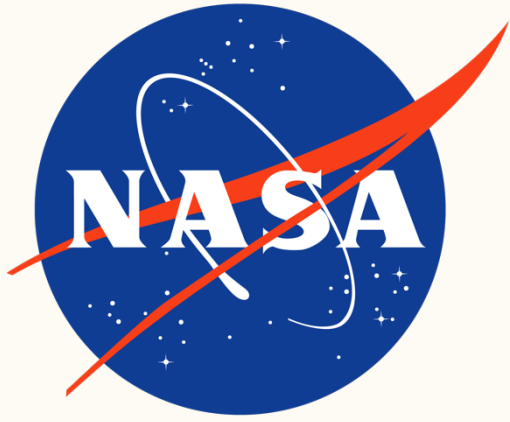


Advances to a Global Agroclimatology Solar Insolation and Meteorological Parameter Data Base: Improved Solar Irradiance up to Hourly Temporal Resolution

ASA-CSSA-SSSA 2021
November 7-10, 2021





Prediction Of Worldwide Energy Resource (POWER)

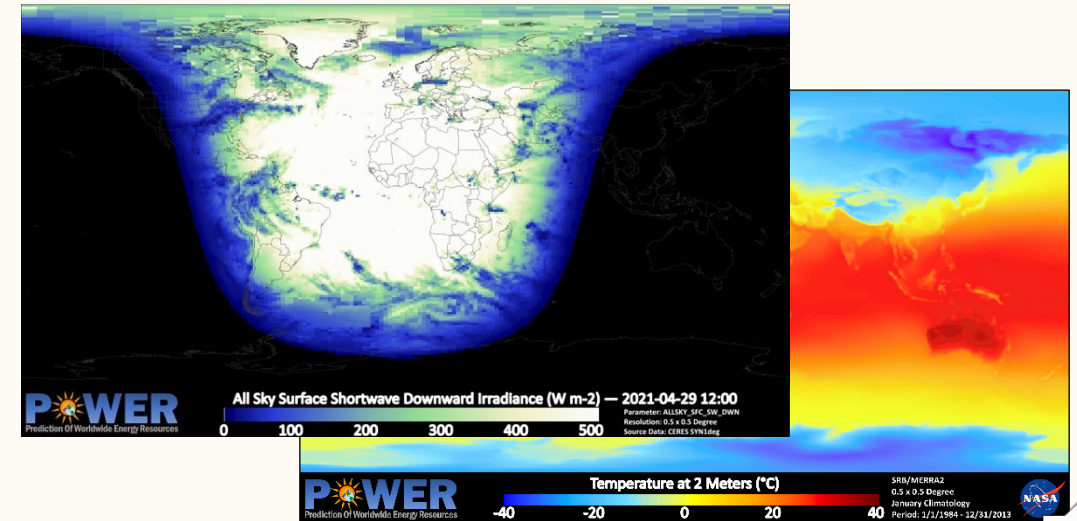
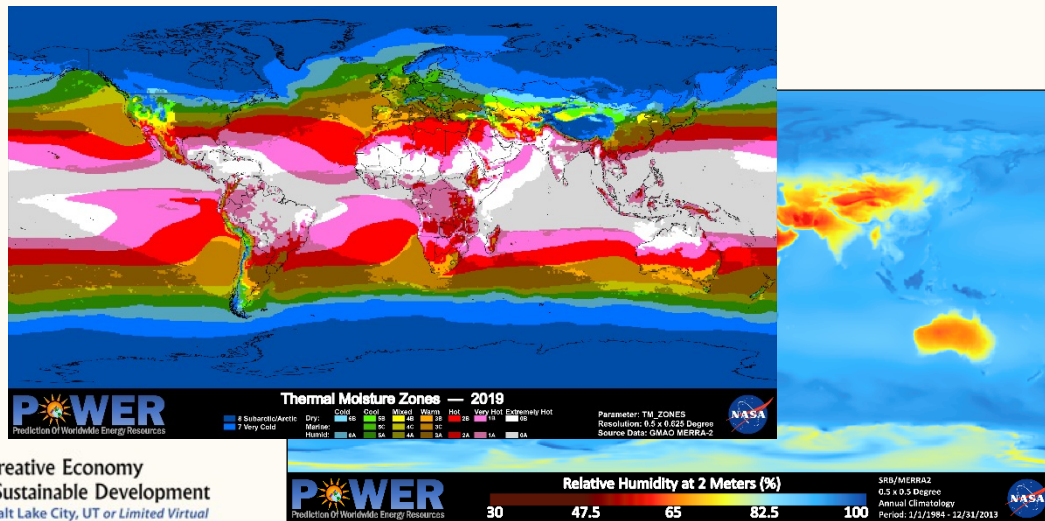
Aiming to improve the nation's public/private capability for integrating environmental data from NASA Earth observations, analysis and modeling, particularly information related to surface solar irradiance, to support increased **renewable energy development, building energy efficiency, and agroclimatology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

