



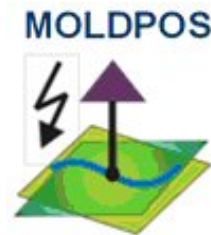
Technical
University
of Moldova

Hochschule Karlsruhe (HSKA)
University of Applied Sciences



Geodetic Infrastructure for GNSS-Positioning-Services (GIGPS)

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Peter Spohn
Ghadi Younis



United Nations/United Arab Emirates/United States of America
Workshop on the Applications of Global Navigation Satellite Systems,
Dubai, United Arab Emirates, 16 - 20 January 2011

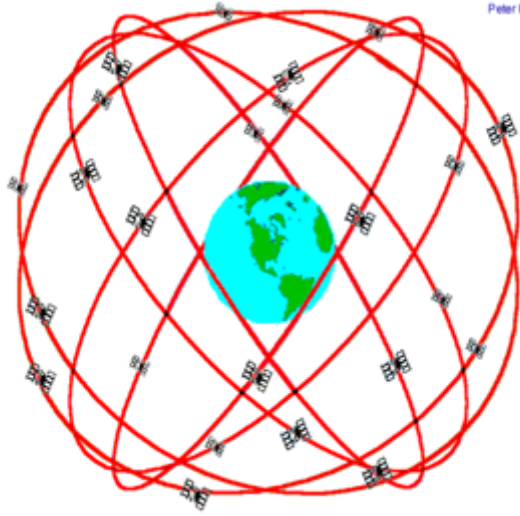


Outline

- **GNSS for Global Positioning in ITRF/ECEF Frames**
- **Precise GNSS-Positioning-Services**
 - Real time European DGNSS-Services
 - National Real Time DGNSS-Services in and outside Europe
 - RTCM-based Positioning DGNSS-Services
- **Reference Transformation components of GIGPS**
 - Horizontal Datum Transition from $(B,L)_{\text{GNSS,ITRF}}$ to Classical Datum $(B,L)_{\text{Classical}}$
 - Use of DLBF/GOPAG Databases
 - Height Problem / HRS Transition
- **Geomonitoring component of GIGPS**
 - MONIKA concept
 - MONIKA algorithms and software
- **Changes in GNSS-Positioning Services**
 - Growth of GNSS-Positioning Services User-Groups
 - Precise Point Positioning (PPP) - Absolute GNSS-Positioning

GNSS for Global Positioning in ITRF/ECEF Frames

GPS 30 satellites 2011



Peter H. Dana 9/22/98

< 50 (2011)

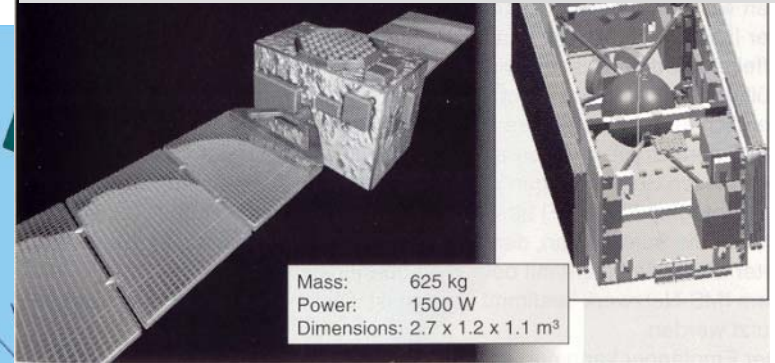
>120? (2020)



Danmark
ESA Lokal Information

Europæisk Rumfarts Organisation

GALILEO 30 satellites 2014-2016



GLONASS -30 satellites 2014



COMPASS >30 satellites
2020



„BeiDou-1/2“
14-April-07

Space Segment

User Segment

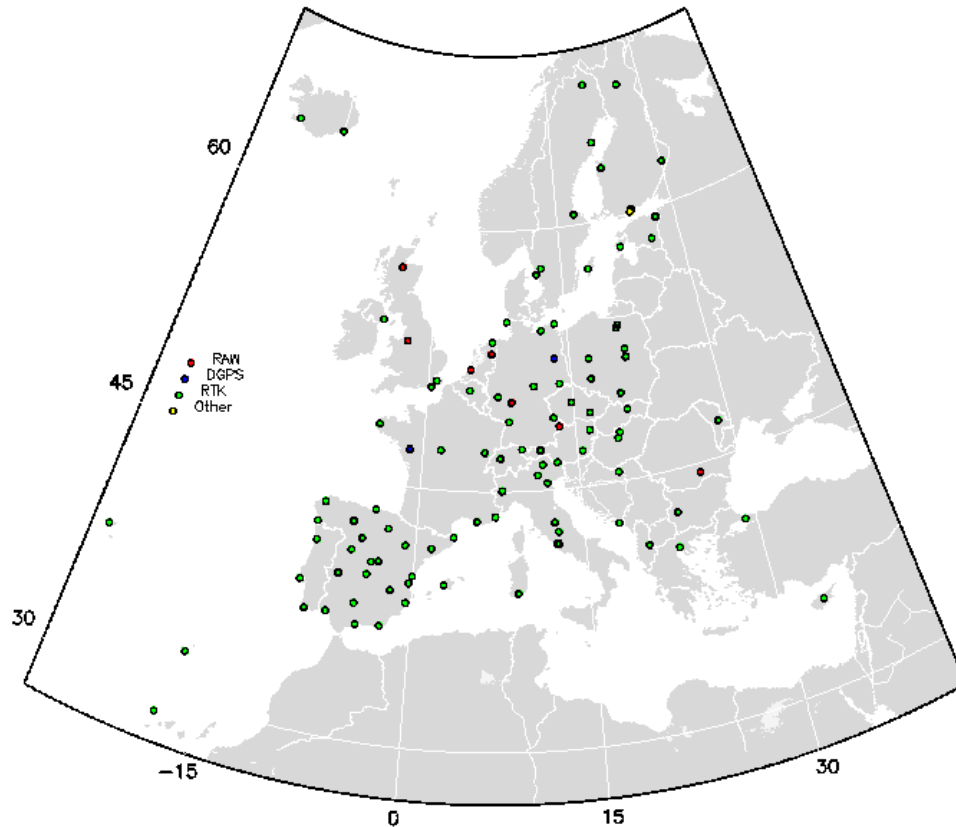
Control Segment

GNSS - Systems

Precise GNSS-Positioning-Services

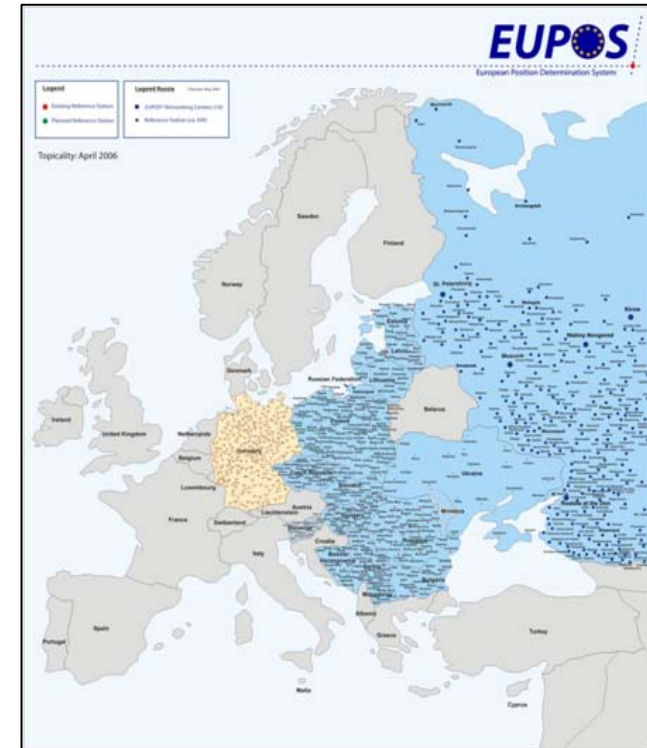
Real time European GNSS-Services

Real Time GNSS EUREF-IP



- 42 GNSS reference stations
- Real Time positioning :
 - DGNSS $\pm 0,7-2\text{m}$
 - RTK $\pm 3-4\text{ cm}$
- Postprocessing : $\pm 1-2\text{ cm}$

Real Time GNSS EUPOS

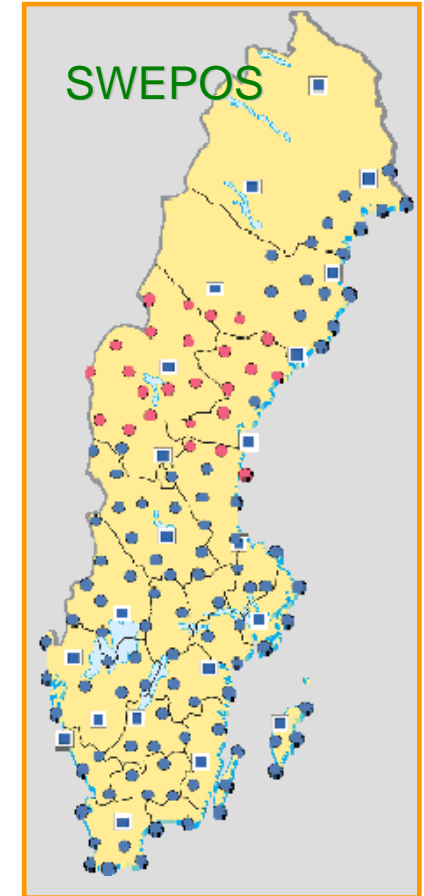
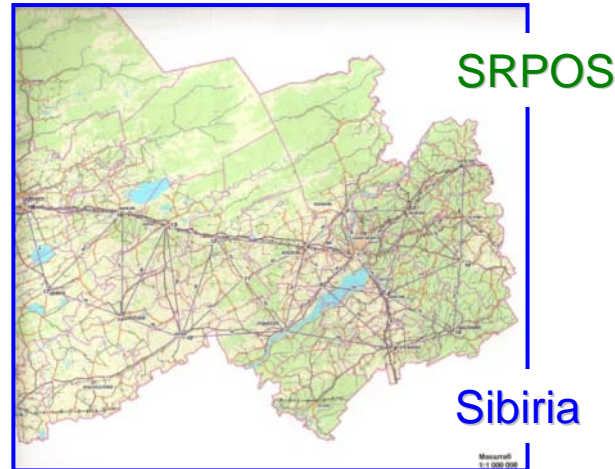
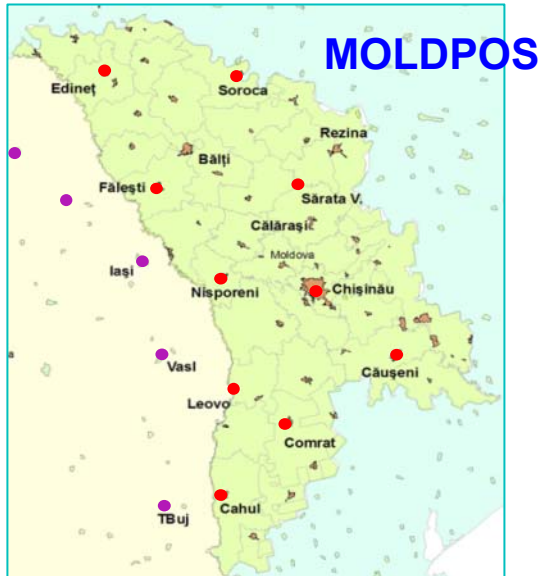


- 368 GNSS reference station
- Real time positioning:
 - DGNSS $\pm 0,5 - 2\text{m}$
 - RTK $\pm 1-2\text{ cm}$
- Postprocessing $\pm 1\text{ cm}$

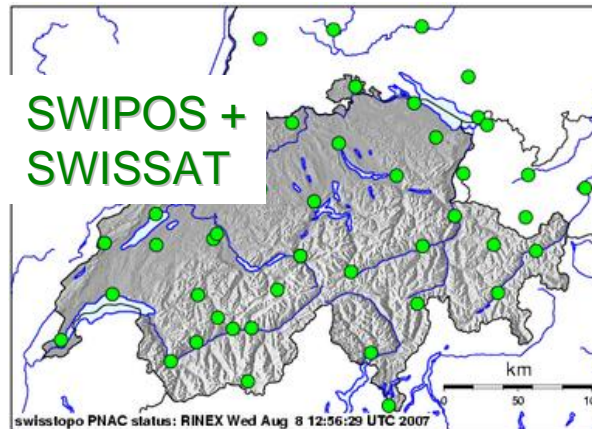
Precise GNSS-Positioning-Services

National Real Time GNSS-Services in and outside Europe

www.moldpos.eu



“cm”
↔
**!Code- and Phase-
Corrections !**
RTCM 3.1



GNSS-Networks in EURASIA: SAPOS®/Axio-Net/VRSNow® , SWIPOS®/SwissSat® ... SwePos®, CzePos®, LatPos®, CroPOS®, HePos® , ... Hungary, Slovenia, Romania, Siberia (SRPOS), ...Moldova (www.moldpos.eu)

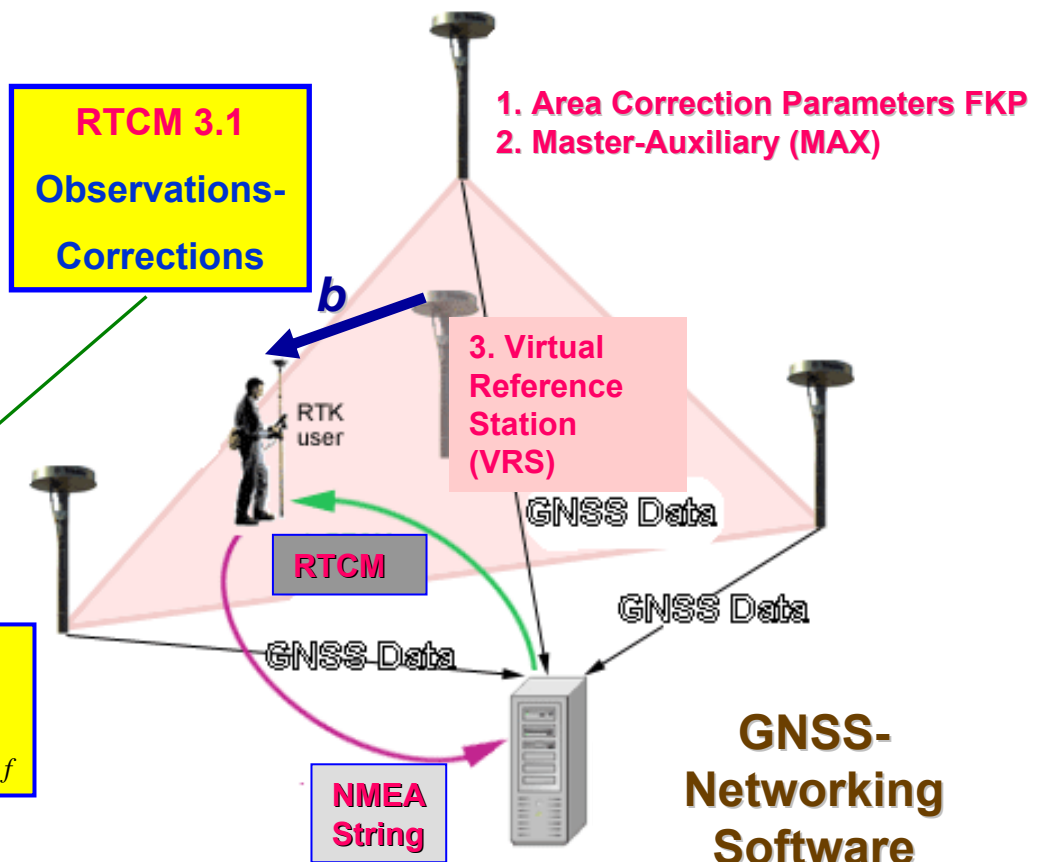
Precise GNSS-Positioning-Services

RTCM-based Positioning GNSS-Services

Basic GNSS-Data collected at the GNSS-Reference-Stations at a Time $t-\Delta t$

$$\nabla \rho(t-\Delta t)_{\text{Ref}}^{\text{Sat}} = \rho[(x, y, z)_{\text{REF}}; (x, y, z)_{\text{SAT}, \Delta t}]_{\text{true, Ref}} - \rho(t-\Delta t)_{\text{Observed, Ref}}$$

$$\nabla \lambda_R(t-\Delta t)_{\text{Ref}}^{\text{Sat}} = \lambda_R[(x, y, z)_{\text{REF}}; (x, y, z)_{\text{SAT}, \Delta t}]_{\text{true, Ref}} - \lambda_R(t-\Delta t)_{\text{Observed, Ref}}$$



