The Use of the BSRN Data as A Benchmark for the POWER Hourly DHI and DNI and in Validating Derived Hourly GTI

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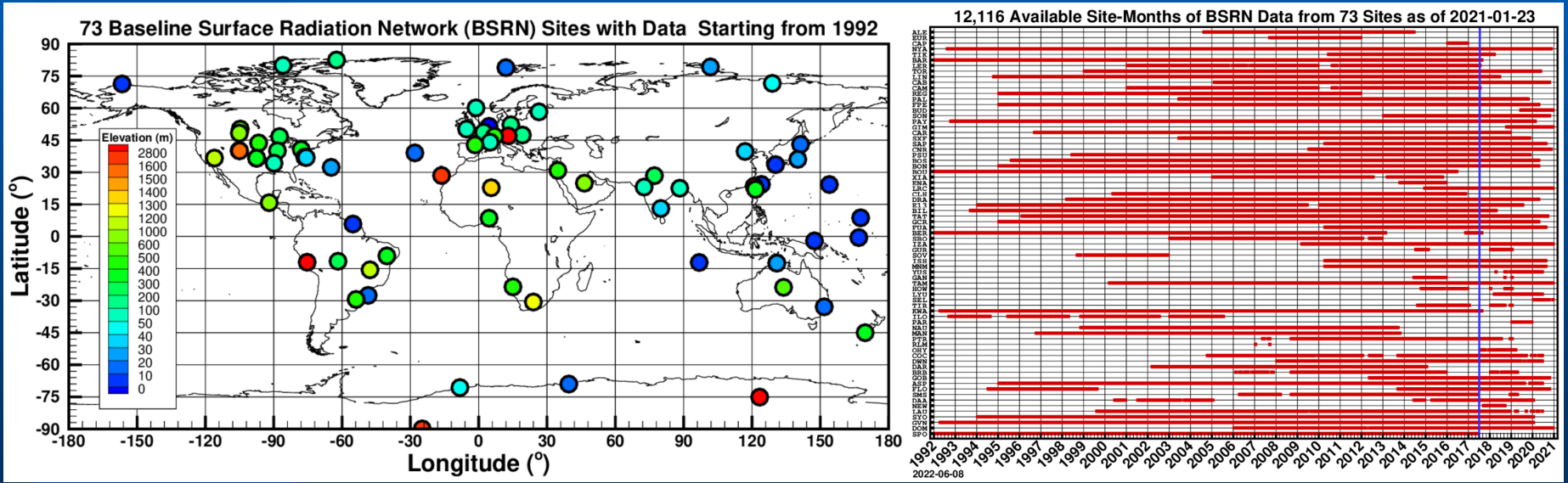
Outline of the Presentation …

- The CERES SYN1deg(Ed4.1) hourly, GHI, DNI, DHI and the BSRN data
- Bias correction of the hourly DNI and DHI
- Derivation of hourly GTI and GTrI
- Comparison of DNI, DHI, GTI and GTrI with the BSRN
- Calculation of daily and monthly means
- Comparison and evaluation of two monthly-mean-based models
- Summary and conclusions

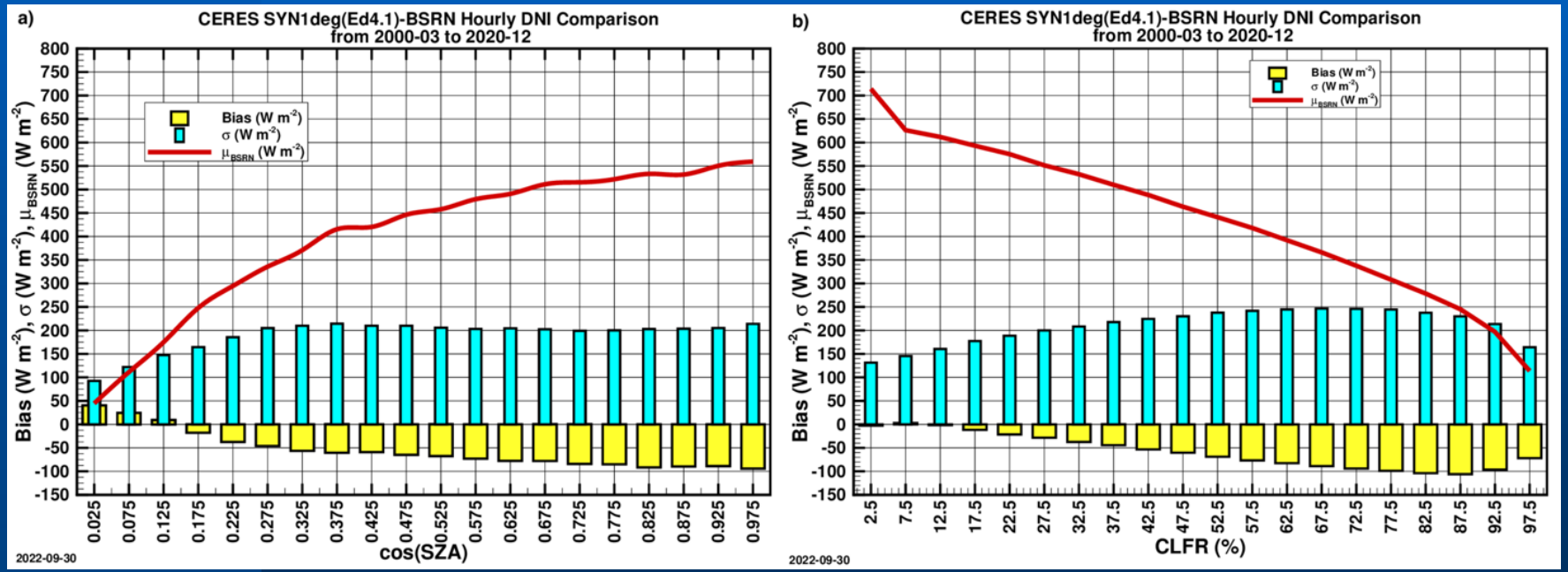
The 73 BSRN Sites and 12,116 Available Site-Months as of 2021-01-23



