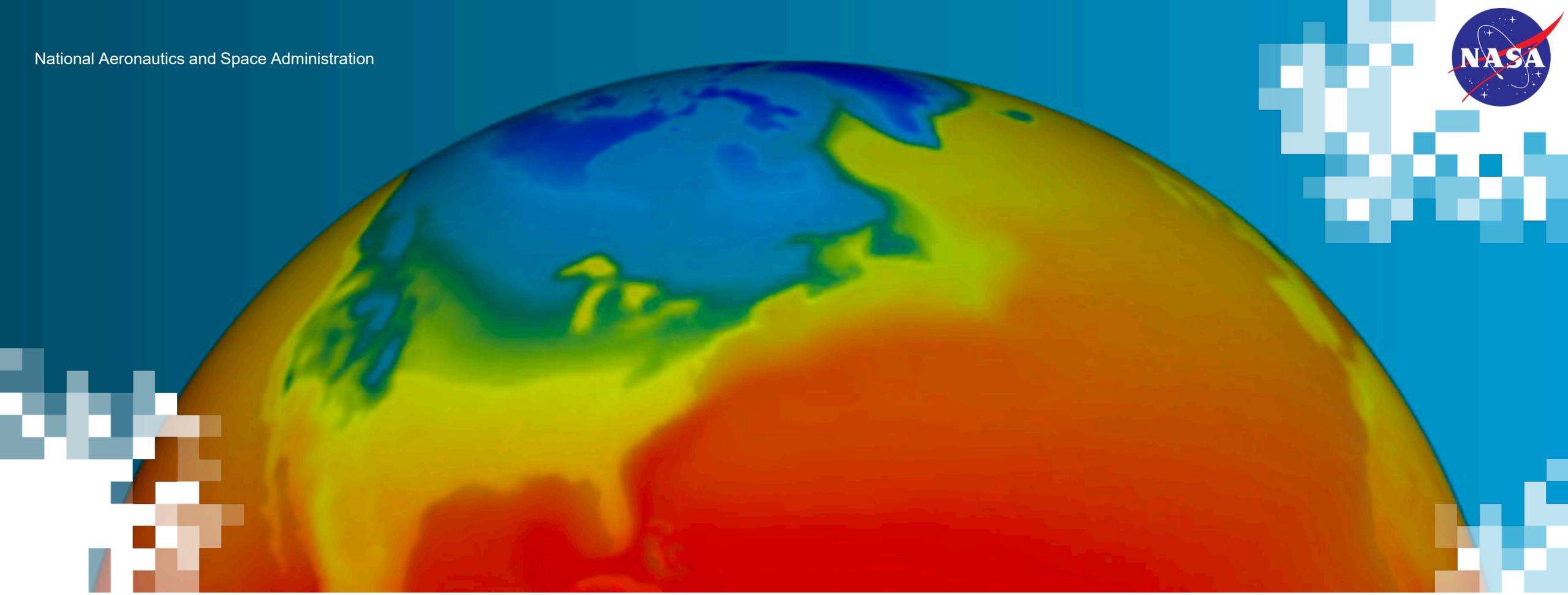
National Aeronautics and Space Administration



Introduction to the POWER Project

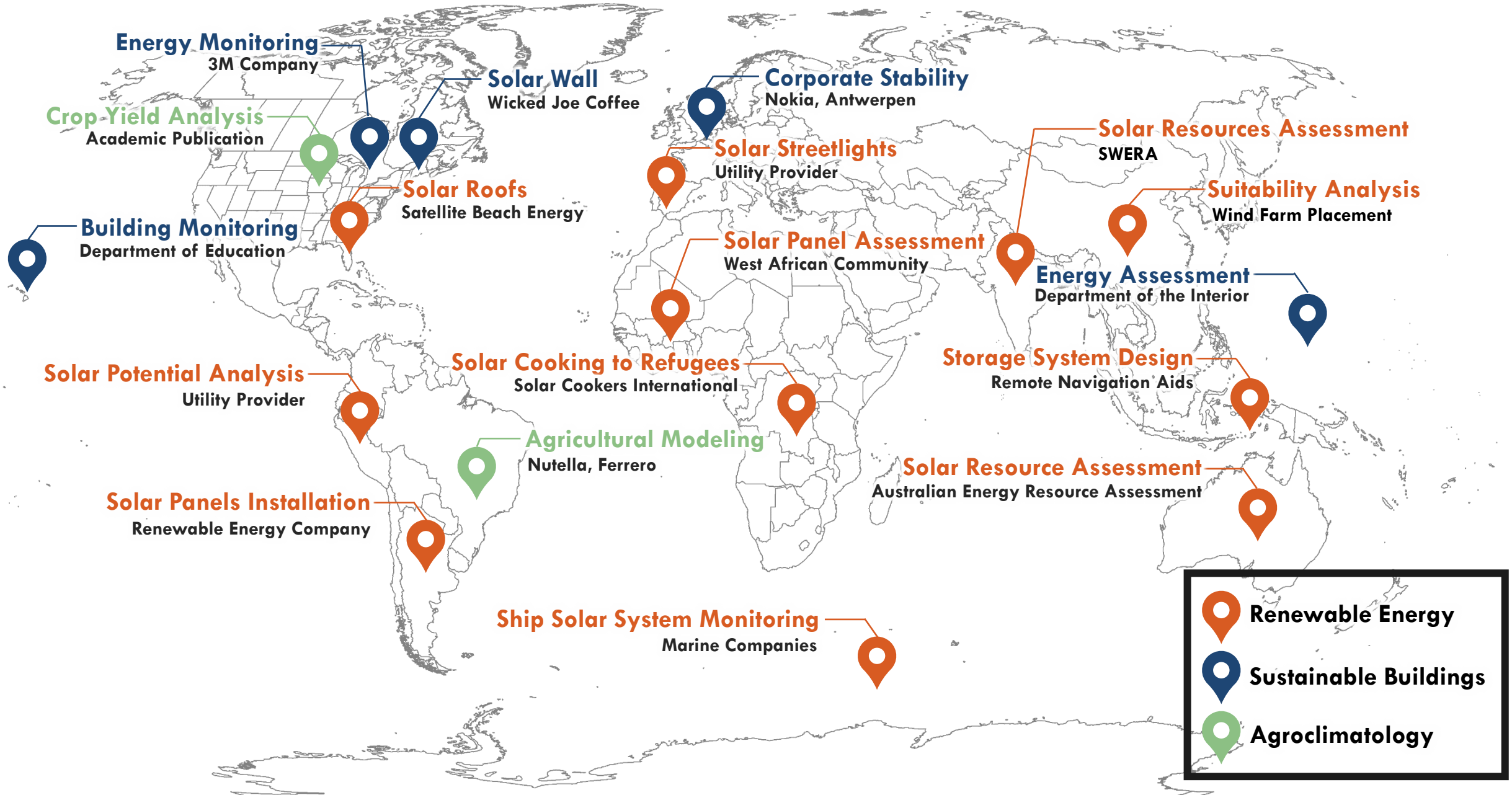
2022 ASA-CSSA-SSSA International Annual Meeting

November 2022

POWER

Prediction Of Worldwide Energy Resources

What are POWER's Impacts on the Community?

