Sea level rise – Northern European coasts

By

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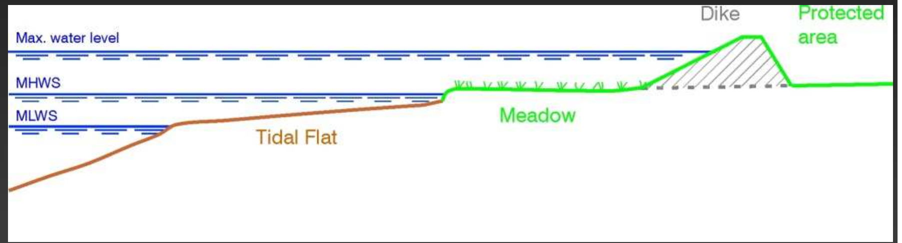
Overview of presentation

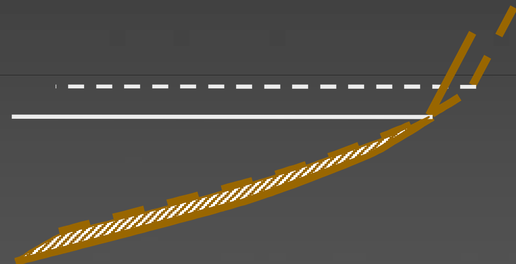
1. Types of coasts
2. Climate change – example of scenario
3. Consequences of climate change on coastal processes
4. Future design conditions
5. Key messages from CEDA WG on CCA: “Climate change adaptation as it affects the dredging community”
6. Examples of sustainable coastal developments/climate adaptation

Climate change leads to:



Sea level rise:

- Coastal flooding
- Coastal erosion, progressive in nature



Increased storm intensity, bigger waves and surges

Changed directional characteristics of waves

New distribution in precipitation =>
Change in supply of sediments

→ Changes in coastal stability and flooding

Sea level rise: 0 m

From: http ://flood.firetree.net

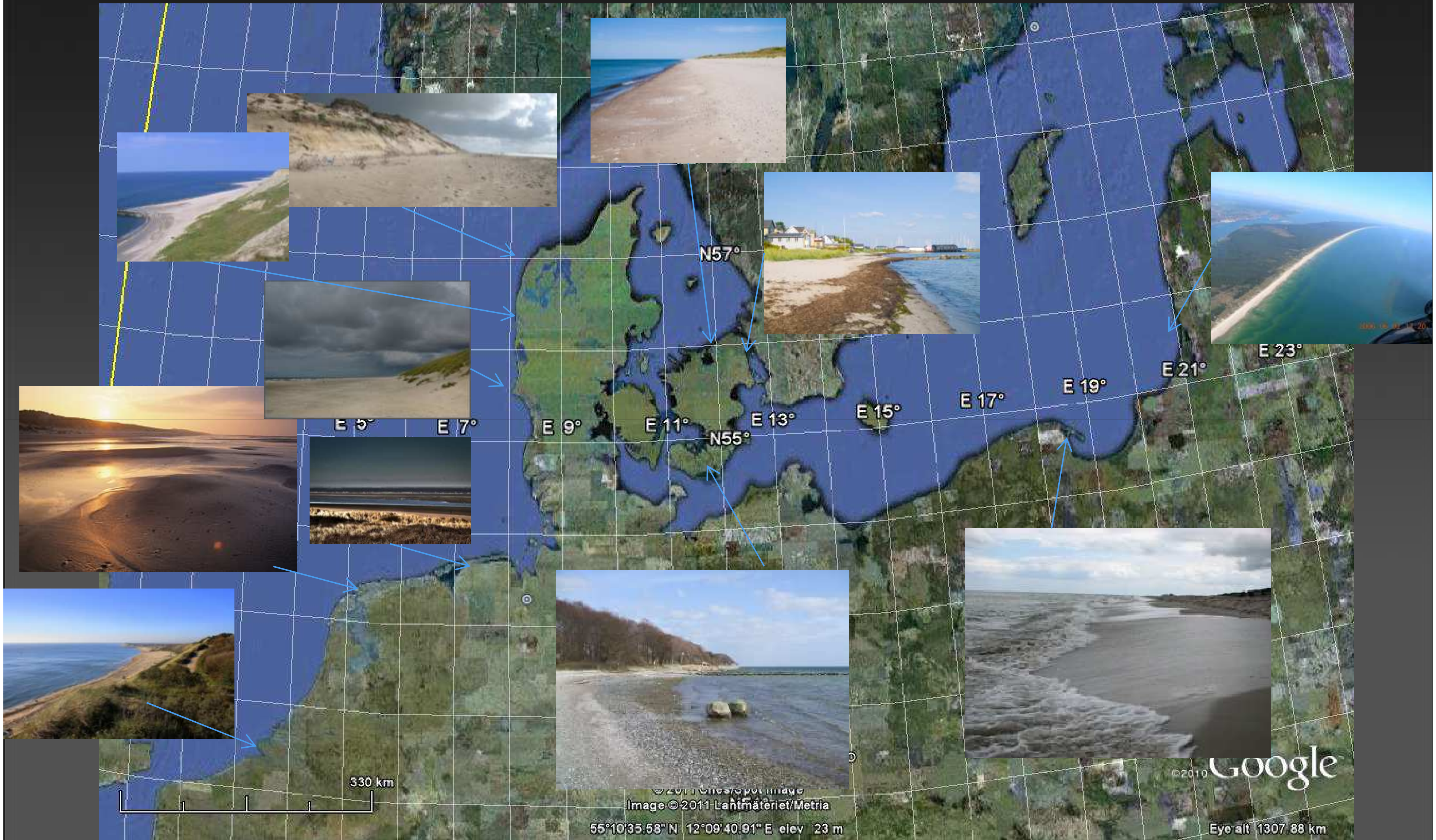
Europe N. America S. A

Sea level rise: +1 m

From: http ://flood.firetree.net

Europe N. America S. Ar

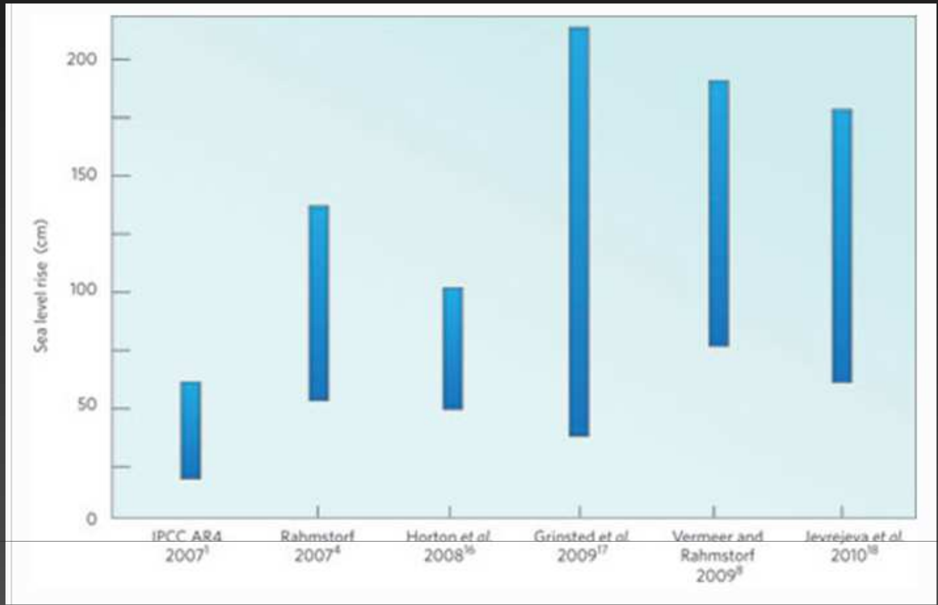
Types of coasts



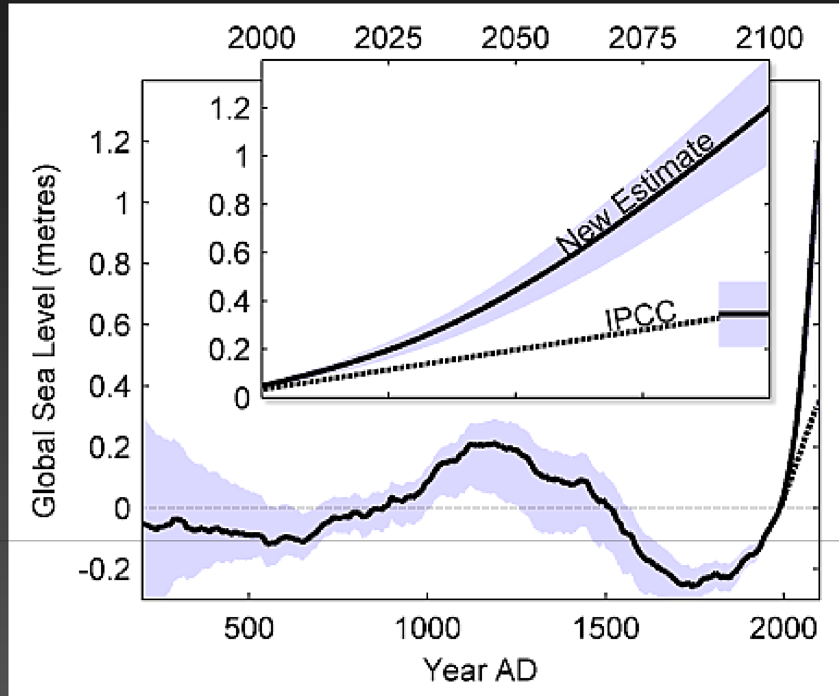
Long stretches of soft coastlines, varying from ”protected” to ”very exposed”

Long stretches with lowlying hinterland – already protected by dikes/other structures

Various estimates of global SLR in 2100:



(from "A new view on sea level rise" by Stefan Rahmstorf)



