Accuracy of solar irradiances derived from GOES satellite data

Solar panels atop EBU2 building on the UCSD campus.

Photo: A. Nottrott

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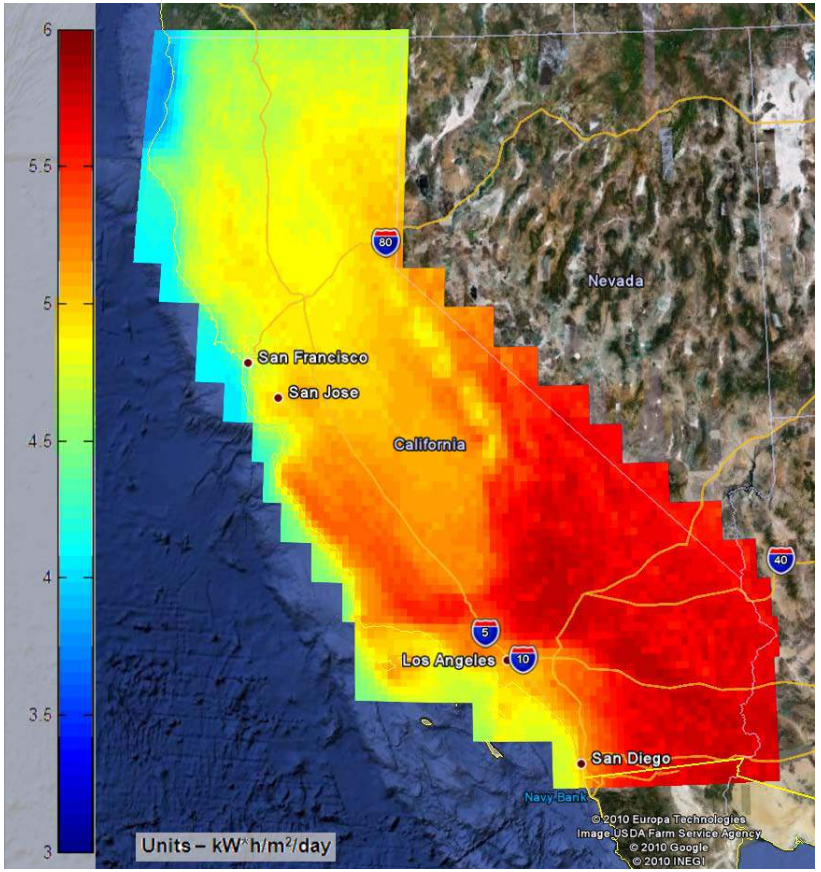
ASES National SOLAR Conference • Phoenix, AZ • May 17-22, 2010

NREL NSRDB Gridded Dataset

- Perez et al (2002), SUNY-Albany
- Surface irradiance data derived from GOES visible image
- Gridded product provides continuous spatial coverage over entire U.S. on a 0.1˚ (~10km) grid
- NSRDB Gridded product developed for the period from 1998-2005
- Modeled global horizontal, direct and diffuse components of surface irradiance

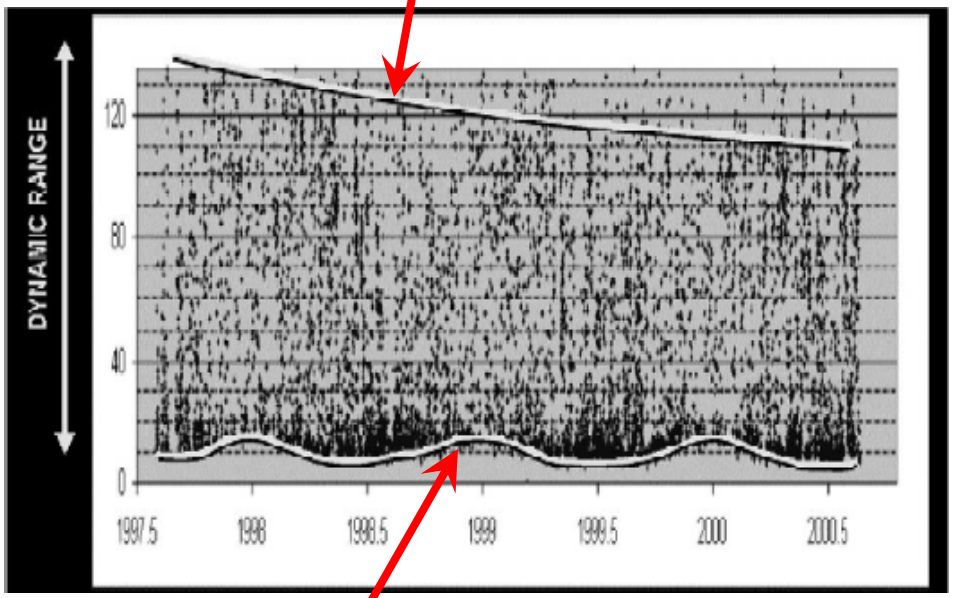


NSRDB SUNY mean annual irradiation for California, USA. © Google, 2010

SUNY Satellite Irradiance Model

- Measure intensity of return radiance from GOES visible image
- 60 day sliding time window to determine lower bound of radiance
- Develop cloud index (CI) to modulate Kasten clear sky irradiance model
- Accounts for atmospheric turbidity, ground snow cover, ground specular reflectance and sun-satellite angle effects.

