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# CIRCULATION MODELING AND FORECASTS FOR THE DANISH SAILORS DURING THE 1996 OLYMPIC YACHTING EVENTS

Jan Borup Jakobsen[1] and Morten Rugbjerg[1]

## Introduction

In the spring of 1995 Danish Hydraulic Institute (DHI) was asked, by Dansk Sejlunion (DS – the Danish Sailing Association), to support the Danish yachting team during the Olympic Games held in the summer of 1996 by providing current forecasts for the Sound of Wassaw – the area where the Olympic Yachting Competitions were to take place. The current forecast would, together with weather forecast, made available by the National Weather Service during the competitions, form a solid basis of knowledge about the conditions in which the Olympic sailing events were to be conducted.

The early contact between DHI and DS enabled the sailors to become acquainted with the current forecasts, as the forecasts were not only provided during the Olympic Games, but also (in a simplified form) during the Pre-Olympic Games held in the summer of 1995. Furthermore, measurements made by the yachting team during the Pre-Olympic Games provided DHI with the possibility to validate the current forecast model.

## Current Model Setup

DHI's generalized hydrodynamic modelling system, MIKE 21, which is based on the two-dimensional shallow water equations, was used to provide the current forecasts. The solution technique applied in MIKE 21 is the alternating direction implicit (ADI) technique known for its robustness and reliability (Abbott et al. 1981).

To obtain a fine resolution of the flow field in an area of interest, like the area around Wassaw Sound, and at the same time limit the computational efforts required, a nesting facility is available in MIKE 21. Nested areas are dynamically coupled,

[1]Danish Hydraulic Institute
Agern Allé 5
DK-2970 Hørsholm

which means that the governing equations are solved for all areas simultaneously. Thus, not only can information from the coarser grid areas affect the finer grid areas, but also information obtained in the finer grid can propagate back into the coarser grid areas. This nesting facility was applied for the current forecast model as described below.

Another facility available in MIKE 21 and applied in the present forecast model is the possibility of flooding and drying computational cells. This facility is very important in order to satisfactorily describe the flow in shallow water areas, like Wassaw Sound, with significant tidal amplitudes.

In MIKE 21 tidal waves are simulated through the boundary conditions typically prescribed as water level variations at all open boundaries. And as the flow through Wassaw Sound and the surrounding stretches of water is dominated by tide, the location of available tidal stations was the most important factor when determining the location of open model boundaries. Thus an open boundary was placed at Charleston and another at Sapelo Sound. Four tidal constituents ($M_2$, $S_2$, $O_1$ and $K_1$) were used to calculate the time varying water levels at these two boundaries (boundaries 1 and 2 in Figure 1). The water level boundary conditions at boundary 3 were calculated as an interpolation of the outermost points from boundaries 1 and 2.

The model covered an area of 92 km by 183 km extending about 80 km away from the coast. Data from sea charts was used to create the model bathymetry. One level of nesting was applied with a grid size of 600 m in the coarse grid and a grid size of 200 m in the fine grid.

The wind applied in the model was constant within the area and varied only in time.

According to Skidaway Institute of Oceanography (1996) the fresh water plume from the River Savannah extends down to Wassaw Sound during certain wind conditions. Furthermore, the plume is influenced by the Coriolis effect, which will deflect the plume towards the south of the river mouth. This baroclinic flow component will have a minor effect on the flow pattern in the area off Wassaw Sound. However, as the tide is the dominating phenomenon in the area, it is assumed that the mixing of the plume and the seawater takes place north of the area of interest and that the density effects can be neglected.

The tidal water level variation in the Savannah River in the city of Savannah is included in the model, thereby taking into account the discharge from the river. The same approach was used for the Colleton River.

**Initial Model Calibration and Current Forecasts during the Pre-Olympic Games**

For the Pre-Olympic Games, the model was run several weeks in advance applying a constant wind of 3 m/s and 140°. Maps showing hourly flow patterns during the daily competitions were produced on transparencies, which could be put on top of the sea chart covering the area, and were given to the Danish yachting team before they left Denmark. Also tables, one for each race area with hourly current speed and direction, were produced and given to the Danish yachting team.

