Impact of a LEO Formation and a LEO/GPS Dual Constellation on the IGS Products

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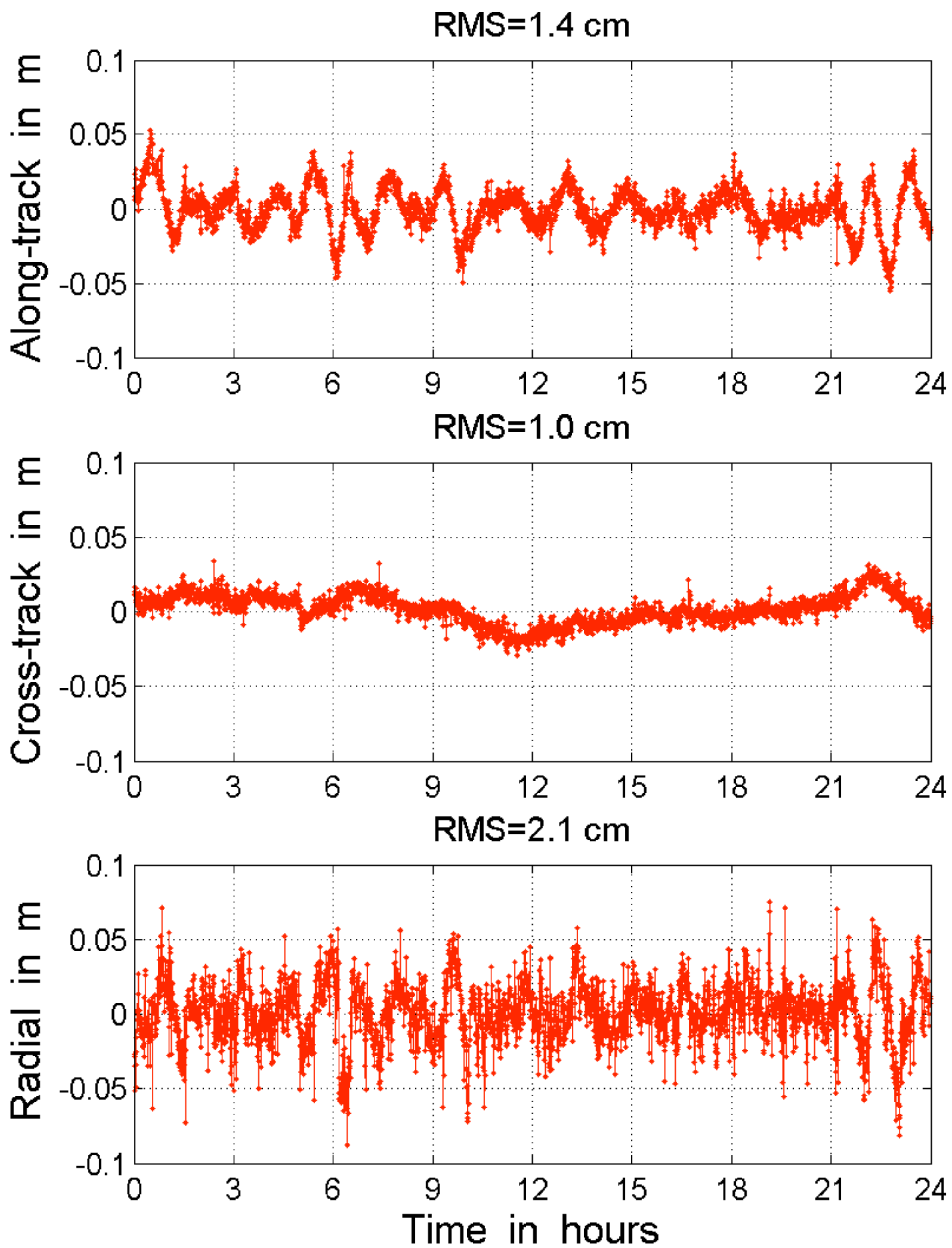
Content

- Kinematic and Dynamic POD, the IGS product?
- LEO formation flying – GRACE
- Ambiguity resolution with GRACE
- Global solution based on CHAMP baselines
- Global solution based on Phase Clocks and GRACE baseline
- COSMIC LEO constellation
- Can reference frame be defined from space?

Kinematic GRACE-A



Differences between kinematic and reduced-dynamic positions day 200/2003

Zero-difference phase measurements.

Sensitive component:

- GPS orbits - along-track
- LEO orbits - radial

Kinematic Orbits, the Product?

$$V = \frac{1}{2}\left(\frac{d\vec{r}}{dt}\right)^2 - \int_{\vec{r}} \vec{a}_{non-gravitational}\, d\vec{r} - \int_{\vec{r}} \vec{a}_{tides}\, d\vec{r} + C$$

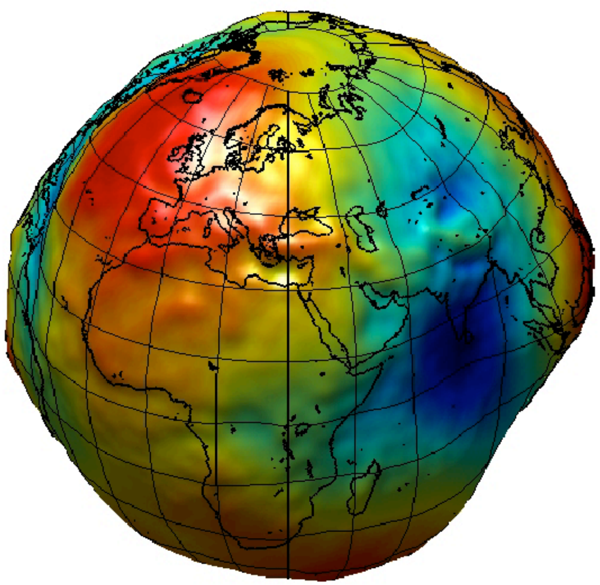
Energy conservation

kinematic orbit (position)

