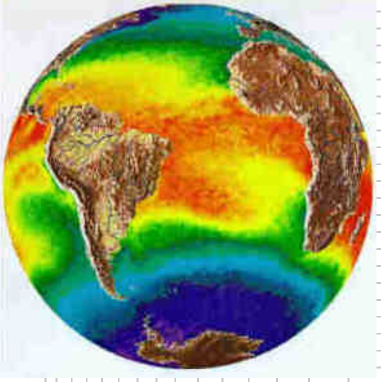
SMHI

Chantal Donnelly and Berit Arheimer

The impacts of climate change and nutrient reduction measures on river discharge and nutrient fluxes to the Baltic Sea



A brief summary…

1. ***Will discharge to the Baltic Sea change in a Future Climate? (Can we say this with any certainty?)***

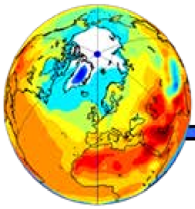
2. ***Will the inputs of nutrients (N and P) to the Baltic Sea change in a Future Climate?***

3. ***Will future climate affect planned remedial measures for nutrient inputs to the Baltic Sea (e.g. BSAP)?***

- Methods Used
- Results
- Major Uncertainties

Experimental Procedure

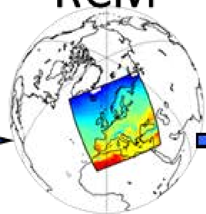
GCM



Global climate modelling:
ECHAM
1.875x1.87 degrees
- ECHAM5-r1-A1B
- ECHAM5-r3-A1B
- ECHAM5-r1-A2

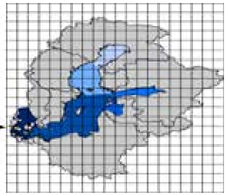
HADLEY
3.75x2.5 degrees
- HadCM3-A1B

RCM



Dynamic regional downscaling:
RCA model,
0.44x0.44 degrees
(RCAO model)

DBS

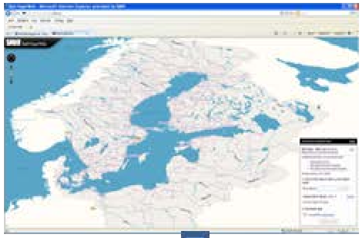


Bias correction and scaling:
Precipitation and Temperature in 5128 subbasins (mean 325 km^2)

BSAP

Remedial measures:
- Improved waste water treatment
- Best agricultural practices
- Combination of above

