POLARIMETRIC GNSS RADIO-OCCULTATIONS FOR HEAVY RAIN DETECTION

E. Cardellach[1], *A. Rius*[1], *F. Cerezo*[2], *M.A. García-Primo*[2], *M. de la Torre-Juárez*[3], *L. Cucurull*[4], *D. Ector*[4]

[1]Institut de Ciències de l'Espai, ICE/CSIC-IEEC, Barcelona, Spain
[2] HISDESAT, Madrid, Spain
[3] Jet Propulsion Laboratory (Caltech/NASA), Pasadena, CA, USA
[4] NOAA, Washington D.C, USA

The Spanish Ministry for Science and Innovation (MICINN) has recently approved a proposal to include a polarimetric Global Navigation Satellite System (GNSS) Radio-Occultation (RO) payload on board of the Spanish Earth Observation satellite PAZ. The PAZ mission, planned to be launched in Spring 2012, was initially designed to carry a Synthetic Radar Aperture (SAR) as primary and sole payload, and included an IGOR+ advanced Global Positioning System (GPS) receiver and corresponding antennas for precise orbit determination. The design and software of this GPS receiver allows the tracking of occulting signals, that is: signals transmitted by GPS satellites setting below the horizon of the Earth (or rising above it). The Radio Occultation technique originated in Planetary sciences for the study of other Planets' atmospheres, and measures the bending caused by the atmospheric refractivity gradients on the propagation of the radio link. This bending can be used to infer vertical radio-refractivity profiles from which ionospheric total electron content can be inferred as well as thermodynamic variables such as atmospheric pressure, temperature, water vapor pressure from the stratosphere down to the boundary layer with a vertical resolution close to 300 m. RO thermodynamical profiles are assimilated operationally into several global numerical weather prediction models (NWPM) [1]. Latest results at NCEP show that ROs improve anomaly correlation scores by $\sim$8hr starting at day 4 and increases with extended forecast range. It also helps reducing model biases. ECMWF compared the impact of 24 operational observation systems, GPS-RO impact resulting among the top-five [2]. The use of GPS RO has been shown to significantly improve models forecast skill, and is a key component of the operational observing system [3].

Missions currently providing this information are the constellation of 6 Low-Earth Orbiters (Taiwan/USA FORMOSAT-3/COSMIC mission), and the EUMETSAT's GRAS instrument aboard the METOP satellite, in the form of globally distributed profiles. However, the number of RO profiles risks to dramatically drop after the decommissioning of the COSMIC constellation. With a mission life-expectancy of 5 years, COSMIC is expected to degrade by 2011. PAZ is planned to be launched when this happens and before a possible new RO constellation is deployed (not approved yet).

Although the frequency of the signals for the Global Positioning System were chosen such that they would suffer low attenuation by clouds or rain and enable all-weather operations, the de-polarization effect induced by the flattening of the heavy precipitation drops may exceed some measurable threshold. Work done for calibration and characterization of similar signals (GOES 11 L-band down-link at 1.5445 GHz and RHCP) have found strong correlation between the de-polarization ratio and heavy rain effects, when measuring a down-link at 14° elevation angle (above the horizon) [4]. The same concept, in backscattering geometry rather than propagation, is used in the NEXRAD network of polarimetric weather radars across U.S.A, working at 3 GHz (against 1.5 for GPS-L1). The de-polarization effect increases as the propagation line aligns with the plane of the drops' flattening (usually parallel to the local horizon). The Radio-Occultation signals cross the lower troposphere tangentially, i.e. along the local horizon, which maximize the de-polarization effect. The concept is sketched in Figure 1.

RO in PAZ funded by ACI2009-1023, MICINN Spain.

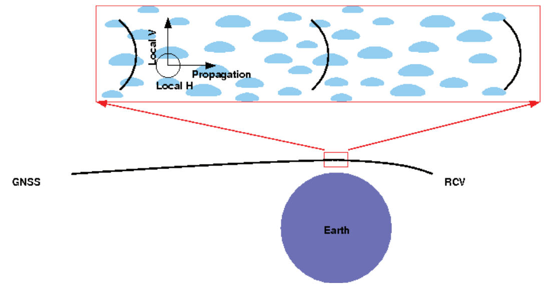

Fig. 1. Sketch of the RO-Heavy Precipitation measurement concept: at lower troposphere, the RHCP GPS signal propagates tangentially, aligned with the plane of flatness of the rain drops, situation in which the de-polarization effect is maximal. The receiver on board the PAZ mission will collect both RHCP and LHCP components.

