Modeling Solar Irradiance and Wind Speeds to Create an Accurate Historical Resource Assessment for Renewable Energy

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Abstract: The increasing utilization of the wind and solar resource as an energy provider has created a need for accurate prediction of the potential at each possible generation site. In the present poster, we discuss a novel method to derive accurate solar irradiance estimations from numerical weather model variables, satellite data, and ground based observations sites. From the irradiance estimation a power prediction can be made for solar renewable energies and here we focus on solar photovoltaic (PV). We show the results of a three-year data set for the period of 2006-2008. In addition to solar irradiance, wind speed and power estimations should be improved and we demonstrate a more sophisticated method to obtain a conversion from wind speed to power and illustrate the difference from the usual practice. These results are more accurate than their predecessors. The main results from the poster are; wind speed, solar irradiance, wind power, and solar PV power estimation datasets for the years 2006-2008 for the US at 13-km resolution and the globe at 30-km resolution and images from this dataset will be shown.

Solar Irradiance Modeling

- Aim: create a high resolution dataset of global horizontal irradiance (GHI), direct normal irradiance (DNI), and diffuse horizontal irradiance (GHI).

- Data: 13-km rapid update cycle (RUC) assimilation model; geostationary operational environmental satellite (GOES) images; and surface radiation budget (SURFRAD and ISIS) observations at 10 sites for the three years of 2006 – 2008.

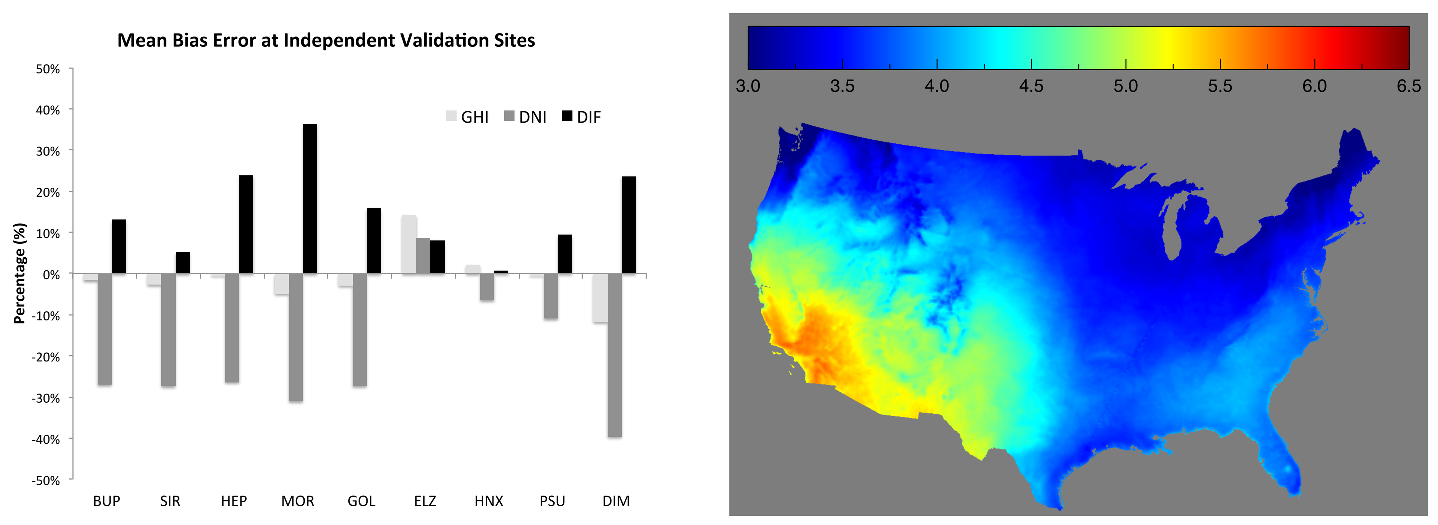

Figure 1: Left panel is the mean bias error for 9 independent sites for GHI, DNI, and DHI. Positive bias indicates the model *over* predicts the irradiance. Right panel is the three year average DNI over the contiguous USA, with units of kWh/m^2/day.