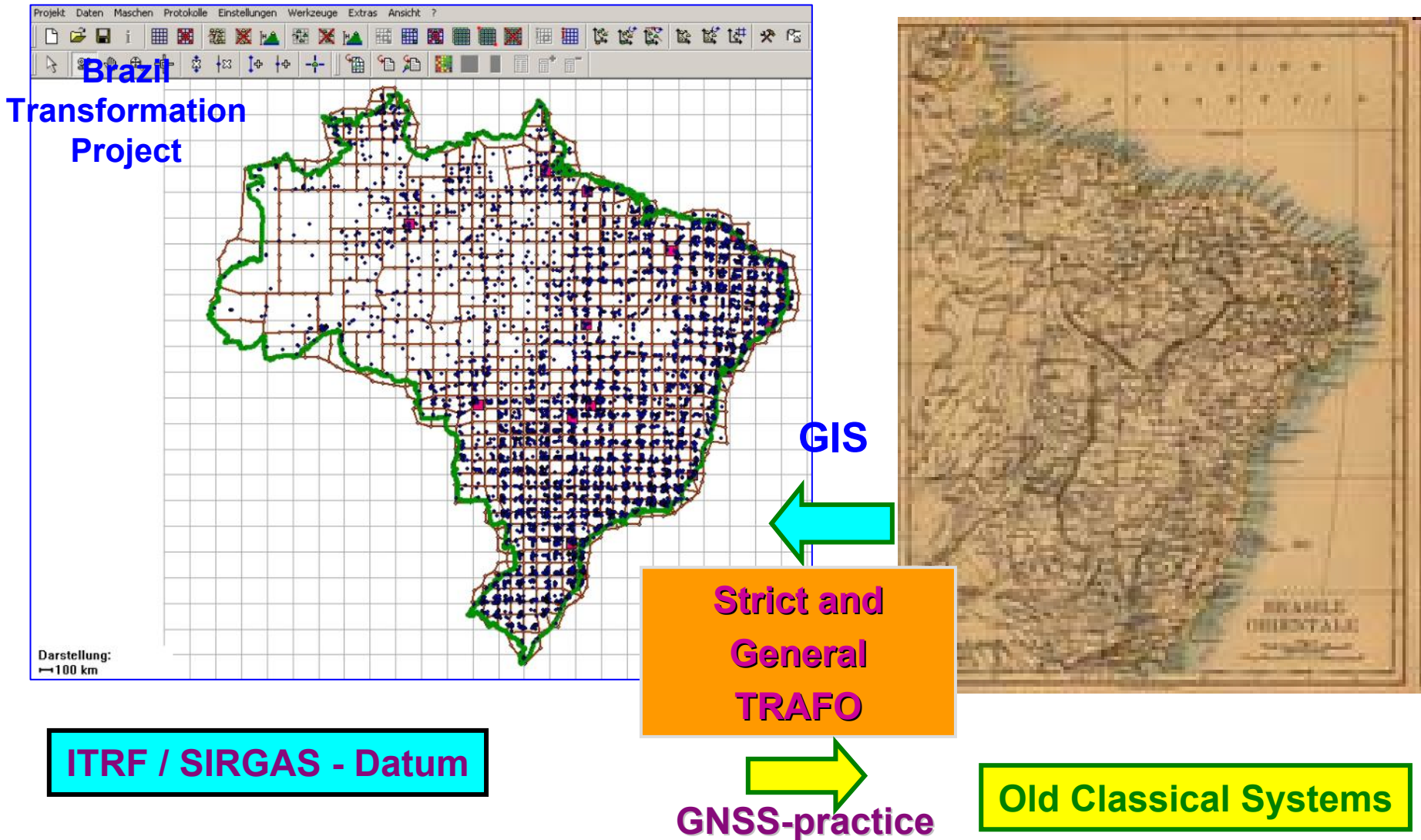
$$\lambda_R(t)_{\text{Rov, corrected}}^{\text{Sat}} = \lambda_R(t)_{\text{Rov, Observed}}^{\text{Sat}} - \nabla \lambda_R(t-\Delta t)_{\text{Re f}}^{\text{Sat}}$$

(B,L,h)_{GNSS-Datum}

1 - 2 cm ITRF-related

Reference Transformation components of GIGPS

Horizontal Datum Transition from $(B,L)_{GNSS,ITRF}$ to Classical Datum $(B,L)_{Classical}$



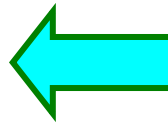
Reference Transformation components of GIGPS

Horizontal Datum Transition from $(B,L)_{GNSS,ITRF}$ to Classical Datum $(B,L)_{Classical}$

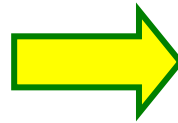


ITRF / ETRF89 - Datum

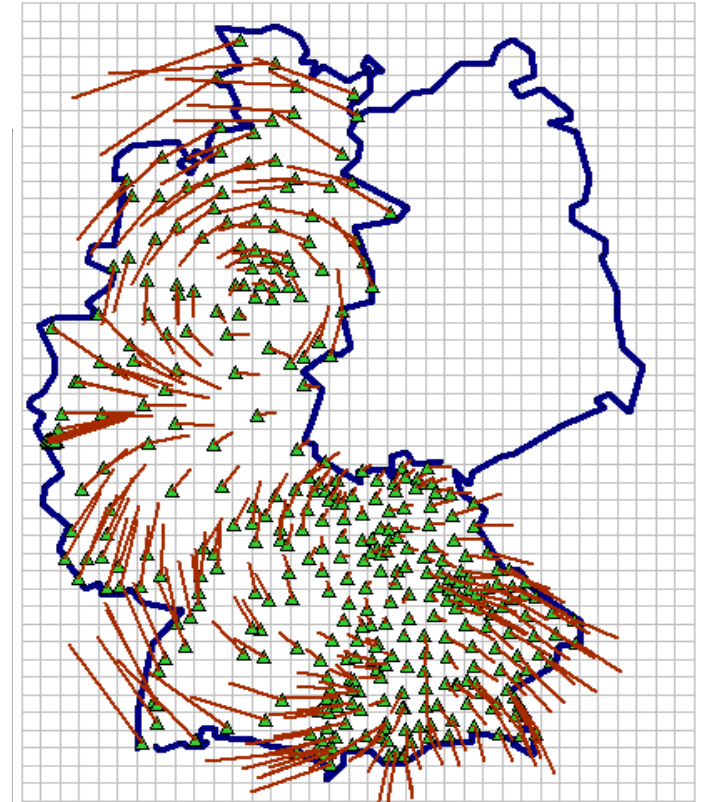
**GIS
Transition to
ITRFGNSS
consistent
frame**



**Strict and
General
TRAFO**



GNSS-practice



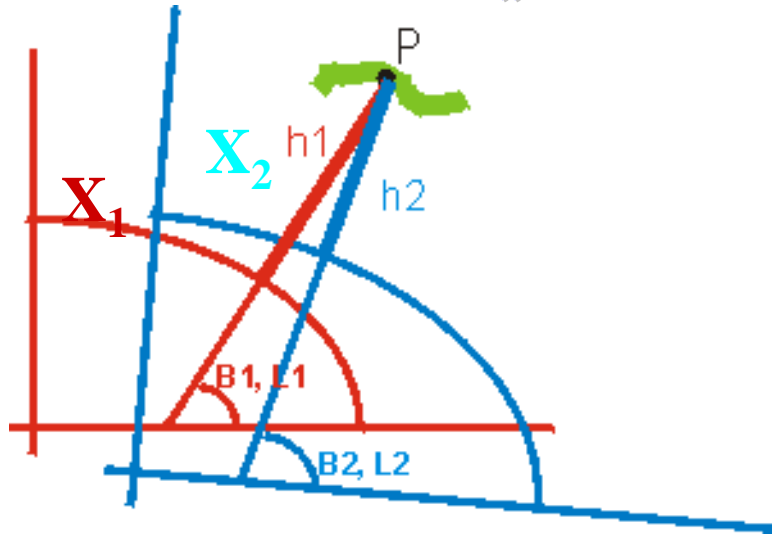
**Residuen-Lage:
1 m
Darstellung:
100 km**

Old Classical Systems

Reference Transformation components of GIGPS

Horizontal Datum Transition from $(B,L)_{\text{GNSS,ITRF}}$ to Classical Datum $(B,L)_{\text{Classical}}$

„All-over-the-World“ Problem



$$x = (N + h) \cdot \cos B \cdot \cos L$$

$$y = (N + h) \cdot \sin B \cdot \sin L$$

$$z = \left(\frac{b^2}{a^2} \cdot N + h \right) \cdot \sin B$$

mit $N(B)$ = Normalkrümmungshalbmesser

3D Similariy Transformation

$$X_2 = m \cdot R \cdot X_1 + t, \text{ mit } X_1 = \begin{bmatrix} x_1(B_1, L_1, h_1) \\ y_1(B_1, L_1, h_1) \\ z_1(B_1, L_1, h_1) \end{bmatrix} \text{ und } X_2 = \begin{bmatrix} x_2(B_2, L_2, h_2) \\ y_2(B_2, L_2, h_2) \\ z_2(B_2, L_2, h_2) \end{bmatrix}$$

**Rotation Matrix
3 Rotations**

Non-Linear Realation (see above)

Reference Transformation components of GIGPS

Horizontal Datum Transition from $(B,L)_{GNSS,ITRF}$ to Classical Datum $(B,L)_{Classical}$

Solution of the horizontal Transformation Problem

3D Similarity transformation Related to (B,L,h)

1D-,2D-,3D-

Identical Points

WTRANS

www.geozilla.de

$$\begin{pmatrix} B \\ L \\ h \end{pmatrix}_2 - \begin{pmatrix} \Delta B_{(a,b)1,(a,b)2} \\ \Delta L_{(a,b)1,(a,b)2} \\ \Delta h_{(a,b)1,(a,b)2} \end{pmatrix} - \begin{pmatrix} B \\ L \\ h \end{pmatrix}_1 + \begin{pmatrix} v_B \\ v_L \\ v_h \end{pmatrix}_i = [\text{Moldenski}]_{(B,L,h)1,i} \cdot \begin{pmatrix} \varepsilon_x \\ \varepsilon_y \\ \varepsilon_z \\ \Delta s \\ t_x \\ t_y \\ t_z \end{pmatrix}$$

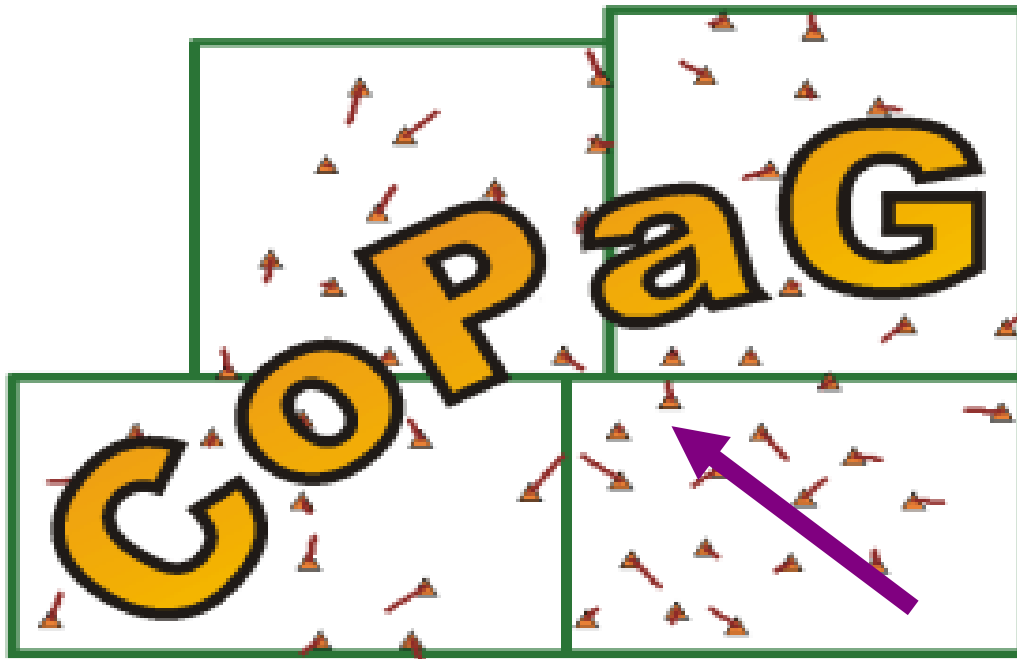
$-\sin(L) \cdot \frac{a \cdot W + h}{M + h}$	$\cos(L) \cdot \frac{a \cdot W + h}{M + h}$	0	$\frac{-\sin(B) \cdot \cos(B) \cdot N \cdot e^2}{M + h}$	$\frac{-\sin(B) \cdot \cos(L)}{M + h}$	$\frac{-\sin(B) \cdot \sin(L)}{M + h}$	$\frac{\cos(B)}{M + h}$
$\frac{\sin(B) \cdot \cos(L) \cdot (N \cdot (1 - e^2) + h)}{(N + h) \cdot \cos(B)}$	$\frac{\sin(B) \cdot \sin(L) \cdot (N \cdot (1 - e^2) + h)}{(N + h) \cdot \cos(B)}$	-1	0	$\frac{-\sin(L)}{(N + h) \cdot \cos(B)}$	$\frac{\cos(L)}{(N + h) \cdot \cos(B)}$	0
$-N \cdot e^2 \cdot \sin(B) \cdot \cos(B) \cdot \sin(L)$	$N \cdot e^2 \cdot \sin(B) \cdot \cos(B) \cdot \cos(L)$	0	$h + a \cdot W$	$\cos(B) \cdot \cos(L)$	$\cos(B) \cdot \sin(L)$	$\sin(B)$

$$W = \frac{a}{N} = \sqrt{1 - e^2} \cdot \sin^2 B \quad e^2 = \frac{a^2 - b^2}{a^2}$$

Reference Transformation components of GIGPS

Horizontal Datum Transition from $(B,L)_{\text{GNSS,ITRF}}$ to Classical Datum $(B,L)_{\text{Classical}}$

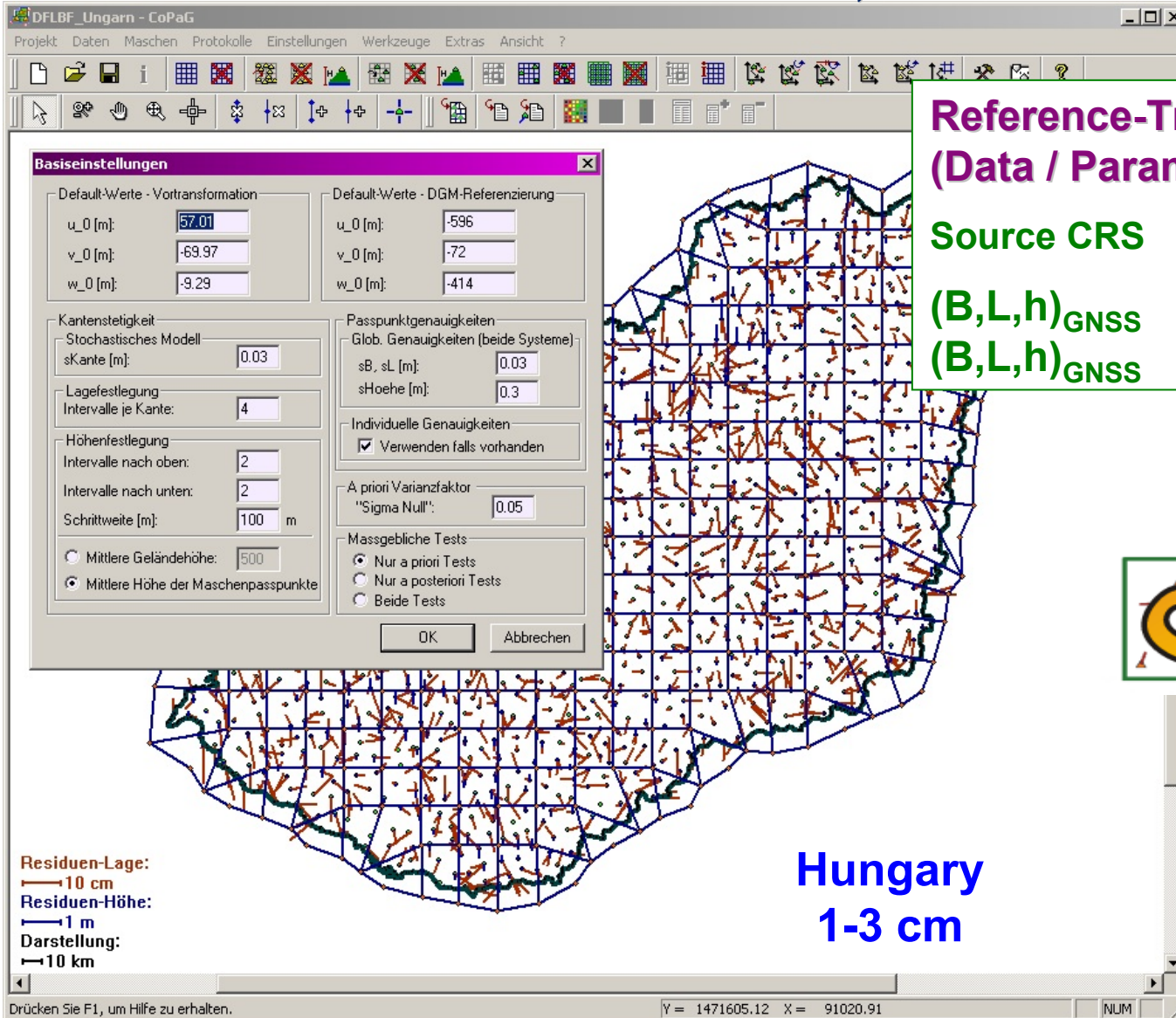
COPAG = Continuously Patched Georeferencing



**Continuity along the
Mesh Borders!**

Reference Transformation components of GIGPS

Horizontal Datum Transition from $(B,L)_{GNSS,ITRF}$ to Classical Datum $(B,L)_{Classical}$



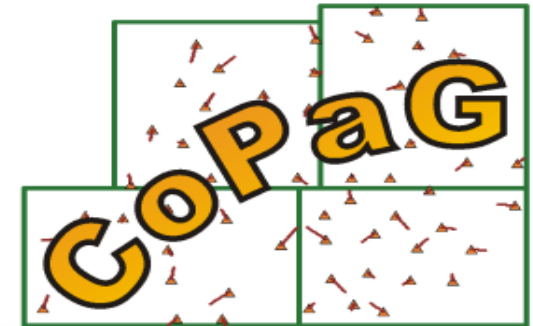
Reference-Transformation
(Data / Parameters / Algorithms)

