VERIFICACION OF THE QUALITY OF DGPS SIGNAL IN RIO GRANDE DO SUL – BRAZIL, COMPARED TO VILLARROBLEDO (SPAIN)

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ABSTRACT

The GNSS (Global Navigation Satellite System) provides georeferenced data for many civil and military applications. Since the removal of noise in the USGPS signal in 2000, civil applications have exploded and correction methodologies have greatly improved the quality of data without additional cost. DGPS make profit of geostationary signal in order to decrease the error level from metric to sub metric range; however such decrease strongly depends upon local circumstances. In this paper we compare the quality of DGPS signal under very dissimilar conditions: North vs South hemisphere, various geoides (ED50 vs WGS84) and distance to the geostationary satellite among others. The data have been acquired during several seasons according, all of them in vine crops (permanent crop and therefore of known position) which allows to easily address the quality of the georeferenced position.

Key words: Precision agriculture, satellites, HDOP

INTRODUCTION

GNSS quality (Global Navigation Satellite system) varies in different parts of the globe and under varying conditions, influenced by: the number of costellations available (i.e. GPS, GLONASS), the geometry of the satellite constellation, the number of accesible units, signal quality and atmospheric interference, objects near the receiving antenna, and antenna type, among others. The importance of signal quality relays on allowing more detailed information on the variability of plots in the case of agriculture, and thus enables performing the local application of inputs adjusted to crop needs, which contributes to the reduction of costs and improves efficiency in the farm management (Smith et al. 2013).

Traditionally, GPS requires at least 4 satellites to pasively reveal the position of the user, DGPS (Differential GPS) positioning is performed by simple baseline (user is positioned relative correction to a single geostationat satellite or alternative correction), while RTK is a real-time correction procedure with the use of two receivers: a static and a dynamic one (Sejas et al. 2013).

Besides, currently Brazil has a statewide GPS network for RTK correction without base anthenna, which is distributed in 18 states. Rio Grande do Sul has 65 GPS stations and 5 post-processing stations (Figures 1a and 1b) that compose the GNSS continuous monitoring network, with access to the Networked Transport of RTMC via Internet Protocol (NTRIP) (IBGE, 2017). However the cost of RTK anthennas is far above that of DGPS (at least 30 times that of DGPS anthenna without base station).

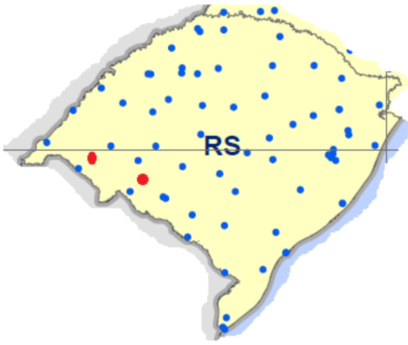
Molin et al. (2011) studied the position deviations caused by DGPS guidance systems in agricultural machinery Compared to GNSS RTK in Brazil, used as reference. RTK provides centimeter location accuracy (0.134m) which erodes due to DGPS and actuation level: manual accoring to light bar, drivewheel control, or hydrostatic control. This study provided average errors between 0.208m and 0.36m.

The objective of this work was to verify the differences in signal quality of three DGPS antennas during the mechanical harvesting of grapes in two farms located in the State of Rio Grande do Sul, Brazil, in the year 2015 and 2016, and in Villarrobledo (Castilla-La Macha), Spain, 2016 harvest as a mean for later comparison with regard to similar previous measurements in Spain (Villafranca del Penedés), as affecting the characterization of machine performance.

MATERIAL AND METHODS

Three Garmin GPS antennas, models 17H, 17X (frequency 1Hz) and 18X (frequency 0.5Hz), were used and configured to obtain NMEA codes, ($ GPGGA, $ GPVTG, $ PGRMM). NMEA codes were recorded by means of free-code software (Visual GPS Application®).
The antennas were installed in the center of four grape harvesters, on the cultivation line (backpack), during the campaigns of 2015 and 2016, in two farms located in the State of Rio Grande do Sul, Brazil (Lat. 30°47' S Long 55°10' W and Lat.31°24'S Long.53°45'W) (Figure 1a, red dots) and in 2016 in VillaFranca del Penedés, Spain (Lat 39°48'N Long 3°00'W).

