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Seismic risks assessment around the Mediterranean region

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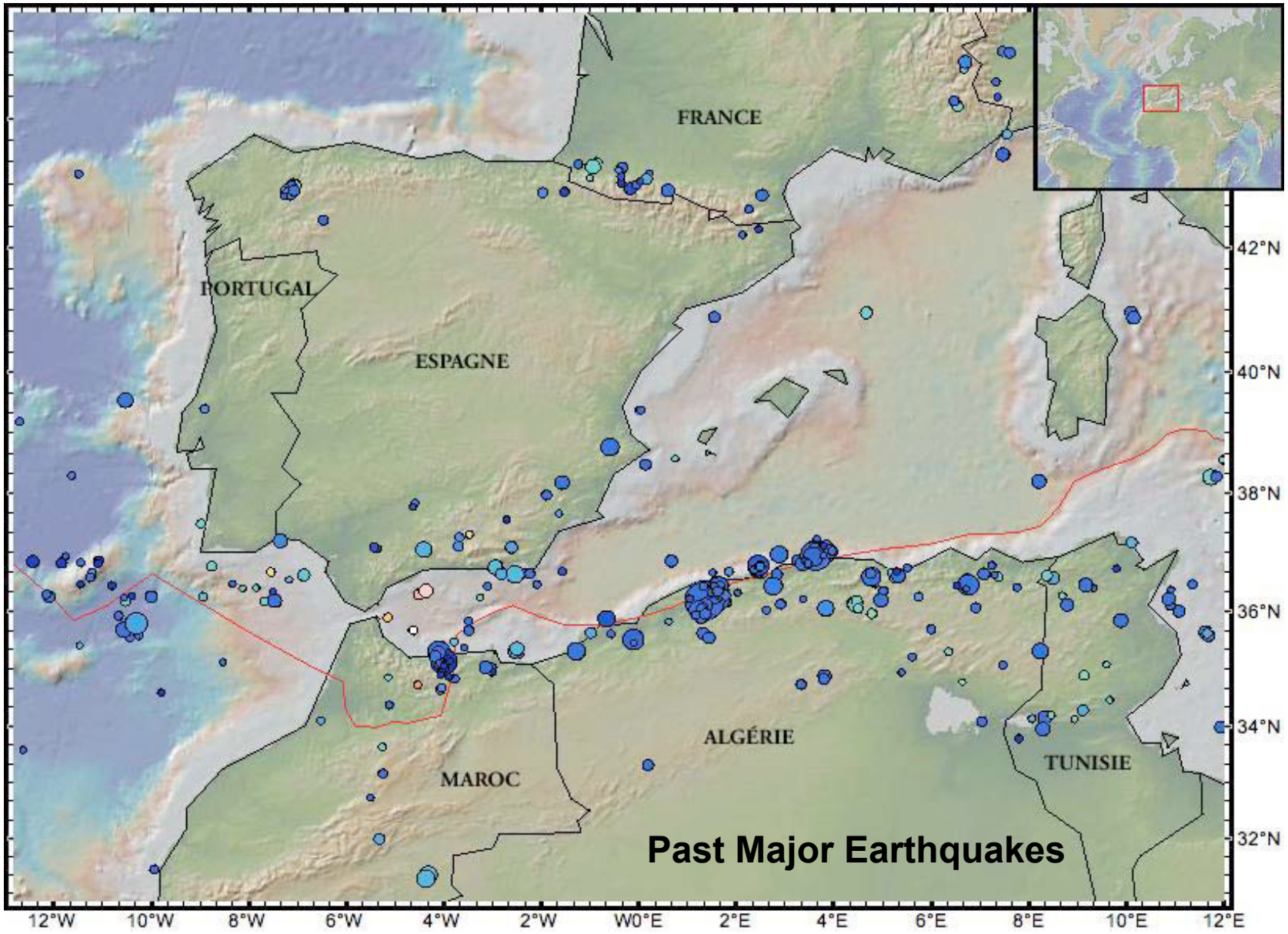
Issues

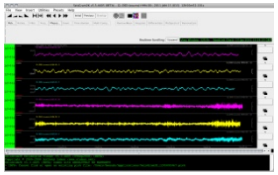
- The majority of the western Mediterranean regions are located on a seismic line which exposes them to an increased risk of earthquakes (Africa/Eurasia plates convergence).
- Many geodynamic models were proposed ?!
- Poor GPS stations cover.
- Many archive data to analyze, how?

Past Major Earthquakes

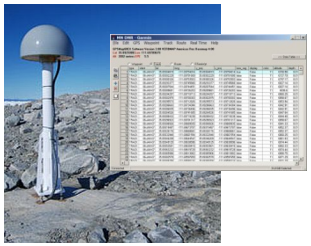


Objectives

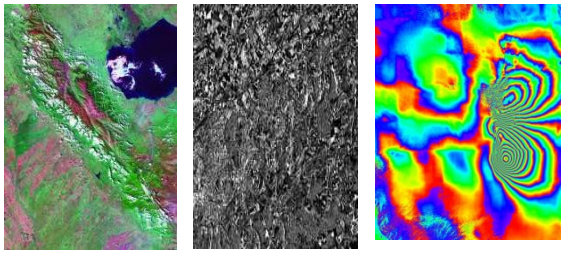
- to focalize on ground surface tectonic deformation related to the seismic activity
- Geodynamic deformation understanding ⇒ Early warning is the way to avoid or minimize damages and help concerned countries to evaluate the risks
- Need to combine different types of data.



Seismic data



GPS data

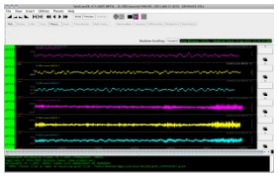


Satellite images

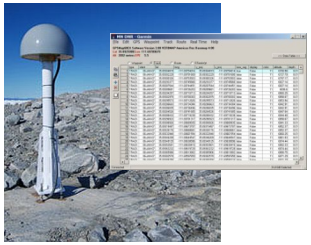
Outline

- Proposed methodology
- INSAR processing
- GPS processing
- Seismic data exploitation
- Resulted deformation model

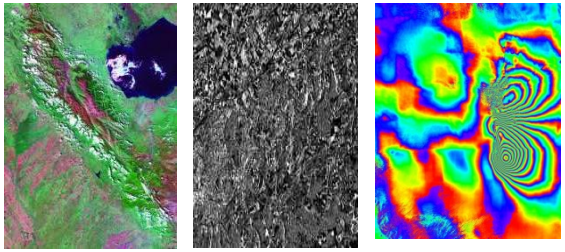
Proposed methodology



Seismic data



GPS data



Satellite images

Data processing

Data processing

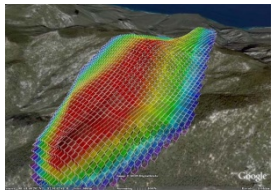
Deformation model

Deformation model

Data fusion

A priori information
Previous researches

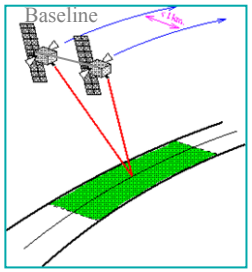
Improved Deformation model



End User

INSAR processing

InSAR principle (1/2)



