Long-term changes and potential future developments of the North Sea wave climate

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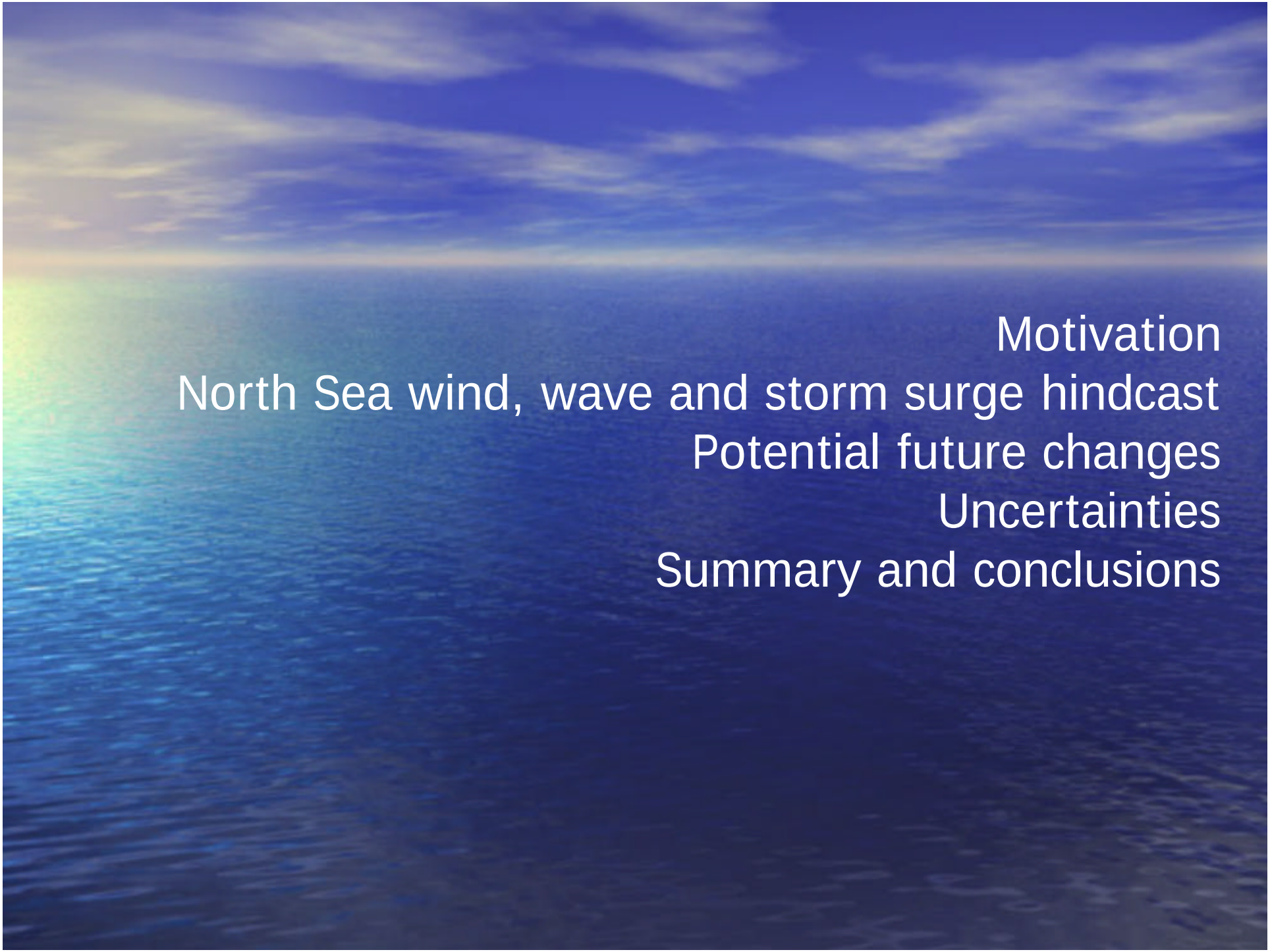
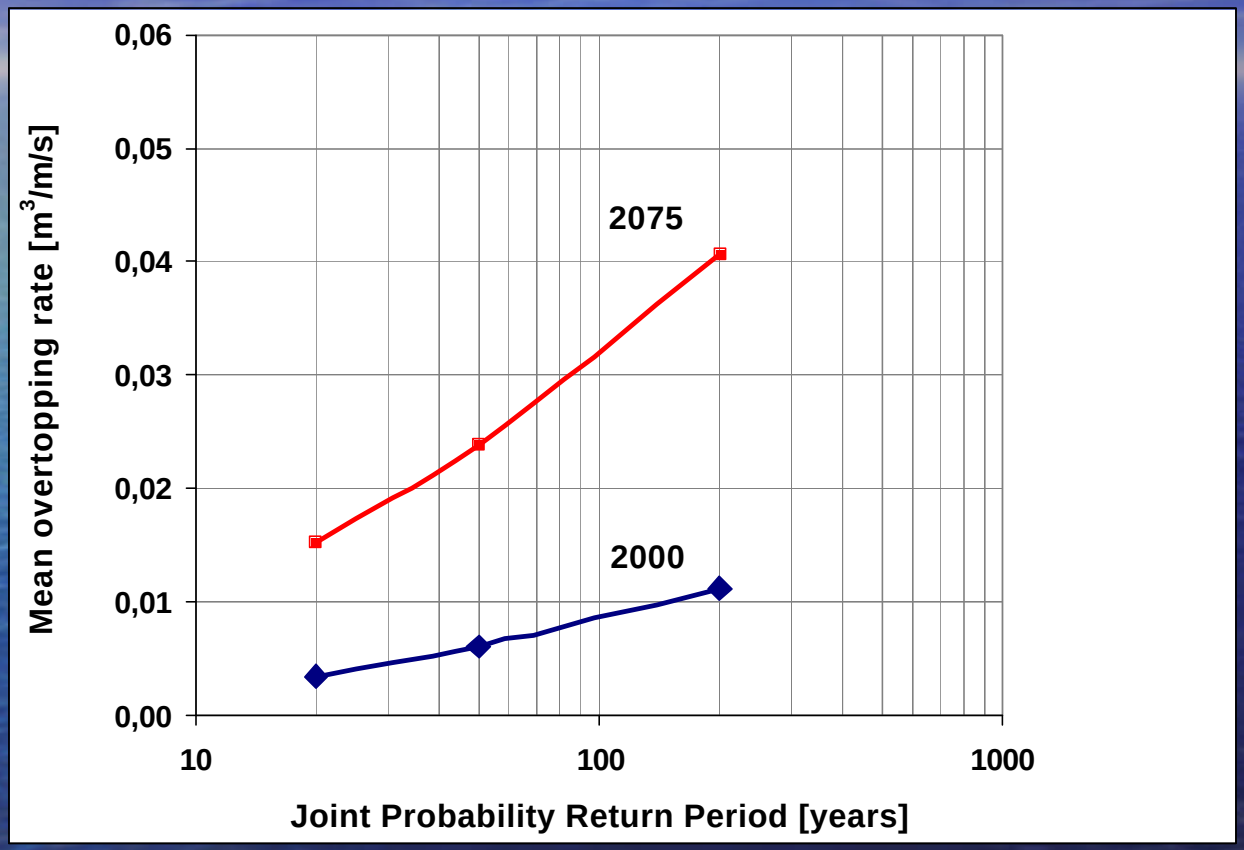
GKSS Research Center
Institute for Coastal Research

