Report of the 17th meeting of the NSHC-TWG to the 29th NSHC Conference

CONTENTS

1. Meetings and attendance

The 17th NSHC-TWG meeting has held at the Danish Maritime Safety Administration (DaMSA) in Copenhagen (19th -20th May 2010) and was attended by representatives from Belgium, Denmark, France, Germany, Netherlands, Norway and United Kingdom. By invitation O. Andersen (the Danish DTU-Space) attended the meeting to provide input about the North Sea research project BLAST.
The present report is submitted to the 29th NSHC Conference together with the report of the 16th meeting of the NSHC-TWG.

2. Current actions

There are a number of ongoing actions within the NSHC-TWG. These include monitoring developments in modern tide gauges, monitoring developments in digital tide tables and website predictions, monitoring tidal reduction methods (and GPS assisted tidal reduction) and on-going co-operation and data exchange between member states.

The TWG agreed on the next draft work plan enclosed as annex A. The main objective for this work plan is to better accommodate the different needs of navigational purposes, especially the increasing need of precise offshore hydrographic surveying and coastal management in the North Sea region as well as to enhance model correlation of land/sea environment. From this objective the TWG has derived the following work plan deliverables:

1. Common MSL in reference to the GRS80 ellipsoid,
2. Common surface for LAT,
3. Common surface for navigational purposes (Chart Datum),
4. Follow developments on geoid, MSL and LAT computations for the North Sea area.

The TWG considers the wording “Seamless MSL” the former work plan as misleading, since the experience has shown that this concept cannot be defined and implemented uniquely.
In the past, NL has coordinated the work for the common surfaces of items 1 to 3 above. This work is planned to complete by July 15, 2010.
The work plan item 4 is related to the BLAST project (“Bringing Land and Sea Together”) and may be used as a reference for the TWG. The BLAST Work Package 3 is designed as a “demonstrator project” and has strong similarity with the NSHC TWG work on a common Geoid, MSL and LAT.

3. List of deliverables and timing

Determination by 2010 of:
- a common MSL in reference to the GRS80 ellipsoid
- a common LAT in reference to the GRS80 ellipsoid
- a common surface for navigational purpose (Chart Datum)
Determination by 2012 of an improved geoid, MSL and LAT for the North Sea area.

With regard to the NSHC request to look into the UK VORF presentation the TWG endorses the UK approach and FR approach to establish MSL and then define the other surfaces accordingly. This TWG endorsement is also reflected in the new work plan that basically has the same approach as presented in the VORF presentation at NSHC28.
The results of the BLAST WP3 should be used as a reference for the TWG.

4. Terms of Reference for the group

These are mentioned in annex B of the minutes of the 17th TWG meeting (annex C to the report of the 17th NSHC-TWG to the 29th NSHC Conference (28th – 29th September 2010)). According to the recommendation of the 28th report, the TOR is reviewed by the Tidal Working Group.

5. Recommendations to the 29th NSHC Conference

The current new actions of the work plan as described above require active international co-operation between member states. On this moment there are too many different methods to deliver a common MSL a corresponding common surface for LAT and a corresponding common surface for navigational purposes (Chart Datum). The NSHC should give guidance to the TWG to reach agreement.

The 29th NSHC Conference is invited to approve and amend, if necessary:

- this report
- the Work Plan TWG (annex A)
- the actions items (annex B)
- the proposed Terms of Reference (annex C)

6. Presentation of the Report

Under rotating chairmanship, the 18th NSHC-TWG (October 2011) will be held in the region of Brest, under French chairmanship. The Danish representative will present the report on behalf of the NSHC-TWG.

ANNEX A: WORK PLAN TWG to be approved by NSHC

Workplan NSHC Tidal Working Group: ([Sept 2010] - to be confirmed by NSHC)				
Item number (TWG/item)	**objective (WHY/priority)**	**task description (WHAT/HOW)**	**HO involved**	**status**
WP 16 / 01	Better accommodate the different needs of both navigational purpose and coastal management	Common MSL in reference to the GRS80 ellipsoid	All, coordination NLHO	Completed by July 15, 2010
WP 16 / 02		Common LAT in reference to the GRS80 ellipsoid	All, coordination NLHO	Completed by July 15, 2010
WP 16 / 03		Common chart datum in reference to the GRS80 ellipsoid	All, coordination NLHO	Completed by July 15, 2010
WP 16 / 04	Enable GNSS-based tidal reduction and the connection with the vertical datum on land	Follow developments on geoid, MSL and LAT computations for the North Sea area	All	Permanent
WP 15 / 02		Update Co-Tidal Chart 5059	DE/UK	[obsolete]
WP 15 / 03		Unified (European) tidal prediction system	FR/UK	[obsolete]

ANNEX B: Actions for internal coordination within TWG

Action items NSHC Tidal Working Group				
Item number (TWG/item)	**objective (WHY/priority)**	**task description (WHAT/HOW)**	**HO involved**	**status**
A 17 / 01	Explain differences in realizations of LAT	Exchange used harmonic constituents and hydrodynamic models	All, coordination NLHO	Completed by June 1, 2010
A 17 / 02	Explain differences in realizations of CD	Exchange used methods and concepts for CD	All, coordination NLHO	Completed by June 15, 2010
A 17 / 03		Circulate draft report on the creation of common reference surfaces among TWG members	NLHO	July 1, 2010
A 17 / 04		Submit final report on the creation of common reference surfaces to NSHC	NLHO	July 15, 2010
A 16 / 02		Publish harmonic constituents for use within IHO community; UKHO acts as coordinator and translation to XML	All and TSMAD	

ANNEX C: Terms of Reference for the North Sea Hydrographic Commission Tidal Working Group

As amended by NSHC 28 and commented on by TWG-16th and TWG-17th

1. Objective
To provide technical advice and promote co-ordination on tidal issues especially within the North Sea Hydrographic Commission (NSHC).

2. Authority
The Tidal Working Group (TWG) is a subsidiary of the NSHC and its work plan is subject to NSHC approval. The TWG acknowledges the IHO Tidal and Sea Level Working Group (TSLWG) as a subsidiary of the Data Acquisition and Transfer Standards Subcommittee (DATS) of the Hydrographic Services and Standards Committee (HSCC). Subject to approval by NSHC the TWG is especially involved with the regional interpretation and implementation of tidal issues as identified by DATS/TSLWG. If applicable the TWG can also give advice to DATS and NSHC for further consideration.

3. Procedures
a. The TWG should:

1. work according to the agreed NSHC work plan;
2. monitor and report the progress of the work plan;
3. propose new work plan items for consideration by the NSHC.

To support the identification of new work plan items deemed relevant for the NSHC, the TWG should:

4. liaise with especially DATS/TSLWG for any emerging development;
5. exchange views and experiences concerning tidal issues like unifying vertical datums, analysis, modelling and related issues like sea level rise and surge.

b. The TWG will conduct its business mainly by correspondence. Meetings and workshops should be scheduled as deemed necessary for the accomplishment of the work plan.

4. Composition and Chairmanship

1. The TWG shall comprise representatives of the NSHC Member State and expert contributors if applicable.
2. Decisions should generally be made by consensus, if a majority is required each Member State has one vote.
3. External contributors can contribute to the work plan but are not entitled to vote.
4. The Chair and secretarial support will be from the Member State hosting the meeting.
5. The Chair should monitor and report on the work plan to the NSHC.

ANNEX D: Merging and comparison of reference surfaces for the North Sea area

Annex to the report of the 17th meeting of the NSHC-TWG to the 29th NSHC Conference

Contents:

1. Introduction

Technical Resolution A2.5 of the IHO specified in 1998 that the Lowest Astronomical Tide (LAT) is to be adopted as the basis for the definition of Chart Datum (CD) for areas where the tides have an appreciable effect on the water level. The North Sea is such an area. Subsequently, the NSHC tasked its Tidal Working Group (TWG) to coordinate the introduction of LAT in its member states, which led to an action item to create a common seamless LAT-level for the North Sea by 2010. This Annex reports on the status of the introduction of LAT.

2. Available data

Besides LAT, several other reference levels can be identified at sea. Each reference surface can only be identified with respect to other reference surfaces. To enable water level reduction of bathymetric data using satellite navigation techniques, a relation between LAT and the relevant ellipsoid, i.e. GRS80, needs to be established. Such a connection cannot be made directly, but needs to be made using Mean Sea Level (MSL) or a geoid as an intermediate surface. Some Member States (MS-s) define their Chart Datum as identical to the latest realization of LAT, others have a need to identify Chart Datum as an additional reference level.

The current state of the realizations of those surfaces with respect to each other for each MS are sketched in Figure 1. BE, NL, and UK have data available that fully cover their North Sea areas, DE and FR have data that partially cover their North Sea areas, and DK and NO only have data available at specific coastal locations.

All available data was collected, and interpolated to a grid of 0.02° for both Easting and Northing. The grid spacing is chosen to equal the spacing of the sparsest data that is used. As the English Channel region is of great importance to the North Sea region, it was included in the grid. North of Scotland, the grid ends at the 4°W meridian. The grid uses WGS84[1] as its geodetic datum.

[1] WGS84 is selected as this datum is used worldwide for the publication of nautical charts are published. In this Annex, WGS84 can be assumed to equal ITRS and its national and European realizations, like ETRS89.

