



New Capabilities in the National Solar Radiation Database (NSRDB)

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Haiku Sky



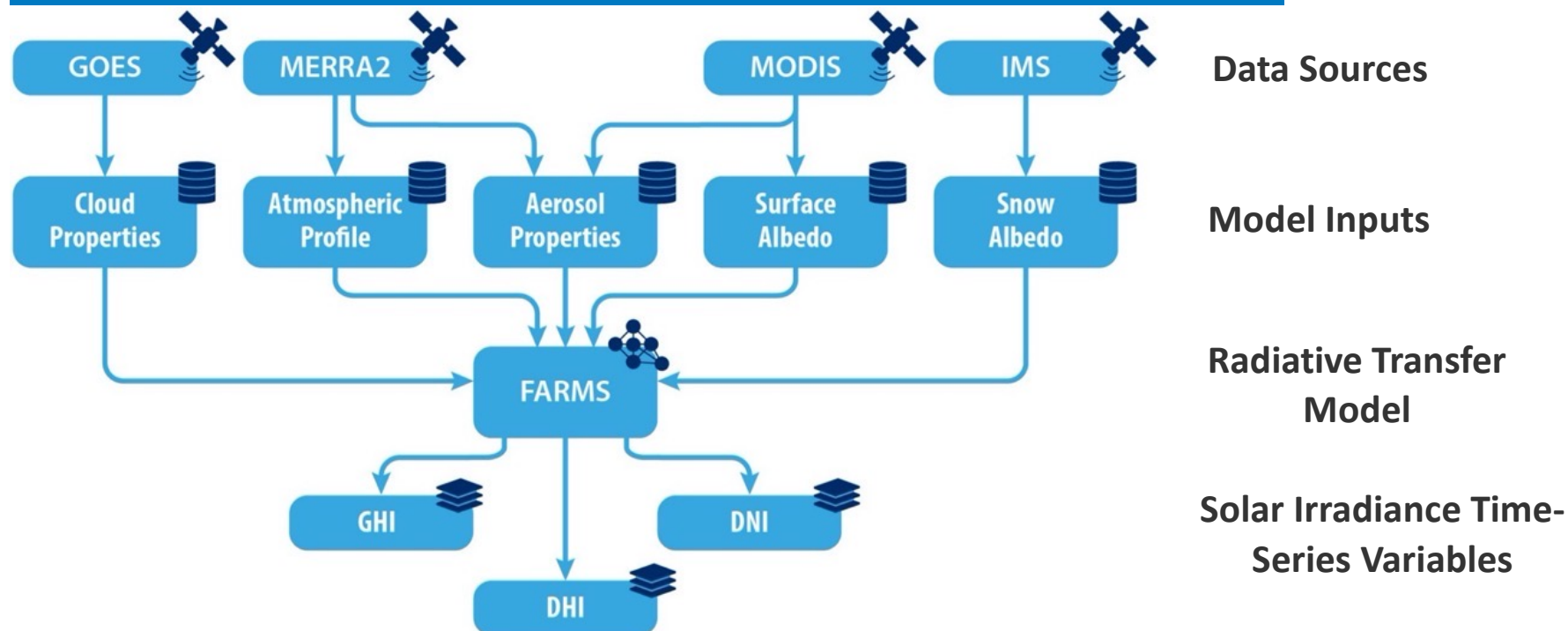
Nicholas Gilroy

Outline

- The Physical Solar Model (PSM)
- What's new in the National Solar Radiation Database (NSRDB)
- Data dissemination
- Future work

The Physical Solar Model (PSM)

The Physical Solar Model



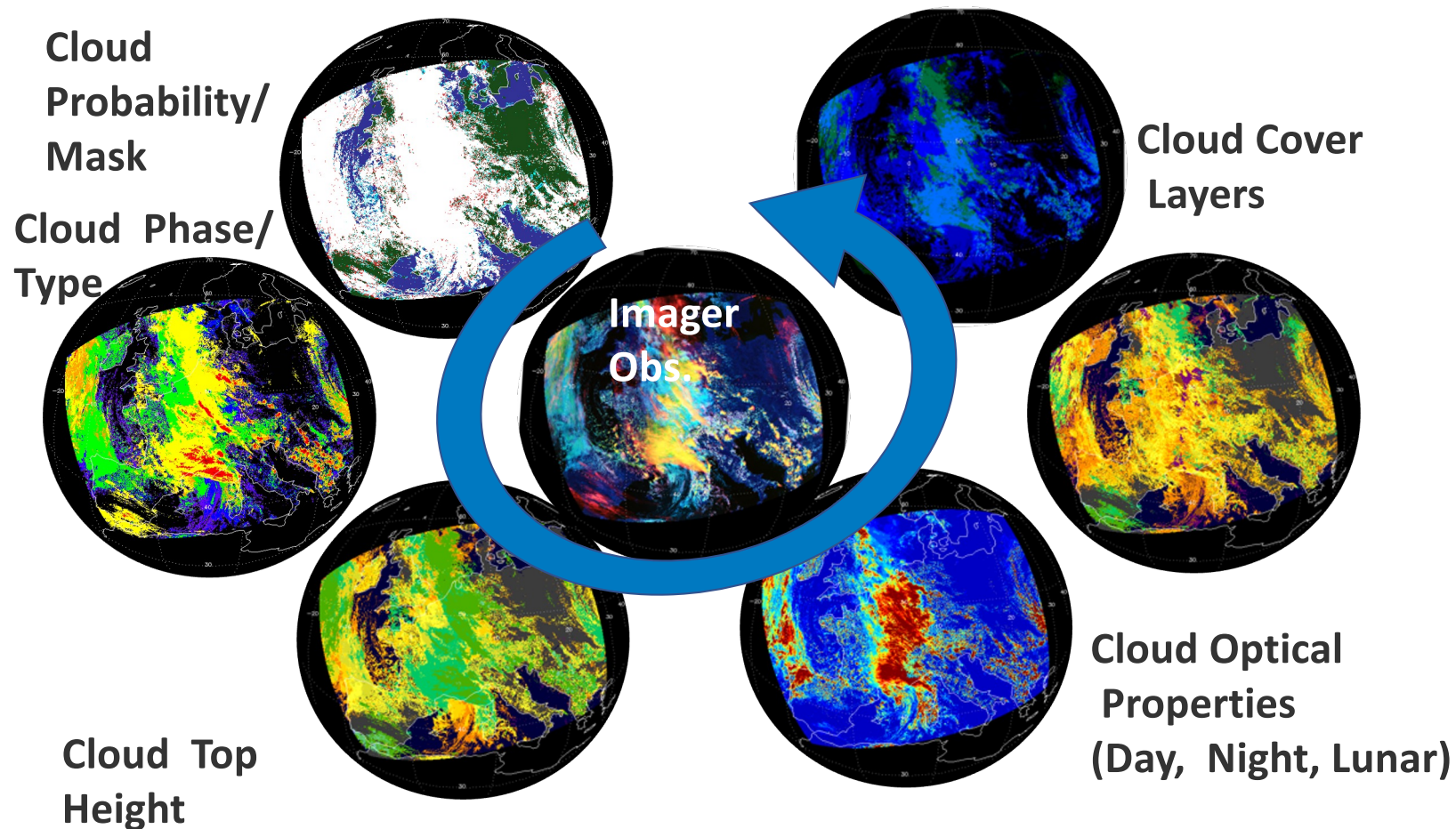
FARMS – Fast All-sky Radiation Model for Solar (FARMS) applications developed by NREL. This is a suite of radiative transfer models that represent how solar radiation interacts with the atmosphere and the Earth’s land cover as it reaches the surface.

MERRA2 – Modern-Era Retrospective analysis for Research and Applications, Version 2 (MERRA-2) provides ancillary meteorological variables including aerosol optical depth (AOD) and the atmospheric profile.