accelerometer

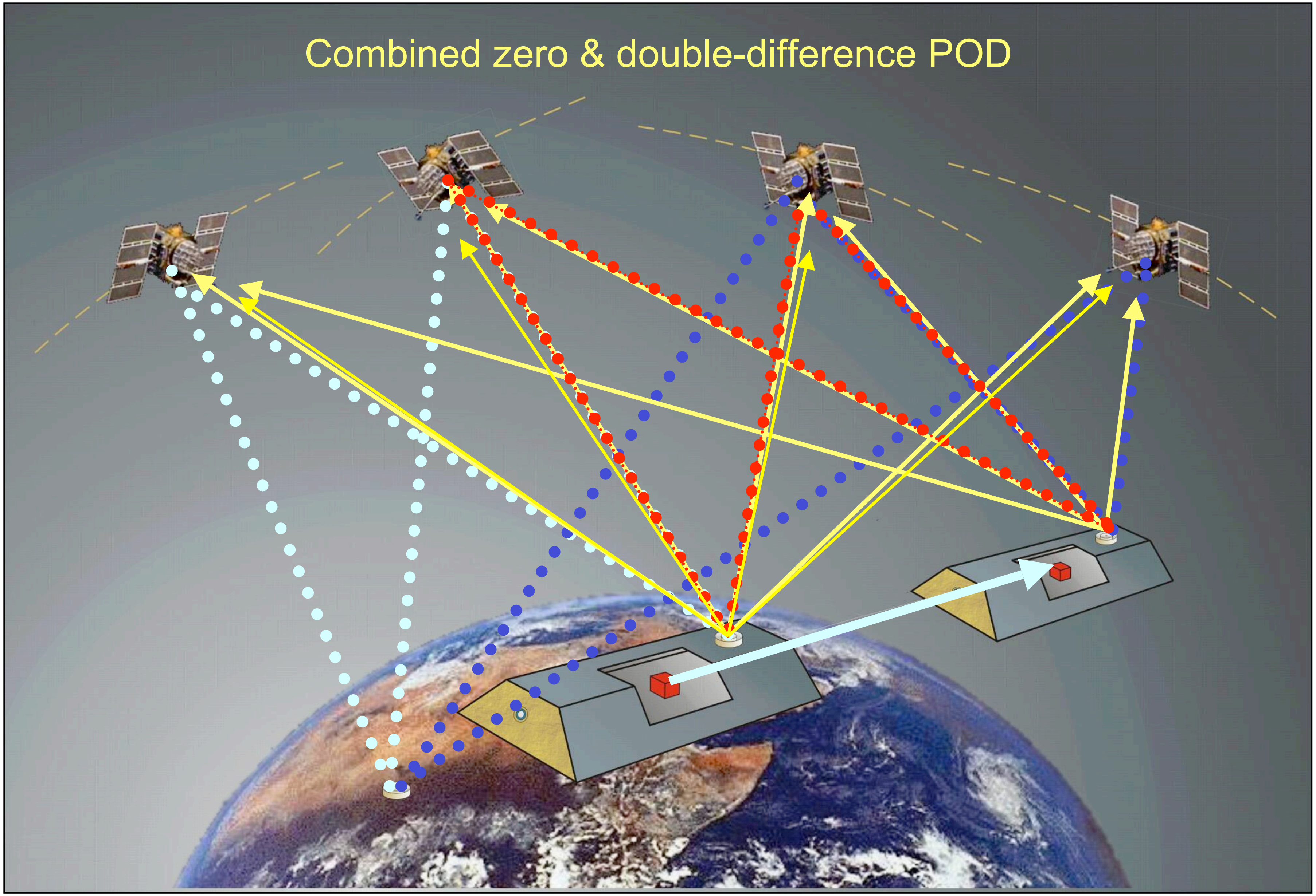
tide models

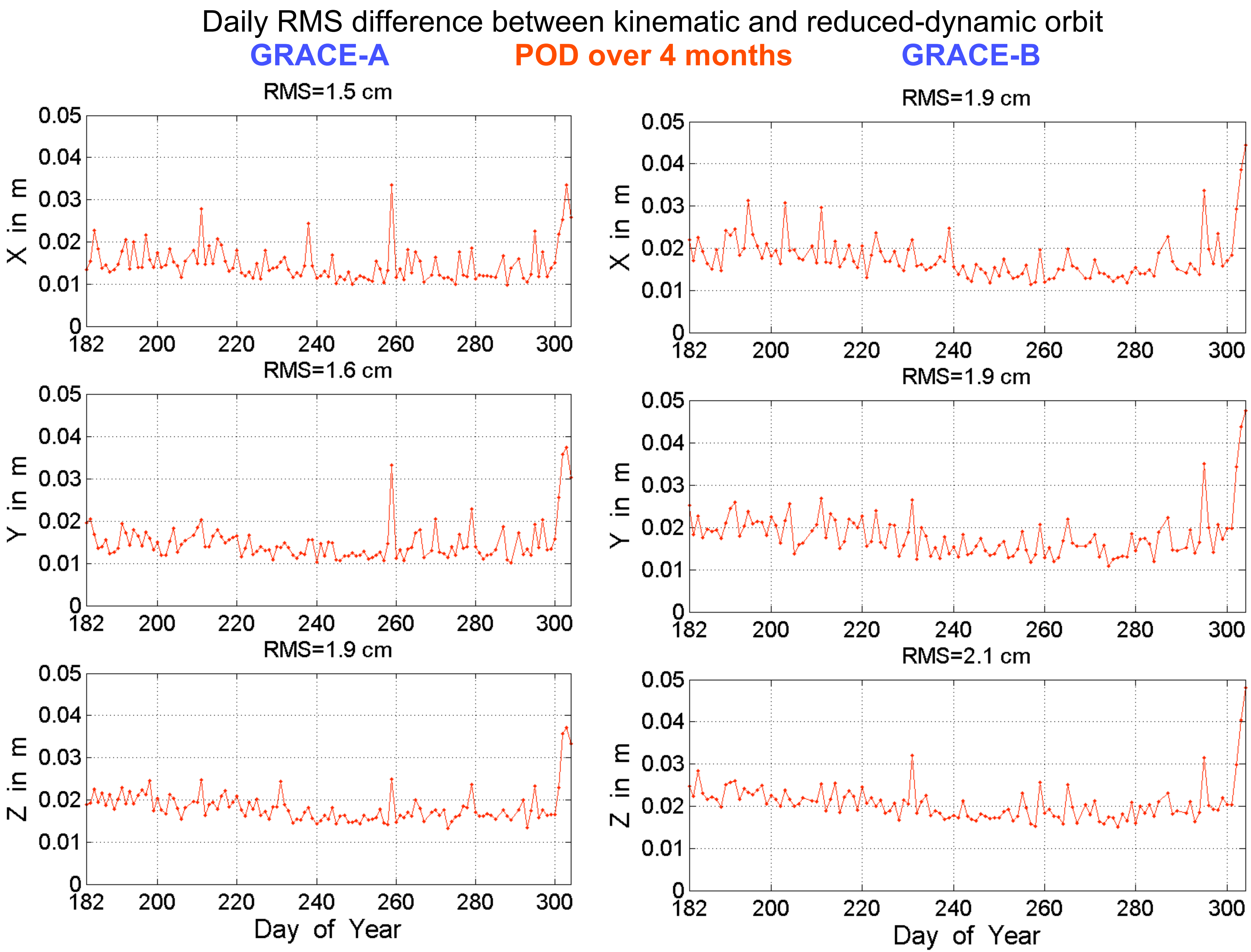
CHAMP kinematic orbits used at 15-20 different institutions
10 gravity field models published so far



Austria	(gravity)
Canada	(gravity)
China	(gravity/POD)
Denmark	(gravity)
Germany	(gravity/POD)
Japan	(POD)
Netherlands	(gravity/POD)
Switzerland	(POD)
Taiwan	(gravity/POD)
UK	(gravity)
US	(POD)

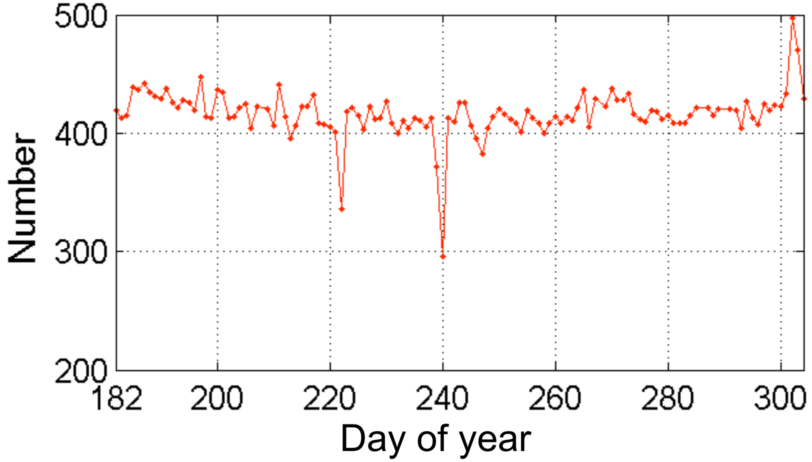
POD for LEO Formation/Constellation Flying



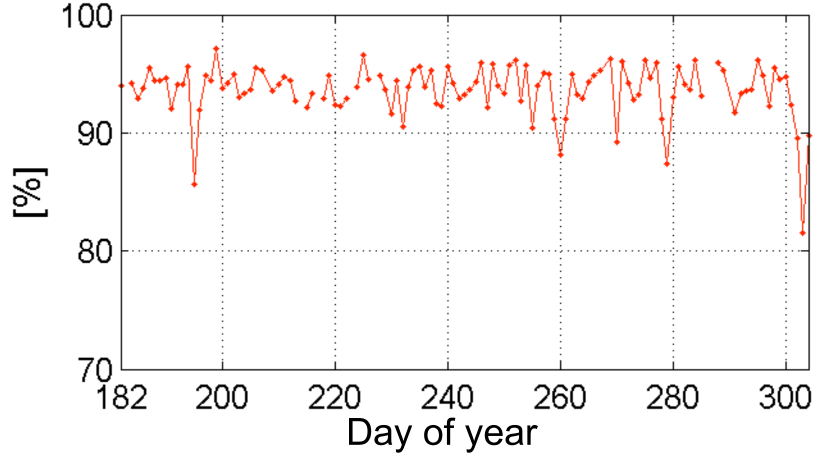

Daily RMS difference between kinematic and reduced-dynamic orbit
GRACE-A
POD over 4 months
GRACE-B
RMS=1.5 cm
RMS=1.9 cm
X in m
RMS=1.6 cm
RMS=1.9 cm
Y in m
RMS=1.9 cm
RMS=2.1 cm
Z in m
Day of Year

Ambiguity resolution with GRACE baseline

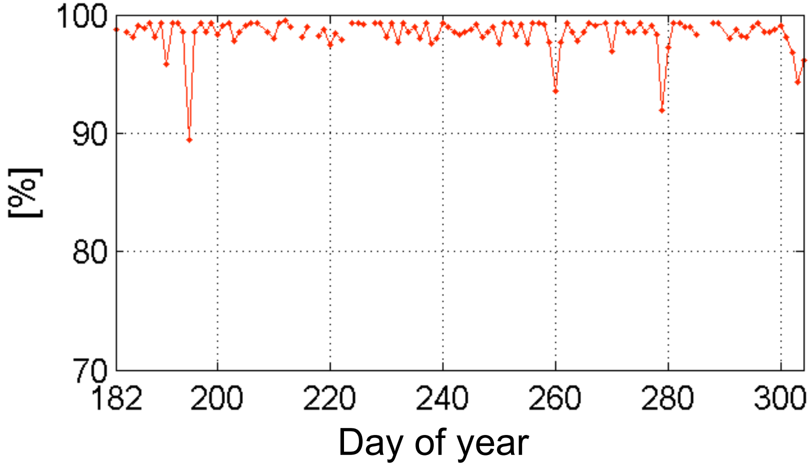
Total number of ambiguities, mean= **416**



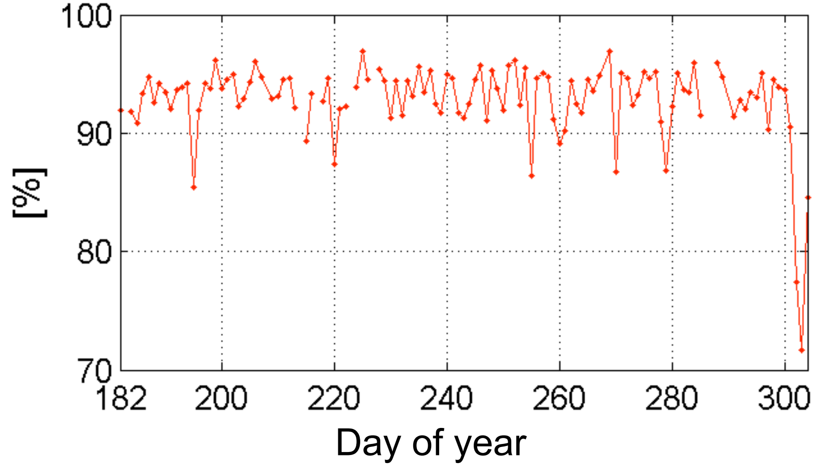
Resolved **narrow-lane** ambiguities using kinematic bootstrapping, mean= **93.6%**



