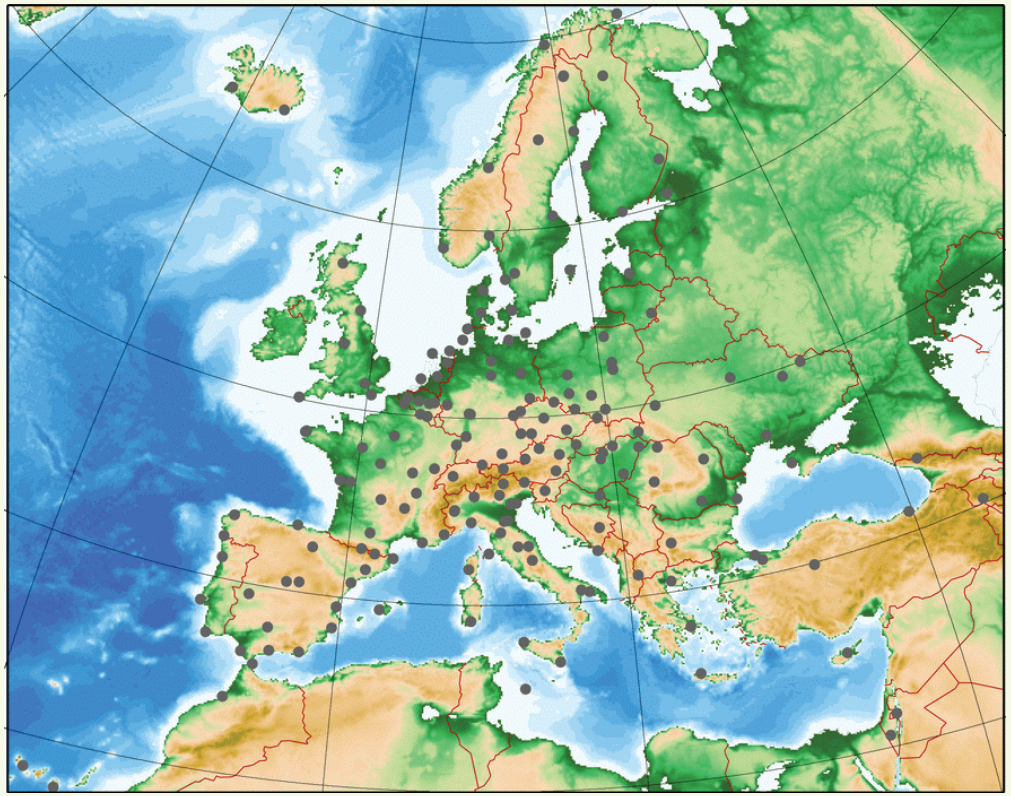
The EUREF Permanent Network : Recent Achievements

C. Bruyninx, F. Roosbeek
EPN Central Bureau

Royal Observatory of Belgium



Content

- Background of the EUREF Permanent Network
- Status of the EUREF Permanent Network
- Evaluation of the EPN Data Flow
- Antenna calibration issues
- New at EPN CB website
- Future plans

CREATION AND DESIGN OF THE EPN (1)

- Initiative of the EUREF TWG (1995)
- Use existing permanent GPS tracking stations in Europe for maintenance of ETRS89
- Structure based on the IGS example
  - Continuous GPS tracking stations
  - Data Centres providing access to the observation data
  - Analysis Centres computing station coordinates and by-products

CREATION AND DESIGN OF THE EPN (2)

- Voluntary contributions
- Redundancy is key issue in order to guarantee reliability
- First EUREF weekly combined solution : Jan. 1996, ITRS coordinates of 29 tracking stations, 4 Analysis Centres
- Primary means to provide access to the ITRS/ETRS89 in Europe (tracking data & coordinates)

EPN DATA CENTRES

Station/OC → Local Data Centre → Regional Data Centre

Local Data Centres

ASI, Agenzia Spatiale Italiana, *Italy*
ROB, Royal Observatory of Belgium, *Belgium*
DUT, Delft University of Technology, *Netherlands*
GOP, Geodetic Observatory Pecny, *Czech Republic*
IGNE, Institut Géographique National, *France*

Regional Data Centres

BKG, Federal Office of Cartography and Geodesy, *Germany*
OLG, Space Research Institute, *Austria*

EPN DATA FLOW

Designed to minimize influence of single point (DC) failure

Principle:

- Each station uploads its data to 2 Data Centres
  - Primary and secondary data centres in site log
- All EPN data are available at two Regional Data Centres
  - Routine data upload to IGS

EPN DATA ANALYSIS

- Daily/Weekly
  - 16 analysis centres
  - each processes subnetwork (30 – 60 stations) of the EPN
  - each EPN station is processed by at least 3 analysis centres
  - compute daily station positions, and provide weekly positions to EUREF
  - all weekly solutions are combined into the official weekly EUREF solution providing coordinates for all stations

- Monthly
  - Time series special project
  - uses all weekly solutions since start of EPN to compute positions/velocities for all EPN stations

EPN PRODUCTS

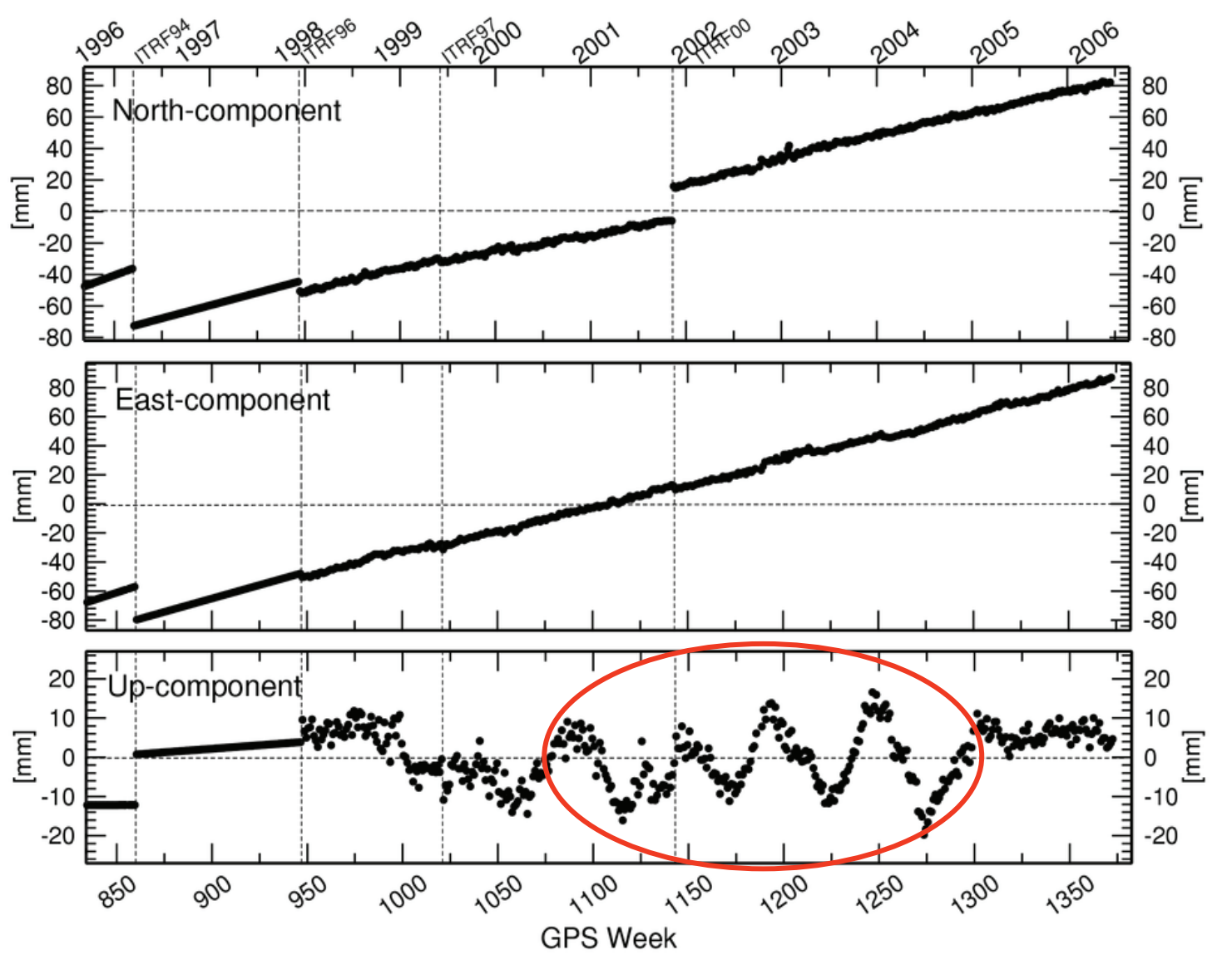
- GNSS data from the tracking stations
  - Daily & hourly
- Site coordinates
  - ETRS89, ITRS
- Tropospheric ZTD delays for each site
- Time evolution of site coordinates

Provides access to ETRS89/ITRS

TIME EVOLUTION OF SITE COORDINATES

- ITRS time series
  - Coordinates extracted from weekly combined EUREF solution
  - Tied to successive realisations of ITRS
- *ETRS89 time series*
  - *Coordinates extracted from weekly combined EUREF solution and converted to ETRS89*
  - *Tied to successive realisations of ETRS89*
- *RAW time series*
  - *Cumulative solution using all weekly combined EUREF files as input and estimation of one set of coordinates & velocities / station*
- *CLEANED time series*
  - *Cumulative solution using all weekly combined EUREF files as input and estimation of one set of coordinates & velocities / station*
  - *Outliers removed, stations discontinuities corrected*

