3D Geomodeling for Europe

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Deliverable 1.2

Documentation Report NLS3D: A harmonized 3D model of 10 main Cenozoic and Mesozoic horizons

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GENERAL INTRODUCTION

In work package 1 (WP1) of 3DGEO-EU Lower Saxony and the Netherlands are involved. Lower Saxony is represented by the Authority for Mining, Energy and Geology (Landesamt für Bergbau, Energie und Geologie, LBEG) and the Netherlands are represented by the Netherlands Organisation for Applied Scientific Research-Geological Survey of the Netherlands (TNO). Both institutions are experienced in three dimensional modelling of the subsurface.
In task 1.2 the harmonization of existing 3D models along the border has been realized (see Figure 1).

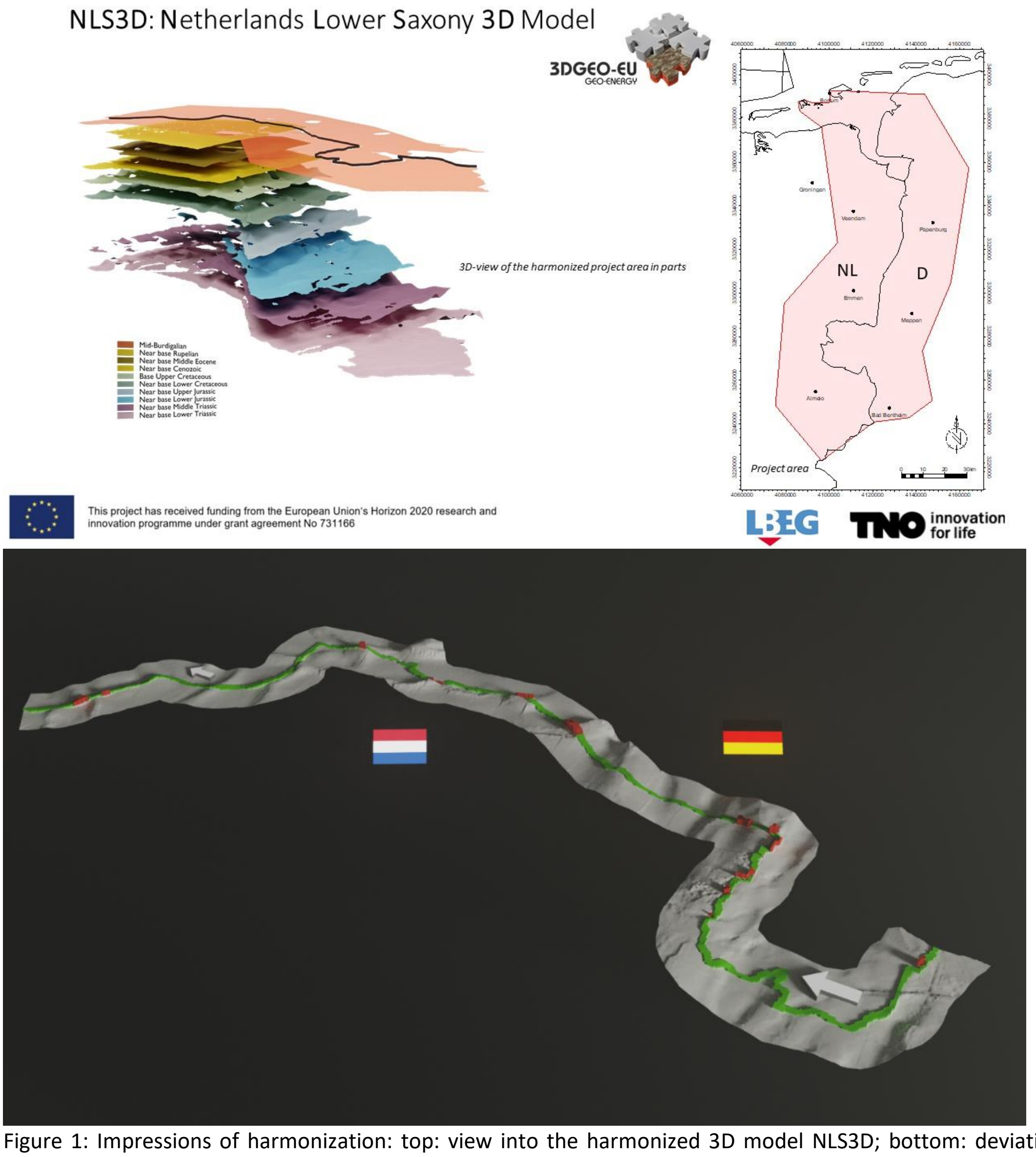

Figure 1: Impressions of harmonization: top: view into the harmonized 3D model NLS3D; bottom: deviation of corresponding horizons; the red colour shows areas where the maximum of accepted deviation is exceeded and the green colour shows areas within the maximum deviation.

This report is a documentation of task 1.2 to provide all information for understanding the new harmonized model “NLS3D”.

- metadata
- input data, corresponding horizons
- methodology of harmonization
- faults
- lessons learned

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1 NEW 3D MODEL "NLS3D"

Comparison of one existing 3Dmodel in Lower Saxony (GTA3D) and two existing 3D models in the Netherlands (DGM deep 5.0 and DGM-NNL) lead to the conclusion, that a new harmonized 3D model "NLS3D" could be created which is consisting of 10 harmonized horizons with a Cenozoic/Mesozoic age. The name "NLS3D" is composed of the abbreviation for the Netherlands "NL" and the abbreviation for Lower Saxony "LS" and the indication of the dimensionality "3D" - NLS3D.

Table 2 documents the origin of data that has been used to derive the new harmonised horizons of the new model. The existing 3D models are containing more modelled horizons (see Inventory Report D1.1 of 3DGEO-EU; Witthöft et al., 2018). For "NLS3D" only corresponding horizons of the existing models on both sides of the border have been used.

1.1 METADATA

- **Name:** NLS3D – harmonized geological 3D model of deeper underground along the national border between Lower Saxony and the Netherlands
- **Data structure:** Regular grids with a 200m x 200m cell size
- **Coordinate system:** EPSG:3034 – ETRS89 / ETRS_LCC
- **Software:** Petrel© E&P Software platform by Schlumberger
- **Editing status:** done
- **Date of publication:** July 2021
- **Contact for information:**

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- **Online availability:** EGDI: http://www.europe-geology.eu/
  LBEG: https://www.lbeg.niedersachsen.de/startseite/
  TNO: https://www.dinoloket.nl/ and https://www.nlog.nl/en
- **Dissemination format:** ASCII files
- **Data format:** multidimensional, digital representatives of objects (modelDigital)
- **Topic:** Geosciences (geoscientific information)
- **Keywords INSPIRE:** Geology
- **Keywords GeoERA:** governance, geo-referenced data, view service, coverage access service, geological model, cross-border, chronostratigraphic unit, earth science
- **Project name:** 3DGEO-EU
- **Spatial scope:** European
- **Limitations on public access:** CC
- **Geometry type:** Bodies (solid)
- **Height system:** NAP and NHN
- **Reference level:** dataset, model
- **Languages:** English

- **RGB colours**

Table 1: RGB colours for the ten horizons.

Horizon	R	G	B
NLS3D 01 Near base Lower Mid Miocene	215	180	20
NLS3D 02 Near base Rupelian	245	224	173
NLS3D 03 Near base Middle Eocene	244	176	132
NLS3D 04 Near base Cenozoic	204	102	51
NLS3D 05 Base Upper Cretaceous	50	150	0
NLS3D 06 Near base Lower Cretaceous	70	110	0
NLS3D 07 Near base Upper Jurassic	51	204	204
NLS3D 08 Near base Lower Jurassic	0	130	210
NLS3D 09 Near base Middle Triassic	140	50	255
NLS3D 10 Near base Lower Triassic	230	90	15

1.2 HARMONIZATION

At the beginning of the project with the comparison of the already existing 3D models it became clear that despite a different method for 3D model creation, the results were similar and harmonizable. Especially the large geological structures were visible on both sides of the border and could be correlated. This made it possible to harmonize the models.
It also became clear that there will be areas that could not be harmonized. E.g. because the input data density in the original models was too low in some areas, different reflectors were picked in the interpretation of the 2D seismic data, or that the geological concept for the formation of the structures was different, etc.
In order to maintain the idea of pure harmonisation, it was decided to preserve these discrepancies and not to re-model these regions. Therefore, it was not possible to harmonize the faults of the models without reinterpreting the data (see chapter 1.5).

1.2.1 INPUT 3D MODELS

For the harmonization of the cross-border lithostratigraphic horizons, depth grids from three models have been used:

- GTA3D (DE)
- DGM-Deep (NL)
- DGM-Northern Netherlands (DGM-NNL) (NL)
- Remodelled horizons (Near Base Rupelian, Near Base Lower/Middle Miocene)

The input models and their horizons were presented and discussed in detail in the Inventory Report (Witthöft et al., 2018). The Inventory Report can be downloaded from the homepage of the GeoERA project (https://geoera.eu/3DGEO-files/3DGEO-EU-D1.1-Inventory-report.pdf).

1.2.2 REMODELLED HORIZONS

One of the deliverables to be delivered in this project by the LBEG are 2 newly modelled horizons: Near Base Lower/Middle Miocene and Base Rupel Formation (FM). Remodelling in the southern part of the project area (see red rectangle in Figure 2) has been carried out in a different way and the data were used for harmonization. The improvement in quality of the remodelling and the differences to the GTA3D horizons can be read in chapter 1.3.

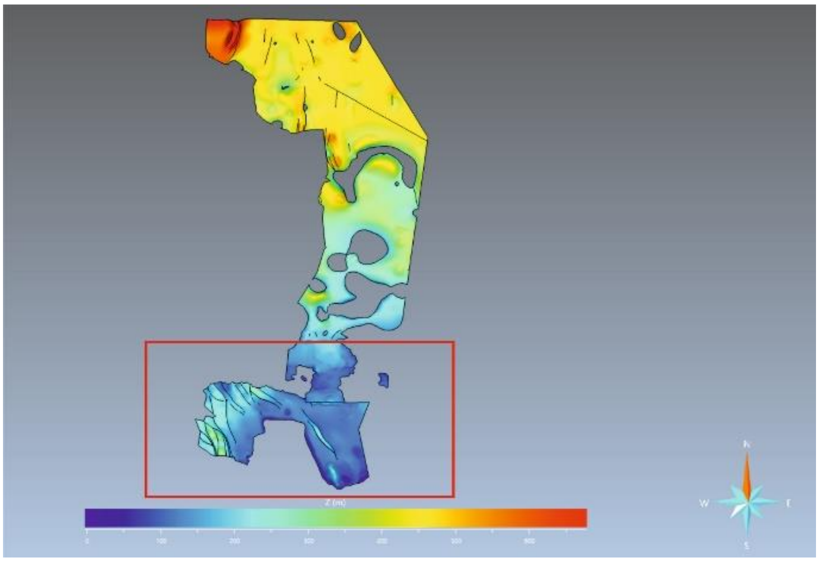


Figure 2: Remodelling of Near Base Lower/Middle Miocene and Base Rupel FM in Lower Saxony. The red rectangle shows the area that was remodelled with SubsurfaceViewer.

For the remodelling of the southern part a different approach was chosen than for the creation of the GTA3D. The remodelling is mainly based on drillings and linked cross-sections.

Approximately 4000 boreholes were used for processing, of which about 1500 reach deeper than the base of Cenozoic. The remaining boreholes are hydrogeological, shallow geothermal and geoengineering boreholes, most of which do not reach Neogene/Paleogene strata. Most of these wells were correlated via linked cross-sections. A total of 136 cross-sections were made. In addition to the two horizons, the main faults of the area were remodelled based on the GTA structural. The software SubsurfaceViewer (R) MX Version 7.2.14 was used for this work.

For the remaining area Base Rupel FM was taken from TUNB model (BGR 2021) and Near Base Lower/Middle Miocene were remodelled based on wells, structural information and 2D seismic in GOCAD.

1.2.3 OVERVIEW OF 10 HARMONIZED HORIZONS OF NLS3D

The 3D model NLS3D is composed of 10 lithostratigraphic horizons. Detailed description of names, a description, approximate age, corresponding input horizons and the source 3D models is given in Table 2. For the 4 cenozoic layers a detailed description is given in Figure 3. This figure shows stratigraphic positions of harmonized input layers for onshore area (NL) and NW Germany.

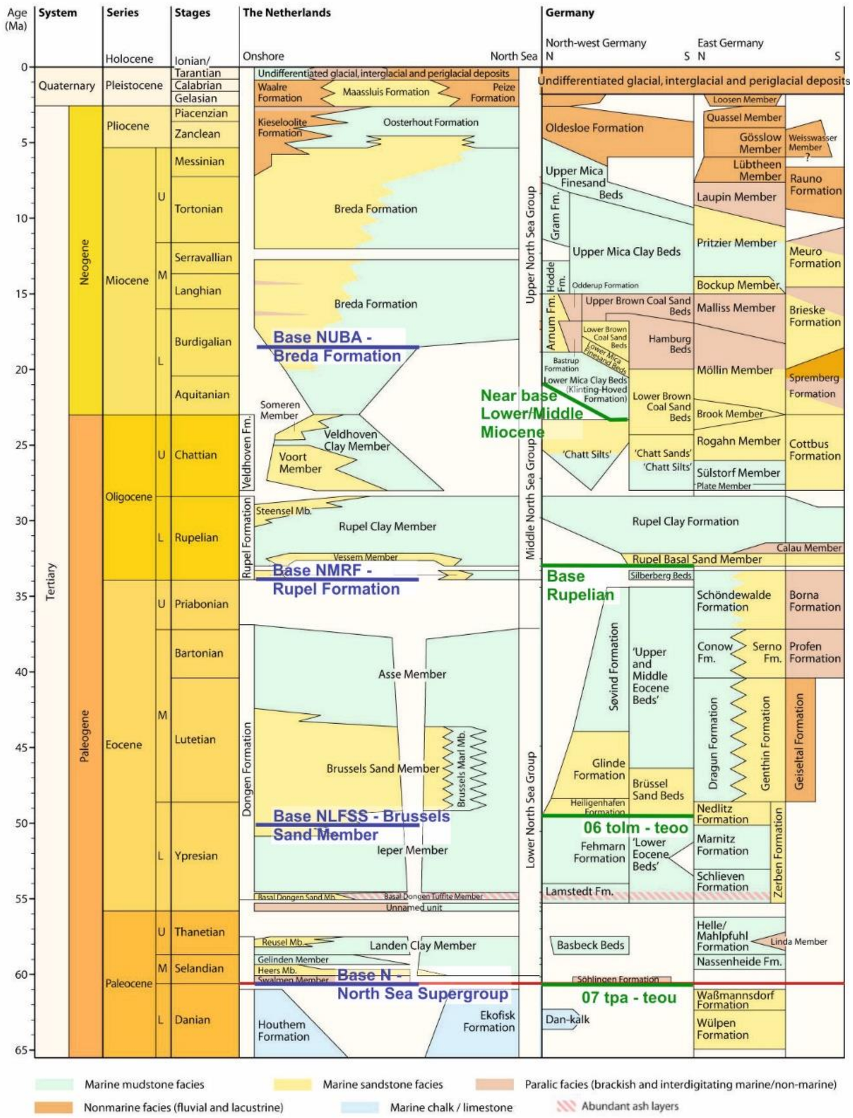


Figure 3: Tectonostratigraphic chart for Cenozoic (modified after (Doornenbal and Stevenson, 2010)). The Blue lines show the input horizons of the Netherlands. Green lines show input horizons of Lower Saxony.