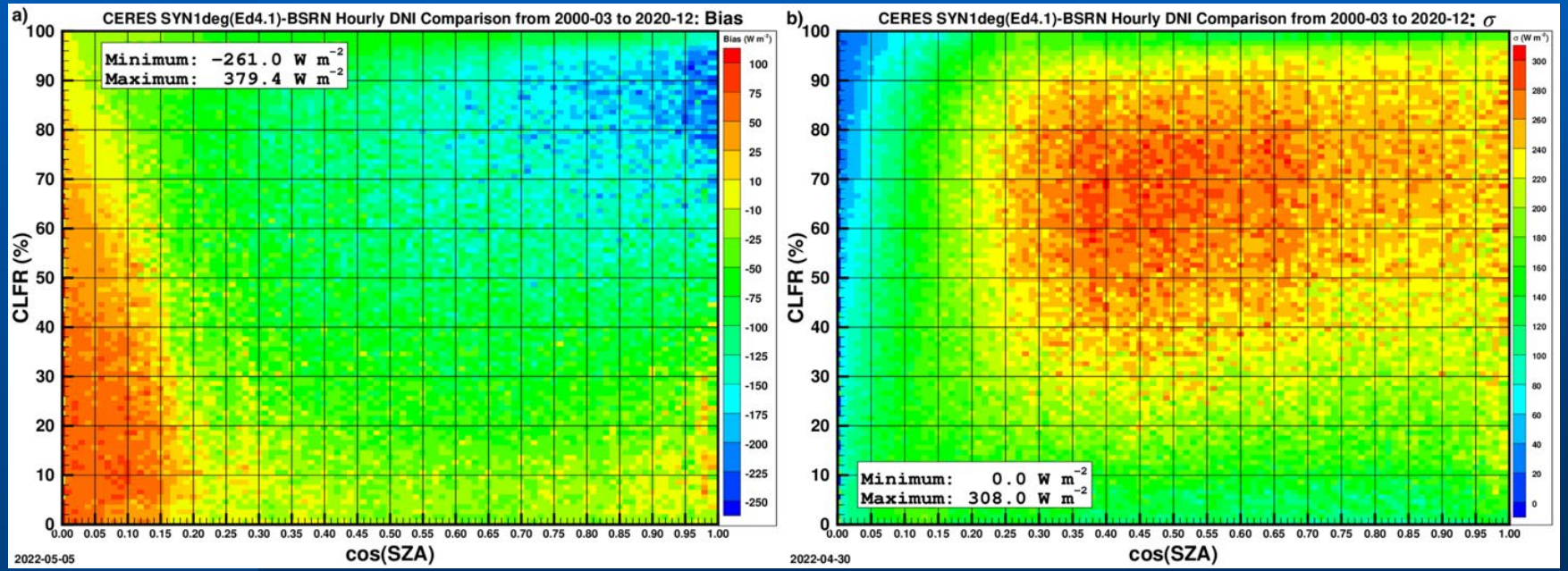
The CERES SYN1deg (Ed4.1) Hourly GHI, DHI and DNI in Comparison with the BSRN Data

All-Sky Hourly	Bias	RMS	ρ	σ	μ_{DATA}	N
Original CERES SYN1deg(Ed4.1) and Derived DNI						
GHI	-2.90	83.46	0.9566	83.41	341.49	3,347,216
DHI	30.54	85.83	0.8314	80.00	168.04	3,452,616
DirHI	-37.07	122.25	0.8882	116.49	192.59	3,023,551
DNI, or DirHI/cos(Z)	-54.29	203.22	0.8233	195.83	343.24	3,010,908
DirIndex Model Derived DNI from CERES SYN1deg(Ed4.1) Hourly GHI						
DNI, from DirIndex	8.54	228.21	0.7580	228.65	444.91	2,195,000

The CERES SYN1deg (Ed4.1) Hourly DNI [DirHI/cos(SZA)] bias as functions of cos(SZA) and CLFR (%)



The CERES SYN1deg (Ed4.1) Hourly DNI [DirHI/cos(SZA)] bias in the cos(SZA)-CLFR phase space

