DERIVING LONG TERM HIGH RESOLUTION SOLAR IRRADIANCES FROM LOW RESOLUTION ARCHIVES VIA MICROSTRUCTURE PATTERNING

Richard Perez & Marek Kmiecik
ASRC, the University at Albany
251 Fuller Rd, Albany, NY
12203
Perez@asrc.cestm.albany.edu

Stephen Wilcox
NREL
1617 Cole Boulevard
Golden, CO 80401
Stephen_wilcox@nrel.gov

Paul W. Stackhouse Jr.
NASA Langley Research Center
21 Langley Blvd.
Hampton, VA 23681
Paul.w.stackhouse@nasa.gov

ABSTRACT

The objective of this work is to explore whether high resolution [microclimatic] solar resource features – hereafter microstructures -- are climatically stable enough, so that recent high-resolution satellite-based solar resource data can be used to enhance the geographic resolution of long term data sets. Observations spanning diverse climatic environment show that this approach has a strong potential. A valuable application would be to enhance the resolution of the NASA Solar Energy and Meteorological data set (currently at 1^o latitude/longitude resolution)

1. BACKGROUND

The National Renewable Energy Laboratory is engaged in an effort to update the National Solar Resource Data Base (NSRDB, e.g., Wilcox et al, 2005) through the 1990's. One of the updates will consist of incorporating high resolution satellite-derived data (0.1^o latitude-longitude resolution) in the new product. Unfortunately, the high resolution satellite data can only be obtained at reasonable cost from 1998 onwards. Another source of satellite-derived data, the NASA Surface Meteorology and Solar Energy (SSE, Stackhouse et al, 2004) data set is available through the 1990s, but its resolution is only 1 degree latitude-longitude.

Hence the proposed approach to explore whether the NASA data set can be enhanced via microstructure patterning. The rationale for this exercise relies on the assumption that insolation variations caused by weather are captured by the large NASA cells -- e.g., extended cloudy or extended clear spans -- and that localized effects -- e.g., orographic, microclimatic, coastal effects -- superimposed on weather-driven variations are predictable and stable over time.

2. METHODOLOGY

We produced high-resolution satellite derived irradiances (Perez et al, 2002, 2004) for 17 one-degree cells -- each including 100 high resolution pixels – distributed throughout the USA (see Fig. 1) and spanning seven recent years (1998-2004).

We then looked at the repeatability of the inner cell structure over the 7-year period. The 17 locations were selected to represent distinct US climatic and geographic environments, with some of the cells selected for their expected strong microclimatic signatures (e.g., San Francisco and Los Angeles areas).

3. RESULTS

3.1 Average cell microstructure

The 7-year average global horizontal irradiance (GHI) microstructure of each selected cell is shown in Figure 2. The metric used in these figures is the percent difference between a cell's average and the average value of each high-resolution pixel within that cell. Patterns are clearly discernible. Some patterns are strongly marked, reflecting intense microclimatic variations within the cell. Such is the case for the selected Pacific Coast cells (Pacific clouds/fog vs. inland arid areas) and for cells spanning rain shadow areas – e.g., Cascades, Appalachia. Even cells where no or minimal microclimatic signatures would be expected