Resolved wide-lane ambiguities (**Melbourne-Wübbena**), mean= **98.4%**



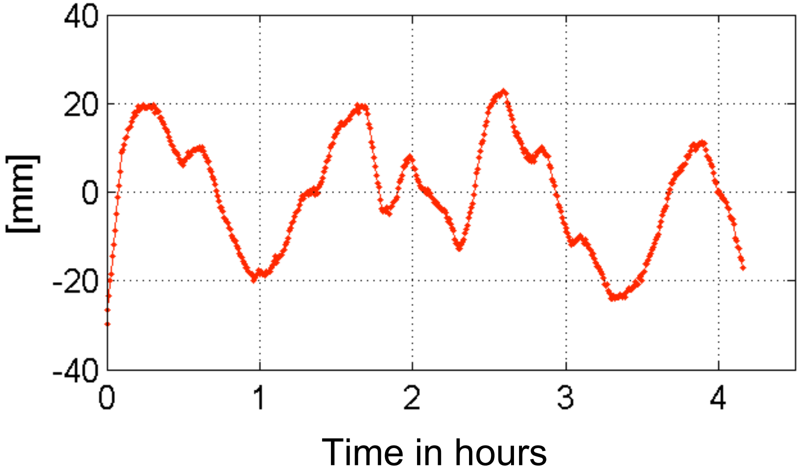
Resolved **narrow-lane** ambiguities using dynamic bootstrapping, mean= **92.8%**



GPS Baseline - Validation with KBR

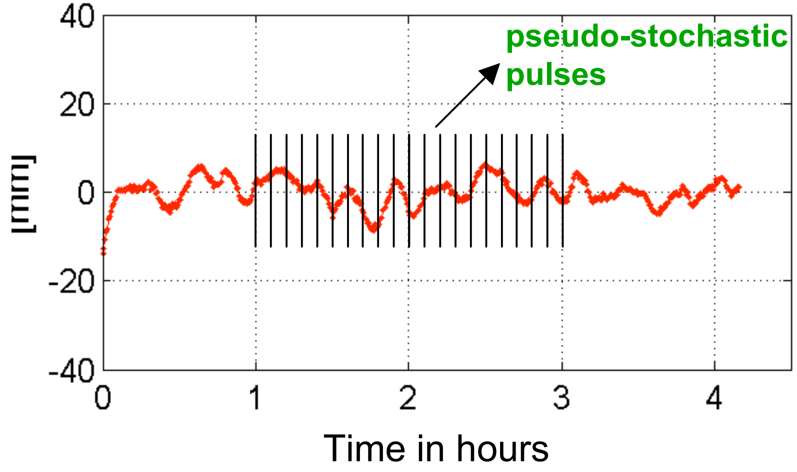
Zero-differences

RMS= 12.6 mm



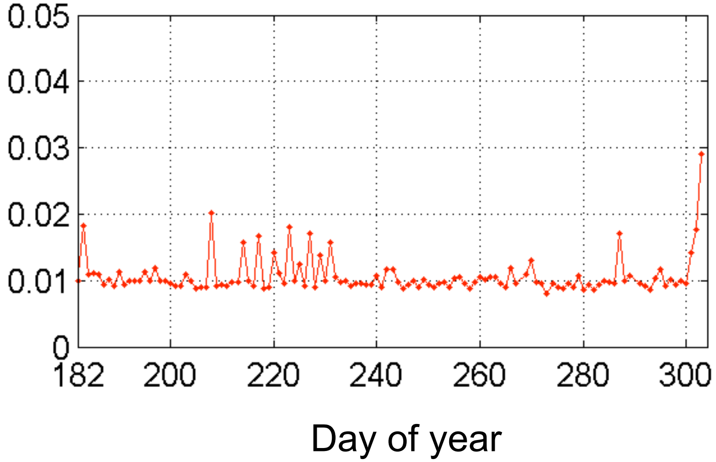
GPS baseline with fixed ambiguities

RMS= 2.8 mm



Kinematic minus Reduced-Dynamic Orbit

RMS=1.1 cm

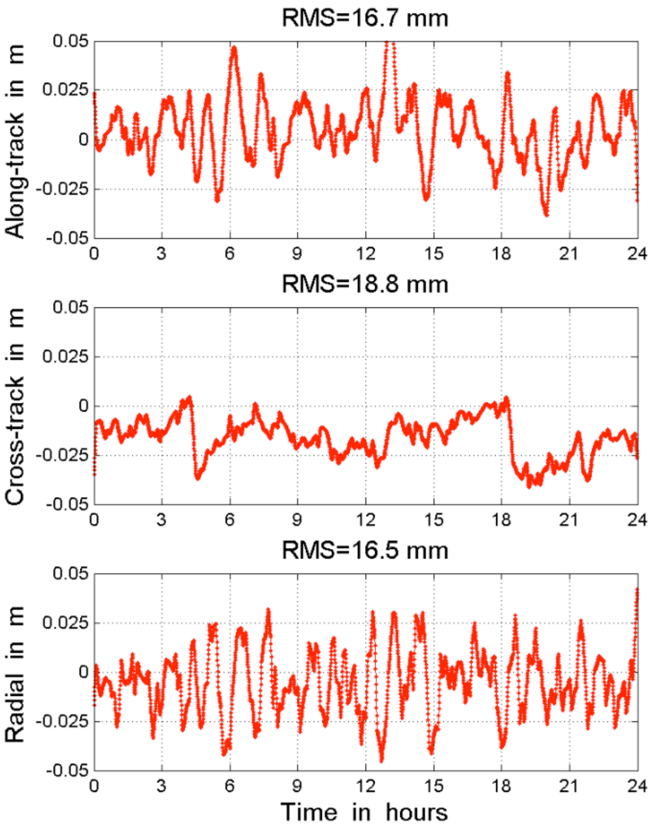


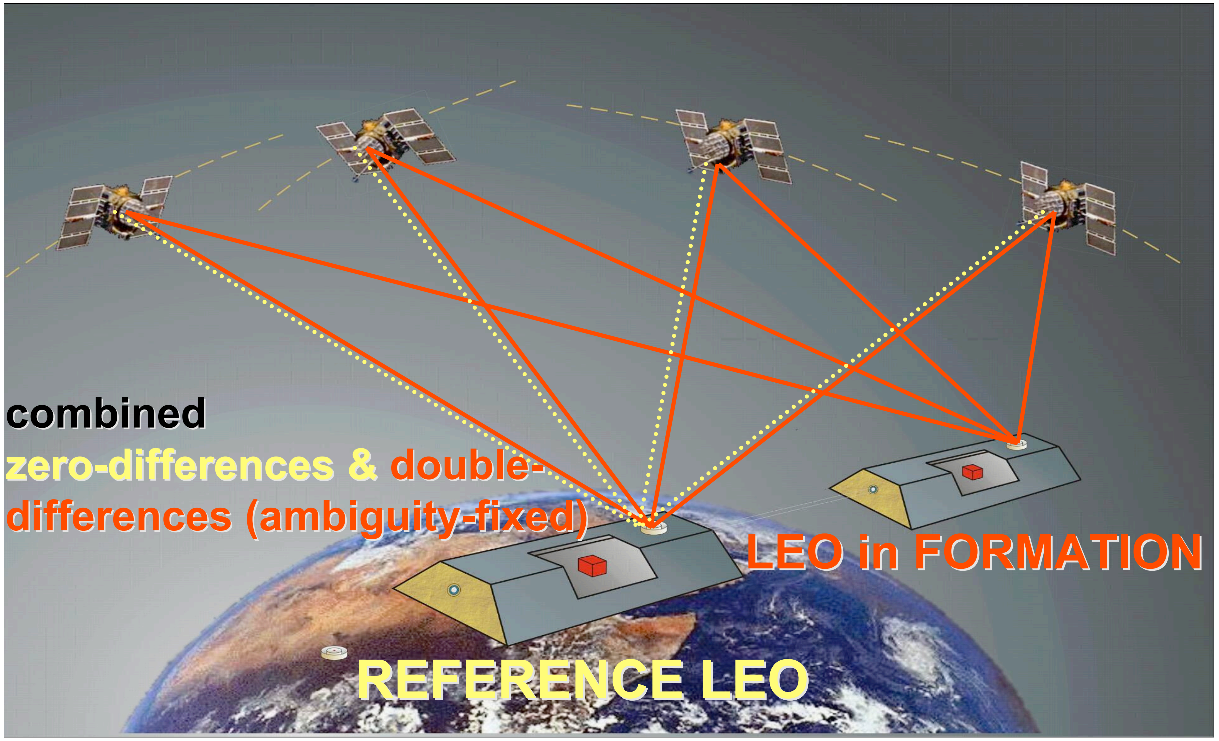
1-cm kinematic POD

Combined Processing of Zero and Double-Difference Measurements

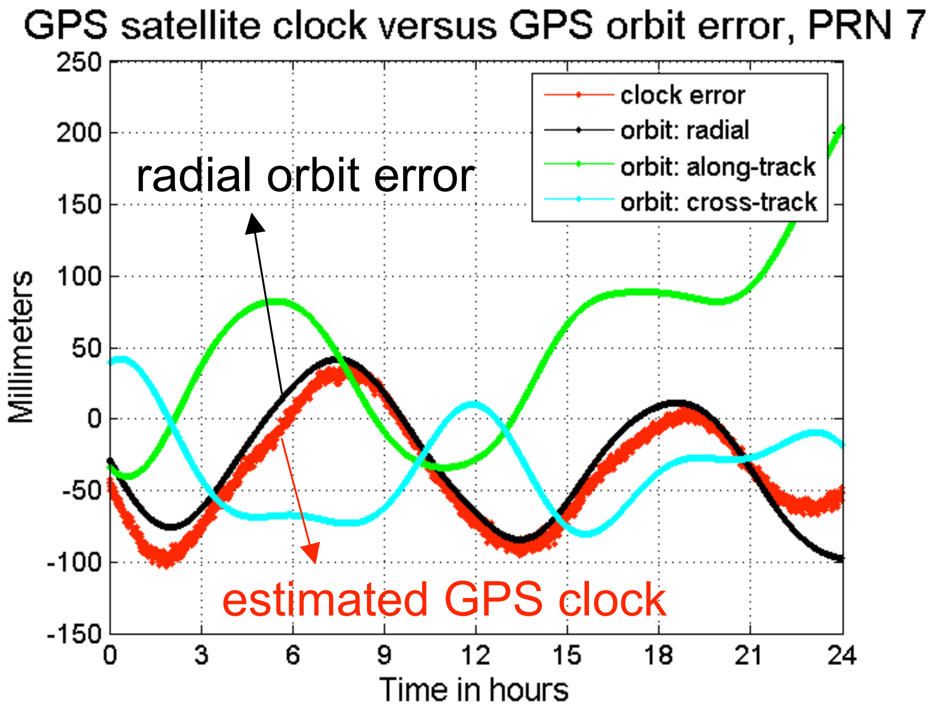
GPS Baseline with FIXED Ambiguities
(GRACE-A and GRACE-B Together)

