Report on the EPN Analysis

Heinz Habrich

EPN Analysis Coordinator

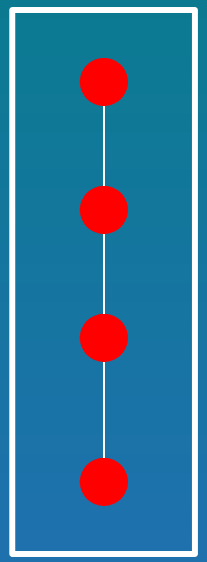
Federal Agency of Cartography and Geodesy,
Frankfurt, Germany

Scope

„EPN Analysis Aspects“:

- Strategy for processing of observations from EPN stations
- Combination of products of the Local Analysis Centres (LACs)
- Generation of multi-year network solution
- Representation of analysis products to other parties

Introduction



- Changes since 4th LAC Workshop
- Upcoming modifications of processing strategies
- Next multi-year EPN network solution
- Points of discussion
  - Geocentric datum definition
  - Daily combined solutions
  - Evaluation of real-time and near real-time strategies
  - EPN upgrade to GNSS
  - EPN re-processing

EPN Processing History

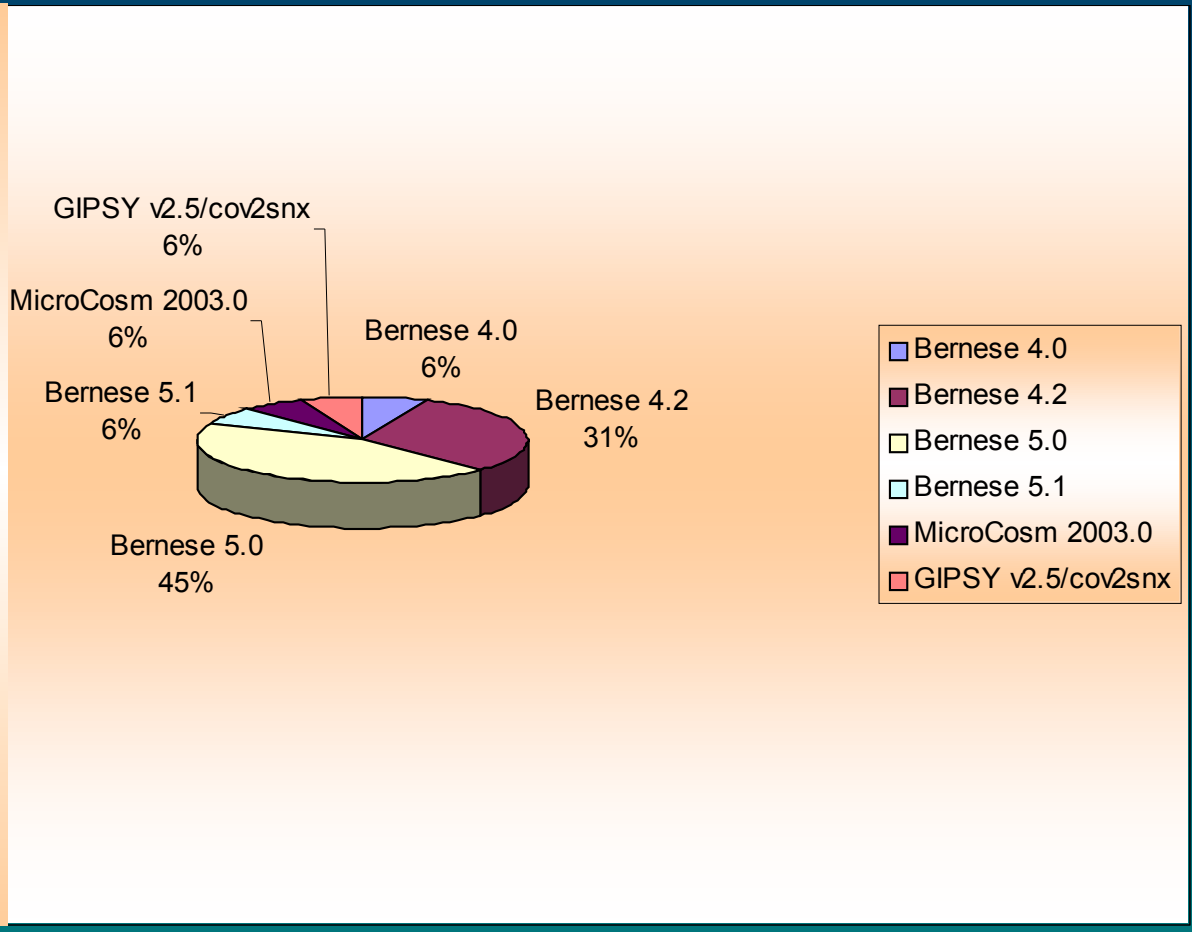
18 – 19 September 2003	■ 4th EPN Local Analysis Center Workshop, Graz, Austria ■ Most agreements concerning analysis modifications require Bernese GPS Software 5.0.
2 – 5 June 2004	■ EUREF 2004 Symposium, Bratislava, Slovakia ■ presentation of a prototype of the new EUREF product catalogue (including analysis results)
26 Dec 2004 (week 1303)	■ ADDNEQ2 of Bernese 5.0 used for sub-network combination ■ Minimum constrained datum definition ■ Termination of multiyear solution and densification of IGS network
20 February 2004 (week 1311)	■ Number of reference stations for EPN weekly combination extended according to IGS reference list (11 expanded to19).
3 April 2005 (1317)	■ LPT uses now Bernese GPS Software 5.0
10 April 2005 (1318)	■ WUT uses now Bernese GPS Software 5.0

EPN Processing History (Cont.)

17 April 2005 (week1319)	■ Update of combination scheme of the sub-network combination with Bernese 5.0, Ref. EPN-LAC Mail 0528 (normalised co-variance factors). Investigation of new scheme continues ■ BKG uses now Bernese GPS Software 5.0
24 April 2005 (week 1320)	■ GOP uses now Bernese GPS Software 5.0
1 May 2005 (week 1321)	■ NKG uses now Bernese GPS Software 5.0
22 May 2005 (week 1324)	■ UPA uses now Bernese GPS Software 5.0
29 May 2005 (week 1325)	■ ROB LAC uses now Bernese GPS Software 5.0
1 – 4 June 2005	■ EUREF 2005 Symposium, Vienna, Austria

LAC Analysis Software week 1352

ASI	MicroCosm 2003.0
BEK	Bernese 4.2
BKG	Bernese 5.0
COE	Bernese 5.1
DEO	GIPSY v2.5/cov2snx
GOP	Bernese 5.0
IGE	Bernese 4.2
IGN	Bernese 4.2
LPT	Bernese 5.0
NKG	Bernese 5.0
OLG	Bernese 4.2
ROB	Bernese 5.0
SGO	Bernese 4.2
SUT	Bernese 4.0
UPA	Bernese 5.0
WUT	Bernese 5.0



Analysis Scheme for Bernese GPS Software Version 5.0

- Use RNX2SNX PCF as default
- Set elevation cut-off angle to 10°
- Disable estimation of tropospheric gradients
- Use unified ocean loading coefficients as provided by EPN CB and AC

Weekly Combination Scheme

- Conversion of SINEX LAC solutions into normal equations (NEQs)
- NEQs stacking
- Automatic reference station check
- Manual consistency check for week
- Manual continuity check from 7 week NEQ stacking
- Submission of summary and solution files

Public Products from Weekly Combination

- Announcement by EUREF-Mail
- Free server-access at BKG and CDDIS
- Files:
  - EURwwww7.CRD (ITRF2000 Coord.)
  - EURwwwwE.CRD (ETRF Coord.)
  - EURwwww7.SNX (SINEX
  - EURwwww7.SUM (Summary)
- Submission of sub-network solution to IGS TIGA Pilot Project