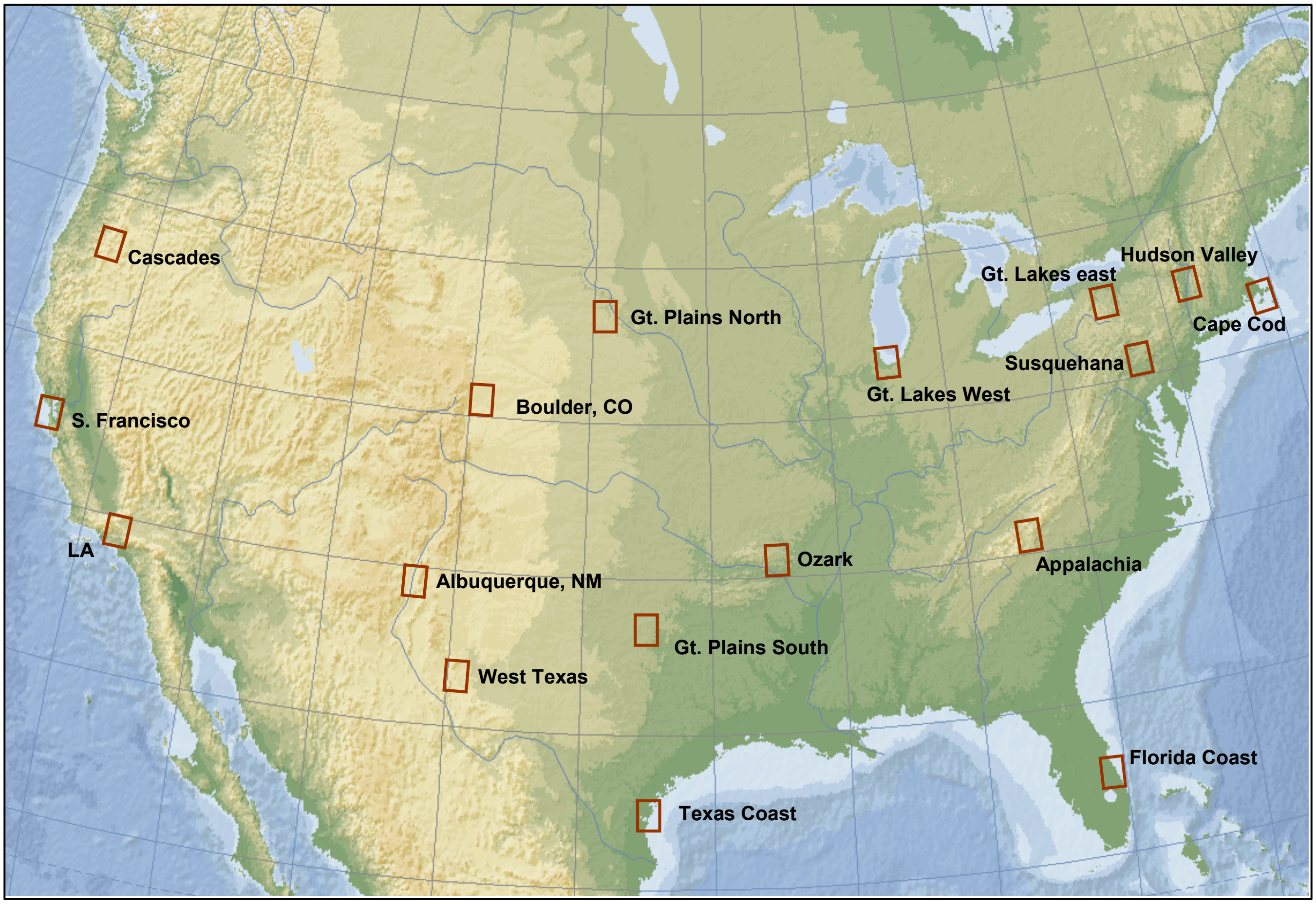

Figure 1: Location of cells selected for microstructure evaluation

(e.g., the Great Plains) exhibit well developed patterns.

3.2 Pattern repeatability

How persistent are the observed patterns? This question is addressed quantitatively by observing the 7-year standard deviation σK_i of the ratio, K_i, between any single pixel ($pixel_i$) and the cell's average. The mean of all 100 individual σK_i within the cell, referred as ***microstructure variability index***, is normalized to the cell's average and compared to the 7-year average cell's min-max range. Results are reported in Figure 3 for GHI and direct normal irradiance (DNI).

In every single case, the year-to-year sub-cell structure variability is found to be only a small fraction (10% or less) than the cell's min-max range.

A qualitative look at actual year-to-year microstructure repeatability is shown in Figure 4 for the Los Angeles cell.

Relative microstructure variability indices [ratio of mean σK_i divided by average cell's min-max range] are shown in Figure 5.

Also reported in this figure are the indices for individual months. Monthly indices are larger than yearly indices, but are still remarkably low, indicating that even at the level of one month, the microstructure of a one-degree cell is very stable.

