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Warsaw, 16-17 October

GNSS Analyses at the National Geographic Institute of Spain

Scientific projects and impact of including Galileo observables in the processing

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Goals:

Short introduction to IGE GNSS AC projects

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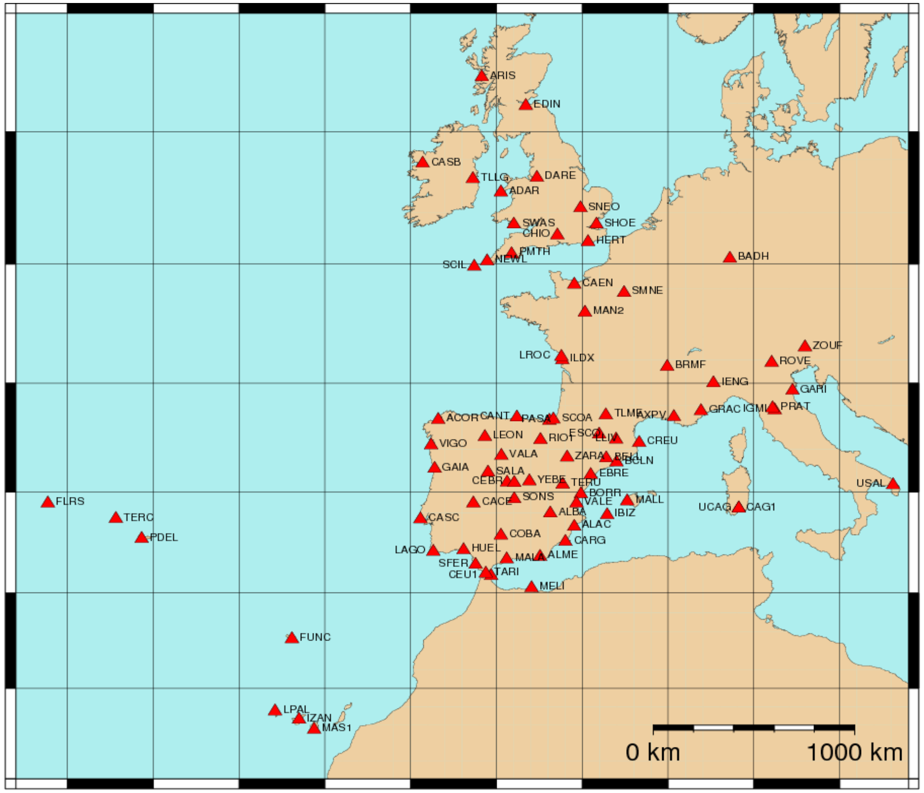
evaluation of the impact of GAL observations

- Precise coordinates
- Troposphere
- Ionosphere
- Reflectometry

Precise coordinate estimation: **EUREF AC**

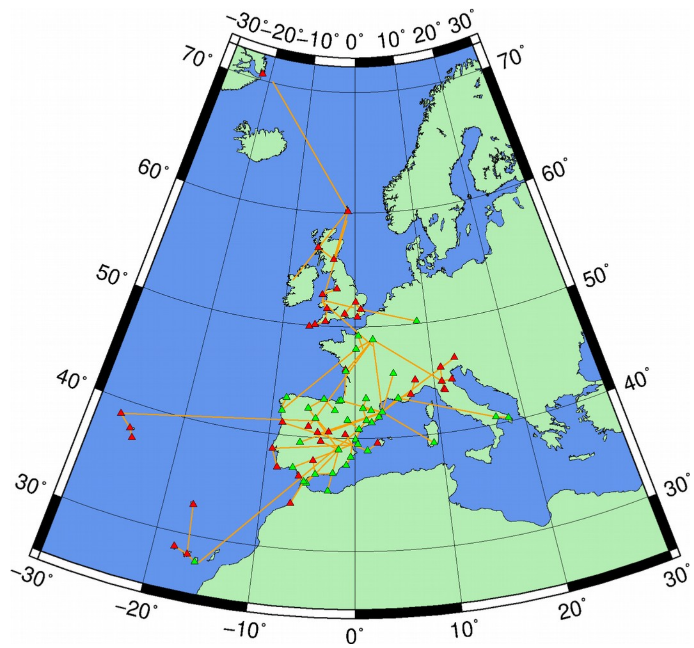
- BSW 5.2.
- Standard double-difference processing.
- Coordinates and troposphere parameters.
- 90 EPN stations (29 IGN).
- 32 individual calibration.
- Daily solutions using rapid and final orbits (latency of 1 day and 3 weeks resp.).
- Recent change: **GALILEO observations included operationally** since Wk 2044.
- EPN densification -> IBERRED



