METOCEAN

Kriegers Flak & Horns Rev 3

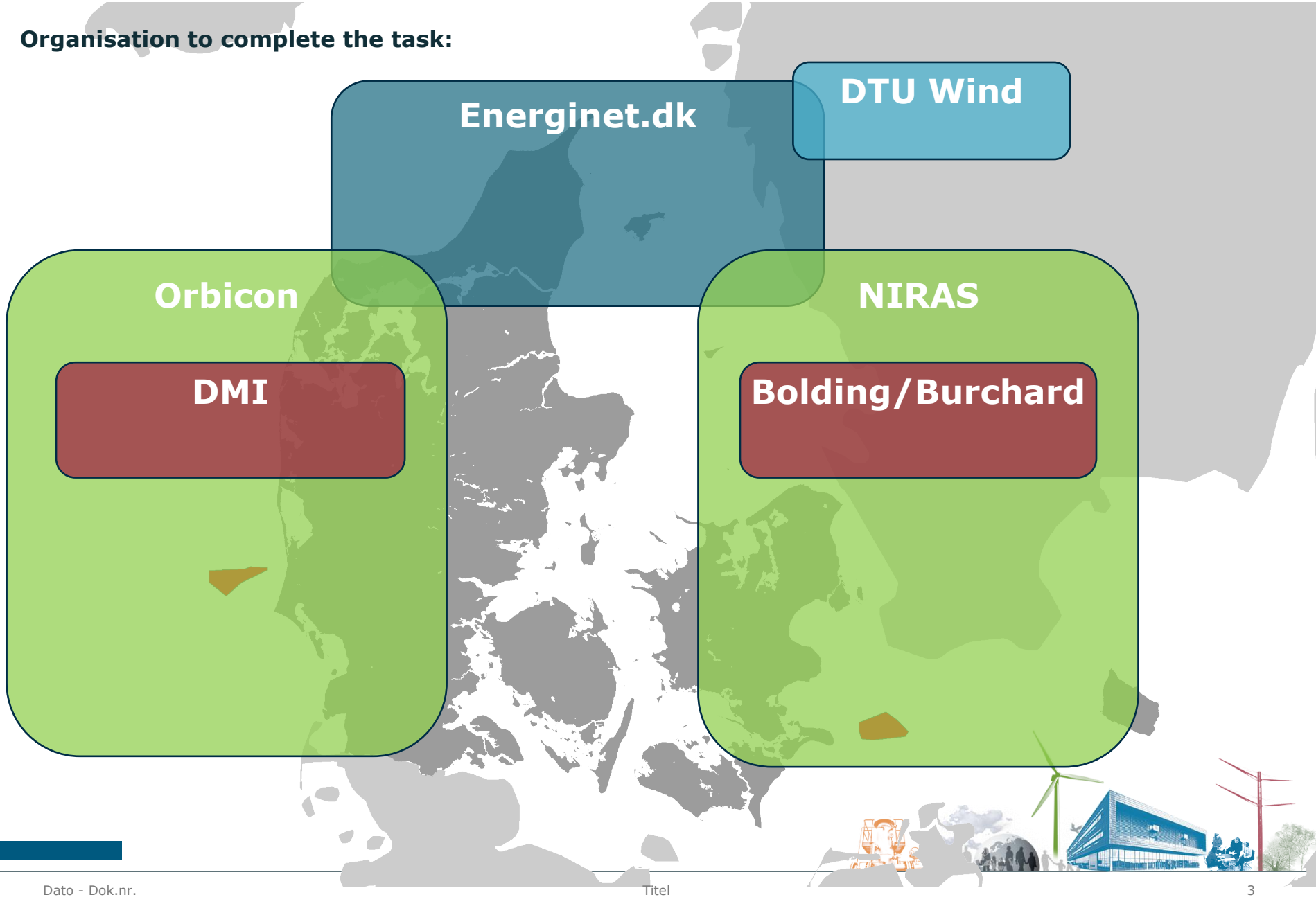
Task assigned to Energinet.dk:

Compilation of information regarding wind-, wave- and current conditions

- *Must conduct pre-investigations of wind-, wave- and current conditions (Metocean) at a level of detail, which allow developers to compile an economically qualified tender regarding construction and operation of the Offshore Wind Farm.*

Danish Ministry of Climate, Energy and Building

Organisation to complete the task:



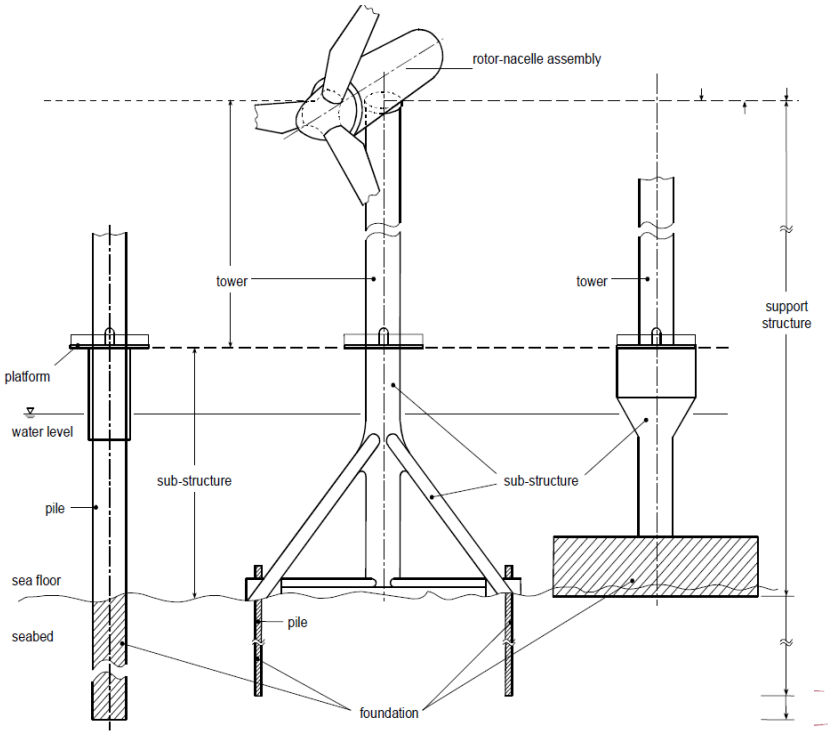
Level of detail:

Pre-investigations of metocean will be based on the international design standard (*IEC614000-3*) for offshore wind turbines

- Design must be based on environmental conditions which are representative of the site at which the offshore wind turbine will be installed.
- Environmental conditions include waves, currents, water depth, seabed properties, sea ice and marine growth.

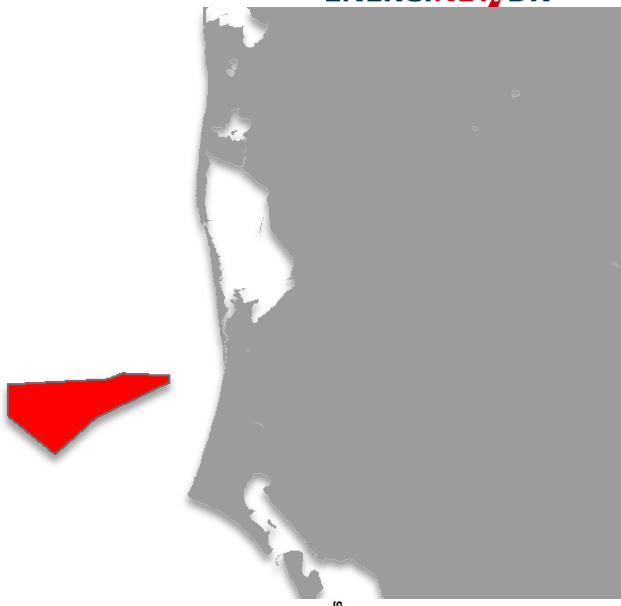
Compilation of Metocean encompassing the following parameters (examples):

- Wind speeds and directions
- Significant wave height
- Water current speed and direction
- Water levels
- Occurrence and properties of sea ice
- Occurrence of icing
- Other related metocean parameters e.g. water temperature and densities, water salinity, site bathymetry, marine growth.