During the Pre-Olympic Games, a time lag of about 50 minutes between forecasted and measured current was found. This time lag was corrected in the forecasts made a year later for the Olympic Games by gradually changing the prescribed phase towards the outermost points for boundaries 1 and 2.

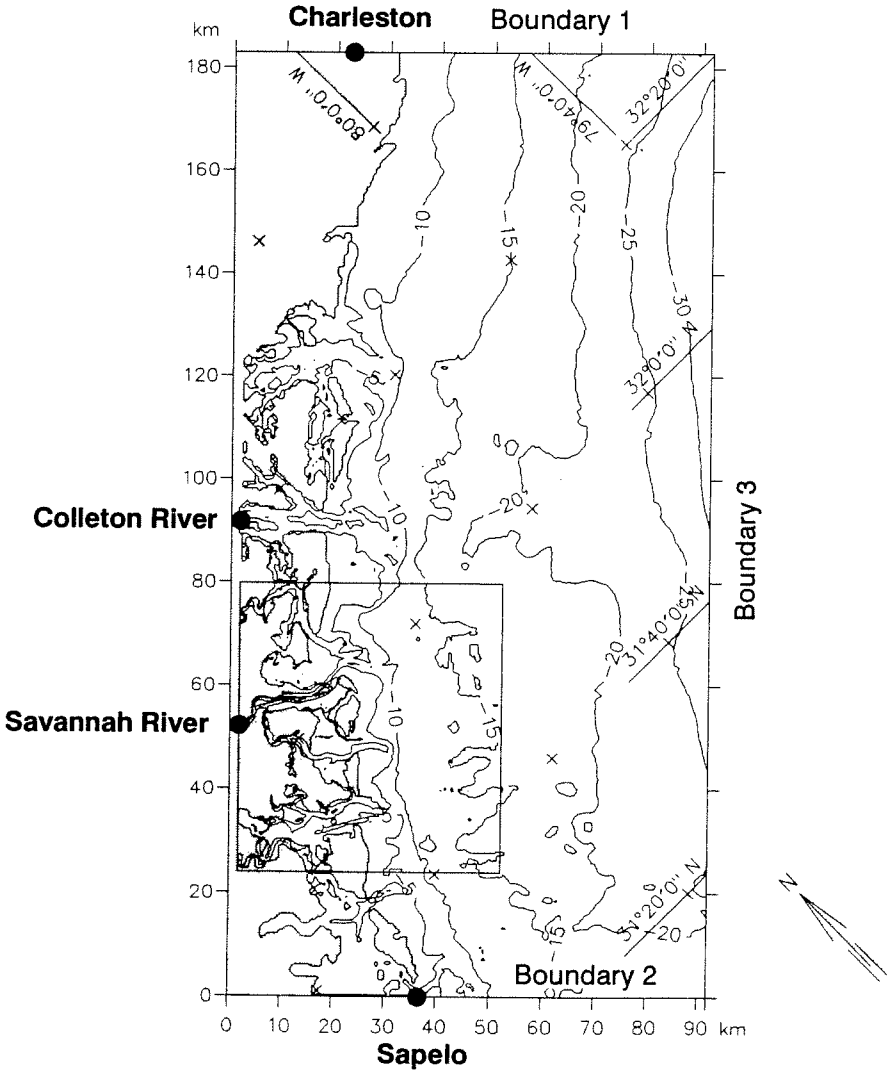


*Figure 1: Bathymetry. The enclosed area is the nested area with finer grid spacing.*

**Current forecasts during the Olympic Games**

Each morning Danish time (ie. 02 EDT), before starting the production of the current forecast on DHI, a daily fax from the Danish coach with a weather forecast and comments about the current forecast for the previous day was studied. The weather forecast received by fax was produced by the National Weather Service. As a secondary source, a weather forecast was available from Savannah airport. Furthermore, on-line measurements of wind and current were available from three buoys placed off Wassaw Sound by NOAA Data Buoy Center (NDBC). All these data were accessible via the Internet and together provided the basis for the wind input to the current forecast.