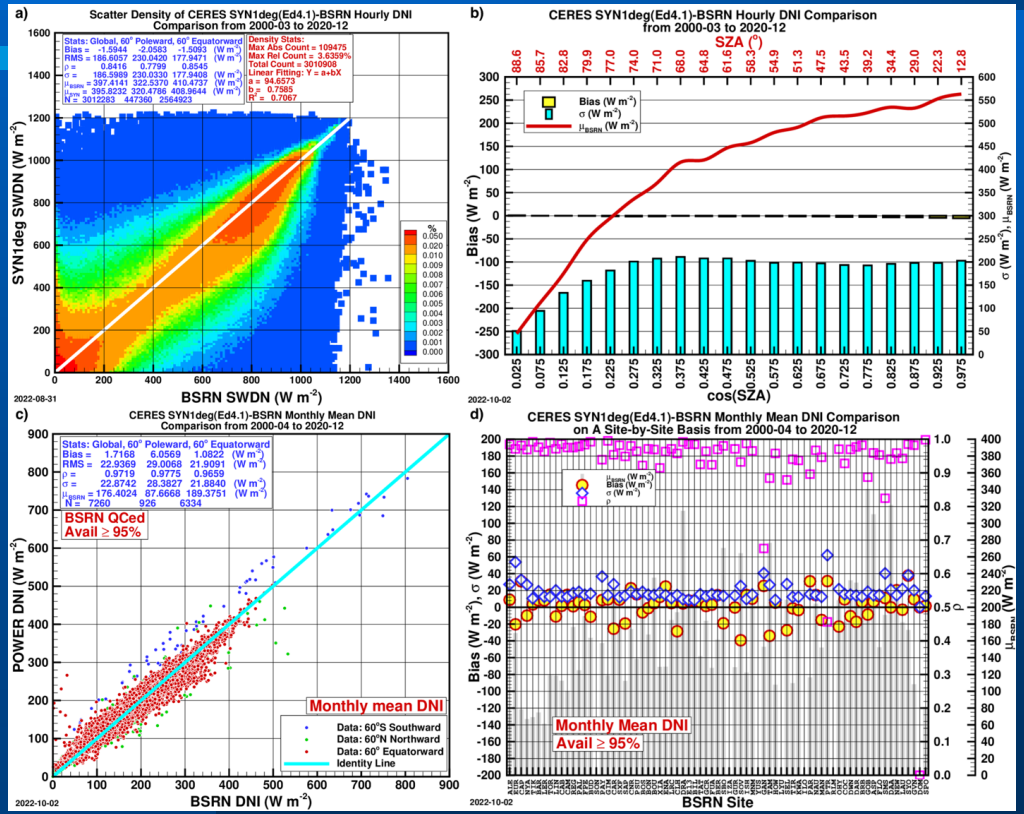


The Bias Correction

The Earth is first divided into 5 latitudinal zones whose latitudinal ranges are, respectively, [-90°, -60°), [-60°, -20°), [-20°, 20°), [20°, 60°) and [60°, 90°]; in each zone, the bias is calculated as percentage of the mean CERES SYN1deg(Ed4.1) DNI in the phase space of cos(SZA) and CLFR. The relative bias, R_{bias}, forms a 3D lookup table. The R_{bias} for each individual hourly DNI is first determined according to its latitudinal zone, cos(SZA) and CLFR, and the correction is done simply by multiplying the DNI by the factor (1-R_{bias}).

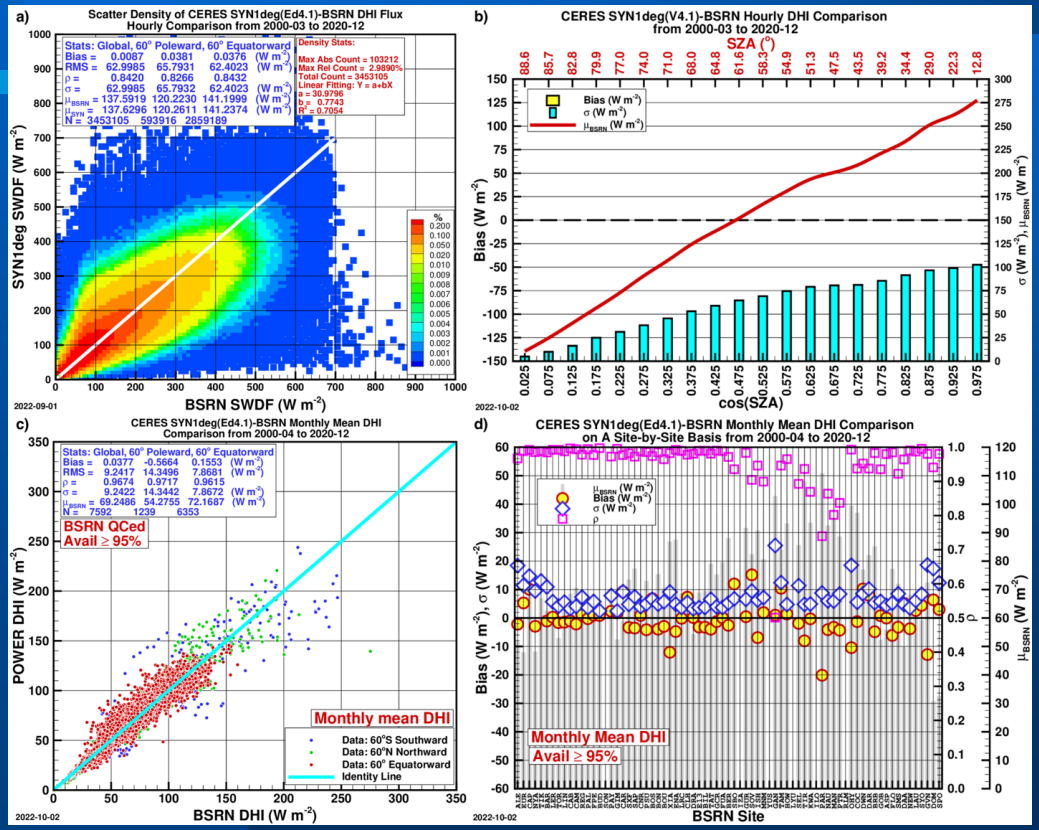
The same method is applied to the correction of the hourly DHI.

