Christian-Albrechts-Universität zu Kiel

SWAT Conference 26-30, June 2023
in Aarhus, Denmark

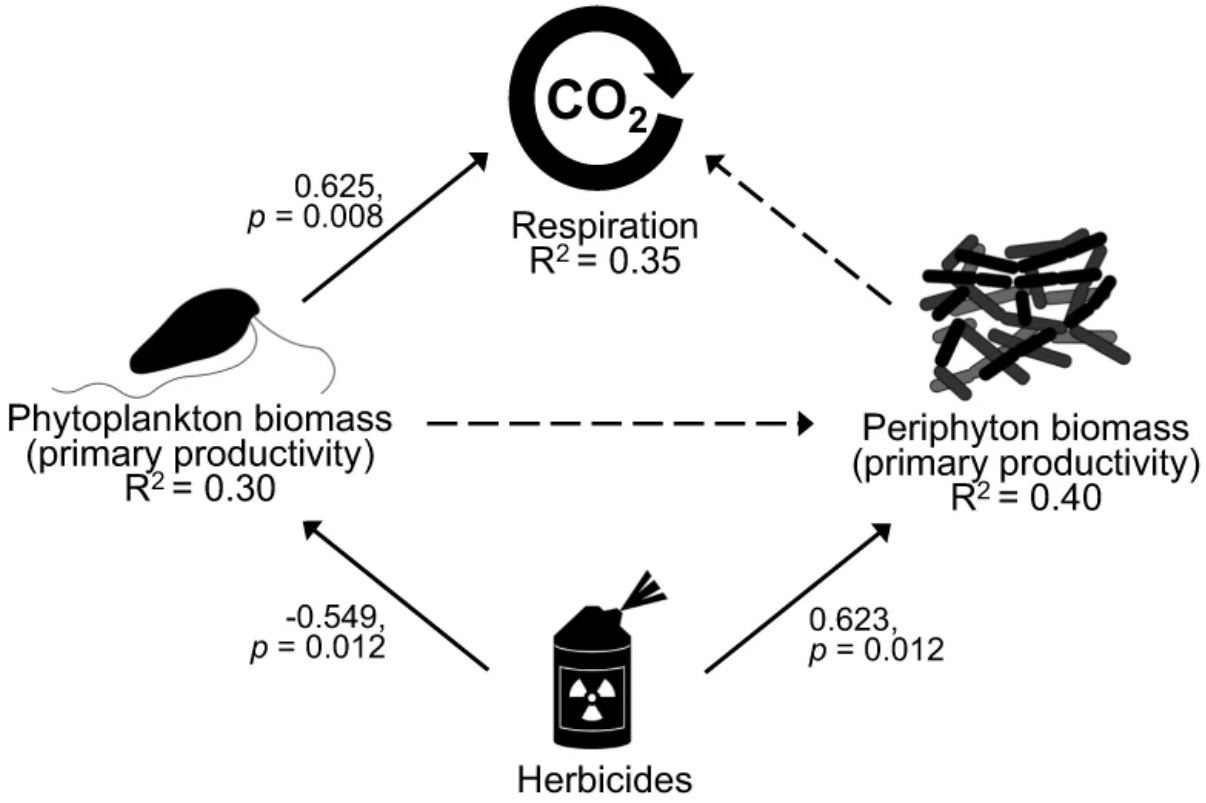
Modeling of herbicide losses in a tile drainage-dominated small catchment and at field level with SWAT+

PhD-project at Kiel University

Anne-Kathrin Wendell, K. Bieger, B. Guse, P. Wagner,
J. Kiesel, U. Ulrich, N. Fohrer

Impacts of herbicide on freshwater ecosystems

Motivation



Bottom-up-effect

Abundance ↓

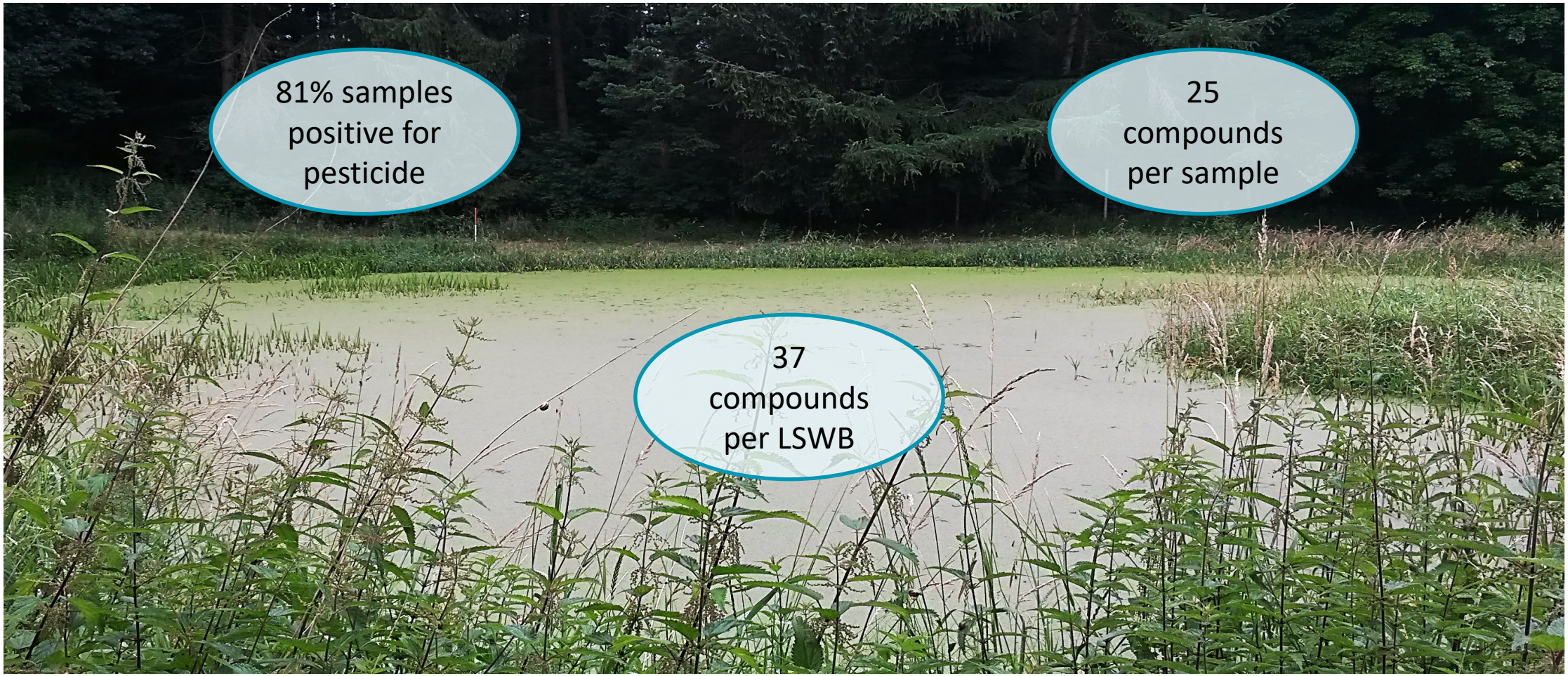
Productivity ↓

Respiration ↓

Rumschlag et al. 2020

Pollution status of lentic small water bodies (LSWB)

Motivation



Ulrich et al. 2021

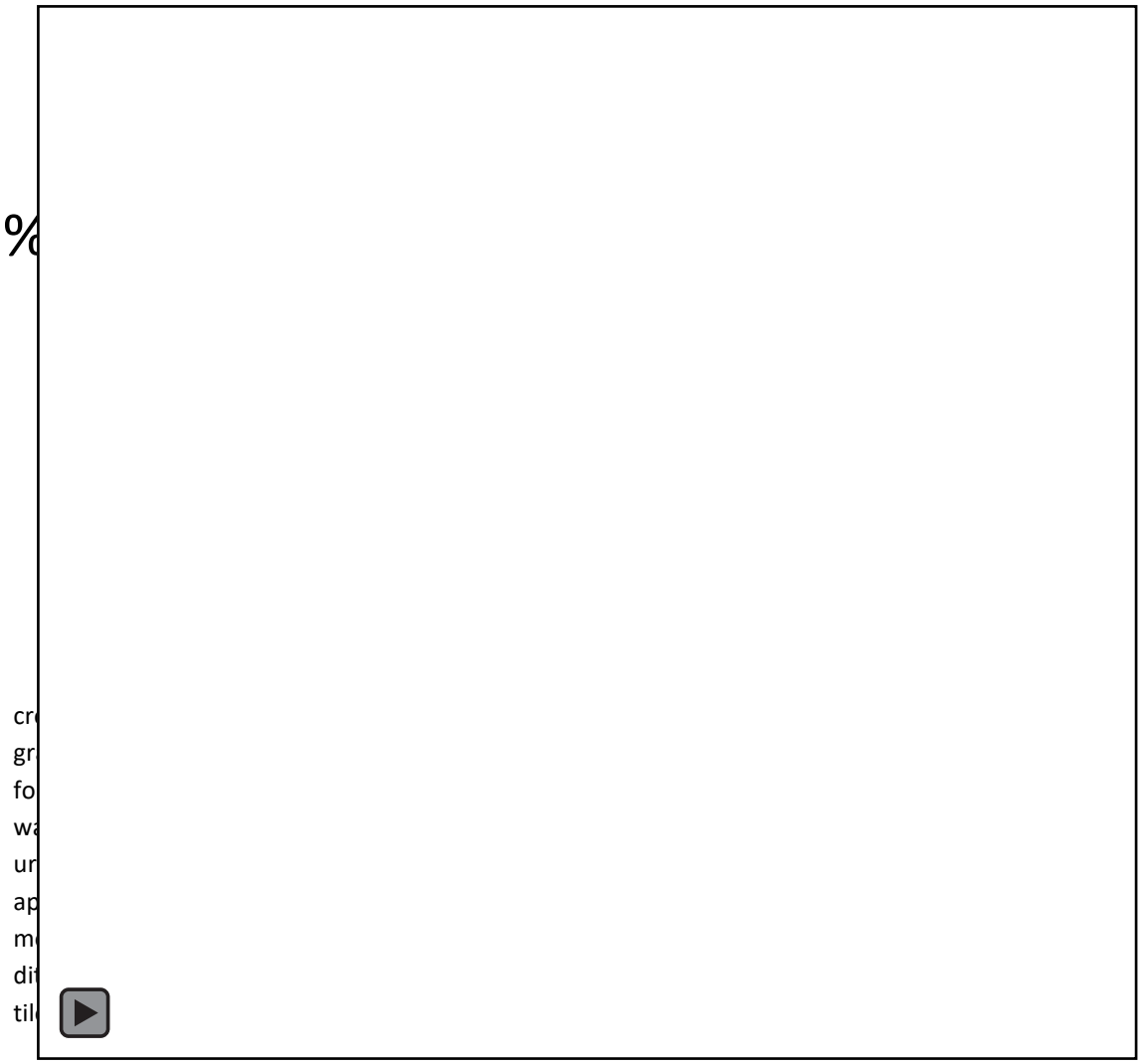
General information about the catchment

Study area

- Measuring period: 2016 to 2020
- Drainage network: 6.3 km (: 13%; : 87%
- Changing application rates and pattern

