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# Analysis of Long-Term Solar Resource Variability Using NSRDB Version 3


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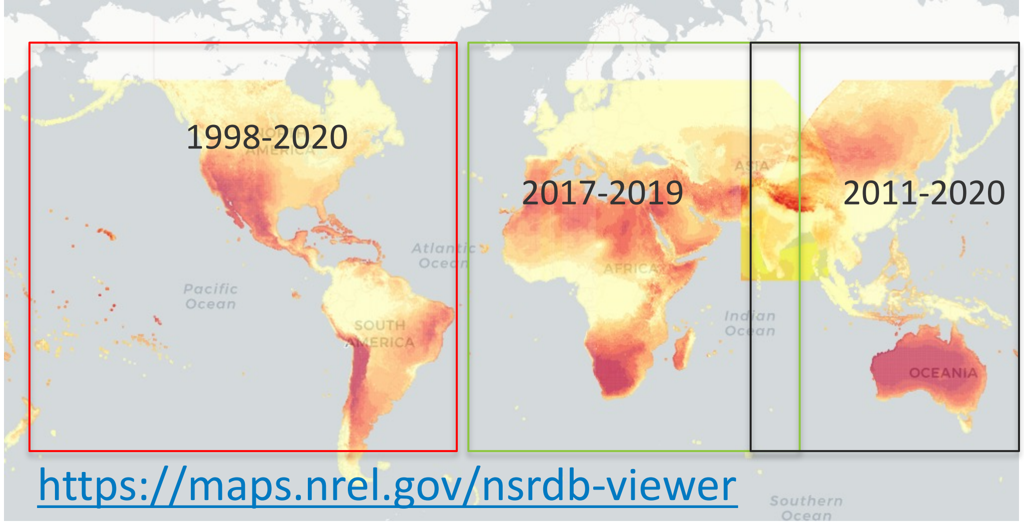
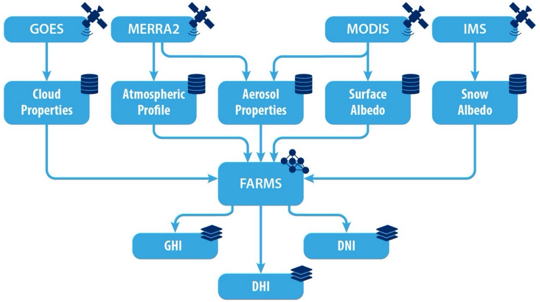
# NSRDB: Global Extent - Data Availability

The data set can be accessed:

- Directly from https://nsrdb.nrel.gov
- Programmatically using an application programming interface. Users can refer to https://developer.nrel.gov/docs/solar/nsrdb for instructions.
- Through AWS cloud service
- The data can also be directly accessed by NREL's System Advisor Model (https://sam.nrel.gov) for performance projection calculations.