DNI after the correction



a) Hourly mean scatter plot;
b) Bias and σ variation with cos(SZA);
c) Monthly mean scatter plot;
d) Monthly mean on a site-by-site basis.

DHI after the correction



a) Hourly mean scatter plot;

b) Bias and σ variation with cos(SZA);

c) Monthly mean scatter plot;

d) Monthly mean on a site-by-site basis.

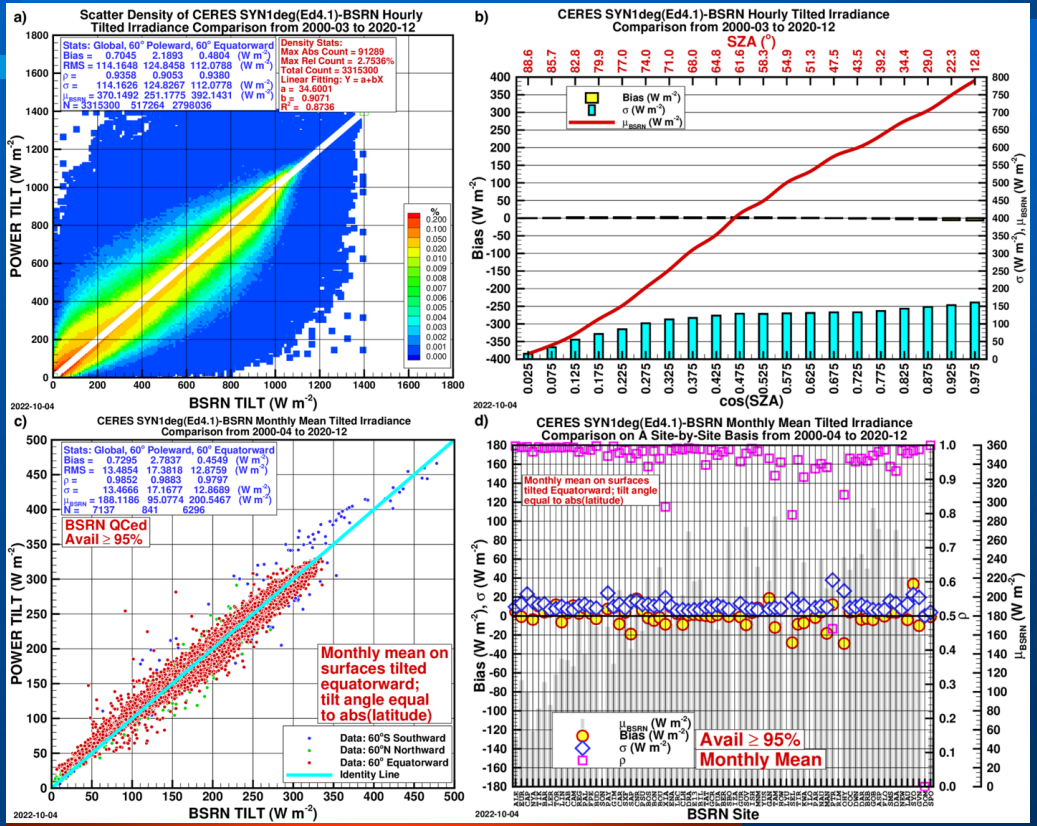
DNI Comparison Statistics after the Correction

Time Scale	Bias	RMS	ρ	σ	μ_{DATA}	N
DNI (Direct Normal Irradiance)						
Hourly	-1.59	186.60	0.8416	186.59	395.82	3,012,283
Daily	1.84	56.56	0.9290	56.53	179.99	273,873
Monthly	1.71	22.93	0.9719	22.87	178.11	7,260

