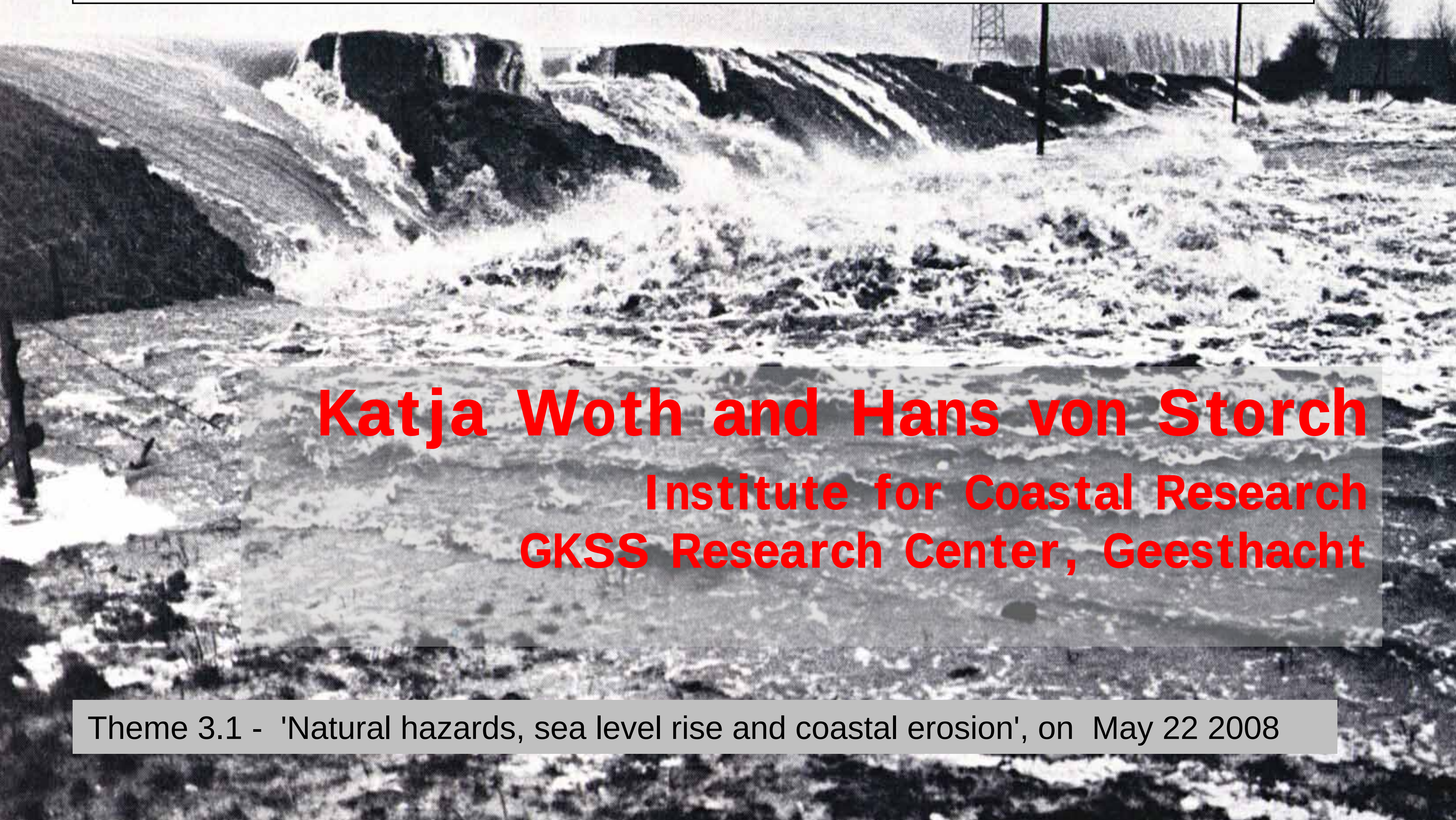
Storm surges, perspectives and options



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GKSS Research Center, Geesthacht

Theme 3.1 - 'Natural hazards, sea level rise and coastal erosion', on May 22 2008

Overview

1. Storm surges – global phenomenon, with regional manifestation.
2. Midlatitude storminess
3. The case of the German Bight
4. The case of Hamburg – assessment and options

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Storm surges are a global phenomenon – in regions, where strong storms happen

- at mid-latitudes (e.g., North Sea, Baltic Sea, Adriatic, Irish Sea ...)

- in the tropics where typhoons emerge.

Storm Nargis

Tropical storms surges: typical spatial scale of storm 500-1000 km; amplitude up to 7-8 m; 200 km coast line affected; several hours up to half a day (Gönnert et al., 2001)

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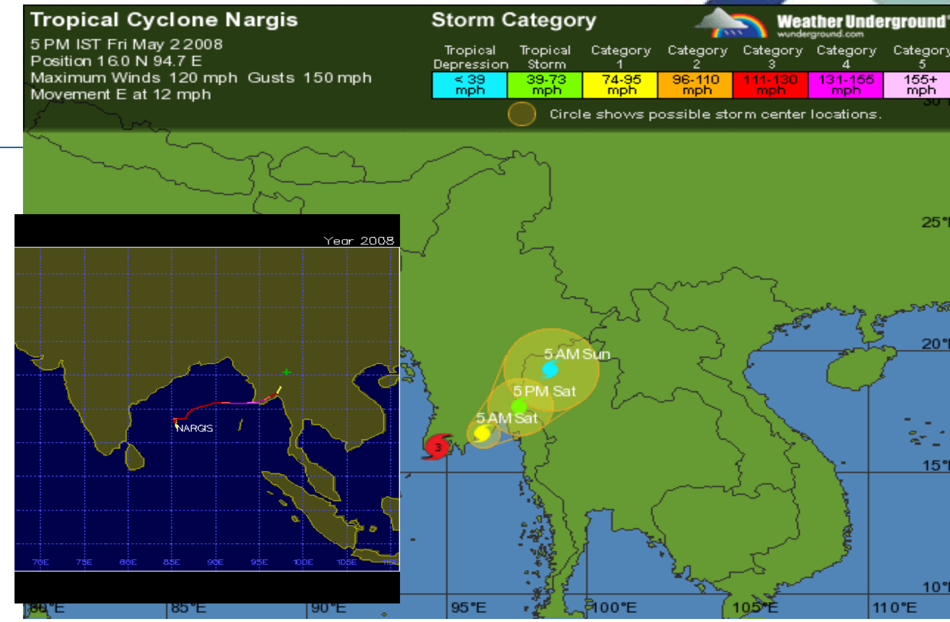
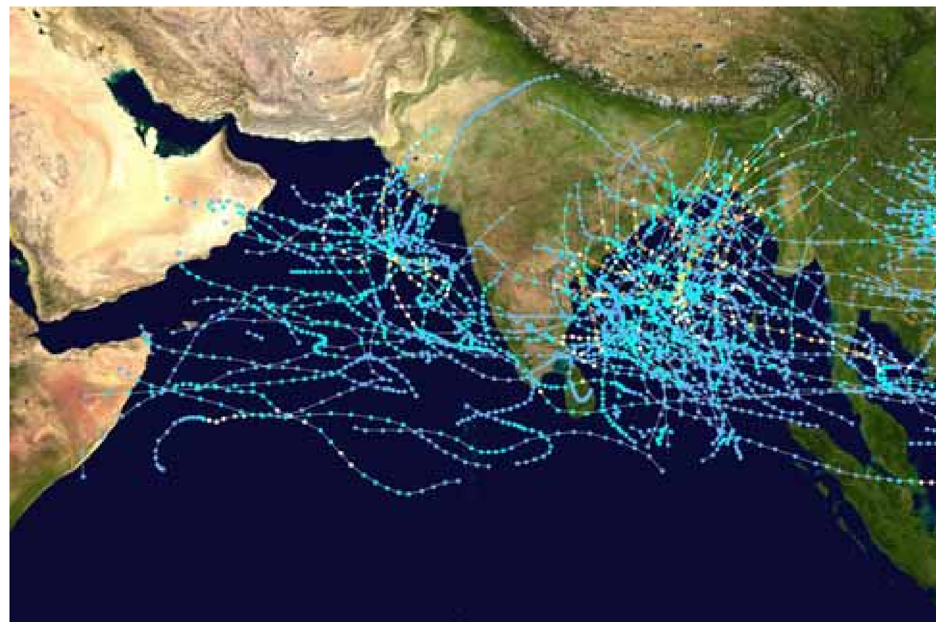
Two scientific tasks:

- operational forecasting
- determining present risk, present change of risk and possible future risk