Further, only data was used that could be connected to the ellipsoid level. The resulting grids represent the MSL levels of the North Sea, the LAT levels of the North Sea, and the CD levels of the North Sea, all in relation to the ellipsoid. The following Subsections will describe each surface.

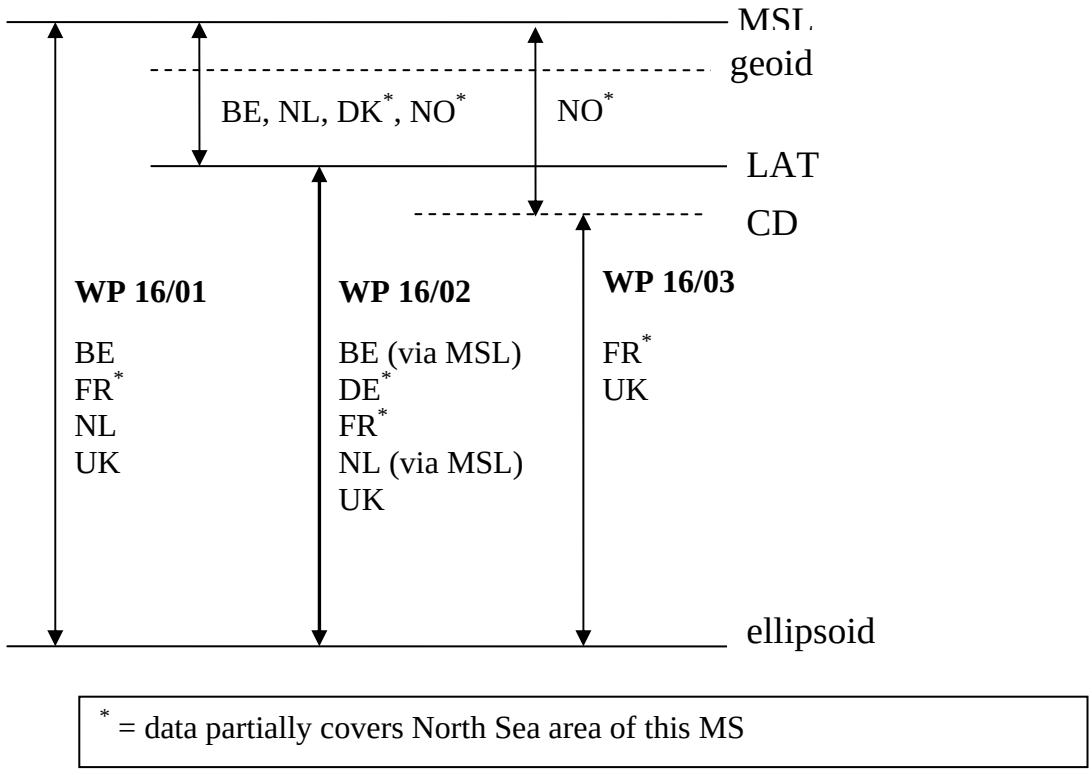


Figure 1: sketch of available data, in relation to Work Plan items (listed in Annex A to the Report).

2.1. MSL in relation to the ellipsoid

The grid of the resulting MSL levels is shown in Figure 2. Note that the surface is not seamless, and covers the North Sea area only partially. The differences at the maritime boundaries are equal to or less than 0.6 m. Graphs of the differences are given in Appendix A.1.

Also, the BE and NL surfaces contain an inconsistency, which is due to the geographic limit of the available part of the GEONZ97 MSL surface. Where this surface is not available, the original EGM96 geoid model is used as a representation of MSL, as the GEONZ97 data are based on the EGM96 geoid. Maps of these differences are given in Appendix B.1.

2.2. LAT in relation to the ellipsoid

The grid of the resulting LAT levels is shown in Figure 3. Note that the surface is not seamless, and covers the North Sea area only partially. The differences at the maritime boundaries are equal to or less than 0.6 m. Graphs of the differences are given in Appendix A.2.

Also, the BE and NL surfaces contain an inconsistency, which is due to the geographic limit of the available part of the GEONZ97 MSL surface. MSL is used as an intermediate surface between the ellipsoid and LAT. See for more information Subsection 2.1.

2.3. CD in relation to the ellipsoid

The grid of the resulting CD levels is shown in Figure 4. Chart Datum equals the latest LAT realization for BE, DE, NL and DK, and these surfaces differ for FR, NO, and UK. Note that the surface is not seamless, and covers the North Sea area only partially. The differences at the maritime boundaries are equal to or less than 0.8 m. Graphs of the differences are given in Appendix A.2.

Also, the BE, FR and NL surfaces contain an inconsistency, which is due to either the geographic limit of the available part of the GEONZ97 MSL surface (BE and NL), or a zoning in the CD definition (FR). MSL is used as an intermediate surface between the ellipsoid and CD. See for more information Subsection 2.1. Maps of the zoning differences are given in Appendix B.2.

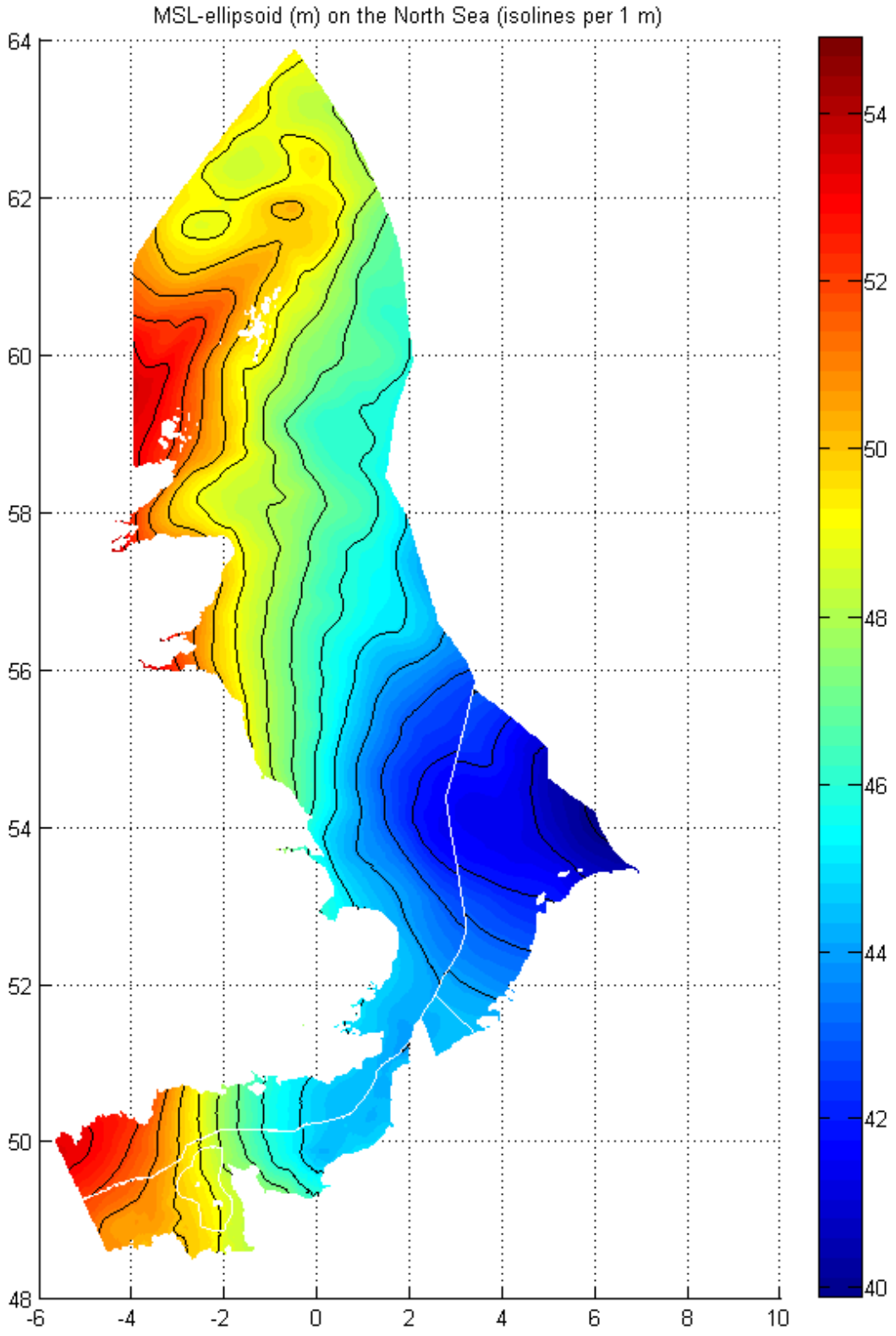


Figure 2: created MSL surface in relation to the ellipsoid, shown in ETRS89/WGS84 in Plate Carrée projection, including one metre isolines in black and maritime boundaries in white.

