Continuous below canopy evaporation

Assessments in a drip-irrigated desert vineyard

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Introduction

Evaporation from the soil surface (*E*) can be a significant source of water loss in arid areas. Wine vineyards have precise water requirements, making assessment of *E* relative to evapotranspiration (*ET*) particularly relevant. The lack of robust continuous and long-term measurement techniques to measure *E* in a vegetated system is a critical problem for *ET* partitioning[1].

In this study we assessed two novel techniques, the **heat-pulse soil heat balance (HP-SHB)** method and an **infrared thermometry (IRT)** based method, for continuous measurement of *E* in a drip irrigated vineyard in an arid environment.

General set-up

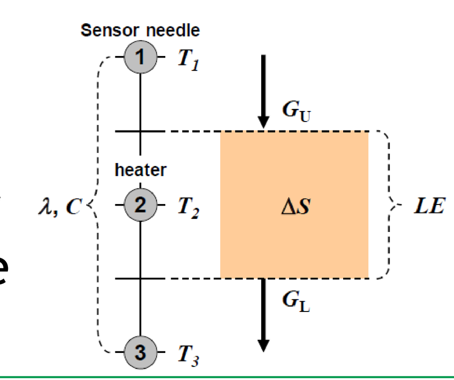
An experiment was conducted in a commercial wine vineyard in the Negev Highlands. Continuous measurements included net radiation, soil heat flux, and air temperature below the canopy, as well as wind speed and direction above the canopy. In addition, short-term micro-lysimeter (ø=10cm) measurements were conducted directly underneath the canopy. Expected values of below canopy *E* were simulated using HYDRUS (2D-3D).

Method I: Soil heat pulse sensor

In a drying soil, *E* initially takes place at the surface, but eventually shifts to lower depths. Sub-surface *E* can be determined using sensible heat balance for a soil layer:

$$LE = (G_U - G_L) - \Delta S$$

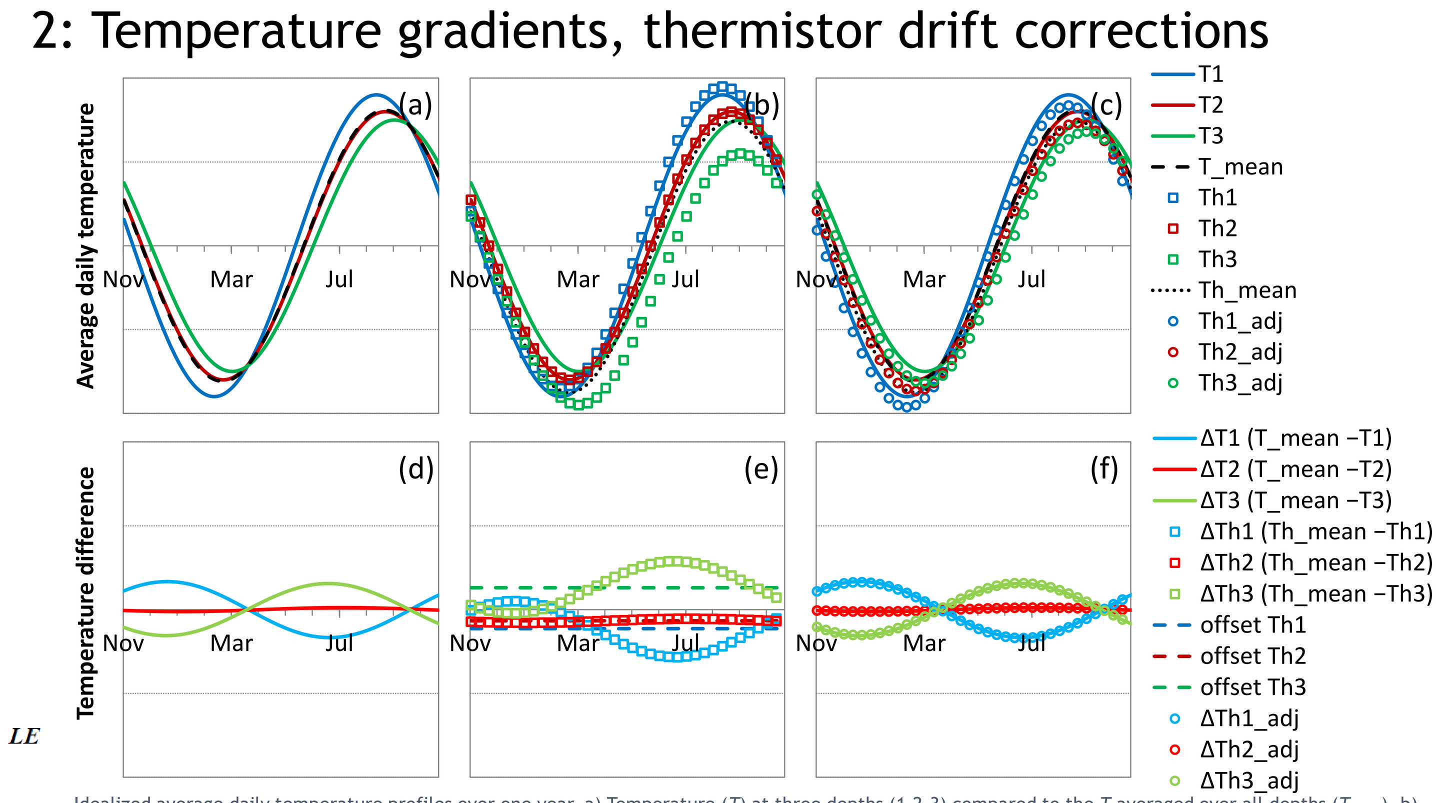
where *L* is latent heat of vaporization, G_U and G_L are sensible heat fluxes at the upper and lower depth of the measured soil layer, respectively, and ΔS is the change in soil sensible heat storage; based on: heat capacity (*C*), thermal conductivity (λ), and temperature (*T*) gradients.



