Journée Scientifique du PIREN-Seine 15/12/2020

Oxygen data assimilation using particle filter in ProSe-PA software

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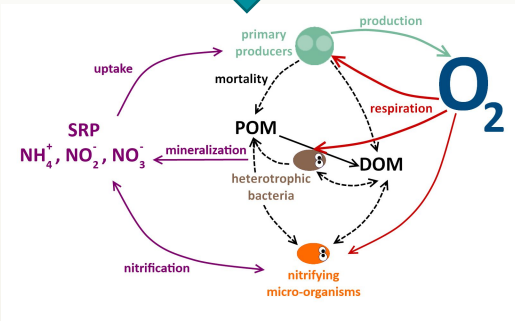
Background: evolution of water quality modeling

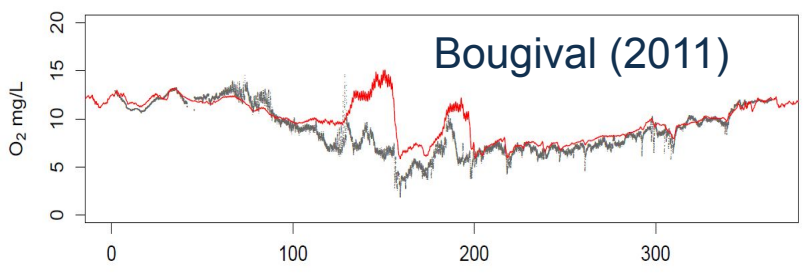
- Dissolved oxygen: a key variable for river system
- First water quality modeling DO-BOD (Streeter and Phelps, 1925)
- Community-centered model RIVE (Billen et al., 1994)
- Water quality modeling program ProSe (Even et al., 2004, Flipo at al., 2007, Vilmin et al., 2016)
- High frequency (HF) data measured by *in-situ* sensors (PHRESQUES-CarboSeine, MeSeine)
- Overestimation of DO during low flow periods (Vilmin, 2014)
- Data assimilation (Particle filter): ProSe-PA

$$\frac{dL}{dt} = k1.L$$



anthropogenic outputs (DO, STEP…), Forcing data (T, irradiance…)

HF measurements



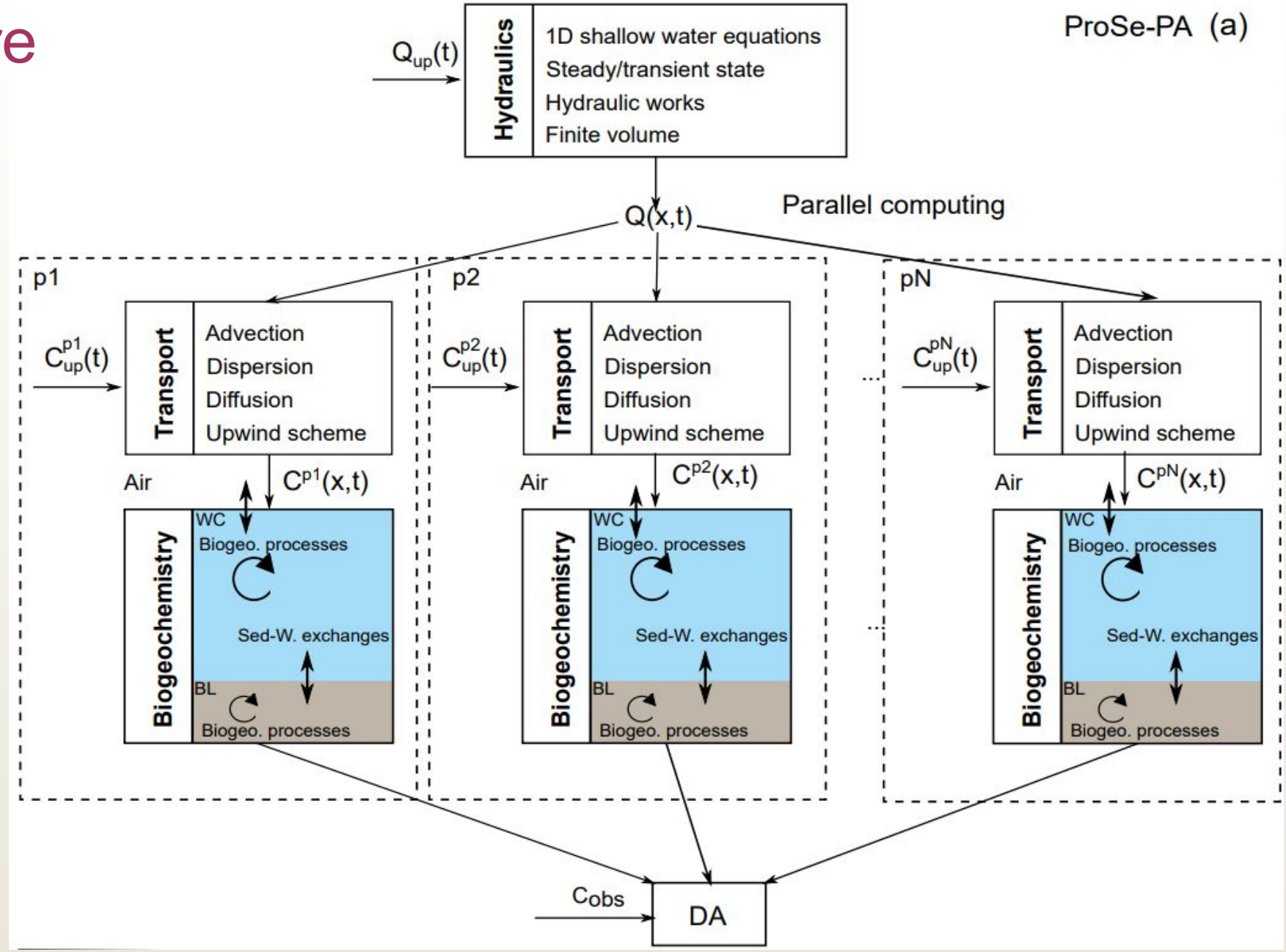
DA (Particle filter) → ProSe-PA

ProSe-PA software

ProSe-PA: **ProSe P**arallel & data **A**ssimilation (Particle filter)

