Modeling the Baltic Sea biogeochemical and inorganic carbon systems

Moa Edman

Why bother with biogeochemical modelling?

The marine inorganic carbon system is dependent on:

- Lateral forcing (river water, atmosphere...)
- Internal biogeochemical system (primary production, mineralization, oxygen conditions...)

Changes in the lateral forcing will change both of the above!

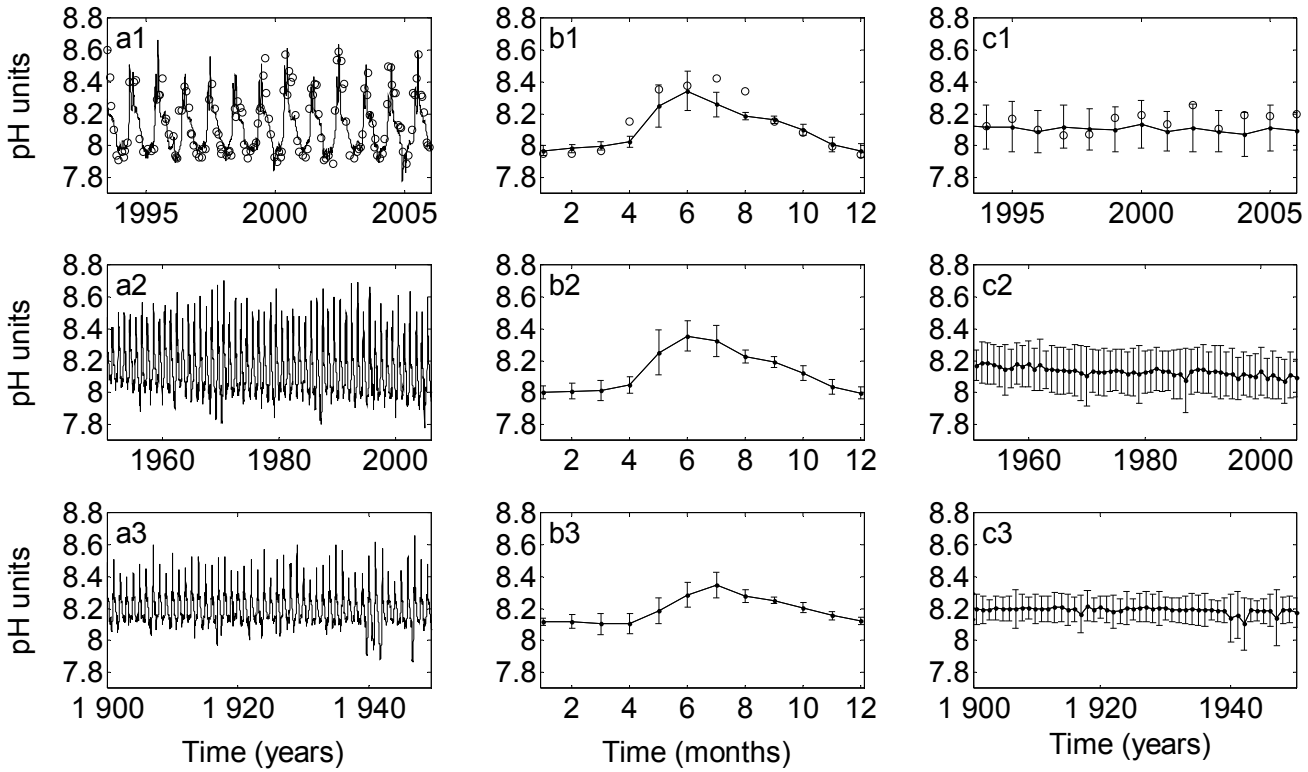
To model the effect on the acid-base balance from climate change realistically, the biogeochemical function in a model need to be able to change if the forcing does.

Previous sea surface pH results from the Baltic Proper

Validation →

Eutrophicated →

Pristine →



Our ambition:

Capability to predict:

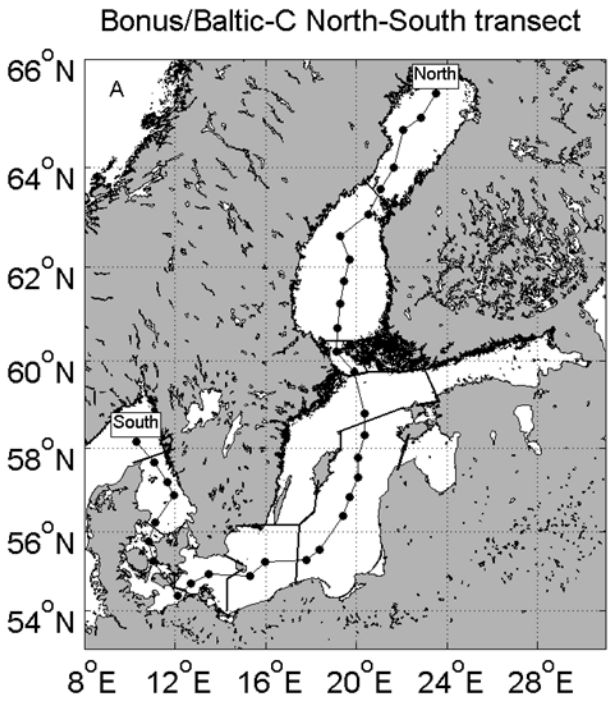
- Generalized biogeochemical formulation: The same constants, definitions and biogeochemical couplings will be applied in ALL Baltic Sea basins, during the ENTIRE simulated period. Here: 50 years in 13 basins

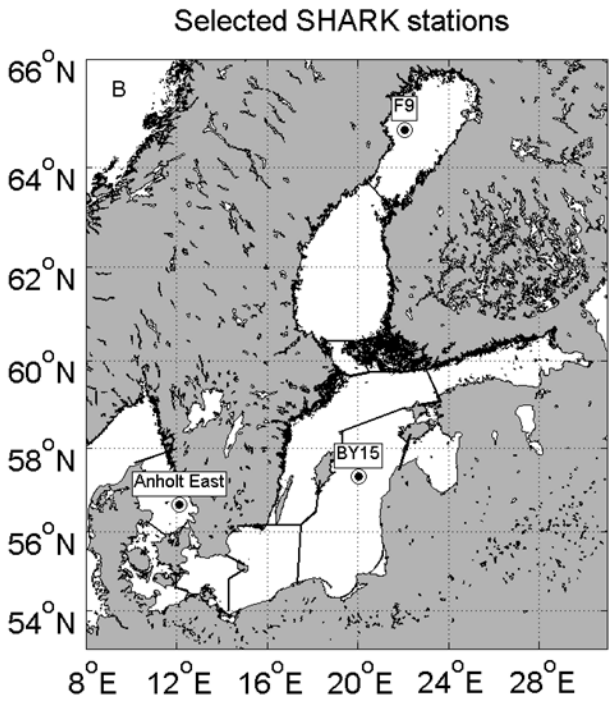
- Include deep water biogeochemical and carbon system dynamics

