Mapping Projects

Martin Schmitz, Gerhard Wübbena, Mark Bachmann

Geo++® GmbH
D-30827 Garbsen,
Germany
www.geopp.de

Organization

- introduction
- modern and official coordinate systems
- DB AG – DB_REF system
- local transformations/adjacency preserving transformation
- GNTRANS
  - principle of transformation
  - transformation model
  - accuracy
- summary

Introduction

- satellite-based surveying techniques
  - applications steadily increasing
  - accuracy range of: (mm) ... cm ... dm ... m
  - use of global cartesian coordinate systems
  - homogeneous coordinates
  - weather independent
  - no inter-station visibility
  - large distances

Modern Coordinate Systems

- three-dimensional coordinate system
  - geocentric, i.e. earth's center-of-mass origin (in practice within a few cm)
  - Z-axis aligned with the earth's axis of rotation (IERS reference pole)
  - X-axis IERS reference meridian
  - Y-axis completes right-handed coordinate system
- why?
  - satellite geodesy, ...
  - accuracy, consistency, internationally, globally, ...
- e.g. WGS 84, ITRS xx, ETRS xx

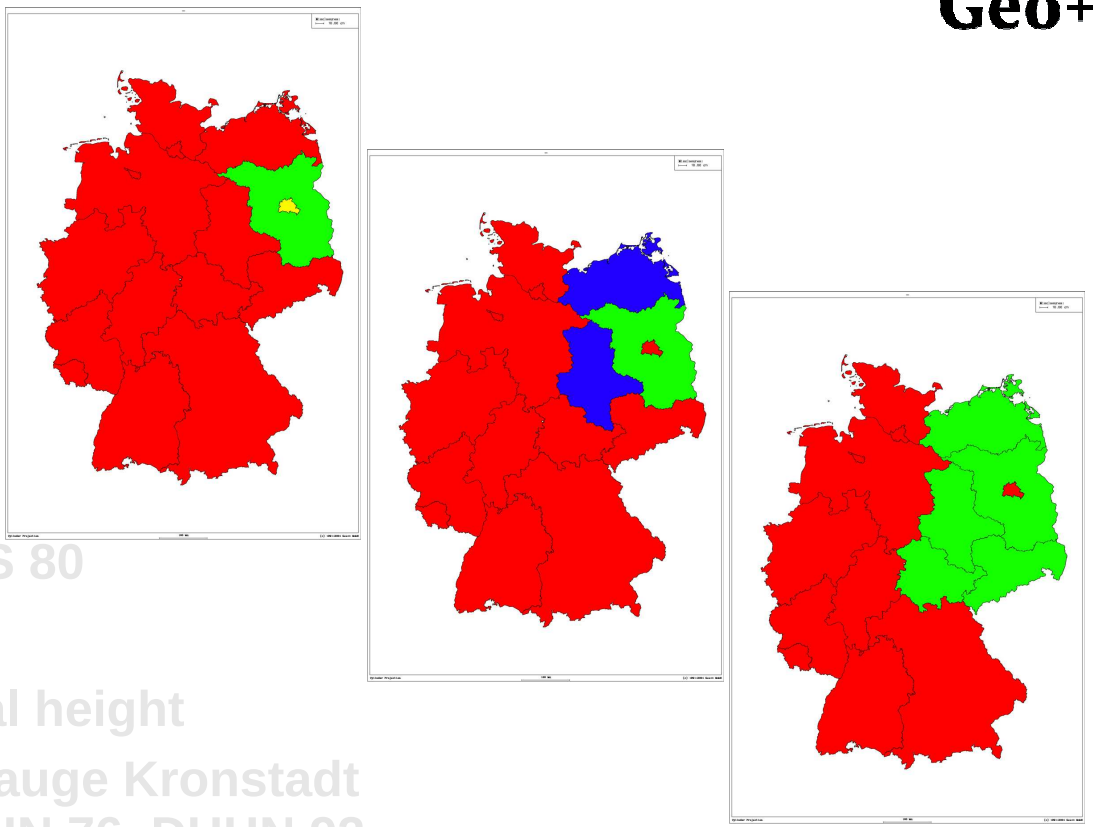
Official Coordinate Systems

- historical development in Germany
  - independent 2D and 1D networks
  - former West German states:
    - different surveying techniques
    - different computation techniques
    - combination of individual networks between 1870 and 1950
  - former East German states:
    - complete re-surveying of network starting in 1954

Official Coordinate Systems

- projections
- datums
- height systems

Rauenberg Potsdam
DHDN STN 42/83 PD 83
RD 83 ETRF 89
Krassowski Bessel GRS 80
Gauß-Krüger Soldner UTM
orthometric height normal height
gauge Amsterdam gauge Kronstadt
DHHN 12 DHHN 85 HN 76 DHHN 92
coordinate status of states



- even more variety through different state surveys

Official Coordinate Systems

- surveying in Germany is a task of the states
  - different geodetic datums
  - different systems
  - different ellipsoids
  - different projections
  - different height systems
- situation German-wide
  - non-homogeneous coordinates for surveying and mapping applications
  - discontinuities/coordinate jumps at state boundaries

Official Coordinate Systems: Future

- Working Committee of the Surveying Authorities of the States of the Federal Republic of Germany (AdV) 1991-1995
  - German reunification and European integration demands for unified reference system
  - reference system identical to WGS 84, realization through ETRF 89
  - normal height of primary leveling network (DHHN 92)
  - Universal Transverse Mercator grid system (UTM)
  - ellipsoid GRS 80

not yet available in all States!

DB AG - German-Wide Applications!

- past
  - positioning in official coordinate systems
- goal
  - one single homogeneous coordinate system German-wide
  - one single height system German-wide
- task & consequence
  - enable **homogeneous** transformations
  - enables rigorous use of modern surveying methods (e.g. GPS, GLONASS, Galileo)

Homogeneous Reference Systems

- properties
  - one transformation parameter set
  - one ellipsoid
  - one projection
- homogeneous reference systems transform
  - without accuracy loss
  - anytime
  - one-to-one

  into each other

DB AG – Considerations

- features of a suitable reference system
- definition
  - minor scale changes for existing data
  - minor coordinate changes (existing maps)
  - systems capable to interact with industry and national systems
  - support of satellite-based surveying techniques
- realization
  - reference stations covering the complete area of applications
  - accuracy sufficient for all applications

DB AG – Definition of DB_REF

- horizontal reference system
  - geodetic datum
    - mean datum of official system of former West German states, Thüringen and Sachsen (7P- transformation)
  - ellipsoid
    - Bessel
  - projection
    - Gauß – Krüger
- height reference system
  - normal height system (DHHN 92)

Scale Factor – Relative to National/ State System

- scale factor for different coordinate transformations starting from national/state system (DHDN)

datum	*ellipsoid*	*projectio*	*scale [mm/km] for distance from center meridian*		
			0 km	*50 km*	*100 km*
DHDN(LS)	BESSEL	GK	0	0	0
		UTM	-400	-400	-400
ETRF89	GRS80	GK	1	1	1
		UTM	-399	-399	-399
DB_REF	BESSEL	GK	±1 bis 10	±1 bis 10	±1 bis 10

