Centre of Space Techniques

EGNOS Performance in Algeria: Real and Simulation Studies

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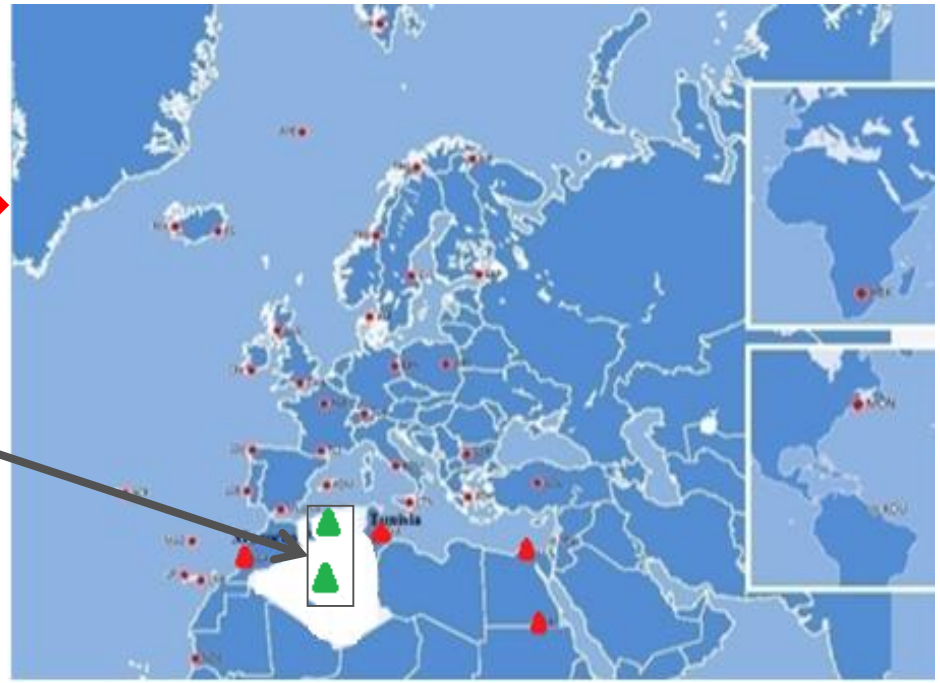
Motivations

The project of **RIMS stations** (Ranging and Integrity Monitoring Station): The interest of these stations is to ensure a good coverage mainly in the Algerian territory, and allows to extend the EGNOS service.

- Need for setting up of RIMS station in Algeria.
- **EUROMED** international project in collaboration with the Algerian Ministry of Transport and the European Commission, with the support of **Algerian Space Agency (ASAL**).

Performance (**accuracy and integrity**)of the EGNOS system without RIMS station at different sites in Algeria.



2 RIMS stations in Algeria→ 2019

- APV-1 availability.
- Grid Ionospheric Vertical Error (GIVE).

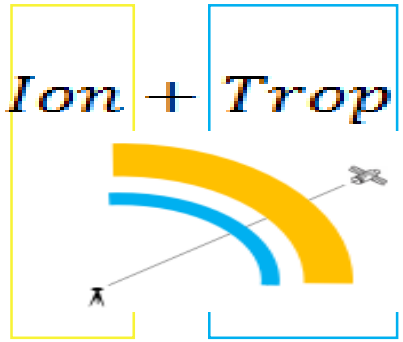
Outline

- Work Context
- GPS accuracy without and with EGNOS
- Performance analysis of the system (integrity & availability)
- Feasibility study & optimal choice of RIMS stations
- Conclusion

Work Context: GNSS Limitations

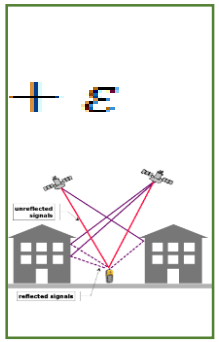
GNSS systems allow to give a position by using satellites constellations.

$$P = \rho + c(dt_r - dt_s) + Ion + Trop + Rel + RDCB_L + SDCB_L + \varepsilon$$

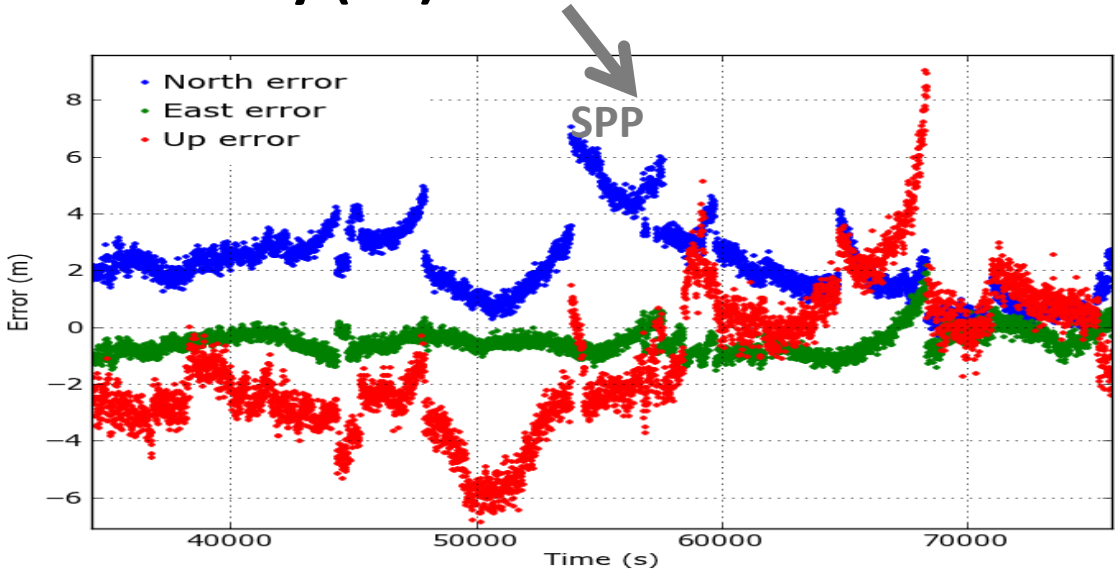


Relativistic correction

Instrumental errors



Accuracy (RT) → 10 m



Problem:

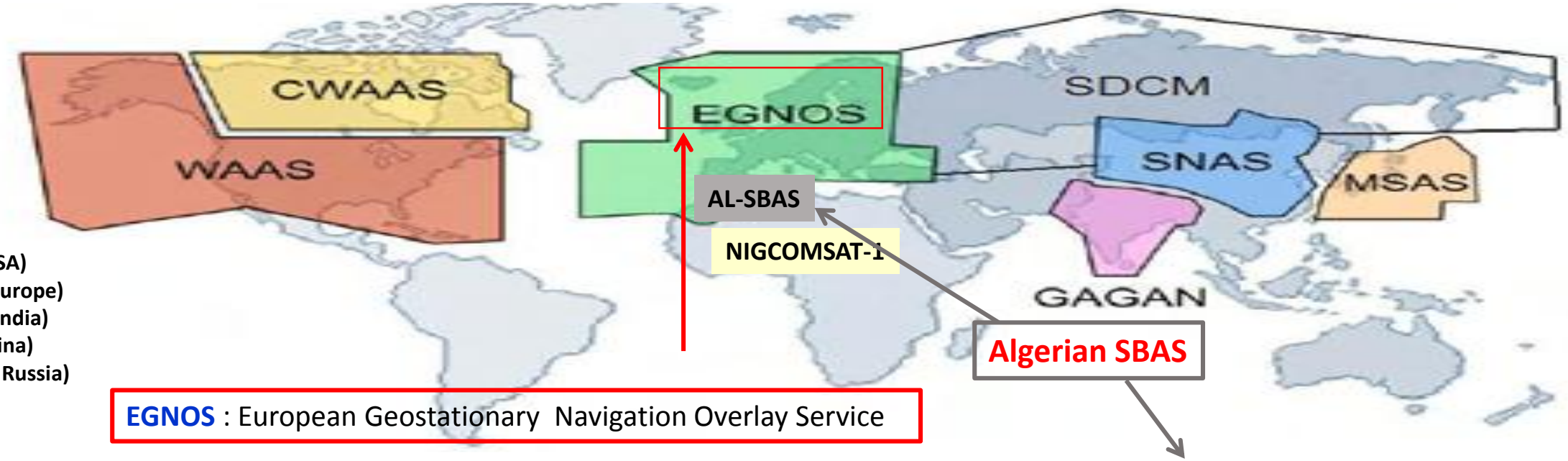
Insufficient accuracy and Integrity (reliability of information), for RT positioning, particularly for civil aviation applications.

Satellite Based Augmentation Systems (SBAS)

Work Context: Solution SBAS

⇒ Augmentations (SBAS) which are necessary to improve the performance → Navigation systems by geostationary coverage.