ITRS TIME SERIES



TIME EVOLUTION OF SITE COORDINATES

- *ITRS time series*
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  - *Tied to successive realisations of ITRS*
- ETRS89 time series
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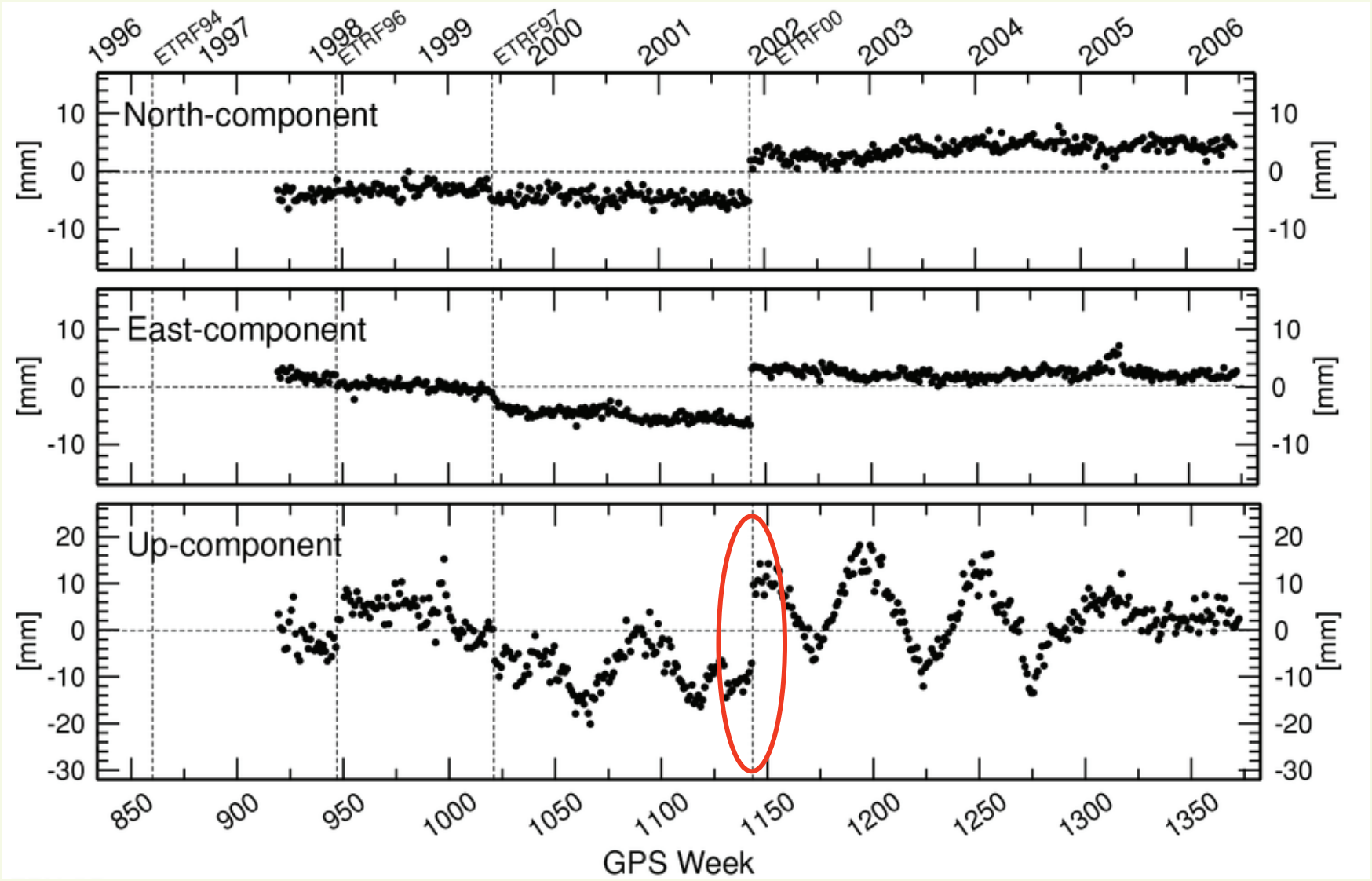
ETRS89 TIME SERIES



TIME EVOLUTION OF SITE COORDINATES

- *ITRS time series*
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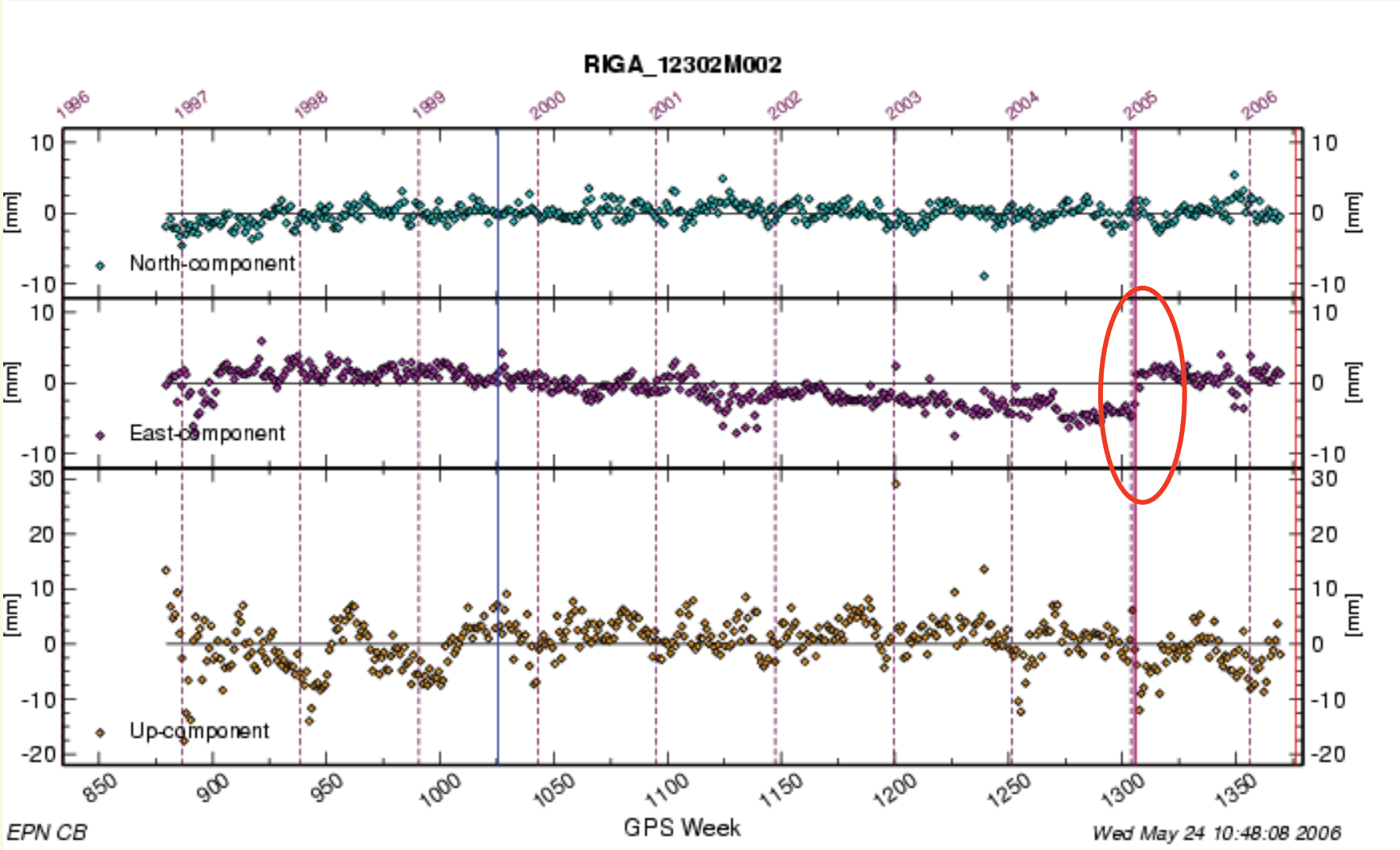
RAW TIME SERIES



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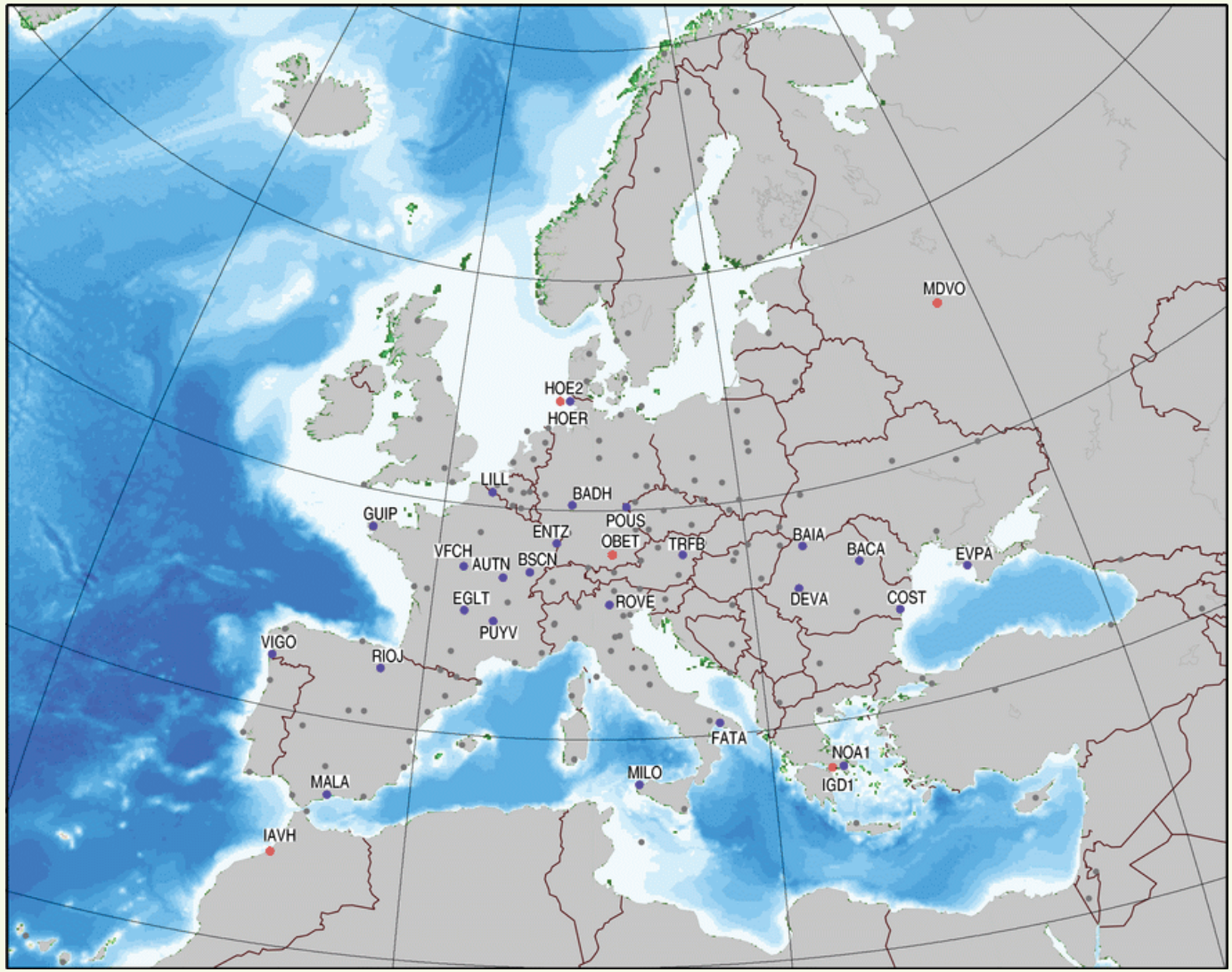
STATUS OF EPN TRACKING NETWORK

