Federal Agency for
Cartography and Geodesy

Modernization of the German Height Reference Frame – First Results

Martina Sacher[1], Gunter Liebsch[1], Jan Müller[1], Cord-Hinrich Jahn[2]

[1]Federal Agency for Cartography and Geodesy

[2]Working Committee of the Surveying Authorities of the States of the Federal Republic of Germany (AdV)

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1. Objectives of the Project

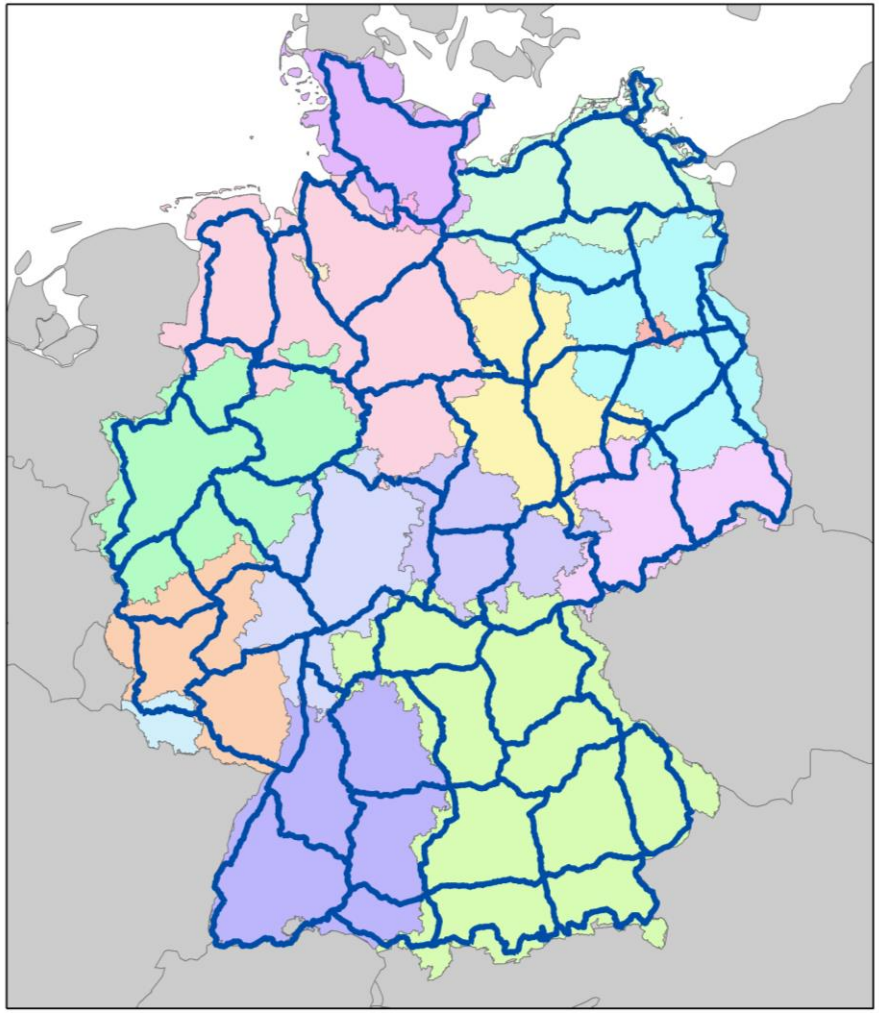
- levelings used in German Height Reference Frame (DHHN92) were up to 30 years old at the beginning of the project
- reliability and validity are limited due to yearly damage of benchmarks and height variations, e.g. caused by mining industry (coal, salt, gas production)
- possible strain in the network because DHHN92 is a combination of two networks with different epochs in the adjustment of DHHN92

Objectives:

- verification and modernization of the height reference frame
- project comprise the relevelings, GNSS observations (250 stations) and absolute gravity measurements (100 stations) during the same observation epoch (2006-2012) as a uniform and consistent basement of all reference frames (positioning, height and gravity)
- improvement of German quasigeoid ⟶ improved possibility of height determination with GNSS methods and SA*POS*®
- detection of height variations and network strains

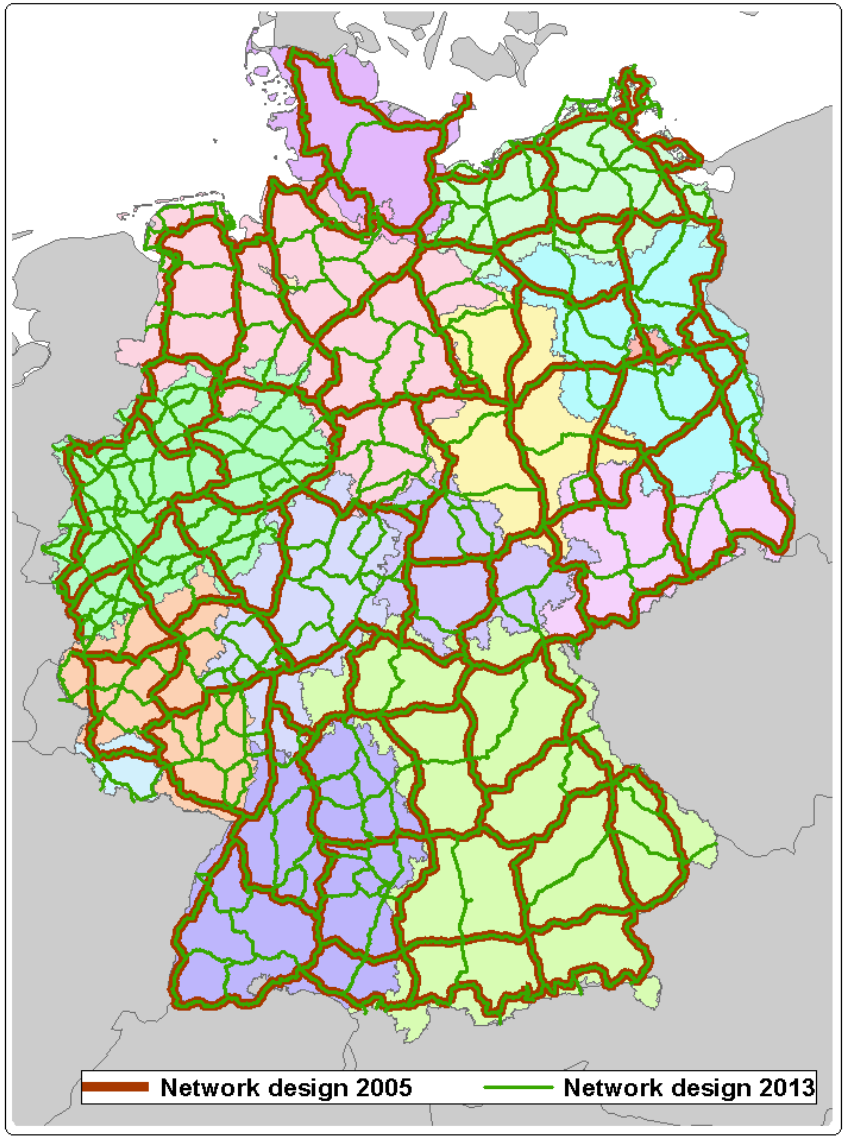
2. Development of the Leveling Network Design (1)

