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The use of satellite data assimilation methods in regional NWP for solar irradiance forecasting

Frederik Kurzrock (1), Sylvain Cros (1), Fabrice Chane-Ming (2), Roland Potthast (3), Laurent Linguet (4), and Nicolas Sébastien (1)

(1) Reuniwatt, Sainte-Clotilde, France, (2) UMR 8105 Laboratoire de l'Atmosphère et des Cyclones (LACy), Université de la Réunion, Saint-Denis, France, (3) German Meteorological Service - Deutscher Wetterdienst, Offenbach, Germany, (4) ESPACE-DEV - Centre IRD de Guyane, Université des Antilles et de Guyane, Cayenne, France

As an intermittent energy source, the injection of solar power into electricity grids requires irradiance forecasting in order to ensure grid stability. On time scales of more than six hours ahead, numerical weather prediction (NWP) is recognized as the most appropriate solution. However, the current representation of clouds in NWP models is not sufficiently precise for an accurate forecast of solar irradiance at ground level. Dynamical downscaling does not necessarily increase the quality of irradiance forecasts. Furthermore, incorrectly simulated cloud evolution is often the cause of inaccurate atmospheric analyses.

In non-interconnected tropical areas, the large amplitudes of solar irradiance variability provide abundant solar yield but present significant problems for grid safety. Irradiance forecasting is particularly important for solar power stakeholders in these regions where PV electricity penetration is increasing. At the same time, NWP is markedly more challenging in tropic areas than in mid-latitudes due to the special characteristics of tropical homogeneous convective air masses.

Numerous data assimilation methods and strategies have evolved and been applied to a large variety of global and regional NWP models in the recent decades. Assimilating data from geostationary meteorological satellites is an appropriate approach. Indeed, models converting radiances measured by satellites into cloud properties already exist. Moreover, data are available at high temporal frequencies, which enable a pertinent cloud cover evolution modelling for solar energy forecasts. In this work, we present a survey of different approaches which aim at improving cloud cover forecasts using the assimilation of geostationary meteorological satellite data into regional NWP models.

Various approaches have been applied to a variety of models and satellites and in different regions of the world. Current methods focus on the assimilation of cloud-top information, derived from infrared channels. For example, those information have been directly assimilated by modifying the water vapour profile in the initial conditions of the WRF model in California using GOES satellite imagery. In Europe, the assimilation of cloud-top height and relative humidity has been performed in an indirect approach using an ensemble Kalman filter. In this case Meteosat SEVIRI cloud information has been assimilated in the COSMO model.

Although such methods generally provide improved cloud cover forecasts in mid-latitudes, the major limitation is that only clear-sky or completely cloudy cases can be considered. Indeed, fractional clouds cause a measured signal mixing cold clouds and warmer Earth surface. If the model's initial state is directly forced by cloud properties observed by satellite, the changed model fields have to be smoothed in order to avoid numerical instability.

Other crucial aspects which influence forecast quality in the case of satellite radiance assimilation are channel selection, bias and error treatment.

The overall promising satellite data assimilation methods in regional NWP have not yet been explicitly applied and tested under tropical conditions. Therefore, a deeper understanding on the benefits of such methods is necessary to improve irradiance forecast schemes.