Algerian Space Agency
Center of Space Techniques

Optimal Choice for the Estimation of Precise GPS Stations Coordinates

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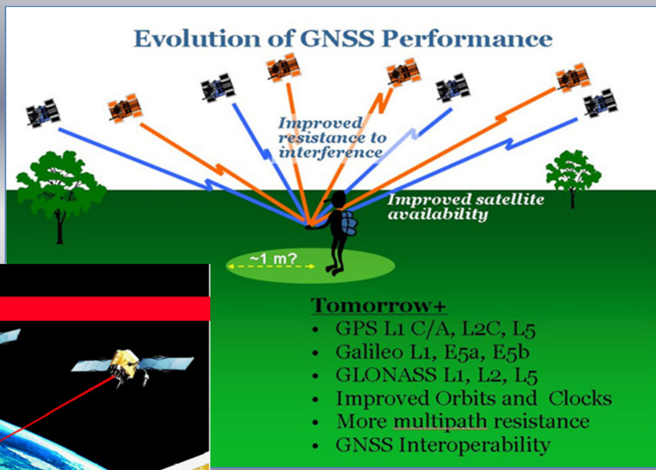
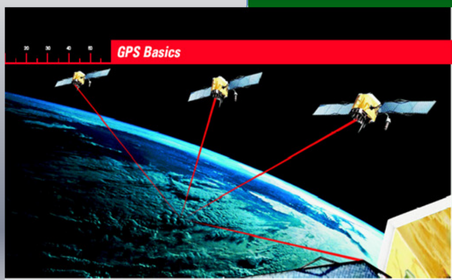
Outline

1. Introduction
2. the GPS signal in atmosphere
3. Theorical Context of tropospheric delay
4. Processing and analyses of results
5. Conclusions and Perspectives

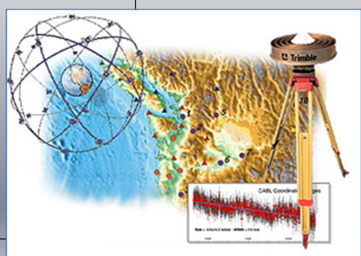
Introduction





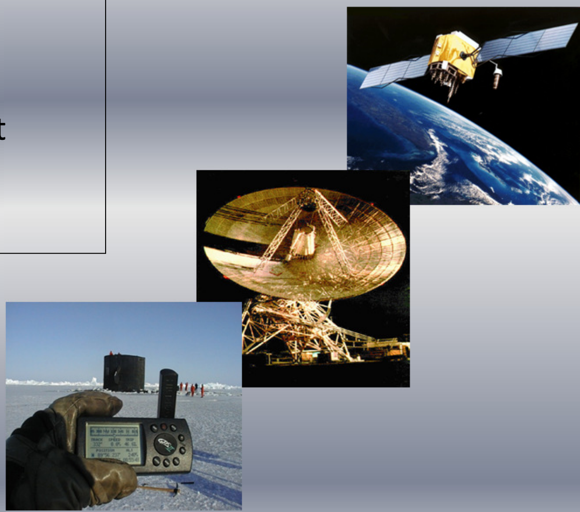
The GPS

- **The Global Positioning System (GPS) is a satellite-based navigation system.**
- **GPS was originally intended for military applications, but in the 1980s, the government made the system available for civilian use.**
- **GPS works in any weather conditions, anywhere in the world, 24 hours a day. There are no subscription fees or setup charges to use GPS**
- **Some civilian uses:**
  - **Navigation on land, sea, air and space**
  - **Geophysics research**
  - **Guidance systems**
  - **Geodetic network densification**
  - **Hydrographic surveys**



Three Parts

- Space segment
- Control segment
- User segment



Principles

- The GPS system operates on the principles of trilateration, determining positions from distance measurements.
- This can be explained using the velocity equation.

