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**ICES/EuroGOOS North Sea Pilot Project
– NORSEPP
ICES/EuroGOOS Planning Group
for NORSEPP (PGNSP)**

**Update report on
North Sea conditions –
2nd quarter 2006**

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Contributors and acknowledgements

Morten Skogen (IMR) provided the NORWECOM model data for water fluxes. Vidar Lien (IMR) produced the plots of sea level air pressure. Didrik Danielsen (IMR) provided the plot of daily temperature recordings at Flødevigen, Arendal.

Stephan Dick (BSH) provided the North Sea plots of sea surface temperature and the seasonal temperature development in the German Bight. Al Joyce and Liam Fernand (CEFAS) provided the time series of salinities and temperatures in the Southern Bight. Virginie Pison (MUMM) provided modeled flux through the Channel and the modeled temperature distributions in the Channel and southern North Sea. Youngje Park and Kevin Ruddick (MUMM) provided the map of satellite-derived monthly mean chlorophyll *a* concentration for March. Martin Holt and John Siddorn (UK MetOffice) provided plots of modeled monthly mean seabed temperature.

Contents

Summary description	p. 3
Preface	p. 3
Air pressure	p. 4
Modeled water circulation	p. 5
Distribution and properties of water masses	p. 10
Seasonal phytoplankton development	p. 16
Annex I. Modelled monthly mean sea bed temperature (UK Met Office).....	p. 18
Annex II. Model results on salinity and temperature distributions in the North Sea and the Channel – MUMM Belgium	p. 21

Summary description

The North Sea water circulation in the 2nd quarter was characterized by stronger than average inflow between the Orkneys and Shetland in April, and strong circulation through the Skagerrak in April changing to low circulation in May. In the central and southern North Sea, the counter-clockwise circulation around Doggerbank was strong in April and May but slackened and partly reversed in June. There was strong inflow to the North Sea through the Channel in May.

The seasonal warming of the North Sea progressed from minimum in March to monthly mean temperatures in June of 11-12°C in the central North Sea and 13-14°C in the coastal waters of the southeastern North Sea. In June, much of the North Sea was cooler (by 0.5-1°C) than normal. Salinities in the Southern Bight were higher than average (about 35.1) in May and June.

The report includes modeled distributions of temperature and salinity at the surface and/or near seabed as monthly mean distributions for April, May, June and July. It also includes satellite-derived data on chlorophyll distributions in the Southern Bight and eastern Channel for the period March-June. Hydrographic observations from the ICES coordinated herring surveys in June-July were intended to be included, but the data were delayed and will therefore be included in the 3Q NORSEPP report.

Preface

ICES and EuroGOOS established in autumn 2001 a Joint ICES/EuroGOOS Planning Group on the North Sea Pilot Project (PGNSP). Establishment of the Pilot Project was one of the recommendations from an ICES/OSPAR/IOC/EuroGOOS Strategic Workshop held in Bergen, 5-7 September 2001.

The Pilot Project - NORSEPP - is focussing on the relationships between oceanography and fish stocks and is promoting the development of operational oceanography for biological applications such as in fish stock assessments. PGNSP (the Planning Group for NORSEPP) decided in 2005 to start producing quarterly update reports on the conditions of the North Sea, with emphasis on the physical conditions as drivers for biological variability. The quarterly reports for 2005 and the first quarter (1Q) 2006 are available at the ICES web-page: <http://www.ices.dk/marineworld/norsepp.asp>

The editor and PGNSP are happy to receive comments and feedback on the quarterly reports so that we can shape them in scope and content to suit the needs of users both within and outside the ICES community.

Air pressure

The air pressure distribution over the northeast Atlantic showed large changes during the 2nd quarter of 2006. The monthly means and quarterly mean sea level air pressures for the first quarter of 2006 are shown in Fig. 1. The monthly mean pressure distribution for April showed a high NAO Index situation with a fairly strong gradient between a Low northeast of Iceland and a High in the Atlantic off Portugal. This was very different from the situation in March, when a High over Greenland pushed the Low south in the Atlantic, so that the pressure gradient was reversed (see the NORSEPP 1Q 2006 report). The mean pressure distribution in May resembled that for March, with the Iceland Low pushed south off the British Isles. The mean pressure distribution in June showed a northwards displacement again, with a high pressure ridge extending northeastwards over the North Sea. This situation continued in July as shown by the mean air pressure distribution for that month (Fig. 2).

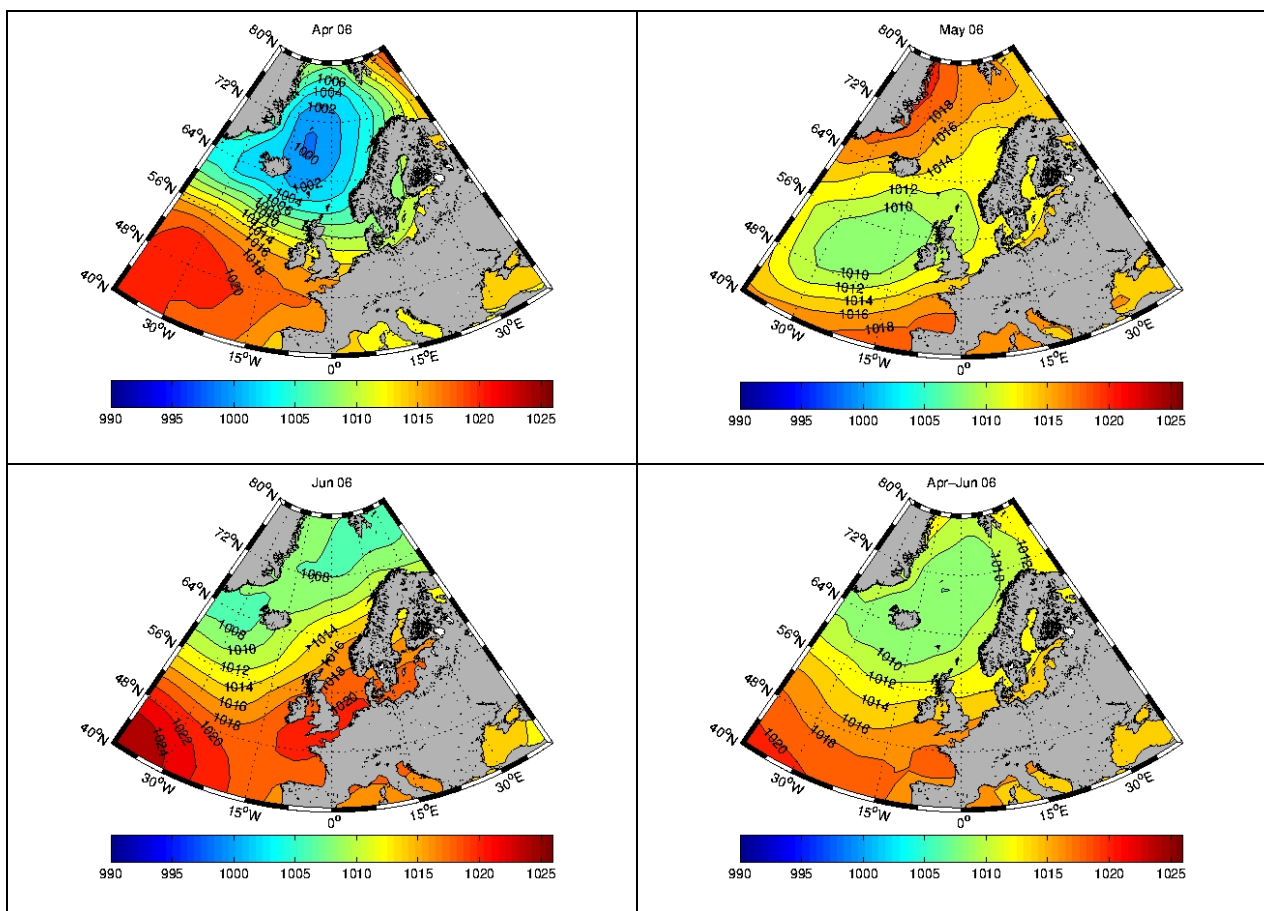


Fig. 1. Monthly mean sea level air pressures for April, May and June 2006 (upper left, right and lower left panels) and the mean for the 2nd quarter (April-May) 2006 (lower right panel).

The winds typically blow parallel to the air pressure gradients into the low-pressure areas. The pressure distributions would indicate moderate westerly winds over the North Sea in April, moderate westerly winds at the western entrance to the Channel in May, and low winds over the North Sea in June and July.

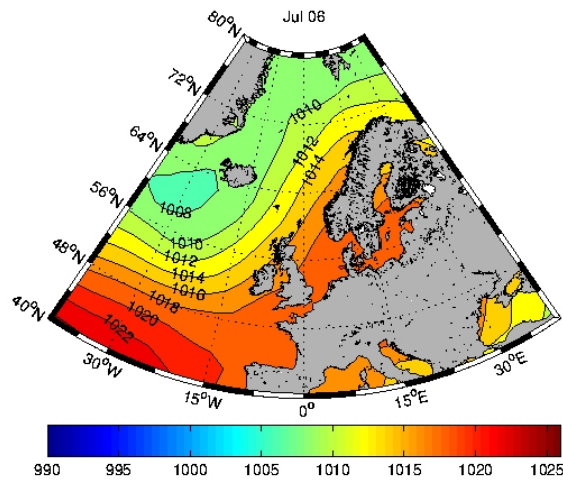


Fig. 2. Monthly mean sea level air pressure distribution for July 2006.

Modeled water circulation

The NORWECOM model has been run with historical meteorological driving forces to simulate the circulation of the North Sea over the period 1955-2004. Monthly mean flux values over this period were presented by Skjoldal *et al.* (2005; REGNS 2005 working paper). The 50-years mean values for monthly and quarterly fluxes across sections (see Fig. 3 for their locations) have been used for comparison with the estimated monthly and 2nd quarterly fluxes for 2006.

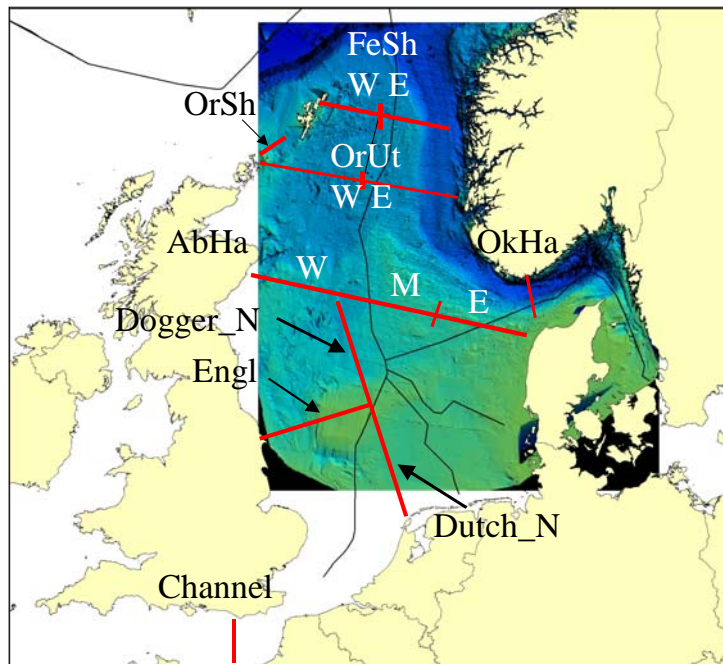


Fig. 3. Sections across various parts of the North Sea used to calculate fluxes of water with the 3-D mathematical circulation model NORWECOM.