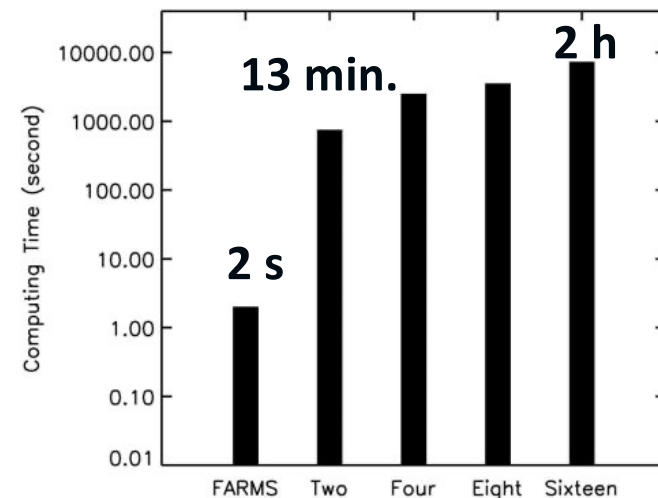
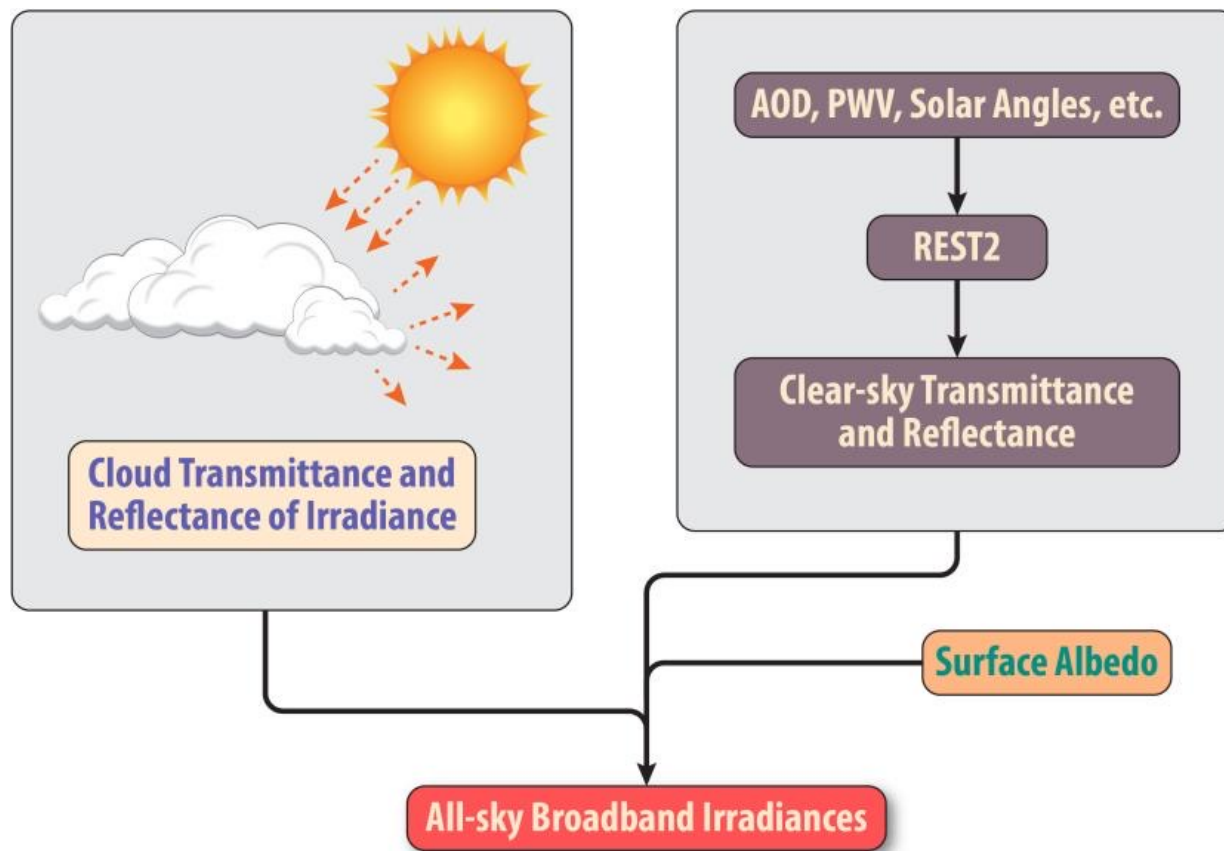
MODIS – Moderate Resolution Imaging Spectroradiometer (MODIS) provides satellite- derived aerosol optical depth (AOD) and albedo.

IMS – Interactive Multisensor Snow and Ice Mapping System (IMS) provides daily snow coverage to represent snow albedo.

Satellite-based Cloud Properties



Fast All-sky Radiation Model for Solar applications (FARMS)



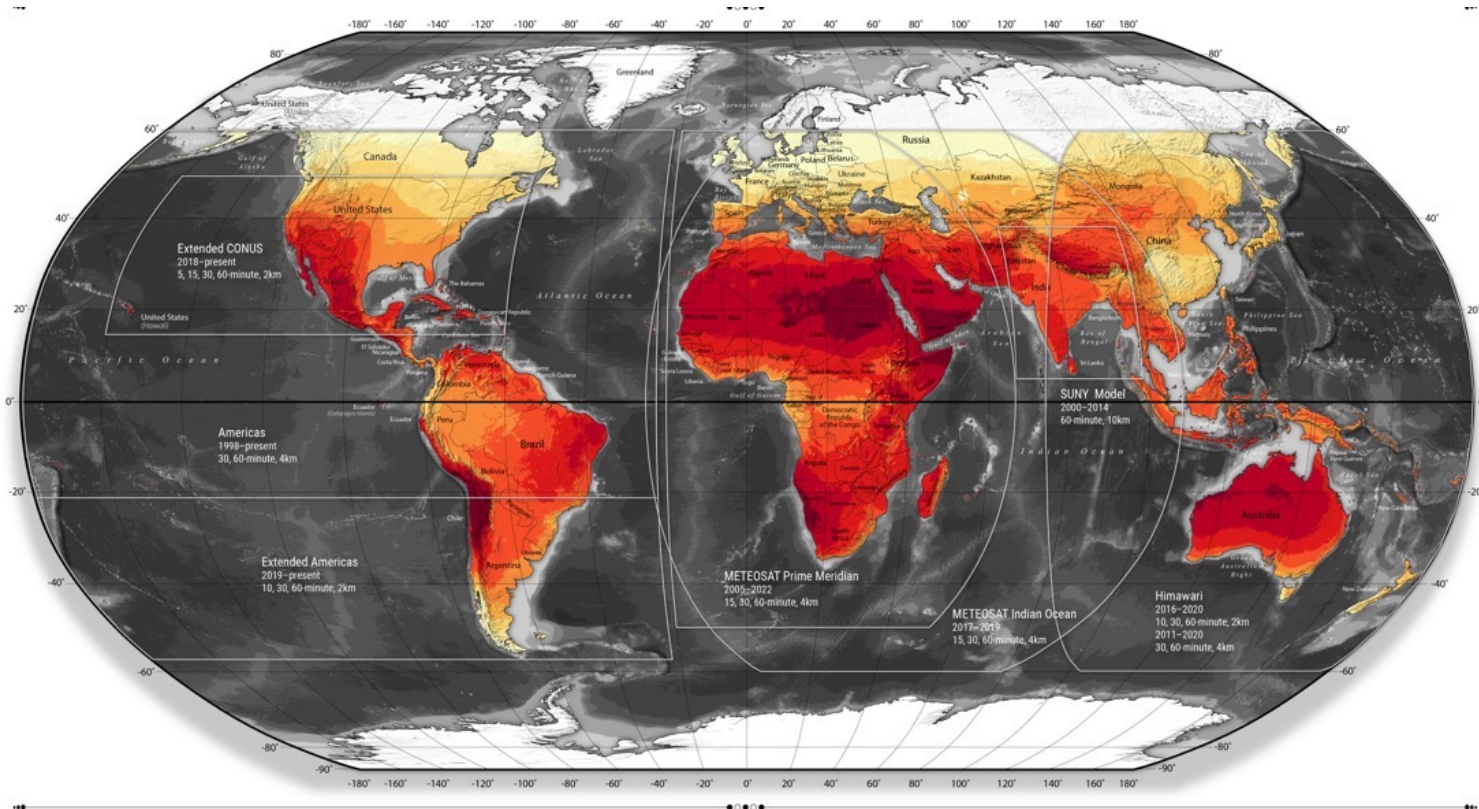
Computation of solar radiation for 10,000 scenarios

FARMS is an extremely fast model.

