Sensitivity of the Regional Climate Model MAR to Vegetation Dynamics in Forested Areas

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I. Context

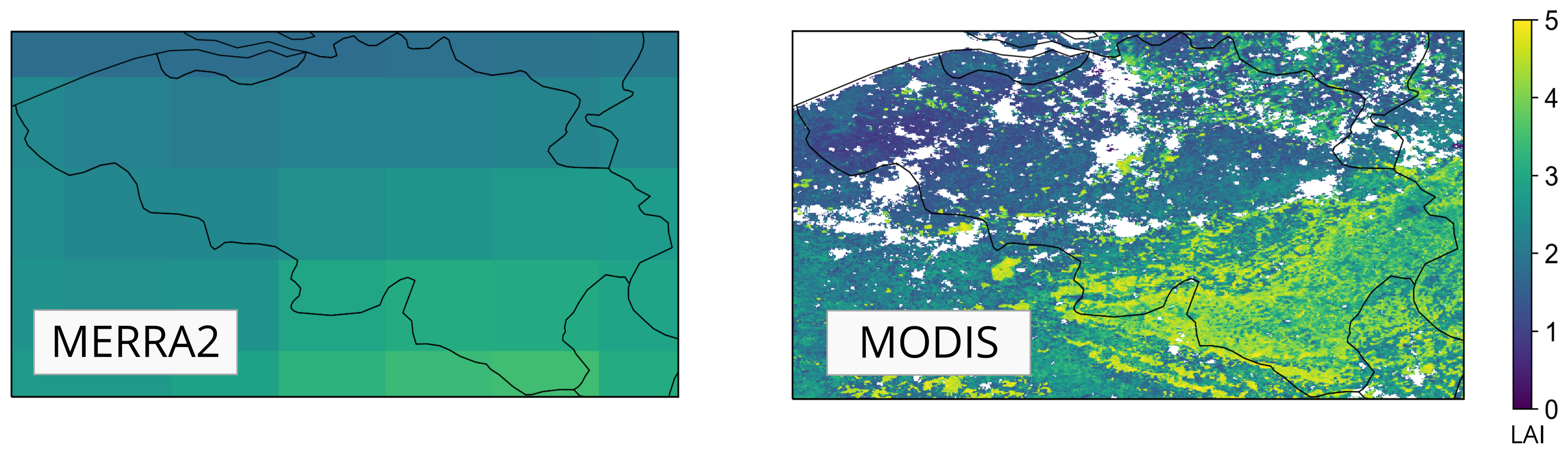
Climate change is having a profound **impact** on **forest** ecosystems, leading to increased occurrences of droughts, wildfires, and disease outbreaks. In recent years, and even in recent weeks, **Belgium** has **experienced** several **forest** and **bush fires**, catching authorities off guard due to limited monitoring and preparedness. These events raise serious concerns, particularly as such extremes are expected to become **more frequent and intense in the future**.

Monitoring could be improved **with** the regional climate model **MAR** (Modèle Atmosphérique Régional) that offers the ability to assess both current and future climate conditions over Belgium at a high spatial resolution of 5 km. However, **uncertainties** remain the model representation of the **vegetation**, which limits the accuracy of near-surface climate projections.

The project aims to investigate the **impacts of climate change on forest ecosystems,** and the **resulting climate feedbacks** by **coupling** MAR with the dynamic **vegetation model** CARAIB. Additionally, the **assimilation** of **remote sensing data**, such as the MODIS Leaf Area Index (**LAI**), will help refine vegetation representation and improve the reliability of model outputs.

