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

Update report on North Sea conditions – 2nd quarter 2007

Editor:
Hein Rune Skjoldal
Institute of Marine Research
Bergen, Norway

Contributors and acknowledgements

IMR (Norway), BSH (Germany), MUMM (Belgium) and UK Met Office (UK) have contributed model results and/or observations to this report.

We thank the following persons for their contributions and help:
Tor Birkeland, Einar Dahl, Didrik Danielsen, Svein Erik Enersen, Vidar Lien, Morten Skogen (IMR)
Stephan Dick (BSH)
Youngje Park, J. Ozer, Kevin Ruddick (MUMM)
Martin Holt, John Siddorn (UK Met Office)

Contents

Summary description

The mean modelled transport of water through the northern boundary to the North Sea for the second quarter of 2007 was close to the long-term average, while the circulation of the central and southern North Sea was lower (by 30–40%) than the long-term average. However, there were marked changes in the circulation pattern during the second quarter. In April, there was strong inflow to the North Sea between the Orkneys and Shetland, and a reversal of the typical circulation in the southern North Sea, to one where the water flowed clockwise around the Dogger Bank. This was associated with westwards outflow through the Channel. In May and June, the circulation changed back to the more typical pattern with counter-clockwise circulation around the Dogger Bank and eastwards inflow through the Channel. In June, the circulation of the northern North Sea was somewhat atypical, with moderately strong outflow between the Orkneys and Shetland.

The warm conditions in the North Sea that had lasted since the summer of 2006, continued in the second quarter of 2007. The temperature anomalies in the first quarter were positive by 0–1 C^o in the northern North Sea and by 2–4 C^o in the southeastern part. These high positive anomalies persisted in April but were somewhat reduced to 1–2 C^o in the southeastern area in June. Seasonal stratification started in April in the waters west of Denmark and by May the waters north of the Dogger Bank were markedly stratified.

The spring bloom in the Southern Bight and the Channel occurred somewhat later in 2007 than in the two preceding years, and vigorous blooms with high chlorophyll content developed in coastal waters in April and May. On the Norwegian Skagerrak coast the spring bloom occurred in late March, which is later than usual. Chlorophyll levels were low in May and June. Based on satellite-observations of chlorophyll, the spring bloom started first (March) in the stratified waters of Kattegat and Skagerrak and in the clear waters of the Dogger Bank, and latest (May–June) in the northwestern part of the North Sea and in the western Channel.

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 focusing 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 2006 and the first quarter report for 2007 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 as monthly averages for April, May, and June and as mean for the second quarter is shown in Figure 1. In April, the high pressure was located over the UK while a low-pressure trough extended between minima in the Irminger and the Barents seas. The pressure gradient was relatively strong to the northwest of the North Sea, indicating strong southwesterly wind in this area. In May, the pressure system moved south, with the high positioned fairly far west in the Atlantic off Iberia while the low was positioned in the Norwegian Sea. The pressure gradients indicated moderately strong westerly winds south of the UK but relatively low winds over the North Sea. In June the whole area was influenced by moderately high pressure with weak gradients.

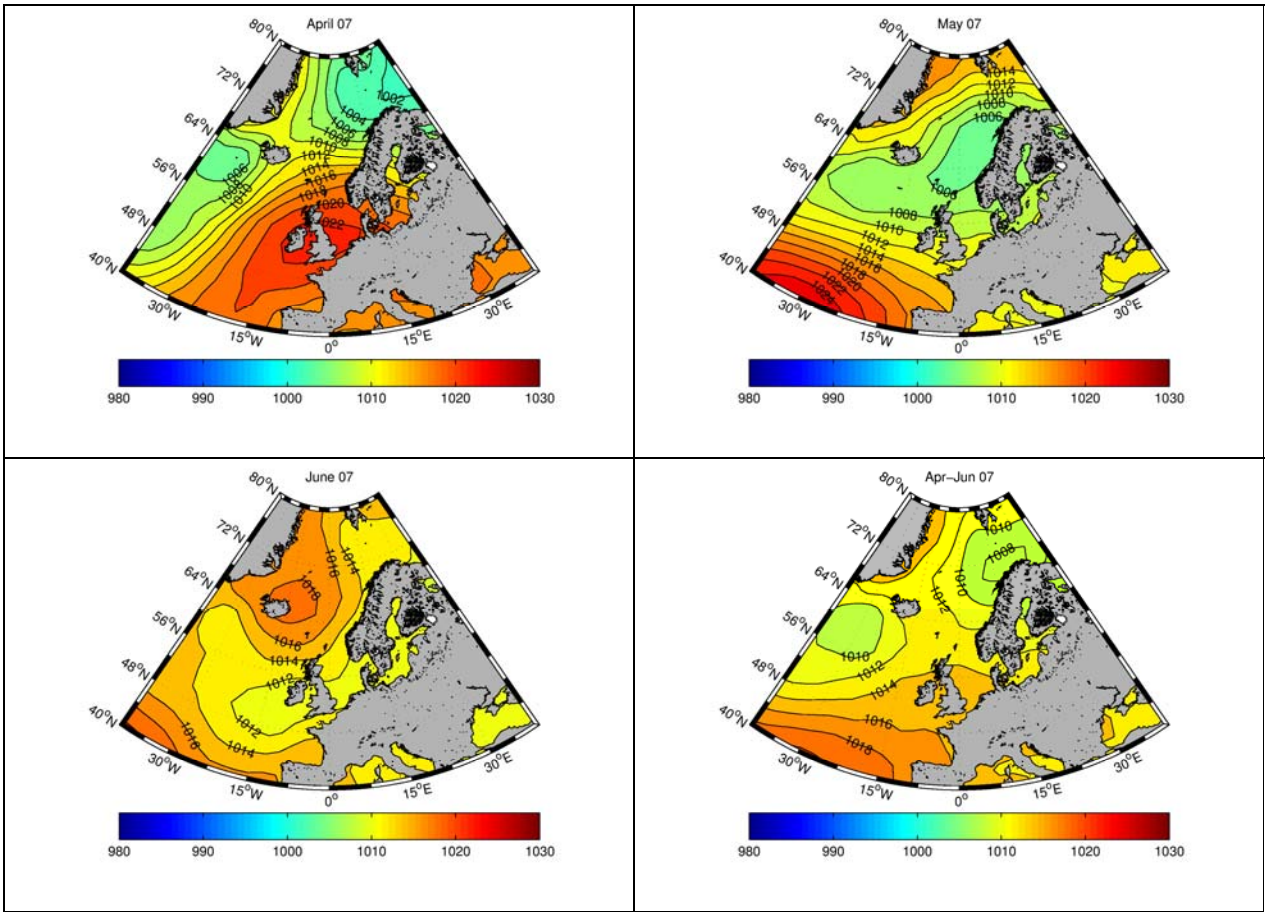


Figure 1. Monthly mean sea level air pressures for April, May, and June 2007 (upper left and right, and lower left panels) and the mean for the 2nd quarter (April–June) 2007 (lower right panel).

Modelled 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 Figure 2 for their locations) have been used for comparison with the estimated monthly and 2nd quarterly fluxes for 2007.

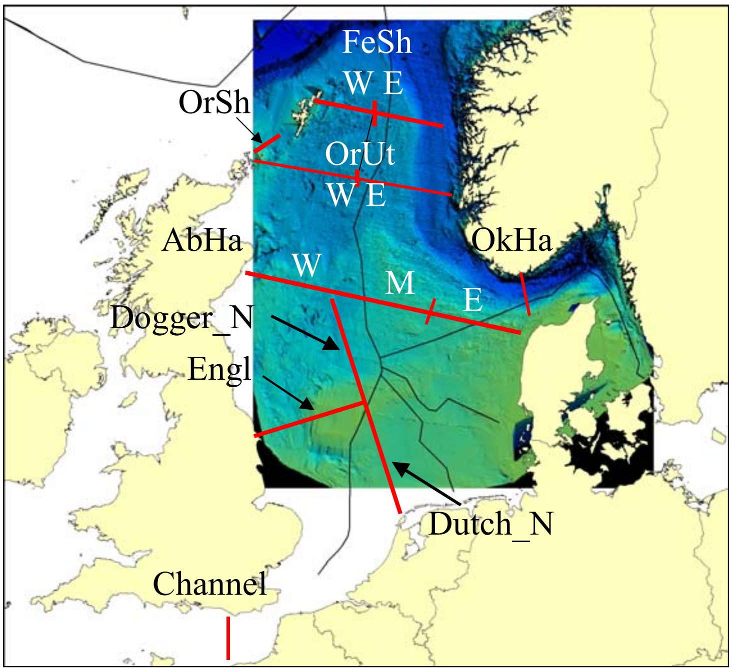


Figure 2. Sections across various parts of the North Sea used to calculate fluxes of water with the 3-D mathematical circulation model NORWECOM.

The modelled mean 2nd quarter (2Q) fluxes in 2007 across the different sections are shown in Figure 3, compared to the long-term (50-year; 1955–2004) modelled mean 2Q flux. The mean monthly fluxes for April, May, and June are shown in Figure 4. Time-series of monthly mean fluxes across the various transects from January 2006 to June 2007 are shown in Figures 5 and 6 along with the long-term averages of the monthly fluxes.

Modelled transport across the northern boundary

The modelled transport across the northern boundary to the North Sea in the 2nd quarter of 2007 was close to the modelled long-term average. The northwards transport in the Norwegian Trench (in the eastern part of the Feie-Shetland transect), which can be used as an indicator for the total flow-through in the North Sea, was lower than the long-term mean by about 15% (Figure 3, upper panel). There were marked differences among the months within the 2nd quarter, however, in the flows across the various portions of the northern boundary. The transport between Orkneys and Shetland was mainly southerly (inflow) in April and May but changed to mainly northerly direction (outflow) in June. The transport over the plateau (the western portion of the Feie-Shetland transect) was predominantly southerly (into the North Sea) in April and May, while the inflow was markedly lower in June. The inflow in the Norwegian Trench (eastern portion of the Feie-Shetland transect) was stronger than that over the plateau and differed by showing an increase from May to June. The outflow (northerly flow) through the Norwegian Trench, on the other hand, decreased by about 40 % between May and June, reflecting the reduced inflow in the western portions of the northern boundary and the outflow between Orkneys and Shetland (Figure 4, upper panel).