The modeled mean 2Q quarterly fluxes across the different sections are shown in Fig. 4, compared to the long-term (50-year; 1955-2004) modeled mean 2Q flux. The mean monthly fluxes for April, May, and June are shown in Fig. 5.

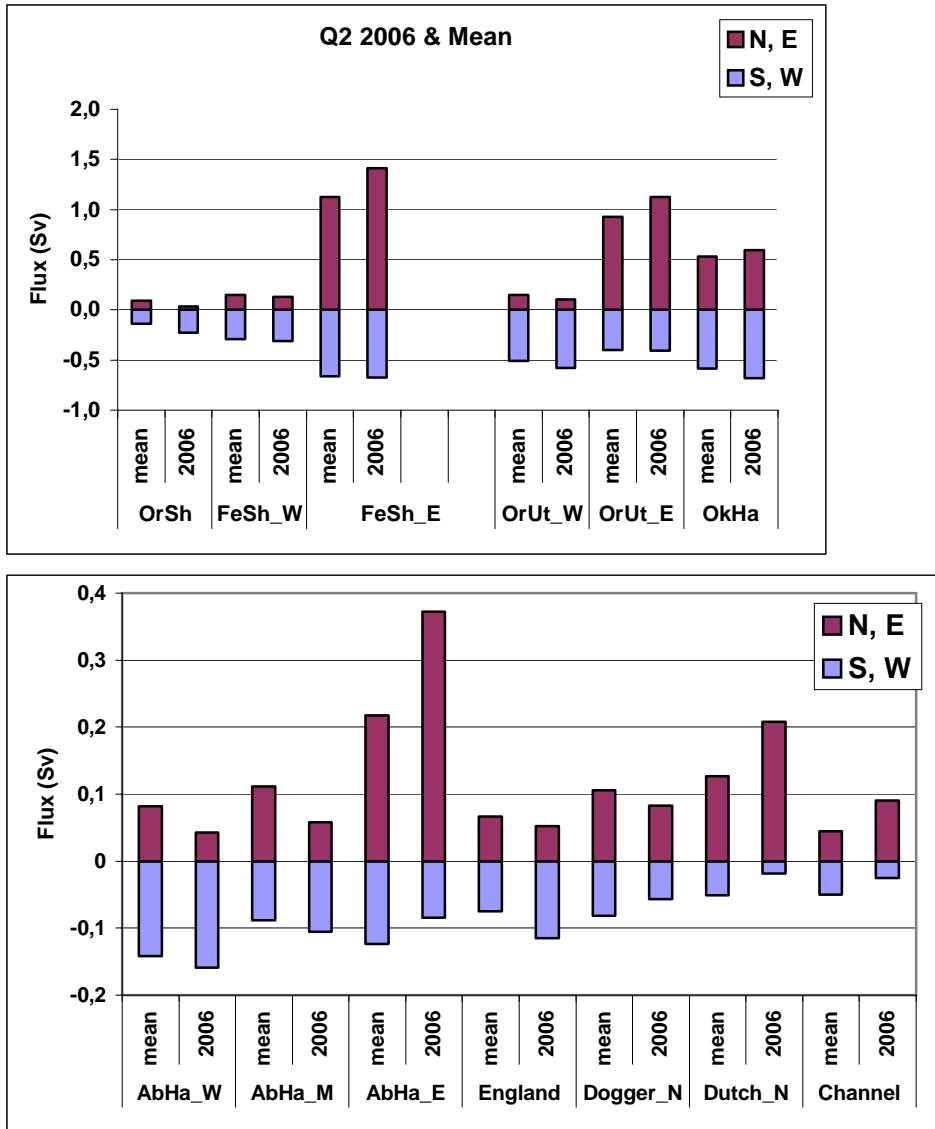


Fig. 4. The 2006 mean 2nd quarterly water fluxes across sections in the North Sea compared to the long-term mean fluxes for the 2nd quarter (1955-2004). NORWECOM model estimates. See Fig. 3 for the location of the sections. Positive values denote northwards or eastwards transport while negative values denote southwards or westwards transport.

The modeled inflow between Orkney and Shetland and the modeled outflow from the North Sea in the Norwegian Trench (Feie-Shetland E) in 2Q 2006 were somewhat larger the long-term modeled averages. This was also the case for the modeled inflow into the North Sea through the Channel (Fig. 4). The circulation in the central and southern North Sea was characterized by somewhat stronger than average southwards flow in the western areas (Aberdeen-Hanstholm W and England) and stronger than average easterly and northerly flows south and east of the Dogger Bank (Dutch_N and Aberdeen-Hanstholm E; Fig. 4).

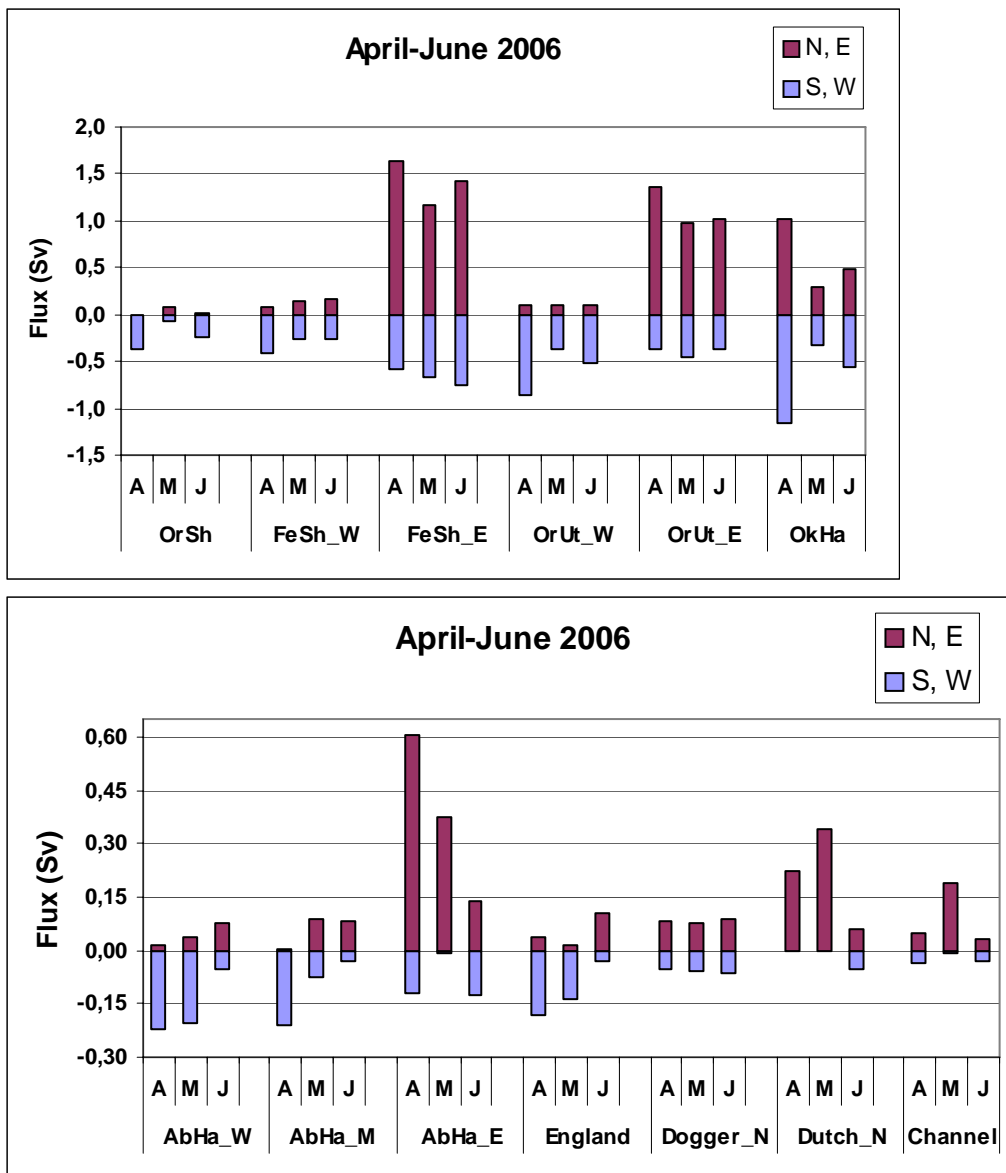


Fig. 5. The mean monthly water fluxes for April, May, and June 2006 across sections in the North Sea (see Fig. 3 for their locations). NORWECOM model estimates. Positive values denote northwards or eastwards transport while negative values denote southwards or westwards transport.

The modeled circulation in the North Sea changed much during the 2nd quarter (Fig. 5). The inflow across the northern boundary was particularly low in May between the Orkneys and Shetland, while it showed a decreasing trend over the plateau east of Shetland (Feie-Shetland W) and an increasing trend in the Norwegian Trench (Feie-Shetland E) from April to June (Fig. 5, upper panel). The modeled circulation trough Skagerrak was high in April (about 1 Sv), very low in May (0.3 Sv) and moderate in June (Fig. 5, upper panel).

The clockwise circulation around Dogger Bank was well established in April and May, as shown by southwards modeled fluxes in the western part of the Aberdeen-Hanstholm section and in the England section between England and the Dogger Bank, and eastwards flow south of the Dogger Bank (Dutch_N section) (Fig. 5, lower panel). The increased flow south of the Dogger Bank from April to May reflect the stronger inflow through the Channel. In June the circulation around the Dogger Bank slackens with a partial reversal of the flow pattern. The

flow across the mid portion of the transect between Aberdeen and Hanstholm changes from southerly flow in April to predominantly northerly flow in June (Fig. 5, lower panel).

