IONOSPHERIC EFFECTS ON GNSS PRECISE POSITIONING APPLICATIONS

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Sources of error in GNSS positioning

- *Satellite related errors :*
  - Clock bias
  - Orbital errors
- *Propagation medium related errors:*
  - Ionospheric refraction
  - Tropospheric refraction
- *Receiver related errors:*
  - Antenna phase center variation
  - Clock bias
  - multipath

Ionospheric effects on GNSS precision

- *Phase advance :* the speed of propagation of the carrier is increased by the presence of electrons. The phase of the carrier arrives at the receiver earlier.
- *Group delay :* the signal that is modulating the carrier is delayed.
- *Position error :* the error between receiver and satellites effect the calculation of the position.

Ionospheric effects

$$P_1 = \rho + c(dt - dT) + d_{orb} + d_{trop} + k_2 I + b_{P_1} - B_{P_1} + d_{mult/P_1} + \varepsilon(P_1)$$

$$\Phi_1 = \rho + c(dt - dT) + \lambda_1 N_1 + d_{orb} + d_{trop} - k_2 I + b_{\Phi_1} - B_{\Phi_1} + d_{mult/\Phi_1} + \varepsilon(\Phi_1)$$

$$\Delta_{ph}^{iono} = \int (1 + \frac{c_2}{f^2}) ds - \int ds_0$$

$$\Delta_{gr}^{iono} = \int (1 - \frac{c_2}{f^2}) ds - \int ds_0$$

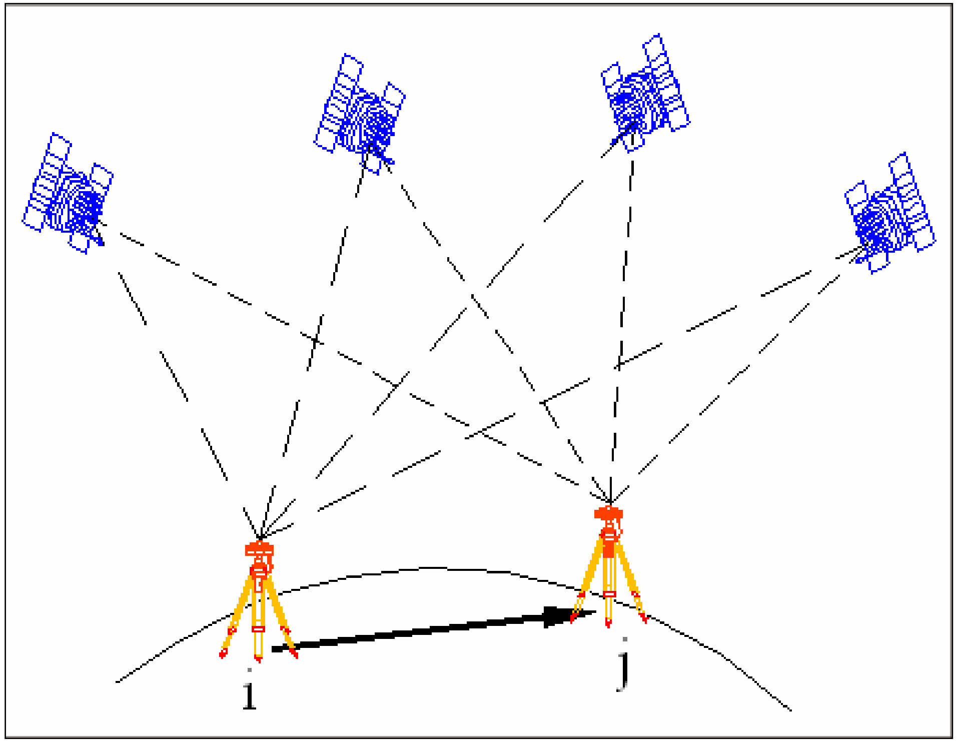
Correction of the ionosphere effects

- Using two signals with different frequencies : case of dual-frequency receivers:

$$L_3 = \frac{1}{f_1^2 - f_2^2}\left(f_1^2 L_1 - f_2^2 L_2\right)$$

- Using ionospheric models : case of single frequency receiver : (Ex. Klobuchar Model)

Differential positioning for other corrections



$$\overrightarrow{B}_{i\to j} = \begin{pmatrix} X_j - X_i \\ Y_j - Y_i \\ Z_j - Z_i \end{pmatrix} = \begin{pmatrix} \Delta X_{ji} \\ \Delta Y_{ij} \\ \Delta Z_{ij} \end{pmatrix}$$