The transport across the Orkney-Utsira transect, located further south in the northern North Sea (Figure 2), showed the same main features as the transport across the northern boundaries. The northwards transport in the eastern part of the Orkney-Utsira transect was about 15% lower than the corresponding transport in the Feie-Shetland transect, reflecting recirculation in the northern North Sea of water that does not penetrate south across the Orkney-Utsira transect (Figures 3 and 4, upper panels).

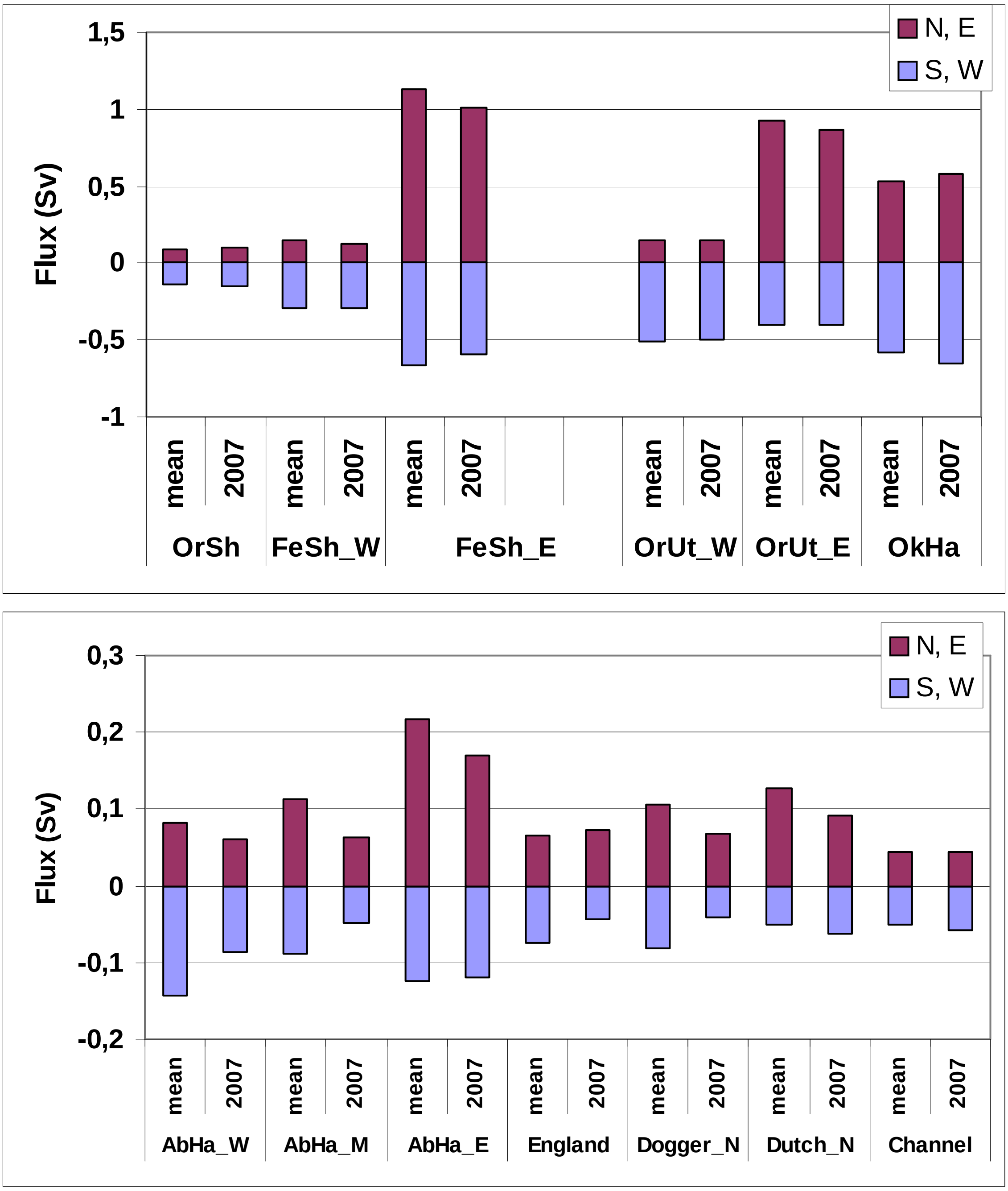


Figure 3. The 2007 mean 2nd quarterly water fluxes across sections in the North Sea compared to the long-term mean fluxes for the 2nd quarter (1955–2004). NORWECOM model estimates. See Figure 2 for the location of the sections. Positive values denote northwards or eastwards transport while negative values denote southwards or westwards transport.

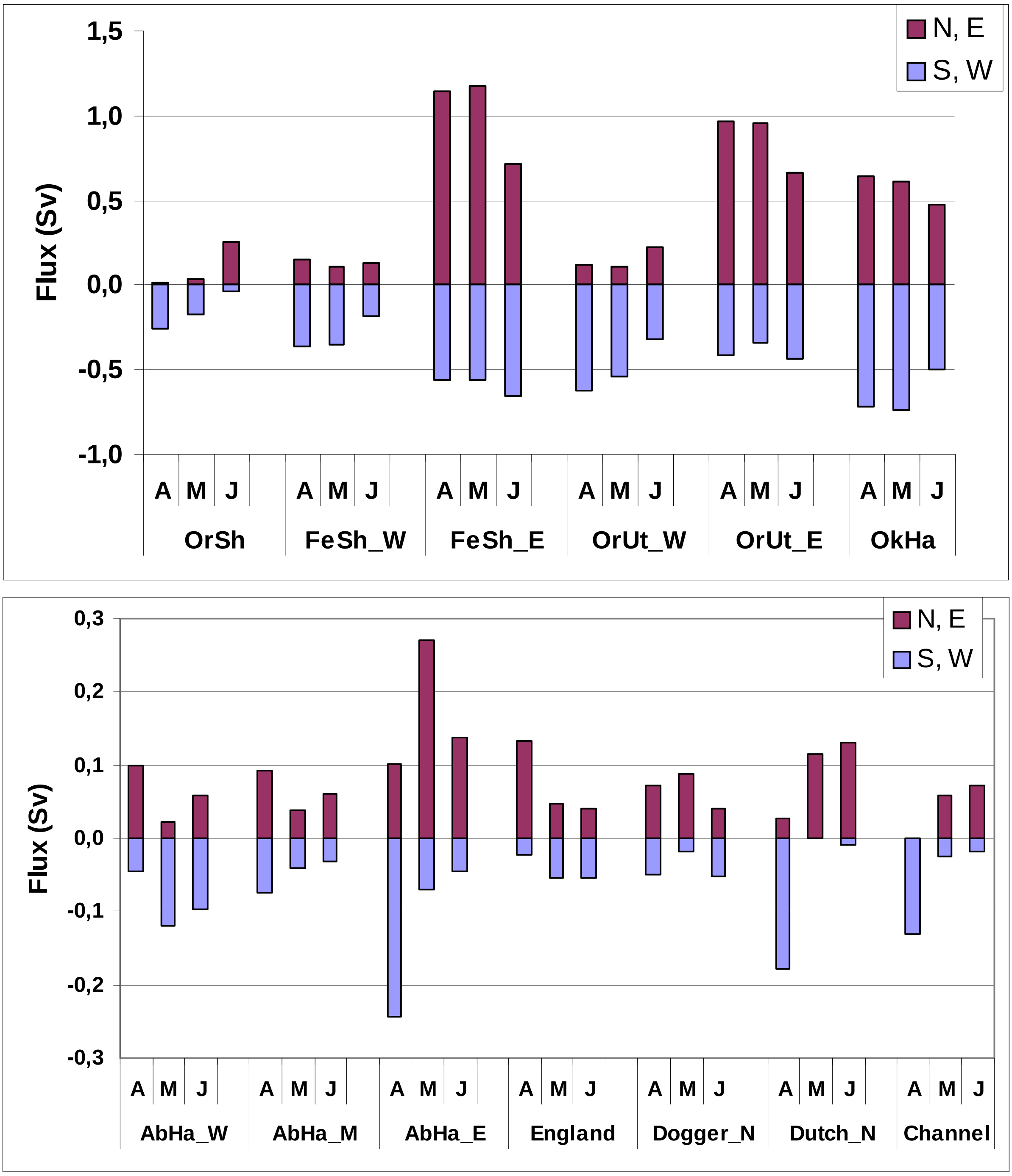


Figure 4. The mean monthly water fluxes for April, May, and June 2007 across sections in the North Sea (see Figure 2 for their locations). NORWECOM model estimates. Positive values denote northwards or eastwards transport while negative values denote southwards or westwards transport.

The monthly mean net transport between the Orkneys and Shetland was stronger southerly (into the North Sea) than the long-term average for April and May, following a trend of stronger than average inflow since November 2006, except for February (Figure 5, upper left panel). The net transport across the plateau (western part of the Feie-Shetland transect) was close to the long-term average in April and June but stronger southerly than average in May. These net transports were much reduced from strong inflow the preceding winter between

November and March (except for February; Figure 5, middle left panel). The southwards inflow in the Norwegian Trench (eastern part of the Feie-Shetland transect) was somewhat lower than the long-term average in April and May, while the northwards outflow was lower than average in June (Figure 5, lower left and upper right panels).

