ROHP-PAZ: Polarimetric GNSS Radio Occultations with the Spanish PAZ Mission

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Why RO in PAZ? (I)

Current RO meta-constellation being assimilated into NWPM:

- METOP (GRAS receiver)
- 6 COSMIC (IGOR receiver)
- GRACE (IGOR receiver)
- → **~2500 daily RO evenly distributed all over the Globe**.

RO data suitable for Climate studies: long time series of RO data required

Why RO in PAZ? (II)

Positive impact in weather forecast: 5th of the 24 assimilated observation systems reducing forecast error, especially between 100 and 500 hPa, and Southern hemisphere:

From: C. Cardinale, ECMWF Tech. Memorandum 599, 2009

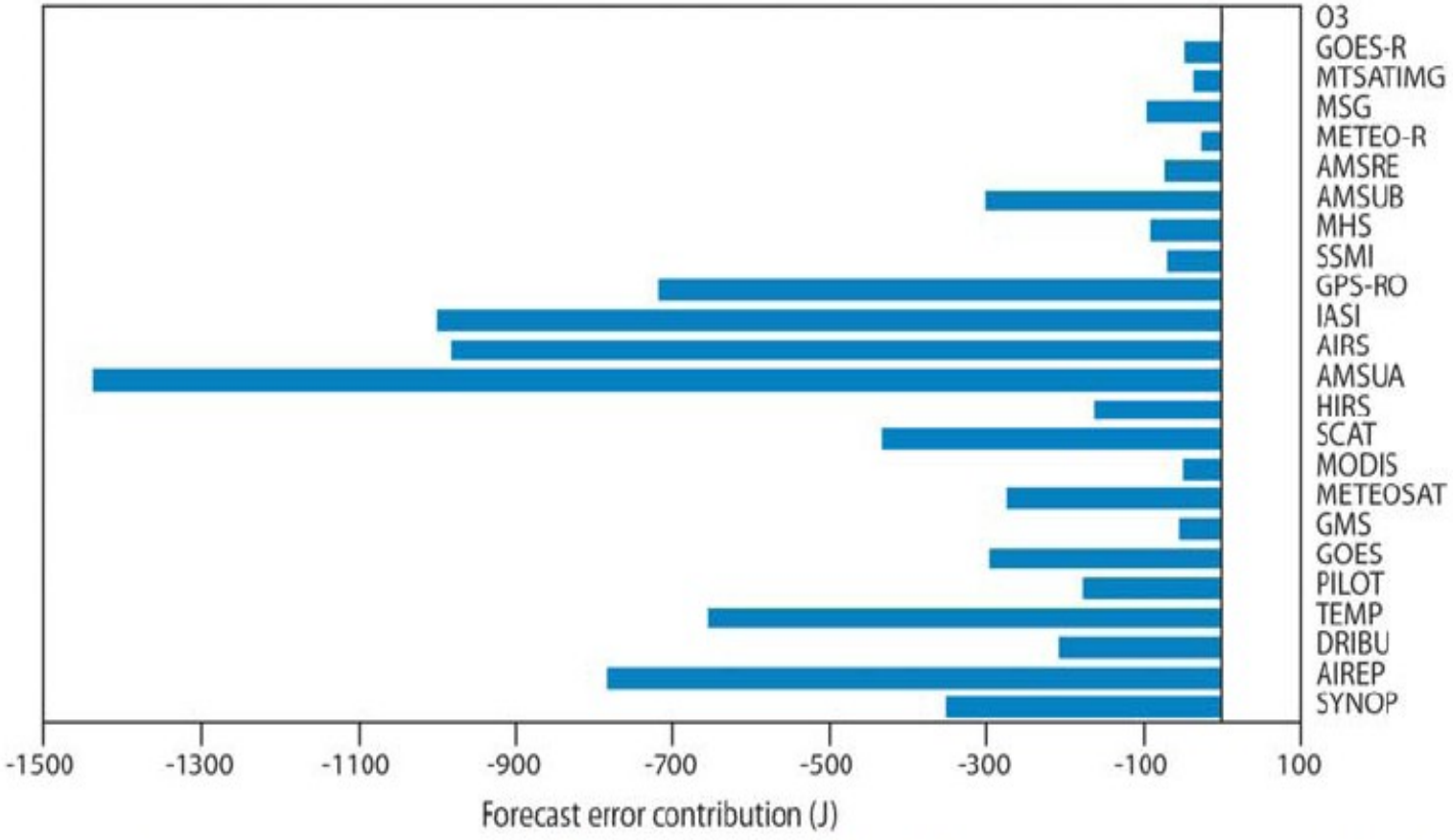


Figure 11. 24-hour forecast error contribution (Joule10^{-4}) of the components (types) of the observing system during September, October, November and December 2008. Negative (positive) values correspond to a decrease (increase) in the energy norm of forecast error.*

Why RO in PAZ? (III)

2011/2012: decommissioning of COSMIC, number of RO events suitable for operational assimilation into NWPM?

→ **post-COSMIC gap must be filled for both NWP assimilation and climate studies continuity**

- PAZ must be ready for launch in Jan 2012: POTENTIAL CONTRIBUTION TO FILLING THE DATA GAP

PAZ mission

- PAZ is a Spanish satellite, managed by **HISDESAT** (mixed private-public company) for a main customer: the **Spanish Ministry of Defense** (**MoD**).
- **PAZ platform**: similar to TerraSAR-X
- **PAZ payload**: originally, a SAR for the MoD, with IGOR+ and zenith-looking GPS antenna for Precise Orbit Determination. The original PAZ project did not include RO.
- **RO-extension**: approved project to add RO antenna and extend IGOR+ functionalities for RO observations.