Tracks 1980-2005

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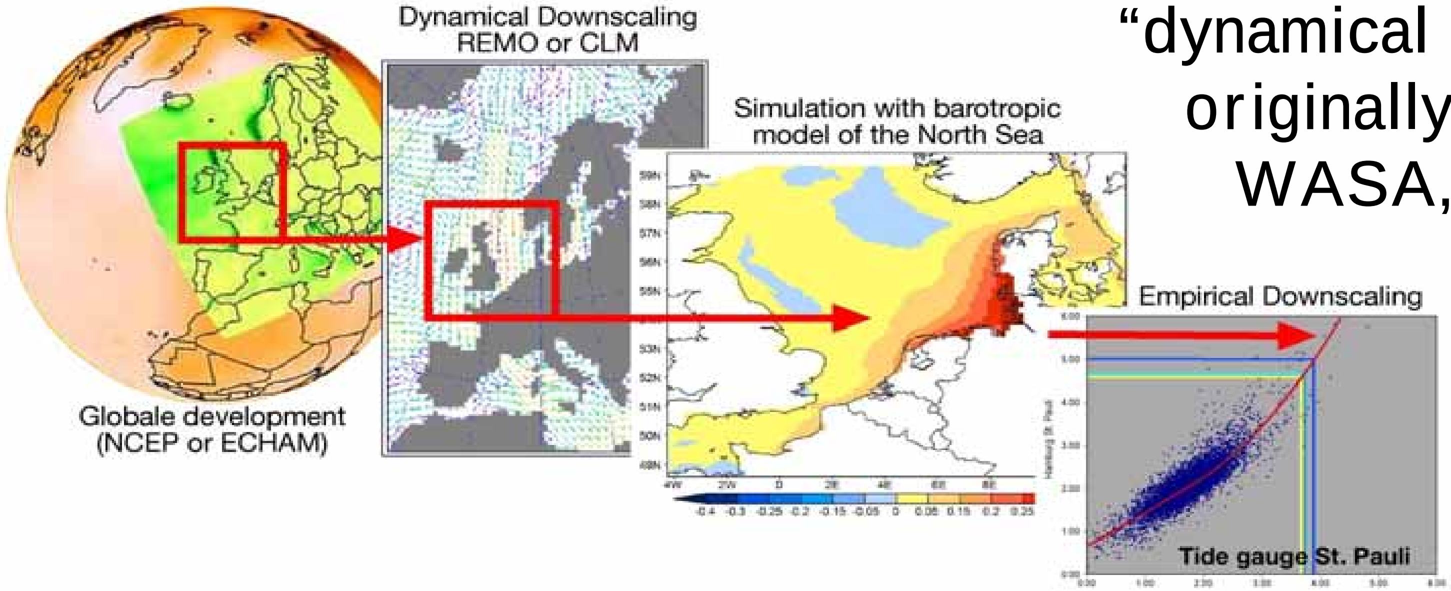
Climate community dealing with recent, present and future storm surge climatology is fragmented.

In Europe since WASA and STOWASUS significant progress has been made (see below); in other parts of the world only little; in tropical regions none.

The European methodology of "dynamical downscaling", originally developed in WASA, is presently exported to other parts of the world.



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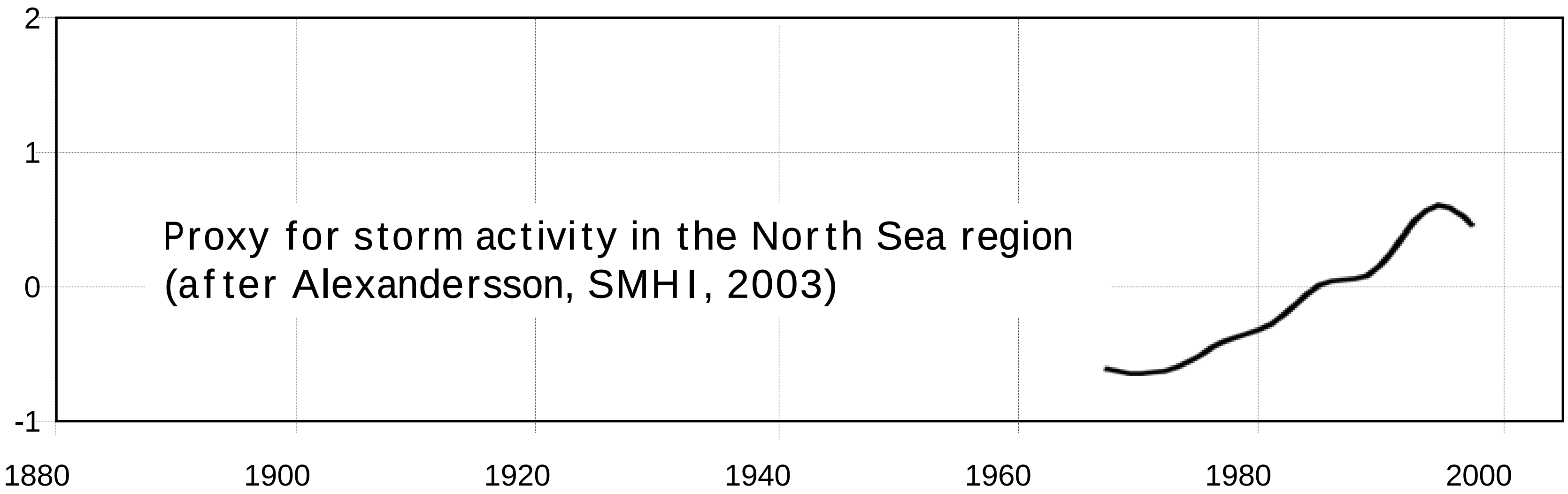
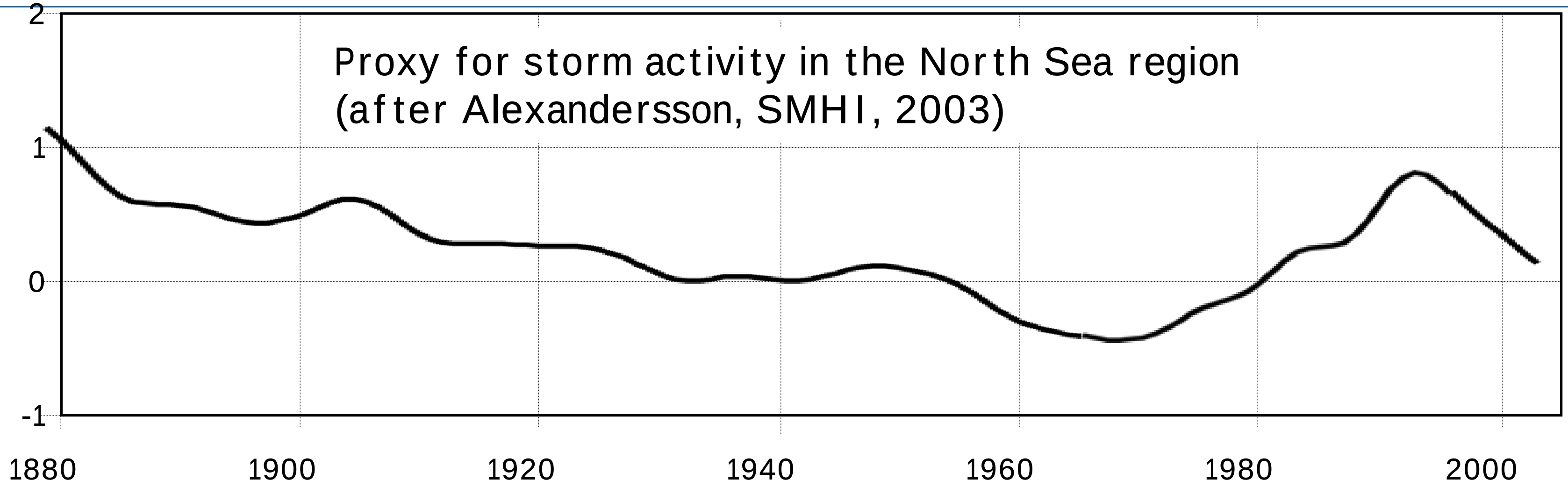
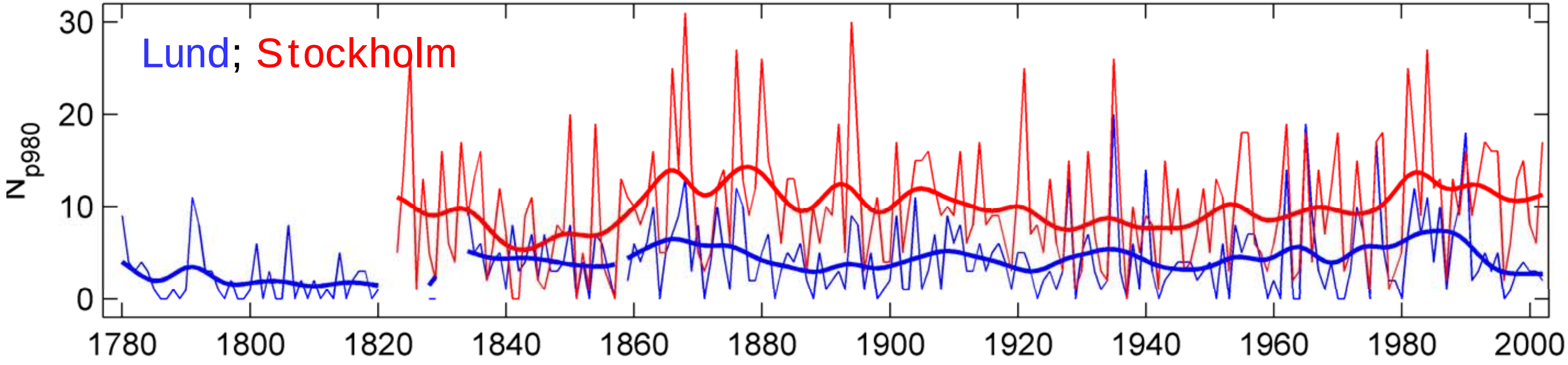
In the early 90s, the specter of Global Warming entered the perception of people. Storm got worse.