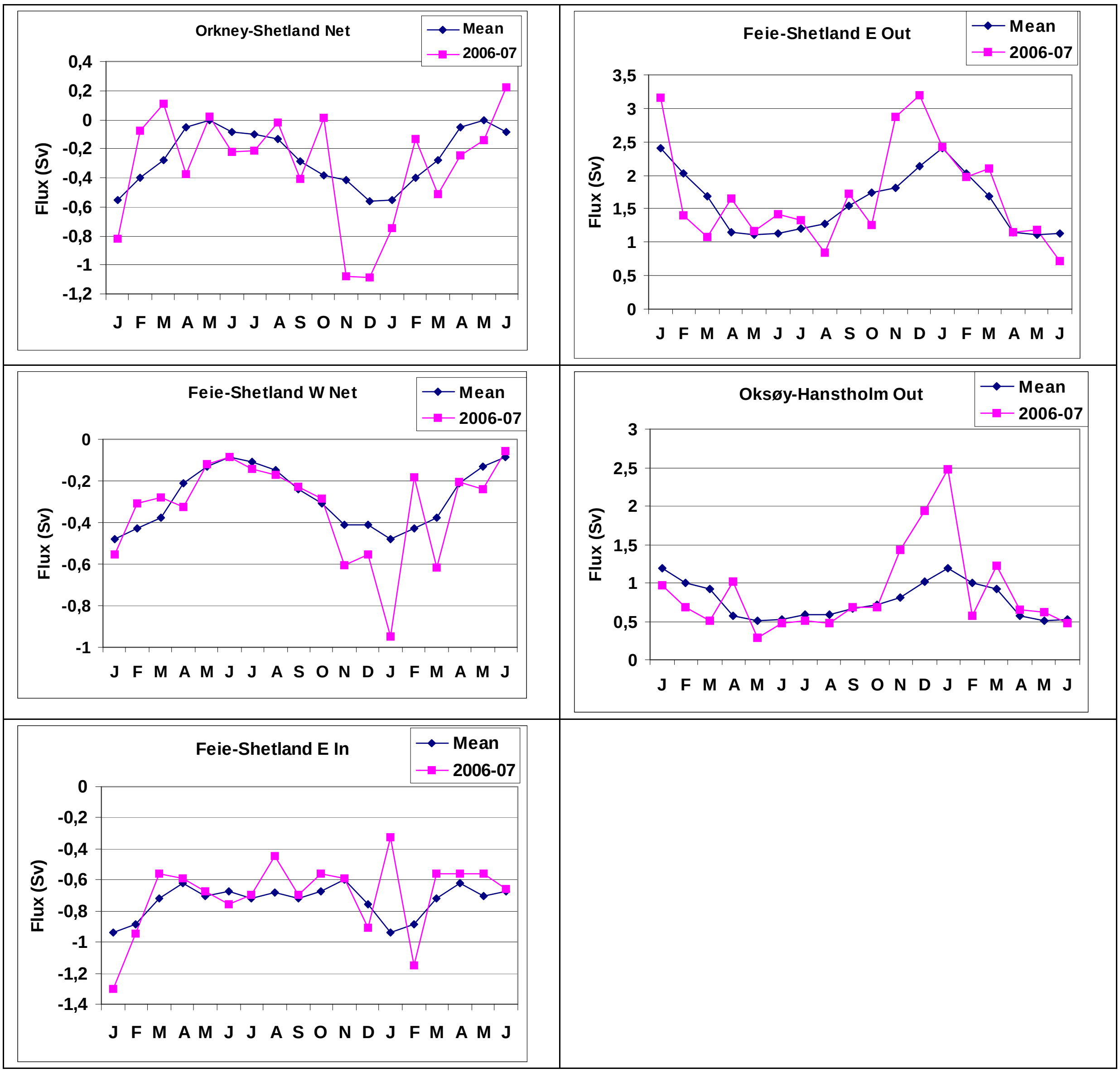


Figure 5. Modelled fluxes of water across sections in the northern North Sea and in the Skagerrak (see Figure 2 for their locations). The mean monthly fluxes from January 2006 to June 2007 are shown along with the long-term mean (1955–2004) monthly fluxes. Net flux is the difference between northwards 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.

Modelled transport through Skagerrak

The transport of water through Skagerrak is reflected in the flux across the Oksøy-Hanstholm transect between Norway and Denmark. The flux through Skagerrak in the 2nd quarter was slightly above the long-term average (by about 10 %) (Figure 3, upper panel). The flux was somewhat higher than the long-term average in April and May and decreased in June when it was close to the long-term average (Figure 4, upper panel, and Figure 5, lower right panel). This followed on from very high transports during the winter, particularly from November to January (Figure 5, lower right panel).

Modelled transport in the central and southern North Sea

The modelled circulation through the central and southern North Sea was generally lower in the 2nd quarter of 2007 compared to the long-term average. The southwards transports through the western portion of the Aberdeen-Hanstholm transect and the transect between England and the Dogger Bank were about 40 % lower than average, while the transports through the middle portion of the Aberdeen-Hanstholm transect and the transect north of the Dogger Bank were around 50 % lower than the average (Figure 3, lower panel). The eastward transport south of the Dogger Bank (Dutch-N) and the northwards transport through the eastern portion of the Aberdeen-Hanstholm transect were about 20–30% lower than average.

The modelled transports through the central and southern North Sea showed major changes during the 2nd quarter. The typical counter-clockwise circulation around the Dogger Bank was reversed in April. During this month there was strong southwards flow in the eastern portion of the Aberdeen-Hanstholm transect, westwards flow south of the Dogger Bank (Dutch-N transect), and northwards flow up on the western side of the Dogger Bank (England transect) and through the western portion of the Aberdeen-Hanstholm transect (Figure 4, lower panel). The circulation changed back to the typical counter-clockwise in May and June, being stronger in May than in June.

The monthly mean net transports through the sections of the middle and southern North Sea were generally low, which is typical for the season when the circulation slackens after the intensified winter flows (Figure 6). Compared to the long-term averages, the net flux in 2007 deviated the most for April, when the typical counter-clockwise circulation was reversed.

The changes in flow pattern between April and May are also shown by model output from the Optos_nos model. Profiles of modelled transports across E-W transects at latitudes of 57, 55, 53, and 51 ^{o}N are shown in Figure 7. These results show northward transport in the western part and southward transport in the eastern part of the sections in April, reversing to the more typical pattern in May and June.

Modelled transport through the Channel

The modelled transport through the Channel was close to the long-term average as a mean for the 2nd quarter, with about equal transports eastwards into the North Sea and westwards out of the North Sea (Figure 3, lower panel). This reflected a marked change from westwards outflow in April to eastwards inflow in May and June (Figure 4, lower panel). The outflow in April corresponded to the period of reversed, clockwise circulation in the southern North Sea, and

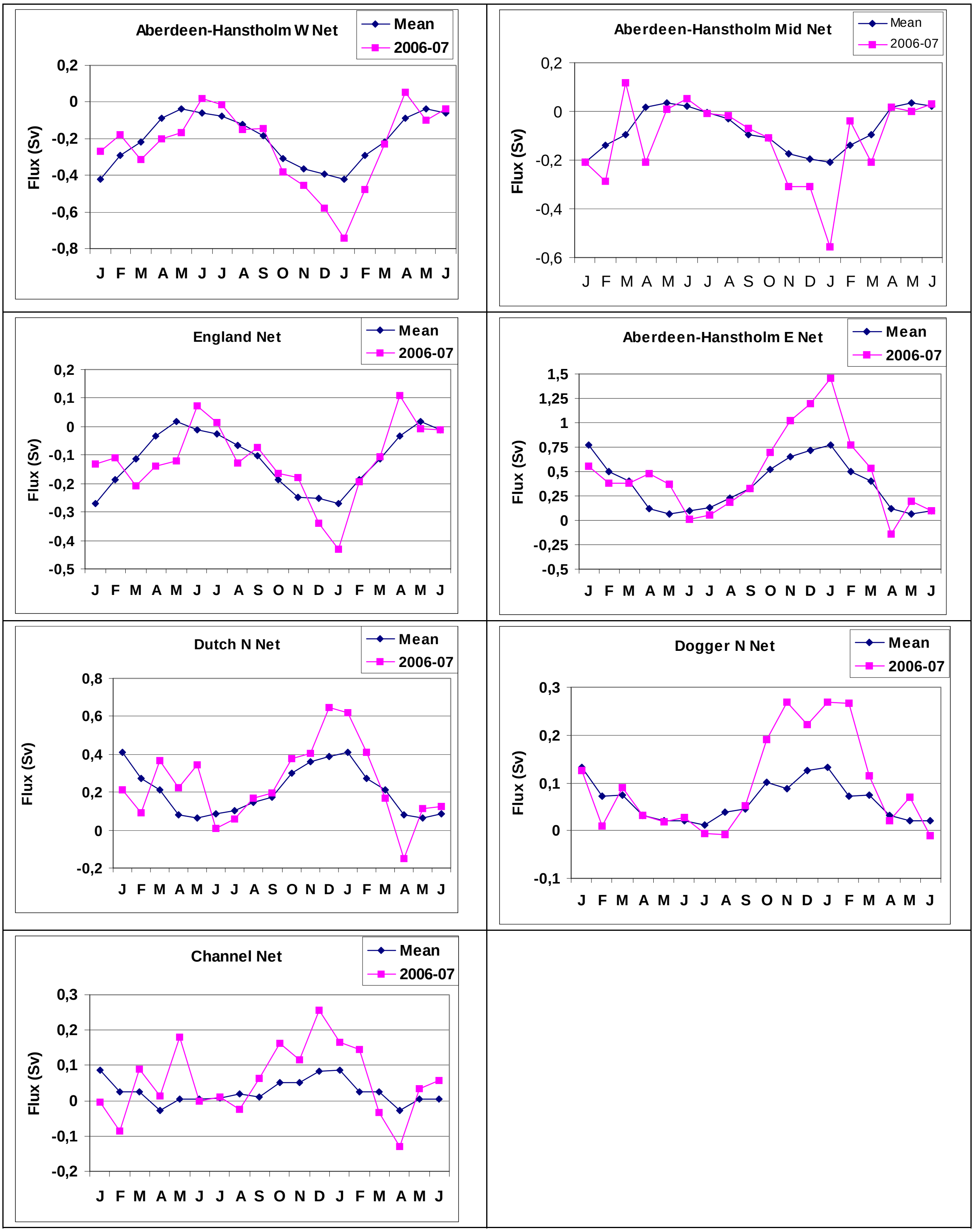
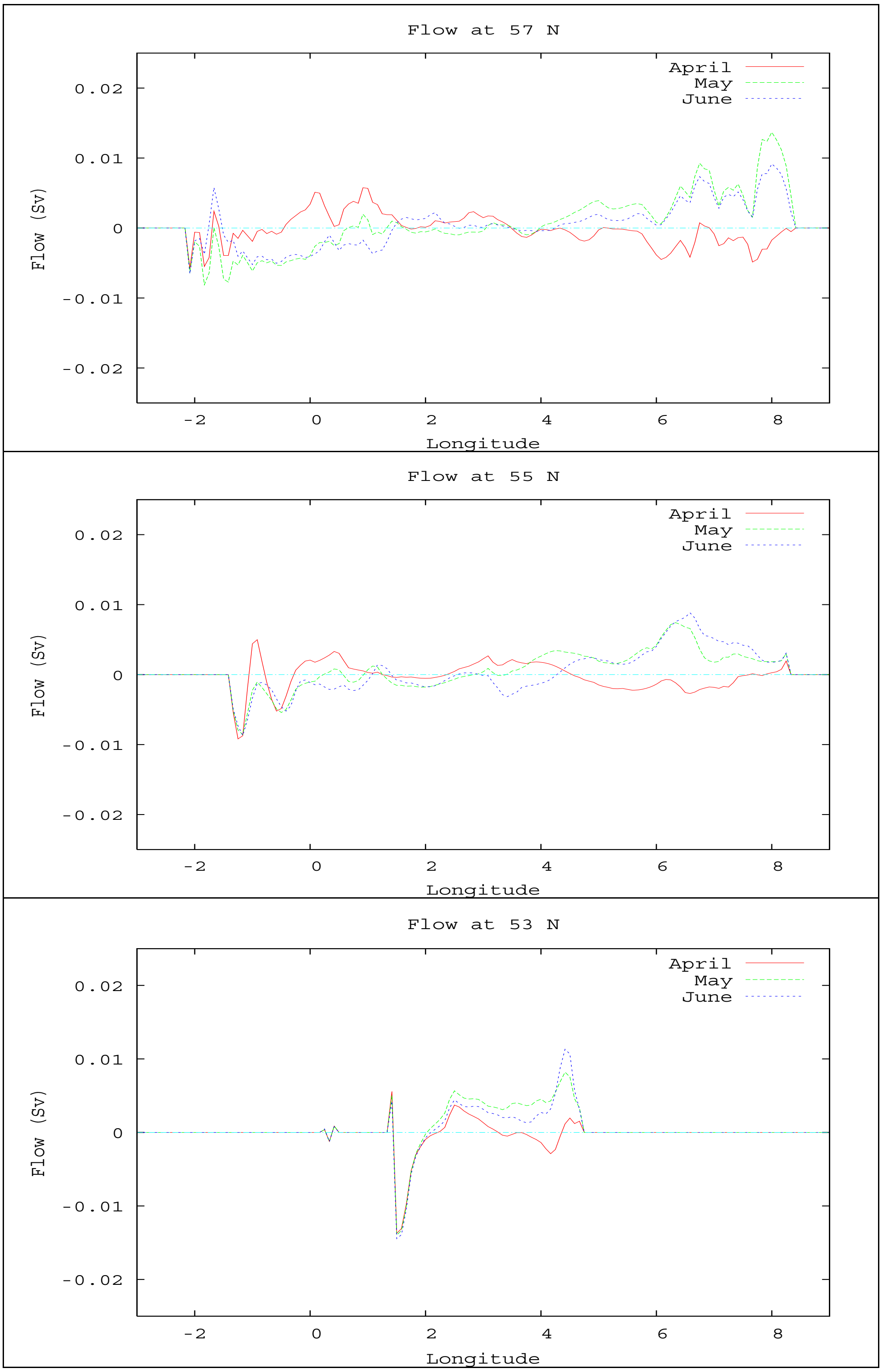


