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Innovation for Our Energy Future

An Example of Solar Resource Spatial Variability Analysis

Central Facility at ARM Climate Research Facility's Southern Great Plains site; ARM Image Library http://images.arm.gov/

Workshop: Improving the Representation of Renewables in IAMs

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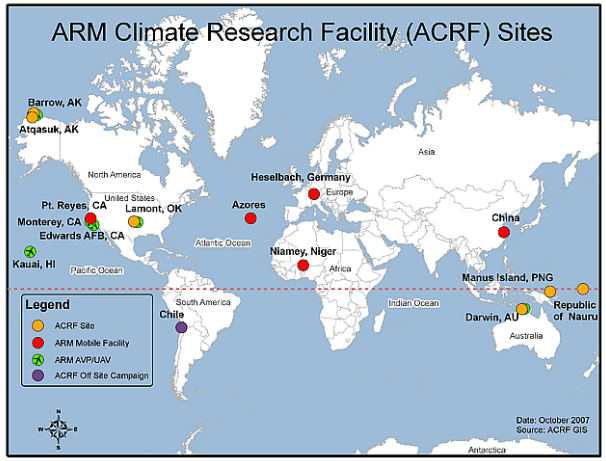
Issues with Determining RE Potentials

- Consistent definitions: theoretical, technical, potential
- Potential nonlinearities due to data scaling: what are the appropriate supply curves or capacity factors in a grid cell?
- Assumptions on land use factors, technology deployments per unit land area, grid and load issues

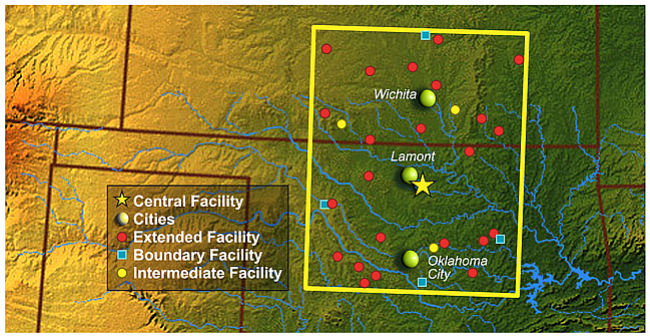
IRENA's Work Plan calls for development of a global renewable energy potentials data base

Purpose

- Examine spatial variability of higher-resolution SUNY data within the NASA cell that overlays high-quality ground stations.
- Identify nonlinearities due to data scaling
- Test site: USDOE's Atmospheric Radiation Measurement (ARM) Program's Southern Great Plains (SGP) Site