Particle filter: Bayesian approach

A particle: a parameter set (p1, p2, …, pN)



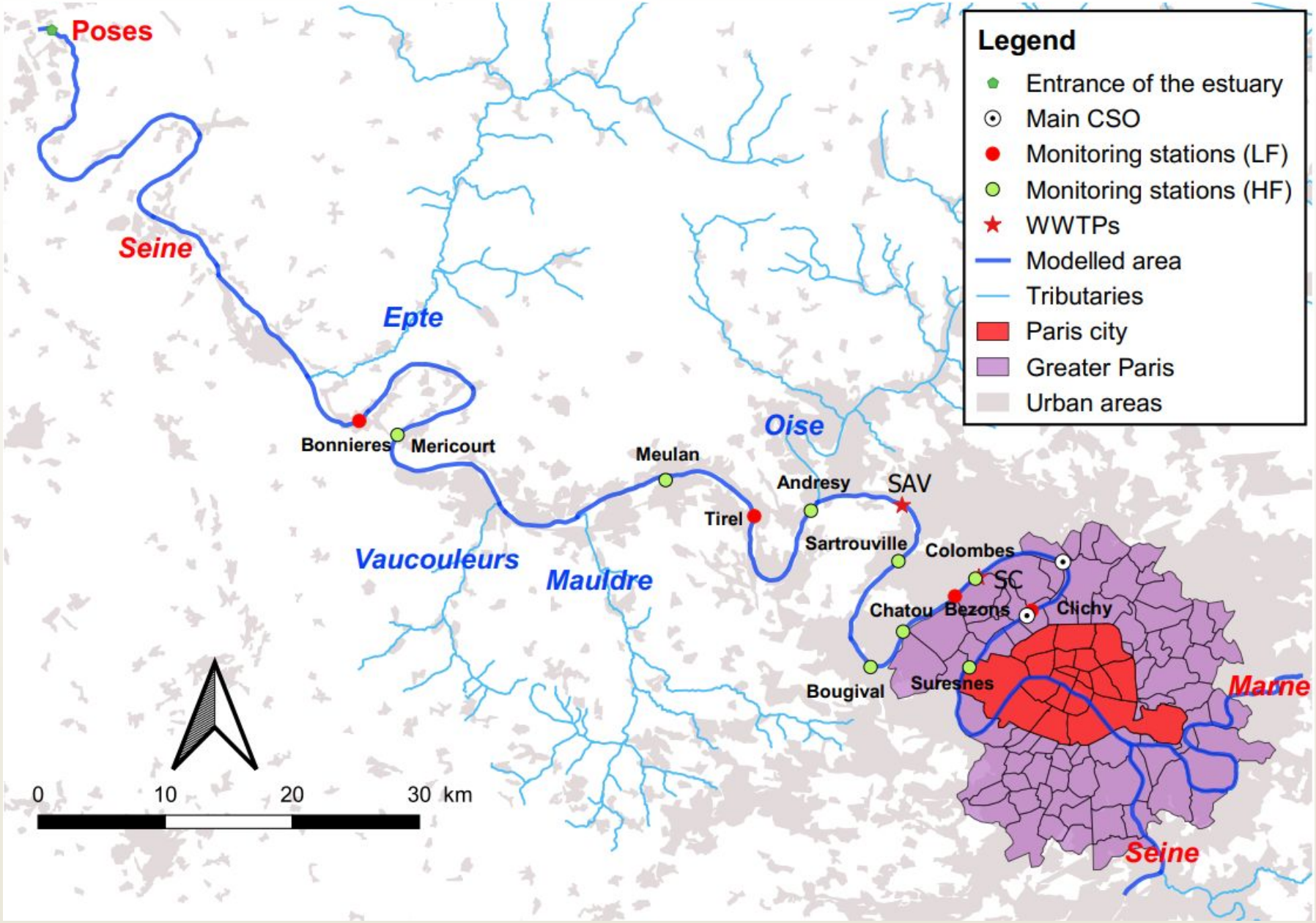
Study area

8 high frequency monitoring stations (MeSeine), in green

4 low frequency monitoring stations (LF), in red

Cross-validation: using measured data at 7 HF stations to predict oxygen concentration at the last station (HF)

Assimilating oxygen data at 8 stations (HF) to predict oxygen concentration at 4 LF stations