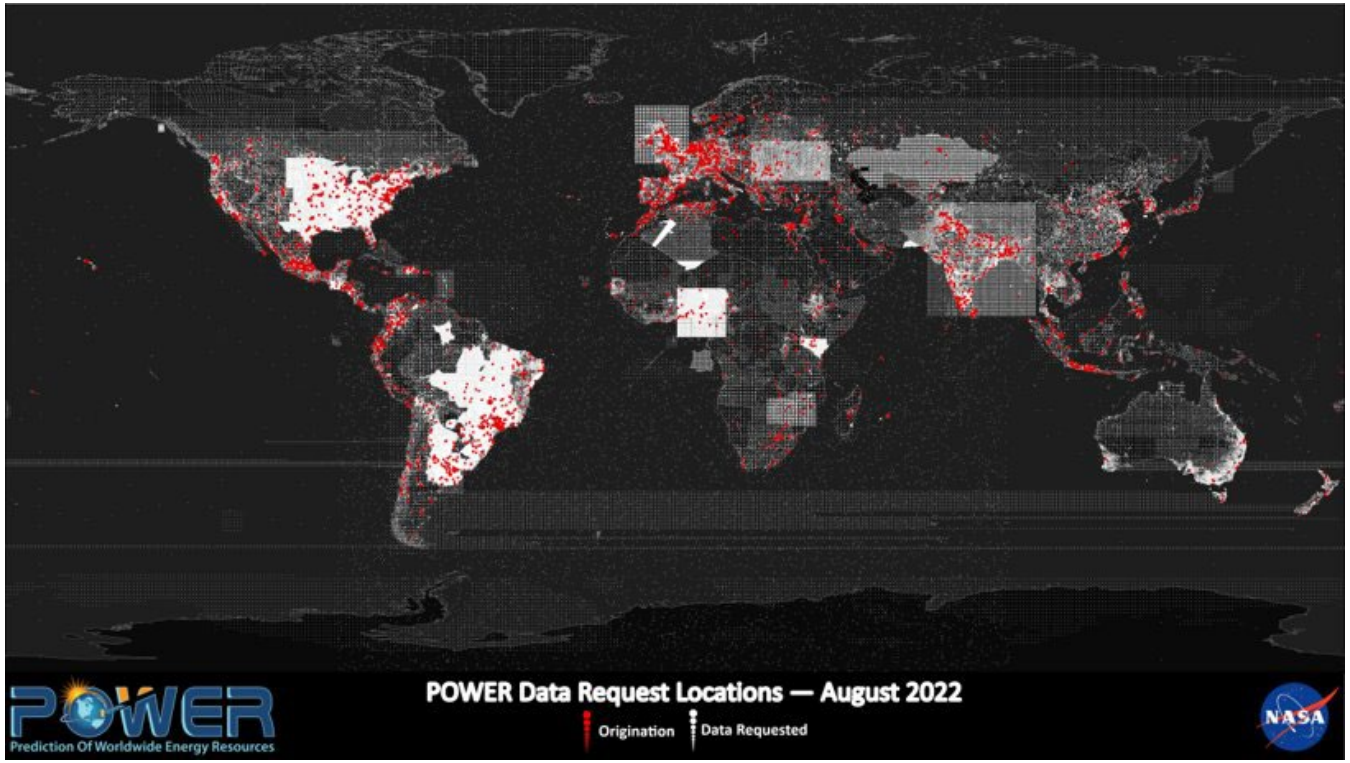


POWER's User Metrics

Access to the POWER Web Services is free and anonymous, but we collect a variety of metrics to assess usage.

- Metrics include: data sources, access methods, user's approximate location, the user's data location, and server performance information, etc.
- POWER fulfills 4+ million data requests for over 17,000 unique users per month
- The POWER metadata object on NASA's Open Data Portal in the Earth Science category is number two (2) with 54,0017 views!
- On NASA ArcGIS Online the POWER project has one of the highest viewed content items with over 1,433,000 views!

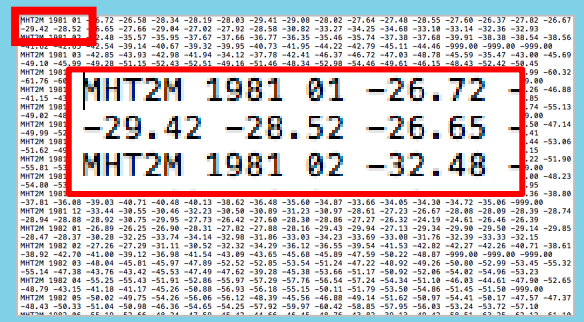
Before Geospatial Services		After Geospatial Services	
1999/06/01 to 2018/05/01		*2018/05/01 to Present*	
Requests	35,988,533	**Requests**	237,937,342
Data Volume	3,612 GB	**Data Volume**	31.17 TB
**The data volume is available from 6/01/2019.*		**Unique Users**	560,189



POWER's Data Distribution Improvements

2014 to 2018

ASCII/Text Files



Web accessible data access
Fast response time for data requests

Parameter structure:

- **64,800** (180 x 360) ASCII Files
- **259,200** (360 x 720) ASCII Files

2018 to 2021

NetCDF

- CF Compliant
- Time Series Chunked
- Limited File Compression
- Multiple Parameters in File
- Common Variables/Dimensions
- Data Update by Data Parameter
- Direct Data Access via OPeNDAP

2021 to Present

Zarr (Cloud Optimized)

~10TB+ Managed Archive

- Time Series Chunked
- Advanced File Compression
- Folder/File Based Parameters
- Common Variables/Dimensions
- Optimized for Cloud Storage and Disks
- Independently Editable Metadata as JSON
- Data Update by All Parameters Concurrently
- Direct Access via Cloud-Based Storage

esri OPeNDAP aws

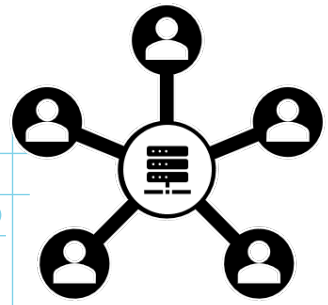
Open Data on AWS Data Exchange

POWER's Analysis Ready Data (ARD) – Access Methods

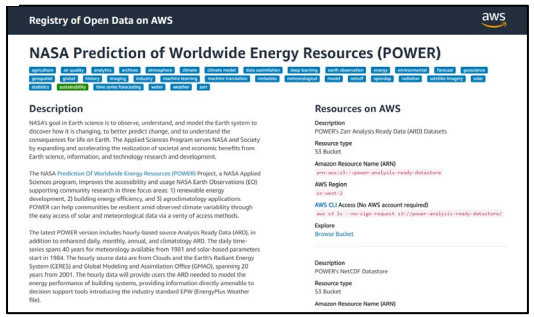
POWER provides an integrated services suite to efficiently access environmental data, pre-computed analysis reports for management of energy production, and monitoring energy efficiently systems, as source data for modeling software.

- 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 multiple services:
  - Application Programming Interface (API)
  - AWS Open Data Registry (S3 Hosted)
  - Geospatial Feature & Image Services
  - OPeNDAP Services

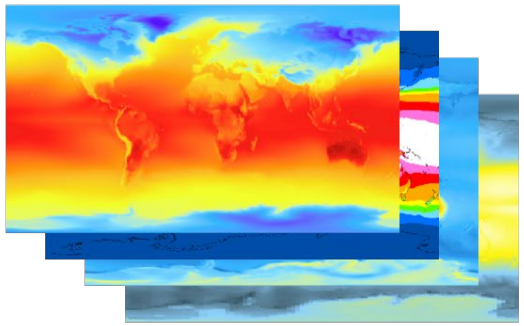
APIs



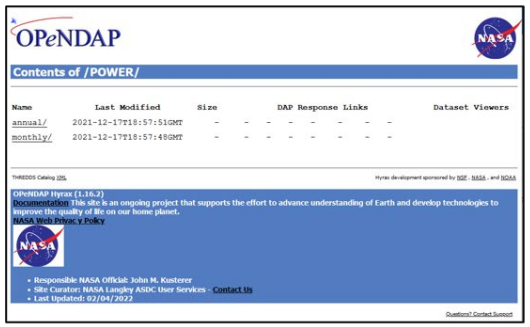
AWS ODR



Geospatial Services



OPeNDAP



POWER's Application Programming Interfaces (API)

The POWER Application Programming Interfaces (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:

