



## DHI CASE STORY

# CREATING A WAVE ATLAS

## Facilitating easy access to wave climates in Danish waters

Whenever wave data for a new location is required, dedicated studies are needed due to lack of an overall data base. As such, The Danish Coastal Authority approached us to develop a wave atlas with data for selected locations in Danish Waters. We conducted several numerical model studies to develop a comprehensive wave atlas – an overview of wave conditions in the Danish waters. This product gives easy access to the said wave conditions, including potential effects of climate change on them.

### DANISH COASTS – SHAPED BY THE WEATHER

Most of the Danish coasts (more than 7,000km) are in essence, shaped by the weather. Waves in particular, determine the type of a coast and its orientation. Therefore it is important to know the local wave climate (for example, when coastal protection is planned and designed).

The Coastal Authority is the official coastal government agency, covering the entire coastline of Denmark. The coastal authority manages the governmental interests within the field of coastal protection. They are responsible for regulatory tasks concerning coastal protection.

Due to a lack of comprehensive knowledge about wave conditions in Denmark's coastal waters, dedicated studies are required each time data is needed for the assessment of coastal impact and for coastal protection plans at a new location. As such, the Danish Coastal Authority approached us to develop an overview of the Danish wave conditions – to determine the wave climate at 40 locations within Danish waters. Furthermore, they wanted the study to address how future climate changes may affect the waves in these waters.

### WE ADOPT A THREE-STEP APPROACH

#### 1. Hindcast modelling of wave conditions applying historical wind and pressure fields

We determined the wave conditions in Danish waters through comprehensive numerical hindcast modelling. For this, we used our third generation spectral wind-wave model – MIKE 21 SW. We modelled the wave conditions hour-on-hour for an 18-year period, based on detailed historical wind fields.

Following the wave modelling, we extracted time series of wave heights, wave periods and wave directions at the selected 40 locations for statistical analyses. The main outputs from the statistical analyses were:

### SUMMARY

#### CLIENT

The Danish Coastal Authority

#### CHALLENGE

- Limited knowledge of possible wave climate changes in Danish coastal waters
- Need for dedicated studies each time data is required for coastal protection at a new location

#### SOLUTION

- Hindcast modelling of wave and water level conditions applying historical wind and pressure fields
- Numerical modelling of waves with different climate models for future climate change scenarios
- Estimation of future wave conditions by combining the abovementioned methods

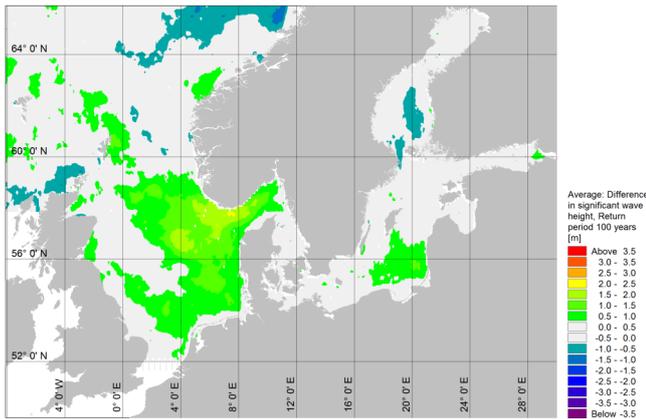
#### VALUE

- Easy access to wave climates in Danish waters
- Dedicated studies not required each time wave climate data is required
- Comprehensive knowledge for the coastal authority to assess possible future changes in wave conditions, and thereby coastal impact, due to climate change

#### LOCATION / COUNTRY

Denmark

- Wave roses – These give a good overview of the dominating wave directions and wave heights at each location. The wave roses and the underlying data can be applied to describe the normal wave conditions and is applied to assessments of sedimentation issues for instance
- Estimates of extreme wave conditions – We calculated estimates of wave conditions with return periods of up to 100 years. Such extreme wave conditions are important in connection with the design of marine structures such as breakwaters and coastal protection works



Example of estimated increase in the 100-year wave height due to climate changes.

## 2. Changes in wave climate due to climate change

To assess the changes in wind, wave and water level conditions in Danish waters due to future climate changes, we carried out comprehensive numerical modelling of current, water level and wave conditions. For this, we applied input from a number of different climate models – both global and regional. We did this via an ensemble method. This means that the same climate scenario was modelled with different climate models.

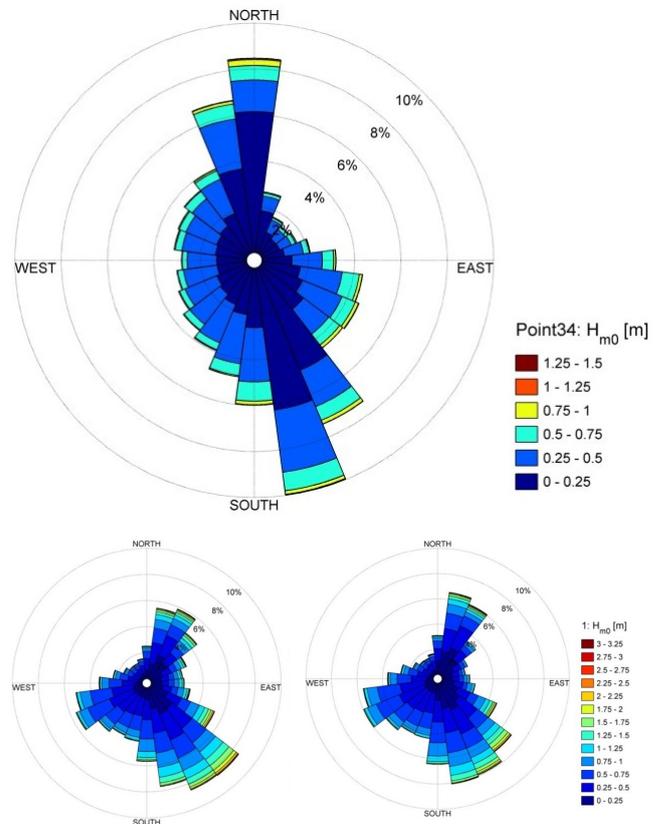
Based on the Intergovernmental Panel on Climate Change (IPCC), climate scenario A1B wind and pressure fields were modelled in the climate models for the period 2070-2099. We then applied these wind and pressure fields as input for our hydrodynamic and wave models. This was used along with an estimated sea level rise to model the current, water level and wave conditions for the 30-year period. We repeated this for a 'today' reference period being the period 1961-1990. It should be noted that the 'today' scenario also was based on wind and pressure fields from the climate models. It was thus not represented in the actual historical data.

Having modelled the conditions for a reference and a future scenario, it was possible to estimate the relative change in certain variables (for example the extreme wave heights or the

extreme water levels at any location within Danish waters).

### 3. Estimation of future wave conditions by combination of Step 1 and 2

Based on the estimated changes in wave conditions through



Example of wave rose. Left: reference/today's conditions. Right: corrected for climate change effects.

the climate change study, we modified the wave climate established in Step 1 through the hindcast modeling. We adapted it to represent an estimate of the wave conditions, including the effect of future climate changes.

The result could be increased design wave heights which could mean that damages to structures should be expected in the future, if not mitigated. The effect could also be changed wave directions which could result in future changes of coastlines.

#### THE WORK WAS CARRIED OUT WITH THE SUPPORT OF

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