No	Name of the harmonized lithostratigraphic horizon	Description	App. age (Ma)	NL code	German code	3D model source NL	3D model source DE	Remark
1	Near Base Lower/Middle Miocene	Early Miocene Unconformity-EMU (NL) Near base Lower/Middle Miocene (NI)	18	Base NUBA - Breda Formation	Near base Lower/Middle Miocene	DGM deep 5.0	remodelling	remapped in Lower Saxony
2	Near Base Rupelian	Base Boom (base clay layer) in Rupel Formation (NL) and Base Rupel Formation (NI)	32	Base NMRF - Rupel Formation	Base Rupel	DGM-NNL	remodelling	remapped in Lower Saxony
3	Near Base Middle Eocene	Base Brussels Sand	51	Base NLFSS - Brussels Sand Member	06 tolm-teoo (teom-tolu)*	DGM-NNL	GTA3D	
4	Near Base Cenozoic	Top Danian or top of the Chalk Group	62	Base N - North Sea Supergroup = base NLLFC- Landen Clay Member	07 tpao-teou	DGM deep 5.0	GTA3D	
5	Base Upper Cretaceous	Base of the Chalk Group (base Cenomanian)	101	Base CK - Chalk Group	08 kro (Cenoman - Danian)	DGM deep 5.0	GTA3D	
6	Near Base Lower Cretaceous	Approximately near base Ryazanian; may correspond to an unconformity	140	Base KN - Rijnland Group	09 kru (marine L. Cret. - Oberalb)	DGM deep 5.0	GTA3D	
7	Near Base Upper Jurassic	This horizon corresponds to a level varying from the Callovian to the base of the Oxfordian.	164	Base S - Upper Jurassic groups	10 jo-Wd (Oxford - Wealden)	DGM deep 5.0	GTA3D	seismic interpreted horizons were picked on different stratigraphic positions
-	Near Base Middle Jurassic	This level corresponds to the top of the Lias Group (base West Sole Group and equivalents in the UK; top of the Posidonia Shale Formation in the Netherlands) and is a marked unconformity over much of the area	176	Base ATPO - Posidonia Shale Fm	11 jutco-jmclo (U. Toarc - highest Dogger)	DGM deep 5.0	GTA3D	seismic interpreted horizons were picked on different stratigraphic positions. This horizon was not incorporated into the NLS3D model due to too big differences at the border
8	Near Base Lower Jurassic	Base of the Lias Group. This level corresponds to the mudstone/ sandstone boundary in the upper part of the Rhaetian, which is often an unconformity	201	Base AT - Altena Group	12 juhe-jutcu (Hettangium - L. Toarc)	DGM deep 5.0	GTA3D	seismic interpreted horizons were picked on different stratigraphic positions
9	Near Base Middle Triassic	Base of the Röt evaporites	247	Base RN - Upper Germanic Trias Group	14 so-m (U. Buntsandstein - U. Muschelkalk)	DGM deep 5.0	GTA3D	
10	Near Base Lower Triassic	Base of the Buntsandstein	253	Base RB - Lower Germanic Trias Group	15 su-sm (Lower - highest M. Buntsandstein)	DGM deep 5.0	GTA3D	

Table 2: Names of the 10 harmonized lithostratigraphic horizons of the new model NLS3D and their corresponding horizon names in the existing 3D models in the Netherlands (NL) and Lower Saxony (NI).

* name is not correct according to the stratigraphic units which are represented, this layer represents stratigraphic units teom-tolu

1.2.4 SEISMIC CHECK OF CROSS-BORDER GEOLOGIC STRUCTURE

At several points along the border, the Dutch and German models are not in agreement. In order to assess the geological structure and make a decision about the feasibility of harmonization at these points, seismic lines on both sides of the border have been compared (see Figure 4).

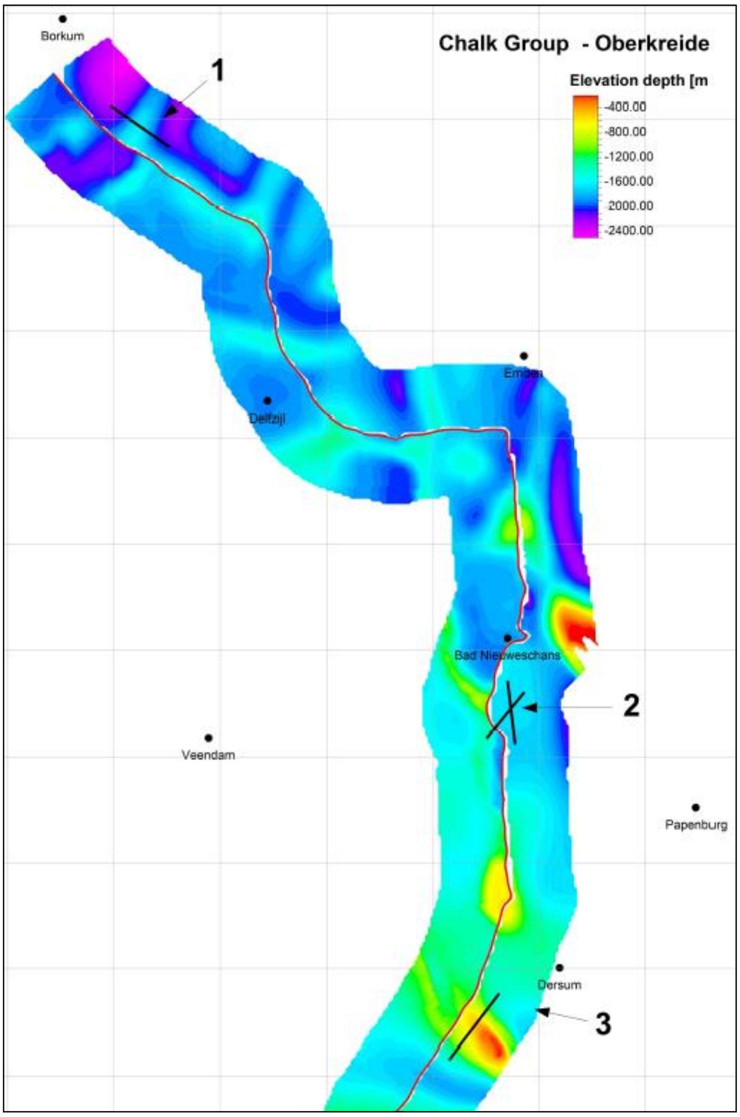


Figure 4: Overview of the three sites of seismic checks, based on deviation along the border; shown for horizon Base CK-Chalk Group and Base 08 kro.

The reason why the model grids might differ at the border in terms of geologic structure could indicate whether or not an area is suitable for harmonization. Three areas were tested for geologic structure with different results.

The first site (Figure 4), in the northern part of area, shows inconsistency in terms of salt structures and faults (Figure 5). The structures are present in both grids but they are misaligned; on the German side the structures are skewed relative to the location of the structures on the Dutch side.

However, according to both Dutch and German seismic lines and surveys, both the Dutch and German grids are conformable to the seismic data. The difference between both grids remains unexplained and harmonization of this area is therefore not feasible.

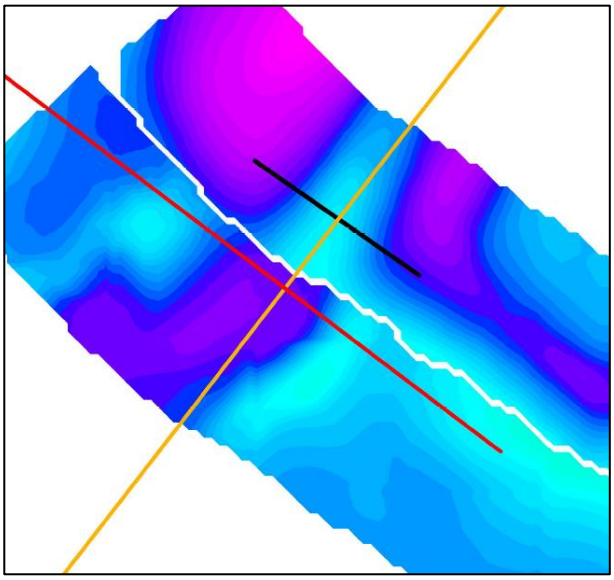


Figure 5: Salt structures in the northern part of the project area (site 1).

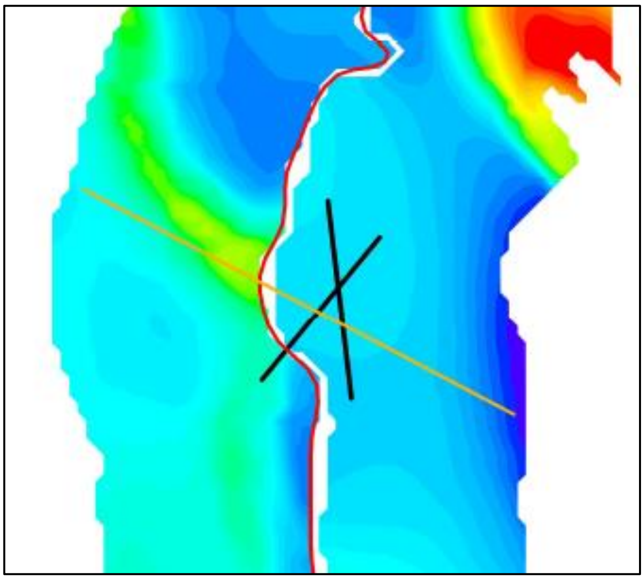


Figure 6: A ridge-like salt structure on the west side of the border (site 2).

The second site (Figure 4) is a ridge-like salt structure on the west side of the border (Figure 6). This structure may have a side branch that continues into Germany. The Dutch Blijham 3D seismic survey (L3NAM1994C) covers a small part of the German border area. According to this seismic survey, it appears that there is no significant salt structure on the German side. This has been confirmed by checking German seismic lines. It is therefore possible to harmonize this part, despite the large difference between the grids at this location, by letting the Dutch grid prevail above the German grid in this area.

The third site (Figure 4) shows on the Dutch side the salt ridge, which is characterized by a collapsing structure in the Mesozoic overburden (Figure 7). This structure can clearly be seen on perpendicular lines of the Blijham 3D seismic survey (L3NAM1994C). This collapsing structure is not present in the German grids. A check of a seismic line on the German side of the border confirmed that there is no collapse of the salt structure in that area. However, the faults associated with the collapsing structure are observed. Since the transition between the collapsed and the non-collapsed salt structure is not observed, this area cannot be harmonized.

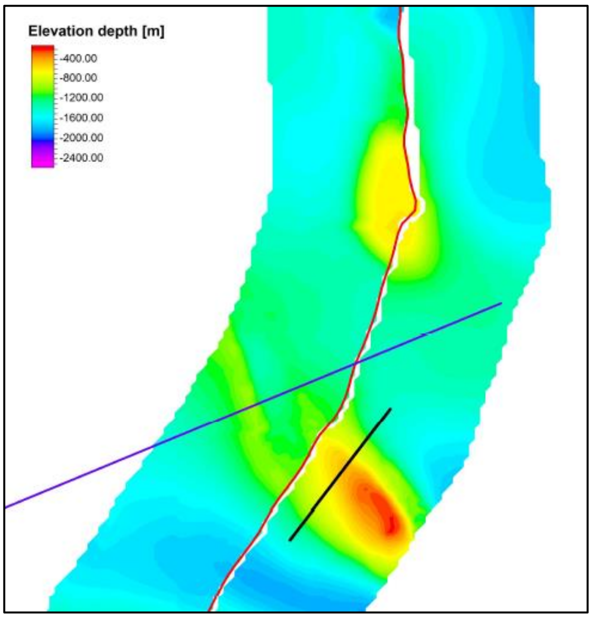


Figure 7: Collapsing structure on the Dutch side of the border (site 3).

1.2.5 METHODOLOGY OF HARMONIZATION

For each corresponding horizon, the depth differences between the two horizons along the border have been calculated (ΔZ). This has been done by extrapolating the grids with two grid-cells and calculating the difference between the overlapping cells, resulting a difference grid (Figure 9). The difference grid is subsequently divided by the average depth of the corresponding Dutch and German grids. The average depth is given by:

$$Z_{average} = Z_{NL} - \frac{Z_{DE} - Z_{NL}}{2}$$

For each stratigraphic horizons a fixed deviation percentage ($grid\ dev\ \%$) is determined that would serve as a harmonization threshold (see chapter 1.2.6). The decision to harmonize an area is determined by whether or not this grid specific fixed deviation percentage is exceeded by the calculated deviation percentage of an area ($calculated\ dev\ \%$), given by:

$$calculated\ dev\ \% = \frac{\Delta Z}{Z_{average}}$$

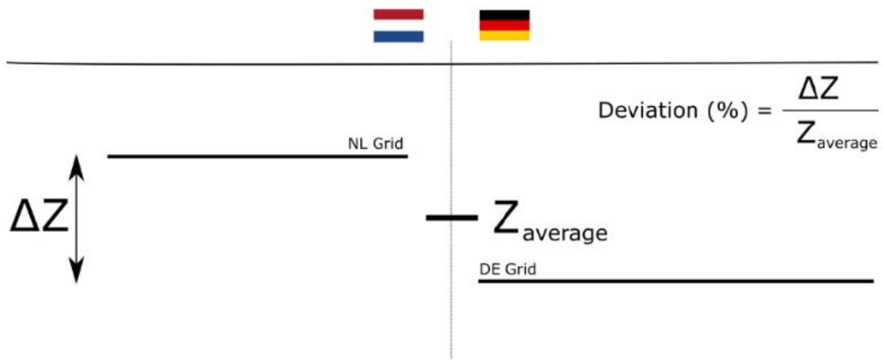


Figure 8: Calculation of percentage of deviation between corresponding horizons.