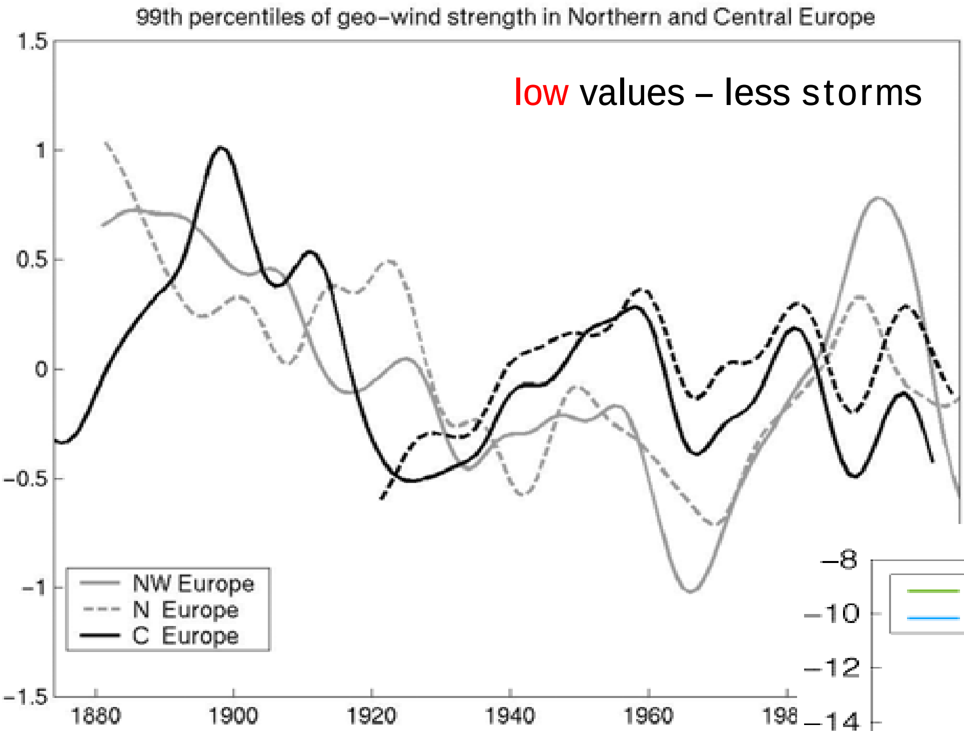
- Scientists related worsening of storm climate to GHG emissions (warmer world > more water vapor > more energy for storms > situation will continue to worsening).
- Insurance companies supported the claims.
- Media took up the message, which is consistent with cultural pre-conception of humans changing climate to become worse.
- Nowadays widely accepted among media and lay-people that storms are getting worse. However, the claim is false.





Bärring, L. and H. von Storch, 2004: Northern European Storminess since about 1800.
Geophys. Res. Letters 31, L20202, doi:10.1029/2004GL020441, 1-4

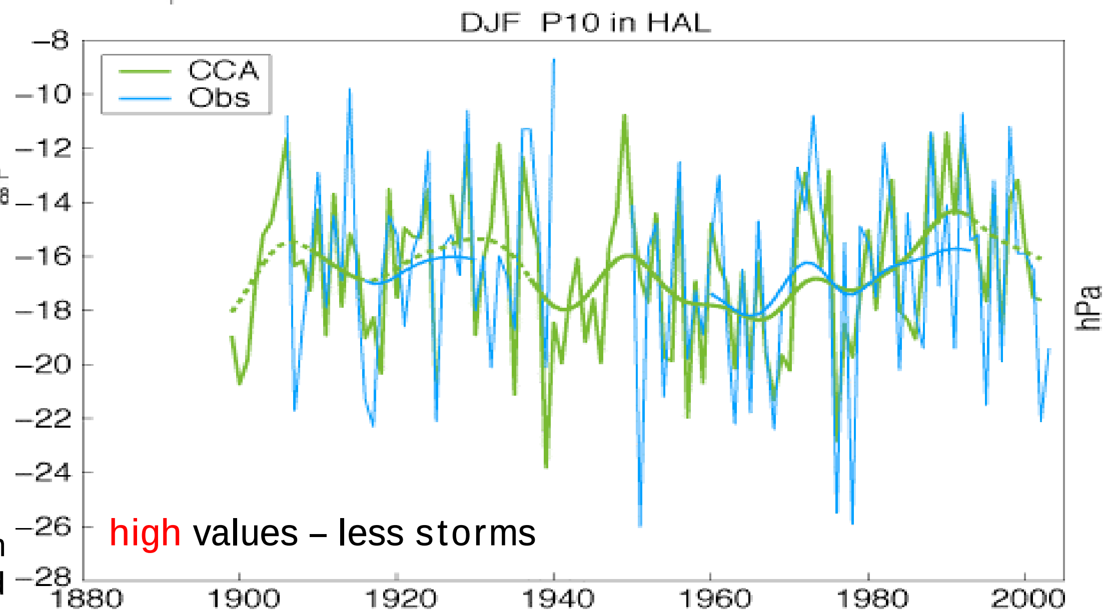
Air pressure-based storm proxies for …



… NW, N and C Europe

Matulla, C., W. Schöner, H. Alexandersson, H. von Storch, and X.L. Wang, 2007: European Storminess: Late 19th Century to Present, Climate Dynamics DOI 10.1007/s00382-007-0333-y

… East Canada



Matulla, C., and H. von Storch, 2008: Changes in Eastern Canadian Storminess since 1880. submitted

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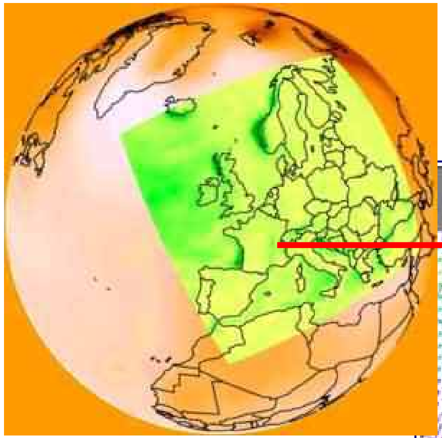
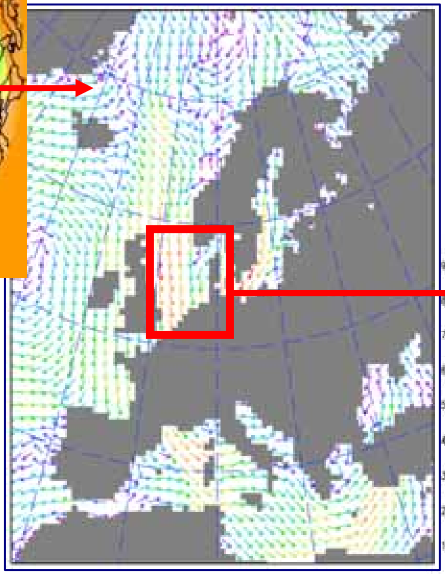
Dynamical downscaling of recent, ongoing and possible future storminess and associated risks

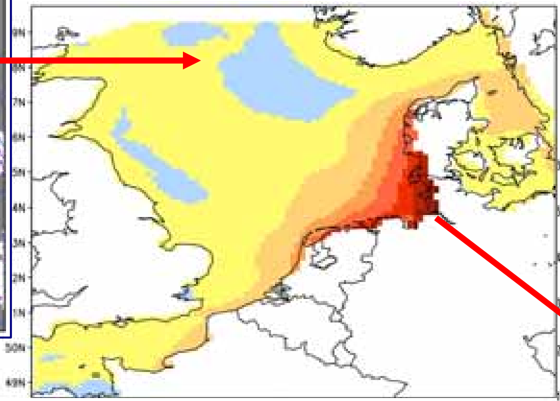


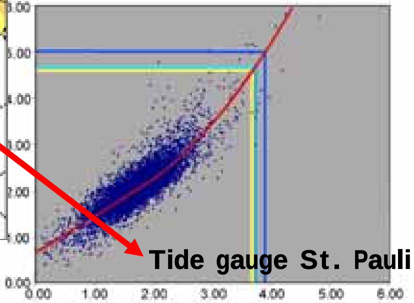
Global scenario



Dynamical Downscaling

Model of
North Sea hydrodynamics





Empirical "localization"

Joint work with regional authorities.