PAZ orbit

- **Orbit type:** sun-synchronous
- **Orbital Height**: ~510 km (LEO)
- **Orbit Eccentricity**: 1.1e-3 to 1.2e-3
- **Orbit Inclination**: 97.4 deg

→ **suitable for RO measurements**

PAZ timeline

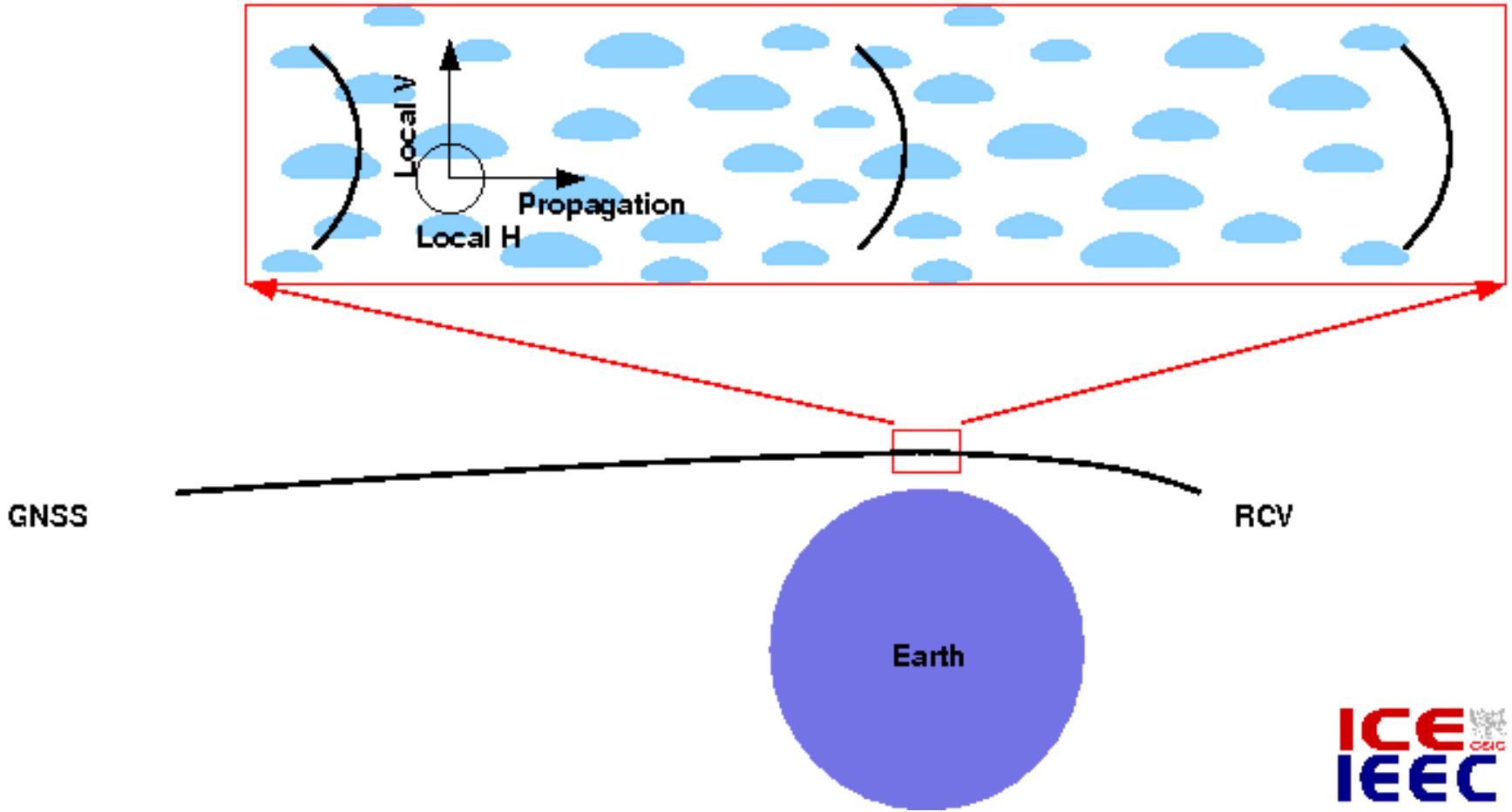
- Critical Design Review: done
- Platform Delivery Review Board: Dec 2010
- RO HW delivery: Jan 2011
- Satellite Integration starts: Feb 2011
- Satellite Test Readiness Review: Jun 2011
- Final Acceptance Review: Dec 2011
- Launch Readiness Review: Jan 2012
- ---------- **L A U N C H 2012** ----------
- Lifetime: **5 years, 2012-2017 → contributes filling the post-COSMIC data gap**

ROHPP experiment

- **ROHPP**: **R**adio **O**ccultations and **H**eavy **P**recipitation with **P**AZ
- 1 single RO antenna (setting observations) with **two** linear **polarizations**.
- The two linear polarization can be recombined in post-processing to get both Right-Hand and Left-Hand Circular Polarization components (**RHCP, LHCP respectively**)
- RHCP: standard RO measurements
- **LHCP**? Polarimetric experiment aiming to capture [heavy] precipitation

Polarimetric Experiment

- Heavy precipitation increase drops size, and they become flattened
- Signal crossing drops along the flattening axis suffers **DEPOLARIZATION**.
- RO cross lowermost atmosphere tangentially (aligned with most common flattening axis)



Examples

- Polarimetric weather radars (USA NEXRAD, at **3 GHz**)

- **[Peters et al., 2008]**: Depolarization linked to heavy rain detected from RHCP signals transmitted at 1.5 GHz (GOES downlink)

Backscattering at 3 GHz

- Polarimetric weather radars: e.g. NEXRAD
- Rain rate, drop size, drop shape derived from polarimetric measurements (linear polarizations)

Weather Radar:

- 3 GHz
- Linear Polarized
- Rayleigh backscattering

GNSS PoI-RO:

- ~1.5 GHz (L1)
- Circular Polarized
- Propagation (Rayleigh forward scattering)

