“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, Dan Yakir.

מכון ויצמן למדע
WEIZMANN INSTITUTE OF SCIENCE

SAERI Sustainability And Energy Research Initiative

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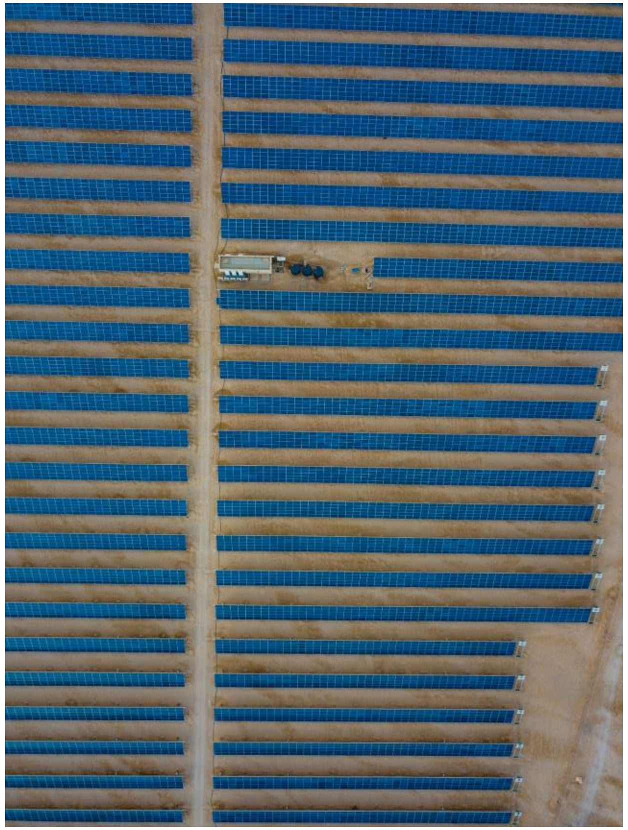
ARAVA POWER COMPANY

Arava Institute
מכון הערבה معهد وادي عربة



A solar panels "forest"

- Will transition from high-albedo desert to low-albedo photovoltaic (PV) fields result in warming (positive radiative forcing) greater than cooling due to energy production?

The surface energy balance can be expressed by the following simplified formula

$$H + LE + G = (1-\alpha)\, S_t + L_d - L_u$$

H = sensible heat, LE = latent heat of evaporation, G (energy storage, for example, in the soil), S_t = solar radiation, α = surface albedo, L_u and L_d are the up- and down-welling long wave radiation.

- PV fields convert ~20% of solar radiation to electricity
- It replaces CO_2 emissions from thermoelectric power generation; equivalent to carbon "removal" mechanism.
- 80% is reflected (α), re-emitted (L_u) or dissipated (H).
- Large sensible heat flux can influence local air circulations and form heat islands

Mobile laboratory for eddy covariance and radiation balance

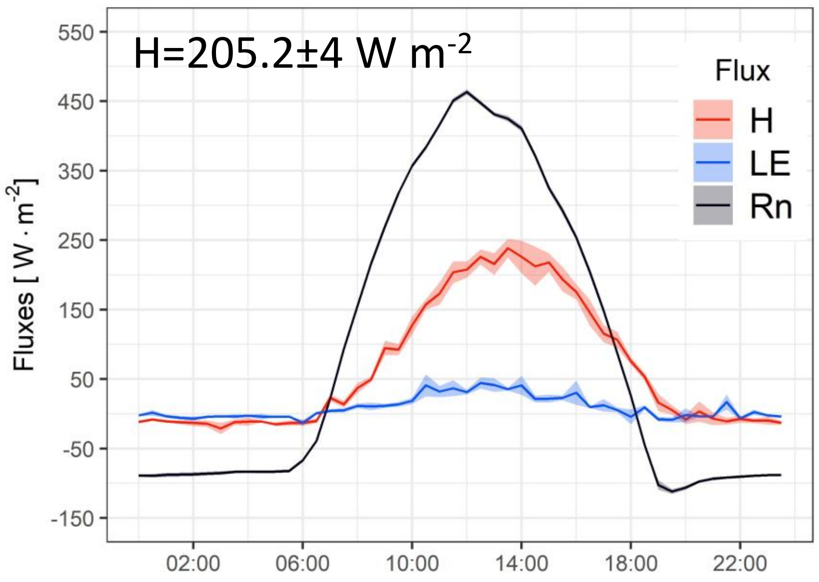
- Fully operational eddy flux system
- Mast height up to 28 m
- Lab conditions for auxiliary equipment
- Independent power and communication

