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REFECTION OF NATIONAL GEODETIC INFRASTRUCTURE USING GNSS TECHNIQUE

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Contents

- National Geodetic System North Sahara 1959
- New National Three-Dimensional datum based on GNSS
- Precise local geoid model
- Mapping industrial areas, touristic zones and Saharan regions using satellite images and GPS networks.
- Conclusion.

National Geodetic System “North Sahara 1959”

What is the Problem of the National Geodetic System ?

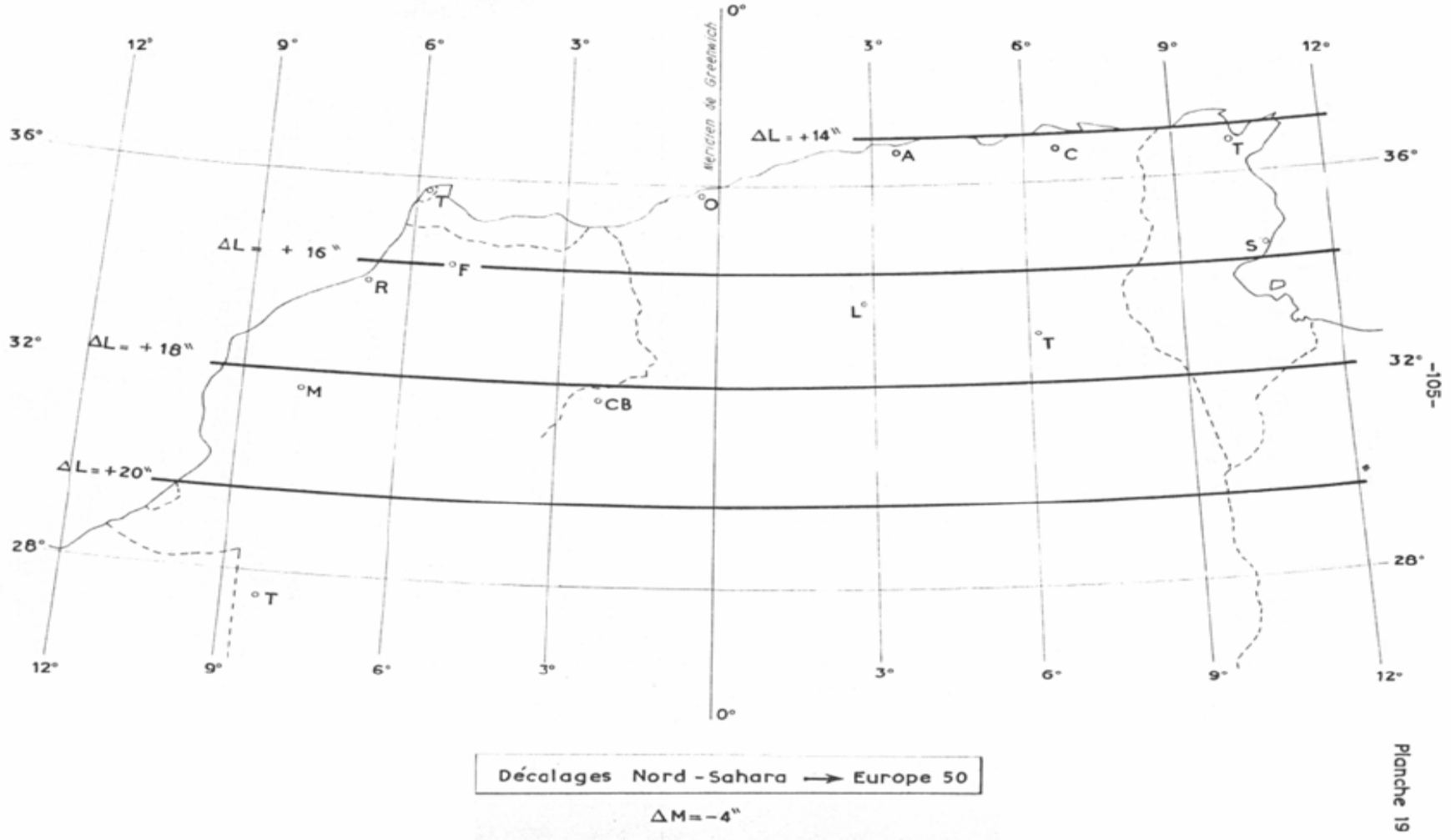
- **“North Sahara 1959”** (***NS-59***): Local Datum, directed by IGN (France) and calculated on the Clarke 1880 ellipsoid (English).
- The calculation was based on **two different data sources**: a geodetic network (first order and first complementary order) calculated in the system **ED50** (***European Datum 1950***) using the **international ellipsoid** for the **North** and an **astronomical network** for the **South Algeria**.
- To reconcile these two networks, a system of meridians and parallels have been considered on the Clarke 1880 ellipsoid, such as discrepancies between the average coordinates from the triangulation and astronomy are minimal.

Thus, the coordinate system resulting from this approach has been called “Geodetic System North Sahara 1959“ : ED50 System derived by a simple transformation (translations of longitude and latitude).

-The characterization of the North Sahara 1959 System poses a problem with the definition of the origin (fundamental point poorly defined).

Repairs of North Sahara59 System and its connection with WGS84

Latitude and Longitude discrepancies between ED-50 and NS-59



ED-50 → NS-59 ⇨ :

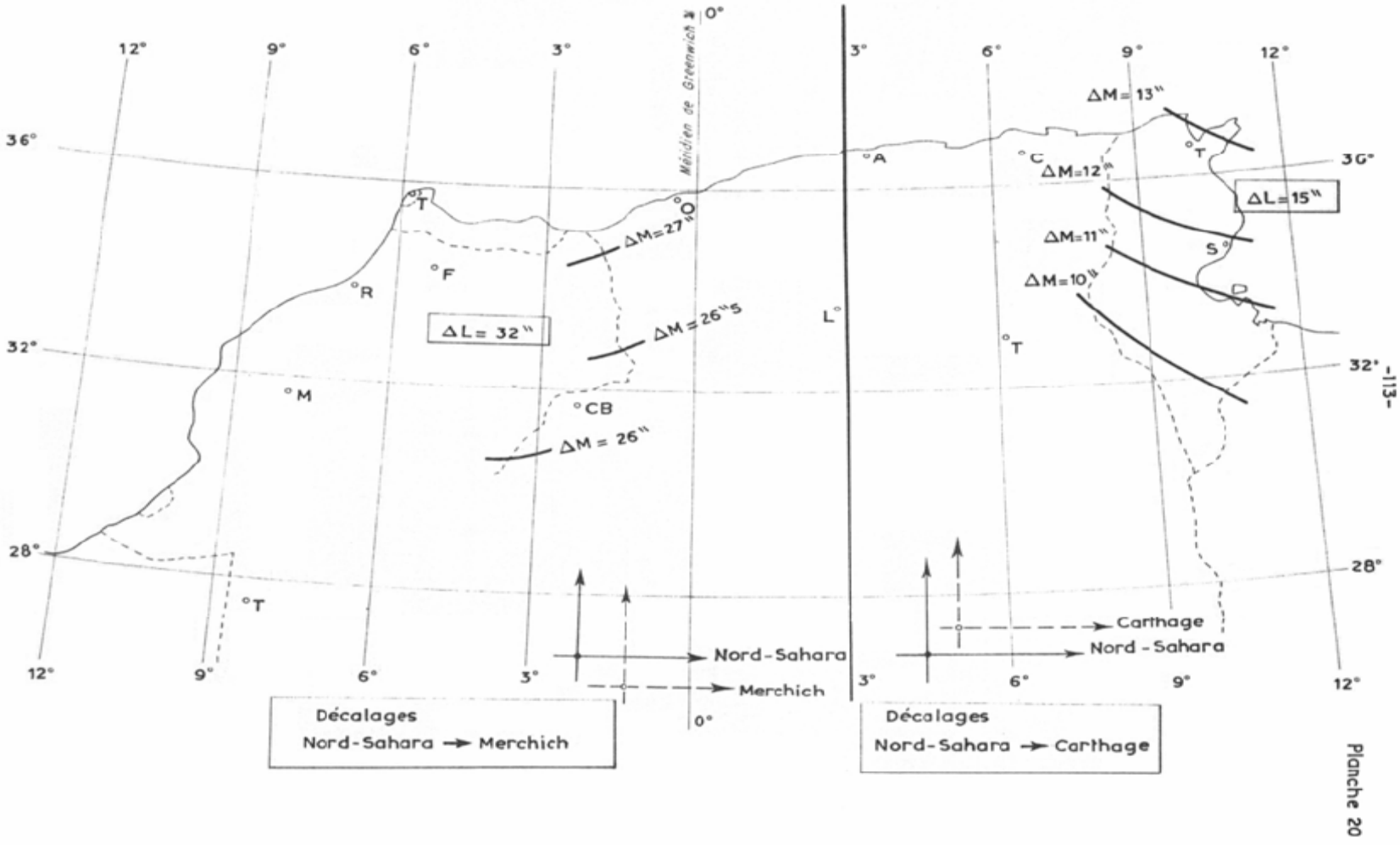
$\lambda_{North\ sahara} = \lambda_{ED50} - 4$ dcmgr

$£_{North\ sahara} = £_{ED50} - 48.4$ dcmgr

With: *ED50 : Europe 50.*
λ : longitude.
£: latitude isométrique

Repairs of North Sahara59 System and its connection with WGS84

Difference between Merchich (Ma) and Carthage (Tu) Systems / NS-59.