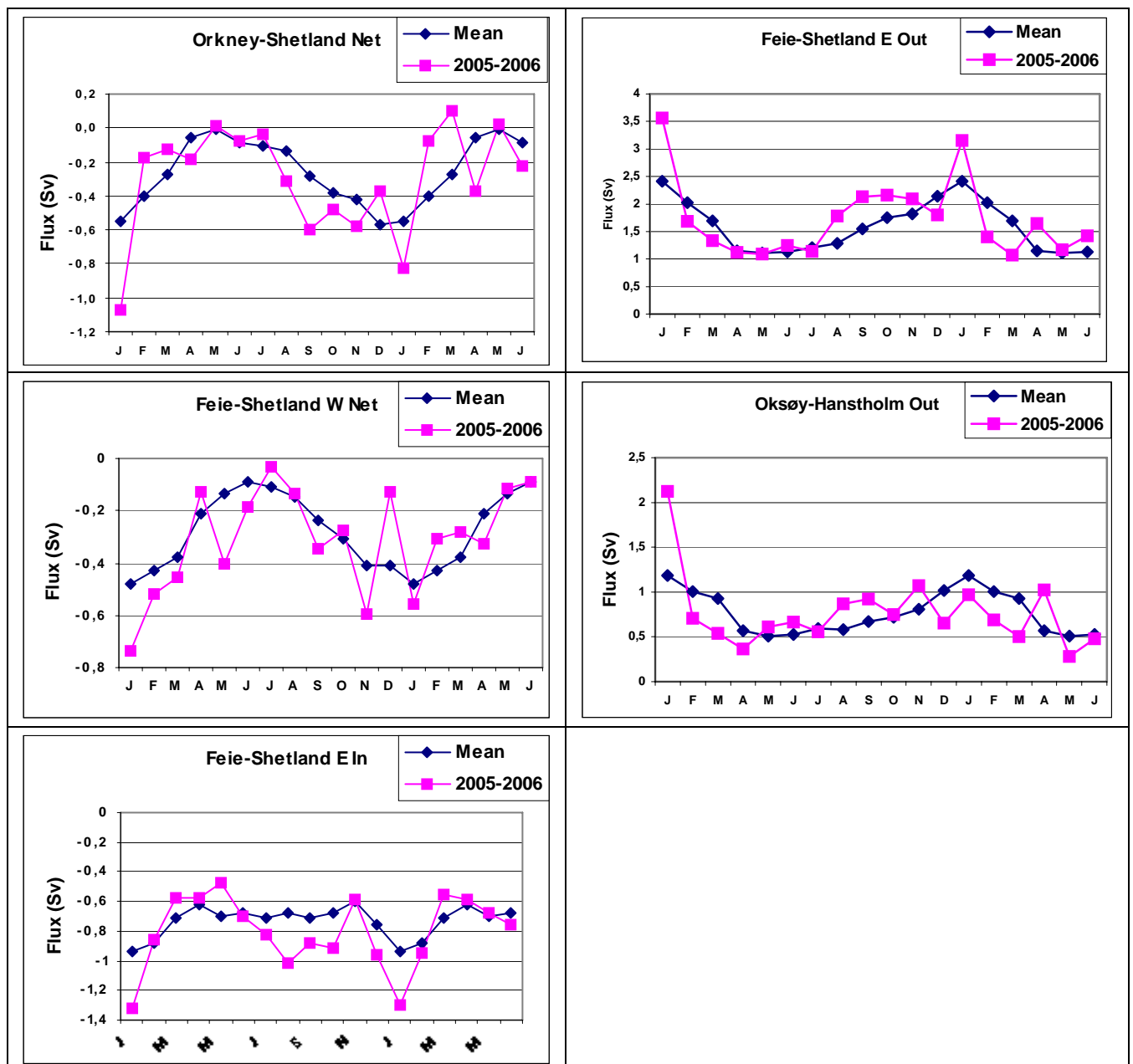


Fig. 6. Modeled fluxes of water across sections in the northern North Sea and in the Skagerrak (see Fig. 3 for their locations). The mean monthly fluxes from January 2005 to June 2006 are shown along with the long-term mean (1955-2004) monthly fluxes. Net flux is the difference between northwards and southwards fluxes for transects oriented in the E-W direction, and between eastwards and westwards fluxes for transects oriented in the N-S direction. *In* and *Out* are used to denote southwards and northwards fluxes into and out of the North Sea across the northern boundaries. *Out* for the Oksøy-Hanstholm section denotes outflow from Skagerrak. Negative values are southwards and westwards fluxes while positive values are northwards and eastwards fluxes for E-W and N-S oriented sections, respectively.

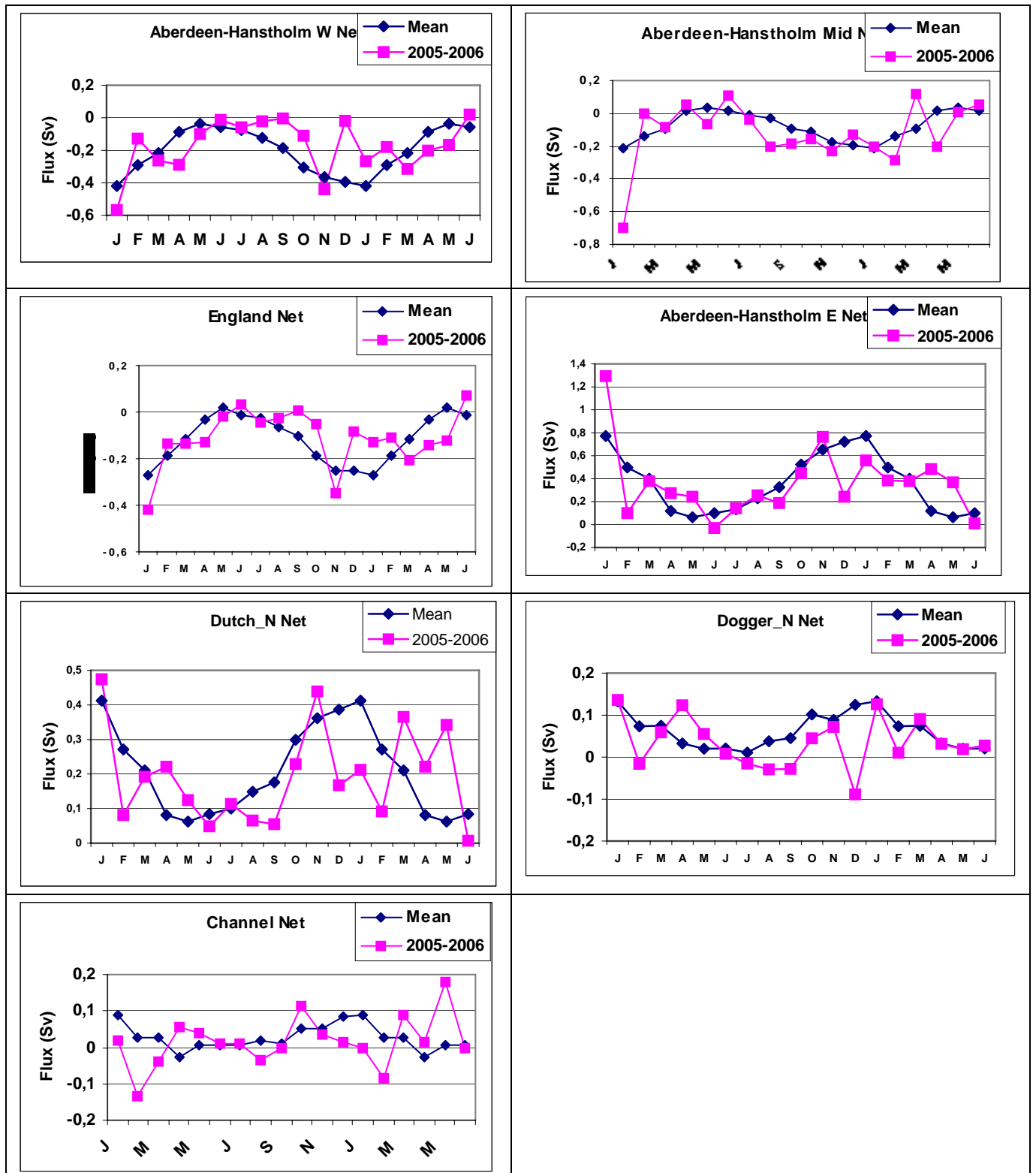


Fig. 7. Modeled fluxes of water across sections in the central and southern North Sea (see Fig. 3 for their locations). The mean monthly fluxes from January 2005 to June 2006 are shown along with the long-term mean (1955-2004) monthly fluxes. Net flux is the difference between northwards and southwards fluxes for transects oriented in the E-W direction, and between eastwards and westwards fluxes for transects oriented in the N-S direction. Negative values are southwards and westwards fluxes while positive values are northwards and eastwards fluxes for E-W and N-S oriented sections, respectively.

Compared to the long-term average monthly mean fluxes, the inflow to the North Sea through the northern boundary was stronger than the average in April and June for the flow between Orkney and Shetland, and for April for the inflow across the plateau (Feie-Shetland W) (Fig. 6, left panels upper and middle). This was reflected in stronger than average outflow through the Norwegian Trench (Feie-Shetland E) in April and June (Fig. 6, right upper panel). The transport through Skagerrak was considerably higher than average in April and lower than average in May (Fig. 6, left panel lower).

The counter-clockwise circulation around the Dogger Bank was higher than average in April and May, continuing a trend that started in March (Aberdeen-Hanstholm W, England, and Dutch_N; Fig. 7, upper three left panels). These flows were lower than average and partly reversed in June. Reflecting the increased circulation around the Dogger Bank, the northwards flow west of Denmark (Aberdeen-Hanstholm E) was higher than average in April and May (Fig. 7, right middle panel). The inflow to the North Sea through the Channel was substantially higher than the long-term average in May (Fig. 7, lower left panel).

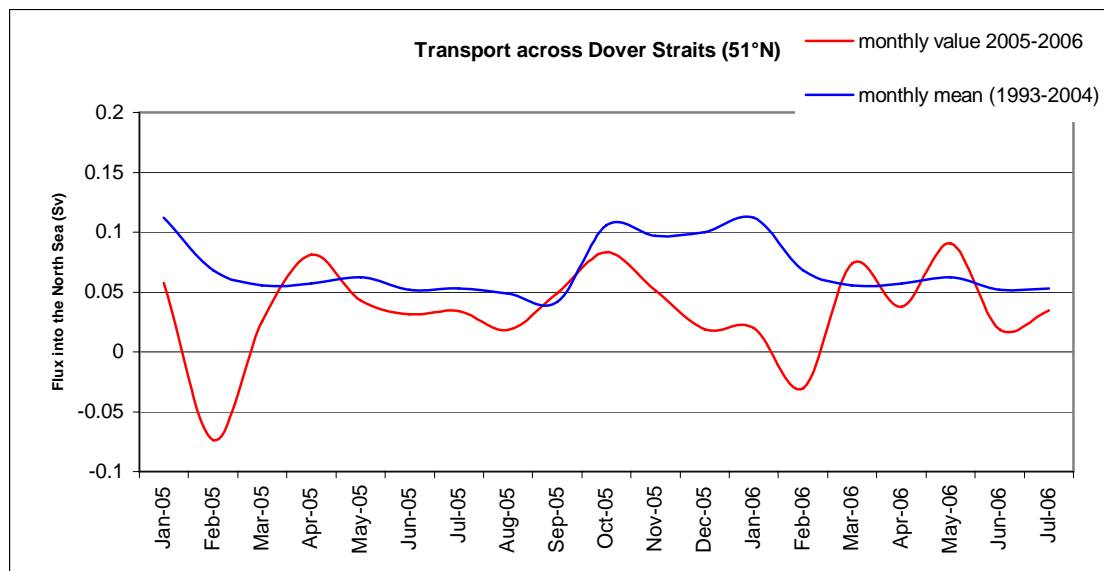


Fig. 8. Modeled monthly mean fluxes of water through the Channel across Dover Strait from January 2005 to July 2006 (red curve) compared to mean monthly fluxes for the period 1993-2004 (blue curve). Results obtained with the Optos_nos model run by MUMM, Belgium.