*) DHDN is datum of former West German states

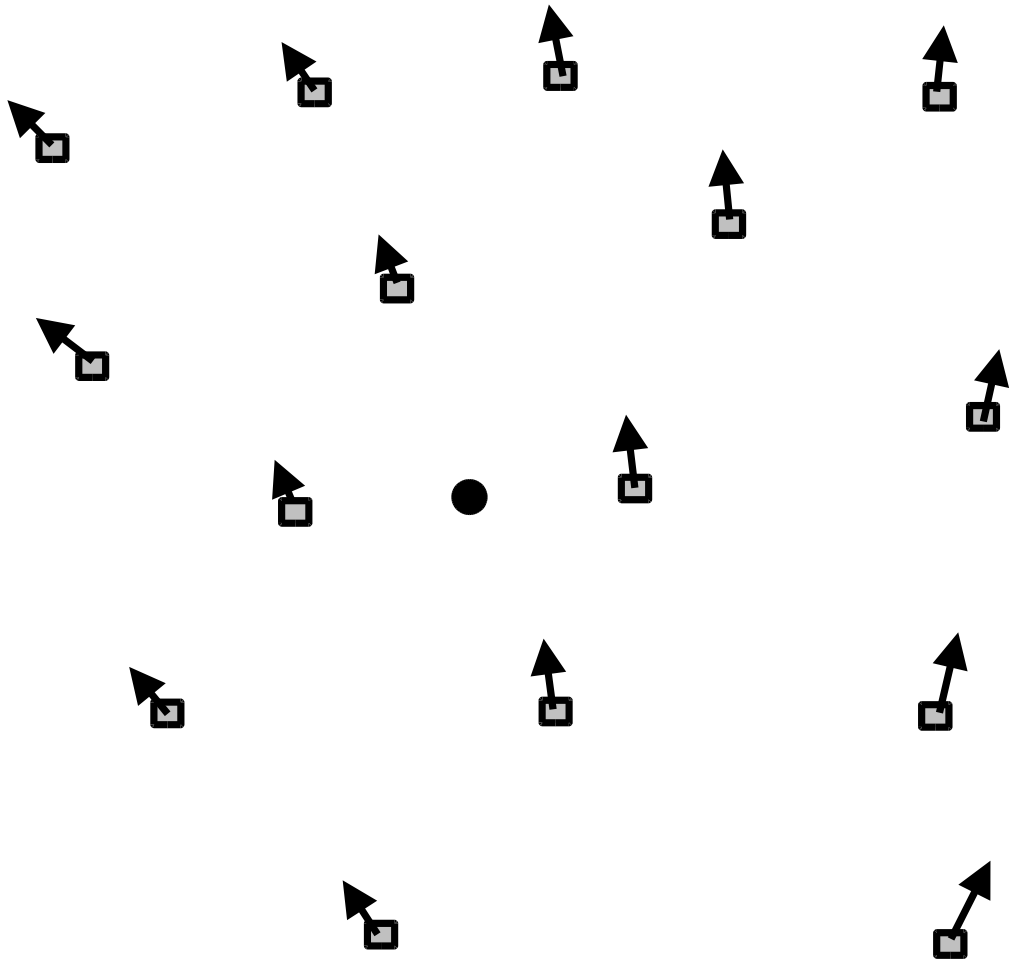
DB_REF Realization

- German-Wide data from Surveying Authorities
- properties of horizontal reference system
  - derived from ~ 1200 identical points
- properties of height reference system
  - official height system (future nation-wide)
  - derived from ~ 340 identical points
- regional (D), homogeneous reference system

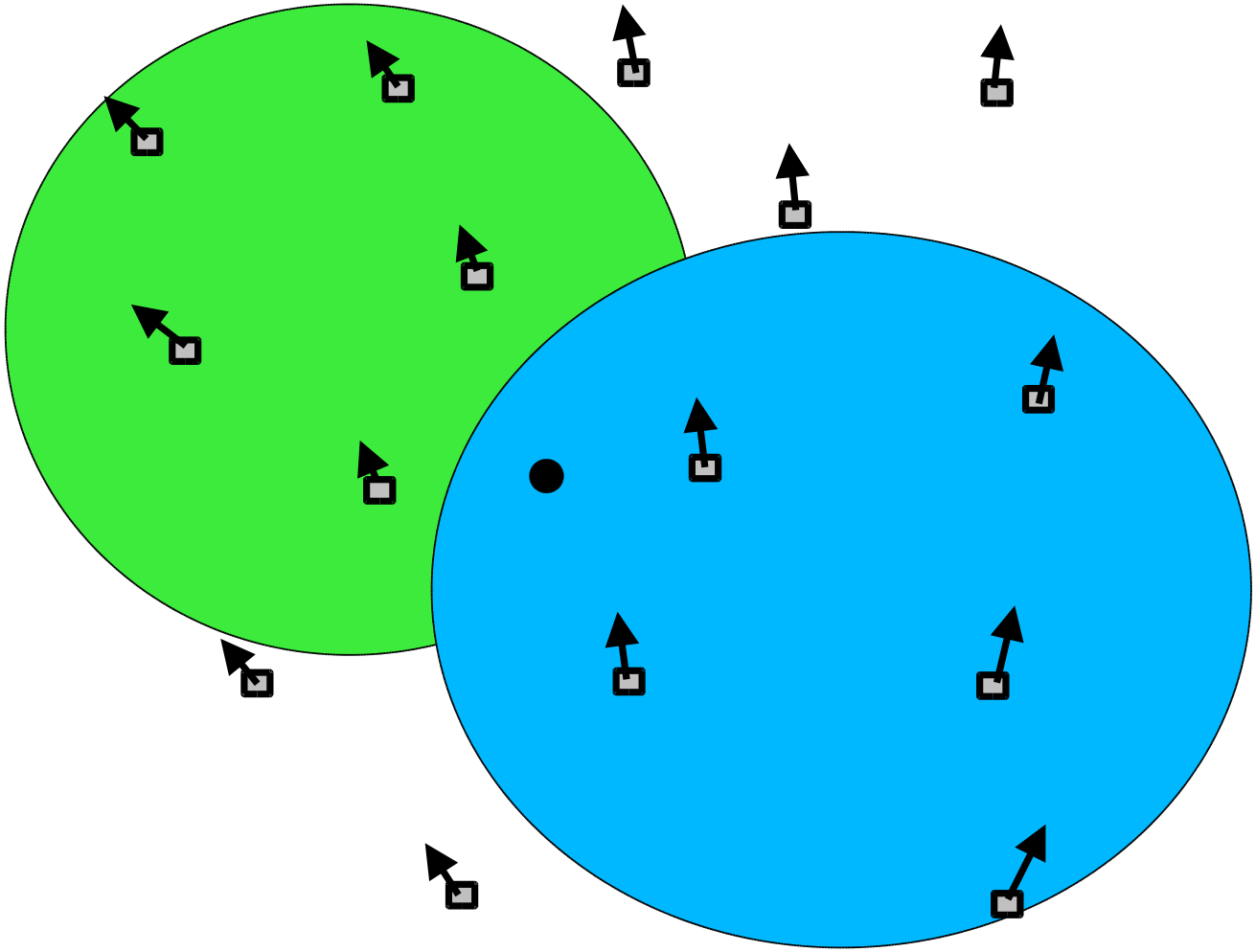
Local Transformation/ Adjaceny Preserving Transformation

