RAIN GAUGE BASED ON A MOBILE PLATFORM

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This project will evaluate an effect of the presence of the wind on measurement systems that capture rainfall and that does not appear in the literature studied, namely the reduction of the capture area due to the inclination of the particles of precipitation.

The goal is to design a system to measure precipitation in which the orifice of the gauge can be aligned with the inclination of the raindrops so that the collection area remains constant. The system design was subject to three constraints:

1. **For economic reasons, measuring equipment was used from other measurement systems that were no longer in service.**
2. **The inclination of the rain drops was not measured directly, as we had no means to do so.**
3. **We will consider precipitation in the liquid phase only.**

1. INTRODUCTION

The method of measuring precipitation is documented in Chapter 6 of the Guide to Instruments and Methods of Observation (WMO-No. 8). The instrument most commonly used to measure precipitation is the rain gauge.

The wind influences the measurement of the characteristics, quantity and intensity of rainfall, resulting in the measured precipitation always being lower than the real value. The wind affects it in two different ways:

- Screening by the situation of the measuring equipment.
- Systematic deformation of the wind field above the orifice of the gauge.

The following table lists the errors made in measuring precipitation.

Symbol	Error component	Magnitude	Meteorological factors	Instrumental factors
k	Loss due to deformation of the wind field above the orifice of the gauge	2-10% 10-50% (snow)	Wind speed at the gauge rim and structure of precipitation	Shape, area and height of the rain gauge collector and container
$\Delta P_1 + \Delta P_2$	Losses due to wetting of the inner walls of the collector and container when it empties	2-10%	Frequency, type and amount of precipitation, instrument drying time and frequency of emptying of the container	Same as the above plus material, colour and age of the rain gauge collector and container
ΔP_3	Losses due to evaporation from the container	0-4%	Type of precipitation, air saturation deficit and wind speed at the orifice of the rain gauge during the time interval between the end of precipitation and measurement	Surface area of the collector and exposure of the container to the sun, colour and type of funnel
ΔP_4	Splashing into and out of the rain gauge	1-2%	Rainfall intensity and wind speed	Shape and height of the collector and rain gauge installation type
ΔP_5	Blowing snow		Intensity and duration of snow storm, wind speed and snow cover	Shape, area and height of the rain gauge collector and container

$$P_a = k\ P_c = k\,(P_g + \Delta P1 + \Delta P2 + \Delta P3 \pm \Delta P4 - \Delta P5)$$

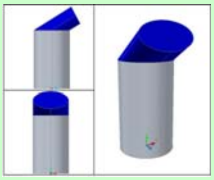
where:

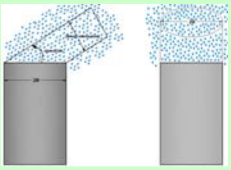
P_a is the adjusted precipitation amount; P_c is the precipitation captured by the gauge collector; P_g is the measured precipitation.

Most errors in measuring precipitation are due to the wind, and they are quite complex to evaluate.

2. REDUCTION OF THE PRECIPITATION CAPTURE AREA

In a wind, precipitation does not fall vertically, but is inclined to the vertical axis of the rain gauge, which makes the effective cross section of the gauge orifice less than the standard values (200 cm2 in the case of a Hellman gauge) so that precipitation is collected over less than the standard area and is therefore underestimated.





Rain collection area in a rain gauge

Collection area = π · R · R · sin (elevation) = Standard area · sin (elevation)

Elevation (°)	90	70	50	0
Area (cm^2)	200	187	153	0

Typical values for a Hellman type rain gauge are as follows:

We introduce a new factor for the correction of the rain

$$P_{real} = k_r P_a = k_r k P_c \qquad k_r = 1/\sin(\text{elevation})$$

where k_r is the coefficient to offset the loss through the reduction of the collection area.

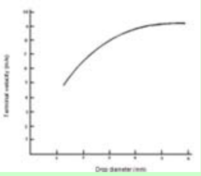
3. INCLINATION ANGLE OF RAINDROPS

- Vertical movement. The raindrops fall from a cloud at the limiting velocity:

$$v_y = 2.17 \cdot \frac{\rho_{water} \cdot g}{\mu} \cdot R^2 \qquad v_y = \sqrt{\frac{8 \cdot \rho_{water} \cdot R \cdot g}{3 \cdot \rho_{air} \cdot C_d}}$$

(laminar flow) (turbulent regime)

	Drops of mist		Cloud droplets				Raindrops		
R (mm)	$4 \cdot 10^{-4}$	10^{-3}	$4 \cdot 10^{-3}$	10^{-2}	$5 \cdot 10^{-2}$	10^{-1}	$5 \cdot 10^{-1}$	2	3.6
v_y (m/s)	$22 \cdot 10^{-6}$	10^{-4}	0.002	0.0125	0.26	0.8	3.9	6	8



Studies indicate that large drop sizes are unlikely, as when the water drops reach a certain velocity, they begin to collapse and break up owing to the resistance of the air. Experimental measures tell that most likely raindrops diameters is 8-9 m/s.

- Horizontal movement. The horizontal velocity of the drop is equal to the wind speed.

