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Evaluation of the performance of $\Delta\phi$ as a precipitation estimator

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Abstract: This paper introduces the application of statistical models to determine the performance of the observable $\Delta\phi$ as a precipitation estimator. Using Precision Recall curves, the study shows the optimal range of heights for transforming the vertical profiles of $\Delta\phi$ into a scalar average. The results show that Using NASA's IMERG precipitation data as our target with the 97th percentile mm/h as True, $\Delta\phi$ achievesan optimal F1 score of 0.54 when averaged between 0.1km and 8.5km.

I. INTRODUCTION

A Global Navigation Satellite System (GNSS) radio occultation (RO) experiment is taking place in the Spanish low Earth orbiter PAZ satellite. The RO payload provides globally distributed vertical profiles of the atmosphere which have been proven to have a high impact on Numerical Weather Prediction Models[referencia]. Moreover, the mission runs for the first time a double-polarization GNSS RO experiment for detecting precipitation events. The performance of this new technique, which has already been proven to detect high precipitation events [], is evaluated in this paper.

The GNSS systems transmit circular-polarized signals that are collected using ROs once they have travelled through the atmosphere. They are collected using two orthogonal linearly polarized antennas (horizontal H and vertical V) with the aim of comparing the phase delay ϕ_H and ϕ_V of each signal. In the case of heavy rain events, water drops experience air friction which causes them to flatten out along their horizontal dimension. The pressence of water drops can cause depolarization between the H and V signals which are affected differently when propagating through a rainy atmosphere. The polarimetric radio occultations (PROs) is a new technique that allows us to measure the differential phase shift $\Delta\phi$ between the H and V signals. One of the objectives of the ROHP-PAZ mission is to use the measured depolarization $\Delta\phi$ as a precipitation estimator.

This paper evaluates the performance of $\Delta\phi$ on detecting precipitation events. To properly evaluate the performance a target must be defined. The target used in this paper is the NASA's IMERG precipitation dataset. From this dataset we can obtain the precipitation at every location in time and space where our PROs took place. The goal is to evaluate and quantify how well does the $\Delta\phi$ estimator perform in detecting precipitation above a certain threshold regarded as *true precipitation.* This way, **our target is defined as a binary True/False variable** being True for precipitation above the elected threshold and False for precipitation below it.

Our observable $\Delta\phi$ is of little use to the Numerical Weather Prediction Models. We must find a way to transform the vertical profiles of $\Delta\phi$ into a variable that is closely related to precipitation data. If achieved, this would justify the need for PROs and the ROHP-PAZ mission as a whole.

This study provides the optimal range of heights $[h_o, h_f]$ for transforming the vertical profiles of $\Delta\phi$ into a scalar average. This optimal range depends on the threshold for defining out target *true precipitation.* It has been found in this study that the performance also depends on the region where the PRO took place as discussed in section (III?). The performance of each average $[h_o, h_f]$ is evaluated using Precision-Recall curves which have been proven to work well with unbalanced datasets [reference]. In our case, the target False (no precipitation event) will outnumber the target True once a proper truth threshold is defined.

It is expected that the average $[h_o, h_f]$ that best predicts the True/False target will be somewhere between $h_o = 0.1km$ and $h_f = 10.0km$ since that is where the signals will experience the most depolarization.

II. DATA

The main observable of the experiment is the differential phase shift

$$\Delta\phi = \phi_H - \phi_V, \tag{1}$$

The dataset is composed of over 85.000 measurements distributed globally providing vertical profiles of $\Delta\phi$ in 100m intervals between 0.1km and 40km. A *true precipitation* is associated with each of these measurements. As an example, PROs at two different locations are shown in Figure 1.

A *true precipitation* is associated with each vertical profile. This *true precipitation* is defined as the precipitation in mm/h where the PRO rays crossed the atmosphere at an altitude of 6km or less.

