DECADAL DIFFERENCES IN SATELLITE DERIVED SOLAR AND METEOROLOGICAL PARAMETERS

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ABSTRACT

NASA's Prediction of Worldwide Energy Resource (POWER - http://power.larc.nasa.gov) project adapts information from satellite observations and modeling into prototype data sets useful for renewable energy resource estimation on a global scale. POWER is supported by the NASA Earth Science Applied Sciences Program.

The Surface meteorology and Solar Energy (SSE) data set and web site (http://eosweb.larc.nasa.gov/sse), now maintained and improved by the POWER project, was developed to assist the renewable energy industry by providing global data for locations where ground site data was not readily available. The wide range of solar radiation and climate estimates available via SSE include monthly average/minimum/maximum temperature, daily temperature range, heating/cooling degree days, parameters for sizing energy-storage systems, diurnal cloud information, and solar radiation on tilted solar panels. Well over 200 parameters are available, presented in both spatial and temporal formats. Additionally, new web applications have been developed to support the use of solar and meteorological data in the fields of Agroclimatology and Sustainable Buildings. This paper describes the availability of the improved higher resolution assimilated data covering a time period of more than two decades. Then, the paper explores potential uses of the new data by examining decadal differences apparent within the expanded time period.

1. INTRODUCTION

Long term changes in the solar radiation at the Earth's surface (Srad) can affect climate and can have significant impacts on the human and terrestrial environment. Studies within the past several decades have detected a dimming of Srad through the early 1990's [1,2] followed by a gradual brightening [3,4]. These studies have relied for the most part on ground-based observations, which while globally distributed, tend to have limited geographical coverage. Here, we examine changes in Srad over the last two decades using a globally distributed data set derived from satellite observations and atmospheric assimilation modeling. We focus on the Srad changes that have occurred over the continental United States (CONUS), primarily to demonstrate how the satellite observations can provide a more comprehensive view than those offered by ground-based observations. The Srad data used in this study is available through the POWER project, which has extended the SSE data set. These results suggest that the dimming or brightening of Srad within CONUS from 1986 through 2005 were due to regional changes in observed cloud cover and that these cloud cover changes are consistent with independent modeling and surface measurements of temperature.

Previously, the input data sets available to POWER were on a spatial grid of 2.0° x 2.5° of latitude and longitude. POWER has taken advantage of higher spatial resolution data made available from the NASA Goddard Earth Observing System Version 4 reanalysis model (GEOS-4) [5] and the NASA Global Energy and Water Cycle Experiment (GEWEX) Surface Radiation Budget (SRB) project [6]. The GEOS-4 data sets assimilates various in situ and satellite measurements to produce meteorological parameters at the horizontal resolution of 1.0° x 1.25°. The POWER project employed a bilinear interpolation scheme to provide these data products on a uniform grid of 1° x 1°. The GEWEX SRB uses the GEOS-4 temperature and humidity parameters along with satellite cloud information to produce the solar radiation values. All of the parameters

are made available through the POWER web site at the 1° x 1° spatial resolution.

In addition, the temporal span of the SSE data set has been extended from a 10-year period to more than 23 years. The earliest available solar radiation data is for July 1983 and climatological monthly averages have been calculated for the 23-year period beginning in July 1983 and ending in June 2006. The data set is being extended to more recent years as the data becomes available. Year-by-year daily, monthly and annual averages of many parameters are now available, providing details of interannual variability. In addition to the Srad data, air temperatures from GEOS-4, are also available from January 1, 1983 through December 31, 2007. The POWER web portal offers the SSE data in user friendly formats ranging from daily, monthly, and annual averages for any globally distributed 1-degree region.

2. DECADAL DIFFERENCES

As noted above, this paper will present a few examples of how the data in the POWER/SSE web site can provide information on regional to global changes in environmental parameters. These results, while preliminary, clearly suggest that satellite and modeling estimates of surface meteorology, clouds and solar radiation provide estimates of changes between the two decades studied here that depend upon the geographical region. The perspective provided by satellite observations over the past two decades may be of particular significance for renewable energy and buildings-related weather parameters. The POWER/SSE web site applications open up numerous avenues for analyzing solar radiation and temperature related data both globally and regionally.