Validation:

- Validation in different climatic environments over the whole depth profile

Validation to cover different chemical and climate regions

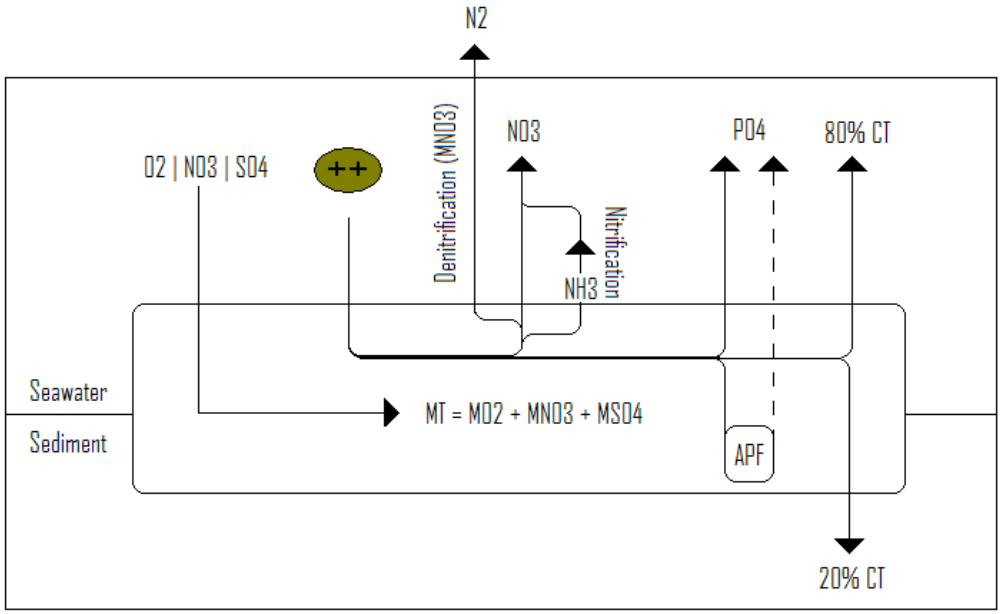




If the generalized formulation recreate the biogeochemical state of different regions it has the capability to predict!

Main biochemical assumptions

- Mineralization at the active sea-sediment boundary
- Mineralization rate set as 3.5 % of organic matter abundance
- 20% of organic carbon is never fully mineralized