Fires occurring in Belgium mid-April © TV Lux

II. MODIS LAI into MAR

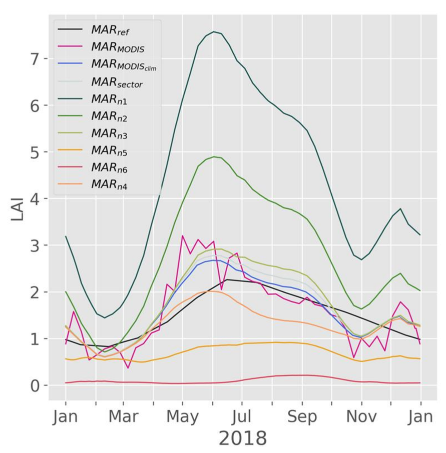


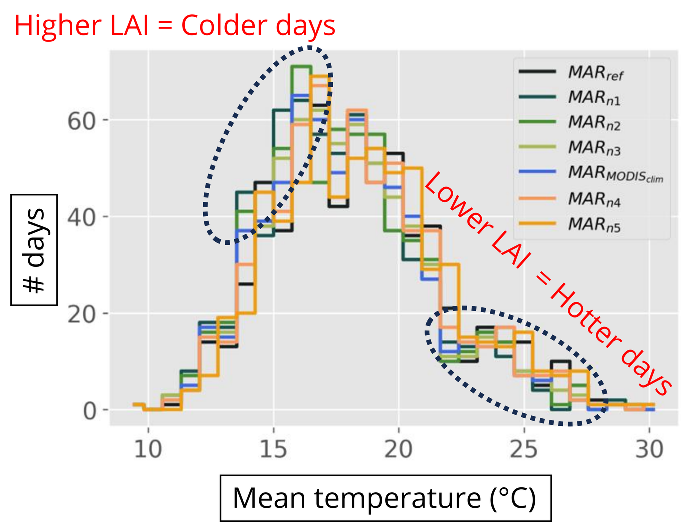
MODIS is included into MAR by replacing its LAI input. MAR was **previously** using the **monthly MERRA2 LAI** database [1]. This database has been **replaced** by a climatology based on **MODIS 8-day LAI at 500m** [2]. The **possibility to use daily observations** of LAI as input as also been implemented into MAR.

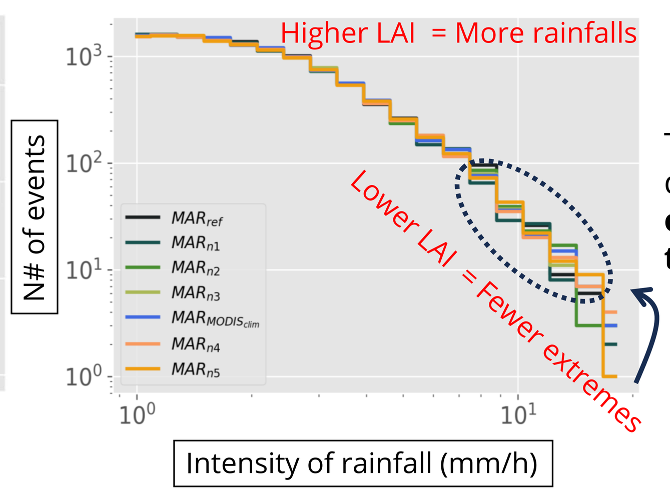
III. Sensitivity of MAR to LAI

We performed **multiple simulations** over the same domain and period but with **noise** applied to the **LAI input**.

The **relation** between the different **variables** and the **change in LAI** is **not straight forward**. For most of the variables, increasing the LAI do not result in a change of the same amplitude than when reducing it.