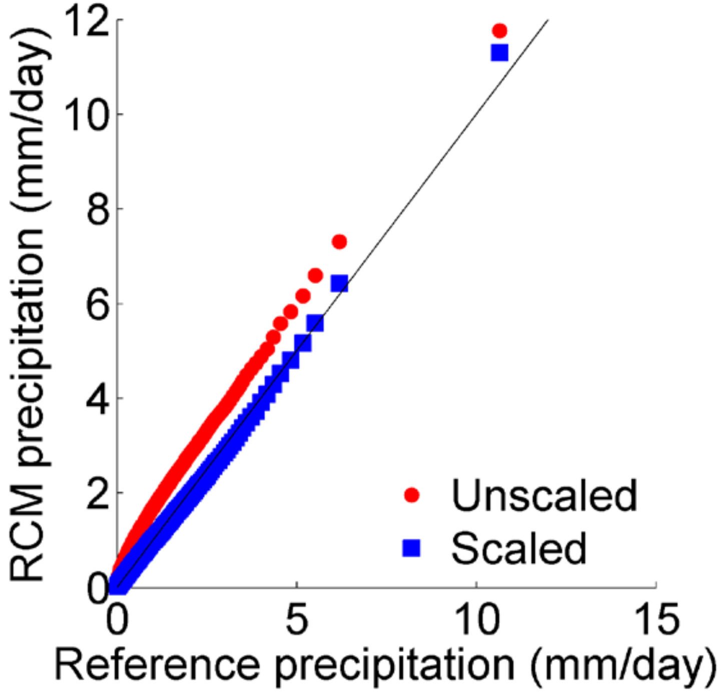
Balt-HYPE

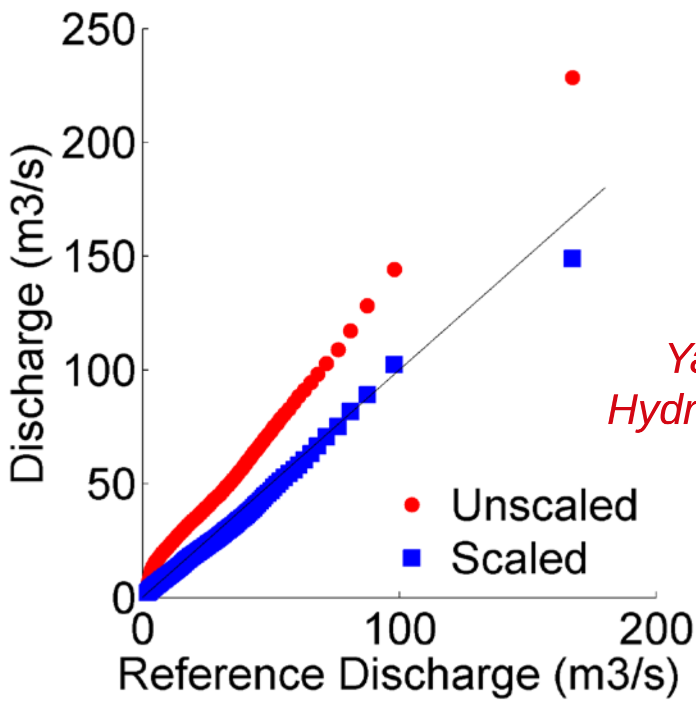


Model experiment:
4 climate projections
x 4 emissions (present+3 remedial measures)
x 2 time-slices (1971-2000, 2071-2100)
= *32 model runs*
x 3 variables (Q, N, P)
= *96 time-series*

Distribution Based Scaling (quantile method)

Each plotted point is a percentile





Yang et al. (2010)
Hydrol Res. 41(3–4)

Precipitation:

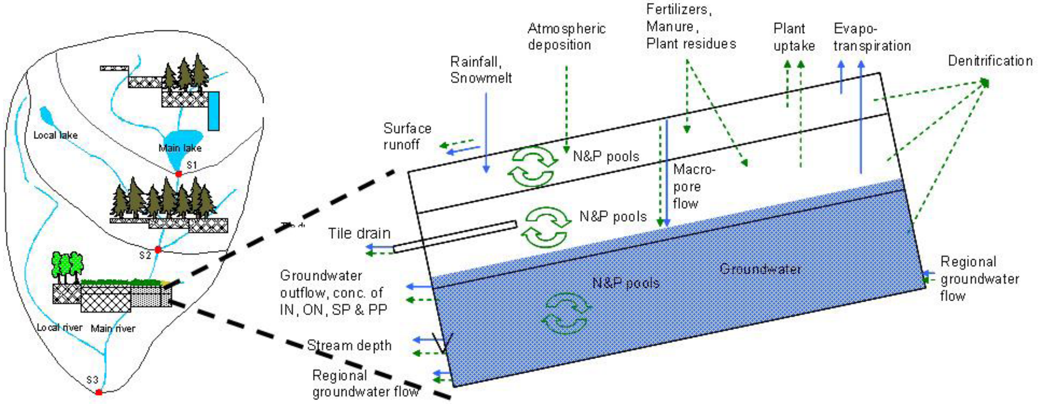
1) "drizzle" generated by RCMs is removed to reach observed % wet days;
2) precipitation is transformed to match the observed frequency distribution (using fit to double gamma distribution)

Temperature:

1) Systematic bias in temperature is adjusted and conditioned on the wet or dry state of the day.
2) Then fitted to a normal distribution whose distribution parameters are smoothed using a 15-day moving window and described by Fourier series

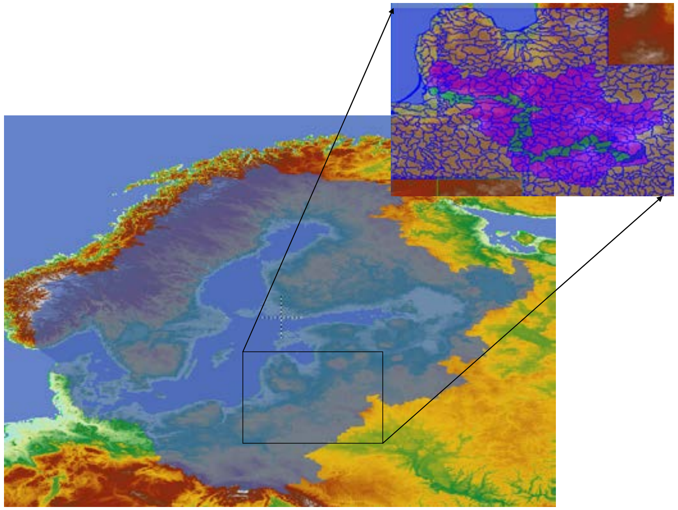
Balt-HYPE: Baltic basin – HYdrological Predictions for the Environment

WHAT?



