GNSS technology for track maintenance

Mark Bachmann, Gerhard Wübbena, Martin Schmitz

Geo++® GmbH
30827 Garbsen
Germany
www.geopp.com

Outline

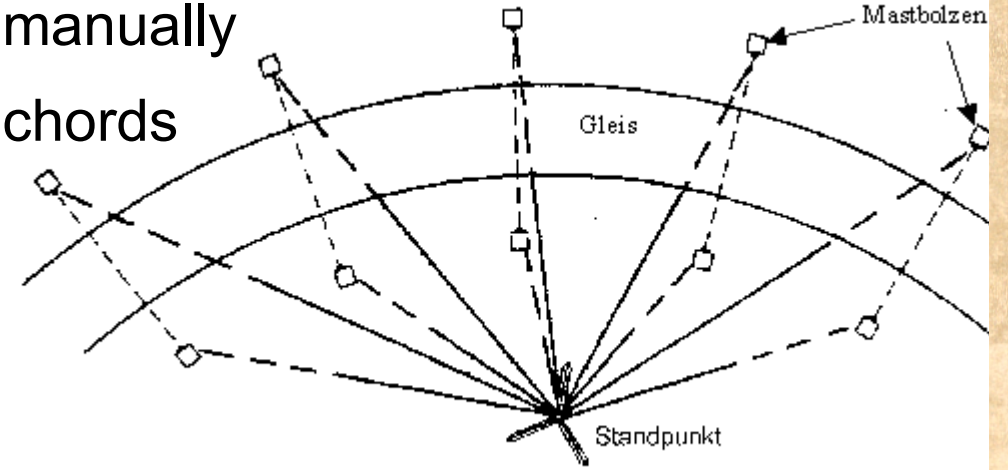
- GNBAHN – Track survey system
  - Why track survey
  - Traditional track survey
  - Satellite aided track survey
- GNTRANS – Coordinate transformation
  - Modern coordinate system
  - Other coordinate systems
    - Case study: Germany
  - Local transformation
  - Adjacency preserving transformation
  - GNTRANS in Germany

Track survey - Why

- Motion dynamics
  - Safety, Comfort, Speed
- Length management
  - Endless welded tracks
  - Risk of twist and splits
- Track determination
  - Theoretic/real comparison of track
  - Offset determination
  - 3D survey of real geometry
  - Computation of theoretic geometry
    (straight line, clothoide, gradient, ramping, ...)
  - Re-construction

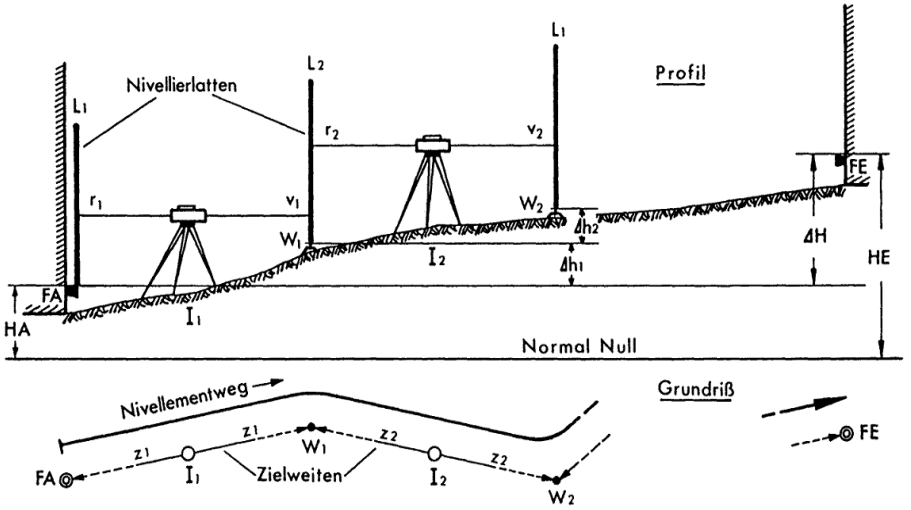
Traditional track survey

- Track determination on special points
  - Surveying of near tack traverses or pylon bolts (free stationing)
  - Distances between pylon bolts
  - Rise of arc measurement by long chords
  - Only several points, approx. all 5 m
- Rise of arc measurement by long chords
  - Traditional manually
  - Laser long chords by EMSAT

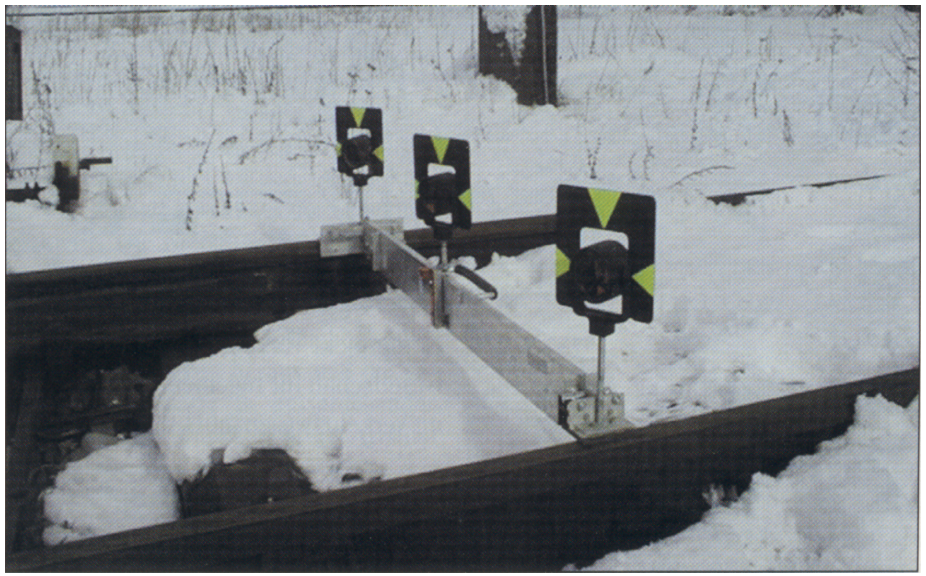


Traditional track survey

- Height measurement
  - Geometric levelling



- Superelvation and gauge
  - Portable measuring instruments

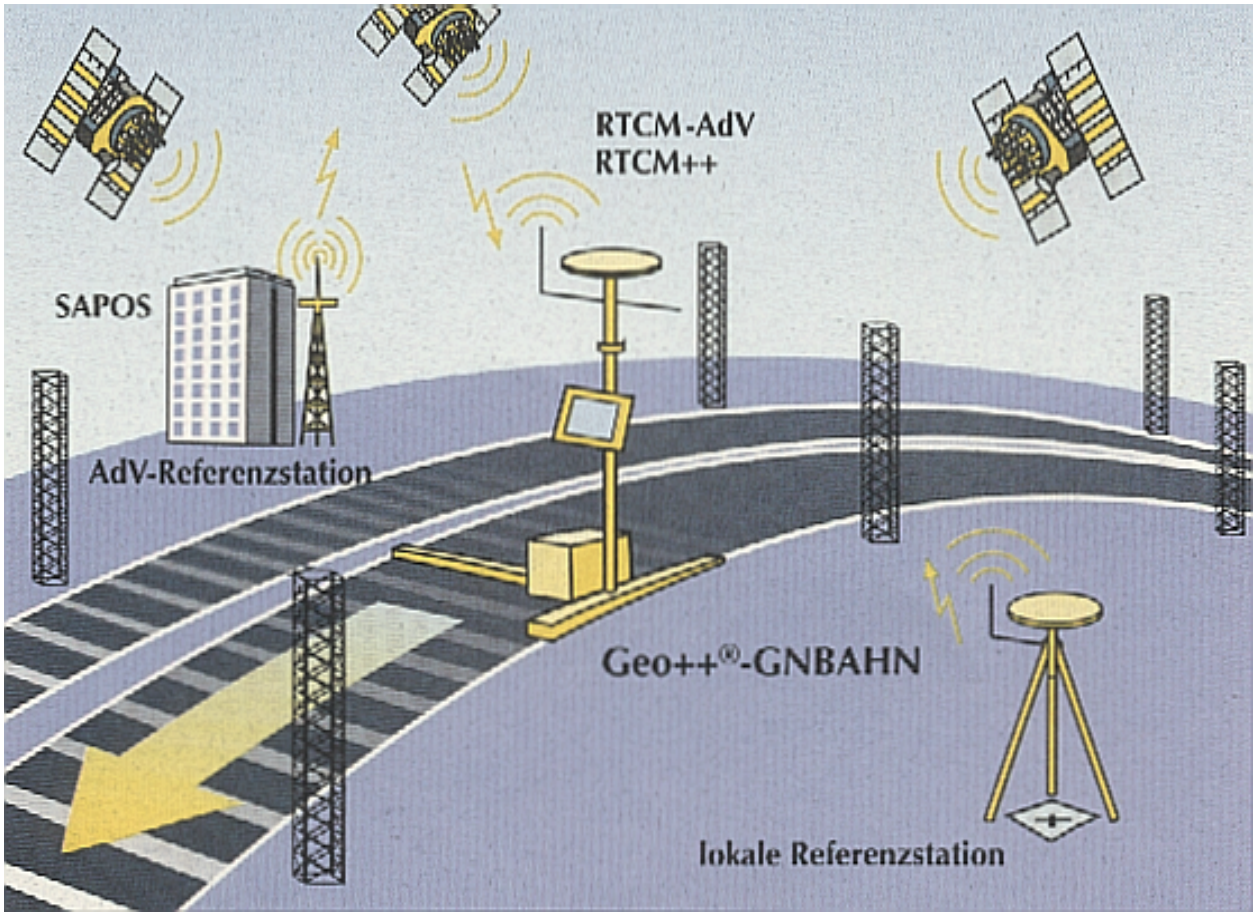


Characteristics of traditional track survey

- Manual measurements
  - High effort for human resources
  - High effort in time
  - Post processing
- Automatic measurements
  - Stop of railway traffic required (closed railway)
  - Risk for periodic offsets
  - High effort for equipment (investment and maintenance)

