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HIROMB validation
Current validation in the Danish Straits

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Abstract

HIROMB forecasts are validated against data from Danish monitoring stations operated by RDANH. The validation study uses HIROMB data calculated in the 3 nautical mile grid and covering 18 months from May 1997 to October 1998. The time step in the data set is 6 hours. The validation study is focused on current data. RDANH has current meters running operationally in Öresund and the Great Belt. A direct comparison of HIROMB output with current meter data reveals that currents through the Danish straits are generally too weak in HIROMB. A direct comparison is not straight-forward (HIROMB predicts volume flow rates per unit area), so HIROMB output is compared also to volume flow rate estimates computed from the sea level difference between the southwestern Baltic Sea and the southern Kattegat. This comparison confirms that currents, i.e. flow rates, through the Danish straits are too small in HIROMB. It is estimated that flow rates through Öresund are underestimated by approximately 40 percent and through the Belt Sea by approximately 60 percent. It is also concluded that the underestimation is caused by a too large flow resistance in HIROMB, either due to too narrow and/or shallow topographies in the HIROMB grid or too large drag.

Introduction

At the 1st HIROMB Scientific Workshop, it was decided that the Royal Danish Administration of Navigation and Hydrography (RDANH, or Farvandsvæsenet in Danish) should perform a current validation in the Danish straits. RDANH operates a national oceanographic monitoring net, which involves current meters in the Danish straits. From these current meters, relatively long, continuous time series of currents have been retrieved and stored. The currents in the Danish straits are generally strong, mainly driven by the sea level difference between the Baltic Sea and the Kattegat. Furthermore, the currents are almost bidirectional, either out- or inflowing, following the coast lines of the straits. Together, this simplifies a current validation, even though it is not straight-forward. This report gives the results based on an 18 month data set of HIROMB forecasts.