$$\text{Velocity} = \frac{\text{Distance}}{\text{Time}}$$

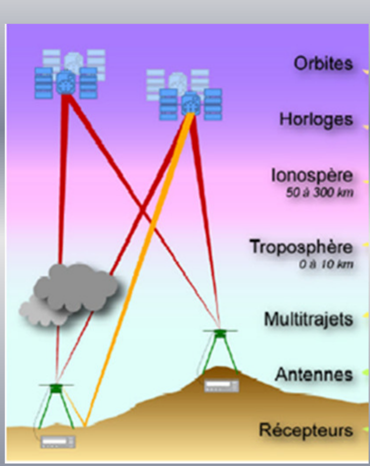
- Rearranging the equation for distance:

$$\text{Distance} = \text{Velocity x Time}$$

- If the system knows the velocity of a signal and the time it takes for the signal to travel from the sender to the receiver, the distance between the sender and the receiver can be determined.

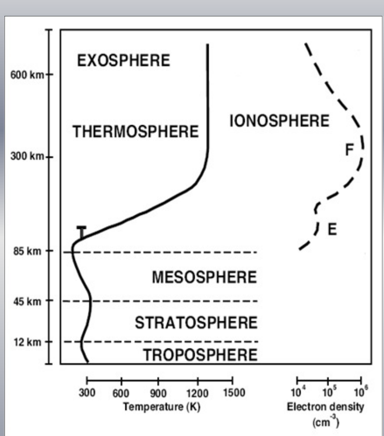
Errors affected GPS signal

- IONOSPHERE
- TROPOSPHERE
- MULTIPATH
- SATELLITE CONFIGURATION/GEOMETRY (DOP)
- CLOCKS
- MONUMENTS
- ORBITS



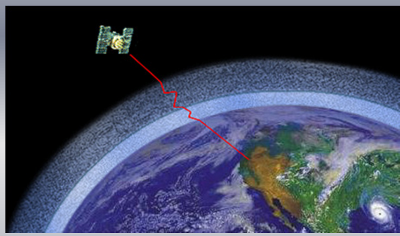
The Signal GPS in Atmosphere

- Refractive zones of the atmosphere:
  - Ionosphere
  - Troposphere
- Impact on GPS Signals:
  - Non-linear path
  - Signal Slowdown
  - Increased travel time satellite-receiver: **Delay**



Tropospheric Effects

- The troposphere is extending from the earth to 50 kilometres
- The troposphere is a non-dispersive medium for signal frequencies below 30 GHz.
- The Tropospheric error cannot be effectively reduced by dual-frequency GPS observations as used to eliminate the ionospheric error.



For further details See Leick (1995)

Tropospheric Delay

(1) – Physical origin and equation

$$L = \int_S n ds$$

$$\Delta L = [\int_S n ds] - G = [\int_S (n-1) ds] + (S - G)$$

$$\simeq \int_S (n-1) ds$$

Propagation Delay

Curvature of the trajectory

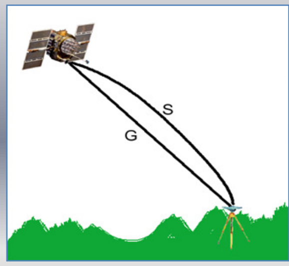
$$\Delta L = 10^{-6} \int_S N ds \qquad N = 10^6 (n-1)$$

Refractivity

$$N = k_1 R_d \rho + R_v [k_2' + \frac{k_3}{T}] \rho_{eau}$$

Density of total air

Density of water vapor



Tropospheric Delay (2) – Decomposition

➢ Dry and Wet component

Hydrostatic Delay (ZHD)
- ~ 2,30 m at zenith
- slow time variation(1 cm / 6 h)
- function of ground pressure, and latitude of the site.

Wet Delay (ZWD)
- up to 20 cm in our latitudes at the zenith.
- highly correlated with weather data.
- function of temperature and density of water vapor along the signal path.

$$\Delta L_h^0 = 0.22768 \pm 0.0024 \frac{P_s}{f(\varphi, h)}$$

[Saastamoinen, 1973]

→ **modeled**

$$\Delta L_w = 10^{-6} R_v \int_S [k_2' + \frac{k_3}{T}] \rho_{eau} ds$$

→ **Measure de ρ_{eau} et T**

The water vapor delay (second term in refractivity) is not so easily integrated because of distribution of water vapor with height.

