High resolution water quality monitoring data for evaluating process-based models (?)

Temporal high resolution water quality monitoring and analysis workshop
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Motivation

- Curiosity: we want to model hydrology and nutrient transport in LARGE areas, how can we benefit recent developments in high-res measurements and (maybe) vice versa
- Temporal high resolution and/or spatial high resolution – what do we need for large-scale performance
- Show what we can achieve today with our models and where our knowledge gaps are

HYPE hydrological model

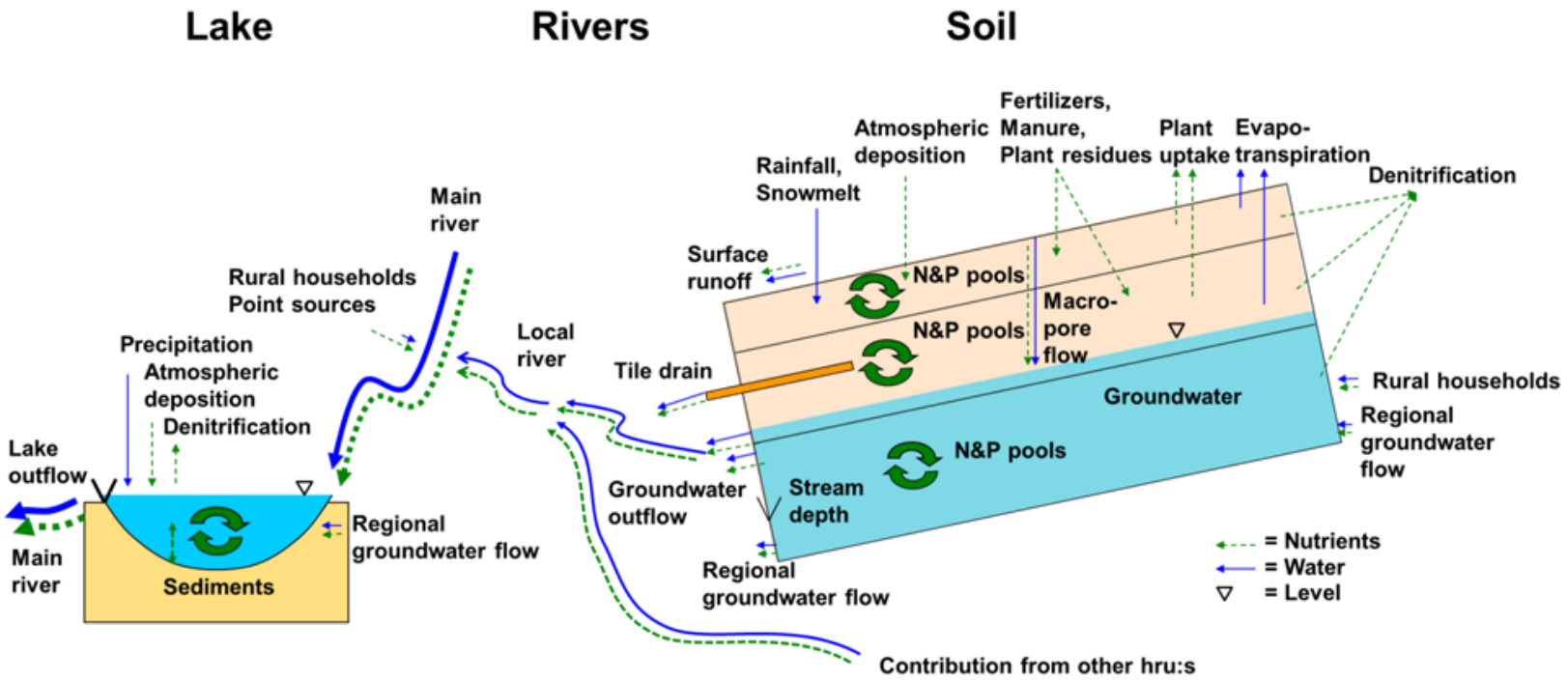
- ”**Hy**drological **P**redictions for the **E**nvironment”

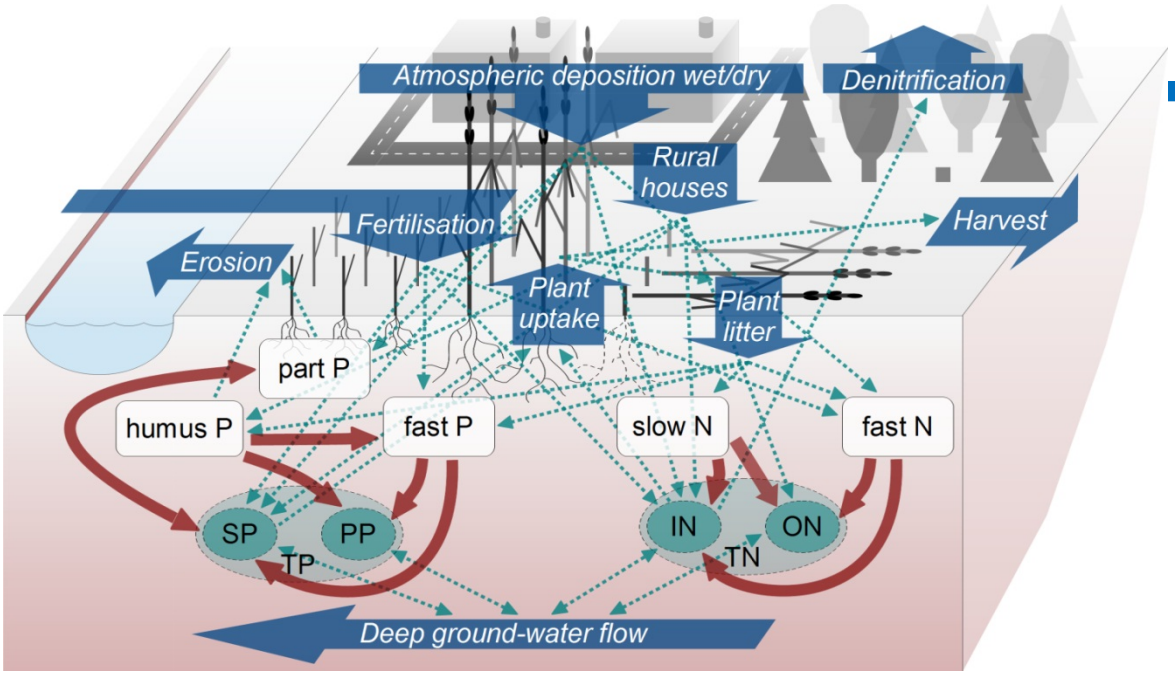
- Conceptual rainfall-runoff model with N and P processes
  - driven with rainfall and (min/max) temperature data
  - N driven with atmospheric deposition
- Scalable application, targeting large model domains
- Model domain divided into sub-catchments (i.e. not grid-based)

- Semi-distributed catchment model with lumped sub-catchment units:
- Soil and landuse classes (SLC), HRU approach
- ”static” information:
  - Land cover
  - Lakes and reservoirs incl. regulation
  - Crop dynamics
  - Point sources

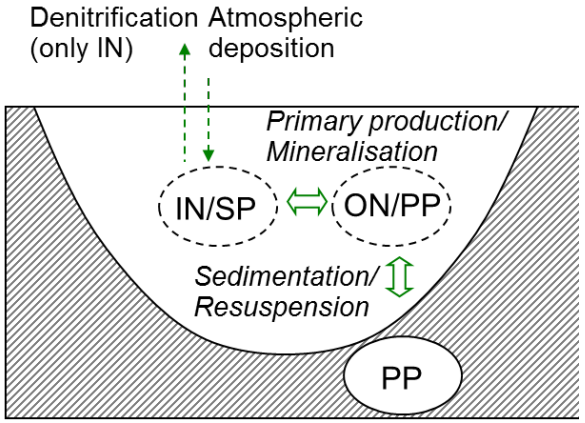
HYPE model – conceptual overview

- Model concept for single HRU unit + routing and outlet lake
- Up to three vertically stacked storages with process concepts for Q and WQ