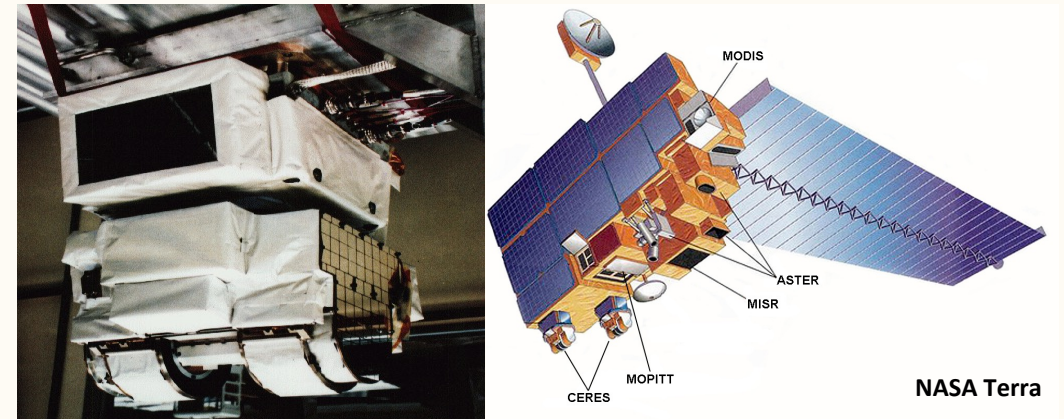


Introducing CERES Top-of-Atmosphere Measurements

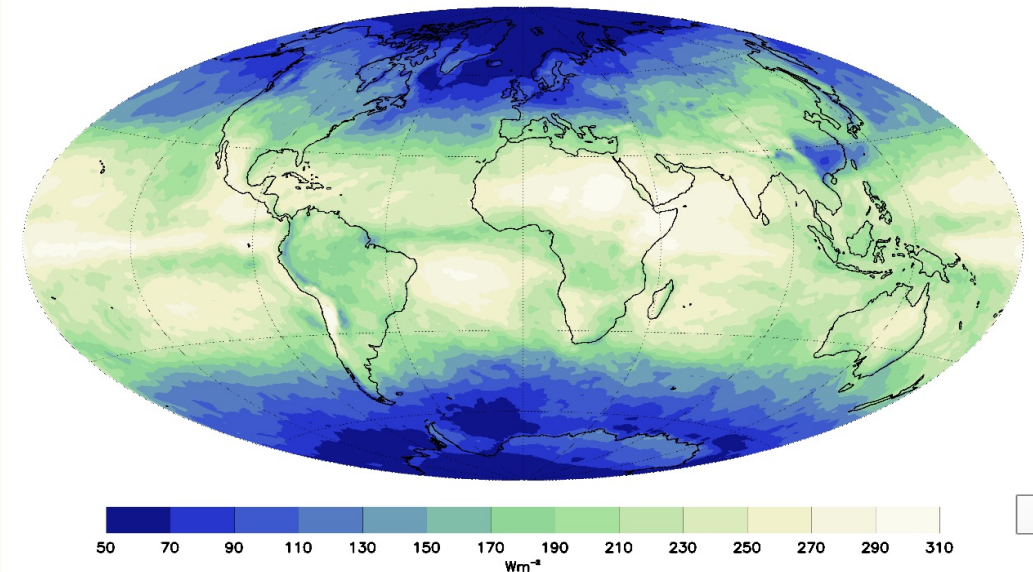


Clouds and Earth's Radiant Energy System (CERES)

- 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
 - High accuracy and stability
 - CERES on 4 different polar orbiters with follow-on instruments in development
- CERES also uses computes global gridded surface radiative fluxes both solar and thermal IR using
 - CERES measurements, co-located cloud retrievals and cross-calibrated retrievals from the world's GEOs
 - Global ancillary information: aerosol, snow/ice
 - Radiative transfer with full atmosphere, cloud and aerosol treatments