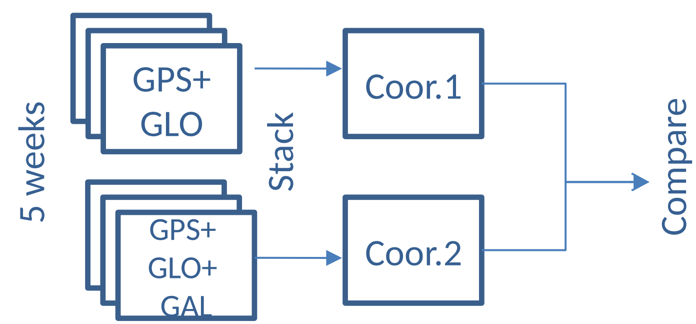
EUREF processing with and without GAL

Assesment of the impact of including GAL obs in the processing:

- Two campaigns (5 weeks, from 2034 to 2038).
- 89 stations (45 G+R, 44 G+R+E)
- Same configuration, only one difference: GPS+GLO observables or GPS + GLO + GAL observables.
- Baseline formation was forced. 1st processing max observation criterion + GAL observables. 2nd processing the same baseline configuration.
- Daily coordinates for both campaings were obtained and **stacked** to obtain the final coordinates of each station for each campaign.



Baselines in yellow; Stations with GALILEO in green; Stations without GALILEO in red



EUREF processing with and without GAL

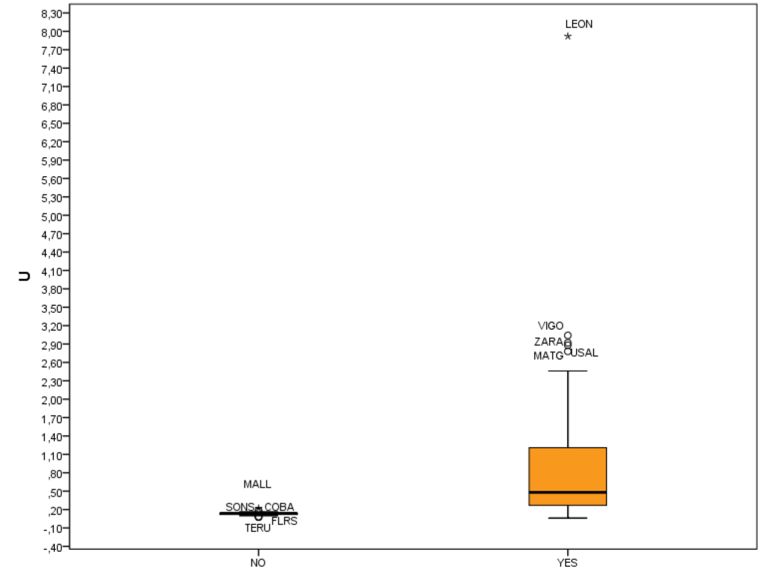
Coordinate differences were analysed:

An exploratory data analysis of the absolute value of the differences in each component (North, East and Up) was done. Results show:

- In **north and east components** these differences are **insignificant** in the most of the stations (below 0.2 mm).

- In the **up component** these differences become more important. In stations with GAL obs the mean is 0.99 mm (st error 0.21, median 0.48) . Stations without GAL are not affected by its inclusion in the campaign, as expected.

Up component (mm)

