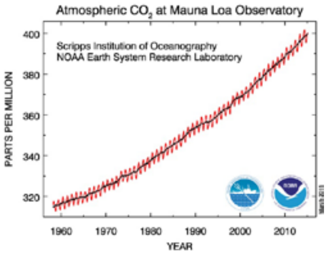
*Presented at: Baltic from space workshop 29-31 March 2017 Helsinki Finland*

# 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/) .



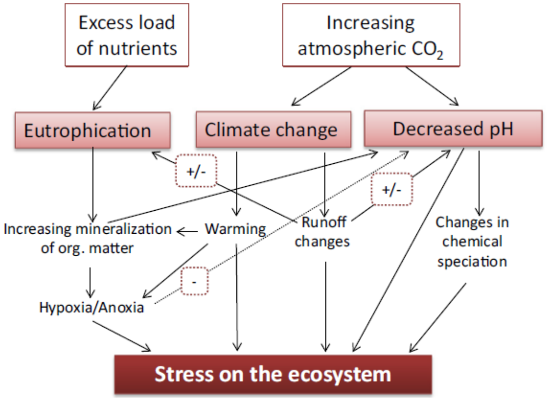




**Fig. 9.** Flowchart of the impact and interconnectivity of the effects from increased nutrient loads and atmospheric $CO_2$.

Jutterström et al 2014

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# Challanges:

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

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# Challanges 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

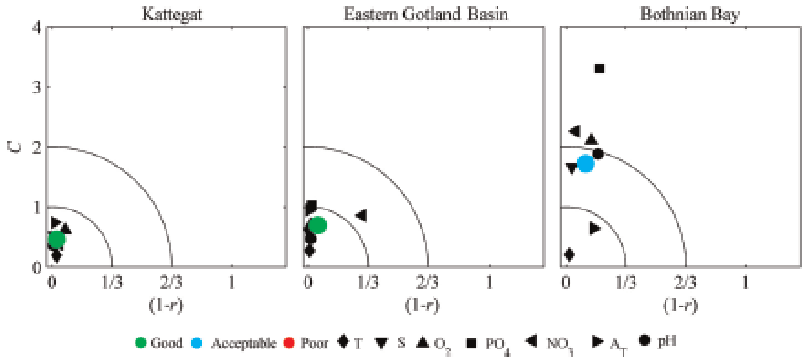


*Fig. 4.* Statistical evaluation of the reference case (1995–2009) where gridded reanalysed weather data are used as forcing. The Kattegat, Eastern Gotland Basin and Bothnian Bay are represented by observations from Anholt East, BY15 and F9, respectively. The evaluated parameters are temperature (T), salinity (S), oxygen ($O_2$), phosphate ($PO_4$), nitrate ($NO_3$), 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.

Omstedt et al 2012

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# Challanges seen from Baltic Sea perspective

Baltic Sea scenario calculations are strongly limited by the biases in the forcing from the climate atmsopheric 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



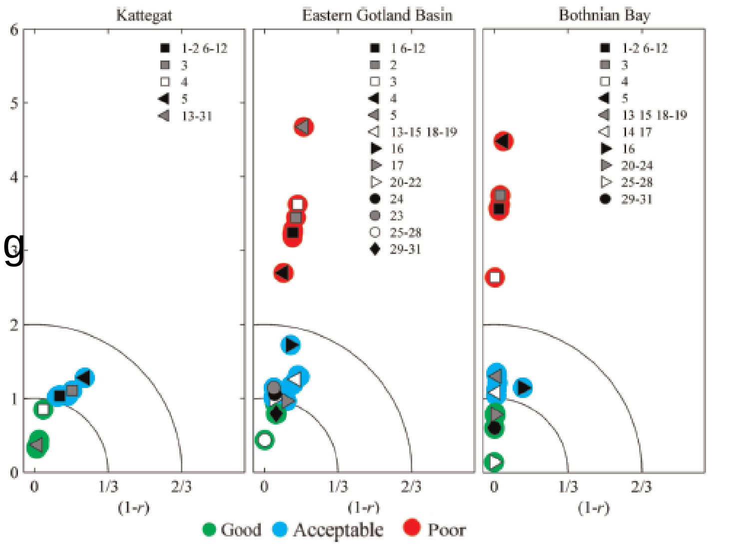


*Fig. 5.* Statistical evaluation of the climate control case (1971–2000) where different climate model runs are used as forcing data and compared with the reference case. The figure illustrates the statistical mean based on seven different parameters (see Fig. 4). The various climate runs are indicated 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.

