"The Water Forecast": Flexible

Combination Global Water and Locally Adapted,

Weather forecasting is a well-established activity, which has been servicing the public for more than a century. Recent operational developments have made it possible to produce similar forecasting for water systems: water forecasts. The forecasting system developed by DHI, called "The Water Forecast" combines global water forecasting with locally adapted, tailor-made forecasts.

By Morten Rugbjerg

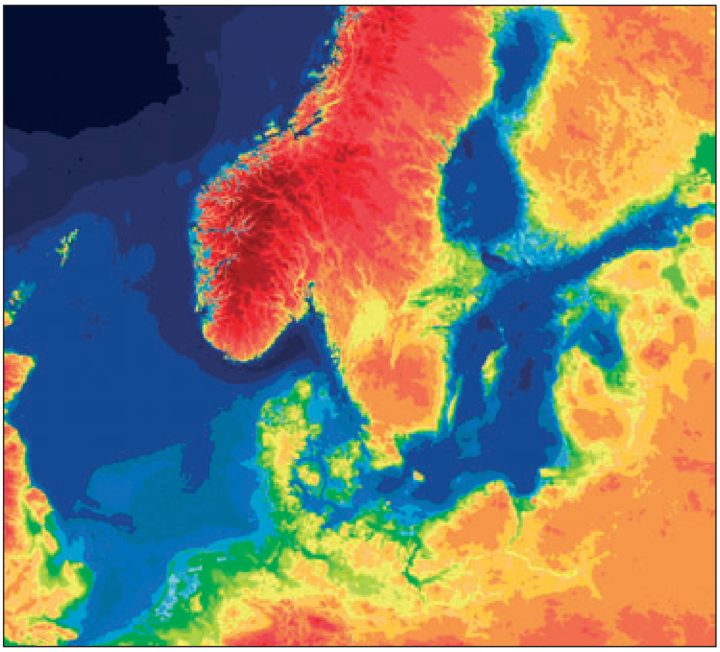

Figure 1; The area initially covered by The Water Forecast when launched in June 2001.

Users of the Water Forecast

In June 2001 DHI launched "The Water Forecast" with 5 days forecasts of waves, swell, water levels, currents, temperature, salinity, dissolved oxygen and chlorophyll-a. At that time it covered the North Sea, the Inner Danish Waters and Baltic Sea, see Figure 1. Since then is has developed to cover globally as well as locally.
Many different groups of people at sea can make use of water forecasts:

- The ferry captain, who crosses an area with the possibility of high seas;
- The captain of a bulk carrier or tanker who is about to enter a port;
- The harbour master, who is planning operations in and out of his port;
- The yachtsman, who wants to know the weekend's wind and current conditions before planning his sailing activities;
- The boat owner, who wishes to know the water level to make sure that his boat remains safely on the shore;
- The construction company operating from or in the marine environment with limitations in operability due to waves, water levels and/or currents;
- The municipality water engineer responsible for hoisting the "blue flag" and for warnings of storm water overflows for the benefit of bathers along selected beaches;
- The professional fisherman, who checks the local current, salinity and temperature conditions in order to indicate the whereabouts of the fish;
- The trolling fishers wanting to know where the thermocline is, in order to locate the salmon;
- The marine farmer, who wishes to know how salt and temperature vary, aiming at an optimum feeding of the fish;
- The county biologist, who wishes to issue a timely warning to the public of an occurrence of poisonous algae;
- The environmental authorities wishing to inform the public of next week's oxygen depletion;
- The angler, in summer, who wants to know where the cold water will hit the shore to increase his chances of finding the salmon;
- The offshore wind farm construction crew, who plans to erect a wind turbine the next day;
- The offshore wind farm operator, who plans the next day's maintenance;
- The tourist, who plans to go to the beach.

The forecasts are distributed via The Water Forecast website (www.waterforecast.com), via dedicated websites and via email.

Behind the Scenes

From The Water Forecast five-day forecasts are provided twice a day for:

- Wave height, wave period and wave direction;
- Swell height, swell period and swell direction;
- Water level;
- Current speed and current direction;
- Water temperature;
- Salinity;
- Dissolved oxygen;
- Chlorophyll-a.