POWER/SSE has a new web application that provides data tables of interannual variability for every one-degree region over the globe. Using this application, any time period from 1983 through 2005 may be chosen. Multi-year averages are calculated for the selected time period, whether the selection is a few years or all 23 available years. Minimum and maximum values are calculated from the difference between the multi-year average and the lowest [highest] value for any single year in the series. Solar radiation minimum and maximum values are provided as percent difference.

Using this new feature and the extended time history of the data in the SSE archive, one can quickly ascertain how the solar radiation and temperature for any location in the world might be changing. For example, figures 1 and 2 show the difference of temperature and cooling degree days over the entire globe for the month of July from one decade to the next.

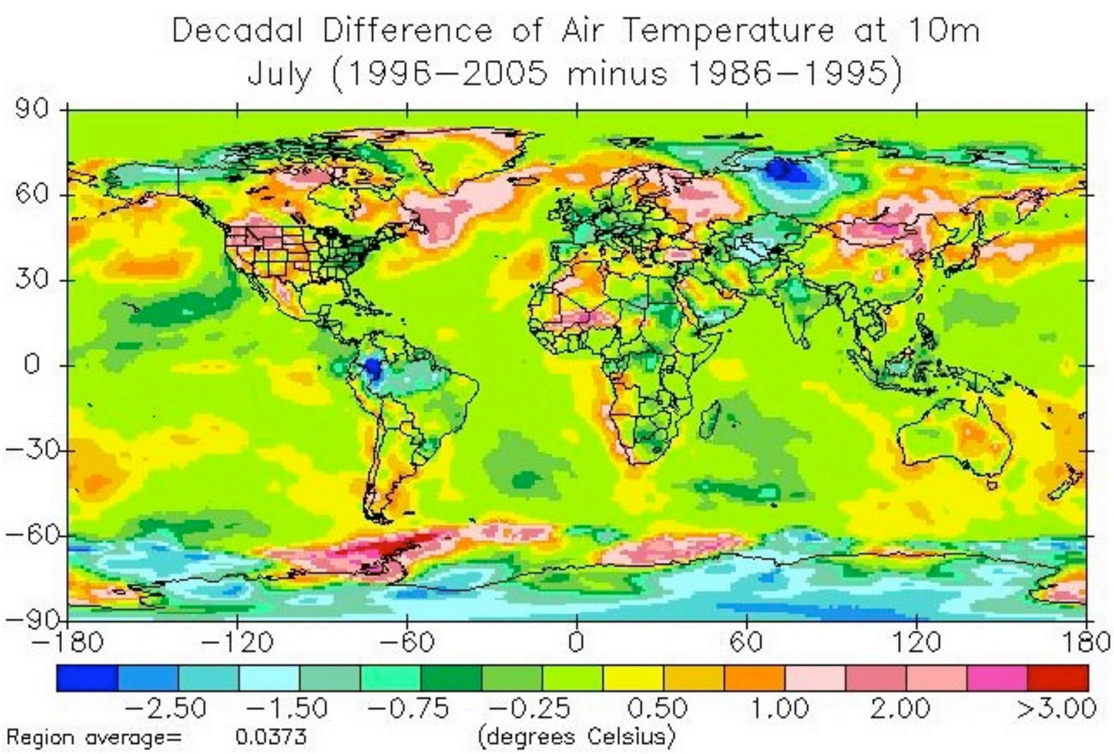

Fig 1. The decadal change in air temperature

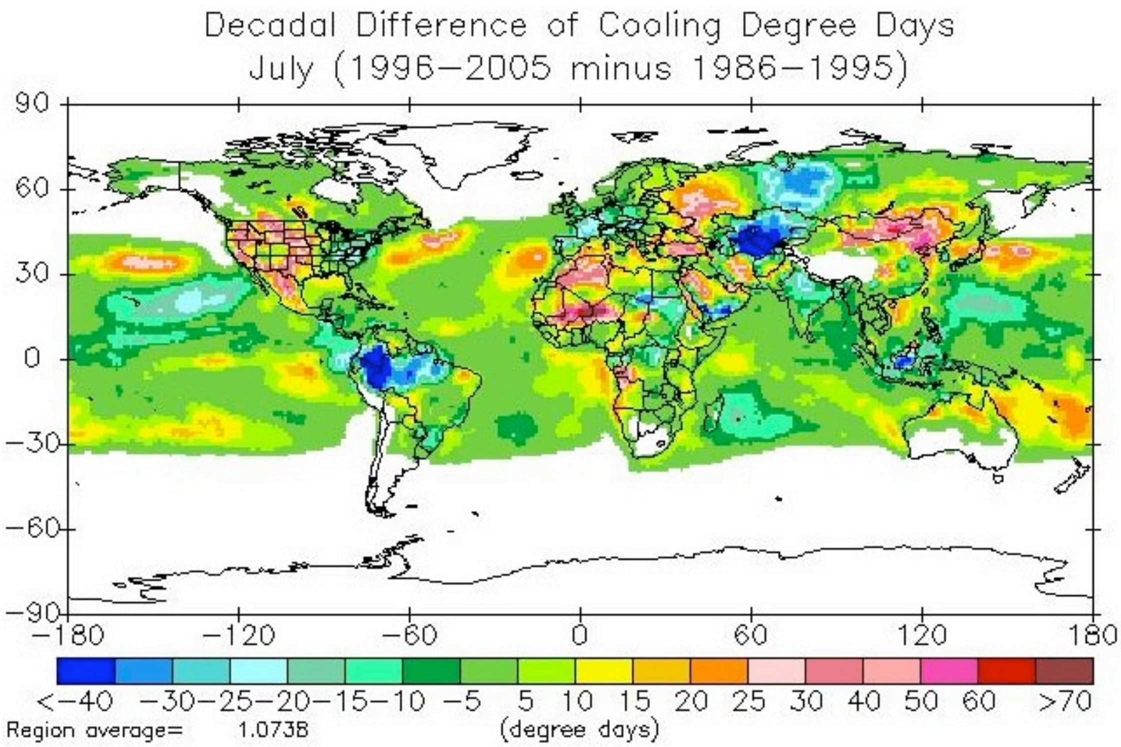

Fig 2. The decadal change in cooling degree days (the white areas indicate regions where there are zero cooling degree days during both decades)

A more detailed analysis for a given geographical region including additional monthly and/or seasonal averages can easily be performed using additional tools and features provided in the POWER/SSE web site. The example illustrated here (figure 3) shows the decadal differences of solar radiation over the CONUS based upon the SSE data for July.