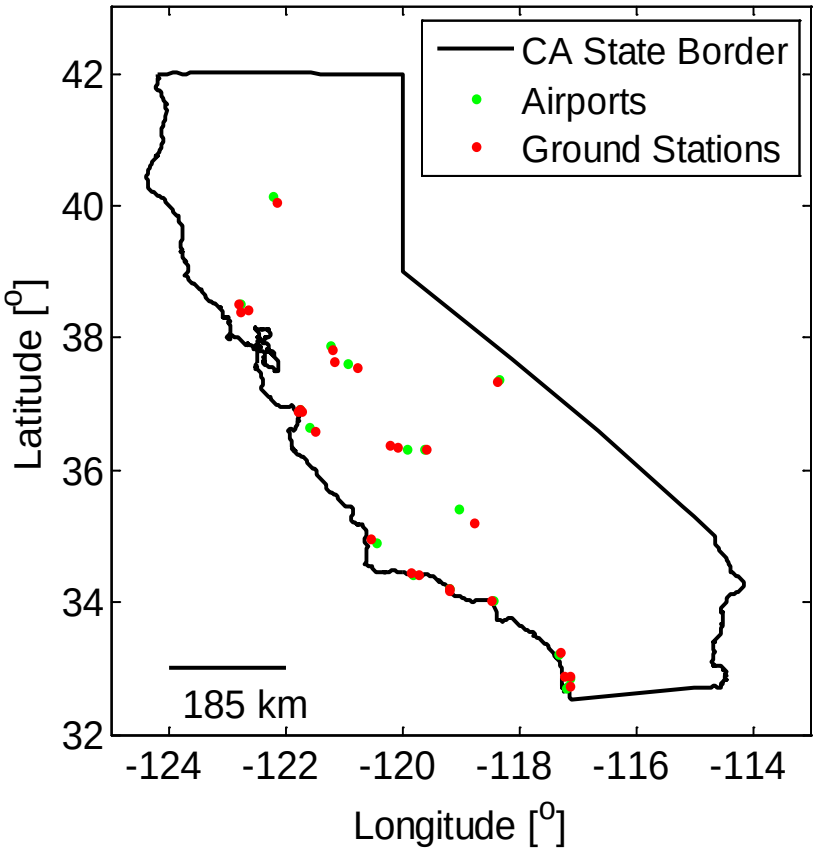
Return radiance upper bound showing sensor calibration drift



Return radiance lower bound showing seasonal variation

Perez et al (2002)

CIMIS Network



Geographic distribution of ground measurement stations used in this study (Nottrott & Kleissl, 2010)

- California Irrigation and Management Information System (CIMIS), California Department of Water Resources (DWR)
- Statewide coordinated network of weather stations designed for ET measurements
- Quality controlled global horizontal irradiance data, sensors recalibrated annually
- Data from 26 CIMIS stations were used to validate NSRDB-SUNY dataset

Limitations of Ground Data

- Silicon photodiode pyranometers only allow for measurement of the Global Horizontal Irradiance (GHI)
- Non-linearity of sensor response results in inaccurate measurements when zenith angle > 80°
- Pyranometer and satellite radiometer have a different field of view
- The sensor does not have a broadband spectral response

Methods

- Spatial discrepancy for ground stations sited at "sub-grid" locations. Distance weighted interpolation applied to 4 nearest SUNY grid points to each ground station