190 permanent stations (including 5 inactive), 24 new, 5 withdrawn



EPN TRACKING NETWORK – New stations

Station	4char-ID	Country	Date inc.				
Autun	AUTN	France	03-07-2005	H			
Egletons	EGLT	France	03-07-2005	H			
Entzheim	ENTZ	France	03-07-2005	H			
Guipavas	GUIP	France	03-07-2005	H			
Le Puy en Velay	PUYV	France	03-07-2005	H			
Villefranche-sur-Cher	VFCH	France	03-07-2005	H			
Hoernum	HOE2	Germany	07-08-2005	H		IP	GLO
Poustka	POUS	Czech Rep.	16-10-2005	H			GLO
Malaga	MALA	Spain	13-11-2005	H		IP	
Logrono	RIOJ	Spain	13-11-2005	H		IP	
Vigo	VIGO	Spain	13-11-2005	H		IP	
Evpatoria	EVPA	Ukraine	13-11-2005	H			
Taranto	FATA	Italy	13-11-2005	H			
Trapani – Milo	MILO	Italy	13-11-2005	H			
Pernitz	TRFB	Austria	13-11-2005	H	ECGN		
Villeneuve d'Ascq	LILL	France	18-12-2005	H			
Besançon	BSCN	France	18-12-2005	H			
Bacau	BACA	Romania	12-02-2006	H			
Baia Mare	BAIA	Romania	12-02-2006	H			
Constanta	COST	Romania	12-02-2006	H			
Deva	DEVA	Romania	12-02-2006	H			
Rovereto	ROVE	Italy	09-04-2006	H		IP	
Bad Homburg	BADH	Germany	07-05-2006	H	ECGN		
Athens	NOA1	Greece	07-05-2006	H			

France (8), Romania (4), Italy (3), Spain (3),Germany (2),Czech Rep. (1),Greece (1),Austria (1),Ukraine (1)

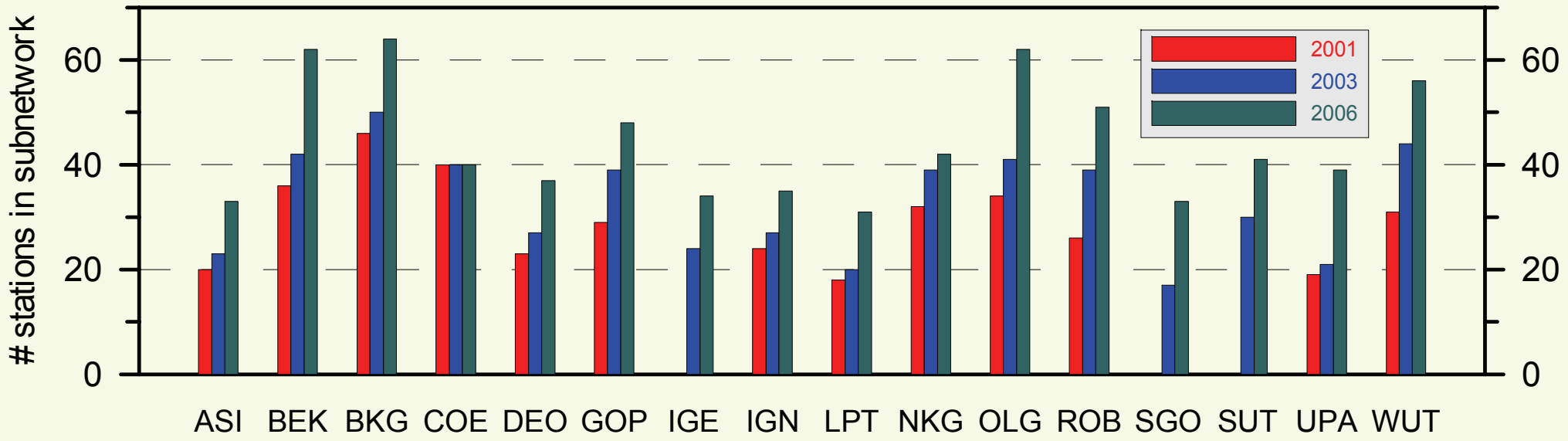
WITHDRAWN STATIONS

- **HOER (Hoernum, Germany)** withdrawn in June 2005
  replaced by HOER; the platform of the HOE2 antenna had to be moved
- **MDVO (Mendeleevo, Russia)** withdrawn in June 2005
  lack of data and perspectives for the future
- **IAVH (Rabat, Morocco)** withdrawn in August 2005 because
  lack of data and perspectives for the future
- **OBET (Oberpfaffenhofen, Germany)** withdrawn in Sept. 2005
  because it did not fulfil the new EPN/IGS guidelines (too large horizontal eccentricities)
- **IGD1 (Athens, Greece)** withdrawn in December 2005
  changes in the company operating the equipment

SIZE OF THE AC SUBNETWORKS

EPN grows with about 15 stations each year

Each station is processed by 3 analysis centres



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DIFFERENT LEVELS

- Daily Data Flow
  - All EPN stations
  - EPN CB checks data availability, latency & quality
- Hourly Data Flow
  - 76 % of the EPN stations
  - EPN CB checks data availability & latency

DAILY & HOURLY DATA FLOW

- New EPN Data Flow has been set up in the last year
  - All EPN data available at OLG and BKG
  - Routine upload to IGS done by BKG; OLG serves as backup
- Proved to work well during recent (planned) outage of BKG (21-24/04)
- Discussion at IGS level to also apply the principle of dual data uploads