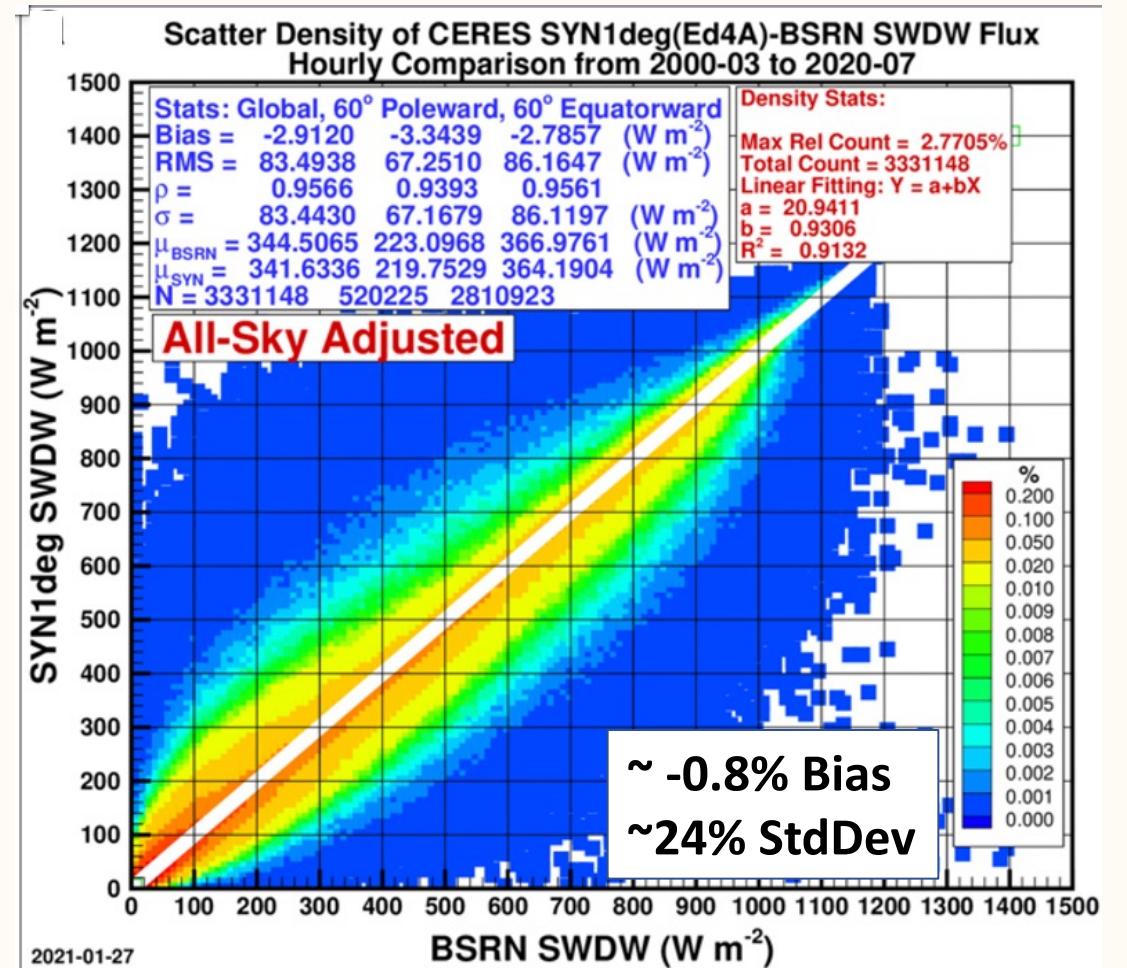
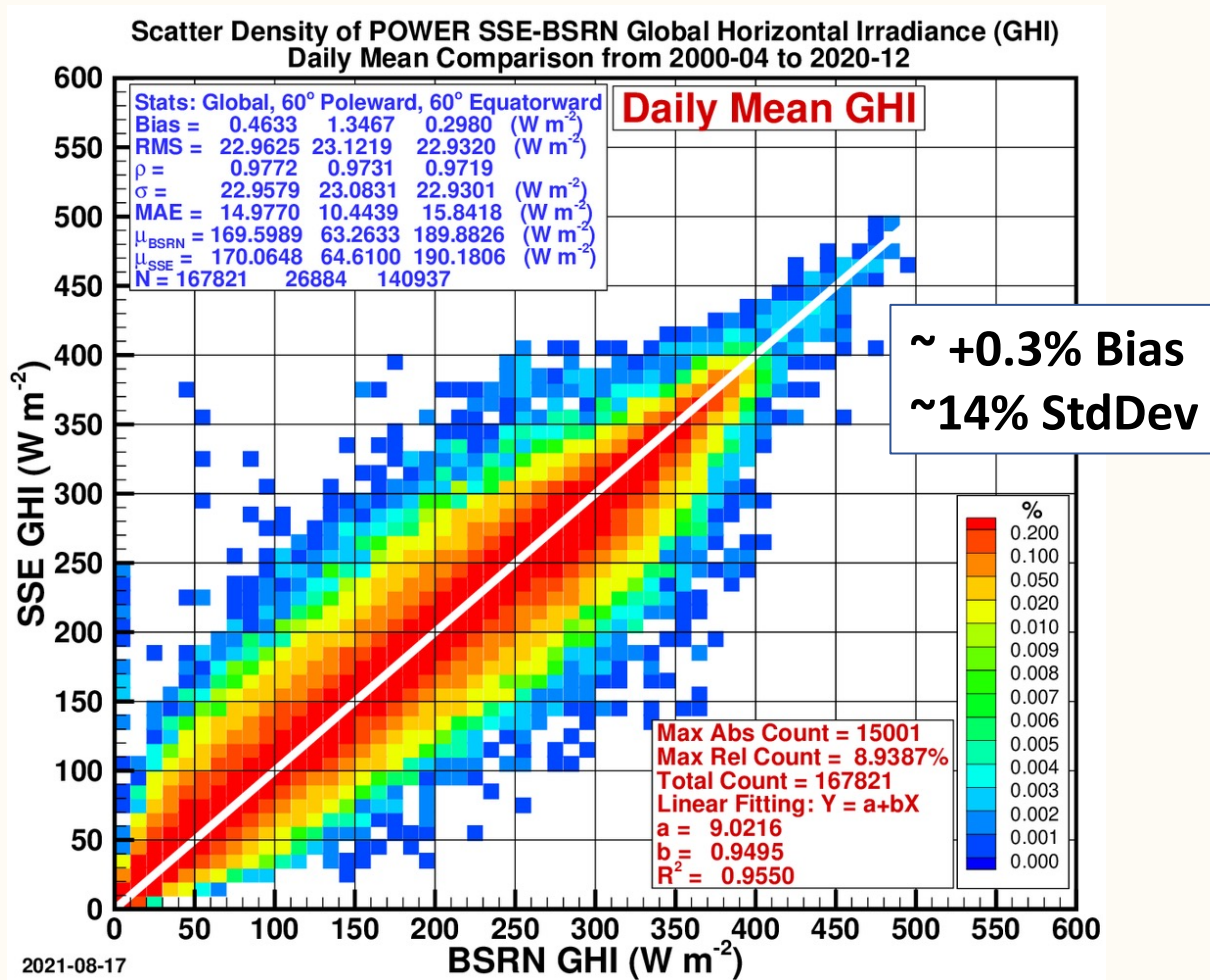
CERES All-sky Shortwave Surface Downward Flux 2001 to 2018 Average



CERES 1x1 degree surface fluxes span March 2000 to near present



Monthly and Daily Mean Validation of SYN1Deg Solar Irradiance



Total solar irradiance is also known as Global Horizontal Irradiance (GHI)

