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PyGACT - a Python toolkit for determination of relative GNSS antenna phase center variations

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1. Motivation

- Many GNSS applications require that the phase center offset (PCO) and phase center variations (PCV) are avaible with high accuracy.
- While absolute calibrations are available for high-end geodetic antennas, most of the low-cost mass-market antennas remain uncalibrated.
- The performance of low-cost single-frequency antennas is evaluated by using a geodetic-grade GNSS antenna as a reference, which is placed in the vicinity of the target.
- In addition to relative PCO and PCV, carrier-phase multipath, code-phase multipath and carrier-to-noise density power ratio (C/N0) values are also analysed.
- Instead of using spherical harmonic (SH) coefficients with global support, we add the option to estimate PCV maps in the form of 2D B-splines. This allows to better adapt to the local satellite visibility conditions.
- The relative antenna characteristics are not only obtained for GPS and GLONASS, but also include Galileo and Beidou frequencies.

2. Method

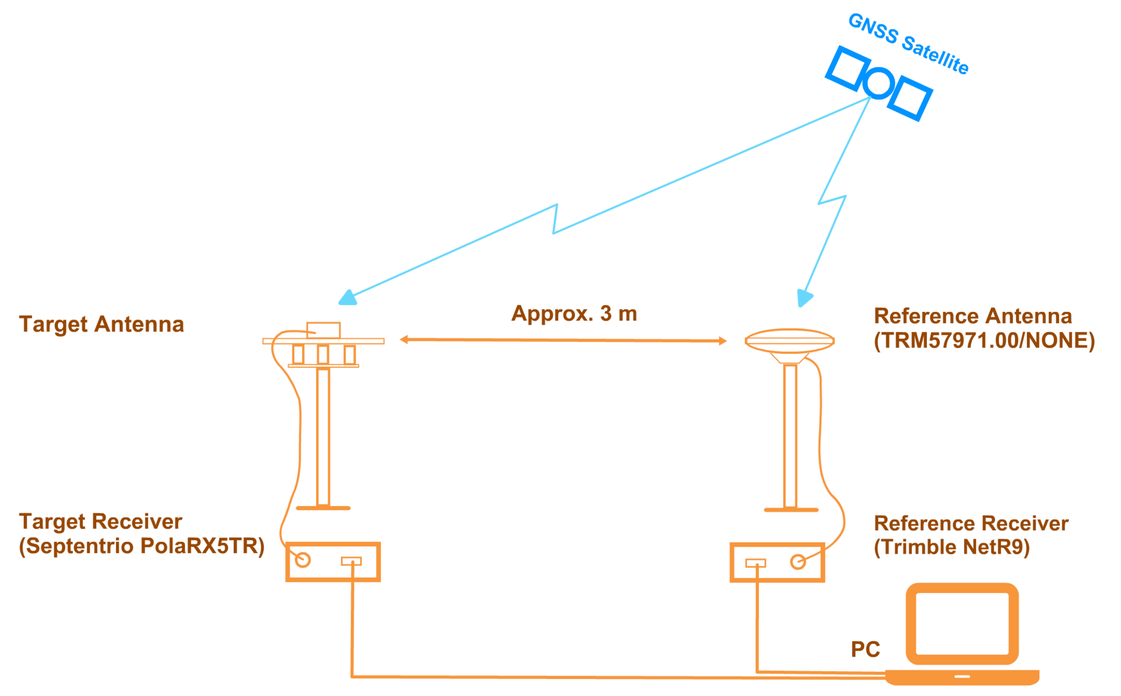

Fig. 1: Configuration for evaluation of the target antenna performance

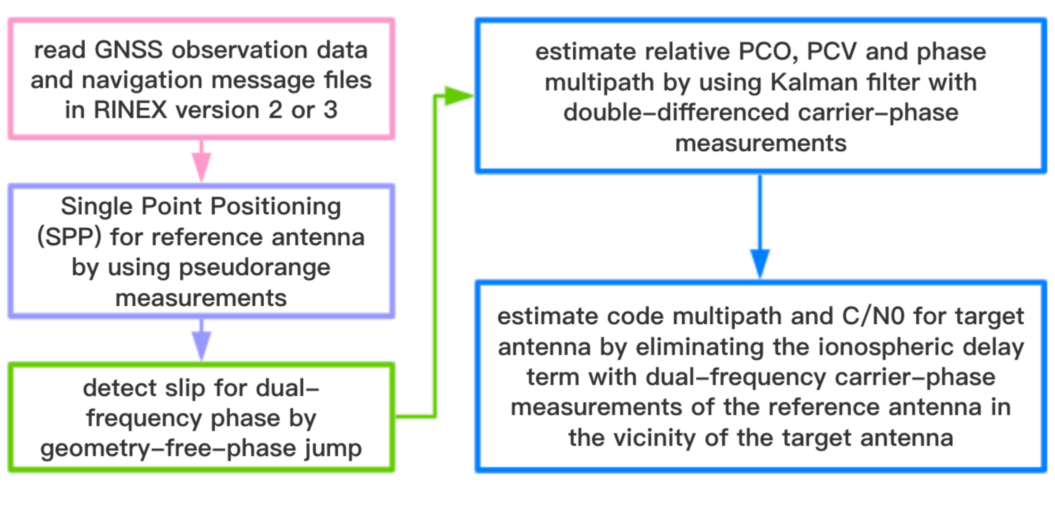

Fig. 2: PyGACT program flow

3. Antenna types

(a)

(c)

(b)

Fig. 3: Images of the antennas calibrated within this project. Depicted are (a) a low-cost ANN-MS antenna, (b) a self-built helix antenna which has been optimized for GPS L1 as well as (c) a geodetic-grade multi-frequency antenna (shown together with the reference antenna)

