



Federal Agency for
Cartography and Geodesy



Challenges of Regional Reference Frame Implementation

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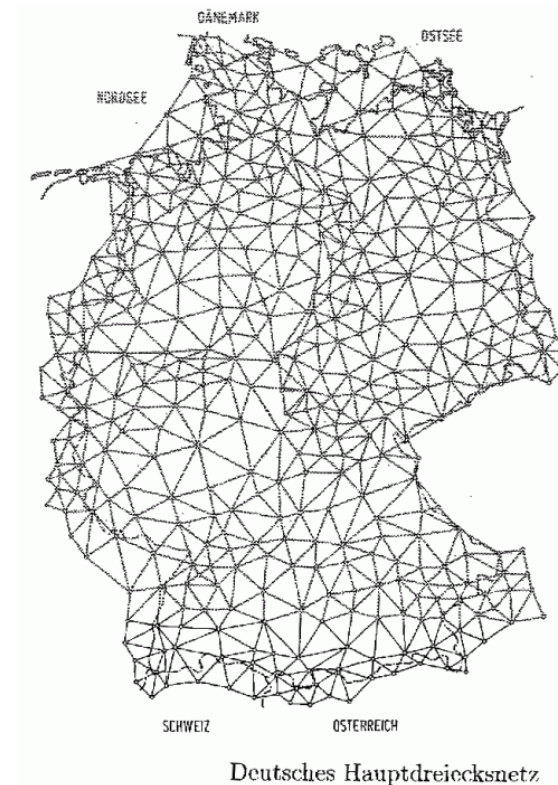


- Development of regional reference frames implementation practice



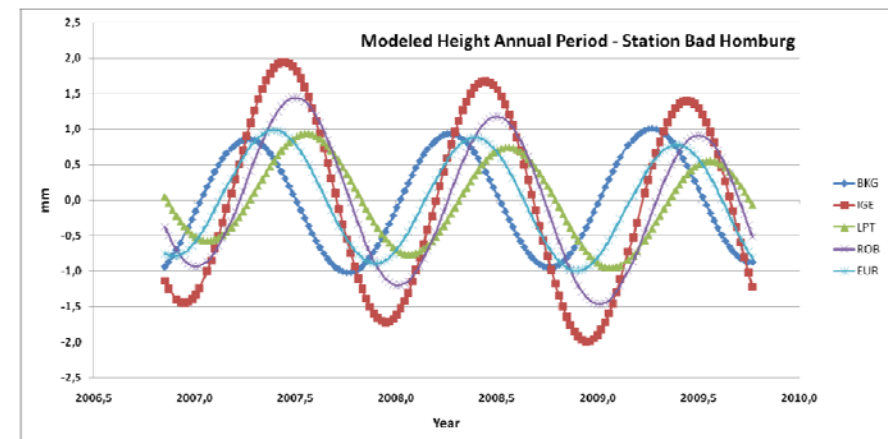


- Renewal of networks within decades
 - e.g., computation of “European Datum ED50” and “ED79” started since 1950



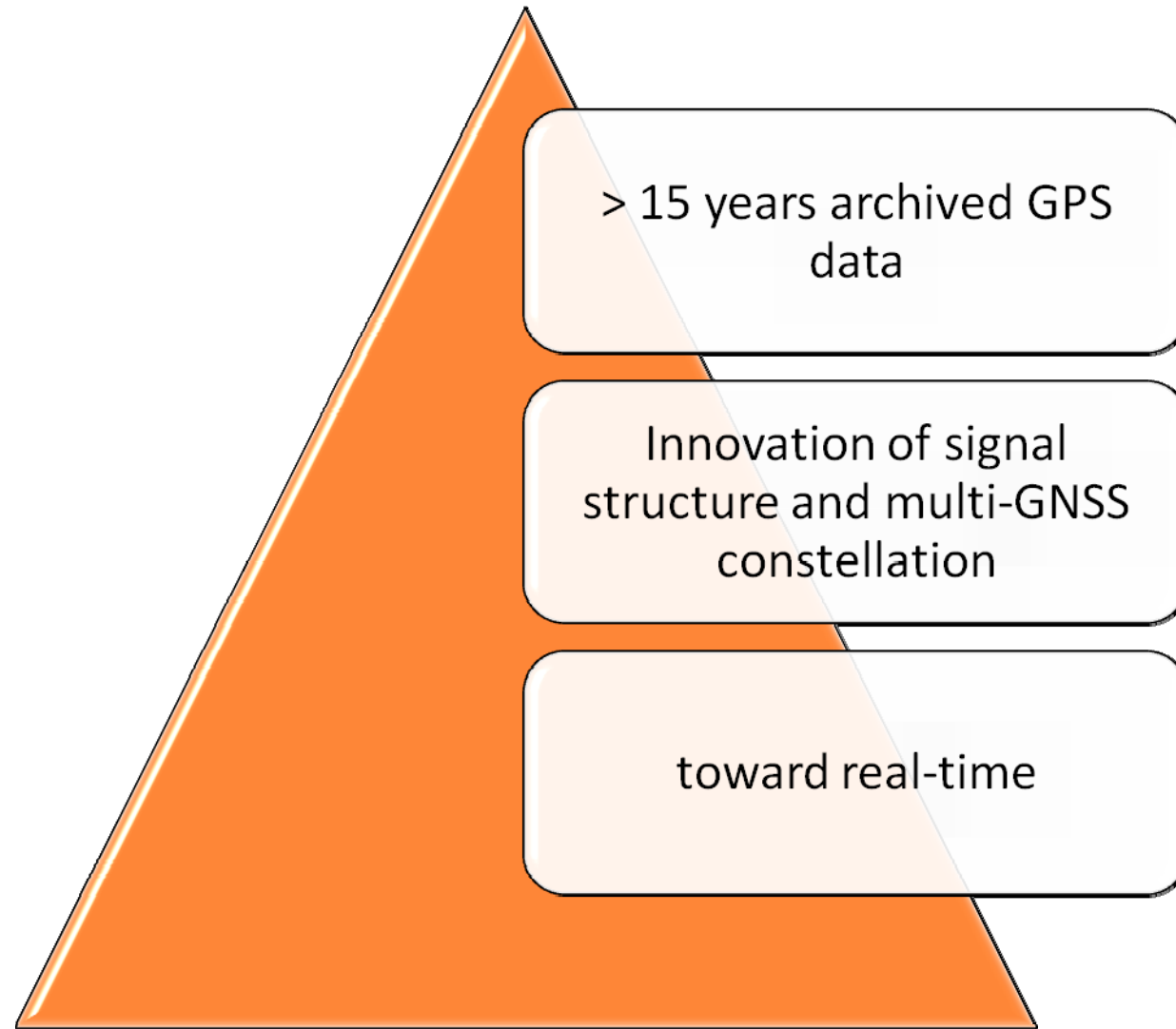


- Permanent tracking sites
 - establishment of EPN in 1995, global GPS sites since 1990
 - new infrastructure goes along with networks → GPS sites, data centers, analysis centers, central bureau
- Update of station coordinates at every week
 - "weekly" is core product today
 - "daily" and "hourly" optional for purpose of monitoring
- Generation of coordinate time series
 - station position and velocity
 - long-term stability, i.e., frame alignment and jump detection
 - tectonic movement
 - equipment changes





Today Challenges of Reference Frame Implementation



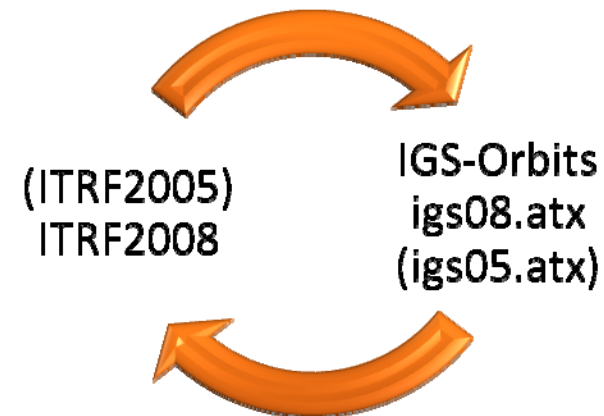


■ Model improvements

- model changes provoke inconsistency in product series
- antenna phase center variations for satellite and receiver
- consideration of numerical weather models in troposphere modeling (mapping function, ray tracing)
- consistent estimation of all relevant parameters (station coordinates, orbits, clocks, ERPs)
- updated model for station displacements due to ocean tidal loading