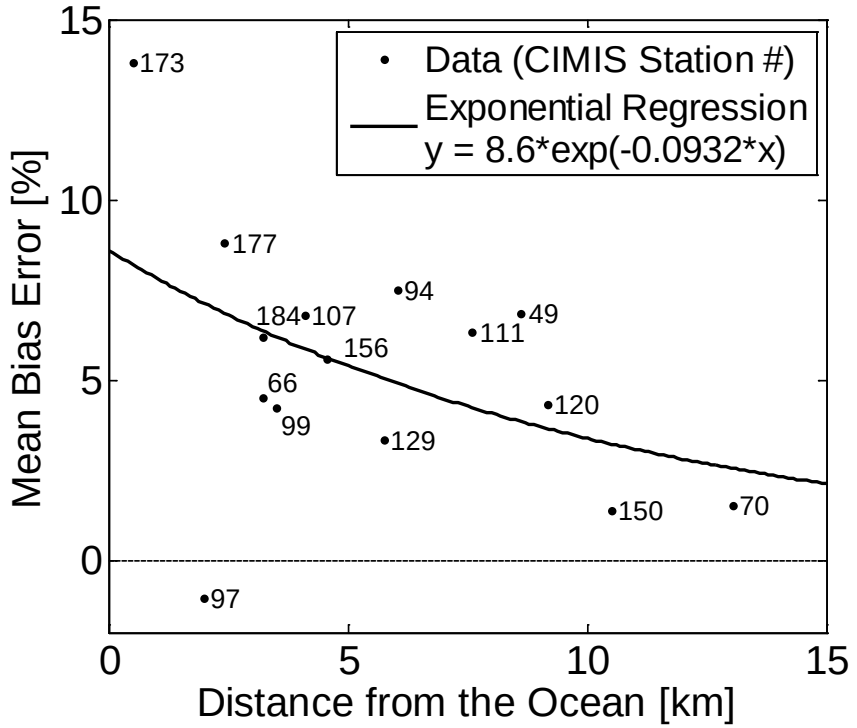
$$R_{S,I} = \frac{\sum_{n=1}^{4} \frac{1}{d_n} R_{S,n}}{\sum_{n=1}^{4} \frac{1}{d_n}}$$

- Statistical metrics including mean absolute deviation (MAD), mean bias error (MBE), root mean squared error (RMSE) and correlation coefficient (r) were used to evaluate datasets

Geographical Dependence of Error

$$MBE = \frac{1}{\overline{GHI_{CIMIS}}} \frac{1}{N} \sum_{n=1}^{N} GHI_{SUNY,n} - GHI_{CIMIS,n}$$

Average MBE over the entire year for
15 coastal CIMIS stations



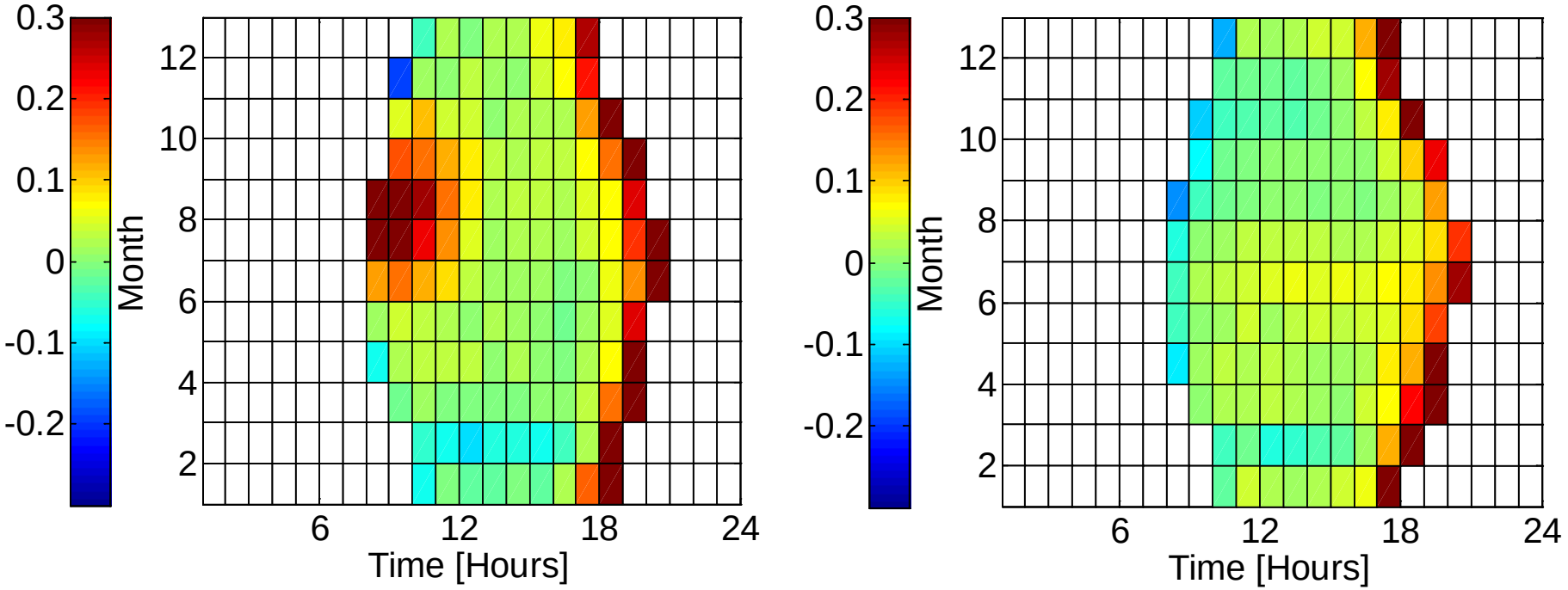
Nottrott & Kleissl (2010)