4. Results for different antenna types

Target antenna: ANN-MS

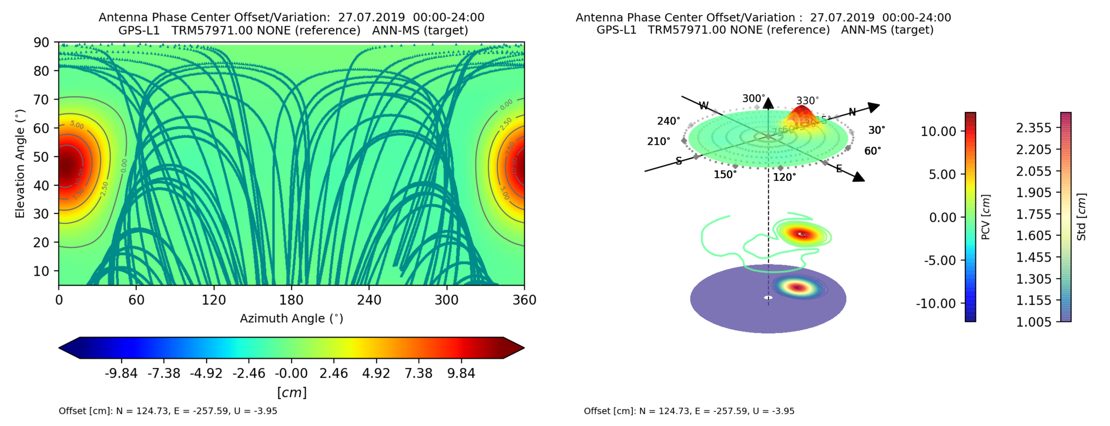

Fig. 4: PCV map in SH representation for GPS-L1

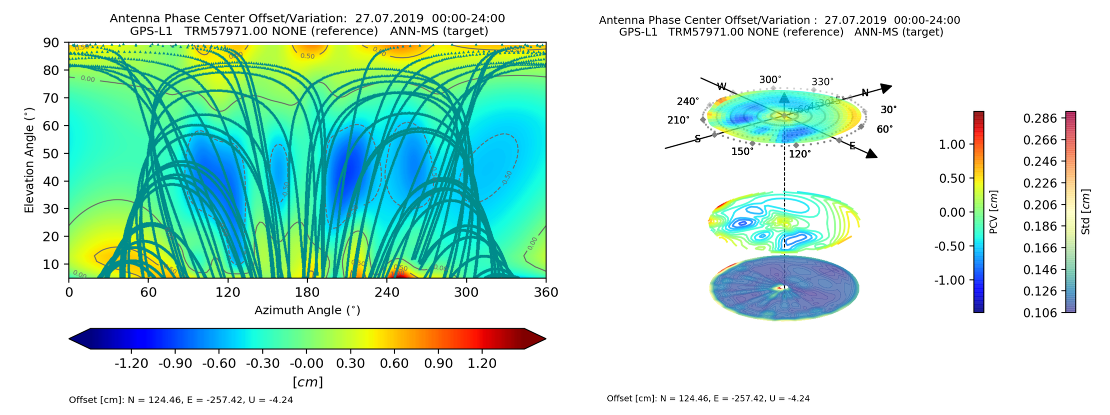

Fig. 5: PCV map with the B-spline model for GPS-L1

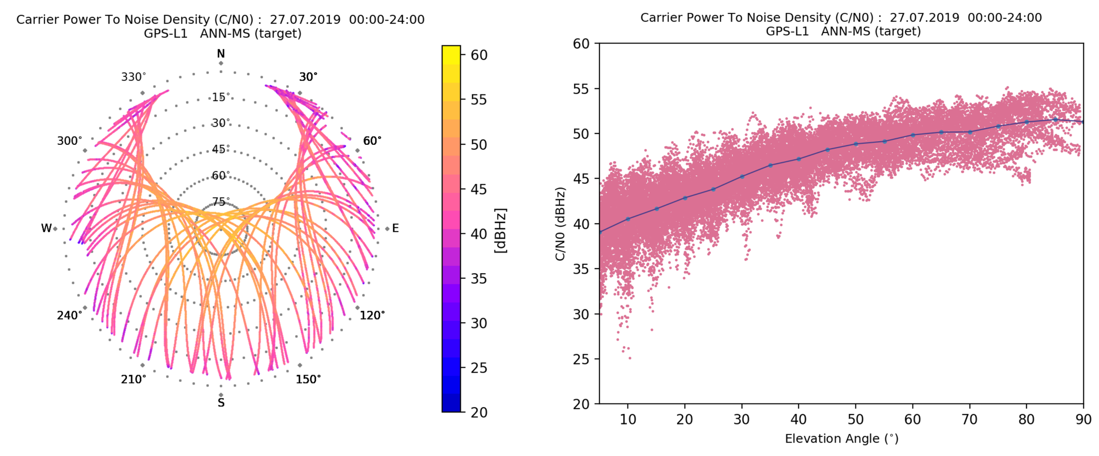

Fig. 6: C/N0 skyplot and C/N0-elevation for GPS-L1

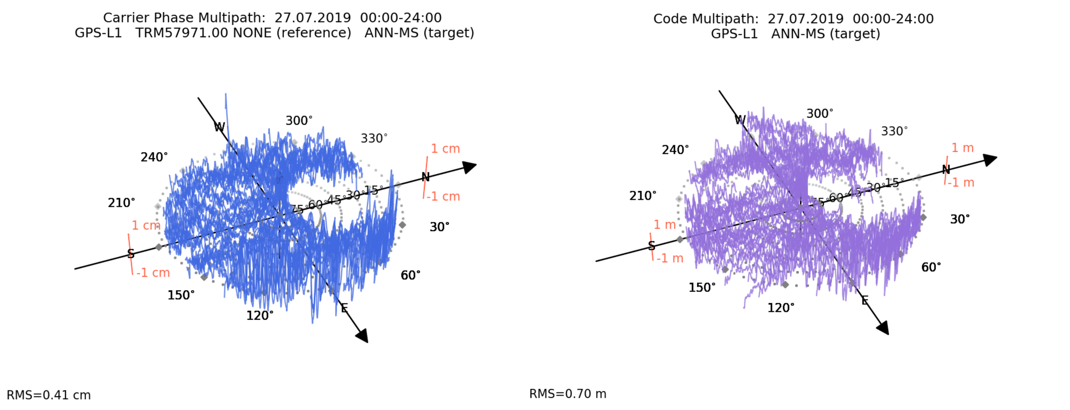

Fig. 7: Carrier-phase and code multipath skyplots for GPS-L1