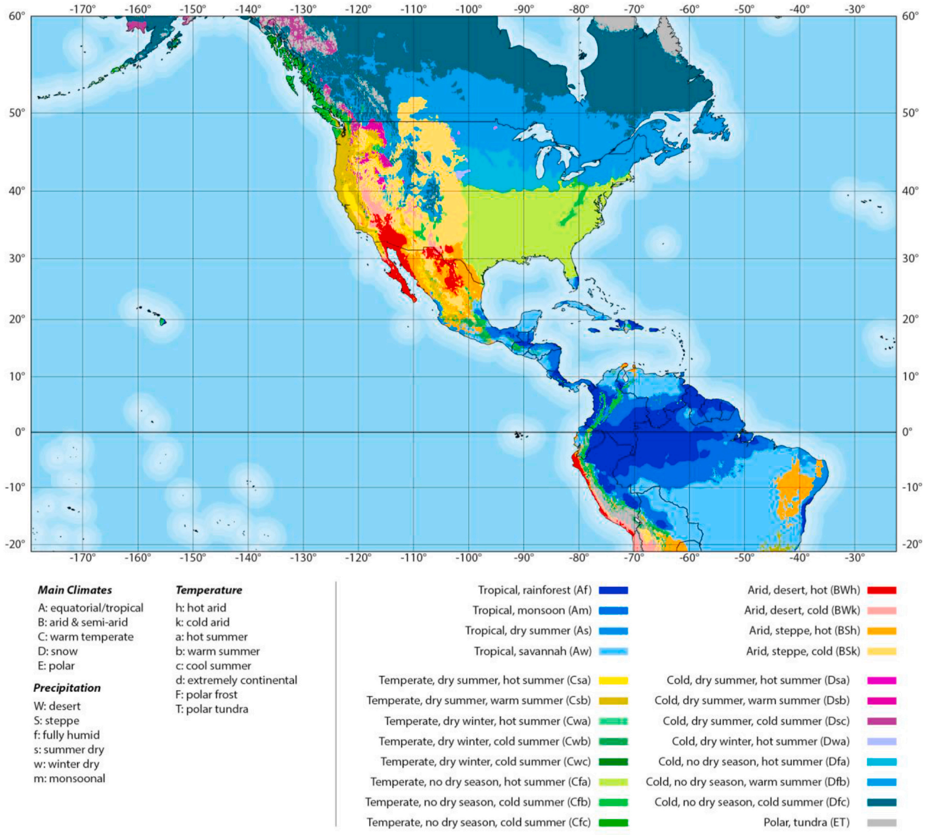



National Solar Radiation Database: Physical Solar Model (PSM) Workflow



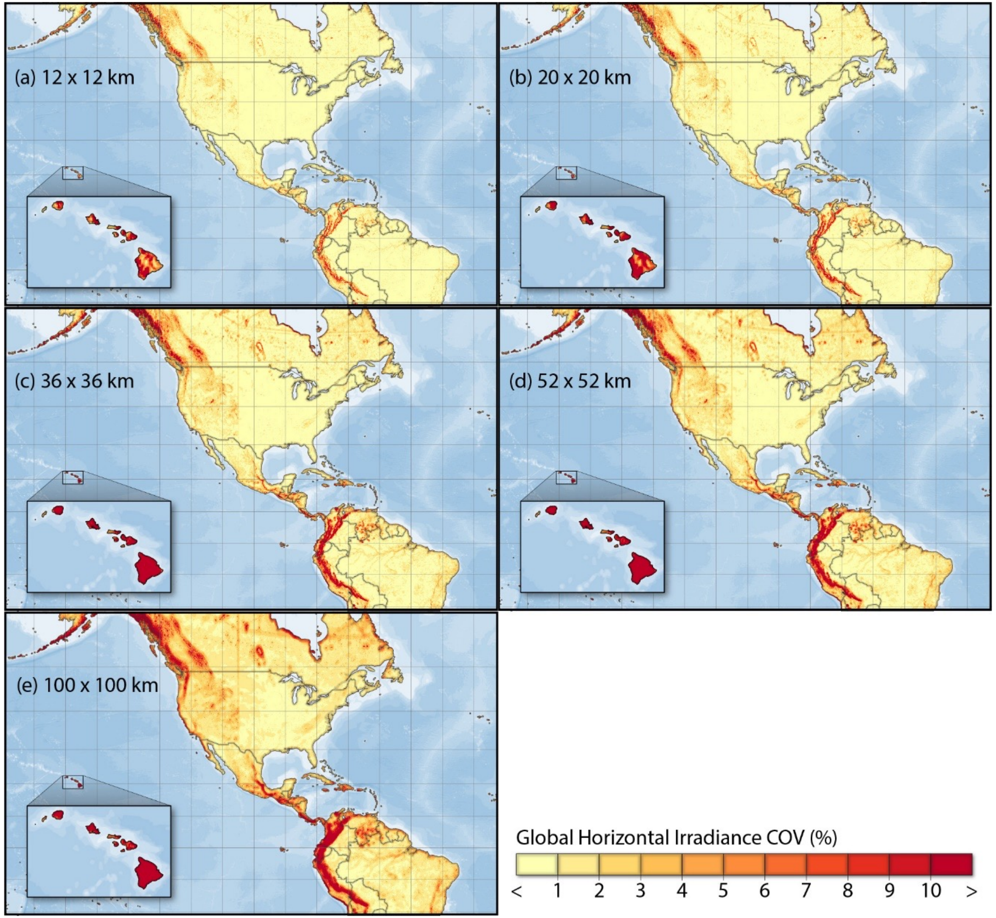
# Solar Resource Variability Study: Outline