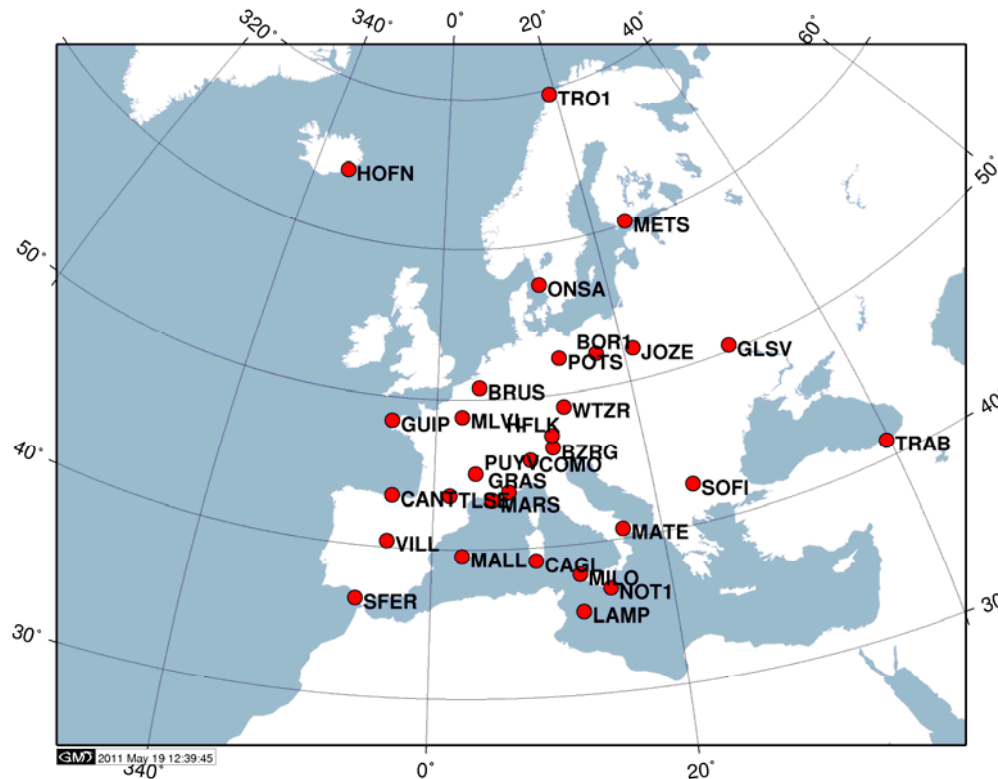
■ Global re-processing

- terrestrial reference frame
- satellite orbits and clocks
- satellite antenna offsets
- **iterative process**





Regional Re-Processing - EPN Repro1 Benchmark Test -



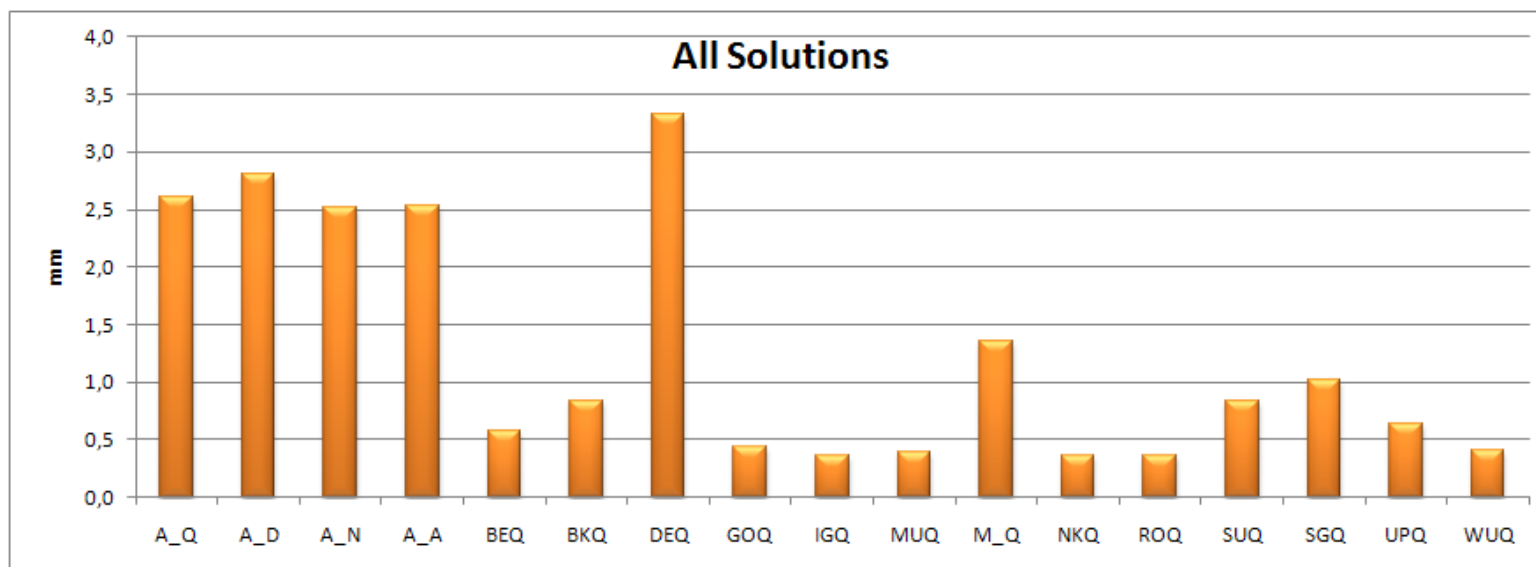
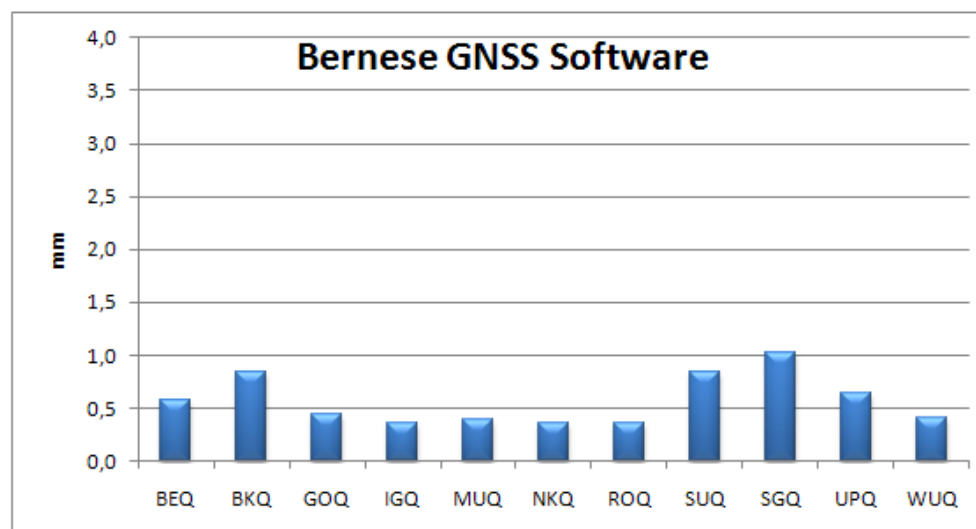
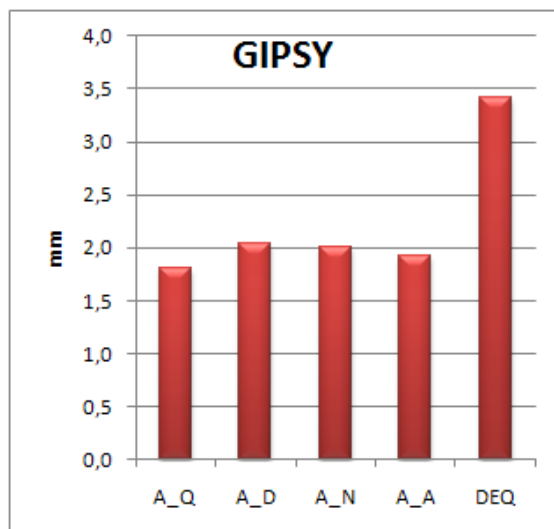
- Select a network of 30 sites.
- Identify a set of identical data (GPSWEEK 1381, July 2006).
- Apply the same PCV model.
- Any reprocessed product is permitted.
- Use the available software to your best knowledge.

