Solar Irradiance on Equator Facing Tilted Surfaces:

An extension of the NASA POWER Project Solar Energy Dataset

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POWER
Prediction Of Worldwide Energy Resources

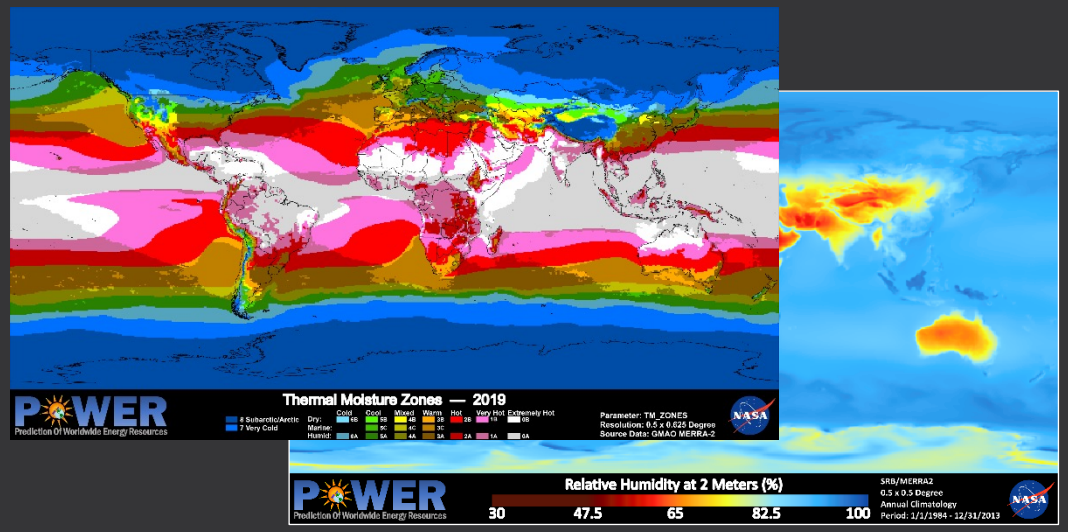
NASA

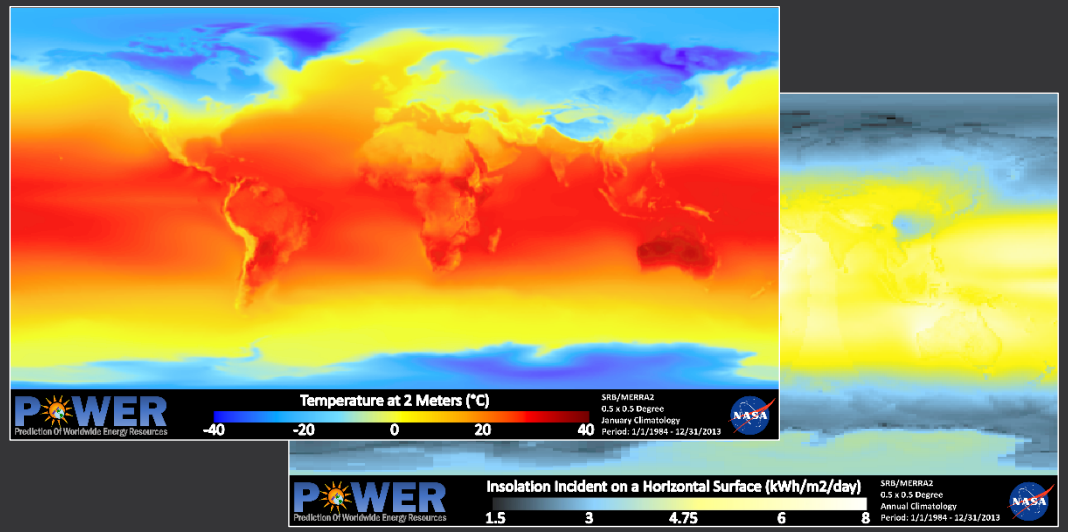
What is NASA POWER?

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/





Solar Irradiance on Equator Facing Tilted Surfaces

Why is it important?

- Panel tilt and orientation allow maximum exposure to solar irradiance and optimize power production for a given period of the year.
- A solar panel perpendicular to DNI is optimal.
- Optimal panel tilt is dynamic with seasons and latitudes.
- Therefore, data supports optimal design and operations.