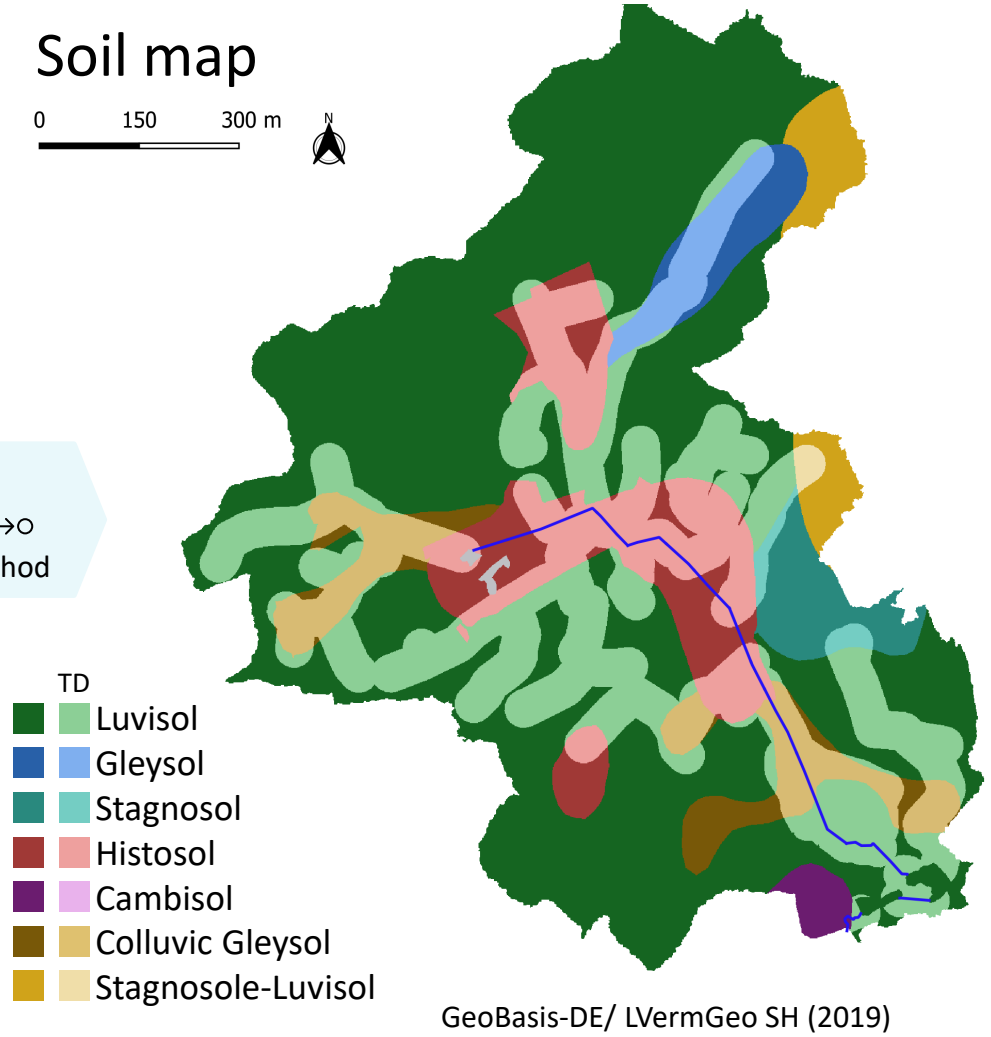
Flufenacet	Solubility: 51 mg/l K_{oc}: 401 DT_{50}: 39.0 d (soil)	Mobility: P < D < F
Diflufenican	Solubility: 0.05 mg/l K_{oc}: 5504 DT_{50}: 64.6 d (soil)	Persistence: F < D < P
Pendimethalin	Solubility: 0.33 mg/l K_{oc}: 17491 DT_{50}: 100.6 d (soil)	

(Pesticide Properties DataBase (PPDB), University of Hertfordshire 2022)



Model information

Method



GeoBasis-DE/ LVermGeo SH (2019)

Model structure

- Tile drains (TD): 30 m buffer zone
- SWAT+ 60.5.4 (groundwater mixing factor of pesticides is added (Rathjens et al. 2023))

Model evaluation

- Calibration of hydrology and pesticides: manual

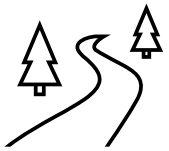
	Hydrology	Pesticide
Calibration	Even months	Every second week
Validation	Uneven months	Every first week
Reasons	Changing weather conditions	Few applications under changing conditions

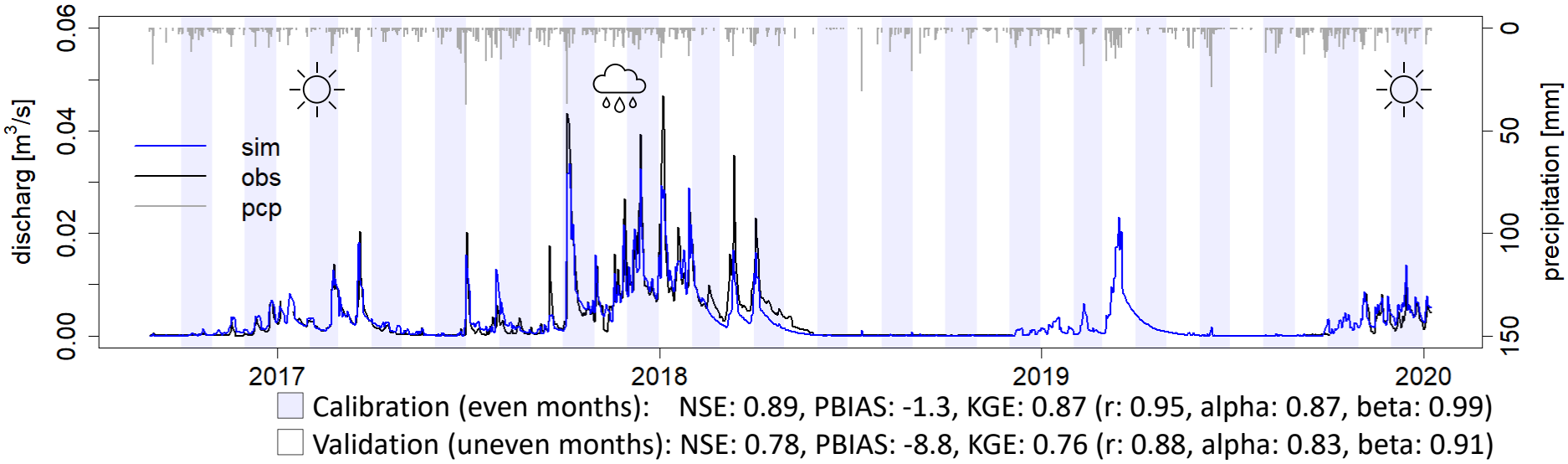
- Model results field scale: plausibility check

Hydrology

Results

Model results for hydrology

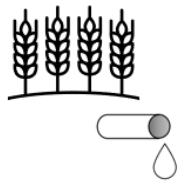


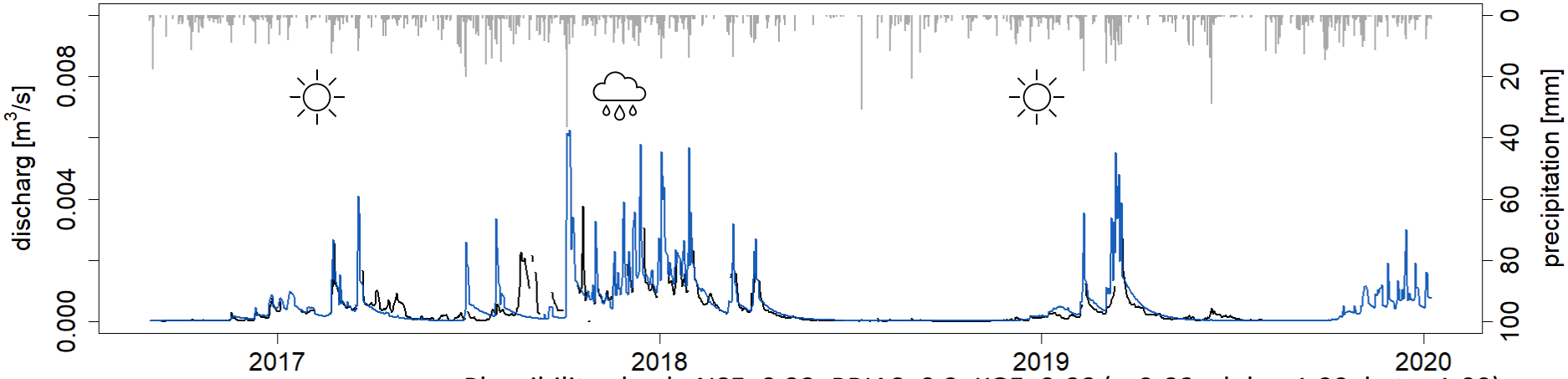


Calibration (even months): NSE: 0.89, PBIAS: -1.3, KGE: 0.87 (r: 0.95, alpha: 0.87, beta: 0.99)

Validation (uneven months): NSE: 0.78, PBIAS: -8.8, KGE: 0.76 (r: 0.88, alpha: 0.83, beta: 0.91)

Results



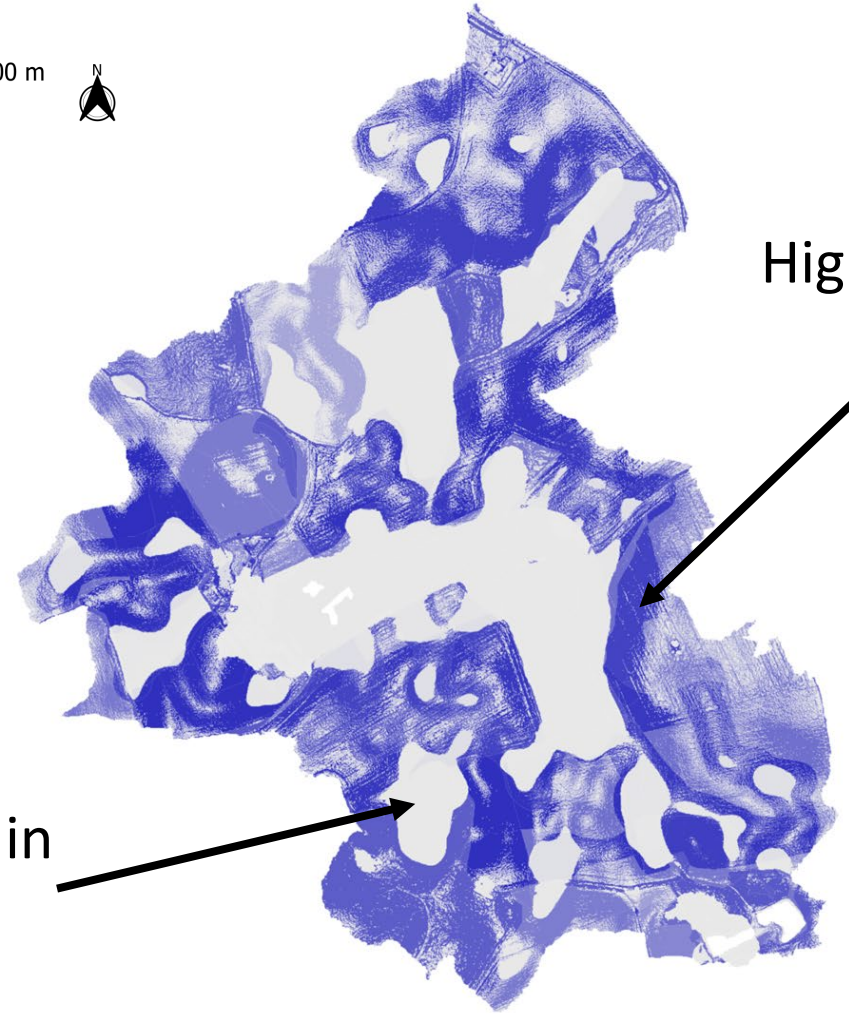


Plausibility check: NSE: 0.32, PBIAS: 0.2, KGE: 0.66 (r: 0.66, alpha: 1.00, beta: 1.00)