Original network design 2005



- surveying is in the responsibility of the German states
- coordinated by the “Working Committee of the Surveying Authorities of the States of the Federal Republic of Germany” (AdV)
- AdV decided in 2005 to start the project
- Initial plan reobservation of only 54% of the first order levelling network DHHN92
- 14 136km length of leveling lines
- Network design was open

2. Development of the Leveling Network Design (2)



- financial and human resources for surveying are different in the German states
- most of them extended their part of the network in the years after 2005
- stepwise modification of the network design
- some states included former 2. order lines
- total length of leveling lines (2013): 29 960 km (114% of DHHN92)

3. Project Management and Leveling Analyzis

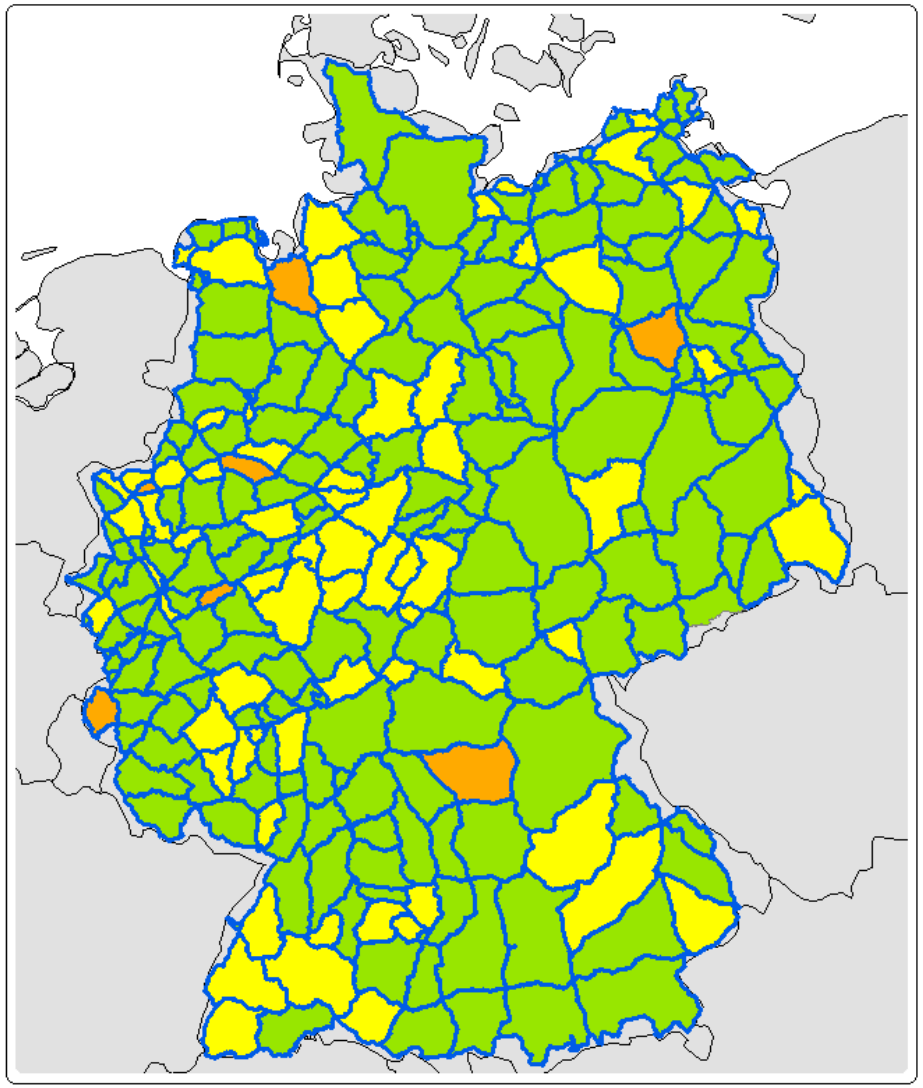
- Project team “Modernization of DHHN”:
  - formulation of instructions concerning measurements, instrument checking and data delivering
  - coordination of network design
  - monitoring of the progress (project time schedule)
  - permanent quality control (closing errors, comparison of height differences along the lines)
  - successive analyzing of incoming measurements
- Analyzing of leveling data by 2 computing centers using different adjustment software and approach
  - surveying authority of North Rhine – Westphalia (NRW) - adjustment of normal heights
  - BKG - adjustment of geopotential values
  - comparison of the resulting normal heights of 2 test networks
  - as a result parts of the software were revised (number of digits, replacement of approximation formulas by exact formulas)

4. Draft of New German Height Reference System

Specification	New realization (draft)	Current realization (DHHN92)
datum	**NAP**	
scale	SI - Meter	
realization of the scale	rod scale and temperature correction, determined by vertical comparator	rod scale and temperature correction
adjustment	free	
realization of the datum	ca. 70 points (fundamental benchmarks + GNSS+ ref. stations)	1 point
heights of the datum points	heights from DHHN92, no velocity supposed	geop. value from UELN 73/86, no velocity supposed
physical parameter	normal gravity field of GRS80	
kind of heights	**normal heights**	
solid earth tides	**mean tide**, variable part eliminated	**mean tide**, variable part not eliminated
ocean load effects	eliminated (Northern Germany)	not eliminated

Motorized Leveling, applied in Mecklenburg – Vorpommern

Closing Errors (status March 2013)