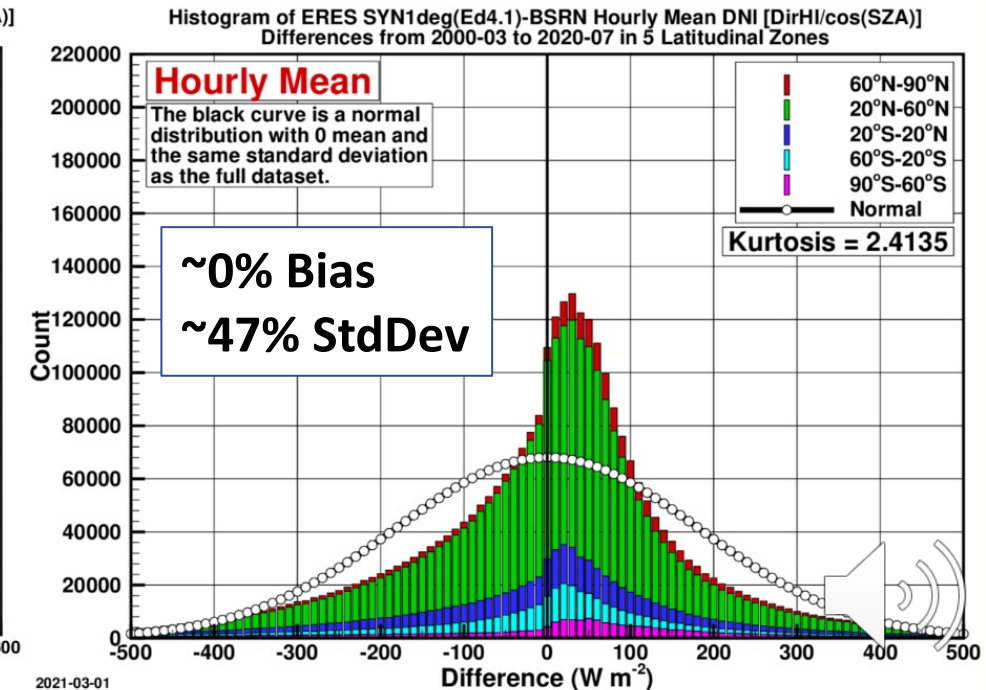
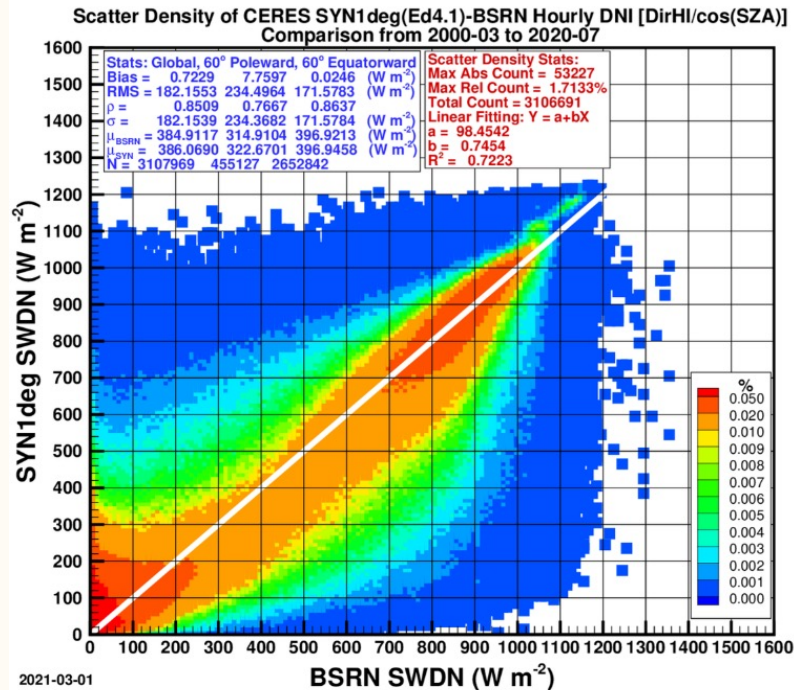
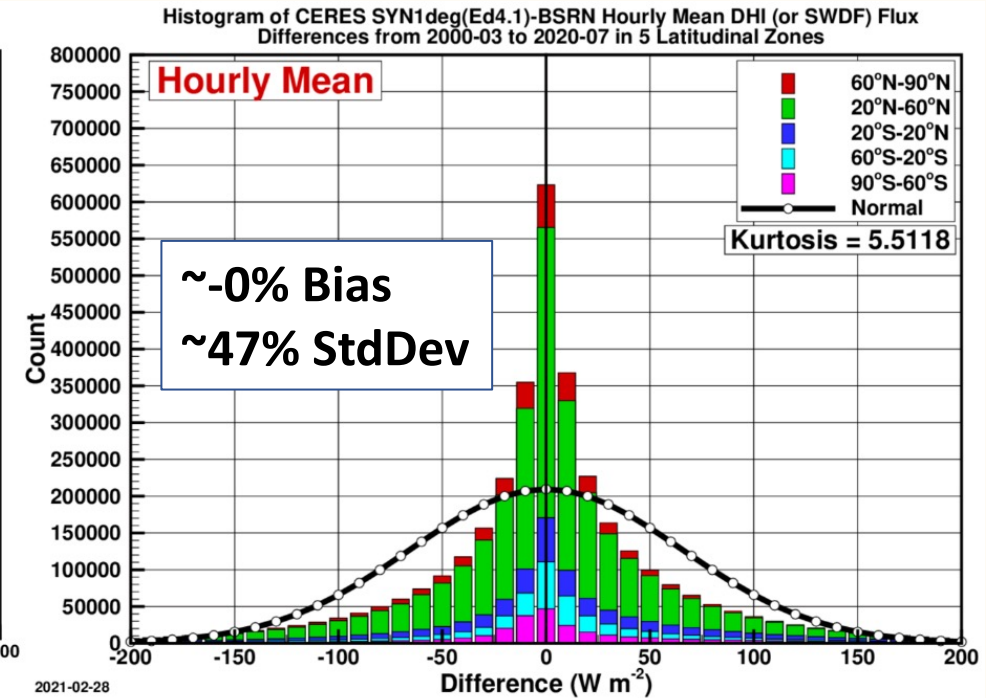
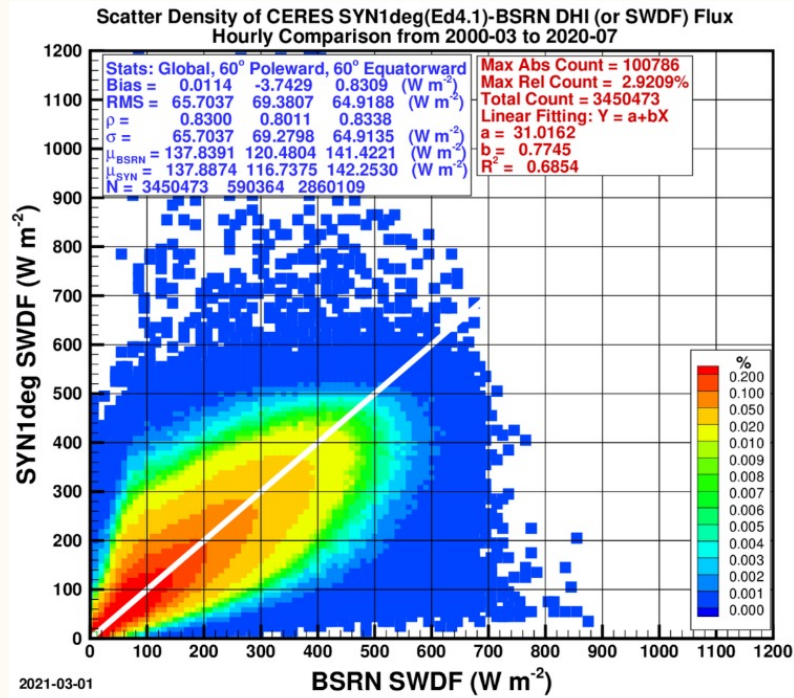