Corresponding grids will not be harmonized in areas for which the deviation percentage exceeds the horizon-specific deviation percentage.

$$Harmonize \Leftrightarrow calculated\ dev\ \% < grid\ dev\ \%$$

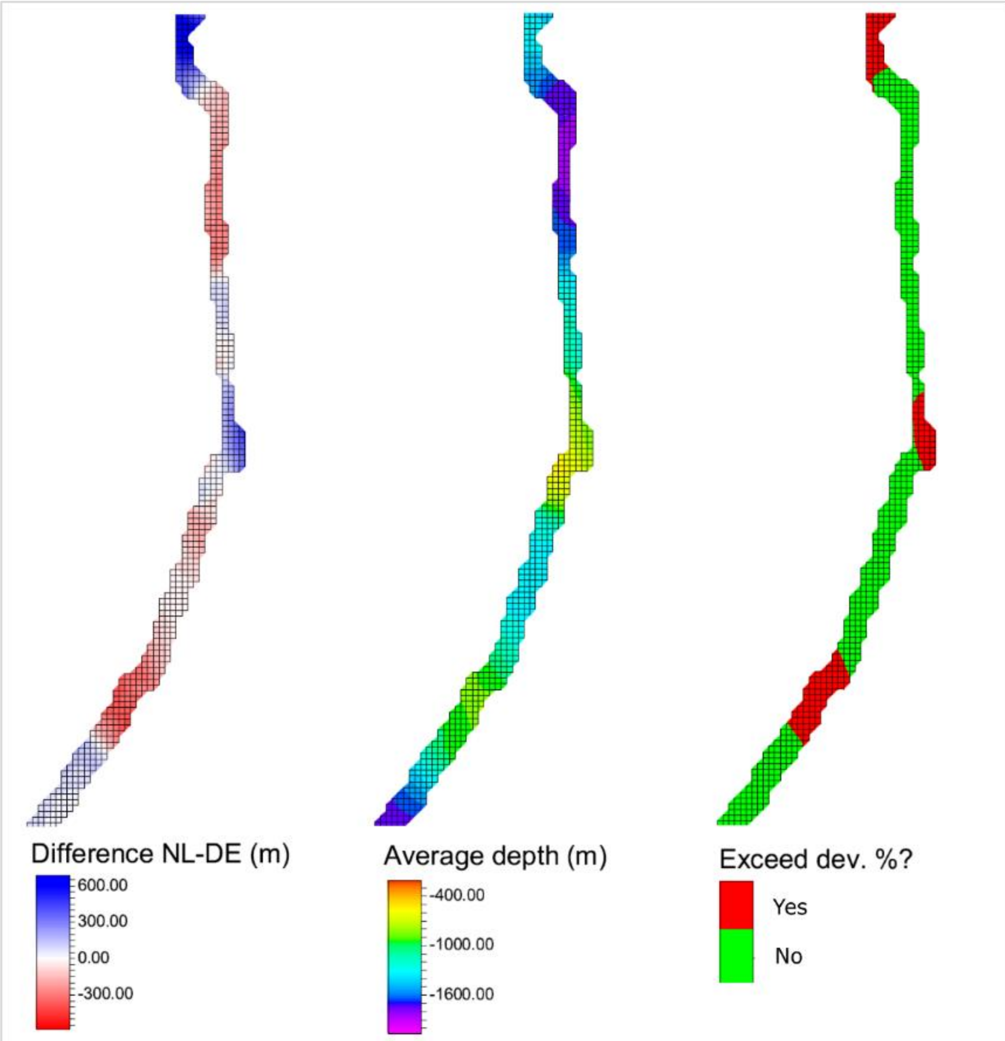
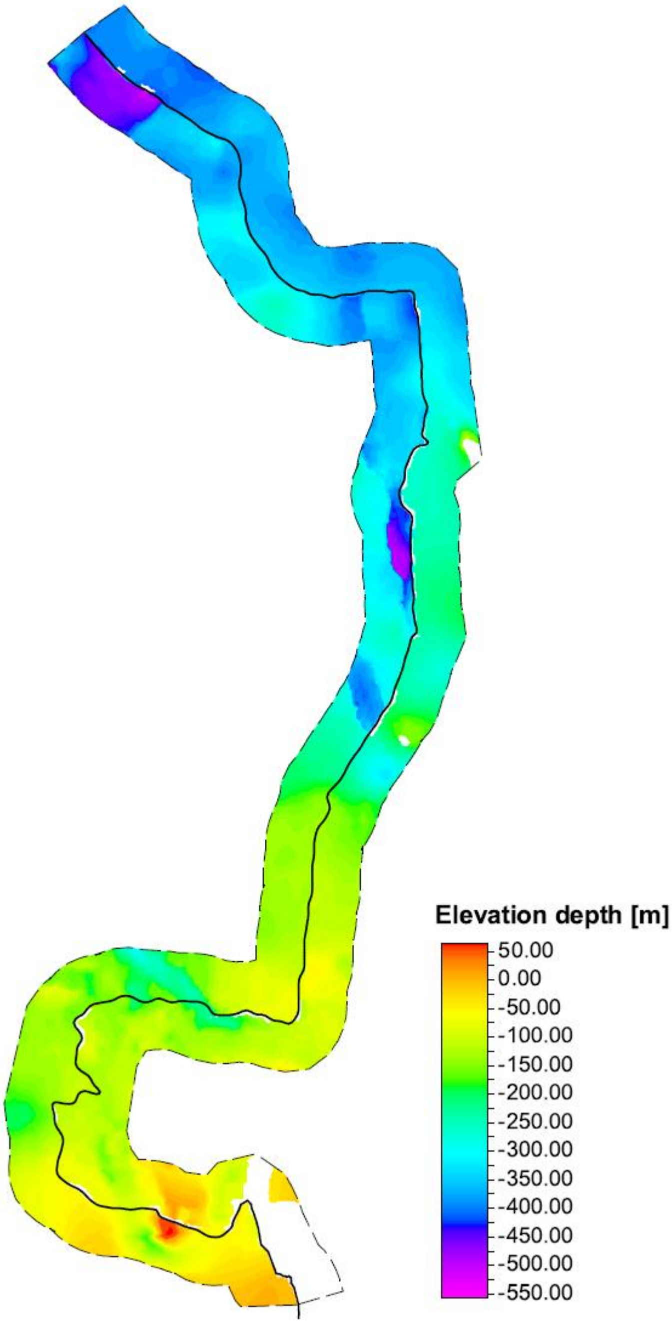


Figure 9: Difference, average depth (m) and exceeded deviation percentage (%?) maps for a portion of the base Chalk Group.

1.2.6 DETAILED REPORT OF HARMONIZATION FOR CORRESPONDING HORIZONS

The following tables show the results of the harmonization. For each harmonized horizon, the new name will be indicated and the horizons of which it is composed. Then follows the illustration of a strip of the new harmonized horizon along the border - the colour coding shows the depth of the horizon. Black line traces the national border, white areas in close vicinity may indicate areas where, based on our assumptions, harmonization should not take place.
The following column shows the selected percentage of deviation (grid deviation (%)), which defines the section of the areas to be harmonized.
The next column compares three different percentage values of the deviation, areas with exceeded percentage of deviation are represented in red, green areas fall below percentage of deviation. This makes it easier to understand that the percentages for grid deviation were not chosen arbitrarily, but that exactly the value was chosen which makes the largest area of the area harmonizable without making the percentage of the deviation too large. Often a higher percentage of deviation has no effective benefit on the extension of the area to be harmonized.
The next part shows on the one hand the histogram of depth difference of the input models and on the other hand the histogram deviation distribution. The black bars show the selected percentage range of the deviation in decimal numbers.
This is followed by a description for the corresponding horizon of why the deviation occurs in this area. This can be due to different causes or combinations of causes: e.g. differences in velocity models, differences in the way the seismic horizons were picked, dipping of the horizons, etc. The main deviations of the horizons can be seen at the salt structures and fault systems, perhaps the faults and subsurface structures on both sides of the border are modelled differently.

Table 3: Documentation of deviation and harmonization of Near base Lower/Middle Miocene.

Lithostratigraphic horizon	Near base Lower/Middle Miocene
Corresponding horizons from existing models	Base NUBA - Breda Formation (DGM deep 5.0) and remodelled Near base Lower/Middle Miocene
New harmonized horizon	
grid deviation [%]	26%

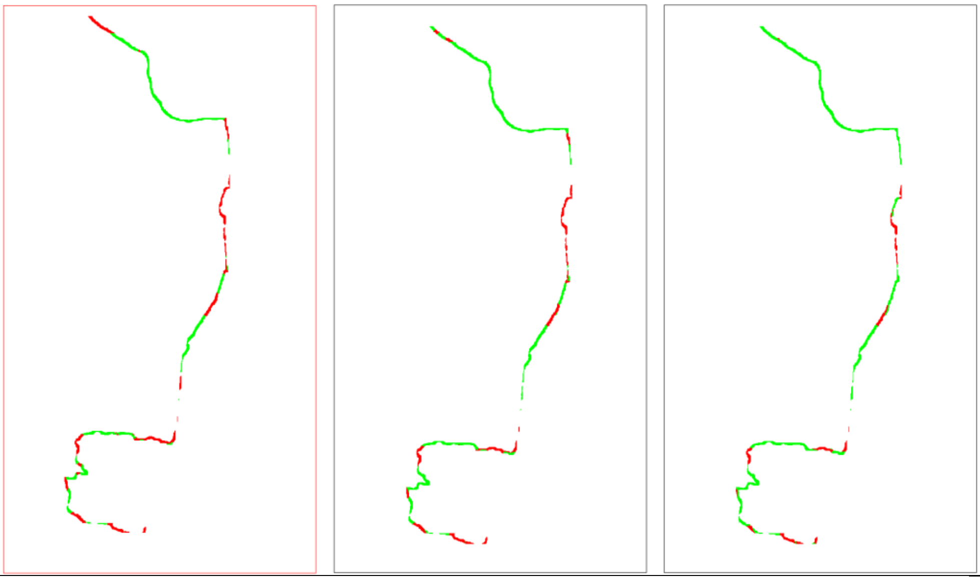
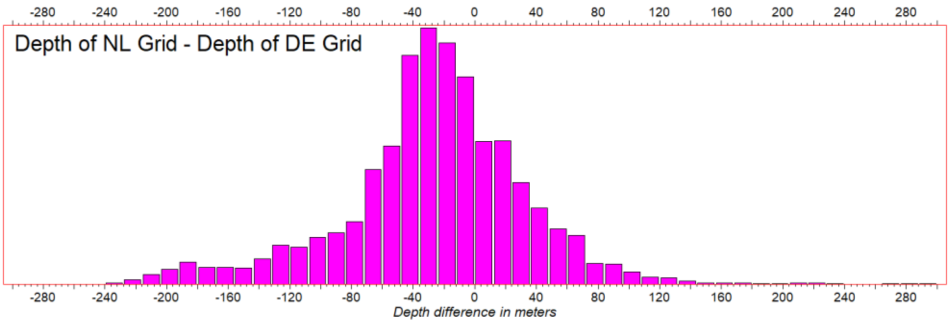
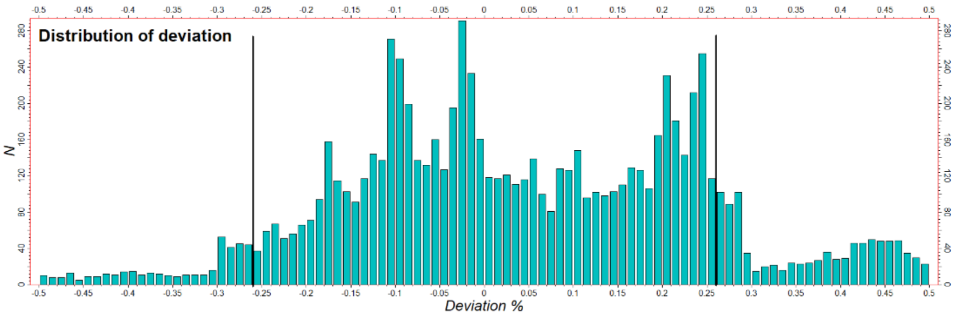
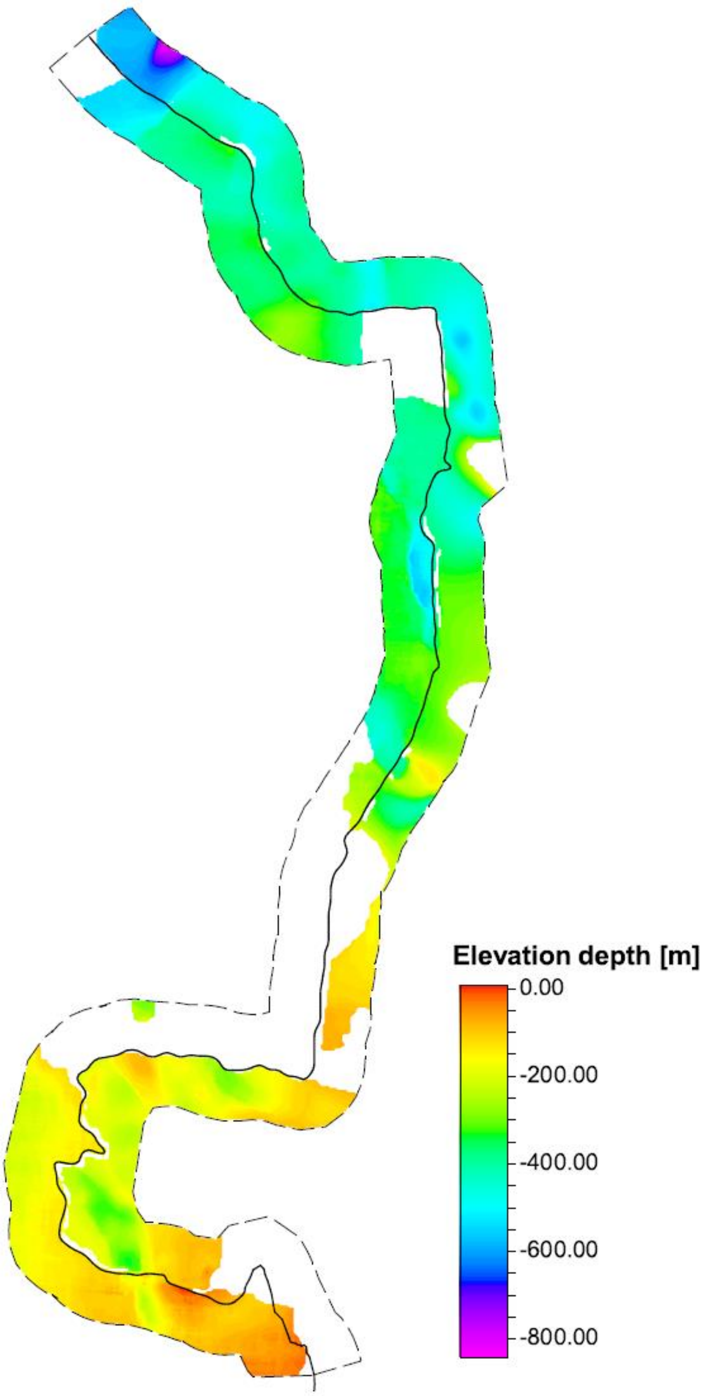
Considered deviations	**NU - 03 mittelmiozan bis pliozan** 18% deviation 22% deviation 26% deviation 
Histogram	 
Possible reasons for deviations	different lithostratigraphic classification, different geological models

Table 4: Documentation of deviation and harmonization of Near base Rupelian.