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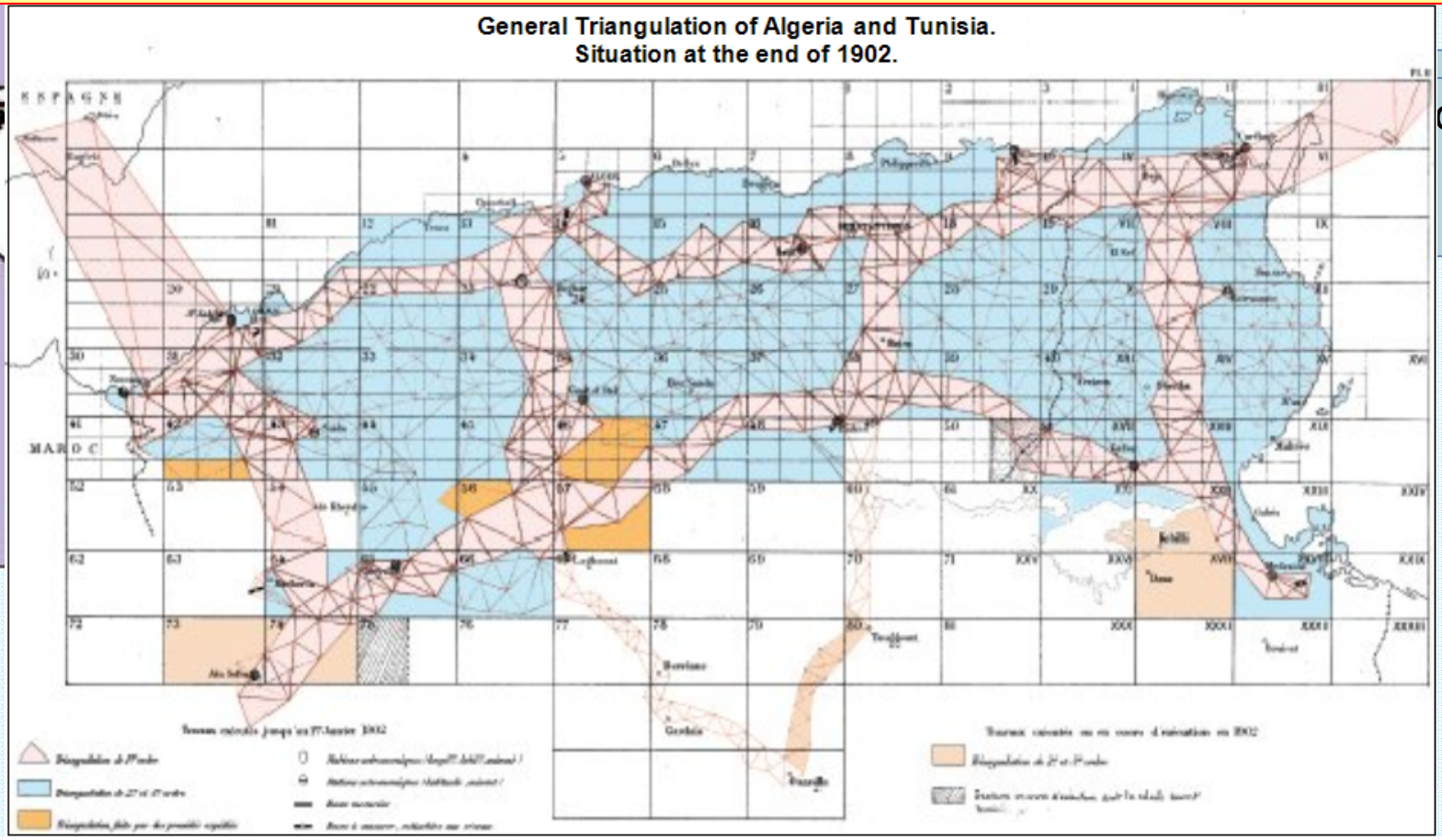
With: *ED50 : Europe 50.*
λ : longitude.
£: latitude isométrique

Heritage: Astronomical and Classical Networks

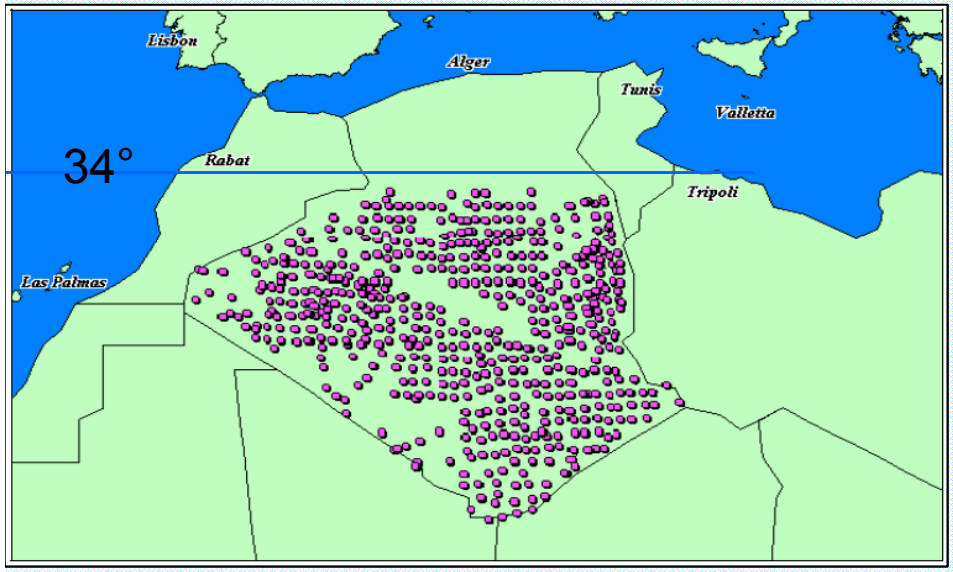
▼ 1- Triangulation Networks:

- Triangulation of Algeria began in 1854 and lasted until 1994,
- Composed of 3740 points,
- Conventional measurements ⇨ $Point_{(i)}\ [X_{(i)},Y_{(i)},Z_{(i)}]$,
- Geodetic levelling using T3 with junction to General Levelling of Algeria (Levelling network).



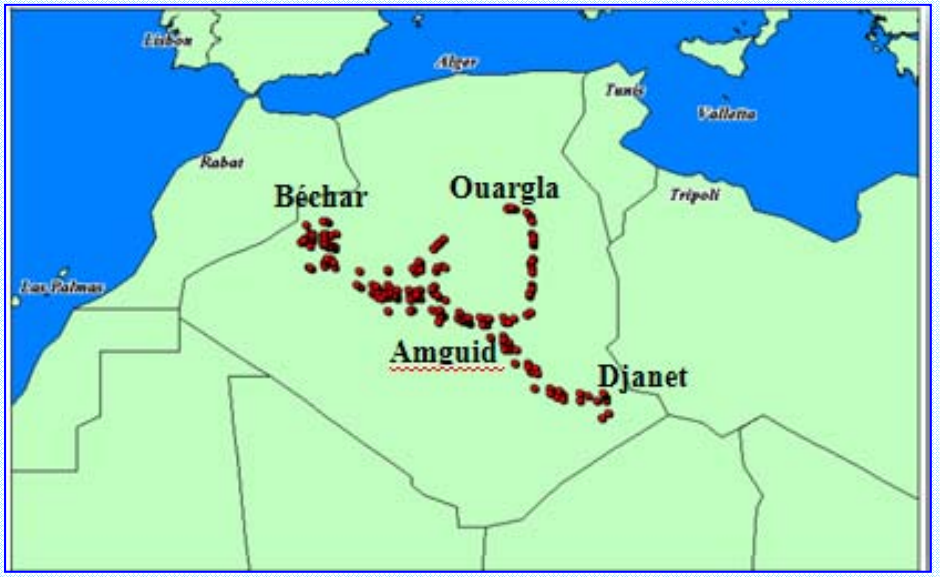
Heritage : Astronomical and Classical Networks

2- Astronomical Network: ▼



- Astronomical measurements: 1900-1968,
- 636 Astronomical points /Clarke 1880 A,
- Precision ≈ 30m,
- Scale Map: 1/200 000 (South Algeria).

