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Evapotranspiration and crop water use efficiency from airborne thermal infrared data at 1 to 4 m spatial resolution

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Agriculture is the largest consumer of water worldwide, accounting for about 70% of the global freshwater withdrawals. Thus, crop water use efficiency and impacts of water stress on crop water consumption are the key concerns for agricultural water management.

Present study investigates the variability of evapotranspiration (ET) and crop water use efficiency by integrating very high spatial resolution (1 – 4 m) thermal infrared (TIR) data from airborne measurements and visible to near infrared data from Planet satellite with a numerical water-energy balance model and a diagnostic surface energy balance model.

The analysis is done for an intensive agriculture area in central Italy near the city of Modena, where several fruit trees fields are present along with fresh vegetables. An intensive airborne campaign was organized in the summer of 2022 for three consecutive days in July. A hyperspectral TIR camera (Telops Hyper-Cam LW) has been operated at a spectral resolution of 8 cm⁻¹, resulting in 64 wavebands, and covering a wavelength range of 850 cm⁻¹ to 1350 cm⁻¹ (7,39 μm – 11,8 μm). During the 3 days of flight acquisitions, three overpasses per day are planned: 9:00, 12:30 and 16:00 h, respectively and two areas were intensively surveyed at both 4 and 1 m spatial resolution. Planet data at 3.7 m spatial resolution were used to derive different vegetation indices, such as vegetation fraction coverage, NDVI and leaf area index. During airborne overpasses ground data of spectral reflectance, vegetation variables, LST and soil water content (SM) were collected in different fields. In addition, two different pear trees fields were monitored with an eddy covariance station and soil moisture profile measurements, respectively.

To investigate the diurnal and spatial patterns of evapotranspiration, soil moisture variability and crop water use efficiency, we used two numerical models: the surface energy balance model STIC based on Penman-Monteith and Shuttleworth-Wallace (Mallick et al., 2018) and the water-energy balance model FEST-EWB which computes continuously in time and is distributed in space soil moisture and evapotranspiration fluxes solving for a land surface temperature that closes the

energy–water balance equations (Corbari et al., 2011).

Differences and similarities in ET estimates have been analysed from the two models for different soil moisture conditions and crop types, considering crop water use efficiency and water stress, and have been compared to eddy covariance measurements for accuracy evaluation considering both instantaneous and daily data. The assimilation of instantaneous estimates of ET into the water-energy balance model allowed to directly derived soil moisture maps at high spatial resolution which have been found in agreement with ground SM measurements.