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Precipitation information from GNSS Polarimetric Radio Occultation observations

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For the first time ever, GNSS Radio Occultations will be collected using a two orthogonal linear polarized antenna. The objective is to measure the phase shift between the horizontal and vertical components of the incoming electro magnetic field that is induced by heavy precipitation flattened raindrops. This new concept is called Polarimetric Radio Occultations (Pol-RO), and will be tested from space with the PAZ satellite, to be launched in January 2018 from Vandenberg, CA. Pol-RO will provide unique products of vertical precipitation information along with thermodynamic profiles (e.g. temperature, moisture, etc.).

Before the launch, a series of studies have been conducted in order to assess the retrieval of precipitation information from the polarimetric observations. These studies have been based on coincident observations from the COSMIC RO satellite constellation, and TRMM and GPM missions.

Complete end–to–end simulations have been performed, where information from the ionosphere, the Earth magnetic field, the along ray precipitation, the impurities at emission, and the effects introduced by the receiver have been taken into account.

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Pol RO concept

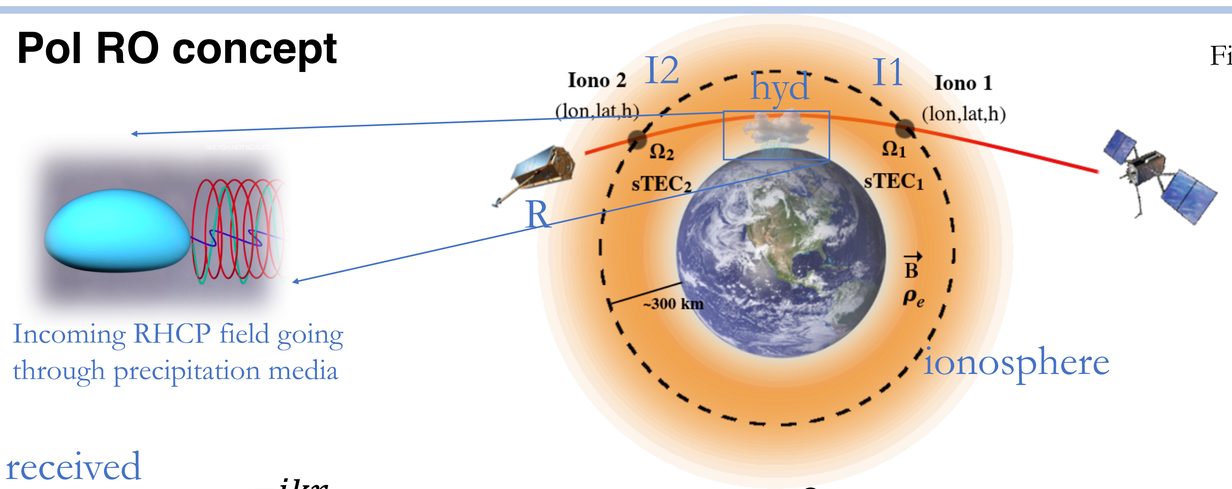

Figure 1: Schematic representation of a Pol-RO event, with all the involved items: GPS transmitting satellite, ionosphere, precipitation and PAZ-like receiver. I1 and I2 represent the ionosphere portion before and after crossing precipitation.

received

$$\boldsymbol{E} = e^{-i\phi}\frac{e^{-ikr}}{r}\underbrace{\begin{bmatrix}1 & 0\\ 0 & e^{i\phi_{arc}}\end{bmatrix}}_{\text{receiver}}\underbrace{\begin{bmatrix}a_{hh} & 0\\ 0 & a_{vv}e^{i\phi_{ant}}\end{bmatrix}}_{\text{antenna}}\underbrace{R(\Omega_2)}_{\text{ionosphere}}\underbrace{\begin{bmatrix}e^{-ik_h} & 0\\ 0 & e^{-ik_v}\end{bmatrix}}_{\text{rain hydrometeors}}\underbrace{R(\Omega_1)}_{\text{ionosphere}}\boldsymbol{E}^{i}_{\{\hat{e}_h,\hat{e}_v\}}$$

transmission

propagation

Aim: to isolate the hydrometeor contribution

Simulation of all effects inducing a polarimetric phase shift using realistic data from the Tropical Rainfall Measurement mission (TRMM), the Global Precipitation Mission (GPM), and International Geomagnetic Reference Field (IGRF) and International Reference Ionosphere (IRI).

