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Wide-range solar resource forecasting by combining radiation measurements, all-sky camera imagery and high-resolution large-eddy simulations on a GPU

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With the current tendency to larger photovoltaic power plants the demand for accurate forecasts of solar radiation increases steadily. In contrast to the traditional, controllable power generation that can handle the power grid variability, renewables must cope with natural power resource fluctuations. To maintain grid stability with an increasing penetration of renewables, the variability of natural power sources has to be accounted for in the operation of the renewables by accurate minutes ahead to days ahead forecasts of natural energy resources.

We present two forecasting methods based on novel techniques. For short-time scale predictions up to 15-30 minutes we use atmospheric observations including an all-sky camera and for longer time scales we use a high-resolution Large-Eddy Simulation (LES) model. These methods allow to cover forecasting time horizons from one minute to several days ahead.

First we discuss results of solar radiation forecasts based on observational techniques. Clouds are observed with an all-sky camera and their effects on the solar radiation are monitored by means of ground-based pyranometers. We use a sophisticated cloud tracking algorithm to derive cloud motion vector fields. In turn, these results are used to predict solar radiative fluxes at the surface every minute up to 15 minutes ahead. Our integrated cloud classification algorithm differentiates between advective and convective cloud fields so that we are able to choose the suitable forecasting method. In the convective cloud case we apply a so-called morphing method which analyses the optical flow of cloudy pixels on several spatial scales. In the advective case the cloud displacement is based on the mean motion vector. In both cases the motion vector field is then applied to the latest cloud mask allowing cloud position and radiation forecasts up to 15 minutes.

The second forecasting technique fully relies on intensive numerical calculations with the Graphics Processing Unit (GPU) resident Large-Eddy Simulation (GALES) model. For this application the GPU offers superior computational speed compared to the more traditional CPU. The lateral boundary conditions as well as the large-scale forcing conditions are obtained from the KNMI Regional Atmospheric Climate Model (RACMO). In contrast to most regional weather forecast models GALES operates at a horizontal grid resolution that is sufficiently fine to explicitly resolve boundary-layer clouds such as shallow cumulus and stratocumulus. Currently GALES runs on a continuous basis. In addition a hindcast for the year 2012 has been made. Because the horizontal domain of GALES includes the Cabauw meteorological measurement platform operated by the KNMI the GALES results can be critically compared against observations.