3- "Axis 3000": ▼



- "Axis 3000": Network of primordial chains in the South of Algeria,
- Conducted by IGN/France : 1958 -1961,
- Composed of about 170 points,
- Precision ≈ 30 cm.

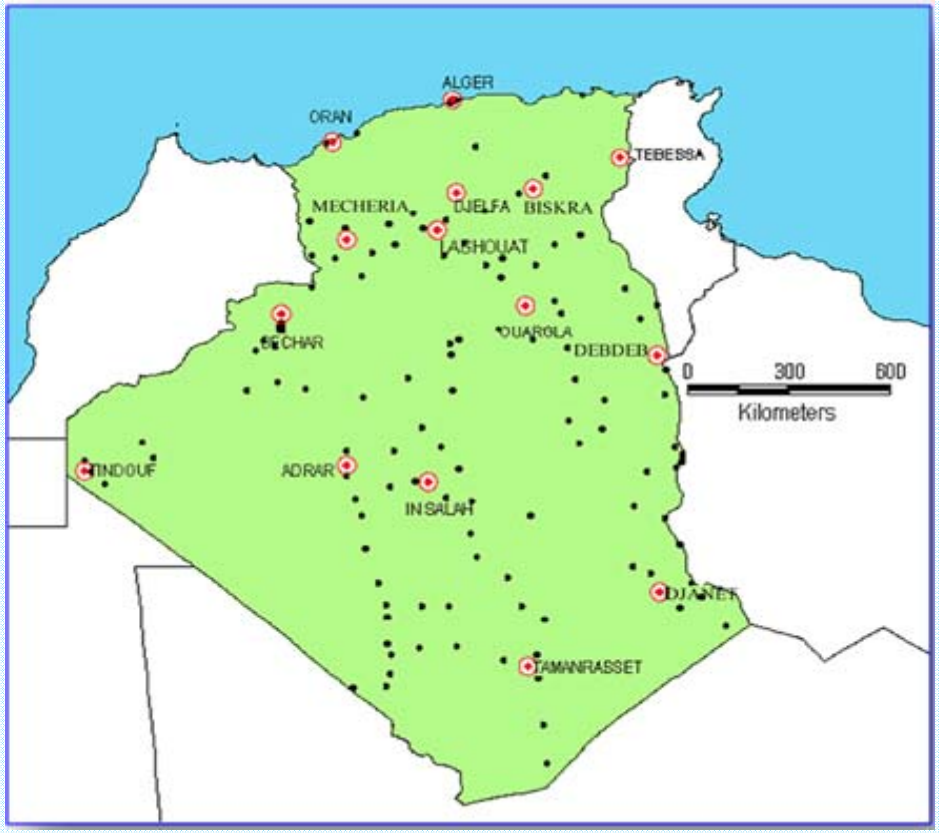
Doppler Geodetic Network

Doppler Network of INCT :

- **122** points (1980-1990),
- Occupations: 03 days,
- Used equipments: JMR receivers,
- GeoDop software on VAX 11/785 computer,
- Accuracy : ≈ meter.

African Doppler Survey Project :

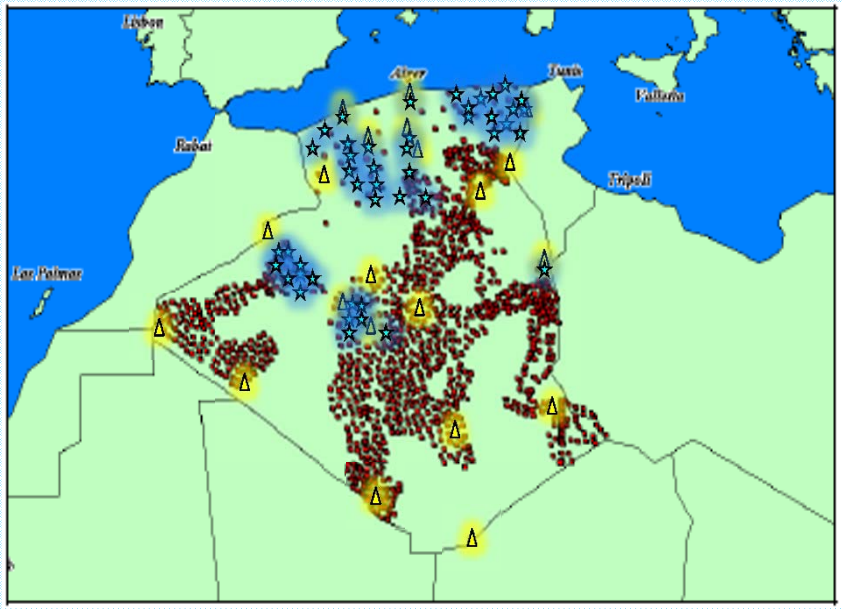
- 18 points included in ADOS
- Accuracy : ≈ 0.8 meter



GPS Networks carried out by INCT during 1998 - 2006.

1- Zero order, Tyrgeonet, Algeonet GPS networks △ :

- 21 points,
- Occupation: 7 days,
- Software: Bernese,
- IGS Precise orbits,
- RMS ≈ 1 cm.



2- Unification GPS network ☆ :

- Redetermination of **42** *NS-59* points (50-150 km),
- Occupation : 2 hours,
- Software : Winprism and Ashtech Solutions,
- GPS broadcast orbits,
- RMS ≈ 2 cm.

3- Densification GPS network • :

- Since 1997: **1290** GPS points (25 à 50 Km),
- Occupation : 2 hours,
- Software : Winprism and Ashtech Solutions,
- GPS broadcast orbits,
- RMS ≈ 2 cm.

Objectives of the Project

- Conducting a **study on the value of the national Geodetic network** (scale and orientation) and **evaluation** of its **deformation** from GPS measurements.
- Using GPS become an indispensable tool for work Geodesy & surveying. It Necessarily requires the setting of the local system NS-59 on the overall system GPS (WGS-84). Thus, **the accuracy of the transformation parameters depend mainly on the quality of the two systems.**
- These repairs to the national geodetic network by **improving the quality of the system** in accordance with standards of a local datum.

Methodology 1/2

A- Knowledge of the quality of the national network:

- **Step 1:** Identification and validation of measurements based networks (available in INCT) and Preliminary process of classical data,
- **Step 2:** Adoption of a specific adjustment to the Algerian territory (adjustment of large networks incorporating minimal constraints),
- **Step 3:** Appraisal (scale and orientation) 2D national network by integrating GPS data.

B- New Algerian Triangulation (NTA):

- **Step 1**: New geodetic Algerian network adjustment using the model of free network adjustment with minimal constraints and including the same ellipsoid (North Sahara - Clarke 1880), the same measurements performed by IGN and INCT, the same map projection (UTM), but the origin of the network will be the fundamental point of Voirol site.
- **Step 2**: Identify any discrepancies in scale and orientation between the two networks.

Methodology 2/2

C- Methodology of Combination: Classical and GPS techniques:

- **Step 1**: Identification and validation of the coordinates of points, the GPS, terrestrial and astronomical data, levelling measurements,…),
- **Step 2**: Methodology of adjustment, combining conventional and GPS data,
- **Step 3**: Writing a software for adjustment of combined measures GPS & Classical for the realization of 3D geodetic networks.