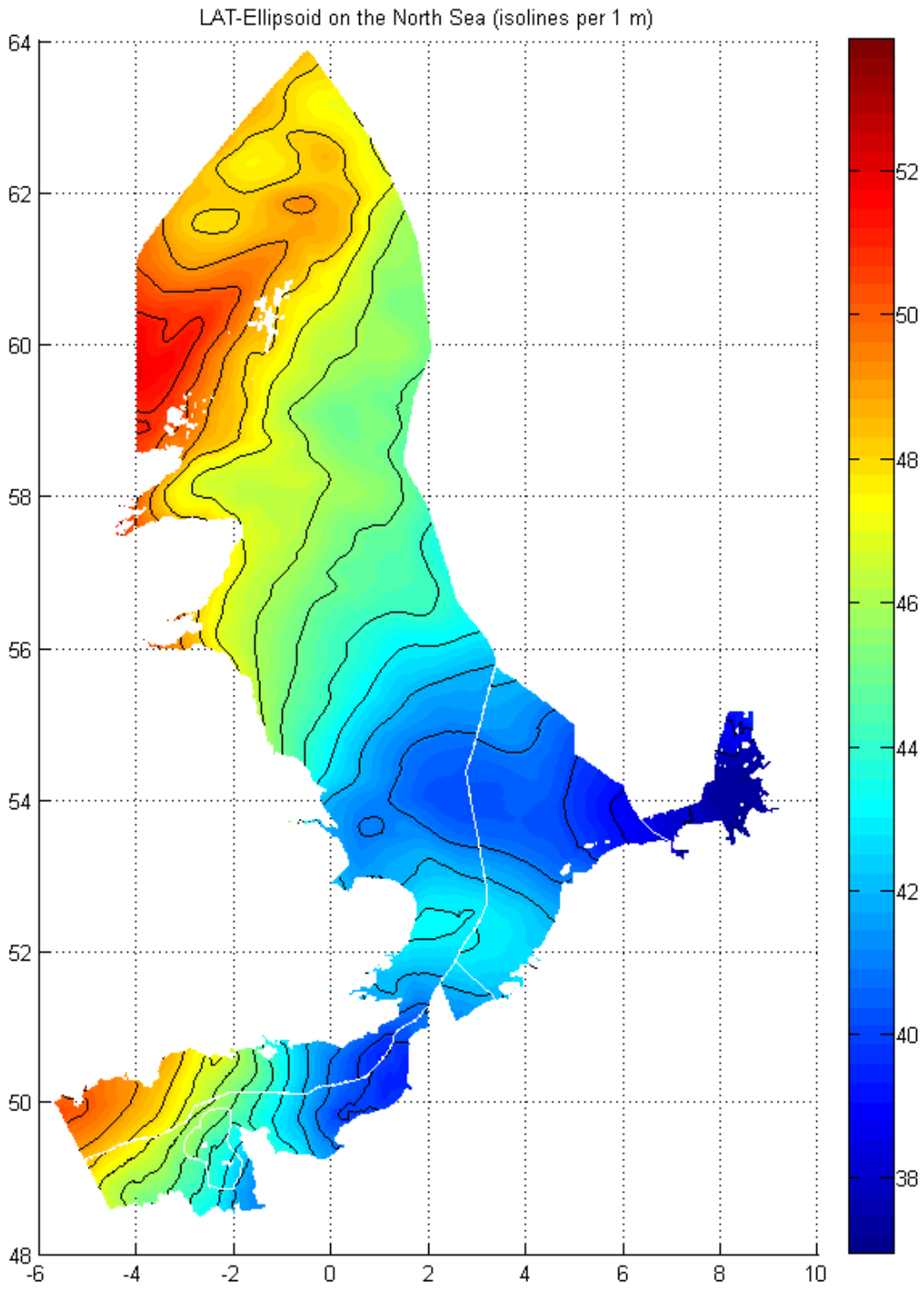


Figure 3: created LAT surface in relation to the ellipsoid, shown in ETRS89/WGS84 in Plate Carrée projection, including one metre isolines in black and maritime boundaries in white[2].

[2] As there is no established maritime boundary between the territorial seas of DE and NL, a new line was created for the purpose of DE/NL data comparison only.

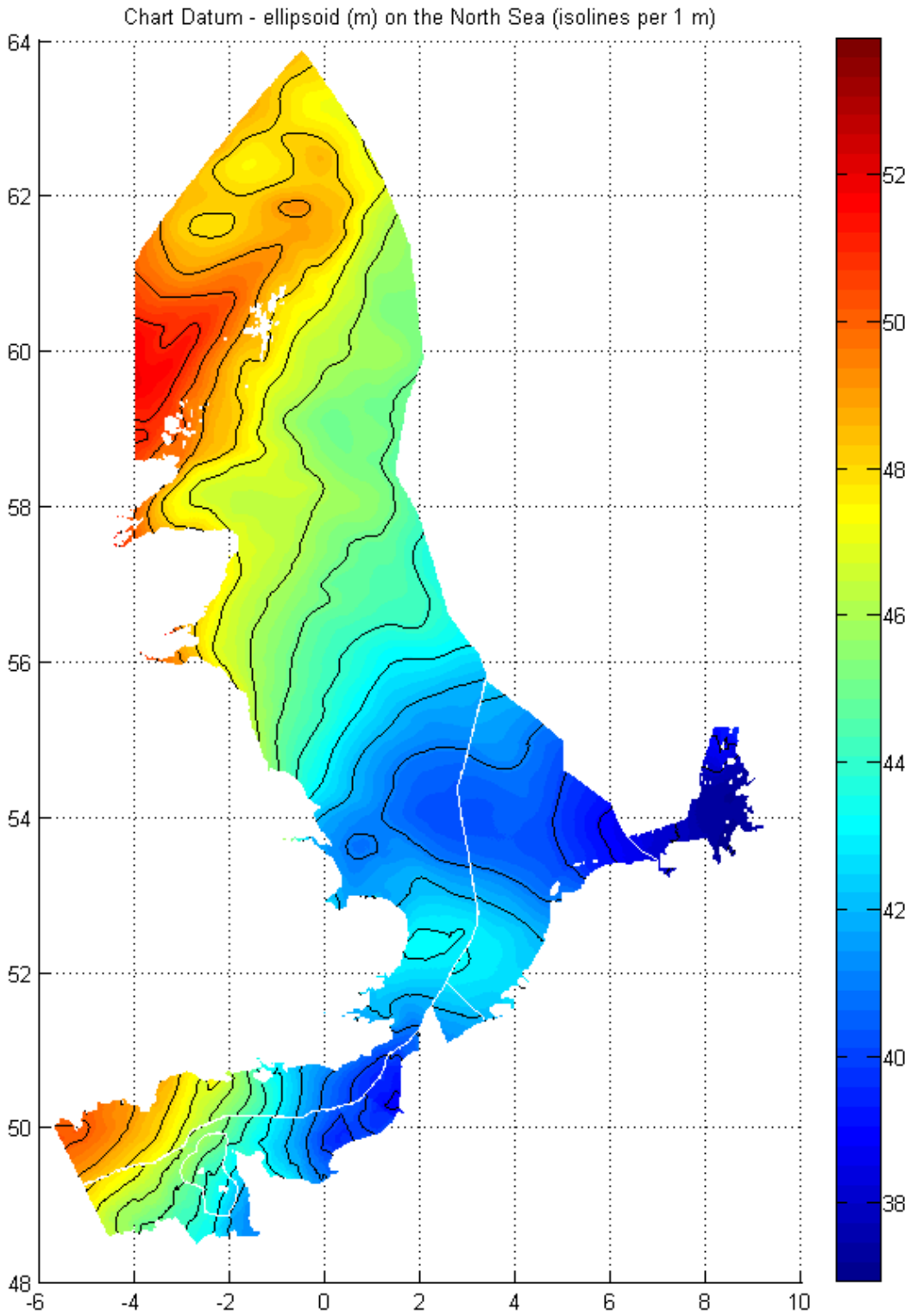


Figure 4: created CD surface in relation to the ellipsoid, shown in ETRS89/WGS84 in Plate Carrée projection, including one metre isolines in black and maritime boundaries in white[3].

[3] As there is no established maritime boundary between the territorial seas of DE and NL, a new line was created for the purpose of DE/NL data comparison only.

3. Choices made in the creation of the data

The choices made by each MS in the creation of their surfaces were expressed during the 16th TWG meeting. The MS-s give additional clarifications in Appendix C.