RELIABILITY OF DAILY DATA FLOW

Jan.-Apr. ‘06

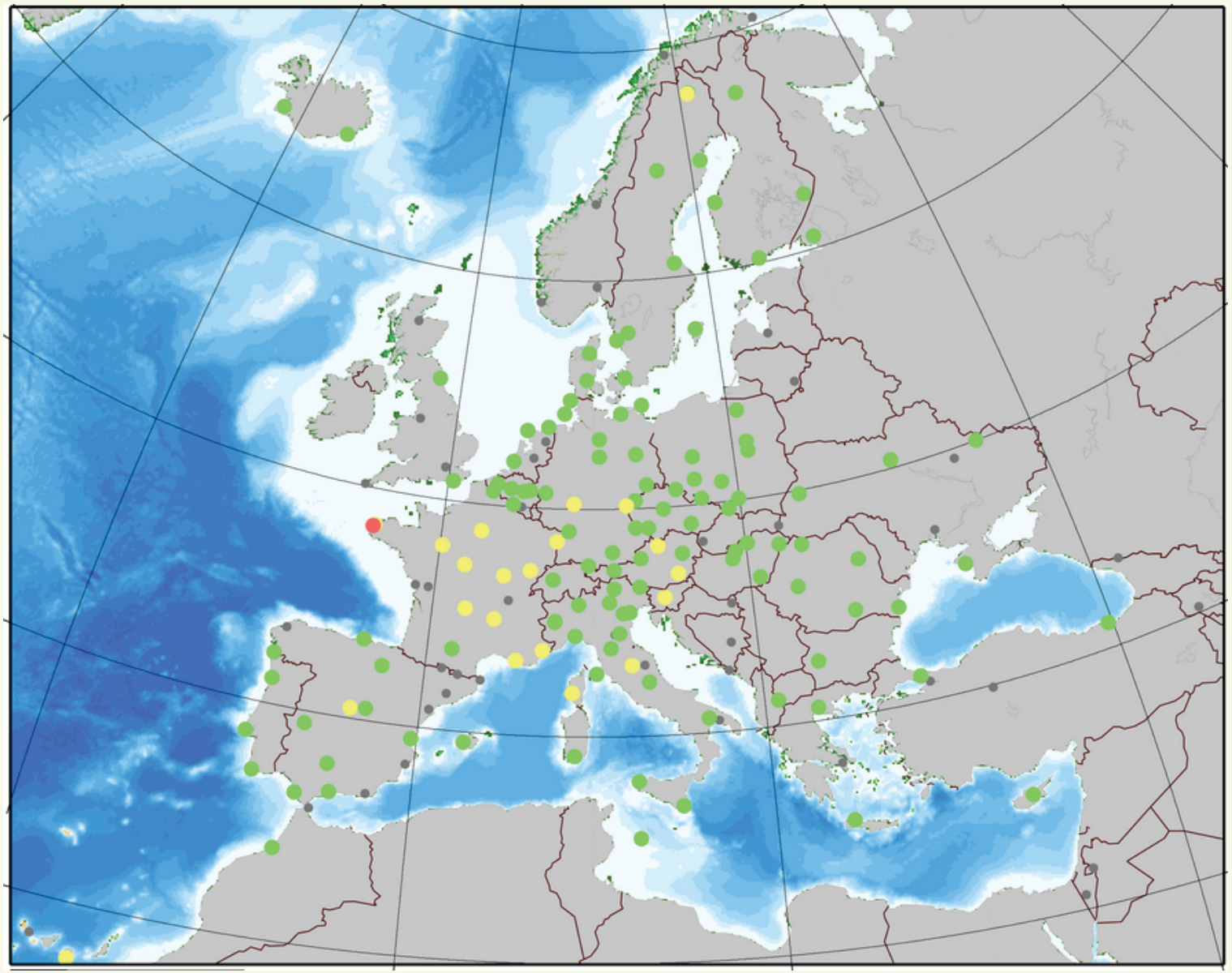
HOURLY DATA FLOW

< 10min

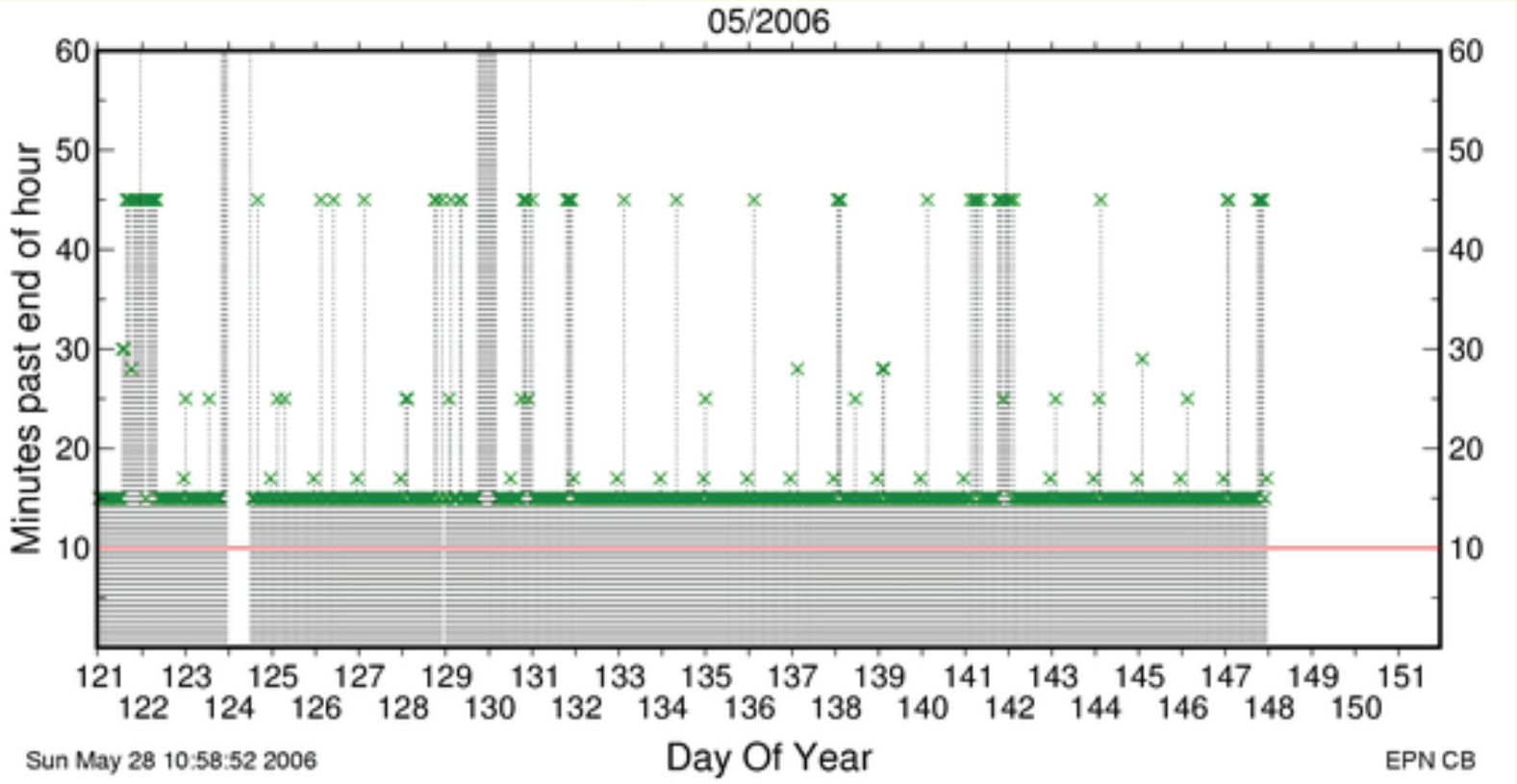
10min – 1h

1h -3d

Jan-Apr.'06



HOW TO IMPROVE DAILY & HOURLY DATA FLOW



http://www.epncb.oma.be/_trackingnetwork/info/SSSS.html

HOW TO IMPROVE DAILY & HOURLY DATA FLOW

Guidelines

3.2.5 Transmission of the data to each DC must be verified to be uncorrupted. In addition, the upload should be retried after failure.

3.2.7 If an upload fails, then a retry should be made as quickly as possible. At least a second retry should be done within the hour.

Stations/OC must implement **AUTOMATED** procedures to resubmit data

- verification of correct upload to data centre
  - File size, ftp log 'Transfer completed'
- If necessary upload data again

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ABSOLUTE PHASE CENTRE VARIATIONS

- IGS will switch to using absolute phase centre models soon
- Antenna + Radome
- Availability of models for EPN stations :

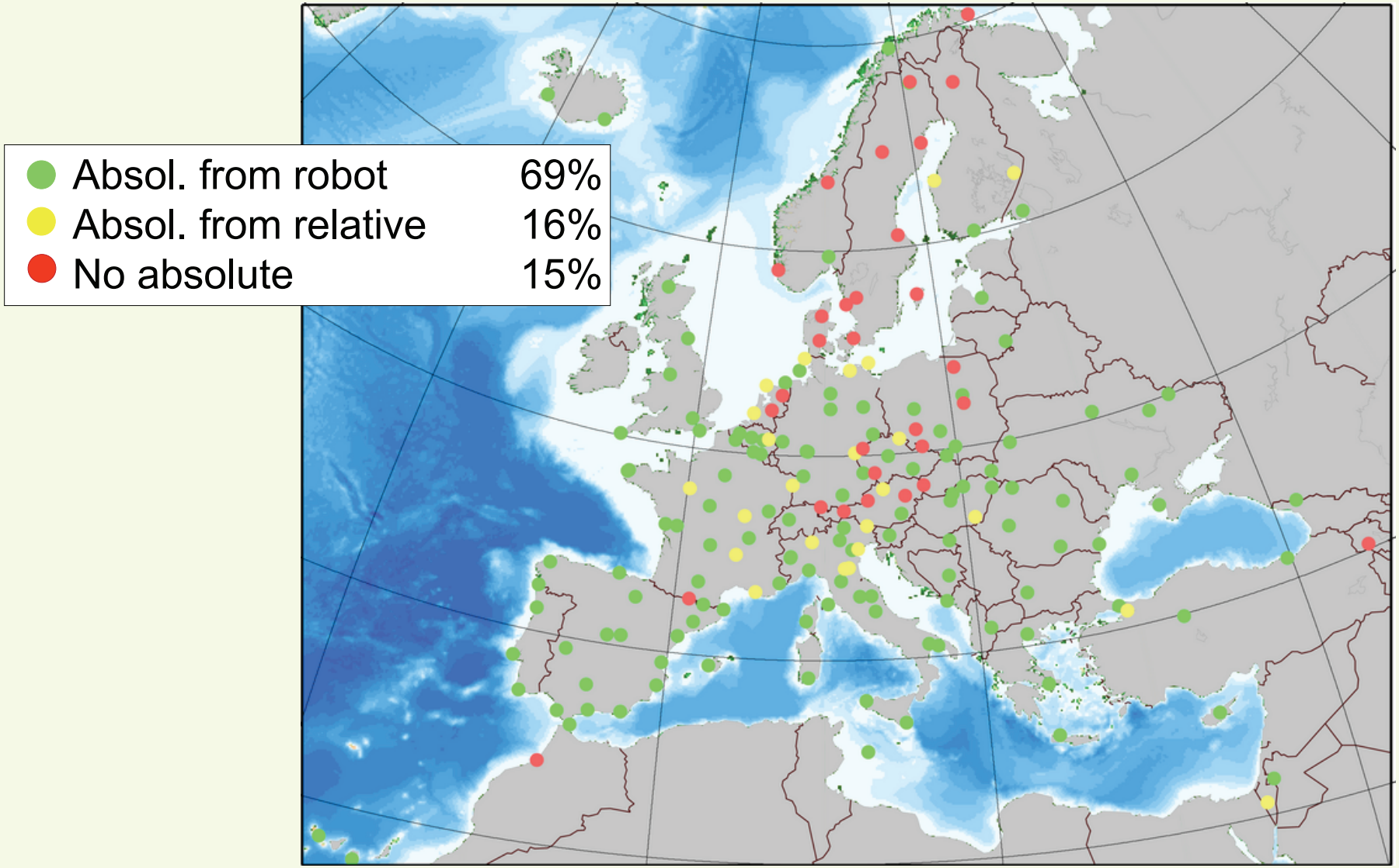
A. Absolute phase centre model available based on robot calibrations

B. Absolute phase centre model based on relative model available (only valid above 10° elev.)

C. No absolute phase centre model is available

BISK,BUDP,ESCO,HFLK,IAVH,JOZ2,KIR0,KOSG,LAMA,MAR6,MARJ,
MOPI,NSSP,NYA1,NYAL,ONSA,PFAN,RABT,SBGZ,SKE0,SMID,SODA,
SPT0,STAS,STAV,SULD,THU3,TRDS,TRFB,TRON,VACO,VARD,VARS,
VIL0,VIS0,WROC,WSRT

CALIBRATIONS OF EPN ANTENNAE



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- Update “papers section”
- Proposed stations web page revisited
- New Coordinates web page
- Frequently Asked Questions extended
- New calendar page with list of relevant meetings
- New interactive map with EPN stations
- Improved support to EPN LAC
- Data quality plots revisited
- Improved time series have been revisited (A. Kenyeres)

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PROPOSED EPN STATIONS

Site	Location	Documentation			Data compliance			Data flow		Relevance to EPN				Interested analysis centres
		CL	SL	SP	SL	AC	TR	Primary	Secondary	D	H	SP	CI	
BBYS	Banska Bystrica, Slovak Republic	✔	✔	✘	✔	✔	✘	BKGE	OLG	✘	✔	✘	✘	GOP - SGO - OLG
SCOR	Scoresbysund/Ittoqqoormiit, Greenland (Denmark)	✔	✔	✘	✘	✔	✔	BKGI	OLG	✔	✔	✘	✘	NKG - IGE - ?