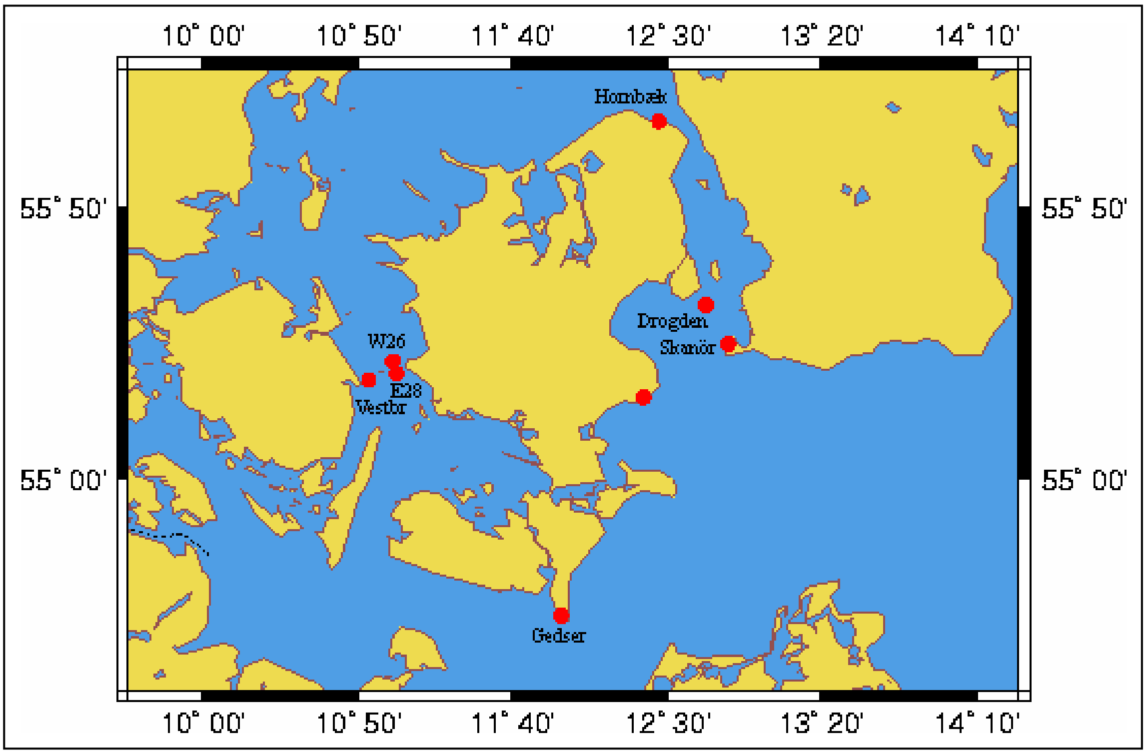

Figure 1. Map showing monitoring stations

Data sets

The current validation uses data from current meters (Aanderaa DCM 12 ADCP) placed at Drogden Fyr, Østerrenden Syd Fyr (E28), Østerrenden Nord Fyr (W26) and Vestbroen. Currents are sampled at 6 levels with a sampling rate of 30 minutes. Data from three sea level stations are also used in the validation study, Gedser, Hornbæk and Skanör. The sea level station at Skanör is operated by SMHI for Øresundskonsortiet, who kindly provided the data needed in the validation study. Sea levels are sampled every 15 minutes.

The HIROMB data is available as GRIB-coded HIROMB fields with a temporal resolution of 6 hours covering 18 months from May 1997 to October 1998. From these, time series of considered variables at grid coordinates corresponding to positions of the monitoring stations are extracted.

The time stamps of the observations do not always coincide with the evenly spaced time stamps of the HIROMB forecasts, i.e. 00:00, 06:00, 12:00 and 18:00 UTC. There also exist some gaps in the time series. To facilitate comparison and statistical calculations, observations are interpolated to these points in time. Also the HIROMB data set contains some small gaps, which are filled with interpolated values. In the end, continuous time series of 2149 values are available for every variable at every station, both from observations and from HIROMB forecasts.

The variable in HIROMB corresponding to velocity is flow rate between grid cells. A variable of dimension velocity is given by dividing the flow rate with the cross-sectional area of the grid cell. Consequently, u and v components of this velocity are not defined at the same place (cf. Figure 2). It follows that there is no direct correspondence to a measured velocity.

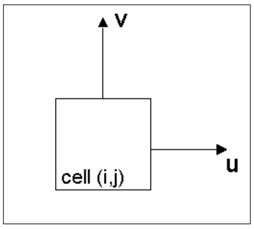

Figure 2.

Results

For a comparison of currents at Drogden Fyr, data at depth level 3 from Drogden ADCP is used. This corresponds to a depth of approximately 3 metres. The main current direction is 45º (Figure 3), and the current vector is projected on that direction. HIROMB data from the surface cell at grid point (82,46) is used. The main current direction at this point in HIROMB is close to 30º.

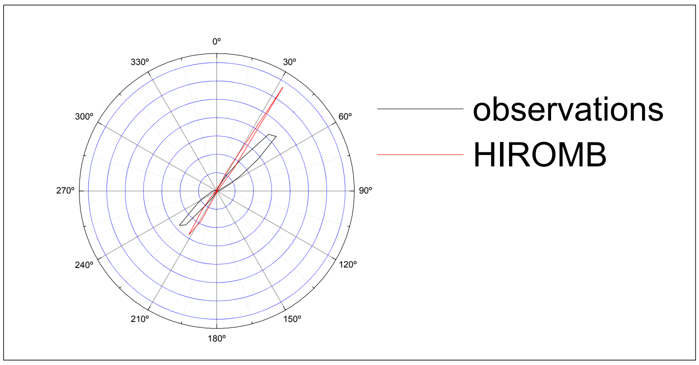

Figure 3. Relative frequency of current direction

Figure 4 shows time series of observed current in the main current direction 45º and HIROMB current projected on 30º. The standard deviations are 38 cm/s and 22 cm/s, respectively, giving a ratio of 0.58, and the explained variance by HIROMB is 56 percent. It appears that the currents at Drogden are underestimated in HIROMB by some 40 percent, but this conclusion needs better foundation.

