

# Modeling sulfur biogeochemistry of beech (*Fagus sylvatica*) stands at the Vienna Woods

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## Background

**Project: Predicting reversibility of soil acidification in beech (*Fagus sylvatica*) stands**

Strong decline of anthropogenic S emission since ~ 1985

→ Decline of atmospheric  $\text{SO}_2$

→ Decline of  $\text{SO}_4$  deposition

High S in Stream Export

**Catchment S output exceeds atmospheric input**

**Causes of S I/O Imbalance:**

**Hidden S input:**

Underestimation of atmospheric Deposition

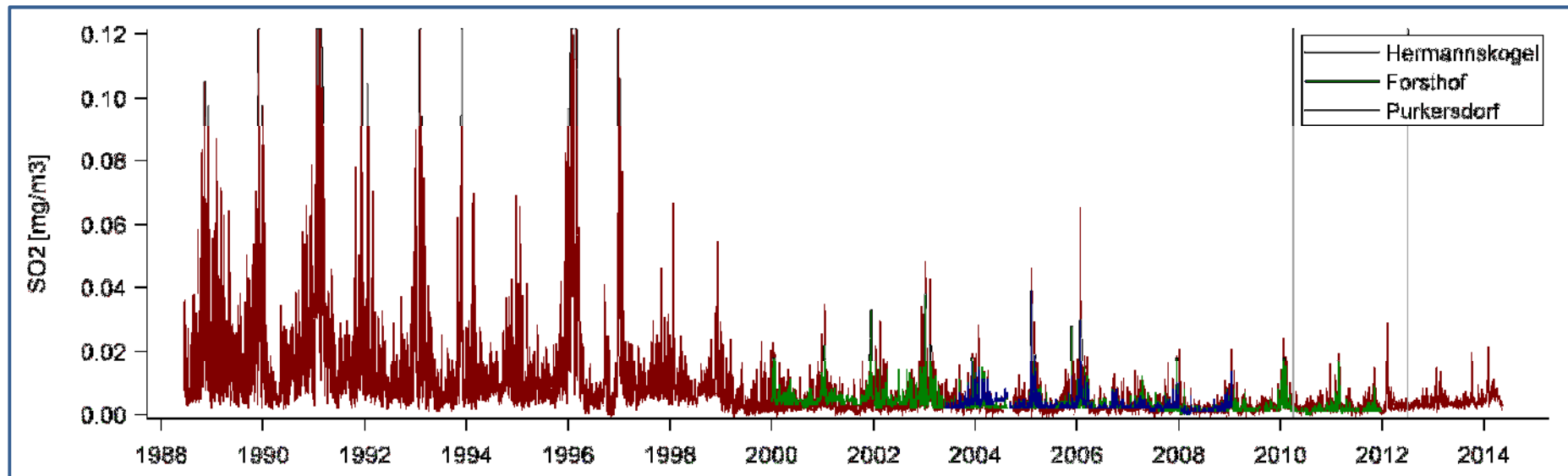
Underestimation of Weathering/Bedrock release

**Depletion of historically accumulated Sulfur:**

Release of  $\text{SO}_4$  from anion adsorber

Mineralization/Mobilization of organically bound S

*Biosphere responded to increased availability with increased assimilation.*



## Research Questions

- What are the key mechanisms controlling the soil S budget?
- Is it possible to assign measured changes in the  $\text{SO}_4$  soil solution to actual processes in the soil?
- Under current legislation emission: How long does it take the system to reach a new steady state ( $I=0$ )?

## Site description

3 beech (*Fagus sylvatica*) stands  
in the Vienna woods

Parent Material: *Flysch*

→ clay rich soils

Temporal waterlogging.

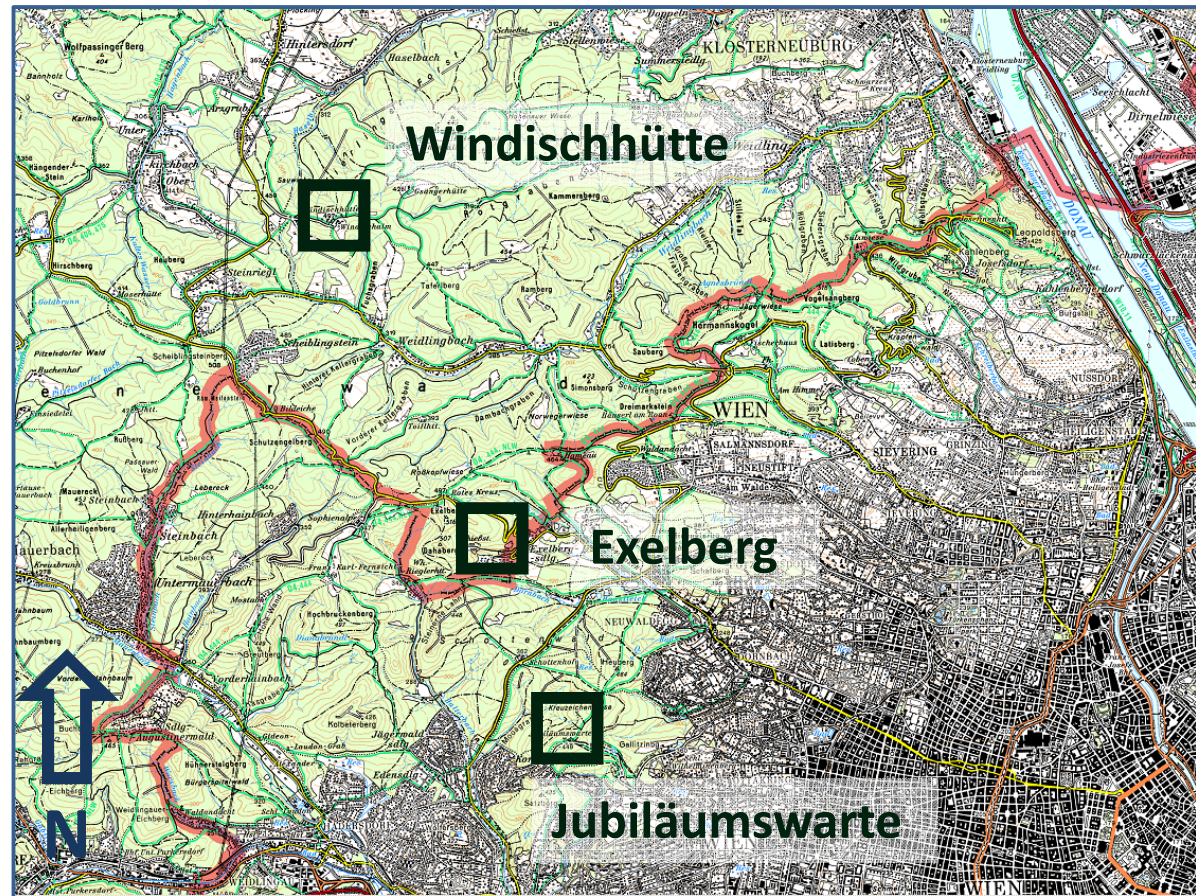
*Pseudogley-Stagnic Gleysol*

Altitude: 450-490 m a.s.l.

Located at upper slope close  
to ridge

Exposition SE-NW

Differences in CEC, base  
saturation, lime content



Soil samples in June 2010 (soil physics, nutrient content)

Biweekly Monitoring April 2010 – June 2012

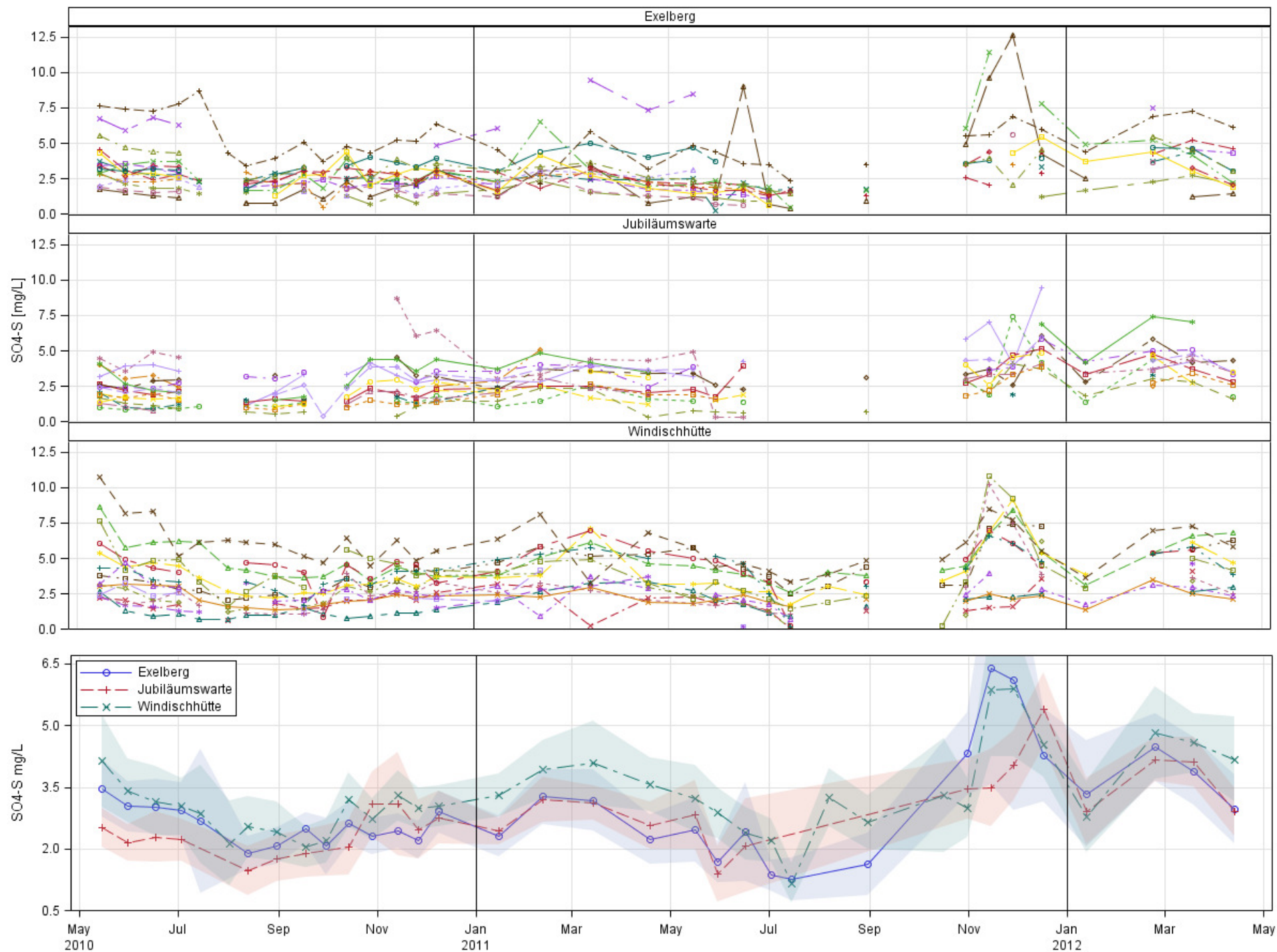
Precipitation Deposition (Open Area, throughfall, stemflow)