Lithostratigraphic horizon	Near base Rupelian
Corresponding horizons from existing models	Base NMRF - Rupel Formation (DGM-NNL) and remodelled Base Rupel FM
New harmonized horizon	

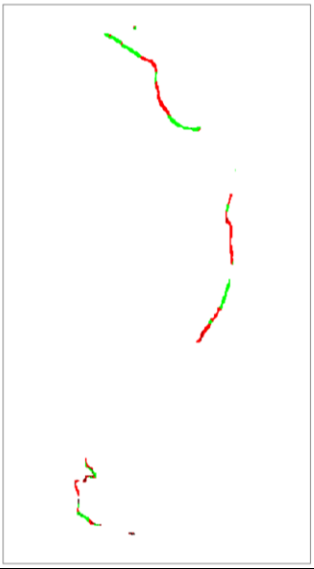
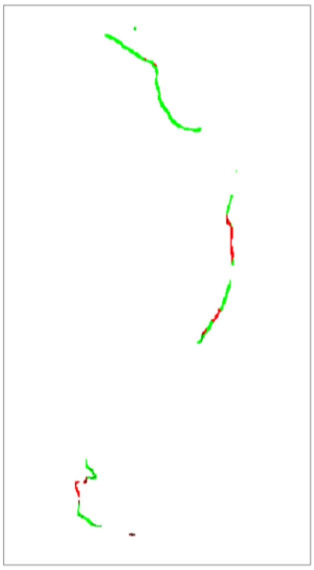
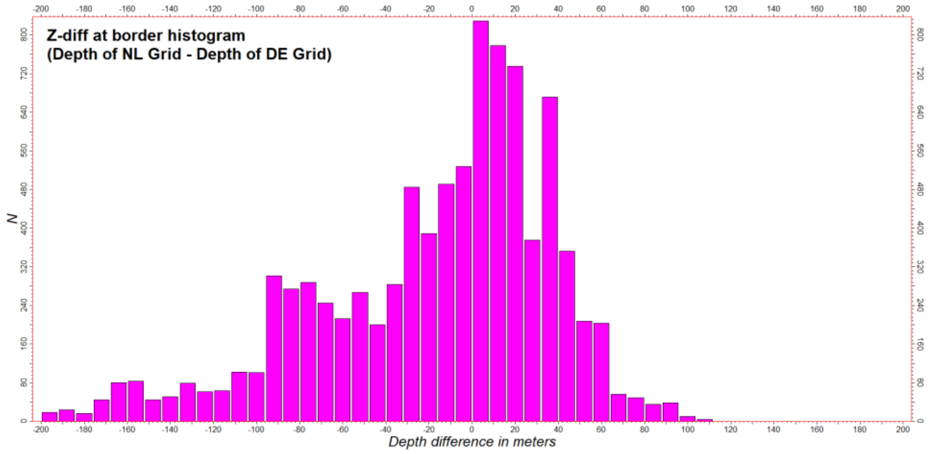
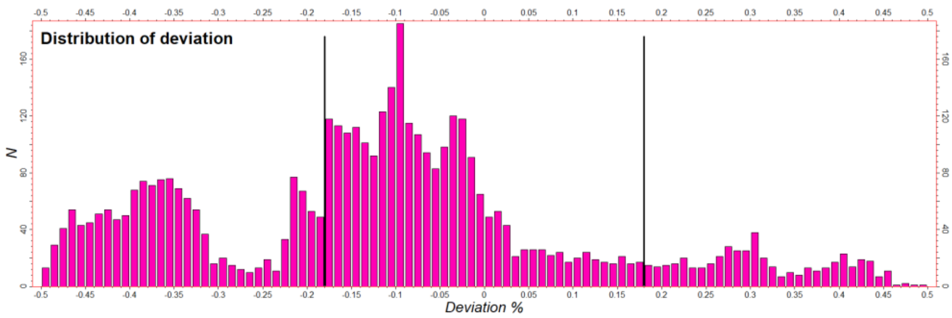
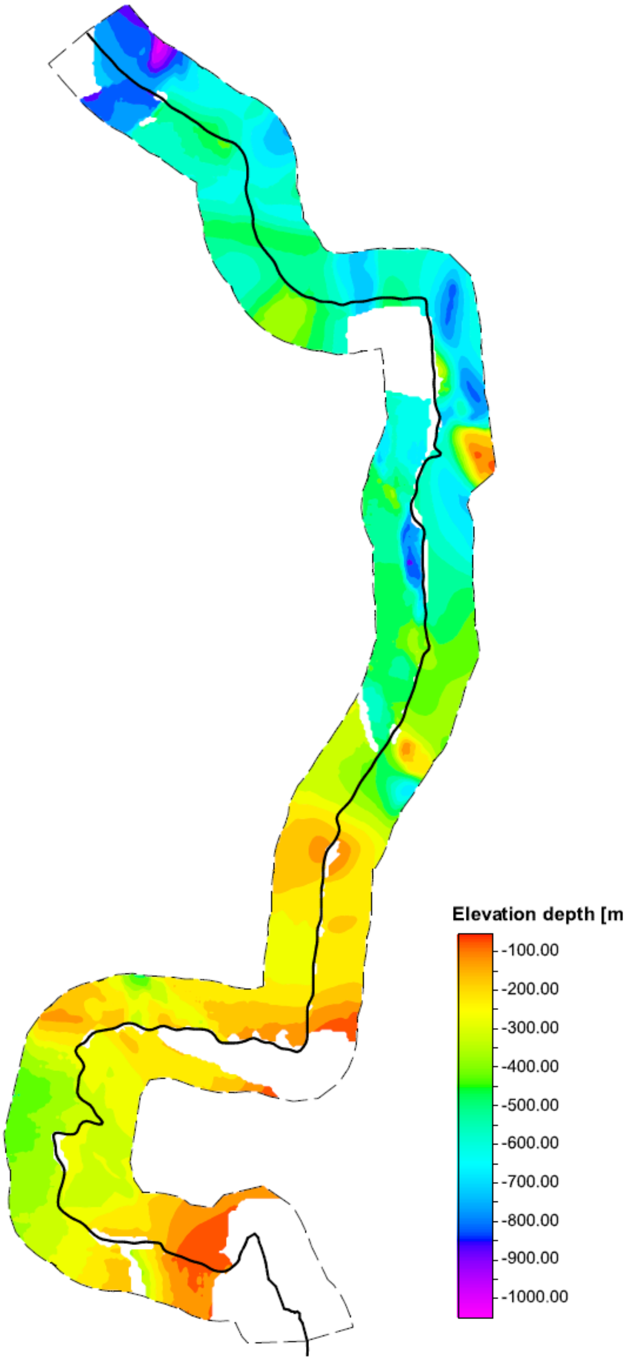
Grid deviation [%]	18%
Considered deviations	14% deviation  18% deviation  22% deviation 
Histogram	 
Possible reasons for deviations	natural dipping of the layers towards the centre of the Lower Saxony Basin, stronger effect on the German side

Table 5: Documentation of deviation and harmonization of Near base Middle Eocene.

Lithostratigraphic horizon	Near base Middle Eocene
Corresponding horizons from existing models	Base NLFSS – Brussels Sand Member (DGM-NNL) and 06_tolm-teoo (teom-tolu) (GTA3D)
New harmonized horizon	

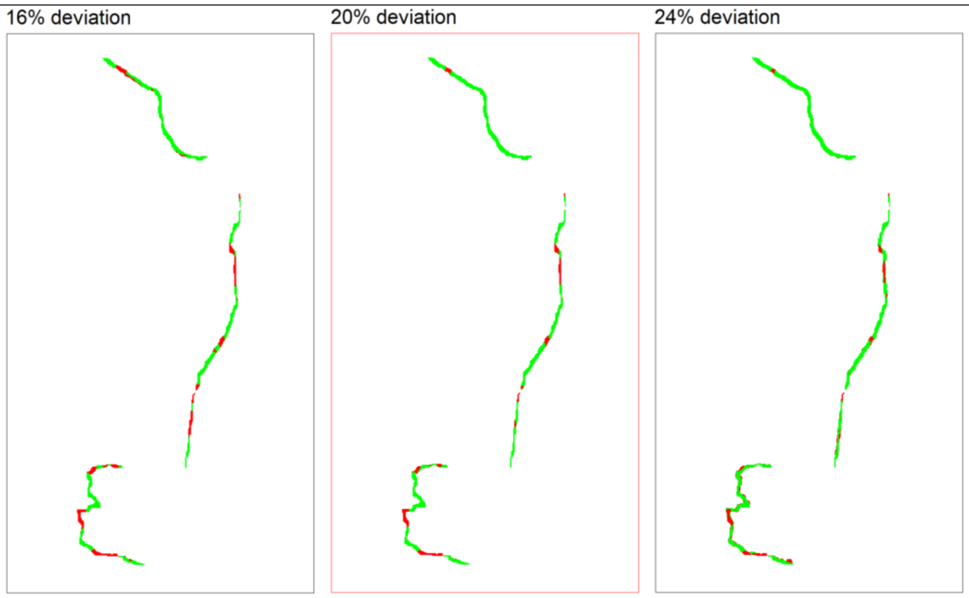
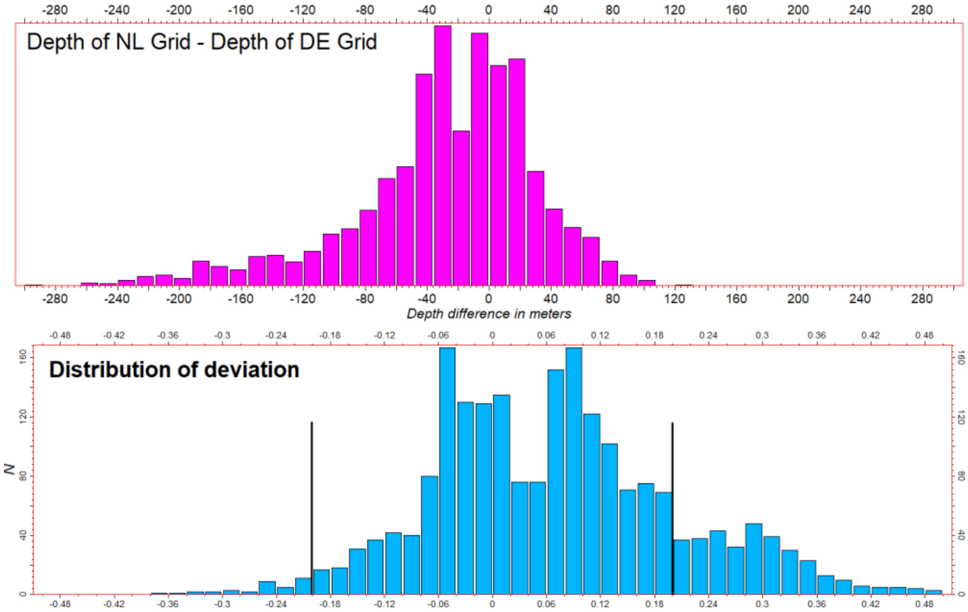
Grid deviation [%]	20%
Considered deviations	
Histogram	
Possible reasons for deviations	natural dipping of the sediments towards the centre of the Lower Saxony Basin, stronger effect on the German side

Table 6: Documentation of deviation and harmonization of Near base Cenozoic.

Lithostratigraphic horizon	Near base Cenozoic
Corresponding horizons from existing models	Base N - North Sea Supergroup = base NLLFC- Landen Clay Member (DGM-deep 5.0) and 07_tpao-teou (GTA-3D)
New harmonized horizon	

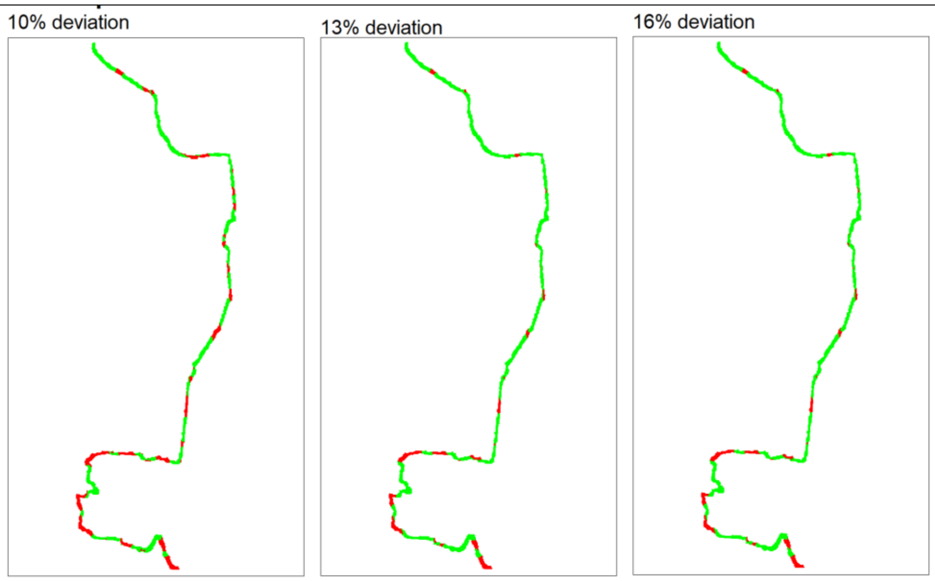
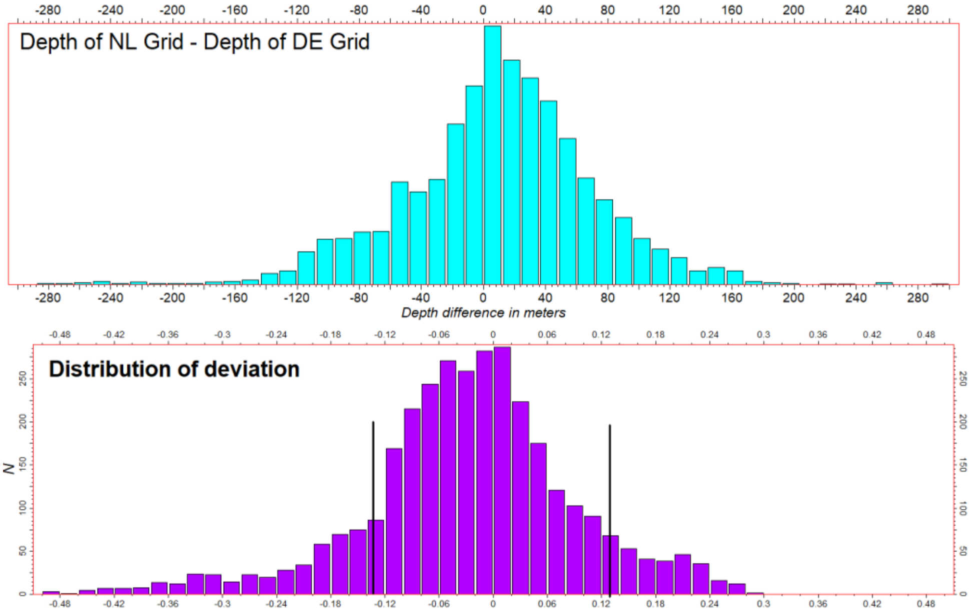
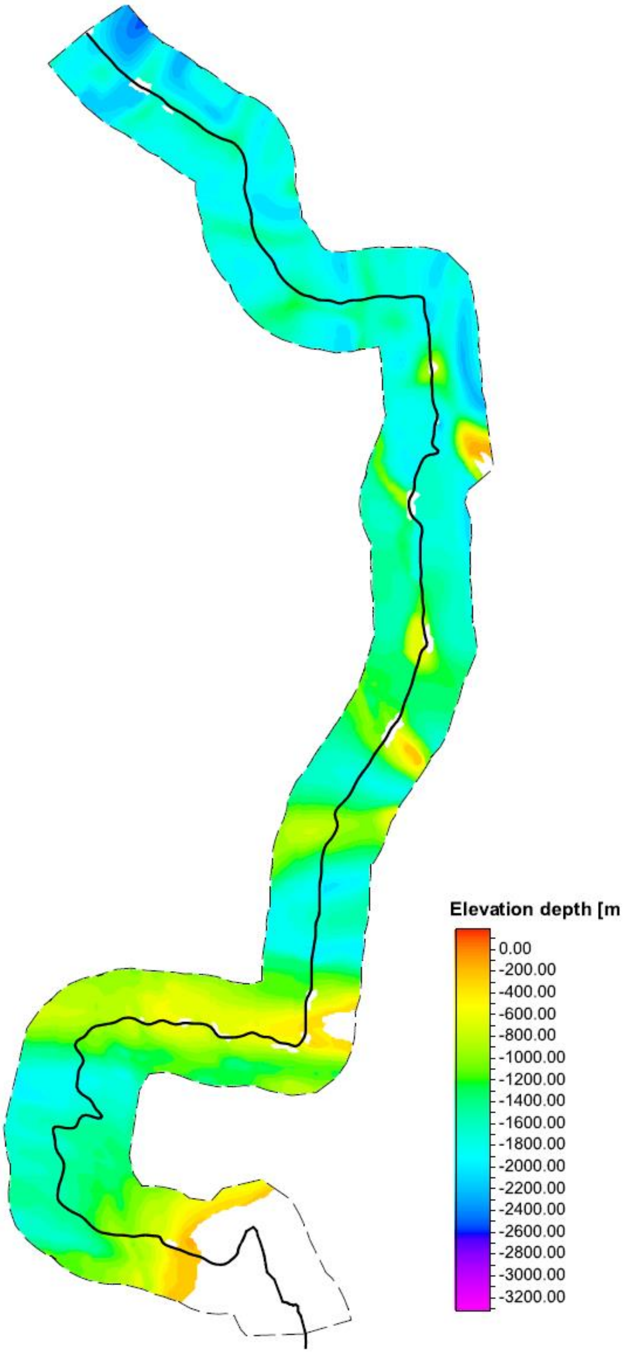
Grid deviation [%]	13%
Considered deviations	
Histogram	
Possible reasons for deviations	different way to model faults and subsurface structures

Table 7: Documentation of deviation and harmonization of Base Upper Cretaceous.

