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Understanding the role of different parametrizations and parameters in calculating evapotranspiration: Insights from flux towers.

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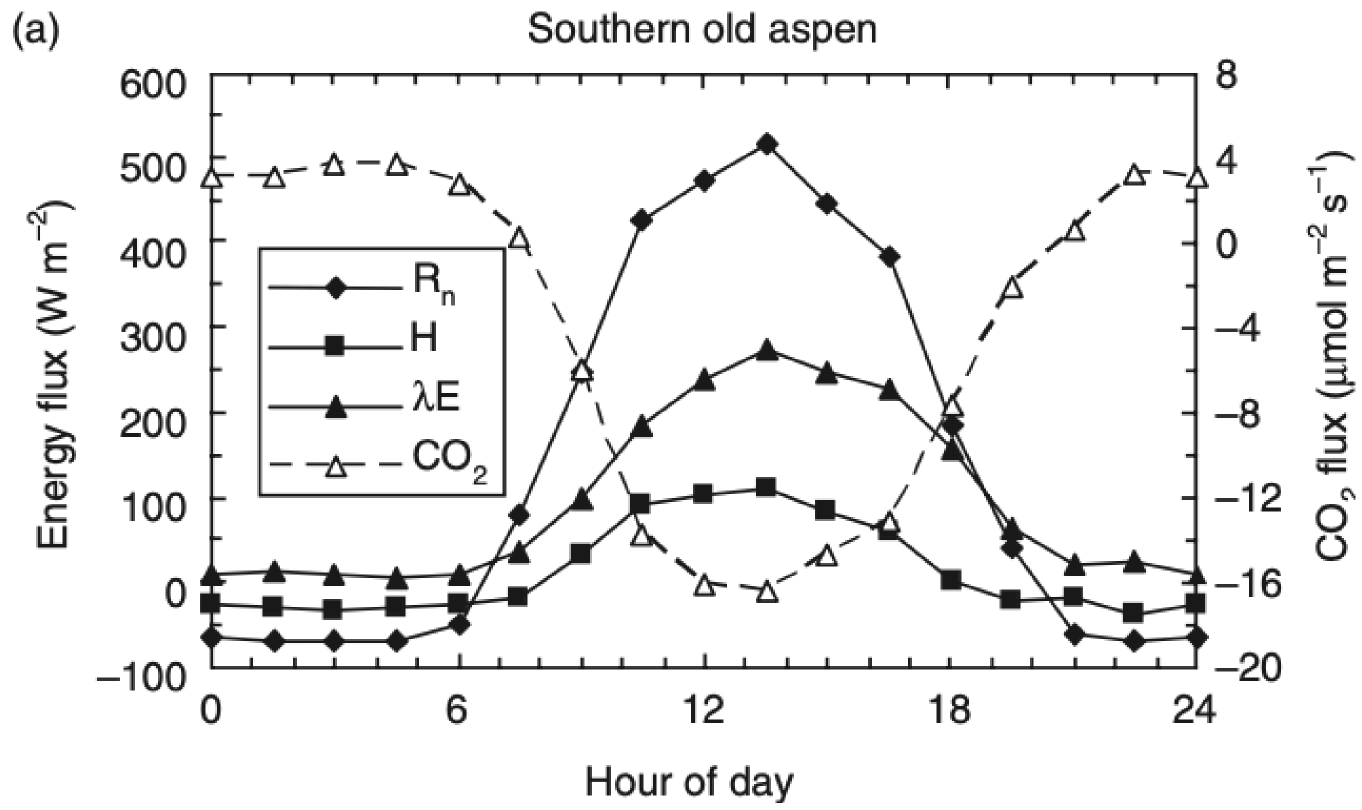
Background

- Current state-of-the-art models are limited in capturing diel latent heat:
  - Large biases on diurnal representation
  - Process mismatch during the night
  - Uncertainties on heat redistribution
  - Biases vary across all vegetation types

