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Irradiance and cloud optical properties from photovoltaic power data under variable atmospheric conditions

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The electricity grid of the future will be built on renewable energy sources, which are highly variable and dependent on atmospheric conditions. In power grids with an increasingly high penetration of solar photovoltaics (PV), an accurate knowledge of the incoming solar irradiance is indispensable for grid operation and planning, and reliable irradiance forecasts are thus invaluable for energy system operators. In order to better characterise shortwave solar radiation in time and space, data from PV systems themselves can be used, since the measured power provides information about both irradiance and the optical properties of the atmosphere, in particular the cloud optical depth (COD). Indeed, in the European context with highly variable cloud cover, the cloud fraction and COD are important parameters in determining the irradiance, whereas aerosol effects are only of secondary importance.

Within the BMWK-funded MetPVNet project (Meilinger et al., 2021), inversion algorithms were developed in order to infer global, direct and diffuse irradiance as well as atmospheric optical properties from PV power measurements, with the goal of assimilating this information into numerical weather prediction (NWP) models. In this work, both the DISORT 1D and MYSTIC 3D radiative transfer schemes within libRadtran ☐ are used to extract cloud properties and irradiance from pyranometer and PV power data, from two measurement campaigns in Allgäu, Germany and under different weather conditions. The DISORT-based algorithm is able to accurately retrieve COD, direct and diffuse irradiance components as long as the cloud fraction is high enough, whereas under broken cloud conditions the presence of 3D effects can lead to large errors. Horizontal photon transport results in radiation overshoots at the edges of clouds, and here these deviations are quantified using simulated cloud fields with known cloud microphysical properties, for different degrees of irradiance variability. In addition, global horizontal irradiance is derived directly from tilted irradiance measurements and/or PV data using a lookup table based on these same cloud fields and MYSTIC 3D simulations. This work will provide the basis for future investigations using a larger number of PV systems and/or irradiance sensors to evaluate the improvements to irradiance and power forecasts that could be achieved by the assimilation of inferred irradiance into an NWP model.

References:

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