Best case → The results are identical!
Expectation → Differences have to be explained by

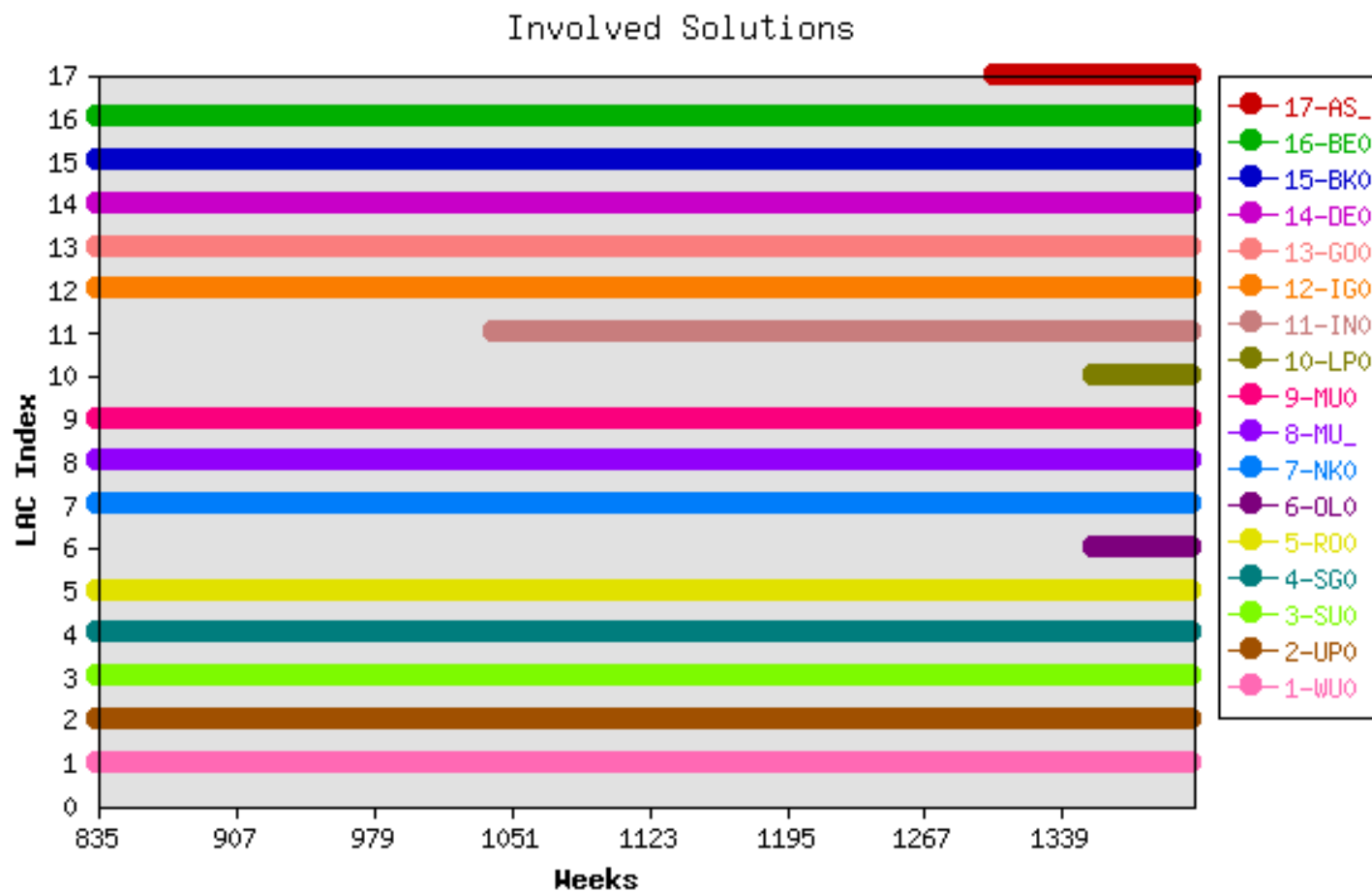
- Different strategies, models
- Impact by the software and the operator

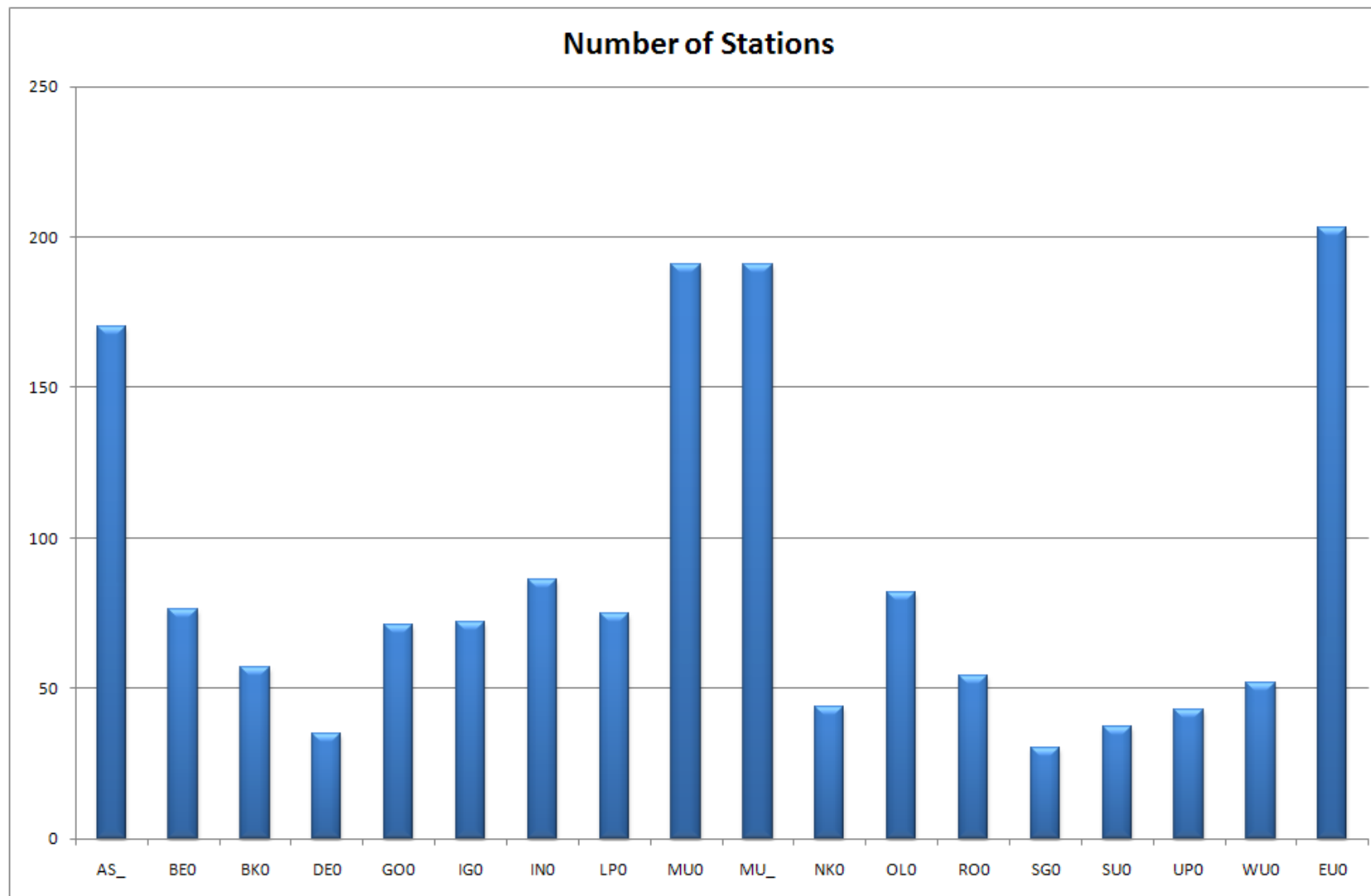


RMS Helmert Transformation (Benchmark Test)



