BACC II

Tallin, Estonia
6 September 2012

The Climate Change Assessment: Report for the Baltic Sea catchment - BACC

An effort to establish which scientifically legitimized knowledge about anthropogenic climate change is available for the Baltic Sea catchment.

Approximately 80 scientist from 10 countries have documented and assessed the published knowledge in 2008 in BACC-1.

The assessment has been accepted by the inter-governmental HELCOM commission as a basis for its future deliberations.

In 2013 the second assessment report (BACC II) will be published.
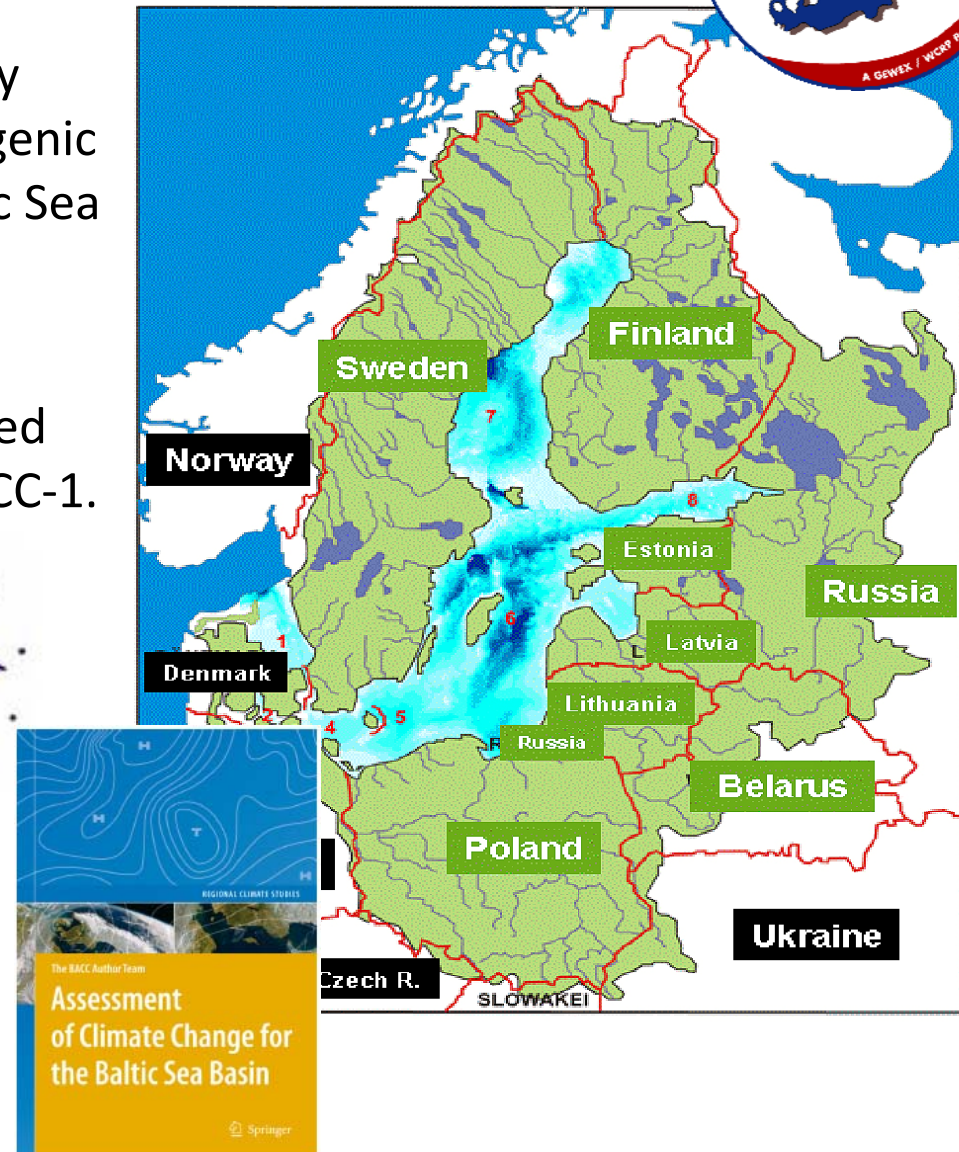
BACC-1 results – in short

➤ Presently a warming is going on in the Baltic Sea region, and will continue throughout the 21st century.

➤ BACC considers it plausible that this warming is at least partly related to anthropogenic factors.

➤ So far, and in the next few decades, the signal is limited to temperature and directly related variables, such as ice conditions.

➤ Later, changes in the water cycle are expected to become obvious.

➤ This regional warming will have a variety of effects on terrestrial and marine ecosystems – some predictable such as the changes in the phenology others so far hardly predictable.
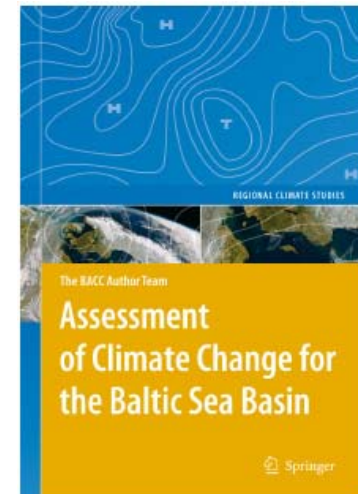
Principles
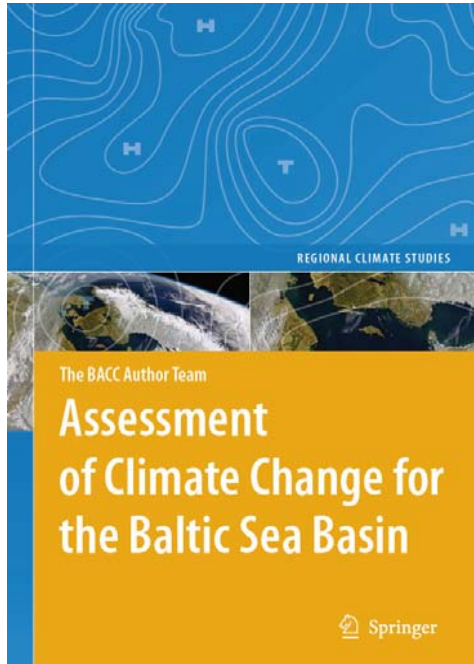
The assessment will be a synthesis of material drawn comprehensively from the available scientifically legitimate literature (e.g. peer reviewed literature, conference proceedings, reports of scientific institutes).

Influence or funding from groups with a political, economical or ideological agenda will not be allowed; however, questions from such groups are welcome.

If a consensus view cannot be found in the above defined literature, this will be clearly stated and the differing views will be documented. The assessment will thus encompass the knowledge about what scientists agree on but also identify cases of disagreement or knowledge gaps.

The assessment is evaluated by independent scientific reviewers.

Timeline of BACC II
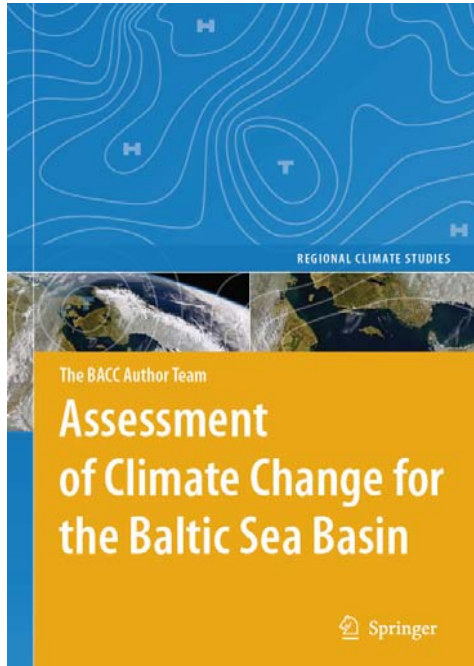
January 2009: 1st BACC II Working Group meeting (Helsinki)

April 2010: 2nd BACC II Working Group meeting (Lund), nomination of BACC II Science Steering Committee (SSC) and suggestions for BACC II Lead Authors

June 2010: BACC II Lead Authors approved

November 2010: 1st meeting of BACC II Lead Authors and SSC (Göteborg)

March 2011: 2nd meeting of BACC II Lead Authors and SSC (Hamburg)

February 2012: 3rd meeting of BACC II Lead Authors and SSC (Copenhagen)

July 2012:   Chapters ready for external review

September 2012: BACC II Conference in Tallinn

End 2012:   External peer-review completed

Mid 2013:   Draft BACC II report finished

End 2013/Beginning 2014: BACC II book published

Assessment of Climate Change for the Baltic Sea Basin
BACC II
International Conference · 6 – 7 September 2012 · Tallinn, Estonia

Chapter Structure

1. Overall assessment and summary

2. Past climate variability

  2.1 Introduction and summary

    2.2 Holocene (12,000 yr)

    2.3 Historical time frame (1,000 yr)

3. Climate change during the last 200 years

    3.1 Introduction and summary

    3.2 Atmosphere

    3.3 Land

        3.3.1. Hydrology

        3.3.2. Terrestrial cryosphere

    3.4 Baltic Sea

        3.4.1. Marine circulation and stratification

        3.4.2. Sea ice

        3.4.3. Sea level and wind waves

4. Future climate change

    4.1. Introduction and summary

    4.2. Skills of methods for describing regional climate futures

    4.3. Projections of future climate change

5. Impacts of current and future climate change

    5.1. Introduction and summary

    5.2. Impacts on the environment

        5.2.1. Atmospheric chemistry

        5.2.2. Terrestrial ecosystems

        5.2.3. Freshwater biogeochemistry

        5.2.4. Marine biogeochemistry

        5.2.5. Marine ecosystems

    5.3. Socio-economic Impacts

        5.3.1 Agriculture and forestry

        5.3.2 Urban complexes

        5.3.3 Coastal erosion and coastline changes

6. Attributing causes of regional climate change

    6.1. Introduction and summary

    6.2. Global warming

    6.3. Aerosols

    6.4. Land cover change

Annexes

    A1. Self Criticism and Reflection on the 'Assessment of Climate Change for theBaltic Sea Basin 2008' and the Communication of the Science to Regional Political Decision Makers

    A2. The concept of detection and attribution

Overall Summary

1.New assessment finds results of BACC-1 valid.