Source CRS

Target CRS

$(B,L,h)_{GNSS} \Rightarrow (B,L)_{Classical}$

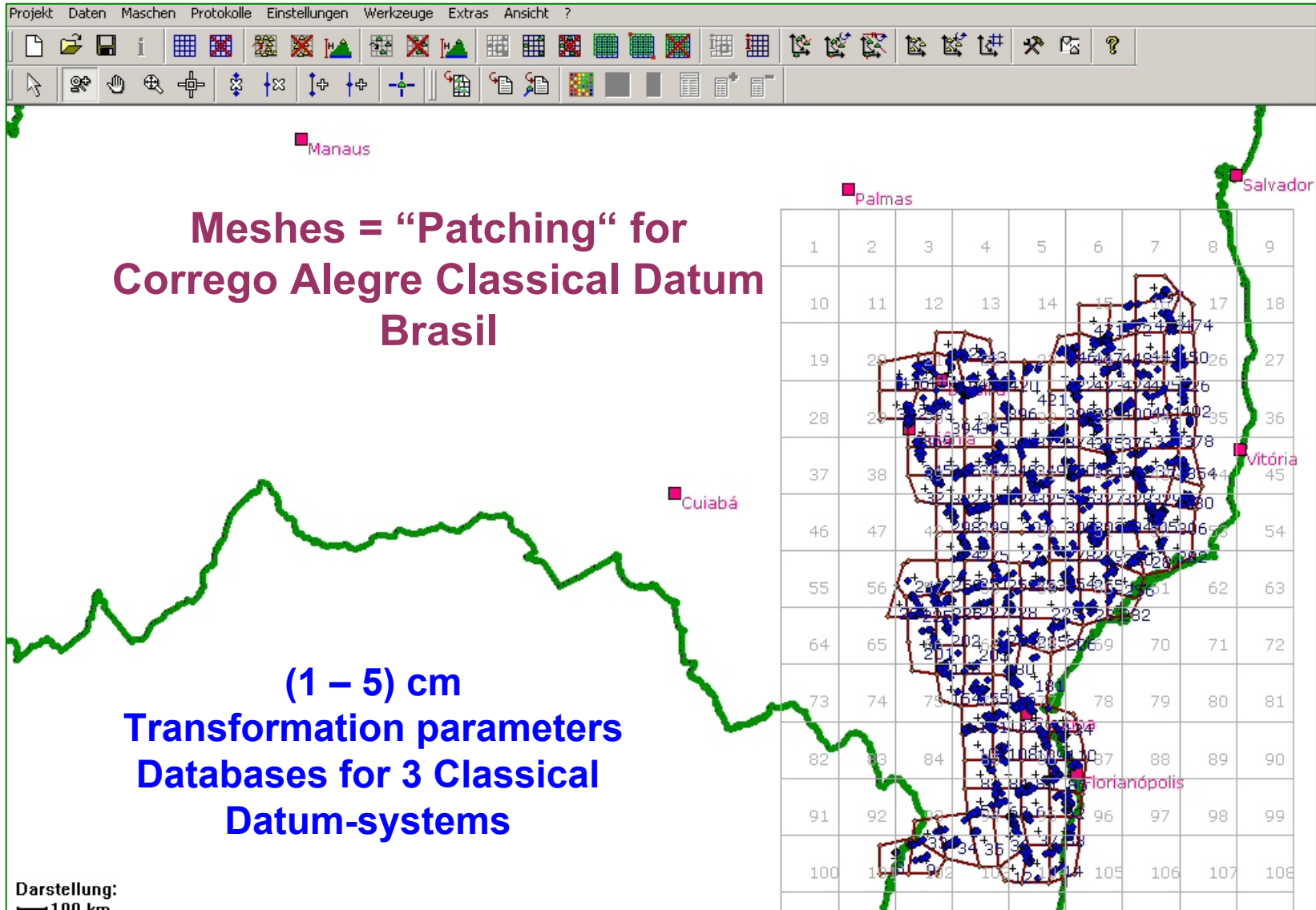
$(B,L,h)_{GNSS} \Rightarrow (B,L,H)_{Classical}$



DFLBF_DB
Transformation
Parameters
& Residuals

Reference Transformation components of GIGPS

Horizontal Datum Transition from $(B,L)_{\text{GNSS,ITRF}}$ to Classical Datum $(B,L)_{\text{Classical}}$



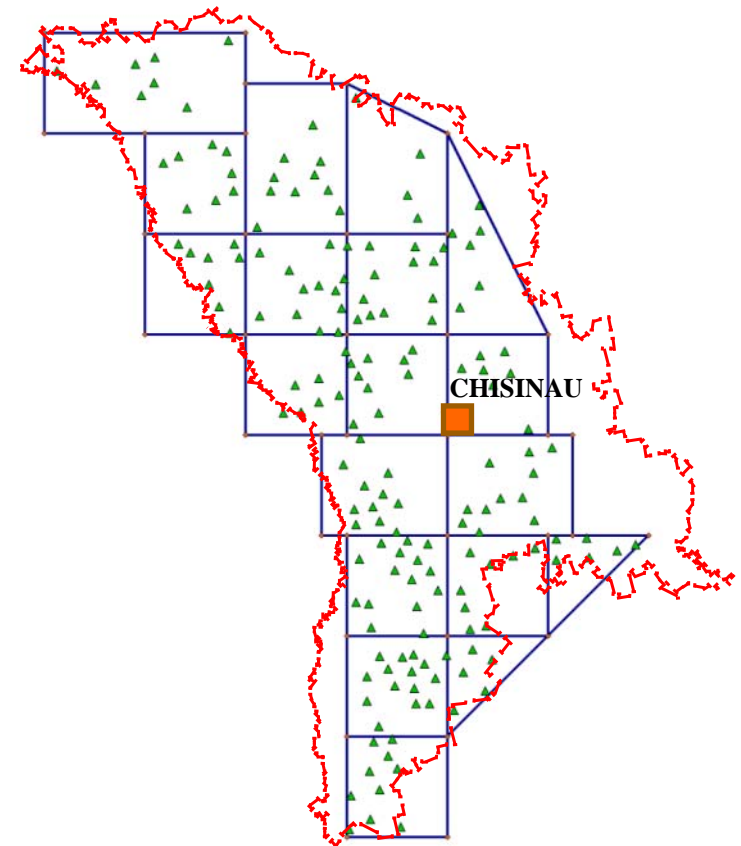
Reference Transformation components of GIGPS

Horizontal Datum Transition from $(B,L)_{GNSS,ITRF}$ to Classical Datum $(B,L)_{Classical}$



Combined Old Classical Triangulation and ETRS89 Control Points from GNSS measurements

Meshes = "Patching" for ETRS89 and Classical Datum-systems of Moldova



(1 – 4) cm transformation parameter Databases for Classical and ETRS89 Datum-systems

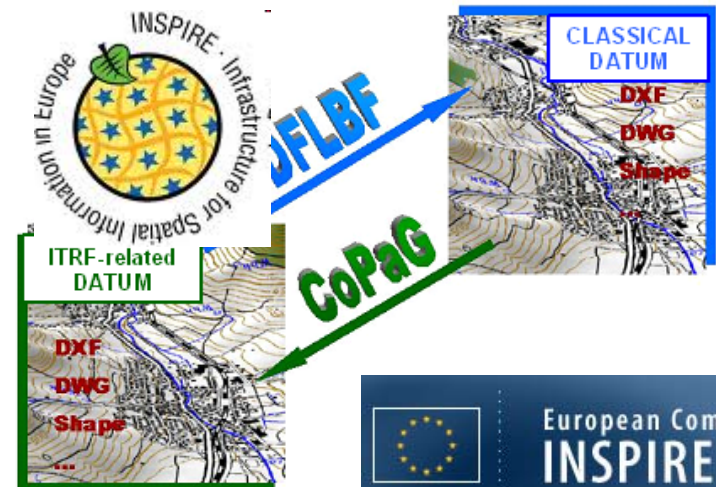
Darstellung:
— 10 km

Reference Transformation components of GIGPS

Use of DLBF/GOPAG Databases

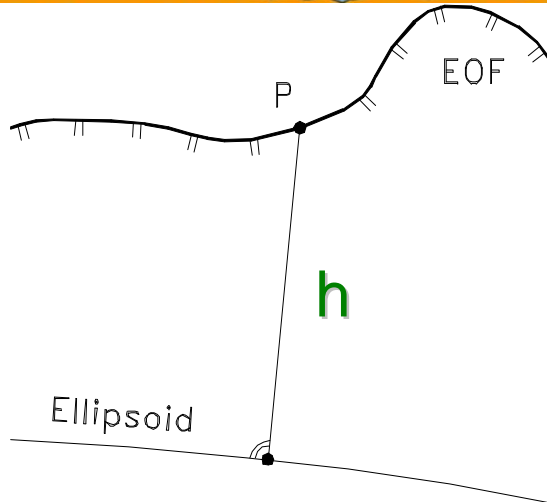
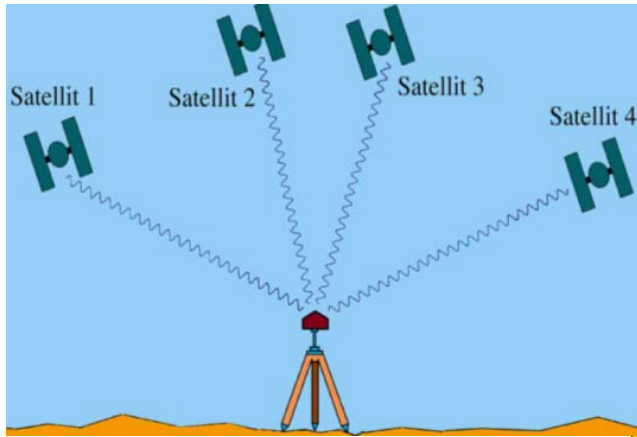
Horizontal Datum Transition
from (B,L)_{GNSS,ITRF} to (B,L)_{Classical}
DFLBF-Databases. Use in GNSS-Services
on controllers and via RTCM
see www.geozilla.de

Horizontal Datum Transition
from (B,L)_{Classical} to (B,L)_{GNSS,ITRF}
COPAG-Databases for GIS
see: www.geozilla.de

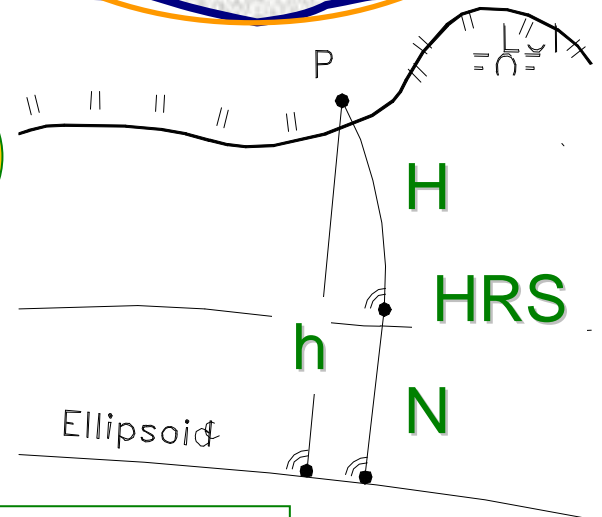


Reference Transformation components of GIGPS

Height Problem / HRS Transition - Karlsruhe Reference Transformation



GNSS Heighting
 „H from h- GNSS“



$$H = h - N(B,L,h)$$

Reference-Transformation
 Source CRS Target CRS
 (B,L,h)_{GNSS} => N

www.dfhbf.de

Reference Transformation components of GIGPS

Height Problem / HRS Transition - Karlsruhe Reference Transformation

$$h_{GNSS} + v = H + \mathbf{f}^T \cdot \mathbf{p} - h_{GPS} \cdot \Delta m$$

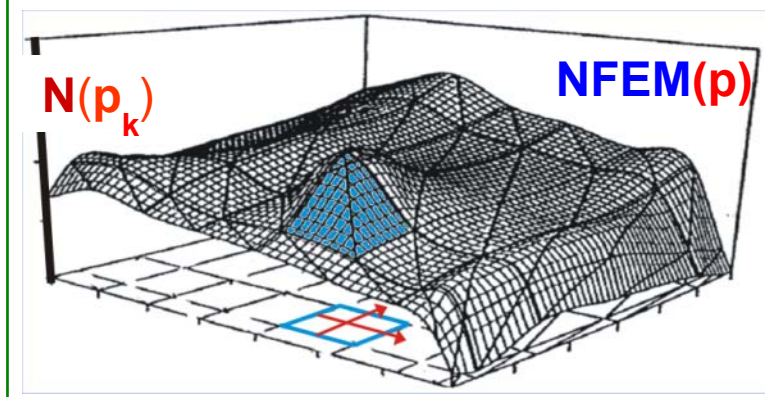
$$H + v = H$$

$$N_G^j + v^j = \mathbf{f}^T \cdot \mathbf{p} + \partial N_G(\mathbf{d}^j)$$

$$\xi^j + v = -\mathbf{f}_B^T / M(B) \cdot \mathbf{p} + \partial \xi(\mathbf{d}_{\xi,\eta}^j)$$

$$\eta^j + v = -\mathbf{f}_L^T / (N(B) \cdot \cos(B)) \cdot \mathbf{p} + \partial \eta(\mathbf{d}_{\xi,\eta}^j)$$

$$\frac{a}{4 \cdot \pi \cdot \gamma(B)} \iint_{\sigma} \Delta \mathbf{g} \cdot \mathbf{S}(\psi) d\sigma + v = \mathbf{NFEM}(\mathbf{p}) = \mathbf{f}^T \cdot \mathbf{p}$$



Reference-Transformation
 Source CRS Target CRS
 (B,L,h)_{GNSS} => N

$$g_{grav}^{LGV}_r + v = \sum_{k=0}^{\infty} \left(\frac{a}{r}\right)^{n(k)+1} \frac{(n(k)+1)}{r} \sum_{m=0}^k (\bar{C}'_{n(k),m} \cdot \cos m\lambda' + \bar{S}'_{n(k),m} \cdot \sin m\lambda') \cdot P_{n(k),m}(\cos \theta') + dg(\mathbf{d})$$

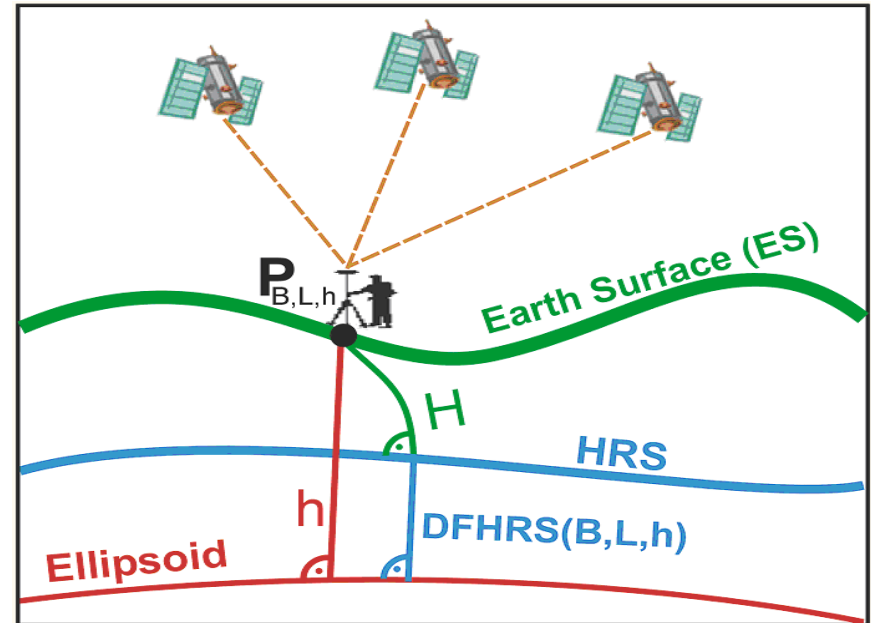
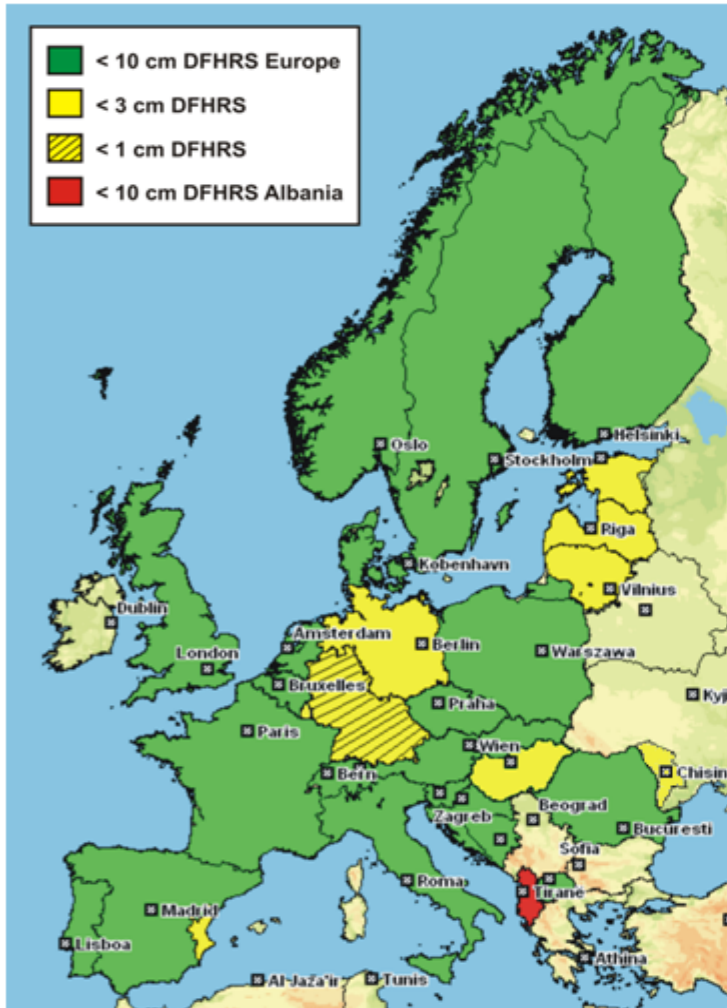
$$N_{GPM}^j + v = N(\bar{C}'_{n(k),m}, \bar{S}'_{n(k),m}) + \partial N(\mathbf{d}^j)$$

$$= \frac{1}{\gamma_Q} \left(\sum_{k=0}^{\infty} \left(\frac{a}{r}\right)^{n(k)+1} \sum_{m=0}^k (\bar{C}'_{n(k),m} \cdot \cos m\lambda' + \bar{S}'_{n(k),m} \cdot \sin m\lambda') \cdot P_{n(k),m}(\cos \theta') - V_{ref} \right) + \partial N(\mathbf{d}^j)$$

$$0 + v_{\Delta N} = N(\bar{C}'_{n(k),m}, \bar{S}'_{n(k),m}) - (\mathbf{f}^T \cdot \mathbf{p} + \Delta m \cdot h)$$