Products from Weekly Combination in EUREF Product Catalogue

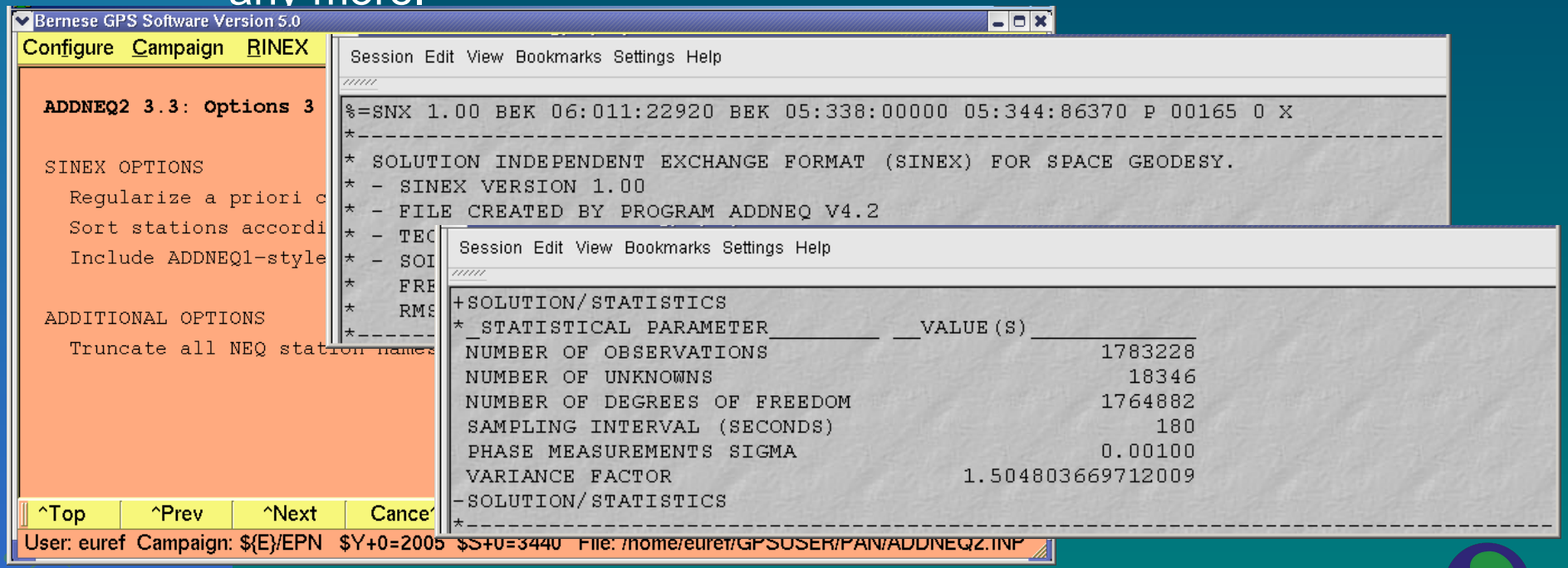
- Prototype at http://igs.ifag.de/euref

EUREF Product Catalogue List

Details	Product No.	Product	Class	Sub-Class	Accuracy	User Profile	Latency	Geodetic Technique	Updates	Availability	Reference Frame	Certification	Validation	Registry
Select	1	Definition of a Coordinate Reference System for Europe, the ETRS89	Reference Systems and Frames	Definition	1 cm	cm accuracy	-	-	-	public	-	-	-	-
Select	5	Weekly EPN coordinates	Station	Coordinates	0.5 to 1.5 cm	cm accuracy	3 weeks	GNSS	weekly	public	ITRF	-	-	-
Select	6	Multi-year solution of EPN station	Station	Coordinates	0.5 - 1.5 cm	cm accuracy	some years	combined	some years	public	ITRF	-	-	-
Select	20	troposphere parameter for EPN stations	Geophysics	Troposphere	-	cm accuracy	3 weeks	GNSS	hourly	public	-	-	-	-
Select	21	Inconsistencies from time series	Geophysics	Geodynamic	-	cm accuracy	-	GNSS	weekly	public	-	-	-	-

Statistics in Weekly SINEX Files from LACs

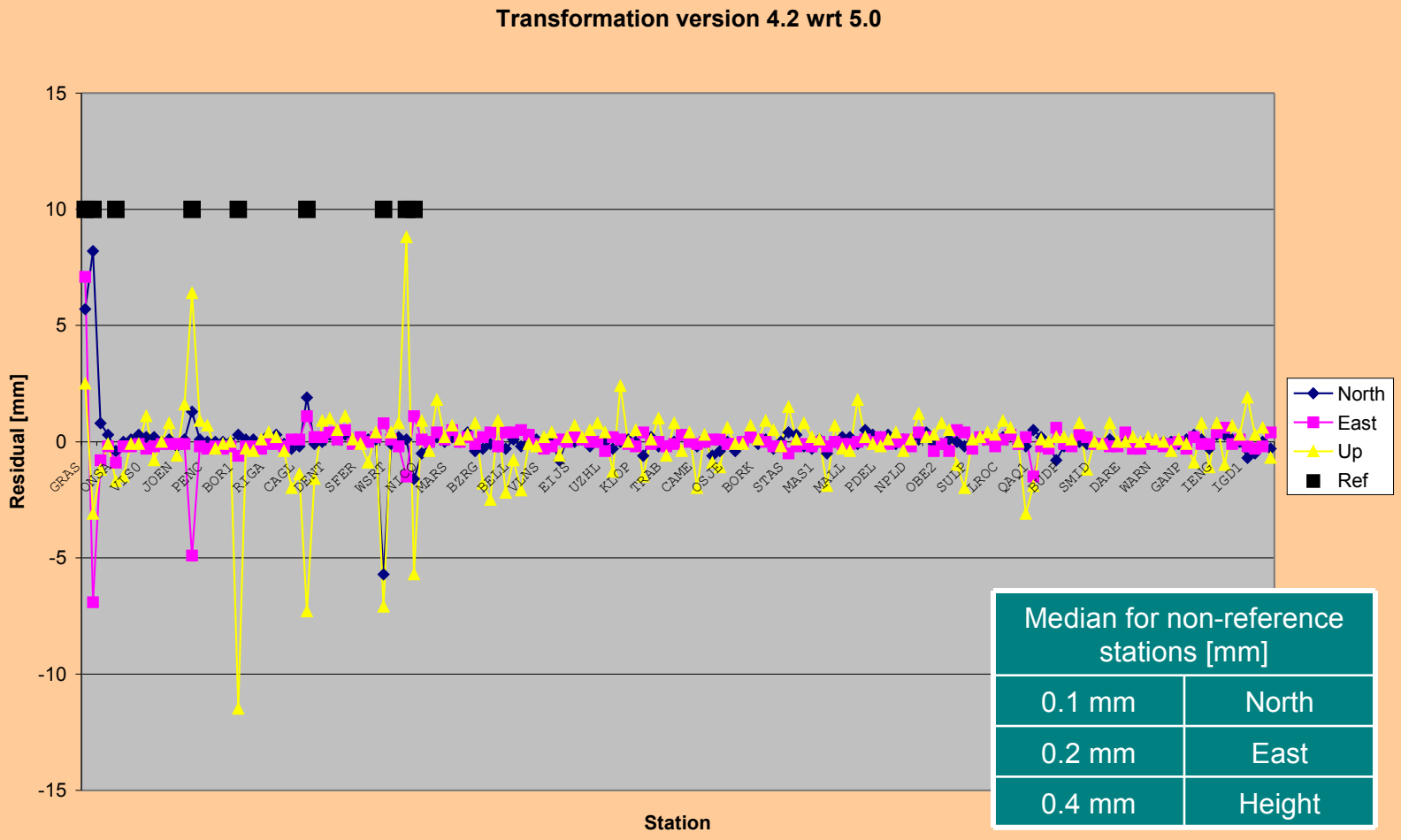
- Generation of „ADDNEQ1 style statistic block“ in the sub-network solutions is still possible with Bernese 50, but no longer used.
- Station coordinates are introduced as observations into the combination and not the original number of satellite observations any more.



Note

- The EPN LACs agreed since the operation of the EPN to use a special „statistic block“ in the head of the SINEX files of sub-network solutions.
- The sub-network combination procedure considered the „EPN statistic block“ in the past.
- The creation of this statistics in SINEX files is continuously supported by the ADDNEQ2 programme of Version5.0, but it is no longer requested in the sub-network combination.
- The SINEX files include today a „+ SOLUTION/STATISTICS“ block.