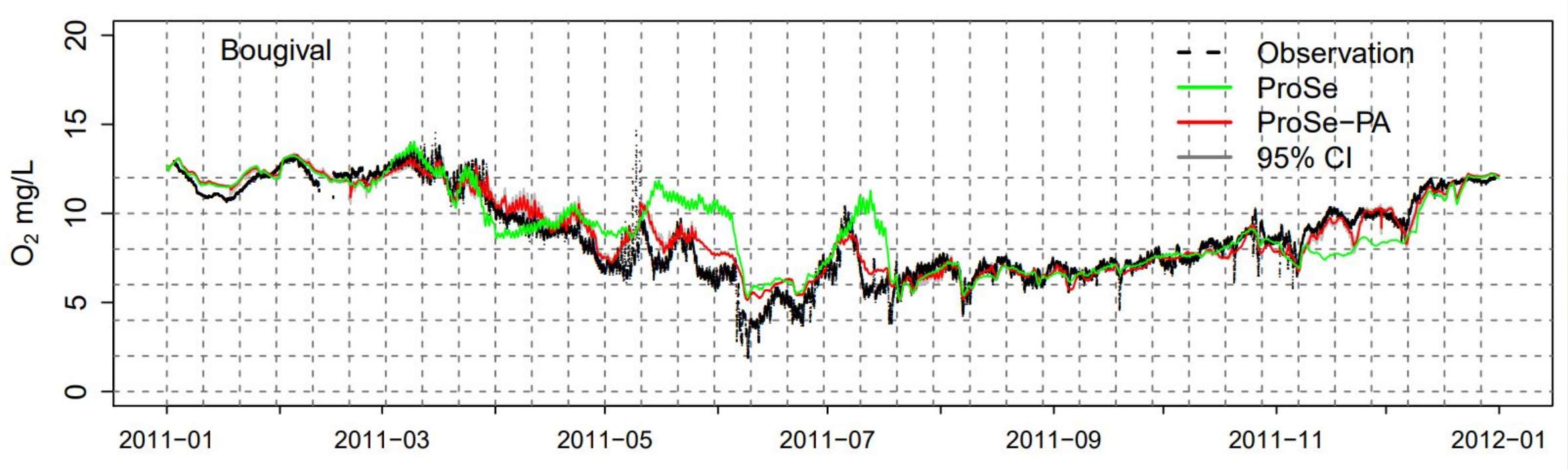


Simulated DO (dissolved oxygen) concentrations at Bougival

ProSe: Static parameter setting (Vilmin, 2014)

ProSe-PA: Weighted mean (500 particles)

95% CI: 95% confidence interval

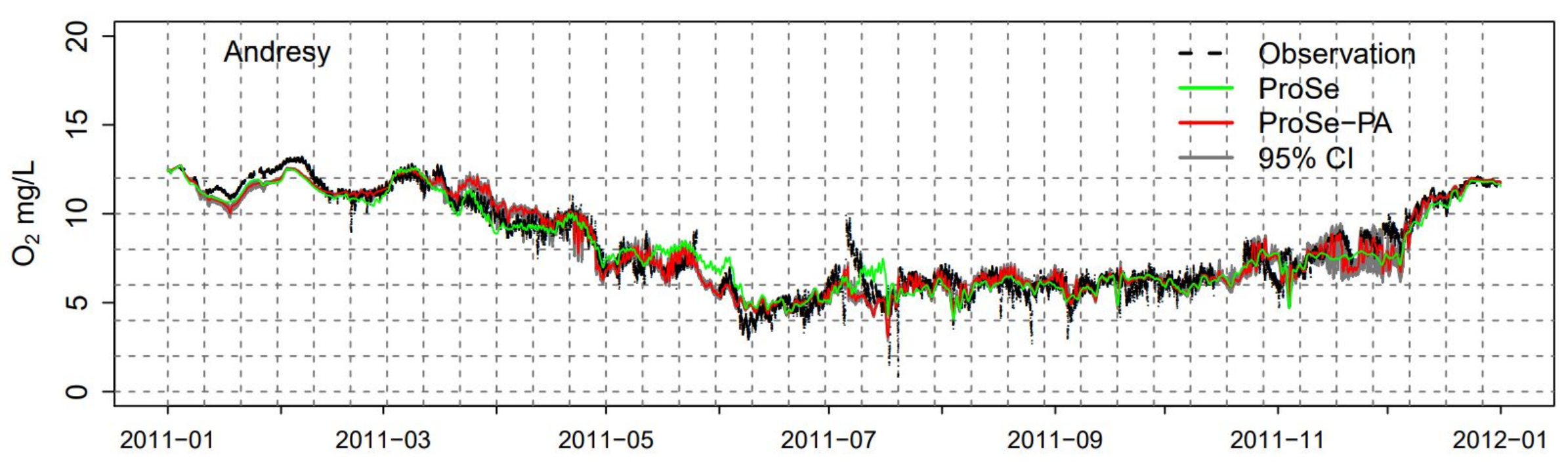


Simulated DO (dissolved oxygen) concentrations at Andresy

ProSe: Static parameter setting (Vilmin, 2014)

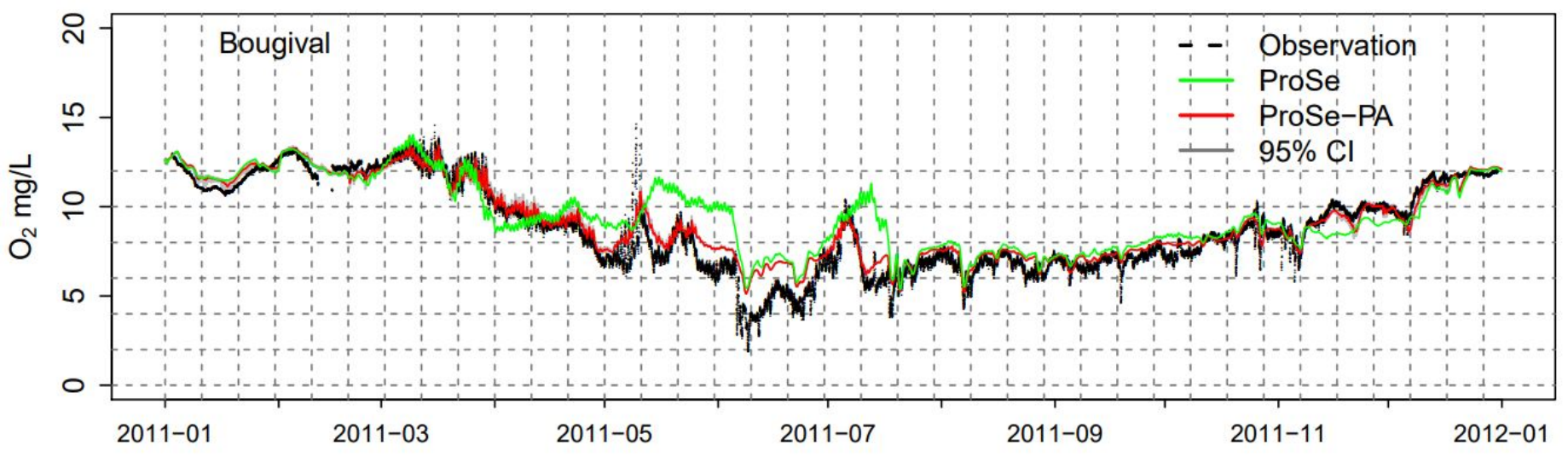
ProSe-PA: Weighted mean (500 particles)

