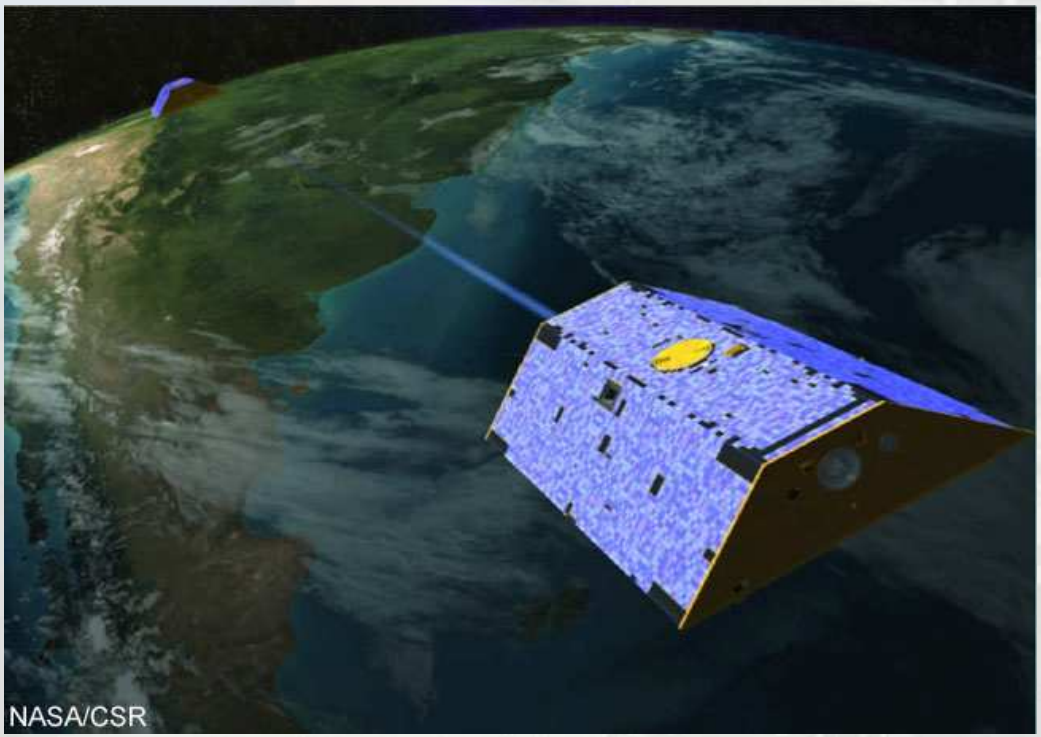
GPS Single-frequency Orbit Determination for Low Earth Orbiting Satellites



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37th COSPAR Scientific Assembly, Montreal, July 13-20, 2008

Astronomical Institute, University of Bern

Motivation

*Nowadays, orbit accuracies of a few cm's are reached for low Earth orbiting satellites (LEOs) using GPS **dual**-frequency (DF) observations.*

Motivation

*=> Which orbit accuracies are possible with GPS **single**-frequency (SF) OD?*

1. Which is the best solution/possibility to handle the ionospheric effect in the observations?

2. How good does the pre-processing work?

3. Is the orbital height and/or the data sampling rate an important quality factor?

Data description

- Days 273-279 (Sep 30 – Oct 06), 2007
- GPS: CODE final orbits and clocks
- GRACE A and B, 10 sec

  ~ 470 km altitude
- MetOp, 1 sec (from ESA/EUMETSAT)

  ~ 820 km altitude
- Reduced-dynamic orbit solutions with 6 min

  piecewise constant accelerations in RSW-system
- Reference solutions: dual-frequency reduced-dynamic orbits

1. Handling of the ionospheric effect

Ionospheric effect in the SF observations can be reduced

A: by modelling the effect using Global Ionosphere Maps (GIMs)

only L1 (carrier-phase) observations

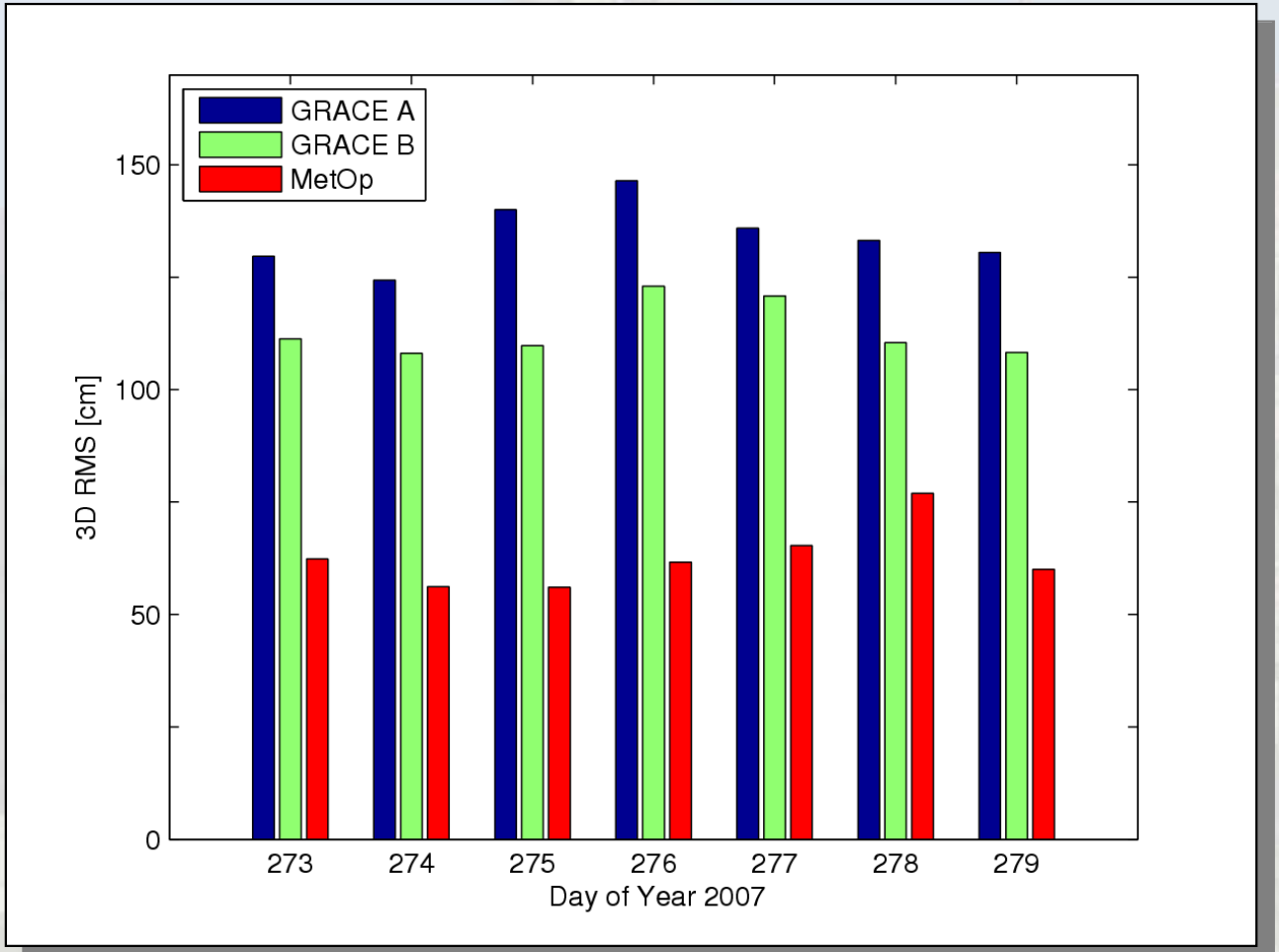
B: by forming ionosphere-free linear combination between the code and the phase observation of the available frequency (L1 + C1)/2 (GRAPHIC combination)

