NUTRIENT RETENTION IN THE SWEDISH COASTAL ZONE

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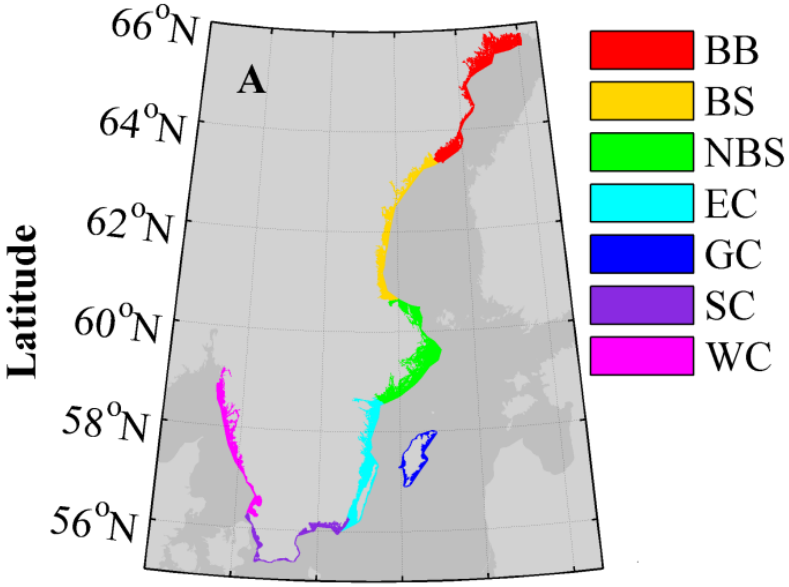
Aim and method

Aim:

- Describe and quantify nutrient retention in the Swedish coastal zone. Covers an array of differnt coastal types, climates and antropogenic settings.
- Why does nutrient retention vary this way?

→ Aid modelling of open coastal and shelf seas, such as the Baltic Sea.

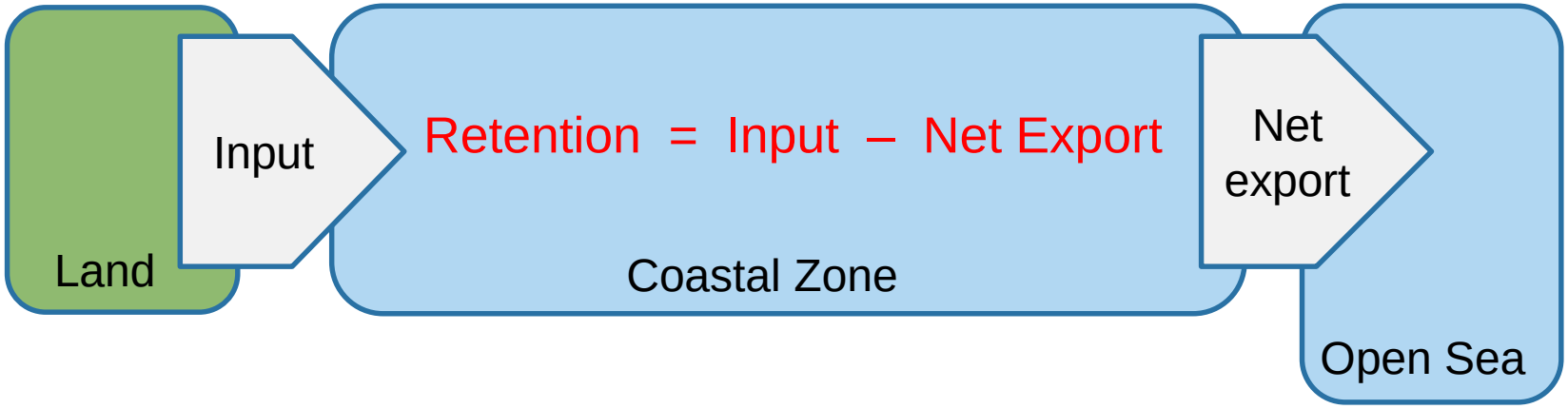
In a near shore context the parameterization of what happens to constituents in the fresh to saline continuum is of importance.



Method:

- Numerical modelling of the Swedish coastal zone
- Which properties are strongly correlated to effective retention of nutrients?

Retention



- Temporary retention (ΔM):
  Nutrients retained in biomass, sediment and water.

- Permanent Net Removal (PNR):
  - P: Burial
  - N: Burial and denitrification

The efficiency to filter nutrient input from land:

$$E_F = \frac{R_{tot}}{\text{Land load}}$$

The efficiency to permanently remove the total input of nutrients:

$$E_R = \frac{PNR}{\text{Total load}}$$

SCM: Swedish Coastal zone Model

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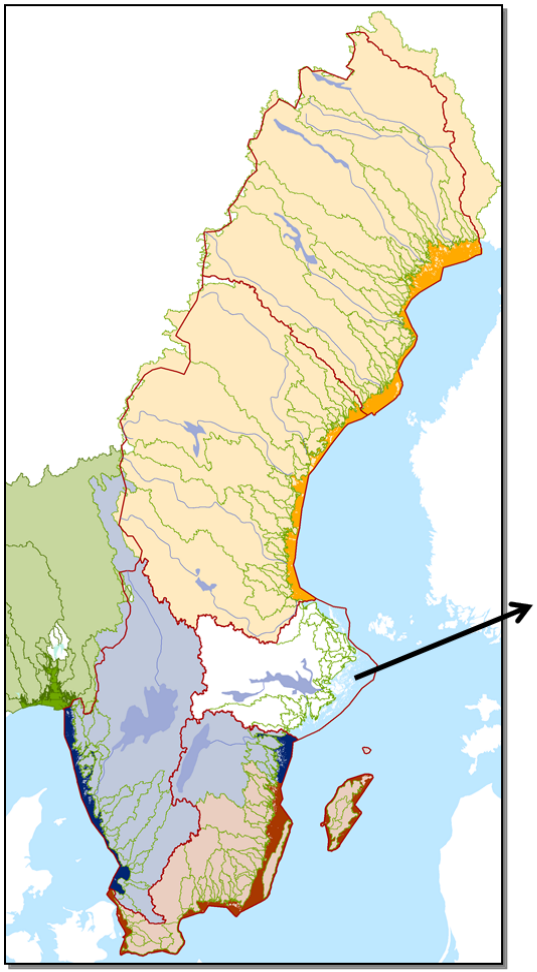
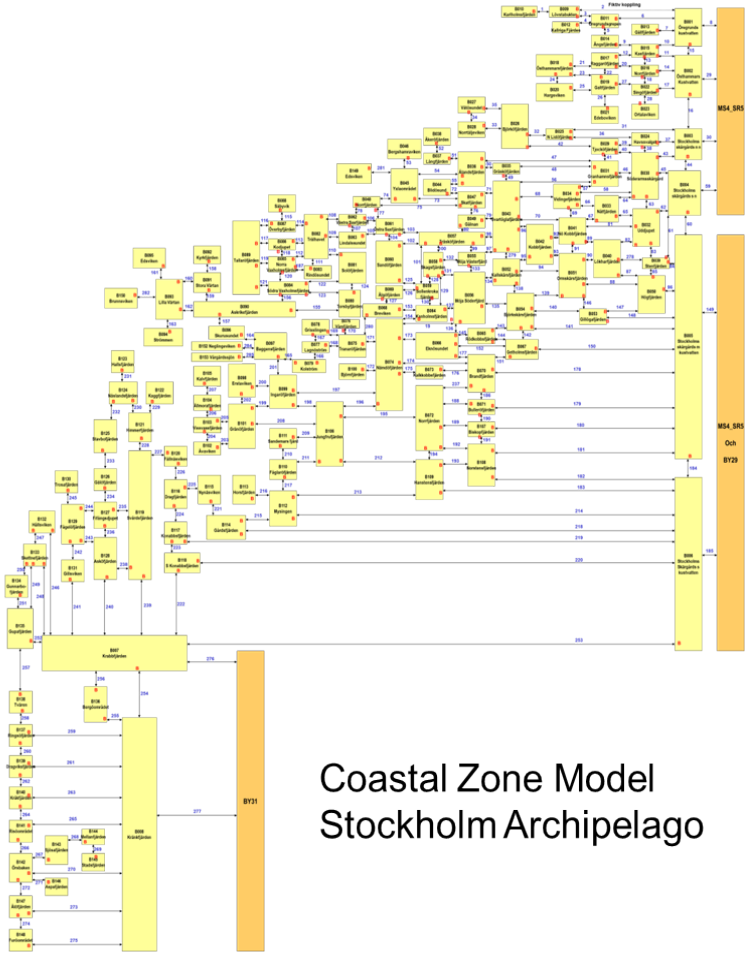
Sweden has an unique and complex shoreline



