GNSS Analysis in a Multi-GNSS and Multi-Signal Environment

Erik Schönemann, Tim Springer
Florian Dilssner, Loukis Agrotis, Werner Enderle

Navigation Support Office, ESA/ESOC
Darmstadt, Hessen, Germany

EGU 30 April 2014, Vienna, Austria

Introduction

- GPS and GLONASS are being modernized
- Galileo and Beidou are emerging
- New signal modulations
    - C/A, P, BOC, MBOC, AltBOC
- Additional frequencies
    - L1, L2, L5 (GPS), E1, E5, E6 (Galileo), B1, B2, B3 (Beidou), etc.
- Data and Pilot components
    - I/Q
- Different observations (tracking, multipath mitigation)
- Vast number of possible linear combinations
- Improved on-board satellite clocks
    - Treating clocks as “white noise” will constitute a significant loss of information

How to optimally process signals from multiple GNSS or on more than two frequencies

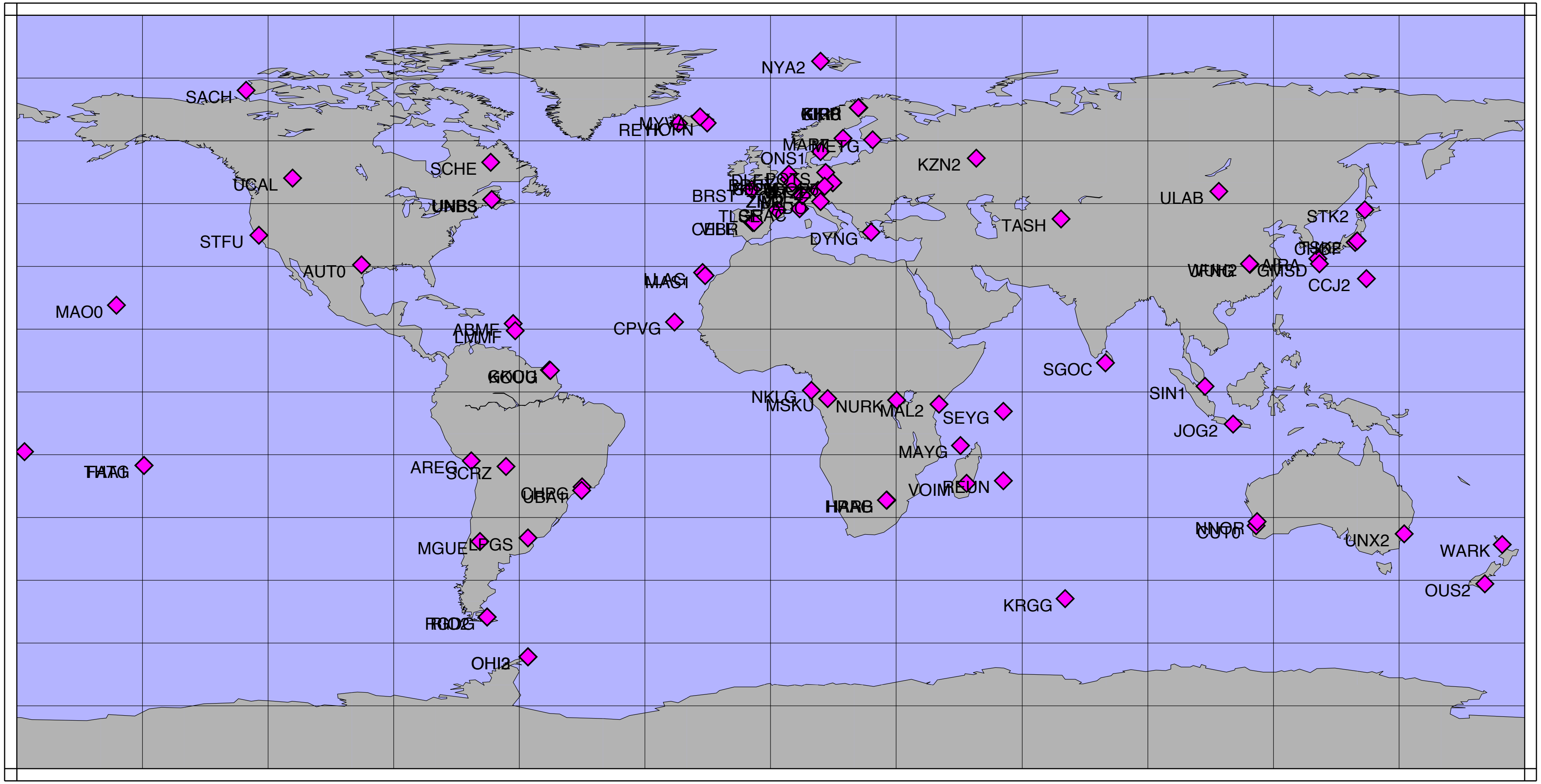
The ESA/ESOC Answer

- ***RAW processing***
  - Satellite clocks are getting very stable
    - ⇒ Avoid differencing that cancels out clocks