Soil solution chemistry, Soil moisture, Soil temperature

3 soil depths x 5 distances to tree = 15 replicates per sample

→ Reduction of  $\sigma_n$





## Dynamical Box Model

Implemented in SAS 9.4

### PROC MODEL:

Iterative solution of system of ordinary differential equations (implicit 2<sup>nd</sup> order runge-kutta)  
 → Newton-Raphson Algorithm  
 Daily timestep

### Components

1. Dyn. Soil Temp. Model
2. Beech Phenology
3. **Water Balance**
4. **Sulfur Dynamics**

### Water Balance

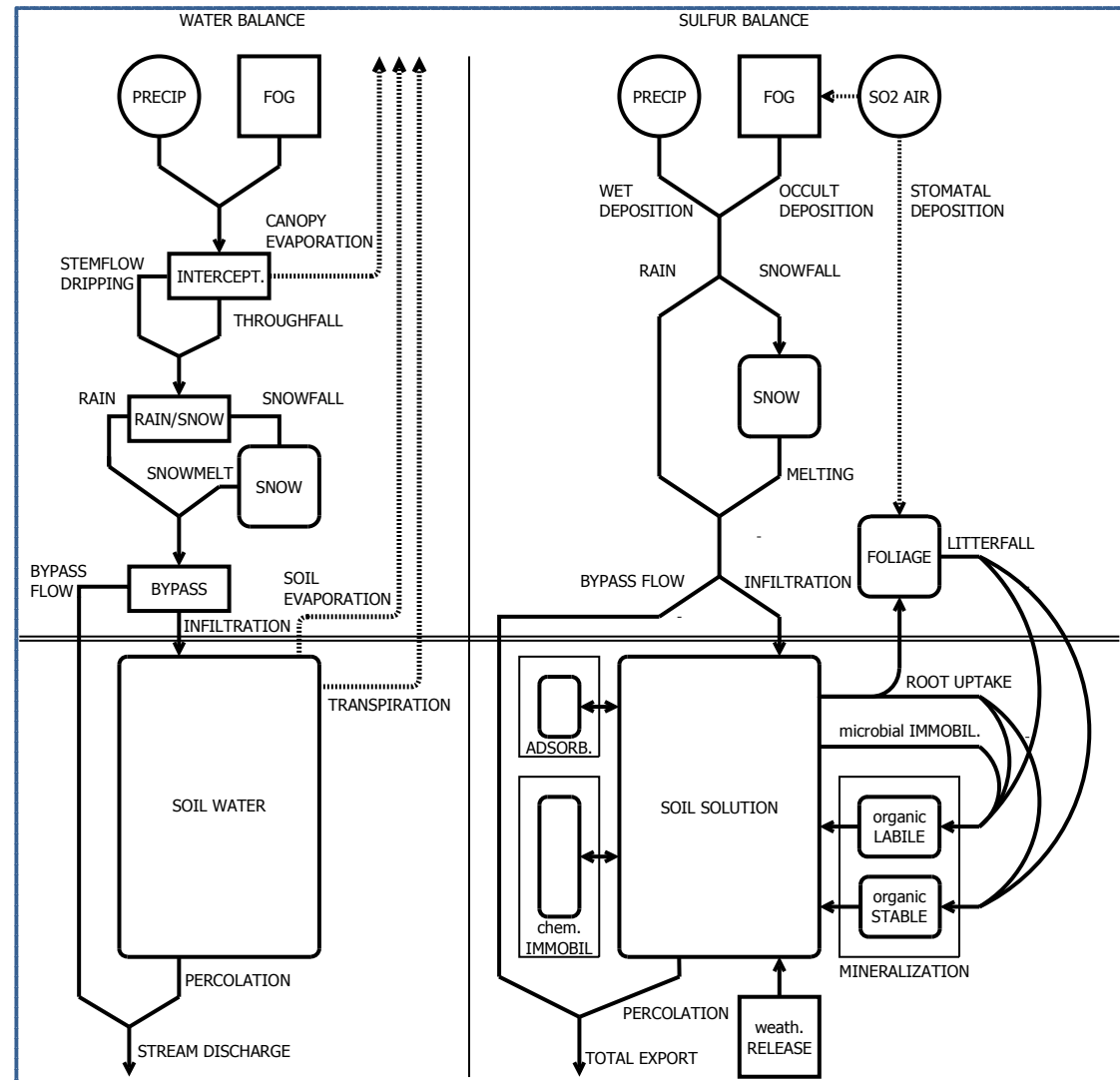
Upstream and Independent

S enters and leaves the system in solute form → I/O is driven hydrologically

Biotic S transformations might respond to soil moisture

### Input data

- Tmin, Tmean, Tmax
- Soil temperature
- Relative humidity
- Precipitation
- Global radiation
- Mean wind speed



# S-Dynamics Model

## Input data

### Output von Water Balance Model:

- Water fluxes
- Soil moisture
- Soil Temperature
- Fog Precipitation
- Growing Season
- Snowpack

