

In-Canopy Controls on VOC and Ozone exchanges a Multi-Layer Canopy Model intercomparison

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1. Introduction

Different 1-D canopy exchange models have been used to study the chemical exchanges between forests and the atmosphere. However, few efforts have been made to characterize errors and sensitivities of this type of models. Here we apply two 1-D canopy exchange models with chemistry and evaluate their performance to describe above-, and below canopy exchanges of reactive trace gases at the Vielsalm ICOS Class 2 ecosystem site for June 2023.

The site has undergone extensive VOC characterization through different long-term campaigns measuring the exchange of O₃ and VOCs in the trunk space (3.5 m a.g.l.; 2023, 2024) and above the canopy (52m a.g.l.; 2022-2024). Additionally, vertical concentration profiles have been measured to do a full characterization of the soil-canopy-atmosphere gradient. Here, we focus on the trunk space and above-canopy measurements to evaluate model performances. More information on the experimental setup and how to access to the full dataset is described in a recent publication by Dumont et al. (2025).

FORCASTv2.0

The **FOR**est **C**anopy **A**tmosphere **T**ransfer model (Wei et al. 2021) is a prognostic 1-D canopy exchange model. Emissions follow Steinbrecher et al. (1999; VOCs) and Yienger and Levy (1995; soil NO). The chemical mechanism is RCIM. Dry deposition schemes are Wesely (1989), Gao et al. (1993), and Nguyen et al. (2015). Initial/boundary conditions are from observations or CAMS Reanalysis data (EAC4). We run the model for 31 day/ consecutive 48 hour periods and test nighttime cloud representation in the model (inrad1 = constant cloudiness, inrad3 = adaptive). The model has 40 layers going up to ~5 km a.g.l. and is setup to offer high spatial coverage in the trunk (8) and canopy (10) spaces.

MLC-CHEM

MLC-CHEM: Offline version of **M**ulti-**L**ayer **C**anopy **C**hemistry-**E**xchange **M**odel implemented in a chemistry-climate model (Ganzeveld et al. 2002). It is driven by observed micro-meteorology and surface layer tracer concentrations (e.g., O₃, NO_x, CO, and CH₃OH). Emissions are described by MEGAN (VOCs), Yienger and Levy (1995; soil NO) and use compensation points for NO_x and NH₃. Deposition is modelled by using the Assimilation-stomatal conductance model (A-g_s). In-canopy chemistry follows a modified CBM4 mechanism. The model is setup with 6 canopy layers of ~4m.

2. Model description

3. Meteorological evaluation: FORCASTv2.0

As FORCASTv2.0 is a prognostic model that solves the energy balance explicitly to determine model temperature, we optimize the model setup to best represent temperatures measured at the site. Fig. 1 shows the net radiation (incoming-outgoing), as well as the sensible heat and latent heat fluxes above the canopy. Fig. 2 shows the measured and modelled temperature above the canopy and within the trunk space. The temperature gradient across the canopy is not well represented by the FORCASTv2.0 model and should be further optimized.