Spatial distribution of the hydrological components

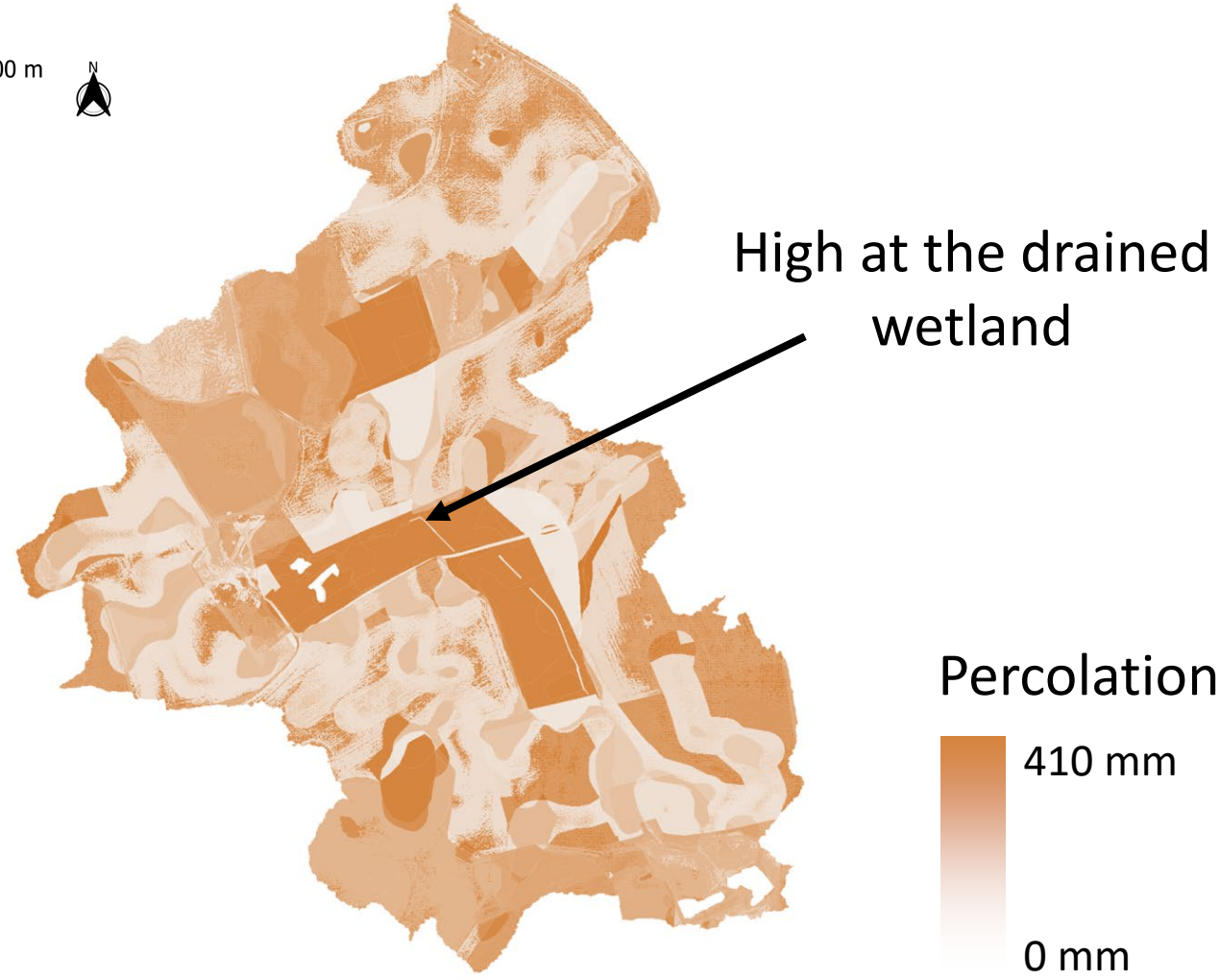
Results

Spatial distribution of the hydrological components



Results

Spatial distribution of the hydrological components



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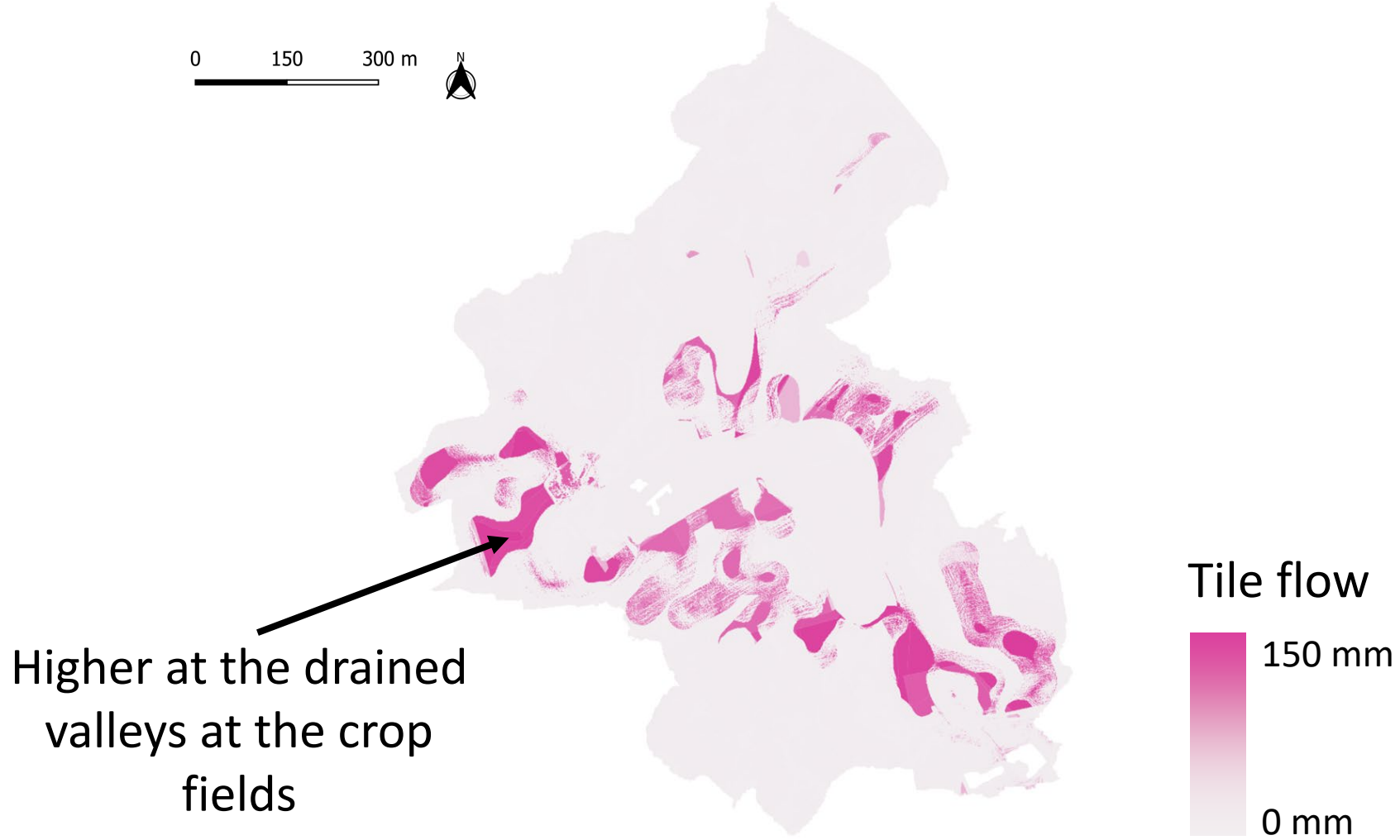

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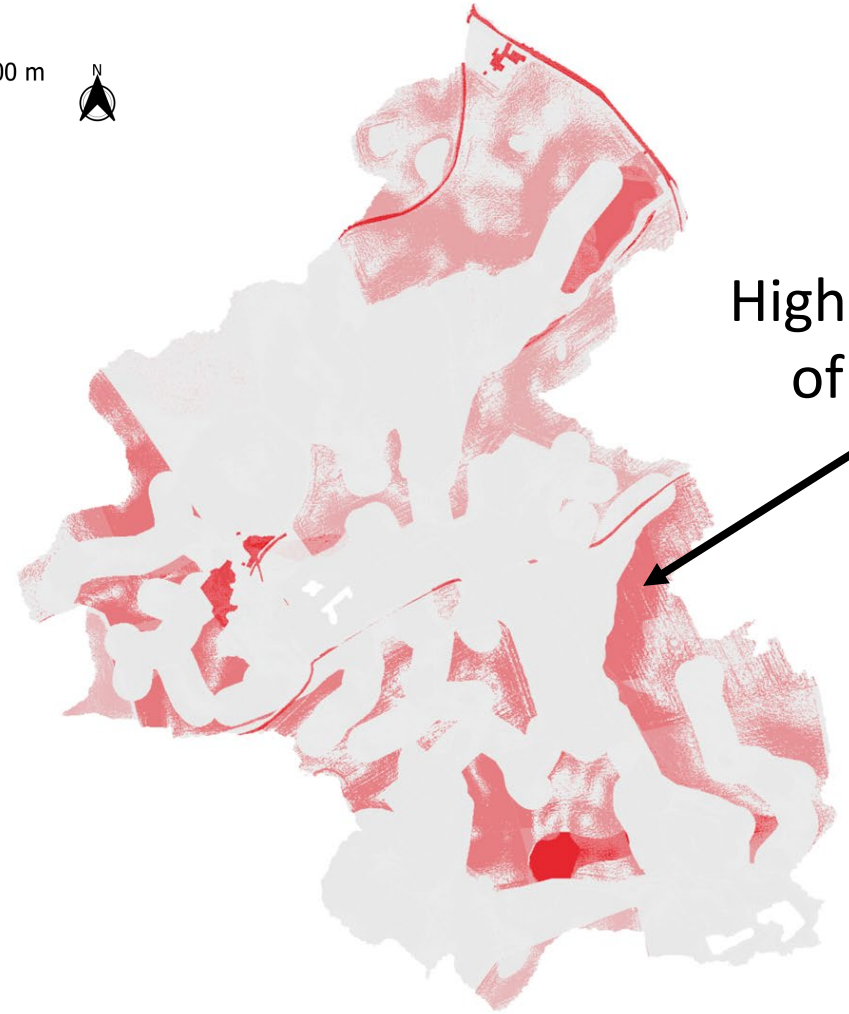
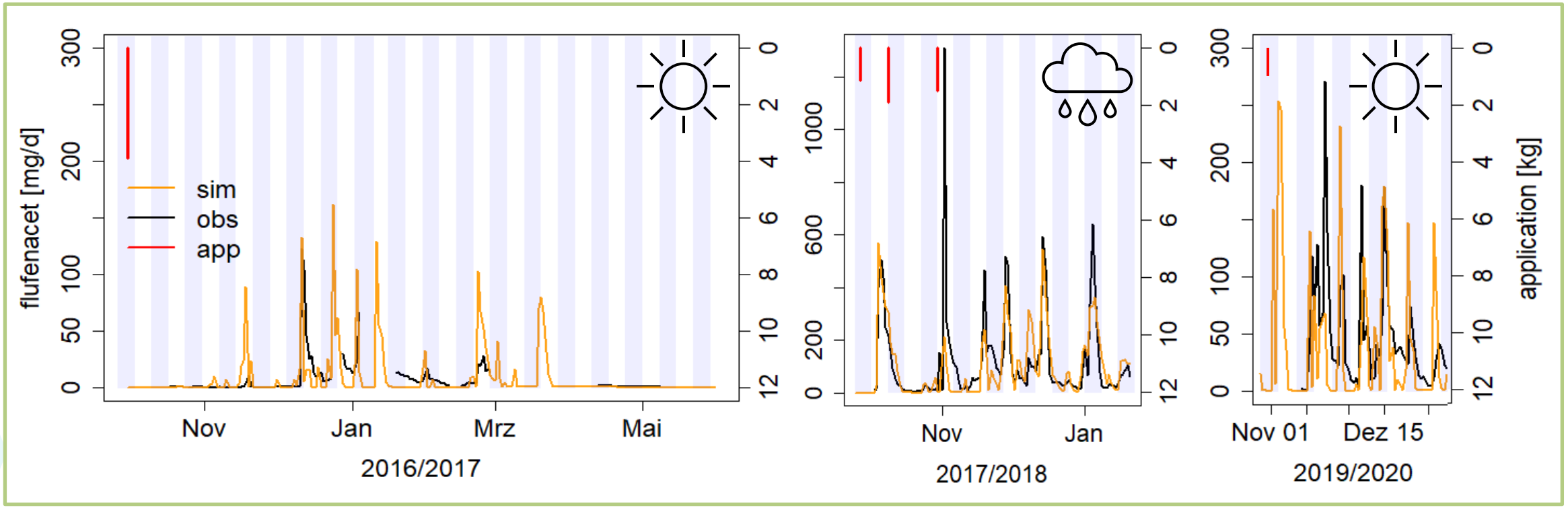
Spatial distribution of the hydrological components



Results

Mobile pesticides

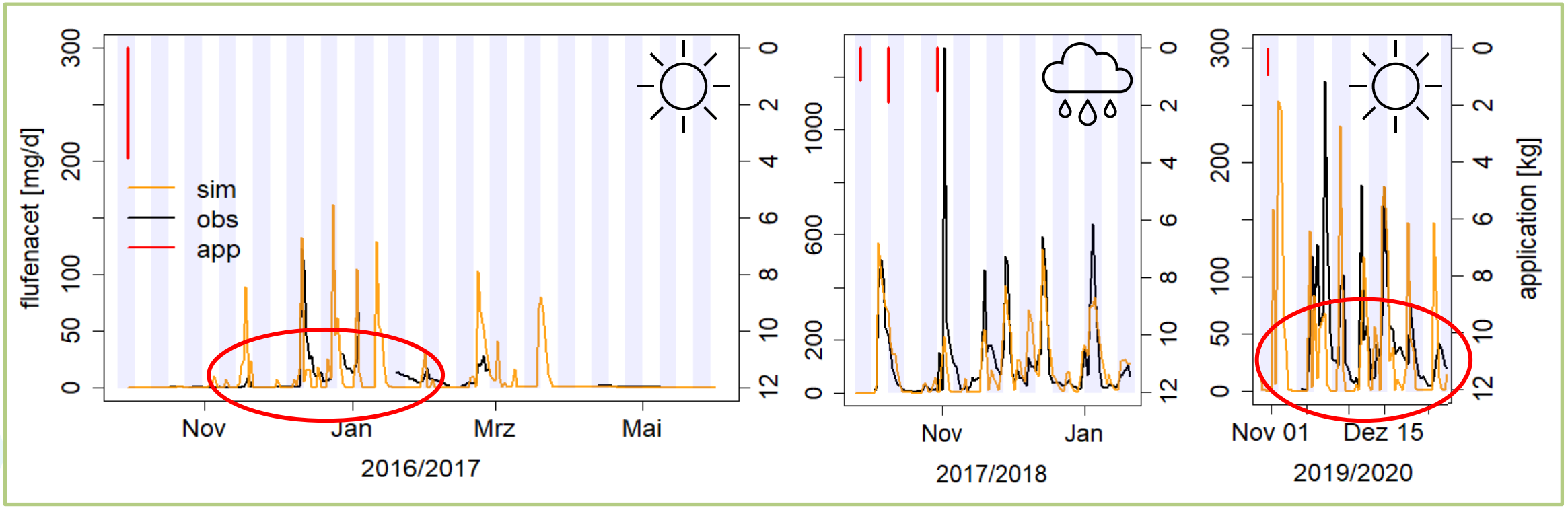
Modelling of flufenacet at catchment scale