- problem: local transformation
  - individual sets of identical points
  - individual sets of transformation parameters
  - distortions
- solution: adjacency preserving transformation
  - pre-requisite for general transformation module

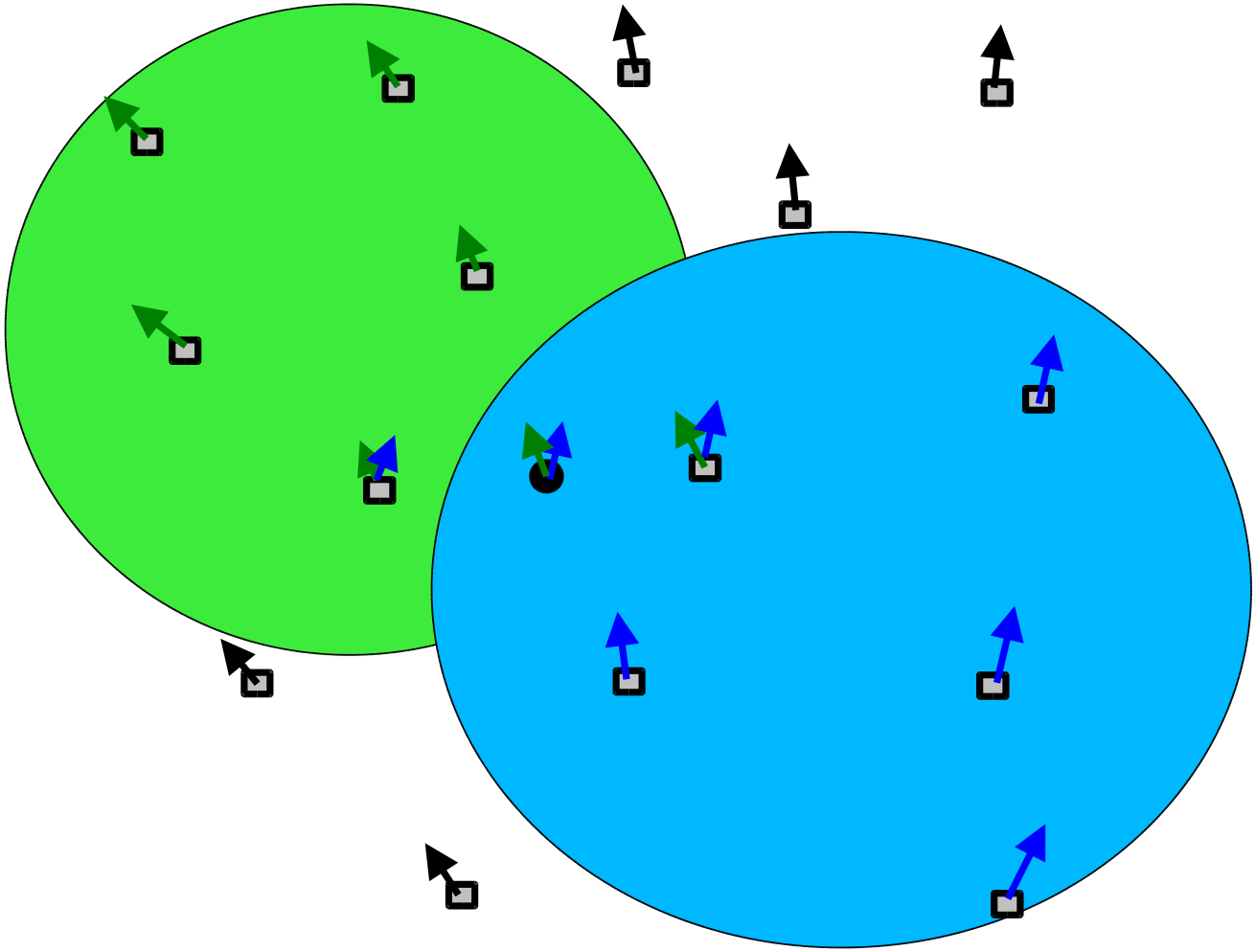
Local Transformation



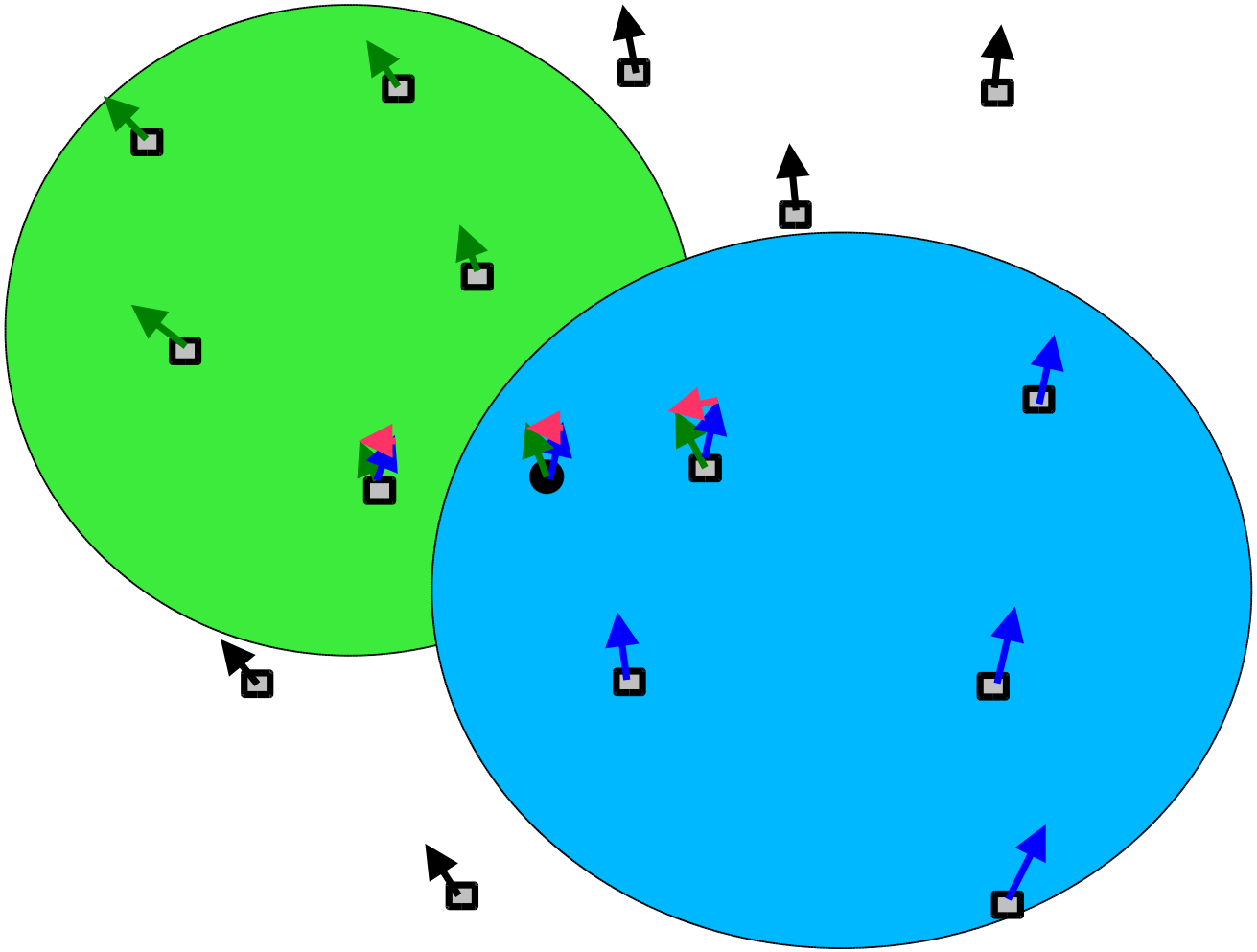
Local Transformation



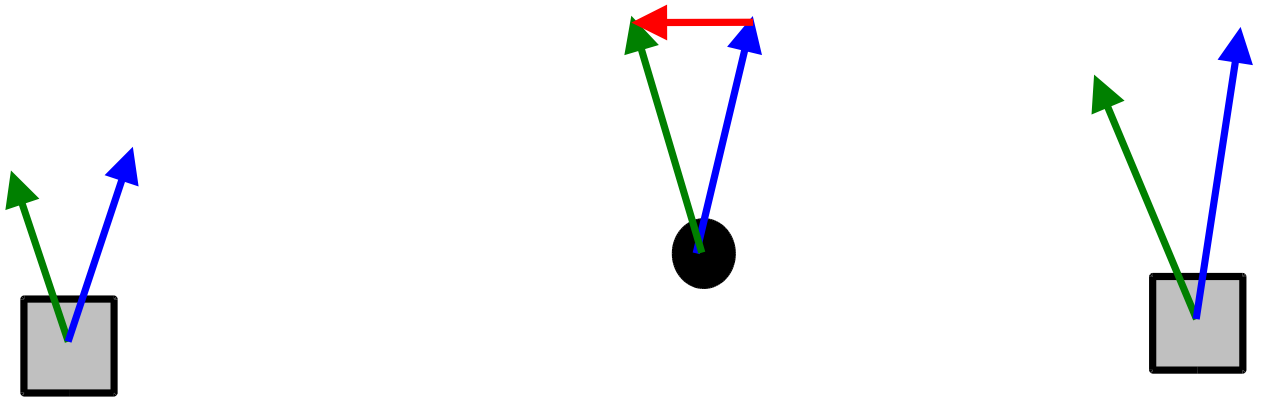