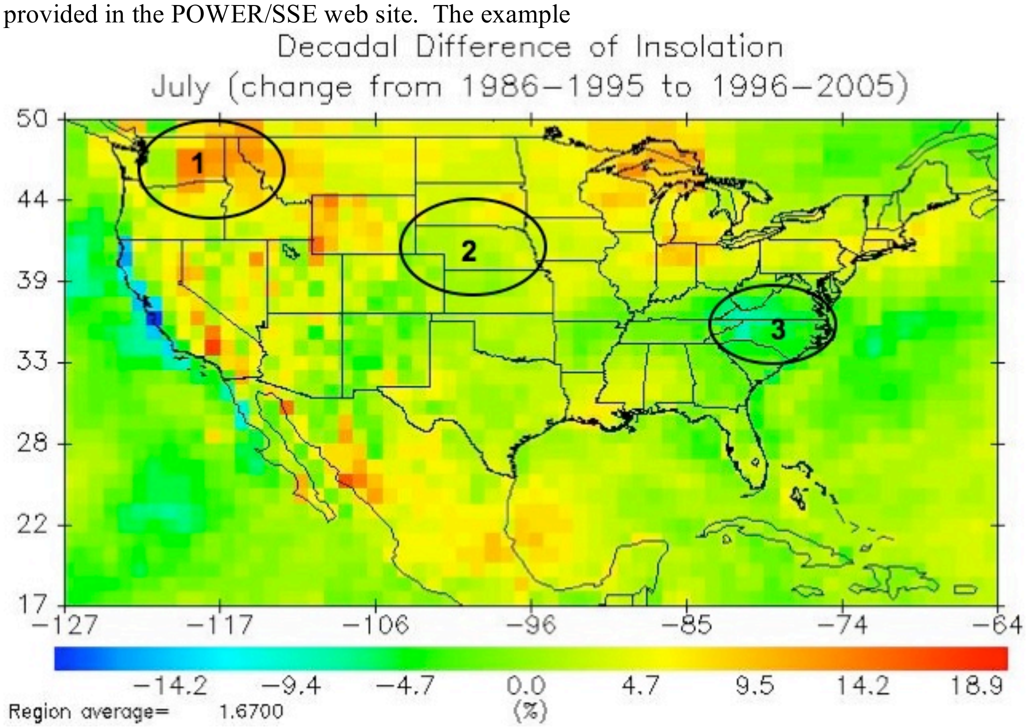

Fig 3. Decadal difference of solar radiation in the CONUS

This Srad decadal difference map illustrates the extent to which changes in Srad are dependent on geographical regions. Note that within the three regions identified, the Pacific Northwest, Great Plains and East Coast, the Srad is changing in three different ways. In particular, the regions chosen represent positive (Region 1), neutral (Region 2) and negative changes (Region 3) in Srad. For comparison with ground-based observations, figures 4 through 6 show the change in Srad over the same time period for January, July, and October monthly averages derived from ground-based observations of Srad.

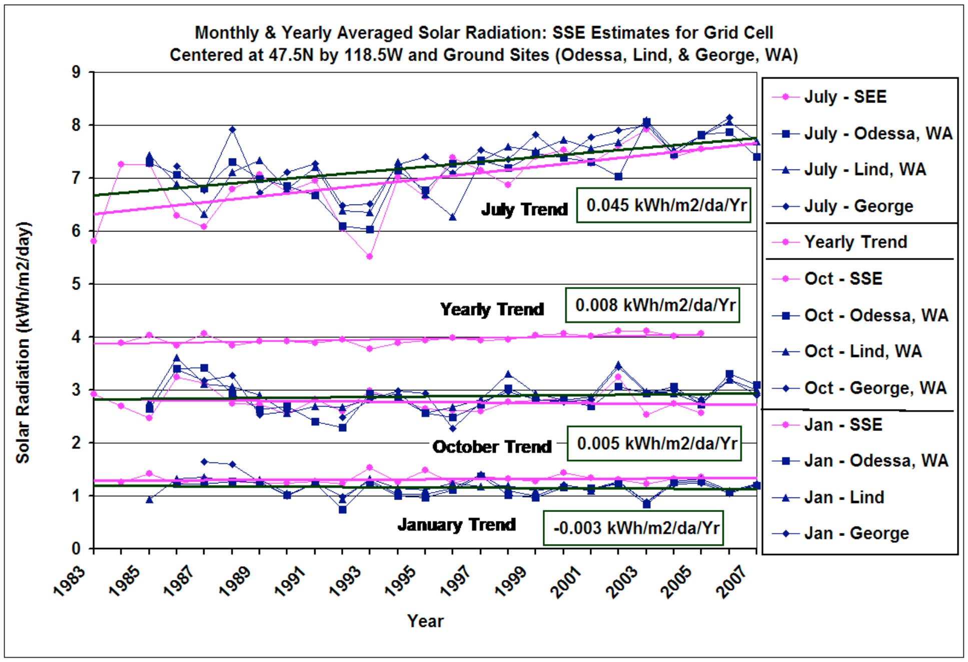

Fig 4. Solar radiation trends in region 1 (identified in figure 3)