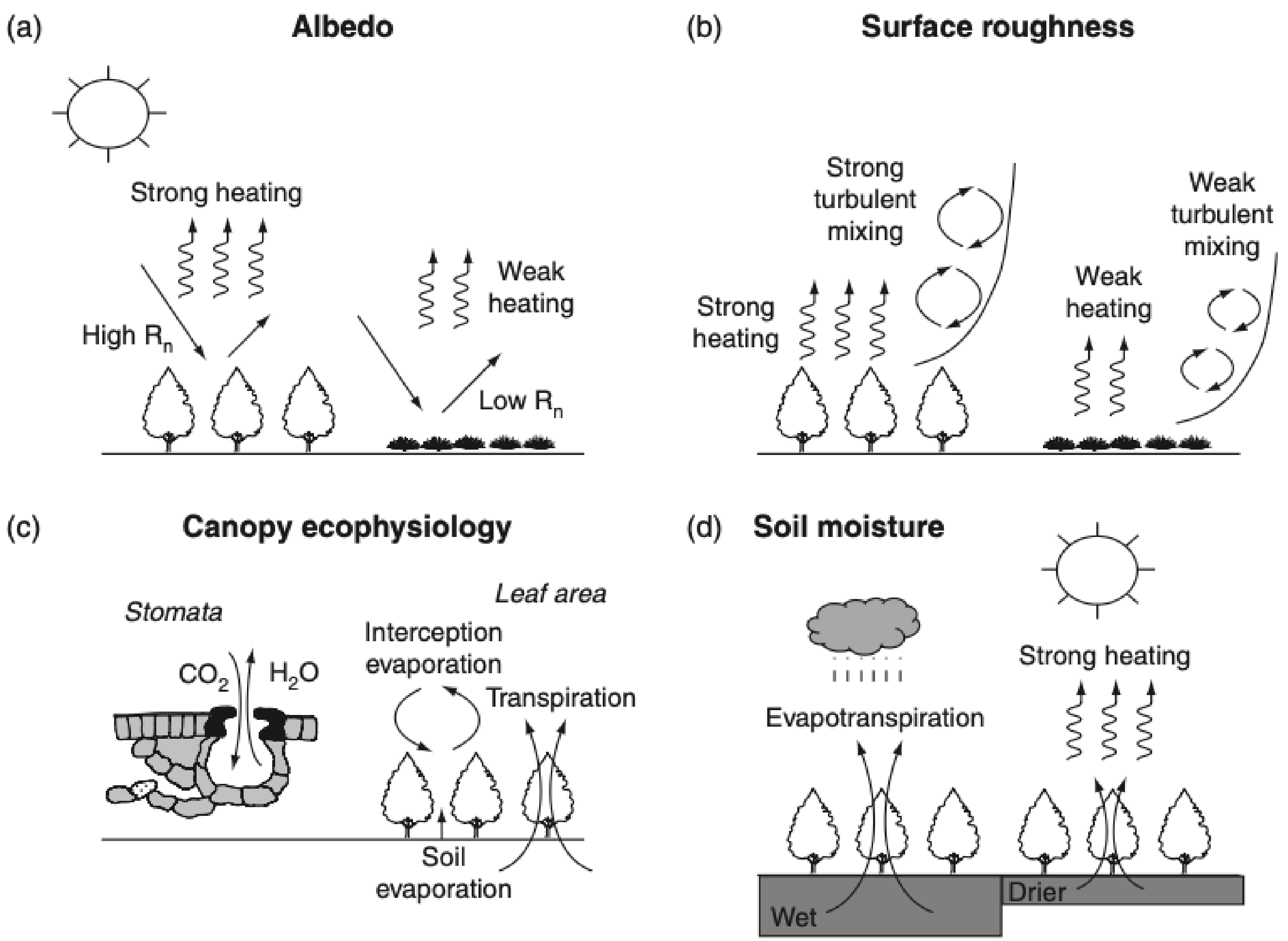


Bonan (2015)

Background

- To model the behavior of latent heat, several processes are involved:
    - Albedo
    - Surface roughness
    - Canopy ecophysiology
    - Soil Moisture

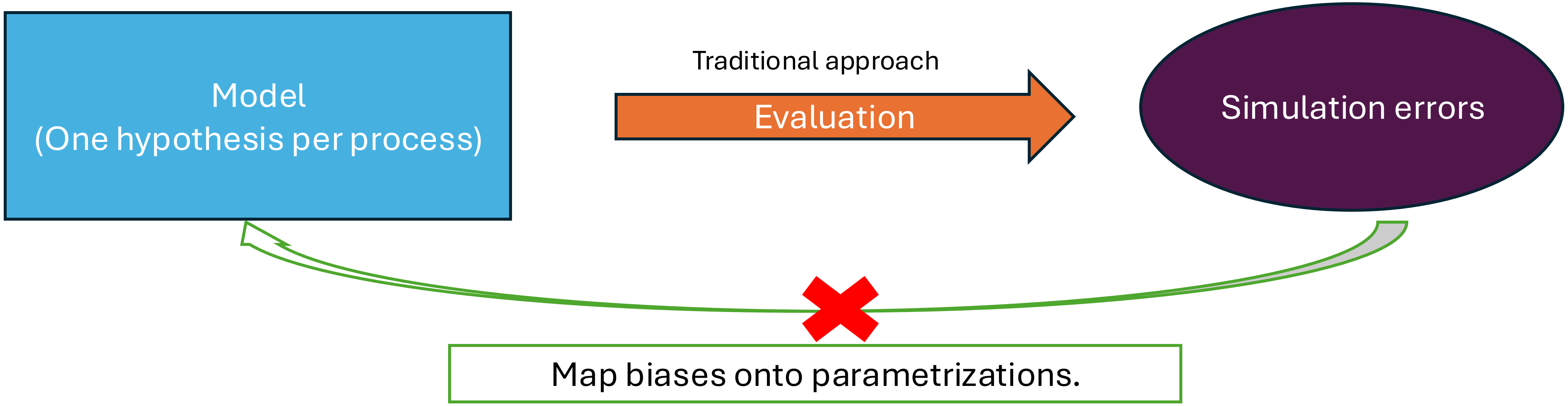
Which of these processes explains the biases observed in the diurnal latent heat?