Consists of dynamically coupled 1D model basins



Coastal Zone Model
Stockholm Archipelago

- Water bodies according to the water directive.
- Vertical resolution 0.5-4 m
- Based on the equation solver PROgram for Boundary layers in the Environment (PROBE)
- Coupled to the Swedish Coastal and Ocean Biogeochemical model (SCOBI)

Biogeochemistry and retention

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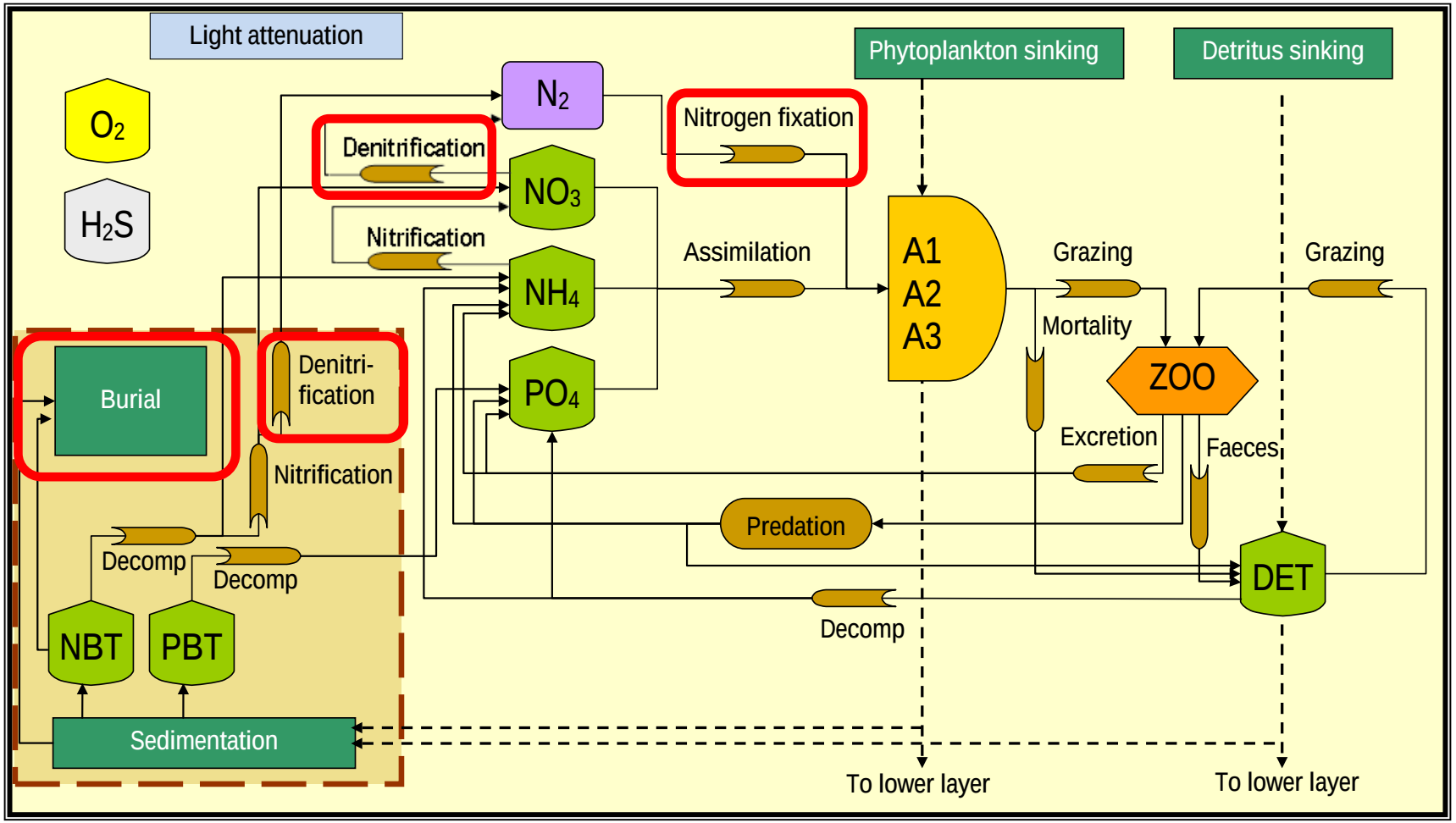
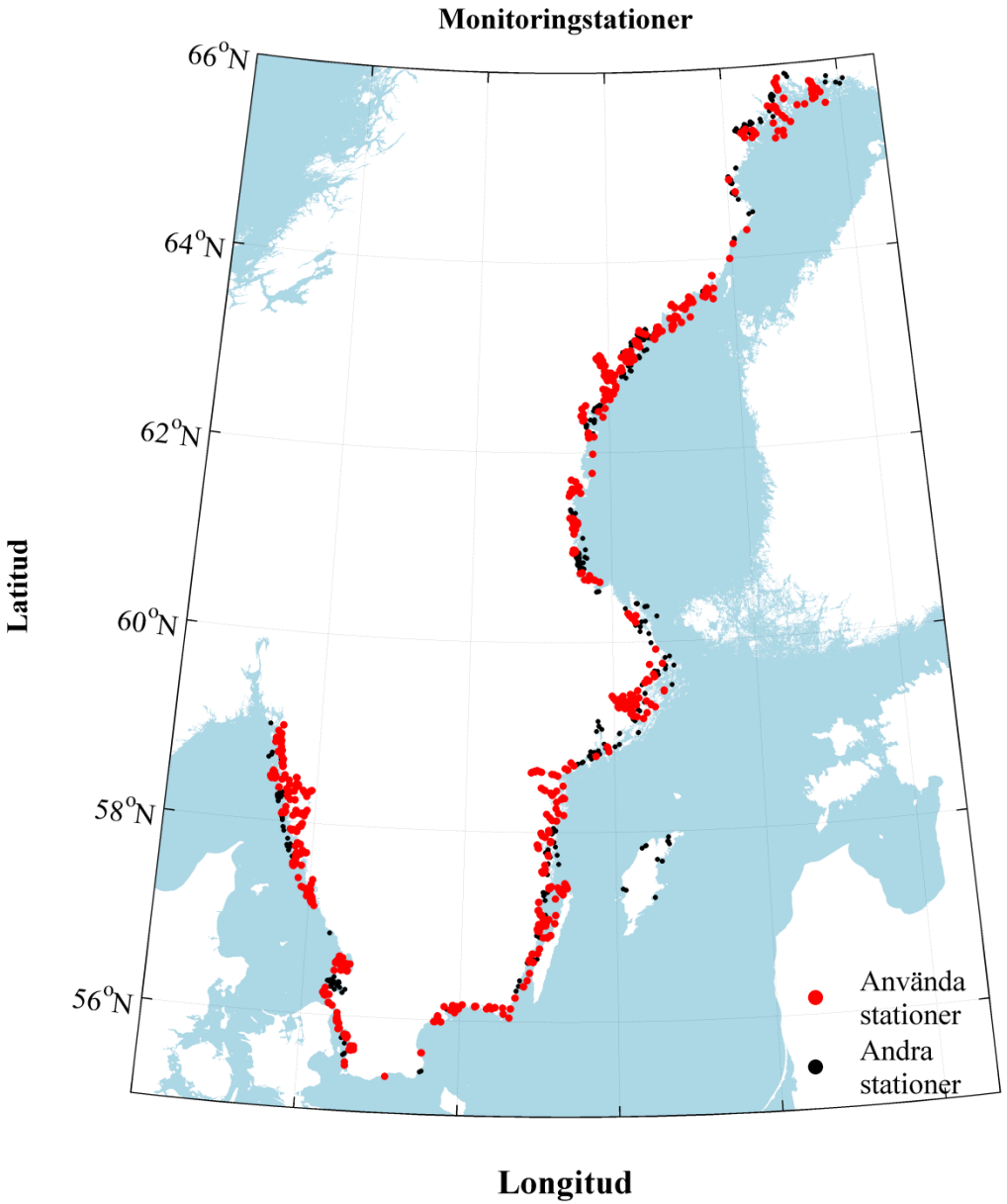