Horns Rev 3
Kriegers Flak

Horns Rev 3 Site description



Salinity

- Salinity in this part of the North Sea is approx. 32 PSU

Currents

- Currents are induced by both: tide, wind and waves, varying in direction and magnitude according to time of the day and season.
- Tide-induced current alone is of a magnitude of up to 0.5 m/s.
- Directions of the currents vary significantly in the area, but the net directions are north-south or reversely.

Wave size

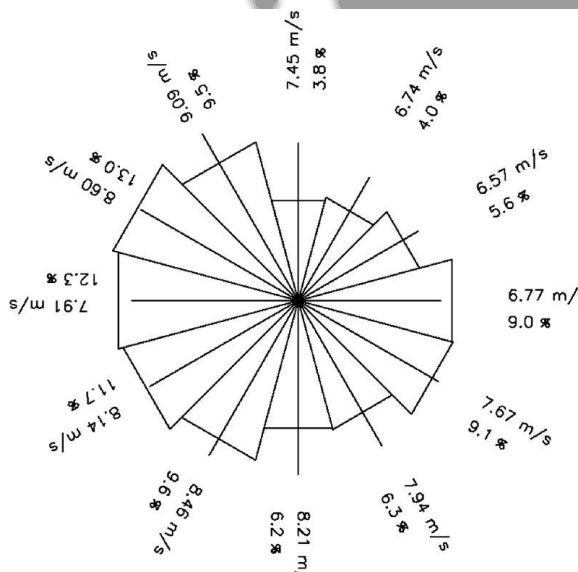
- Wave sizes are in general influenced by the shallow water at Horns Rev with waves breaking on the reef.
- Consequently, Horns Rev significantly limits the near shore wave condition east of the reef.

Tides

- The tide vary between 0.8 m in Hvide Sande north of Horns Rev to 1.5-1.8 m in Esbjerg south of the Horns Rev area.

Wind

- Winds are predominantly westerly throughout the year.
- The wind and wave climate can be rough during both summer and winter, but especially during fall and winter



Kriegers Flak Site description

Salinity and density

- Rapid vertical change in salinity is permanent in the Baltic (halocline).
- Temperature create stratification during the summer. The termocline is situated in 10-20m depth.

Currents

- The current condition is very variable and mainly controlled by: wind, horizontal density gradients and differences in water level.

Wave size

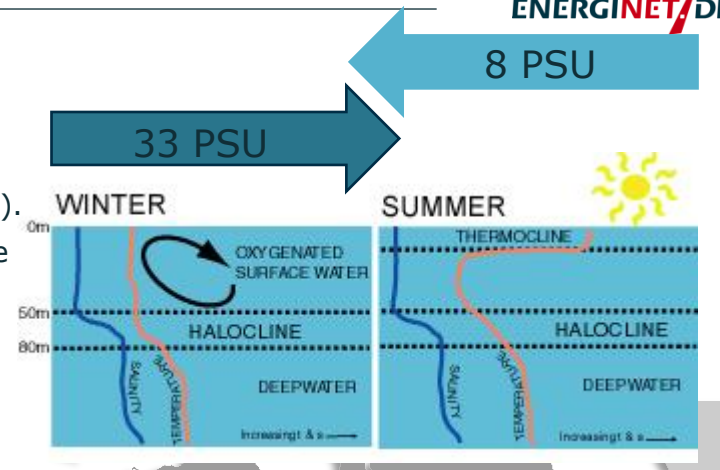
- Rough seas (wave averages of 2 to 3 m) are common from November to December, while calm sea(0-0.5 m waves) are predominant from May to August.
- Swells play a minor role at Kriegers Flak and may occur 4% of time.