Radar image1

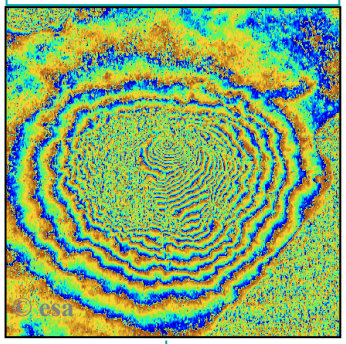
Radar Image2

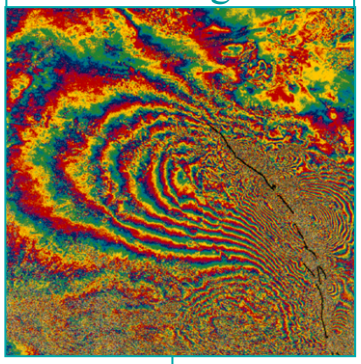
DTM ou Radar Image3

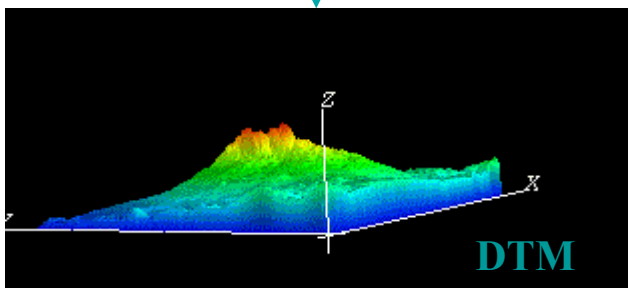
Phase

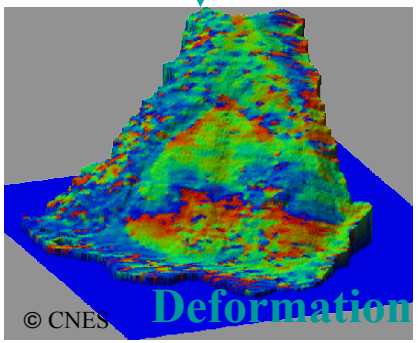
interferogram

différential interferogram

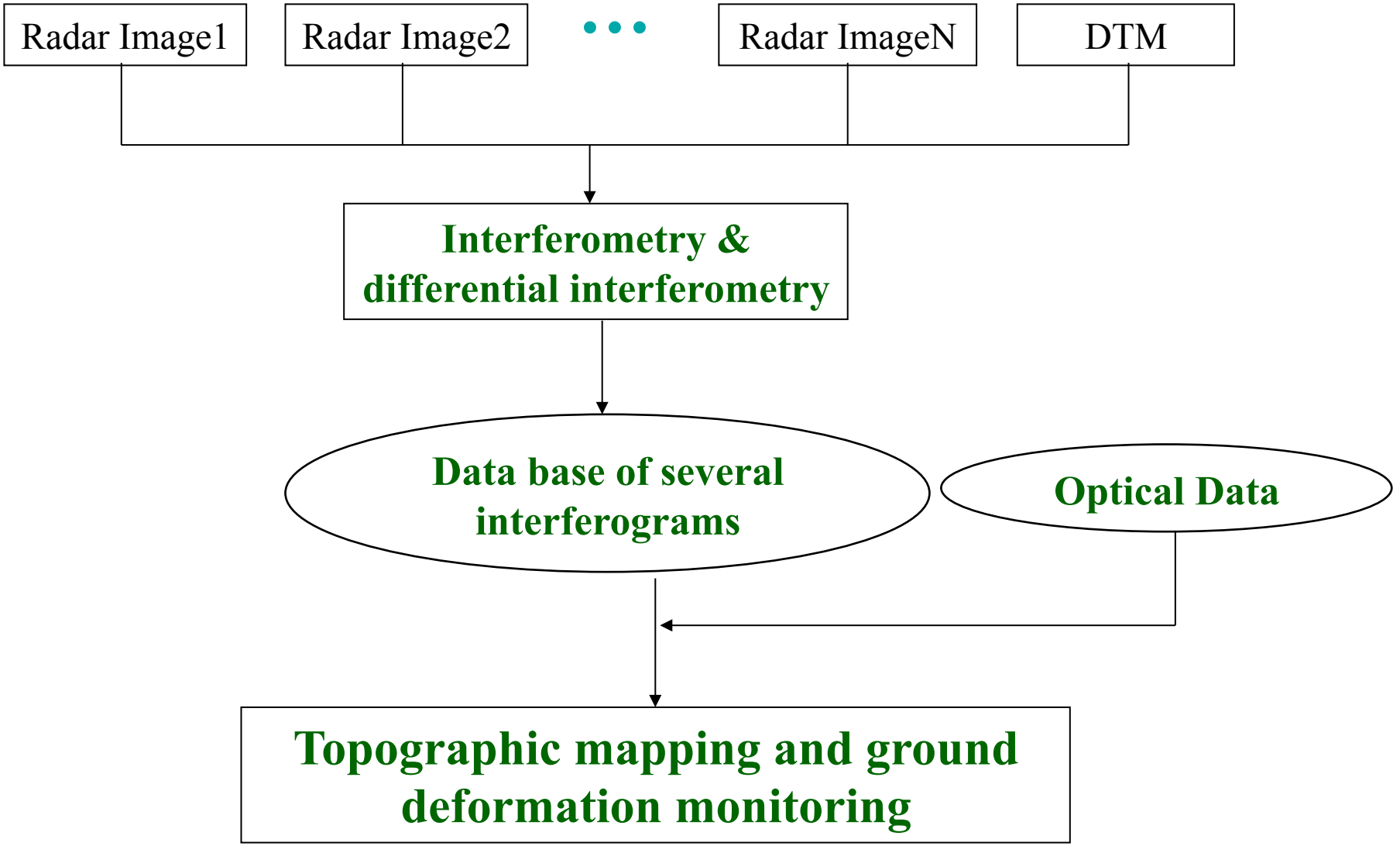








InSAR principle (2/2)



INSAR processing strategy

Four steps:

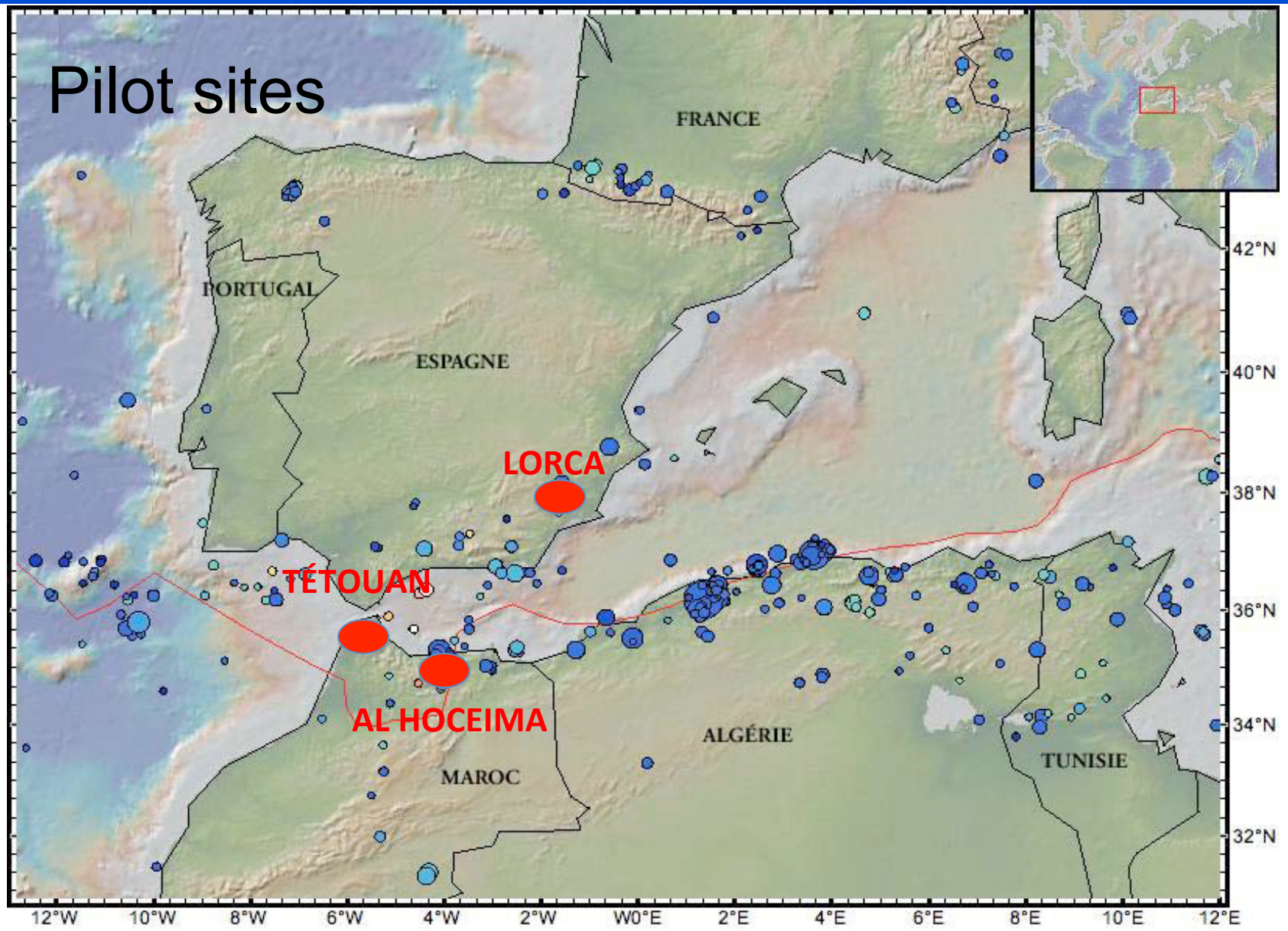
- Choice of the priority targets

- Acquisition of the images and formation of a data base

- Development of new techniques for ground deformation measurements

- Starting of geological interpretations and numerical modelling.

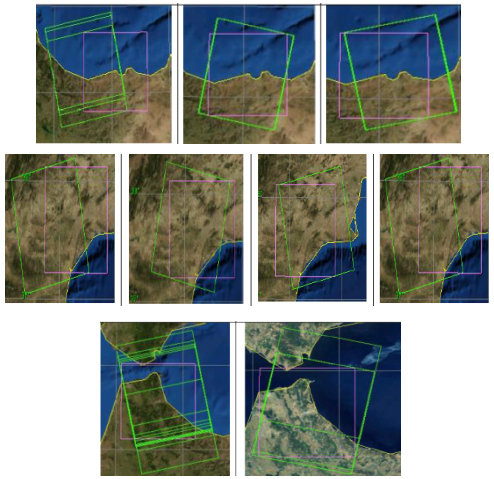
Pilot sites


Pilot sites
FRANCE
PORTUGAL
ESPAGNE
LORCA
TÉTOUAN
AL HOCEIMA
ALGÉRIE
MAROC
TUNISIE
42°N
40°N
38°N
36°N
34°N
32°N
12°W
10°W
8°W
6°W
4°W
2°W
W0°E
2°E
4°E
6°E
8°E
10°E
12°E

INSAR database

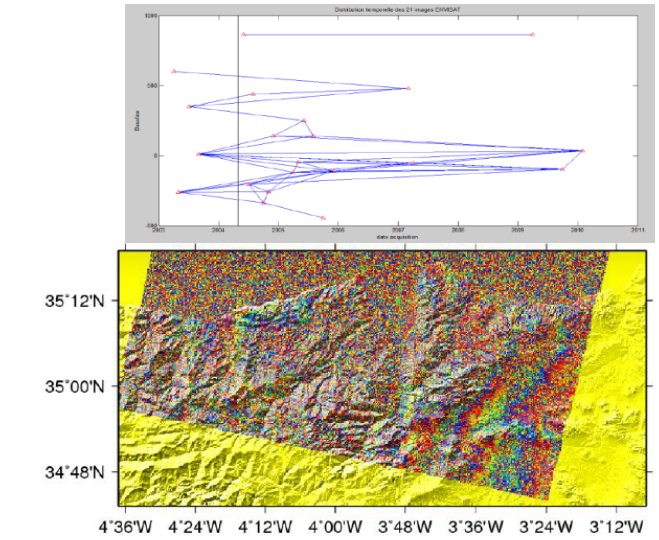
- Satellite images data base : **ESA Category1 project** ⇒ All the archive data (ERS1-2, ENVISAT): about 200 images for the 3 areas of study

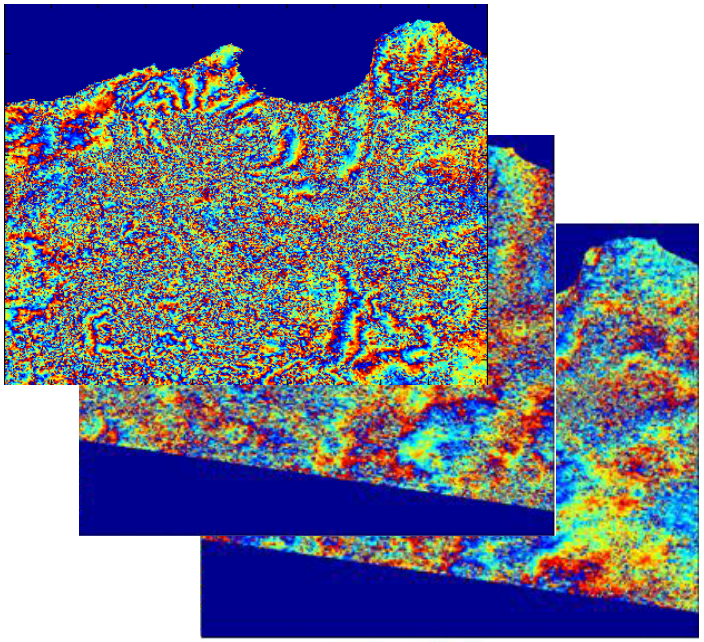
  - Al Hoceima 37 ENVISAT + 24 ERS
  - Lorca 36 ENVISAT + 24 ERS
  - Tétouan 35 ENVISAT + 45 ERS



- Development of a **Virtual Machine** to facilitate the exploitation of the developed interferometric tools

INSAR results (1/2)