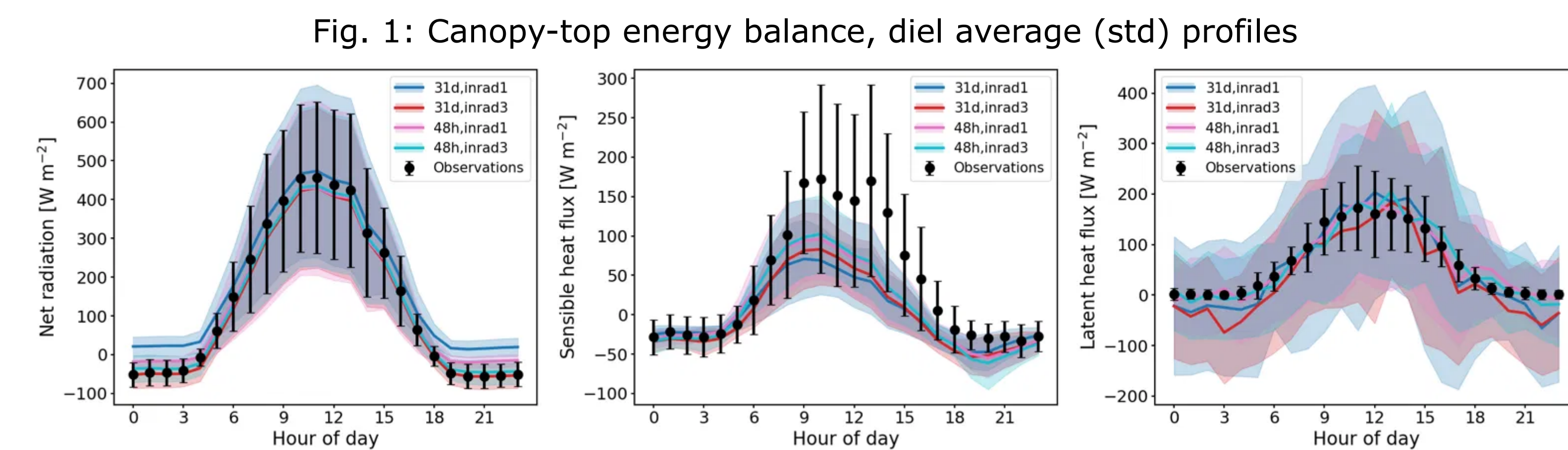
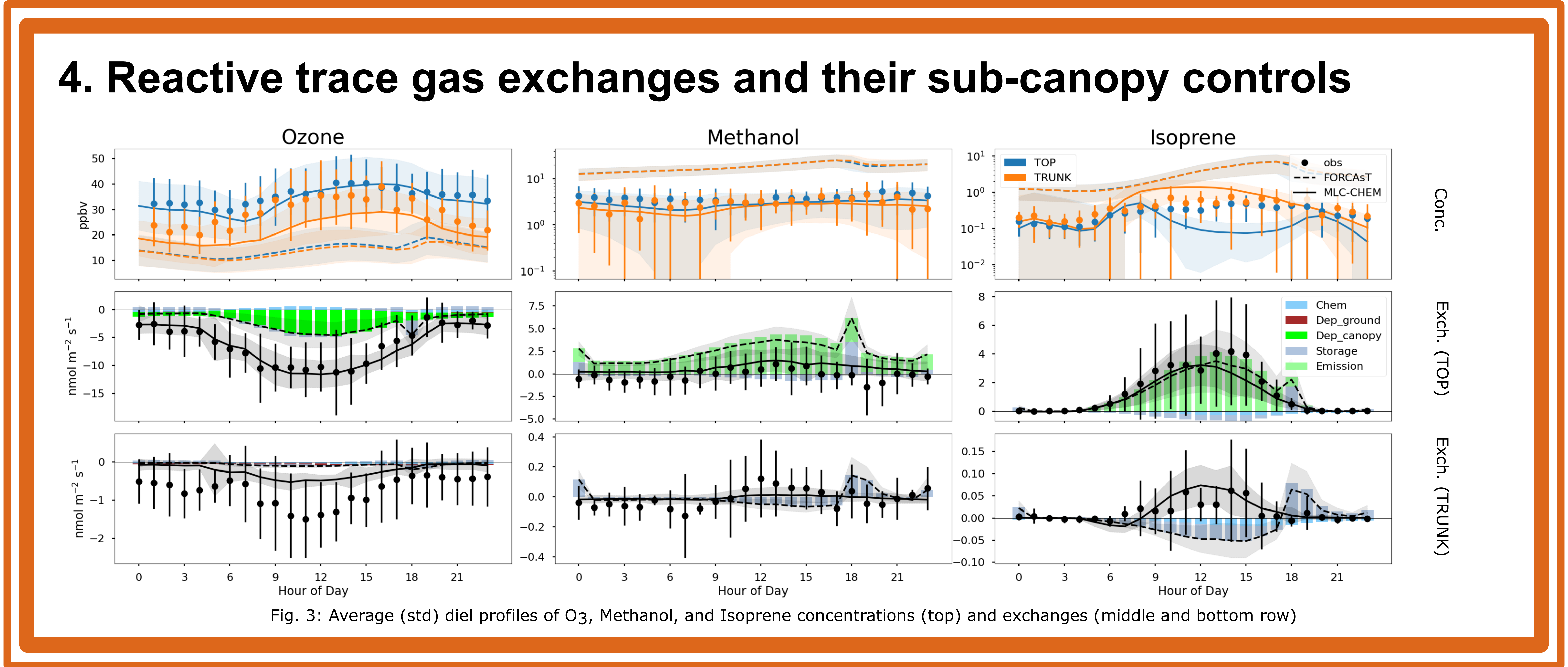
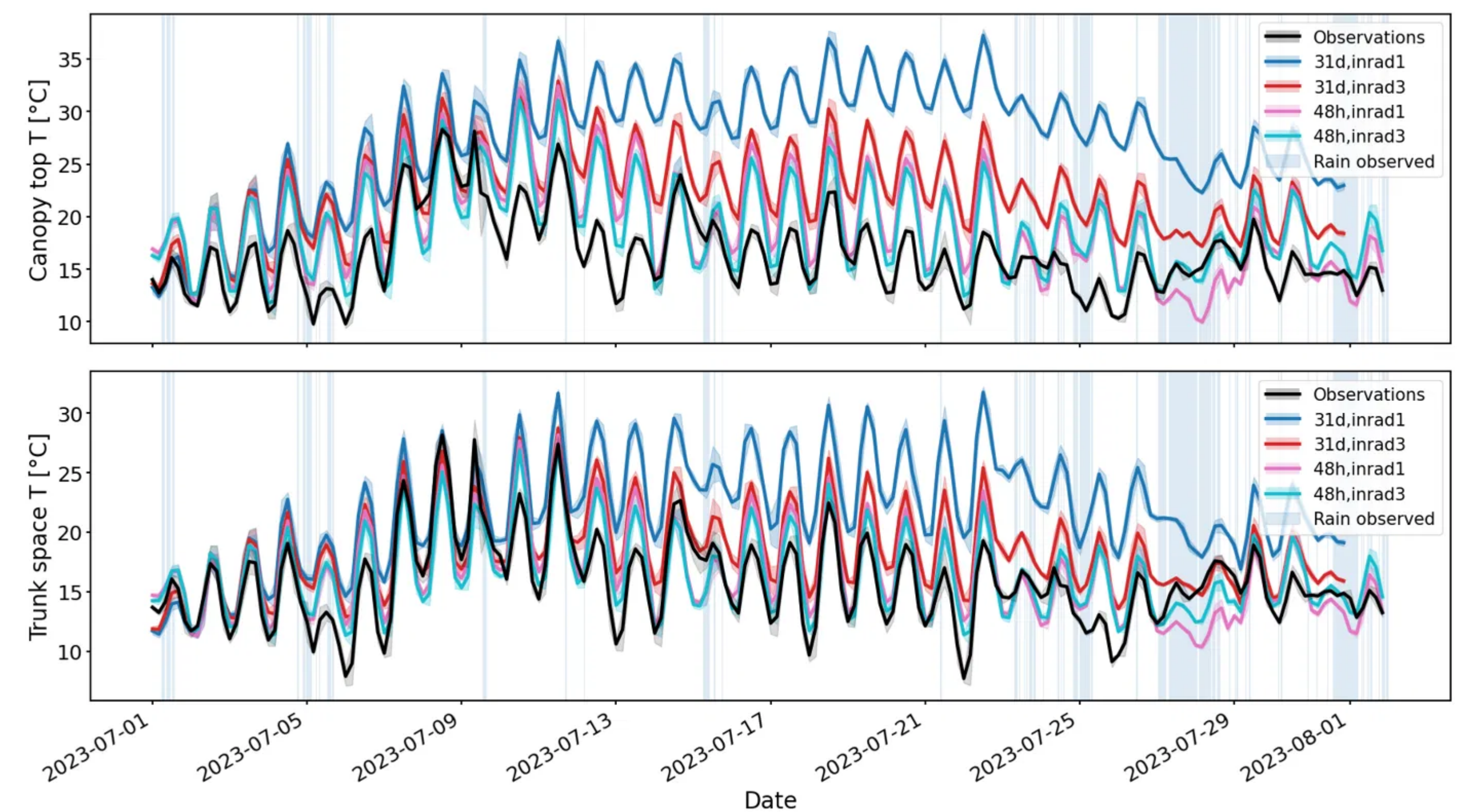


Fig. 2: Modeled and observed temperatures at 51 (TOP) and 3 (TRUNK) m a.g.l.



5. Conclusions

While MLC-CHEM reproduced well the concentrations and exchanges in the model, FORCASTv2.0 still needs further fine-tuning to better reproduce the temperature gradient in the canopy and setup the chemical environment to balance out the VOC-NO_x-O₃ interactions. Irrespectively of this chemical issue, methanol concentrations in the FORCASTv2.0 model are one order of magnitude too high due to a lack of deposition to the canopy.

6. Prospects

FORCASTv2.0 and MLC-CHEM will be used to analyse data from different VOC flux datasets across different sites in the Netherlands and Belgium to evaluate performance, uncertainties, and the role of physico-chemical processes affecting reactive trace gas exchanges at these ecosystems. For this, we are constructing a python environment to configure and run the FORCASTv2.0 model in a way that is more adaptable to a multi-site long-term study.