- Calibration uneven weeks: NSE: 0.52, PBIAS: -1.7, KGE: 0.74 (r: 0.75, alpha: 0.94, beta: 0.98)
- Validation even weeks: NSE: 0.52, PBIAS: -18.7, KGE: 0.56 (r: 0.73, alpha: 0.81, beta: 0.81)

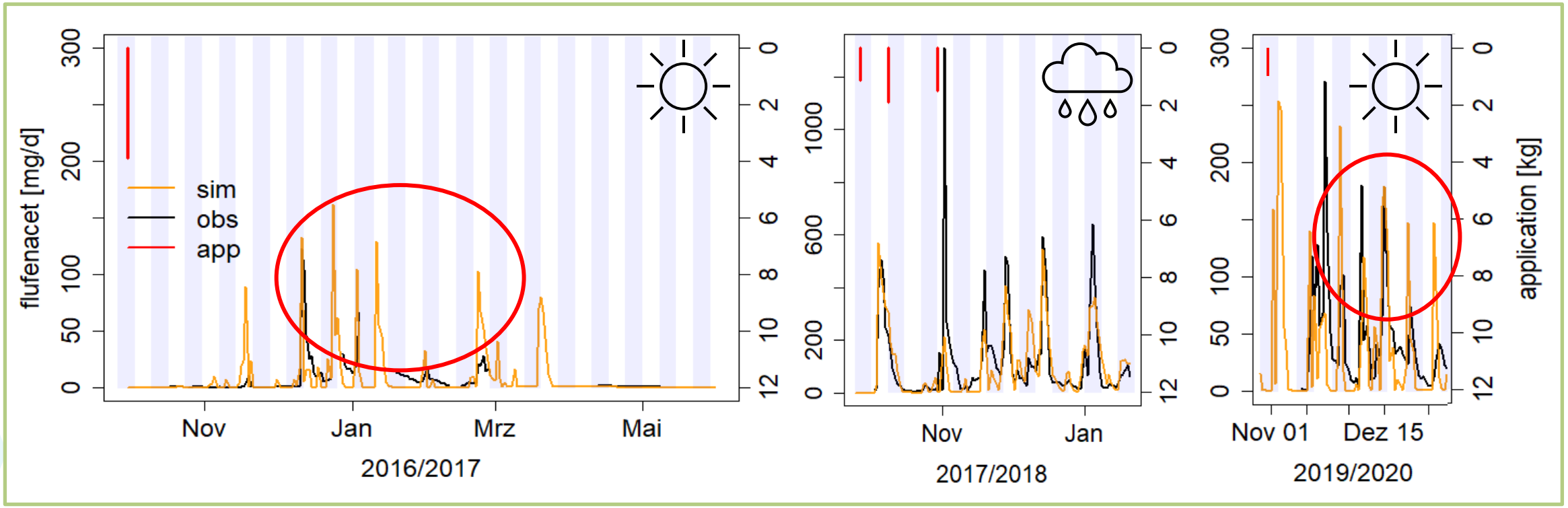
Results

Modelling of flufenacet at catchment scale



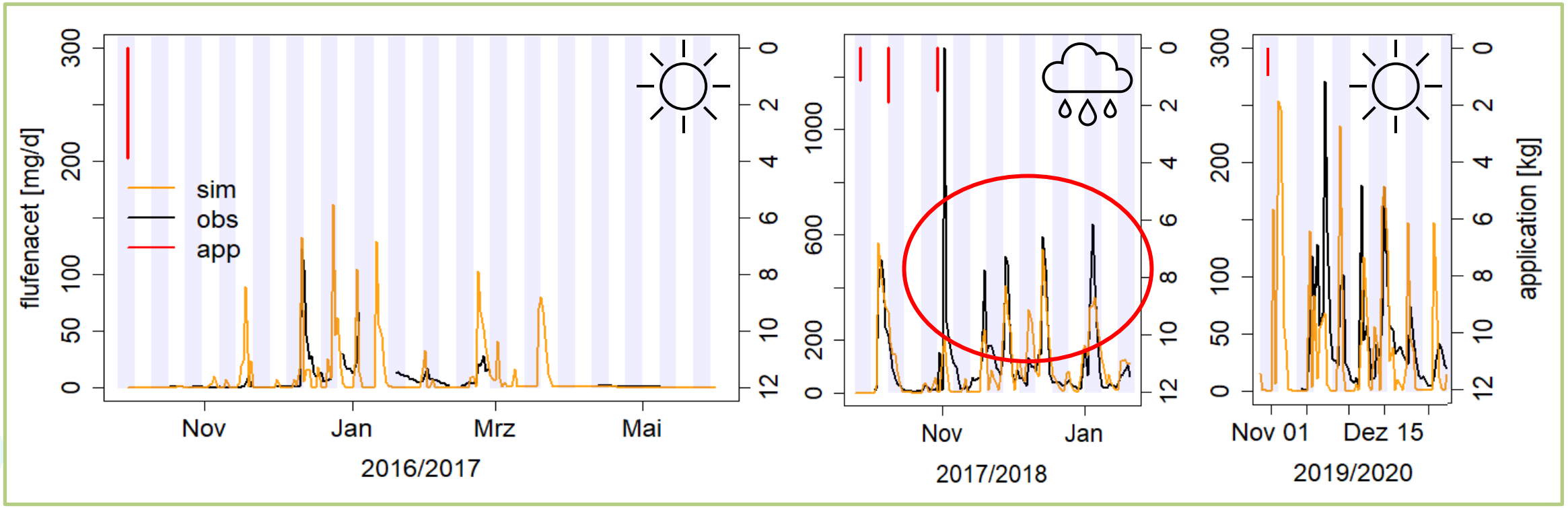
Underestimating the low flow loads at the dry years

Modelling of flufenacet at catchment scale



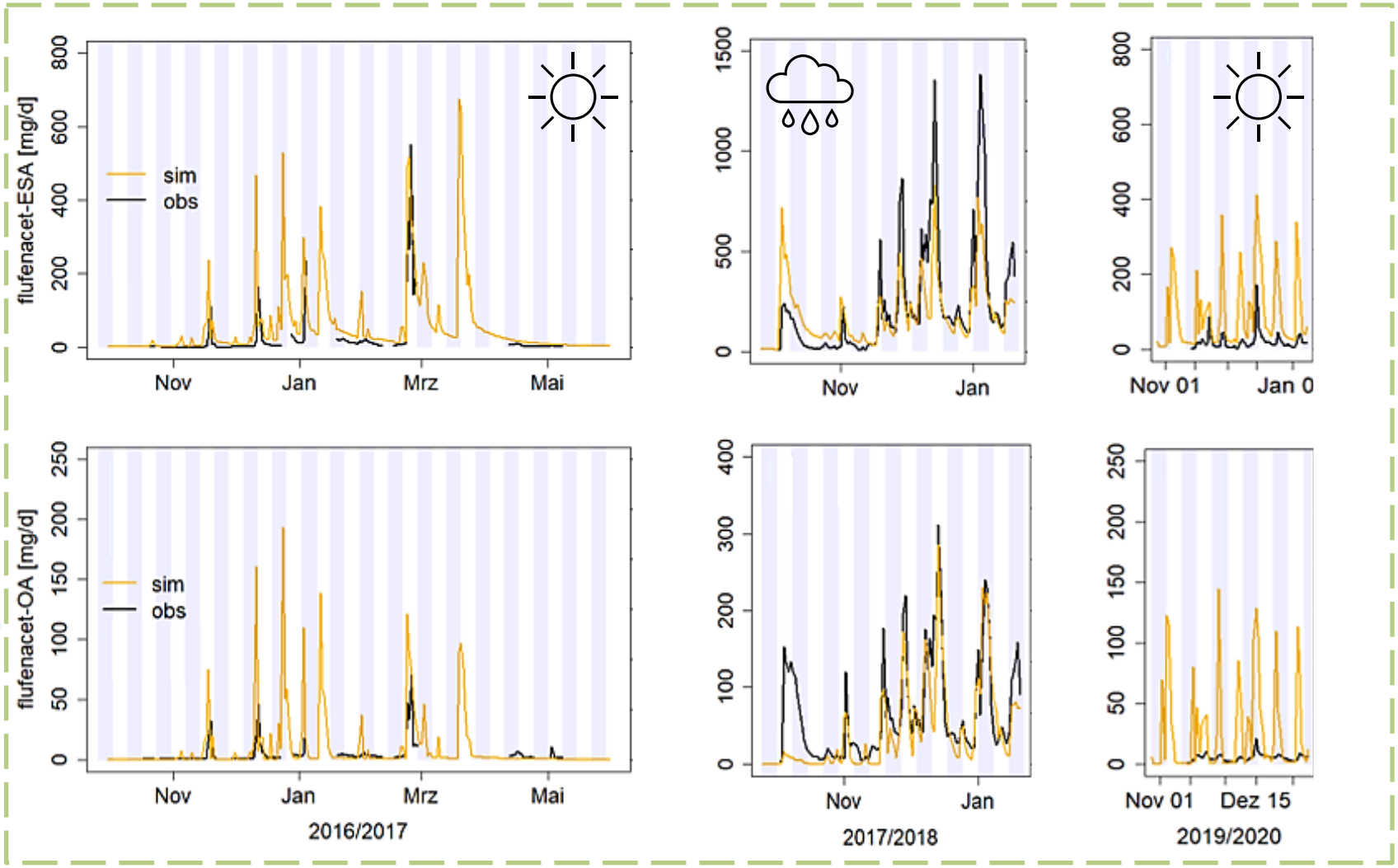
Overestimating the peak loads at the dry years

Modelling of flufenacet at catchment scale



Underestimating the peak loads at the wet year

Emergence & transport of transformation products



Flufenacet sulphonic acid (ESA)

Calibration uneven weeks:
NSE: 0.60, PBIAS: 8.1
KGE: 0.57
(r: 0.79, alpha: 0.64, beta: 1.08)

Validation even weeks:
NSE: 0.52, PBIAS: 19.3
KGE: 0.56
(r: 0.73, alpha: 0.71, beta: 1.19)