Evaluation – Measument data

- From SHARK data base.
- Quality checked by the data host.
- Recipient control, monitoring, measument campaigns, et.c.



Evaluation – What is good?

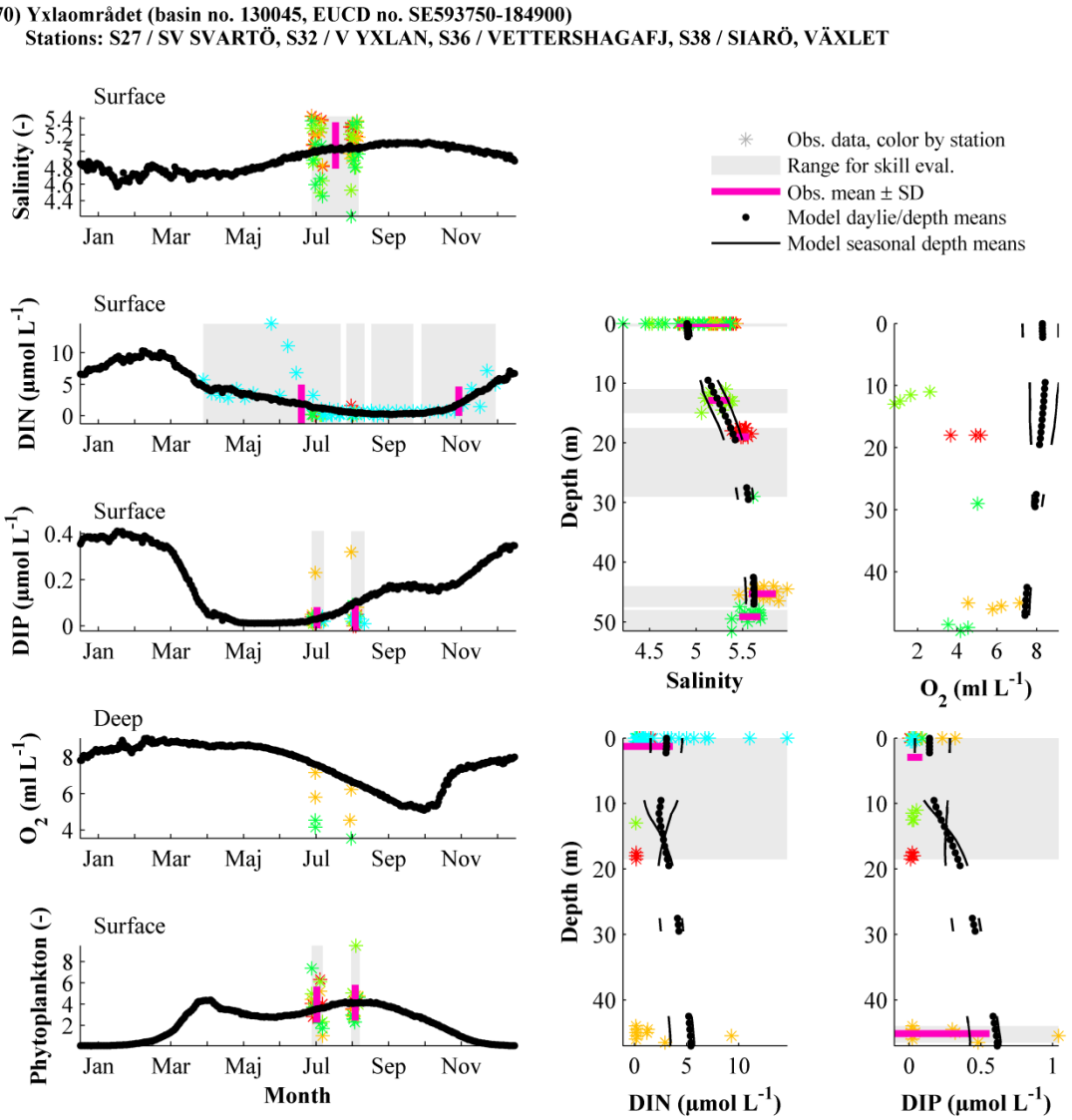
Based on statistical properties:

Mean profiles and mean seasonal cycle.