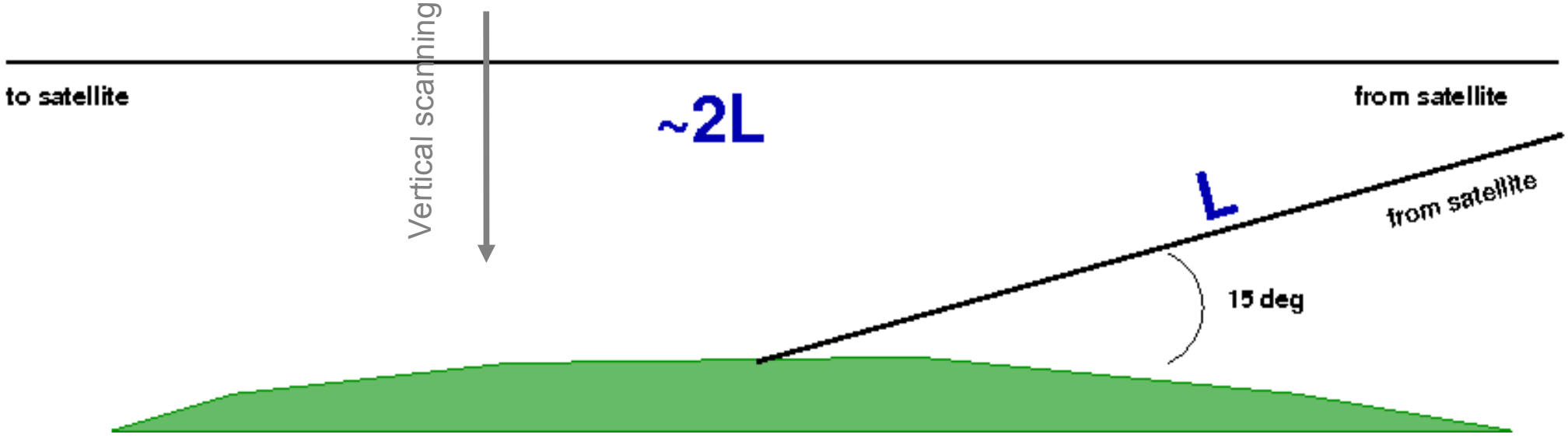
GOES downlink vs RO

[Peters et al., 2008] GOES:

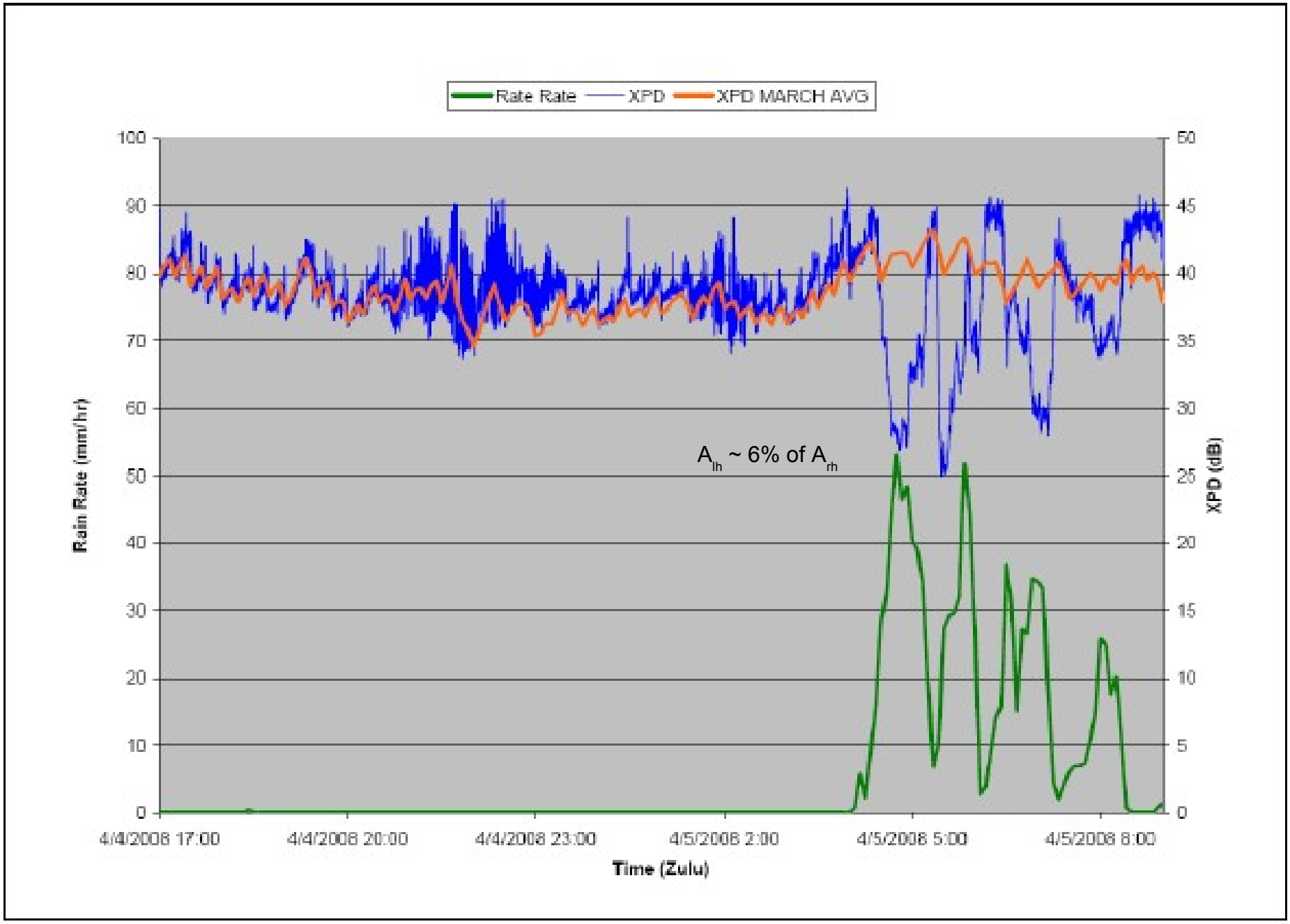
- 1.5445 GHz
- RHCP transmitted
- 15 deg elevation
- Sat-ground, fixed