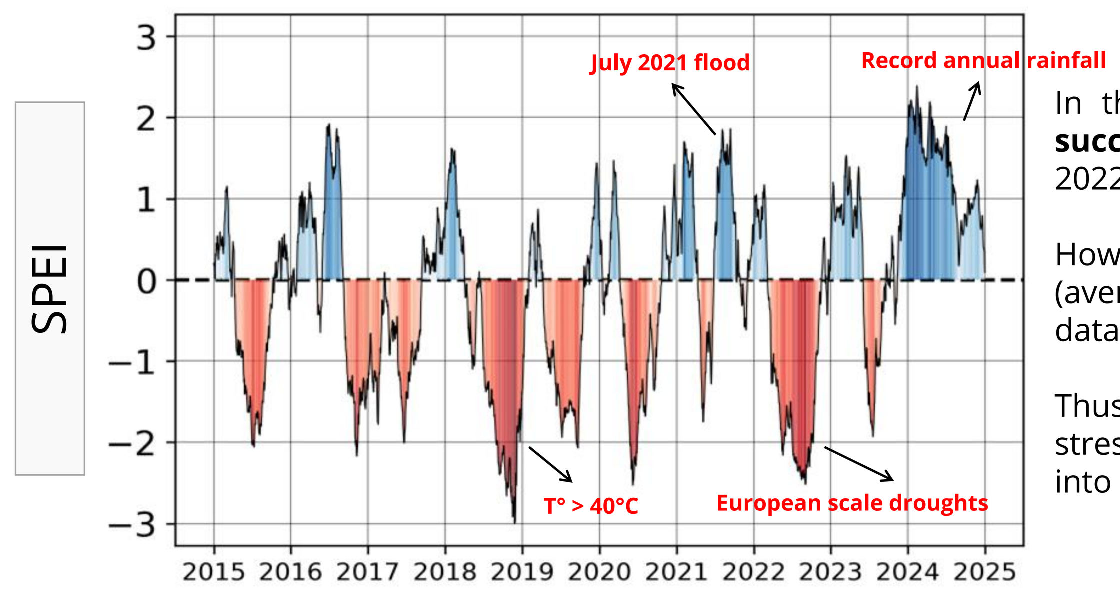


The **impact** was different **depending on the season and the variable.**

LAI input | 50km ➡ 500m | Monthly ➡ 8-days | **LAI Sensibility** | **Unsymmetrical**/nonlinear | Depends on the **season**

IV. Extremes in Belgium

With climate change, Belgium is experiencing more and more hot days as well as an increase in droughts frequency. Here we use the **Standardized Precipitation Evapotranspiration Index (SPEI)** to better identify extreme events [3].