Local Transformation



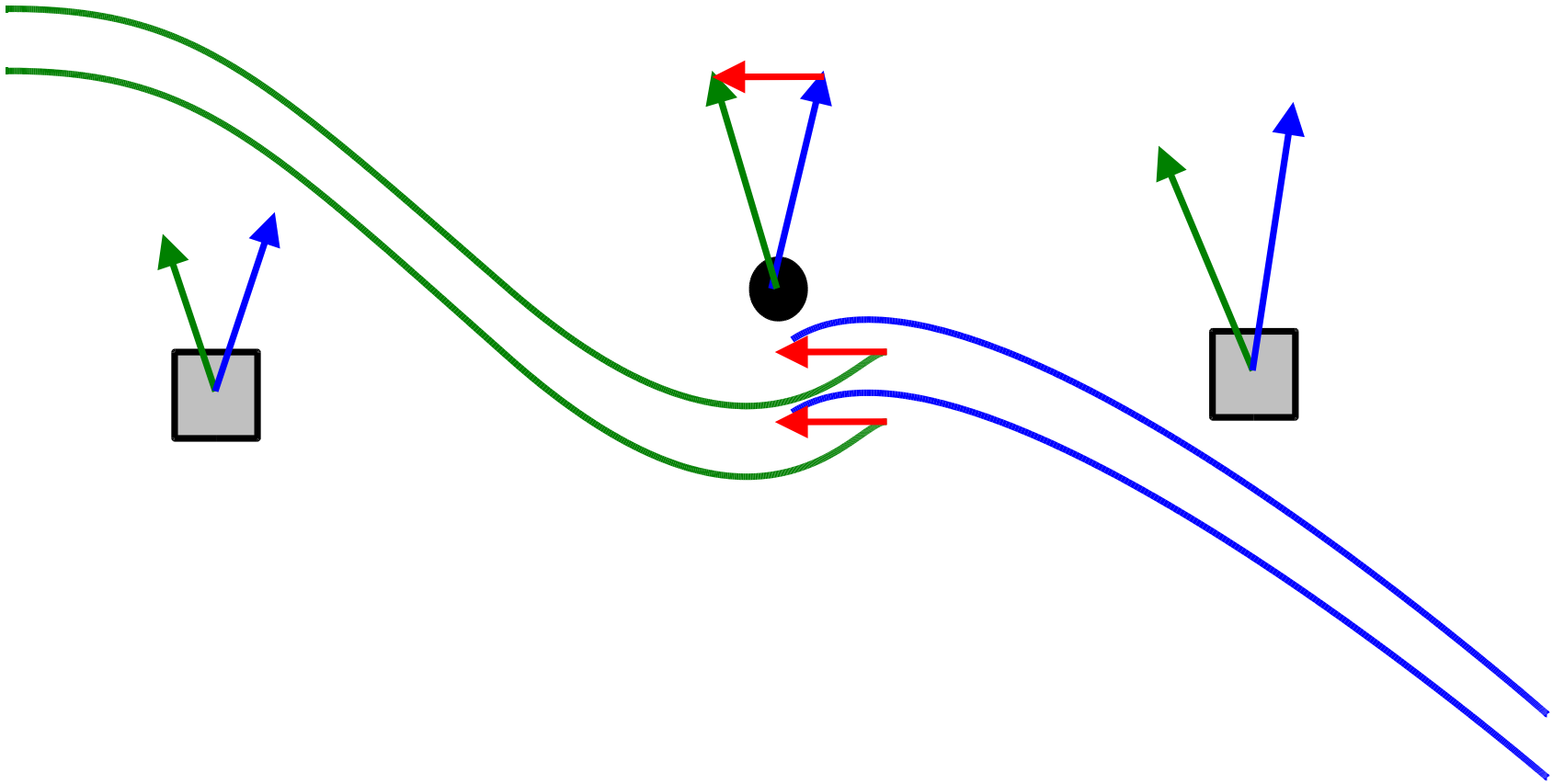
Local Transformation



Local Transformation

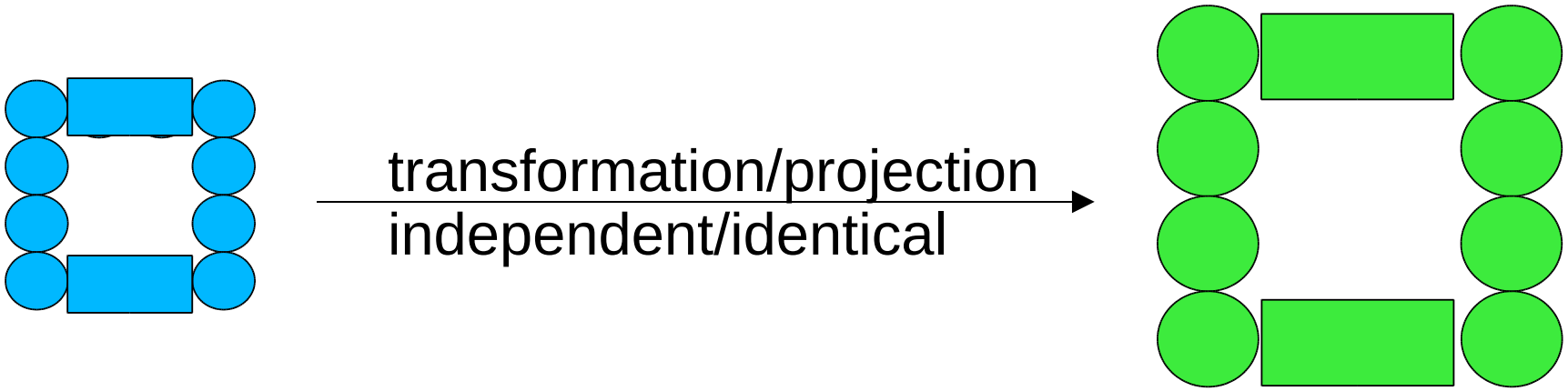


Local Transformation



Adjacency Preserving Transformation

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



GNTRANS

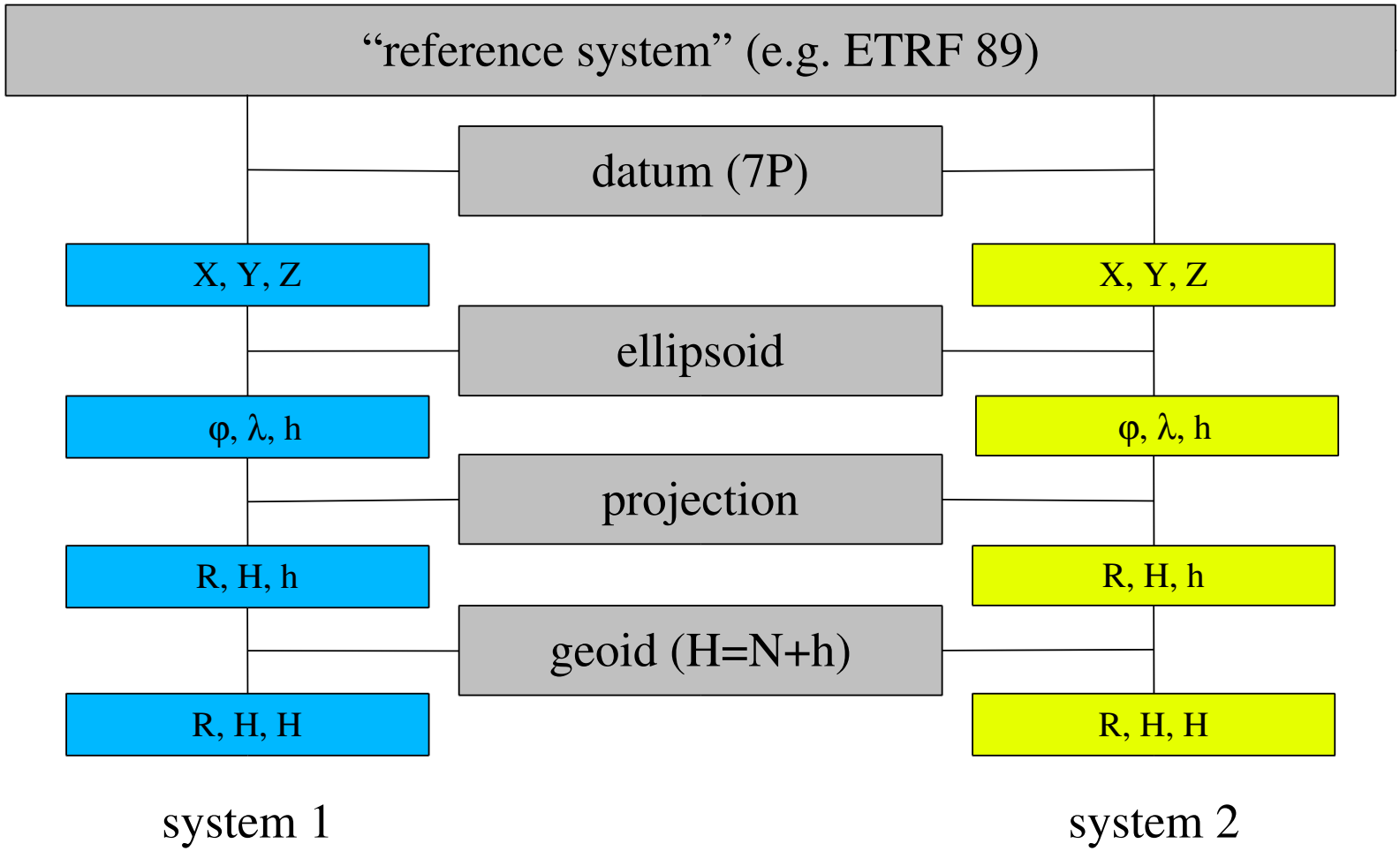
GNTRANS is a

- transformation model for the transition of ETRF 89 coordinates and official state coordinates into a homogeneous coordinate system: DB_REF

GNTRANS

- motivation
  - different applied coordinate systems nation-wide
    - non-homogeneous, inconsistent databases and documentation
  - network distortions in former systems
    - not adequate for modern surveying techniques
  - satellite-based techniques not easily integrated
    - no uniform transformation regulations
    - no uniform documentation regulations