North Shore, Oahu, Hawaii November 14-19, 2004

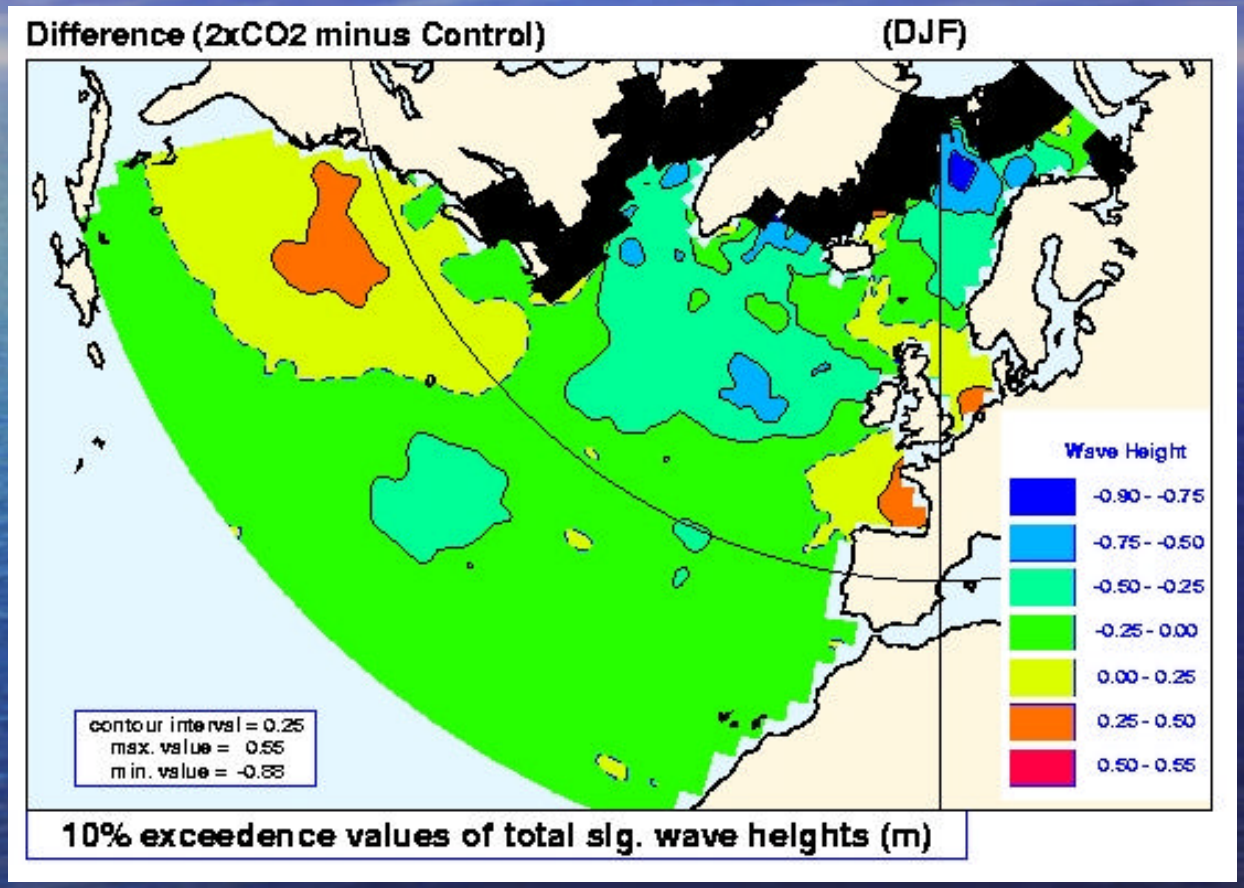

Motivation
North Sea wind, wave and storm surge hindcast
Potential future changes
Uncertainties
Summary and conclusions

Overtopping of a seawall in Lincolnshire for present and future climate conditions



Courtesy J. Sutherland

Scenario of future changes in the annual 90%-percentile of total significant wave height



From WASA (1998)

Frequently estimates are based on
only one scenario and/or
only one realization of that scenario

Reliable estimate of long-term variability missing

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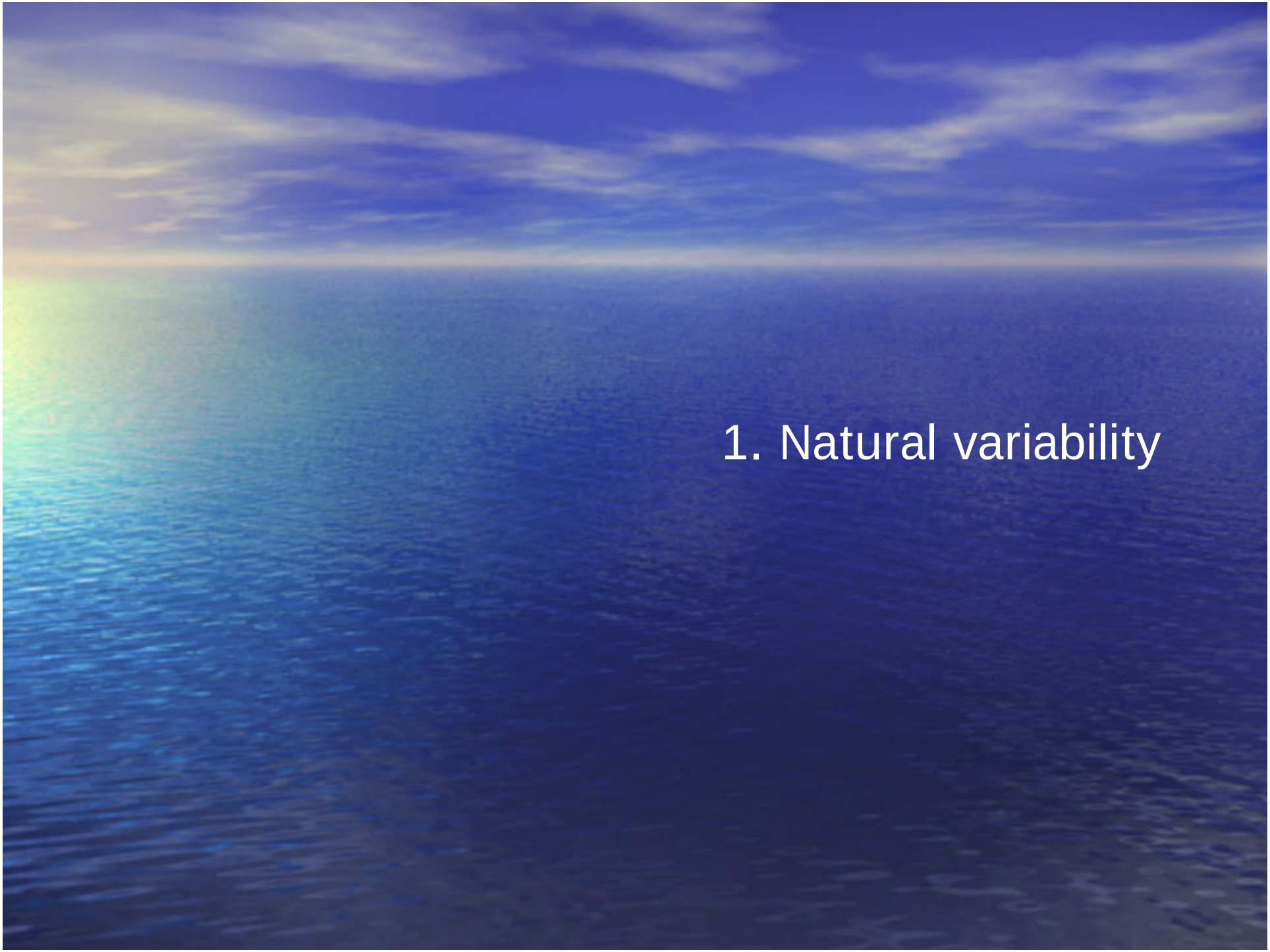
Reliable estimate of long-term variability missing

➡

Need of ensemble simulations
Need of reliable estimate of long-term natural variability


Approach for the North Sea

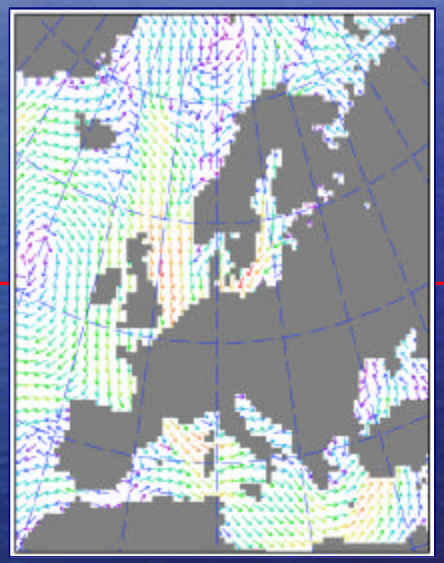

1. Natural variability

NCEP Global Reanalyses (210 km x 210 km)
1958 - 2002

HIPOCAS:

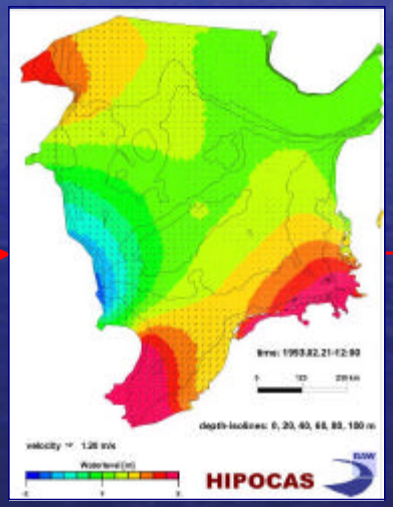
High-resolution hindcast of wind, waves and storm surges

