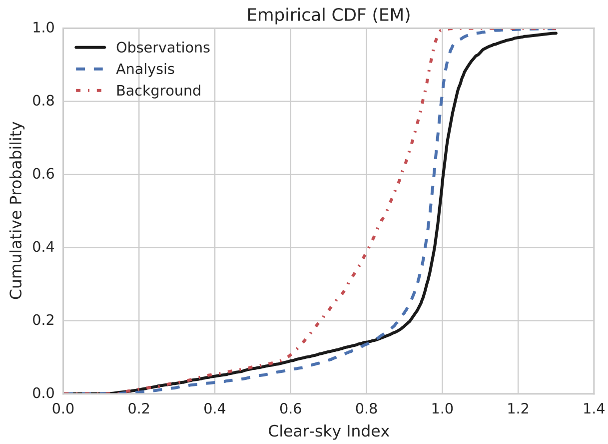

Fig. 5. The empirical cumulative distribution function for the EM model. The black line is the CDF of the observations, the red dashed-dotted line is the CDF of the background, and the blue dashed line is the CDF of the analysis. The background EM model seems to make clouds thicker than they are in reality. The analysis corrects much of this bias and changes the shape of the CDF to more closely match the observations.

obscures a pixel that is to the NE of the cloud, so the actual location of the cloud is to the SW of what the satellite tags the pixel as. Thus, when the OI algorithm tries to compare the observations with the background derived from the satellite image, the observations and background may disagree about whether a cloud is present at all.

This issue is illustrated in Fig. 6 where many sensors are near the edges of the estimated clouds. Some of the sensors locations that are reported as clear in the background are actually cloudy. The OI algorithm tries to rectify this by adjusting the areas that were clear in the background to be cloudy. When we compare this analysis to the background and adjusted visible albedo image, we see the analysis does not look physical. If we shift the satellite image by a small amount to the SW and rerun OI, we see that this shifted analysis looks more like what one would expect given the visible albedo image. This suggests that we first need to correct the parallax issue before performing OI, and that the error statistics calculated over 1200 image times are likely skewed by these errors.

V. Future Work

We plan to improve this work in several aspects. An important task will be to correct the issue of parallax that can cause large errors in the OI analysis. We have experimented with estimating the cloud top height and adjusting for parallax on a pixel by pixel basis, but found this is challenging to do well. In the future, we plan to group classes of clouds together to then determine a height for each cloud group and shift the group appropriately.

This work focused only on the area around Tucson, AZ. One future experiment could examine how OI can improve background estimates using observations that are very far apart and may experience different weather conditions.

VI. Conclusion

There are a number of models to convert satellite images to ground irradiance, and all are prone to errors. These satellite derived irradiance images are important to many phases of PV integration, from siting to forecasting the output of a fleet. We describe how to improve the irradiance estimates using ground data and optimal interpolation.

The optimal interpolation technique uses satellite derived estimates of GHI, ground observations, and the associated error estimates to produce a GHI estimate that has, on average, better error statistics. An important consideration for the method as described is the specification of the error correlation between pixels in the satellite image. We propose using the (almost) raw visible image from the satellite to correlate pixels based on the cloudiness at each pixel. We apply this method to a physically based satellite image to GHI model and show that the distribution of the estimated GHI more closely matches the data. Similarly, the method applied to an empirical satellite image to GHI model removes a large bias from the GHI estimate.

One limitation in the optimal interpolation method is that errors in the estimated locations of the clouds in the satellite GHI estimate can produce analysis images that are unreasonable. Thus, future work will explore correcting this issue of parallax or recognizing when this issue occurs so that optimal interpolation can be avoided for those times. Other future work includes producing a forecast from these improved satellite derived GHI nowcasts.

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