- Method: perform a linear multiple multivariate regression of the data with the observations to train the estimation algorithm for GHI, DNI, and DHI.

- Validation: the trained algorithm is tested on independent sites and the statistics are computed for mean bias error, root-mean squared error, coefficient of variation, and correlation coefficients.

- Results: the method employed creates an hourly, 13-km dataset for the contiguous USA (40,000 locations and 26,000 time steps) that is more accurate than the current methods available. See Fig. 1 for independent site MBEs and the DNI average for the three year period.

- A similar procedure was performed for a global dataset that used the flow-following finite volume icosahedral model (FIM).

Historical Resource Assessment Analysis

- Aim: produce high resolution solar PV and wind power resource assessment for the contiguous USA and globally. To compare against existing datasets and assist foundational model improvement in appropriate regions for renewable energy deployment.

- Data: the irradiance and wind speeds provided by the investigation in the columns to the left and right.

- Method: design and build algorithms that mimic solar PV cells and wind turbines to convert the solar irradiance and wind speeds to power estimations. The algorithms also use additional weather data such as temperature, humidity, cloud cover, etc.

- Results: highly accurate historical resource assessment for solar PV and wind turbines over the continental USA and the globe. See Fig. 4 for the capacity factors of wind and solar PV over the contiguous USA for 2006 – 2008 and Fig. 5 for the globe.