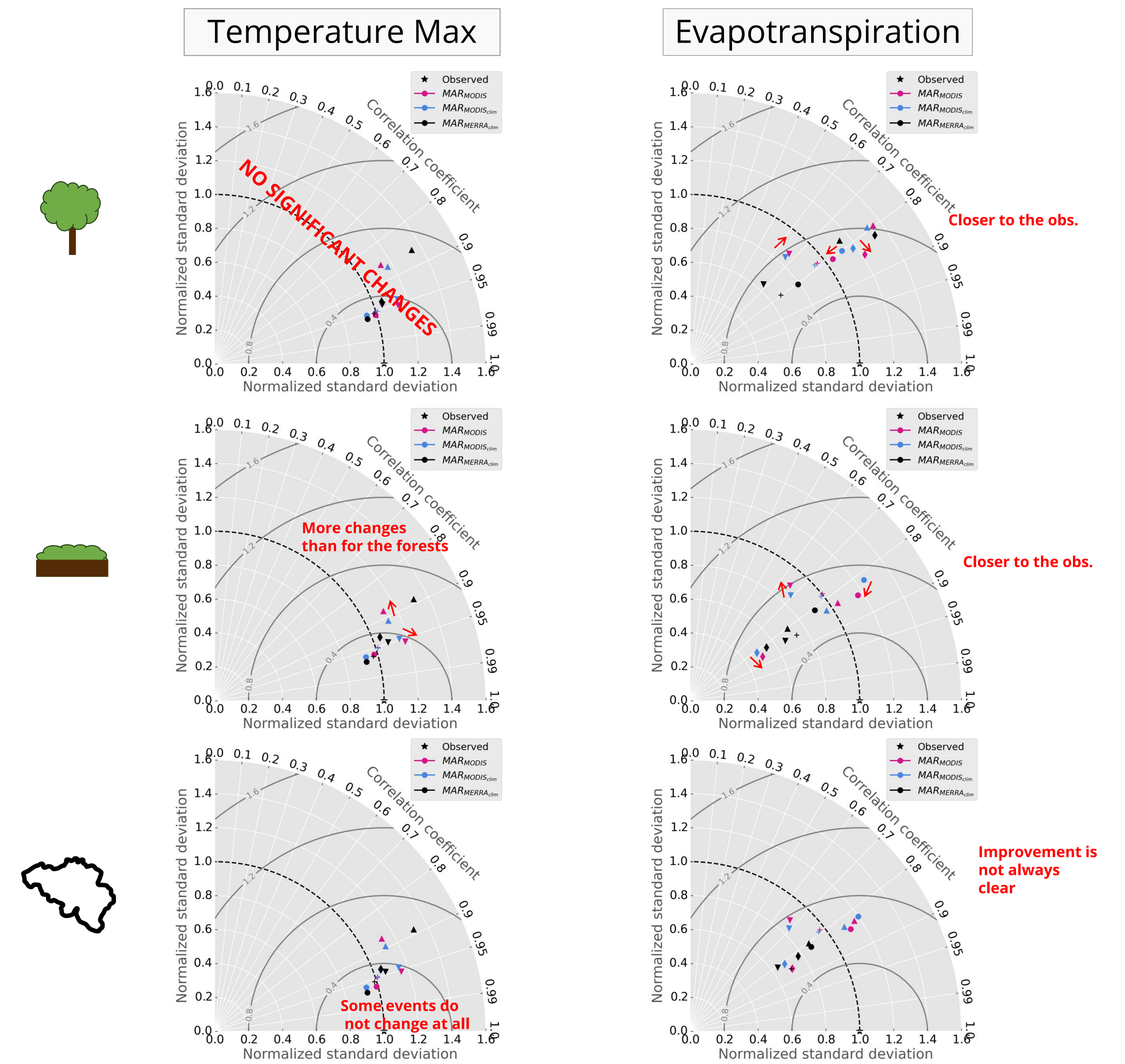


In the past years, Belgium undergoes **successions of droughts** (2018-2019-2022) **and pluvial periods** (2021-2024).

However, **MAR uses LAI climatology** (average) computed on multiple years of data.

Thus, the **change in LAI** caused by the stress on the vegetation **is not included** into MAR.

V. Impact during extreme events



While **MAR** represents the climate **accurately on average**, it **struggles** to replicate **specific events**.

The **problem** partially comes from MAR using a **climatology of LAI**. Thus, during extreme events, the model tend to **overestimate / underestimate the vegetation** cover. By using the **8-days LAI from MODIS**, we can provide MAR a **more accurate LAI** during these periods.