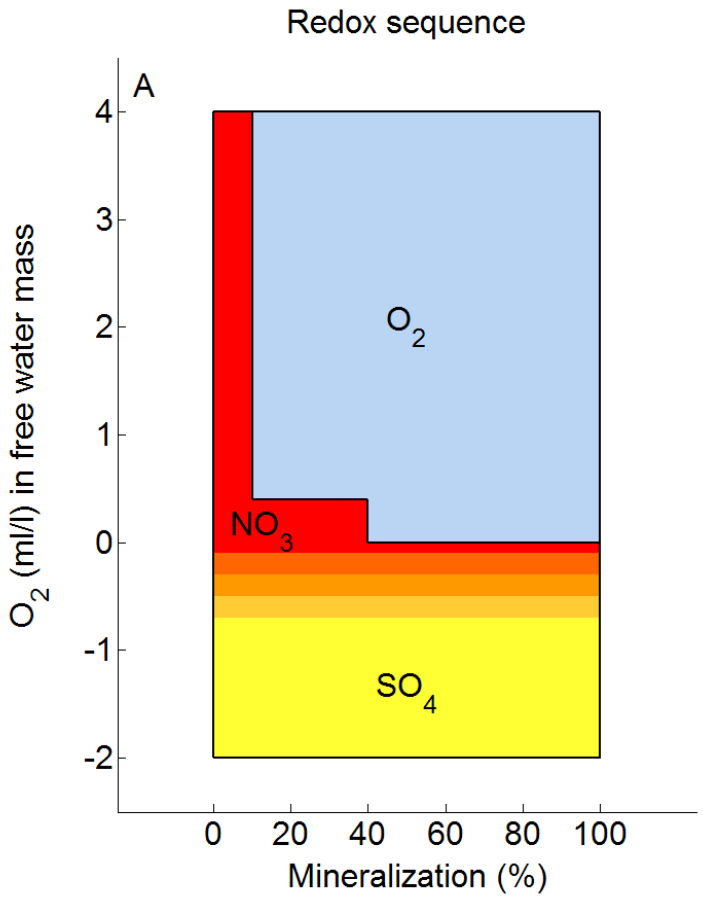


Mineralization

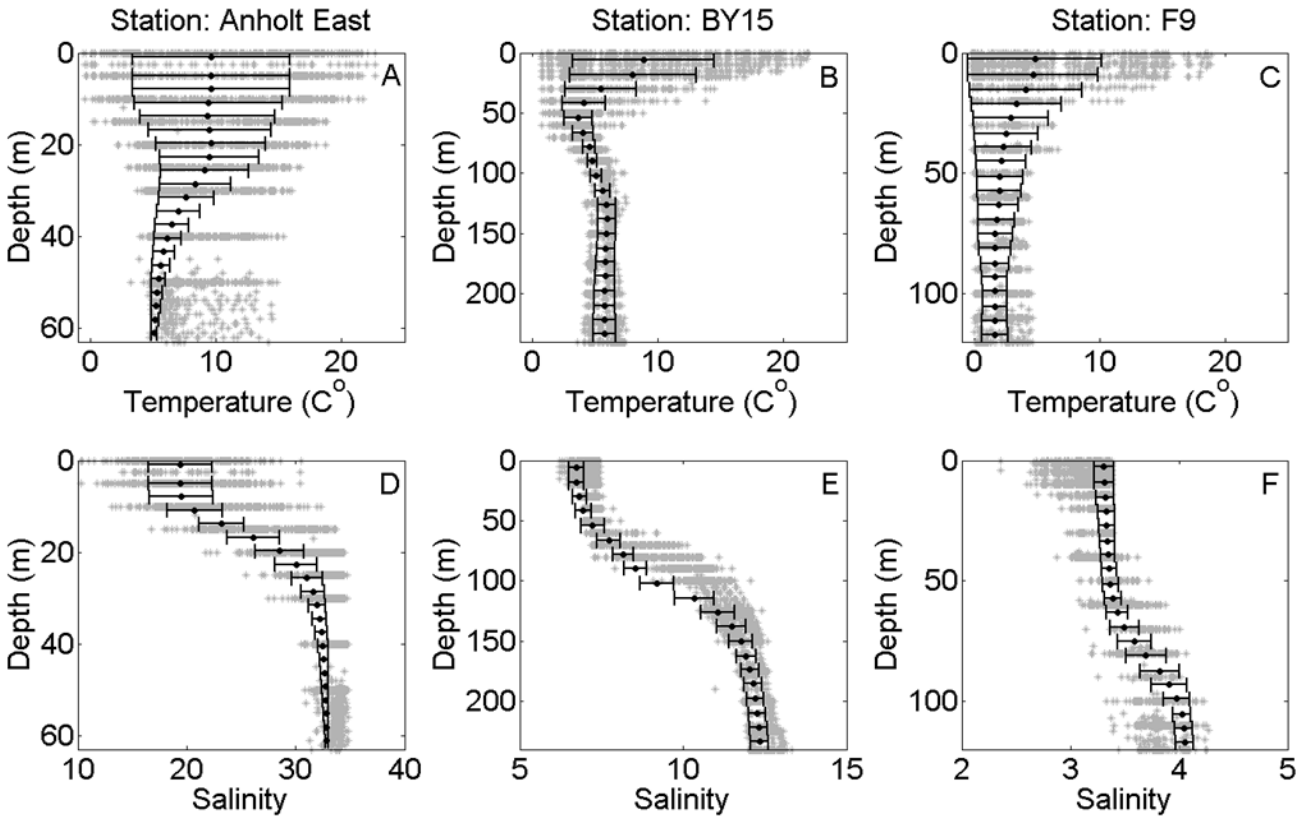
Mineralization defined as:

$M_T = M_{O2} + M_{NO3} + M_{SO4}$

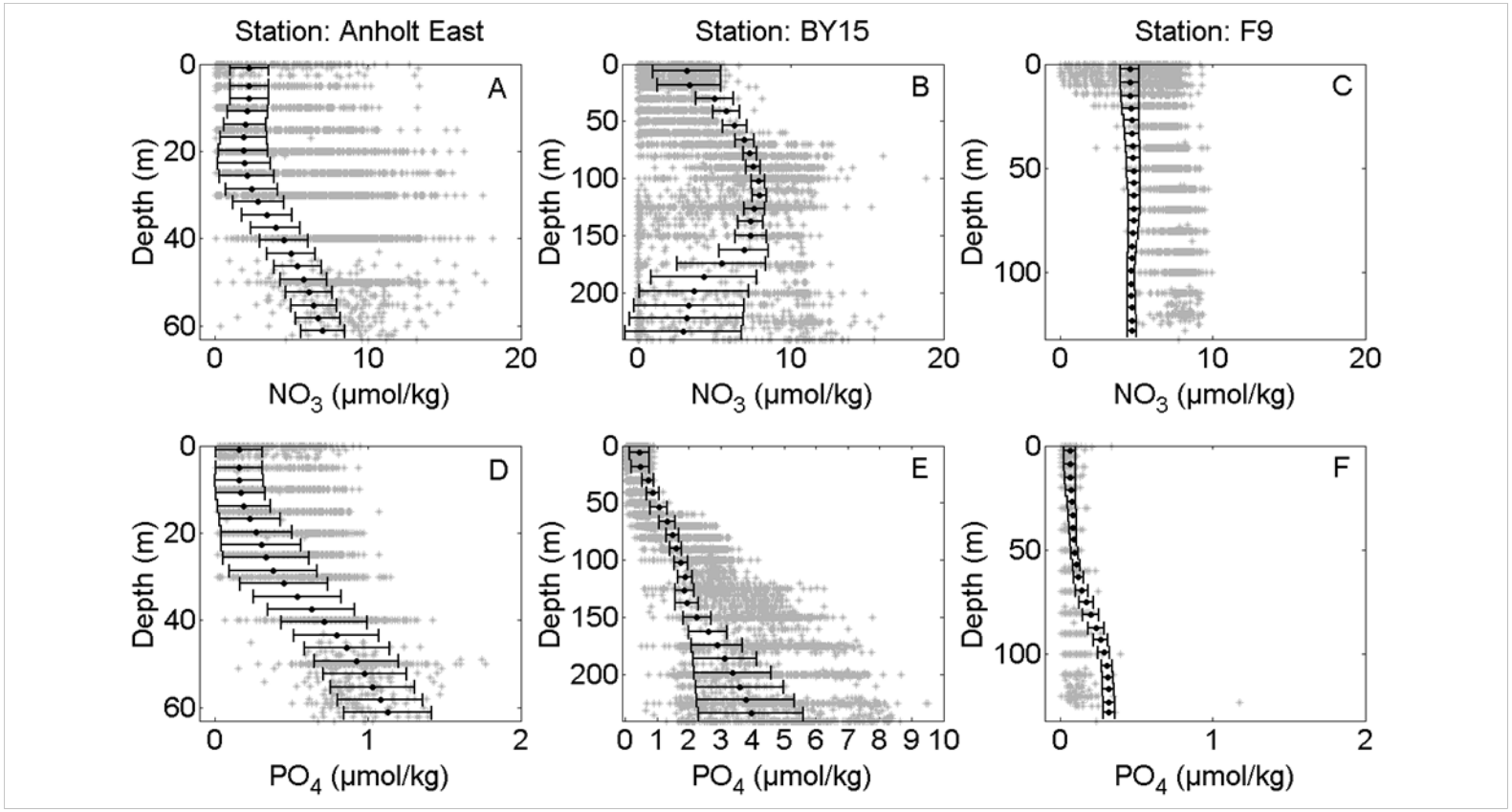
Oxidation agents according to fixed redox sequence.