Helmert Transformation, Week 1302
- *Verification of New Combination* -

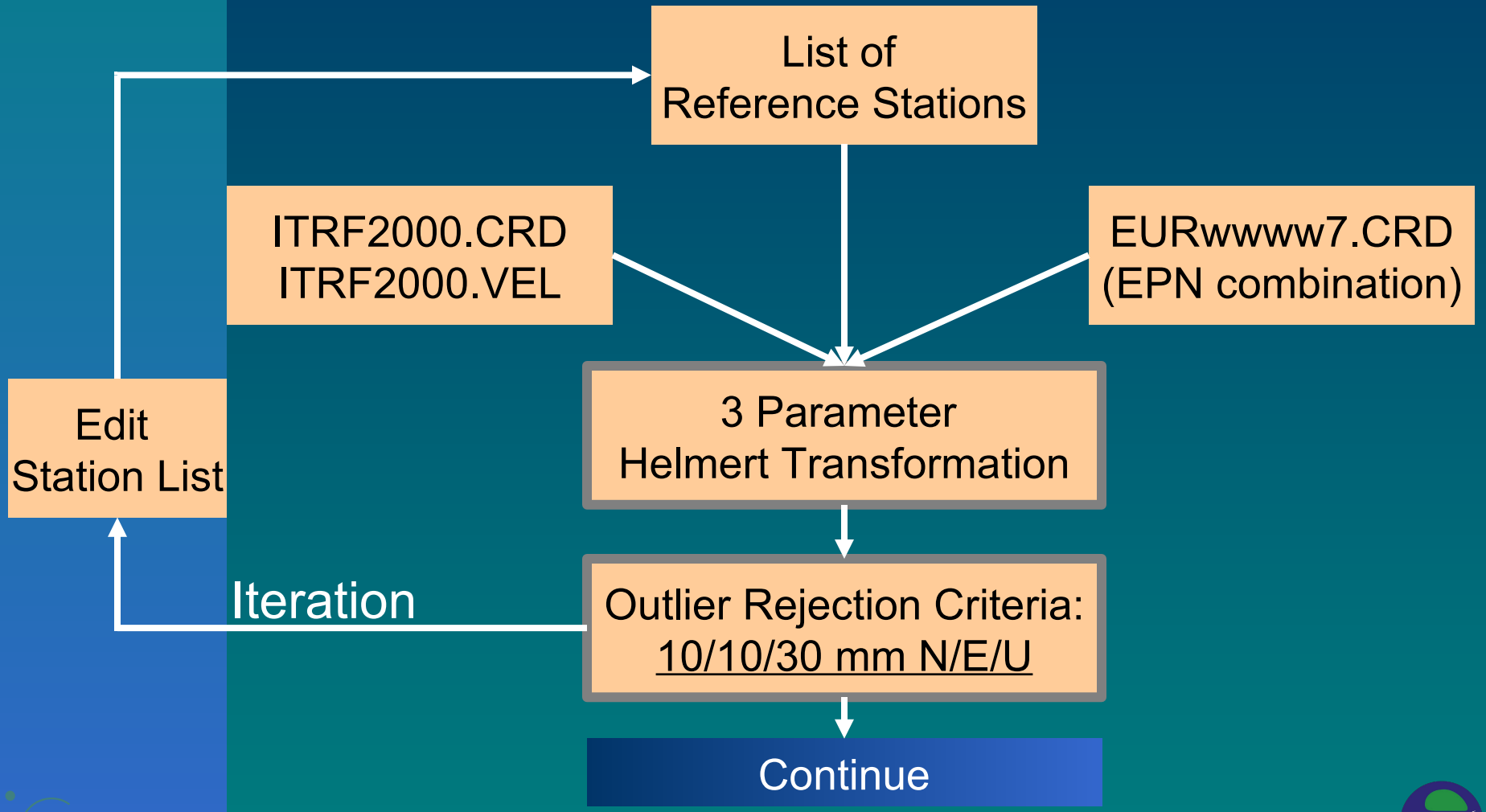


Median for non-reference stations [mm]	
0.1 mm	North
0.2 mm	East
0.4 mm	Height

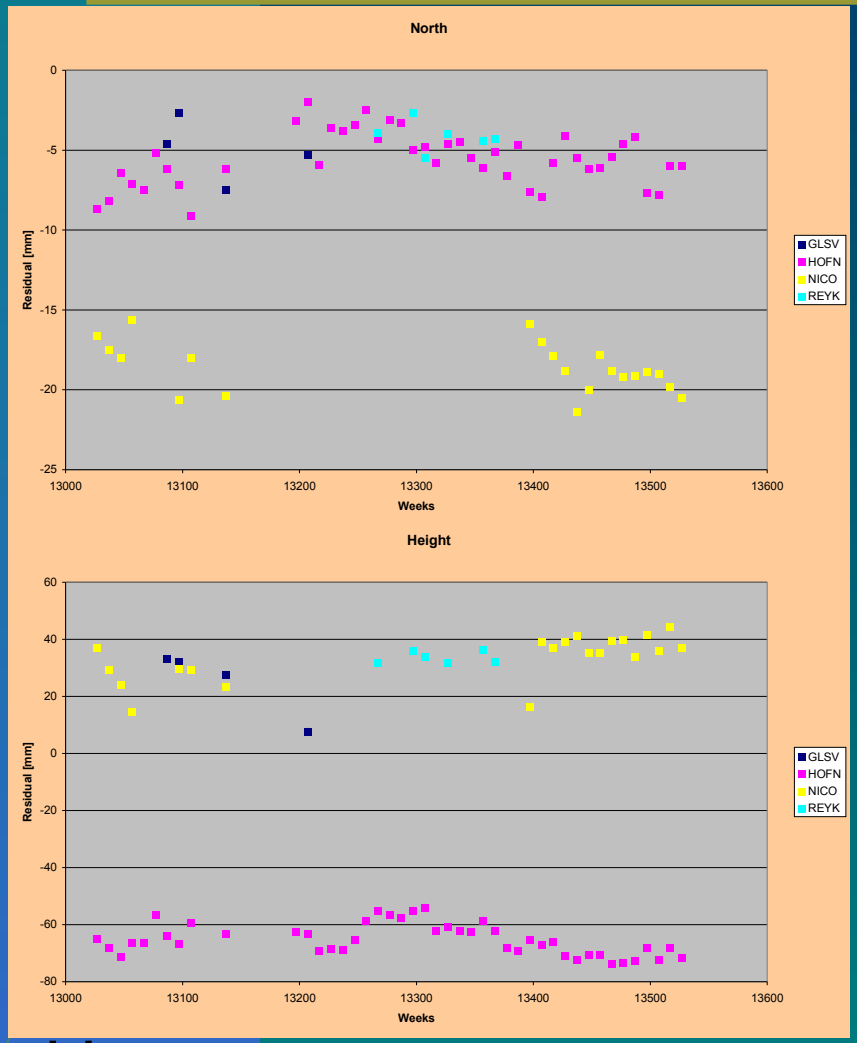
Note

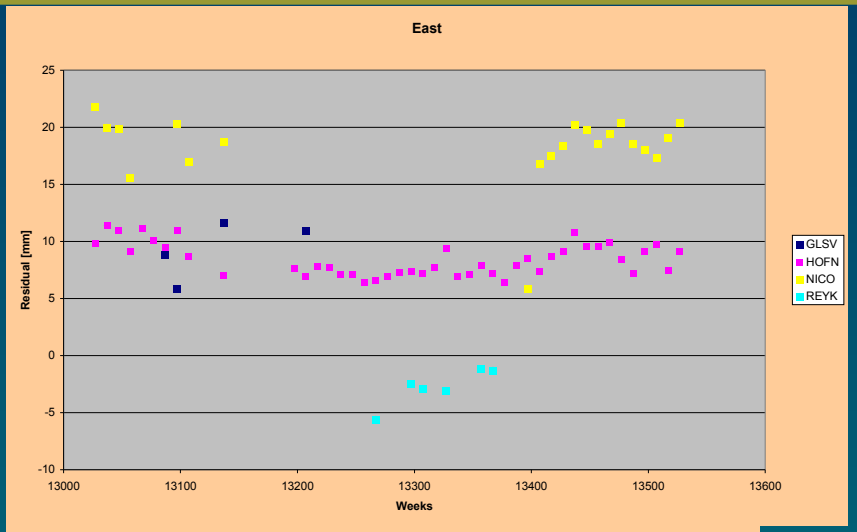
- Verification of new combination:
  - Significant difference basically show up for the reference stations. These are caused by „applying minimum constraint conditions“ in V5.0 instead of the „fixed coordinates approach“ in V4.2.
  - The median of residuals for non-reference stations result in 0.1/0.2/0.4 mm for N/E/H.