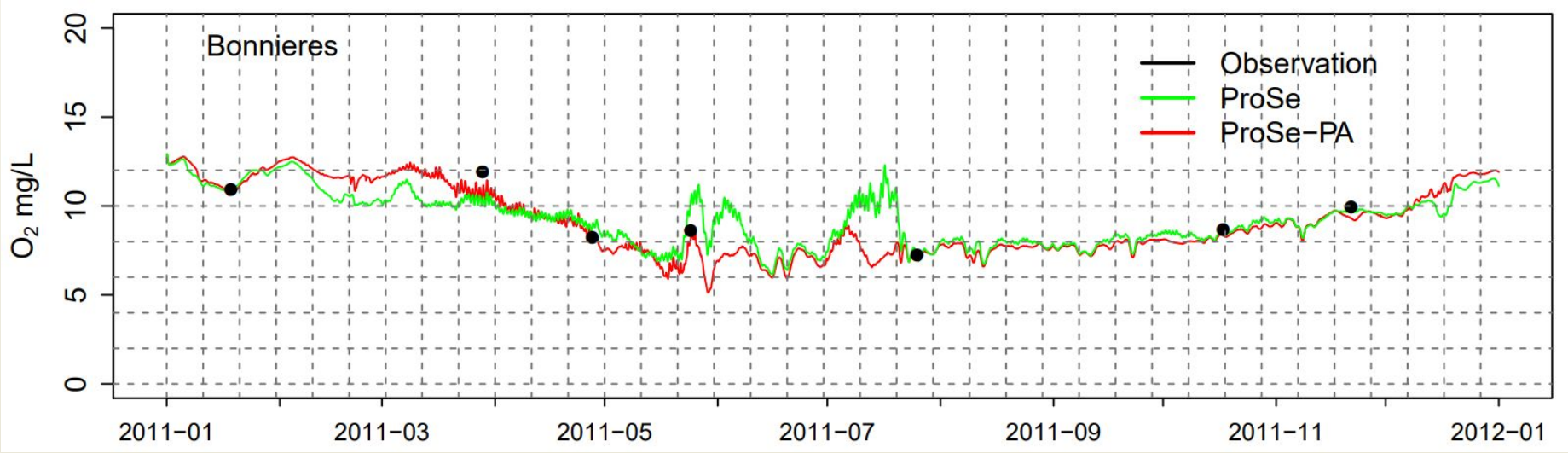
95% CI: 95% confidence interval



Simulated DO concentrations at Bougival and Bonnieres assimilating oxygen data at 8 stations

Particle filter:
Improvement of DO concentrations simulation, particularly for algae blooms period