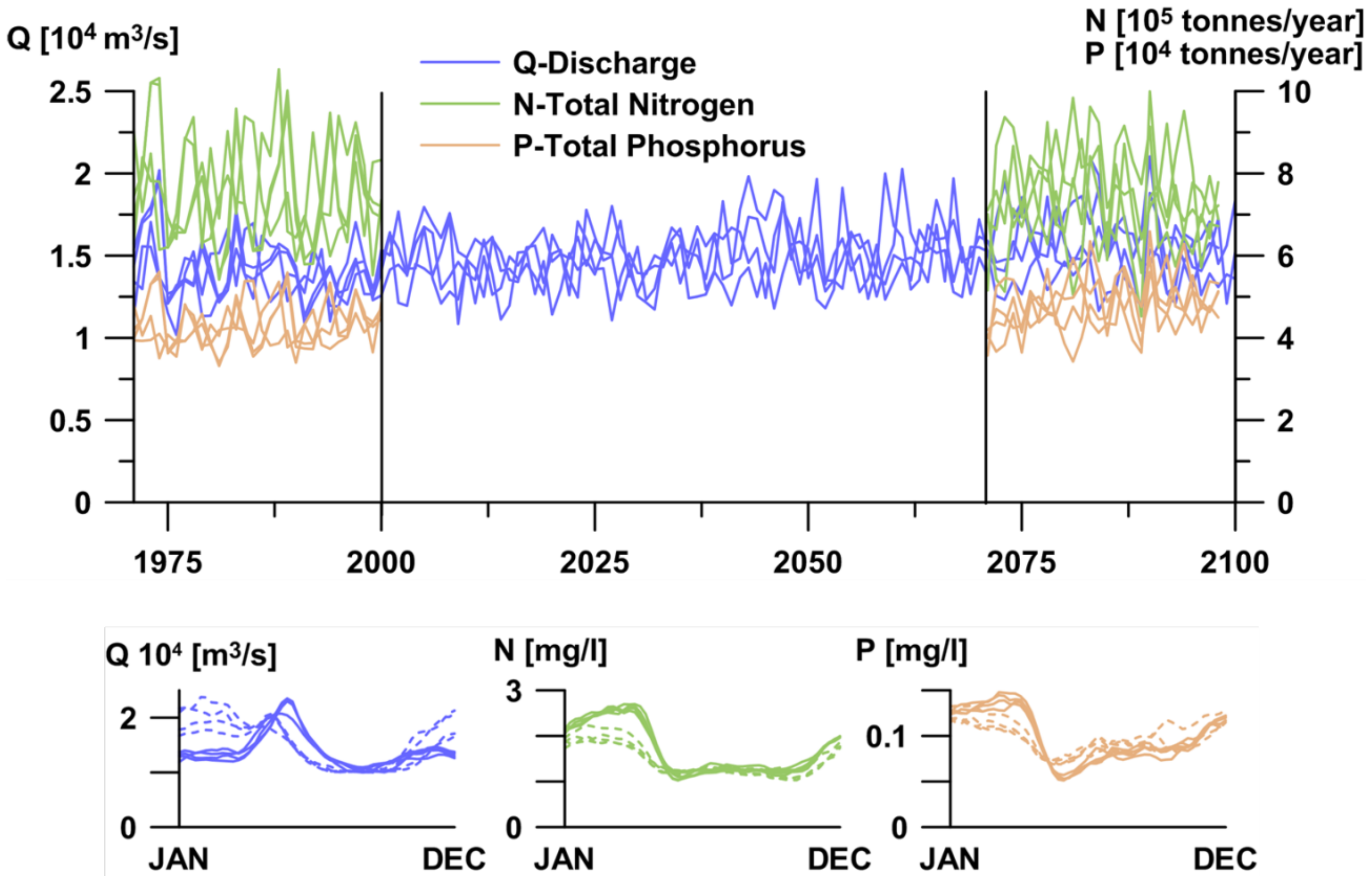
- HYPE is a a semi-distributed process oriented rainfall-runoff model for water (e.g. flow rates, soil moisture) and water quality (N, P) variables

<u>Lindström et al. 2010</u>



- BALT-HYPE: High resolution model (325 km^2), daily model over *the entire basin*
- *Uses readily available regional/global databases as inputs*