Xie et al., *Solar Energy* (2016)

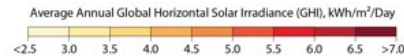
What's New in the NSRDB

NSRDB Coverage: Worldwide



The National Solar Radiation Database is a collection of solar irradiance and atmospheric data from various geostationary weather satellites around the world. The map shows data availability for all current NSRDB coverage areas, including year range, temporal resolution, and spatial resolution. For information about the data sources, available attributes, and methodology, or to view and download data, visit the NSRDB online at: <https://nsrdb.nrel.gov>

Map is shown in the Robinson projection and optimized for use as a poster at 20x14 inches.



This map was produced by the National Renewable Energy Laboratory for the US Department of Energy. By J. Roberts | February 13, 2024

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

5 satellites

- GOES East
- GOES West
- Meteosat
- Meteosat IODC
- Himawari

NSRDB Datasets

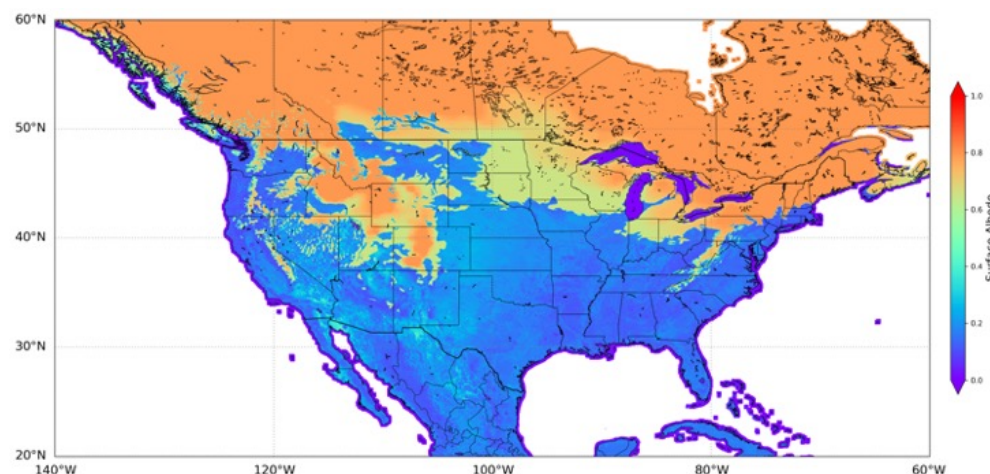
- Time series data – depends on satellite (e.g. GOES coverage 1998-2022)
- Typical Meteorological Year (updated every year)
- Cloud type, optical depth and effective radius
- Aerosol optical depth
- Surface Albedo including snow – Northern Hemisphere only
- Temperature, humidity and wind speed
- Ultraviolet radiation (UV-A and UV-B)
- Spectral data (2001 wavelengths) and spectral mismatch factors

PSM Versions

Version	Effective Date	Data Years*	Notes
3.1.0	9/23/2019	2018+	Complete refactor of NSRDB processing code for NSRDB 2018
3.1.1	12/5/2019	2018+, TMY/TDY/TGY-2018	Complete refactor of TMY processing code.
3.1.2	6/8/2020	2020	Added feature to adjust cloud coordinates based on solar position and shading geometry.
3.2.0	3/17/2021	2020	Enabled cloud solar shading coordinate adjustment by default, enabled MLClouds machine learning gap fill method for missing cloud properties (cloud fill flag #7)
3.2.1	1/12/2021	2021	Implemented an algorithm to re-map the parallax and shading and corrected cloud coordinates to the nominal GOES coordinate system.
3.2.2	2/25/2022	1998-2021	Implemented a model for snowy albedo as a function of temperature from MERRA2 based on the paper "A comparison of simulated and observed fluctuations in summertime Arctic surface albedo" by Becky Ross and John E. Walsh
Spectral 3.2/4.0	6/31/ 2023	1998-2022	Implement clear-sky spectra Implement spectral-mismatch correction factor for multiple PV technologies
4.0.0	6/31/2023	2022	Implemented FARMS-DNI model to calculate solar radiation under cloudy conditions.

PSM Updates Included in Current NSRDB (1998-2022)

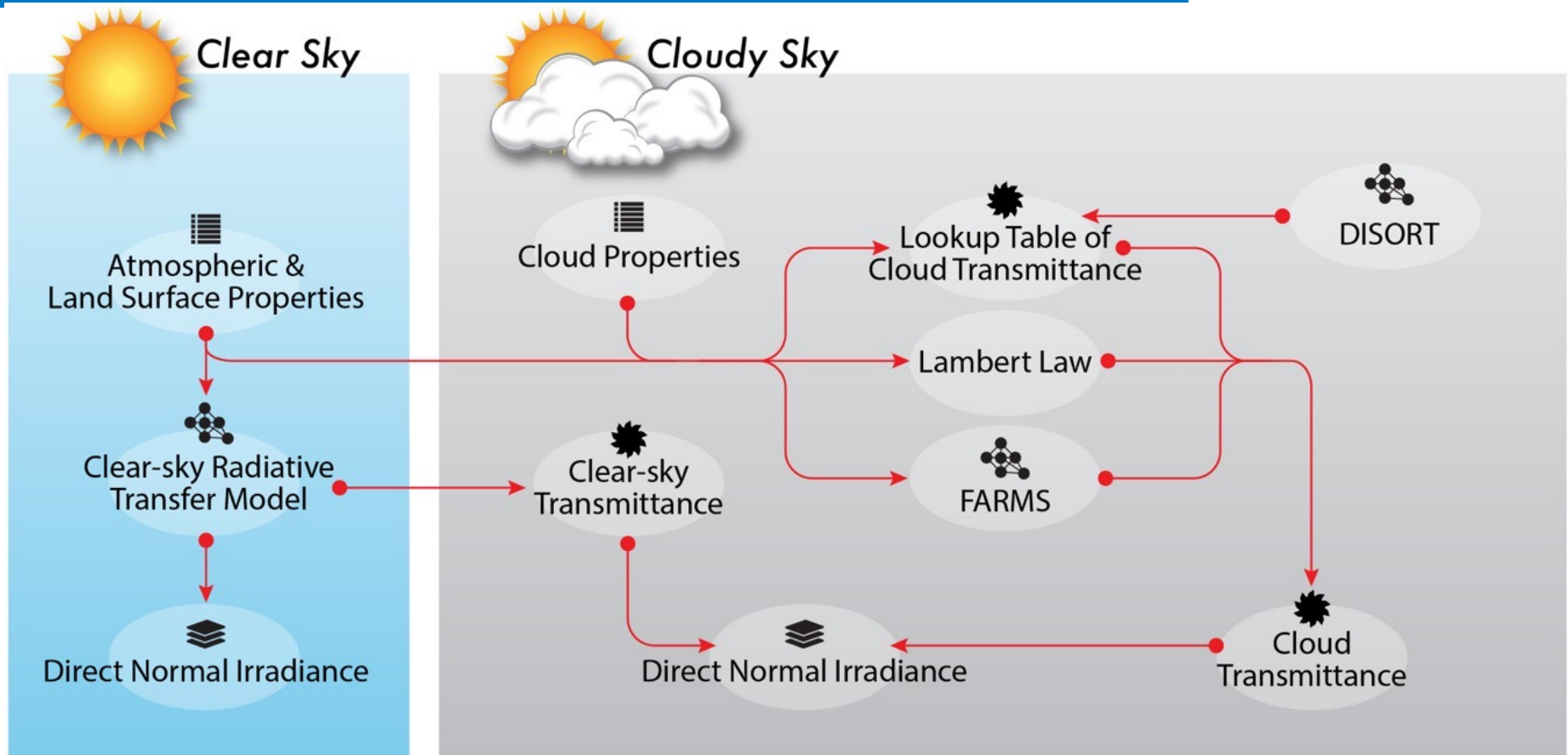
- Parallax correction for cloud location, cloud shading and remapping
- Gap-filling of missing cloud properties
- New algorithm for snow-albedo based on surface temperature
- Spectral mismatch factors for common PV technologies