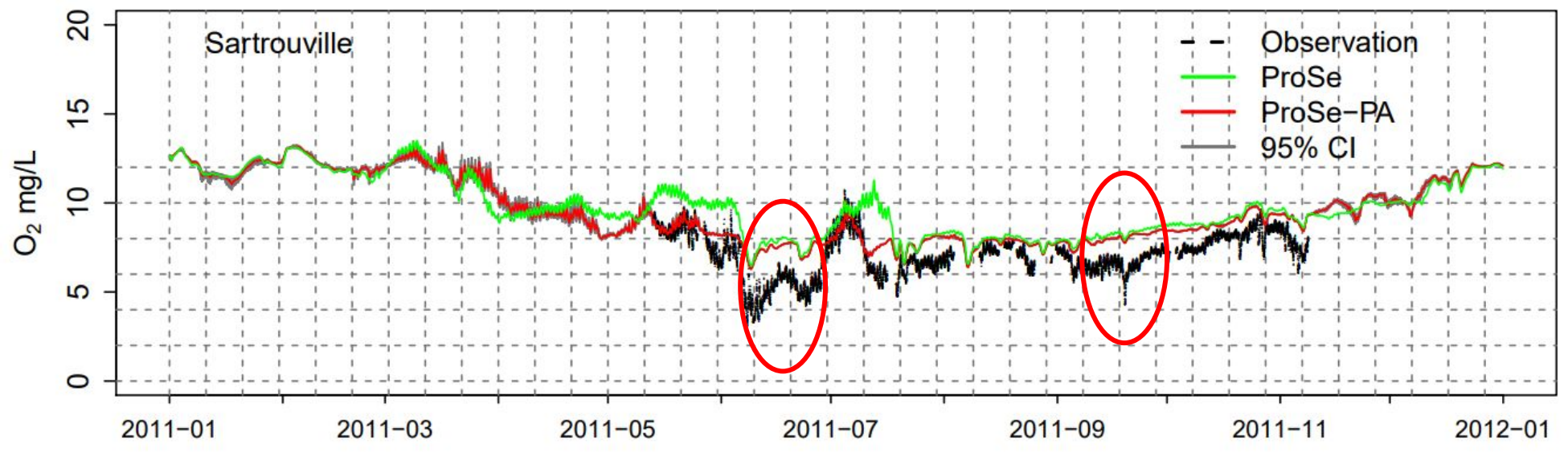


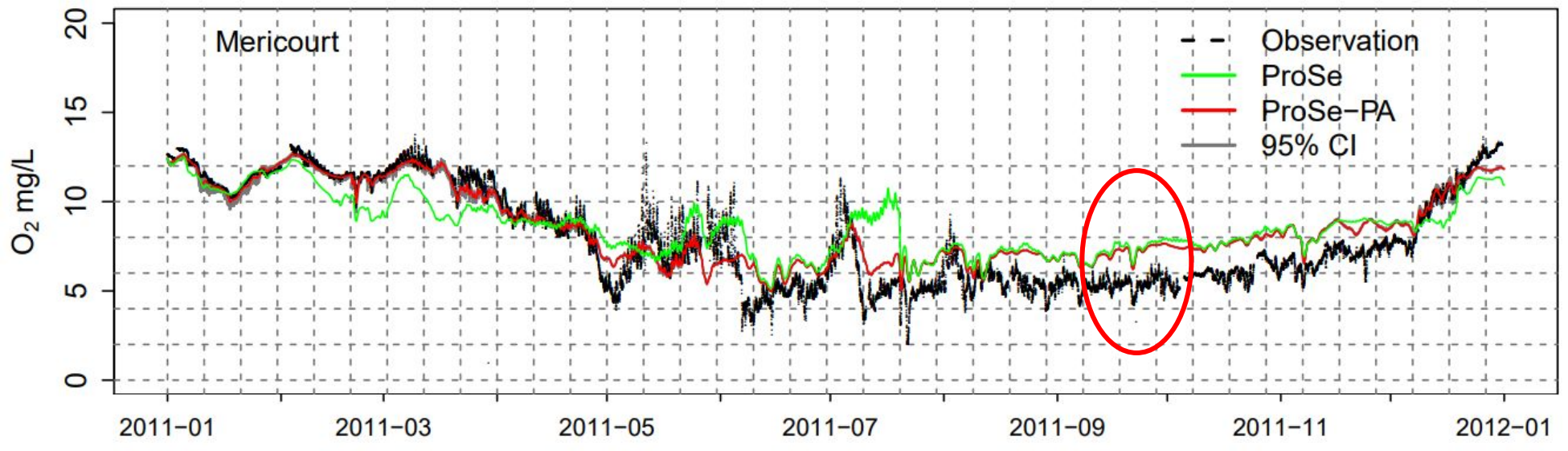


Simulated DO concentrations during low flow without algae blooms

Overestimation of DO concentrations during low flow periods

Deficit of BDOM ?