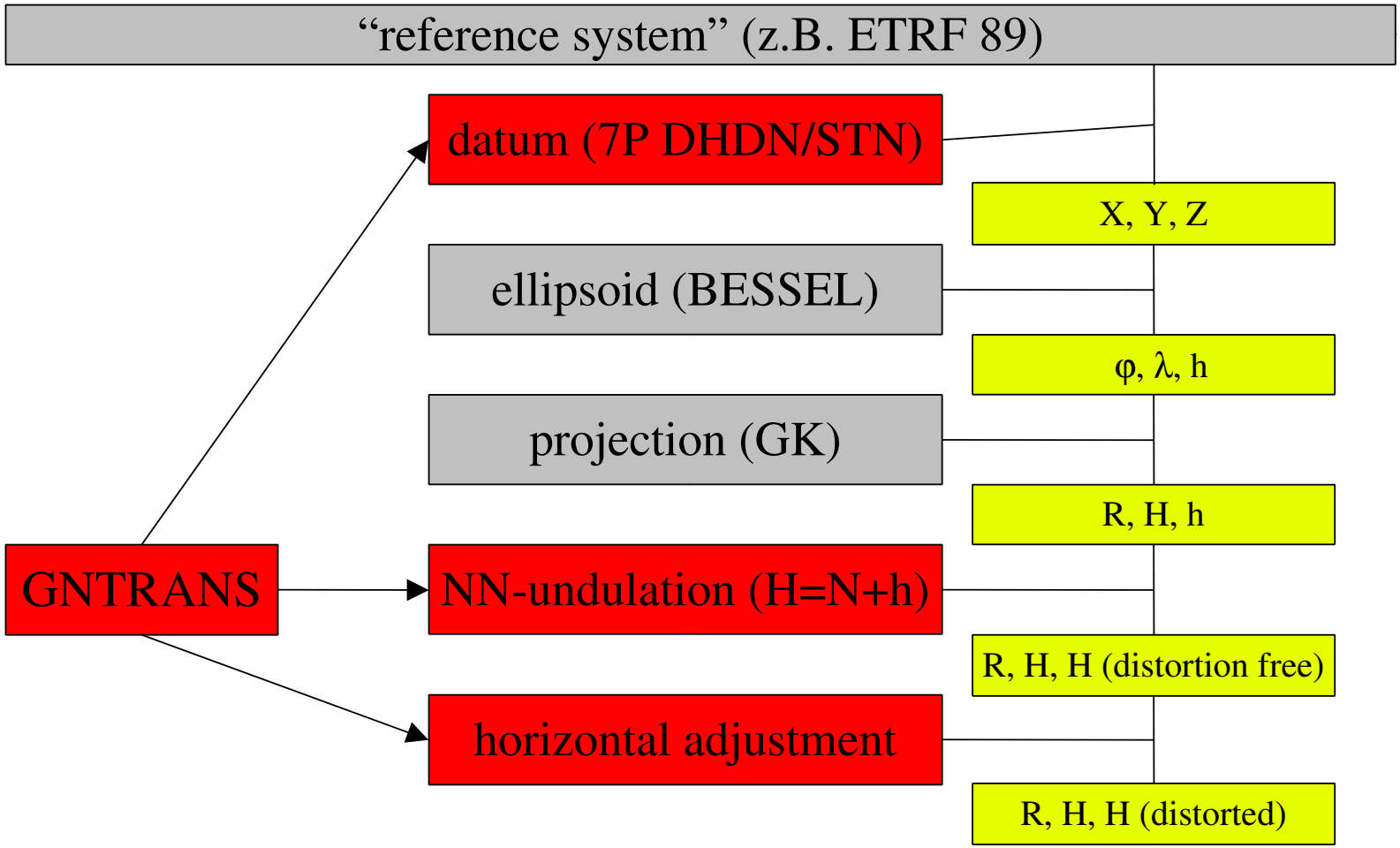
Principle of GNTRANS Transformation - Coordinate Systems



GNTRANS – Model

- multistage transformation
  e.g. ETRF/national or state systems
  - 7P- transformation
  - continuous functional transformation
    - mathematical functional approach to describe remaining residuals after 7P- transformation
  - stochastic part
    - stochastic prediction of remaining discrepancies considering topological neighborhood (decorrelation along topology of discontinuity)

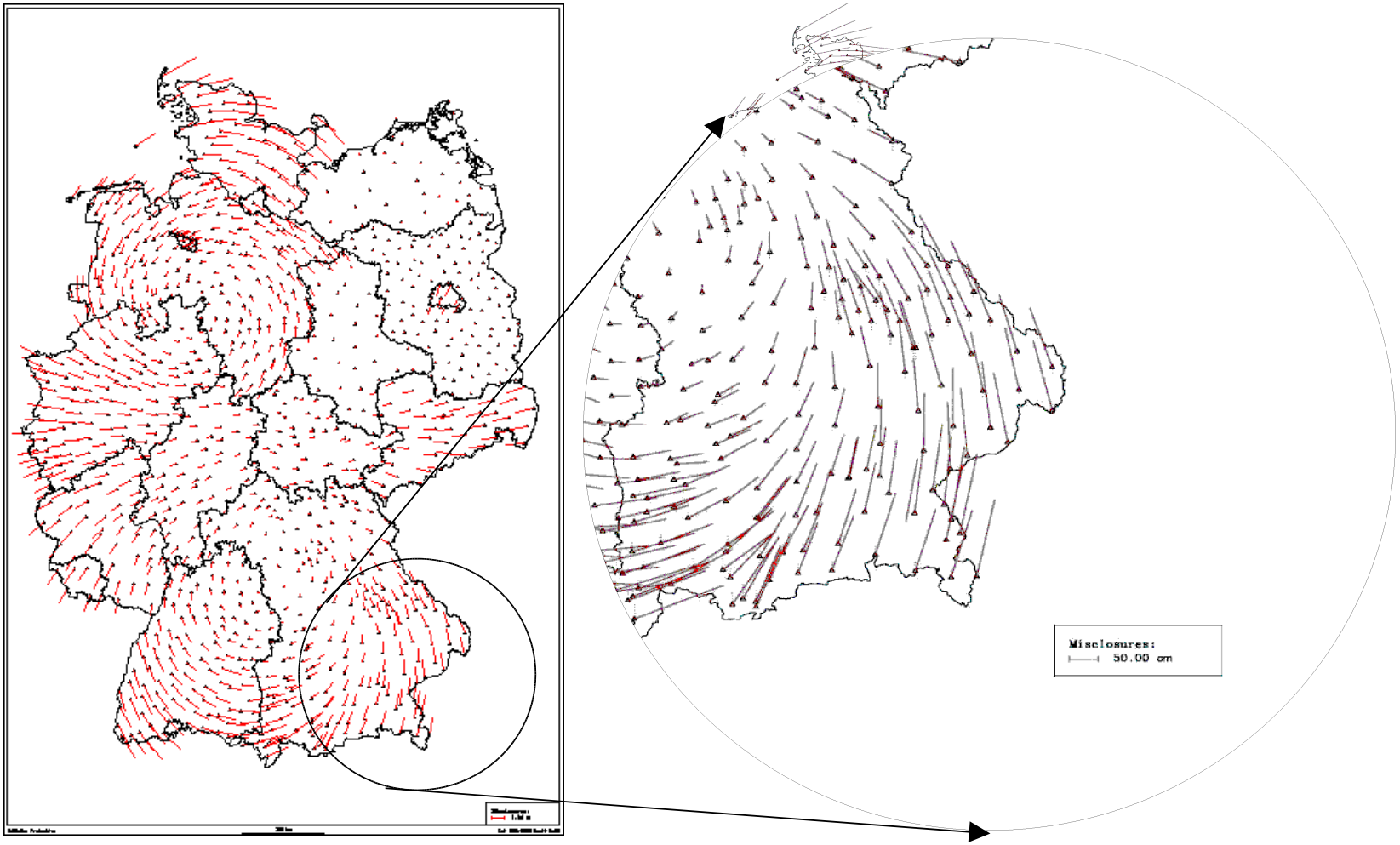
Principle of GNTRANS Transformation – National/State Systems



