

Climate change and its impact on regional seas: What do we know?

Marine weather and its impact

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Marine weather and impact

- ... is mostly determined by the statistics of storms
- ... major impacts refer to storm surges and waves, but also currents and mixing ...
- Institute for Coastal Research@GKSS has simulated past and ongoing changes of storminess and its impact as well as scenarios of future changes in the Northern European region (**CoastDat**)

This presentation
extra-tropical storms
in the NE Atlantic /
North Sea / Baltic
Sea

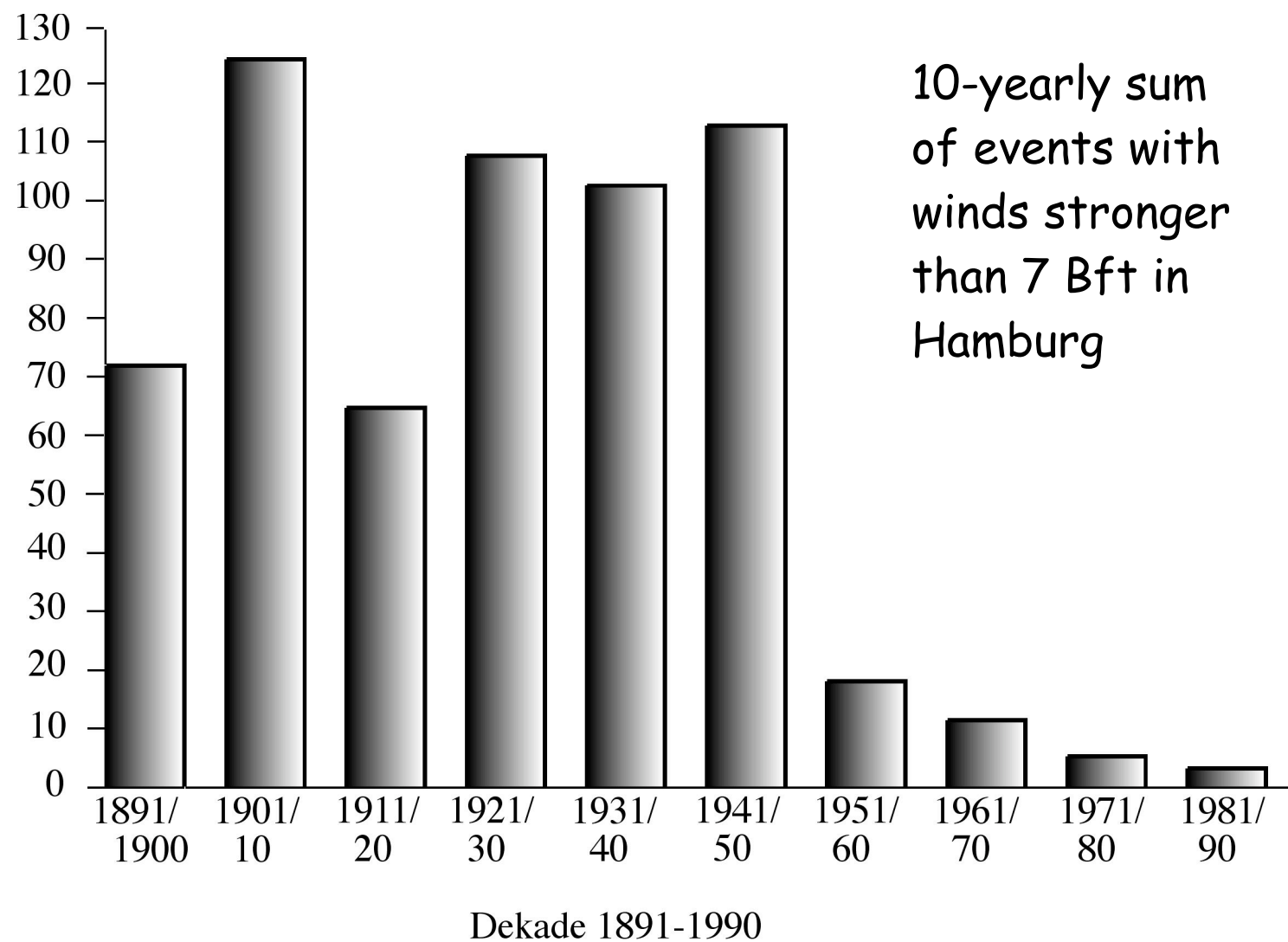
The background image is a grayscale satellite view of a large-scale weather system, likely a cyclone or storm, over the North Atlantic Ocean. The storm's eye and spiral cloud bands are visible. To the left of the storm, a vertical column of numerical values represents a pressure scale, ranging from 4388 at the top to 1338 at the bottom, with increments of 180. The text is overlaid in a large, bold, red font with a yellow outline.

1. How to determine decadal and longer variations in the storm climate?
2. How has the NE Atlantic storm climate developed in the last few decades and last few centuries?
3. How did the impact of wind-storms on storm surges and ocean waves develop in the past decades? What may happen in the future?

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Changes of the wind climate

- Climate = statistics of weather, as given by distributions or parameters thereof, such as means, percentiles etc.
- Changes of wind stats difficult to determine, because of changing observation practices. Earlier: visual assessment, nowadays: instrumental.
- Another difficulty is that the recorded values depend on the immediate environment of the location where the observation is made. This environment is subject to gradual and abrupt changes.
- Almost all long record of wind observations are **inhomogeneous**, i.e., they do not only reflect changes of the wind statistics but also other factors, such as observation method, practice, location, analysis method ....
- **Inhomogeneity** is a key constraint, which is usually overseen by non-experts. Improved instruments and analysis introduces into data records such inhomogeneities (and thus, false signals); therefore satellite data are in most cases unsuitable for the



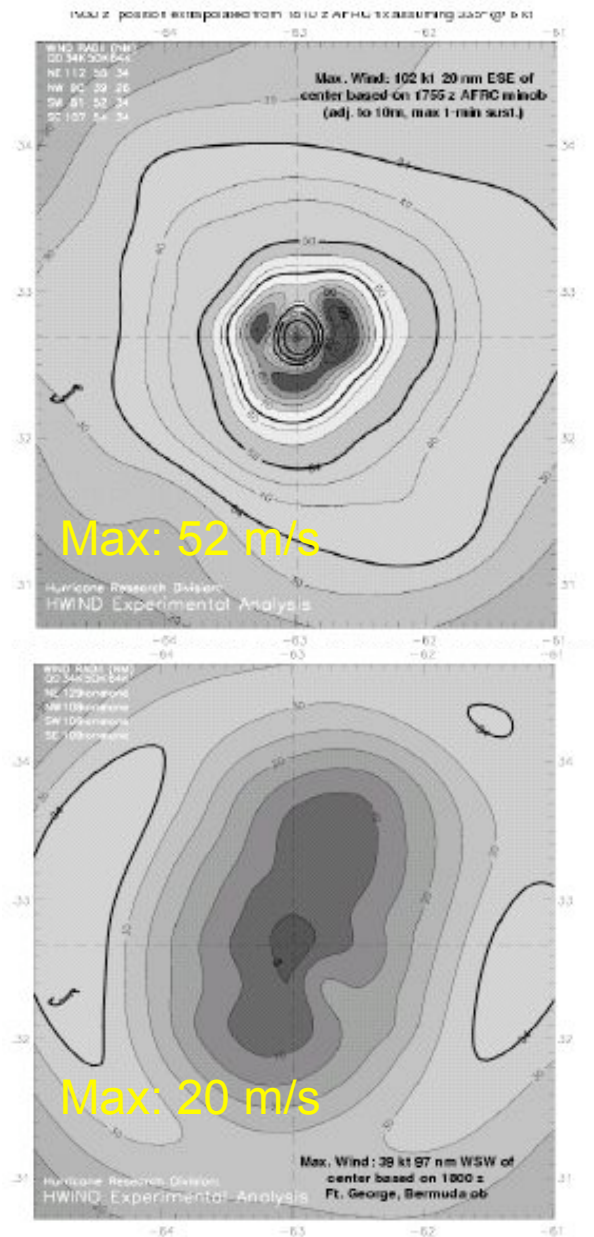


Figure 7.2 Same as Figure 3, but without the benefit of surface-reduced aircraft reconnaissance flight-level winds. In this case, highest analyzed surface winds were only 39 kt (20 m s^{-1}) based upon observations from Bermuda about 100 nmi (160 km) from Erin's center. Such an analysis is typical of data available before the advent of aircraft reconnaissance data in the mid-1940s and is illustrative of the underestimation bias that occurred for many tropical cyclones during the era of the late 19th and early 20th Centuries being re-analyzed.