❑ **SBAS : geostationary satellites (2-3) + RIMS network (EGNOS: 39)**



WAAS (USA)
EGNOS (Europe)
GAGAN (India)
SNAS (China)
SDCM (la Russia)

EGNOS : European Geostationary Navigation Overlay Service

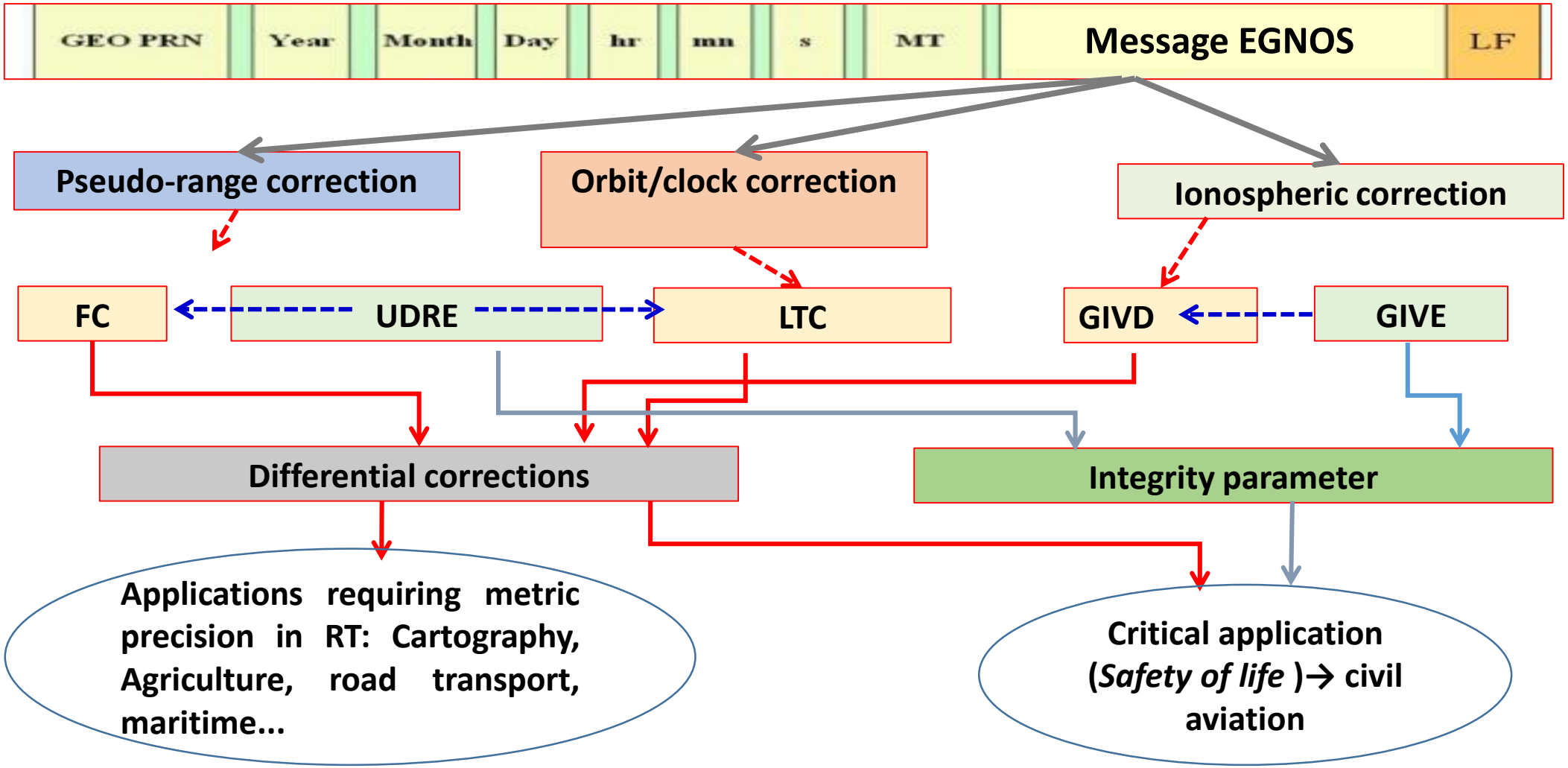
ALCOMSAT-1, launched in December 11, 2017 (PRN 148)→ ASAL.

Principal objectives:

- Improve the accuracy of GNSS systems (differential correction message);
- Inform users about GNSS malfunctions (integrity message).

Precision concept

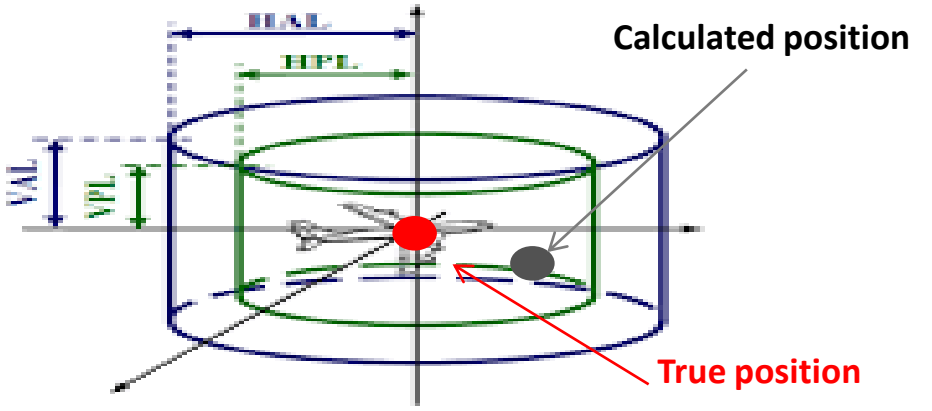
EGNOS transmits messages on the L1 band (1575.42 MHz) → The raw navigation message of EGNOS contains 250 bits, transmitted each second.

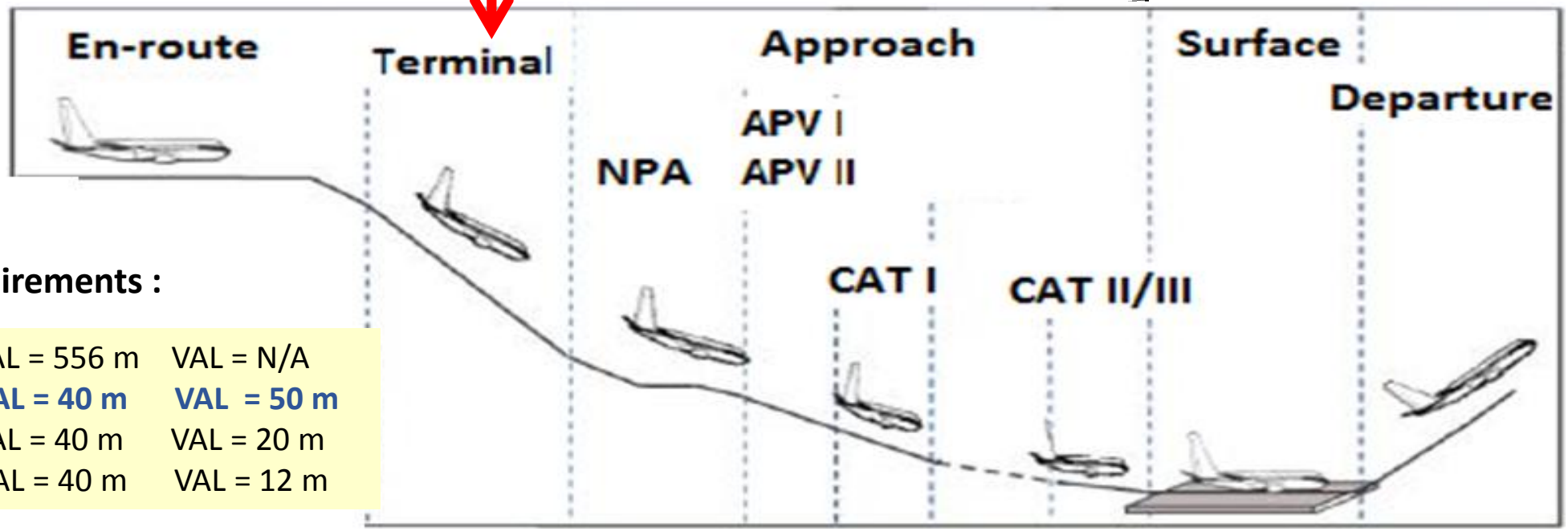


Integrity concept

Integrity is a measure of confidence in information provided by the system.

- ❑ Position error PE;
- ❑ Protection level PL;
- ❑ Alarm limit AL.



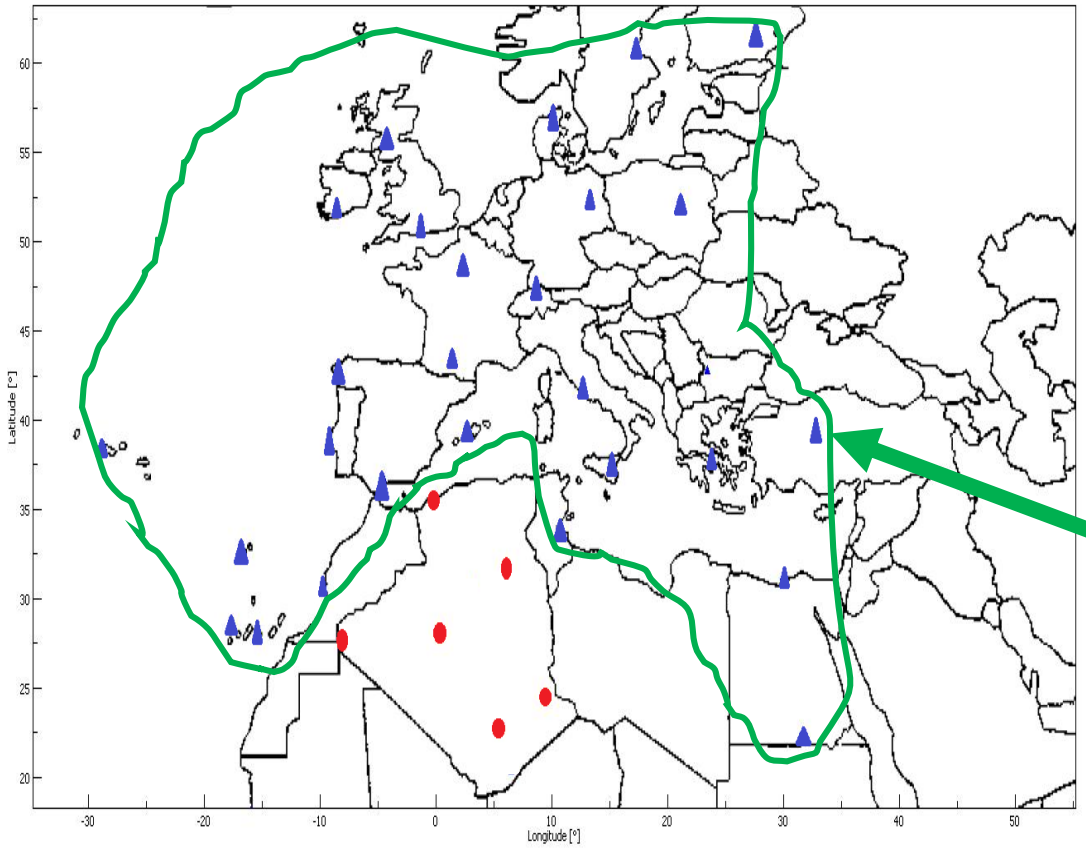


ICAO Requirements :

–NPA	HAL = 556 m	VAL = N/A
–APV I	**HAL = 40 m**	**VAL = 50 m**
–APV II	HAL = 40 m	VAL = 20 m
–Cat I	HAL = 40 m	VAL = 12 m

GPS accuracy without and with EGNOS

Current performance in terms of accuracy and integrity of EGNOS system without RIMS station at selected sites in Algeria → geodetic multi frequency receiver.