Location of ARM facilities globally

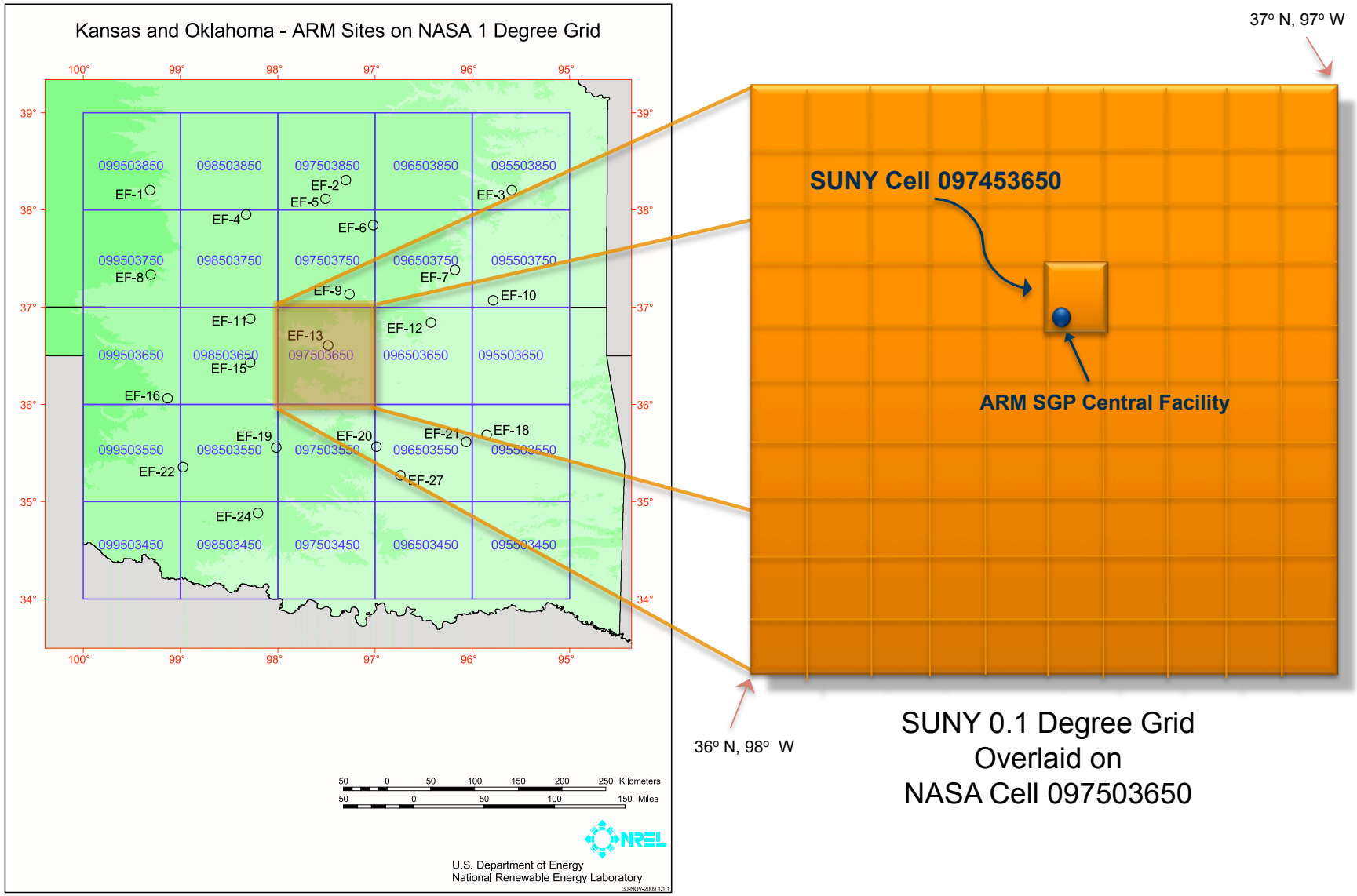


The ARM SGP Site in Central Kansas And Oklahoma

A collection of instruments at the SGP site

Image Sources: ARM Image Library

The Study Area: The ARM SGP Site



Approach

Two satellite-derived data sets inter-compared with each other, and with ground-based data at ARM-SGP site

- Continuation of study originally conducted by Perez, et al (2007)
  - sub-grid variability of the NASA SSE cells
  - Determine degree of consistency in sub-grid spatial patterns from year to year.
- Examine more closely the average distribution of variability within NASA/SSE coarse-grid cells
  - statistical structure of variability: how use of coarser NASA data may be influenced by sub-grid variability
  - Focus on long-term, concurrent monthly and annual average daily total GHI (global horizontal insolation) data derived from the NASA and SUNY data and the ground-based solar monitoring station at the ARM SGP Central Facility (CF).

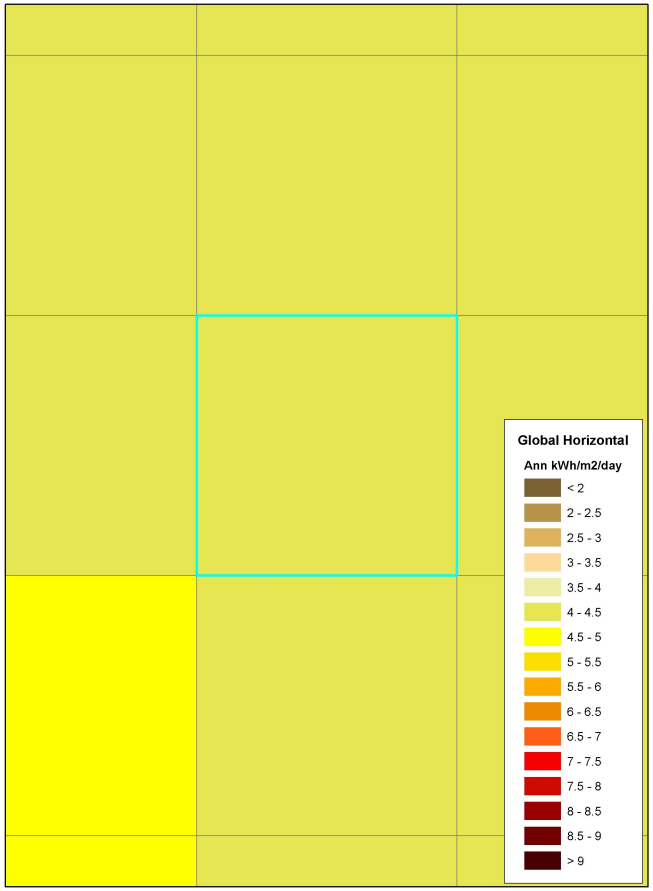
Data Sets

- NASA Surface Solar Energy (SSE) Data Base
  - Daily global horizontal insolation
  - July 1983 – June 2006
  - 100-km (1^{o}x1^{o}) resolution