Calculation

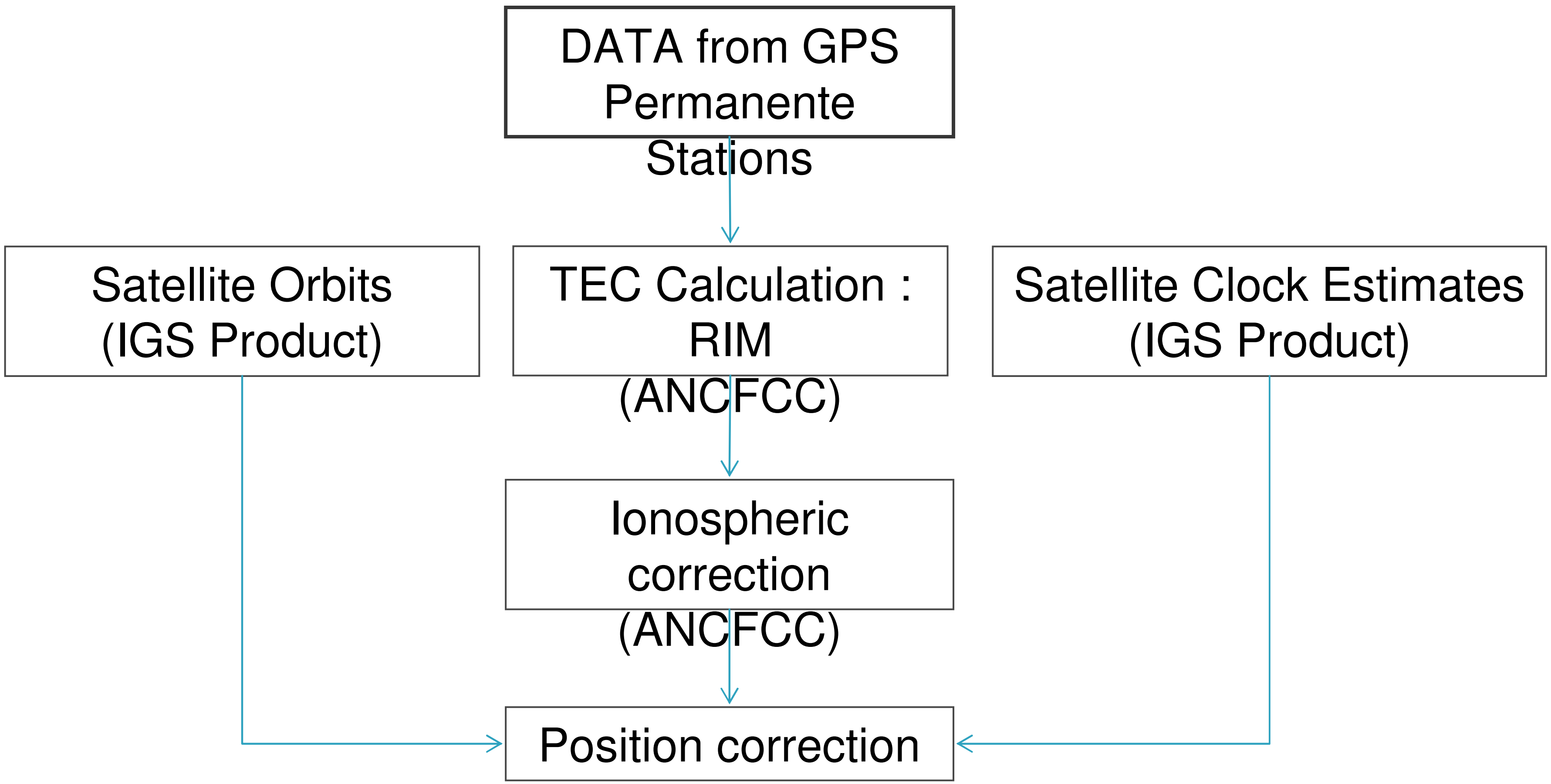
- Simple difference : eliminate the satellite clock bias.
- Double difference : eliminate the receiver clock bias.
- Triple difference : eliminate the ambiguity.