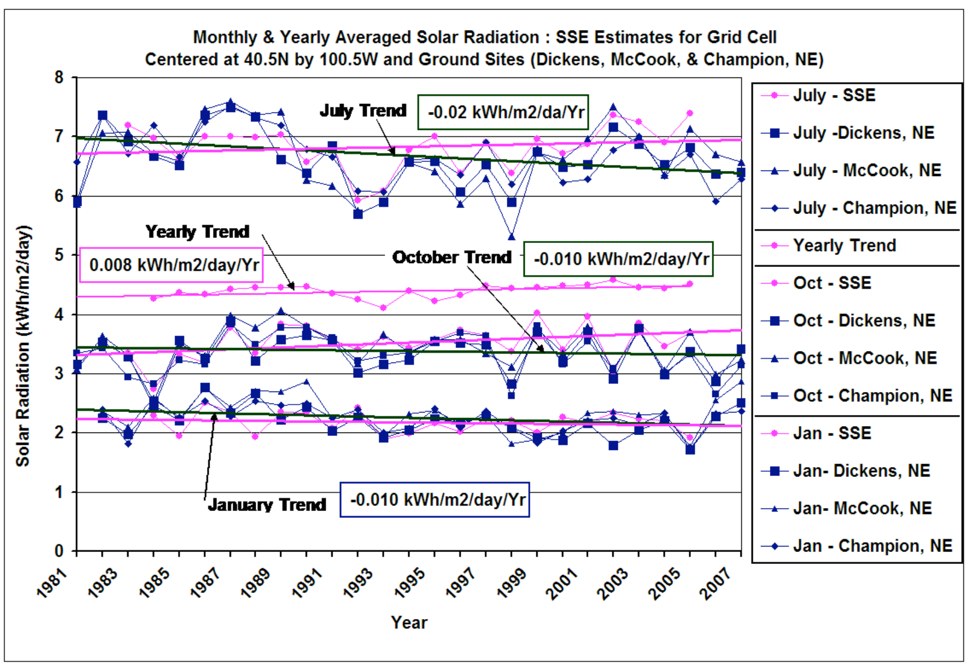

Fig 5. Solar radiation trends in region 2 (identified in figure 3)

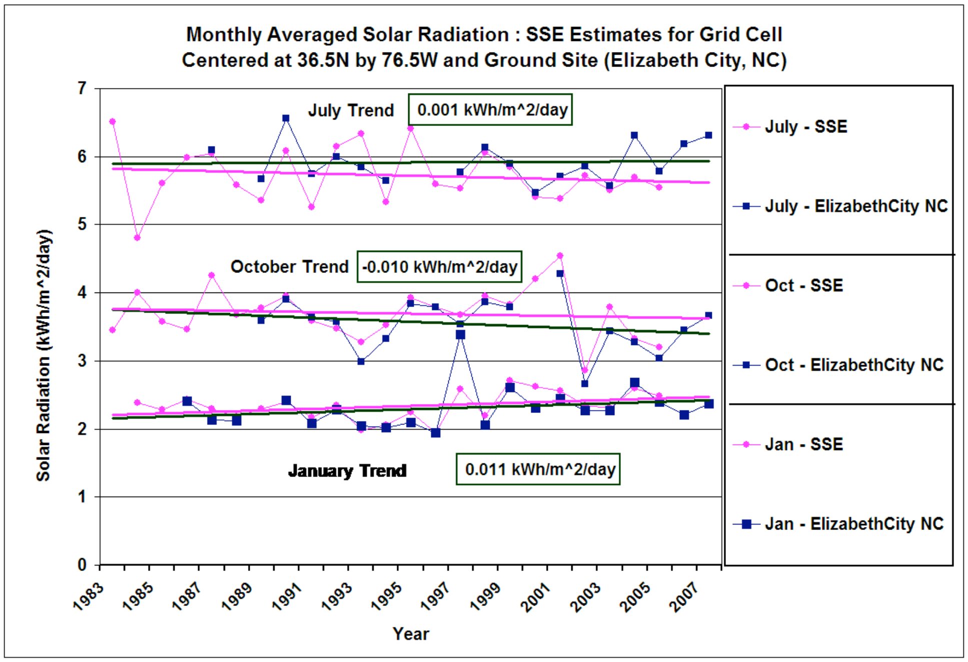

Fig 6. Solar radiation trends in region 3 (identified in figure 3)

The ground-based observations in Region 1 are from three sites in the Pacific Northwest Cooperative Agricultural Weather Network (http://www.usbr.gov/pn/agrimet/); in Region 2, three sites in the High Plains Regional climate Center (http://www.hprcc.unl.edu/index.php); and in Region 3, a single site from the Measurement and Instrumentation Data Center (http://www.nrel.gov/midc/ecsu/). In general the ground site data for July within these three regions tends to agree with the decadal difference map for July shown in figure 3. In each plot the trend line for SSE data is shown in pink and the trend line for the average of the ground sites is shown in green. The ground-based changes for January and October have been included to indicate that regional trends show a seasonal signature.

Figure 7 is presented to further illustrate the range of parameters available through the POWER/SSE web site and to explore how the decadal change in other parameters are reflected in the changes evident in Srad. Figure 7 shows the decadal difference map of air temperature in July over the CONUS. These surface temperatures are independent from the cloud and solar radiation data sets. We have highlighted the same three regions as in figure 3, and we note corresponding changes in the monthly averaged July temperature. In particular, in Region 1, there is a 2 to 3 degree increase in air temperature corresponding to the increase in Srad; Region 2 exhibits little change in air temperature corresponding to the neutral change in Srad; and Region 3, exhibits a slight decrease in air temperature of about 1 °C.