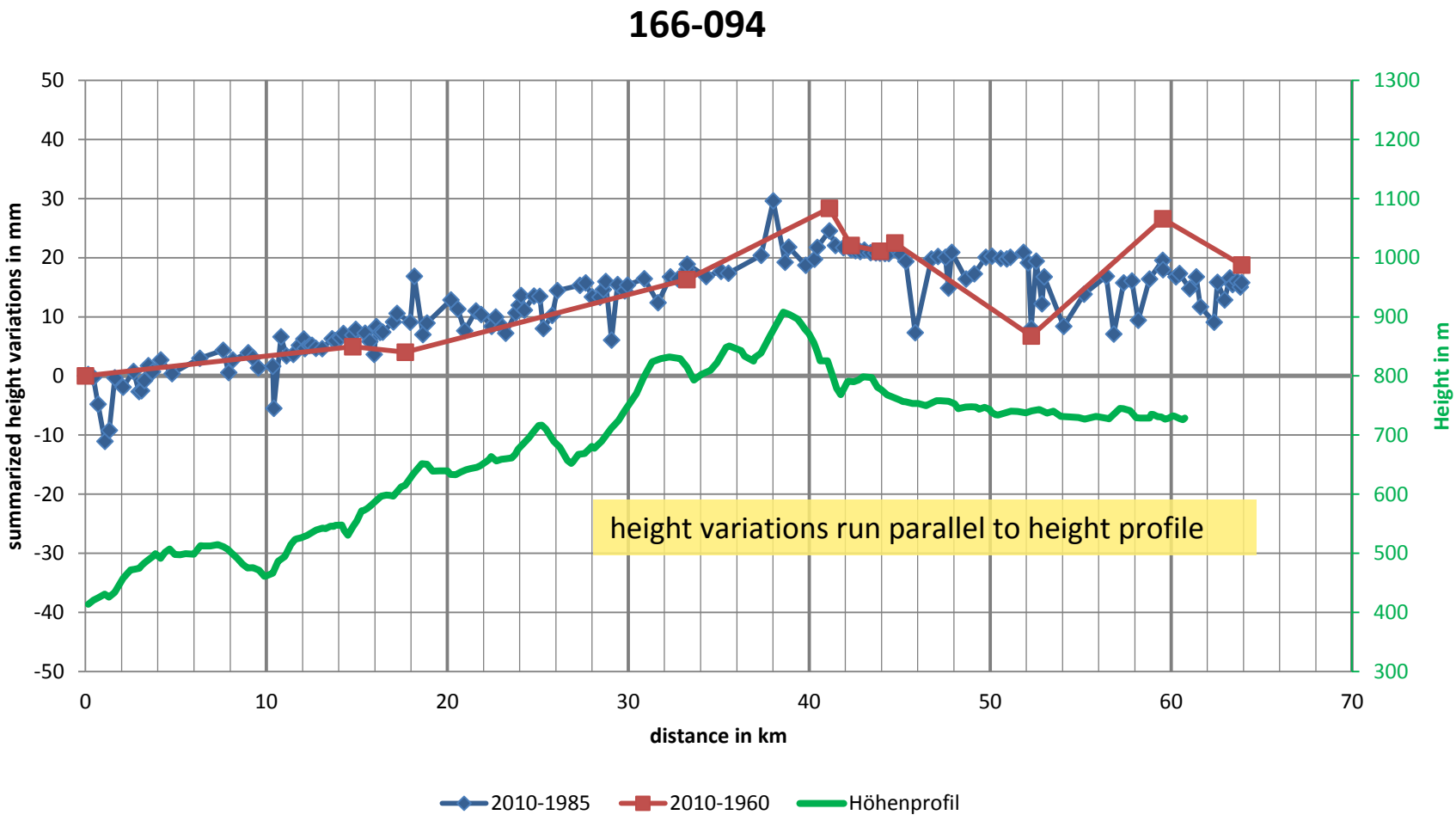


Closing error

- < 33%
- between 33% and 66%
- > 66%
- exceeding

of the permissible value $Z_U = \pm 2 \cdot \sqrt{U}$
(Z_u in mm, U perimeter in km)

Example of Suspected Systematic Errors Correlating with Height



Statistical Data

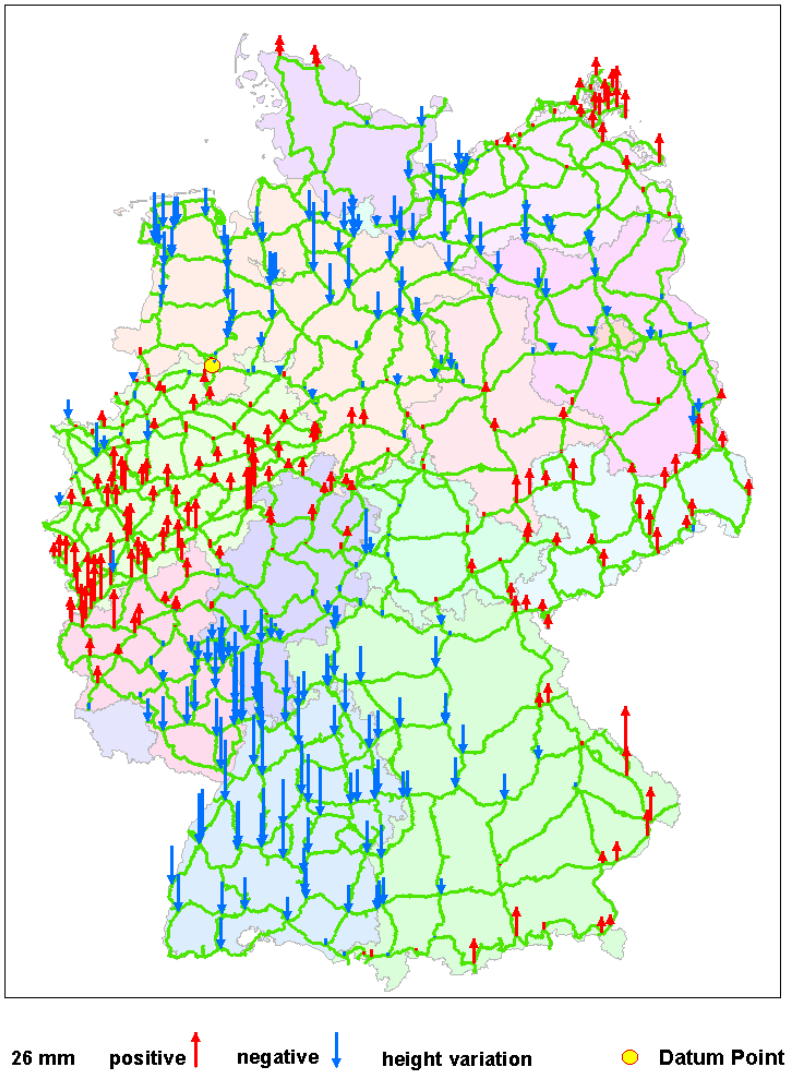
- total length of the observed lines available at analyzing centers: 29 660 km
- still expected before July 2013: ca. 300 km lines

Preliminary adjustment March 2013 computed with 99% of the data:

- observations: 58 168
- points: 57 885
- degrees of freedom 285
- s_0 1km leveling: 0,67 mm (*DHHN92: 0,86 mm*)

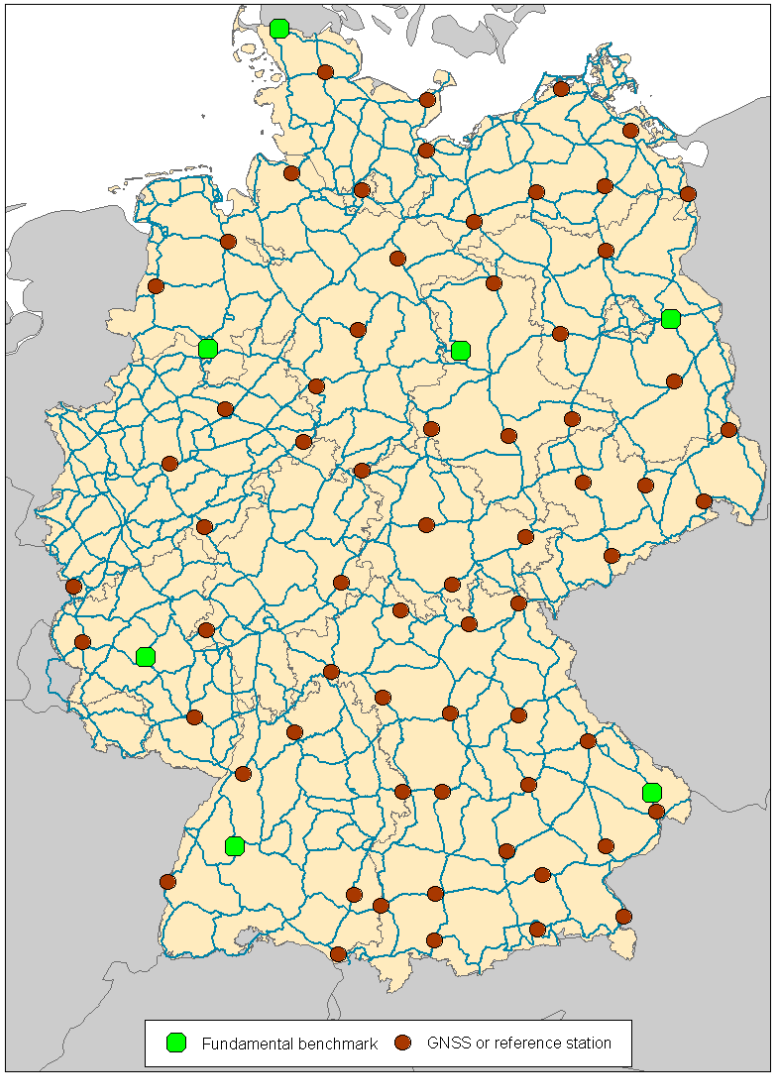
Height Variations Compared to DHHN92 after Preliminary Adjustment