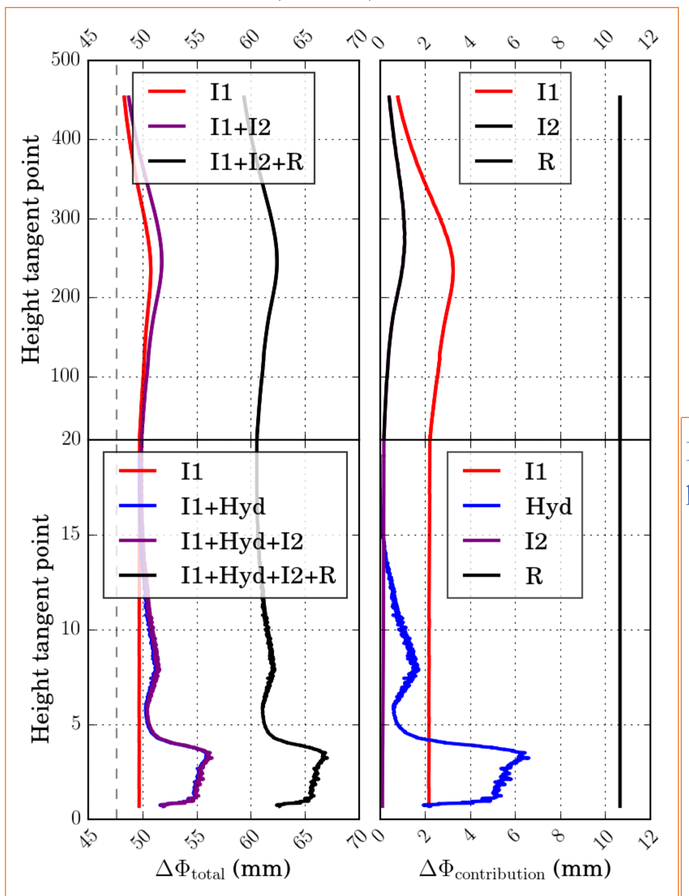

Figure 2: Phase shift between H and V components induced by each individual layer, identified in Fig. 1.

The emitted EM field is not perfect RHCP (up to a 10% of orthogonal component is expected). Then, the Faraday rotation (Ω) induces a phase shift between the H and V components of the EM field. Can be expressed as a rotation matrix $R(\Omega)$.

Realistic precipitation information is obtained with co-locations between COSMIC RO, and TRMM and GPM. Then, the particle size distribution is used to simulate the differential phase shift induced by hydrometeors, using the T-matrix code to compute the scattering amplitude matrix (S).

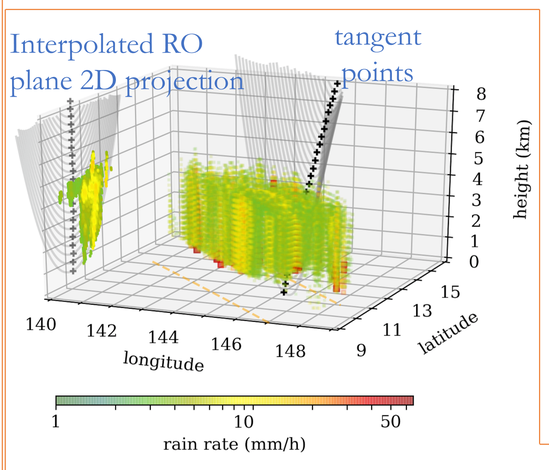

Figure 3: Example of a 3-Dimensional co-location between a RO and the precipitation structure measured by TRMM satellite. The set of RO rays define the RO plane; the precipitation information is interpolated into this plane.

$$K_{dp} = \frac{2\pi}{k_0}\int Re\{S_h - S_v\}N(D)dD$$

$$\Delta\Phi_{hyd} = \int_L K_{dp}dl$$

$S_{h,v}$: co-polar components of the scattering amplitude matrix
N(D): drop size distribution as a function of drop diameter

Isolation of the hydrometeor contribution to $\Delta\Phi$ is achieved removing the *background*, defined as the extrapolation of $\Delta\Phi_{total}$ between 20 and 70 km to the surface level.