L1 and C1 (code) observations

C: by estimating Stochastic Ionosphere Parameters (SIPs), one per epoch and satellite link, e.g., 10 satellites are tracked at one epoch => 10 SIPs for this epoch

L1 and C1 observations

1. Handling ionosphere effect: no

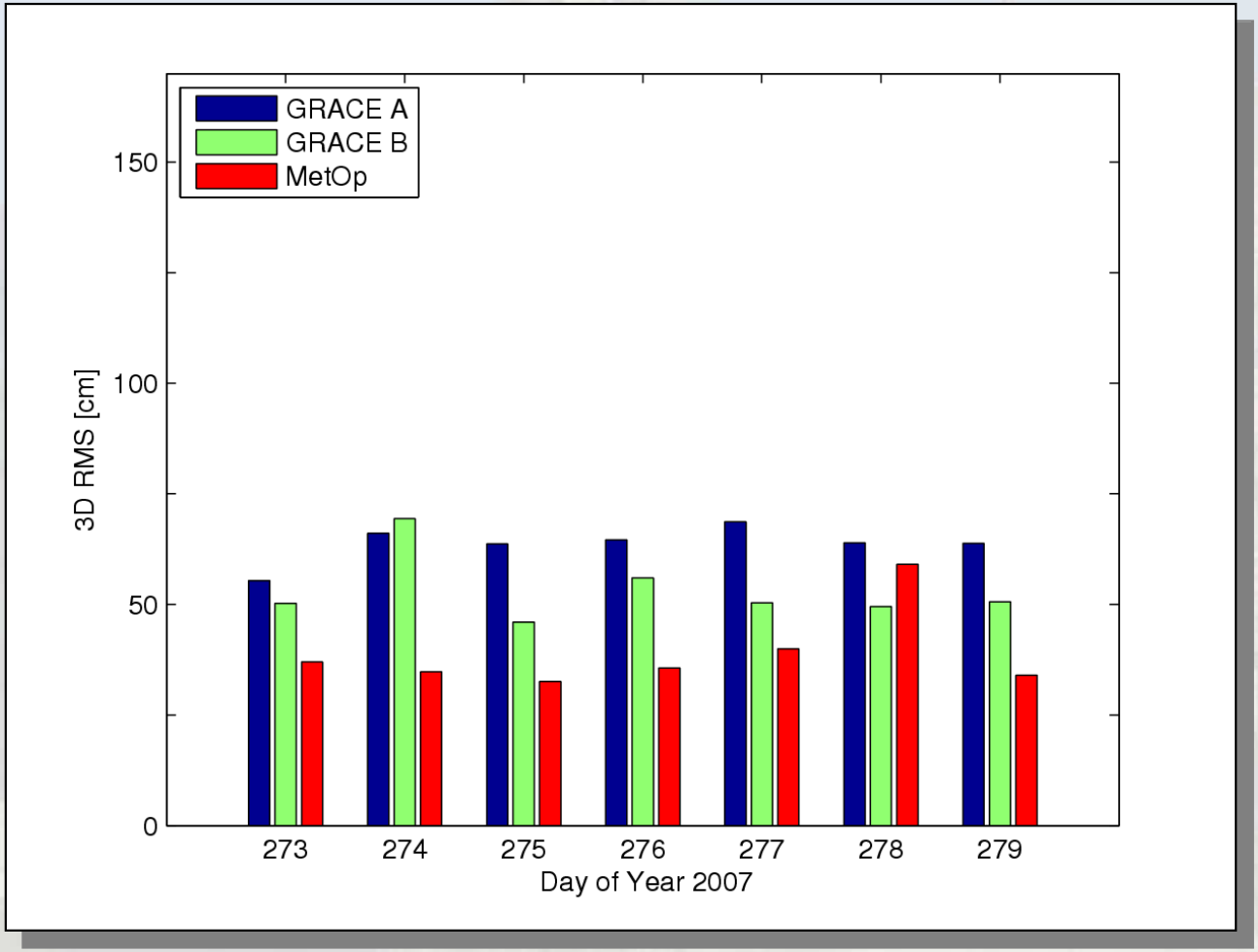


Mean 3D RMS:
134.3 cm
113.1 cm
62.6 cm

- Phase (L1) solution
- **MetOp** is at higher altitude
- **GRACE A** phase data quality is worse than for **GRACE B**