2.Significant detail and additional material has been found and assessed. Some contested issues have been reconciled (e.g., sea surface temperature trends)

3.Ability to run multi-model ensembles seems a major addition; first signs of detection studies, but attribution still weak.

4.RCMs need further development.

5.Homogeneity is till a problem and not taken seriously enough in some scientific quarters.

6.The issue of multiple drivers on ecosystems and socio-economy is recognized, but more efforts to deal with are needed.

7.Climate change is a serious issue, but in many cases is remains questionable if it is a dominant issue.,

2. Past climate variability
2.2 Holocene (12,000 yr)

Summer temperature anomalies shown as deviations from the modern value. Lake Kurjanovas, south eastern Latvia, 56°31'N (Heikkilä and Seppä 2010).
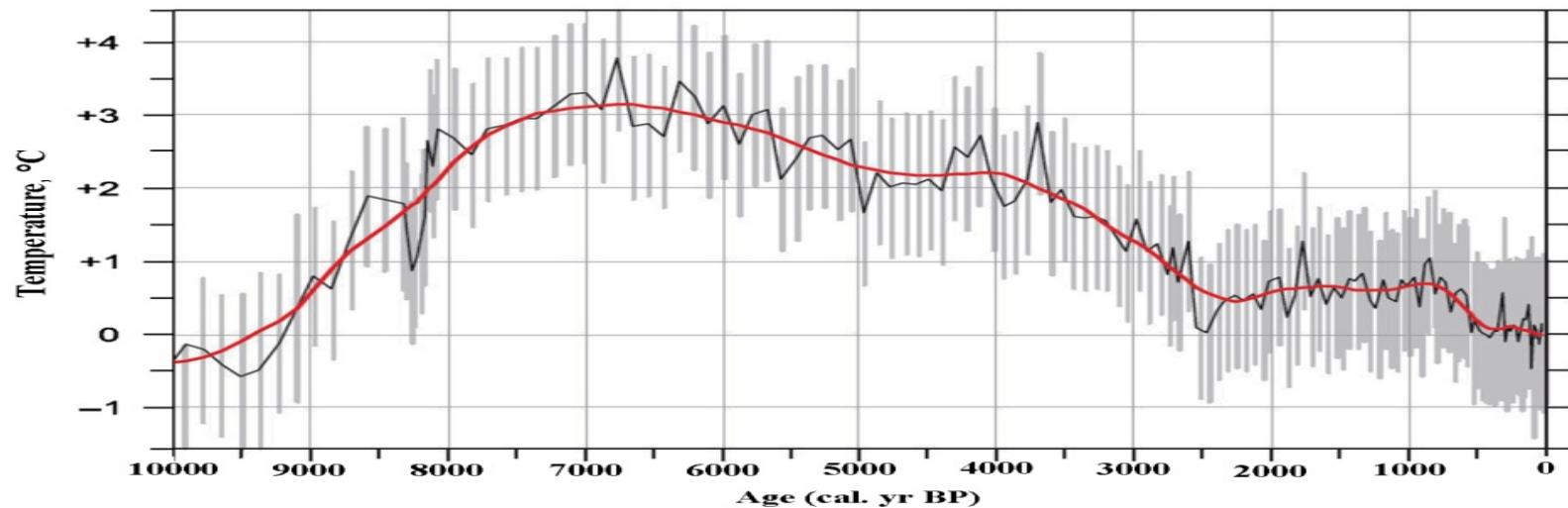
The Baltic Sea region has seen remarkable changes since the end of last ice age (last 10 – 12,000 years).

The externally forced climate variability in the Baltic Sea basin is most likely attributable to orbital forcing at millennial time scales, to changes in solar irradiance at multi-decadal or centennial timescales, and to volcanic activity at multidecadal timescales. In addition to the external climate drivers factors, non-linear mechanisms in the different components of the climate system and within each subsystem give rise to internal climate variability at all timescales.

2. Past climate variability
2.3 Historical time frame (1,000 yr)

- Historical climatic periods such as Medieval warm period and Little Ice Age are real for Northern Europe.
- But as expected also for future warming, the warmings/coolings are not uniform but represent a shift of the frequency of warm/cool seasons.
- No analogues for ecological impact available.
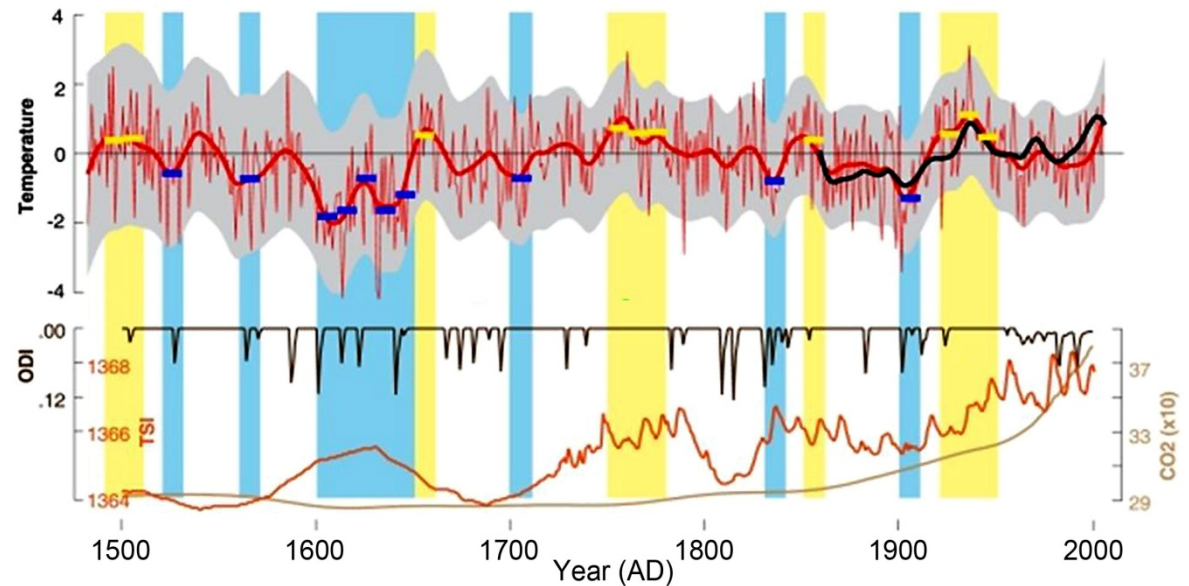
Reconstructed and modelled Northern Scandinavian summer temperature variations over the past five centuries (From Büntgen et al. 2011a).

Top: Actual (black) and reconstructed (red) summer (JJA) temperature anomalies (ºC) with error estimates (grey) and the ten warmest and coldest decades superimposed (colour boxes).

Bottom: Solar (TSI; Total Solar Irradiance), volcanic (ODI; Optical Depth change in the visible band), and CO_2 (ppm) forcing as used in the model simulation.

3. Climate change during the last 200 years

In general the **conclusions from BACC-1** (2008) are confirmed.

→ Important to stress the extremely high inter-annual and inter-decadal variability in most variables.

→ Variability is much higher than long-term trends, trends depend very much on the selected period.

New results includes:

→ Persistence of weather types has increased.

→ Upwelling analysis

→ Evidence of recent sea water warming (indicated in BACC 2008, now verified).

→ More extensive results for several parameters, in particularly on sea level.

→ Runoff explained by temperature, warming is associated with less runoff in southern regions and more runoff in northern regions.

Summary

3. Climate change during the last 200 years

Disagreements in literature includes:

→ Winter storminess: a significant long-term increase in winter storminess since 1871 is shown by for example Donat et al. (2011). This is suggested by several other studies to be an artefact due to the changes in density of stations over time.

Missing knowledge:

→ Changes in circulation patterns due to less ice in the Arctic (cold winters, moist summers are suggested).

→ Ground frost properties.

→ Trends in extreme events.

→ Lack of data for some parameters for example clouds and radiation.

Summary

3. Climate change during the last 200 years

Air temperature

The warming of the low level atmosphere is larger in the Baltic Sea regions than the global mean for the corresponding period. Warming continued for the last decade

→ Not in winter

→ Largest in spring

→ Largest for northern areas

No recent "stagnation" except for winter.