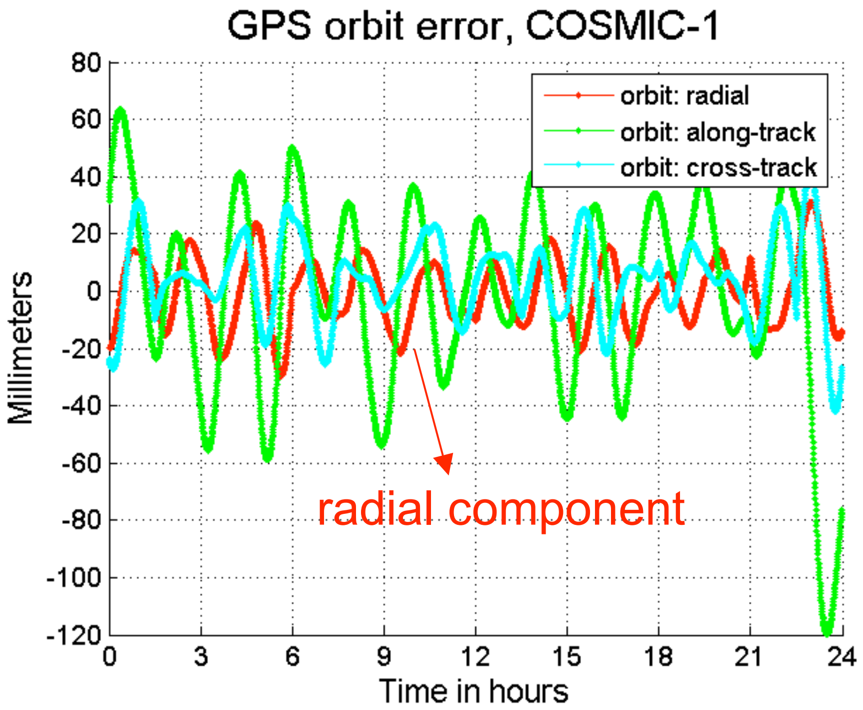
Zero-Difference Versus Combined Zero- & Double-Difference Baseline



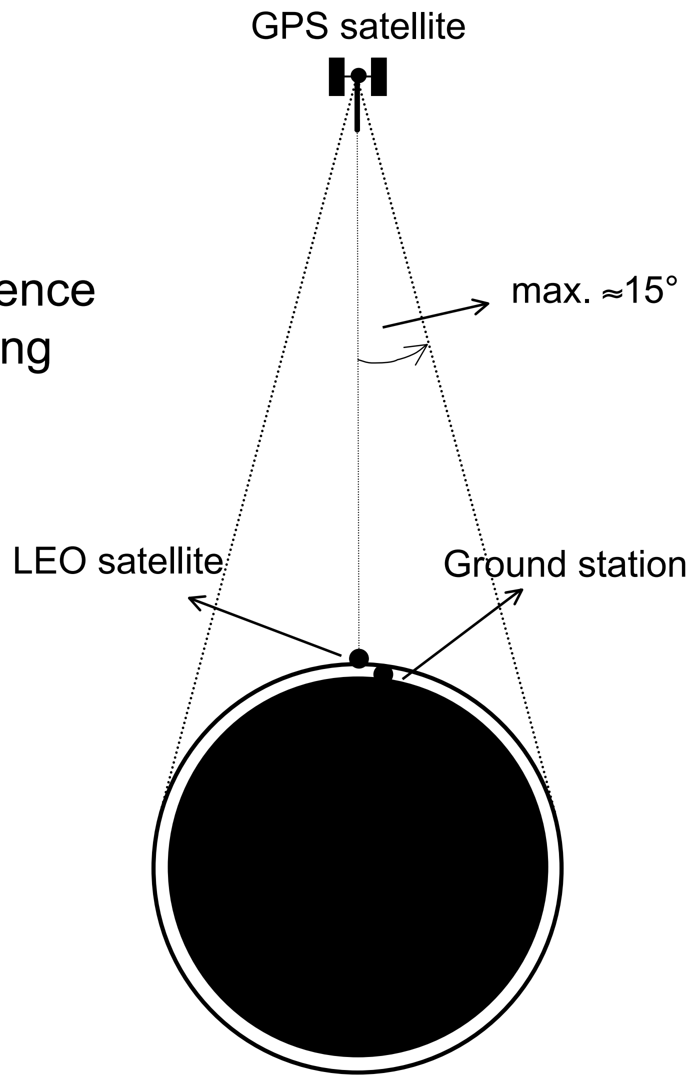


LEO POD limited by the GPS POD





zero-difference processing



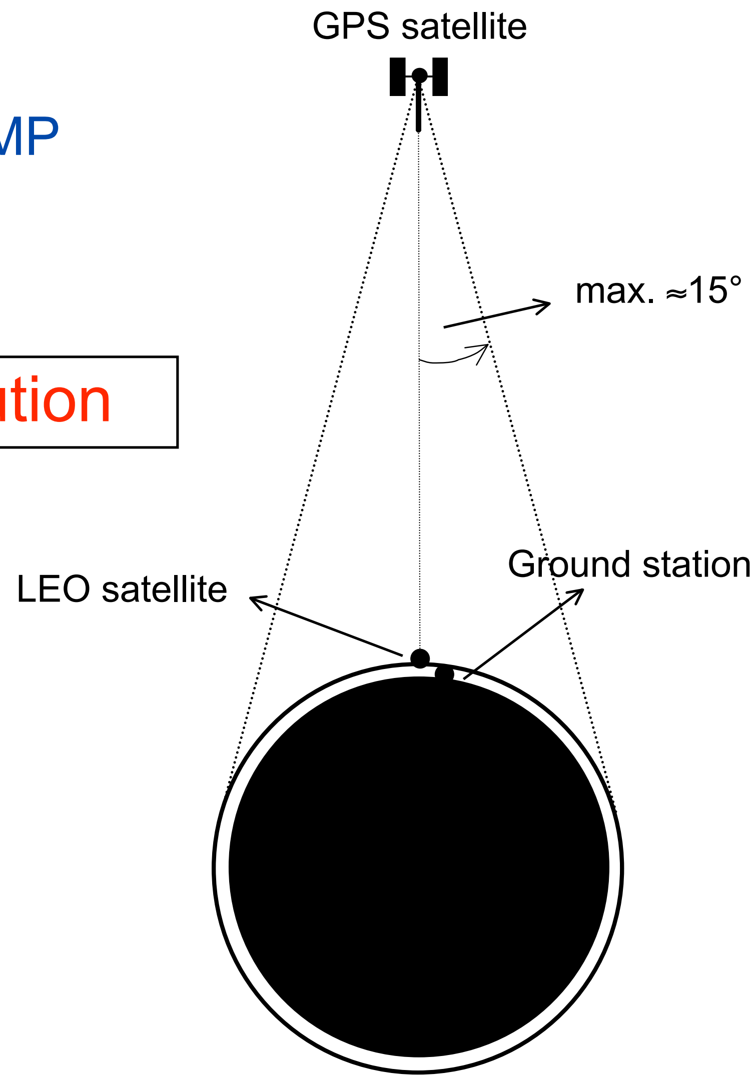
Global solution based on a CHAMP satellite

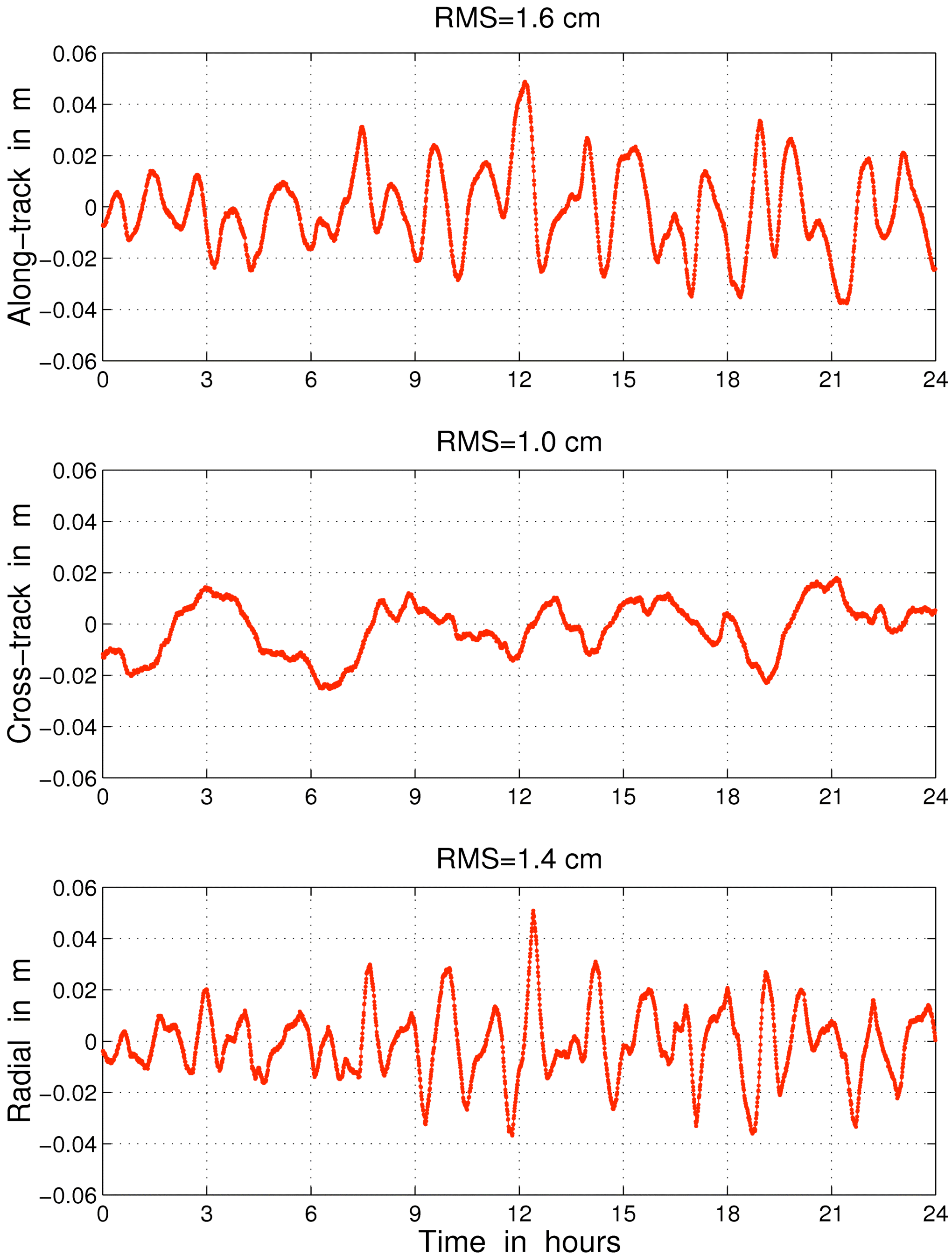
GPS week 1175/2002:

baselines between IGS stations and CHAMP
60 stations ≈ 8000 ambiguities:

- 5000 ambiguities/day → **weak solution**
- resolved ambiguities 20.4%

narrow-lane bootstrapping
10 ambiguities fixed/NEQ inversion





Reduced-Dynamic POD CHAMP

impact of the ambiguity resolution

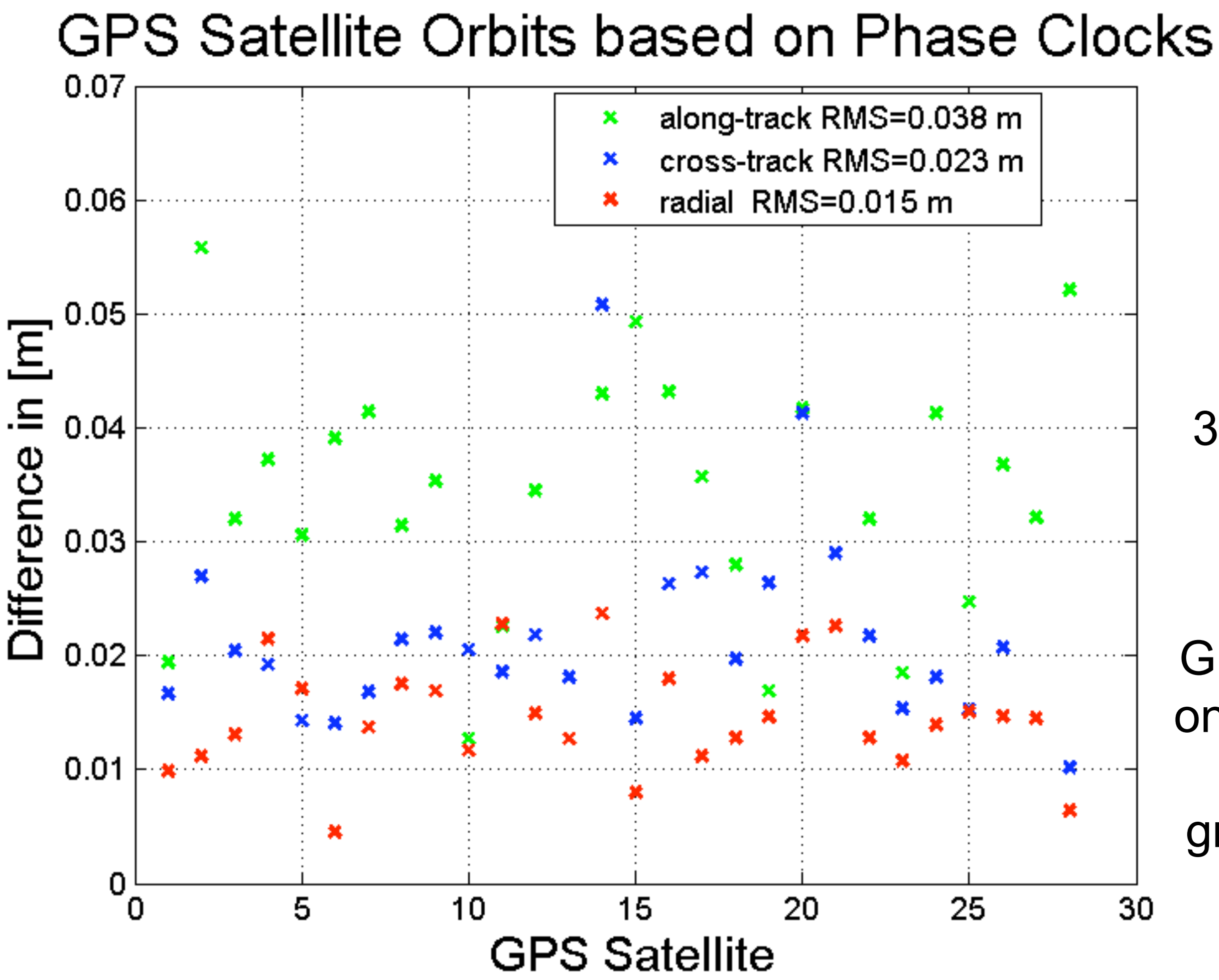
Baselines **IGS-LEO** (length up to 10 000 km)

Double-differences with **FIXED** ambiguities.

Differences between reduced-dynamic positions with fixed and float ambiguities

All global products were kept fixed, day 200/2002.

Global Solution Based on Phase Clocks and GRACE Baseline



65 stations stacked from two clusters +GRACE baselines

zero-differences +double-differences

3-day solution compared to the IGS re-processing

GRACE GPS baseline helps only if a solution is computed with the small number of ground stations which is not the case in reality

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Global Solution based on Phase Clocks

→ **PHASE CLOCKS:** GPS satellite/station clocks estimated using **only phase data**

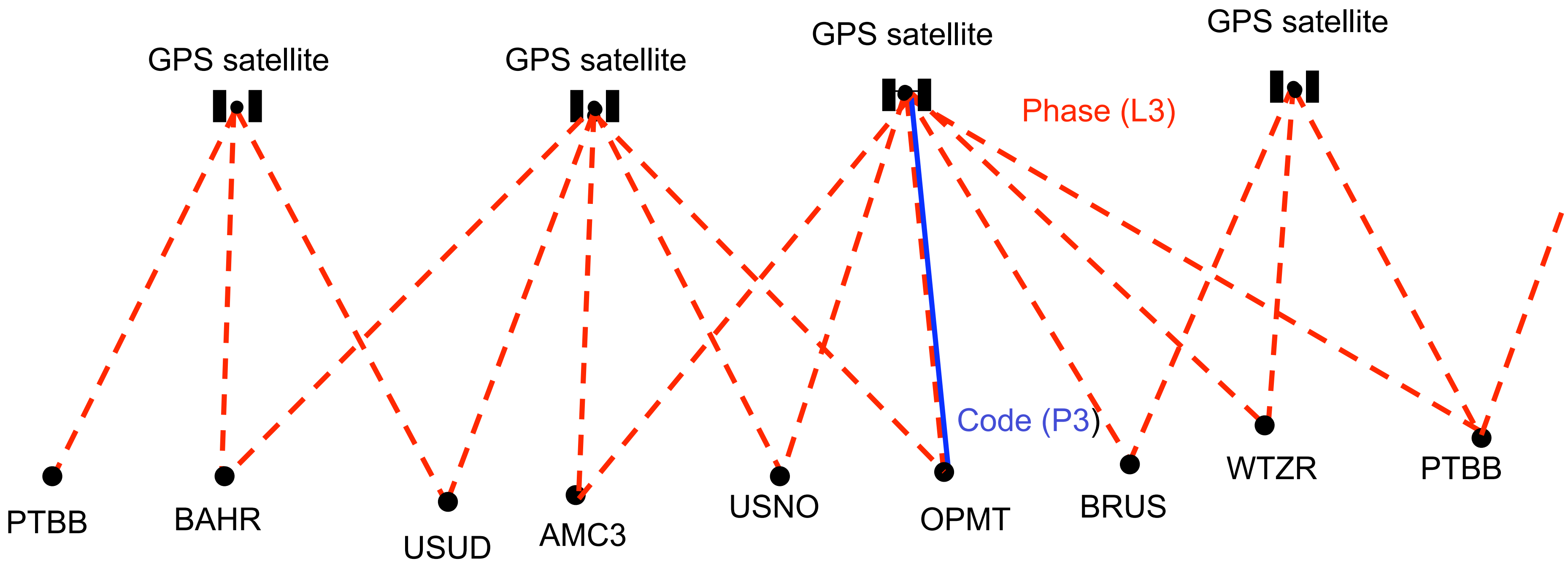
→ **Estimated Parameters :** GPS/station clock parameters every 30 sec + ambiguities

→ one clock bias over all clock labs (PPP is done using phase data only)