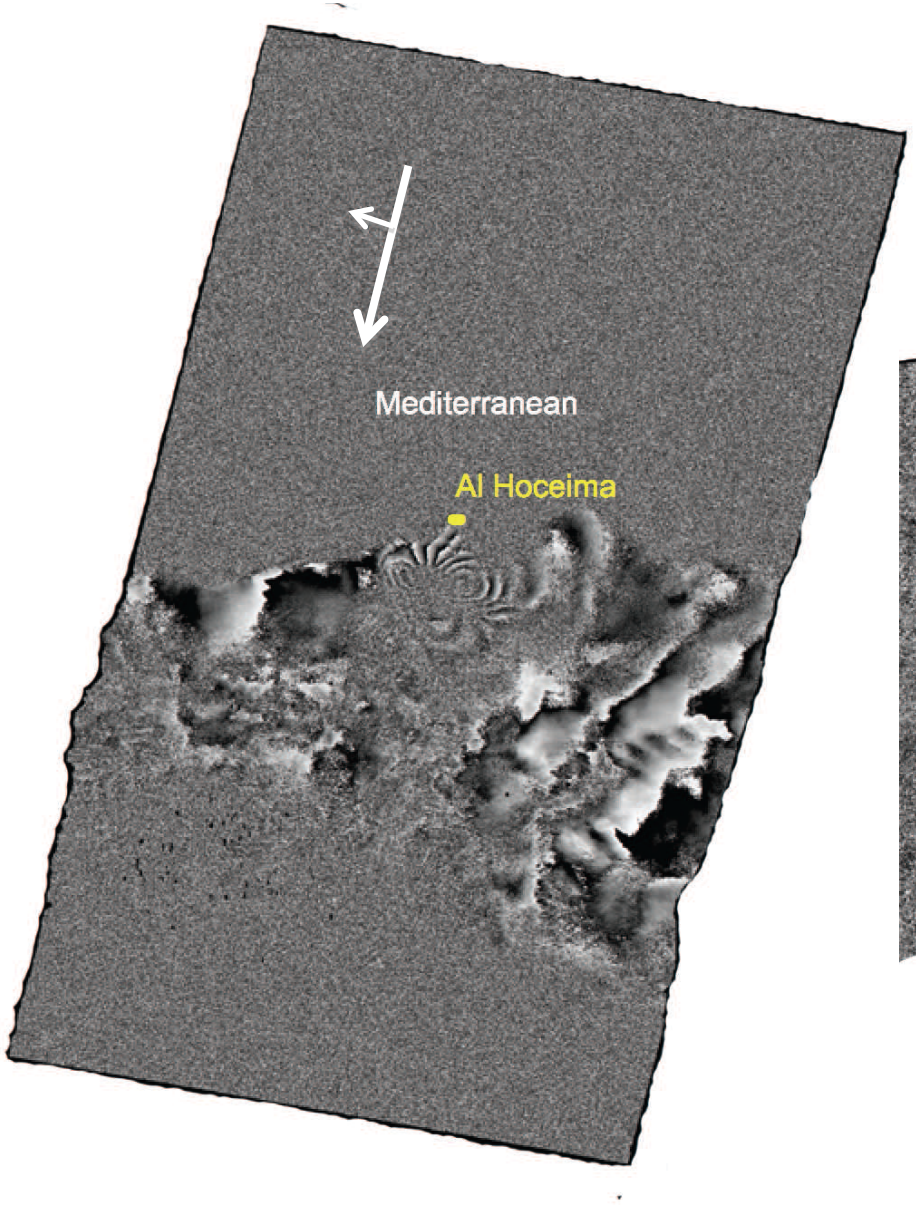


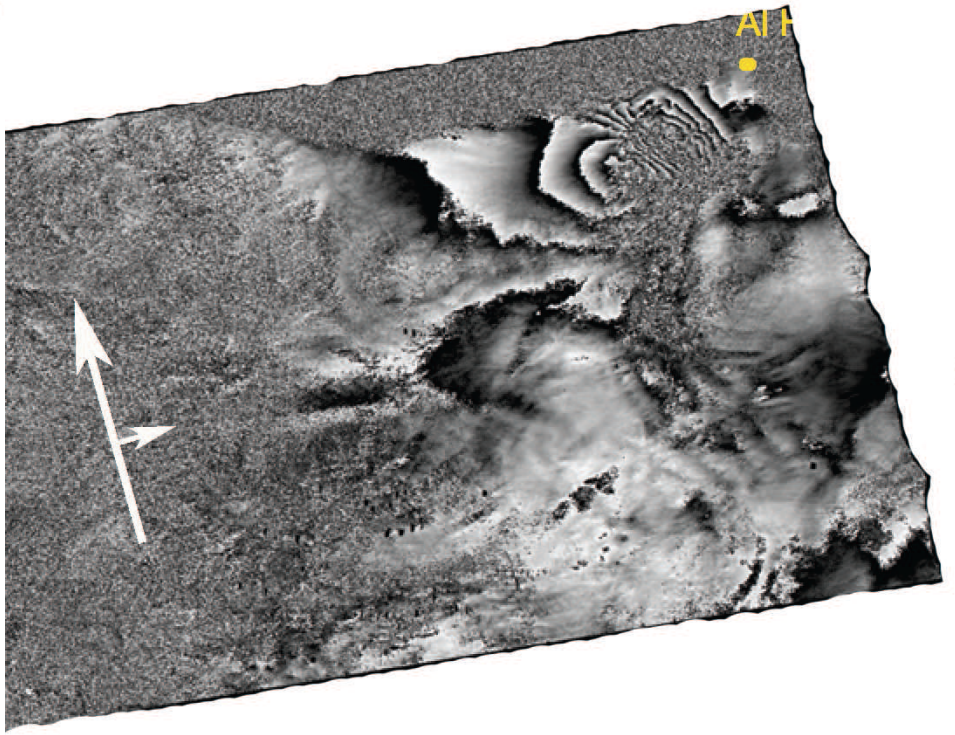
- Case of Al Hoceima pilot site : 31 differential interferograms has been generated (baseline<150m)

- Interferometric processing: filtering (spatial and temporal), atmospheric correction, unwrapping, etc.

INSAR analysis ⇒ Maximum of information about the deformation model

INSAR results (2/2)