DHI and DNI — After Bias Correction

DHI

DNI [(GHI-DHI)
/cos(SZA)]

Cos(SZA)
modified when
SZA > 75°



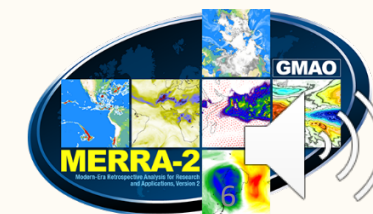
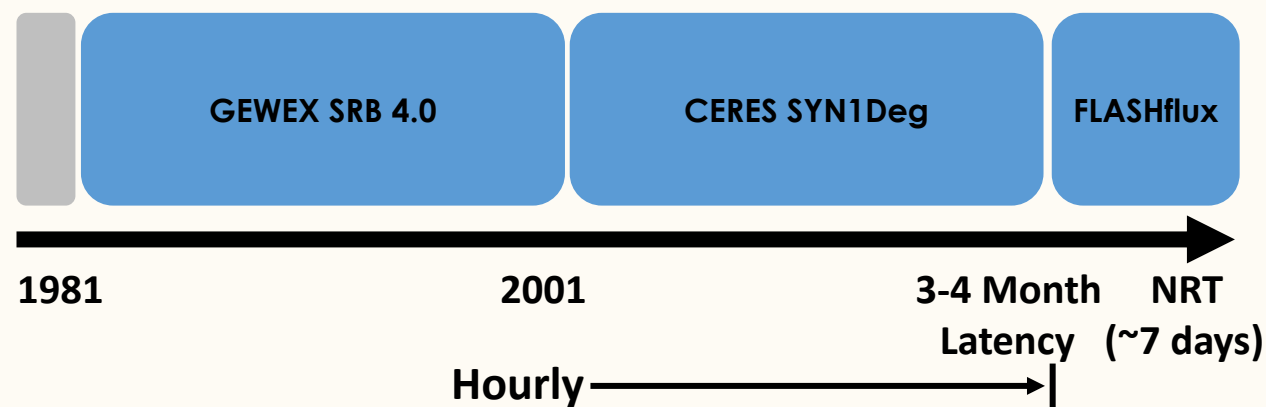
POWER's Surface Solar Irradiance Sources

Source	Temporal Span		Temporal Average		Description
	Start	End	Input	Output	
<u>GEWEX SRB 4.0</u>	Jan 1, 1984	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
<u>CERES SYN1Deg (Ed 4A)</u>	Jan 1, 2001	End of SYN1Deg	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
<u>CERES FLASHFlux V4</u>	End of SYN1deg	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)

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

Production Data Timeline



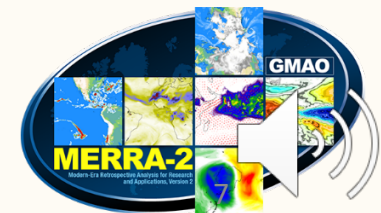
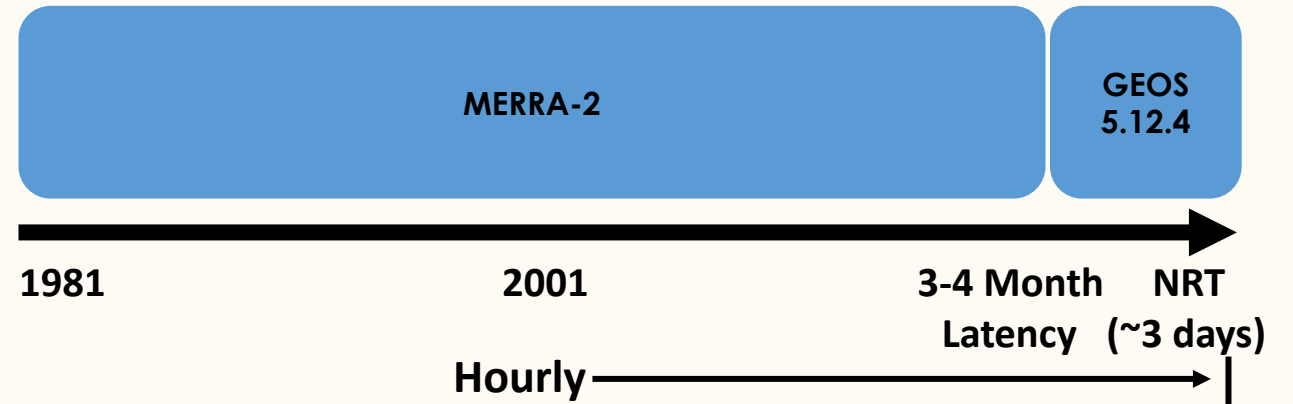
POWER's Surface Meteorology Sources

Source	Temporal Span		Temporal Average		Description
	Start	End	Input	Output	
<u>MERRA-2</u>	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)
<u>GMAO FP-IT (GEOS 5.12.4)</u>	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

Production System:

- Daily solar data products from 1981 provided through 3 days of real-time
- MERRA-2 to GEOS 5.12.4
- Hourly from 2001 through 3 days of Near Real Time (NRT)