Bonan (2019)

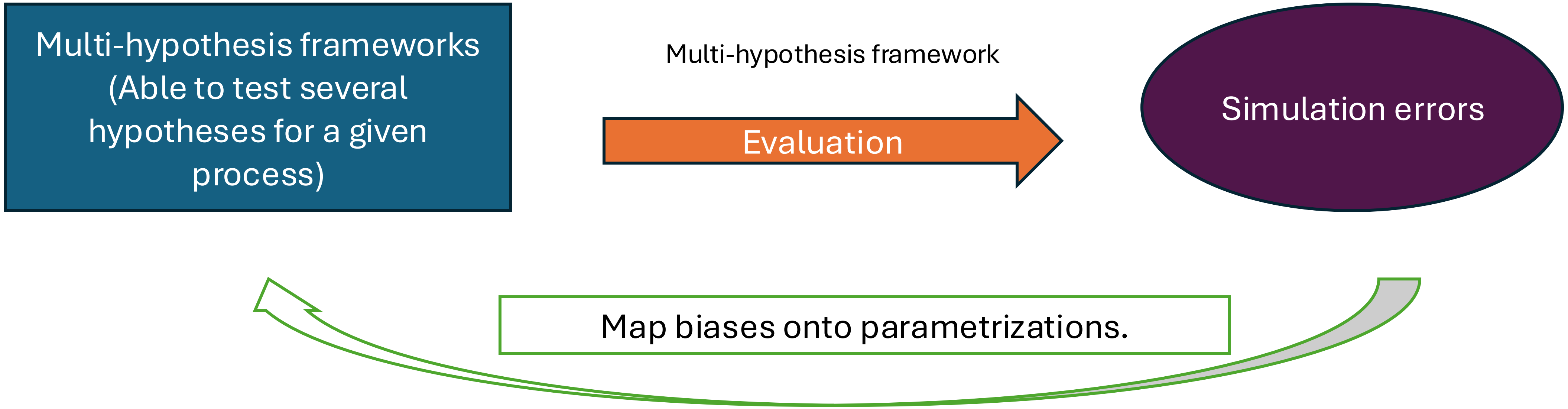
Current limitations: ad-hoc experiments

However, given the design of the Plumber experiments (e.g., parametrizations and parameters are unknown), **we cannot map these uncertainties onto specific parametrizations/processes or parameters** to improve the representations and reduce the simulation errors.



Paradigm shift: controlled hypothesis testing

- To tackle the problem, we used a multi-hypothesis framework (SUMMA, Clark et al., 2015) **to purposely evaluate the impact of several parametrizations on the simulation errors.**
- By isolating the impact of each hypothesis (e.g., how to represent a specific process), we can map simulation errors onto parametrizations and guide the improvements.



