UPDATE LAKE MODELLING IN MÄLAREN

MEWS

2025-10-15

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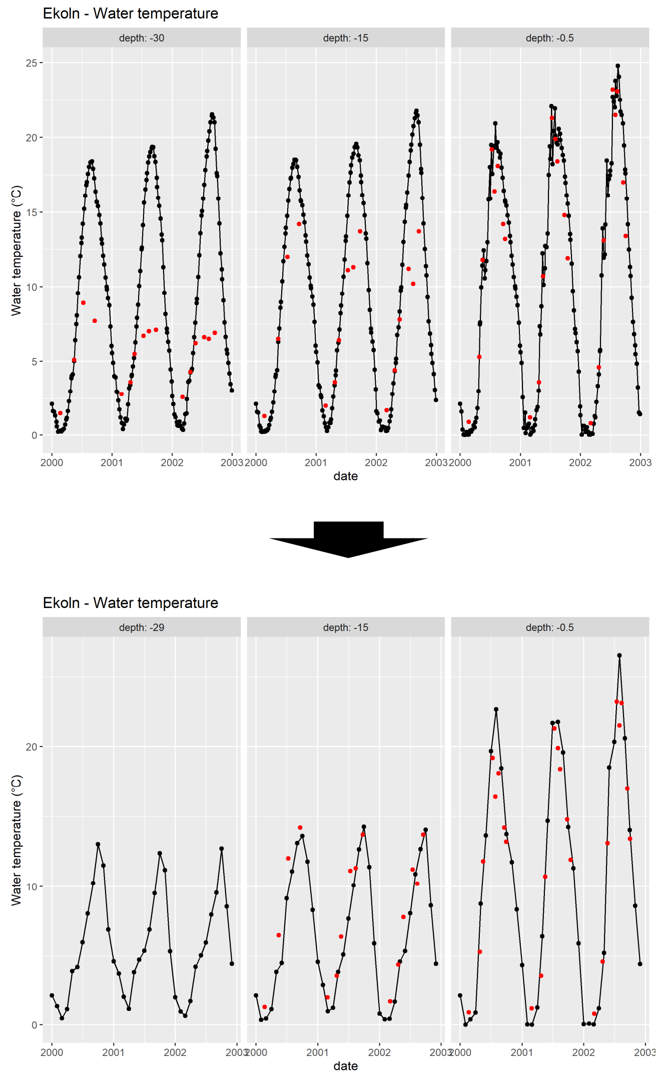
Stratification issue solved

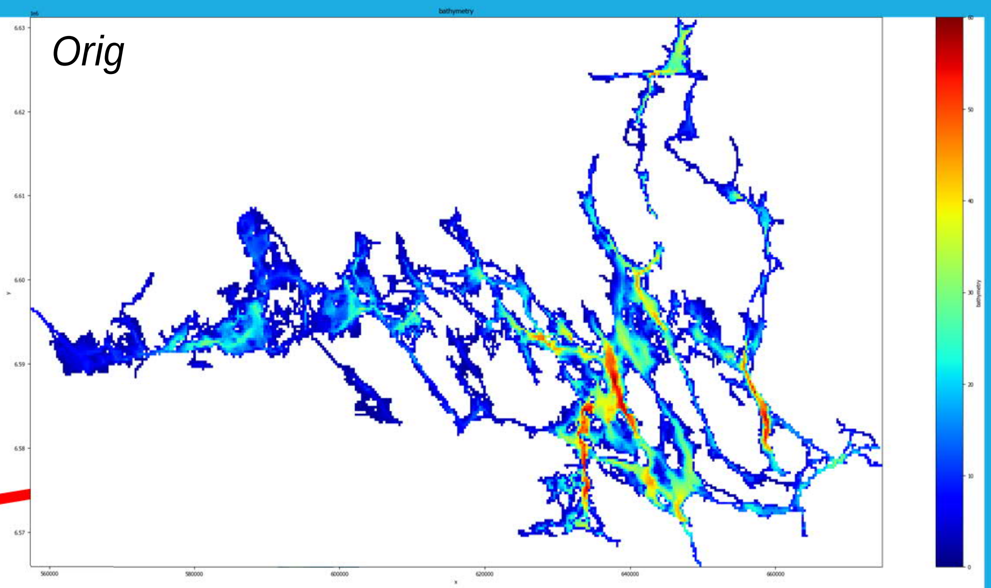
- Previously, no or weak stratification in 3D model
- Solution was a combination of:
  - Smoothing, using *rx0* physical ratio
  - Minimum depth of cells
  - (Naturally) turbid water
  - A lower *k_min* turbulence parameter
- Still need to do a more thorough comparison with observations
  - Numerical mixing still present, but could be reduced further

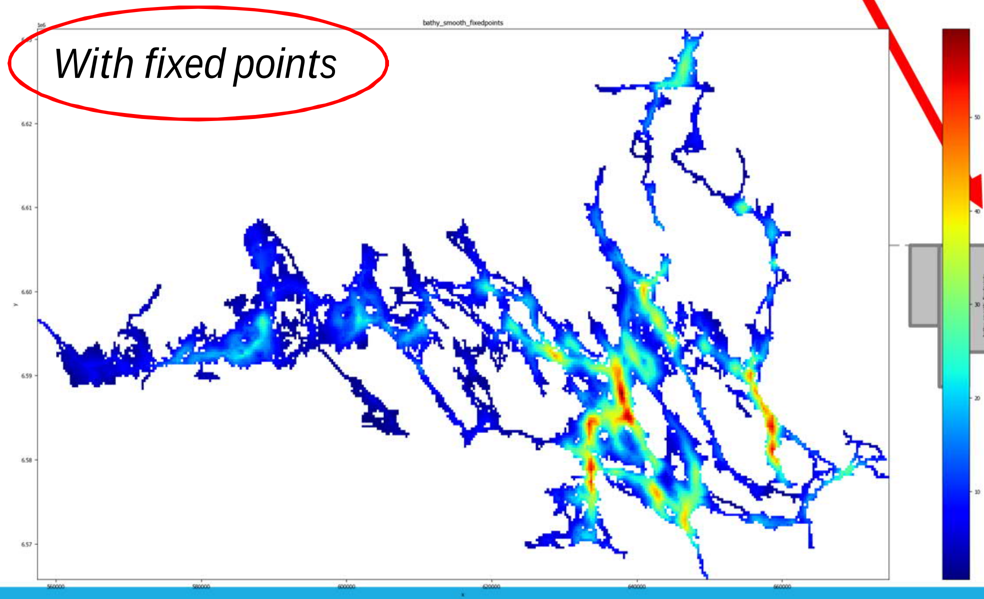
$$rx0 = \frac{(h_i - h_{i-1})}{(h_i + h_{i-1})}$$