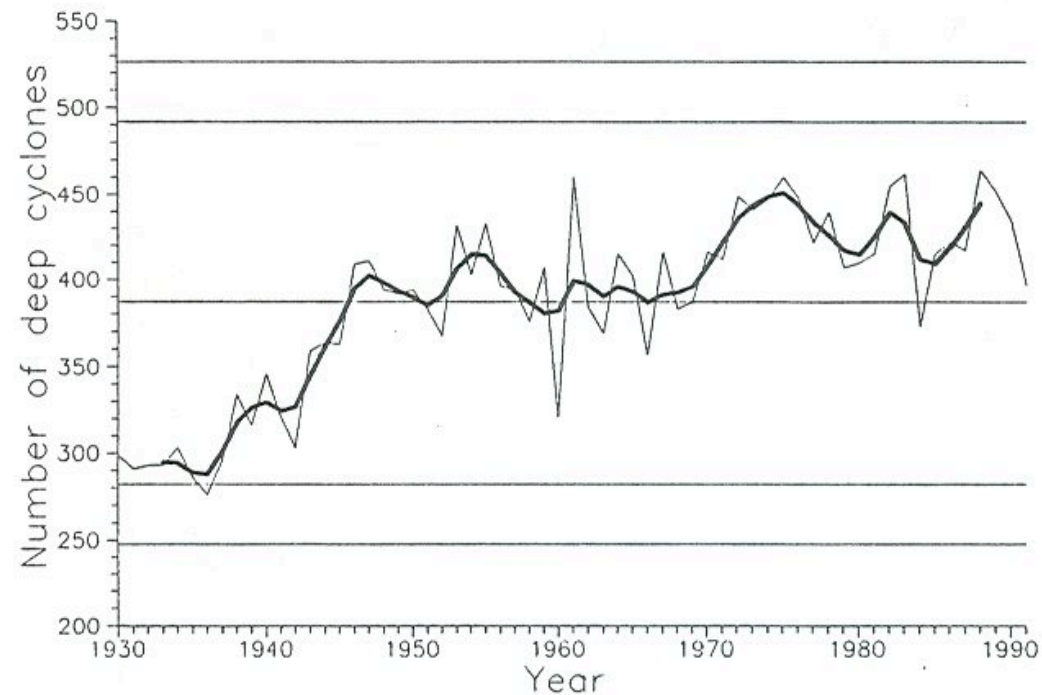


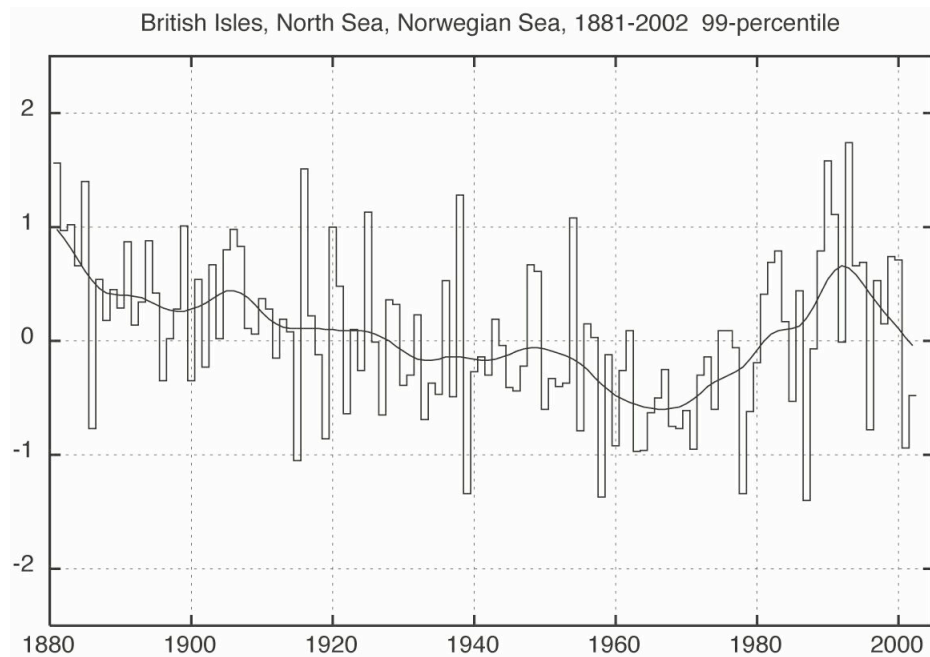
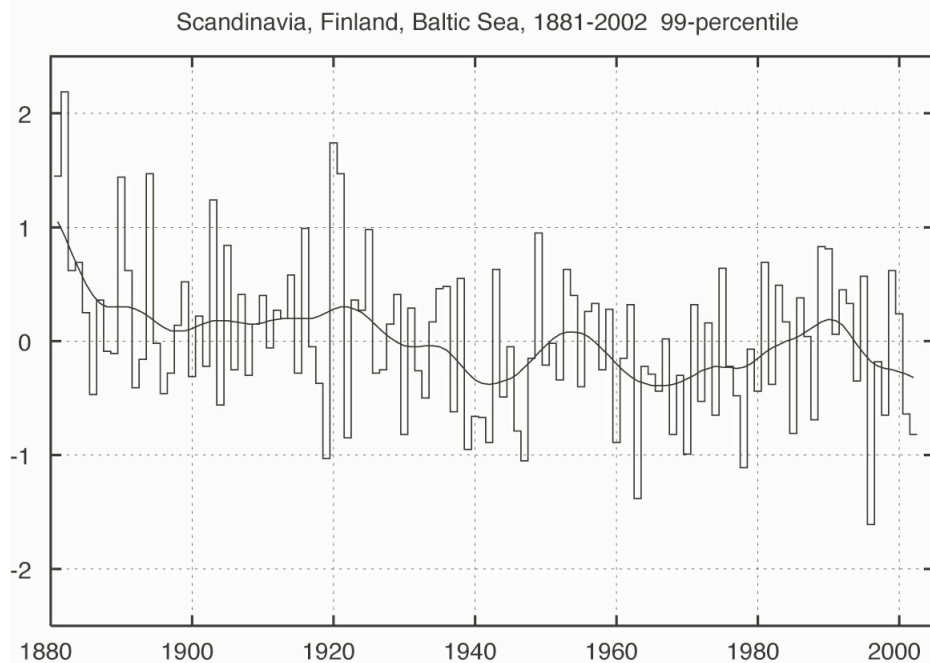
Figure 2 Absolute annual number of deep cyclones 1930–1991¹⁾

Counting storms in weather maps - steady increase of NE Atlantic storms since the 1930s ....

Storm indicators

- Annual percentiles of geostrophic wind (e.g., 95 or 99%iles)
- Annual frequency of 24 hourly local pressure change of 16 hPa in a year
- Annual frequency of pressure readings less than 980 hPa in a year
- Variance of local water levels relative to annual mean (high tide) water level.
- Microseismic activity
- Repair costs of dikes in historical times.
- Sailing times of ships on historical routes.

