Adaptation and evaluation of a PV model for urban climate modeling systems

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By 2040, solar photovoltaics (PV) are projected to make up the largest share of renewable energy production worldwide (International Energy Agency, 2017). This transformation could lead to a considerable increase of rooftop solar PV. The potential direct effects of PV systems on urban climate have been seldomly studied so far and generally with simplified approaches such as an effective albedo, which takes the conversion efficiency of PV modules into account (Taha, 2013). What these studies do not account for is the fact that PV modules installed on roof tops might generate an additional sensible heat flux compared to a roof that has the effective albedo of a PV system. Also, there seems to be a discrepancy between numerical modeling studies who found that PV can reduce urban heat islands (UHI)(Masson et al., 2014; Salamanca et al., 2016) and experimental studies who found a PV heat island (Barron-Gafford et al., 2016; Broadbent et al., 2019). To elucidate this problem, a more detailed energy balance model is needed which takes into account the two sides of PV modules that are exposed to the surrounding air layer. This approach should also reflect that these PV systems are typically mounted on metal frames with a small air gap between the roof and the module. Therefore, the wind speed below the PV panel must be considerably lower than above the PV panel.

In this study a PV energy balance model (Heusinger et al., 2019) is adapted and evaluated with measured surface temperatures of a rooftop PV system installed in Braunschweig, Germany together with local meteorological data. The results indicate that the thermal behavior of the investigated PV panel is dependent on wind direction. With north-western winds, the panel is at the windward edge of the PV array and therefore more exposed to the wind than when wind direction is south-east and the panel is at the downwind edge of the PV array. This can result in module temperature differences of up to 15 K on clear sky days. However, the PV model can be adapted to both situations by adapting the forced and natural convective heat transfer calculation of both sides of the panel. After thorough evaluation the PV model is planned to be integrated in the BEP module of the Weather Research and Forecasting (WRF) model to examine the potential impact of rooftop PV systems on the urban climate and urban heat islands in detail.

References

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