BE: *For BE region CD equals LAT, in the past CD equalled MLLWS. The LAT is calculated from harmonic tide prediction over a period of 19 years.*

DE: *Since 2005 LAT is the official CD in Germany. The surveys, tide tables and most of the nautical charts of the North Sea are referred to LAT.*

DK: *In Danish waters the tides are small. Along the North Sea-coast the difference between MLWS and LAT increases southward and reaches 0.35 m at the German border. Future nautical charts for the Danish part of the North Sea will be published showing the difference between LAT and MLWS for the North Sea area, where differences between both levels are in the order of 0.2 to 0.3 m.*

FR: *FR currently uses a level of CD close to LAT. The coast is subdivided in 15 tidal zones, the maximum of difference reaches 50 cm in the river Gironde. LAT is always above CD, except in a zone where it's only 5 cm below CD. On charts, it is precised "soundings related approximately to LAT". For the same reasons as UK, we don't move CD exactly to LAT. We change CD only when the difference between CD and LAT becomes significant.*

NL: *NL has established CD precisely at LAT.*

NO: *Before 2000 our CD was "Equinoctial spring low water" where Z_0 (vertical distance between MSL and CD) was defined as the sum of the amplitudes of the tidal constituents M_2, S_2, N_2, K_2, K_1 and $0.5 \cdot Sa$. As from 1987, an extra safety margin was added. During surveys they used a vertical datum that varied between 10 cm and 40 cm below CD, lowest along the southern coast where the astronomical tide is small compared to the meteorological surge. The CD that is used today is LAT, except for the southern part where CD is lower for safety reasons (30 cm in the inner Oslo-fjord and 20 cm from Stavanger to the Swedish border). The difference between the CD calculated in 2000 and the "old" datum used for surveys vas less than 10 cm, and the charts have not been changed.*

UK: *UK currently uses a level of Chart Datum as close to LAT as possible, in accordance with IHO Technical Resolution A2.5. Therefore the statement used on the relevant Admiralty Charts reads “approximately the level of Lowest Astronomical Tide”. To have to establish Chart Datum precisely at LAT would present a significant financial problem to UK as all soundings on charts would have to be amended, and continue to be amended each time the level of LAT was updated. Any subsequent rises in Mean Sea Level (MSL) affecting the true depth of water can be accommodated by the data published in Admiralty Tide Tables (ATT). There would be no requirement to re-adjust the level of Chart Datum until the change in MSL becomes significant in terms of safety to navigation.*

4. Request for further guidance

The TWG has created MSL, LAT and CD surfaces for the North Sea in relation to the ellipsoid that are neither seamless nor fully covering the North Sea area. In order to create common seamless reference surfaces for the full North Sea area, coherent common calculations need to be agreed upon on the full scale of the North Sea and the surrounding bodies of water. The present MS-by-MS approach hampers these activities.

Initiatives like the EU Interreg IVb project BLAST will provide opportunities to create common reference surfaces. The TWG might adopt a role of supervision of the BLAST WP3 activities and implementation of the BLAST WP3 results. This role could include separate decisions on common surfaces for MSL, LAT and CD, either seamless or allowing inconsistencies at the international maritime boundaries.

The NSHC is requested to:
1. note the present state of the reference surfaces for the North Sea area, presented in this Annex;

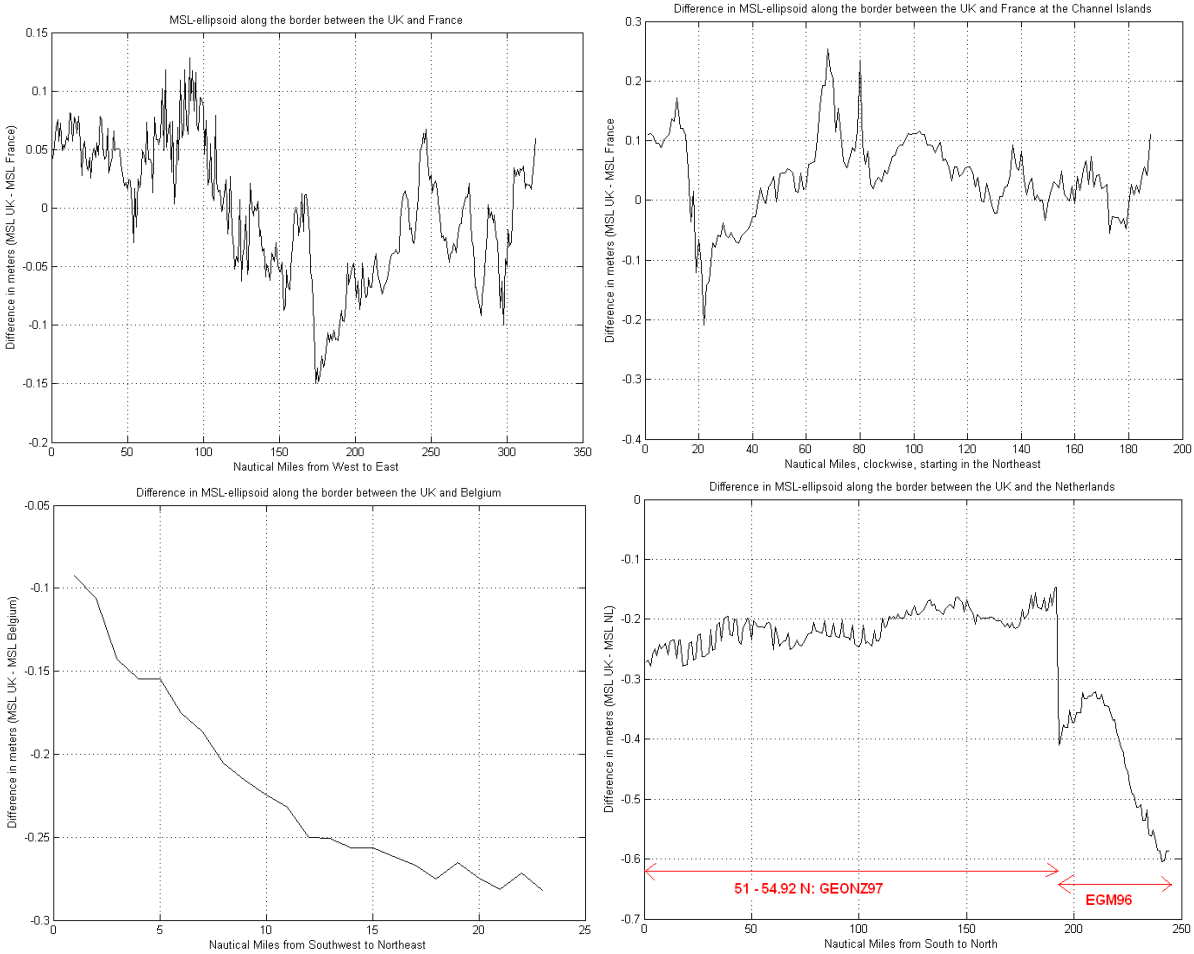
2. discuss potential ways forward to create seamless reference surfaces for the full North Sea area relative to the ellipsoid, based on the presented information;

3. task the TWG with the formulation of recommendations on the creation of such surfaces;

4. task the TWG to adapt their Terms Of Reference and Work Plan accordingly.

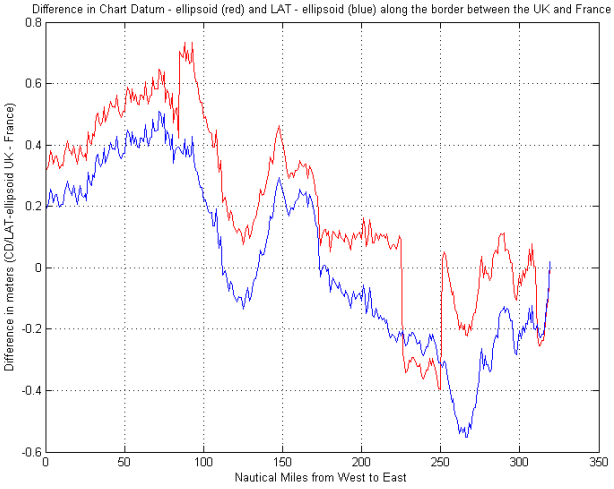
Appendix A.1. Size of international inconsistencies in the MSL surface

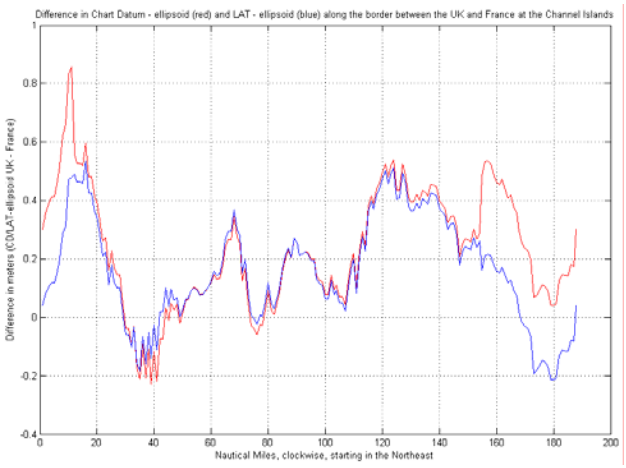
The size of the inconsistencies between BE and NL are negligable. No mutual data is available at the maritime boundaries that are not shown. The horizontal and vertical scales of the graphs differ.