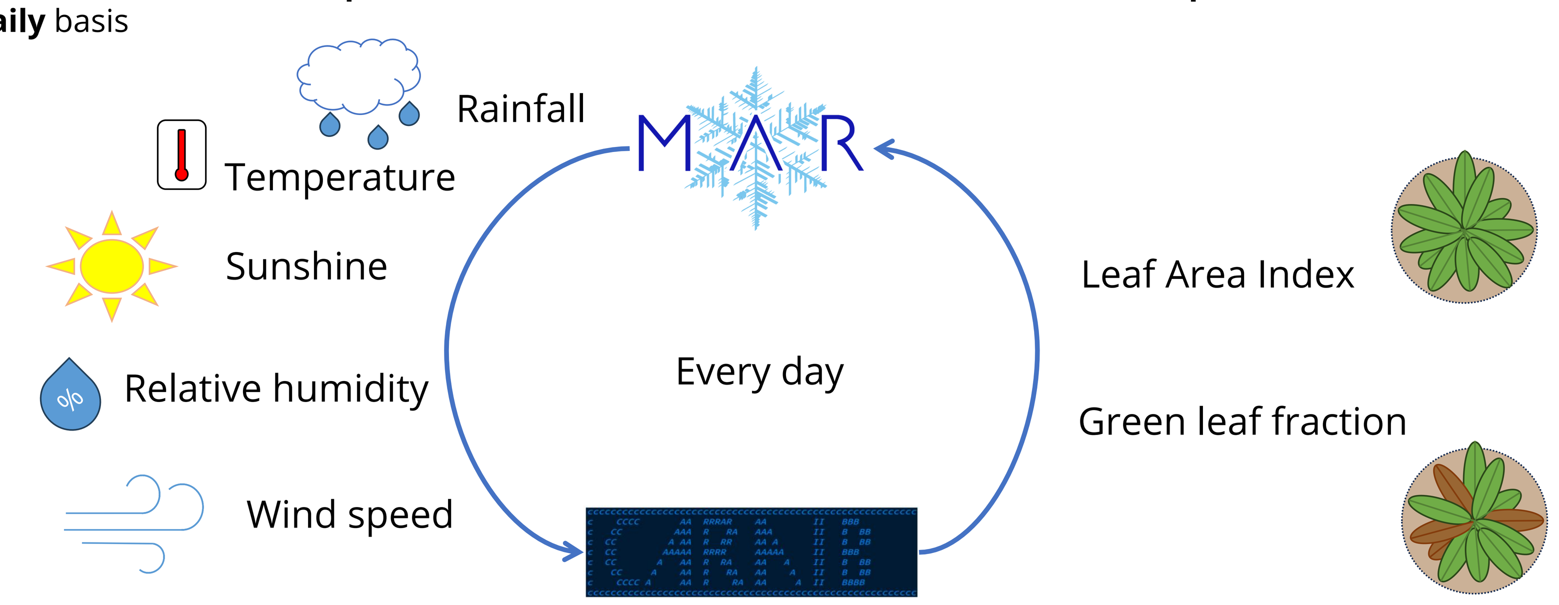
8-days LAI | **Less changes in Forests** as they are **more resilient** than low vegetation **to extreme events**

VI. Coupling with a vegetation model

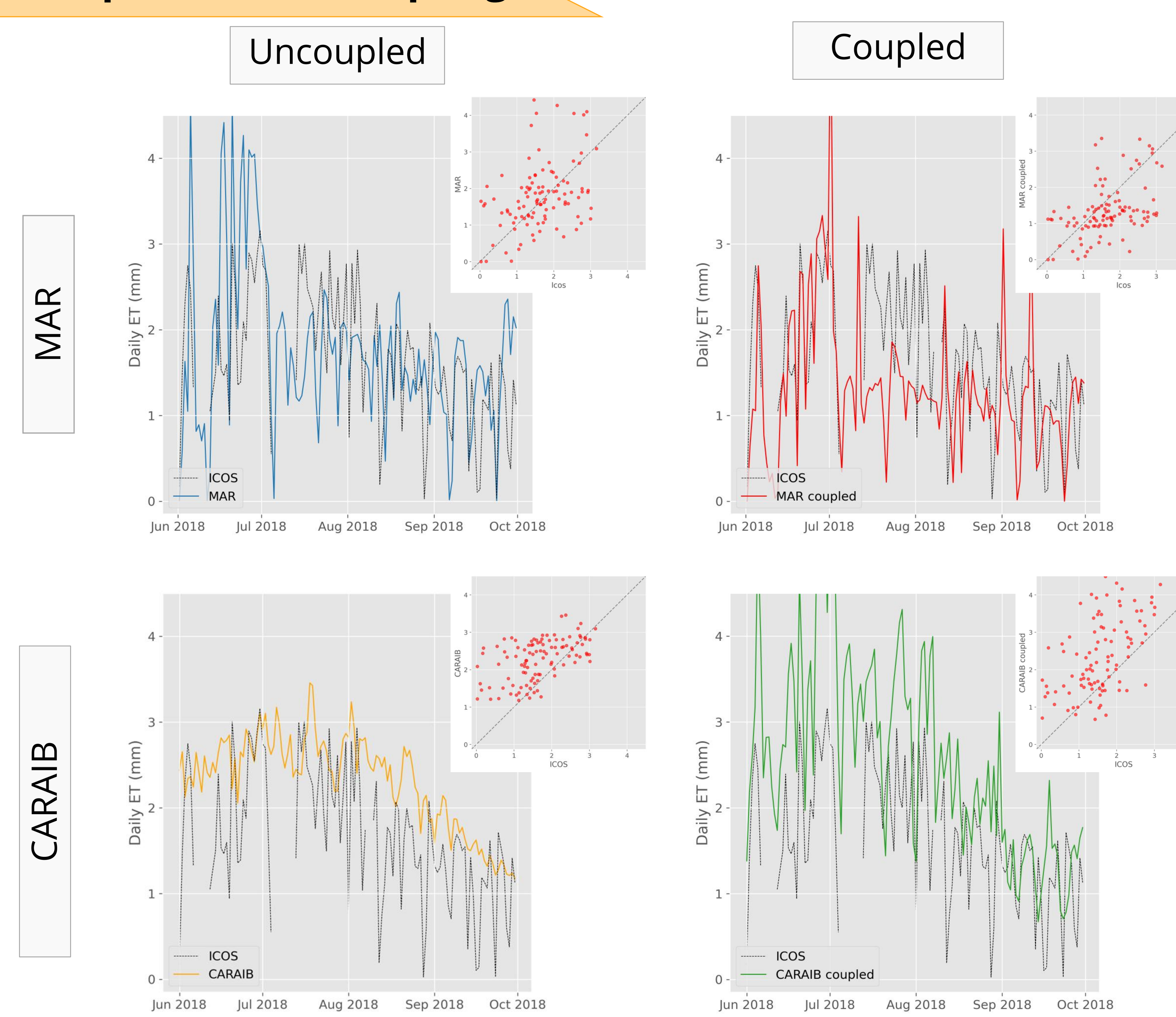
Decreasing the sensitivity of MAR to vegetation and consequently decreasing the uncertainties in the vegetation-climate interaction, can be reached by **coupling MAR with a dynamical vegetation model**.

