S, T-climatologies of the North Sea using the Variational Inverse Method

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EGU General Assembly 2009
Session OS13:
Temporal variability of ocean temperature (heat content) and salinity (freshwater content)

1 Context

SeaDataNet is an integrated infrastructure financed by the European Union that brings together a unique group of major institutes and marine data centres from countries bordering the North-East Atlantic, and its adjacent seas: the Mediterranean, the Black Sea, the Baltic, the North Sea and the Arctic. The consortium is developing standards, tools and procedures in order to ease the on-line access to in-situ and remote sensing oceanographic data, meta-data and products is provided through a unique portal.
In order to demonstrate the power and the coherence of the system, synthesised regional and global statistical products are currently being prepared. These products are built using "Ocean Data View" for the preparation selection, quality control and consistency checks of the data, and DIVA for the analysis data and the production of the integrated products
This work presents the progresses made so far in establishing salinity and temperature climatologies for the North Sea (Fig.1). To this end, CTD data from various sources are analyzed using the Variational Inverse Method (Brasseur *et al.*, 1996) over the period 1975-2005.

2 The North Sea region

The North Sea basin connects with three other regions for which synthetic products need also to be produced. Practical sea limits have been agreed by the partners, together with common buffer zones for which the same data subsets will be used (Fig.1).

FIGURE 1: *Delimitation of the region for the North Sea climatology. Overlap zones are defined between the North Sea and the Baltic, and between the Channel and the Norwegian Sea.*

3 Data

Version **V1** of the synthetic products deals with salinity and temperature. In the future version **V2** will also address the distribution of other parameters like nutrients and chlorophyll. The period of reference extend from January 1^{st}, 1975, till December 31^{st}, 2005.
CTD profiles for the selected region have been extracted from the World Ocean Data Base and from the ICES collection. In total, 325 701 profiles have been treated, corresponding to more than 1.3 million measurement points (Fig.2). The bathymetry has been extracted from the GEBCO $1' \times 1'$ dataset.

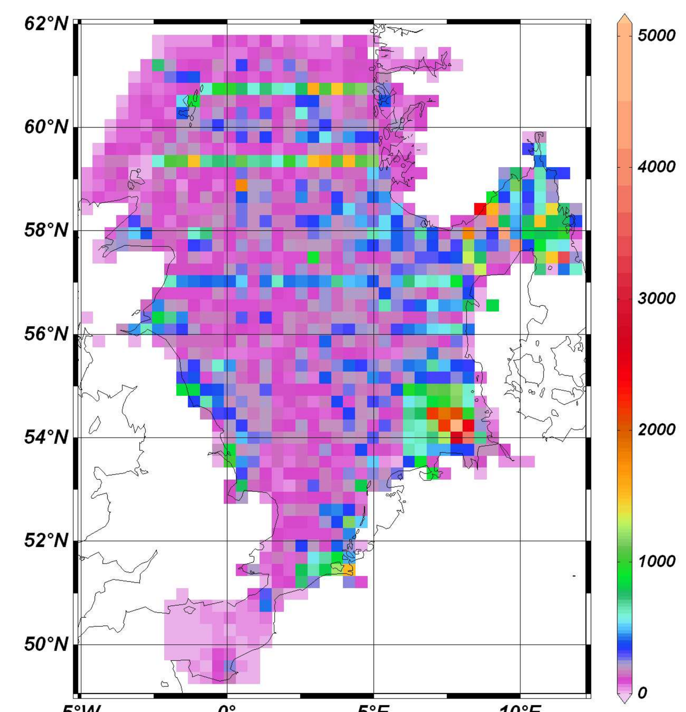

FIGURE 2: *Data count over the region of interest. Elbe river plume ($54°N$, $8°E$) appears as the most sampled zone, while zonal tracks in the northern part of the domain seem to origin from repeated sections.*