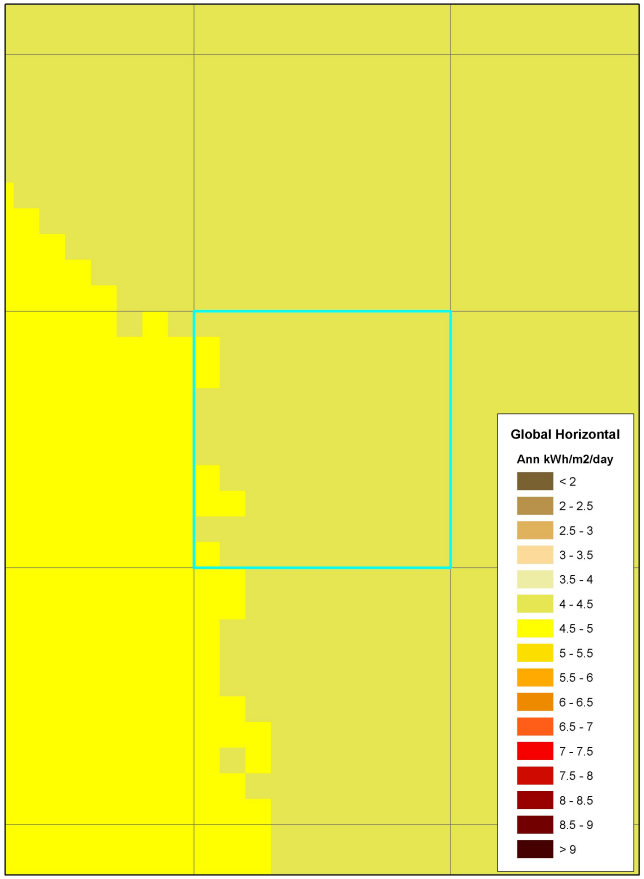
- SUNY/Albany Data Set
  - Hourly "snapshots" of global horizontal insolation
  - January 1998 – December 2005
  - 10-km (0.1^{o}x0.1^{o}) resolution

- ARM SGP Best Estimate Flux (BEFlux)
  - 1-minute global horizontal insolation
  - ~April 1997 to present
  - SGP Central Facility

Monthly Annual Daily Total GHI



NASA

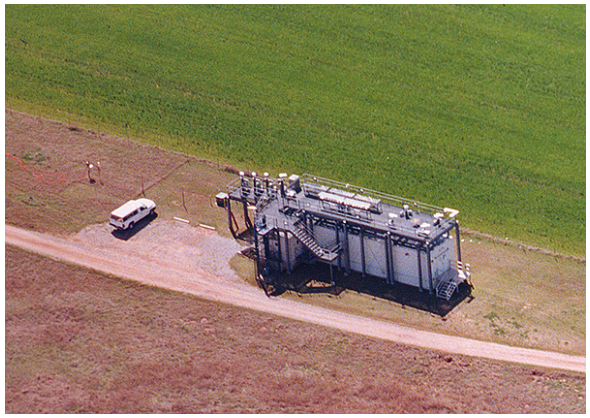


Perez

Monthly and Annual Average Daily Totals

Monthly, seasonal and annual average daily totals for all three data sets calculated for July 1998 – June 2005

- Each of the calendar months: January – December
- Seasonal average daily total GHI for each season
- Annual average daily total GHI for each full year 1999 – 2004.