Data sets	Year	Winter	Spring	Summer	Autumn
Northern area	**0.11**	0.10	**0.15**	**0.08**	**0.10**
Southern area	**0.08**	**0.10**	**0.10**	**0.04**	**0.07**

Linear surface air temperature trends (K per decade) for the period 1871-2011 for the Baltic Sea Basin. Northern area is latitude > 60°N. Bold numbers are significant at the 0.05 level.
Data updated for BACCII from the CRUTEM3v dataset (Brohan et al. 2006)
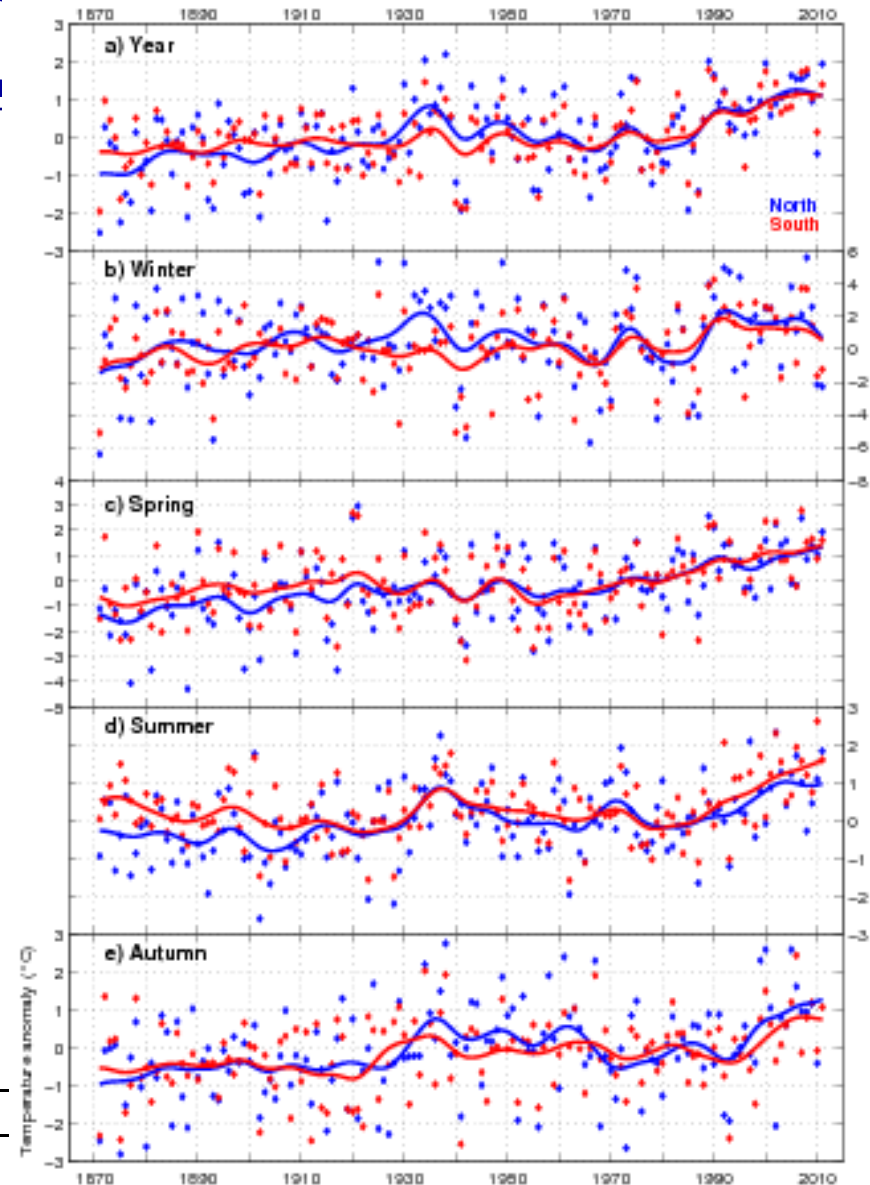
Annual and seasonal mean surface air temperature anomalies for the Baltic Sea Basin 1871-2011, Blue colour comprises the Baltic Sea basin to the north of 60°N, and red colour to the south of that latitude.

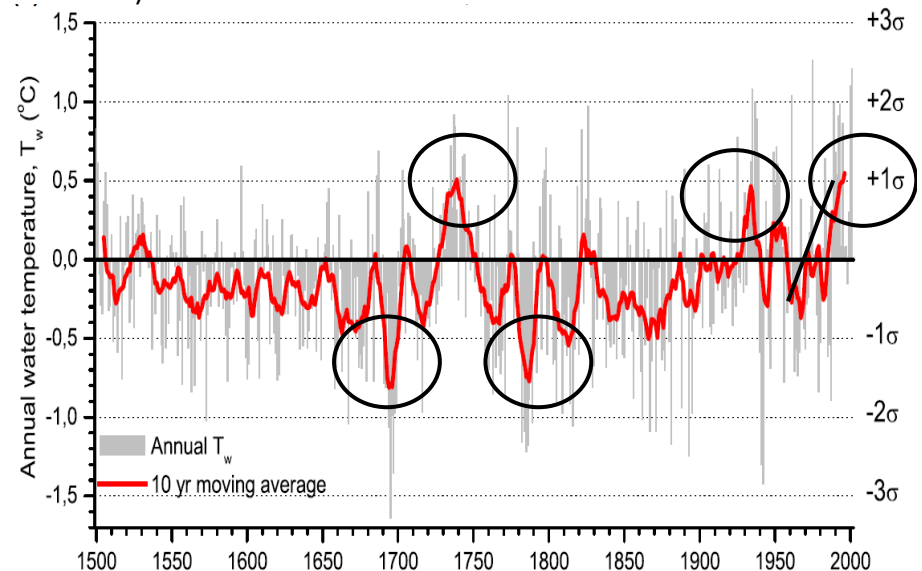**3. Climate change during the last 200 years**

Sea Surface Temperature

•The warming of the water basin is significant during the last decades.

•Highest linear trend of in the Bothnian Bay, Gulfs of Finland and Riga and in the Northern Baltic Proper .

•Largest warming in August in Bothnian Bay

•Cooling in March.

•Longer perspective – present strong warming not unique.

Anomalies of the annual and decadal moving average of the modeled Baltic Sea spatially mean water temperature over the period 1500–2001. The dotted horizontal lines are the standard deviations of the water temperature during the standard period 1900–1999 (Hansson and Omstedt 2008).
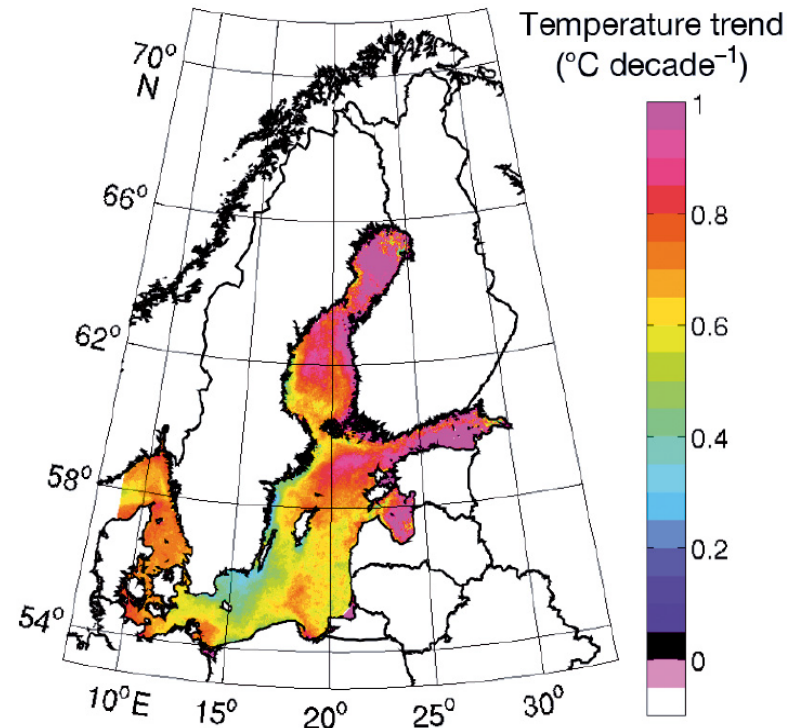
Linear trend 1990–2008 of the annual mean sea surface temperature based on infrared satellite data (Lehmann et al, 2011).

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3. Climate change during the last 200 years

Sea Level

Isostatic changes following the last glaciation:

- falling in the northern Baltic (crust is uplifting at roughly 10mm/yr)

- rising in parts of the Southern Baltic (crust sinking at 1mm/yr).

- recent studies: a more easterly peak uplift placed in the middle of the northern Gulf of Bothnia

- quasi-linear long-term trend in Baltic Sea-level is dominated by isostatic land movement effects
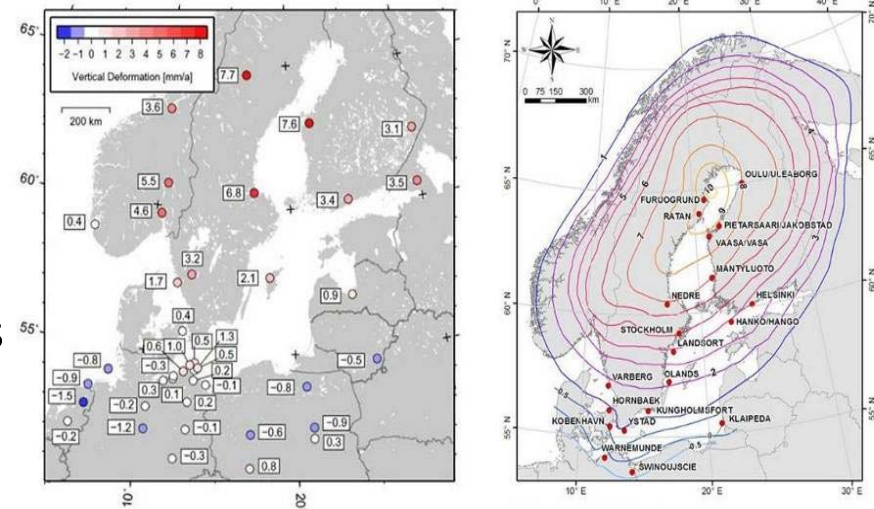
Estimations of crustal deformation rates in the Baltic Sea Region derived by different methods. From Richter et al. (2011) and Harff et al. (2010).