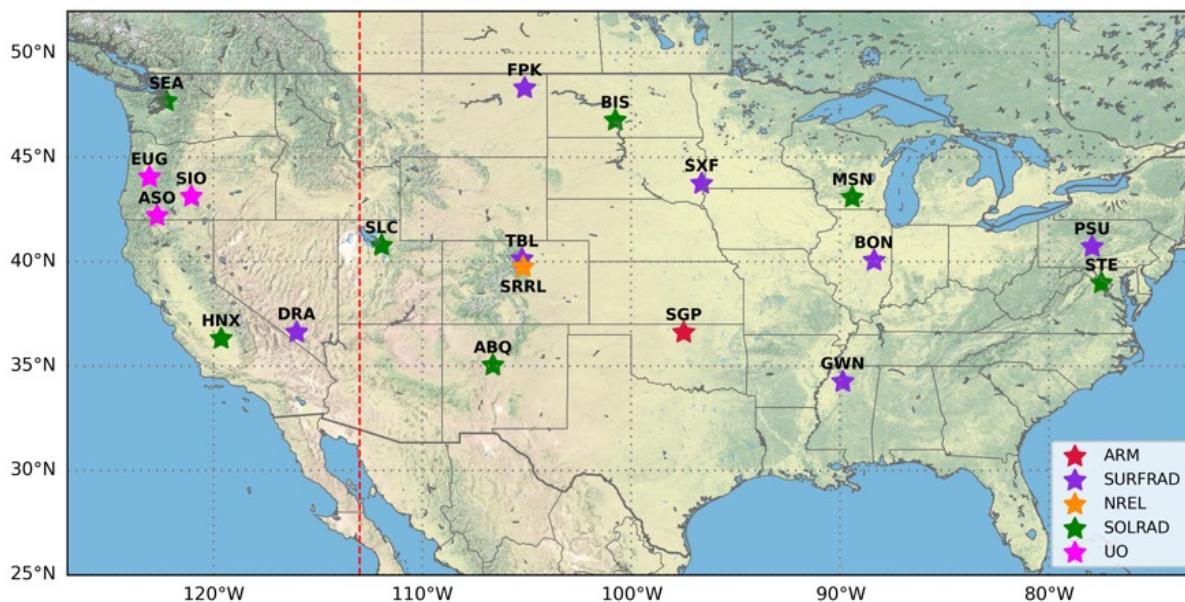
Updated surface albedo on March 1, 2020
(based on Ross and Walsh (1987)).

Ross, Becky and John E. Walsh. "A comparison of simulated and observed fluctuations in summertime Arctic surface albedo." *Journal of Geophysical Research* 92 (1987): 13115-13125.

FARMS-DNI



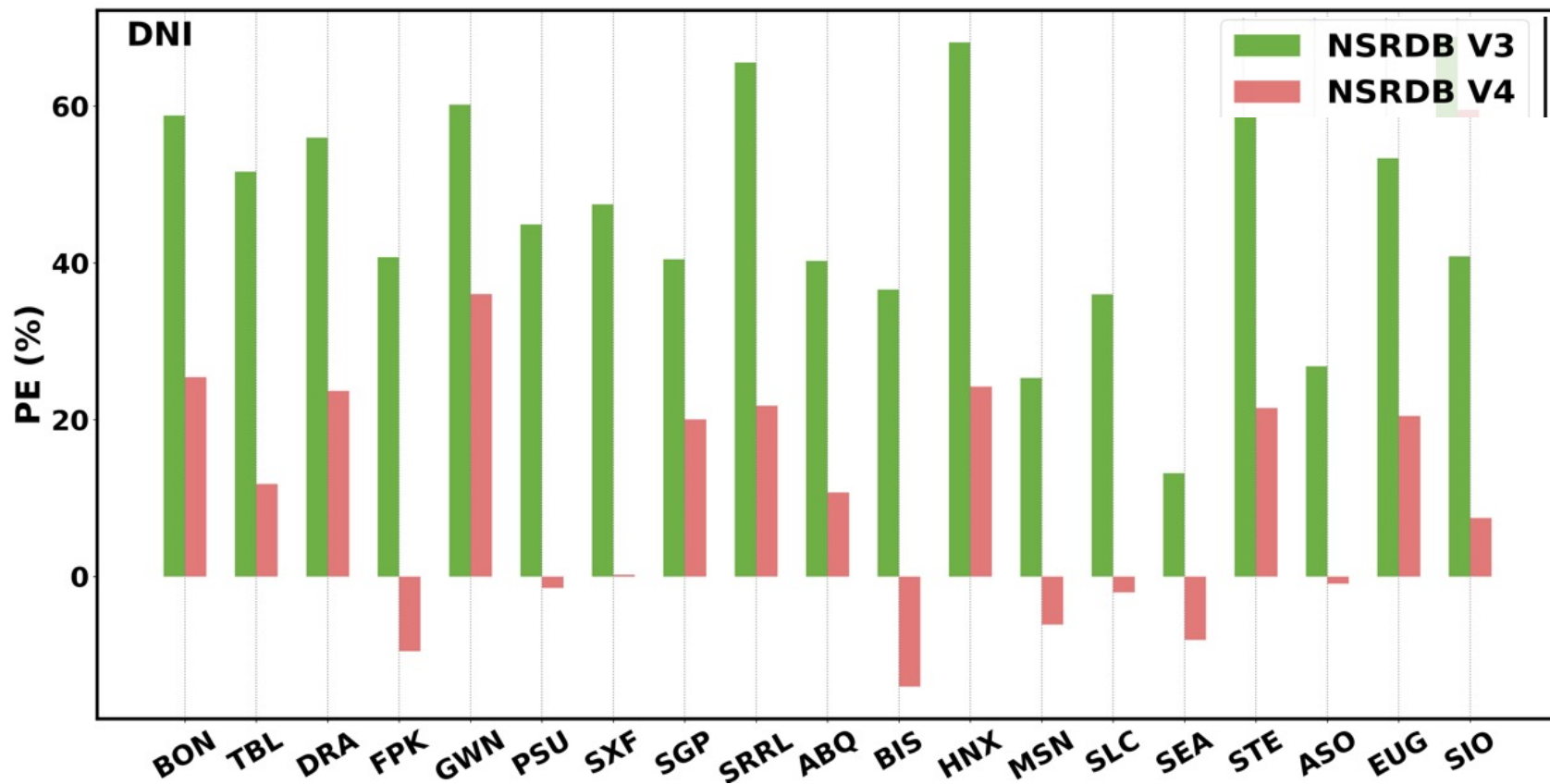
Validation of the FARM-DNI model



- DNI for 2 km grids every 5 min from 2019-2022 is computed using the NSRDB PSM with Lambert law, DISC, and FARMS-DNI.
- The satellite-based simulation is validated using surface observations.
- 6 and 13 stations (divided by the red line) are used to validate the data from GOES-West and GOES-East, respectively.