Corrections for desert conditions:

1: Thermal properties, ambient temperature corrections

2: Temperature gradients, thermistor drift corrections



Idealized average daily temperature profiles over one year. a) Temperature (*T*) at three depths (1,2,3) compared to the *T* averaged over all depths (T_{mean}). b) Hypothetical comparison between measurements (*M*) of *T* and actual *T*, where *M*1 was chosen to overestimate *T*1, *M*2 to equal *T*2 and *M*3 to underestimate *T*3 using hypothetical thermistor offsets for absolute *T*. c) Adjusted *M* (*M*_adj = *M* + offset) for each depth compared to actual *T*. d) Difference between *T* and T_{mean} for each depth. e) Difference between *M* and M_{mean} for each depth. The measurement offset is calculated as the annual average deviation from zero. f) Comparison of (T_{mean} -*T*) and (M_{mean}_adj -*M*_adj) for each depth.

Method II: Infrared thermometry

Infrared thermometry can be used to compute below canopy sensible heat (H_s):

$$H_s = -\rho c_p \frac{T_s - T_a}{r_{as}}$$

where ρc_p is the volumetric heat capacity of air, *T* is temperature at the soil surface (subscript *s*) and below-canopy air (subscript *a*), and r_{as} is the resistance to heat transfer between the soil surface and a below-canopy reference point. Combined with net radiation (R_n) and soil heat flux (*G*) measurements, *LE* is:

$$LE = R_n - G - H_s.$$

Considerations:

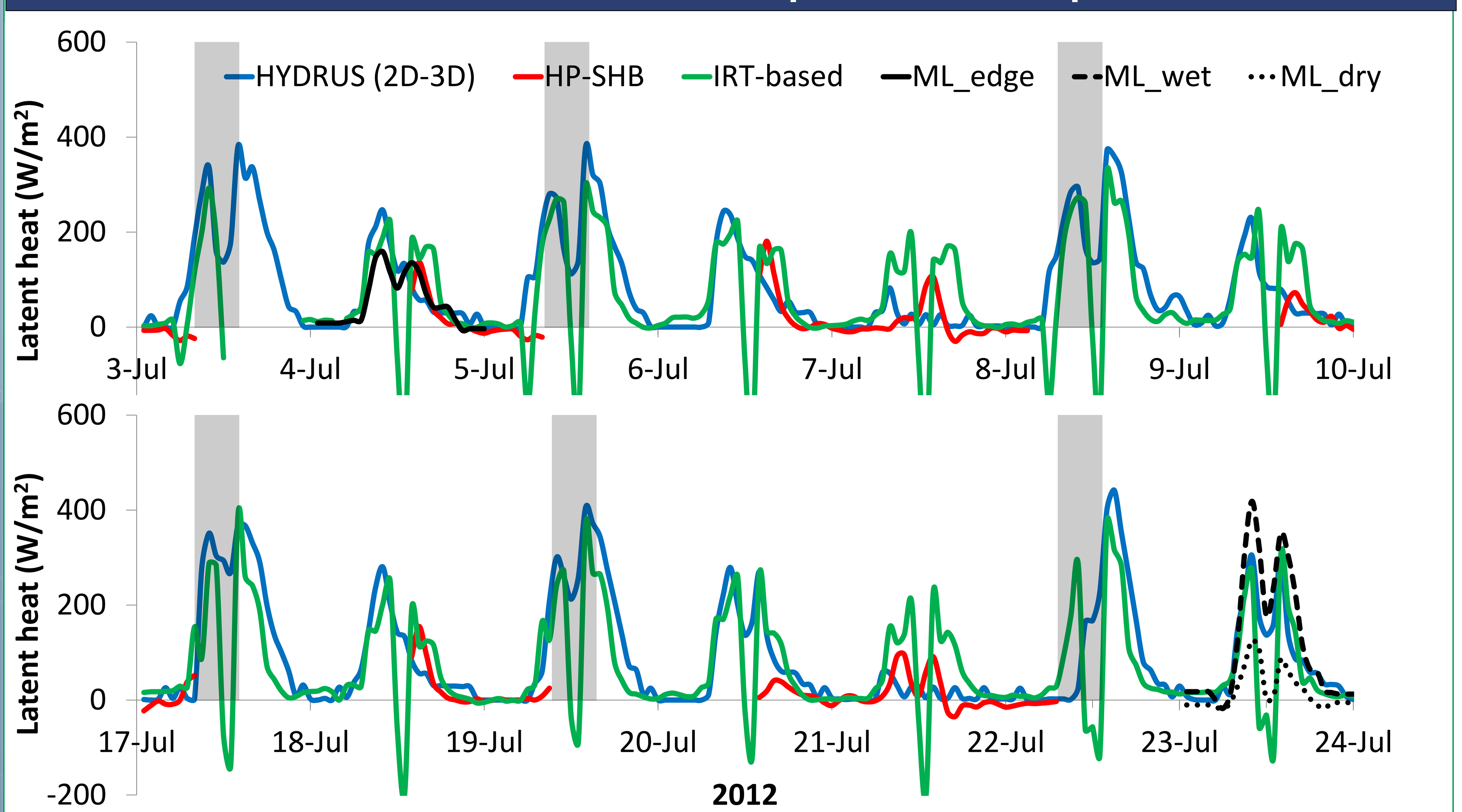
1: Several equations exist to compute r_{as}, best fit:

$$r_{as} = 1/\left[c(T_s - T_c)^{1/3} + bu_s\right]$$

where *c* = 0.0025, T_c is canopy temperature, *b* = 0.0012, u_s is wind speed near the soil surface.

2: Best derivation of u_s from above canopy *u*: Massman 1987.

Continuous below vine evaporation, comparison



Evaporation directly underneath the vine for early (upper panel) and late (lower panel) July 2012. Heat-pulse soil heat balance (HP-SHB) and Infrared thermometry (IRT) based measurements were compared to intensive micro-lysimeter (ML) measurements taken from areas below the vine that were relatively wet, relatively dry, and on the edge from wet to dry. Simulations using HYDRUS (2D-3D)[2] are shown as a reference. Grey areas indicate irrigation periods.

Discussion/Conclusions

HP-SHB	IRT-based
++ Stand alone ++ Detailed below-surface information ++ Does not interfere with roots ++ Weather-proof	++ Fully continuous ++ Representative area can be adjusted by positioning the sensor higher or lower ++ Does not interfere with roots
-- Can only detect sub-surface E -- Point measurement	-- Requires net radiation and soil heat flux measurements -- Below canopy obstructions (e.g. grass) may change resistance functions

The HP-SHB successfully measured sub-surface *E* continuously over a season, though high irrigation frequency limited the amount of days when the measurement was relevant. In-situ IRT measurements with under-canopy micro-meteorological data allowed fully continuous measurement of *E*. Both methods can be used without disturbing either the micro-climate or soil water fluxes.

[1]Kool et al. (2014) A review of approaches for evapotranspiration partitioning. Agric Forest Meteor., 184.

[2]Kool et al. (2014) Spatial and diurnal below canopy evaporation in a desert vineyard: measurements and modeling. Water Resour. Res., 50

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