Again, for comparison with ground-based observations, figures 8 through 10 show the two decade change in the January, July, and October monthly average air temperature derived from ground-based observations. With the exception of the temperature data for Region 3, the ground-based observations are from the same networks as the Srad ground-based observations. For Region 3, the temperature data is from two stations that were available via the National Climate Data Center. We note here again the change in the July data tends to agree with the results of the decadal temperature difference map shown in figure 7, and the January and October trends are included to indicate that geographical regions can have a seasonal signature with respect to decadal changes.

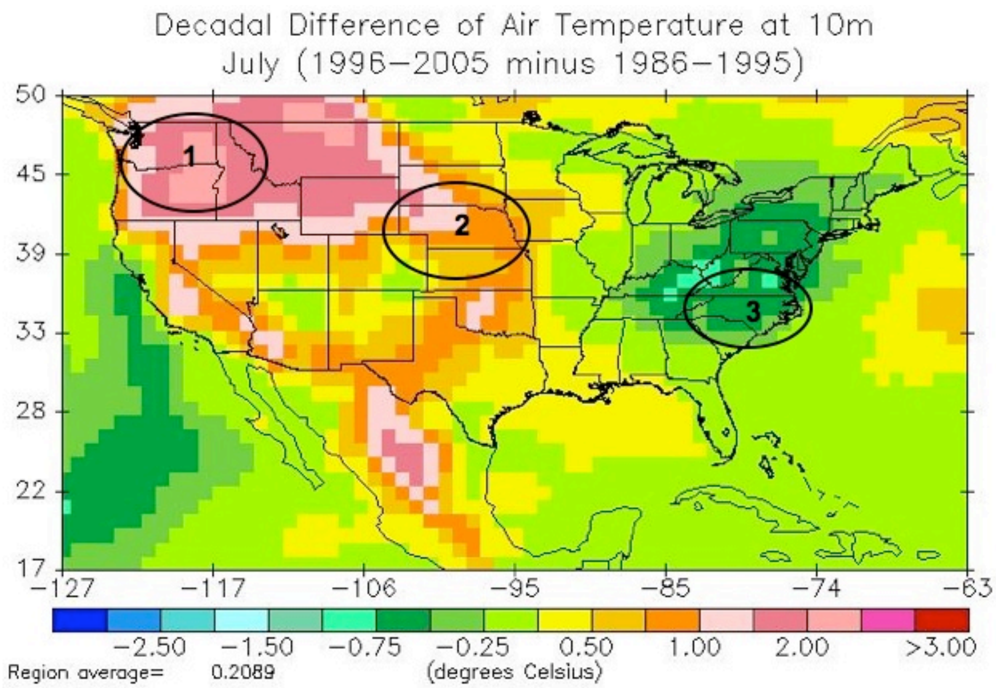

Fig 7. Decadal difference of air temperature in the CONUS

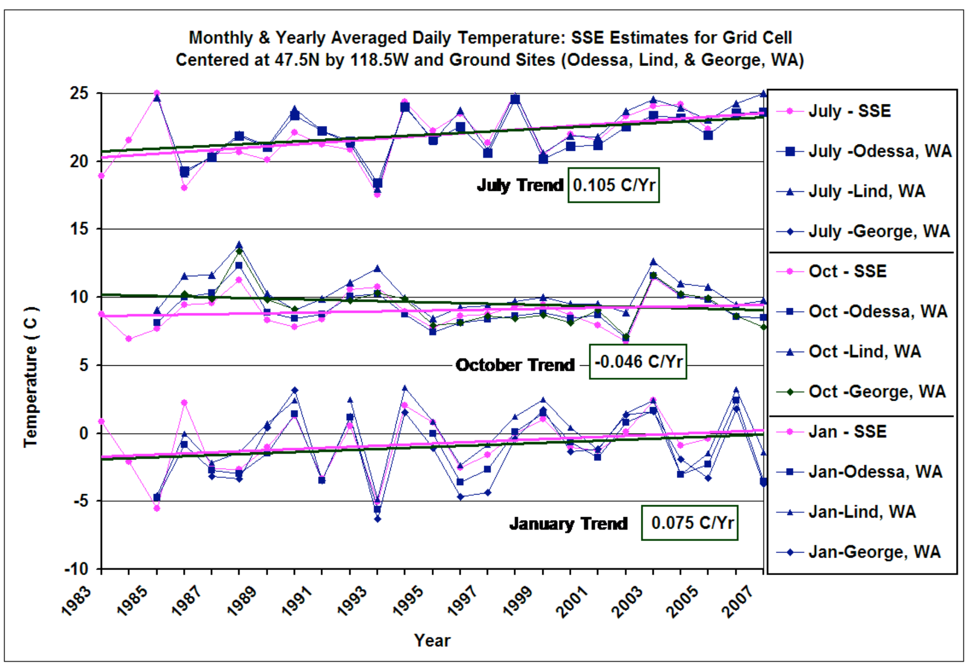

Fig 8. Air temperature trends in region 1 (identified in figure 7)