Production Data Timeline



Access to the Hourly Parameters is Supported

Category	Parameters	Source
Solar Parameters	Top-Of-Atmosphere Shortwave Downward Irradiance, Direct Normal Radiation	CERES (SORCE, TSIS)
	All Sky & Clear-sky Surface Shortwave Downward Irradiance (horizontal), Diffuse Horizontal, Direct horizontal, Direct Normal Irradiances (Corrected)	CERES SYN1Deg Ed4
	All Sky and Clear sky Spectral Fluxes: PAR, UVA, UVB and an UV Index	CERES SYN1Deg Ed4
	Insolation Clearness Index, Clear-sky clearness index, and normalized clearness index	CERES SYN1Deg Ed4
	Surface Albedo	CERES SYN1Deg Ed4
	Solar Zenith Angle	CERES SYN1Deg Ed4
Thermal Infrared Irradiance	All Sky and Clear-sky Surface Longwave Downward Irradiance	CERES SYN1Deg Ed4
Cloud	Cloud fraction, optical depth, cloud top and base heights	CERES SYN1Deg Ed4
Aerosol	Aerosol optical depth at 0.55 and 0.85 micrometers	CERES SYN1Deg Ed4
Surface Meteorology	Surface pressure, temperature (2, 10 m), surface air density (2m), specific humidity (2, 10m), relative humidity (2, 10m), dew/frost point temperatures (2m), wet bulb temperature (2, 10m)	MERRA-2
	Earth Skin temperature	MERRA-2
	Wind Components (at 2, 10, 50 Meters)	MERRA-2
	Precipitation, Land Precipitation, Snow/Snow Depth	MERRA-2
	Total Column Precipitable Water	MERRA-2



Link provides listing of all hourly parameters relevant to the Ag community

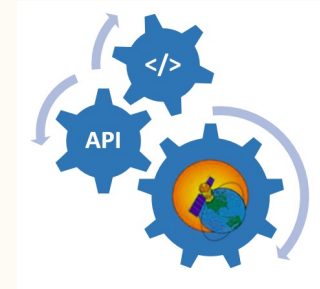
<https://power.larc.nasa.gov/api/system/manager/parameters?community=ag&temporal=hourly>



POWER Data Access Methods (<https://power.larc.nasa.gov/>)

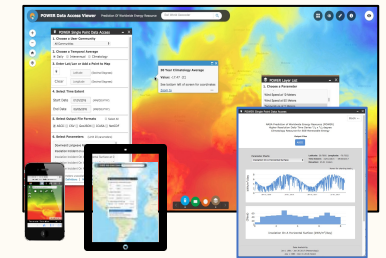
POWER enhances data discovery, access, and distribution as Analysis Ready Data (ARD) for direct application of inputs to decision to support tools, modeling and forecasting packages, and as inputs to scientific research is provided via three basic services:

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

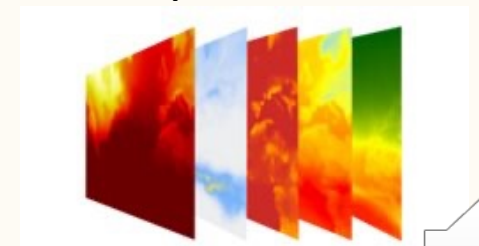


Data Access Viewer

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.*



POWER Agroclimatology Support: ICASA Format

- DAV offers access to time series for solar and met. parameters
- Units of solar irradiance customized from MJ hr⁻¹ (hourly) to MJ m⁻² day⁻¹ (daily+)
- Various output formats supported including ICASA format for DSSAT

POWER | Data Access Viewer Prediction Of Worldwide Energy Resource

POWER Single Point

- 1. Choose a User Community**
Agroclimatology
- 2. Choose a Temporal Average**
Daily
- 3. Enter Lat/Lon or Add a Point to Map**
40.7328 (-90 to +90 decimal degrees)
-111.8437 (-180 to +180 decimal degrees)
- 4. Select Time Extent**
Start Date: 10/01/2015 (MM/DD/YYYY)
End Date: 10/22/2021 (MM/DD/YYYY)
- 5. Select Output File Format**
ICASA
- 6. Select Parameters**
Based on the format selected the parameters are predetermined. For the format specific parameters please review the output's header file.
Parameter Definitions | Methodology
- 7. Submit and Process**
Submit

22 Year Climatology Average
Value: 4.7 (kWh/m²/day)
See bottom left of screen for coordinates
[Zoom to](#)

POWER Layer List

- 1. Choose a Parameter**
Insolation on Horizontal Surface
Minimum Insolation on Horizontal Surface
Maximum Insolation on Horizontal Surface
Direct Normal Radiation

Month: Annual
Opacity: 62%

Map Grid Layer Swipe

Left-Click on map for data set values by location.

High : 9.86
Low : 0.06
Units: (kWh/m²/day)

POWER_Point_Daily_20151001_20211022_040d7328N_111d8437W_LST.txt

```

SWEATHER DATA: NASA
! T2M      Temperature at 2 Meters (C)
! TMIN     Temperature at 2 Meters Minimum (C)
! TMAX     Temperature at 2 Meters Maximum (C)
! TDEW     Dew/Frost Point at 2 Meters (C)
! RH2M     Relative Humidity at 2 Meters (%)
! RAIN     Precipitation Corrected (mm)
! WIND     Wind Speed at 2 Meters (m/s)
! SRAD     All Sky Surface Shortwave Downward Irradiance (MJ/m^2/day)
! Mean elevation for source NASA/POWER data tile (0.5 x 0.625 grid cell) = 1744.82m
@ INSI    WTHLAT  WTHLONG  WELEV   TAV  AMP  REFT  WNDHT
NASA     40.733  -111.844  1744.82  4.3  33.0  2     2
@ DATE    T2M      TMIN     TMAX     TDEW    RH2M    RAIN    WIND    SRAD
2015274   20.7    16.0    26.9     8.4    47.2    0.7    2.0    15.1
2015275   13.9     9.7    16.8     4.9    55.4    5.7    1.6     9.1
2015276   12.5     9.2    17.5     6.3    68.0    5.8    1.1     9.8
2015277   14.7     8.6    22.2     4.2    54.9    0.6    1.5    15.7
2015278   13.7     9.5    19.8     5.4    58.8    2.6    1.4    10.5
2015279   13.3     8.0    19.7     6.3    66.3    0.4    1.3    13.5
2015280   14.5     9.8    21.1     5.2    57.1    0.0    1.4    18.5
2015281   15.8    11.9    22.4     5.4    52.0    0.0    1.6    17.0
2015282   16.3    11.7    23.0     4.3    46.9    0.0    0.9    13.2
2015283   17.4     9.8    26.0     5.0    46.0    0.0    2.2    18.4
2015284   15.5    11.8    20.6     3.8    47.2    0.0    2.3    18.5
2015285   16.0    10.3    23.3    -2.9    28.9    0.0    1.3    18.4
2015286   17.8    12.0    25.3    -0.7    29.6    0.0    1.5    18.0
2015287   18.4    13.8    24.8     0.9    31.8    0.0    1.3    17.8
2015288   17.8    13.1    25.2     0.3    32.4    0.0    1.2    17.1
2015289   16.6     9.4    25.6     2.0    41.2    0.0    1.6    15.9
2015290   14.4    11.4    20.4     8.5    68.9    2.8    1.8     8.0
    
```