Status April 2013



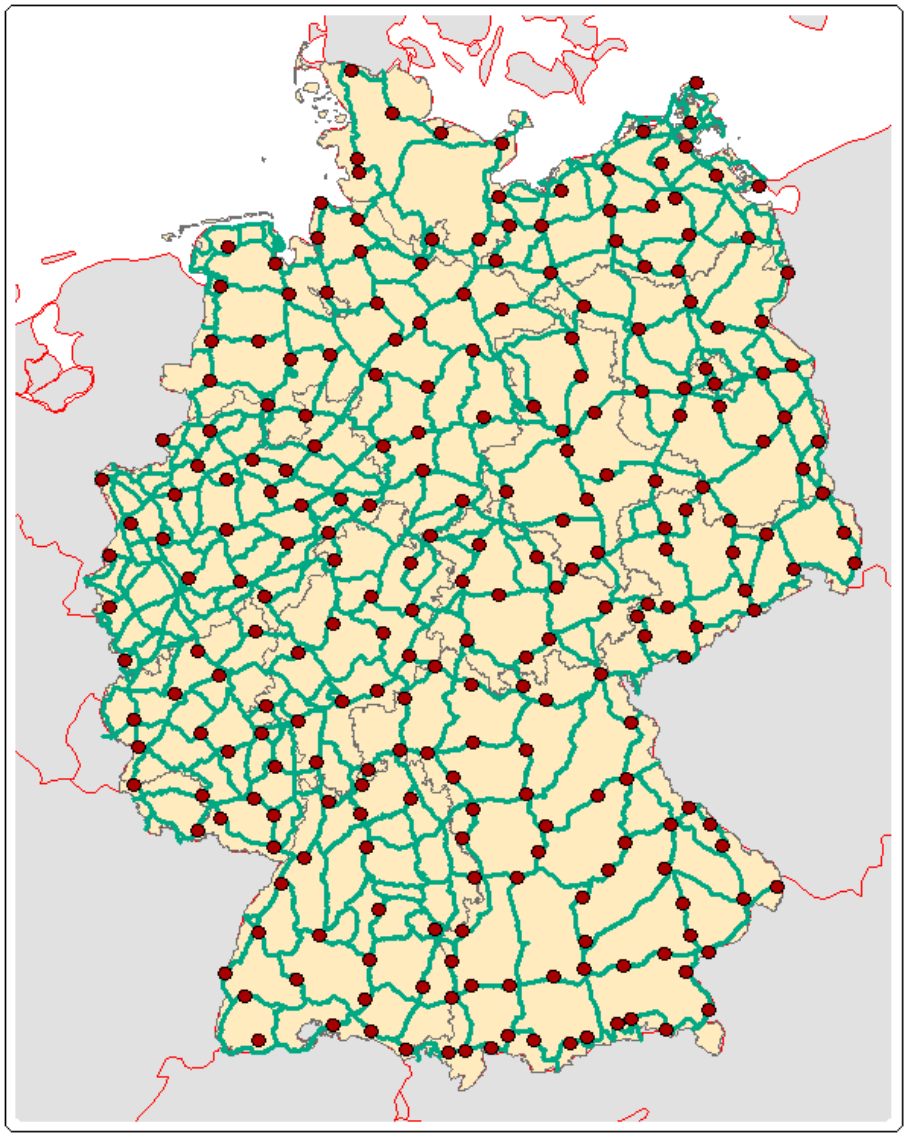
- interpretation is pending
- in the DHHN92 adjustment had been included border loops to some neighboring countries (CZ, AT, CH), in the current adjustment no foreign loops are included
- northernmost area (island of Rügen) : assumed uplift because of postglacial rebound

Planned Datum Points



- 7 fundamental benchmarks
- future possibility to maintain the datum by GNSS:
- 3 reference stations
  - HOBU (EPN)
  - GELL, HOFJ (GREF)
- 63 stations of the GNSS campaign 2008
- selection criteria
  - sited at old line of DHHN92
  - geologically stable area
  - special pillar marker
  - at least 2 reference markers

GNSS Campaign as Part of the Project



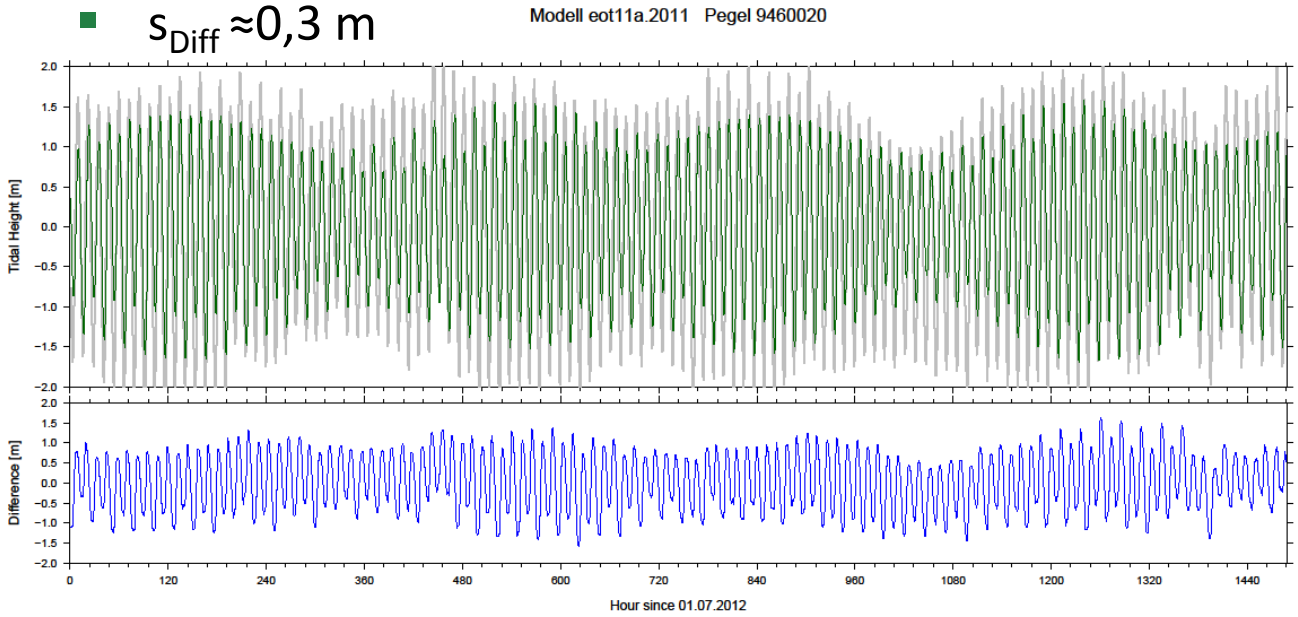
- leveling, GNNS and absolute gravity measurements on 250 identical points
- observation campaign in May/June 2008
- 2 X 24 h
- precision position ≈ 1 mm, height ≈ 3 mm
- absolute gravity observed by A10
- GNSS stations will be part of the German Geodetic Fundamental Network

