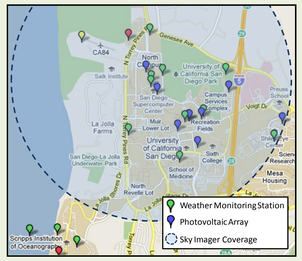
Intra-hour forecasting with a Total Sky Imager at the UC San Diego solar energy testbed

Chi Wai Chow[1], Bryan Urquhart[1], Matthew Lave[1], Jan Kleissl[1], Janet Shields[2]

[1]Department of Mechanical and Aerospace Engineering, [2]Marine Physical Laboratory, Scripps Institution of Oceanography, University of California, San Diego

Abstract

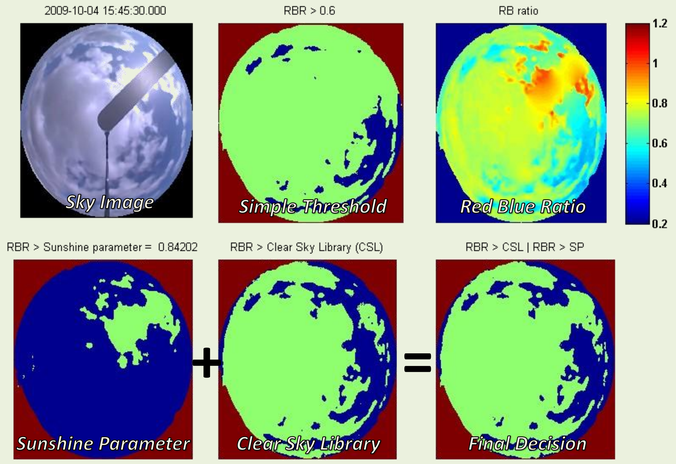
A ground-based total sky imager can provide continuous monitoring of the sky hemisphere above a solar energy system. We present a method to forecast global horizontal irradiance using fractional sky cover and cloud motion vectors. Sky images taken every 30 seconds are processed to determine sky cover. Cloud motion vectors are generated by cross-correlating two consecutive sky images. Future cloud locations are then computed by applying the vector field to the frozen sky scene.



Map of UCSD showing sky imager coverage, weather stations, and PV arrays. The coverage area of the sky imager is a function of cloud base height.

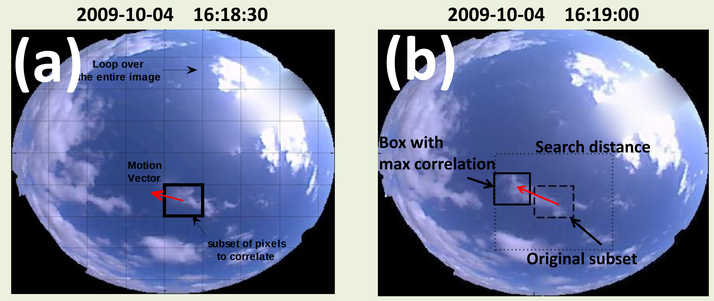
TSI 440A Total Sky Imager

Cloud Decision Image



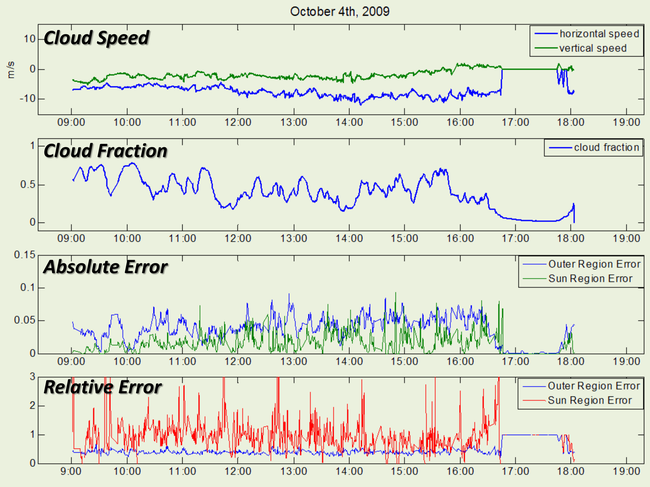
The sky image is processed to obtain the ratio of the red and blue channels. Thresholds are then applied to the red blue ratio (RBR) image to determine sky cover.

Cloud Motion



Using 2 images taken 30 sec apart, a region of pixels from (a) is correlated to (b) within a search distance. The location of the highest correlation is found and a motion vector is defined.

Cloud Forecast Error for 30 seconds ahead



Cloud speed, cloud fraction and error for 30 seconds ahead cloud forecast. Absolute error is defined as the ratio of number of mismatched pixels to number of available pixels. Relative error is the ratio of number of mismatched pixels after advection to number of mismatched pixels before advection.

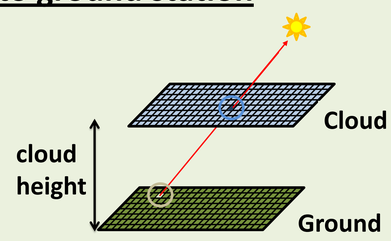
Nowcast compared to ground station

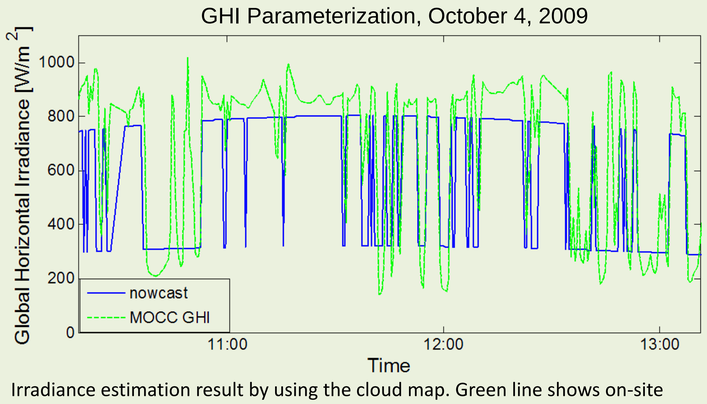
Binary parameterization

$GHI = kt \cdot GHI_{csk}$

without cloud: $kt = 1$

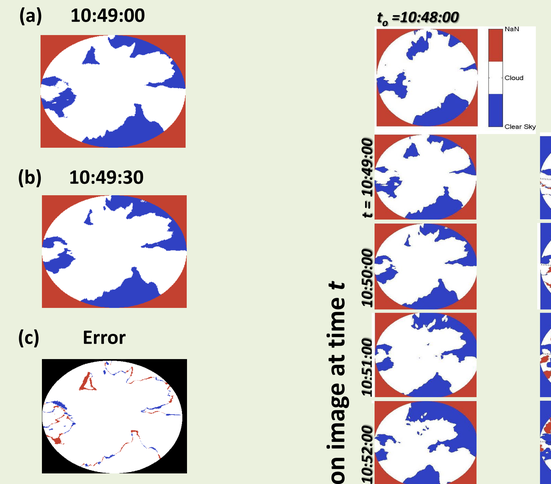
with cloud: $kt = 0.4$





Irradiance estimation result by using the cloud map. Green line shows on-site irradiance measurements. Blue line shows irradiance estimation by our method.

Cloud Forecasting



The forecast cloud cover is produced by advecting the cloud decision image (a) in the direction of the motion vector. To determine accuracy, the future image(b) is compared to the forecast (a) to determine the forecast error . Blue and red colors in (c) shows the forecast errors (blue: forecast cloudy and but actually clear; red: forecast clear but actually cloudy) and white marks accurate forecasts.