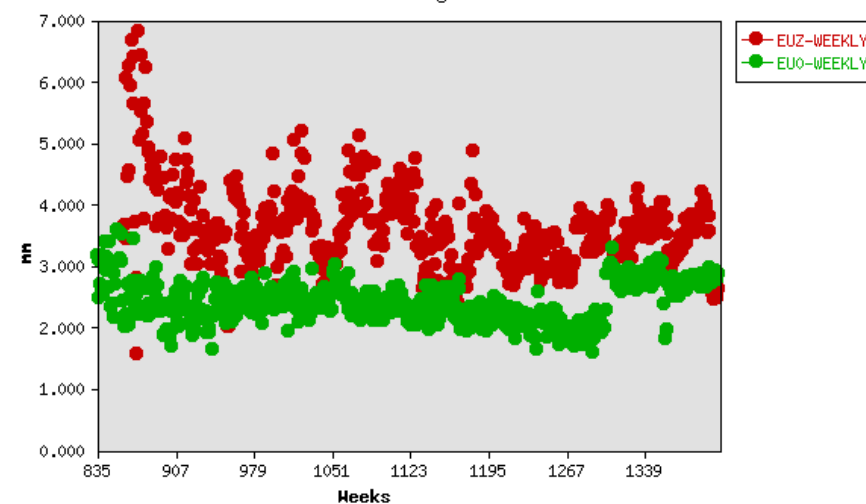
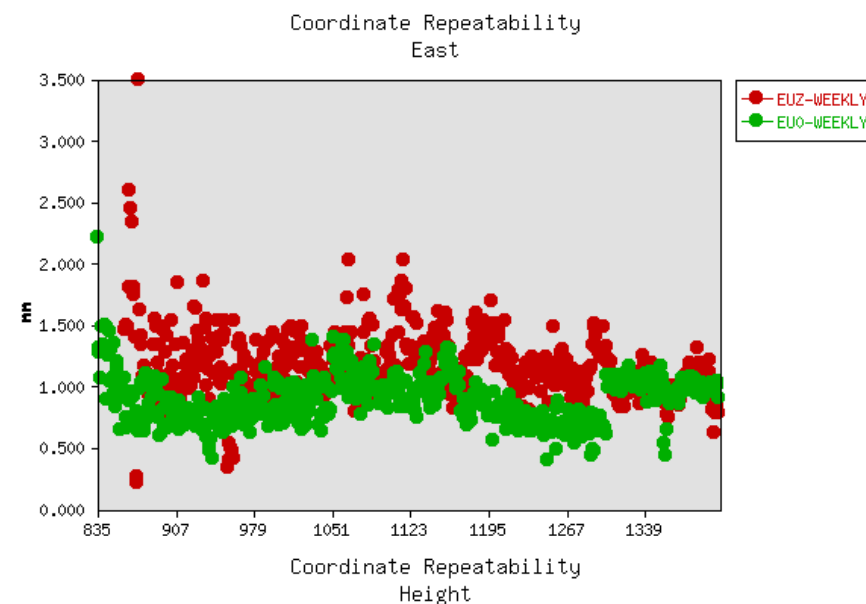
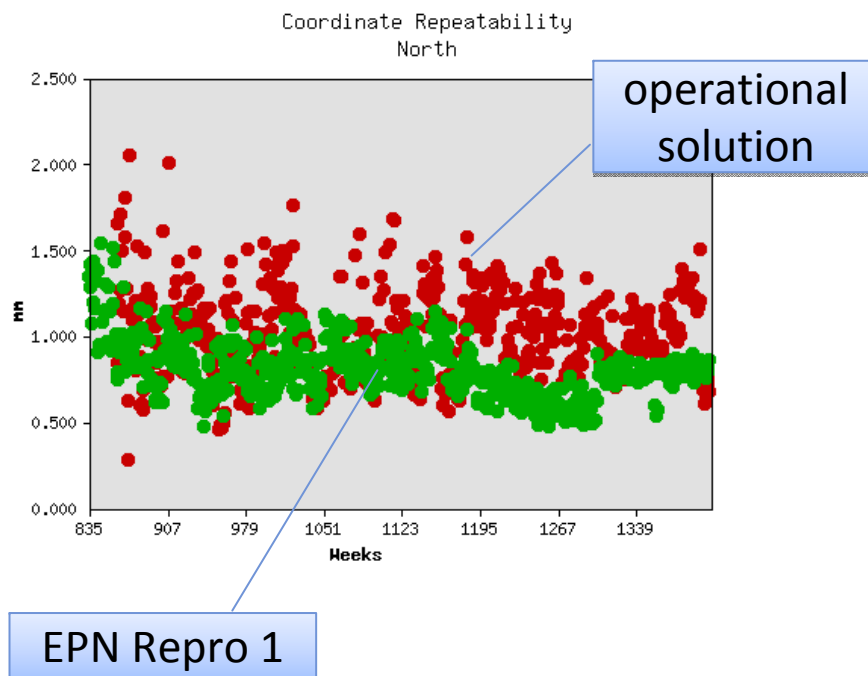
Actually Combined Weekly Solutions







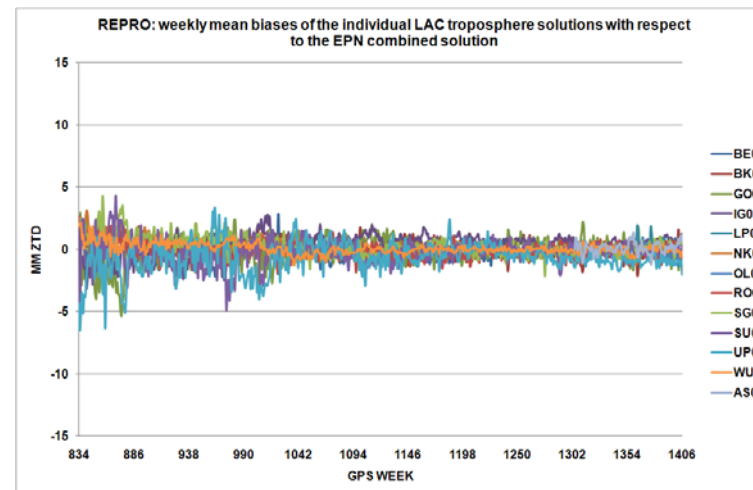
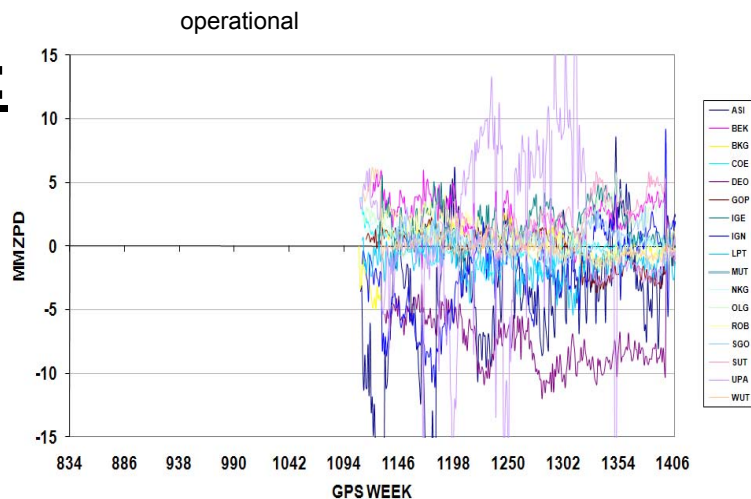
Consistency of LAC Contributions



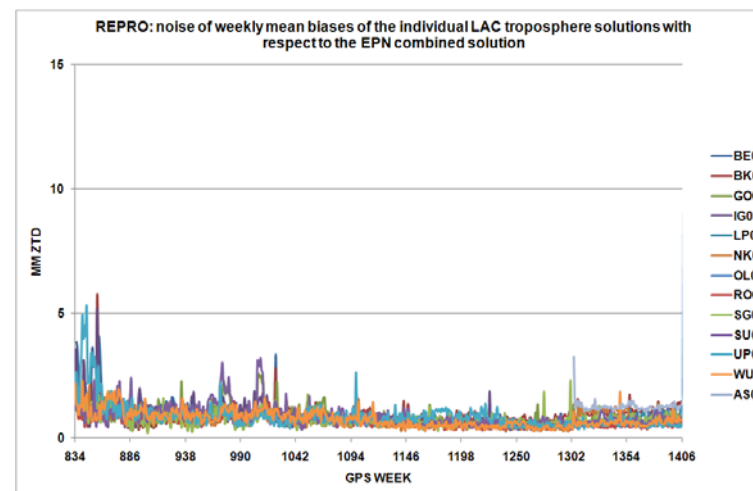
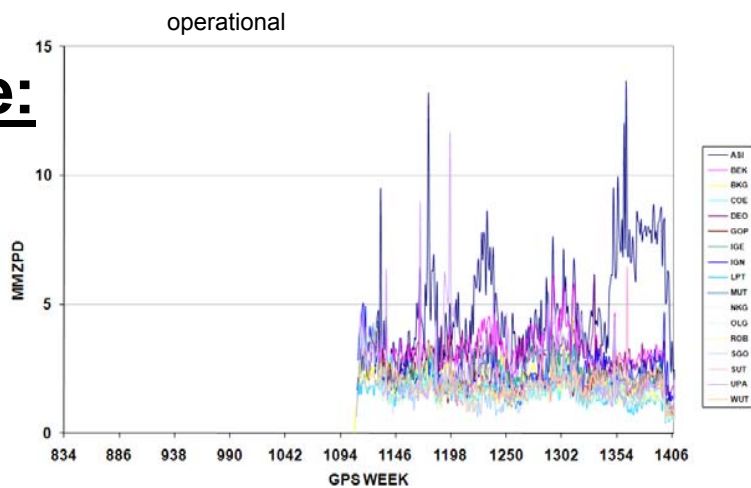


EPN-Repro1 Troposphere

Bias:

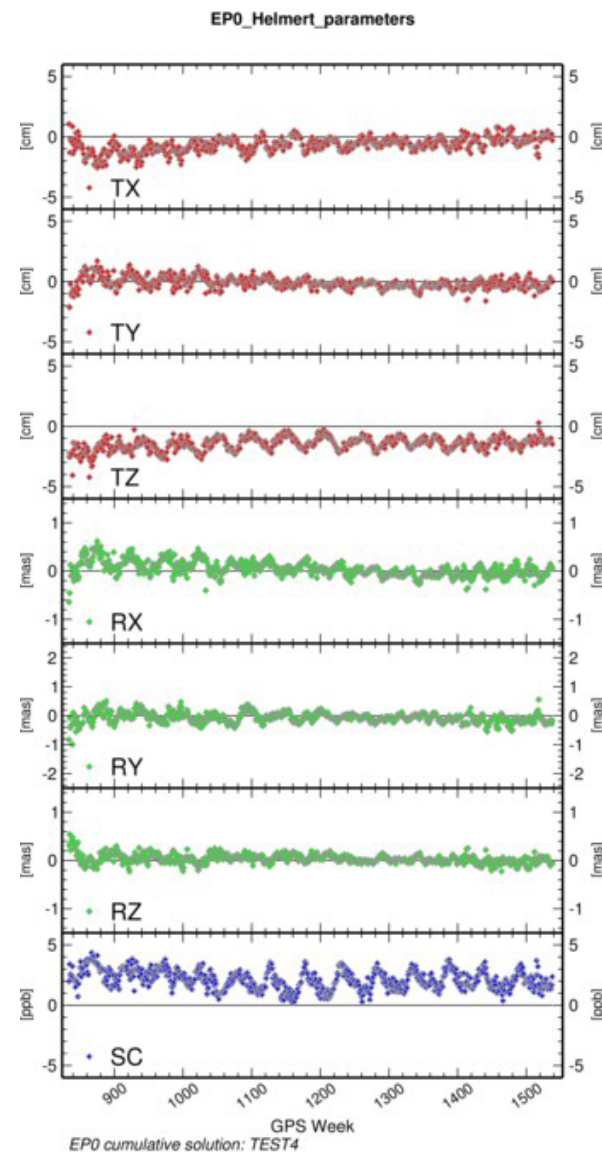
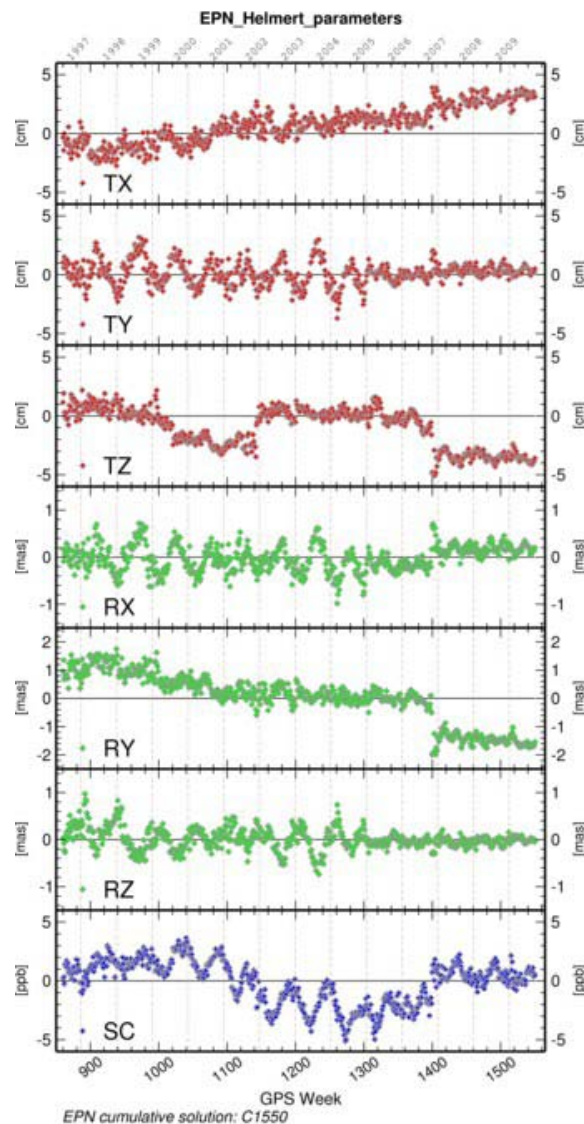


Noise:





ITRF2008 Cumulative: Helmert Transformation





Planned Re-Processing Actions - EUREF -

- Model update of analysis software
 - Analysis Centers using Bernese GPS Software will use version 5.2
 - recent version of GIPSY and GAMIT
- Use new re-processed satellite orbits and clocks
 - IGS repro 2 if available (based on IGS08 reference frame, igs08.atx calibration numbers and IERS Convention 2010)
 - re-processed CODE orbits alternatively
- Extension by global sites
 - IGS core-network (91 stations) proposed
- Contribution to IGS Tide Gauge Benchmark Monitoring (TIGA)
 - re-processing scheduled for 2012



New Signals and Multi-GNSS Constellation



- Add GLONASS, Galileo, COMPASS, QZSS,...
 - is a core issue of ICG
 - EUREF accepted GLONASS observation in analysis since 2006
- Biases and calibration
 - inter-system
 - inter-channel
 - inter-frequency
 - Workshop of IGS-BCWG in Berne, Switzerland in January 2012
- Format issues
 - RINEX 2 vs. 3 (draft 3.02 including QZSS)
 - RTCM to RINEX conversion
 - RTCM HP Multiple Signal Messages (MSM)



Multiple Signal Messages (MSM) - Draft RTCM Standard -

Generate GNSS receiver
observables in a universal manner

MSMs are designed to
cover

Message
organization for

Maximum
compatibility
with RINEX-3

Universality
for all existing
and future
GNSS signals

No ambiguity
in
interpretation

Fully
deployed
GNSS

GNSS
transition
period



Galileo E5-AltBOC Code-Plus-Carrier (CPC)

Observable:
$$\frac{\rho + \phi}{2} = r - \frac{\lambda}{2} \cdot N + \left(\frac{c_2}{4 \cdot f^3} + \frac{c_3}{3 \cdot f^4} \right)$$

Noise:
$$\sigma_{CPC} = \frac{1}{2} \cdot \sqrt{\sigma_{\rho}^2 + \sigma_{\phi}^2} \approx \frac{\sigma_{\rho}}{2}$$

ρ : code range measurement [m]
 ϕ : carrier phase measurement [m]
 r : geometrical distance [m]
 λ : wavelength of carrier signal [m]
 N : ambiguity term [cycles]

eliminates
ionospheric
delay

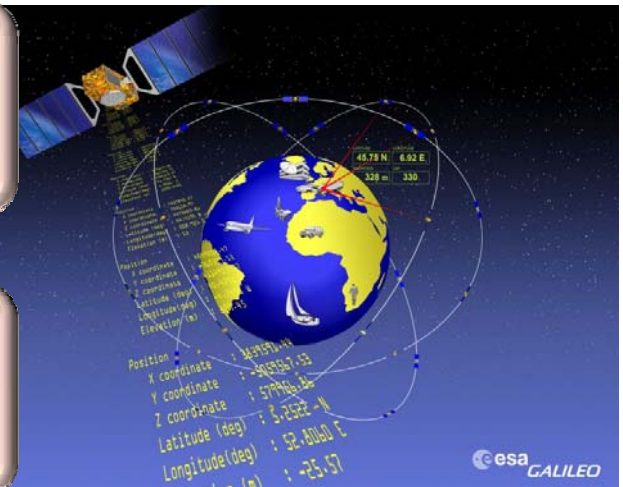
- higher order remain

ultra-low
multipath

- 90 MHz bandwidth

half the noise
of code range

- cm level

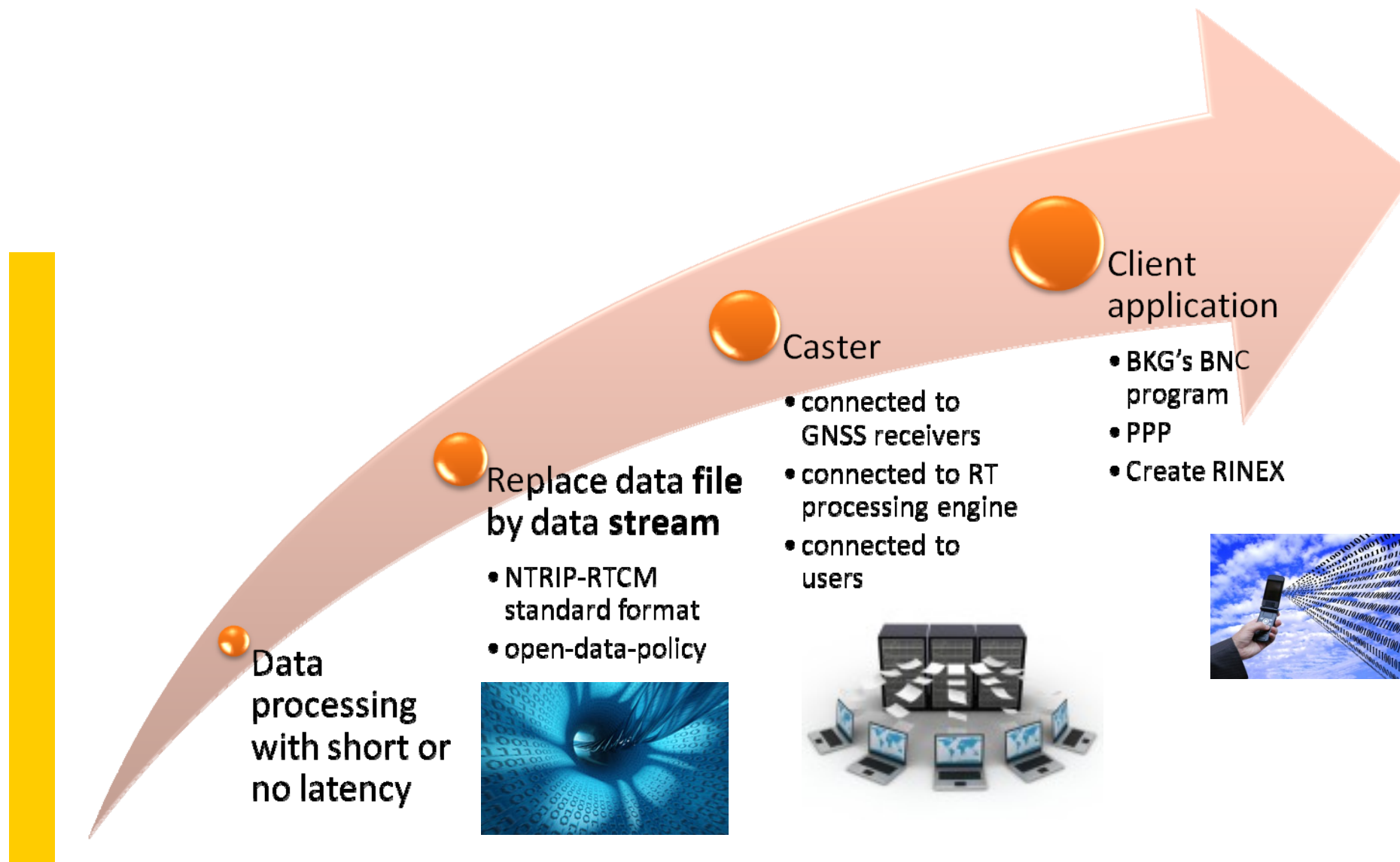


Reference:

SX5 Workshop held on
18 October 2011
University FAF Munich
Germany



Towards Real-Time - The Concept -





Local and regional RTK-Services

- for the most part
commercial

Global PPP approach

- IGS Real Time Pilot Project
- Providing real time satellite
orbits and clocks
- open data policy

Europe

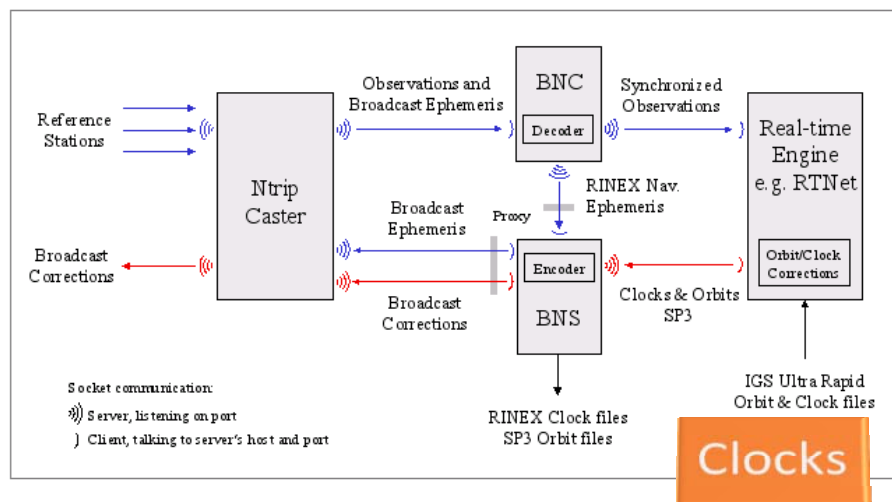
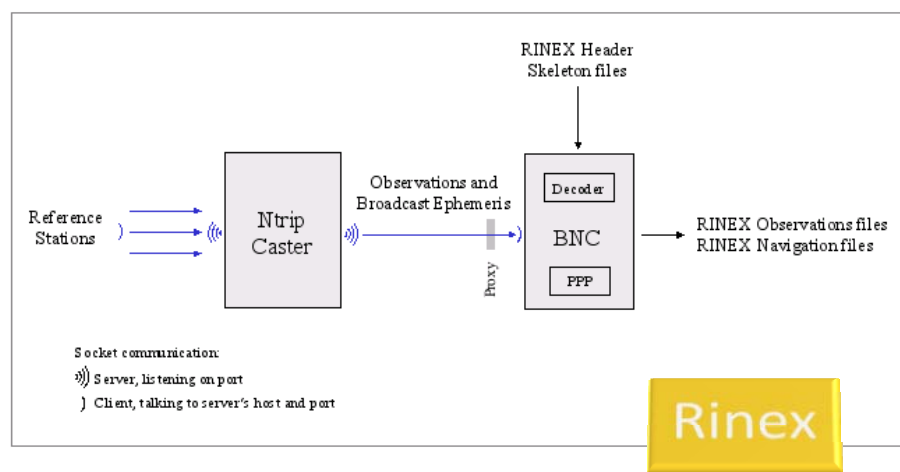
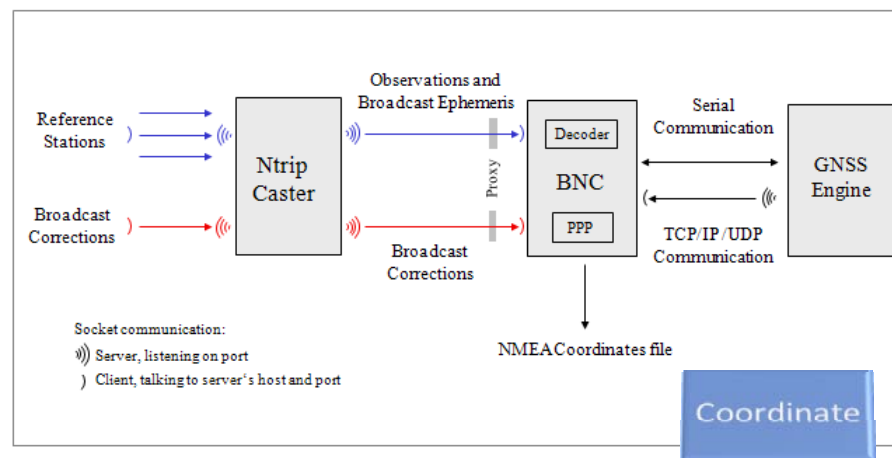
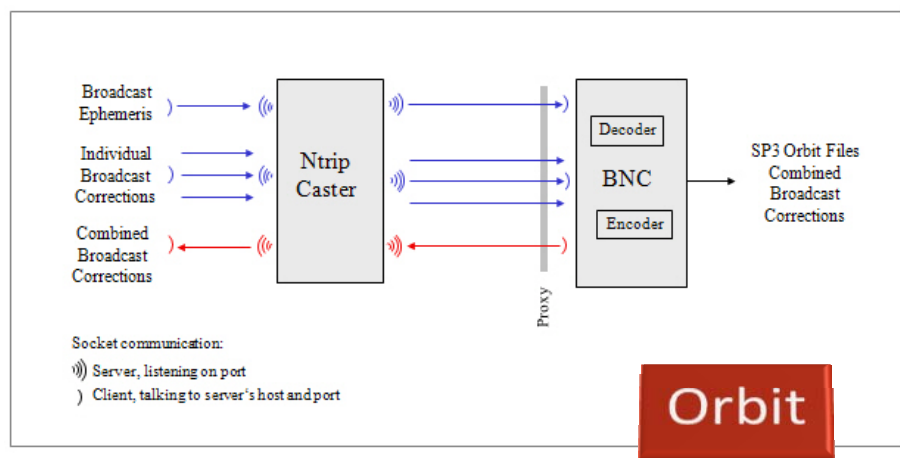
- EUREF-IP
- Providing real time
observation and products