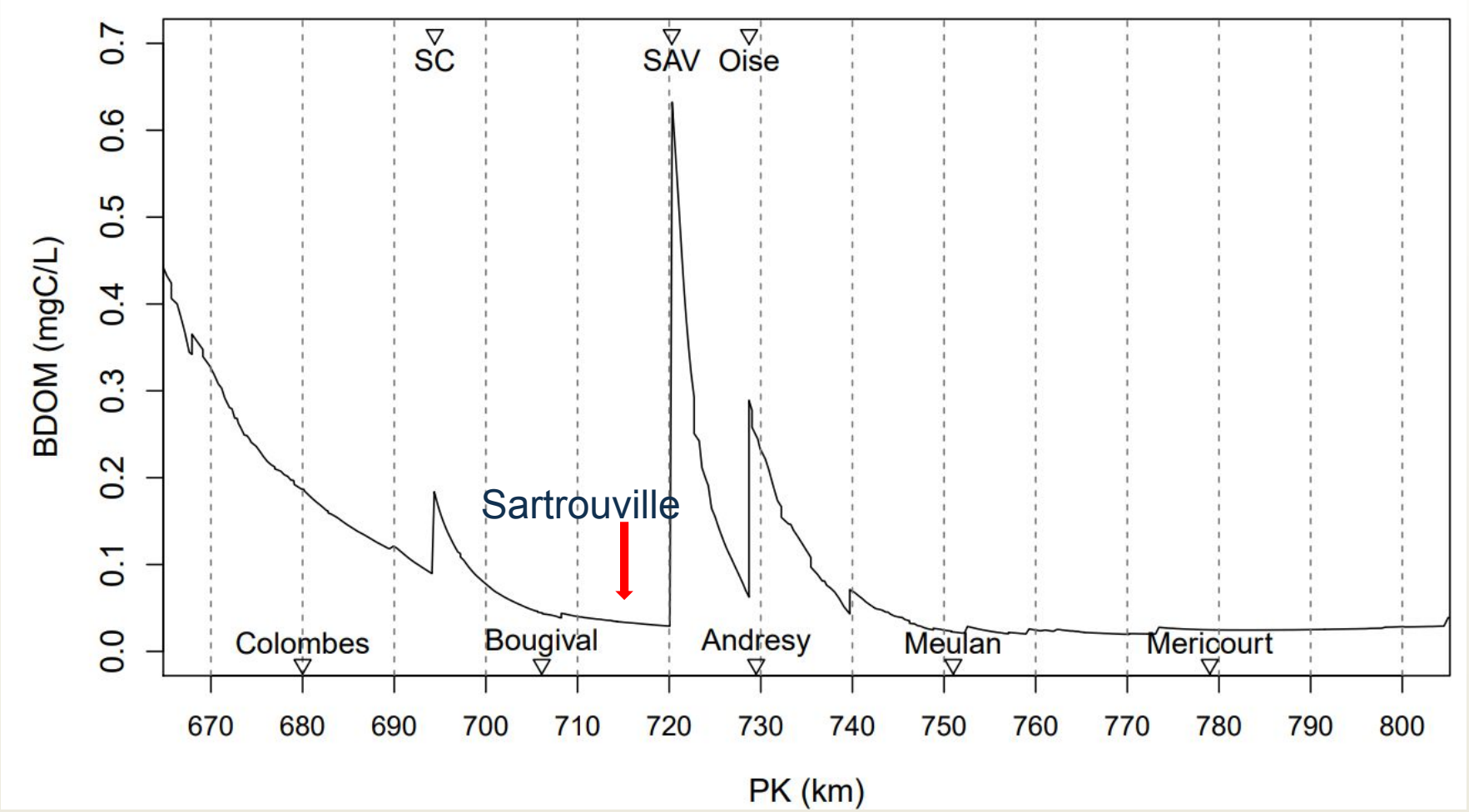


Uncertainties of BDOM concentrations in boundary conditions

C_{BDOM} < 0.02 mgC/L at Meulan, Mericourt

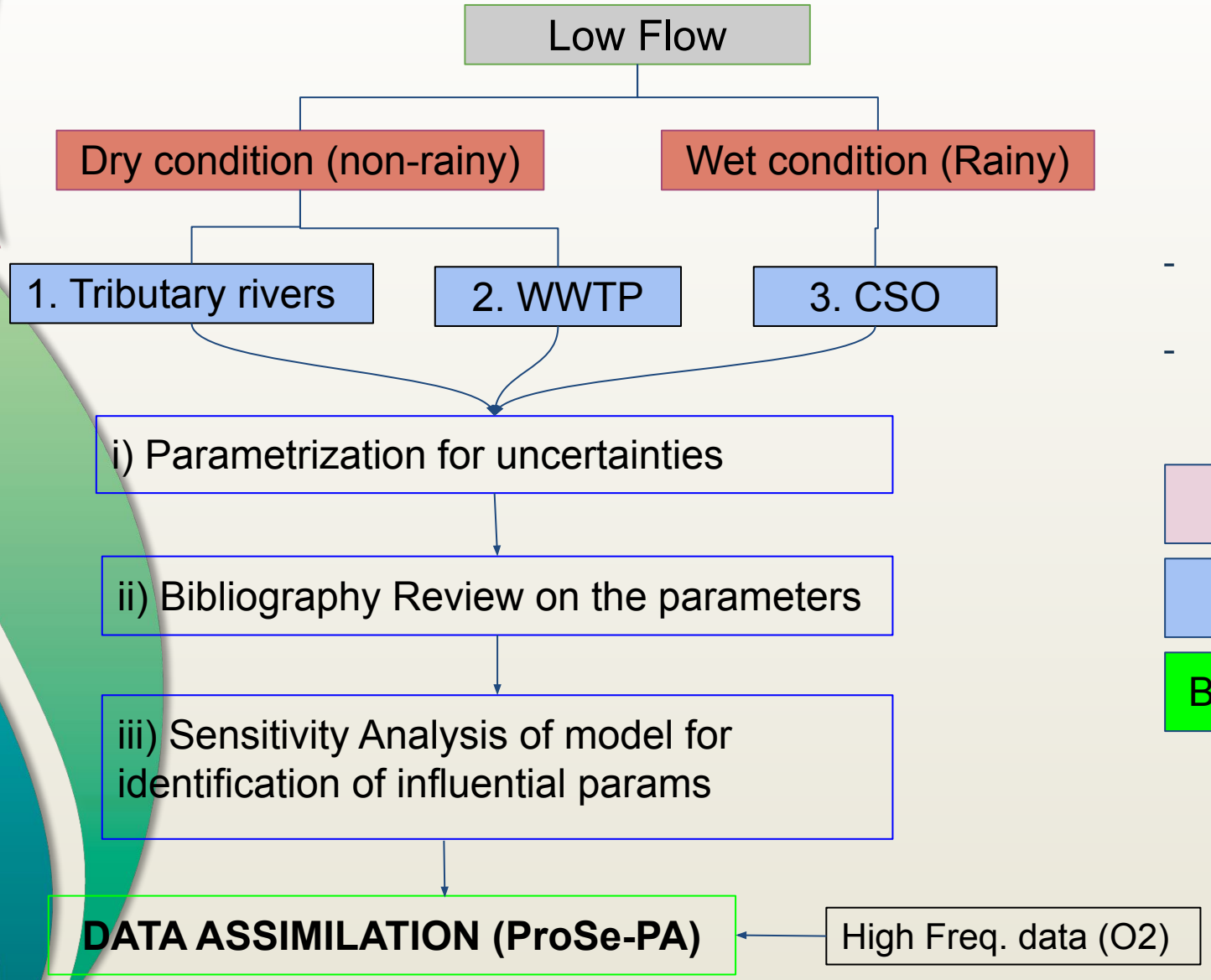
Assumption of perfect boundary conditions

Need to study the uncertainties of BDOM (parameters, concentrations)



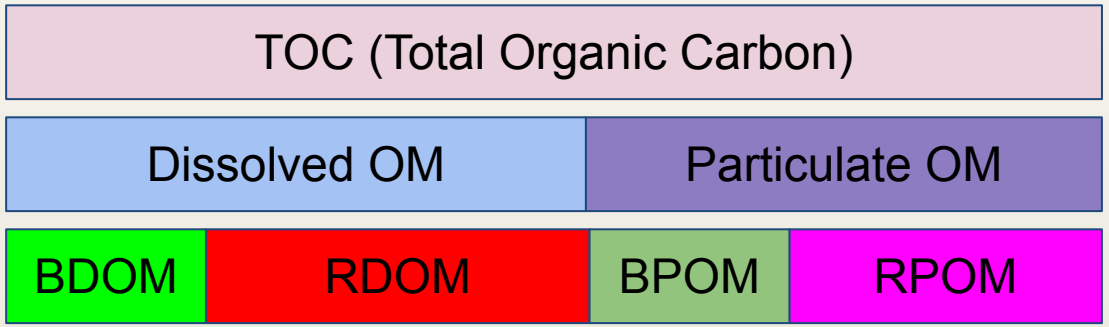
Average concentration of BDOM from 2011-09-07 to 2011-09-27 (Wang et al., 2020 in preparation)

Uncertainty Analysis related to Organic Matter (OM) & BDOM



Parameterization

- 8 Parameters for Degradation and Repartition of OM into biodegradable and refractory portions
- 7 Bacterial & 2 Physical