34.473 -94.837 Degrees

100mi



POWER Analytic Data Services Reports

The POWER API provides custom timeseries based reports!

Timeseries Anomalies reports for user specified time period and parameters.

POWER Reports

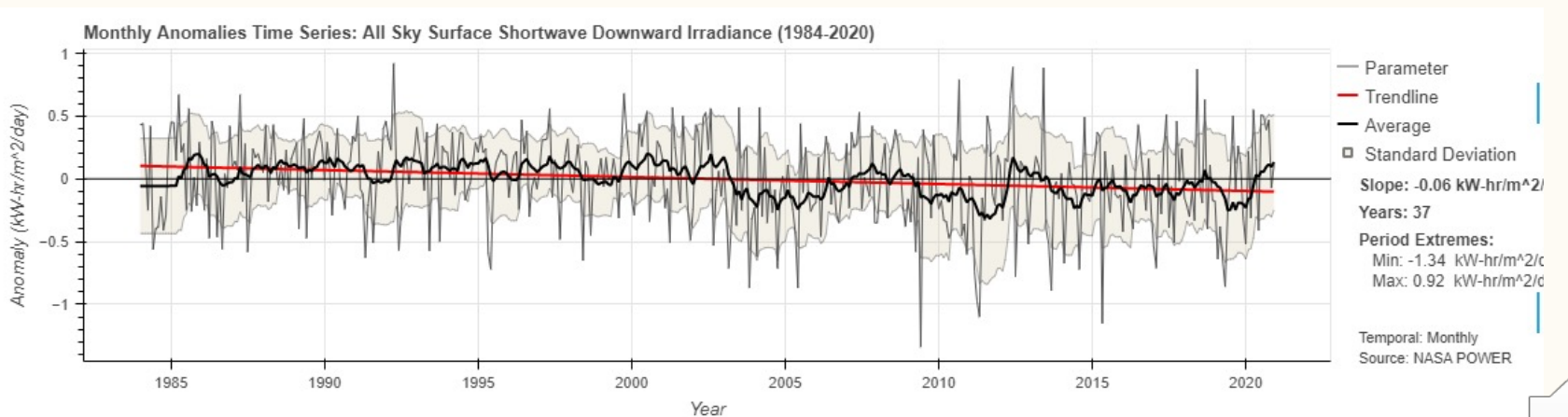
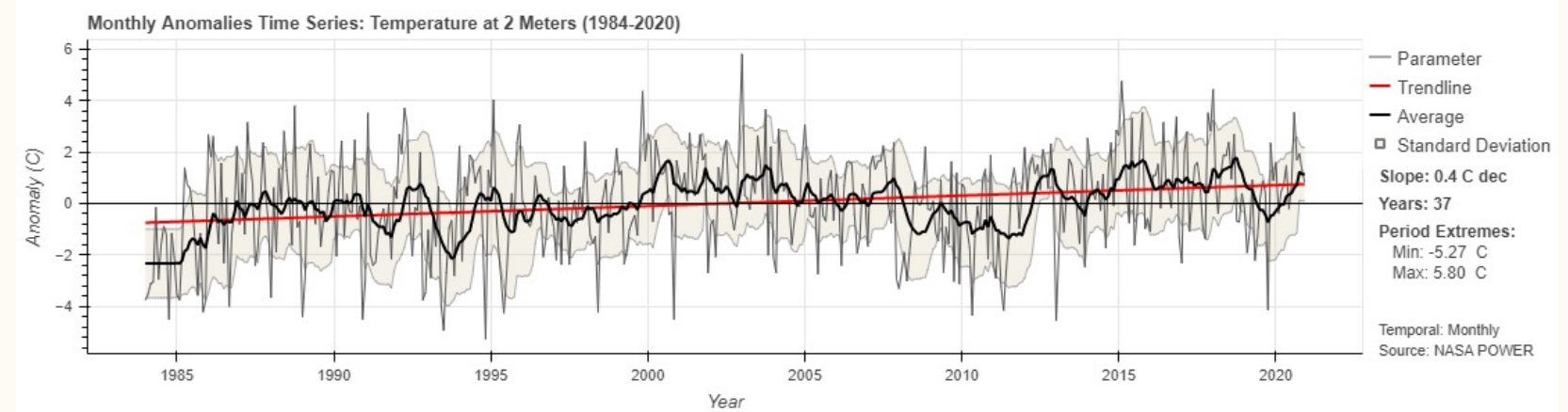
1. Choose a Report Type
Climatic Design Conditions