3. Climate change during the last 200 years

Gauge records show an upward trend:

- absolute sea level increase (1800-2000): 1.3 mm/yr to 1.8 mm/yr. Lies within error bars of global mean (1.7 ±0.5mm/yr).

- present rates of Baltic sea level rise are not unprecedented in the observational record.
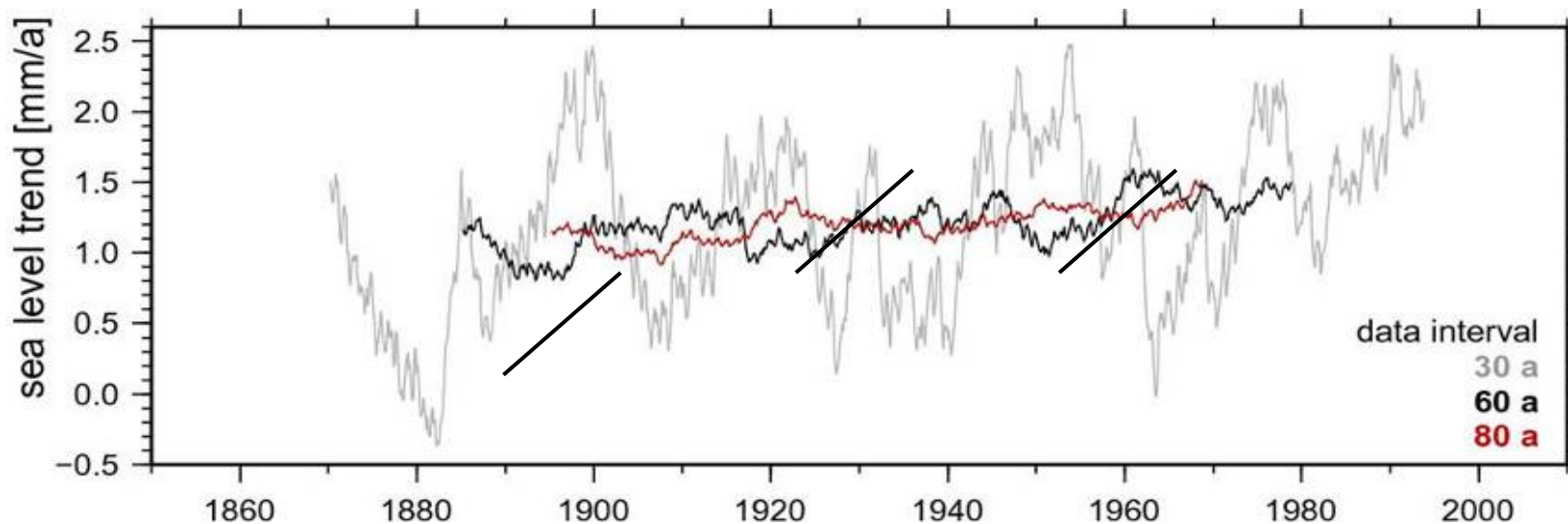
Linear trends calculated in sliding windows of fixed lengths of the annual sea-level record in Warnemünde (Germany). From Richter et al. (2011).

Sea Level

3. Climate change during the last 200 years

Variable	Long term trend	Last decades	Variable	Long term trend	Short term trend
Air temperature	positive	positive	Clouds	x	Mainly negative
Water temperature	positive	positive	Radiation	x	Positive and negative
Precipitation	no trend	Mainly positive	Diurnal temperature amplitude	negative	negative
Wind	no trend	Mainly positive			
Run off	no trend	positive	Length of growing season	positive	positive
Sea level	positive	positive			
Ice extent	negative	negative			
Snow cover	negative	negative			
Heavy precip	x	positive			

Summary

RCMs are not yet a perfect tool

- Large biases reproducing observed climate, in particular with the energy and water cycle, both amounts, but also extremes.

-Inability to deal with other drivers, in particular aerosol lloads and changing land surface conidtions

-- Disregard of dynamic coupling of Baltic Sea, atmosphere and other compartments
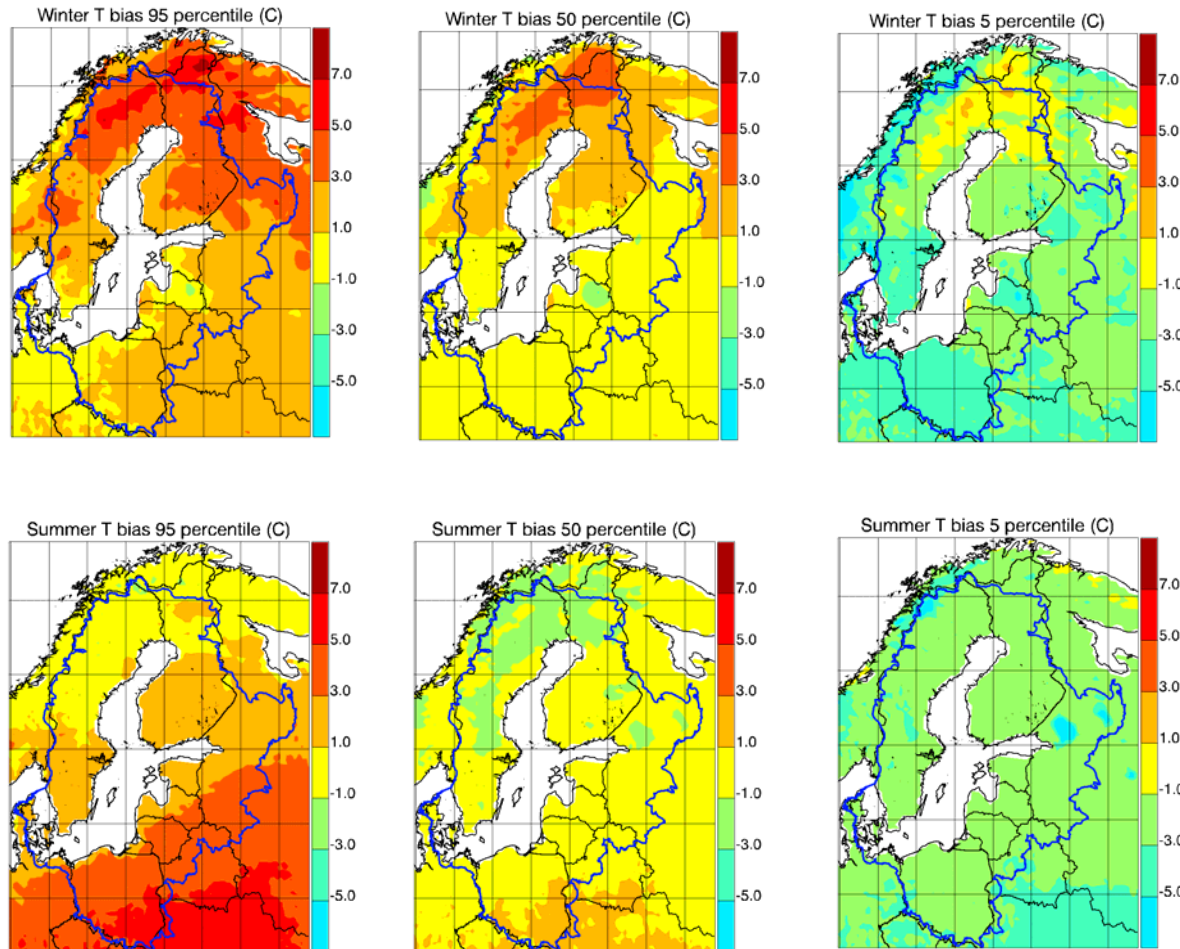
Simulated temperature bias (◦C) w.r.t. E-OBS for 1961-2000. The maps show the pointwise smallest (left), median (middle) and largest (right) bias taken from an ensemble of 10 RCMs with lateral boundary conditions taken from ERA40