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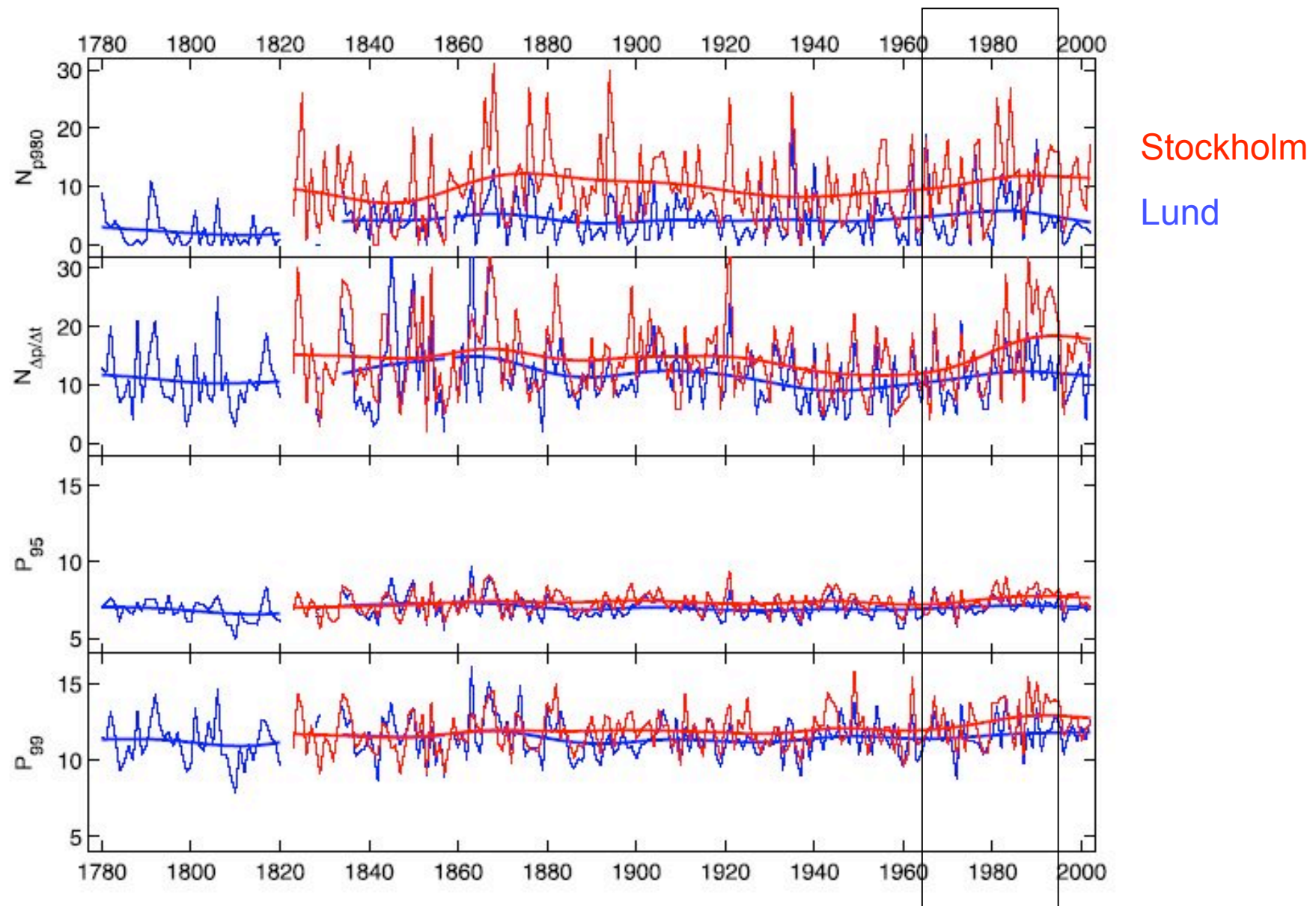


99%iles of annual
geostrophic wind speeds
for a series of station
triangles in the North Sea
regions and in the Baltic
Sea region.

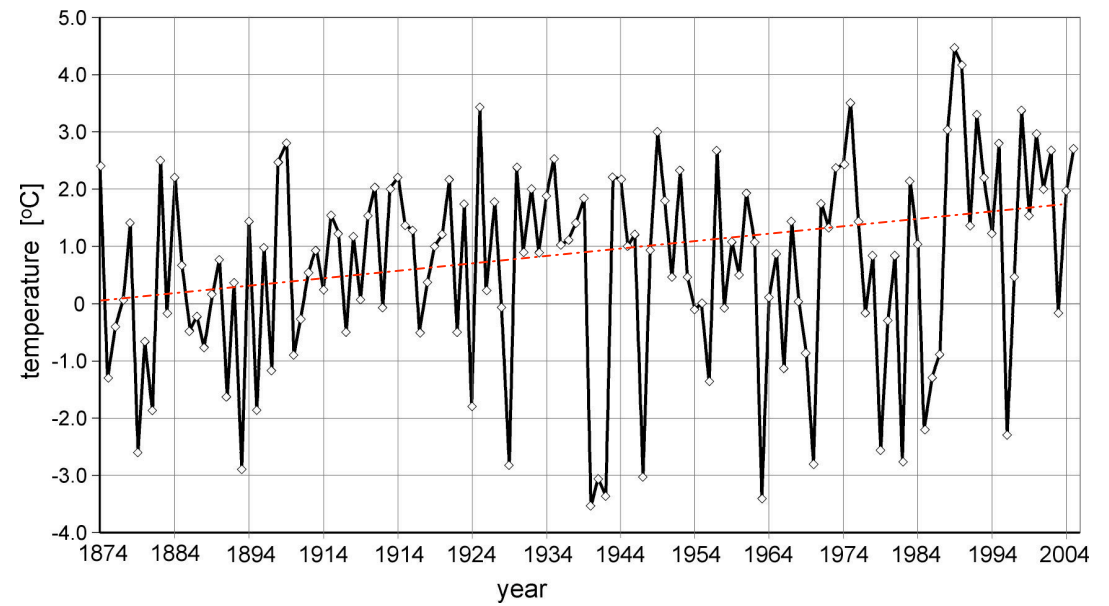


Fig. 1. Stations with long time series of 3 pressure observations per day

Alexandersson et al., 2002



Time series of pressure-based storminess indices derived from pressure readings in Lund (blue) and Stockholm (red). From top to bottom: Annual number of pressure observations below 980 hPa (N_{p980}), annual number of absolute pressure differences exceeding 16 hPa/12 h ($N_{Dp/Dt}$), Intra-annual 95-percentile and 99-percentile of the pressure differences (P_{95} and P_{99}) in units of hPa. From Barring and von Storch, 2005 (GRL)