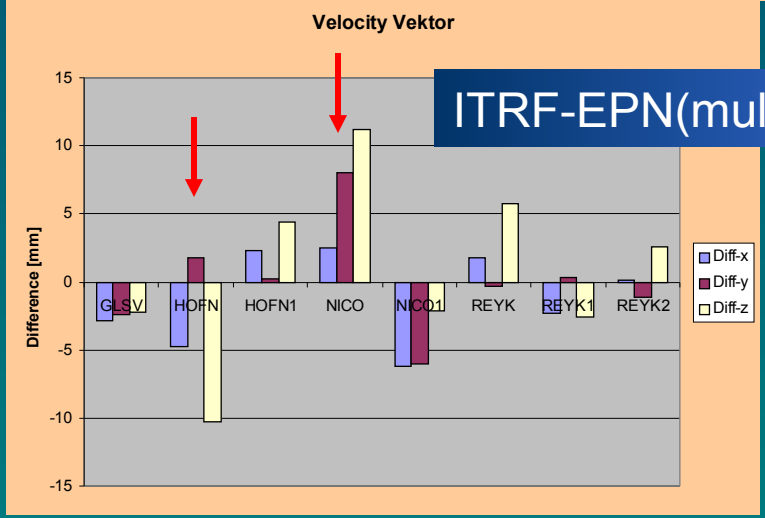
V5.0 Combination Scheme
-Validation of Reference Coordinates -



Rejections of Reference Sites Weeks 1302 – 1352 (appr. Year 2005)







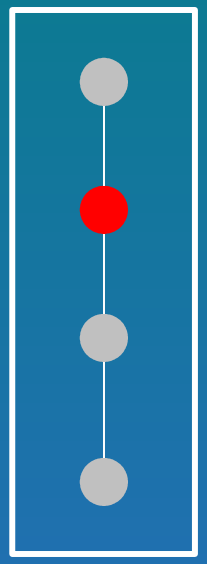
Note

- The validation scheme rejected 4 stations in 2005. Corresponding residuals are given in North, East and Height components.
- Systematic residuals of the comparison may be explained by differences between the velocity vectors of ITRF2000 (that is applied in the datum definition) and the most recent EPN multiyear-solution. Differences of the velocity vectors are shown in the bottom right plot.

Rejections for 2005

- 4 stations have been rejected as reference in 2005: GLSV, HOFN, NICO, and REYK.
- NICO and REYK show continuously significant residuals (Note: Observation gap for NICO and second solution no.). Such behaviour may be explained by differences between ITRF2000 and estimated velocities.
- NICO and REYK are not suitable as reference stations and should be withdrawn from the list.

Upcoming Modifications: *- Absolute PCV and ANTEX -*



- IGS is planning to switch to absolute receiver and satellite antenna phase centre variations (PCVs).
- It is scheduled to carried the switch at the same time as the change to ITRF2005 (April/May 2006).
- Consequences for EPN:
  - EPN should follow the IGS strategy
  - Preparation of analysis software, e.g., usage of Bernese GPS Software 5.0
  - Adoption of IGS ANTEX file, adding of new EPN receiver/antenna pairs and agreement on notation of antenna specification

Existence and Requirements:

- Bernese GPS Software 5.0 is already prepared for absolute PCV and ANTEX.
- EPN network includes receiver/antenna pairs that are not included in IGS ANTEX files.
  - EPN needs expansion of IGS file.
- Notation of this expansion has to be defined for the antenna phase centre variation file and the resulting SINEX file.

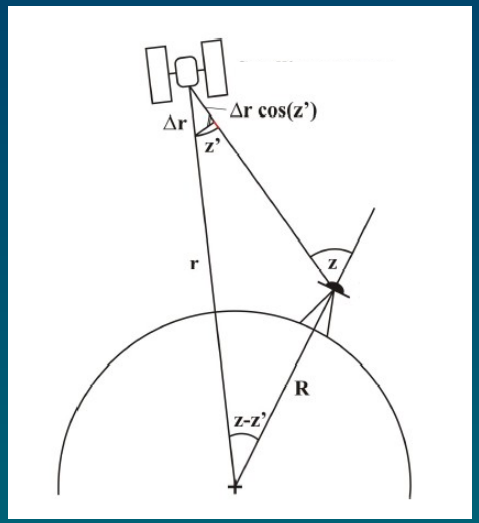
Our Reference: IGS Mail No 5272, December 19, 2005 (1/5)

- The ANTEX file has been accepted by all IGS ACs.
- GLONASS PCVs and offsets will be delivered by CODE.
  - Completed and announced in IGS Mail 5318 (March 6, 2006): „Absolute PCV for GLONASS satellites now available.“
- File name convention:
  - Base_wwww.atx, e.g.

    igs05_1325.atx

Our Reference: IGS Mail No 5272, December 19, 2005 (2/5)

- Current IGS satellite antenna offsets are modelled as:
  - Satellite-specific z-offsets
  - Block-specific x-, y-offsets
  - block-specific nadir-dependent patterns (0 – 14°, 1°steps)
  - no azimuth-dependent corrections



Note

- The error of the satellite antenna offset Δr is mostly absorbed by the satellite clock parameter. But this is only true for the nadir direction. All other direction require a nadir-dependent PCV.

Our Reference: IGS Mail No 5272, December 19, 2005 (3/5)

- Current IGS receiver antenna offsets are modelled as:
  - absolute elevation- and azimuth-dependent corrections from robot calibrations

  or

  - elevation-dependent corrections from relative field calibrations converted to absolute corrections

  use

  - „fallback“ for antenna/dome combinations with no numbers in ANTEX file is „NONE“

Our Reference: IGS Mail No 5272, December 19, 2005 (4/5)

- Considering ANTEX in the data blocks of a SINEX file:
  - Introduction of SINEX 2.0 by IGS planned
    - S/N „-----“ fallback, if no antenna specific corrections available
  - Dome „NONE“ if no dome specific corrections
  - Different meaning of dome and S/N specification in SINEX file:
    - +SITE/ANTENNA (corresponds to real equipment)
    - +SITE/GPS_PHASE_CENTER (corresponds to modelling in the analysis)

Important notation agreement for EPN LAC solution files!

Our Reference: IGS Mail No 5272, December 19, 2005 (5/5)

Example given by Gerd Gendt (IGS AC):

1. Check ANT + RADOME + S/N , if not found
2. Check ANT + RADOME + '-----' , if not found
3. Check ANT + NONE + '-----' (valid for all not explicitly given Radomes)

```
+SITE/ANTENNA
*SITE   P       ____DESCRIPTION_____ _S/N_
 STA1   A  .... ASH701945B_M    SCIS 12345    --------
 STA2   A  .... ASH701945B_M    SCIS CR519    -----    |
 STA3   A  .... ASH701945B_M    OSOD 020      --    |  |
-SITE/ANTENNA                                   |  |  |
                                                |  |  |
+SITE/GPS_PHASE_CENTER                          |  |  |
*___DESCRIPTION_____ _S/N_                      |  |  |
 ASH701945B_M    NONE -----          STA3   <--    |  |
 ASH701945B_M    SCIS -----          STA2   <-----    |
 ASH701945B_M    SCIS 12345     for  STA1   <--------
-SITE/GPS_PHASE_CENTER
```

SINEX 2.0 ?

- Will IGS introduce SINEX 2.0 at the same time as ANTEX and ITRF2005?
- It is recommended in this context to introduce the satellite antenna z-offset as a constrained parameter in the SINEX files (again IGS Mail 5272).
  - *Is this a requirement for EPN solutions?*

Absolute PCV in EPN Analysis (preliminary)

Preparation of analysis software:
Bernese GPS software users must switch to version 5.0

Conversion of IGS ANTEX file into Bernese PHG-file:
a) programme PHCCNV
b) download from AIUB (appropriate pair of satellite information and phase eccentricity, E-Mail Andreas Gaede, December 8, 2005)

Adding new EPN station equipment:
a) Following convention of IGS Mail
b) Following checklist from AIUB Mail

Antenna	Dome
ASH760936F_C	SNOW
ASH781073.1	SNOW
ASH791073.1	SCIS
ASH701941.1	SNOW
ASH701941.B	UNAV
ASH701941.B	SNOW
ASH701945C_M	GRAZ
ASH701945C_M	UNAV
ASH701945E_M	UNAV
AOAD/M_T	DUTD
AOAD/M_T	OSOD
AOAD/M_B	DUTD
AOAD/M_B	OSOD
TRM29659.00	SNOW
TRM29659.00	TCWD
TRM29659.00	SCIS

