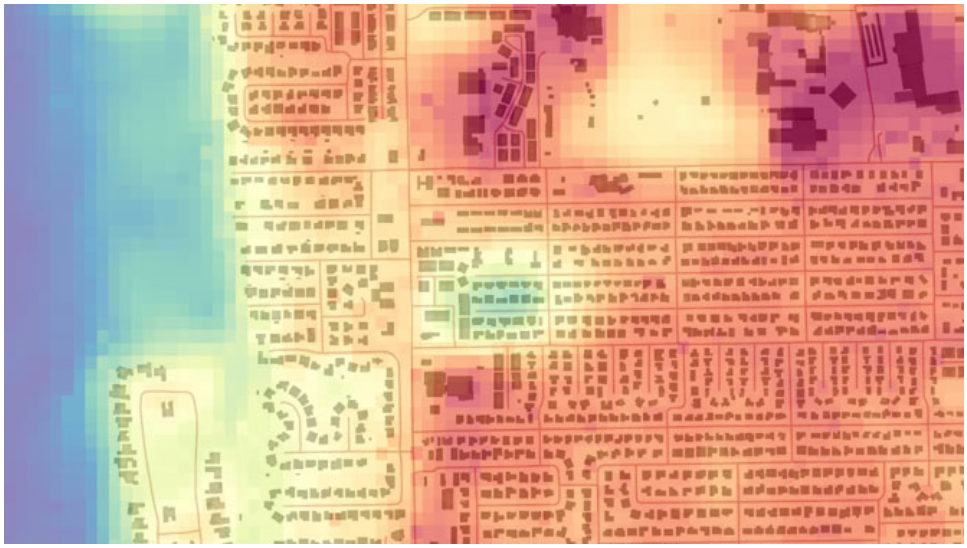
The rapid expansion of the solar industry across the state of Georgia has a detrimental effect on the habitats of keystone and threatened species, such as the gopher tortoise and the American black bear.

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.

DEVELOP

Identifying Habitat and Solar Site Conflict in Georgia by Developing an Environmental Sensitivity Public Mapping Tool 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...

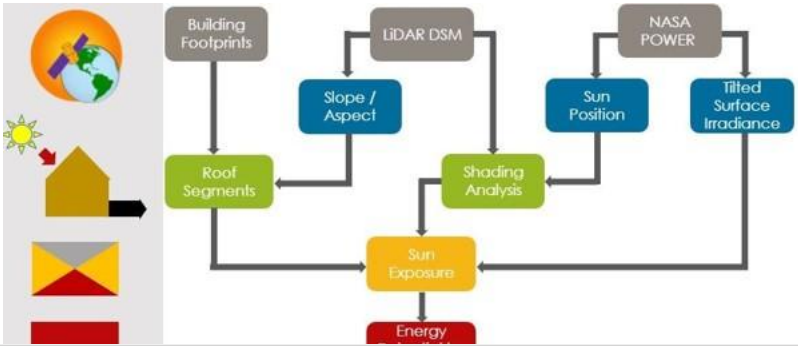
https://develop.larc.nasa.gov/2020/summer/GeorgiaEnergyIII.html



User Story: NASA DEVELOP, 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 NASA DEVELOP Team estimated rooftop solar power potential using a high-resolution Light Detection and Ranging (LiDAR) dataset and a POWER dataset to assist Satellite Beach in reaching their solar renewable energy goals.



DEVELOP

Restructuring the Energy Balance in Satellite Beach, Florida, by Quantifying Solar Energy Production Potential using NASA POWER Data Products and LiDAR The City of Satellite Beach, Florida, has committed to supplying 100% of its energy use from renewable energy, primarily...

https://develop.larc.nasa.gov/2020/summer/SatelliteBeachEnergy.html

Building Energy Efficiency

POWER's Sustainable Buildings Archive is designed to provide industry-friendly parameters for the buildings community, to include parameters in multi-year monthly averages.

The Sustainable Buildings (SB) solar and meteorological parameters are available as climatologically, monthly, and annually average values, as well as in a daily time series format. All parameters are provided on the original resolution grid, which is dependent on the parameter. The climatologically averaged parameters are calculated to support the preliminary design and site selection for building projects. Monthly and annually averaged parameters are provided as monthly and annual averaged values by year. The daily time series include a range of the basic solar and meteorology parameters as well as additional calculated parameters such as diffuse and direct normal radiation, heating and cooling degree days, climate zones, etc. The hourly time series is a smaller subset of the solar and meteorology parameters.

