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Influence of canopy foliage on turbulence above tall deciduous vegetation

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In this study, the role of tree phenology on the atmospheric turbulence over tall vegetation is investigated. Our aim is to study dimensionless mean gradients, variances, and the turbulent kinetic energy (TKE) within the roughness sublayer (RSL), and their dependence on the leaf state of the canopy and the stability regimes. To do this, we analyse observations, that are continuously collected over a whole season above and in a walnut tree orchard during the Canopy Horizontal Array Turbulence Study (CHATS) field experiment near Dixon, California. To support this data analysis, we compare profiles of vertical fluxes and co-variances, as well as vertical gradients of mean wind, temperature and humidity, with empirically derived dimensionless gradients from previous studies and results from a second-order closure turbulence diagnostic model. In doing so, we study the differences in the calculation of the dimensionless gradients between recently developed model approaches that account for the RSL effects on these gradients against representations that omit those effects. The observations and model results are non-dimensionalized using atmospheric surface layer scaling, paying special attention to the displacement height. The latter is calculated from the observations and depends on the variable under consideration and the leaf state. Our results for the dimensionless gradients of momentum, heat and moisture show a reduction of these variables closer to the canopy top compared to the standard Monin-Obukhov similarity theory (MOST) for both unstable and near neutral conditions. We find that the reduction is larger for canopy with leaves than for leafless canopy. This confirms the applicability of the aforementioned RSL models. Their results are in better agreement with the observations for the fully vegetated canopy then for the leafless canopy. With regard to the TKE-budget, our analysis shows that turbulent transport is increasingly important term of the budget when approaching heights closer to the canopy top. However, the results are very sensitive to the choice of the displacement height. Our findings indicate the need (a) to account for the effects of the roughness sublayer in calculating and interpreting flux-gradient relationships and TKE above a deciduous forest, and (b) to include in these calculations a displacement height that takes the canopy leaf state into account.