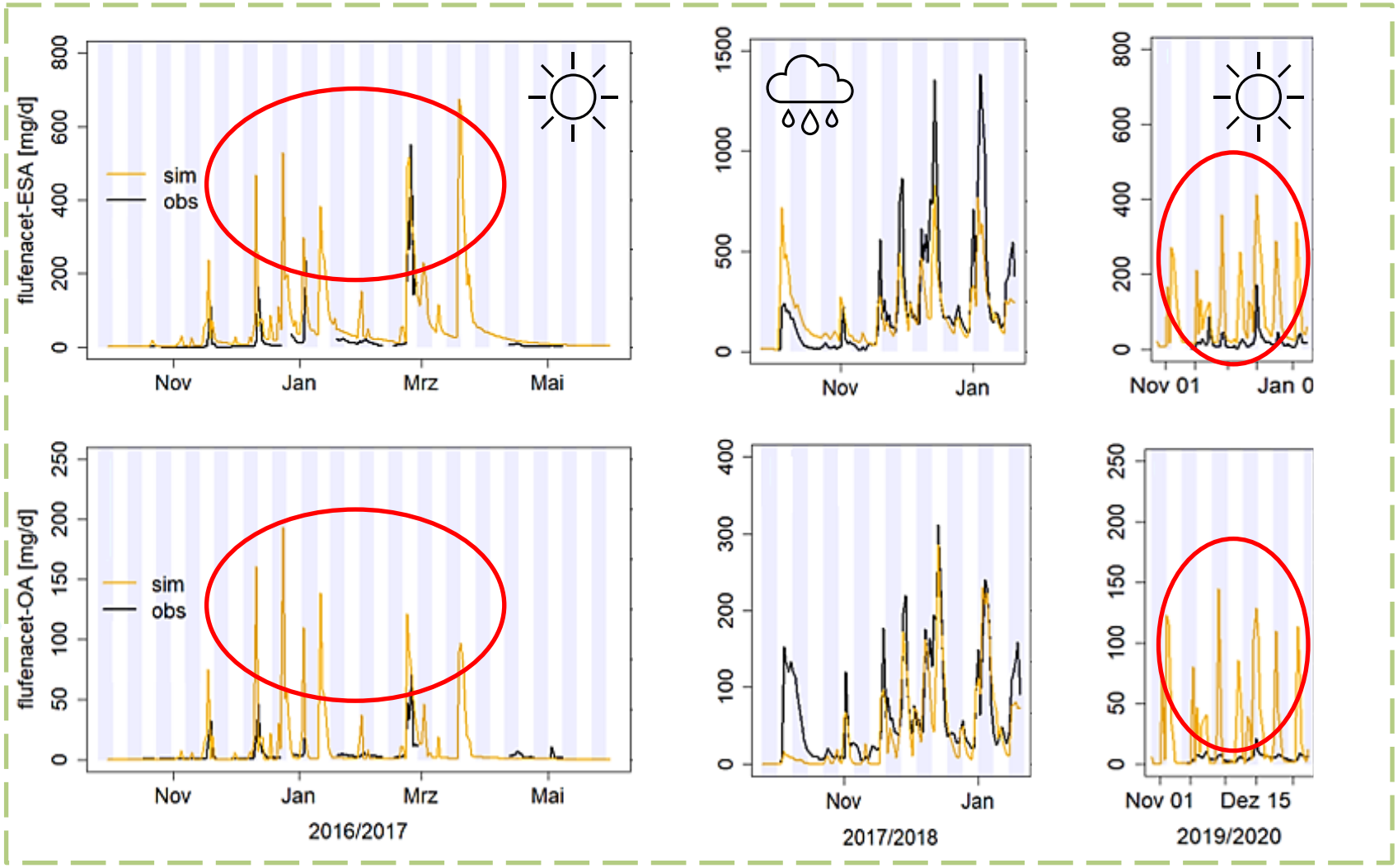
Flufenacet oxalate (OA)

Calibration uneven weeks:
NSE: 0.50, PBIAS: 1.4
KGE: 0.75
(r: 0.75, alpha: 0.99, beta: 1.01)

Validation even weeks:
NSE: 0.51, PBIAS: -9.0
KGE: 0.68
(r: 0.73, alpha: 0.86, beta: 0.91)

Results

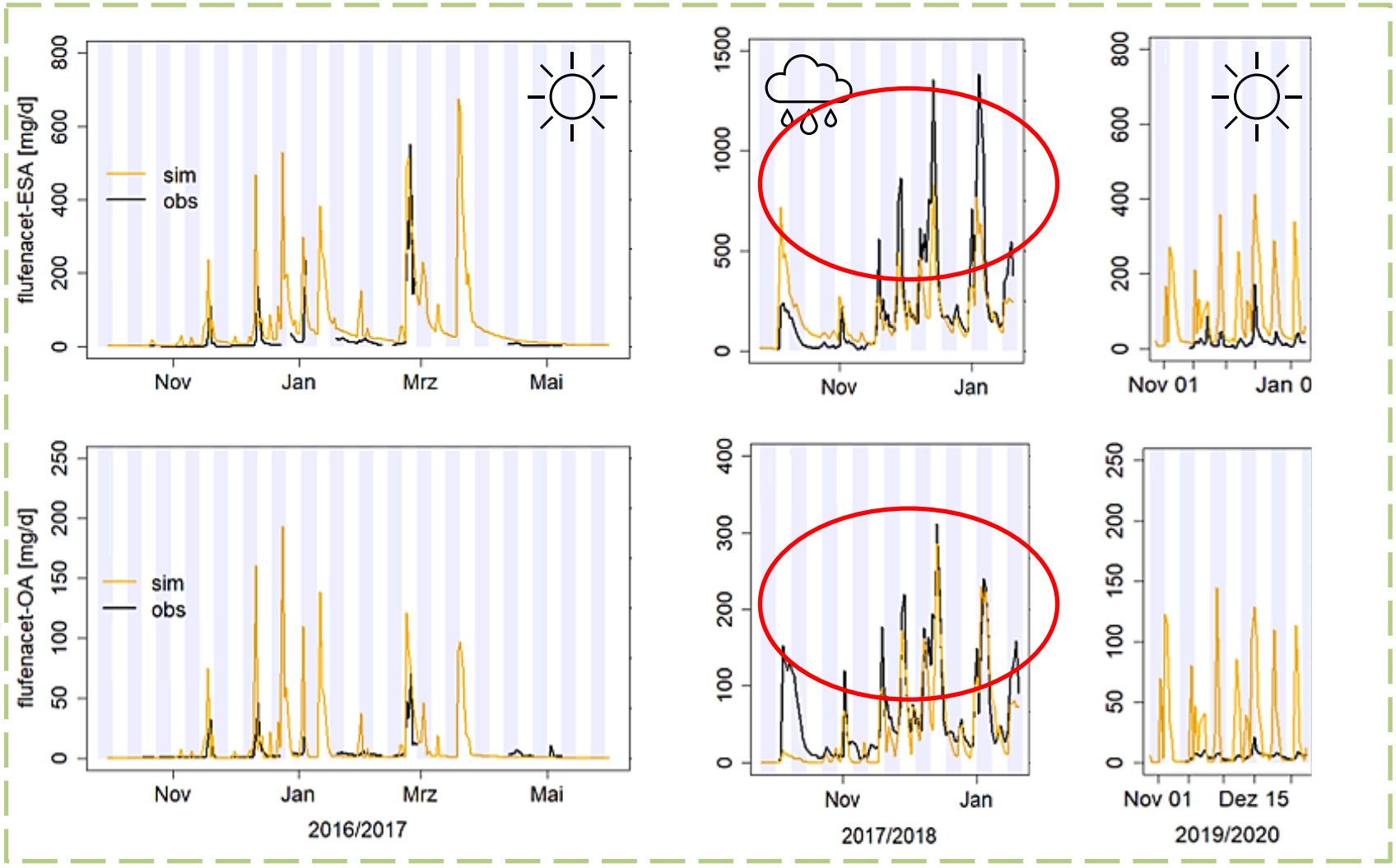
Emergence & transport of transformation products



Overestimating the peak loads at the dry years

Results

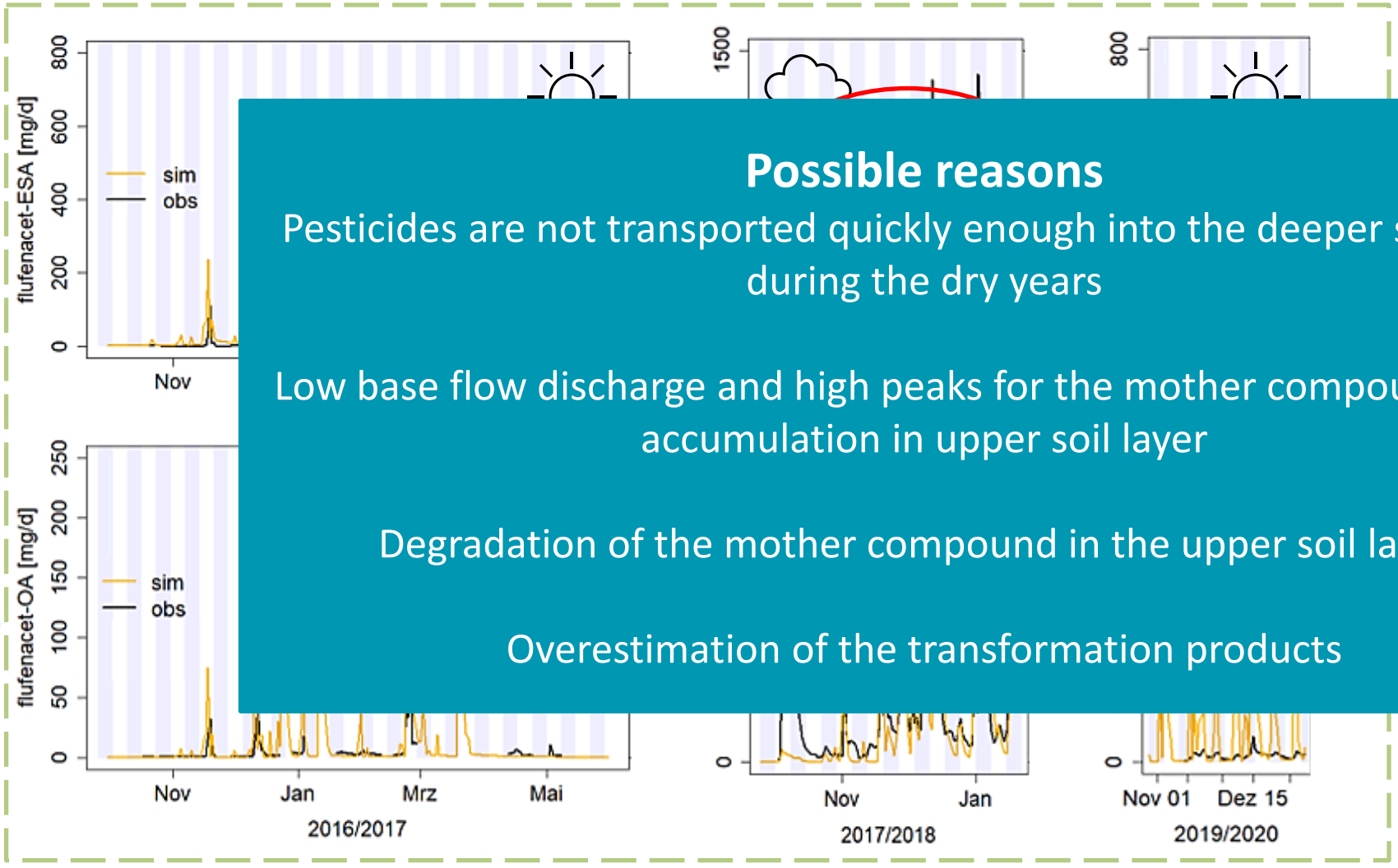
Emergence & transport of transformation products



Underestimating the peak loads at the wet year

Results

Emergence & transport of transformation products



Possible reasons

Pesticides are not transported quickly enough into the deeper soil layers during the dry years

Low base flow discharge and high peaks for the mother compound due to accumulation in upper soil layer

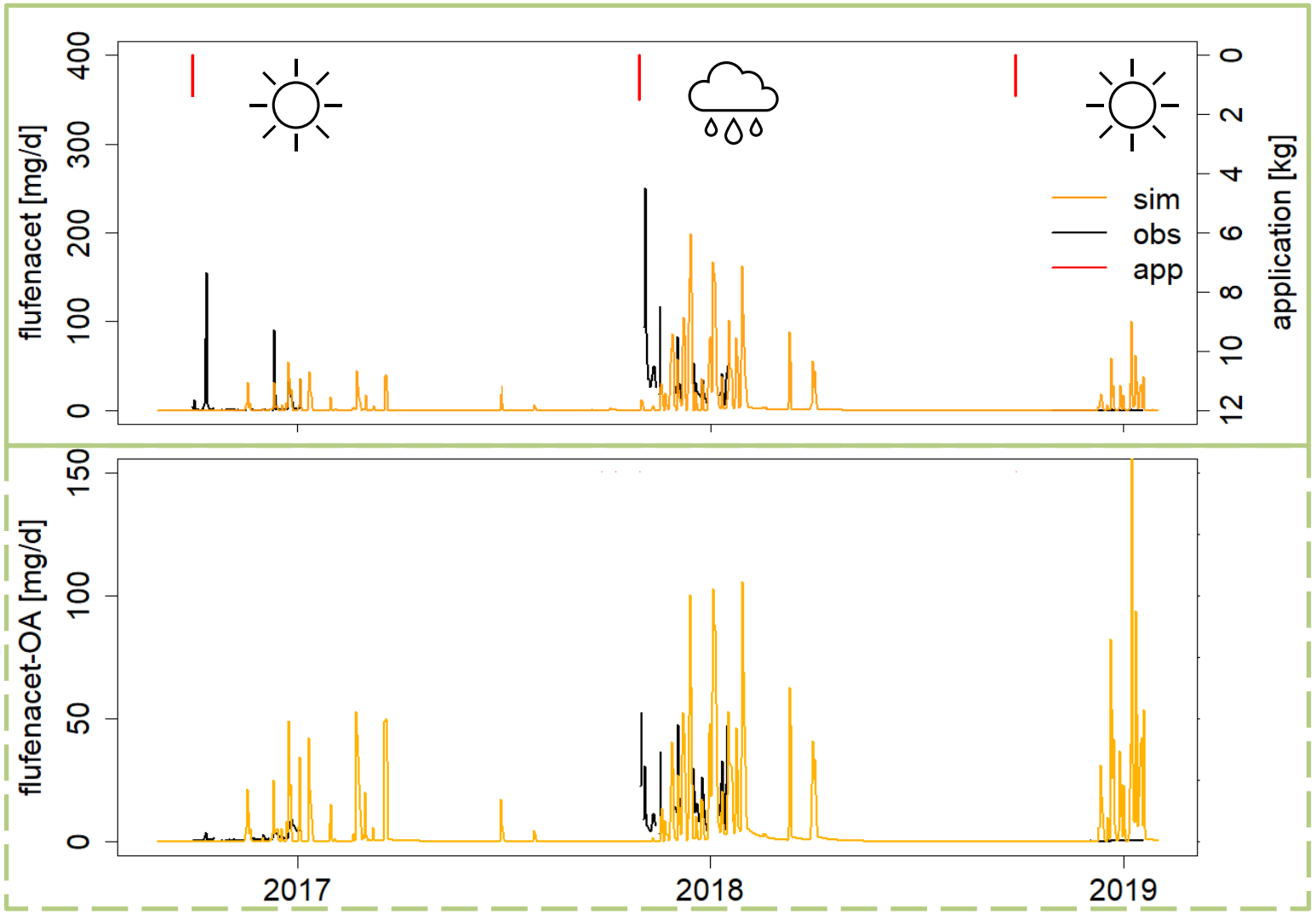
Degradation of the mother compound in the upper soil layers