Temporal Variation of MBE

MBE between SUNY model and CIMIS GHI measurements

CIMIS #111 – Green Valley, Santa Cruz Co.
7.5 km from the coast

CIMIS #008 – Gerber, Tehama Co.
93.0 km from the coast



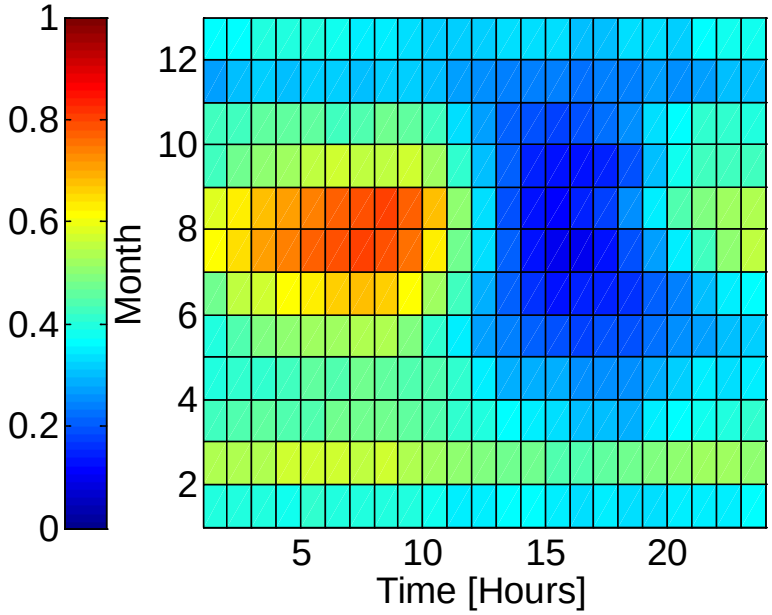
Units →[%·10^{-2}]

Geographical separation between sites is ~**350 km**

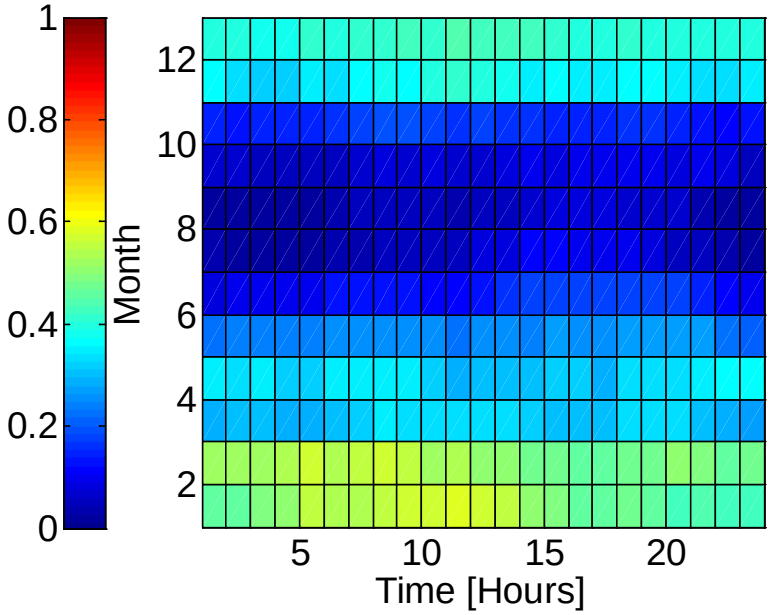
Nottrott & Kleissl (2010)

Monthly/Hourly Cloud Cover

CIMIS #111 – Green Valley, Santa Cruz Co.
7.5 km from the coast



CIMIS #008 – Gerber, Tehama Co.
93.0 km from the coast



- Sky Cover Fraction – The fractional area of the sky which is covered by opaque clouds (measured in octas)

- Strong correlation between dense morning cloud cover and large MBE between SUNY and CIMIS datasets