EUREF Permanent Tracking Network
Stations belonging to the EUREF-IP network



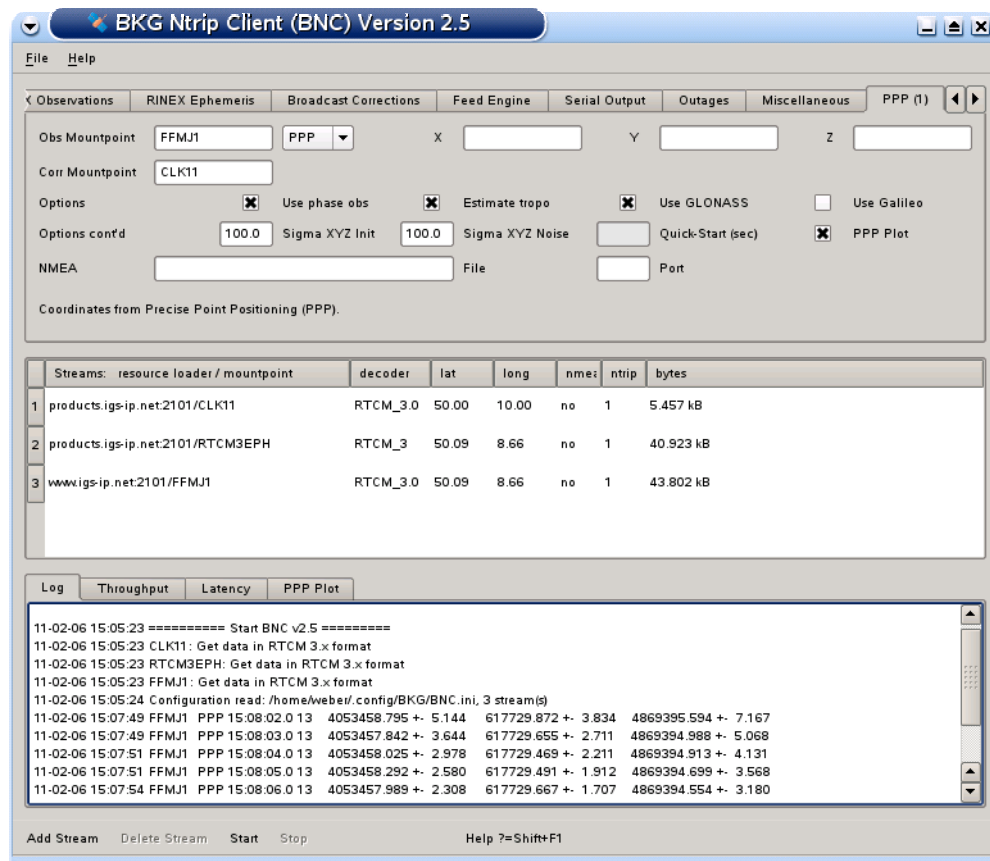


Real-Time Applications - Examples for BNC-



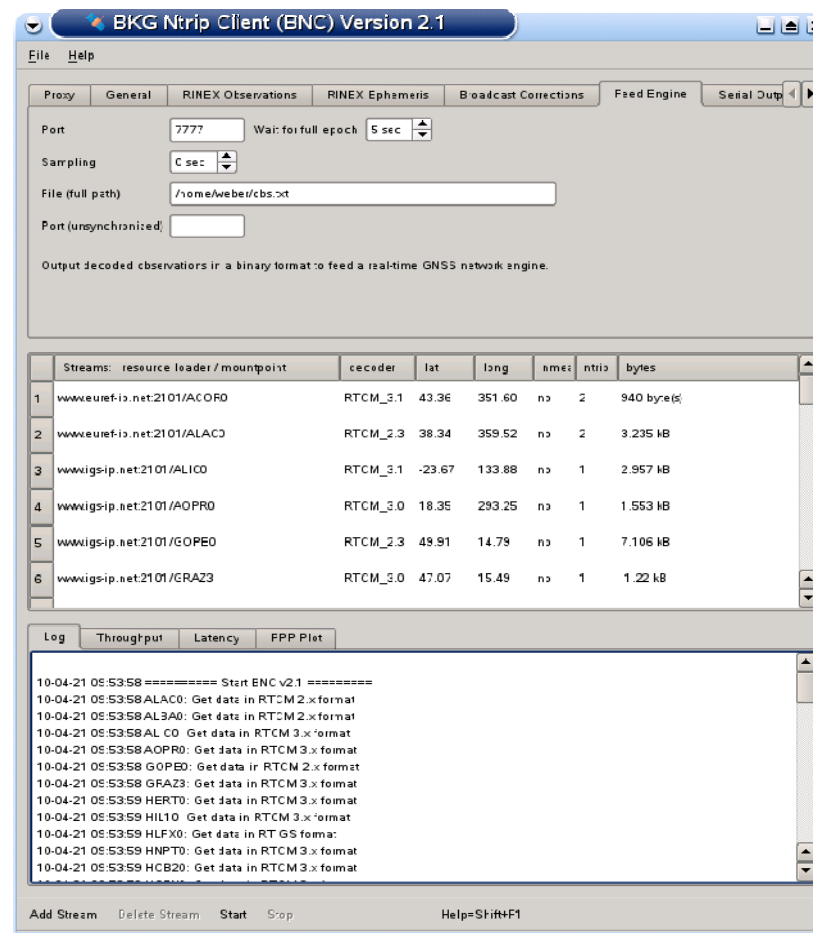


BNC Performance



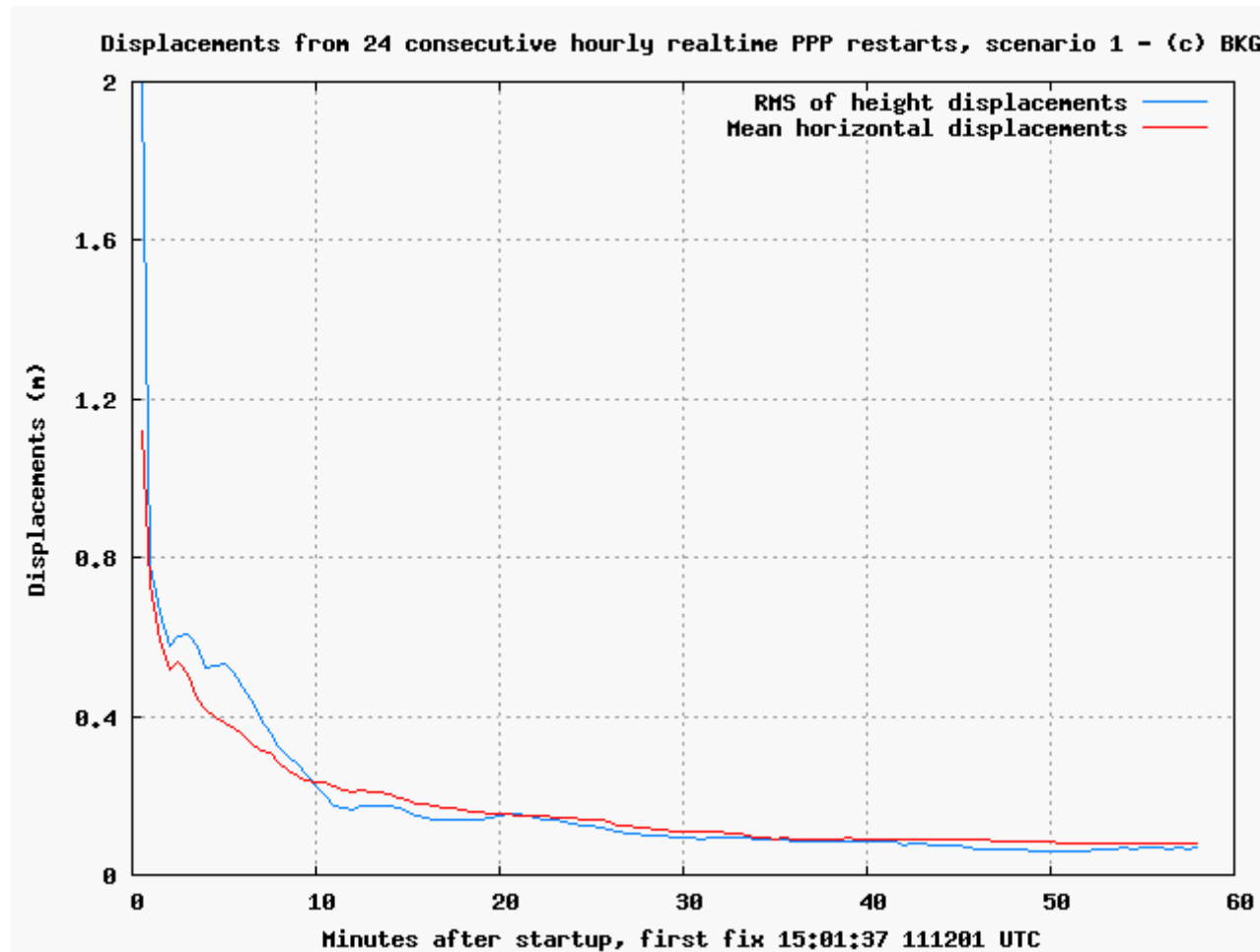
PPP-Mode

- stream of orbit, clock and receiver data



Feed Engine

- stream synchronization for RT engine





Real-Time - Recent Developments -

- Combination of various RT clock solutions and streaming of combined clock product
- Definition of RTCM HP MSM to support all GNSSs
- Definition of RTCM State Space Representation, e.g. Troposphere information in real-time
- Ambiguity resolution on zero-difference level, e.g. , for instantaneous PPP solution on the cm-level
- Handling of phase biases





Access to Reference Frames - Why fundamental ?

Navigation Solution may not satisfy the user needs

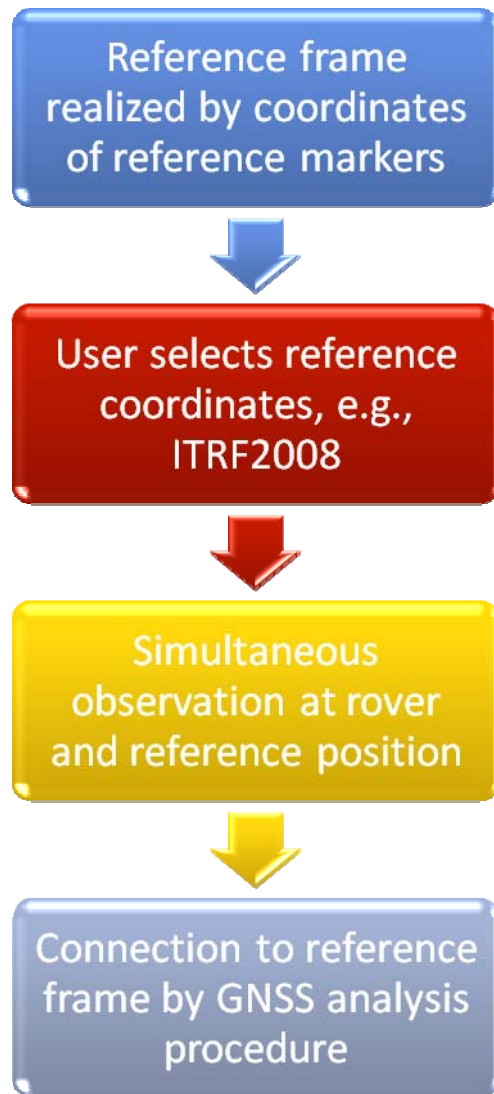
- broadcasted WGS84 satellite orbit and clocks applied