Lithostratigraphic horizon	Base Upper Cretaceous
Corresponding horizons from existing models	Base CK - Chalk Group (DGM-deep 5.0) and 08_kro (GTA-3D)
New harmonized horizon	

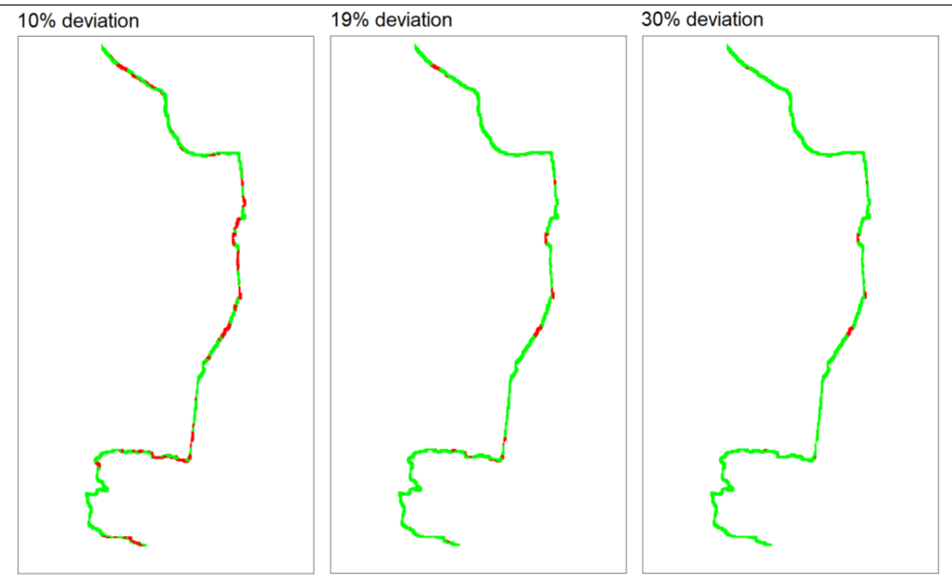
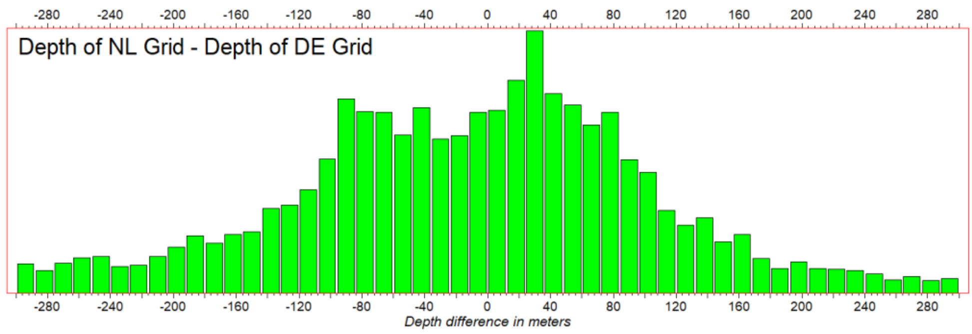
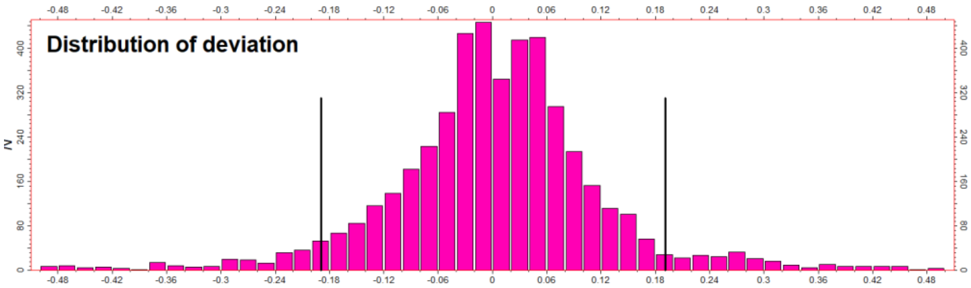
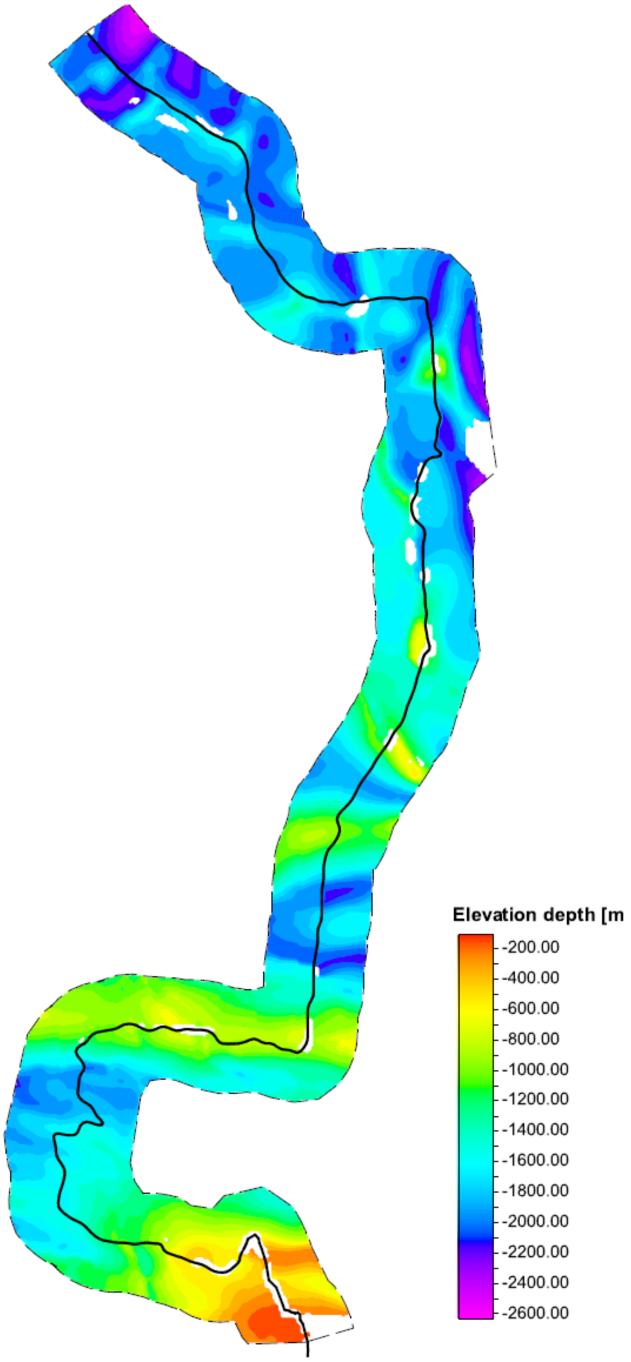
Grid deviation [%]	19%
Considered deviations	
Histogram	 
Possible reasons for deviations	different way to model faults and subsurface structures

Table 8: Documentation of deviation and harmonization of Near base Lower Cretaceous.

Lithostratigraphic horizon	Near base Lower Cretaceous
Corresponding horizons from existing models	Base KN - Rijnland Group (DGM-deep 5.0) and 09_kru (GTA-3D)
New harmonized horizon	

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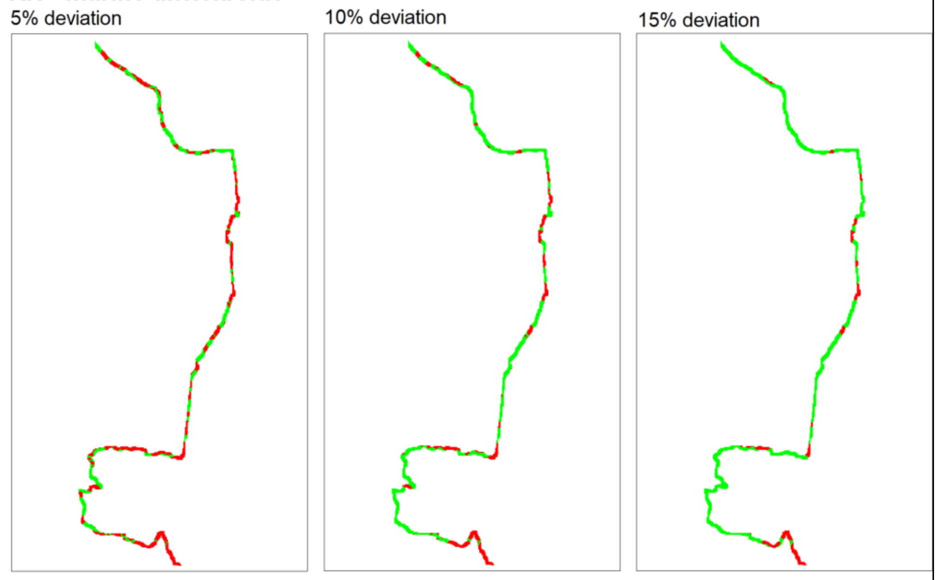
<tr><td>Considered deviations</td><td>
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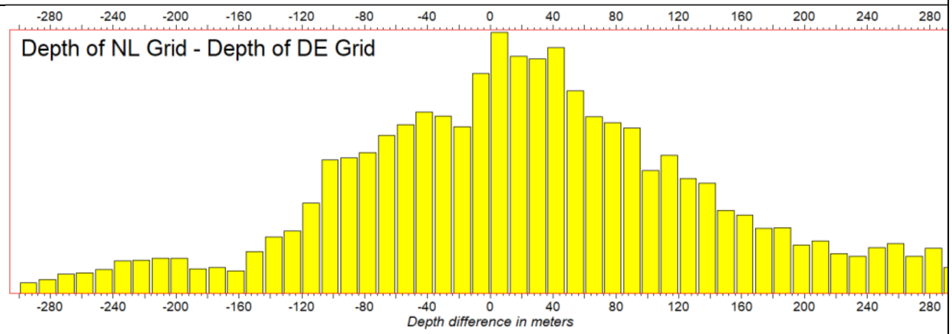
<tr><td>Histogram</td><td>

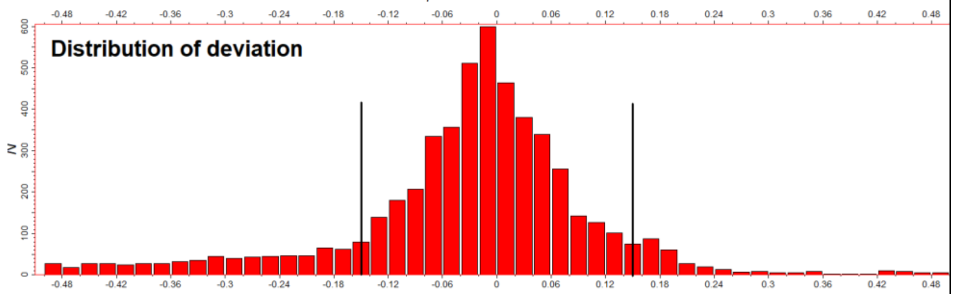
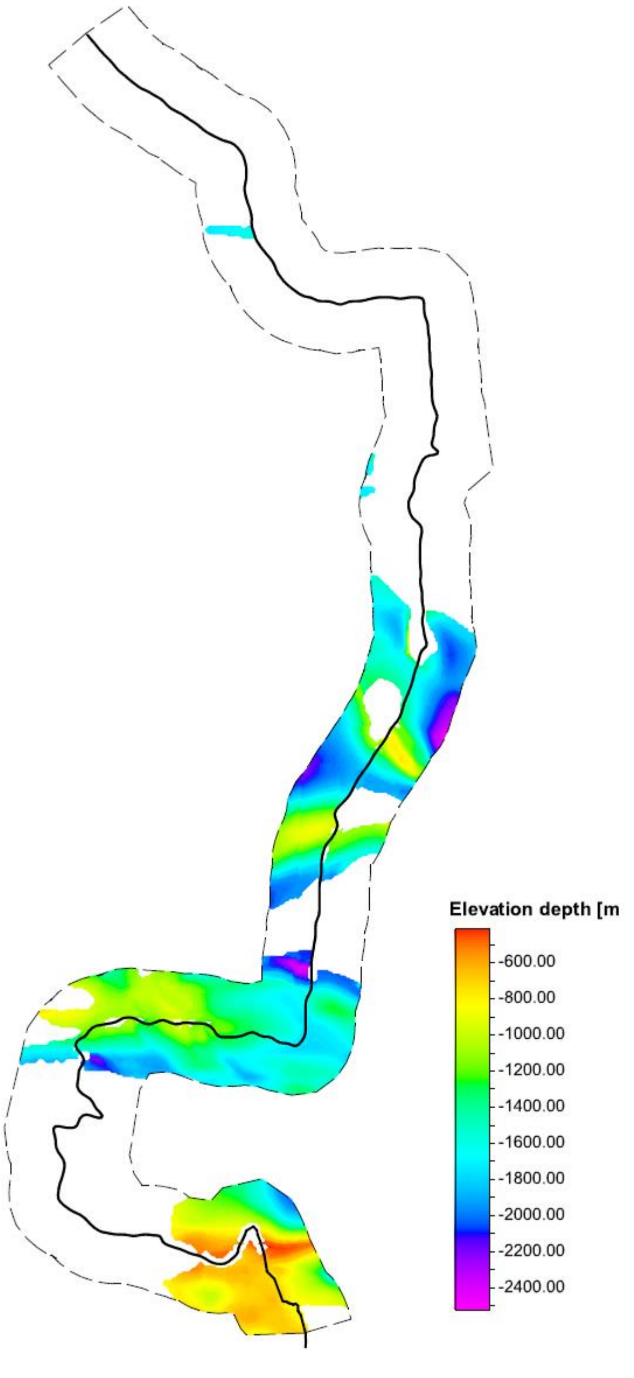

</td></tr>
<tr><td>Possible reasons for deviations</td><td>different way to model faults and subsurface structures</td></tr>
</table>

Table 9: Documentation of deviation and harmonization of Near base Upper Jurassic.

