Managing agricultural fields: from observation to prediction

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Climate change and especially hydro-meteorological extremes, such as droughts, are affecting the land surface of the Earth and socioeconomic well-being. Current analyses and projections indicate that the frequency of extremes will increase in the next decades, and that drought events like the years 2003, 2015 and 2018 in Europe will occur more regularly and might be more disruptive as terrestrial ecosystems will have no time to recover. Heat waves in combination with longer drought periods caused a loss in agricultural productivity but also impacted the availability of water resources (e.g. low water levels in rivers) and led to a decrease of the storage capacity of grass- and agricultural lands for carbon storage (e.g., Ciais et al., 2005). In addition, we observed a worldwide increase in risk of forest fires and pest outbreaks. At present, we face the challenge of quantifying and predicting the resilience and adaptiveness of our terrestrial ecosystems, both natural and managed, in view of the expected increase in extreme events. In Central Europe, the 2018 extreme drought affected agricultural production and forests leading to damages on the order of billions of Euro. Similar losses occurred during the drought 2003.The consequences of these damages motivated the EU to upgrade its civil defense mechanism by launching a risk data hub to enhance EU resilience.

Forecasting methodologies based on the combination of observations and integrated models provide a unique opportunity to inform farmers and stakeholders in order to better adapt to extreme drought events. New sensor technologies such as cosmic ray sensors for measuring soil moisture, Unmanned Aerial Systems (UAS) equipped with multispectral and thermal infrared cameras, Lidar systems and smart sensors to determine greenhouse gas emissions and soil and water quality offer a unique opportunity to provide such information. In addition, new developments such as remotely sensed solar-induced fluorescence (SIF) at high spatial and temporal resolution and new satellite missions will allow to better inform land surface and crop growth models in order to adjust irrigation management before crops are being severely damaged by droughts.

In this presentation, we will highlight the current capabilities of predicting the future state of the land surface from groundwater into the atmosphere and address the value of continuous observations in constraining predictions of hydrological states and fluxes as well as vegetation parameters. We will show how the Terrestrial Systems Modeling Platform, TerrSysMP, (Gasper et al., 2014; Kurtz et al., 2016;) is able to forecast the soil moisture status and evapotranspiration of the European land surface at the 12 km scale for several days and up to one week (Kollet et al., 2018). Recent work of Naz et al. (2019) showed how predictions of soil moisture and runoff can be improved at the 3 km scale across Europe using remotely sensed soil moisture leading to a new reanalysis product for monitoring surface soil moisture and hydrologic fluxes. Using TerrSysMP, we demonstrated that at catchment scale assimilating soil moisture measurements using cosmic rays sensors showed a great potential to improve predictions of soil moisture (Baatz et al., 2017). Space-borne and UAS observations were used to retrieve small-scale evapotranspiration patterns to detect plant stress according to root zone soil properties (Bayat et al., 2019). We are also studying the value of using SIF measurements to better constrain crop growth predictions under water stress conditions. This is done by forward simulation of the SIF signal based on AgroC (Klosterhalfen, 2017) and SCOPE (van der Tol et al., 2009) and using inverse methods to estimate parameters of the root water uptake function. The effect of specifically adapted root architectures on mitigating drought stress can be included in such simulations by parameterizing the root water uptake function using explicit 3D root architecture as obtained from models (CRootBox, Schnepf et al., 2018) or experiments.

Digital avatars are currently under development that allow integrating UAS technologies to inform robots performing interventions at the field scale using a multi-scale simulation platform. In this multi-scale platform functional-structural plant models operating at the plant-stand level can be linked to functional structural plant models to better quantify the sensitivity of crops to the environment. In addition, very good knowledge of the subsurface properties at field scale is essential to obtain realistic predictions of crop growth. Hydrogeophysical measurement techniques like Electro-Magnetic Induction (EMI) and Ground Penetrating Rader (GPR) offer unique possibilities to characterize within field heterogeneities of soil properties and soil moisture status and to relate this to agronomic variables (von Hebel et al., 2018; Brogi et al. 2019). We are convinced that an integration of smart sensor technologies in combination with State-of-the-Art terrestrial and crop growth models will contribute to secure agricultural production under a changing climate

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