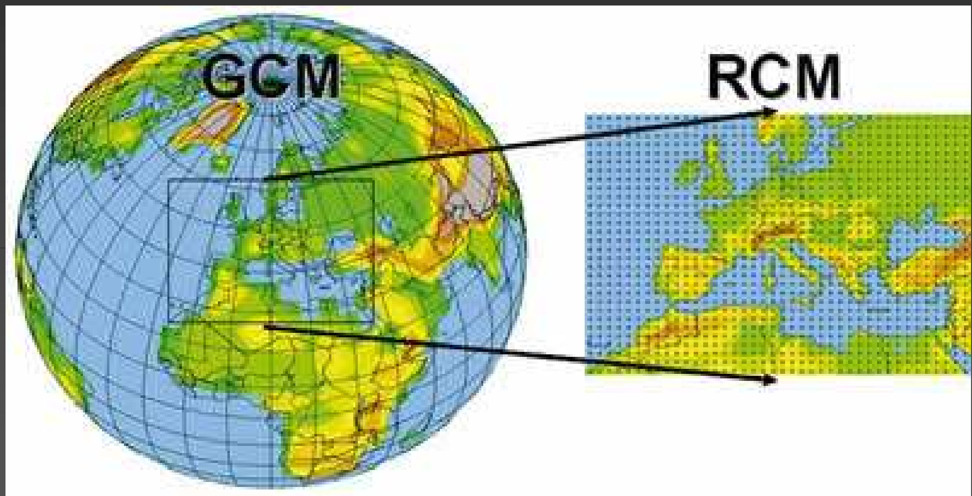
Reconstructing sea level from paleo and projected temperatures 200 to 2100 AD, A. Grindsted et al., 2009, Clim. Dyn., DOI 10.1007/s00382-008-0707-2

Consequences of climate change on coastal processes

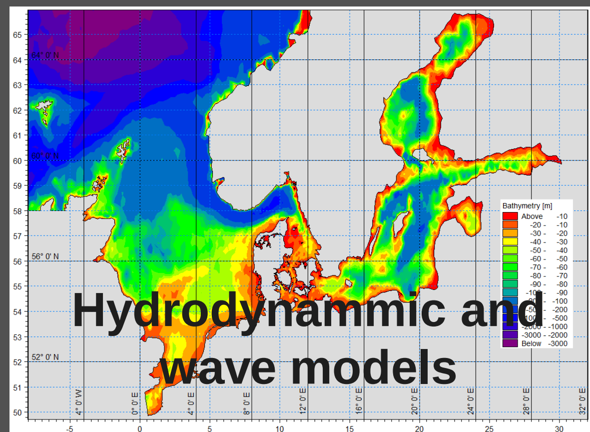
Downscaling to coastal processes:

Scenario: A1B from IPCC

Global model : ARPEGE from Centre National de Recherches Météorologiques
Regional model: HIRHAM5 from Danish Meteorological Institute
SLR: Grindsted et al. (2009): 2090-2099
SLR, 5 - 95% percentiles: 0.91-1.32 m



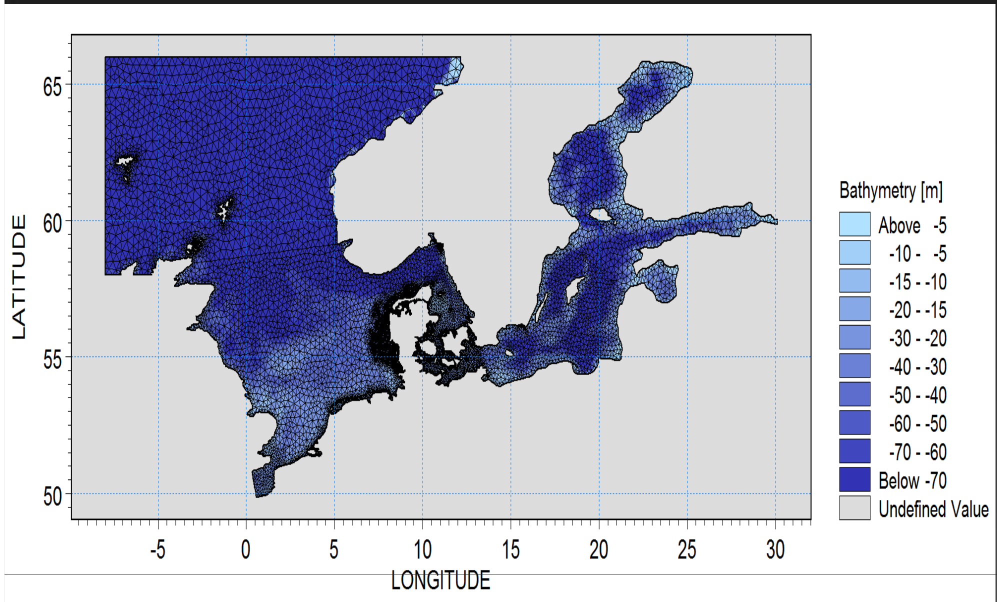
Wind and pressure fields

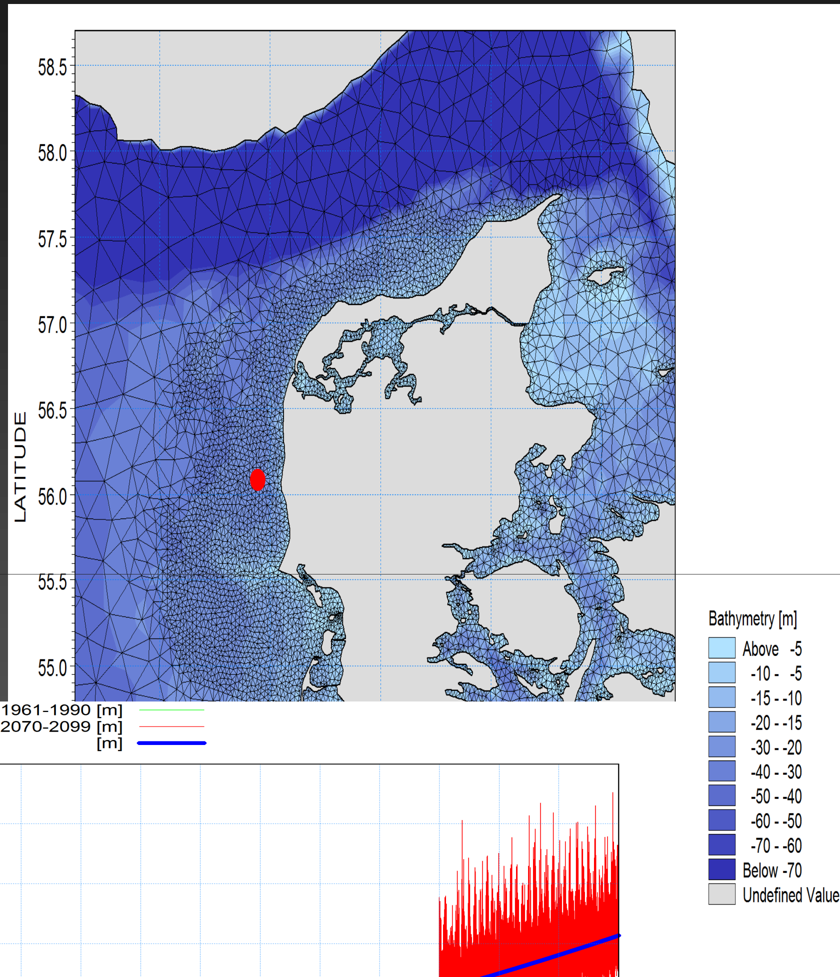


Water levels, currents and waves

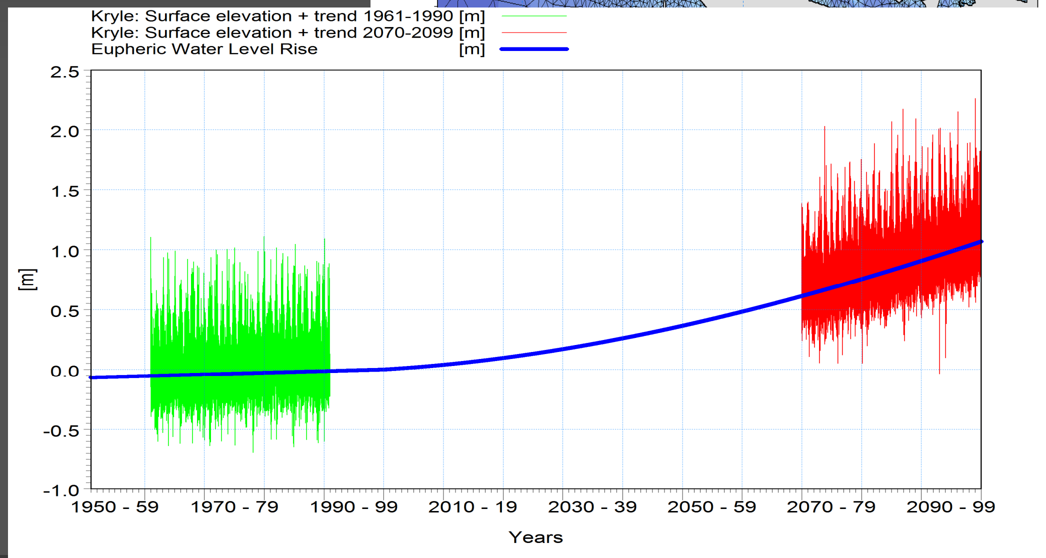
Characteristic and extreme marine conditions

Model domain





Depth adaptive flexible mesh models for hydrodynamics (tide+storm surge) and waves