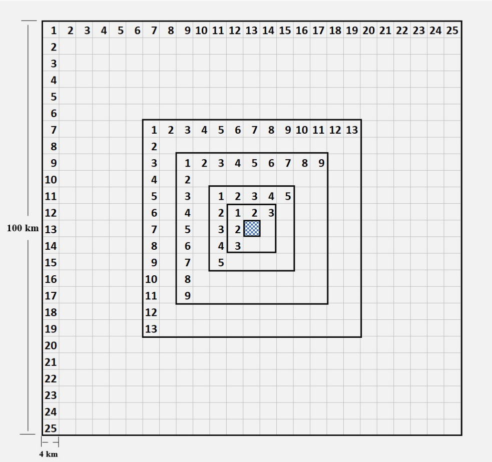
- The NSRDB's 20-year satellite-based solar resource database is used over America .
- The study uses Köppen–Geiger climate classification to understand variability by climate zones at a regional scale
- Spatial and temporal variability in both DNI and GHI was analyzed
- Interannual variability and annual anomalies were also analyzed.




*Habte A, Sengupta M, Gueymard C, Golnas A, Xie Y. Long-term spatial and temporal solar resource variability over America using the NSRDB version 3 (1998–2017). Renewable and Sustainable Energy Reviews. 2020;134:110285.*
*https://www.sciencedirect.com/science/article/pii/S1364032120305736*

# Long-term Spatial Variability



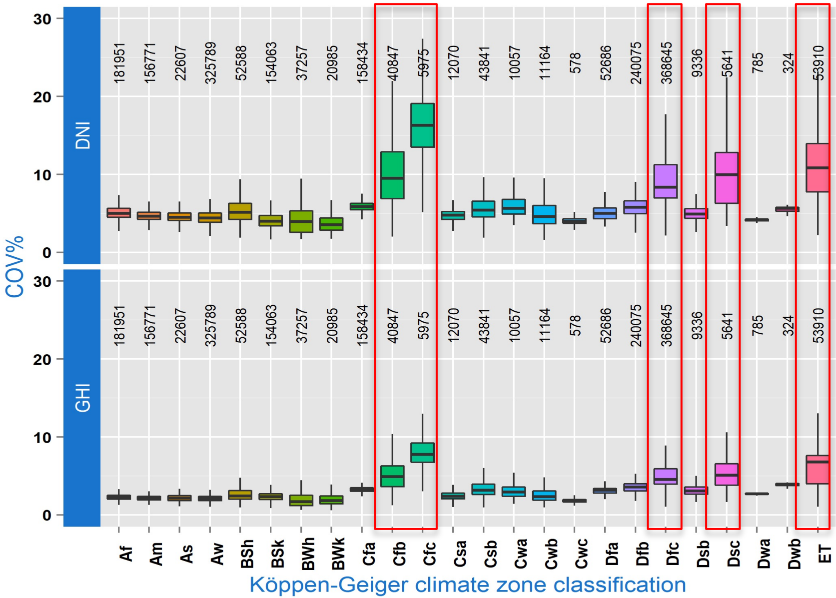

- Variability increases as the distance from the center pixel increases.
- DNI's spatial COV is about twice that of the GHI COV
- Hawaii, the western and southwestern United States, parts of Canada, and western South America showed higher variability

# Long-term Temporal Variability

***<u>NSRDB Domain:</u> The Temperate (C), Continental(D) and Polar (E) climate zones show slightly higher temporal variability***

***<u>CONUS:</u> Some of the Dry (B), Temperate (C), Continental(D) climate zones show slightly higher temporal variability.***

- Some of the climate zones which were available for the NSRDB domain are not available in CONUS.
- The variability appears to be lower for CONUS than the NSRDB domain

