EMS Annual Meeting Abstracts
Vol. 15, EMS2018-96, 2018

Benchmarking cloud height and cloud motion measurements

Pascal Kuhn (1), Marco Wirtz (1), Stefan Wilbert (1), Niels Killius (2), Juan Luis Bosch (3), Guang Wang (4), Natalie Hanrieder (1), Bijan Nouri (1), Jan Kleissl (4), Lourdes Ramirez (5), Luis Zarzalejo (5), Marion Schroedter-Homscheidt (6), Detlev Heinemann (6), Andreas Kazantzidis (7), Philippe Blanc (8), and Robert Pitz-Paal (9)

(1) Institute of Solar Research, German Aerospace Center (DLR), Almería, Spain (Pascal.Kuhn@dlr.de, marco.wirtz@eonerc.rwth-aachen.de, Stefan.Wilbert@dlr.de, Natalie.Hanrieder@dlr.de, Bijan.Nouri@dlr.de), (2) Earth Observation Center, German Aerospace Center (DLR), Weßling - Oberpfaffenhofen, Germany (niels.killius@dlr.de), (3) Departamento de Ingeniería Eléctrica y Térmica, Universidad de Huelva, Huelva, Spain (jlbosch@gmail.com), (4) Dept. of Mechanical and Aerospace Engineering, UCSD Center for Energy Research, University of California, USA (g3wang@eng.ucsd.edu, jkleissl@eng.ucsd.edu), (5) CIEMAT, Energy Department - Renewable Energy Division, Madrid, Spain (Lourdes.ramirez@aei.gob.es, lf.zarzalejo@ciemat.es), (6) Institute of Networked Energy Systems, German Aerospace Center (DLR), Oldenburg, Germany (Marion.Schroedter-Homscheidt@dlr.de, Detlev.Heinemann@dlr.de), (7) Laboratory of Atmospheric Physics, Department of Physics, University of Patras, Patras, Greece (akaza@upatras.gr), (8) MINES ParisTech, PSL Research University, Sophia Antipolis CEDEX, France (philippe.blanc@mines-paristech.fr), (9) Institute of Solar Research, German Aerospace Center (DLR), Cologne, Germany (Robert.Pitz-Paal@dlr.de)

The stability of electricity grids with high solar penetrations is challenged by the short-term variability of the solar resource, mainly caused by clouds. Therefore, analysing cloud properties has recently gained significant relevance.

For energy meteorological applications, cloud motion vectors and heights are especially important. For instance, faster clouds reduce the time available to react to shading events at solar plants. Ramp rate regulations thus might soon make cloud speeds paramount for solar site assessments. Besides, cloud heights are crucial for solar nowcasting systems: Deviations in determined heights can lead to large deviations for the predicted shadow positions.

This study compares five cloud height measurement systems on 59 days and evaluates their use in all-sky imager based nowcasting systems. These five systems are (1) a ceilometer, (2) NWP cloud heights taken from the ECMWF model, (3) a system based on one all-sky imager and a Cloud Shadow Speed Sensor (ASI-CSS), (4) a novel system consisting of one all-sky imager and a downward-facing camera (ASI-SC) and (5) a system using two all-sky imagers (ASI-ASI).

The ASI-ASI system showed the overall smallest deviations in comparison to ceilometer measurements (19 % mean absolute deviation, MAD) and derived the most measurements. Cloud heights derived from both the NWP model (40 % MAD) and the ASI-CSS system (37 % MAD) showed larger deviations than the ASI-ASI and the ASI-SC system (32 % MAD).

Furthermore, a novel approach to obtain cloud motion vectors is developed and used to validate a Cloud Shadow Speed Sensor on 59 days. This approach uses a downward-facing camera, taking geo-referenced images, which are transformed into orthoimages with a known meter-per-pixel ratio. Cloud (shadow) motion vectors are derived from a set of three concurrent orthoimages without detecting shadows. This novel differential algorithm is considered to be more robust than segmentation based tracking algorithms. The validation of the Cloud Shadow Speed Sensor revealed potential for further optimization (15.7 % MAD, low detection rate), which could be achieved by reducing the dead time and adding a clear sky forecast algorithm.

In summary, a benchmark campaign found two all-sky imager systems to be most feasible for camera based nowcasting applications. A Cloud Shadow Speed Sensor was validated and, although leaving room for improvements, is thought to have great potential for an in-a-box nowcasting and site evaluation system. A novel camera based approach to measure cloud shadow motion vectors was developed.

This research is published in
Kuhn, P., et al., Benchmarking three low-cost, low-maintenance cloud height measurement systems and ECMWF

cloud heights against a ceilometer, Solar Energy, 2018, https://doi.org/10.1016/j.solener.2018.02.050, and Kuhn, P., et al., Field validation and benchmarking of a cloud shadow speed sensor, Solar Energy, under review.