Mitigation of unmodelled non–tidal atmospheric pressure loading into parameters of a global GNSS solution

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Motivation

- Atmospheric pressure loading (APL) can clearly be detect in space–geodetic solutions and needs to be corrected.
- With the global coverage of the tracking network and the continuous tracking capability, GNSS is in a comfortable situation among the space–geodetic techniques.
- In the frame of the series of Unified Analysis Workshops a discussion was initiated on how to correct for the APL effect:
  - correcting each individual observation
  - correcting station coordinates with the mean value

Outline

Motivation

Description of the experiment

APL and GNSS–derived coordinates

APL and GNSS–derived troposphere

APL and GNSS–orbits

Conclusion

Description of the experiment

- CODE reprocessing effort from 2011:
  - Time interval:
    January 1996 to May 2003 GPS–only solution
    May 2003 to December 2010 GPS+GLONASS solution
  - fully consistent with IGS08.ATX and IGS08.SNX
  - following the IERS 2010 conventions

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  - validate the model from GNSS data,
  - easily compute two consistent solutions with/without APL corrections.

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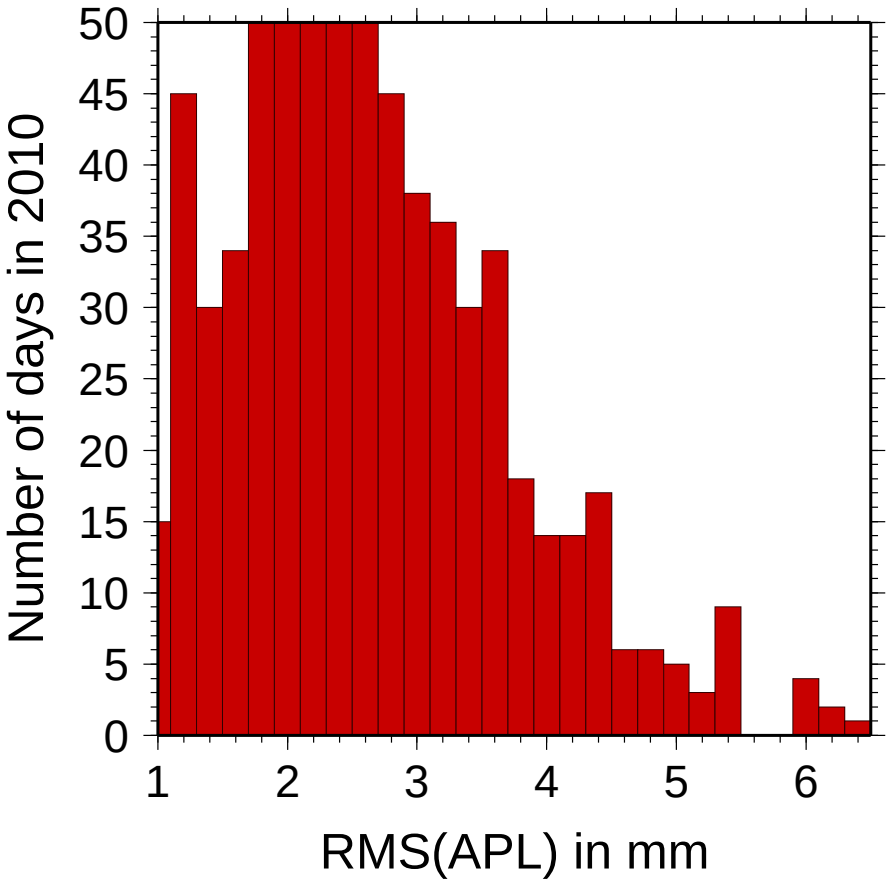
- The CODE reprocessing has included the Vienna APL model (Wijaya et al. 2011) with scaling factors allowing to
  - validate the model from GNSS data,
  - easily compute two consistent solutions with/without APL corrections.
- This dataset is used to support the "IERS Call for atm-load corrected solution" .
- We focus here on the solutions from the year 2010.

APL Effect from Vienna APL model



- Inland stations may have an effect up to a few cm, whereas coastal stations are almost not affected.
- *RMS*(*APL*):
  RMS of the APL effect over all stations for each day

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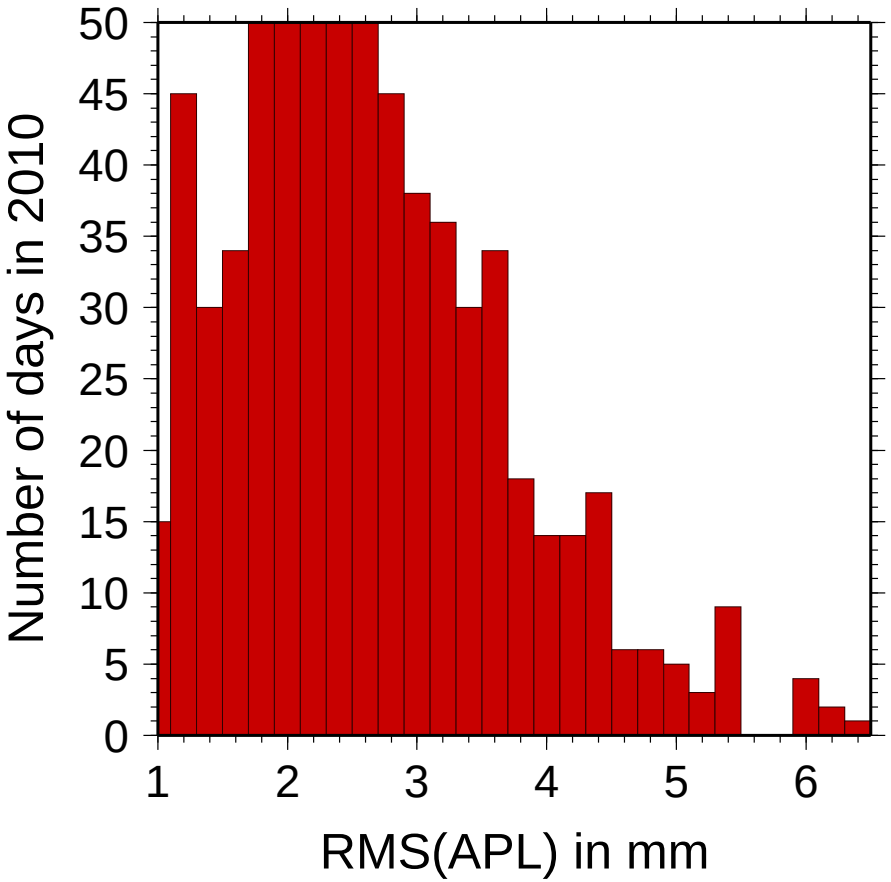


- Inland stations may have an effect up to a few cm, whereas coastal stations are almost not affected.
- *RMS*(*APL*):
  RMS of the APL effect over all stations for each day

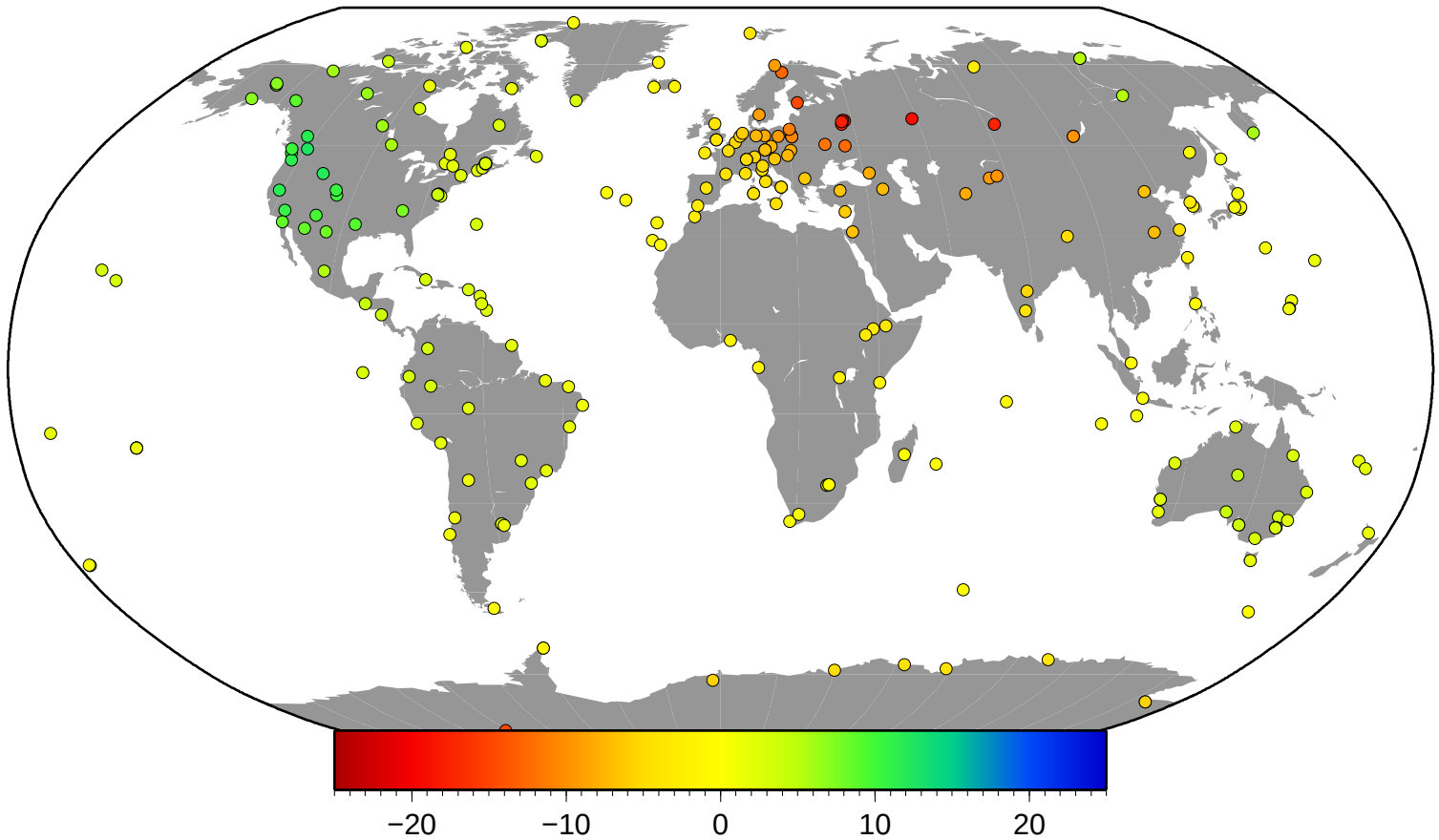
21. January: most pronounced APL for all stations of the network

01. July: moderate APL in all stations of the network

29. May: smallest APL in all stations of the network

APL and GNSS–derived coordinates

Mean APL corrections for each station
extracted from Vienna model during data processing