Such stability at the monthly level opens the door for possible time series generation on a high resolution mesh starting from the NASA low-resolution time series using the Time Series Generator previously developed by the authors

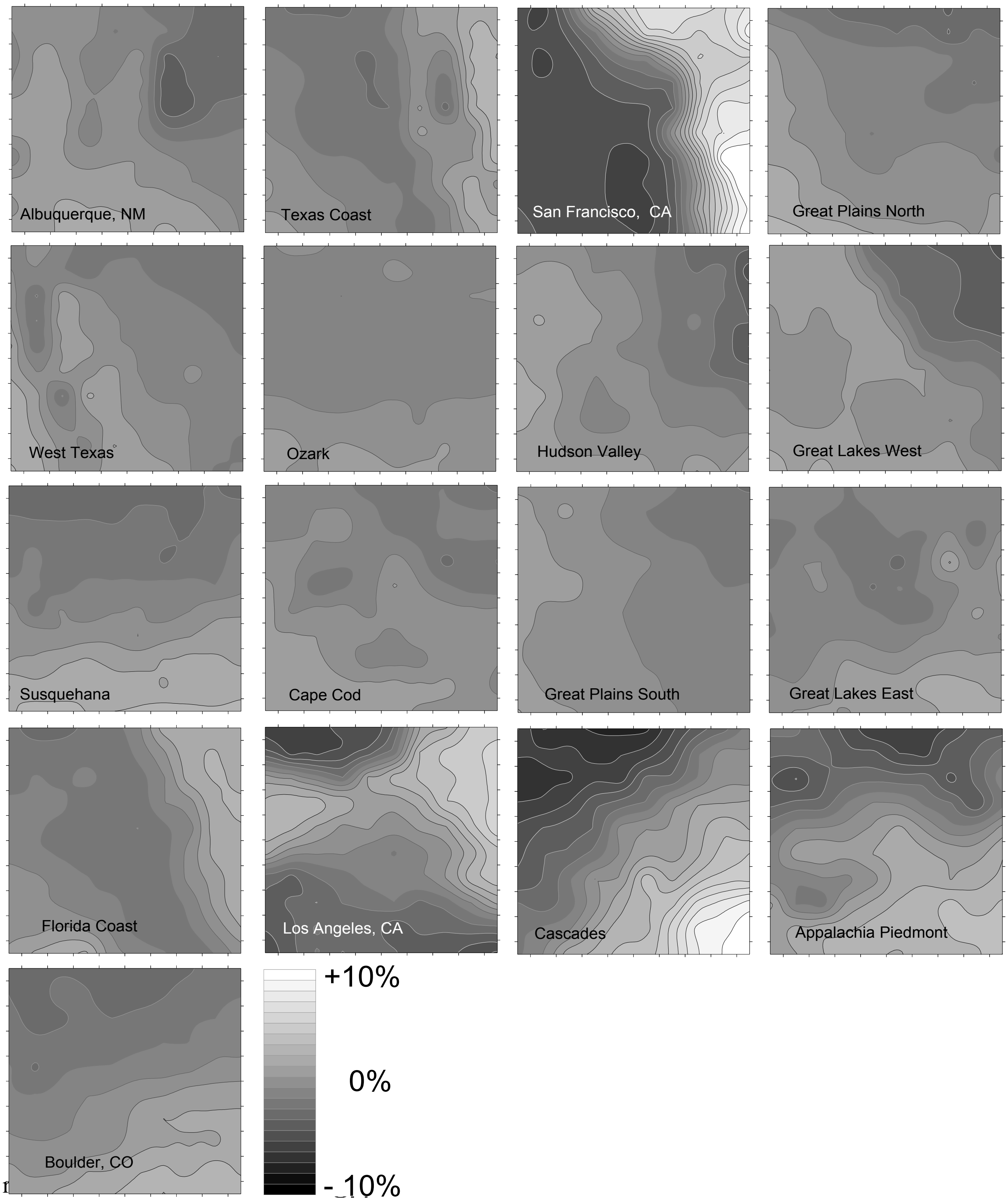

Figure 2: Average cell microstructure (% departure from cell average)