GNBAHN - Principle of satellite aided track survey

- PDGPS (precise differential GPS) / RTK
- Superelevation with inclinometer
- Gauge with extensometer



PDGPS with GNNET-RTK

- Use of GPS and GLONASS (GNSS)
- Rigorous processing of multiple reference stations
- Optimal modeling of GPS error budget through undifferenced observation
- Absolute antenna calibration considering antenna tilt
- Mitigation of systematic multipath through moving SURVER
- Signal to noise weighting of satellite observations

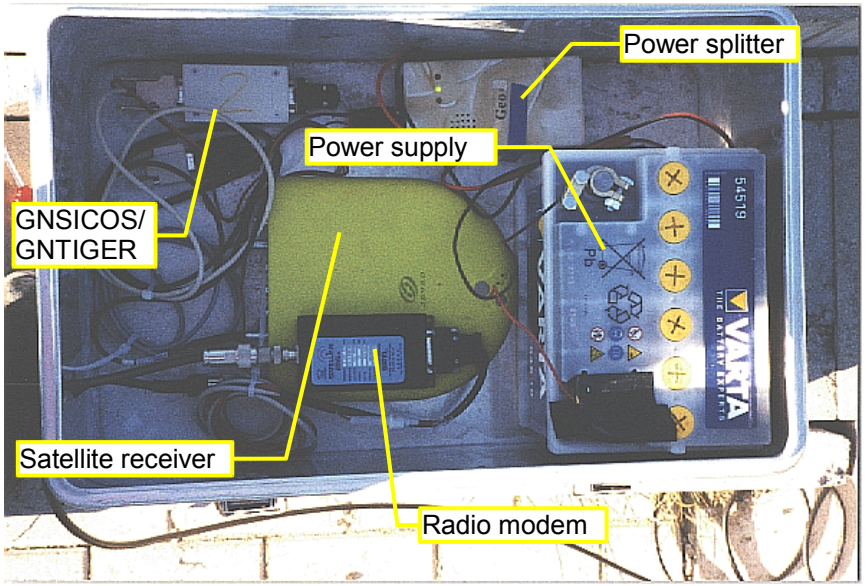
→ **Fast ambiguity fixing (5 - 10 seconds)**

→ **High reliability**

→ **High accuracy**

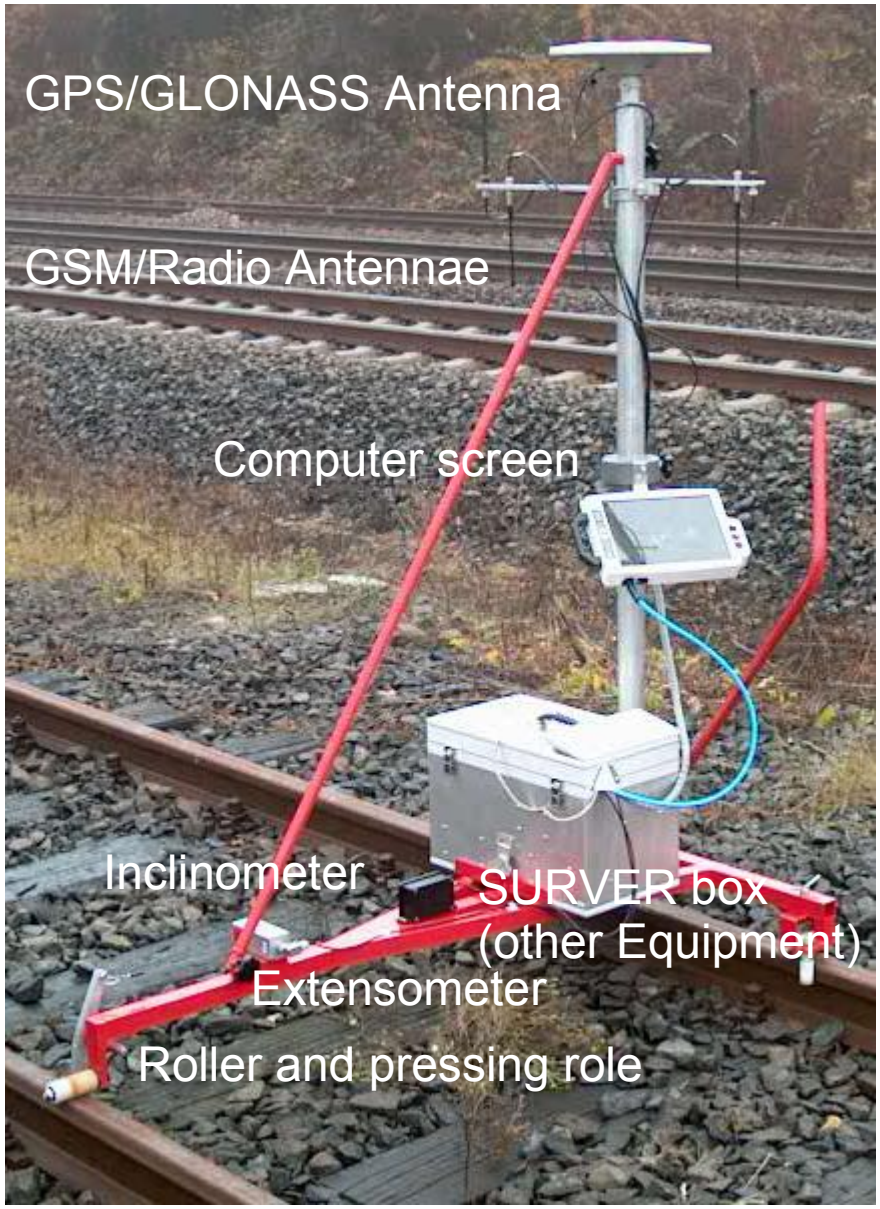
GPS/GLONASS Reference Station

- Provides correction or raw data
- Equipment
  - GPS/GLONASS receiver and antenna
  - GSM/Radio modem and antenna
  - Micro computer
  - Power supply