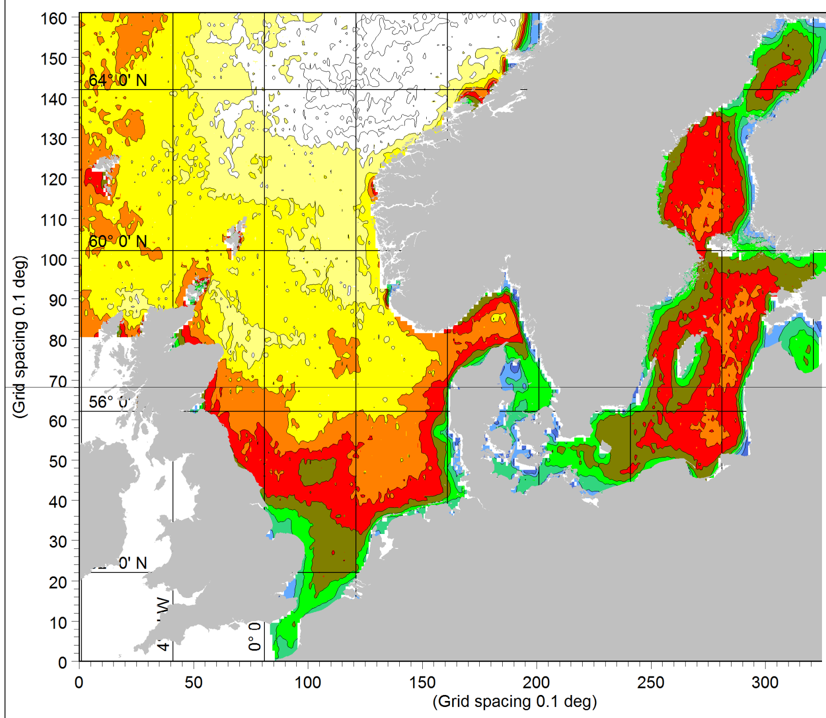


MIKE BY DHI

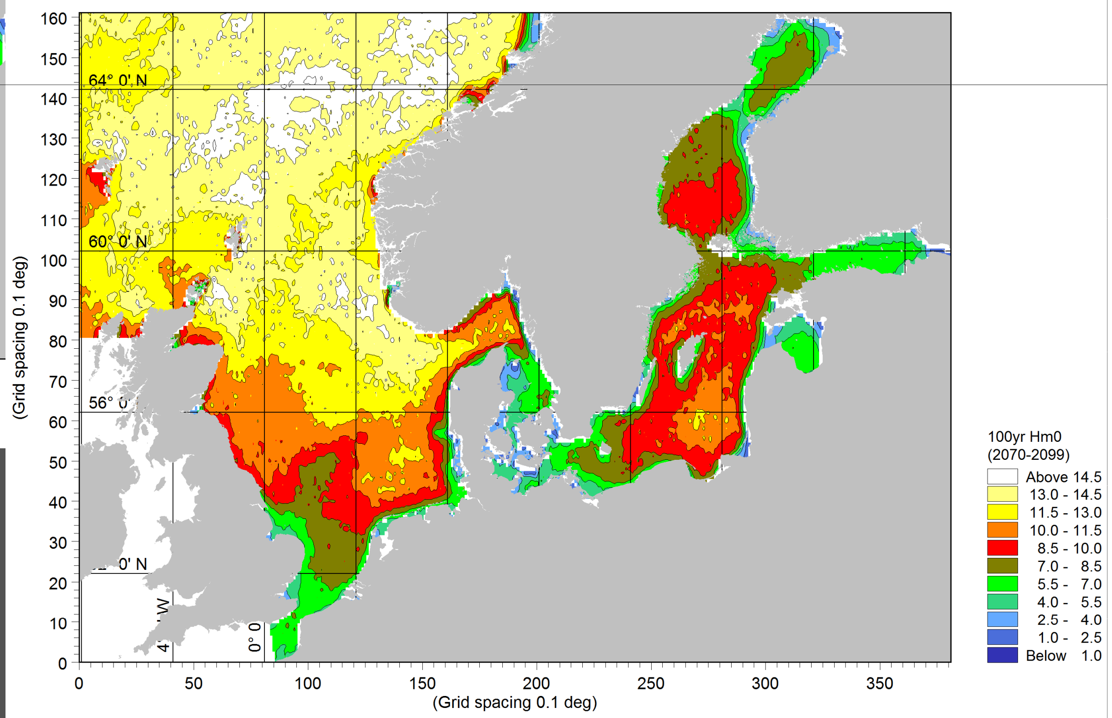
Design wave conditions

Significant wave height (3-hourly) with a return period of 100 years

1961-1990

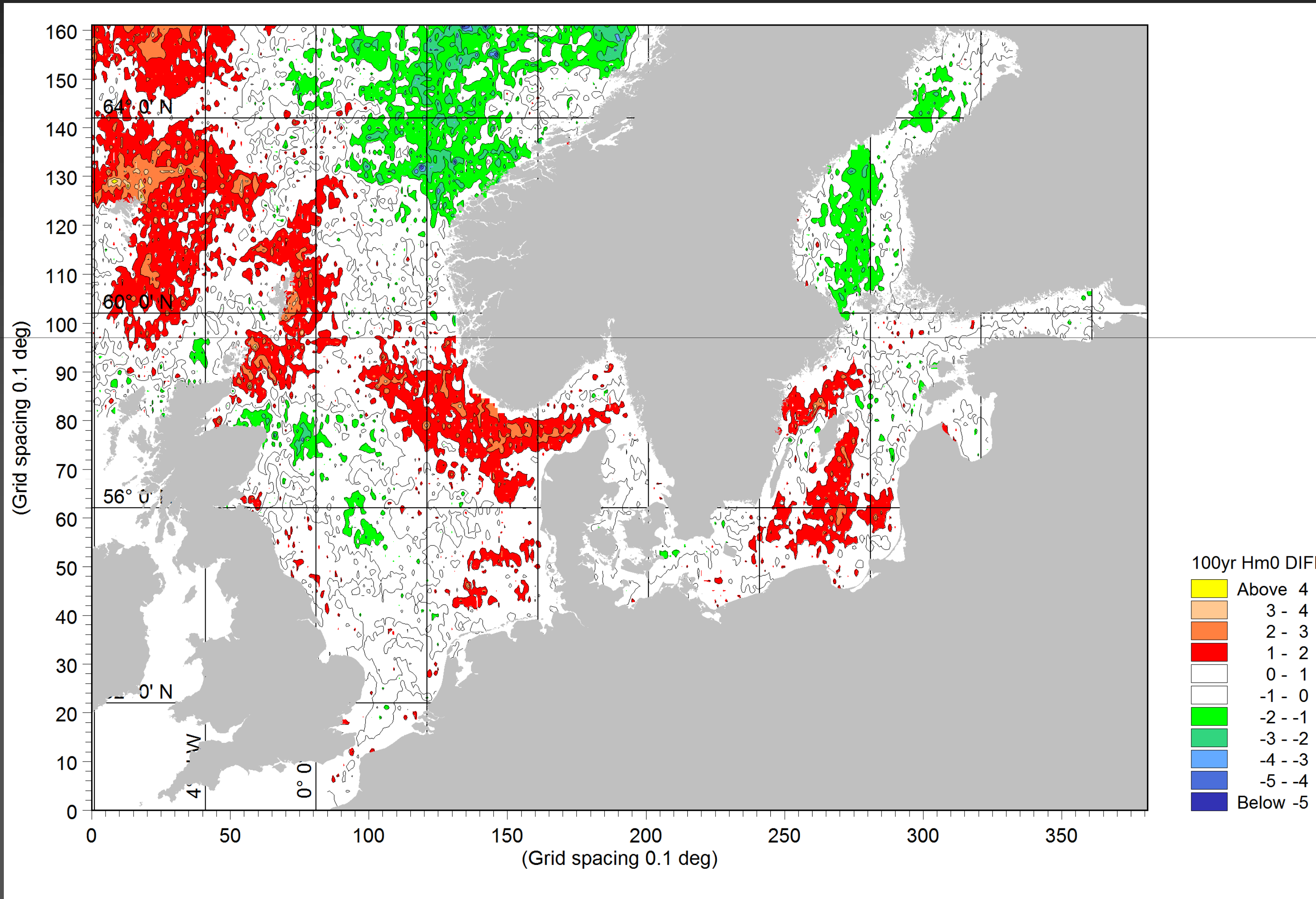


2071-2100



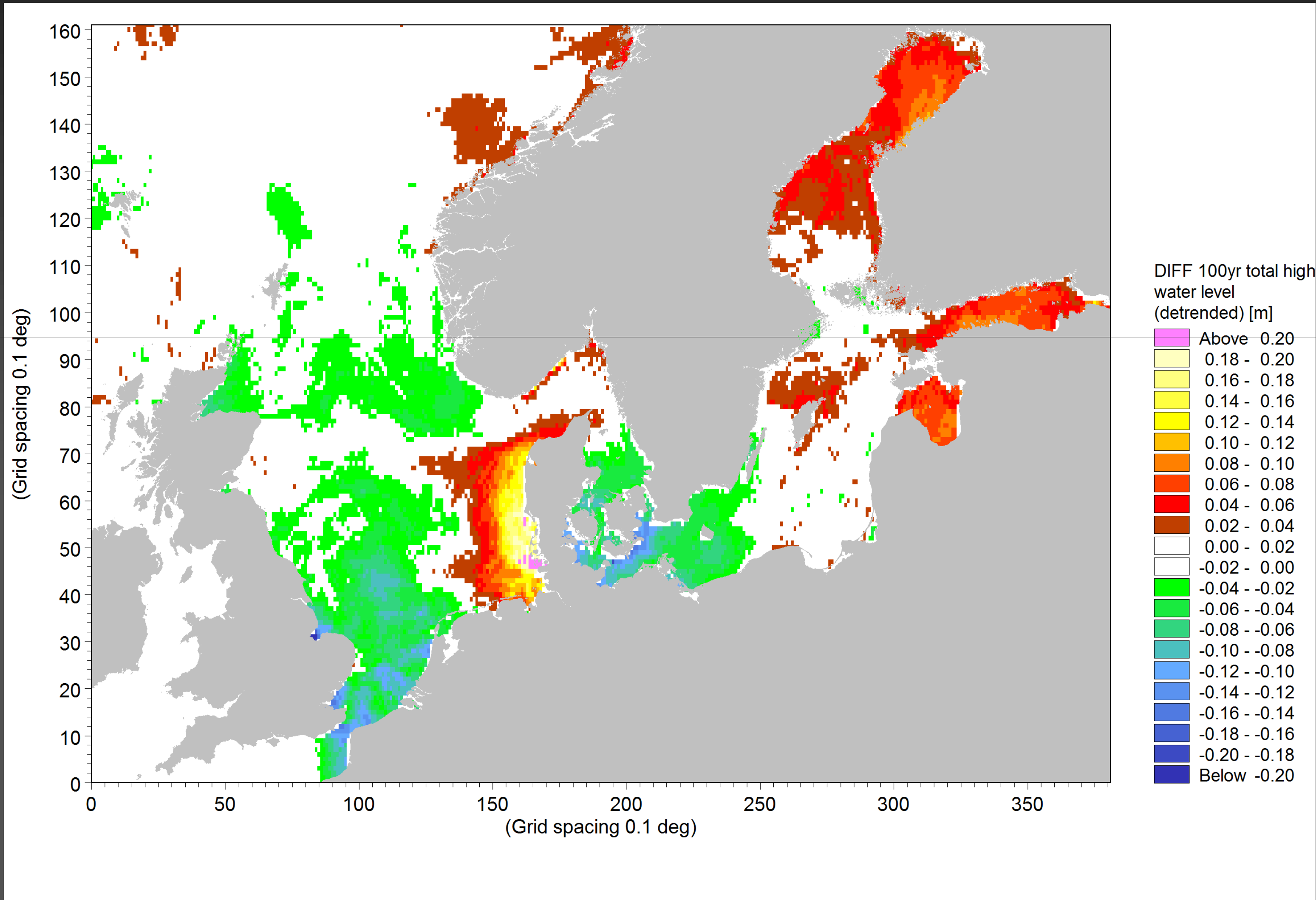
Design wave conditions

Increase / decrease in significant wave height (3-hourly) with a return period of 100 years



Design water level conditions (surge)

Increase / decrease in water level (surge) excluding SLR with a return period of 100 years