Modeled fluxes of water through the Channel obtained with the Optos_nos model (MUMM, Belgium; Fig. 8) are qualitatively similar to those described above, obtained with the NORWECOM model. The modeled flux was high and positive (into the North Sea) in May and lower and close to zero net transport in June (Fig. 8). The low net transport through the Channel continued in July.

Distribution and properties of water masses

BSH (Bundesamt für Seeschifffahrt und Hydrographie) in Hamburg compiles information on North Sea temperatures and display them on their web-page as maps for weekly or monthly mean conditions

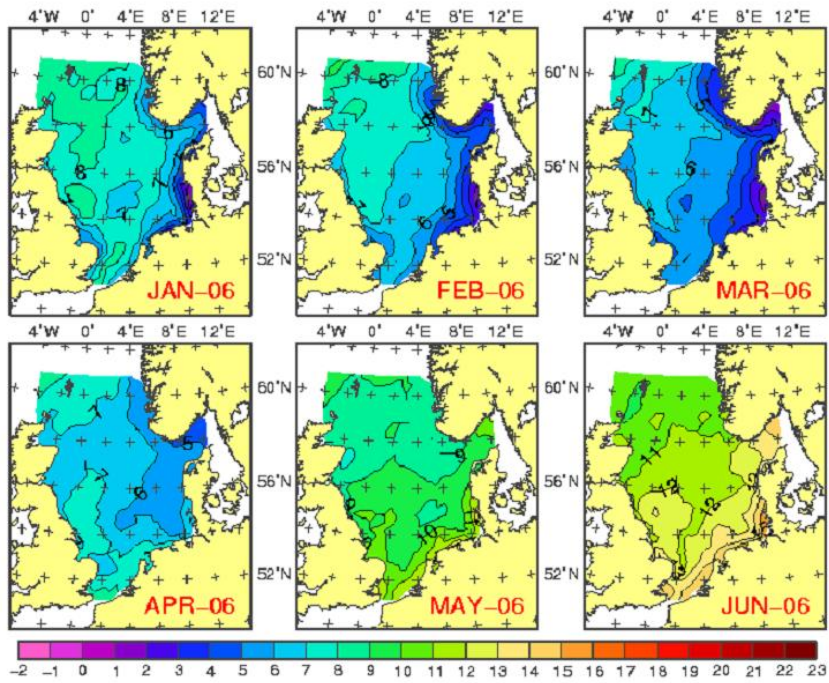


Fig. 9. Monthly mean sea surface temperature for January – June 2006. Data from BSH.

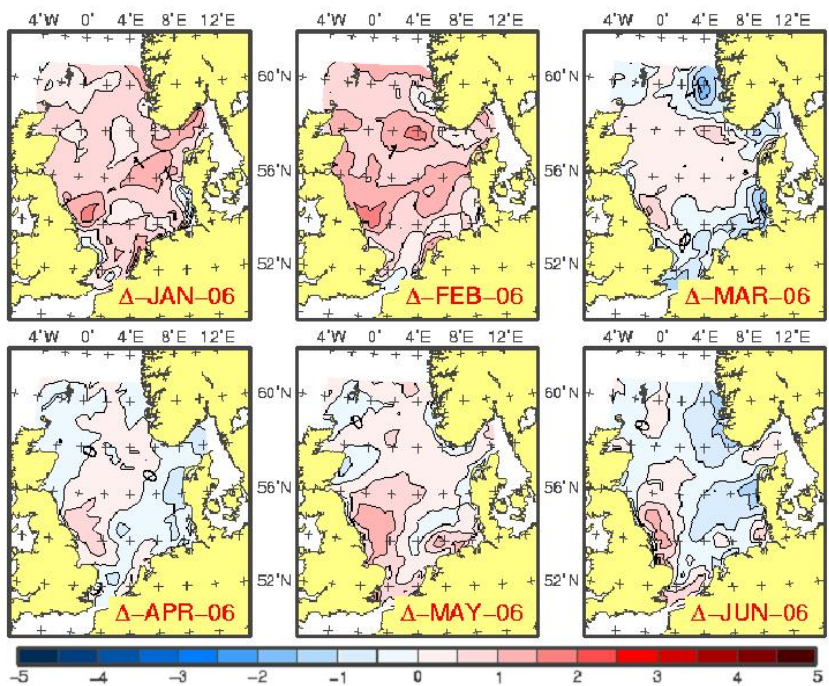


Fig. 10. Anomalies for monthly mean sea surface temperature for January - December 2005. Data from BSH.

(<http://www.bsh.de/en/Marine%20data/Observations/Sea%20surface%20temperatures/index.jsp>).

Monthly mean sea surface temperatures for each month during 2006 are shown in Fig. 9, while temperature anomalies (deviation from long-term means) are shown in Fig. 10.

The lowest temperatures were seen in March with only a slight warming in April. The sea surface temperature increased during May and June, to about 11-12°C over most of the northern and central North Sea and 13-15°C in the coastal areas of the southeastern North Sea in June (Fig. 9). The temperature anomalies showed warmer than average conditions in much of the North Sea in May and cooler than average conditions in June (Fig. 10).

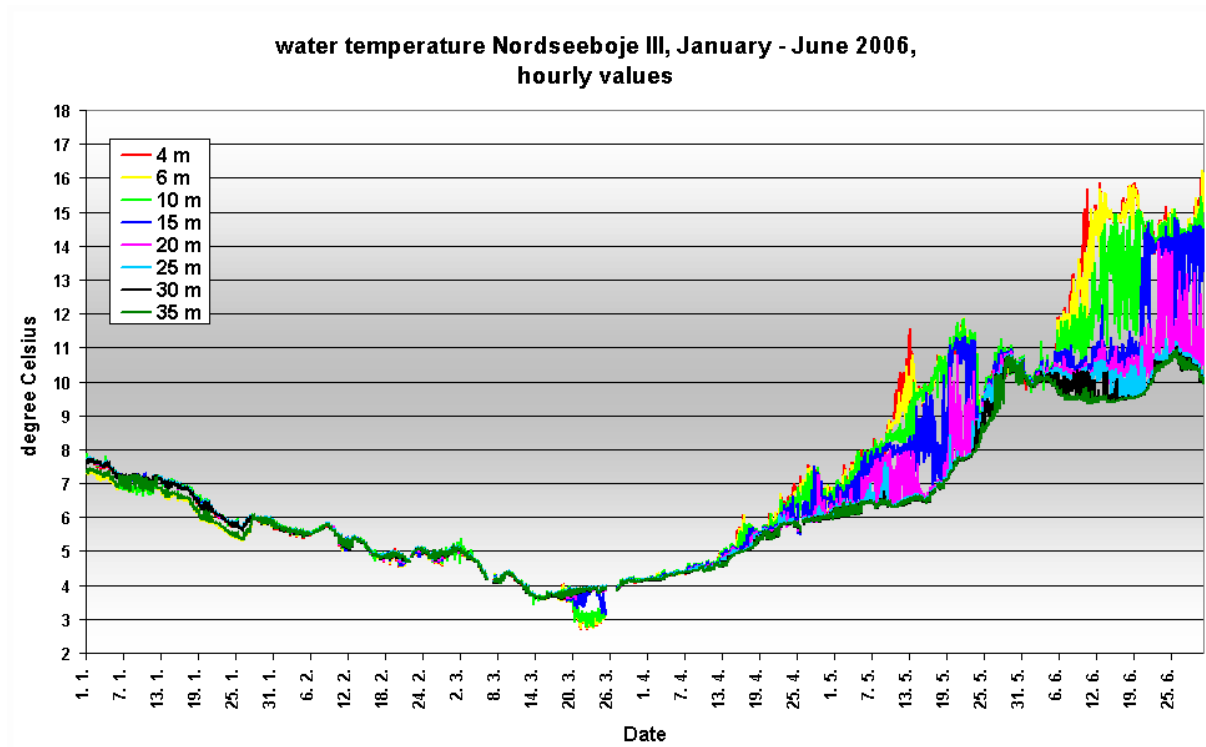
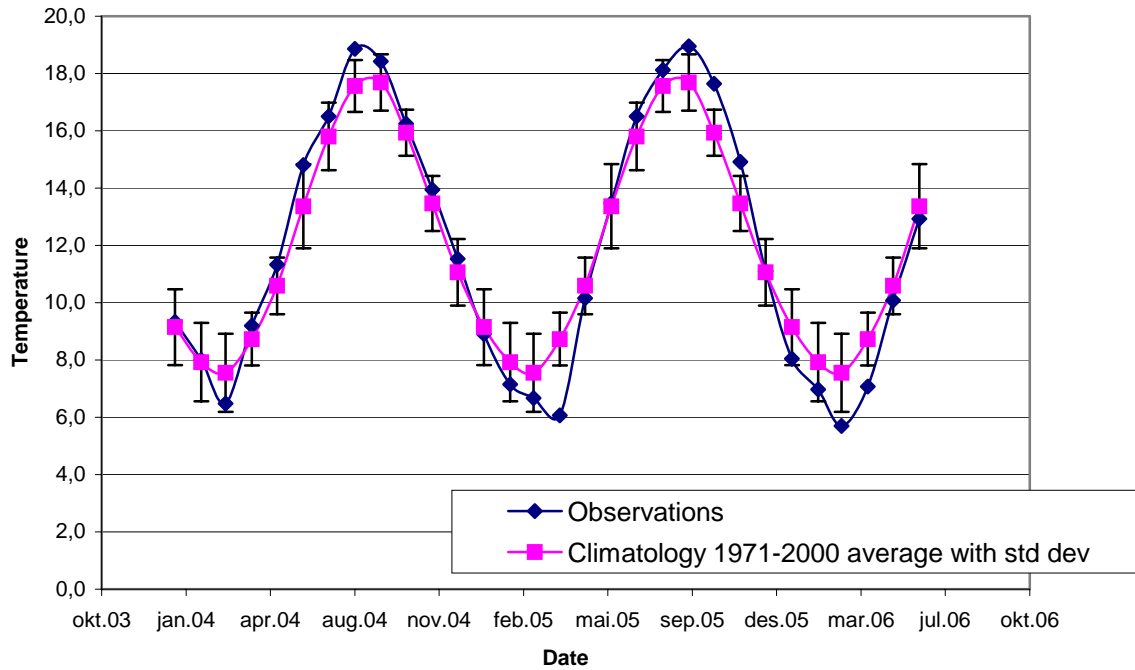


Fig. 11. Seasonal temperature development at different depths in the German Bight from January through June 2006. From BSH.

The seasonal temperature curve for a monitoring station in the German Bight showed that the minimum temperature of about 3.5°C occurred in the latter part of March. Thereafter the temperature increased to about 15-16°C in the upper layer in late June (Fig. 11). Stratification, as indicated by temperature gradient in the water column, occurred from mid March, followed by mixing and homogenization in late May, and renewed stratification in early June (Fig. 11).