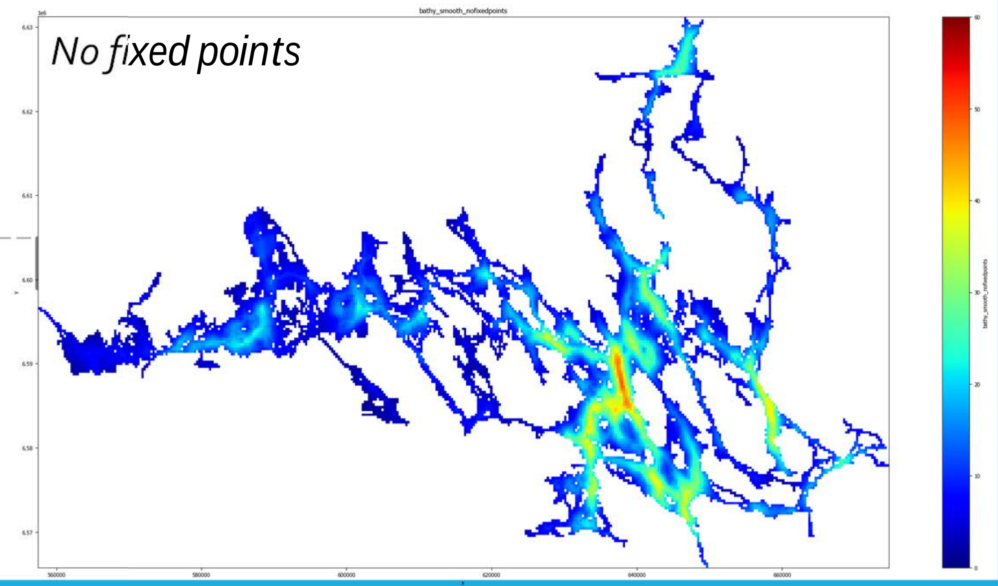


Smoothing

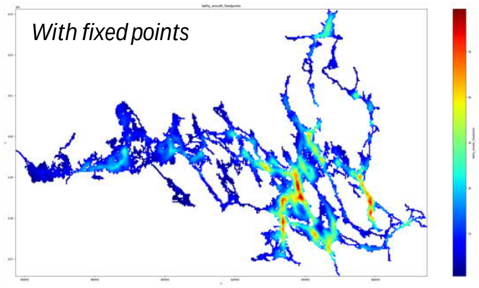
- Necessary, but could be done in many ways
- pygetmtools::smooth_bathy_matrix
  - Arguments *max_val*, *min_depth*, *optim_val*, *box_width*, *inflexibility*, *track_volume* and usage and locations of fixed points



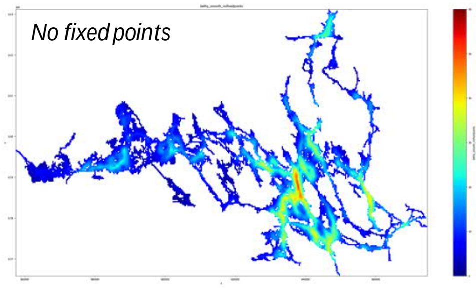




Smoothing



Basin	Volume change (%)
Whole lake	0.5
Arnfjärden	0.8
Blacken	-5.5
Ekoln	0.5
Fiskarfjärden	-3.4
Galten	-13.5
Gisselfjärden	-4.7
Görväln	16.4
Granfjärden	-7.3
Gripsholmsviken	5.8
Långtarmen	-5.8
Lårstaviken-Gorran	-8.1
Norra Prästfjärden	0.4
Oxfjärden	-8.9
Riddarfjärden	5.9
Rödstensfjärden	-3.6
Skarven	13
Skofjärden	-12.8
Sörfjärden	-26.7
Södra Prästfjärden	2.8
Tynnelsöfjärden	-11.8
Västeråsfjärden	-9.7

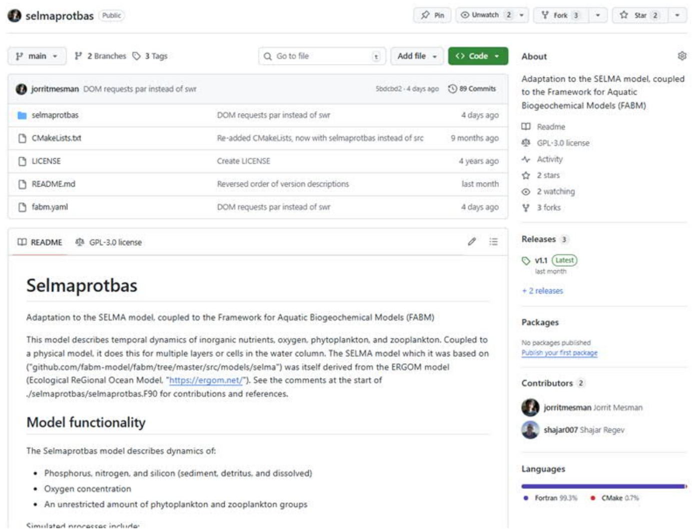


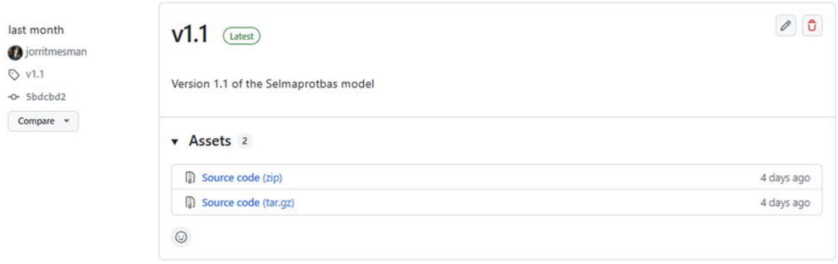
Basin	Volume change (%)
Whole lake	0
Arnfjärden	0.1
Blacken	0
Ekoln	0.1
Fiskarfjärden	0.1
Galten	0.1
Gisselfjärden	0.4
Görväln	0.2
Granfjärden	-0.3
Gripsholmsviken	0.5
Långtarmen	0
Lårstaviken-Gorran	-0.1
Norra Prästfjärden	0
Oxfjärden	0
Riddarfjärden	0
Rödstensfjärden	0.1
Skarven	0
Skofjärden	0.1
Sörfjärden	0.1
Södra Prästfjärden	0
Tynnelsöfjärden	-0.2
Västeråsfjärden	0.6

