Augmenting the Mesoscale Hydrologic Modeling system (mHM) with adequate vegetation dynamics for improved representation of coupled water and carbon cycles

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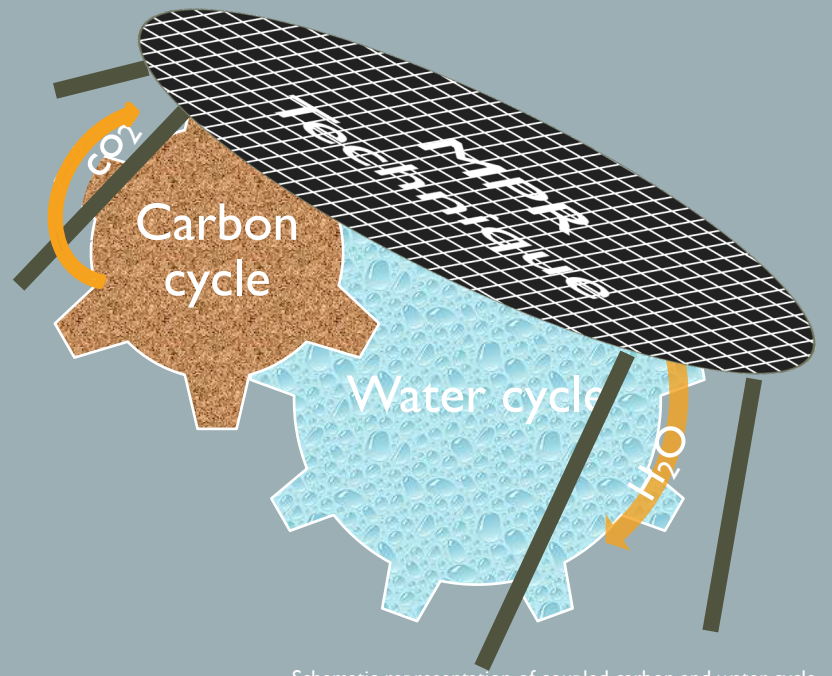
1) Introduction

- Investigating the potential of coupling a simplified Vegetation Model (VM) in the existing Mesoscale Hydrologic Model (mHM).

- We seek to improve the representation of coupled and interlinked processes of water and carbon fluxes, particularly under extreme events.

- The focus of this study is on developing a low complexity vegetation model with the least possible loss of accuracy.



Schematic representation of coupled carbon and water cycle

2) Study sites

- Central Germany within the Bode catchment – Central German Lowland in Saxony-Anhalt.
- Part of the TERENO (TERrestrial ENvironmental Observatories) Project and ICOS (Integrated Carbon Observatories) research infrastructure.

3) Data

- Daily carbon, water and energy flux measurments (from 2015 to 2019) using Eddy covariance technique.
- Recorded soil related data and properties.