Tides

- No rise and fall of tide in the Baltic.

Wind

- Winds are predominantly westerly during summer, whilst easterly winds are quite common during winter.
- The wind direction is between southwest and northwest just over 50 % of the time.



MetOcean – numerical models

MetOcean – numerical models

The numerical modelling is a three step operation where the following steps depends on the previous.

1) Meteorology:
   - Output: Wind speed & direction, Pressure
2) Ocean:
   - Input: Wind speed & direction, Pressure
   - Output: Water level and current
3) Waves:
   - Input: Wind speed & direction, water level
   - Output: Wave height, period and direction

Model setup

Model Setup	Model Name	Resolution	Layers	Period	Time Resol.
Meteorology	**DMI-HIRLAM**	10 km	30	40year 1970-2010	1hour
Ocean 3D	**DMI-HBM**	5 km	up to 50	10year - up to present	1hour
Wave	**DMI-WAM**	2 km	1	5year - up to present	1hour

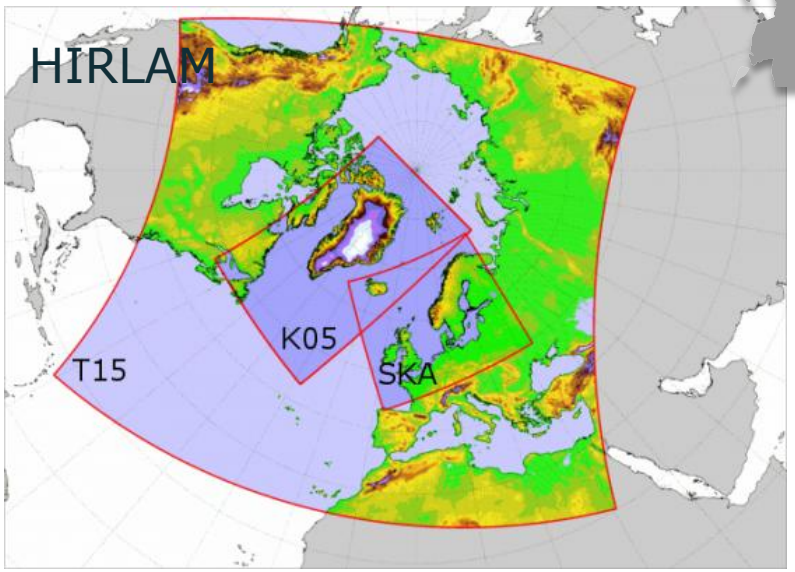
Model setup - meteorology

DMI-HIRLAM is the focing atmospheric model for the DMI ocean model setup

For more information:
http://ocean.dmi.dk/models/index.uk.php#hydrodynamik

Output:

Wind, Pressure, temperature, absolute og relative humidity etc.

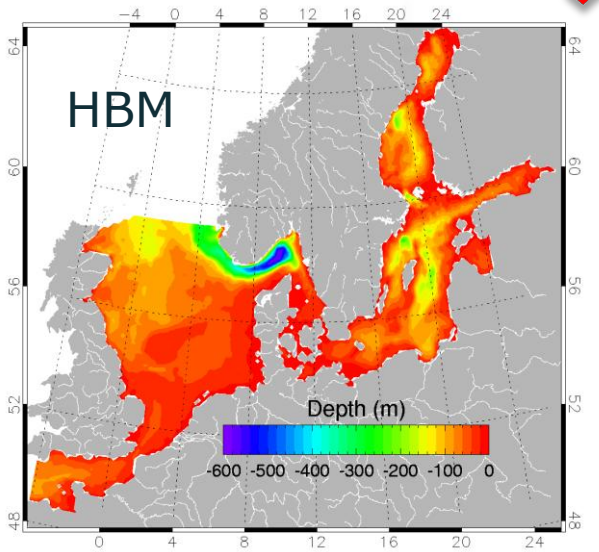


Model setup – current and waves

Current model:

Regional 3D ocean model *HBM* for the North Sea – Baltic

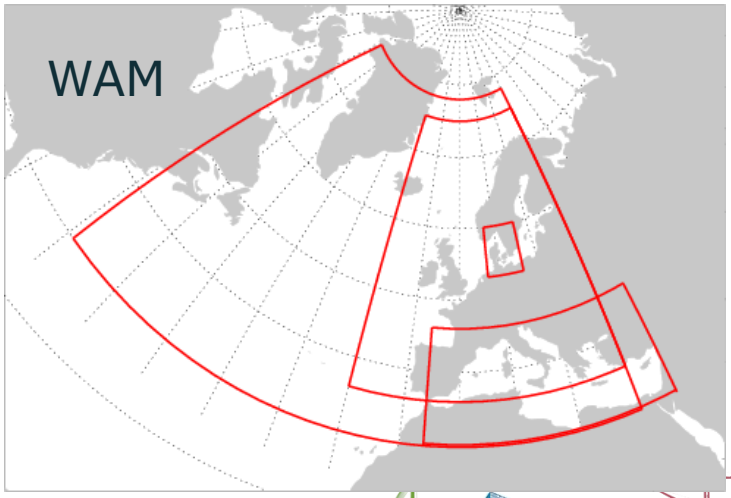
For technical specifications see:
http://ocean.dmi.dk/models/hbm.uk.php



Wave model

DMI-WAM, 3rd generation spectral Wave model '*Cycle4.5'*

For technical specifications see:
http://ocean.dmi.dk/models/wam.uk.php



Output:

Current , Water level, salinity, Water temperature, waves, Swell
…

Model setup

Model Setup	Model Name	Resolution	Layers	Period	Run	Time Resol.
Meteo 1	MSEPS	0.25 deg	32	2003-2012	Standard	1h
Meteo 2	MSEPS	0.08 deg	32	2003-2012	Standard	1h
Meteo 3	MSEPS	0.015deg	32	2003-2012	Multi Scenario	15 min
Ocean 2D NA	GETM		1	2003-2012	Standard	
Ocean 3D NS/BS	GETM	1nm		2003-2012	Standard	
Ocean 3D KF	GETM	400m	30	2003-2012	Multi Scenario	1h
Wave	MIKE 21 SW	300m-3km	1	2003-2012	Standard	1h

Model setup - meteorology

Met 1 setup:

- Used solely for forcing 2D setup. Hourly gridded data has been archived

Met 2 setup:

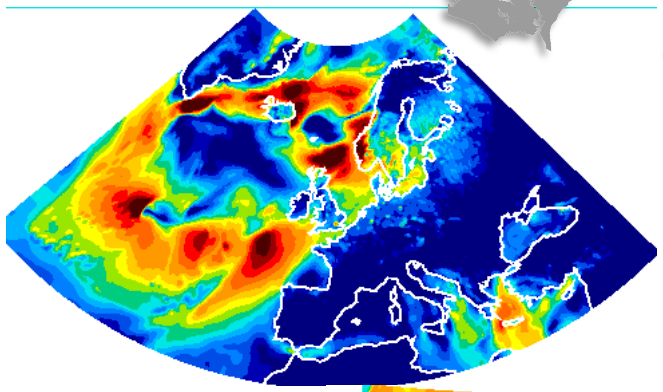
Hourly resolution of any model variable from Met 2 setup is possible

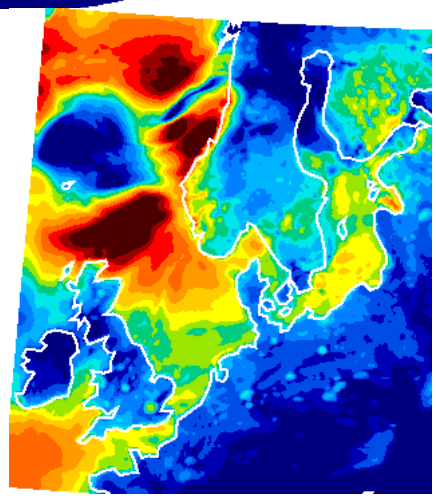
Met 3 setup:

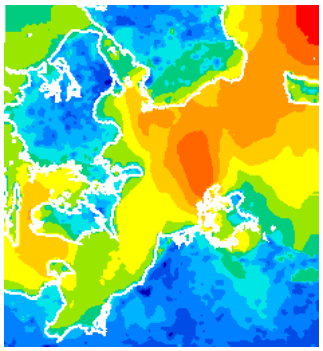
Time series over 10 years, gridded data around Kriegers Flak per 15 min.

Variables:

- Wind speed and direction 10m, 35m, 100m and 170m
- Temperature 2m, 35m and 100m
- Mean sea level pressure
- Relative humidity 2m
- Cloud cover, 4 altitudes
- Momentum flux
- Sensible and laten heat
- Radiation short/long wave







Model setup - current

Ocean 1 setup:

- North Atlantic 2D surge-model (app. 4nm resolution) Provides boundary data for the next level (elevations and transport)

Ocean 2 setup:

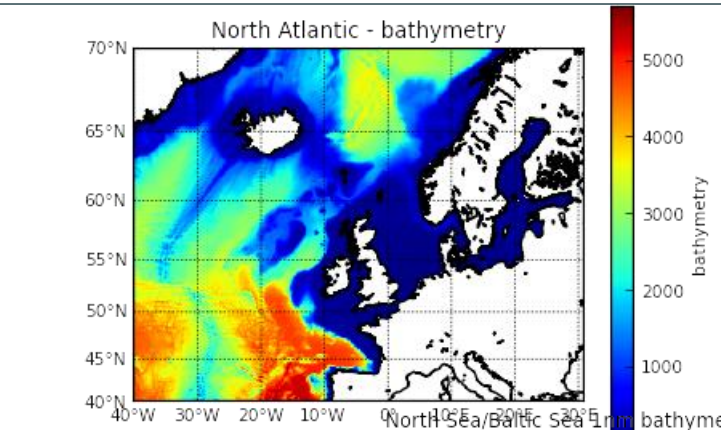
North Sea/Baltic Sea 1nm setup, Fully barocline – provides boundary data for the next level.

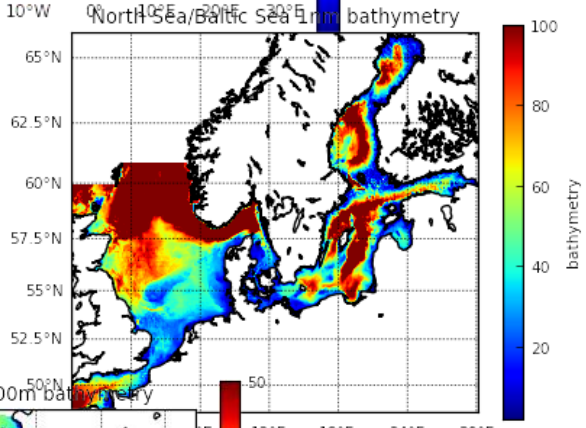
Ocean 3 setup:

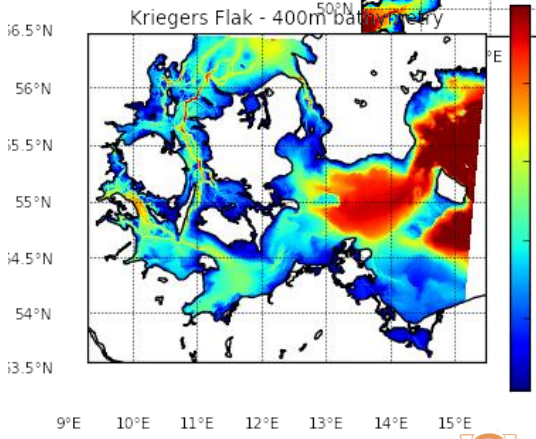
Kriegers Flak 400m setup, Surface/bottom saved for entires area. All model data are stores (30 levels) on hourly basis. Format NetCFD.