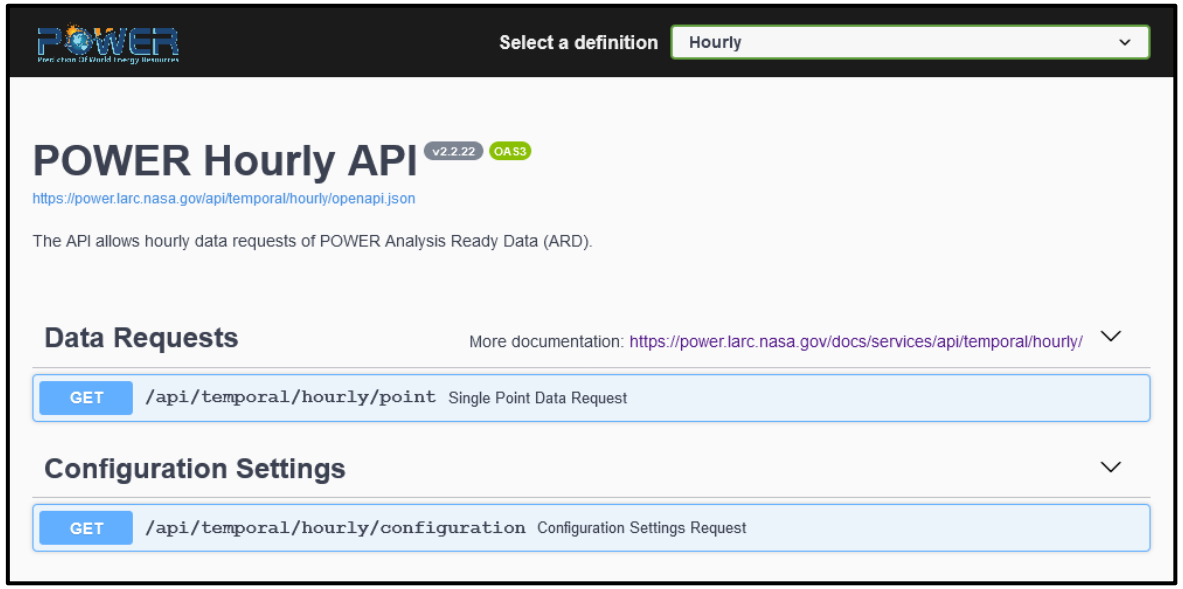
- Complete access to entire database without any other services
- Direct integration into external applications; users can submit a request and a response will be returned without leaving their application!
- User specified subsets converted into user community specific units and provides formats like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

Data Requests: ~140,000 a Daily

Follow Open Standards: OpenAPI, GeoJSON, and more

Links:

- https://power.larc.nasa.gov/api/pages/
- https://power.larc.nasa.gov/docs/services/api/

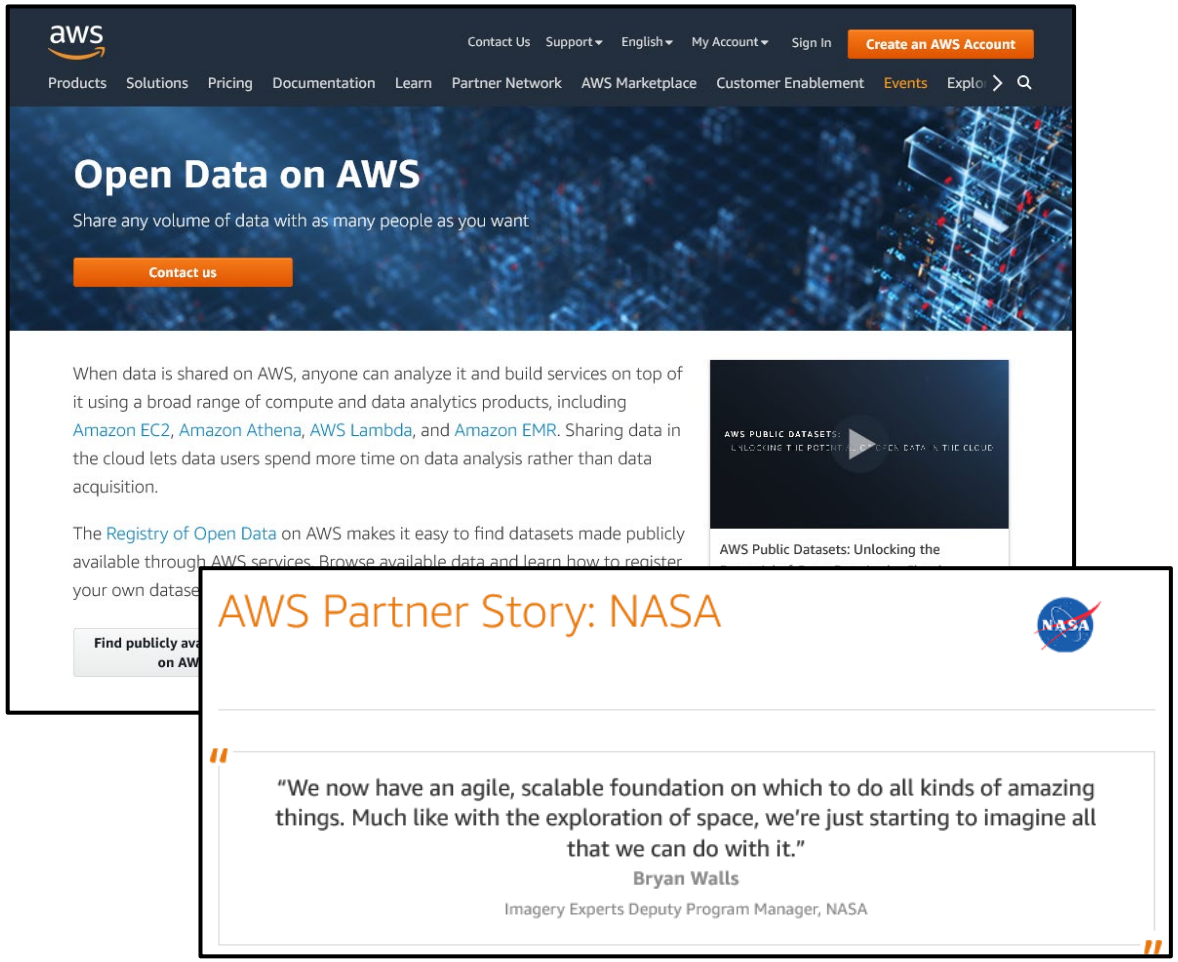


Example API Request:
https://power.larc.nasa.gov/api/temporal/daily/point?start=20210801&end=20210830&longitude=-4.75&latitude=-4.750&&community=ag&parameters=ALLSKY_SFC_SW_DWN,T2M

POWER Data in the Cloud

POWER is a part of a NASA Space Act Agreement with EOSDIS Earthdata.

- This Space Act enables direct data store access via cloud-based services.
  - Allowing users to directly access the POWER Analysis Ready Data (ARD) of ~8.5TB
  - The ARD grows at ~.5 TB/Year
  - The data is:
    - Cloud and Analysis Optimized
    - Have Community-Driven Parameters
    - Machine Learning Ready
  - Enable interactive tutorials with large amounts of data
- The POWER data archive is listed in the AWS Open Data Portal (sustainable data initiative).



Geospatial Feature & Image Services

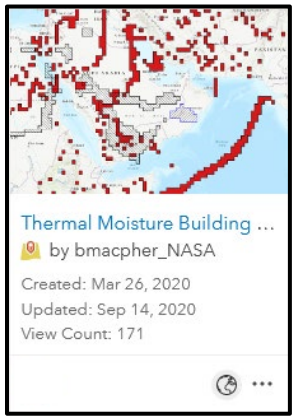
POWER provides Esri® ArcGIS Image and Feature Services that allow users to efficiently interact with the POWER data in Geographic Information System (GIS) applications and related tools.