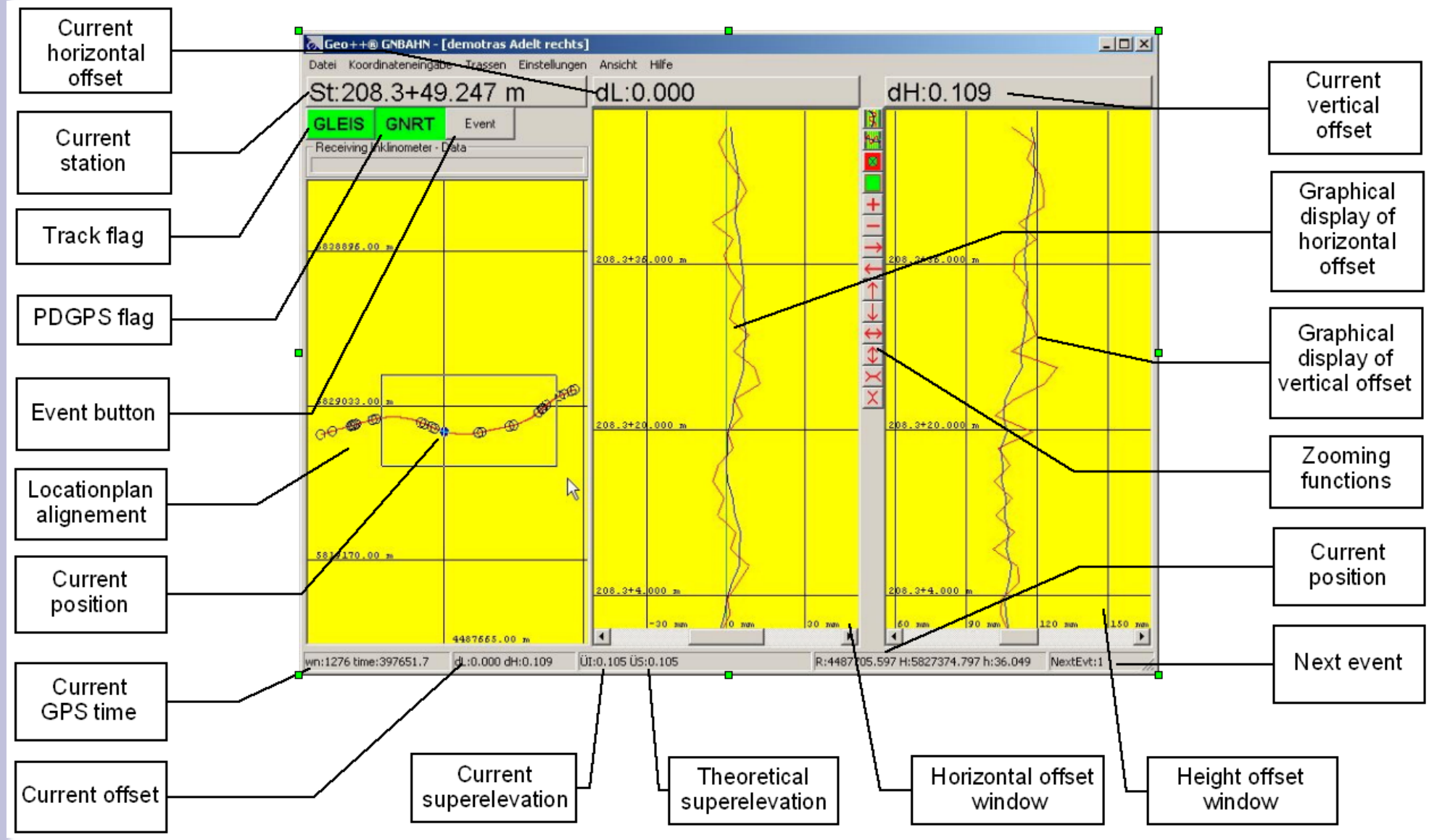


GNBAHN – Hardware

- SURVER
  „Spurzentrierter und Rollender Vermessungsträger“
- GPS/GLONASS receiver
- GPS/GLONASS antenna
- GSM/Radio modem
- GSM/Radio antennae
- Inclinometer (superelevation)
- Extensometer (gauge)
- Notebook
- Power supply



GNBAHN – Main window



GNBAHN – Range of application

- 3D determination of real track
  - Coordinates, superelevation, gauge
  - Computation of theoretic geometry (straight line, clothoide, gradient, ramping, ...)
- Malposition in real time
  - Machine control
  - Control survey
- Advantages
  - Two person transport and employment
  - Measurement velocity 3km/h
  - Stop of railway traffic not required
  - Disassembly possible for easy transport

GNBAHN – Procedure

- Measurement
  - Prepare reference stations on reference points
  - Prepare SURVER
  - Starting of PDGPS and GNBAHN System on SURVER
  - Calibration of Extensometer and Inclinometer (one time per day)
  - Observations of track in 2 directions (in real time: 3D coordinates, offsets, superelevation and gauge)
- Analysis
  - Combination of measurement in 2 directions
  - Filtering
  - Further processing like route selection (straight line, clothoide, gradient, ramping, ...)

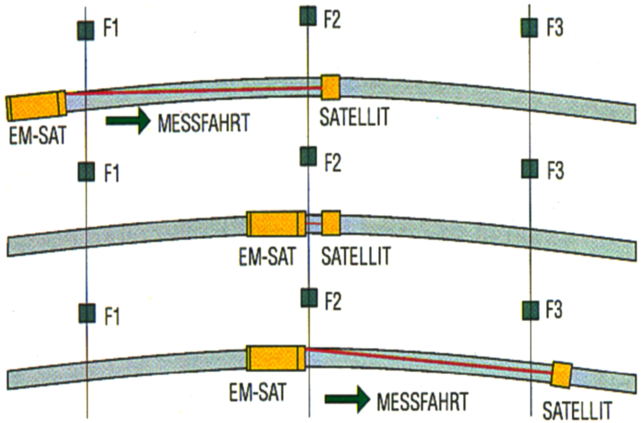
GNBAHN – Accuracy

- Horizontal 5 - 10 mm, vertical 10 - 15 mm
- A posteriori standard deviation of route selection adjustment
  - Source: company „Vermessungsbüro Riemenschneider“

From [km]	To [km]	Distance [km]	One track	Two tracks	Count of tracks	Surveyed (away+back) [km]	Std.Deviation horizontal [mm]	Std.Deviation vertical [mm]
41	50	9		X	2	36		
5	9	4	X		1	8		
22,8	25,1	2,3	X		1	4,6	6	10
30,3	35,4	5,1		X	2	20,4	8	13
45,1	46,3	1,2		X	2	4,8	5	6
47,4	48,8	1,4		X	2	5,6	6	8
49,6	50,7	1,1		X	2	4,4	6	9
76,6	83	6,4	X		1	12,8	7	10
30,36	35,42	5,06		X	2	20,24	8	13
68,86	72,05	3,19	X		1	6,38	8	14
84,97	88,14	0,83	X		1	1,.67	6	10
87,52	88,14	0,62	X		1	1,24	6	16
32,34	35,56	3,22	X		1	6,44	7	13
3,75	48,9	18,5		X	2	74	6	17
32,7	47,6	6,3	X		1	12,6	6	17
83,8	101,2	17,4	X		1	34,8	4	8
23	30,8	7,8	X		1	15,6	5	10
44,9	46,2	1,3	X		1	2,6	4	8
		Sum [km] 94,72				**Sum [km] 270,5**	**Mean [mm] 6**	**11**

GNBAHN - EMSAT

- Combination
  - GNSS absolut information
  - Laser long chord relative information
- Advantages
  - Improved absolute accuracy (1 – 5 mm)
  - By-pass of shadowing effects of GNSS (Bridges, ...)



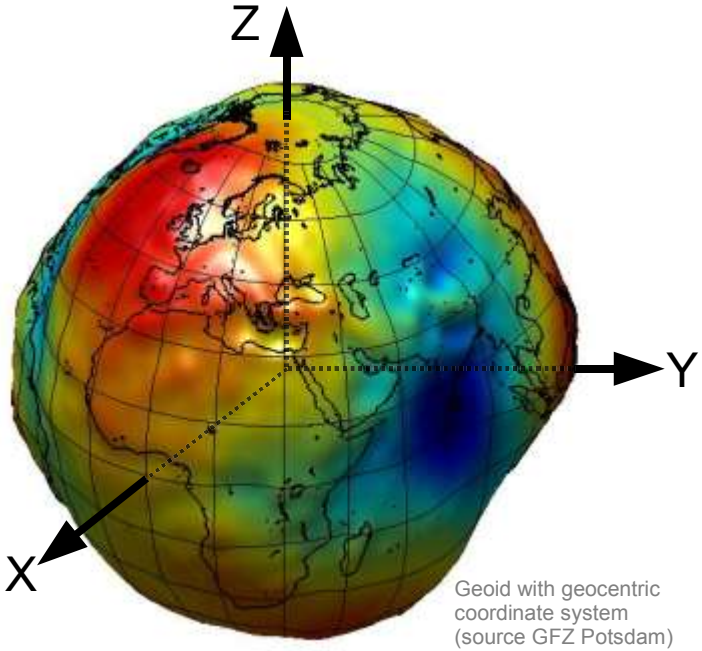
- Coordinates
  - Local
    - Crossing status within country
    - Crossing bourders between country
  - European
    - Homogenous coordinates Europe-wide

Coordinate transformation

- Enables
  - Transformation between global and local systems
  - Simultaneous use of global and local systems

Modern coordinate systems

- Three-dimensional coordinate system
  - Geocentric

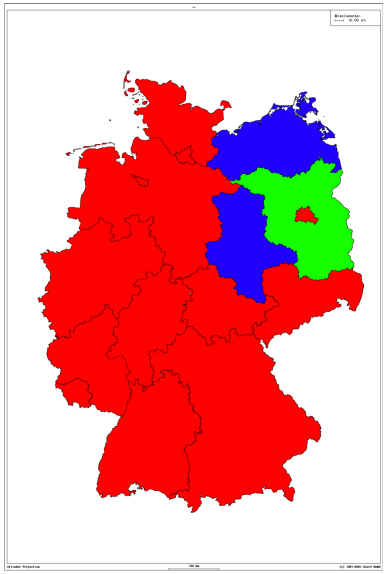


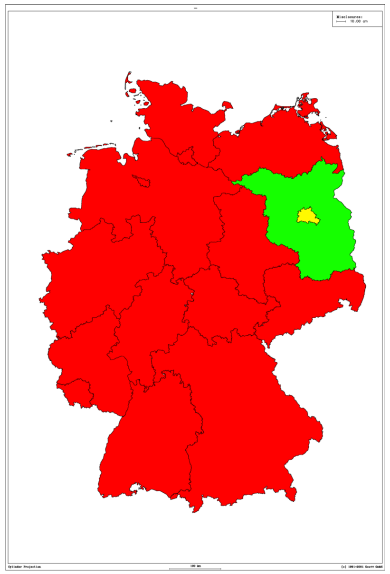
Geoid with geocentric coordinate system (source GFZ Potsdam)

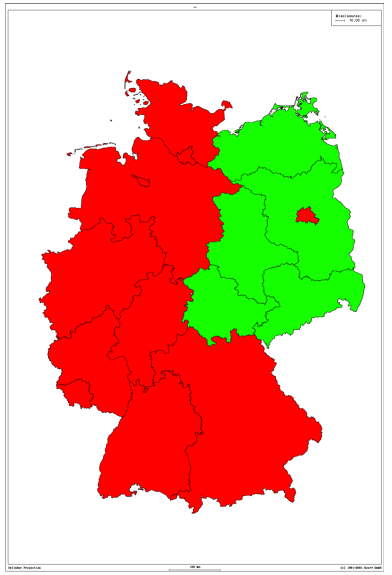
- Why?
  - Satellite geodesy, ...
  - Accuracy, consistency, internationally, globally, ...
- e.g. WGS 84, ITRS xx, ETRS xx

