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Effect of a coupled soil water - plant gas exchange on forest energy fluxes - simulations with the vegetation-boundary layer model HIRVAC

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Long-living plant communities like forests reduce the transpiration by closure and opening of the leaf stomata as a common strategy to save water in dry periods. Meteorological models including vegetation should consider this mechanism to simulate a realistic water transport from the plant to the atmosphere. Results of the German network project VERTIKO showed that commonly used meso-models like, e.g., Lokalmodell (German Weather Service) often overestimate evapotranspiration of vegetated surfaces during dry periods. This is, among others, due to the lack of a plant-specific coupling between the soil water content and the physiological reactions of leaf stomata in the implemented simple SVAT modules. This study presents an approach to describe the above mentioned coupling mechanism by upgrading the coupled vegetation boundary layer model HIRVAC using a parameterised stomata reaction on soil moisture change in the included gas exchange model PSN6. HIRVAC (HIgh Resolution Vegetation Atmosphere Coupler) is a 1.5 dimensional boundary layer model (120 layers between 0 and 2 km) including a highly resolved canopy (60 layers between 0 and 30 m). Vegetation is considered by additional terms in the model equations for momentum, temperature and humidity which are parameterised by the output (leaf boundary layer and stomata resistance) of a mechanistic photosynthesis module for C3 plants (PSN6, University of Bayreuth). In the new HIRVAC version several parameters of the model PSN6 were scaled by a power function of matrix potential to consider the stomata reaction to a change in soil water content. This leads to a reduction in the additional humidity source term in the basic equation of HIRVAC. As a result the humidity profiles in the canopy air, the latent heat flux and the energy balance of each canopy model layer are changed. The new parameterisation of PSN6 was

applied in HIRVAC for the VERTIKO special observation period in May and June 2003 for vegetation parameters adapted to the Anchor Station Tharandt (experimental site of the Dresden Department of Meteorology). The HIRVAC modification leads to a decrease of LE for dry soil conditions. Without coupling between soil moisture and transpiration LE increases continuously for the dry soil caused by an increase of atmospheric driving parameters vapour pressure deficit (vpd) and temperature. Despite the differences during the night the simulated and measured H agree very well, especially under dry soil conditions, while the correlation between measured and simulated LE is only moderate (perhaps caused by the higher fault liability of the used measuring system). The best agreement between simulated and measured atmospheric driving parameters vpd and crown temperature was reached under moderate soil moisture conditions. The modified parameterisation of stomata resistance in the HIRVAC submodel PSN6 reflects the effect of soil moisture dependent plant stomata control on atmospheric humidity and evapotranspiration fairly well. This simple modification led to a noticeable improvement of the simulated canopy air temperature and moisture regime in comparison to measurements and allows to adapt HIRVAC simulations to measurements dependent on soil moisture (and without the use of new “tuning” parameters). Considerable progress towards one central goal of HIRVAC was achieved: To simulate realistic turbulent heat fluxes together with realistic values for temperature and humidity - could be reached.