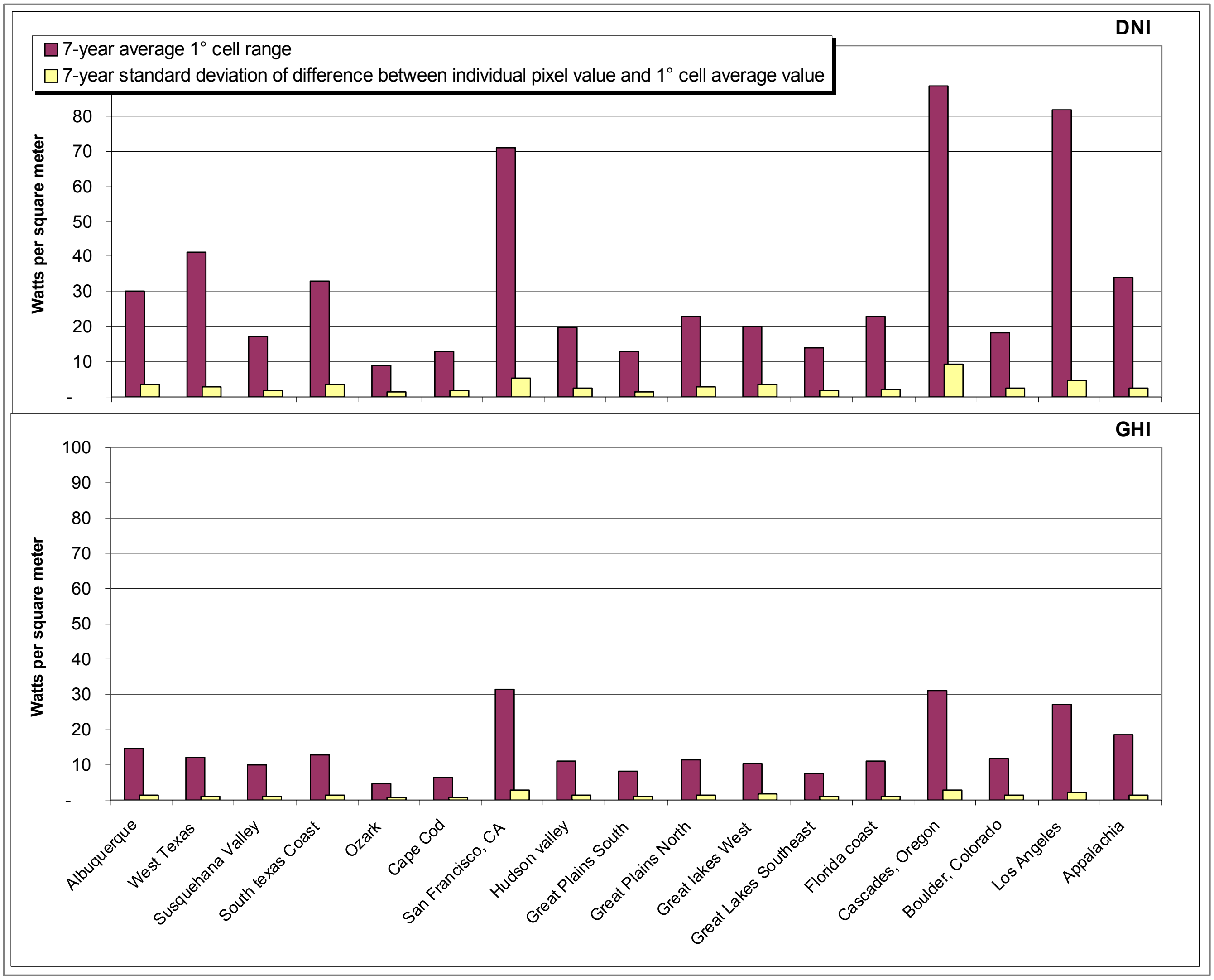

Figure 3: Comparing mean cell range and average pixel 7-year standard deviation

(Perez et al., 2000). This generator uses a known time series – e.g., a low-resolution NASA time series -- and a monthly average clearness index differential – e.g., the difference between a given pixel's and the cell's average -- as inputs to generate a new time series with a higher/lower monthly clearness index, while conserving time-specific features, such as cloudy and clear occurrences.

4. DISCUSSION

Well-defined and stable microclimatic patterns are found to exist within small microclimatic regions of the size of a NASA cell. This observation is valid for all cases analyzed which were selected for their climatic and geographic diversity/uniqueness. The microstructures are sometimes very pronounced, with inner 1-degree cell ranges exceeding ± 10% of mean cell value, but even in regions of low variability, such as the Great Plains, the microstructures remain well defined.

The microstructures are found to be stable over time with a variability index [year-to-year "noise"-to- cell min-max range ratio] of the order of 7-12% on a yearly basis and 15-21% on an individual month basis. The consistency of this observation throughout the US is remarkable.