Biogeochemical model updates

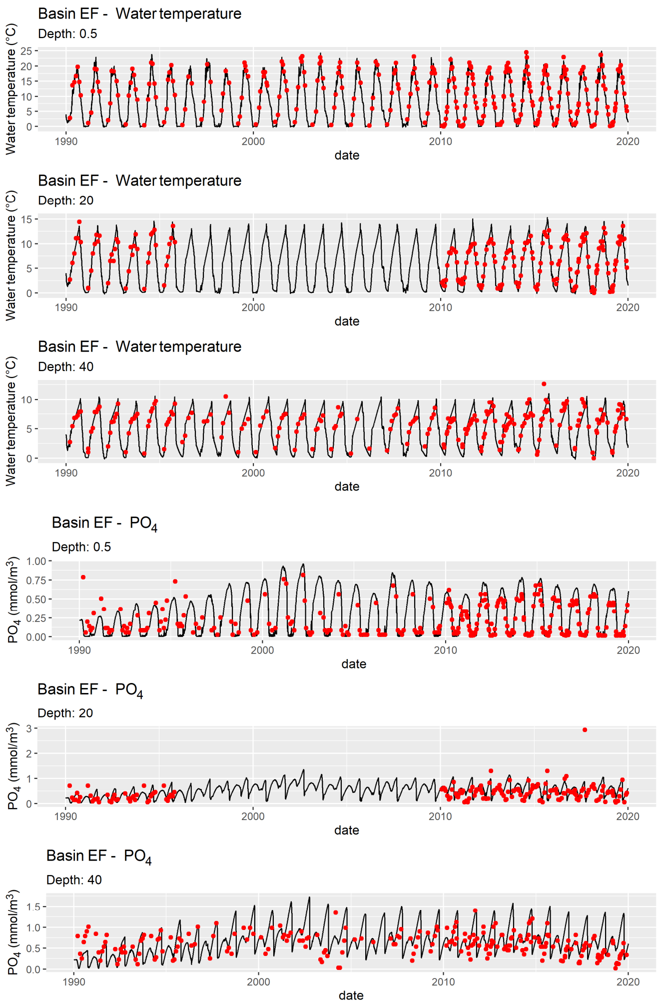
- Addition of DOM module (based on DOMCAST model)
  - Labile and semi-labile
  - Sinks: Mineralisation, photo-oxidation, flocculation
  - Sources: leaching from POM and dying phyto- and zooplankton
- Improved phytoplankton parameters
  - 24h averaged light
  - New light and temperature limitation functions
- Updated mineralisation constants
- Incorporation of sulphate and anammox dynamics
- Bug fixes

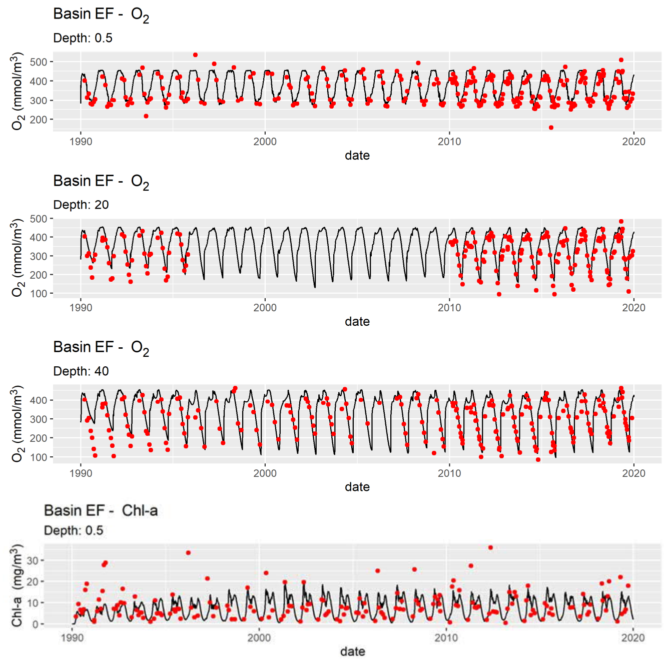
https://github.com/jorritmesman/selmaprotbas





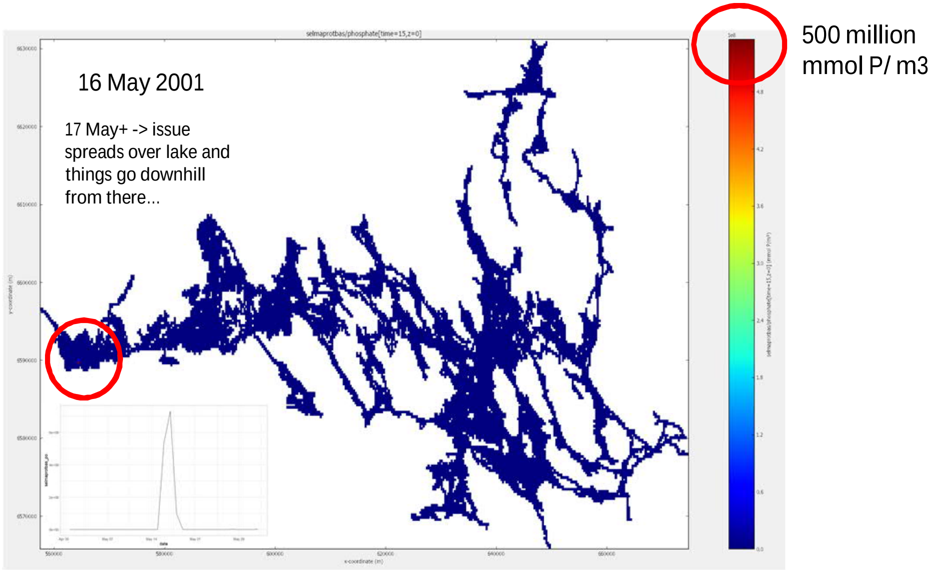
New calibration in 1D (5-basin setup)