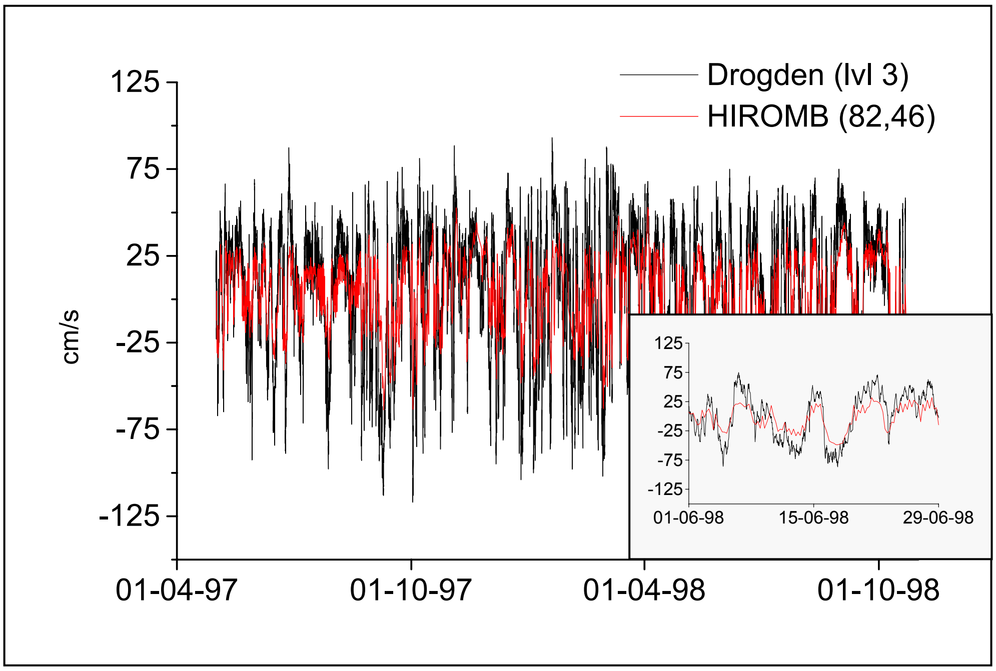

Figure 4. Current at Drogden

There are no observations of the volume transport in Öresund, but there exist good models for the transport given the sea level difference between the Baltic Sea and Kattegat. The time series of "observed" flow rate in Figure 5 and 6 are produced using the sea level difference between Skanör and Hornbæk and a model $Q(\Delta\eta) = (\Delta\eta / K)^{1/2}$, K = 2.03e-10. Q is flow rate and $\Delta\eta$ is sea level difference. The flow rate through Öresund in HIROMB is simply the sum of the v component times the area in a cross section line of grid cells across Öresund, here cells (82,47), (83,47) and (84,47) for all depths.

