RADIO OCCULTATION AND HEAVY PRECIPITATION ABROAD THE PAZ ORBITER (ROHP-PAZ) AND ITS GROUND CAMPAIGN

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1. THE ROHP-PAZ MISSION AND ITS POTENTIAL IMPACT

The ROHP-PAZ is a mission of opportunity. The Spanish Earth Observation PAZ satellite, that will be be launched in Q1 2015, 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 augment 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 to improve 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.

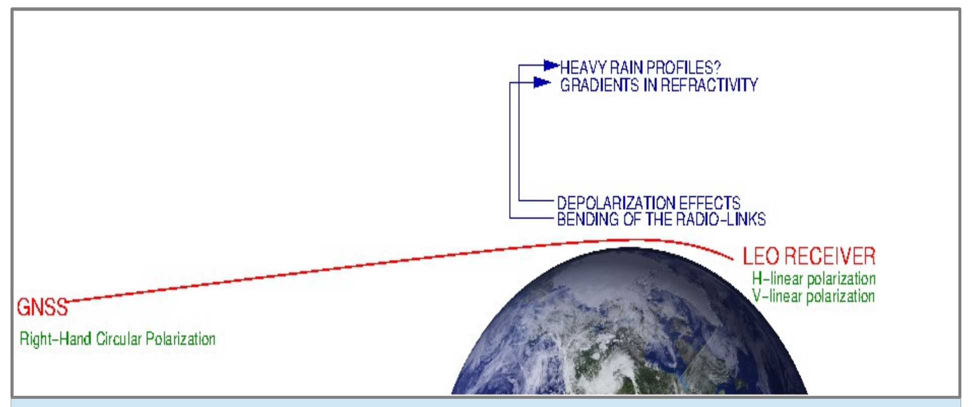
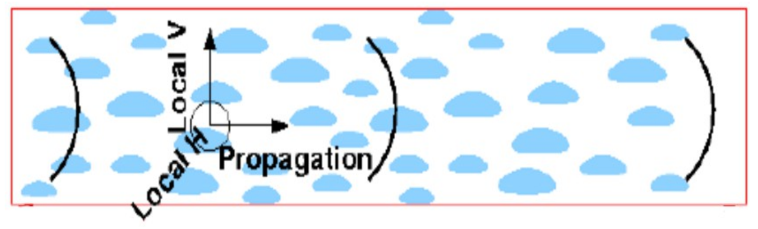


Figure 1. *Polarimetric-RO concept: heavy rain and other atmospheric effects (e.g. cloud ice) induce polarimetric effects.*

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)

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

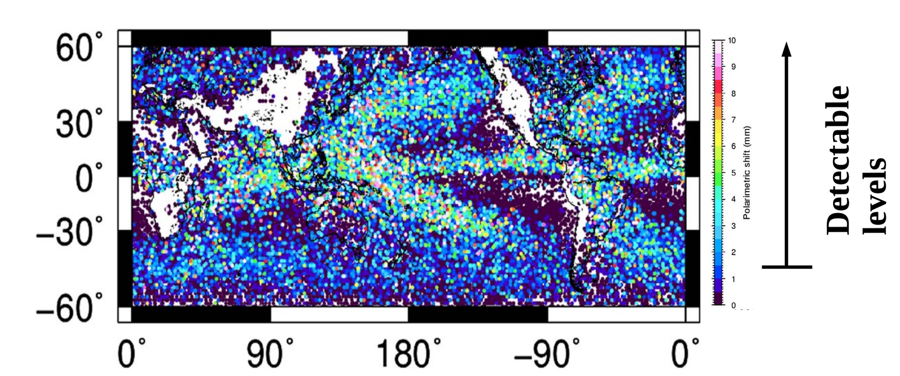
Where λ is the GNSS carrier wavelength, f_H and f_V are the forward scattering amplitudes, D is the equivol. drop diameter and $N(D)$ is the drop size distribution.

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	≥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	≥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 to 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

OBJECTIVES

To identify and understand the factors that affect the polarimetric RO signal before the launch of the satellite, by collecting heavy rain data 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

DATA ANALYSIS

From the data provided by our receiver, we have been able to extract the relative phase delay between the H and V channels. To do so, we have subtracted the absolute phase difference mean from each observation, in order to remove the difference in the initial phase of each channel (phase ambiguity).

Data were collected between March 21st and October 10th, with some periods in between in which the experiment was stopped. During this period, there were approximately 100 days without rain, ~ 20 with rain events and ~ 3 days with heavy rain events.