Single Frequency Point Precise Positioning

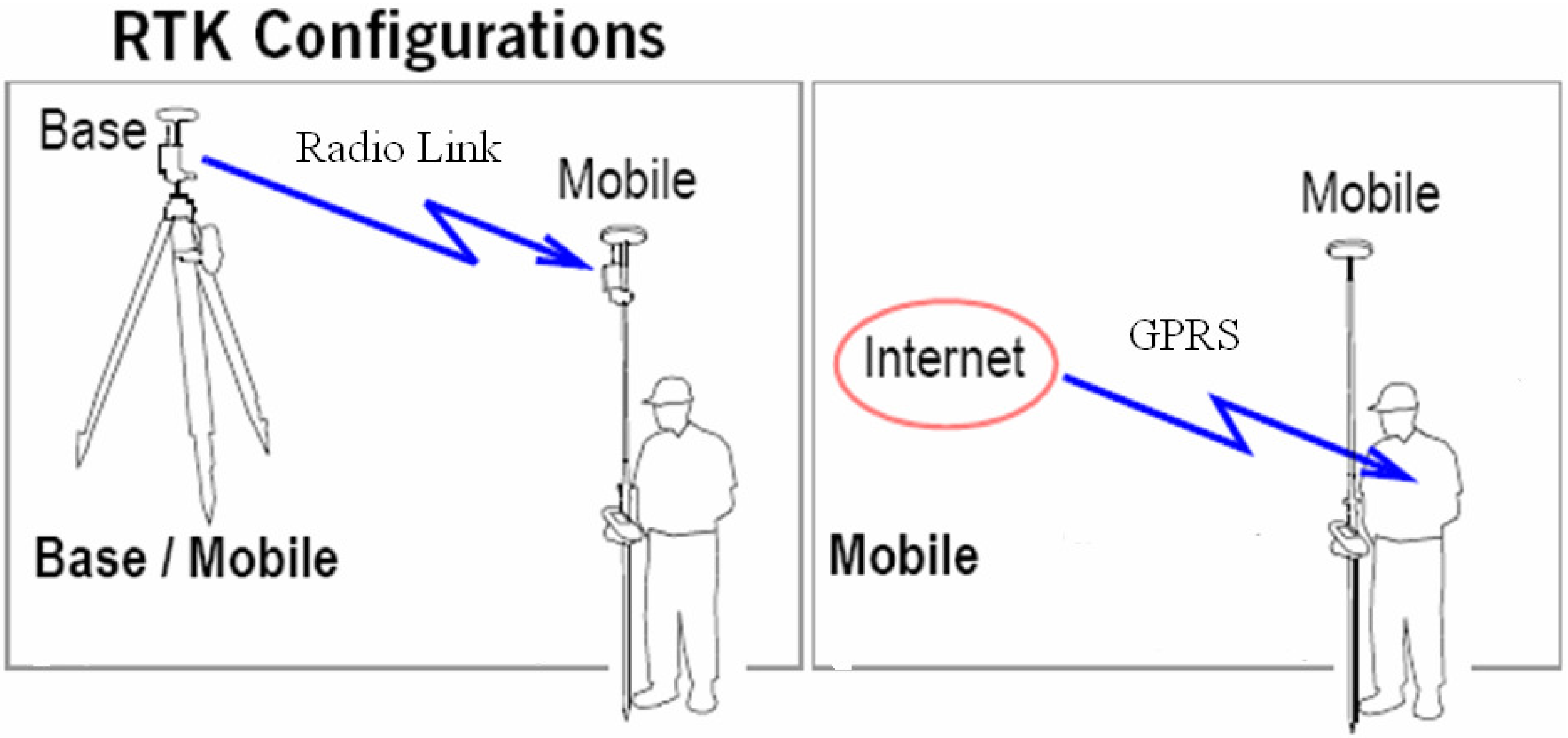
- Many applications require good positioning precision in real-time and at low-cost.
- With local or regional differential infrastructure, theses demands could be met.
- Single frequency precise point positioning could also be used and can provide good positioning precision.
- The precision can be improved when precise GPS data products are used : satellite orbits, satellite clocks, ionospheric maps.