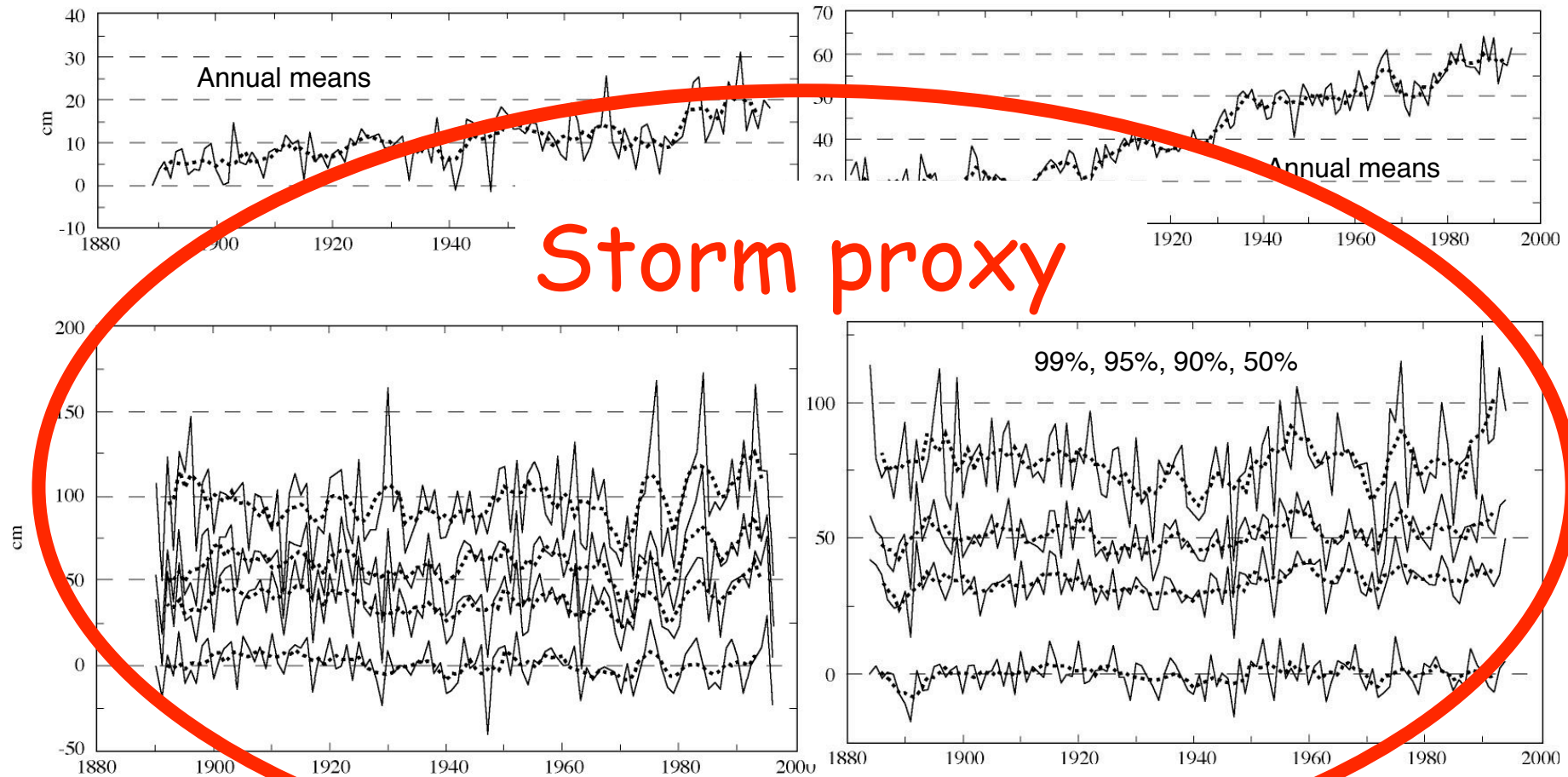


Changing mean temperatures in Denmark in Winter (DJF)

High tide stats, 1890-1995

Esbjerg

Den Helder



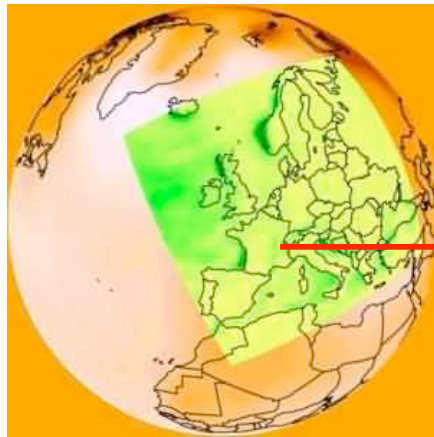
Pfizenmayer, ca. 2000

How did wind-storm impact on storm surges and ocean waves develop in the past decades?

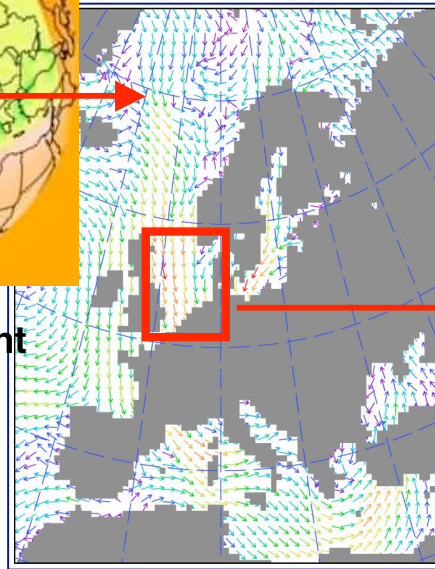
- In the decades 1960-1990 an increase of marine storminess was recorded.
- Since 1995 this trend has reversed in most marine areas.
- The limited evidence available for longer times (100-200 years) indicates no systematic increase of marine storminess in the NE Atlantic region.
- No link between ongoing anthropogenic warming (the existence of which has been demonstrated) and NE Atlantic storminess has been established.

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Regional and local conditions - in the recent past and next century?

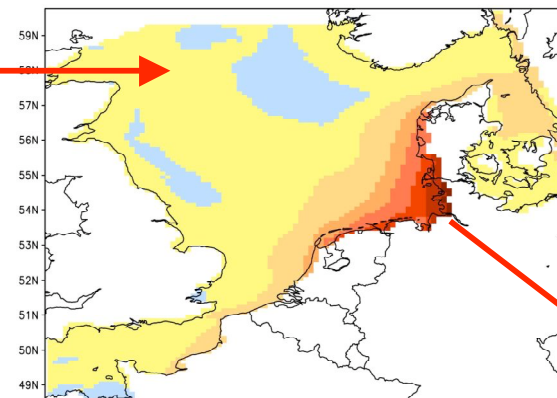
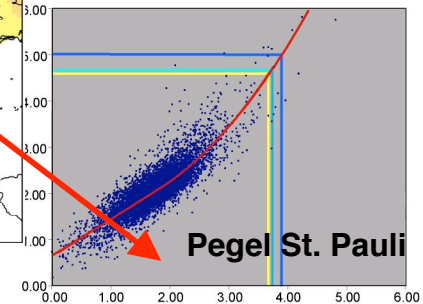


Globale development
(NCEP)



Dynamical Downscaling
REMO or CLM

Simulation with barotropic
model of North Sea

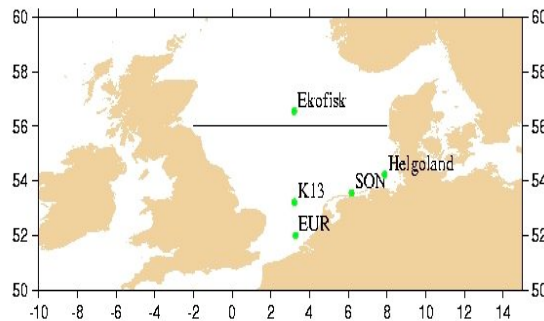


Empirical

Cooperation with a variety of
governmental agencies and with a
number of private companies