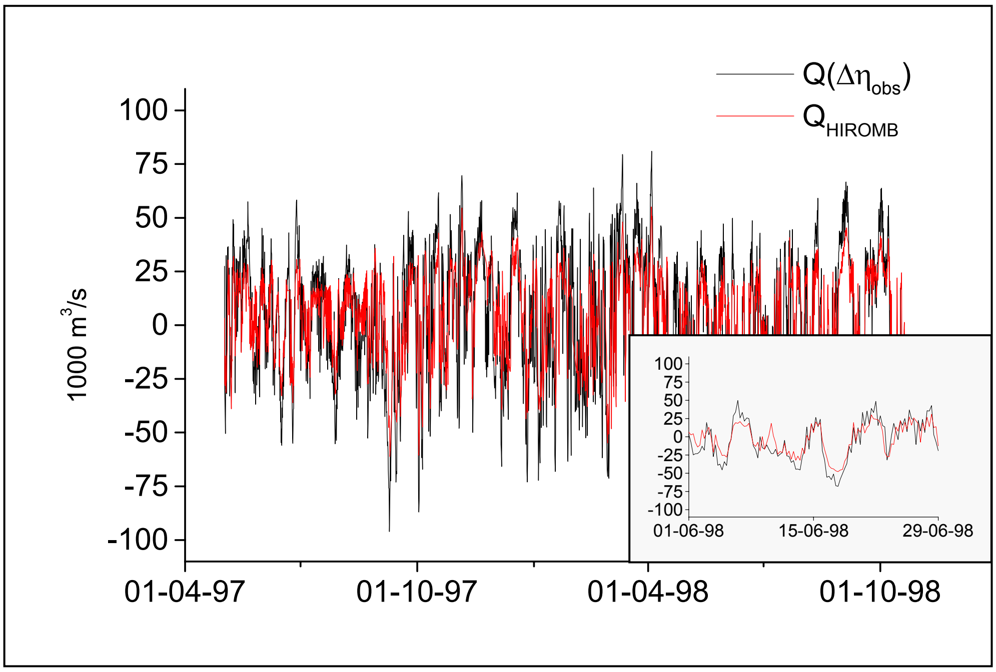

Figure 5. Flow rate in Öresund

The standard deviations are 31 000 m^3/s and 21 000 m^3/s, respectively, with ratio 0.68, and explained variance 61 percent. The flow rate comparison confirms the previous conclusion that HIROMB currents are too weak in Öresund.

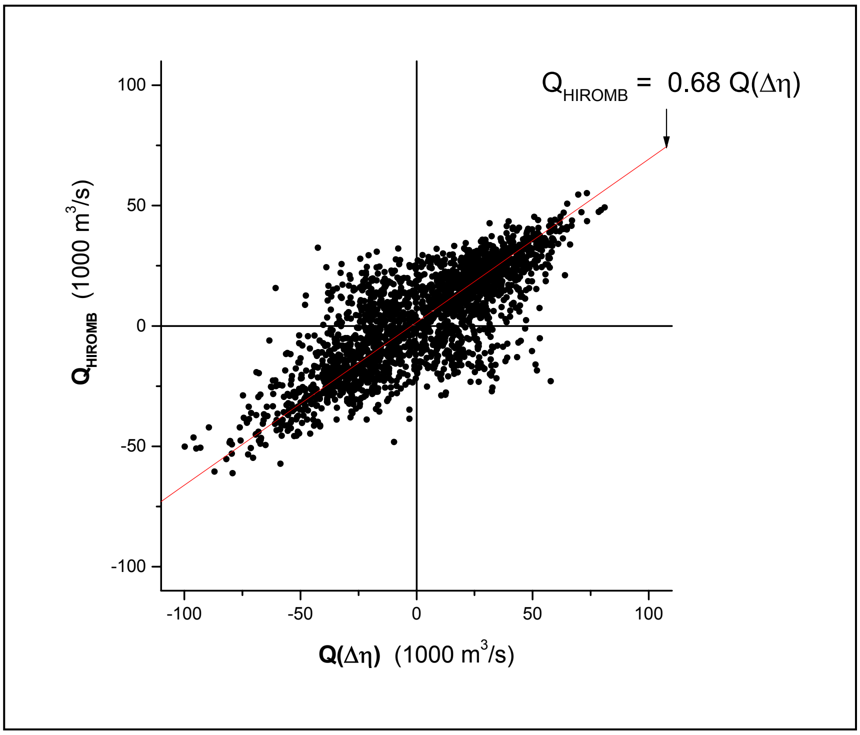

Figure 6. Flow rate in Öresund, HIROMB vs. "observed"