  - Multi-frequency processing should only “estimate” ionosphere once
  - Number of possible linear combinations exploding
    - ⇒ Avoid linear combinations, esp. those that cancel (“estimate”) the ionosphere
  - Simplest solution is to process the observations “as they are”
    - ⇒ ***RAW processing***
- Besides being “simple” it allows for
  - Monitoring all signals and their biases
  - Straightforward Integer Ambiguity resolution
    - Including inter system fixing? At least on interoperable signals
  - Satellite PCO/PCV estimation per frequency!

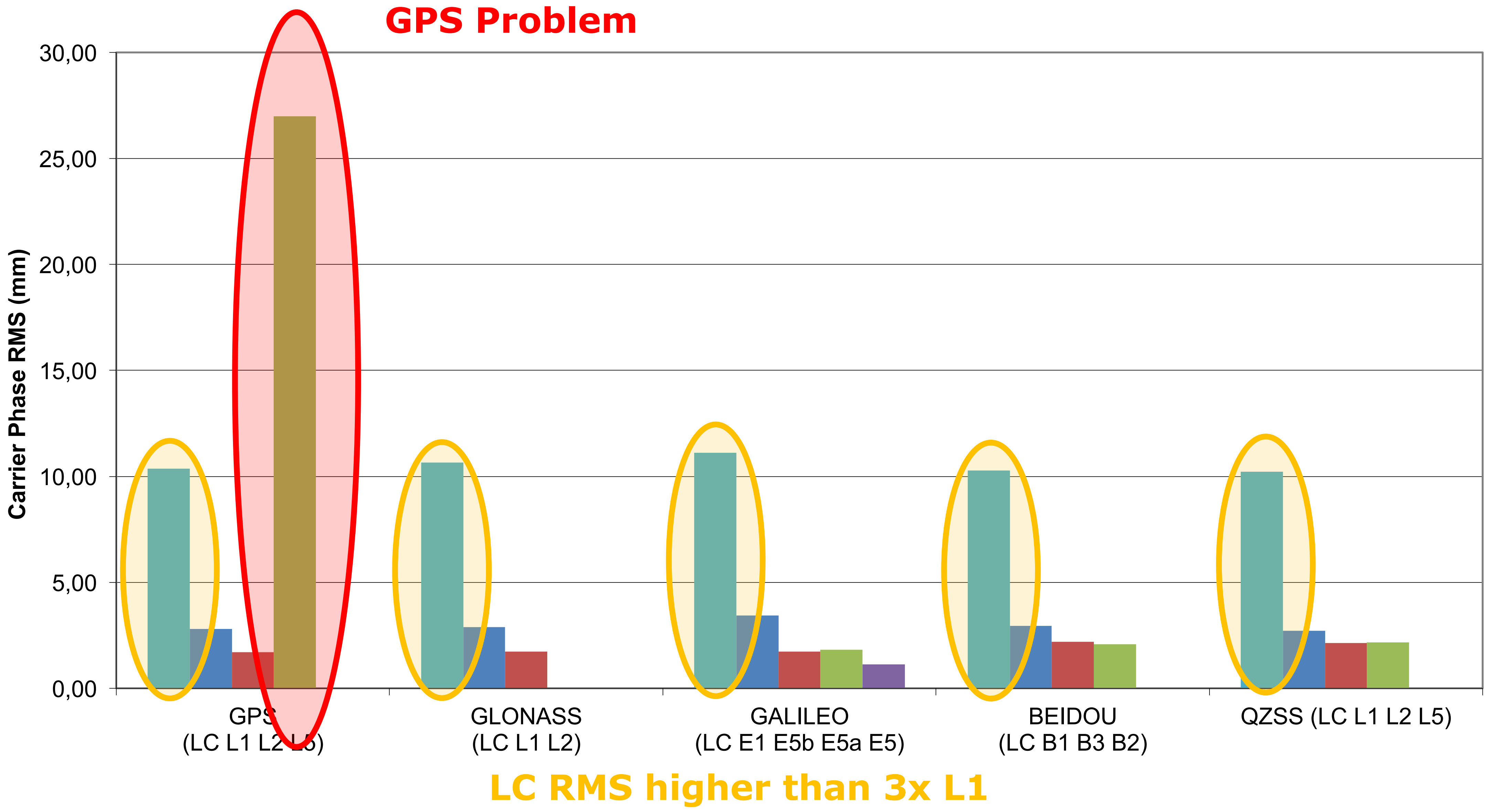
Experiments

- All results shown in the following are based on MGEX data
  - MGEX: IGS Multi GNSS Experiment
  - > 83 globally distributed multi GNSS stations (GPS+GLO+GAL)
    - ~34 stations tracking Beidou
    - ~22 stations tracking QZSS
- Analysis focussed on a 16 day data set from March 2014
  - No routine processing but in-depth analysis of the data
  - Data set processed using “normal” (ionosphere free) and “raw” processing method