Extreme wind speeds over sea

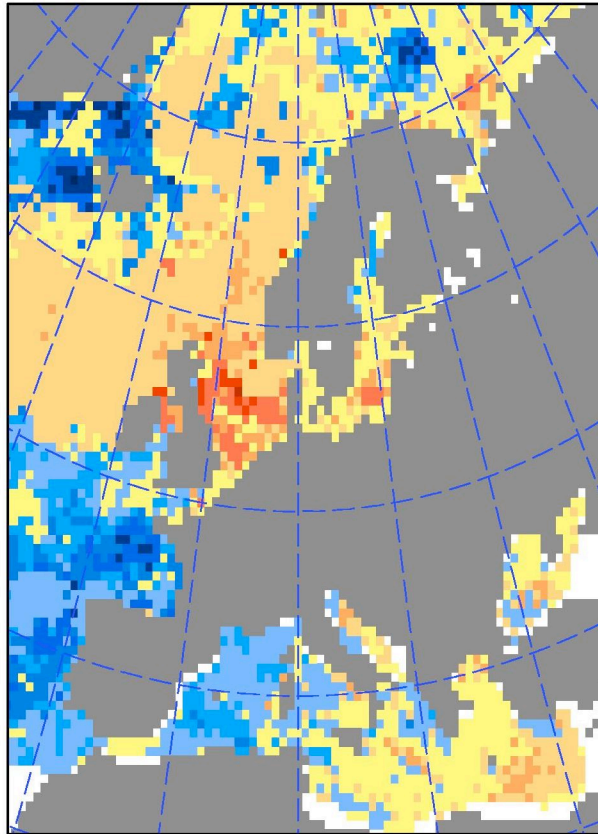
– simulated and recorded



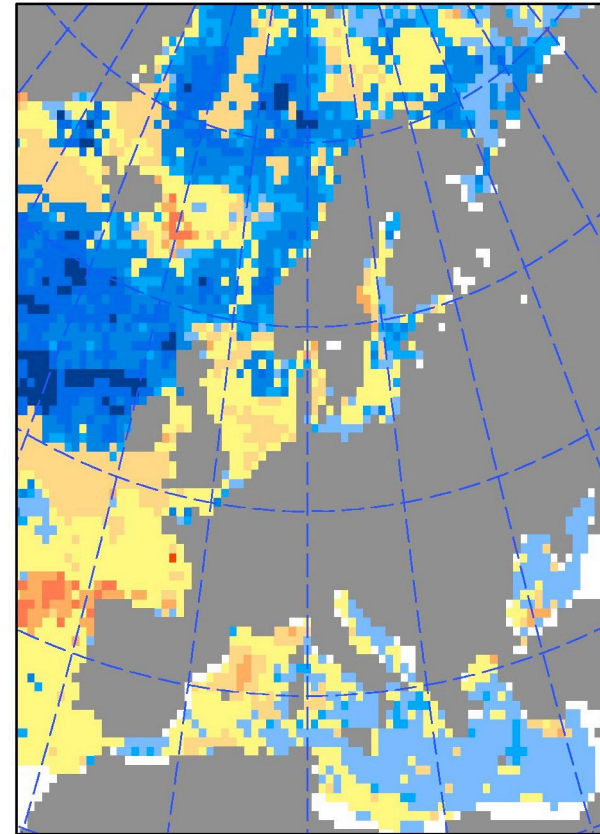
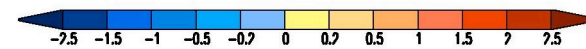
		Wind [m / s]					
		simuliert			Beobachtet		
Years		x_{γ}^{90}	x_{γ}	x_{γ}^{90}	x_{γ}^{90}	x_{γ}	x_{γ}^{90}
K13	2	24.38	25.17	25.96	24.05	25.21	26.37
	5	25.86	27.28	28.70	25.75	27.64	29.53
	25	28.44	31.33	34.22	28.09	32.77	37.45
EUR	2	22.50	23.16	23.82	23.16	24.03	24.90
	5	23.76	24.82	25.88	24.33	25.94	27.55
	25	25.67	28.00	30.33	26.43	29.75	33.07
SON	2	23.29	24.15	25.01	23.11	24.03	24.95
	5	24.89	26.32	27.75	24.15	25.94	27.73
	25	26.68	30.70	34.72	26.42	29.75	33.08

Piecewise linear trends

Remo5 1958–2001 Total N Storms 1.Trend



Remo5 1958–2001 Total N Storms 2.Trend



(Weisse et al. 2005)

Changing significant waveheight, 1958-2002

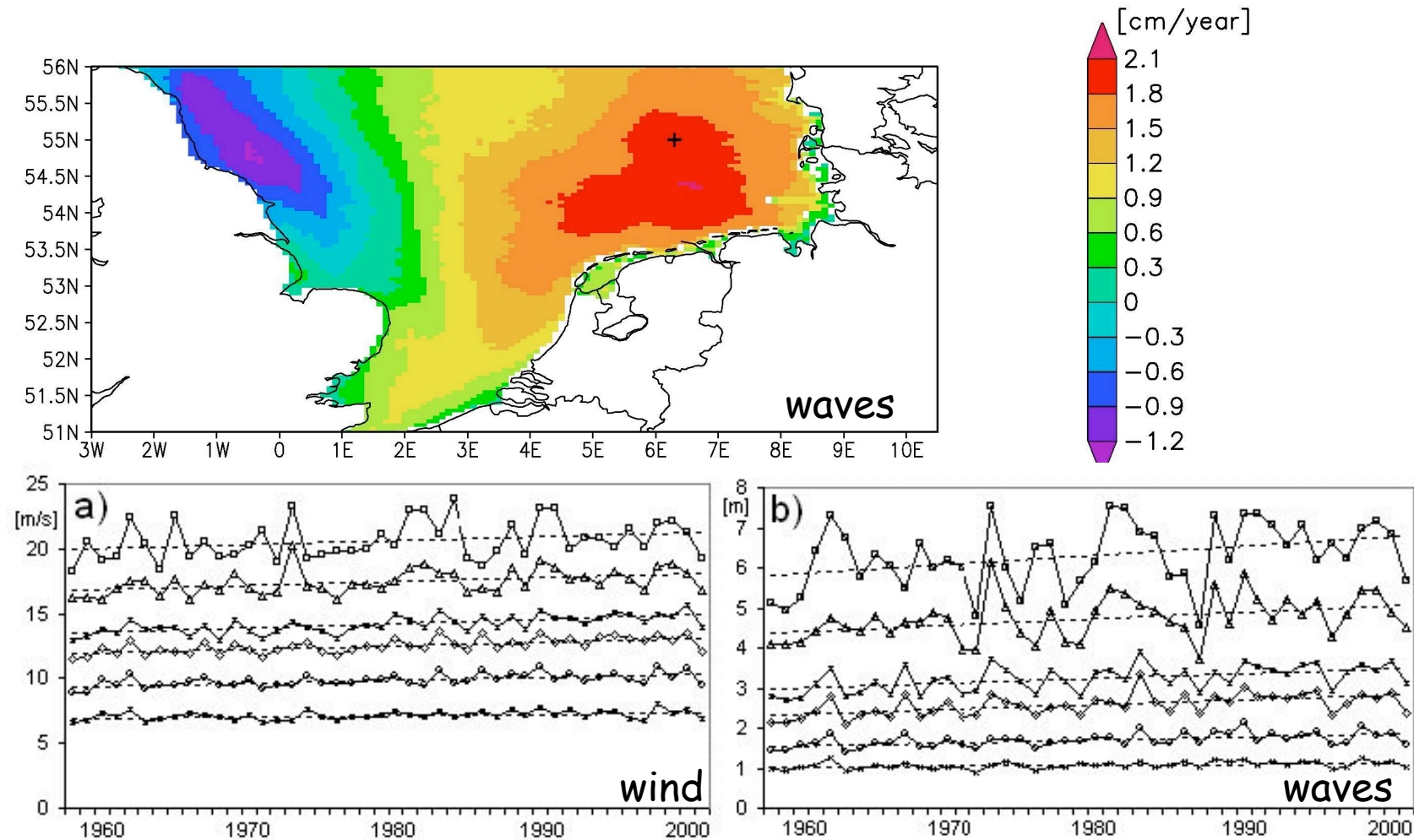
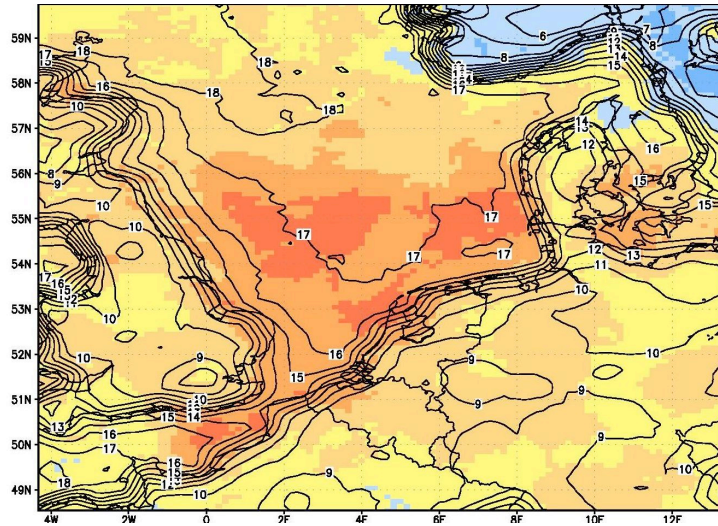