Nottrott & Kleissl (2010)
Data – NCDC DSI-3505

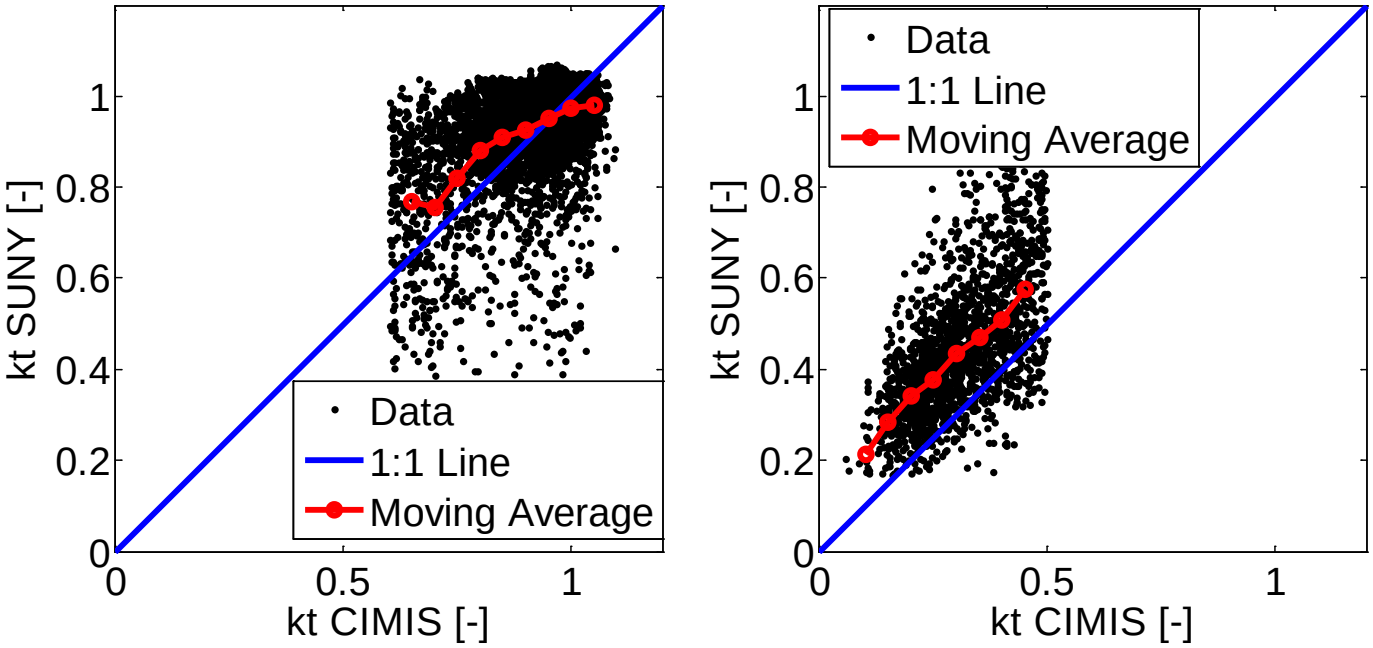
Correlation Between Datasets

- *Clear-sky index (kt)* is defined as

$$kt = GHI/GHI_{skc}$$

- Filter data seasonally to capture cloudy periods, e.g. June-Sept at coastal sites and Oct-May at inland sites
- SUNY model overestimates surface irradiance under cloudy conditions