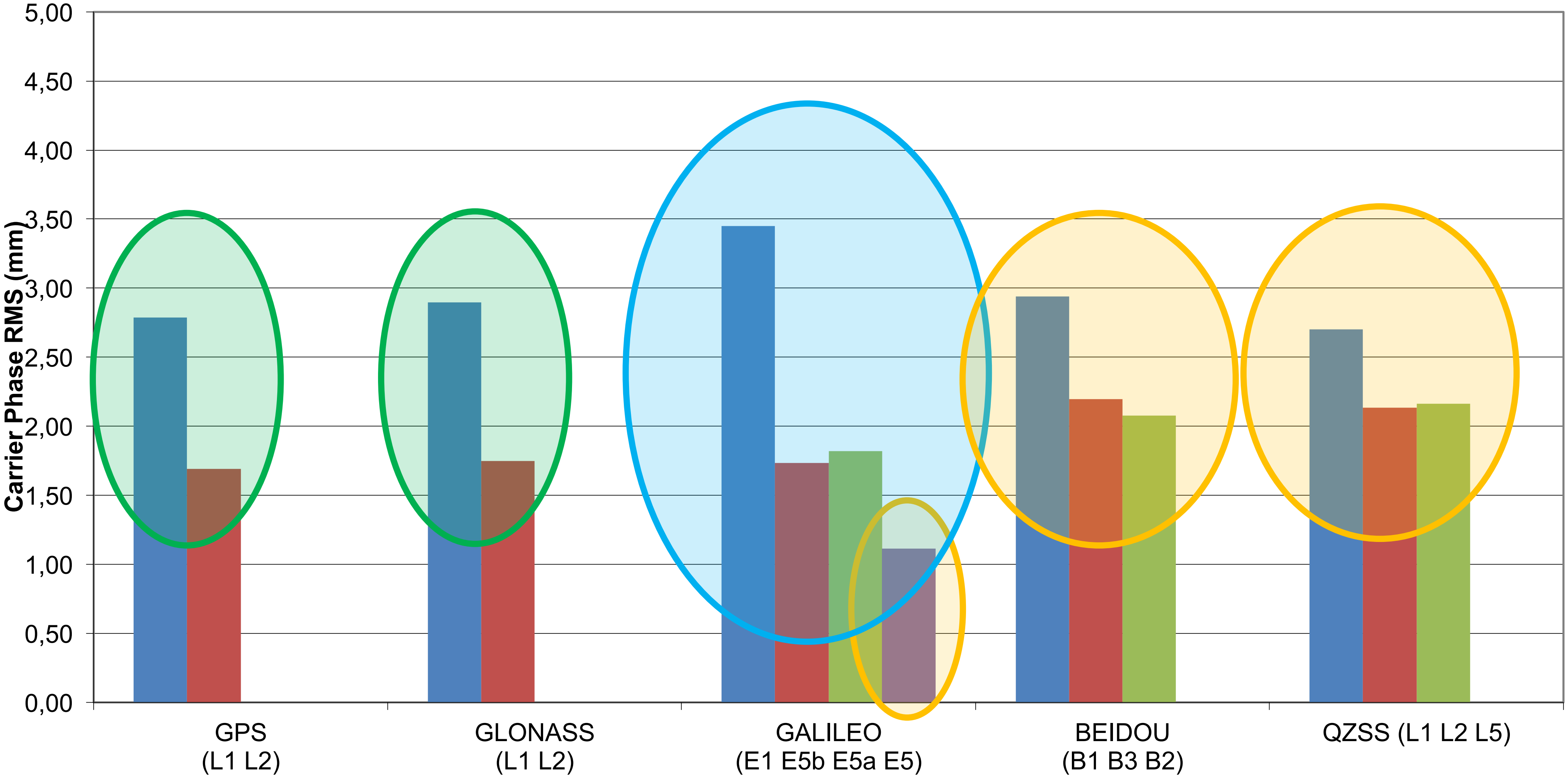
MGEX stations used



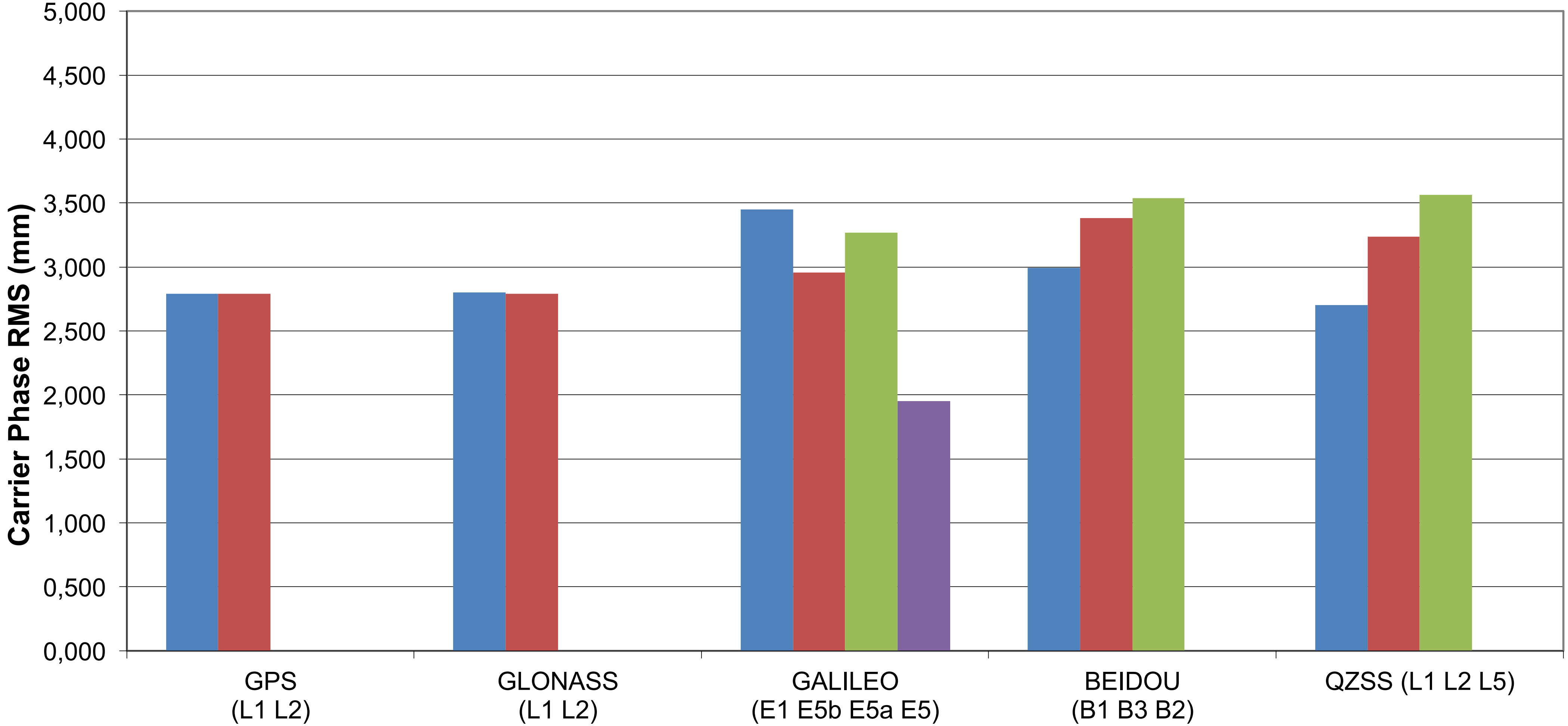
A look at the Individual Phase Signals



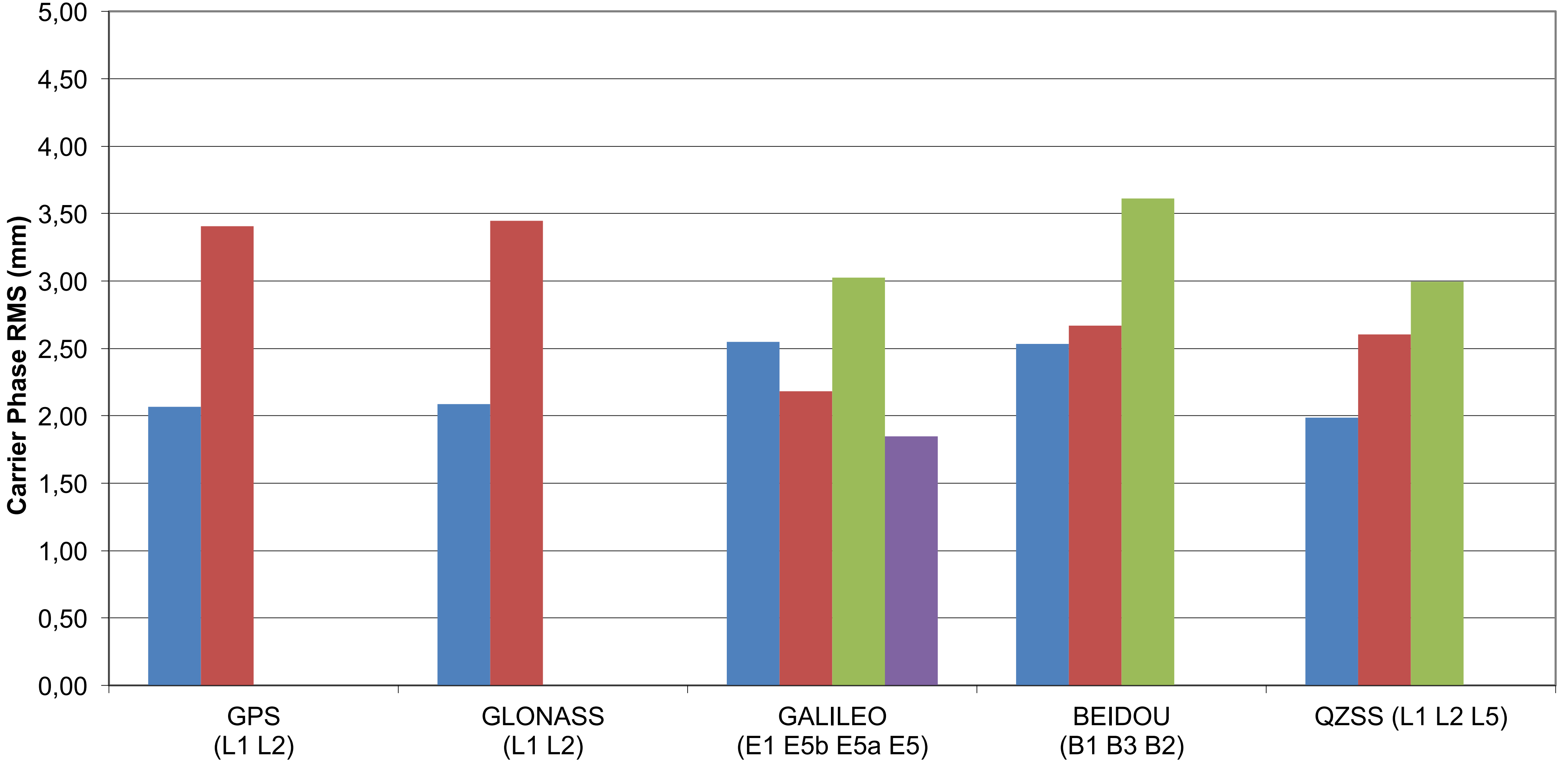
A look at the Individual Signals (now ignoring GPS L5 and LC)