Figure 6. Modelled fluxes of water across sections in the central and southern North Sea (see Figure 2 for their locations). The mean monthly fluxes from January 2006 to June 2007 are shown along with the long-term mean (1955–2004) monthly fluxes. Net flux is the difference between northwards and southwards 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.

followed a period of intensified eastward inflow during autumn and winter from October 2006 to February 2007 (Figure 6, lower left panel). The transports across the Dover Straits (at 51°N) computed with the Optos_nos model showed the same pattern with westwards transport in April and eastwards in May and June (Figure 7, lower panel).



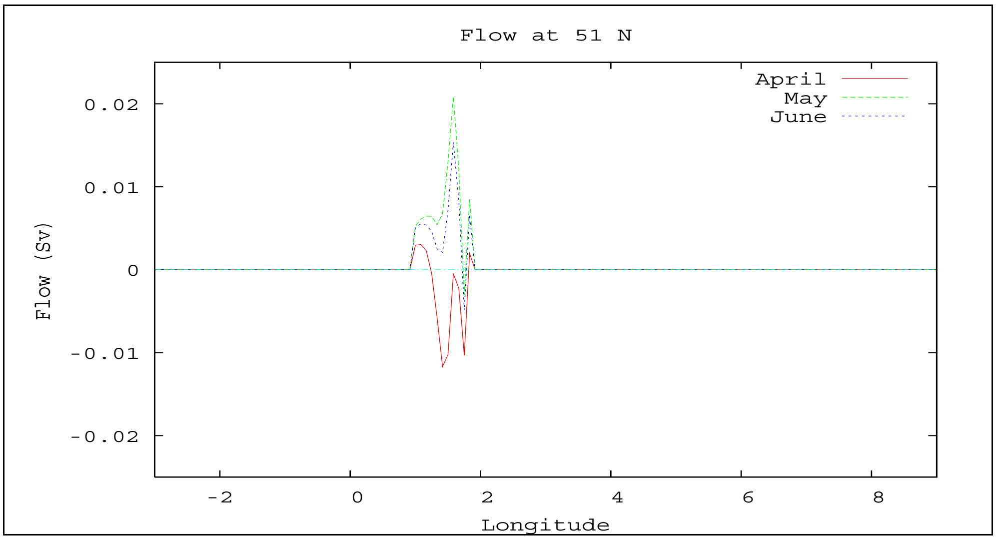


Figure 7. Modelled monthly averaged transports across 4 E-W sections in the North Sea at 57, 55, 53, and 51^{o}N latitude, computed with the Optos_nos model (MUMM, Belgium).

Distribution and properties of water masses

Sea surface temperature

Monthly mean sea surface temperatures over the North Sea for January through October 2007 are shown in Figure 8, while monthly mean temperature anomalies (deviation from long-term climatology) for the same time period are shown in Figure 9.

The sea surface temperature increased somewhat from the winter minima in February and March to around 8–10 ^{o}C in April. The temperature increased further during the 2nd quarter to mean values of 11–12 ^{o}C in the northern and 15–16 ^{o}C in the southeastern parts of the North Sea (Figure 8). The North Sea had been unusually warm during the preceding autumn and winter, with positive temperature anomalies of 1–4 ^{o}C over the central and southern areas. This situation persisted during the 2nd quarter although the anomalies decreased somewhat to about +1–2 ^{o}C in June (Figure 9).

Modelled monthly mean sea bed temperature

The UK Met Office runs the POLCOMS shelf seas modeling 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 40km global NWP model, or for the NW European shelf the 12 km mesoscale (to be replaced by 12 km North Atlantic European) NWP model.

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 Atlantic Margin Model (AMM) is nested into the Atlantic FOAM model at the open ocean boundaries. A summary of the model configurations was given in the NORSEPP 2Q report. Further information on the shelf seas models can be found on http://www.metoffice.com/research/ncof/shelf/index.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

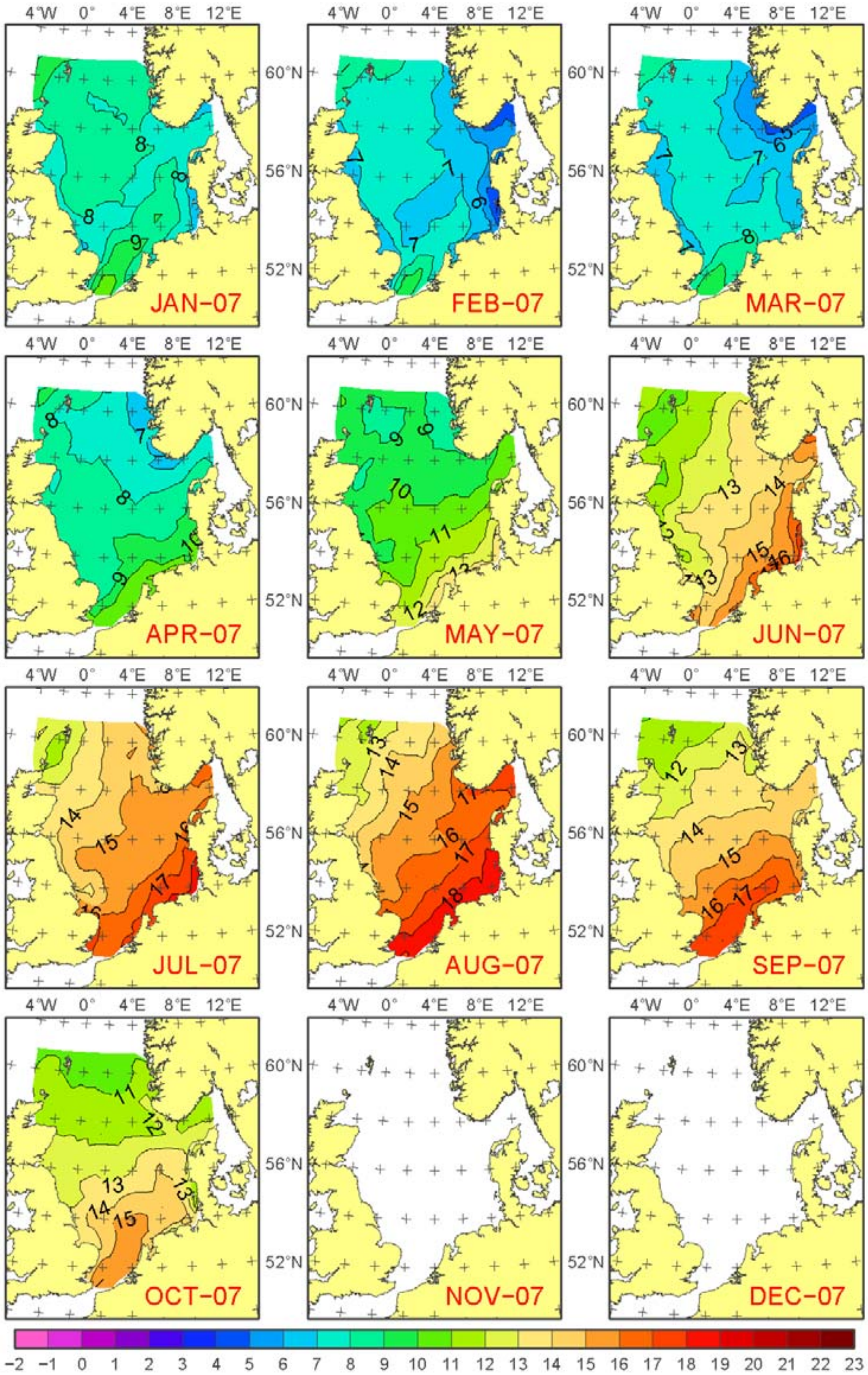


Figure 8. Monthly mean sea surface temperature for January–October 2007. Data from BSH, Hamburg.