Functional flow program Chabaka:

PROJECT CREATION

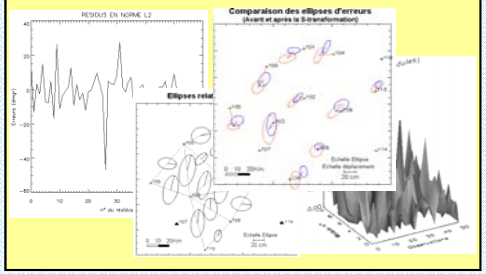
DATA FILES

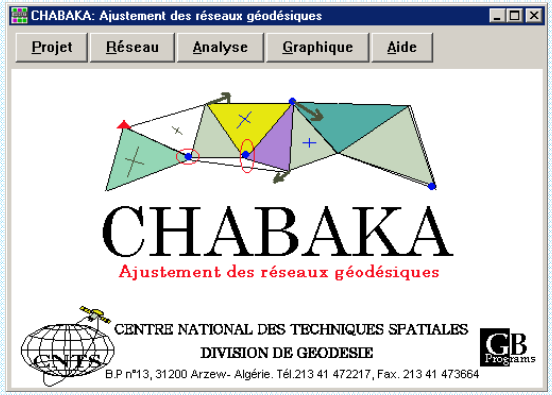
PROCESS

OPTIONS

ADJUSTMENT

GRAPHIC REPRESENTATION





ANALYSIS

- ***Stochastic Analysis***
- ***Network reliability***
- ***Network robustness***
- ***S-Transformation***

The main impacts of the Project:

- Using the geographic coordinates system instead of the mapping system in the adjustment,
- Establishment of the transformation processing parameters (**2D**) between the NTA network (adjusted) and NS-59 network (current): Reference ellipsoid (Clarke 1880A),
- National mapping (more accurate),
- National geodesy ⇨ **cm** precision network instead of **dcm** and more.

DEFINITION OF THE NEW GEODETIC NATIONAL 3D SYSTEM BASED ON THE GNSS TECHNIQUE.

Algerian Permanent GPS Network

AFREF (AFrican REference Frame) Project

- 2006 - 2007: Three (03) operational Permanent GPS stations (Algiers, Oran and Constantine).

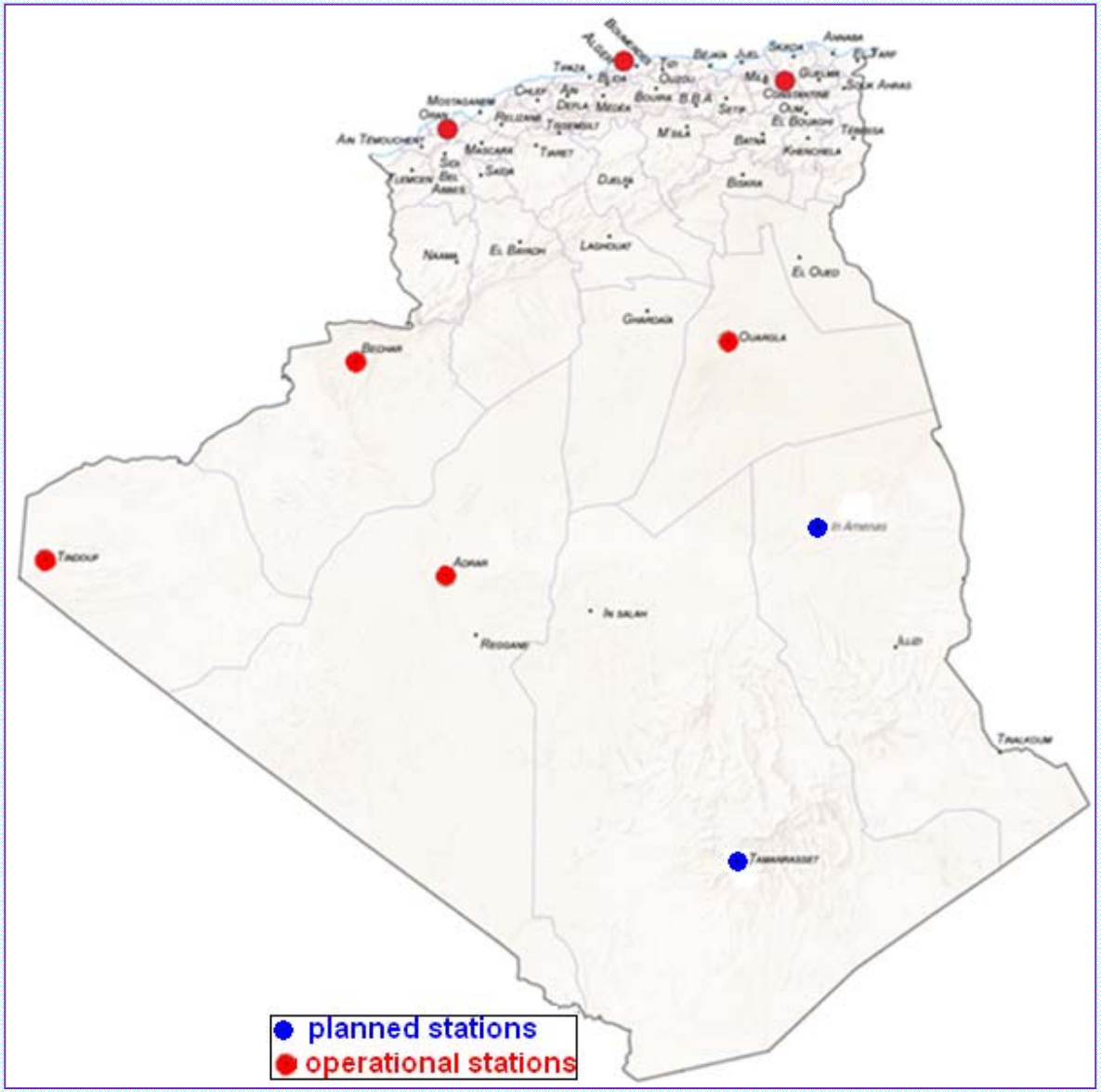
Used GPS equipment:

- ASHTECH μZ-12 receivers and ASH701945E_M Snow D/M Chokering antenna for Algiers, Oran and Constantine stations.

- Leica GRX1200 GNSS receivers and Chokering Antenna for Ouargla, Bechar, Tindouf , Adrar stations during 2012.

- Daily sessions in Rinex format, with sampling rate of 30 seconds.

Present day Permanent GPS Network (INCT):



In the context of the Convention between INCT and IGN (France), the GPS data of the 3 first permanent stations were diffused to permit the connection to the ITRF.

Actual system:

- Reference System: Nord Sahara,
- 2D Network,
- Ellipsoid: Clarke 1880 A ,
- Coordinates System :
  - Longitudes, latitudes in gon,
  - Lambert VLU 1960, UTM,
- Precision : ?

Futur system:

- Reference System:
  - 3D Network,
  - Linked to the International Terrestrial Reference System (ITRS),
- Ellipsoid: IAG GRS80,
- Origin Meridian: Greenwich,
- Coordinates System :
  - Longitudes, latitudes in degrees
  - Ellipsoidal Heights in meters,
  - UTM,
- Precision: cm.

The new GNSS system will enable well performing:

- Methodology of measurements,
- Data processing for precise GPS networks,
- Methods of (GPS) geodetic network adjustment,
- Determination of the transformation parameters between two geodetic systems (Nord Sahara, ITRF,…).

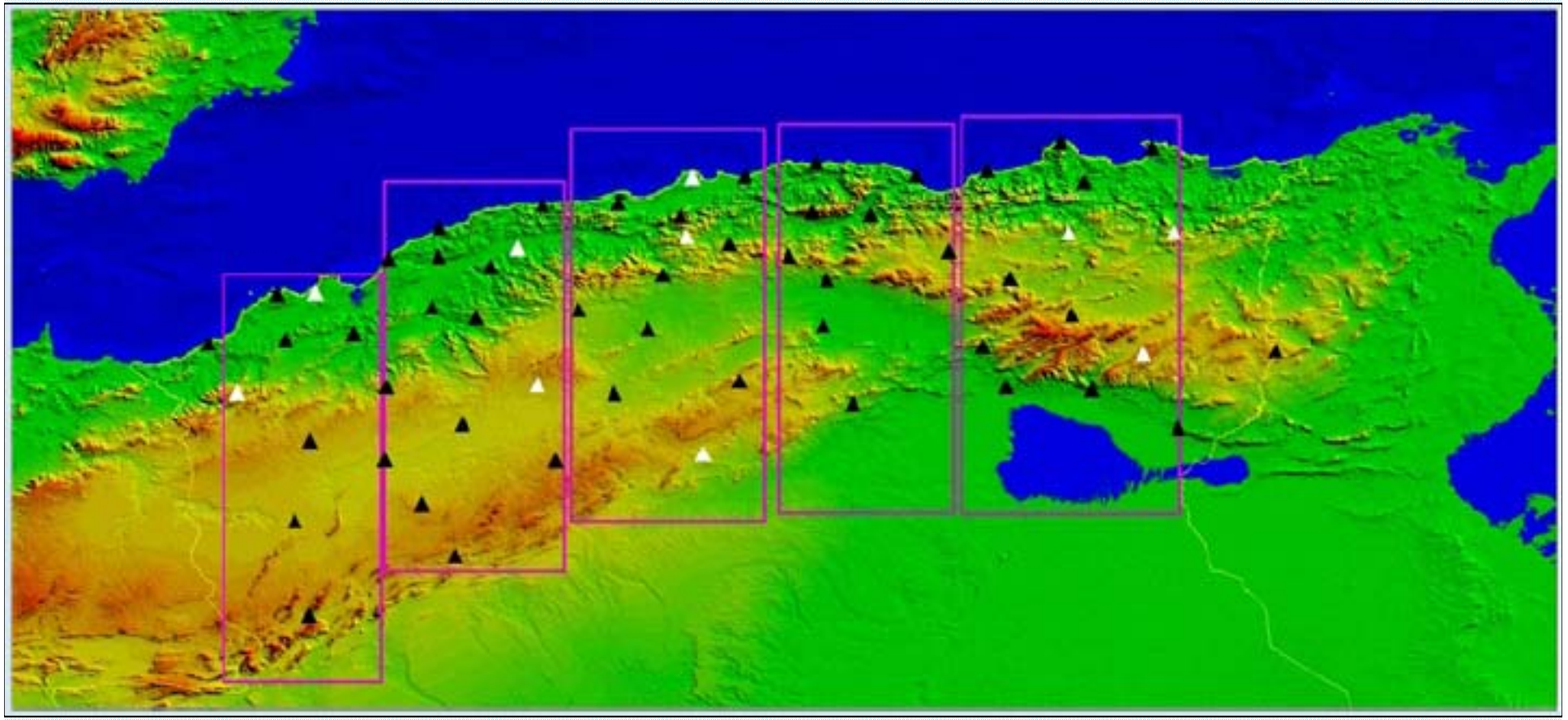
➢ General features of the GPS campaigns :