Same as previous but now scaled the RMS a posteriori with sigma = sigma * GPS L1 freq² / signal freq²

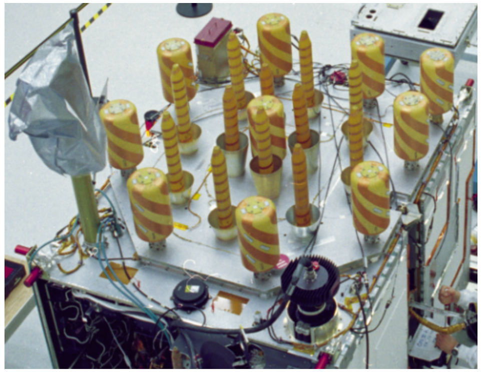


Similar as previous but now scaled the RMS a priori with sigma = sigma * GPS L1 freq² / signal freq²



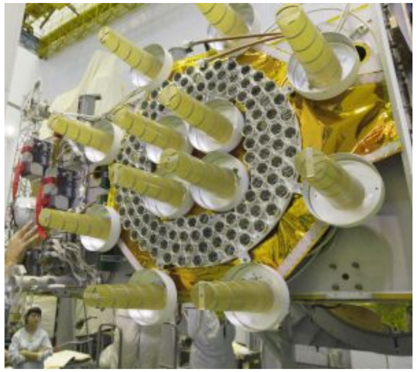
Satellite Antennas PCO/PCV

GPS IIA (Credits: Geo++)



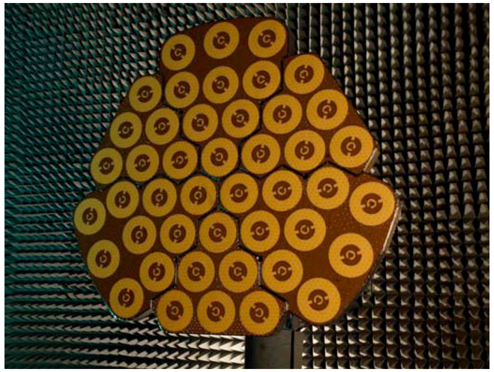
GPS IIR (Credits: Lockheed)

GPS IIF (Credits: Boeing)



GLONASS-M (Reshetnev)

GLONASS-K1 (Reshetnev)