Results Q, N and P: 4 Future Climate Scenarios



1. ECHAM5_A1B_1
2. ECHAM5_A1B_3
3. ECHAM5_A2B_
4. HADLEY_A1B

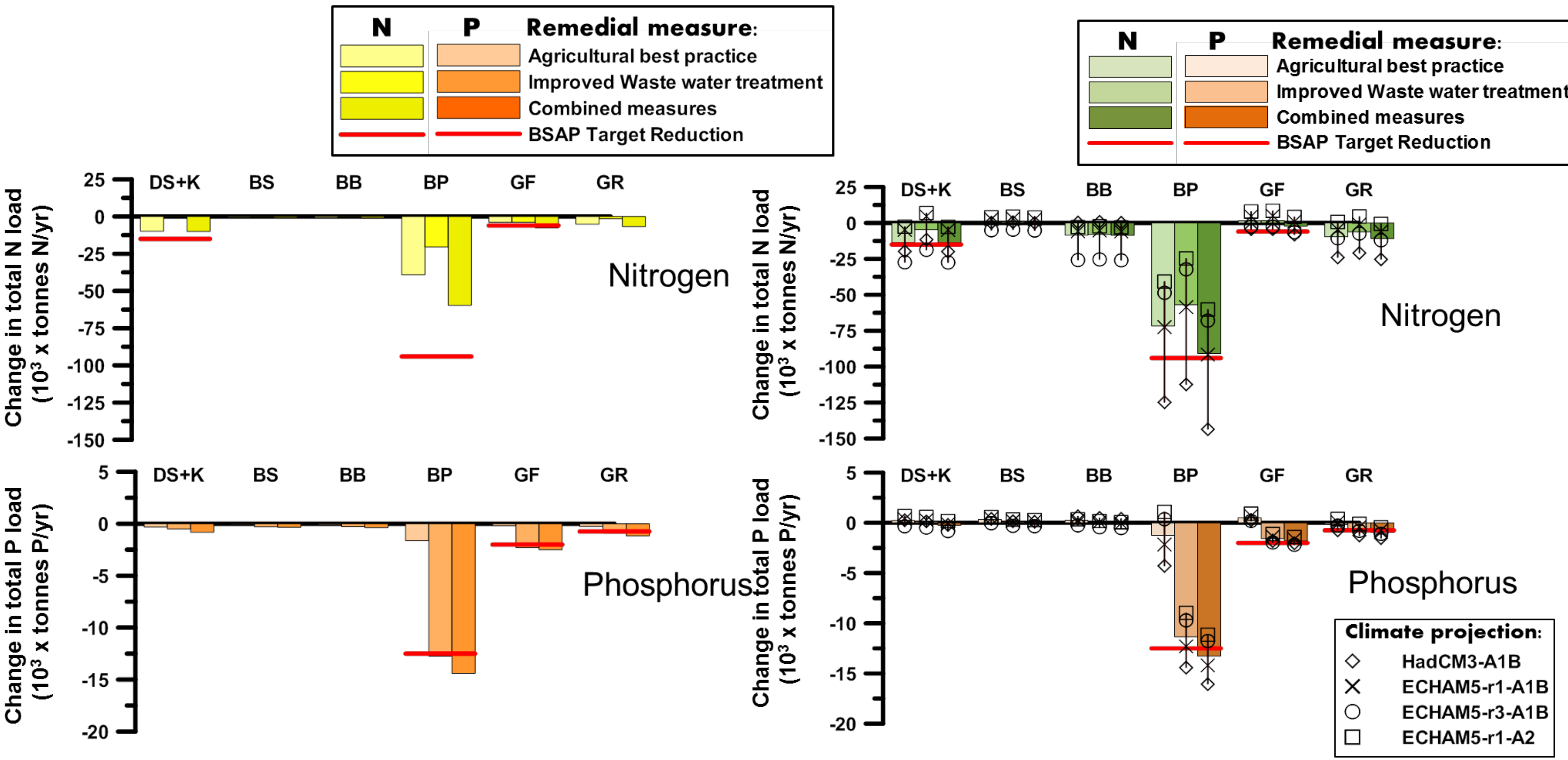
(All downscaled to 25 km by RCAO)

Arheimer, B., Dahné, J. and Donnelly, C. How will climate change impact on riverine nutrient load and land-based remedial measures of the Baltic Sea Action Plan? *Ambio41:600-612.*

Percent changes to the Baltic Sea.
Period 2 (2071 to 2100) – Period 1 (1971-2000)

Percent Change in Mean Annual:	Q to sea	TN load to sea	TP load to sea
E5_RCAO_A1B_3_25 km	3 %	-8 %	6 %
E5_RCAO_A1B_1_25km	12 %	-3 %	6 %
E5_RCAO_A2_25 km	14 %	3 %	17 %
Hadley_RCAO_A1B_25km	12 %	-15 %	2 %
Reduced fertiliser use in Agriculture	0 %	-7 %	-6 %
Improved WWT	0 %	-3 %	- 38 %
Combined Fertiliser Red & WWT	0 %	-11 %	-43 %

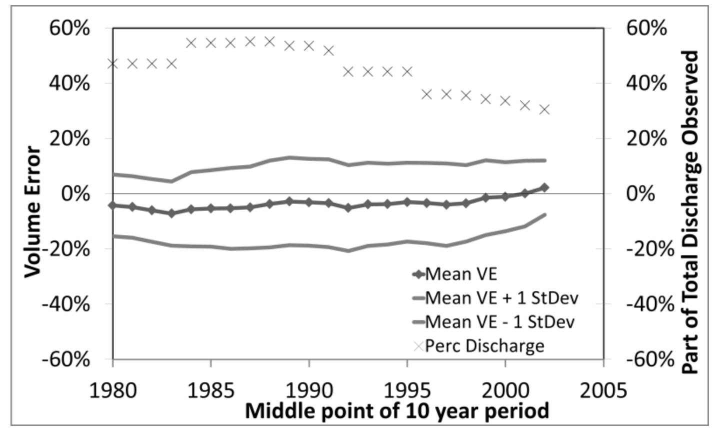
Will future climate affect planned remedial measures for nutrient inputs to the Baltic Sea (e.g. BSAP)?