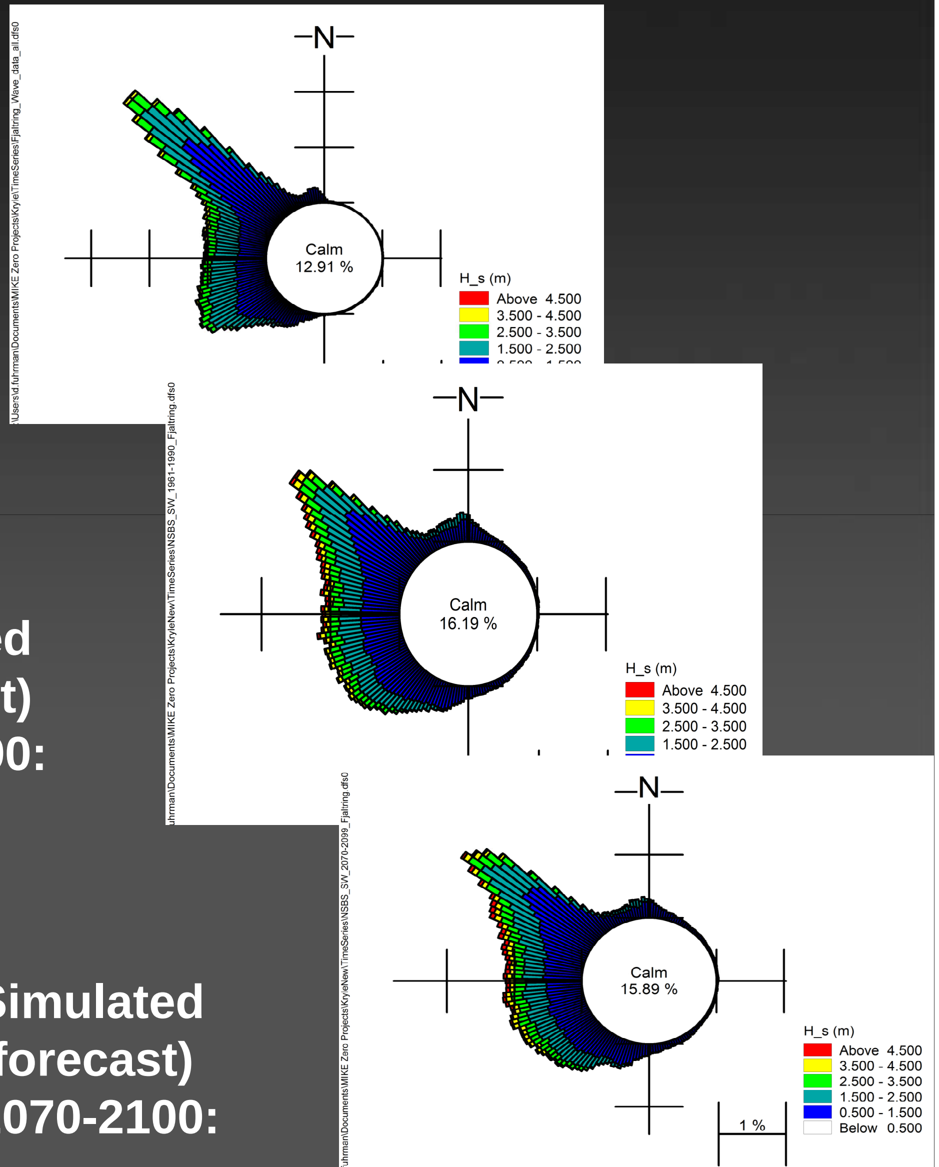
Nearshore wave conditions

Three data sets:

Measured (Buoy) 1992-2007:

Simulated (hindcast) 1960-1990:

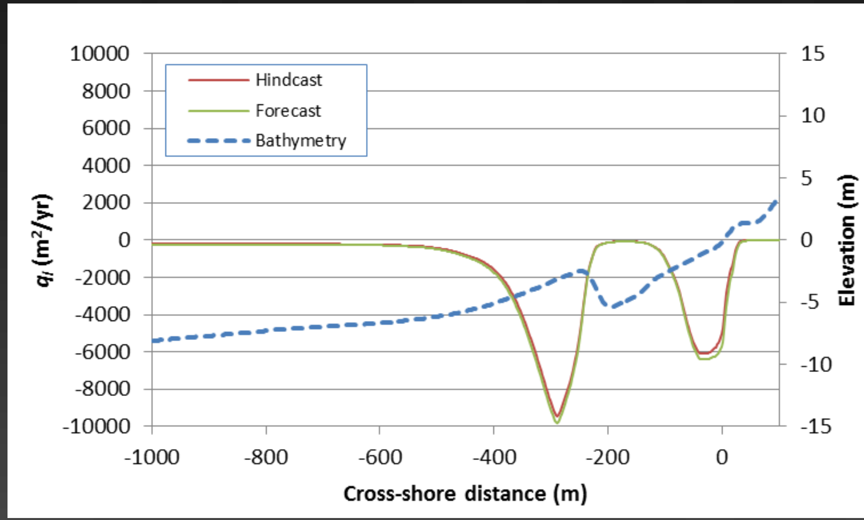
Simulated (forecast) 2070-2100:



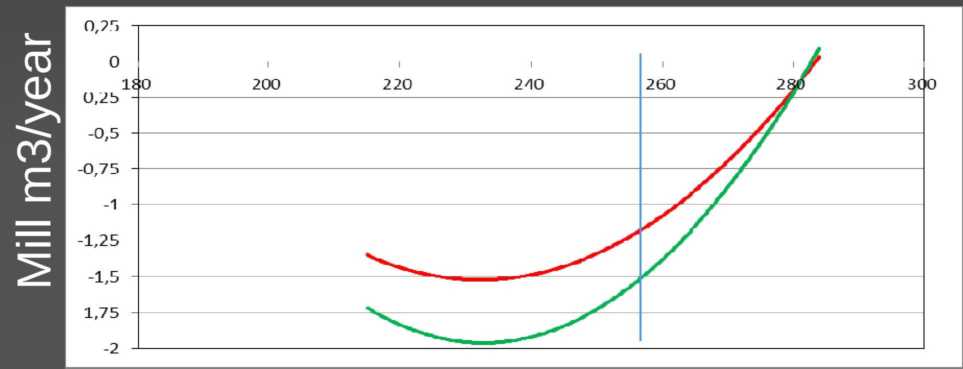
Littoral drift

Simulated littoral drift at
Hvide Sande (southward)

(based on down scaling)



Orientation



Hind cast

Forecast

- Increase in littoral drift 10%
- Shift in equilibrium orientation

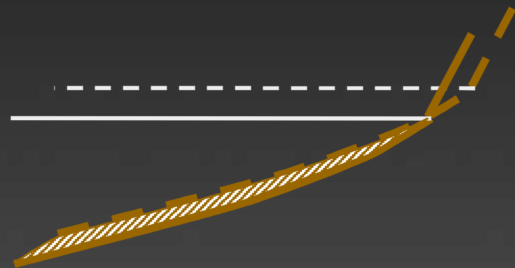
Uncertainty due to down scaling: +/- 4 deg 10-20%

- Time scale for profile changes << change in mean sea level

Nourishment at The Danish West Coast

Magnitude of existing erosion problem relative to erosion caused by SLR only:

Typical natural erosion rate: 3 m/year



SLR in year 2100: 0.5 m -1.0 m
Slope of beach: 1:100
Coastal erosion due to SLR: Δx = 50m-100m /90yr

or 20-40% of present natural erosion.

The present yearly nourishment: approx 3 mill m^3 – stabilises selected stretches

The required nourishment will increase: **20-40 % from SLR**, **10%** from increased littoral drift

“Climate change adaptation as it affects the dredging community” draft CEDA position paper

Pol Hakstege

Chairman CEDA WG CCA

Dredging Days November 10 Rotterdam

Objectives of CEDA position paper on climate change adaptation (draft)

- To raise awareness of the dredging community to be prepared for climate change;
- How can dredging contribute to adaptation measures?
- What are the implications for the dredging community?
- Focus is on anticipation on consequences of climate change not on causes.

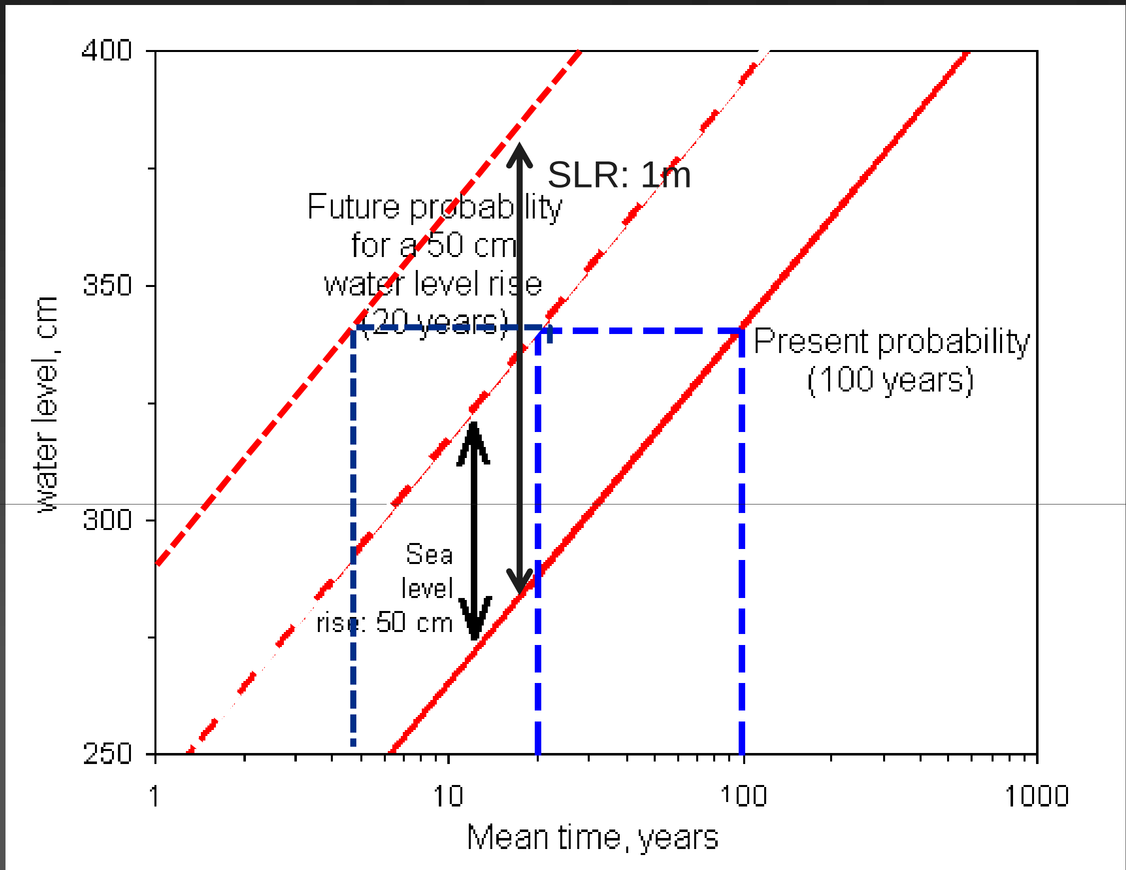
Adaptation measures

- Absolutely necessary to reduce the consequences of climate change by reducing vulnerability and/or improving resilience
- Integrated sustainable approach:
  - safety against flooding,
  - environmental protection and improvement,
  - economics, stakeholder and societal interests
- Short term: data collection and monitoring (understanding and risk assessment)
- Long term: realise adaptation measures (flexibility)