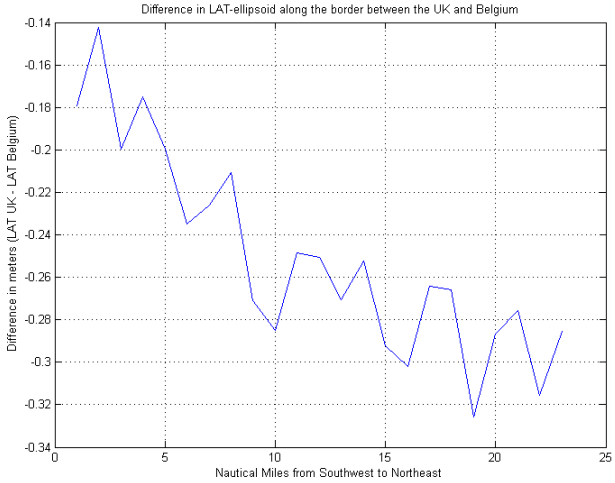


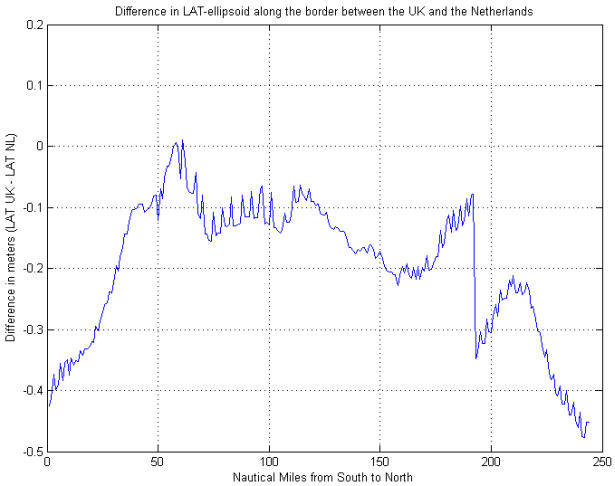
Appendix A.2. Size of international inconsistencies in the LAT and CD surfaces

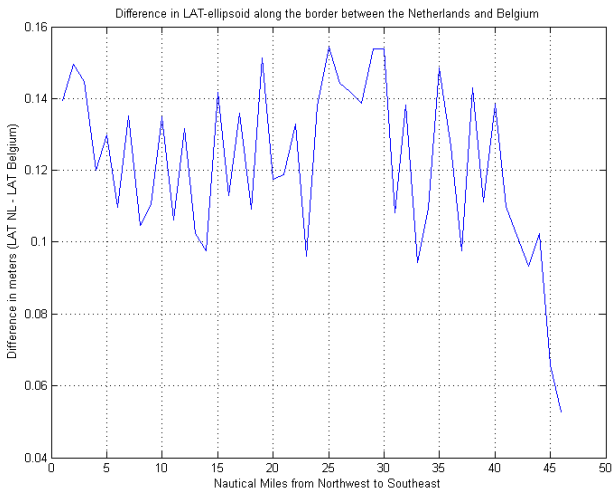
No mutual data is available at the maritime boundaries that are not shown [4]. The horizontal and vertical scales of the graphs differ.

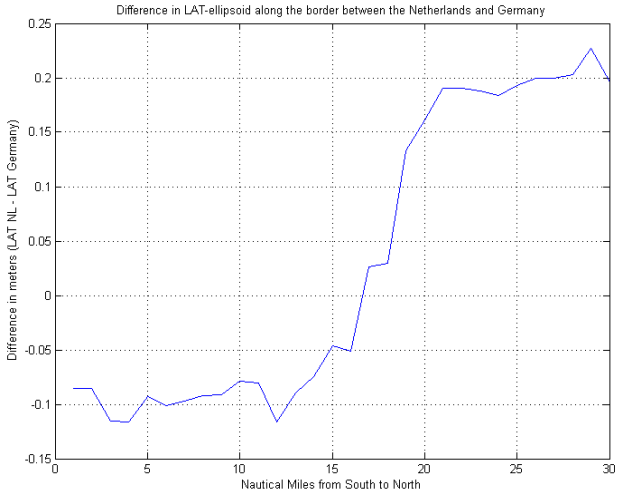








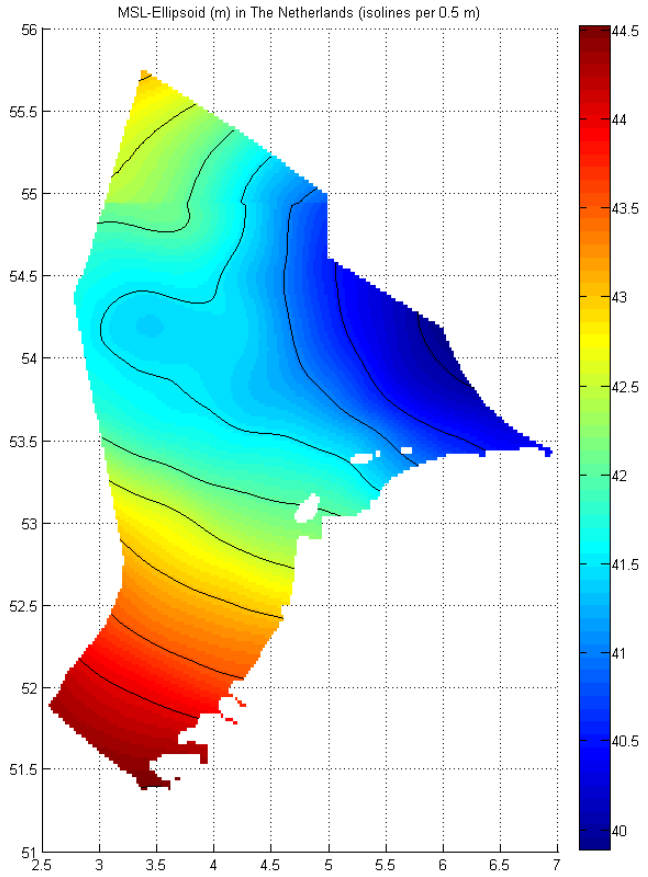


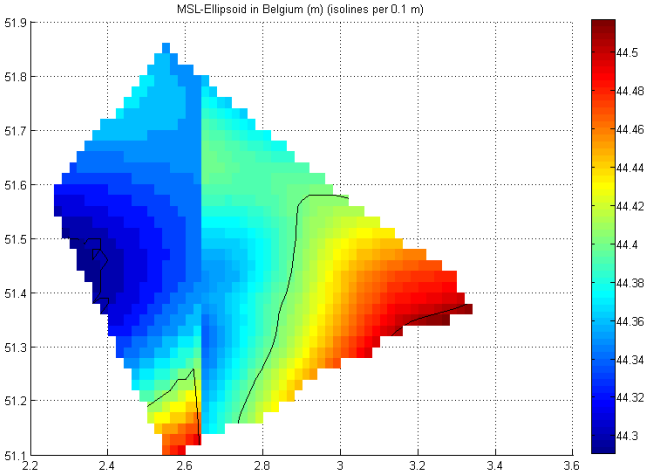


[4] As there is no established maritime boundary between the territorial seas of DE and NL, a new line was created for the purpose of DE/NL data comparison only.

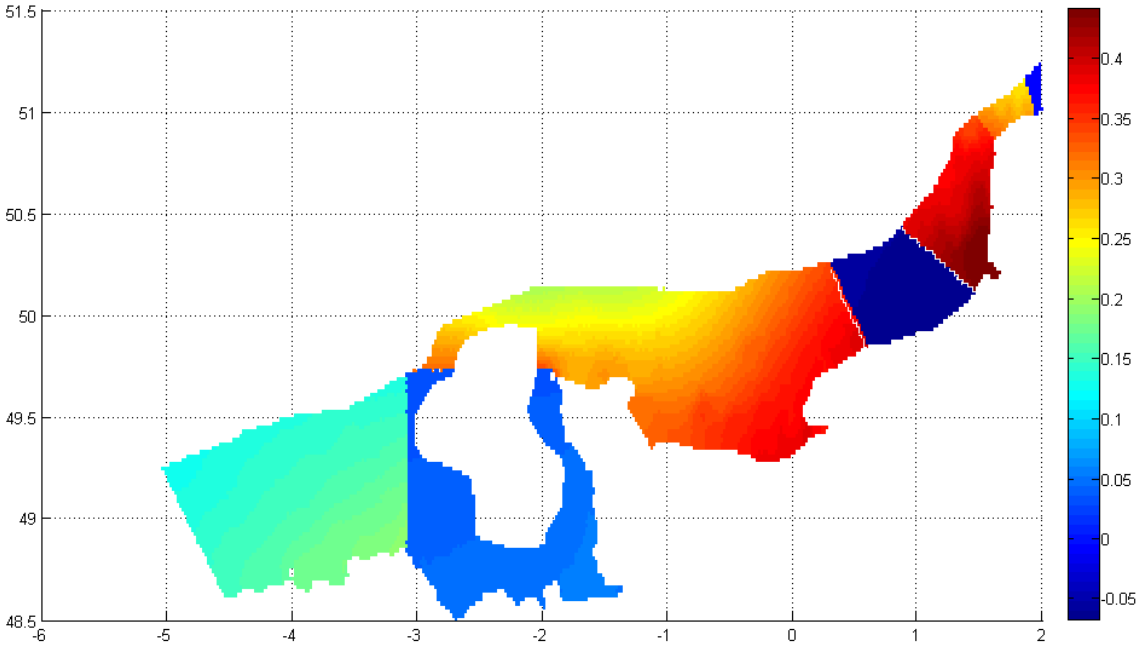
Appendix B.1. Presence of national inconsistencies in the MSL surface

The isoline spacing, horizontal and vertical scales of the graphs differ. Due to that, apparent differences in grid size and effect of the inconistency appear. However, grid size is equal for both the maps, and the maximum size of the inconsistencies between GEONZ97 and EGM96 is larger for NL than for BE.