Lithostratigraphic horizon	Near base Upper Jurassic
Corresponding horizons from existing models	Base S - Upper Jurassic groups (DGM-deep 5.0) and 10_jo-Wd (GTA3D)
New harmonized horizon	

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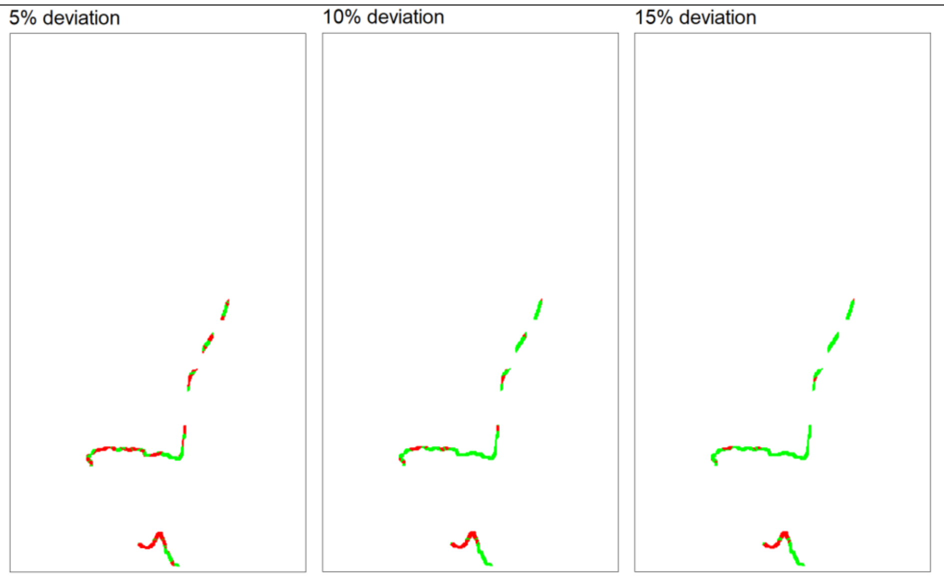
<tr><td>Considered deviations</td><td>
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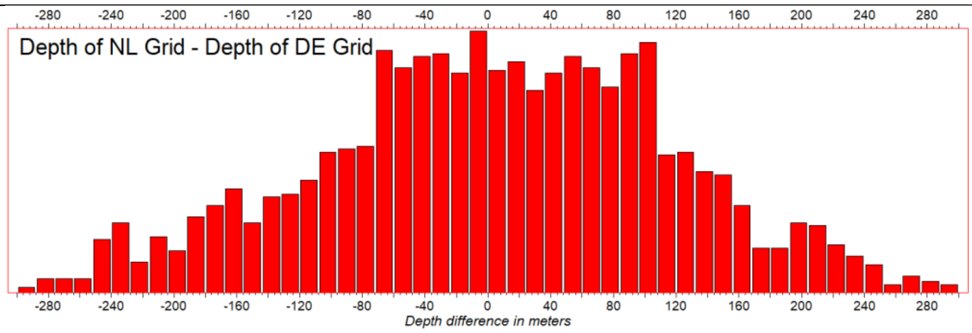
<tr><td>Histogram</td><td>

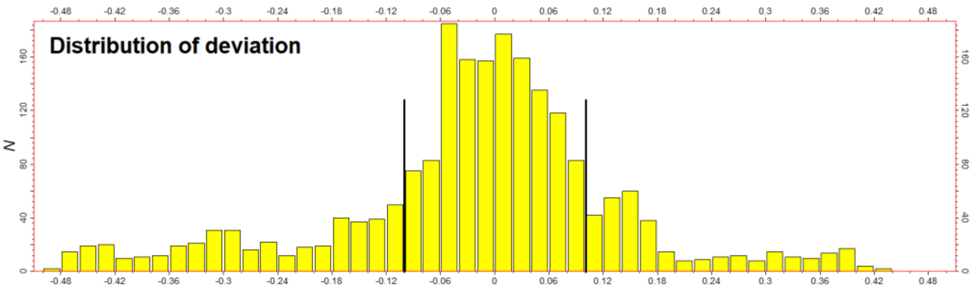

</td></tr>
<tr><td>Possible reasons for deviations</td><td>different way to model faults and subsurface structures</td></tr>
</table>

Table 10: Documentation of deviation and harmonization of Near base Middle Jurassic.

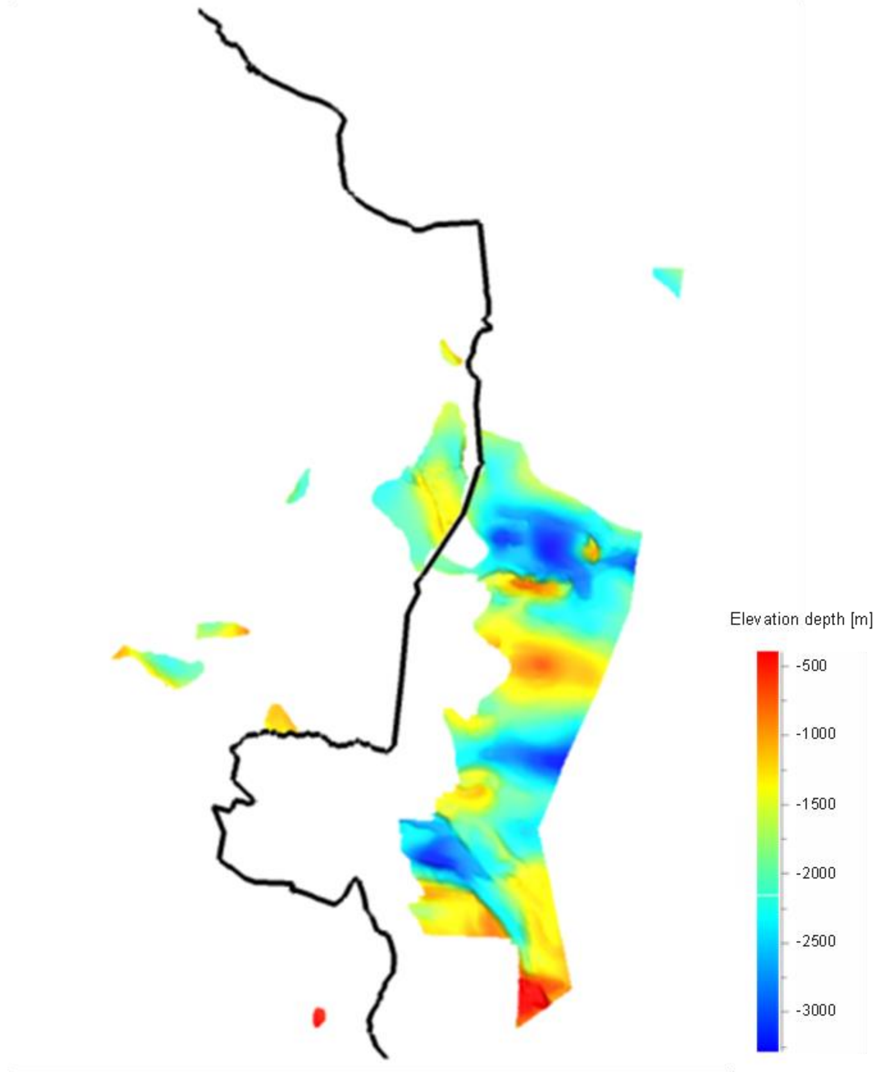
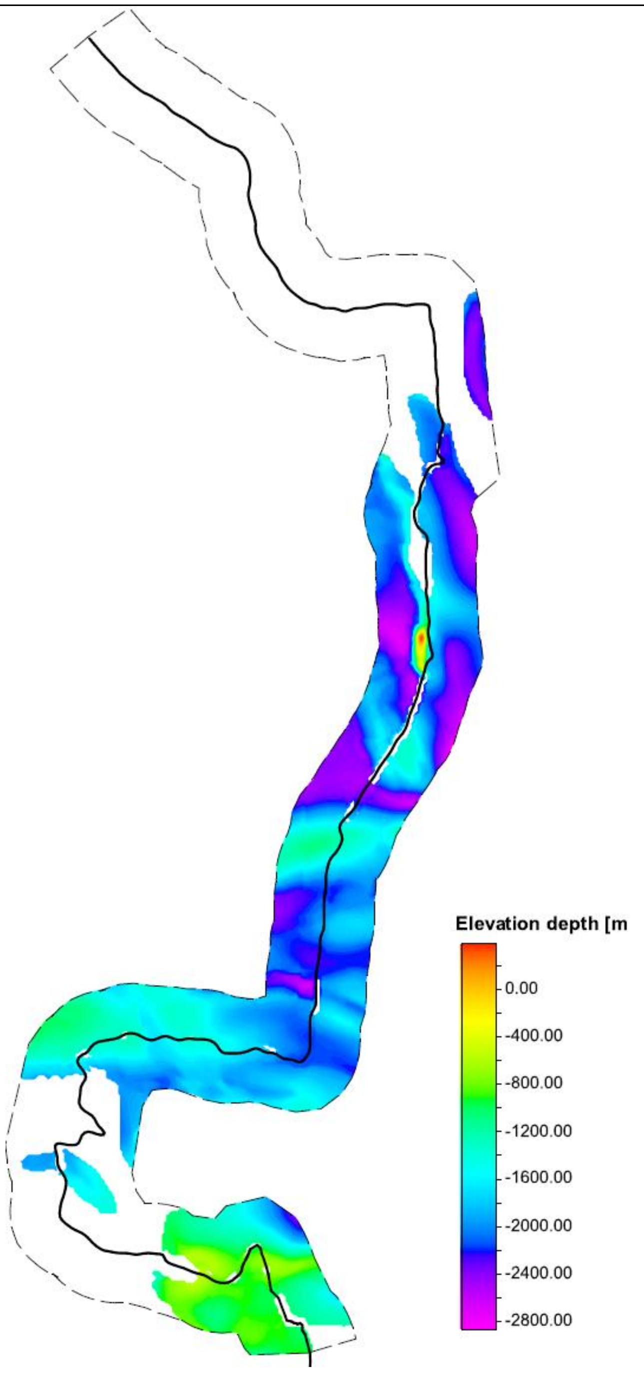
Lithostratigraphic horizon	Near base Middle Jurassic (distribution map)
Corresponding horizons from existing models	Base ATPO – Posidonia Shale FM (DGM-deep 5.0) and 11_jutco-jmclo (GTA3D)
Corresponding horizons	
Remarks	Due to too big differences of the Dutch and the German horizons along the border, we decided not to incorporate the horizon in the new NLS3D model.

Table 11: Documentation of deviation and harmonization of Near base Lower Jurassic.

Lithostratigraphic horizon	Near base Lower Jurassic
Corresponding horizons from existing models	Base AT - Altena Group (DGM-deep 5.0) and 12_juhe-jutcu (GTA3D)
New harmonized horizon	

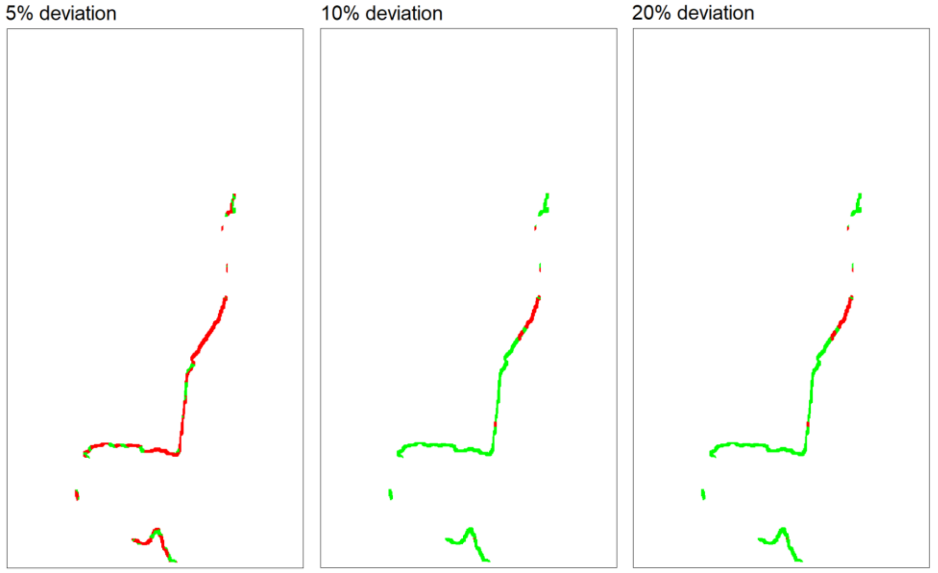
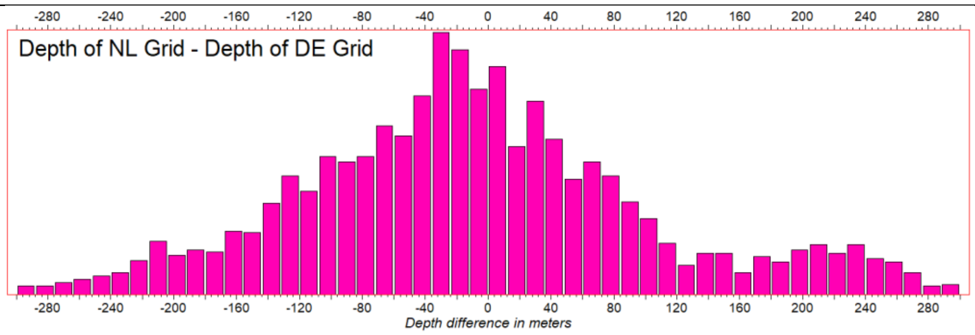
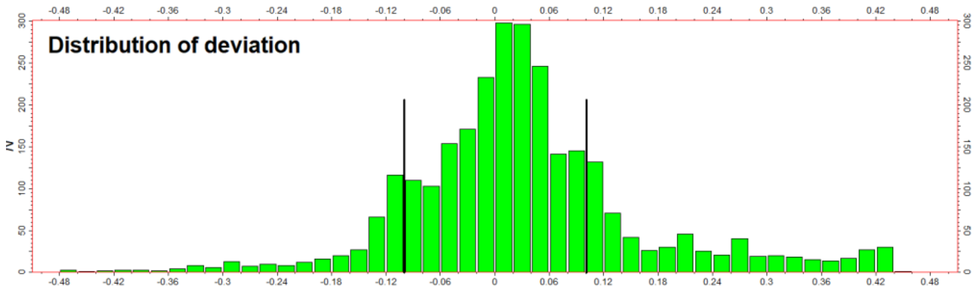
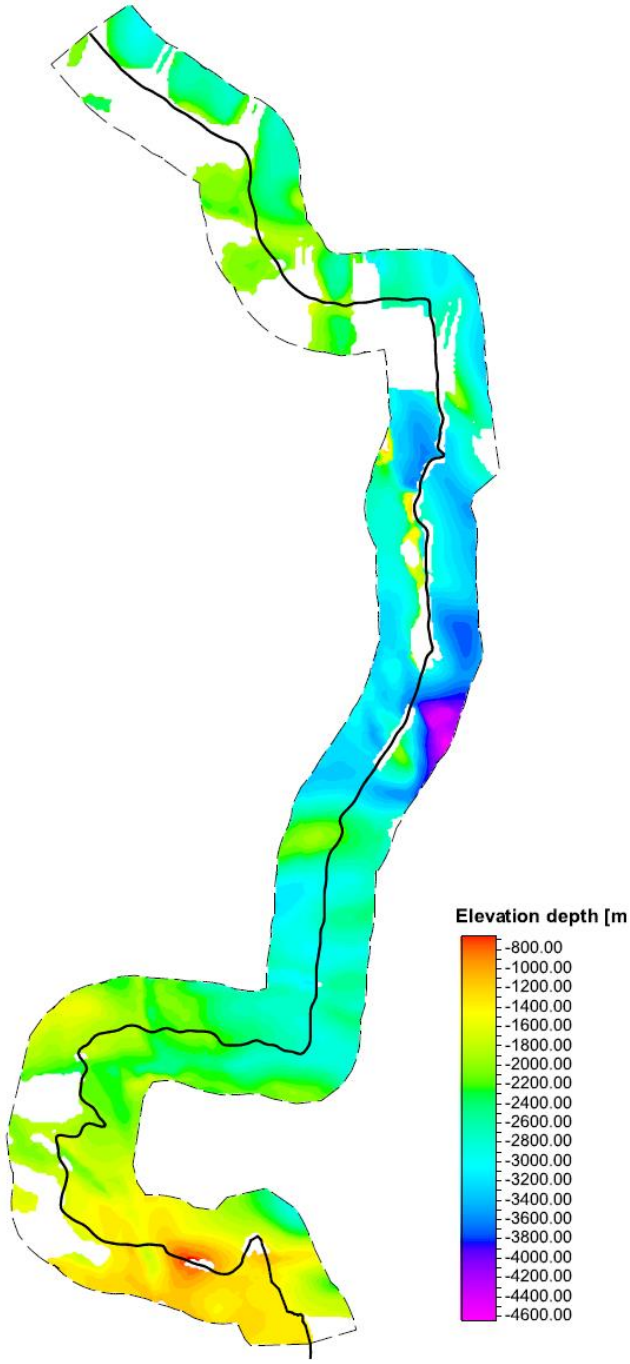
Grid deviation [%]	10%
Considered deviations	
Histogram	 
Possible reasons for deviations	different way to model faults and subsurface structures