Potential climate change implications for dredging community

- Changes in dredging volumes and/or locations
- Sustainable sediment management solutions
- **Flexibility is vital** (uncertainties, extreme events)
- Dredging methodologies (reactive or proactive)
- New and innovative solutions are required
- Specific equipment for new types of operations

Effect of SRL on design water level



-with no changes in surge

Red and blue: Example from Denmark (100-year to 20-year event for 0.5 m)
(100-year to 5-year event for 1.0 m)

Examples

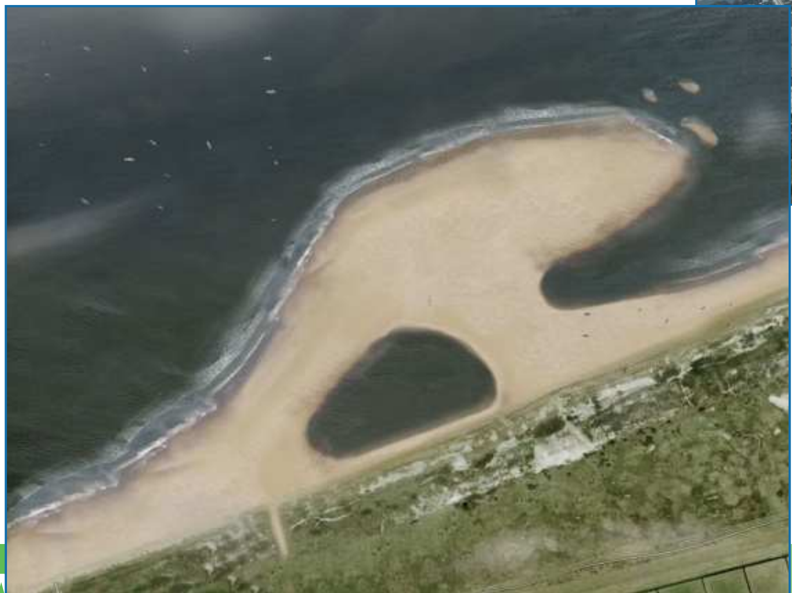
Maintenance of Dutch coast line by beach nourishment

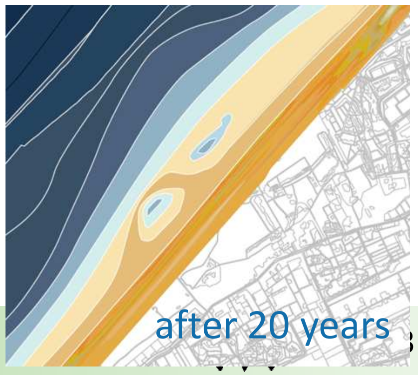
- At this moment: 12 million m^3/yr
- Expectation for coming decades: 20 mill m^3/yr, in the future 4 times more
- Increase in sand supply and sources further away
- Complexity: logistics, ecological and morphological response

Working or Building with Nature

- Use dynamics of natural system as starting point for the design
- Example Sand Engine: mega nourishment Dutch Coast
- Combining safety with space for nature development and recreation, use natural processes for distribution of sand
- From defensive (minimize environmental impacts) to proactive approach (optimize full economic and environmental potential)

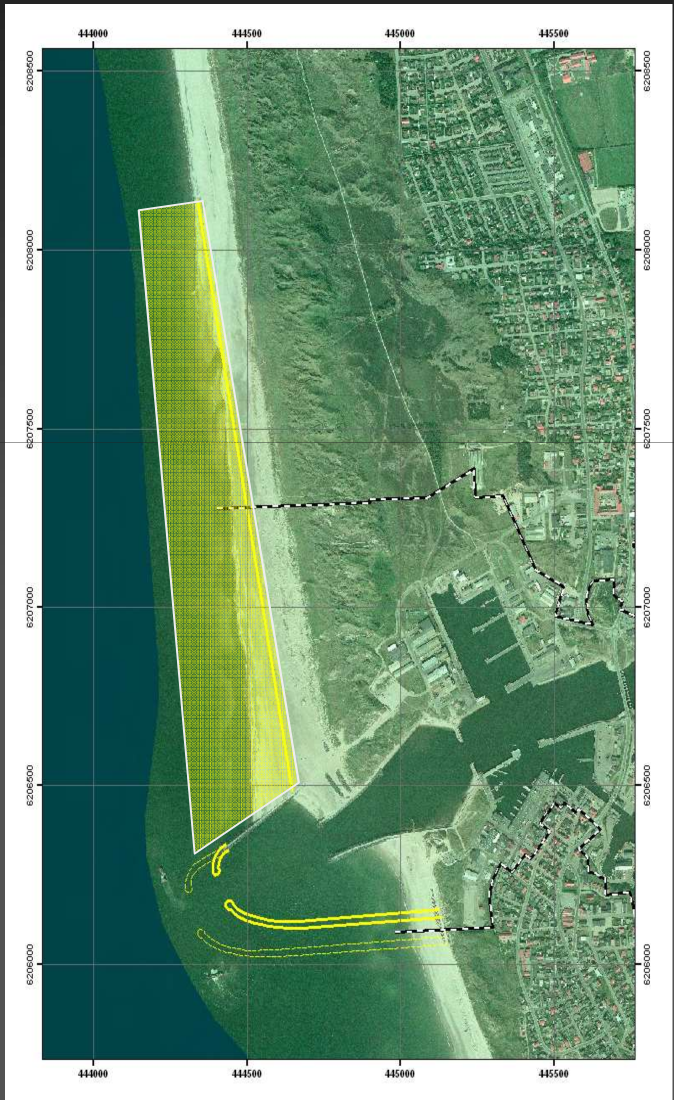




Hvide Sande, Denmark

- Proactive dredging, innovative dredging scheme



Future harbour:

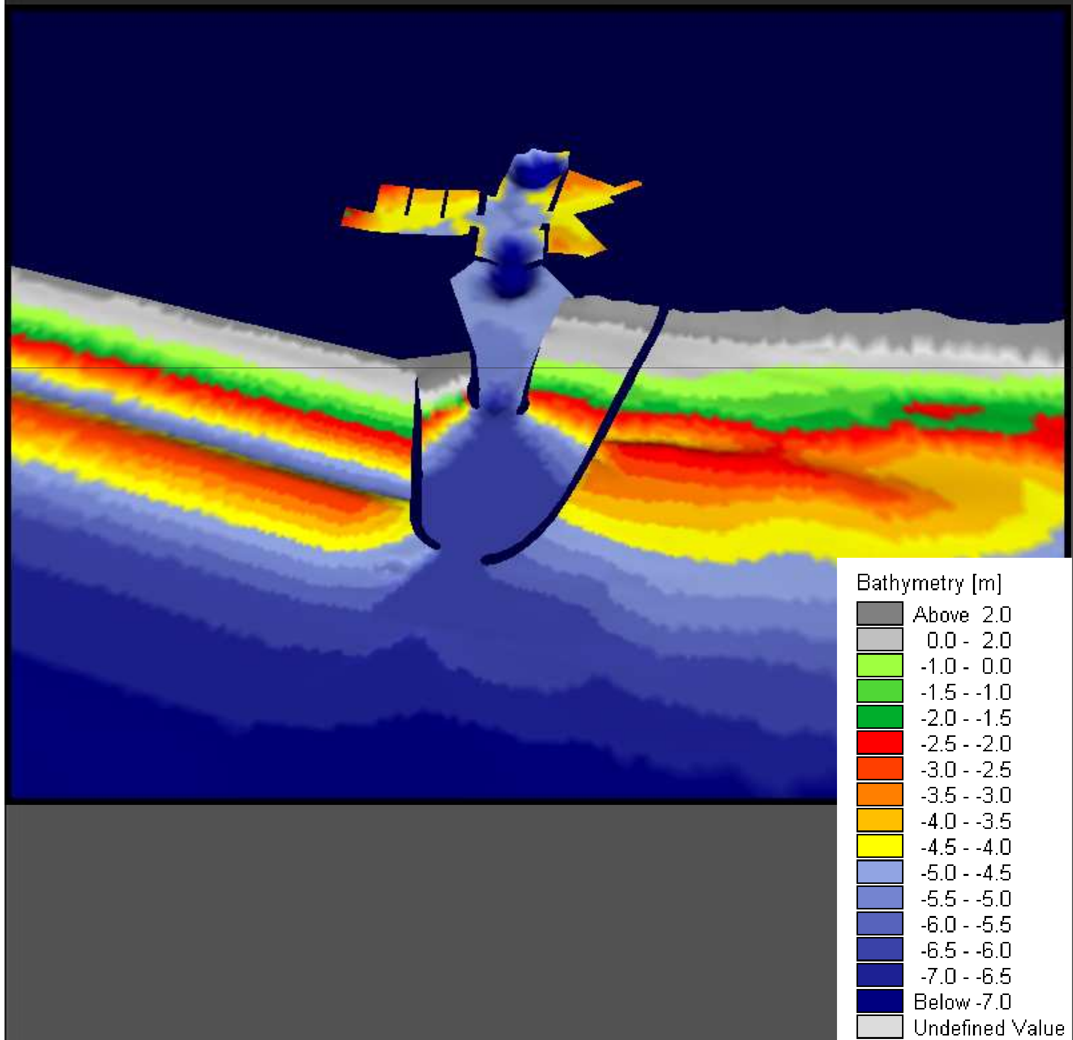
Harbour wishes to increase navigation depth to 6.0 m *and* reduce sedimentation in the access channel

Main elements of the future harbour are:

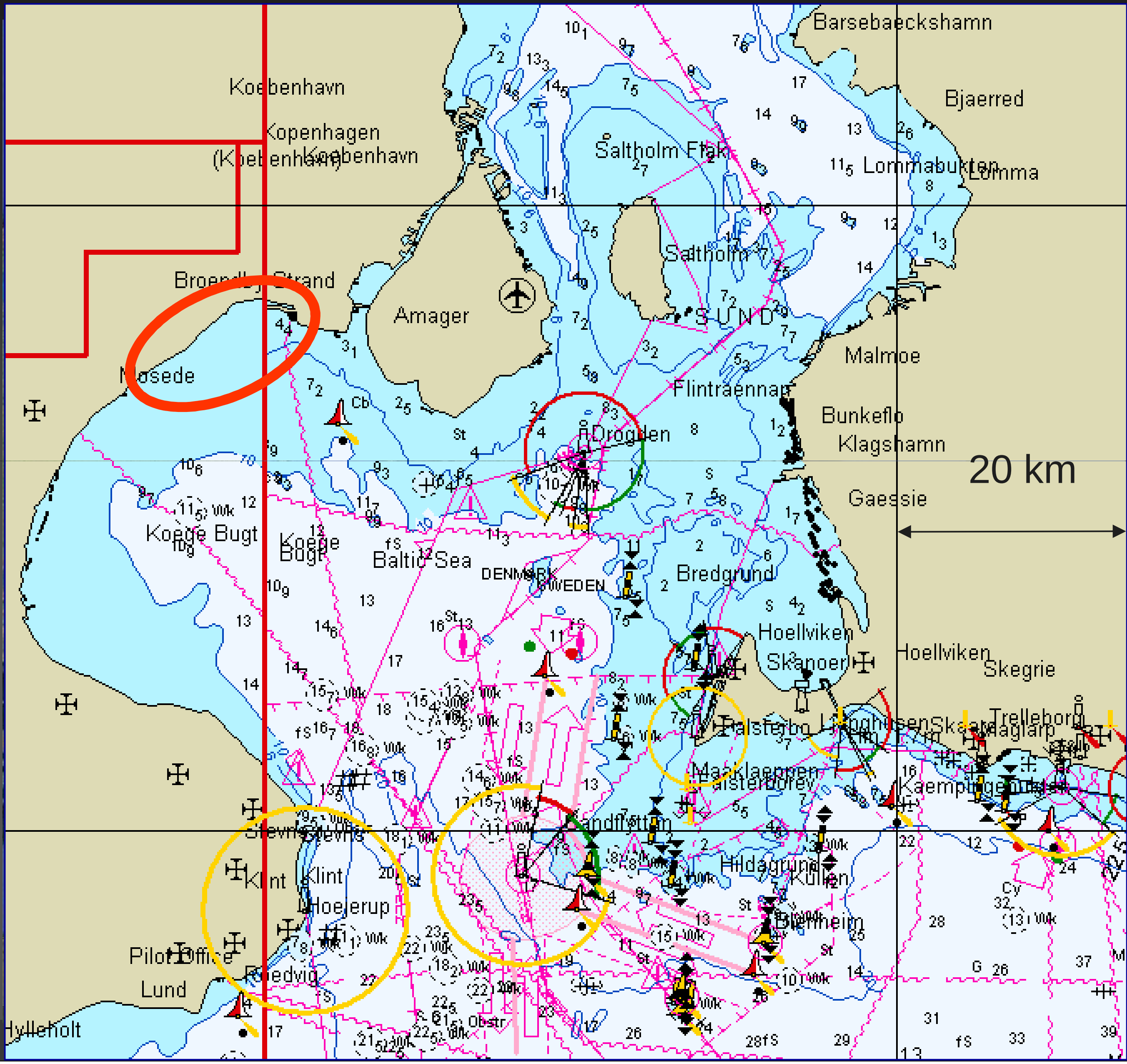
- 70 m extension of existing breakwater
- new southern breakwater (~750 m)
- capital dredging of 1,200,000 m^3 over 1,600 m north of the harbour
- Maintenance of the ”retreated” up-drift beach to optimize natural bypass

Equilibrium bathymetry for future harbour

Model is run until new dynamic equilibrium is reached
– obtained within 2 design periods/typical winter seasons



Combined Scheme: Køge Bay Beach Park



Combined scheme

- Køge Bay Beach Park: Combining coastal and lagoon rehabilitation, marinas and sea defence

Completed in 1980
Beach length: 7 km
Sand fill. 5.0 mill m^3
4 marinas
10 km dikes
Lagoons/marinas: 2 mill m^2

Closing remarks

Technicalities

- IPCC and the scientific community provide forecast for future global conditions
- Meteorological institutes scale climate scenarios to regional scale
- Regional scale results provide boundary conditions for local scale

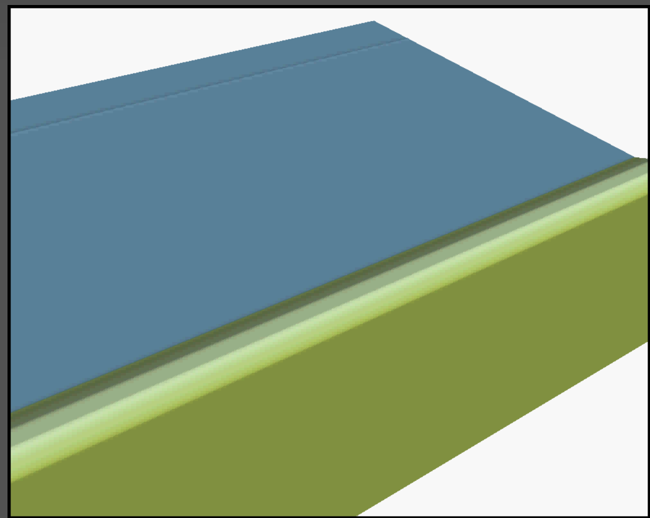
Challenges

- Uncertainty in forecast
- Which planning horizon to choose

And note

Climate changes do not stop in year 2100

Innovative sustainable and integrated projects and management schemes shall be developed to service the needs of the society

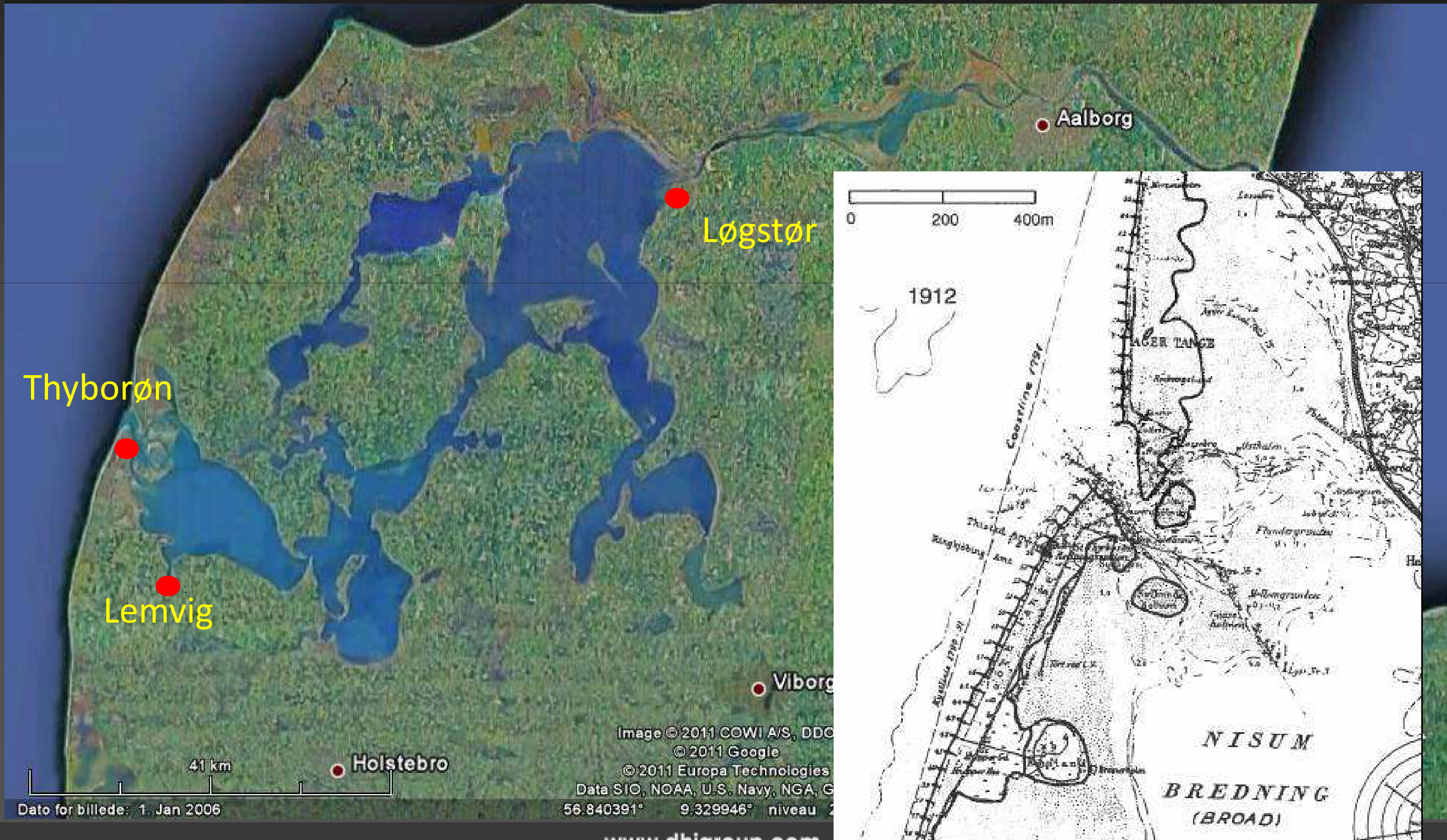


(From COADAPT)

Extra

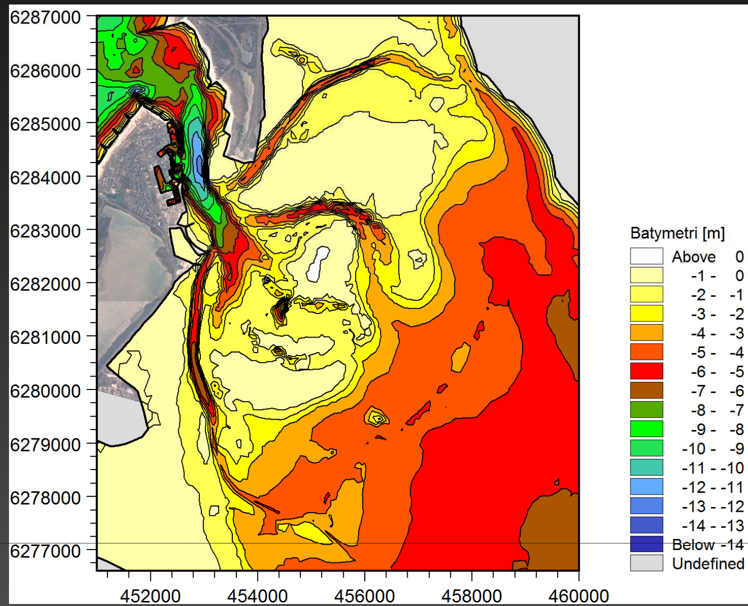
Storm surges in the Limfjord

Investigation of morphological and climate effects on storm surge levels in the Limfjord system