PERFORMANCE OF RCMS IN REPRODUCING THE CLIMATE
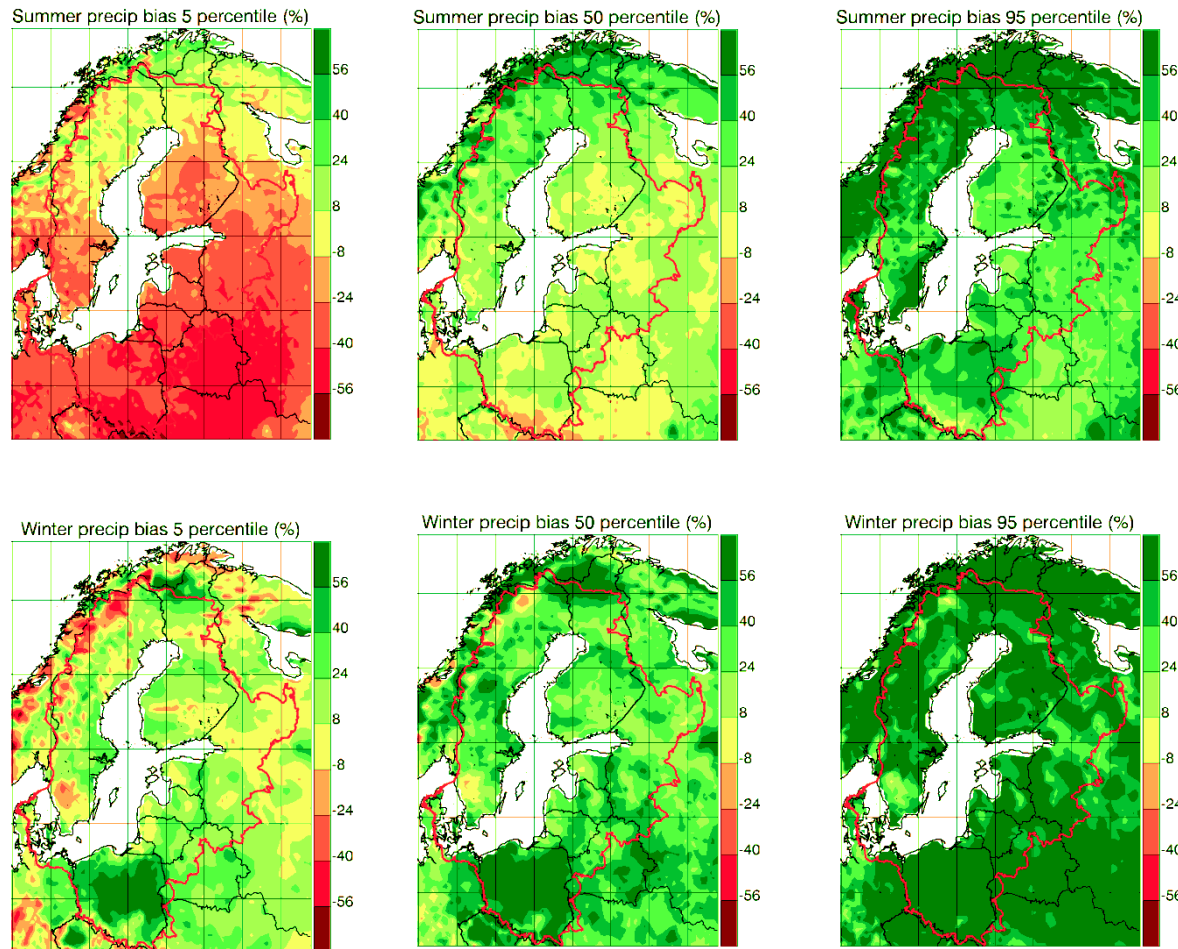
Simulated precipitation bias (%) w.r.t. E-OBS for 1961-2000. The maps show the pointwise smallest (left), median (middle) and largest (right) bias taken from an ensemble of 10 RCMs with lateral boundary conditions taken from ERA40.

PERFORMANCE OF RCMS IN REPRODUCING STATISTICS OF RPECIPITATION AMOUNTS

4. Future climate change

- **Confirmation of BACC1-scenarios**
- **Horizontal resolution improved (typical gridsizes 25 km atmosphere, 3.6 km ocean)**
- **multi-model ensembles:**

13 RCM simulations from the ENSEMBLES project change between 1961-1990 and 2070-2099
The 13 numbers are sorted, resulting in an approximate 5th percentile corresponding to the lowest value, a median, and an approximate 95th percentile.
http://ensemblesrt3.dmi.dk/

Scenarios
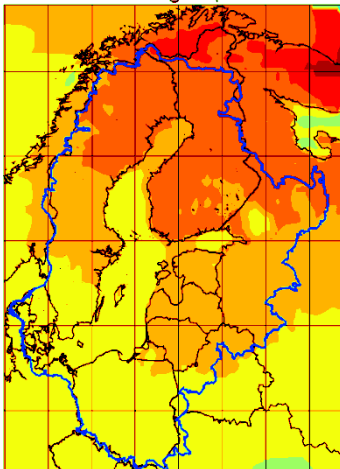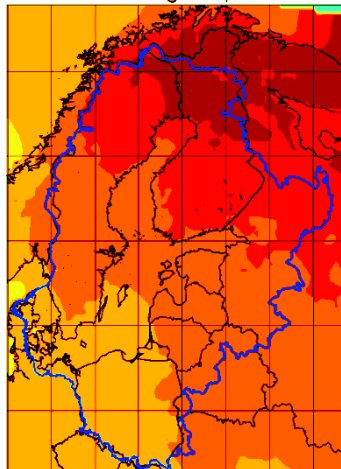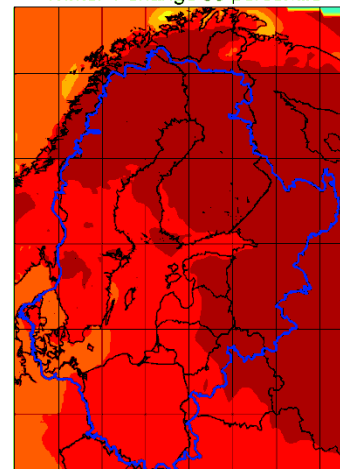
4. Future climate change

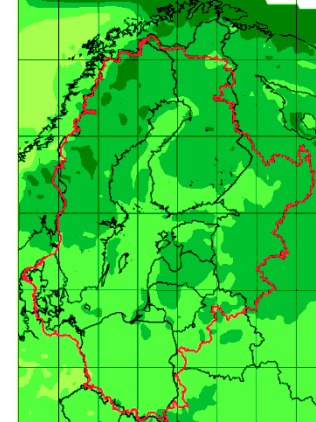# Temperature
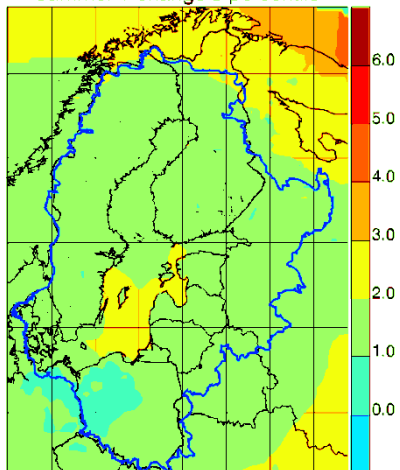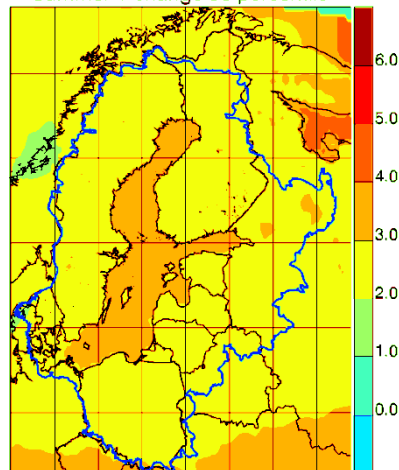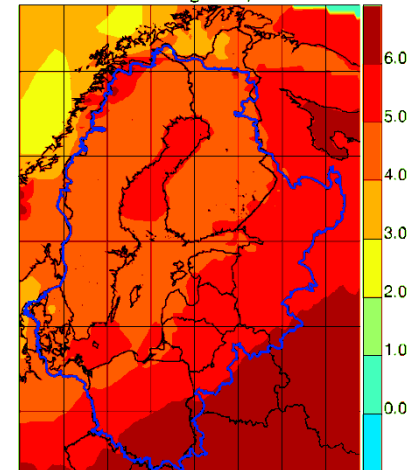
4. Future climate change

Winter precip change 5 percentile (%)
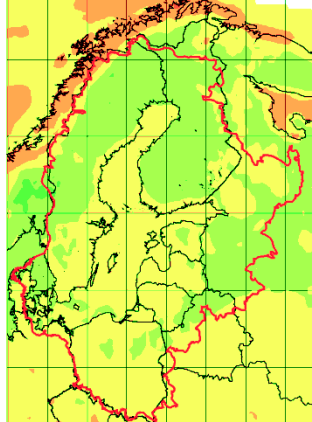
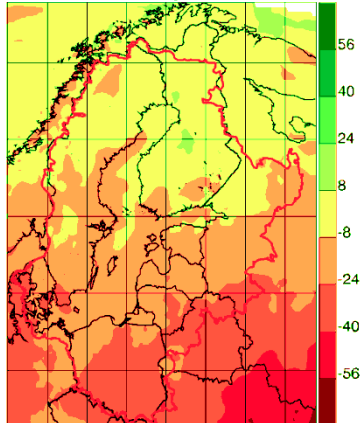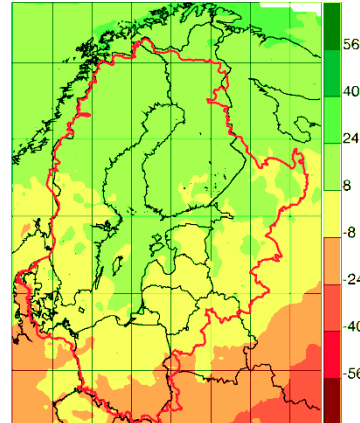Winter precip change 50 percentile (%
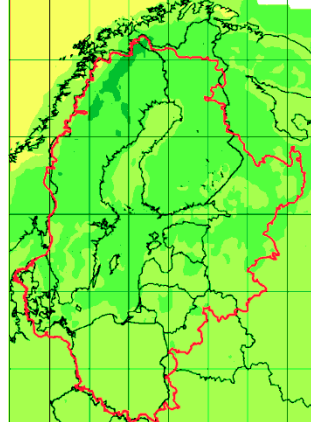
Winter precip change 95 percentile (%