Pre-processing based on DF data (L1/L2), 10 sec

1. Handling ionosphere: Solution A - GIMs

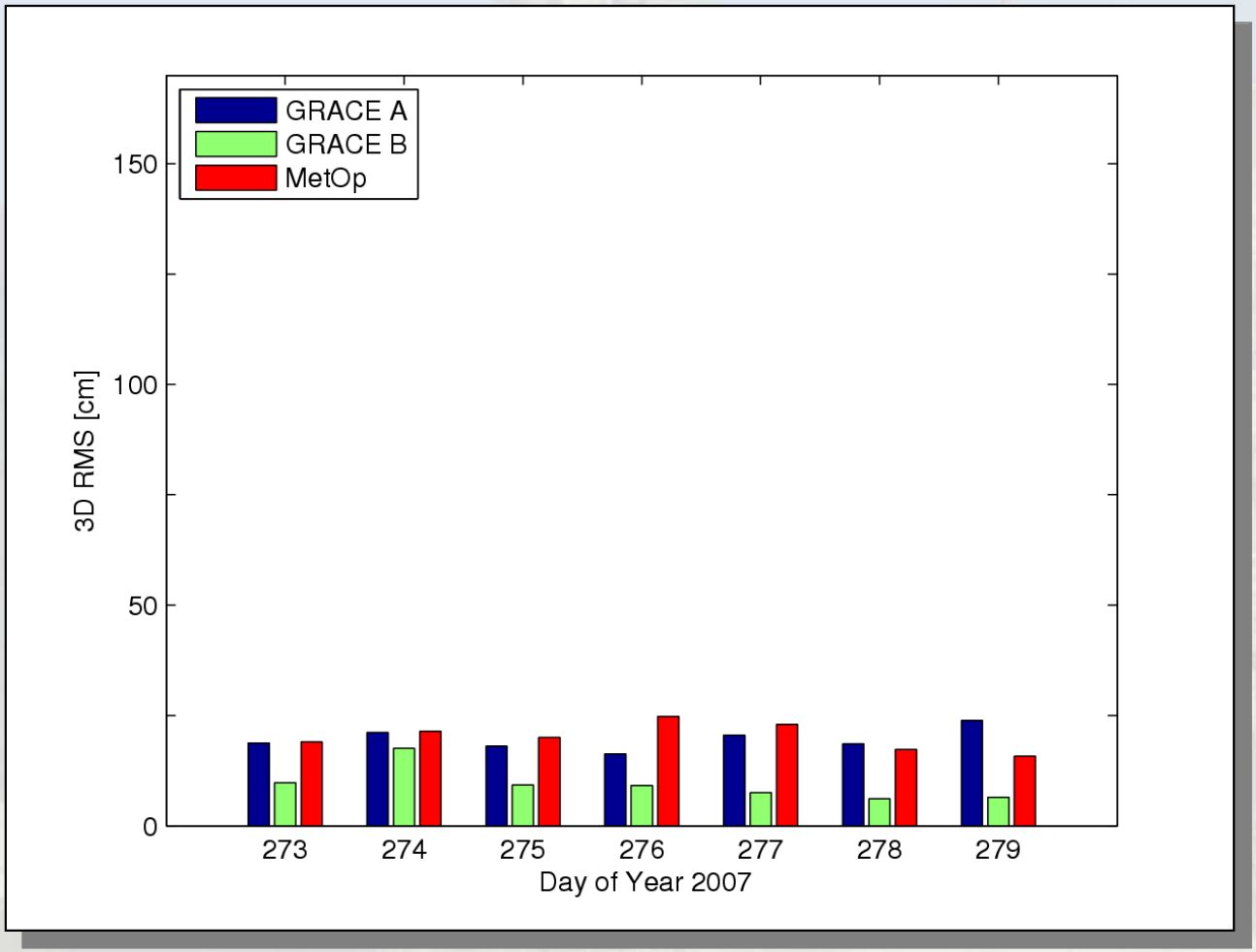


Mean 3D RMS:
63.7 cm
53.2 cm
39.0 cm

Pre-processing based on DF data (L1/L2), 10 sec

50-60% improvement (mainly in radial direction) by modelling ionosphere

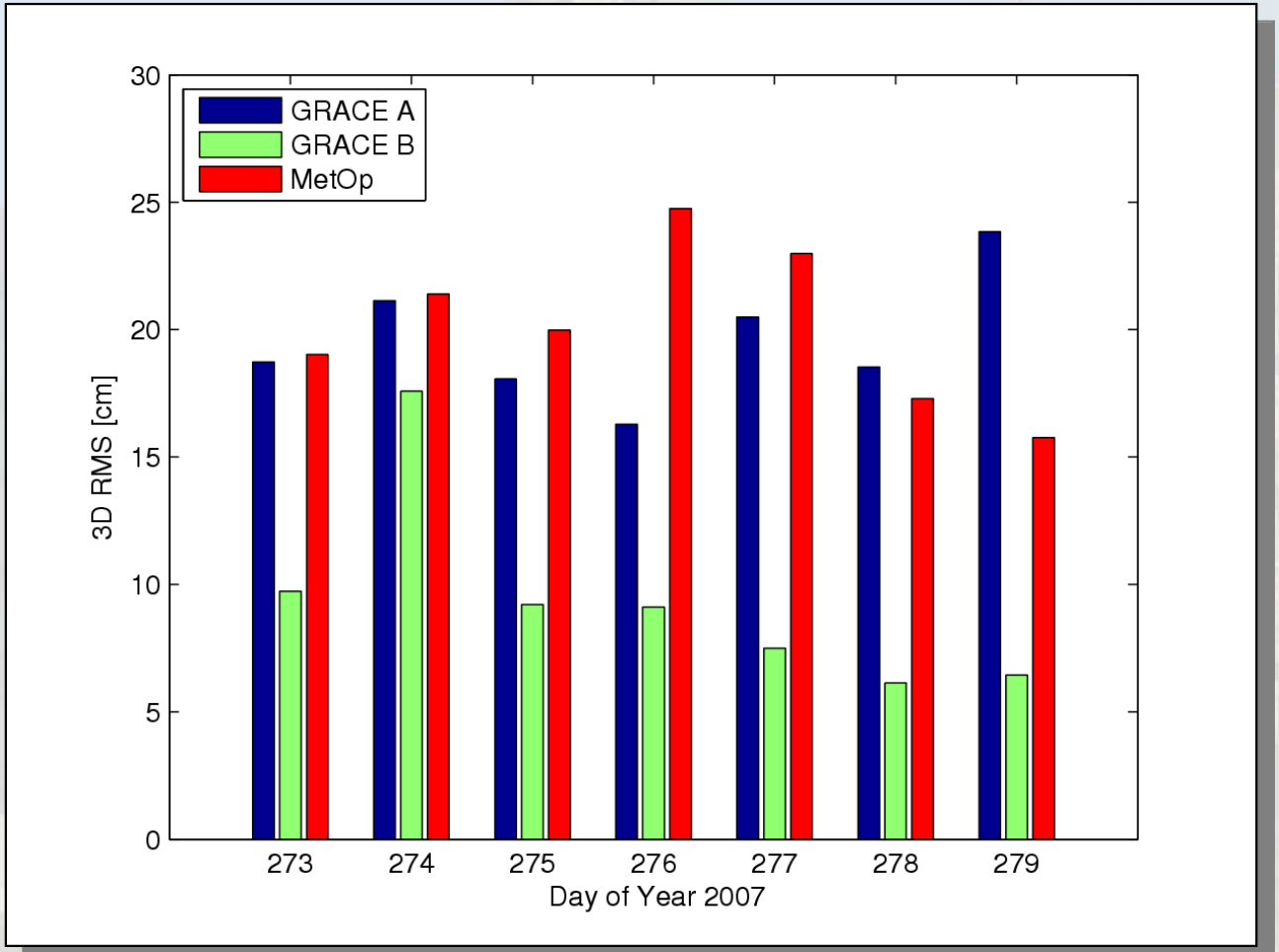
1. Handling ionosphere: Sol B - GRAPHIC