GNSS PoI-RO:

- 1.57542 GHz (L1)
- RHCP transmitted
- 0 deg elevation → aligned with oblate drops
- Sat-sat → crossing atmosphere ~ twice, vertical scanning



Peters et al., 2008



ROHPP equipment

- **IGOR+**: Modified as in other RO missions, modifications made by Broad Reach Engineering

- **Antenna**:
  - Azimuth range: +- 55-65 degrees
  - Elevation range: +- 3-7 degrees
  - Dual Polarization: Vertical/Horizontal
  - Dual Frequency: GPS L1/L2
  - Gain 10-12 dB each port (V/H) → 13-15 dB circular

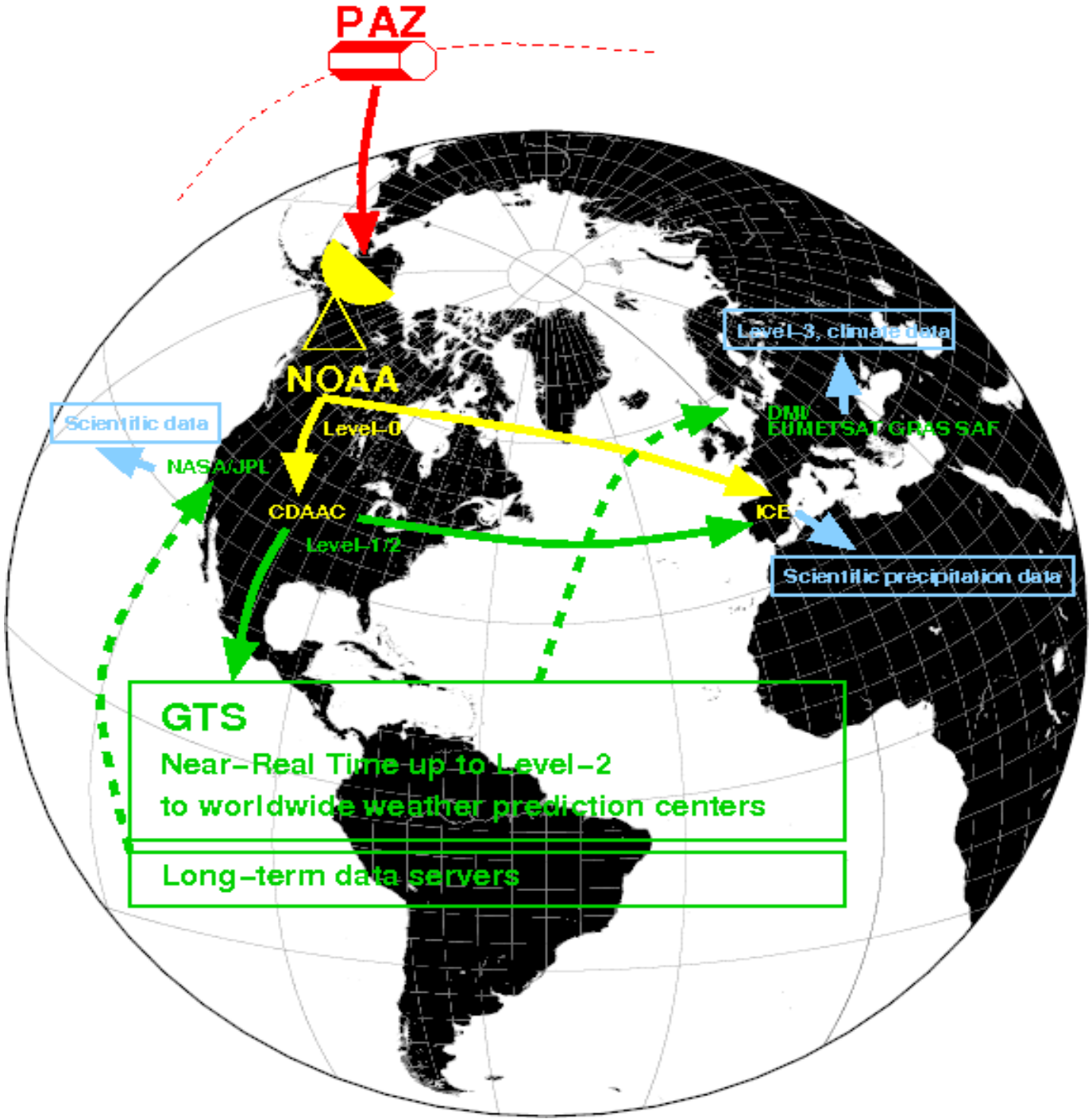
RO ground segment (GS)

- **PAZ NOMINAL GS**: RO data as downlinked by HISDESAT, with the rest of the mission data: once per day, **NOT NRT**!!

- **3rd party: IGOR data can be separated and telemetered to 3rd party facilities, once per orbit (95 minutes, NRT).**

  NOAA is interested in this activity, from telemetered data to distribution of Level-1 and upper data. It would not restrict other possible 3rd parties to participate. No formal agreement signed yet, work in progress.

