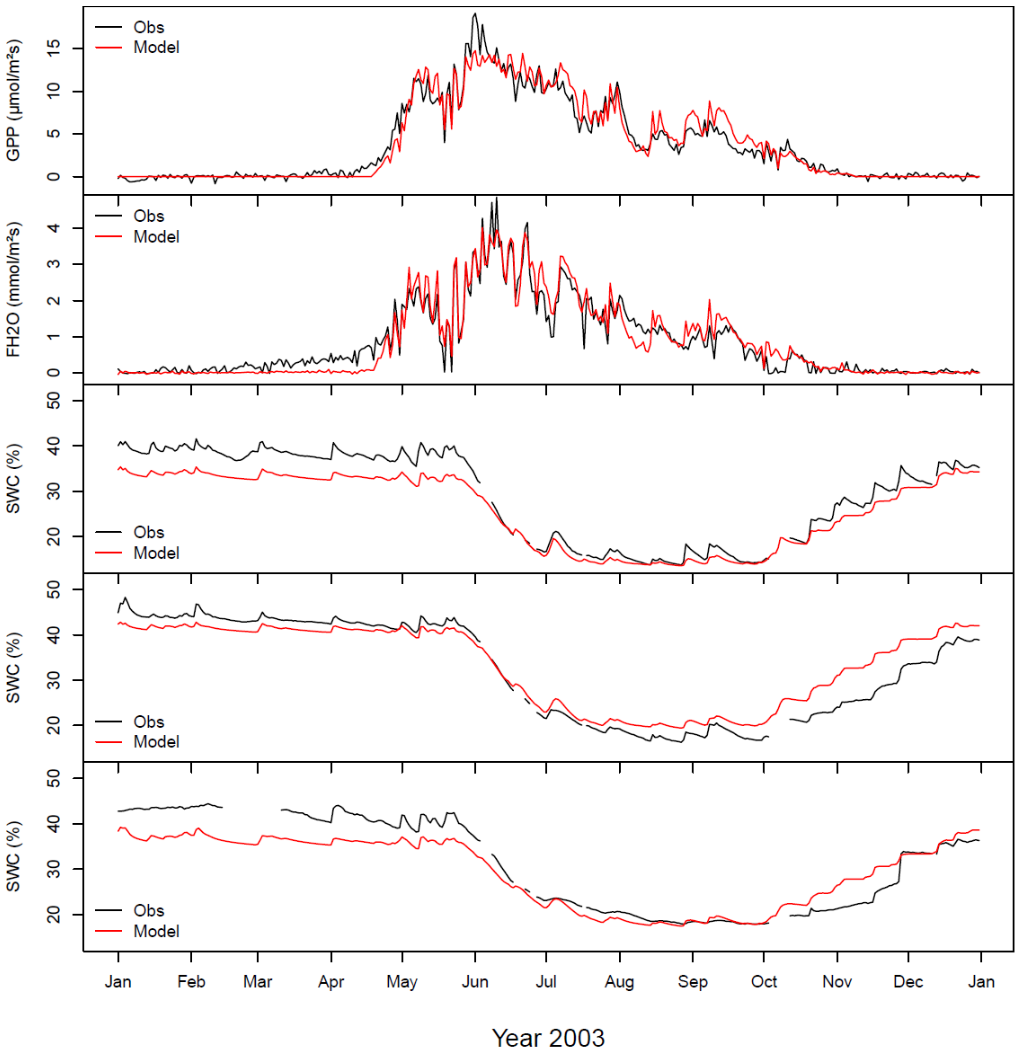
ROOTUP



Root water uptake in ecosystem models constrained by water isotopes and chloride concentrations

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Context — Water availability for plant growth is a critical issue in a changing climate as it determines ecosystem dynamics especially during drought events. However, the interconnection between several processes complicates the plausible forecast of soil water storage and fluxes. Among the critical processes, plant available water is strongly influenced by the rate of root water uptake, and by the partitioning between fast (i.e. preferential) and slow (i.e. matrix) soil water flows. These processes are not well represented in ecosystem models, which tend to overreact to hydroclimate variations and produce biased ecosystem responses.

Objectives — Within ROOTUP we have two major objectives. First, we want to improve mechanistic descriptions of soil water flow in ecosystem models using as benchmark long-term observations of ecosystem fluxes and of water flux tracers. Second, we want to investigate with modelling experiments forest ecophysiological responses to drought events under current and future climate conditions.

