“Solar panels forest” and its radiative forcing effect: preliminary results from the Arava Desert

Rafael Stern, Madi Amer, Jonathan Müller, Fyodor Tatarinov, Lior Segev, Eyal Rotenberg, and Dan Yakir

Weizmann Institute of Science, Earth and Planetary Sciences Department, Rehovot, Israel (rafael.stern@weizmann.ac.il)

The production of electricity from solar radiation should replace power production by burning fossil fuel and help reduce atmospheric concentrations of CO₂. However, large photovoltaic (PV) fields can also influence the climate in more direct ways. The albedo of solar panels is low to allow efficient light absorption, but actual conversion efficiency is below 20%. The remaining 80% of the energy is reflected, re-emitted as thermal radiation or dissipated as sensible heat (H). These effects can heat the surface, influence local air circulations, and lead to the formation of “heat-islands”. Such effects are particularly significant in desert areas with high radiation load and high background albedo. The ultimate objective of this study will be to estimate the cost (in number of years) of CO₂ emission suppression of a PV power generation (a “cooling effect”) associated with the albedo radiative forcing and the surface “warming effects” and the partitioning to its components.

We used a state-of-the-art field laboratory to carry out eddy covariance flux measurements of sensible and latent heat, and the radiative balance of incoming and outgoing short- and long-wave radiations. A research drone equipped with a thermal and a multi-spectral camera was used to estimate the spatial average reflected and emitted radiation from the solar panels field. Measurements were carried out on campaign basis during 2018-2019, both inside and outside a PV field in the Arava desert in southern Israel.

The preliminary results indicated that summer noon incoming solar radiation (S) is ~1000 Wm⁻² and the desert surface albedo is on average 0.40. The mean solar panel field albedo is 0.23 (with panels projected area about 1/3rd of the PV field area), which is translated to ~170 Wm⁻² higher S absorption by the PV field. A large fraction of the energy is converted to sensible heat flux with mid-day H values of 450 Wm⁻², compared with 250 Wm⁻² in the desert, or about 200 Wm⁻² of extra heating above the PV field. A first approximation of the summer daily carbon suppression (assuming 12h daily average sunlight of ~500 Wm⁻², PV efficiency of 0.2, and conventional power efficiency of ~200 gC/KWh) indicated ~0.08 Kg C per day per m² PV area. These preliminary results are being extended to include thermal emission effects and the annual scale perspective to assess the “PV forest” radiative forcing effect. But it is evident that the land use change examined here has a large impact on the surface energy budget and its surrounding environments.