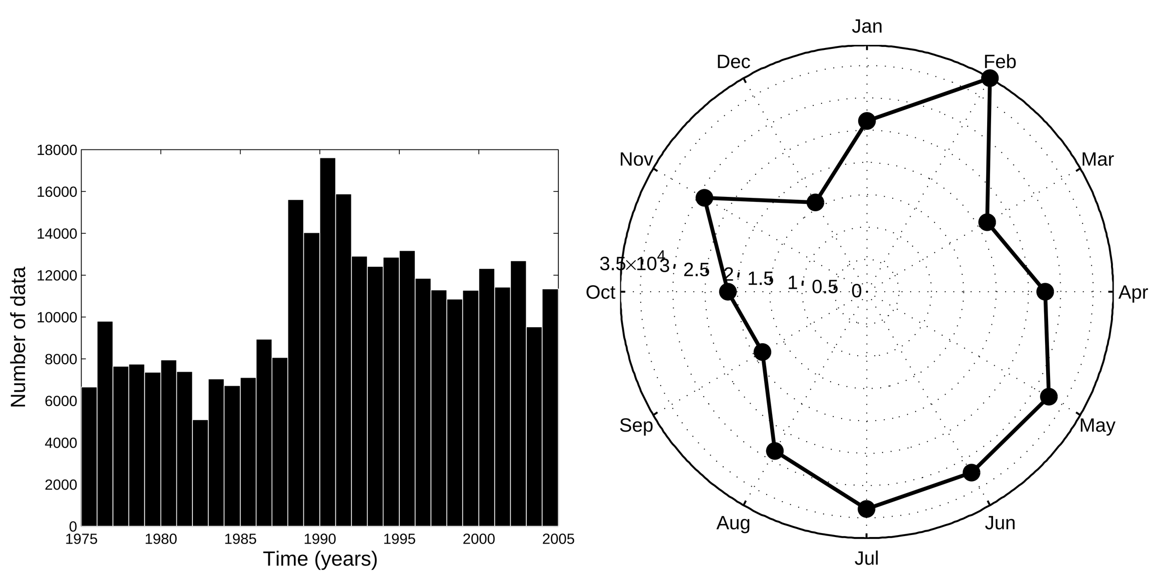

FIGURE 3: *Time histogram (left) and monthly distribution of data (right). The contrast between summer and winter is evident, except in February, which is the month with the larger number of available profiles.*

4 Method

The data have been either directly extracted (WODB) or later interpolated (ICES) to the 14 first standard levels as proposed in 1936 by the International Association of Physical Oceanography: 0, 10, 20, 30, 50, 75, 100, 125, 150, 200, 250, 300, 400 and 500 m below sea level.
Afterward they were split on a monthly basis (Fig.3), and each data subset parameter, month, level has been analysed using DIVA.
DIVA is one of the standard tools used and refined in the frame of SeaDataNet. It allows to spatially interpolate data in a way comparable to optimal interpolation, by solving a variational problem of elliptic type using the finite element method. Therefore, it can take into account coastlines, sub-basins and advection.

As a first step in the analysis, a finite element mesh has been generated for each of the standard levels (Fig.4).

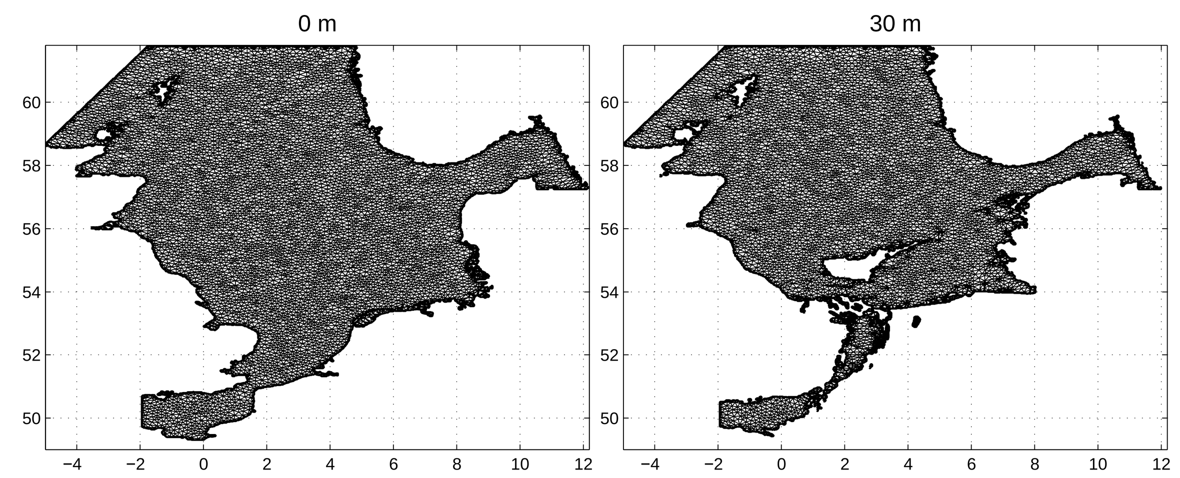

FIGURE 4: *Finite-element meshes at surface (left) and at 30 m depth.*

5 Results

Monthly climatologies of salinity and temperature have been produced at the fourteen standard levels.
The Variational Inverse Method implemented in DIVA has two key-parameters: the correlation length and the signal-to-noise ratio. The method allows, after iteration, the optimization of these two parameters in accordance with the data being treated. In the results shown (Fig.5), the correlation length has been optimized while the signal-to-noise ratio has been kept low (< 0.5) according to the expected high variability of the information.