Reference Transformation components of GIGPS

Height Problem / HRS Transition - Karlsruhe Reference Transformation



DFHBF DB

Reference Transformation components of GIGPS

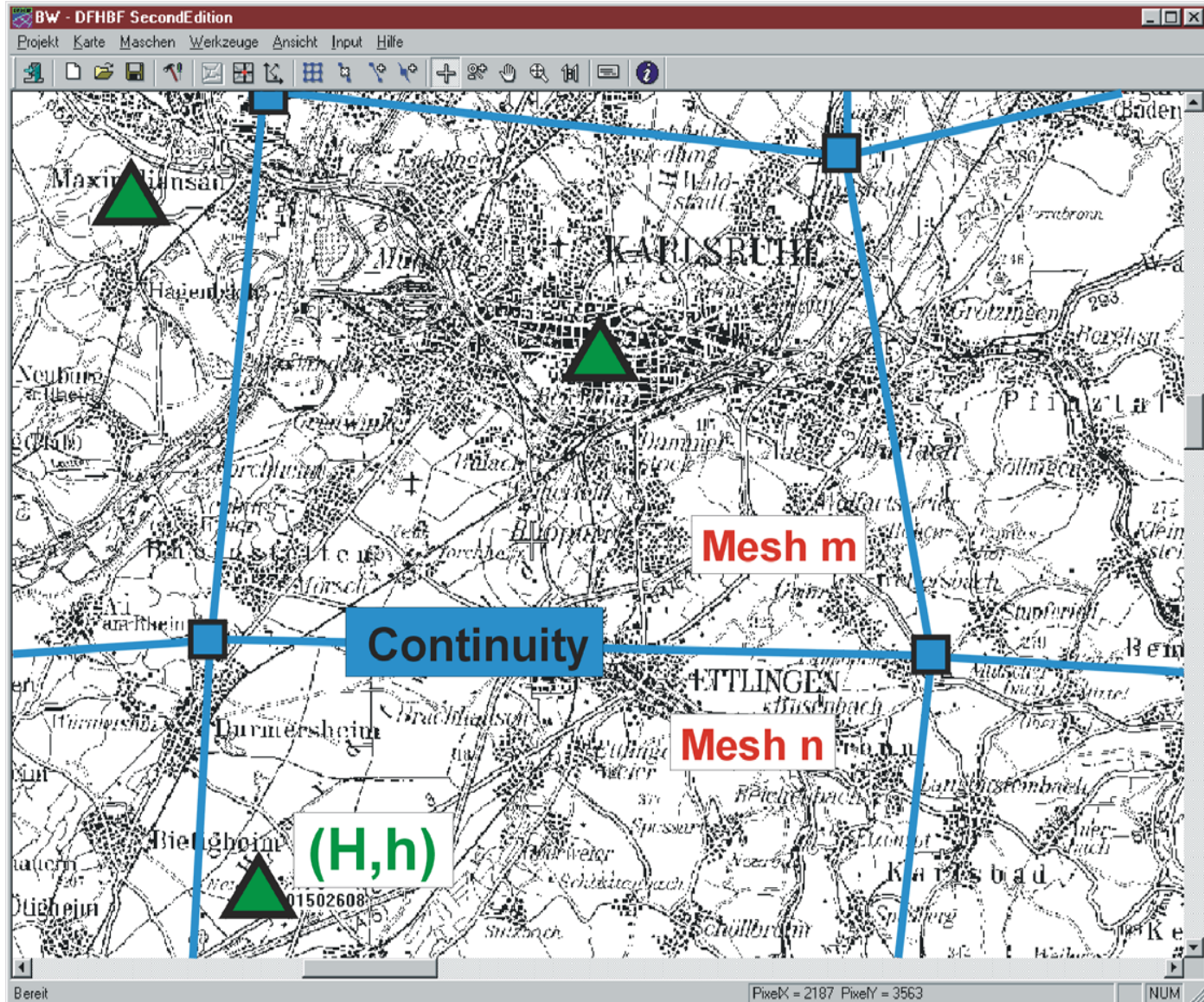
Height Problem / HRS Transition - Karlsruhe Reference Transformation



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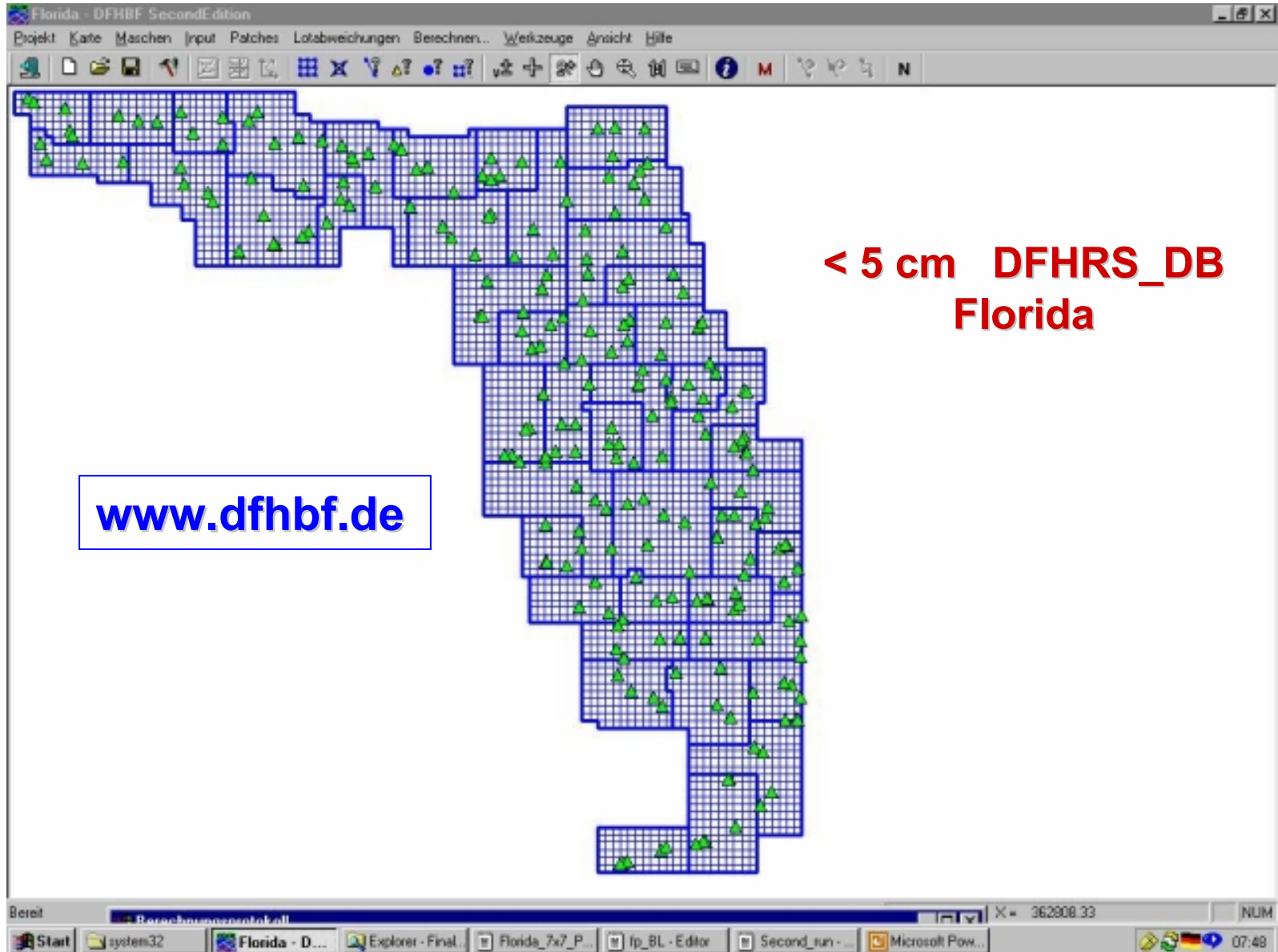
Software
Screenshot

- Identical „Fitting“ Points (B,L,h;H)
- Meshes



Reference Transformation components of GIGPS

Height Problem / HRS Transition - Karlsruhe Reference Transformation



Reference Transformation components of GIGPS

Height Problem / HRS Transition - Karlsruhe Reference Transformation

< 10cm DFHRS
Europe
„Fittingpoint-Design“

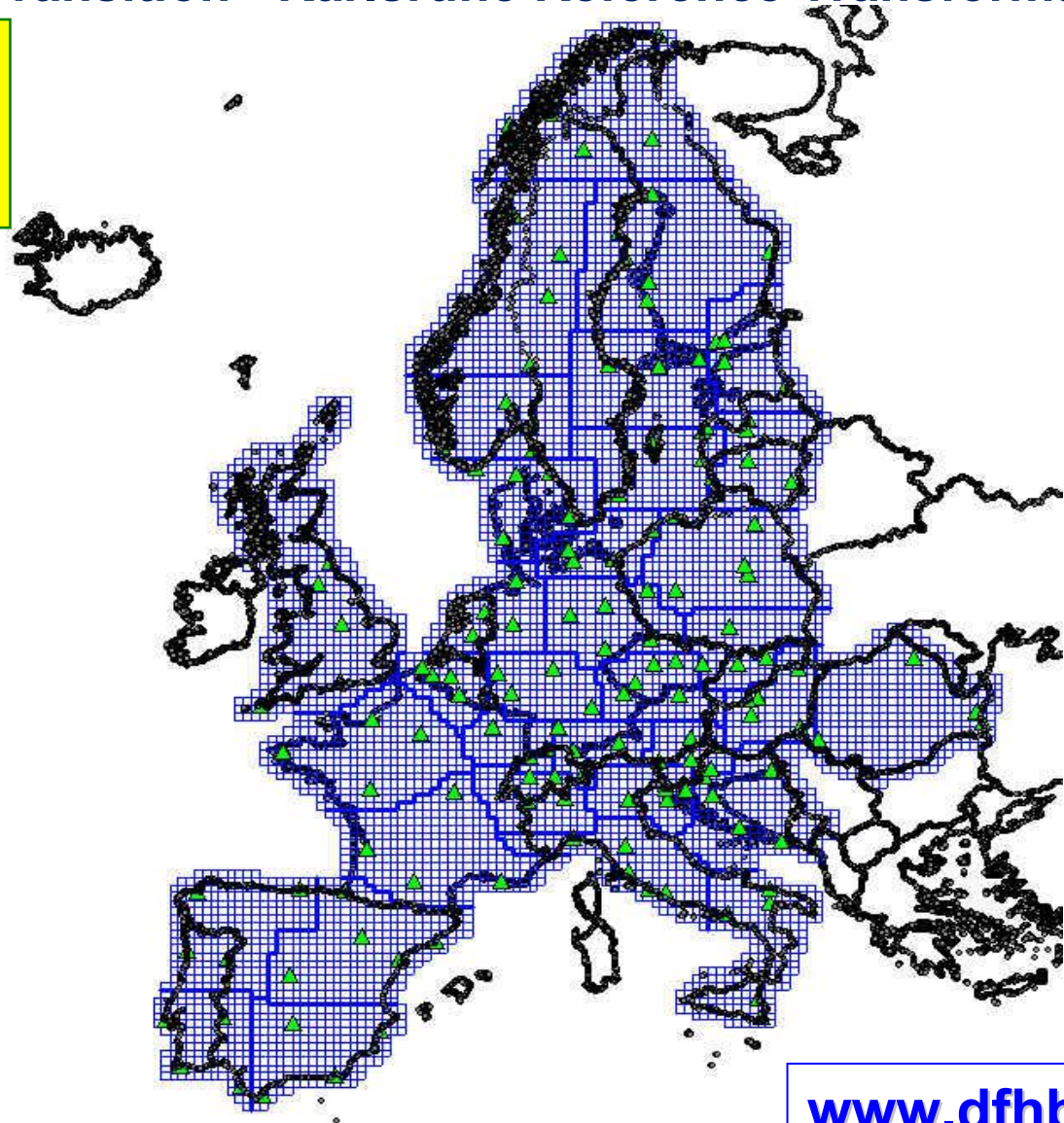
ETRS89/EVRS

„GPS-/Levelling-
Points of EVN“

Fitting Points
 $NFEM(p) =: h - H$

Used for the
1st Version
< 10_cm DFHBFS

Europe



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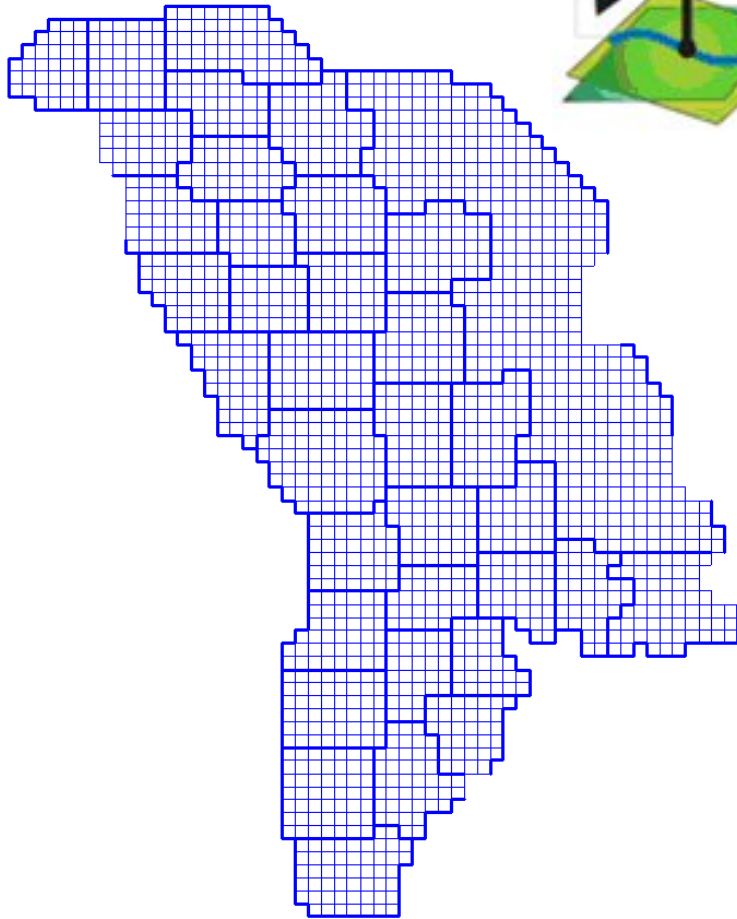
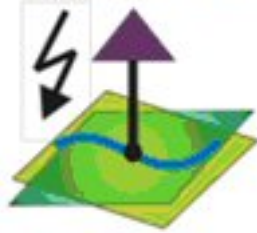
Reference Transformation components of GIGPS