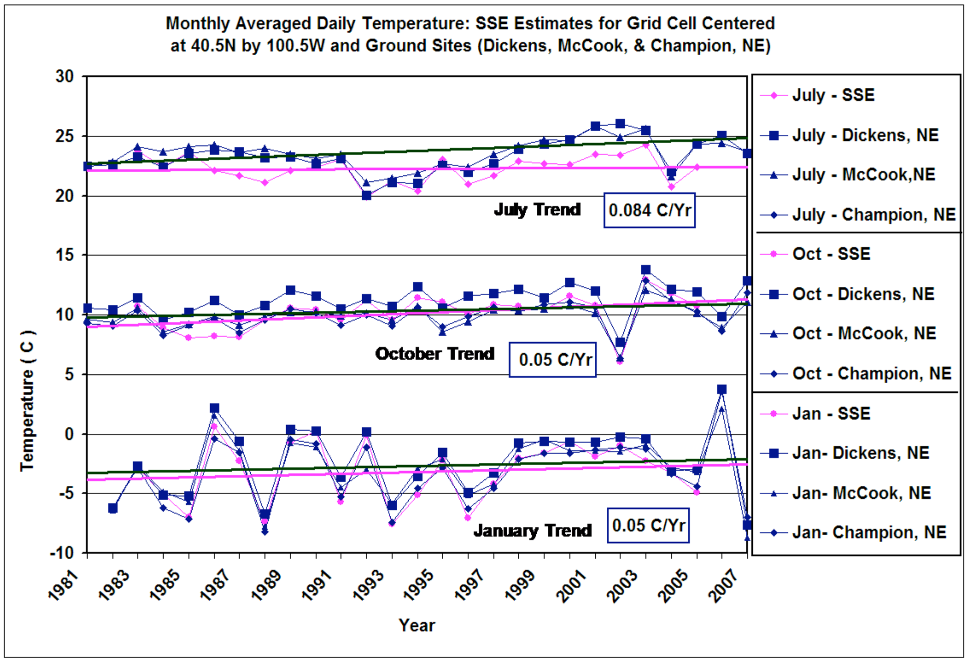

Fig 9. Air temperature trends in region 2 (identified in figure 7)

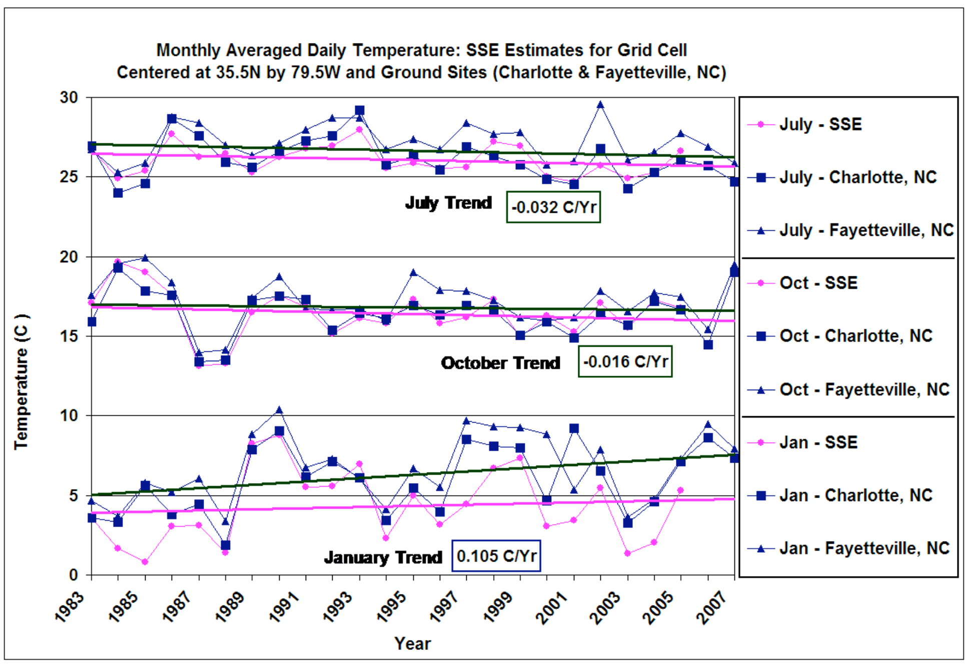

Fig 10. Air temperature trends in region 3 (identified in figure 7)