Other coordinate systems, case study: Germany

- Surveying in Germany is a task of the states
  - Therefore different:
    - Geodetic datums
    - Ellipsoids
    - Projections
    - Height systems

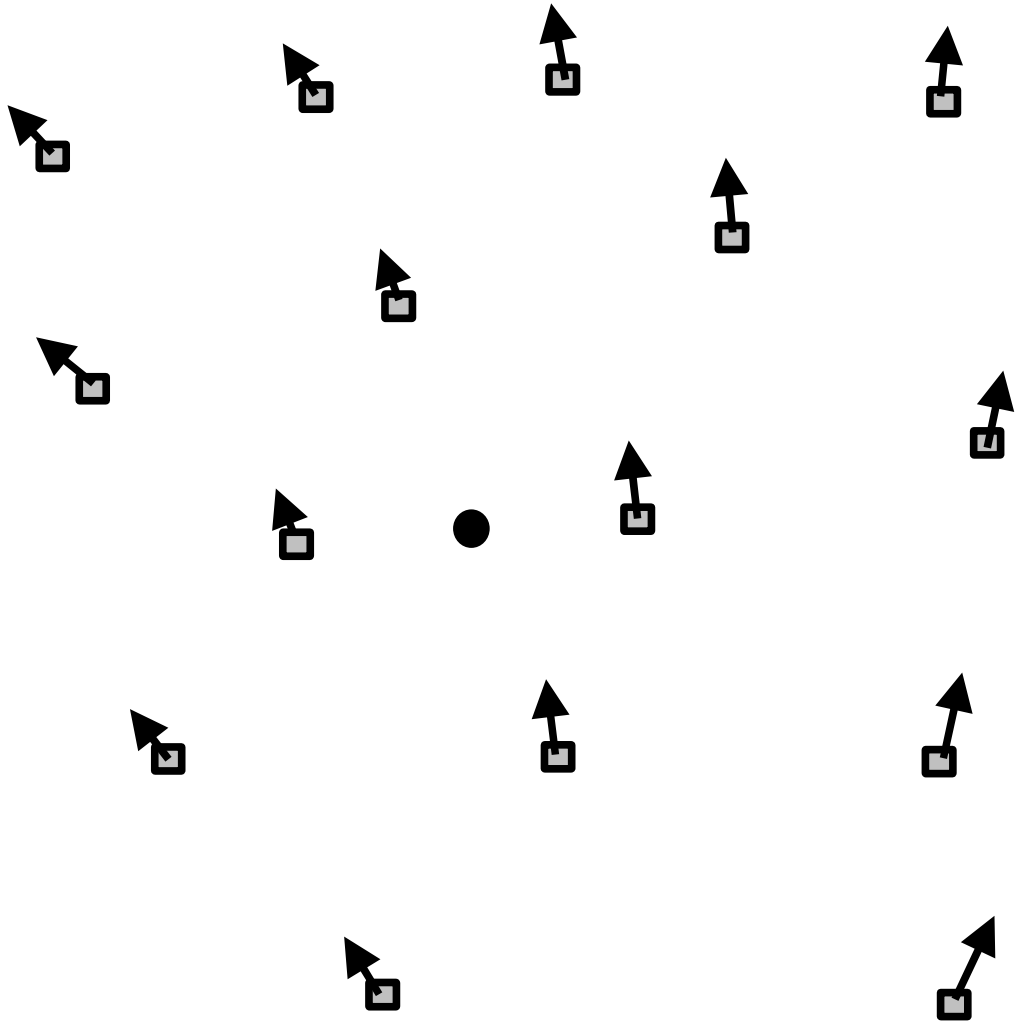






- Situation German-wide
  - Non-homogeneous coordinates for surveying and mapping applications
  - Discontinuities/coordinate jumps at state boundaries

Local transformation



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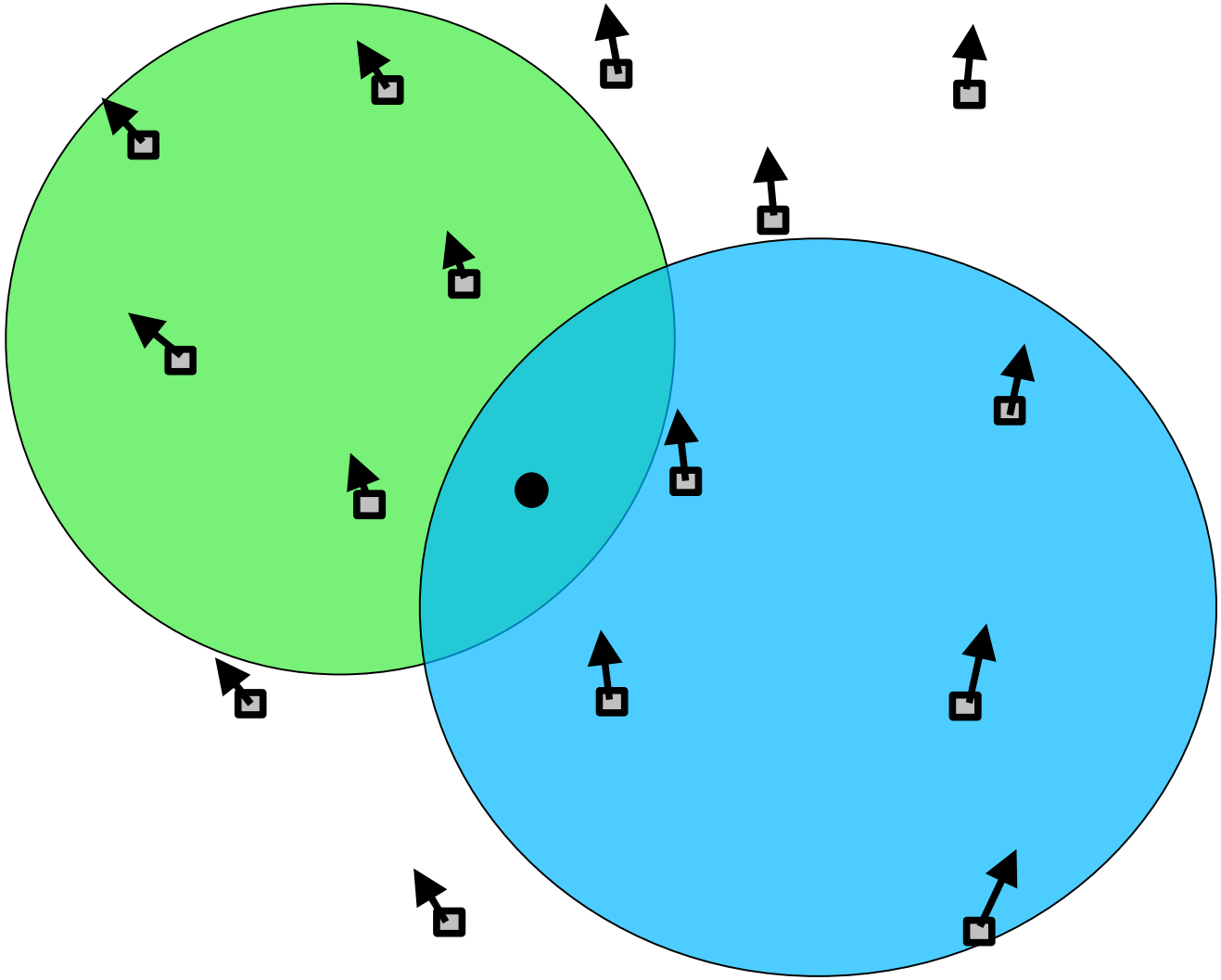