Time series of temperature and salinity from a station in the Southern Bight (52°N, 2°20'E) are shown in Fig. 12. The temperature was below average during the winter from January to April, by a maximum extent of 2°C in March. The temperature was close to average in May and June (Fig. 12, upper panel). The salinity was close to average in March and April but increased to much higher than average (by 0.25-0.35 units) in May and June (Fig. 12, lower panel). This corresponded to the period with strong inflow to the southern North Sea through the Channel in May (Fig. 7, lower left panel, Fig. 8).



Salinity time series from Southern Bight
52° N 2° 20' E

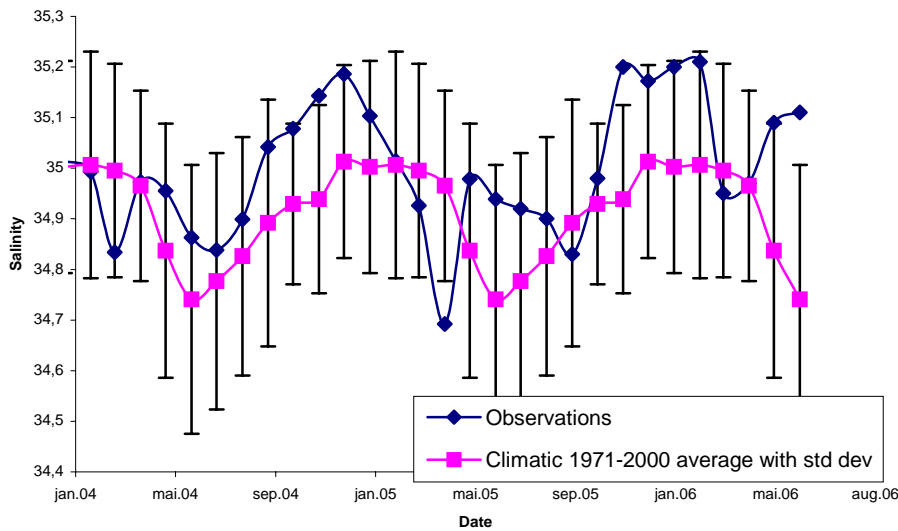


Fig. 12. Temperature (upper) and salinity (lower) data from one station in the Southern Bight, mid route, from the Harwich – Rotterdam ferry. The ship borne observations as monthly mean values from January 2004 to June 2006 (blue) are shown along with the climatic monthly mean (pink) and standard deviation (error bars). (From Liam Fernand and Al Joyce, Cefas).

A time series of daily measurements of sea surface temperature at Arendal on the Norwegian Skagerrak coast is shown in Fig. 13. The temperature increased from about 3°C in early April to about 18°C in late June and was generally close to the long-term average.

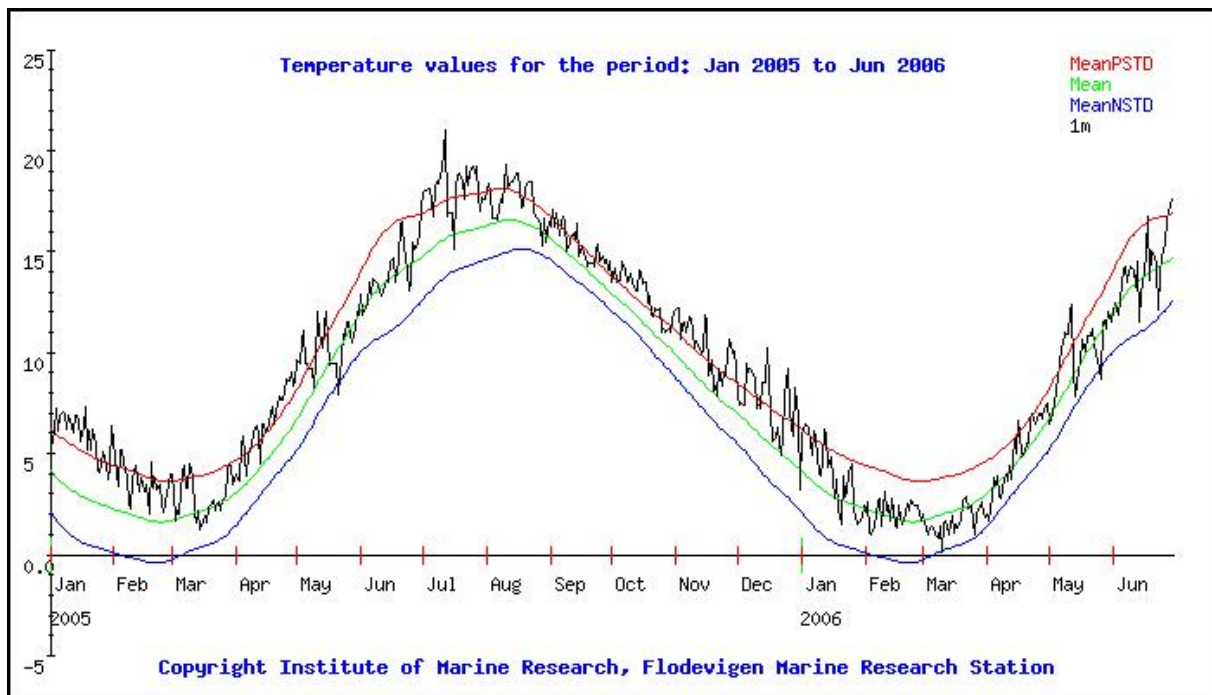


Fig. 13. Daily sea surface temperature recordings at Arendal on the Norwegian Skagerrak coast from January 2005 to June 2006. Also shown is the long-term average temperature ± 1 SD (standard deviation). Data from Institute of Marine Research (IMR).

Model results of temperature distributions close to the seabed from January to July are shown in Fig. 14. These results are obtained with the POLCOMS shelf seas modeling system developed by Proudman Oceanographic Laboratory and run by the UK Met Office. More information on the model is given in Annex I. This annex also contains model comparisons with hydrographic observations from the 1Q 2006 IBTS survey, IBTS climatology, and the World Ocean Atlas climatology.

The modeled temperature distributions show the warming from April to July of the shallow and well-mixed waters of the southeastern North Sea and the eastern Channel, and the small changes in temperature that takes place at the bottom in the central and northern North Sea with stratified waters.

Model results of distributions of surface salinity and surface and bottom temperature in the North Sea south of 57°N and in the eastern Channel for April, May, June and July are given in Annex II. Comparisons of model results with observations are also included here.

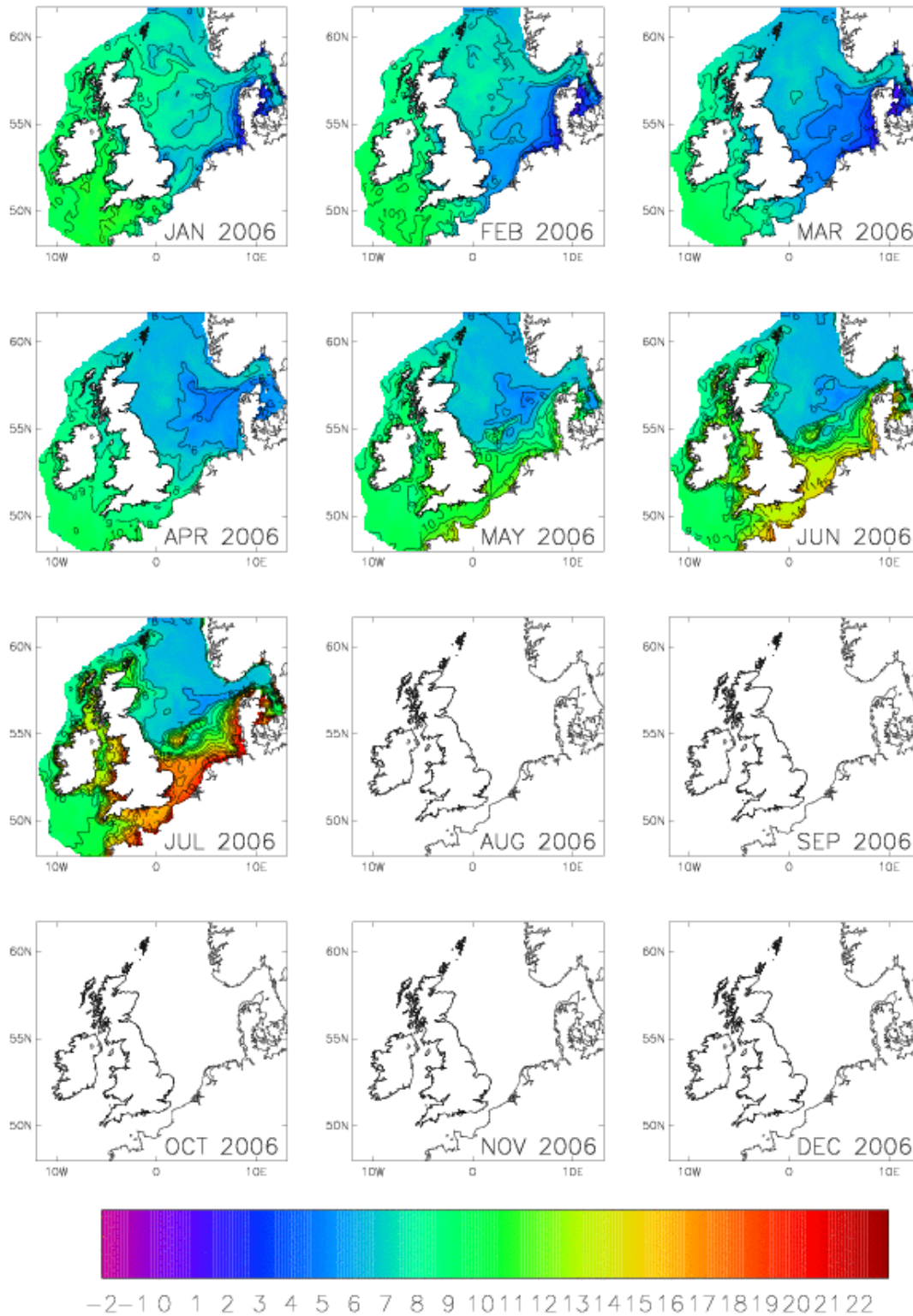


Fig. 14. Monthly mean modeled near-bed temperature from the Met Office run of the MRCS polcoms model. See Annex I for more details and comparisons with IBTS 1Q 2006 observations and climatologies.

Seasonal phytoplankton development

Monthly mean maps of chlorophyll *a* concentration (Chl *a*) from the MERIS sensor onboard ENVISAT are presented in Figure 15 for March-June 2006. All data has been quality controlled using the MERIS product confidence flag and suspect data has been excluded from this analysis.

In March 2006, moderate to high Chl *a* concentrations (of order 3-10 $\mu\text{g/l}$) are found in the Southern Bight of the North Sea, particularly in Belgian coastal waters (3°E , 51.3°N), indicating the start of the spring phytoplankton bloom there. When compared with corresponding imagery for March 2005 [NORSEPP 2005-Q2 report] the bloom appears to have started earlier in 2006. In the Eastern Channel there is a noticeably stronger (earlier) bloom in March 2006 along the coast of Boulogne/Baie de la Somme (1.5°E , 50.5°N). In the Central and Western Channel Chl *a* concentrations are generally low as in March 2005.

