

2016 ASHRAE Annual Conference



Anthony Lopez
National Renewable Energy
Laboratory
Anthony.Lopez@nrel.gov
303-275-3654

Seminar 63 –Moving Beyond Typical Year Weather Data

Understanding the Temporal and
Spatial Variability of New Generation
Gridded TMYs

June 27, 2016

St. Louis, Missouri

Learning Objectives

Objective 1: Learn about what's new and different in the Climatic Design Conditions Table in the 2013 ASHRAE Handbook of Fundamentals

Objective 2: Learn about the new 2013 edition of ASHRAE Standard 169 Climatic Data for Building Design Standards

Objective 3: Learn about new climatic data products from the U.S. National Climatic Data Center, including advanced GIS and Web services that allow for direct access to data, including surface-based observations for thousands of stations, climate reanalysis data, and products derived from satellite data

Objective 4: Understand new developments in NREL's solar databases based on both observed data and satellite-derived gridded data, status of TMY3 weather files, and NREL's plans for the next-generation TMY weather files

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Acknowledgments

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- We would like to thank the contributors of this work; Manajit Sengupta, Aron Habte, Yu Xie and Andrew Weekley.



Outline/Agenda

- Background - National Solar Radiation Database (NSRDB)
- Current Methodology
- Meteorological Data
- Validation
- Typical Meteorological Year (TMY) Data
- Spatiotemporal Variability of TMY
- NSRDB Website and Data Access



National Solar Radiation Data Base

<http://nsrdb.nrel.gov>

Evolution of Solar Resource Data

1952-1975 SOLMET¹ [ERDA, NOAA, 1979]

1961-1990 NSRDB² [DOE, NOAA, 1994]

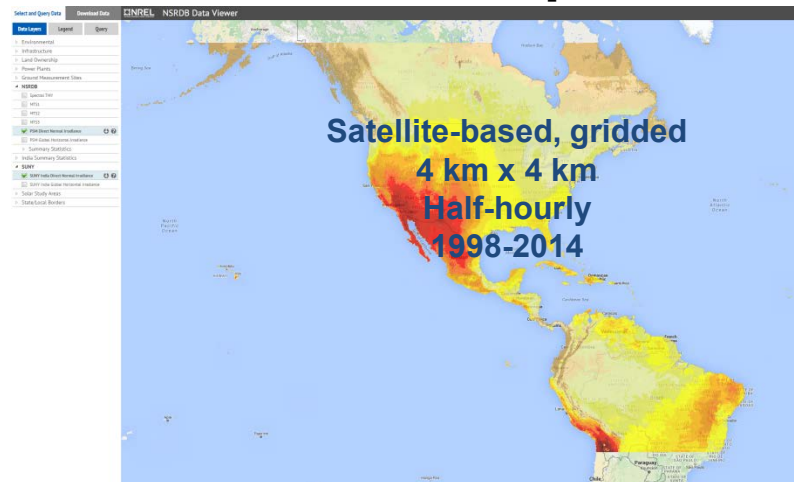
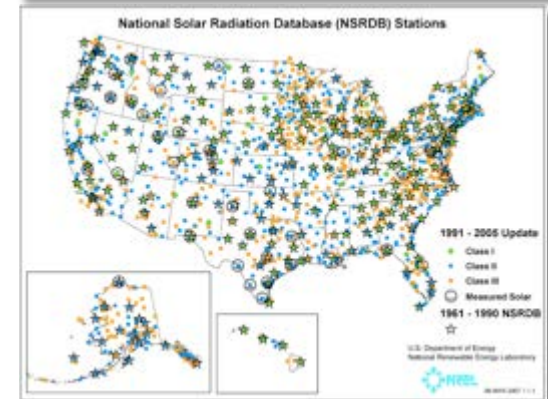
1991-2005 NSRDB-II³ [DOE, NOAA, 2007]

1998-2014 NSRDB [DOE, NOAA, UW 2015]

(1)
248 stations with
26 *Measurement*
Stations
1977-80

(2)
239
Modeled
Stations with
56 partial
measureme
nt stations
1990

(3)
1,454 *Modeled*
Locations
1991-2005

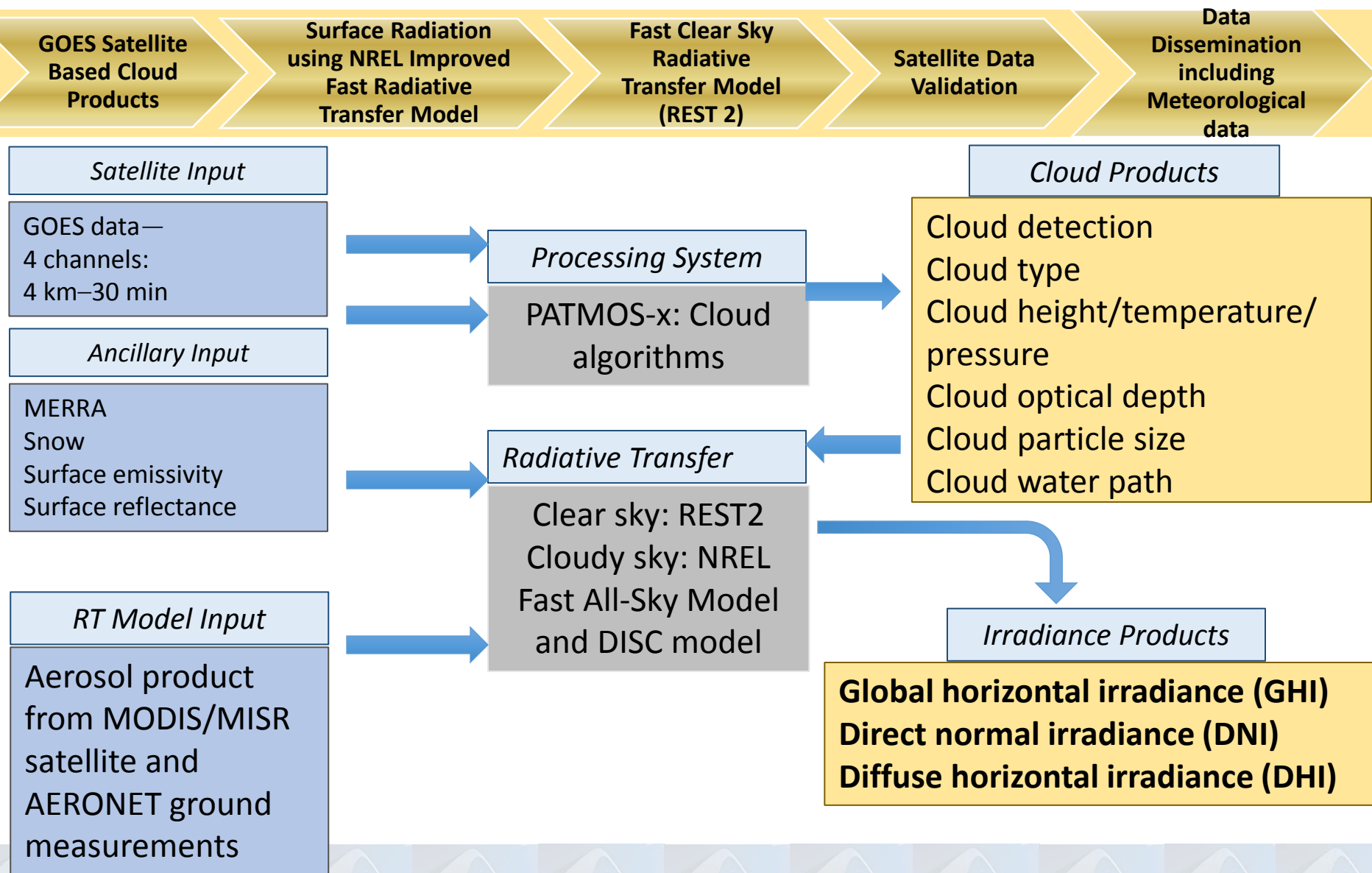


How do satellites model surface radiation?

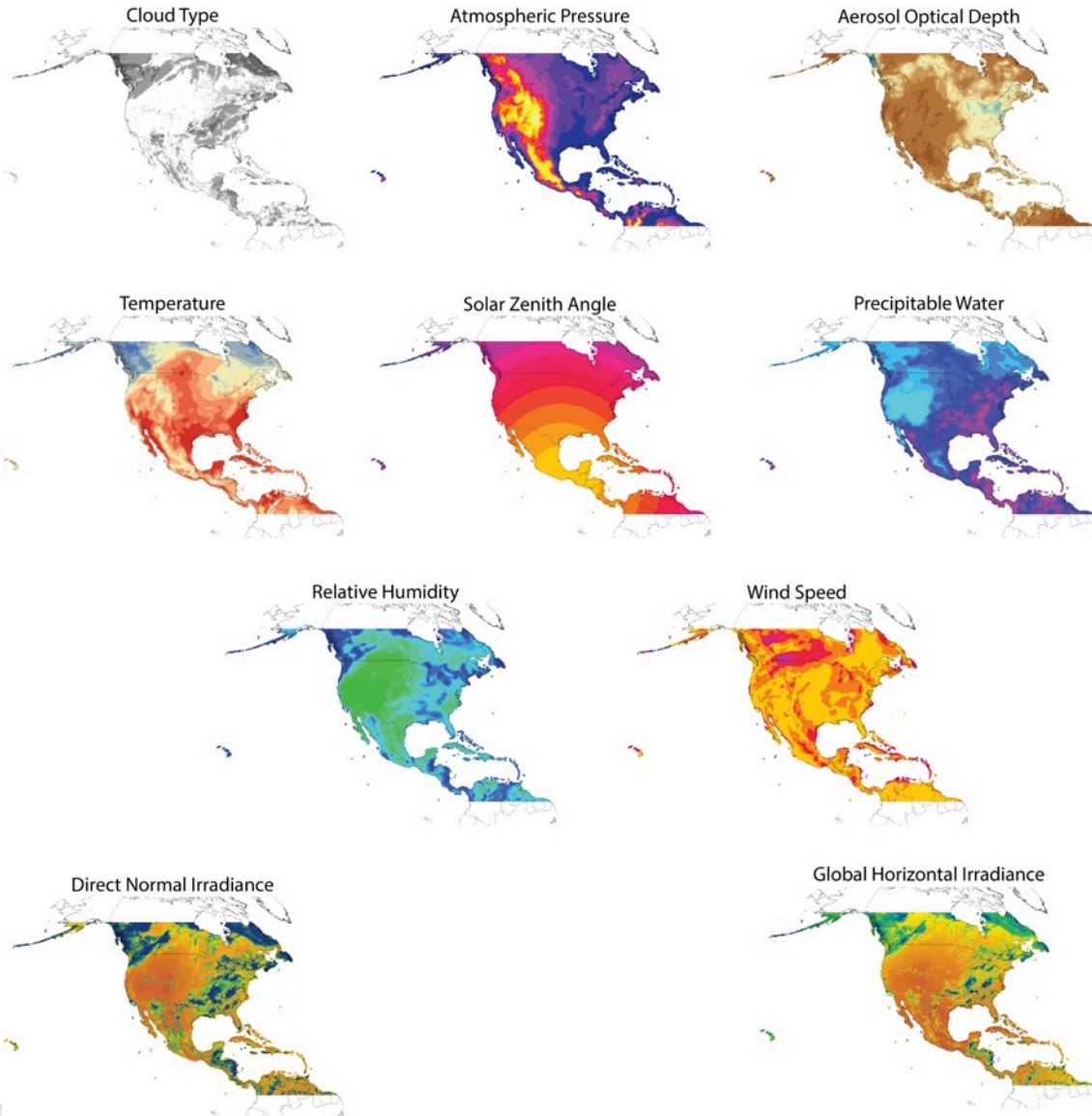
- **Empirical Approach (Industry standard traditional approach):**
 - Build model relating satellite measurements and ground observations.(cloud index and clearness index)
 - Use those models to obtain solar radiation at the surface from satellite measurements.
- **Physical Approach: (the new approach)**
 - Retrieve cloud and aerosol information from satellites
 - Use the information in a radiative transfer model