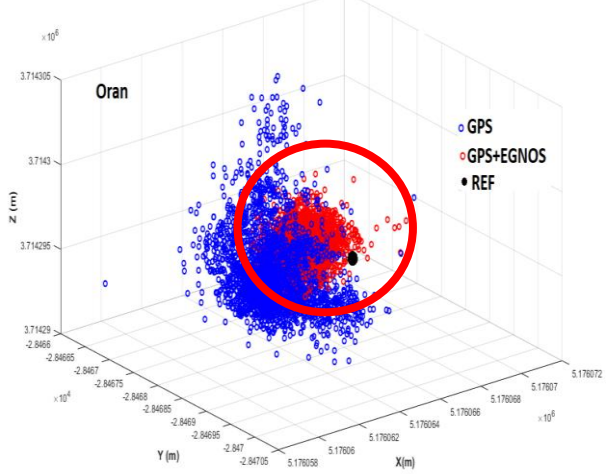


Sites	Latitude (°)	Longitude (°)
Oran	35.50°	-0.18°
Hassi Messaoud	31.76°	6.05°
Adrar	28.12°	0.32°
Tindouf	27.66°	-8.14°
Djanet	24.48°	9.52°
Tamanrasset	22.81°	5.52°

Assessment on the impact distance between each site and EGNOS RIMS station network in Algeria.

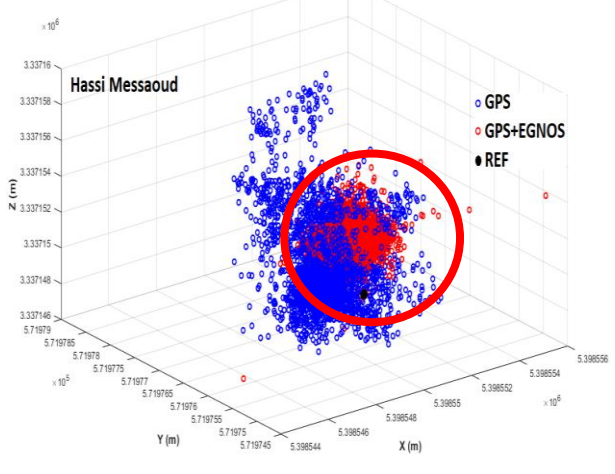
Analysis of Positioning Accuracy in Algeria

Lat: 35.50°



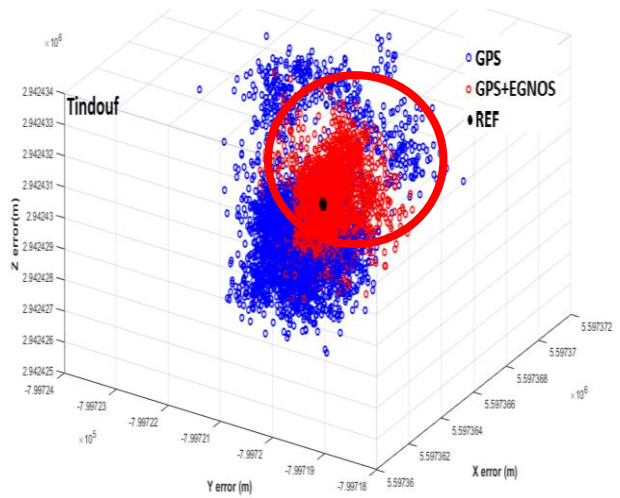
Std GPS : X(1.03), Y(0.44) and Z(1.17)
Std (GPS+EGNOS): X(0.71), Y(0.30) and Z(0.59)

Lat: 31.76°



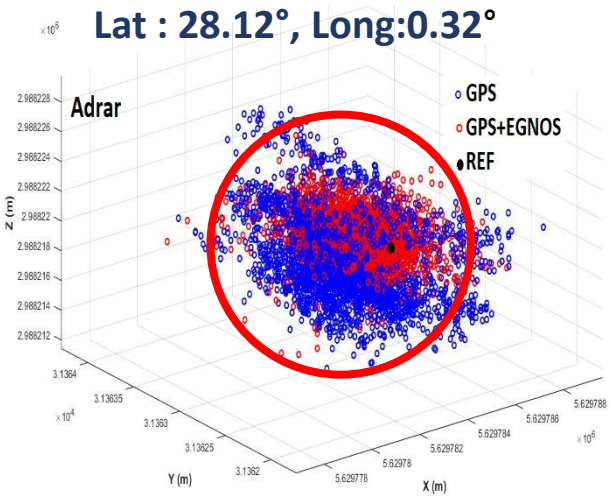
Std GPS : X(1.03), Y(0.46) and Z(1.50)
Std (GPS+EGNOS): X(0.81), Y(0.28) and Z(0.72)

Lat : 27.66°, Long: -8.14°



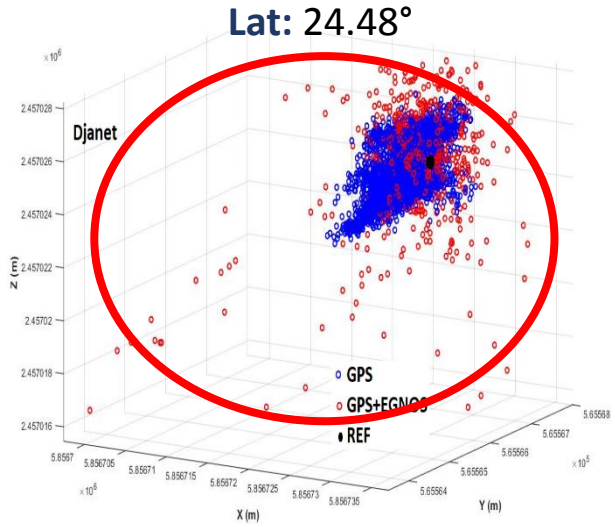
Std GPS : X(1.29), Y(0.58) and Z(1.71)
Std (GPS+EGNOS): X(0.75), Y(0.35) and Z(0.76)

Lat : 28.12°, Long:0.32°



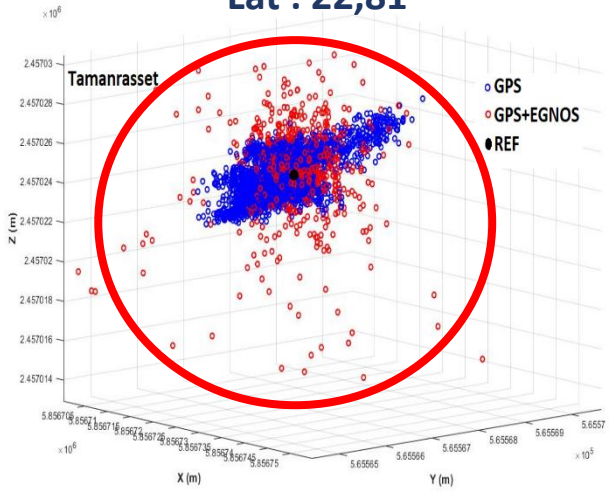
Std GPS : X(1.21), Y(0.55) and Z(1.71)
Std (GPS+EGNOS): X(1.44), Y(0.53) and Z(1.63)

Lat: 24.48°



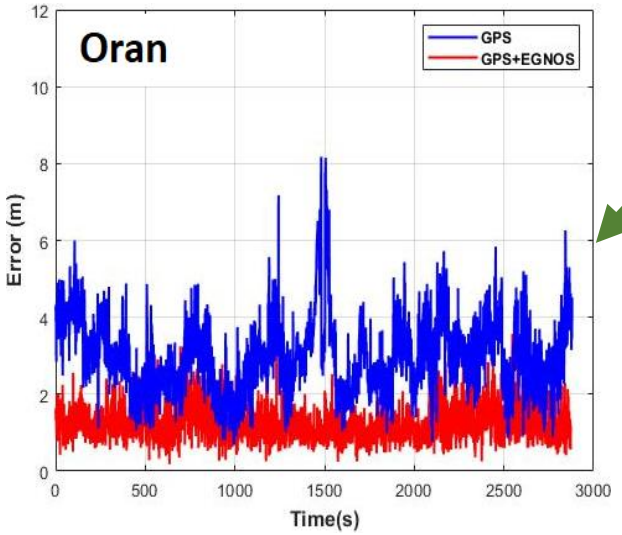
Std GPS : X(1.25), Y(0.63) and Z(1.20)
Std (GPS+EGNOS): X(4.10), Y(1.43) and Z(12.90)