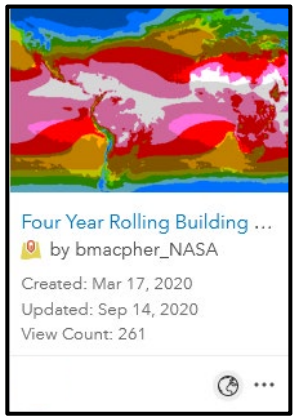
- **Image Services:** new image services for annual radiation, annual meteorology, monthly radiation, and monthly meteorology.
- **Feature Services:** global long-term ASHRAE® building climate thermal-moisture zones, 4-year rolling thermal zones, and period differences

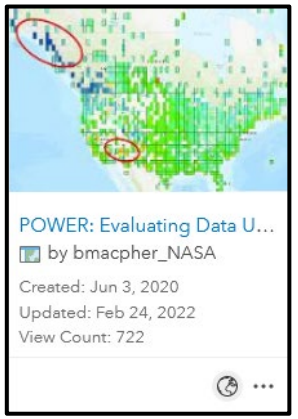
Available on:

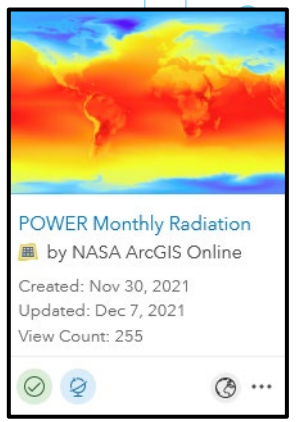
- Esri Living Atlas of the World
- NASA ArcGIS Online (AGOL)
- ASDC ArcGIS Enterprise

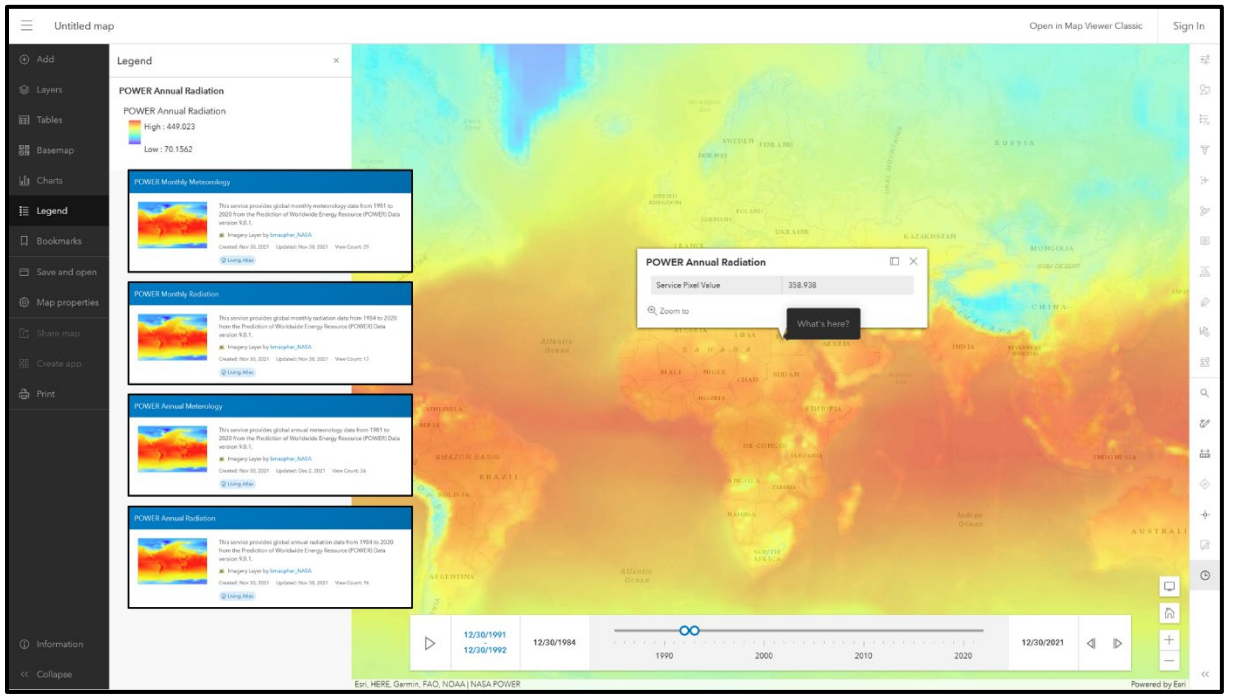
Hyperlink: NASA AGOL - POWER











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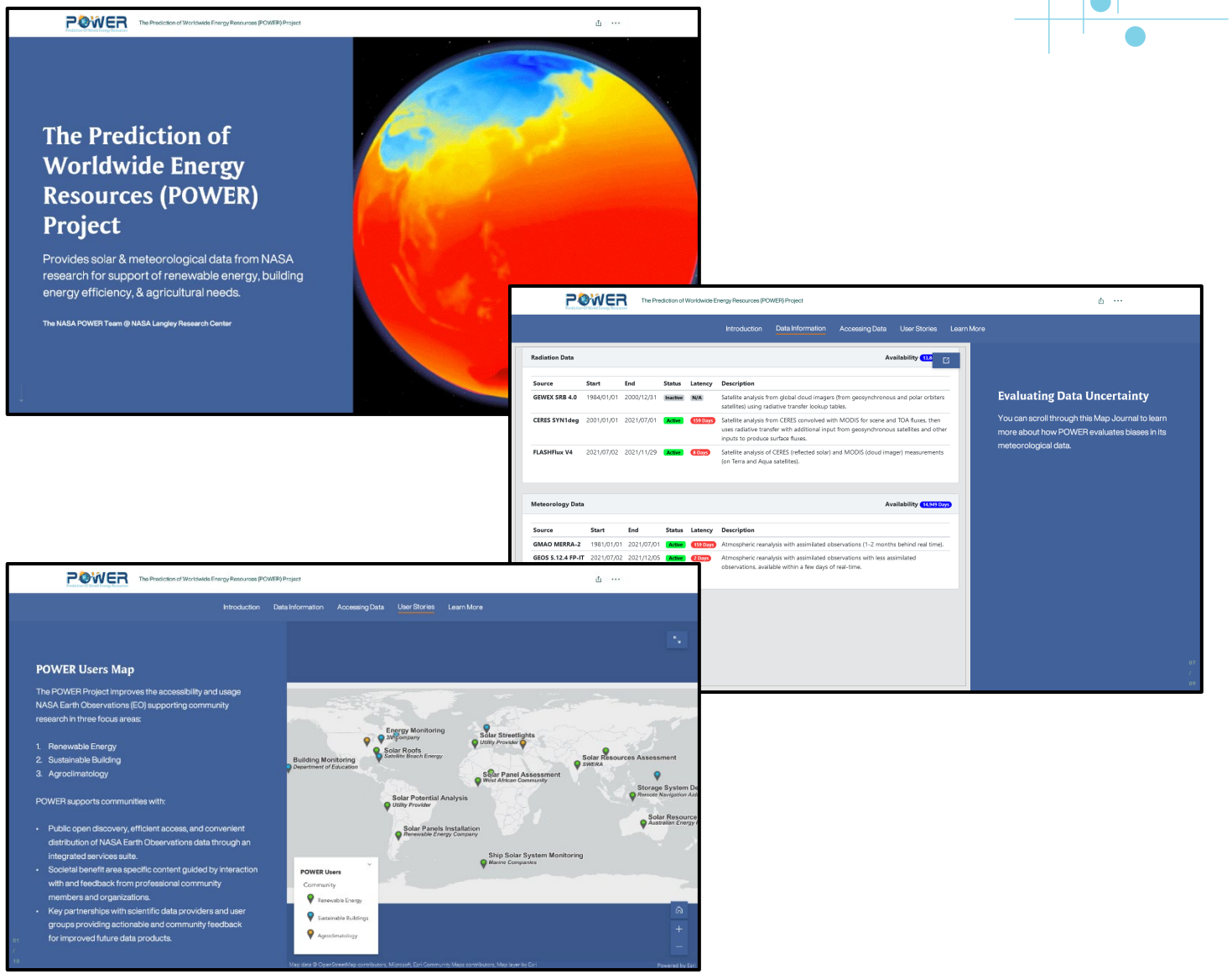
ASHRAE®: is a registered trademark of the American Society of Heating, Refrigeration and Air Conditioning Engineers

Want to Learn More? Check out POWER's StoryMap.