Physical Solar Model (PSM) Framework



Met Data for the NSRDB



**Gridded NSRDB –
Comprises various
variables which include
meteorological
parameters that are
obtained from the
Modern Era-
Retrospective Analysis
(MERRA) dataset.**

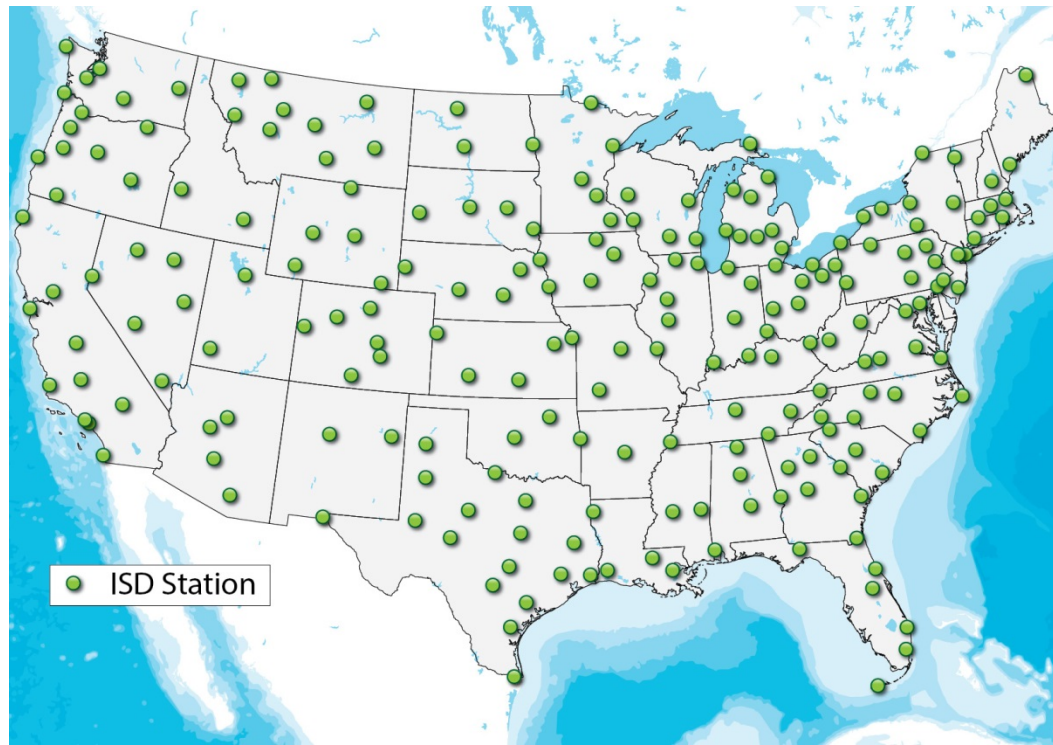
**Note: Some of these parameters
are part of the NSRDB release data
and some are used for processing
the gridded data.**

Meteorological Data Comparison

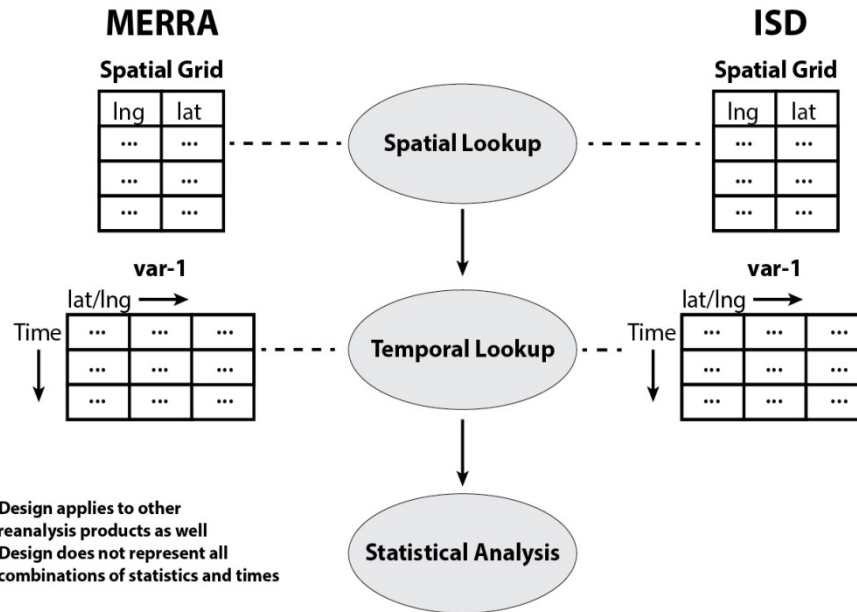
The three data sets evaluated are:

- Modern-Era Retrospective Analysis for Research and Applications (MERRA),
- North American Regional Reanalysis (NARR), and
- Climate Forecast System Reanalysis (CFSR).

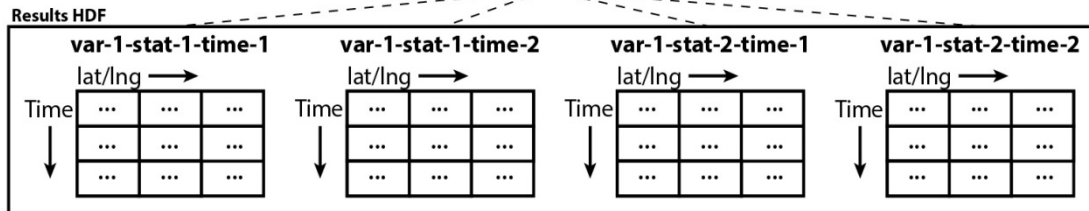
These datasets were evaluated against 216 ISD stations located in the contiguous United States.



Analysis Sequence

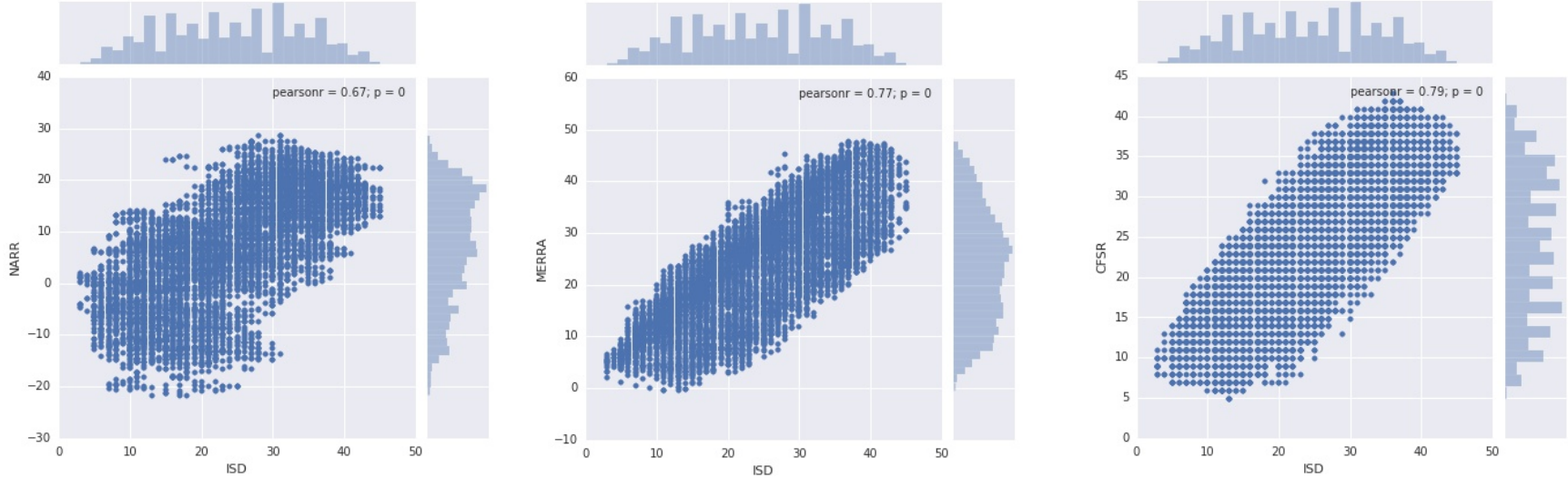


* Design applies to other reanalysis products as well
* Design does not represent all combinations of statistics and times