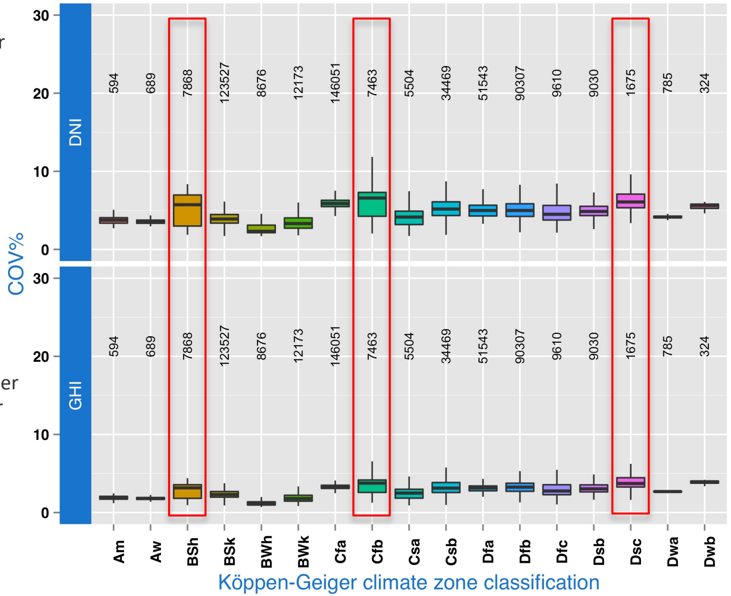



Climate zones based on Köppen-Geiger

**<u>Main Climates</u>**
A: equatorial/tropical
B: arid & semi-arid
C: warm temperate
D: snow
E: polar

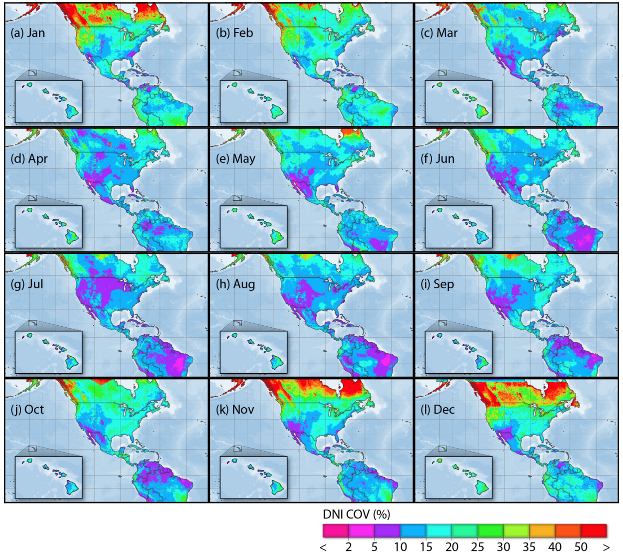
**<u>Precipitation</u>**
W: desert
S: steppe
f: fully humid
s: summer dry
w: winter dry
m: monsoonal

**<u>Temperature</u>**
h: hot arid
k: cold arid
a: hot summer
b: warm summer
c: cool summer
d: extremely continental
f: polar frost
T: polar tundra

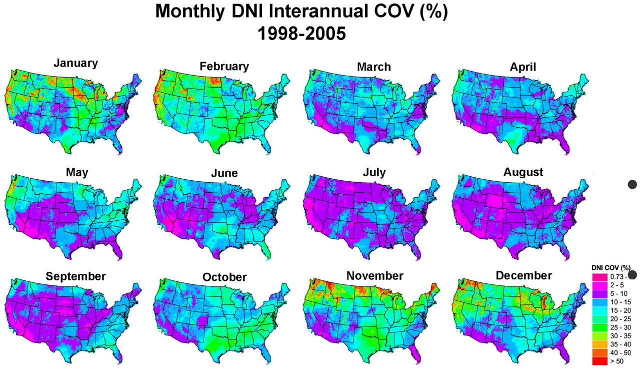



**The temporal variability in GHI and DNI for the full NSRDB domain. The top numbers in each panel provide the pixel count in each climate zone. This assists in the interpretation of the results.**