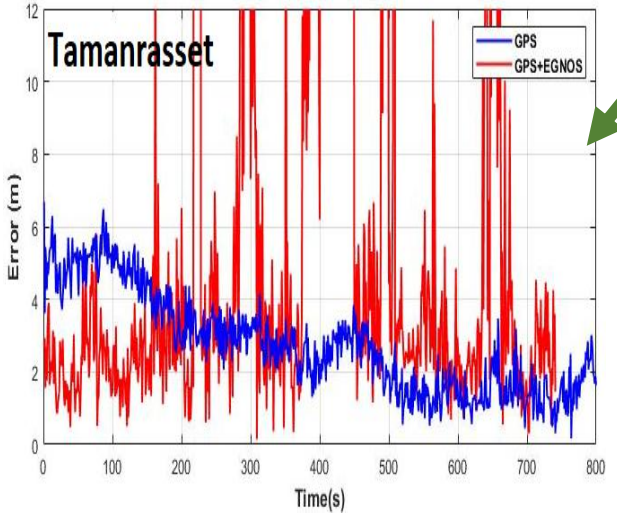
Lat : 22,81°



Std GPS : X(1.33), Y(0.64) and Z(1.10)
Std (GPS+EGNOS): X(38.69), Y(7.19) and Z(18.14)

3D positioning accuracy (GPS& GPS+EGNOS)

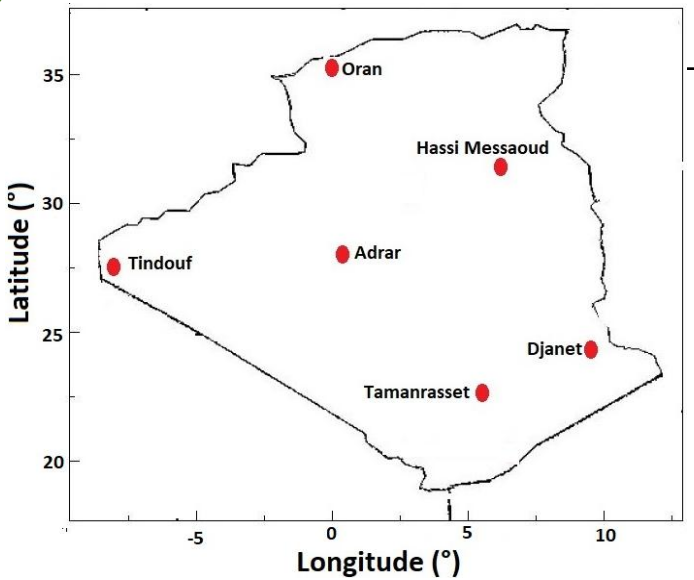




Site	GNSS	3D Positioning Error (m)			
		HPE 95% (m)	VPE 95 % (m)	A3D (m)	3D RMS(m)
Oran	GPS	2.30	3.83	2.83	2.99
	GPS+EGNOS	1.07	1.61	1.21	1.30
Hassi Messaoud	GPS	3.19	4.03	2.40	2.65
	GPS+EGNOS	1.31	1.85	1.60	1.82
Adrar	GPS	4.23	3.86	2.74	2.97
	GPS+EGNOS	2.44	2.5	1.66	2.39
Tindouf	GPS	4.46	4.03	3.00	3.21
	GPS+EGNOS	1.66	1.90	1.23	1.35
Djanet	GPS	3.44	4.17	2.81	3.03
	GPS+EGNOS	8.20	4.10	4.16	13.86
Tamanrasset	GPS	3.05	4.44	2.76	3.00
	GPS+EGNOS	13.79	28.94	11.05	43.72

A3D : Average 3D Positional Error (m)

3D RMS : 3D root mean square

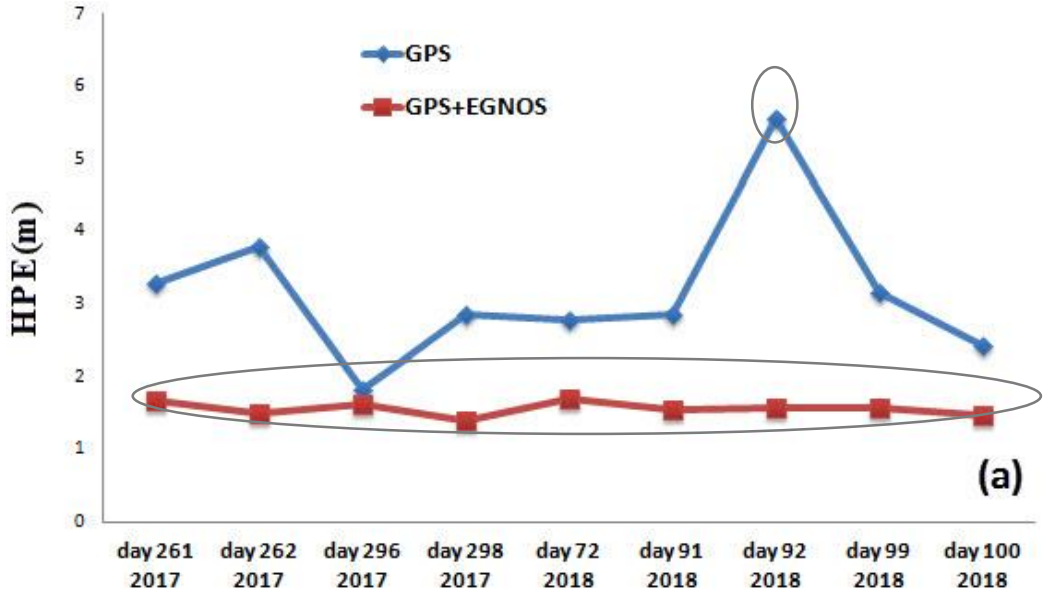


The accuracy depends on the location of each site, in particular on the latitude and longitude.

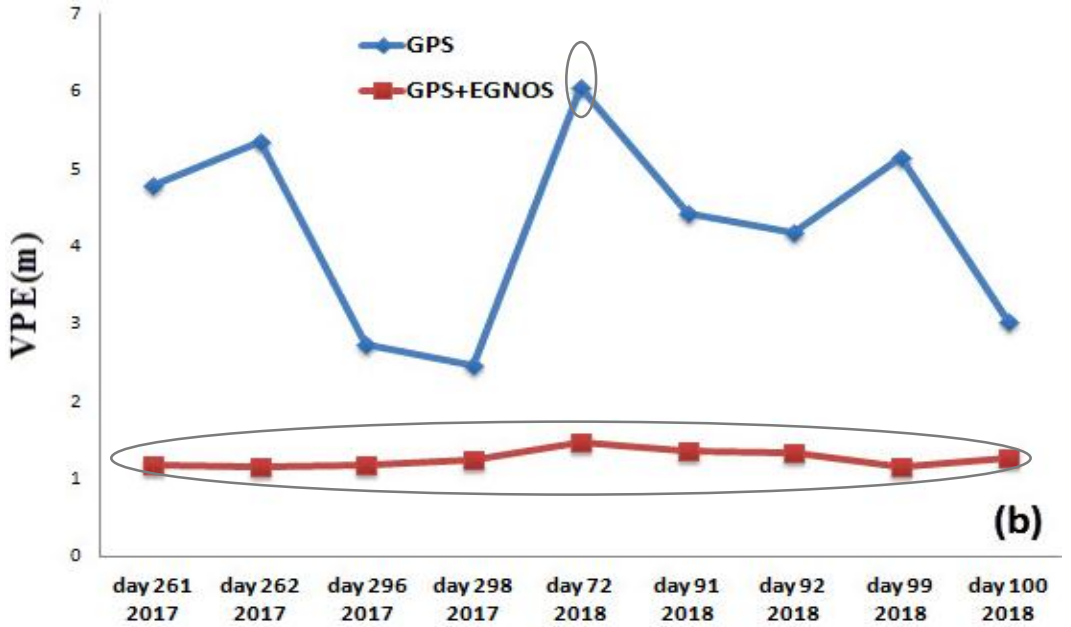
The accuracy using EGNOS corrections degrades with the distance between each site and the RIMS network