Approach

(1) Analysis of different parametrizations

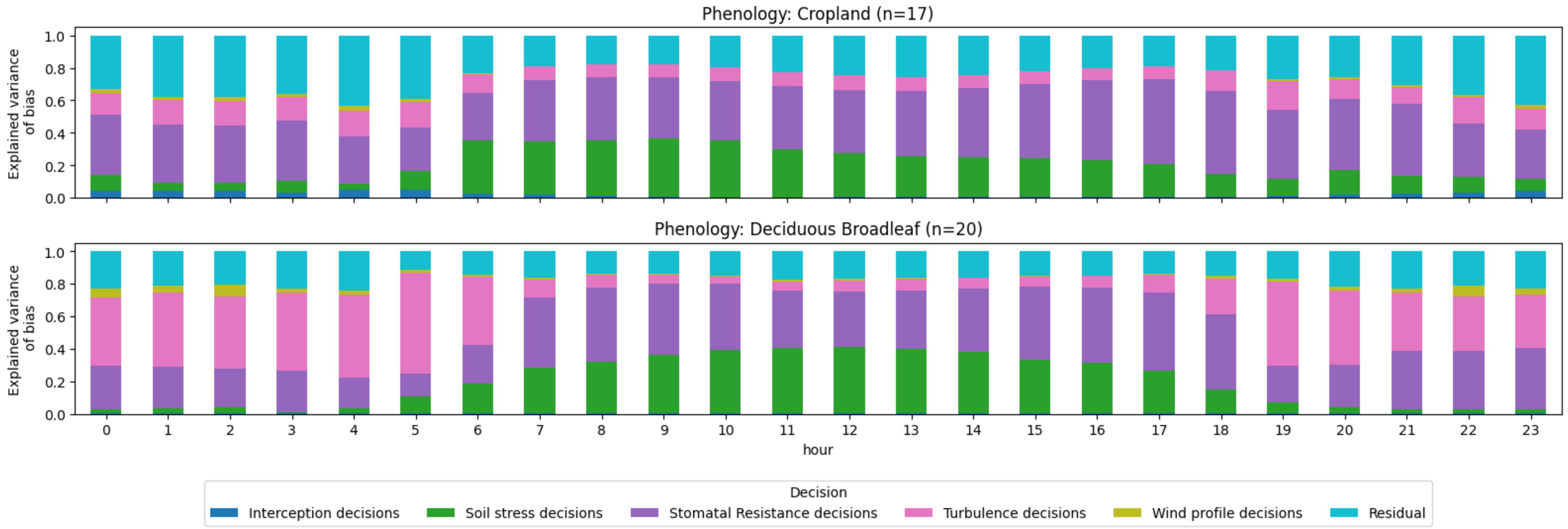
(2) Sensitivity analysis

(3) Calibration

(4) Model evaluation vs benchmarks

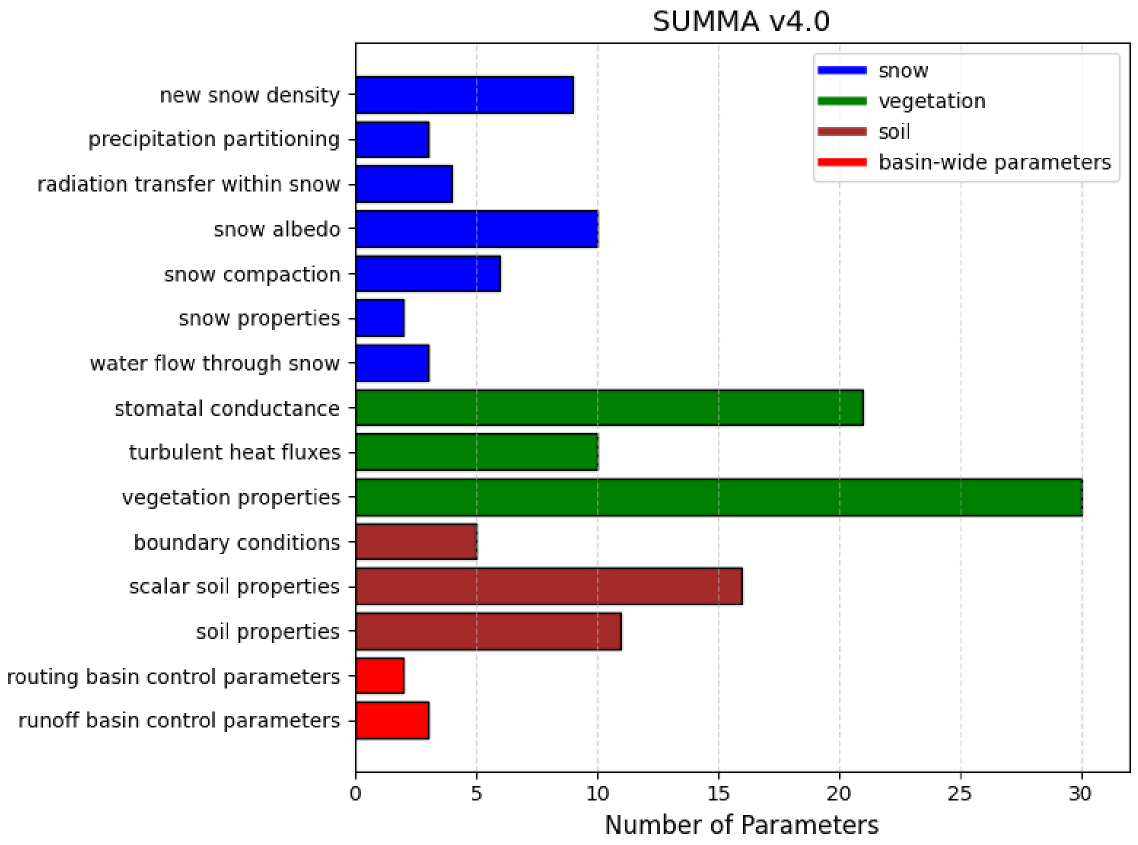
Analysis of different parametrizations

- 108 ensembles were run with different equations for stomatal resistance, soil stress function, interception, wind profile, and canopy turbulence.
- Different processes explain the biases in different vegetation types.
  - Stomatal and turbulence process representations explain most of the biases in forests.
  - Turbulence does not play a key role in short vegetation (croplands).
- **These ensembles utilized default parameters, raising questions about the influence of parameters on the results.**



Methodology for the Sensitivity Analysis

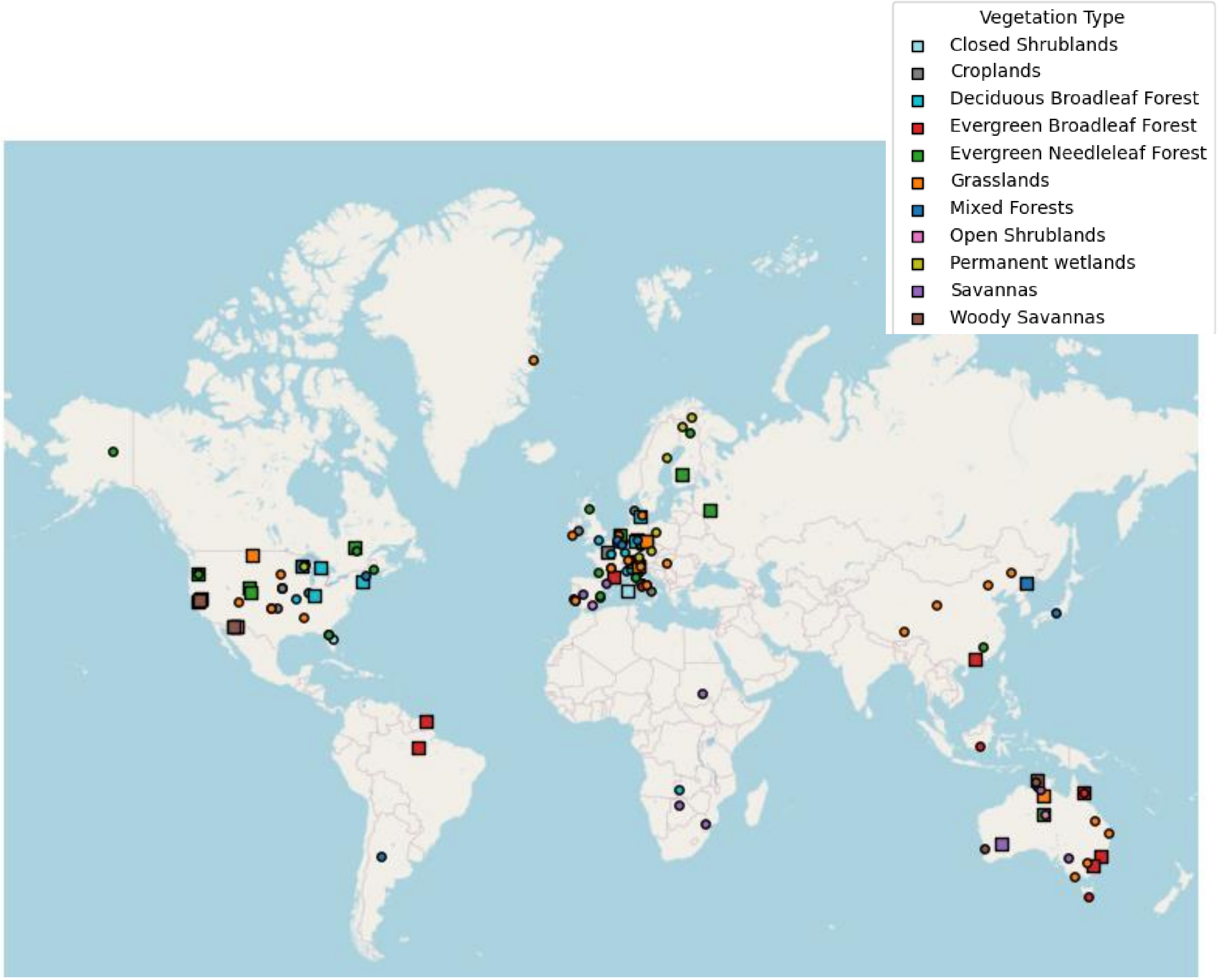
1. We determined minimum and maximum for each parameter based on literature and previous results.
2. Using these bounds, 4000 samples were generated using the Latin-Hypercube sampling to evaluate all 130 parameters.
3. We ran the sensitivity analysis in 43 sites in SUMMA and evaluated latent and sensible heat against measured-only values.
4. We determined first-order sensitivity analysis using PyVISCOUS (Liu et al., 2024)
5. We identified key parameters that accounted for 85% of the first-order sensitivity.