- Occupations : Permanent or 5 to 7 days
- Time window : 24 h,
- Sampling Rate : 30 s,
- Cut off angle : 15°,
- Bifrequency Receivers

➢ Tools and parameters of GPS data processing :

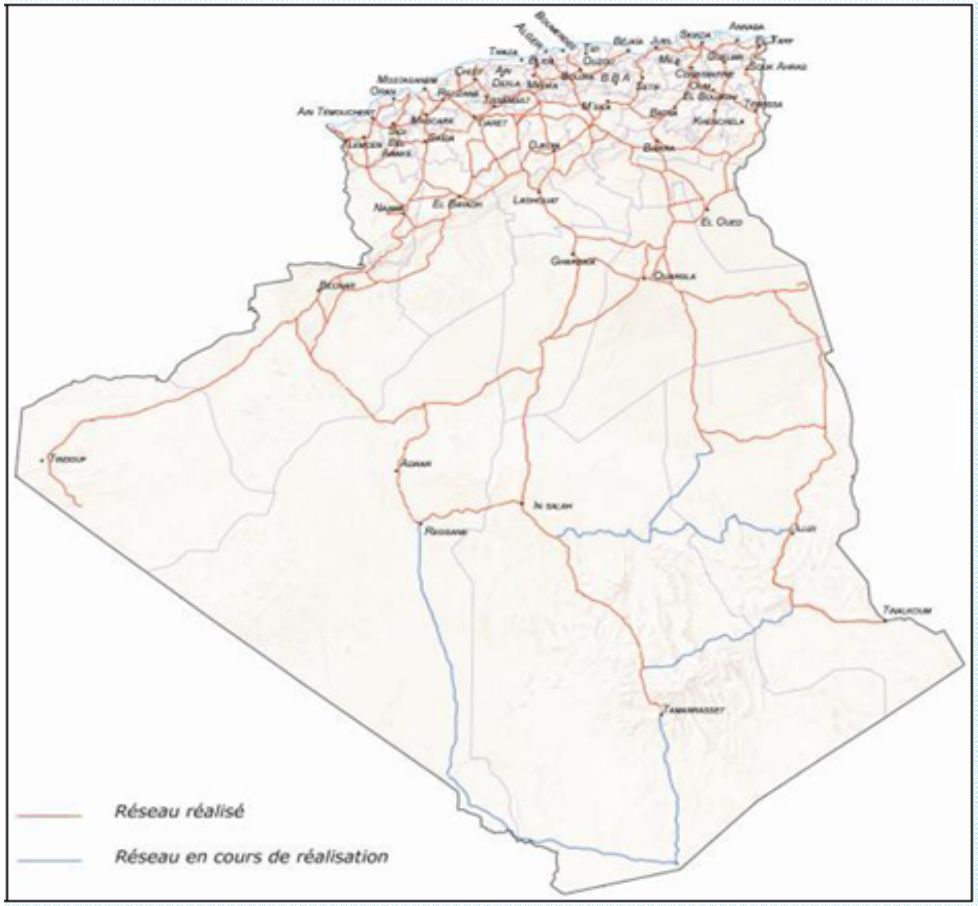
- Software used : Bernese v. 5, Teqc/Unavco & Leica GNSS QC,
- Use of IGS precise ephemeris, satellites clocks corrections ,
- The ionospheric dispersion taken into account ,
- Troposphere : Saastamoinen standard model used ,
- Used Strategy: QIF.
- Eccentricity of the phase centres reduced (orientation) ,
- Other effects (Tides,...): Averaged over a period of 7 days of observations,

PERMANENT GPS NETWORK: REGAT PROJECT



- **White Triangles** represent stations installed during the **first phase**,
- **Black Triangles** represent stations for the **second phase.16 stations** (during 2012),
- **Actually,** there are **56 permanent stations**, to be **extended** to about **70** GPS stations.

Recasting of the Vertical Datum in Algeria



Classical levelling networks

Levelling networks:

- Established over the last 100 years,
- 31171 km of levelling lines,
- Few thousand benchmarks,
- *Laborious, expensive,*
- *Limited coverage of the country,*
- *Benchmarks are unstable,*
- *Local networks,*
- *High maintenance costs.*

The geoid model:

- Complete coverage of the territory (land, lakes and oceans),
- Compatible with the spatial positioning (GNSS altimetry),
- Less expensive to maintain,
- More stable reference surface,
- Reduced susceptibility to geodynamical activity…

Plan of work:

Step 1: Collection and validation of data

- Collection, analysis and homogenization of gravity data acquired from national and International organizations (INCT, SONATRACH, GRAAG, BGI GETECH, KMS),
- Identification and collection of GPS levelled points,
- New investigation for the optimal choice of a global geopotential model for Algeria including new models from new global space missions (CHAMP, GRACE and GOCE),
- Development and use of cross-validation technique for detecting outliers in the gravimetric measurements,
- Qualitative study of the accuracy of available Digital Terrain Models (INCT, SRTM, ETOPO, etc.).

Step 2: Modeling (geoid model determination)

- Computation of local gravimetric geoid model,
- Evaluation of the effect of lateral density variations on the geoid model,
- Comparison of new model with all existing local available solutions.

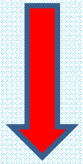
Step 3: Definition of a new vertical datum for Algeria

- Study of the quality of each data introduced in the combined adjustment of GPS, levelling and geoid (statistical study),
- Defining a new vertical datum for Algeria based on the concept of the correction surface.

Objectives of the Project:

- **In the medium term, calculation by gravimetric method of a local geoid model for Algeria, which will be used mainly to support the operations of GPS levelling to densify the levelling networks of the lower orders,**

- **In the long term, modernizing the Algerian vertical datum (NGA: General Levelling of Algera) → definition of a new vertical datum for Algeria based on the concept of the correction surface.**



This new approach will reduce the dependence of users on networks of benchmarks for access to the datum and the maintenance costs of the benchmarks.