The model to be coupled with MAR is the CARbon Assimilation In the Biosphere (**CARAIB**) model [4]. By running concurrently, **the two models** can **provide** each other with the **variables** they require **as inputs** or replace the outputs of the other model.

In this case, **MAR** would **provide** CARAIB with **climatic data** and **CARAIB** would **provide** MAR with **LAI**, on a **daily** basis



VII. Impact of the coupling



Preliminary results from **comparing evapotranspiration** (ET) simulated by the two models, both in **standalone** and **coupled** configurations, **with ICOS** observations indicate that coupling **increases the daily variability** of **CARAIB** and **reduces** the average **ET** produced by **MAR**.

For both models, **coupling** also leads to a **higher correlation** with the observed data.

MAR | **Better correlation** | **CARAIB** | **Increased daily variability**

[1] Global Modeling and Assimilation Office (GMAO) (2015), *inst3_3d_asm_Cp: MERRA-2 3D IAU State, Meteorology Instantaneous 3-hourly (p-coord, 0.625x0.5L42), version 5.12.4*, Greenbelt, MD, USA: Goddard Space Flight Center Distributed Active Archive Center (GSFC DAAC), Accessed on 07-02-2024 at doi: 10.5067/VJAFPLI1CSIV [2] Myneni, R., Knyazikhin, Y., Park, T. (2015). MOD15A2H MODIS Leaf Area Index/FPAR 8-Day L4 Global 500m SIN Grid V006. NASA EOSDIS Land Processes DAAC. http://doi.org/10.5067/MODIS/MOD15A2H.006 (Terra) http://doi.org/10.5067/MODIS/MYD15A2H.006 (Aqua) [3] Schneider, D. P., Deser, C., Fasullo, J., and Trenberth, K. E. (2013). Climate Data Guide Spurs Discovery and Understanding, *Eos Trans*. AGU, 94, 121–122, https://doi.org/10.1002/2013eo130001 [4] Warnant, P., L. François, D. Strivay, and J.-C. Gérard (1994). CARAIB: A global model of terrestrial biological productivity, *Global Biogeochem. Cycles*, 8(3), 255–270, https://doi.org/10.1029/94GB00850