Sites

43 sites from the Plumber 2 experiment (Abramowitz et al., 2024) were selected based on the following criteria:

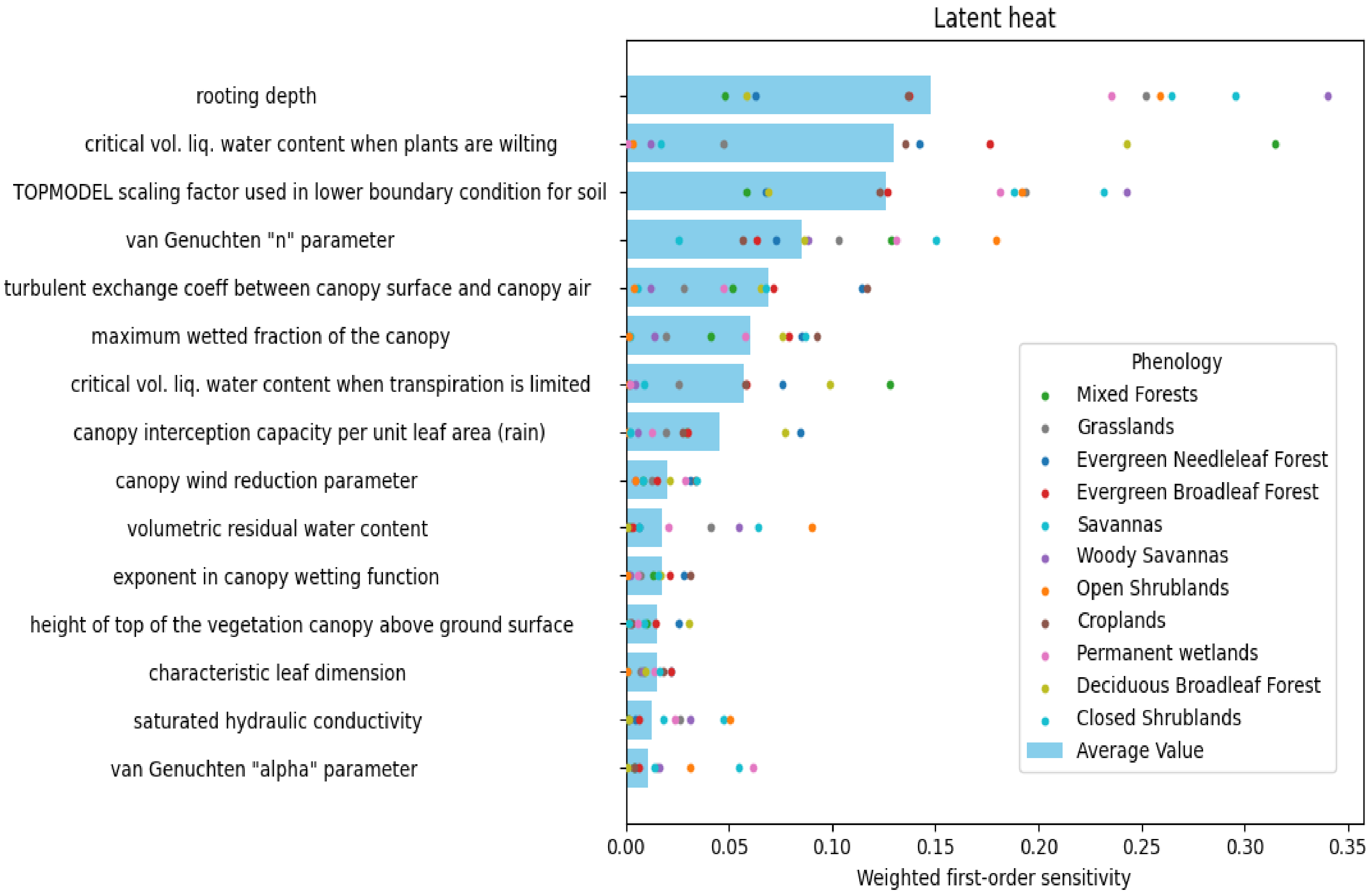
1. **Minimal Data Gaps:**
   Sites with a low number of missing observations were prioritized to minimize the need for gap-filling.
2. **Extended Observation Period:**
   Only sites with more than three years of recorded observations were included.
3. **Diverse Environmental Representation:**
   Sites were chosen to encompass a range of phenological patterns and climatic conditions.