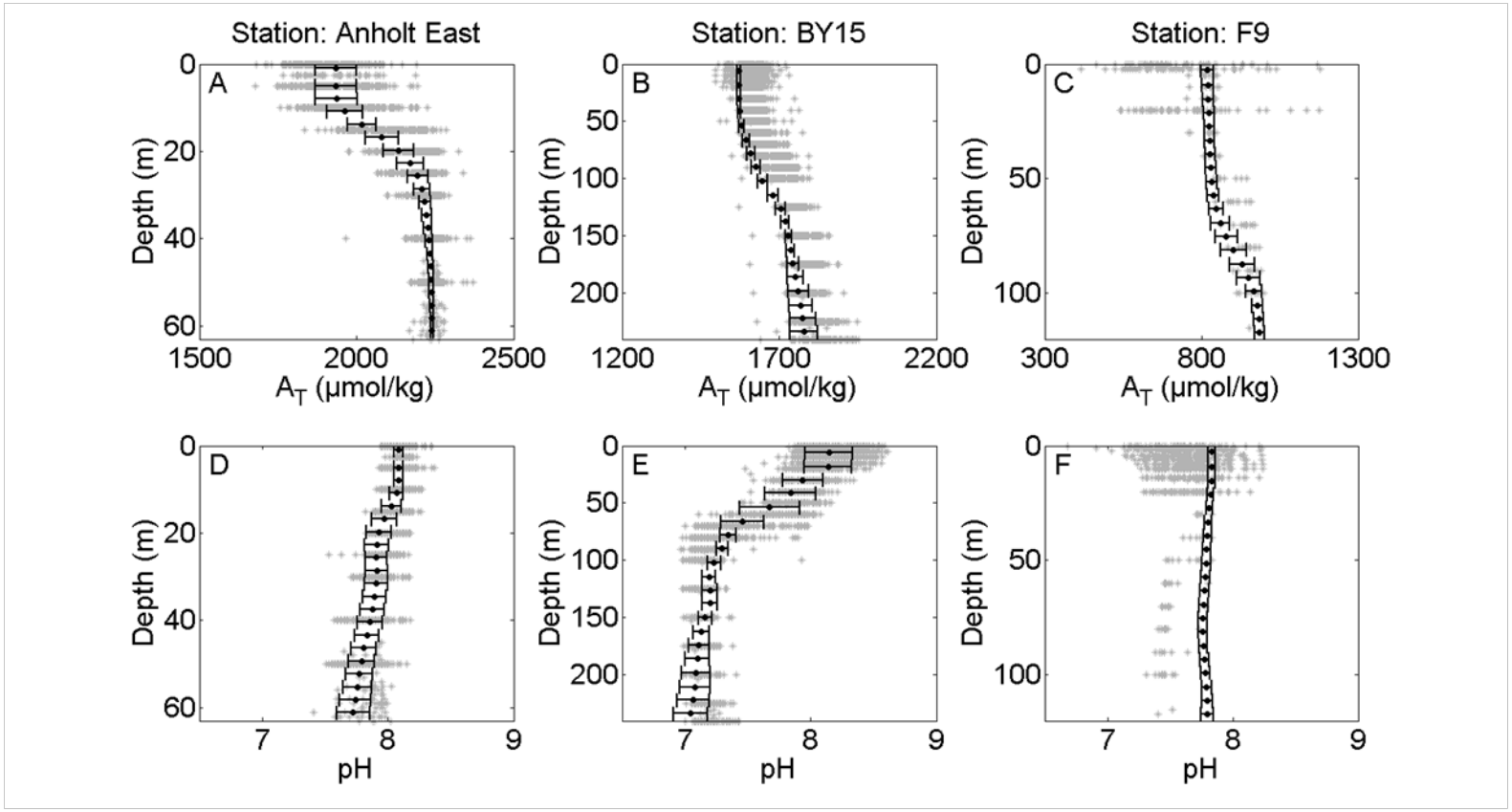
Mean depth profiles for S and T (C°)