Approach — Enhanced formulations of soil water fluxes are tested in the framework of the mechanistic ecosystem model MuSICA and constrained using long-term observations of chloride concentrations (Cl^-) and isotopic ratios in precipitation and soil water. Cl^- fluxes may be good tracers of water movements at sites with high Cl^- deposition. Our team collected soil water and measured Cl^- over several years with different types of lysimeters at two beech forest sites (Hesse in Lorraine and Fougères in Brittany). This dataset offers a unique opportunity to enhance modelling and process understanding. Simultaneously, we perform modelling experiments with MuSICA to study forest ecophysiological responses to drought events at Hesse. We want to quantify the impact of well-known past droughts on forest water and carbon uptakes, partitioning the role of high temperatures and of low precipitations. We also investigate temperature and precipitation thresholds during drought events and the impact of different drought trajectories (e.g. fast and slow drought onsets).

Key results —

- We analyzed the available long-term dataset of Cl^- in soil water from the Hesse forest experimental site (years 2002-2008 and 2017). Cl^- enrichment at the top and the bottom of the soil profile suggests solute discrimination during evaporation and root water uptake, respectively. We thus confirmed that Cl^- can be used to inform water movement.
- Another long-term Cl^- dataset from the forest of Fougères was identified. This new dataset is more suitable to disentangle matrix flow, preferential flow and root water uptake because two types of lysimeters were used to collect soil water on several sites of a beech chronosequence: ceramic cups, collecting slow-mobile water mixed with rapid drainage water, and zero tension plates, collecting rapid drainage water only. The Fougères dataset will be exploited during a 4-month extension of the ROOTUP project which was funded by the LabEx ARBRE.
- The first measurements of the water isotopic ratios in precipitation and soil water at Hesse are now available (water collected in 2017-2018). These measurements are coupled to the Cl^- observations to inform the ecosystem model MuSICA.
- MuSICA was enhanced by allowing the separation of soil water flow in matrix flow (i.e. water transported by pressure gradients) and preferential flow (i.e. water flowing quickly in macropores or fractures), and by developing a module for solute transport in soil water including advection, diffusion, and root uptake.
- MuSICA's numerical representation of water transport in soil was improved and is now much more robust against extreme weather events.
- We performed sensitivity analyses to understand how water and carbon fluxes simulated by MuSICA are sensitive to specific model parameters. These sensitivity analyses were used to inform model optimizations at Hesse. MuSICA was optimized during average meteorological years and model skills were assessed during the extreme year 2003. Figure 1 shows the model performance during validation for the dry year 2003.
- Simulations are currently ongoing investigating the impact of recurring drought events.

Main conclusions including key points of discussion — The results of ROOTUP indicate that Cl^- concentrations are a promising tracer to inform and improve the description of matrix flow, preferential flow and root water uptake in ecosystem models. The ecosystem model MuSICA was made fit to describe this tracer as well as water isotopes in soil moisture. The model is thence a powerful tool to explore how water fluxes influence ecosystem processes during drought events.

Future perspectives — The year 2018 was in several respects very similar to the extreme year 2003. It is very fortunate that both Cl^- and water isotopes were collected this year at Hesse. We envisage that his data will strongly constrain the processes implemented in the ecosystem model MuSICA. These results will hopefully be available during the extension of the project but this also depends on data availability and hence on the "plateforme SilvaTech". At the end of the ROOTUP project, we should be able to finalize improved mechanistic descriptions of soil water flow in ecosystem models. These descriptions are in line with newer ecophysiological theories, such as the "two water world hypothesis" theorizing that two distinct water pathways of fast and slow flow have different fate in the hydrosphere. Furthermore, a realistic representation of water fluxes is essential in forecasting drought impact on forests. Drought severity and frequency are projected to increase in Central and Western Europe over the next decades. We hence believe that our results will be very useful to the ARBRE community to predict future forest ecosystem functioning under climate change.

Valorization —

Disentangling soil water movements to improve the forecast of drought impact on forest ecosystems (2018). Gennaretti F.; Ogée J.; Legout A.; Van Der Heijden G.; Didier S.; Cuntz M. *The 3rd ICOS Science Conference, Prague, Czech Republic, 11-13 September 2018.* [English]