DHI Comparison Statistics after the Correction

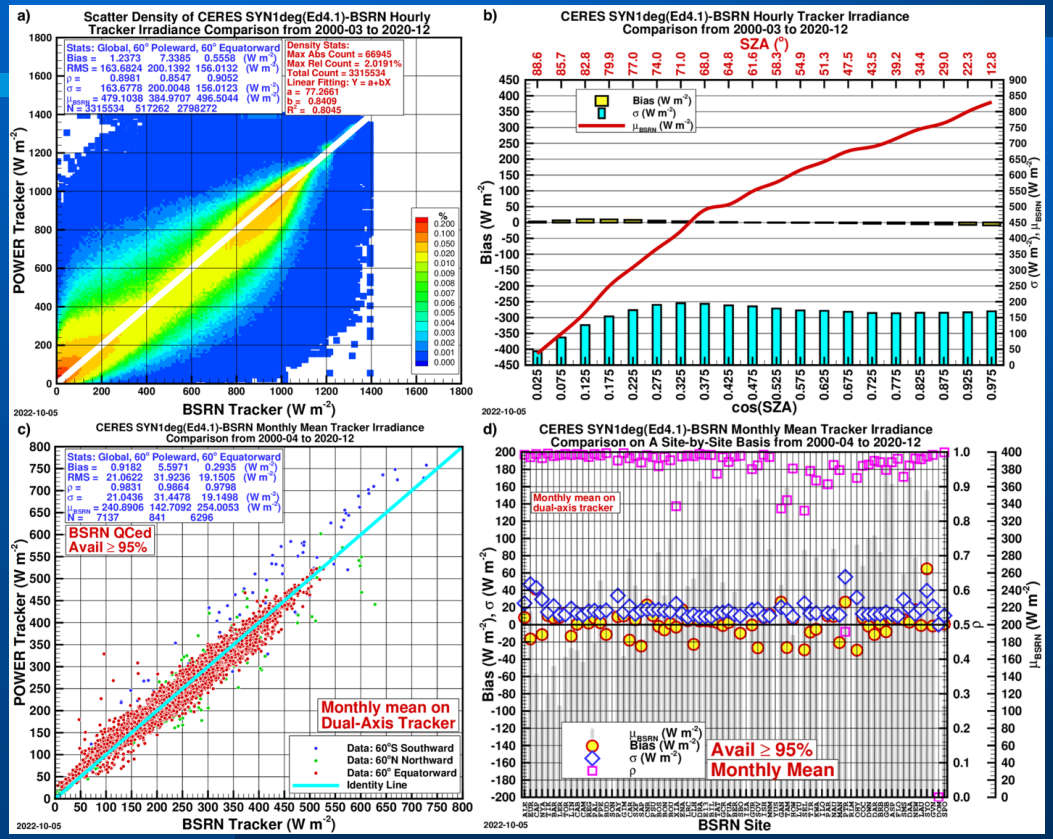
Time Scale	Bias	RMS	ρ	σ	μ_{DATA}	N
DHI (Diffuse Horizontal Irradiance)						
Hourly	0.01	62.99	0.8420	62.99	137.62	3,453,105
Daily	-0.07	19.49	0.9070	19.49	70.58	277,630
Monthly	0.03	9.24	0.9674	9.24	69.28	7,592

GTI after the correction



a) Hourly mean scatter plot;
b) Bias and σ variation with cos(SZA);
c) Monthly mean scatter plot;
d) Monthly mean on a site-by-site basis.

GTrl after the correction



a) Hourly mean scatter plot;

b) Bias and σ variation with cos(SZA);

c) Monthly mean scatter plot;

d) Monthly mean on a site-by-site basis.

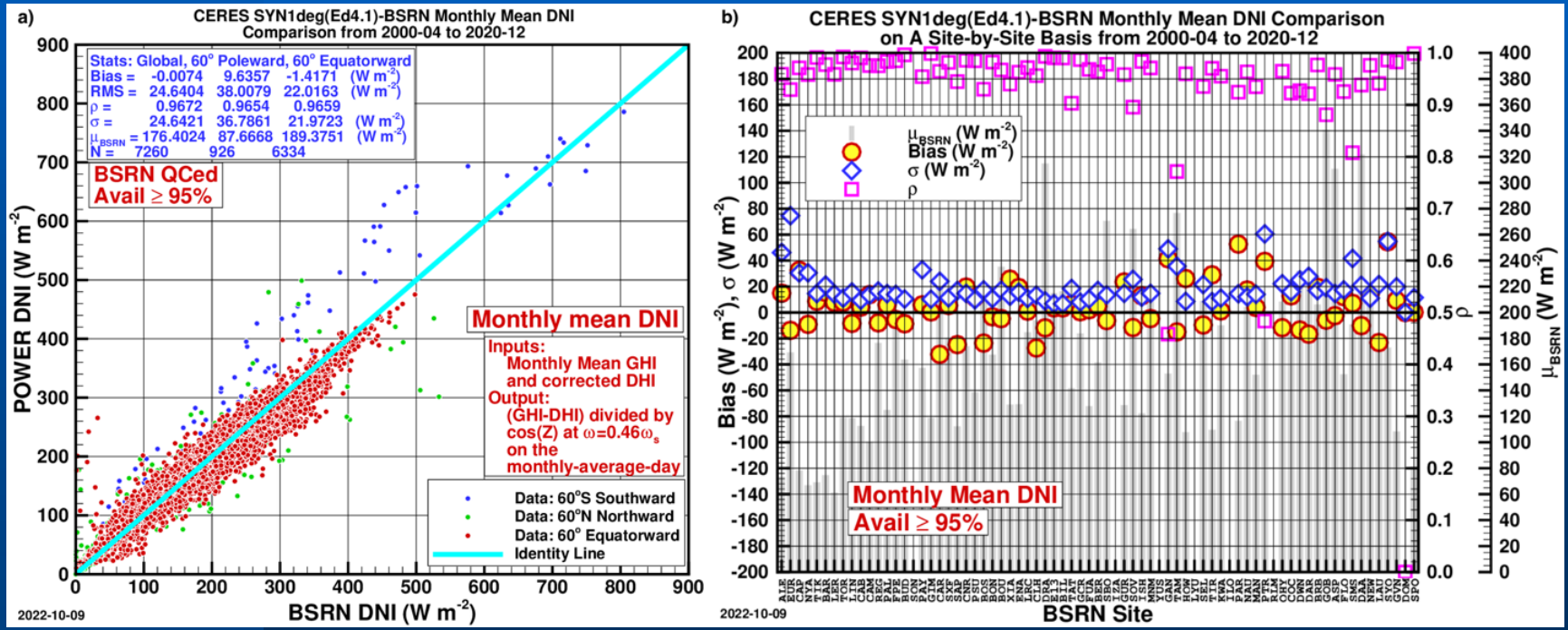
GTI Comparison Statistics after the Correction