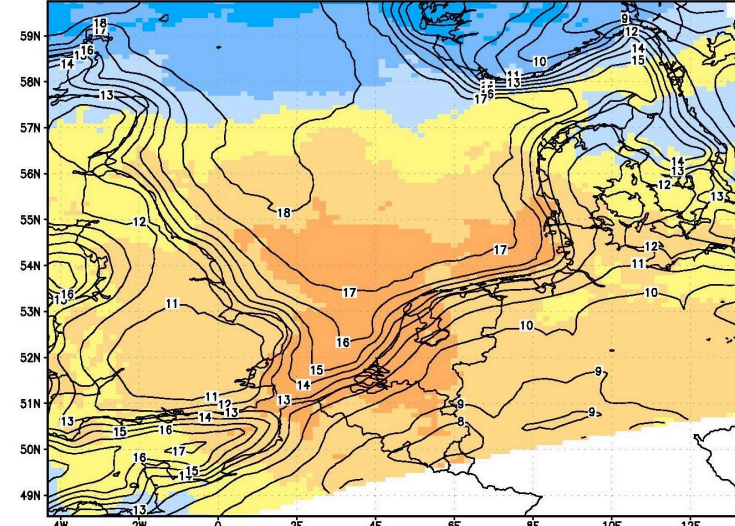
Figure 4.1: 50, 75, 90, 95, 99, 99.9 annual percentiles of the a) wind speed (solid) in m/s and linear trends (dashed) in m/s per annum b) SWH from HF in meters and linear trends.

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

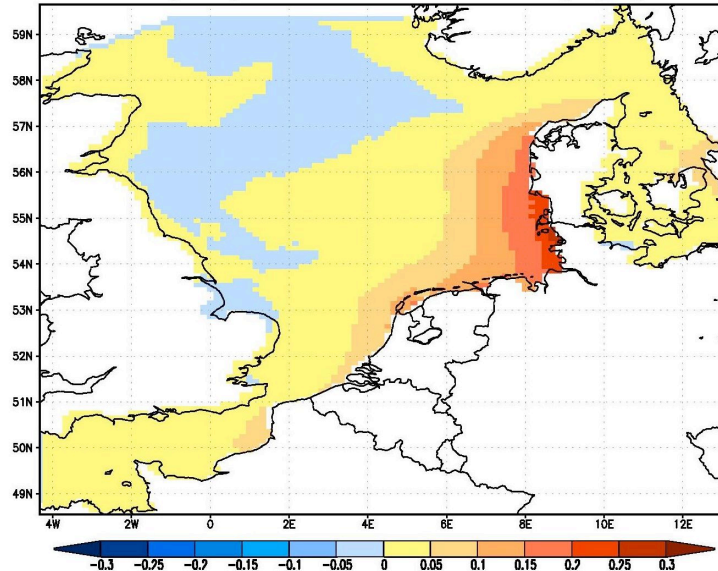
HIRHAM



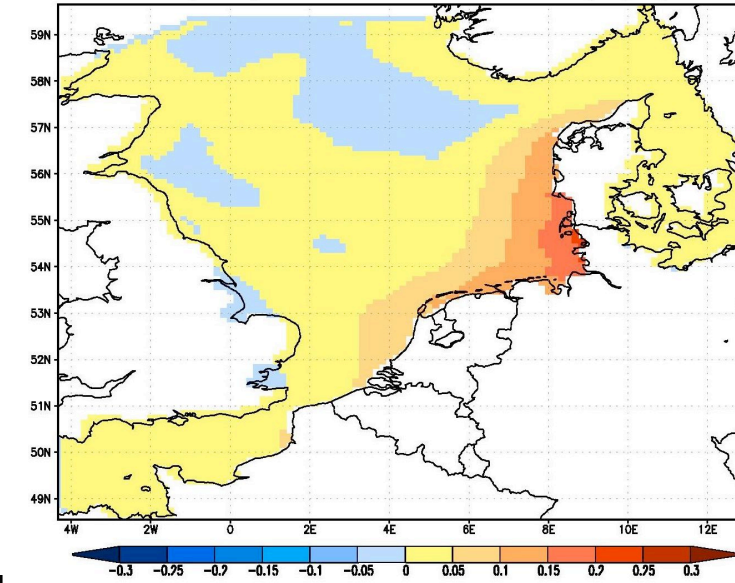
RCAO



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

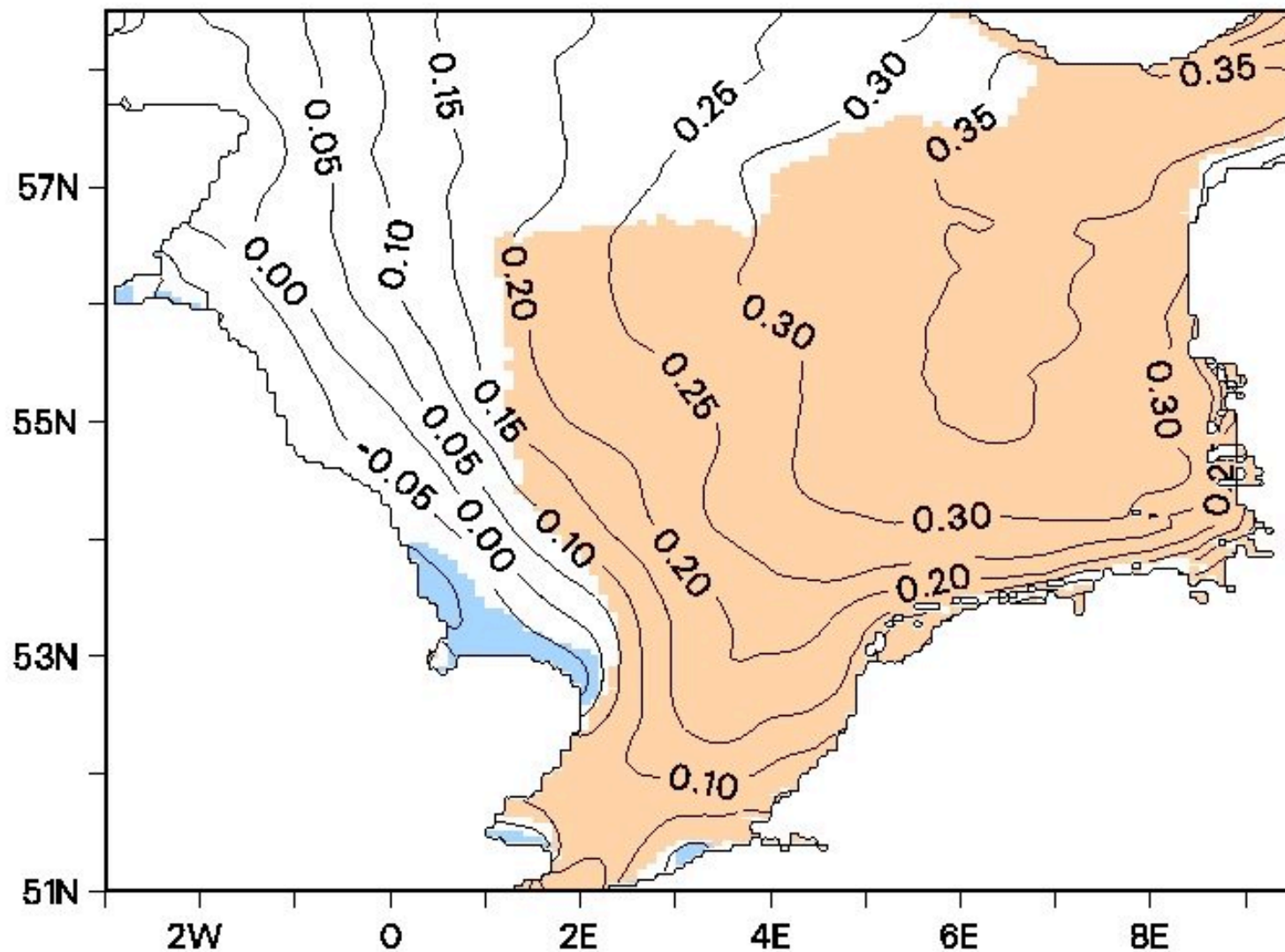


TRM/Surge winter Mean 99%tile Surge [m]