Documentation

CL : commitment letter available at EPN CB
SL : correctly formatted site log available at EPN CB
SP : site pictures available at EPN CB

Data flow

Green : low latency data are available
Red : low latency data are not available

Data compliance

SL : site log and header of RINEX observation file are consistent
AC : antenna (+radome) has calibration values known to IGS/EUREF
TR : GNSS data quality responds to EPN standards (cut off, obstructions, ...)

Relevance to EPN

D : densification site (no existing EPN station within a radius of 300 km)
H : submission of hourly data
SP : contributing to one of the EPN Special Projects
CI : collocation with a relevant instrument

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On-line at the EPN CB website, three types of coordinates (in ETRS89 and ITRS)*:*

1. *(X_{IERS}, Y_{IERS}, Z_{IERS}) and (VX_{IERS}, VY_{IERS}, VZ_{IERS}),*
   the official coordinates/velocities issued the IERS

2. *(X_{EPN}, Y_{EPN}, Z_{EPN}) and (VX_{EPN}, VY_{EPN}, VZ_{EPN}),*
   the coordinates/velocities computed by the "EPN Project for time series monitoring"

3. *(X_{weekly}, Y_{weekly}, Z_{weekly}),*
   the weekly coordinates computed by the EPN Combination Centre

Usage

- If no coordinate discontinuity after 2000 (ITRF00), use (1)
- If (1) not available, use (2)
- If (2) not available, use (3)

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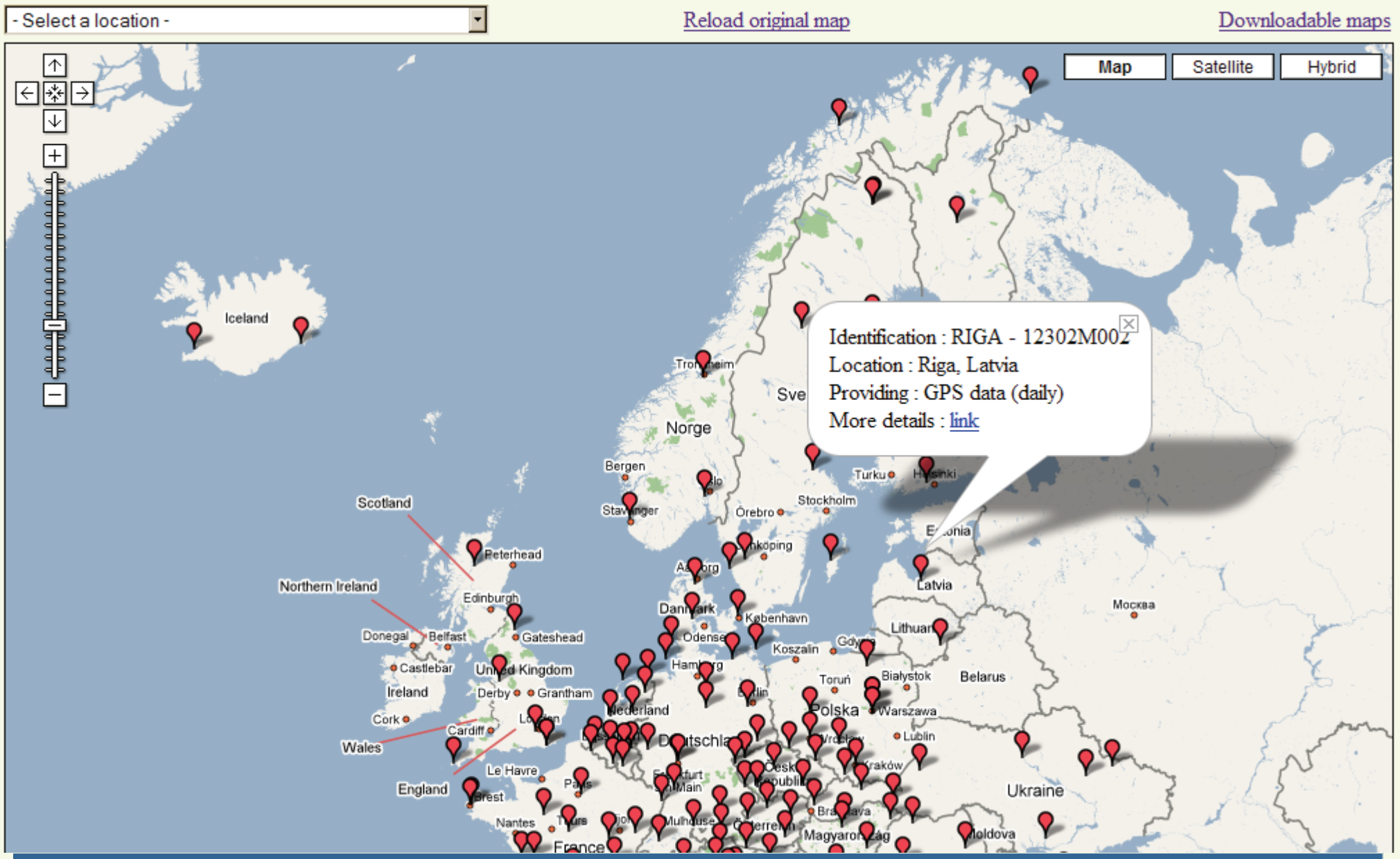
NEW INTERACTIVE MAP



EPN Central Bureau | EUREF 2006, Riga, Latvia | Royal Observatory of Belgium

NEW INTERACTIVE MAP

WTZR (Koetzting, Germany)

Reload original map

Downloadable maps

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IMPROVED SUPPORT TO EPN LAC

- File with station metadata in Bernese format (EUREF.STA)
- Weekly file (excluded.WWWW) with list of stations to be excluded from weekly submission (inactive, equipment change)
- List of calibrated antenna/radomes

In progress:

- Include station discontinuities in EUREF.STA

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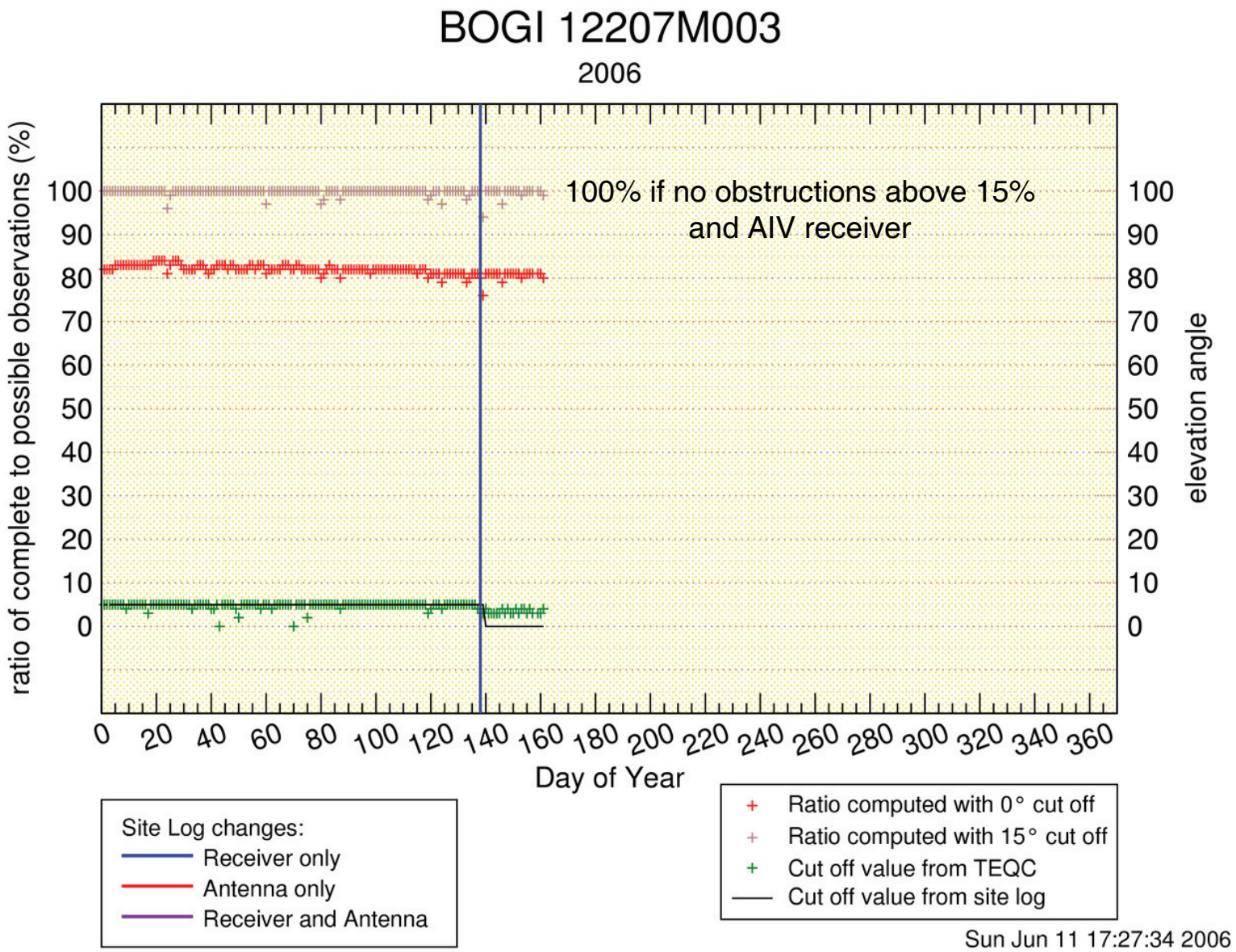
BOGI 12207M003
2006
100% if no obstructions above 15%
and AIV receiver
ratio of complete to possible observations (%)
elevation angle
Day of Year
Site Log changes:
Receiver only
Antenna only
Receiver and Antenna
Ratio computed with 0° cut off
Ratio computed with 15° cut off
Cut off value from TEQC
Cut off value from site log
Sun Jun 11 17:27:34 2006

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Future plans

EPN= Near Real-time Network

EPN = NEAR REAL-TIME NETWORK !

- 76% of the EPN stations submit hourly data
- All new stations submit hourly data

2000 38%
2001 45%
2002 51%
2003 58%
2004 61%
2005 74%
2006 76%

Future plans

Real-time Data Flow ?