Appendix B.2. FR zoning in the LAT-CD differences



Appendix C.1. Additional clarifications on LAT calculations by BE

The definition of LAT states that this stands for the lowest astronomical tide. In order to determine this, predictions have to be made for a period that is equal to the nodal cycle, eg 18.33 years. Within the Flemish Hydrography, it was chosen to extend this period to 19 years. The LAT reference surface is determined is by the following steps:

Firstly, predictions are calculated for a period of 19 years for 3 reference stations in harbours.
Secondly, predictions offshore are calculated at a grid with a spacing of 1000 m, using a reduction method equal to the predictions determined in the first step. The core of this method is the relationship between the amplitude and phase of the tide in the reference stations in the harbours on one hand, and the phase and amplitude of the tide at sea on the other hand.
Thirdly, the lowest astronomical tide is determined for this grid.

On the Belgian Continental Shelf (BCS), chart datum has been equal to LAT since the beginning of 2008. There are no additional safety margins. Therefore, LAT equals Chart Datum for the BCS.

Although LAT is based on a calculation of a 19 year cycle, a similar update scheduled period will be handled as for MLLWS. This would imply that an update could be expected in the beginning of 2011. However, the 10 year update schedule does not imply that LAT is fixed in between the 10 year period. Changes in Chart Datum will only be implemented in between the updates if the differences between the old and new LAT surfaces are large enough to be significant. Thus, in case of a few centimetres change, Chart Datum will not be changed.

Appendix C.2. Additional clarifications on LAT calculations by DE

DE makes a distinction between LAT and Chart Datum, but the differences occur in rivers mouths and in some areas close to the coast. Seawards, LAT is Chart Datum. The data (LAT-Ellipsoid) have been recently new computed and extended seaward. Seaward, except in the vicinity of Helgoland, the precision of LAT should slightly decrease.

The used method to define the LAT (CD) surface which results in a seamless distribution of relative corrections (to tidal model) and absolute corrections (to quasi geoid) with the help of reference stations. The methodology is based on interpolation and stochastic methods, on results of a finite element model as well as on tidal analysis. Due to the interpolation, the accuracy decreases at seaward limits.

Appendix C.3. Additional clarifications on LAT calculations by DK

Along the Danish west coast (in the North Sea) the chart datum was MLWS, but in the nautical maps being released from now on DK will refer to LAT. The difference between MLWS and LAT is small. It is about 28 cm close to the German border and decreases to about 4 cm at the most northern tip of Denmark (Skagen). (Our tide tables are changed accordingly). The depth soundings in the Danish part of the North Sea are rather old and so a difference of below 30 cm is small compared to the accuracy of the depths at that time.

The survey effort in the Danish North Sea has been nil and therefore the chart datum surface in the Danish part of the North Sea has not been in focus.

For the west coast ports along the Danish North Sea coast and included in the Tide Tables LAT is computed from time series and used for computing the tidal heights with reference to chart zero (LAT).

We are in contact with the National Space Institute in Denmark which use the GOT 4.7-model for the tide globally. The model include 20 harmonic constants on a grid (½ degr. x ½ degr.) In this way we are able to supply a LAT-surface (with reference to MSL) derived from LAT-computations based on the 20 constants.

Appendix C.4. Additional clarifications on LAT calculations by FR

LAT

LAT is computed using an iterative method based on harmonic constituents (it is not based on a 19-year period predictions) at each port. These levels are published :

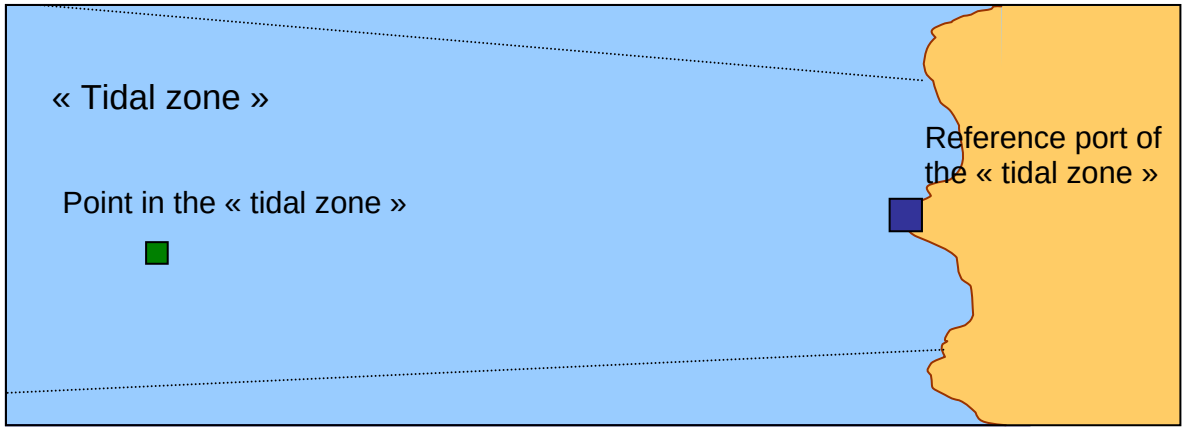
- in french paper tide tables for each reference port of "tidal zones",
- on SHOM website for all ports (reference ports, primary and secondary ports), see RAM product ("Références Altimétriques Marines", Marine Altimetric References) http://www.shom.fr/fr_page/fr_act_oceano/RAM/RAM_P1.htm

Regularly, LAT is updated when new measurements are available.

CD

CD is determined by establishing a relationship (concordance method) between a secondary tide gauge and the tide gauge of the reference port of the "tidal zone". Onshore, CD is connected to ITRS ellipsoid, with 24 to 48h GPS measurements.

In France, CD is ***approximately*** identical to the LAT (Lowest Astronomical Tide). The difference between LAT and CD varies in each "tidal zones". Along french coasts, there are 15 tidal zones, and the difference between LAT and CD is from -5 cm to 50 cm (LAT is generally above CD). French Hydrographic Office changes CD only when differences between LAT and CD become significant.



French coasts are divided in 15 "tidal zones"; in each "tidal zone" CD at a secondary port is determined by "concordance" with reference port of "tidal zone"

Tidal Model

To reduce soundings, SHOM uses a tidal model based on analysis of a hydrodynamic numerical model. After numerical model validation, 1-year simulation is analysed and harmonic constituents are computed. There are adjusted with measurements, and the product is a tidal model (grid with amplitude and phase of each harmonic constituent at each grid point). This tidal model is used to determine CD/ellipsoid in BATHYELLI project, and mainly for soundings reduction.

BATHYELLI

BATHYELLI project is :

- a set of models of reference surfaces in hydrography : MSL, LAT, CD, geoid, IGN69 (terrestrial vertical reference), ITRS ellipsoid.

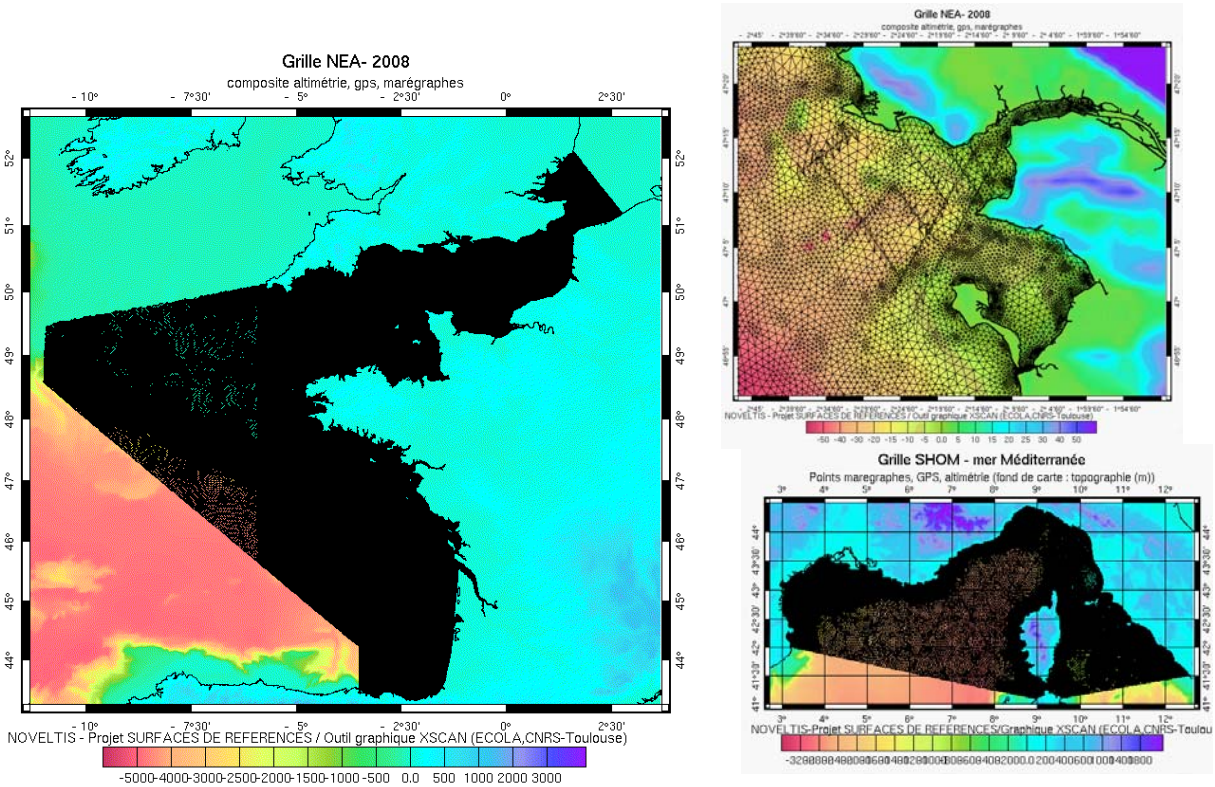
- a software (still in progress) to allow users to change from a vertical reference to another, particularly from a marine to a terrestrial reference.