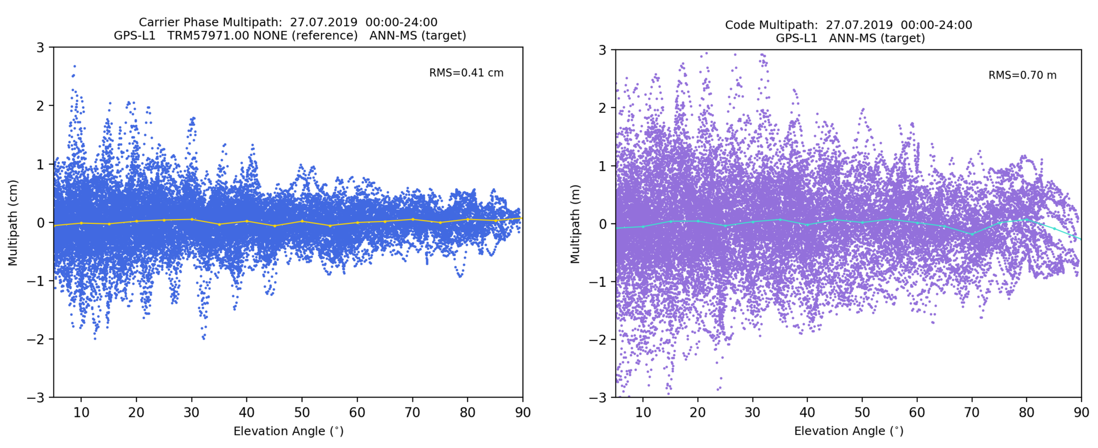

Fig. 8: Elevation dependency of GPS-L1 carrier-phase and code multipath

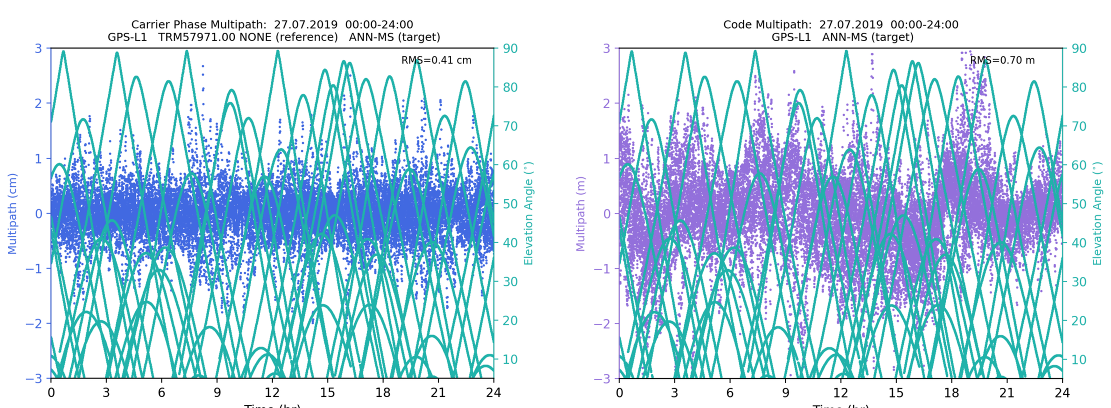

Fig. 9: Temporal variation of GPS-L1 carrier-phase and code multipath

Target antenna: TRM115000.00/NONE

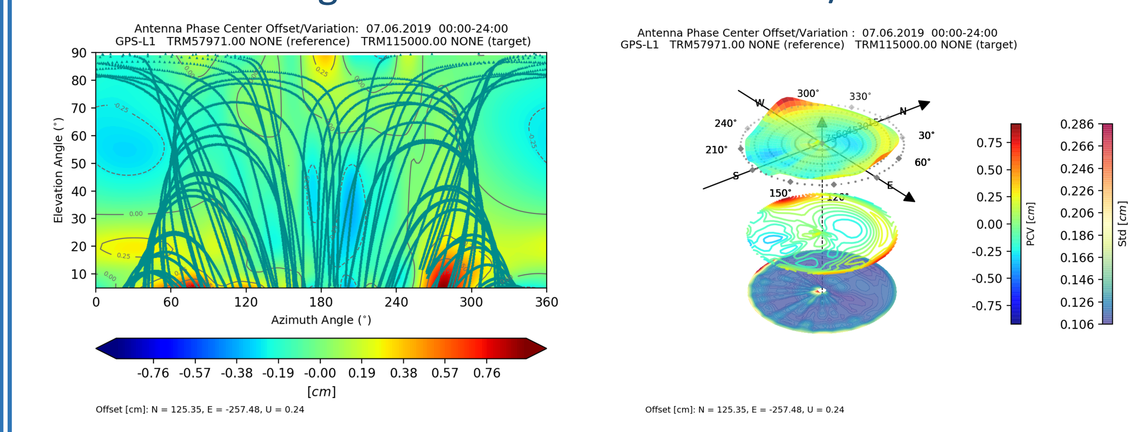

Fig. 10: PCV map with the B-spline model for GPS-L1

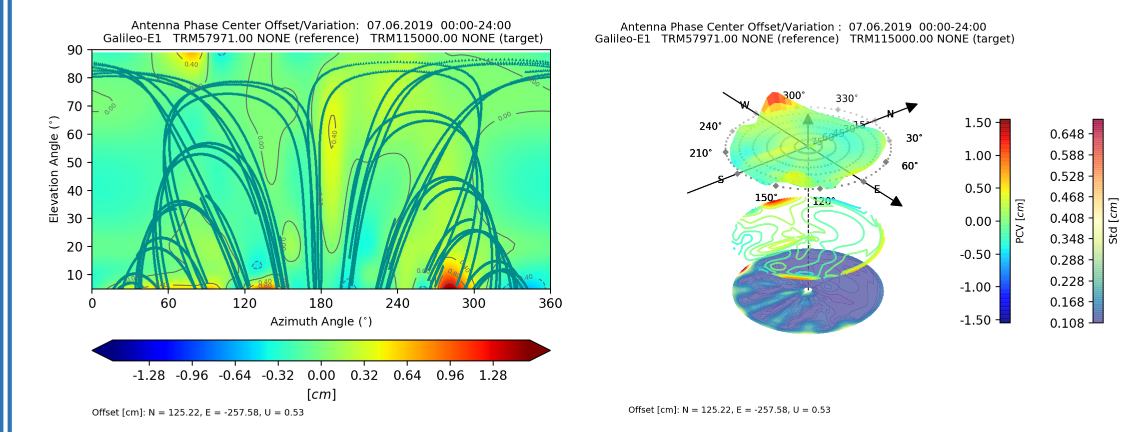

Fig. 11: PCV map with the B-spline model for Galileo-E1