Results: Latent Heat (LH)

LH is controlled primarily by:

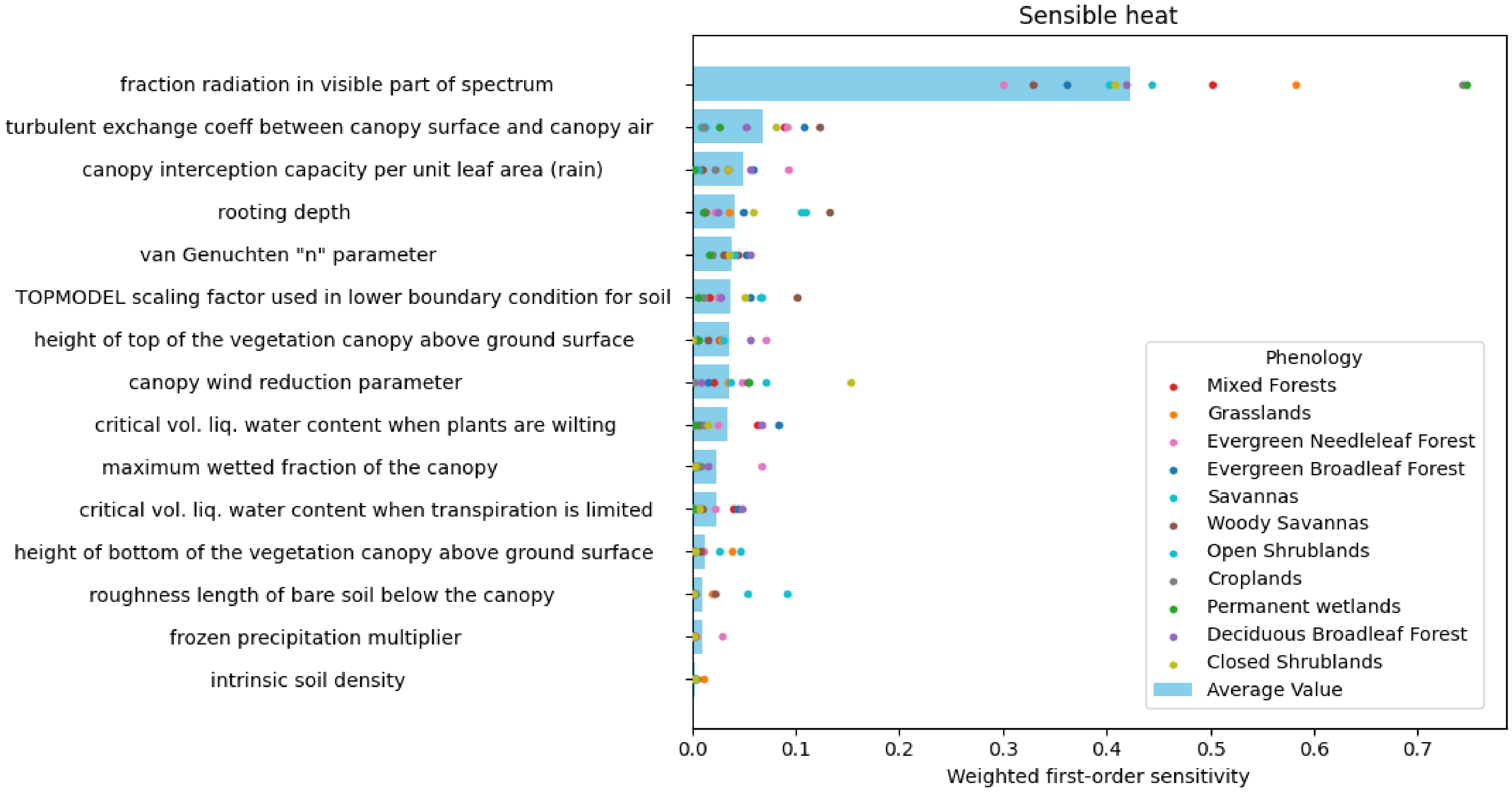
- 8 soil parameters (control the available water to evaporate)
- 2 turbulent parameters (control the available energy)
- 3 vegetation parameters (control the role of the plant in the evapotranspiration, e.g., canopy interception capacity)



Results: Sensible Heat (SH)