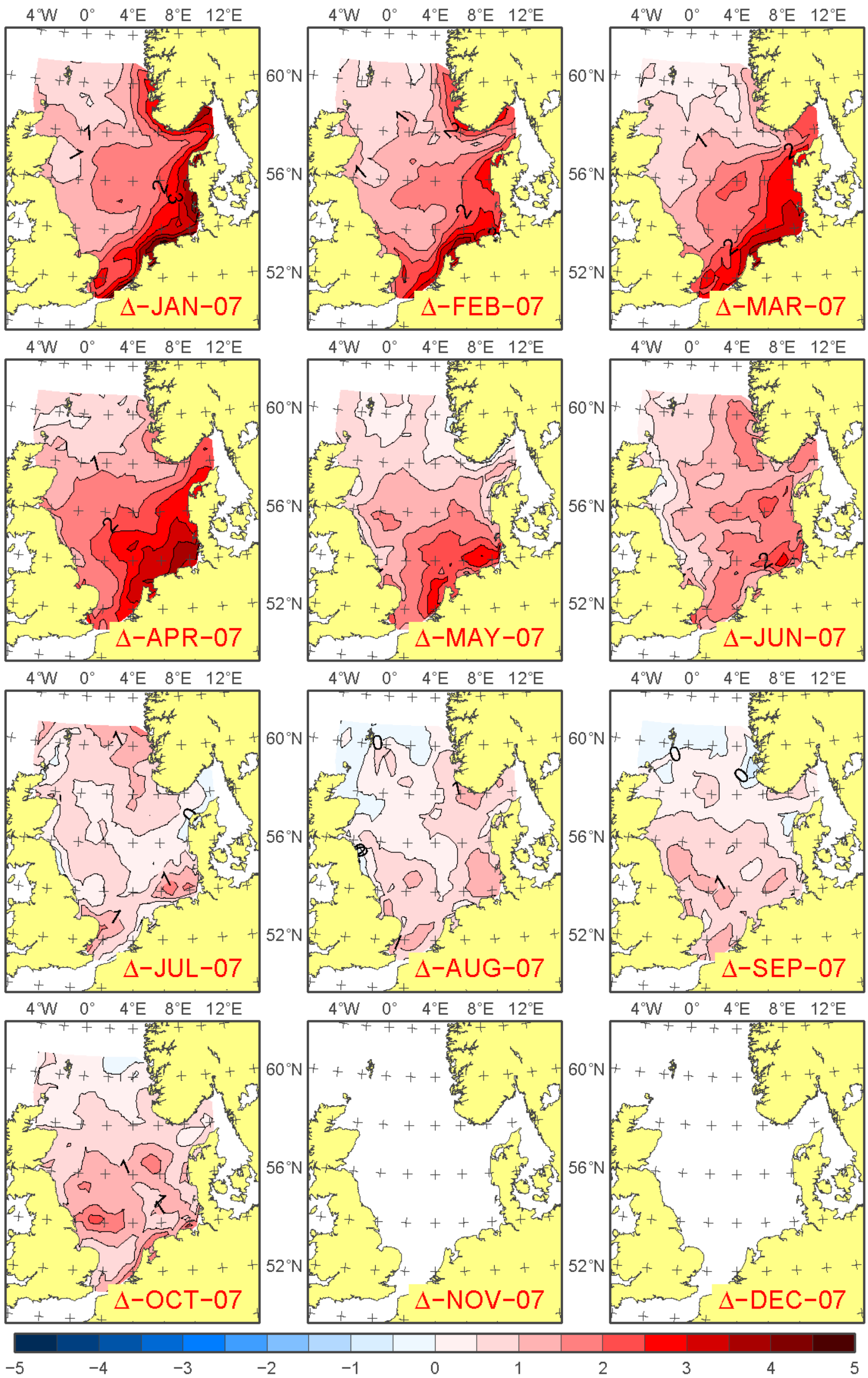


Figure 9. Anomalies for monthly mean sea surface temperature for January – October 2007. Data from BSH, Hamburg.

The monthly mean modelled seabed temperature for January to October 2007 is presented in Figure 10. The modelled seabed temperature increased little during the 2nd quarter for the northern and central North Sea where seasonal stratification typically develops. The shallow waters of the southern and eastern North Sea in contrast warmed to around 15–16 °C in June.

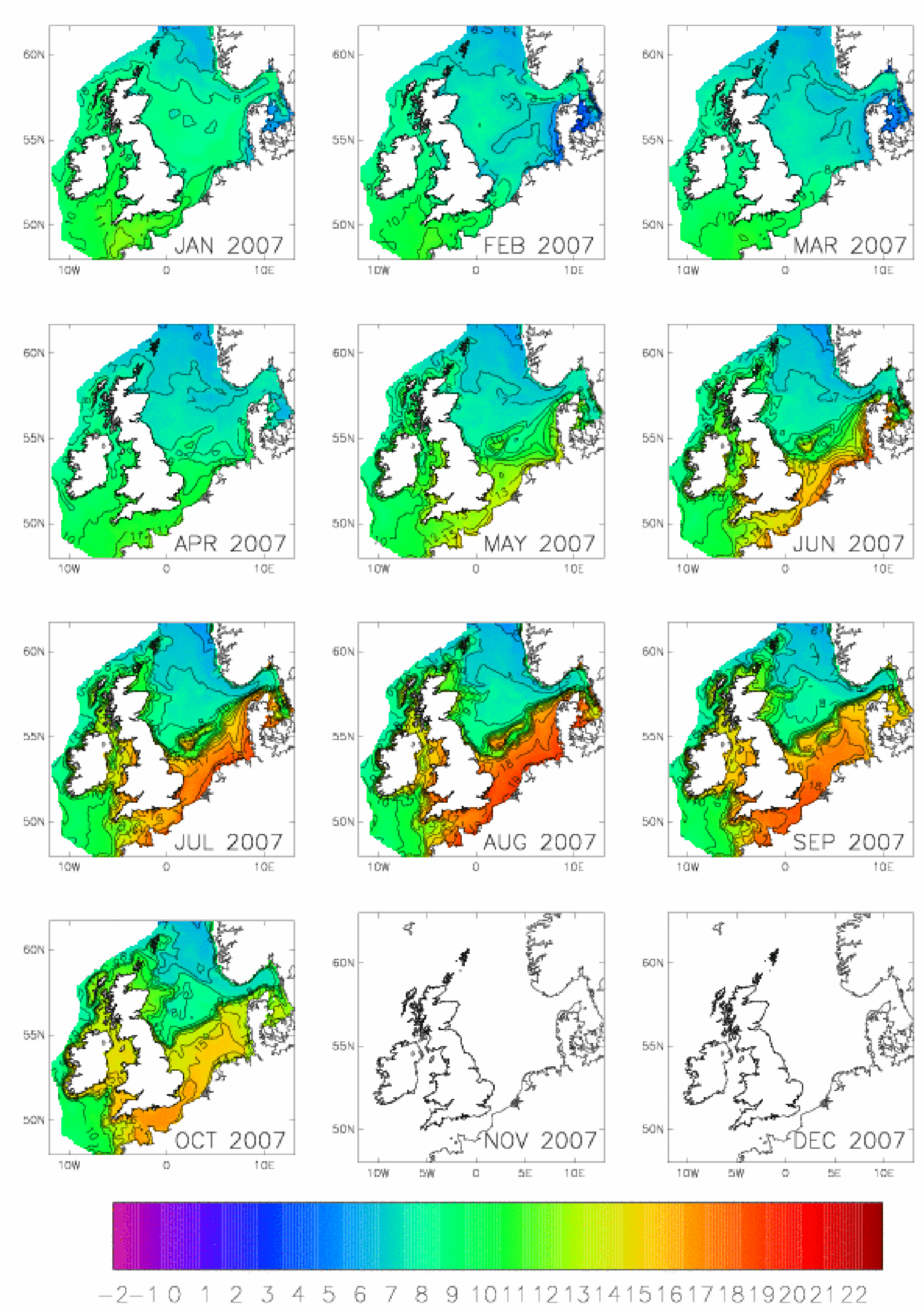


Figure 10. Monthly mean modelled near-bed temperature from the Met Office run of the MRCS POLCOMS model, from January to October 2007.

Modelled distributions of temperature and salinity in the central and southern North Sea

Maps of modelled monthly averaged surface and bottom temperatures and salinities computed by the Optos_NOS model operated by MUMM (Belgium) are presented in Figures 11 and 12.

Higher temperatures in the surface than at the bottom are indicative of stratification. This took place in the offshore areas west of Denmark in April and over most of the central North Sea in May (Figure 11). The Southern Bight and the eastern part of the Channel are typically tidally mixed with little difference in temperature or salinitiy between the surface and bottom.