Model data extracted at sample depths and at sample times

$$C = \frac{\sum_{i=1}^{n} \left| \frac{P_i - O_i}{sd(O_i)} \right|}{n}$$

$$r = \frac{\sum_{i=1}^{n} (P_i - \overline{P})(O_i - \overline{O})}{\pm \sqrt{\sum_{i=1}^{n} (P_i - \overline{P})^2 \sum_{i=1}^{n} (O_i - \overline{O})^2}}$$



Evaluation – Compact

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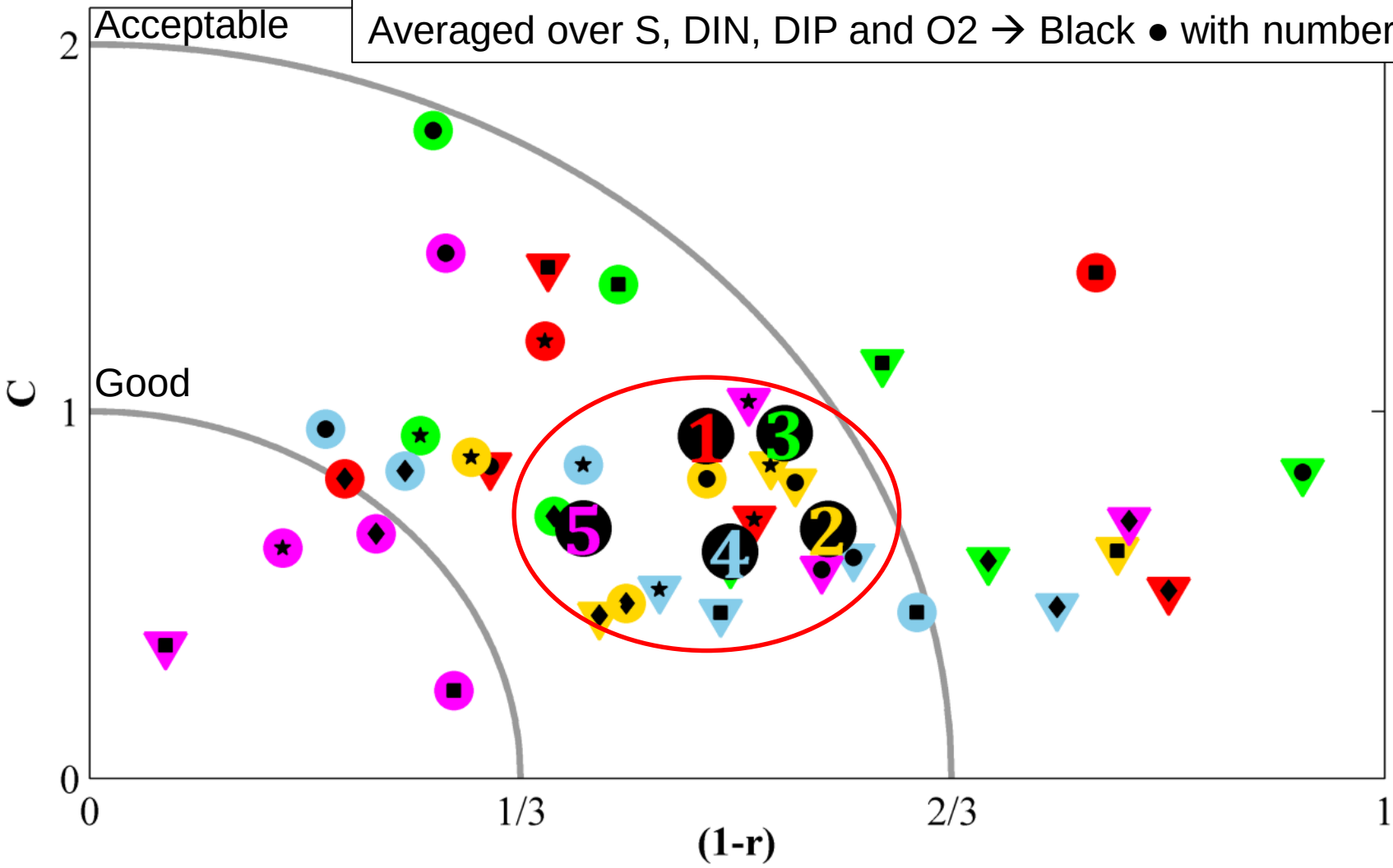
- Model skill of mean seasonal cycle within water districts
- ▼ Model skill of mean vertical profiles within water districts

Averaged over S, DIN, DIP and O2 → Black ● with numbers.