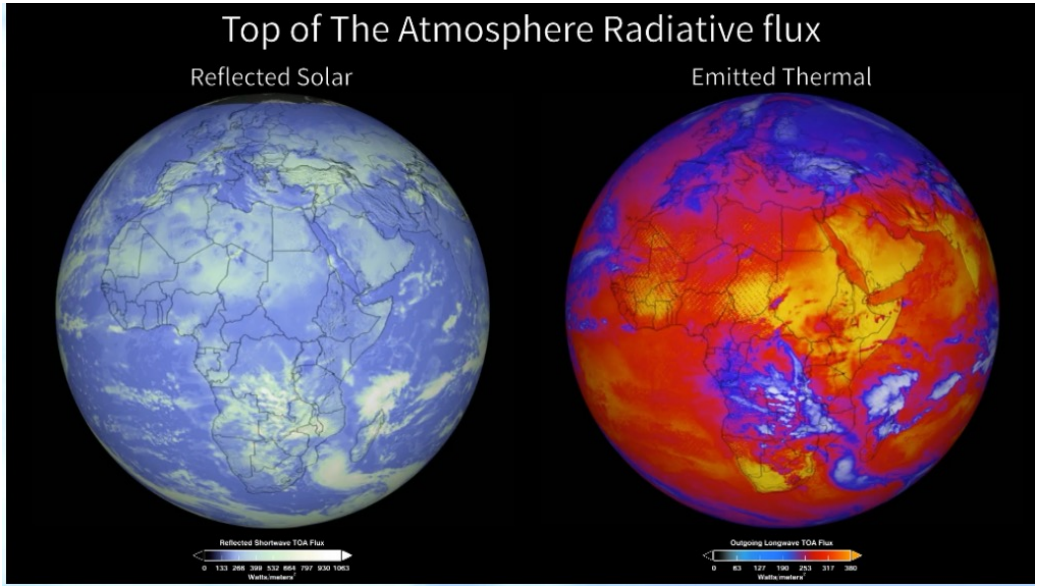
Solar Irradiance

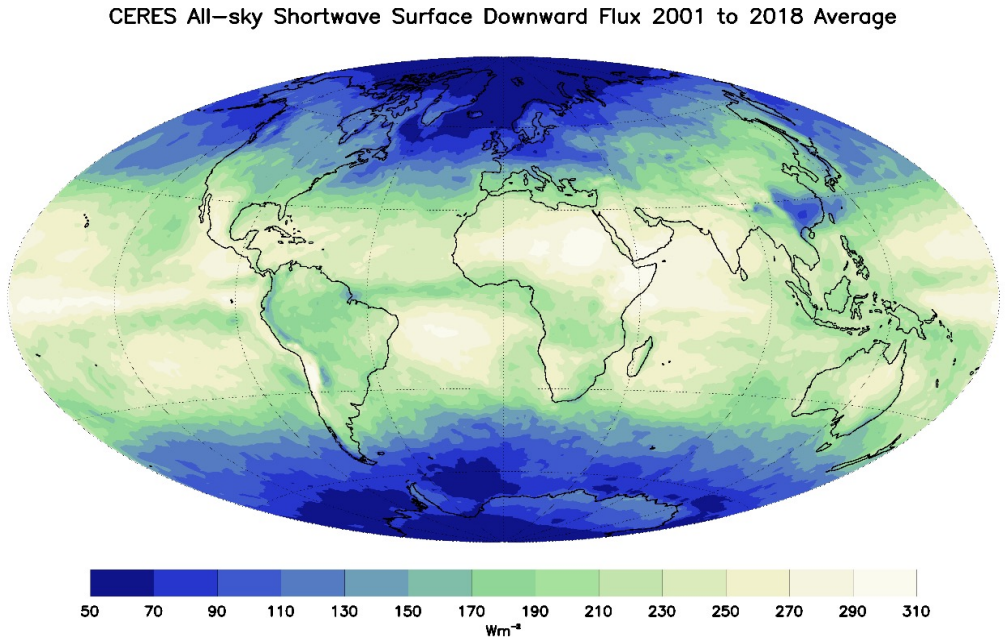
Development:

The POWER API and DAV provide estimates of the of the following solar irradiance parameters:

- Global Horizontal Irradiance (GHI)
- Diffuse Horizontal Irradiance (DHI)
- Direct Normal Irradiance (DNI or Beam)
- Albedo
- Declination

Input data are from NASA CERES (Clouds and Earth's Radiant Energy System) SYN1deg(Ed.4.1) dependent on temporal extent.





Solar Irradiance on Equator Facing Tilted Surfaces

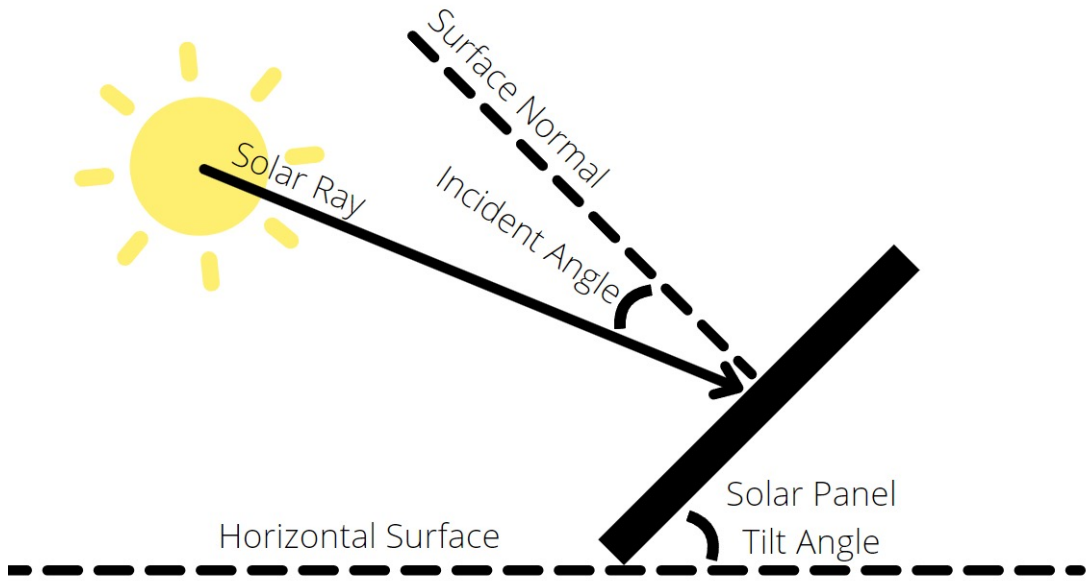
Database Available Parameters:

Solar irradiances in kW-hr/m^2/day are computed on surfaces vertical tilt at the following angles using industry standard tilted irradiance equations*:

- Horizontal Tilt (0°)
- Tilt angle equal to absolute latitude
- Tilt angle equal to absolute latitude +15°
- Tilt angle equal to absolute latitude -15°
- Vertical Tilt (90°)
- Optimal Tilt

Additionally, the following parameters are computed:

- Optimal Angle Orientation (North/South)



** See POWER methodology documentation*

Parameter Development

- Validation performed against adjusted BSRN ground observation parameters, where near-instant (1-, 2-, 3-, 5-min average) DNI and DHI are measured.
- The tilted surface radiation on the BSRN surface can be estimated through an isotropic diffuse model derived by Liu and Jordan (1963).
- The irradiance on the titled surface derivation includes the following components:
  - Beam
  - Isotropic diffuse from the sky
  - Isotropic diffuse from ground reflection

Isotropic Diffuse (Sky)

$$I_T = I_b R_b + I_d \left(\frac{1 + \cos\beta}{2} \right) + I \rho_g \left(\frac{1 - \cos\beta}{2} \right)$$

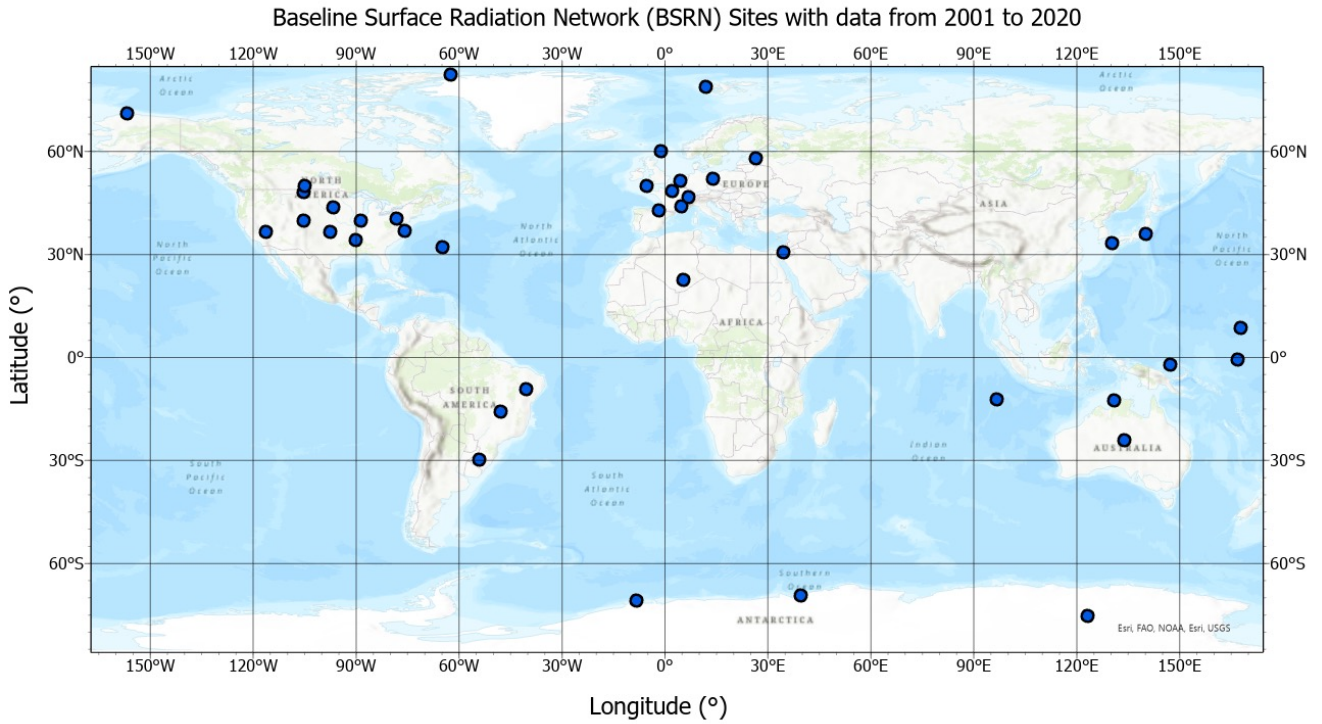
Beam **Isotropic Diffuse (Ground Reflected)**

Source: Duffie, J.A. and Beckman, W.A., 2013. Solar Engineering of Thermal Processes (4th Ed). John Wiley & Sons, Inc.