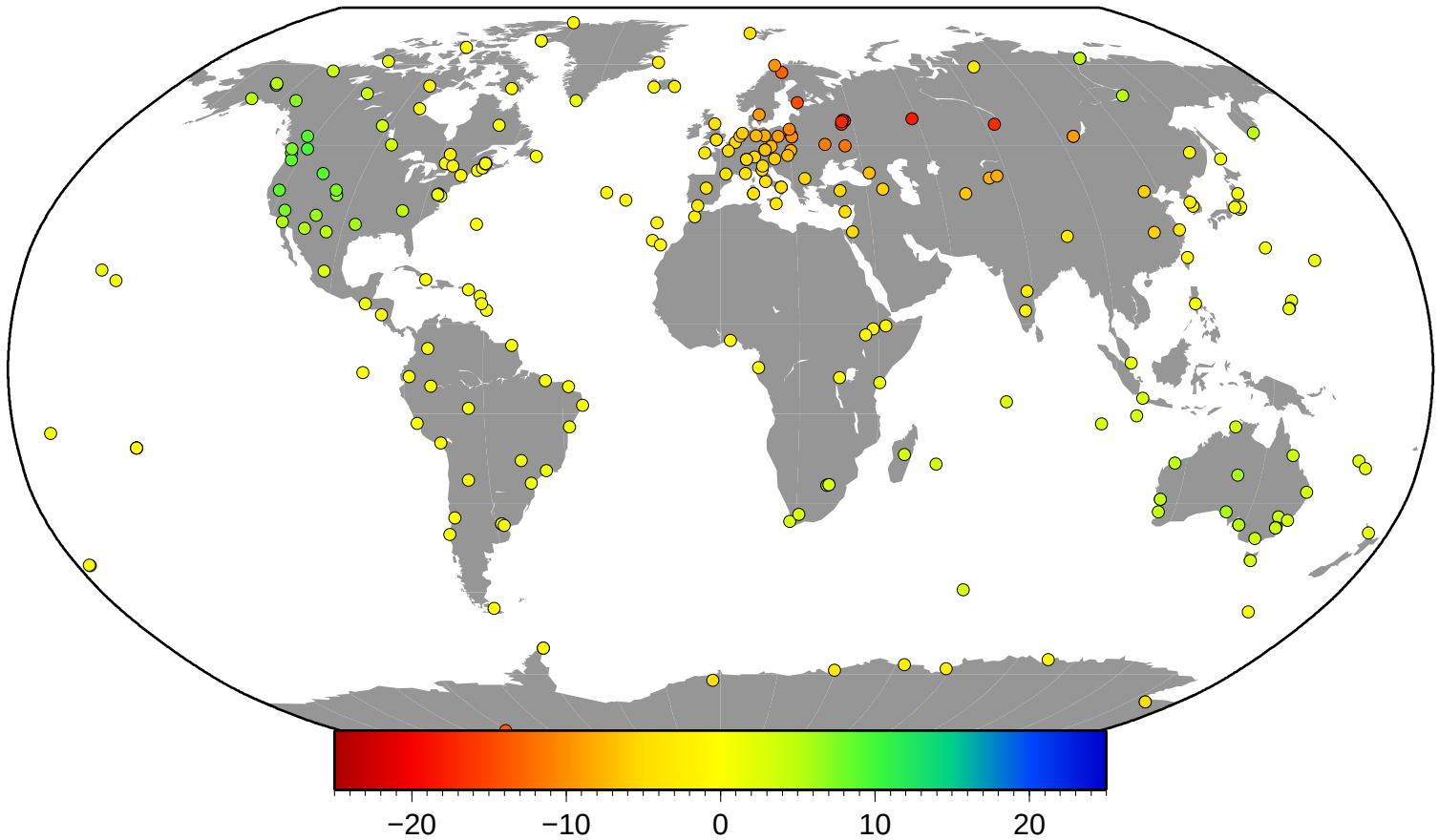


vertical component

21. January 2010

APL and GNSS–derived coordinates

Coordinate difference between solutions
applying/not applying APL corrections

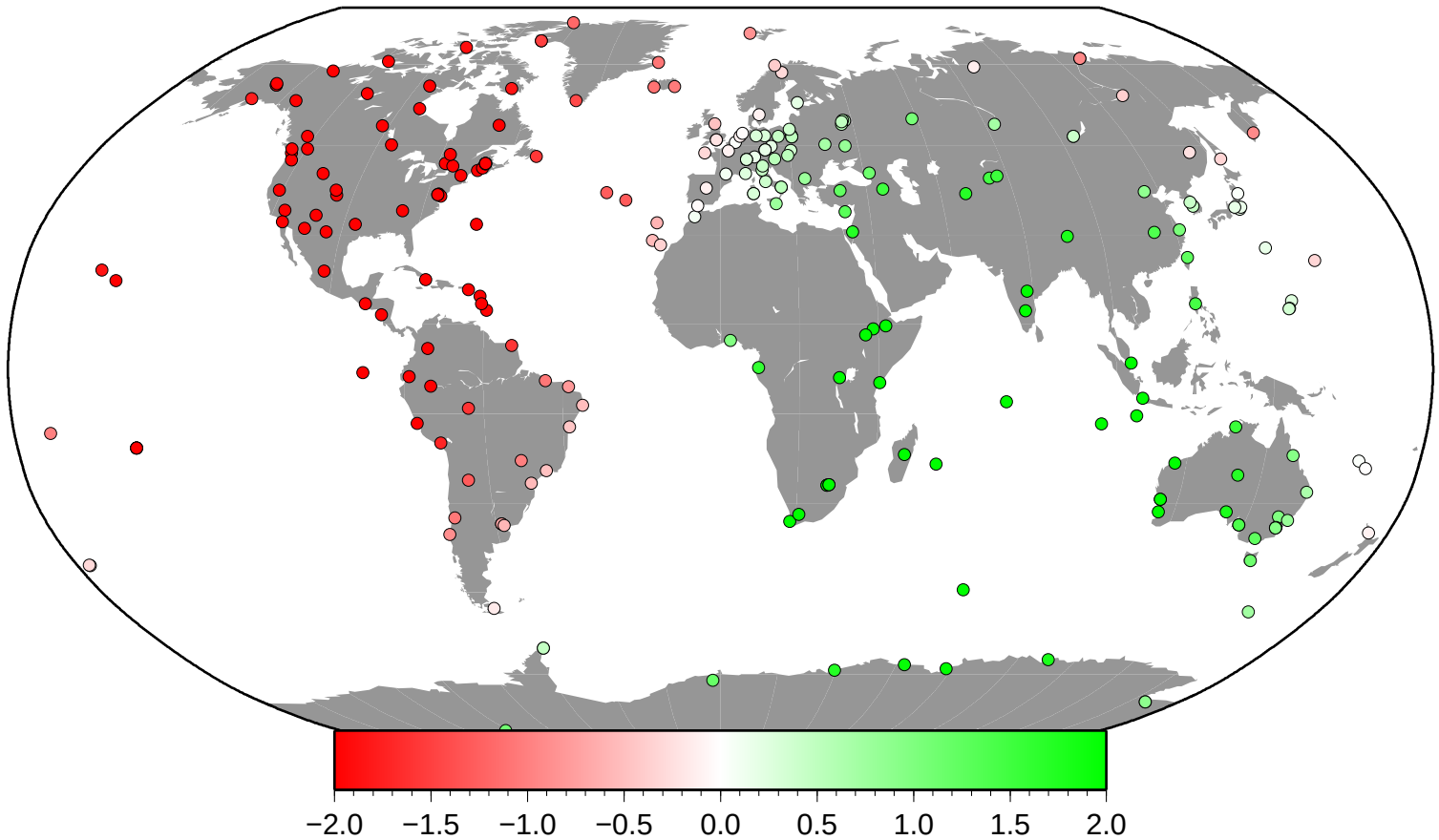


vertical component

21. January 2010

APL and GNSS–derived coordinates

Coordinate difference between solutions
applying/not applying but correcting for APL effect



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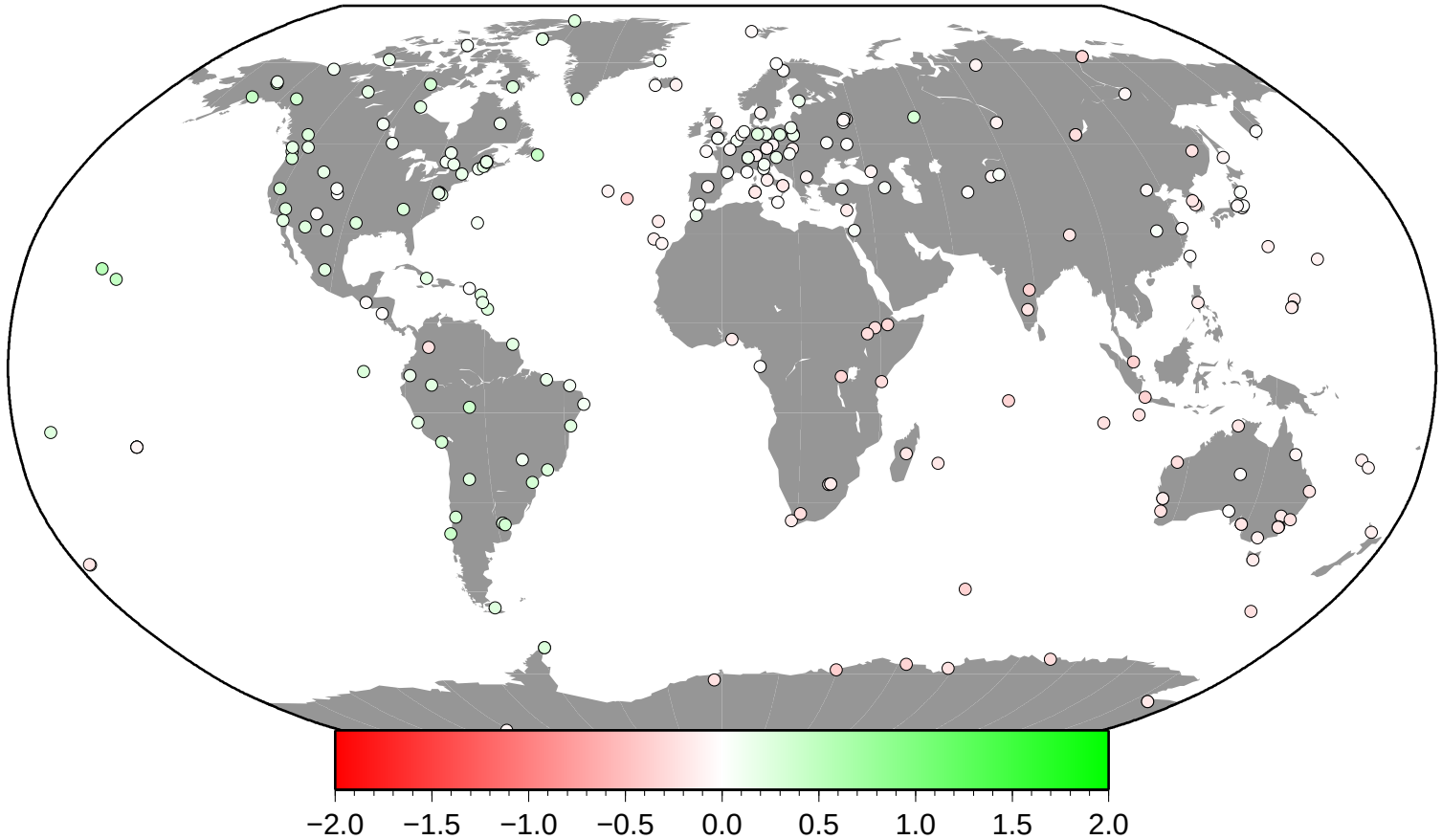
APL and GNSS–derived coordinates

Residuals of a Helmert–transformation between solutions applying/not applying but correcting for APL effect



vertical component

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APL and GNSS–derived coordinates

RMS of coordinate comparison

APL and GNSS–derived coordinates

RMS of coordinate comparison

- Difference of the solution without applying APL corrections...

21. January 2010			01. July 2010		
RMS_N	RMS_E	RMS_U	RMS_N	RMS_E	RMS_U
1.1 mm	1.4 mm	5.3 mm	0.4 mm	0.4 mm	2.3 mm

...with respect to the solution applying the APL corrections on observation level.

APL and GNSS–derived coordinates

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21. January 2010			01. July 2010		
RMS_N	RMS_E	RMS_U	RMS_N	RMS_E	RMS_U
1.8 mm	2.5 mm	1.7 mm	0.6 mm	0.9 mm	0.6 mm

...with respect to the solution applying the APL corrections on observation level.

APL and GNSS–derived coordinates

RMS of coordinate comparison

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- Residuals of a Helmert–transformation of the solution without applying but correcting for the APL effect...

21. January 2010			01. July 2010		
RMS_N	RMS_E	RMS_U	RMS_N	RMS_E	RMS_U
0.1 mm	0.1 mm	0.2 mm	0.1 mm	0.1 mm	0.1 mm

...with respect to the solution applying the APL corrections on observation level.

Summary

- The station coordinates between the solution without applying but correcting after the processing for the APL effect agrees on the 0.1 mm RMS–level with the solution applying APL corrections on observation level.

- This includes differences of up to ± 0.5 mm for individual stations even on days with a moderate magnitude of the APL effect.

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- Such a correction can be done on 1-day SINEX level.