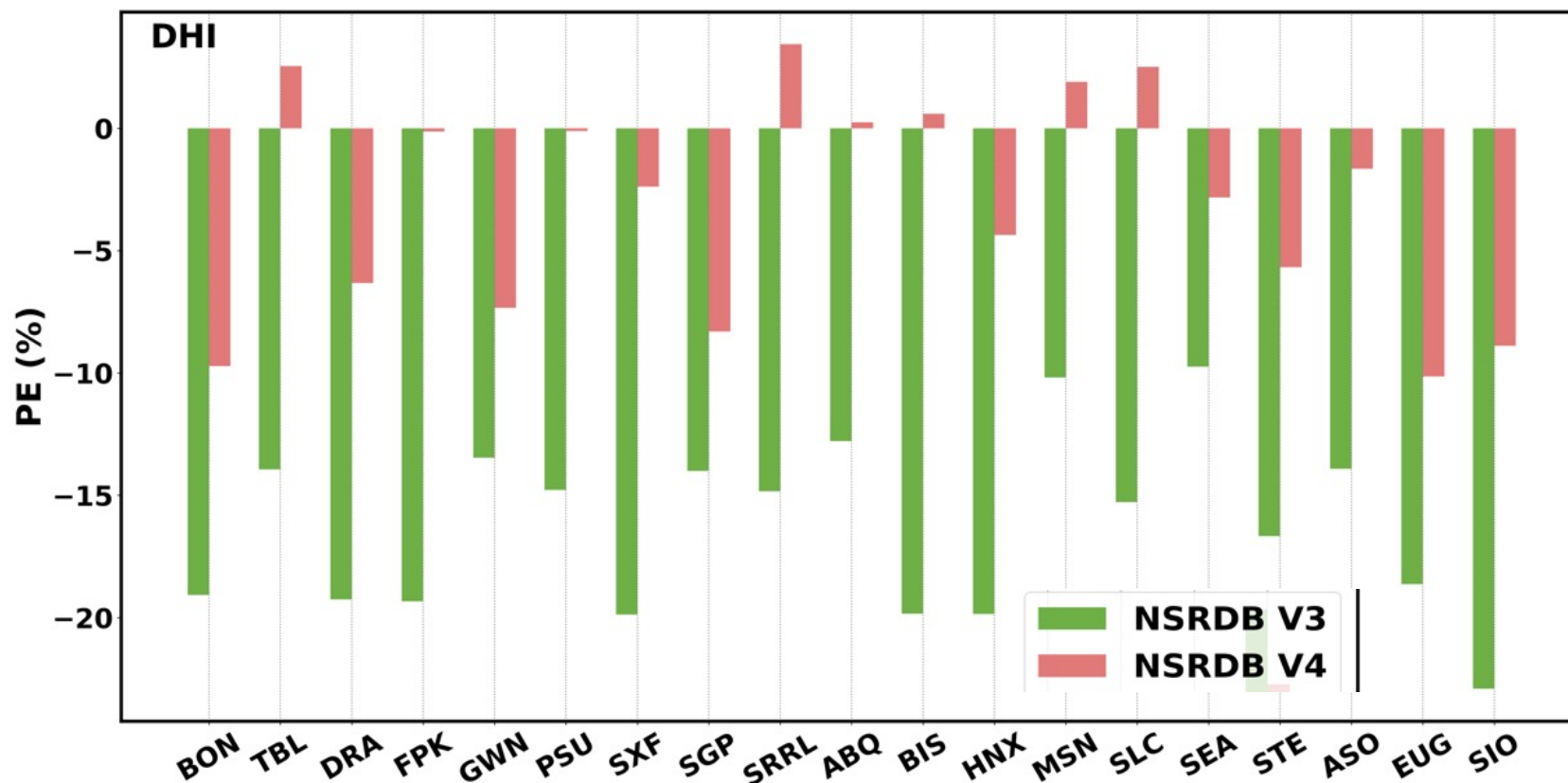
- Yang, J., Xie, Y., Sengupta, M., Liu, Y., & Long, H. (2022). Parameterization of cloud transmittance for expeditious assessment and forecasting of all-sky DNI. *Journal of Renewable and Sustainable Energy*, 14(6). <https://doi.org/10.1063/5.0127454>
- Yu Xie, Jaemo Yang, Manajit Sengupta, Yangang Liu, Xin Zhou, (2022), Improving the prediction of DNI with physics-based representation of all-sky circumsolar radiation, *Solar Energy*, Volume 231, 758-766, <https://doi.org/10.1016/j.solener.2021.12.016>.
- Xie, Y., Sengupta, M., Liu, Y., Long, H., Min, Q., Liu, W., Habte, A., (2020), A Physics-Based DNI Model Assessing All-Sky Circumsolar Radiation, *iScience*, 23(3), 100893, <https://doi.org/10.1016/j.isci.2020.100893>.

Evaluation of cloudy-sky DNI



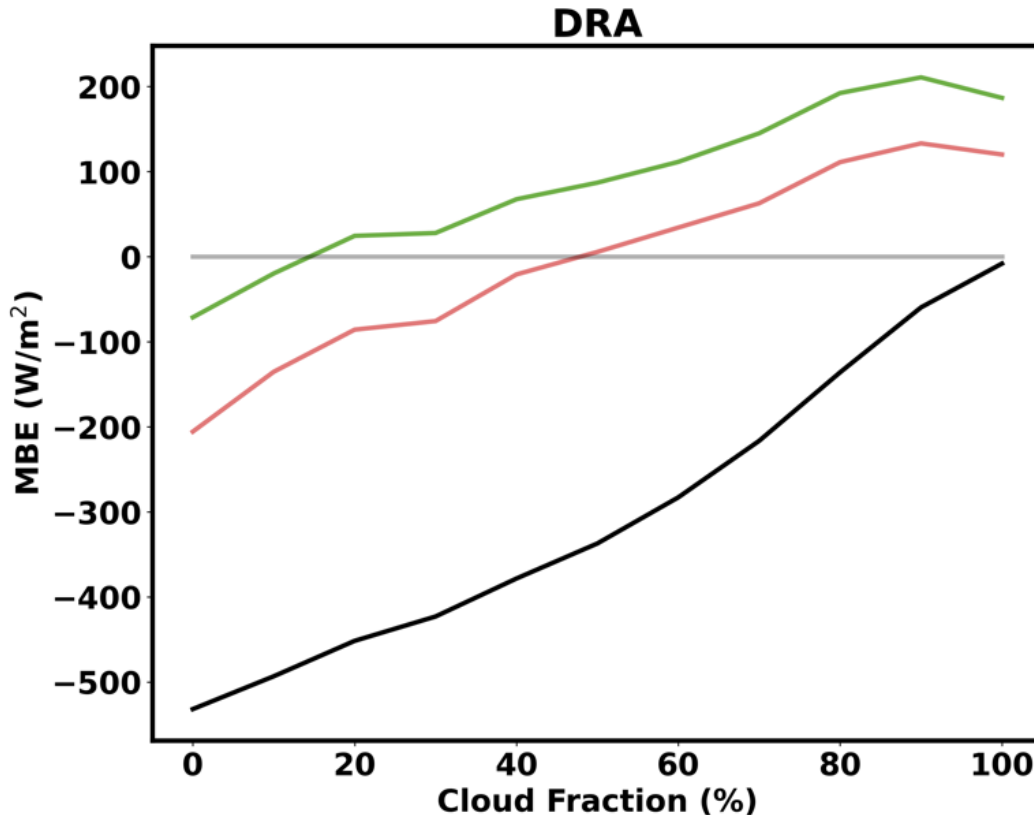
The cloudy-sky scenes are identified by both satellite and surface data when surface radiation is smaller than the clear-sky radiation.