REMO wind speed and direction 21.02.1993 12 UTC



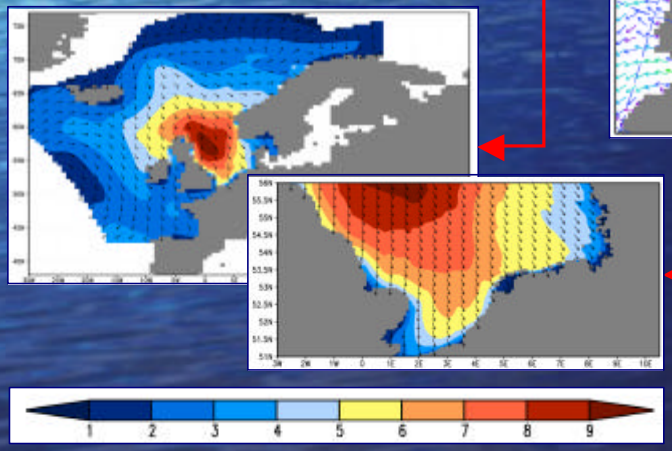
Resolution about 50 x 50 km

BAW - TELEMAC 2D water level and barotropic currents 21.02.1993 12 UTC

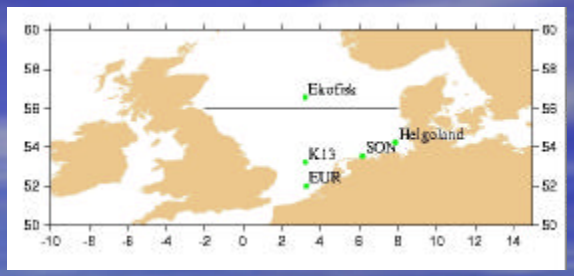


Resolution between about 100 m and 5km

WAM sig. wave height and direction 21.02.1993 12 UTC



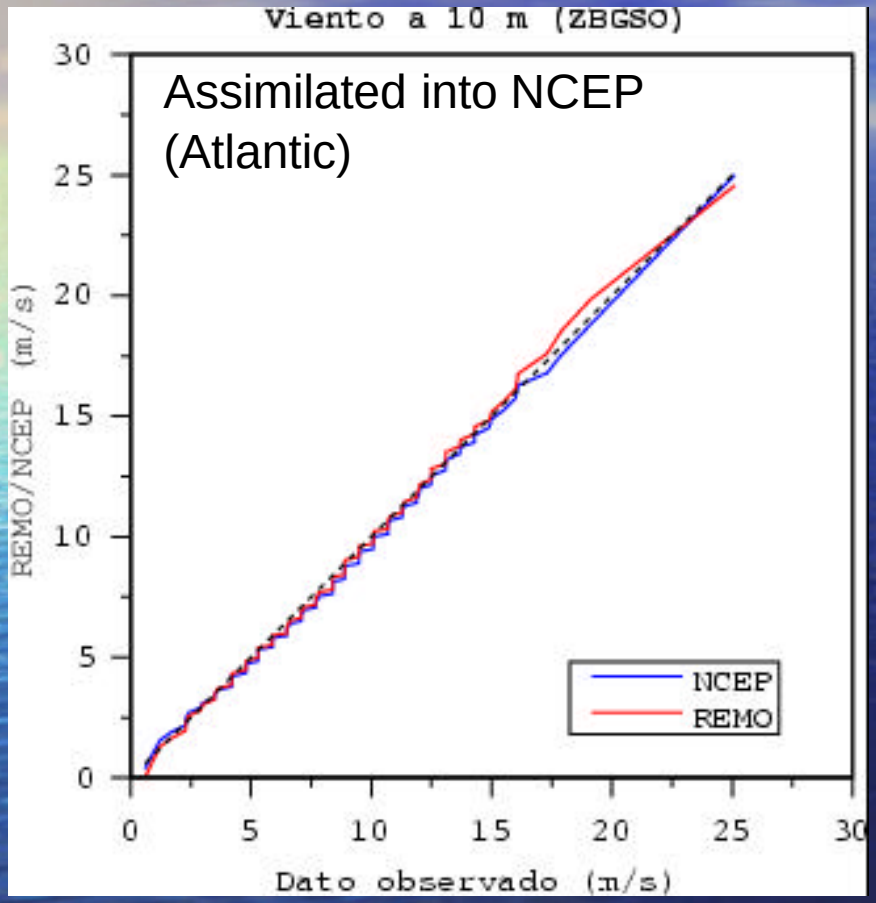
Resolution about 5 x 5 km

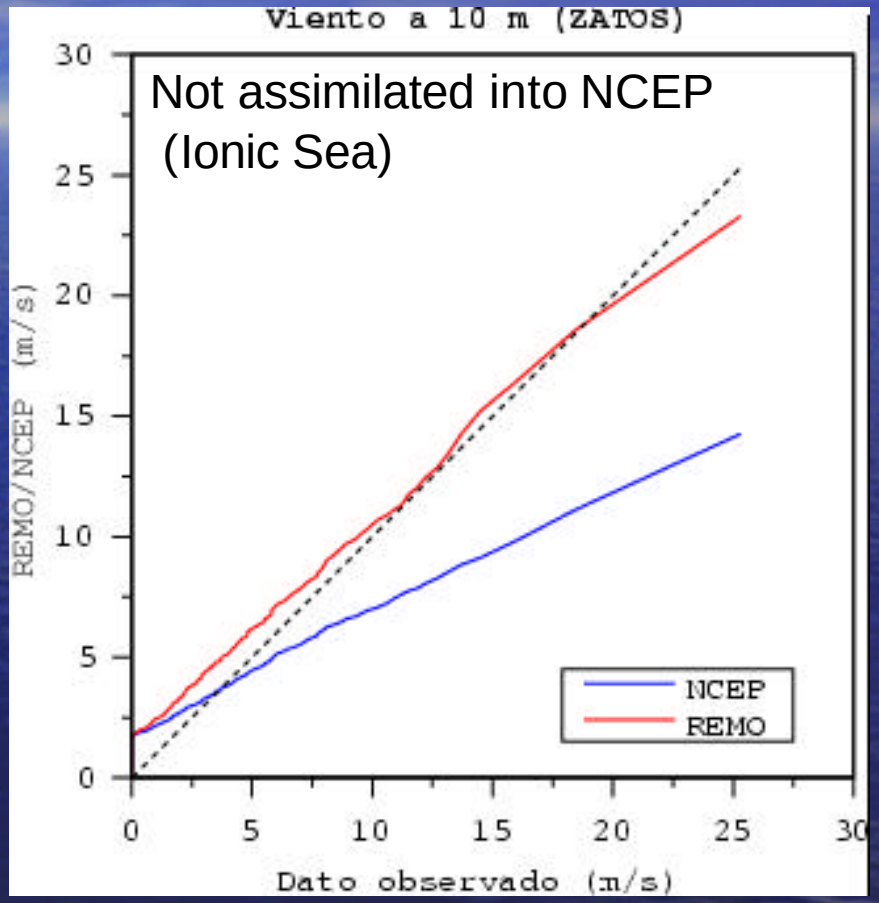


	Years	Wind [m/s]						Waves [m]					
		Hipocas			*Observed*			*Hipocas*			*Observed*		
		χ_r^{90}	χ_r	χ_r^{90}	χ_r^{90}	χ_r	χ_r^{90}	χ_r^{90}	χ_r	χ_r^{90}	χ_r^{90}	χ_r	χ_r^{90}
K13	**2**	24.38	25.17	25.96	24.05	25.21	26.37	7.12	7.49	7.86	6.41	6.77	7.13
	5	25.86	27.28	28.70	25.75	27.64	29.53	7.84	8.44	9.04	6.93	7.54	8.15
	25	28.44	31.33	34.22	28.09	32.77	37.45	8.99	10.35	11.71	7.52	9.21	10.90
EUR	**2**	22.50	23.16	23.82	23.16	24.03	24.90	5.89	6.15	6.41	5.52	5.84	6.16
	5	23.76	24.82	25.88	24.33	25.94	27.55	6.34	6.83	7.32	5.89	6.46	7.03
	25	25.67	28.00	30.33	26.43	29.75	33.07	6.90	8.20	9.50	5.99	7.88	9.77
SON	**2**	23.29	24.15	25.01	23.11	24.03	24.95	6.78	7.06	7.34	5.60	5.84	6.08
	5	24.89	26.32	27.75	24.15	25.94	27.73	7.37	7.79	8.21	5.97	6.46	6.95
	25	26.68	30.70	34.72	26.42	29.75	33.08	8.04	9.03	10.02	6.34	7.88	9.42

2, 5, and 25-year return values with 90% Confidence limits based on 1000 Monte Carlo simulations.