→ code measurements only for approximate clock synchronization

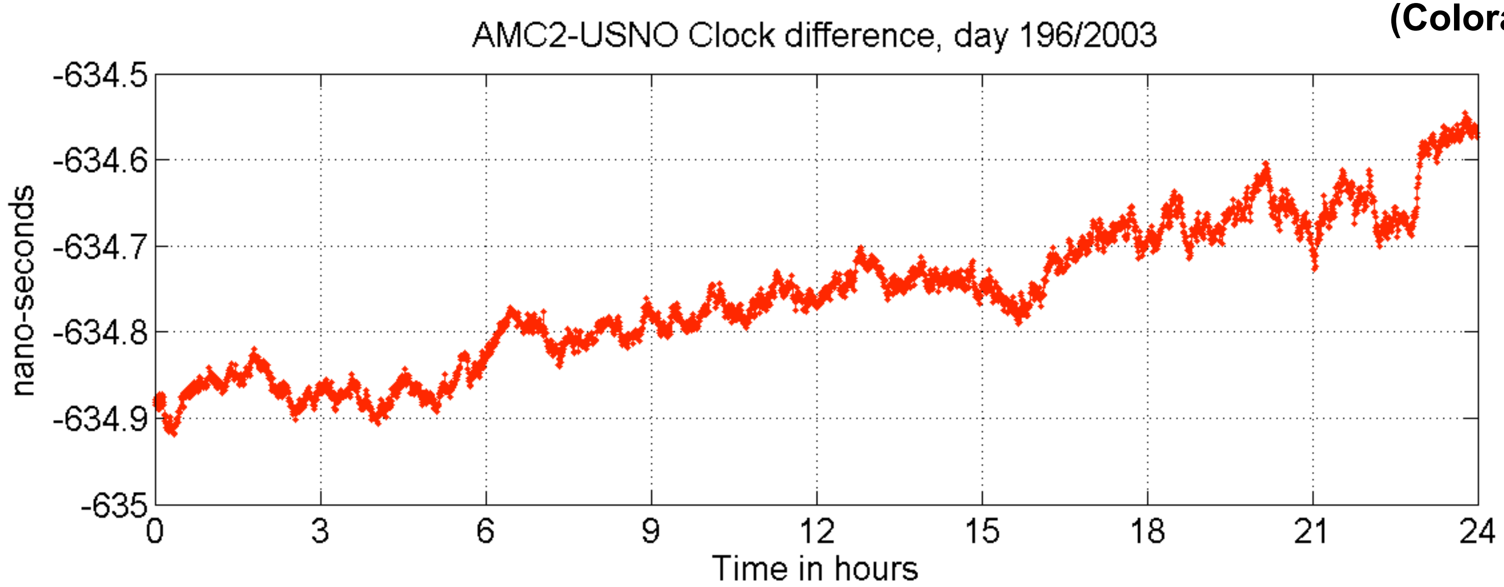
→ **code noise+multipath+DCBs+ICB are avoide**

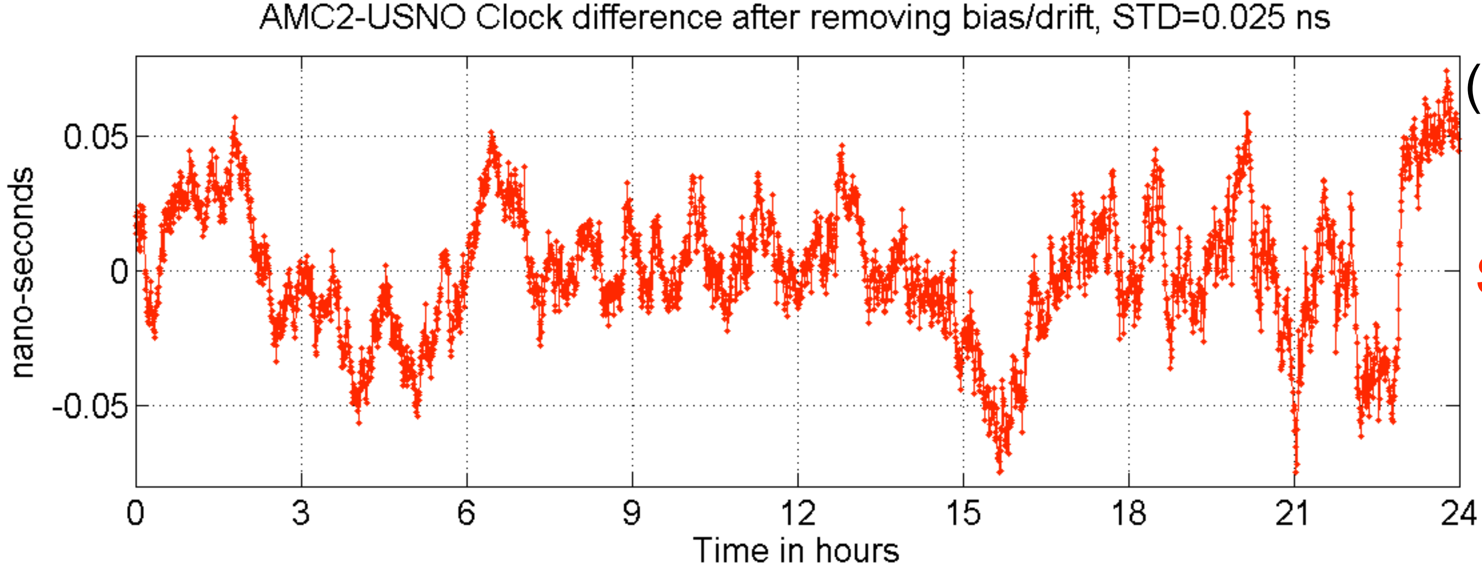
→ combined GALILEO/GPS solutions: inter-GNSS clock bias absorbed by ambiguities



Phase Clocks

(Colorado Springs – USNO)





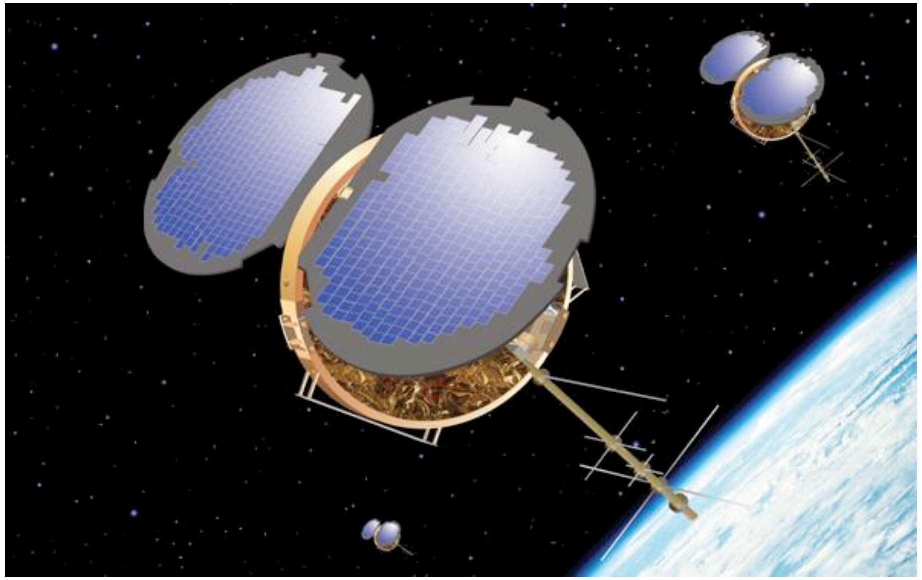
(2.9×10^{-16} per day)

≈ 7 mm

Stability of GPS receiver and H-maser

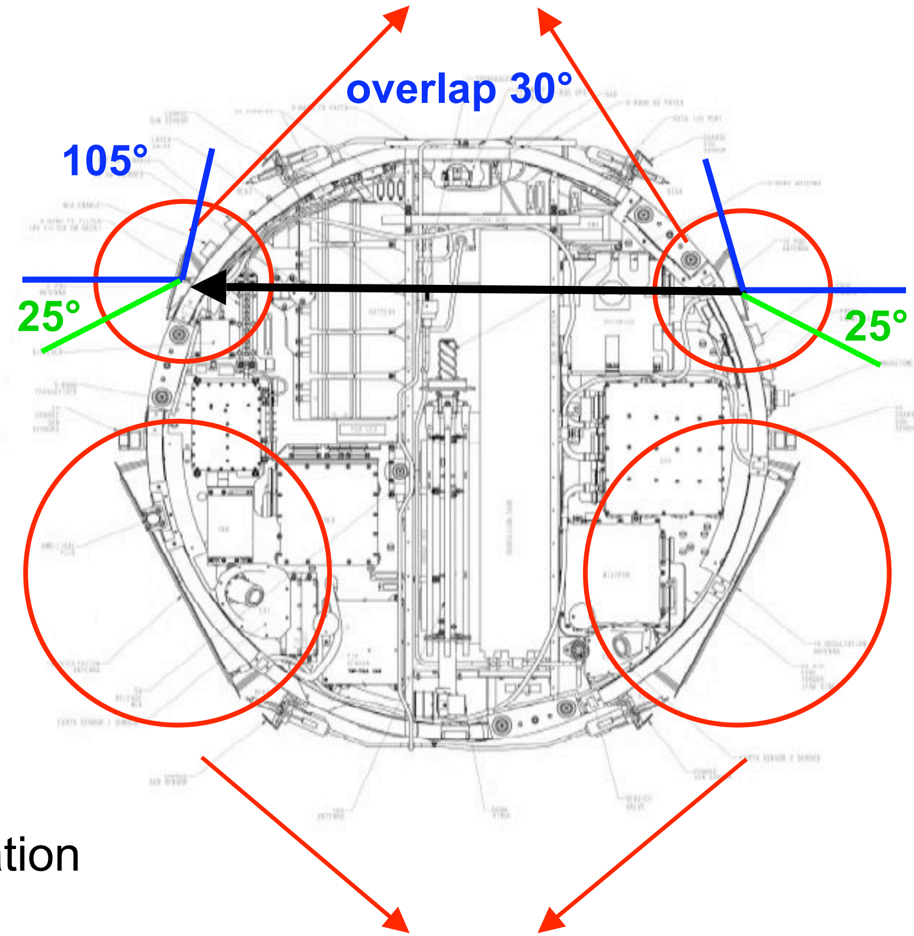
Only phase clocks estimated. Troposphere (TZD), station coord., EOPs, etc., fixed to IGS

