

CLIMATE CHANGE IN THE BALTIC AND IMPACT IN THE WATER CYCLE



Northern Europe on 1 April 2004, as seen from the SeaWiFS satellite (NASA/Goddard Space Flight Centre, <http://visibleearth.nasa.gov/>).

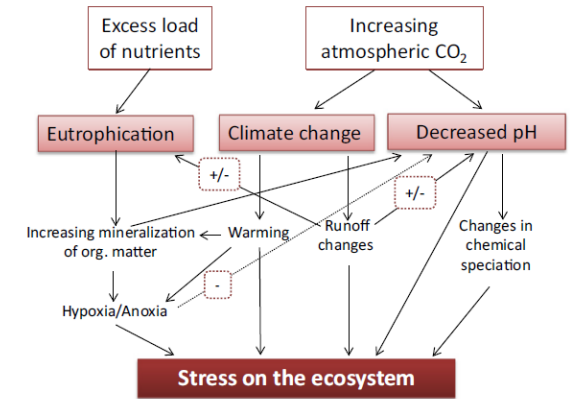
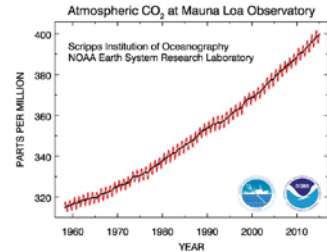


Fig. 9. Flowchart of the impact and interconnectivity of the effects from increased nutrient loads and atmospheric CO₂.

Jutterström et al 2014

Challenges:

We are living in a time of accelerating information flows and with many actors working in competition on national and international levels. Fragmentation and overselling can make all of us resistant against important changes on Earth. Integrated and trustful information platforms are therefore strongly needed.

Challenges seen from Baltic Sea perspective

Baltic Sea models can when forced by "observed" forcing realistically reproduce the water, heat, salt, nutrient and carbon cycles. However the modelling is strongly limited by delays in forcing particularly river run off and river loads.

BALTIC SEA ACID-BASE (pH) AND OXYGEN BALANCES

9

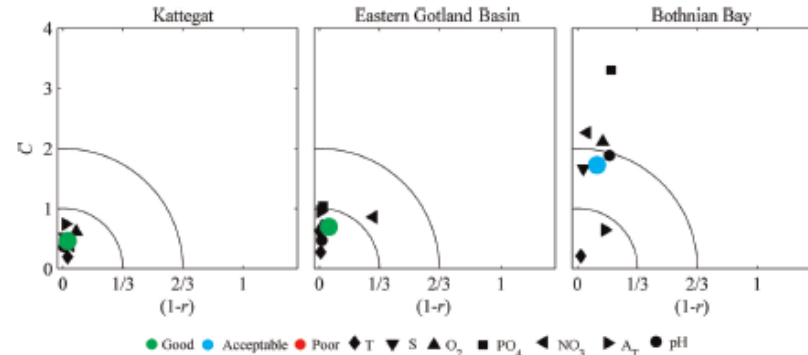


Fig. 4. Statistical evaluation of the reference case (1995–2009) where gridded reanalysed weather data are used as forcing. The Kattegat, Eastern Gotland Basin and Bothnian Bay are represented by observations from Anholt East, BY15 and F9, respectively. The evaluated parameters are temperature (T), salinity (S), oxygen (O₂), phosphate (PO₄), nitrate (NO₃), total alkalinity (A_T) and pH, as indicated in the figure legends. The coloured circles indicate a mean based on all parameters. Calculated parameters inside the inner and outer circles are classified as good and acceptable, respectively; parameters outside the outer circle are classified as poor.

Challenges seen from Baltic Sea perspective

10

A. OMSTEDT ET AL.

Baltic Sea scenario calculations are strongly limited by the biases in the forcing from the climate atmospheric models that often are too wet. Presently the only way to use the forcing is introducing bias corrections which is problematic as it violence all conservation principles and changes in time. Predictions of future climate changes in the Baltic Sea are therefore highly uncertain.