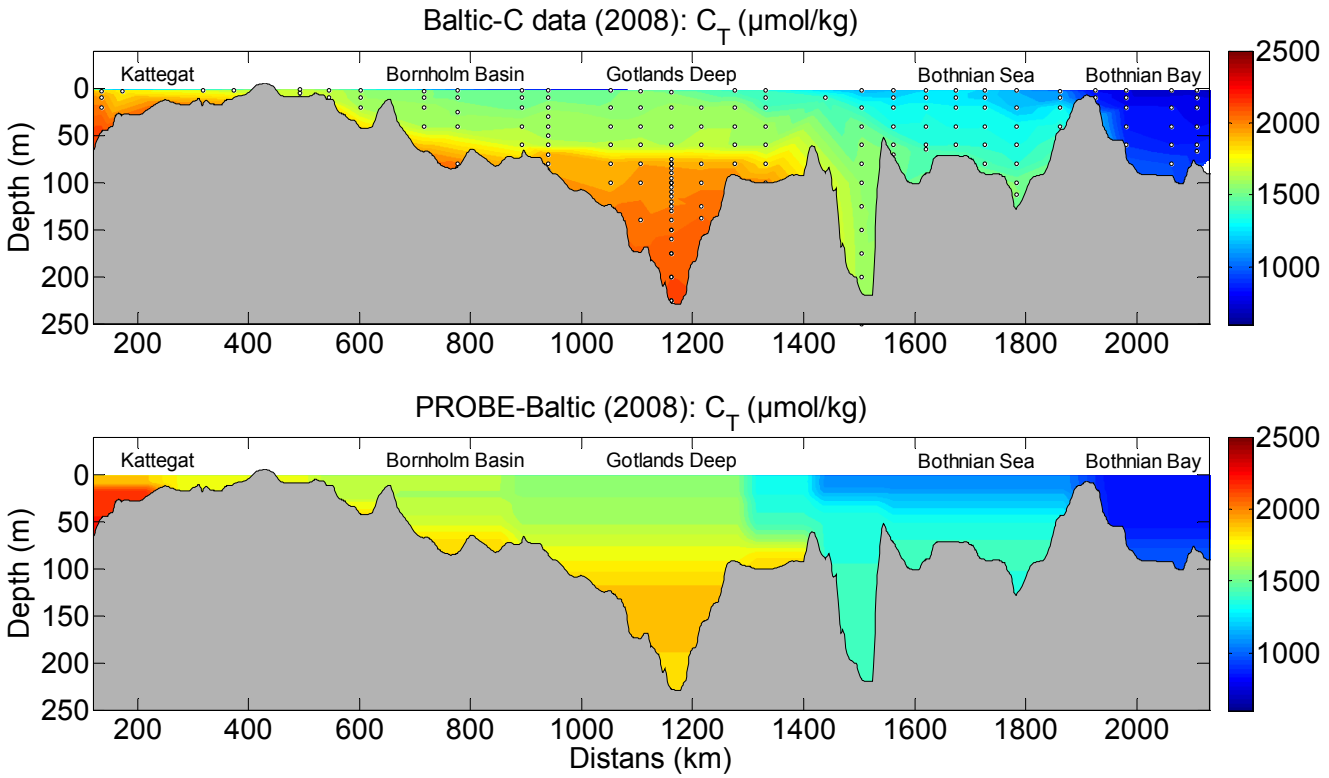
Mean depth profiles for PO_4 and NO_3



Mean depth profiles for A_T and pH

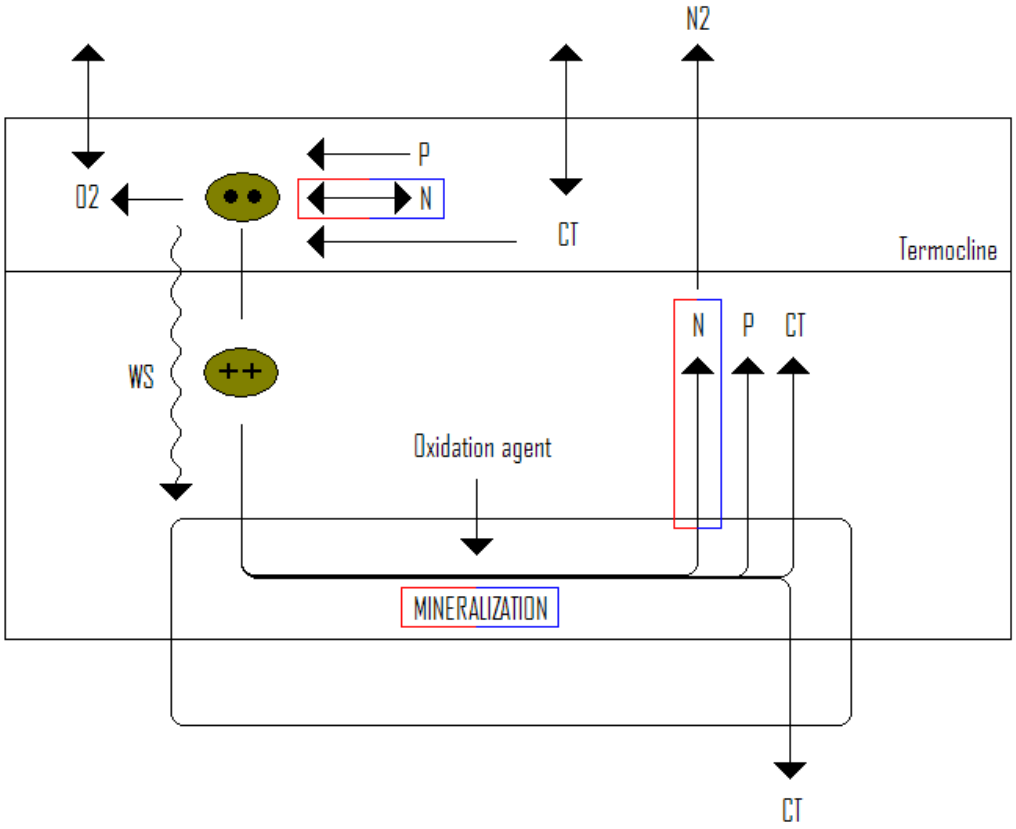


C_T transects thru the Baltic Sea system



Horizontal differences in the Baltic Sea system are captured by the model

Internal generation/depletion of total alkalinity



Main A_T generation/depletion assumptions:

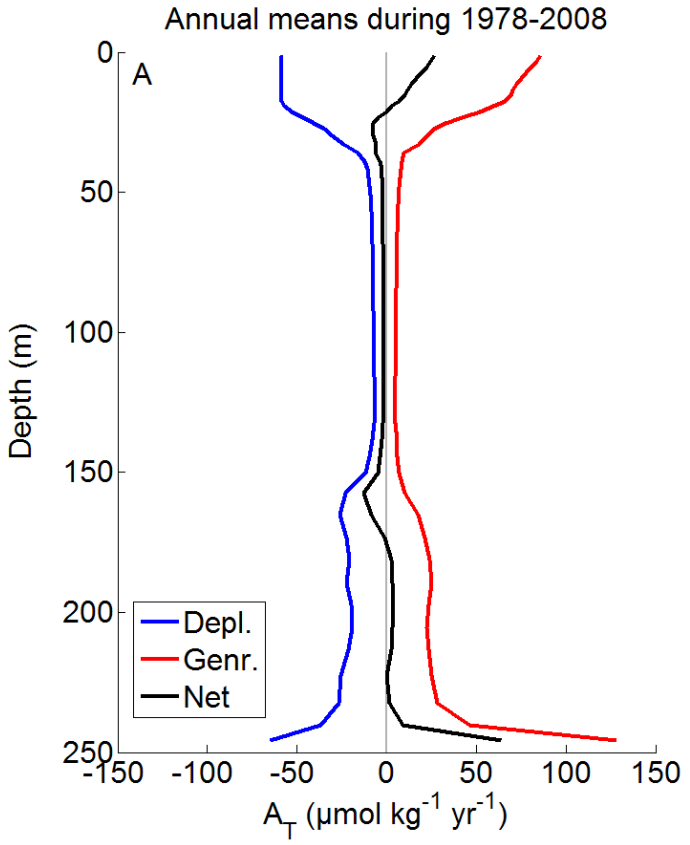
- Sulphate reduction reversible reaction: No net A_T change
- Denitrification irreversible effect: Net A_T generation
- Other N-dynamics change A_T in the water column, but its an almost closed cycle of A_T generation and depletion. The sedimentation of organic matter will however shift reactions vertically. This include the process:
  - Primary production
  - Mineralization with O_2 as oxidation agent
  - Nitrification
  - Plankton respiration