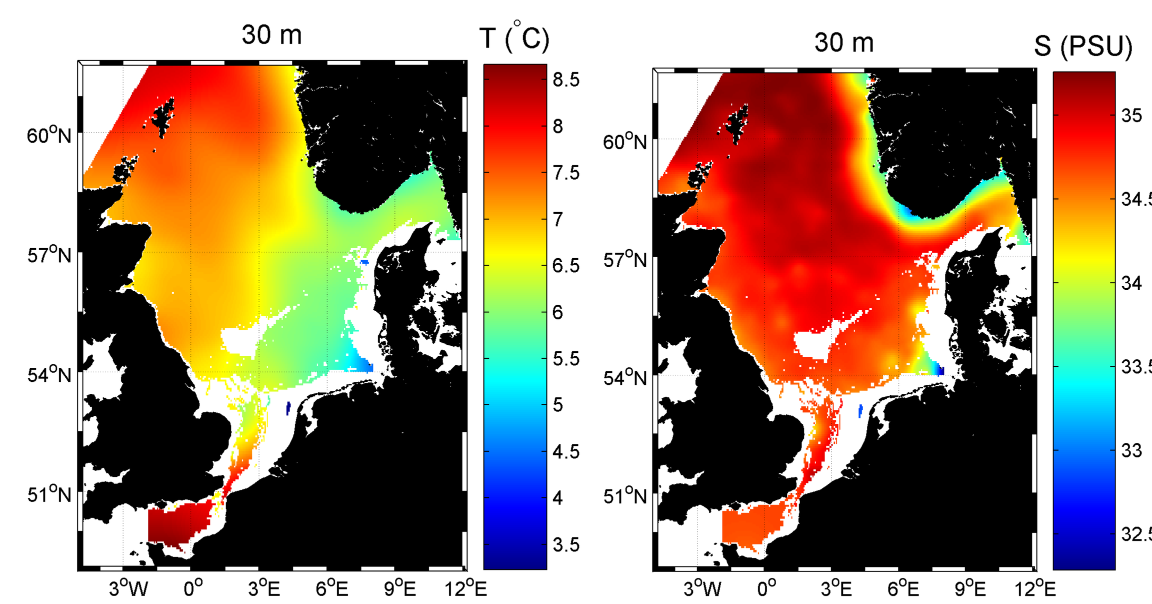

FIGURE 5: *Temperature (left) and salinity at 30 m in February.*

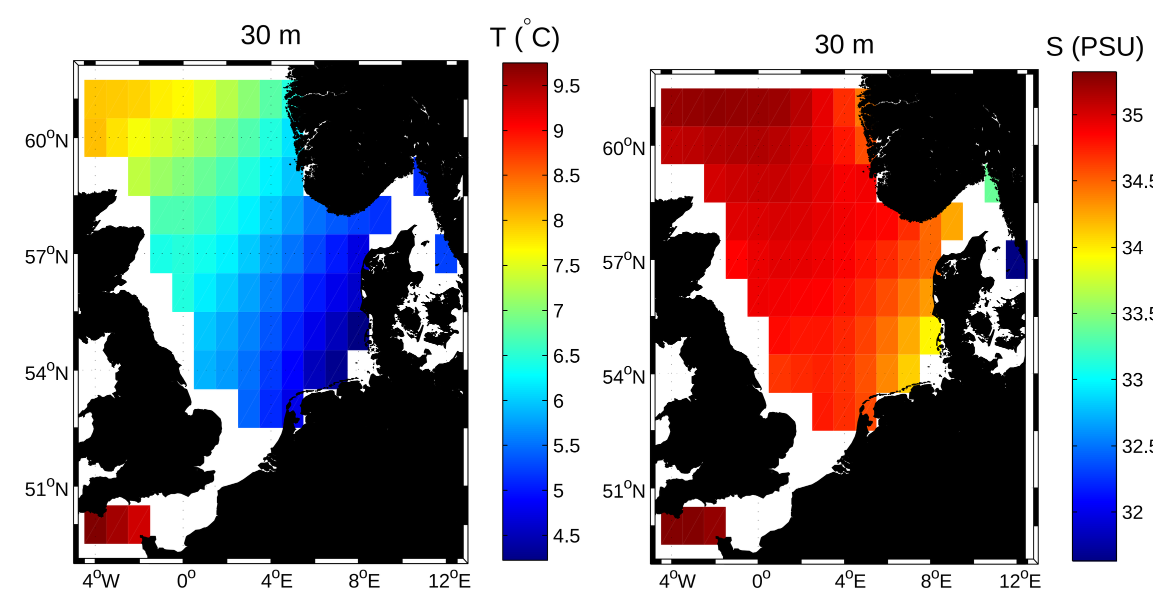

FIGURE 6: *Temperature (left) and salinity at 30 m in February extracted from the World Ocean Atlas 2005.*

6 Error fields

Associated with the analysis, error fields are produced in a coherent way. They are mostly influenced by data coverage, as shown in Fig.7. Estimated errors are higher in the Eastern Channel, where examination of data reveals a very weak density of observations in winter.

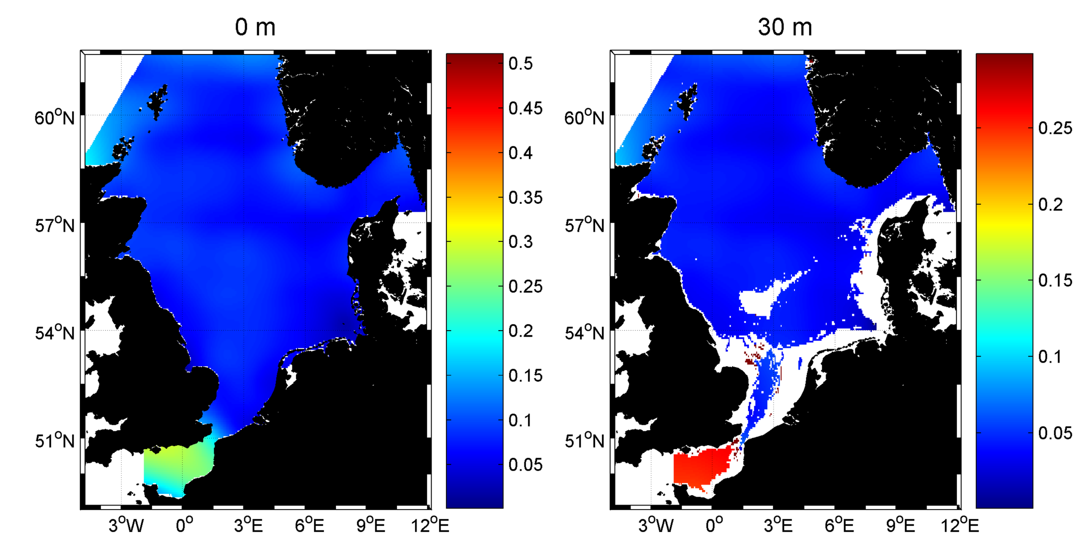

FIGURE 7: *Error fields for temperature at surface (left) and at 30 m in February.*

7 Conclusions

A first set of climatologies prototyping a possible use of the SeaDataNet integrated infrastructure for oceanographic data management has been produced. These early results look promising, mainly thanks to the specificities of the method used for the interpolation: based on a finite-element mesh it takes into account the actual shape of the basin, ignoring islands and isthmus, where other methods just mask the results of the interpolation. The resolution can be very fine in coastal areas, which is of the highest importance in shallow basins like the North Sea.
Data inventory has shown some gaps (like in the Eastern Channel during the winter) that will need to be filled in by national data sets wherever possible before proceeding.
Further work will include finer optimisation of the parameters like the signal-to-noise ratio and incorporation of the information given by the outlier detection.

8 Web references

SeaDataNet: http://www.seadatanet.org/
Ocean Data View: http://odv.awi.de/
DIVA: http://modb.oce.ulg.ac.be/projects/1/diva
WODB: http://www.nodc.noaa.gov/OC5/SELECT/dbsearch/dbsearch.html
ICES: http://www.ices.dk/ocean/aspx/HydChem/HydChem.aspx
GEBCO: http://www.gebco.net/

Acknowledgments

We thank Hjalte Parmer from the ICES data centre for supplying data. DIVA was developed by the GHER and improved in the frame of the SeaDataNet project. SeaDataNet project is an Integrated Infrastructure Initiative of the EU Sixth Framework Programme.