In order to produce the daily current forecast, the model was run every day for a period of 48 hours. During the first 34 hours the actual measured wind was used. For the last 14 hours the wind from the weather forecast was used. In the case of a discrepancy when shifting from measured to forecasted wind data, a manual data merging was applied. The last 5 hours of the current forecast covered the actual time of the races.

When the production of the daily current forecast was finished, data were extracted and the hourly current plots and tables produced. An example of the flow field is shown in Figure 2. The current forecast was then faxed to the Danish coach, who received the forecast early in the morning (06 EDT) due to the time difference of 6 hours.

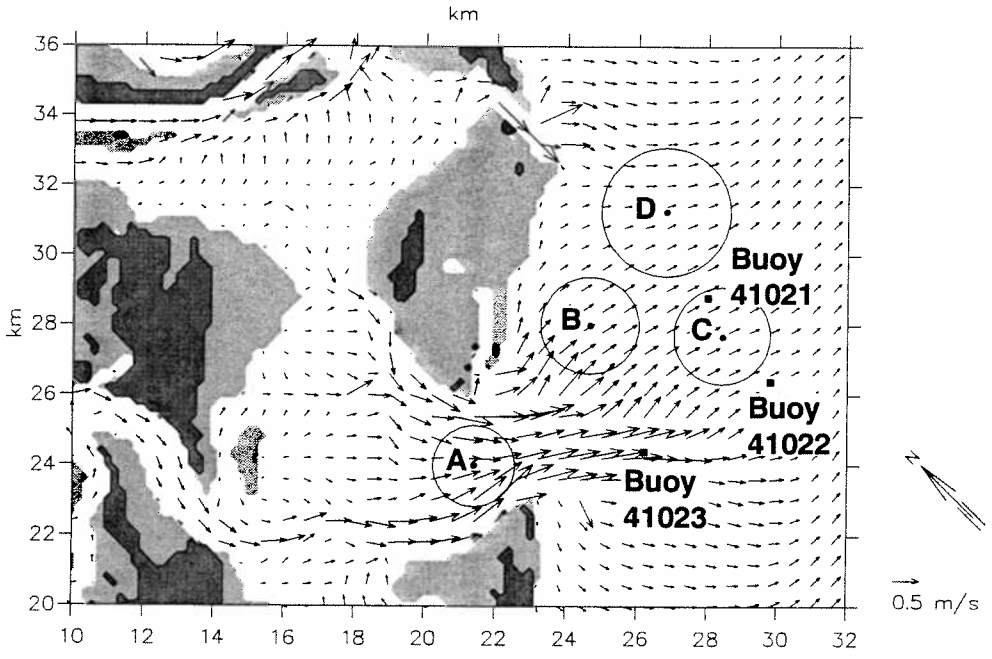


*Figure 2: Flow field at 26th July 1996 09 EDT. Circles A,B,C and D indicate the racing areas.*

During the Olympic Games, a daily evaluation of the current forecasts was performed at DHI. Two different sources of information were used for the evaluation:

- A subjective evaluation based on the feedback from the sailors was received, as part of the daily correspondence with the Danish coach.
- An objective comparison of forecasted and measured current speed and direction was possible due to the hourly measurements from the on-line buoys.

Figure 3 shows a comparison between forecasted and measured current speed and direction. Good agreement between forecasted and measured turning of the tide is observed, keeping in mind the sampling rate of one hour. Generally, the forecasted current speeds compared well with the measured ones. However, during certain periods the forecasted current speeds were somewhat smaller than the measured ones as also observed by the sailors.