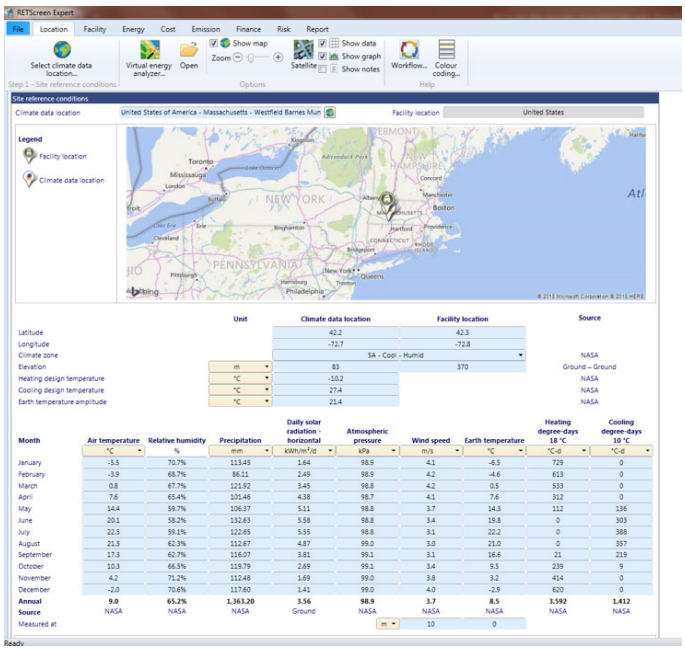
User Story: Wicked Joe Coffee

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.

Space For U.S. | NASA Applied Sciences

To build Wicked Joe's solar wall, designers used the RETScreen Clean Energy Management Software, an open-access energy analysis tool from Natural Resources Canada. The RETScreen software automatically fetches climate and weather data from NASA's Prediction of...

https://www.nasa.gov/SpaceforUS/?story=4079



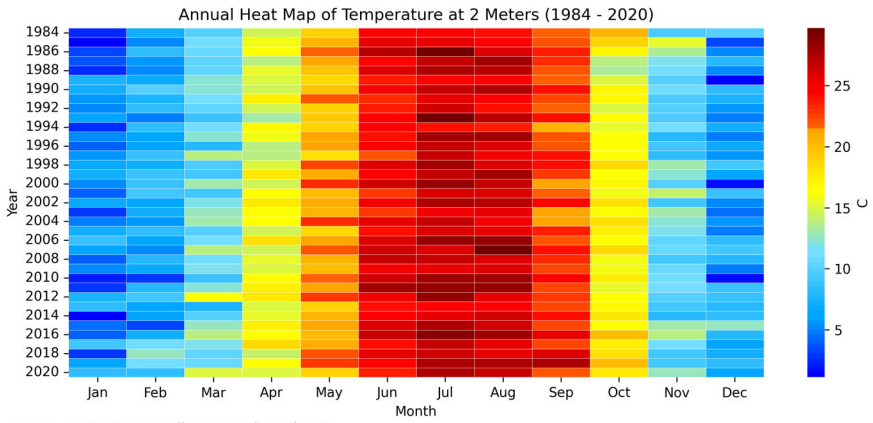
POWERUserStories_Map

User Story: RETScreen/The 3M Company

Natural Resource Canada's *RETScreen® Clean Energy Management Software* serves NASA POWER data parameters directly to its costumers.

RETScreen® is the world's leading clean energy decision-making software, with 575,000+ users in all countries, growing at 50,000+ new users per year. The software provides energy efficiency, heating/cooling, and power generation/cogeneration data to owners and managers of residential, commercial, institutional, and industrial buildings. NASA time series complements surface measurements data to within several days of real time fed into analysis package

Users of RETScreen® software include the University of Michigan and the 3M company. The 3M Company manages 11 facilities using RETScreen® and POWER (CERES FLASHFlux) data: "The NASA datasets we use are critical to our energy analysis since they are used as major variables that predict our energy use."