Variables:

- Elevations, transport, velocities, temperature, salinity, bottom stresses, turbulence properties.







Model setup - wave

Wave 1, fare field setup:

Baltic Sea

Wave 2, near field, setup step one:

Kriegers Flak and vicinity

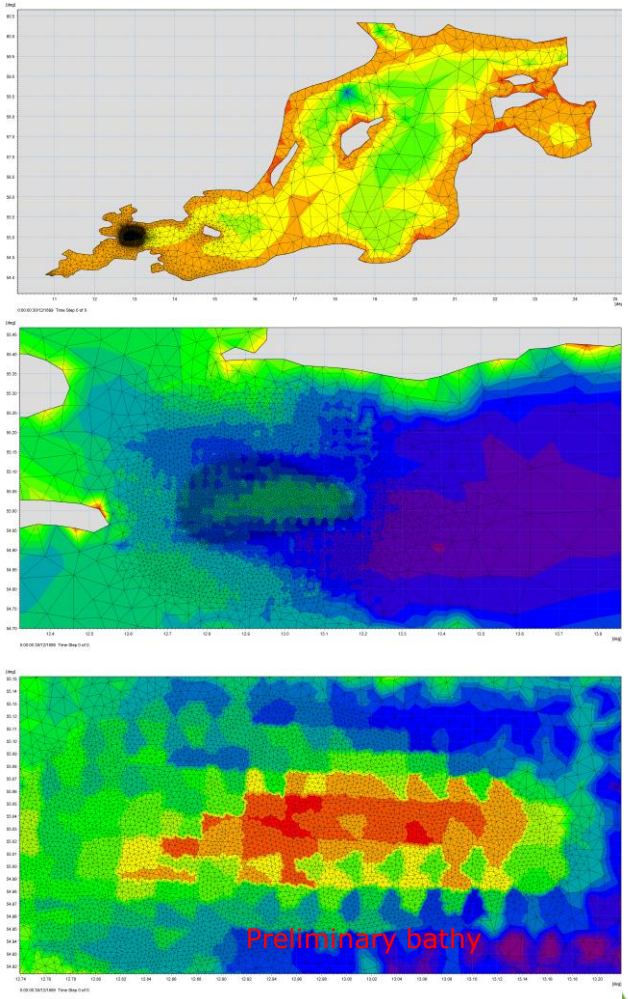
Wave 3, near field, setup step two:

Kriegers Flak 300m setup

(Preliminary bathy)

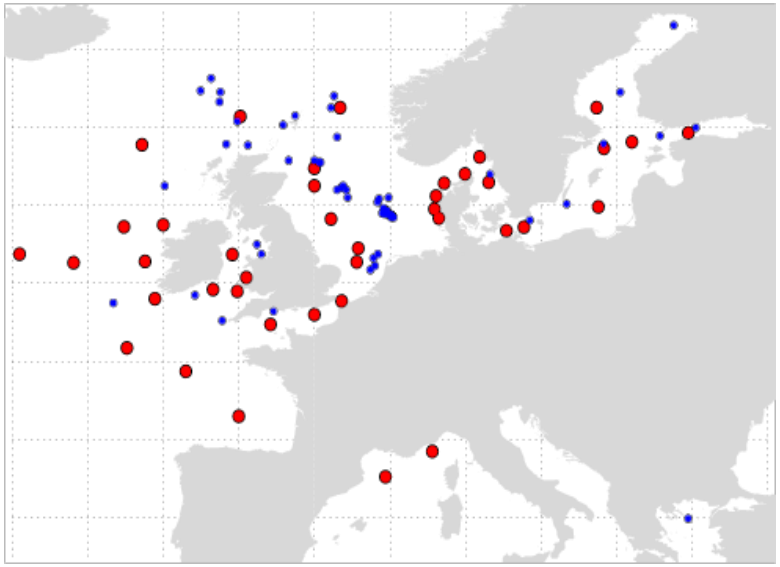
Variables per hour:

- Significant wave height, maximum wave height, wave period peak and zero crossing, wave direction.