Characteristics of the new Algerian geoid model

And Results

Data :

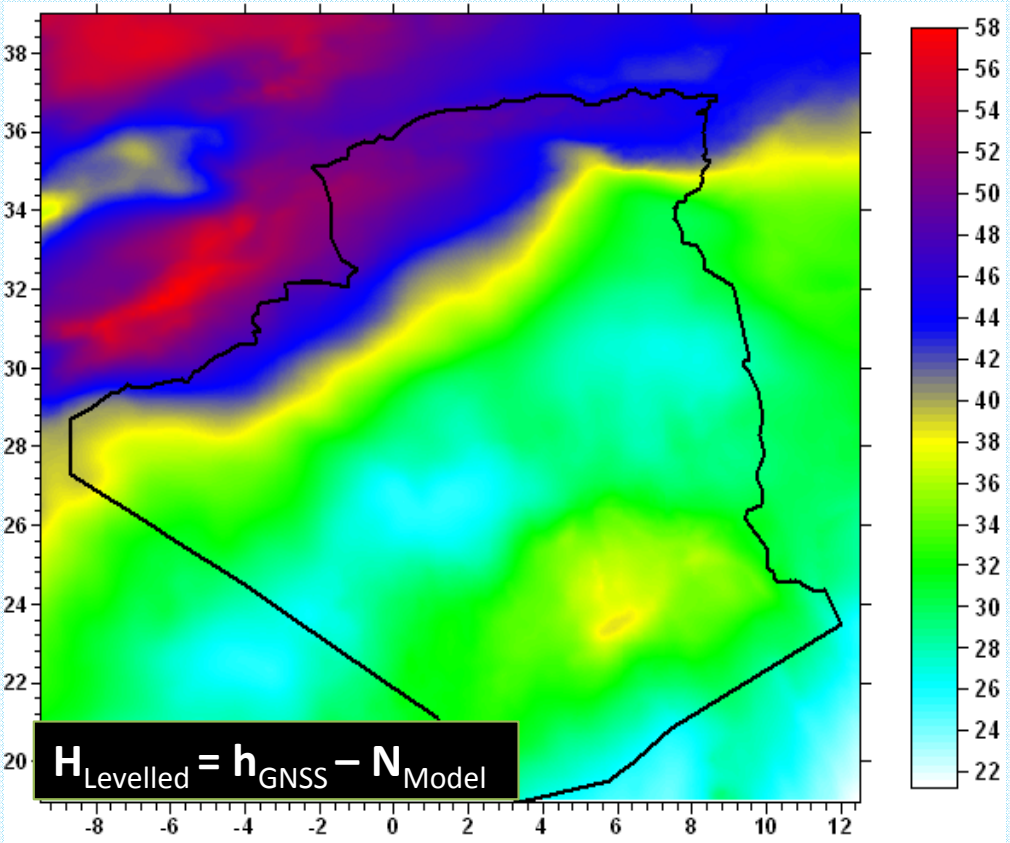
- **Gravity data**: BGI (Terrestrial, 12472 points) and KMS (grid resolution 2’, **Accuracy**: between 03 and 14 mgals),
- **Geopotential model** : **EGM2008,**
- **DEM** (Digital Elevation Model) based on SRTM data (15' x 15'),

Method of calculation:

- **Remove-Restore** technique **FFT**,
- Radius of terrain corrections: **100 km**,

Software :

Gravsoft (*Tscherning & Forsberg).*



Map of the new Algerian gravimetric geoid
(Contour interval 2 m)

DEFINITION OF THE ALTIMETRY REFERENCE SYSTEM FOR ALGERIA

Objective of the Project:

1. Definition of a new datum (mean sea level) from tide gauge data. This reference will be used as a reference (zero origin) for the NGA network,
2. Improving the accuracy and the quality of the NGA network by applying the necessary corrections, including the orthometric correction.

Steps for the realization of the first phase of the project:

Step1: Inventory of the available tide gauge data and software dedicated to data processing tide,

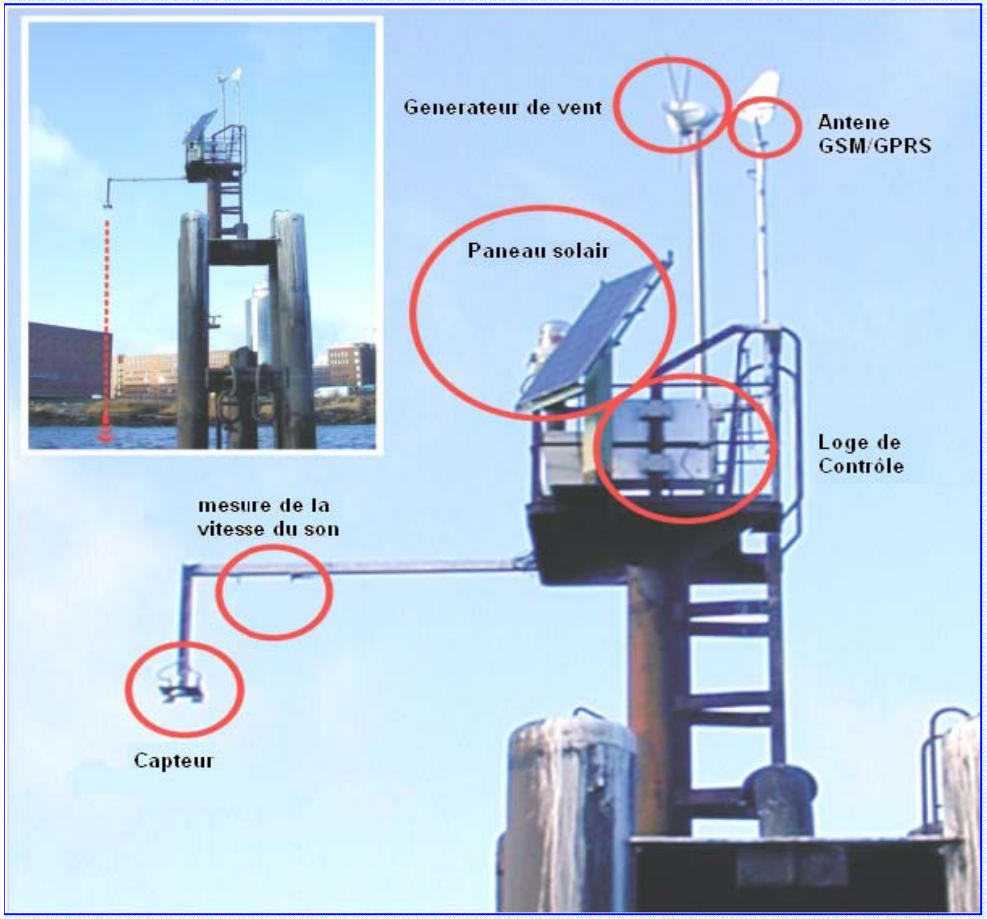
Step 2: Analysis of tide gauge data: control and calibration,

Step3: Definition of zero elevation reference.

Data and Means requested:

- Tide gauge data of Algiers from 11/12/2011 to 26/11/2012.
- Software for preprocessing data: Log-ALEVel and FileJester.

Tide gauge data of Jijel: less than 1 year measurements.



Tide gauge of **Algiers** harbor

Tide gauge in **Jijel** Harbor.

Data processing and Definition of the zero reference:

The determination of tidal harmonic constants from the analysis of tide gauge data is based on three approaches that allow us to estimate the average level of the sea:

1- The Sampling of 1 minute offers a mean level of 43.8 cm (distance between the sea level and the hydrographic zero) ⇨ a **difference of 9.8 cm** compared to the **current reference** (**34 cm**).

2- The Sampling of 5 minutes offers a mean level of 43.8 cm ⇨ a difference of 9.8 cm compared to the **current reference**.

3- The Sampling of 1 hour offers a mean level of 43.7 cm ⇨ a difference of 9.7 cm compared to the **current reference**.

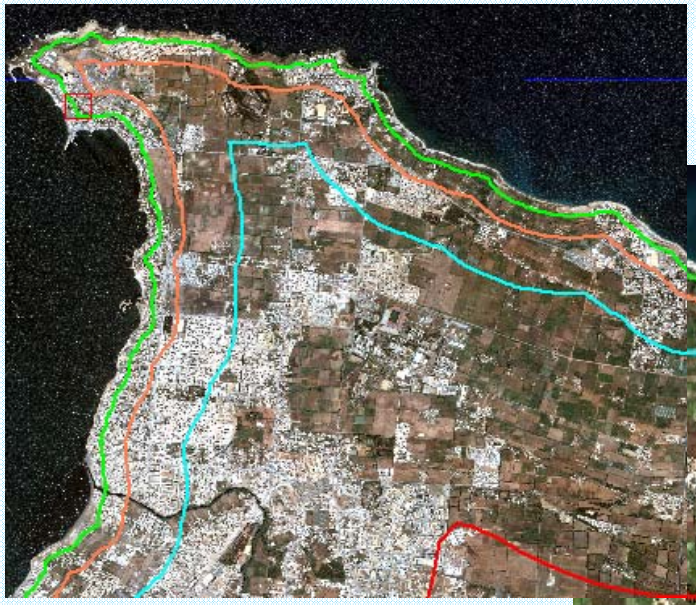
MAPPING OF TOURISTIC REGIONS USING SATELLITE IMAGES AND GPS NETWORKS

Objective of the project :