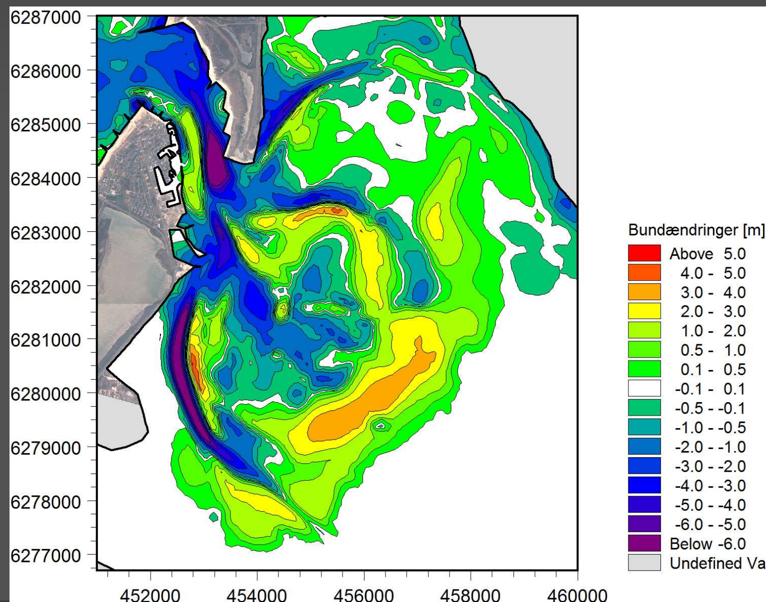


On-going morphological development interact with CC

- Rise of mean sea level
- Increased wind speed
- Change in wind direction
- Increased surge levels in the North Sea



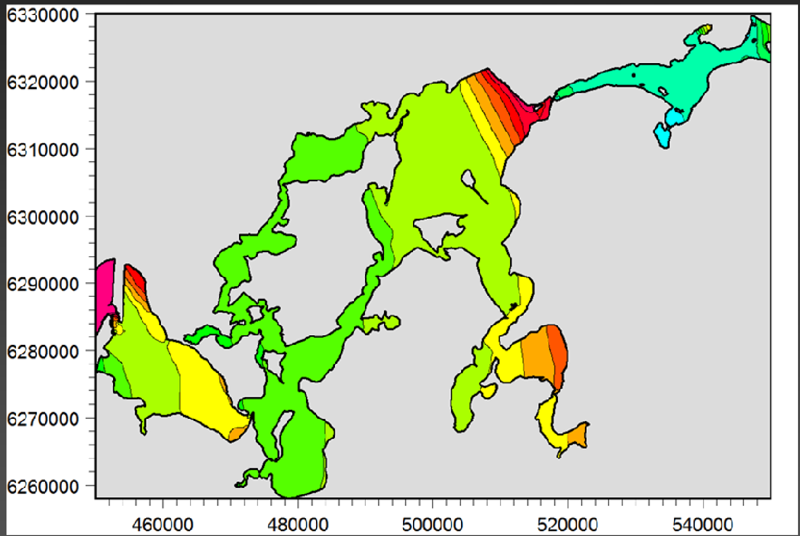
1958

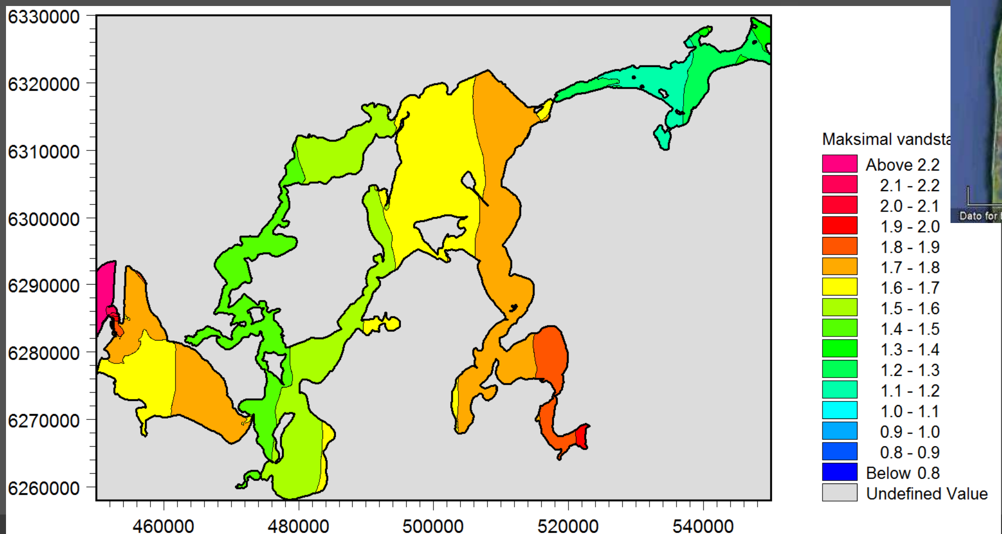


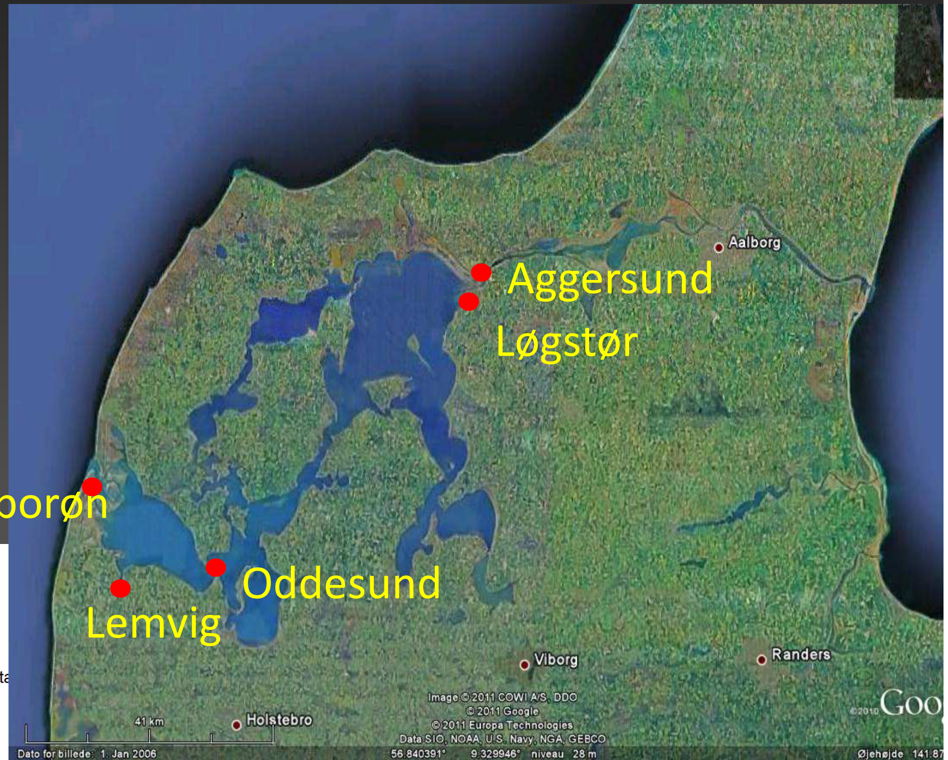
bed level change from 1958 to 2005

Examples: Max surge level for two storms

Short storm, the North Sea surge level peaks at the same time as the wind







the North Sea surge level is maintained for a long time after the storm has peaked.

Historical storms (wind conditions and water level at the North Sea boundary) were simulated for 2005 and 2060 bathymetry.

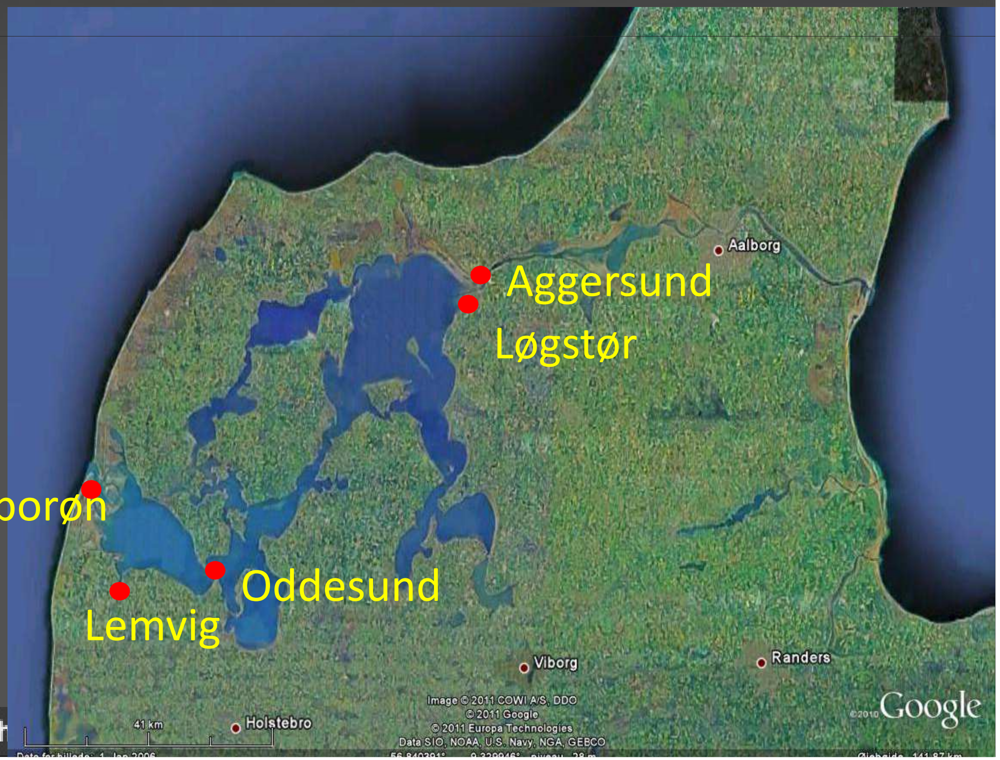
The effect of increased cross-section at Thyborøn