### S Input

- Wet  $\text{SO}_4$  Deposition
- $\text{SO}_2$  Concentration

Time frame 1600-2200

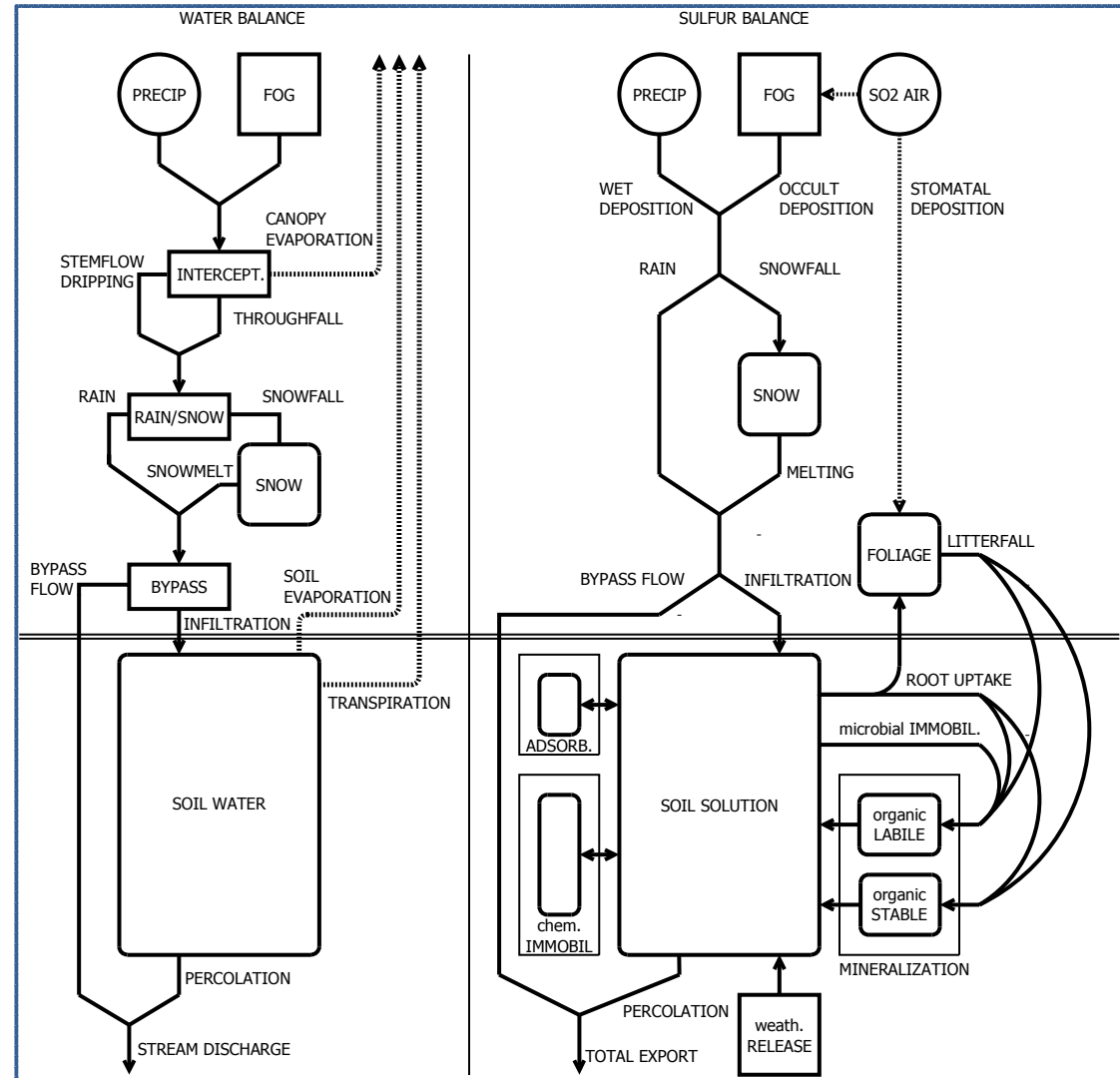
Spin Up Period

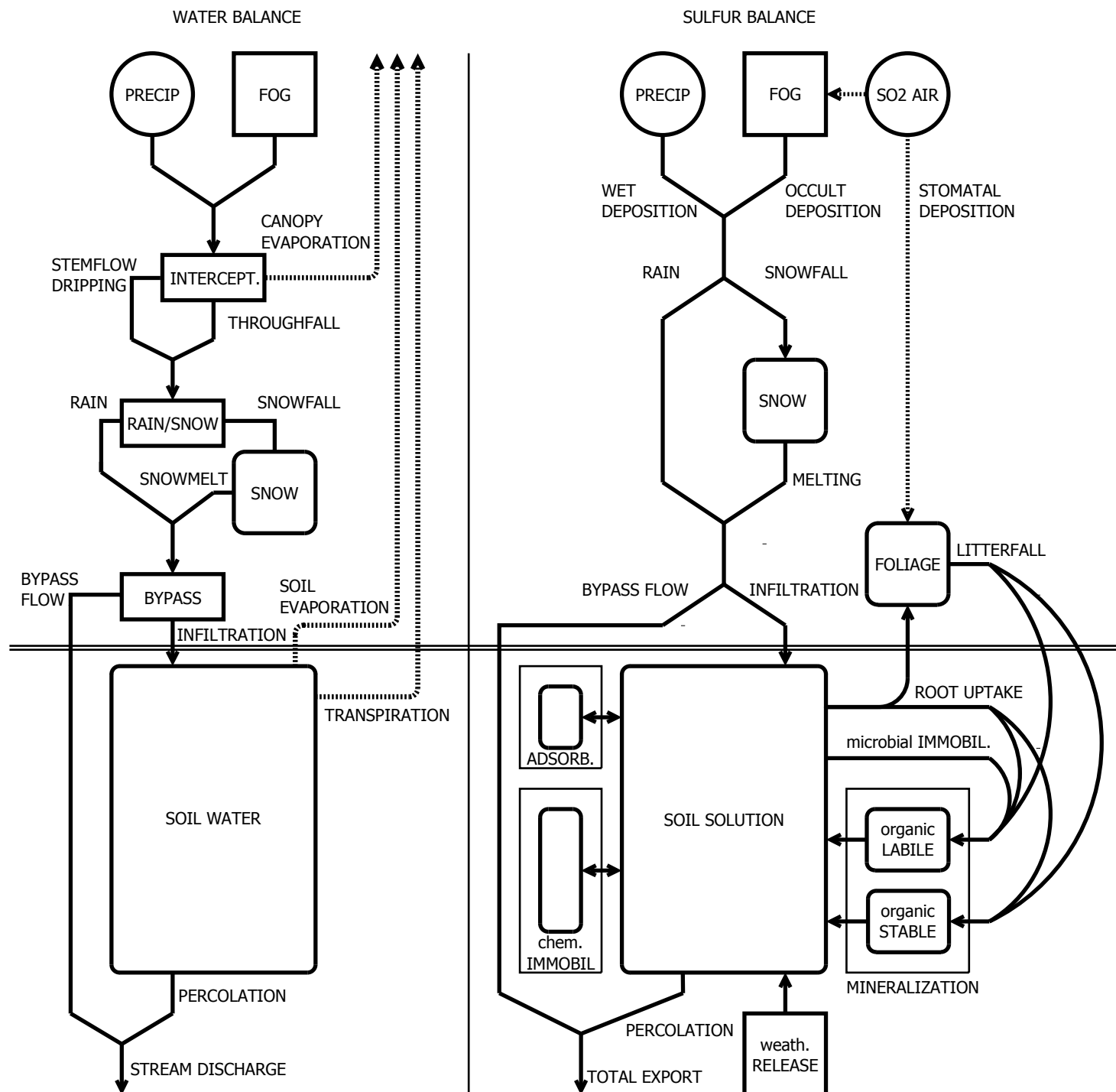
Weather Generator (no climate change)

→ Extrapolation of measured wet deposition with historic deposition estimations (**EMEP-Grid**)

Breakdown of annual deposition sums to single precipitation events

→ Extrapolation of  $\text{SO}_2$  concentration on *DoY* base







# S-Dynamics Model

Daily Time Step

Time frame 1600-2200

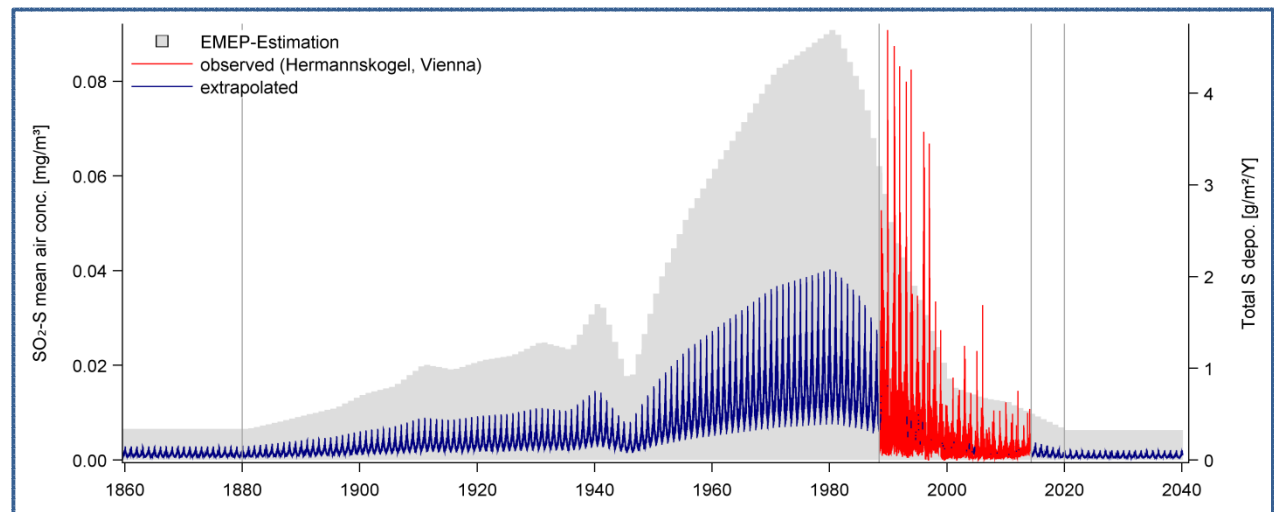
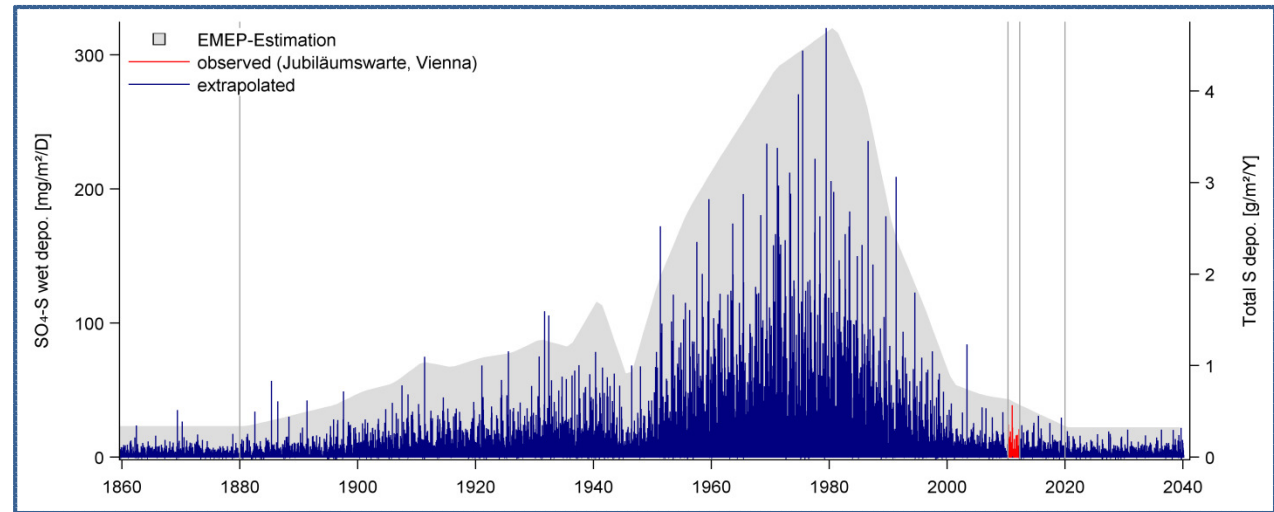
Spin Up Period

Regression/Loop of observed weather

→ Extrapolation of measured wet deposition with historic deposition estimations (**EMEP-Grid**)

Breakdown of annual deposition sums to single precipitation events

→ Extrapolation of obs.  $\text{SO}_2$  concentration on *DoY* base



# S-Dynamics Model

## Target Criteria

- Steady State before 1880
- Belowground Pool of 2010 [ $\sim 120\text{g/m}^2$ ]
- Annual Litterfall S [ $\sim 0.9\text{g/m}^2/\text{a}$ ]
- $\text{SO}_4$  soil solution dynamics

