Geodetic Infrastructures for GNSS Positioning Services (GIPS)

Hochschule Karlsruhe Technik und Wirtschaft (HSKA)
- University o Applied Sciences -
Faculty for Information Management and Media (IMM)
Course Director International Master Study Programme Geomatics (MSc)

Prof. Dr.-Ing. Reiner Jäger

Head and Project Leader at „Institute of Geomatics“ at (IAF)

RaD

www.dfhbf.de, www.goca.info, www.geozilla.de, www.monika.ag, www.moldpos.eu, www.navka.de

Honorary Professor of the Siberian State Academy of Geodesy (SSGA)

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Geodetic Infrastructures for GNSS-Positioning Services (GIPS)

TECHNOPROM, Novosibirsk, June 05-06-2014

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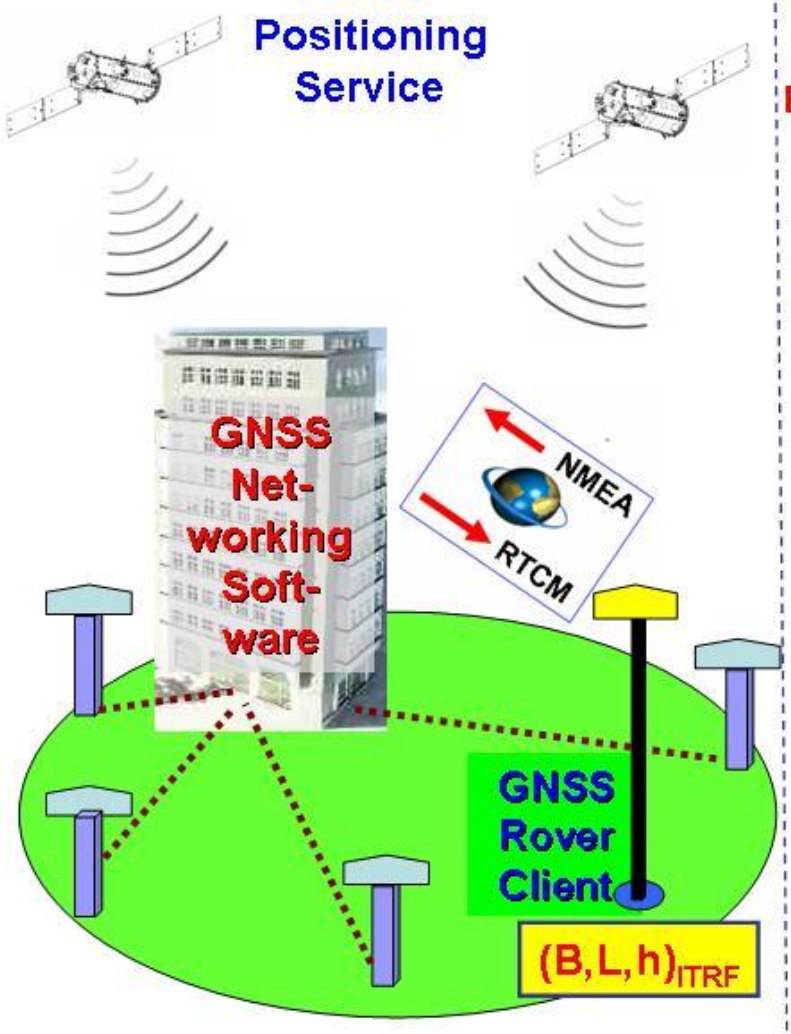
Technik und Wirtschaft (HSKA)
IAF
Institut für Angewandte Forschung (IAF)

Geodetic Infrastructures for GNSS-Positioning Services (GIPS)



e.g www.moldpos.eu

Geodetic Transformation Infrastructure

GIPS-1: Horizontal Referencing $(B,L)_{blass}$ Trafo-1 and Trafo-2

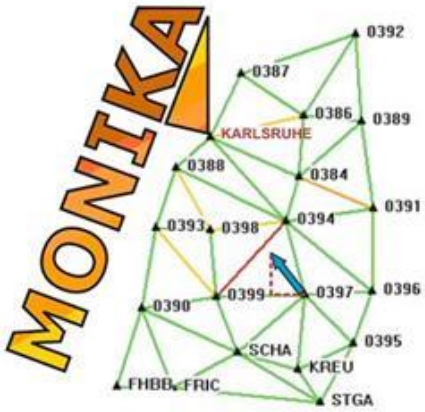
GIPS-2: Height Reference Surface and Transition (h→H). Trafo-3

www.geozilla.de

www.dfhbf.de

GIPS-3: RTCM Transformation Messages. Trafo-4

GIPS 4: Geomonitoring-Infrastructure



Coordinate-Integrity

www.monika.ag

Georisk Mitigation

www.goca.info

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GNSS Positioning Services and GNSS-Positioning Trends

TECHNOPROM, Novosibirsk, June 05-06-2014

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Precise Positioning Services – e.g. Germany

1

2

SmartNet EUROPE
powered by Leica Geosystems

3

AXNET

4

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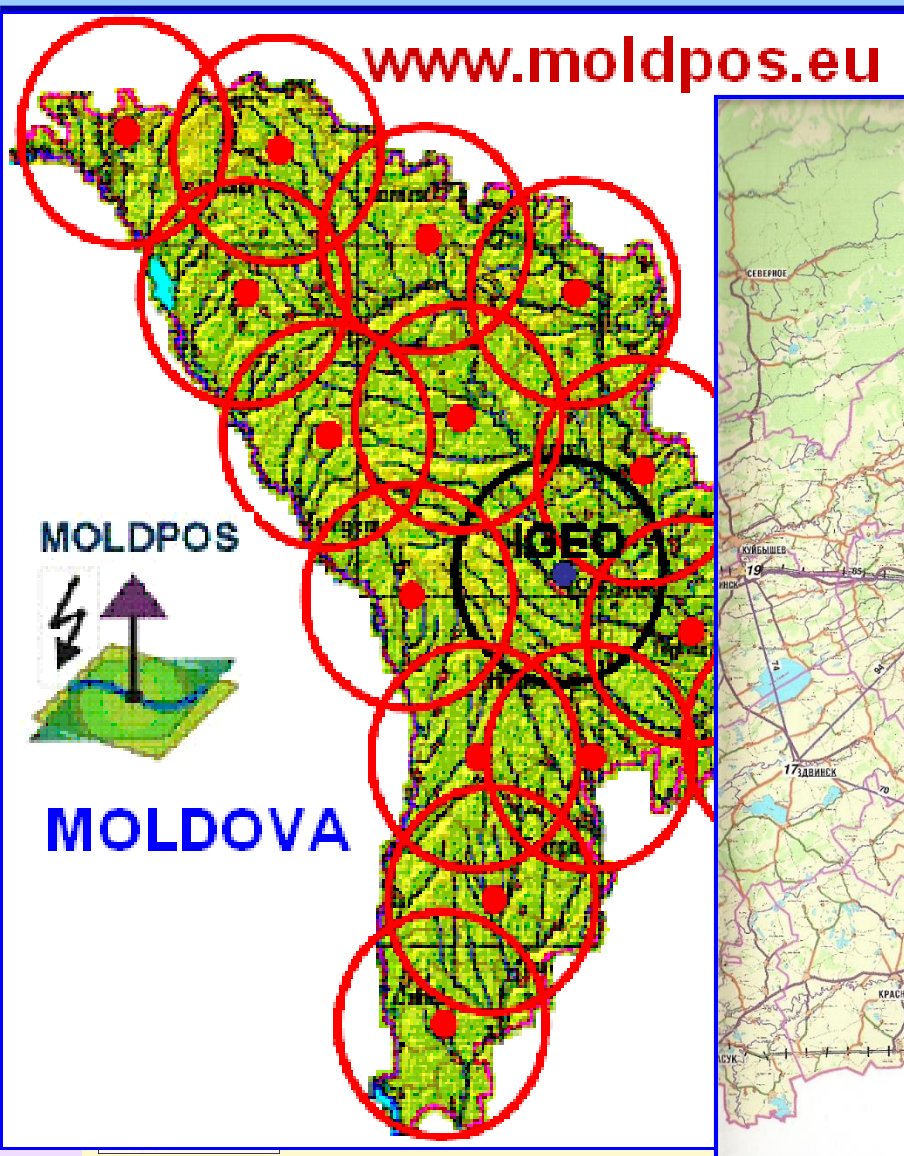
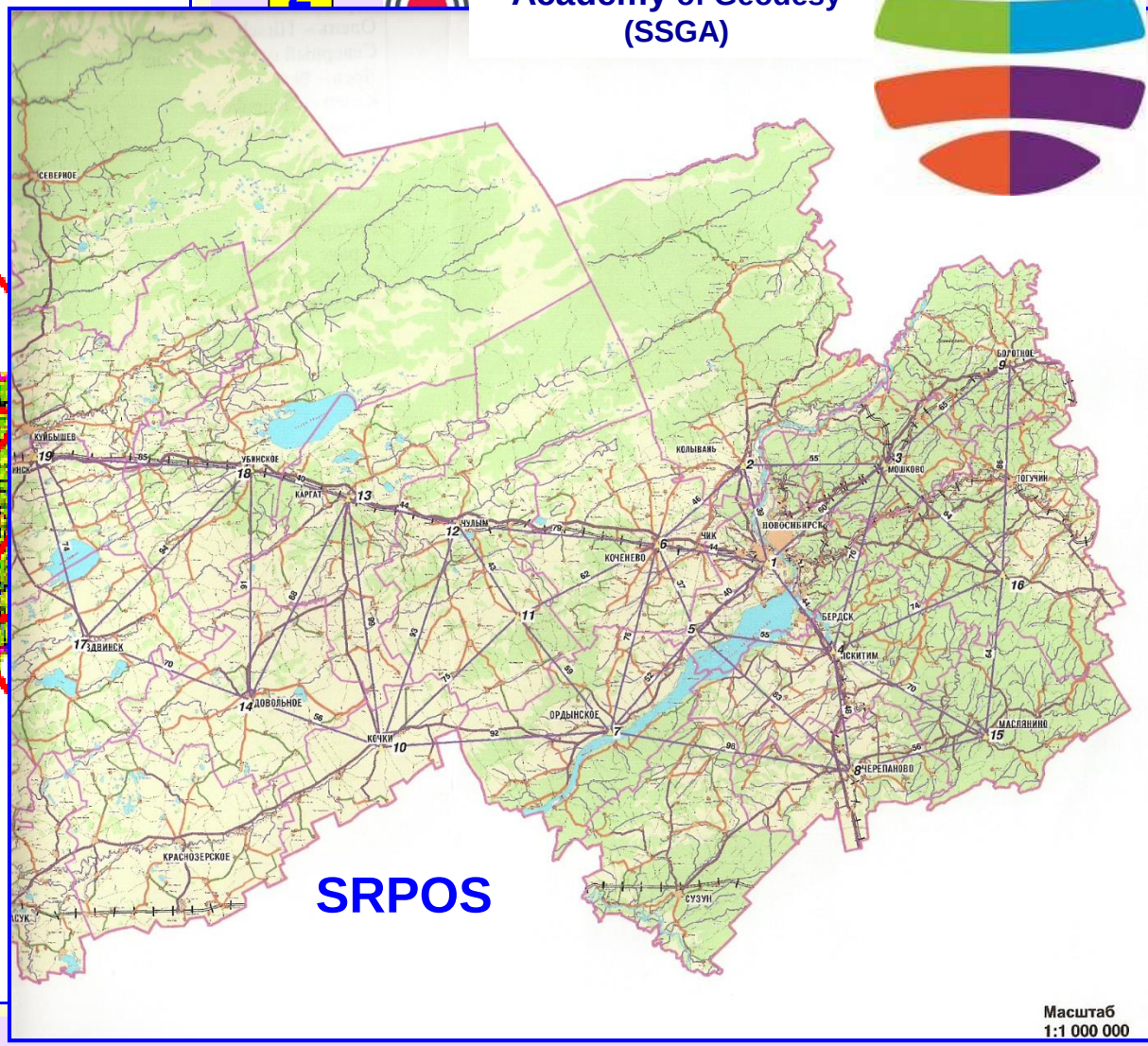
Precise Positioning Services – e.g. Germany





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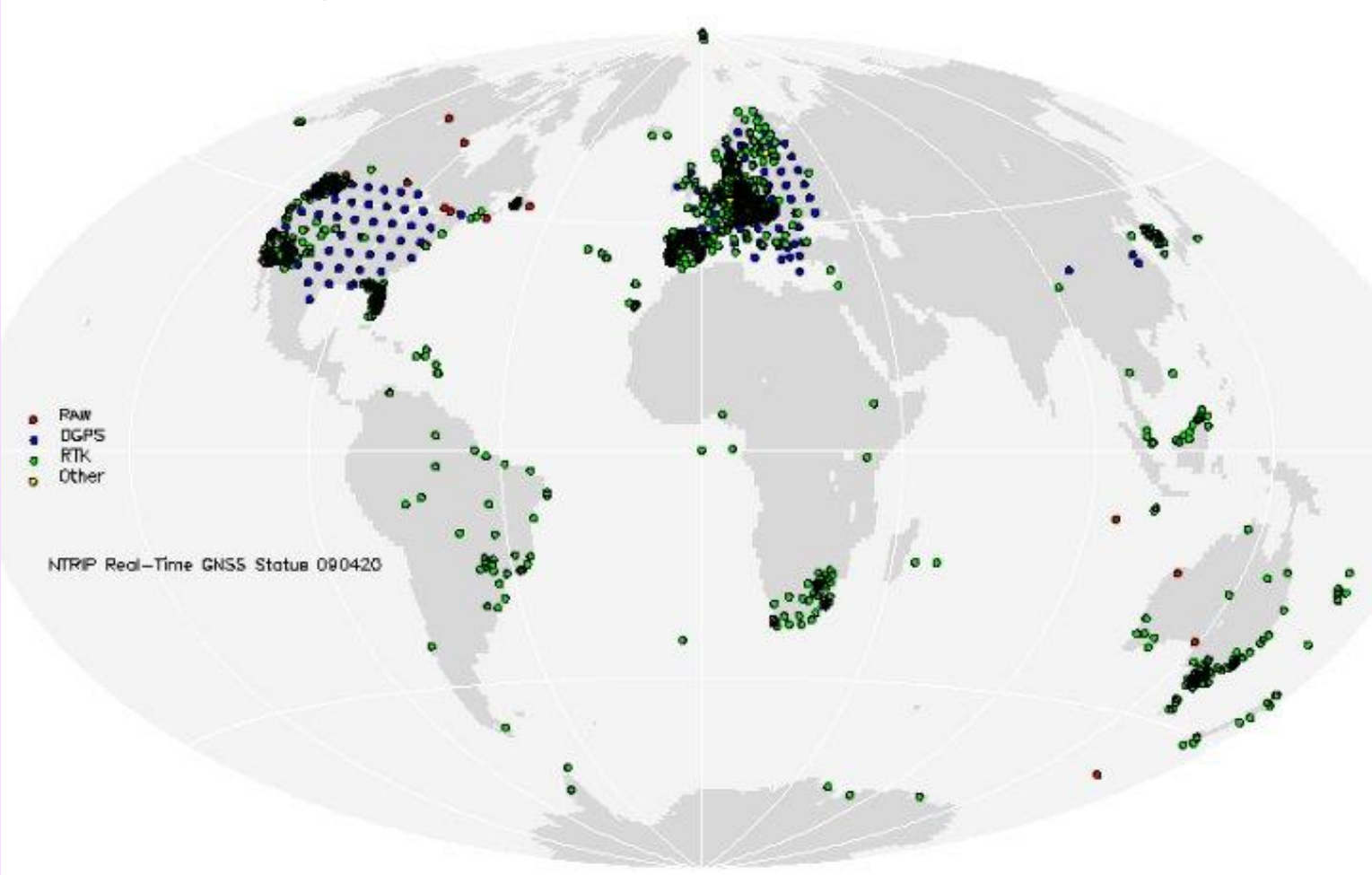
Global IGS-IP Service – GNSS-raw and Correction data and SSR Product via NTRIP Mobile Internet

Non-Networked RTCM Data and Corrections and SSR-procucts (OPPP) for free - Networking Project under Preparation



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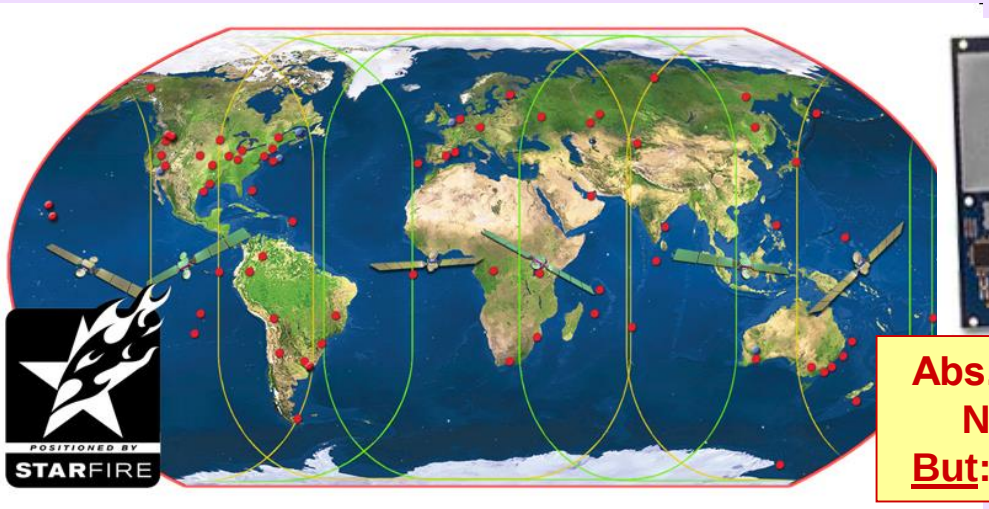
Satellite-/Internet-based global GNSS Position-Services



- **SSR-based: Abs. Prec. OPPP**
- **Starfire™GPS-Corrections**
- **Starfire Receiver (left)**
- **Global Accuracy: „dm“**

Abs. GNSS = „Non-DGNSS“
No Reference-Stations
But: NAVCOM Roverclients!

NAVCOM
A John Deere Company

OmniSTAR. The Global Positioning System
Trimble.