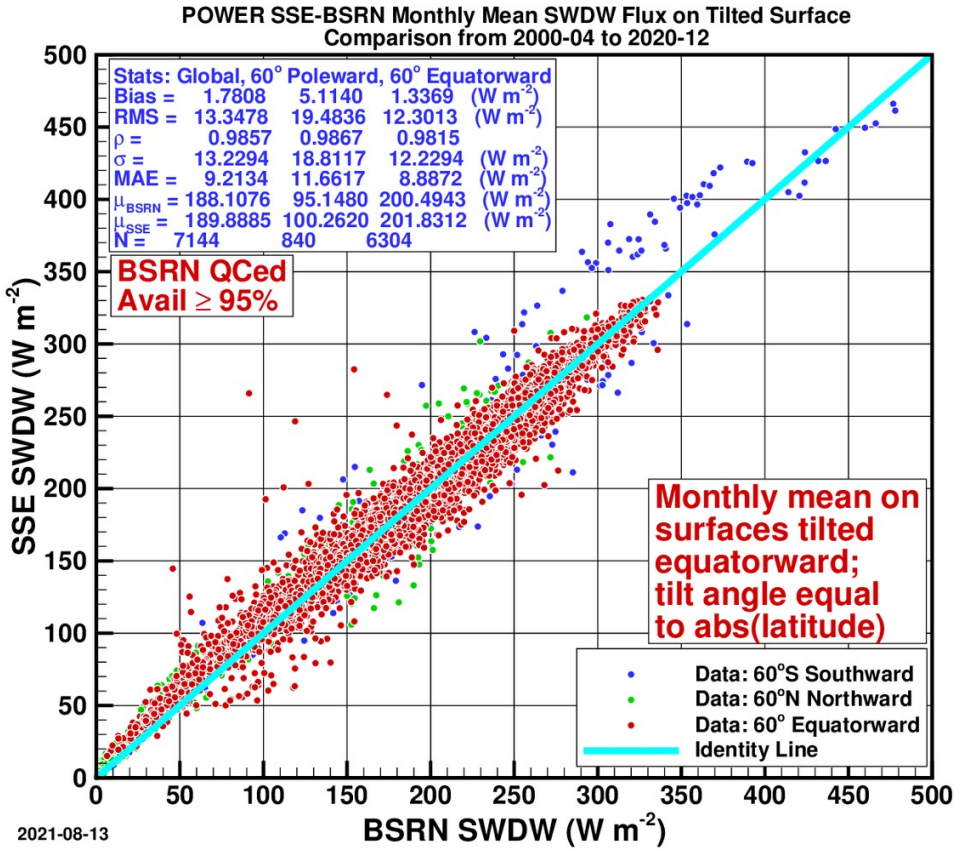
Parameter Validation

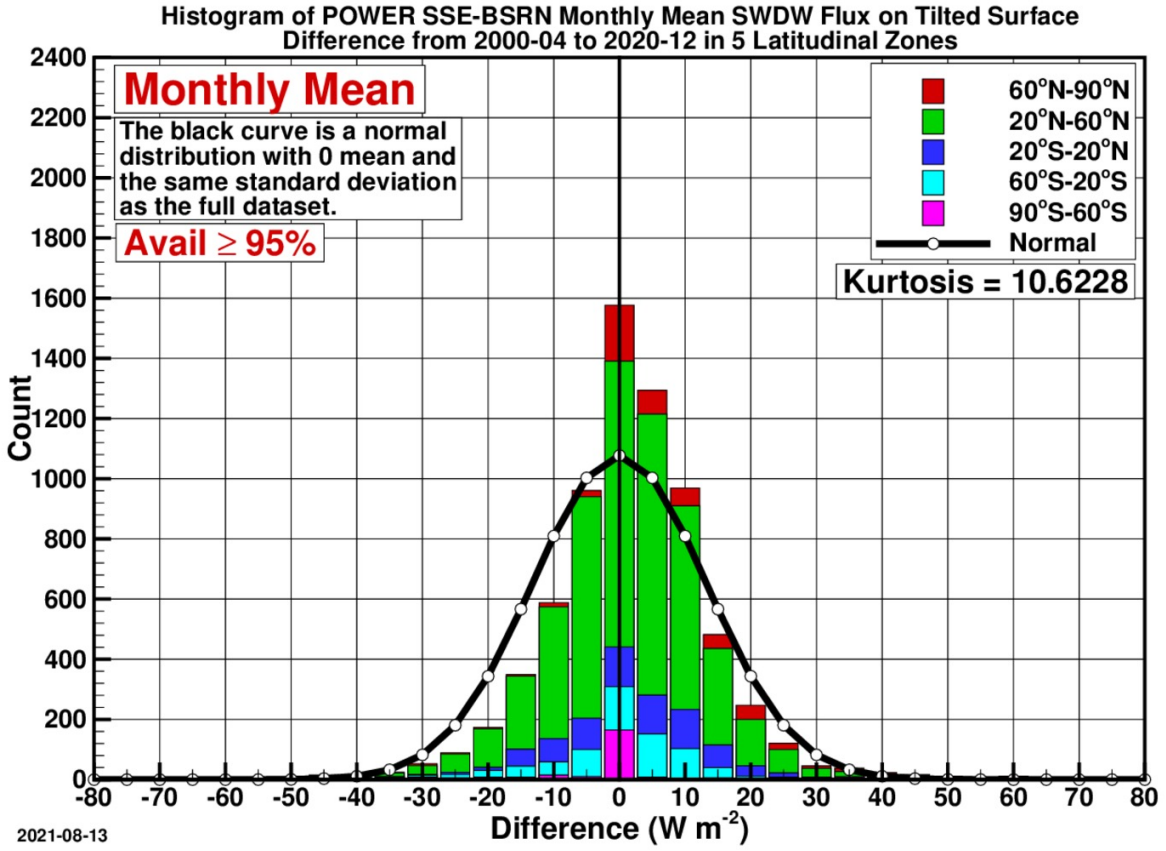
Validation performed against adjusted BSRN ground observation parameters:

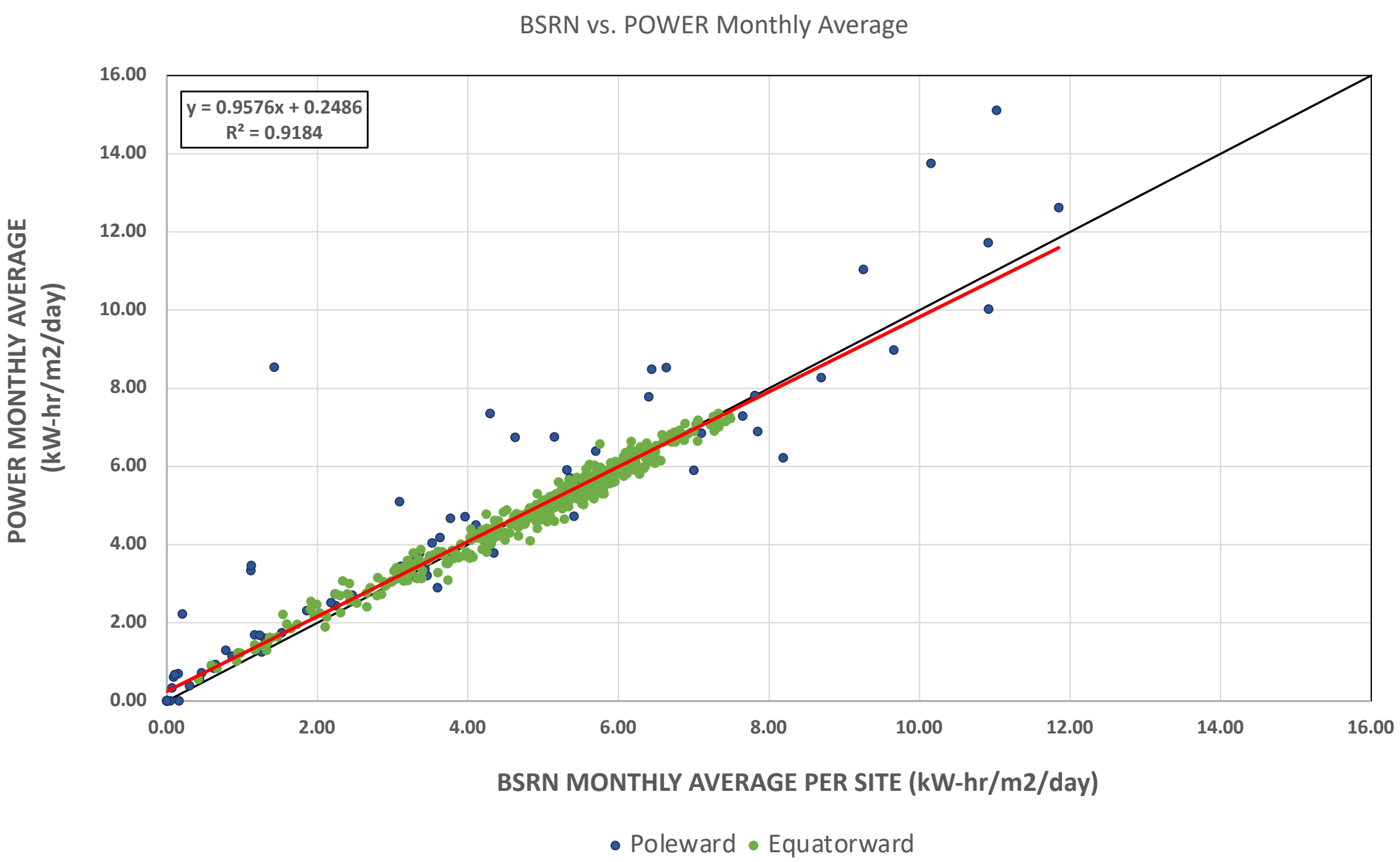
- Data are quality control and processed by POWER team
- Only included data from the range of 2001 through 2021
- Only included data with 10 years+ consecutive years of observations
- 80%+ data is available