The POWER Team has developed an Esri® ArcGIS StoryMap.

- Through text, GIFs, videos, and interactive map content, viewers can become more familiar with the project.
- By scrolling through the StoryMap, users learn more about the POWER Project, its data sources, how to access POWER data, POWER's communities and users, and how to discover more POWER-related information.
- Link: https://arcg.is/0Xe851

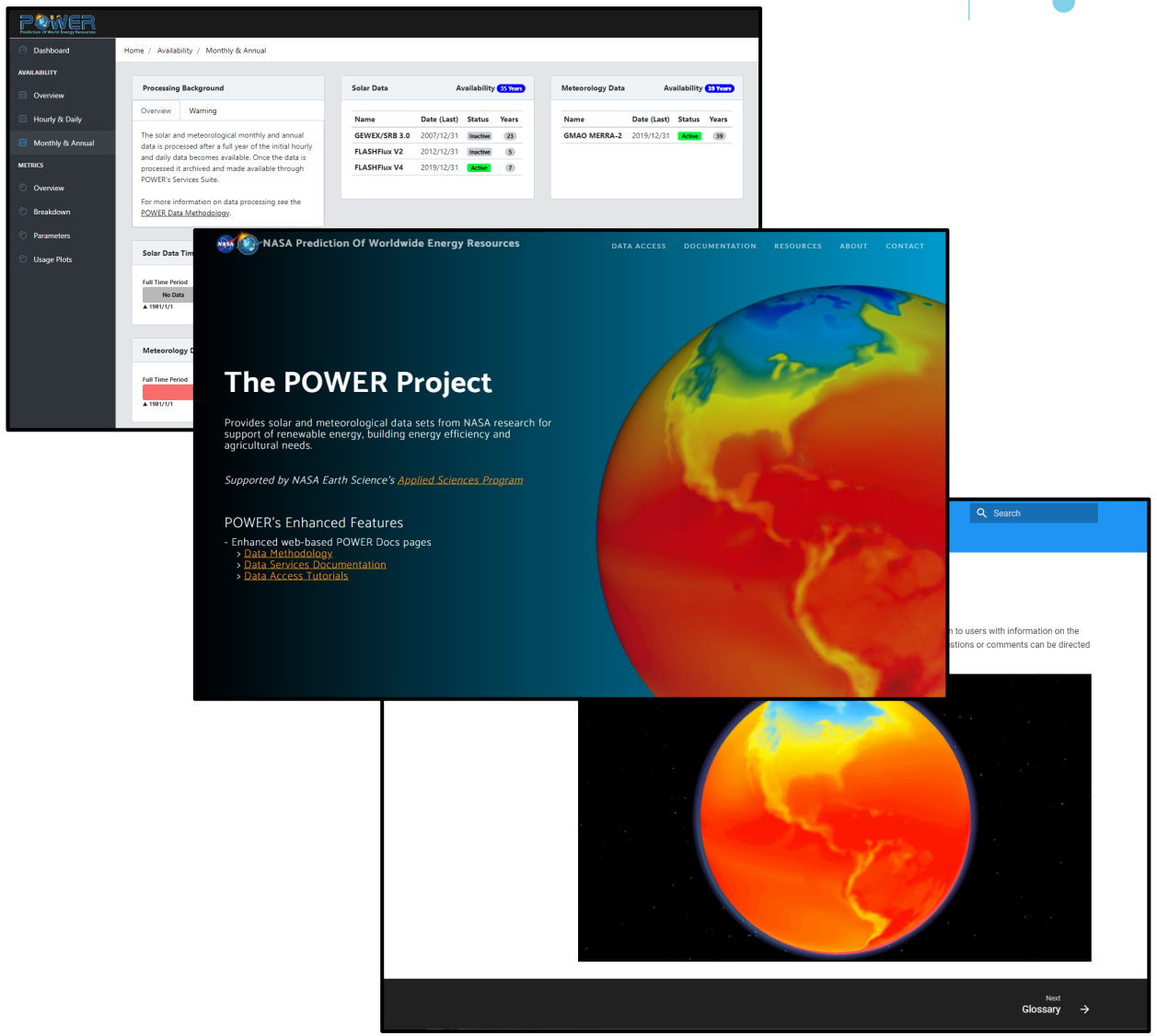


Where is the POWER Documentation?

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.
- **API Pages:** the API landing pages that use the OpenAPI specification to create interactive pages for the API endpoints.
- **Methodology Docs:** the projects documentation and methodology providing accurate and detailed information to users.

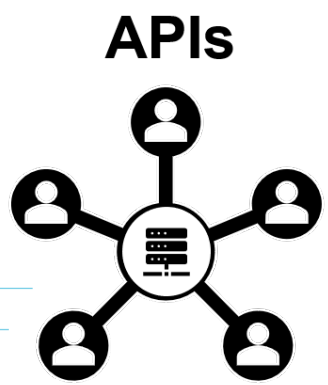
https://power.larc.nasa.gov/
https://power.larc.nasa.gov/docs/

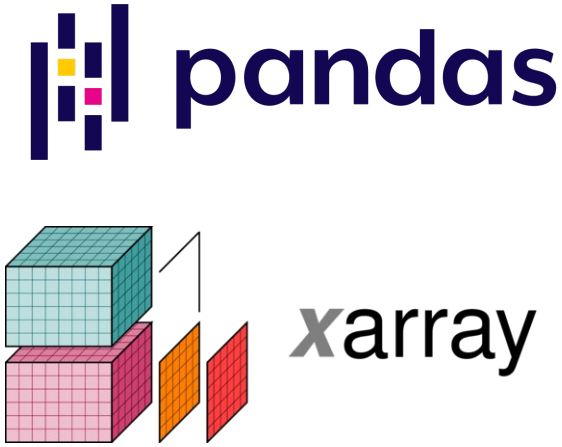


Data Access and Analysis Demo Using Jupyter Notebooks

The POWER services and data access methods provides efficient access to POWER datastore:

- POWER API data access
- Direct Datastore access from AWS S3 (Zarr access)
- Example use-case of monthly anomalies
  - Pandas, Xarray formats in Python





Demo Notebook: Direct API Access

Construct the API URL ¶

This fills the base_url based on the inputs provided.

```
[6]: base_url = r"https://power.larc.nasa.gov/api/temporal/{temporal}/point?Time=LST&parameters={parameters}&community=RE&longitude={longitude}&latitude={latitude}&start={start}0101&end={end}1231&format=JSON"
query_url = base_url.format(temporal=temporal, parameters=",".join(parameters), start=start, end=end, latitude=latitude, longitude=longitude)
print ("Here is the API URL:", query_url)
```

```
Here is the API URL: https://power.larc.nasa.gov/api/temporal/daily/point?Time=LST&parameters=ALLSKY_SFC_SW_DWN,CLRSKY_SFC_SW_DWN,ALLSKY_SFC_LW_DWN,CLRSKY_SFC_LW_DWN&community=RE&longitude=-0.461389&latitude=51.4775&start=20010101&end=20011231&format=JSON
```

Request Data

This requests the data from the POWER API URL and convert the JSON response to a Python dictionary object.

```
[7]: %%time
main_response = requests.get(url=query_url, verify=True, timeout=30) # Fix this to have timeout.
json_response = json.loads(main_response.text)
```

```
Wall time: 3.02 s
```

Turning the API response Dictionary and into a Pandas DataFrame.

```
[8]: df = pd.DataFrame.from_dict(json_response['properties']['parameter'])

if temporal == 'hourly':
    df.index = pd.to_datetime(df.index, format='%Y%m%d%H')
elif temporal == 'daily':
    df.index = pd.to_datetime(df.index, format='%Y%m%d')

df = df.replace(-999.0, 0)
df.head()
```