Height Problem / HRS Transition - Karlsruhe Reference Transformation

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MOLDPOS

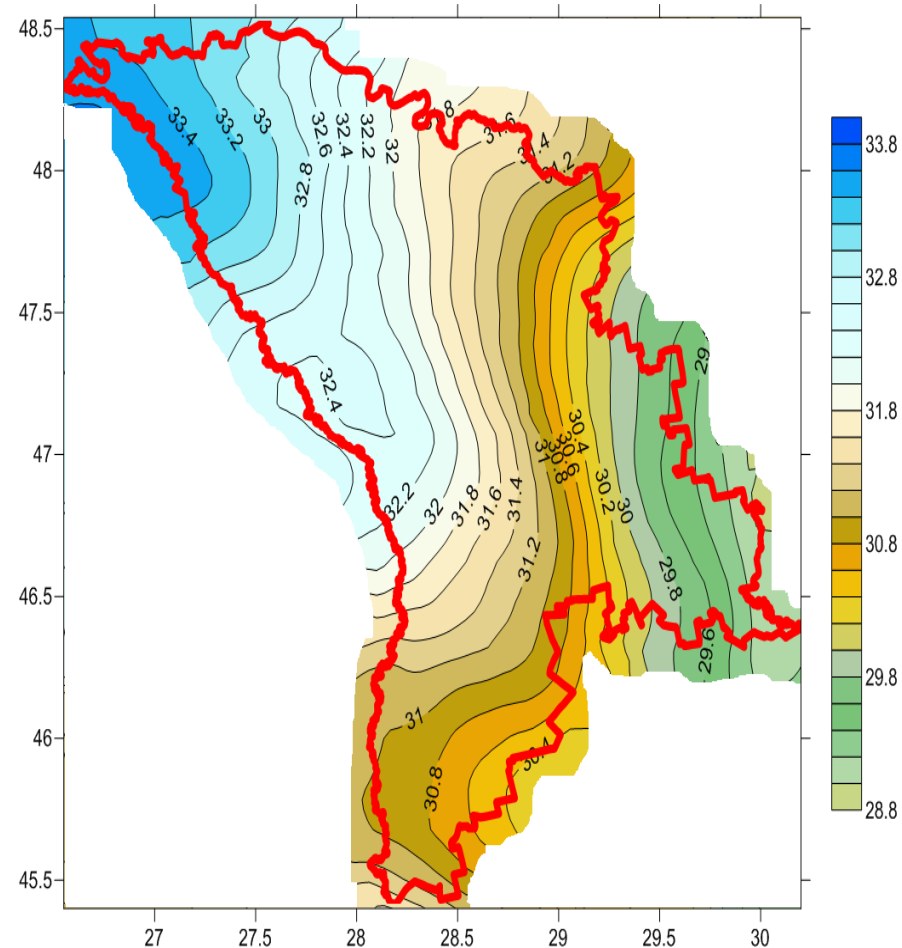


1-3 cm Quasigeoid for Moldova

Patching of

EGG97 or EGM2008 GPM

Nearly same results



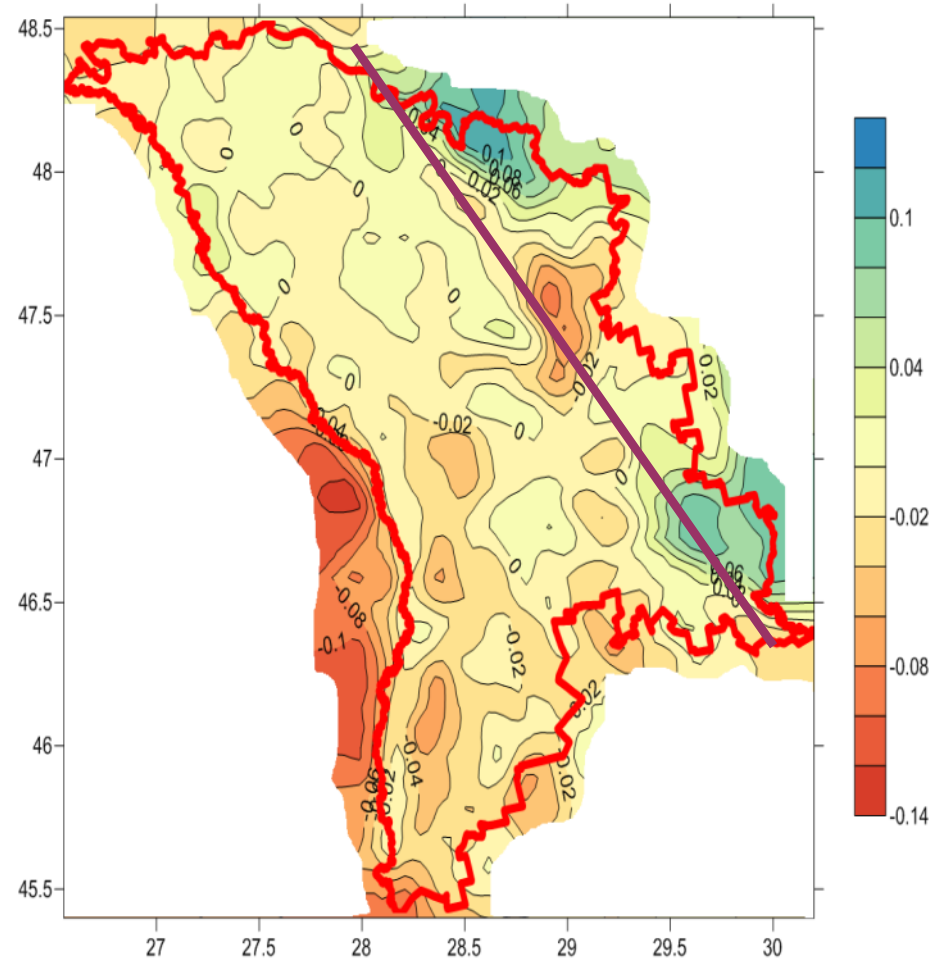
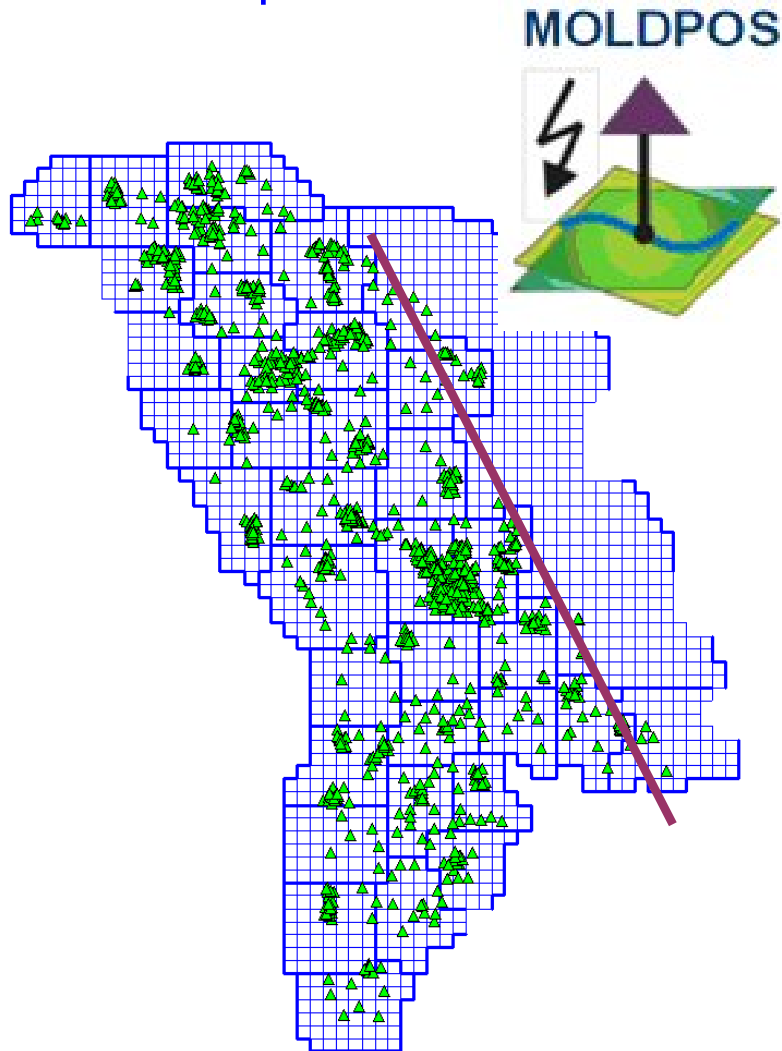
Reference Transformation components of GIGPS

Height Problem / HRS Transition - Karlsruhe Reference Transformation

www.moldpos.eu

1-3 cm Quasigeoid for Moldova

Patching of
EGG97 or EGM2008 GPM
Nearly same results



Reference Transformation components of GIGPS

Reference Transformations and RTCM Transformation messages

RTCM 3.1 Observations Corrections

&

„Seven RTCM Transformation Messages“

(Scientific Member of International RTCM-Working Group 2004-2007)

- Transformation-Parameters (1021,1022)
- Residual-Grids and/or Geoid-Representations (1023,1024)
- Projection-Information (1025,1026,1027)

sent by GNSS-Positioning-Service

to

GNSS-Positioning-User



NMEA-based request to RTCM-Transformation Messages Server)

Reference Transformation components of GIGPS

Reference Transformations and RTCM Transformation messages



**Willkommen
zur Intergeo
2004**

Trimble ist stolz darauf, auch in diesem Jahr ein offizieller Sponsor des Intergeo-Kongresses und Intergeo-Treffs zu sein.

Wir von Trimble haben es uns zum Ziel gesetzt, Ihnen die neueste Technologie bereitzustellen, die es Ihnen ermöglicht, die Vorteile lokalisierter, integrierter Vermessungslösungen zu nutzen und Ihre Effizienz, Produktivität und Ihren Gewinn zu erhöhen. Als Beweis unseres Engagements präsentieren wir in diesem Jahr eine Reihe von Lösungen, die speziell für unsere europäischen Kunden entwickelt wurden.

Durch die Akquisition der GeoNav GmbH sind wir in der Lage, Ihnen eine neue Feldsoftwarelösung, den Trimble Survey Manager, an die Hand zu geben. Die Software ist auf Anwendungen in der europäischen Vermessungsindustrie, und insbesondere auf Katastervermessungen, zugeschnitten. Des Weiteren haben wir unser GPS-Produktportfolio mit dem Trimble R8 um den „ultimativen VRS-Rover“ ergänzt.

Der Trimble R8 ist eine Kombination aus einem leichten, kabellosen Rover ohne externes GSM-Modem und der L2C-fähigen GPS-Technologie für den Einsatz in europäischen VRS-Netzen.

Anwendern von Robotic-Totalstationen bieten wir das lizenzfreie 2,4 GHz GeoRadio mit modernster Spread Spectrum-Technologie an, die Interferenzen von anderen Funkgeräten auf belebten Baustellen

Neue Trimble Survey Manager Software

Die fortschrittliche Trimble Feldlösung für präzise Echtzeit-Vermessungen.

Trimble Survey Manager basiert auf der beliebten DCTools Software von Trimble GeoNav. Es ist eine flexible, einfach zu verwendende Oberfläche für Ihr Vermessungssystem. Trimble Survey Manager besteht aus Softwaremodulen für Feld und Büro und wurde speziell für die Datenerfassung, Datenverarbeitung und die Dokumentation präziser Echtzeit-Vermessungen entwickelt.

ALLES UNTER KONTROLLE – MIT DEM TRIMBLE SURVEY MANAGER

Das Trimble Survey Manager Feldmodul läuft unter Windows 9x, 2000, XP und Windows CE. Sie können Feldvermessungen auf der Plattform ausführen, die den Projektanforderungen am besten entspricht, einschließlich Notebooks, Tablet PCs oder unseren robusten und leistungsstarken Trimble Controllern: TSCe™, ACU oder Trimble Recon™. Trimble Survey Manager ist vollständig mit Trimble GPS- und Trimble Totalstationssystemen kompatibel und erlaubt die komplette Steuerung aller Instrumente und Messmethoden im Feld.

Die Trimble Survey Manager Software enthält die offiziellen Referenzkoordinaten des amtlichen Koordinatensystems, bietet volle SAPOS®- und ascos®-Unterstützung und die Implementierung von DFLBF und DFHBF. Sie gewährleistet die exakte Datenerfassung, -verarbeitung und Dokumentation nach amtlichen Vorgaben und wurde speziell für katasterspezifische Anforderungen in Deutschland optimiert.



Bewährte GPS-Technologie in einer kostengünstigen L1-Lösung: das NEUE Trimble 5700 L1 GPS-System

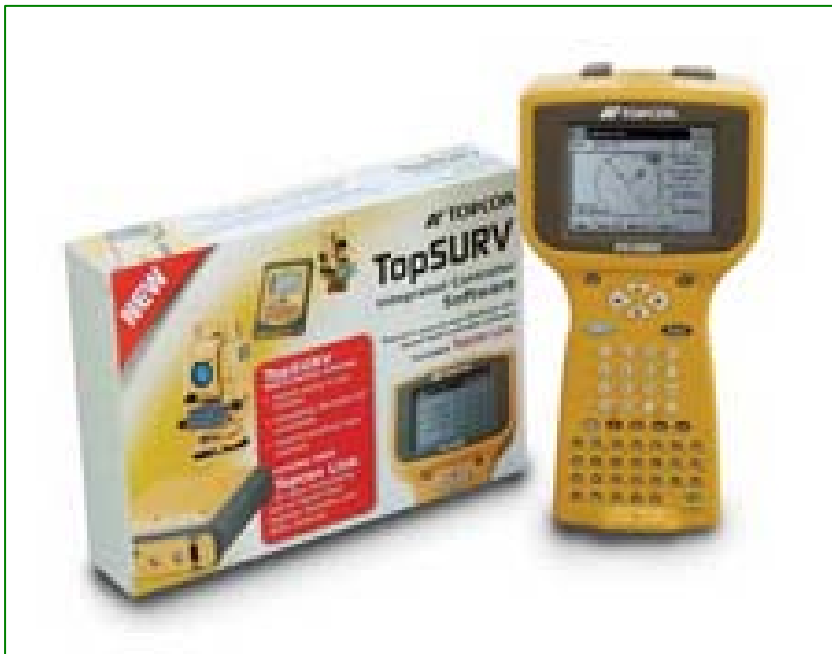
Der 5700 L1 GPS-Empfänger von Trimble ist ein bedienerfreundlicher GPS-Empfänger speziell für statische, L1-FastStatic und kinematische Vermessungen. Er ist eine flexible, kostengünstige Vermessungslösung mit bewährter Trimble GPS-Technologie.

UNTERNEHMEN

Beginnen Sie mit einer preisgünstigen Trimble GPS-Einstiegslösung und rüsten Sie diese später für erhöhte Produktivität zu einem leistungsfähigen Zweifrequenz-System auf. Sie können Ihr System bei Bedarf sogar mit RTK nachrüsten.

Reference Transformation components of GIGPS

Reference Transformations and RTCM Transformation messages



Reference Transformation components of GIGPS

Reference Transformations and RTCM Transformation messages



Sensor Firmware Version 4.20

- *Optimale Vernetzungslösung*
 - Flächenkorrekturparameter
 - Verschlüsseltes RTCM-AdV
 - Virtuelle Referenzstation
 - Monitoring der FKP/VRS-Out Position
- *Moderne Datenkommunikation*
 - RTCM 2.3
 - Automatische Erkennung der Referenzantenne
 - Siemens TC35 Dualband GSM-Telefon
- *Deutschlandweit passpunktfreies Messen*
 - DFHBF für 3 cm-genaue Höhenbestimmung
 - DFLBF für 5 cm-genaue Lagebestimmung
 - Integration anderer Geoidmodelle/ Koordinatensysteme realisiert

Hauptsitz:

Leica Geosystems GmbH
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Hans-Bunte-Straße 5
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Tel. 089 / 14 98 10 0
Fax 089 / 14 98 10 33
www.leica-geosystems.de

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Leica
Geosystems

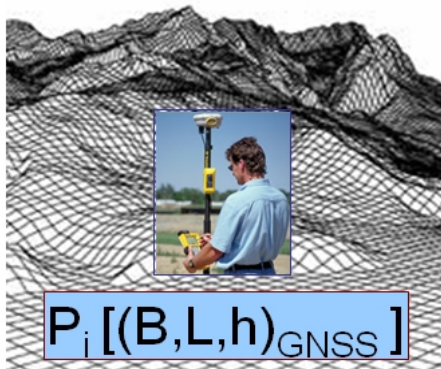
Reference Transformation components of GIGPS

Reference Transformations and RTCM Transformation messages

„Gridding“ of Reference Transformations

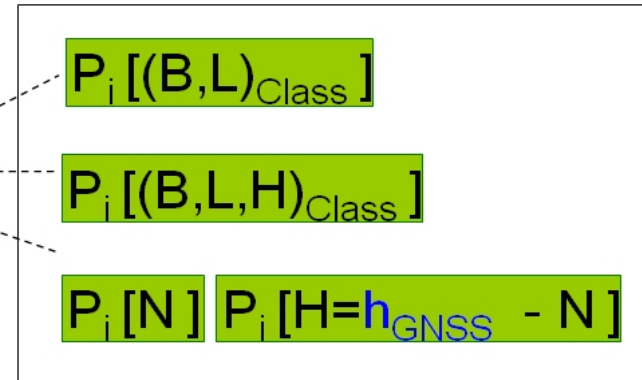
Source CRS - Grid

Target CRS - Grid



Generated Grid of Local Virtual Fitting Points P_i

Any kind of individual
Reference Transformation



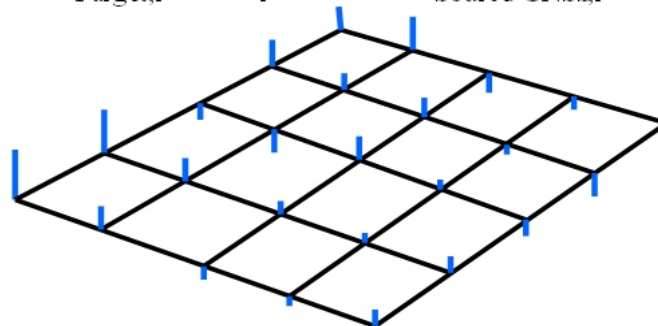
Resulting Local Virtual Fitting Points P_i

Gridding into 1.] and/or 2.]