After the first data treatment, we have computed the mean and the corresponding standard deviation for each PRN for all the days without rain. We show in **Figure 3** the 2 and 3-sigma contours (blue and gray respectively) around its 0 mean, together with 5 observations during rain events.

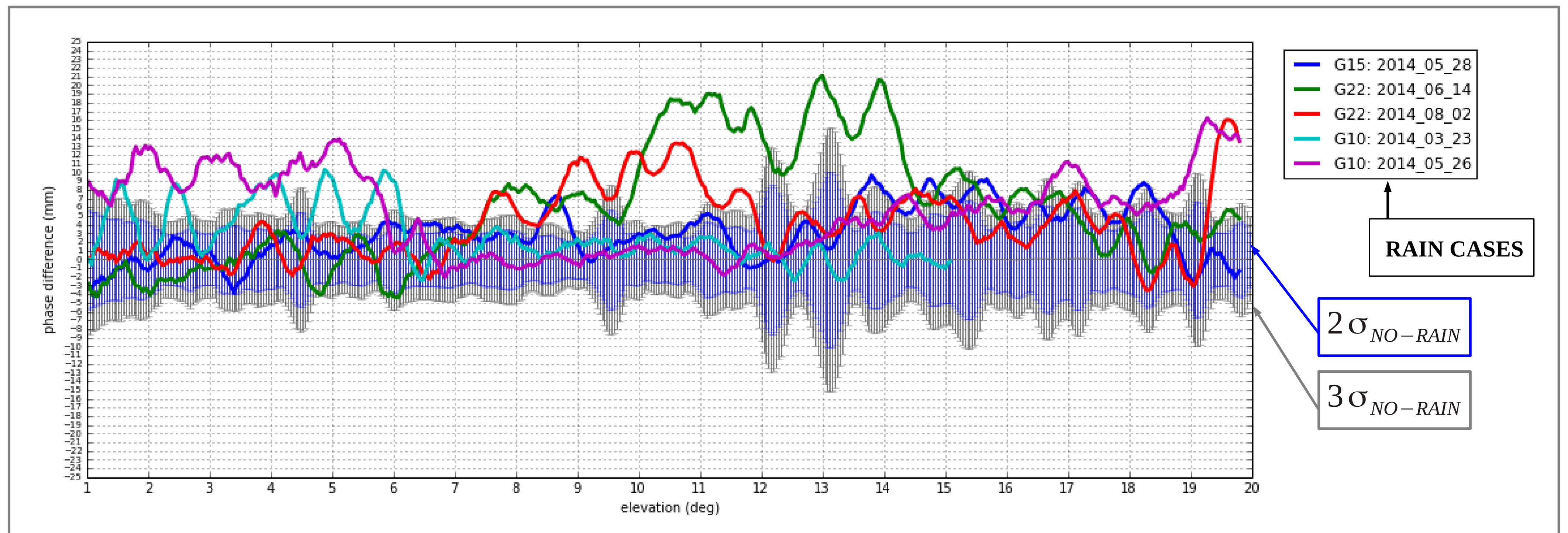


Figure 3. *Phase difference (H – V) in mm for 5 different observations. These observations are coincident in time with rain events. The blue and gray shadowed areas show the 2 and 3-sigma contours around the mean of all the observations during days without rain.*