Table 12: Documentation of deviation and harmonization of Near base Middle Triassic.

Lithostratigraphic horizon	Near base Middle Triassic
Corresponding horizons from existing models	Base RN - Upper Germanic Trias Group (DGM-deep 5.0) and 14_so-m (GTA3D)
New harmonized horizon	

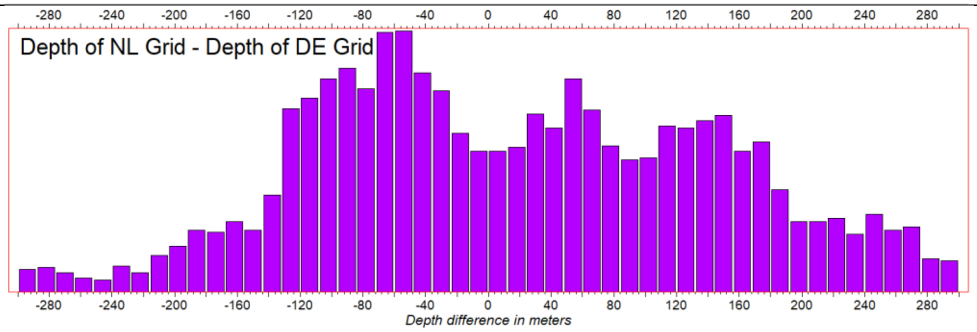
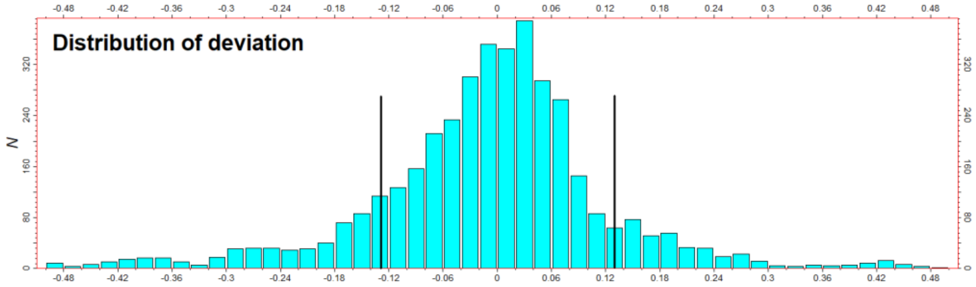
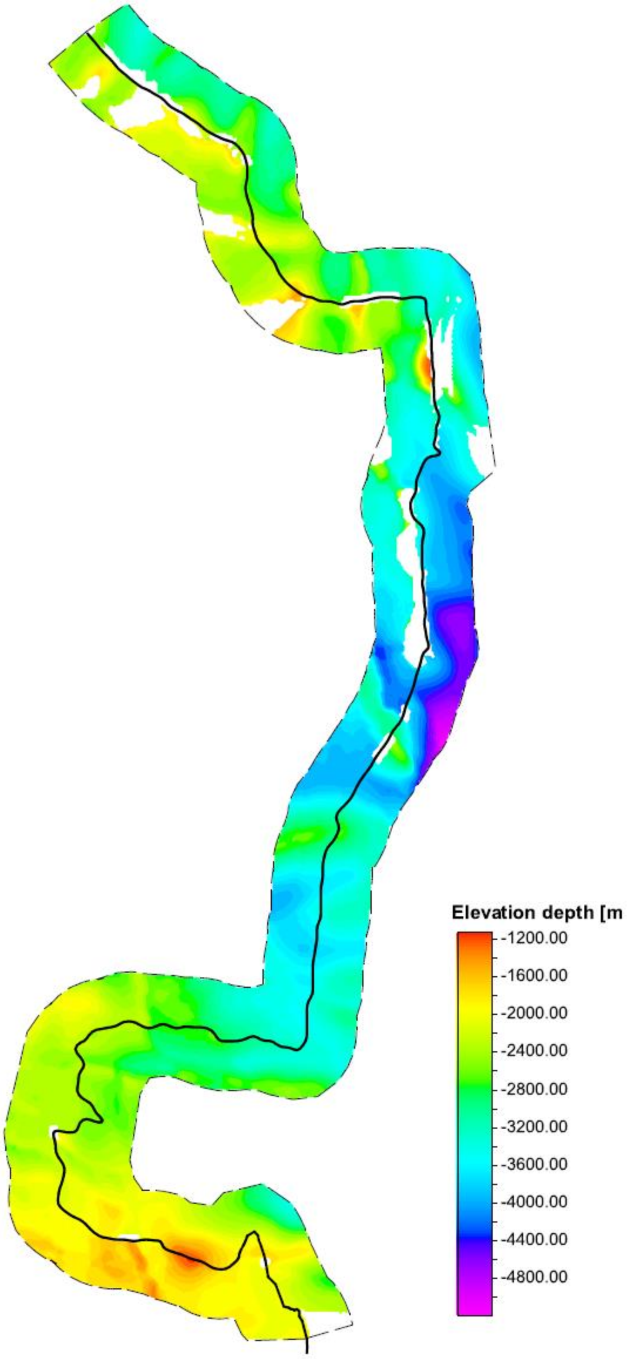
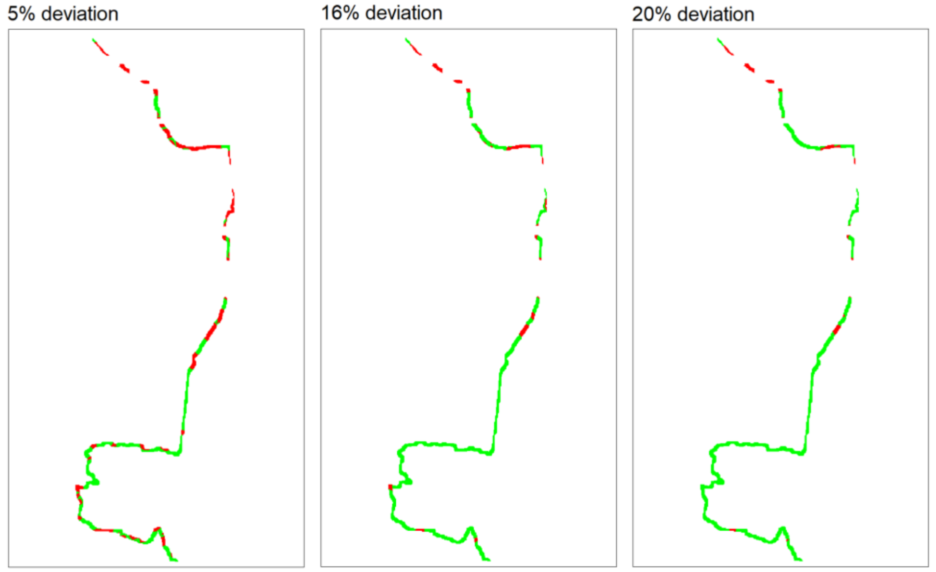
Grid deviation [%]	13%
Considered deviations	
Histogram	
Possible reasons for deviations	different way to model faults and subsurface structures, problematic salt tectonics, differences in the velocity model

Table 13: Documentation of deviation and harmonization of Near base Lower Triassic.

Lithostratigraphic horizon	Near base Lower Triassic
Corresponding horizons from existing models	Base RB - Lower Germanic Triassic Group (DGM-deep 5.0) and 15_su-sm (GTA3D)
New harmonized horizon	

<table>
<tr><td>Grid deviation [%]</td><td>16%</td></tr>
<tr><td>Considered deviations</td><td>
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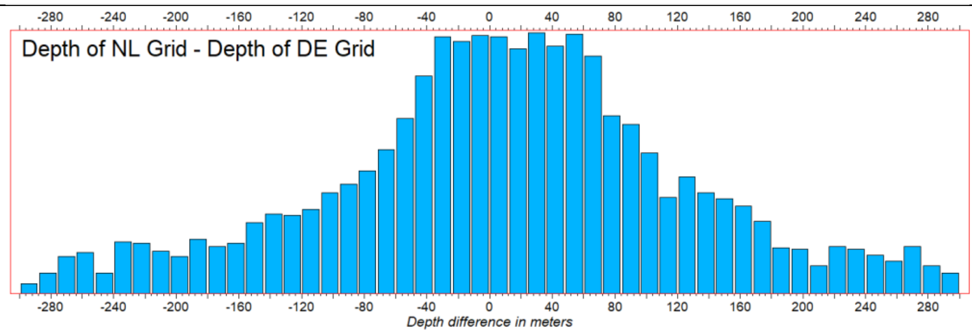
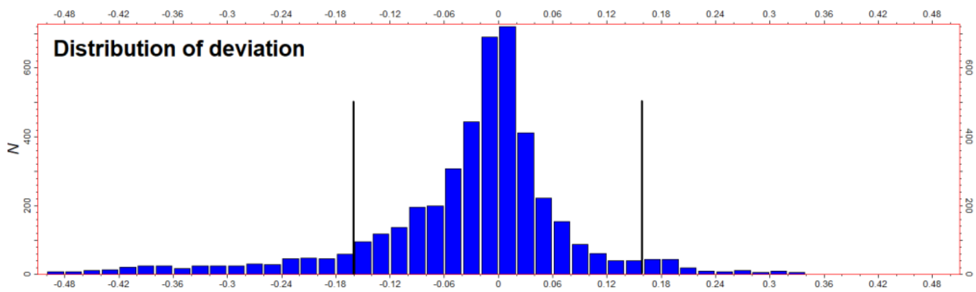
<tr><td>Histogram</td><td>


</td></tr>
<tr><td>Possible reasons for deviations</td><td>In the north the models do not fit very well - problematic salt tectonics, differences in the velocity model, false seismic horizon picked</td></tr>
</table>

1.3 INVOLVED NEW MODELLED HORIZONS

On the German side, the Near base Lower/Middle Miocene and the Base Rupel FM were remodelled (see chapter 1.2.2). The newly modelled horizons have been integrated into the harmonization. In the following two sections it will be shown exemplary how the two models differ on the German side and which one has been included in the harmonization.

1.3.1 BASE MIOCENE

During the remodelling of the "Nordhorn area" it became clear that only the Middle Miocene occurs in this area, since the Lower Miocene was not deposited in this area. Thus, it was possible to model the base Middle Miocene in this area without mixing the Miocene units.

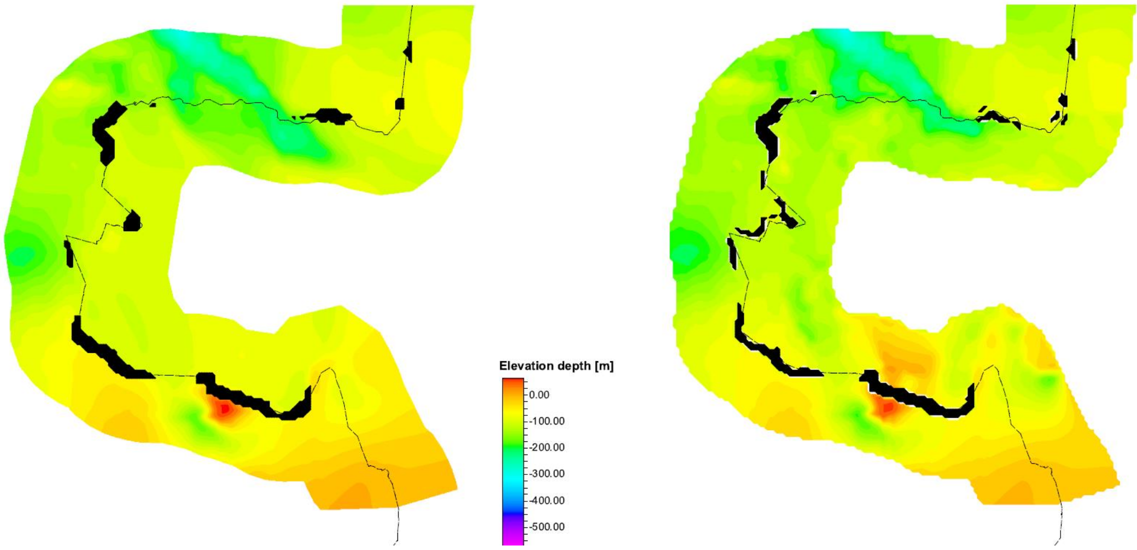


Figure 10: Comparison of the German models with their depth position; left: 03_tmim_tpl from GTA3D; right: remodelled "Nordhorn area". Black spots show areas of no harmonization.

