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Quantitative Ceilometer-Radar Studies of Clouds Field Campaign Report

P Kollias

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Acronyms and Abbreviations

BNL	Brookhaven National Laboratory
BP	British Petroleum
DOE	U.S. Department of Energy
FOV	field of view
HD	high-definition
IMB	Infrastructure Management Board
LIPA	Long Island Power Authority
LISF	Long Island Solar Farm
TSI	total sky imager

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1.0 Summary

The Long Island Solar Farm (LISF) is a 32-megawatt solar photovoltaic power plant built through a collaboration including BP Solar, the Long Island Power Authority (LIPA), and the U.S. Department of Energy (DOE). The LISF, located on the Brookhaven National Laboratory site, began delivering power to the LIPA grid in November 2011, and is currently one of the largest solar photovoltaic power plants in the eastern United States. It is generating enough renewable energy to power approximately 4,500 homes and is helping New York State meet its clean energy and carbon reduction goals.

Brookhaven National Laboratory (BN)L has the LISF instrumented and is capturing solar insolation and power data that can be used for research purposes. Additional information on LISF is available here: https://www.bnl.gov/lisf/

A network of nine high-definition (HD cameras) and 32 pyranometers are deployed within the LISF for the purpose of monitoring the location and characteristics of clouds and available global horizontal irradiance at the surface across the region. Information collected by this network every 30 s is currently used in BNL's solar NowCasting algorithm, which forecasts near-term solar energy availability accounting for the behavior of clouds.

The most important parameters for forecasting the near-term solar energy availability are accurate estimations of their horizontal extend, horizontal motion, and cloud base height. Currently, images from nearly located cameras are used to estimate the cloud base height. In order to evaluate the potential of this method for estimating the cloud base height, we decided to deploy a Vaisala ceilometer at the LISF.

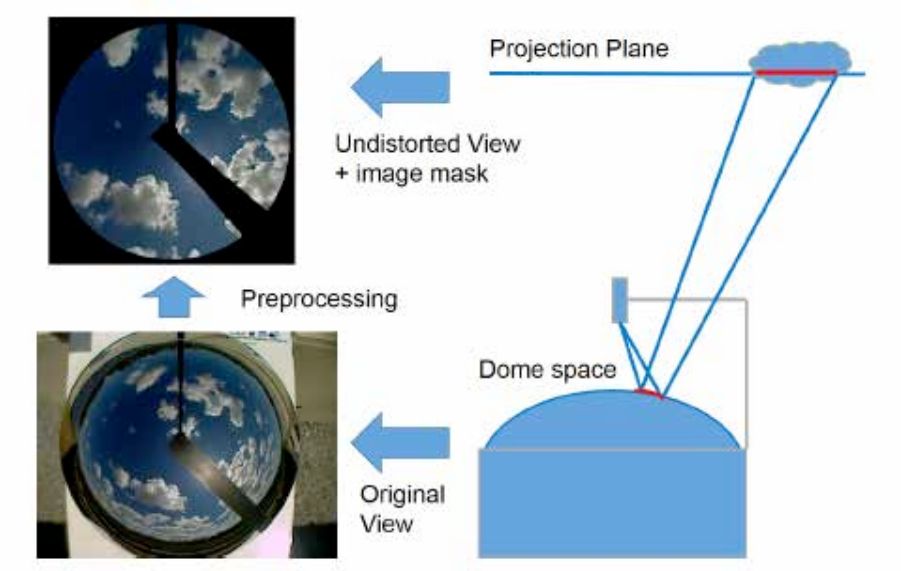

Figure 1. Procedure for preprocessing the total sky imager (TSI) images. The original image is undistorted from the original dome space to the planar space via coordinate transformation. The output image is cropped based on a pre-determined field-of-view (FOV) range and masked to remove irrelevant areas, such as the supporting arm and the shadow band (Peng et al. 2014).

2.0 Results

The Vaisala ceilometers are a field-proven, robust lidar system operating at 905 nm that can measure the cloud base height and boundary-layer attenuated backscatter from aerosols and hydrometeors. The DOE's Atmospheric Radiation Measurement (ARM) user facility has been operating Vaisala ceilometers since its early days and they have been a valuable source of information regarding cloud occurrence, cloud base height, and cloud fraction.

In 2017, the Principal Investigator (Pavlos Kollias) submitted a proposal to the ARM facility for the three-year loan of an ARM ceilometer at the BNL/LISF to support the solar forecasting project. The "Quantitative Ceilometer-Radar Studies of Clouds" field campaign was reviewed and approved by DOE and the ARM Infrastructure Management Board (IMB). The approved operational period of this effort is February 1, 2018-January 31, 2021. After initial testing, the ceilometer was installed near the LISF facility.