# DNI Seasonal Variability: Comparison with Previous Study




Previous study

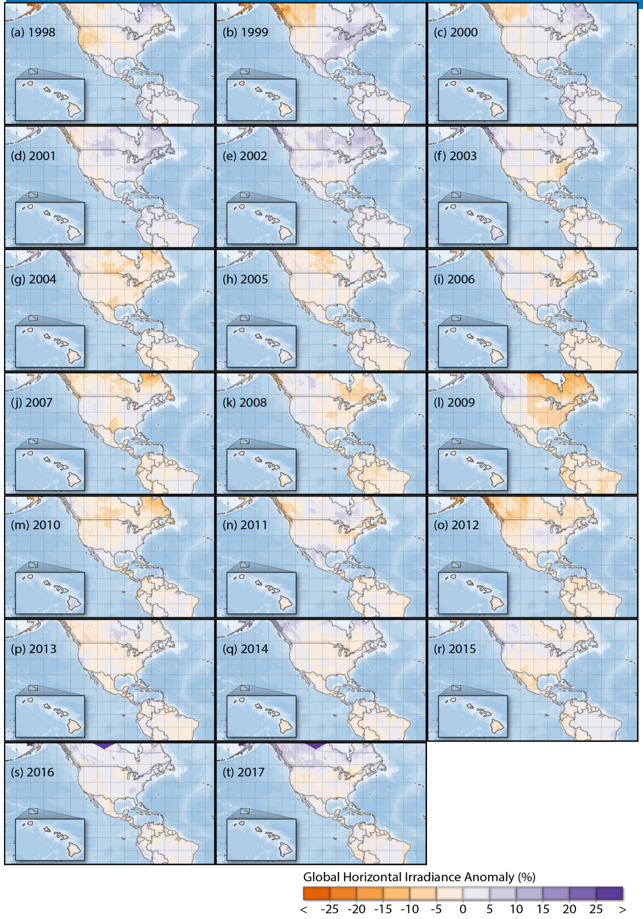



- Previous study used semi-empirical State University of New York satellite model covering 1998–2005 and present study used PSM covering 1998-2017.
- The trends for each months are similar between the two studies.
- The current study demonstrated higher variability because of:
  - Model differences
  - Increased spatial resolutions (10x10 km vs. 4x4 km for current study)
  - Longer period of the newer study.

Monthly interannual variability of DNI (left: present study and right: earlier study*)

* **C.A. Gueymard, S.M. Wilcox, Assessment of spatial and temporal variability in the US solar resource from radiometric measurements and predictions from models using ground-based or satellite data. Sol Energy, 85 (2011), pp. 1068-1084. https://www.sciencedirect.com/science/article/pii/S0038092X11000855**