26 Free Model Parameters

## Optimization

„Simulated Annealing“

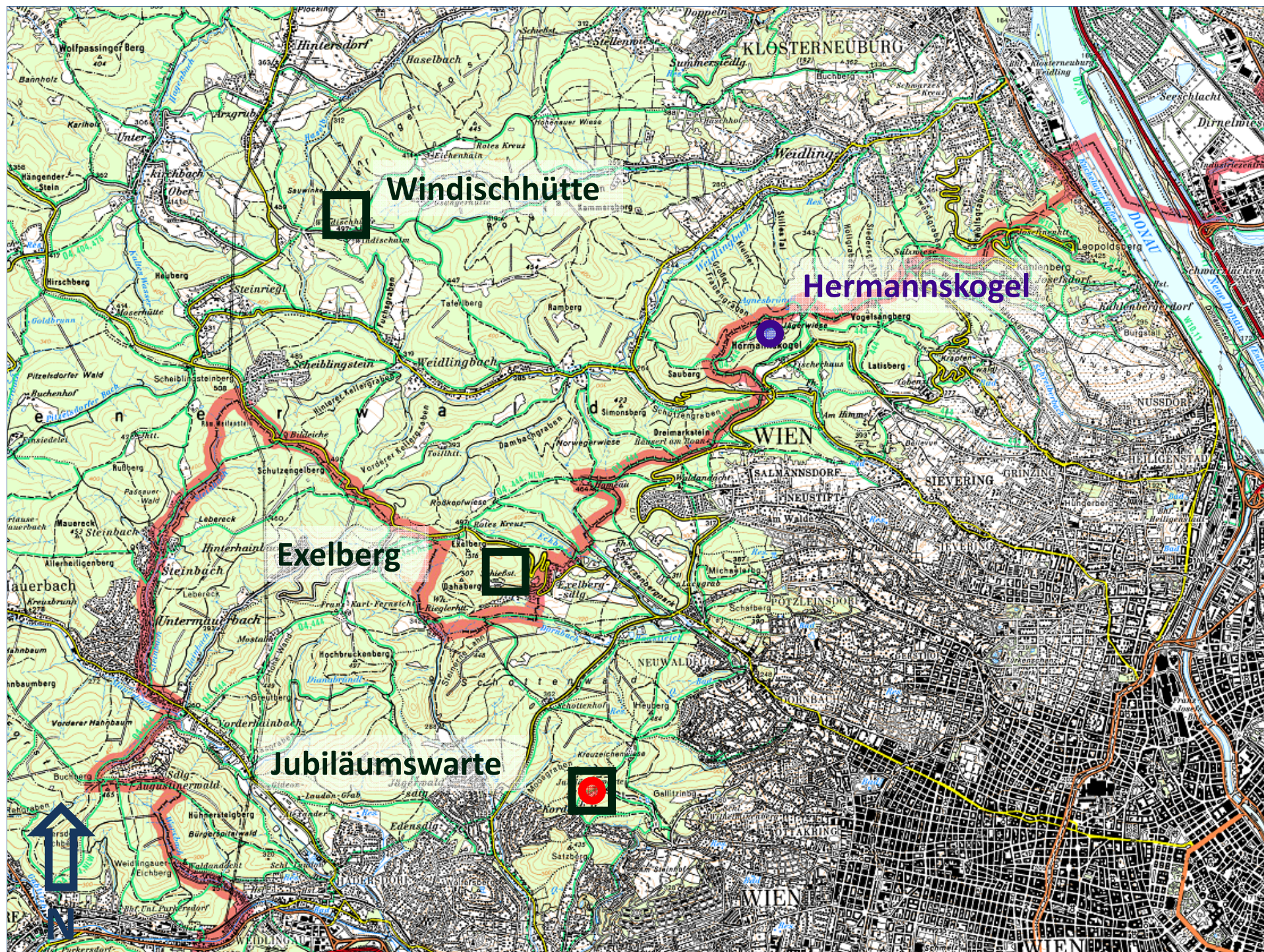
$$NSE = 1 - \frac{\sum_{t=1}^T (Q_o^t - Q_m^t)^2}{\sum_{t=1}^T (Q_o^t - \bar{Q}_o)^2}$$

```

/*****GLOBALISIERUNG*****/
      call symputx(NAME,actual);
/*****
cards;
FOG_ENRICHMENT          2090          2190
APSIM_DRY                .1792          .1799
APSIM_STAR_1            .3267          .3275
APSIM_PLATEAU            .0582          .0606
APSIM_DROWN             .429           .433
IMMO_DRY                .1780          .180
IMMO_STAR_1             .354           .357
IMMO_PLATEAU            0              0
IMMO_DROWN             .412           .4134
Q10_MINERAL             1.0           1.0
Q10_IMMOBIL             1.0           1
Vmax_TREE               1.33           1.358
Vmin_TREE               .10            .12