In April 2006, peak Chl *a* concentrations are reached throughout the Southern Bight of the North Sea corresponding to the spring phytoplankton bloom. Analysis of individual satellite images from April 2006 (available at <http://www.mumm.ac.be/BELCOLOUR>) and observations from the Research Vessel *Belgica* cruise in mid-April suggest that the bloom has peaked in early April in Belgian waters, a few weeks early than is usual. In the Channel blooms are seen with moderate Chl *a* ($\sim 3 \mu\text{g/l}$) between the Isle of Wight and Cherbourg (1°W , $49.5\text{-}50.5^\circ\text{N}$) and in Mont St Michel Bay (1.5°W , 48.7°N).

In May 2006, Chl *a* has decreased through almost the entire Southern Bight of the North Sea, as in May 2005, indicating the end of the bloom. The exception is nearshore Dutch coastal waters, where very high concentrations (10-25 $\mu\text{g/l}$ and higher) are recorded, exceeding those found in May 2005. In the Channel the blooms in the Baie de la Seine (0° , 49.0°N) and Mont St Michel Bay (1.5°W , 48.7°N) persist and a new bloom is observed in the deeper waters of the central Channel (2.5°W , 50°N), as in May 2005 but weaker.

In June 2006, Chl *a* throughout the offshore waters of the Southern Bight of the North Sea and the Channel is observed to have decreased to low concentrations ($< 2 \mu\text{g/l}$) and the offshore blooms found in the Southern Bight and the Eastern Channel in June 2005 do not recur in 2006. For the nearshore waters the most noticeable bloom occurs in the Baie de la Seine (0° , 49.0°N), similar to that found in June 2005 but stronger.

The most important conclusion that can be drawn from analysis of the satellite Chl *a* imagery for March-June 2006 is that the spring phytoplankton bloom occurred a few (2-4) weeks earlier in 2006 than in 2005 for the Southern Bight of the North Sea and the Eastern Channel.

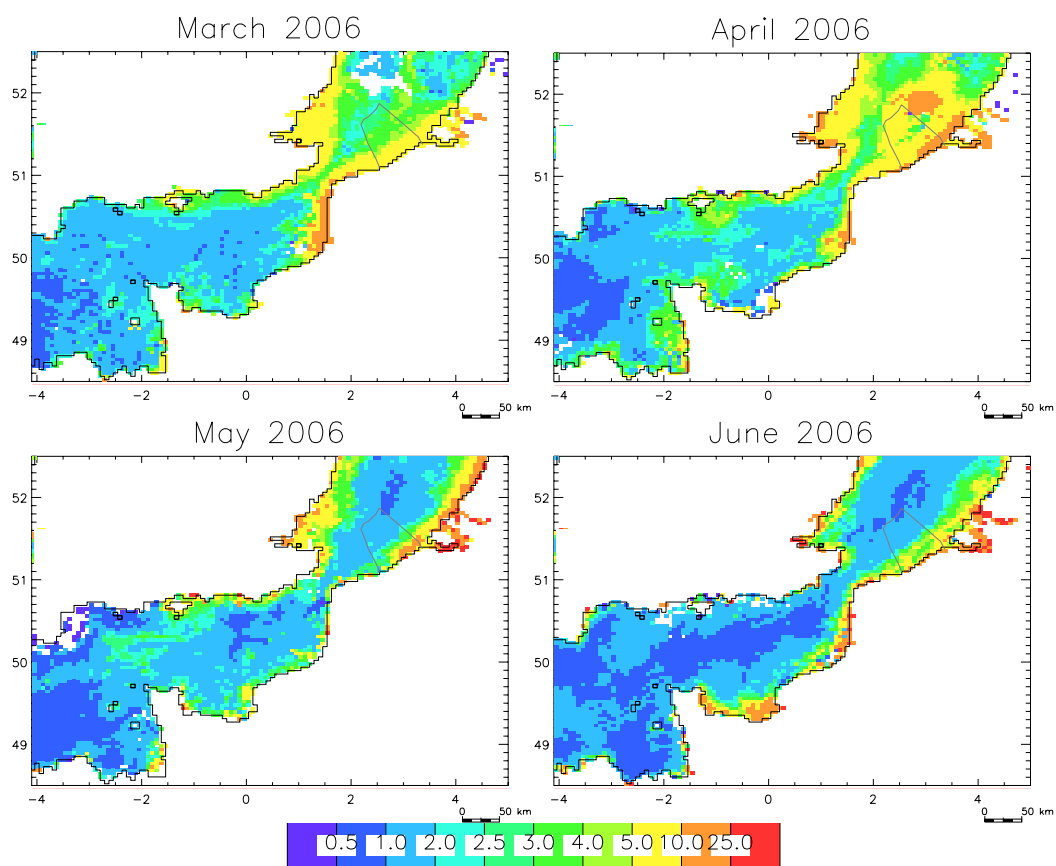


Figure 15. Monthly mean chlorophyll *a* concentration in March-June 2006 derived from ENVISAT-MERIS for the Southern Bight of the North Sea and the Channel. White areas denote land and pixels where no acceptable satellite data was available (because of clouds or failure of quality control checks). Belgian waters are delineated by the thin grey lines. Data provided by the European Space Agency in the framework of Envisat AOID 698, processed by MUMM (BELCOLOUR project).

ANNEX 1

Modelled monthly mean sea bed temperature

The UK Met Office runs the POLCOMS shelf seas modelling system developed by Proudman Oceanographic Laboratory, POL, (www.pol.ac.uk) for a variety of configurations for the NW European shelf and adjacent waters.

Surface forcing is taken from the available Met Office numerical weather prediction (NWP) models, either the 40 km global NWP model, or for the NW European shelf the 12 km mesoscale (to be replaced by 12 km North Atlantic European) NWP model. Surface fluxes of heat and moisture from the mesoscale model are used as three-hourly averages, and hourly values of 10 m wind and surface pressure forcing are used.

The results presented below are taken from the 7 km Medium Resolution Continental Shelf POLCOMS model, which is nested within the ~12 km Atlantic Margin POLCOMS model. In turn the AMM model is nested into the Atlantic FOAM model at the open ocean boundaries.

A summary of the model configurations is given below, and further information on the shelf seas models can be found on <http://www.metoffice.com/research/ncof/shelf/index.html>

(i) Atlantic Margin model (AMM)

The AMM model is a ~12 km resolution physical model, extending from approximately 40°N to 65°N and 20°W to 13°E, nested into 1/9° Atlantic FOAM. The model has 32 vertical levels and is run operationally on a daily basis. Information about the model domain can be found at <http://www.metoffice.com/research/ncof/shelf/amm.html>.

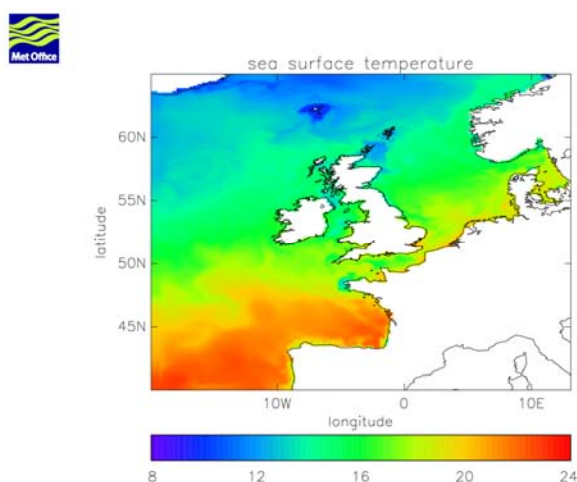


Figure 1. The area covered by the POLCOMS Atlantic Margin Model.

(ii) MRCS (Medium-Resolution Continental Shelf) model

The MRCS (Medium-Resolution Continental Shelf) model is a coupled hydrodynamic-ecosystem model, where the hydrodynamics are supplied by the Proudman Oceanographic Laboratory Coastal Ocean Modelling System (POLCOMS) developed at Proudman Oceanographic Laboratory (POL) and the ecosystem component is supplied by the European Regional Seas Ecosystem Model (ERSEM), developed at Plymouth Marine Laboratory (PML).

The model is located on north-west European continental shelf, ranging from 12°W to 13°E and 48°N to 62°N, as shown in the figures in the next section. It has an open boundary which follows the 200 m

depth contour around most of the domain. The resolution is approximately 7 km in the horizontal and in the vertical there are 18 s-coordinate levels.

Further details of the MRCS model, including plots of near real time conditions, updated weekly, and a summary of model verification, are available from:

<http://www.metoffice.gov.uk/research/ncof/mrcs/browser.html>

The Met Office is a partner in the UK National Centre for Ocean Forecasting. Gridded datasets of the model output plotted below are available on request from enquiries@ncof.gov.uk

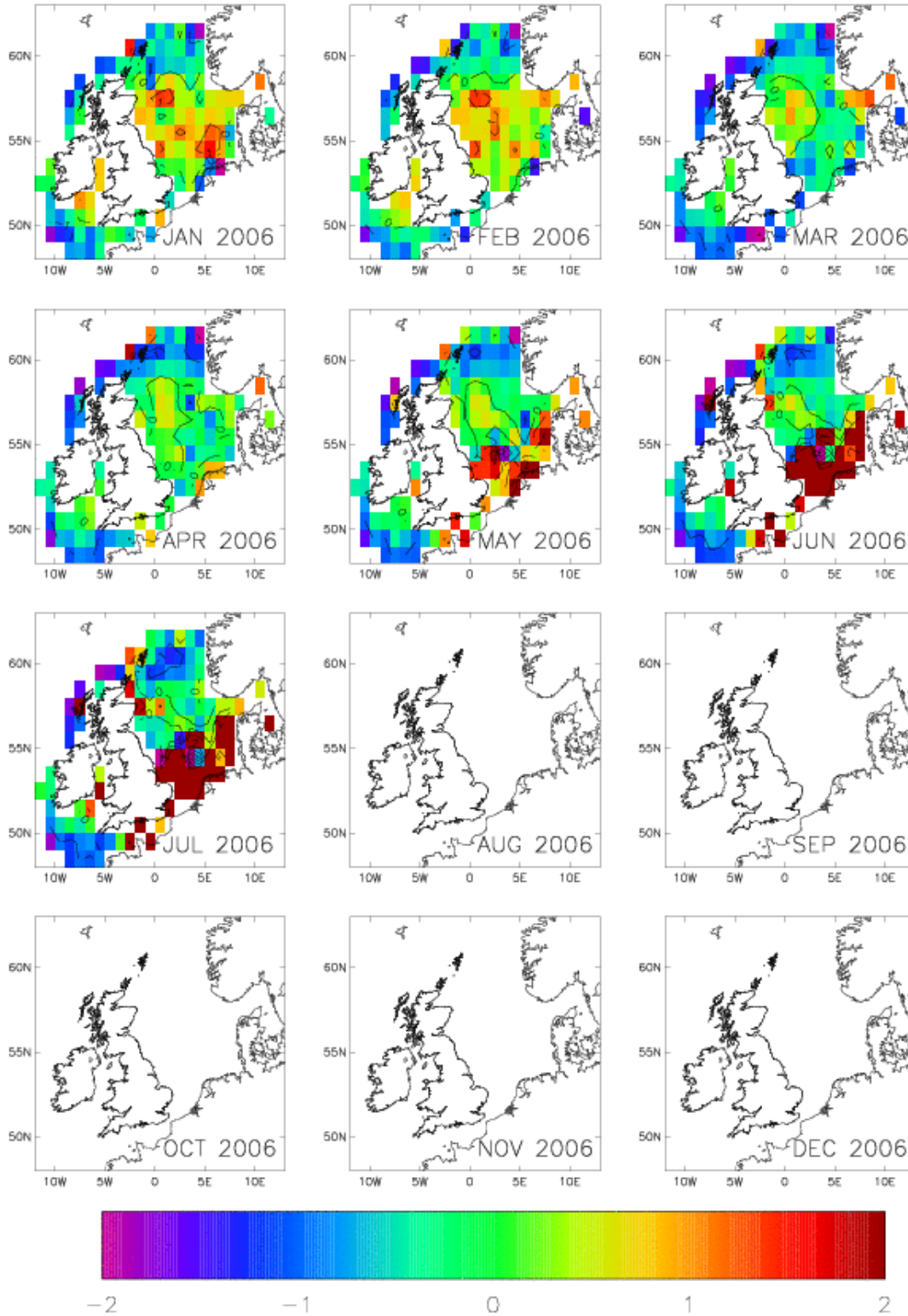
a) 2006 Quarter 1 and Quarter 2 near-bed temperature

The monthly mean modelled seabed temperature for each month up to up to July 2006 is presented as Fig. 14 in the main text.