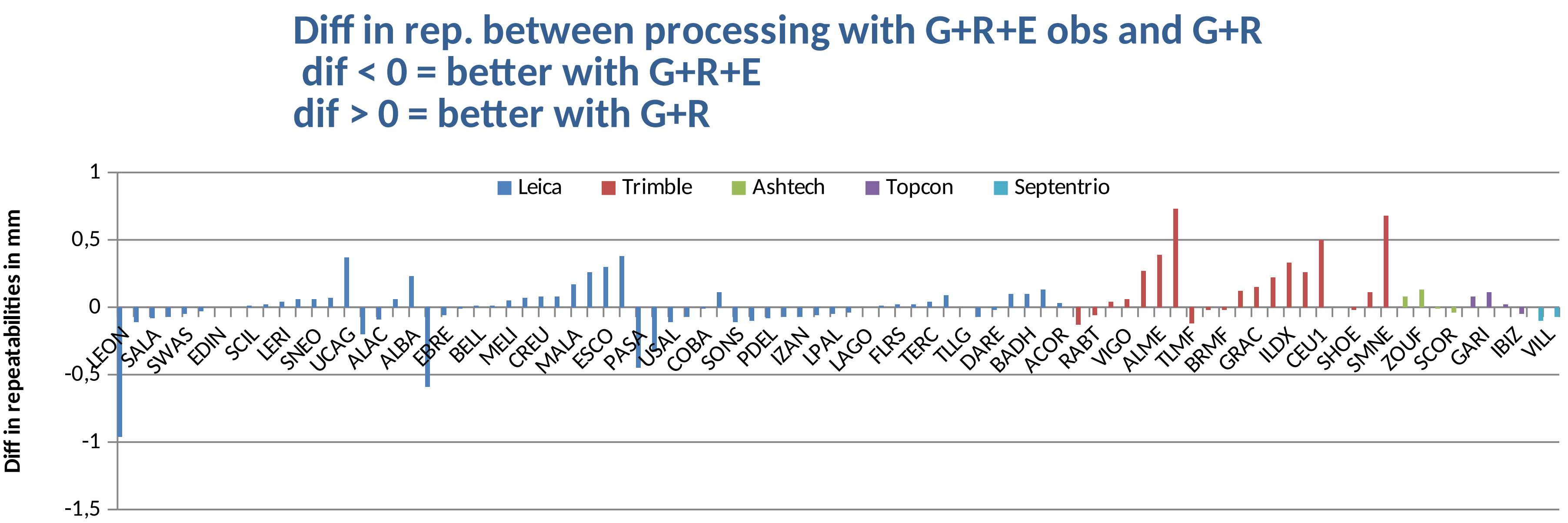


Descriptives

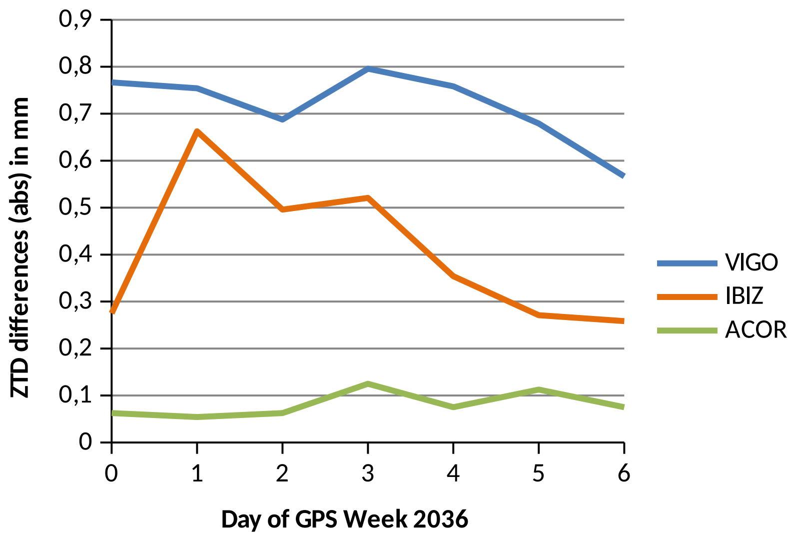
	Galileo			Statistic	Std. Error
U	NO	Mean		,1302	,00425
		95% Confidence Interval for Mean	Lower Bound	,1217	
			Upper Bound	,1388	
		5% Trimmed Mean		,1293	
		Median		,1400	
		Variance		,001	
		Std. Deviation		,02848	
		Minimum		,08	
		Maximum		,22	
		Range		,14	
		Interquartile Range		,02	
		Skewness		,446	,354
		Kurtosis		1,212	,695
	YES	Mean		,9941	,20634
		95% Confidence Interval for Mean	Lower Bound	,5780	
			Upper Bound	1,4102	
		5% Trimmed Mean		,8095	
		Median		,4800	
		Variance		1,873	
		Std. Deviation		1,36868	
		Minimum		,06	
		Maximum		7,92	
		Range		7,86	
		Interquartile Range		,99	
		Skewness		3,383	,357
		Kurtosis		14,839	,702

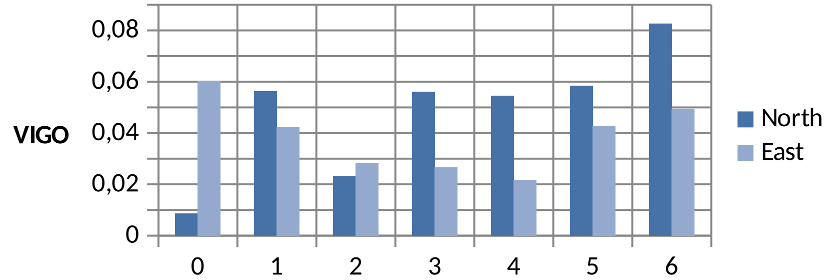
EUREF processing with and without GAL

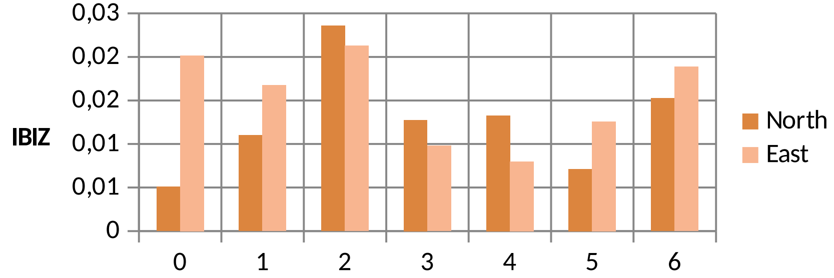
Weekly repeteability (week 2036) in up component:

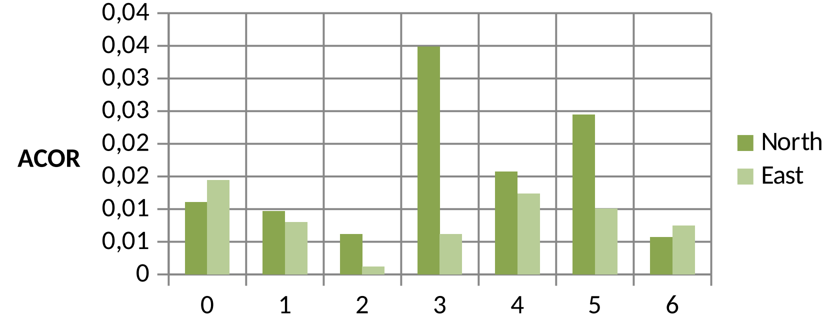


EUREF processing with and without GAL





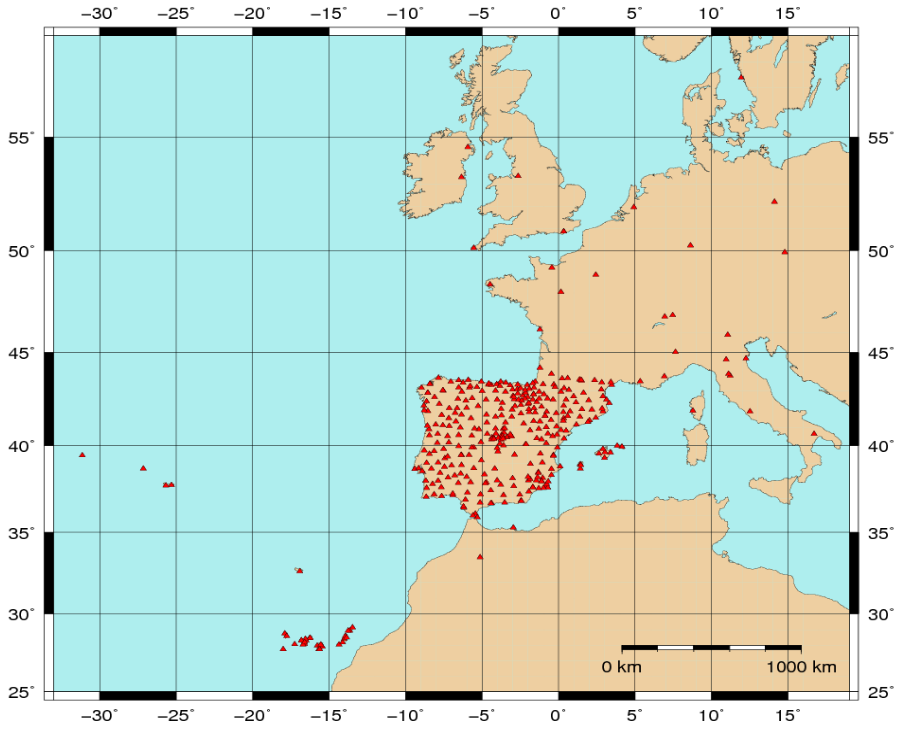




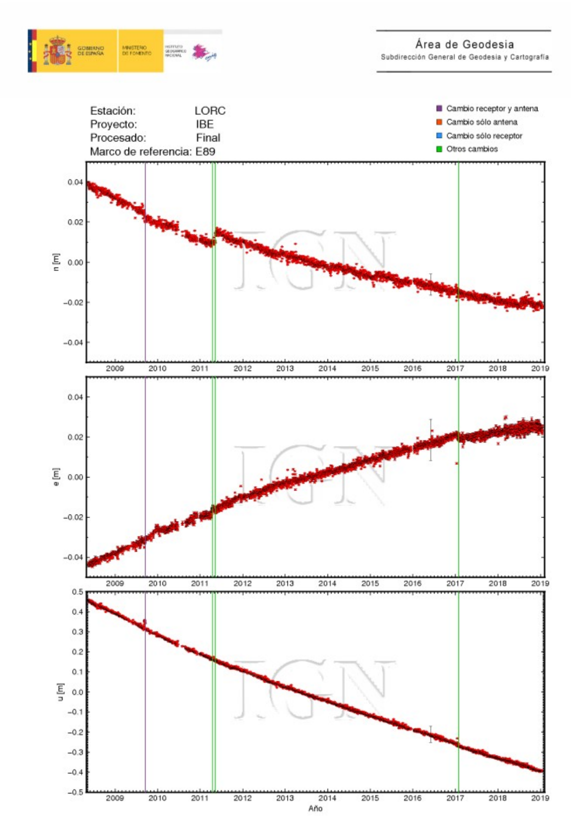
- No relevant variations in ZTD were found. In the most of the cases these variations are less than 1 mm.
- The influence in gradients seems to be slightly bigger. Variations of 8% of the gradient value were found in some stations, but the results are highly station dependent.