Figure 1. Network GPS and GNSS in Rio Grande do Sul



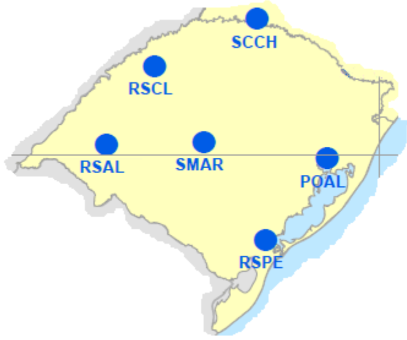
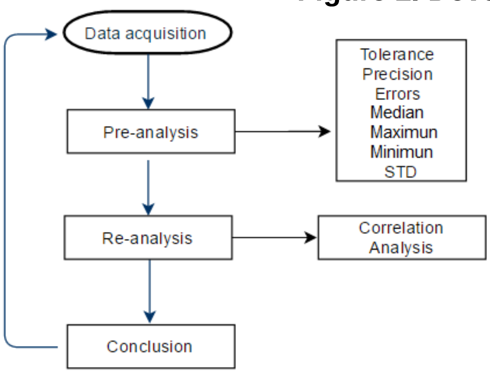


Figure 1a **Figure 1b**

For the treatment of the data, specific routines were developed in the MatLab environment (Mathworks Inc.) in order to obtain quality related information such as HDOP (Horizontal Dilution of Precision), signal quality (GPS or DGPS), number of accesible satellites and variation of the signal over time, composing the steps of Pre-analysis and Re-Analysis summarized in Figure 2a.

Figure 2. Developed steps and signal quality on field



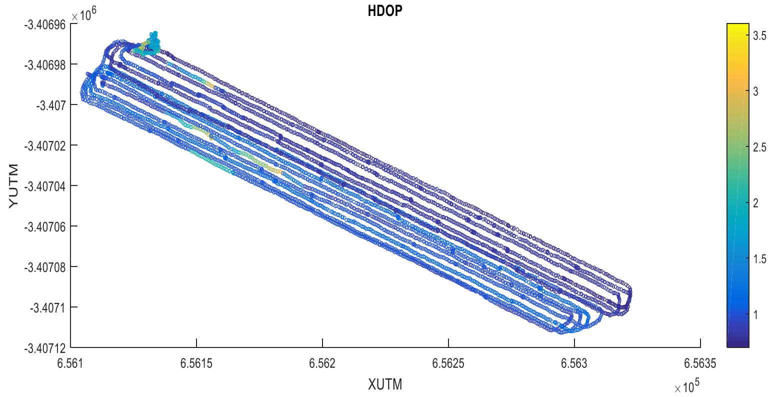


Figure 2a **Figure 2b**

In this study several HDOP tolerance values where set as 1 and 1.25 m based on inter-row distances in the vines; the tolerance level is fixed as half the distance between rows. Figure 2b, as an example, represents in colors the individual HDOP values (m) in a plot (Alma 3 in 2015, 17H anthena). Two particular features arise: firstly the HDOP error rose for a large period (6 lines above 1m and 6 lines below 1m), and secondly local areas with very large HDOP errors (above 2m) are also found (yellow dots).

The mean, median, maximum, minimum in HDOP, the total number of position points and time were calculated for each plot and work activity in a farm located in Brazil and a corresponding one in Spain, (see Table 1).

RESULTS AND DISCUSSION

Table 1. Pre-Analysis

Antenna	File	Tolerance (m)	Average HDOP error (m)	HDOP Std (m)	HDOP Error Median	HDOP Error Max	Error Min	%> tol.	Records
BRAZIL – 2015									
17H	Alma3	1.25	0.983	0.319	0.9	3.6	0.7	8.5	12015
17H	Alma4	1.00	0.920	0.120	0.9	2.5	0.8	4.0	13470
BRAZIL – 2016									
18X	Alma2016(1)	1.25	0.893	0.092	0.9	1.4	0.7	0.5	7901
18X	Alma2016(2)	1.25	0.894	0.071	0.9	1.4	0.8	0.2	6619
18X	Seival2016(1)	1.25	0.900	0.005	0.9	1.0	0.9	0	376
	Seival2016(2)	1.25	0.900	0.063	0.9	1.2	0.8	0	1862
18X	Seival_2_2(1)	1.25	0.826	0.065	0.8	1.4	0.8	0.4	2456
18X	Seival_2_2(2)	1.25	0.976	0.136	0.9	1.4	0.8	6.2	1539
18X	Seival_2_2(3)	1.25	0.920	0.085	0.9	1.9	0.8	0.6	5052
SPAIN – 2016									
17X	Pellenc(1)	1.25	0.7955	0.104	0.8	1.0	0.7	0	9710
17X	Pellenc(2)	1.25	0.8249	0.076	0.8	1.0	0.7	0	13460
18X	Cabezamezada	1.25	0.9627	0.063	1.0	1.3	0.8	0.04	2409

Twelve fields of different plots were evaluated: eight in Brazil (two in 2015 and six in 2016), resulting in 29 hours of data; in Spain, 7.7h of recording corresponding to three fields were available. This data constitute the basis for machine performance analysis: field capacity (ha.h^{-1}), and field efficiency (in-line time over total duration).

It was noticed that position accuracy in Brazil was worse in the 2015 season with the use of the 17H antenna, compared to anthenna 17X in Spain conditions (2016). Thus in 2015, between 4 and 8.5% of the points records (539 and 1021, 26 minutes) were above the defined tolerance regarding a full period of 425 min; which represents 0.16ha and 0.08ha with poor signal respect to 4.5ha; field capacity of 0.58 ha.h^{-1} and 0.51ha.h^{-1} in Alma 3 and Alma 4 respectively (2.3km/h and 2.5km/h, with 2.5m and 2m vine distance respectively).