OSR (= Observation-related): Networked, scalabe („dm – cm“) DGNSS RTCM Correction (VRS-Concept)
- **RTCM-Standard =>Open for any Rover- and Software-Type**

Comparison of HP and other DGPS service characteristics

Centimetre-level RTK
Network RTK
OmniSTAR-HP
State Space Solution
Wide Area DGP

OmniSTAR-HP
- Uses range and phase data from a network of L1/L2 reference stations
- Iono effects removed by using stations within 500-1000km
- Orbit corrections broadcast alongside data to remove this as an error source
- Multiple stations combined into L1/L2 VBS solution for redundancy of observations
- Smooth decimetre level positioning - with scope for further gains ?

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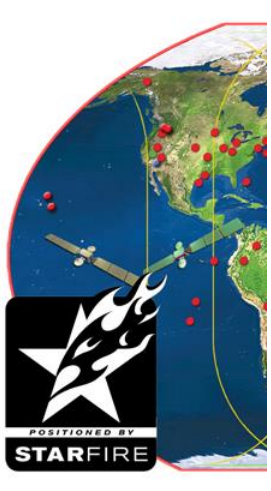
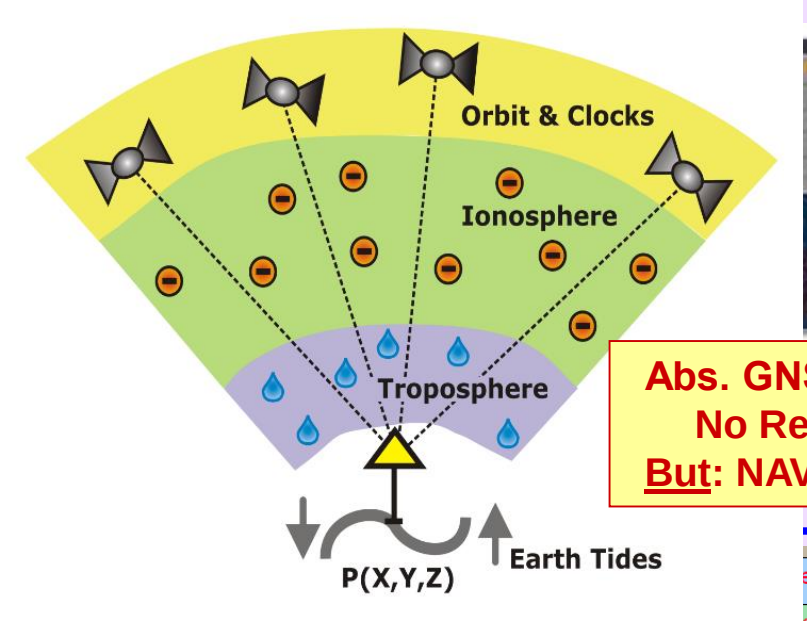
Satellite-/Internet-based global GNSS Position-Services





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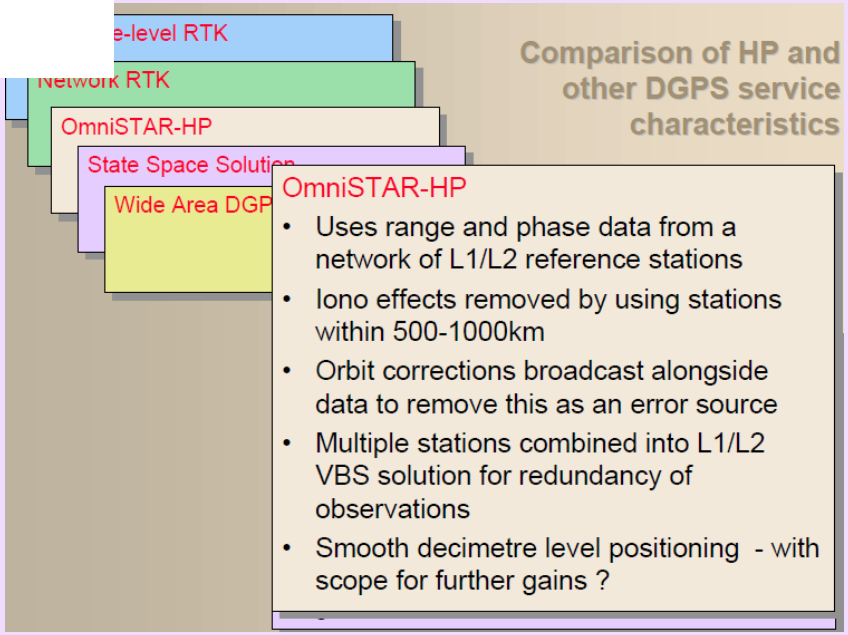

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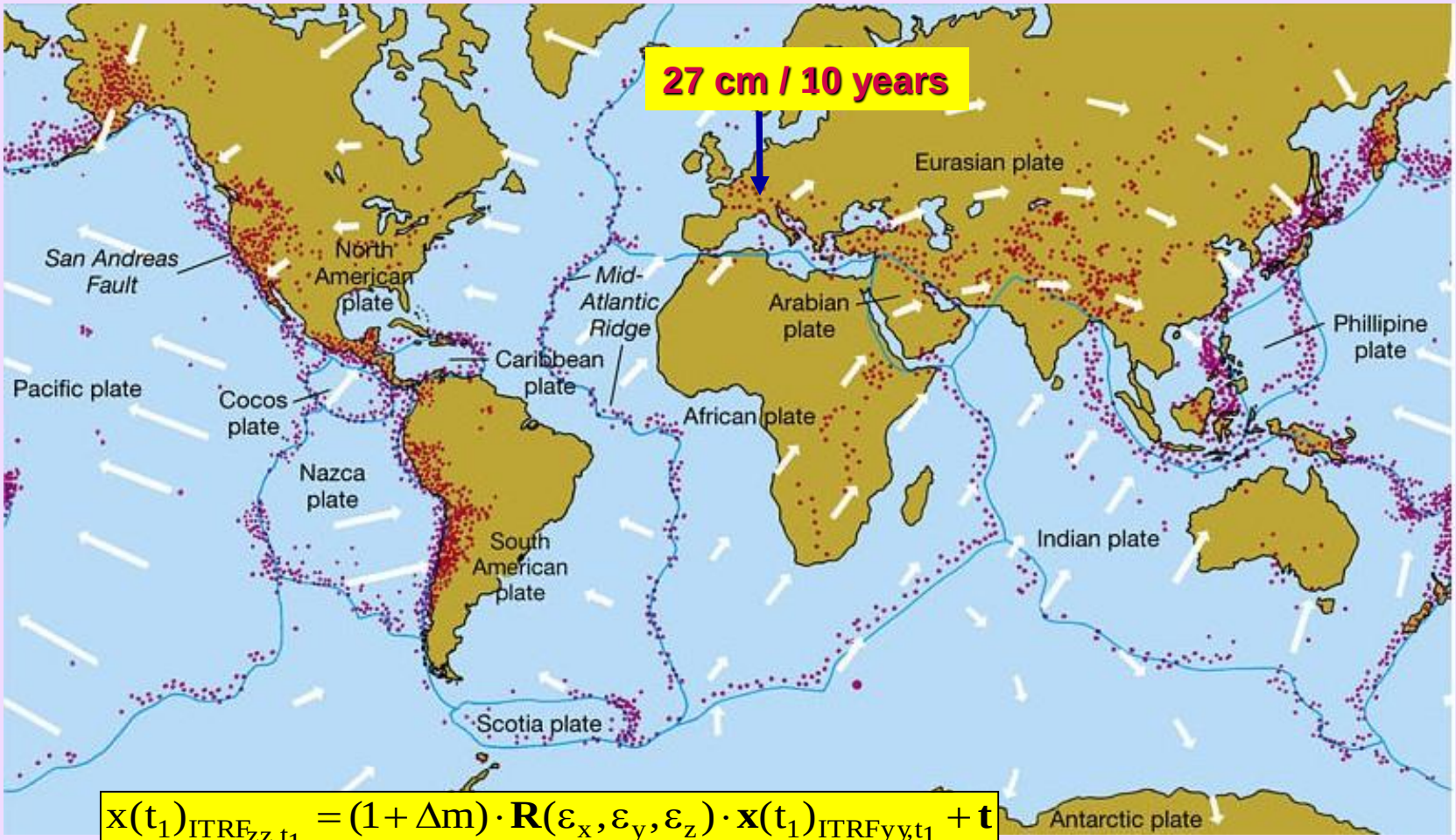
Considering Datum, Datum-Drift and Plate-Movement Rates



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

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

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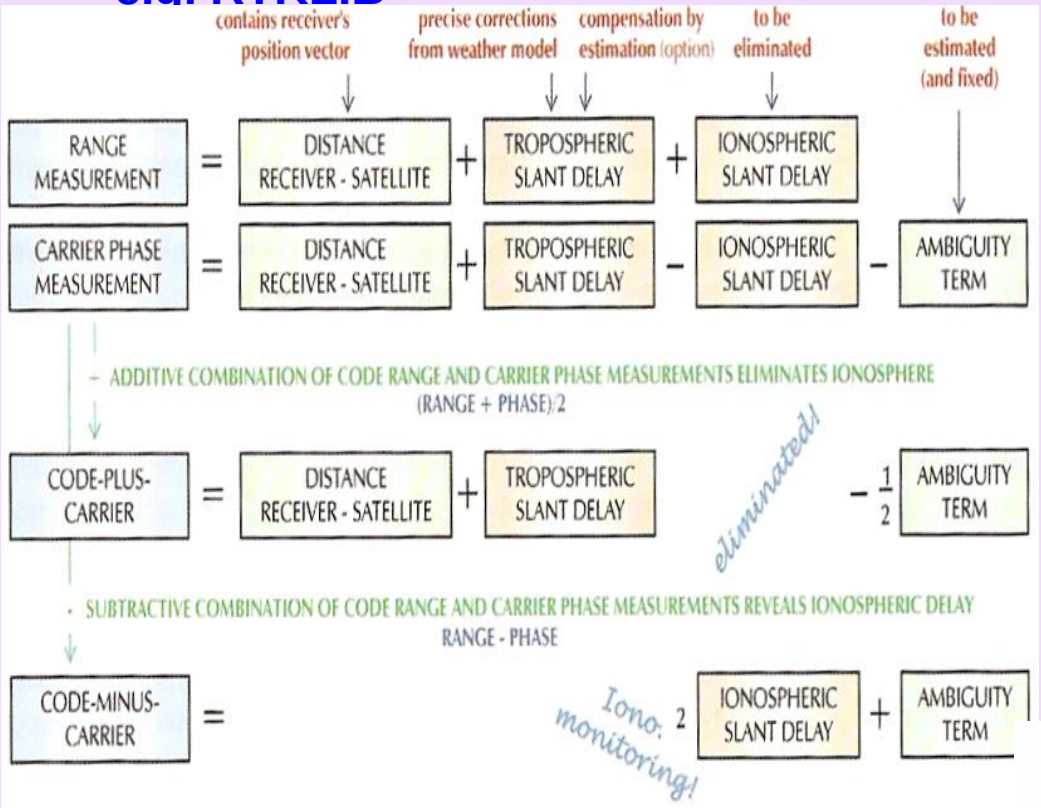
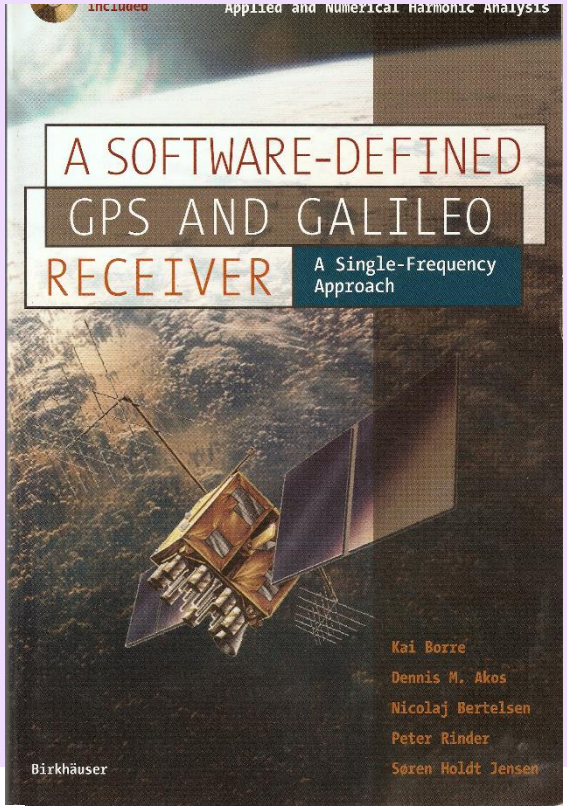
Low-Cost – High Precise GNSS and Trends

1.) „LowCost- High-Precise“ – „Software-Receiver“ e.g. RTKLIB

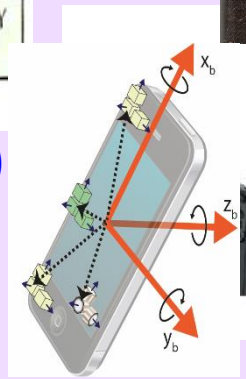


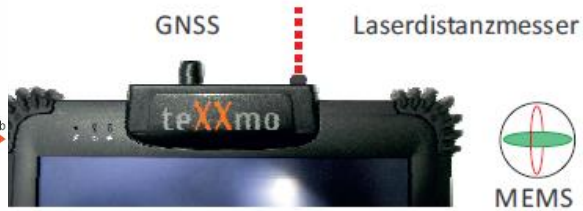


2.) Online Precise Point Positioning (OPPP) „Non D-GNSS“

3.) GNSS + MEMS Multisensor-Platforms

www.navka.de





Geodetic Infrastructures for GNSS-Positioning Services (GIPS)

Reference Station Setup and Integration

TECHNOPROM, Novosibirsk, June 05-06-2014

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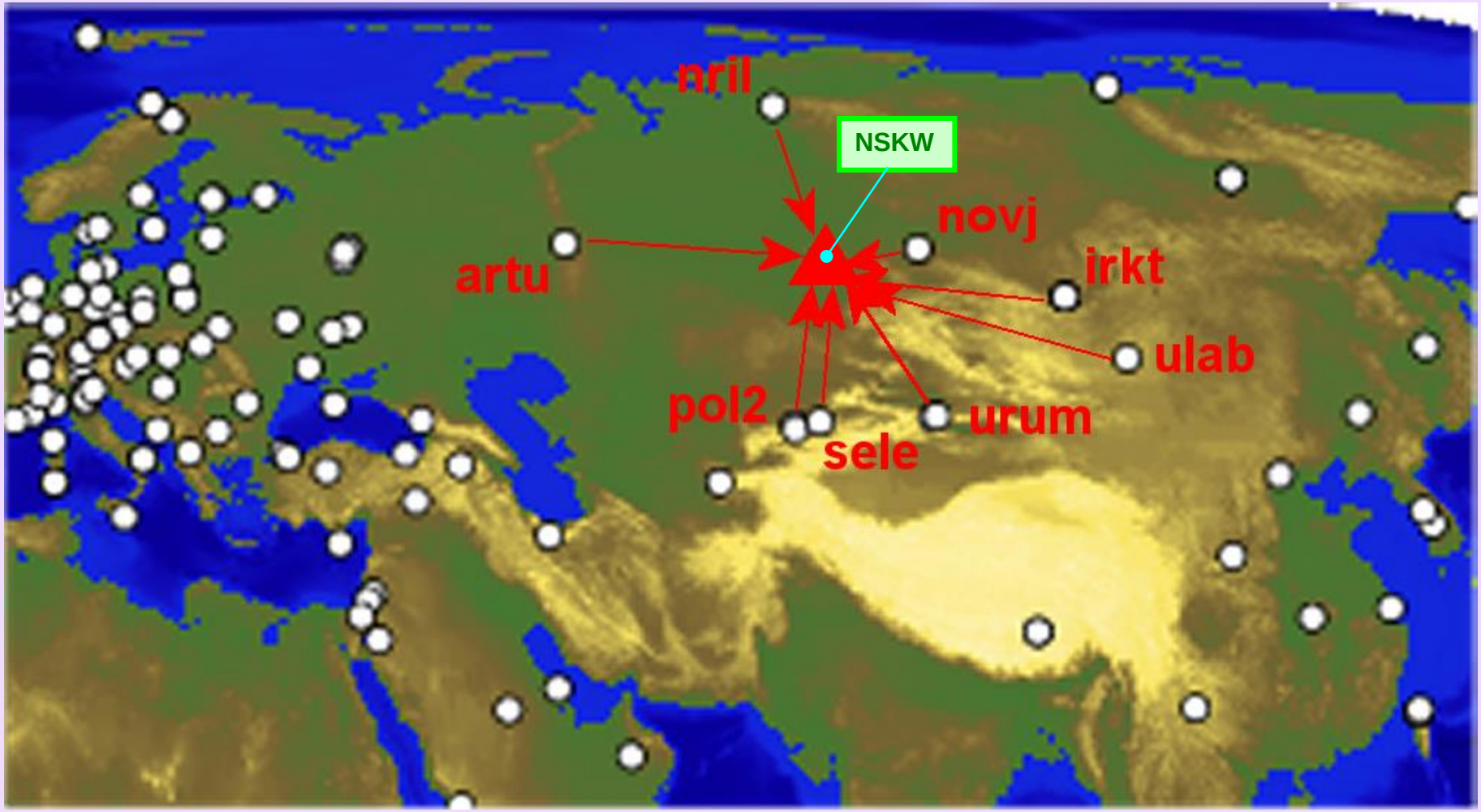
1. Own GNSS-data & Software. E.g. „ITRF embedding of Novosibirsk GNSS-Station NSKW“, Bernese Software (Jäger, Steinbach)



Reference Station Setup and Integration

ONLINE PPP SERVICES

- Home
- Purpose
- Online PPPs
- Submit Data
- Examples
- Software Registration
- News & Updates
- Contact Us

This section contains links to free online PPP services. When s
on this website, the data will be processed by those servic
However, accessing those services directly allows users to s
options and perhaps obtain additional information.

CSRS-PPP

by Natural Resources Canada (NRCan)

http://www.nrcan.gc.ca/earth-sciences/geomatics/geodetic-refere
/10925#ppp

Note: Access to this service is **FREE** but you need to register.