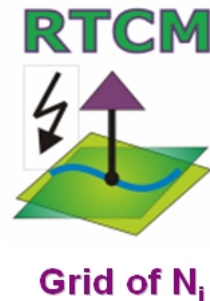
1.] 7 Parameter Transformation

$$\begin{bmatrix} x_T \\ y_T \\ z_T \end{bmatrix}_{\text{Target},i} + \begin{bmatrix} r_x \\ r_y \\ r_z \end{bmatrix}_i = s \cdot \mathbf{R} \cdot \begin{bmatrix} x \\ y \\ z \end{bmatrix}_{\text{Source/GNSS},i} + \begin{bmatrix} t_x \\ t_y \\ t_z \end{bmatrix}$$

2.] Geoid/HRS Grid



7 Parameter Trend and 3D „Small“ Residual Grid



Grid of N_i

Reference Transformation components of GIGPS

Reference Transformations and RTCM Transformation messages

Message 1021 or 1022

Data FIELD	DF NUMBER	Values	Remarks
Message Number	DF002	1021	
Source-Name Counter	DF+1	4	
Source-Name	DF+2	4258	ETRS89, Europa
Target-Name Counter	DF+3	7	
Target-Name	DF+4	31467	DHDN, GK-3
System identification number	DF+5	1	
Involved Transformation message	DF+6	0000000110	
Plate number	DF+7	7	
Computation Indicator	DF+8	1	
Height Indicator	DF+9	2	
ϕ_V	DF+10	49.0102	
λ_V	DF+11	8.3921	
$\Delta\phi_V$	DF+12	0.04	
$\Delta\lambda_V$	DF+13	0.06	
dX	DF+14	-617.880	
dY	DF+15	-253.456	
dZ	DF+16	-315.690	
R ₁	DF+17	5.79748	
R ₂	DF+18	-2.44443	
R ₃	DF+19	-5.1534	
dS	DF+20	-13.51806	
add a _s	DF+24	8137.000	GRS80
add b _s	DF+25	6752.314	
add a _T	DF+26	7397.155	Bessel
add b _T	DF+27	6078.963	
Horizontal 7P Quality Indicator	DF+76	2	

Geoid-Grid or not

Grid
Location&Size

7 Parameters


Ellipsoid
Parameters
Source / Target

Reference Transformation components of GIGPS

Reference Transformations and RTCM Transformation messages

Message 1023 or Message 1024

::		::	
δN_{14}	Residuals P_{14}	DF+71	0.001
δE_{14}		DF+72	0.013
δh_{14}		DF+73	0.049
δN_{15}	Residuals P_{15}	DF+71	0.005
δE_{15}		DF+72	0.009
δh_{15}		DF+73	0.088
δN_{16}	Residuals P_{16}	DF+71	0.006
δE_{16}		DF+72	-0.002
δh_{16}		DF+73	0.129
Horizontal interpolation method indicator		DF+74	0
Vertical interpolation method indicator		DF+75	0
Horizontal Grid Quality Indicator		DF+78	1
Vertical Grid Quality Indicator		DF+79	1
Modified Julian Day (MJD) Number		DF+80	53570

Height Indicator = 1  „dh_i„ = Physical Heights' Residuals dH_i

Height Indicator = 2  „dh_i„ = Geoid / HRS Heights N_i (dN_i)

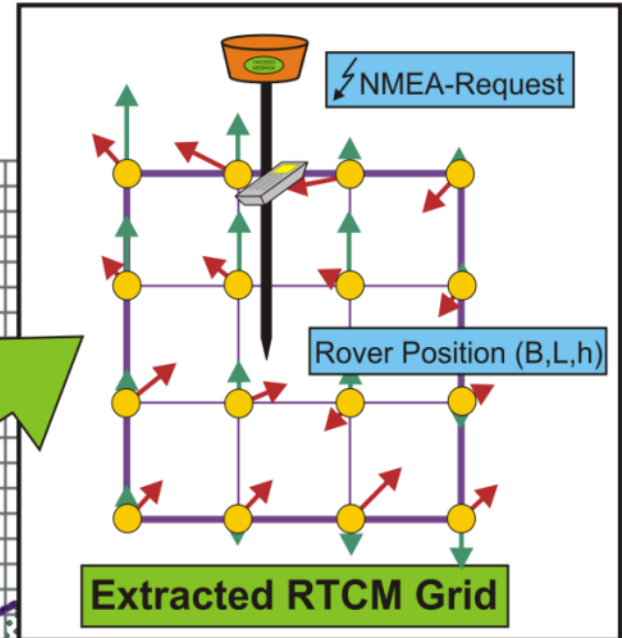
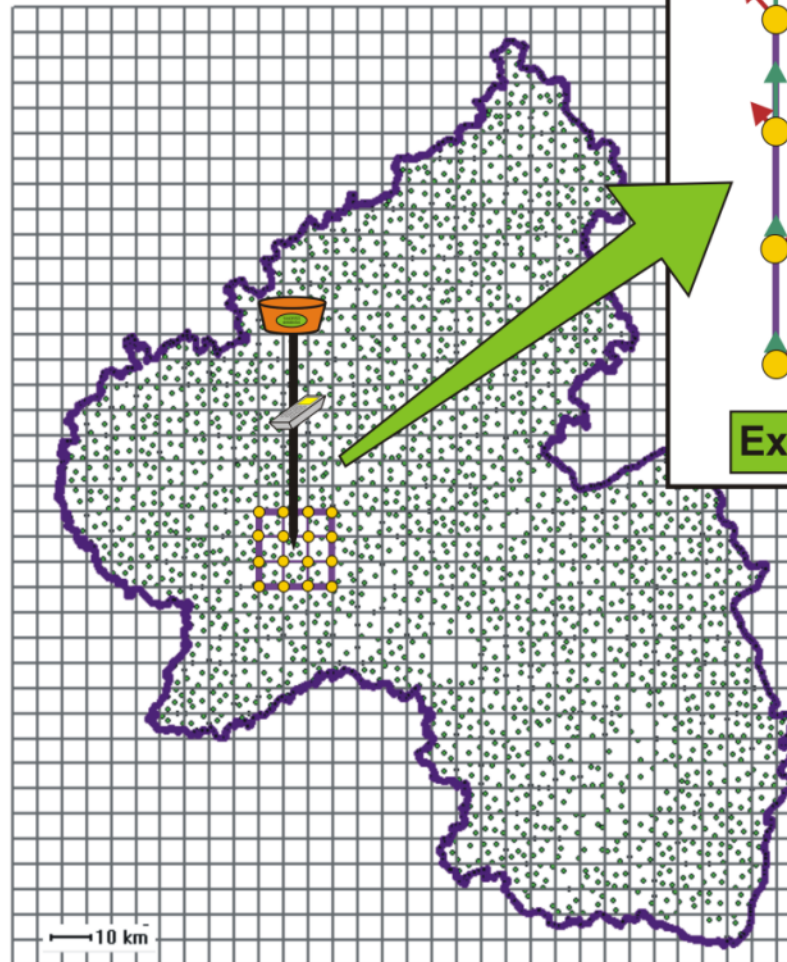
Reference Transformation components of GIGPS

Reference Transformations and RTCM Transformation messages

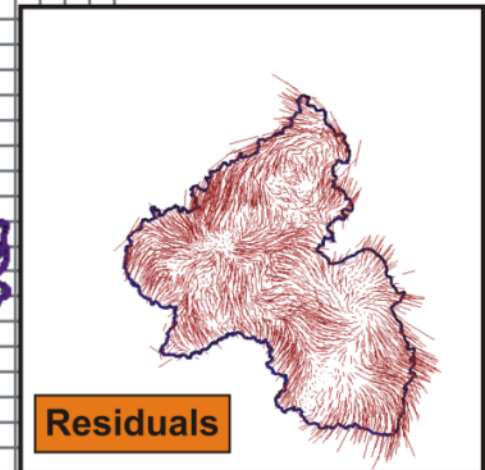
Using
Reference
Transformations

to
compute
a
country-wide

Original Static
'Large Residuals' Grid



Extracted RTCM Grid



Residuals

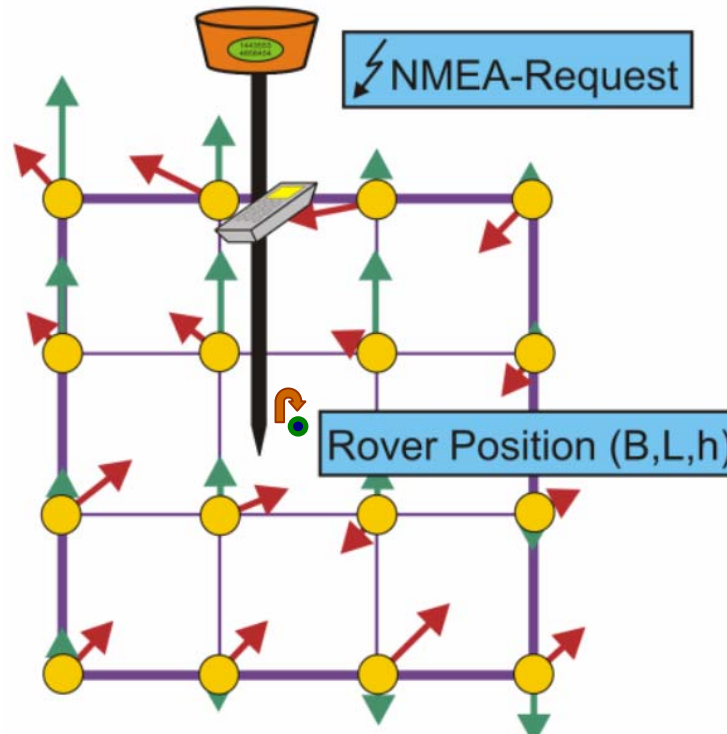
1.)
„STATIC
GRID“
(„Large Residuals“ Grid)

Reference Transformation components of GIGPS

Reference Transformations and RTCM Transformation messages

Using Reference Transformations to compute country-wide grids dynamically online on NMEA-request by virtual fitting points

2.) „Dynamic Grid“



Advantages

- 1.) No preceding „Gridding“ Discretization Error
- 2.) Small Residuals
 - Small Interpolation error
- 3.) De facto
 - De facto independence of the residual interpolation method in the rover

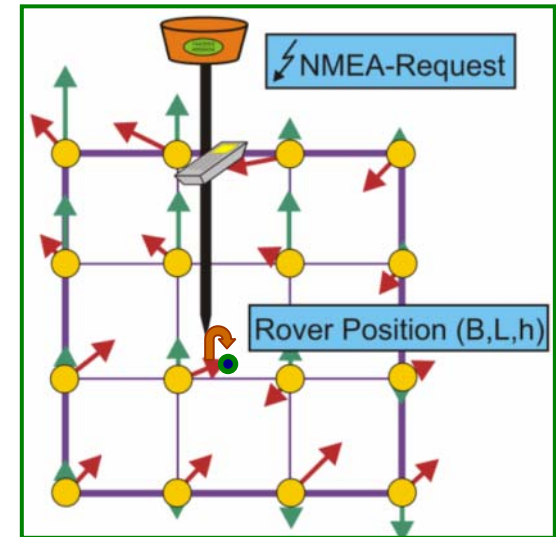
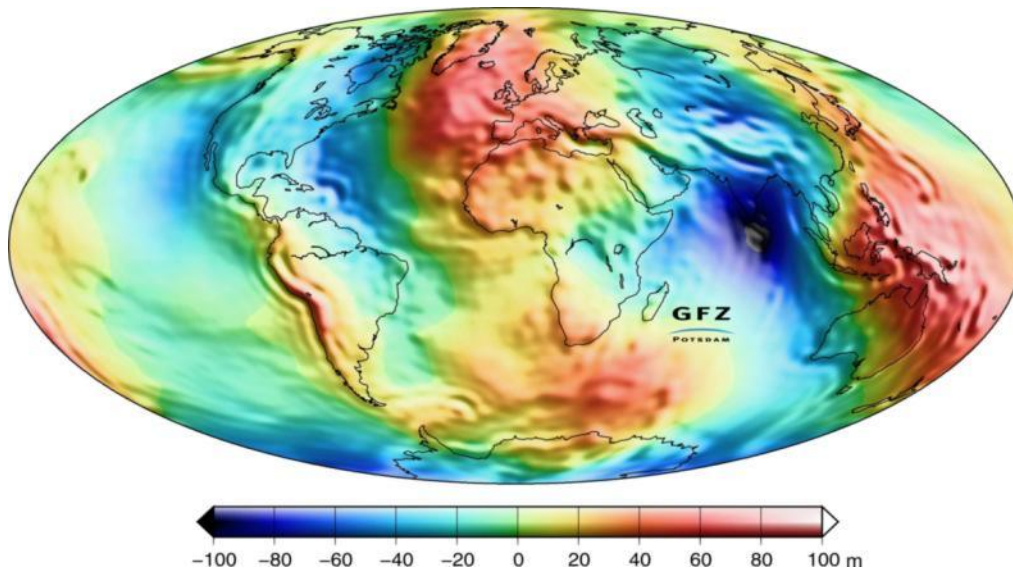
Reference Transformation components of GIGPS

Reference Transformations and RTCM Transformation messages

Using Reference Transformations to compute grids dynamically

„Dynamic Grid“

Direct use of Original Reference Transformations



$$W(r, \vartheta, \lambda) = \left\{ \frac{GM}{r} \cdot \left(1 + \sum_{n=2}^{\infty} \sum_{m=0}^n \left(\frac{a_{GRS80}}{r} \right)^n \cdot (C_{nm} \cos m\lambda + S_{nm} \sin m\lambda) \cdot P_{nm}(\cos \vartheta) \right) \right\}$$

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} u_1 \cdot \sqrt{1 + \varepsilon^2 / u^2} \cdot \cos \beta \cdot \cos \lambda \\ u_1 \cdot \sqrt{1 + \varepsilon^2 / u^2} \cdot \cos \beta \cdot \sin \lambda \\ u \cdot \sin \beta \end{bmatrix}$$

$$U = U(a, \varepsilon, \omega, M)_{REF} | (\beta, \lambda, u)$$



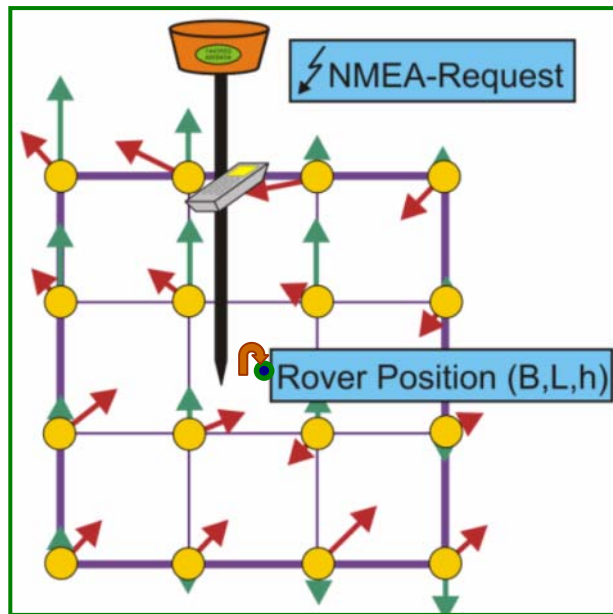
$$N((x, y, z)_{GNSS}) = \frac{W - U}{\gamma_{h-N}}$$

Reference Transformation components of GIGPS

Reference Transformations and RTCM Transformation messages

Using Reference Transformations to compute grids dynamically „Dynamic Grid“

5.) „Combined Message Generation“



Part 1 - Plate Models

$$[(B,L,h)_{ITRF-related}]_i \Rightarrow [(B,L,h)_{GNSS,ITRF}]_i$$

Virtual Fitting-Points

Part 2 - Standard Reference Transformations

$$[(B,L,h)_{ITRF-related}]_i \Rightarrow [(B,L)_T, H_T \text{ or } N]_i$$

Virtual Fitting Points

Dynamic Message Set up by local 7PT Gridding

Reference Transformation components of GIGPS

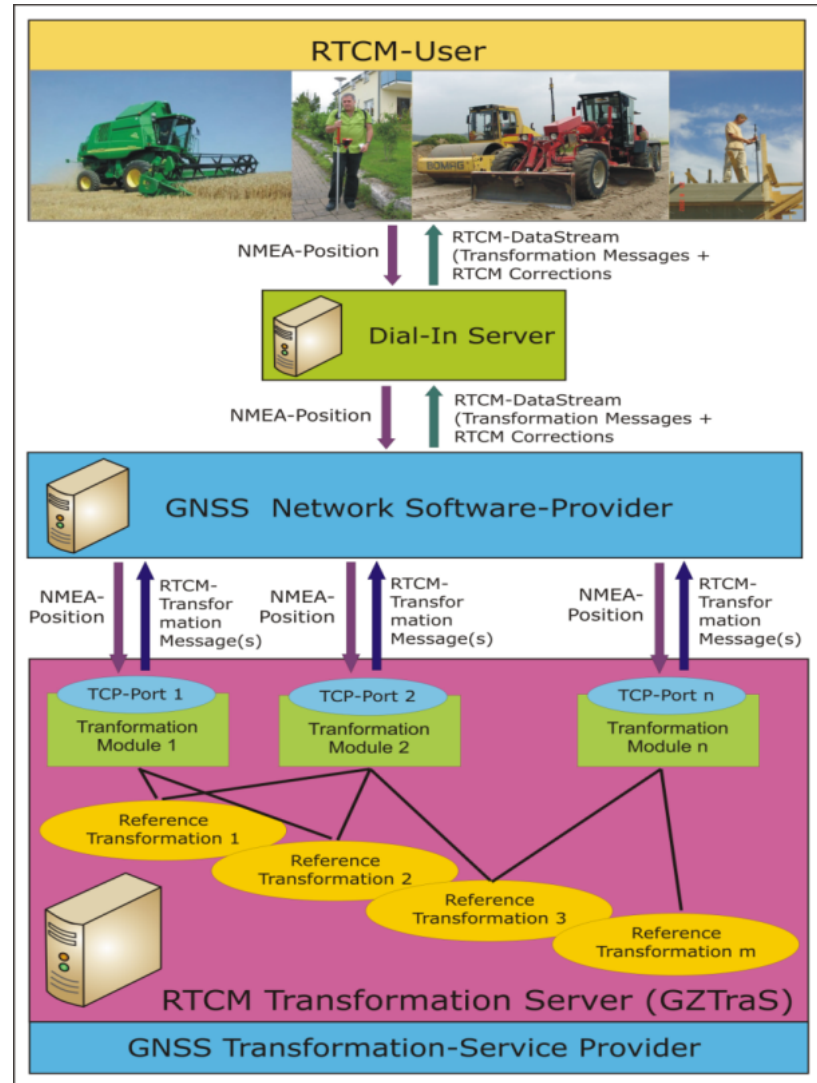
Reference Transformations and RTCM Transformation messages