CIMIS #111 – Green Valley, Santa Cruz Co.
7.5 km from the coast

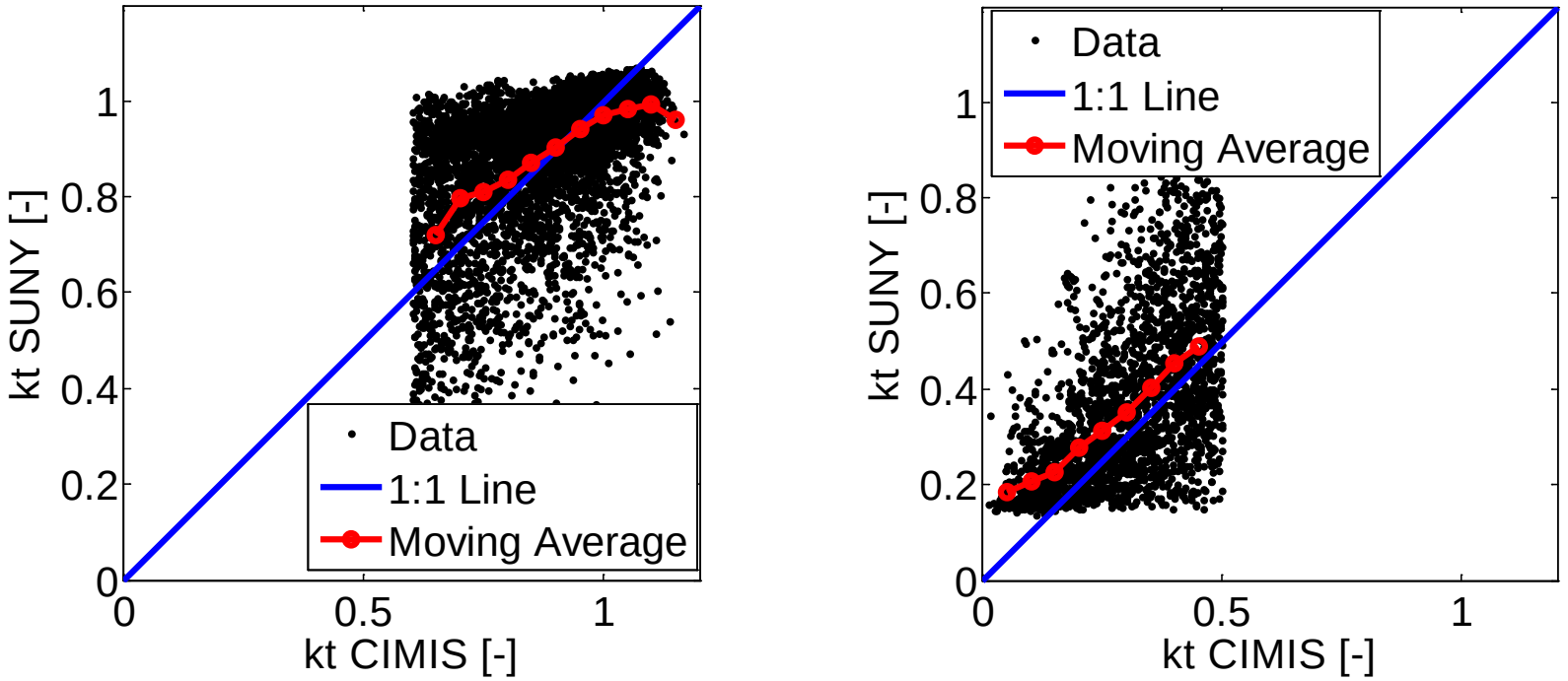


Nottrott & Kleissl (2010)

Correlation Between Datasets

- A similar trend is observed for inland sites.

CIMIS #008 – Gerber, Tehama Co.
93.0 km from the coast

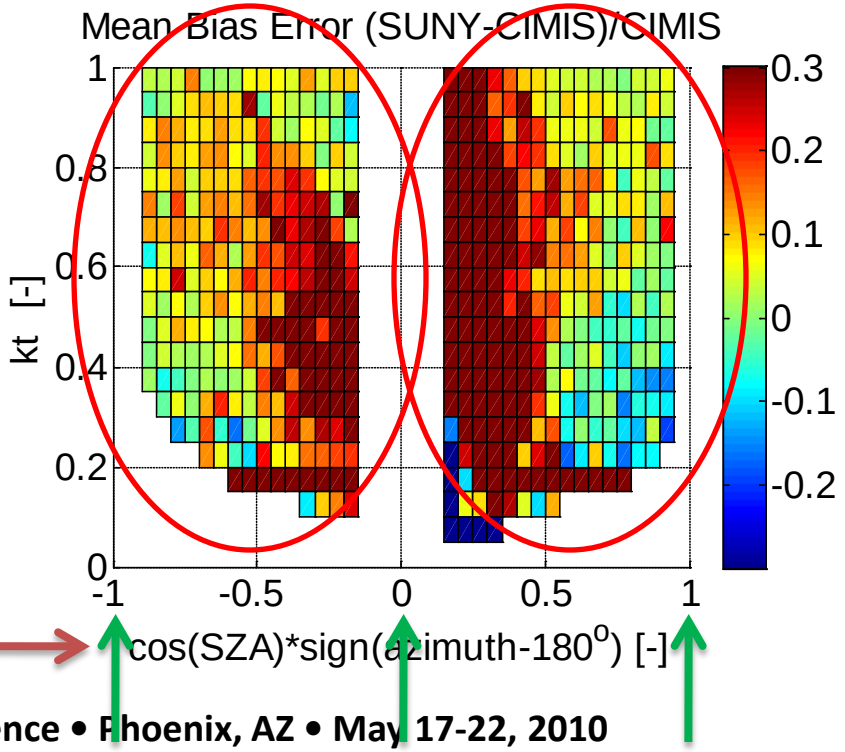


Nottrott & Kleissl (2010)

MBE as a function of kt and SZA

- Following Lorenz *et al.* (2009) we examine the dependence of MBE on solar altitude (i.e. solar zenith angle, SZA) and clear-sky index for data before and after solar noon.
- Positive morning MBE depends on cloudiness and solar altitude.
- Year-round evening MBE is primarily related to solar altitude and not dependant on cloudiness
- These data can be used to develop a post-processing error correction for the NSRDB SUNY dataset

Morning Data



Evening Data

Nottrott & Kleissl (2010)