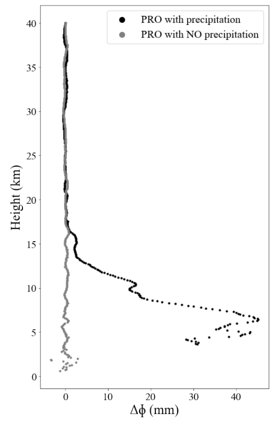

FIG. 1: Vertical profile of $\Delta\phi$ for two different PROs

III. DEVELOPING SECTIONS

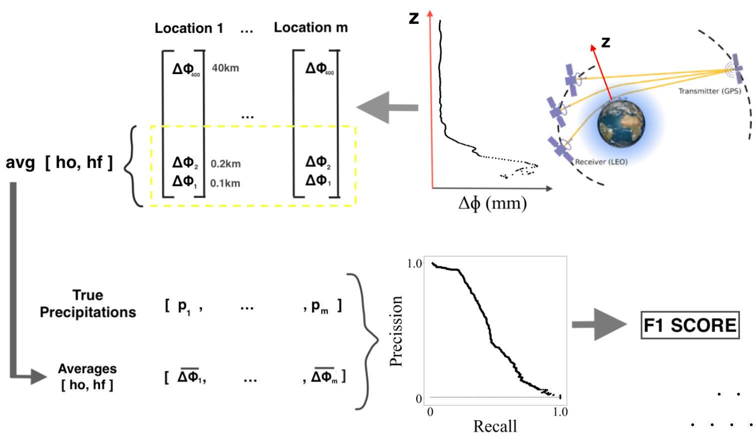

FIG. 2: F1 Score of m PROs averaging between $\mathrm{h}_o and h_f$

TABLE I: Another table.

M1	Teoria:	Galileo	A11G
(11:45)	Problemes:	Newton	A11G
	Problemes	Planck (M1A)	A11G
(12:45)	tutoritzats:	Fermi (M1B)	A23M
M2	Teoria:	Clausius	A12G
(8:30)	Problemes:	Goeppert Mayer	A12G
	Problemes	Boltzmann (M2A)	A12G
(9:30)	tutoritzats:	Maxwell (M2B)	A24M
T1	Teoria:	Gibbs	A12G
(18:00)	Problemes:	Helmholtz	A12G
	Problemes	Bohr (T1A)	A12G
(19:00)	tutoritzats:	Einstein (T1B)	A24M

A. Subsection 1

This is the first subsection.

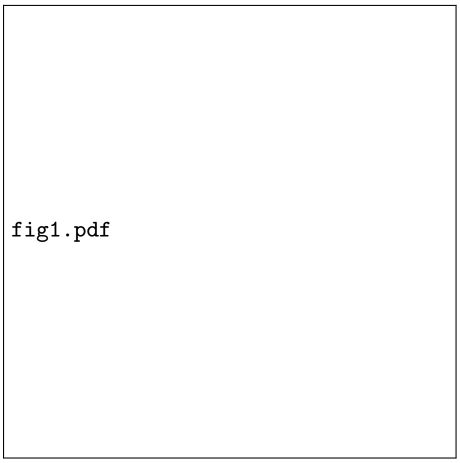

FIG. 3: A sample figure made smaller by changing the width parameter.

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B. Subsection 2

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IV. CONCLUSIONS

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V. APPENDIX

You can add your appendix if needed, or you should like to do so. The following equation,

$$\vec{F} = m\vec{a}, \tag{2}$$

is important in Physics.

Acknowledgments

Be sure to thank your advisor, your colleagues, and granting agencies (e.g. parents, etc...) as well.

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[1] Helmut Kopka and Patrick W. Daly, *A Guide to LaTeX: Document Preparation for Beginners and Advanced Users*, 3rd. ed. (Addison-Wesley, Reading, MA, 1999).
[2] It is necessary to process a file twice to get the counters correct.
[3] J.D. Jackson, *Classical Electrodynamics*, (John-Wiley & Sons, New York 1975, 2nd. ed.).
[4] Hinshaw, G. et al. (WMAP Collaboration). "Five-Year Wilkinson Microwave Anisotropy Probe Observations: Data Processing, Sky Maps, and Basic Results". The Astrophysical Journal Supplement **180**: 225–245 (2009).
[5] Weinberg, S.. "High-Energy Behavior in Quantum Field Theory". Phys. Rev. **118**: 838–849 (1960).