A comparison of the two German models (Fig. 10) shows that the recalculated model is more detailed and that the model fits better with the Dutch model. The histogram shows the differences in depth compared to the Dutch model (Fig. 11) and whether the difference has been reduced.

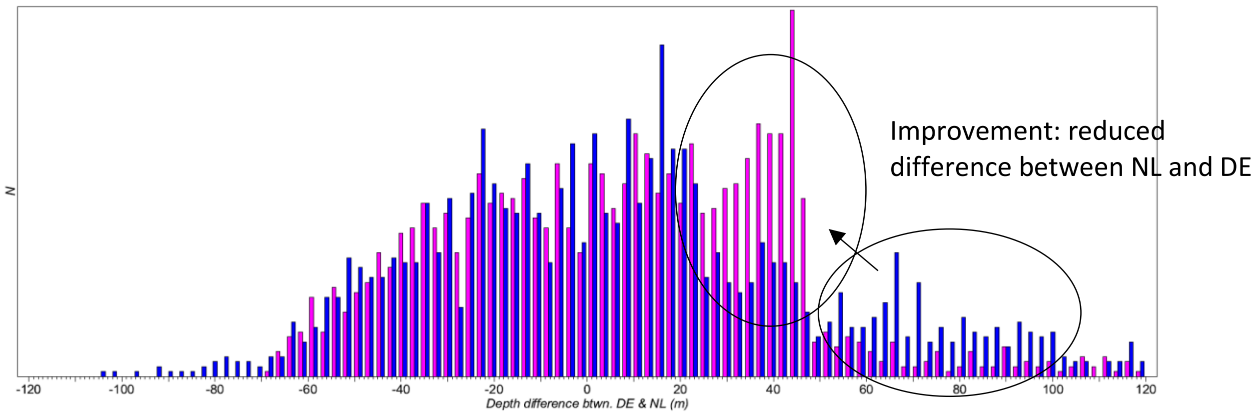


Figure 11: Comparison of the histograms of the depth differences between DE and NL for the remodelled "Nordhorn area" (pink) and the GTA3D (blue).

The histogram shows a reduction of the depth differences between the German and the Dutch model.

1.3.2 BASE OLIGOCENE /RUPEL FORMATION

During the remodelling of Base Rupel FM, local changes in thickness and the distribution limit of the deposits were modelled in detail. Especially the faults and graben structures have an enormous influence on the depth of the Rupel FM.

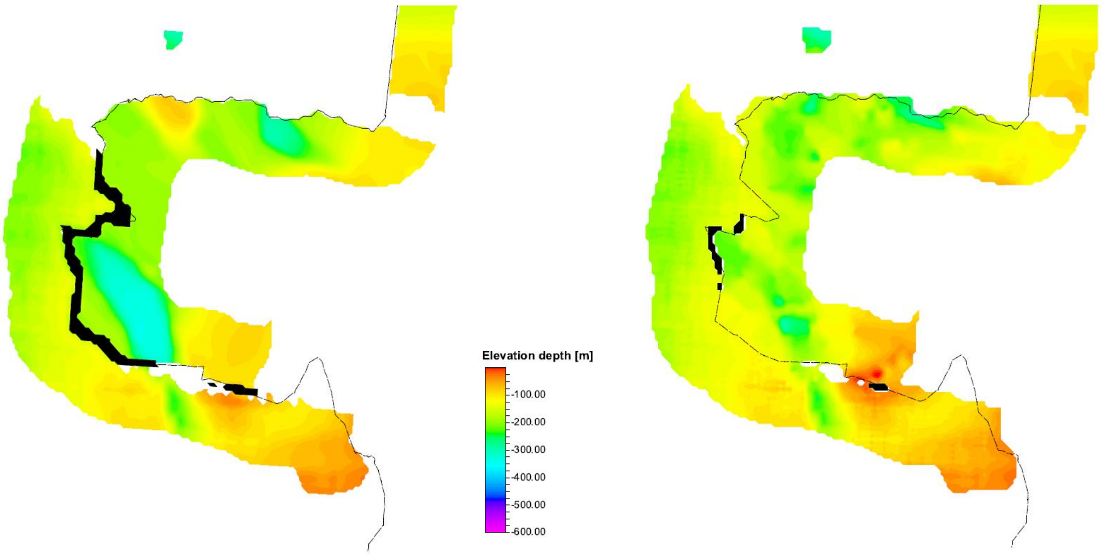


Figure 12: Comparison of the German models with their depth position; left: 05_tolm-tolo from GTA3D; right: remodelled "Nordhorn area". Black spots show areas of no harmonization.

The comparison of the two German models (Figure 12) shows that the new model provides much more detailed depth information than the GTA3D layers.
Comparing the histograms, which show the differences in depth between the German and Dutch models (Figure 13), it becomes clear that the remodelled surface matches the Dutch ones much better and represent a significant improvement.

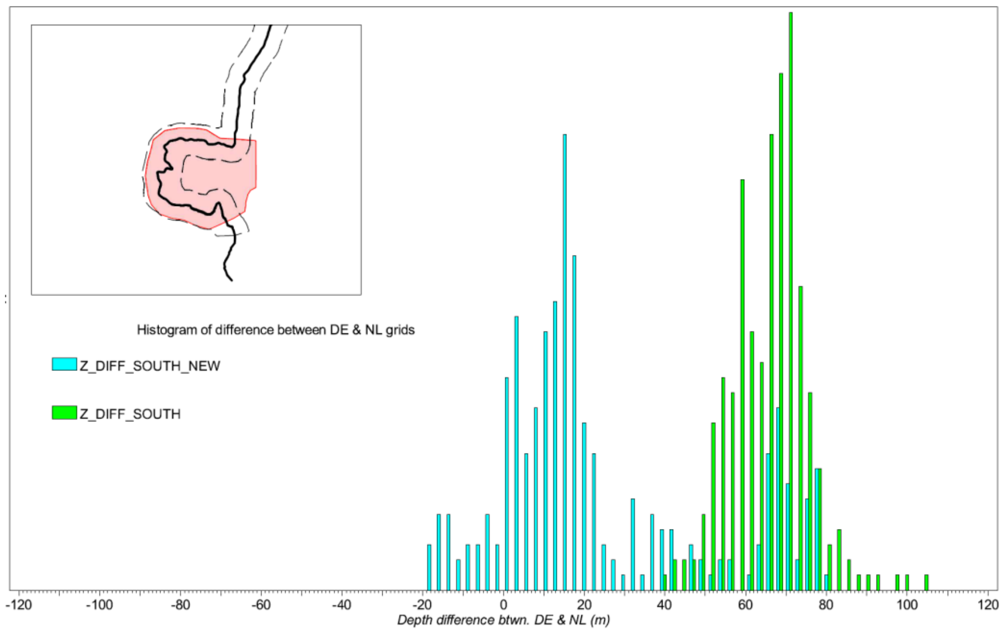


Figure 13: Comparison of the histograms of the depth differences between DE and NL for the remodelled "Nordhorn area" (blue) and the GTA3D (green).

1.4 STRATIGRAPHIC CHART OF THE CROSS BORDER AREA

The ten harmonized horizons are indicated in Figure 14 to show the stratigraphic overview.

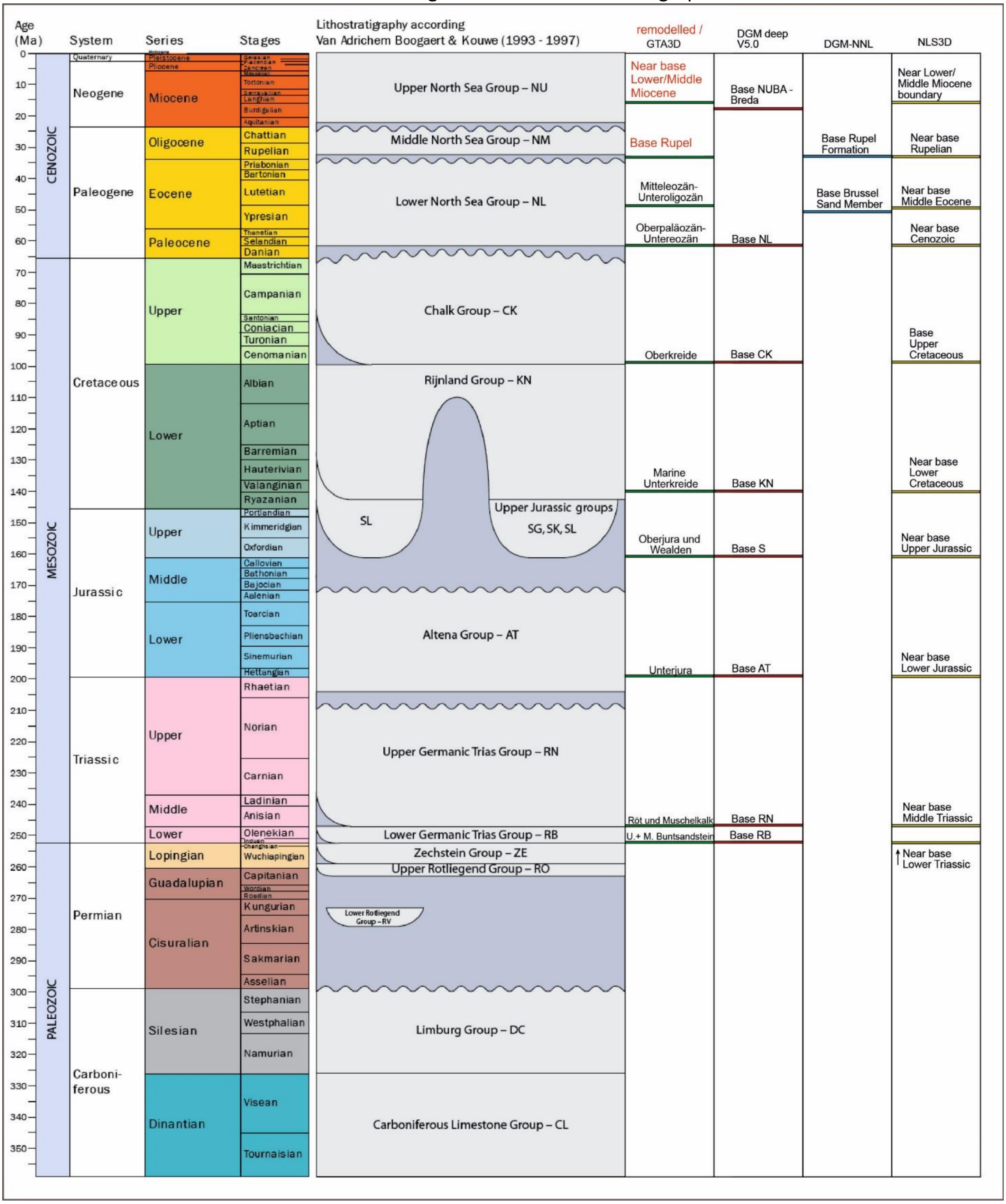


Figure 14: Correlation of modelled horizons for GTA3D and remodelled (green lines), DGM deep (red lines), DGM NNL (blue lines) and NLS3D (yellow lines) with names of the modelled horizons (mod. after Kombrink et al., 2012).

1.5 FAULTS

Although an initial goal of this project, faults in the border area have not been harmonized. An attempt has been made to harmonize the Gronau fault-zone. This fault-zone has been chosen because of its complexity and a working proof of concept would mean a working method for the entire border area.

Unfortunately, the basis for a harmonized fault model is thin. There is no fault model present in the German GTA3D model. For the faults on the German side of the border reconstructed fault planes deduced from fault-gaps would have to be made that could serve as a fault model surrogate. Not only would this be a laborious activity, it would also result in a sub-par fault model and an unsatisfactory harmonized cross-border fault model.

1.6 INTERSECTIONS OF HORIZONS WITH NEAR BASE RUPELIAN

Local intersections in the Cenozoic units occur when comparing the Near Base Rupelian with the units above and below it. In some areas, the depth of the Near Base Rupelian horizon is lower than that of the Near Base Lower/Middle Miocene horizon (see Figure 15).

Figure 15: View of occurring intersections between Near Base Rupelian (beige) and Near base Lower/Middle Miocene (orange).

The most important reason for this overlap is that different input models have been used, which differ significantly in their resolution, type of input data, etc. Another reason is that horizons from DGM-NNL model (Base NMRF - Rupel - Formation and Base NLFSS - Brussels Sand Member) are present at locations above saltdomes, although interpretations for these horizons show no occurrence above saltdomes.
The horizons generated in the 3D input models or modelling methods used are not aligned with each other. When calculating thickness maps for Cenozoic units from NLS3D (Deliverable 1.3 of this work package), these overlaps create gaps. As a result, the distribution of the Cenozoic units is partially incompletely represented.

2 LESSONS LEARNED

Existing 3D models end at national borders, but geological sediments or structures are not correlated with national borders. By comparing the 3D models at both sides of the border a methodology for harmonization has been developed. During this harmonisation process the following lessons have been learned:

- In general the 3D models fit better as expected.
- Horizons based on seismic picked horizons fit better, than horizons only based on a few wells.
- Data gaps or areas with low density of input data towards the border of the model lead to fuzziness and generate deviations due to uncertainty. These data gaps may have a reason in the circumstances, that data exchange with Germany was not possible in former times.
- Some horizons fit very well, because these horizons are characterized by prominent reflectors, which are strongly formed and can be traced over several tens of kilometres in seismic datasets.
- Differences in depth and/or in structure, which exceed the threshold for harmonization, result in areas, which cannot be harmonized.
- Different interpretations of the sediments in boreholes are used, this lead to misinterpretations of the layers/horizons. For example strongly generalized layer descriptions in boreholes (like North Sea Super Group) might result in invisibleness of geological units during automatic interpretation.
- Changes in the stratigraphic classification and assignment of individual sediments to certain chronostratigraphic stages over the last 70 years led to the fact that in some cases the horizons from boreholes were assigned to the wrong horizons during modelling.
- Vulnerability of the method for harmonizing corresponding horizons - the method was designed to be able to map and compensate the expected high deviation of the deepest horizons very well. Contrary to expectations, the shallowest horizons showed the greatest deviation in the harmonization in relation to the depth.
- It is not possible to harmonize the faults from these 3D models, due to the fact that the Dutch 3D model has interpreted and modelled fault-planes in 3D and the fault planes at the GTA3D model had to be reconstructed and deduced from fault-gaps at horizon levels.
- By comparison of the national stratigraphic charts a separate, transnational stratigraphic classification has been developed, which is perhaps only valid for the model area.
- Intersection problems occurring because of usage of layers from different models To create a harmonized 3D model without gaps, it is inevitably necessary to start again with the raw data. First of all, the raw data must be harmonized, especially with regard to structural features such as faults and salt domes. Then the harmonized raw data can be implemented in a new 3D model.

3 LIST OF REFERENCES

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