Vertical distribution of A_T generation/depletion

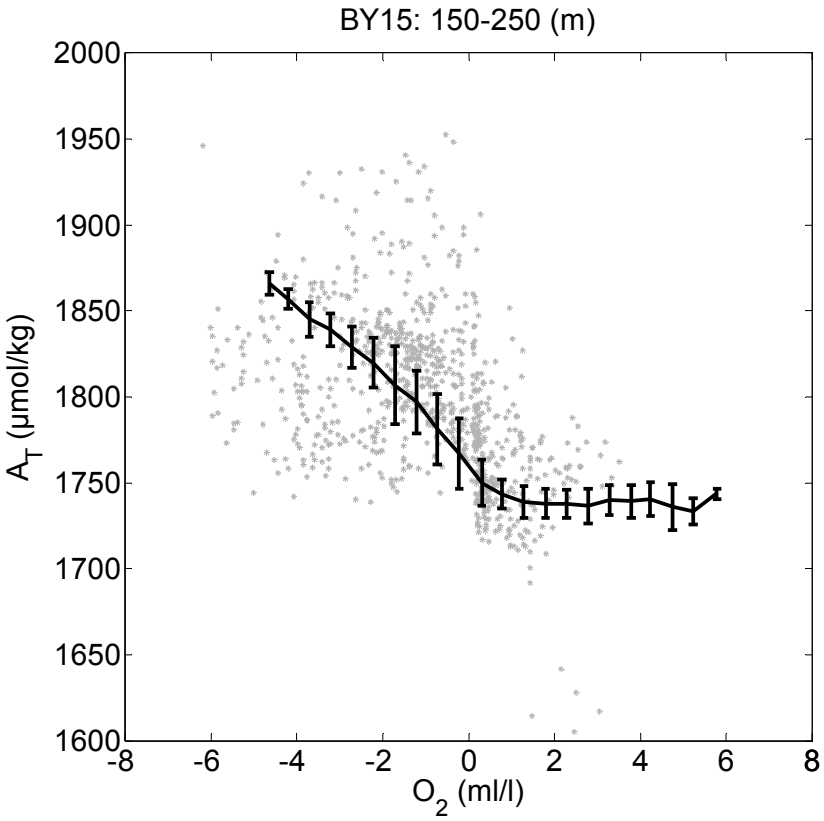
Net generation:
90.4 Gmol/yr

Net depletion:
85.2 Gmol/yr

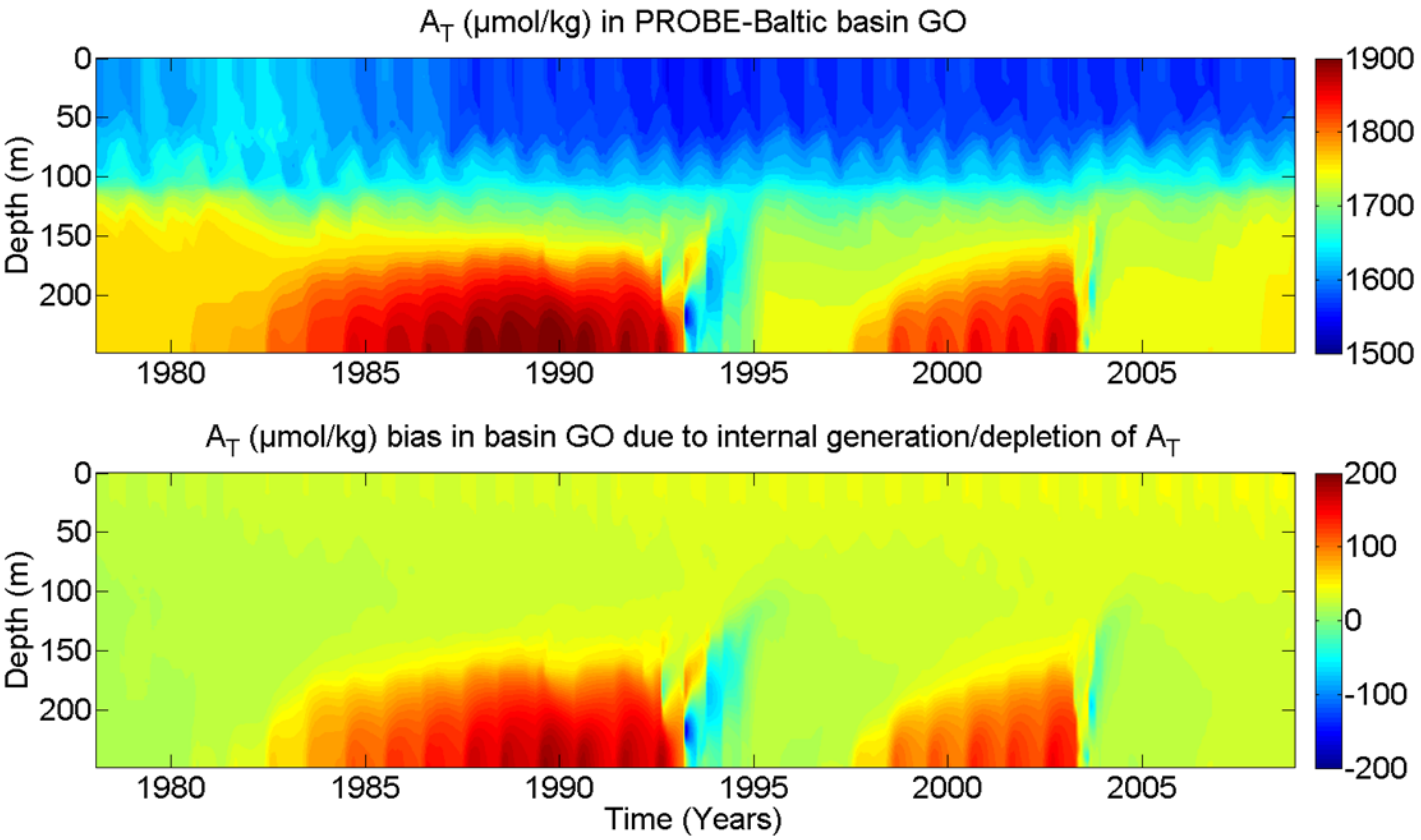
→ Net source of A_T



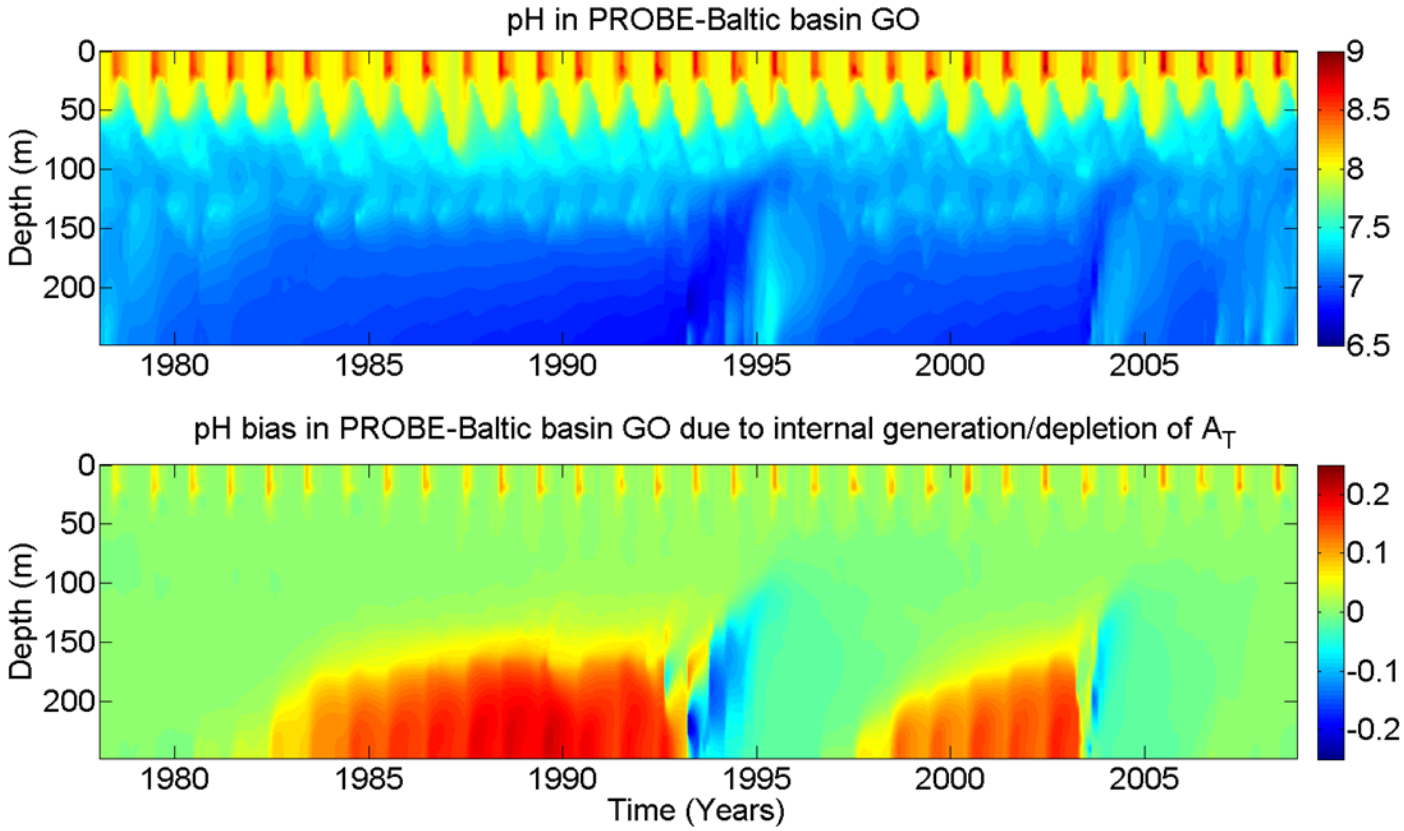
Modelled A_T as a function of O_2



Modelled A_T and the A_T bias due to internal A_T dynamics



Modelled pH and the pH bias due to internal A_T dynamics



Issues:

- The insufficient knowledge of several biogeochemical processes (especially nutrients and complex forming metals) in the Gulf of Bothnia limit the ability to model these regions realistically.