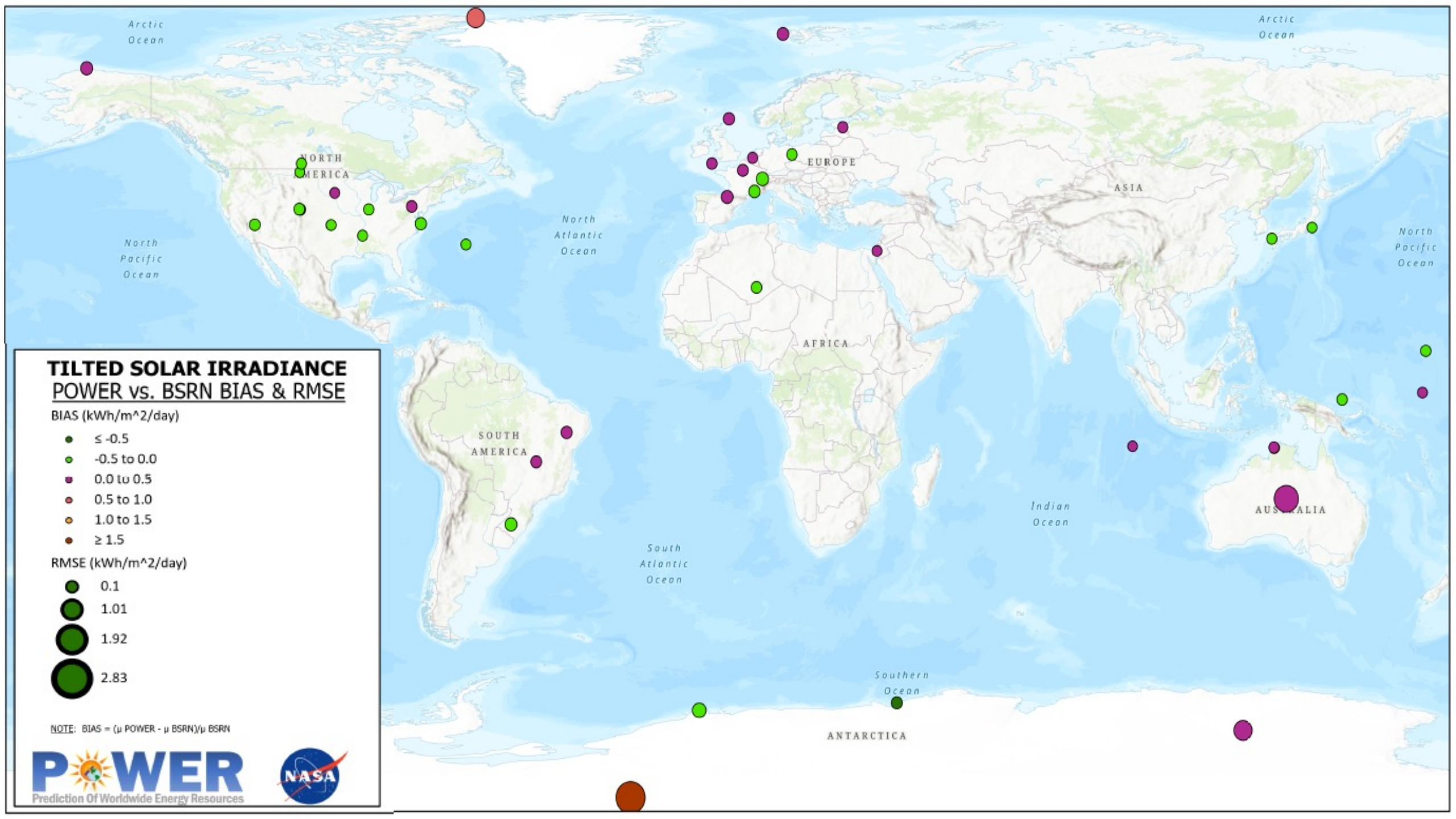


Validation of the Solar Irradiance on Equator Facing Tilted Surfaces (Global)






BSRN vs. POWER Monthly Average
y = 0.9576x + 0.2486
R² = 0.9184
POWER MONTHLY AVERAGE (kW-hr/m2/day)
BSRN MONTHLY AVERAGE PER SITE (kW-hr/m2/day)
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
Poleward
Equatorward