Temporal performance of EGNOS on Oran site

Horizontal



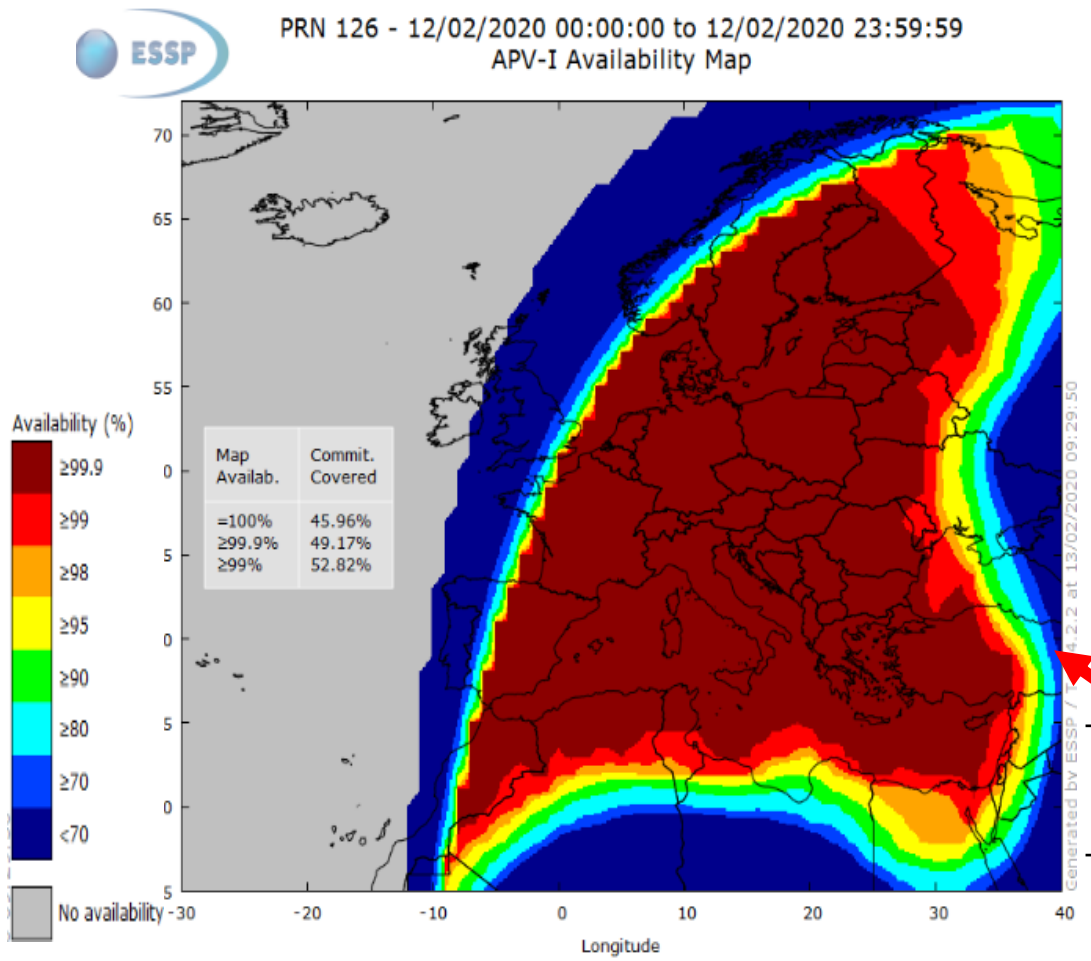
Vertical



- HPE **(+ EGNOS corrections)** < **than 2 m**, however, in case of **(+GPS),** HPE range between **1.80 and 6 m.**
- VPE **(+ EGNOS corrections)** average of **1.5 m**, while **(+ GPS)** VPE **Є [2.5, 7].**

Improvement of a single frequency GPS positioning performance based on EGNOS corrections in Algeria.
Journal of Navigation, 2020, Cambridge University, UK. DOI:10.1017/S037346331900095X.

Availability of the EGNOS system in Algeria



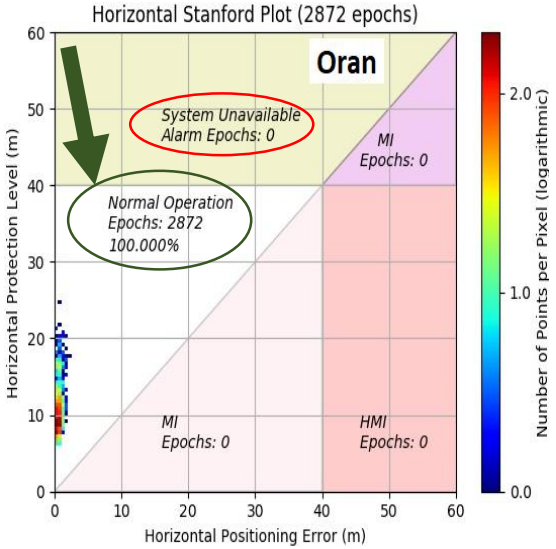
The systems satisfied the APV-I availability performance requirements at Oran site.

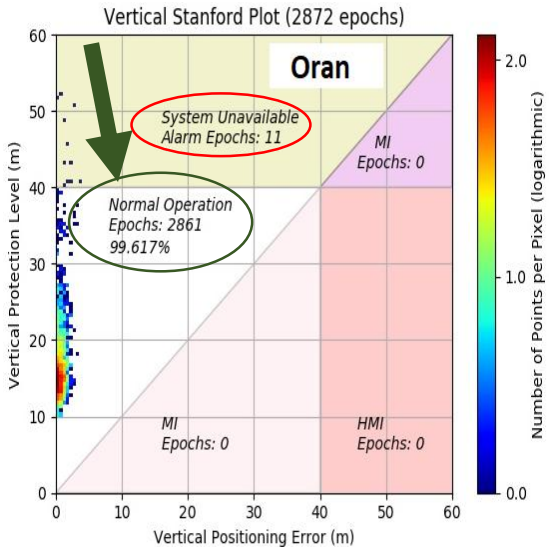
Sites	Availability		
	APV I	LPV200	APV II
Oran	99.92 %	99.44 %	93.18%
Hassi Messaoud	96.96%	94.03%	77.84%
Adrar	78.40%	70.77%	45.25%
Tindouf	99.38	98.42%	83.81%
Djanet	10.85 %	3.61%	0.83%
Tamanrasset	5.90%	3.82 %	2.29%

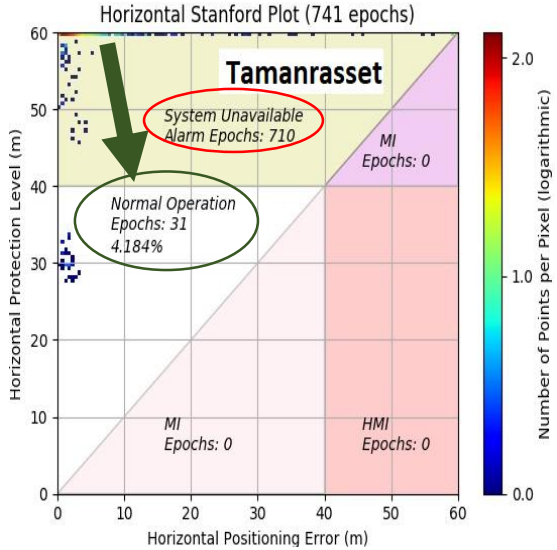
https://egnos-user-support.essp

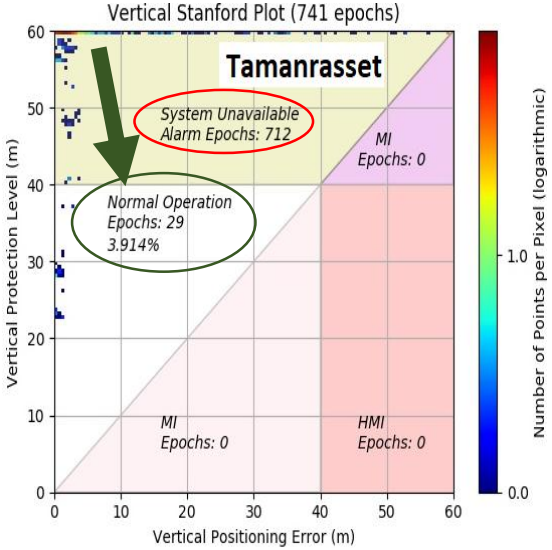
The horizontal and vertical availability in APV I for the six sites are comparable to those obtained by the official EGNOS site.

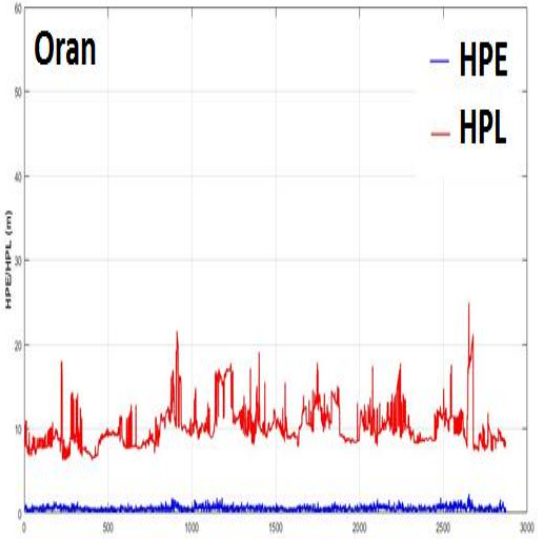
Integrity of the EGNOS system (Oran & Tamanrasset)