In order to forecast all these variables, three different types of numerical forecast models are run: wave models (for waves and swell), hydrodynamic models (for water levels, currents, temperatures and salinities) and eutrophication models (for dissolved oxygen, chlorophyll-a and other variables).
As input to these models forecasts from meteorological models, giving winds, atmospheric pressure and other variables, are required.
Each type of model is set-up for different areas thus ranging from small models covering a harbour and its surroundings to large global models. All forecast results are entered into a database, which also receives measurements and input from meteorological models.
The set-up of The Water Forecast system is shown in Figure 2.

System for Different Users

Tailor-made Forecasting

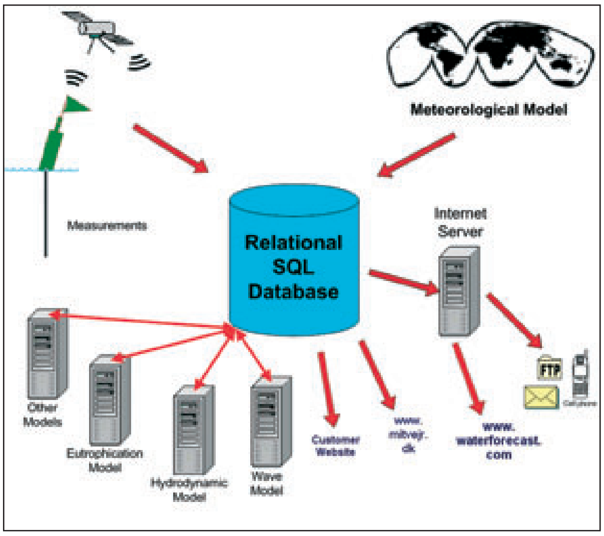

Figure 2; The Water Forecast system set-up.

Global Wave Forecasting

One of the wave models set-up within The Water Forecast system is the global wave model. Like the other models it provides forecasts 5 days ahead in time twice a day. The forecasts can be used directly (an example of forecast wave heights in the North Atlantic is shown in Figure 3) or as input to local wave forecast models.

The wave model applied for the global wave forecast - as well as for the local forecasts described later - is the spectral wave model developed at DHI, MIKE 21 SW. It is based on the internationally developed and used spectral wave model, WAM. A special feature of the DHI MIKE 21 SW model is the usage of a flexible mesh, which makes it possible to refine the mesh in areas of interest while having a more coarse resolution elsewhere in the model area. This is an advantage especially for local wave models, which can be developed into very precise models.

The quality of the wave forecasts is being monitored by comparing them to measurements from for example offshore buoys. If differences are found repeatedly, wave model parameters are tuned, so that an improved comparison with the measurements is achieved.

Furthermore, satellite data may be assimilated into the computations thus improving the wave hindcasts on which the forecasts are based. In Figure 4 a map of computed wave heights from the wave model without data assimilation on 2004-11-15 06:00 UTC is shown (upper picture) together with measurements obtained simultaneously from the JASON satellite (lower picture). The satellite measurements shown have been collected within one orbit, which takes less than two hours. As can be seen there is a good correlation between the global forecast and the satellite data.

Local Wave Forecasting

A local wave forecast model is set up when detailed forecasts for a small area are required. An example of such a model is the one which is being run as a part of The Water Forecast system for the Chiloe area in southern Chile. The area covered by the model is shown in Figure 5. To determine the wave conditions within the area, which is mostly protected from The Pacific Ocean but exposed to its heavy seas in the central part, wave input at the open central section of the local model is taken from the global forecast model.

This local water forecast is set-up for and used by the many salmon farmers in the area, who are then provided with advance knowledge of some of the factors that may be critical for the salmon farming. Dependent on the location certain events may cause the death of some or all the fish. Examples are: quick (that is: within 10 minutes) increases in temperature to plus 20-degree levels, toxic algal blooms, which may poison the fish, spreading of diseases between farms.

For all these events early warnings are necessary or the fish farmer may stand by and look at fish dying, without being able to do anything. These events are not very frequent, but lethal when they occur. The fish farmers need warning lead times for at least 24 hours and preferably 48 hours to be able to act on the event.