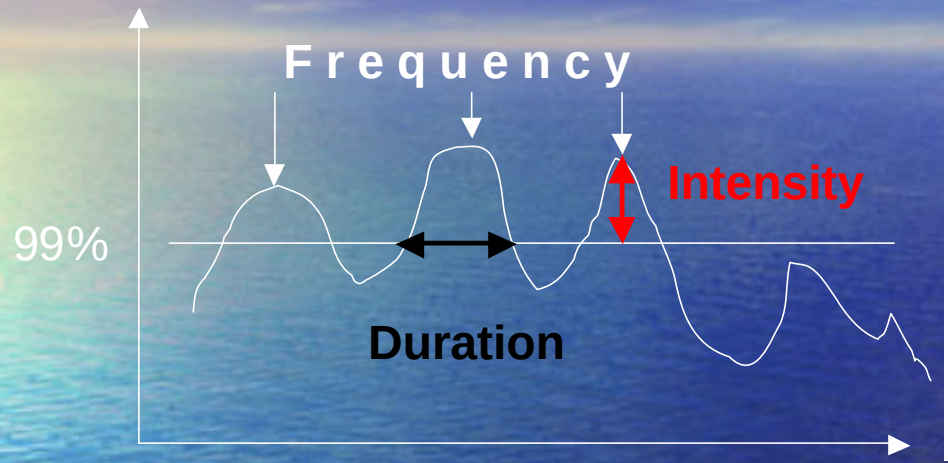
Wind speed at two buoys

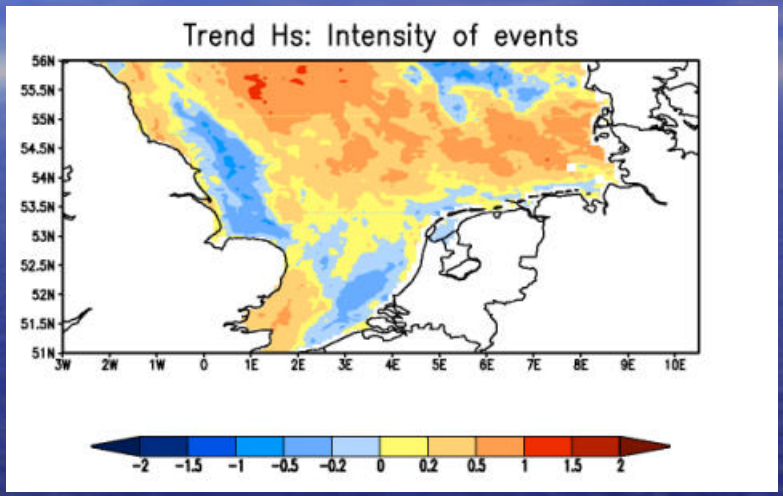


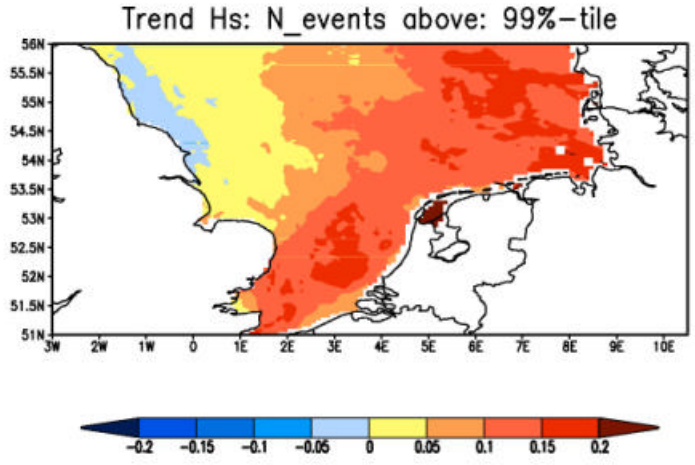


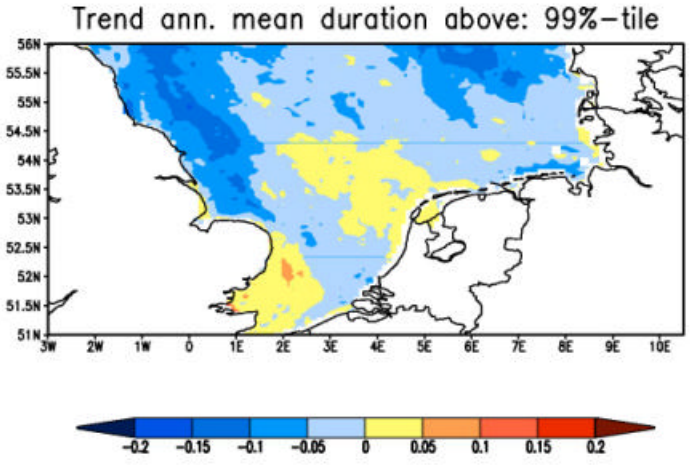
Courtesy: Marcos Garcia Sotillo, 2003

Linear trend of extreme event characteristics for total sig. wave height 1958-2002 from HIPOCAS hindcast










2. Scenarios / Ensembles

Global Climate Model (HadAM3)

IPCC A2 SRES Scenario

(1961-1990 / 2071-2100)

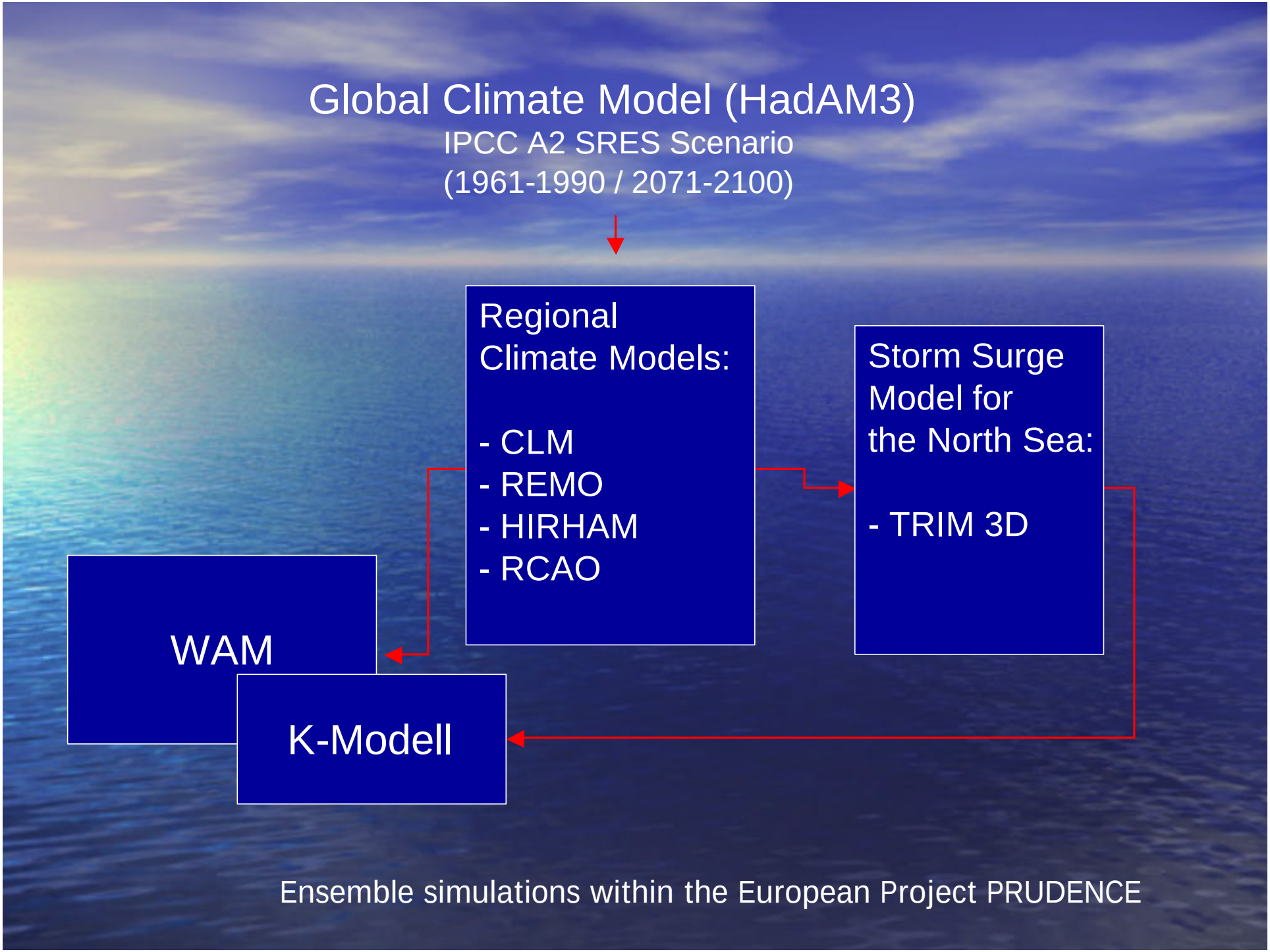
Regional Climate Models:

- CLM
- REMO
- HIRHAM
- RCAO

Storm Surge Model for the North Sea:

- TRIM 3D

Ensemble simulations within the European Project PRUDENCE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Climate Models:
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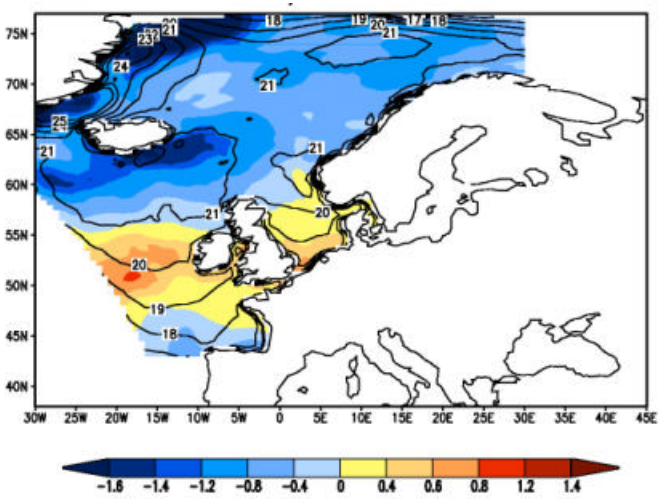
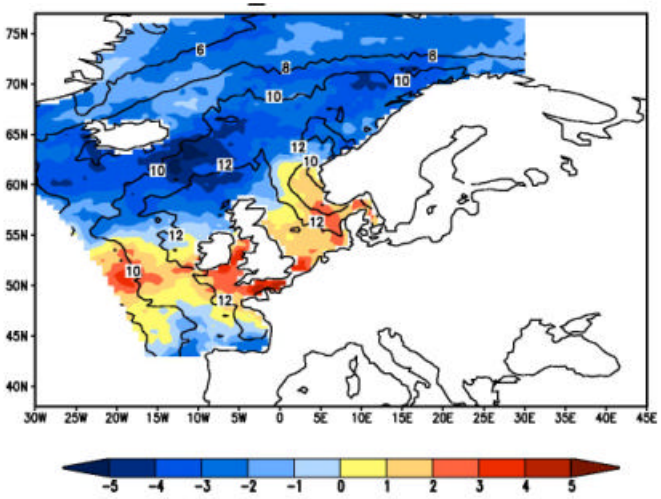
- RCAO
Storm Surge
Model for
the North Sea:
- TRIM 3D
WAM
K-Modell
Ensemble simulations within the European Project PRUDENCE