GPS Analysis and Positioning Software (GAPS)

by University of New Brunswick (UNB)

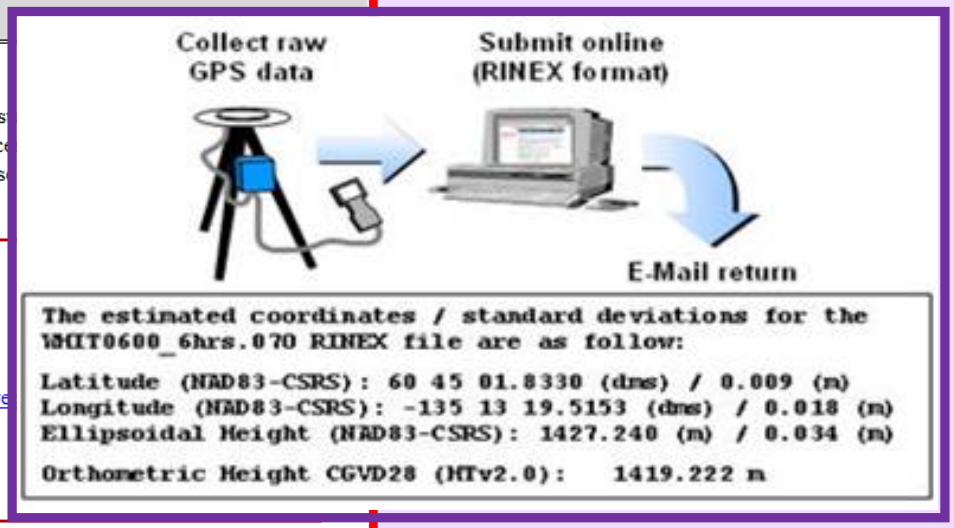
http://gaps.gge.unb.ca/

Automatic Precise Positioning Service (APPS)

by Jet Propulsion Laboratory (JPL)

http://apps.gdgps.net/

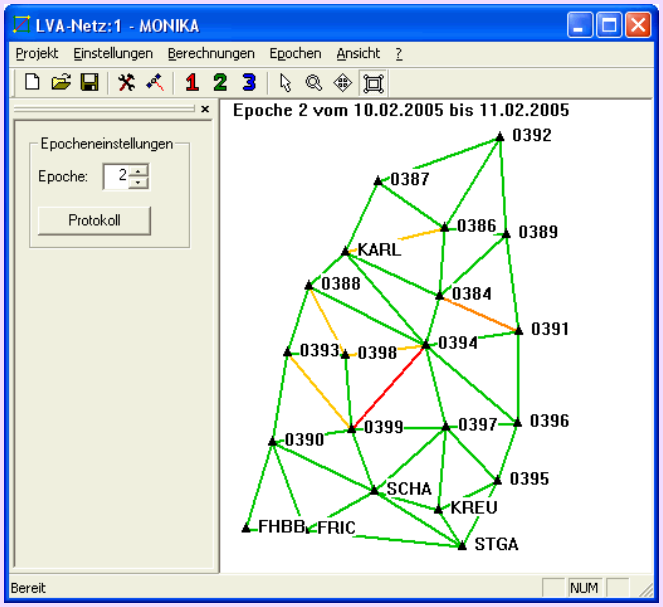
Note: This service replaces Auto-GIPSY.



2.) Own GNSS-data & Cost-Free PPP-Services

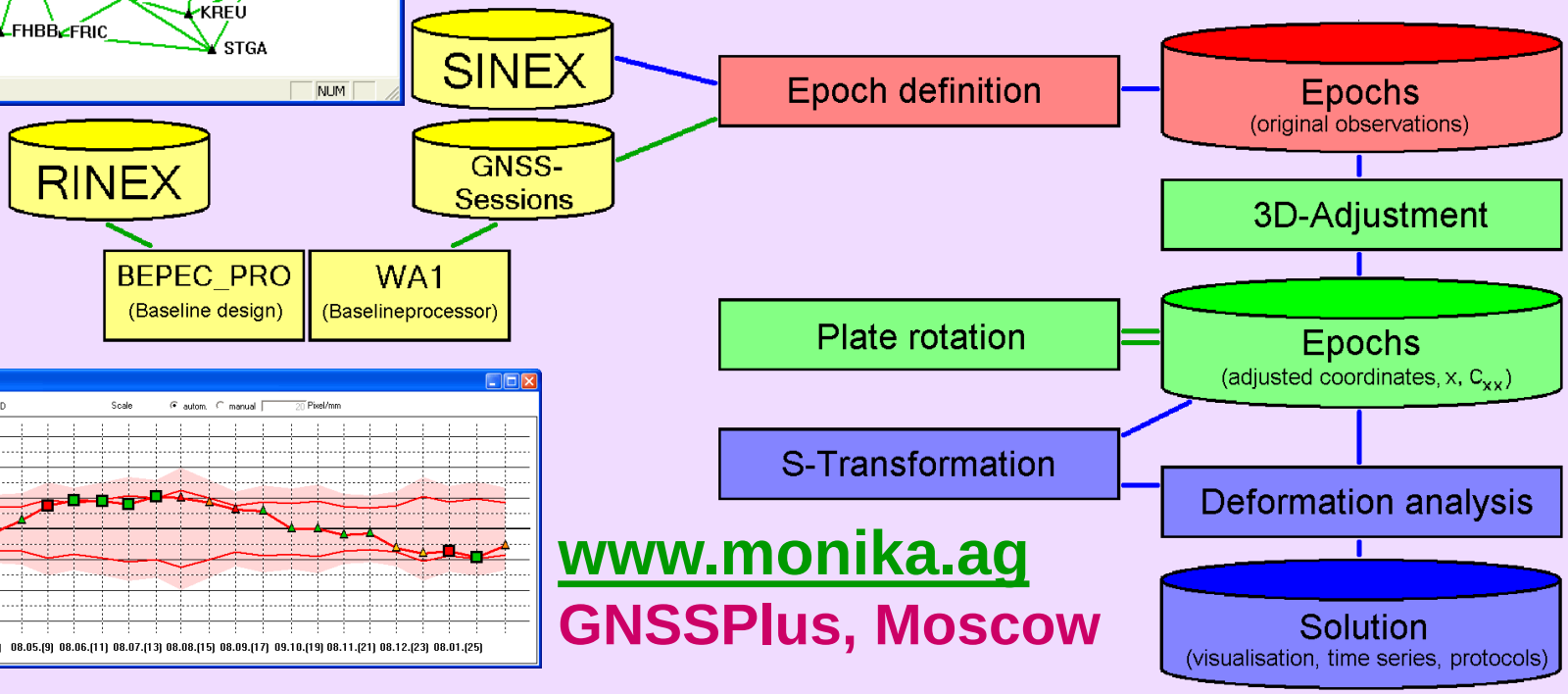
http://www2.unb.ca/gge/Resources/PPP/OnlinePPPs.html

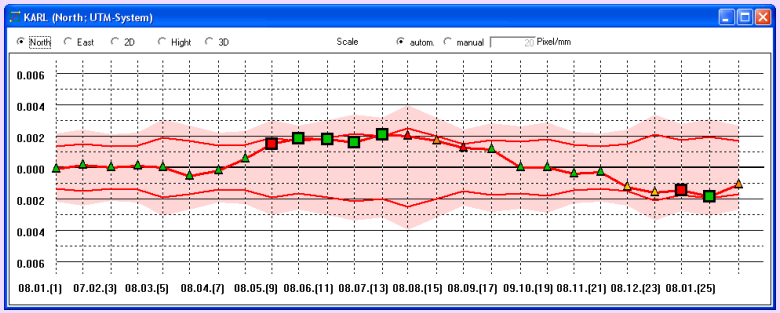
Reference Station Setup and Integration



3.) Own GNSS-data & GNSS-Processing and Monitoring Software

MONIKA - Deformation Integrity & Hazard MONItoring for GNSS-Services by the KA Approach





www.monika.ag

GNSSPlus, Moscow

Geodetic Infrastructures for GNSS-Positioning Services (GIPS)

GIPS -1
Trafo-1 and Trafo-2

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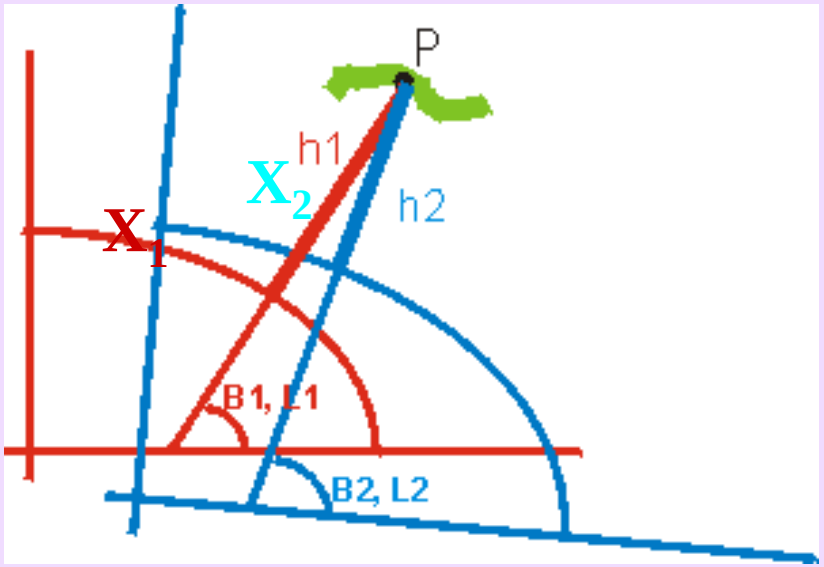
„All-over-the-World“ Problem



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

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

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

mit $N(B) = \text{Normalkrümmungshalbmesser}$

3D Similarity Transformation

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

Rotation Matrix
3 Rotations

Non-Linear Relation (see above)

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GIPS-1: Horizontal Datum-Trafo from $(B,L)_{GNSS,ITRF}$ to Classical Datum $(B,L)_{Classical}$ - COPAG-Approach and COPAG/DFLBF-Database Computation

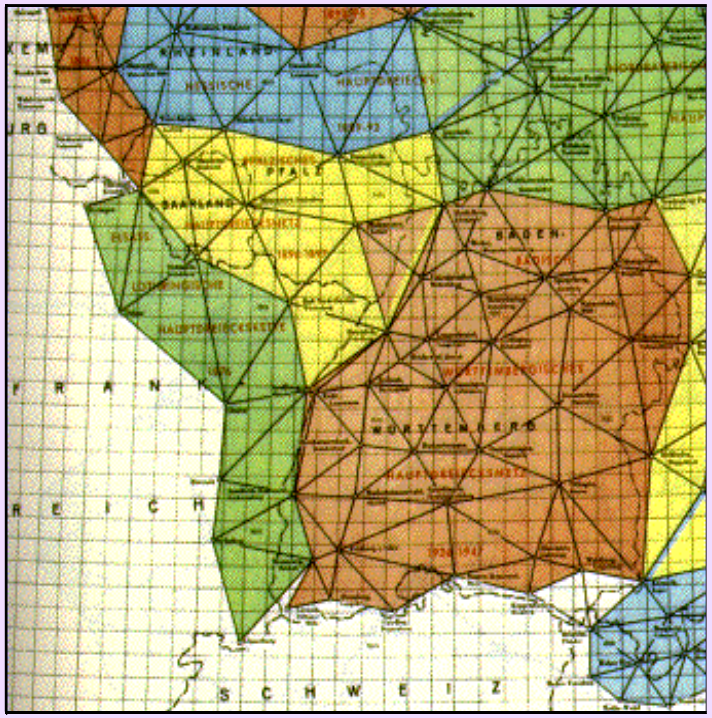
ITRF / ETRF89 – Datum
ITRF2000.2008.0 (Albania)

GIS
Transition to
ITRF/GNSS
consistent
frame.Trafo-1

Strict and
General
Trafo

GNSS-practice
Trafo-2

Long waved deflections - „Weak shapes“



Old Classical Systems

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GIS Transition to ITRF/GNSS consistent frame.Trafo-1

Strict and General Trafo

GNSS-practice Trafo-2

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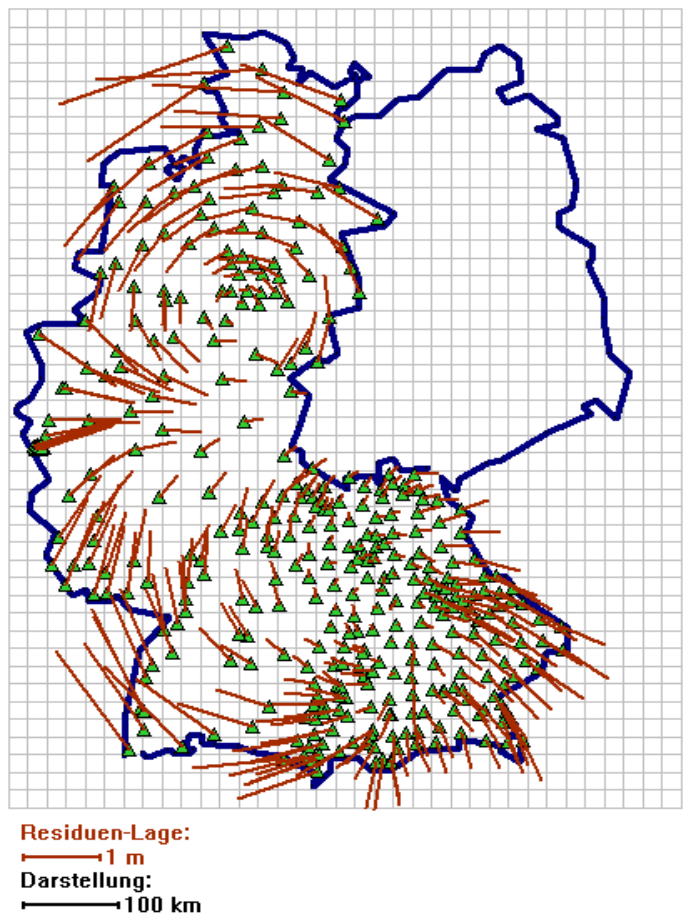

Old Classical Systems

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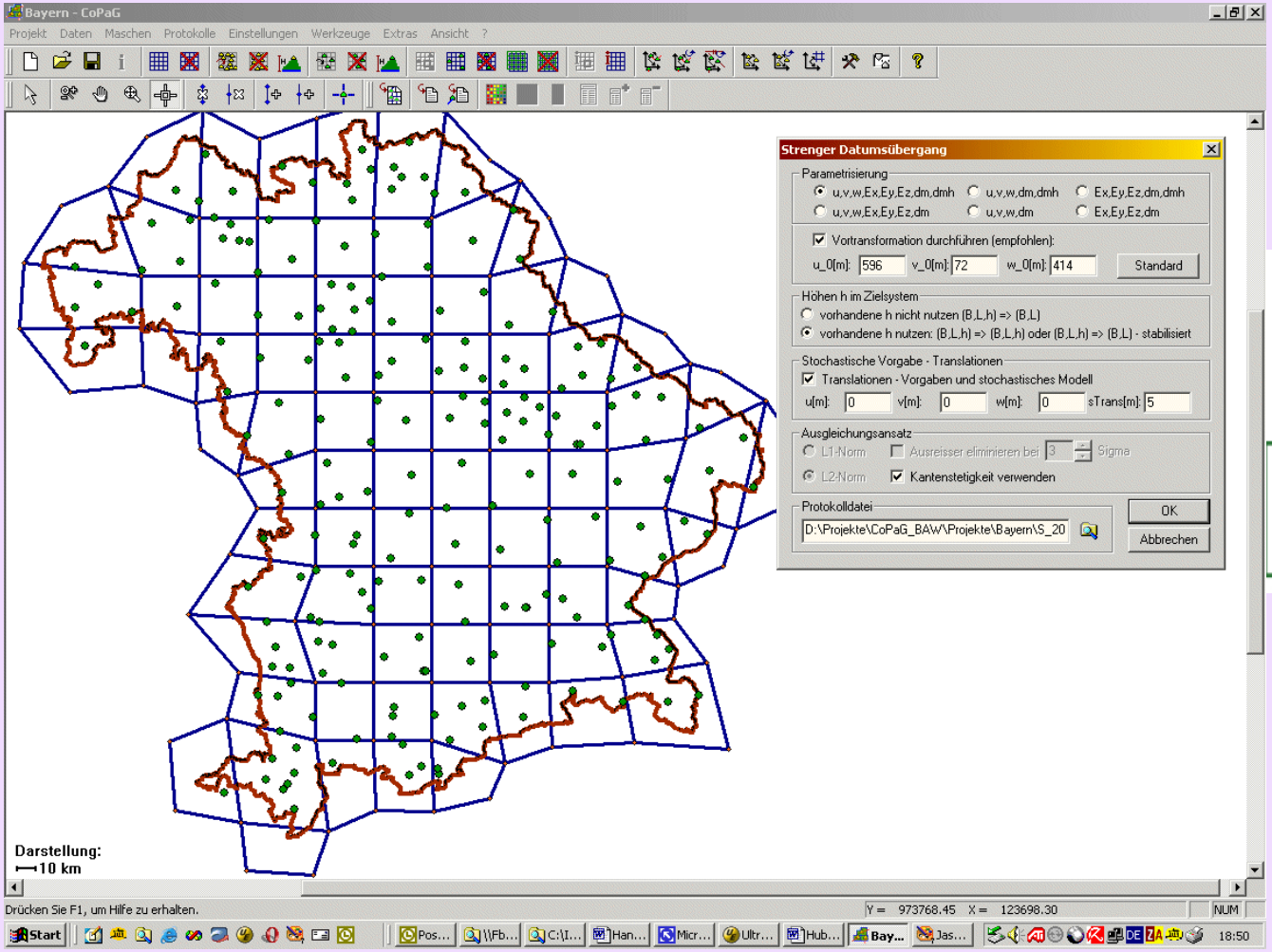
CoPaG = Continuously Patched Georeferencing



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www.moldpos.eu

Continuity along the Mesh Borders!