Offshore Wind Farm Operators

Another example of a detailed model is the one covering the Danish waters, see Figure 1. From this model detailed wave forecasts for the world's two largest offshore wind farms, Horns Rev (158 MW) and Nysted (160 MW), were delivered during the construction period. An example showing two forecast web pages for Nysted Offshore Wind Farm is depicted in Figure 6. Forecasts for Horns Rev was forwarded to the client (via ftp) for presentation on their website. After the construction was finished the delivery of forecasts has continued and is being used to predict wave heights when planning maintenance of the wind turbines.

If local measurements are available the quality of the local forecasts can be checked. If the measurements are furthermore available online and in near-real-time, the quality of the forecasts can be improved. Especially the forecast for the first 24 hours can be improved considerably. The effect of this correction is illustrated in Figure 7. Here the blue line is the uncorrected forecast, while the black line

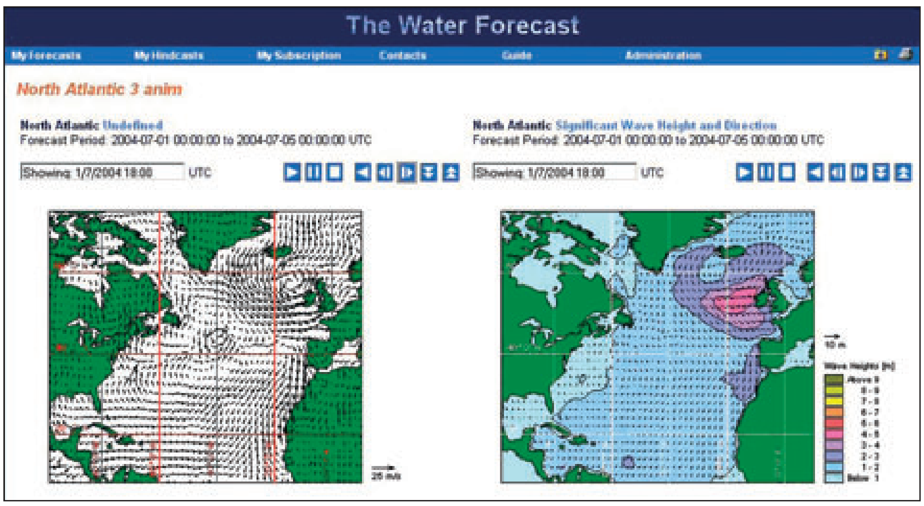

Figure 3: Example of forecast wind (left) and wave heights (right) in the North Atlantic from the global wave forecast model. Arrows indicate wind and wave direction.

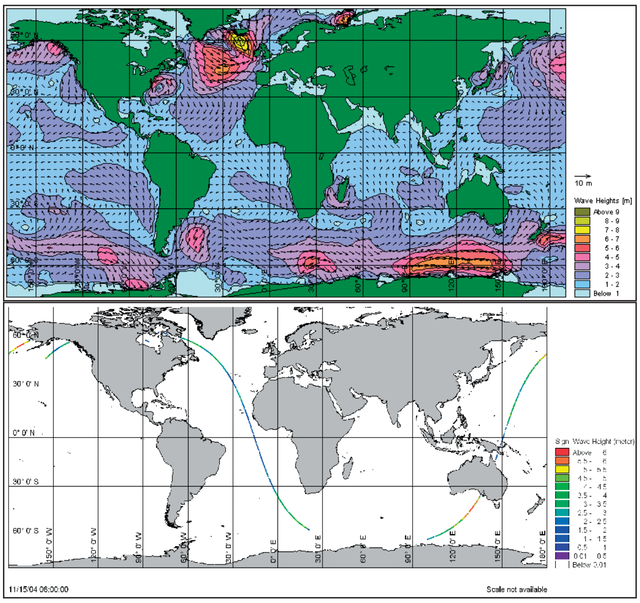

Figure 4; Wave heights from global wave model (upper picture) and as measured by satellite (lower picture).

is the forecast corrected on 2002-09-01 12:00 based on the measurement at that time. Measurements after 2002-09-01 12:00 are also shown to evaluate the effect of the correction. Quite clearly the result is that if forecasts are corrected using near real-time measurements, the forecasts become very reliable for the local users.