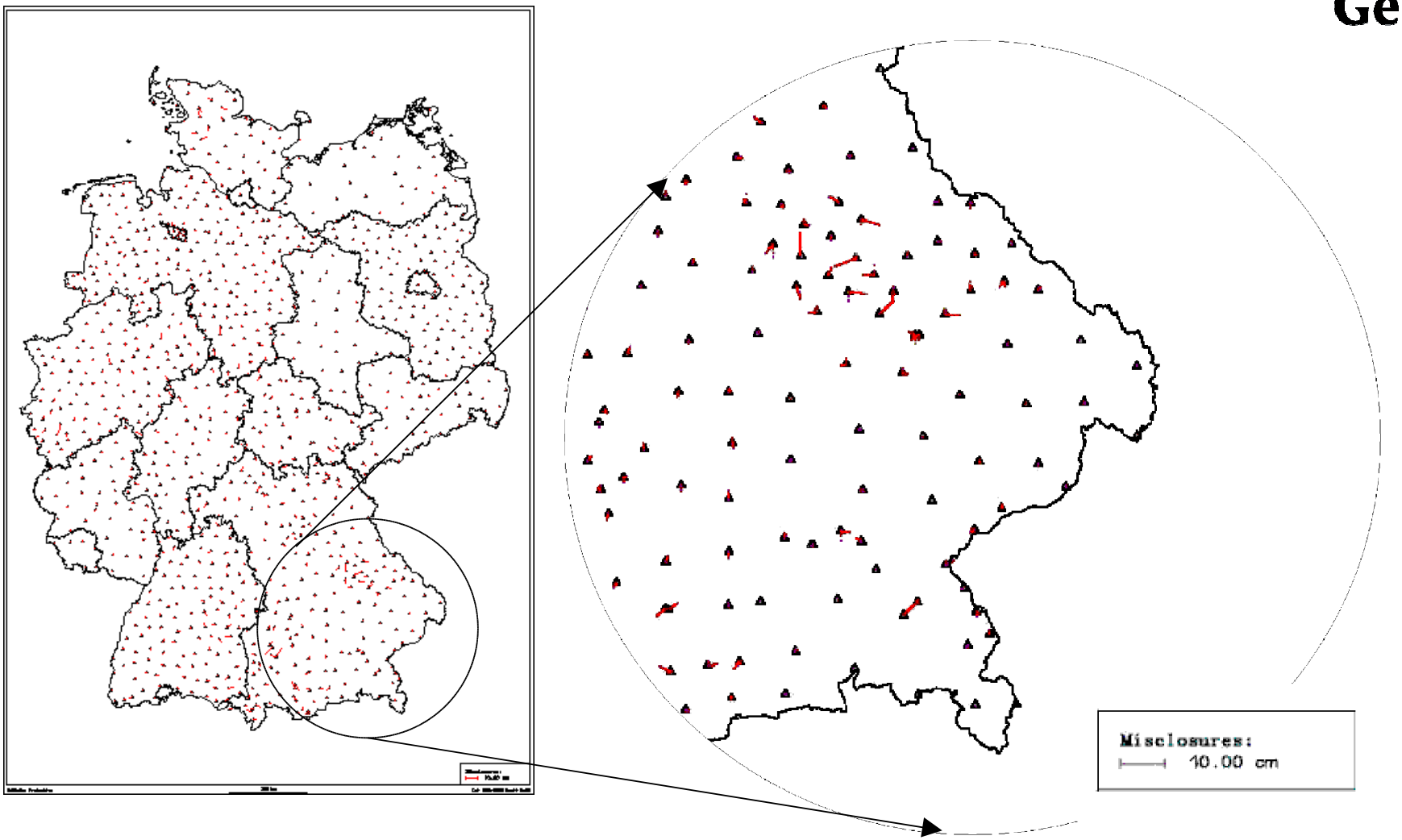
GNTRANS – Model

- multistage transformation
  e.g. ETRF/DB_REF
  - 7P- transformation
    - gives already transformed horizontal coordinates
  - height component
    - continuous functional transformation
    - stochastic part

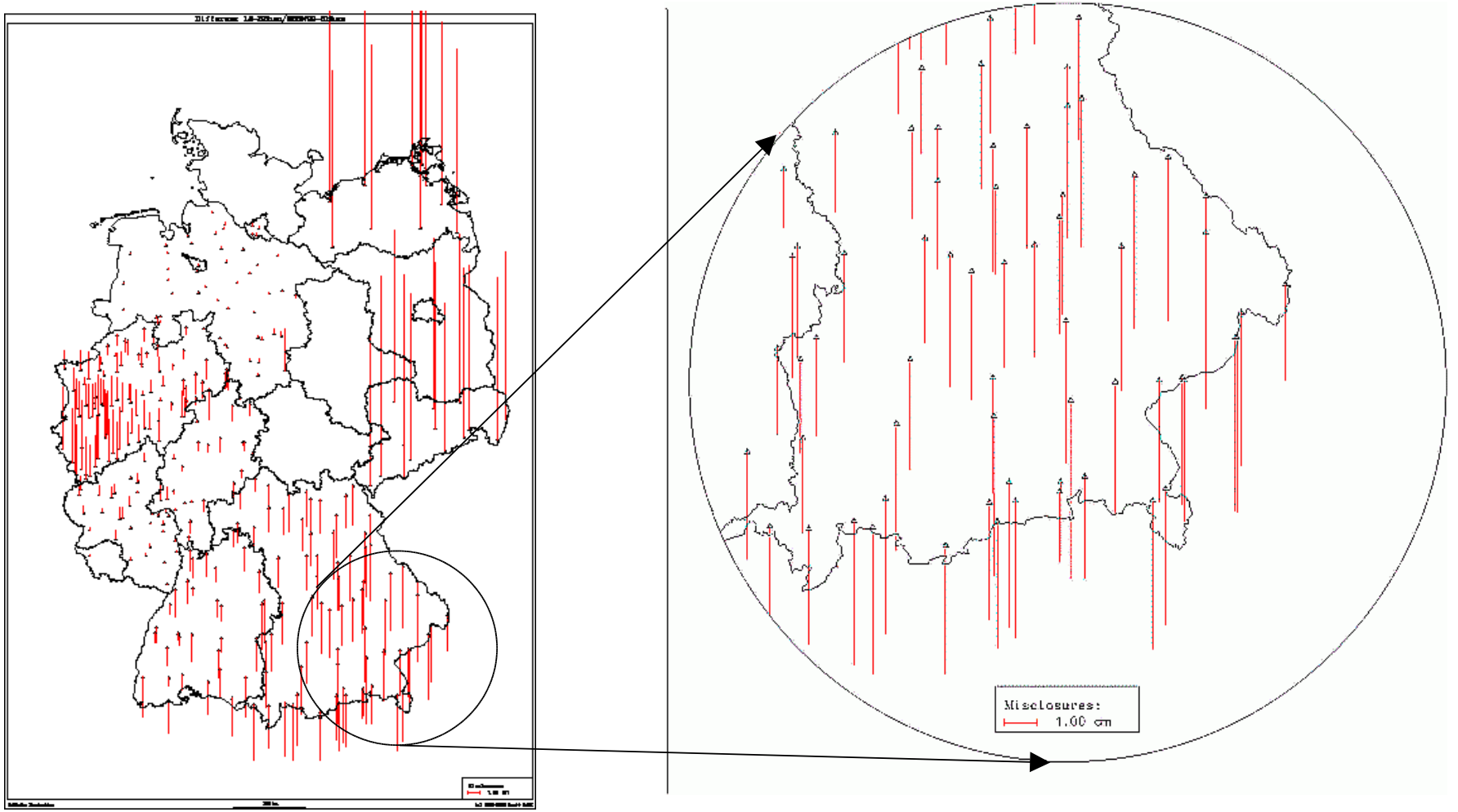
GNTRANS – Horizontal Residuals after 7P- Transformation