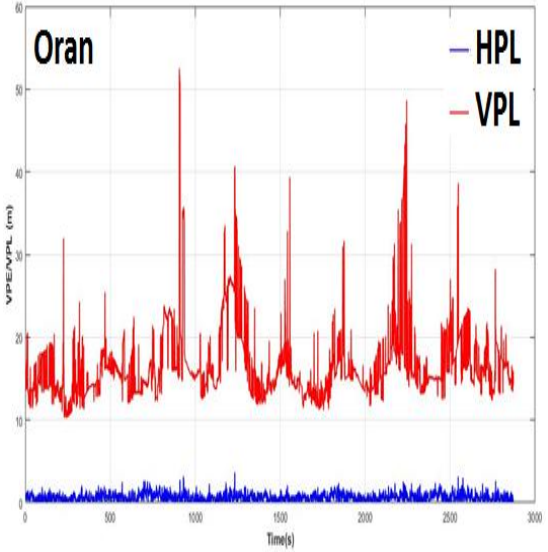


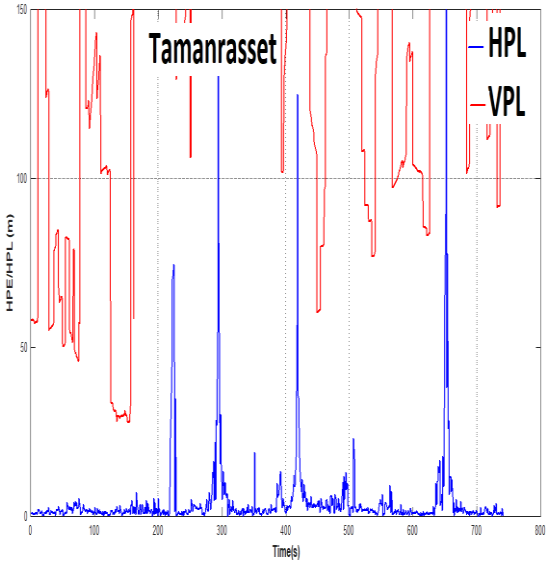


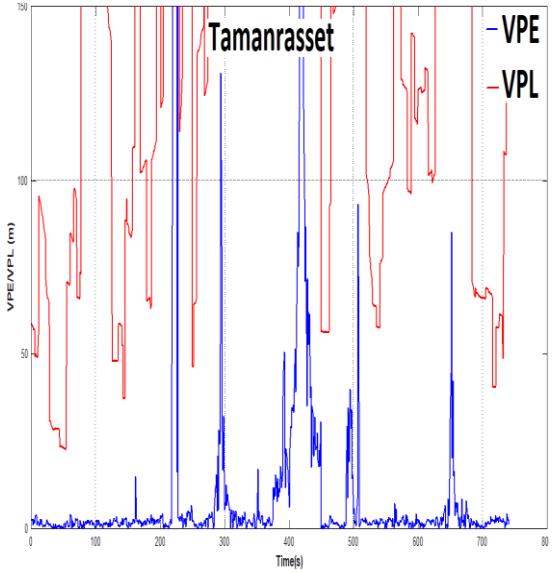








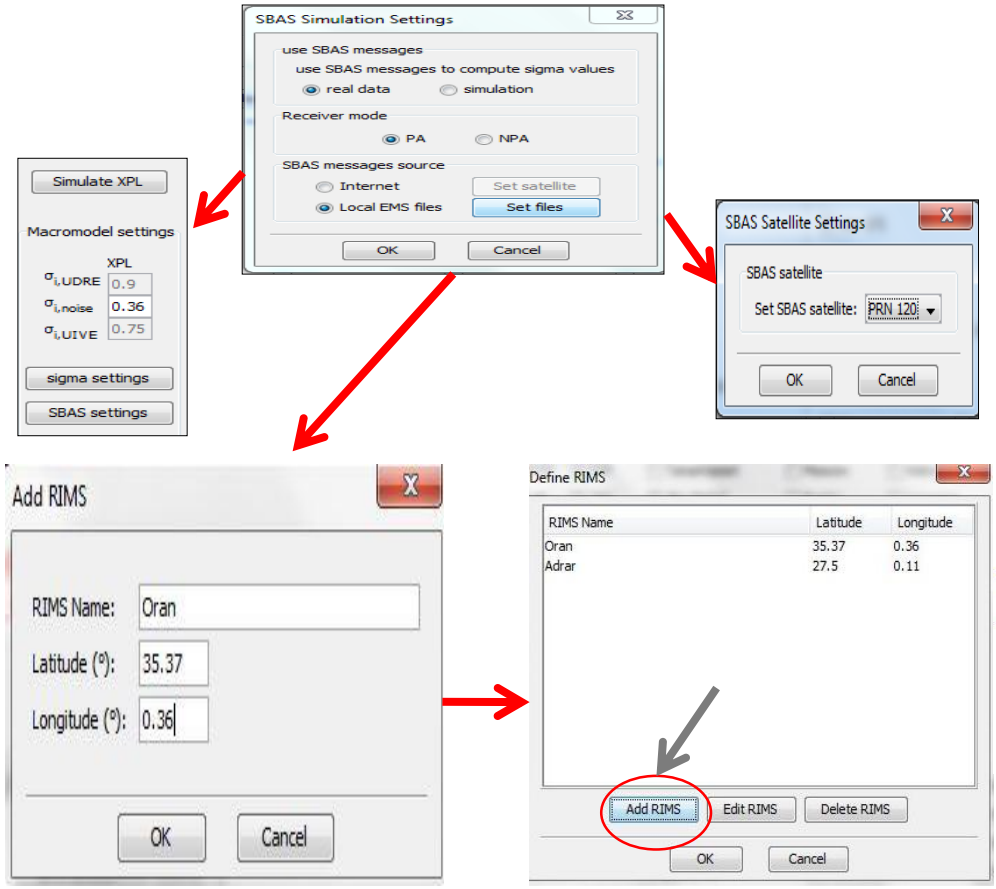




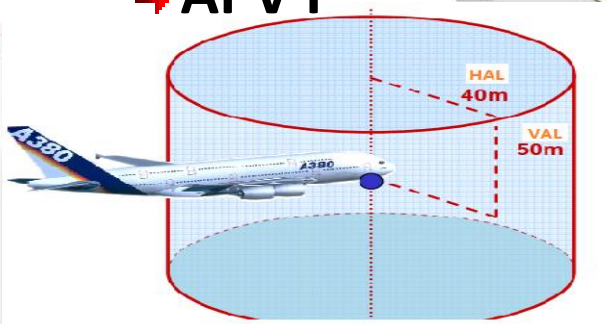
Integrity : Accuracy < Protection Limit < Alarm limit

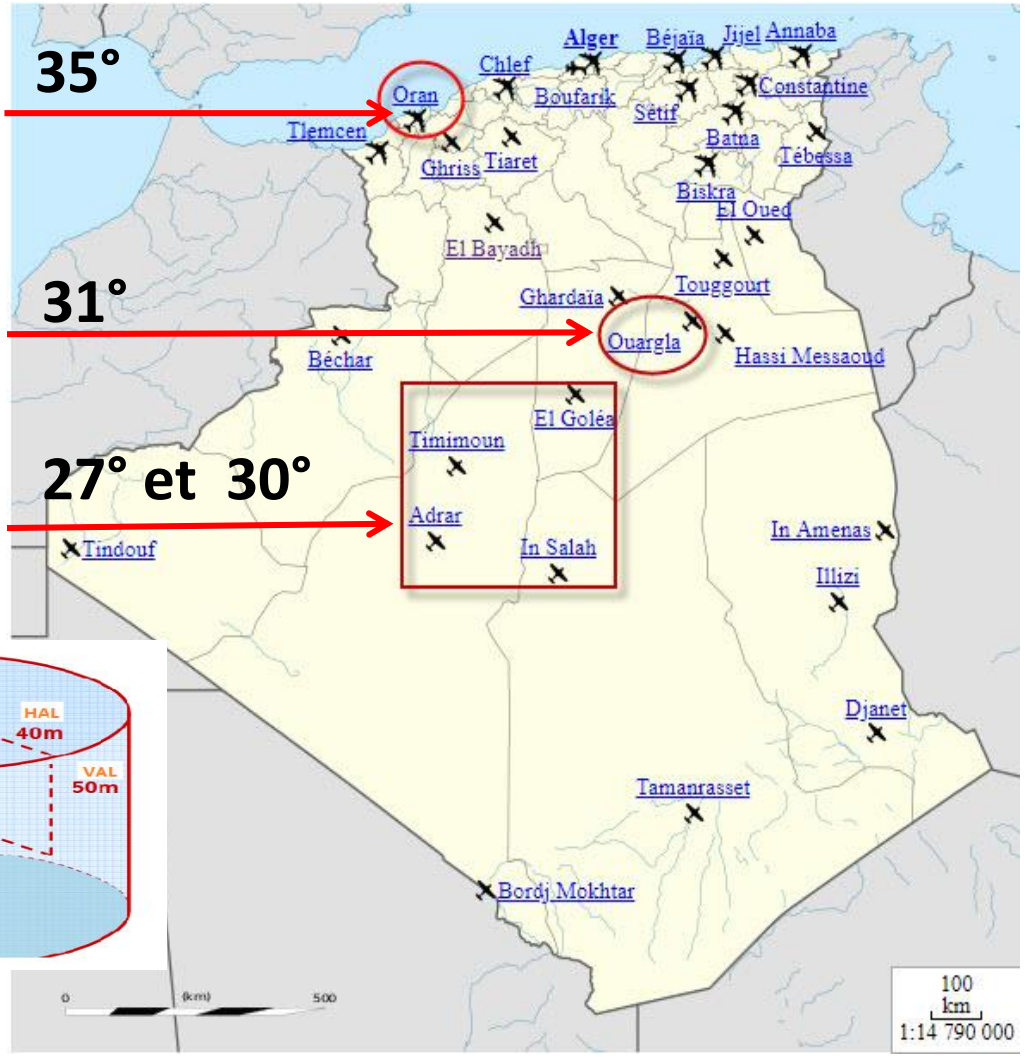
Feasibility study and simulation of optimal choice of RIMS stations in Algeria

Improvement of EGNOS extension by adding two RIMS stations in Algeria +39 RIMS.