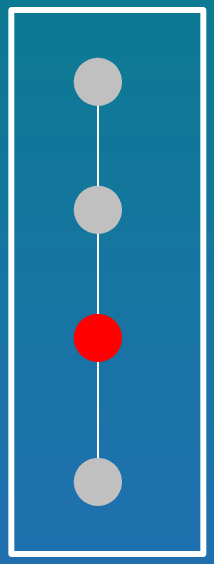
Procedure for Bernese Users

- E-Mail from Andreas Gaede not distributed as BSW-Mail but to individual addresses (perhaps no final version)
- BSW-Mail 0214, February 28, 2006:
  - "… A BSW Mail with information concerning relative and absolute antenna patterns will be issued soon. …"

Upcoming Modifications
- Analysis Options -

	2003	2006
Minimum constraint (MCC) datum definition	Fixed reference coordinates	MCC in combination
Absolute PCV	Postponed	Waiting for IGS and *workshop topic*
GLONASS observations	Individual tests proposed	Presentation of test results
Tropospheric gradients	Not estimated	*Workshop topic*
Weighting scheme for LAC sub-networks	Mixture of static and variable factors	New scheme realized, but still under investigation
Usage of satellite dependent weight	postponed	*Workshop topic*
EPN re-processing	Postponed	*Workshop topic*

New EPN Multi-year Solution
- Background -



- New ITRF realization is currently in preparation and a new EPN multi-year solution yields in a regional densification of ITRF within the scope of IAG sub-commission 1.3.
- Outline:
  - 4 time-series are available at EPN CB for purpose of monitoring of stations, equipment and reference frames and...
  - Multi-year solution as computed from EPN AC is for appointing **one particular set of coordinates and velocities** as a reference (and perhaps labelled as ITRF2005).

New EPN Multi-year Solution 2005
- Strategy -

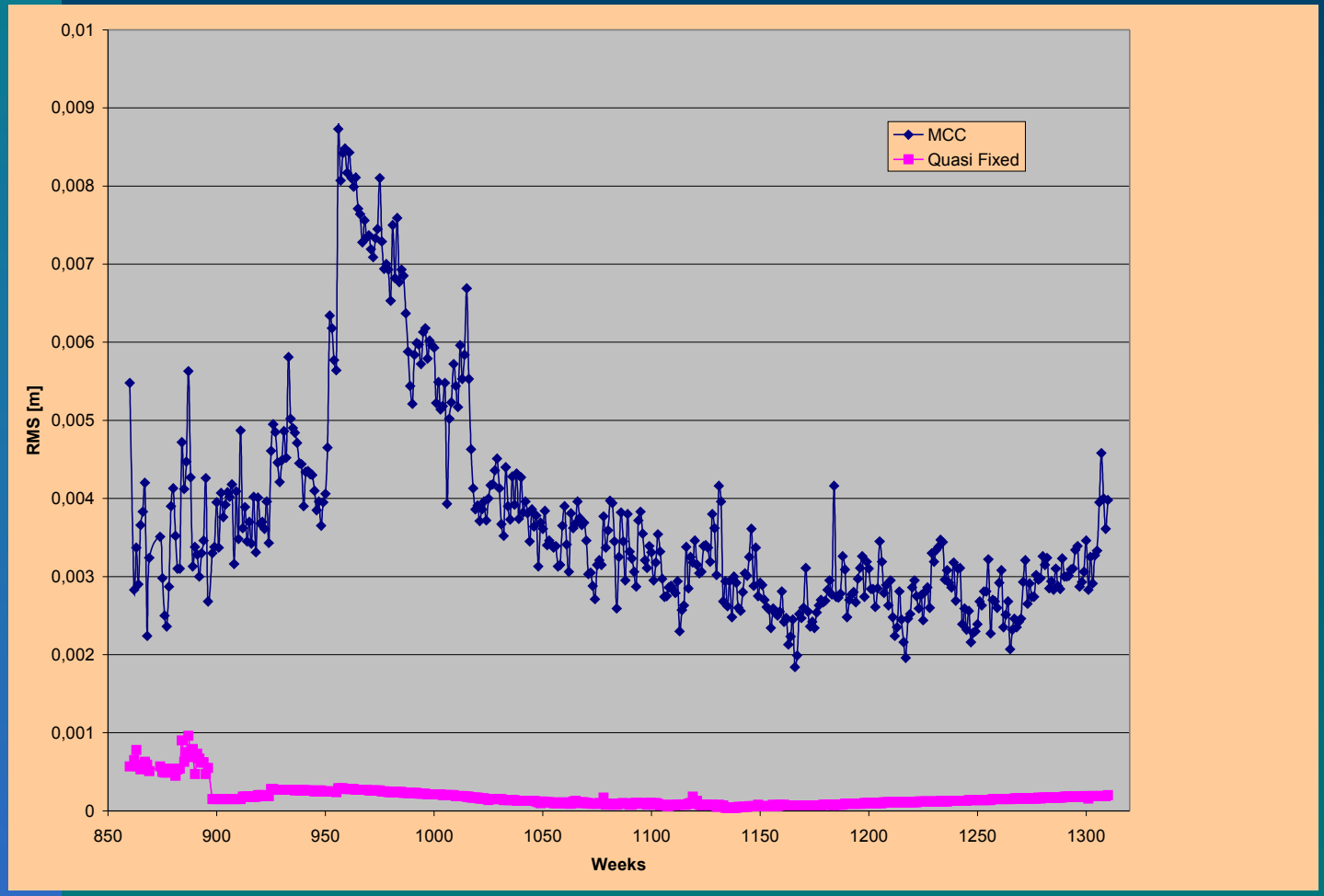
- Conversion of all EPN weekly SINEX files into normal equations (NEQs) without option „reconstruction of original NEQ“ (coordinate=observation).
- Inconsistency file from time series SP as a-priori information, but additional editing because of singularities in ADDNEQ2.
- Minimum constraint conditions (MCC) for datum definition (2 step approach).
- Setup of stations velocities.
- Observations of weeks 860 – 1310 (8 weeks of ADDNEQ2 weekly combination).

New EPN Multi-year Solution
- Processing Statistics-

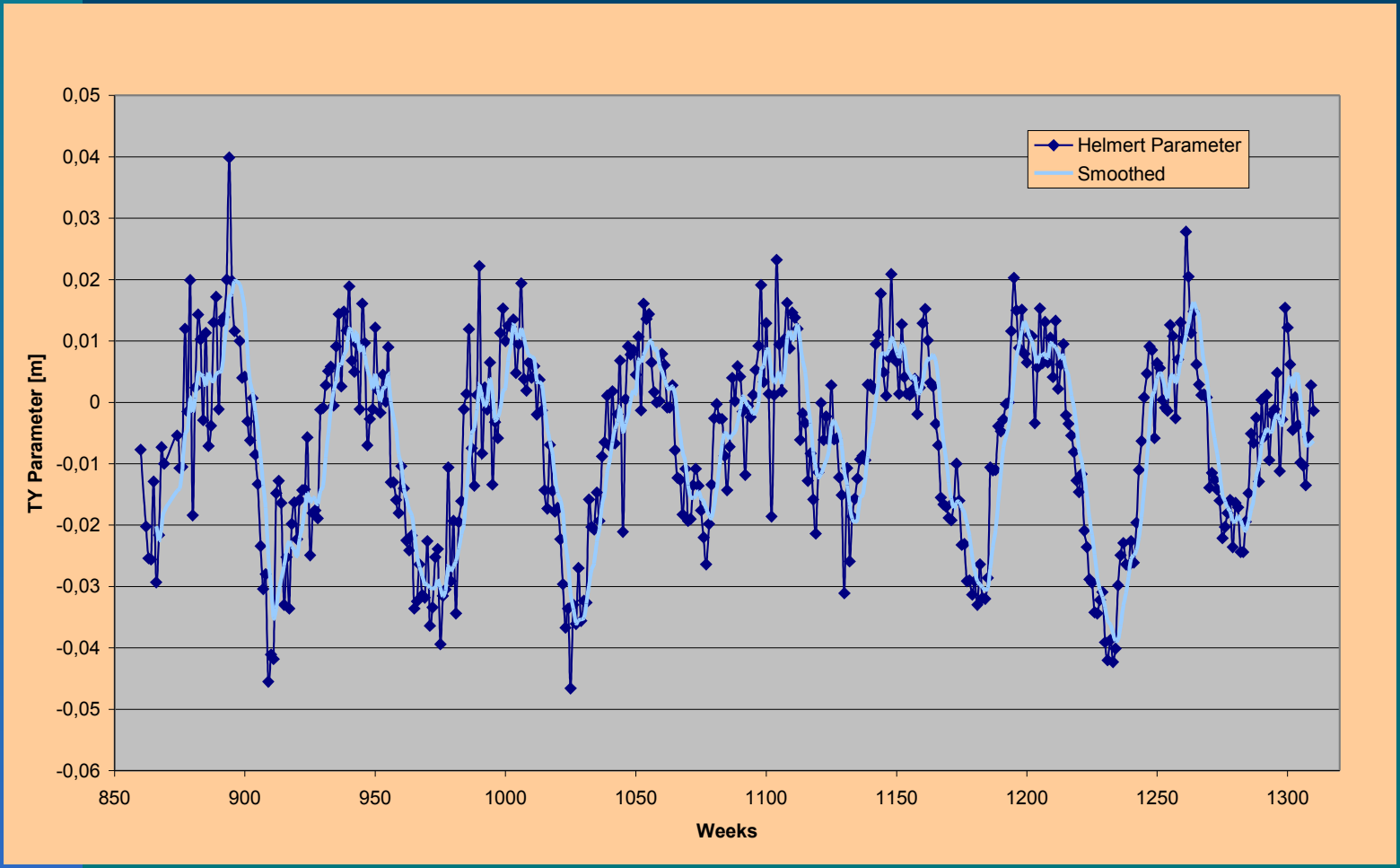
	MCC	Quasi Fixed
Number of parameters/observations	1431/133275	1431/133275
A-posteriori RMS	3.37 mm	3.37 mm
Number of stations	239	239
Processing Time for ADDNEQ2	32 min	3h 37 min ?
Coordinate comparison	RMS = 0.1 mm	