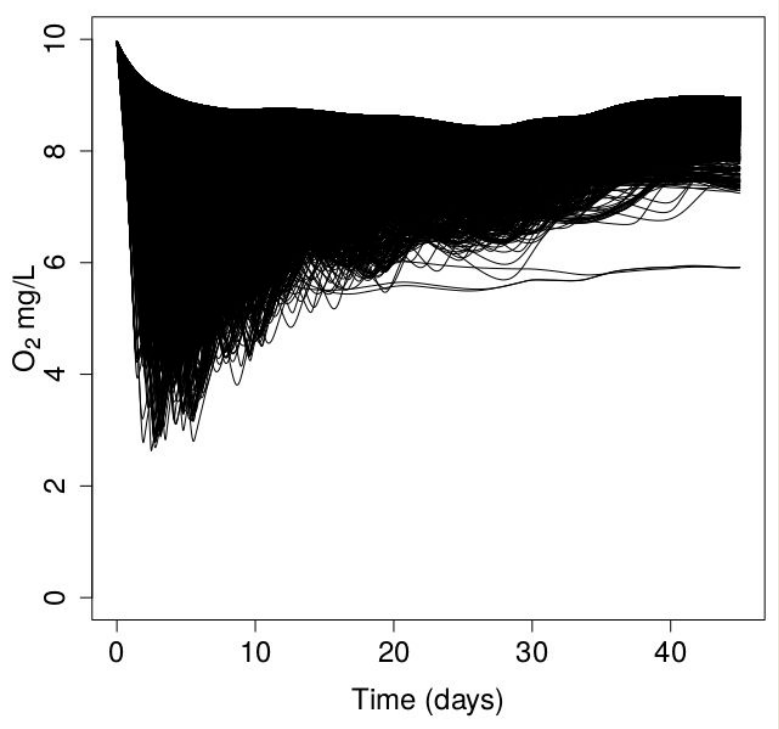


Sensitivity Analysis: Methodology (*Wang et al., 2018)*

1. Four sensitivity analysis were done
2. The effect of 12-17 parameters were analyzed
3. 260K-360K simulations were run in the model
4. The Sobol' method *(Sobol', 1993)* was used for investigating the sensitivity of model against the parameters

Bact. Growth, BDOM, Bact. Yield, BPOM, …., ….,

[260K-360K] x [12~17]

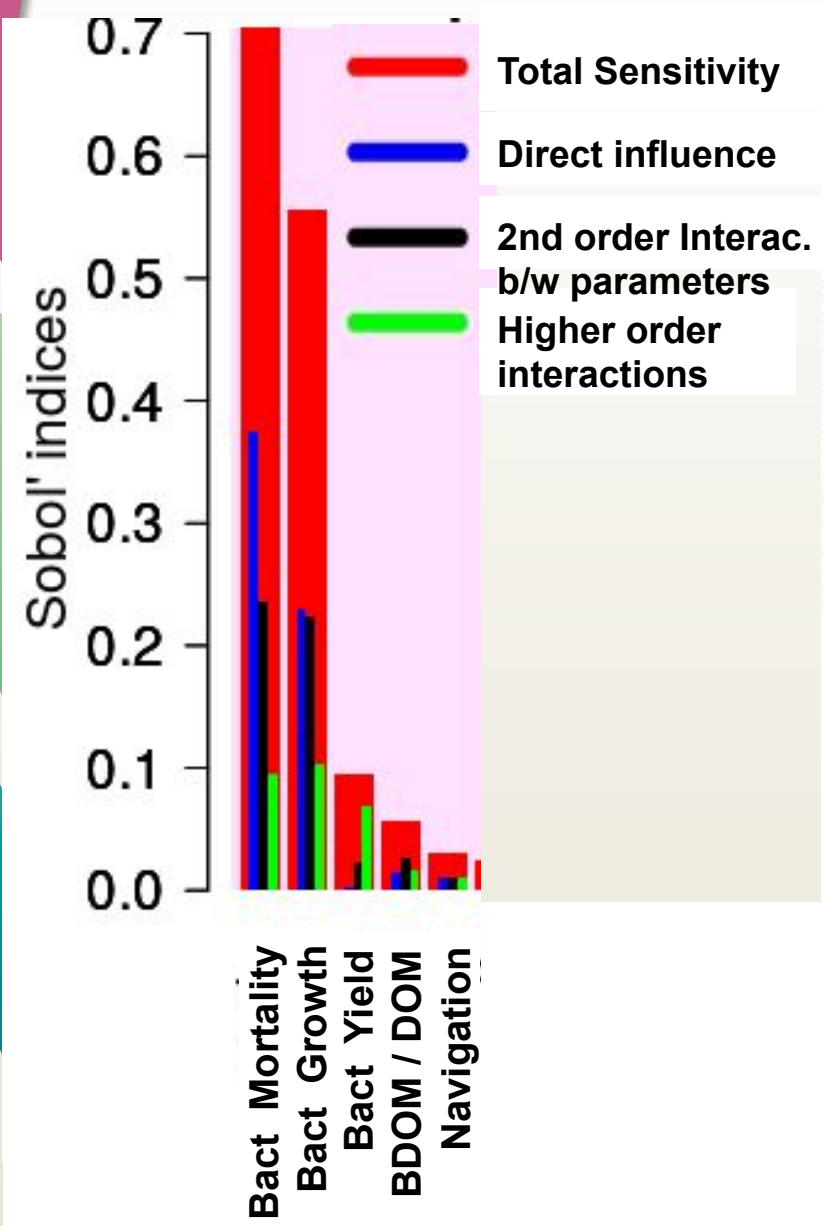


Sobol', I.M., 1993. Sensitivity estimates for nonlinear mathematical models. Mathematical Modelling and Computational Experiments 1 (4), 407

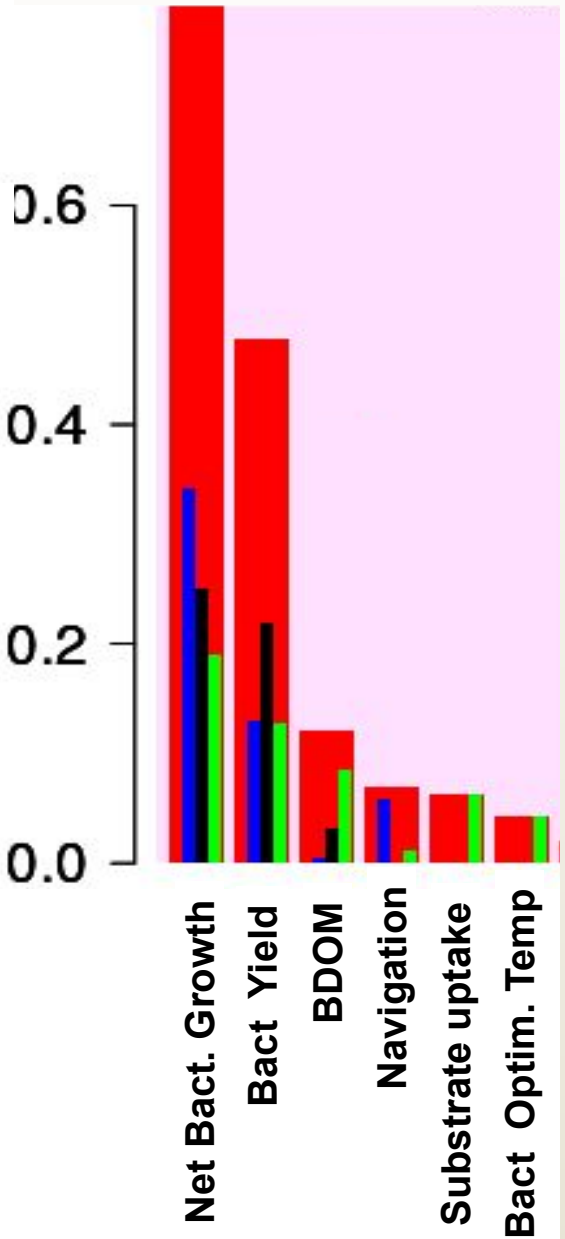
Wang, S., Flipo, N., Romary, T., 2018. Time-dependent global sensitivity analysis of the C-RIVE biogeochemical model in contrasted hydrological and trophic contexts. Water Res. 144, 341e355.