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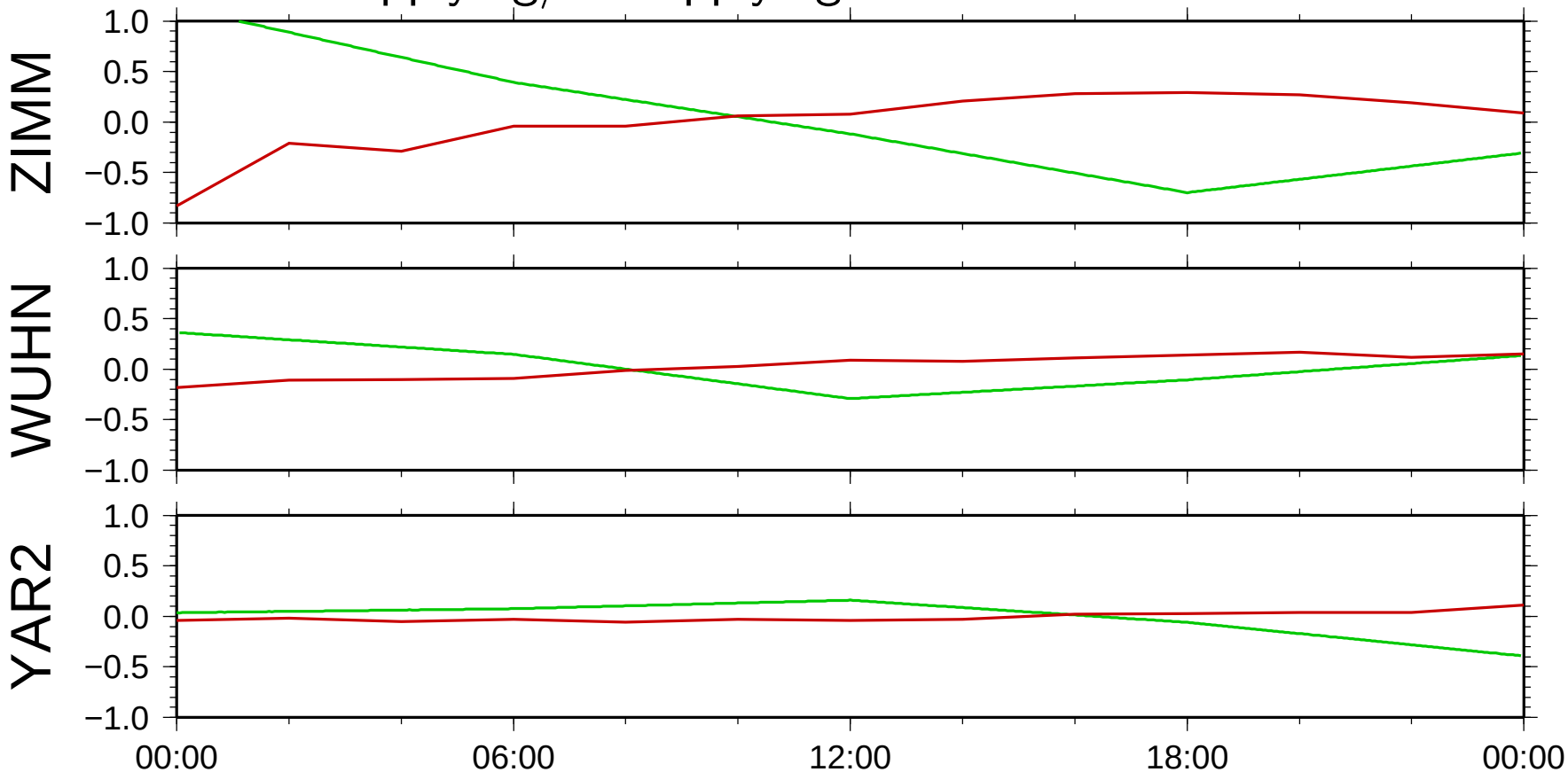
- This includes differences of up to ± 0.5 mm for individual stations even on days with a moderate magnitude of the APL effect.
- Such a correction can be done on 1-day SINEX level.
- But what about other GNSS–derived parameters that are not in the SINEX files?

APL and GNSS–derived troposphere

Differences between troposphere estimates from solutions applying/not applying APL corrections



units: mm

red: difference of troposphere estimates, green: APL effect

21. January 2010

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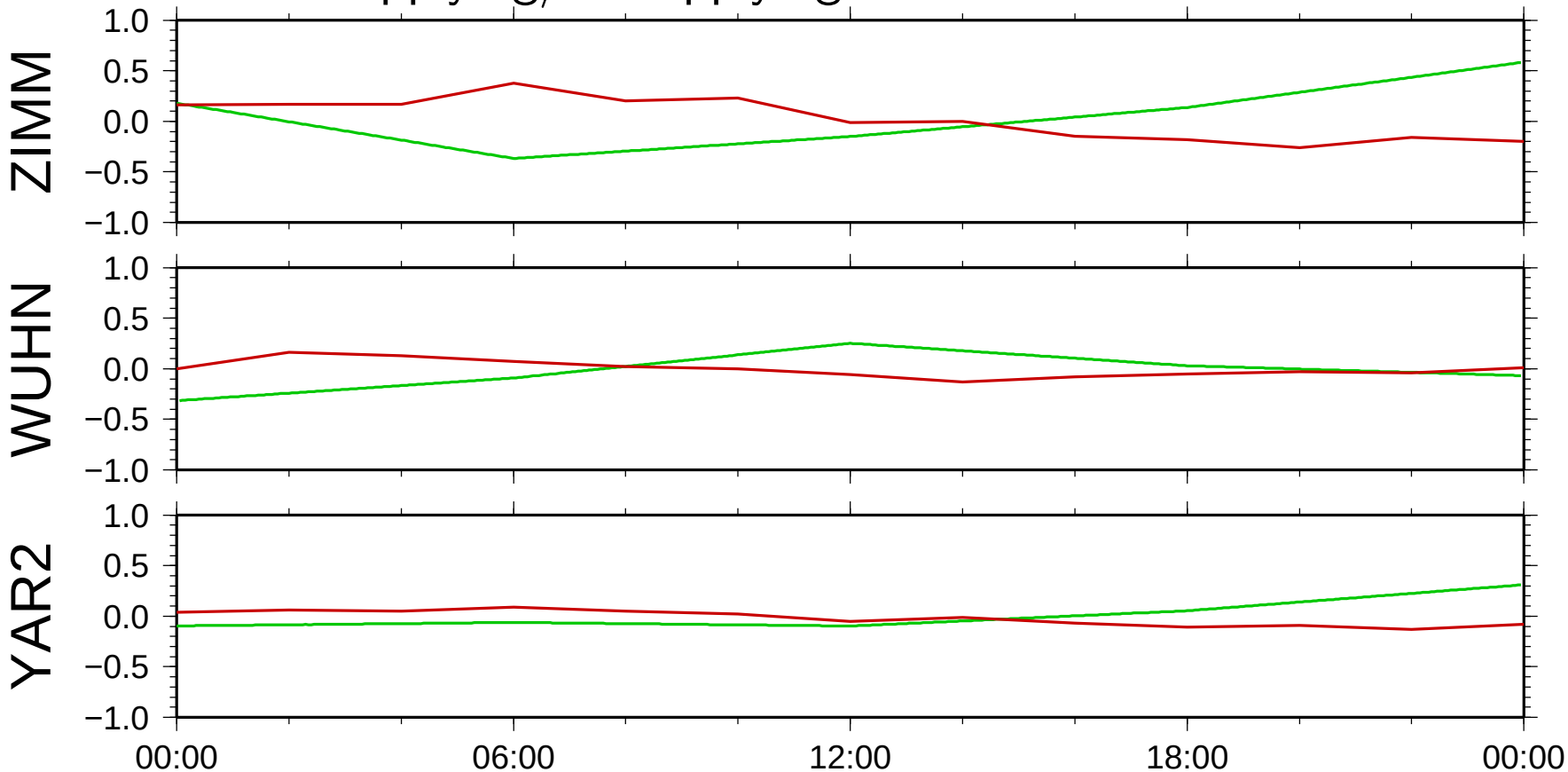

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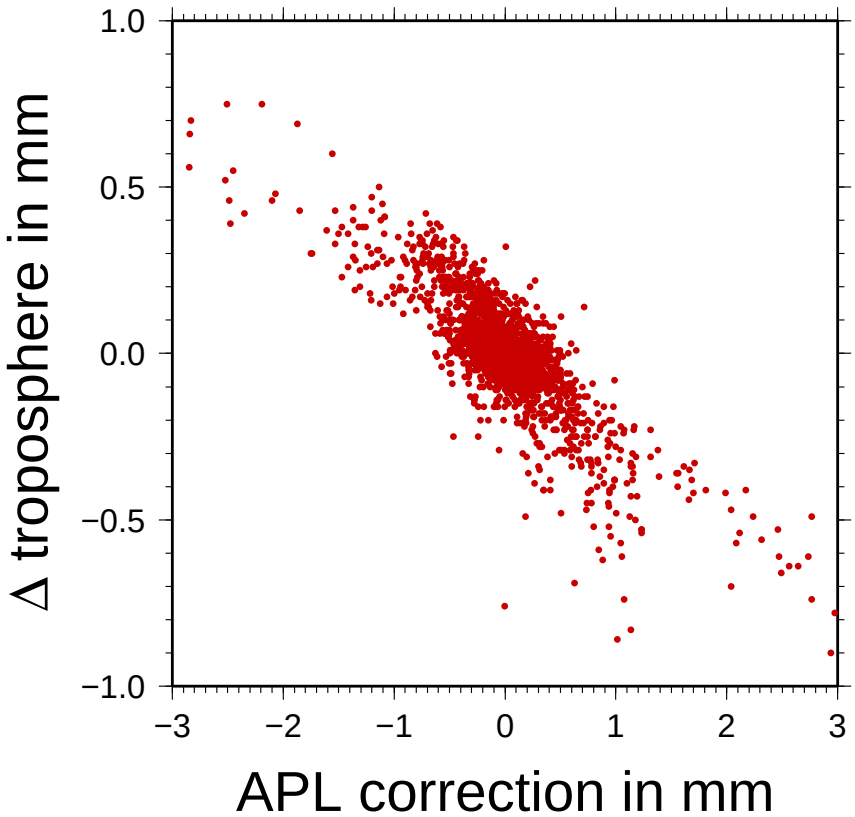
29. May 2010

APL and GNSS–derived troposphere

Differences between troposphere estimates from solutions applying/not applying APL corrections versus APL correction



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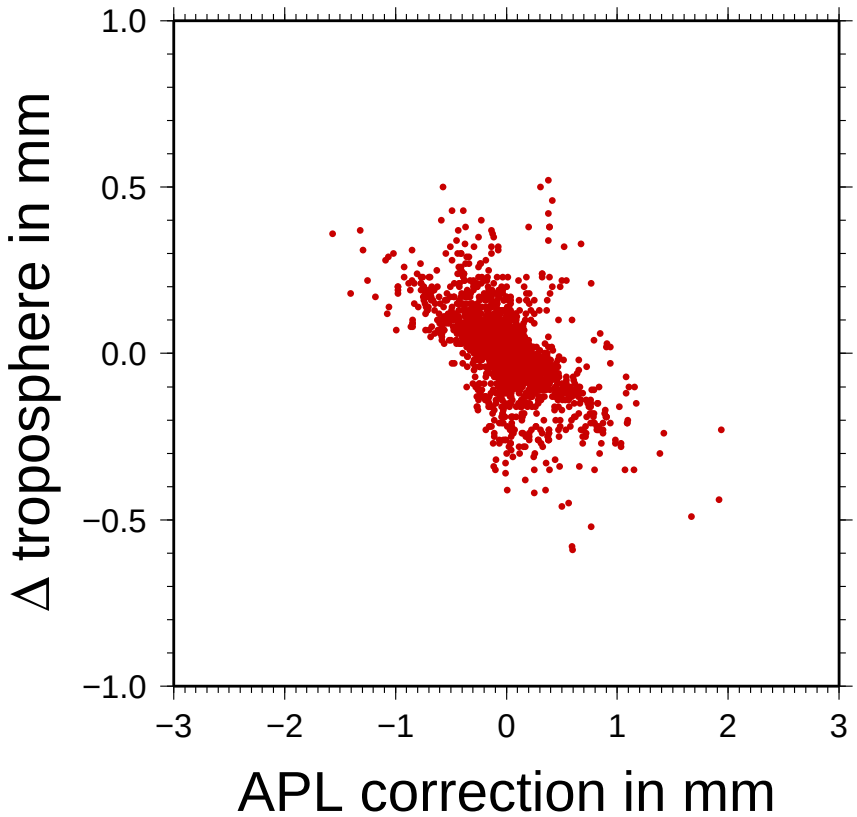