Mean 3D RMS:
19.6 cm
9.4 cm
20.2 cm

Pre-processing based on DF data (L1/L2 and C1/P2), 10 sec

1. Handling ionosphere: Sol B - GRAPHIC

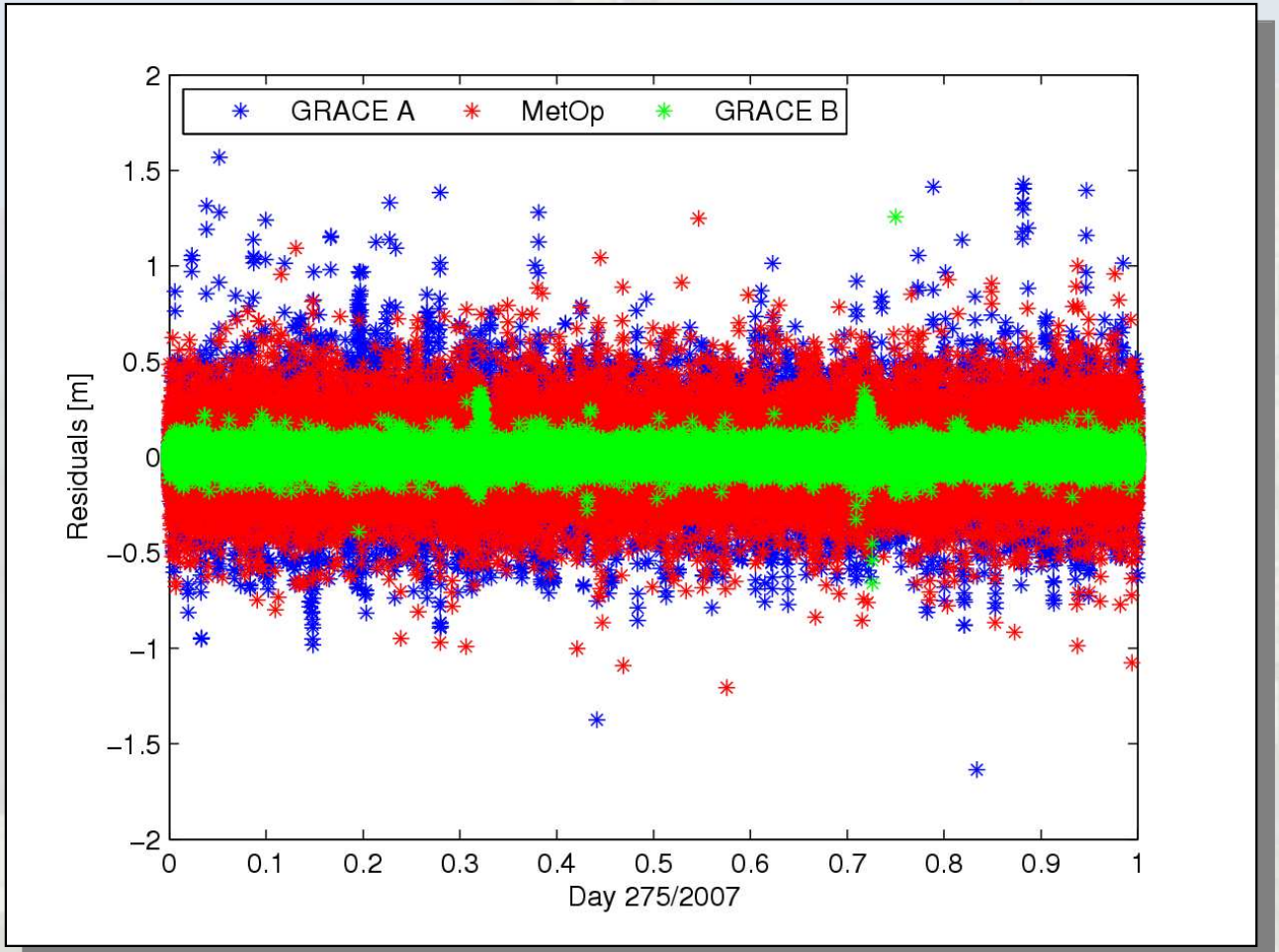


Mean 3D RMS:
19.6 cm
9.4 cm
20.2 cm

GRACE A:
Data quality worse (occultation antenna)
GRACE B:
C/A-code noise is very low (~10 cm)
MetOp:
Observation noise is ~3 times larger than for GRACE B