This project will particularly allow :

- to carry out bathymetric surveys with GPS, avoiding tidal and meteorological corrections,
- to merge land and sea.

2009 BATHYELLI surfaces are now available but will be improved during the two next years. The validation of these surfaces is still in progress, comparing classical surveys and GPS surveys. The software should be soon under development. As soon as surfaces are successfully validated, SHOM will release the models.

For more details on methodology, please look at paper *BATHYELLI project : set-up of CD using altimetry and GPS*.



BATHYELLI grid

Appendix C.5. Additional clarifications on LAT calculations by NL

CD vs LAT:
Chart datum equals latest LAT-realization, no difference. New LAT realizations approximately every 10 year. Maasvlakte 2 land reclamation project might make an early new realization necessary.

LAT vs MSL:
Calculated in 2006 based on a series of hydrodynamic models of Rijkswaterstaat's RIKZ, nowadays part of Deltares: DCSM version 5, Kuststrookmodel fijn, Kustzuid. These models did not yet make a difference between MSL and the geoid (NAP). Estimated uncertainty 7cm (95%). Used hydrodynamic models were state-of-the-art for NCS in 2006. New models and new reclamation project Maasvlakte 2 changes this situation. Future models will also use an explicit reference to either the geoid of MSL.

MSL vs geoid:
Currently no difference, under study of TUDelft project. Future hydrodynamic models will use an explicit reference to either the geoid of MSL.

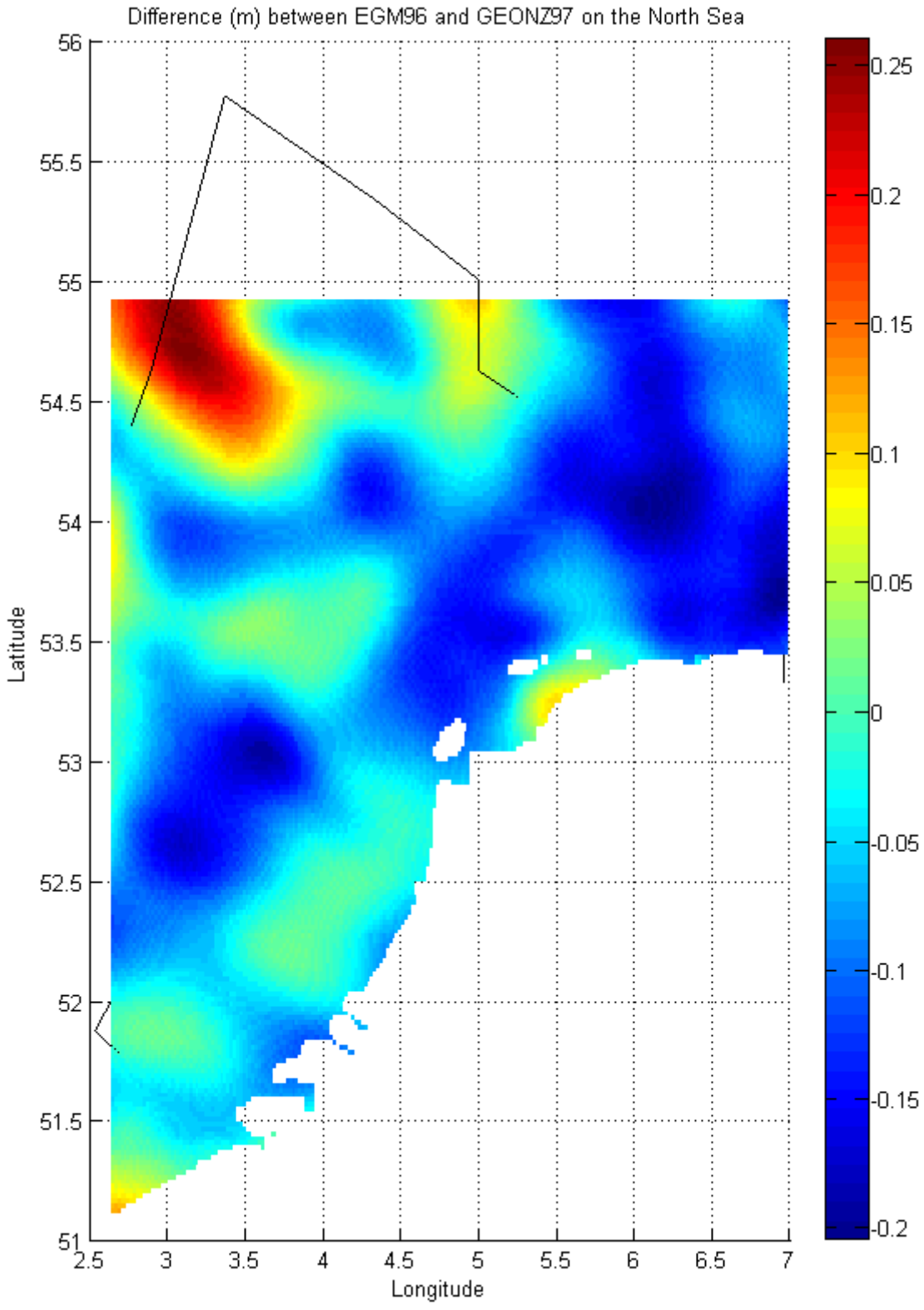
geoid vs GRS80:
GEONZ97 was a preliminary surface, new surface under study of TUDelft project. Claimed uncertainty of GEONZ97 of less than 1dm (95%) now regarded as unlikely. Where GEONZ97 is not available, the EGM96 geoid was used instead. The differences between the two surfaces are given in the map here under. More information on new North Sea geoid at http://www.lr.tudelft.nl/live/pagina.jsp?id=325e7a6f-16cc-4fdc-a123-eb3d2378712f&lang=en.

More information on GEONZ97 in Bollettino di Geofisica Teorica ed Applicata Vol. 40, n.3-4, September-December 1999, pp. 597-602, for Abstract see here under.

A preliminary geoid model for the North Sea from gravimetry and altimetry, GPS and levelling

A. De Bruijne, R. Haagmans and E. De Min

The main goal of the study is to obtain a consistent height and depth reference system in the form of a geoid for the Dutch mainland and marine area. For this purpose a procedure has been developed and tested to combine available gravity data and external data from satellite altimetry, GPS and levelling in an optimal manner. The initial, purely gravimetric geoid is adjusted in longer wavelengths by means of the external geoid data. The preliminary North Sea geoid GEONZ97 has a precision of better than 4 cm at sea and along the Dutch coast. As soon as instantaneous GPS height components in off-shore applications reach a comparable accuracy, tides and meteorological response can be eliminated in an efficient and effective way simply by subtracting the geoid. (source: http://www2.ogs.trieste.it/bgta/provapage.php?id_articolo=300)


Difference (m) between EGM96 and GEONZ97 on the North Sea
Latitude
Longitude
56
55.5
55
54.5
54
53.5
53
52.5
52
51.5
51
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2

Appendix C.6. Additional clarifications on LAT calculations by NO

Definition of Chart Datum in Norway

North of a small island called Utsira (N59°18', E04°53', north of Stavanger) we use LAT as Chart Datum (CD). The amplitude of the astronomical tide is small at the southern coast of Norway and the meteorological surge often dominates the sea level. In situations with high air pressure and wind from north and east the sea level might be below LAT for a week or more. Thus, for safety reasons, we have defined CD to be 20 cm below LAT between Utsira and the Swedish border. In the inner Oslo Fjord CD is 30 cm below LAT. We have not decided how far out from the coast we will use this definition, and we have not discussed our CD with Sweden. I suppose there is a "jump" in CD at the border between Norway and Sweden.

Calculation of LAT

There is not a strict definition of how to calculate LAT. The LAT we use today was calculated in 1999 after a period with much testing and "experimenting". In the Southern Norway, with a small to moderate astronomical tide it is important how you treat the long period constituent. At most of our permanent tide gauges we had 25 years of good quality data and we compared the long period constituents from yearly harmonic analyses. We found that the phase of Sa varied with a standard dev. around 20° and the amplitude with a standard dev. around 2 cm. The phase of the other long period constituents had a more random variation from year to year. The reason is, I suppose, that most of the energy comes from the meteorological input. This is also the case with Sa, but this is a seasonal signal that is more predictable. The amplitude and phase we have used for Sa is a vector average of 25 years, and we have used the same period at all of our tide gauges.

The other harmonic constants were calculated from about 10 years of data, and the same period on all the stations. We used 10 years because all the data were from digital tide gauges with much better quality than the old analog data, the most important is that the timing errors are at a minimum.

To sum up: our calculations of LAT are based on sets of harmonic constants where the only long period constituent is Sa. We have compared the residuals between neighbor harbors using constant sets with and without long period constituents (except Sa). The difference between the residuals are much noisier with the long period constituents than without, and we take this as a "proof" that we have done the right thing.

The Table contains a list of LAT relative to MSL on the tide gauges at the North Sea. All the numbers are in cm.