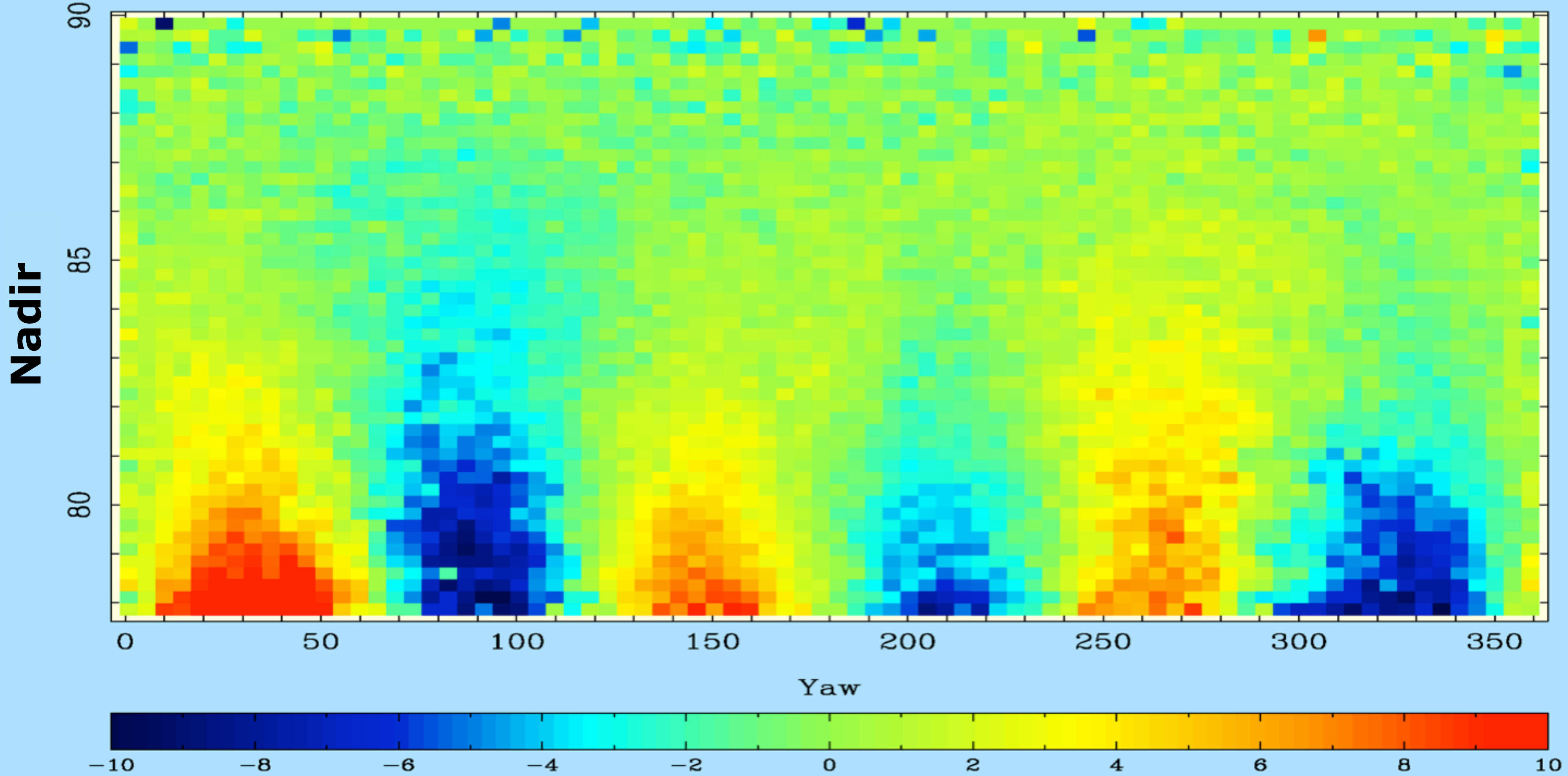


GALILEO-IOV (and GIOVE-B) (ESA)