GPS processing

GPS processing strategy

GPS networks data will be collected as far as their temporal compatibilities

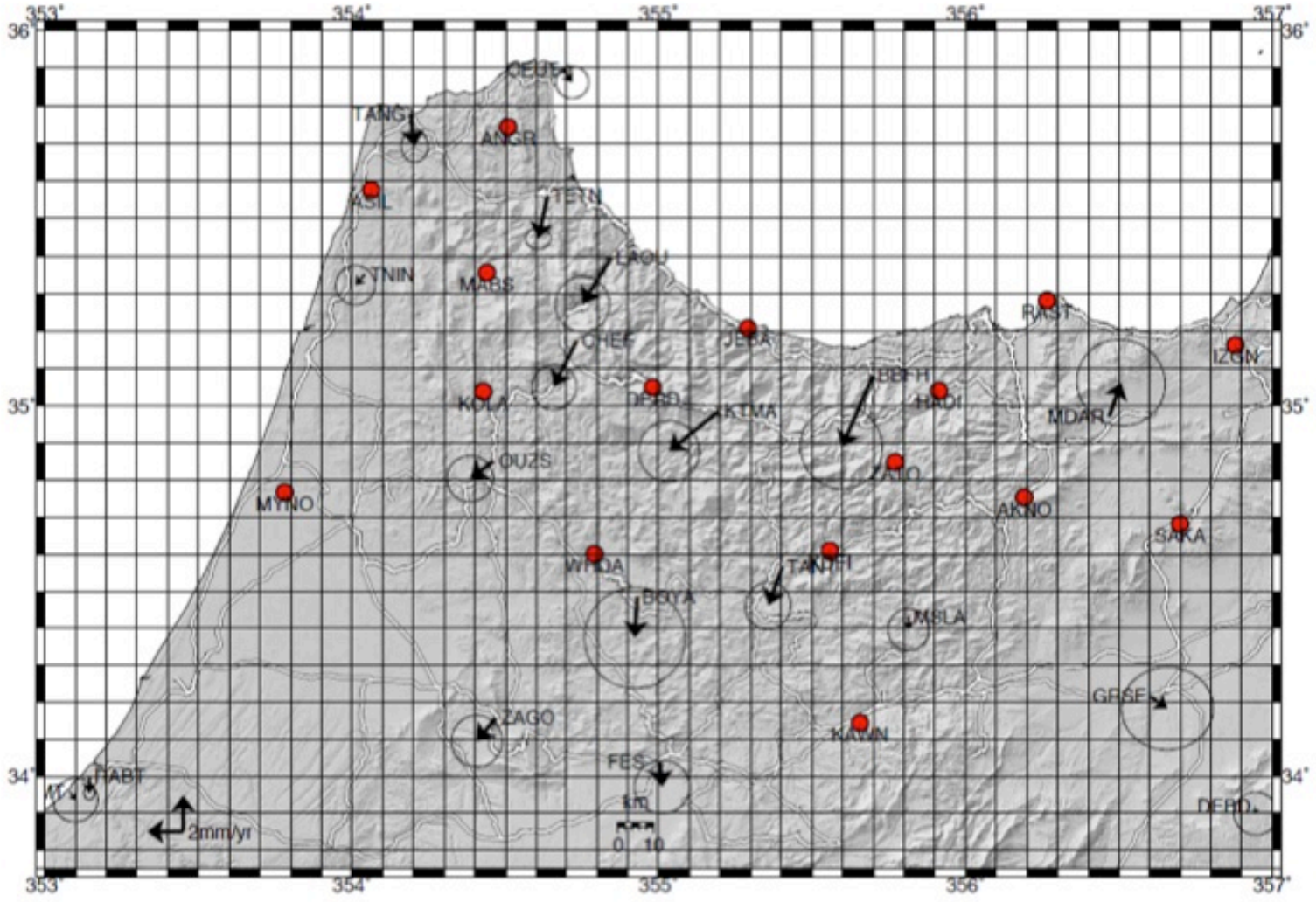
⇒ initiate a coordination of measurements of these networks in a joint way.

- Installation of additional permanent GPS stations in Morroco

- Apply processing and monitoring of permanent GPS stations covering all the region of study.

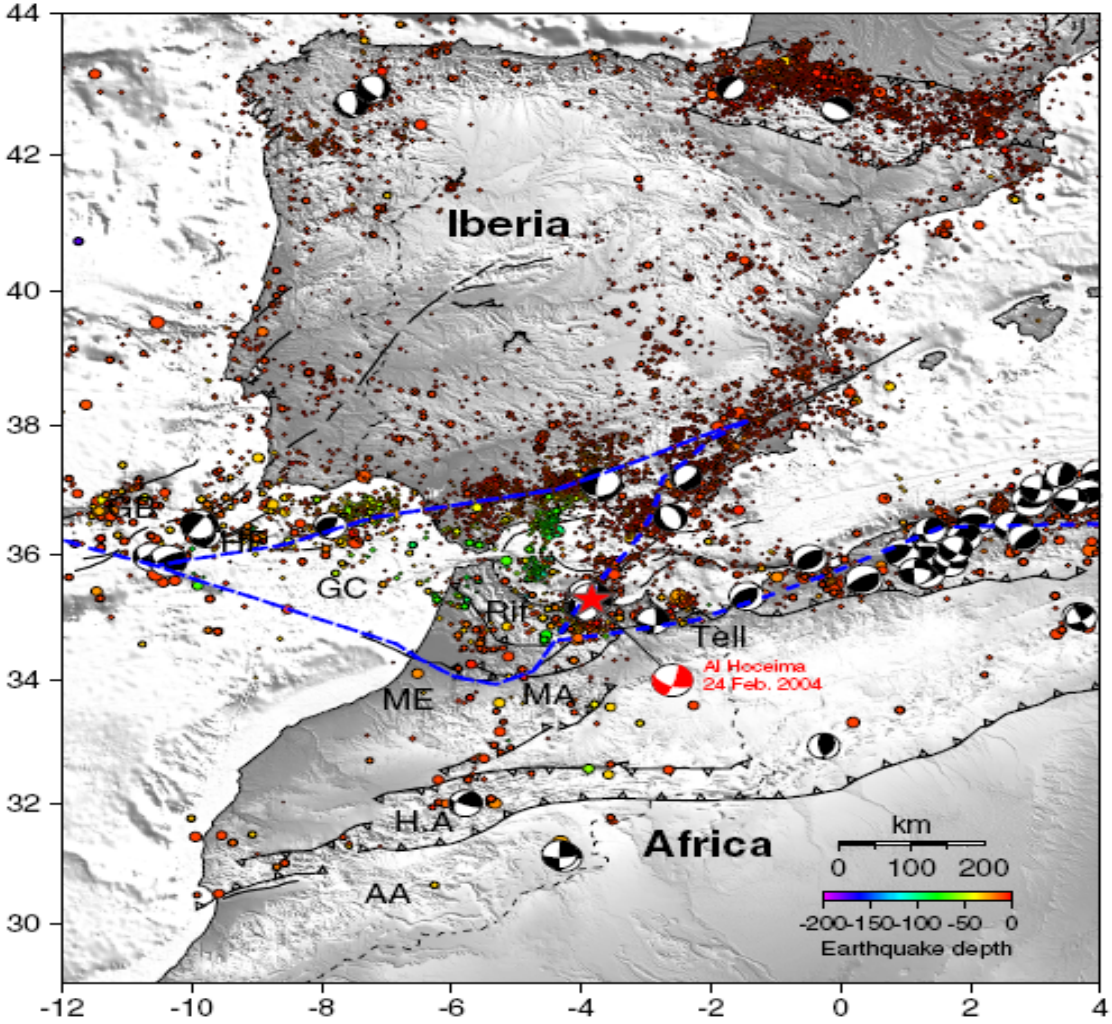
GPS network densification

New GPS sites in the Rif: better resolution



General information for the Iberia-Africa region

Seismicity is broadly distributed over ~300 km and earthquakes are of moderate to low magnitude and mostly occur at shallow depths



New GPS constraints along Africa-Iberia boundary

- To investigate present day deformation
- To estimate the geometry and rates of strain accumulation
- To determine a new velocity field across the most western part of the Africa-Iberia plate boundary,