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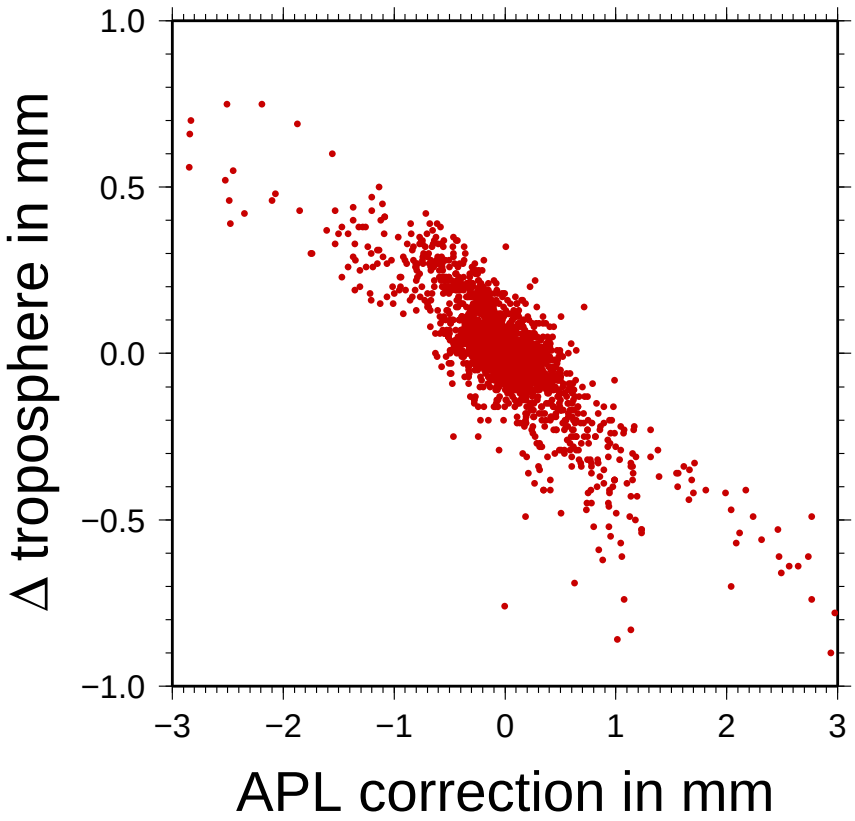

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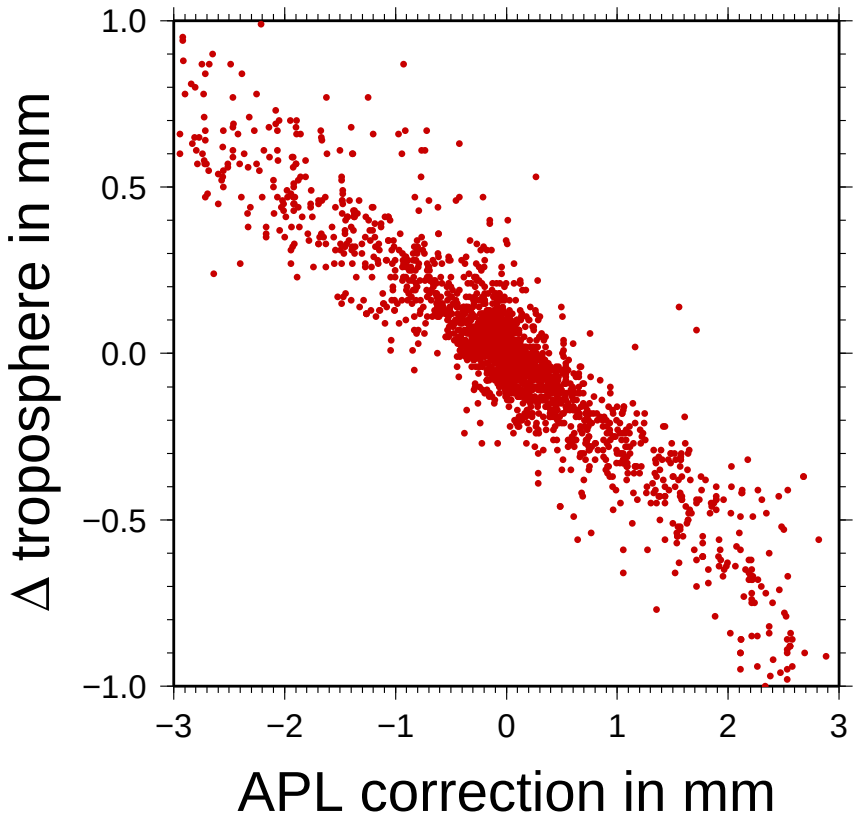

27. January 2010

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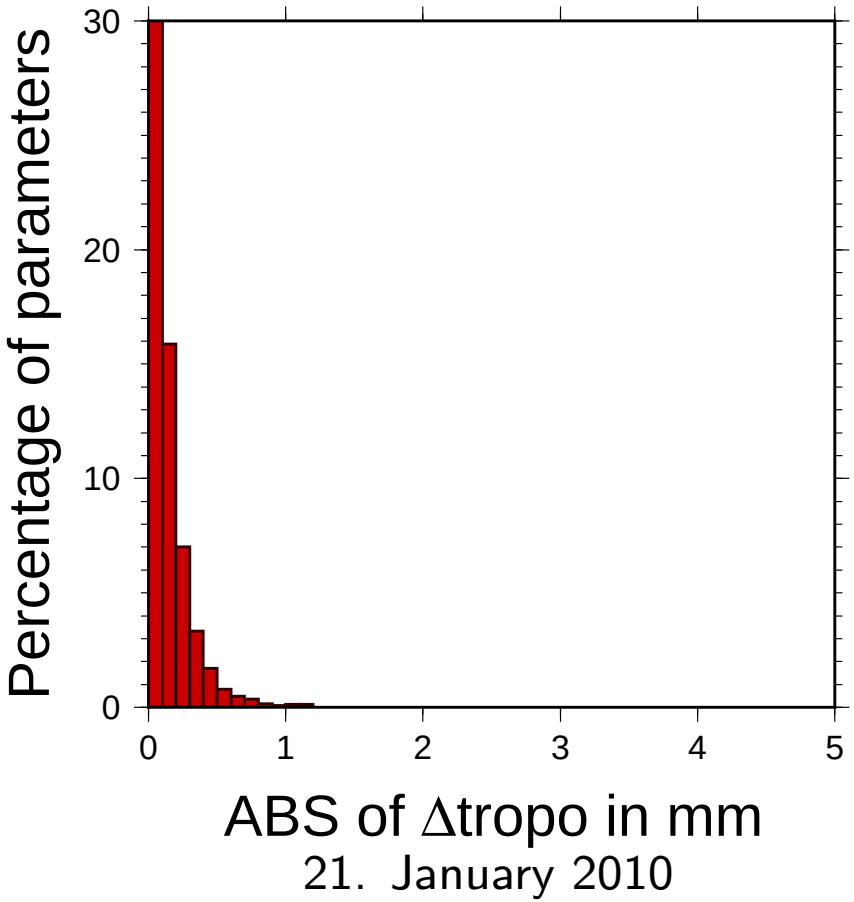

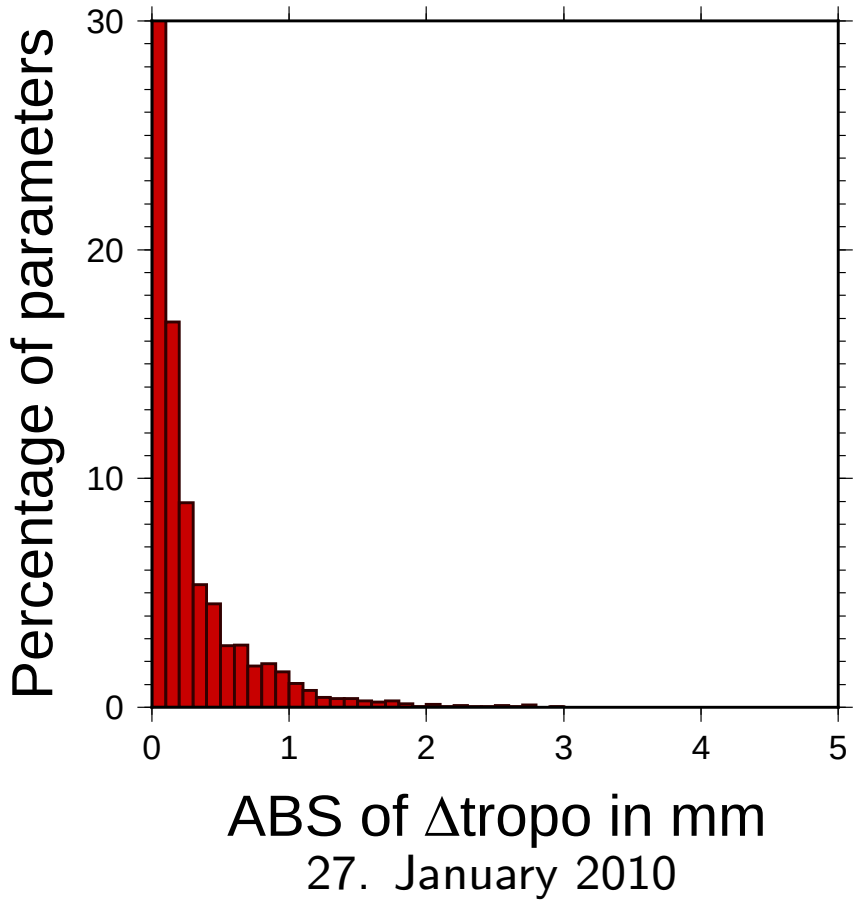

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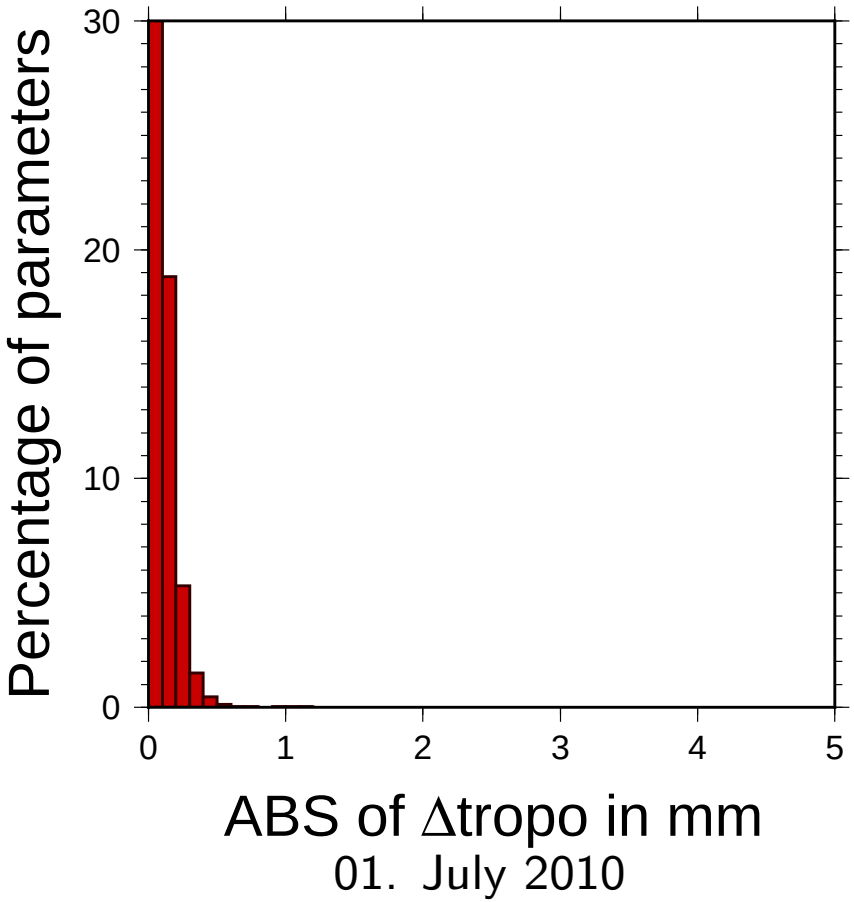
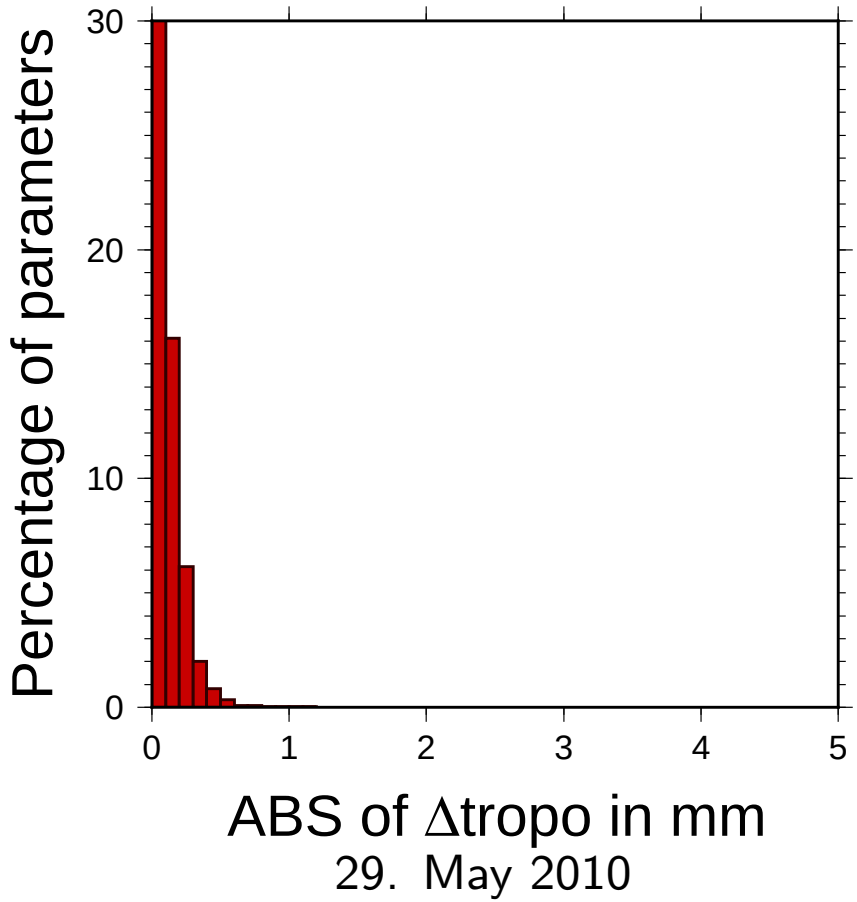
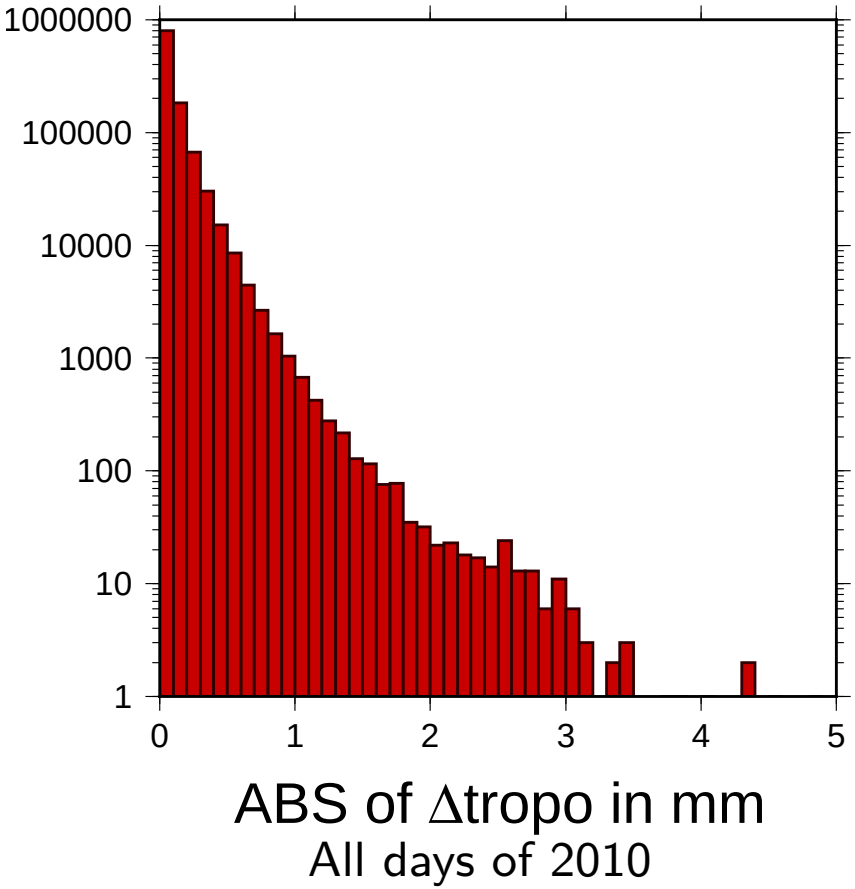