PAZ will include RO capabilities with a new approach for the relatively small limb-oriented GPS antennas. The proposed RO antenna will use the GPS L-band Right Hand Circular Polarized (RHCP) transmitted signals to capture both co- and cross-polarized components of the GPS propagated signal for the first time in a space-based GPS receiver. This experiment will be a proof-of-concept to exploit the potential capabilities of polarimetric radio occultation towards detecting and quantifying heavy precipitation events. If successful, PAZ will provide a new application of GNSS Radio-Occultation observations by providing coincident thermodynamic and precipitation information with high vertical resolution within regions with thick clouds.

Just flagging the existence of precipitation within RO refractivity profiles will help a better understanding of the thermodynamic conditions underlying precipitation. Precipitation remains a poorly predicted event with current climate and weather model parameterizations. 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 [5, 6]. The particular advantage of GNSS RO is that their signals are in the microwave spectrum which is influenced little by clouds. A few infrared sensors, such as AIRS, can profile atmospheric temperature/humidity with high vertical resolution but cannot penetrate through the thick clouds typically associated with heavy precipitation.

To support the PAZ mission concept, analysis of non-polarimetric COSMIC RO is been performed to evaluate the possibility that de-polarization effects could be identified clearly via attenuation measurements of the RO signal, but it is unclear that they can be detected yet. In parallel, we are applying the theory of radio-wave propagation through a precipitating medium at the GPS frequencies [7, 8] to predict the rain rates to which PAZ can be sensitive. Preliminary estimates suggest that the PAZ RO experiment will require very strong de-polarization effects associated to very heavy precipitation events along long RO ray-paths. Work remains to quantify the sensitivity more precisely, The outcome of the experiment will help defining the real sensitivity of the concept, together with requirements for the optimal design of future precipitation-RO instruments.

The PAZ mission will partially overlap with the core instrument of the Global Precipitation Mission (GPM), to be launched in 2013. The timing of the PAZ RO-Heavy Precipitation concept will enable to compare RO coincident thermo-dynamical and precipitation information with the GPM mission. This synergy might also make PAZ a potential candidate to complement GPM by measuring additional aspects of precipitation processes. PAZ orbit is near-polar, which ensures dense coverage over high latitudes, one of the requirements of the GPM.

1. REFERENCES

[1] S.B. Healy, A.M. Jupp, and C. Marquardt, "Forecast impact experiment with GPS radio occultation measurements," *Geophys. Res. Lett.*, vol. 32, 2005.

[2] C. Cardinali, “Forecast sensitivity to observation (FSO) as a diagnostic tool,” Tech. Rep., ECMWF Technical Memorandum 599, Reading, UK, 2009.

[3] NRC Committee on Earth Science and Applications from Space, “A community assessment and strategy for the future, earth science and applications from space, national imperatives for the next decade and beyond,” Tech. Rep., The National Academies Press, Washington DC, USA, 2007.

[4] R. Peters, P. Woolner, and E. Ekelman, “Analytic calculation of noise power robbing, NRP, and polarization isolation degradation,” in *Proceedings of 26th International Communications Satellite Systems Conference (ICSSC)*. AIAA, June 2008.

[5] F.J. Wentz, L. Ricciardulli, K. Hilburn, and C. Mears, “How much more rain will global warming bring?,” *Science*, vol. 317, no. 5835, 2007.

[6] R.P. Allan and B.J. Soden, “Atmospheric warming and the amplification of precipitation extremes,” *Science*, vol. 321, no. 5895, pp. 1481–1484, 2008.

[7] T. S. Chu, “Microwave depolarization of an earth-space path,” *Bell Syst. Tech. J.*, vol. 59, pp. 987–1007, 1980.

[8] W.L. Flock, “Propagation effects on satellite systems for frequencies below 10 GHz,” *NASA Ref. Publ.*, vol. 1108, no. 2.