Climate change sensitivity (two examples)

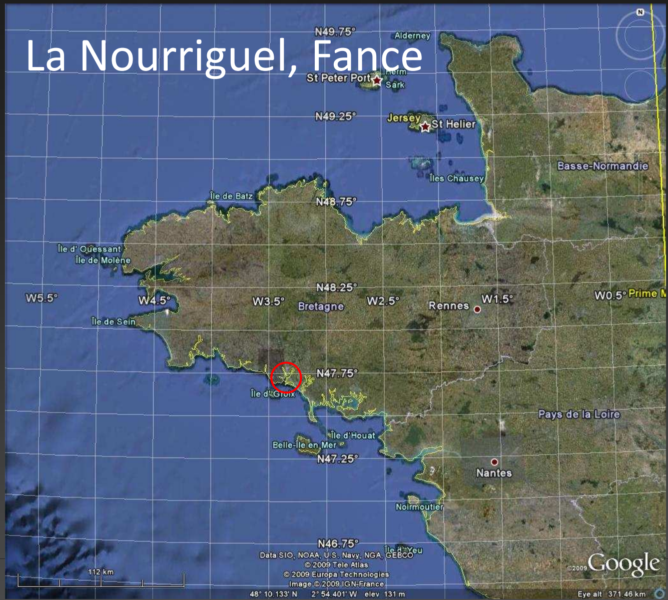
Average for 6 storms:		Surge +20%	Duration +30%	wind +10%
Thyborøn Harbour:	**8 cm**	33/35 cm	1/5 cm	3/0 cm
Lemvig:	**15 cm**	33/34 cm	5/8 cm	4/-1 cm
Løgstør:	**5 cm**	16/25 cm	6/17cm	32/10 cm
East of Aggersund:	**<3 cm**			

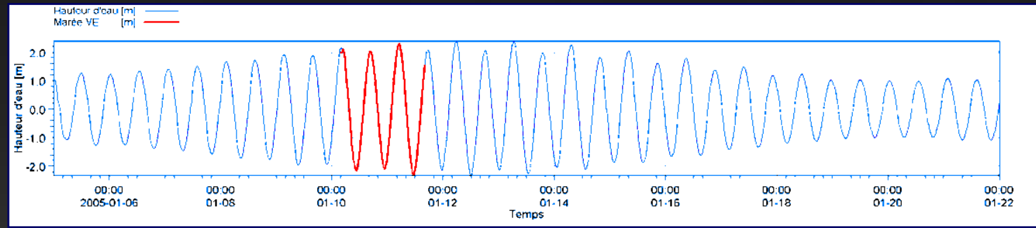
CCA design shall include:

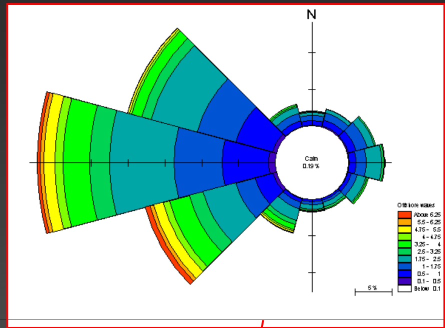
SRL
+
Effects of morphological change
Storm surge
Storm duration
Local wind set-up

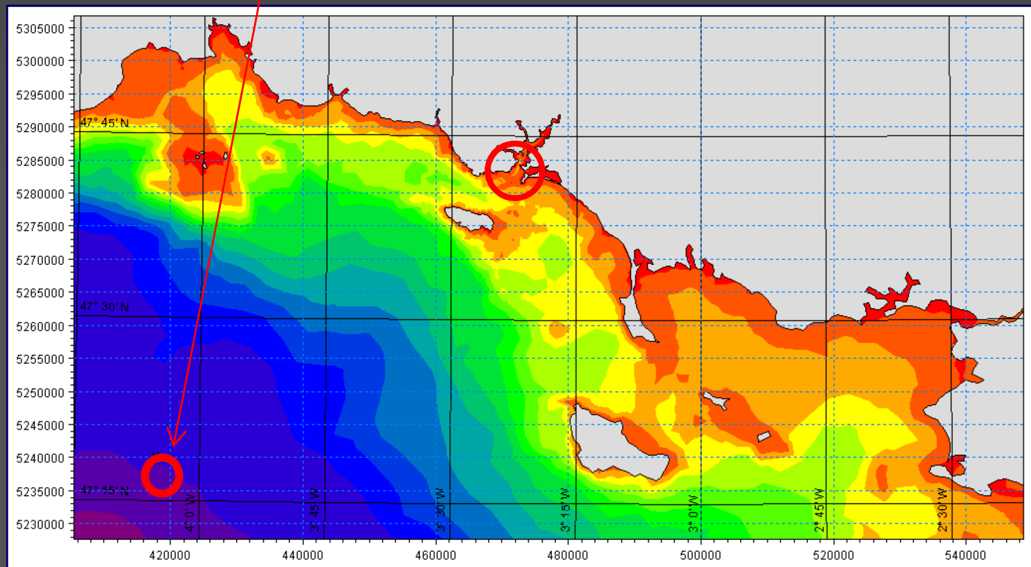


Soft protection against overtopping





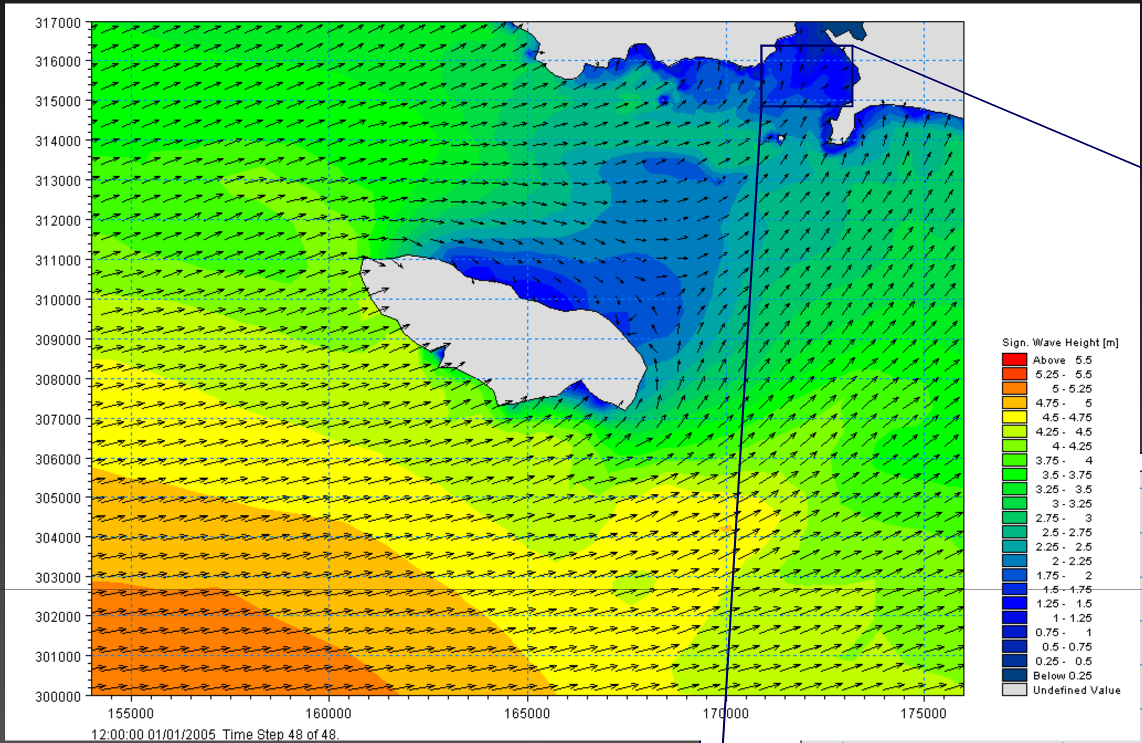


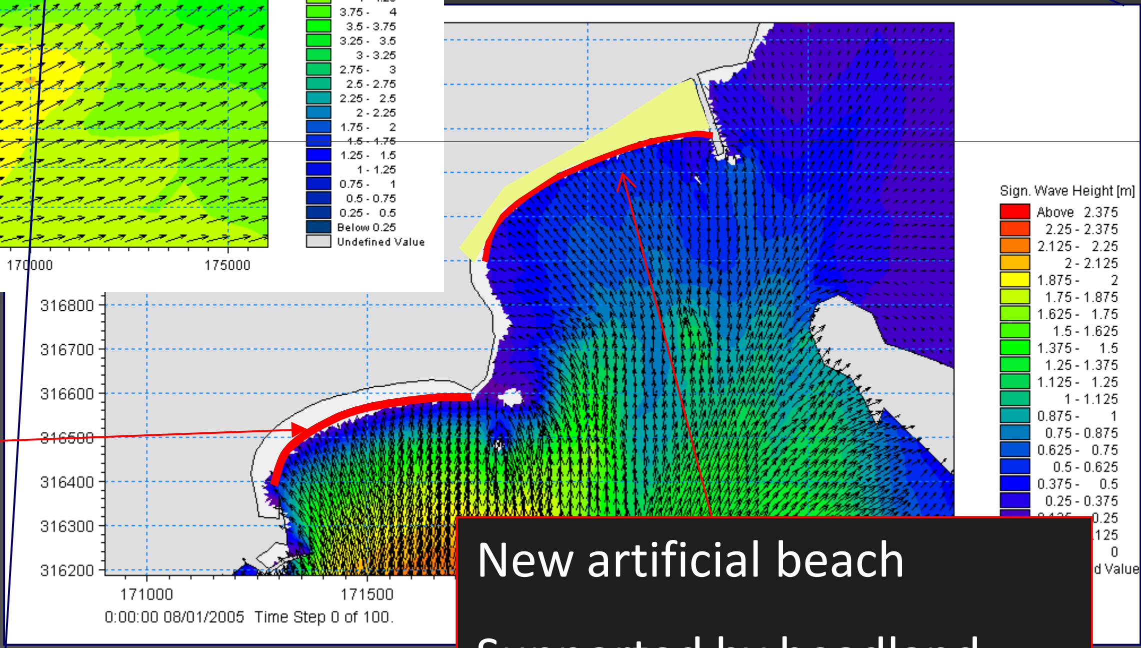


Present conditions

Bad weather ..

Regional and local waves





Natural stable beach aligned to face the dominant waves

New artificial beach

Supported by headland

Aligned to dominant wave direction

After …

Wave, current and sediment transport modelling has supported the design of the future stable sandy beach and headland

Sandy beach will dissipate wave energy before waves hit the wall

Designed also for SLR