[8]:

	ALLSKY_SFC_SW_DWN	CLRSKY_SFC_SW_DWN	ALLSKY_SFC_LW_DWN	CLRSKY_SFC_LW_DWN
2001-01-01	0.77	1.14	310.71	270.59
2001-01-02	0.46	1.13	328.62	269.72
2001-01-03	0.81	1.18	290.86	256.02
2001-01-04	0.28	1.14	322.09	265.77
2001-01-05	0.42	1.14	312.04	257.60

```
[10]: metadata = pd.DataFrame.from_dict(json_response['parameters'])
metadata
```

[10]:

	ALLSKY_SFC_SW_DWN	CLRSKY_SFC_SW_DWN	ALLSKY_SFC_LW_DWN	CLRSKY_SFC_LW_DWN
units	kW-hr/m^2/day	kW-hr/m^2/day	W/m^2	W/m^2
longname	All Sky Surface Shortwave Downward Irradiance	Clear Sky Surface Shortwave Downward Irradiance	All Sky Surface Longwave Downward Irradiance	Clear Sky Surface Longwave Downward Irradiance

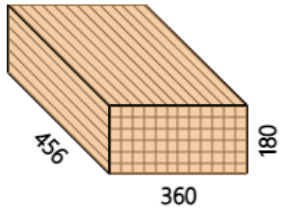
Retrieve & read data from request

- Build url using string format method, variables
- Execute the request, receive the output
- JSON > Dict > Pandas
- Handle date and null values
- Metadata!

Demo Notebook: Data Access - Zarr

```
[3]: %%time
     ds.ALLSKY_SRF_ALB

     Wall time: 0 ns

[3]: xarray.DataArray 'ALLSKY_SRF_ALB' (time: 456, lat: 180, lon: 360)
```

	Array	Chunk
Bytes	225.44 MiB	3.13 MiB
Shape	(456, 180, 360)	(456, 30, 30)
Count	73 Tasks	72 Chunks
Type	float64	numpy.ndarray

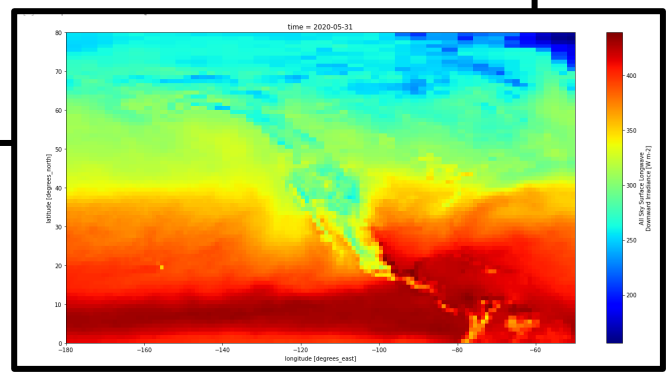


▼ Coordinates:

lat	(lat)	float64	-89.5 -88.5 -87.5 ... 88.5 89.5
lon	(lon)	float64	-179.5 -178.5 ... 178.5 179.5
time	(time)	datetime64[ns]	1984-01-31 ... 2021-12-31

▼ Attributes:

long_name :	All Sky Surface Albedo
standard_name :	All_Sky_Surface_Albedo
units :	dimensionless
valid_max :	1.0
valid_min :	0.0
valid_range :	[0.0, 1.0]



Xarray: Multidimensional Dataset

- Like pandas, xarray is built off numpy
- More powerful than 2-dimensional Pandas DataFrame
- Perfect for reading 3D data from zarr
- Dask chucks data, references it where the Zarr resides
- Xarray dataset from zarr uses less memory than a Pandas DataFrame

xarray

dask

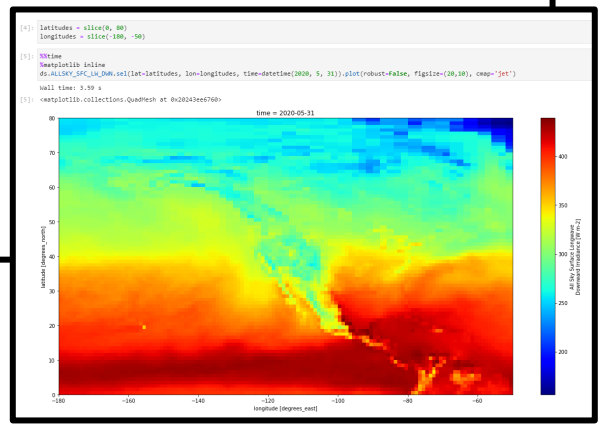
Zarr

Demo Notebook: Use Case Scenario – Monthly Anomalies

```
[5]: def make_anomalies(series: pd.Series) -> pd.Series:
         '''
         This function creates monthly anomalies.

         series: the pandas series to compute the anomalies (required)
         '''

         monthly = series.resample('M').mean() # Avg for each individual month

         monthly_mean = monthly.mean() # 12.024

         return monthly - monthly_mean
```

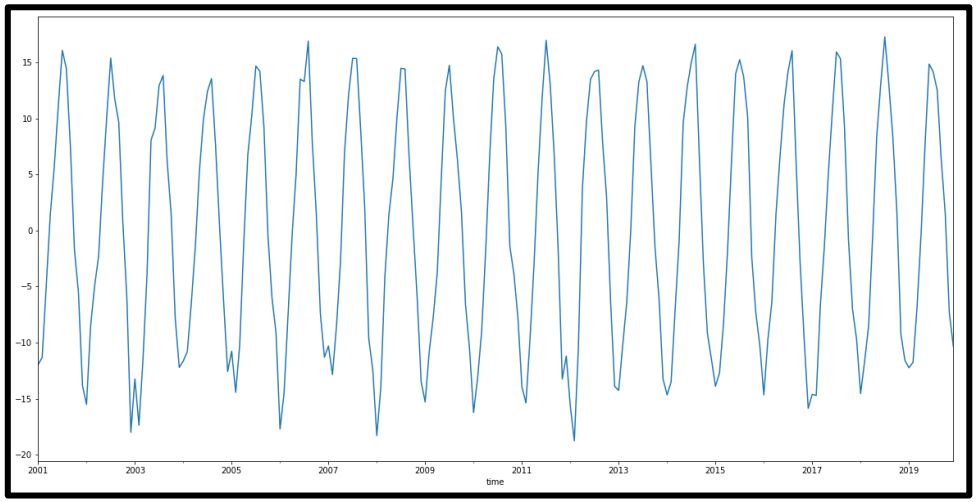
```
[6]: anomalies = make_anomalies(df[parameter])
     anomalies.head(12)
```

```
[6]: time
     2001-01-31   -11.955329
     2001-02-28   -11.329753
     2001-03-31    -4.982426
     2001-04-30     1.349961
     2001-05-31     5.692090
     2001-06-30    11.127961
     2001-07-31    16.060155
     2001-08-31    14.422413
     2001-09-30     7.503961
     2001-10-31    -1.677910
     2001-11-30    -5.577039
     2001-12-31   -13.844362
     Freq: M, Name: T2M, dtype: float64
```