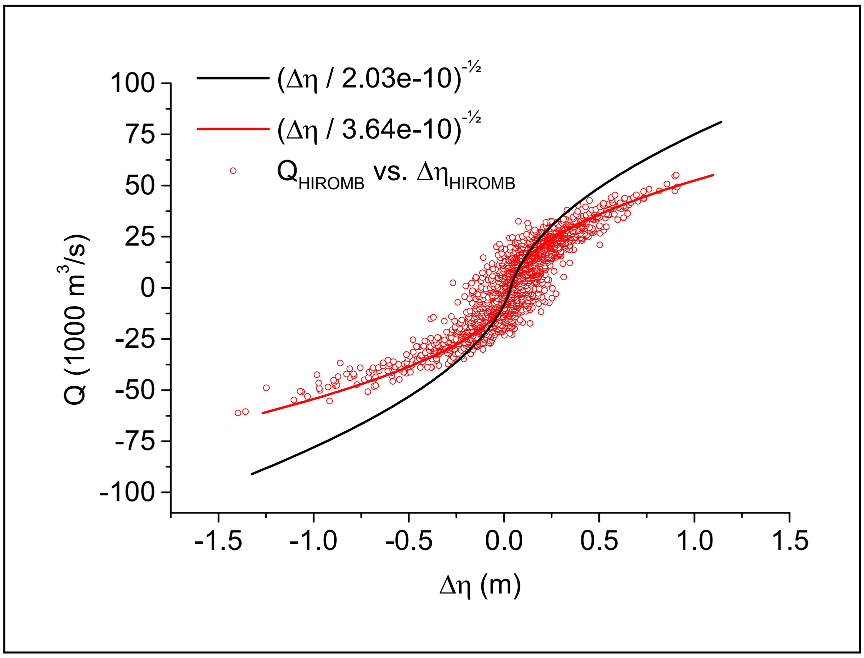

Figure 7. HIROMB flow rate vs. HIROMB sea level difference

The transports through Öresund are mainly driven by the sea level difference, so either are the sea level differences too small in HIROMB or the flow resistance too large. Figure 7 shows the flow rate in HIROMB as a function of the sea level difference in HIROMB. The black line corresponds to the correct flow resistance. The flow resistance is apparently too large in HIROMB. Furthermore, the sea level difference predicted by HIROMB is rather good (Figure 8). It is slightly underestimated (by approximately 10 percent), and the explained variance is relatively high (72 percent). Interestingly, this is better than the explained variance for the individual sea level stations at Hornbæk (63%) and Skanör (53%).

