POLARIMETRIC RADIO-OCCULTATIONS FOR RAIN DETECTION: THE ROHP-PAZ MISSION AND ITS GROUND CAMPAIGN

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ABSTRACT

This poster presents the Radio Occultations and Heavy Precipitation (ROHP) experiment aboard the Spanish Low Earth Orbiter (LEO) for Earth Observation: PAZ. This mission will run for the first time a double polarization GNSS -RO experiment to asses its capabilities for sensing heavy rain events.
A theoretical analysis of the concept and the L-band GNSS polarimetric observables to be used are presented. Also, the results of an evaluation of these observables sensitivity to moderate to heavy precipitation events are shown. According to this study, intense rain events will induce polarimetric features above the detectability level.
Prior to the launch of the satellite, a ground campaign is being conducted with the goal of identify and understand all the factors that might affect the polarimetric observables. The first results are presented. These results show how not only the precipitation, but many other factors are affecting the signal, which makes the polarimetric observables more interesting than was previously thought.

1. THE ROHP-PAZ MISSION AND ITS POTENTIAL IMPACT

The ROHP-PAZ is a mission of opportunity. The Spanish Earth Observation PAZ satellite, planned to be launched in Q4 2014, was initially designed to carry a Synthetic Radar Aperture (SAR) as primary and sole scientific payload. It included an IGOR+ advanced Global Navigation Satellite System (GNSS) receiver for precise orbit determination. The design of this particular GNSS receiver allows the tracking of occulting signals, that is, signals transmitted by navigation satellites setting below the horizon of the Earth (or rising above it). The Spanish Ministry for Science and Innovation (MICINN) approved a proposal to modify the original plans of PAZ, by including a polarimetric GNSS Radio-Occultation (RO) payload, the ROHP-PAZ experiment.

Coincident thermodynamic and precipitation information with high vertical resolution within regions with thick clouds will help understanding the thermodynamic conditions underlying intense precipitation, which is relevant because these events remain poorly predicted with the current climate and weather model parametrizations.
A better understanding of the thermodynamics of heavy precipitation events is necessary towards improving climate models and quantifying the impact of climate variability on precipitation. The particular advantage of GNSS polarimetric RO is that their signals are in the L-band of the microwave spectrum which, unlike infrared or higher microwave frequency band sensing technologies, is little influenced by clouds, not even by the thick clouds that are typically associated with heavy precipitation.

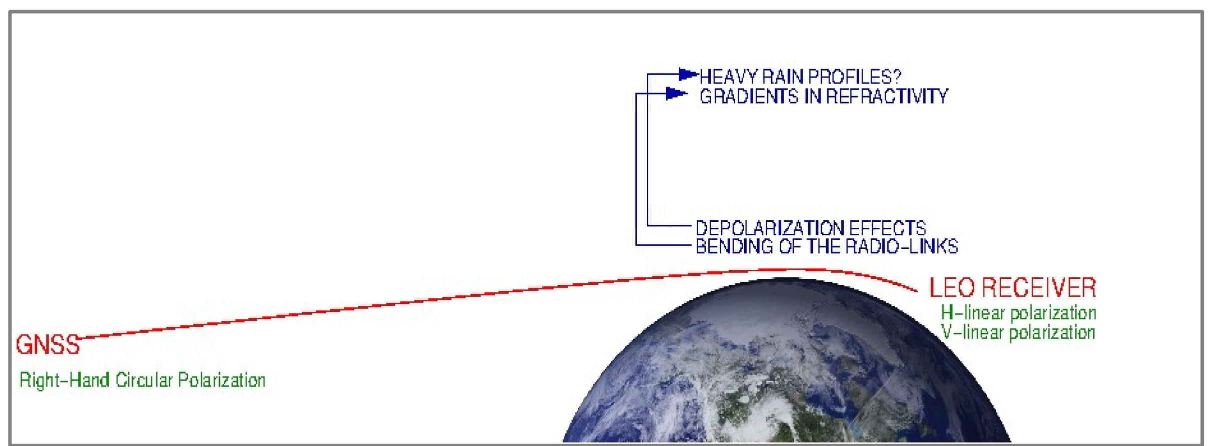
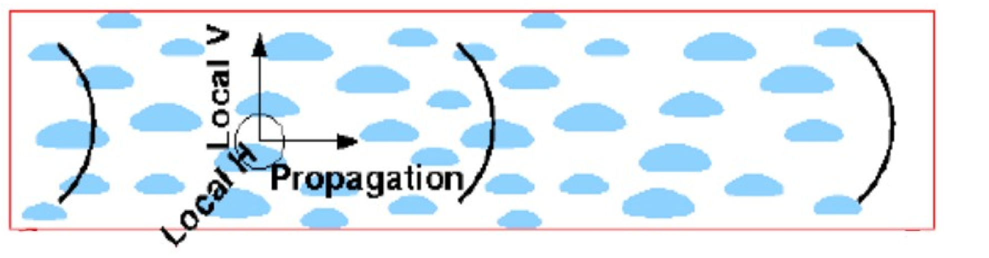