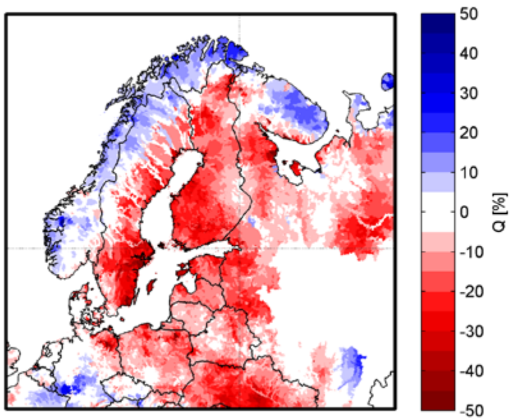
Arheimer, B., Dahné, J. and Donnelly, C. How will climate change impact on riverine nutrient load and land-based remedial measures of the Baltic Sea Action Plan? *Ambio41:600-612.*

How certain are we about changes in discharge to Baltic Sea?

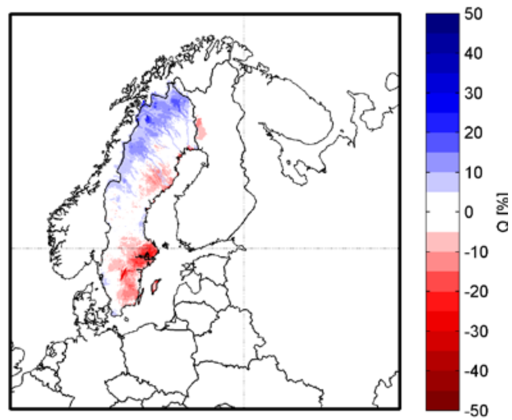
Previously published studies have predicted net changes in total Q to the Baltic Sea ranging from around -14 to + 33 % (Graham 2004, Meier et al. 2006, Hansson et al. 2011, Hagemann et al. 2012). *No information regarding uncertainties due to methodogy!*



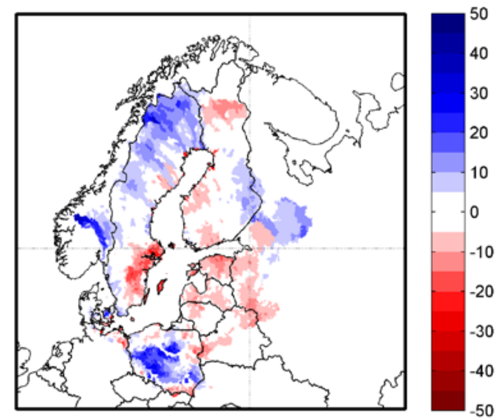
EHYPE Q CC signal
2071-2100 wrt 1971-2000



SHYPE Q CC signal
2071-2100 wrt 1971-2000



BHYPE Q CC signal
2071-2100 wrt 1971-2000



How certain are we about changes in discharge to Baltic Sea?

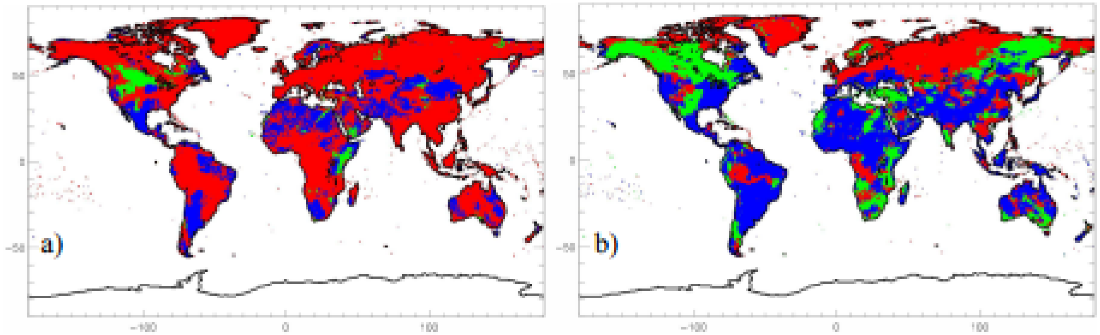
Effect of bias-correction:

RCM Resolution	Run	Raw Mean Annual Basin Precipitation (mm)	RE (%) in Raw RCM Precipitation	Adjusted Mean Annual Basin Precipitation (mm)	RE (%) in Adjusted Precipitation	Mean Annual Basin Discharge (m^3/s)	RE (%) in Ref Discharge	Change in Discharge (2071 to 2100)
11 km	**ERAMESAN Hindcast**	631	na	631	na	15609	na	na
50 km	**$RCA3E5A1B_{3*}$**	903	43 %	652	3.4 %	15822	1.4 %	+ 1 %
25 km	**$RCAOE5A1B_3$***	901	43 %	638	1.0 %	14677	-6.0 %	+ 3 %
25 km	**$RCAOE5A1B_1$***	886	40 %	630	-0.1 %	14569	-6.7 %	+ 12 %
25 km	**RCAOH3A1B**	875	39 %	610	-3.3 %	14982	-4.0 %	+ 12 %
25 km	**RCAOE5A2**			625	-1.0 %	14979	-4.0 %	+14 %

(Donnelly et al. *Under revision*) (Dahné et al. 2013, IAHS Proceedings 2013)

How certain are we about changes in discharge to Baltic Sea?