RO ground segment



Expected data quality/amount

AMOUNT AND DISTRIBUTION:

- **Setting only**: ~½ of potential total data
- **Orbit height**: less even distribution of the RO events than COSMIC/GRAS missions

QUALITY:

- **IGOR+** well known performance, moreover
- PAZ will have **higher antenna gain** than COSMIC
- 2 linear polarizations → circular? It should not drop quality

RISK:

- Low risk aspects: IGOR+ widely used, platform as TerraSAR-X, ground segment as COSMIC...
- Risk factor: Linear polarization? It shouldn't

ROHPP user needs

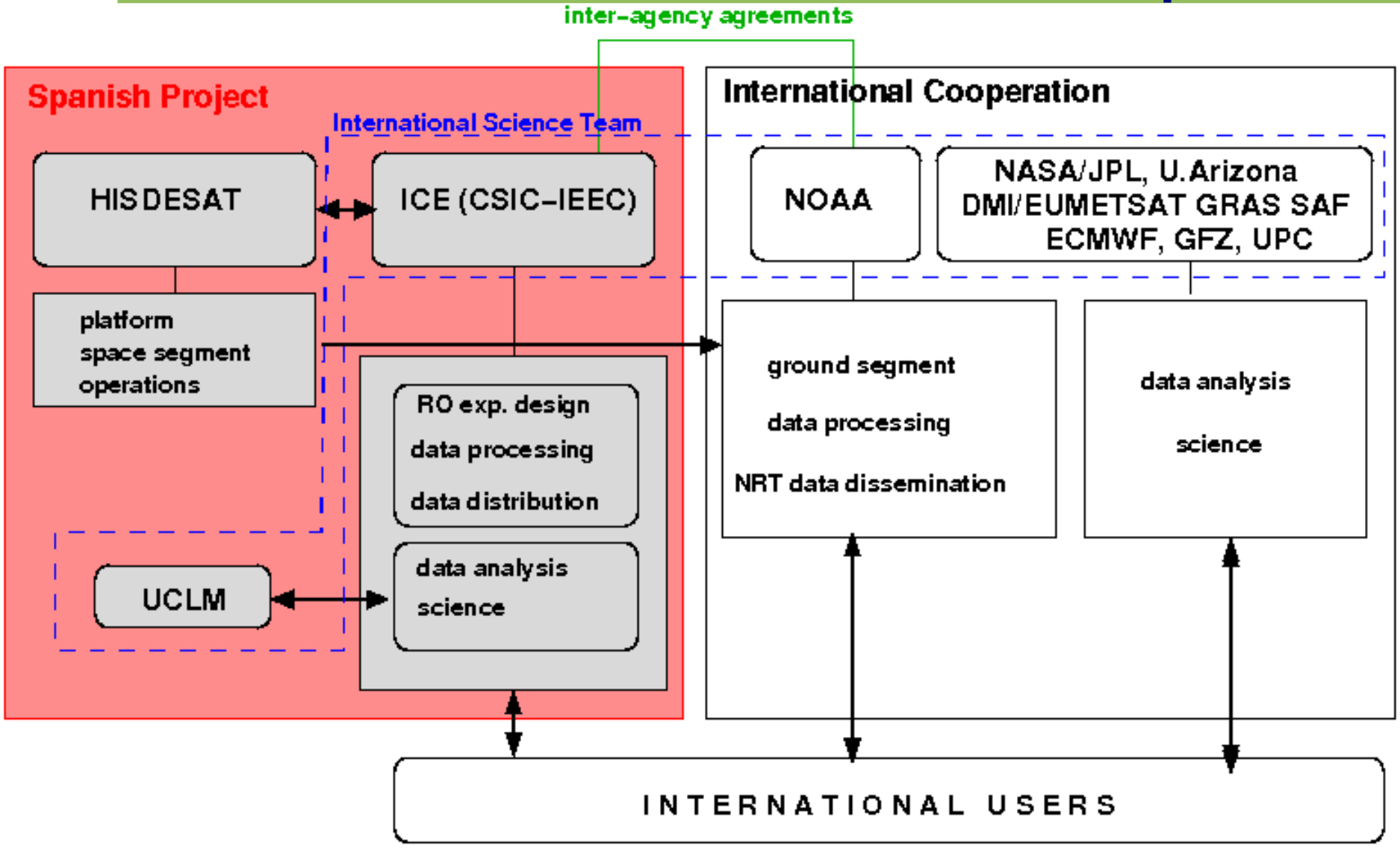
- **OPERATIONAL:**
  - Must be **NRT**!! It is possible, but it needs 3rd parties (NOAA GS).
  - Quality: expected quality would fit requirements
- **CLIMATE**: important to help filling the RO data "gap" when COSMIC will be decommissioned (post 2012). Same receiver family than other RO missions: COSMIC, TerraSAR-X, Tandem-X.
- **PRECIPITATION**: Proof-of-concept experiment, scientific use solely, operational products not expected.

ROHPP user needs

PRECIPITATION User Needs:

- RO cannot "compete" with TRMM, future GPM precipitation missions: wide swath images, 3h revisiting time...
- But RO will potentially provide a unique data set: combined atmospheric profiles of **precipitation + thermodynamic** parameters → potential improvement of heavy precipitation model
- This is relevant for better forecast (minimize damages) and better assessing how climate change might affect extreme precipitation

