Forecasting Global Horizontal Irradiance Using the LETKF and a Combination of Adveted Satellite Images and Sparse Ground Sensors

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Summary

Motivation: Intra-hour irradiance forecasts are required for integrating PV power into the electrical grid.

Idea: We combine satellite derived irradiance estimates with a cloud motion field in a data assimilation framework to create intra-hour irradiance forecasts.

Results: Combining cloud motion information from numerical weather prediction, optical flow, and satellite images can improve irradiance forecasts by 22% for 45 minute forecasts.

Previous work: satellite images & ground data

Normalized irradiance data are derived from two sources: geostationary satellite images and ground irradiance measurements from sensors and PV systems.

Ensemble forecasting system

- Ensemble includes irradiance and cloud motion fields.
- The Local Ensemble Transform Kalman Filter (LETKF) is used to reduce computational cost with a large state and small ensemble number [2].
- Irradiance fields are perturbed using a smooth random field targeting clouds in order to increase the ensemble variance.
- Data assimilation introduces additional divergence.
- Divergence is removed by solving Poisson’s equation.

Data Availability

Initial Ensemble  
Advection  
Background Ensemble  
Assimilation  
Analysis Ensemble

Error is reduced by 15%, 20%, and 22% for forecast horizons of 15, 30, and 45 minutes for the day shown here (5/29/2014).

References


Forecasting irradiance

- An advection model is used to create forecasts from the satellite derived irradiance field, \( \mathbf{I} \), a two dimensional scalar field.
- This advection model requires a two dimensional vector field known as a cloud motion field, \( \mathbf{C} \).

\[
\frac{\partial \mathbf{I}}{\partial t} = - \nabla \cdot (\mathbf{C} \mathbf{I})
\]

- When forecasting only irradiance over short time scales (intra-hour) it is advantageous to use a simplified model rather than a full numerical weather model due to lower computational cost and ease of data assimilation.
- The forecasts produced by this model are sensitive to errors in the initial irradiance estimate and the cloud motion field.

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