Difference scenario-control (color) and mean control conditions (contours) for extreme wind speed conditions (CLM)

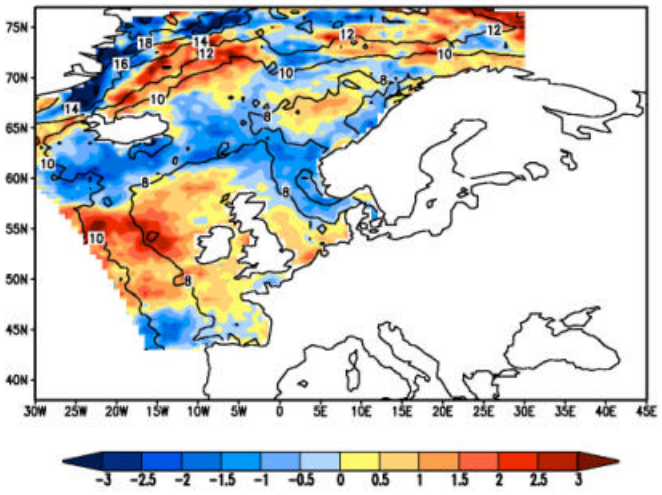
Avg. annual 99%-ile [m/s]



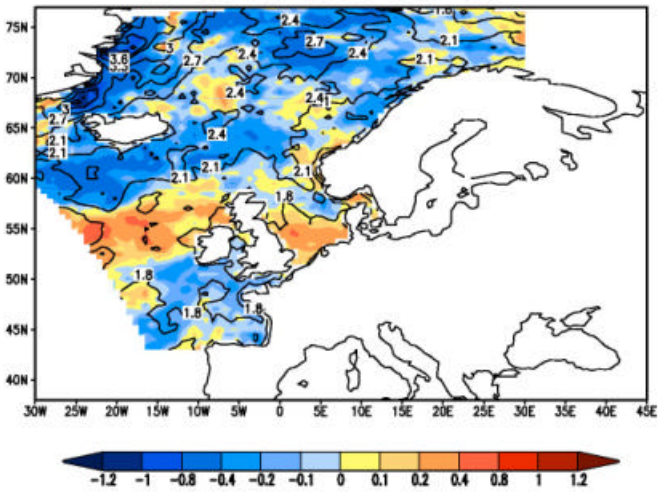
Number of events above 99%-ile



Avg. duration above 99%-ile [hours]



Avg. intensity above 99%-ile [m/s]



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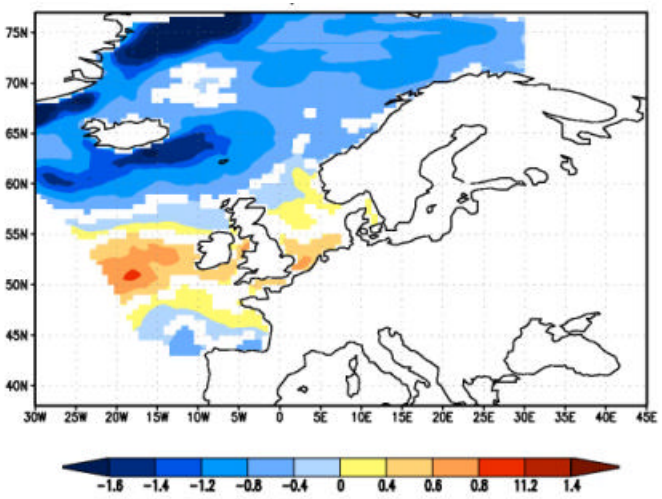
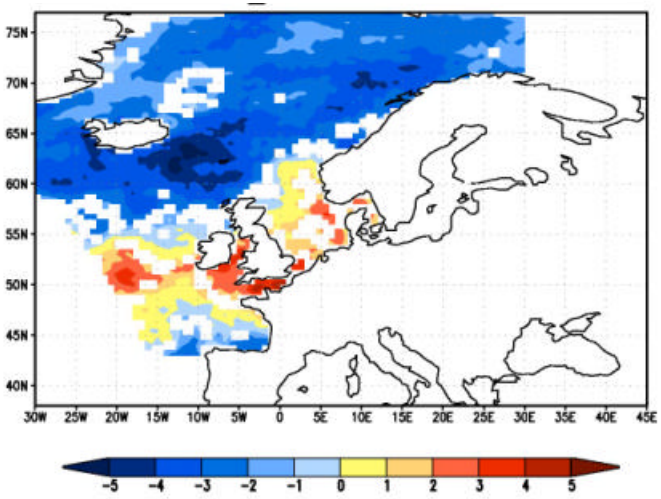


Number of events above 99%-ile



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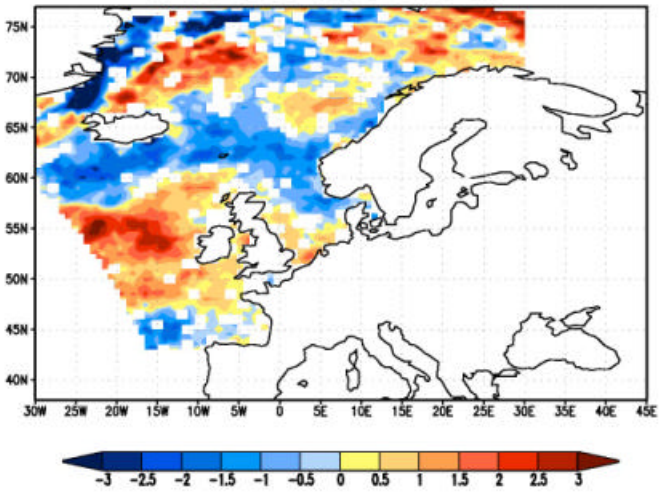

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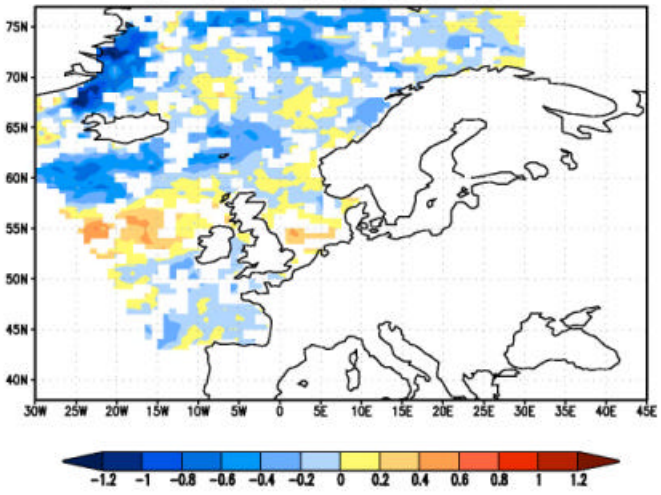
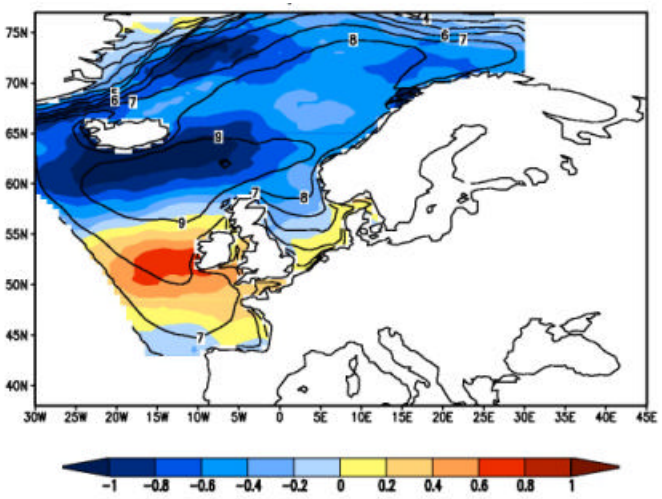
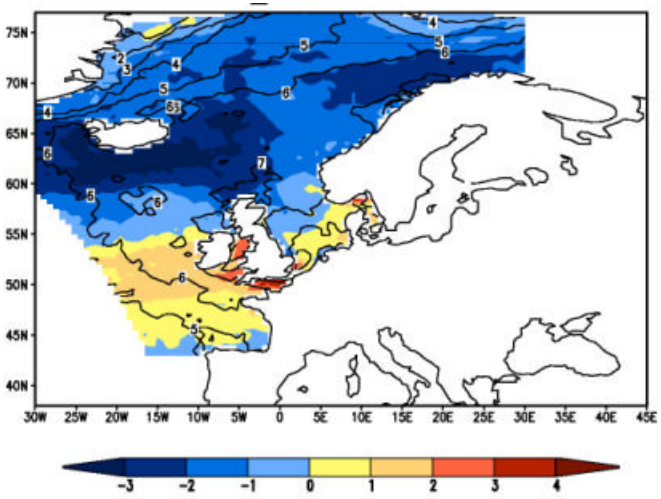


Difference scenario-control (color) and mean control conditions (contours) for extreme sig. wave heights (WAM)

