On the Impact of GPS phase centre corrections on geodetic parameters: analytical formulation and empirical evaluation by PPP

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Introduction

It is very complex to evaluate in a general way the impact of phase centre corrections (PCC) in geodetic positioning due to the different positioning concepts, implementation philosophy as well as various PCC patterns. This poster tries to categorize the impact of PCC on all geodetic parameters. The approach is based on a simulation method investigated by [Geiger, 1988] and [Santerre, 1989] and uses generic PCC patterns.
In an analytical step the mathematical model from Geiger is enlarged to incorporate different observation weighting and to approximate better the satellite sky distribution. Furthermore the propagation of error functions for several generic antenna models is investigated. The following empirical step evaluates these findings by experiments. The generic PCC patterns are added to existing absolutely calibrated antennas. Precise Point Positioning (PPP) is computed with different software packages and the impact on all estimated parameters is analysed.

Generic patterns

1. Several generic PCV are proposed by [Geiger, 1988]:

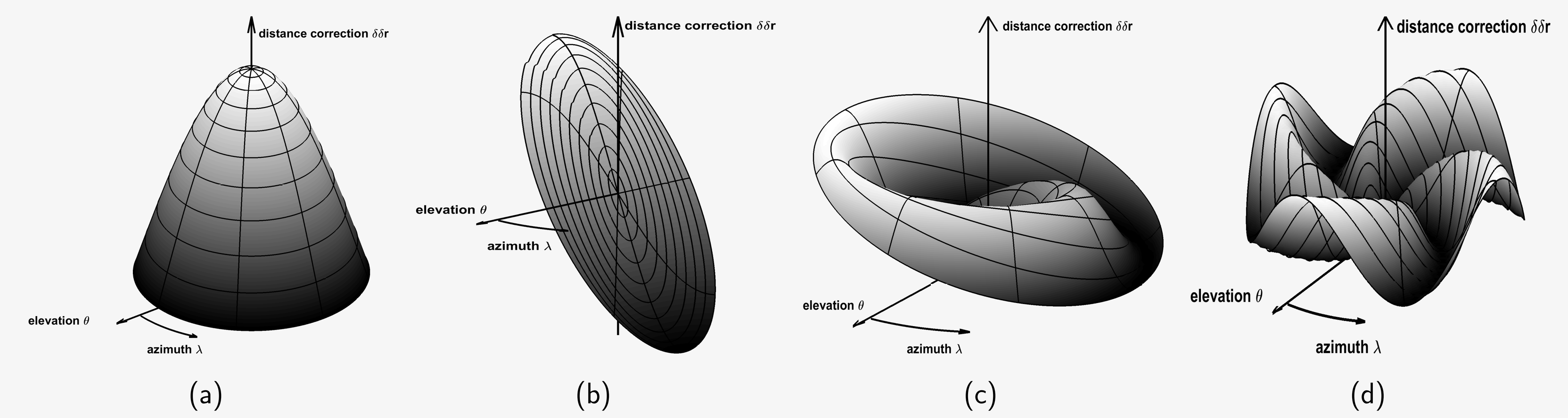

Figure 1: Generic patterns of Turnstile (a), Micro-Strip (b), 1-wire helix (c) and 4-wire helix (d)

(a)	P1:=Turnstile	$\delta\delta r(\theta,\lambda) = a \cdot cos(\theta)$	a=1cm
(b)	P2:=Micro-Strip	$\delta\delta r(\theta,\lambda) = a \cdot sin(\theta) \cdot cos(\lambda - a_0)$	a=1cm
(c)	P3:=1-wire helix	$\delta\delta r(\theta,\lambda) = a \cdot sin(\theta) + d \cdot sin(\theta) \cdot cos(\lambda - 4\theta - 1a_0)$	a=d=0.5cm
(d)	P{4/5}:=4-wire helix	$\delta\delta r(\theta,\lambda) = a \cdot sin(\theta) + d \cdot sin(\theta) \cdot cos(4\lambda - 4\theta - 4a_0)$	a={0.5cm/2cm}, d=0.5cm

2. The relationship between the Phase Center Corrections (PCC) and the positioning parameters is given by:

$$\delta \mathbf{x} = (\mathbf{A}^T\mathbf{P}\mathbf{A})^{-1}\mathbf{A}^T\mathbf{P}\delta\delta r(\theta,\lambda)$$

with: **A**: design matrix; **P**: weight matrix; $\boldsymbol{\delta\delta r(\theta,\lambda)}$: Phase Centre Variations (PCV); $\boldsymbol{\theta}$: zenith angle; $\boldsymbol{\lambda}$: azimuth angle

Given the amplitudes (a,d) the formula for δx yields the theoretical impact on the positioning parameters. Figure 2 shows in the black bars the reference values obtained by the model.