REAL-TIME DATA FLOW – Choices to be made

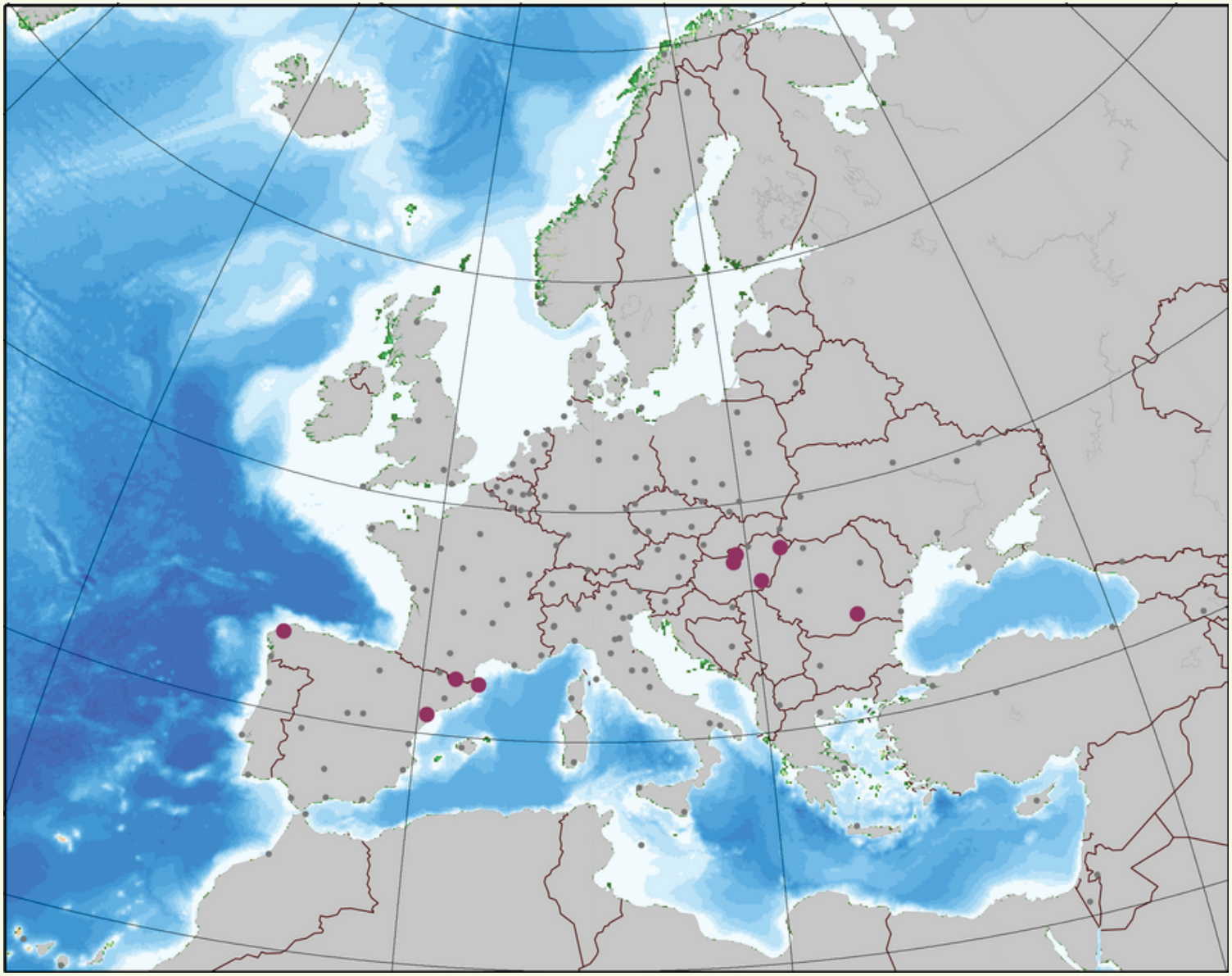
Will real-time data streams become integral part of EPN data flow?

Discussion on-going within EUREF TWG

- Minimal requirements ?
  - for an EPN station to be considered real-time EPN station? RAW, DGPS, RTK , RTCM 3.0 format?
  - for an Ntrip broadcaster to become EPN broadcaster? Free of charge, EPN, long-term commitment
- Is EUREF responsible for the correctness of the coordinates used to generate the DGPS/RTK data ? ETRS89, realization?
- Do we (EUREF) check the quality of the DGPS/RTK or raw data from the real-time EPN stations? No, only verification of daily data