As a final example of the data products available through the POWER/SSE web portal and to provide an explanation for the decadal changes just noted, the decadal differences in cloud amounts over the CONUS for July is shown in figure 11. The cloud data is derived from the NASA International Satellite Cloud Climatology Project (http://eosweb.larc.nasa.gov/PRODOCS/isccp/table_isccp.html) [7]. As seen in figure 11, the cloud cover in Region 1 for July decreases by 10 to 15%, in Region 2 there is little change and in Region 3 there is 1 to 5% increase in cloud amount. Since cloud amount is a primary factor, along with other factors such as aerosols, in determining the amount of solar radiation reaching the Earth's surface, it is not surprising that the Srad decadal difference map reflects these changes corresponding respectively to an increase, neutral and positive changes in Srad for the three regions.

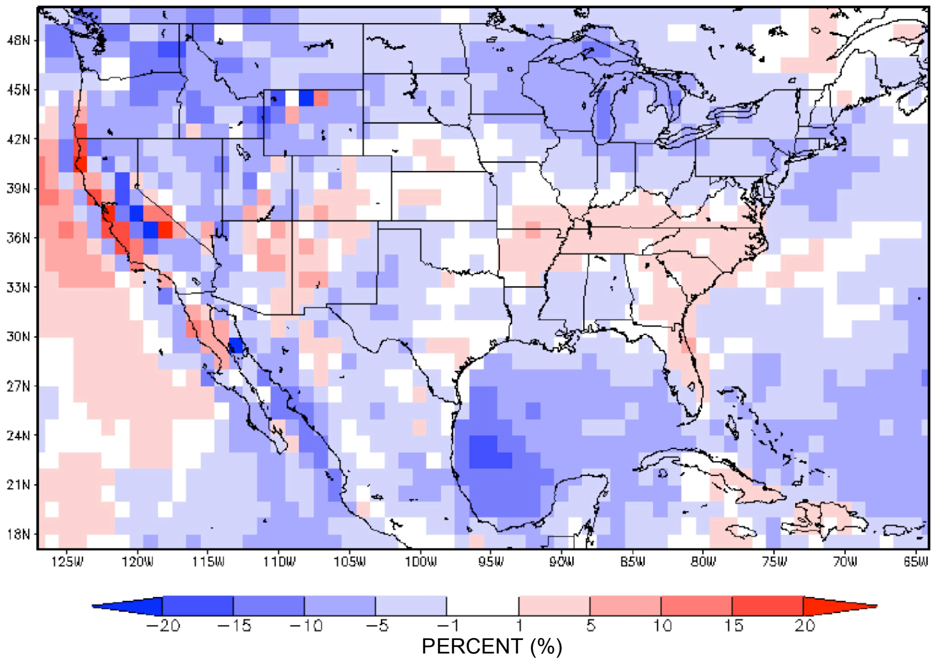

Fig 11. Decadal difference of cloud amount in the CONUS

3. SUMMARY

The study described in this paper is preliminary and serves as much to provide examples of data available in the POWER/SSE archive as an analysis of decadal changes. However, our results clearly suggest that satellite and modeled data can provide a more comprehensive picture of how changes in the environmental parameters are occurring than can be determined from ground-based observations. In particular the examples we present demonstrate that these changes can have a significant regional signature that is easier to assess than through the analysis of surface measurements alone. Yet, the consistency between those surface measurements and the satellite and model assimilation data sets give confidence in the ability of the these data sets to properly characterize regional changes.

In summary, we emphasize the POWER/SSE web site provides data to facilitate the study of changes in environmental parameters for any region of the globe. For example, the implications in heating/cooling needs and solar resource availability through time can be explored and monitored as data sets are updated into the future.

4. REFERENCES

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