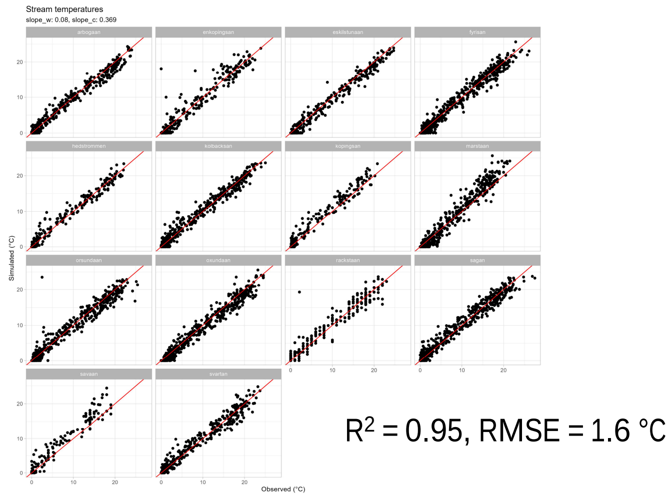


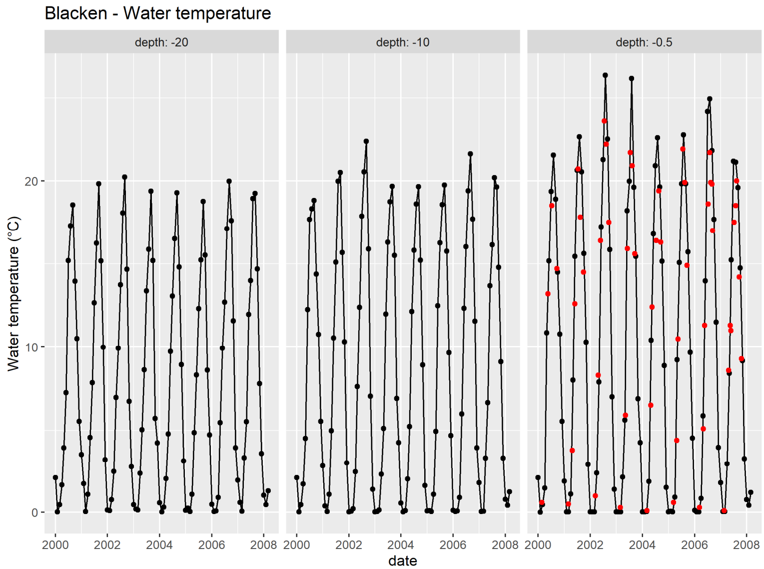


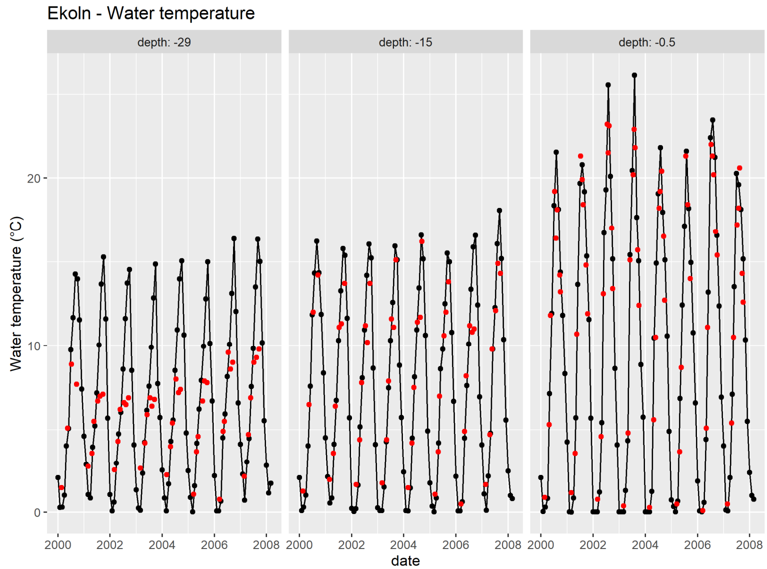
Biogeochemistry in 3D

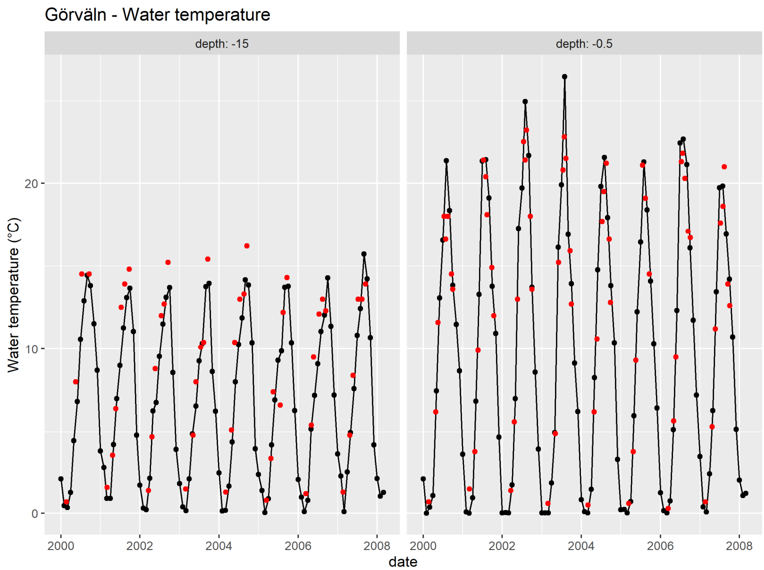
- Issue arose: exponentially increasing concentrations of detritus, phosphate, chlorophyll…
- Constrained by providing all river concentrations
  - Si-detritus and iron-bound P
- Temperature and oxygen in rivers are now provided
  - Simple temperature model from Hampus
- Comparison between observations and 3D simulations still ongoing, but…