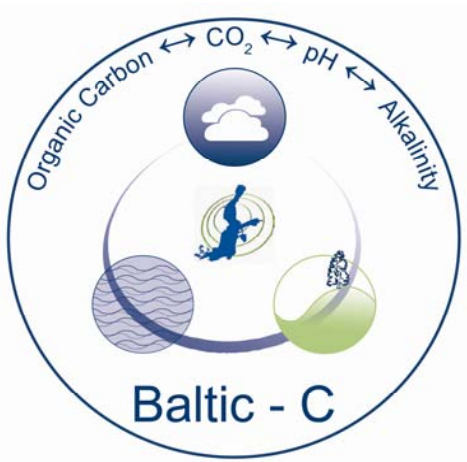
- More extensive, and more reliable, carbon system lateral forcing data in the freshwater sources, preferably with seasonal resolution.

Main conclusions:

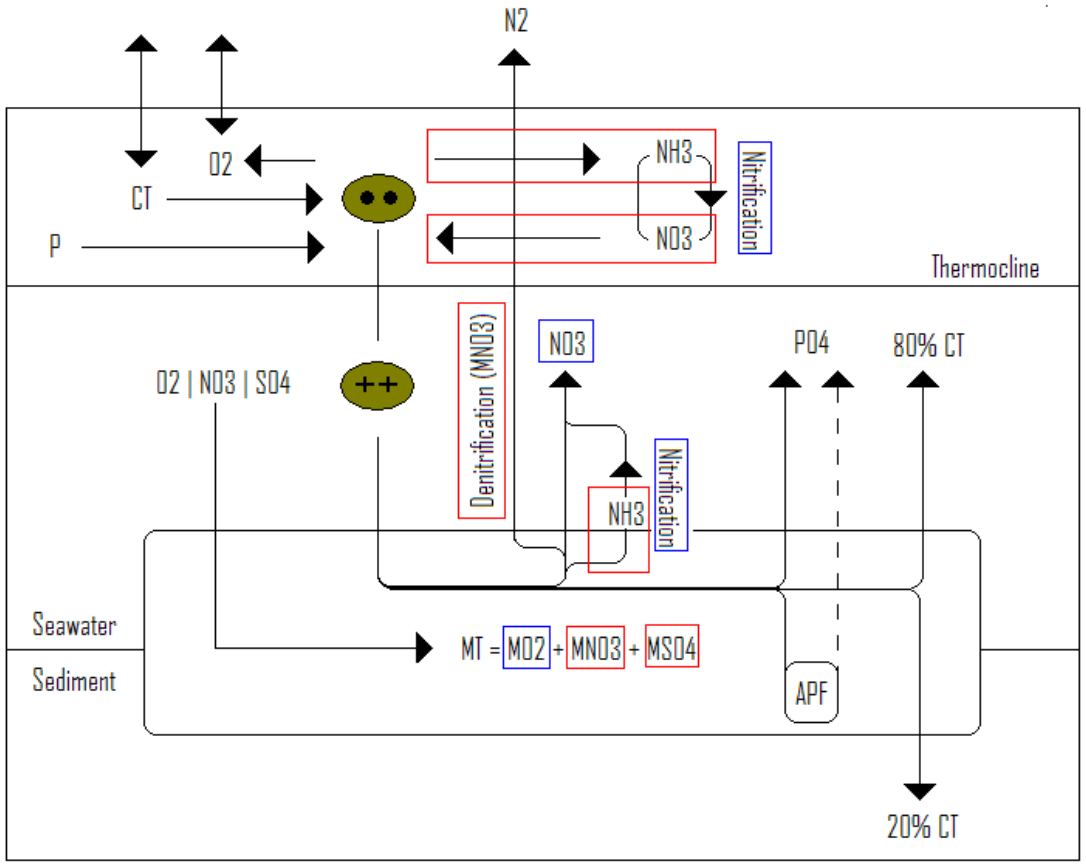
- One generalized formulation can return several realistic biochemical situations, only through differences in forcing.
- Denitrification is the only A_T generating process that is not chemically reversible, or reversible as a part of the constant cycling of organic matter, in the Baltic Sea system.
- The internal generation/depletion of total alkalinity is a net source of total alkalinity in the Gotland basin.