Results

1) All Parameters



2) Variable Net Growth (= Growth- Mortality)



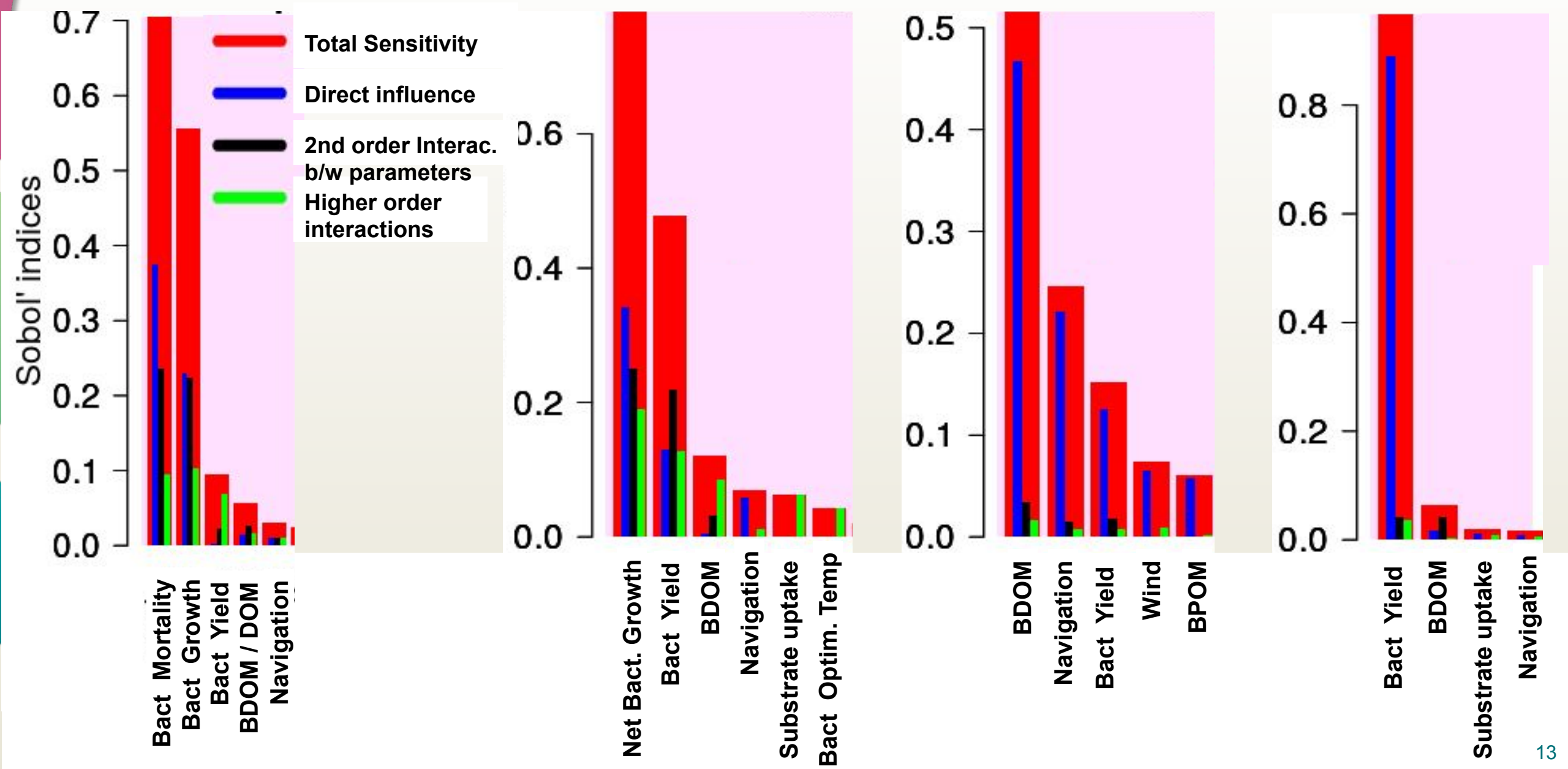
- Bact. Growth and mortality are the most influential parameters
- Other parameters have less influence

- Investigation of NET GROWTH effect
- Net Growth is the key parameter
- Better estimation of net growth parameters is essential for modeling the bacteria community

- BDOM influence under high Net Growth rates

Results

1) All Parameters 2) Variable Net Growth 3) High (Fixed) Net Growth 4) Low (Fixed) Net Growth



Conclusions

- ProSe-PA is:
  - capable of determining temporal evolution of parameters
  - a very good O2 estimator especially during blooms and also high flows at low temperature
- Discrepancies exist at summer low flow:
  - Given a SA, we identified the key params to improve ProSe-PA performance at low flow
  - Confirmation of the assumption on O2 overestimation at summer low flow periods
- To reduce uncertainties, new quantifications on outflows and Seine upstream under Axe 4.
- Integration of ProSe-PA in an urban water management system

Thanks For Your Kind Attention