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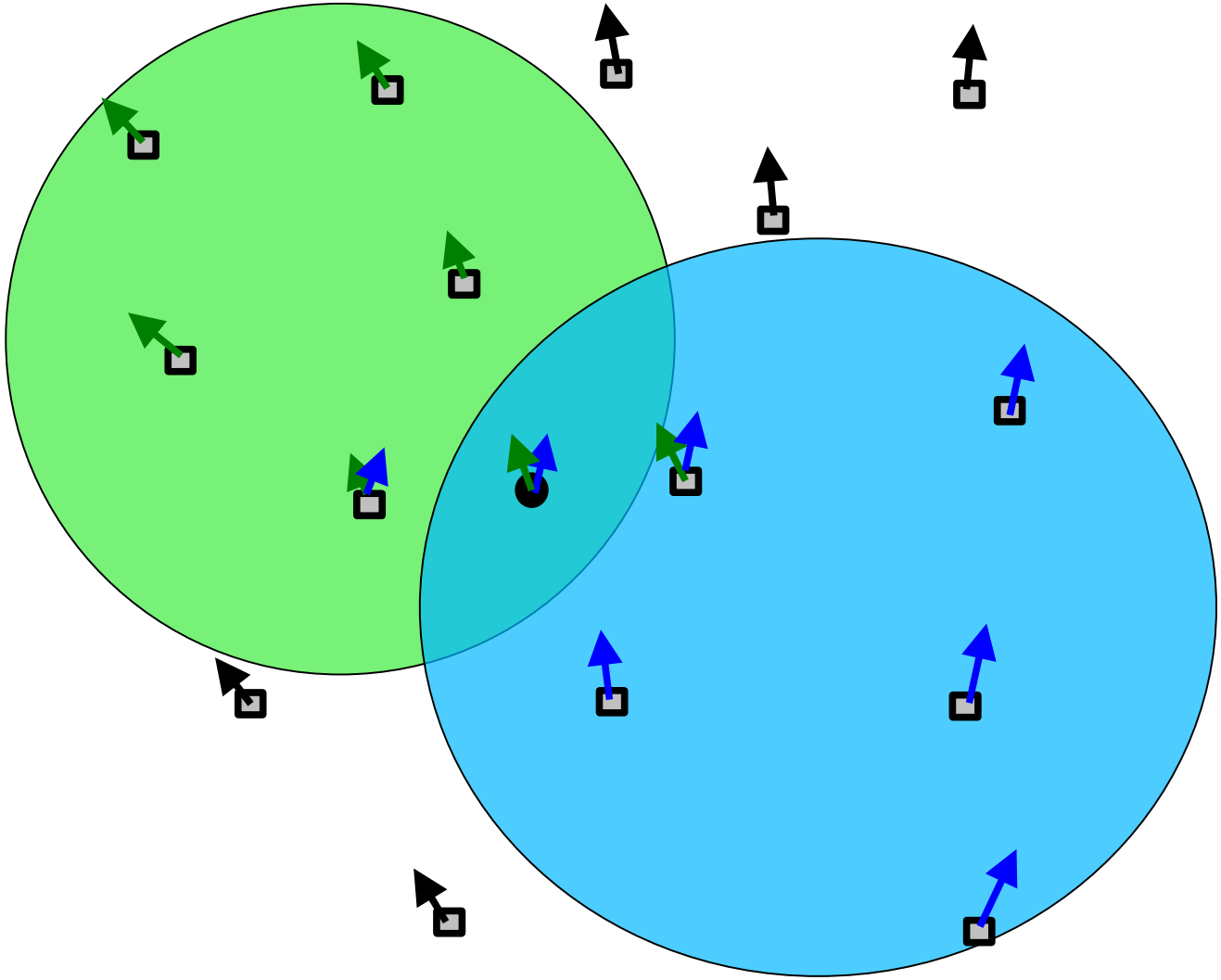

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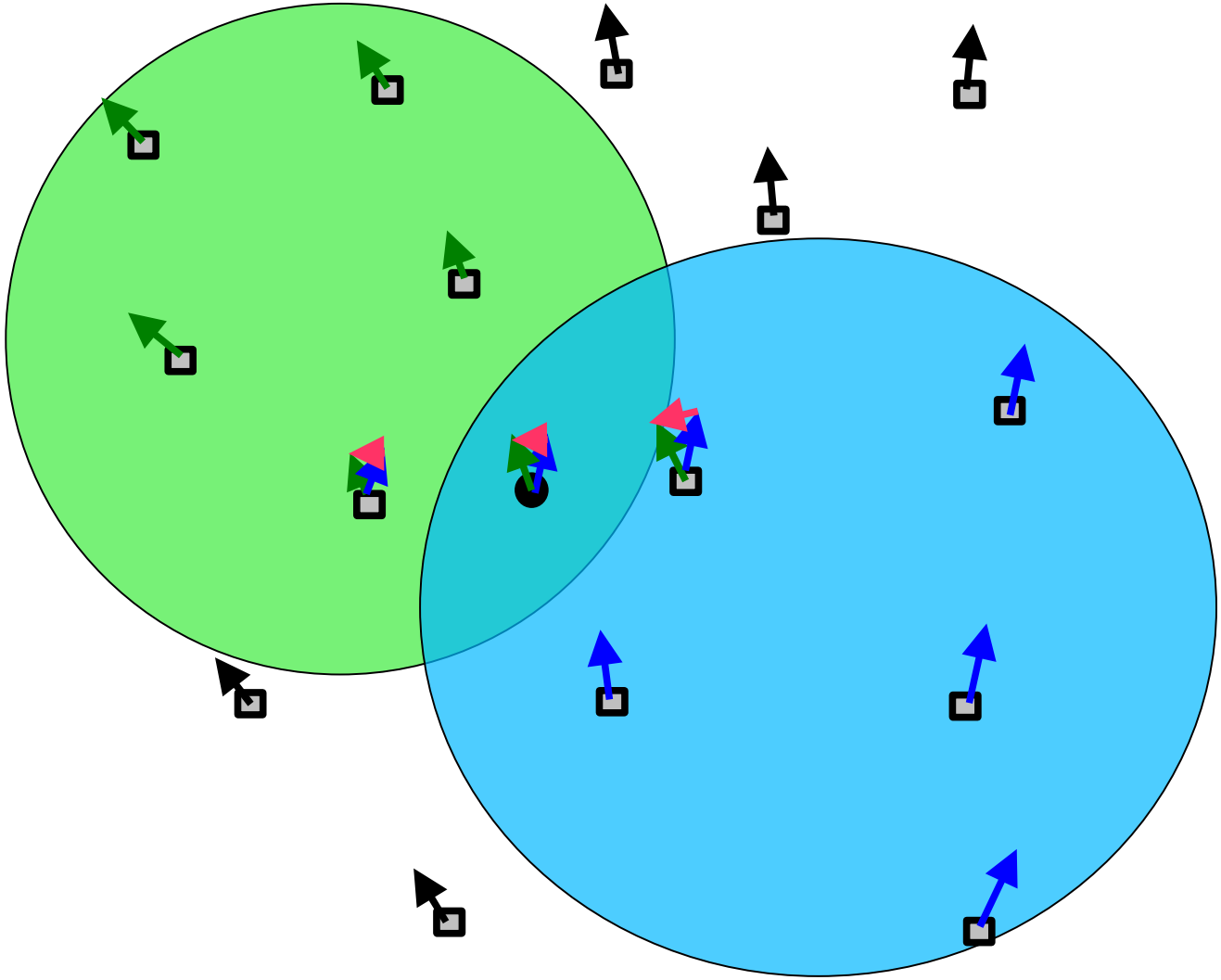

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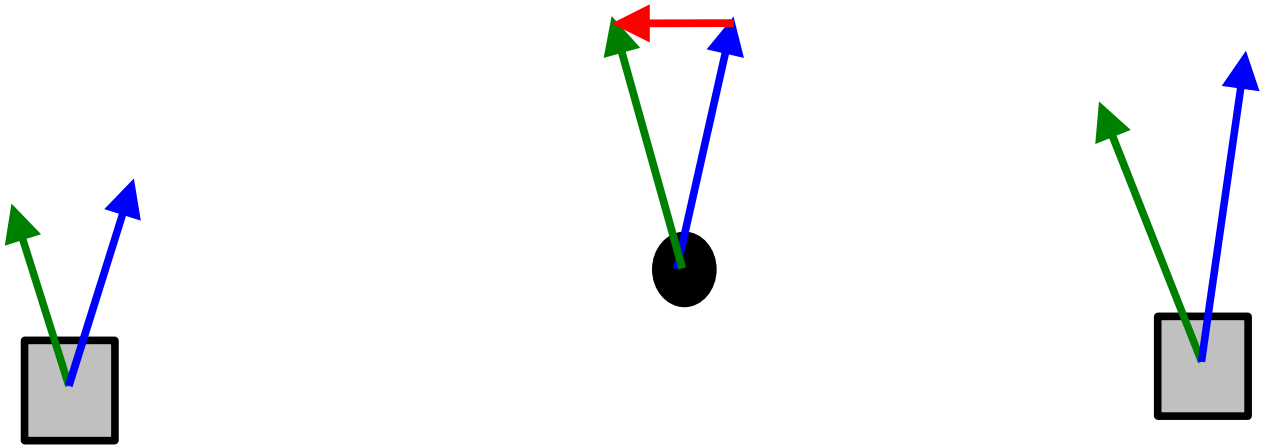