Pre-processing based on DF data (L1/L2 and C1/P2), 10 sec

1. Handling ionosphere: Sol B - GRAPHIC

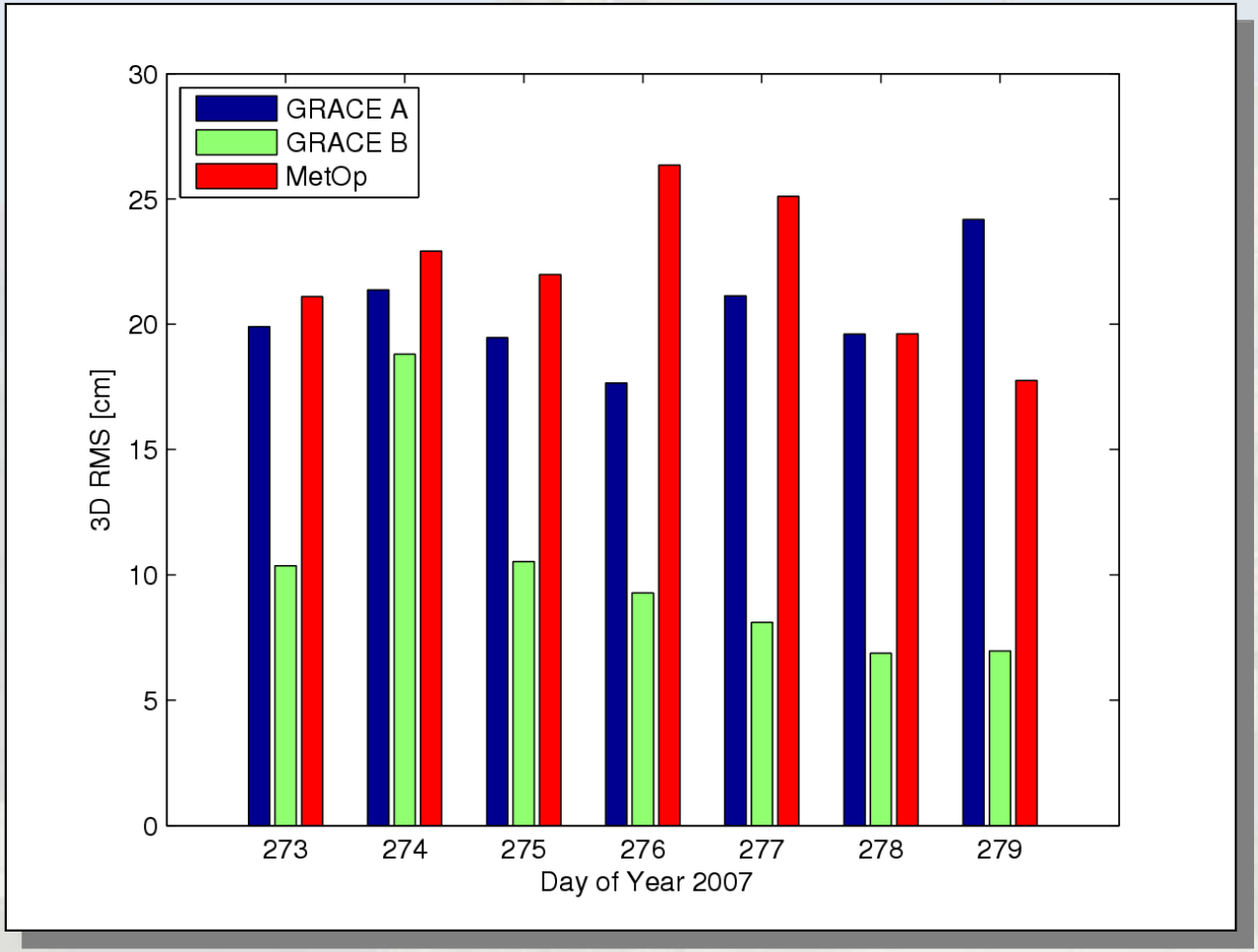


Mean 3D RMS:
19.6 cm
9.4 cm
20.2 cm

GRACE A:
Data quality worse (occultation antenna)
GRACE B:
C/A-code noise is very low (~10 cm)
MetOp:
Observation noise is ~3 times larger than for GRACE B

Pre-processing based on DF data (L1/L2 and C1/P2), 10 sec

1. Handling ionosphere: Solution C - SIPs

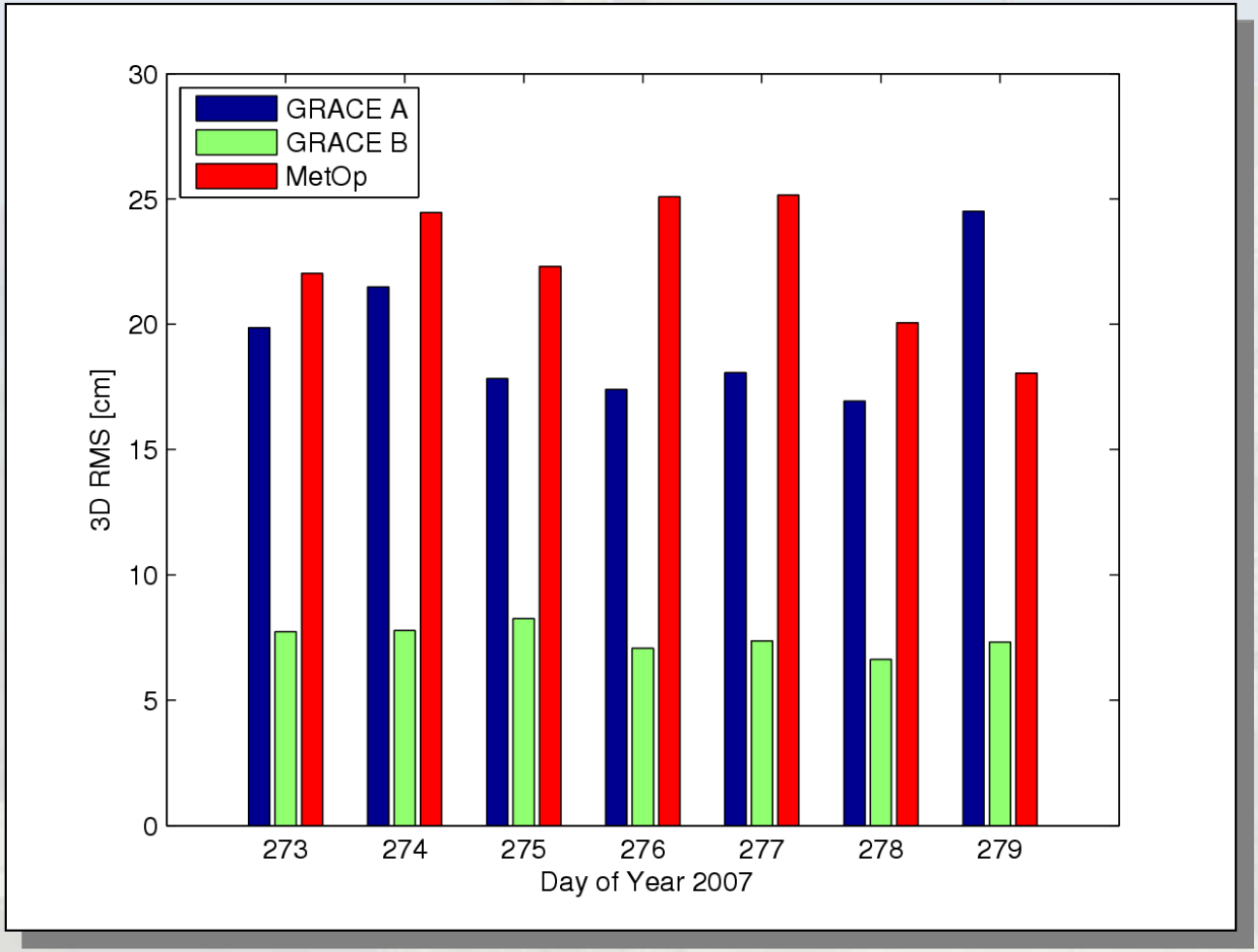


Mean 3D RMS:
20.5 cm
10.1 cm
22.1 cm

SIP solution (C) is slightly worse (5-10%) compared to GRAPHIC solution (B)