Evaluation of cloudy-sky DHI



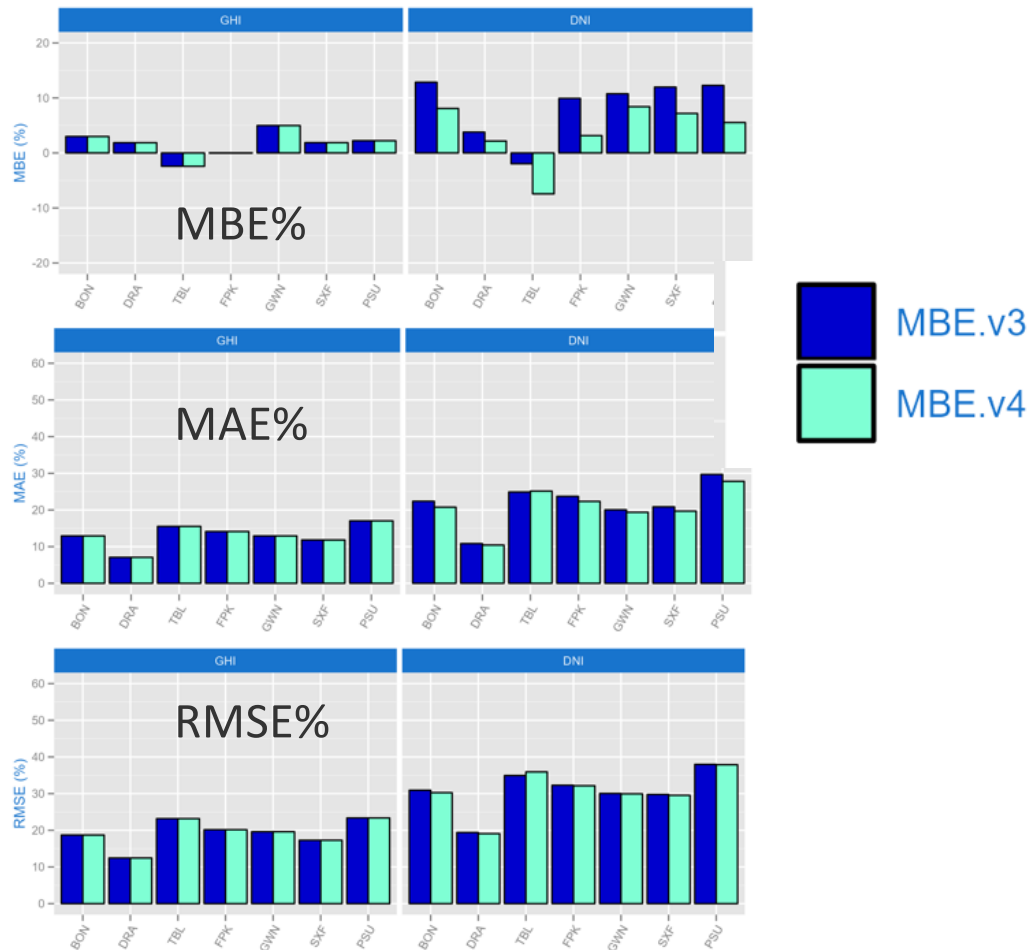
The cloudy-sky scenes are identified by both satellite and surface data when surface radiation is smaller than the clear-sky radiation.

MBE of DNI as a function of cloud fraction



- The cloudy sky is divided into 11 bins according to cloud fraction.
- For all sites, DISC has larger bias than FARM5-DNI in more cloudy scenes.
- FARM5-DNI has larger bias in the relatively clear sky.
- DISC model has better performance in scattered clouds when FARM5-DNI considers the whole scene as cloudy.

NSRDB Validation: PSM V3 vs V4



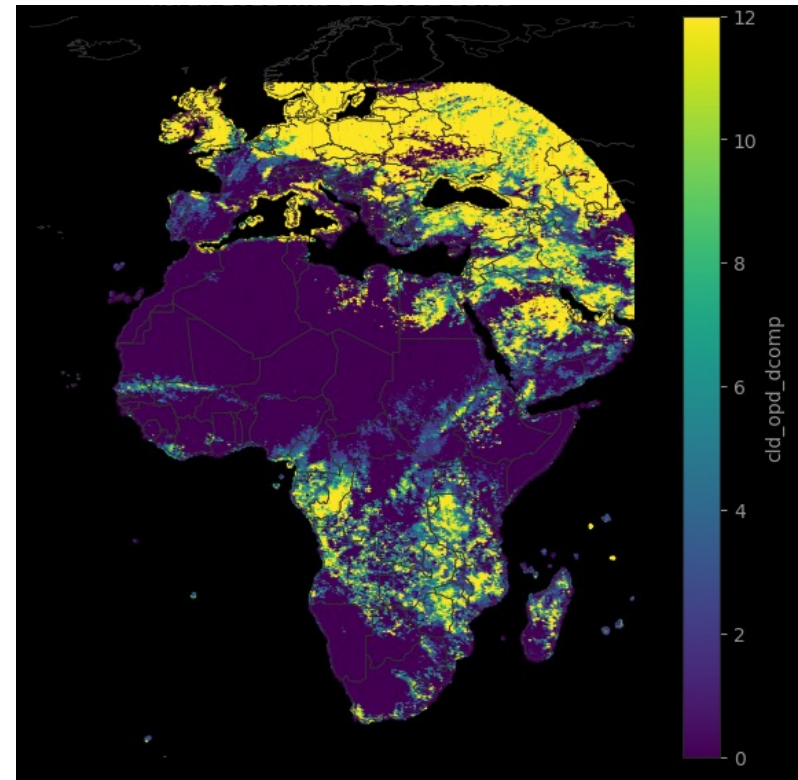
MBE for GHI lies between $\pm 5\%$ for all stations

MBE for DNI is significantly improved when PSM v4 is used with the MBE lying between $\pm 8\%$

RMSE is less than 25% for GHI and 35% for DNI

New Addition: Meteosat

- Cloud characteristics are a key input for the PSM to estimate absorption and scattering of the incoming solar radiation.
- High spatial and temporal resolution imagery from the European Union's Meteosat weather satellite system covers Africa, Europe, and the Middle East.
- NREL partners with the University of Wisconsin to model cloud properties, including cloud type and optical thickness.