# Solar Resource Anomaly from Long-term Mean

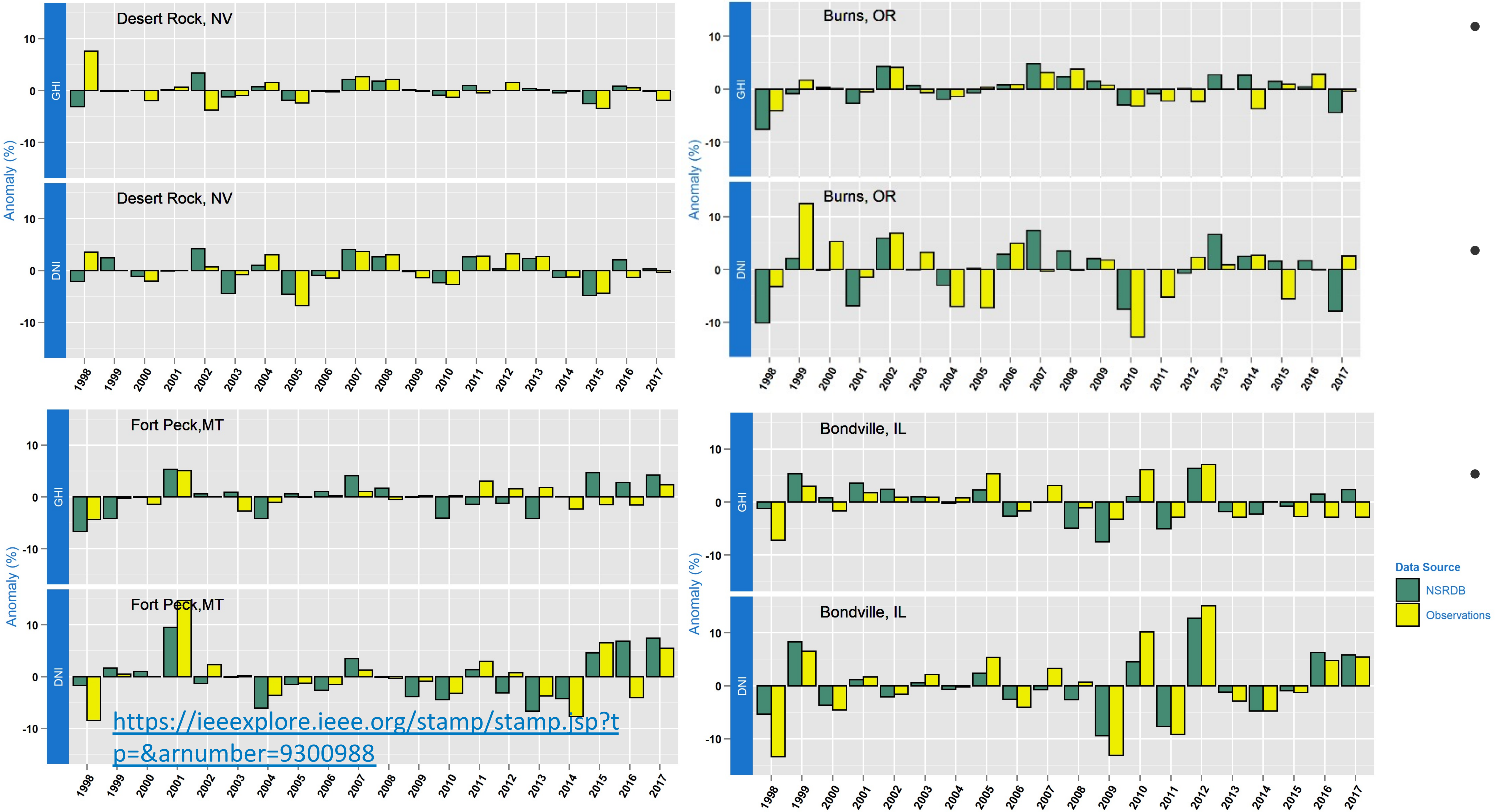



The annual anomalies are found to be particularly significant during a few specific years:

- During 2002, for instance, most of CONUS and Canada benefitted from an increase of up to ≈10% in both GHI and DNI.
- Conversely, the central and southern plains of CONUS tended to be affected by up to 5%–10% reduction in irradiance in 2015

This anomaly analysis seems to be impacted by known calibration issues of the Geostationary Operational Environmental Satellite (GOES) and calibration adjustments may be needed.

# Solar resource anomaly: Comparison with Ground Measurements



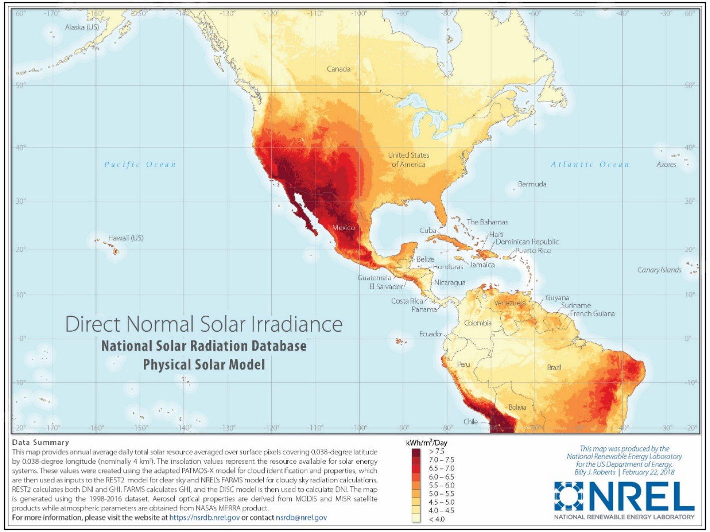

[https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=9300988](https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=9300988)

Percent annual anomaly of ground measurements (yellow bar) and NSRDB (green bar) for GHI (top row) and DNI (bottom row) at four locations during the period 1998–2017 (X-axis).

- The NSRDB and surface measurements capture similar positive or negative deviations and magnitudes.
- This gives confidence that the NSRDB data are potentially able to predict long-term variability accurately.
- Exceptions do occur during some years, when the anomaly magnitudes differ.

# Summary

- This study assessed the long-term spatiotemporal variability in the solar resource at continental scale, which can have substantial impacts on the design, bankability, and operation of solar energy conversion systems.
- A data-reduction technique using Köppen-Geiger (KG) climate classes provided insight into interpreting the results. Similarly, the temporal variability of each pixel and KG climate class was analyzed with respect to the long-term average GHI or DNI irradiance components.
- The long-term temporal variability results have been found to be typically 5% for GHI and 10% for DNI. Moreover, the NSRDB domain's COV has been found roughly twice that of CONUS.
- Spatial variability, the present results have shown that it is an increasing function of the distance from the center pixel. The spatial COV typically reaches up to 5% DNI and 3% for GHI for the highest grid layout (100 km × 100 km), but some areas exhibit COVs of 10% or more.
- Annual solar irradiance anomalies have been found to reach ±25% for both GHI and DNI (and even exceed that value in some instances) during each year of the 20-year period, which is significant.
- The NSRDB and surface measurements capture similar positive or negative deviations as well as their magnitudes. This gives confidence that the NSRDB data are able to accurately predict long-term variability, even though exceptions do occur during some years.




# Thank you!

**www.nrel.gov**

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