**General Configurable
RTCM Transformation
Messages Server**

*All kind of Reference
Transformations
in so called
Transformation
Modules*

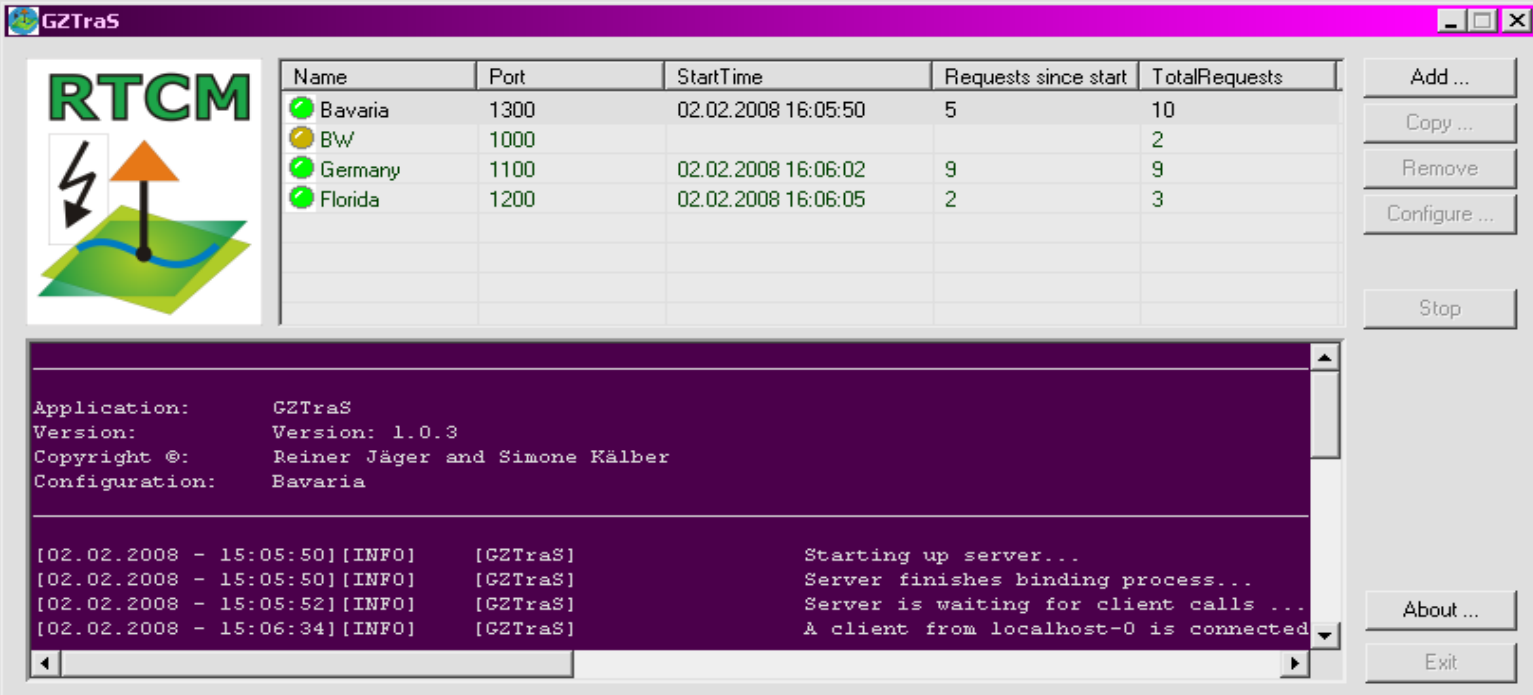
**Dynamic & Combined
& Static RCTM-Messages**

**Commuication
Design
in case of passing
RTCM Transformation
Messages
through GNSS-Networking
Software**



Reference Transformation components of GIGPS

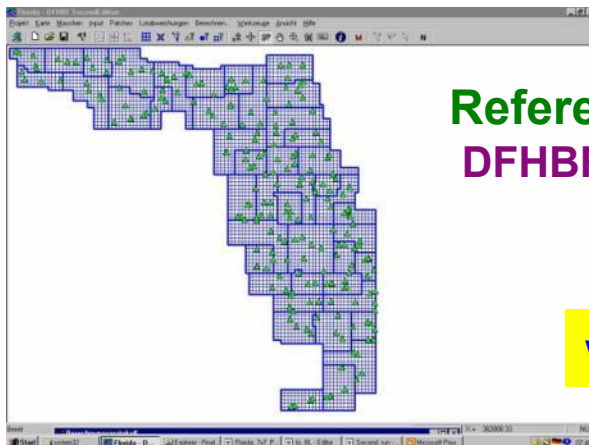
Reference Transformations and RTCM Transformation messages



Name	Port	StartTime	Requests since start	TotalRequests
● Bavaria	1300	02.02.2008 16:05:50	5	10
● BW	1000			2
● Germany	1100	02.02.2008 16:06:02	9	9
● Florida	1200	02.02.2008 16:06:05	2	3

Application: GZTraS
Version: 1.0.3
Copyright ©: Reiner Jäger and Simone Kälber
Configuration: Bavaria

```
[02.02.2008 - 15:05:50] [INFO] [GZTraS] Starting up server...  
[02.02.2008 - 15:05:50] [INFO] [GZTraS] Server finishes binding process...  
[02.02.2008 - 15:05:52] [INFO] [GZTraS] Server is waiting for client calls ...  
[02.02.2008 - 15:06:34] [INFO] [GZTraS] A client from localhost-0 is connected
```



Reference Transformations

DFHBF Florida

DFHBF Bavaria

DFLBF Bavaria

www.geozilla.de



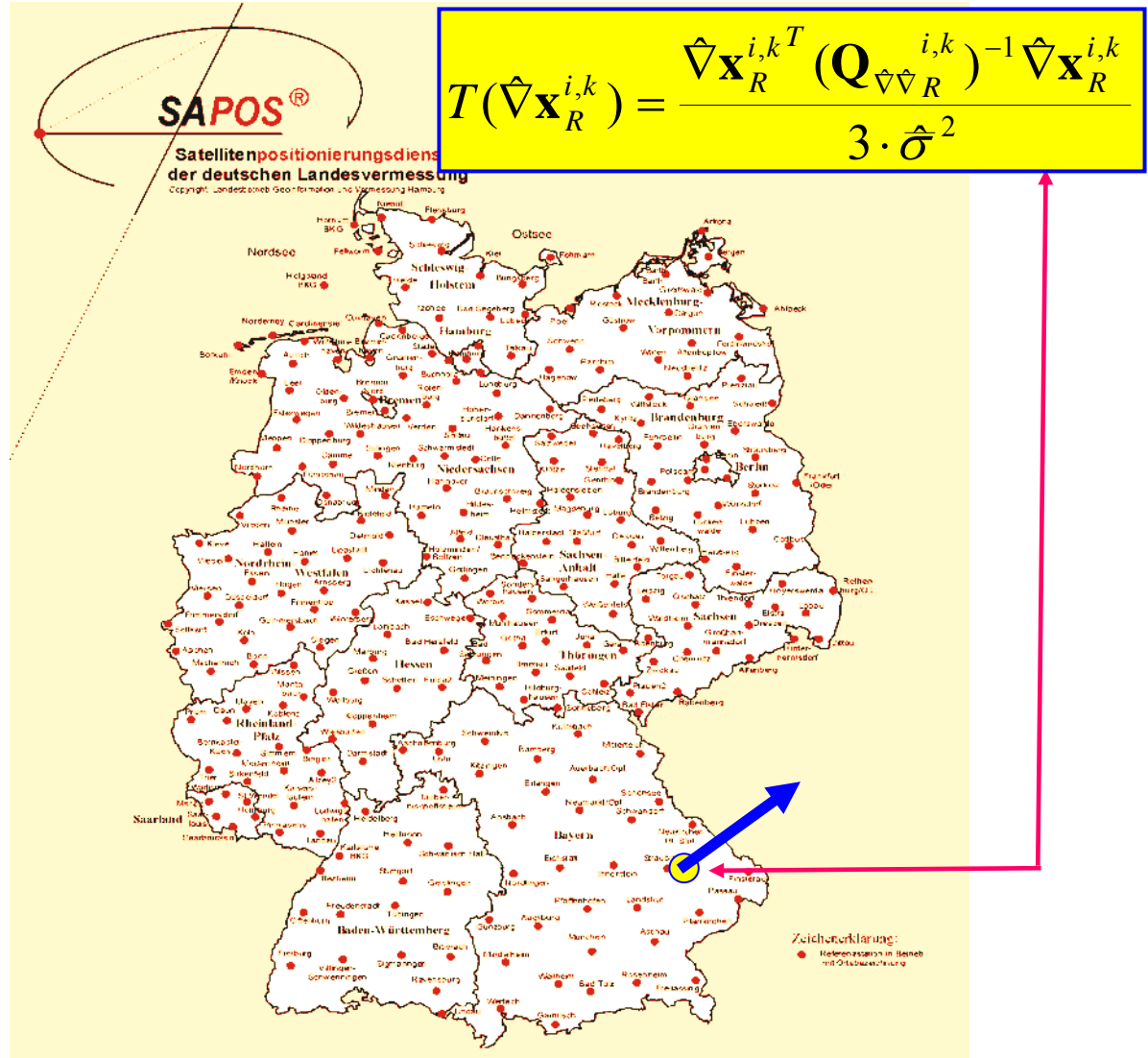
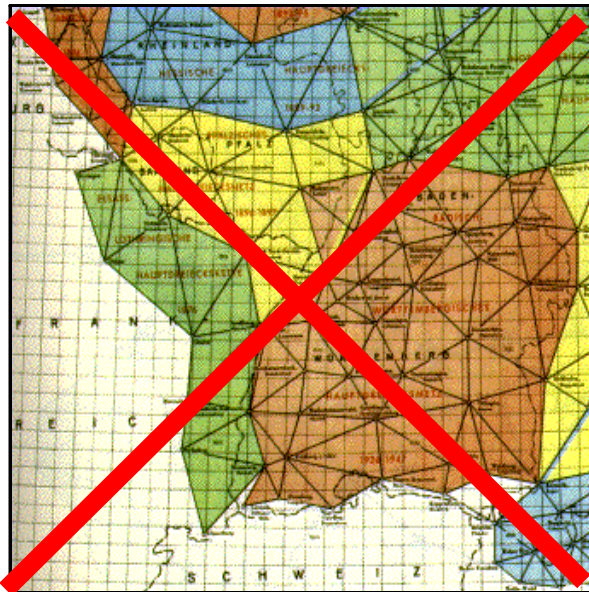
GNSS-Reference Station Monitoring

MONIKA concept

GNSS Reference Station
MONIToring
 by the **KAR**lsruhe
 approach and software
 (**MONIKA**)

www.monika.ag

Old Classical Systems



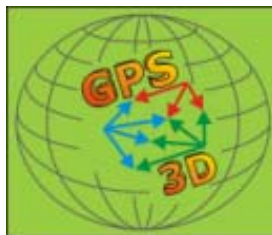
GNSS-Reference Station Monitoring

MONIKA algorithm and software

MONIKA Step 2

- Baselines
- Epoch Networks
- Partial networks
- Daily Solutions

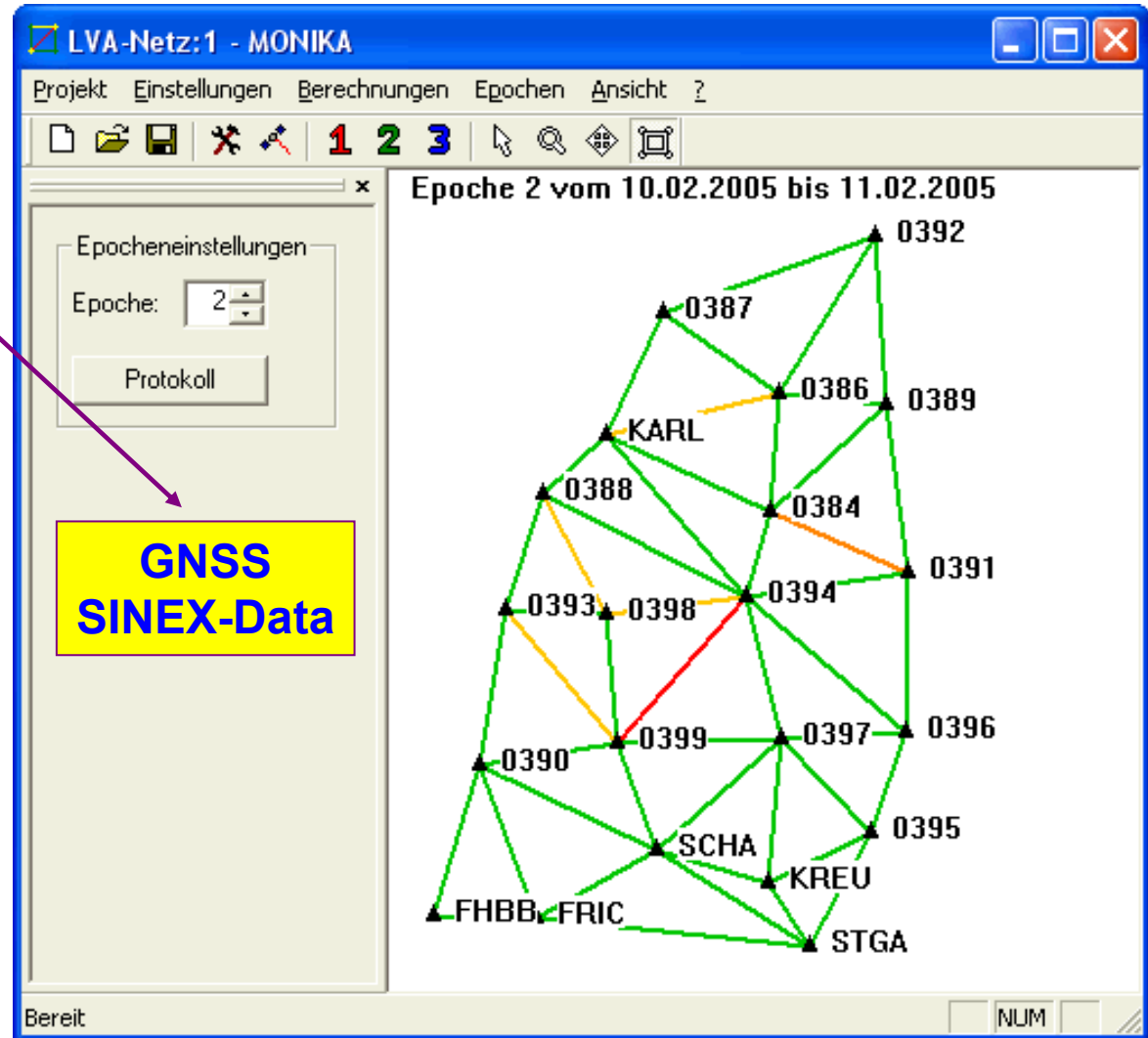
$$\bar{X}(t_i)_j, \bar{C}_X(t_i)_j$$



Δt

$$\bar{X}(t_i), \bar{C}_X(t_i)$$

- Epoch States



GNSS-Reference Station Monitoring

MONIKA algorithm and software

MONIKA Step 2 – Coordinate related Referencepoint-Deformation analysis

MONIKA

Free GNSS-network
Deformation
Analysis Concept

Original GNSS observations
RINEX

$$I(t)_i, C_1(t)_i$$

SINEX

$$\bar{X}(t_i), \bar{C}_X(t_i)$$

Epoch States
MONIKA Step 2

Singular

x_0 ?