Precipitation amount

Summer precip change 5 percentile (%)

Summer precip change 50 percentile (%)

Summer precip change 95 percentile (%)
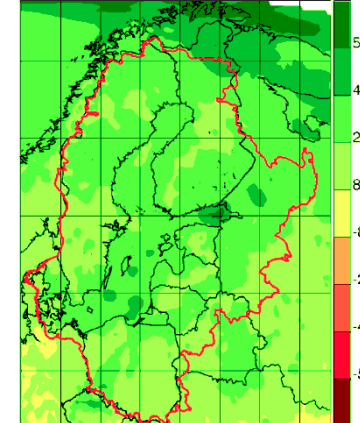
4. Future climate change
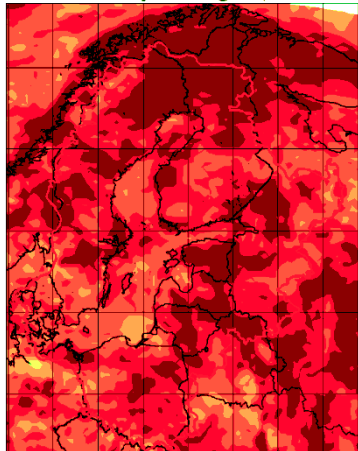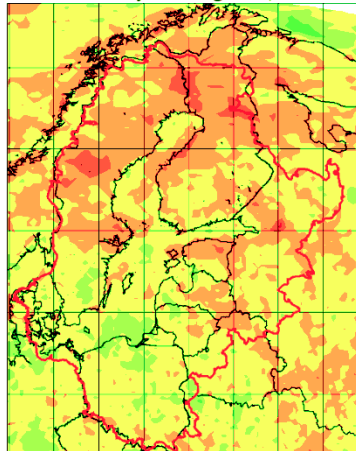
Winter wssmax 10yrv change 5 percentile (Winter wssmax 10yrv change 50 percentile   Winter wssmax 10yrv change 95 percentile
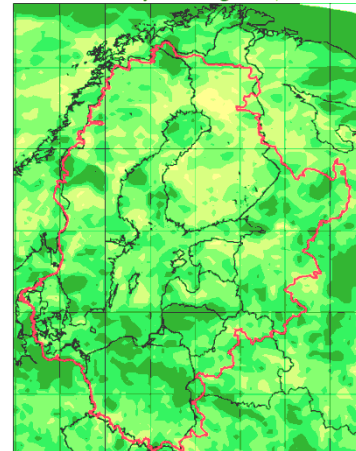
Maximum wind
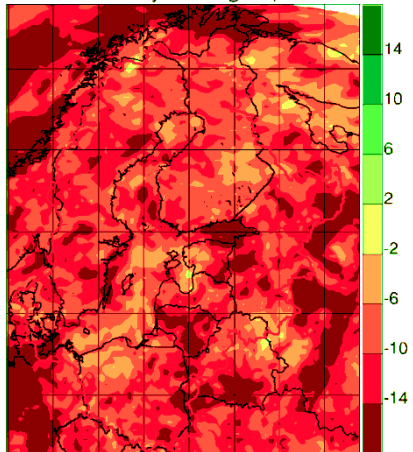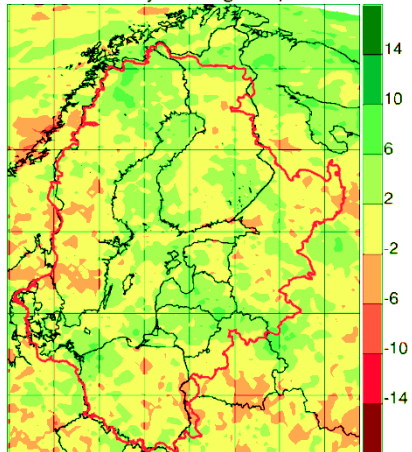
ummer wssmax 10yrv change 5 percentile   ımmer wssmax 10yrv change 50 percentile   Summer 10yrv change 95 percentile (%)
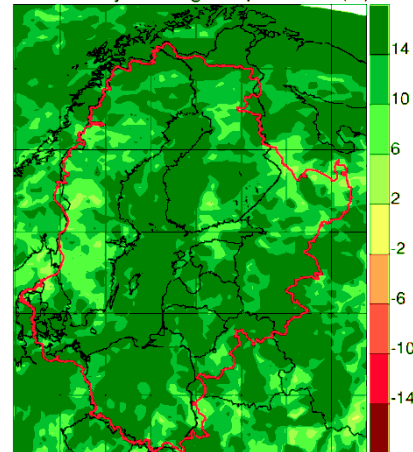
4. Future climate change

- Same general expectations as before
- More quantitative information (*e.g.* estimates of cc span)
- Winter warming, mostly in the North
- Summer warming less than winter
- More winter precipitation
- Summer precipitation grows in the North, decreases in the South
- Insignificant changes in winds
- Increase in warm and wet extremes, also in summer

Summary atmosphere

4. Impacts: . Atmospheric chemistry

▪The main changes in air pollution in this region are due to changes in emissions rather than climate-change itself.

▪Concentration and deposition changes of the acidifying components (SOx, NOx, NHx, PM) generally follow emission changes within the European area

4. Impacts: Terrestrial ecosystems

BACC-1 found poleward movement of species.

For coniferous trees temperature change is dominant for this movement

In the northern boreal forests, temperature is dominant driving force in the climate response with generally positive effects on coniferous tree growth, whereas in the temperate forests in the southern part of the Baltic Sea Basin precipitation becomes more important

Pine_Biomass Rovaniemi

Pine_Biomass Kuopio

Pine_Biomass Chorin
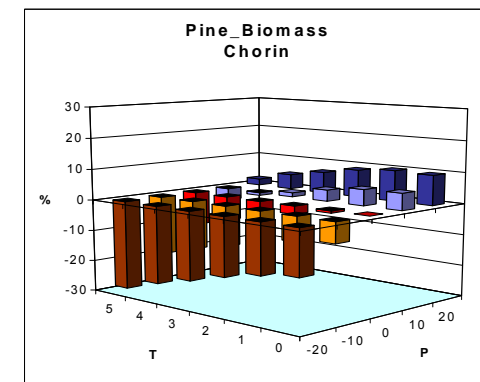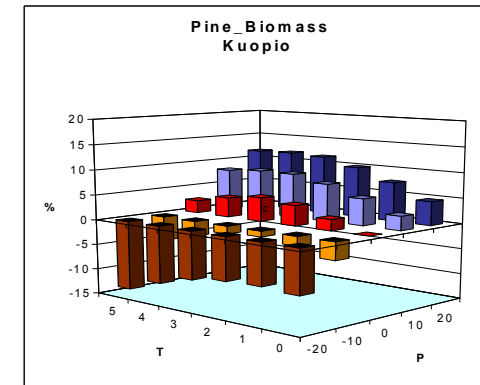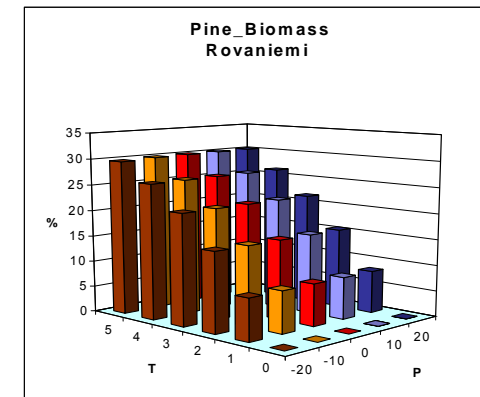
4. Impacts: Terrestrial ecosystems

• Coastal areas play a key role in the intreaction between the terrestrial and aquatic ecosystems.

• Areas with high coastal area densities (for example A) represent high biodiversity of plant and animal communities and ecosystems.

• Coastal and archipelago ecosystems are sensitive to environmental changes like climate or related changes (salinity etc).