Filter efficiency

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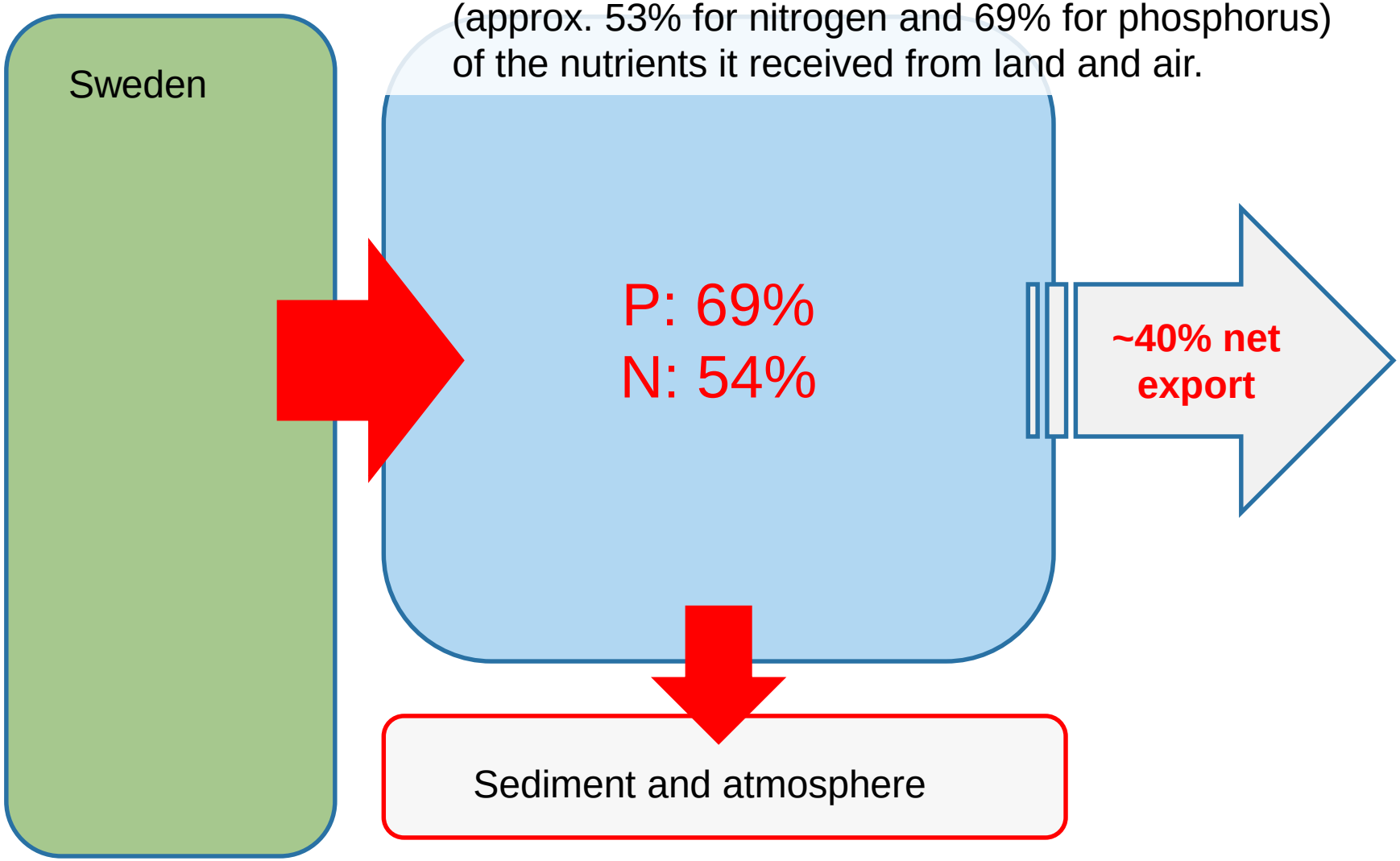
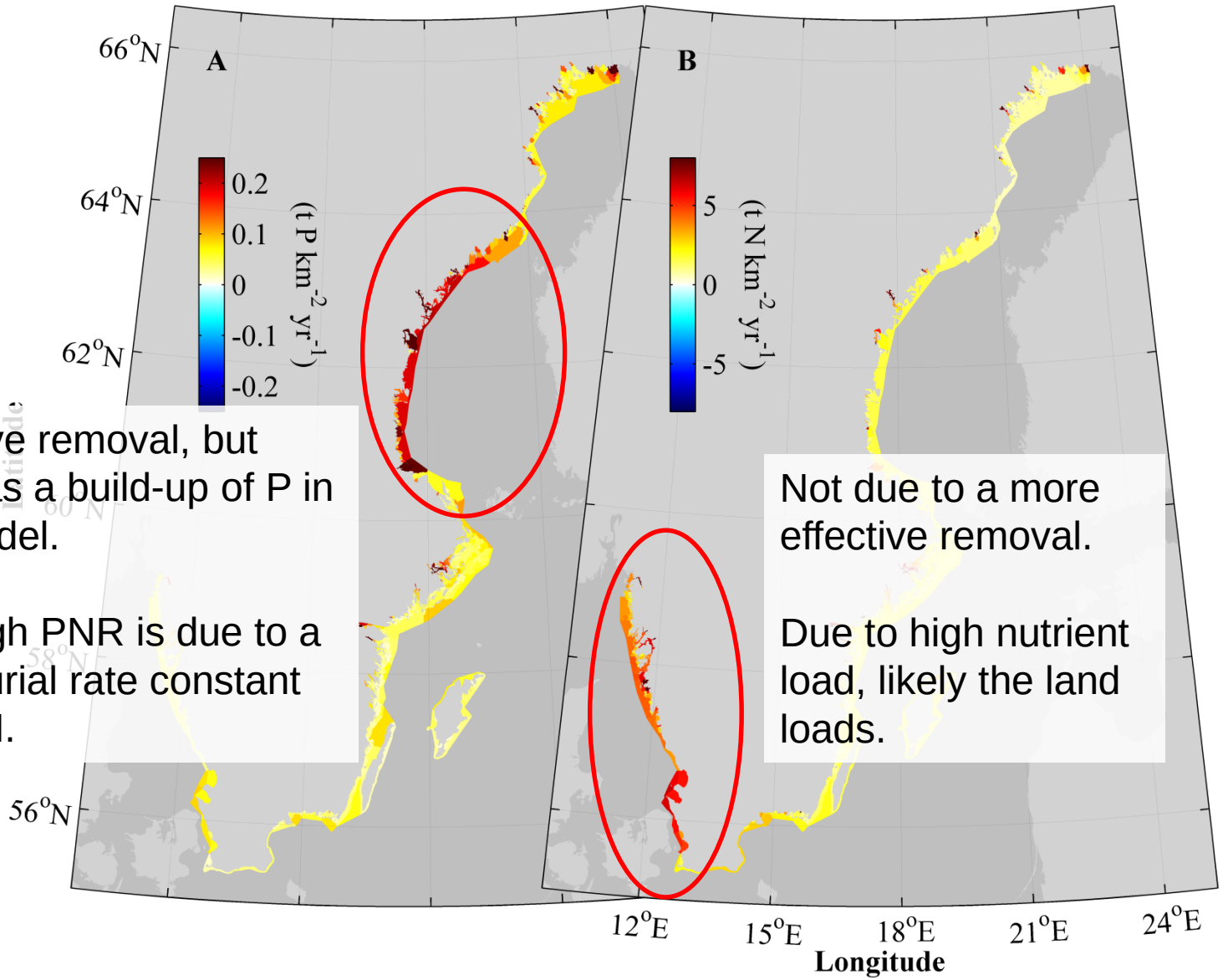
- The Swedish coastal zone filters about 60% (approx. 53% for nitrogen and 69% for phosphorus) of the nutrients it received from land and air.



Total nutrient retention



Effective removal, but also has a build-up of P in the model.

The high PNR is due to a high burial rate constant in SCM.

Not due to a more effective removal.

Due to high nutrient load, likely the land loads.