Cloud optical thickness on Jan 1, 2022. Figure by Brandon Benton

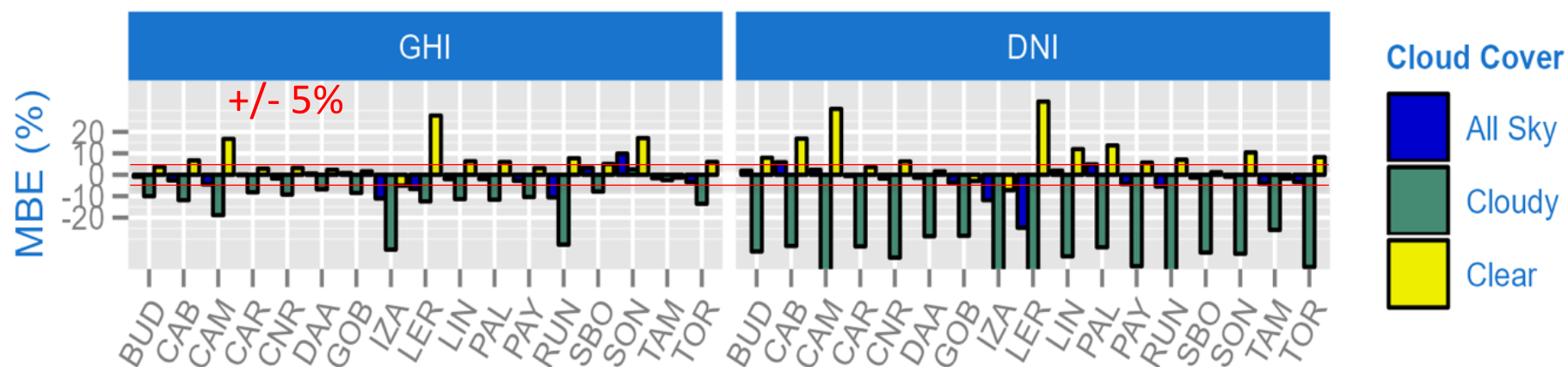
BSRN Stations Used in the Validation (2005-2022)

Station	Abbreviation	Location	Latitude	Longitude	Elevation	Years-Used
Budapest-Lorinc	BUD	Hungary, Budapest	47.429	19.182	139.1	2020-2022
Cabauw	cab	Netherlands	51.968	4.928	0	2008-2022
Camborne	CAM	United Kingdom	50.217	-5.317	88	2005-2017
Carpentras	CAR	France	44.083	5.059	100	2005-2018
Cener	CNR	Spain, Navarra	42.816	-1.601	471	2010-2022
De Aar	DAA	South Africa	-30.667	23.993	1287	2005,2016-2020
Gobabeb	GOB	Namibia, Namib Desert	-23.561	15.042	407	2013-2022
Iza	IZA	Spain, Tenerife	28.309	-16.499	2372.9	2010-2022
Lerwick	LER	United Kingdom, Shetland Island	60.139	-1.185	80	2005-2017
Lindenberg	LIN	Germany	52.210	14.122	125	2005-2022
Palaiseau, Sirta	PAL	France	48.713	2.208	156	2005-2022
Observatory	PAY	Switzerland	46.812	6.942	491	2005-2022
Payerne	PAY	Switzerland	46.812	6.942	491	2005-2022
Reunion Island, University	RUN	Reunion	-20.901	55.484	116	2020-2022
Sede Boqer	SBO	Israel	30.860	34.779	500	2005-2012
Sonnblick	SON	Austria	47.054	12.958	3108.9	2013-2022
Tamanrasset	TAM	Algeria	22.790	5.529	1385	2005-2022
Toravere	TOR	Estonia	58.264	26.461	70	2005-2020

Map Showing BSRN Locations Used for Validation



Validation Result (2005-2022)



Key Takeaways:

- for all sky condition, most of the locations exhibit the following:
 - MBE for GHI and DNI are below +/- 5%.
 - MAE and RMSE for GHI and DNI are <30% deviation.

NSRDB Spectral-on-demand Data

1. Click "Download Data."

Select and Query Data

Download Data

NSRDB Data Download (Point)
Download resource data from the National Solar Radiation Database by point. This tool will return data for the station closest to the point drawn.

NSRDB Data Download (Box)
Download resource data from the National Solar Radiation Database by box. This tool will return data for all stations falling within the drawn region.

2. Select query by point or area.

3. Choose point or area on the map.

4. Select "Spectral On-Demand" from pop-up window.

Data Download Wizard

Spectral TMY India **PSM v3** SUNY India Spectral On-demand **PSM TMY**

Spectral PSM
The National Solar Radiation Database (NSRDB) is a serially complete collection of hourly and half-hourly values of the three most common measurements of solar radiation—global horizontal, direct normal, and diffuse horizontal irradiance

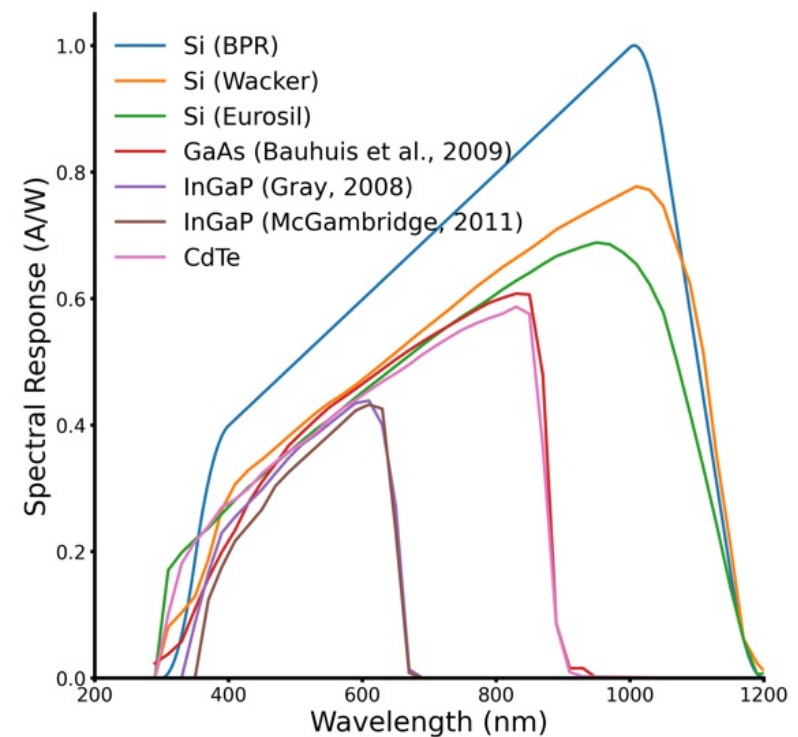
Select Year

☐ 1998 ☐ 1999 ☐ 2000 ☐ 2001 ☐ 2002 ☐ 2003
☐ 2004 ☐ 2005 ☐ 2006 ☐ 2007 ☐ 2008 ☐ 2009
☐ 2010 ☐ 2011 ☐ 2012 ☐ 2013 ☐ 2014 ☐ 2015
☐ 2016 ☐ 2017

- FARMS-NIT is designed to solve the radiative transfer equation for individual photon paths and thereby compute spectral irradiance in the POA.
- The spectral on-demand data is available online at the NSRDB viewer.
- **We now deliver spectral mismatch correction factors for common PV technologies.**

Spectral Mismatch Factor

- PV is characterized by the spectral response function applied to a reference spectrum that is different from actual measured/modeled spectrum.
- A spectral mismatch correction factor is used to quantify the difference and assess PV performance under standard solar resource.
- We collected the spectral response function for a theoretical baseline performance reference (BPR) for typical silicon PV panels as well as other technologies.
- The spectral mismatch factor for various PV types for every hour is now available through the NSRDB.



Data Dissemination

Data Dissemination

NSRDB Access:

- By point location or a small area can be downloaded through the NSRDB Data Viewer (<https://maps.nrel.gov/nsrdb-viewer/>)
- By application programming interface to access larger quantities of data through automated approaches (<https://developer.nrel.gov/docs/solar/nsrdb/>)
- Through the Highly Scalable Data Service hosted on Amazon Web Services (https://github.com/NREL/hsds-examples/blob/master/notebooks/03_NSrDB_introduction.ipynb).

Fully reprocessed data for the GOES extent using PSM V4 covering 1998-2022 will be released in August 2024.

2023 data calculated using PSM V4.0 will be released in September 2024.

Future Development



Investigate the availability of aerosol data sets from GOES-16 and GOES-17 satellites.



Improvement in the accuracy of spectral datasets from the NSRDB



Custom Typical Meteorological Year in the plane-of-array.