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Solution of the horizontal Transformation Problem

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

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

1D-,2D-,3D-

Identical Points

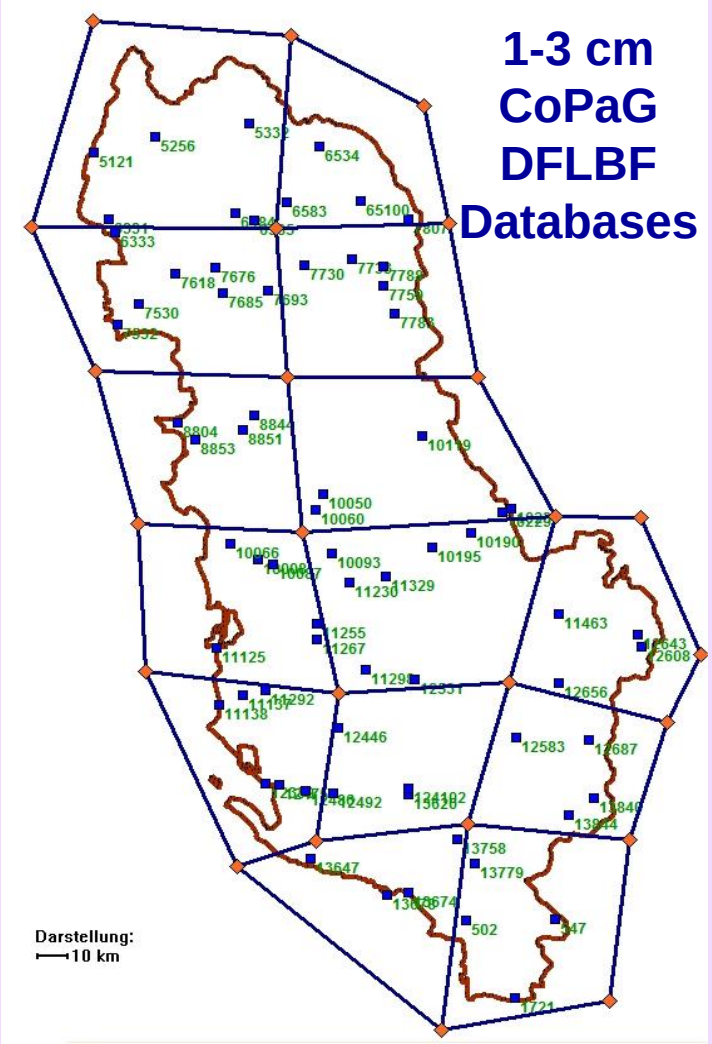
WTrans
www.geozilla.de

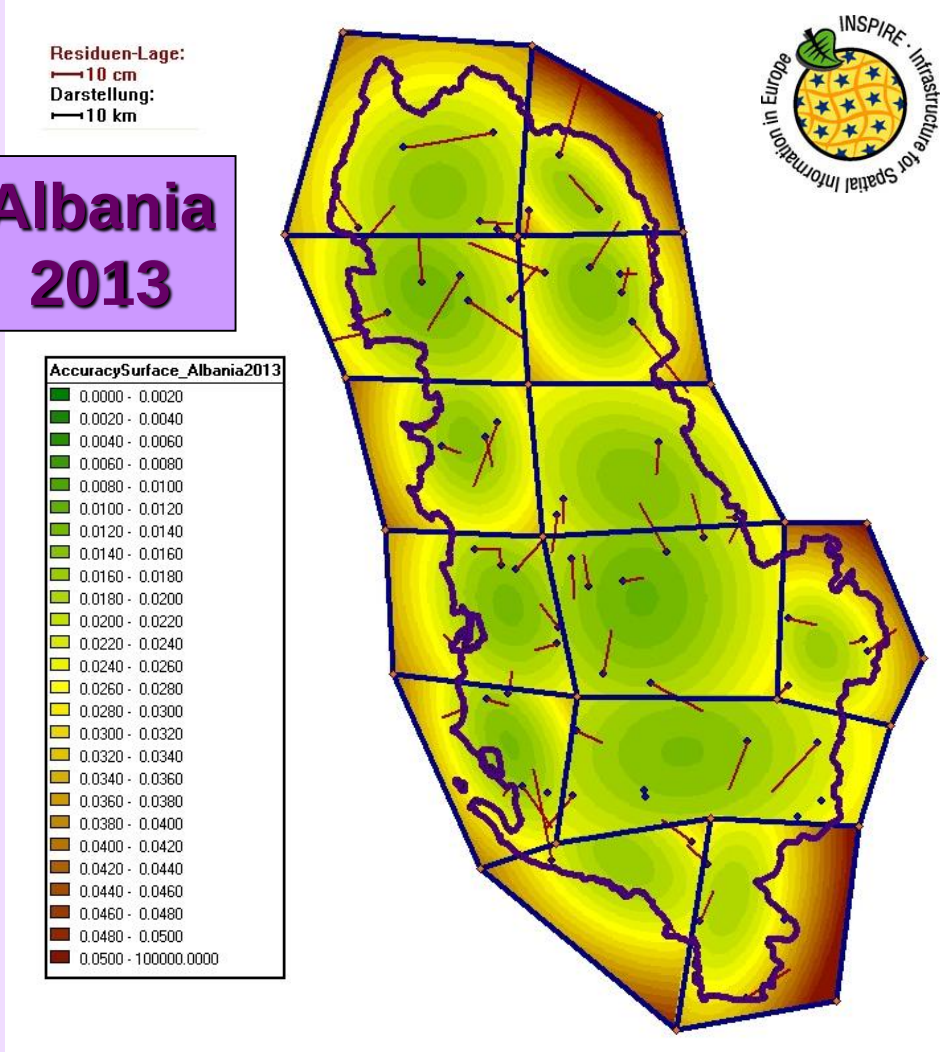
$$\begin{bmatrix} -\sin(L)\cdot\frac{a\cdot W+h}{M+h} & \cos(L)\cdot\frac{a\cdot W+h}{M+h} & 0 & \frac{-\sin(B)\cdot\cos(B)\cdot N\cdot e^2}{M+h} & \frac{-\sin(B)\cdot\cos(L)}{M+h} & \frac{-\sin(B)\cdot\sin(L)}{M+h} & \frac{\cos(B)}{M+h} \\ \frac{\sin(B)\cdot\cos(L)\cdot(N\cdot(1-e^2)+h)}{(N+h)\cdot\cos(B)}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

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

GIPS-1: Horizontal Datum-Trafo from $(B,L)_{GNSS,ITRF}$ to Classical Datum $(B,L)_{Classical}$ - COPAG-Approach and COPAG/DFLBF-Database Computation

DFLBF/COPAG Databases for Albania. Mesh-Design ITRF2000.2008.0 ⇔ ALB87





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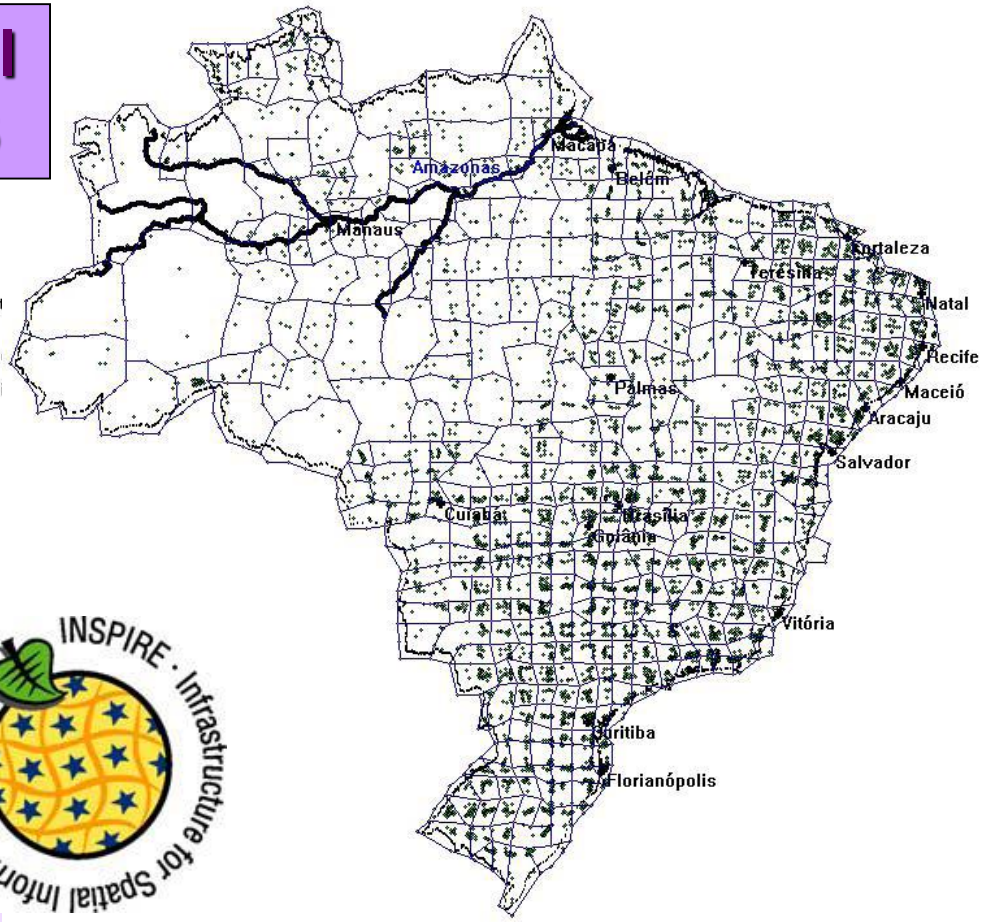
DFLBF/COPAG Databases for Brazil Meshes SAD69 ⇔ SIRGAS

DFLBF/COPAG Databases for Brazil Meshes SAD96 ⇔ SIRGAS



INSPIRE · Infrastructure for Spatial Information in Europe

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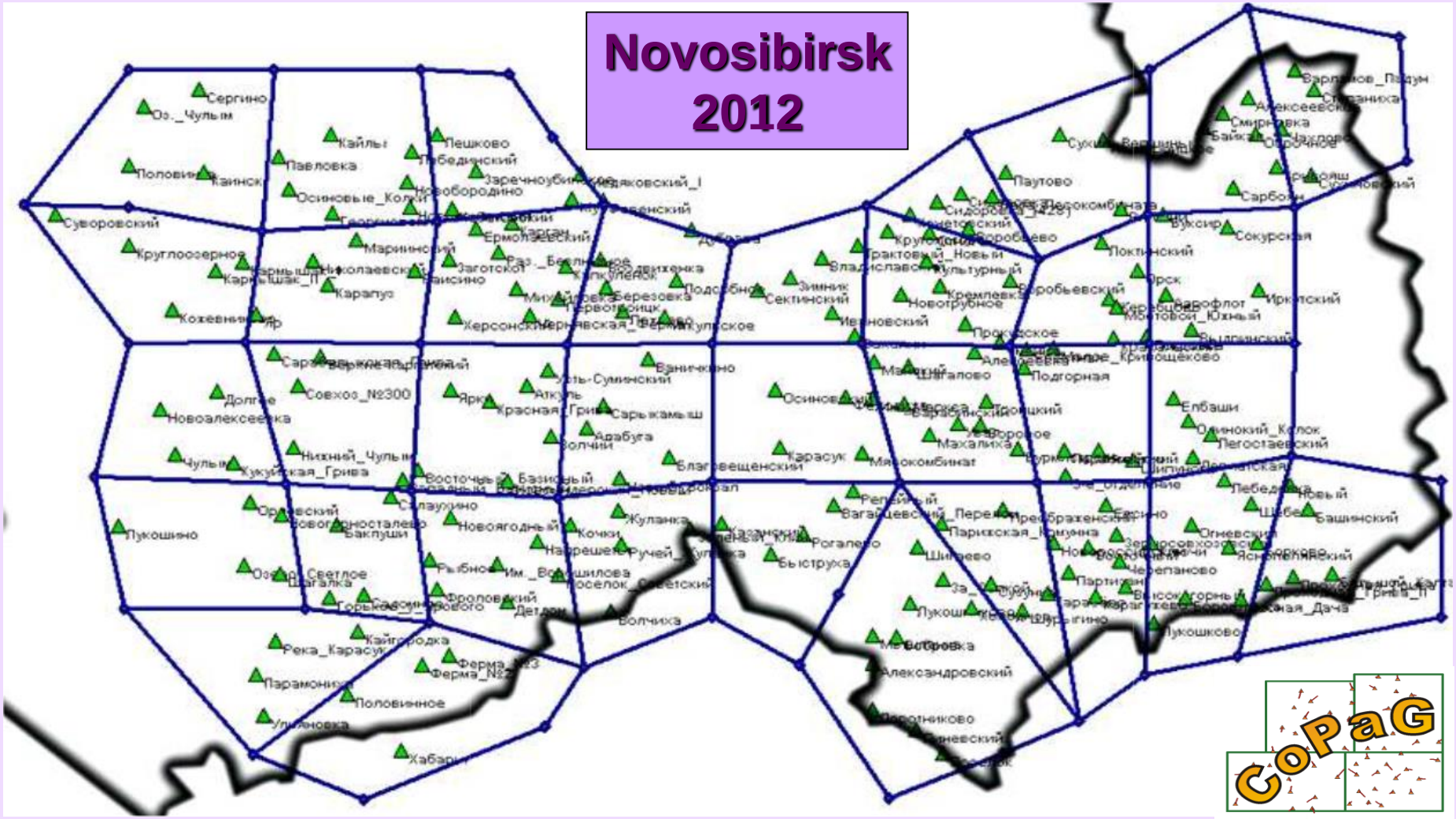
IAF Institut für Angewandte Forschung (IAF)

GIPS-1 Continuous Datumtransformation Parameters between SG95 and SC42 for SRPOS (Novosibirsk Region)



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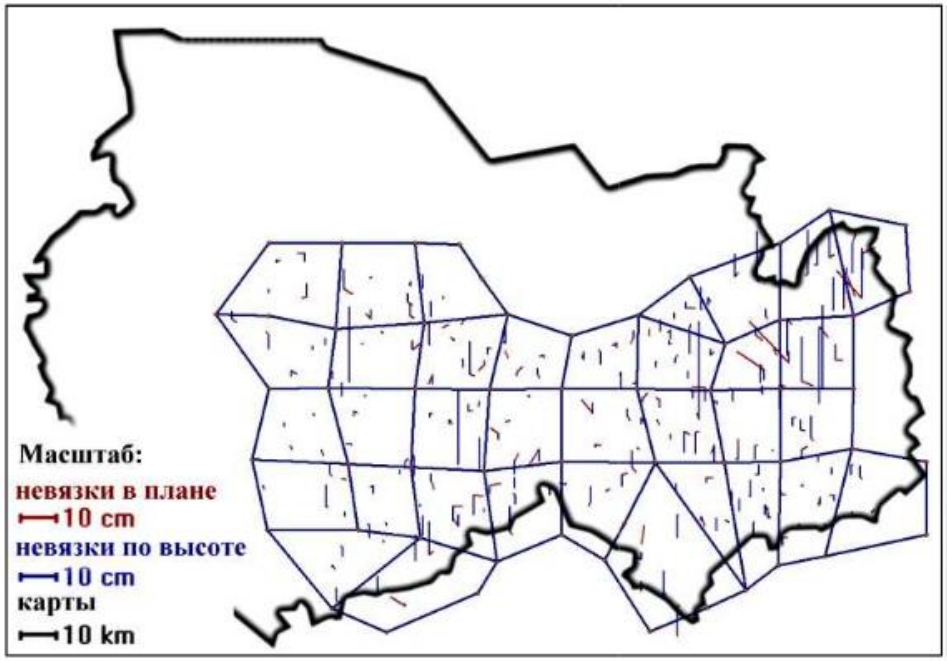
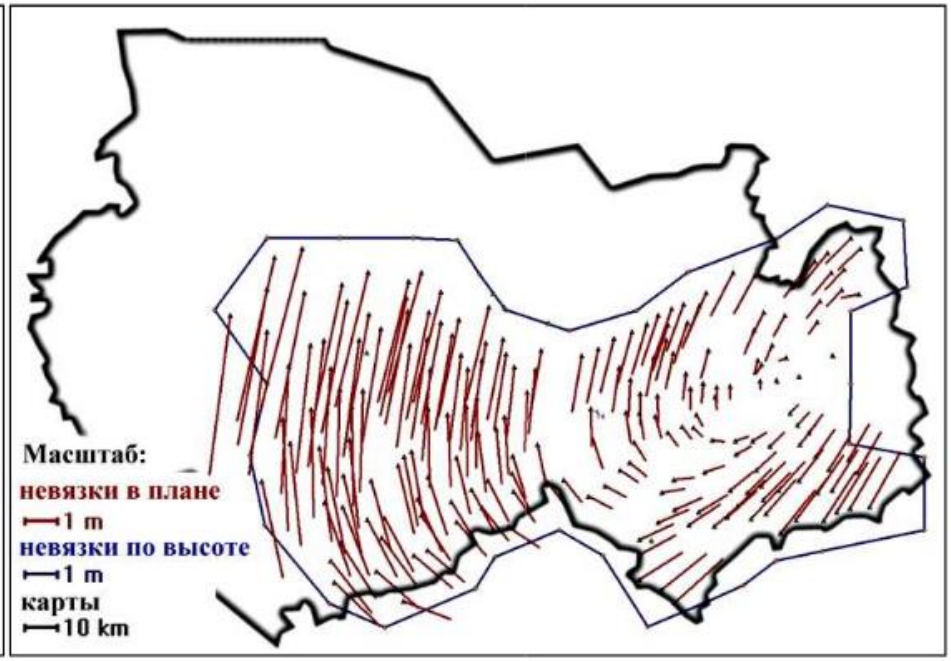
GIPS-1 Continuous Datumtransformation Parameters between SG95 and SC42 for SRPOS (Novosibirsk Region)