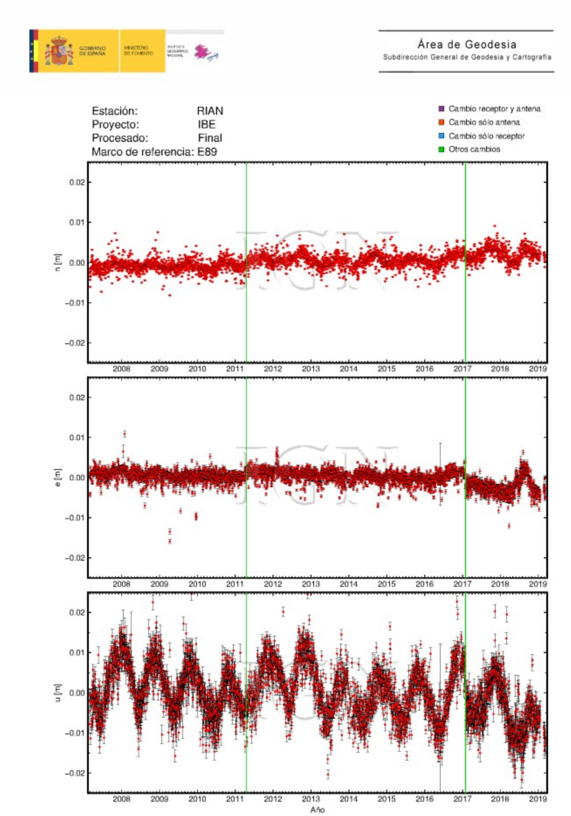
Precise coordinate estimation: **IBERRED**

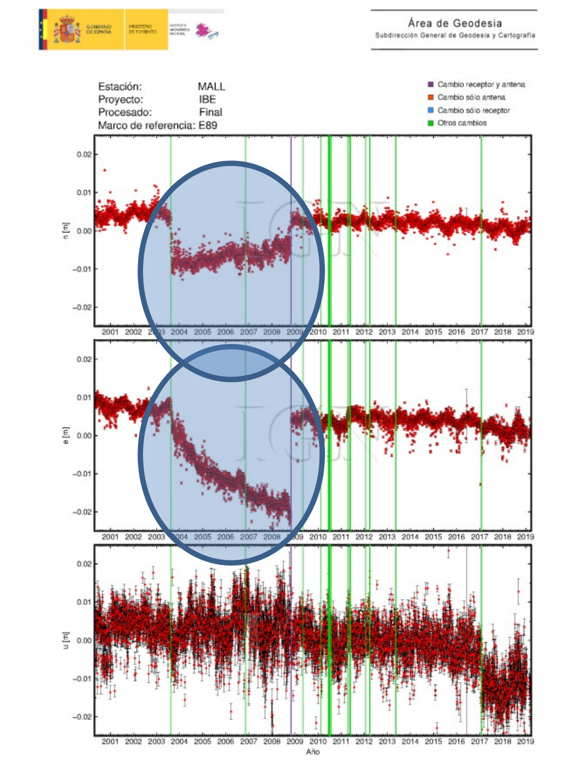
- EPN-D.
- Products: coordinates, time series, velocities.
- Around 400 stations.
- EPN + IGN + 12 regional networks + Portugal (IGP)…
- Finished a complete reprocessing from 2000-2019.
- Same processing options as EUREF LAC processes. Cluster configuration.