Omstedt et al 2012

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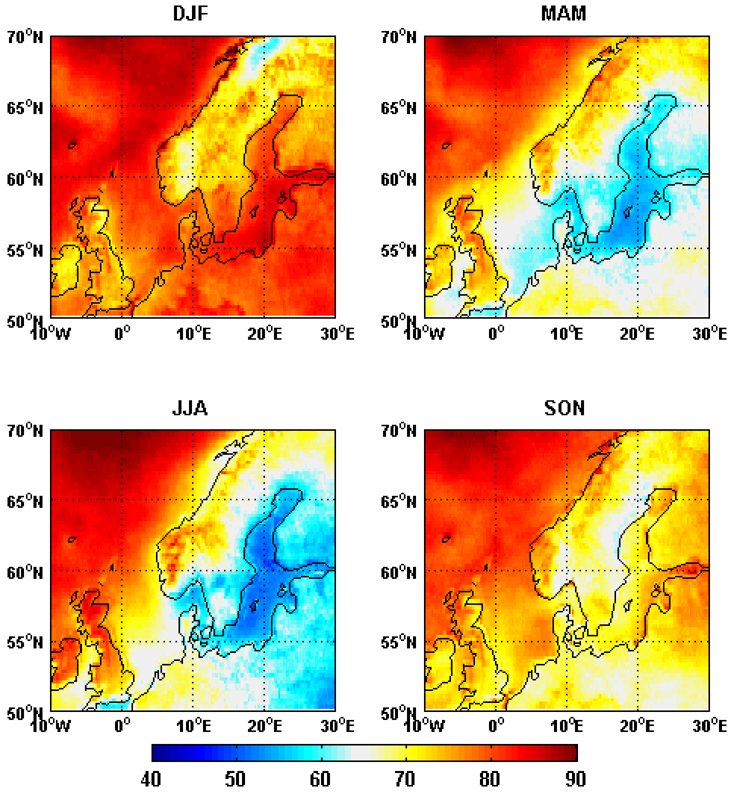
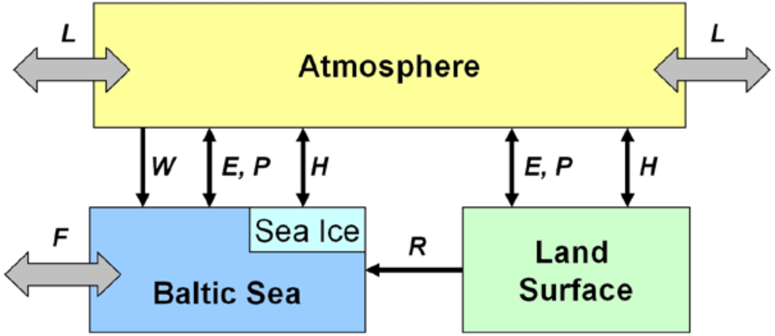
# Baltic Sea and climate change

- Presently an atmospheric $CO_2$ 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

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# Baltic Sea water and salinity balances

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

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

So if we could measure P, E, z, Sin we could calculate all aspects of these balances
Similar considerations holds for the heat and $CO_2$ balances

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## 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.

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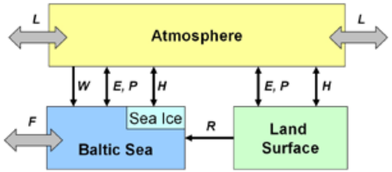
# Discussion 1:

ESA and Baltic Earth should develop satellite and model products relevant to all aspects of the water, heat, and $CO_2$ cycles and integrate these into the BALTEX Box concept both in real time and as long-term averages.




Research plan for coming years?

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# 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?

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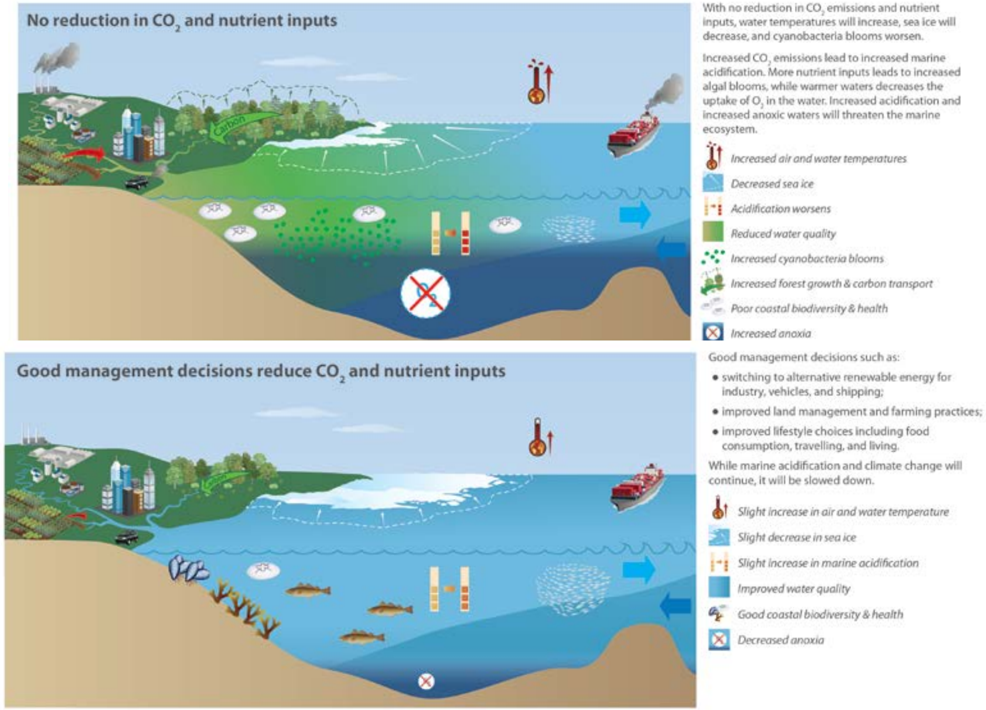
# Thanks for your interest!




BACC II, 2015