Picture taken from: www.ufz.de/index.php?en=46

MOMENT

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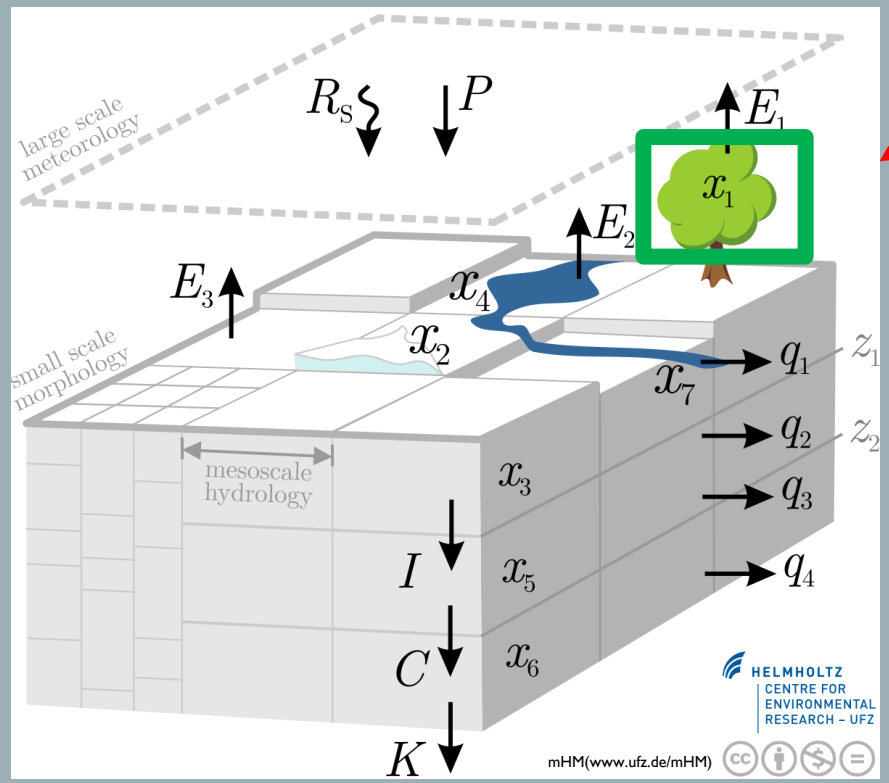
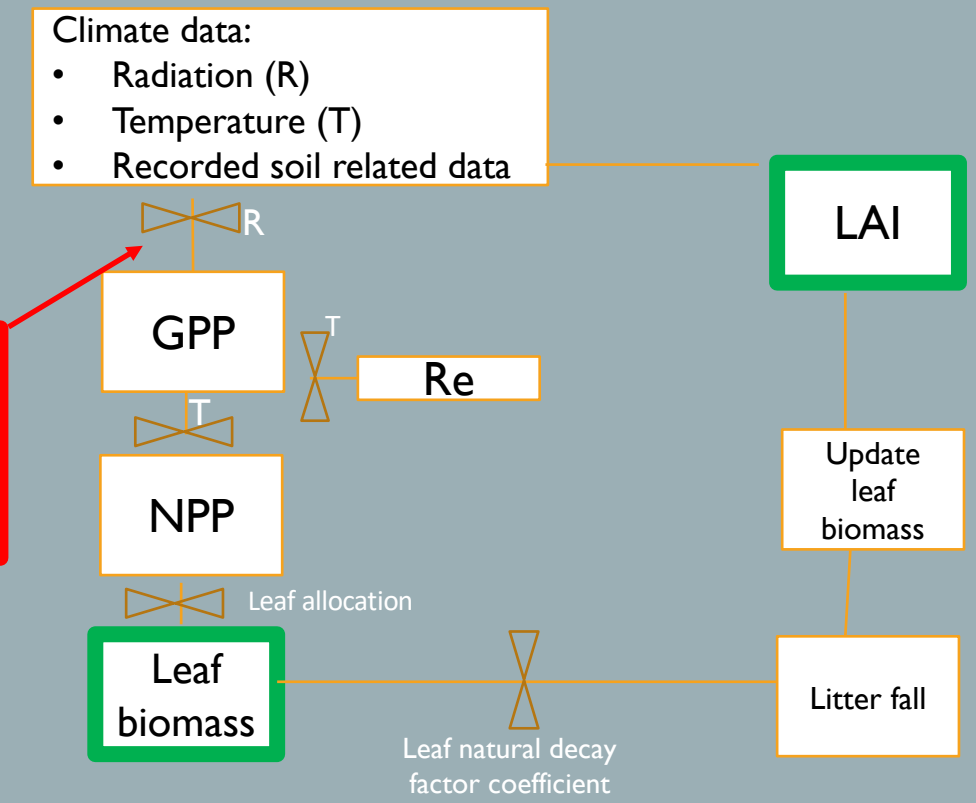
4) Methodology and Model Development

- Developing a parsimonious Vegetation Model (VM) to simulate above ground carbon biomass (Leaf biomass referred to as B_l).





Schematic representation of mechanistically linked vegetation and hydrological processes;

- The core of the VM model is composed of: Light use efficiency (LUE), Photosynthetically Active Radiation(PAR), GPP, NPP, Respiration (R_{eco}), allocation ratio ($\emptyset_l$), decay factor (K_l), and SM and T stress factors (ε).

$$\frac{dB_l}{dt} = (LUE * \varepsilon_{(t)} * PAR_{(t)} * fPAR_{(t)} - Re) * \varphi_l(B_l)_{(t)} - k_l * B_{l(t)}$$ - Management factor

(Ruiz-Pérez Guiomar et al., 2016, HESS)