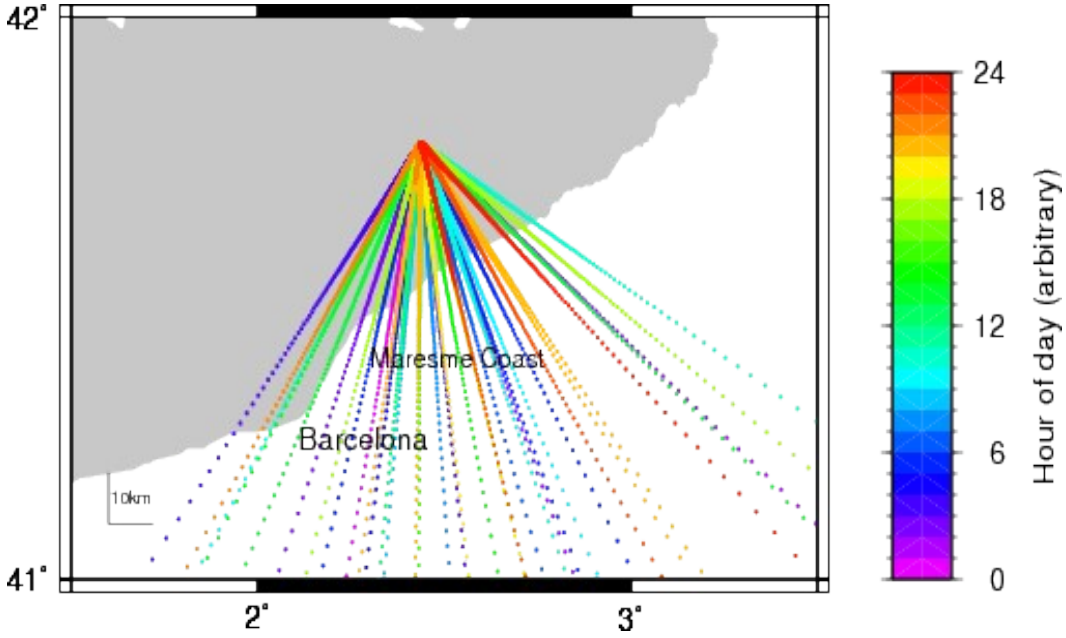
International Cooperation



Besides Ground Segment, international cooperation has also emerged as an International Science Team: NASA/JPL, U.Arizona, DMI-ECMWF/EUMETSAT's GRAS SAF, GFZ, UCLM, UPC, AEMet