Time Scale	Bias	RMS	ρ	σ	μ_{DATA}	N
Tilted Irradiance on Equatorward Tilted Surfaces [tilt angle = abs(latitude)]						
Hourly	0.70	114.16	0.9358	114.16	370.89	3,315,300
Daily	0.63	32.78	0.9743	32.78	194.17	257,719
Monthly	0.72	13.48	0.9852	13.46	188.84	7,137

GTrI Comparison Statistics after the Correction

Time Scale	Bias	RMS	ρ	σ	μ_{DATA}	N
Total Irradiance on a Dual-Axis Tracking Panel (Tracker)						
Hourly	1.23	163.68	0.8981	163.67	480.71	3,315,543
Daily	0.91	51.37	0.9457	51.36	250.73	257,719
Monthly	0.91	21.06	0.9831	21.04	241.80	7137

Monthly mean DNI from the POWER SSE (V6.0) Method

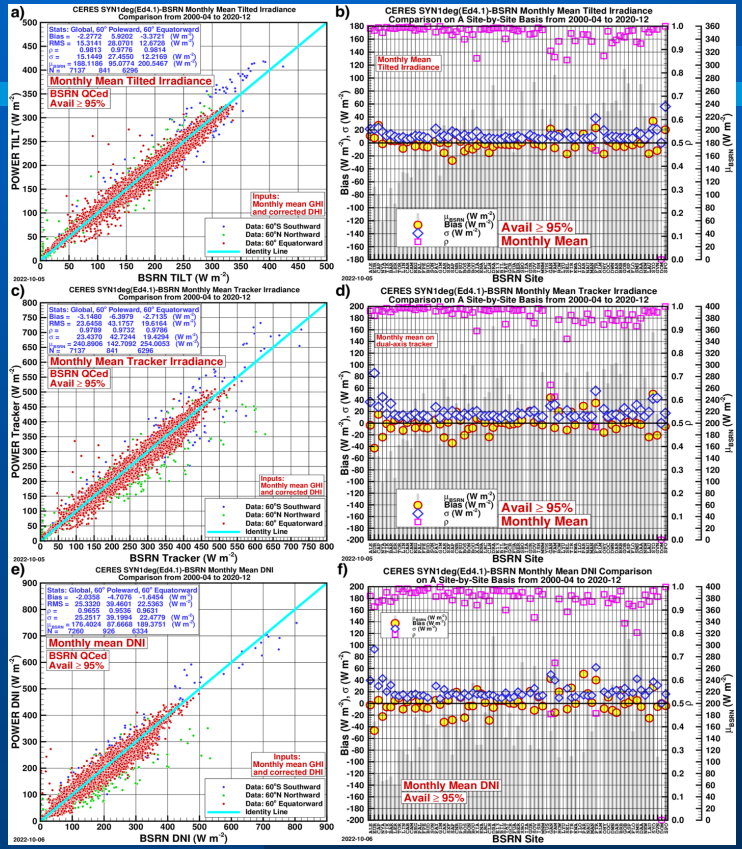


The POWER SSE (V6.0) Method

Case 4: Whitlock Method II

Case No.	Parameter	Bias	RMS	ρ	σ	μ_{DATA}	N
1	Monthly DHI	-7.11	15.04	0.9328	13.25	62.13	7,592
2	Monthly DNI	24.50	46.20	0.9311	39.17	200.90	7,260
3	Monthly DNI	11.10	28.13	0.9651	25.85	187.50	7,260
4	Monthly DNI	-0.00	24.64	0.9672	24.64	176.39	7,260
5	Monthly DNI	30.61	41.56	0.9669	28.12	207.01	7,260