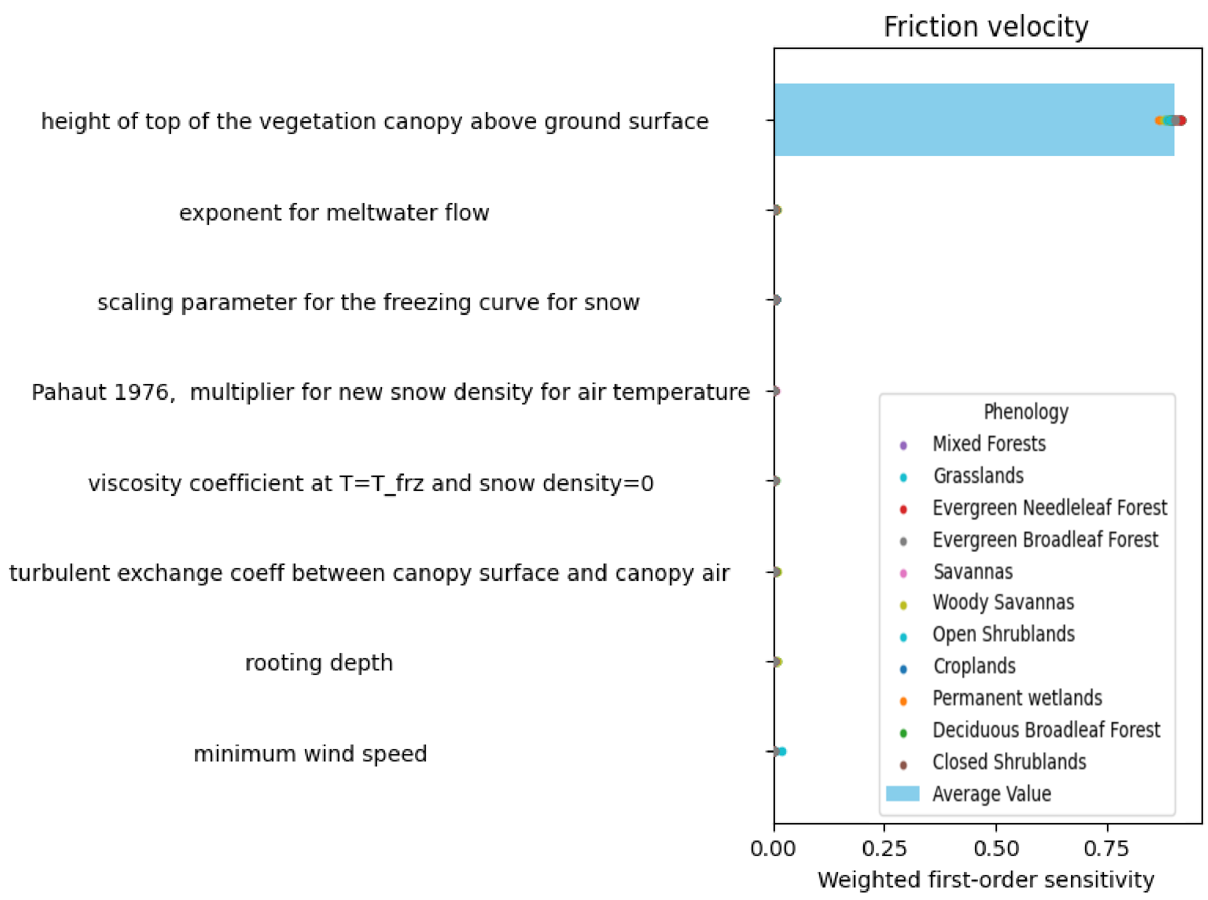
As expected, SH is controlled by the parameters related to the available energy.

- The key parameter is the radiation fraction in the visible part for photosynthesis, which accounts for 40% on average alone.
- Soil parameters and vegetation parameters have a secondary role.