Scenarios for 2085

Woth, personal communication

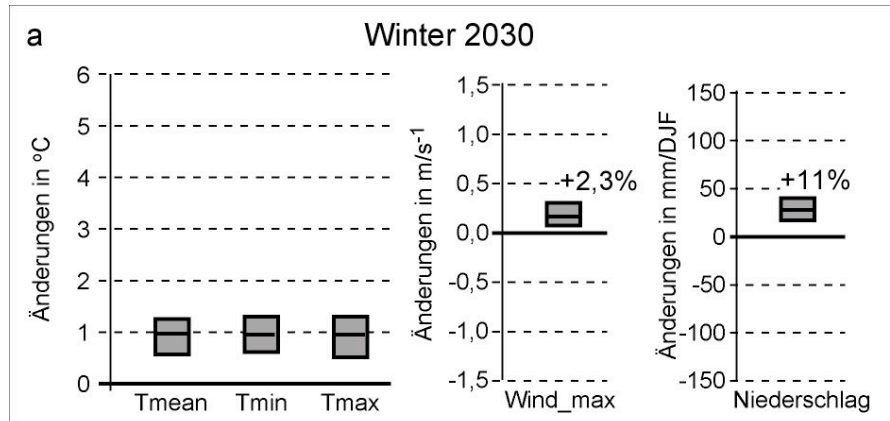
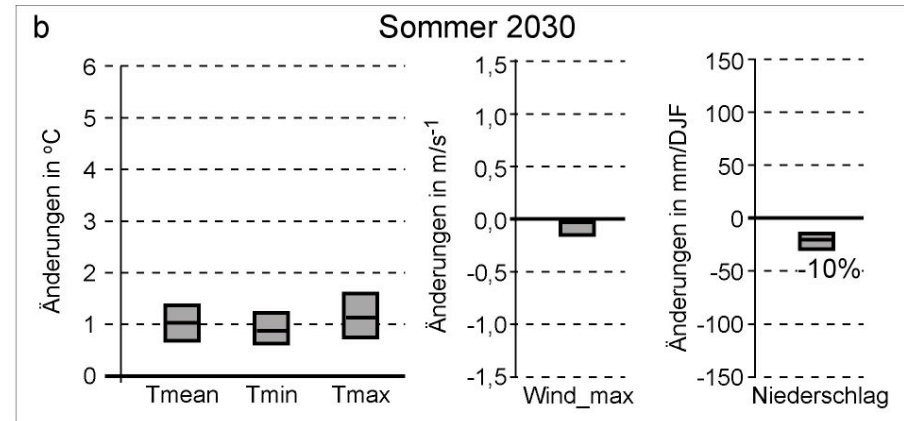
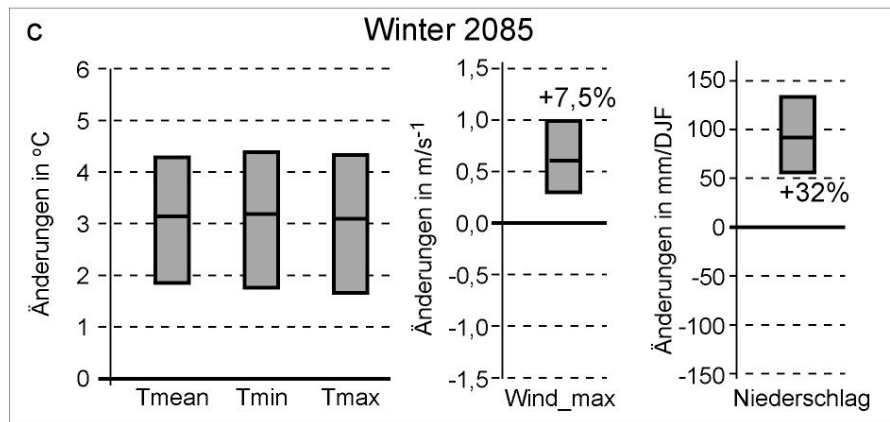
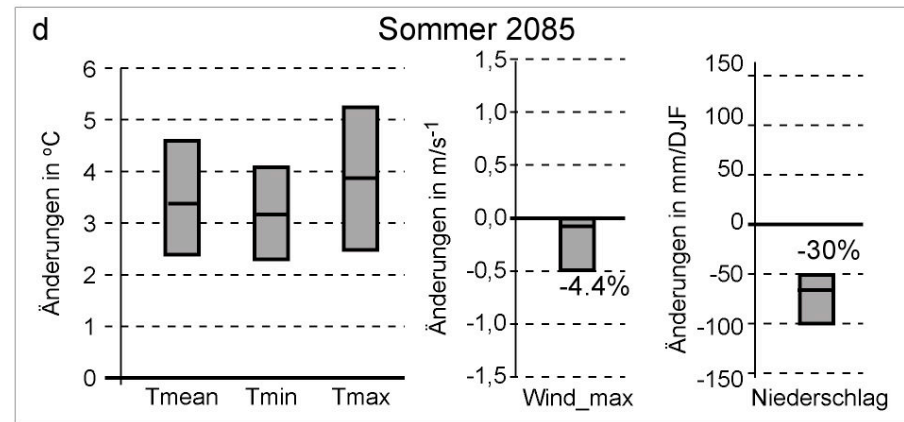


Changes of annual 99-percentile wave heights averaged across a series of simulations using different models and scenarios (in m).

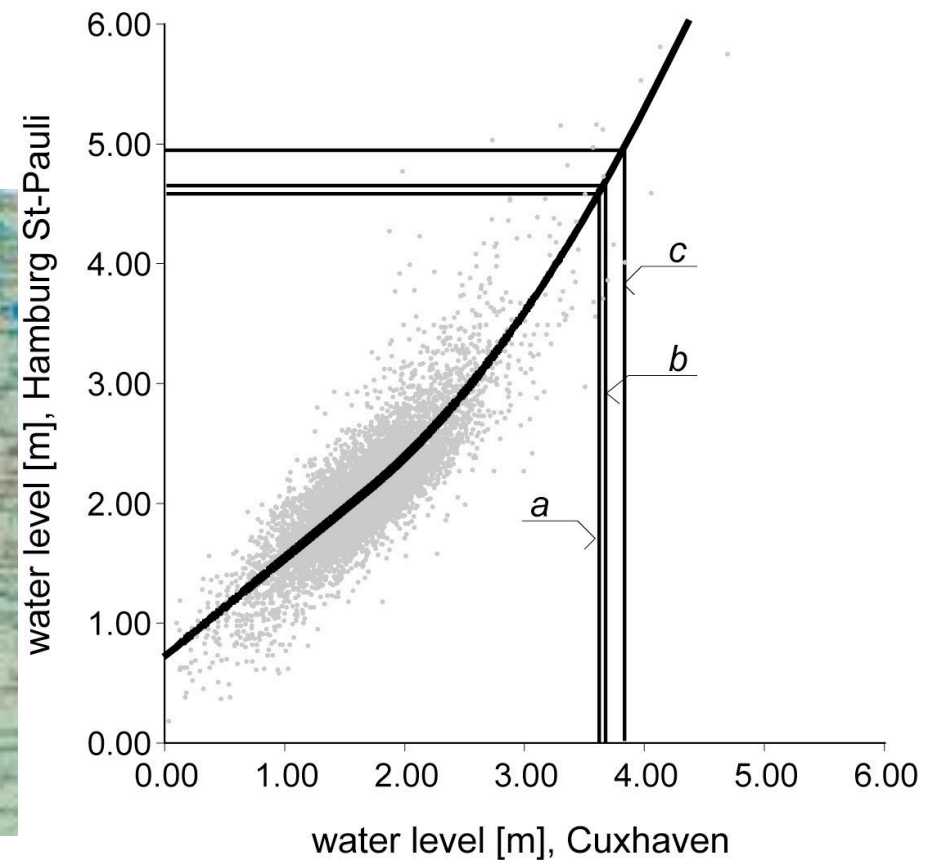
Colouring indicates areas where signals from all models and scenarios have the same sign; red-positive, blue-negative.