IBERRED products (I): Time series

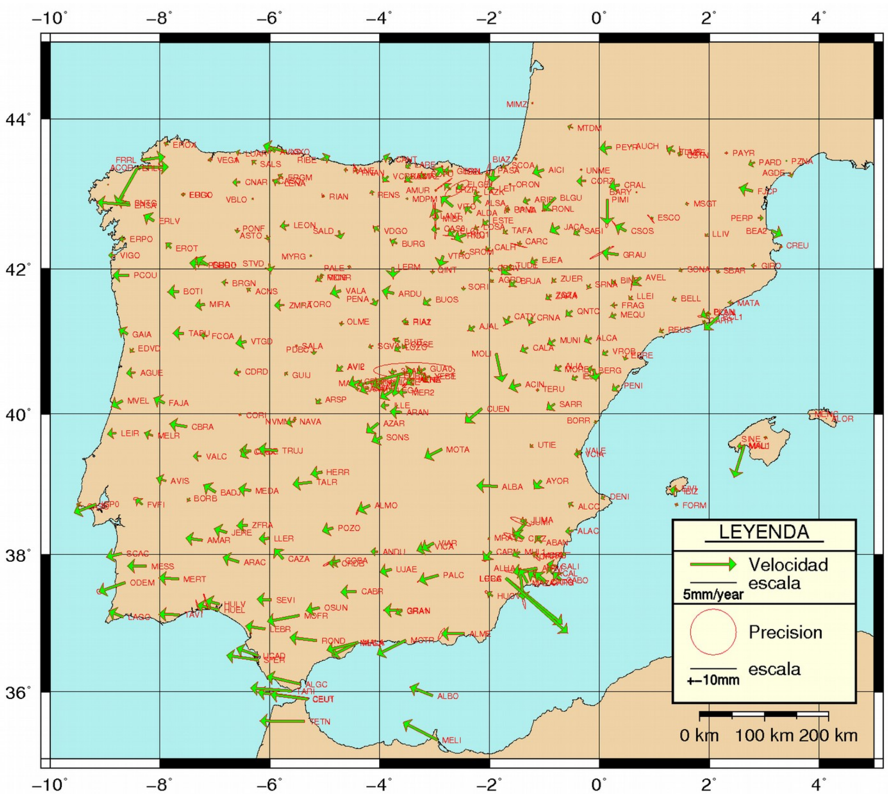




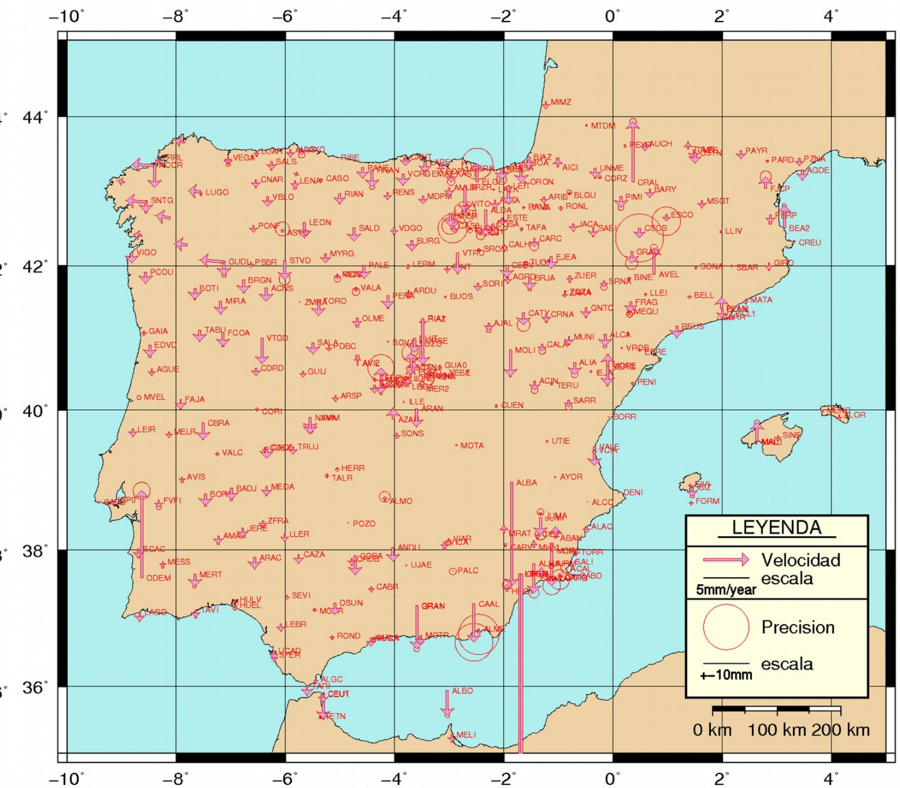


- Subsidences
- Seasonal effects
- …

IBERRED products (II): Velocities estimation (CATS, S. Williams)



Horizontal ETRF00 velocities



Vertical ETRF00 velocities

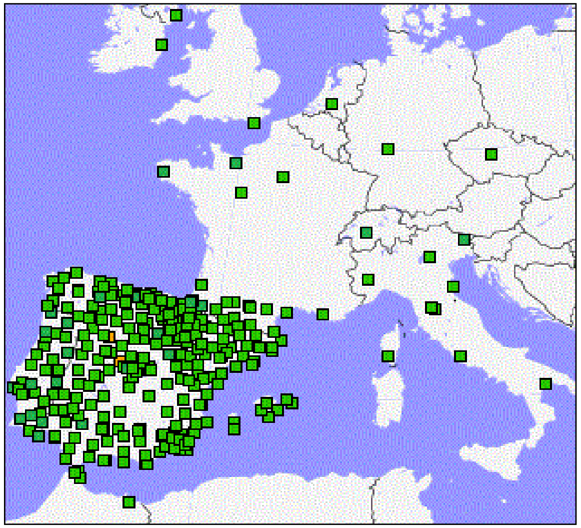
IBERRED: GAL obs impact?