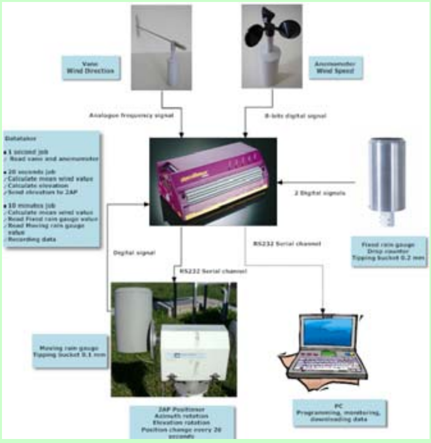
$$V_x = V_{wind}$$

- Total movement.

We supose that all the raindrops fall at the same velocity → 8 m/s

$$\alpha = arctg\left(\frac{8}{v_{wind}}\right)$$

4. PROPOSED SYSTEM



5. RESULTS AND SYSTEM VALIDATION

- Period of observation 27/10/2009 to 30/04/2011 in Santander Observatory (Spain)

We have 57744 records of 10-minute values, 1.095 records with rain.

FBP - Precipitation of fixed rain gauge with tipping bucket

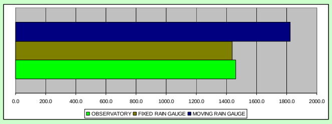
MBP - Precipitation of moving rain gauge with tipping bucket

OP - Manual rain gauge of Aemet Observatory in Santander

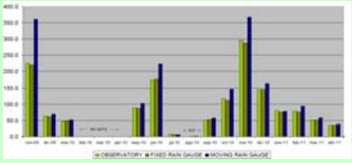
- Total precipitation

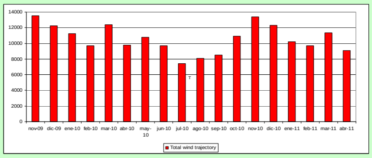
MEASURING EQUIPMENT	VALUE
MOVING RAIN GAUGE WITH TIPPING BUCKET	1824.4
FIXED RAIN GAUGE WITH TIPPING BUCKET	1437.4
MANUAL RAIN GAUGE IN OBSERVATORY	1460.5

DIFFERENCE (MBP – FBP) = 387 (26.9 %)

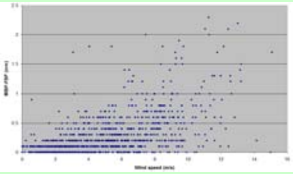


- Precipitation and total wind trajectory by month





- Correlation of wind speed and MBP-FBP difference.



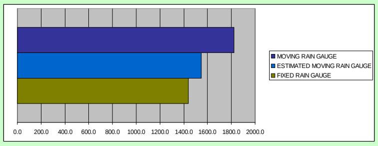
CORRELATION [WIND SPEED, (MBP-FBP)] = 0.59

- Estimating MBP → EMBP

Essentially, the problem at hand is the reduction of the collecting area of the gauge as a consequence of the inclination of the flow of rain in relation to the horizontal plane. This being so, we can calculate the value of the MBP starting from the FBP and the ratio between the standard horizontal area and real collection area in 10 minutes data.

$$EMBP = FBP\,\frac{stadard\ area}{actual collection\ area} = \frac{FBP}{\sin(elevation)}$$

MEASURING EQUIPMENT	VALUE
FIXED RAIN GAUGE WITH TIPPING BUCKET	1437.4
MOVING RAIN GAUGE WITH TIPPING BUCKET	1824.4
ESTIMATED MOVING RAIN GAUGE	1546.8



$$P_{real} = k_r\,k\,Pc \quad \begin{cases} FBP = P_c \\ EMBP = k_r\,FBP \end{cases} \quad P_{real} = k\ EMBP$$

We thought that MBP was aproximatly equal to EMBP but we found that MBP>EMBP so we not only have offset the effect of reducing the rainfall collection area, but we have also offset part of the decrease due to the deformation of the wind field.

Bibliography

- Guide to Meteorological Instruments and Methods of Observation. WMO Nº 8. Seventh Edition. 2008.
- WMO Solid Precipitation Measurement Intercomparison. Final Report. WMO/TD No. 872 1998.
- Methods of correction for systematic error in point precipitation measurement for operational use. WMO No. 589. Boris Sevruk.
- World water balance and water resources of the Earth. Studies and Reports in Hydrology No. 25, 1978. United Nations Educational, Scientific and Cultural Organization.
- Do all raindrops fall at terminal speed? Geophysical Research Letters Vol. 36, L11818. G. Montero-Martinez, A. B. Kostinski, Raymond A. Shaw.
- Measurements of the fall velocity of water drops and rain drops. Transect American Geophysical Union. Hydrology 22 709-721. Laws J.O. 1941
- Toward elucidating the microstructure of warm rainfall: A survey. Rev Geophys 45. Testik F.Y. Barros P.
- The wind-induced loss of precipitation measurement of small time intervals as recorded in the field. Technical conference 2002 WMO/TD No. 1123. Branislav Chvila, Miroslav Ondras, Boris Sevruk.
- The wind-induced loss of thunderstorm precipitation measurements. Atmospheric research 77 (2005) 29-38. B. Chvila, M. Ondras, B.Sevruk.
- Estimation of wind-induced error of rainfall gauge measurements using a numerical simulation. Journal of Atmospheric and Oceanic Technology Volume 16 Issue 4 April 1999 450-464. Vladislav Nespor, Boris Sevruk.
- Wind-induced error of raindrop size distribution measurement using a two-dimensional video disdrometer. Journal of Atmospheric and Oceanic Technology Volume 17 2000 1483-1492. Vladislav Nespor, Witold F. Krajewski, Anton Kruger.