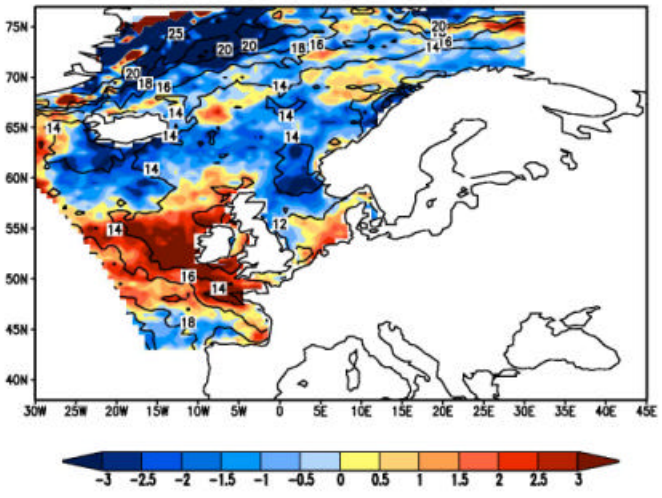
Avg. annual 99%-ile [m]



Number of events above 99%-ile



Avg. duration above 99%-ile [hours]



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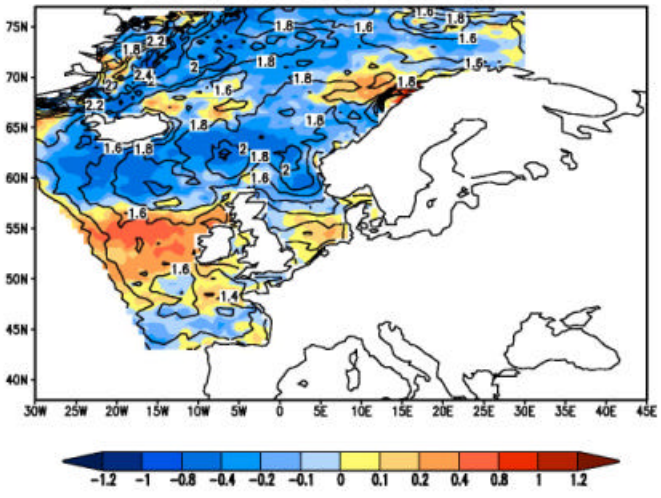

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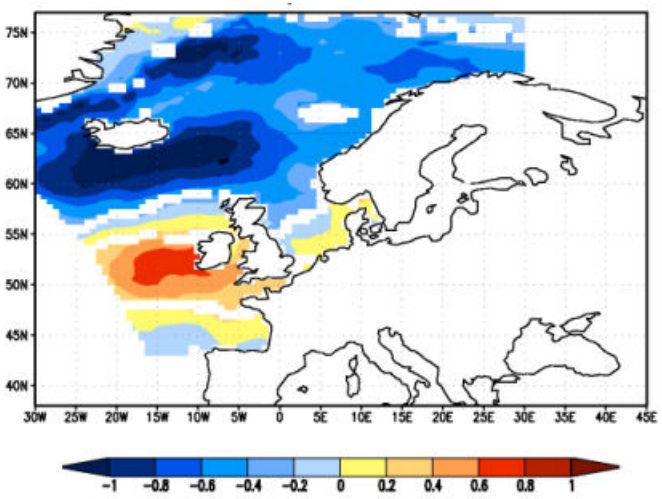
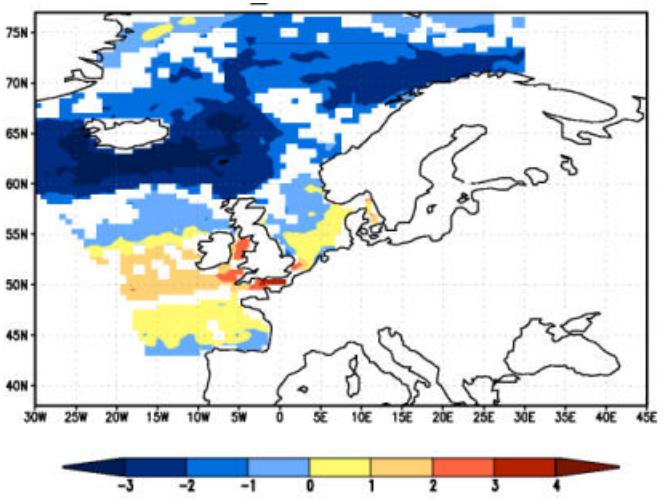


Number of events above 99%-ile



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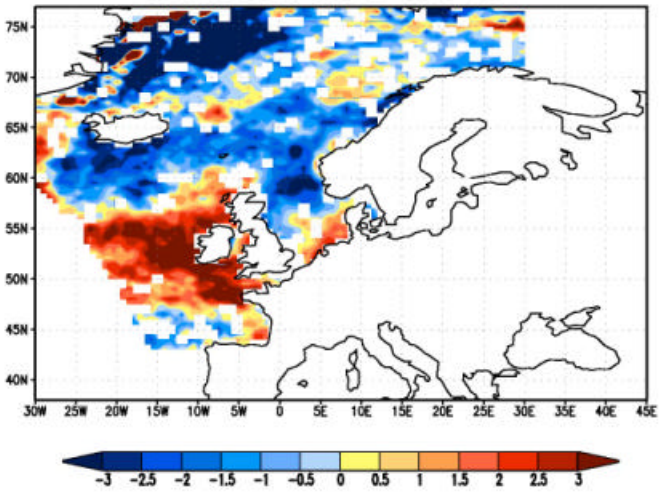