Methodology of the PPP analysis

- The analysis is based on 24 hour observations with a cut-off angle at 3 degree of a choke ring antenna installed on a pillar of the laboratory network of Institut für Erdmessung (IfE), 52 °23'N, 9 °42'E.
- First a PPP solution is processed with the original absolute PCV of the antenna.
- Then the original pattern is manipulated adding the generic patterns on L1/L2 (see Figure 1).
- The differences of subsequent PPP solutions show the relative impact on the coordinates, clock error, tropospheric delay as well as ambiguities caused by the generic patterns.
- The impact is analysed with different software packages: Bernese GNSS Software 5.2, GPS Toolkit, CSRS-PPP (NRCan), Toolbox of IfE and RTKLib 2.4.2; only exemplary results from the first three packages are shown.
- In addition Bernese processing is carried out with weighted ($cos\theta$) and equally weighted observations as well as different tropospheric mapping functions in order to study their impact.

Impact of generic PCC in different software packages

- Assignment of the bars in figure 2: **1**:Turnstile; **2-8**:Micro Strip with orientations a_0 from 0° to 30°; **9**:1-wire helix; **10**:4-wire helix; **11**:4-wire helix with higher amplitude

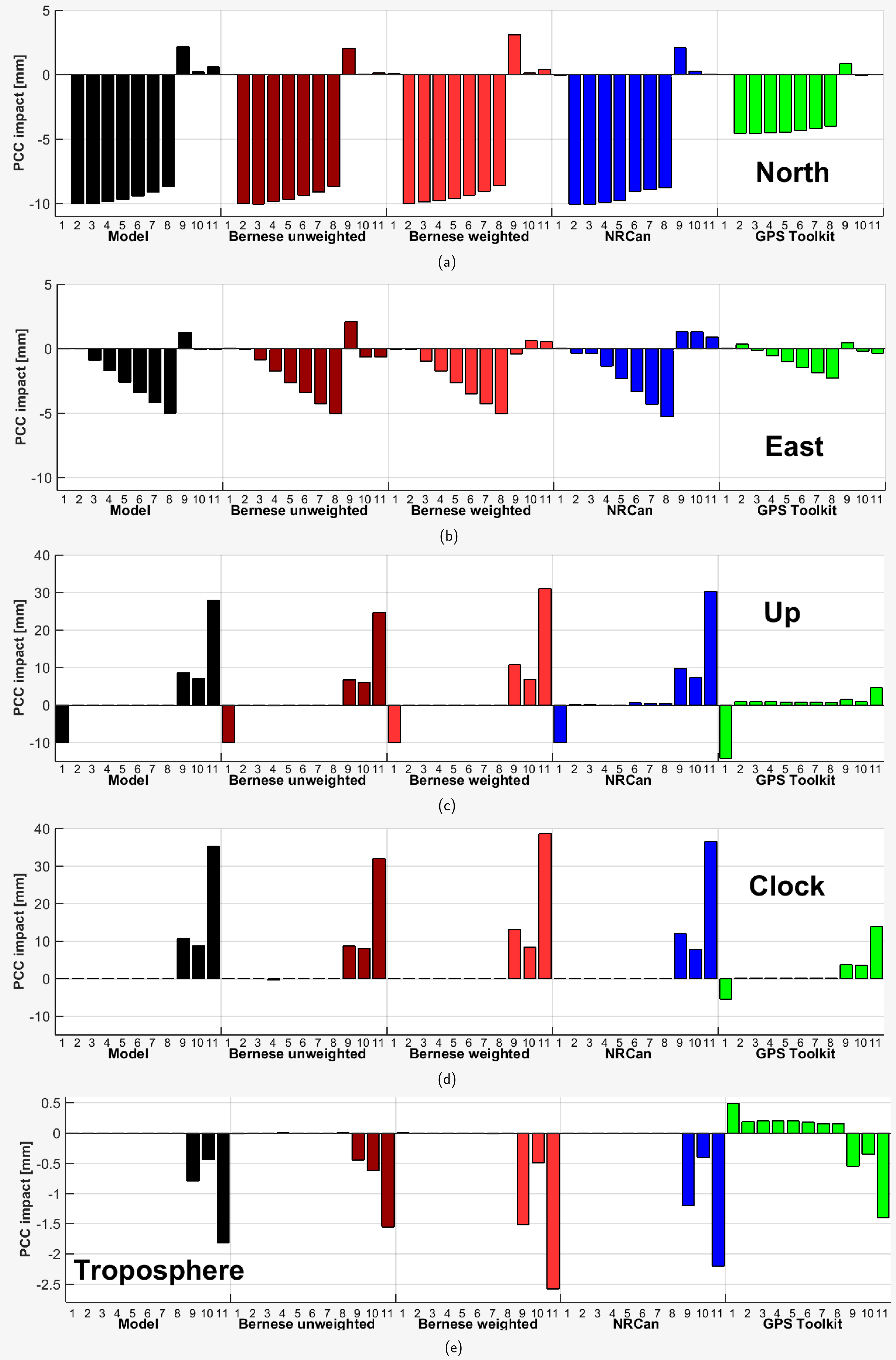

Figure 2: Differences between the solutions obtained with different software packages.

Findings

- Simple patterns Turnstile (a), Micro Strip (b)
  - As expected pattern a (bar 1) affects only the height. Pattern b (bars 2-8) only affects the horizontal component.
  - All software packages agree at the sub-mm level and w.r.t. the model solution (except GPS Toolkit).