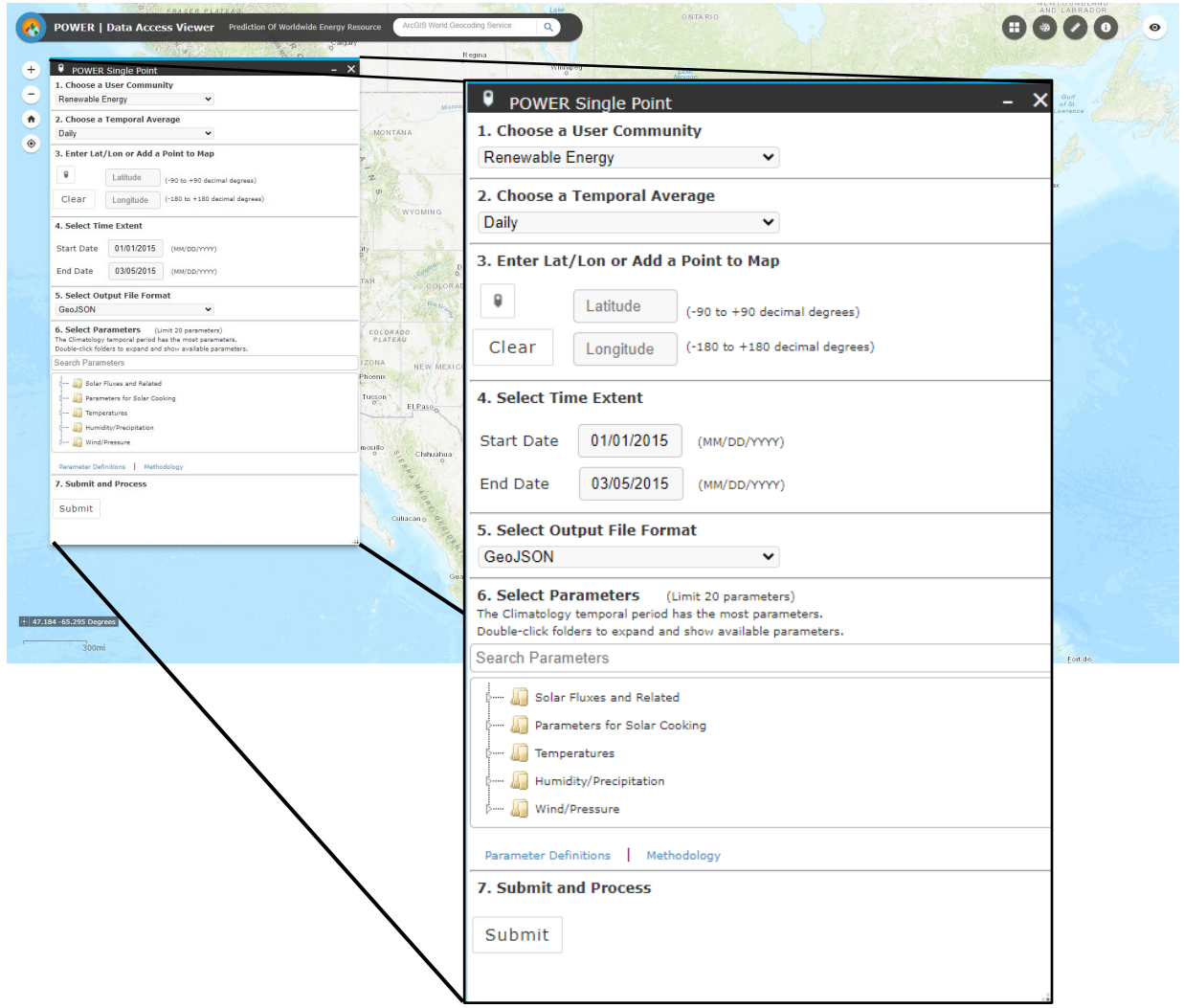
Anomalies: Average difference from the mean.

- Calculate MONTHLY Average from Jan2001 to Dec2019
- Calculate the OVERALL Average temp for the entire time range! (12°C)
- Find the difference for each month in the range



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.

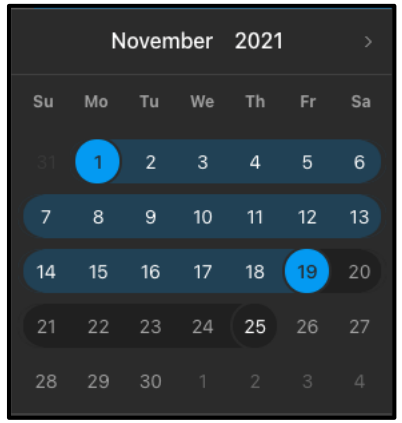


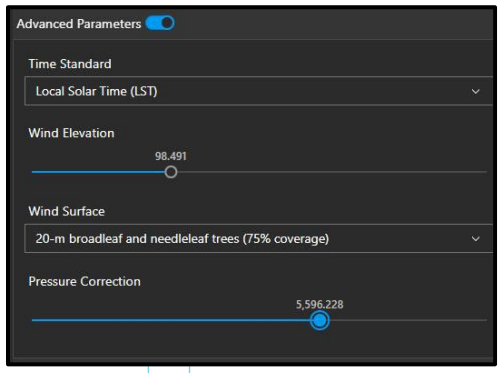
https://power.larc.nasa.gov/data-access-viewer/

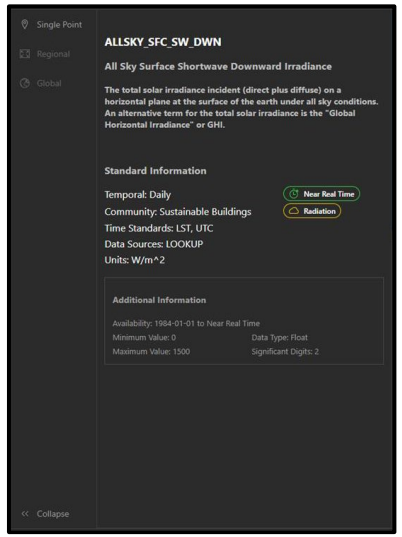
- DAV Quick Start Guide
- DAV User Guide

POWER's Data Access Viewer (enhanced)

Leveraging Esri's Calcite Design System to implement new user-driven requirements.



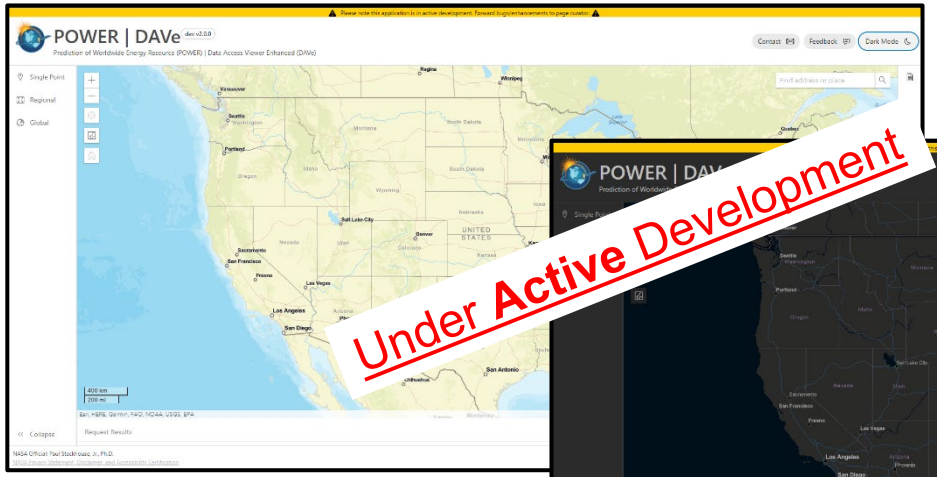


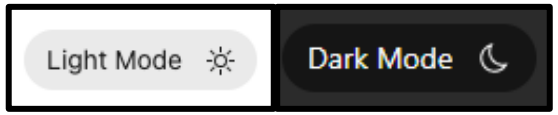


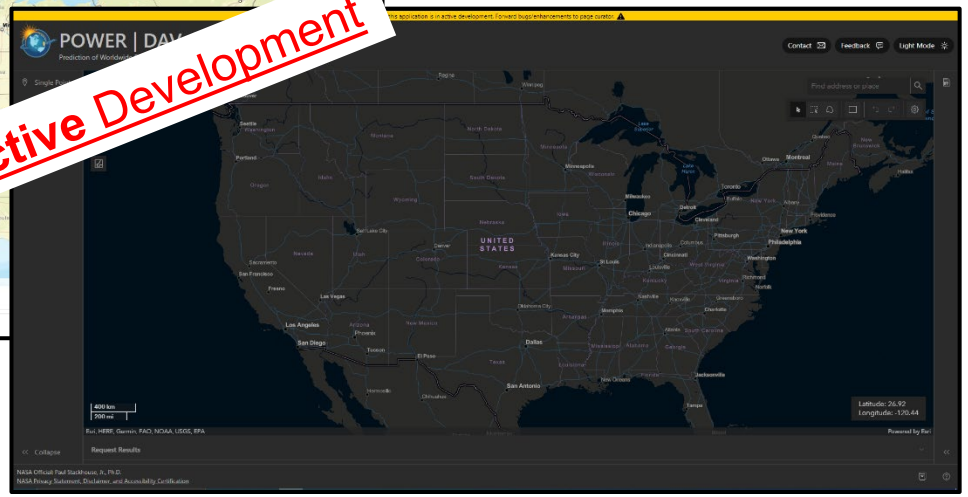
Annual Cooling, Dehumidification, and Enthalpy Design Conditions