Comparison and Validation of Ocean Tide Models (1)

- used Software: SPOTL, *D.C Agnew, IGPP, University of California* in combination with software by *Mirko Scheinert (TU Dresden*)
- comparison of global models of ocean tides:
  1. eot11a.2011 *(DGFI Munich)*
  2. dtu10.tr.2010 *(DTU Space, Copenhagen)*
  3. fes.2004 *(LEGOS, CLS, CNES, France)*
  4. got4p7.2004 *(Goddard Ocean Tide Model)*
  5. osu.tpxo72.2010 *(Oregon State University-OSU)*
  6. osu.tpxo72atlas.2011 *(Oregon State University-OSU)*
- in the area of North Sea the global model was replaced by regional model:
  7. eot11a.2011+ osu.europeshelf.2008
  8. dtu10.tr.2010+ osu.europeshelf.2008

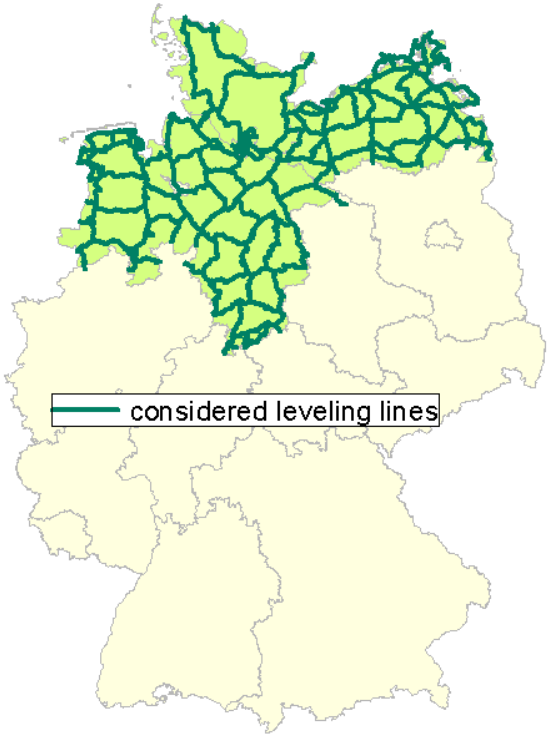
Comparison and Validation of Ocean Tide Models (2)

- validation of ocean tide models by data of 9 tide gauges at the German North Sea coast
- best results arised from:
  - dtu10.tr.2010+ osu.europeshelf.2008 (model 8) *(DTU Space, Copenhagen)*
  - eot11a.2011+ osu.europeshelf.2008 (model 7) *(DGFI Munich)*
  - s_{Diff} ≈0,3 m



grey: tide gauge time series ***green***: Tidal height from the model ***blue***: difference

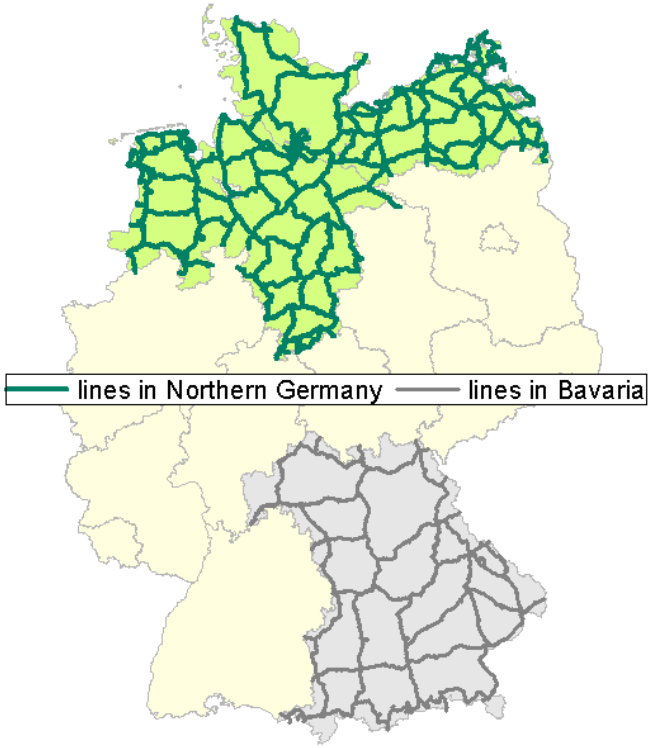
Consideration of Ocean Load Effects (1)



- network parts of 4 Northern German states (82 loops)
- use of 8 different ocean tide models
- comparison of the standard deviation from loop errors in mm/km
- best results: eot11a.2011(DGFI) + North Sea (OSU)

Without tidal correction	Solid earth tides	Mean tide + Ocean load							
		1	2	3	4	5	6	7	8
0.551	0.542	0.536	0.539	0.539	0.540	0.539	0.539	0.535	0.539

Consideration of ocean load effects (2)



- network parts of 4 Northern German states (82 loops)
- use of 8 different ocean tide models
- comparison of the standard deviation from loop errors in mm/km
- best results: eot11a.2011(DGFI) + North Sea (OSU)
- Network part of Bavaria in the South of Germany: no influence of ocean load effects in leveling results