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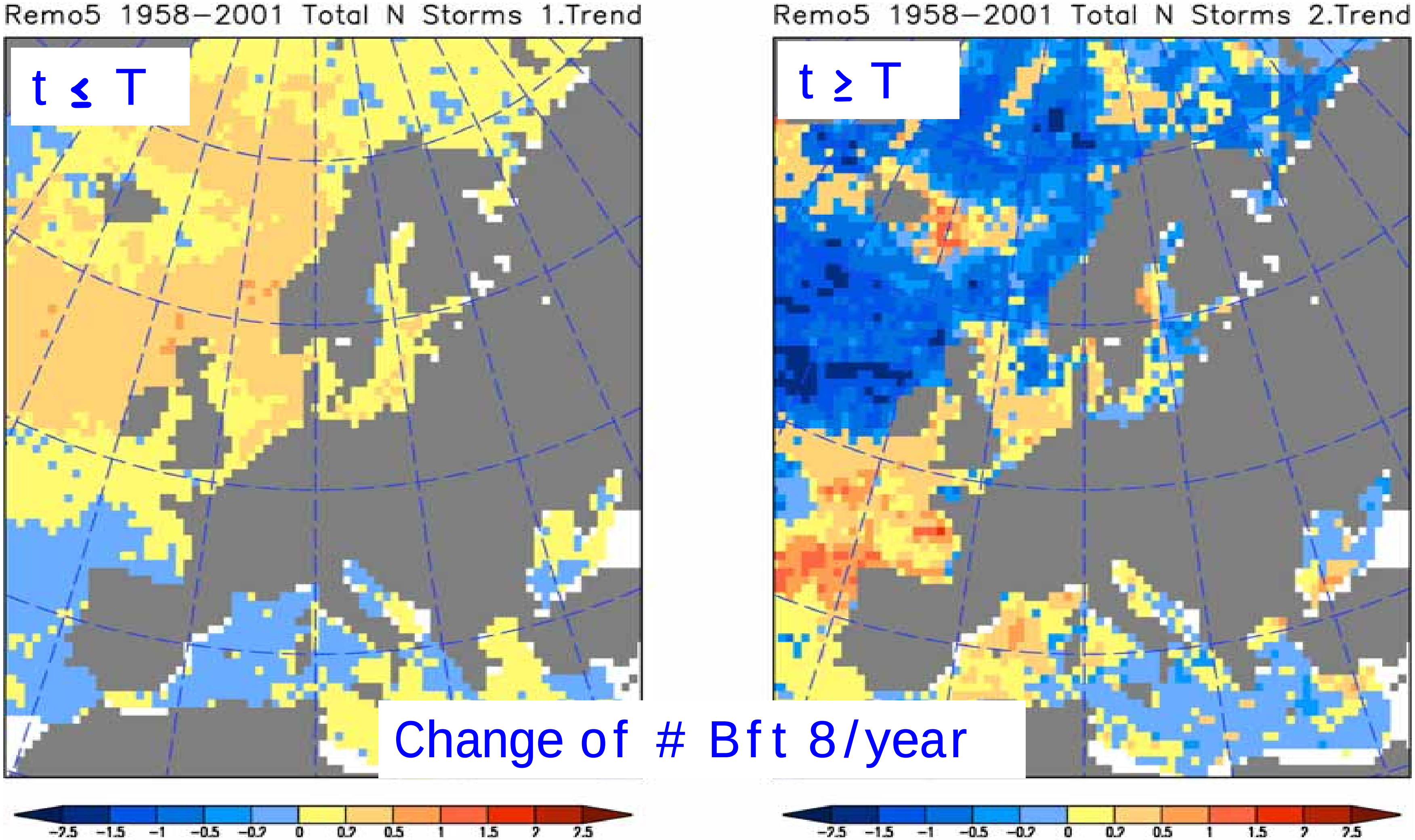
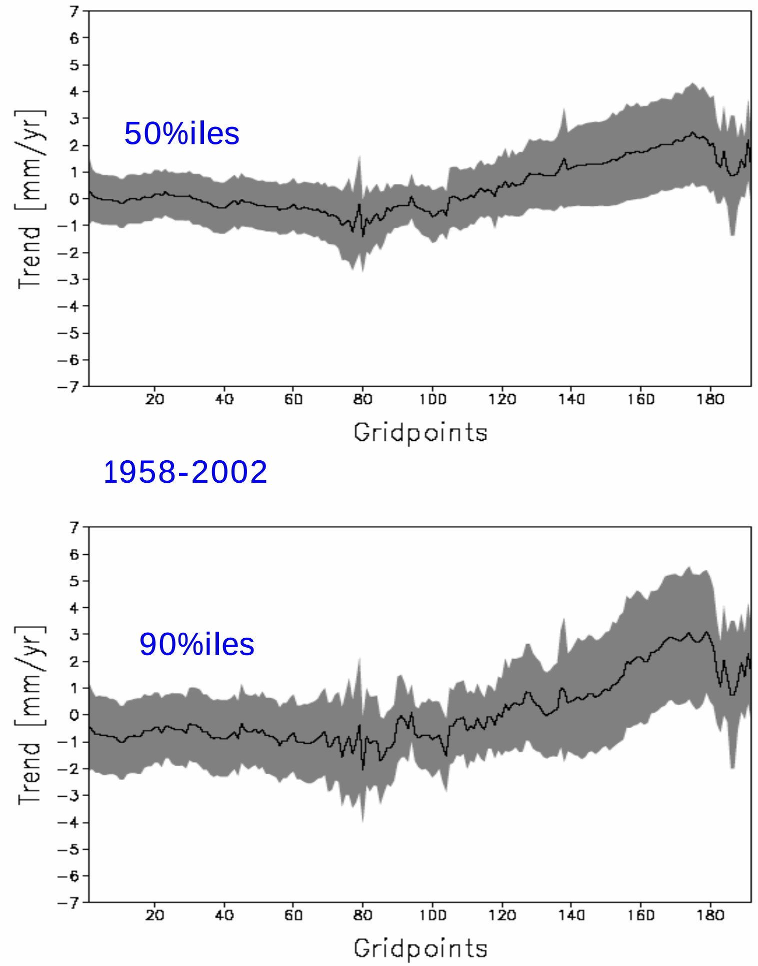
Stormcount 1958-2001



Weisse et al., J. Climate, 2005

1958-2002 Trends of annual percentiles of storm surge heights



Weisse & Plüß, 2005

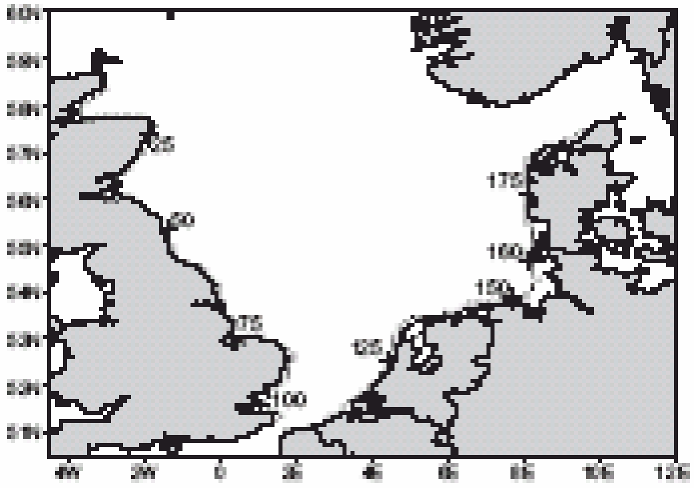


Fig. 8. Linear trend 1958-2002 in mm year^{-1} (solid) of winter (Nov-Mar) mean (upper) and 90%-tile (lower) high water. The 95% confidence interval based on a local t-test is indicated in grey. The x-axis represents grid points along a cross section. The exact location of the cross section can be inferred from Figure 9.

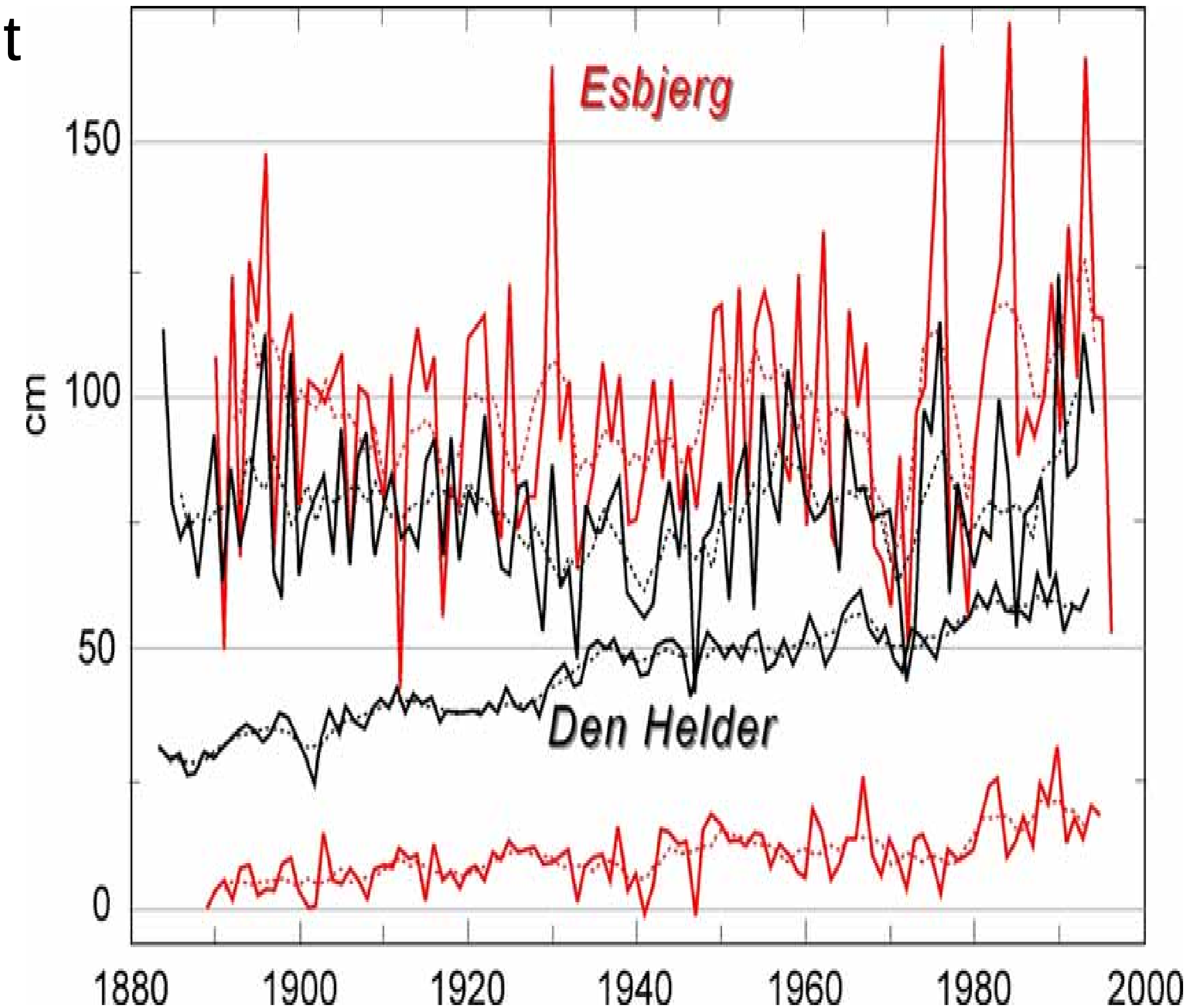
Case of German Bight

Temporal development of intra-seasonal 99%ile of high tide levels AFTER subtraction of annual mean high tide

and mean annual high tide

in Esbjerg (Denmark) and Den Helder (The Netherlands)

until 1995.