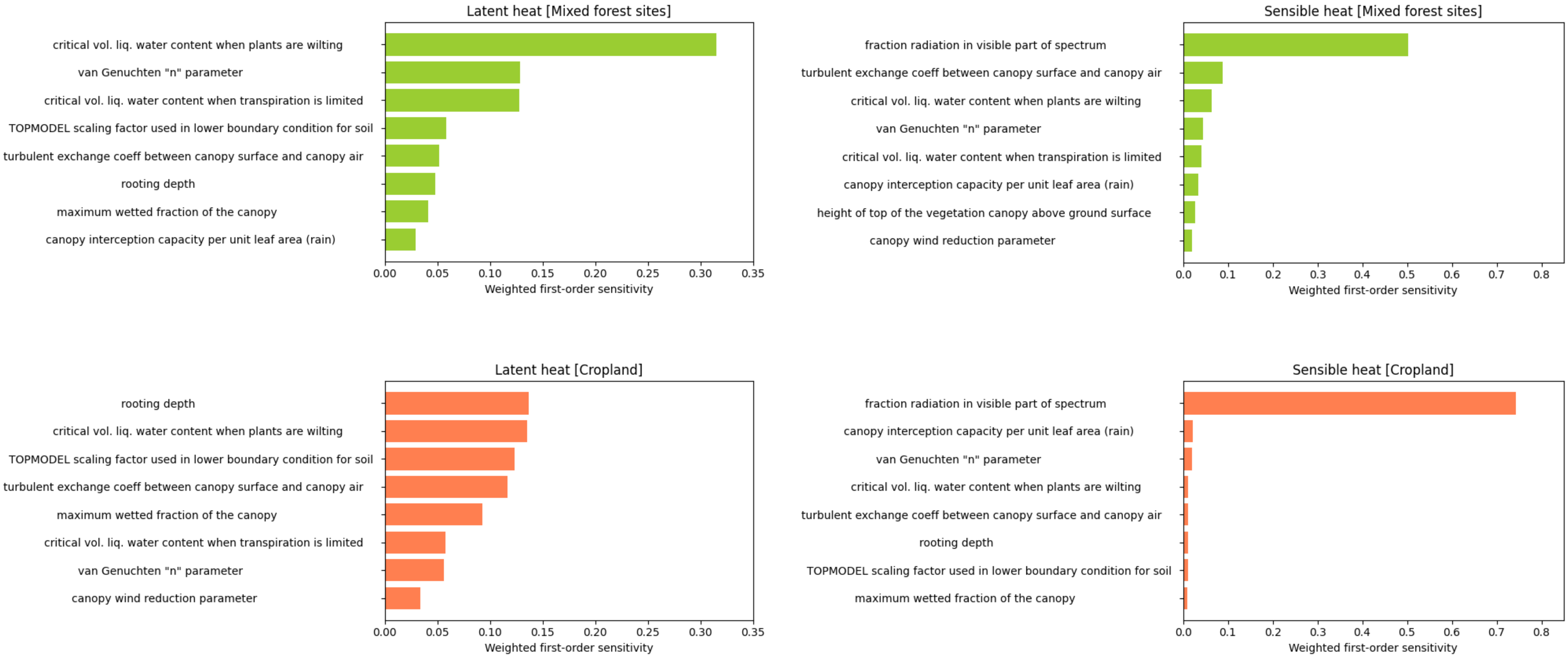


Results: Friction Velocity (u*)

- Friction velocity has received little attention in previous SA studies.
- Friction velocity is primarily governed by canopy height across all vegetation sites.
- Parameters related to within-canopy and above-canopy turbulence and wind canopy profiles did not exhibit significant control over friction velocity.
- While flux tower data provide direct measurements of canopy height, assessing its impact is crucial for large-scale and ungauged regions where such measurements are unavailable.

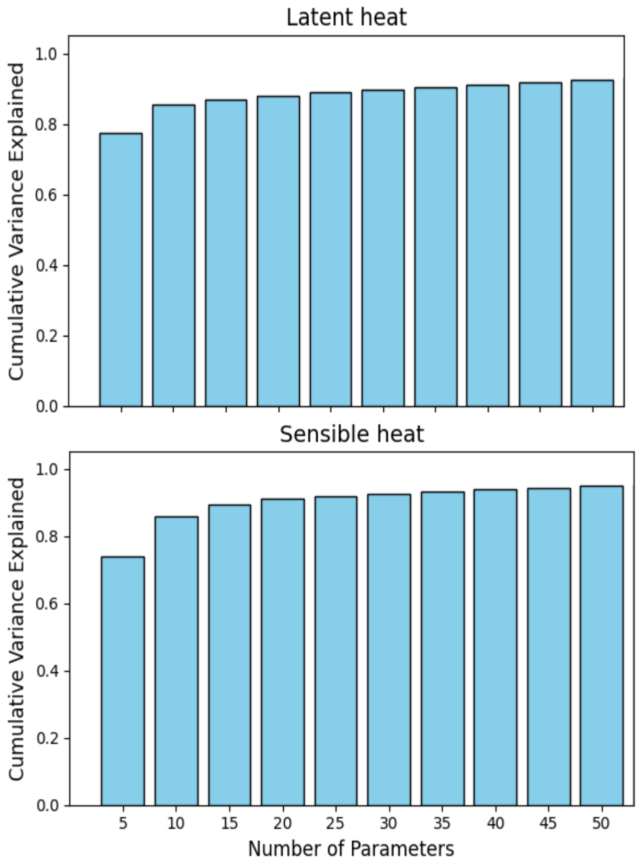


Results: Differences in vegetation types



Take home messages

- Evaluating parameter sensitivity using flux towers offers key advantages:
  - Reduced computational cost (vs running a gridded domain)
  - The role of forcing uncertainty is limited given the absence of upscaling observations.
- Defining minimum and maximum bounds for parameters can be challenging due to limited information.
- A few parameters explain a large part of the variance in latent and sensible heat.
  - Any of the studied variables responds to all 130 parameters.
  - The effective parameter space for key fluxes (LH, SH) can be around 30 parameters.
  - This emphasizes the need to treat parameters as uncertain values rather than hard-coded values
- The parameters' main effect (or first-order sensitivity) varies in different vegetation types.
  - This emphasizes that selecting parameters for calibration need to be location (e.g., phenology, climatic) different



Future work

- Using these parameter sensitivity results, perform parameter estimation (i.e., calibration) on different SUMMA configurations using single-site emulators and large sample emulators following the approach of Tang et al. (2024) to advance the parametric and structural uncertainty characterization.
- Evaluate, quantify, and understand how parameter sensitivity and their estimation vary in CLM v5.0 (Lawrence et al., 2020), given the different domain parametrizations available, including:
  - Hydrology
  - Biochemistry
  - Biophysics
  - Stomatal conductance and photosynthesis
  - Fire

Eric R Stoner (2015)

Questions and contact

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