⇒**Rigorous GPS Modeling Combined with Kinematic block modeling**

Data

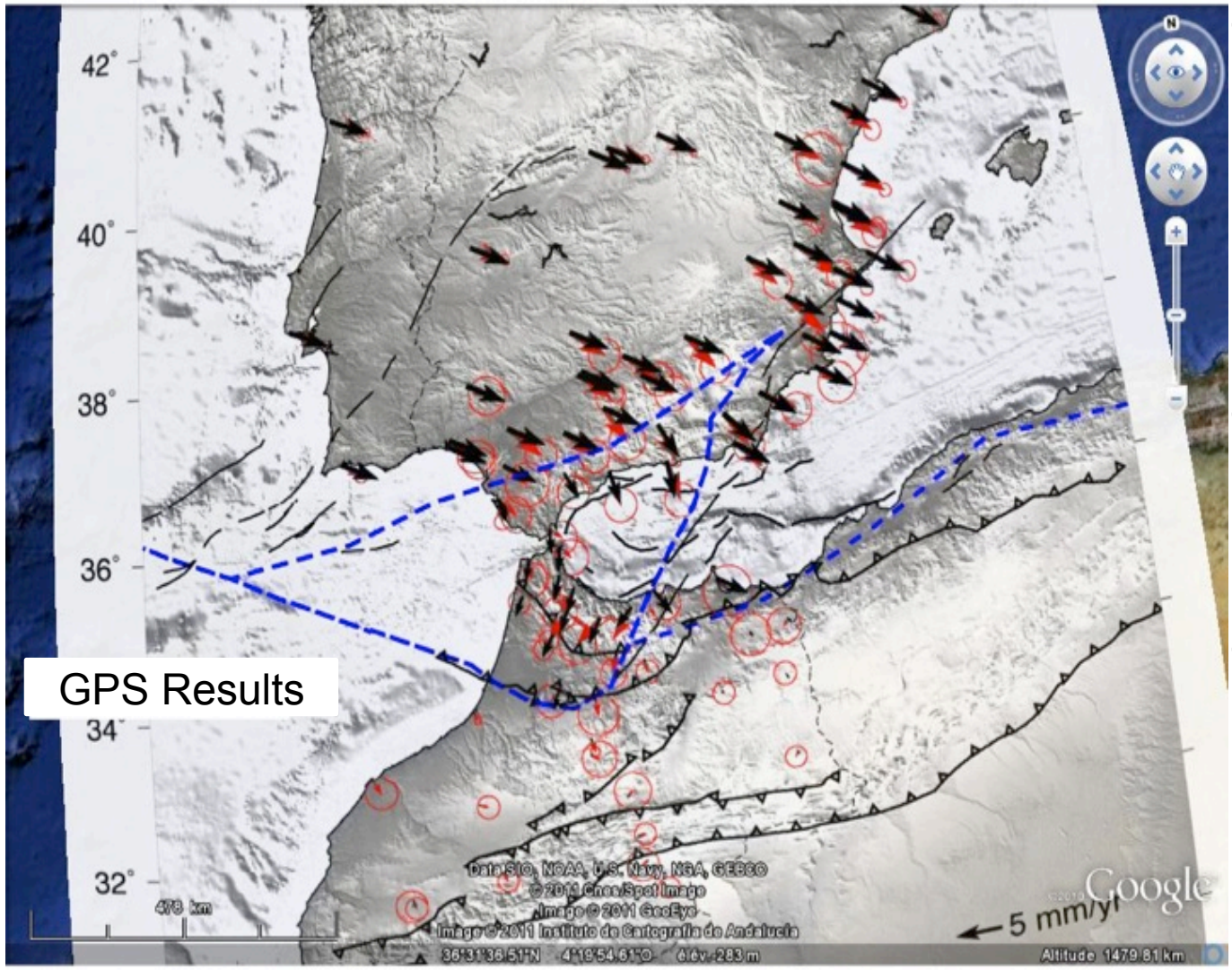
- GPS observations : 65 permanent stations, 31 survey-mode GPS sites, new continuous stations in Morocco and southern Spain.

GPS observations

- GPS three steps approach:
  - GPS phase observations ⇒ to estimate daily positions using loose a priori constraints
  - Combine daily positions with similar solutions for over 200 global GPS stations
  - Combine all the data in a single solution ⇒ estimate positions, velocities, etc.

GPS results

GPS / Kinematic block modeling results



- The GPS velocity field shows south-west motion of the central part of the Rif Mountains in north Morocco /Africa (3.5-4.0 mm/yr)
- The Betic Mountains of south Spain move west–southwest/ Eurasia (~2–3 mm/yr)
- GPS velocities for stations in the southwest Betics and in Central Rif show a clockwise rotation

Seismic data exploitation

Seismic processing strategy

- Data is analyzed in order to improve :
  - Precise details of locations,
  - Focal mechanisms,
  - Fault characterization,
  - The crustal structure, etc.

- Analyze seismicity of the zone of study according to the results obtained in geodesy.

Seismic investigations

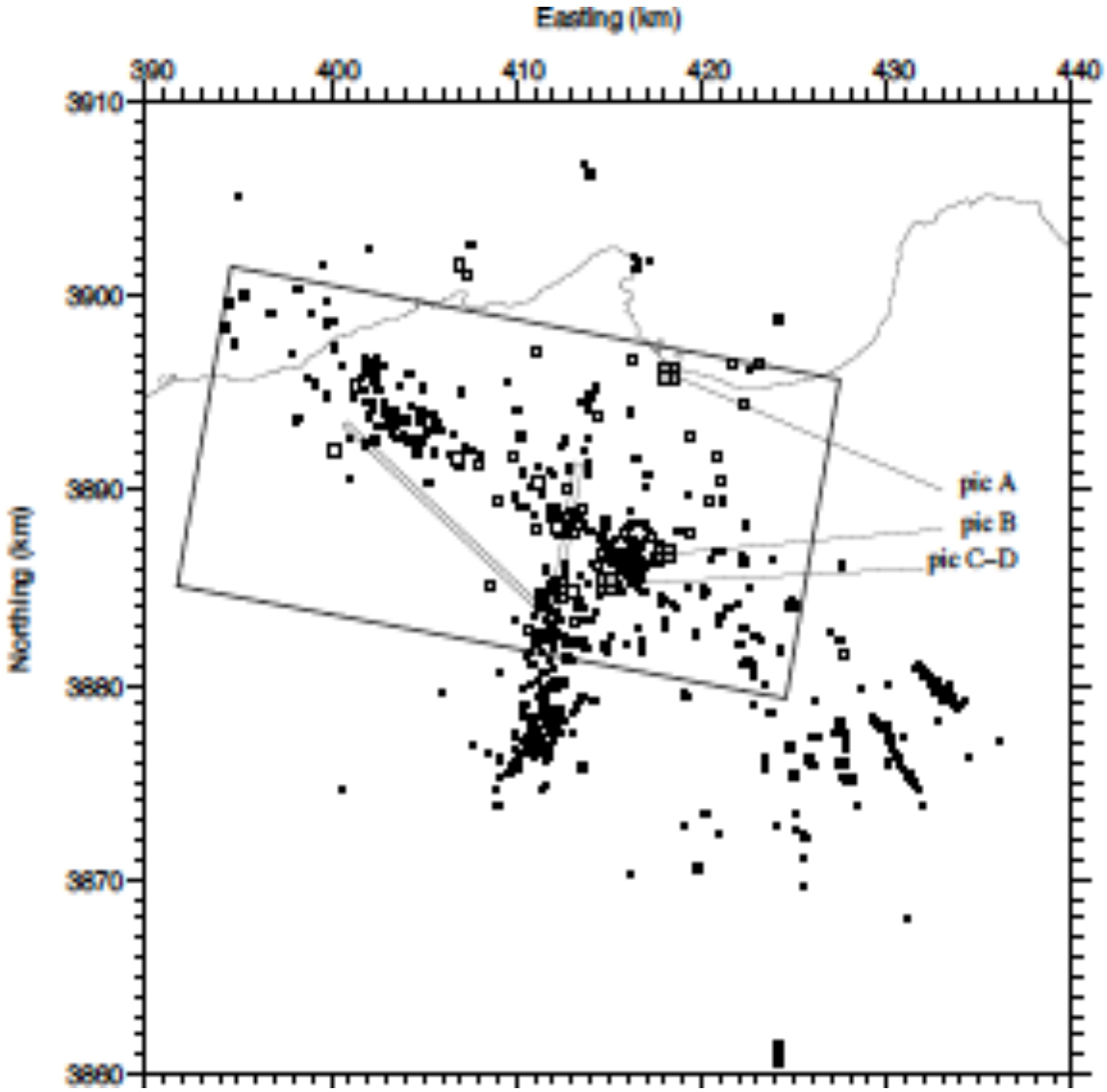
Case of Al Hoceima pilot site:

- Previous seismological works: similar focal mechanisms and parallel faults for the two Al Hoceima main shocks: not agree with GPS and InSAR results.

- Inversions of P and SH waveforms were carried out from a dozen teleseismic stations to determine the detailed rupture history for the two main shocks

- Twenty autonomous seismological stations were deployed during two weeks following the main shocks in the epicentral zone of Al Hoceima => Aftershock magnitudes

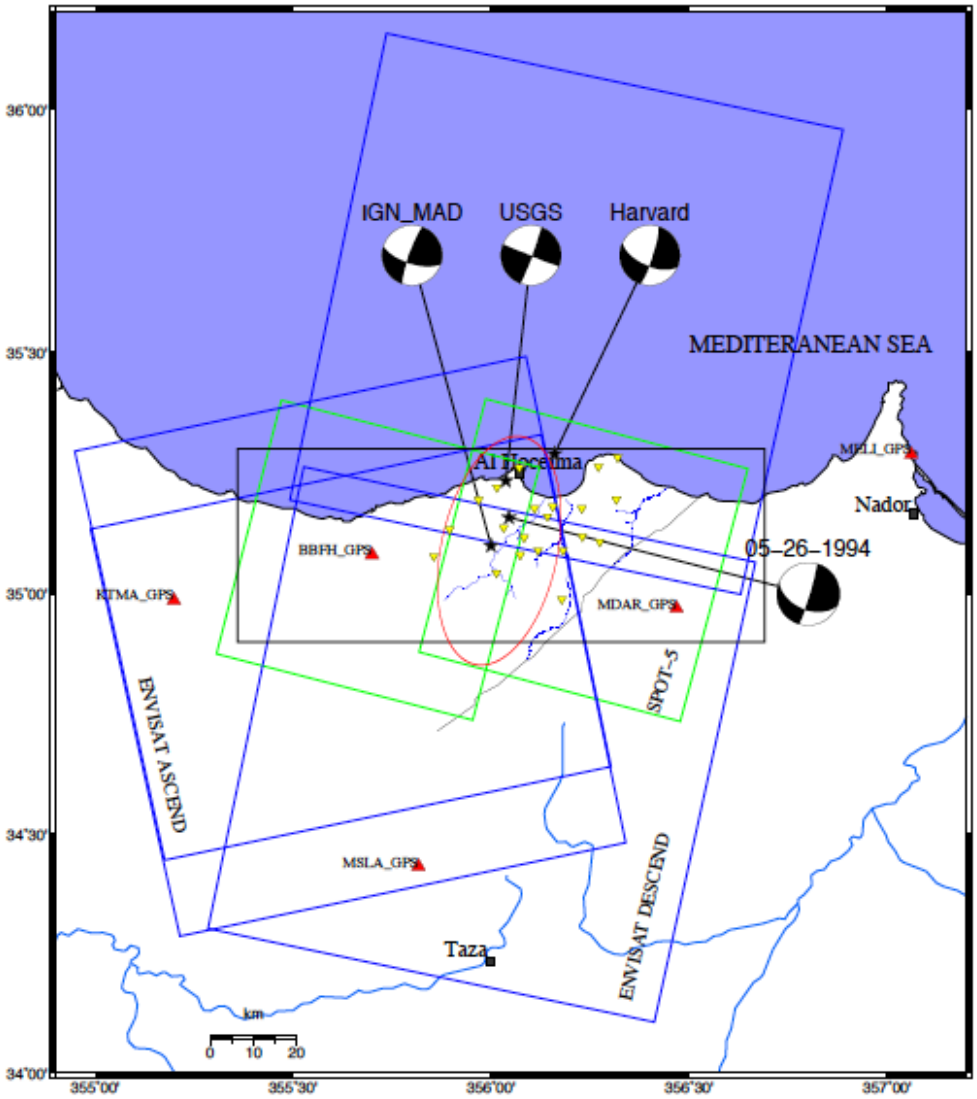
Seismic investigations



- Bars are the two modeled faults (GPS/ INSAR).
- Rectangle:the cross-section frame.
- picA, picB and picC-D indicate location of ground photographs.