Case of German Bight

Change of regional sea level and of tidal range in the North Sea –

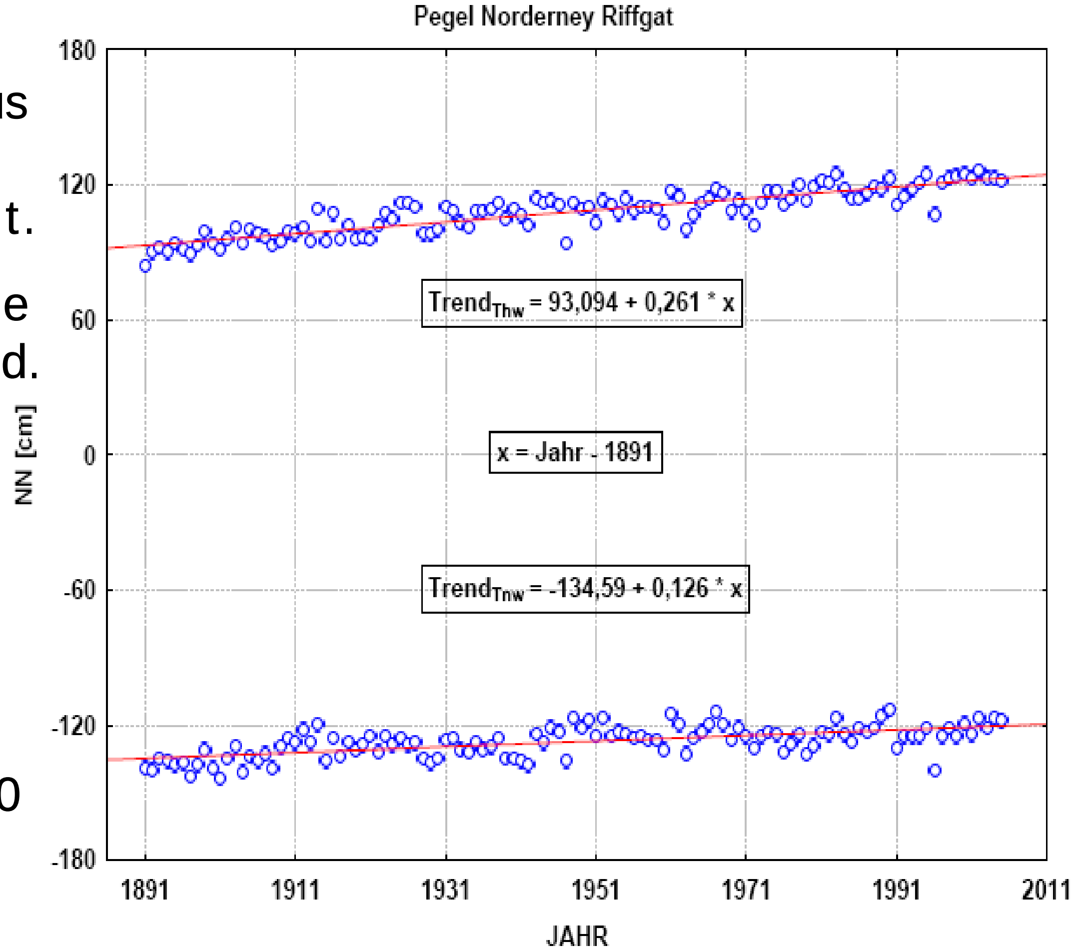
at most locations, data inhomogenous because of ubiquitous water works in harbours along the coast.

One exception is “Norderney”, where the “Forschungsstelle” is situated.

It shows:

a) A monotonous increase of both mean high tide levels, low tide levelks, and of the mean tidal range.

b) Sea level rise amount to about 20 cm/100 years without acceleration.



H.-D. Niemeyer, Norderney, pers. comm

Recent, ongoing:

Natural climate variability in storminess

Effect of water water works

Mean sea level rise possibly about 2 mm/yr

Scenarios of possible future conditions:

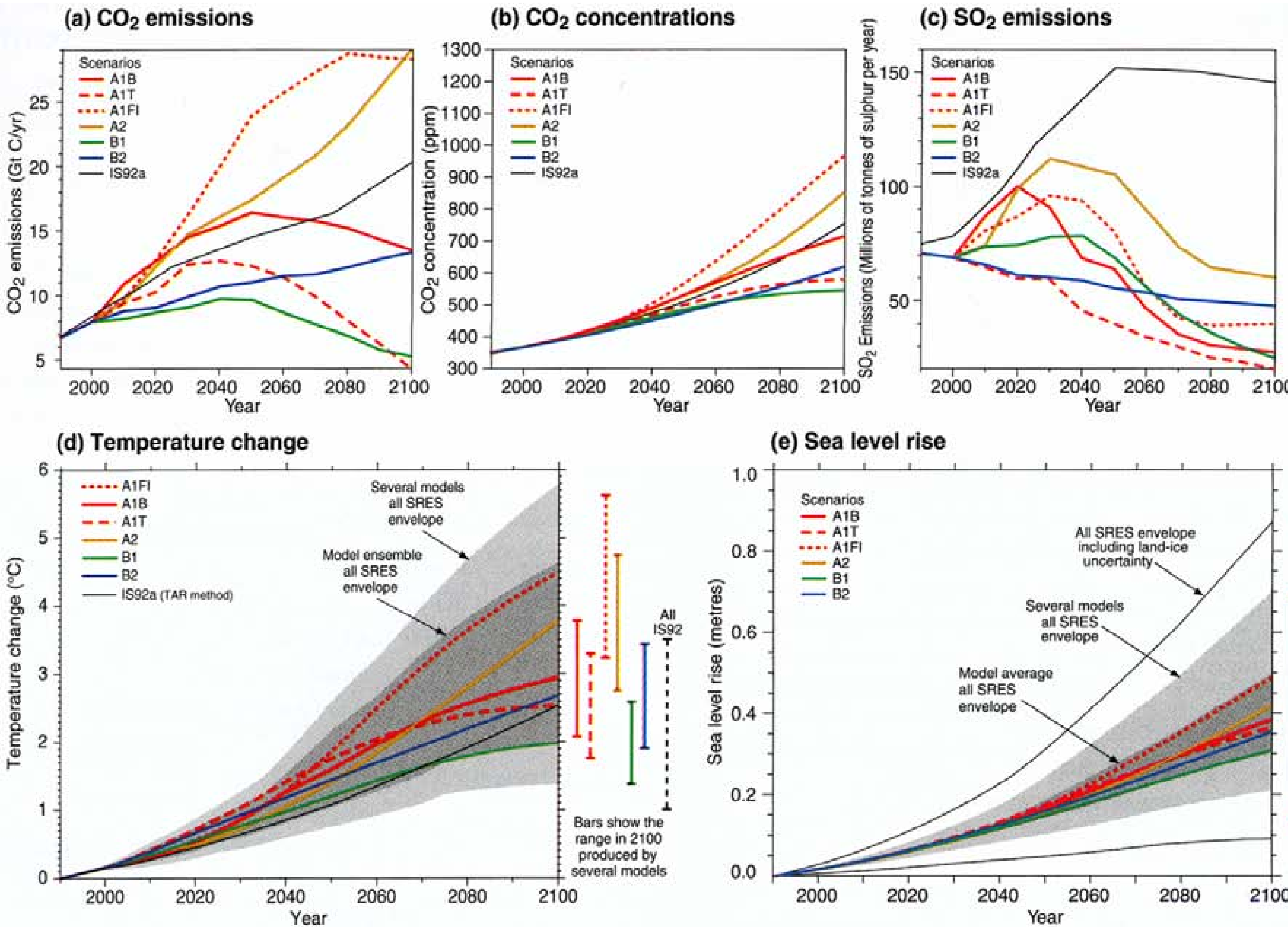
To the end of 21st century, strongest westerly winds enhanced by about 10%.

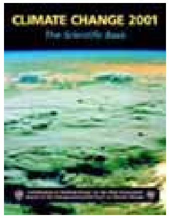
Wind/Air pressure induced increase of storm surges: 20-25 cm.

Mean sea level rise – unclear, likely larger than global mean sea level.

Increase in storm surge heights in 2030 about 20 cm, in 2085 about 60

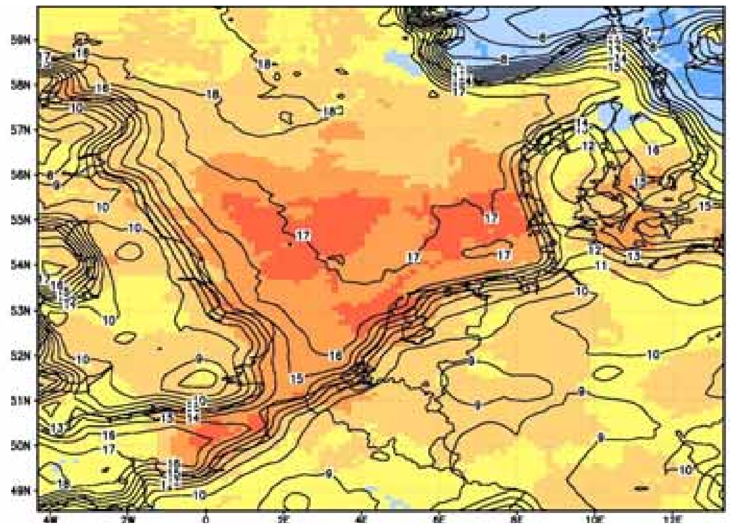
“SRES” Scenarios
SRES = IPCC Special Report on Emissions Scenarios



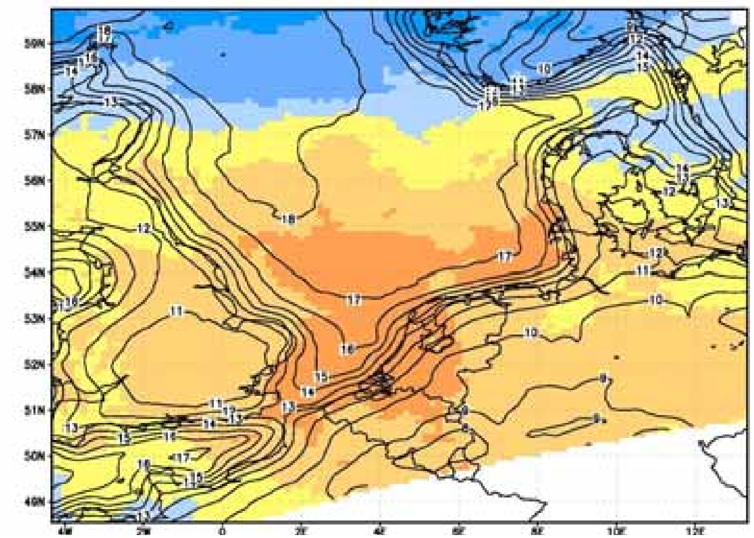


A2 - CTL: changes in 99 % - iles of wind speed (6 hourly, DJF): west wind sector selected (247.5 to 292.5 deg)