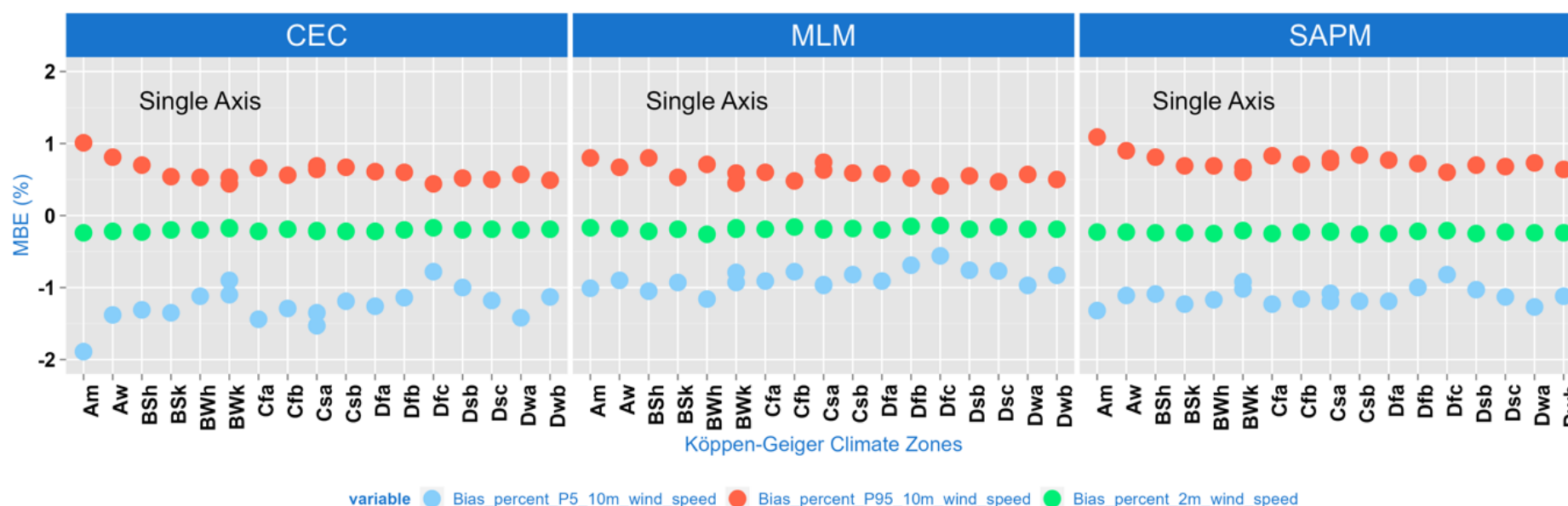
High-resolution cloud properties (500 m) to get cloud fraction and improved cloud optical depth.



A 100-year projected solar radiation data set going out to 2100 from regional climate models.

Sensitivity of Windspeed in Solar Modeling

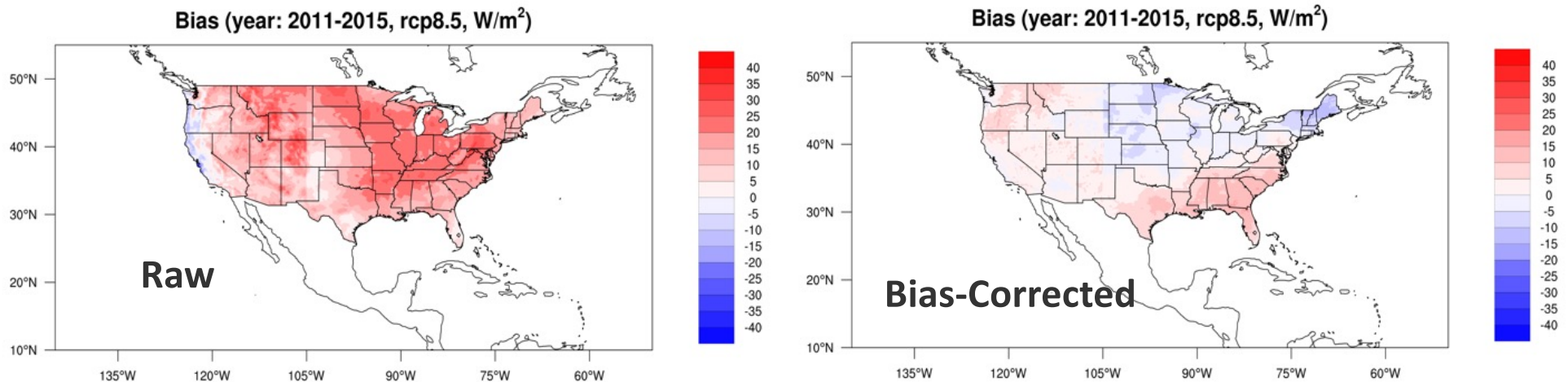
Energy yield using 10 m wind-speed is 0.2-0.3% higher compared to 2 m wind



POSTER: An Assessment of the Impact of Height Dependent Windspeed on Energy Yield Estimation

The National Climate Database

100 years of climate model based high-resolution data for solar modeling
Available September 2024



POSTER: The National Climate Data Base (NCDB): A Bias-Corrected High-Resolution Climate Dataset

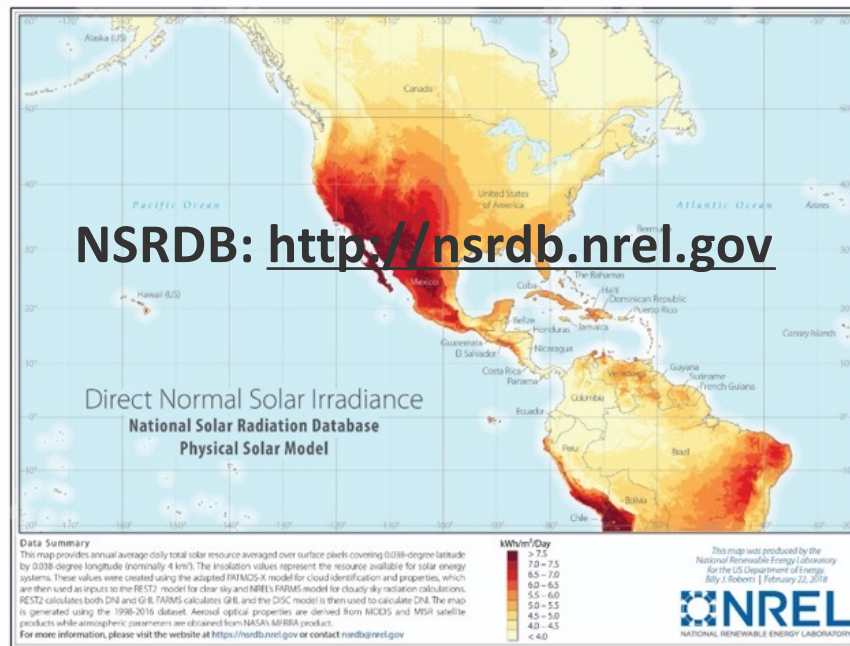
The NSRDB paper:

Primary reference

Publication freely
available on website
(<https://nsrdb.nrel.gov>).

Sengupta, Manajit, Yu Xie, Anthony Lopez, Aron Habte, Galen Maclaurin, and James Shelby. 2018. "The National Solar Radiation Database (NSRDB)." *Renewable and Sustainable Energy Reviews* 89: 51–60. SSN 1364-0321.
<https://doi.org/10.1016/j.rser.2018.03.003>.

Thank You! Contact: Manajit.Sengupta@nrel.gov



Sengupta, Manajit, Yu Xie, Anthony Lopez, Aron Habte, Galen Maclaurin, and James Shelby. 2018. "The National Solar Radiation Data Base (NSRDB)." *Renewable and Sustainable Energy Rev.* 89: 51–60. <https://doi.org/10.1016/j.rser.2018.03.003>.

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