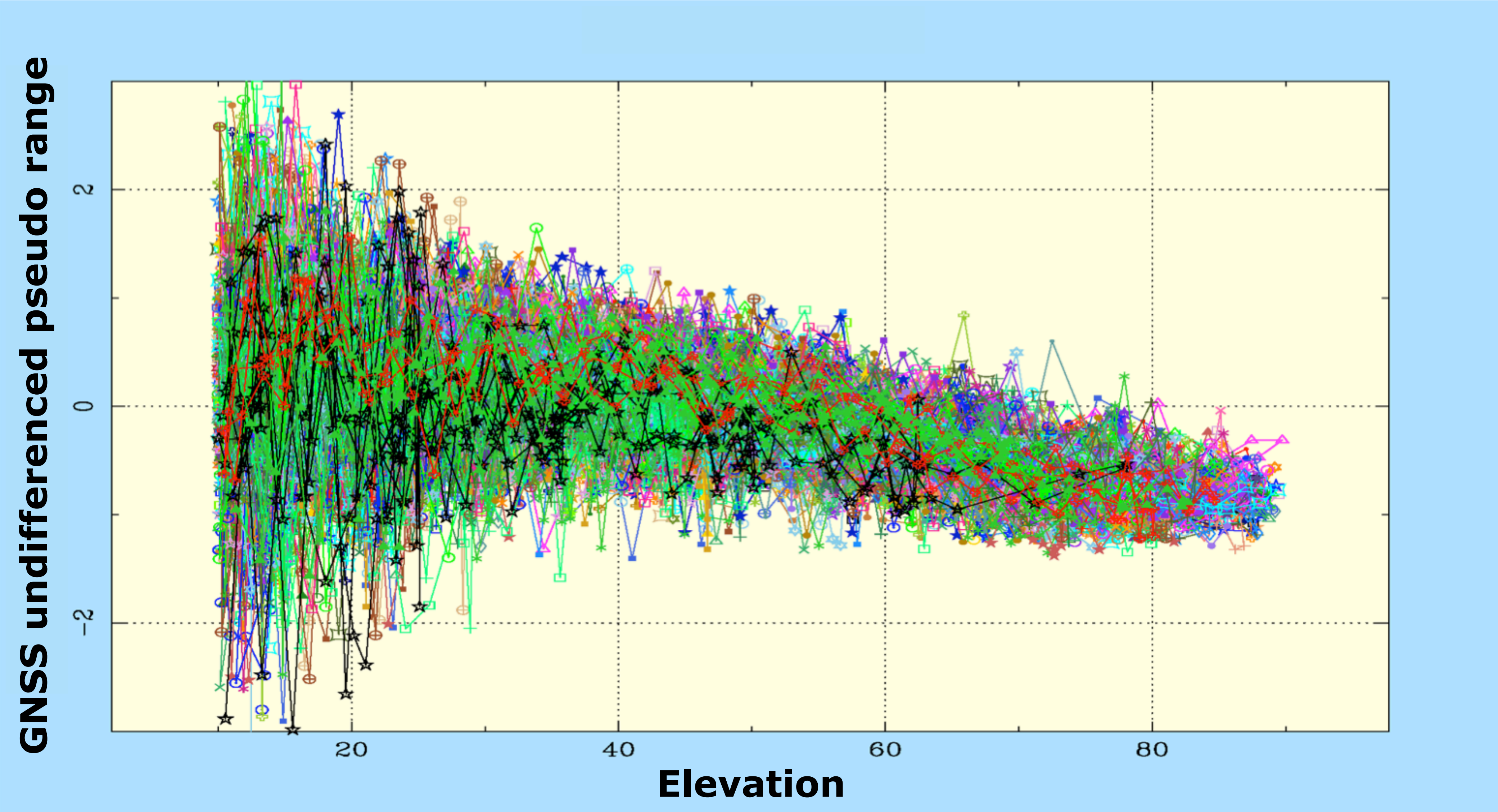
→ **12 element helix design common to all GPS and GLONASS antenna types** ←