Novosibirsk 2012

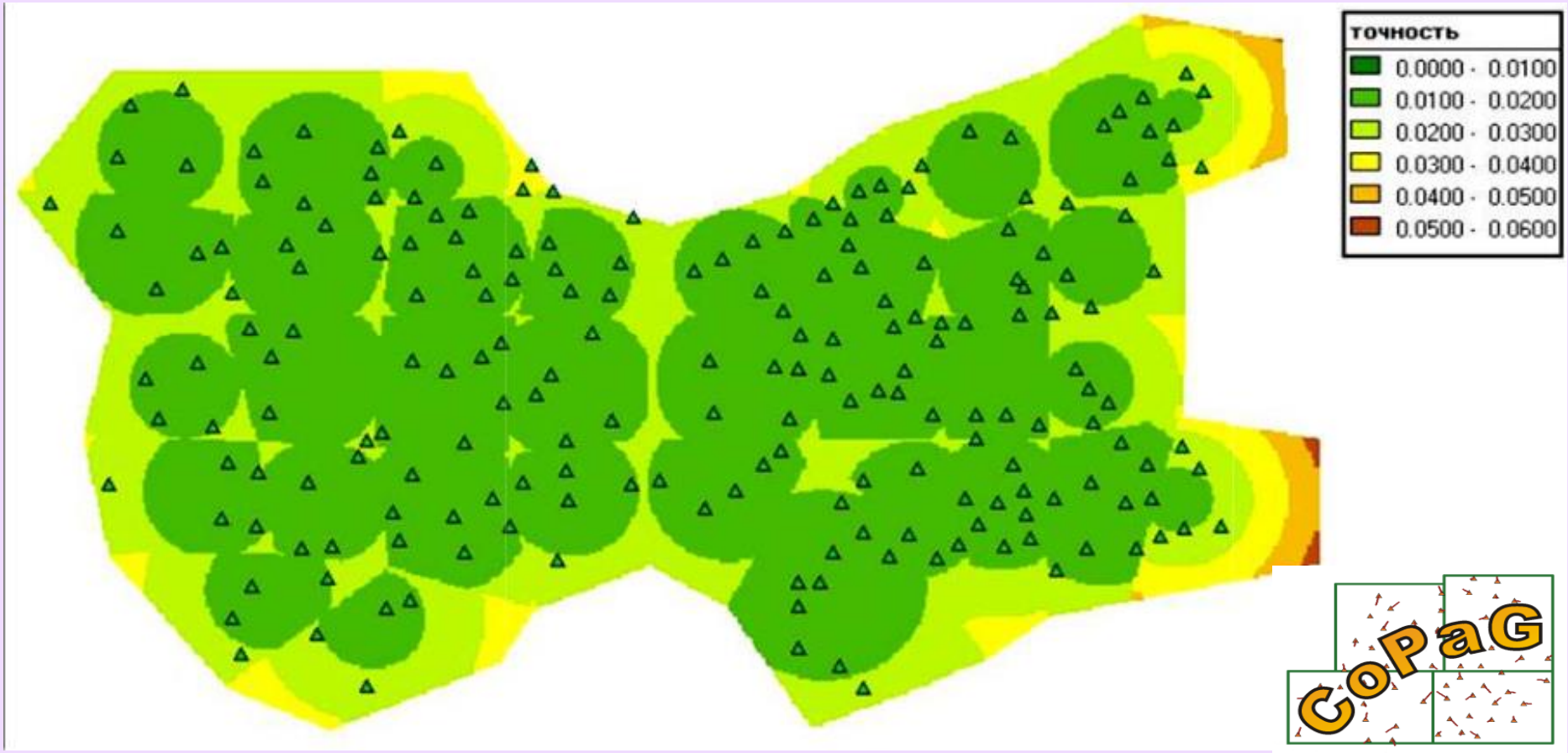




Reiner Jäger

GIPS-1 Continuous Datumtransformation Parameters between SG95 and SC42 for SRPOS (Novosibirsk Region)

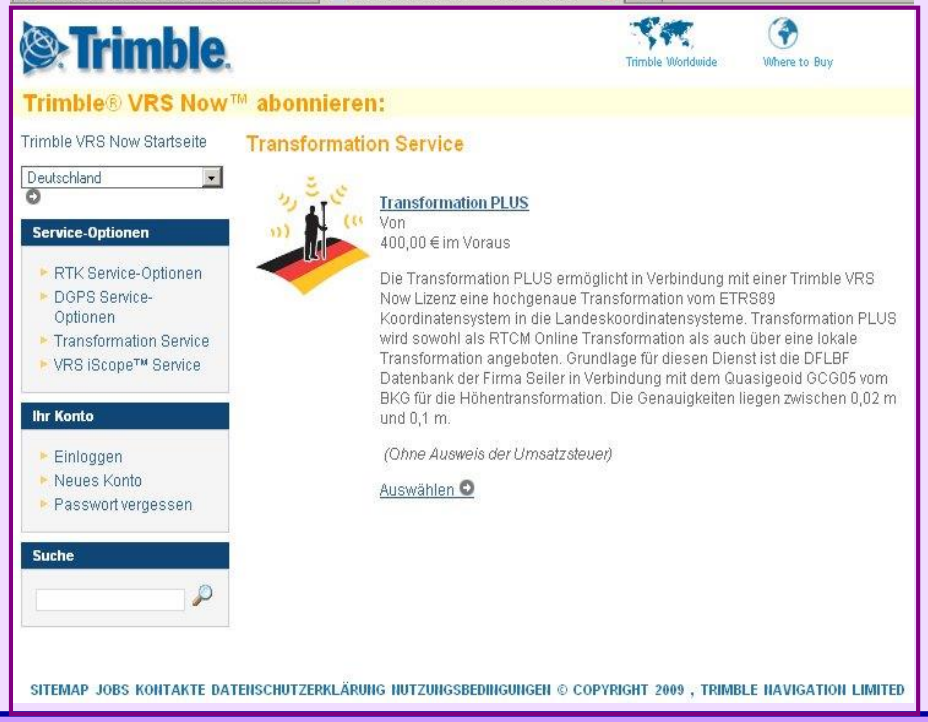
Reiner Jäger, Simone Kälber, Lagutina Elena and Tatyana Gorokhova (2012): "Determination of transformation parameters between international and state coordinate systems on the territory of the Novosibirsk region" ("ОПРЕДЕЛЕНИЕ ПАРАМЕТРОВ ПЕРЕХОДА ОТ ОБЩЕЗЕМНОЙ К ГОСУДАРСТ ВЕННОЙ СИСТЕМЕ КООРДИН АТ НАТЕРРИТОРИЮ НОВОСИ БИРСКОЙ ОБЛАСТИ"). Paper presented by Tatyana Gorokhova at the Interexpo Geosiberia 2012, Novosibirsk, Russia, 17.04.2012 - 19.04.2012.

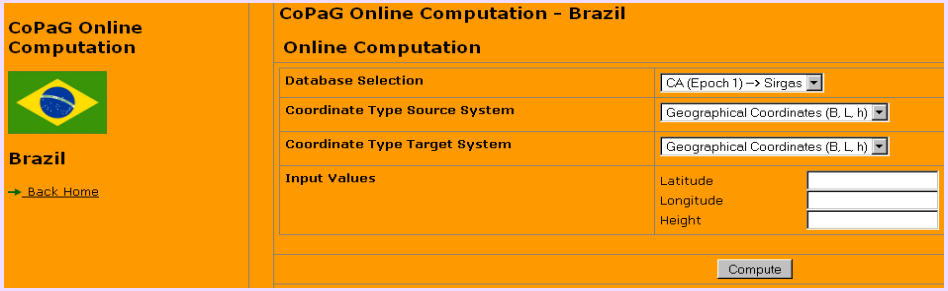


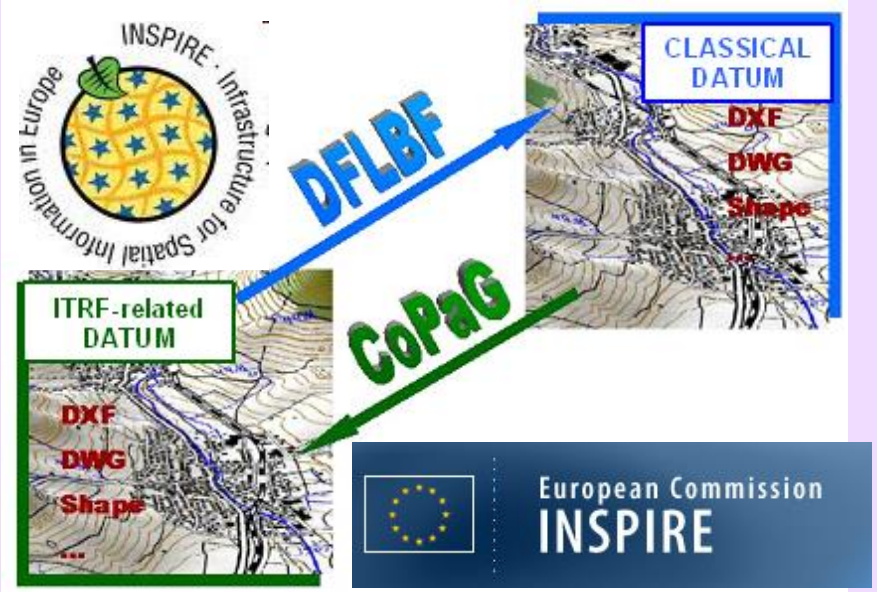
GIPS-1: Horizontal Datum-Trafo from $(B,L)_{GNSS,ITRF}$ to Classical Datum $(B,L)_{Classical}$ - COPAG-Approach and COPAG/DFLBF-Database Computation

GIPS-1-Trafo-2: Horizontal Datum Transition from $(B,L)_{GNSS,ITRF}$ to $(B,L)_{Classical}$ *DFLBF-Databases*. Use in GNSS-Services on controllers and via RTCM

GIPS-1-Trafo-1: Horizontal Datum Transition from $(B,L)_{Classical}$ to $(B,L)_{GNSS,ITRF}$ *CoPaG-Databases* for GIS







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GIPS-2
GNSS-Heighting

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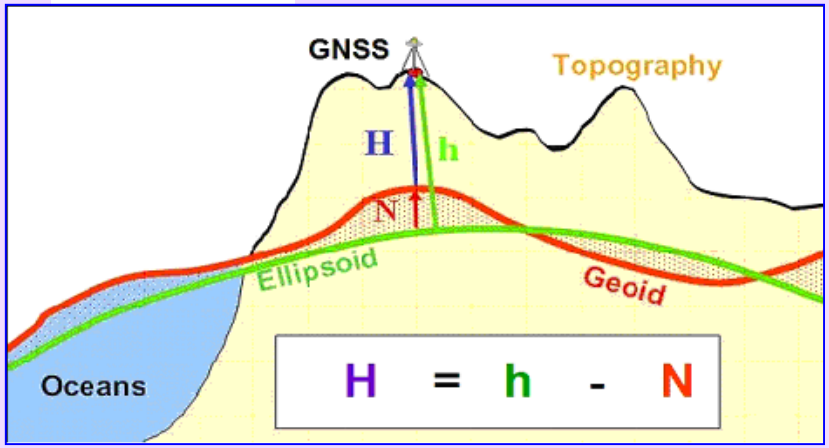
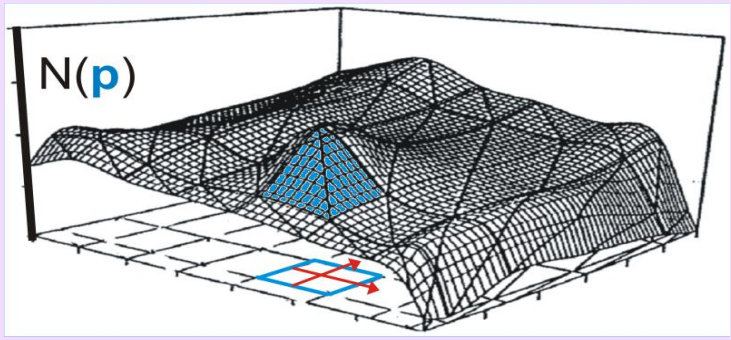
Institut für Angewandte Forschung (IAF)

GIPS-2: Height Reference Surface (HRS) Qgeoid/Geoid (N) for Transition $h_{GNSS,ITRF}$ to Physical Heights H = h-N - Karlsruhe Approach (DFHBF) and DFHBF-DB Computation



Continuous FEM Polynomial N(p)=NFEM(p)



Observation Equations - DFHBF Vers. 4

$$h_{GNSS} + v = H + NFEM(p) - h_{GPS} \cdot \Delta m$$

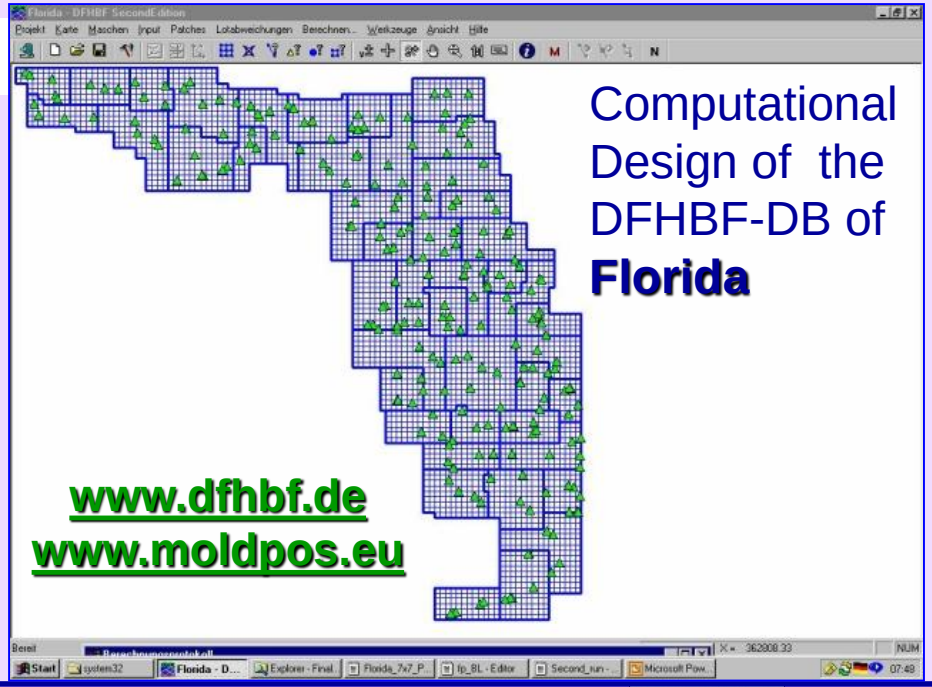
$$H + v = H$$

$$N_G^{j} + v^{j} = NFEM(p) + \partial N_G(d^{j})$$

$$\xi^{j} + v = -F_B / (M(B)+h) \cdot p + \partial \xi (d_{\xi,\eta})^{j}$$

$$\eta^{j} + v = -F_L / ((N(B)+h) \cdot \cos(B)) \cdot p + \partial \eta (d_{\xi,\eta})^{j}$$

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



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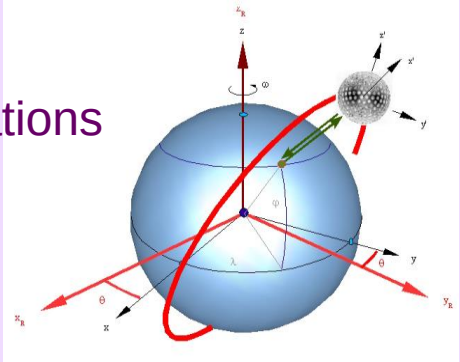
Observation Equations - DFHBF Version 5



1. SCHA-Coefficients computed from global SH as direct observations

$$C'_{n(k),m}(t) + v = \hat{C}'_{n(k),m} \quad \text{and} \quad S'_{n(k),m}(t) + v = \hat{S}'_{n(k),m}$$

2. Gravity Observations rotated to SCHA

$$g^{LGV}_{grav_r} + v = \sum_{k=0}^{\infty}\left(\frac{a}{r}\right)^{n(k)+1}\frac{(n(k)+1)}{r}\sum_{m=0}^{k}(\overline{C}'_{n(k)),m}\cdot\cos m\lambda' + \overline{S}'_{n(k),m}\cdot\sin m\lambda')\cdot P_{n(k),m}(\cos\theta')$$

3. Vertical Deflections from Zenith Cameras **(T = (V+Z) – U)**

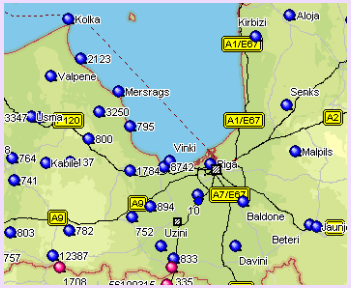
$$\xi = -\frac{\partial N_{QG}}{\partial B}\cdot\frac{\partial B}{\partial s_N} = -\frac{\partial B}{\partial s}\cdot\frac{\partial N_{QG}}{\partial B} = \frac{-1}{(M+h)}\cdot\frac{1}{\gamma_Q}\cdot\frac{\partial}{\partial B}T_p = \frac{-1}{\gamma_Q\cdot(M+h)}\cdot\left(\frac{\partial T}{\partial B}\right)_P$$

$$\eta = -\frac{\partial L}{\partial s}\cdot\frac{\partial N_{QG}}{\partial L} = \frac{-1}{(N+h)\cdot\cos B}\cdot\frac{1}{\gamma_Q}\cdot\frac{\partial}{\partial L}T_P = \frac{-1}{\gamma_Q\cdot(N+h)\cdot\cos B}\cdot\left(\frac{\partial T}{\partial L}\right)_P$$