The LJCR Method, as used by RETScreen



a) and b): GTI

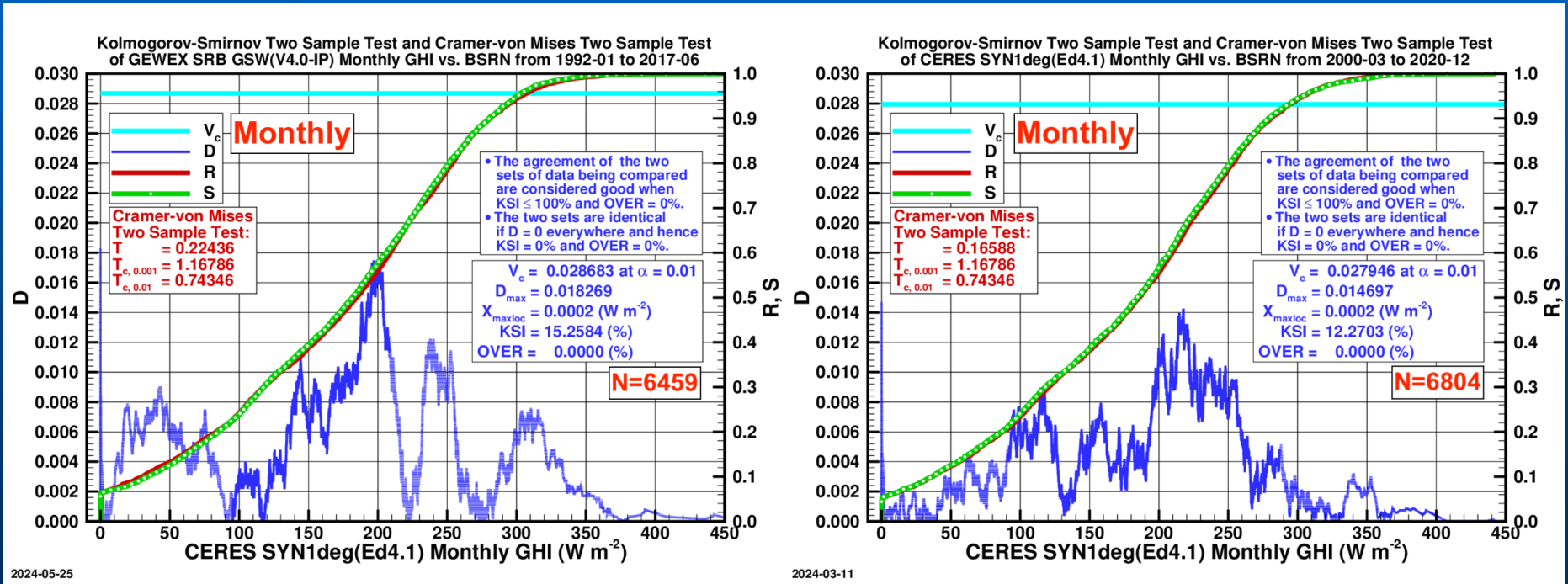
c) and d): GTrI

e) and f): DNI

The LJCR Method Results Comparison Statistics

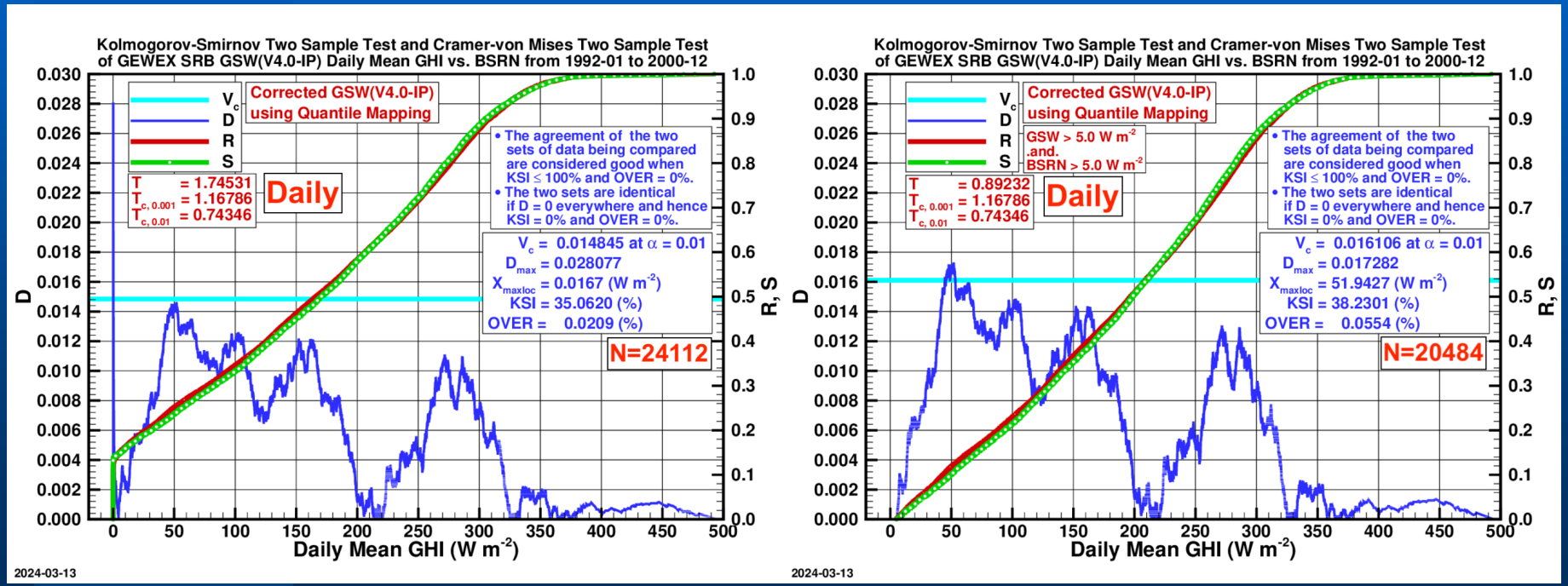
	Bias	RMS	ρ	σ	μ_{DATA}	N
Monthly Mean Tilted (GTI)	-2.27	15.31	0.9813	15.14	185.84	7,137
Monthly Mean Tracker (GTrI)	-3.14	23.64	0.9789	23.43	237.74	7,137
Monthly Mean DNI	-2.03	25.33	0.9655	25.25	174.36	7,260

Kolmogorov-Smirnov Two Sample Test and Cramer-von Mises Two Sample Test of GEWEX SRB GSW(V4.0-IP) and CERES SYN1deg(Ed4.1) *Monthly* Mean GHI