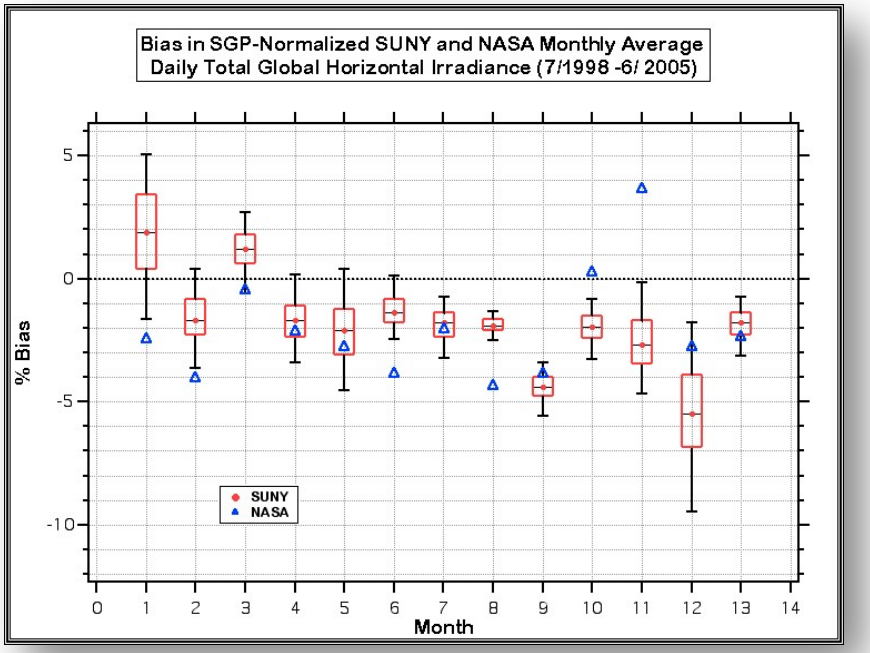


Source: ARM Image Library

Intercomparison of the Data Sets

Both NASA and SUNY underpredict GHI relative to BEFlux during summer and fall; overpredict during winter.

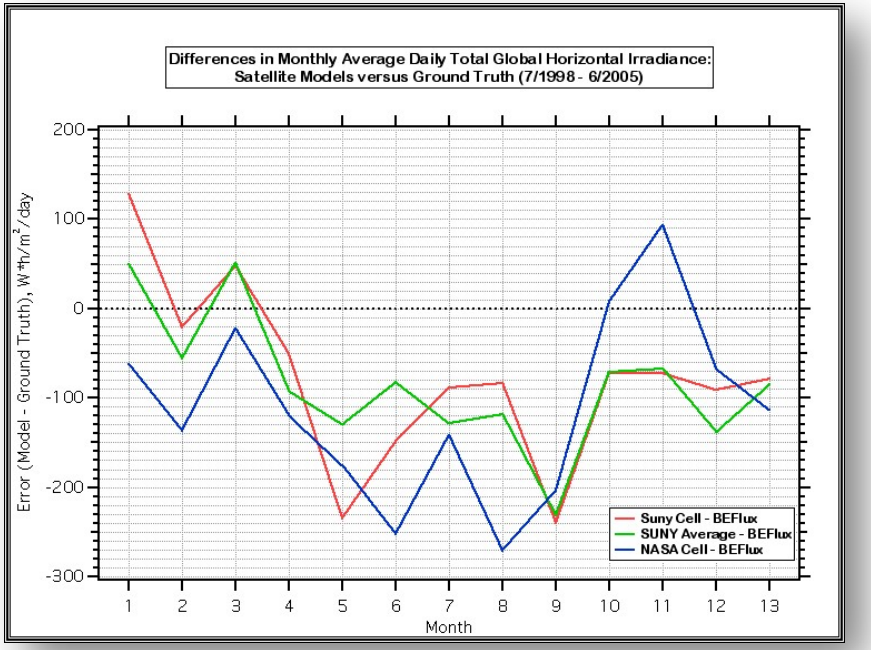
- Variability of SUNY cells within NASA cell higher in winter than summer.
- Annual bias is negative for both models



The spread shown in the SUNY values represents the standard deviation (red box) and total spread of the 100 values within the NASA grid cell.