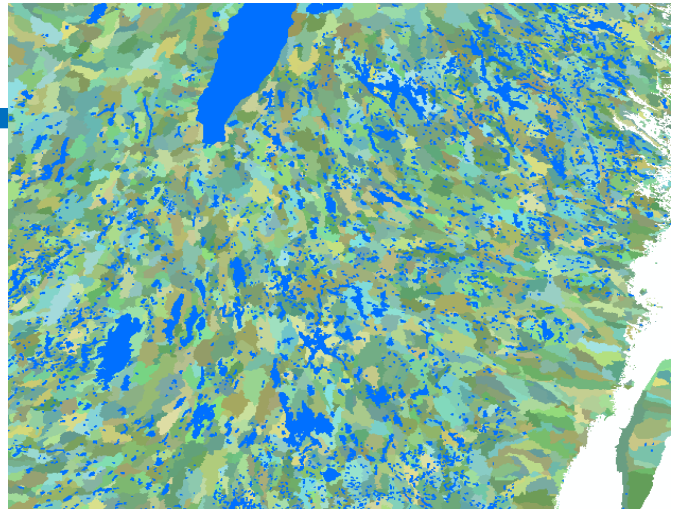
Land surfaces



Water bodies

Nitrogen (N) and phosphorus (P) processes

- Modeled reservoir boxes host N and P pools
- Total N (TN) divided into inorganic and organic species (IN, ON)
- Total P (TP) divided into soluble reactive and particulate species (SP, PP)
- Water bodies with generic lake processes sedimentation and re-suspension

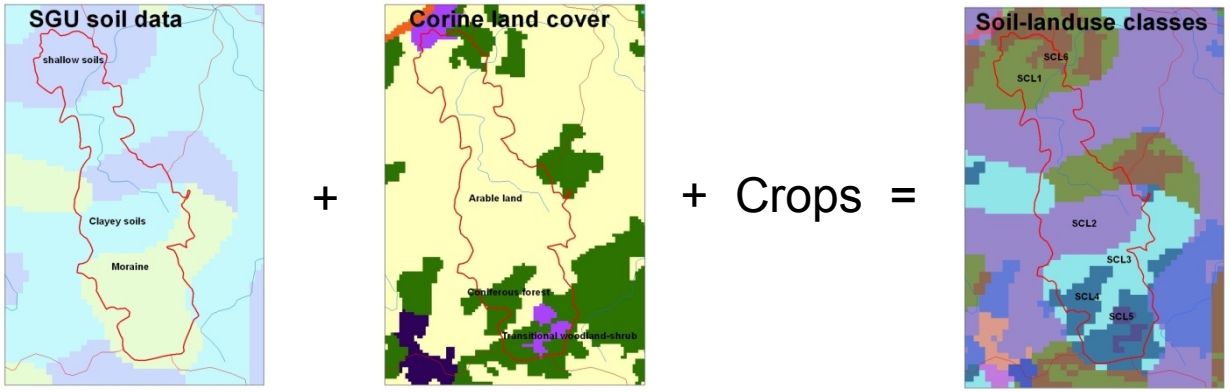


HRUs and Spatial delineation

- HRUs = soil – land use – crop classes (SLC)

- Domain-wide classification
- Parametrisation coupled to SLCs => regional calibration
- Calibration with single-HRU headwaters, iteration over all HRUs

- Sub-catchment delineation and flow network: no formal restrictions, but coupled to measurement network

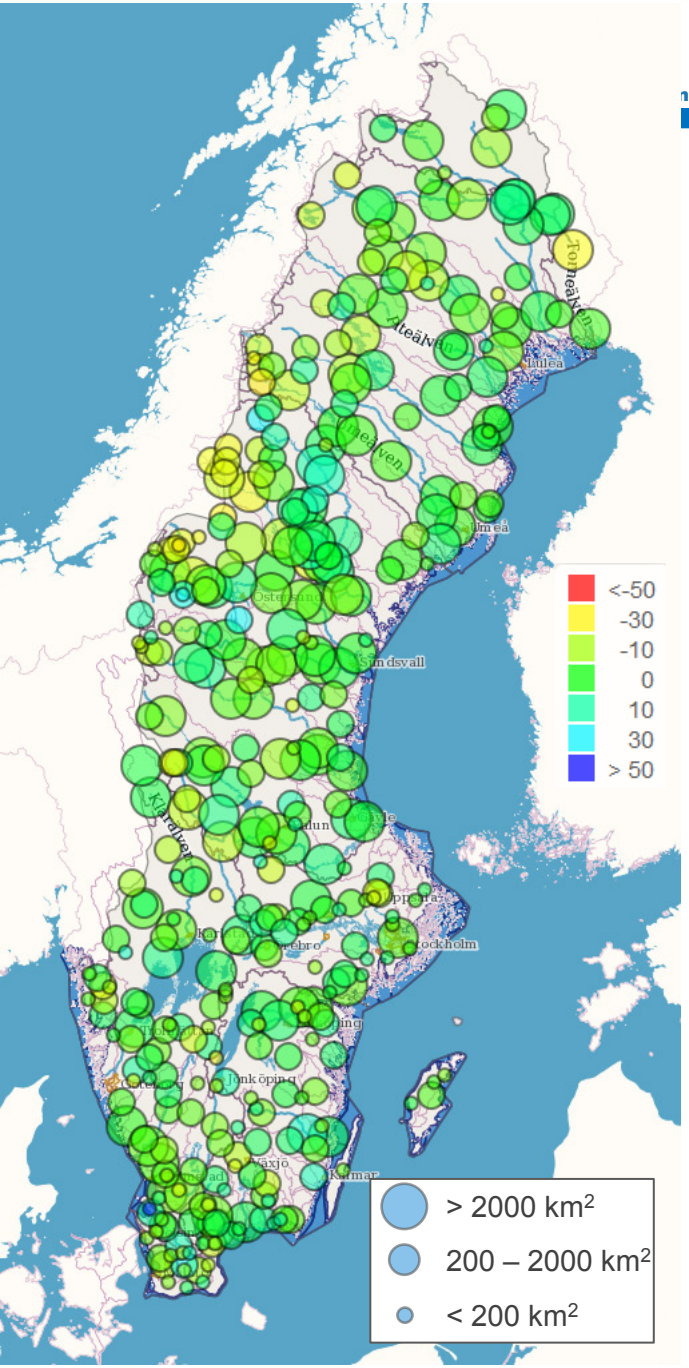


S-HYPE – performance in Sweden

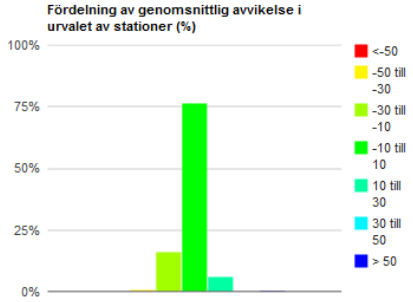
- Model with production and research branches
  - Real-time discharge forecasting
  - Decision support for WFD implementation (e.g. effective measures)
    => ambition to correctly model nutrient cycling

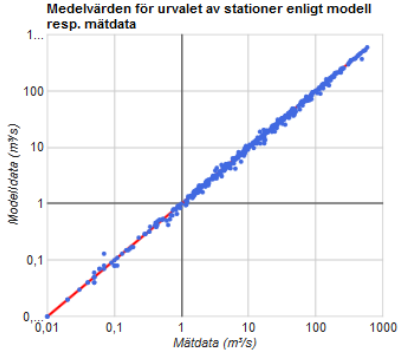
- Latest S-HYPE version:
  - 65 SLCs based on 9 soil and 13 land use classes
  - ~ 36000 sub-catchments, 119 basins
  - Mean sub-catchment size ~ 13 km^2
  - Gridded forcing data 4 km, PTHBV, daily
  - National databases for crop distribution, fertiliser application, point sources
  - Single deterministic calibration result

S-HYPE - discharge



- ~ 440 Q stations for evaluation during 1999 to 2008 period
- ~ 50% influenced by upstream regulation: lakes and reservoirs
- Mean relative error performance:
  - no obvious catch-ment scale dependency
  - Mountains under-estimated
  - Single regional outliers