2. Enter Lat/Lon or Add a Point to Map
Latitude (Decimal Degrees)
Longitude (Decimal Degrees)

3. Select Time Extent
Start Date 2001 (YYY)
End Date 2018 (YYY)

4. Choose a Report Type
HTML

5. Submit and Process
Click Submit to Download a Report.
This request will take up to a minute to complete.
Submit



Summary and Conclusions

- **New POWER Web Services Suite Available**

- Complete upgrades to solar irradiance for entire time record (begins in 1984)
- Features, CERES SYN1Deg Data from 2001 to within several months of real time
 - is an excellent resource for Total Solar Irradiance (or GHI) at multiple temporal resolutions from hourly, to daily, monthly, annual and climatology
 - Clear and All-sky fluxes provided including corrected Direct/Diffuse components
 - LW, PAR and UVA, UVB also provided
- MERRA-2 surface meteorology still provided, now up to hourly

- **POWER Web Services Suite Provides Access to new Data Products**

- Full API access with more user friendly Data Access Viewer supporting the Agroclimatology application community
- Finalizing validation and documentation, but included on the web site

- **Future Work:**

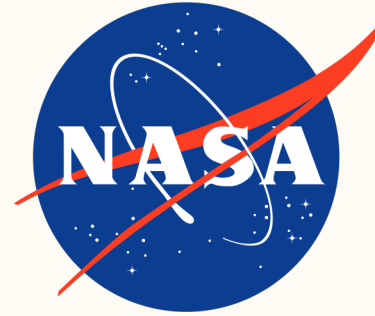
- Continue to improve web services and documentation
- Work with Ag community in upgrade of precipitation and soil moisture

Want to Learn More?

Check out the ARSET Webinars!

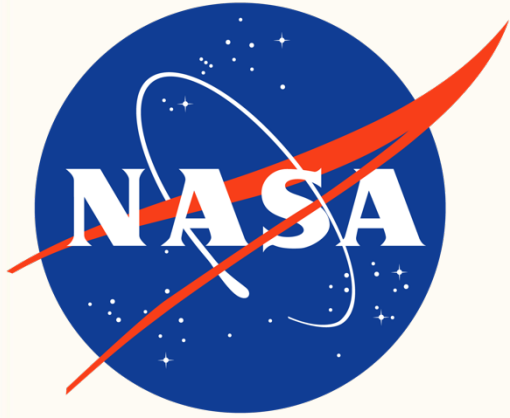
The POWER Team gave a series of ARSET webinars this past June. [You can access the webinars on the Energy Management section of ARSET's website](#) and learn about the following topics:

- 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





Thank you!

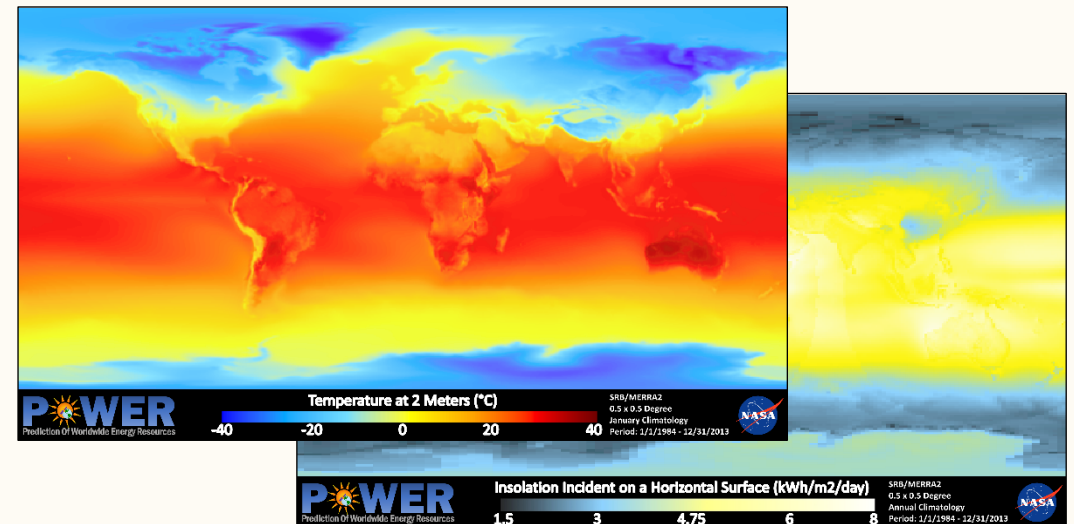
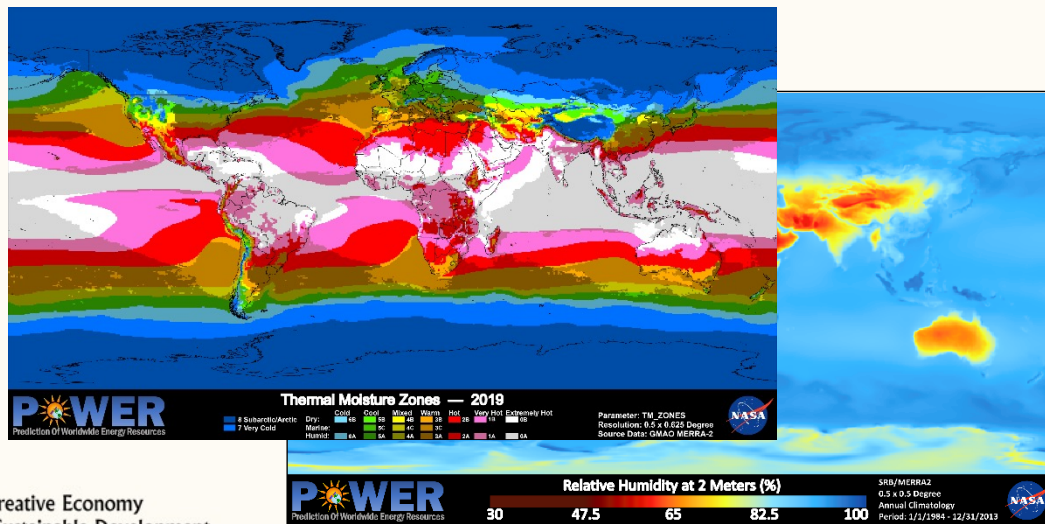
Email: larc-power-project@mail.nasa.gov

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

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

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