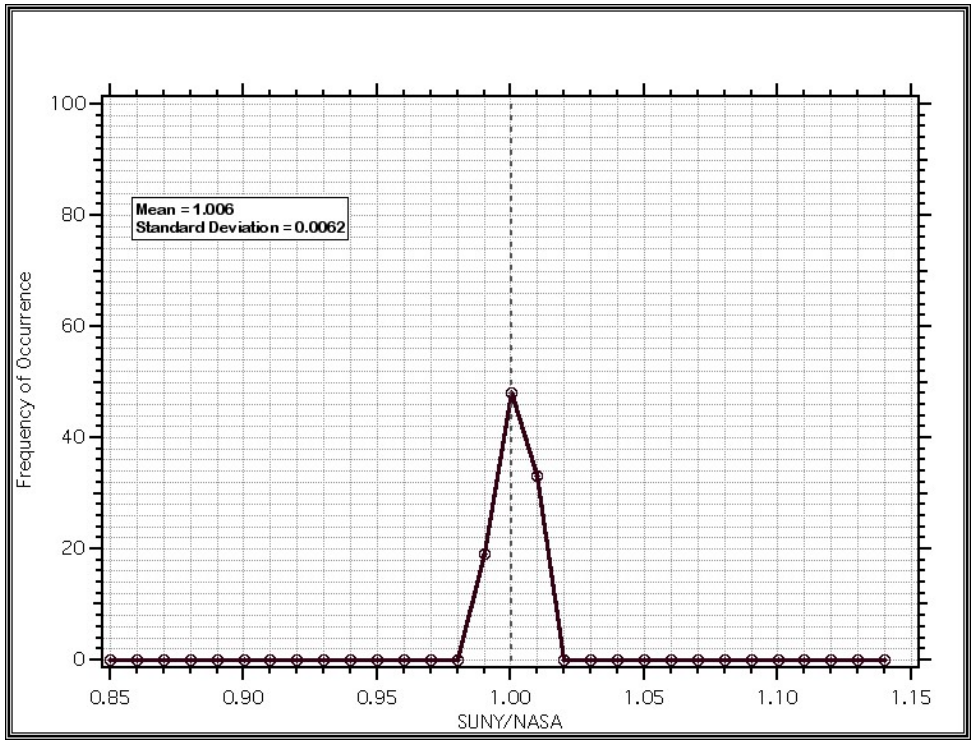
Cell-Specific Intercomparisons

NASA and SUNY tend to underpredict solar resources during the summer months.



Percent differences of monthly average daily total GHI: NASA/SSE and SUNY cells that coincide with the SGP Central Facility.

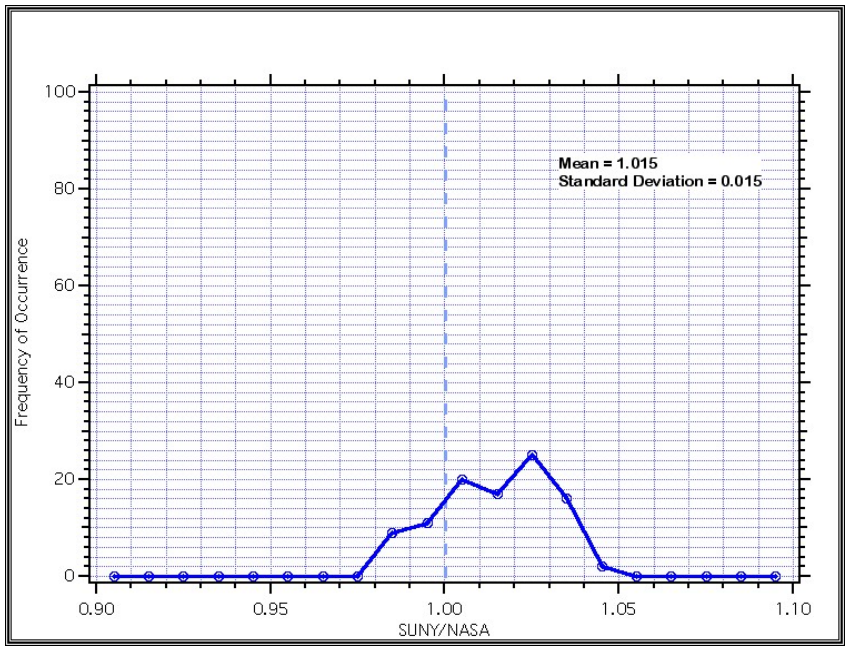
Distribution of SUNY Data within the NASA Cell



Annual distribution of the ratio of SUNY/ NASA annual mean global irradiance for the 100 SUNY cells within the NASA cell overlaying the SGP Central Facility.