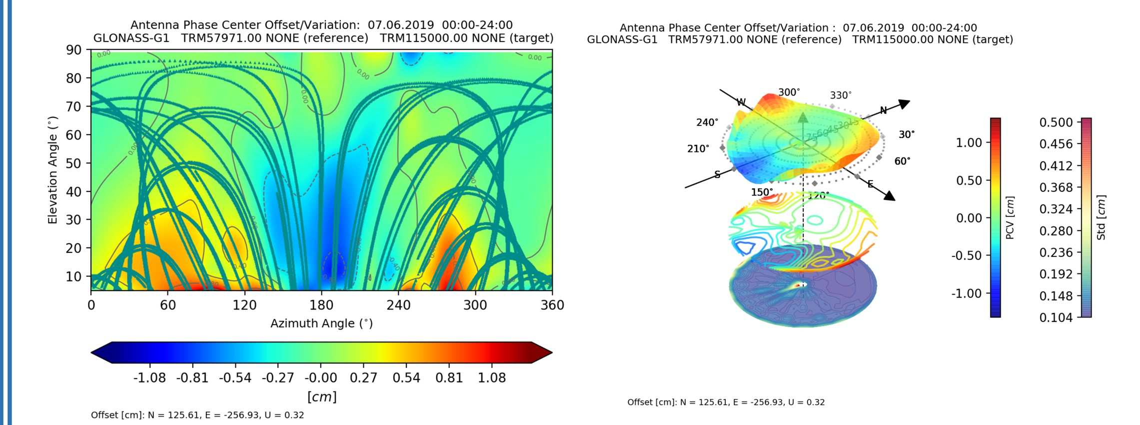

Fig. 12: PCV map with the B-spline model for GLONASS-G1

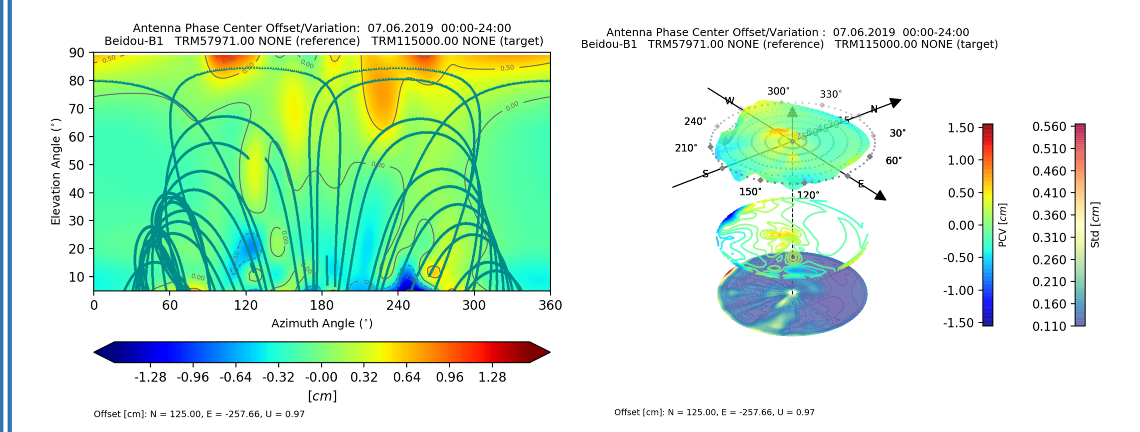

Fig. 13: PCV map with the B-spline model for Beidou-B1

Target antenna: Helix

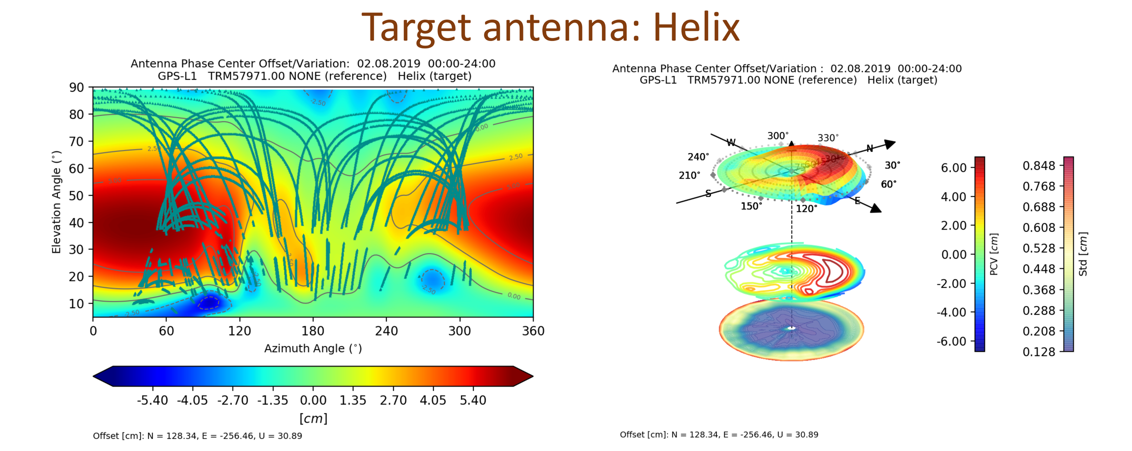

Fig. 14: PCV map with the B-spline model for GPS-L1

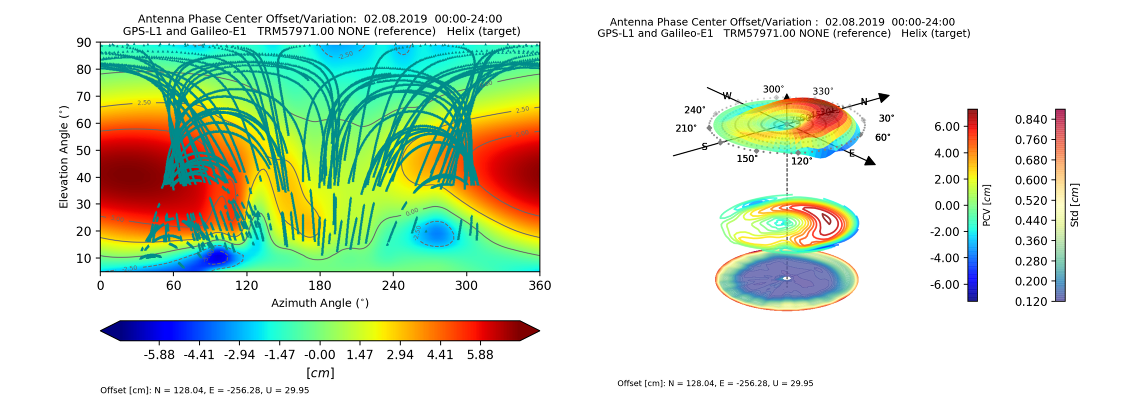

Fig. 15: PCV map with the B-spline model for GPS-L1/Galileo-E1

5. Discussion

- ANN-MS (consumer-grade antenna): the standard deviations of estimated relative PCV maps based on the SH representation are in the range of 1.0-2.4 cm, which is nearly 10 times larger than those of the B-spline model; SH models tend to oscillate and produce artifacts in areas where no observations are available.
- Helix (consumer-grade antenna): although the satellite signals are faint in the range between 25 to 40 degrees of elevation, similar relative PCV maps are obtained from GPS and Galileo data; the accuracy could be improved by combining data from GPS and Galileo.
- TRM115000.00/NONE (geodetic-grade antenna): every satellite system has its own trajectory distribution, so PCV maps have small differences; in general the standard deviations are less than 7 mm.

6. Conclusions

- The B-spline model is suitable for representing data of varying density. The estimated relative PCV maps using 2D B-splines reach an accuracy that does not exceed 1 cm.
- It is feasible to use consumer-grade antennas for precise GNSS positioning by applying results from this simple antenna calibration method.

7. Acknowledgements

This work was greatly supported by IGS products.

The authors gratefully acknowledge the helpful discussions with Dipl.-Ing. Doris Becker and valuable comments from M.Sc. Tomke Jantje Lambertus.

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