Arctic Ocean
Arctic Ocean
NORTH AMERICA
EUROPE
ASIA
North Atlantic Ocean
North Pacific Ocean
North Pacific Ocean
AFRICA
SOUTH AMERICA
Indian Ocean
AUSTRALIA
South Atlantic Ocean
Southern Ocean
ANTARCTICA
TILTED SOLAR IRRADIANCE
POWER vs. BSRN BIAS & RMSE
BIAS (kWh/m^2/day)
≤ -0.5
-0.5 to 0.0
0.0 to 0.5
0.5 to 1.0
1.0 to 1.5
≥ 1.5
RMSE (kWh/m^2/day)
0.1
1.01
1.92
2.83
NOTE: BIAS = (μ POWER - μ BSRN)/μ BSRN
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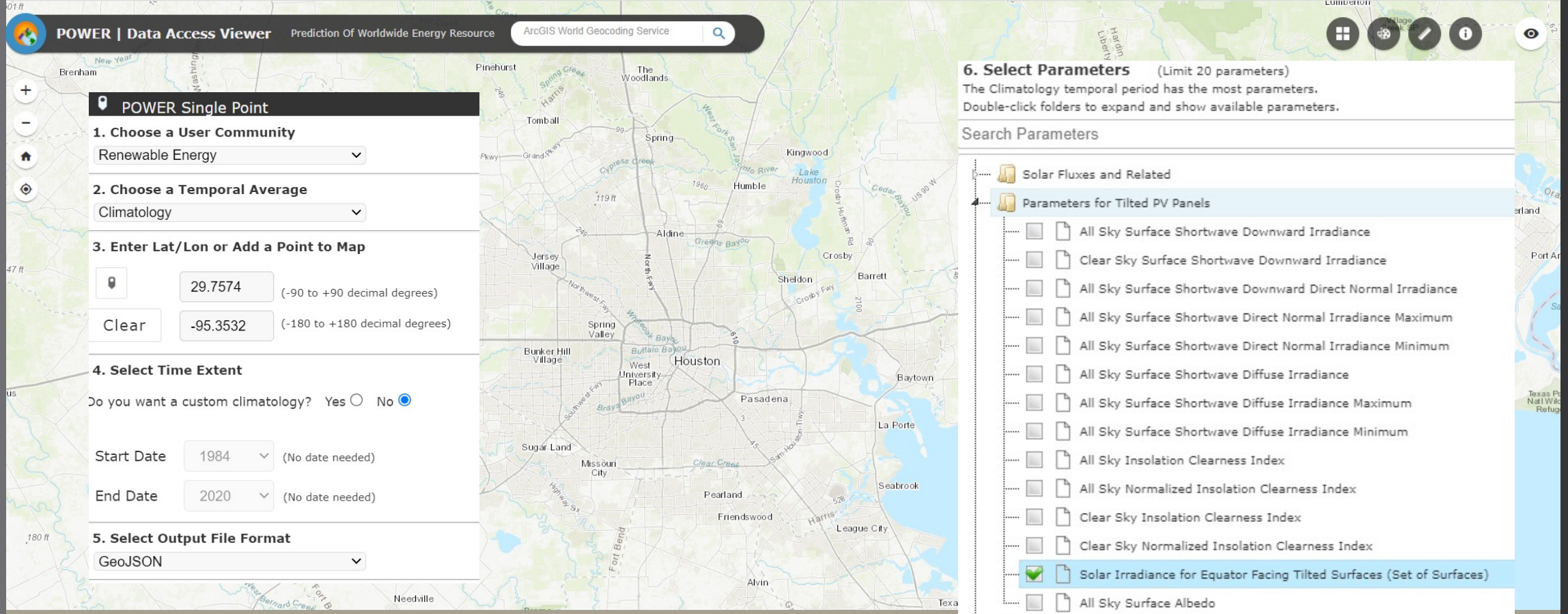

POWER Data Access Viewer & API

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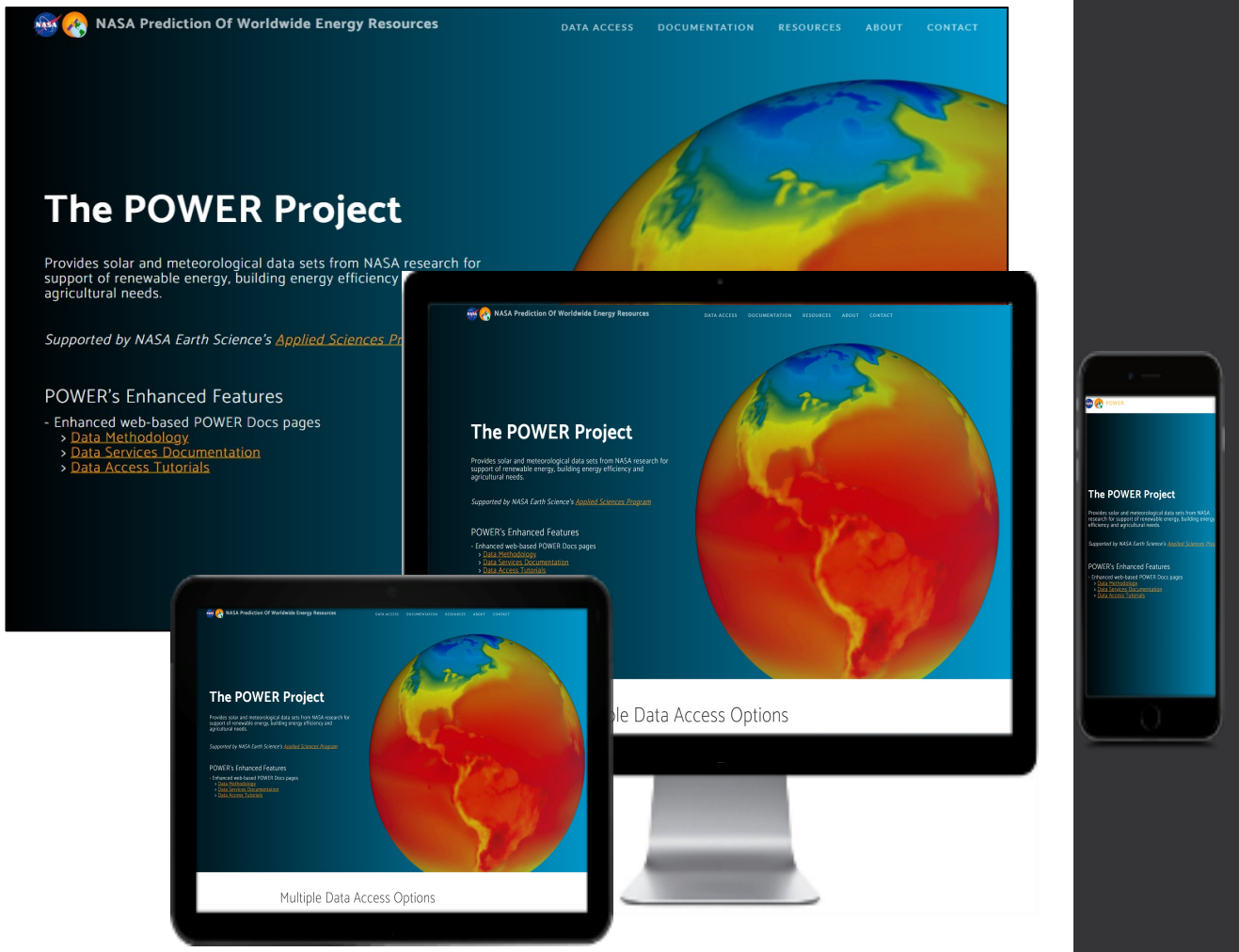
The POWER Project Development and Validation of Solar Irradiance on Equator Facing Tilted Surfaces:

- Accessible through POWER's Data Access Viewer (DAV) & API
- Quarriable custom climatological temporal range and location.
- Multiple file formats available
  - ASCII
  - CSV
  - GeoJSON
  - NETCDF

Solar Energy Industry

Summary

- What is NASA POWER?
- POWER Solar Irradiances Definitions
- Development methodology for POWER & BSRN Adjusted Solar Irradiance on Equator Facing Tilted Surfaces
- Overview of Data Validation
- POWER API & DAV Capabilities



Thank you!

Questions & Comments

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Extras

Validation of the Solar Fluxes from CERES SYN1deg(Ed4.1) Hourly DHI, DirHI and DNI

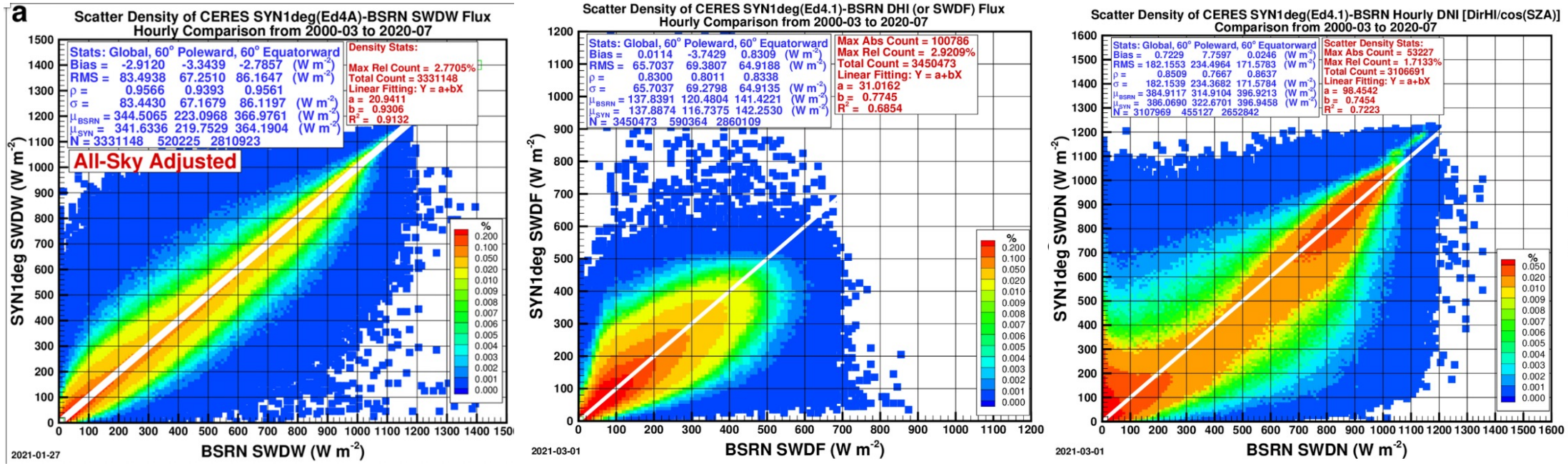

Table 1. CERES SYN1deg(ED4.1)-BSRN hourly all-sky GHI, DHI, DirHI and DNI comparison statistics from 2000-03 to 2020-07 after a bias correction procedure is applied.

All-Sky Hourly	Bias	RMS	ρ	σ	μ_{DATA}	N
DHI	0.01	65.70	0.8300	65.70 (48%)	137.88	3,450,473
DirHI, or GHI-DHI	-0.02	106.45	0.9058	106.45 (48%)	222.64	3,107,945
DNI, or DirHI/cos(Z)	0.72	182.15	0.8509	182.15 (47%)	386.06	3,107,969