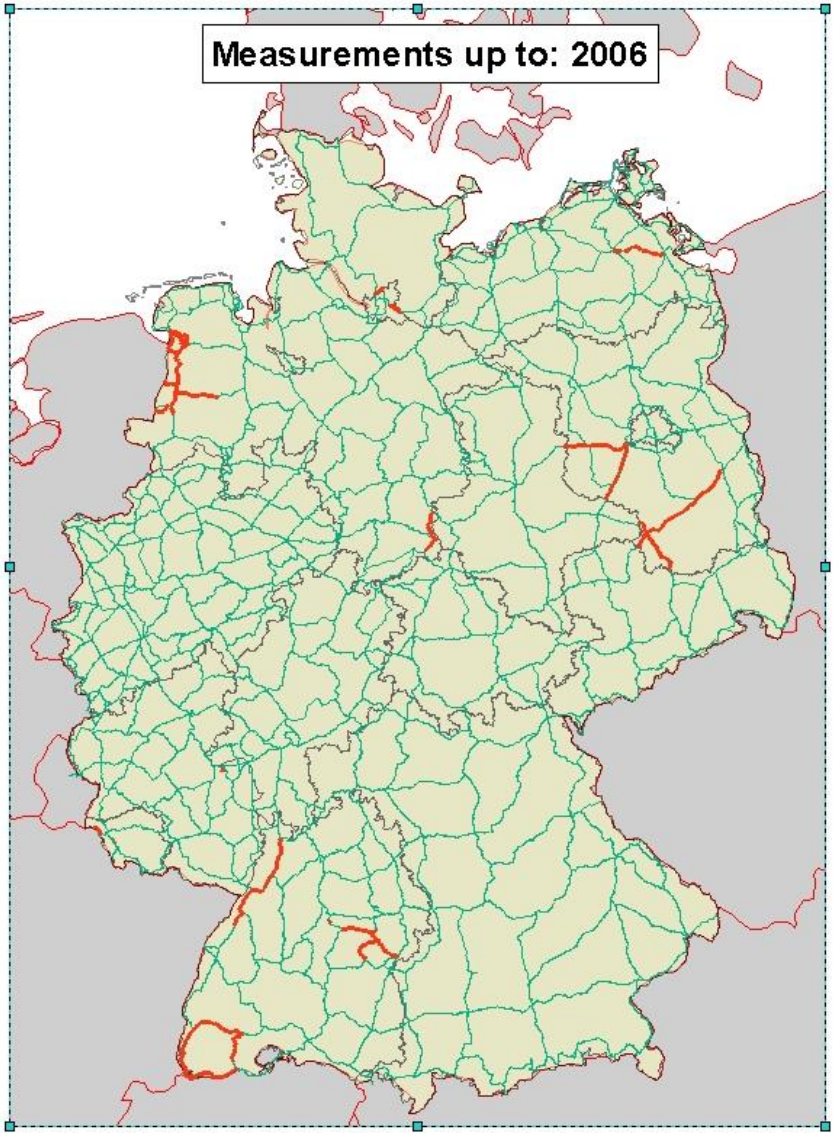
Influence of tidal corrections and ocean load effects

- Standard deviation from the adjustment of 4 Northern German states in mm/km:

	Without tidal correction	Mean tide	Mean tide + Ocean load (eot11a.2011+North sea)
4 Northern states	**0.59**	**0.59**	**0.58**
s_0 of single states from variance component estimation:			
HH	0.37	0.35	0.35
MV	0.52	0.51	0.50
NI	0.65	0.65	0.65
SH	0.36	0.35	0.34

- Variation of adjusted heights:
  - Mean tide – without correction: **-1.6mm … 2.3mm**
  - Additional effect of ocean load: **-0.5mm … 1.0mm**

Monitoring of Work Progress



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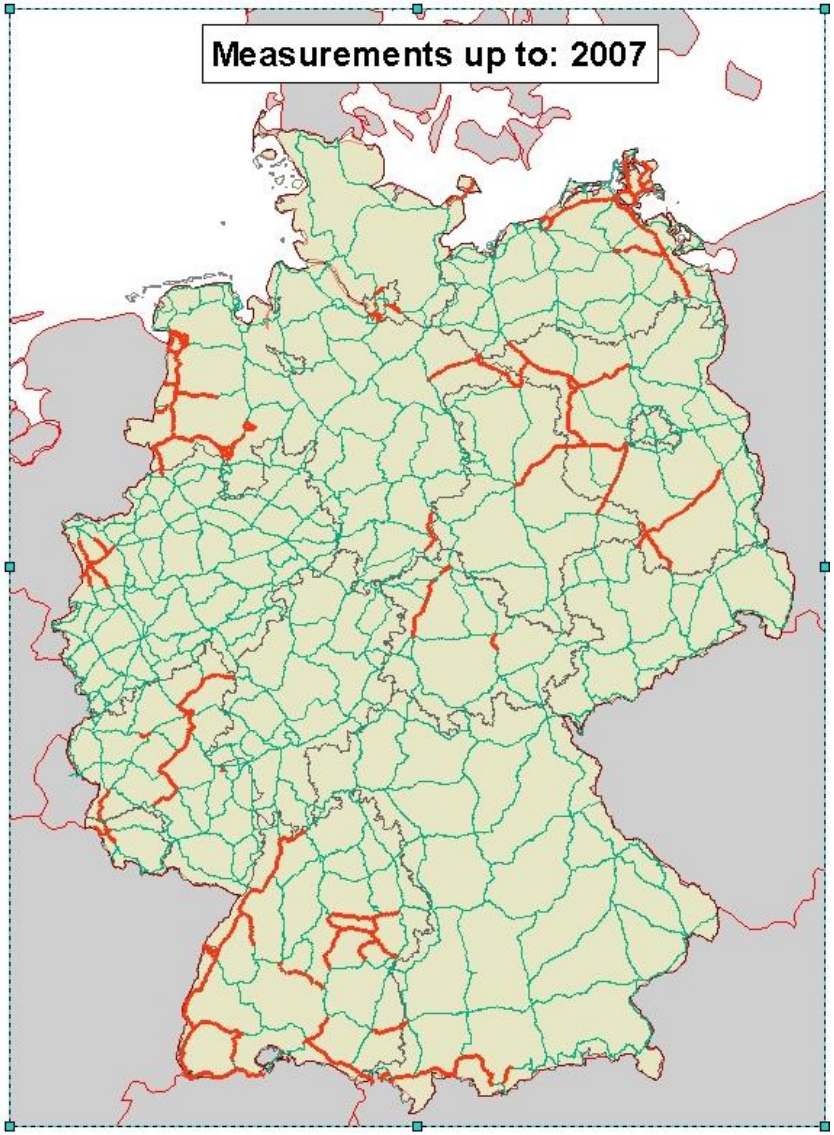