Pre-processing based on DF data (L1/L2 and C1/P2), 10 sec

2. Pre-processing: Solution C - SIPs

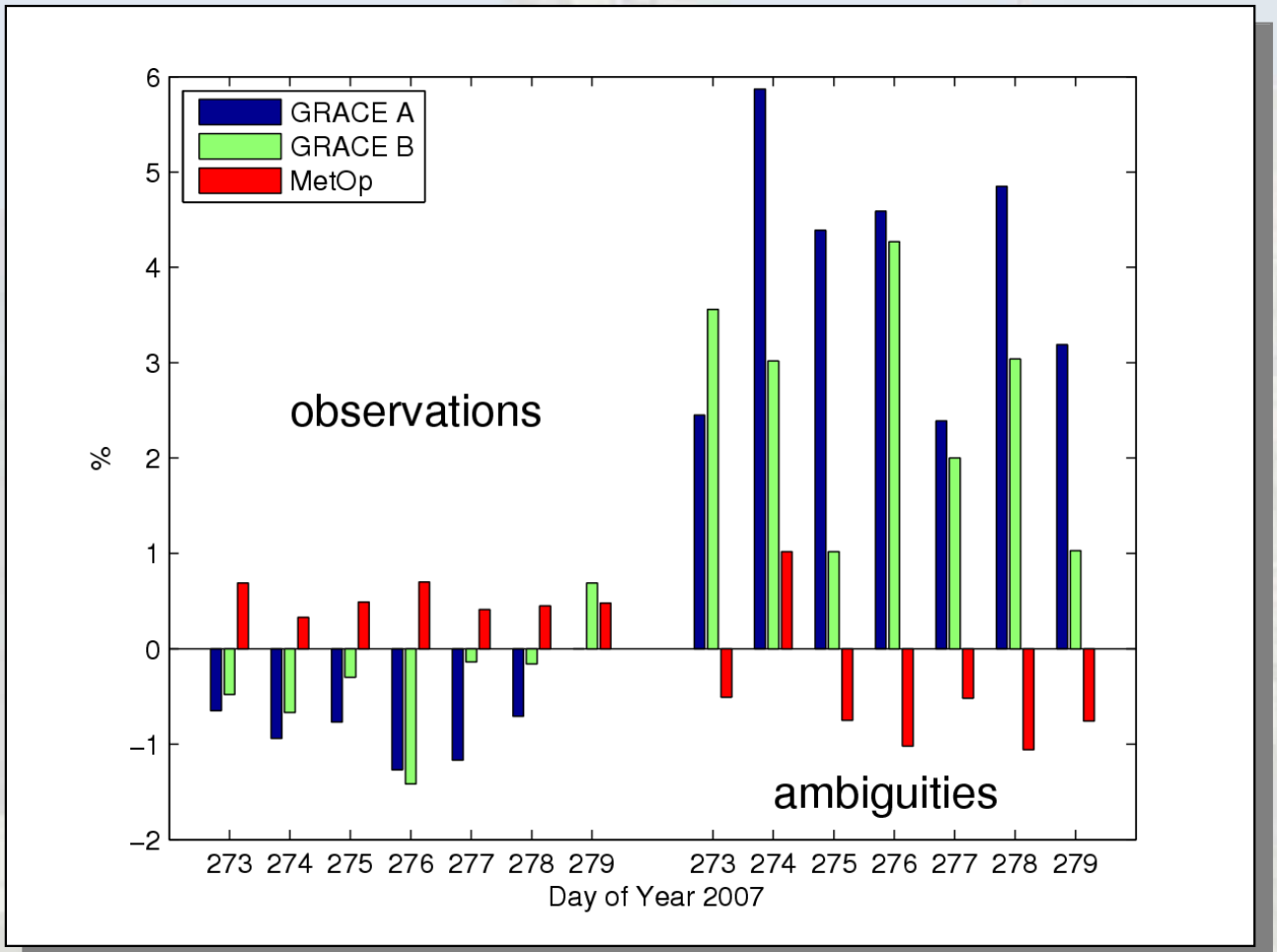


Mean 3D RMS:
19.4 cm
7.5 cm !!
22.5 cm

Pure SF results are of comparable quality => pre-processing also works with SF data

Pre-processing based on SF data (L1 and C1), 10 sec

2. Pre-processing: Quality



Percentage relative to DF reference solution

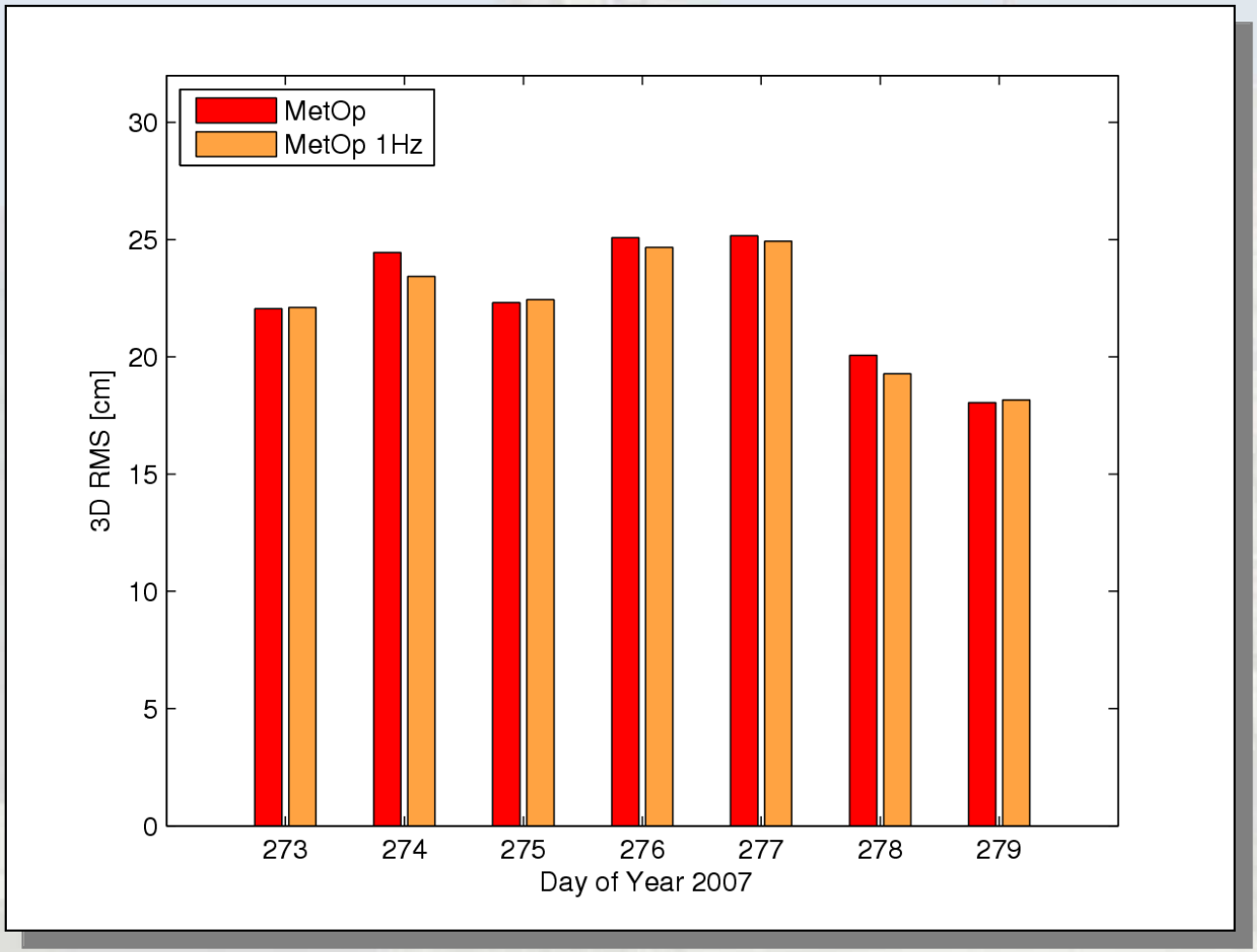
GRACE A/B:
- less observations
- more ambiguities