Thank you for you attention!

Any questions or other input are most welcomed!



Generation/Depletion:

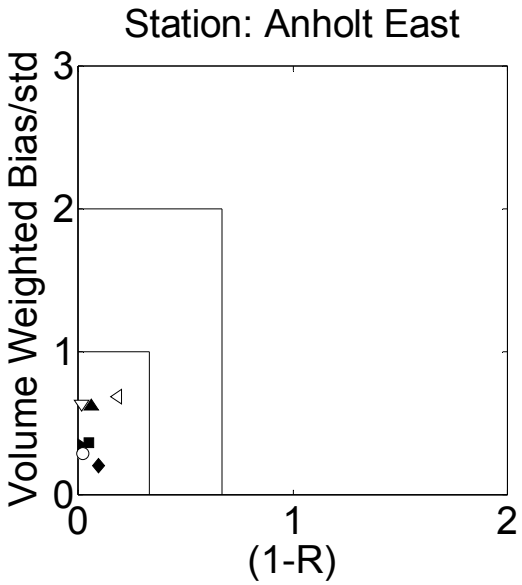


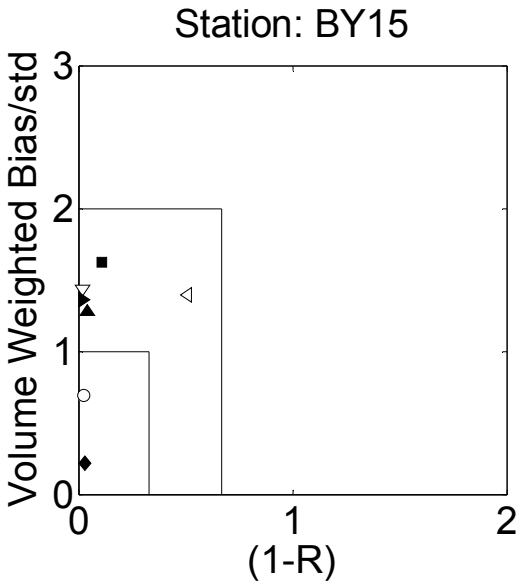
Dimensionless quality metrics

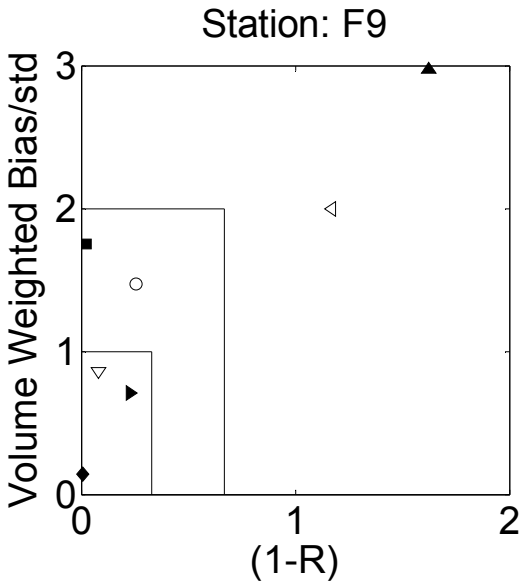
Black diamond - T
White down arrow - S
Black up arrow – O_2

Black square – PO_4
White left arrow – NO_3

Black right arrow – A_T
White circle – pH







→ Good agreement
→ Strong correlation

→ Reasonable agreement
→ Strong correlation

→ Not good enough

The Carbon System:

- Internal generation/depletion of A_T

Lateral forcing:			Internal dynamics:	
Rivers	→	A_T	←	Primary Production
Ocean	→		←	Respiration
			→	Nitrification
			↔	Mineralization
				→ M_{O2}
				← M_{NO3}
				← M_{SO4}
Rivers	→	C_T		
Ocean	→		→	Primary Production
Atmosphere	→		←	Mineralization

The introduction of internal sinks and sources of total alkalinity change the acid-base balance

The updated use of quality metrics

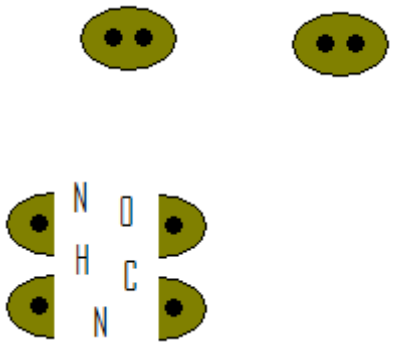
- AE – Average error (bias)
- RMSE – Root mean squared error
- Dimensionless:

  The correlation coefficient: R
  → Do the model results and observations co vary?

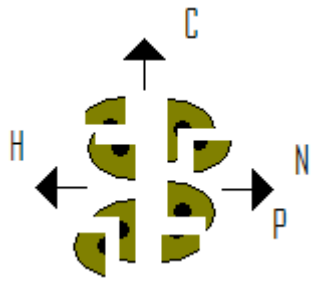
  The bias (M - D) to std (D) ratio: Bias/std
  → Are the model results within the std of observed data?

Main biochemical assumptions

- Two phytoplankton types:
  - Spring blooming plankton (Limited by N and P)
  - Cyano bacteria (Limited by P only)



- Composition of organic matter according to:
  $(CH_2O)_{53}(CH_2)_{28}(NHCH_2CO)_{12}(CHPO_4T)$
  → composition ratio: -138:106:12:1



- Mineralization rate set as 3.5 % of each plankton type