It should therefore be possible to considerably enhance the NASA-SSE data set by "transplanting" recent high resolution patterns onto earlier years, and thus create high resolution maps for the 1990s. As needed, high resolution time series could also be extrapolated from the low

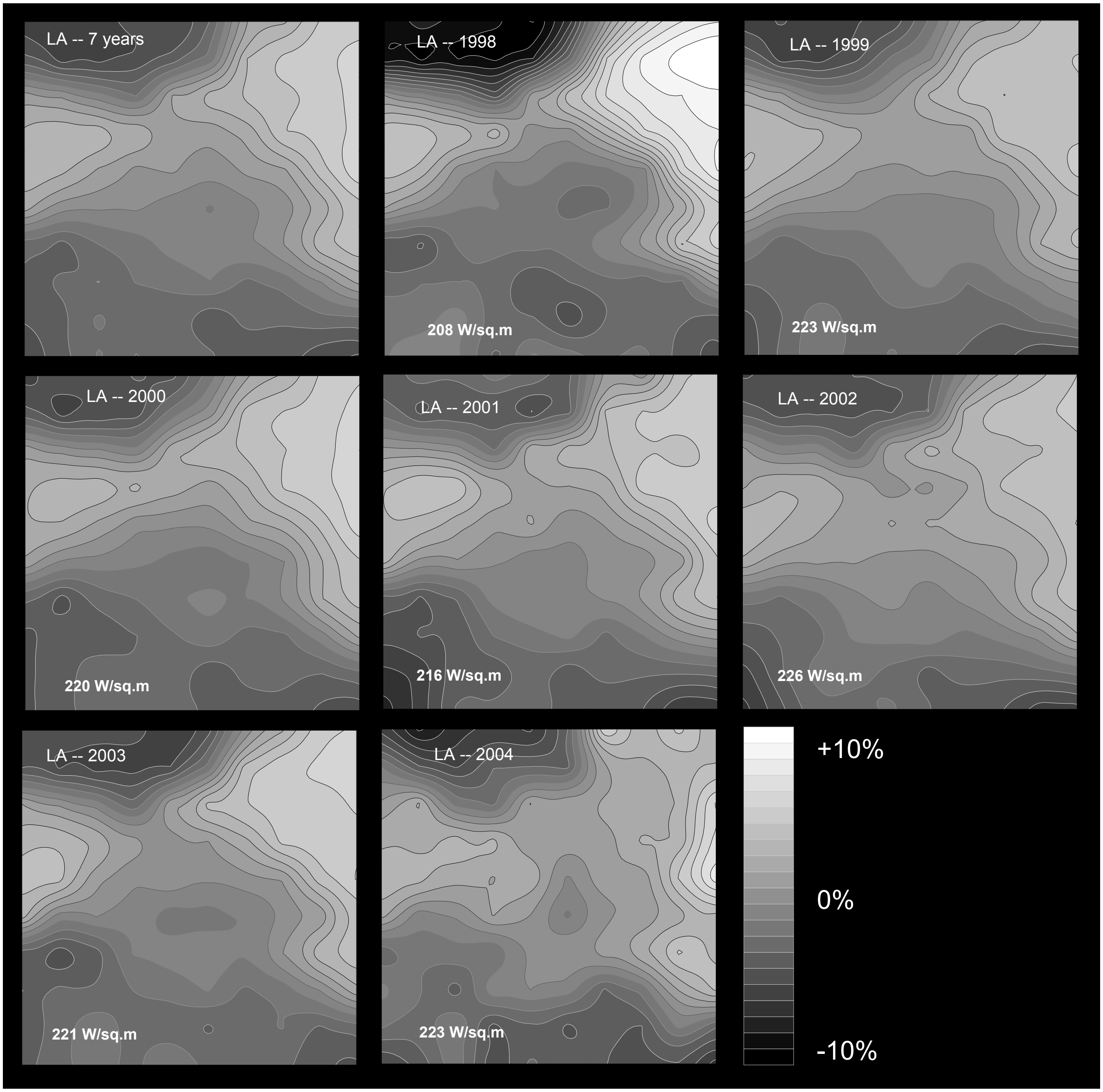

Figure 4: Los Angeles cell microstructure for individual years

resolution data by using the algorithm previously developed by the authors to extrapolate a known time series to a neighboring site with different monthly averaged clearness index.

5. CONCLUSION

These results show the potential for enhancing the NASA-SSE data set by developing fine-gridded patterns from available high resolution data and "transplanting" them onto lower resolution grids from earlier years. Using the overlaid grids, high resolution solar resource maps of the U.S. could be produced at minimal cost using the Time Series Generator.