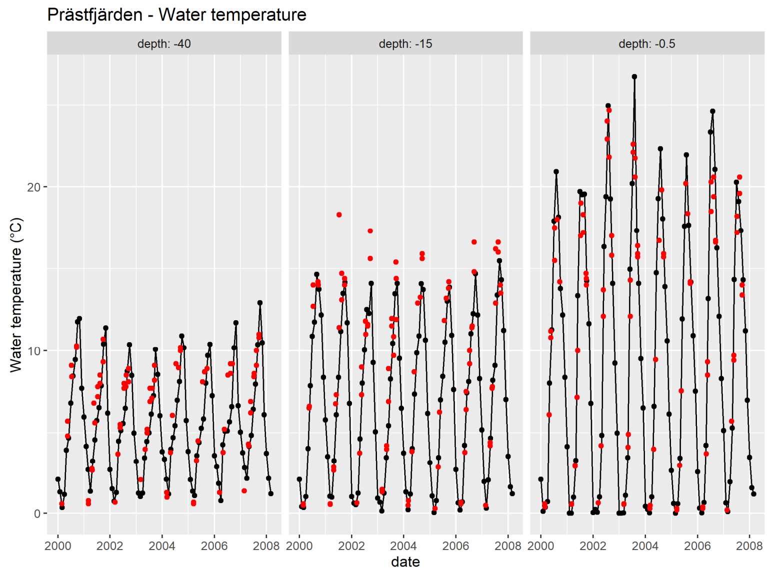


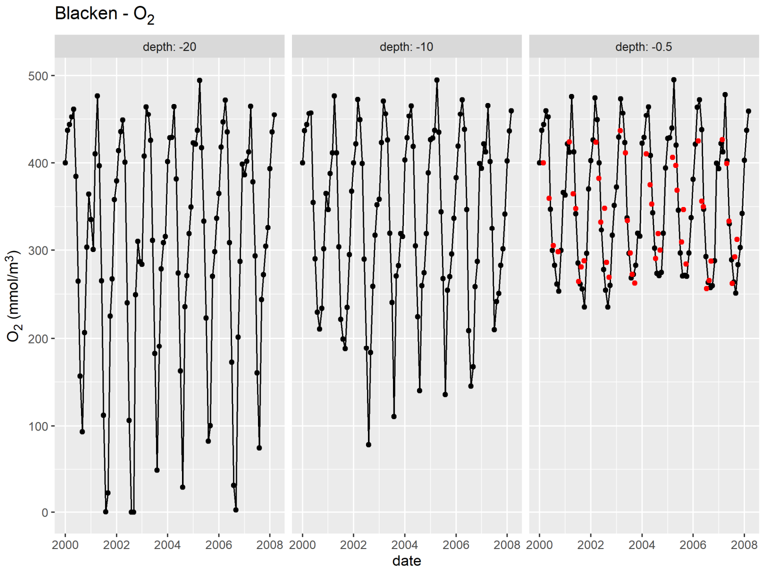


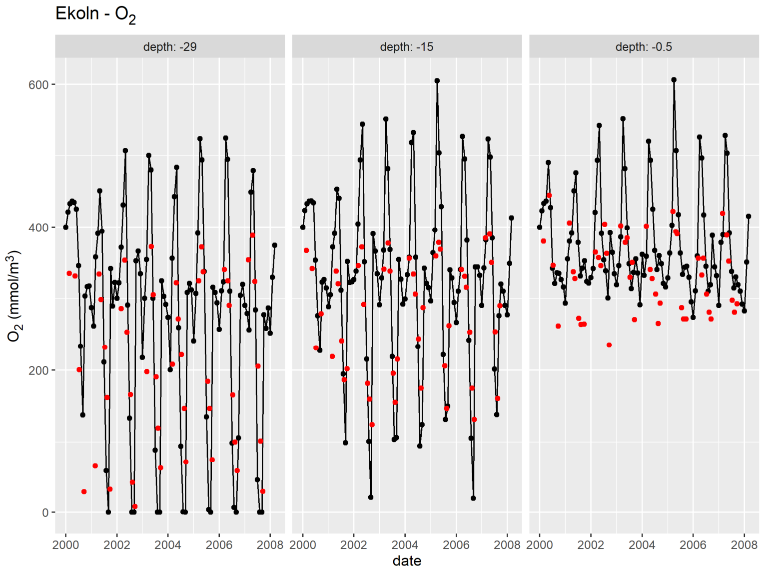

Blacken - Water temperature
depth: -20
depth: -10
depth: -0.5
Water temperature (°C)
date

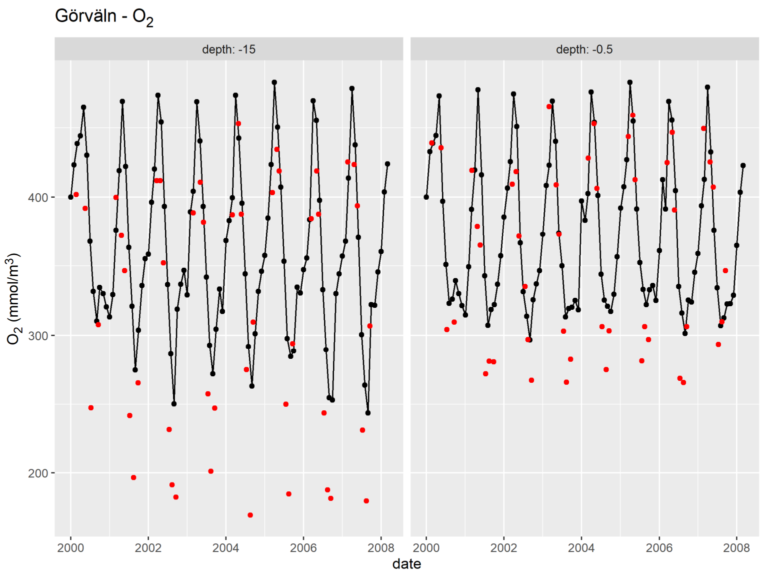

Ekoln - Water temperature
depth: -29
depth: -15
depth: -0.5
Water temperature (°C)
date

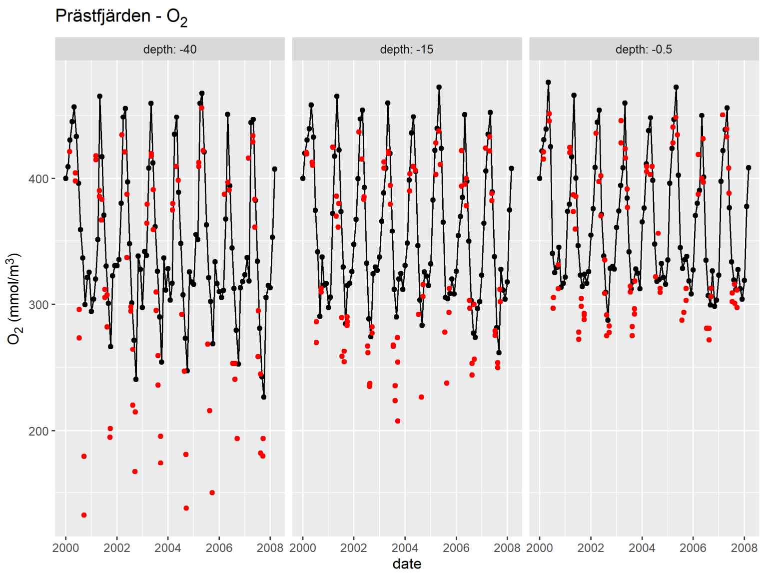

Görväln - Water temperature
depth: -15
depth: -0.5
Water temperature (°C)
date

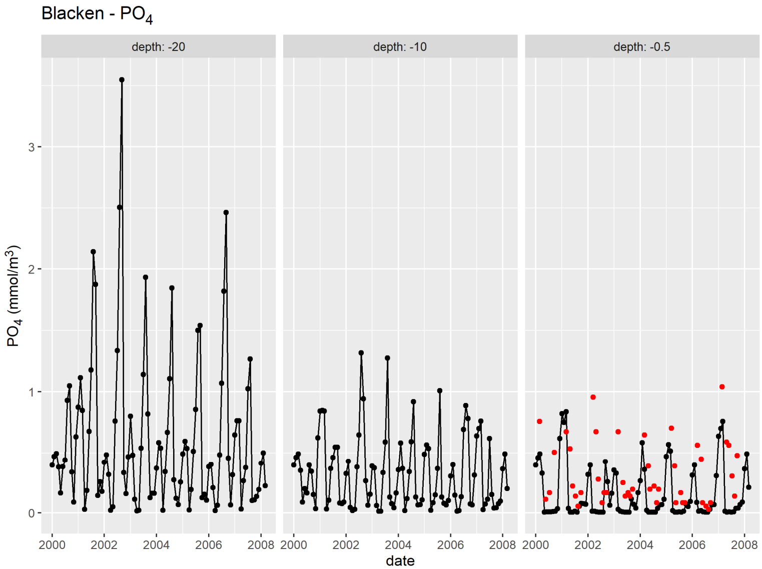

Prästfjärden - Water temperature
depth: -40
depth: -15
depth: -0.5
Water temperature (°C)
date

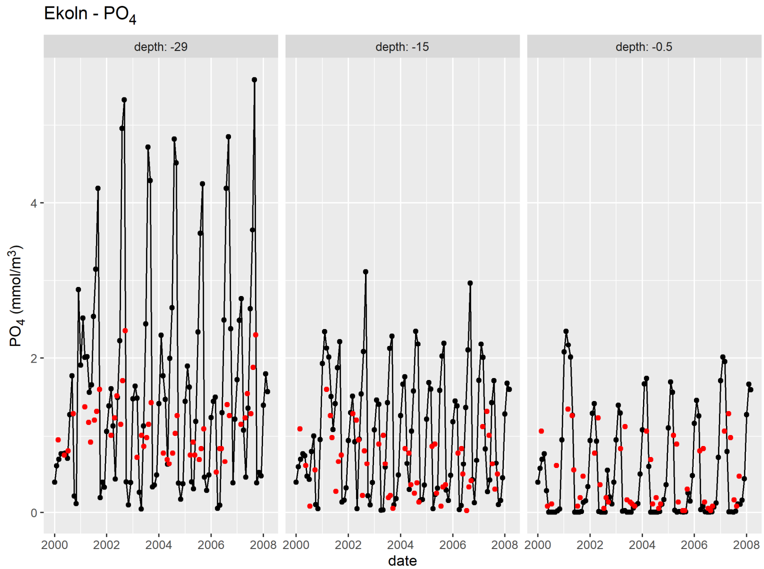

Blacken - O_2
depth: -20
depth: -10
depth: -0.5
O_2 (mmol/m^3)
0
100
200
300
400
500
2000
2002
2004
2006
2008
date

