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Comparing three gap filling methods for eddy covariance crop evapotranspiration measurements within a hilly agricultural catchment

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Hilly watersheds are widespread throughout coastal areas around the Mediterranean Basin. They experience agricultural intensification since hilly topographies allow water-harvesting techniques that compensate for rainfall storage, water being a strong limiting factor for crop production. Their fragility is likely to increase with climate change and human pressure.
Within semi-arid hilly watershed conditions, evapotranspiration (ETR) is a major term of both land surface energy and water balances. Several methods allow determining ETR, based either on direct measurements, or on estimations and forecast from weather and soil moisture data using simulation models. Among these methods, eddy covariance technique is based on high-frequency measurements of fluctuations of wind speed and air temperature / humidity, to directly determine the convective fluxes between land surface and atmosphere.
In spite of experimental and instrumental progresses, datasets of eddy covariance measurements often experience large portions of missing data. The latter results from energy power failure, experimental maintenance, instrumental troubles such as krypton hygrometer malfunctioning because of air humidity, or quality assessment based filtering in relation to spatial homogeneity and temporal stationarity of turbulence within surface boundary layer. This last item is all the more important as hilly topography, when combined with strong winds, tends to increase turbulence within surface boundary layer.
The main objective of this study is to establish gap-filling procedures to provide complete chronicles of eddy-covariance measurements of crop evapotranspiration (ETR) within a hilly agricultural watershed. We focus on the specific conditions induced by the combination of hilly topography and wind direction, by discriminating between upslope and downslope winds. The experiment was set for three field configurations within hilly conditions: two flux measurement stations (A, B) were installed in the two opposite rims of the watershed and one flux measurement station (C) was installed in flat conditions. Among the existing gap filling methods (e.g. mean diurnal variation, look-up tables, non-linear regressions), we tested three approaches that rely on different formulations for ETR: the ratio ETR/Rn, multiple linear regressions that involve atmospheric variables, and evaporative fraction.
For each station, there were 140 days of flux measurements. The quality controls retained 48%, 24% and 78% of the data for stations A, B and C, respectively. The three gap filling methods generally showed good overall performances. In most cases, discriminating between upslope and downslope winds was relevant. The method using the evaporative fraction slightly over-performed the two other ones, but the LE / Rn ratio method allowed to reconstitute more data (almost 100% of missing data). An uncertainty analysis showed that the quadratic errors on the reconstructed ETR data were close to the accuracy of the measurements. Finally, the consistency of ETR chronicles was verified though energy balance closure data.

Keywords: Eddy covariance, gap filling, hilly terrain, evapotranspiration.