Testing the impact of Galileo observables in this project is not possible at the moment, because of the lack of RINEX 3 production in the majority of the stations.

Currently only around 20% of the stations are submitting RINEX 3 format. In the future, one of the main goals is to encourage the institutions to produce these files and adding Galileo to the processing.

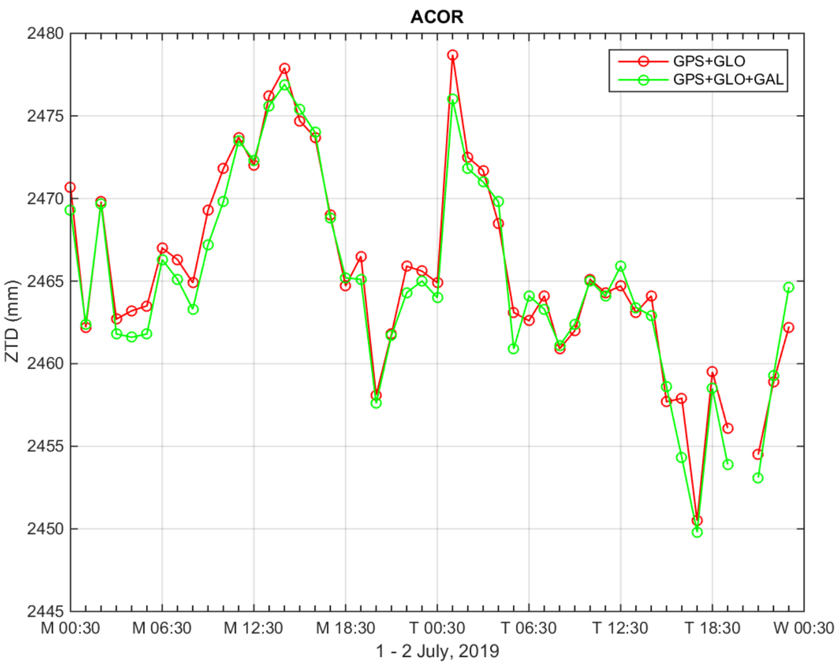
Troposphere estimation: **EGVAP**

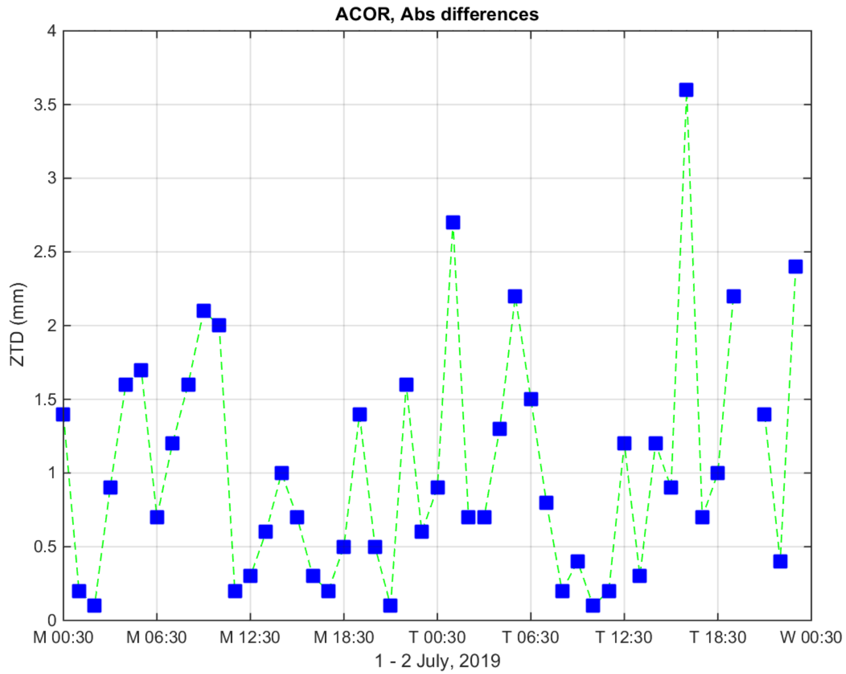
- EUMETNET project: IVW in «near real time» for meteorological forecast.
- Iberian area and «supersites» for validation.
- Almost same stations EPN-D (~400).
- Hourly processing using coordinates from IBERRED process.
- Results: ZTD hourly files 15 min sampling in COST2.2 format.