COSMIC Constellation



Scientific objectives: atmosphere sounding
gravity field determination

POD Antenna

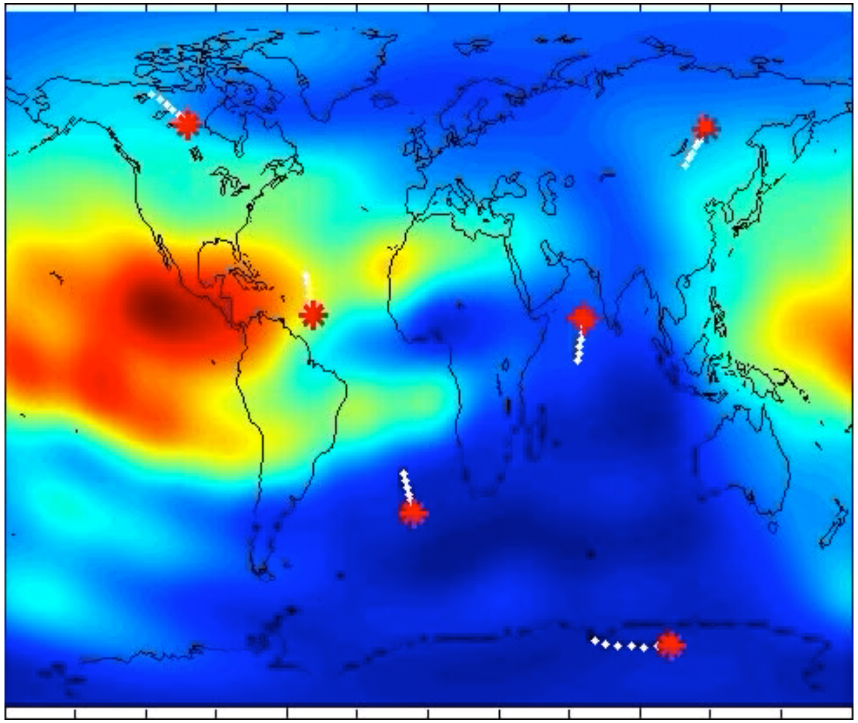


Radio-Occultation Antenna

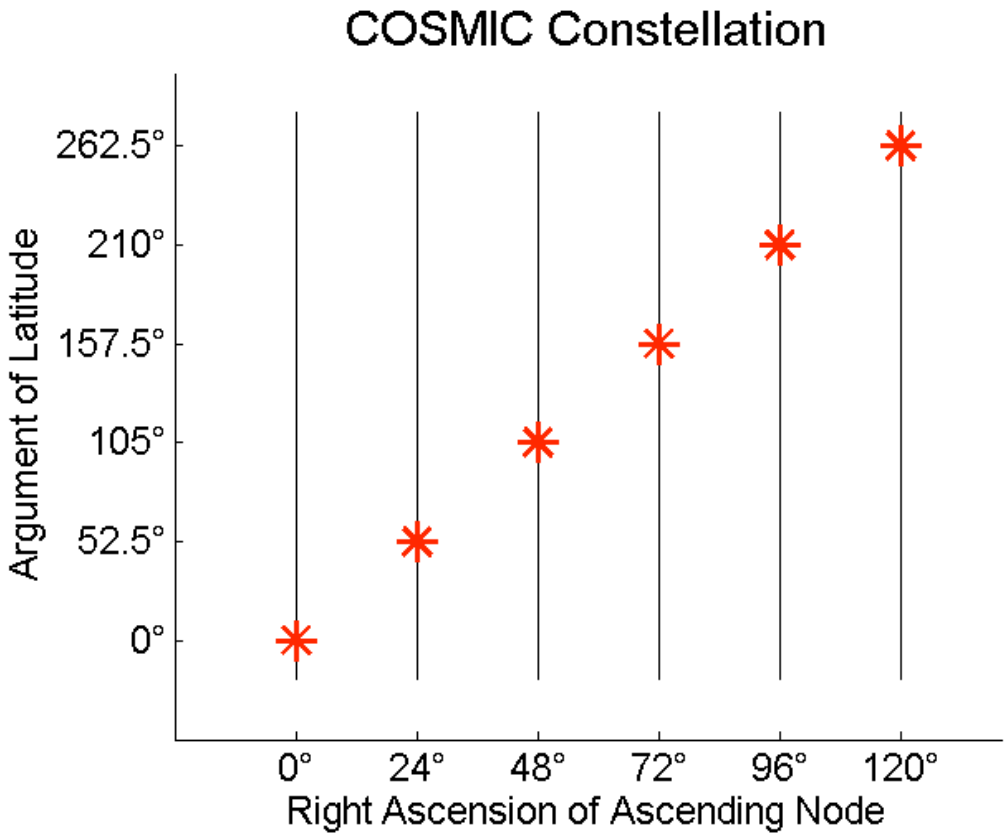
<u>Antenna field of view:</u>
POD antennas: 230°
All antennas: 360°

COSMIC Constellation - Design

COSMIC Constellation and Ionosphere



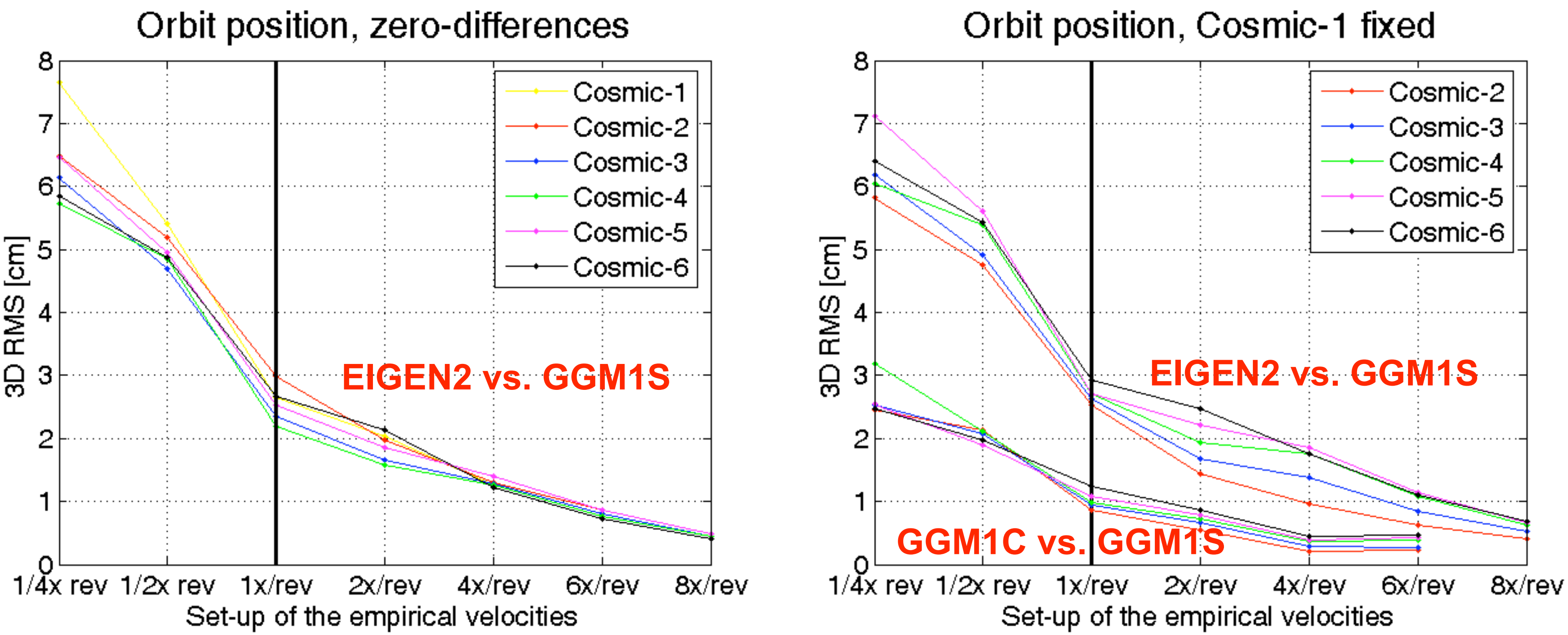
Constellation will be fully deployed in 12 months



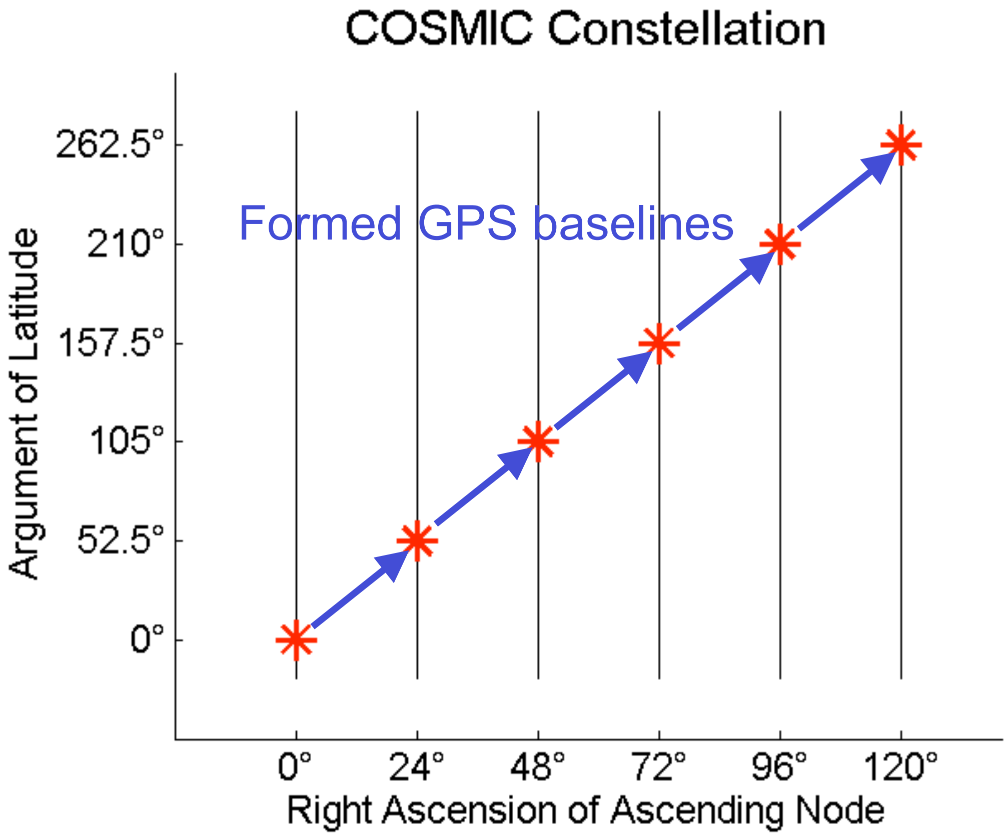
orbit height = 800 km
inclination = 72°

COSMIC POD - Simulation

Simulated COSMIC orbit positions based
on different gravity field models



Ambiguity Resolution for combined COSMIC/GPS POD



Correlations between baselines treated correctly

Simulation: **P1,P2 code noise 10 cm,**
L1,L2 phase noise 1 mm

-Melbourne-Wübbena LC is used to resolve wide-lane ambiguities

-Narrow-lane bootstrapping performed with the following COSMIC/GPS orbit parameters (per day):