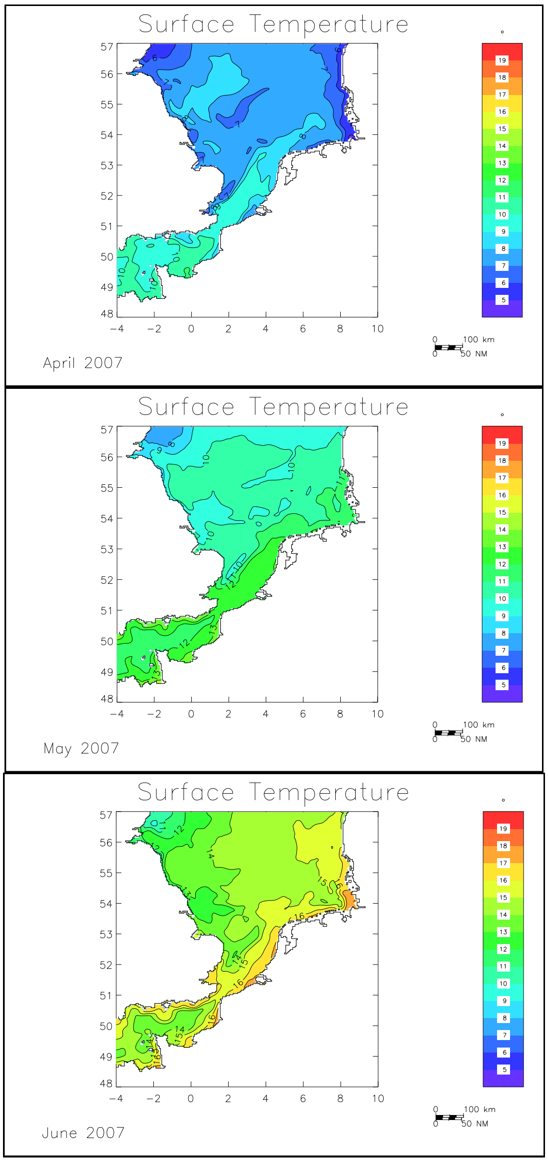


Figure 11. Monthly average of the surface and bottom temperature computed with the Optos_nos model in April, May and June 2007. From MUMM, Belgium.

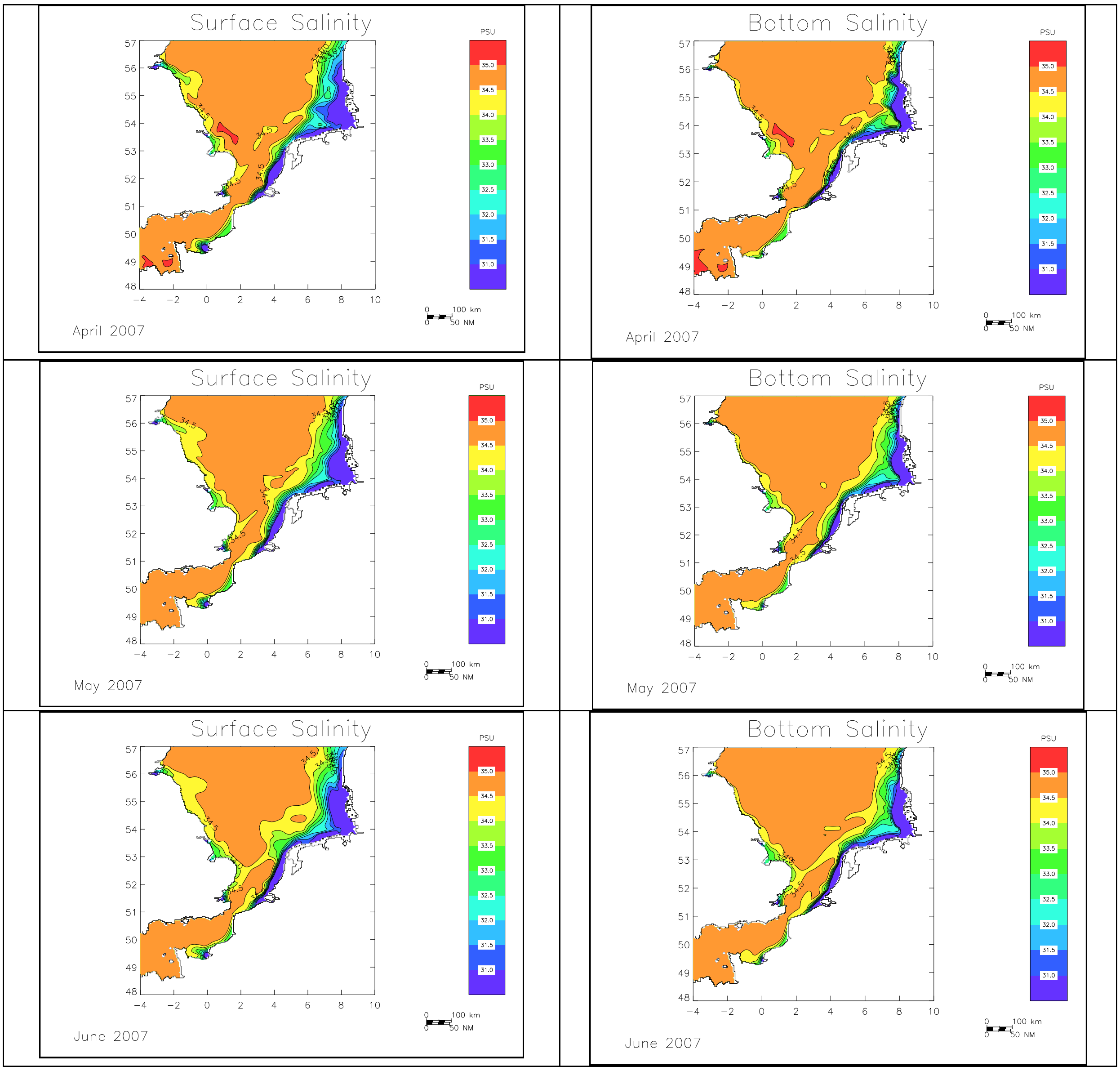


Figure 12. Monthly average of the bottom and surface salinity computed with the Optos_nos model in April, May and June 2007. From MUMM, Belgium.

Seasonal temperature development in the German Bight

Temperature recordings from the Ems station in the German Bight are shown in Figure 13. The temperature increased from about 8 ^{o}C in the beginning of April to 15–16 ^{o}C by the end of June. Periods of stratification, evidenced by higher temperature in the surface layer than deeper down, occurred around mid April, in late April and early May, and again in June. Stratification was particularly strong in the first part of June when the sea surface temperature reached 17–18 ^{o}C.

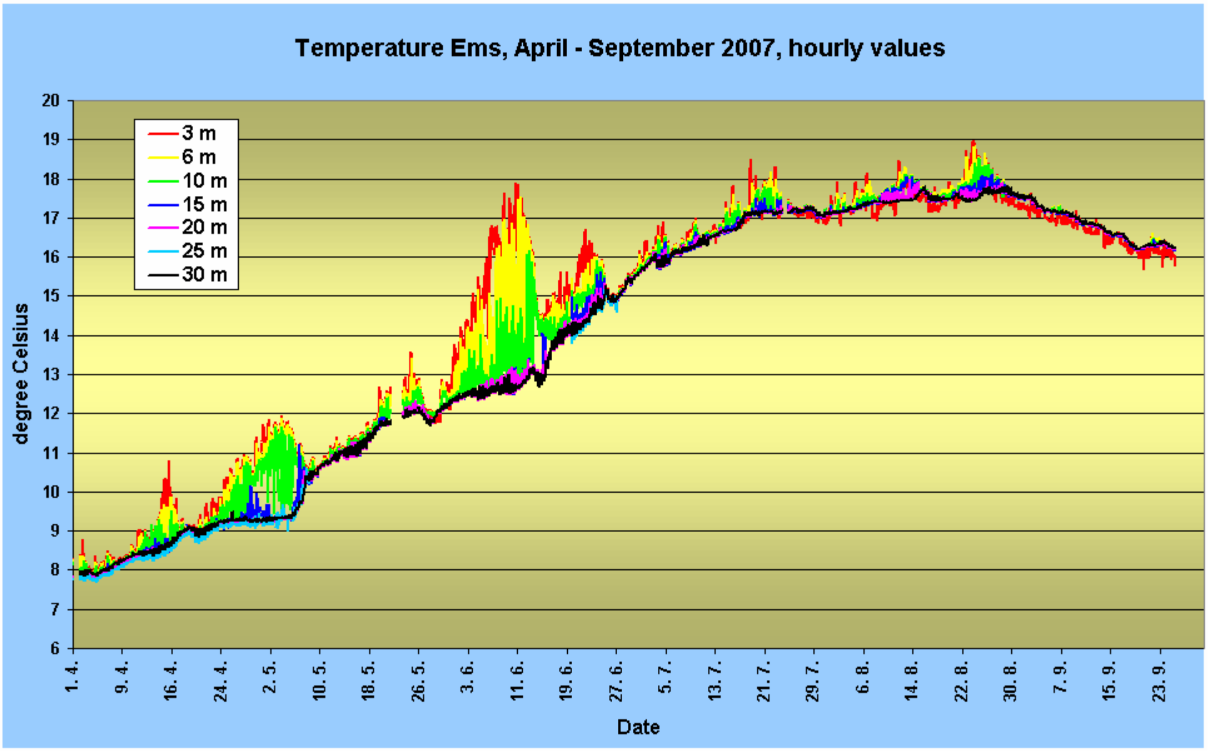


Figure 13. Temperature at different depths of the water column at the Ems monitoring station in the German Bight from 1 April to the end of September 2007. From BSH.

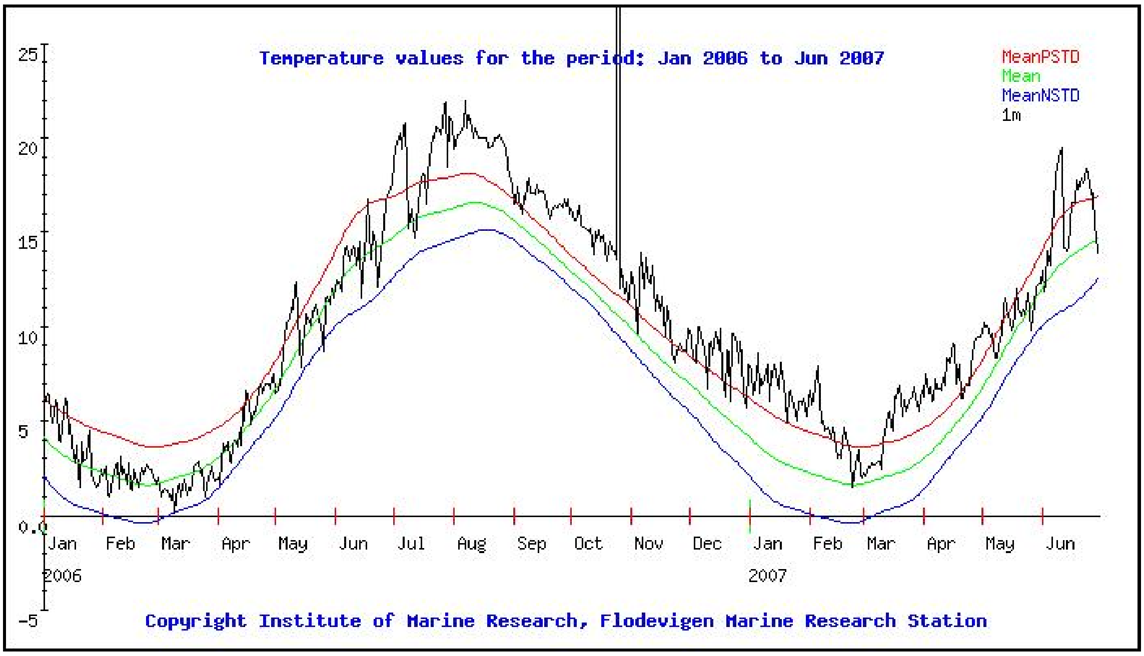


Figure 14. Daily sea surface temperature recordings at Arendal on the Norwegian Skagerrak coast from January 2006 to June 2007. Also shown is the long-term average temperature +/− 1 SD (standard deviation). Data from Institute of Marine Research (IMR).