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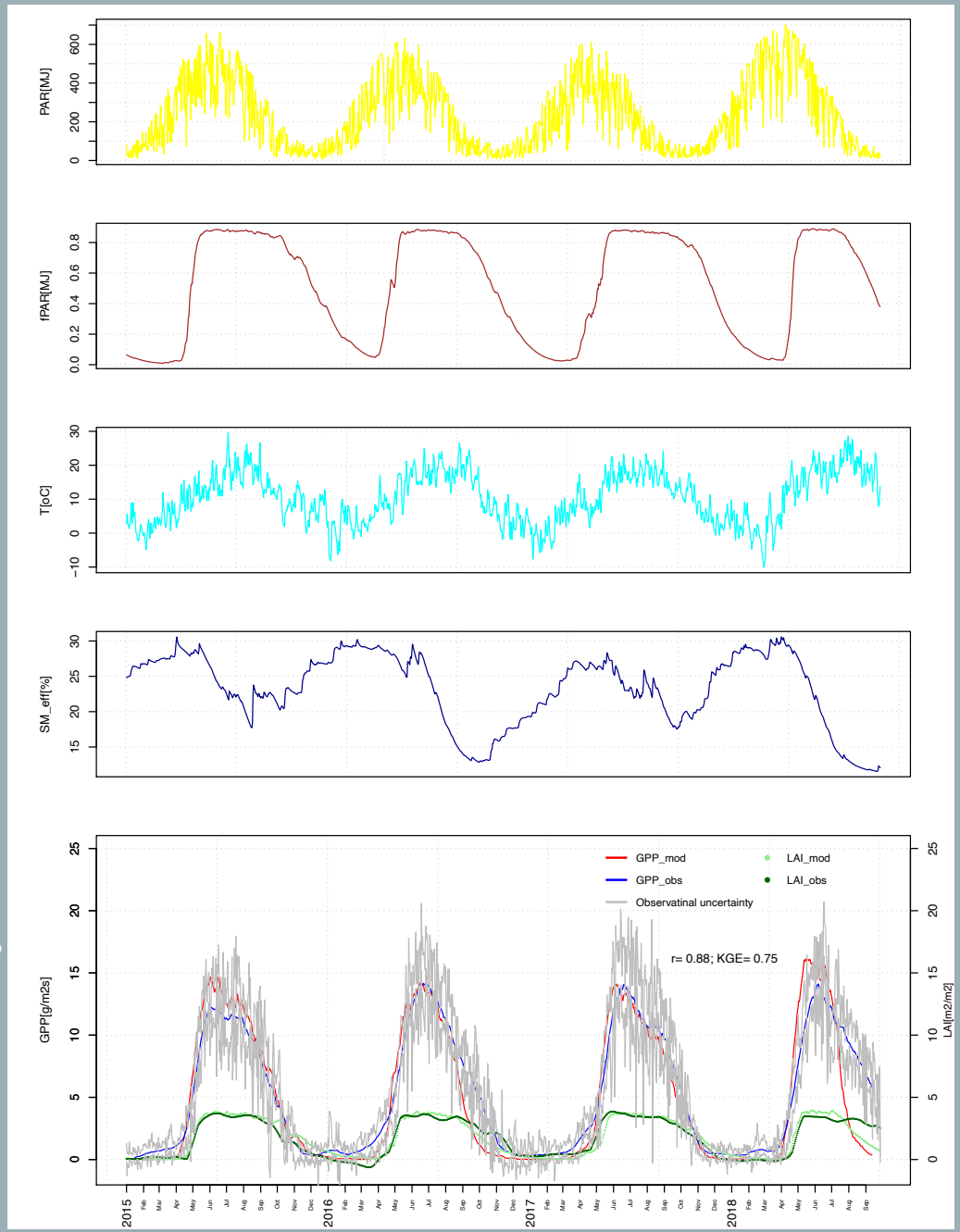
5) Preliminary Results