Summary

The many different groups of users of forecasts require different types of forecasts. To provide these a very flexible forecast system is required. The wave forecasting within DHI's "The Water Forecast" has been presented as such a system, being able to provide forecasts on a global scale as well as on a local and very detailed scale. New local wave forecast models are readily be set-up within the system to provide tailored forecasts for the specific needs of a user group. Three examples of such local forecast have been described. Using this combination of global and local modelling DHI is able to set up local wave models all over the world. The accuracy of the forecasts is of course very important to the users. Therefore the quality of the wave forecasts are being monitored and improved in different ways using measurements from satellites, offshore buoys and coastal stations. Especially local wave forecasts can be improved significantly if near real-time measurements are available from the area of interest.

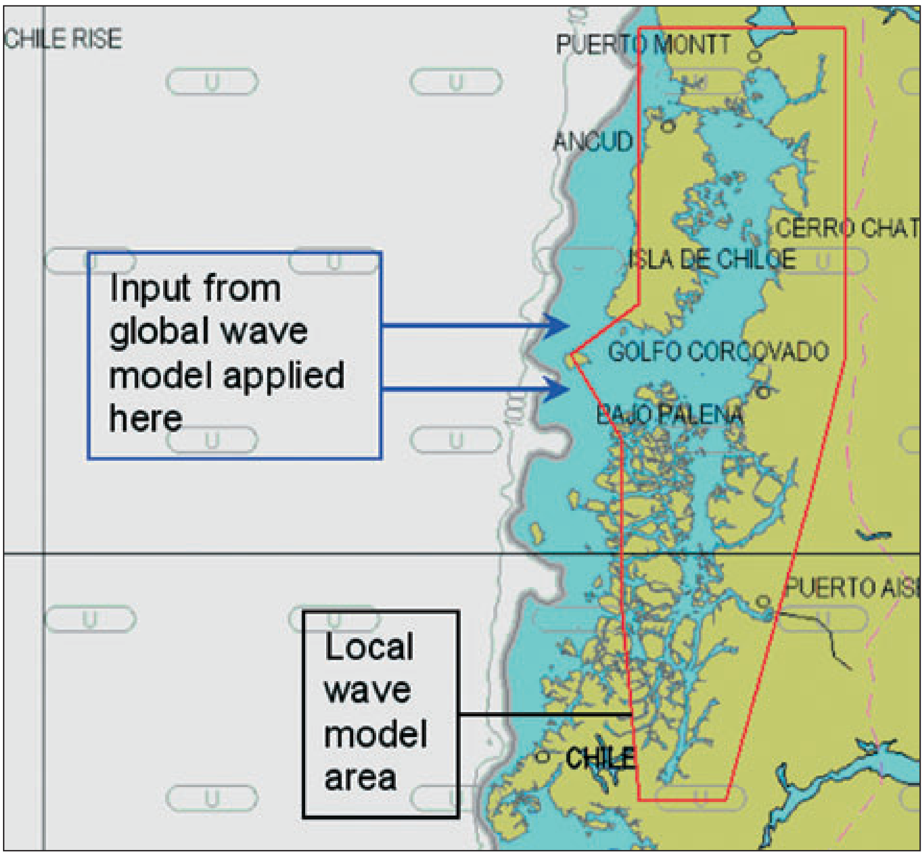

Figure 5: Local wave model as part of water forecast system for Chiloe in southern Chile.

Bathing Water: Quality, Monitoring and Information

DHI has developed tools and models to meet rising demands for secure bathing water that manage water from sources to treatment plants, from sewers and to the sea. This is based on integrating water data with dynamic models such as MIKE URBAN - a complete system for analysis of urban water. MIKE URBAN is also able to predict overflow from sewers due to heavy rain, which causes polluted bathing water.

The water quality at the beaches can be treated with the two-dimensional hydro-dynamic model MIKE 21. DHI is experienced in analyzing bathing water quality and tracking reasons for poor quality such as sources for bacteria pollution. The results can be used for local bathing water forecasts developed in accordance with relevant stakeholders. The information is disseminated to the users on web pages and by other means of communication.