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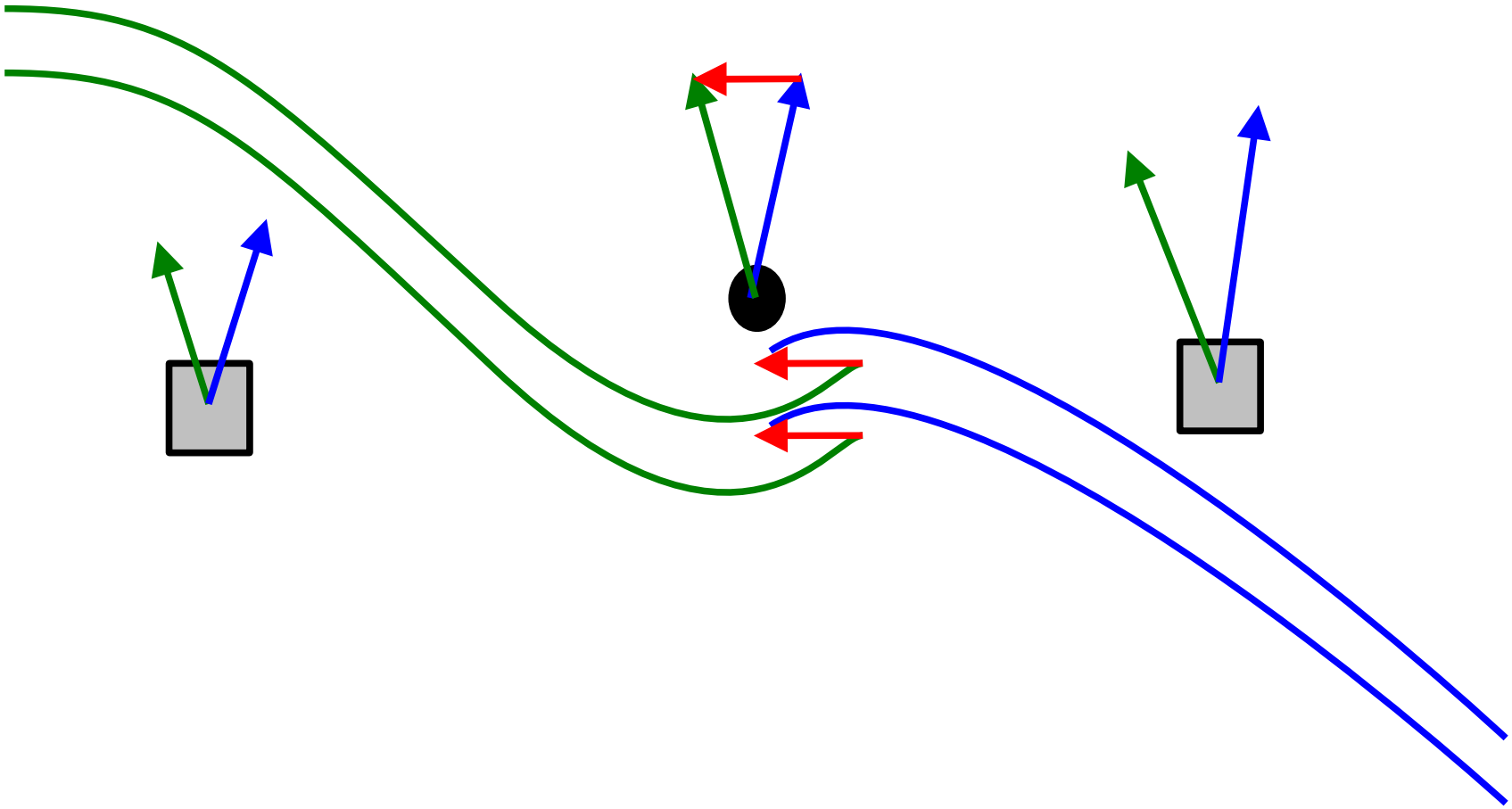
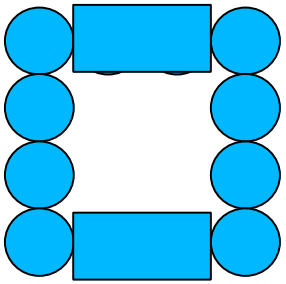
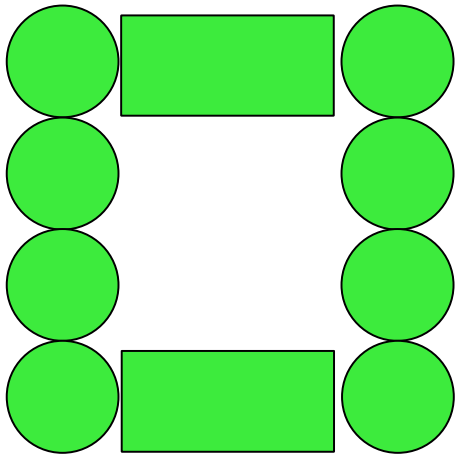


Adjacency preserving transformation

- **starting with**
  - consistency
- **resulting in**
  - consistency

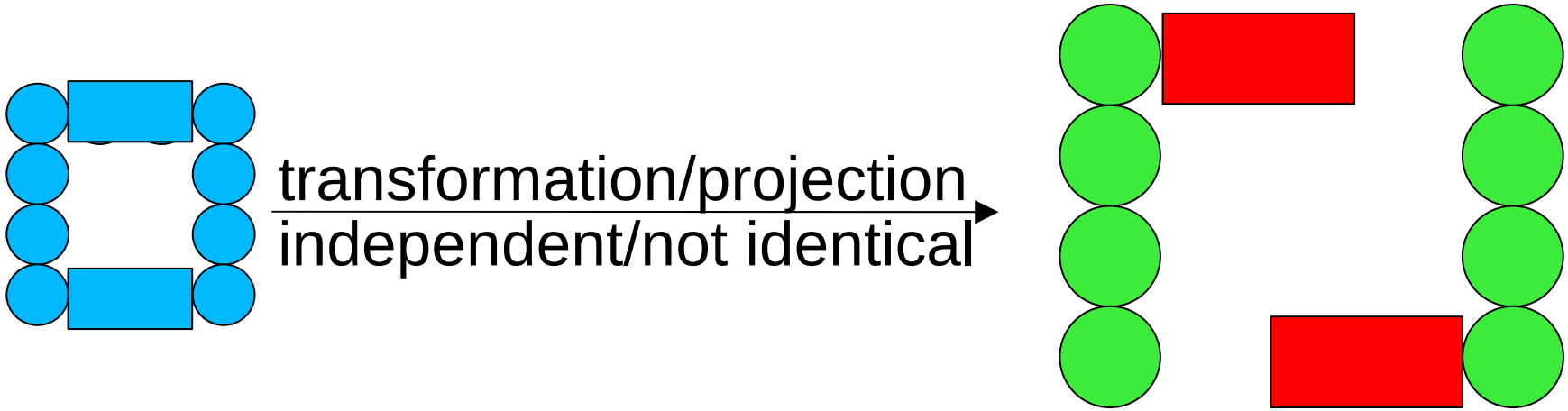


transformation/projection
independent/identical



Disturbed adjacency (non-continuous)

- **starting with**
  - consistent projection
- **resulting in**
  - inconsistent projection



Local transformation/
Adjaceny preserving transformation

- Problem: local transformation
  - Individual sets of identical points
  - Individual sets of transformation parameters
  - Distortions
- Solution: one consistent adjacency preserving transformation
  - Pre-requisite for general transformation module