Overestimation of the transformation products

erestimating
eak loads at
e wet year

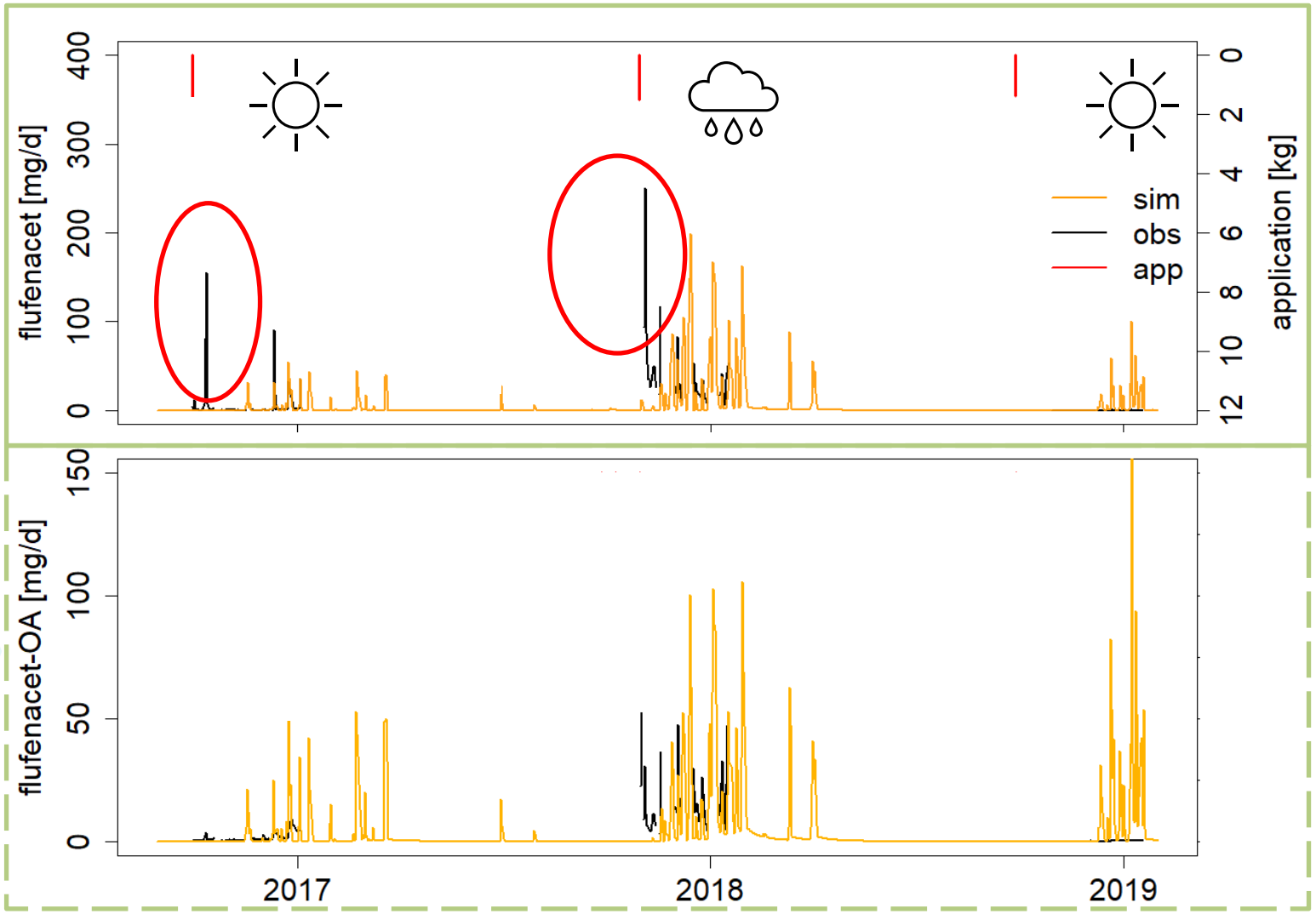
Results

Field scale losses of flufenacet and one transformation product



Results

Field scale losses of flufenacet and one transformation product



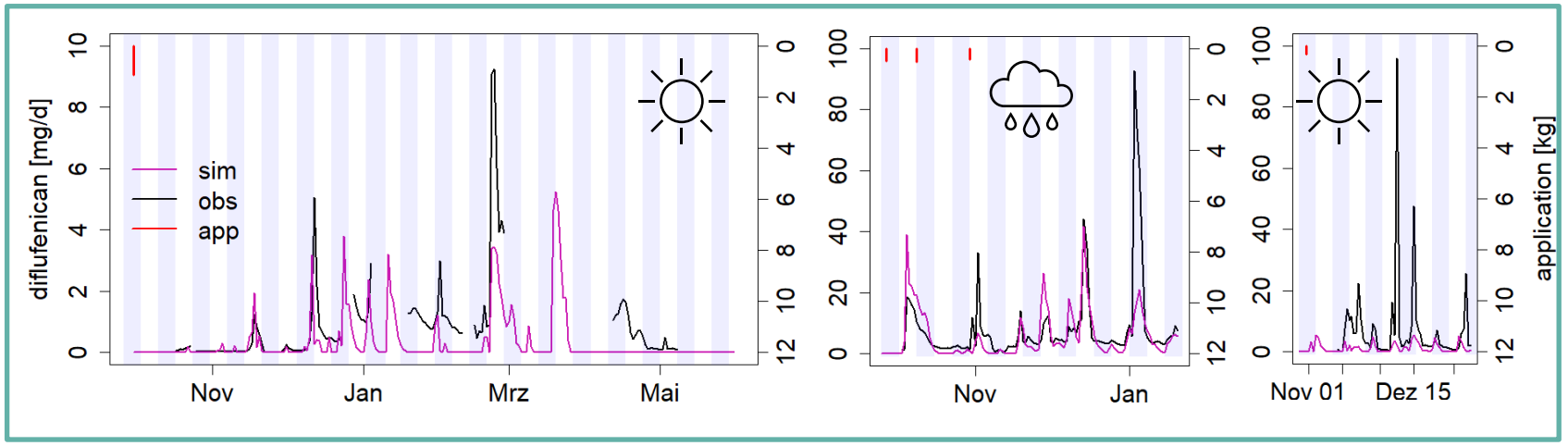
The model can't simulate the first peak load shortly after the application

General overestimation of the peak loads

Results

Non-mobile pesticides

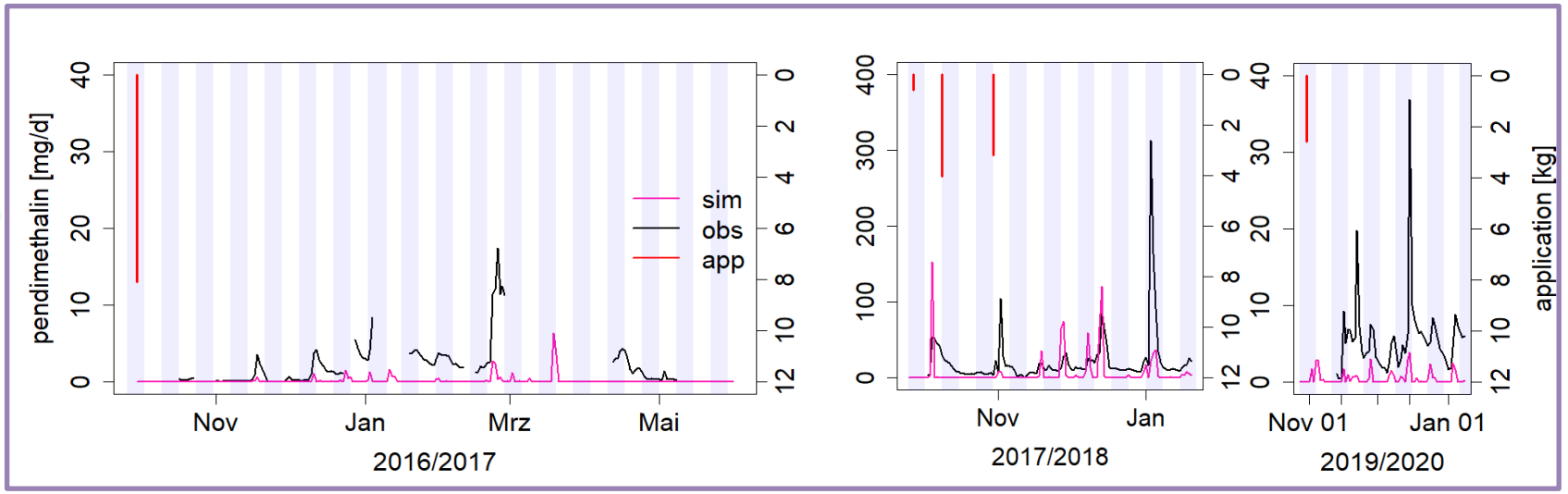
Model results for the non-mobile pesticides diflufenican and pendimethalin



Diflufenican

Calibration uneven weeks:
NSE: 0.17, PBIAS: -56.6
KGE: -0.01
(r: 0.51, alpha: 0.32, beta: 0.43)

Validation even weeks:
NSE: 0.42, PBIAS: -28.7
KGE: 0.58
(r: 0.71, alpha: 0.94, beta: 0.71)



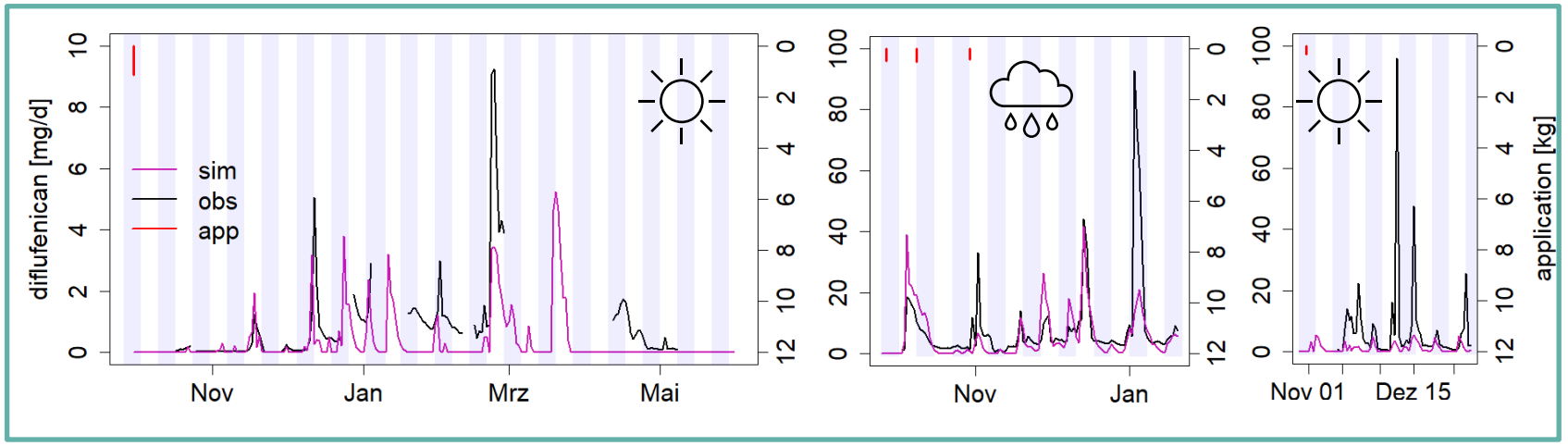
Pendimethalin

Calibration uneven weeks:
NSE: 0.10, PBIAS: -84.7
KGE: -0.24
(r: 0.54, alpha: 0.23, beta: 0.15)