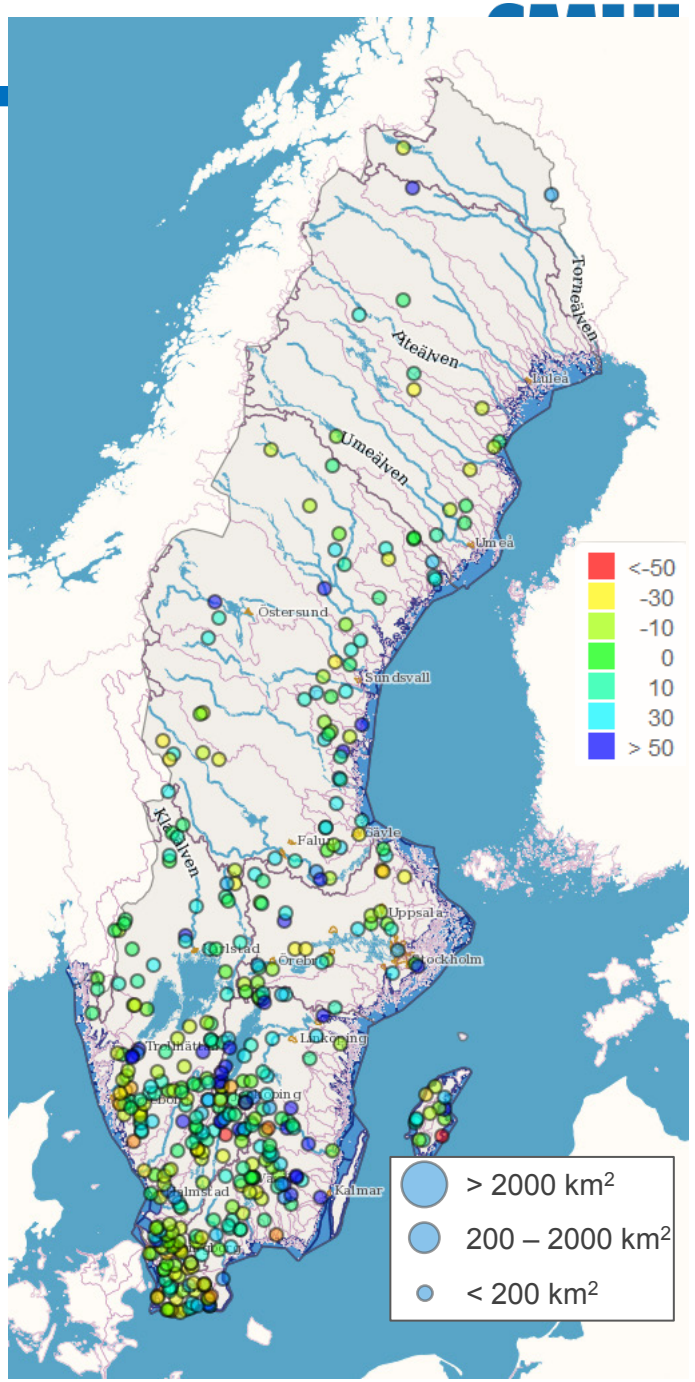


S-HYPE – Total nitrogen

- Sources in the model:
  - Atmospheric deposition (modeled)
  - Agricultural practice
  - Point sources
  - Internal pools

- Strong scale dependency in rel. error

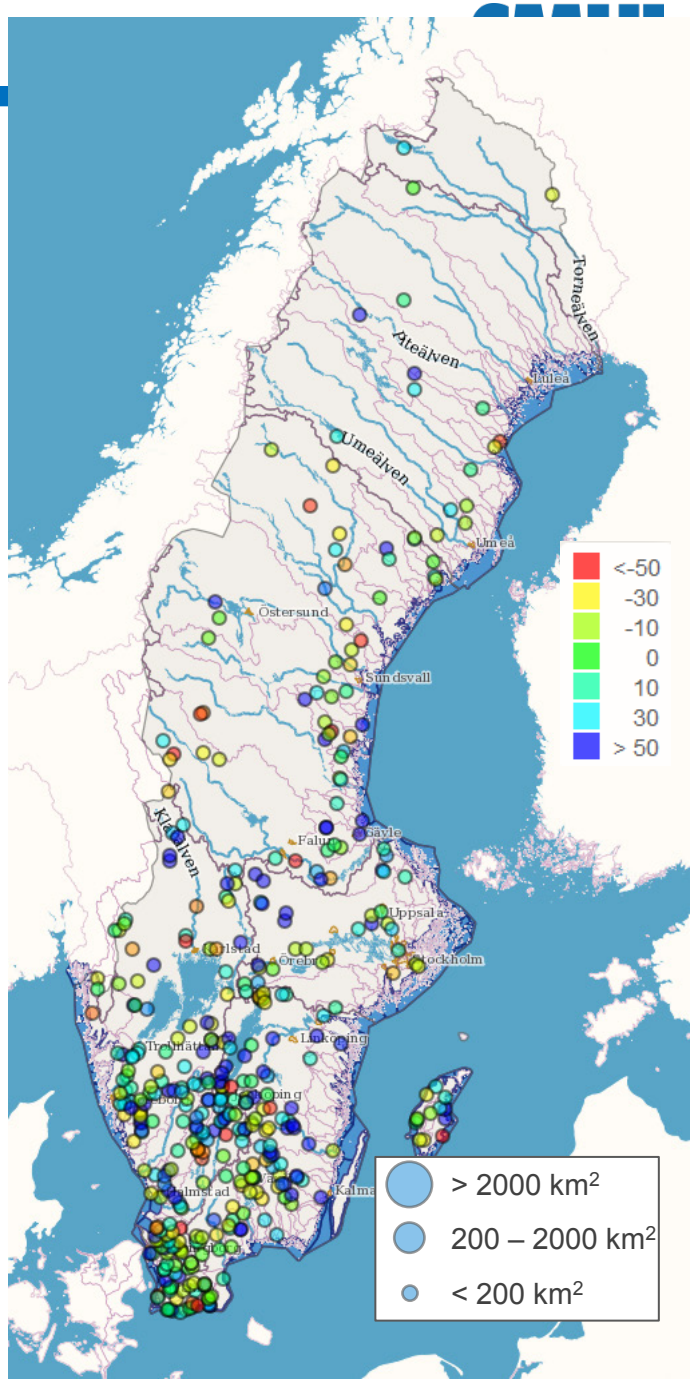
Small catchments



S-HYPE – Total phosphorus

- Sources in the model:
  - Agricultural practice
  - Point sources
  - Internal pools
- Strong scale dependency in rel. error