Zenit-Cameras

4. Fitting Points

$$h - N_{Normal} = N_{QG} = \frac{(V - V_{ref})_P}{\gamma_Q} = \frac{T_P}{\gamma_Q}$$



www.dfhbf.de
www.moldpos.eu

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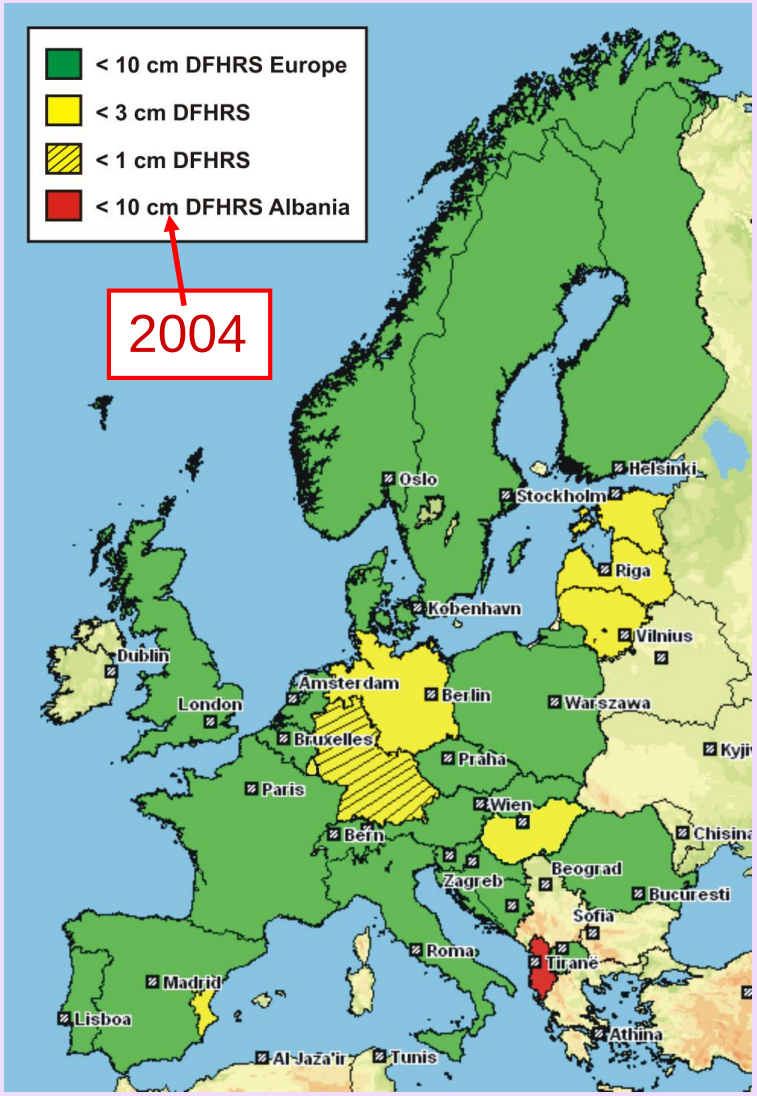
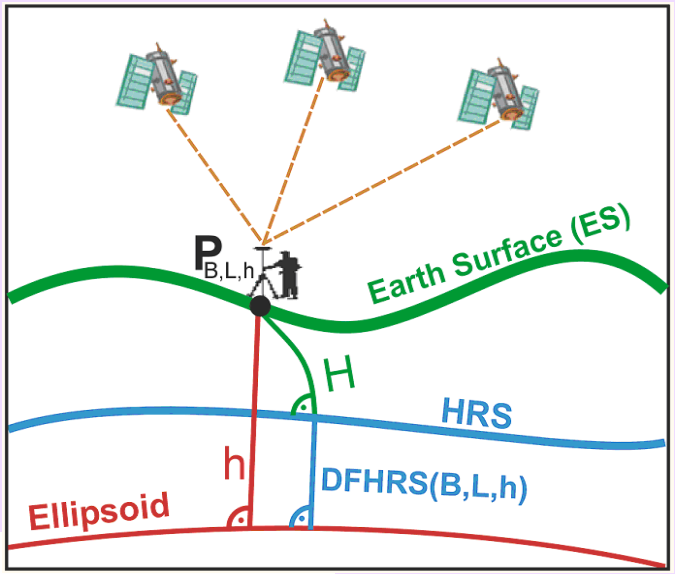
GIPS-2: Height Reference Surface (HRS) Qgeoid/Geoid (N) for Transition $h_{GNSS,ITRF}$ to Physical Heights H = h-N - Karlsruhe Approach (DFHBF) and DFHBF-DB Computation



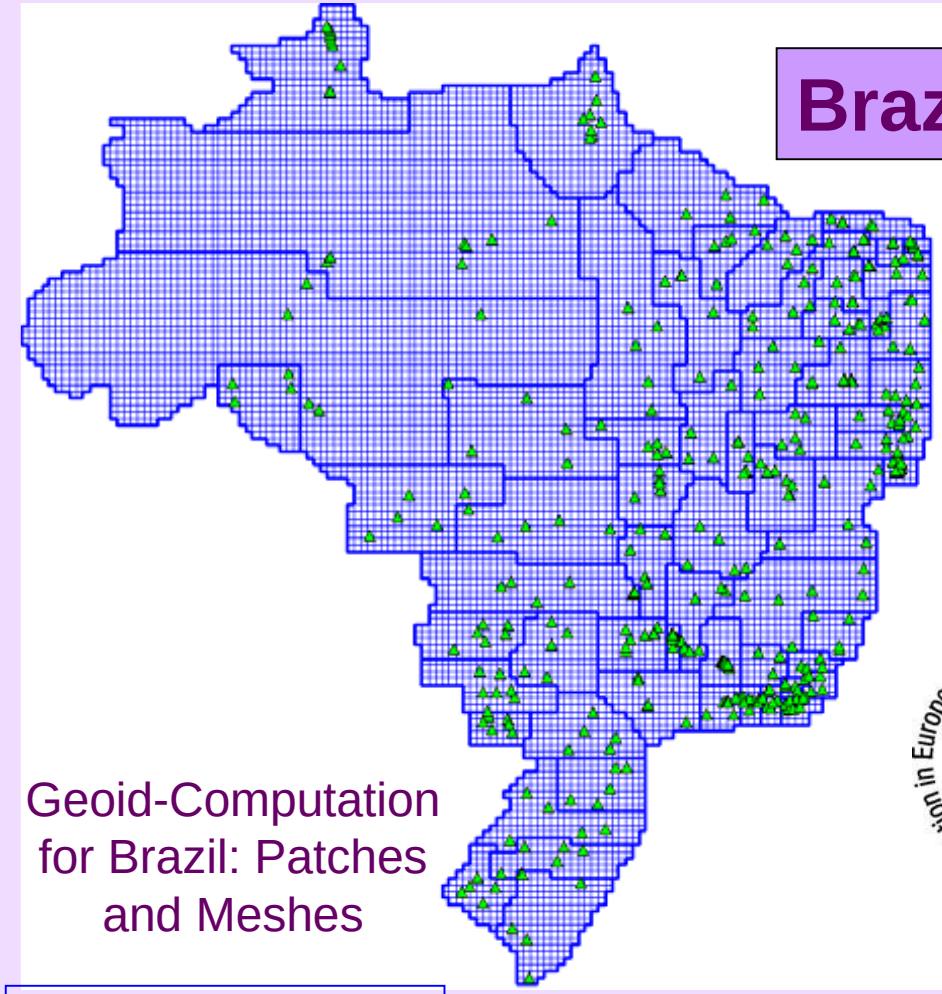


DFHBF - Databases

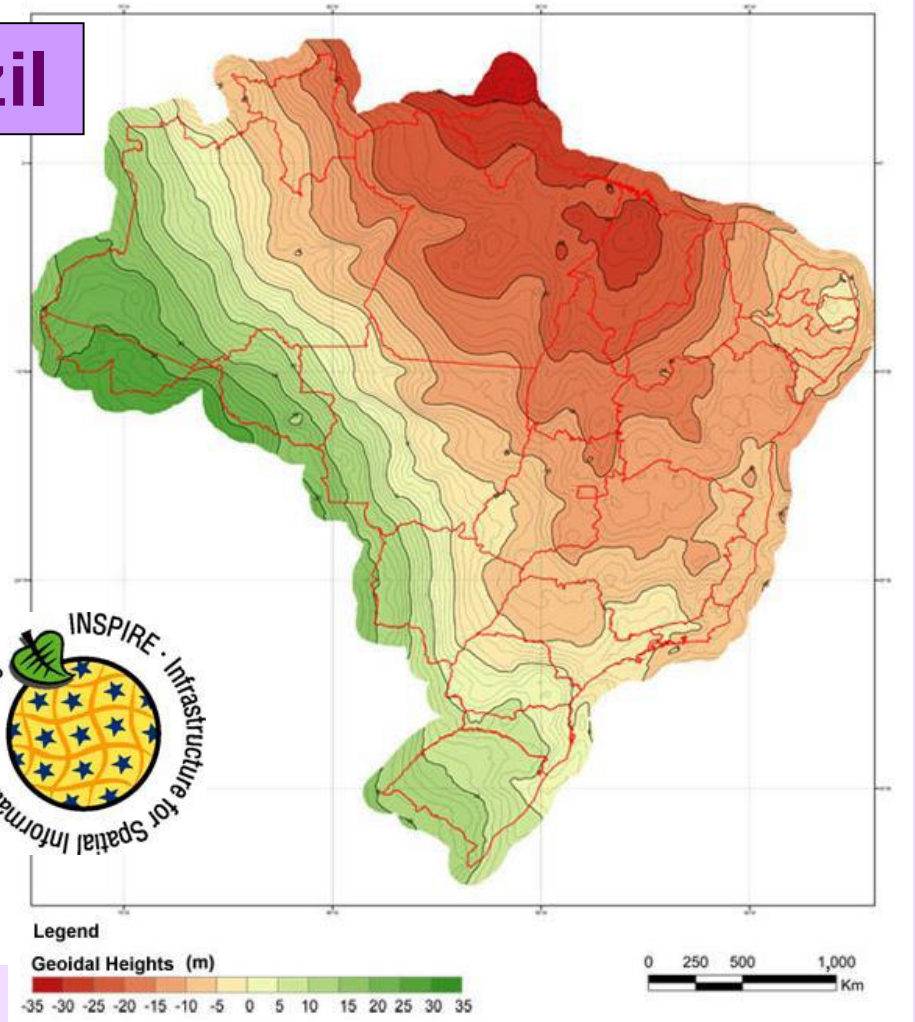
Quasi-Geoid N_{QG} Quasi-Geoid N_G

$$N_G = N_{QG} + \frac{\bar{g} - \bar{\gamma}}{\bar{\gamma}} \cdot H$$

GIPS-2: Height Reference Surface (HRS) Qgeoid/Geoid (N) for Transition $h_{GNSS,ITRF}$ to Physical Heights H = h-N - Karlsruhe Approach (DFHBF) and DFHBF-DB Computation



Brazil



Geoid-Computation for Brazil: Patches and Meshes

www.dfhbf.de

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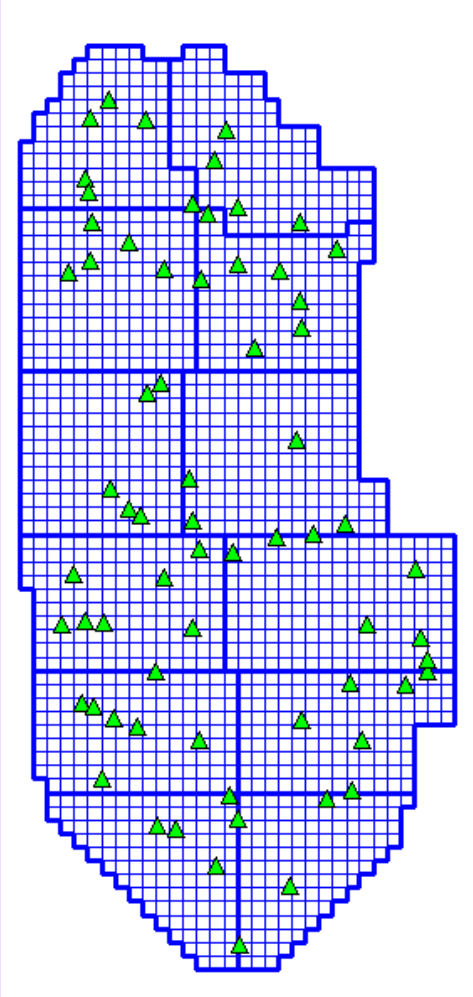
GIPS-2: Height Reference Surface (HRS) Qgeoid/Geoid (N) for Transition $h_{GNSS,ITRF}$ to Physical Heights H = h-N - Karlsruhe Approach (DFHBF) and DFHBF-DB Computation

Geoid-Computation for Albania
Patches and Meshes (Version 4)

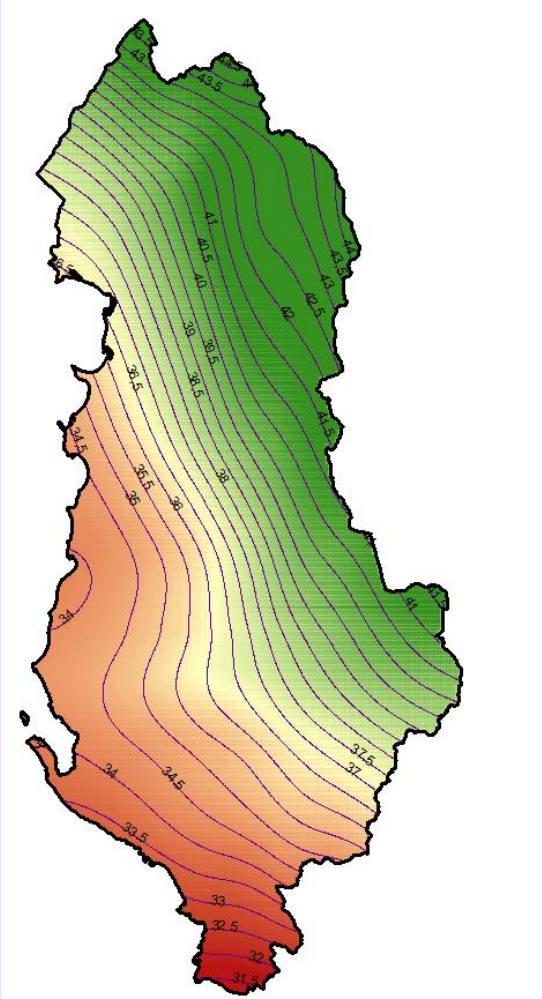


1-3 cm DFHBF based Geoid Database for Albania

Albania 2013

www.dfhbf.de

Albanian Geoid-Surface N



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GIPS-3
RTCM Transformation Messages

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Institut für Angewandte Forschung (IAF)

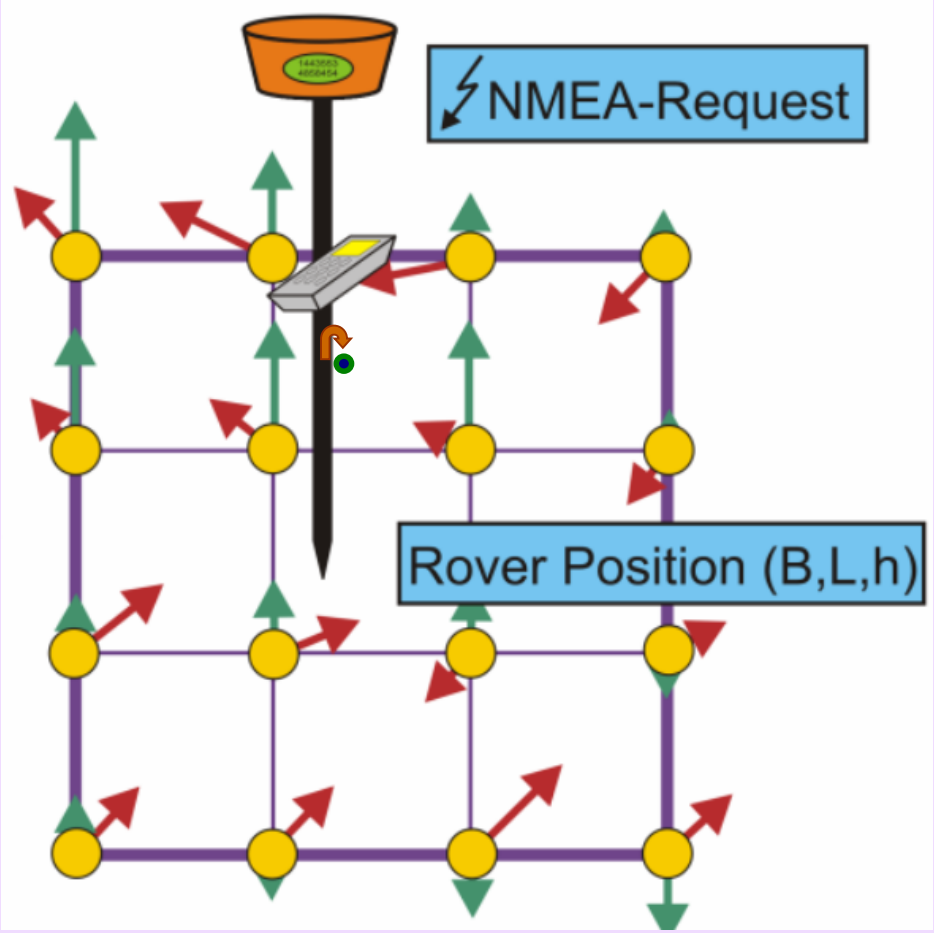
GIPS-3: RTCM Transformation Messages and Setup from Reference Transformations - Karlsruhe Approach

Present or „old“ standard:Trafo-Databases or„Grids“ in GNSS-controllers (Trimble, Leica-Geosystems, Topcon, etc.)