MetOp:
- more observations
- less ambiguities

Pre-processing:
remaining ionospheric effect in observations
⇔
cycle slip detection

➢ phase ambiguity setting

3. Higher sampling rate

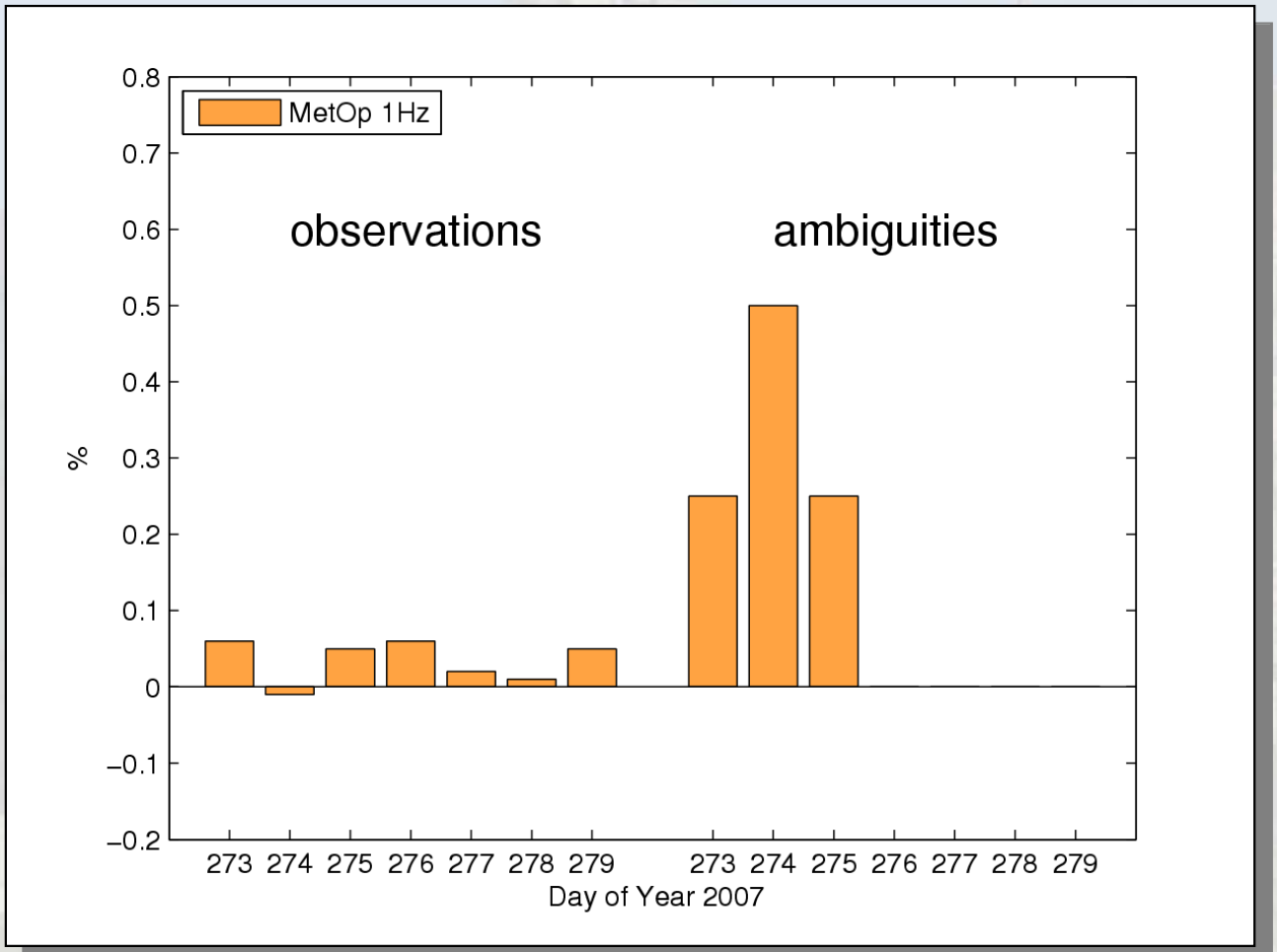


Mean 3D RMS:
22.5 cm
22.1 cm

The orbital altitude from **MetOp** is already too high to profit from the higher sampling rate for the pre-processing.