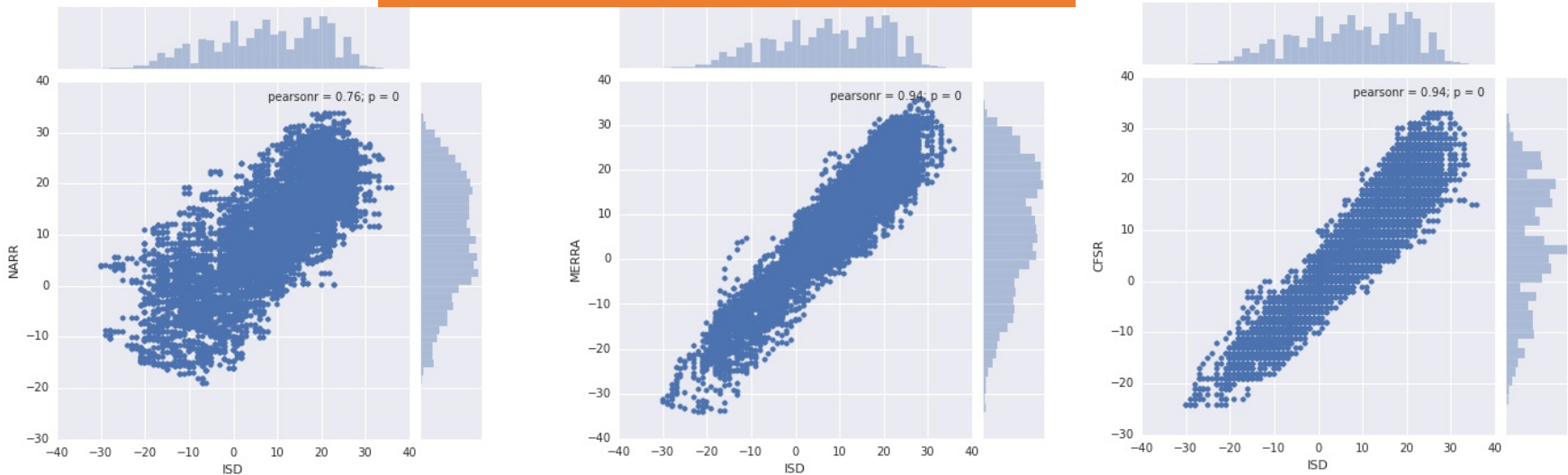


Meteorological Data Comparison

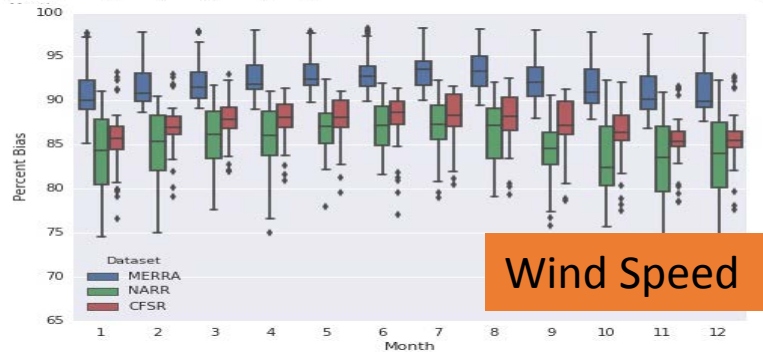
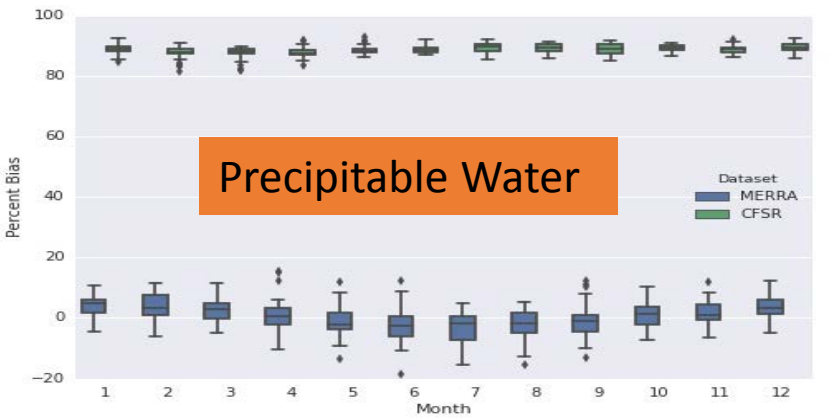
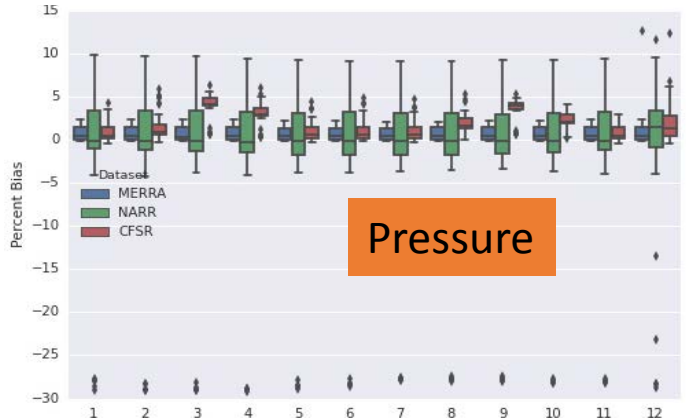
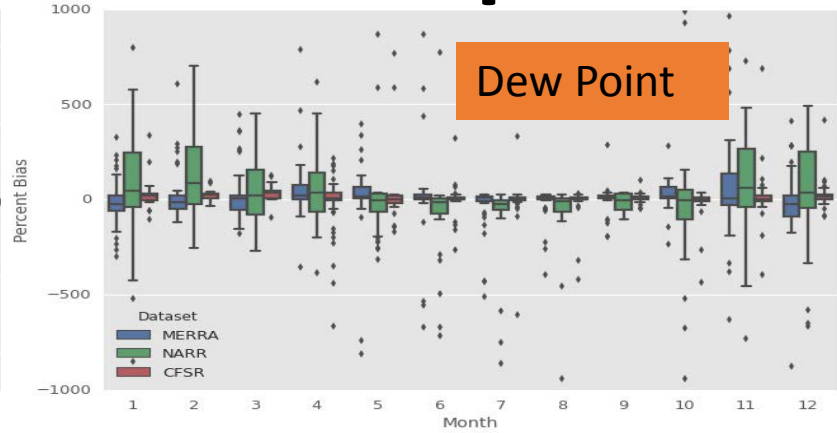
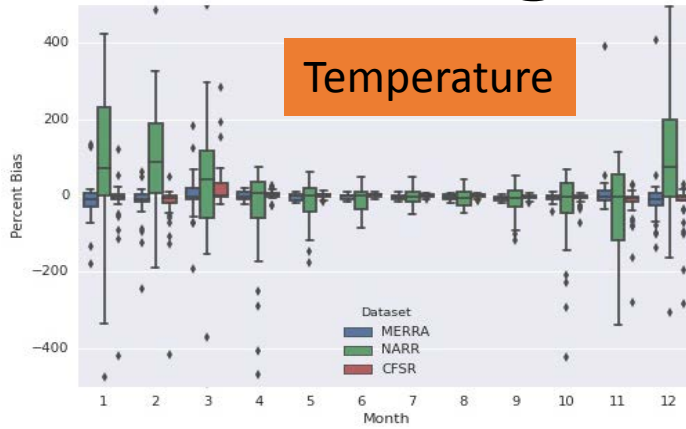
Temperature Comparison for Phoenix, AZ



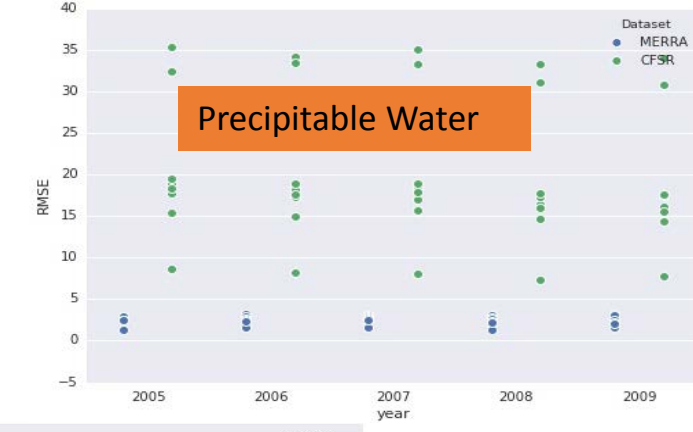
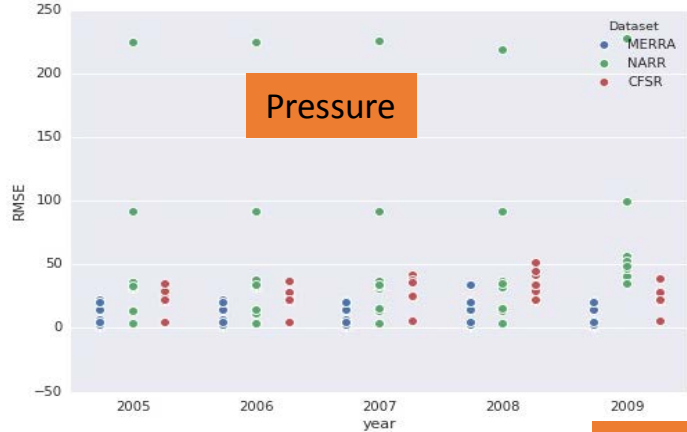
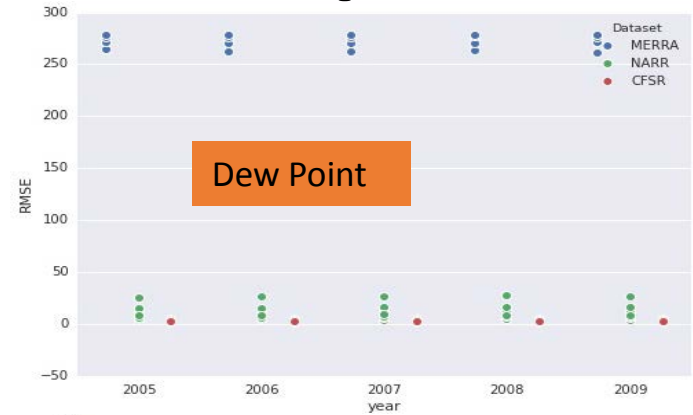
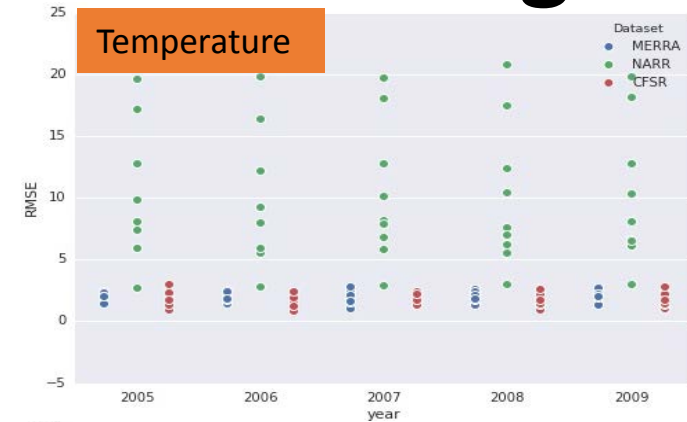
Temperature Comparison for Minneapolis, MN