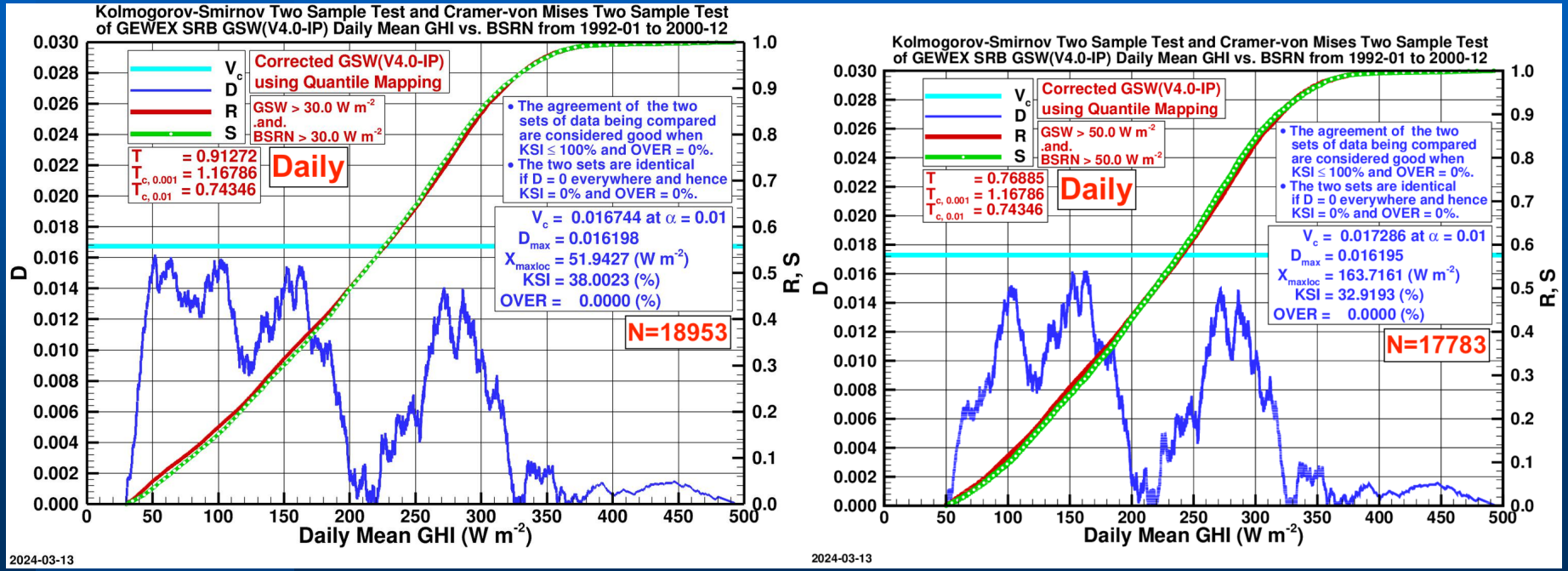
Kolmogorov-Smirnov Two Sample Test and Cramer-von Mises Two Sample Test of *Daily* Mean GEWEX SRB GSW(V4.0-IP) GHI Adjusted According to CERES SYN1deg(Ed4.1) Data Using Quantile Mappting:

Case 1.) GHI > 0 W m^{-2}; Case 2.) GHI > 5 W m^{-2};



Kolmogorov-Smirnov Two Sample Test and Cramer-von Mises Two Sample Test of *Daily* Mean GEWEX SRB GSW(V4.0-IP) GHI Adjusted According to CERES SYN1deg(Ed4.1) Data Using Quantile Mappting:

Case 3.) GHI > 30 W m^{-2}; Case 4.) GHI > 50 W m^{-2};



Summary and Conclusions (1/3)

- The bias correction of the CERES SYN1deg(Ed4.1) hourly DNI produces a dataset of DNI that is less biased against the BSRN and has a smaller uncertainty than that of the DirIndex model;
- The isotropic model applied to the hourly DNI and DHI produces GTIs that agree well with the BSRN data whose hourly, daily and monthly means are from the near-instantaneous tilted irradiances from the same model;
- In the modified Whitlock method, the bias of the monthly DNI is reduced to practically zero; the bias/σ (-1.4/21.9) for sites 60° equatorward, where 85% of the BSRN sites are located, is nearly as good as those of the hourly-based results (1.0/21.8); the bias/σ at sites 60° poleward are somewhat larger, though;

Summary and Conclusions (2/3)

- The monthly mean DNI from the RETScreen method is by and large the same as the modified Whitlock method, though the latter is slightly better;
- The monthly mean GTI and tracker irradiance from the RETScreen method are nearly as good as those of the hourly-based method on the whole; only at sites 60° poleward, the results show noticeably larger standard deviations. Reformulation for higher latitudes may improve its performance in polar regions.
- The POWER SSE (V6.0) method and the LJCR method proved themselves as well as the current dataset.

Summary and Conclusions (3/3)

- The GEWEX SRB GSW(V4.0-IP) and CERES SYN1deg(Ed4.1) *monthly* mean GHI can pass both the K-S two-sample test and Cramer von-Mises two-sample test at α=0.01 significance level with all comparable data points included;
- Their *daily* mean counterparts fail the tests even at α=0.001 with all comparable data points included; however …
- The GEWEX SRB GSW(V4.0-IP) *daily* mean GHI adjusted according to CERES SYN1deg(Ed4.1) using quantile mapping for the years 1992-2000 can pass the tests when the lower limit of GHI is set to 30 W m^{-2}.

ありがとう ございます!

Thank you!

Information about the NASA POWER Project:

https://power.larc.nasa.gov

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Extras