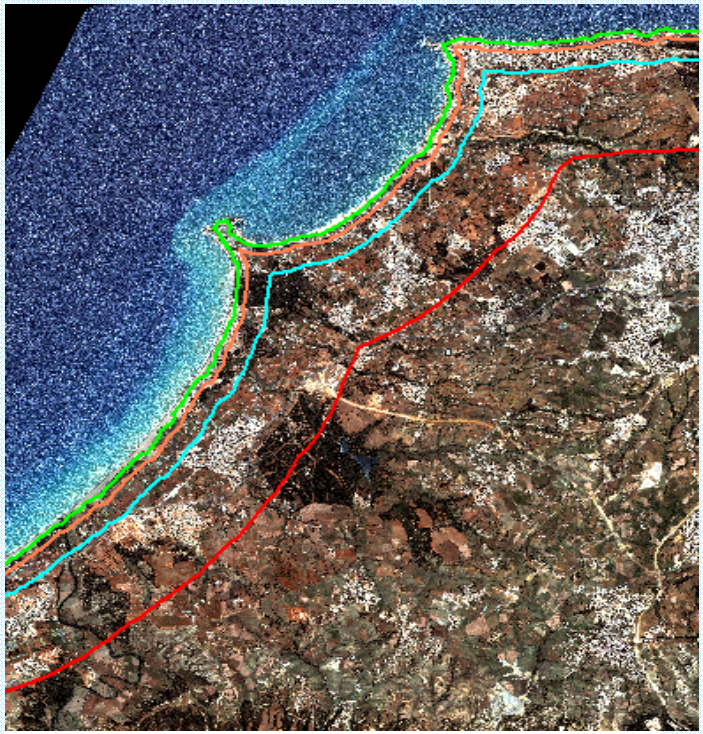
1. **The main goal of this study is to satisfy the needs of the National Agency of the Tourism Development : boundaries and mapping of the touristic regions.**

2. **To provide the ANDT Geographic Information System (GIS) to assist in the management of these areas.**

DELIMITATION OF THE BUFFER ZONES



Eastern touristic area ▼

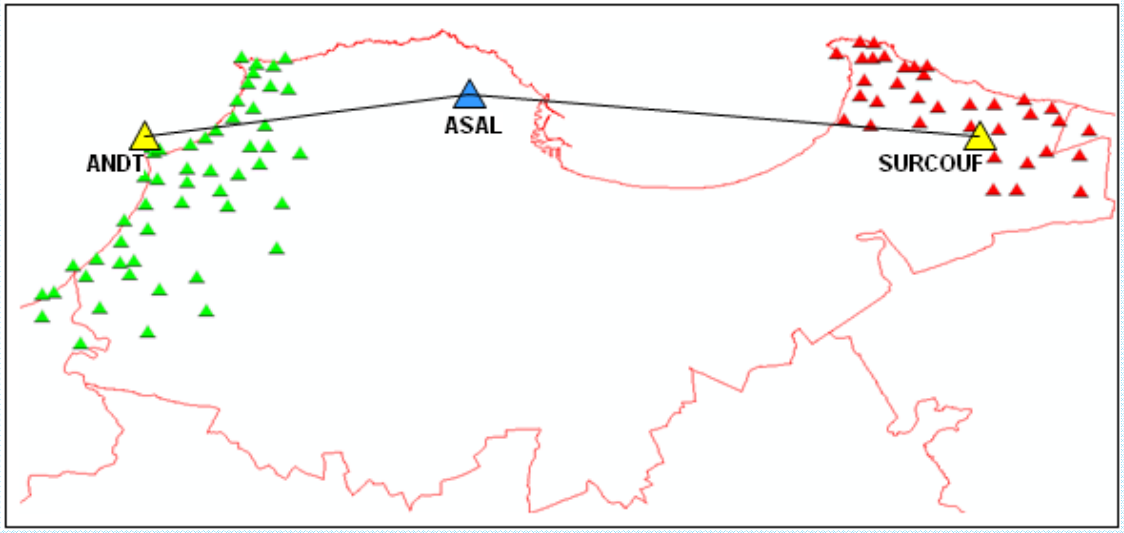


Western touristic area ▲

According to the law on the coast, buffer zones of 100 m, 300 m, 800 m and 3000 m were calculated with respect to the coastline for all areas of interest.

General characteristics of the GPS campaign

- Bifrequency GPS receivers Ashtech ZXII-3,
- Sampling rate : **15 s** with **static mode**,
- Broadcast ephemeris,
- Software: Winprism v2.1,
- Network consists to about **90 GPS stations**,
- Precision**: mm in (X,Y), cm in (Z).**



ARZEW reference GPS Station
◄ *(linked to IGS network since 1996).*

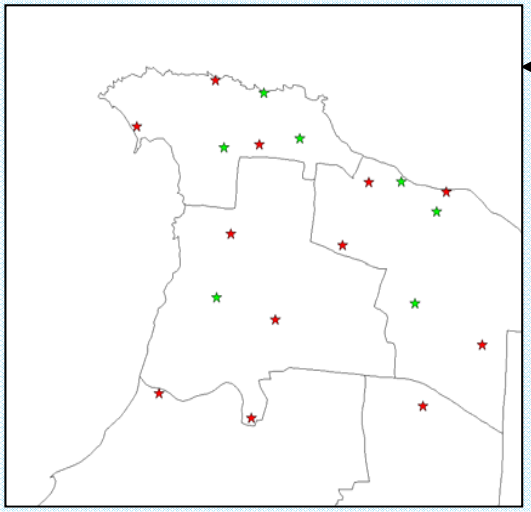
ASAL GPS Station ▲

ANDT GPS STATION ▲

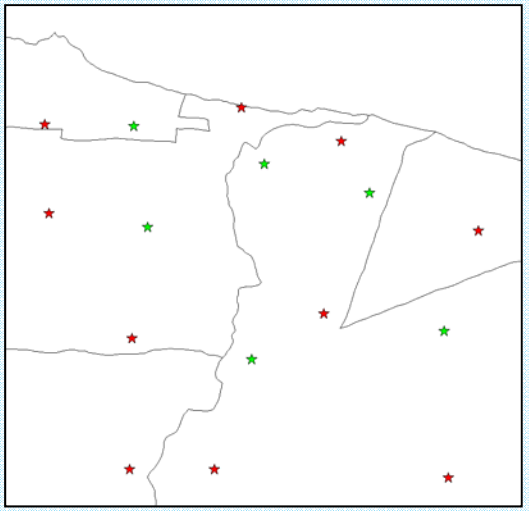
SURCOUF GPS STATION ▲

Location of zones of tourist expansion (ZET) et choice of GPS points:

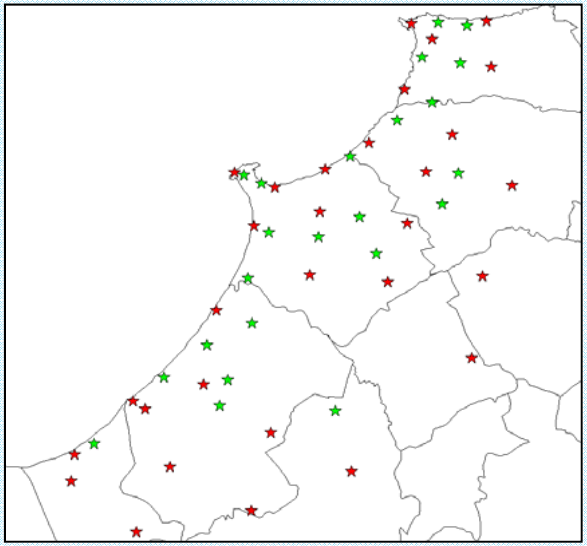
- Location of zones of tourist expansion from cartographic and legal.
- Selection of the characteristic points for the GPS measurements.



East of Algiers:
22 support points
13 control points



West of Algiers:
29 support points -
24 control points



SURVEYING INDUSTRIAL ZONES USING GPS:
1- Case of the Underground LNG Tank.

- 01 underground tank with frost ground at (-161°C) (38 000 m3),
- In exploitation since 1965, it represents 50% of the storage capacity of the complex.

Encountered Problems

Natural causes :

- Uplift of the Tank (50 cm),
- Deformations, blowing up and ground crack,...

Exploitation problems:

LNG leak caused by a ground crack and probable landslide (uplift)?

Structural problems:

Disorders at the level of the roof structure .

Methodology

- Implantation of the reference network (basic),
- Optimal configuration of the targets,
- Monitoring of the evolution and/or the stability of the Tank (GPS and levelling campaigns):

  - First GPS campaign : February 2000
  - Second GPS campaign : July 2002
  - Third GPS campaign : July 2004
  - Forth GPS campaign : July 2004
  - Last GPS campaign : June 2006

- Determination of the displacements,
- Geometric interpretation of the results.