➡ **APV I**

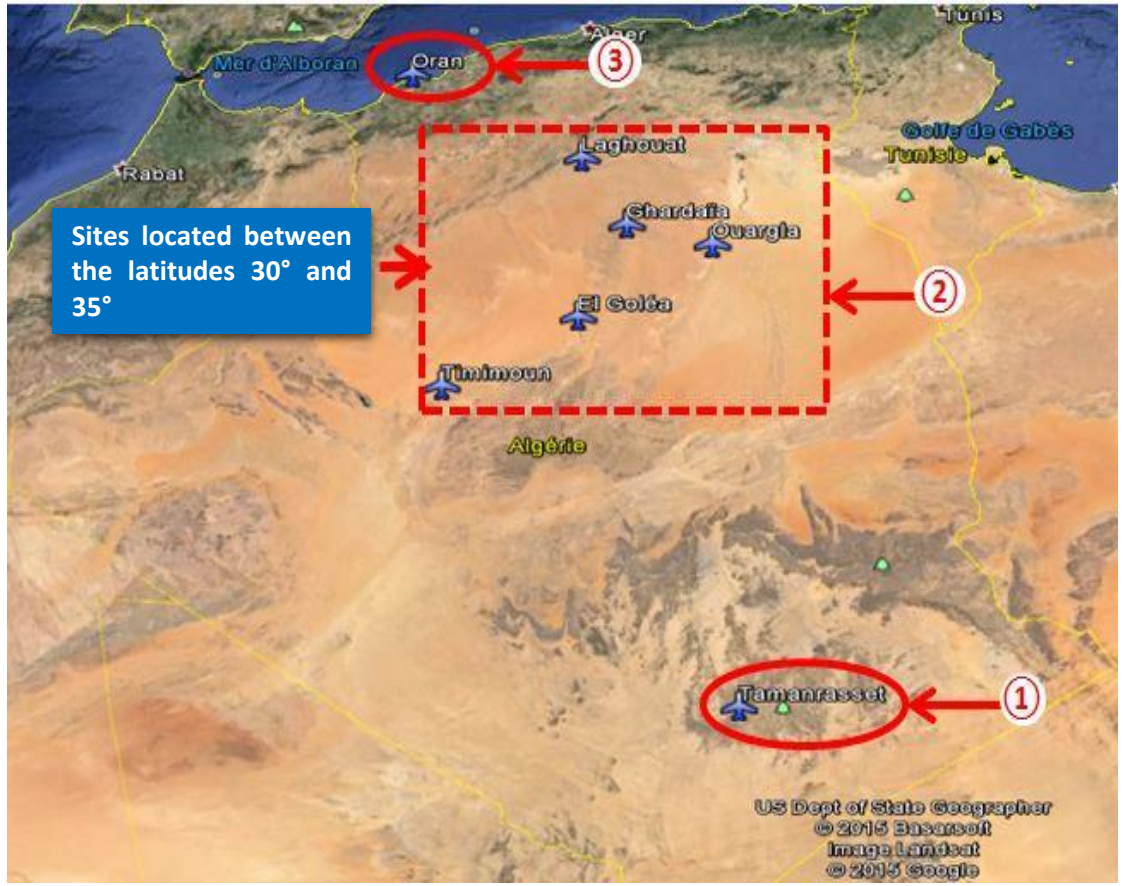




Simulation to setting up a unique RIMS station in Algeria

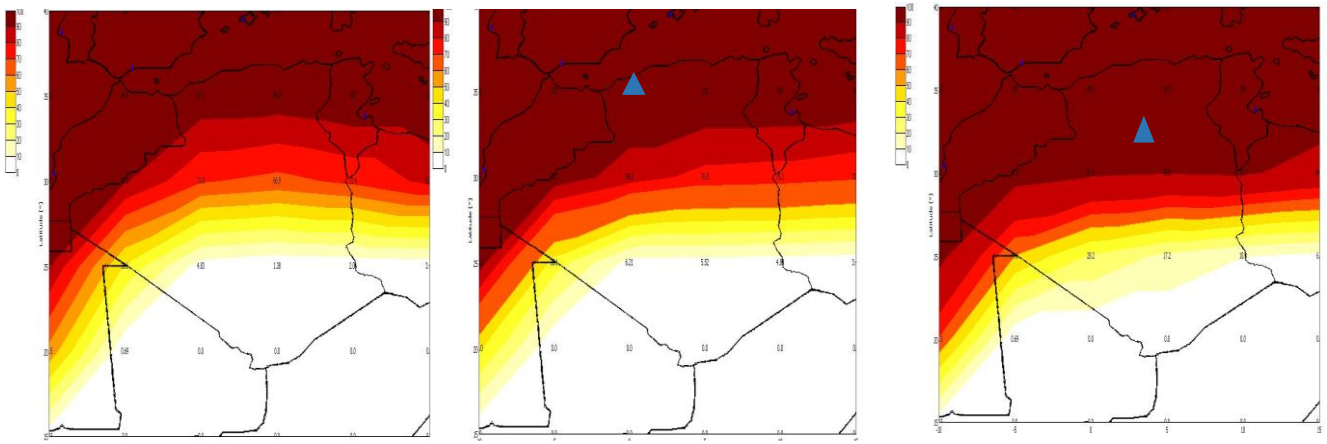
→ Availability simulation by adding an unique RIMS station (proposition August, 2015)

System available→ PL ≤ AL specified by the type of operation (HAL= 40 m, VAL= 50 m).



Comparison of combined availability using 39 RIMS + unique RIMS station in %.

	Longitude λ [0° 5°]		
latitude φ	25°	30°	35°
39 stations	6.20	65.47	94,60
Oran	6,55	88,22	100
Ghardaïa	53.92	**99.65**	100



EGNOS APV I horizontal and vertical availability (two RIMS station in Algeria)

→ **Availability simulation by adding two RIMS stations (last proposition August, 2019).**

Horizontal availability using 39 RIMS stations including Oran site and a selected site in %.

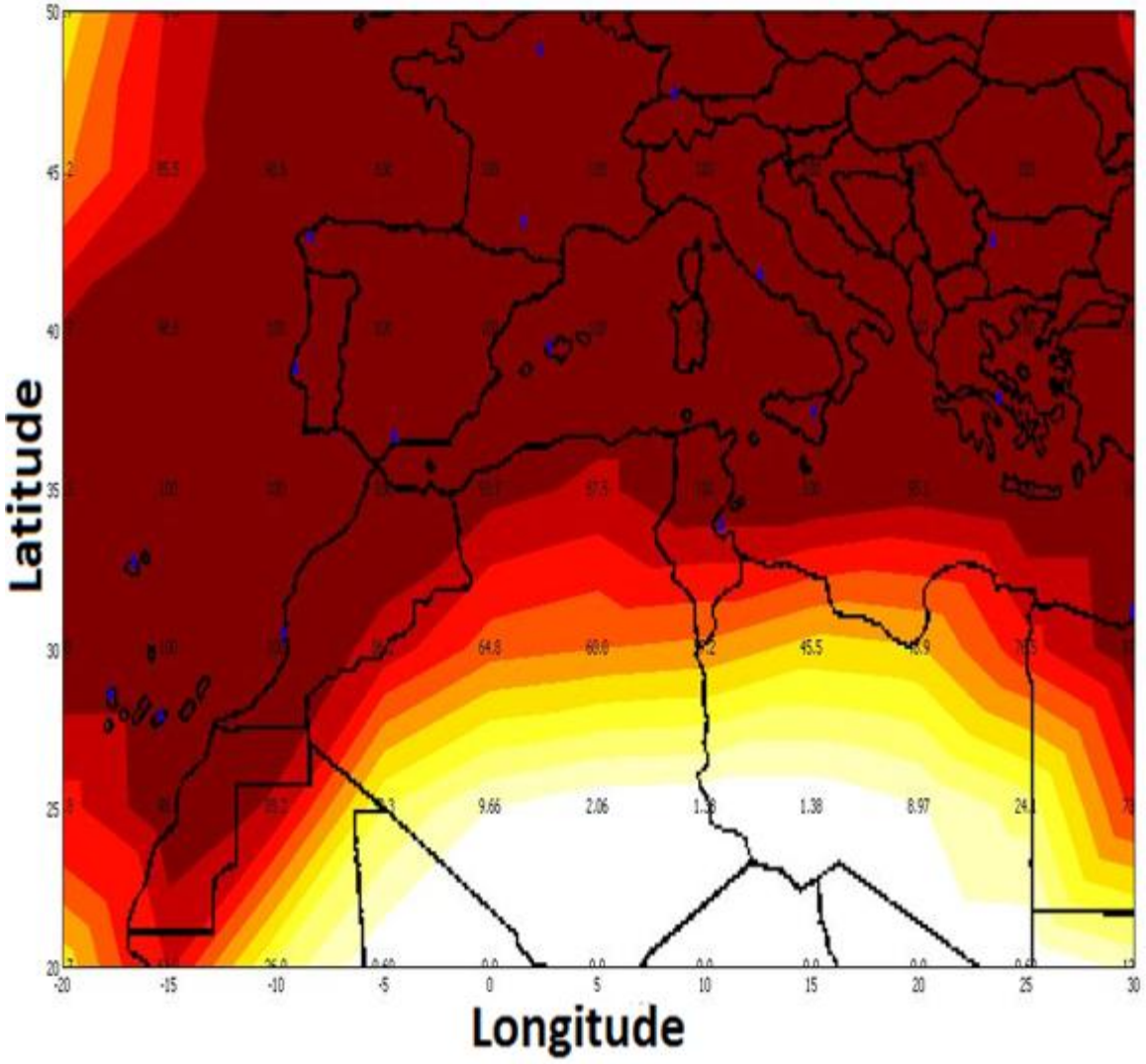
λ : Longitude / φ : Latitude	25°	[0° 5°] 30°	35°
39 stations	[2.06 9.66]	[60.0 64.8]	[87.5 93.7]
39 stations +Oran + Ouargla	[28.2 39.3]	[88.9 91.0]	100
39 stations + Oran+ El Goléa	[33.1 64.1]	[93.7 98.6]	100
39 stations + Oran +Timimoun	[26.9 73.1]	[96.5 100]	100
39 stations + Oran + Adrar	[30.3 79.3]	[98.6 100]	100
39 stations +Oran + In Salah	[42.0 82.7]	100	100

Vertical availability using 39 RIMS stations including Oran site and a selected site in %.