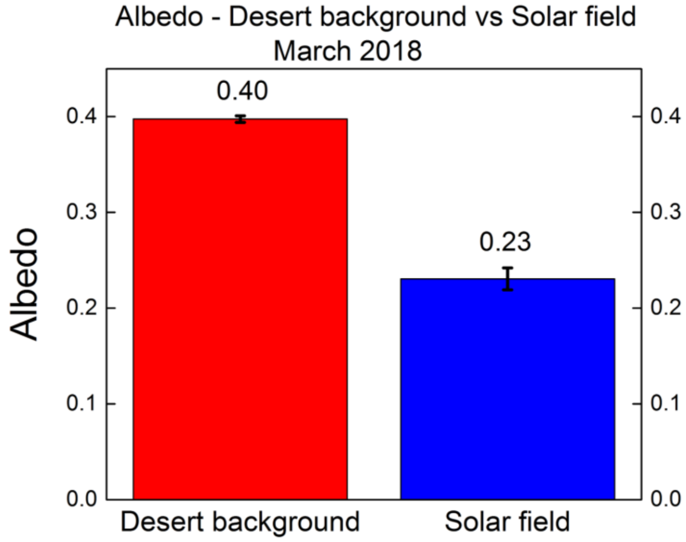
Sensible heat flux: $H = \rho_a C_p \overline{w'T'}$

- Measurements campaigns of at least one week in each site in: March 2018, October 2018, July 2019

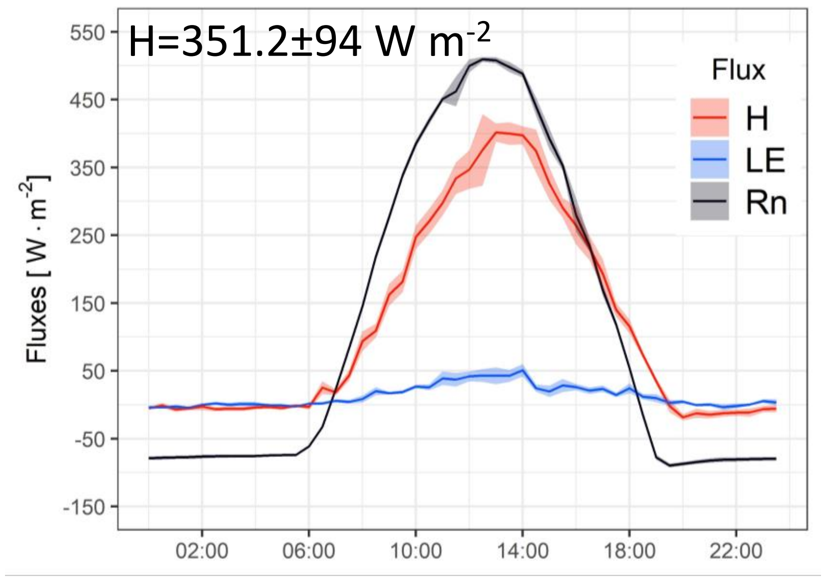
Results – albedo and energy budget

Desert Background - summer





Solar panels field - summer



Annual average incoming solar radiation (Eg) = 245 W m^{-2}

Albedo desert – albedo solar field = 0.17

Albedo radiative forcing = 245 * 0.17 = + 42 W m^{-2}

(could double when long-wave radiation effects will be considered in the next steps of this research)

PV field radiative forcing balance

0.11 kgC/kWh 0.05 kgC/kWh

Coal Natural Gas

Albedo positive radiative forcing

VS.

CO_2 emissions avoidance negative radiative forcing:

Coal emissions scenario = 1.8 years

Natural gas emissions scenario = 3.4 years

$$C\ radiative\ forcing = \frac{\delta C * \zeta * \eta}{k * C_0}$$

η = CO_2 radiative forcing potential (5.35 W m^{-2})

δC = change in atmospheric carbon

ζ = airborne fraction (0.44)

k = ppm of CO_2 to kgC conversion ($2.13 * 10^{12}$ kgC ppm^{-1})

C_0 = atmospheric mixing ration of CO_2

PV annual "Photosynthesis":

Production = 150 kWh m^{-2}

C emission avoidance (coal) = **15 kgC m^{-2}**

C emission avoidance (natural gas) = **8 kgC m^{-2}**

Conclusions

- Our measurements of overall PV field albedo of 0.23 are consistent with estimates of 50% PV land cover and PV albedo of 0.05 and desert soil albedo of 0.4 and "effective albedo" reported in the literature (Li et al., 2018).

- 50% larger H over PV field than over the adjacent desert could have implications for local air circulation, and at large scale for climate (Yosef et al., 2018; Brugger et al., 2018; Li et al., 2018).

- Warming albedo effect is rapidly compensated for (1.8 to 3.4 years) by CO_2 emission avoidance in PV field, in contrast with ~40 years in a semi-arid pines forest in the same region (Rotenberg and Yakir, 2010), supporting climatic benefits of PV energy source.

- Research will be extended to include surface temperature and long-wave radiation effects.

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