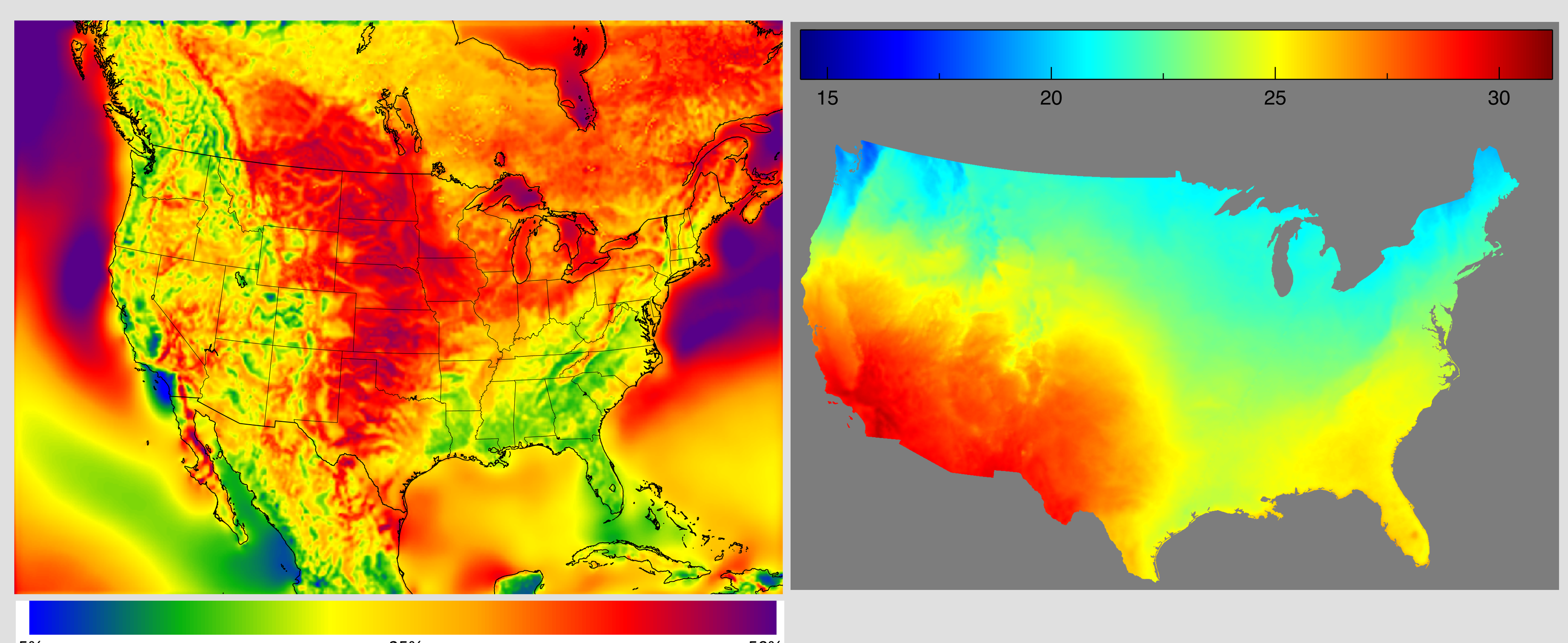

Figure 4: Left is the capacity factor (%) of the wind turbines over the USA. Right is the capacity factor (%) of the solar PV plants over the contiguous USA. The scales for the two panels are different, wind has a maximum of 50%, while solar PV has a maximum of 32%. The USA resource assessment is currently based upon 2006 – 2008 data only.

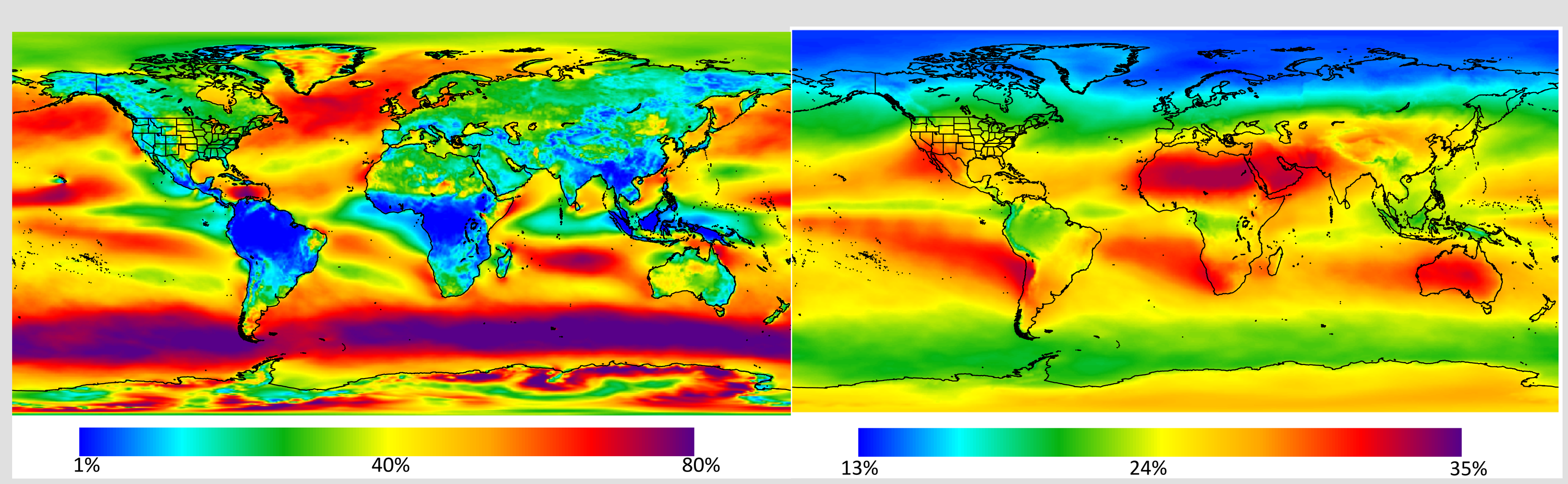

Figure 5: Left is the capacity factor (%) of the wind turbines over the globe. Right is the capacity factor (%) of the solar PV plants over the globe. The scales for the two panels are different, wind has a maximum of 80%, while solar PV has a maximum of 35%. The global resource assessment is currently only based only on 2008 data. There is clear similarities between the USA and global assessment where they intersect.

Hub Height Wind Speed Modeling

- Aim: investigate the difference in wind speed magnitudes when comparing hub-height wind speed (HUB) and rotor equivalent speed (RES).

- Data: 13-km RUC assimilation model for 2006 – 2008.