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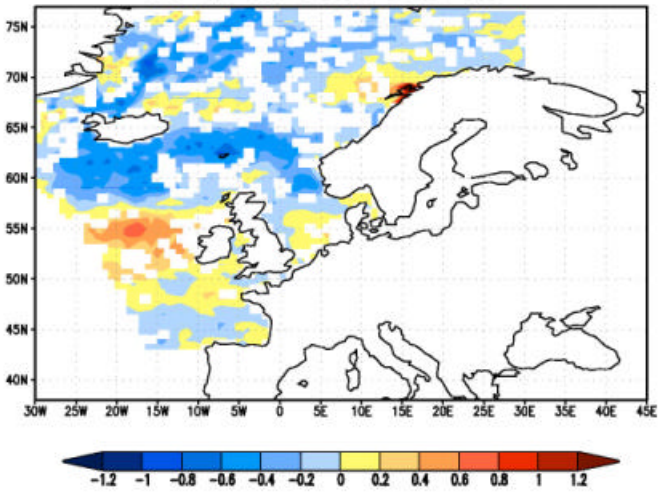
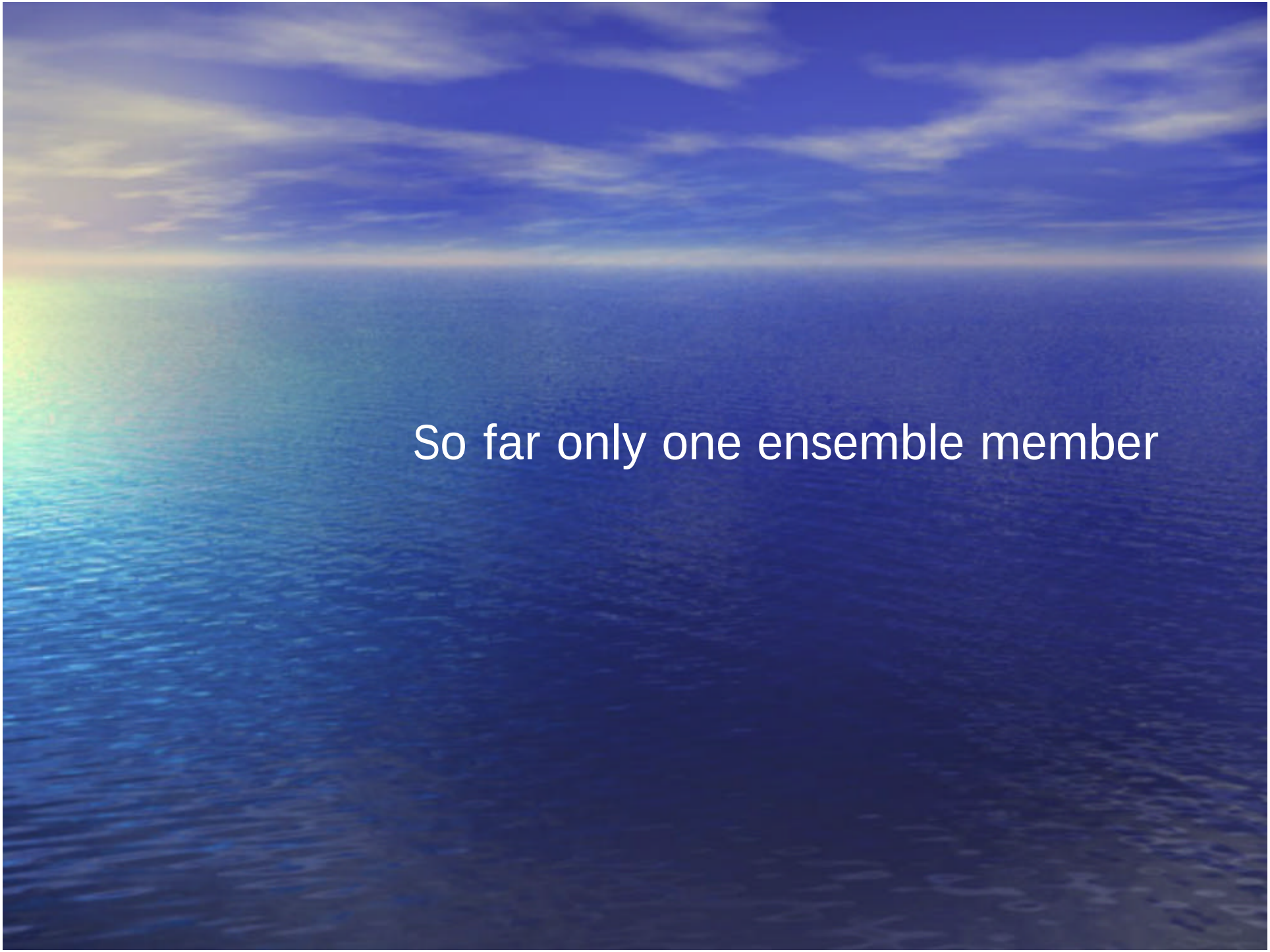
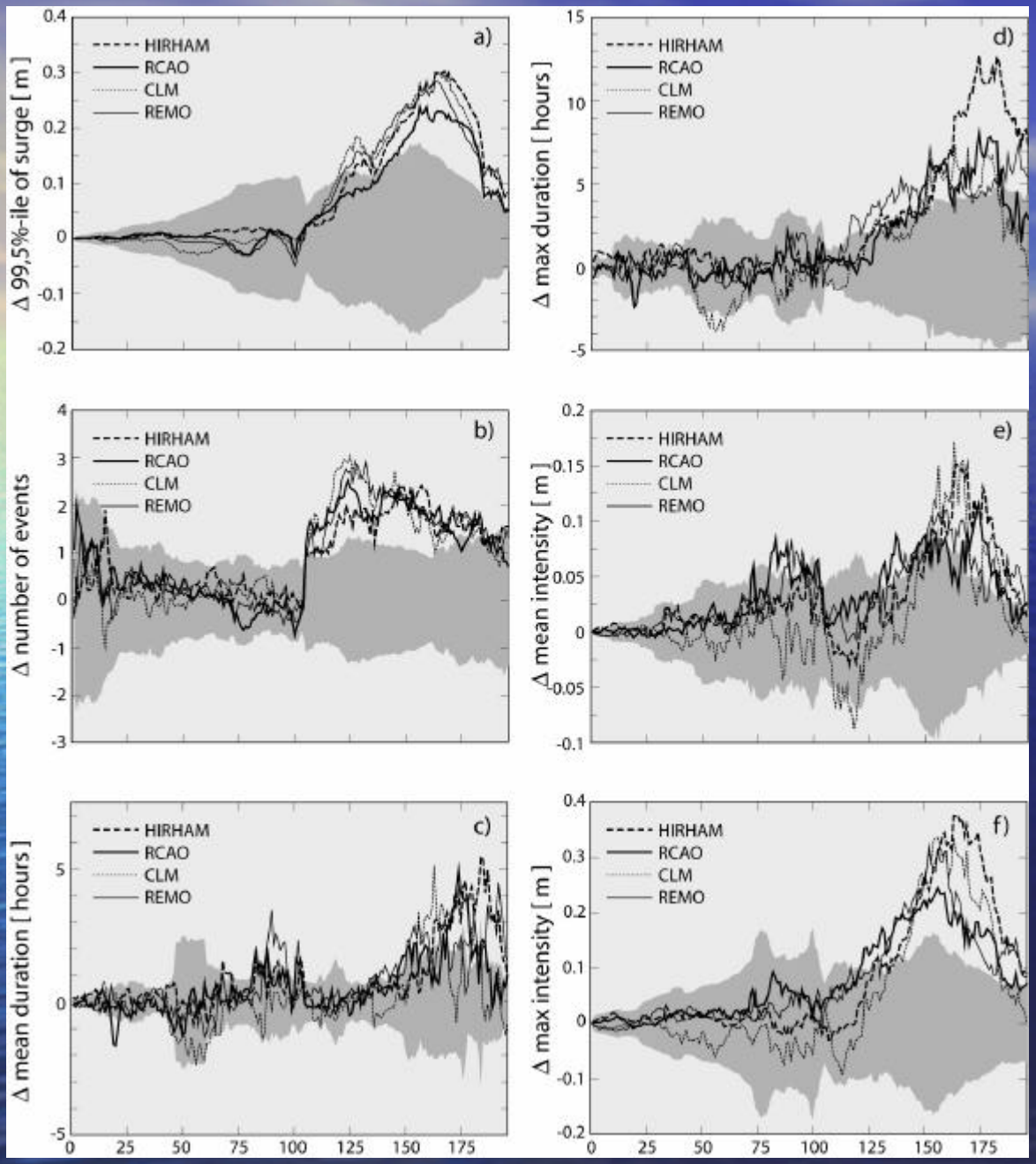
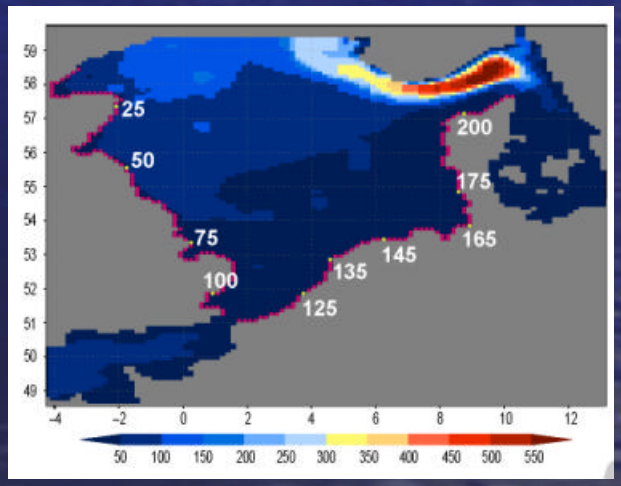



So far only one ensemble member

Ensembles for storm surge changes

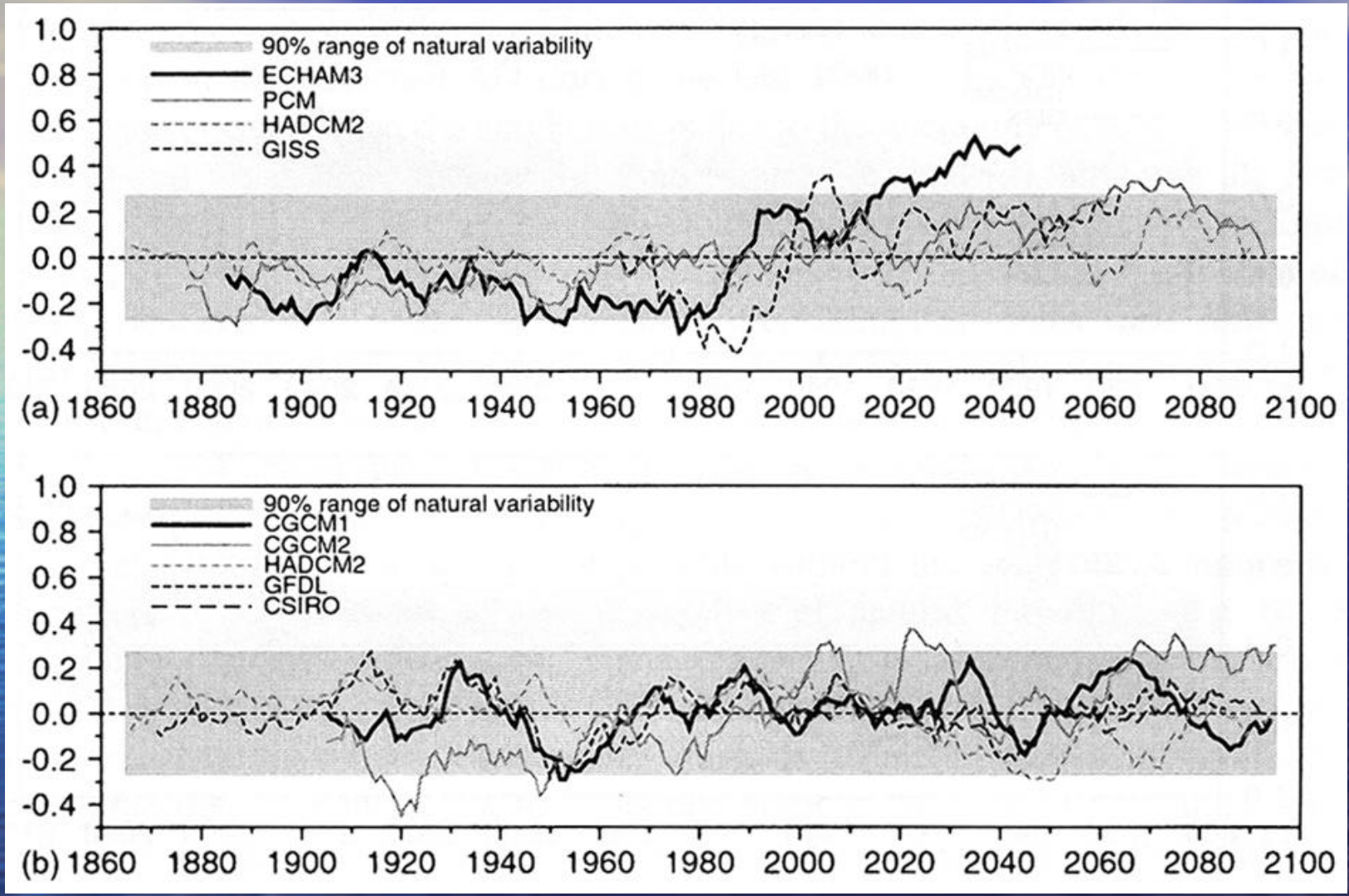




Courtesy: Katja Woth


So far uncertainties due to different RCMs
Different GCMs?