Small catchments

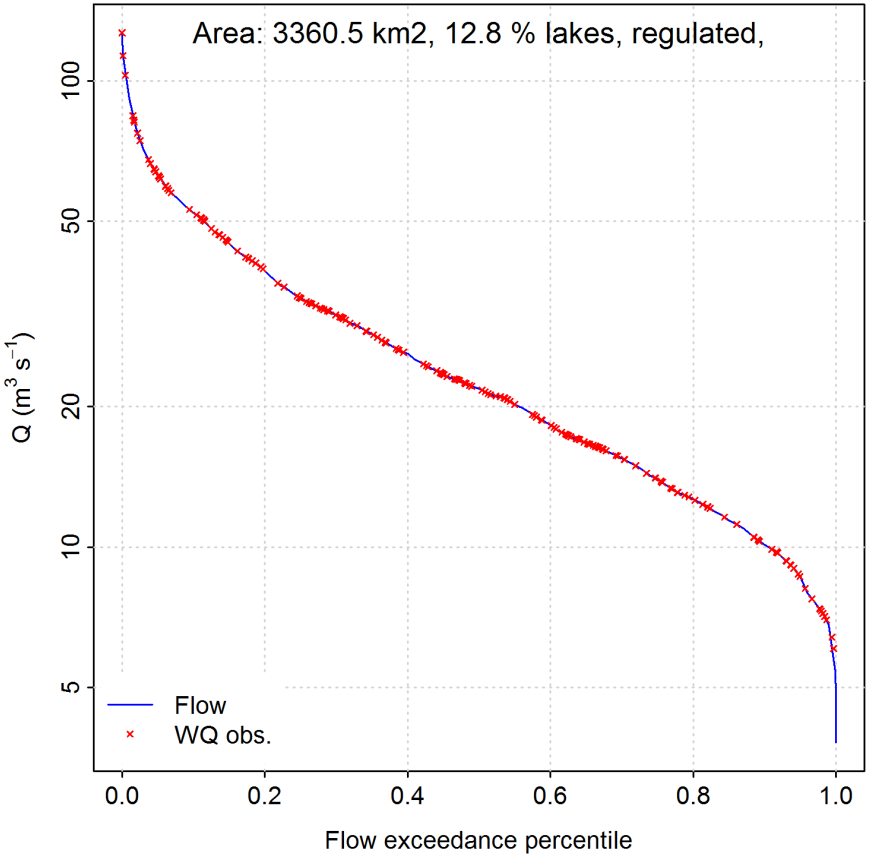


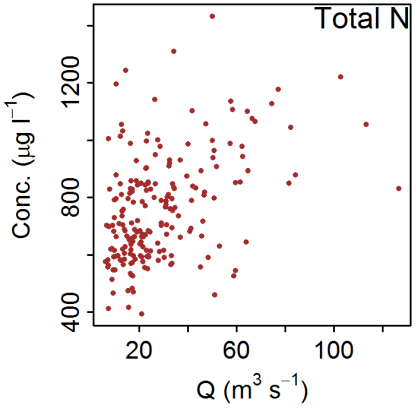
Observed and modeled temporal dynamics

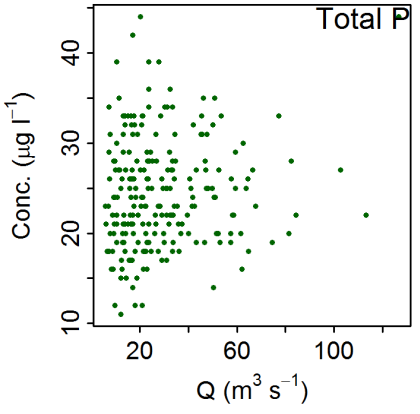
- Three example catchments from the S-HYPE model set-up
- Multi-variable observations – low frequency but long time, Information content sufficient?

Mörrumsån, South-eastern Sweden

- Catchment area 3400 km^2
- 73% forest, 11% agriculture, 13% lakes
- Catchment discharge dynamics influenced by regulated lakes
- Flow range well covered by TN/TP observations
- No clear relationship between TN/TP and Q at this scale
- Low concentrations
- Mixing of spatial sources + large lake system in catchment centre

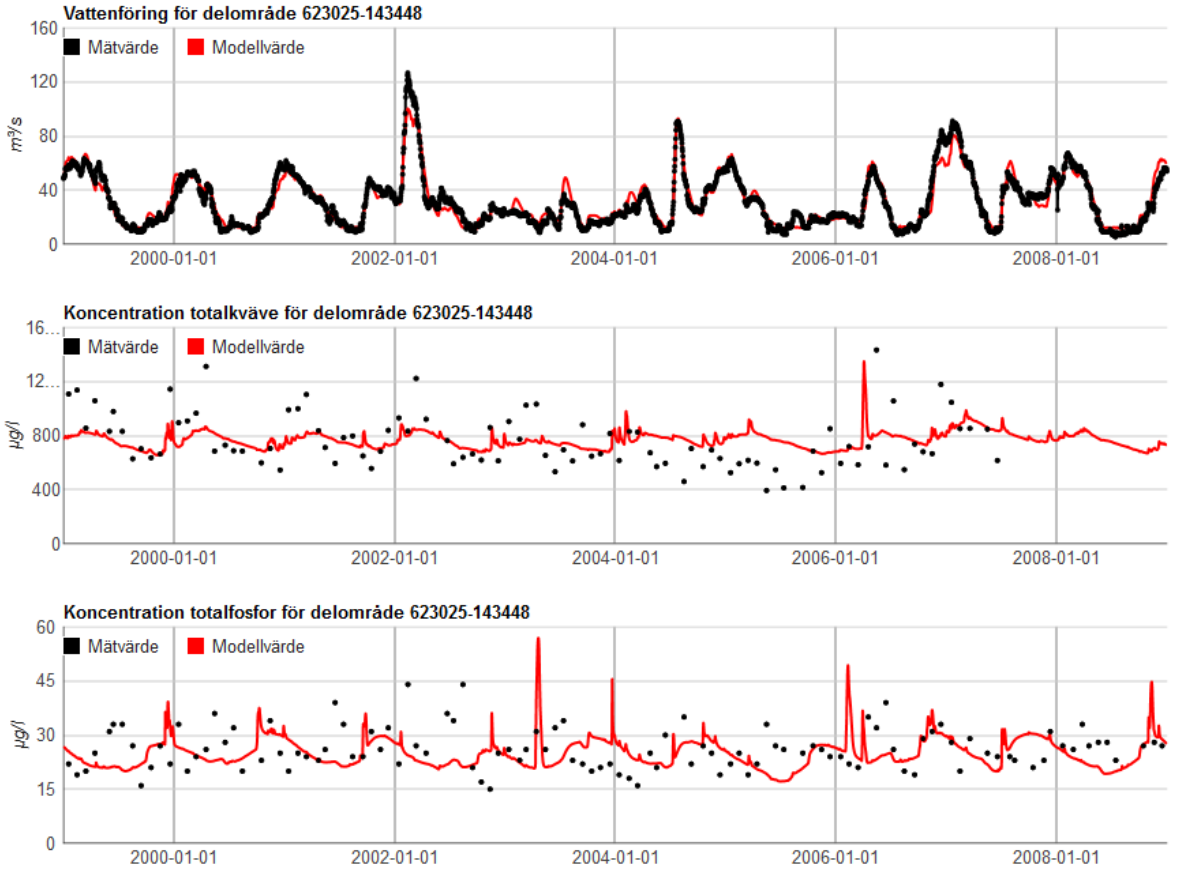


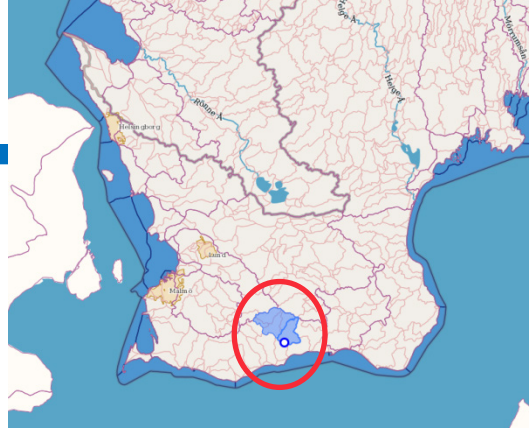




Mörrumsån, South-Eastern Sweden

- Discharge calibration satisfactory, NSE 0.89 for 1999 to 2008 period
- Modeled TN and TP:
  - Concentration levels ok
  - Observed dynamics only partly matched
  - Time stepping issue?