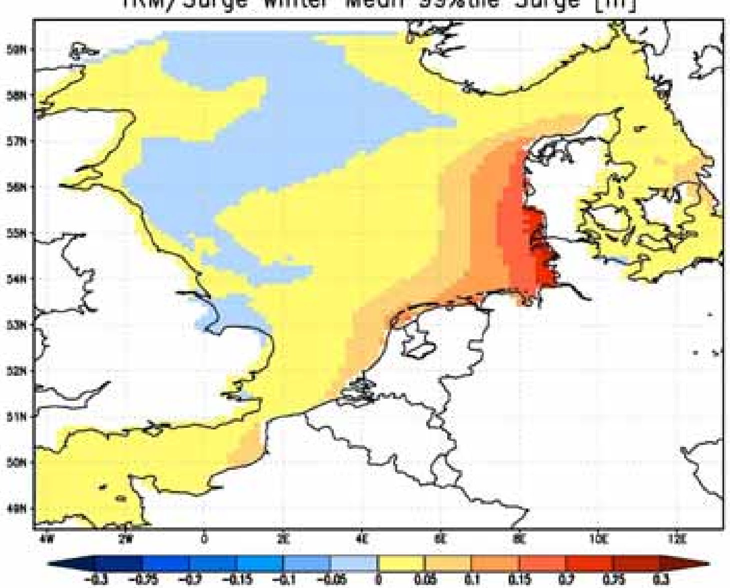
HIRHAM



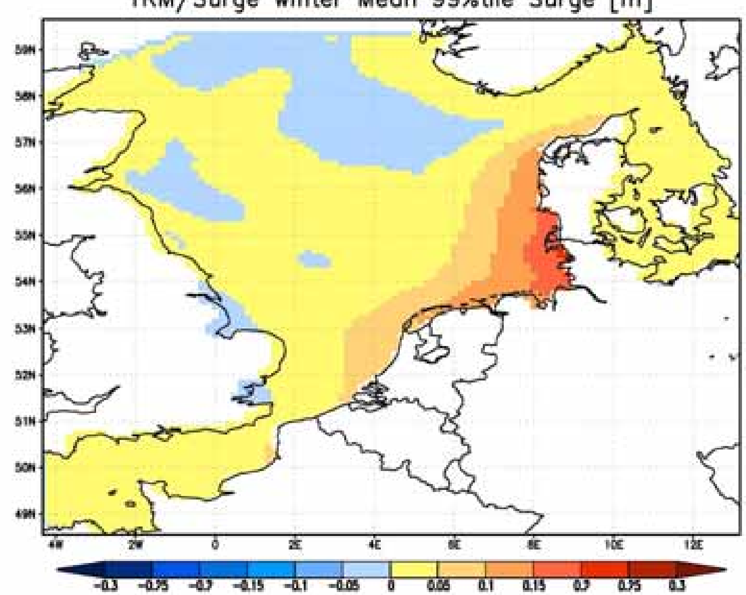
RCAO



TRM/Surge winter Mean 99%tile Surge [m]



TRM/Surge winter Mean 99%tile Surge [m]



Scenarios for 2085

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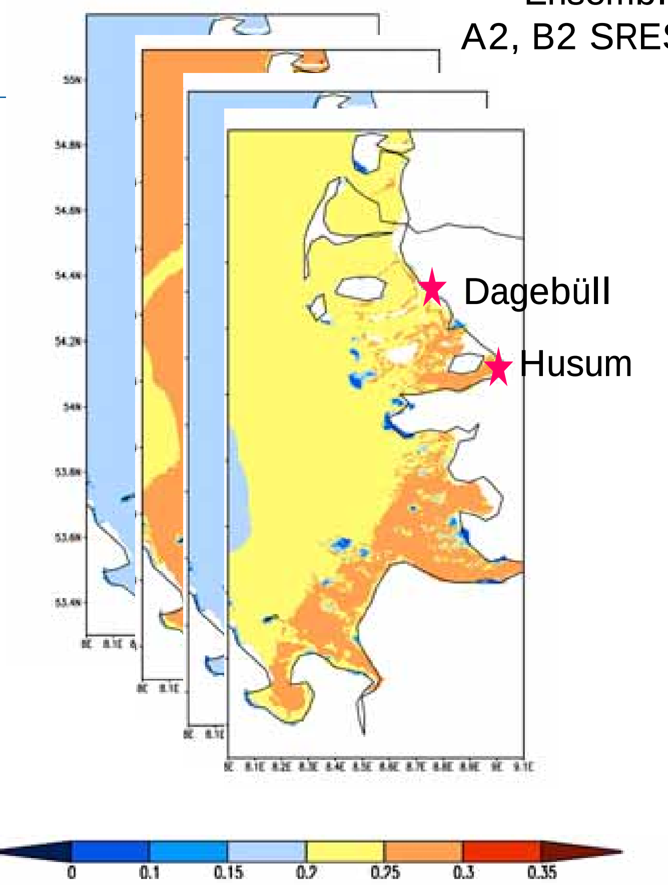
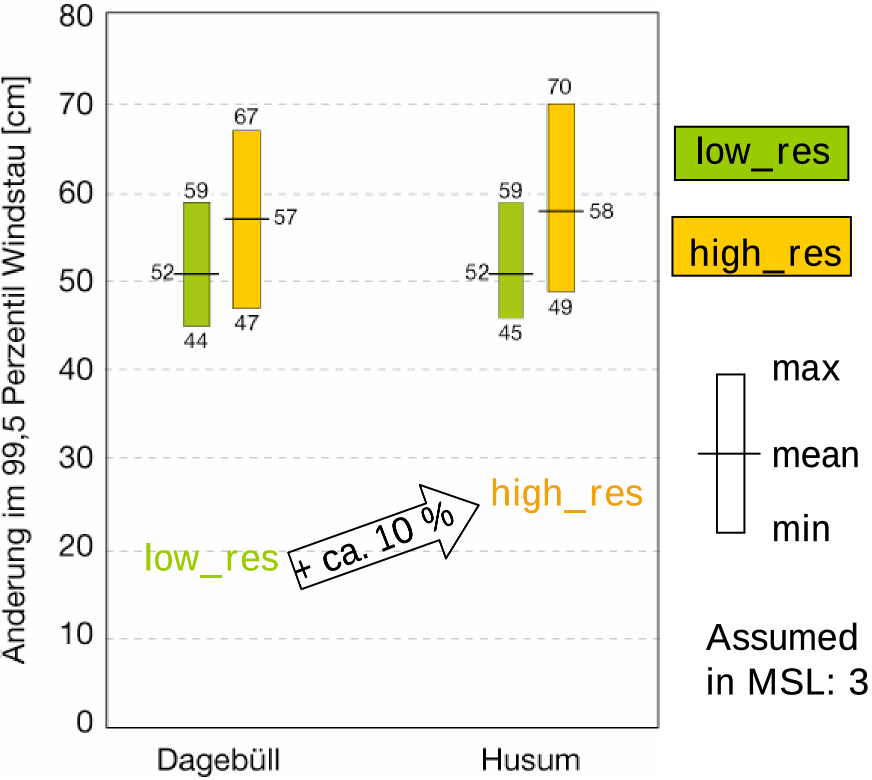
"Localisation": From the 10 m line to the shore

Δ wind effect, 99.5%-ile [m], Ensemble A2, B2 SRES



Change of winter 99.5%ile of wind and air pressure related water levels (6 hourly data)

Δ wind effect, 99.5%-ile [cm] +increase MSL



Assumed increase in MSL: 30 cm

Estimated with a regression model, trained with high resolution hindcast.