→ **GALILEO is very different**

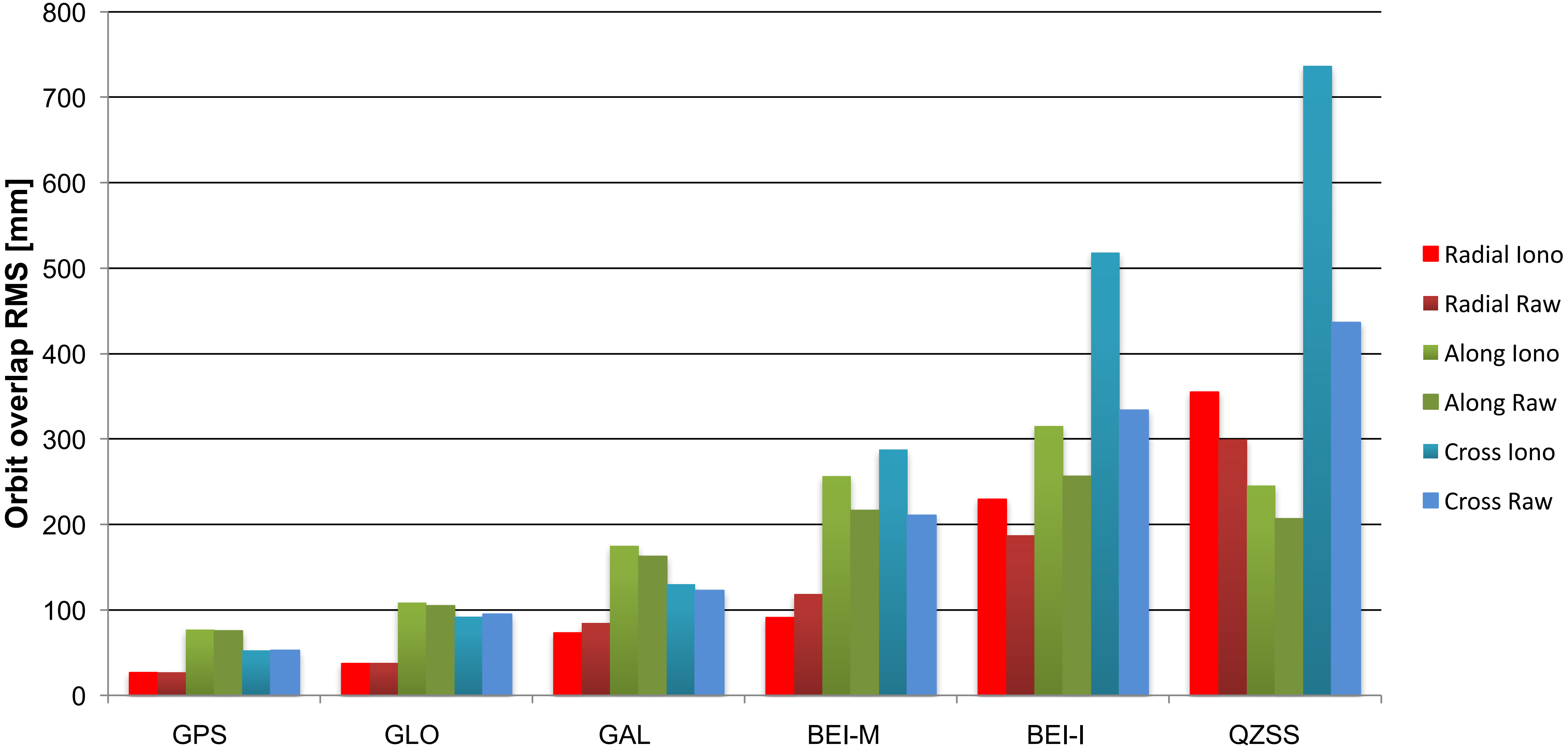
Satellite "azimuth" (yaw) angle dependent residuals for Galileo



Strong code residual pattern for BeiDou (strongest on B1/C2)



2 day orbit overlaps
Ionosphere free LC vs. Raw



Summary

esa

- The raw processing method has (significant) potential for signal analysis
    - In particular when the third signal is on a frequency that is significantly different from the other two
    - With only two frequencies (signals), except for bad conditioned cases, the “raw” method shows comparable results
- The noise of the ionosphere free linear combination appears to be more than a factor of 3 higher compared to the noise of the original observations (L1, L2, etc.)
- Differential bias stability (between signals/frequencies) is a key factor for combinations of more then two signals/frequencies
    - In this sense the differential GPS phase biases appeared to be problematic
- Galileo E5 (AltBOC) has “outstanding” performance on both code and phase measurements!

Conclusions

Main benefits of the ESA/ESOC "***RAW processing***" method are:

- Avoidance of noise and multipath amplification
  - Raw observations have significantly lower noise
- Ionosphere is obtained from phase, thus keeping the code noise low
  - Especially important for high quality code signals (AltBOC)
- Ambiguity resolution becomes trivial
  - In particular with Galileo AltBOC (E5) signal
- Access to PCO/PCV on the individual frequencies
- Access/visibility of original biases
  - The biases on the individual (raw) observations
- Availability of biases for PPP and other applications
  - Biases can be "serviced", e.g. by the IGS

For more information see:

Erik Schönemann: *Analysis of GNSS raw observations in PPP solutions.* Schriftenreihe der Fachrichtung Geodäsie (42). Darmstadt.

ISBN 978-3-935631-31-0 [Book], (2013)

http://tuprints.ulb.tu-darmstadt.de/3843/

THANK YOU

Erik.Schoenemann@esa.int

Announcement

ESA/ESOC is **organising a dedicated POD conference at ESOC, Darmstadt, Germany in May 2015 (TBC). Details will be announced in June 2014. The POD conference** will cover all areas of POD, including:

- **Constellations and orbits**

  GNSS, LEO, MEO, GTO, GEO
- **Techniques**

  GNSS, Satellite Laser Ranging, Doris, Radar Altimetry
- **Algorithms and models**

  Force models, Data processing, Optimisation, …
- **Hardware and Processing concepts**

  Onboard Receivers, Real Time, Batch processing …
- **Interaction between different POD stake holders**

  Service providers, System providers, Science community, End Users,…

Contact: Werner.Enderle@esa.int