Correction Algorithm

•Apply a correction to the NSRDB SUNY hourly GHI data (Lorenz *et al*., 2009) using CIMIS GHI data from 25 stations as a reference

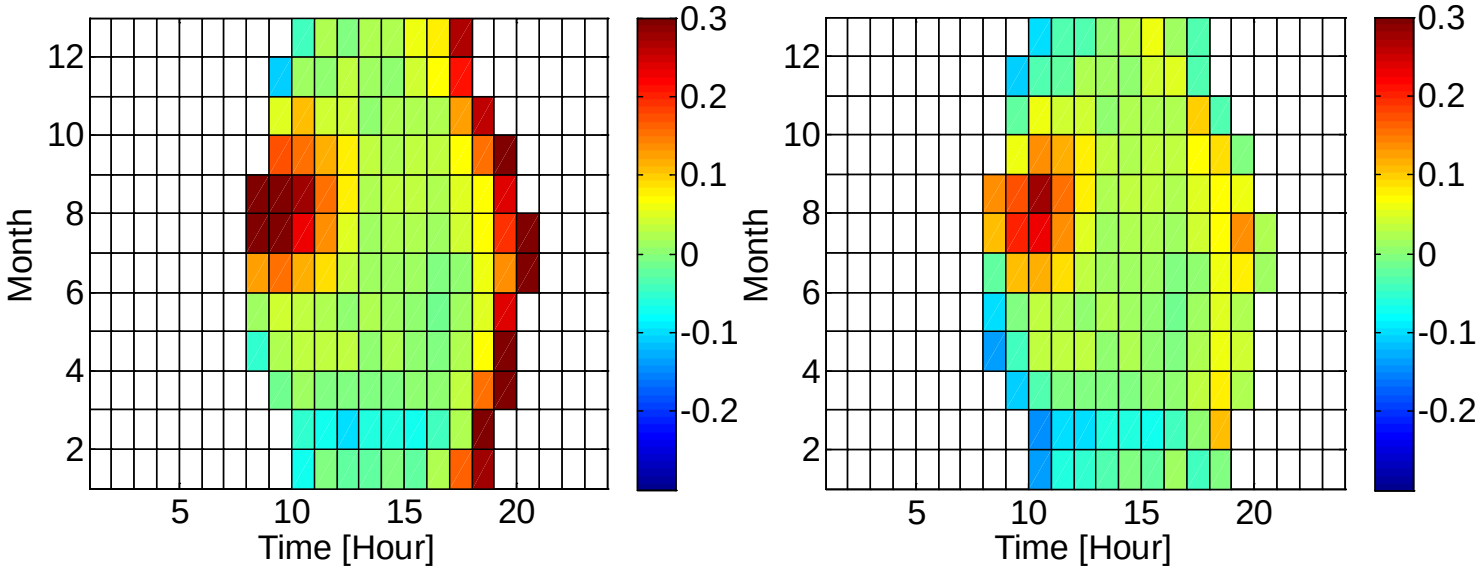
•Advantages

- Corrects SUNY data in "post-processing"
- Only inputs are SUNY hourly GHI, modeled Clear-sky Irradiance, Solar Geometry

• Disadvantages

- Empirical coefficients are used
- Individual corrected hourly measurements may not be accurate

CIMIS #111 – Green Valley, Santa Cruz Co. (7.5 km from the coast)