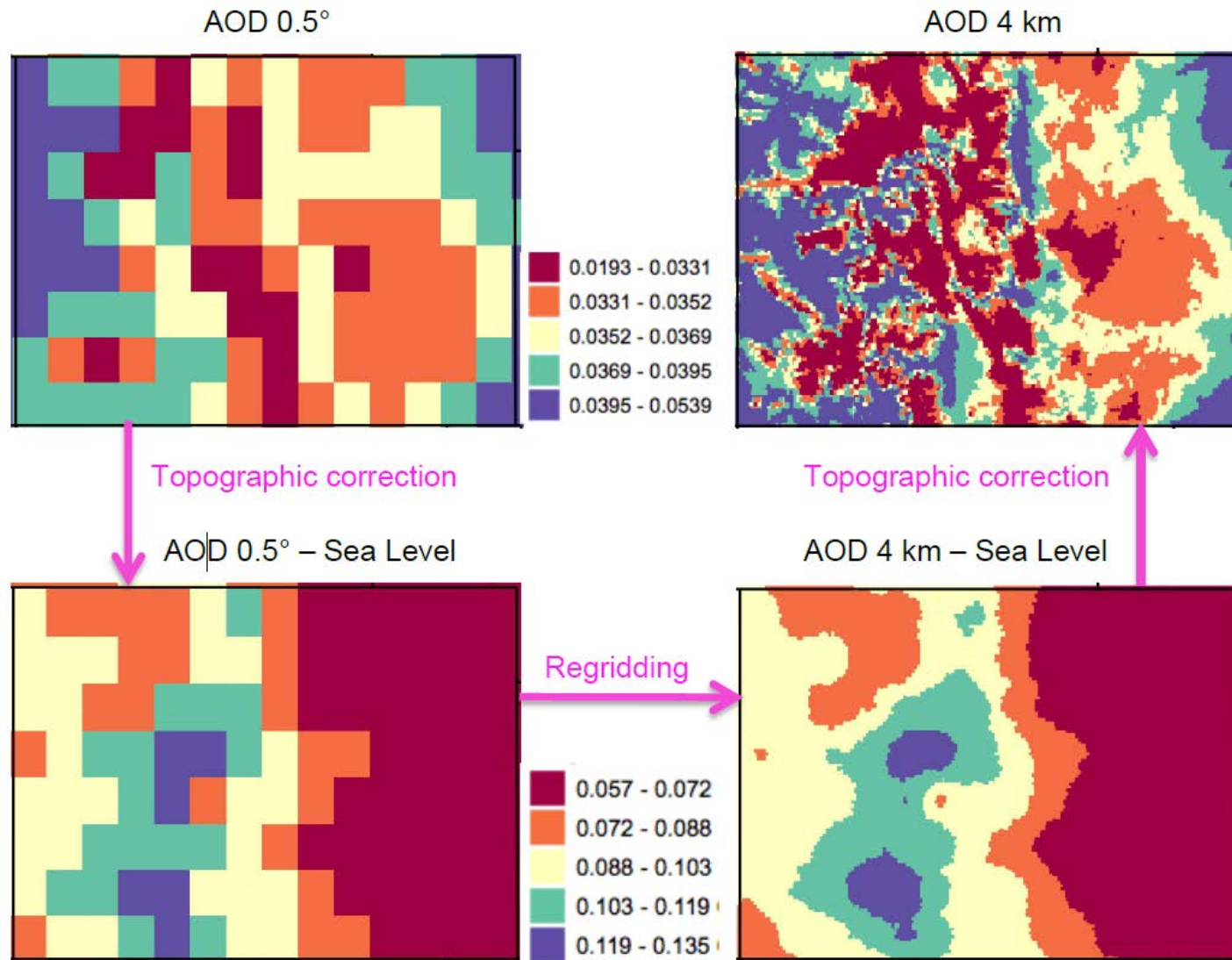
Meteorological Data Comparison



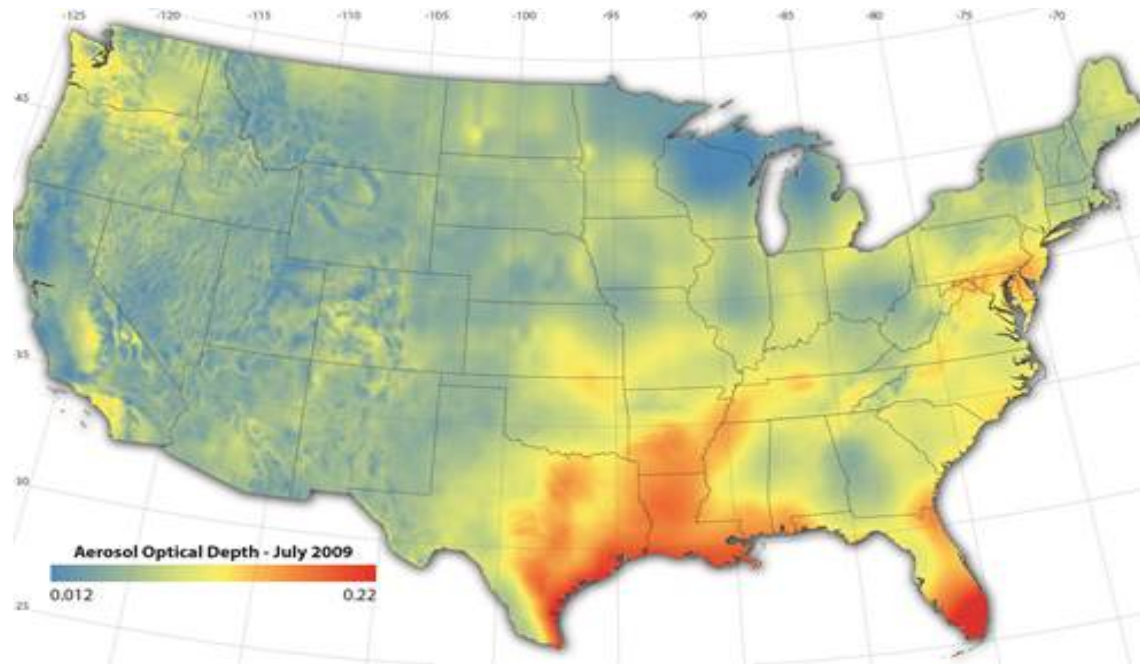
Meteorological Data Comparison



Current AOD Retrieval Process



AOD



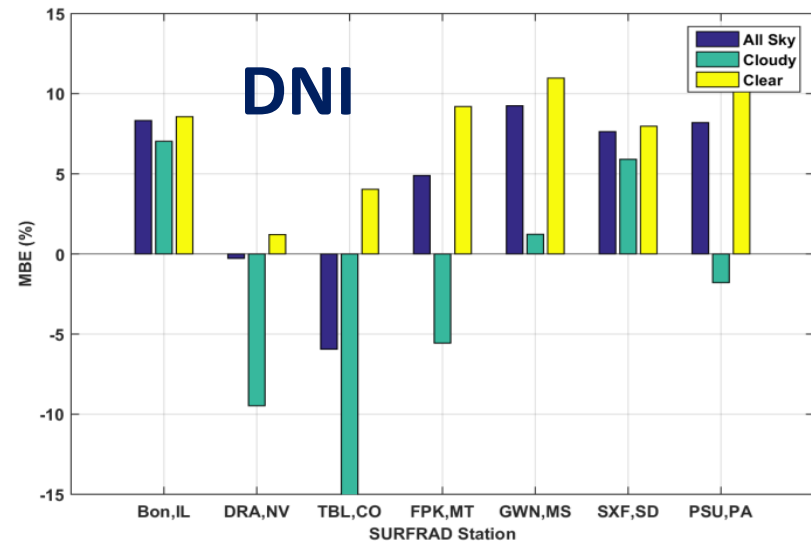
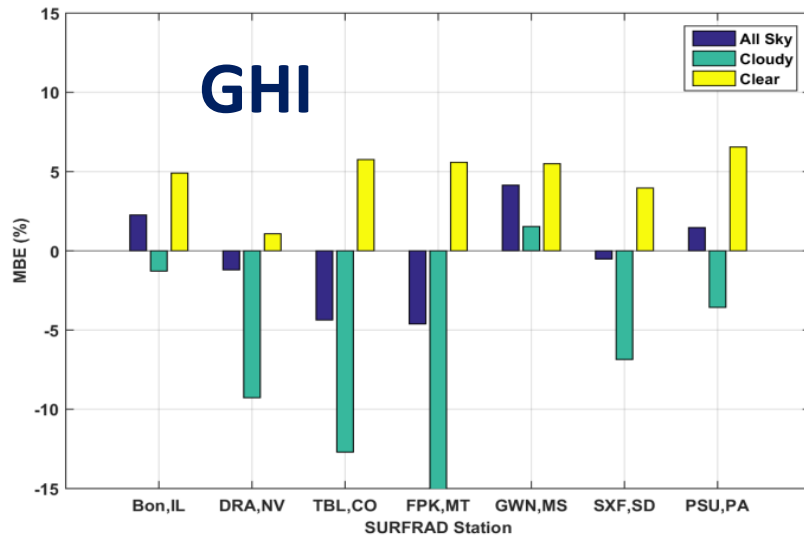
	AOD	MAE(W/m ²)	MAE(%)	RMSE(W/m ²)
Desert Rock, NV	Monthly	17	1.84	20
	Daily	12	1.34	16
Goodwin Creek, MS	Monthly	47	5.96	53
	Daily	30	3.76	36
Bondville, IL	Monthly	62	7.76	67
	Daily	37	4.65	48
Table Mtn., Co	Monthly	35	3.84	41
	Daily	24	2.57	30

Validation of the NSRDB

Validation of NSRDB

- Validation of gridded NSRDB dataset

- Evaluation of the new NSRDB dataset was carried out using high quality SURFRAD ground stations.
- Accuracy of NSRDB datasets is significantly high.

