Mountain-valley flow impacts on canopy turbulence and gradients in open and closed canopies

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Stable stratification of the nocturnal lower boundary layer inhibits convective turbulence, such that turbulent vertical transfer of ecosystem carbon dioxide (CO_2), water vapor (H_2O) and energy is driven by mechanically forced turbulence, either from frictional forces near the ground or top of a plant canopy, or from shear generated aloft. The significance of this last source of turbulence on canopy flow characteristics in a closed and open forest canopy is addressed in this paper. We present micrometeorological observations of the lower boundary layer and canopy air space collected on nearly 200 nights using a combination of atmospheric laser detection and ranging (lidar), eddy covariance (EC), and tower profiling instrumentation. Two AmeriFlux/Fluxnet sites in mountain-valley terrain in the Western U.S. are investigated: Wind River, a tall, dense conifer canopy, and Tonzi Ranch, a short, open oak canopy. On roughly 40% of nights lidar detected down-valley or downslope flows above the canopy at both sites. Nights with intermittent strong bursts of "top-down" forced turbulence were also observed above both canopies. The strongest of these bursts increased sub-canopy turbulence and reduced canopy virtual potential temperature (θ_v) gradient at Tonzi, but did not appear to change the flow characteristics within the dense Wind River canopy. At Tonzi we observed other times when high turbulence (via friction velocity, u_*) was found just above the trees, yet CO_2 and θ_v gradients remained large and suggested flow decoupling. These events were triggered by regional downslope flow. Lastly, a set of turbulence parameters is evaluated for estimating canopy turbulence mixing strength. The relationship between turbulence parameters and canopy θ_v gradients was found to be complex, although better agreement between the canopy θ_v gradient and turbulence was found for parameters based on the standard deviation of vertical velocity, or ratios of 3-D turbulence to mean flow, than for u_*. These findings add evidence that the relationship between canopy turbulence, static stability, and canopy mixing is far from straightforward even within an open canopy.