Final results:

Vertical displacements: 163 mm (2000-2004); 252 mm (2000-2006)

Direction of the Planimetric displacement

Horizontal displacements: 90 mm (2000-2004); 168 mm (2000-2006)

The last LNG underground tank in the world was disaffected in July 2007

and its exploitation stopped by the petroleum company .

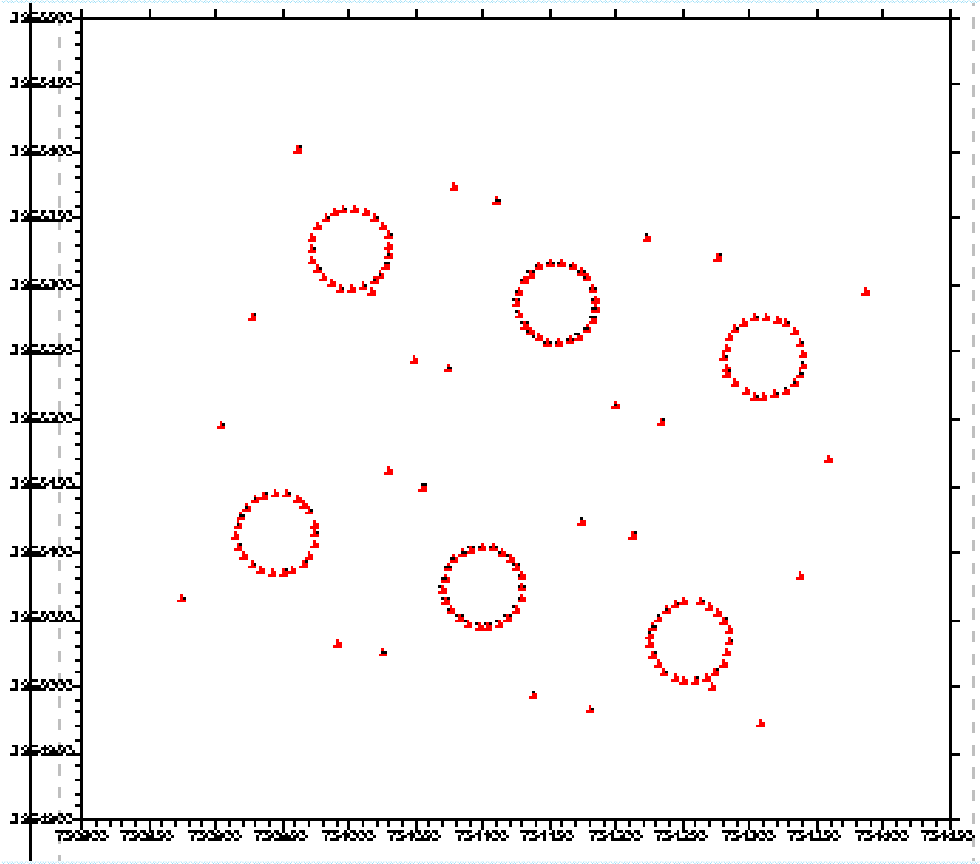
2- Case of the surface LNG Tanks (Current project)

Presentation:

- Location: in same industrial Complex,
- Built in 1983,
- Total Capacity:420 000 m^3.

Main Reasons for the auscultation:

- Age structures and their dimensions,
- Proximity of the sea,
- Nature of the ground,
- Upwelling of water source.



Methodology:

Measurements:

- GPS, static mode (Ashtech ZXII-3),
- Occupation: 20 mn,
- Triangulation (T2 Wild),
- Precise levelling (N3 Wild).

Data processing:

- Winprism v2.1 used,
- Calculation of the local geoid and GPS leveling,
- Software developed in CTS for classical measurements.

The auscultation network is composed of:

- 26 concrete pillars (48 GPS marks),
- 187 targets.

MAPPING OF SAHARAN REGIONS

The platform implementation at the Center for Remote Sensing of INCT enabled through spatial imagery to:

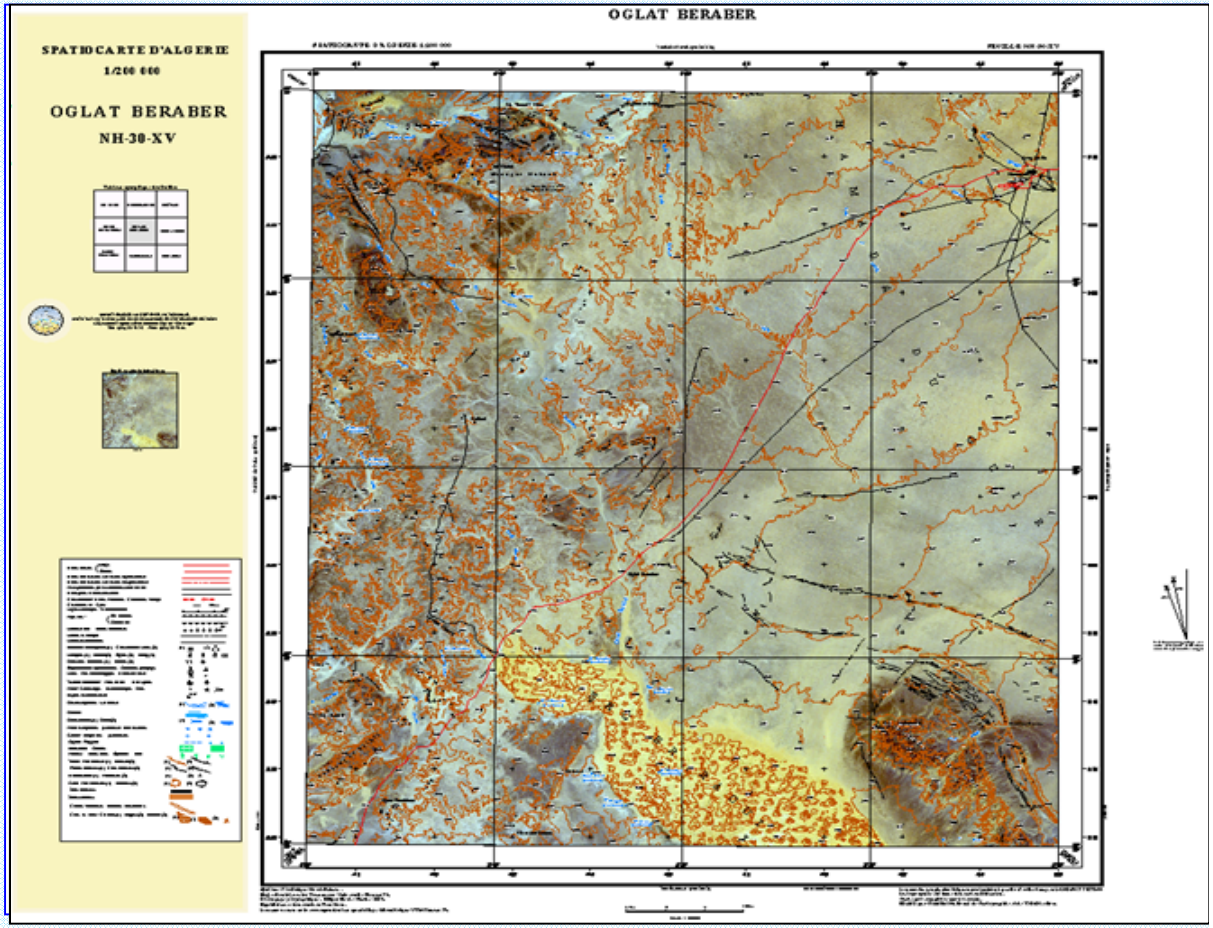
- Fill the void in map, scale 1/200 000,
- Ensure national coverage with the satellite images.

Cases of use of satellite image maps:

- Emergency mapping,
- Mapping of inaccessible areas,
- Updating of conventional maps,
- GIS and spatial database.

Classification of satellite image maps:

- Satellite image maps oriented topographic,
- Satellite image maps oriented thematic.



CONCLUSION

Large field of GPS applications in Algeria with high precision:

- **Geodetic Networks ⇨ Define precise reference frames (regional and worldwide),**
- **Geodynamical studies,**
- **Signaling and maritime navigation by Differential GPS,**
- **Bathymetric surveys of national coats,**
- **Auscultation of hydraulic dams,**
- **Reduction of natural and industrial disasters (seismic, flooding, petrochemical complex...).**

PERSPECTIVES:

- **Transportation: Surveys of many thousands km of Rail and Road,**
- **Integrating all the national permanent GPS networks,**
- **Unify GPS networks of the North Africa countries .**
- **Implementation of DORIS and EGNOS RIMS stations at Tamanrasset,**