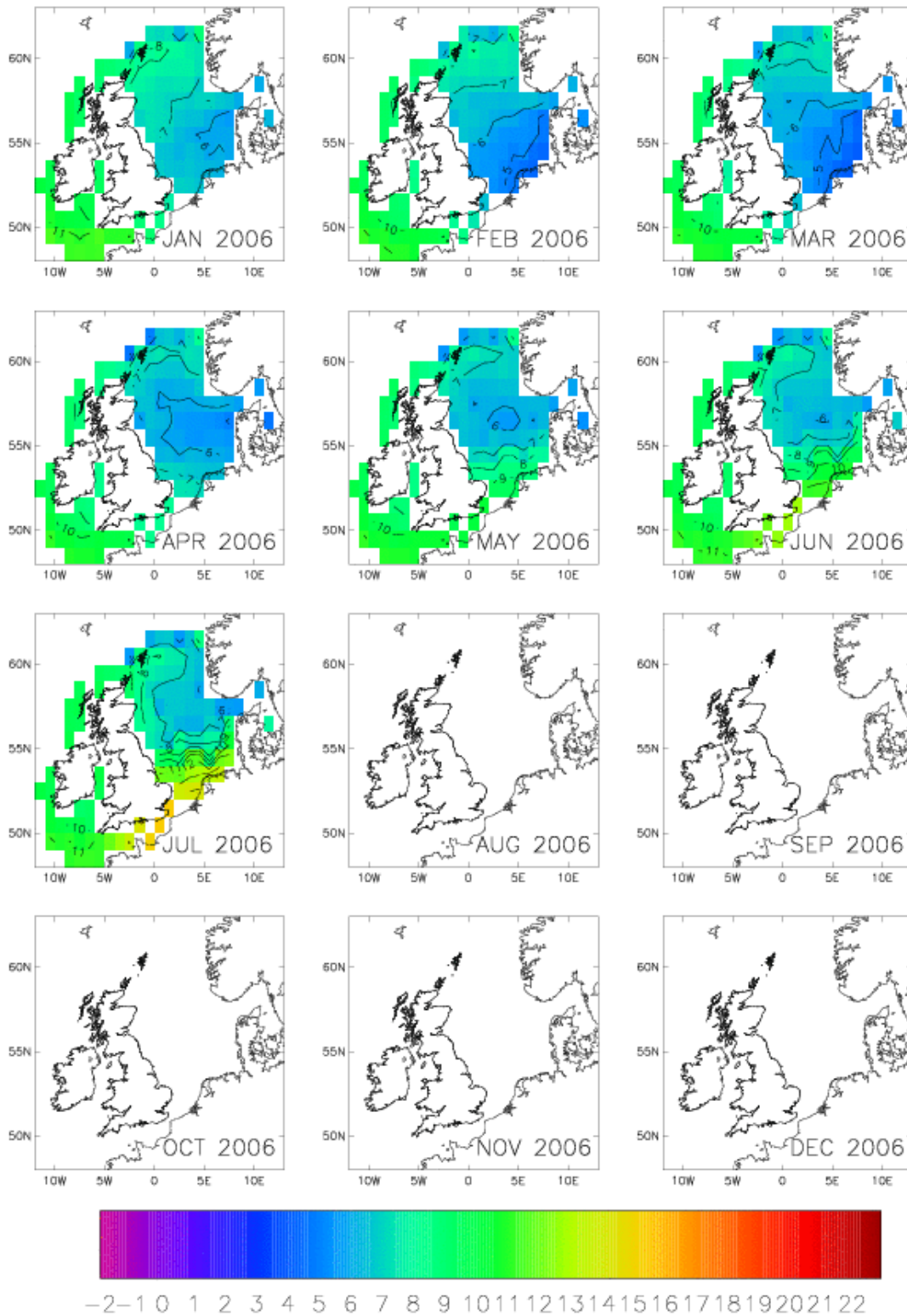
A comparison of the monthly mean modelled data to the World Ocean Atlas climatology is presented in the figures below.

Comparisons of the modelled seabed data for February 2006 with IBTS Q1 temperature climatology and IBTS Q1 temperature and salinity observations are presented in sections b) and c) below.

**Monthly mean modelled near-bed temperature
from the Met Office run of the MRCS polcoms model:
anomaly from the World Ocean Atlas climatology**



World Ocean Atlas climatology values of near-bed temperature

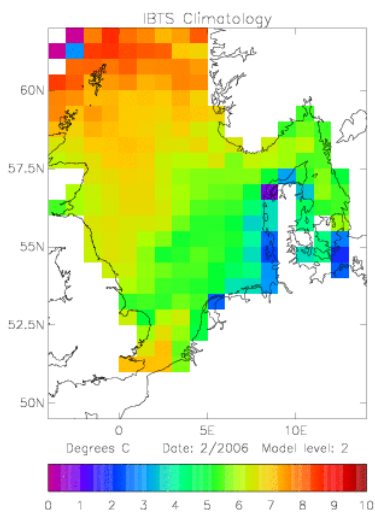


b) Comparison of February near-bed temperature with IBTS climatology

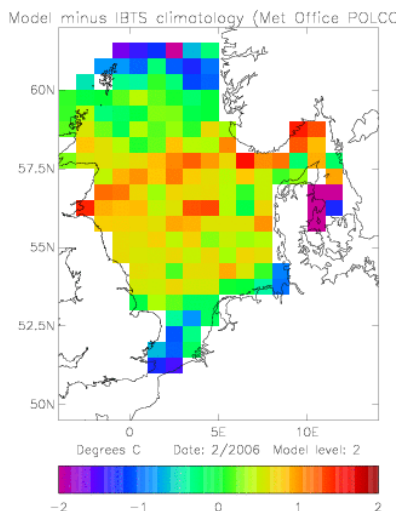
The IBTS ~20 year climatology of Quarter 1 seabed temperature was provided by Bill Turrell to the PGNSP in 2004. This consists of the Q1 near-bed temperatures averaged into 1 degree by ½ degree grid boxes. The climatology is plotted in Figure a) below. Figure b) shows the difference between the climatology and the February 2006 MRCS model near-bed temperatures extracted onto this coarse grid.

At the present time it is known that the heat transport along the shelf break is underestimated in the model that provides boundary forcing to MRCS, so the cold conditions in the north are probably unrealistic. Work is in hand to improve this. Elsewhere, in central and southern North Sea the MRCS model shows good comparison with available sea surface temperature observations, so there can be more confidence in the model results in these waters.

Figure b) suggests warmer than average conditions near bed in the central and southern North Sea, with cooler than average waters around the Dover Straits.



a) the IBTS ~20 year climatology of near bed temperature (°C)



b) Difference: Modelled monthly mean for February minus climatology (°C)

c) Colocation of model data with IBTS 2006Q1

The IBTS data for Q1 2006 became available in May. Below is plotted a colocation of model and observed values of temperature and salinity. Model values are from the day of the observation, and are from the nearest model level to the depth of the CTD cast. The model data in this run come from the MRCS POLCOMS V5 configuration, which is known to underestimate the northward heat transport. The model under-estimate of the highest observed temperatures reflects this. These are at points along the northern boundary of the North Sea.

Figure

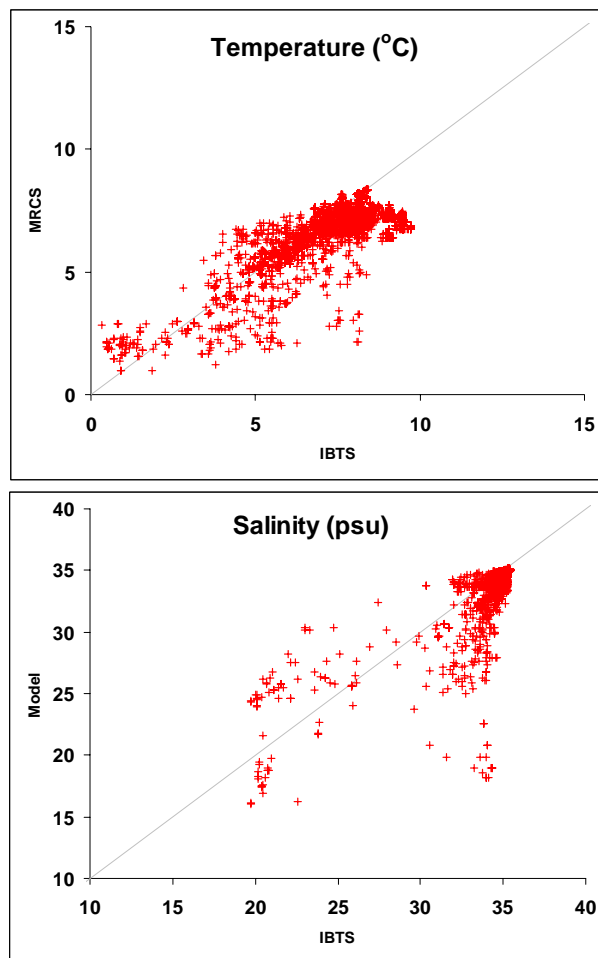


Figure C Colocations of 2006 Q1 IBTS observations for temperature and salinity with MRCS model (POLCOMS V5 configuration)

ANNEX II

Model results on salinity and temperature distributions in the North Sea and the Channel – MUMM Belgium

Salinity maps

Maps of monthly averaged surface salinity are presented on Figure A2-1. The width of the fresh water plume seems to increase in the German Bight and to decrease along the Dutch and Belgian coast. Surface salinity in the Channel decreases slightly as well.