Better understandig of the water and heat cycles are of major importance

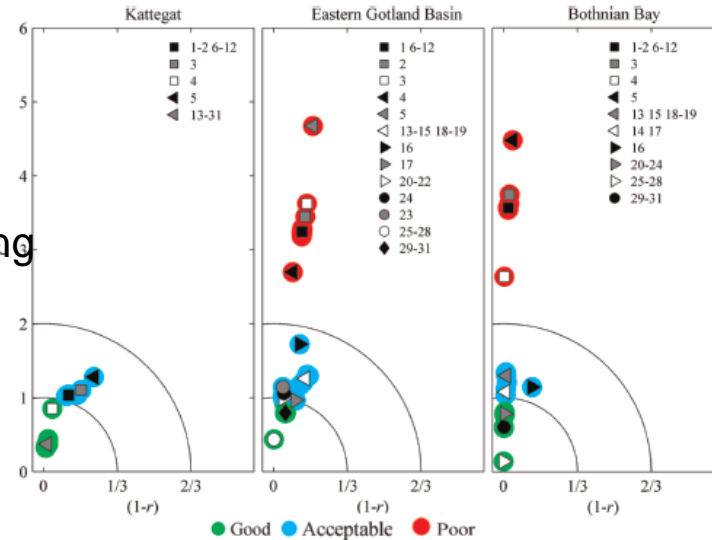
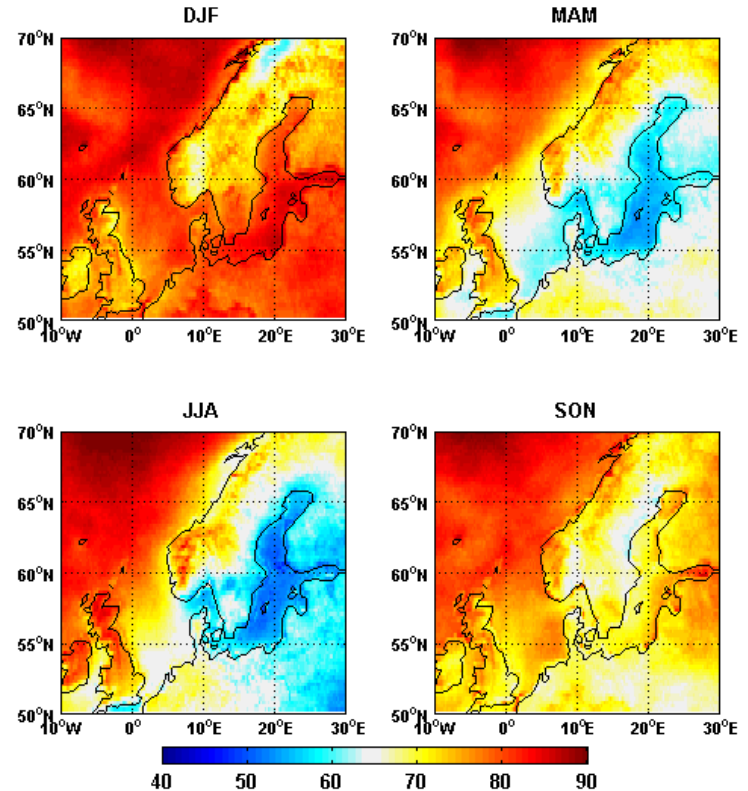


Fig. 5. Statistical evaluation of the climate control case (1971–2000) where different climate model runs are used as forcing data and compared with the reference case. The figure illustrates the statistical mean based on seven different parameters (see Fig. 4). The various climate runs are indicated by their run numbers in the figure (see Table 1). Calculated parameters inside the inner and outer circles are classified as good and acceptable, respectively; parameters outside the outer circle are classified as poor.

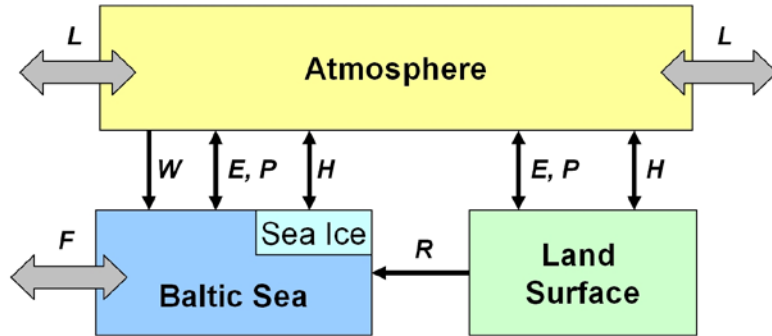
Baltic Sea and climate change

- Presently an atmospheric CO₂ increase and a climate warming is going on in the Baltic Sea region, and will continue throughout the 21st century (BACC I; II).
- Later, changes in the water cycle are expected to become obvious (BACC I; II).
- Changes in heat and water balances will have a variety of effects on terrestrial and marine ecosystems – some predictable and some hardly predictable (BACC I; II).



Seasonal variations in cloudiness (in %) over Northern Europe based on CLARA-A2 satellite data (covering the period 1982 – 2015 (Karlsson, et al., 2016, courtesy of Karl-Göran Karlsson and Abhay Devasthale, SMHI, Sweden).