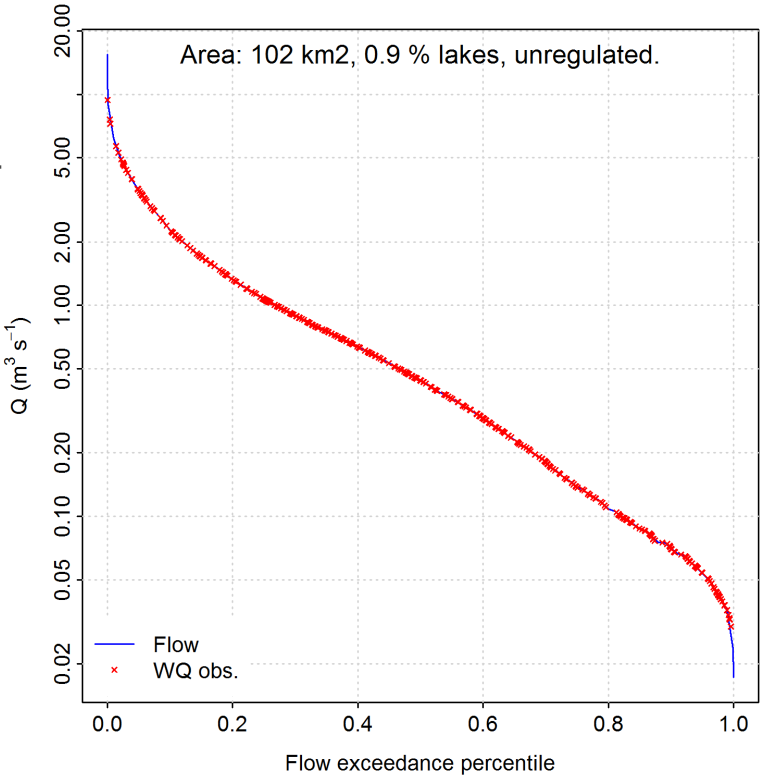


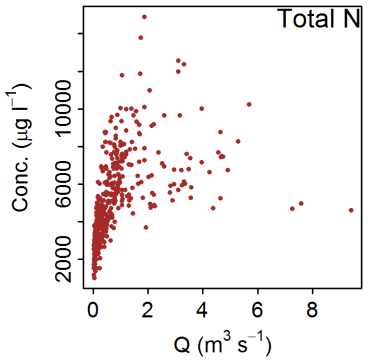


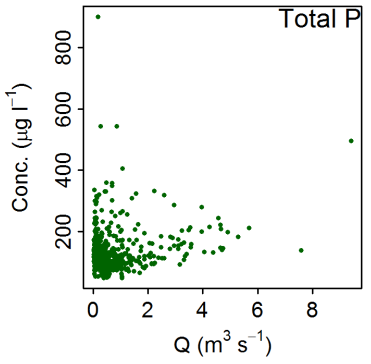
Skivarpsån, Southern Sweden

- Catchment area 100 km^2
- 10% forest, 80% agriculture, < 1% lakes

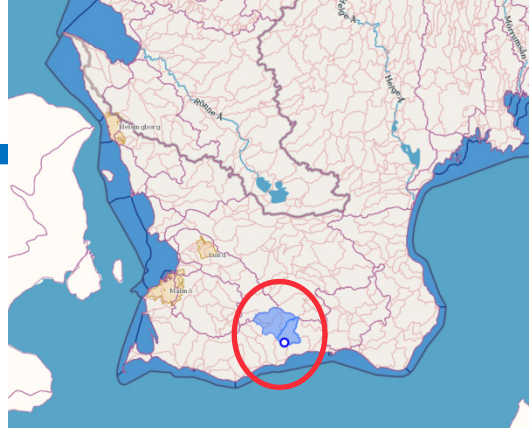
- Agriculture, high nutrient concentrations
- TN: Conc.-Q dependency, catchment size and homogeneity





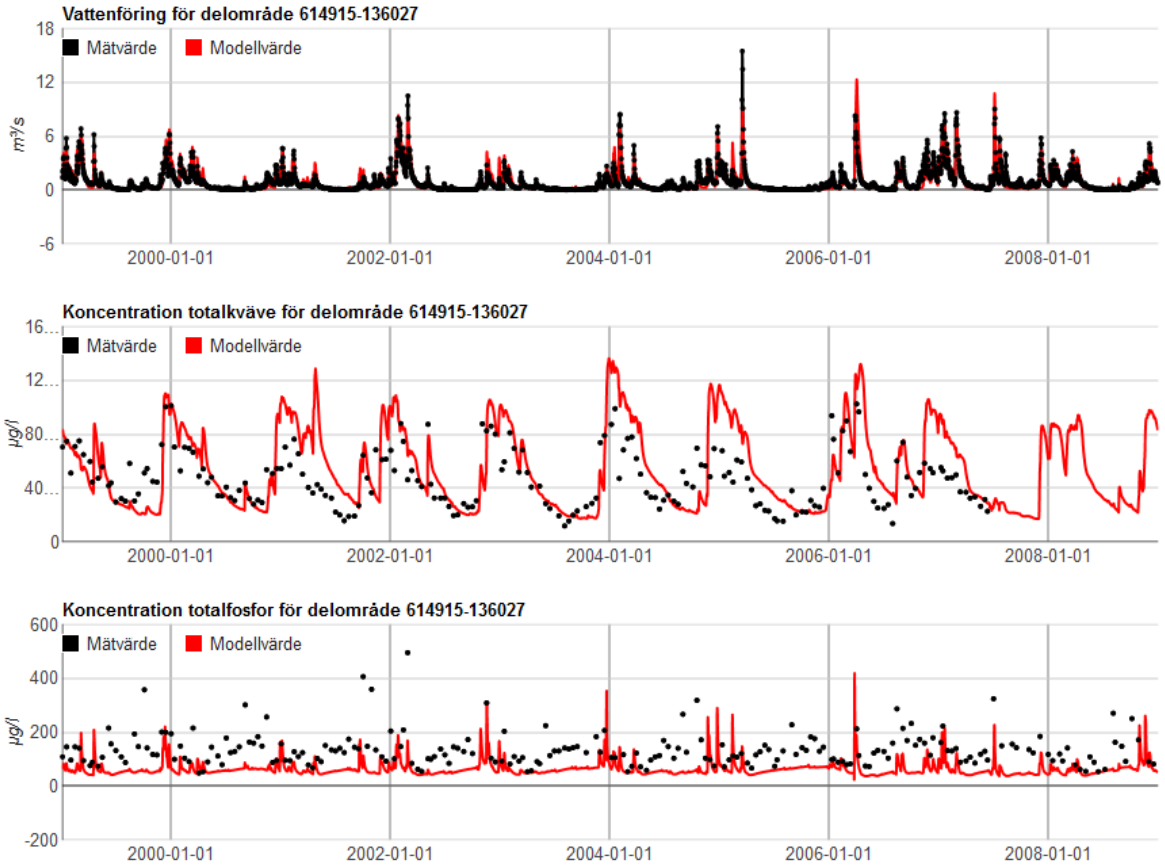


Skivarpsån, Southern Sweden

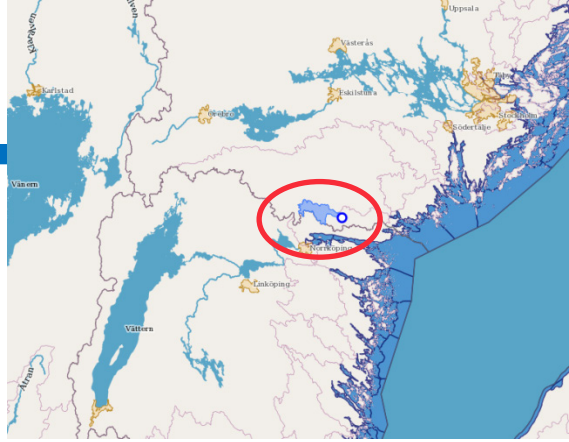


- NSE 0.76 for 1999 to 2008 period
- Peak flow underestimated at times

- Seasonal TN dynamics lag in model
- TP with wrong dynamic, particulate vs. soluble P?