6 Keplerian parameters

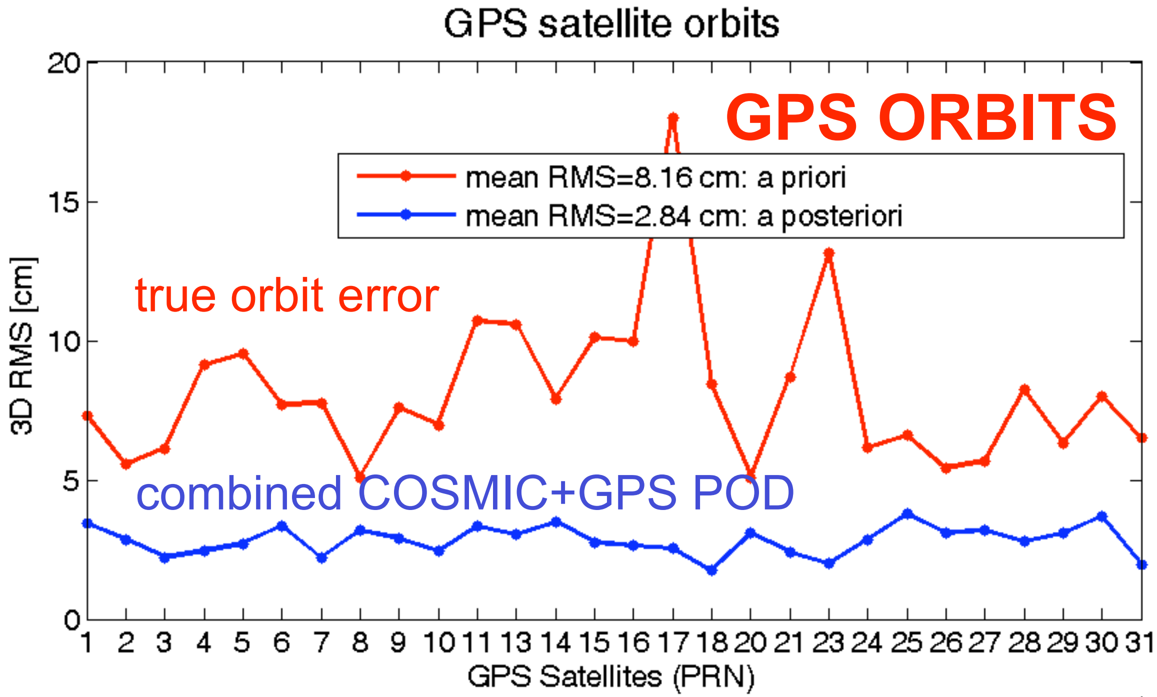
9 solar radiation parameters

+ for LEO: 1/rev. empirical velocity

Total amount of ambiguities: 1817
Resolved ambiguities 99%

10 ambiguities resolved per inversion of one-day normal-equation matrix

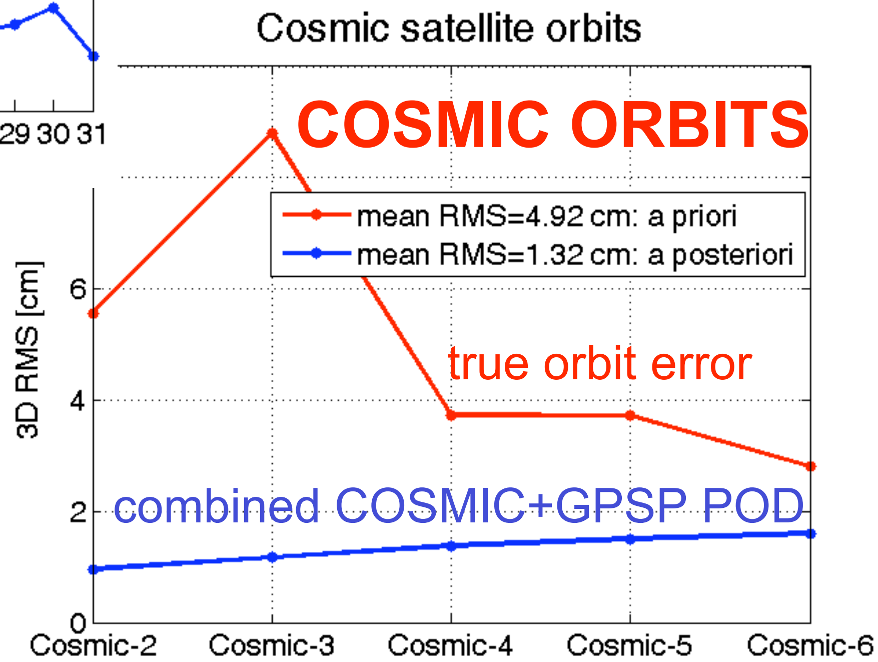
GPS Satellite Orbits Without Ground GPS Network



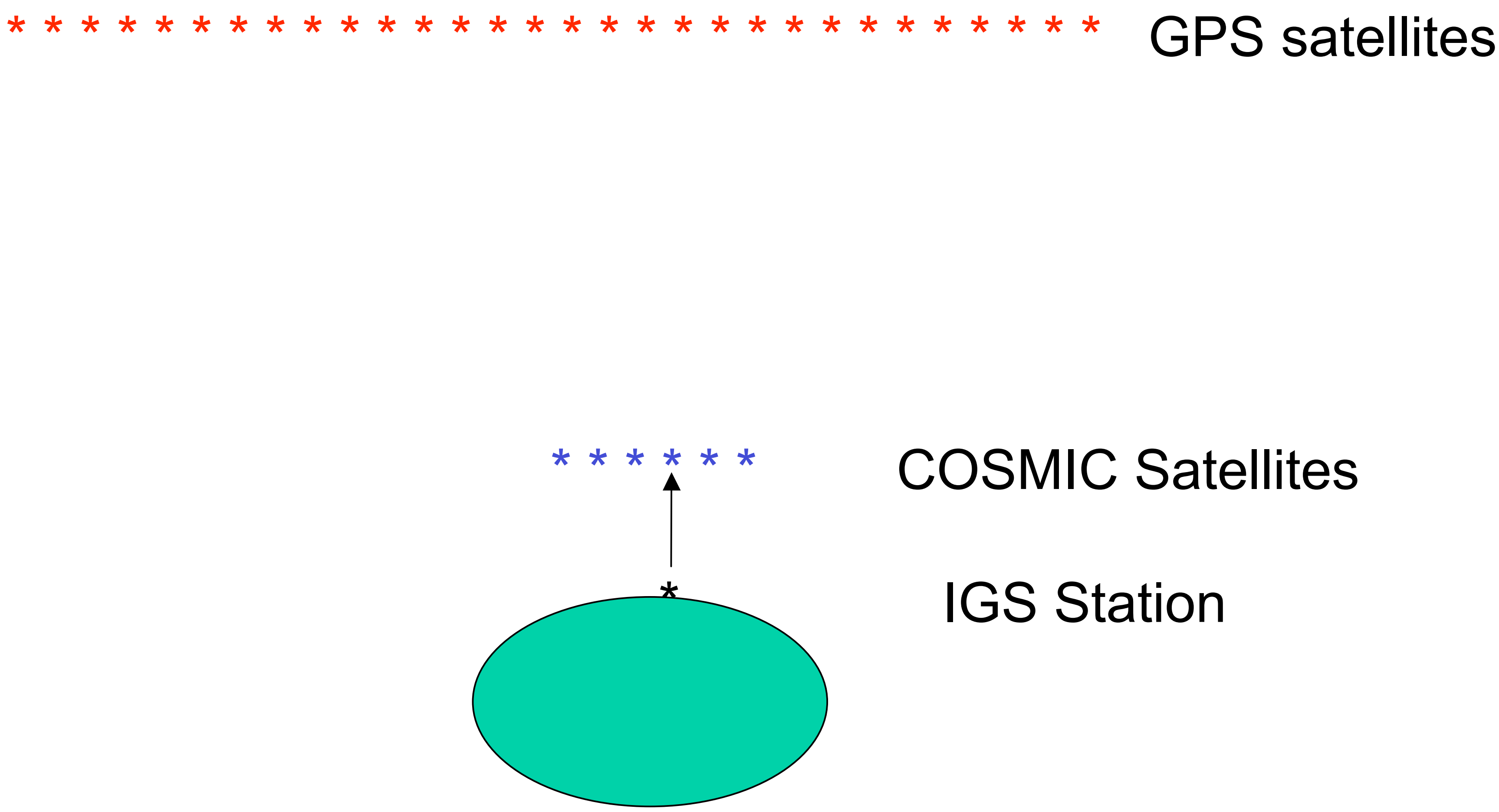
Ambiguities fixed to their integer values

Error introduced to GPS orbits:
difference betwen two IGS AC solution

Datum problem:
the reference LEO satellite in the constellation
Solution:
ground IGS-to-LEO baselines or SLR



GPS reference frame defined from Space?



Thank You