Distribution of SUNY Data within the NASA Cell

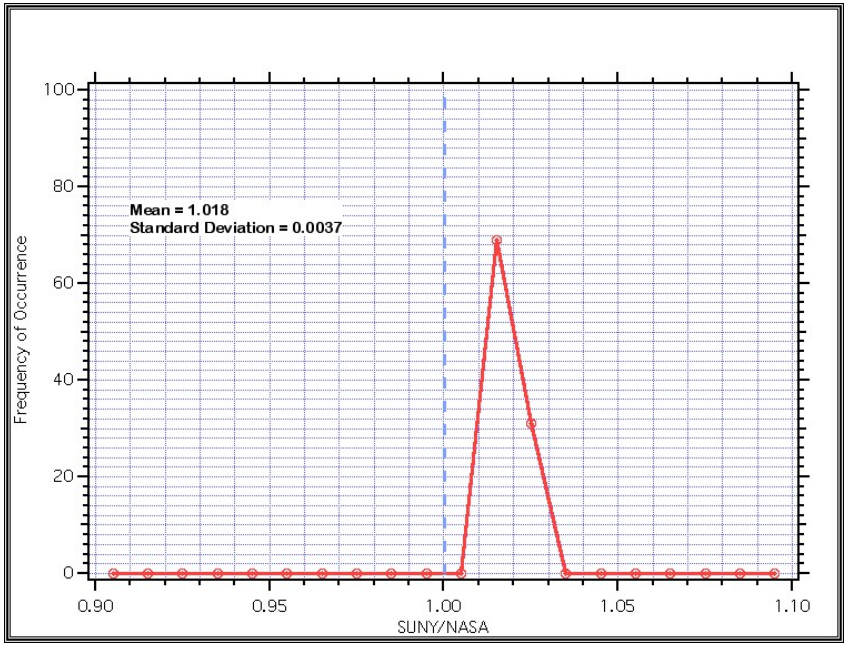
More variability in microscale solar insolation values during winter than any other season for a continental mid-latitude climate regime represented by the SGP. This variability is most likely due to the changes in cloud characteristics between winter and summer.



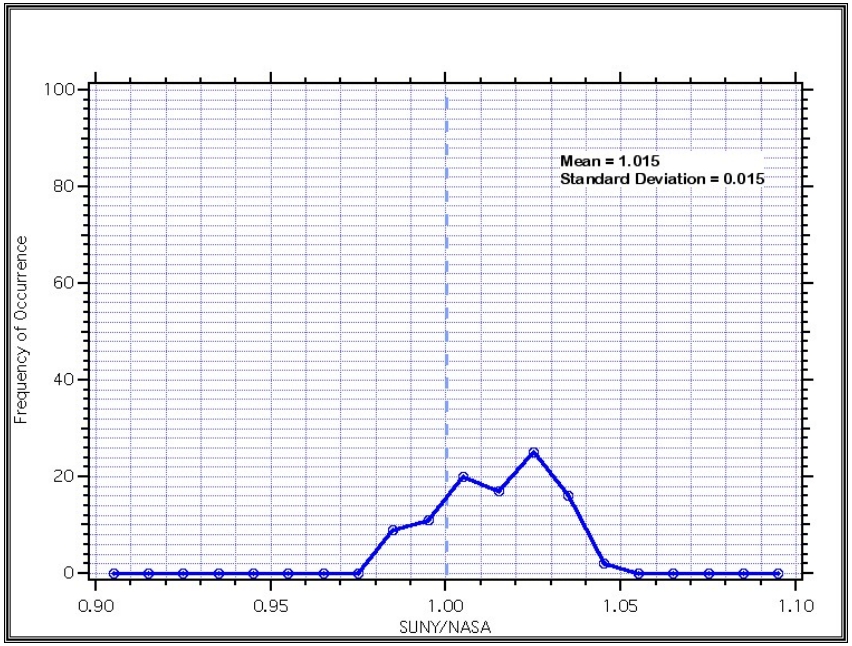
Winter distribution of the ratio of SUNY/ NASA annual mean global irradiance for the 100 SUNY cells within the NASA cell overlaying the SGP Central Facility.

Distribution of SUNY Data within the NASA Cell

Seasonal distributions of the ratio of SUNY/NASA annual mean global irradiance for the 100 SUNY cells within the NASA cell overlaying the SGP Central Facility.