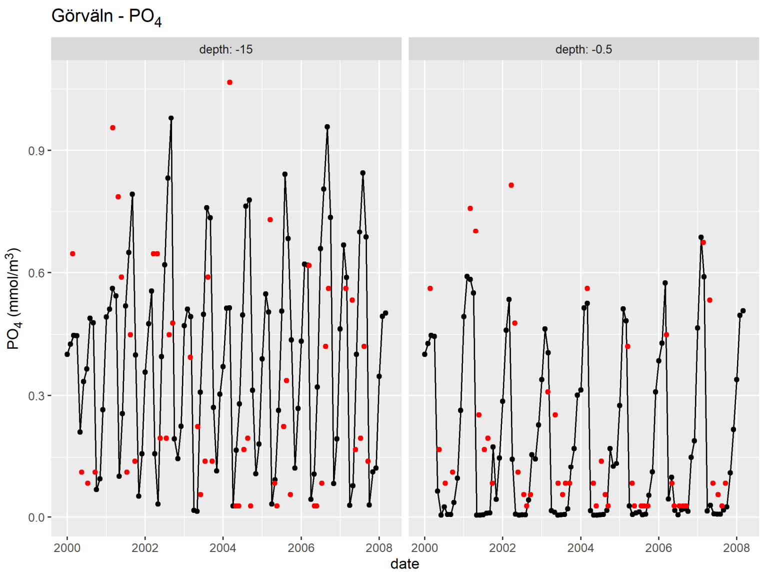

Ekoln - O_2
depth: -29
depth: -15
depth: -0.5
O_2 (mmol/m^3)
0
200
400
600
2000
2002
2004
2006
2008
date

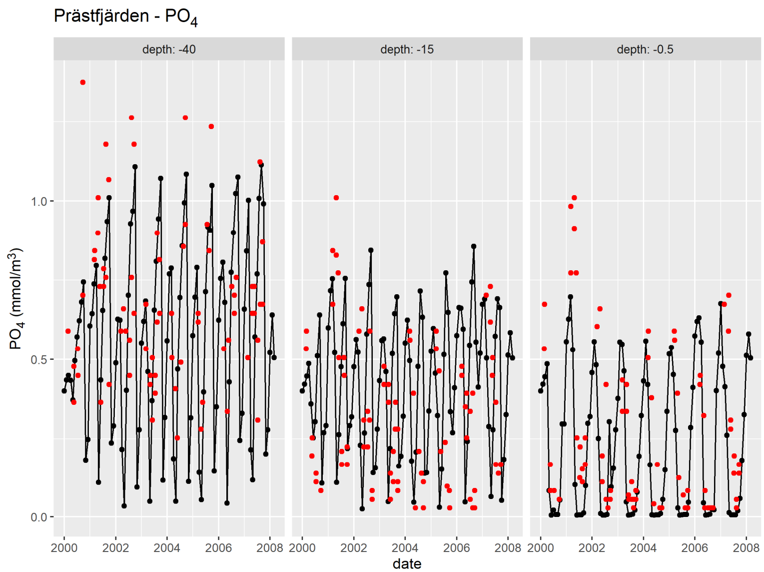

Görväln - O_2
depth: -15
depth: -0.5
O_2 (mmol/m^3)
200
300
400
2000
2002
2004
2006
2008
date


Prästfjärden - O_2
depth: -40
depth: -15
depth: -0.5
O_2 (mmol/m^3)
200
300
400
2000
2002
2004
2006
2008
date

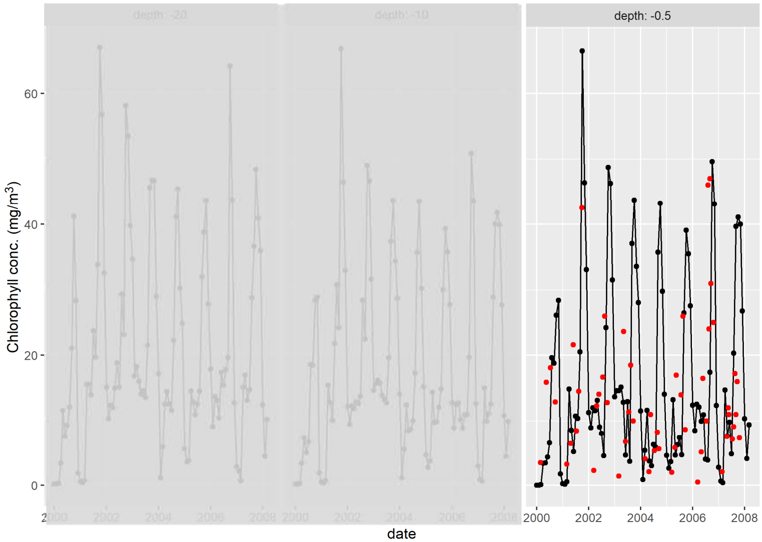

Blacken - PO_4
depth: -20
depth: -10
depth: -0.5
PO_4 (mmol/m^3)
0
1
2
3
2000
2002
2004
2006
2008
date


Ekoln - PO_4
depth: -29
depth: -15
depth: -0.5
PO_4 (mmol/m^3)
0
2
4
2000
2002
2004
2006
2008
date

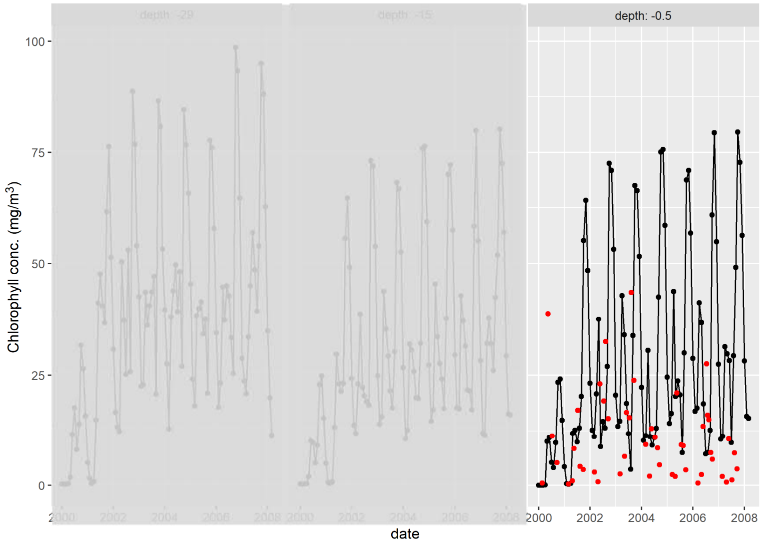

Görväln - PO_4
depth: -15
depth: -0.5
PO_4 (mmol/m^3)
0.0
0.3
0.6
0.9
2000
2002
2004
2006
2008
date