Unknown
Datum

$$\bar{X}(t_i), \bar{C}_X(t_i)$$

New x_0

Helmert-Transformation d=3

$$x(t_i) =: \bar{X}(t_i) \mid x_0$$

S-Transformation d=3

$$C_X(t_i) = S \cdot \bar{C}_X(t_i) \cdot S^T$$

MONIKA Trafo 2 - Step 2

www.monika.ag

GNSS-Reference Station Monitoring

MONIKA algoritm and software

MONIKA Step 2 – Coordinate related Referencepoint-Deformation analysis



Use
of
IERS
Parameters

Reference time

t_0

Epoch time

t_i

Consideration of Datum-drift and Plate-Movement Rates

$$\mathbf{x}(t_1)_{ITRF_{zz,t_1}} = (1 + \Delta m) \cdot \mathbf{R}(\varepsilon_x, \varepsilon_y, \varepsilon_z) \cdot \mathbf{x}(t_1)_{ITRF_{yy,t_1}} + \mathbf{t}$$

$$\mathbf{x}(t_2)_{ITRF_{zz,t_2}} = \mathbf{x}(t_1)_{ITRF_{zz,t_1}} + \left(\left(\dot{\mathbf{R}} + \Delta \dot{m} \right) \cdot \mathbf{x}(t_1)_{ITRF_{zz,t_1}} + \dot{\mathbf{t}} \right) + \left(\dot{\mathbf{R}}_{P(j)} \cdot \mathbf{x}(t_1)_{ITRF_{zz,t_1}} \right) \cdot (t_2 - t_1)$$

GNSS-Reference Station Monitoring

MONIKA algorithm and software

MONIKA Step 3 – Coordinate related Reference-Point-Deformation analysis

$$(\mathbf{x}(t_i) - \mathbf{x}_0^i) + \mathbf{v}_{x(t_i)} = \mathbf{D}_R^i \cdot d\hat{\mathbf{x}}_R^i + \mathbf{D}_O^i \cdot d\hat{\mathbf{x}}_O^i \quad \text{and} \quad \mathbf{C}_X(t_i)$$

 ΔT

$$(\mathbf{x}(t_i) - \mathbf{x}_0^i) + \mathbf{v}'_{x(t_i)} = \mathbf{D}_R^i \cdot d\hat{\mathbf{x}}_R^i + \mathbf{D}_O^i \cdot d\hat{\mathbf{x}}_O^i + \mathbf{B}_i^k \cdot \hat{\nabla} \mathbf{x}_R^{i,k}(t_i)$$

$$\mathbf{B}_i^k \cdot \hat{\nabla} \mathbf{x}_R^{i,k}(t_i) = \begin{bmatrix} \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} & \dots & \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} & \dots & \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \end{bmatrix}^T \cdot \hat{\nabla} \mathbf{x}_R^{i,k}(t_i)$$

$$\hat{\nabla} \mathbf{x}_R^{i,k}(t_i) = -(\mathbf{B}_i^{kT} \mathbf{P}^i \mathbf{Q}_{vv}^i \mathbf{P}_i \mathbf{B}_i^k)^{-1} \cdot \mathbf{B}_i^{kT} \mathbf{P}^i \cdot \mathbf{v}_{x(t_i)} \quad \text{and} \quad \mathbf{Q}_{\hat{\nabla} \hat{\nabla} R}^{i,k}(t_i) = (\mathbf{B}_i^{kT} \mathbf{P}^i \mathbf{Q}_{vv}^i \mathbf{P}_i \mathbf{B}_i^k)^{-1}$$

GNSS-Reference Station Monitoring

MONIKA algorithm and software

MONIKA Step 3 – Coordinate related Reference-Point-Deformation analysis

3D a-posteriori Test statistics – Significance of $\nabla_{\mathbf{x}_R^{i,k}}$

$$T(\hat{\nabla}_{\mathbf{x}_R^{i,k}}) = \frac{\hat{\nabla}_{\mathbf{x}_R^{i,k}}^T \cdot (\mathbf{Q}_{\hat{\nabla}\hat{\nabla}_R}^{i,k})^{-1} \cdot \hat{\nabla}_{\mathbf{x}_R^{i,k}}}{3 \cdot \hat{\sigma}^2} =$$

$$= \frac{\hat{\nabla}_{\mathbf{x}_R^{i,k}}^T \cdot (\mathbf{B}_i^{kT} \mathbf{P}^i \mathbf{Q}_{vv}^i \mathbf{P}_i \mathbf{B}_i^k) \cdot \hat{\nabla}_{\mathbf{x}_R^{i,k}}}{3 \cdot \hat{\sigma}^2} \sim F_{3,r-3}$$

$$\hat{\sigma}^2 = \frac{\mathbf{v}^T \mathbf{P} \mathbf{v} - \hat{\nabla}_{\mathbf{x}_R^{i,k}}^T \cdot (\mathbf{Q}_{\hat{\nabla}\hat{\nabla}_R}^{i,k})^{-1} \cdot \hat{\nabla}_{\mathbf{x}_R^{i,k}}}{r-3}$$

Test related to $1-\alpha$, e.g. = 95%
Confidence ellipsoid

Sensitivity ellipsoid
 $\alpha = 5\%$, $\beta = 95\%$

**Detectability of GNSS
Reference Station
Deformations** $\nabla_{\mathbf{x}_R^{i,k}}$

$$\hat{\nabla}_{\mathbf{x}_R^{i,k}}^T \cdot (\mathbf{Q}_{\hat{\nabla}\hat{\nabla}_R}^{i,k})^{-1} \cdot \hat{\nabla}_{\mathbf{x}_R^{i,k}}$$

$$= \lambda(F'_{3,r-3}, \alpha, \beta) = 17.3$$

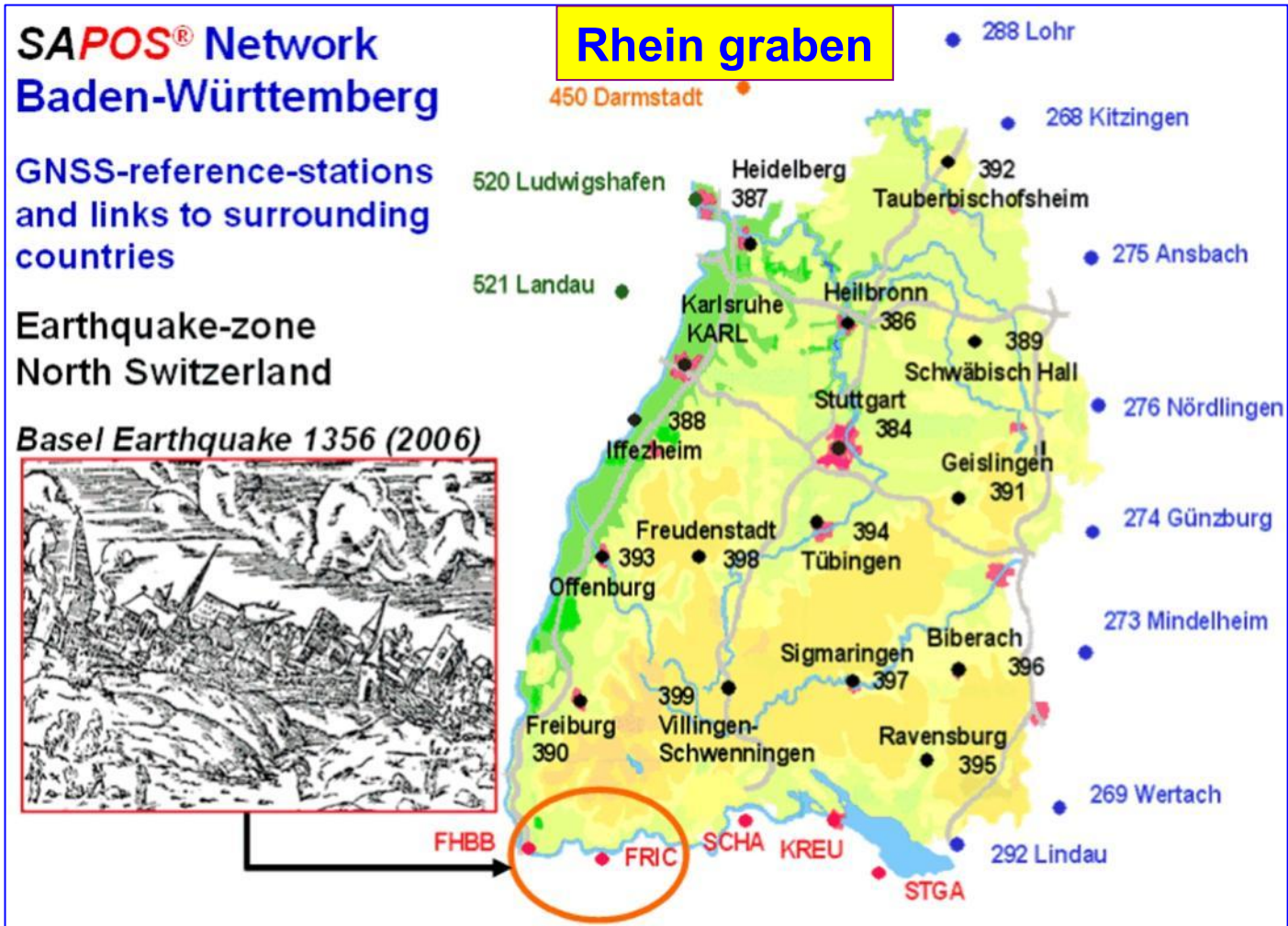
$\beta\%$ -Sensitivity

$$f = \sqrt{17.3} = 4.2$$

(= 1.0 accuracy, $1-\alpha = 19.9\%$ error ellipsoid)

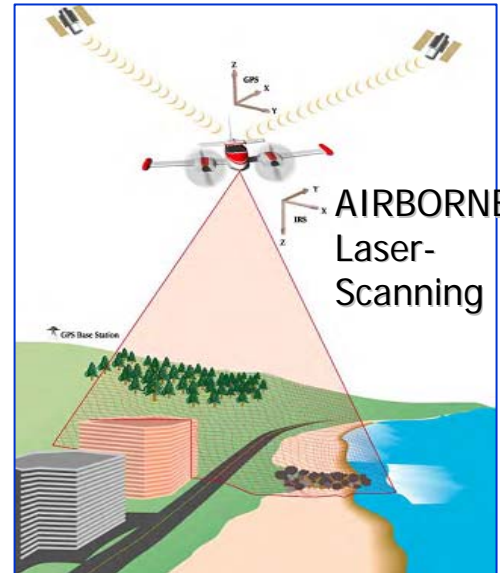
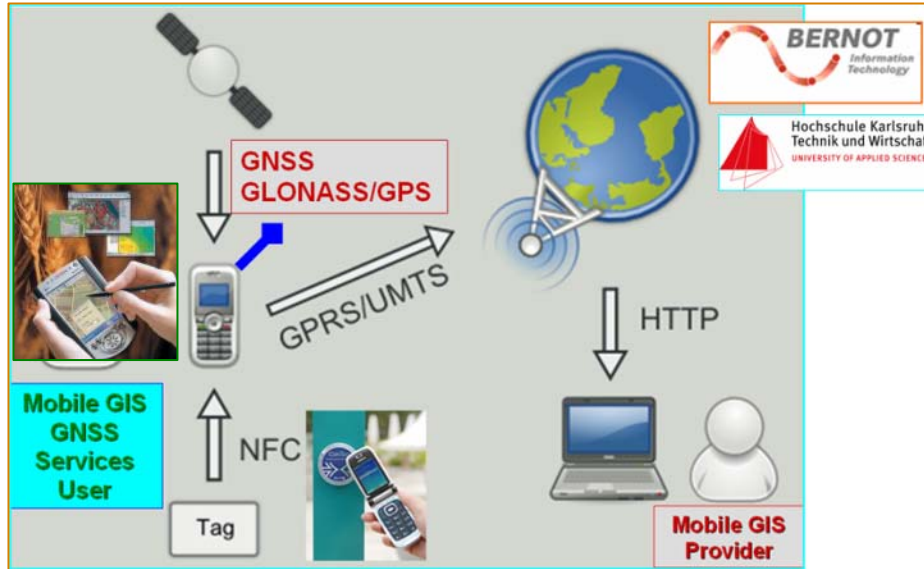
GNSS-Reference Station Monitoring

GNSS-Positioning-Service of Baden-Württemberg (SAPOS)



Changes in GNSS-Positioning Services

GNSS-Positioning Services – User-Groups



GNSS-based and Multisensor Low-Cost Platforms for Navigation and Object-Georeferencing

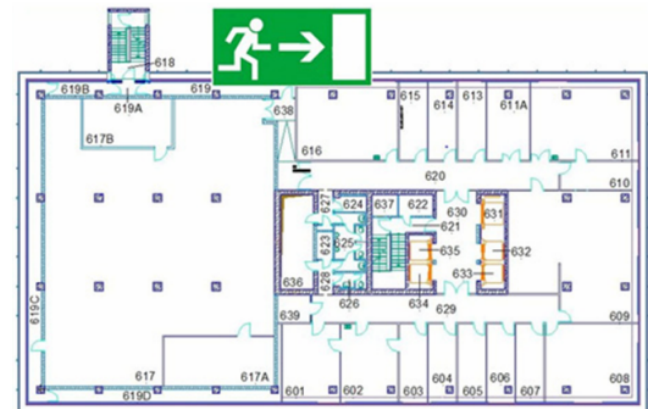


Hochschule Karlsruhe
Technik und Wirtschaft (HSKA)

IAF
Institut für Angewandte
Forschung (IAF)



Weitere Anwendung: Nahtlose GNSS +
INS(-Weiter-) Navigation und Objektreferenzierung
in Gebäuden



Changes in GNSS-Positioning Services

Growth of GNSS-Positioning Services User-Groups

Präzises Monitoring und Navigation bewegter Objekte

ASCOS Rechenzentrum

NTRIP Datentransfer über das Internet

EUREF oder IGS RTCM-Korrekturen

NTRIP-Format

Mobiles Internet (USB-Stick) und InterNet GNSS-Radio

Axio Net

GNSS Internet Radio 1.4.11

Broadcaster: START STOP

Settings: Stream Details Bytes: 0

Select Network: All Unprotected

Select Stream or Update: Update source table

Adjust Settings or press START.

JOHN DEERE Hochschule Karlsruhe Technik und Wirtschaft UNIVERSITY OF APPLIED SCIENCES

Ort	Basislinie [km]	Beobachtungsdauer [min]	EUREF IP		John Deere MRTK	
			Nord [m]	Ost [m]	Nord [m]	Ost [m]
Karlsruhe	ca. 20km	15 Minuten	0,0513	0,0604	0,0072	0,0055
Dresden	ca. 430km	15 Minuten	0,1657	0,2758	0,0088	0,0082
Warnemünde	ca. 610km	15 Minuten	0,1033	0,0742	0,0098	0,0054

BLOM

ENavigation and Location Based Services (NLS)

6:00

Talflugstraße

50 3:0 1,5 36

Startlingstraße

DRIVE

NOKIA

BoniRob-Feldroboter schafft Basis für die Landtechnik der Zukunft

Schwärme kleiner Roboter, die selbstständig auf den Feldern herumschwirren, um gezielt Dünger auszubringen oder Unkraut zu bekämpfen – das könnte schon bald Wirklichkeit werden.

BOSCH Technik fürs Leben

Hochschule Karlsruhe Technik und Wirtschaft UNIVERSITY OF APPLIED SCIENCES

Hochschule Karlsruhe Technik und Wirtschaft (Hska)

IAF Institut für Angewandte Forschung (IAF)

GNSS/INS Drones

SEABEX ONE

Changes in GNSS-Positioning Services

Precise Point Positioning (PPP) - Absolute GNSS-Positioning

? *Breaking the Monopole of present DGNSS / Reference Station Services ?*

Static Absolute
(Non-D)GNSS ✓
Upload of Data for
Processing

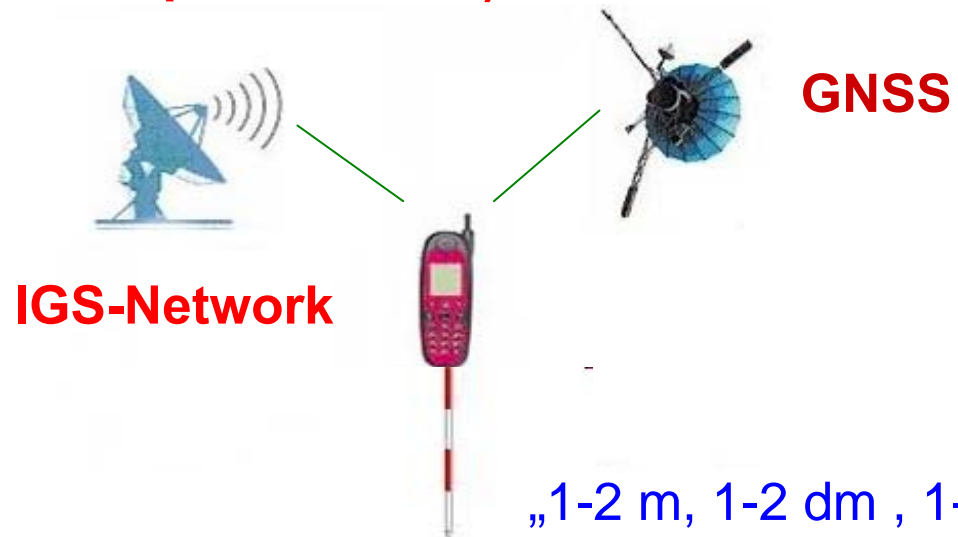


```
The estimated coordinates / standard deviations for the
WHIT0600_6hrs.070 RINEX file are as follow:
Latitude (NAD83-CSRS): 60 45 01.8330 (dms) / 0.009 (m)
Longitude (NAD83-CSRS): -135 13 19.5153 (dms) / 0.018 (m)
Ellipsoidal Height (NAD83-CSRS): 1427.240 (m) / 0.034 (m)
Orthometric Height CGVD28 (HTv2.0): 1419.222 m
```

SSR (State-space representation)
-Provider

Dynamic Absolute GNSS
Online PPP („OPPP“) RTK

- **Server-Client for SSR?**
- **cm-RTK?**
- **LowCost-Sensors**



„1-2 m, 1-2 dm, 1-2 cm“



Technical
Univesrity
of Moldova

Hochschule Karlsruhe (HSKA)
University of Applied Sciences



Thank you for attention

www.euref.eu

www.geozilla.de,

www.galileo-bw.dewww.goca.info,

www.monika.ag,

www.dfhbf.de

www.moldpos.eu

www.hs-karlsruhe.de/servlet/PB/menu/1090714/index.html



United Nations/United Arab Emirates/United States of America
Workshop on the Applications of Global Navigation Satellite Systems,
Dubai, United Arab Emirates, 16 - 20 January 2011