For the second year (2016), with the use of the 18X antenna in Brazil, the total number of records above the tolerance was 188 (7.2% of total), equivalent to 6.3 min of records from a total of 860 minutes, which represents almost 0.06ha of work with poor signal considering a field capacity of 0.58ha.h^{-1} (2.3 km/h and 2.5m vine distance). Our HDOP errors are far above those reported by Molin et al. (2011) under similar conditions.

When analyzing the plots in Spain, it can be seen that the HDOP of the signal ranged from 0.8 to 1.0m with the 17X antenna, therefore, all the values obtained met the tolerance level (1.25m). Similarly, the results found with the 18X antenna indicated that only 0.04% of the time was above the tolerance, equivalent to 2s.

Figure 3 shows a bar plot indicating the minimum, median and maximum number of satellites accessible for each plot, antenna an country, also indicating the percentage of points above the HDOP tolerance level; the minimum number of satellites always being higher in Spain than in Brazil.

A correlation analysis (Table 2) reveals that the minimum number of accesible satellites during a task period is highly and negatively related with the number of points above the tolerance (r=-0.74) and the maximum error during the task (r=-0.88). This circumstance was more frequent in Brazil than in Spain, especially in 2015.

On the other hand having a large maximum HDOP error, as well as registering a significant number of data above the HDOP tolerance, highly correlated with the percentage of points with GPS quality (variable 4 in Table 2): r=0.82 and 0.71 respectively; remember that GPS quality is lower than for DGPS signal.

CONCLUSIONS

The main conclusion points to significant differences in positioning error between seasons and countries accounted by means of the average HDOP error (m) and percentage of points above HDOP tolerance. Positioning errors are assigned to constellation differences (mainly due to minimum of accessible satellites) related to GPS quality. A significant difference in the availability of GPS signal quality was found: 0% DGPS (100% GPS) in 2015 in Brazil, 99.9% DGPS for Brazil and Spain in 2016. Still relevant local variations in percentage of points above HDOP tolerance are found in Brazil 2016 (from 0% to 6.2%). The loss of DGPS signal can be withstand when the goal is characterization of tasks (machine performance ha.h^{-1} and field efficiency) in permanent crops as vines, since vine distance is known above hand and ground speed is properly computed by the GPS, but it makes machine auto-guidance useless under current circumstances.

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Figure 3. Minimum, median and maximum number of satellites accessed in the different plots.

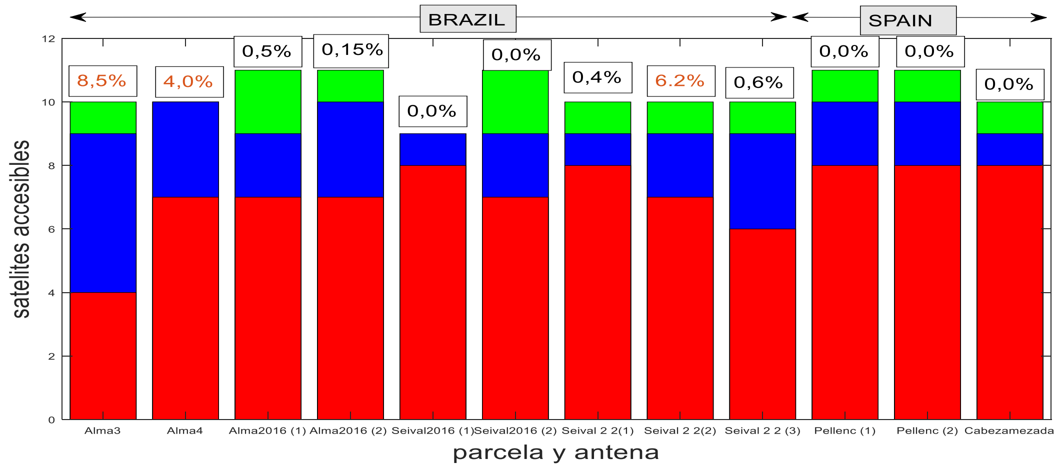

Table 2. Correlation Analysis

	Min. num. of Satellites (1)	Median num. satellites(2)	Max. num. of satellites(3)	GPSq (%)(4)	HDOP > tol. (5)	Median HDOP (6)	Average HDOP (7)	Maximum HDOP(8)
1	1.00							
2	0.26	1.00						
3	0.08	0.47	1.00					
4	-0.41	**-0.61**	-0.46	1.00				
5	**-0.74**	-0.17	-0.29	**0.71**	1.00			
6	-0.25	-0.43	-0.32	0.04	0.16	1.00		
7	-0.59	-0.52	-0.46	0.37	**0.66**	**0.82**	1.00	
8	**-0.88**	-0.11	-0.25	**0.82**	**0.80**	0.22	0.55	1.00