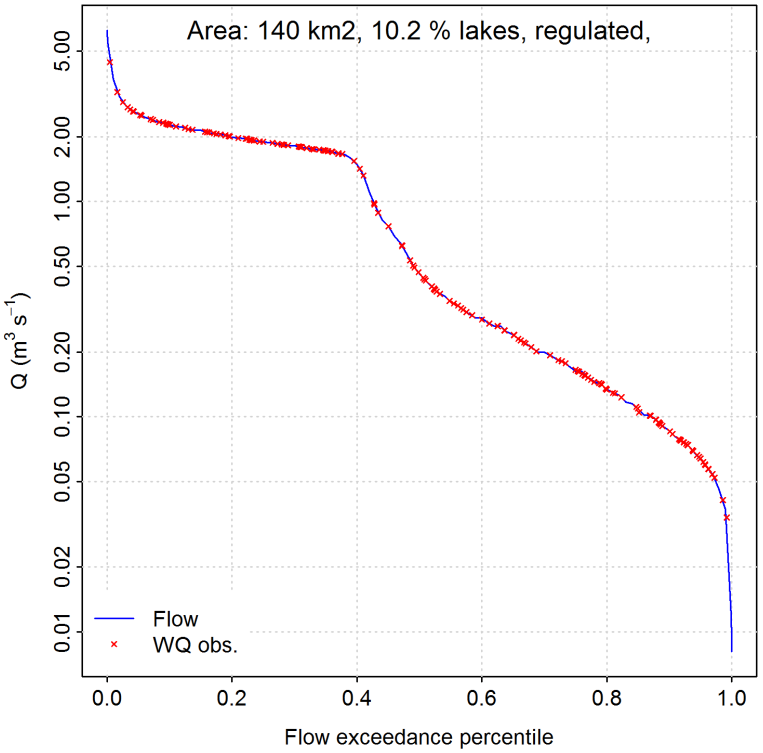


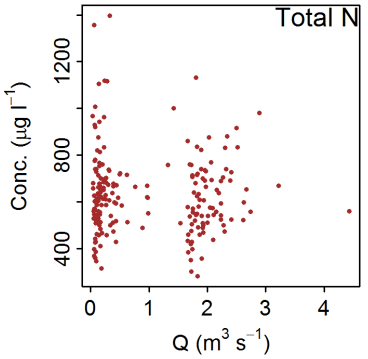
Kilaån – Eastern Sweden

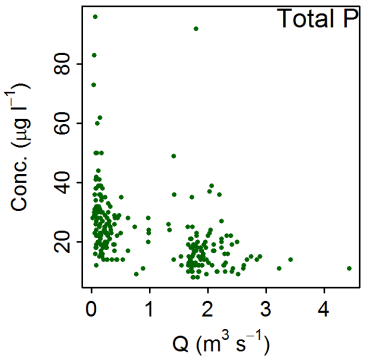


- Flow dynamics massively influenced by regulation
- 140 km^2, 60% forest, 20% agriculture, 20% urban

- High flows capped, two-part FDC
- Small-scale hydropower dams







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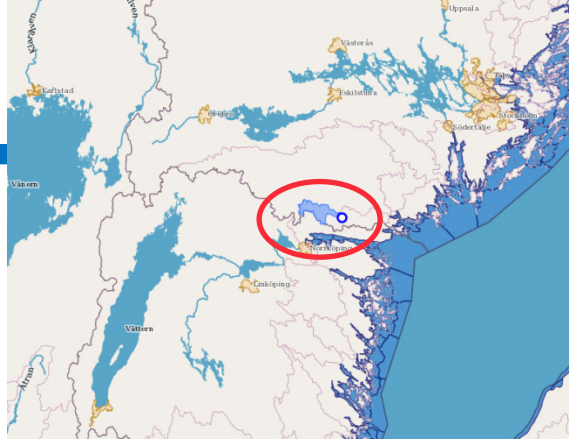
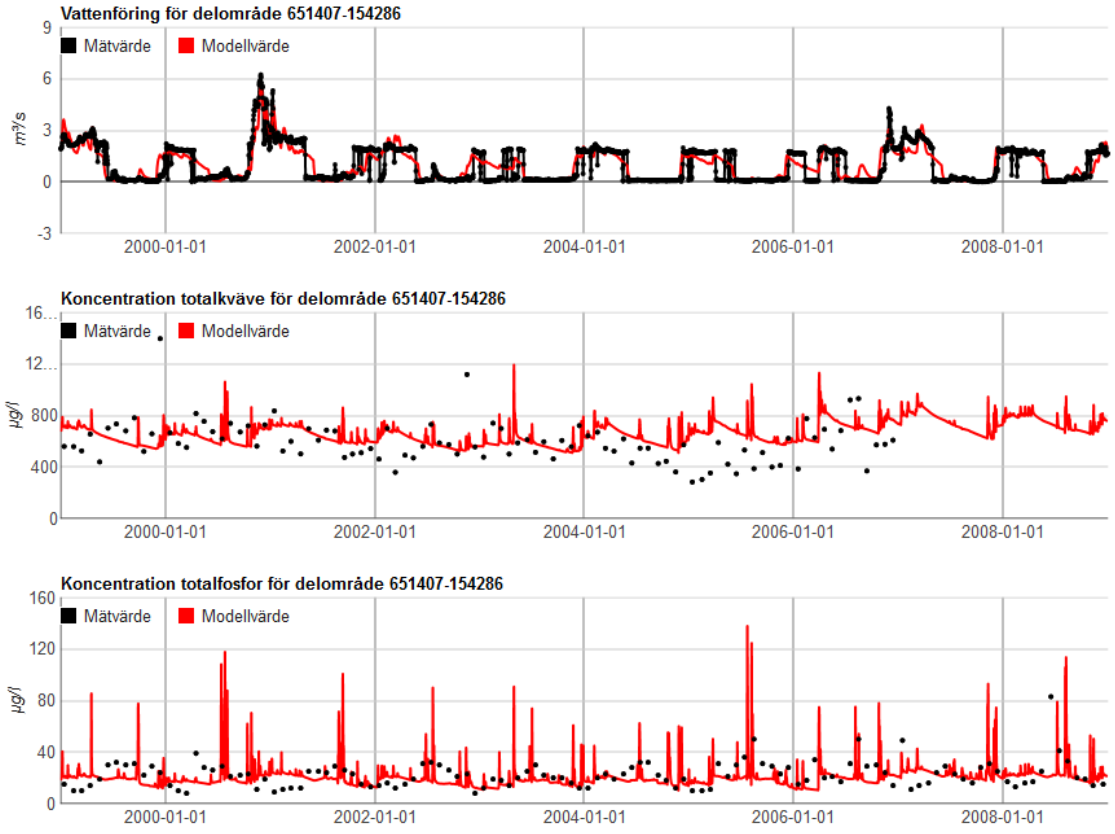


- Regulation not fully represented in modeled discharge
- NSE 0.56 (Q)

- Volume error passed down to nutrient dynamics

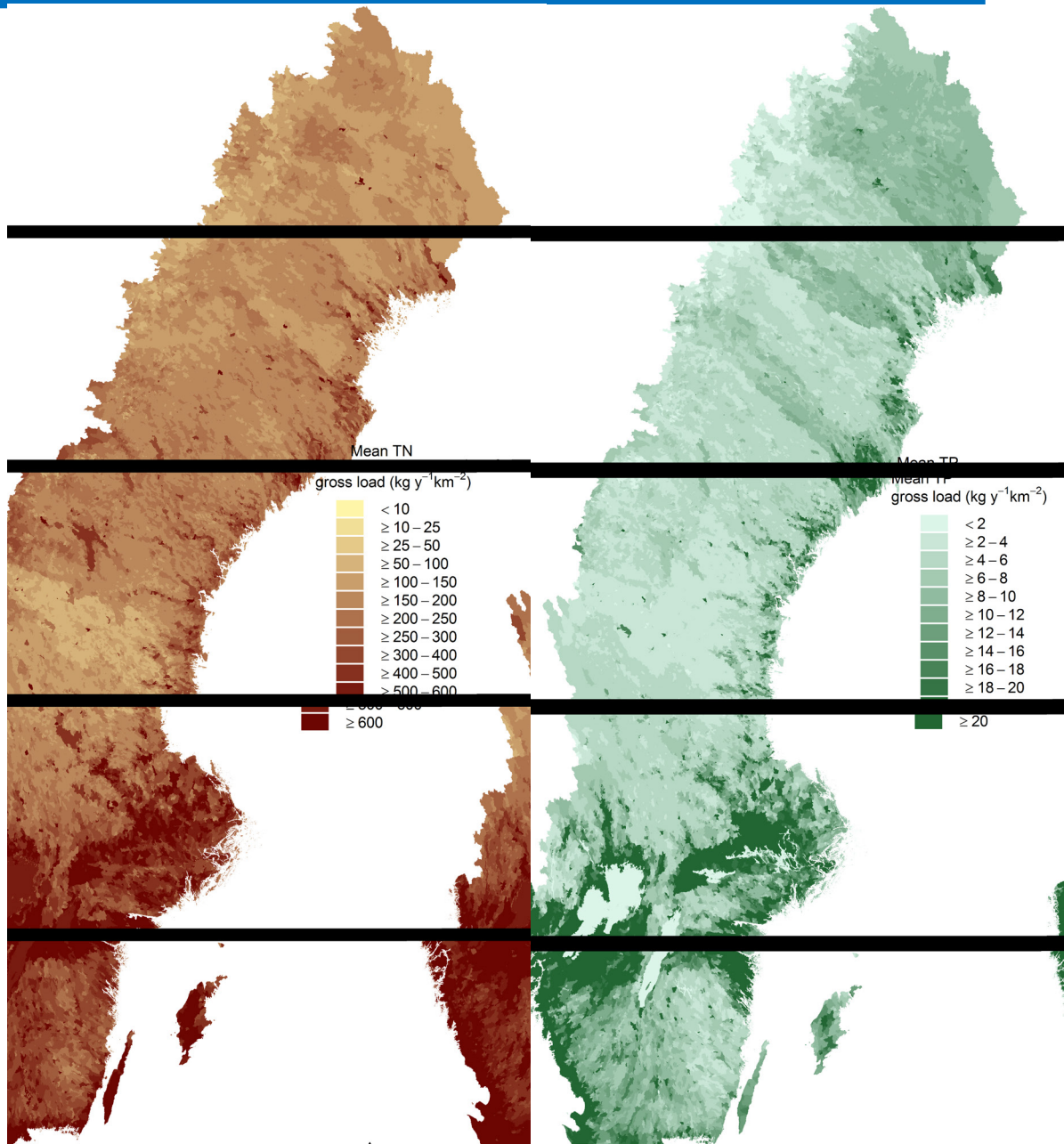
- Modelled TP peaks too high, systematic model error