Name	Lat	Lon	LAT rel. MSL	CD rel. MSL
Viker	59° 02'	10° 57'	-31	-51
Oscarsborg	59° 41'	10° 37'	-35	-65
Oslo	59° 54'	10° 44'	-36	-66
Helgeroa	59° 00'	09° 52'	-30	-50
Tregde	58° 00'	07° 34'	-25	-45
Stavanger	58° 58'	05° 44'	-45	-65
Bergen	60° 24'	05° 18'	-90	-90
Måloey	61° 56'	05° 07'	-113	-113
Aalesund	62° 28'	06° 09'	-120	-120
Kristiansund	63° 07'	07° 45'	-128	-128

Appendix C.7. Additional clarifications on LAT calculations by UK

Lowest Astronomical Tide (LAT)
UK currently uses a level of Chart Datum as close to LAT as possible, in accordance with IHO Technical Resolution A2.5. Therefore the statement used on the relevant Admiralty Charts reads "*approximately the level of Lowest Astronomical Tide*". As described in the preliminary pages of Admiralty Tide Tables (ATT), LAT is defined thus:
LAT (Lowest Astronomical Tide). *The lowest level which can be predicted to occur under average meteorological conditions and under any combination of astronomical conditions; this level will not be reached every year. LAT is not the extreme level which can be reached, as storm surges may cause considerably lower levels to occur.*
Therefore LAT is a predicted level that is obtained from an investigation of a 19-year period of tidal predictions at a specific port. These levels are published for Standard Ports in Table V of ATT, and are also included in the digital software TotalTide. TotalTide also displays LAT for Secondary Ports (again based on a 19-year prediction cycle), but these values should be treated with greater caution as the quality of the underlying data for Secondary Ports is not always as good as a Standard Port.

Chart Datum (CD)
As described above, UKHO considers CD to be ***approximately*** the level of Lowest Astronomical Tide. The differences are given in the map here under. The traditional surveying procedures which are followed when establishing CD in the field are as follows (*Source: Admiralty Tidal Handbook No. 2, NP122(2), Datums for Hydrographic Surveys and other related subjects*):-

Recovering a former datum
In the case of areas which have been previously surveyed, and which are being re-surveyed, the original datum should be used. Except in the case of very old surveys, the recovery of the former datum should not present much difficulty; the level of Chart Datum below one or more benchmarks, cut by the original surveyor, is usually known. In this case, re-establishment of the datum is simply a matter of levelling between the bench mark and the pole, and establishing datum at the known level below the bench mark.

Sometimes the only recorded bench mark has been destroyed but, when the original connection was made, connection may also have been made to the Land Levelling System (on the mainland of the British Isles, this is
Ordnance Datum, Newlyn). The original datum can then be recovered from any other bench mark included in the levelling system.

If no benchmarks are available, the datum may be recovered from its known connection to the mean level of the sea. In Part II of Admiralty Tide Tables, the value of ML (Mean Level) is given for places where it is known. In such cases, the original datum can be recovered, approximately, by taking observations for Mean Sea Level and establishing datum, so that ML corresponds with the figure given in Admiralty Tide Tables.

TRANSFER OF DATUM

General considerations

On an open coast, of which an original survey is being carried out, the surveyor's objective should be to establish a datum which, at the beginning of the survey, is suitable, and then to transfer the datum along the coast. The object of the transfer is to ensure that, when the tide falls to datum in one place, it falls to datum at all other points in the survey. This, in its turn, ensures not only that the survey will give a realistic picture of the sea bed but also that, where two areas with different datums join, the soundings will agree.

In most cases today the survey commences in an area close to one previously surveyed and so the original datum already exists. If the latter is satisfactory, datum should be transferred at intervals along the coast. The length of the interval between tidal stations will vary with different tidal conditions. Where tidal conditions alter rapidly, it may be necessary to have tidal stations every mile or so; generally speaking, however, on an open coast where tidal conditions alter only gradually, a maximum distance between stations of about ten miles should be the aim.

Re-Reference Calculations

Traditionally, tidal data collected at sites away from shore-based locations for which tidal data already existed was 'transformed' to Chart Datum by the use of co-tidal charts. So it would be true to say that until relatively recently UKHO has not routinely undertaken any re-calculations or transformations of tidal data collected with respect to a particular datum and transformed it another datum over a wide area.

Vertical Offshore Reference Framework (VORF)

VORF is:-

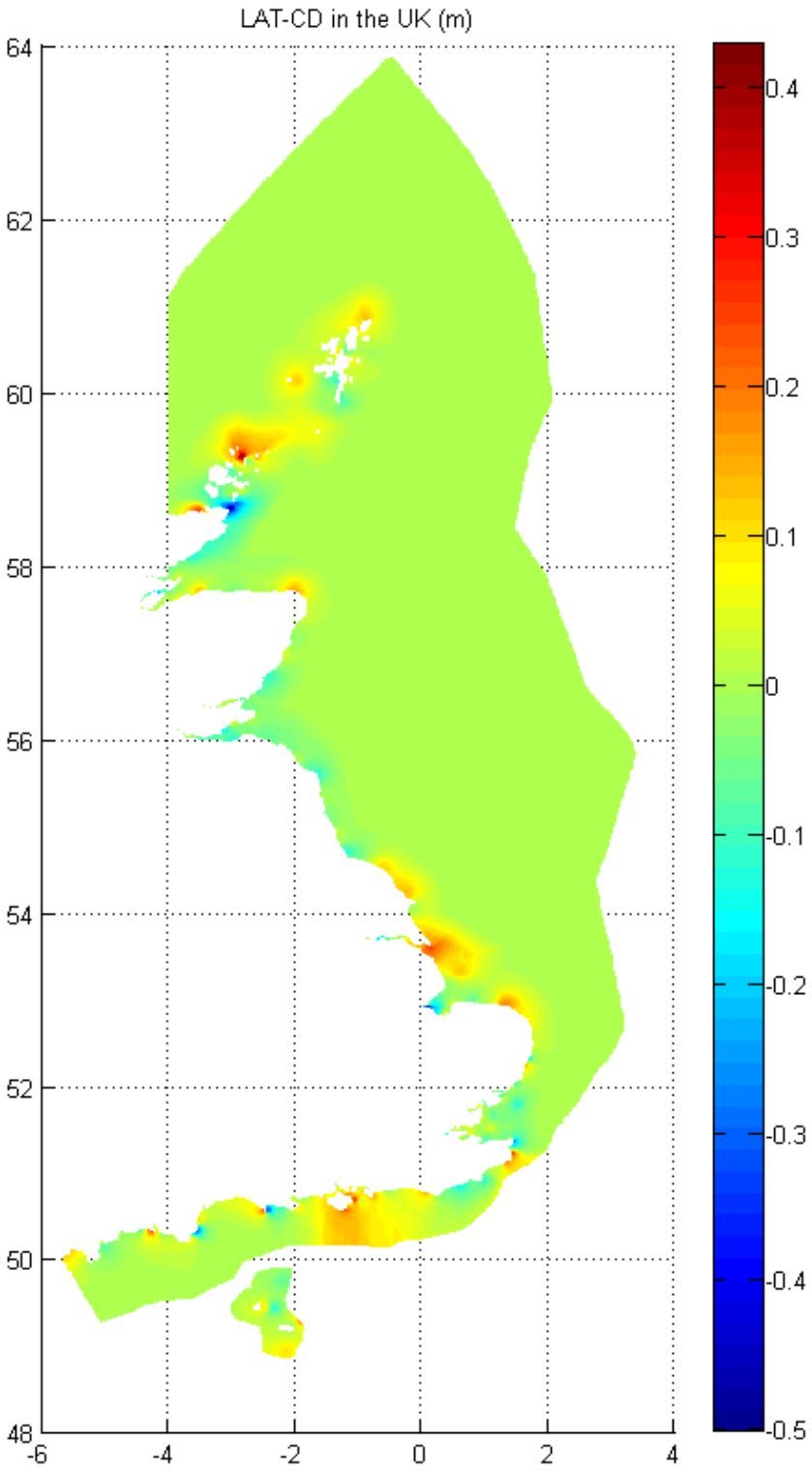
1. A set of mathematical models of the major surfaces used in the current and future charting of UK home waters.
2. A suite of software utilities allowing the transformation of mapping and positioning data between the VORF surfaces.

So VORF will provide the facility for data collected with respect to one surface to be transformed to another surface as and when required (on the assumption that the surfaces are included within the VORF software).

For more detail on the VORF project see:-
http://www.cege.ucl.ac.uk/research/geomatics/vorf
http://www.agi.org.uk/SITE/UPLOAD/DOCUMENT/Event_Presentations/20070423_MCZM/JonathanIlliffe.pdf

VORF has completed the development stage, and is undergoing final testing and in situ validation. UKHO will then give consideration to releasing the model (and software) once the testing has reached a successful conclusion.

To compliment the testing UKHO has been working with a number of survey organisations to provide extra validation of the model, in exchange for use of the model over a given area on a *quid pro quo* basis. These activities mean that UKHO supply the model for a defined area, and the survey company compares the GNSS derived results against a tide gauge within the area.


LAT-CD in the UK (m)
64
62
60
58
56
54
52
50
48
-6
-4
-2
0
2
4
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5