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Parsimonious modeling of coupled soil moisture-vegetation dynamics

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Modeling phenology in water-controlled ecosystems remains a difficult task because of high spatial and temporal variability in the interaction of vegetation and soil moisture. In this paper we pursue the objective of identifying a parsimonious and robust ecohydrological model that couple the dynamics of vegetation and soil moisture that can be forced by a limited number of climate variables. Our purpose is to seek a simple and portable model that can be used with readily available remotely-sensed data and that will enable its inclusion in global land surface models.
The temporal dynamics of soil moisture has been described as the sum of two signals working at different time-scales: the first one has high frequency variability influenced by the rainfall intermittency; the second one has low frequency variability influenced by the climatic seasonality through the potential evapotranspiration cycles and base-flow runoff. The temporal dynamics of vegetation were modeled as a water-limited process dependent upon net solar radiation, soil relative water content and a parameter that accounts for plant carbon-water transformation ability. The dynamics of vegetation is governed by a logistic growth and a mortality term.
The Arno River basin, located in central Italy, has been selected as the study area because of its stability of land use and because water is a major limiting factor for vegetation. The ecohydrological model was successfully calibrated and validated using a 10 yr time series dataset (2000–2009) of estimates of Fraction of Absorbed Photosynthetically Active Radiation (FAPAR) derived from MODIS and Soil Moisture derived from MOBIDIC, a complete balance distributed hydrological model developed at the Department of Civil and Environmental Engineering of the University of Florence. Our results showed that ecohydrological model including feedbacks between soil moisture and plant growth adequately predicts leaf dynamics. Discussion on the comparisons between soil moisture-vegetation model and the uncoupled model is provided.