Water, heat and carbon cycles key climate change components



$$\left(\frac{P - E}{A_{land}} \right)_{land} \approx Q_{riv}$$

Lateral atmospheric exchange $L_{in} - L_{out}$ drives the system and can be calculated using satellite information

Baltic Sea water and salinity balances

$$\frac{dV_{baltic}}{dt} = A_{baltic} \frac{dz}{dt} = Q_{riv} + \left(\frac{P - E}{A_{baltic}} \right)_{sea} + Q_b (z_{kattogat} - z_{baltic}) + \dots$$

$$\frac{dV_{baltic} S}{dt} = S_{in} Q_{in} - S Q_{out} - S ((P - E) A_{baltic} + Q_{riv}) + \dots$$

So if we could measure P, E, z, S_{in} we could calculate all aspects of these balances
 Similar considerations holds for the heat and CO₂ balances

Observing the Water Cycle ?

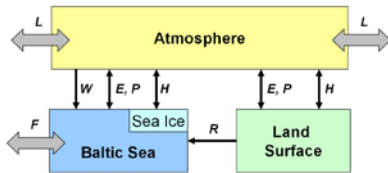
(<https://earthobservatory.nasa.gov/Features/Water/page4.php>)

Orbiting satellites are now collecting data relevant to all aspects of the hydrologic cycle, including evaporation, transpiration, condensation, precipitation, and runoff. NASA even has one satellite, Aqua, named specifically for the information it is collecting about the many components of the water cycle.

Major challenge today is to integrate, to make visible and to communicate reliable Earth observations on climate change. Here satellite products may take the lead to integrate the large amounts of available observations.

Discussion 1:

ESA and Baltic Earth should develop satellite and model products relevant to all aspects of the water, heat, and CO₂ cycles and integrate these into the BALTEX Box concept both in real time and as long-term averages.



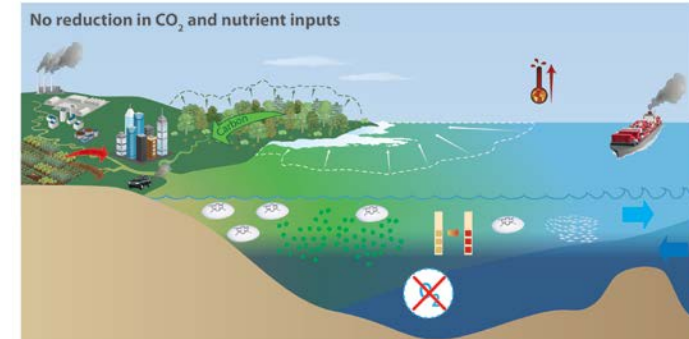
Research plan for coming years?

Discussion 2:

ESA and Baltic Earth should develop a joint internet information platform that together with expert statements review and comments the outcome from a program such as indicated under discussion 1.






Research plan for coming years?

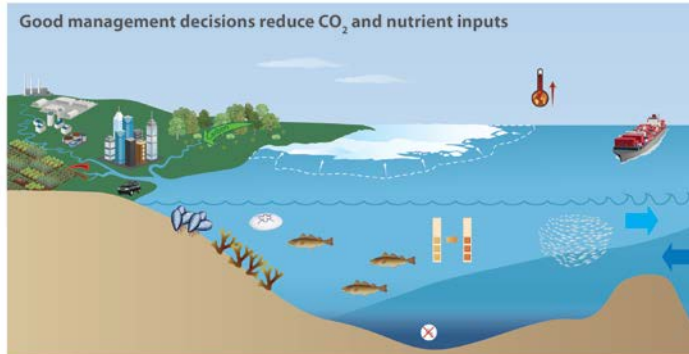
Thanks for your interest!



With no reduction in CO₂ emissions and nutrient inputs, water temperatures will increase, sea ice will decrease, and cyanobacteria blooms worsen.

Increased CO₂ emissions lead to increased marine acidification. More nutrient inputs leads to increased algal blooms, while warmer waters decreases the uptake of O₂ in the water. Increased acidification and increased anoxic waters will threaten the marine ecosystem.






-  Increased air and water temperatures
-  Decreased sea ice
-  Acidification worsens
-  Reduced water quality
-  Increased cyanobacteria blooms
-  Increased forest growth & carbon transport
-  Poor coastal biodiversity & health
-  Increased anoxia



Good management decisions such as:

- switching to alternative renewable energy for industry, vehicles, and shipping;
- improved land management and farming practices;
- improved lifestyle choices including food consumption, travelling, and living.

While marine acidification and climate change will continue, it will be slowed down.

-  Slight increase in air and water temperature
-  Slight decrease in sea ice
-  Slight increase in marine acidification
-  Improved water quality
-  Good coastal biodiversity & health
-  Decreased anoxia