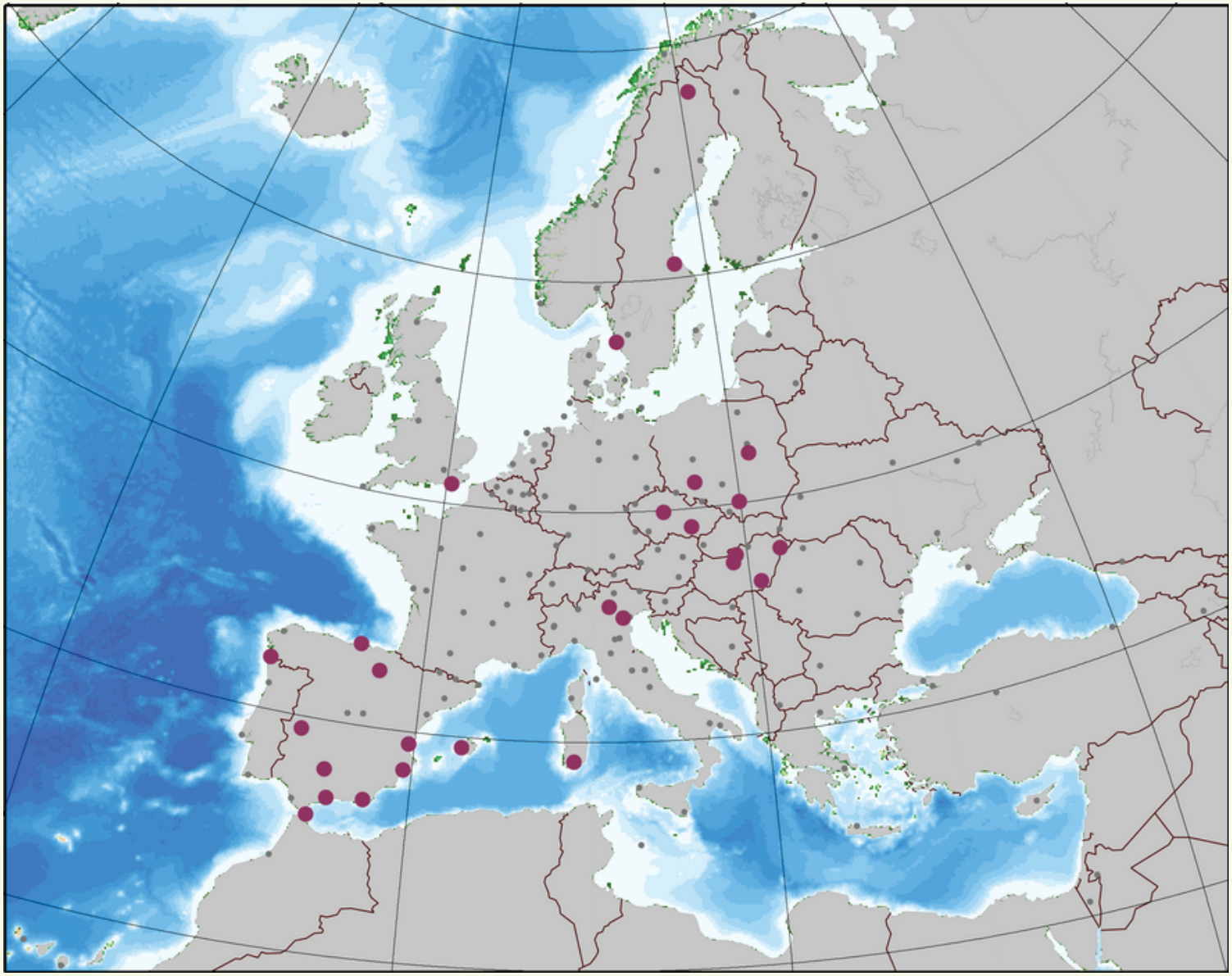
EPN STATIONS CONTRIBUTING TO EUREF-IP

DGPS 11



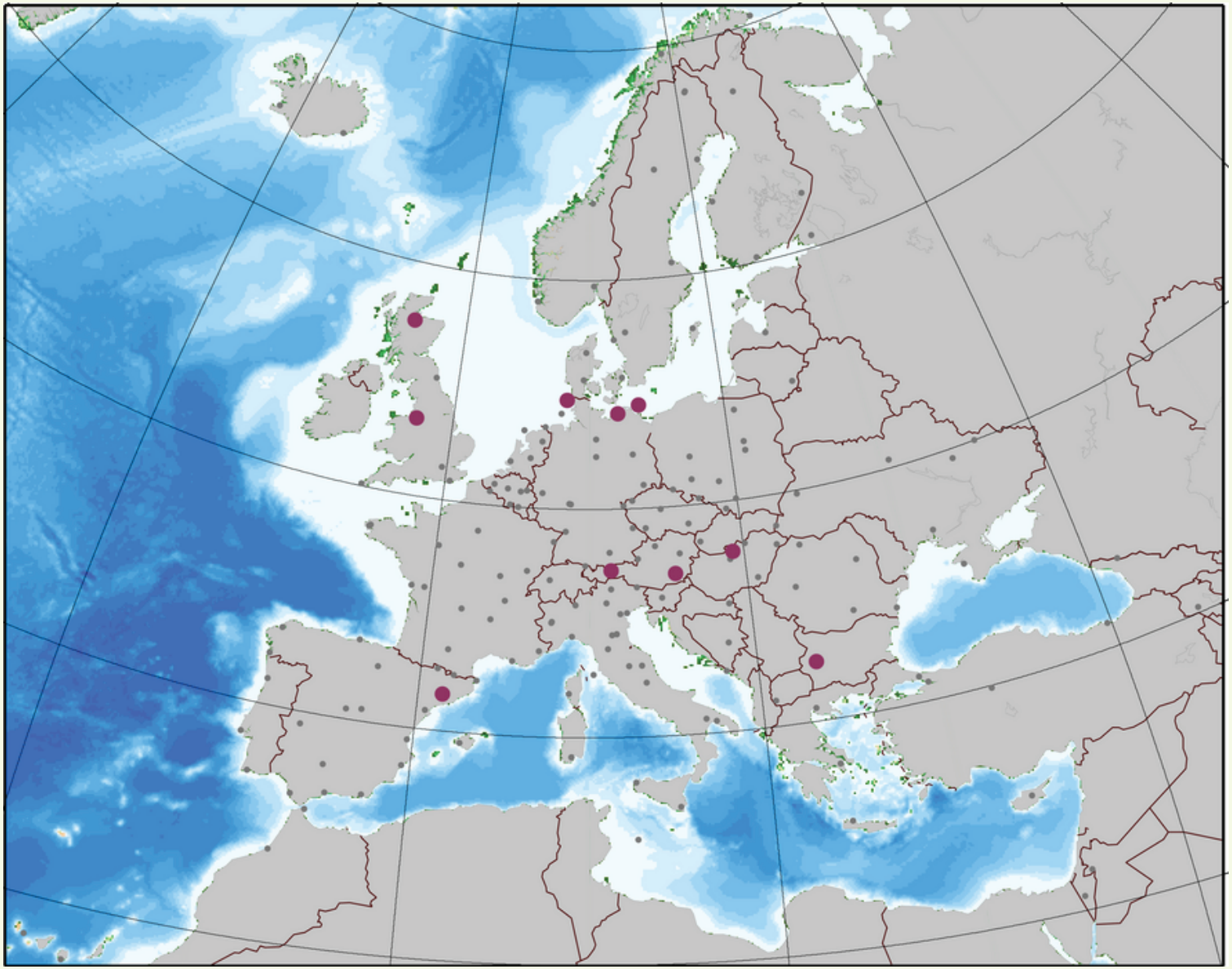
EPN STATIONS CONTRIBUTING TO EUREF-IP

RTK 29



EPN STATIONS CONTRIBUTING TO EUREF-IP

Raw 10



Future Plans

Integration of GLONASS in the EPN ?

PRESENT SITUATION

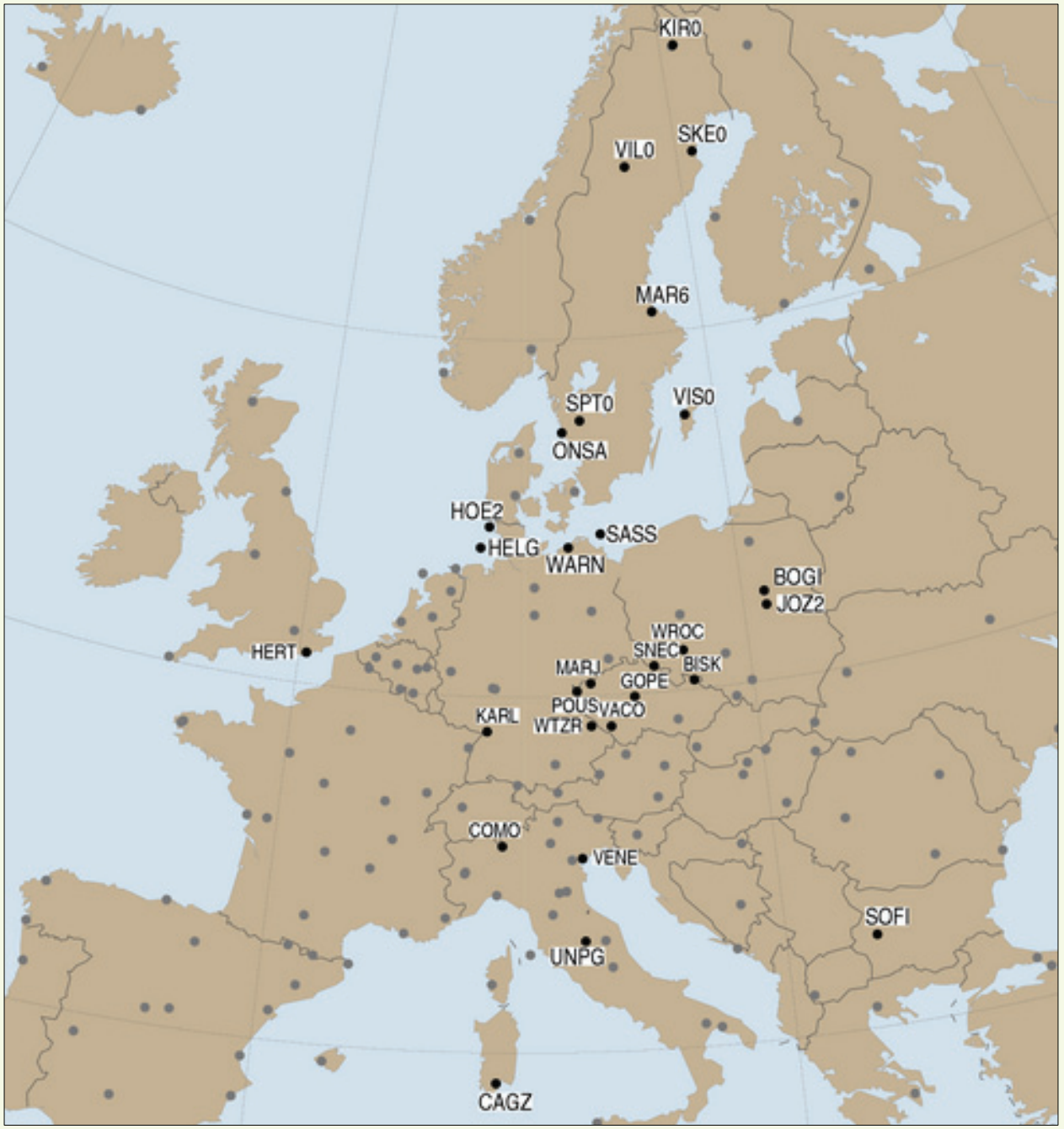
Up to now, all **EPN coordinates** have been based on **only GPS** data and no GLONASS data is used

Why?

- few GPS+GLONASS stations
- no combined GPS+GLONASS IGS orbits
- IGS orbits for GLONASS not available with a reasonable latency

MOTIVATION FOR ADDING GLONASS TO EPN

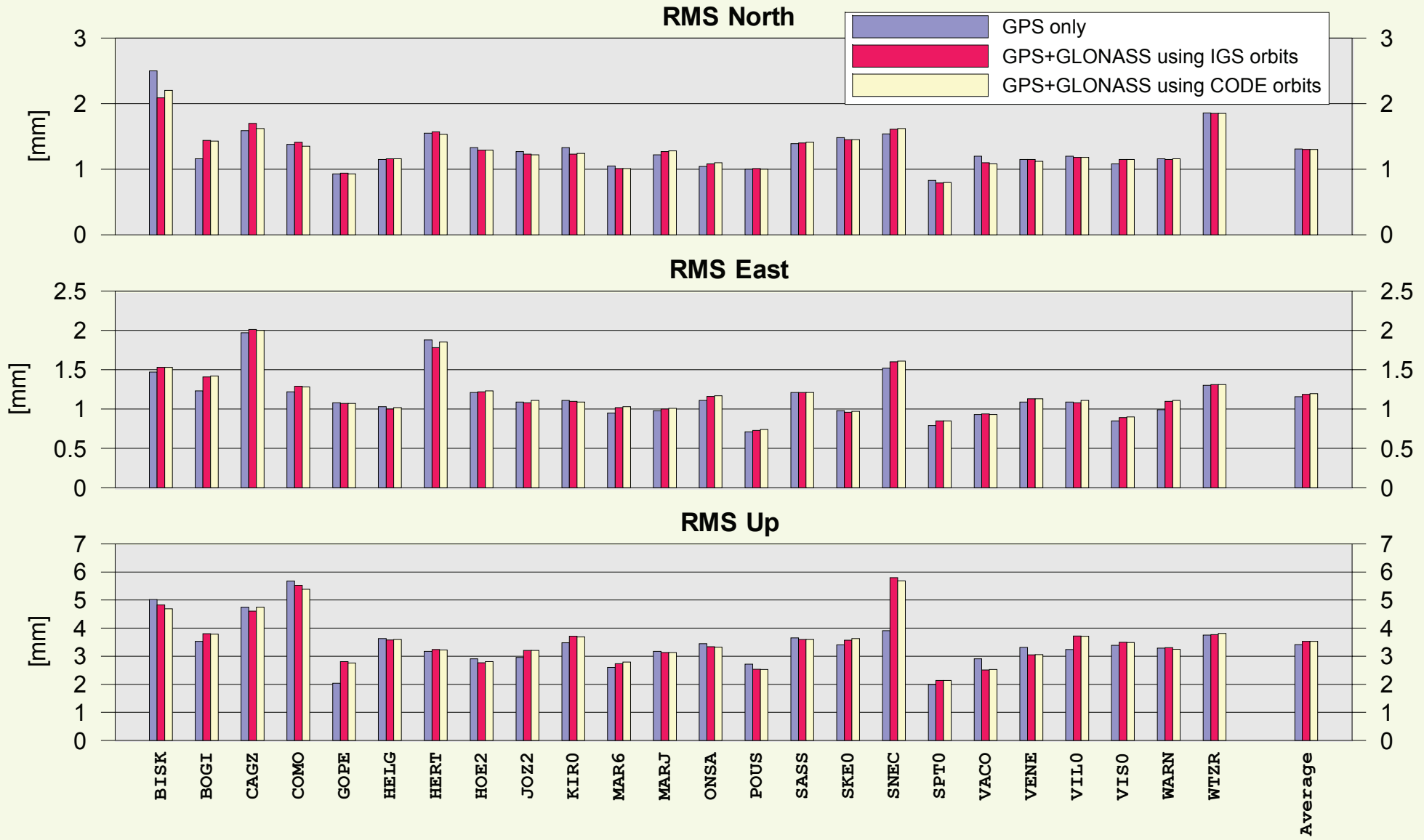
- 29 EPN stations are submitting GPS+GLONASS data
- growing number of commercially available GPS+GLONASS receivers (Trimble, Leica, Topcon, …)
- recent revitalization of GLONASS (with a constellation of 18 satellites expected in 2007)
- availability of short latency precise IGS orbits for GLONASS and consistent GPS+GLONASS CODE orbits
- GLONASS is now standing where GALILEO will stand within a few years: an incomplete constellation and a network of mixed receivers


