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Understanding the diurnal variation in evaporation using pattern-based evaluation of evaporation schemes: a case study in Luxembourg

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The diurnal forcing of solar radiation is the largest signal within the land-surface system and dominates the diurnal cycle of the turbulent heat fluxes and evapotranspiration (λE). Thus to first order, λE should linearly respond to incoming solar radiation (R_{sd}), while the influence of other drivers, in particular heat storage and land-atmosphere interactions would lead to consistent deviations. For example a lag in time would form a loop (hysteresis) when plotted against solar radiation. Here we evaluate simple evaporation schemes in their ability to reproduce the diurnal course of observations under sunny conditions comparing wet and dry days. Observations from an Eddy Covariance site over grassland in Luxembourg show a remarkable linear relationship of λE with R_{sd}, which tends towards a counter-clockwise (CCW) hysteresis with higher values in the afternoon during wetter periods. This CCW hysteresis in λE is compensated by a clockwise (CW) hysteresis of sensible heat flux. Under dry conditions when atmospheric boundary layer growth is larger we observe a higher aerodynamic conductance and a more linear relationship of the fluxes to R_{sd}. We find that single and a two source energy balance model which both use a gradient - resistance scheme for the derivation of the sensible heat flux reproduce the patterns relatively well for both wet and dry conditions. However, a scheme based on the Penman-Monteith equation which typically also use vapor pressure deficit (VPD) as input variable is less able to reproduce the reduction of hysteresis in λE under dry conditions. This may arise from the conceptual difficulty to compensate for the strong CCW hysteresis in VPD which reflects the influence of temperature and boundary layer development on λE. We conclude that a pattern-based evaluation on the diurnal response to solar radiation provides physical insights into land-atmosphere coupling to improve existing land-surface schemes.