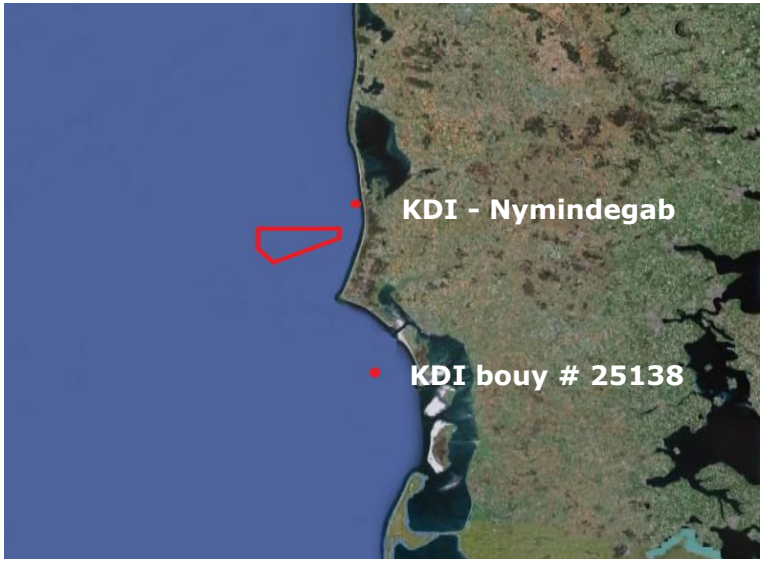


Validation

Validation



Overview of the stations included in validation



Horns Rev 3 with the closest stations for validation

- The DMI ocean model, HBM & WAM, is validated against observations from water level gauges and bouyes with profiles of salinity, temperature as well as waves.
  http://ocean.dmi.dk/validations/waves/background.uk.php
- 10 years validation against Nymindegab and Fanø stations
- The models are validated constantly, see online display:
  http://ocean.dmi.dk/validations/waves/online.php

Validation

Meteorology:

- Wind, Kriegers Flak - FINO 2
- Wind, FINO 1 and FINO 3

Ocean:

- 10 years water level, Danish stations
- 10 years current, Danish stations
- 10 year water level & current German stations

Wave:

- Wave data from the German part of Kriegers Flak, approx. 6 months

Data analysis

MetOcean analyses

Normal conditions:

1. Wind rose (year/month)
2. Wave rose (year/month)
3. Current rose (year/month)
4. Water level distribution (year/month)
5. Current distribution speed/direction (year/month)
6. Scatter-diagram wave height vs. wind speed (year, month and direction)
7. Scatter-diagram wave height vs. peak wave period (year, month and direction)
8. Scatter-diagram misalignment wave vs. wind
9. Table wave height vs. wave period (year)
10. Weather windows and downtime for combined waves and/or wind
11. Salinity
12. Temperature
13. Ice

Extreme conditions:

1. Wind speed at 10 and 100 m MSL (year/month per 30 degrees), return period: 1, 2, 5, 10, 25, 50 and 100 year
2. Significant wave height (year/month), return period: 1, 2, 5, 10, 25, 50 and 100 year
3. Water level, high and low water (year and month)
4. Current speed (year/month), return period: 1, 2, 5, 10, 25, 50 and 100 year
5. Maximum wave height (year/month per 30 degrees), return period: 1, 2, 5, 10, 25, 50 and 100 year

Reports / deliverables

- Technical reports for documentation of the individual model setup regarding meteo, ocean and waves including calibration and verification.

- MetOcean report covering the background for the statistical analyses and the results.

- Discrete modelled data output of wind, water level, current and waves?