10-yr running mean NAO index (a) ensemble means of GHG runs and (b) ensemble means of GHG+SUL runs



From Rauthe et al. 2004

Summary and Conclusions

Analysis of high resolution hindcast shows increase in extreme wave events for 1958-2002

Future scenarios suggest an increase in extreme wave events south of about 55 N

Uncertainties associated with the response of extra-tropical circulation in different climate models are high

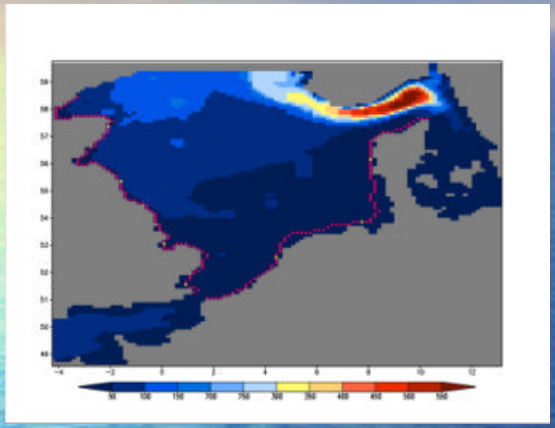
Results for future North Sea wind, wave, storm surge climate represent a consistent and plausible, but not necessarily likely future development


RESERVE

Projections for the future from RCM ensemble AND RCAO with ECHAM forcing:

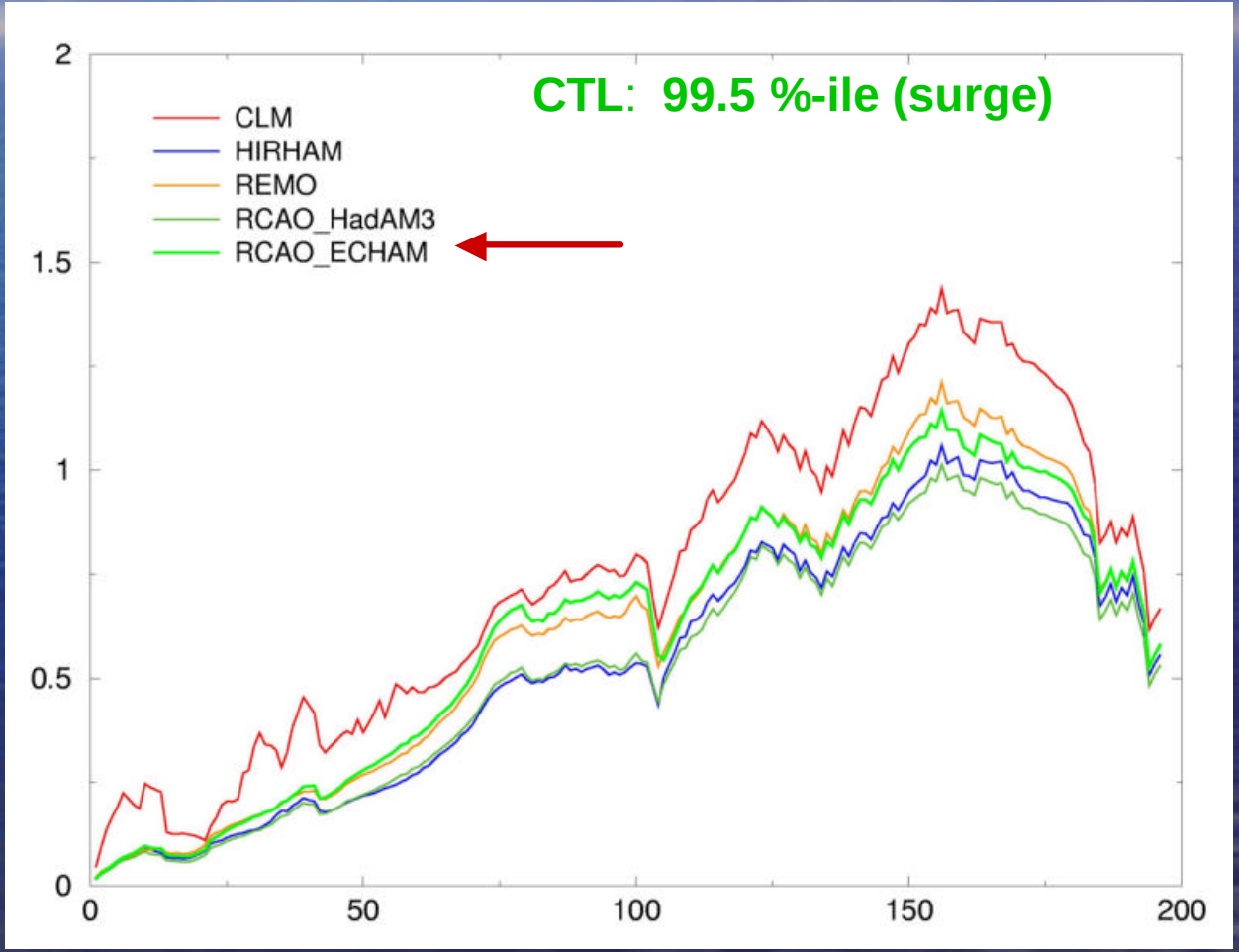
Surge [m]

Courtesy: Katja Woth



storm surge projection, driven with ECHAM_RCAO is laying in the range of ensemble, driven with HC model

But: diff of 15 cm -> 20 %



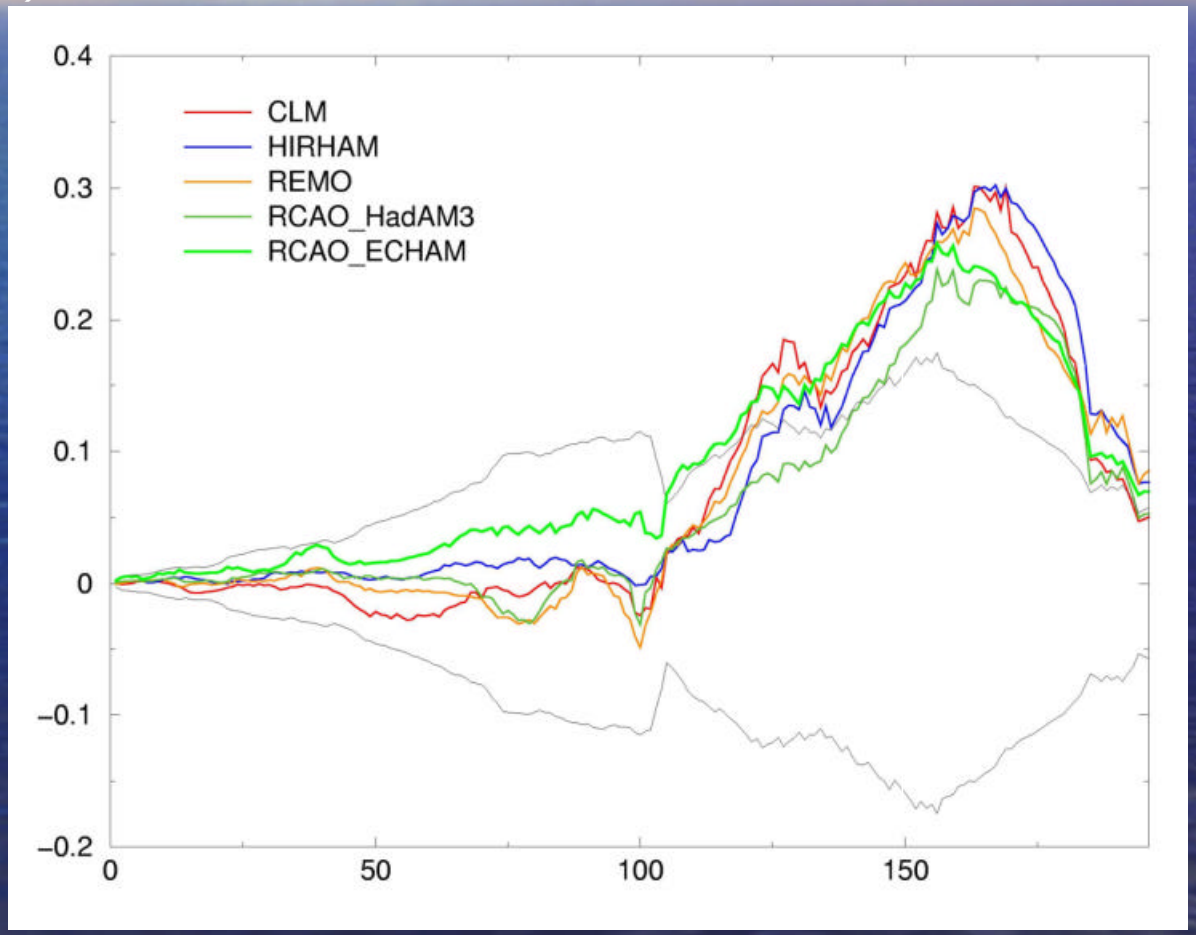
grid cells: 10 m depth line along the coastline

Projections for the future from RCM ensemble AND RCAO with ECHAM forcing

changes in surge (99.5 %-ile)

Courtesy: Katja Woth

?S [m]



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