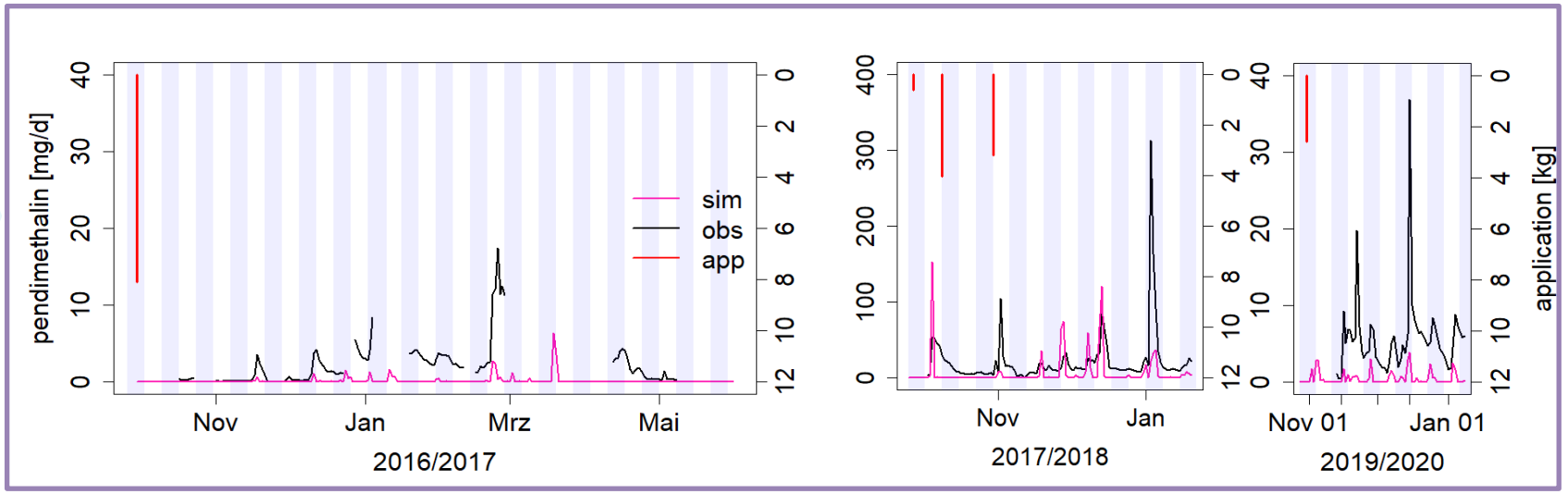
Validation even weeks:
NSE: -0.34, PBIAS: -57.3
KGE: 0.23
(r: 0.51, alpha: 1.21, beta: 0.43)

Results

Model results for the non-mobile pesticides diflufenican and pendimethalin



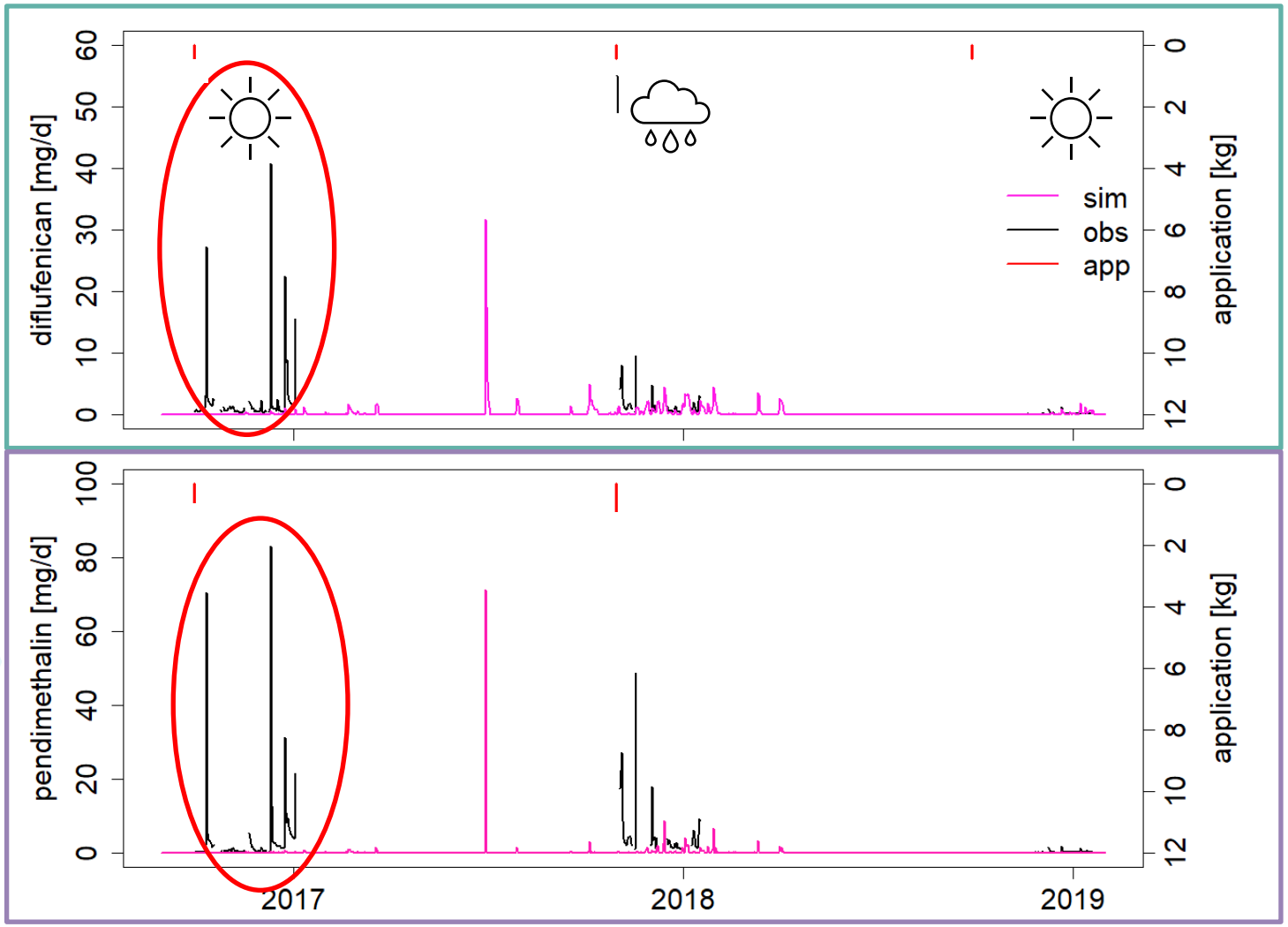
Increase of underestimation with increase of non-mobility



The temporal dynamics of the peak loads are maintained

Results

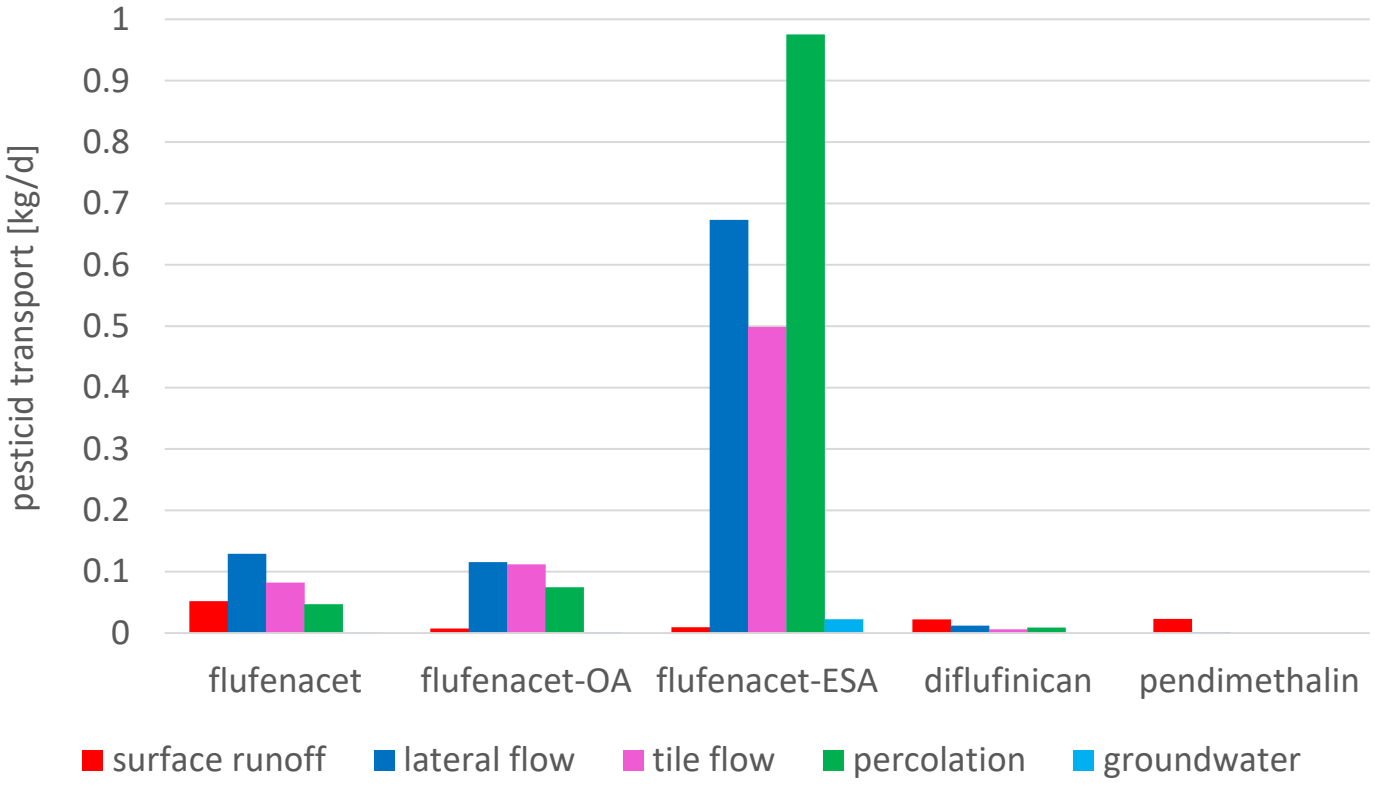
Modelling of diflufenican and pendimethalin at field scale



Massive underestimation at the tile drainage outlet during the dry winter of 2016/2017

Results

Transport pathways of pesticides

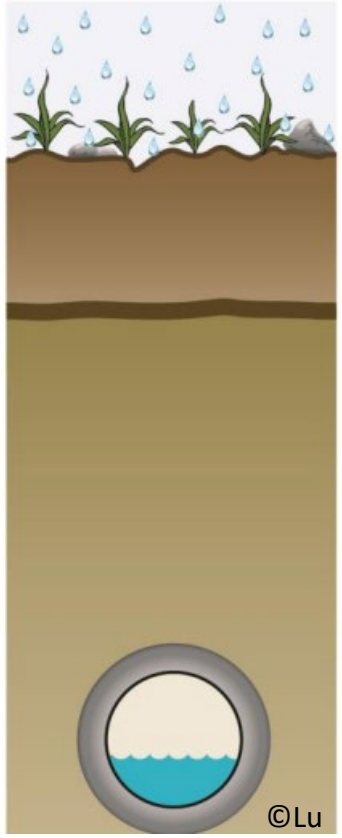


- Mobile pesticides are mainly transported due to lateral and tile flow
- Non-mobile pesticides are transported by surface runoff
- Subsurface transport of non-mobile pesticides having low impact for pesticides discharge

Results

Conclusion

What SWAT+ is good at

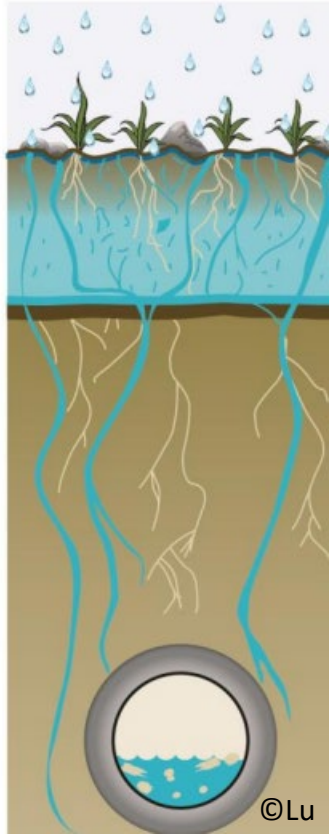


The modelling of **mobile** pesticides and their transformation products can be represented with **good model quality**.