Figure 1. *Polarimetric-RO concept: heavy rain and other atmospheric effects (e.g. cloud ice) induce polarimetric effects.*

2. POLARIMETRIC RADIO OCCULTATIONS

ROHP-PAZ is a proof-of-concept experiment. For the first time ever, GNSS RO measurements will be taken at two polarizations, to explore the potential capabilities of polarimetric radio occultation from space for detecting and quantifying heavy precipitation events and other de-polarizing atmospheric effects (e.g. cloud ice).

- Tangential propagation: asymmetric drops induce difference phase delay at H and V polarizations.



- Selected observable: **phase shift between the received H and V polarized fields**

$$\Delta\Phi = \Phi_H - \Phi_V = \Delta\Phi^{\text{atm}} + \Delta\Phi^{\text{ins}}$$

$$\Delta\Phi^{\text{atm}} = \int_L K_{dp}(l)dl$$

- Rain's specific differential phase: K_{dp} (Polarimetric phase shift induced by rain along 1 km propagation, in mm-shift / km-rain)

$$K_{dp} = \frac{\lambda^2}{2\pi}\int_L \Re\{f_H(D) - f_V(D)\}N(D)dD$$

Where λ is the GNSS carrier wavelength, f_H and f_V are the forward scattering amplitudes, D is the equivol. drop diameter and $N(D)$ is the drop size distribution.

rohp-PAZ

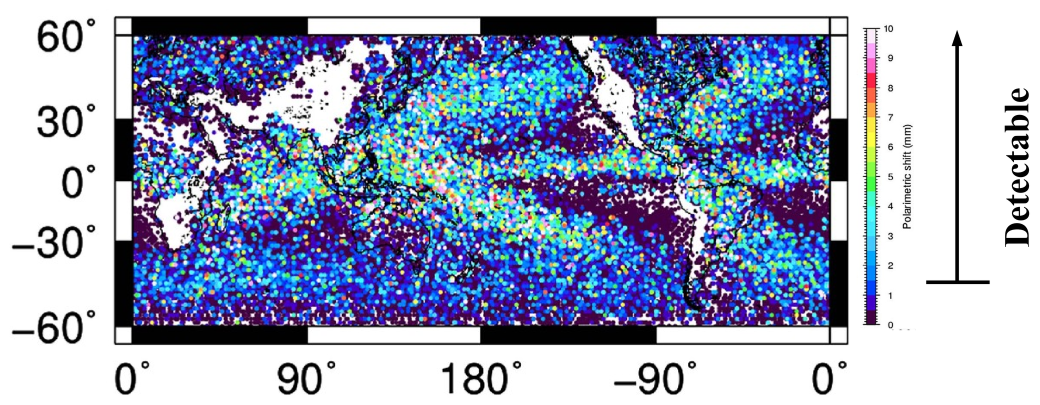
More information and data acces:
http://www.ice.csic.es/paz

3. SENSITIVITY ANALYSIS (*Cardellach et al. 2014*)

- Expected precision of PAZ's IGOR receiver: $\sigma_\Phi = \frac{\lambda}{2\pi}\,\text{atan}\left(\frac{1}{SNR}\right)$ $[mm]$
- 420,000 COSMIC RO events collocated with TRMM precipitation mission (25km x 25km x 3hour): ~28% of events cross rain => ~120,000 RO cases.