DHI has carried out activities on Bathing Water Quality in Pattaya, Thailand, where models demonstrated the relationship between the drainage system, the treatment plant and the recipient sea. On the island of Ischia, Italy, an integrated modelling of the sewer system and the receiving waters, based on the 2D hydrodynamic and water quality model MIKE 21, was used to decide whether the water should be treated on the island or transported to the mainland.

In three municipalities in Denmark a web-based Bathing Water forecast has been established.

It predicts the water quality, is updated daily and users can check the quality at a bathing water homepage. The solutions are not alike, but both provide operational real-time and forecasting tools, and have proven to be very useful in their municipalities. As a result of this it is now possible to go swimming in the harbour right in the centre of Copenhagen.

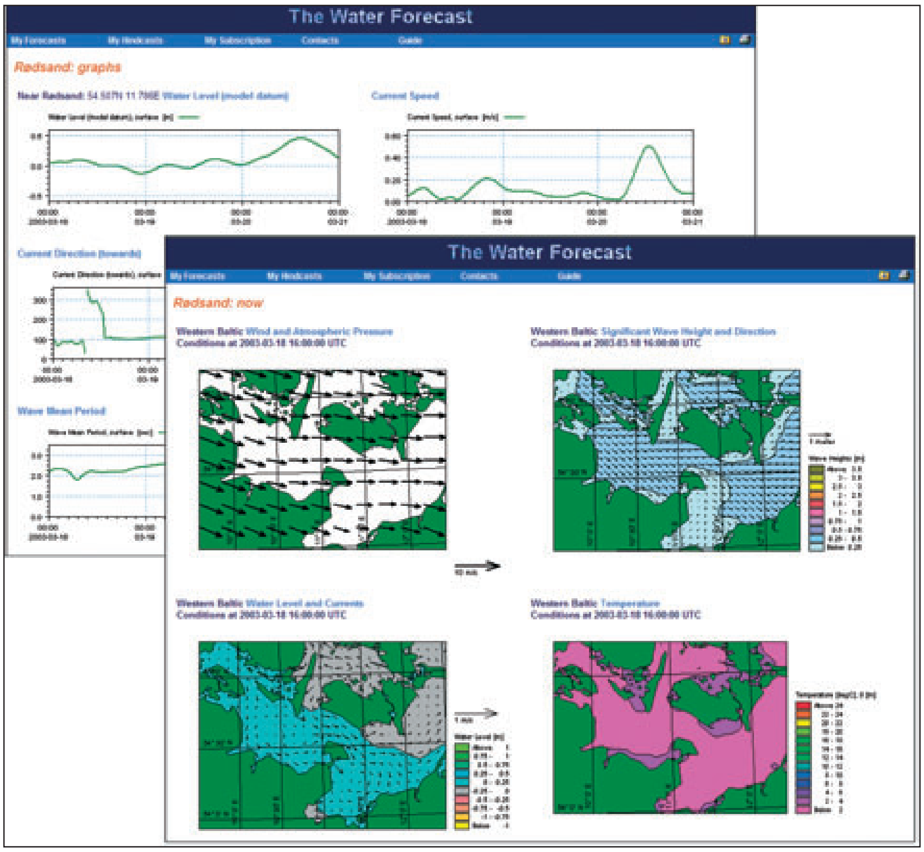

Figure 6: Examples of two web pages from a forecast for Nysted Offshore Wind Farm between Denmark and Germany in the Baltic Sea.

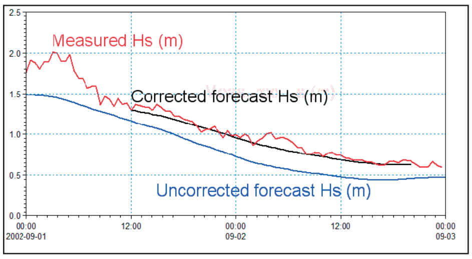

Figure 7: Example of wave forecast on 2002-09-01 12:00 without any correction and including a correction based on near-real-time measurements.

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Readers who would like to check out the Water Forecast can get a free 14 days trial subscription. The full functionality of the Water Forecast will be available during this period. Details can be found on www.waterforecast.com.