6. ACKNOWLEDGEMENTS

This project was the byproduct of research funded by NREL (Subcontract # AE144444101) and NASA via SAIC contract # 4400113425

7. REFERENCE

(1) Perez, R. (2000): A Time Series Generator. Technical Status Report No.3, NREL subcontract AXE-0-30070-01, NREL Golden, CO.

(2) Perez, R., P. Ineichen, K. Moore, M. Kmiecik, C. Chain, R. George and F. Vignola (2002): A New Operational Satellite-to-Irradiance Model. Solar Energy 73, 5, pp. 307-317

(3) Perez R., P. Ineichen, M. Kmiecik, K. Moore, R. George and D. Renné, (2004): Producing satellite-derived irradiances in complex arid terrain. Solar Energy 77, 4, 363-370

(4) Stackhouse, P.W., Jr., C. H. Whitlock, W. S. Chandler, J. M. Hoell and T. Zhang, (2004): Solar Renewable Energy Data Sets from NASA Satellites and Research. Proc. ASES National Conference, Portland, OR.

(5) Wilcox, S., R. Perez, R. George, W. Marion, D. Meyers, D. Renné, A. DeGaetano, and C. Gueymard, (2005): Progress on an Updated National Solar Radiation Data Base for the United States. Proc. ISES World Congress, Orlando, FL

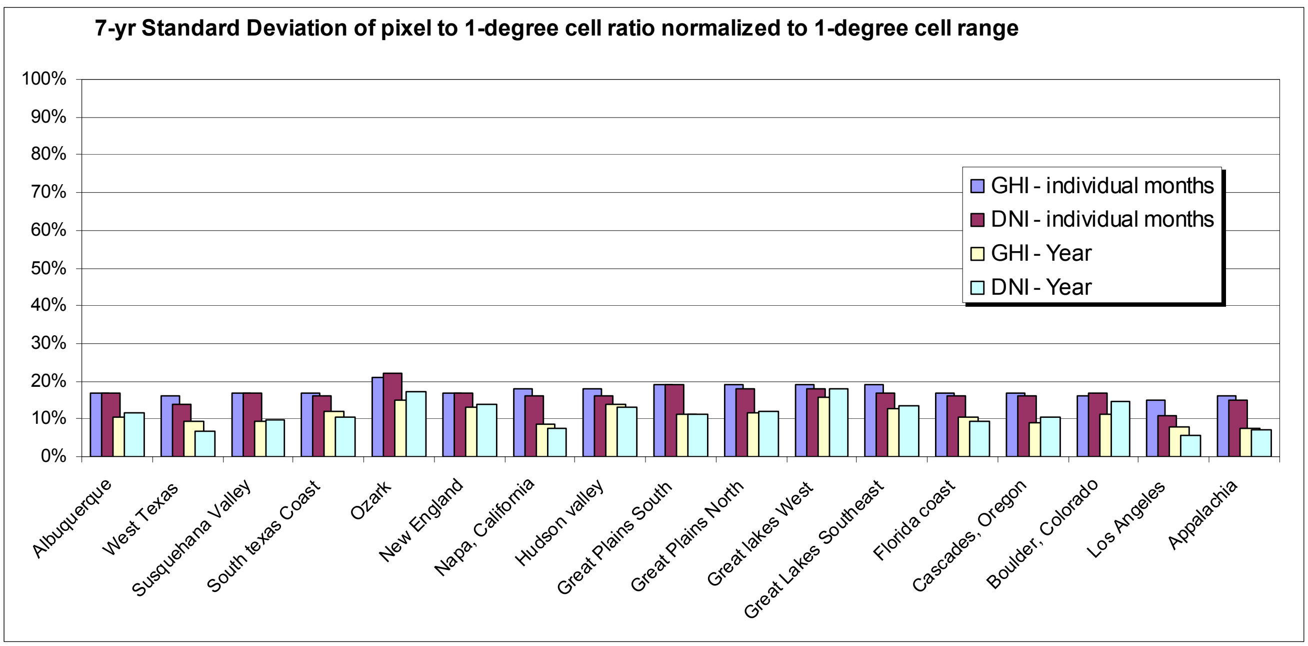

Figure 5: Relative yearly and monthly microstructure repeatability indices.