Evapotranspiration is major source of uncertainty: Methods to simulate evapotranspiration vary between HMs

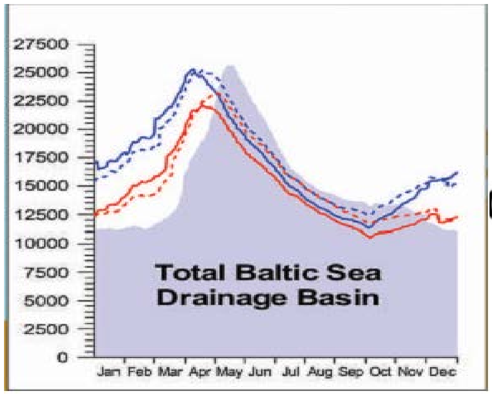


Study uses 3 GCMs to drive 8 GHMs

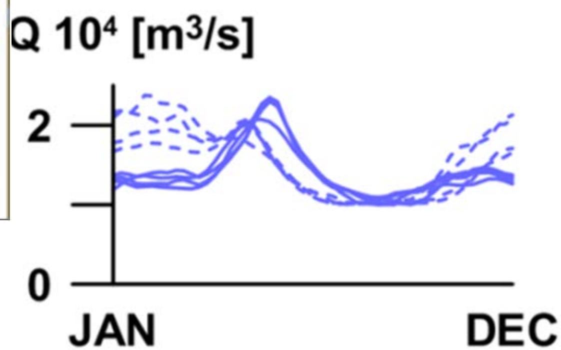
Fig. 3. Areas where the maximum spread in projected evapotranspiration **(a)** and runoff **(b)** changes (2071–2100 compared to 1971–2000) is due to the choice of the GCM (blue), GHM (red) or scenario (green). *(Hagemann et al. 2012, Earth System Dynamics, from the WATER-MIP project)*

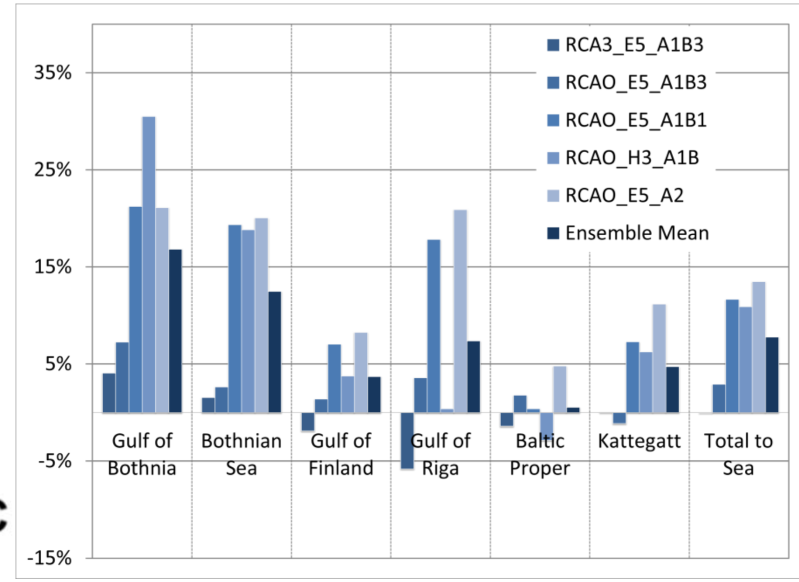
For ET (Fig. 3a), the un-certainty in the projected changes is largely dominated by the spread due to the choice of the Global Hydrological Model (GHM). Especially over high latitude regions, GHMs cause noticeable uncertainty patterns where the spread originating from the GCMs is rather low (Hagemann et al. 2012, Earth System Dynamics)

Changes in discharge to the Baltic Sea – What can we say?



Graham 2004

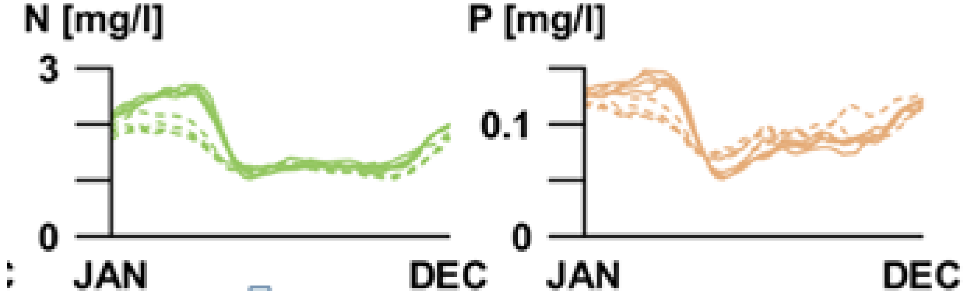




- Changes in seasonality consistent over all studies - seem likely
- Most studies predict increase to northern Baltic
- Most studies (except those that were purely statistical) predict change ranging from negligible to increase in total Q

How certain are we about changes in Nutrients to Baltic Sea?