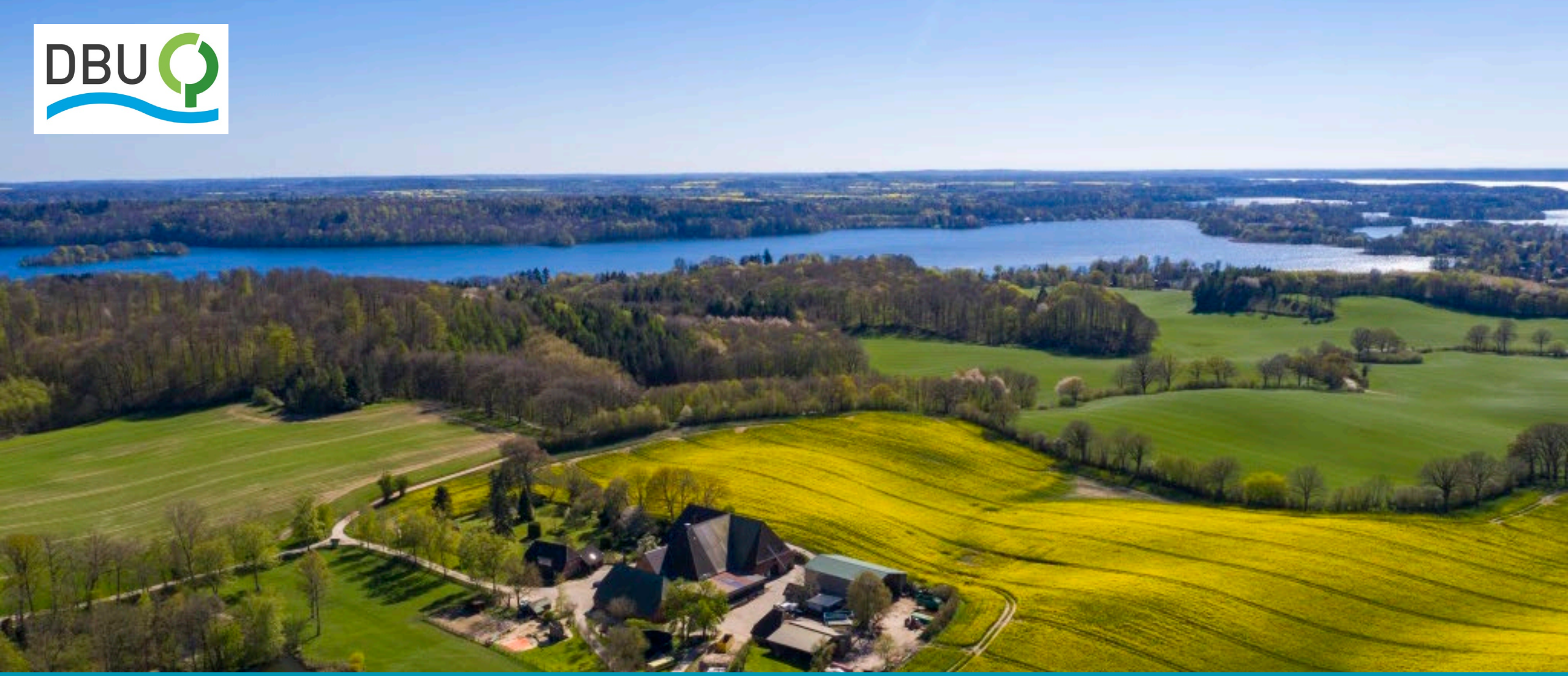
With increasing affinity of the pesticides for **particle transport**, the ability of the model to represent this is **decreasing**.

Subsurface transport of non-mobile pesticides under **dry conditions** is systematically **underestimated** in the model.

What SWAT+ is not good at



Conclusion



Thank you for your attention

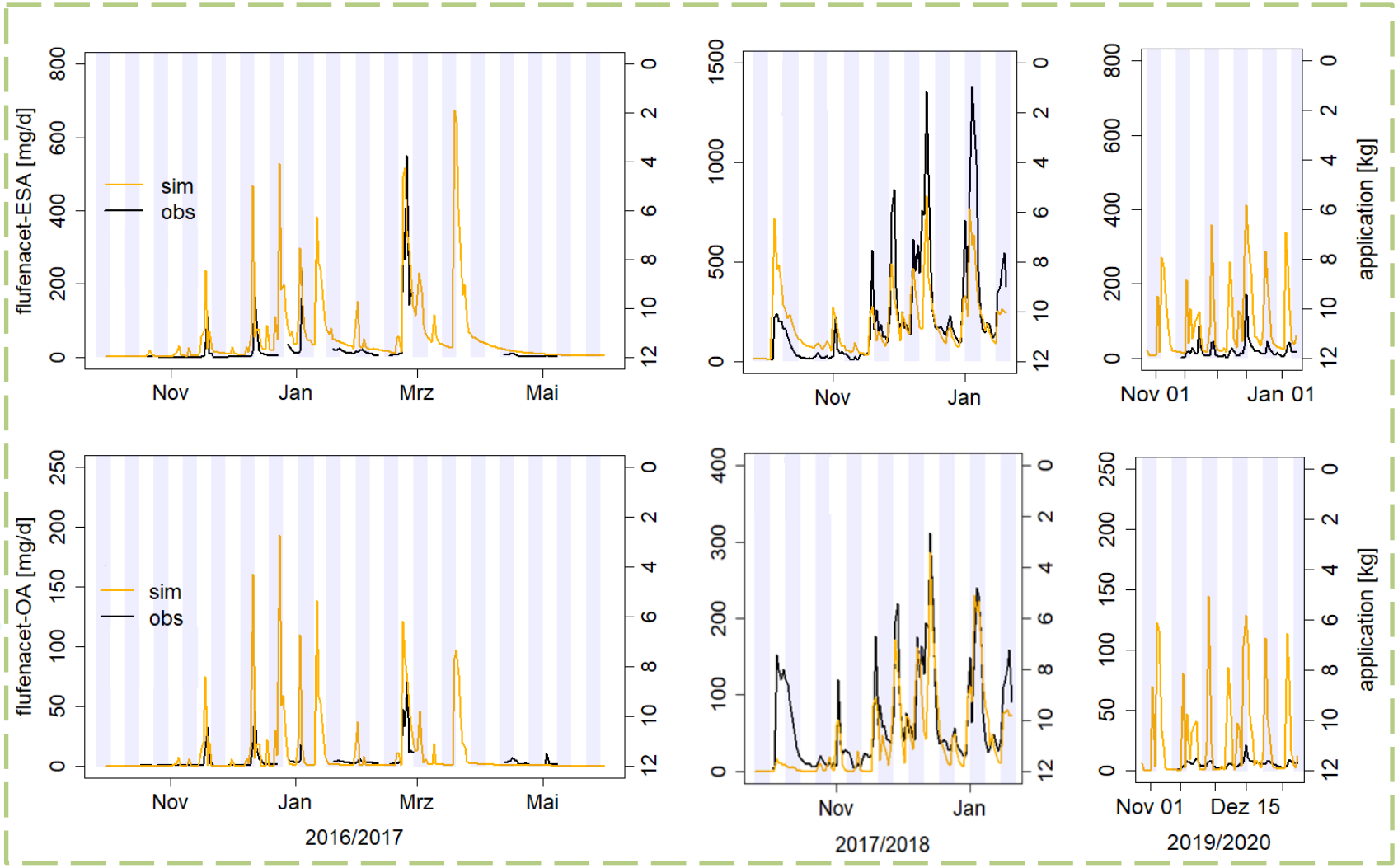
awendell@hydrology.uni-kiel.de

Approval procedure for pesticides in the EU

Approval procedure via FOCUS (Forum for the Co-ordination of Pesticide Fate Models and their Use)

Step 1	Step 2	Step 3	Step 4
One-time losses after application	Losses based on a temporal application pattern of pesticides	Losses through drift, runoff, erosion & tile drainage via "Realistic worst Case-scenarios"	Takes into account the impact of mitigation measures
	Specific scenario descriptions are missing	→4 R-szenarien →6 D-szenarien **Models:** PRZM, MACRO & TOXSWA	  

Emergence & transport of transformation products



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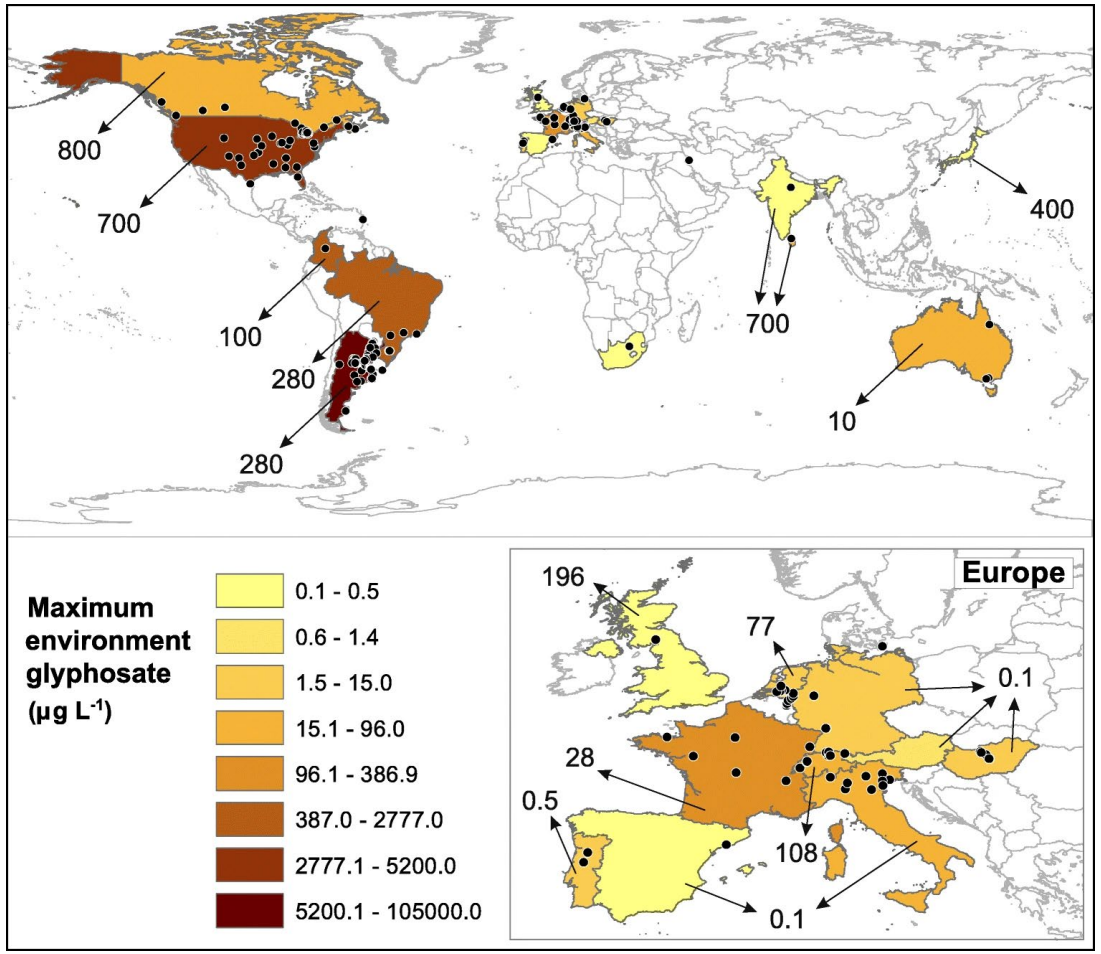
Validation even weeks:
NSE: 0.51, PBIAS: -9.0
KGE: 0.68
(r: 0.73, alpha: 0.86, beta: 0.91)

Results

Maximum glyphosate concentration in freshwater systems and maximum allowed values



Pesticides are often exciding the legal limits in freshwater systems

Brovini, E.M., Cardoso, S.J., Rabelo Quadra, G., Vilas-Boas, J.A., Paranaíba, J.R., de Oliveira Pereira, R., Fernandes Mendonça, R. (2021): Glyphosate concentrations in global freshwaters: are aquatic organisms at risk?. Environmental Science and Pollution Research volume 28, p. 60635–60648.