Hottest Month	Hottest Month DB Range	Cooling DB/MCWB						Evaporation WB/MCDB						MCWS/PCWD to 0.4% DB	
		0.4%		1%		2%		0.4%		1%		2%			
		DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	WB	MCDB	MCWS	PCWD
7	16.6	37.0	Ø	35.6	Ø	34.3	Ø	21.4	Ø	20.5	Ø	19.6	Ø	Ø	Ø

Dehumidification DP/MCDB and HR									Enthalpy/MCD						Extreme Max WB
0.4%			1%			2%			0.4%		1%		2%		
DP	HR	MCDB	DP	HR	MCDB	DP	HR	MCDB	Enth	MCDB	Enth	MCDB	Enth	MCDB	
37.0	12150.0	Ø	13.2	11290.0	Ø	12.0	10440.0	Ø	Ø	Ø	Ø	Ø	Ø	Ø	24.5

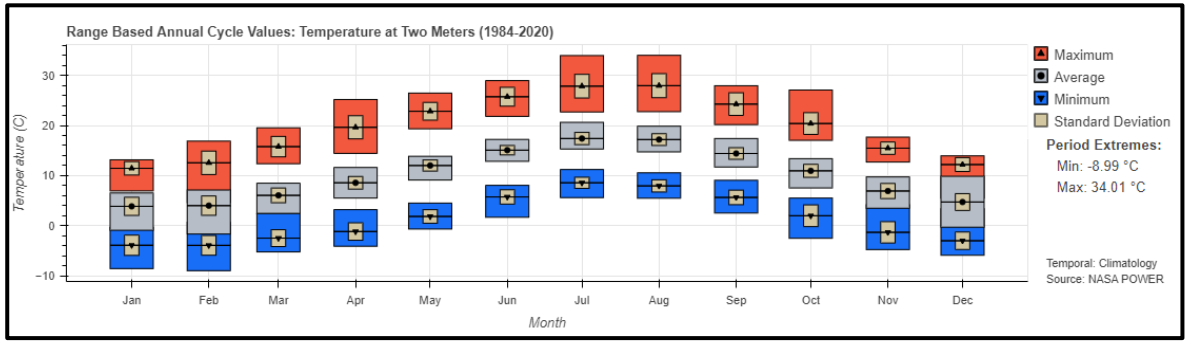




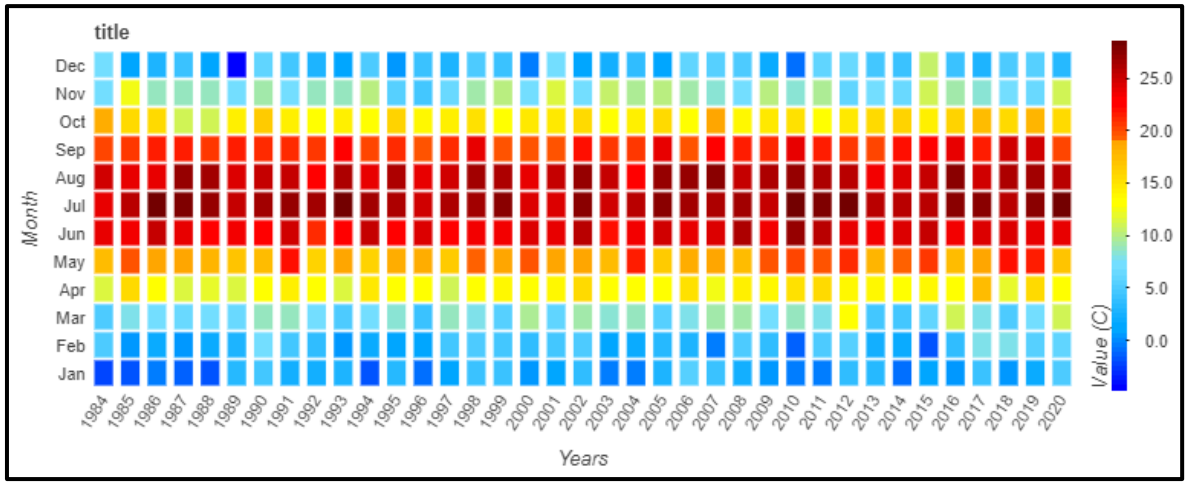


Climate Means and Variability – DAVe Plot Template Examples

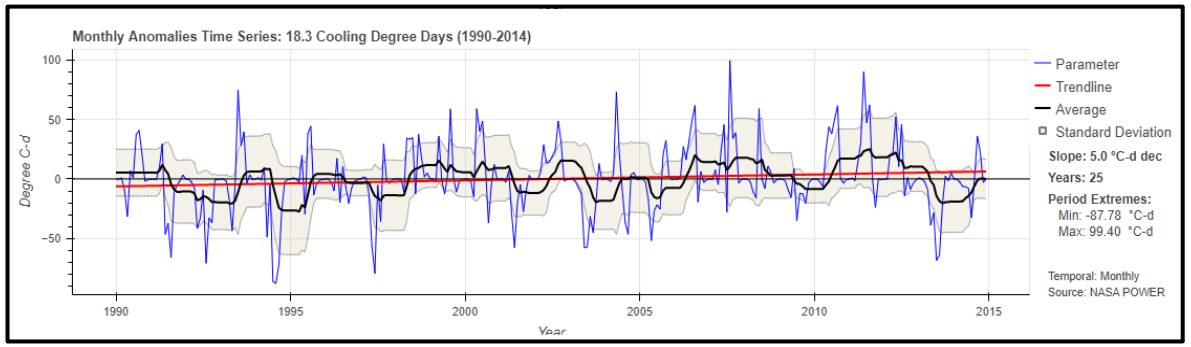
Range Based Annual Cycle



Heatmap: Climatological Days or Annual Based

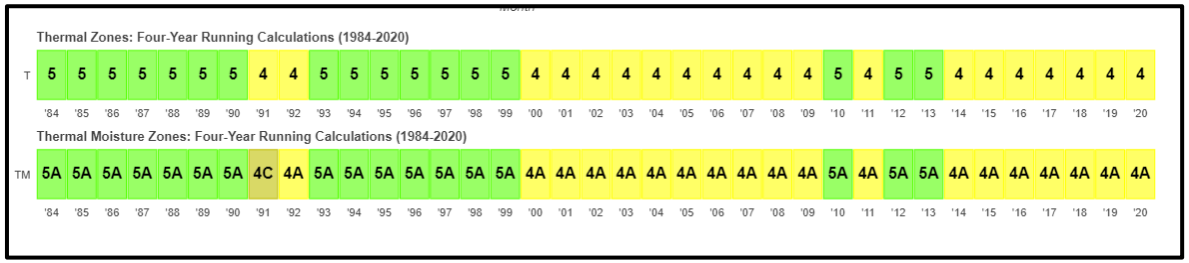


Temporal Variability with Statistics*



**can have advanced statistics integrated.*

Rolling 4-Year Thermal Zones



The plot types are currently available in Anomalies report from the DAV to streamline the developed actives and save time since they have been vetted and approved by the POWER Team.