Retention efficiency **WHY?**

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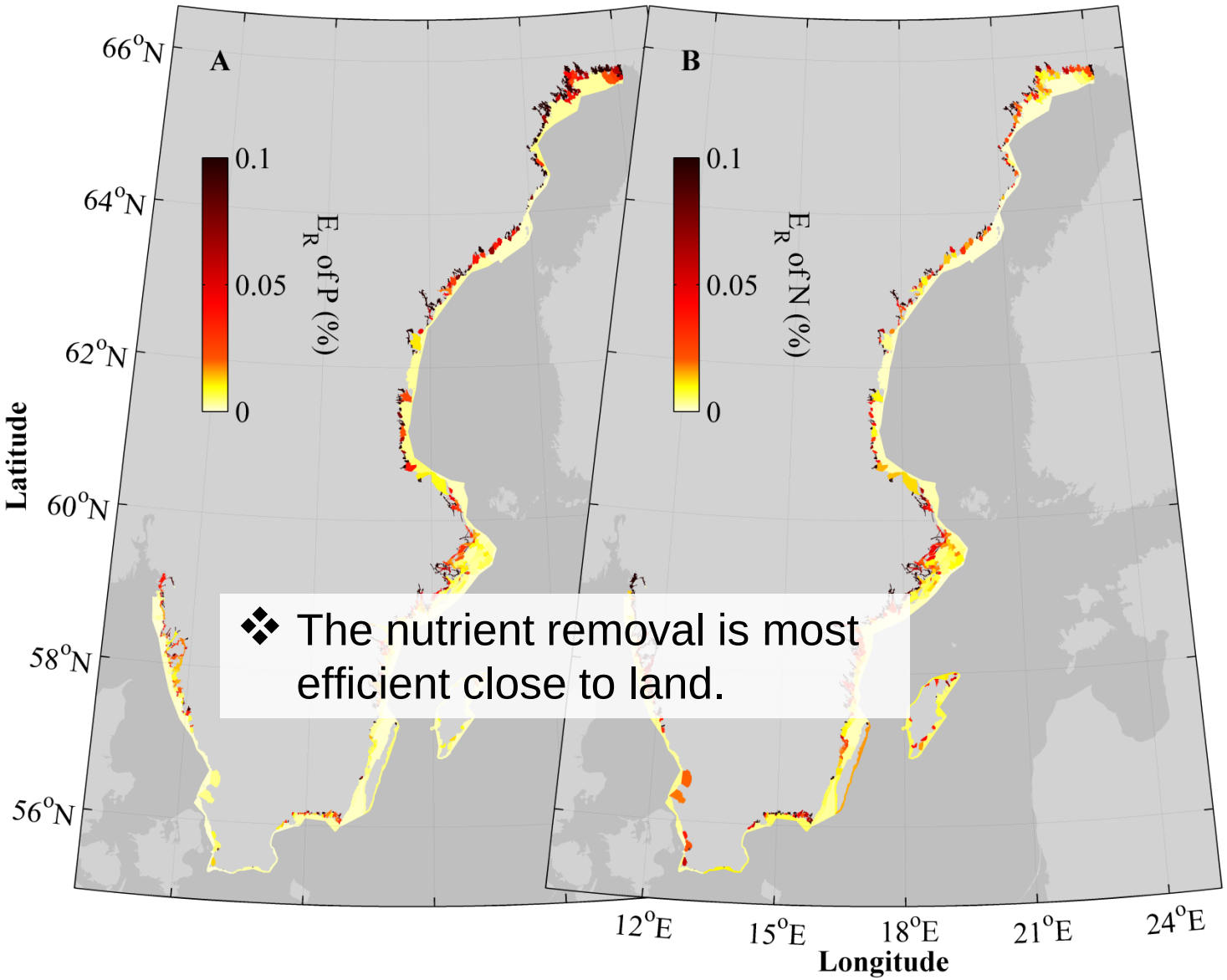
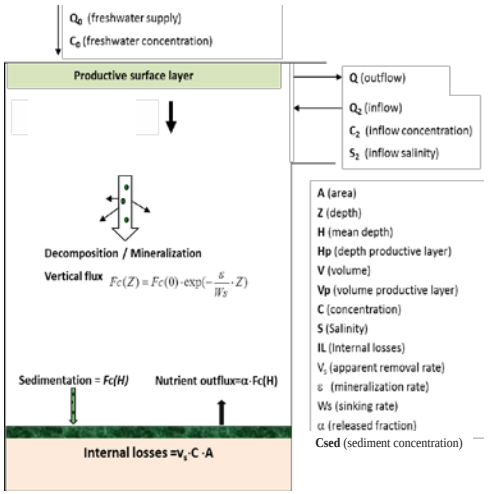


- The nutrient removal is most efficient close to land.

Steady state retention



Assume mass conservation and a steady state water body.

$$E_R = \frac{1}{1 + \frac{H}{V_S \cdot \tau}}$$

The retention efficiency of the coastal zone is determined by water depth and residence time as well as on the apparent removal rate V_S that depends on the environmental state.

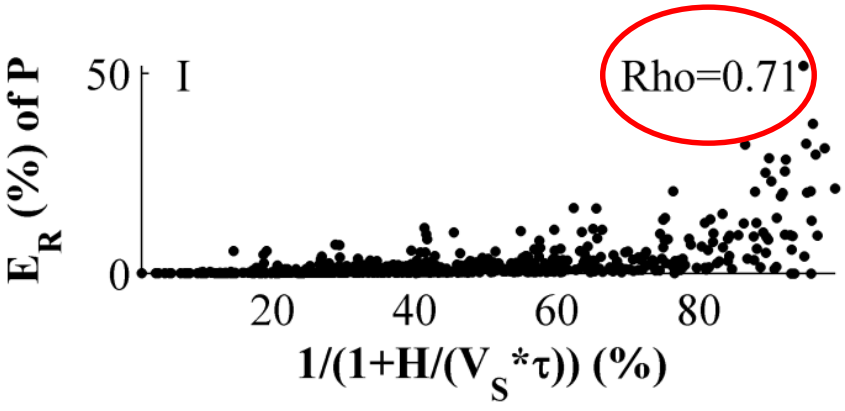
H and τ are easily available from the model set-up.

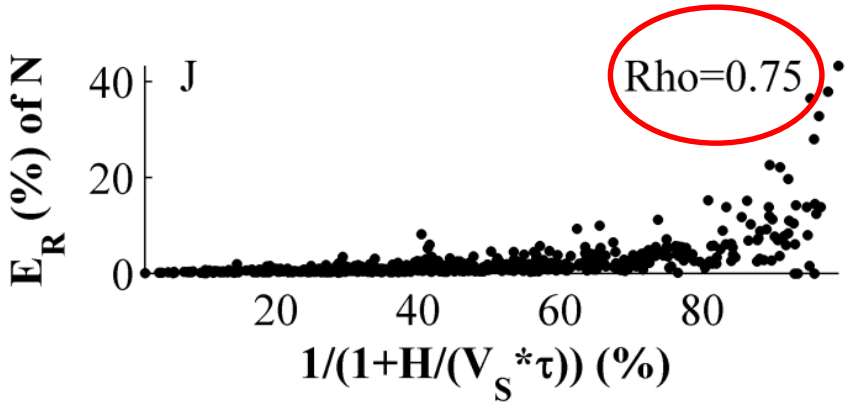
V_S set to 1.

Association of E_R to physical properties SMHI

$$E_R = \frac{1}{1 + \frac{H}{V_S \cdot \tau}}$$

- The long-term retention efficiency can be well estimated from expressions derived from a steady state situation and be reasonably well estimated from a simple expression based on physical properties.





Apparent removal rate?

Assume mass conservation and a steady state water body.