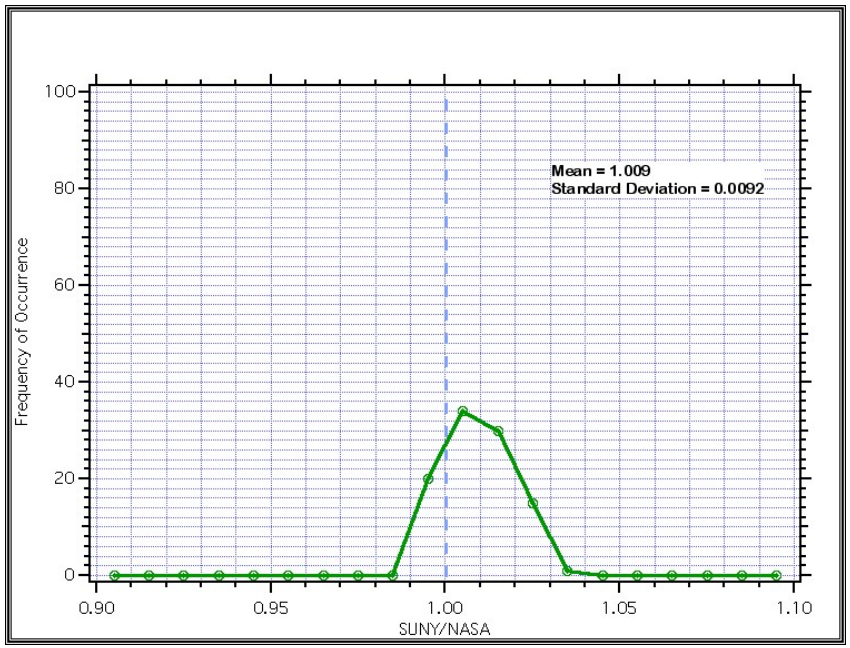
Summer



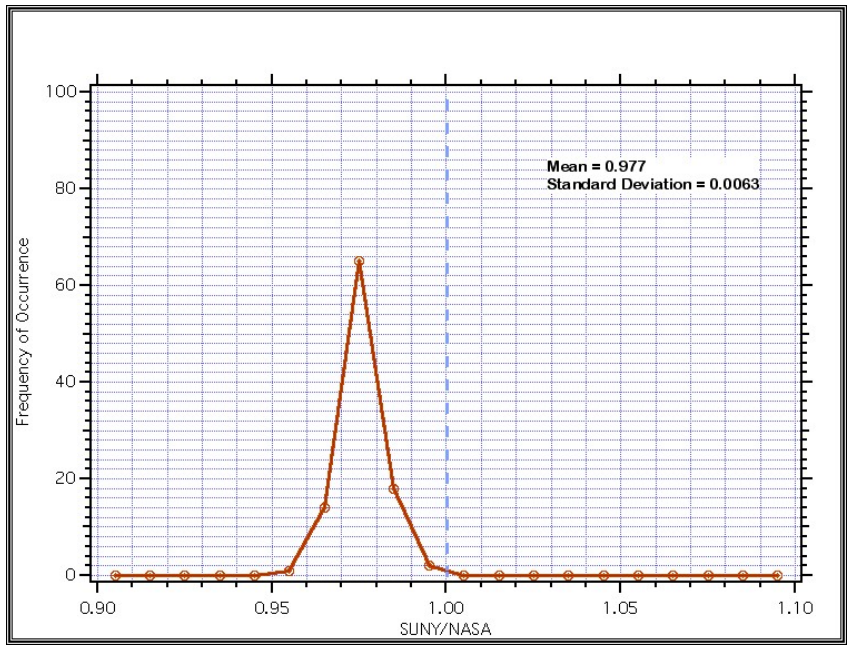
Winter

Distribution of SUNY Data within the NASA Cell

Seasonal distributions of the ratio of SUNY/NASA annual mean global irradiance for the 100 SUNY cells within the NASA cell overlaying the SGP Central Facility.