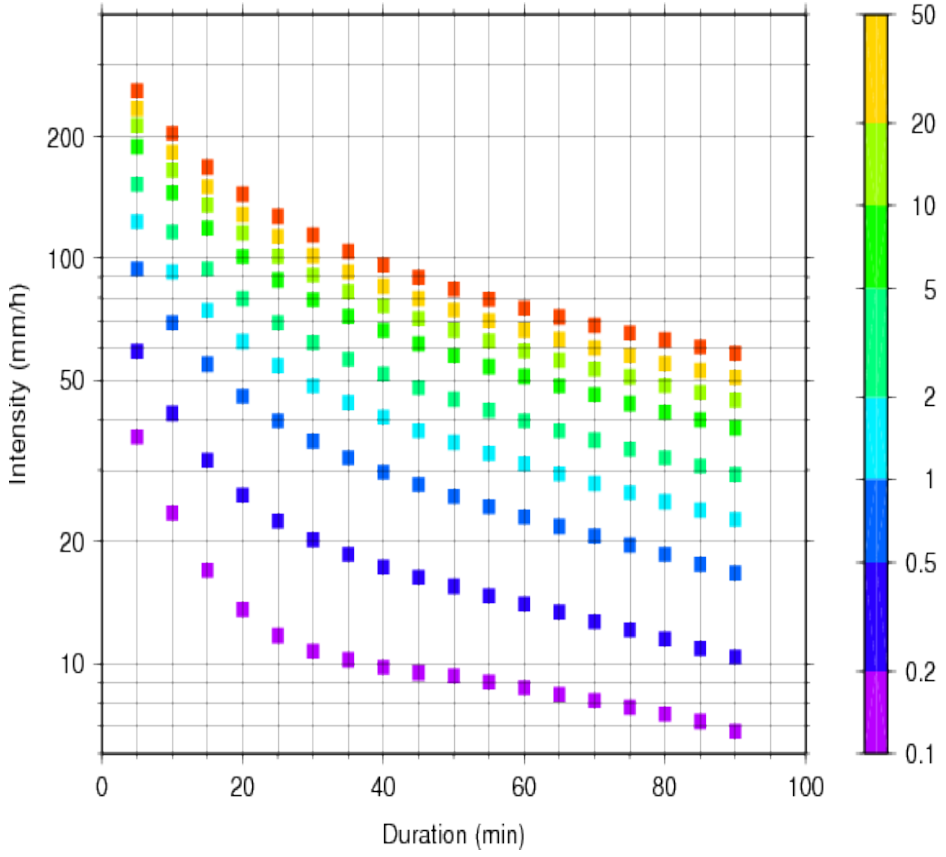
PoI-RO: Ground Campaign

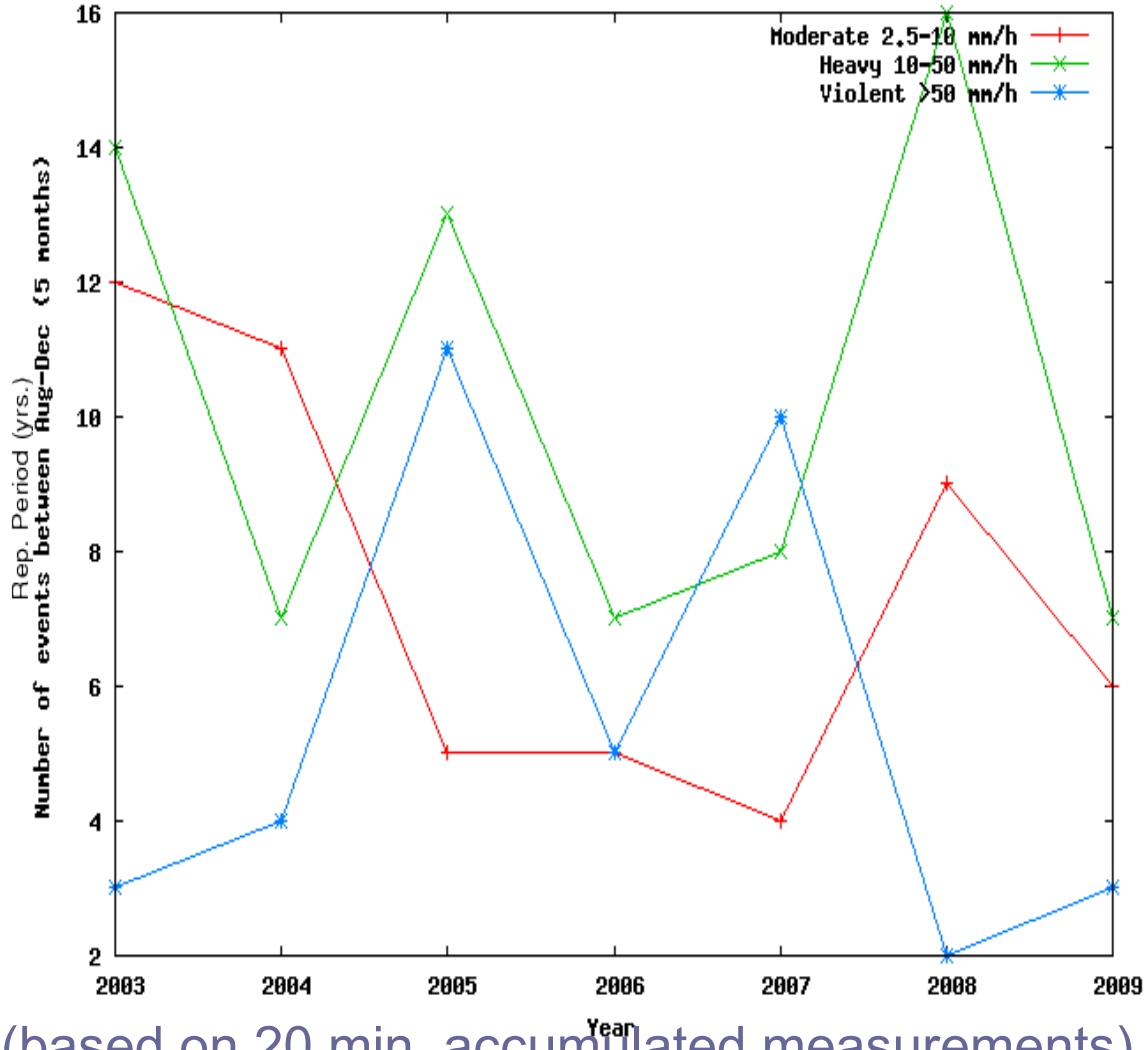
- **GOAL:** to understand the polarimetric RO data, to “catch” a heavy precipitation event
- Fall 2010 (TBC)
- ICE's GOLD-RTR receiver (open-loop) and UPC's steerable high-gain polarimetric antenna
- Fixed site, elevated, good visibility over horizon, probability of some heavy-rain showers



Ground Campaign

Precipitation over BCN area (data from CLABSA):

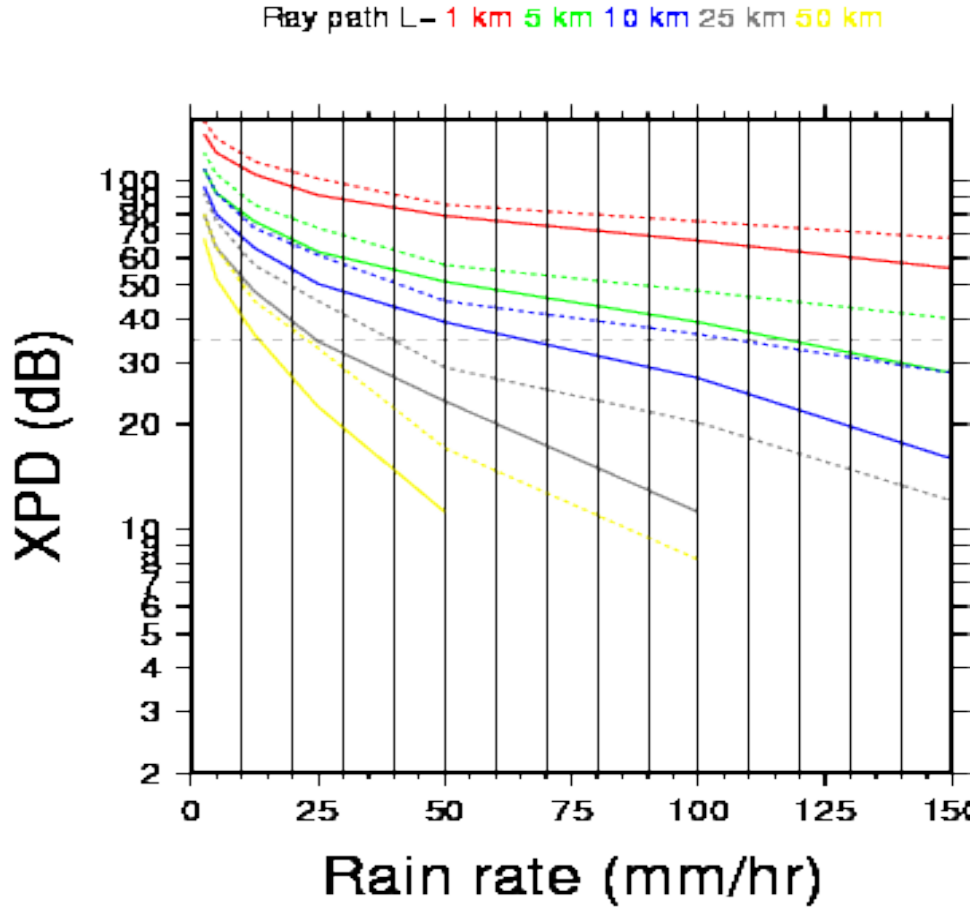




(based on 20 min. accumulated measurements)

Some preliminary studies...