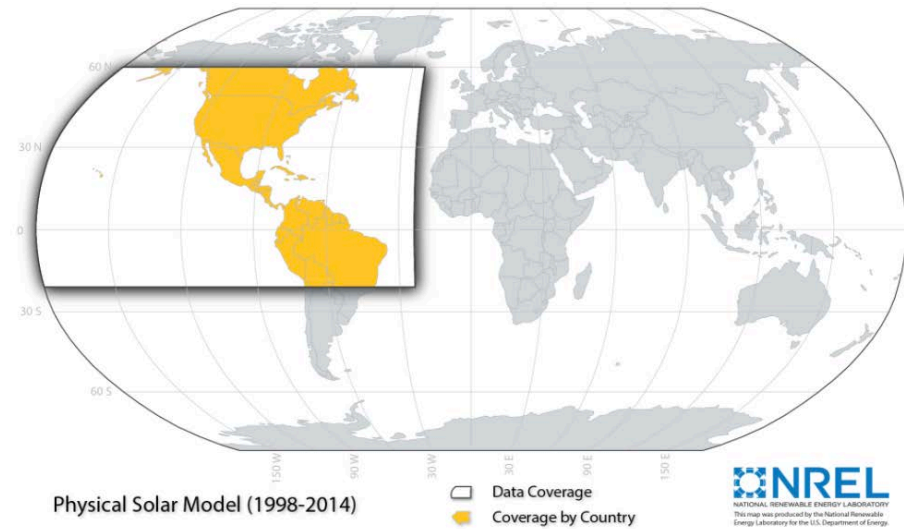


MBE in percent for all years (1998-2014) for the seven SURFRAD sites.

Gridded TMY

Product Variables

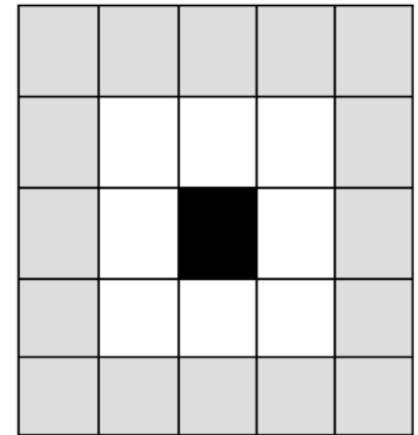
Element	Unit or Description
Year	1998-2014
Month	1-12
Day	1-28,1-30 or 1-31
Hour	1-23
Minute	0
Dew Point	Degree C
DHI	Watt per square meter
DNI	Watt per square meter
GHI	Watt per square meter
Temperature	Degree C
Pressure	Millibar
Wind	
Direction	Degrees
Wind Speed	meter per second



TMY Spatial Variability

$$COV(TxY_a, TxY_b) = \frac{\left(\sqrt{\frac{\sum_{i=1}^n (\overline{TxY_{b_i}} - \overline{TxY_a})^2}{n}} \right)}{\overline{TxY_a}}$$

5 by 5

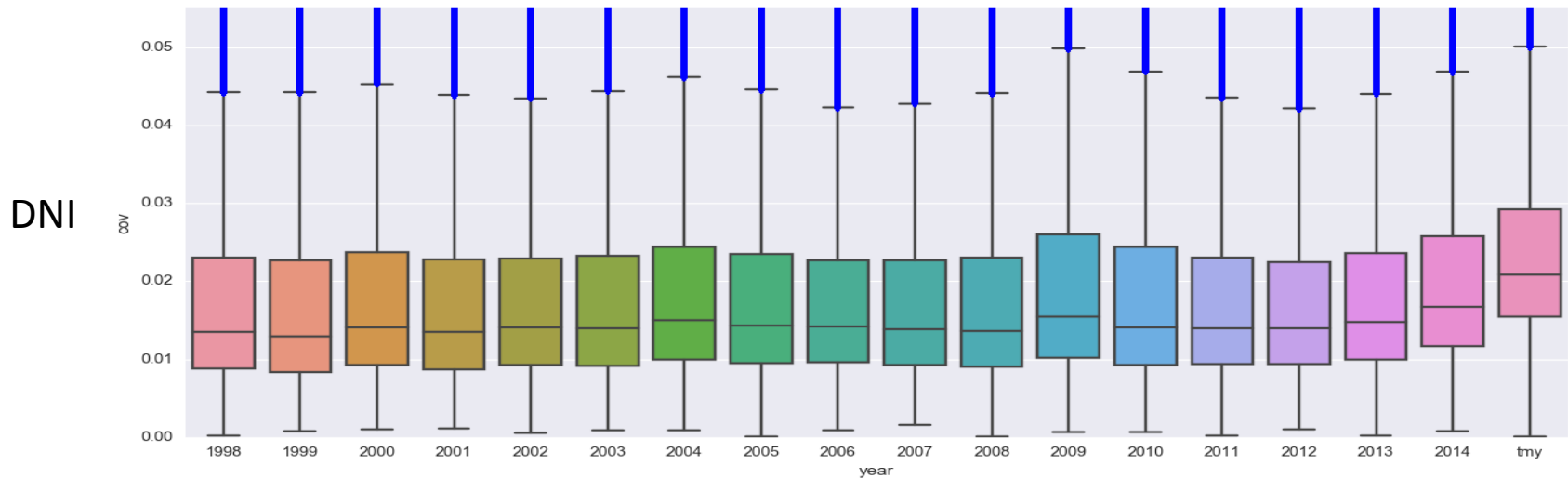
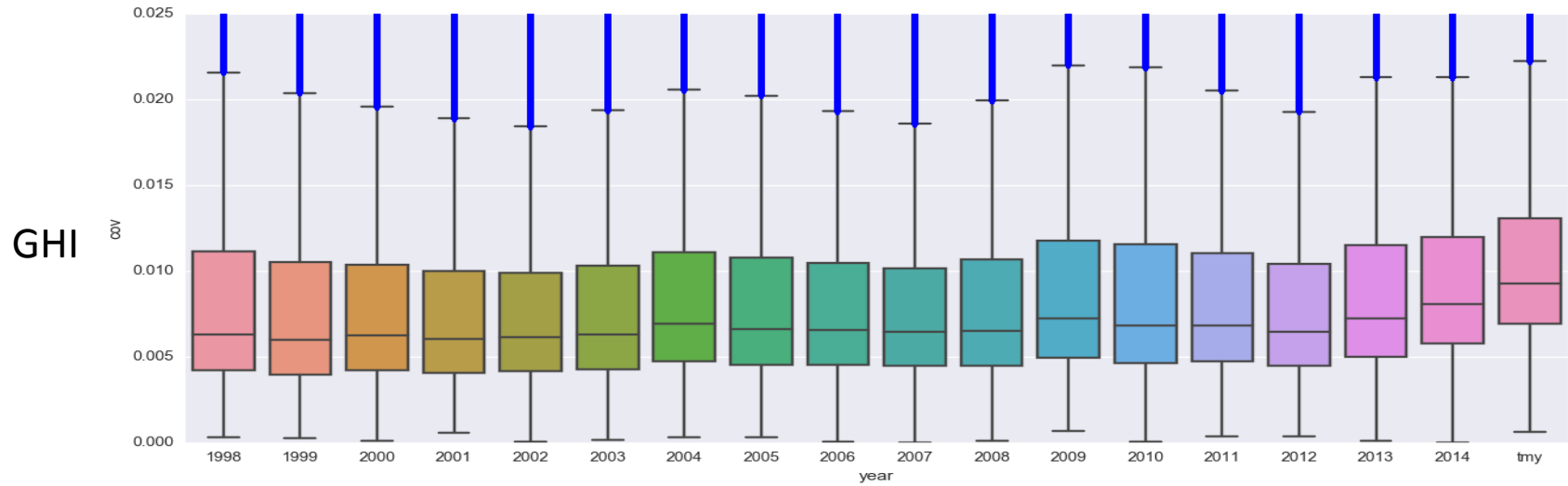