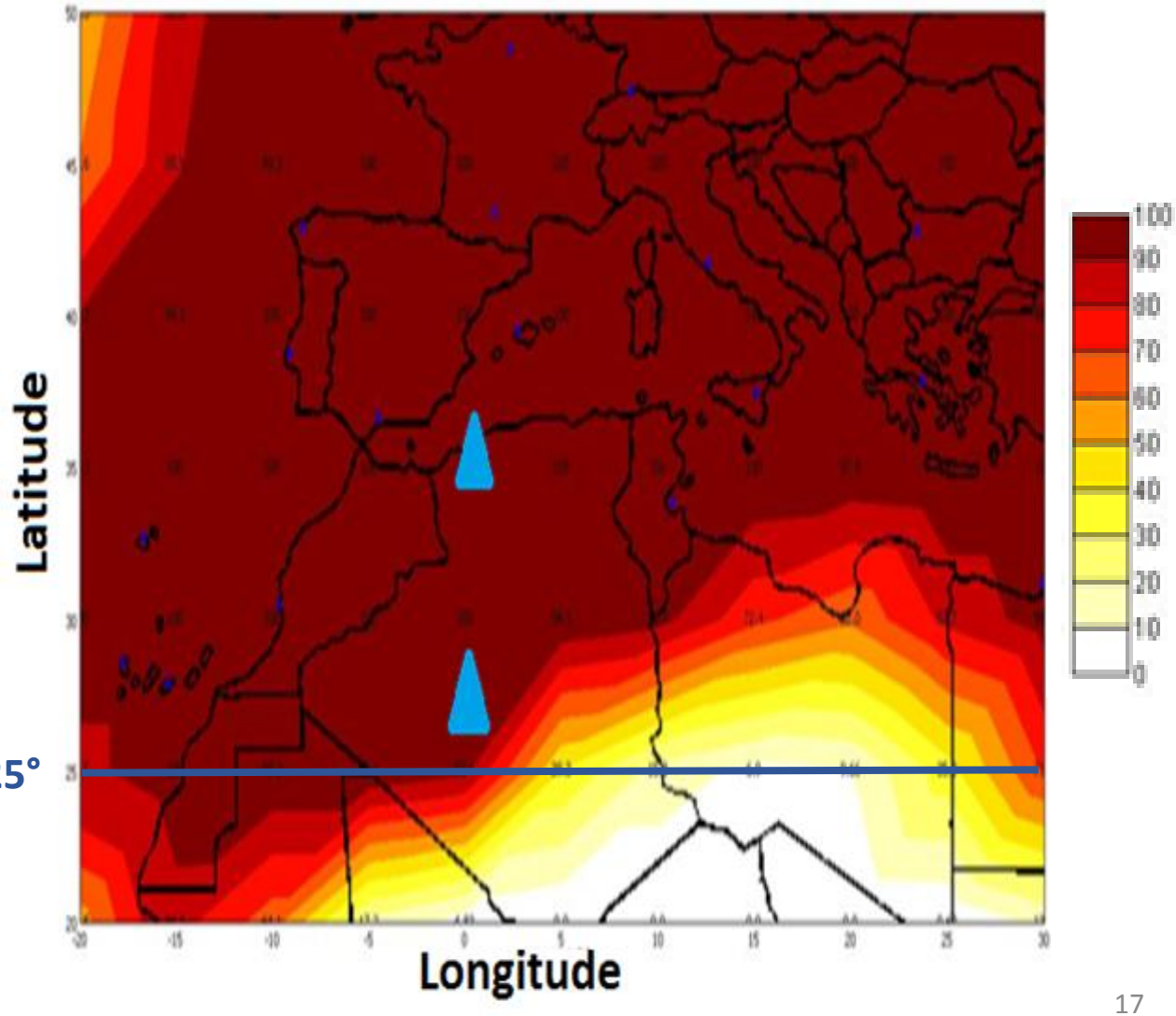
λ : Longitude / φ : Latitude	25°	[0° 5°] 30°	35°
39 stations	[3.45 9.66]	[67.5 69.6]	[97.9 99.3]
39 stations + Oran + Ouargla	[34.4 42.7]	[98.6 100]	100
39 stations + Oran + El Goléa	[44.1 76.5]	[99.3 100]	100
39 stations + Oran + Timimoun	[36.5 82.0]	[98.6 100]	100
39 stations + Oran+ Adrar	[39.3 92.40]	[99.3 100]	100
39 stations + Oran + In Salah	[48.9 94.4]	[99.3 100]	100

EGNOS APV I horizontal and vertical availability, August 1, 2019

Coverage before extension



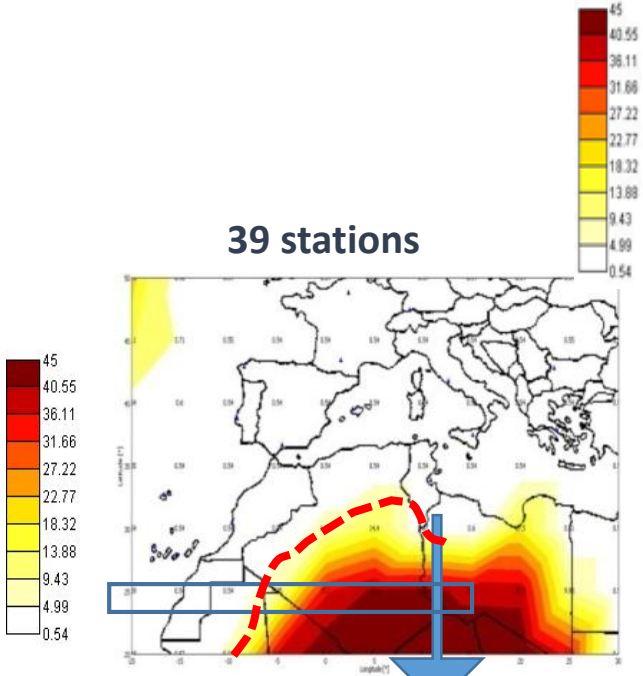
Coverage after extension : Oran and Adrar



Accuracy of grid ionospheric vertical error (GIVE)

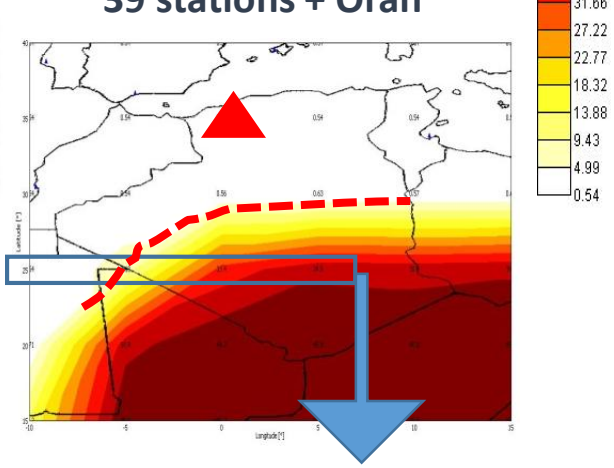
λ : Longitude / φ : Latitude	25°	[0° 5°] 30°	35°
39 stations	[35.2 41.6]	[6.79 14.4]	0.54
39 stations +Oran + Ouargla	[14.4 25.7]	0.54	0.54
39 stations + Oran+ El Goléa	[4.38 7.77]	0.54	0.54
39 stations + Oran+ Timimoun	[2.19 6.85]	0.54	0.54
39 stations +Oran+ Adrar	[0.62 2.25]	0.54	0.54
39 stations +Oran +In Salah	[0.62 0.64]	[0.54 0.55]	0.54

39 stations



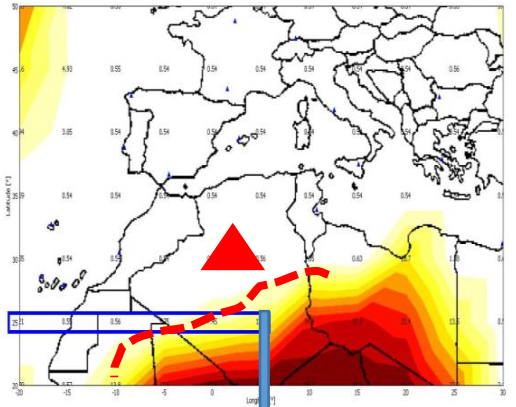
38.4 m

39 stations + Oran



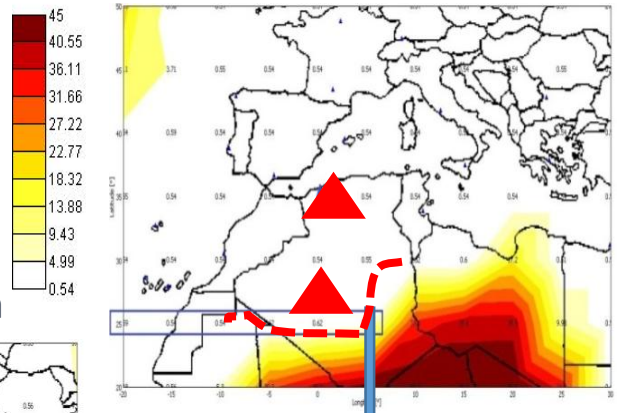
36.45 m

39 stations + Ghardaïa



9.98 m

39 stations +Oran+ Adrar



1.44 m

The addition of 2 stations (Oran +Adrar) allows to have a mean value of σ_{GIVE} = 1.44 m at latitude 25°, while its value can reach 9.98 m when added a unique site in Ghardaïa.

Conclusions

- The results show that there are different levels of performance depending on the position of the sites in relation to the RIMS station networks.

- EGNOS improves the quality of the calculated positions and integrity, in the area covered by RIMS stations (7 m to 1,5 m).

- The lack of RIMS stations in Algeria results in a worse accuracy and integrity of positioning, particularly in the central and southern part of the country.

- The results shows that availability and integrity decrease with increasing southern direction and attain its lowest percentage (5%) at Tamanrasset (24.48°N, 9.52°W) for APV I procedure.

- The simulation results (with the add of two RIMS) show that the performances of EGNOS system in terms of availability and ionospheric grid are substantially improved, in particular in the area between 0° and 5° in longitude and 25° in latitude (38 m to 1,5 m).

Thank you for your attention