Prästfjärden - PO_4
depth: -40
depth: -15
depth: -0.5
PO_4 (mmol/m^3)
0.0
0.5
1.0
2000
2002
2004
2006
2008
date

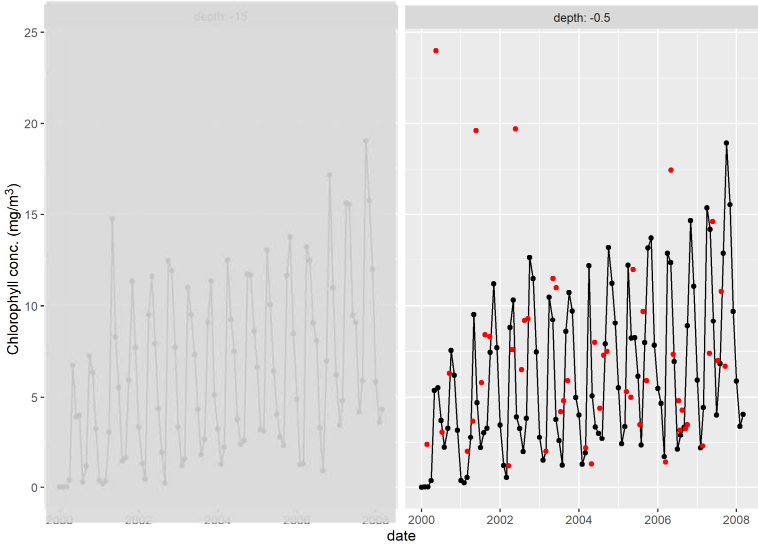
Blacken - Chlorophyll conc.



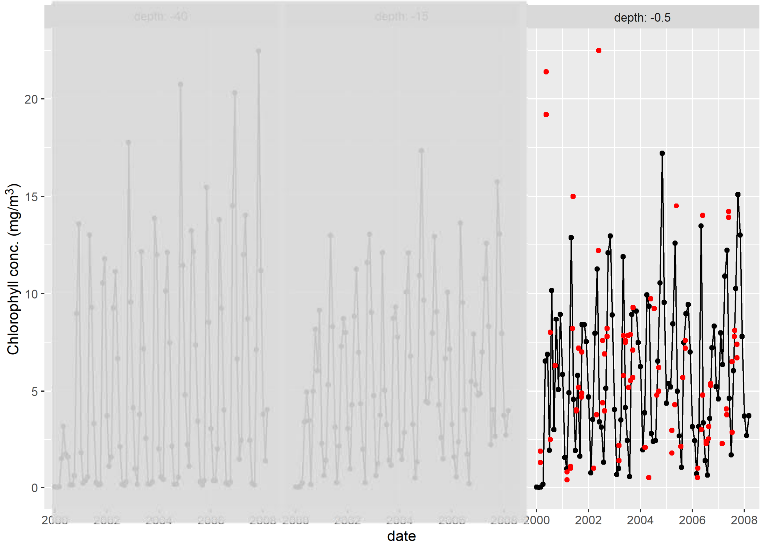
Ekoln - Chlorophyll conc.

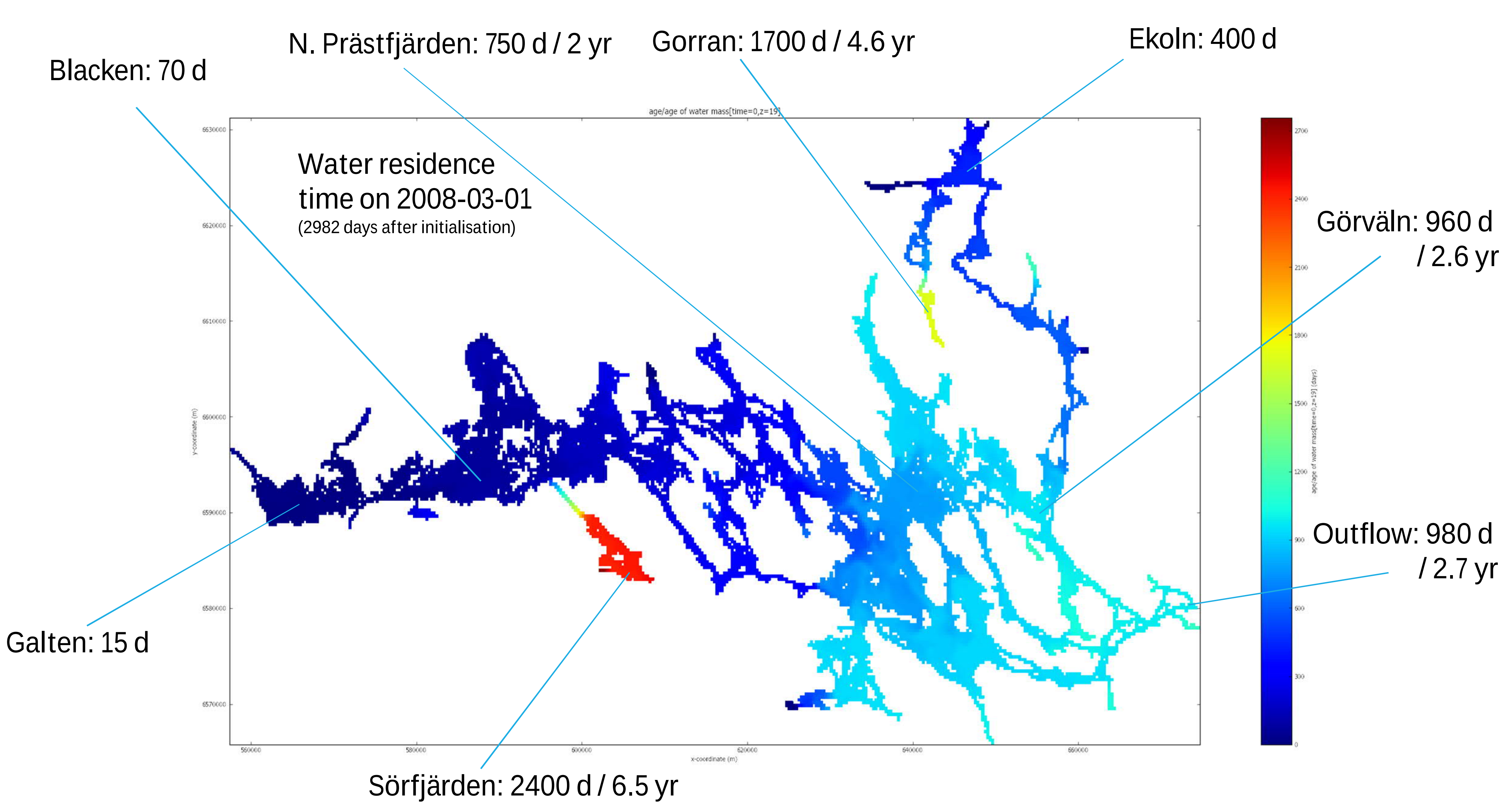


Görväln - Chlorophyll conc.