- Such studies even limited for catchment scale studies
- Consistency between climate projections for changes in seasonality, but only 1 impact model used
- Large need to understand WHY we get changing nutrient loads with changing climate, i.e. improved process understanding from small to large scale!
- Nevertheless, first process based study with sufficient resolution to resolve process changes as a result of changing climate for all of Baltic Sea Region – much to learn from these results!



Importance of Process Modelling!

- Future climate simulations indicate decreases in N concentrations in South WHY?

	Kymijoki	Oder	Wistula
Mineralisation	4360 (42%)	31049 (15%)	51263 (16%)
Plant Uptake	6105 (20%)	10789 (2%)	16174 (2%)
Denitrification (soil)	685 (20 %)	36069 (11 %)	52089 (12 %)
Net Change to Soil from Above Processes	-2430	-15809	-17000
Load in Leachate	219 (4 %)	86 (0 %)	- 4205 (-4 %)
Denitrification (streams and lakes)	86 (69 %)	150 (41 %)	1415 (52 %)
Net load to Sea	292 (4.2 %)	-199 (-0.3 %)	-6189 (-5.7 %)

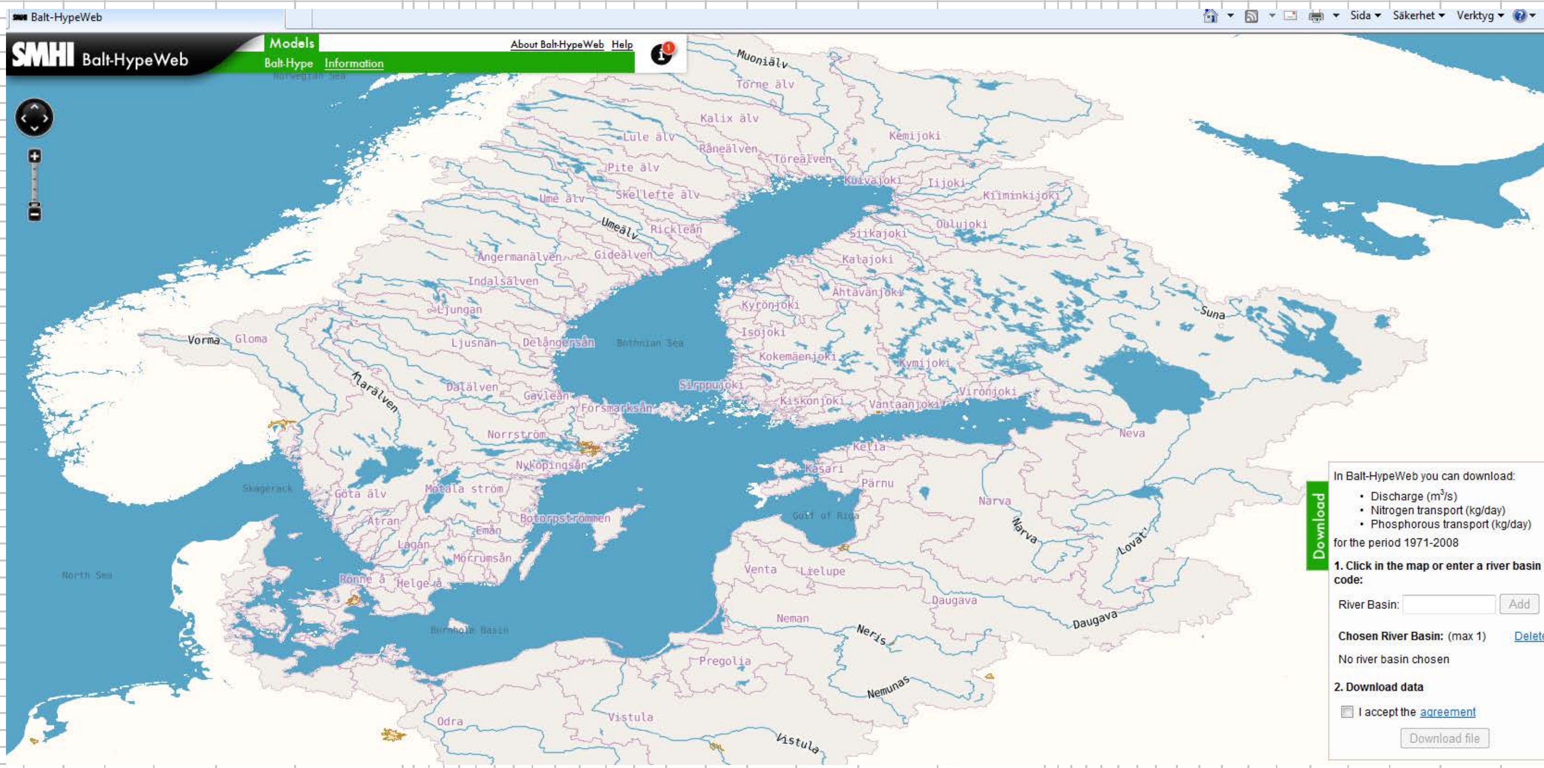
- Changes in storage in soil! Dependent on assumed initial values and more….Needs more research! Here only time-slice runs made….