Summary

APL and GNSS–derived troposphere



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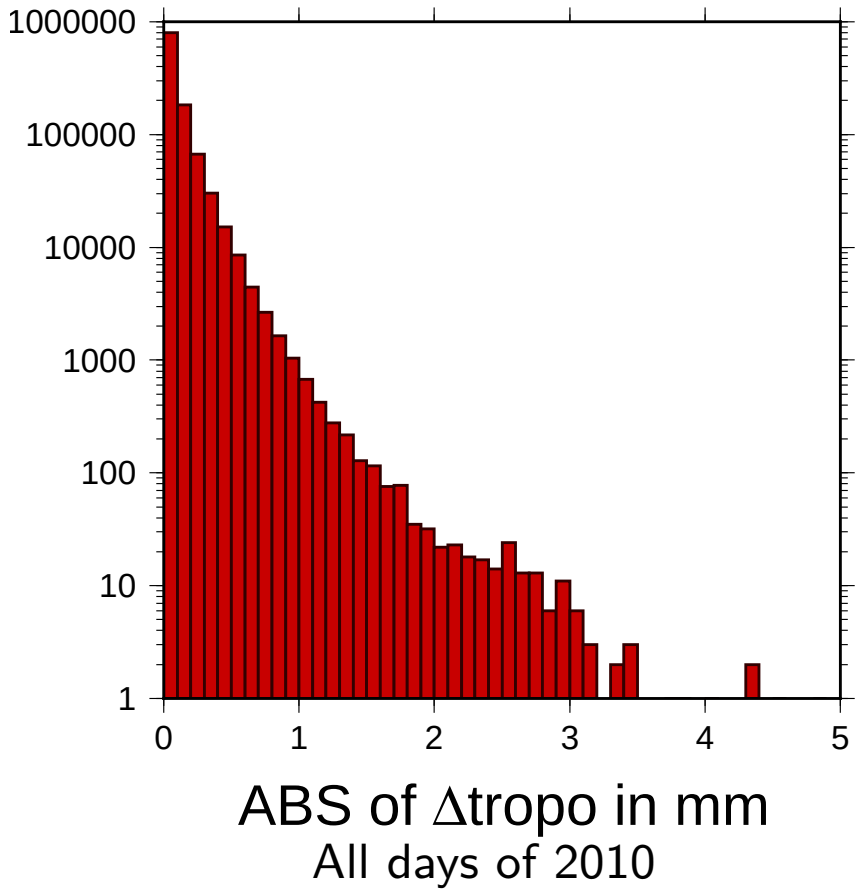

- Vertical APL corrections are correlated with a factor of 1/3 with the estimated troposphere parameters.

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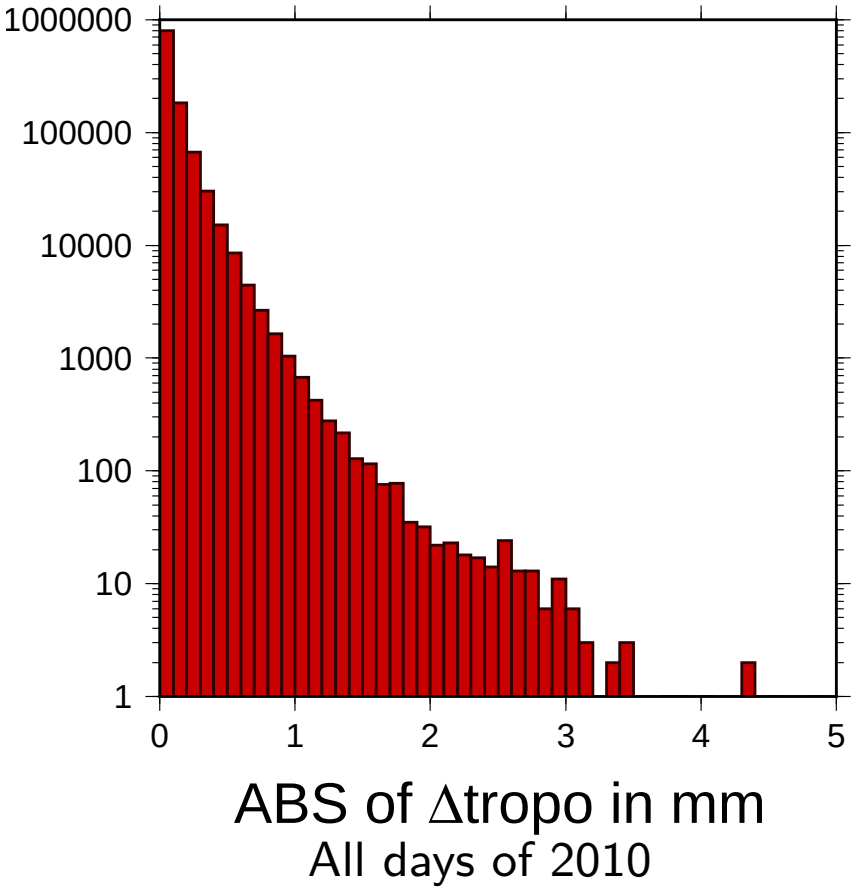

- Vertical APL corrections are correlated with a factor of 1/3 with the estimated troposphere parameters.
- Only the variation of the APL effect during one day (processing batch length) is relevant — the influence exceeds 1 mm only in extremely rare cases.

APL and GNSS–orbits

RMS of Earth-fixed satellite positions

- Difference of the solution without applying APL corrections. . .

21. January 2010			29. May 2010		
RMS_X	RMS_Y	RMS_Z	RMS_X	RMS_Y	RMS_Z
5.5 mm	14.7 mm	14.2 mm	2.6 mm	2.2 mm	2.7 mm

. . . with respect to the solution applying the APL corrections on observation level.

APL and GNSS–orbits

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- Residuals of a Helmert–transformation of the solution without applying APL corrections...

21. January 2010			29. May 2010		
RMS_X	RMS_Y	RMS_Z	RMS_X	RMS_Y	RMS_Z
5.2 mm	14.5 mm	13.9 mm	2.0 mm	2.1 mm	2.1 mm

...with respect to the solution applying the APL corrections on observation level.

APL and GNSS–orbits

RMS of Earth-fixed satellite positions

- Difference of the solution without applying APL corrections...

21. January 2010			01. July 2010		
RMS_X	RMS_Y	RMS_Z	RMS_X	RMS_Y	RMS_Z
5.5 mm	14.7 mm	14.2 mm	1.6 mm	1.8 mm	1.6 mm

- Residuals of a Helmert–transformation of the solution without applying APL corrections...

21. January 2010			01. July 2010		
RMS_X	RMS_Y	RMS_Z	RMS_X	RMS_Y	RMS_Z
5.2 mm	14.5 mm	13.9 mm	1.5 mm	1.6 mm	1.5 mm

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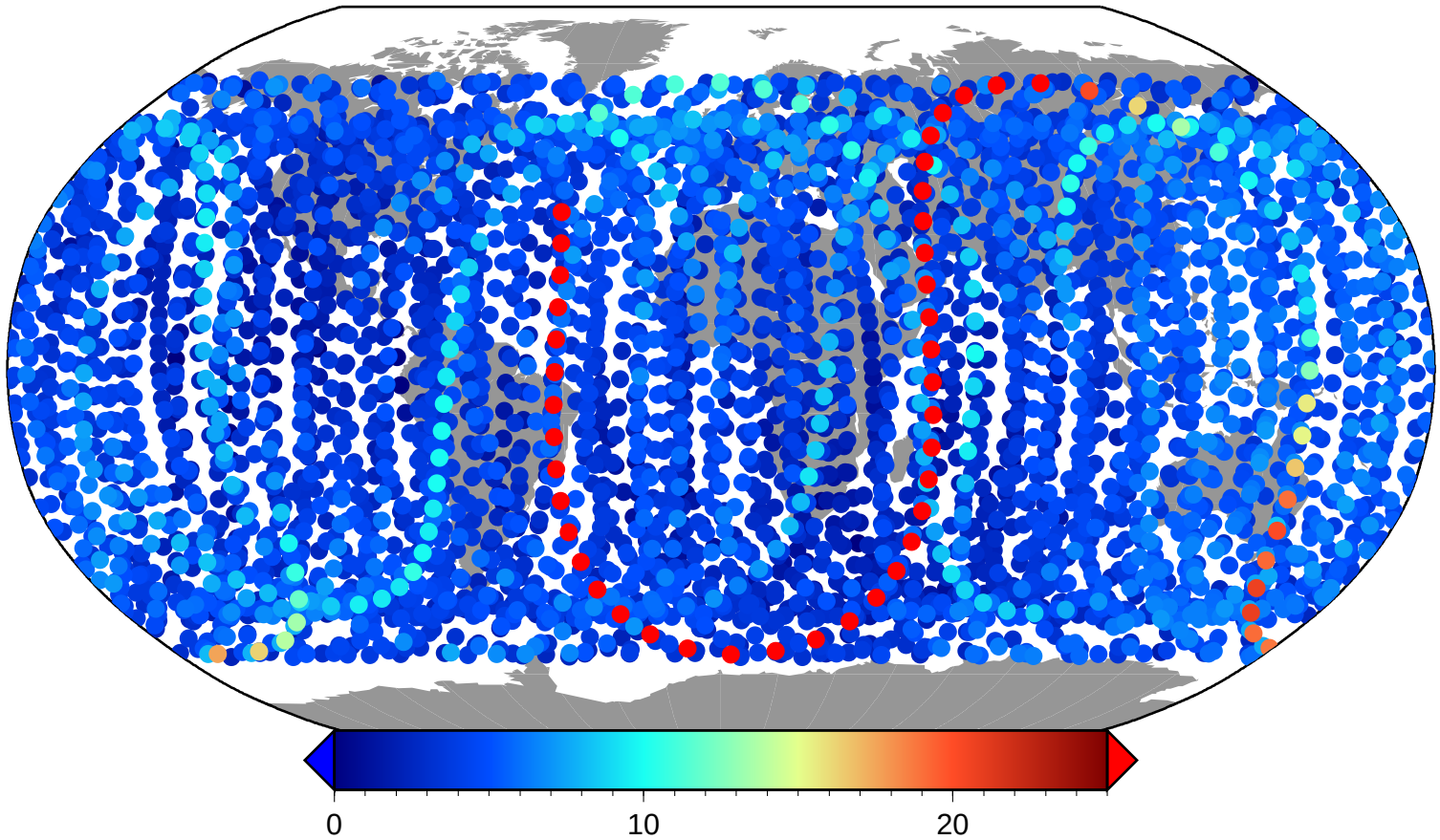
APL and GNSS–orbits