Local transformation/ Adjaceny preserving transformation

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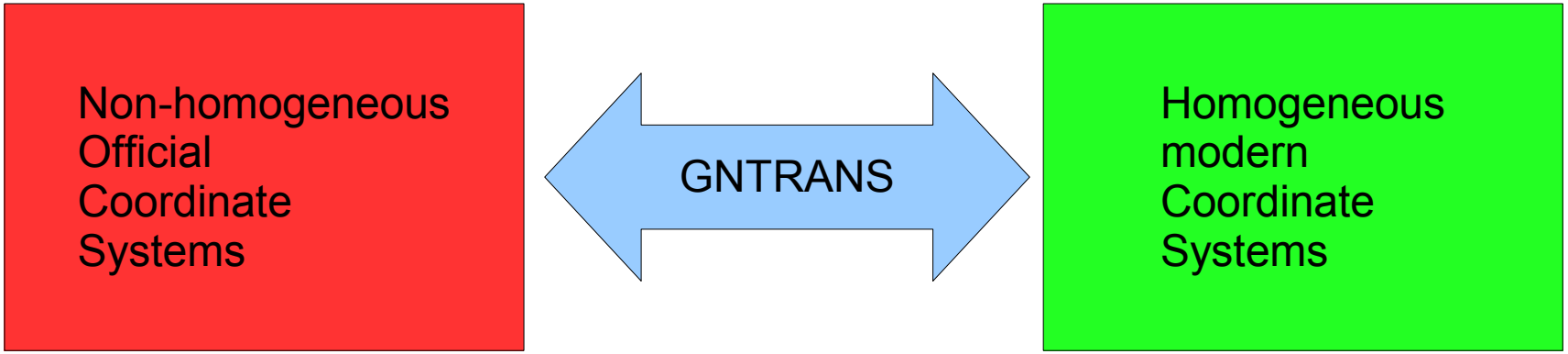
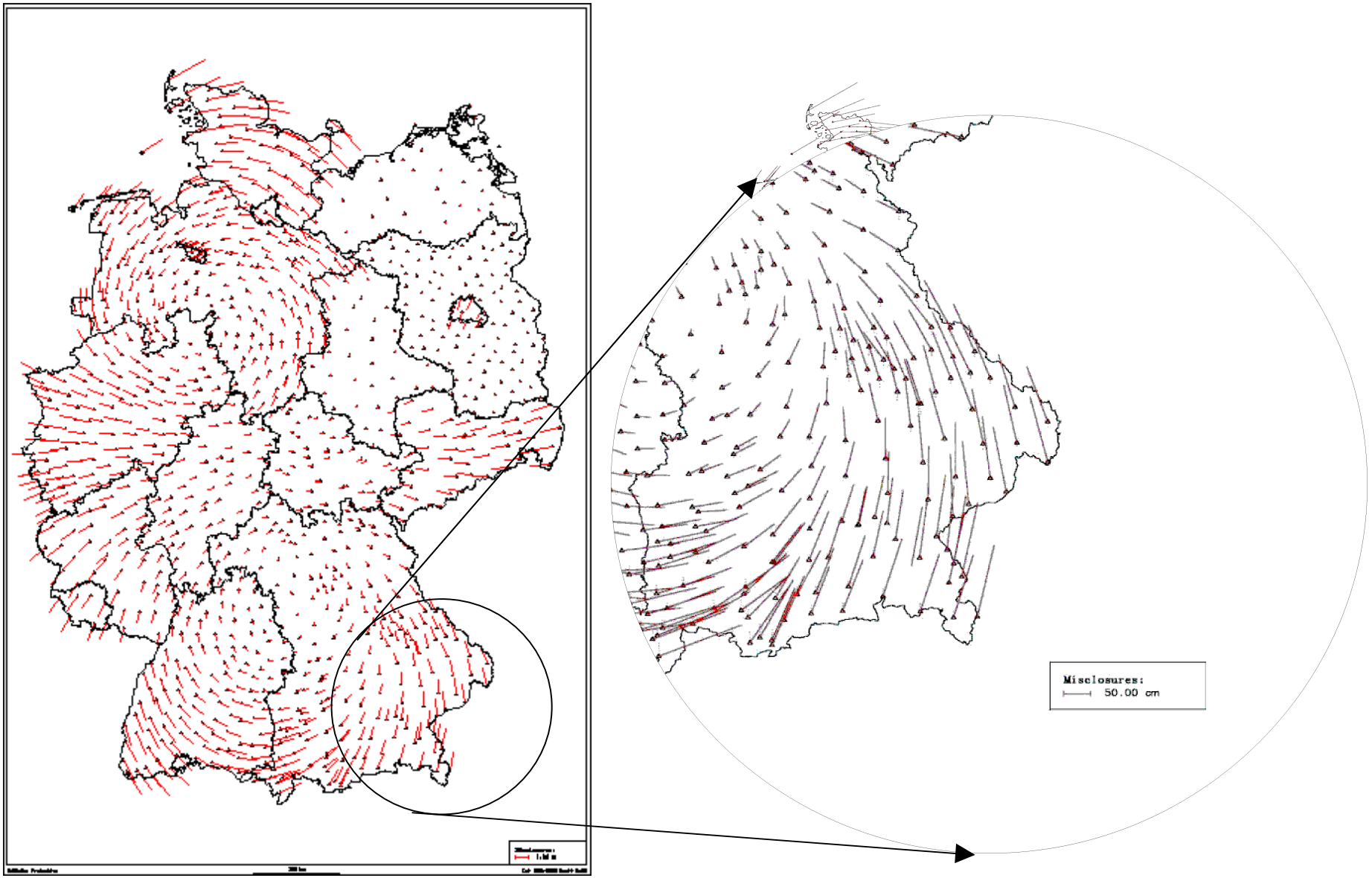
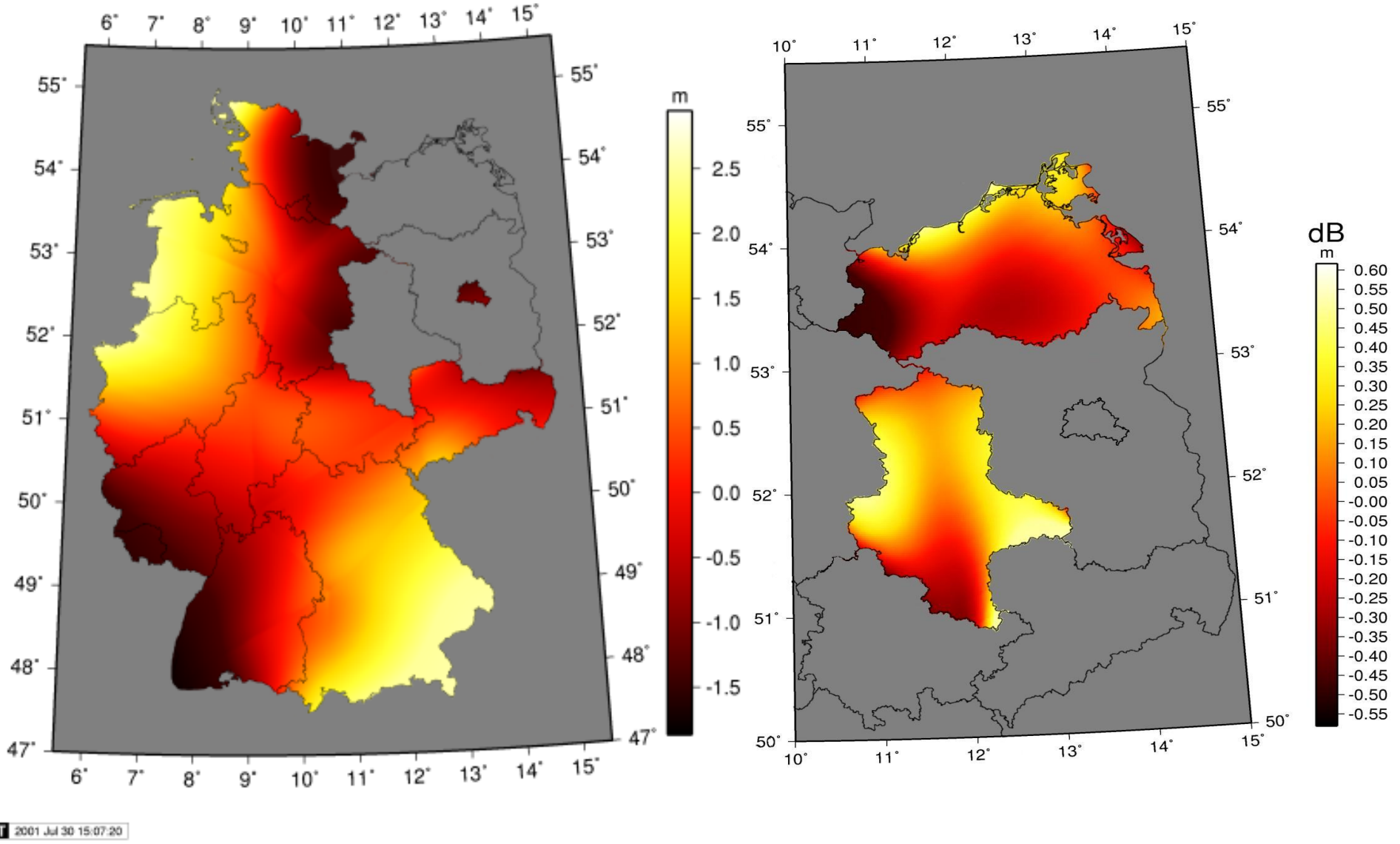


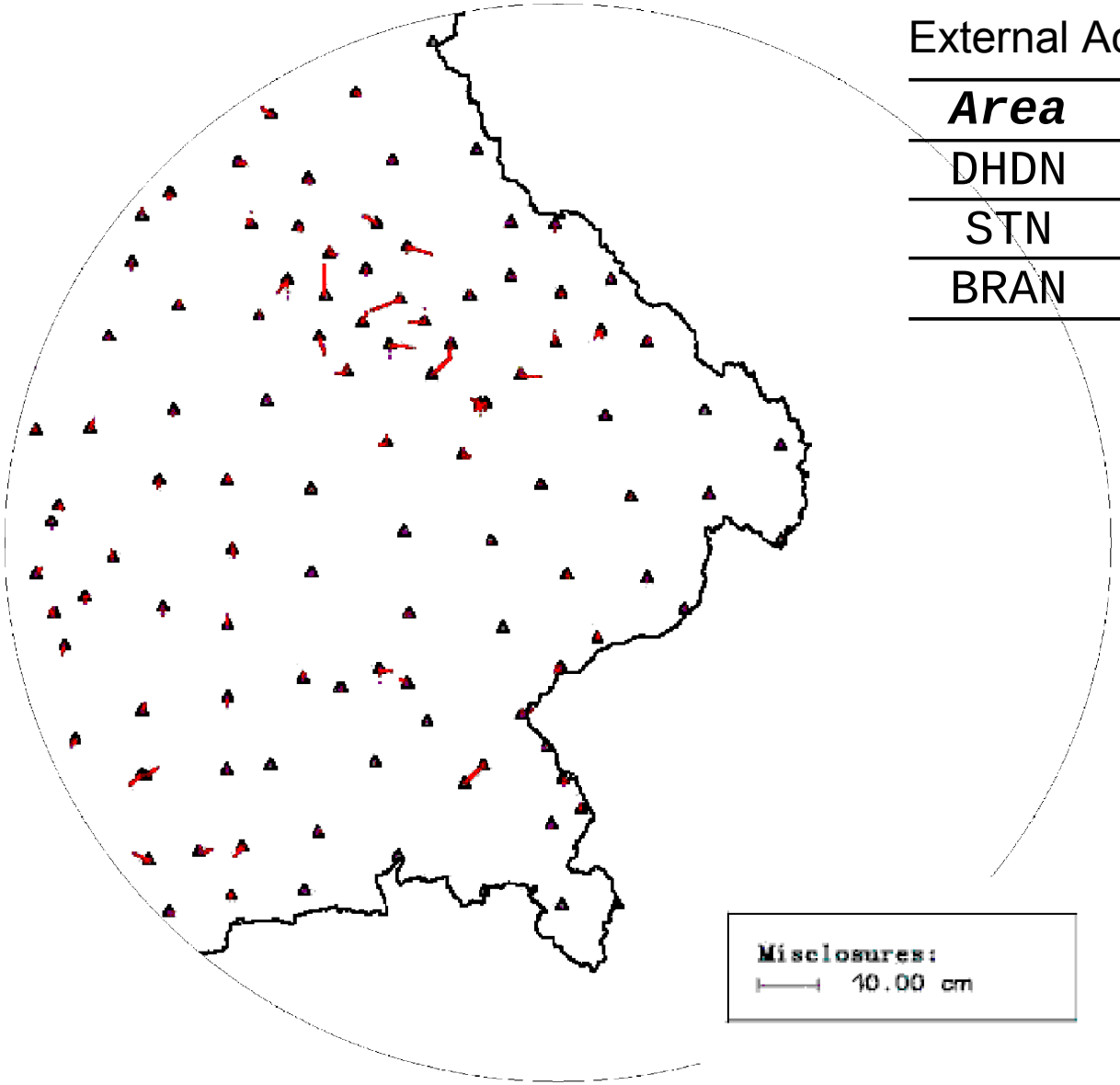
GNTRANS – Distortions of official coordinates