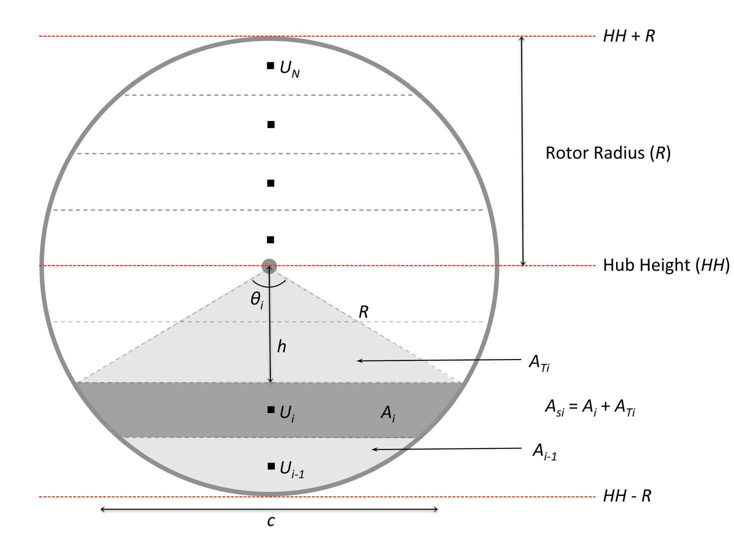

Figure 2: Schematic diagram of how to compute the rotor equivalent speed (RES). The rotor diameter is divided into 8 horizontal strips. The wind speed is calculated at each level. The weighted average of all these wind speeds is taken to give the RES. The weighting is given by the normalized area of each level.

- Method: compute the RES using cross-sections of the rotor area and compare this to the hub-height calculated speed (see Fig. 2).

- Results: the RES shows a decrease in magnitude compared with HUB. The lower RES will result in lower power from wind turbines. The effect is greater over complex terrain (partly due to better model vertical resolution). See Fig. 3 for the average percentage difference between RES and HUB wind speeds for the years 2006 – 2008.

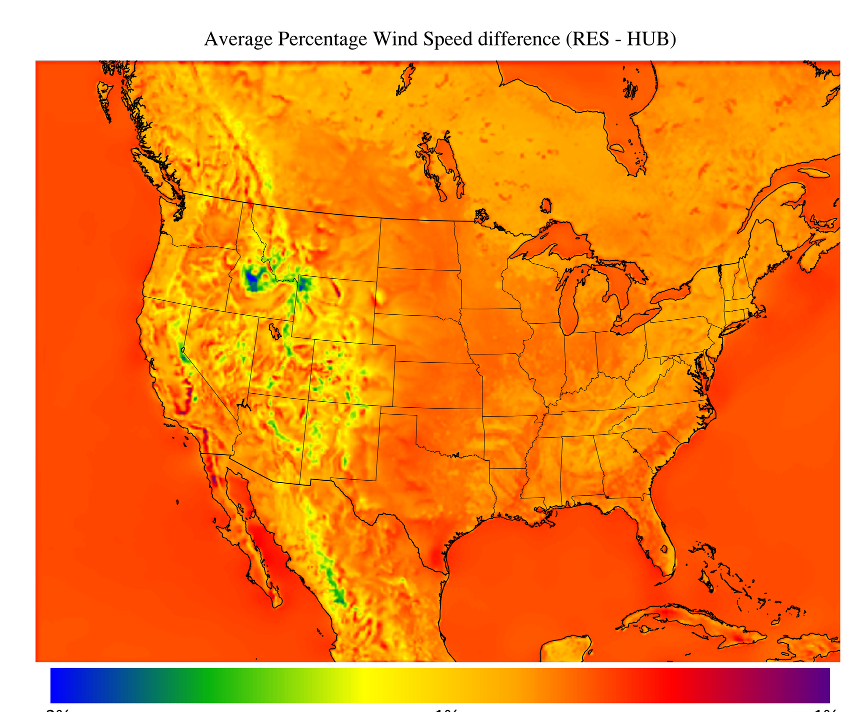

Figure 3: The percentage difference between the rotor equivalent wind speed and the hub height speed (90m AGL). The largest differences are over complex terrain. There is almost no difference only over the ocean.

Interested, and want to know more? Email Dr. Clack at **christopher.clack-1@colorado.edu** and look for the papers by Clack *et al.* in Wind Energy and Solar Energy