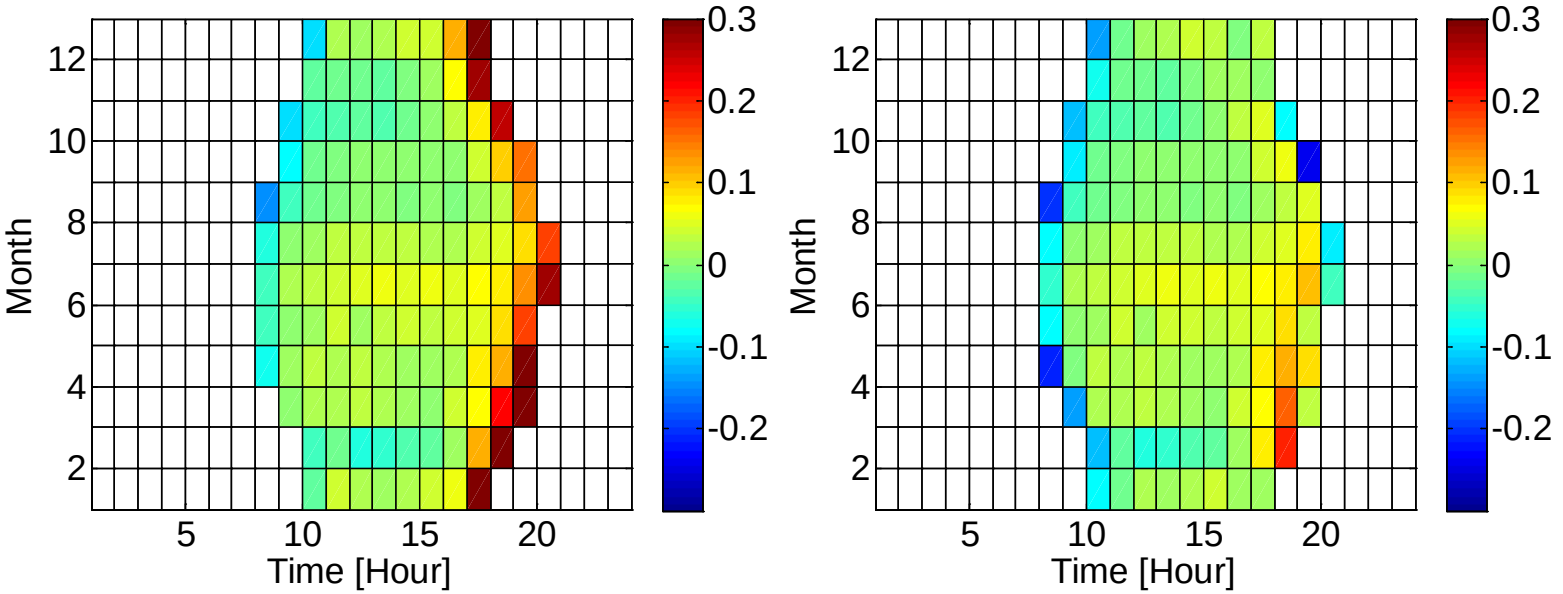
Before: MBE = **9%**

After: MBE = **4%**

Nottrott & Kleissl (2010)

Correction Algorithm

CIMIS #008 – Gerber, Tehama Co. (93.0 km from the coast)



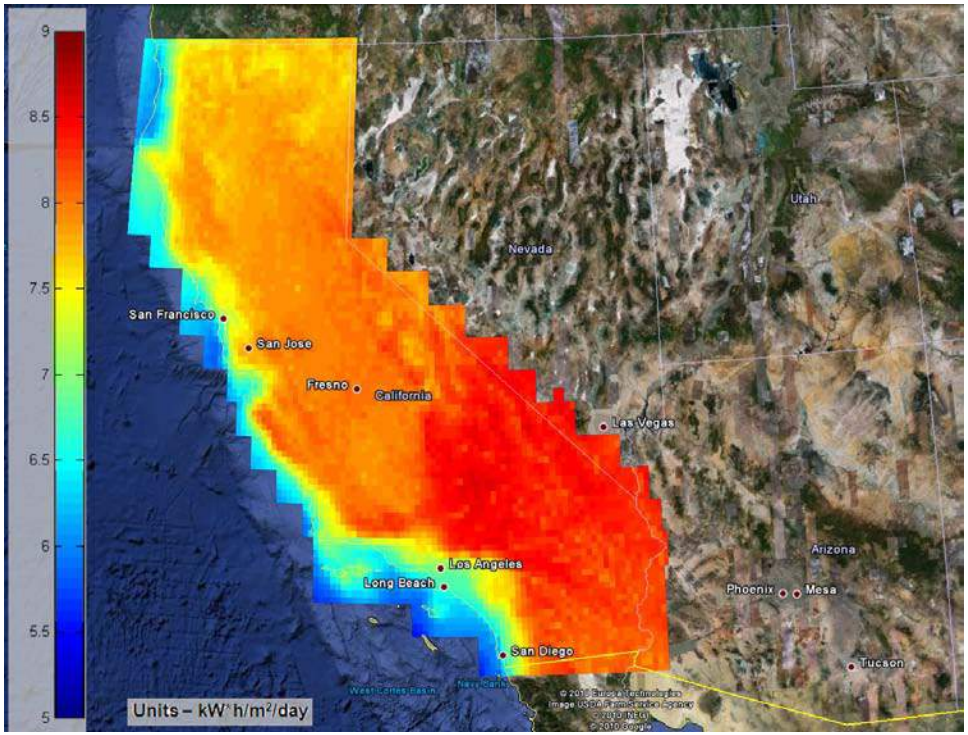
Before: MBE = **6%**

After: MBE = **2%**

Nottrott & Kleissl (2010)

Corrected Solar Maps for CA

- We have applied the correction algorithm to generate a corrected GHI data set for the entire state of California
- The data is visualized using Google Earth (**Free Software!**)
- GIS tool facilitates accurate solar resource assessment and economic analysis for planned/existing solar energy conversion systems



Corrected NSRDB SUNY mean irradiation during June for California, USA. © Google, 2010

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