$$E_R = \frac{1}{1 + \frac{H}{V_S \cdot \tau}}$$

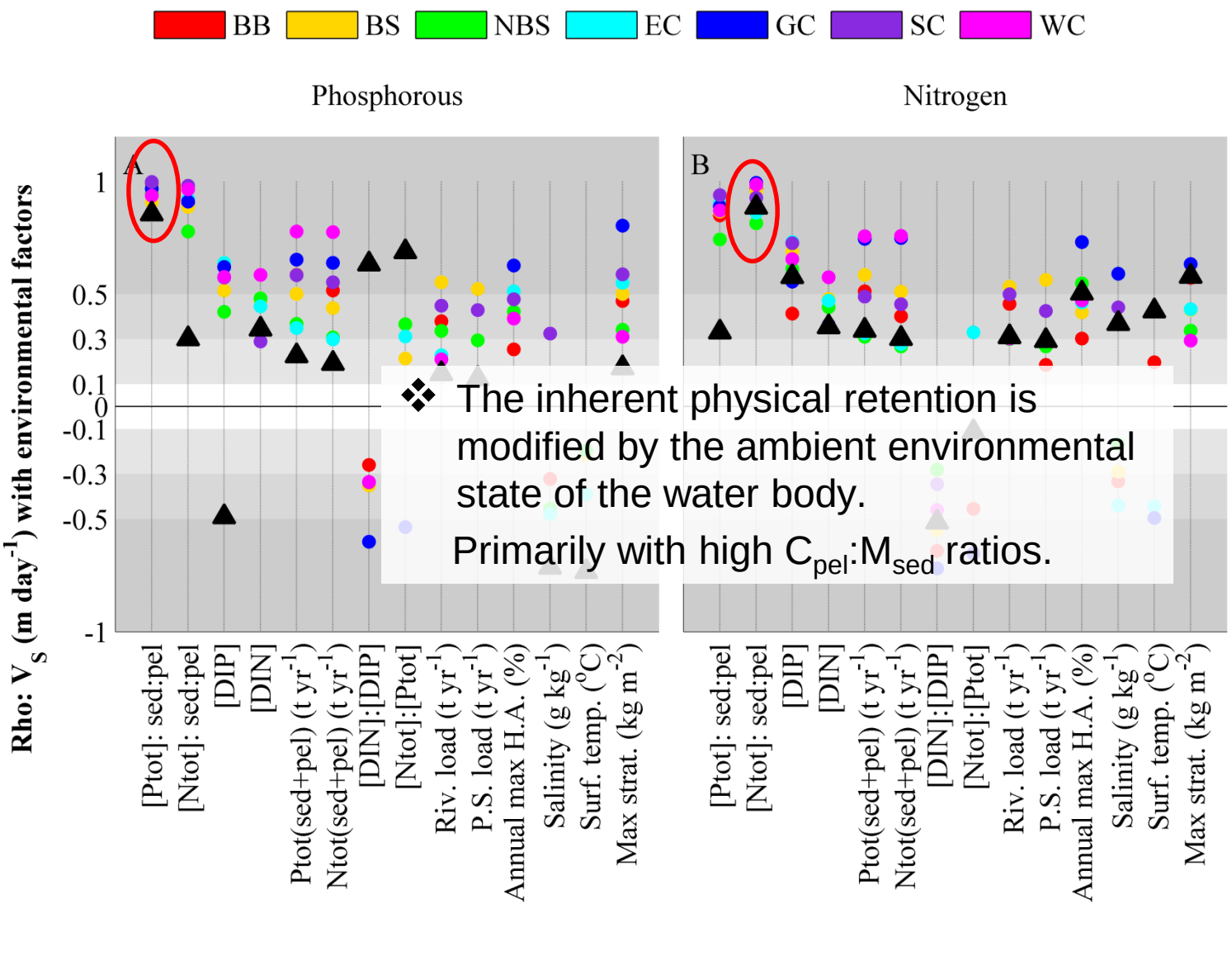
→

$$V_S = \frac{H \cdot E_R}{\tau \cdot (1 - E_R)}$$

The retention efficiency of the coastal zone is determined by water depth and residence time as well as on the apparent removal rate V_S that depends on the environmental state.

What environmental factors is V_S associated with ?

Association to environmental factors



- The inherent physical retention is modified by the ambient environmental state of the water body.
- Primarily with high C_{pel}:M_{sed} ratios.

Conclusions

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- The Swedish coastal zone filters about 60% (approx. 53% for nitrogen and 69% for phosphorus) of the nutrients it received from land and air.
- The northern and eastern Baltic Sea coasts, including the Stockholm archipelago, all retain more than 100% of the land and air load they receive. Thus, they also filter the Baltic Sea water.
- The nutrient removal is most efficient close to land.
- The long-term retention efficiency can be well estimated from expressions derived from a steady state situation and the area specific retention can also be reasonably well estimated from a simple expression based on physical properties.
- The inherent physical retention is modified by the ambient environmental state of the water body. Higher nutrient retention was found to be associated primarily with high C_{pel}:M_{sed} ratios.

Conclusions

- The Swedish coastal zone filters about 60% (approx. 53% for nitrogen and 69% for phosphorus) of the nutrients it received from land and air.

- The northern and eastern Baltic Sea coasts, including the Stockholm archipelago, all retain more than 100% of the land and air load they receive. Thus, they also filter the Baltic Sea water.

- The nutrient removal is most efficient close to land.

- The long-term retention efficiency can be well estimated from expressions derived from a steady state situation and the area specific retention can also be reasonably well estimated from a simple expression based on physical properties.

- The inherent physical retention is modified by the ambient environmental state of the water body. Higher nutrient retention was found to be associated primarily with high C_{pel}:M_{sed} ratios.

… continues…

SMHI

- Nutrient retention cannot strictly be estimated only from the coastal type of the water body. Long term retention efficiency depends mainly on physical characteristics, i.e. mean depth and residence time.

- On interannual timescales, the retention in a water body changes due to changes in its nutrient storage, i.e. the water body withholds or releases nutrients.

- The most effective filtering of nutrients occurs in areas with low land load normalized to the area that receives them, e.g. the southern part of the Swedish East Coast

Thank you for your attention! Questions?

Nutrient retention in the Swedish coastal zone

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Previous studies

Almroth-Rosell et al. (2016) :

- Showed that only around 30% of the land load to the Stockholm archipelago reached the Baltic Sea.
- Area specific retention efficiency was highest in the inner part of the Stockholm archipelago.
- The filter efficiency increased as the coastal area that receives the nutrient load increased.