Pre-processing based on SF data (L1 and C1), 10 sec/1 sec

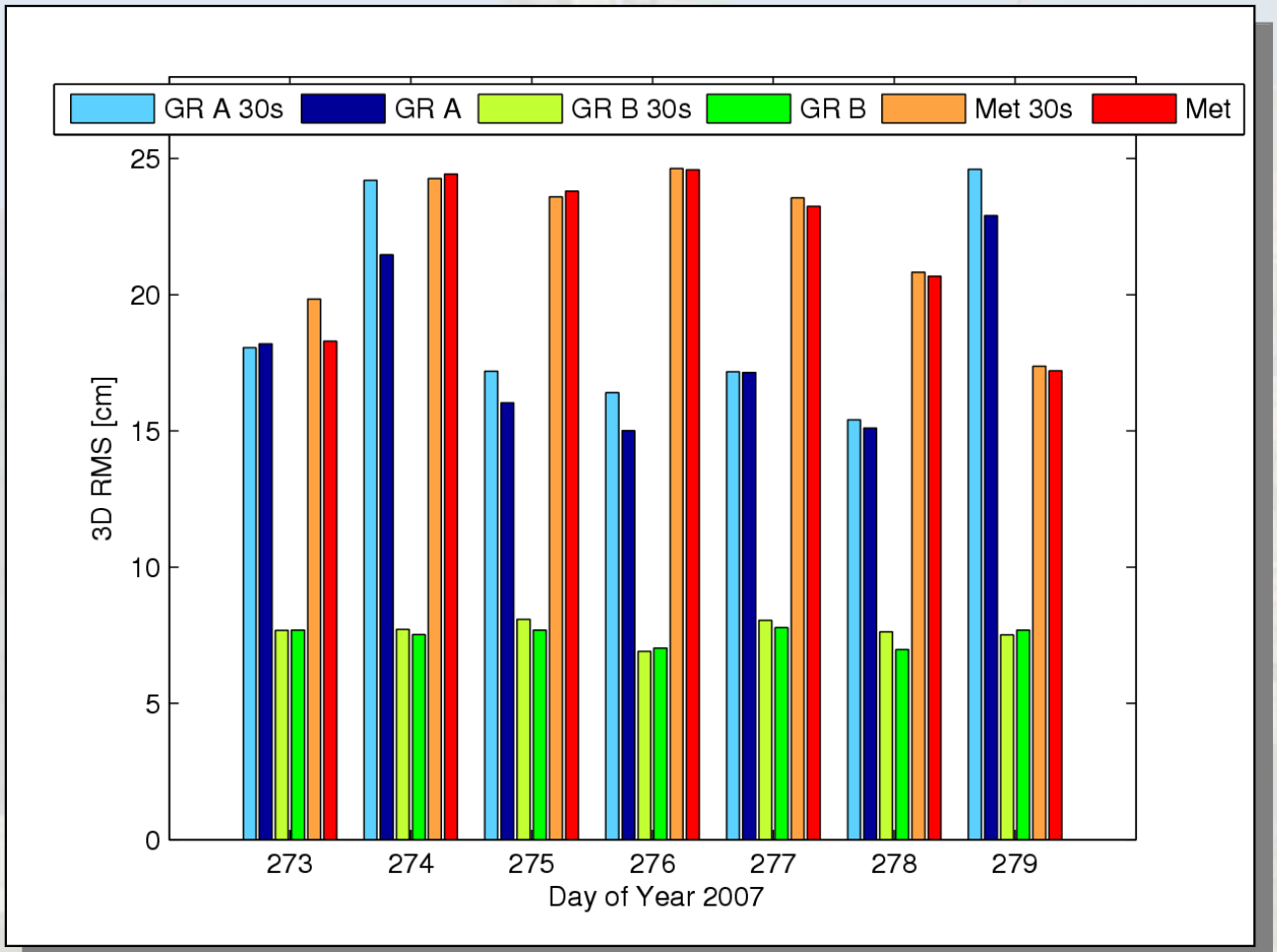
3. Quality, higher sampling rate



Percentage relative to SF 10 sec solution

The orbital altitude from **MetOp** is already too high to profit from the higher sampling rate for the pre-processing.

3. Lower sampling rate

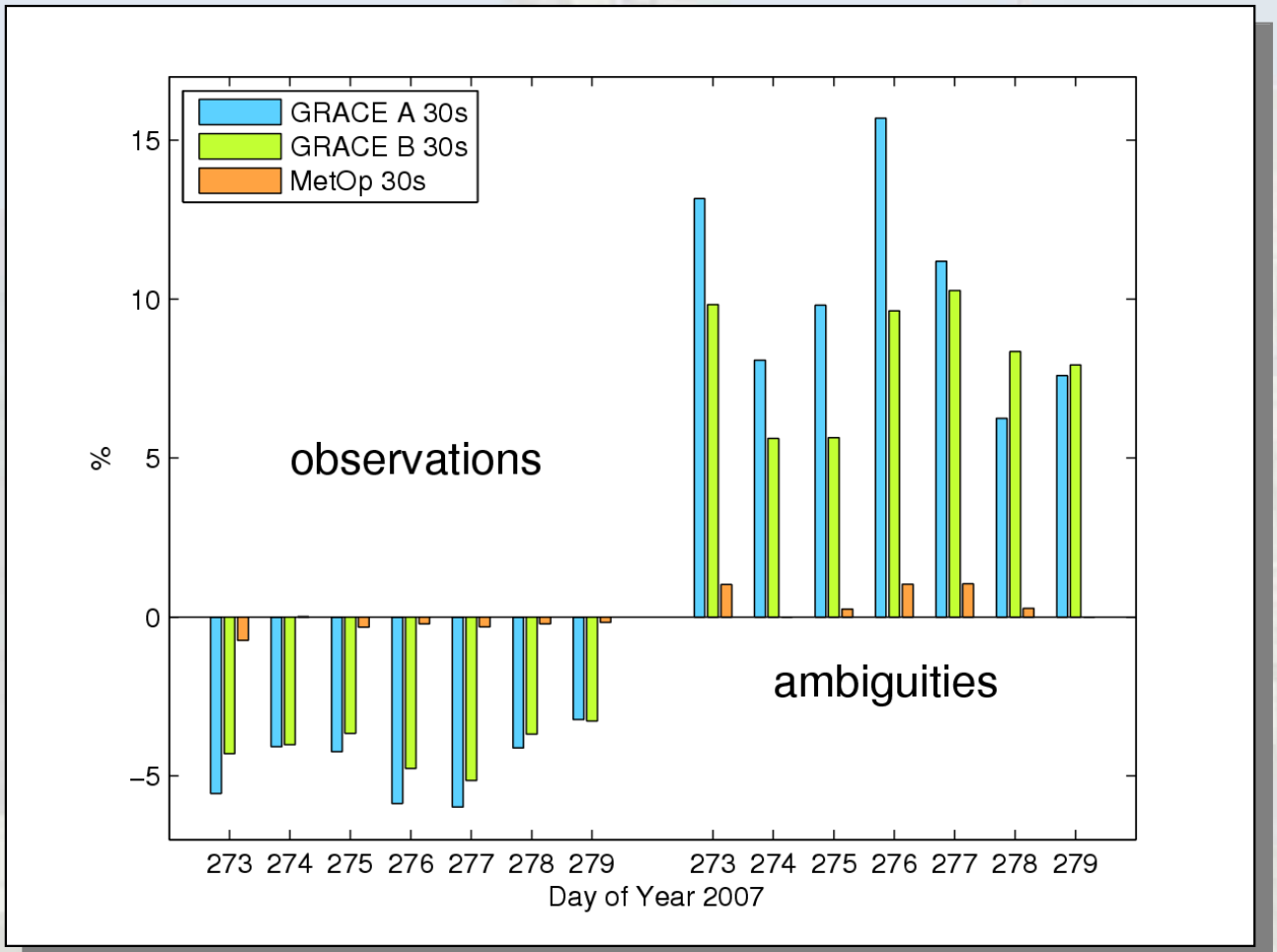


Mean 3D RMS:

19.0 cm
18.0 cm
7.7 cm
7.5 cm
22.0 cm
21.8 cm

Pre-processing based on SF data (L1 and C1), 30 sec/10 sec, orbit solutions with 30 sec sampling

3. Quality, lower sampling rate



Percentage relative to 10 sec SF solution

GRACE A/B:
- **less** observations
- **more** ambiguities

MetOp:
- no significant differences

Pre-processing with lower sampling rate is much more difficult for lower satellites (ionosphere)

Conclusion

Which orbit accuracies are possible with GPS SF OD?

=> 1 – 2 dm 3d RMS; < 1 dm, if C/A code is good.

1. Which is the best solution/possibility to handle the ionospheric effect in the observations?

=> L1 and C1 observations, GRAPHIC (B) or SIP (C).

2. How good does the pre-processing work?

=> Comparable quality as the DF pre-processing.

3. Is the orbital height and/or the data sampling rate an important quality factor?

=> Yes, the lower the satellite the better a higher sampling rate for a good pre-processing.

End: Orbit differences