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Overview

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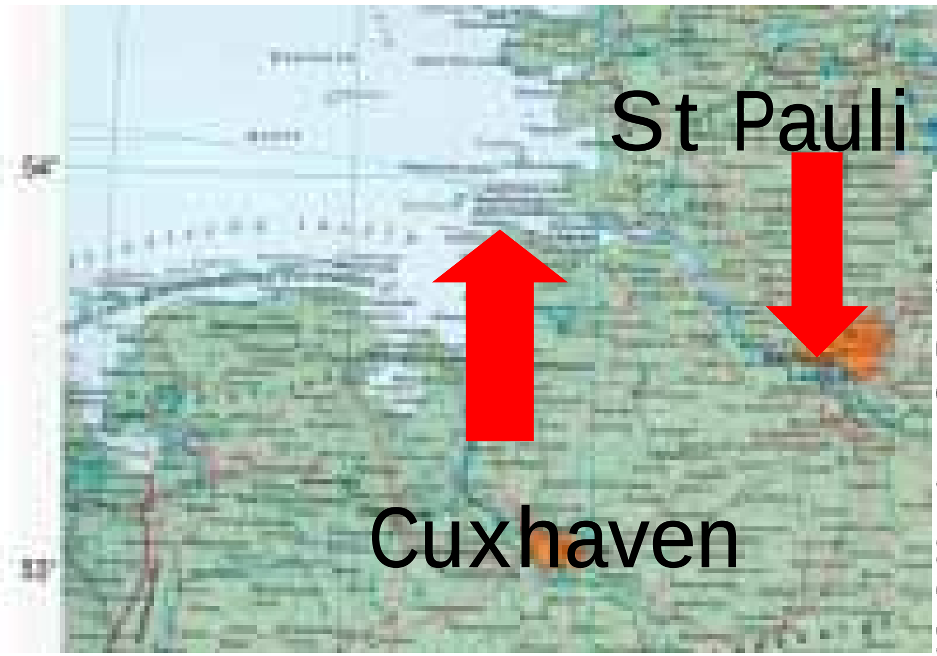
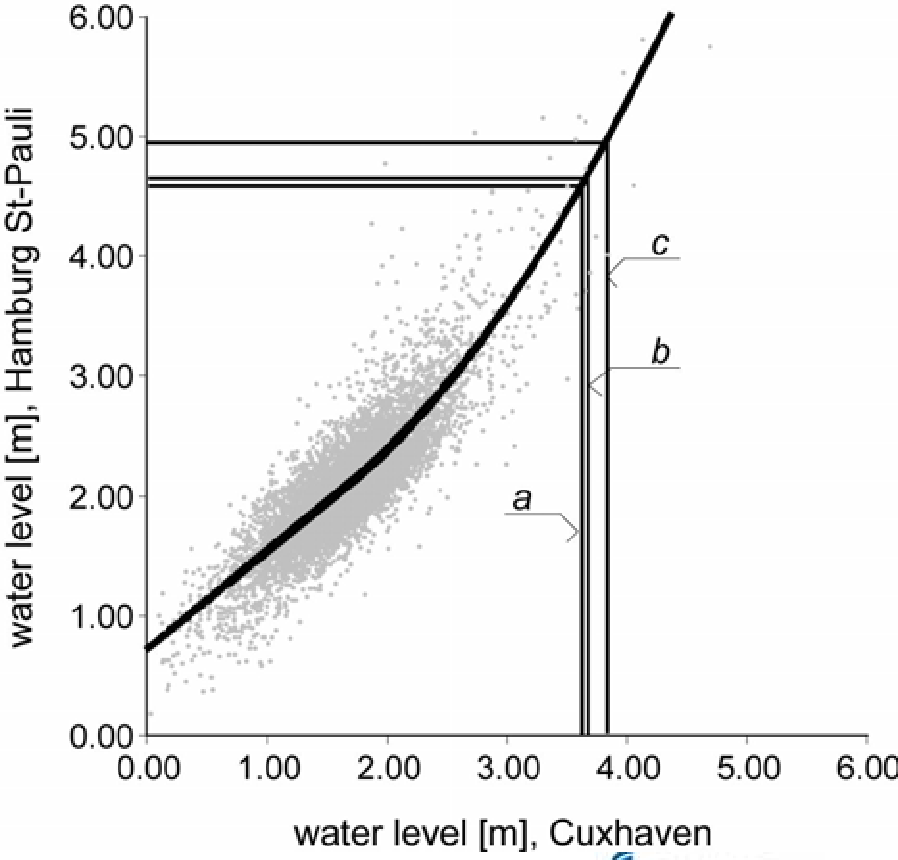
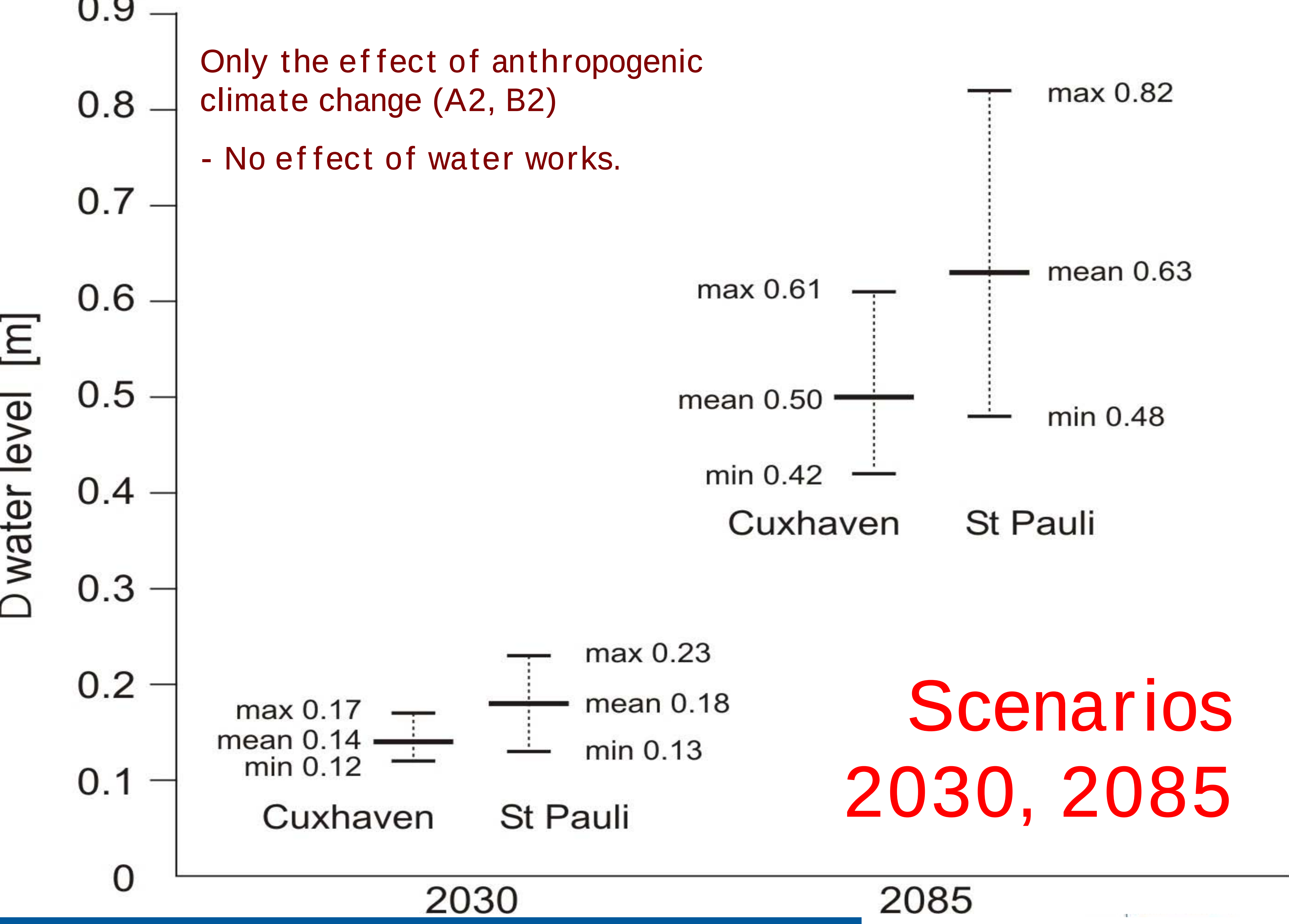
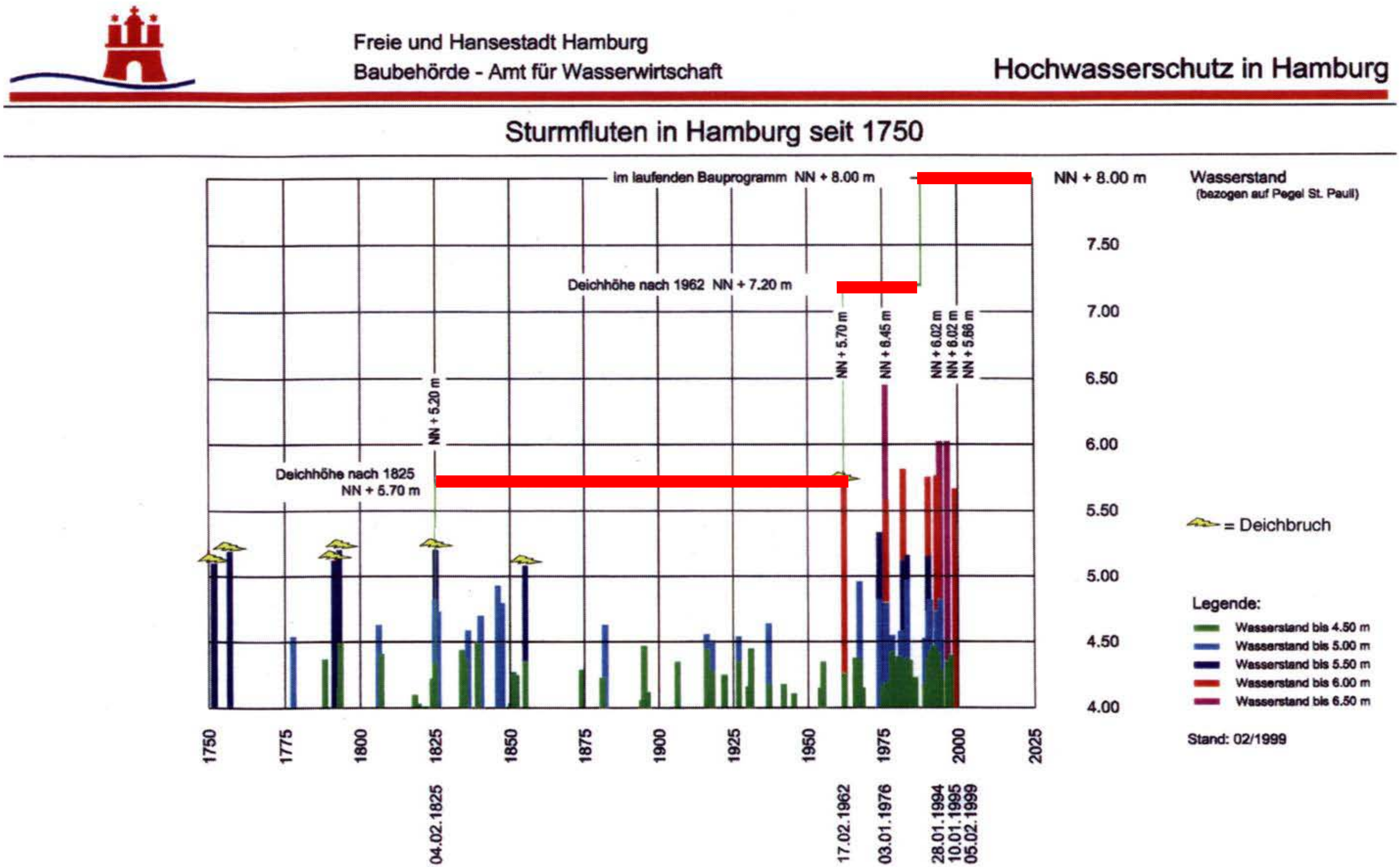
"Localisation": From the coast into the estuary






Only the effect of anthropogenic climate change (A2, B2)
- No effect of water works.
Scenarios 2030, 2085
D water level [m]
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
max 0.17
mean 0.14
min 0.12
max 0.23
mean 0.18
min 0.13
Cuxhaven
St Pauli
2030
max 0.61
mean 0.50
min 0.42
max 0.82
mean 0.63
min 0.48
Cuxhaven
St Pauli
2085

Hamburg – storm surges



Where does the enhanced storm surge levels Hamburg come from?