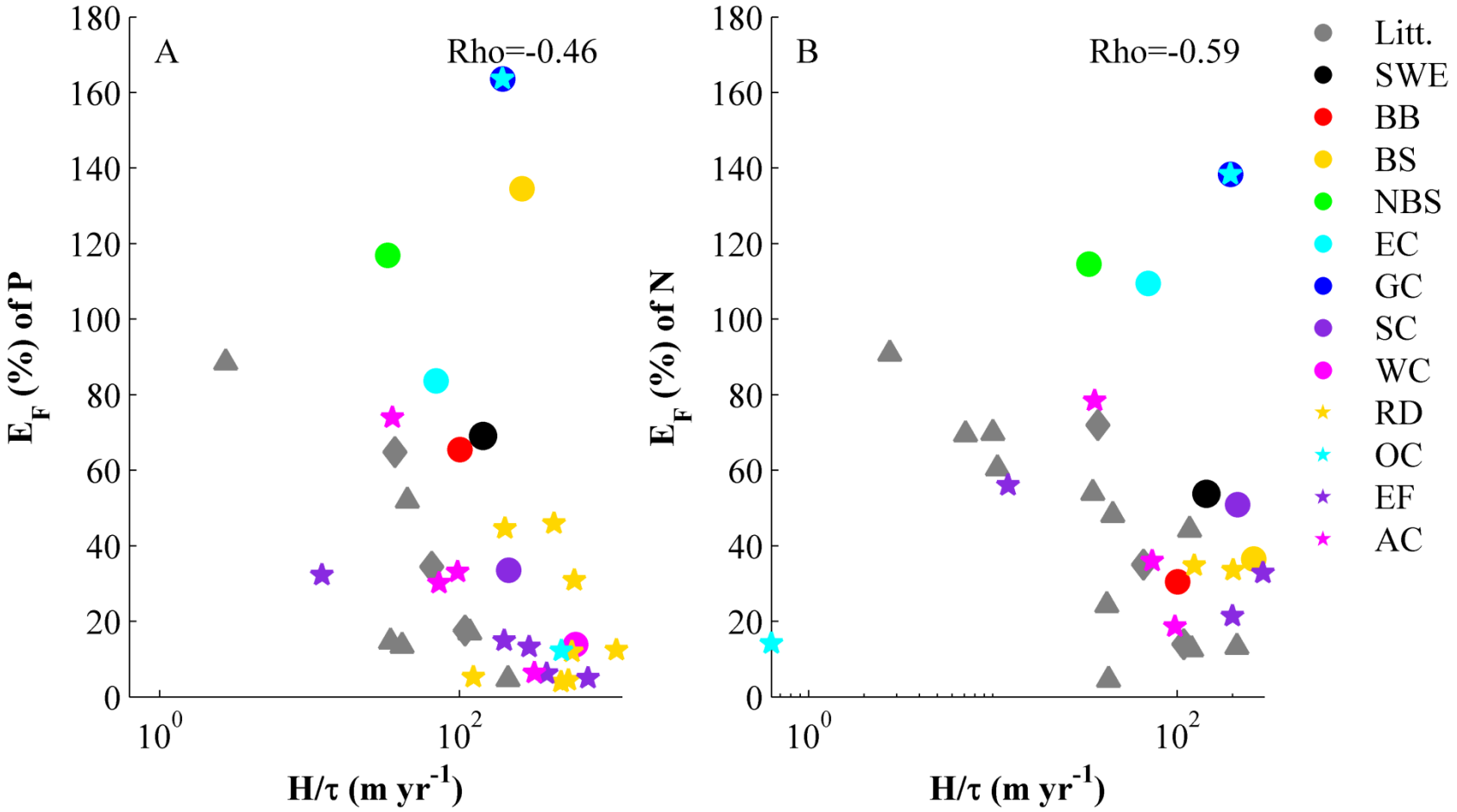
Asmala et al. (2017):

- The coastal filter of the entire Baltic Sea removes 16% of nitrogen and 53% of phosphorus inputs from land.
- Their estimates indicated that the coastal region around the Baltic Proper alone accounted for 50% of the total Baltic Sea denitrification in their study, even though it contributed only 25% of the total area.

Savchuk (2018) :

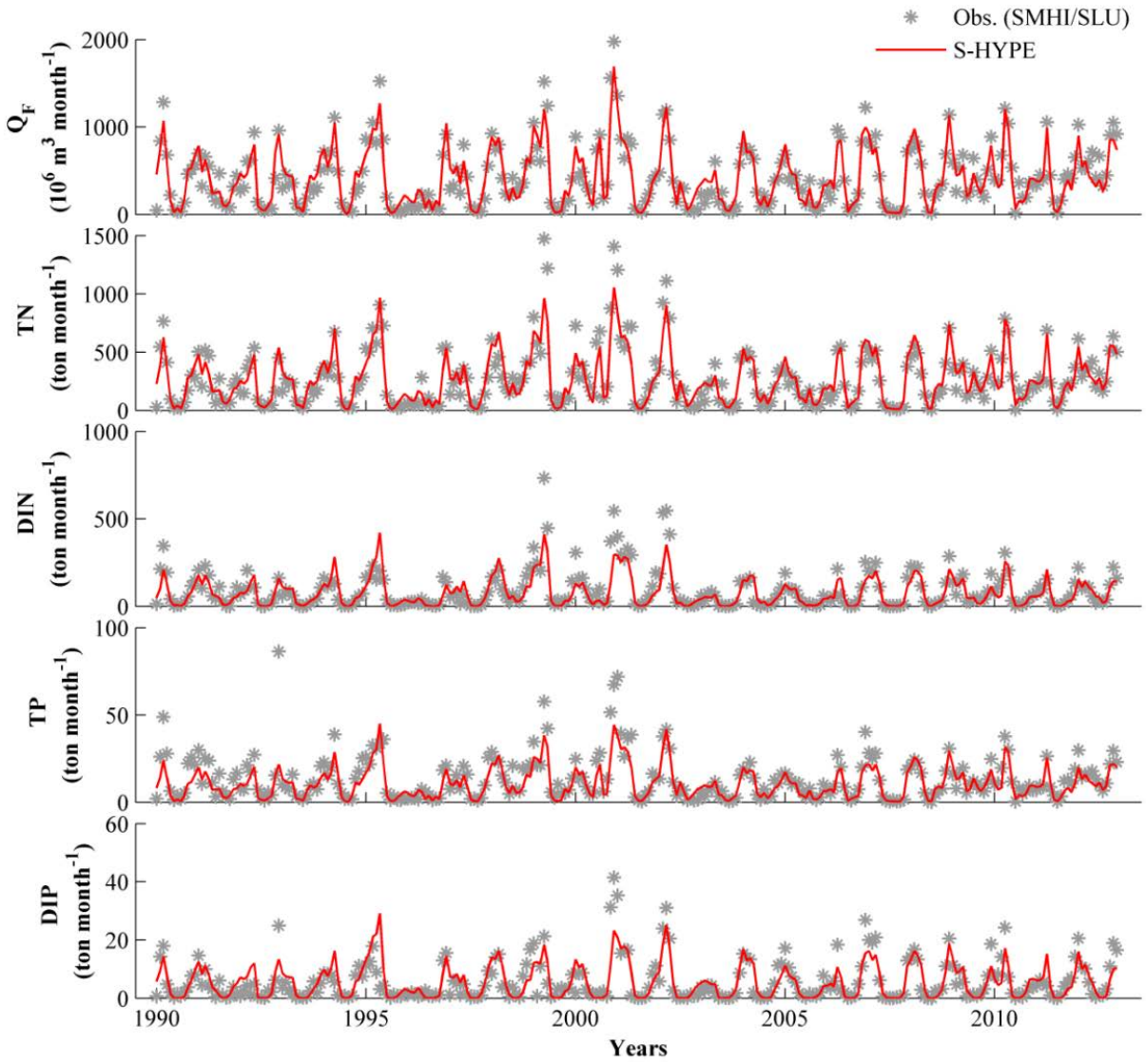
- The high filter efficiency for phosphorus in the coastal zone is questioned when set in context of the overall nutrient budget of the Baltic Sea.

Filter efficiency in literature



Almroth-Rosell et al. (2016), Billen et al. (2011), Hayn et al. (2014), Nixon et al. (1996)
Edman et al. (2018)

Evaluation, river forcing



Model system

The Swedish Coastal zone Model (SCM)

- multi-basin 1D-model
- based on the equation solver PROgram for Boundary layers in the Environment (PROBE)
- coupled to the Swedish Coastal and Ocean Biogeochemical model (SCOBI)
- Vertical resolution 0.5-10 m