INSAR, GPS and Seismic data analysis
Deformation modeling

Data diversity

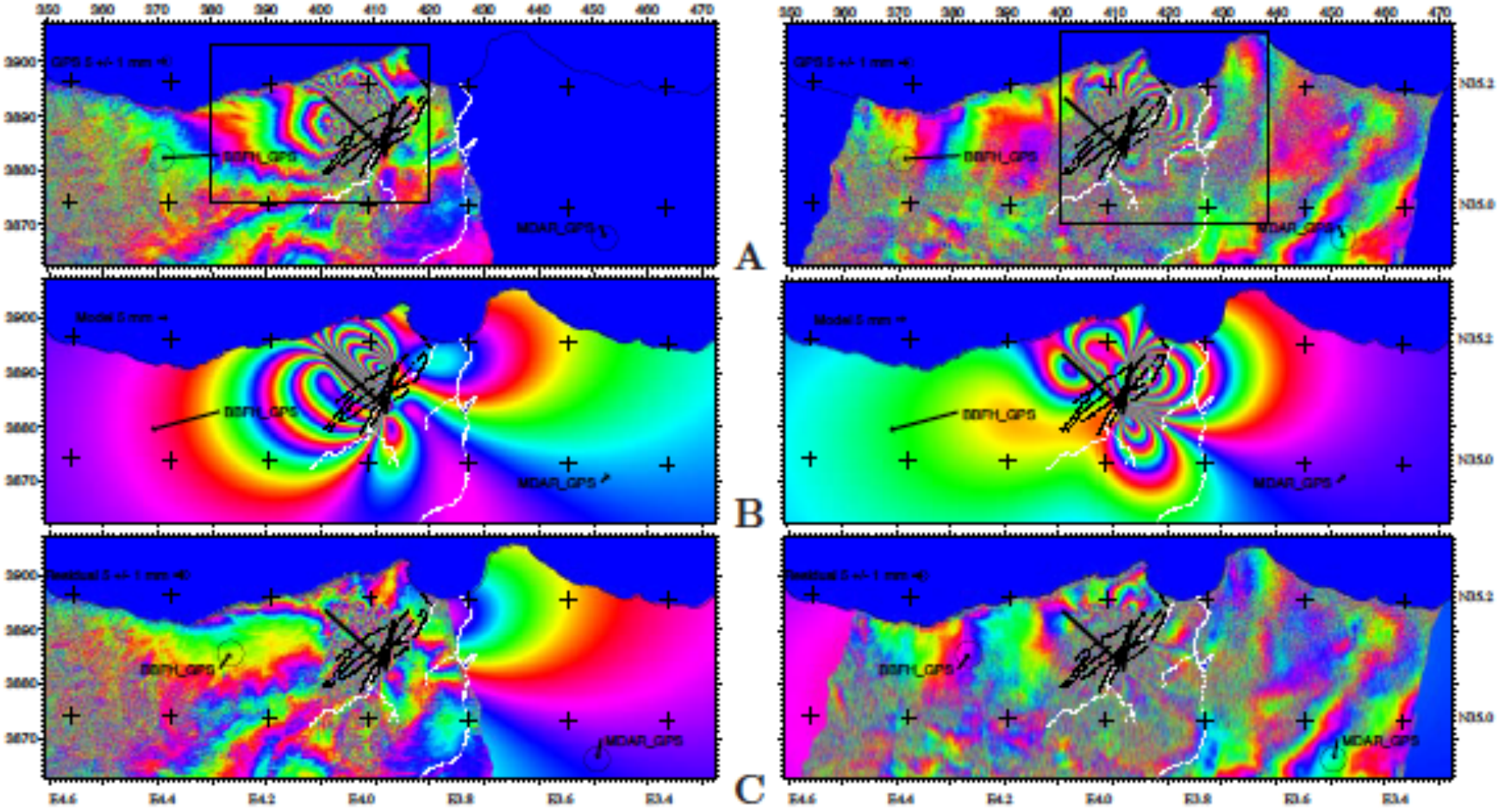


- Red ellipse delimits the damaged area.
- Stars show the epicenter locations of the Al Hoceima main shock with corresponding focal mechanisms estimated by different data centers.
- Blue rectangles denote subsets of ENVISAT ASAR images
- Red triangles are GPS stations : MDAR and BBFH have GPS measurements of coseismic displacements included in the modeling.
- Yellow triangles represent seismic temporary array stations used to collect
- Rectangle oriented E-W delimits the area covered by the showed interferograms

Deformation model (1/2)

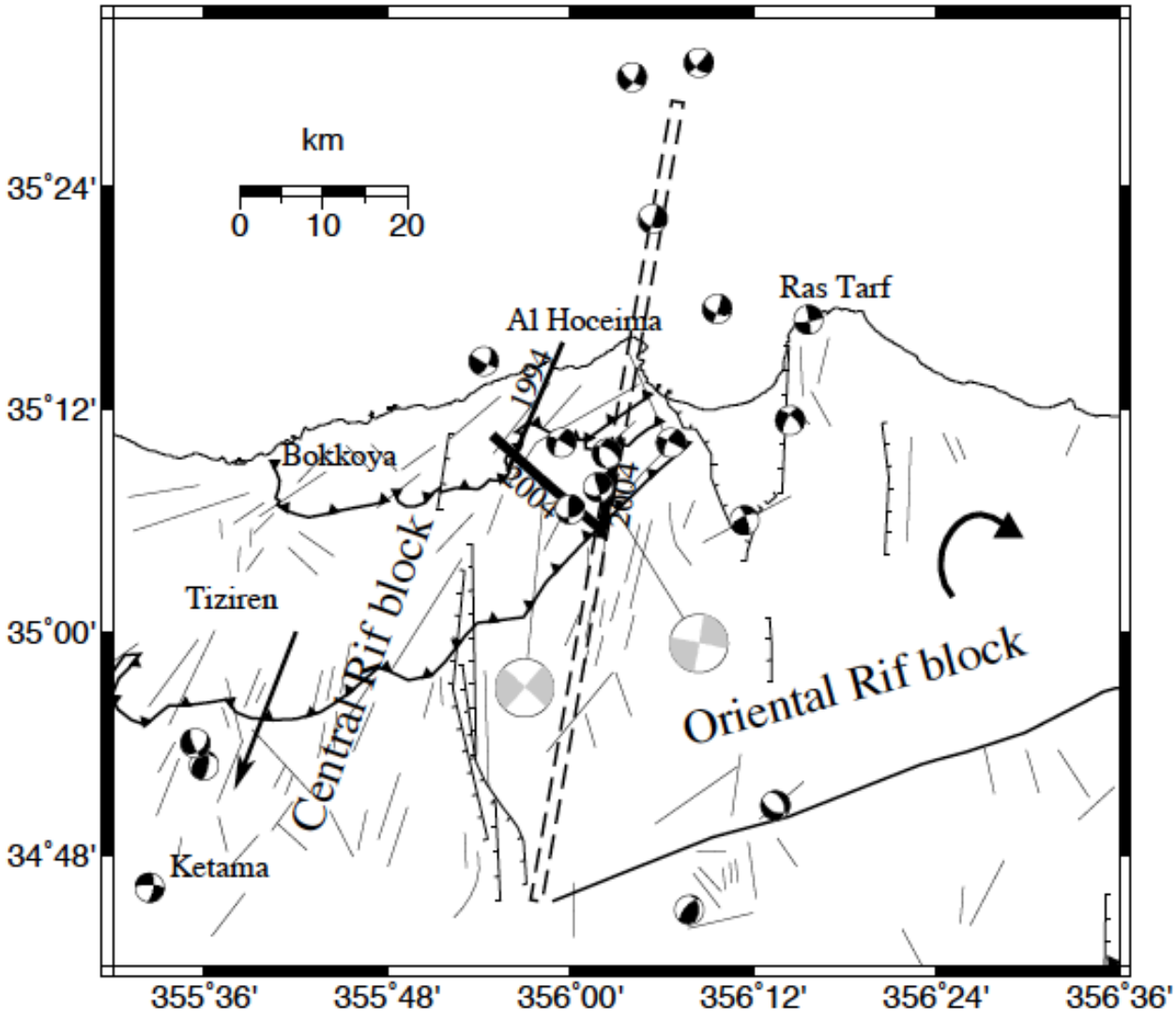
To fit the available observations, we suggest a model with two abutting, conjugate faults

The result of a comprehensive modelling procedure considering quantitative and qualitative contributions from InSAR/GPS/seismological information



Deformation model (2/2)

Tectonic interpretation of the cross-fault model inferred in this study



Arrows indicate the relative movements of these blocks with respect to the Africa plate.

Conclusion and perspectives

- Western Mediterranean = scientific and educational challenge for the next 10 years

- GPS data + satellite imagery + seismic data combination ⇒ Geodynamic comprehension and tectonic risk

- establishing a long-term Mediterranean partnership with common scientific objectives and exchanges of ideas

- Allowing all the countries to benefit of the recent spatial imageries and processing developments

Thank you for your attention