Shore line density along the coasts of the Baltic Sea
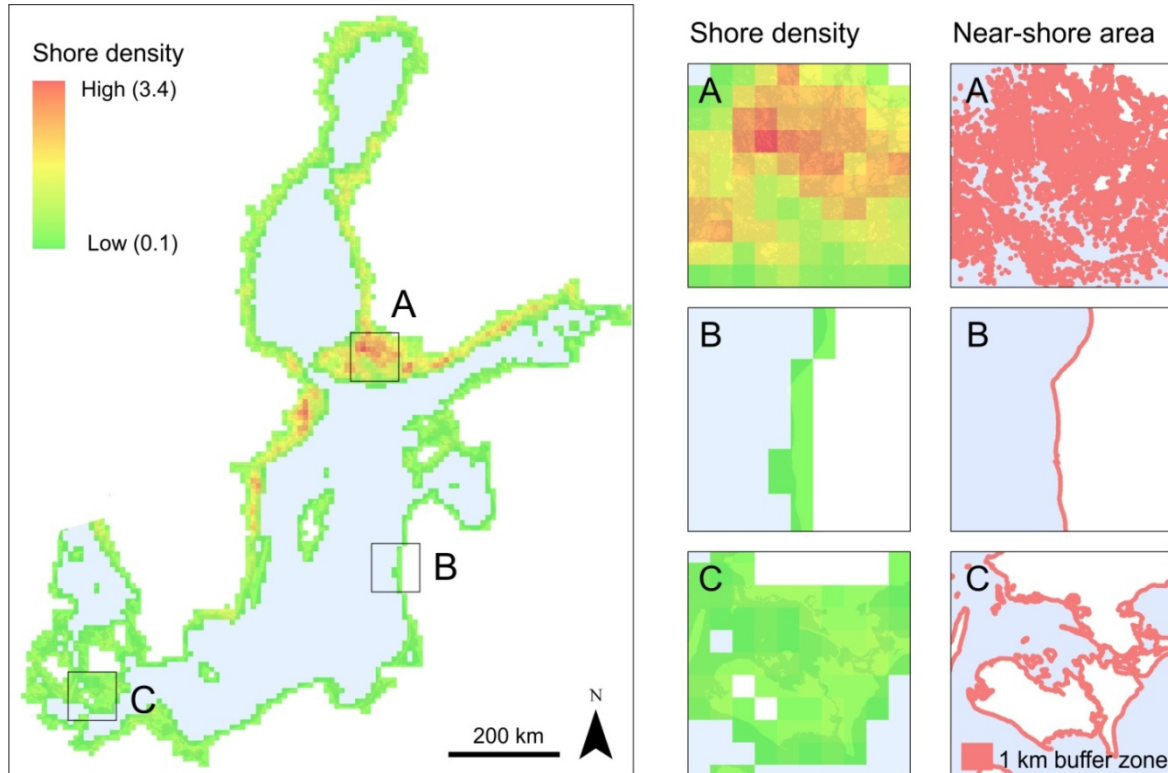
New issue: Coastal area

4. Impacts: Marine Biogeochemistry
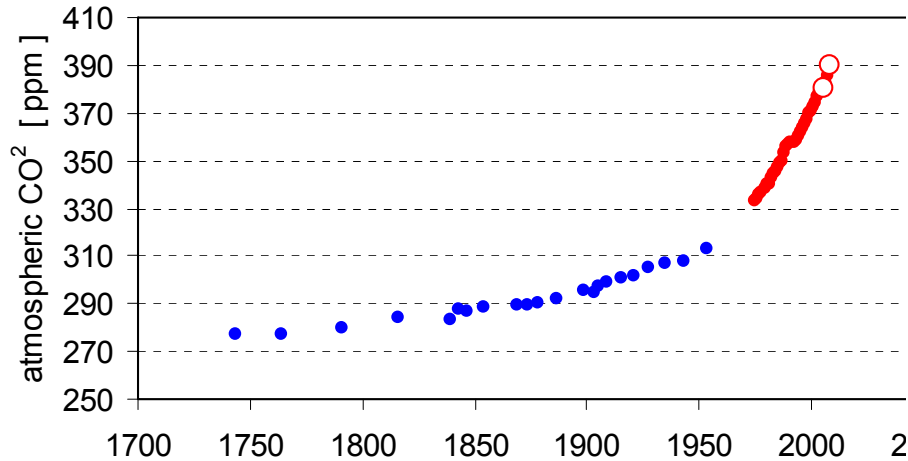
The concentrations of CO_2 in the atmosphere increased from the preindustrial level of 280 ppm to currently about 400 ppm. Open circles represent data from the atmosphere over the Baltic Sea.
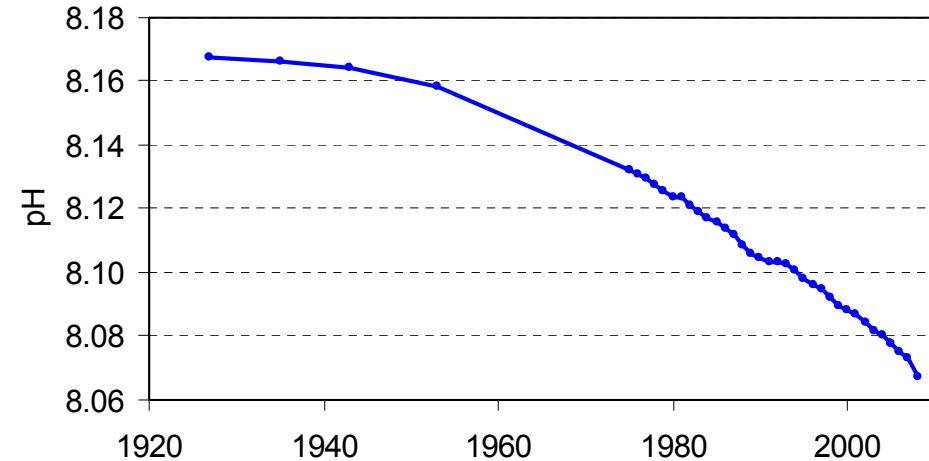
Surface water pH decrease calculated on the basis of increasing atmospheric CO_2 and constant alkalinity.

Rising atmospheric CO_2 leads to increasing dissolution of CO_2 in seawater and thus to a pH decrease.

4. Impacts: Marine Biogeochemistry

To simulate **scenarios for the future development of oxygen depletion and pH** on the basis of biogeochemical modelling (5) two combinations of forcing scenarios are used:

a. Climate model ECHAM with emission scenario A2   (CO_2 in 2100 = 840 ppm)

   +

   nutrient inputs according to „Business as usual"

b. Climate model ECHAM with emission scenario B1   (CO_2 in 2100 = 530 ppm)

   +

   nutrient inputs according to „Baltic Sea Action Plan"

4. Impacts: Marine Biogeochemistry
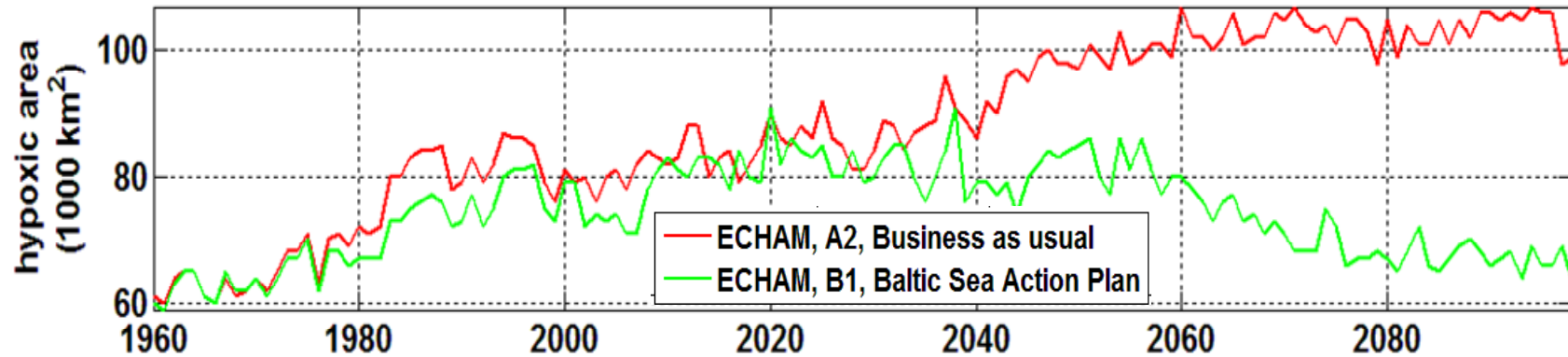
Mainly due to the Baltic Sea Action Plan the extent of the hypoxic areas ($O_2 <$ 2 mL/L) will be reduced until 2100 whereas „business as usual" will result in a continuous extension of hypoxia.
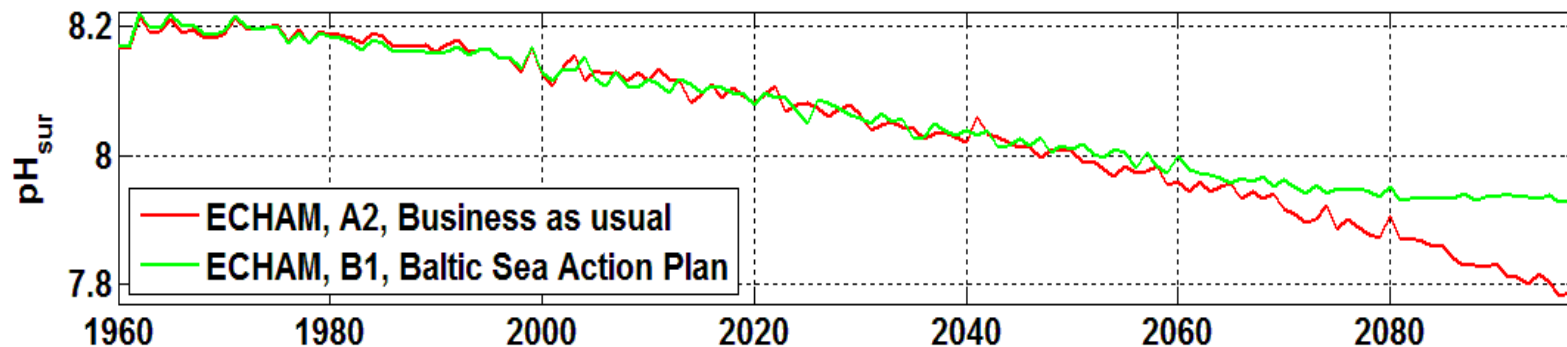
Despite the moderate B1 CO_2 emissions, the pH will continue to decrease but much slower than for A2 emission scenario.