5.1) Model performance: GPP and LAI Simulations

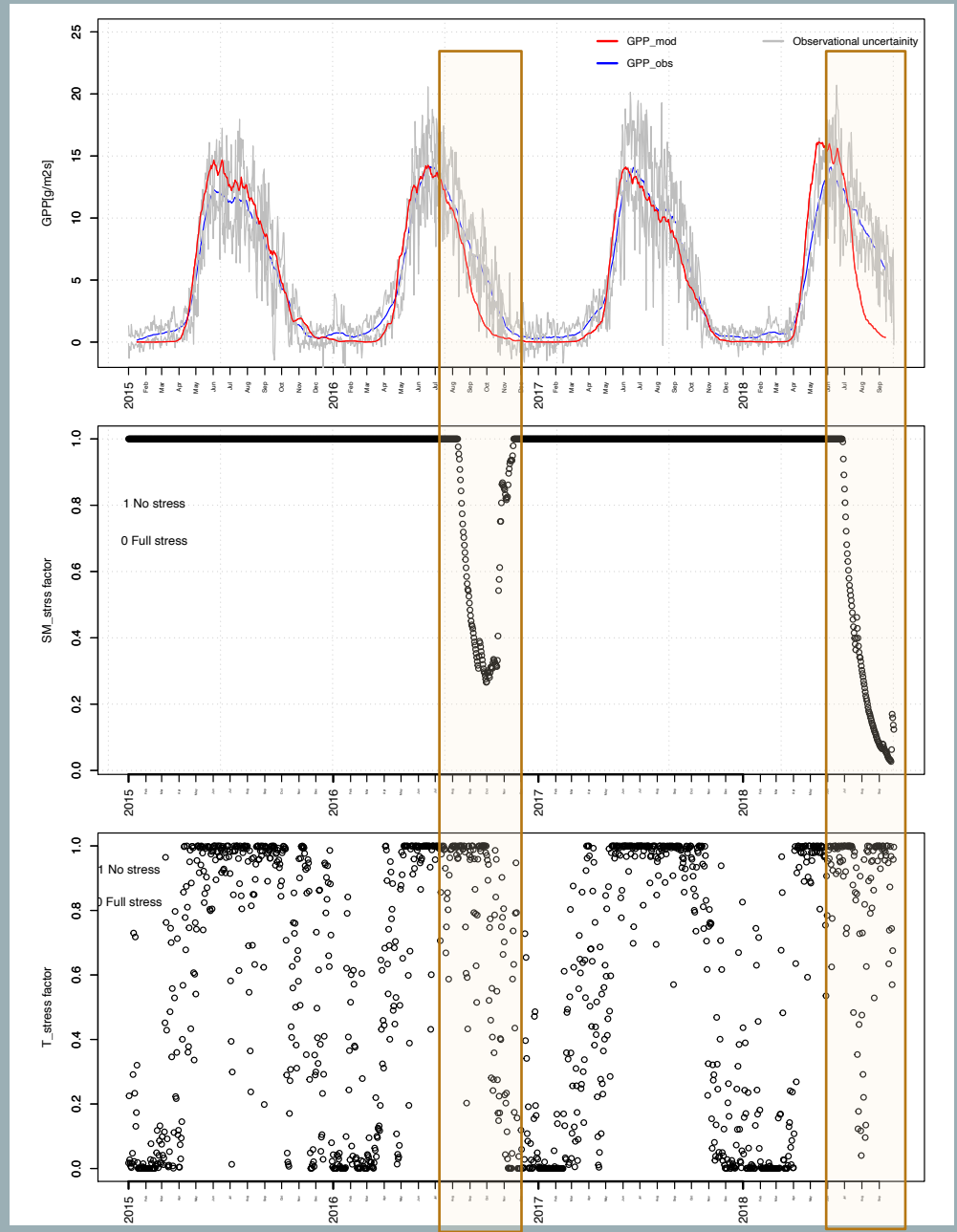
This figure shows daily dynamic simulations of GPP and LAI with the forcings shown in the top four panels.

- LAI dynamic is mainly evolving within the GPP simulation. In overall, simulated and observed values show good match.
- GPP simulation shows a reduction, during late 2016 and 2018, therefore LAI dynamic is not reproduced well either.
- A phenology module, as a functions of accumulated daily temperature, still needs to be added to the model.



5.2) Environmental Modifiers: soil moisture (SM) and temperature (T) stress

- This figure illustrates the simulated GPP with the grey lines shows observational uncertainty range.
- Some underestimation of GPP shown in the shaded area can be seen in the extreme events of 2016 and 2018 drought.
- The middle figure shows temporal development of an effective soil moisture (SM) stress derived based on observations at different soil depths.
- The bottom figure represents the temporal evolution of temperature stress applying an optimal temperature and normal curve distribution.



6) Outlook

- Despite the simplifications in the Vegetation Model structure, the model captures GPP and LAI dynamics reasonably well.
- During the extreme events (2016 and 2018) there is a noticeable reduction in simulated GPP. At this step, it is still unclear whether some processes are missing in the simplified VM or, it is related to plant response to drought stress.
- Further improvement in the Vegetation Model structure and its coupling to mHM are work in progress.
- It is expected that the VM within mHM improves our understandings of interlinked water and vegetation dynamics, particularly under extreme events, across spatial scales.