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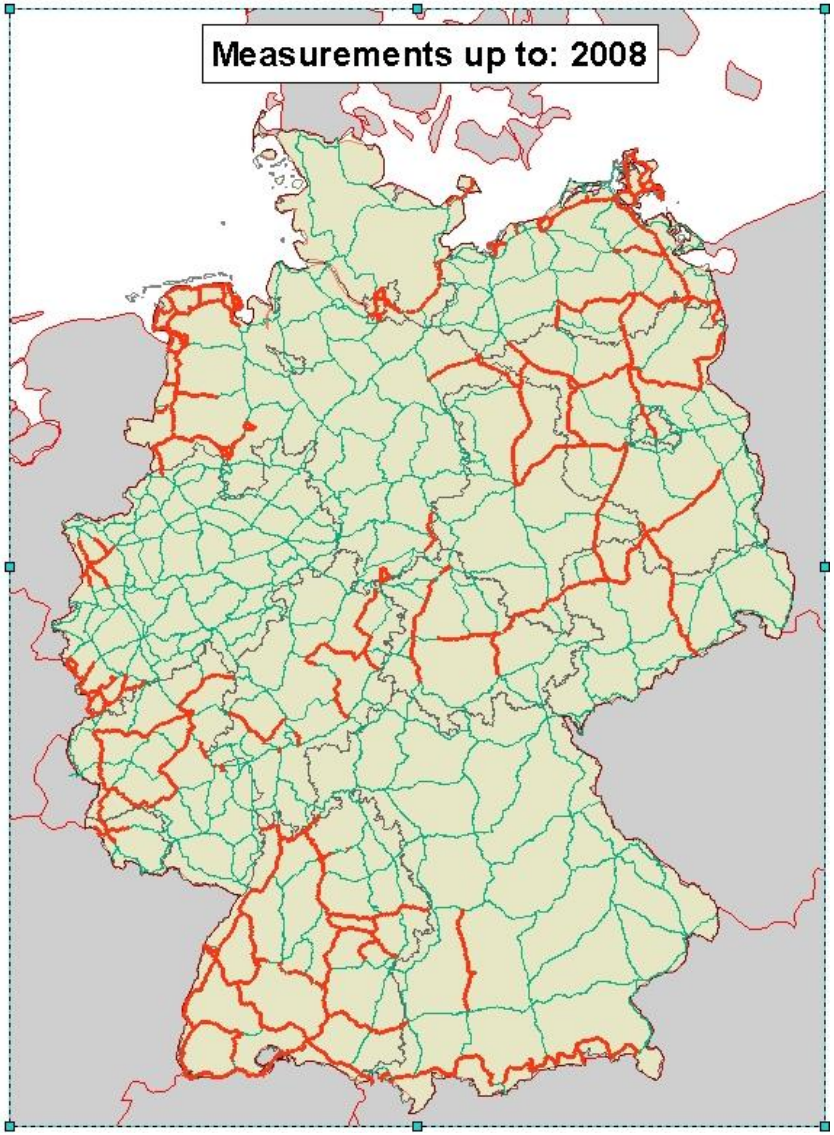

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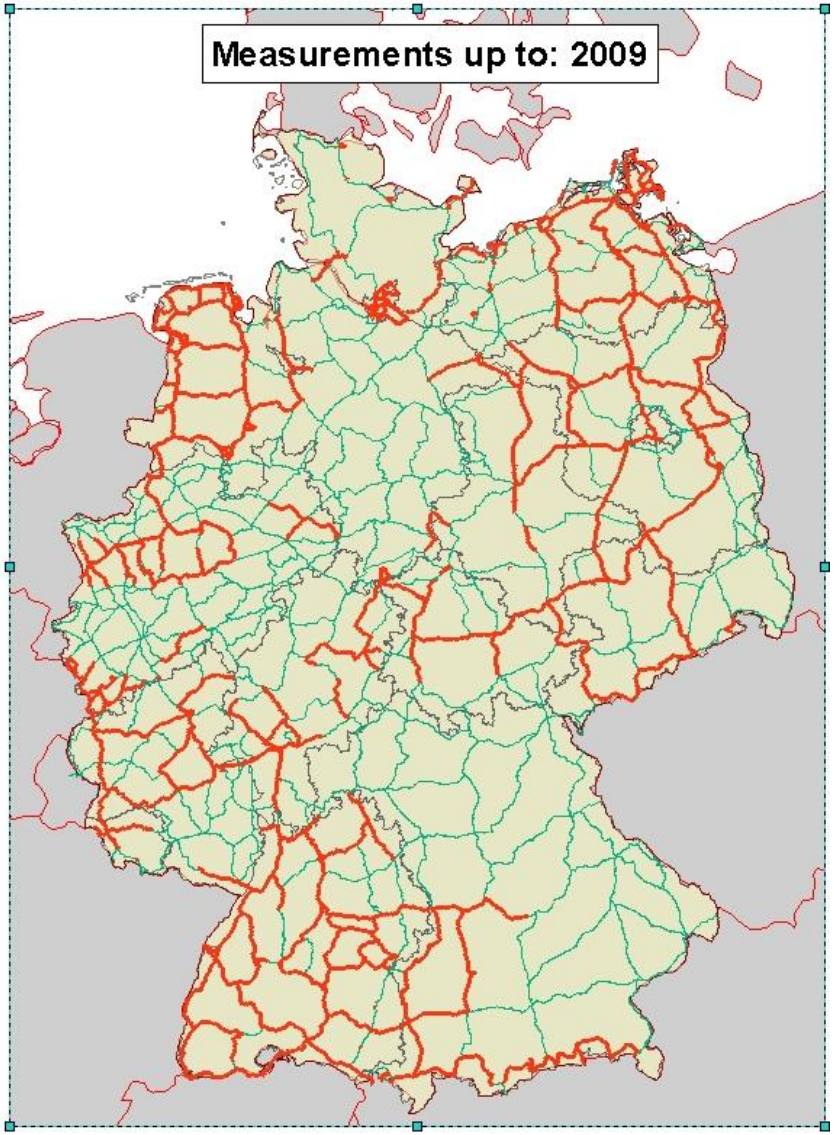

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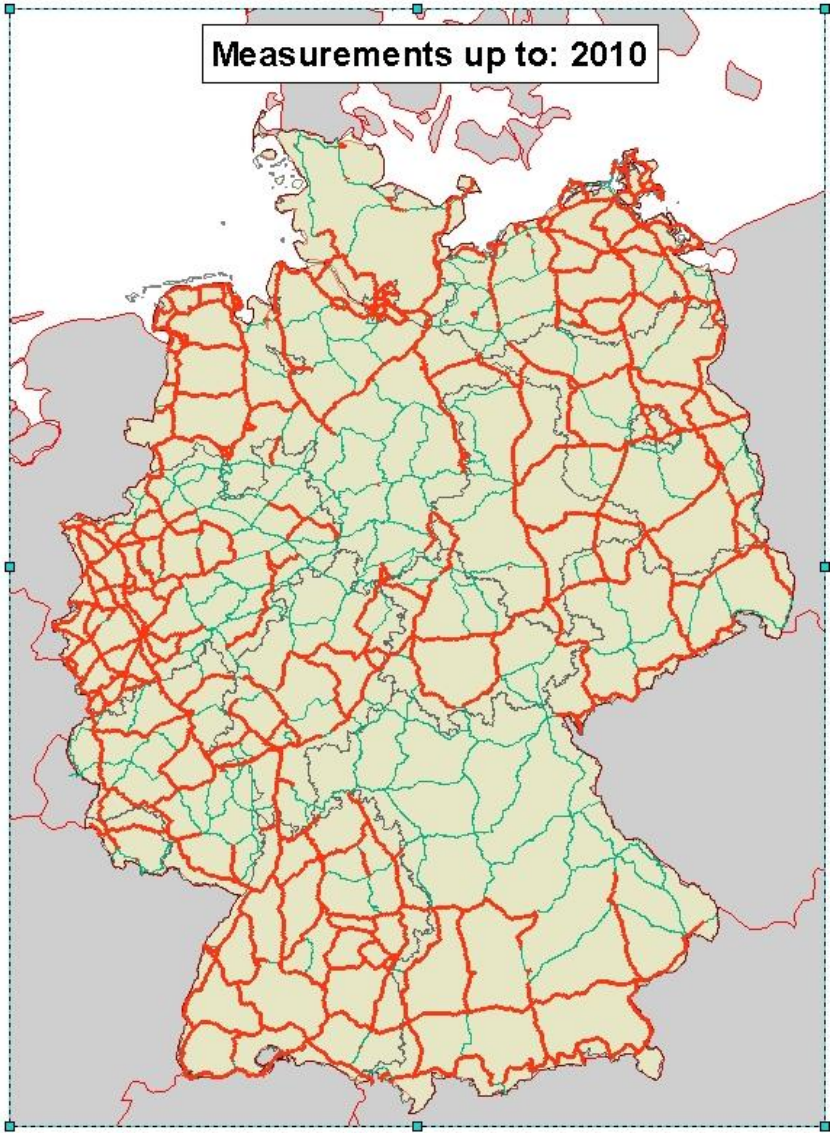