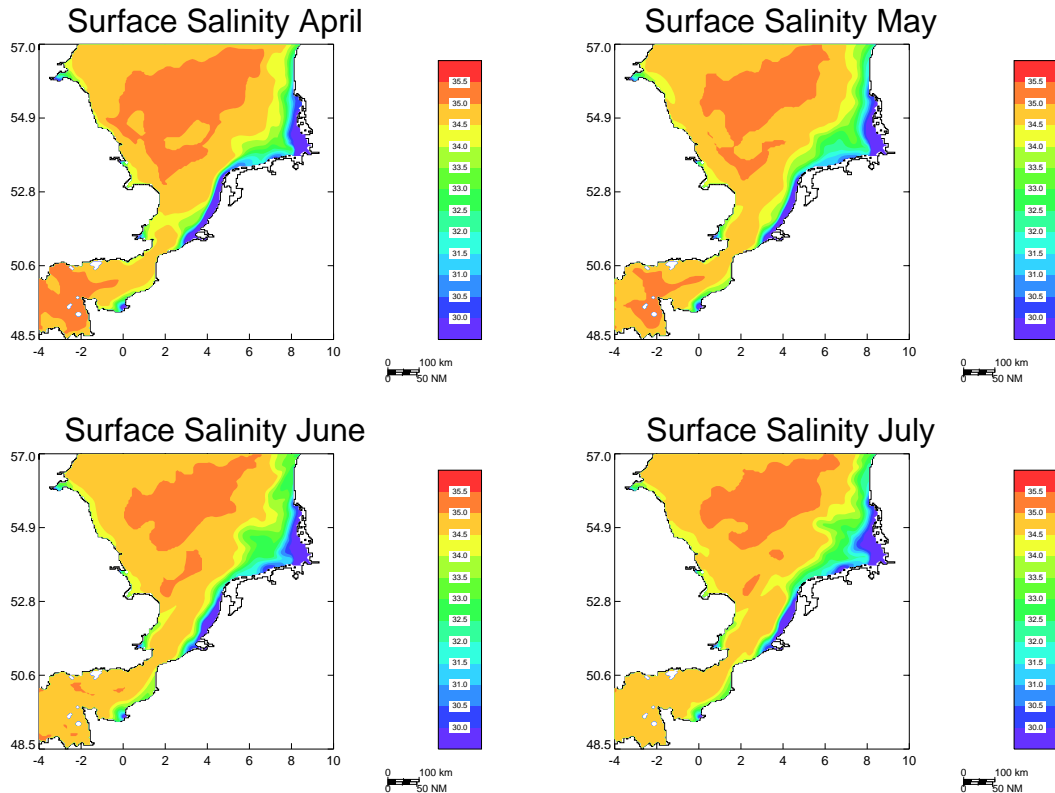


Figure A1-1. Monthly average of the surface salinity computed with the Optos_nos model between April and July 2006 (expressed in PSU)

The bottom salinity maps (not shown) are very similar to the surface maps.

Temperature maps

Maps of monthly averaged bottom and surface temperature are presented on Figure A2-2. Since May, the temperature shows a strong stratification in the deeper northern part of the North Sea. Compared with previous years, the surface water temperature in April is quite fresh while in July it is very hot.

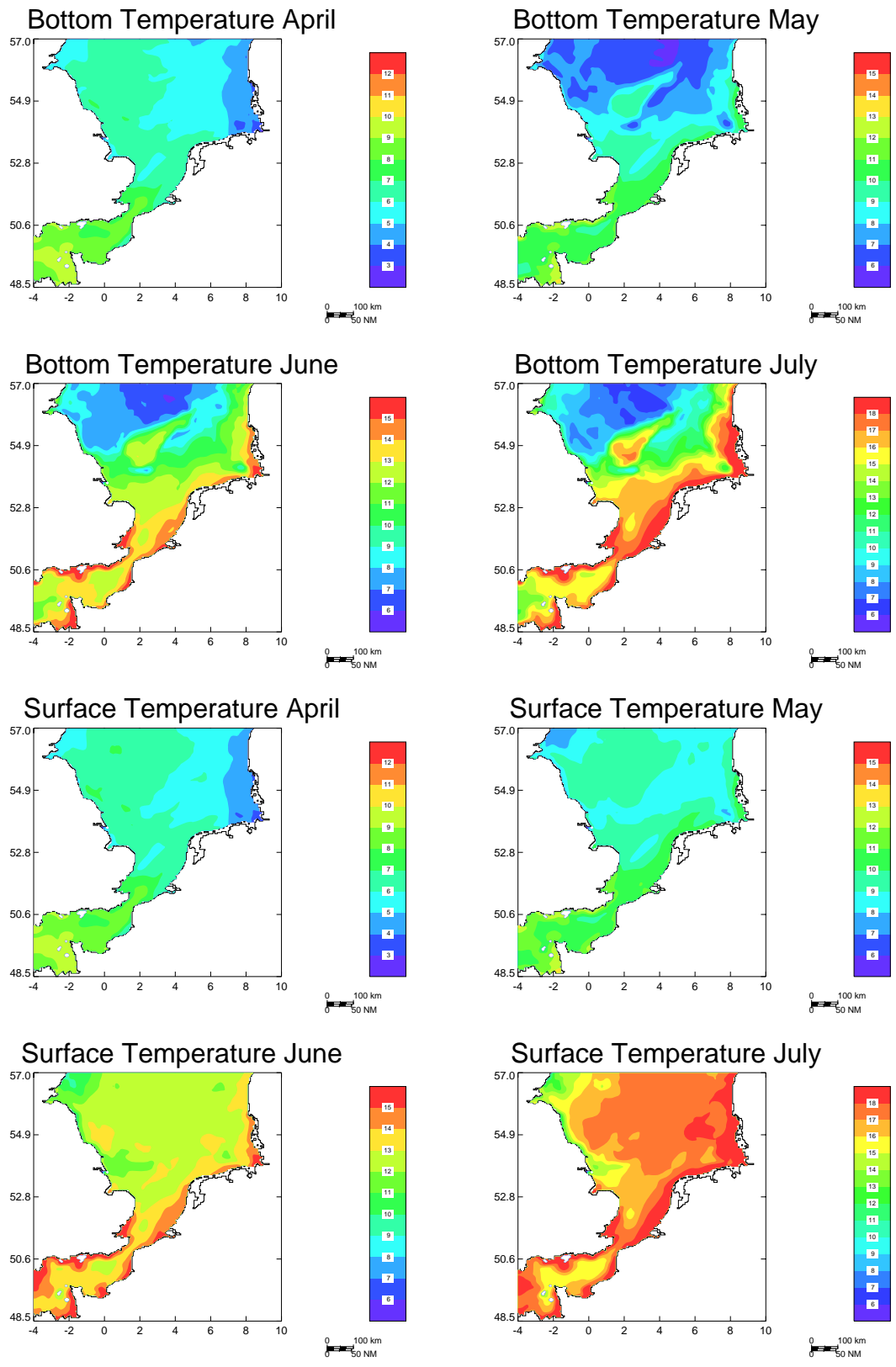


Figure A2-2. Monthly average of the bottom and the surface sea temperatures computed with the Optos_nos model between April and July 2006 (expressed in °C)

Validation of the temperature and the salinity

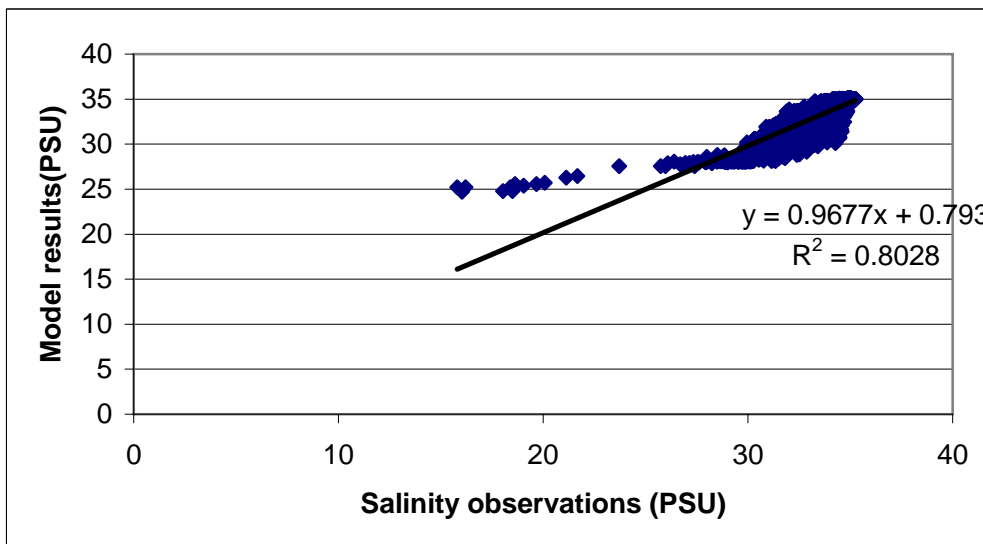
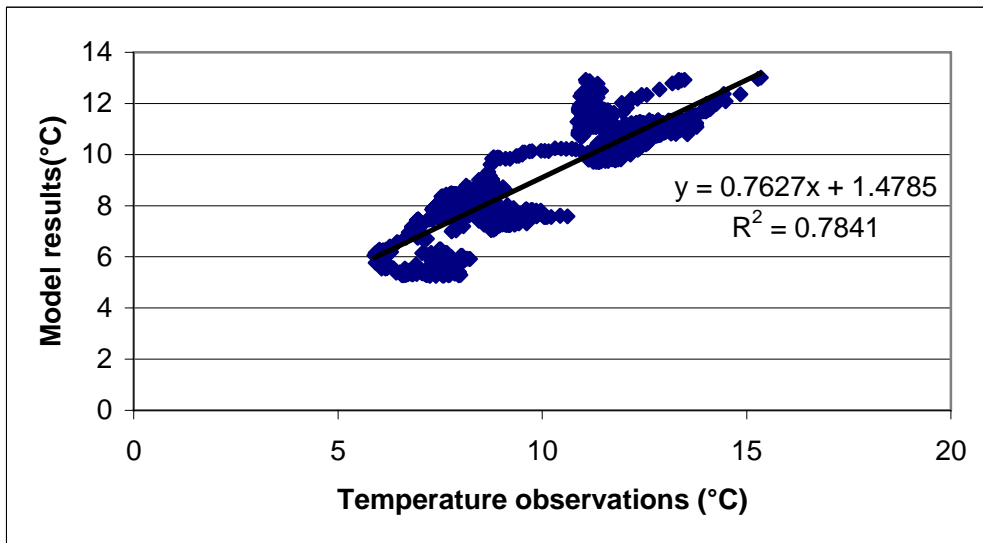


Figure 3 Observations of temperature and salinity along the track of the R/V Belgica and corresponding Optos_nos model results in April and May 2006.

The observations of salinity and temperature along the track of the R/V Belgica have been used to validate our results in April and May. In term of R^2 , the agreement is slightly better for salinity than for temperature. The model however clearly overestimates the salinity below 25 PSU. These values are coming from measurements made in the mouth of the Scheldt river that is not very well represented in the model. For the temperature, the model results are clearly below the observations.