New EPN Multi-year Solution
- Matrix of Correlations -

New EPN Multi-year Solution
-RMS of Weekly Helmert Transformation-



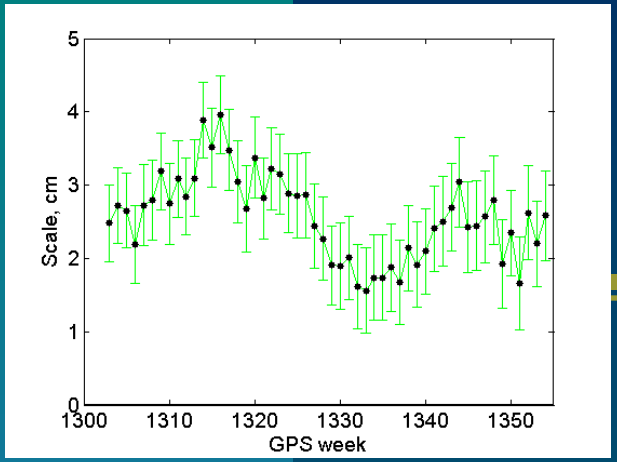
New EPN Multi-year Solution
- Weekly Y-axis Shift -

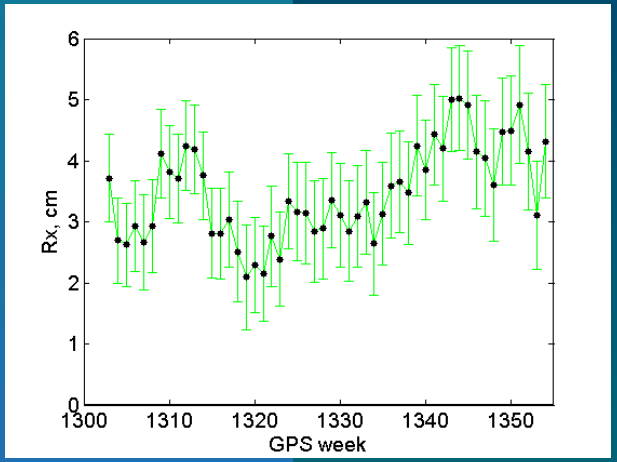


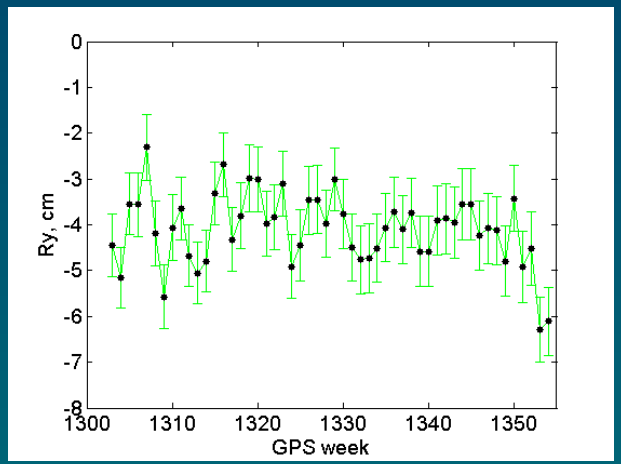
Note:

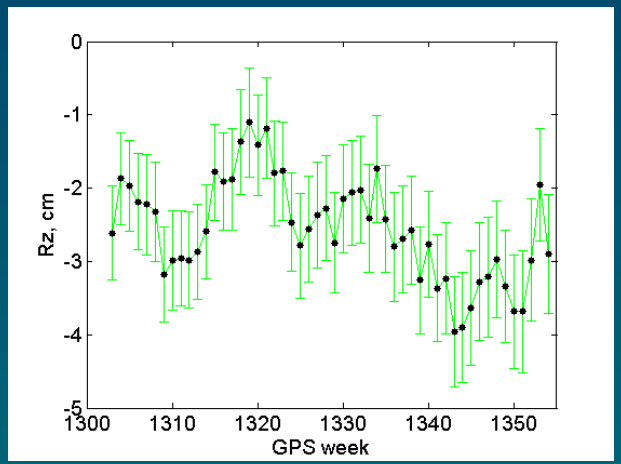
- Helmert Parameters show variations with a yearly signal.
- Reference System for Helmert Transformation is unclear (Translation may cancel rotation partly).
- Datum definition of weekly coordinate sets is unclear.
- Are there correlations with geocentric motion of IGS?

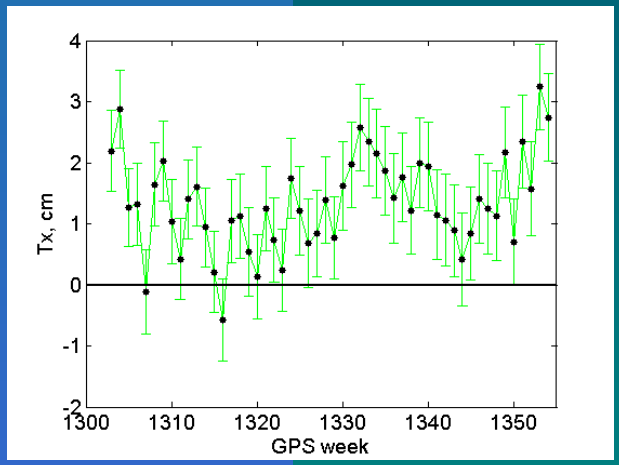
Results from Natascha Panafidina (No Weights)