	COSMIC (mm)	COSMIC-3dB (mm)	H (km)
1-port σ_ϕ	0.1	0.15	$\geq$10
	0.3	0.35	5-10
	0.6	0.8	2-5
	0.7	1	<2
Polarimetric $\sigma_{\Delta\phi}$	0.1	0.2	$\geq$10
	0.4	0.5	5-10
	0.9	1.1	2-5
	1	1.4	<2

- On the conservative side, we then expect that PAZ will be able to measure **polarimetric phase-shift better than 1.5 mm delay** (2.8 degrees pol. phase-shift) in 1 second integration (1 Hz).



Precipitation intensity $< R >$:	Percentage of detectable cases
$>$ 0.5 mm/h	24 %
$>$ 1 mm/h	41 %
$>$ 2 mm/h	72 %
$>$ 3 mm/h	83 %
$>$ 4 mm/h	88 %
$>$ 5 mm/h	90 %
$>$ 10 mm/h	95 %

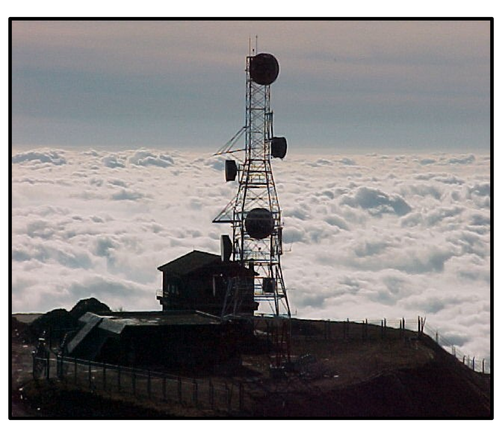
Figure 2. *(top) COSMIC – TRMM collocations geolocalizated. (bottom) Statistical results for the collocation. More than the 90% of the events with a precipitation intensity above 10 mm/h will be detectable.*

4. GROUND CAMPAIGN: TOP MOUNTAIN BASED RADIO OCCULTATIONS

Aim: To identify and understand the factors that affect the polarimetric RO signal before the launch of the satellite, by collecting heavy rain together with free-rain data from ground.

The selected site is the top of a 1700m. mountain peak (Puigsesolles). The site has clear views over the horizon to the south (east to west) direction, an area in which intense precipitation tends to occur several times per year.

Experimental set-up:
- PAZ's engineering model antenna
- JAVAD commercial receiver (provided by the German research center for geosciences GFZ), locked inside a shelter



First results

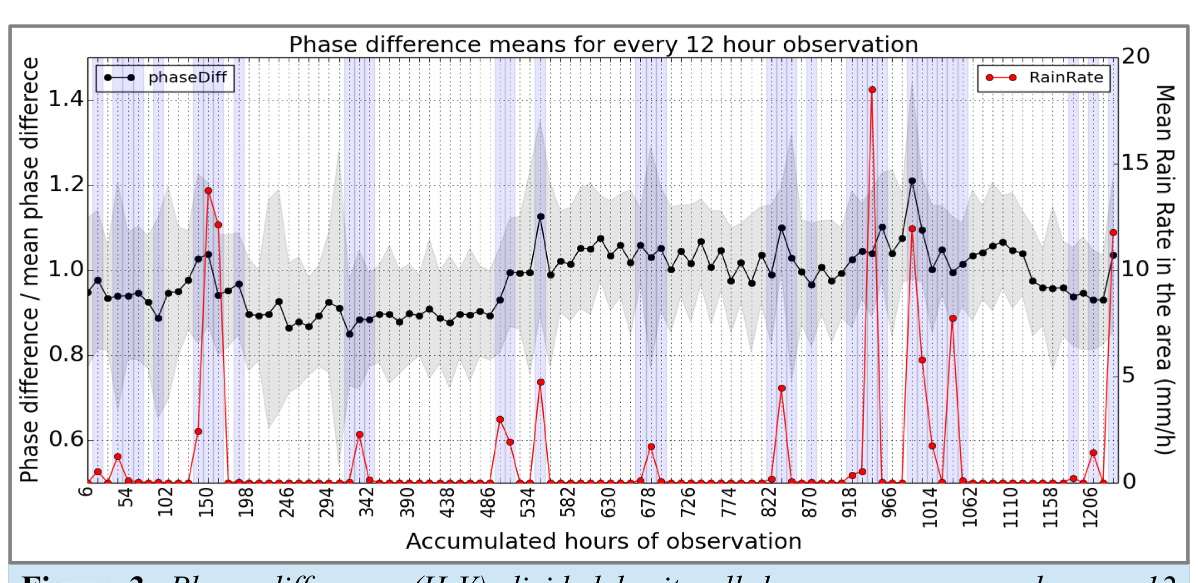


Figure 3. *Phase difference (H-V) divided by its all-days-mean, averaged every 12 hours. Standard deviation in gray. Rainy periods shaded in blue. The periods when the SNR drops significantly are not taken into account.*

- Good correlation between local phase difference positive peaks and rain events.
- Variability in the phase difference that we do not understand yet.
- Rain data taken from 5 ground stations placed within 20 km around the observation site.