- Sea level rise – a few centimeters
- Intensification of storm activity 1960-1995

- What else has happened in the coastal/estuarine environment?

Difference in storm surge heights – mouth of Elbe estuary and Hamburg, 1900- 2005

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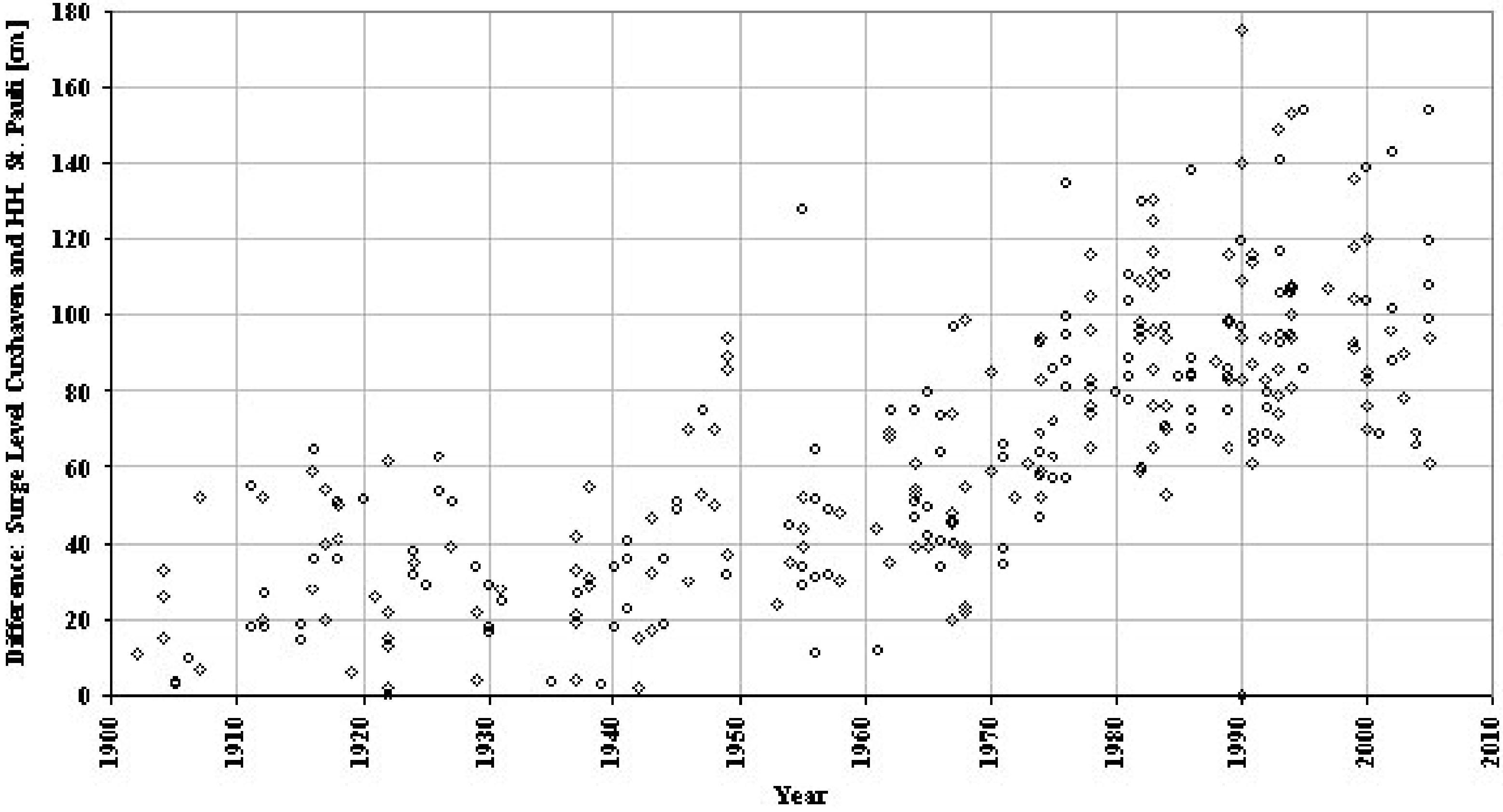

The tidal change is due to coastal protection measures and modifications of the tributaries, and to the deepening of the shipping channel. These measure also had an effect on the heights of severe storm surges – estimates are 45 cm caused by measures of coastal defense and 15 cm by deepening the shipping channel (Haake, 2004: 27).

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Options for dealing with future elevated storm surge levels

- at the coast:

  + fortifying, extending presently installed coastal defence
  + flexible response strategies;
  + design dykes such that the amount of water which may safely spill over for a few hours, is considerably larger than allowed today.

- in the estuary: partial undoing of previous man-made increases

Dyke overtopping tolerance

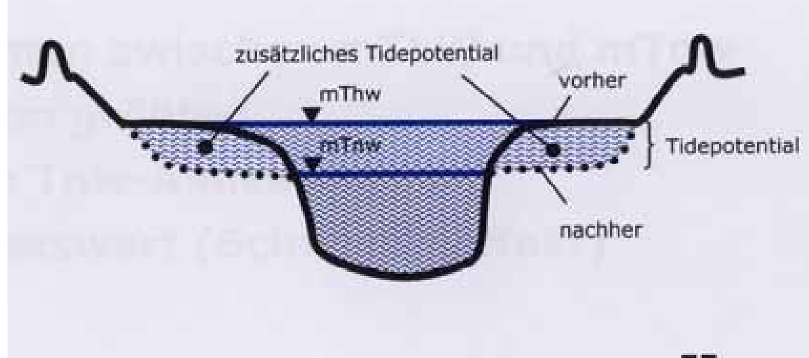
- **Currently overtopping tolerances:**
  - 3% of all – Lower Saxony
  - 2 l/(m·s) – Masterplan Schleswig-Holstein
  - 0,1-1,0 l/(m·s) – The Netherlands

- **Results of overtopping test in Delfzijl/NL**
  - No damage up to **50 l / (m · s)**
  - No severe damage at 50 l (m · s)
  - after artificial damage still functioning

Niemeyer & Kaiser 2008, NLWKN

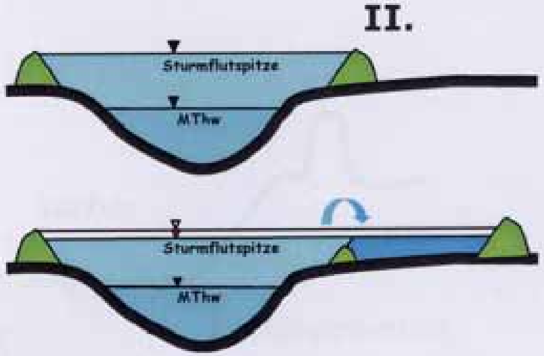
Dealing with rising sea level and elevated storm surge heights in Hamburg

1. Additional flooding areas

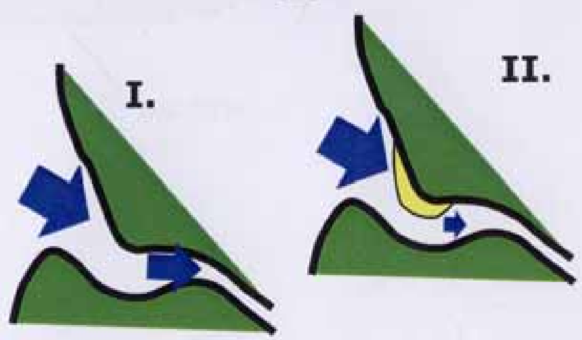


The Tidal Elbe concept of Hamburg Port Authority

2. Availability of additional polders to be flooded during severe storm surges to cap the peaks of such surges.



3. Additional dissipation of tidal (and surge) energy by narrowing the mouth segment of the estuary



Heinz Glindemann, HPA, pers. comm.

Conclusions

- Storm surges are a serious issue
- Storm surges are an interesting issue.
- We have developed a methodology to characterize recent, ongoing and possible future storm surge conditions
  - by analyzing air-pressure proxies available for the 20th century and longer, and
  - by running a cascade of global/regional/impact models
- The North Sea is the best studied area, with no indications for present man-made change but perspectives for increases of 20 cm and 70 cm in 2030 and 2085 in its SE storm surges. These numbers are uncertain and represent scenarios.

Conclusions

- Most of the increase will take place even if the ambitious climate control measures will be successful. Thus the preparation of adaptive mearues are needed.
- Novel adaptive measures need to be developed and examined, e.g.,
  - damping of incoming tidal energy in estuaries
  - improving dyke design to allow for stronger overtopping.
- The same type of studies need to be implemented in tropical regions.