Hydrographical classification of The Jutland Coastal Current

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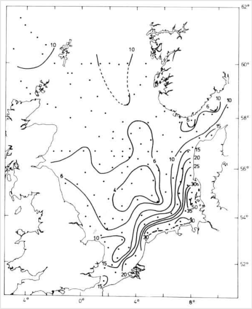

Figure 1: Typical surface distribution of NO_x (μmol/l) in late winter and early spring. (after Brockmann et al, 1990)

Goal:

The goal of this investigation is to estimate the amount of nutrient rich German Bight Water entering the Kattegat by The Jutland Coastal Current.

Background:

During the last decade, there has been a lot of discussion concerning The Jutland Coastal Current's role in transporting nutrient rich German Bight Water into the bottom layer or spring layer of the Kattegat. The Jutland Coastal Current is a fresh water influenced current that closely follows the danish westcoast. It is part of the general cyclonic circulation in the North Sea and so the direction of the mean current in The Jutland Coastal Current is northward. The main river sources are the Elbe, the Weser and the Ems, which all run into the German Bight, as well as the Seine and the Rhine and small rivers along the Danish coast. Of special interest are the 3 German rivers, because they all contain large concentrations of phosphate and nitrate (see Figure 1).

Measurements:

- Hydrographical surface measurements for a 9 to 16 year period to 1998 along the west coast of Jutland.
- Hydrographical measurements from Hirtshals for a period of 16 years.
- Wind measurements from Thyborøn.

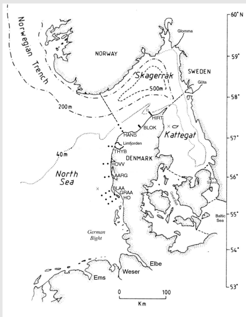

Figure 2: Location of hydrographical stations. In the sections only the outermost stations are used in the calculations to minimize errors due to local effects.

Methods:

As seen from figure 1, the distribution of NO_x has much the same features as a release from a point source or a plume. The idea of this method is to use this information to make the non conservative tracer NO_x conservative, so it can be used in a hydrographical classification of the water masses.

The transport equation to solve is:

$$\frac{\partial \bar{c}}{\partial t} = -\bar{u}_j \frac{\partial \bar{c}}{\partial x_j} - \frac{\partial}{\partial x_j}\left(K_{jj} \frac{\partial \bar{c}}{\partial x_j} \right) + S_i(\mathbf{x}_k, t) \qquad (1)$$

where c is the concentration, u the advection speed, K_{jj} the diffusion tensor (k-closure) and S the sources and sinks.

Assuming instantanous release, well mixed water in the vertical, only advection in the x-direction and reflection at y=0 (the west coast of Denmark) the solution is

$$\overline{c(x,y,t)} = \frac{S}{4(\pi t)(K_h)} \exp\left[-\frac{(x-\bar{u}t)^2}{4K_h t} - \frac{y^2}{2K_h t} \right] \qquad (2)$$

The solution is shown in Figure 3 which has to be compared with figure 1. Actually, a little modification is made. An identical instantaneous release exactly one year before is added to the solution, because far away from the source the concentration gets it's maximum value very late.

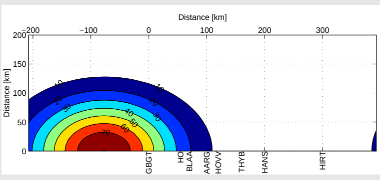

Figure 3: The calculated concentration of NO_x at the first of January.

Equation 2 is used to predict the maksimum concentration of NO_x as a function of time and position. Together with salinity the hydrographical classification is given by the equations (q: fraction of the given watertype):

$$\begin{aligned} 1 &= q_1 + q_2 + q_3 \\ S &= S_1 q_1 + S_2 q_2 + S_3 q_3 \\ NO_x &= NO_{x,1}(t) q_1 + NO_{x,2}(t) q_2 + NO_{x,3}(t) q_3 \end{aligned} \qquad (3)$$

Results and conclusions:

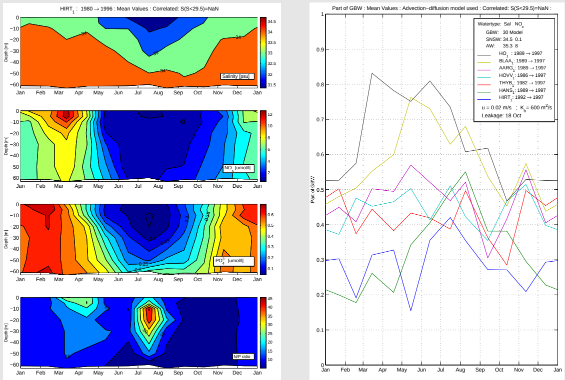

Figure 4: Calculated mean fractions of German Bight Water at Hirtshals (left) and along the Danish west coast (right).

The following results are obtained:

- Outside Hirtshals only the upper approximate 10 meters contain more than 30 % German Bight Water on averange of a year with maximum fractions in July and August not exceeding 50 % (Figure 4).
- Only under very special wind conditions with strong wind blowing from SSW for a long period in the months January to April, the Jutland Coastal Current can transportate large amounts of nutrient rich German Bight Water to the Skagerrak and possibly further into the Kattegat (Figure 5).

It is concluded, that German Bight Water transported by The Jutland Coastal Current into the Kattegat hardly affect the concentrations of nitrate, phosphate, silicate and other nutrients in the Kattegat in mean, because it is uptaken before it reach the area.

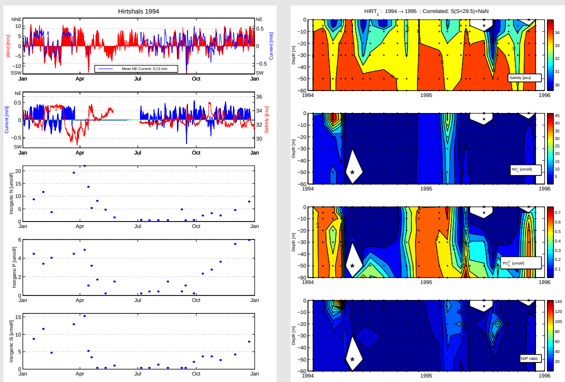

Figure 5: At left measurements from 1994 of the NE directed current at Hirtshals together with the NNE directed wind at Thyborøn, the NE directed current together with salinity, inorganic N, P and Si. At right measurements at Hirtshals from 1994.

References:

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