GIPS-3: RTCM Transformation Messages and Setup from Reference Transformations - Karlsruhe Approach

Present new standard: Using Reference Transformations to compute country-wide RTCM-grids static or dynamic online on NMEA-request by virtual fitting points

RTCM Grid“



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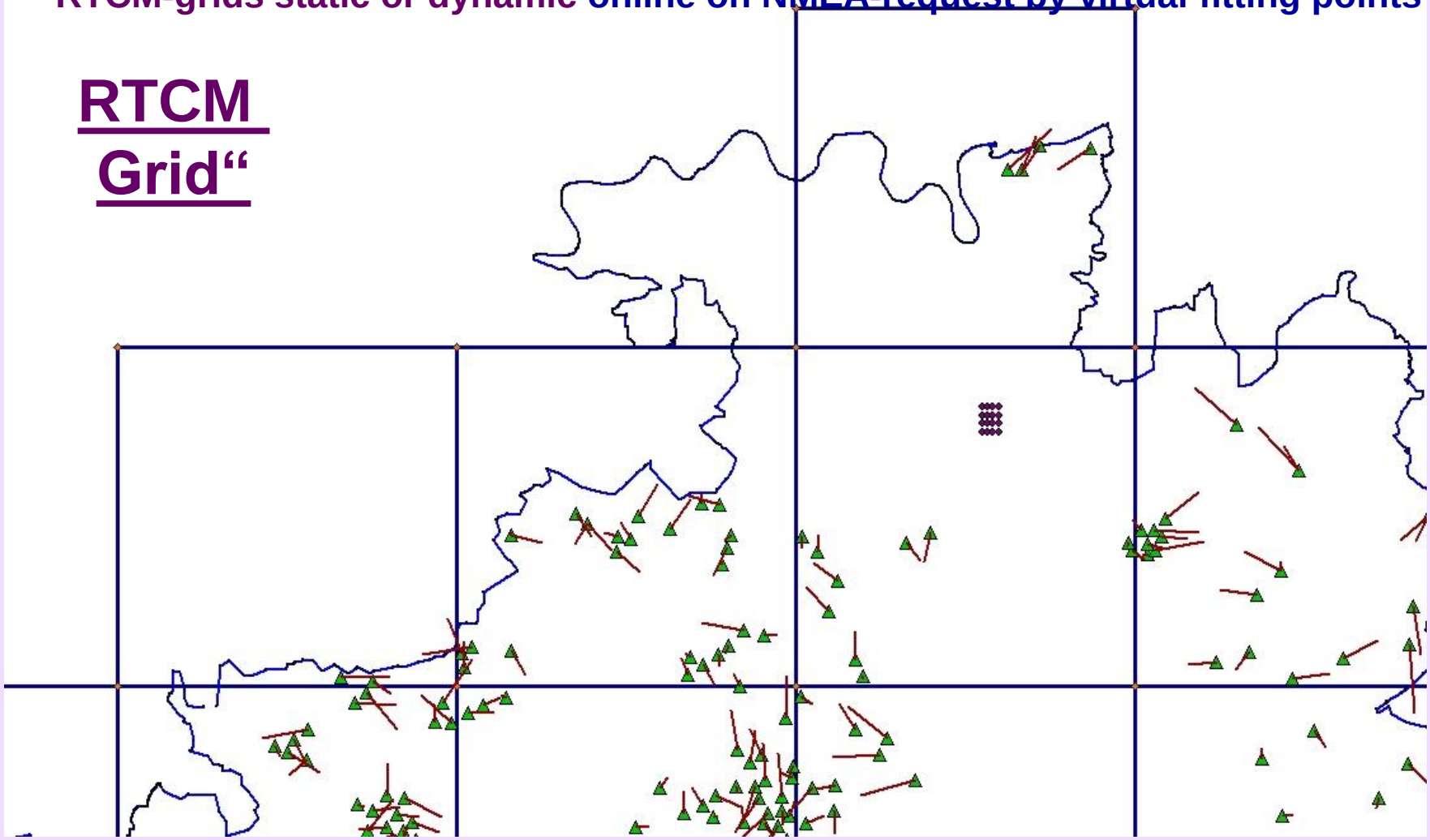
GIPS-3: RTCM Transformation Messages and Setup from Reference Transformations - Karlsruhe Approach

Present new standard: Using Reference Transformations to compute country-wide RTCM-grids static or dynamic online on NMEA-request by virtual fitting points



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Institut für Angewandte Forschung (IAF)

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

GIPS-3: RTCM Transformation Messages and Setup from Reference Transformations - Karlsruhe Approach

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	

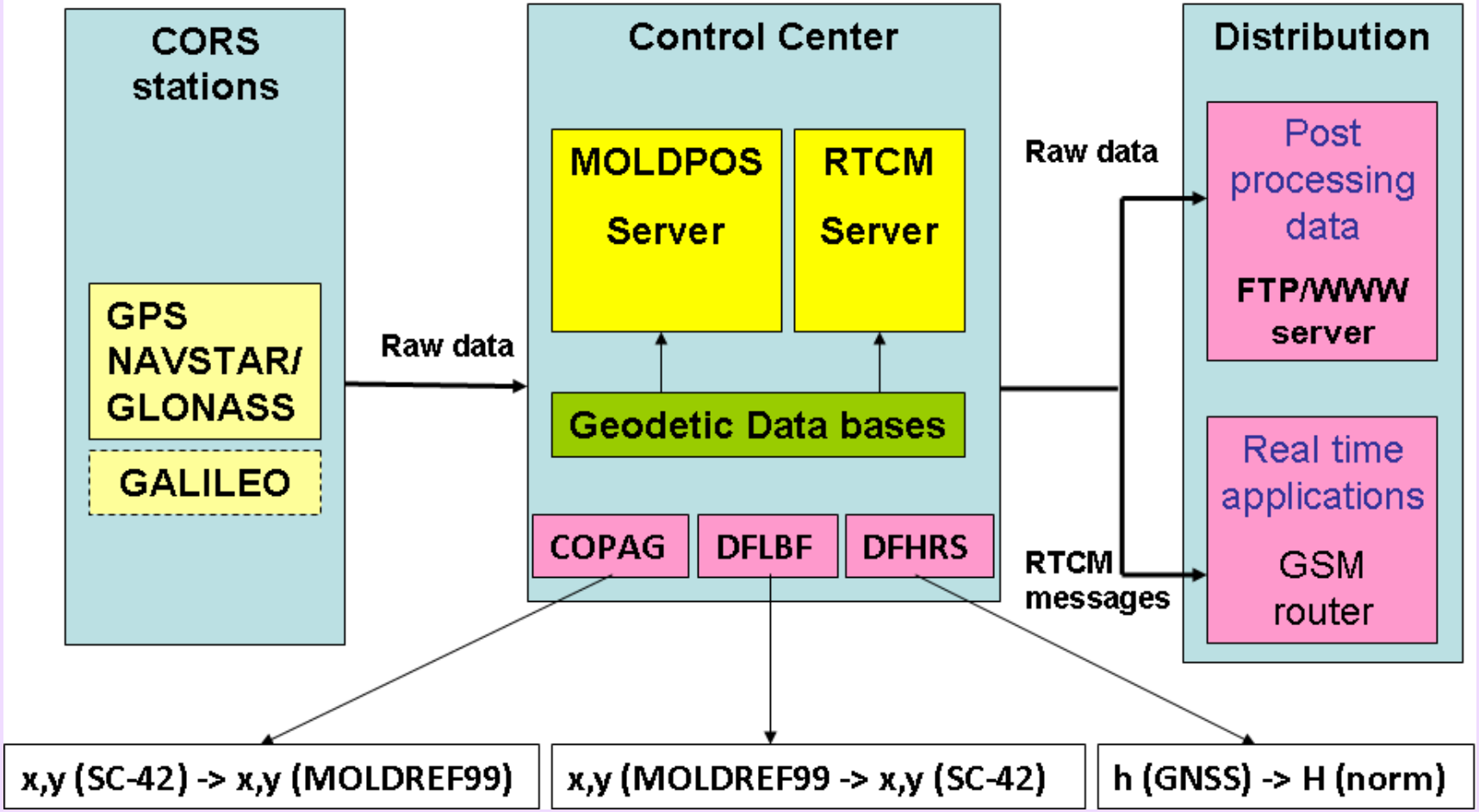
Height Indicator = 1 → **„dh_i„ = Physical Heights‘ Residuals dH_i**

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

HS Karlsruhe BMBF-Project 2010-2011: www.moldpos.eu

MOLDPOS

Geodetic databases development



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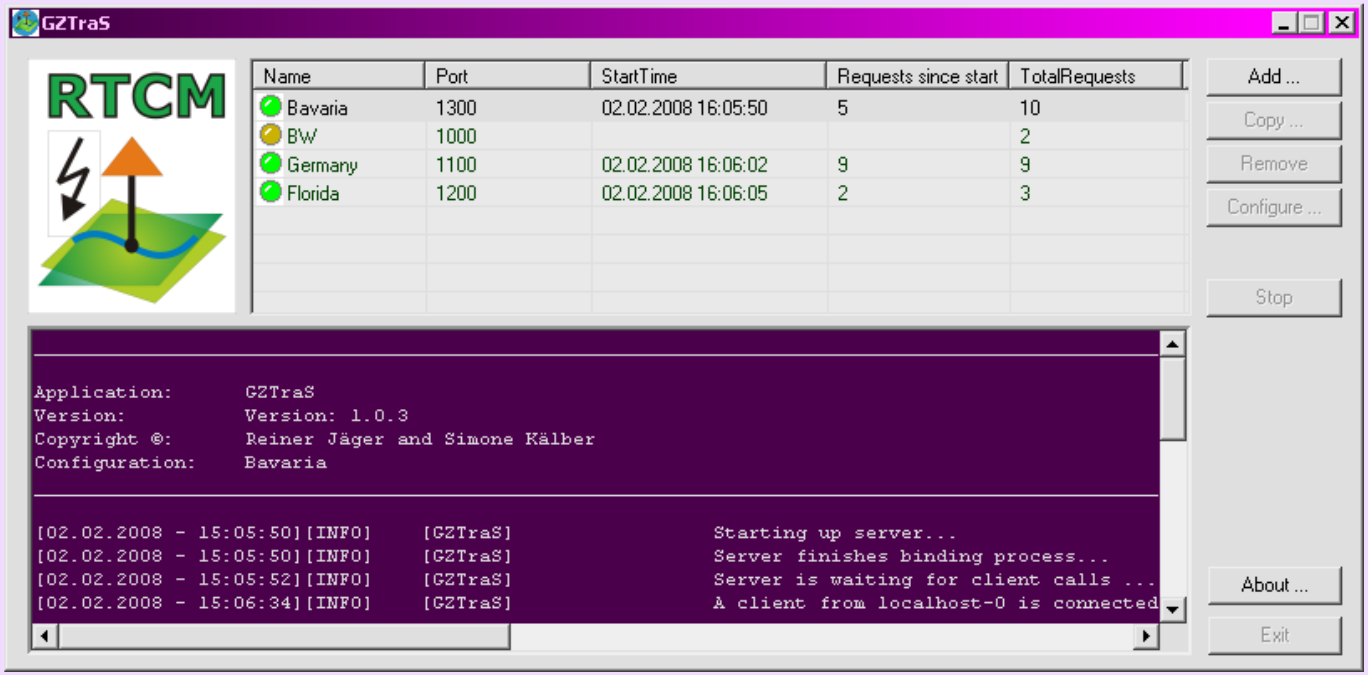
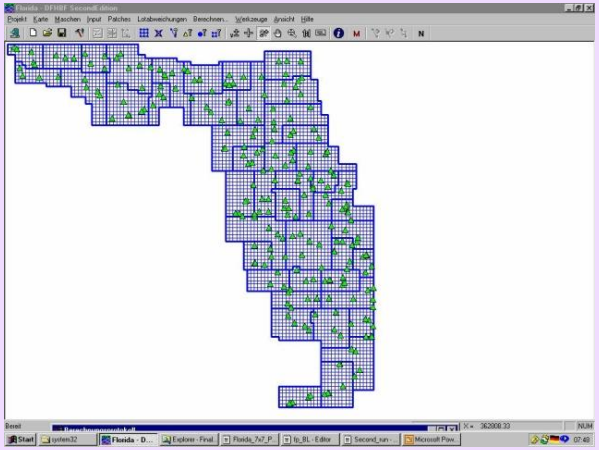
GIPS-3: RTCM Transformation Messages and Setup from Reference Transformations - Karlsruhe Approach





Reference Transformations

DFHBF Florida

DFHBF Bavaria

DFLBF Bavaria

www.geozilla.de

GIPS-4
GNSS-Reference Station Monitoring

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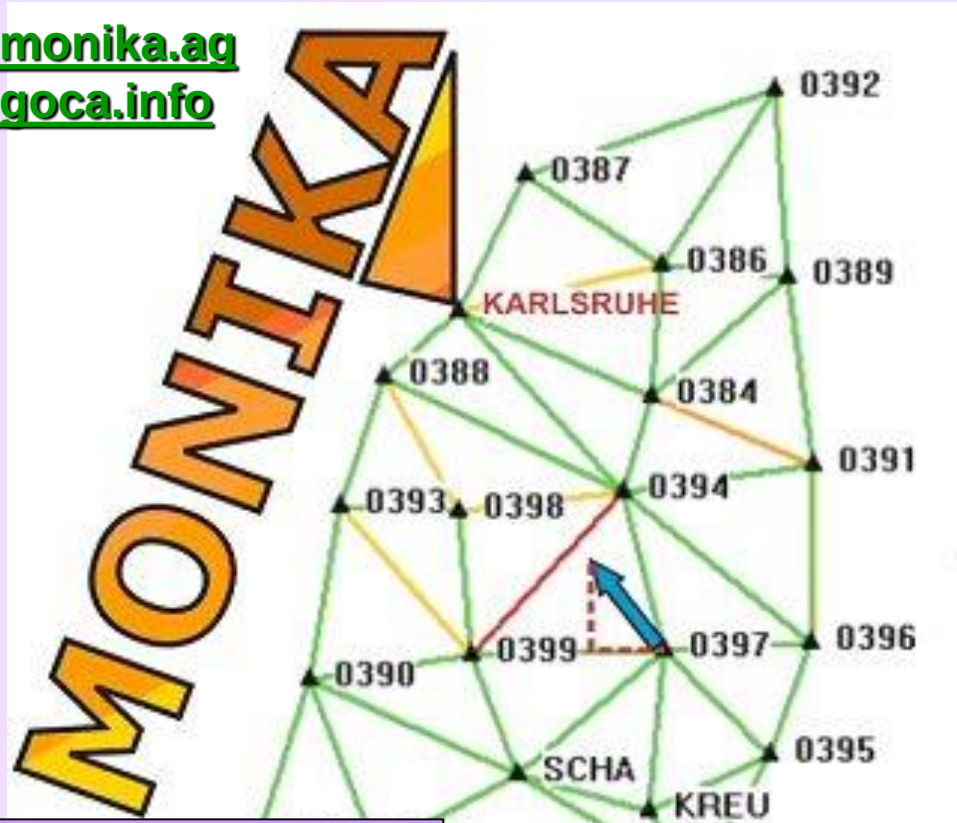
Institut für Angewandte Forschung (IAF)

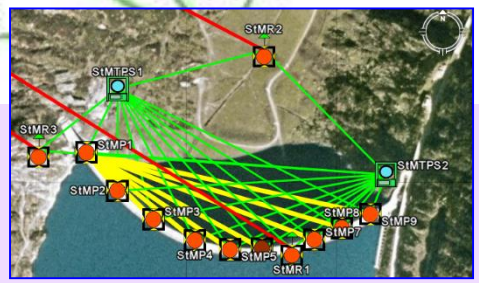
GIPS-4 - GNSS-Reference Station Monitoring and Use as Geosensor-Networks for Geomonitoring and Hazard Mitigation – Karlsruhe Approach (MONIKA) -

www.monika.ag
www.goca.info



GNSS-Positioning-Service of Rheinland-Pfalz (SAPOS) - Volcano Monitoring -

MONIKA-users
SAPOS Baden-Wüttemberg
SAPOS Rheinland Pfalz
MOLDPOS Moldova
EPOSA Austria
GNSSPlus Russia



GNSS-Positioning-Service Geomonitoring of Technical Installations and Buildings

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Need of GIPS in „Surveying and Landmanagement“ and … ++ High Amount of Interdisciplinary Potentials

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IAF
Institut für Angewandte Forschung (IAF)

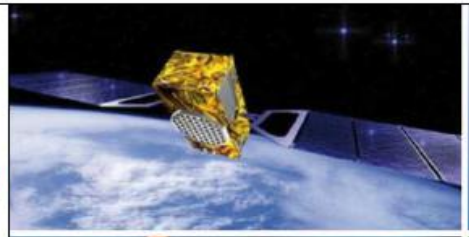
GNSS-Positioning Services – GIPS Users

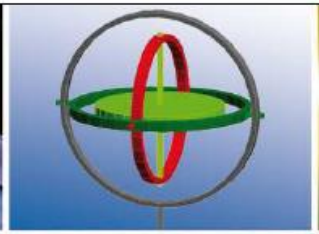
$$\mathbf{y}(t) = [x^e\ y^e\ z^e \mid \dot{x}^e \dot{y}^e \dot{z}^e \mid r^e\ p^e\ y^e \mid\mid \ddot{x}^e\ \ddot{y}^e\ \ddot{z}^e \mid \omega^b_{eb,x}\ \omega^b_{eb,y}\ \omega^b_{eb,z} \mid \mathbf{s}]^T$$

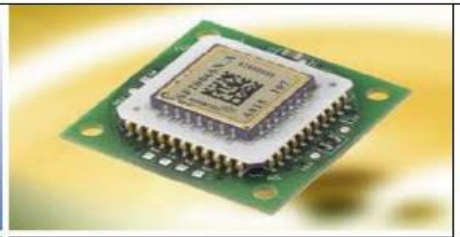
GNSS

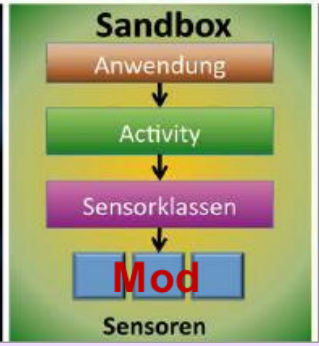
Deep Coupling
- Code
- Phase
- Doppler

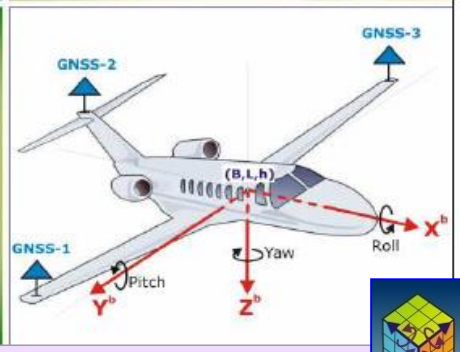
Tight Coupling
- Position
- Velocity









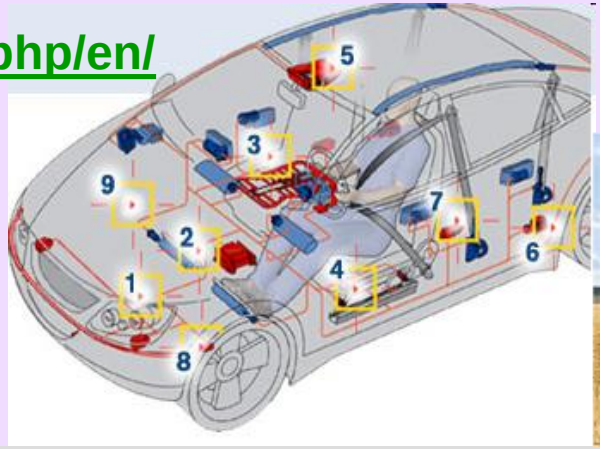


MEMS

Deep Coupling
- Gyroscopes
- Accelerometers
- Magnetometers
- Camera
- Barometer

www.navka.de
http://www.navka.de/index.php/en/aktuelles-2/news

Modeling of Distributed Sensors and Platforms
NAVKA Multi-Sensor-Multiplatform Concept
Mathematical Models
Algorithms and Software