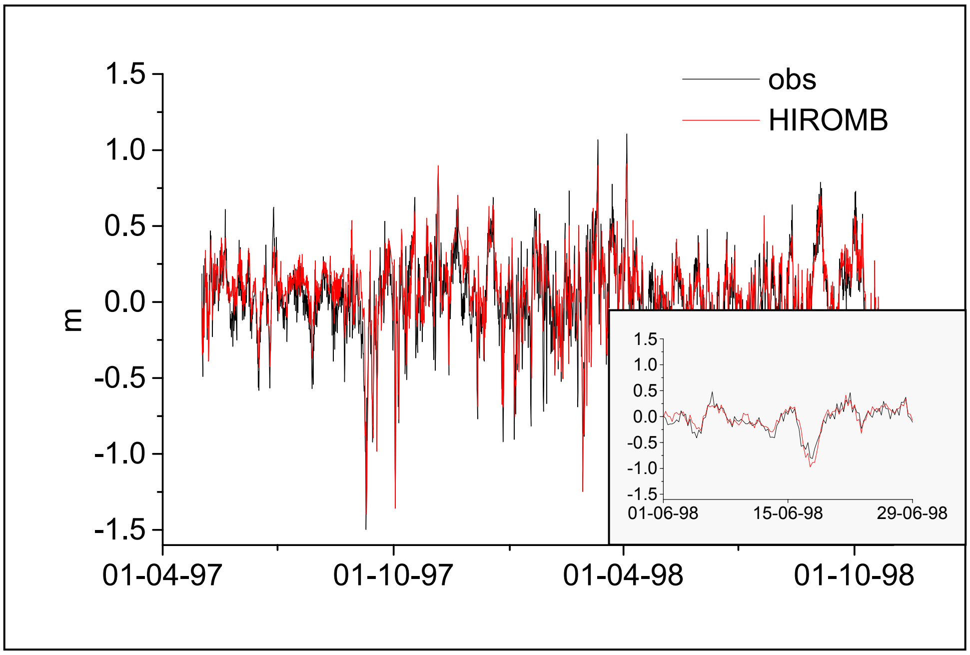

Figure 8. Sea level difference between Skanör and Hornbæk

It appears that the general conclusions for Öresund: too weak currents and consequently too small flow rates in HIROMB, are also valid in the Great Belt. Below is shown a comparison of the currents at Vestbroen, where the currents have been calculated in the same manner as at Drogden (Figure 9). Here the degree of underestimation is even worse. The standard deviation of observed currents is 48 cm/s, while in HIROMB it is 16 cm/s, giving a ratio of 0.33. The explained variance is 38 percent.

Even though there are no as simple but still good models for the flow rate through the Belt Sea as for Öresund, it is still possible to produce quite accurate estimates based on the sea level difference. Starting from an existing model for the total transport between the Baltic Sea and the Kattegat, and subtracting the modelled transport through Öresund, one gets a model $Q(\Delta\eta) = (\Delta\eta / K)^{½}$, K = 0.125e-10, applicable for the transport at Darss sill, for instance. $\Delta\eta$ is now the sea level difference between Gedser and Hornbæk.

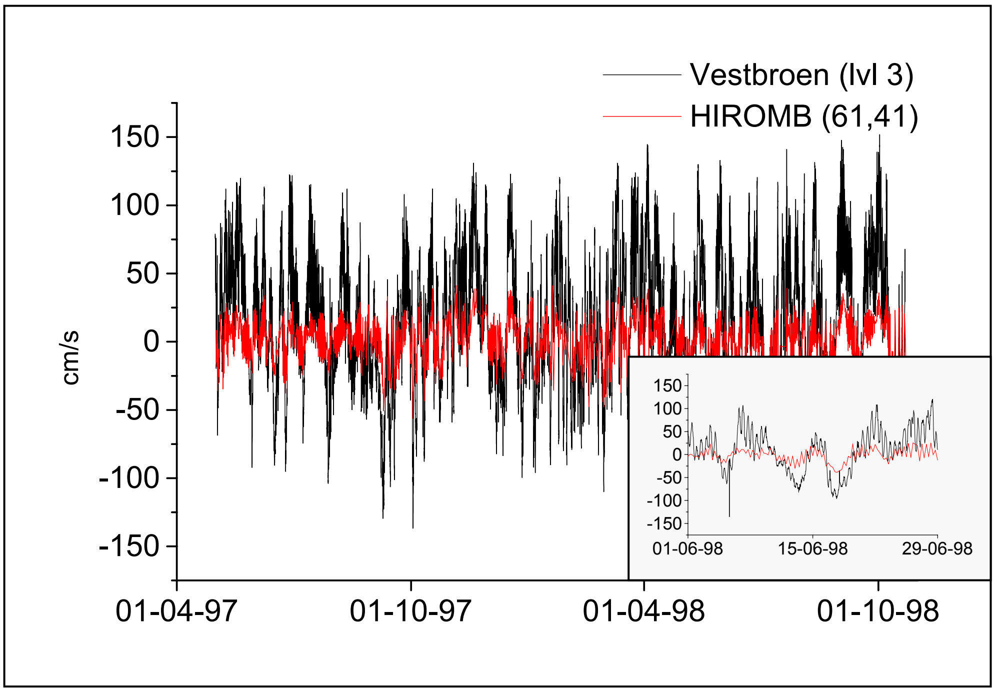

Figure 9. Current at Vestbroen

Figure 10 shows a comparison where the transport in HIROMB is calculated through a cross section at the Darss sill. The explained variances are 139 000 m^3/s and 55 000 m^3/s, respectively, ratio 0.40, and explained variance 28 percent. The very low percent explained variance is partly due to the simplified model for the flow rate being too simple, but the ratio should be accurate. It is similar in magnitude to the ratio of currents at Vestbroen, and confirms that the currents are underestimated in the Great Belt as well.