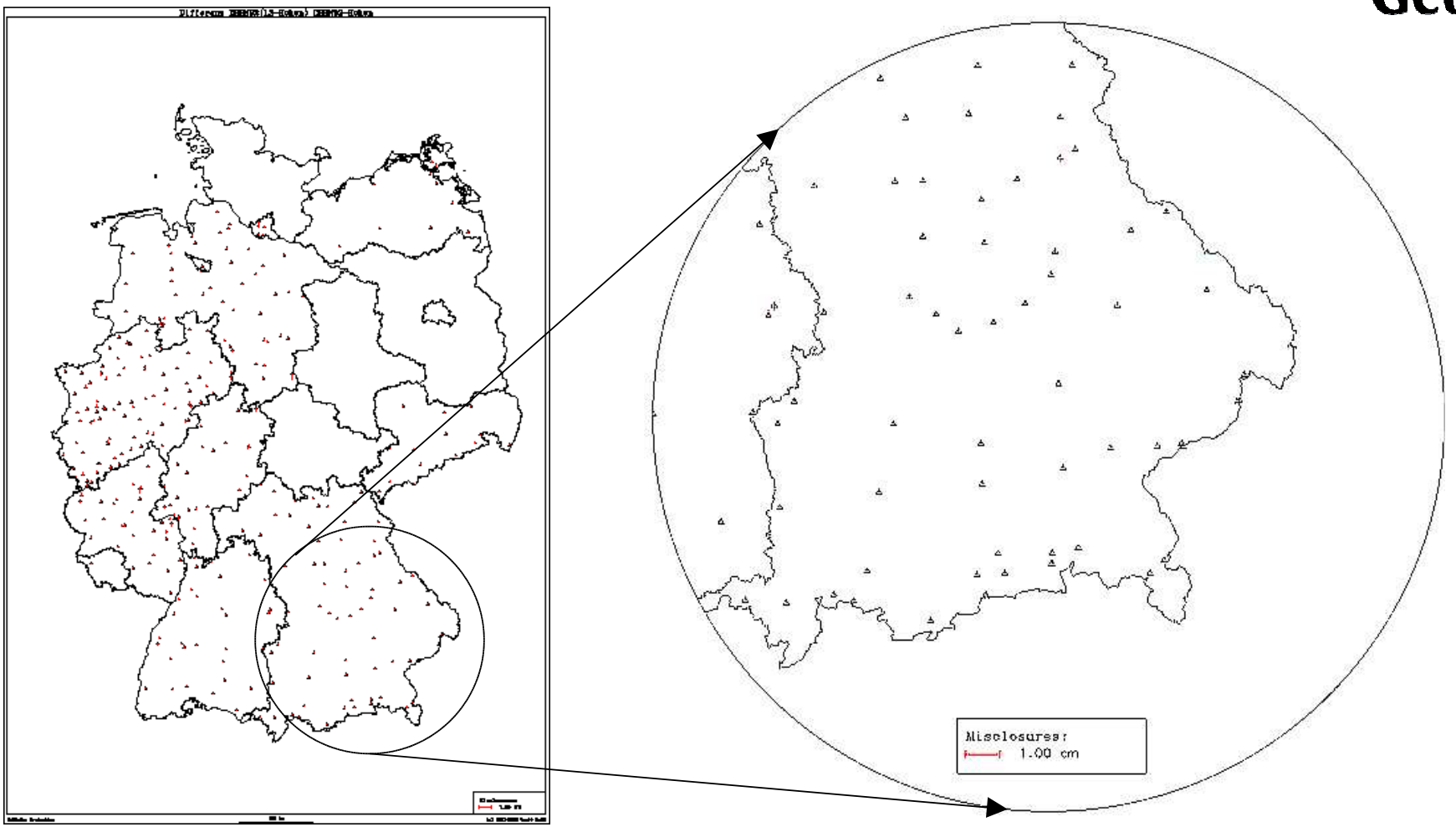
GNTRANS – Horizontal Residuals after Multistage Transformation



GNTRANS – Height Differences State Systems/DHHN 92 (DB)



GNTRANS – Height Residuals after Complete Transformation



GNTRANS - Accuracy of Transformation Module German-Wide

- internal accuracy

area	sx [m]	sy [m]	sz [m]
DHDN	0.010	0.010	0.010
STN	0.001	0.002	0.001
BRAN	0.000	0.000	<0.010

- external accuracy

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

*) DHDN is datum of former West German states
STN is datum of former East German states
BRAN is datum of Brandenburg

GNTRANS – Model Properties

- properties of transformation models
  - preservation of adjacent metric properties
  - uniqueness/standardized
  - homogeneity
  - continuity
  - consideration of discontinuities
  - biuniqueness (one-to-one mapping)

GNTRANS – Application

- GNTRANS Executable
  - command line - simple handling in batch files
  - graphical user interface – transformation with a “Mouse Click”
- GNTRANS-DLL
  - simple integration of GNTRANS-Module in any application software (e.g. technet verm.esn)
- GNTRANS-RT
  - real time application in RTK-networks

Summary

- satellite-based applications demand for modern coordinate systems
- coordinate variety in Germany
- problems for German-wide applications
- homogeneous transformation
- GNTRANS model and performance
  (one module, always valid)
- transformation model for the transition of
  ETRF 89 coordinates and official state coordinates into a homogeneous coordinate system DB_REF