Existing demand of “cm “or even “sub-cm “ accuracy in a specified reference frame

Augmentation of satellite signals is required and combined with the question, how to access the reference frame in a suitable way



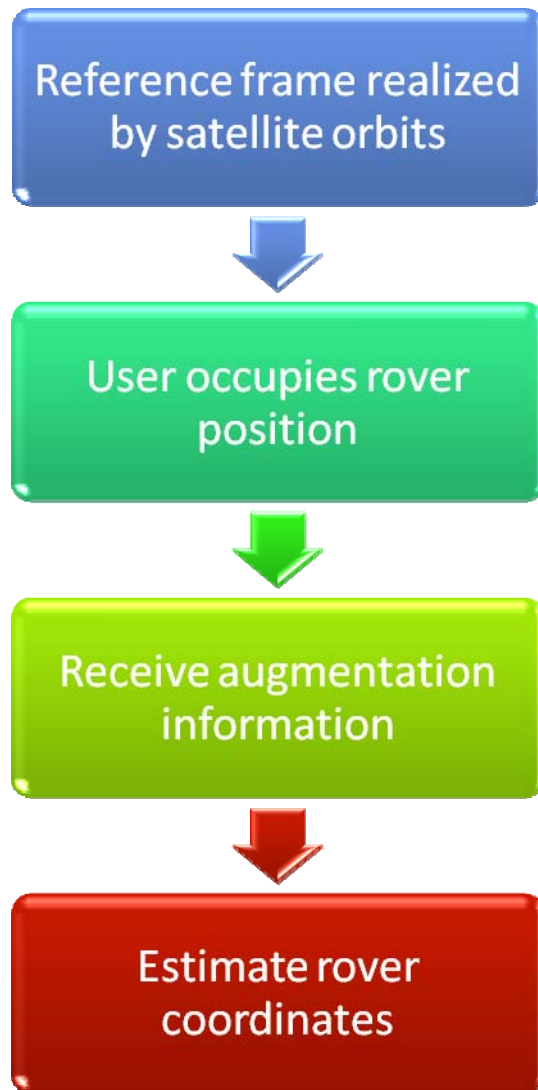
Access to Reference Frames - Fixed Terrestrial Coordinate List -



- User defines reference frame during GNSS analysis
 - easy to change the selected reference frame



Access to Reference Frames - Fixed satellite Coordinates -

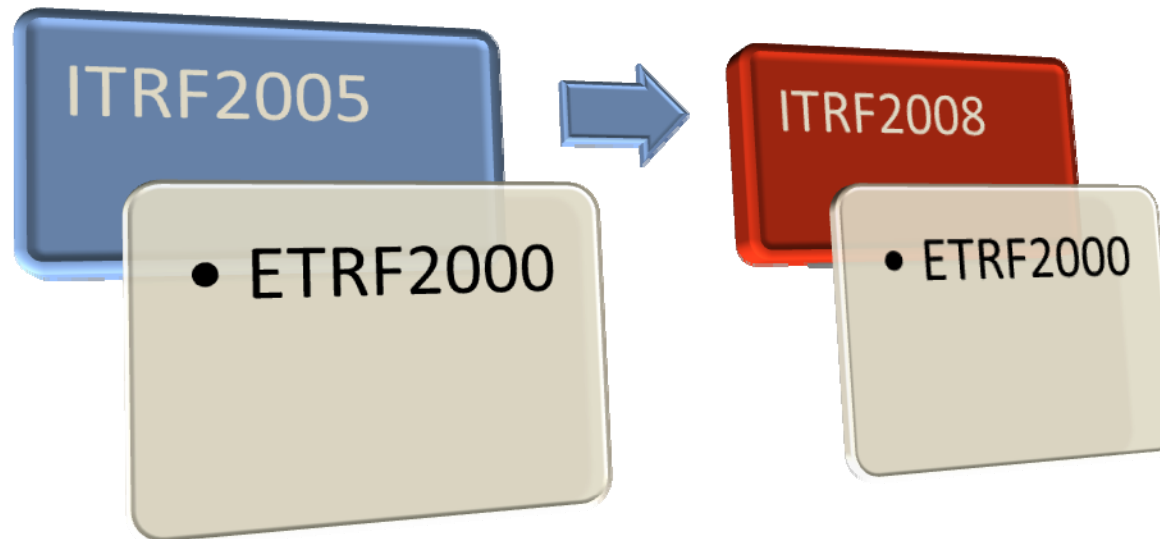


- RTK
 - local
 - PPP
 - local or global
 - real-time or post processing
 - Transformation into requested reference frame
 - transformation of satellite orbits (and clocks) → service provider
 - transformation of rover coordinates on client site → user
- Users like this approach to access the RF



Maintenance of Regional Reference Frames

- Movement of surface points caused by
plate tectonics, earthquakes, post-glacial uplift, ...
- Coordinate comparison for 5 epochs:
1995.0, 2000.0, 2005.0, 2010.0, 2015.0
(ITRF velocities applied)





ETRF2000 (1) vs ETRF2000(2)

Epoch	RMS Trans.	RMS North	RMS East	RMS UP	TX mm	TY mm	TZ mm	T North mm	T East mm	T Up mm
1995	6.4	1.8	2.7	11.2	-	-	-	-	-	-
	2.7	1.5	1.9	4.0	-5.7	1.0	-8.3	-0.9	2.1	-9.8
2000	4.2	0.8	1.7	7.5	-	-	-	-	-	-
	1.8	0.8	1.1	2.8	-4.1	0.6	-5.3	-0.3	1.4	-6.5
2005	2.5	0.5	1.0	4.5	-	-	-	-	-	-
	1.7	0.5	0.5	2.8	-2.5	0.3	-2.2	0.5	0.7	-3.2
2010	2.4	1.3	1.2	4.0	-	-	-	-	-	-
	2.4	0.9	1.2	3.9	-0.9	-0.1	0.8	1.2	0.0	0.1
2015	4.0	2.3	2.2	6.7	-	-	-	-	-	-
	3.5	1.5	2.1	5.5	0.8	-0.6	3.9	2.0	-0.7	3.4

- Significant translation before and after epoch 2010.0
- Trend for translation in height, minimum at epoch 2010.0



Maintain “Static” ETRS89 Coordinates in Europe, e.g. Official National Coordinates



Repeat and re-define the realization of the national reference frame

- Define „lifetime“ of coordinates, A. Caporali et al., 2011

Apply local velocities to extrapolate the reference coordinates to the epoch of observations

- Mostly not accepted by nation mapping agencies

Apply velocity model of the surface area to extrapolate observed coordinates to the reference epoch

- Determine and provide surface model to the users



Perspectives 1/3 - Identification of User Groups and User Needs



- Conclusions for regional reference frame implementation
 - Today's range of products: Approaches from cm/dm-level in RT to few mm in long-term
- High-end users
 - ☒ mm – level
 - ☒ science
 - ☒ global change
- Mass market
 - ☒ satisfied with few cm or even less accurate
 - ☒ GIS applications
 - ☒ may request monitoring of reliability, vulnerability ?





- Contribution of regional reference frames to global Earth monitoring
 - IGS Tide Gauge Monitoring (TIGA) and expansion of EPN by global stations
 - Tide gauge time series corrected by GPS
- GEO/GEOSS, GGOS
 - Contributions from regional GNSS networks for densification



Perspective 3/3 - Upgrade the Tracking Networks to GNSS

- Important to foster developments of GNSS applications
- IGS M-GEX experiment launched
- XXth EUREF Symposium in Gävle, June 2 – 6, 2010, Resolution No. 3
 - “... Encourages members of EUREF to provide the necessary infrastructure, data and analysis from these new GNSS developments...”
- CONGO network

GNSS DATA CENTER

User: Password:

Home About Us GNSS/Files NTRIP Links

Project Filter: ALL

GNSS/Files > Data Archive > File Browser

File-Information of ven13410.11d.Z

Station:	Venezia
Receiver:	LEICA GRX1200GGPRO
Antenna:	LEIAT504GG NONE
Received:	2011-12-08 00:48:07
Filename:	ven13410.11d.Z
Filepath:	archive/EUREF/obs_v3/2011/341/
Filesize:	540.51 kB
Number of Observations:	
Maximal Observations:	

Info

Click on the folder's name at the left hand side and select the file you are interested in. A window will open, which shows detailed information about the file. Then you have the possibility to download the file directly, add it to your cart, look into the file or show the station details to the station, if the selected file is a



COoperative Network for GIOVE Observations

- Global real-time tracking network for GPS and GIOVE signals
- Established in 2009, currently 21 stations
- O'Higgins added in 2010

Jointly operated by



+ local station hosts