Future Work

- Evaluating and comparing CC due to different evapotranspiration routines
- Evaluating and comparing CC due to difference BC methodologies
- Improved model calibration as more data becomes available
- European scale nutrient studies (E-HYPE)

- Upscaling of nutrient soil and surface water retention processes from field to catchment to Baltic Sea basin scale (New BONUS project, *Soils2Seas*) for better understanding. Scenarios of area targeted nutrient reduction plans.

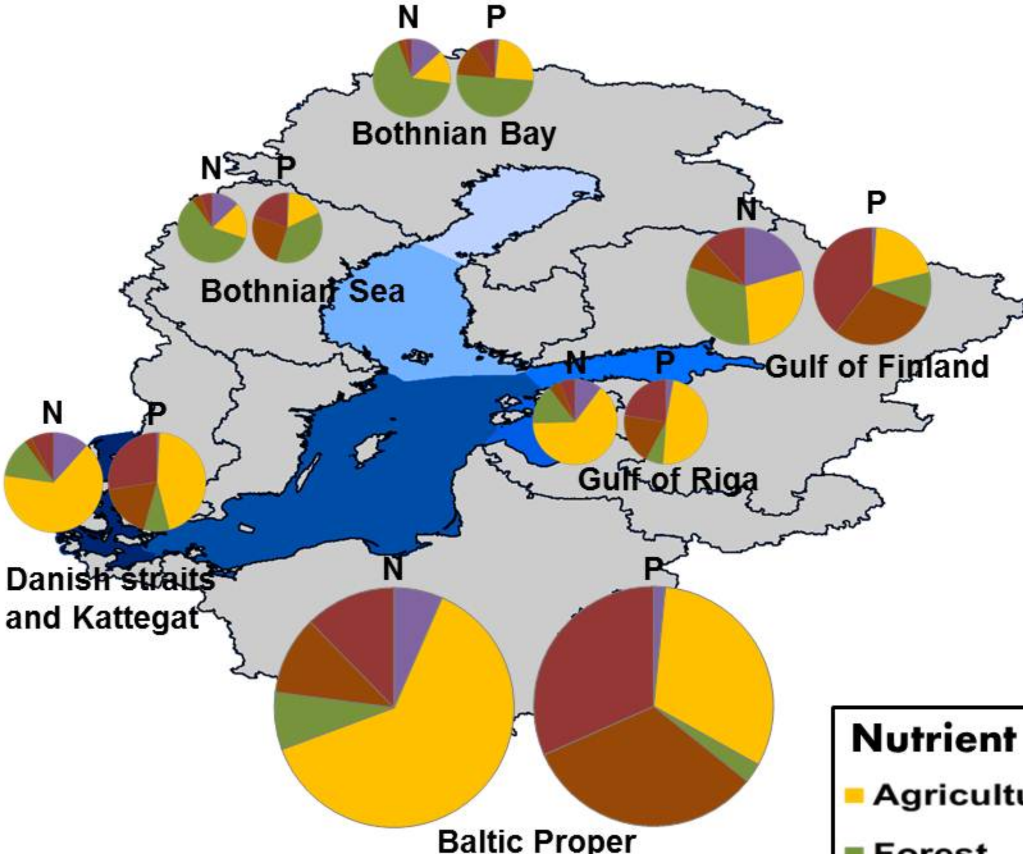
Thanks for your Attention



OBS!! Download Balt-HYPE hindcast from Balt-HYPEweb: http://balt-hypeweb.smhi.se/

Operational forecast data also available from SMHI

Results: Source Apportionment of Nutrient loads to Baltic Sea



Riverine loads (tonnes/year)

Basin	Nitrogen	Phosphorus
Baltic Proper (BP)	412 000	28 200
Gulf of Finland (GF)	117 000	5 800
Danish straits and Kattegat (DS+K)	92 000	2 900
Gulf of Riga (GR)	61 000	2 800
Bothnian Bay (BB)	52 000	2 100
Bothnian Sea (BS)	45 000	1 600
TOTAL	**779 000**	**43 400**

Nutrient sources:
- Agricultural land
- Forest
- Rural households
- WWTP
- Other (lakes incl.)