Differences in the satellite positions between solutions with and without correcting for APL



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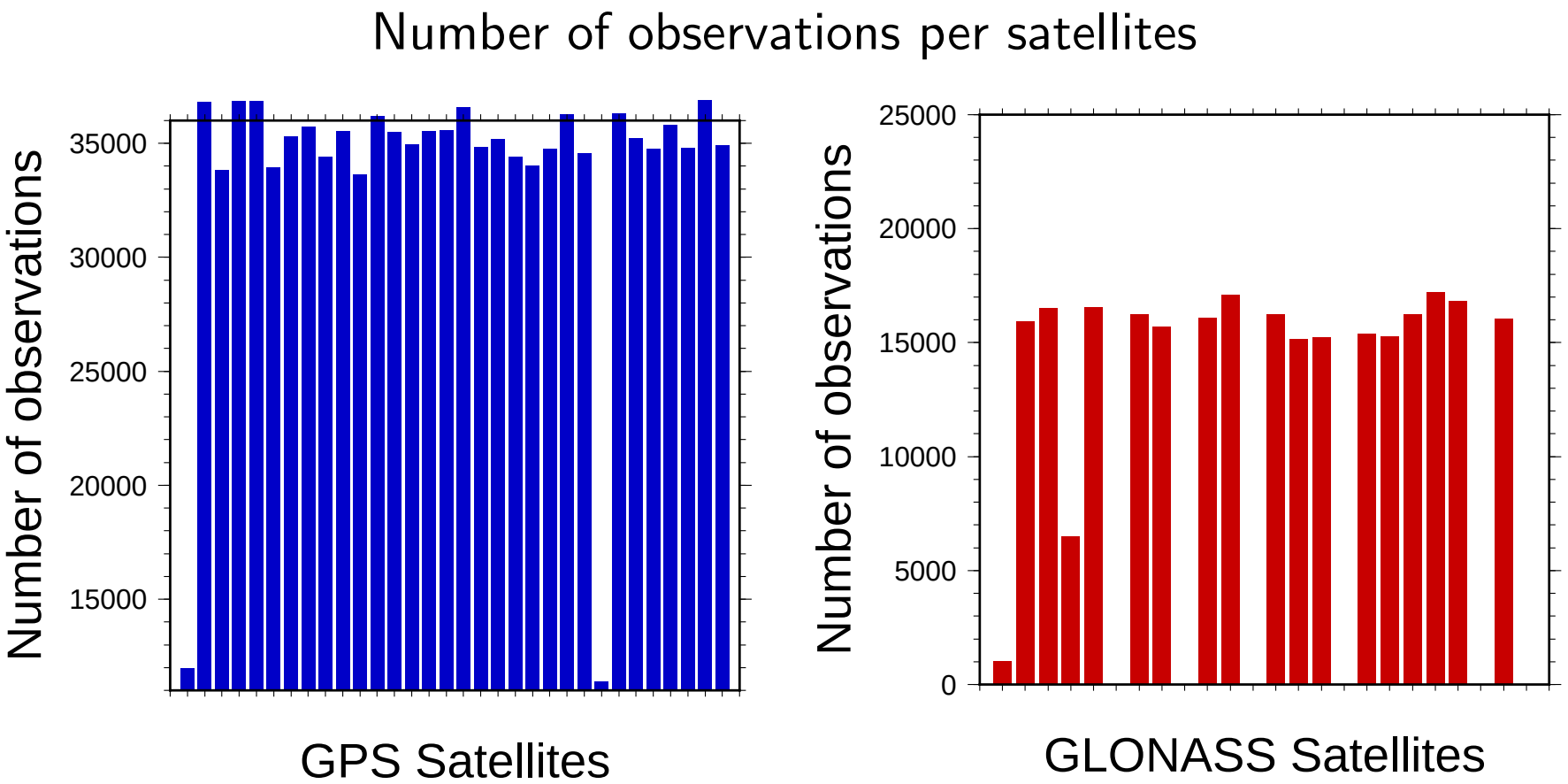
APL and GNSS–orbits



- Satellite R01 has only 1000 observations causing a very weakly determined orbit from a one–day solution.

APL and GNSS–orbits

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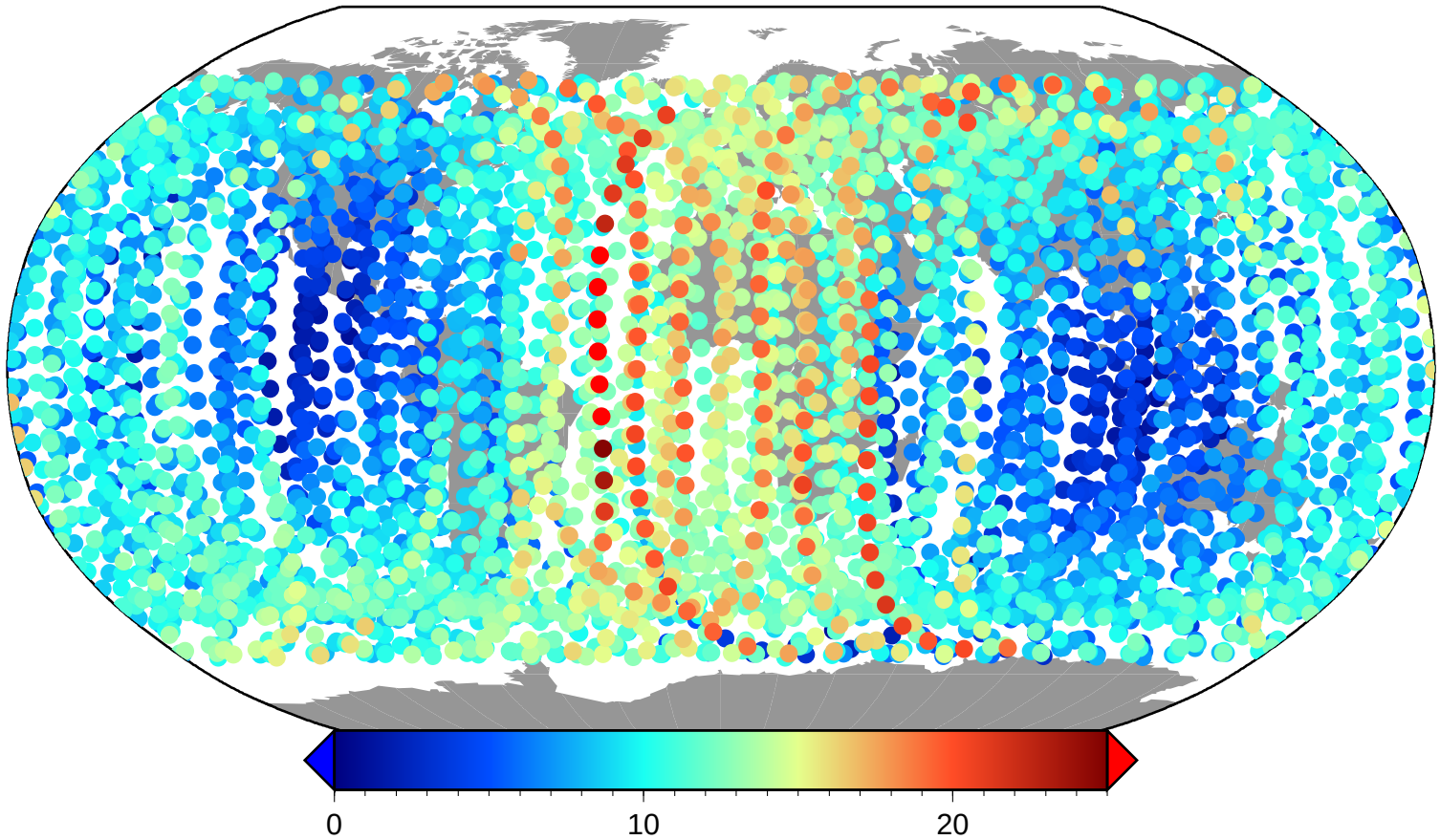
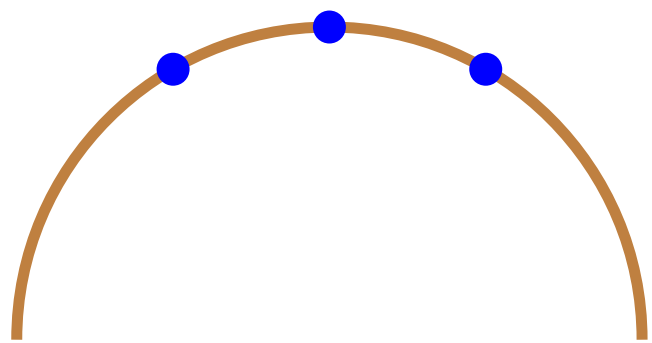


23. December 2010

How APL may mitigate into GNSS orbits?



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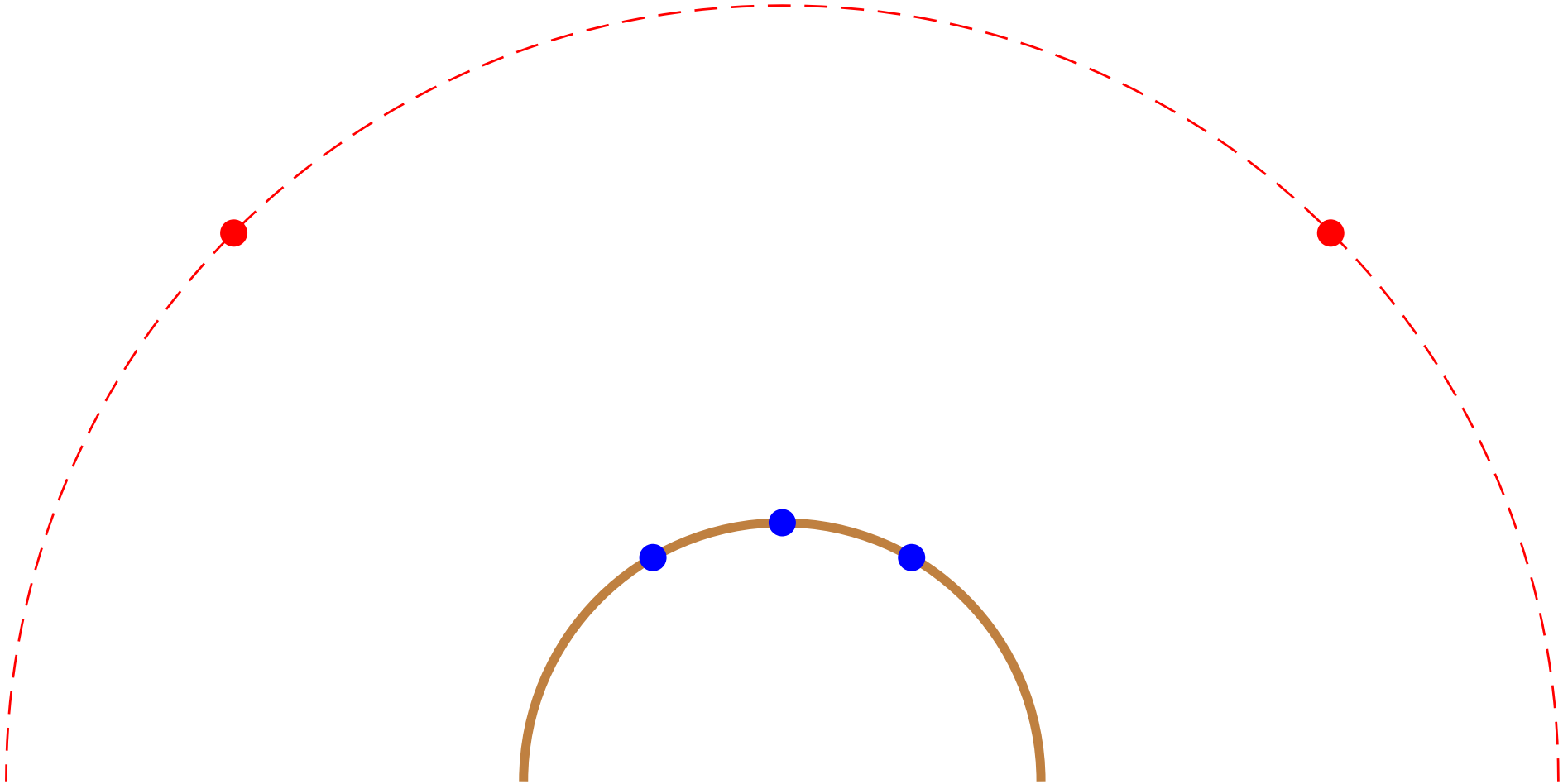