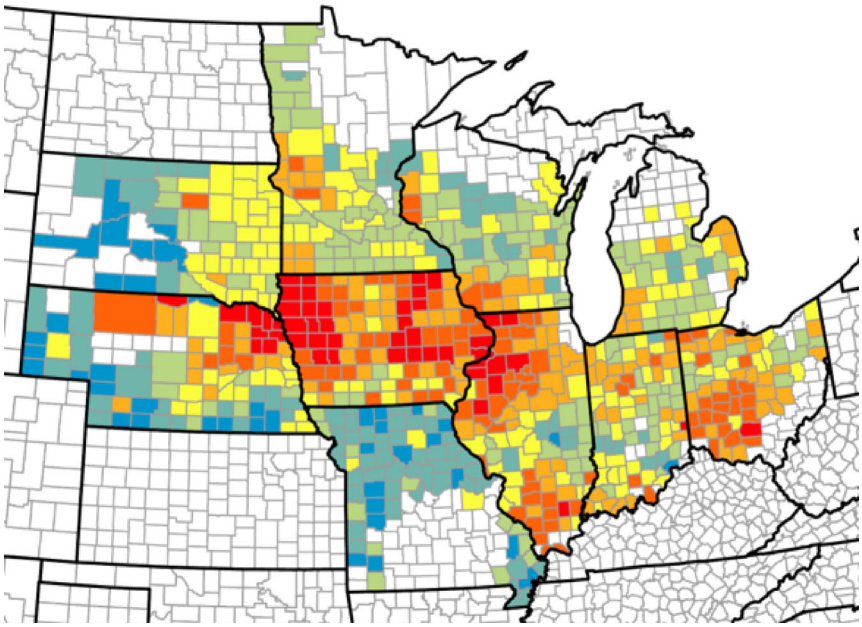
Source: NASA POWER Daily Temporal Level Data
Location: Longitude -84.43, Latitude 33.64

Agroclimatology Applications

POWER's Agroclimatology Archive is designed to provide web-based access to industry-friendly parameters formatted for input to crop models contained within agricultural DSS.

The Agroclimatology (AG) solar and meteorological parameters are available as daily mean time series formats. All parameters are provided on the original resolution grid, which is dependent on the parameter. The daily time series include the basic solar and meteorology parameters to support agricultural decision support tools such as the Decision Support System for Agro-technology Transfer. The hourly time series is a smaller subset of the solar and meteorology parameters.

The image to the right shows a monthly based time series of Temperature at 2 meters used to visualize climatic trends over time. This example is for Atlanta, Georgia, USA.

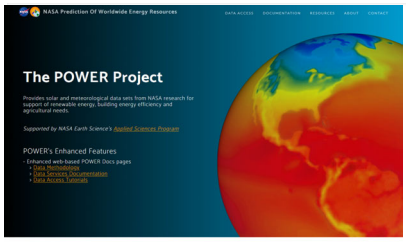


Map data © OpenStreetMap contributors, Microsoft, Esri Community Maps contributors, Map layer by Esri Powered by Esri

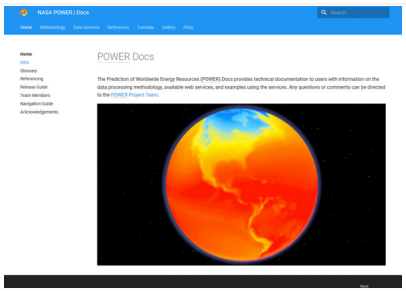
User Story: Crop Yield Analysis

In the article 'The contribution of solar brightening to the user maize yield trend', published in *Nature Climate Change*, POWER Data was used to help explain a 25% productivity increase in US corn-belt states.

Learning More about POWER



Multiple Data Access Options



POWER Homepage (1), Docs (2), Dashboard (3), and API Pages (4) - ALT TEXT WITH LINK

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

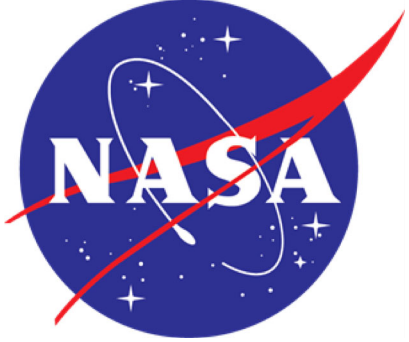
1. **Homepage:** the project overview with links to all POWER resources.
2. **Docs:** the projects documentation and methodology providing accurate and detailed information to users.
3. **Dashboard:** a series of dynamic web pages that provide real-time status information on data processing.
4. **Pages:** the API landing pages that use the OpenAPI specification to create interactive pages for the API endpoints.

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:

NASA ARSET: Introduction to Earth Observations (EOs) for Energy Management, Part 1/4

- 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

> *Email POWER at larc-power-project@mail.nasa.gov*



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