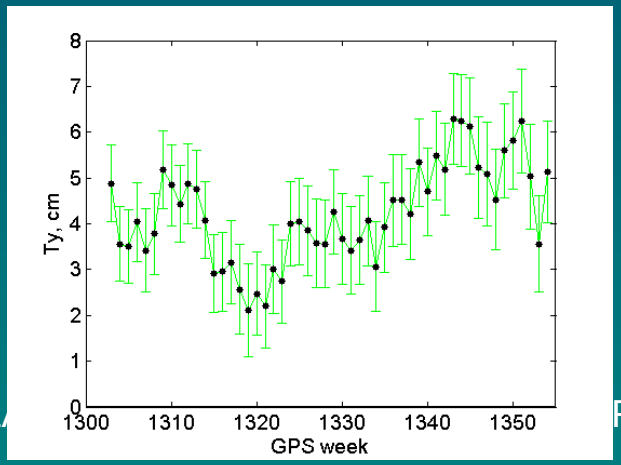


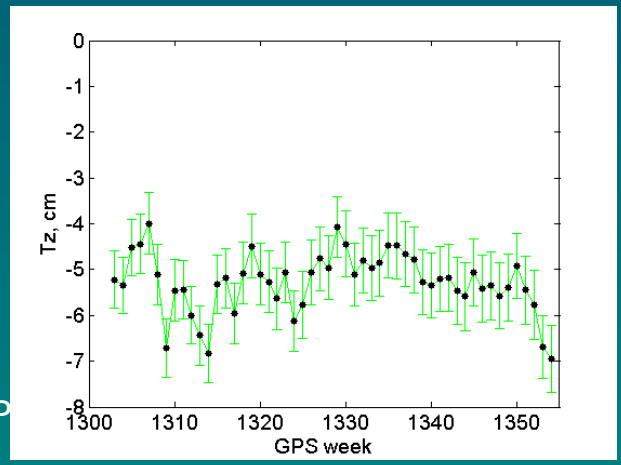




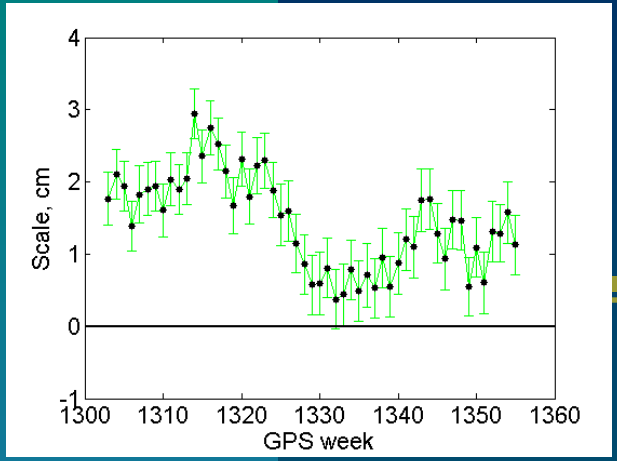


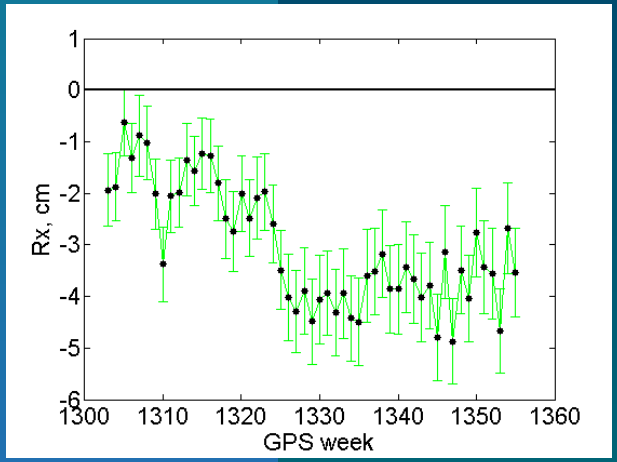


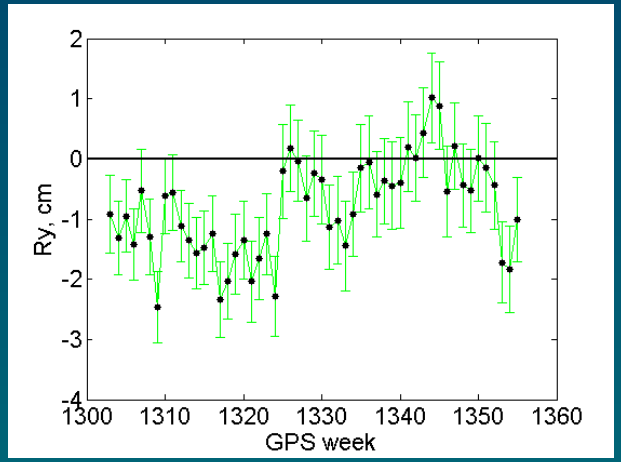


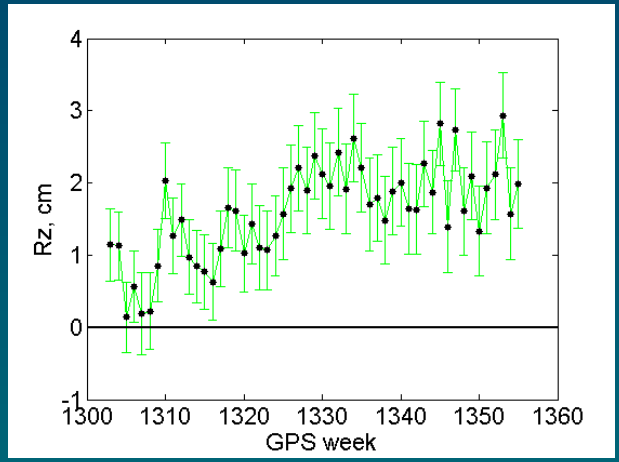


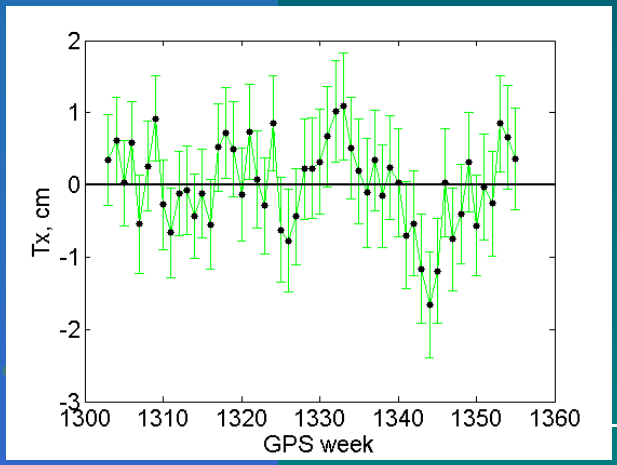
Results from Natascha Panafidina (Weighted)