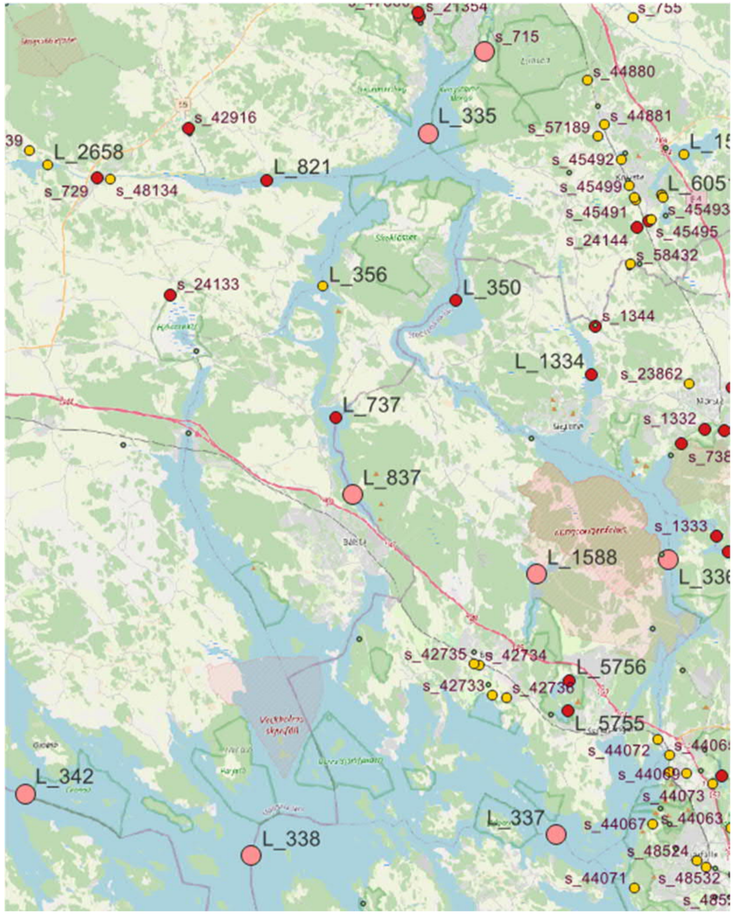
Prästfjärden - Chlorophyll conc.




Water residence time on 2008-03-01
(2982 days after initialisation)
Blacken: 70 d
N. Prästfjärden: 750 d / 2 yr
Gorran: 1700 d / 4.6 yr
Ekoln: 400 d
Görväln: 960 d / 2.6 yr
Outflow: 980 d / 2.7 yr
Galten: 15 d
Sörfjärden: 2400 d / 6.5 yr

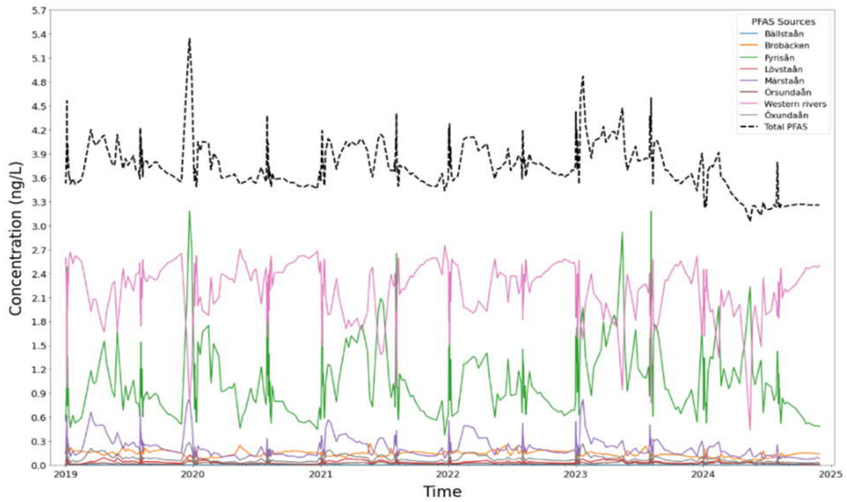
SLU observations update

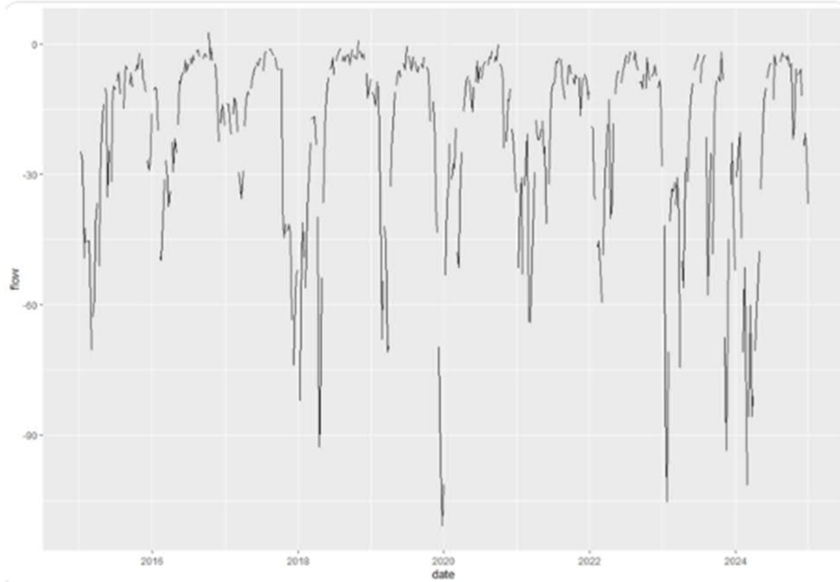
- Thanks to Hampus, updated observations until 2024/2025!
- Updating our database is easier now
- For the rivers, we still need to think of a solution in order to expand into 2025



Student work

- MSc Students working with PyGETM, 2025
  - Reports almost finished
- “Project in Data Science”
  - Students developed a function to calculate in-lake discharge
  - Try to explain variations in inter-basin exchange
  - Function will be added to *pygetmtools*
- MSc theses for 2026
  - A student will work on simulating bottom temperatures in Erken/Bolmen (loose connection to Mälaren as well)
  - Alexandra: PFAS simulations
  - Another student on transport times in Mälaren?





Next steps

- Assess 3D model fit and potential for improvement
- DOM inputs and simulation
- Include outflow dynamics (Norrström, Slussen, Södertälje)
- Upcoming presentations
  - DRICKS (Swedish drinking water research cluster) online seminar
    - 21 Oct
  - Mälarseminariet 2025
    - 20-21 Nov
  - Baltic University Programme symposium
    - 26-28 Nov