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The need for surface-parallel sensor orientation to address energy balance closure on mountain slopes

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Measurements of turbulent fluxes in varying environments are one of the tools scientists and decision makers rely on for assessing and forecasting global warming. Thus, in the last two decades eddy-covariance (EC) towers have proliferated around the globe. Yet, ideal sites are rarely found, and there is a great need to extend the EC method and its theoretical underpinning to more complex terrain. In particular, several principal challenges are aggravated by sloping terrain. Nevertheless, various studies have concluded that the EC method is a useful tool to determine ecosystem energy and CO_2/H_2O fluxes on mountain slopes.
Following the first law of thermodynamics, the validity of EC measurements is often evaluated in terms of their ability to close the balance of energy entering [net radiation minus the soil heat flux] and leaving [sum of the latent and sensible heat, measured by EC] an ecosystem. In sloping terrain, this criterion is applied with results comparable to sites located in more ideal terrain. Arguably, fluxes perpendicular to the surface are needed to assess the energy budget. However, even in sloping terrain instrument installations are frequently referenced perpendicular to the geo-potential (e.g. using a bubble level). Here, we demonstrate several advantages of installing the net radiometer and soil heat flux instruments parallel to a 16% slope with a southwest orientation. Our results reveal a diurnal hysteresis in the energy balance closure as large as 30% when net radiometer and soil heat flux instruments are installed perpendicular to the geo-potential. Installing the net radiometer and soil heat flux instruments slope-parallel mitigates this discrepancy.