TxYa: average irradiance of the center pixel

TxYb: average irradiance of the comparison pixel(s)

n: number of surrounding pixels compared

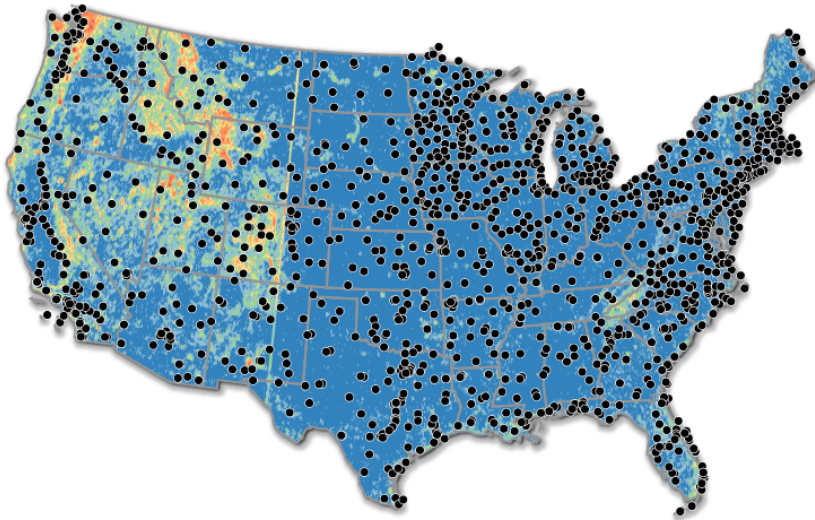
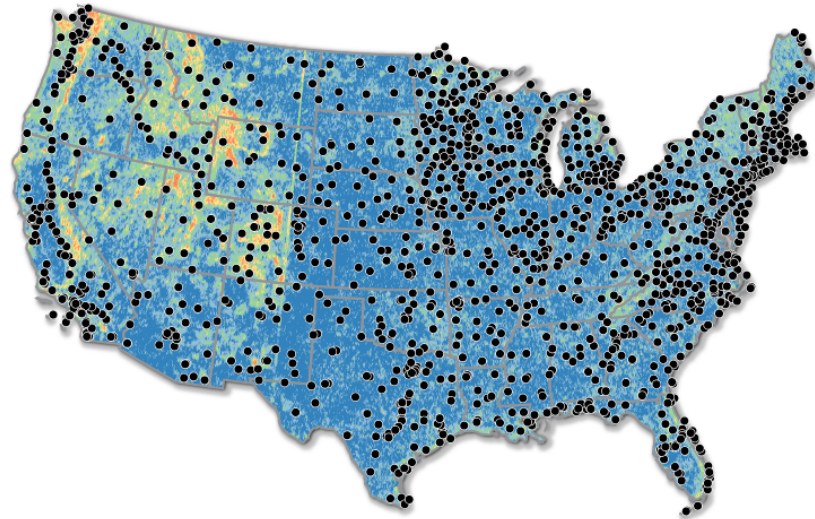
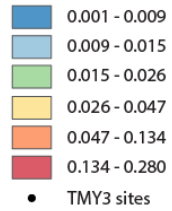
TMY Spatial Variability



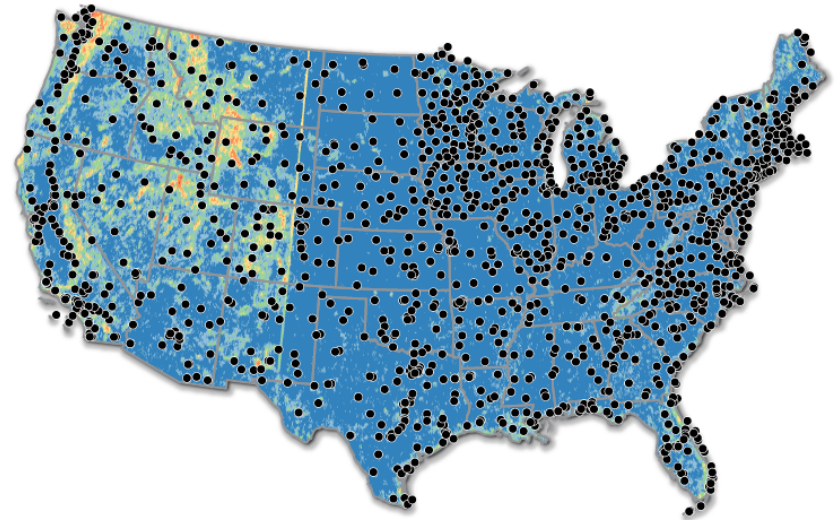
TMY Spatial Variability

TMY

GHI COV

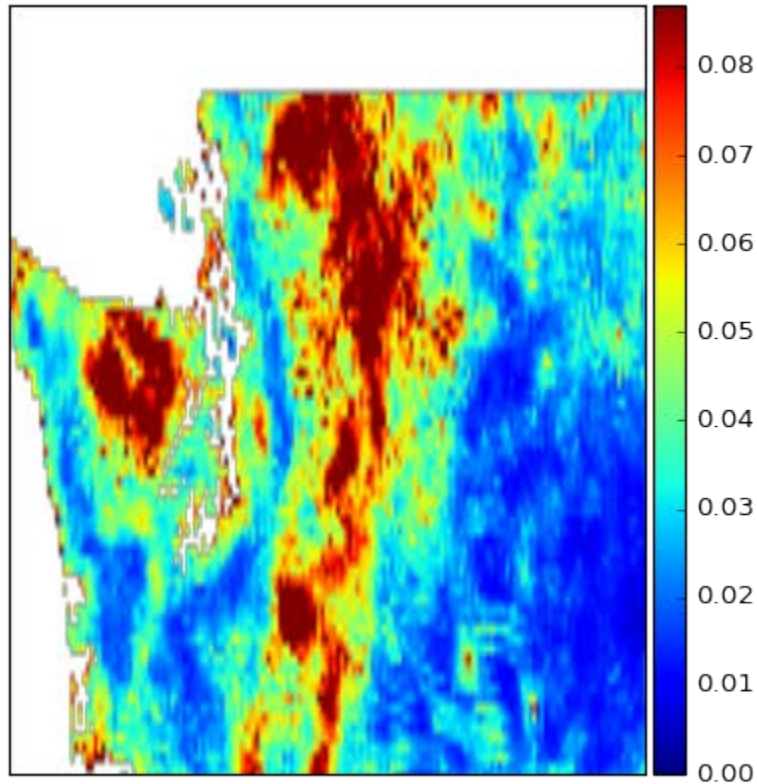


Min Difference (2014)

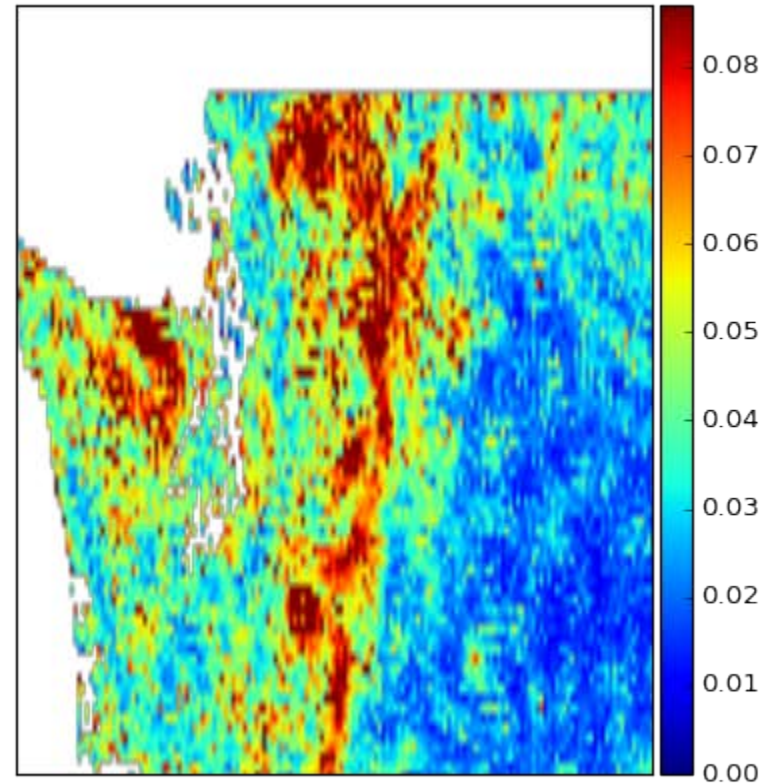


Max Difference (2002)