Vmax_IMMO               9.91           10.3
Km_IMMO                 .430           .45
Km_0_TREE               2.45           2.88
Km_5_TREE               .83            .90
annual_DEMAND_1         940           1020
annual_DEMAND_2         2290          2320
PERMEABILITY_min        0              0
PERMEABILITY_max        0              0
factor_STOMATAL         290           320
share_FOLIAGE            .65           .72
share_FAST_TREE         .49           .53
share_FAST_IMMO         1              1
HALFLIFE_SOS_STABLE     29.6           30.4
HALFLIFE_SOS_LABILE     6.10           6.33
HL_SULFATASE_0          6.00           6.05
HL_SULFATASE_10         6.05           6.1
adsorb_KL                7.2           8.2
adsorb_MAX_mgm2         8000          8810
INIT_ORGANIC_SLOW       82300         83000
INIT_ORGANIC_FAST       11400         11600
;
run;

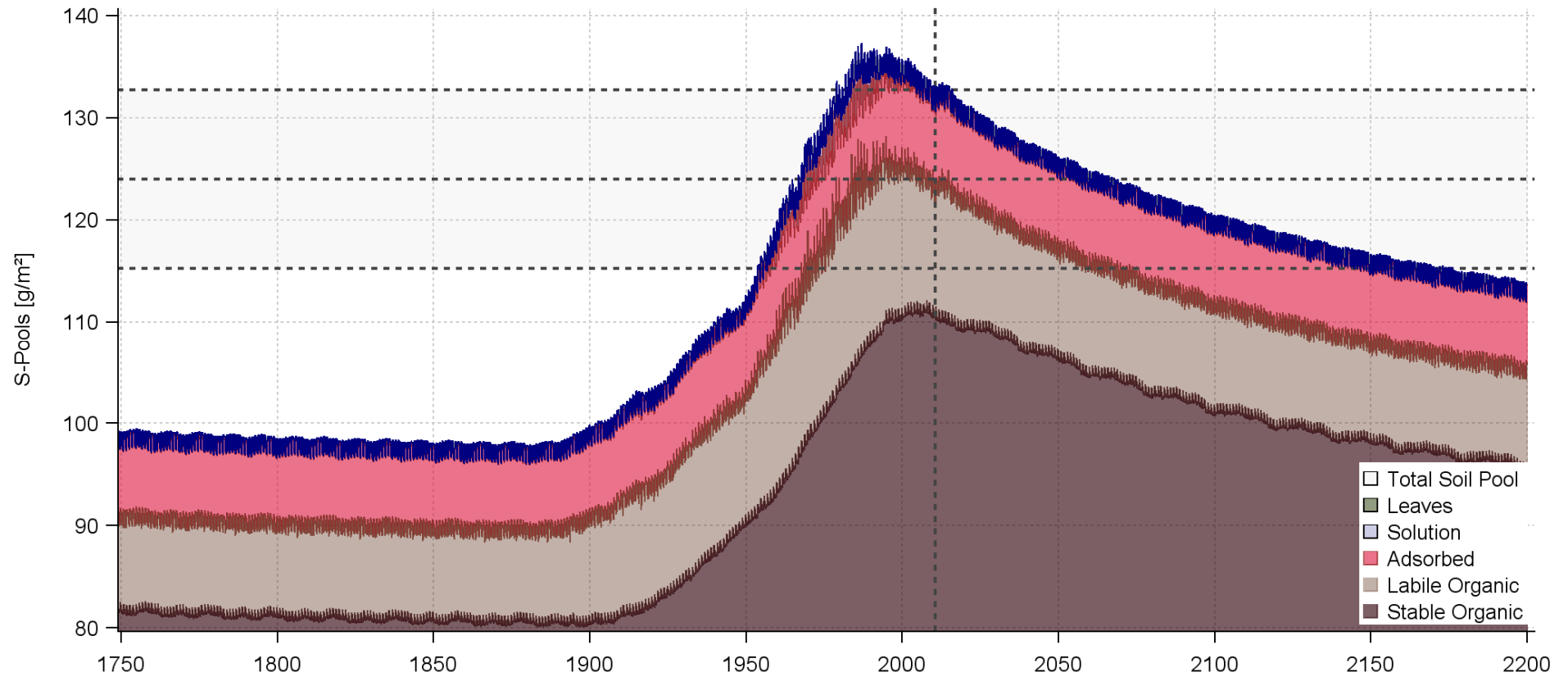
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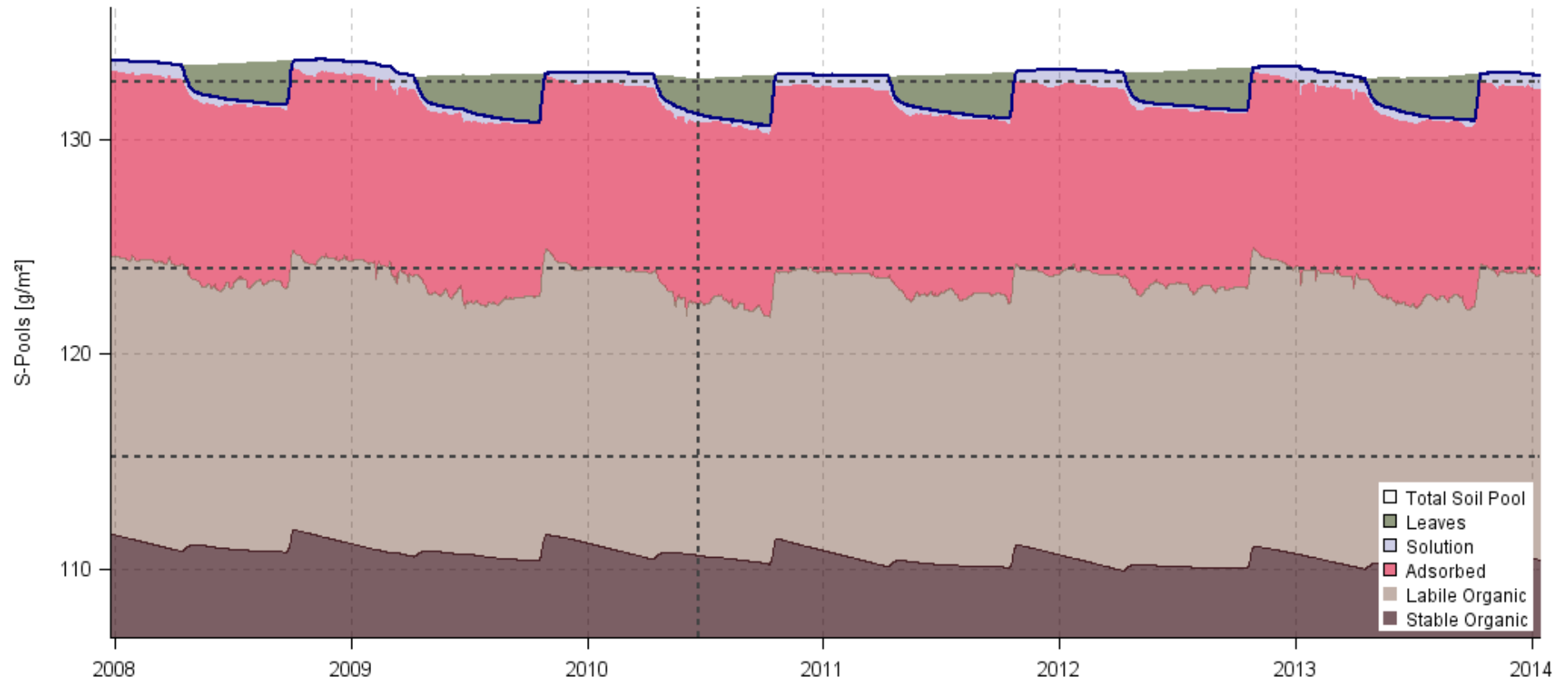




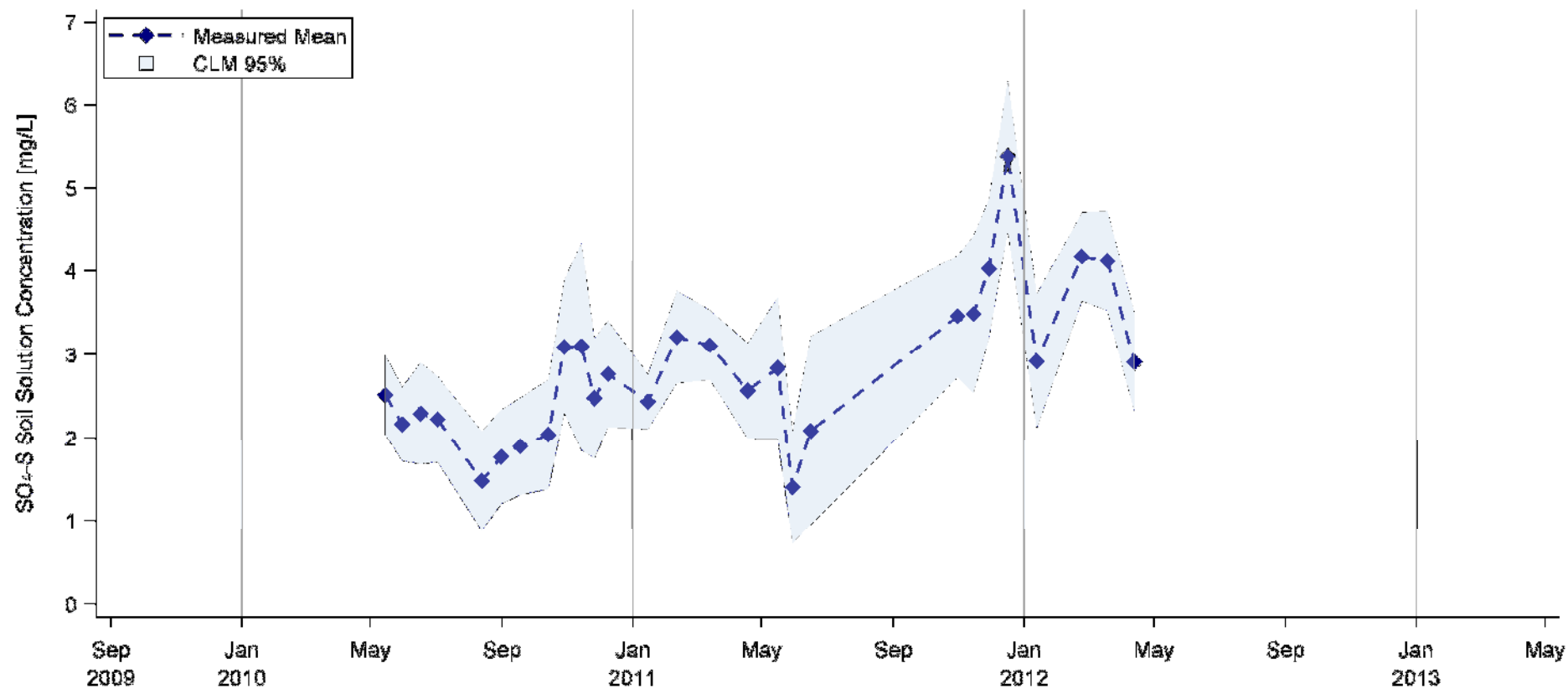
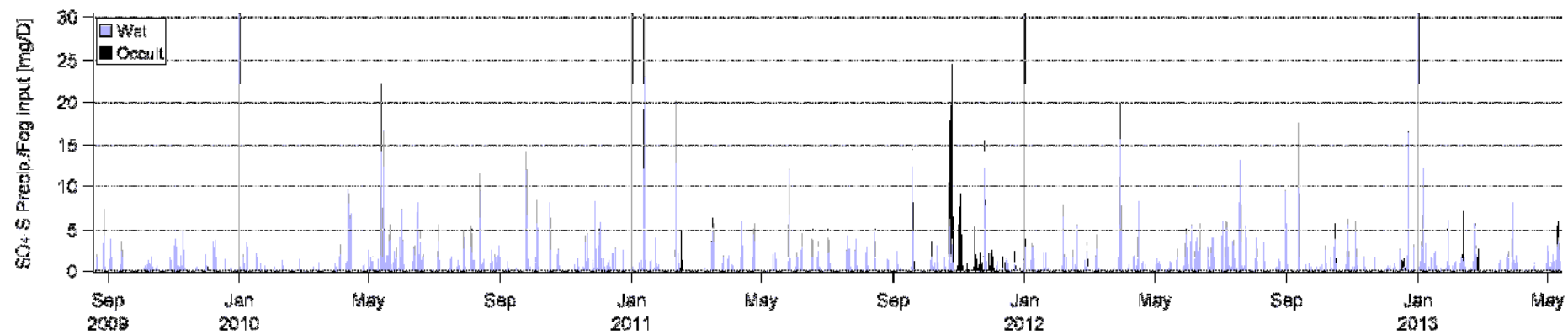
**Jubiläumswarte, Total S-Pool, June 2010: 115- 133 g/m<sup>2</sup> [O + 00 - 50cm]**

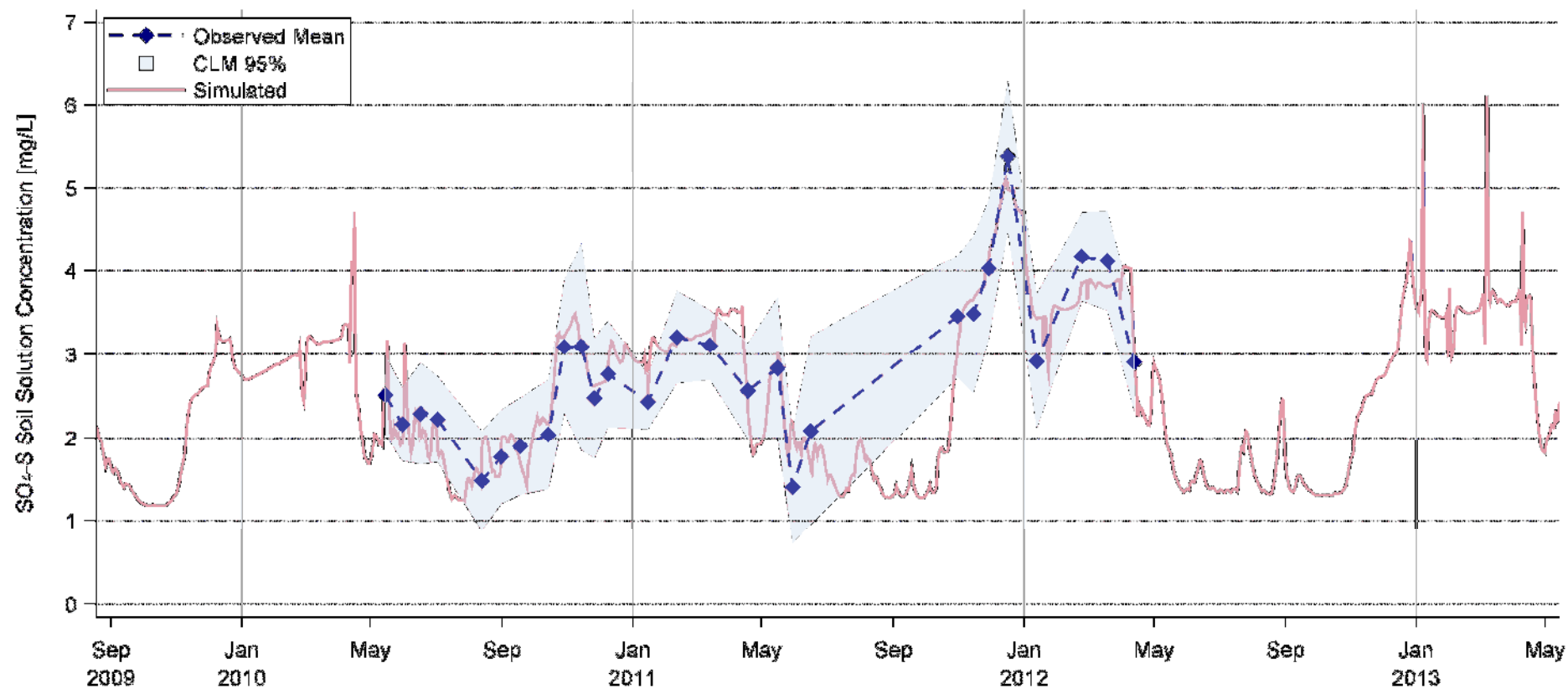
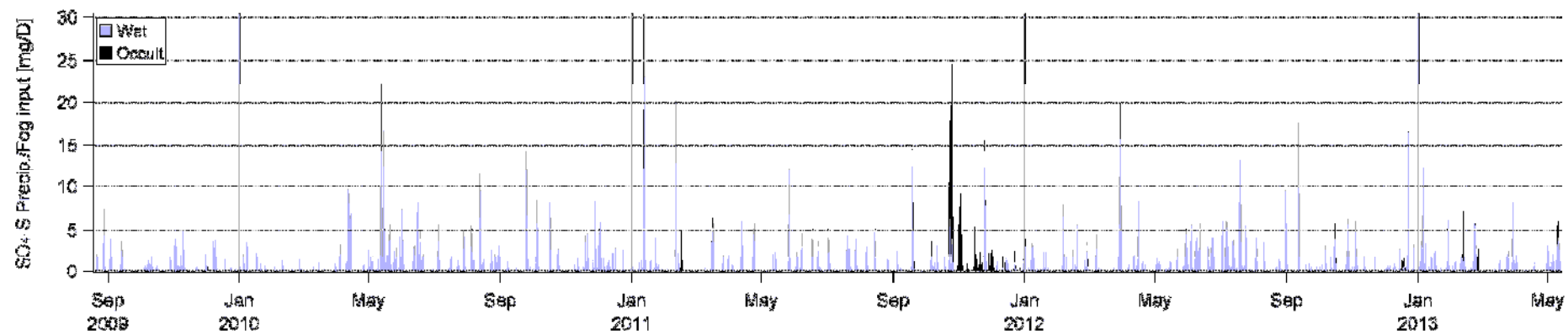


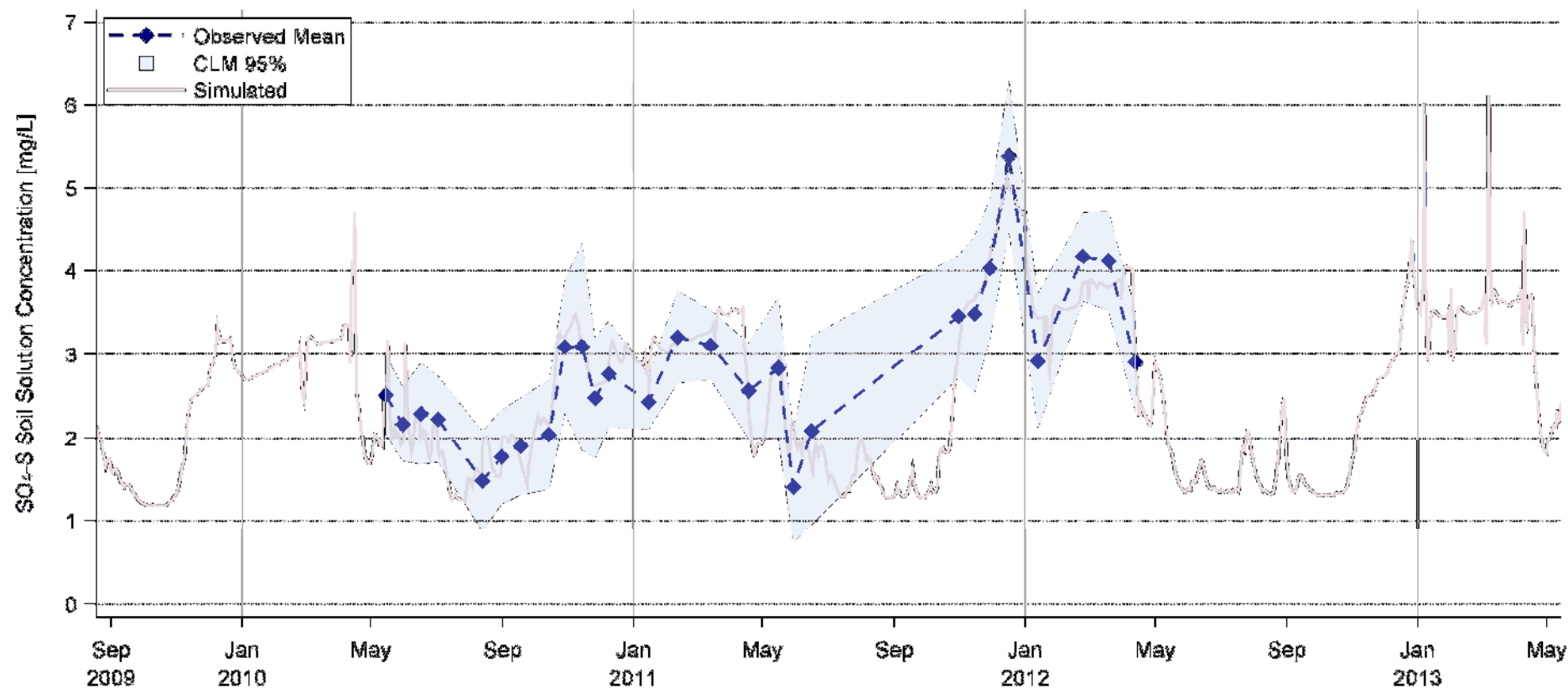
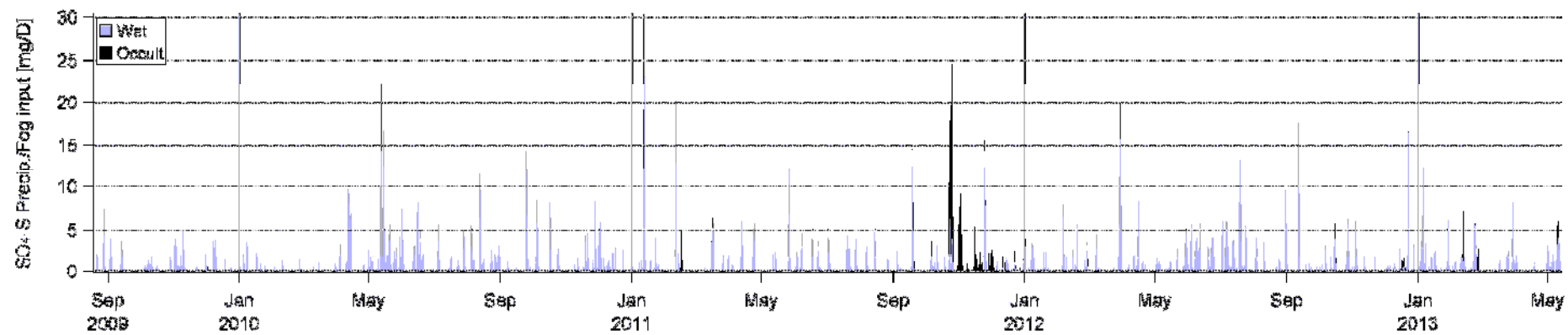
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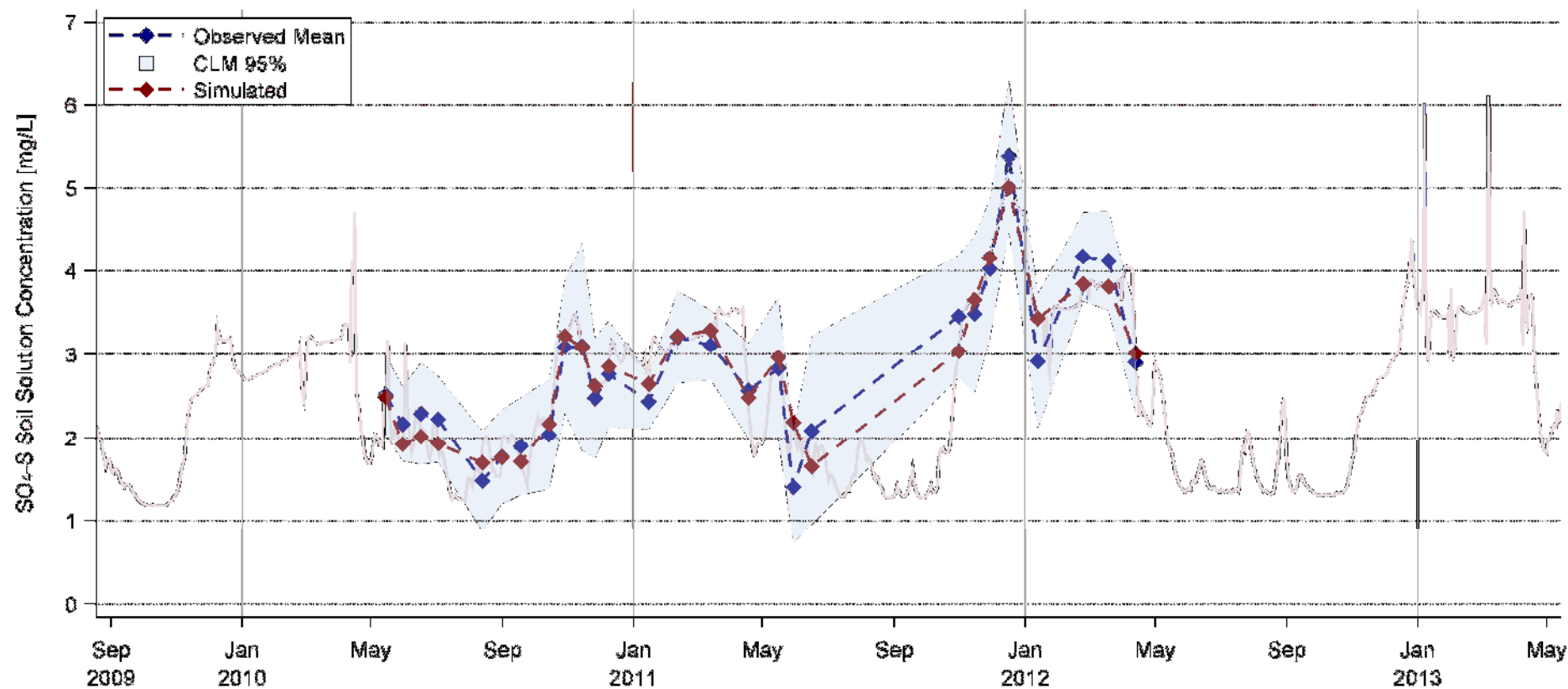
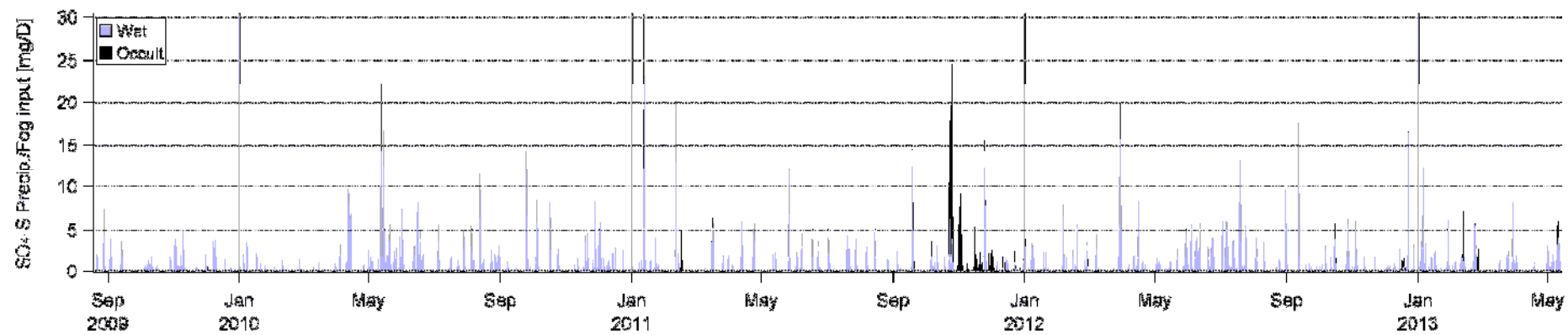












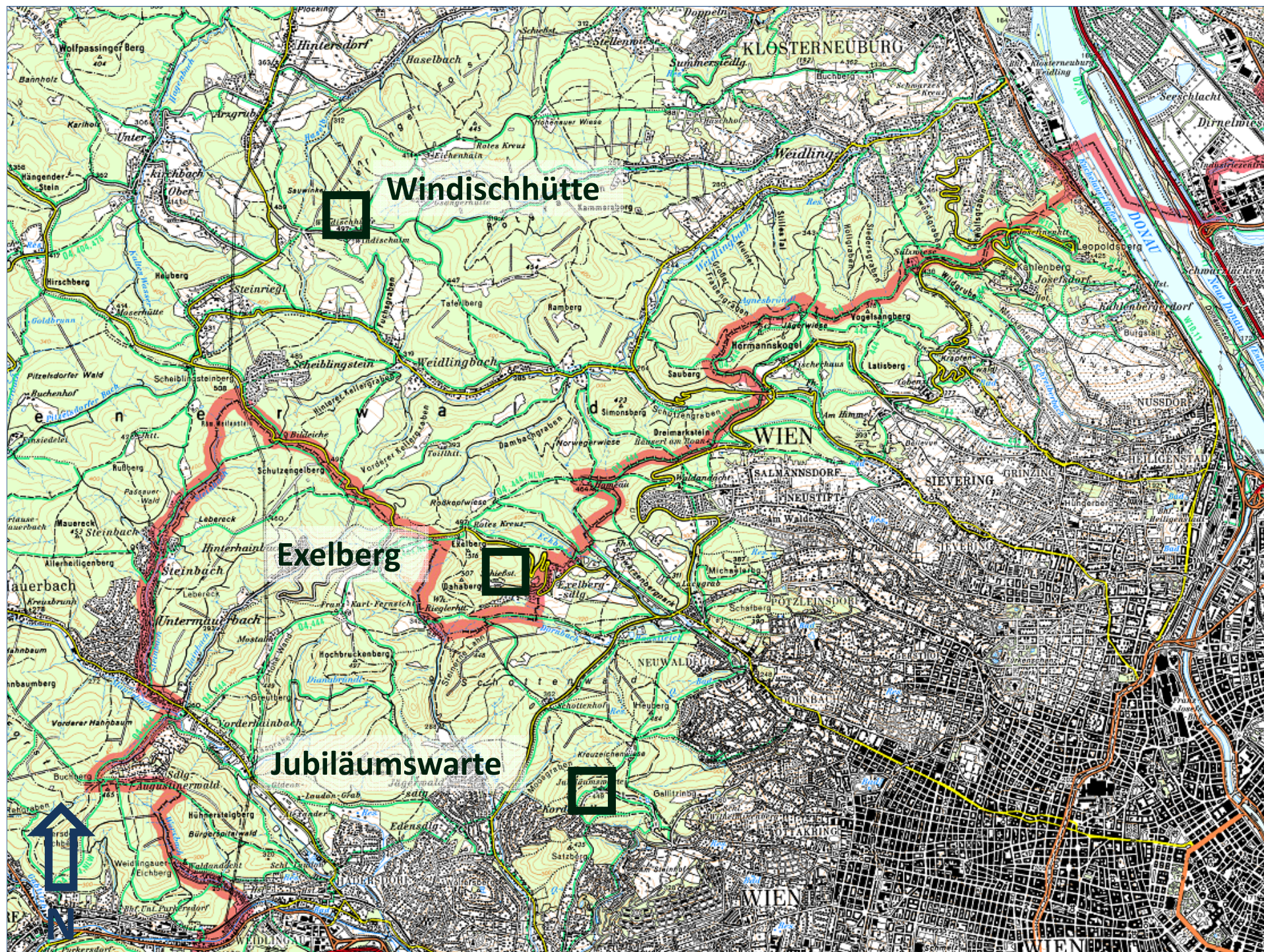
# Conclusion

The model is not suitable to make forecasts to future states of the system (high uncertainty, insufficient calibration data, no validation).

The configuration of the model is sufficient to draw a *plausible picture* of the present state.  