From: E-GVAP web (egvap.dmi.dk)

EGVAP processing with and without GAL



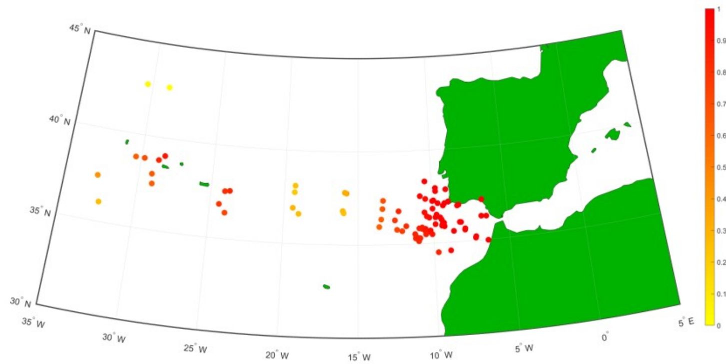


- Two parallel processings with and without Galileo .
- The baselines have been forced to minimize the network effect.
- Ultra-rapid orbits have been used and ZTD has been estimated hourly (at 15 min rate) during a week.
- No relevant differences. The 95% confidence interval for the mean of the ZTD differences in the stations with Galileo is (0.95, 1.34) mm, but further analysis will be necessary because of the highly station and weather dependence.

GNSS for National Tsunami Warning System: Cantavella, J.V., Herraiz, M., Puente, V., González-López, A., Gaite, B., Azcue, E. , González, C. (2019) **"Tsunami ionospheric disturbances detected by GNSS derived data. Prototype implementation in the Spanish National Tsunami Warning System." Pure and applied geophysics** (In press)

Ionosphere monitoring: **GNSS for tsunami warni**

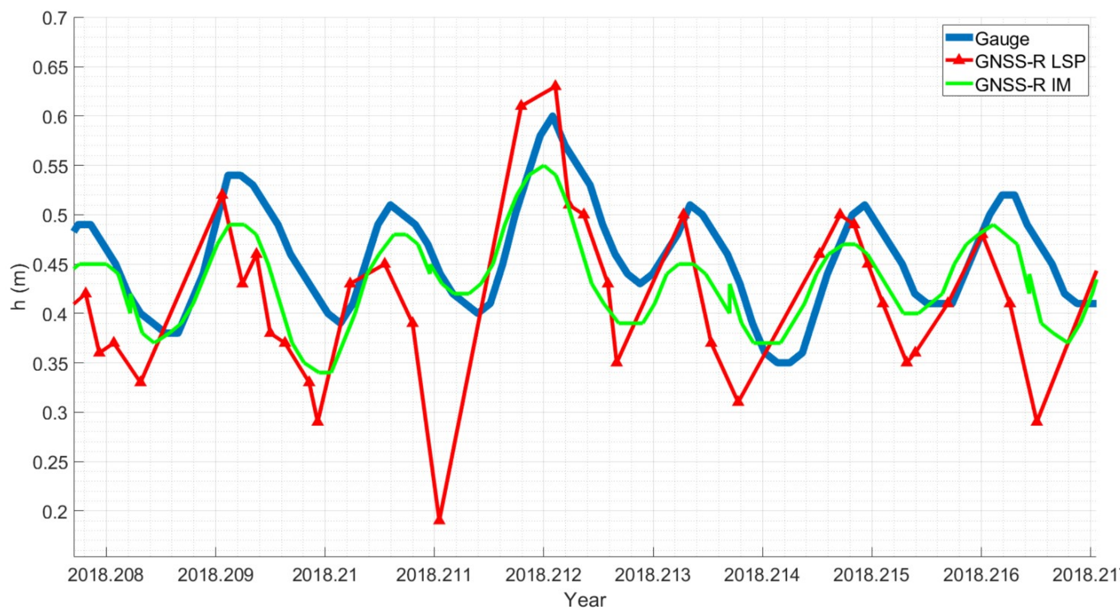
- **Earthquakes and tsunamis,** perturb the electronic **Ionospheric Disturbances** (TID) **can be remotely detec**
- Integration of the GNSS data into the Spanish Natio verification of the occurrence of a tsunami before the
- Detecting TID -> The **ionospheric pierce point (IPP).** Th probable the tsunami detection will be.
- Adding Galileo observations to the system directly increases the number of IPP.
- Mean probability [0-1] of having at least two IPP for each surrounding fault to the Iberian Peninsula . 7 min after an earthquake within 100 km of the epicentre and in view for 30 minutes using **only GPS is 0.76** whereas **adding Galileo** constellation **increases to 0.82**.



GNSS reflectometry: **GNSS for sea level monito**

GNSS-R: Puente V., Valdés M. (2019) **“Sea level determination in the Spanish coast using GNSS-R”.** Proceedings II Congreso en Ingeniería y Geomática.

- Comparison between direct and reflect signal
- Importance: connect sea level measurements with T
- Previous steps: Define az/el of interest, extract SNR from RNX, select satellites that fullfill az/el conditions, convert SNR to l
- LSP (Lomb-Scargle Periodog
- IM (inverse modelling), mu
- Comparisons with radar tide accuracy and correlation.



Thank you very much.
Any questions?

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