GNTRANS – Functional models



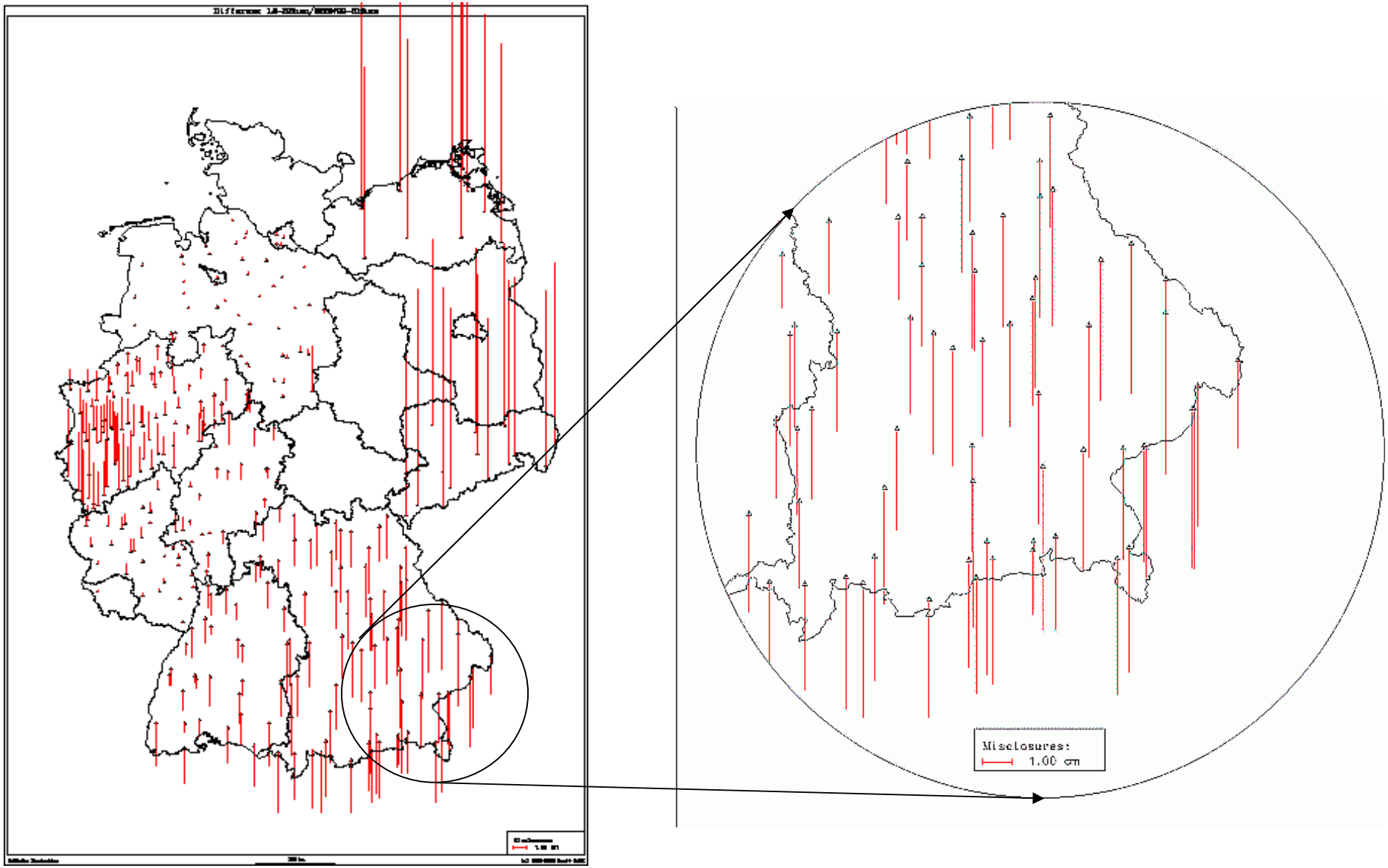
GNTRANS – Horizontal residuals after transformation



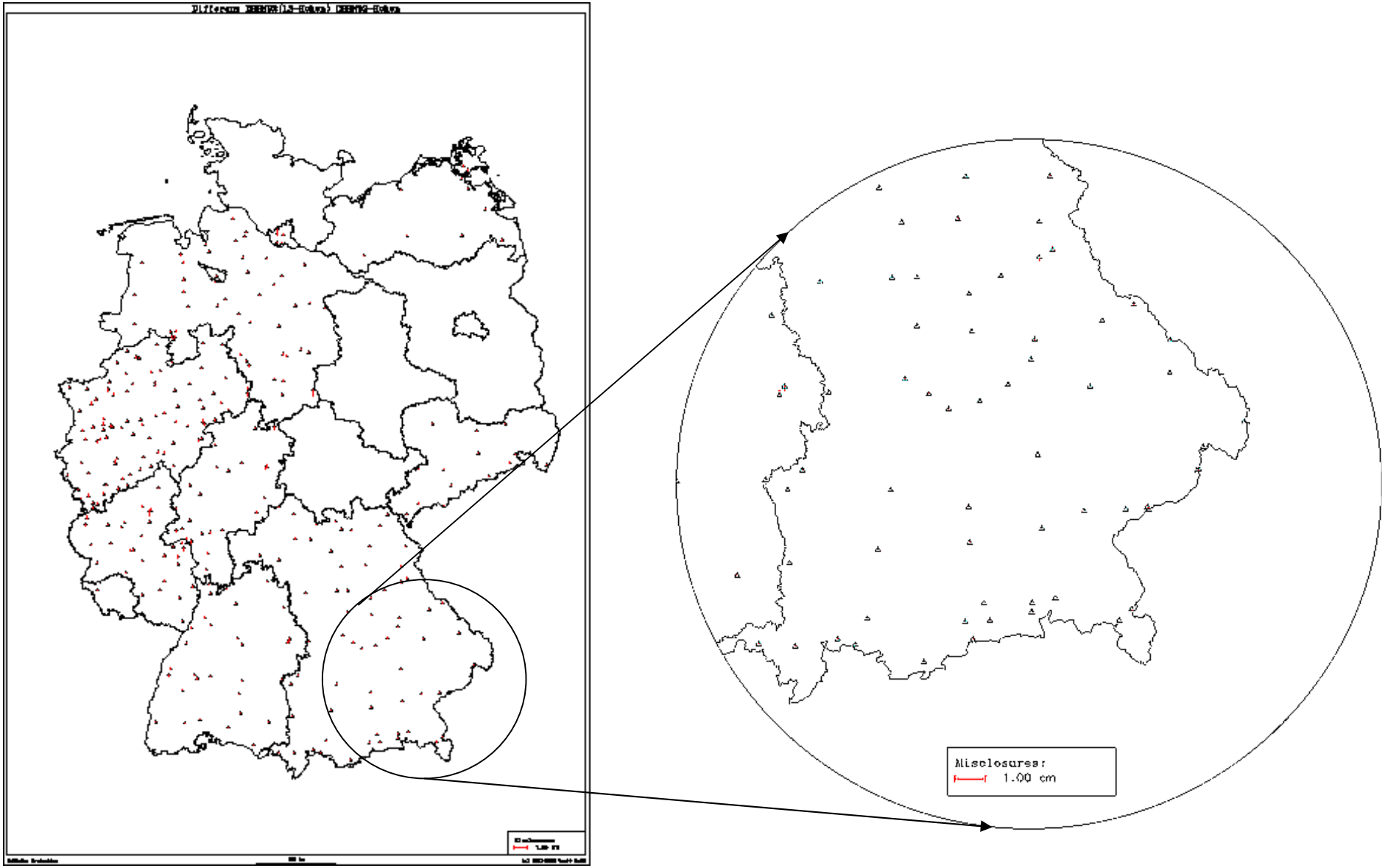
External Accuracy (GNTRANS-D)

Area	*sx [m]*	*sy [m]*	*sz [m]*
DHDN	0.047	0.046	0.027
STN	0.007	0.013	0.006
BRAN	0.000	0.000	0.010

GNTRANS – Vertical differences



GNTRANS – Vertical residuals after transformation



GNTRANS – Advantages

- Properties of transformation model
  - Preservation of adjacent metric properties
  - Uniqueness / standardized
  - Homogeneity
  - Continuity
  - Consideration of discontinuities
  - Bejective (one-to-one mapping)
- One transformation model
  - Better integration and automation
  - Minimal logistic effort
  - User-friendly
  - Economics

Summary

- GNBAHN
  - Satellite aided track survey
  - Equipment and software for determination of absolute 3D track coordinates
- GNTRANS
  - Transformation instrument to handle modern and inhomogeneous coordinates

GNSS technology
no matter what coordinates

Thank you for your attention!