TMY Spatial Variability

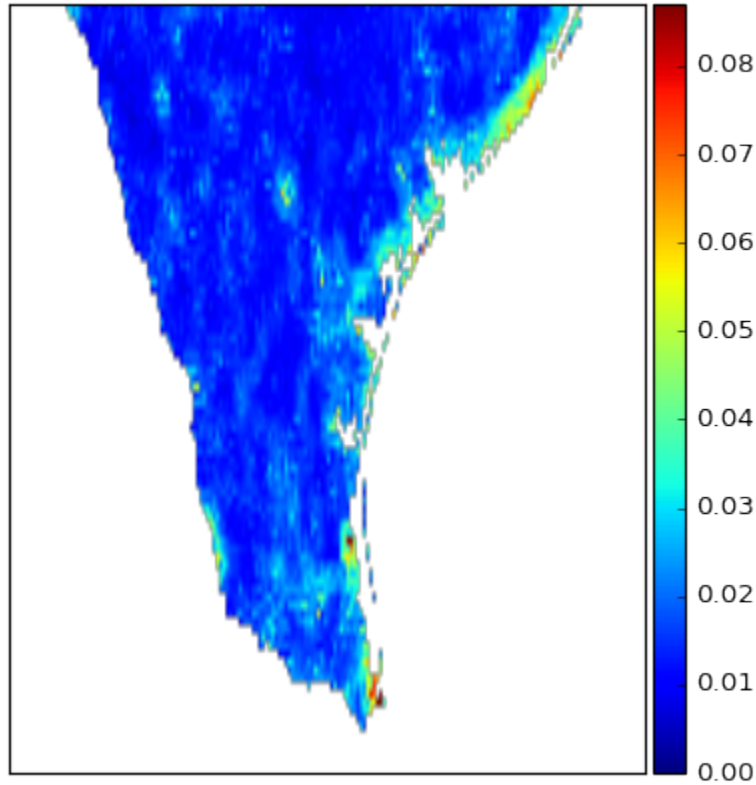


1998-2014 COV

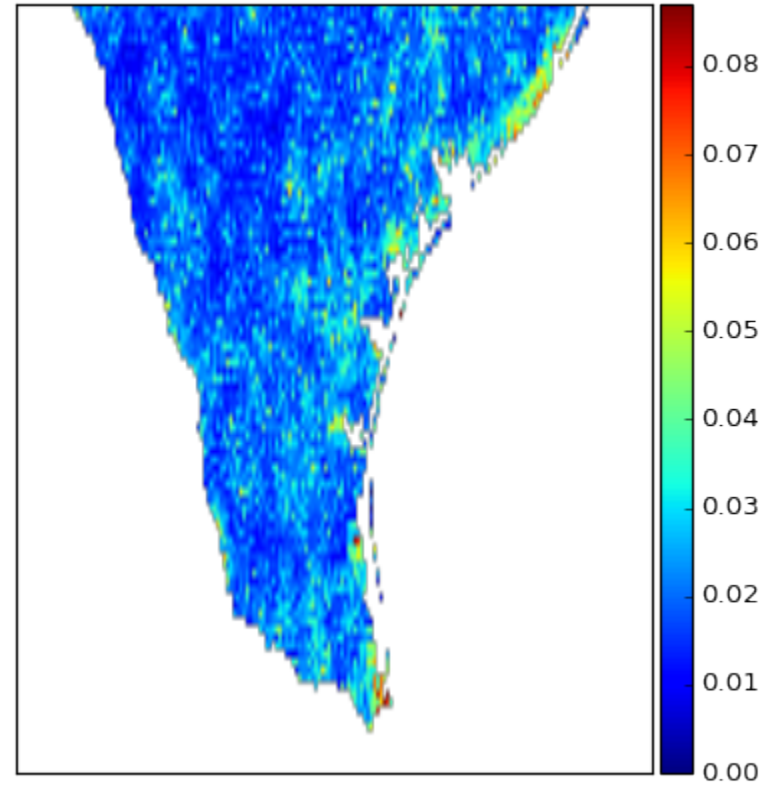


TMY COV

TMY Spatial Variability

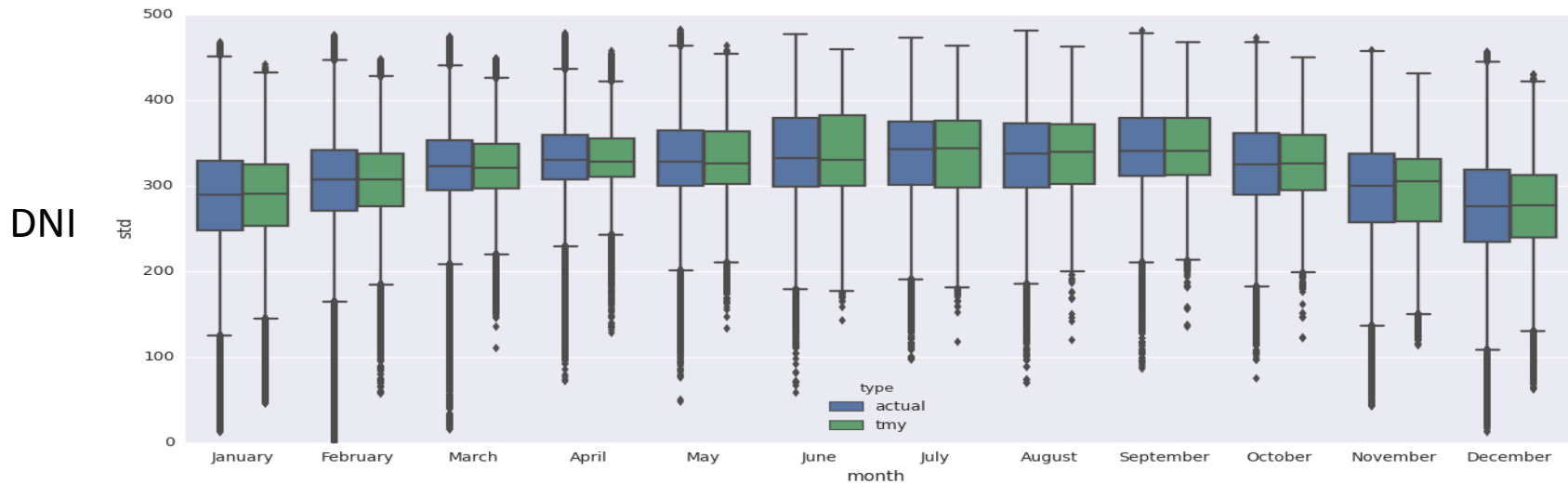
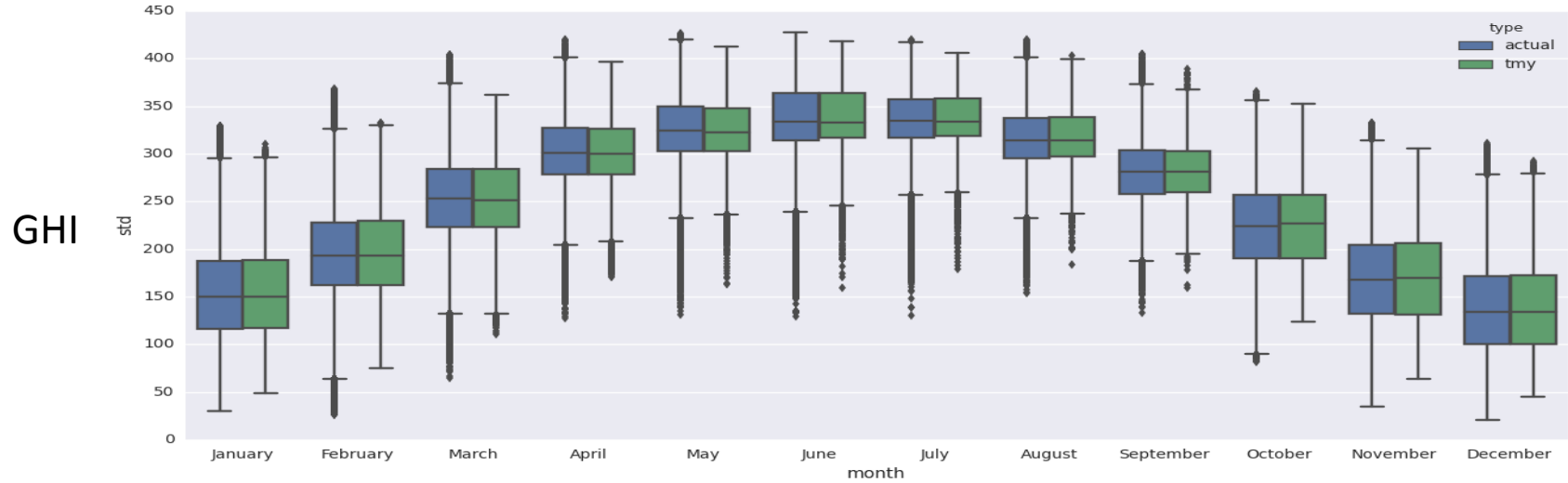


1998-2014 COV

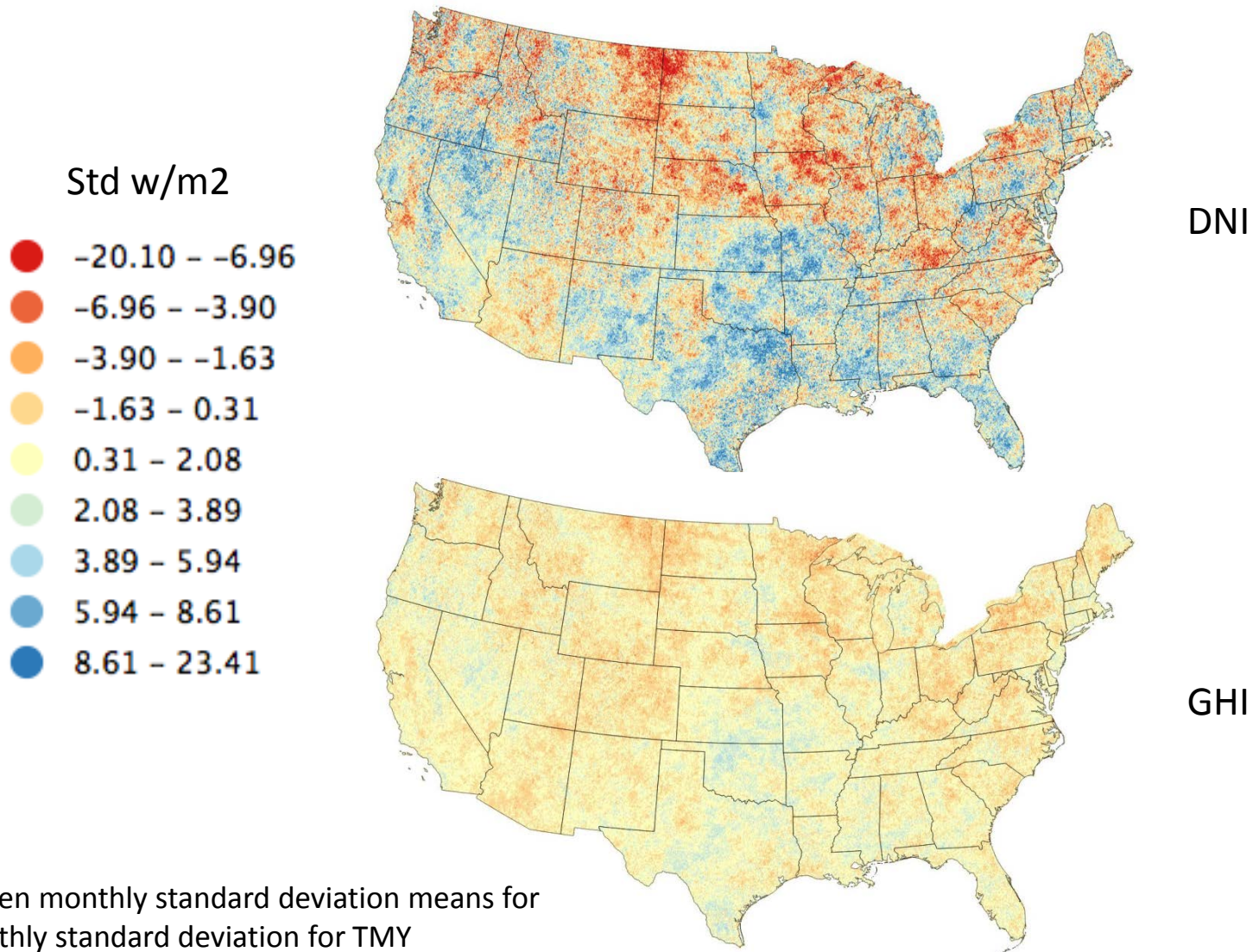


TMY COV

TMY Temporal Variability



TMY Temporal Variability



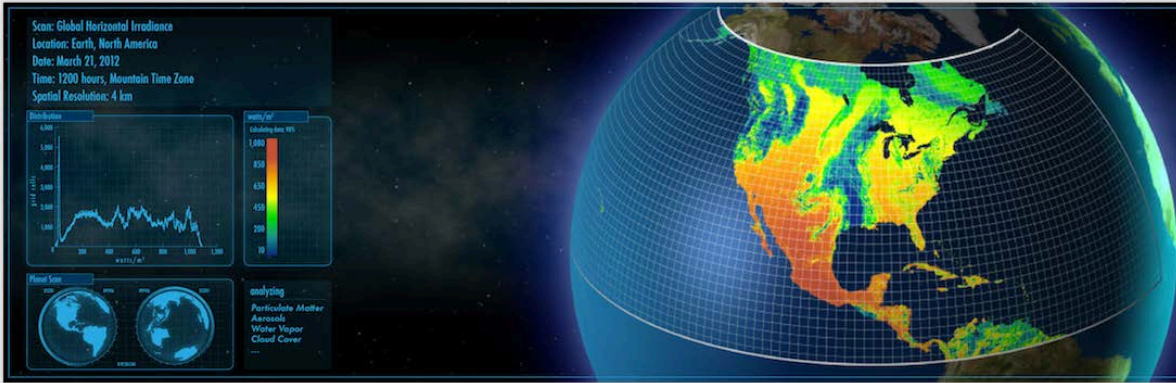
NSRDB Website



National Solar Radiation Database (NSRDB)