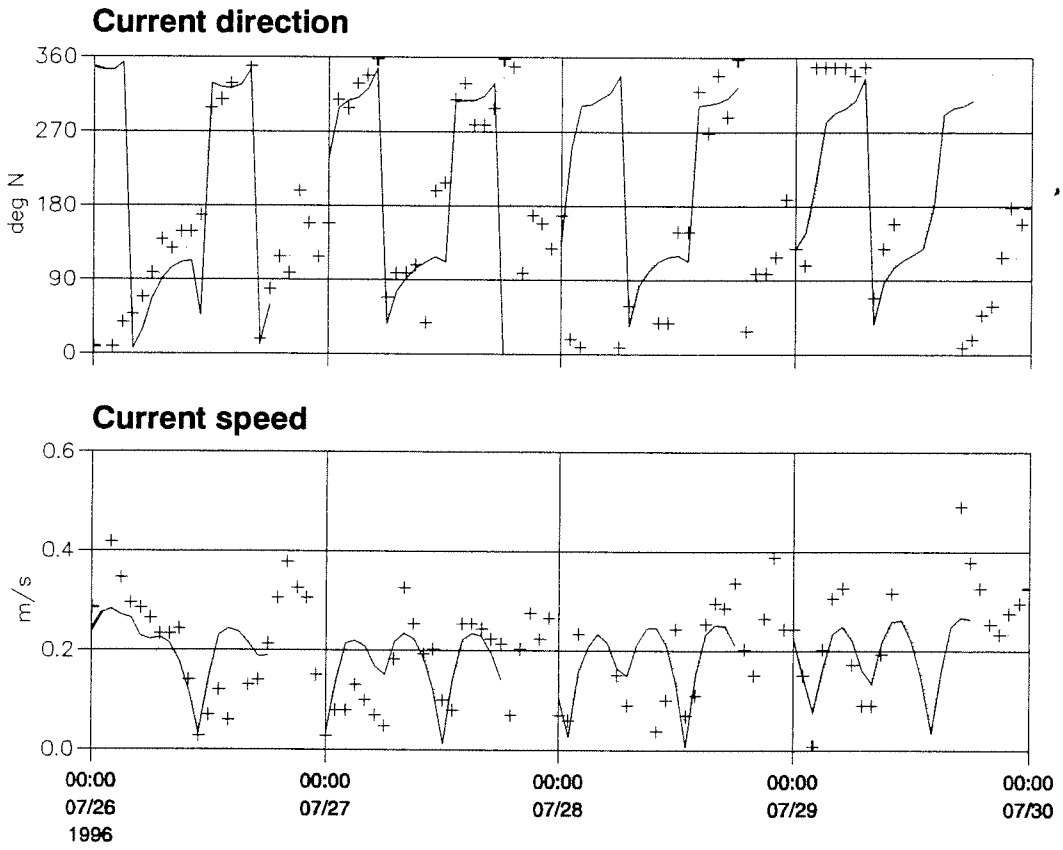


*Figure 3: Current direction and speed at location of buoy 41022 for four days. Current forecast with standard wind is shown with a dotted line, current forecast with measured/forecasted wind is shown with a full line (only last 18 hours for each forecast) and measurements of current are shown with crosses.*

For comparison a model run was performed for the entire period of the Olympic Games with a 'standard' wind, consisting of a land-sea breeze with speeds ranging from 1 to 4 m/s. Comparing the current forecast based on the 'standard' wind with the current forecast based on the measured/forecasted wind gives a good indication of the importance of the wind. As seen from Figure 3, the current is, as expected, dominated by the tide, but the difference in wind speed and direction between the measured/forecasted wind and the standard wind can alter the direction of the current up to 20°.

Given the two facts, that a spatial constant wind was applied and the applied model was depth-integrated, the discrepancies found between forecasted and measured current were qualitatively understandable and quantitatively acceptable. The continuing evaluation thus indicated a satisfactorily performance of the current model setup and no further adjustments were found necessary.

**Conclusions**

After the Olympic Games a meeting between the forecast team at DHI and the coach for the Danish yachting team was held in order for the forecasters to get feedback from the sailors regarding the quality and usefulness of the current forecasts. In general the sailors made use of the current forecasts and would not have been without them.

In order to make this kind of operational set-up, it proved to be very useful to have readily and accessible data such as the daily weather forecasts and current measurements from the NDBC on-line buoys off Wassaw sound. Because of the easy accessibility of these data through the Internet it turned out to be an advantage to do the current forecast at DHI due to the time difference between Denmark and Savannah.

The Danish yachting team won one gold medal during the Olympic Games, and was very close to winning another two medals

**References**

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**Key Words**

Current Forecast, MIKE 21, Olympic Games, Danish Sailing Association.