From Pol-RO observable to precipitation information

Once the precipitation contribution is isolated, each observation is compared against the Look Up Tables (LUT) to infer which is the most probable mean rain rate that the observation (at each height and for each $\Delta\Phi_{hyd}$) would have crossed, according to the simulated statistics.

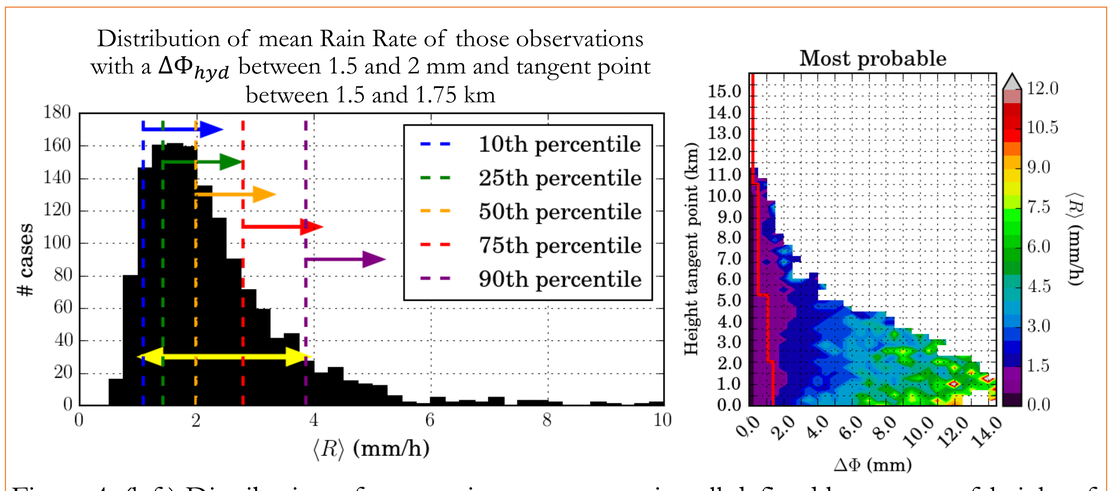

Figure 4: (left) Distribution of mean rain rate at a certain cell defined by a range of height of the tangent point and the observed $\Delta\Phi_{hyd}$. (right) LUT built using the most probable mean rain rates for every cell. To build the LUTs, artificial co-located profiles have been used to represent all the geographic locations and account for statistical significant number of data.

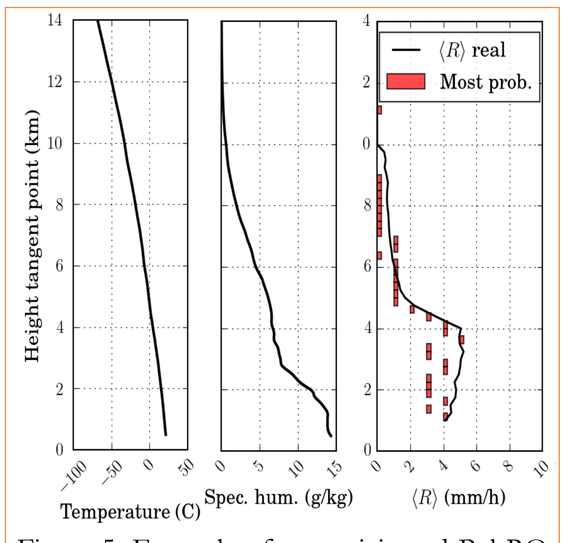

Figure 5: Example of an anticipated Pol-RO product. From left to right, vertical temperature profile, specific humidity profile and most probable mean rain rate.

References: Cardellach et al., 2017, QJRMS doi: 10.1002/qj.3161; Cardellach et al., 2014, TGRS doi: 10.1109/TGRS.2014.2320309;