*One configuration of many possible configurations!*

- An S-Source from bedrock weathering/chemical mobilization not necessary to describe present state.
- The contribution of  $\text{SO}_4$ -Adsorption to the entire soil pool is small (~10%) , but adsorption is necessary to model the observed dynamics.
- Short-time fluctuations in the S soil solution concentration seem to be the result of the microbially mediated interplay of immobilization and mineralization.
- Both processes show strong response to soil moisture and **no** response to soil temperature.
- The rate of microbial S immobilization exceeds the rate of plant root uptake by magnitudes!
- The high storage of organically bond S seems to originate from plant residuals.
- Under current conditions dry (stomatal) deposition contributes only a negligible fraction to plant S supply.
- Plants are able to suppress the uptake of excess sulfur *to a certain degree*.
- Fog shows a strong enrichment of S compared to rain/snow. An influence of occult deposition is visible in the soil solution (Site in immediate proximity to city, autumn-winter fog episodes coincide with SE-current).

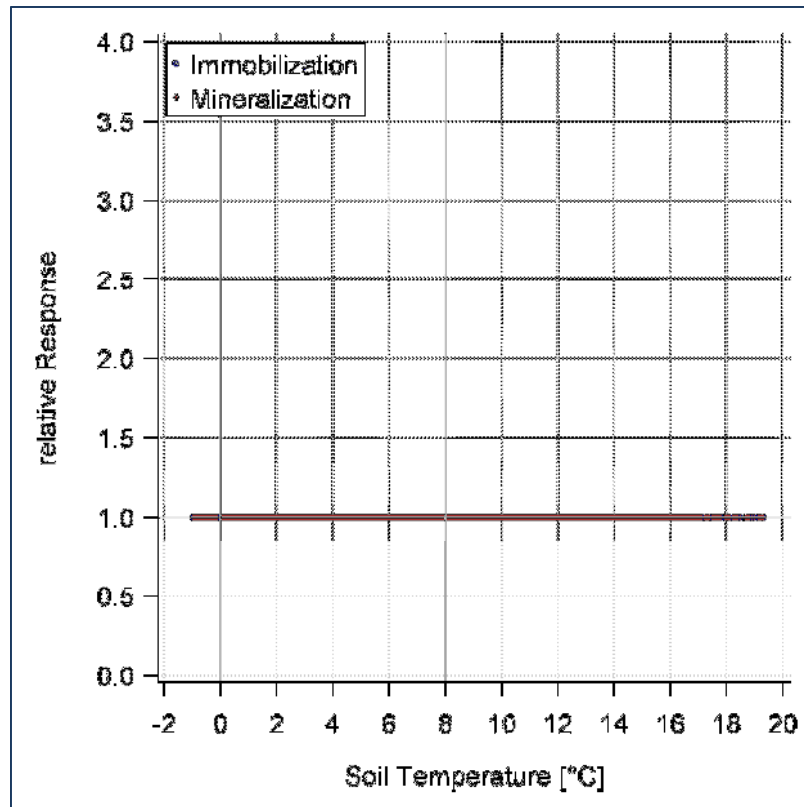




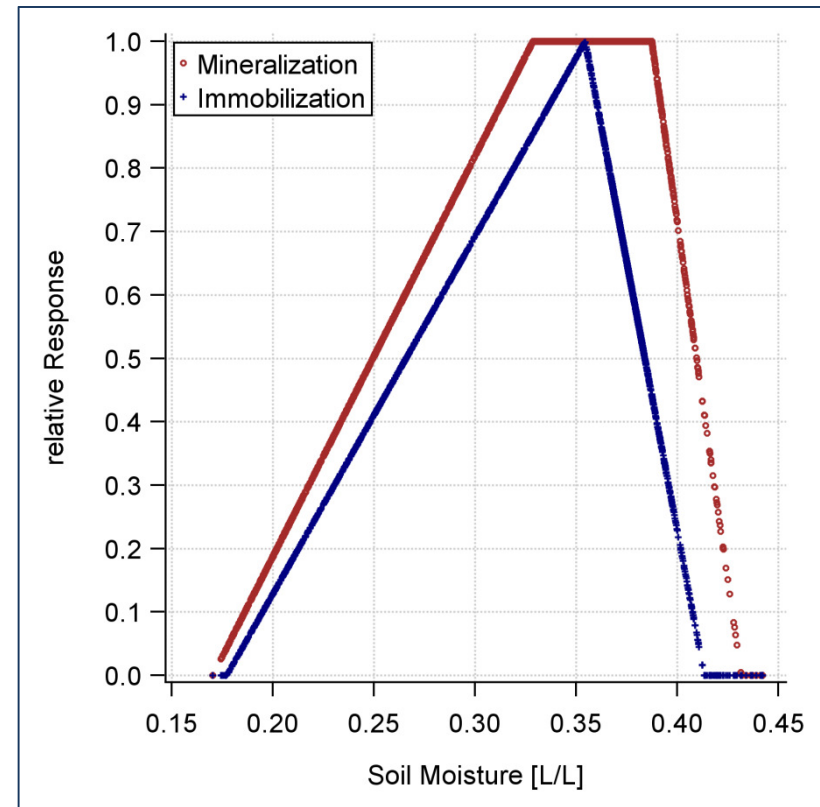


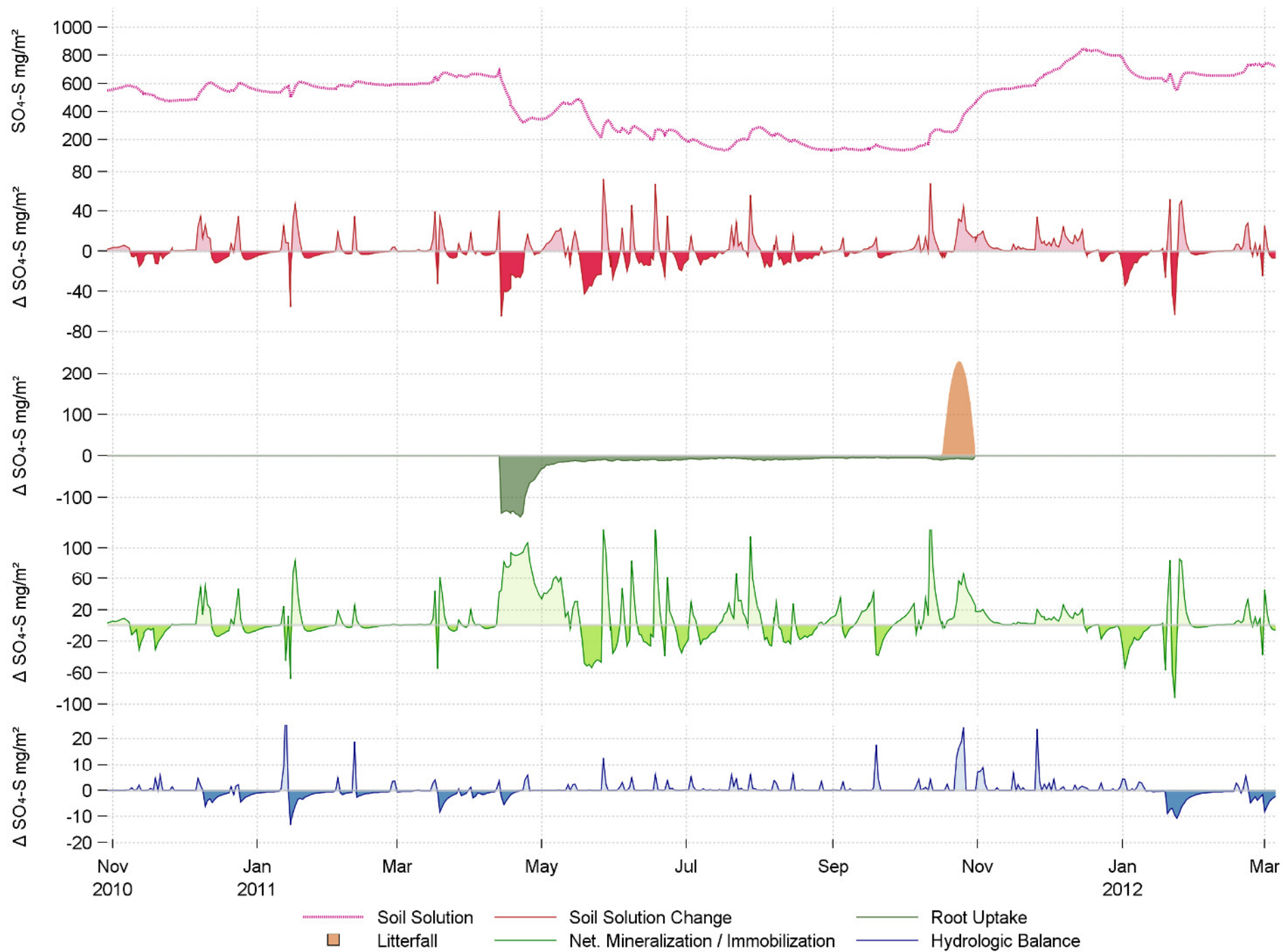
Thank You!

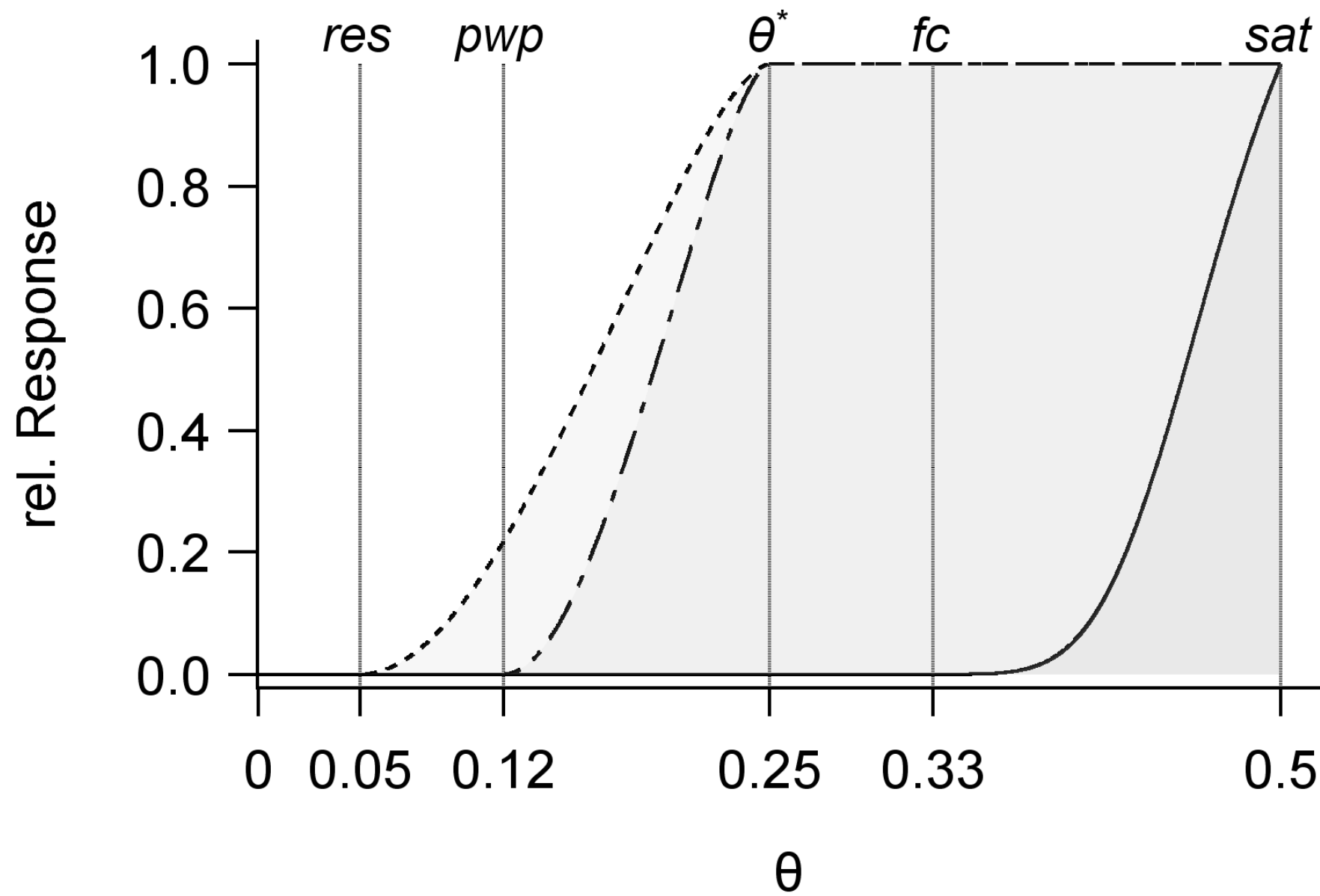
## Temperature Response



## Soil Moisture Response





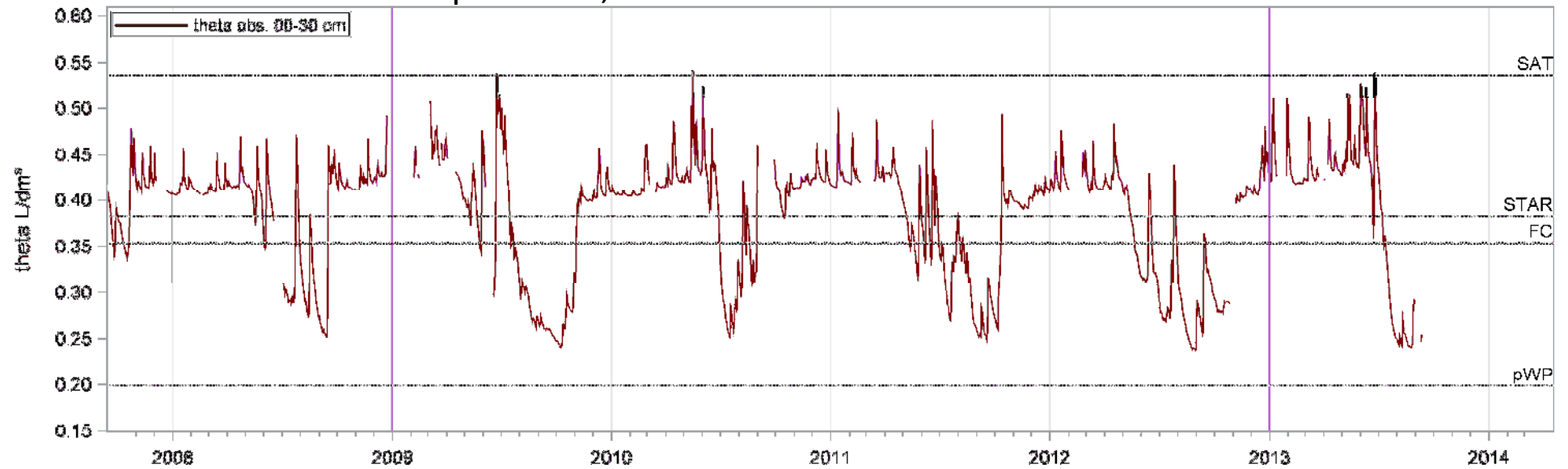




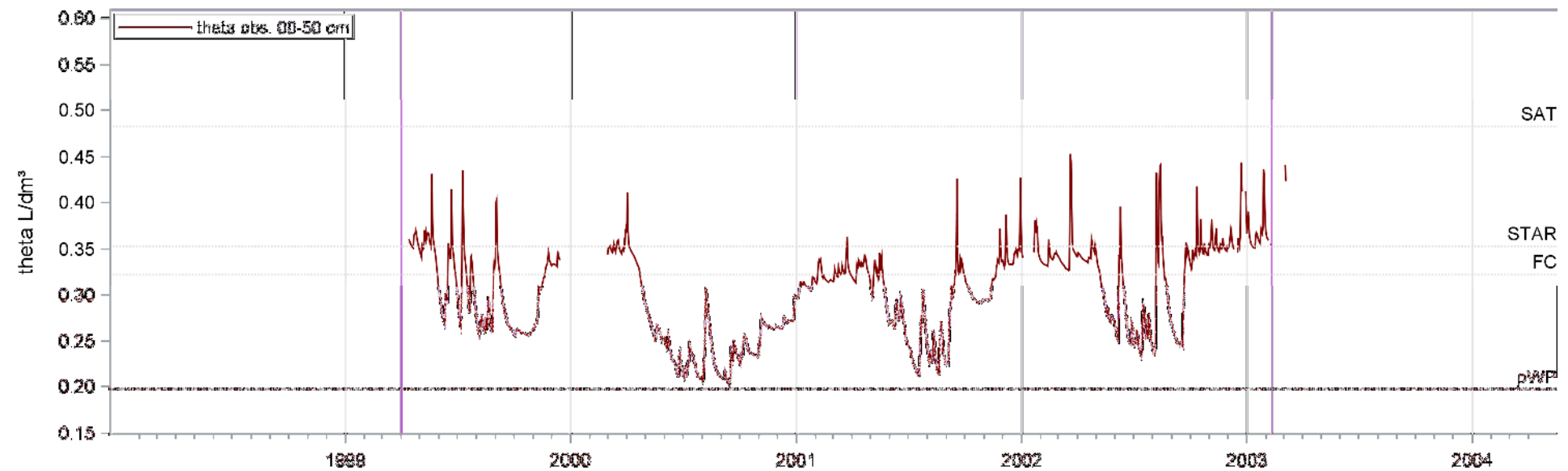




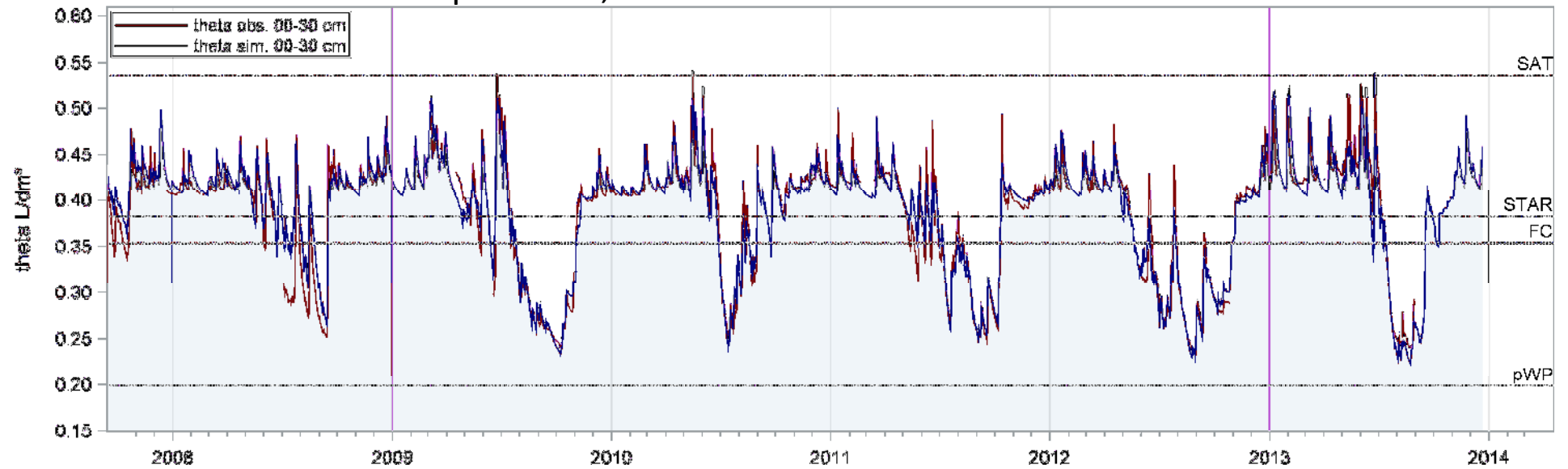
## LEVEL II – Klausen Leopoldsdorf, Calibration + Evaluation



## Kreisbach (mixed spruce-beech), Calibration



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