Home About Data Sets Resources Contact



Advancing the Science of Solar Data

The National Solar Radiation Database (NSRDB) is a serially complete collection of meteorological and solar irradiance data sets for the United States and a growing list of international locations. The data are publicly available at no cost to the user. The NSRDB provides foundational information to support U.S. Department of Energy programs, research, and the general public. Comparable products are also available from commercial vendors.

Supported by the U.S. Department of Energy's SunShot Initiative, the NSRDB is a widely used and relied-upon resource. The database is managed and updated using the latest methods of research by a specialized team of forecasters at the National Renewable Energy Laboratory (NREL).

Learn more about the NSRDB, access the data sets, or ask a question.

New International Data Sets

Our international data sets are growing—the NSRDB now includes solar data from India.

[Learn more](#)

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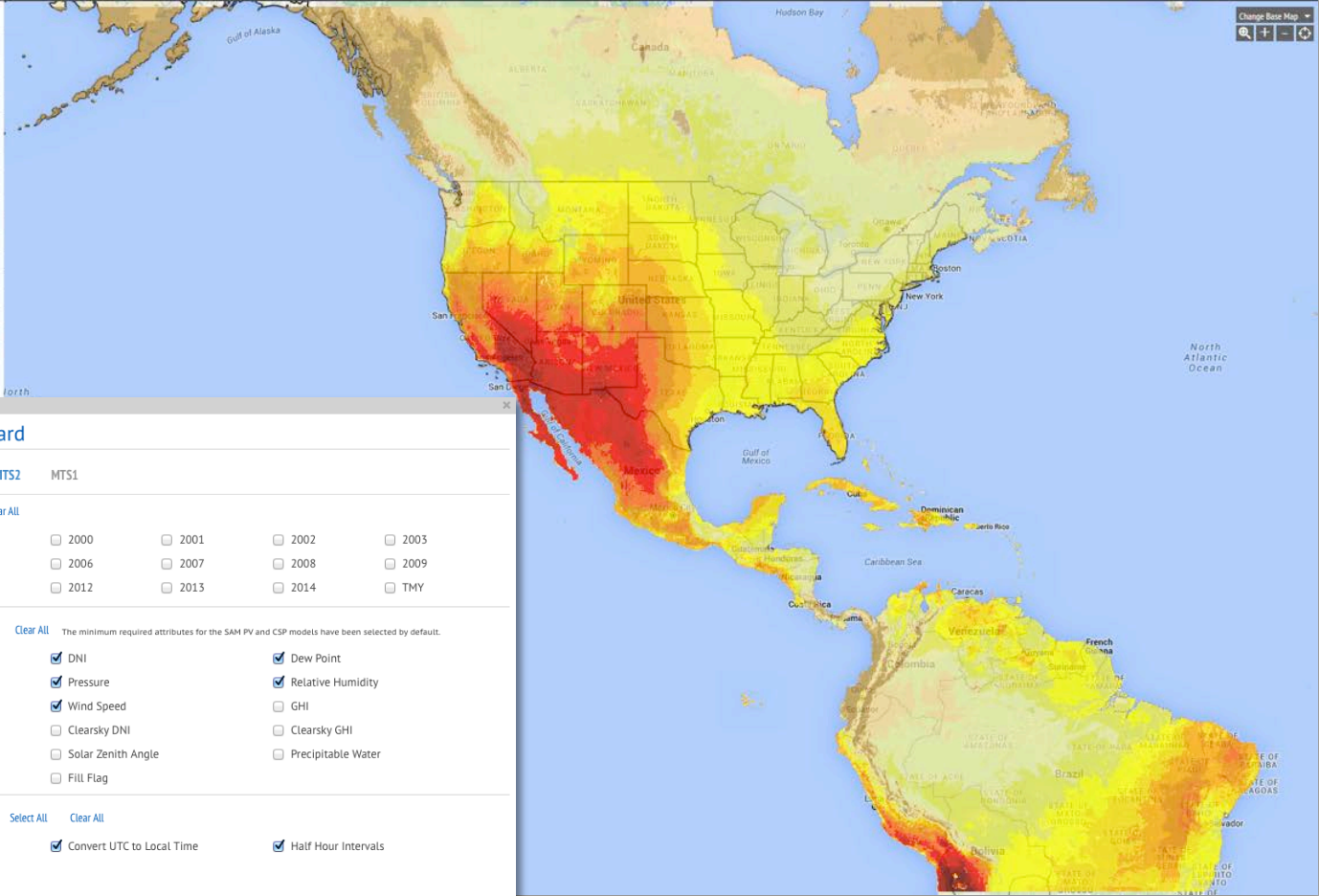
<http://nsrdb.nrel.gov>

NSRDB Viewer

Select and Query Data Download Data **NREL** NSRDB Data Viewer Home Print Feedback

Data Layers Legend Query

- Environmental
- Infrastructure
- Land Ownership
- Power Plants
- Ground Measurement Sites
- NSRDB**
 - MTS1
 - MTS2
 - MTS3
 - PSM Direct Normal Irradiance**
 - PSM Global Horizontal Irradiance
- Solar Study Areas
- State/Local Borders**
 - County Borders
 - ReEDS Regions
 - State Borders**
 - Tribal Lands



Data Download Wizard

PSM SUNY MTS3 **MTS2** MTS1

Select Years [Select All](#) [Clear All](#)

<input type="checkbox"/> 1998	<input type="checkbox"/> 1999	<input type="checkbox"/> 2000	<input type="checkbox"/> 2001	<input type="checkbox"/> 2002	<input type="checkbox"/> 2003
<input type="checkbox"/> 2004	<input type="checkbox"/> 2005	<input type="checkbox"/> 2006	<input type="checkbox"/> 2007	<input type="checkbox"/> 2008	<input type="checkbox"/> 2009
<input type="checkbox"/> 2010	<input type="checkbox"/> 2011	<input type="checkbox"/> 2012	<input type="checkbox"/> 2013	<input type="checkbox"/> 2014	<input type="checkbox"/> TMY

Select Attributes [Select All](#) [Clear All](#) The minimum required attributes for the SAM PV and CSP models have been selected by default.

<input checked="" type="checkbox"/> DHI	<input checked="" type="checkbox"/> DNI	<input checked="" type="checkbox"/> Dew Point
<input checked="" type="checkbox"/> Temperature	<input checked="" type="checkbox"/> Pressure	<input checked="" type="checkbox"/> Relative Humidity
<input checked="" type="checkbox"/> Snow Depth	<input checked="" type="checkbox"/> Wind Speed	<input type="checkbox"/> GHI
<input type="checkbox"/> Clearsky DHI	<input type="checkbox"/> Clearsky DNI	<input type="checkbox"/> Clearsky GHI
<input type="checkbox"/> Cloud Type	<input type="checkbox"/> Solar Zenith Angle	<input type="checkbox"/> Precipitable Water
<input type="checkbox"/> Wind Direction	<input type="checkbox"/> Fill Flag	

Select Download Options [Select All](#) [Clear All](#)

<input type="checkbox"/> Include Leap Day	<input checked="" type="checkbox"/> Convert UTC to Local Time	<input checked="" type="checkbox"/> Half Hour Intervals
---	---	---

Download Limit Indicator

[Edit User Info](#) [Download Data](#)

Data API



API Instructions

NSRDB and SAM Python APIs: Automated download of resource data and SAM simulation

- NSRDB Website: <https://nsrdb.nrel.gov>
- Get NSRDB API Key: <https://developer.nrel.gov/signup/>
- SAM Website: <https://sam.nrel.gov>
- Download the SAM Software Development Kit (SDK): <https://sam.nrel.gov/sdk>

This example shows how to use the NSRDB API for automated data download in Section 1 and then provides an example of using these data with the SAM Software Development Kit (SDK) in Section 2. A plotting example is offered in Section 3.

```
In [1]: import pandas as pd
import numpy as np
import sys, os
```

Conclusions

- Reanalysis meteorological data sets demonstrated different levels of accuracy compared to the ISD data sets. MERRA data set demonstrated relatively better agreement than NARR and CFSR data sets (especially in precipitable water).
- The TMY data set demonstrated relatively good comparison with the time series NSRDB data set. However the results are aggregated results which could cancel some of the difference over longer period of time/aggregation.
- TMY does impact spatial variability structure of the data
- Depending on the funding, we have a plan to update the TMY process to make it more representative of the long term data set
- TMY data set will be updated on yearly basis, current TMY is generated using the 1998-2014 NSRDB data set.

Bibliography

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- Habte, A.; Lopez, A.; Sengupta, M.; Wilcox, S. (2014). *Temporal and Spatial Comparison of Gridded TMY, TDY, and TGY Data Sets*. 30 pp. NREL/TP-5D00-60886.
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Questions?

Anthony Lopez

Anthony.Lopez@nrel.gov