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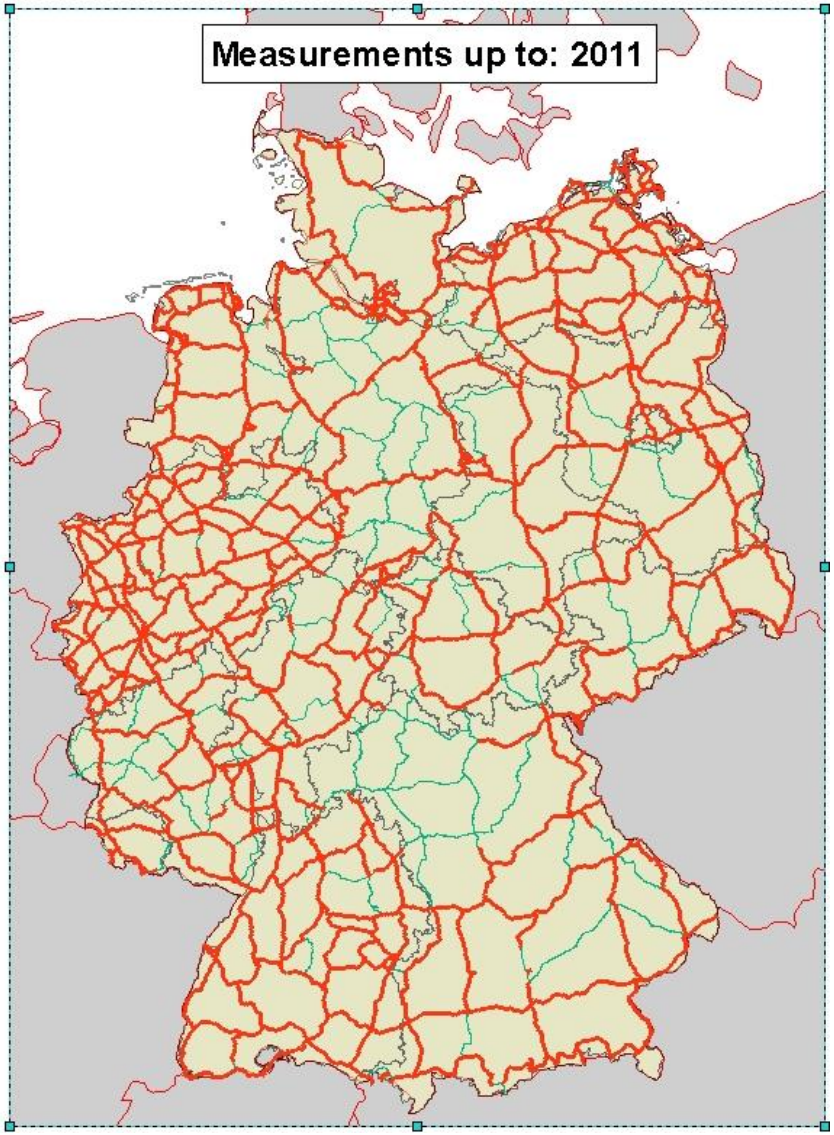

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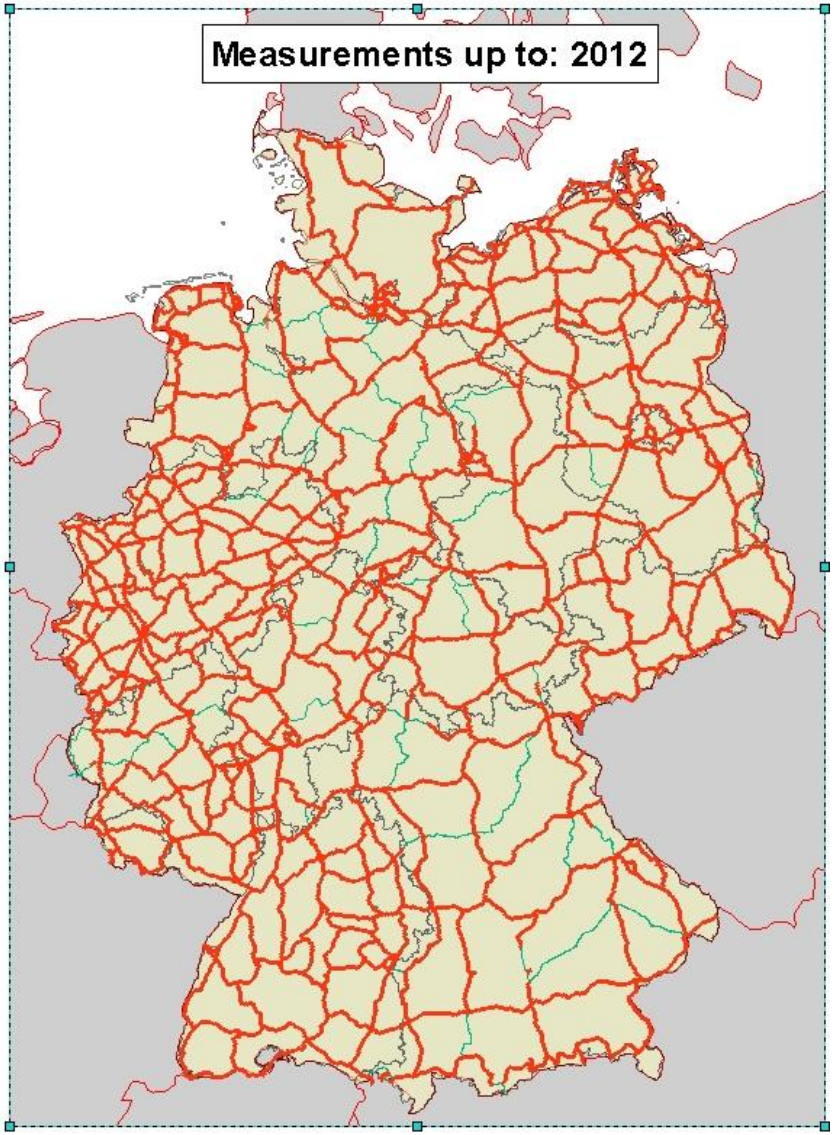

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