General Methodology

Single Frequency Point Precise Positioning



Research in progress



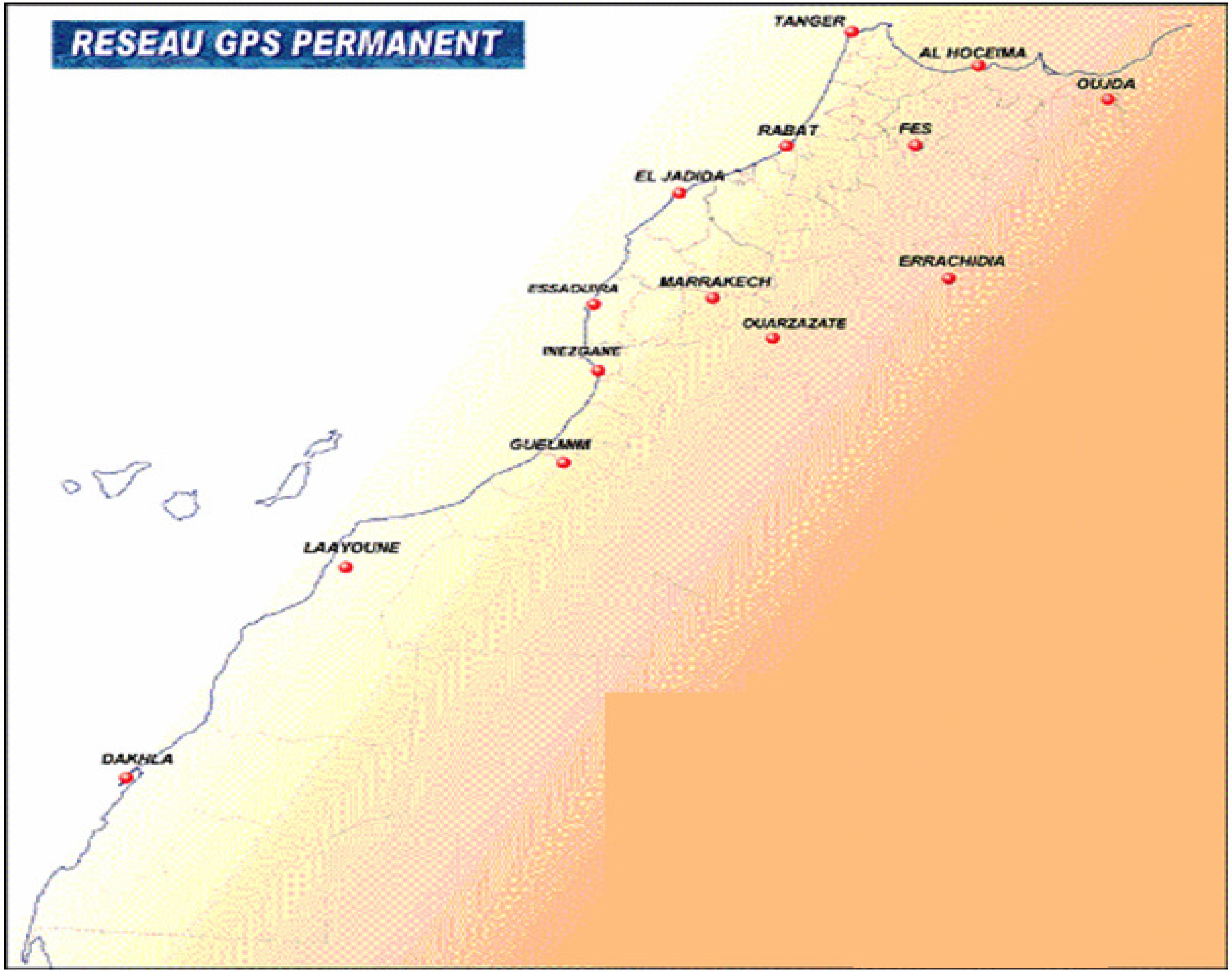
Real Time applications :

•Land delimitation.
•Road vehicle applications.
• Precision agriculture.
•Infrastructure monitoring.