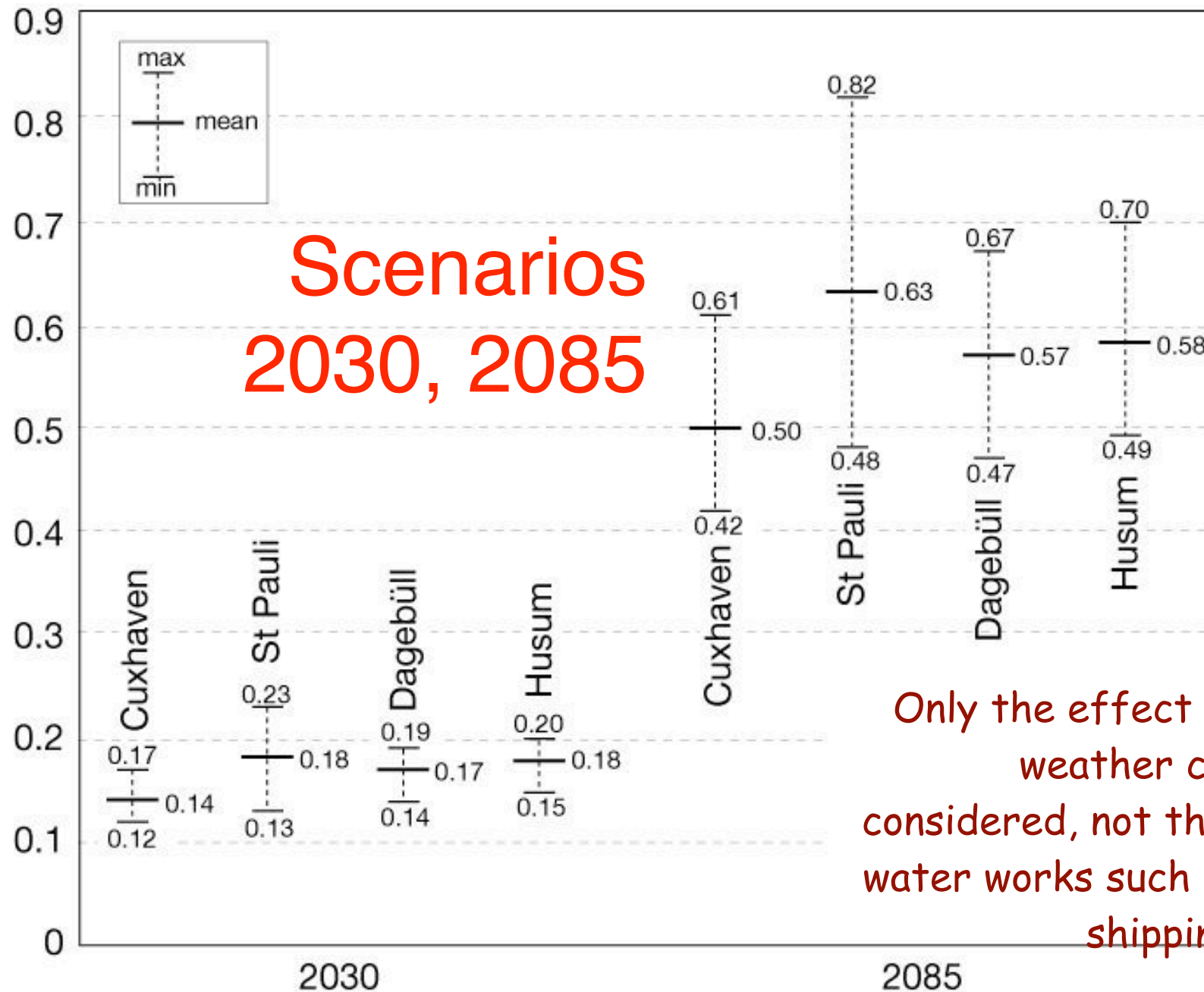
Weisse und Grabemann, 2006

Possible futures in Northern Germany



“Localisation”: From the coast into the estuary





Only the effect of changing weather conditions is considered, not the effect of water works such as dredging shipping channels.

How did wind-storm impact on storm surges and ocean waves develop in the past decades, and what may happen in the expected course of anthropogenic climate change?

- In the recent decades, 1960-1990, an increase of marine storminess was recorded - simultaneous with an intensification of the NAO (North Atlantic Oscillation);
- Since 1995 this trend has reversed in most marine areas.
- Scenario simulations with regional models - and subsequent simulations with storm surge and ocean wave models - point to an increase of marine storminess in the Southern North Sea in the course of emerging anthropogenic climate change. Expected increases of strong winds are of the order of 10% for the end of the 21st century.
- Storm surge heights are expected to rise along the German North Sea coast by about 70 cm (with less than half due to changing storminess) at the end of the 21st century. For high waves, the increase may be of the order



by GKSS Forschungszentrum Geesthacht

The CoastDat data set:

- Long (50 years) and high-resolution reconstructions of recent offshore and coastal conditions mainly in terms of wind, storms, waves, surges and currents and other variables in N Europe
- Scenarios (100 years) of possible consistent futures of coastal and offshore conditions
- extension – ecological variables, Baltic Sea, SE Asia, Laptev Sea

Clients:

- Governmental: various coastal agencies dealing with coastal defense and coastal traffic
- Companies: assessments of risks (ship and offshore building and operations) and opportunities (wind energy)
- General public / media: explanations of causes of change; perspectives and options of change

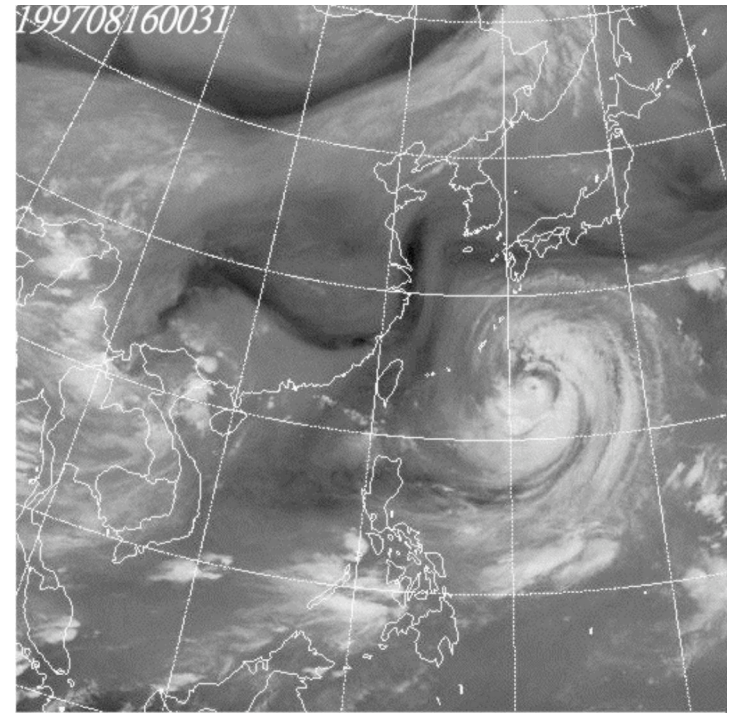
www.coastdat.de

Outlook

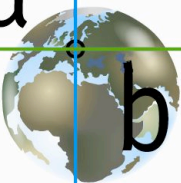
- Similar problems with assessing changes of other storms - tropical „typhoons“ and extra-tropical „polar lows“:
  - > homogeneity of data
  - > time series lengths of observational evidence insufficient in view of the significant natural long-term variability

New efforts underway at GKSS

- New regions - Baltic Sea, B. Arctic and Laptev Sea



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Klimabüro

Praxis

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- Fischerei
- Versicherungen

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