  - The magnitude in the position domain equals the amplitude (10mm) in the observation domain.
  - The observation weighting has no impact.
- Complex patterns 1-wire helix (c), 4-wire helix (d)
  - All parameters are affected (bar 9-11).
  - The elevation depending observation weighting increases the magnitude of the parameter variations and the impact of asymmetries in the satellite sky distribution.
  - The different software solutions vary at some-mm level, however below the PPP accuracy.
  - Model values predict the overall behaviour well, however values are smaller than from observations.
  - The float ambiguities significantly change under different patterns (not shown here).
  - The mean receiver clock parameter is the most affected parameter with variations of up to 39 mm.
  - The magnitude for Up and Clock can be larger than the maximum amplitude of the pattern (here: 10mm for P{3,4}, 25mm for P5).

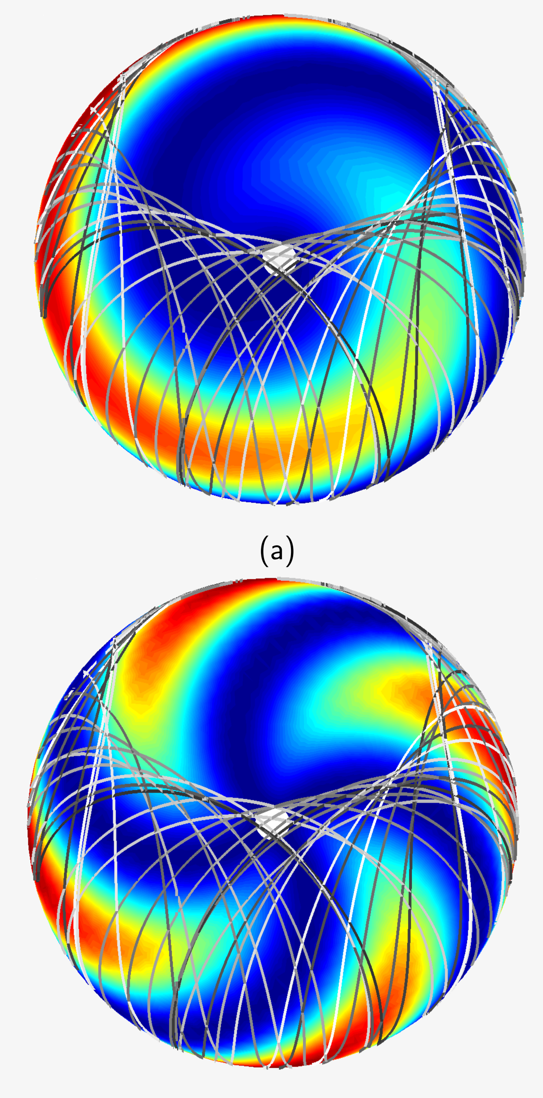

Figure 3: Sampling of generic PCC of 1-wire helix P3 (a) and 4-wire helix P4 (b) with satellite sky distribution.

Conclusions

- Theoretical model gives valuable qualitative information on the impact of PCC pattern.
- Further improvements are needed for a quantitative comparison
  - introducing ambiguity terms.
  - considering the inhomogeneity of the satellite distribution.
- All estimated parameters should be studied, including clock, troposphere and ambiguities.

Acknowledgement

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References

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