Sweden-wide model estimates

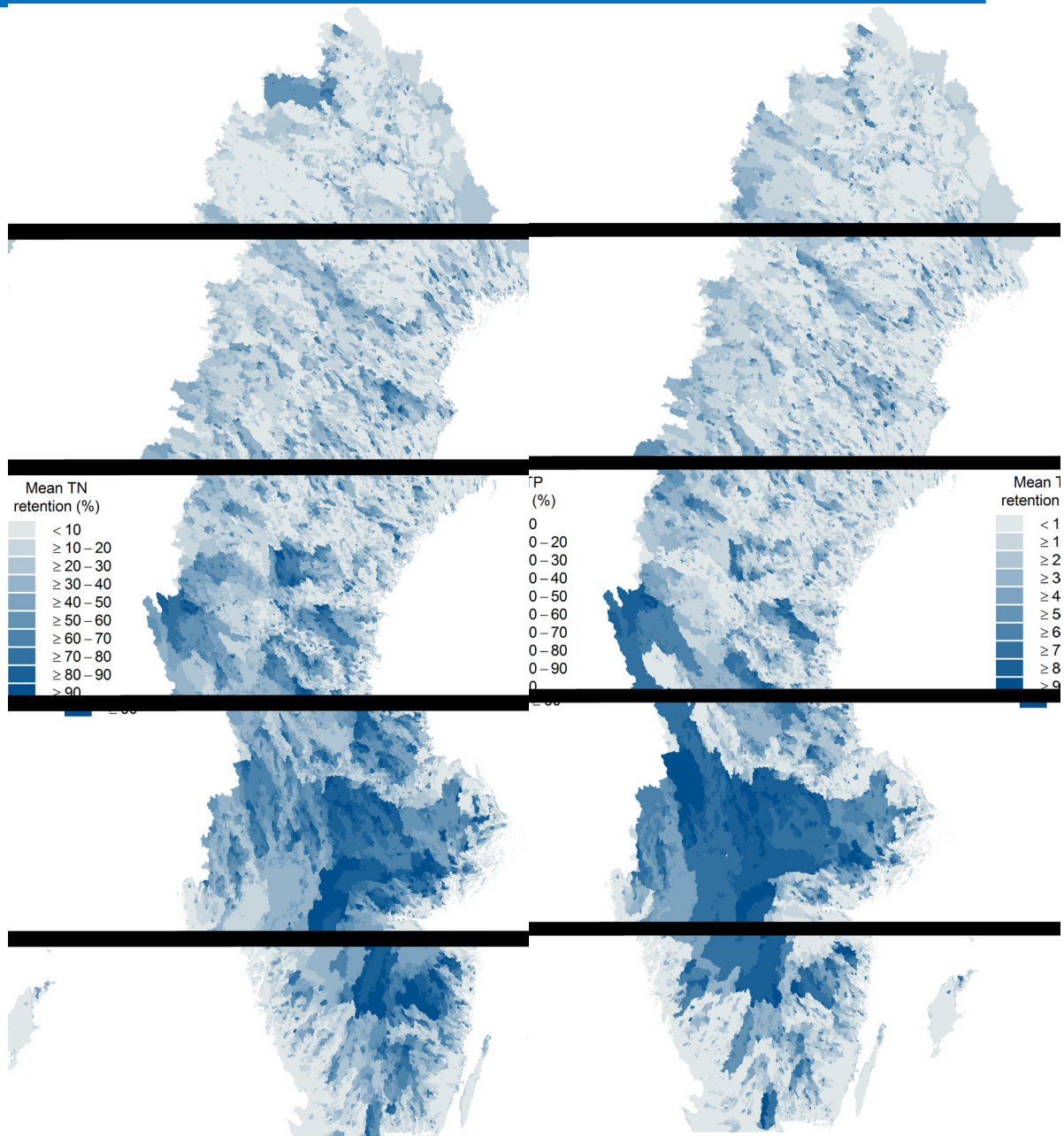
Back to the large scale:

- Modeled local gross loads to main river
- 10year annual average
- Large uncertainty, locally 100% deviation possible
- Agricultural areas



- Modeled retention to sea outlets (%)
- Benefit of large model domain with high spatial resolution

- Retention high where loads high
- Large central lakes prominent, ”masking” upstream contributions
- Implications for identification of critical release areas