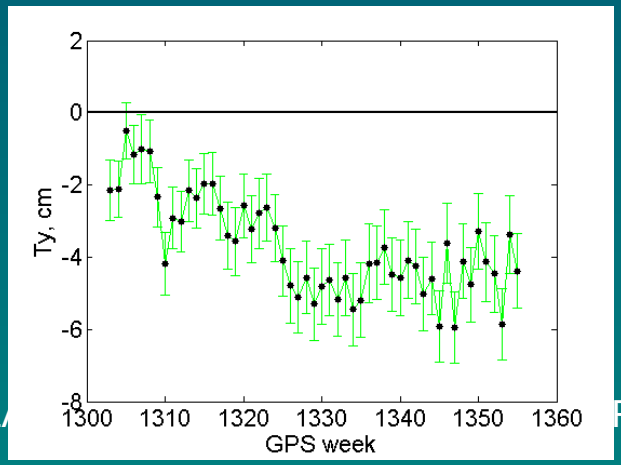


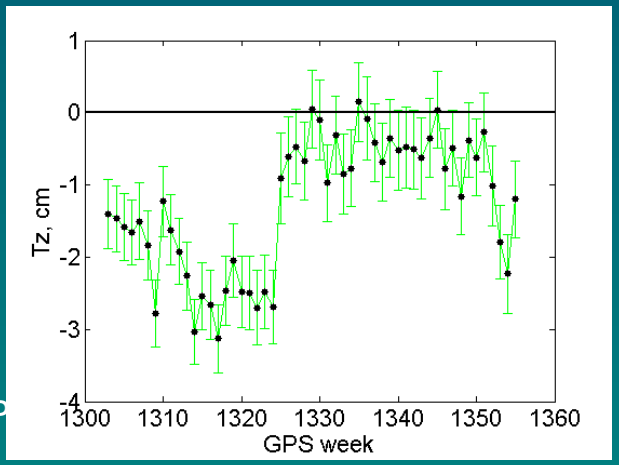




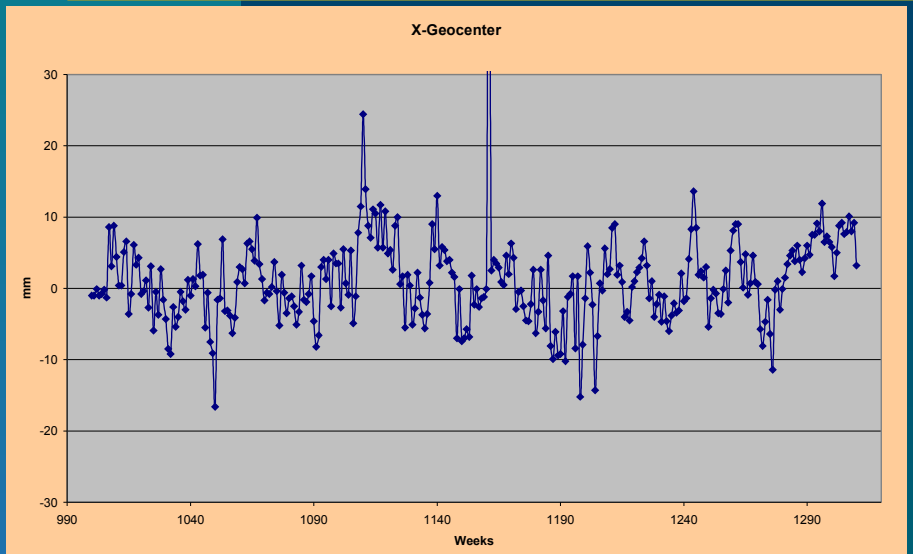




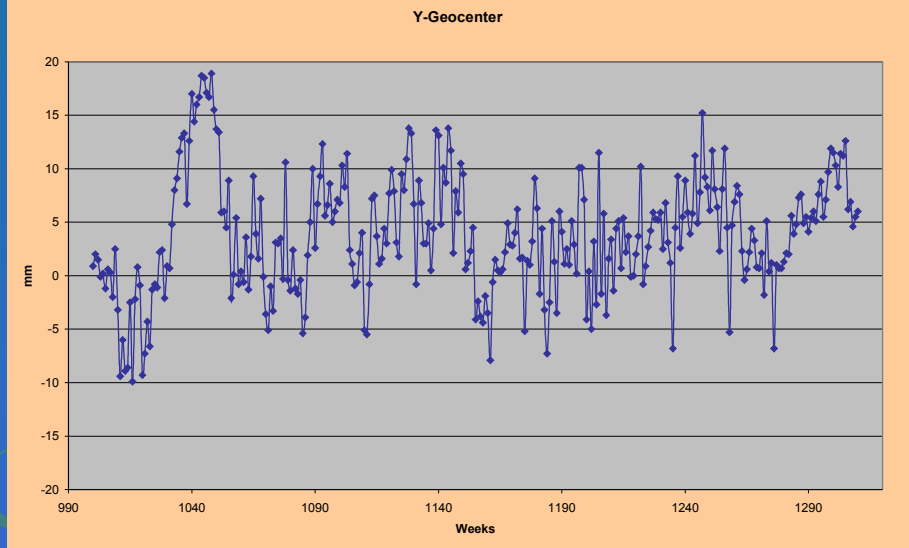


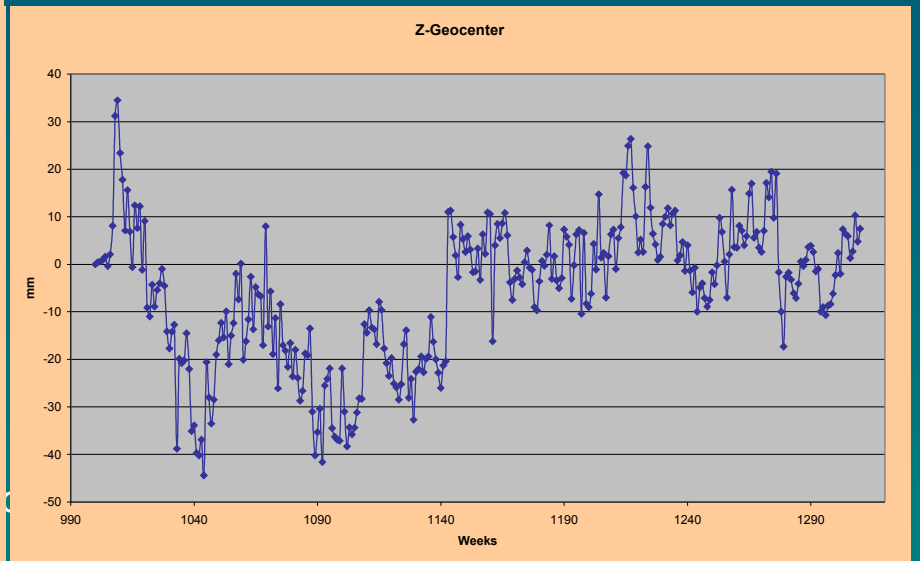


IGS Geocenter Motion



Mean Error [mm]		
X	Y	Z
3,44	3,43	6,15





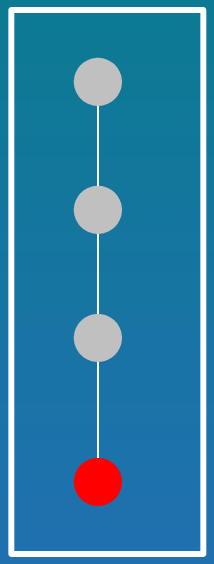
New EPN Multi-year Solution
- Next Steps -

- Submission of preliminary solution to Z. Altamimi and others (IERS?).
- Explanation of the variation of Helmert parameters.
- Understanding several error messages of ADDNEQ, e.g., „A-posteriori RMS...set to 0.001“, long processing time for “quasi fixed” solution and further investigation of the multi-year combination.
- Appointing a final observation interval, e.g., similar to the new ITRF.

Note

- Approximate barycentre coordinates of the EPN network:
  - Latitude: 49 42 57.46
  - Longitude: 10 21 1.96
  - Height: -163.018 KM
- What could we explain from a time series of weekly barycentre coordinates?

Points of Discussion
- Geocentric Datum Definition -



- Motivation:
  - ESEAS asks for strictly geocentric datum definition to observe ocean surface motion with GPS.
- Action:
  - Collect experience from LACs

Points of Discussion
- Daily EPN Product -

- Motivation:
  - ESEAS requests daily GPS time series for comparison with tide gauge measurements.
- Findings:
  - 2 EPN LACs submit daily SINEX files. Both series have been combined for a test period.
  - Not all 16 LACs are able to submit daily solutions.
- Action:
  - Identify potential users
  - Call for expression of interest for Analysis Centres?

Points of Discussion
- Evaluation of Real-Time Strategies -

- Motivation:
  - EUREF-IP Pilot Project provides real-time observations
  - IGS real-time analysis initiative announced (Pilot Project of IGS Real-time working group)
  - EPN LACs should initiate real-time analysis strategies
- Actions:
  - General agreement on real-time analysis from LACs
  - Discussion of strategic plan
    - Call for expression of interest
    - Identification of real-time products

Points of Discussion
- Near real-time troposphere/ coordinates -

- Motivation:
  - Near real-time (NRT) processing for monitoring of EPN stations (see situation of station SNEC in January 2006)
  - NRT troposphere parameter for supporting international „water vapour“ initiatives
- Action:
  - ?

Points of Discussion
- EPN Upgrade to GNSS -

- Motivation:
  - EPN Tracking network holds GPS/GLONASS observations
  - First Galileo test satellite launched
  - Following the GNSS activities of the International ***GNSS*** Service
- Action:
  - Performing GNSS test analysis
  - Adoption of a resolution for GPS/GLONASS analysis of the EPN by LACs
  - Proposal of this resolution for next EUREF symposium

Points of Discussion
- Improvement of height -

- Motivation:

  LAC Workshop 2003, Graz

  - How can the EPN improve the height component to better support ECGN, TIGA and ESEAS?
  - Recommendation 4 (LAC Workshop 2003):
    - Contact the IERS Special Bureau for the Atmosphere and inform them about EUREFs interest for the modelling of the atmospheric loading.
    - Other methods to improve the height component can only be implemented when using the Bernese V5.0.
- Action:
  - Is this topic completed with switch to Bernese 5.0 ?

Points of Discussion
- Satellite Dependent Weights -

- Motivation:

  LAC Workshop 2003, Graz

  - Should we introduce satellite dependent weights, e.g., the accuracy codes as given in the IGS orbits?
  - Recommendation 7.3:
    - Presently, the use of satellite dependent weights needs further testing and should be re-discussed in the future.
- Action:
  - Postpone this topic again?

Points of Discussion
- EPN Re-processing -

- Motivation:

  LAC workshop 2003, Graz

  - Improvement of EPN time series
  - EPN will follow IGS activities
- Action:
  - Weight, until IGS has done a re-processing and new orbits are available !
  - Get opinions from LACs

Summary

Thank you!

Changes since last workshop: Bernese 5.0 implementation	Upcoming modifications: Absolute PCV and ANTEX
Next multi-year EPN solution: ITRF2005 densification in progress	Points of discussion: Write opinions to the minutes