Correcting Tropospheric Errors (3) – Processing

Two opportunities to reduce Tropospheric errors within GPS measurements processing :

1. Correction of a priori hydrostatic delay (ZHD) + **Estimation** of Zenithal Wet tropospheric parameters Delay (ZWD) by Mean Squares fiting

2. **Correction** a priori or precise of hydrostatic Delay (ZHD) + **External Correction** of Slant Wet Delay (SWD) by steam measure instrument

Tests and Results

To conduct our study, several tests were performed:

1. Baseline ECRN-Murdjadjo
2. Baseline Algiers-Tamanrasset (ALGEONET 1998)

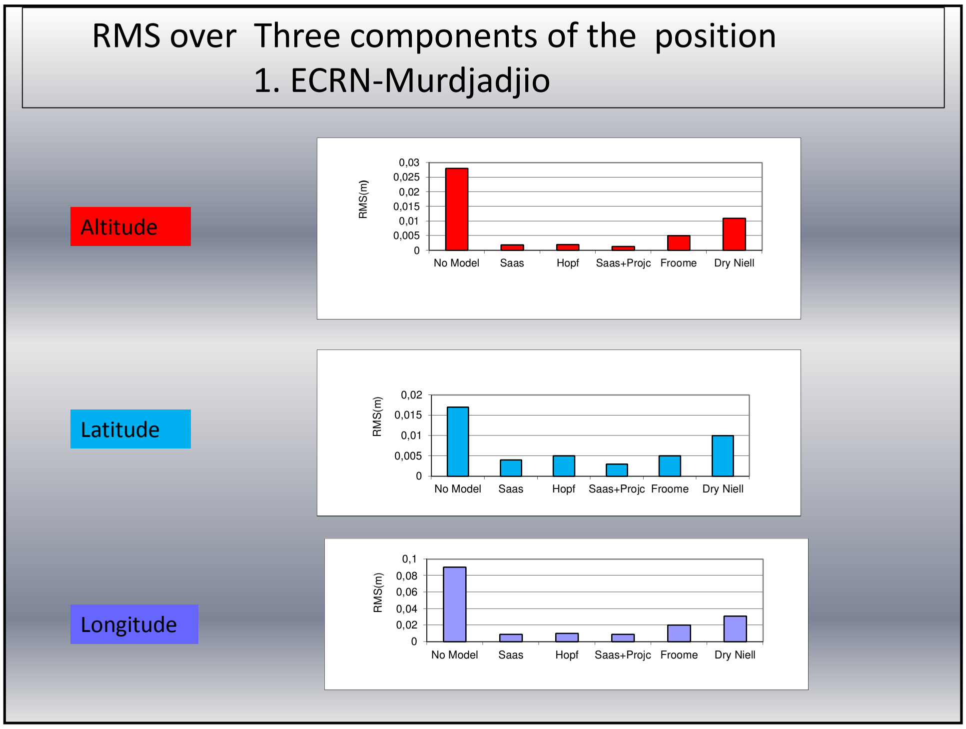
Baseline ECRN-Murdjadjo
✓ short baseline (9km)
✓ Big slope Baseline (550km)