Sea surface temperature recordings at Arendal

Daily recordings of sea surface temperature at Arendal on the Norwegian Skagerrak coast from January 2006 to June 2007 are shown in Figure 14. The temperature had remained above average from summer 2006 through the 1st quarter of 2007, most of the time about 2 SD above the long-term average (climatology). This situation continued during the first part of April. Thereafter the temperature increased less sharply to be around the average in late May before increasing to above average for most of June.

Biological conditions

Chlorophyll and phytoplankton development in Skagerrak and W coast of Norway

Chlorophyll *a* concentration in the surface layer is measured 3 times per week in Flødevigen Bay at Arendal on the Norwegian Skagerrak coast (Figure 15). The station is representative for the Norwegian Coastal Current in the Skagerrak. The data from winter and spring 2007 demonstrated a somewhat late and narrow spring bloom peak on 23 March dominated by diatoms with *Skeletonema costatum* as the most common species.

Following the peak of high chlorophyll during the spring bloom in late March, the chlorophyll level fluctuated around the long-term average in April. In May and June, chlorophyll was lower than the average, most of the time below the first quartile value for the variability in the time-series (1989–2005).

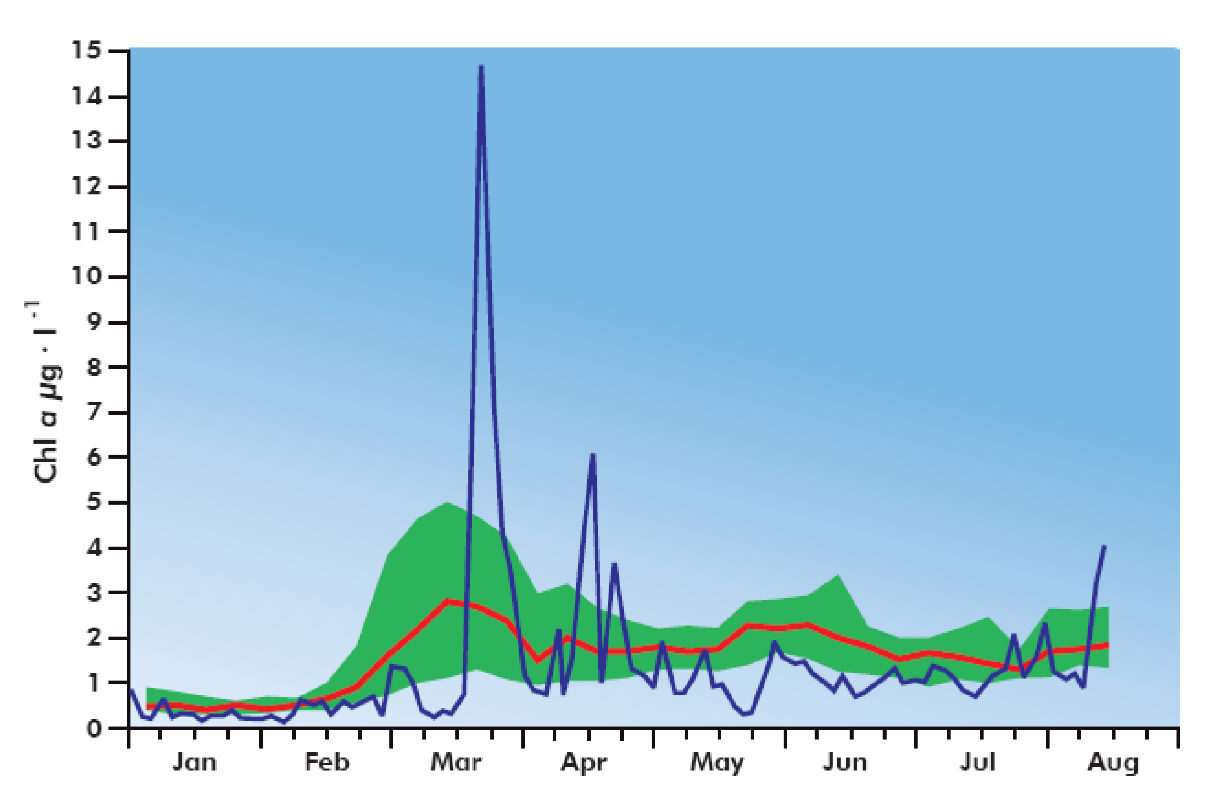


Figure 15. Chlorophyll *a* in Flødevigen Bay, 0–3 m depth, measured three times a week (Monday, Wednesday, Friday). The blue line is data from January–August 2007. The red line is medians for every week based on all data for the period 1989–2005. The green-shaded area denotes the range between the first and third quartiles.

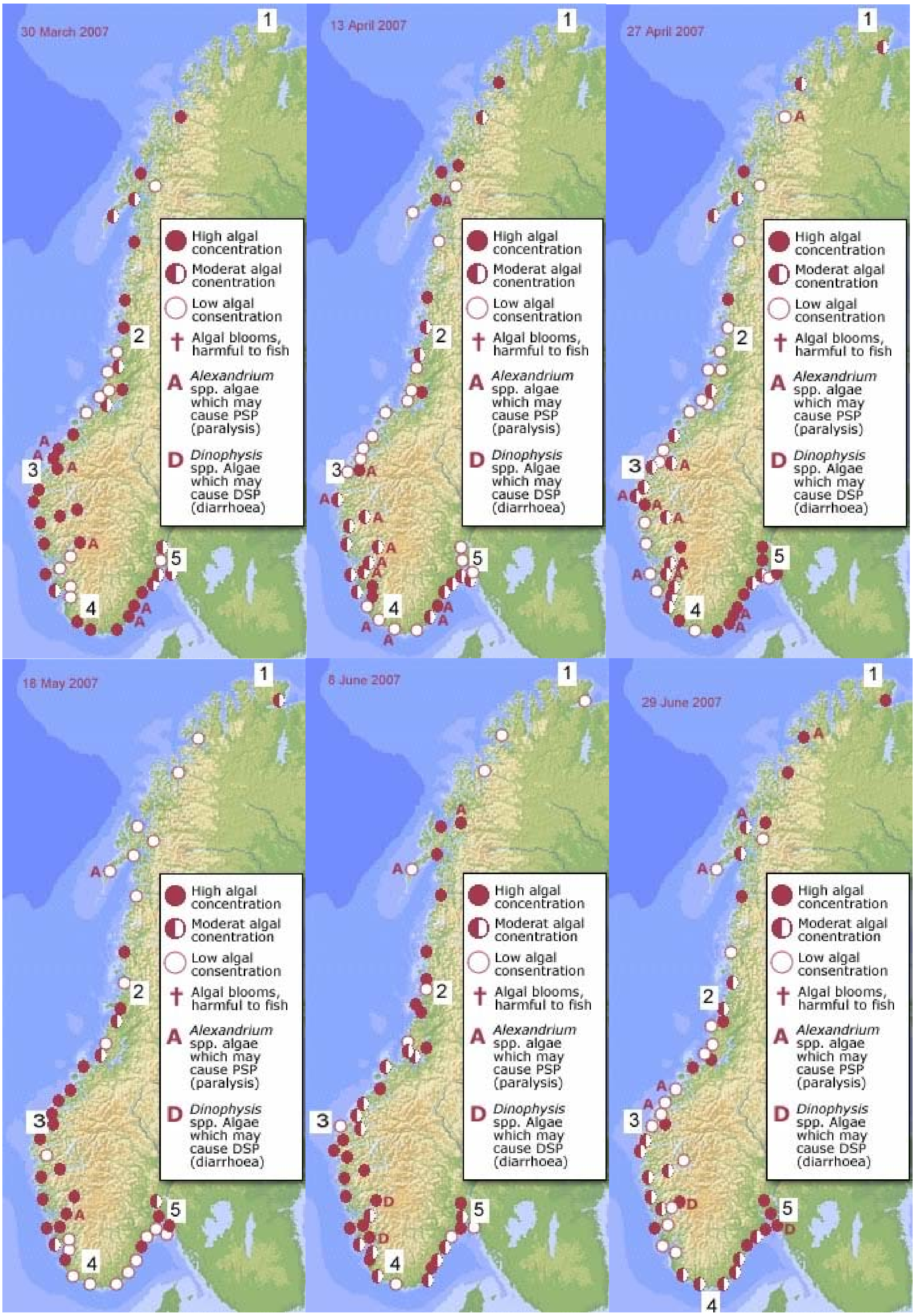


Figure 16. Maps of algal occurrences along the coast of Norway for 30 March, 13 April, 27 April (upper panels), 18 May, 8 June, and 29 June 2007 (lower panels). The symbols show algal densities as high (filled circles), moderate (half-filled circles), and low (open circles). Occurrences of harmful

algae are indicated by A (for *Alexandrium* spp.) and D (for *Dinophysis* spp.). Numbers from 1 to 5 denote coastal regions for which summary texts are provided in the algal infos.