Although the **impact of the rain in the phase difference is noticeable**, further analysis is needed to understand the false negatives as well as what else is affecting the signal.

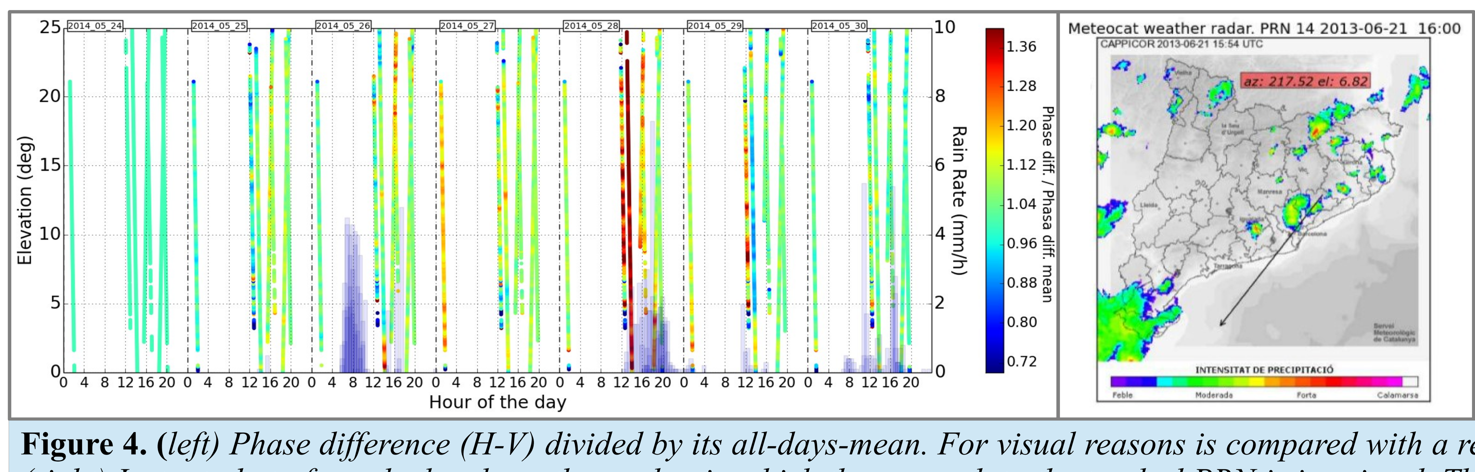


Figure 4. (*left) Phase difference (H-V) divided by its all-days-mean. For visual reasons is compared with a reference day (first one). (right) Instant photo from the local weather radar, in which the ray-path to the tracked PRN is imprinted. The image shows how the rain can be present close to the site and still not affect the signal. This could explain false negatives cases (close rain but no detection). Weather radar data with high temporal resolution are fundamental to better understand the signal.*

5. CONCLUSIONS

- ROHP-PAZ will test for the first time the polarimetric RO concept from space.
- Selected polarimetric observable: phase-delay difference between H and V linear polarizations.
- The expected instrumental precision is better than 1.5 mm (1 Hz) at the surface level, improving with altitude.
- COSMIC RO – TRMM collocation: 90% of the events with mean rain rate above 5 mm/h should induce detectable polarimetric phase shifts.

- The first results from the ground campaign suggest that rain is affecting the polarimetric signal, as expected.
- We are requesting more data from meteorological agencies to confirm the current interpretations (e.g: local weather radar 3D data)
- Beside rain, other effects are detected by the signal. Variability among days, strong multipath, and long-term trends still need to be understood.

ONGOING AND FUTURE WORK

- Further analysis of ground campaign data with new and better weather data sets.
- Testing other atmospheric effects that might induce polarimetric phase-delays (e.g. cloud ice).
- Developing of new techniques to improve the along-ray resolution.

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