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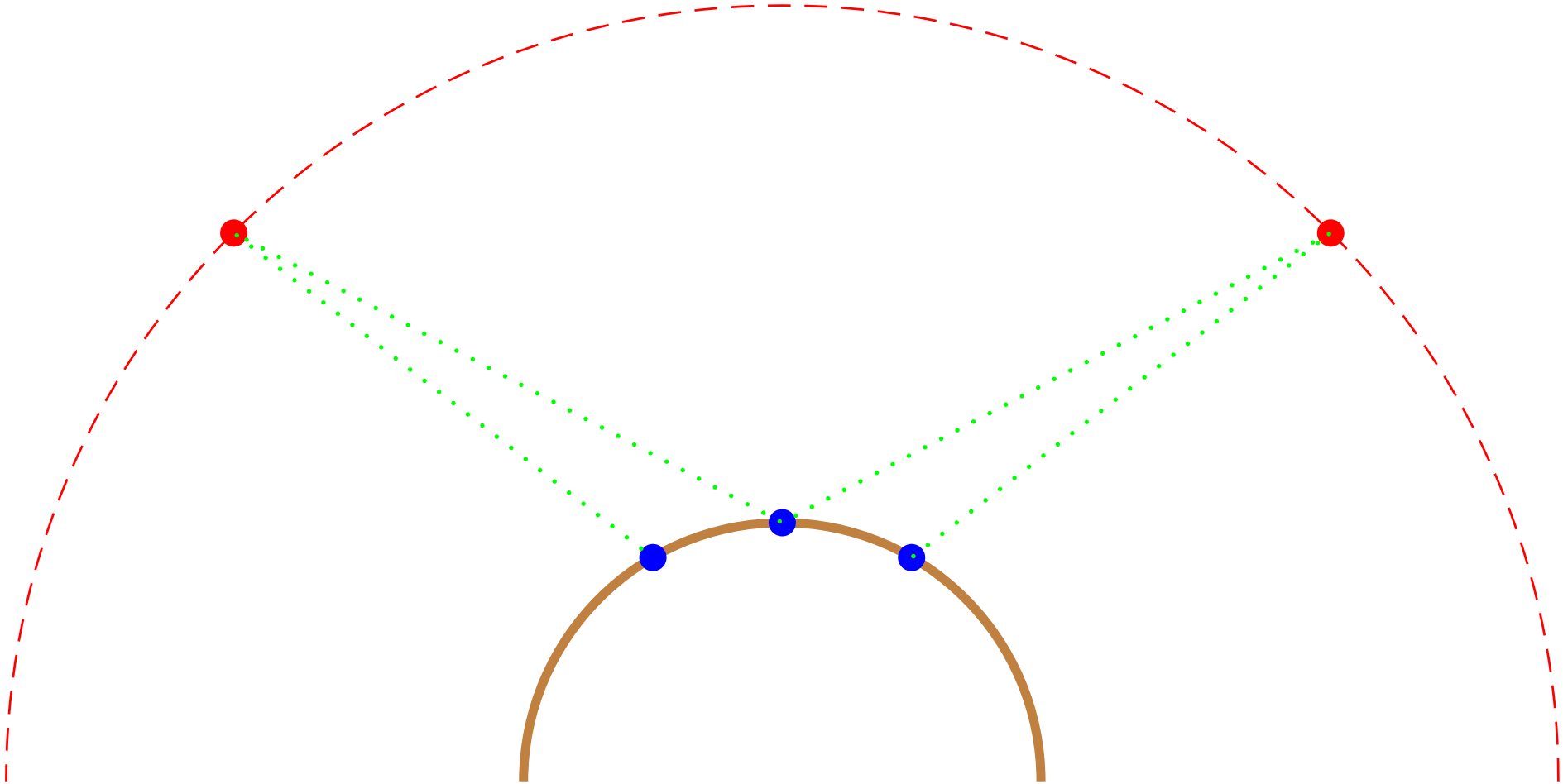

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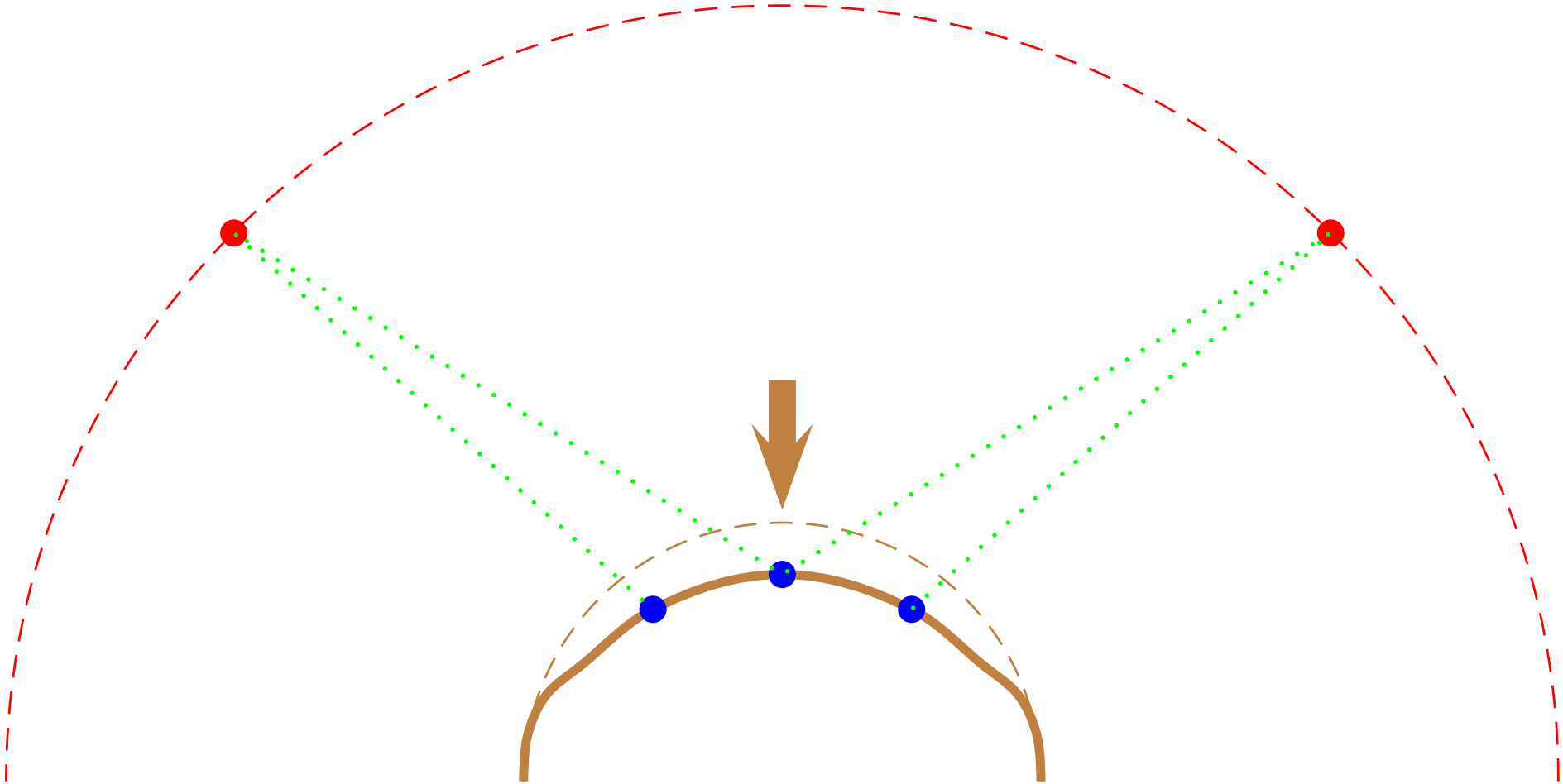

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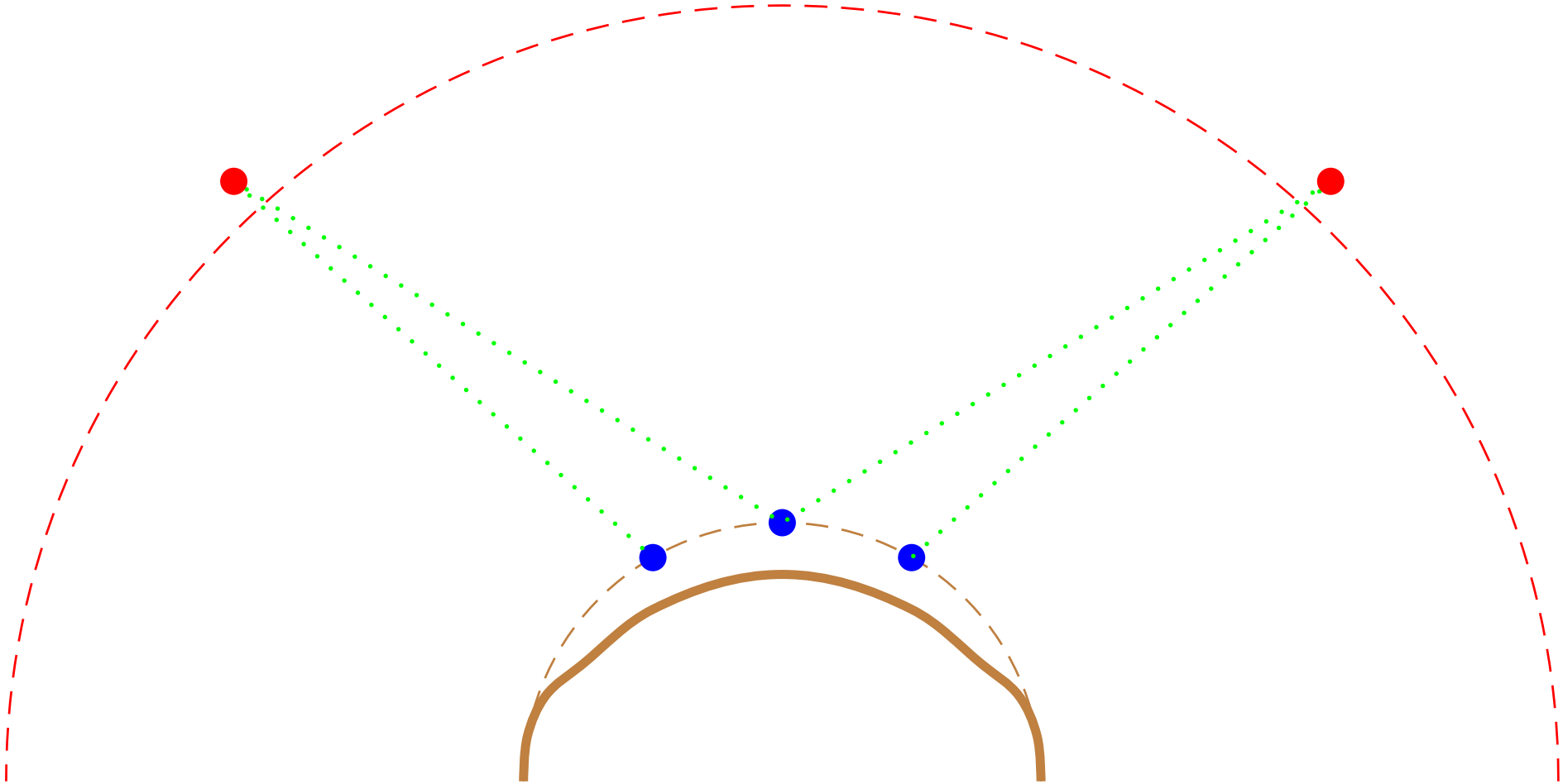