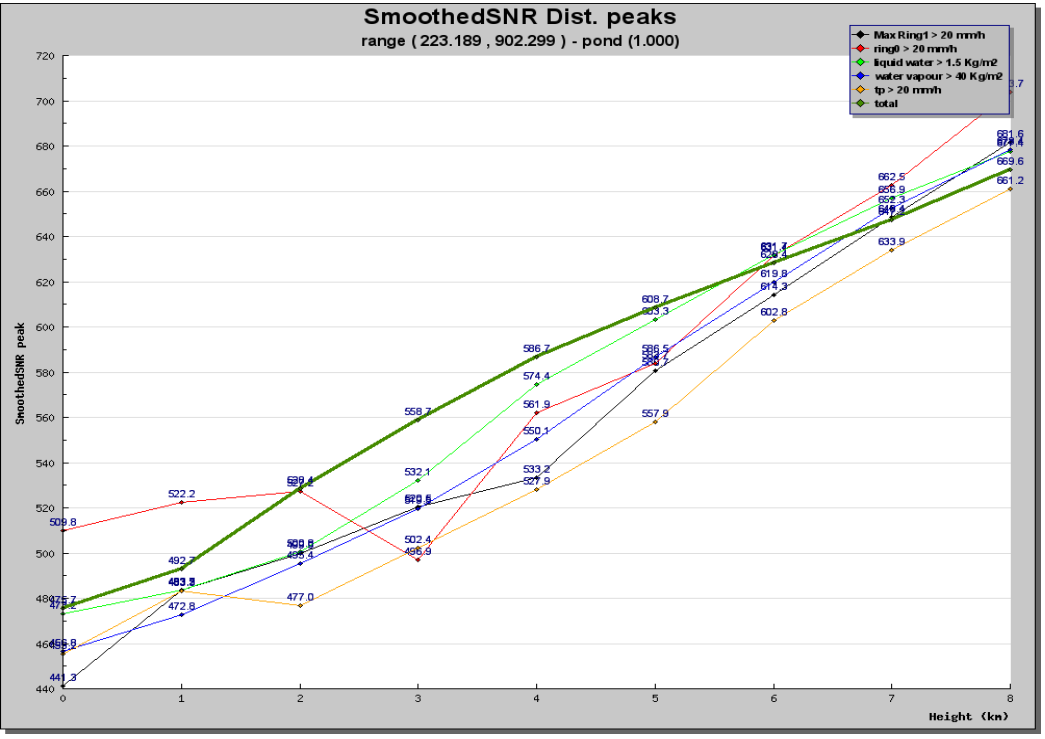
- The amount of cross-polar component depends on rain rate as well as path length across the precipitation area (Figure by M. de la Torre-Juárez/JPL):

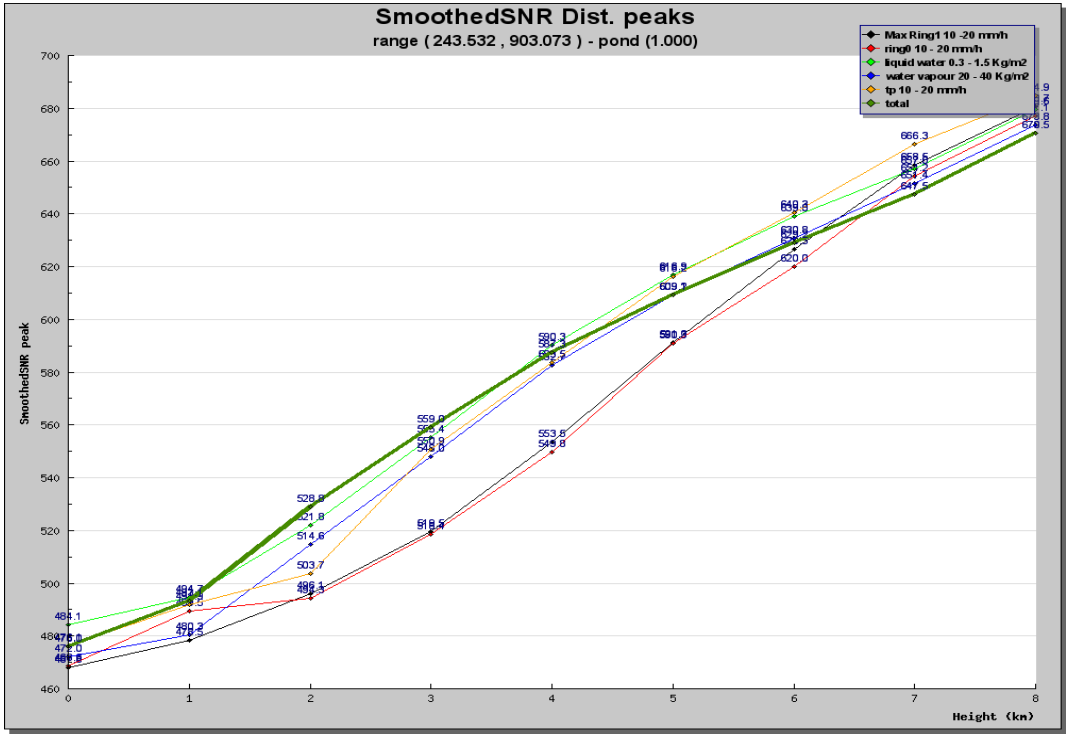


Where XPD=RHCP/LHCP (in dB).

Some preliminary studies...

- Since LHCP comes from “depolarized” RHPC, the amplitude of RHCP observed under heavy rain conditions should drop with respect to non-heavy rain situations.
- Statistics of collocation between COSMIC RO and TRMM (0.25deg x 0.25deg, 3h batched), ECMWF (1.5deg x 1.5deg, 3h batched) precipitation. ~600000 RO events:





Summary

- ROHPP: Opportunity to upgrade Spanish PAZ mission with polarimetric RO capabilities
- Launch 2012, 5 years time-life: contribution to fill gap between COSMIC and COSMIC-II
- IGOR+ receiver with 2-pol 13-15 dB (recombined) antenna gain
- Platform, orbit and main payload very similar to TerraSAR-X/Tandem-X
- Ground segment likely to be provided by NOAA: NRT delivery of data suitable for NWP operational assimilation
- 1st RO-Polarimetric experiment: capturing precipitation? E.g. GOES 1.5 GHz downlink detected, NEXRAD weather pol-radars at 3GHz
- Some preliminary studies: Ground Campaign, COSMIC-TRMM-ECMWF precipitation collocation, …