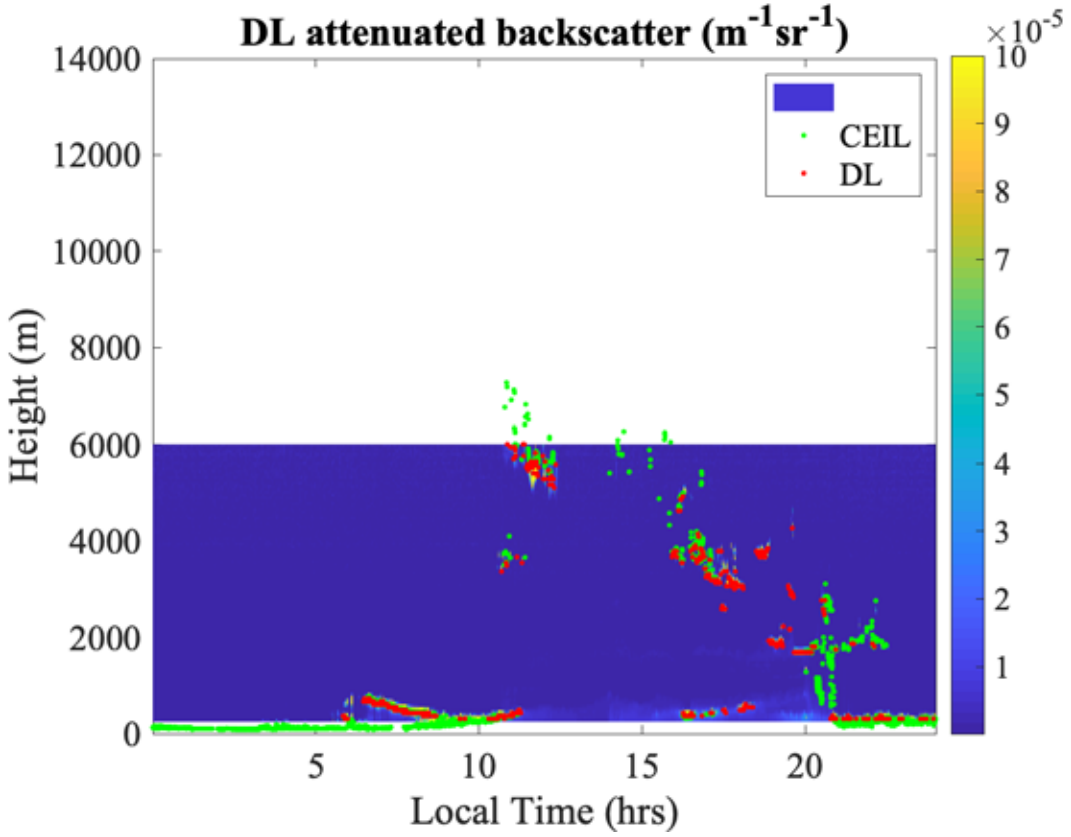

Figure 2. Example of cloud base height estimates from the ARM ceilometer and the BNL Halo Doppler lidar.

With regard to solar forecasting, the ceilometer data allow us to demonstrate that the BNL NowCasting tool is capable of accurately calculating the cloud base height from multiple imager data.

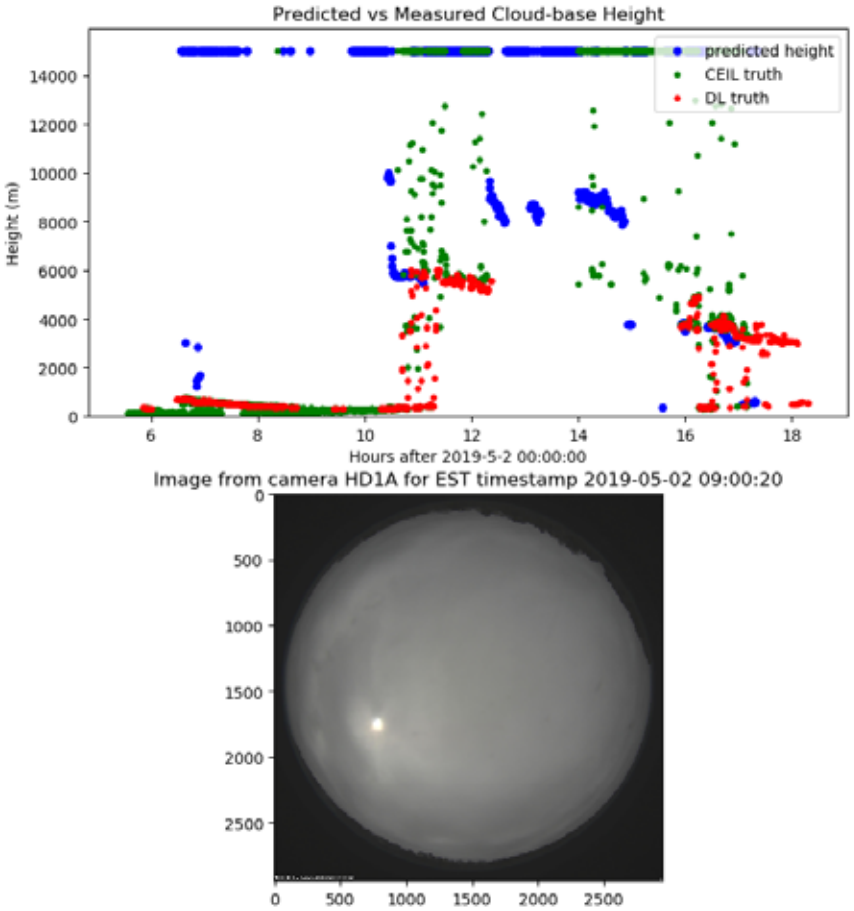

Figure 3. Example of cloud base detections from the BNL solar Nowcasting model (blue), the ARM ceilometer (green), and the Halo Doppler lidar. Quicklooks of the ARM ceilometer observations are available at https://you.stonybrook.edu/radar/data/archive/

3.0 References

Peng, Z, S Yoo, D Yu, D Huang, P Kalb, and J Heiser. 2014. "3D cloud detection and tracking for solar forecast using multiple sky imagers." In *Proceedings of the 29th Annual ACM Symposium on Applied Computing (SAC '14)*. Association for Computing Machinery, New York, pp. 512-517, https://doi.org/10.1145/25548502554913

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