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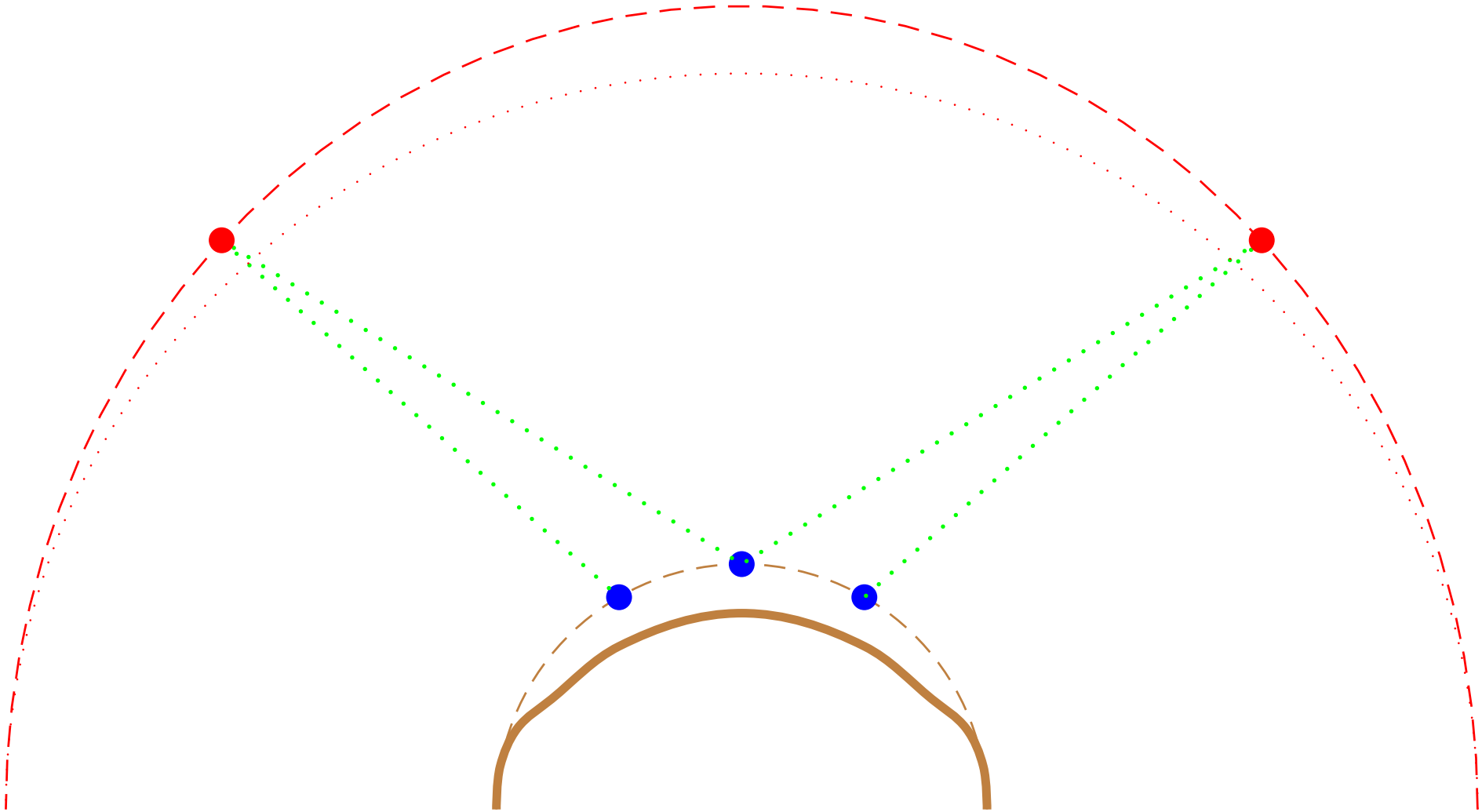
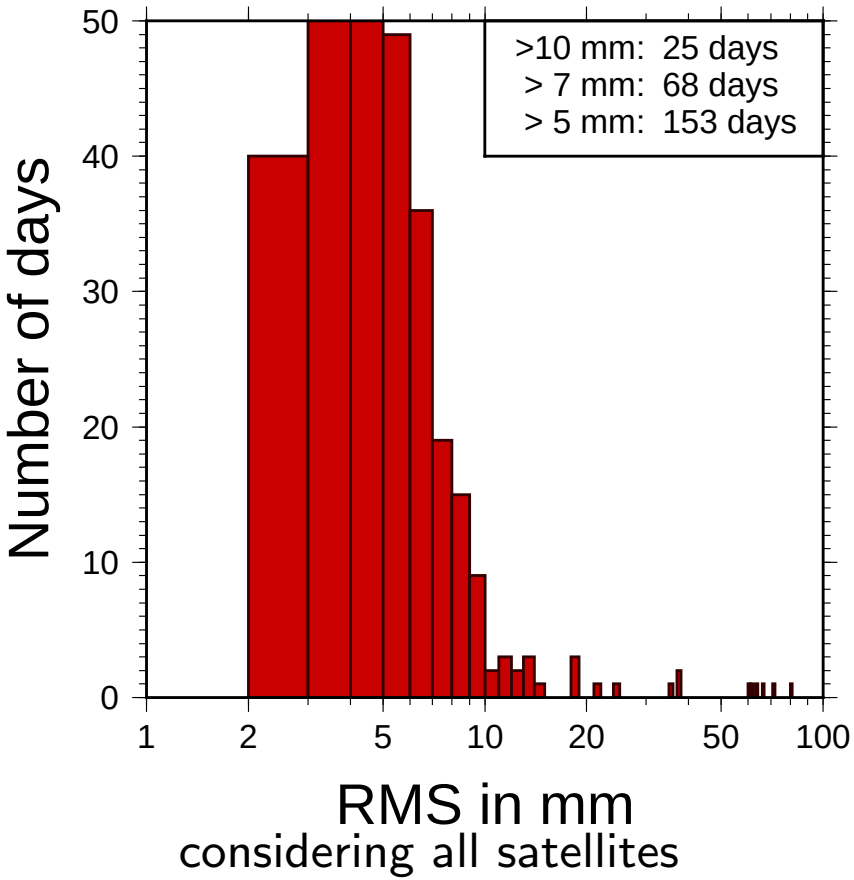


APL and GNSS–orbits

Differences in the satellite positions between solutions with and without correcting for APL



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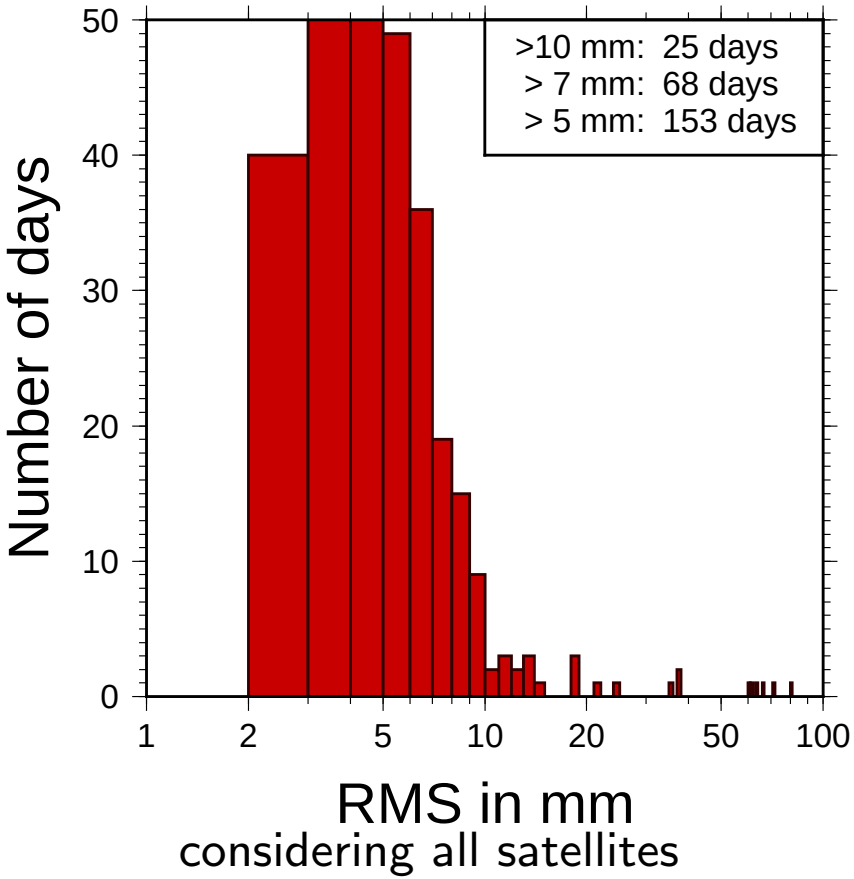
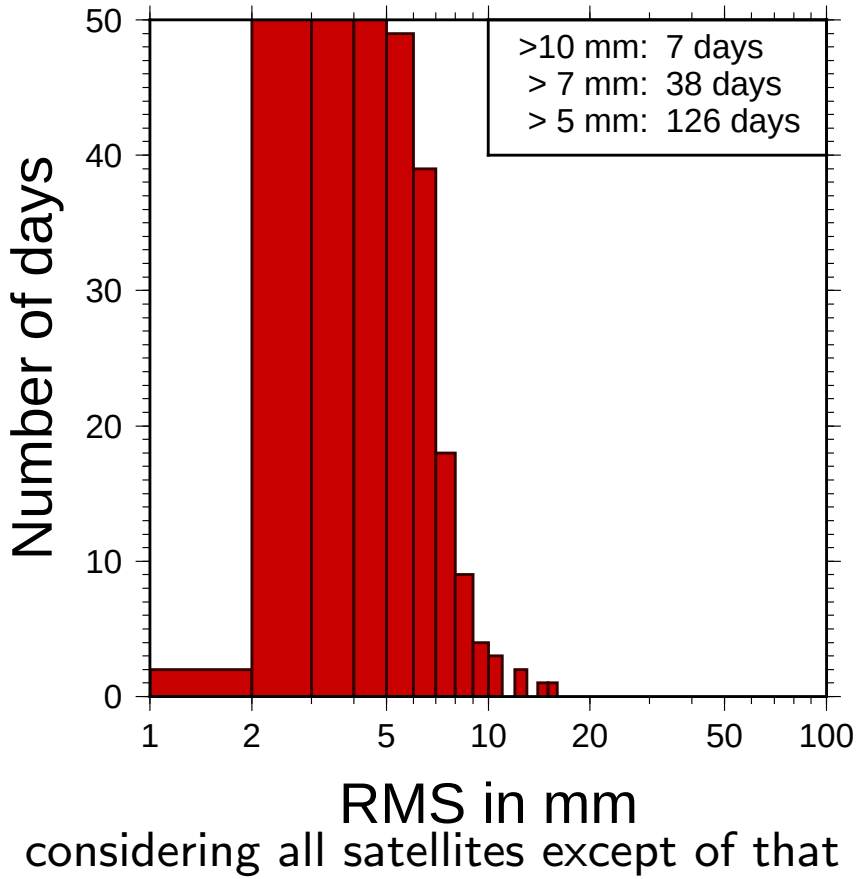


considering all satellites



considering all satellites except of that one with the biggest RMS of orbit differences

Summary

- Unmodeled APL–effect can mitigate into GNSS satellite orbits if a large area is affected by APL deformation.

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- Weakly observed satellites can easily be shifted by few centimeters (depending on the start and end point of their trajectory with respect to the deformed area).

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- Unmodeled APL–effect can mitigate into GNSS satellite orbits if a large area is affected by APL deformation.
- Weakly observed satellites can easily be shifted by few centimeters (depending on the start and end point of their trajectory with respect to the deformed area).
- For all other satellites the difference between applying APL or not may exceed 5 mm RMS over all satellites for a reasonable number of days.

Conclusion

- Correcting APL on observation level is the only approach without any compromises.

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Conclusion

- Correcting APL on observation level is the only approach without any compromises.
- When applying mean APL corrections to station coordinates after the processing, the variation in time of the APL effect is absorbed by the troposphere parameters (one third of the effect — typically very small)
- An new realization of the geodetic datum is required after applying mean APL corrections to the station coordinates. This has to be done as long as all relevant parameters are accessible, e.g., in a software–internal normal equation.
  In case of SINEX the orbit parameters are missing, which may absorb a part of the unmodeled APL effect.

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Everybody has to decide by its own which level of compromises can be accepted to get the benefit of exchangeable APL models after the processing.

Final Remark

The results can also be interpreted as a general error mitigation study that act in the same way for comparable (unmodeled) effects in the GNSS analysis:

1. Atmospheric pressure loading
2. Ocean non–tidal loading
3. Hydrologically induced deformations

THANK YOU
for your attention

Publications of the satellite geodesy research group:

`http://www.bernese.unibe.ch/publist`