*Review*

Title: Atmospheric polarimetric effects on GNSS Radio Occultations: the ROHP-PAZ field campaign

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This paper describes an experiment done in preparation for a satellite mission that itself is a proof-of-concept for detecting precipitation using GNSS limb sounding. The observation principle is that water and other atmospheric meteors induce a polarization on GNSS signals traversing the atmosphere. With polarization-sensitive antennas, it is expected that precipitation events in the GNSS ray-path should be detectible in GNSS radio occultation geometry, GNSS RO being a new yet significantly advanced field in remote sensing of the atmosphere. The space mission will be PAZ; this paper is a field campaign with a GPS receiver placed on a mountaintop to investigate the viability of the method in situ before PAZ is deployed. The mountaintop receiver tracked 5 GPS satellites over the course of the course of approximately a half year in 2014. Significant signal processing was undertaken to eliminate the effects of ill-determined total phase and local multipath in signal propagation to the best of the authors' capability. After "correcting" the data, limb soundings whose differential phase—representing the difference in phase between horizontal and vertical polarizations—are outliers, are considered as influenced by precipitation. Simulations of differential phase based on water meteors underestimate the observed differential phase for these soundings. Simulations of differential phase with ice and snow in addition to water meteors are more consistent with observations than simulations with water meteors only.

The manuscript is in need of major clarification and possibly a large effort in revised data analysis. While there may or may not be enough detail presented to recreate the data analysis, the manuscript is lacking in justification for some of the steps taken. Moreover, the authors possibly commit a serious error in their interpretation of their statistical analysis.

- Paragraph, lines 10–23 of p.18749: The authors state that only 5 GPS satellites fall within the occultation antenna pattern. Why does this come about? How many times daily for each satellite? Are these both rising and setting satellite trajectories, or just setting trajectories? What do the trajectories for each GPS satellite look like in elevation-azimuth coordinates? Where are the multipath sources in this space?
- Equation 1: In the presence of "bi-refraction" (my term), do the GPS rays follow the same path through the atmosphere? Would path separation lead to an amplification or diminution of phase differential?
- Line 25ff, p.18751: Where does the "initial measurement" take place? It was previously stated that tracking took place between 0º and 20º elevation. (Hopefully the receiver actually tracked into negative elevations.) How long are the tracking arcs typically? Shouldn't it be possible to get a pseudo-range without L2 inasmuch as the receiver was able to track L1/CA and the ionospheric influence is very much the same for both polarizations as argued in section 2.3? I can imagine many methods one might use to establish $K^H - K^V$ absolutely and not have to subtract a profile mean $\Delta\Phi$.
- p.18753: Twice the term "homogenize" is used to describe to different steps in data processing. What does this term mean? If a data segment is "homogenized" once, why

must it be “homogenized” a second time? The authors should decide whether to spell the term “homogenize” (l.1) or “homogenise” (l.24).

- Section 2.2: The authors use the term “multipath” where the radio occultation community customarily uses the term “local multipath”. Isn’t it possible that the atmospheric boundary layer also induces multipath? That would be “atmospheric” multipath.
- Line 27, p.18753: The average of all arcs for each GPS satellite respectively can be expected to give the observational response to the mean environmental conditions. The authors have made differential phase a function of satellite elevation but not of satellite azimuth. Do all the trajectories for a given satellite follow the same elevation-azimuth track? If not, then a component of the standard deviation is due to changes in geometry (different azimuth track). Otherwise, the standard deviation represents the dynamic range of the observations due to changes in environmental conditions and is not error in the multipath signal, which is implied in the manuscript. Error in the multipath signal is better described by the standard error, or the standard deviation divided by the square-root of the number of arcs considered in the mean.
- Lines 25-26, p.18754: Offer some support for this statement.
- Line 5, p.18756: What does it mean to “properly collocate our observations”?
- Lines 1-6, p.18758: It is not clear in the text what the standard deviation is. I infer that it is the root-mean-square of the “corrected” phase differential by satellite $\Delta\Phi_{\mathrm{day}}^{\mathrm{PRN}}(\epsilon)\big|_{\mathrm{corrected}}$ for non-moist conditions only. What is responsible for this quantity? The authors imply that it is measurement error, but no estimate of measurement precision is given in this manuscript. I find it rather unlikely that measurement error is responsible for this standard deviation. Rather, there are intermittent structures in the non-moist environment that induce polarization. What are they? Is the atmosphere ever truly devoid of structures that induce polarization on GPS signals?
- Table 2: The authors conclude that atmospheric water meteors induce additional polarization to the GPS signal because the variance of $\Delta\Phi_{\mathrm{day}}^{\mathrm{PRN}}(\epsilon)\big|_{\mathrm{corrected}}$ for rainy days is greater than the same for dry days. The authors should use the statistical F-test to establish a confidence level. Such a test determines whether or not two estimates of variance, each determined from a limited but different ensemble, are drawn from the same pool or not. It is ideally suited to this problem.
- Generally: What is the difference between “melting ice” and “graupel”?
- Equation 6 is incorrect. It should instead be

$$\Delta\Phi_{\mathrm{S}}(\epsilon) = \Delta\Phi(\epsilon) - \left(\Delta\Phi(\epsilon_{\mathrm{min}}) + 2\sigma_{\text{no-rain}}(\epsilon_{\mathrm{min}})\right)$$

- Lines 21-23, p.18758: This analysis is odd. What is the statistical significance of this finding? If 82% of $A_\Phi > 0$ cases are rainy, are the other 18% of such cases dry? How many of the rainy cases had $A_\Phi > 0$? How many of the dry cases had $A_\Phi > 0$? Is this condition a strong test for the presence of rain?
- Figure 9 is illegible, as is Figure 11.
- Regarding the ray-path simulator: Has it been validated against any data? Has there ever been a successful simulation of differential phase based on ground-truth atmospheric parameters, even in dry conditions?

- Lines 13-14, p.18763: “Also, the model has been applied with the same…” I do not understand this sentence. What relation? What is an event? What are the conditions?

I would be interested in further review after these questions are answered.