Weekly reports (*http://algeinfo.imr.no/*) on occurrence of phytoplankton along the Norwegian coast, with emphasis on the toxic ones, are produced in a broad cooperation between the Institute of Marine Research, Norwegian Veterinary College, SINTEF, NIVA, Directorate of Fisheries, and the Norwegian Food Safety Authority. The phytoplankton data are mainly generated in a national monitoring programme, operating from March to November, with about 52 stations covering the entire coast from the Swedish to the Russian border.
In the panels in Figure 16, maps on occurrence of phytoplankton from 30 March to 29 June 2007 are shown.

The spring bloom along the Skagerrak coast developed in the last week of March, while along the west coast of Norway, the spring bloom was reported to start early in March. The highest algal densities were recorded on 30 March with generally lower densities on 13 April. Diatoms with *Skeletonema* and *Chaetoceros* were the dominant species of phytoplankton during the spring bloom.

Algal densities along the Skagerrak coast varied from high in late April to low in mid May, and were generally moderate in June (Figure 16). Along the west coast of Norway, the algal densities were moderate to low in April, high in mid May and early June, and moderateto low in late June (Figure 16).

Seasonal plankton development in the Southern Bight and the Channel

Monthly mean chlorophyll *a* maps from the MERIS sensor onboard ENVISAT are presented in Figure 17 for March–June 2007. All data has been quality controlled using the MERIS product confidence flag and suspect data has been excluded from this analysis.

March 2007 corresponds to pre-phytoplankton bloom conditions for most waters. One notable exception was at the French-Belgian coastal border (2.6°E, 51.0°N) where moderate (of order 5 µg/l) chlorophyll *a* concentration indicates the start of a bloom. Compared to 2006 (see the NORSEPP 2Q 2006 report), the spring phytoplankton bloom along the French-Belgian-Dutch coast was noticeably later in 2007. A start to the phytoplankton bloom is also seen along part of the French coast between Le Havre and Cherbourg (49.4°N, 1°W).

In April 2007, a strong phytoplankton bloom was observed, with chlorophyll *a* concentrations exceeding 10 µg/l or even 25 µg/l in nearshore regions, throughout the continental coastal waters of the Southern Bight from South of Boulogne (50°N, 1.5°E) along the coast of North-East France, Belgium and the Dutch West coast (52.5°N, 4.5°E). This is the strongest and latest spring bloom that has been recorded there over the NORSEPP reporting period (2005–7). Further moderate to strong blooms were also recorded in April 2007 along the South East coast of England, both South and North of the Thames Estuary (50.6°N, 1°W to 1°E) and (51°N to 52.5°N, 1.7°E) and West of Lyme Bay (3.4°W, 50.5°N). The latter bloom is also the strongest recorded over the period 2005–2007. The bloom along the French North coast from 3°W to 0.5°E strengthened in April 2007. The exceptionally strong and widespread bloom observed in Belgian waters and near the East Anglia coast (51.7°N, 1.7°E) was confirmed by seaborne measurements on 23–26 April 2007 from the Research Vessel *Belgica*.

In May 2007, the strong bloom generally persisted in the Southern Bight and the southern coast of England and was strengthened along the coast of East Anglia (51.7°N, 1.7°E) and in the Bay of the Seine (49.5°N, 0° E). Some isolated blooms were seen in offshore waters at lower concentrations, such as the patch with about 3µg/l in the Western Channel (49.7°N, 3°W).

In June 2007 most of the spring blooms had diminished except in the Bay of the Seine (49.5°N, 0° E).

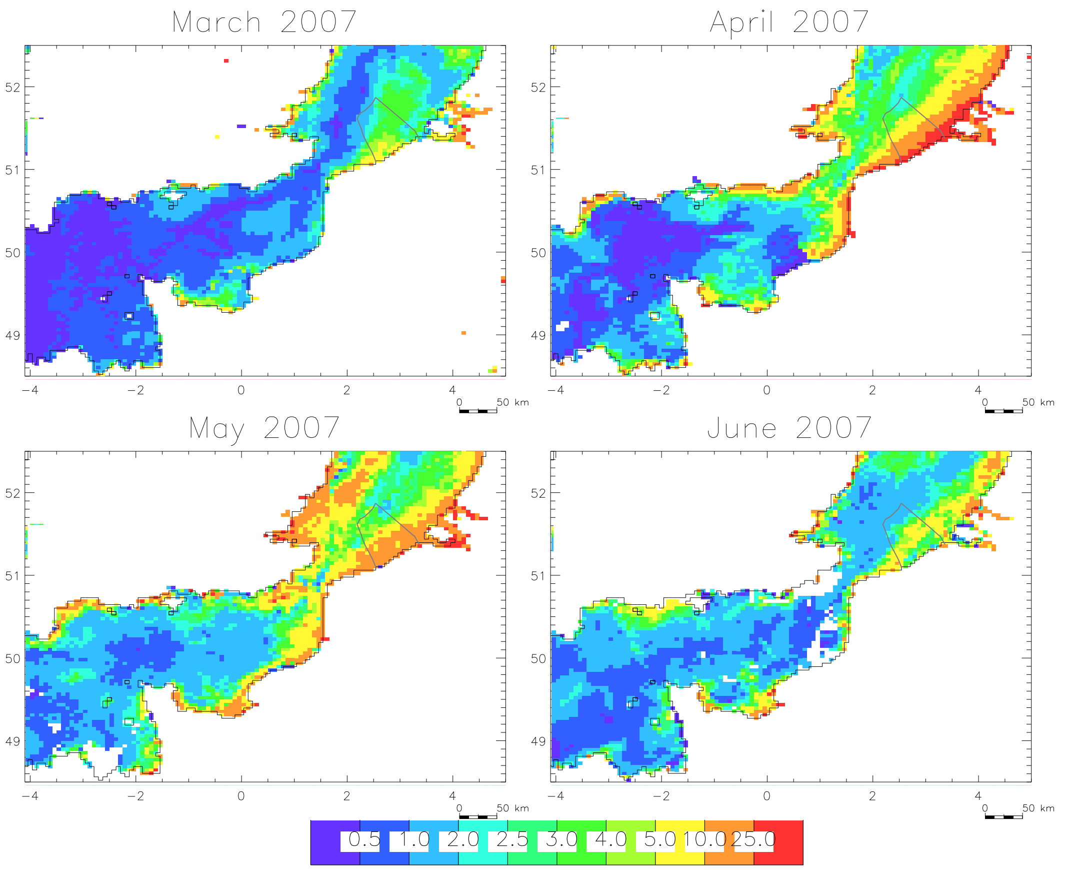


Figure 17. Monthly mean chlorophyll *a* concentration in March–June 2007 derived from ENVISAT-MERIS for the Southern Bight of the North Sea and the Channel. White areas denote land and pixels where no acceptable satellite data was available (because of clouds or failure of quality control checks). Belgian 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).

Timing of the onset of the spring bloom

Figure 18 shows the timing of the onset of the spring bloom for the North Sea as Julian day number, calculated by the method of Park and Ruddick (2007; Detecting algae blooms in European waters. Proceedings of ENVISAT symposium. European Space Agency, SP-636). This new product shows the first day on which the satellite-derived chlorophyll *a* concentration is higher than a threshold value, where the threshold varies from pixel to pixel and is based on the 90 percentile concentration from multiyear satellite data. From this map it is clear that the spring bloom in 2007 occurred first (March) in the clearest waters along the Norwegian coast and over the Dogger Bank (55°N, 3°E) as well as in the nutrient-rich waters of the Belgian and Dutch coasts (March/April). Later (April–May) blooms occurred in the German Bight (54°N, 8°E), the South East of England (52°N, 2°E) and the northern North Sea (57°N, 2°E). The latest blooms (May–June) were recorded in the Western Channel (48.5°N, 4°W), North of East Anglia (53°N, 2°E) and North of Scotland (61°N, 2°W). Information on the interannual variability of bloom timing for this whole region is not yet available.

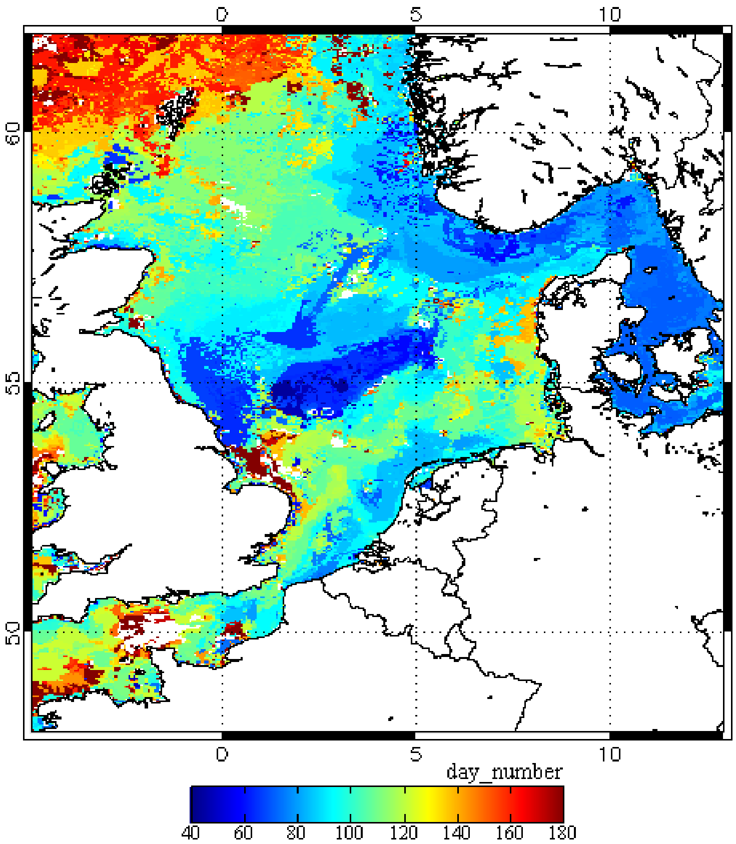


Figure 18. Algae bloom timing (based on seasonal chlorophyll build-up) for the North Sea in the year 2007 derived from MERIS and MODIS data. White areas denote land and pixels where no bloom was detected in first half of year. Chlorophyll data was received from ACRI-ST in the framework of the GMES-MARCOAST project (and ESA Cat 1 A/O 1521) and processed by MUMM using the method of Park and Ruddick (2007).