Mobile Receiver

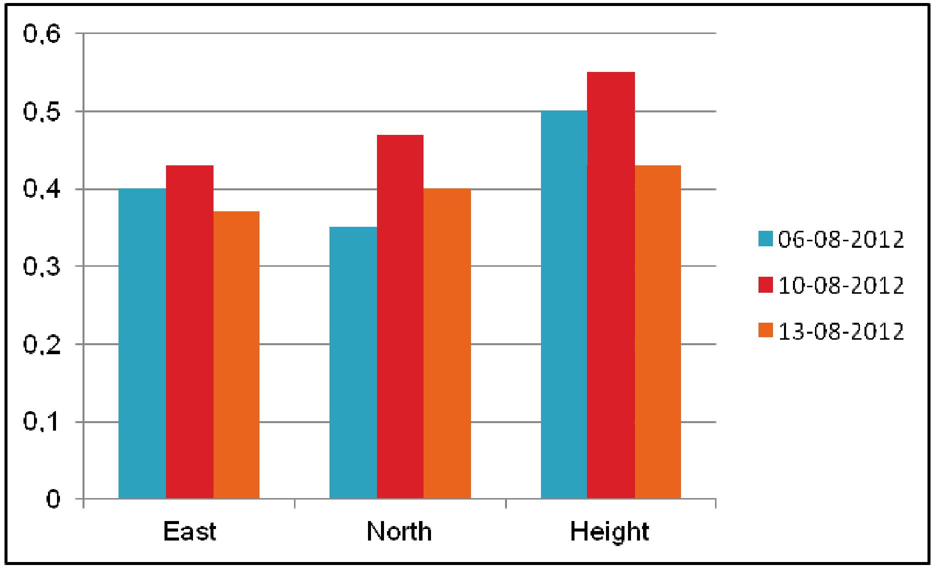
Permanent Station

GPS Permanente stations in Morocco

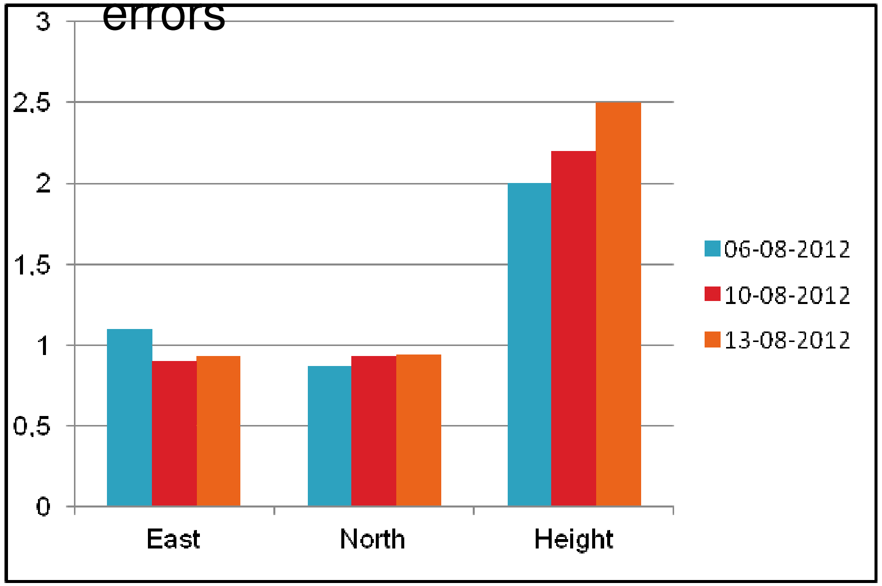


Preliminary results (Road mapping)

95% position errors



95% Difference position errors



Societal dependence on GNSS

- Societal dependence on the Global Navigation Satellite System has increased.
- Many applications depend on GNSS services :
  - Emergency
  - Navigation
  - Aviation
  - Infrastructure monitoring
  - Road and railway control
  - Precision agriculture
  - Mapping

GNSS development

- Global constellations : GPS, GLONASS, Galileo, Compass/Beidou.
- Regional constellations : Egnos, IRNSS , QZSS
- Availability of satellites even in critical situations.
- Rapid and precise positioning.
- Many frequencies.
- Applications have rapidly expanded around the world.

Vulnerability of GNSS to Space weather

- GNSS users need to be concerned about space weather.
- The next sunspot maximum will test much the GNSS-based technology installed last years.
- The two primary effects of space weather on GPS are:

  1. Propagation delay of signals caused by the presence of the ionosphere. The result is increased errors in position and navigation.

  2. Loss of signal due to scintillation effects. The result is increased errors due to the decreased number of useable satellites and the possible inability to navigate.

Vulnerability of GNSS to Space weather

- Space weather is the single largest contributor to single-frequency GNSS errors.
- Use of a dual frequency receivers can minimize the errors.
- However, they can still be affected by scintillation, solar radio bursts, and major ionospheric disturbances.
- Ionospheric effects tend to be stronger at lower frequencies : where the GPS new civilian L2C and the safety of life L5 signals are located.

Conclusion

- The research community is making advances in space weather knowledge and heliophysics.
- For GNSS users, improved regional ionospheric models are required for real-time assimilation to capture the true nature of the ionospheric disturbances.
- GNSS Service providers should be integrating space weather products in their operations and alert users for their effects. The users can take mitigating actions.

Thank you for your attention