KIR0
SKE0
VIL0
MAR6
SPT0
VIS0
ONSA
HOE2
SASS
HELG
WARN
BOGI
JOZ2
WROC
SNEC
HERT
MARJ
BISK
GOPE
POUS
VACO
KARL
WTZR
COMO
VENE
SOFI
UNPG
CAGZ

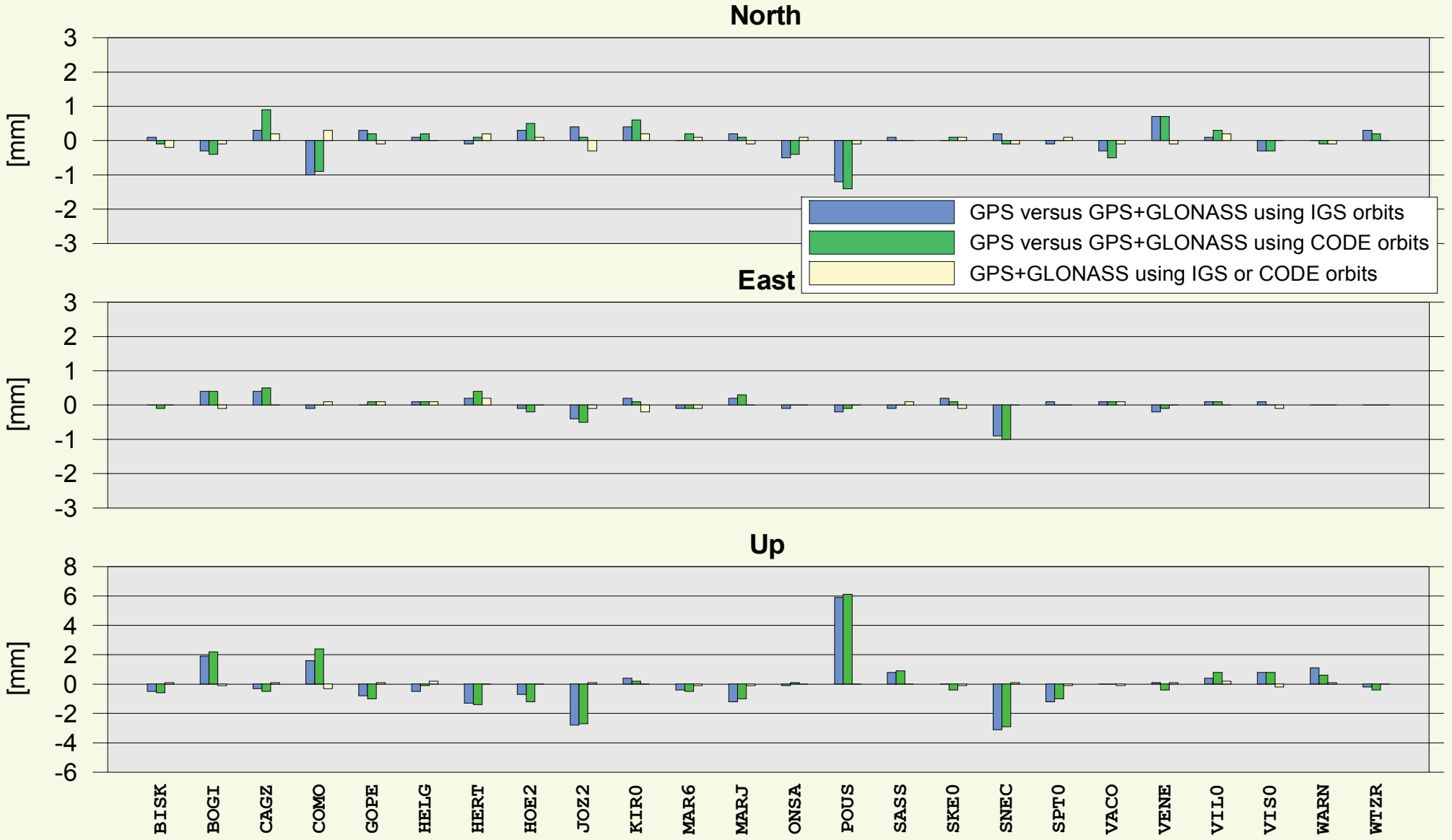
PREPARATION STEPS

- 14 of the 16 EPN LAC use GNSS processing software capable of processing GPS + GLONASS data
- Several EPN LAC have started to perform first tests to evaluate influence of combined GPS+GLONASS data analysis on station coordinates
- EPN CB is will soon add GLONASS to quality checks

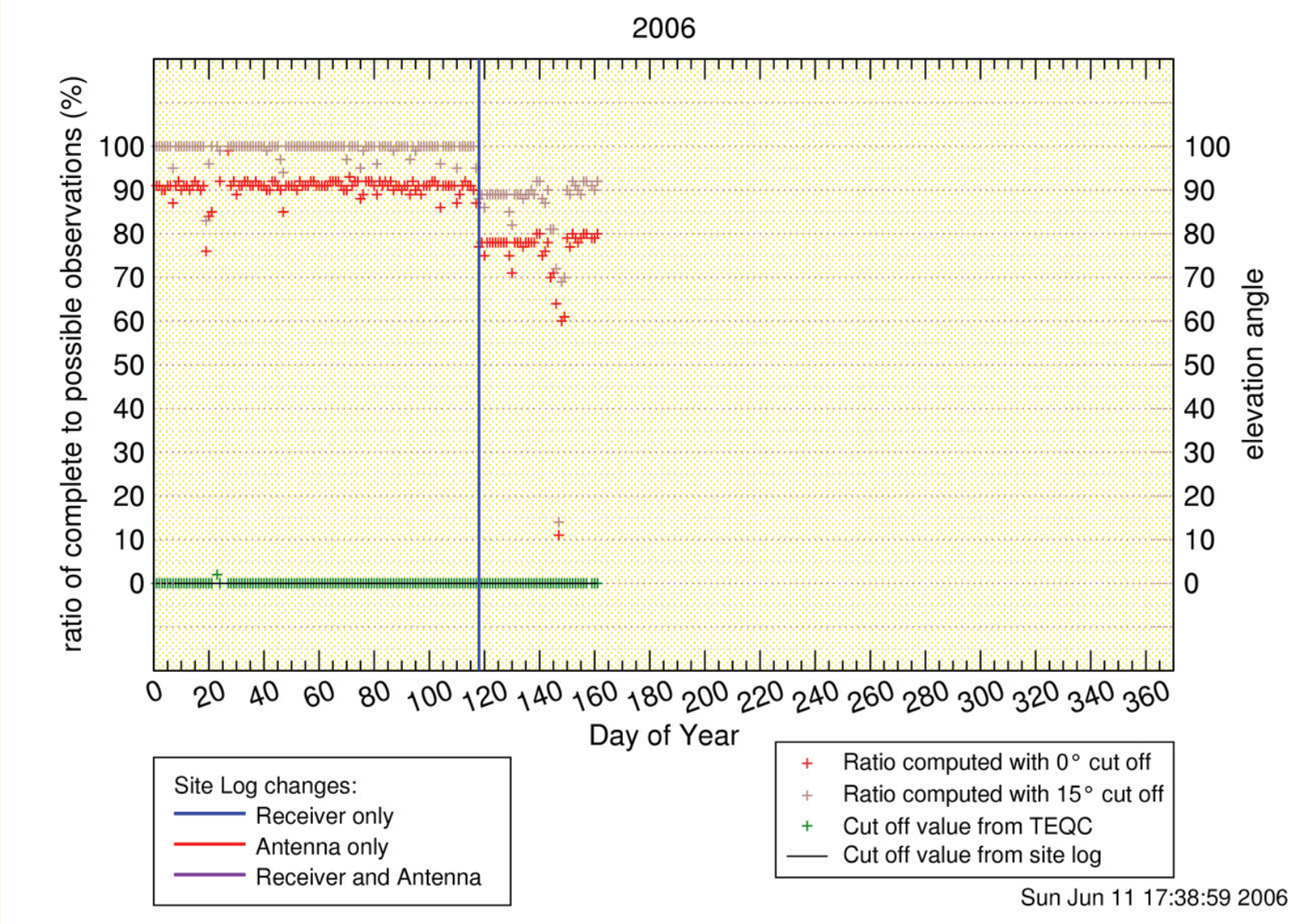
COORDINATE REPEATABILITIES



COORDINATE COMPARISONS



From ASHTECH Z-XII3 (GPS) to Ashtech Z-18 (GPS+GLONASS)



Future Plans

EPN Reprocessing

MOTIVATION FOR EPN REPROCESSING

- Numerous improvements in modelling and processing of GNSS observations
  - Reference frame changes
  - Additional effects (e.g. ocean loading, receiver antenna phase centre variations, …) taken into account
  - Ambiguity resolution
  - Improved orbits … and many more …
- Time series of products (coordinates and ZTD) are inhomogeneous
- Two major changes will take place in the near future
  - Absolute antenna phase centre model
  - ITRF2005
- Topic is under discussion amongst EPN Analysis Centres

Summary

- EPN data and coordinates are the primary means to access the ETRS89
- EPN network continuously grows with about 15 stations each year
- EPN reliability is guaranteed
  - redundancy in all components
  - extensive operation guidelines
  - continuous monitoring
- EPN CB informs station managers when problems occur, but it is the responsibility of the station manager to check
  - Data availability & latency
  - Data quality

- Challenges for the future:
  - Switch to ITRF2005
  - Switch to absolute antenna phase centre values
  - Introduction of GLONASS
  - Decision on real-time policy
  - Re-processing of the EPN
  - Set up of a quick EPN solution for monitoring purposes

Thank You

To all Station operators and their agencies

Data centres

Analysis centres

For your support to the EPN Activities

Please submit site pictures to EPN CB: ANKR AQUI BELL BOGI BZRG CAGL CREU DRAG DRES DUBR EBRE ELBA ESCO GENO HELG HOFN JOEN KELY KOSG LLIV MEDI METS NICO NSSP NYA1 OBE2 OSJE OSLS POTS QAQ1 RABT RAMO REYK RIGA SFER SODA THU3 TRDS TUBI VARS VLNS WTZR ZECK