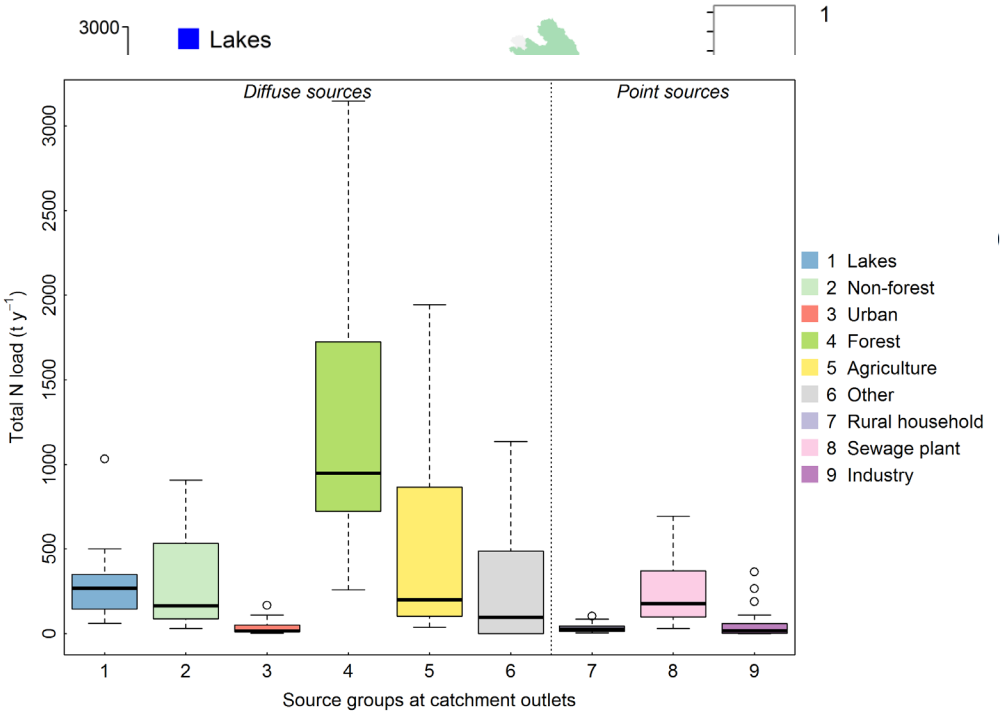
TN sources at sea outlets

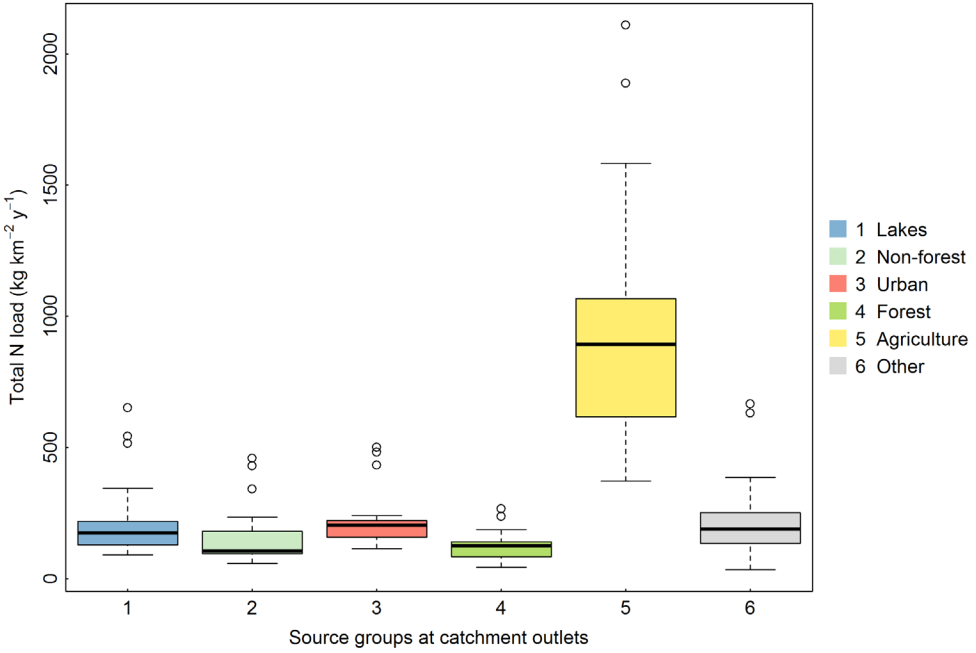
- Model results
- Annual loads in tons $^{y-1}$ for large catchments
- Grouped by land cover and point sources

- North-south split into forest and agriculture dominated areas

- Point source releases near population centres

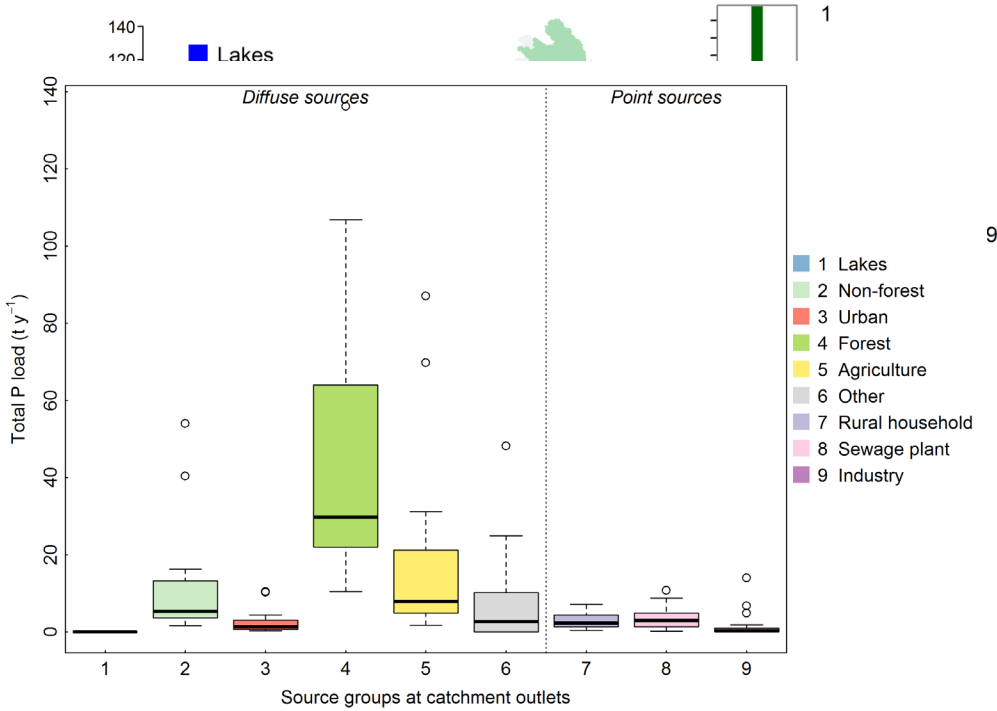
- Absolute loads reflect land cover fractions, while area-specific loads reveal ”main offenders” from a pollution perspective

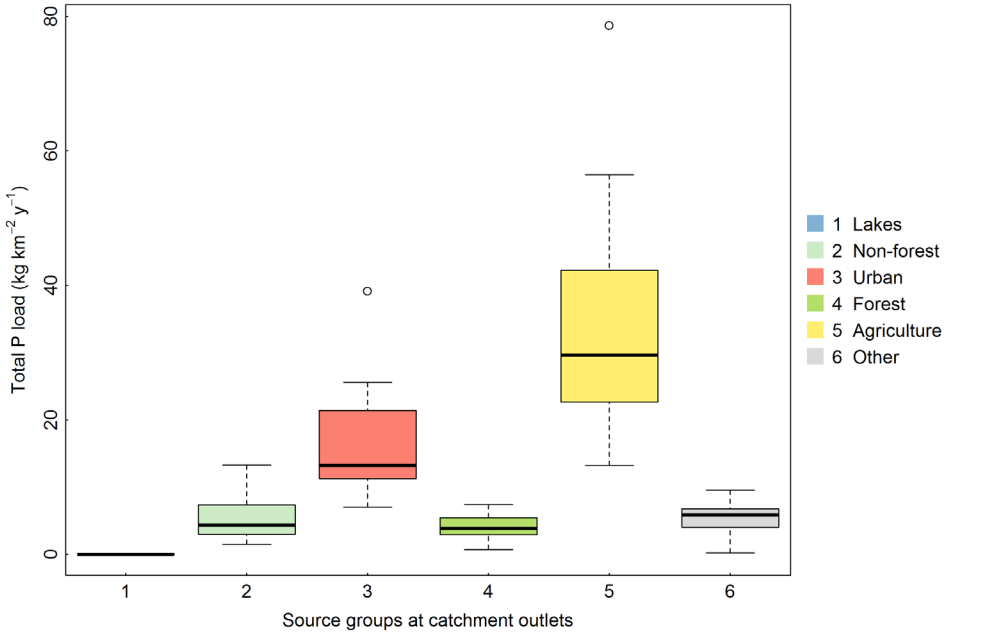




TP sources at sea outlets

- Similar pattern as TN
- Less pronounced point sources
- Load in northern catchments: observed high release from boreal forests/bogs
- Specific load from urban classes





Conclusions – take home messages

- Multi-measurements at the same site for model evaluation => confront model with data and higher time resolution
  - holistic picture
  - higher confidence in model performance
  - easier to constrain parameter uncertainty

- Important factors for in-stream nutrient dynamics and loads in large scale river systems might be different from small scale patterns

- Increasing complexity and diversity
  - Upstream area contribution, mixing and retention
  - spatial dynamics may be more dominant than temporal dynamics

- Large scale areas are “always” highly modified and managed by humans, which will influence observed dynamics

Thank you – open resources

http://hype.sourceforge.net/

http://vattenwebb.smhi.se/

https://github.com/rcapell/RHYPE

http://hypeweb.smhi.se/