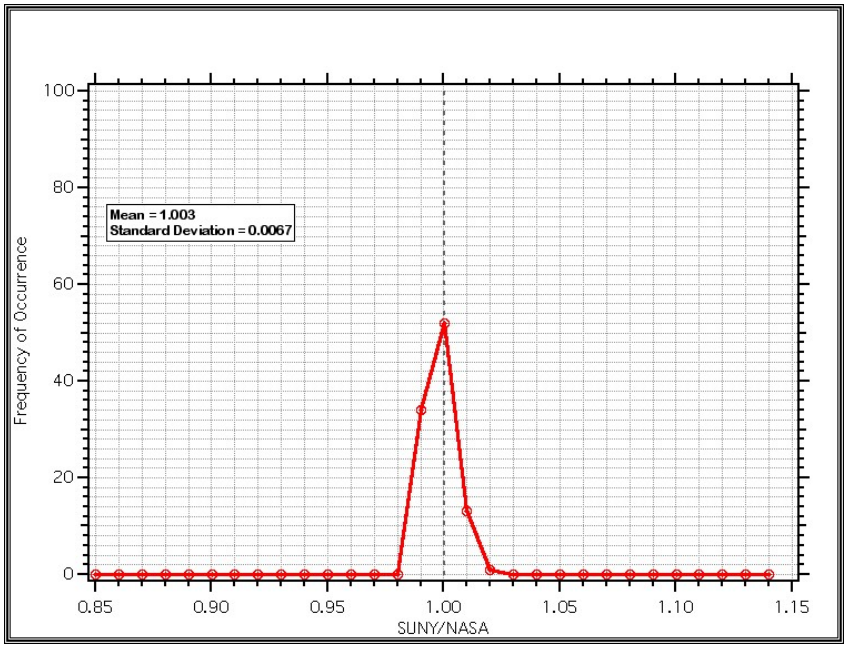
Spring



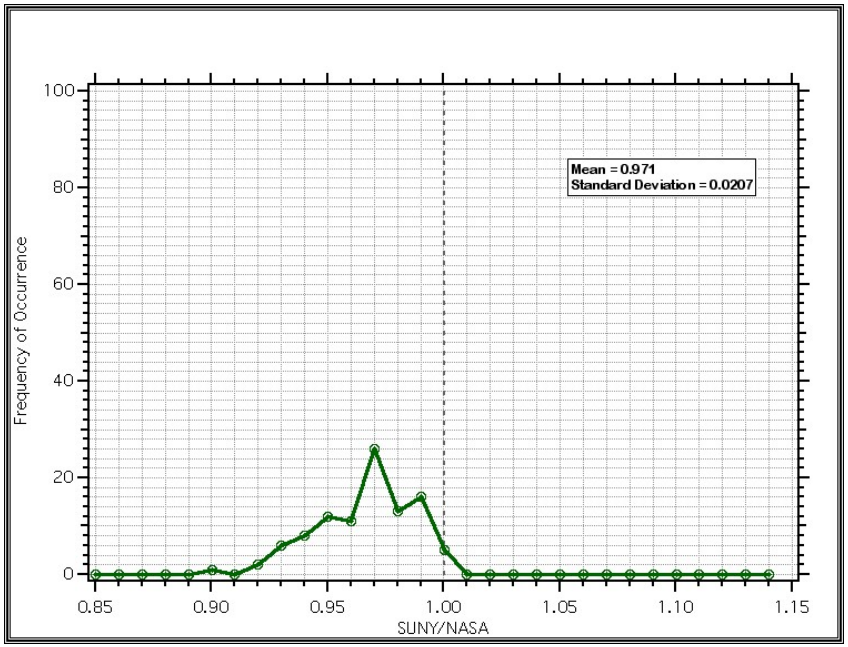
Fall

Distribution of SUNY Data within the NASA Cell

Monthly distributions of the ratio of SUNY/NASA annual mean global irradiance for the 100 SUNY cells within the NASA cell overlaying the SGP Central Facility.



July



December

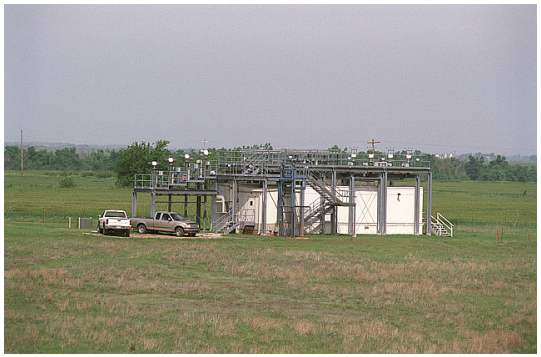
Summary and Conclusions

- Both satellite-derived methods tended to underpredict GHI resources during the summer months and slightly over-predict during the winter,.
- The SUNY method produced higher values than the NASA method for all months except during the fall.
  - The SUNY model also came somewhat closer to the ground truth values.
- The long-term monthly average mean bias errors for both methods were generally less than ±5%, and for the annual means, the bias errors were approximately -2%.
- The distribution of the 100 SUNY grid cells benchmarked against the NASA cell value was broader during the winter and spring months.
  - This is probably indicative of the more complex cloud conditions during these periods.
  - Distributions are generally normal

What's Next?

- Expand this study to the larger ARM/SGP site to compare the two satellite methods with a more geographically dispersed set of ground observations.

- Conduct similar studies in other climatic regimes and for DNI as well as GHI values.
- Look for potential non-linearities due to non-normal distributions of sub-grid variability



Source: ARM Image Library

Thank You!