PRELIMINARY RESULTS

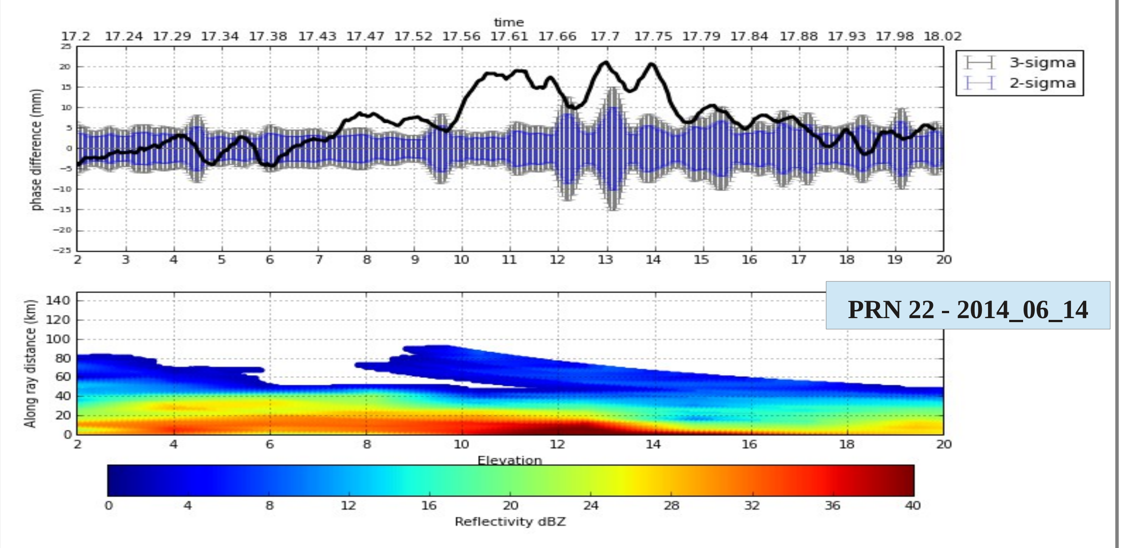


Figure 4. *(top) The relative phase difference as a function of elevation, with the mean and std. from Figure 1, for the PRN 22 on June 14th. (bottom) The RO rays collocated with the meteorological radar data, where the y axis represents the distance along each ray, and the color represents the Reflectivity (dBZ).*

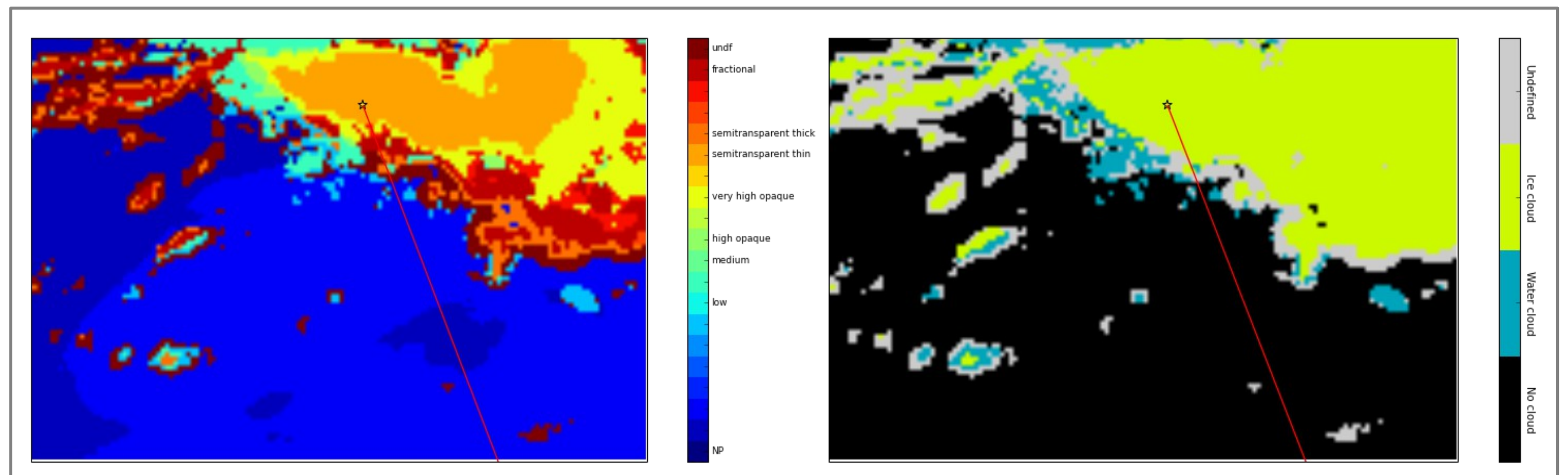


Figure 5. *Products from the Support to Nowcasting and Very Short Range Forecasting (SAF NWC), for June 14th at 17:45 UTC and for the observation area surroundings. (left) Cloud type product. (right) Cloud Phase product. The red line shows the PRN 22 direction, and the star shows the observation site.*

- Many RO events that their rays have crossed heavy rain cells show phase difference peaks that are well above the 3-sigma level. Five cases can be seen in **Figure 3**, and a more detailed example in **Figure 4**.
- However, the magnitude of the peak is higher than expected: We can not reproduce the observations using the most common models for the Reflectivity – Rain Rate (Z – R) relationship and the forward scattering simulations.
- We are exploring other possibilities, such as ice clouds, that could also induce polarimetric phase differences.

- The *Support to Nowcasting and Very Short Range Forecasting* (SAF NWC) cloud products show **ice clouds** in the observation area for most of the explored cases.
- Forward scattering simulations (using DDScat code) require highly horizontally oriented ice crystals, and them to be very pristine to reproduce polarimetric phase shifts of this magnitude (between 10 – 20 mm).

rohp-PAZ

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

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