4. Impacts

- The main changes in **air pollution** in the Baltic Sea region are due to changes in emissions rather than climate-change itself
- More **riverine disolved organic matter**, effects of climate on cultivated watersheds unknown, both positive and negative feedbacks on nutrient fluxes, agricultural practices will adopt fast.
- Terrestrial **ecosystems near the coast** most prone to climate change; significant increase in spruce growth in the North
- Higher turnover of **algal biomass** may lead to larger anoxic areas; pH will decrease
- Climate variability has led to **regimes shifts** in the Baltic Sea ecosystem; lower salinity will lead to less marine benthic species, unknown for pelagic groups (more nutrients and DOM may result in opposite effects)

- ***Very few evidence for impacts of climate change as such!***

Socio-economic impacts

BACC II – new subchapter : **Socio-economic impacts**

▪**Agriculture and forestry**: Update of BACC I (Forest Productivity) and new subchapter drawing on impacts on agriculture; Climate change affects directly vulnerability and productivity of agricultural and forestry systems- Predominantly by changes in precipitation and temperature patterns. Indirect impacts are altered risks for damage, such as increased stress periods (droughts etc.)

▪**Urban complexes**: **Impacts differ due to location** of urban complexes, be they in the northern or southern part of the catchment, directly at the Baltic Sea coast or more inland. **Every urban complex is a unique mixture** of infrastructure and urban services, inhabitants, natural resources and green spaces, built structures, economic and societal factors - hardly possible to generalize potential extent of climate change impacts from single-case studies. Urban complexes are subject to **other change processes** as well (demographic, economic, social, political, technological, land-use) which might interact with climate change impacts

▪**Coastal erosion and coastline changes**: Many natural and human influences on coasts – difficult to identify specific climate change impacts. **Key climatic factor for coastal development: wind driven factors.** Seasonal climate change (high water level, storm events, ice periods, heavy rain) can cause erosion, landslides, flooding
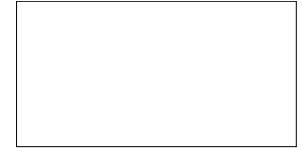
Socio-economic impacts: forests

KEY MESSAGES:

Improving conditions for forest management in the north may be counteracted by unfavorable impacts in the south.

The review adds on BACC I: c**changing conditions with different impacts from north to south**.
•**North**: Growing conditions tend to improve
•**South:** Declining growing conditions (reduced precipitation and increasing temperatures)
•This will also **cause changes in forest structures and diversity.**

Socio-economic impacts: urban systems
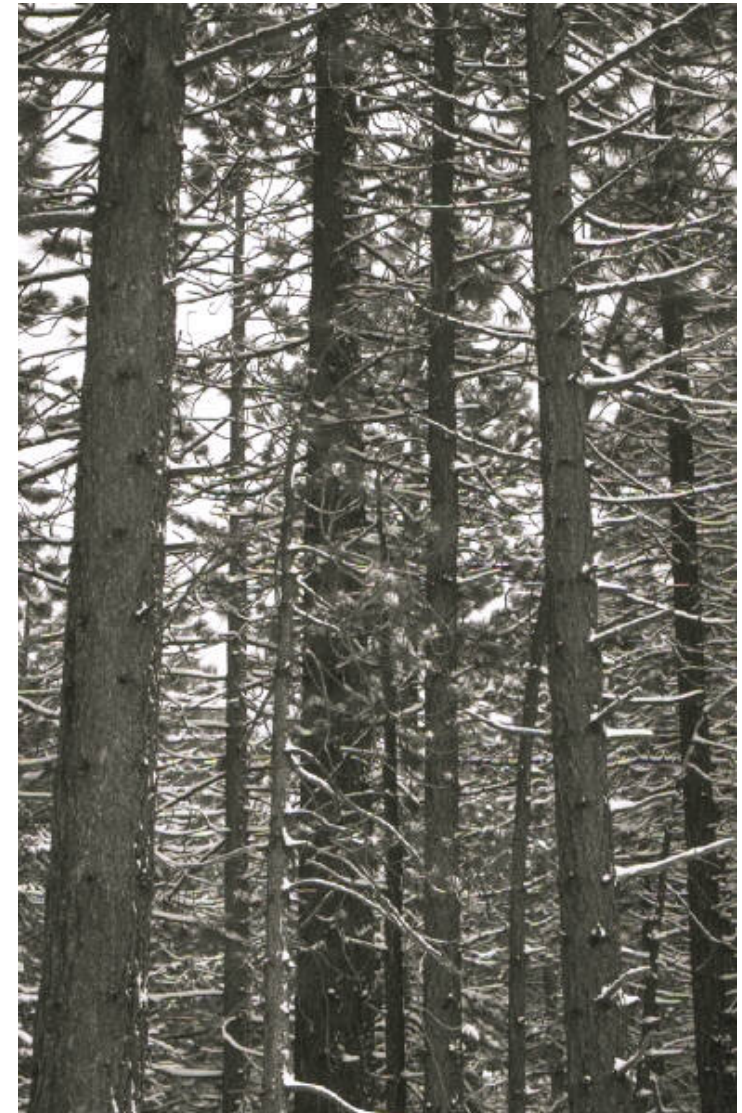
KEY MESSAGES:

Climate change impacts, which affect **urban services and technical infrastructure, building, housing and settlement structures** most: sea level rise, extreme events like storm surges and changing precipitation patterns, particularly expected increase in heavy precipitation events => flooding.

As the net-sea level rise is expected to be higher in the southern Baltic Sea, southern coastal cities such as Gdansk will be more affected

Wastewater: enhanced runoff, surface floods, overflow of sewage systems
Drinking water supply: decrease in water quality, saltwater intrusion (coastal cities),
Transport: less salting and gritting, threats to roads and railways through sea-level rise and floods

Socio-economic impacts: coastal systems

Changes in coastal erosion and coastlines over the last years:

1. Higher water overflow on the coast during storm surges, caused by sea level rise and beach lowering.

2. Bigger rate of erosion of beaches, dunes and cliffs. Now each Baltic country notices up to 2 m coast erosion per year on average in most threatened places.

3. Coasts withdraw with higher rate. Till end of 20th century it was 0.2 to 0.5 m/y, and now it is 0.5 to 1 m/y

4. After above average storm surge (differently in each country) retreat is 5-10 m of the land.

5. More flooding of low lying areas or river mouths and lagoons.

6. Longer coast sections are subject to protection measures.

▪**Difficult to come to general conclusions:**
▪**Other changes are occuring** next to climate change – difficult to detect specific climate change impacts
▪There are **lacking general studies** on specific topics or specific fields taking into account a greater number of urban complexes in the Baltic Sea Basin

Possible socio-economic impacts:

Potential benefits for tourism, human health in the north (less cold stress), less heating in buildings, improved growing conditions for agriculture and forestry in the north
Possible drawbacks: Loss of economic values and of private property at the coastline and in cities. Increased costs for management for protection and adaptation of urban of coasts, infrastructures and settlement structures, for insurances and health care. Worsened conditions for agriculture and forest productivity in the south

But: Adaptation is possible and required in forest management and agricultural production as well as in urban complexes. At the coasts beneficial strategies depends on the specific place and chosen priority.

Assessment of Climate Change for the Baltic Sea Basin
BACC II
International Conference · 6 – 7 September 2012 · Tallinn, Estonia

Detection and attribution

Terminology

Climate change: Deterministic response to changes in external forcing

Internal variability: Random fluctuations independent of external forcing

Detection: "The observed climate change is unlikely due to internal
                     variability alone" = detection of (some) external forcing

Attribution: Mix of plausible external forcing mechanisms that best
                     explain the detected change.
i) Consistency: simulated response to forcing is consistent with
                     observed change
ii) Exclusiveness: no other plausible forcing (or combination) is able to explain
                     the observed change

Detection and attribution

- Detection of non-natural influence on regional **warming.** Can be explained only by increased greenhouse gas concentrations. Present trend consistent with model scenarios.

- Detection of non-natural component in trends of **precipitation amounts**; present rends much larger than what is anticipated by models; thus no consistent explanation for the time being.

- Lack of studies on detection of changes in other variables (e.g. snow cover, runoff, sea ice)

Detection and attribution

▪ very few studies dealing with the **regional** questions; a large body of literature for global issues exists

▪ Meaningful regional attribution studies hardly possible, because expected changes due to regional aerosol and land-use forcing unavailable-

▪ Commonly used regional models fail to describe the effect of varying aerosol atmospheric loads; this is a serious limitations of the tool box of regional climate science.

▪ Basic research on the climatic effect of changing regional land-use needs more attention.

▪ ***The finding that present warming can quantitatively only be explained by assuming GHG forcing to be dominant driver is conditional upon the assumption that neither reduction of aerosol loads nor regional land use are skilful explanatory variables. This represents a serious limitation in knowledge.***

Overall Summary

1. New assessment finds results of BACC-1 valid.

2. Significant detail and additional material has been found and assessed. Some contested issues have been reconciled (e.g., sea surface temperature trends)

3. Ability to run multi-model ensembles seems a major addition; first signs of detection studies, but attribution still weak.

4. RCMs need further development.

5. Homogeneity is till a problem and not taken seriously enough in some scientific quarters.

6. The issue of multiple drivers on ecosystems and socio-economy is recognized, but more efforts to deal with are needed.

7. Climate change is a serious issue, but in many cases is remains questionable if it is a dominant issue.,