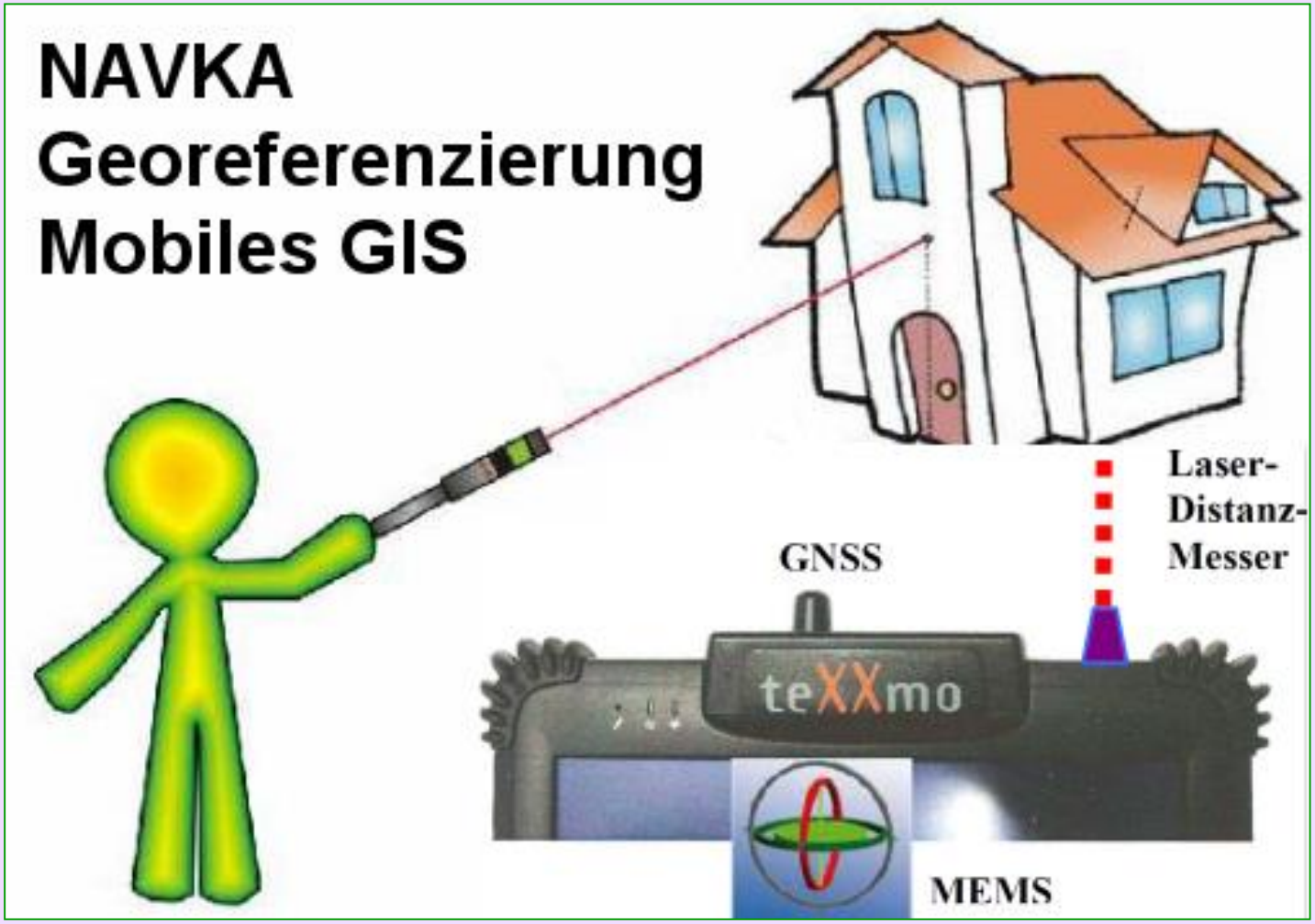
Smartphone as one of the multimodal „Multisensor Navigation Platforms“

Reiner Jäger

GNSS-Positioning Services – GIPS Users

Smartphone and Tablets – Application „KALEO-Georeferencer“ www.texxmo.de

$$\mathbf{x} = \left[x^e \; y^e \; z^e \mid v_x^e \; v_y^e \; v_z^e \mid r^e \; p^e \; y^e \mid\mid \ddot{x}^e \; \ddot{y}^e \; \ddot{z}^e \mid \omega_{eb,x}^b \; \omega_{eb,y}^b \; \omega_{eb,z}^b \right]^T$$



Full 15 parameter navigation solution necessary

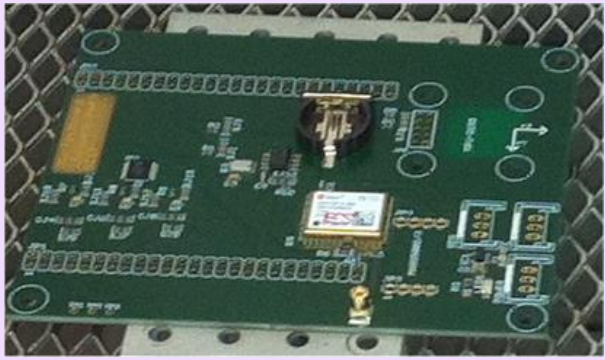
http://www.navka.de/images/files/texxmo_kaleo.pdf

http://www.navka.de/images/files/Jger_et_al_GeoSiberia2014_SmartphoneRtkAndMobileGis.pdf

GNSS-Positioning Services – GIPS Users

<u>IAF/HSKA ZIM-Projekt</u>: ***Entwicklung eines mehrfach redundanten konfigurationsoptimierten Multisensorsystems zur Ermittlung des Navigationsstatus und eines daran anknüpfenden selbsttätigen sowie interaktiven Steuerungssystems***

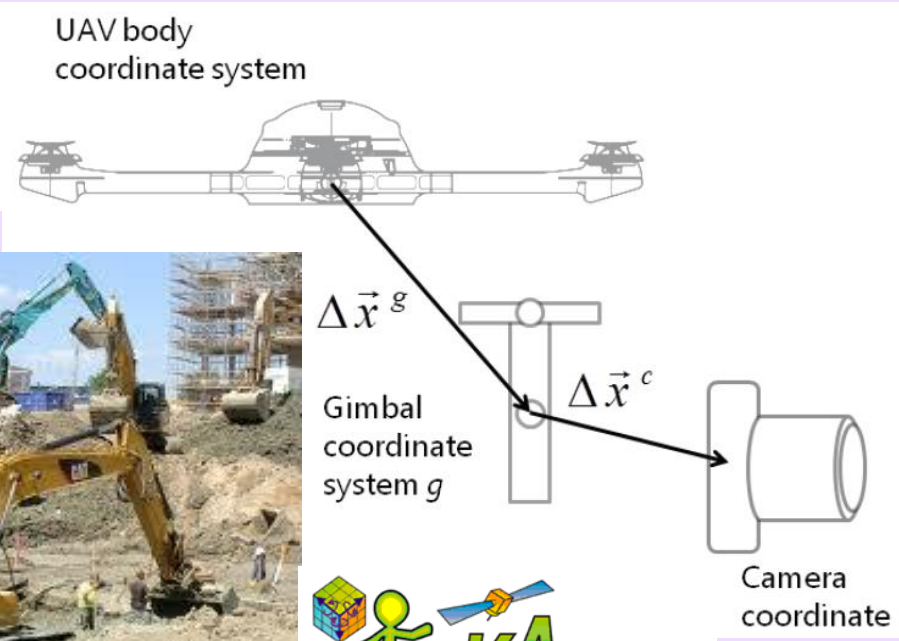
HSKA-GNSS/MEMS-Sensorboard

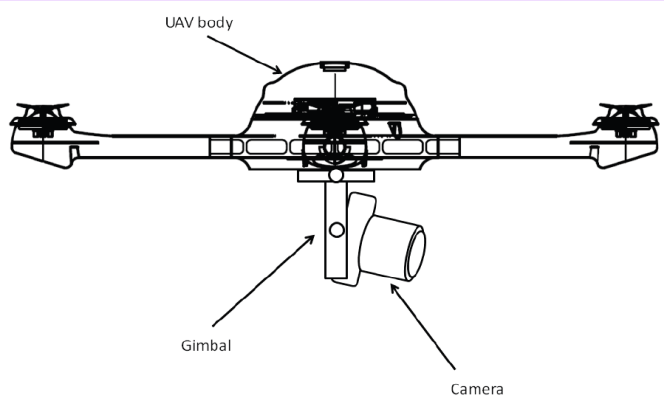


&
NAVKA-Navigation Algorithms&Software
&
Flight-Control-Algorithms & Software

GNSS-Positioning Services – GIPS Users

High Precise GNSS/MEMS multisensory navigation of UAV including the georeferencing of cameras





NAVKA www.navka.de

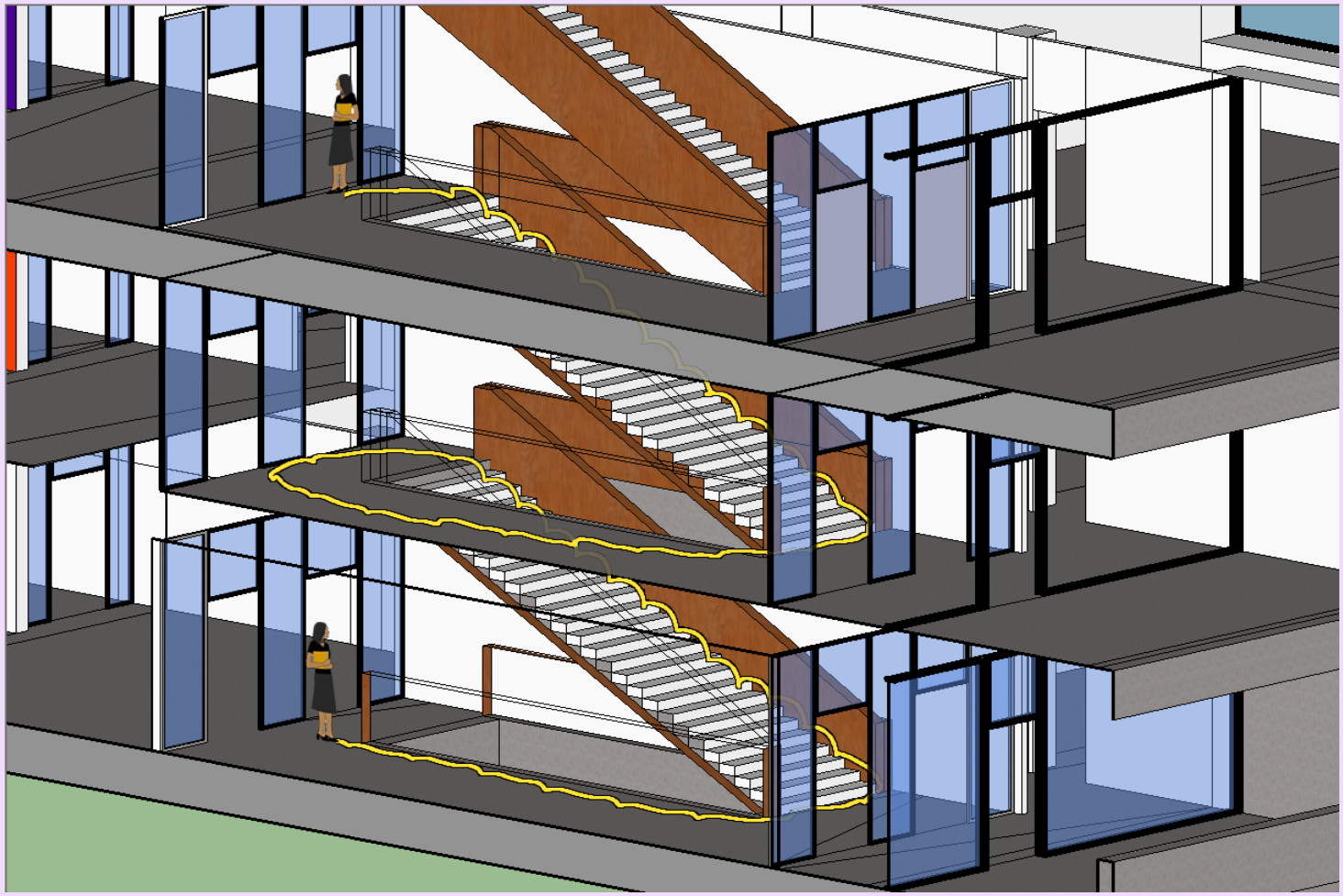
$$\mathrm{R}^e_{cam} = \underbrace{\underbrace{\mathrm{R}^e_n(\varphi,\lambda)\cdot \mathrm{R}^n_b(\Phi,\Theta,\Psi)}_{=\mathrm{R}^e_b}\cdot \mathrm{R}^b_g(\rho,\kappa)}_{=\mathrm{R}^e_g}\cdot \mathrm{R}^g_{cam}(\Delta\alpha,\Delta\beta,\Delta\gamma)$$

$$\vec{p}^{\,e}_0 = \vec{p}^{\,e}_{INS} + \underbrace{\mathrm{R}^e_b\cdot\Delta\vec{x}^{\,g}}_{\text{UAV to gimbal offset}} + \underbrace{\mathrm{R}^e_g\cdot\Delta\vec{x}^{\,c}}_{\text{Camera to gimbal offset}}$$

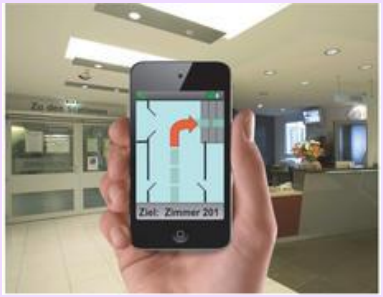
GNSS-Positioning Services – GIPS Users

$$\mathbf{x} = \left[x^e \; y^e \; z^e \,|\, v_x^e \; v_y^e \; v_z^e \,|\, r^e \; p^e \; y^e \,\|\, \ddot{x}^e \; \ddot{y}^e \; \ddot{z}^e \,|\, \omega_{eb,x}^b \; \omega_{eb,y}^b \; \omega_{eb,z}^b \right]^T$$

Indoornavigation with Smartphones and Shoesensors

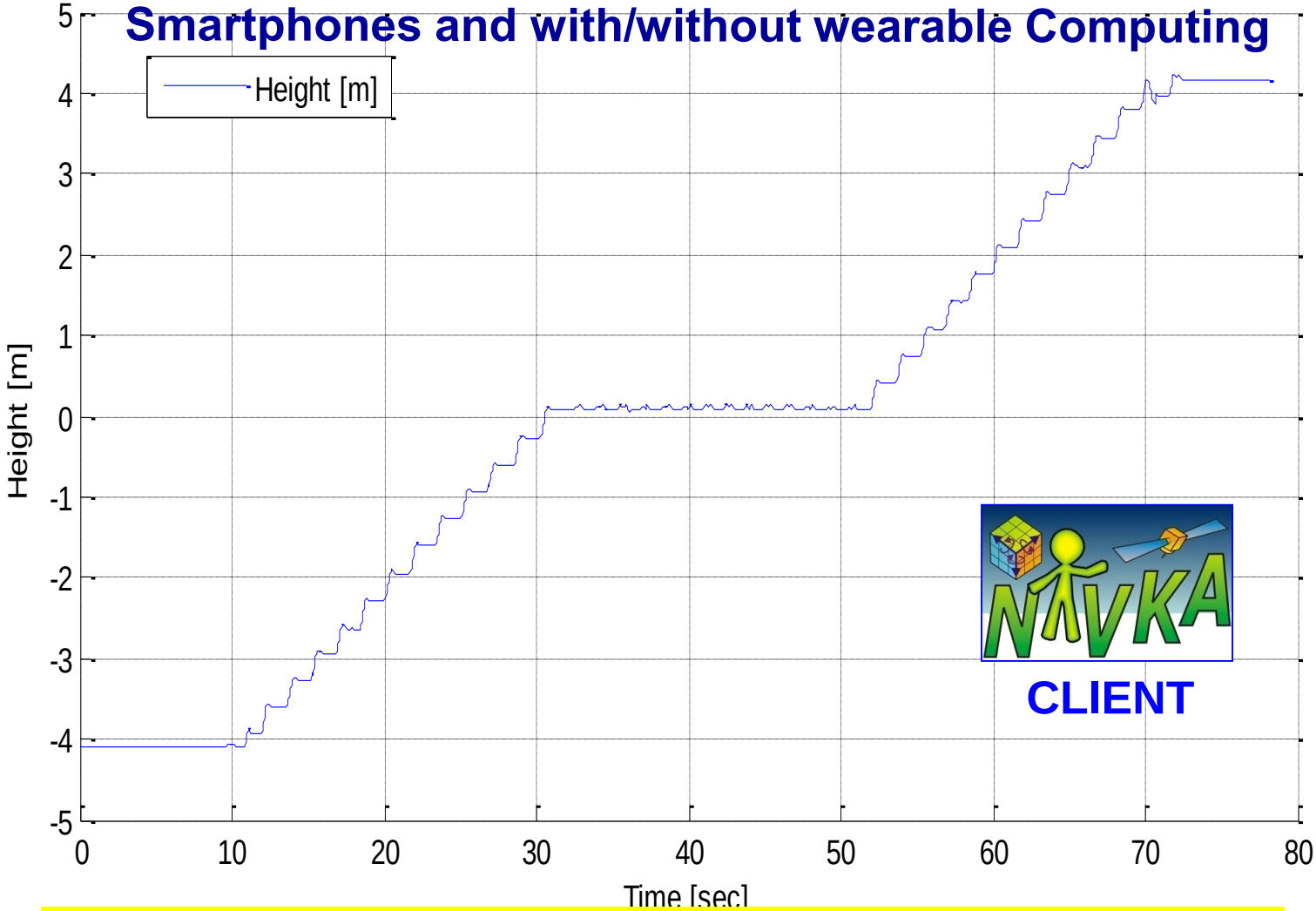


CLIENT



GNSS-Positioning Services – GIPS Users

Seamless Out- and Indoor-Navigation with Tablets, Smartphones and with/without wearable Computing



http://www.navka.de/index.php/en/publikationen-und-downloads-2

Reiner Jäger

GNSS-Positioning Services – GIPS Users

„3D-Kataster“ „GIS-LOD4“ (Level of Detail 4 „LOD4“), Berlin, Bayern, Baden-Württemberg (IKT 2020) and Russian Federation

http://www.navka.de/images/files/jaeger_geosiberia2014.pdf

Visualization at Server Site, e.g. IN GmbH Sphinx Open

Smartphone / Tablet CLIENT

Seamless Out- and Indoor-Navigation with Smartphones and LOD4 Models

"Virtual Markers"

$$u_i = cx + \left(\frac{r_{11} * (X_i - X0) + r_{12} * (Yi - Y0) + r_{13} * (Z_i - Z0)}{r_{31} * (X_i - X0) + r_{32} * (Yi - Y0) + r_{33} * (Z_i - Z0)}\right) * f$$

$$v_i = cy + \left(\frac{r_{21} * (X_i - X0) + r_{22} * (Yi - Y0) + r_{23} * (Z_i - Z0)}{r_{31} * (X_i - X0) + r_{32} * (Yi - Y0) + r_{33} * (Z_i - Z0)}\right) * f$$

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Hochschule Karlsruhe Technik und Wirtschaft (HSKA) IAF Institut für Angewandte Forschung (IAF)

THANK
YOU
THANK