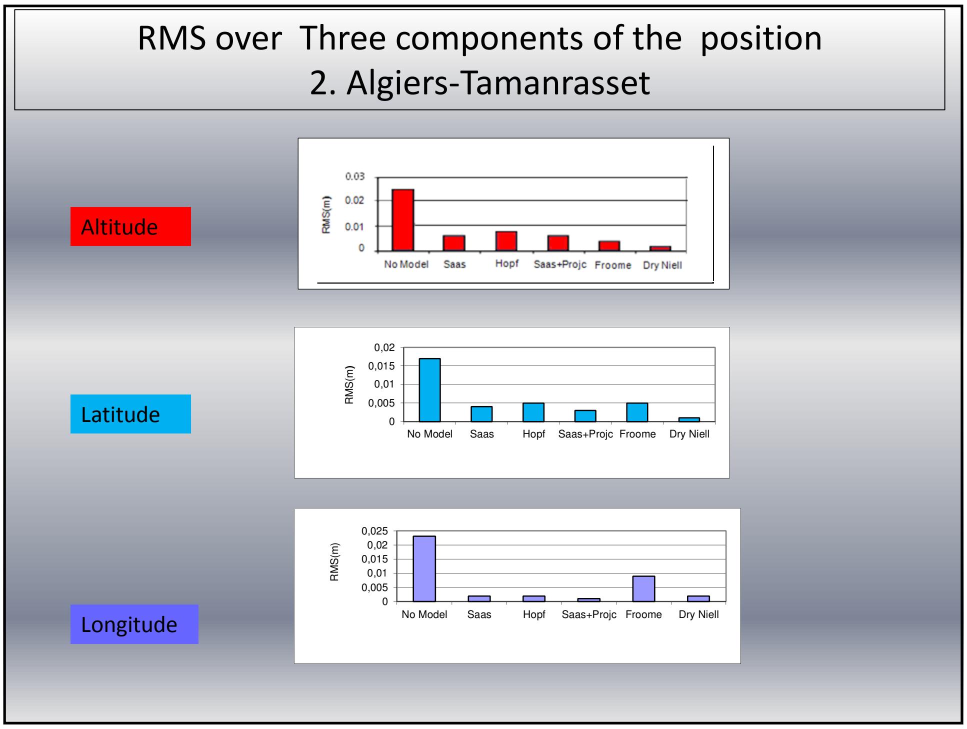
The Bernese is a processing GPS data software, developed at the University of Bern it's feature are :

- Data processing of permanent networks.
- The determination of precise orbits.
- Parameter estimation of rotation of the earth.
- The calculation of an ionospheric model or the calibration antenna

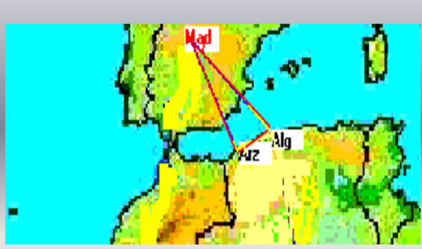
The variation of RMS based on the computational strategy

- The strategies used are:
  1. Without tropospheric model
  2. Saastamoinen without projection function
  3. Hopfield without projection function
  4. Saastamoinen with its projection function
  5. Essen and Froome
  6. The function of Dry Niell without a priori model

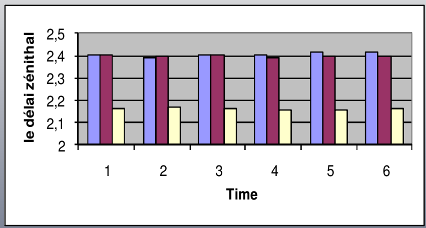

RMS over Three components of the position
1. ECRN-Murdjadjio
Altitude
Latitude
Longitude
RMS(m)
0,03
0,025
0,02
0,015
0,01
0,005
0
No Model Saas Hopf Saas+Projc Froome Dry Niell
0,1
0,08
0,06
0,04
0,02


RMS over Three components of the position
2. Algiers-Tamanrasset
Altitude
Latitude
Longitude
RMS(m)
0.03
0.02
0.01
0
0,025
0,02
0,015
0,01
0,005
No Model Saas Hopf Saas+Projc Froome Dry Niell

Results of a permanent network (Algiers, Arzew and Madrid)



- The Base Algiers -Arzew (500km)
- The Base Algiers -Madrid (800km)



Algiers

Arzew

Madrid

Conclusions

- The tropospheric delay experienced by GPS signals affects the positioning accuracy.

➢ Case of short baselines

- The best results are obtained using the Saastamoinen model with its projection function..
- No-use of models with or without tropospheric features projections give less accurate results

➢ Case of long baseline

- No modeling of the troposphere, remove significantly the reference solution.

- For the two components, latitude and longitude, the two models Saatamoinen and Hopfield, with or without their projection functions gives almost the same results
- For the vertical component, using these two models with their duties projections can have the best result.

- Validate the results obtained on bases known on their exact components because the points coordinates relevant which we compared our results are themselves determined by GPS.

- Generalize the obtained conclusions through this work by using other data sets, with multiple configurations.