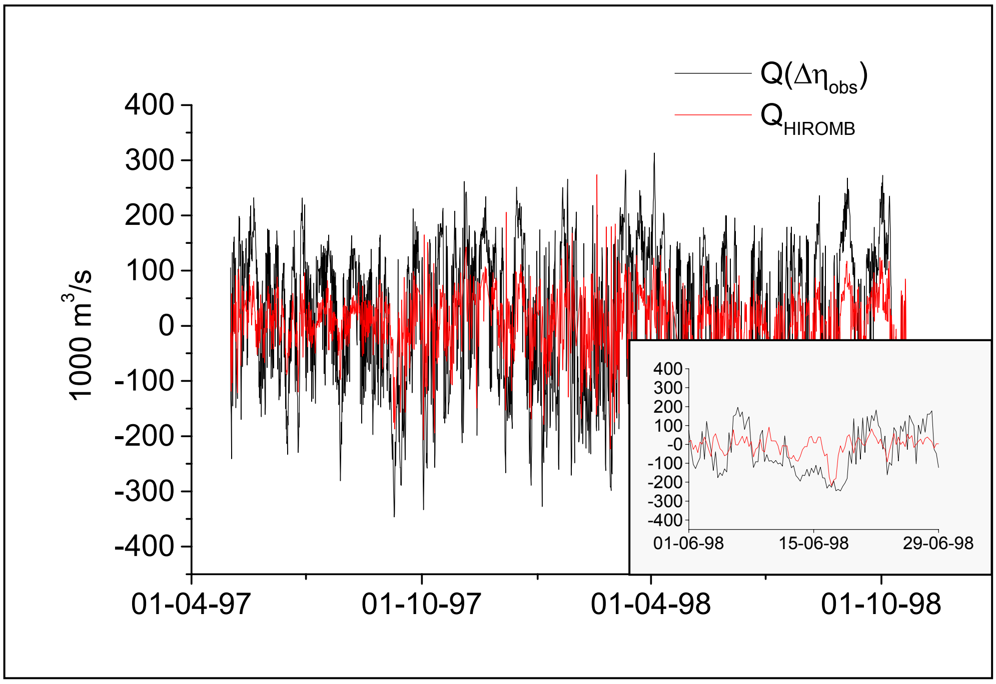

Figure 10. Flow rate in the Great Belt

Again the conclusion must be that the flow resistance is too large in HIROMB, as the sea level difference between Gedser and Hornbæk is well predicted by HIROMB. It is underestimated by 10 percent, and the explained variance is 75 percent.

Conclusions

It is concluded that currents, and therefore also transports through the Danish Straits, are underestimated in HIROMB. The following table summarizes the results:

	Ratio of standard deviations	Explained variance
Öresund	≈ 0.65	≈ 0.60
Belt Sea	≈ 0.40	≈ 0.40

Too small transports through the Danish Straits are a serious problem, most probably giving erroneous results with respect to the exchange of water, salt and energy between the Baltic Sea and the Kattegat. Fortunately, the increased resolution of 1 nautical mile that will become operational during spring 2000 may very well, at least partly, solve the problem. Too large flow resistance can be due to the straits being too shallow, too narrow or/and too long in the model bathymetry. It can be difficult with coarse resolution to have simultaneously a correct width, depth, "effective" length and cross-sectional area. Nevertheless, it is important that the transports are validated again when the new resolution is in use, to either confirm the coarse resolution explanation or to look for other possibly more unpleasant explanations.