exploration & production

SUBSIDENCE MONITORING AS KEY FACTOR FOR ENVIRONMENTAL SUSTAINABILITY OF THE OIL AND GAS PROJECTS

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Bologna, 12 giugno 2012

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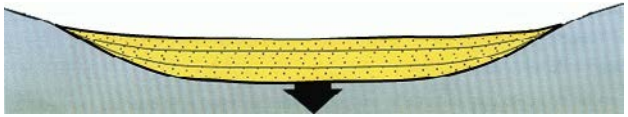
SUBSIDENCE

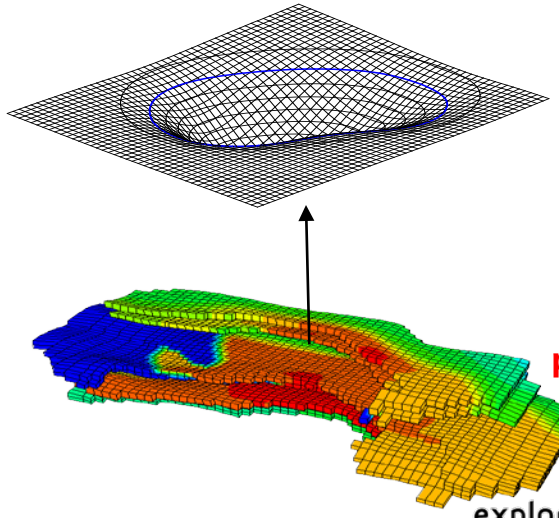
"it is a slow and progressive vertical lowering of the earth surface due to various factors"

Two main types:

- ***natural***: during burial of rocks, the weight of the overlying materials reduce pore volume and causes compaction.



- ***Induced***: the extraction of fluids from the ground decreases the pore pressure, increases the effective stress with a consequent compaction of the soil.



Subsidence at the surface

Compacation of producing reservoir

COMPACTION AND SUBSIDENCE THEORY

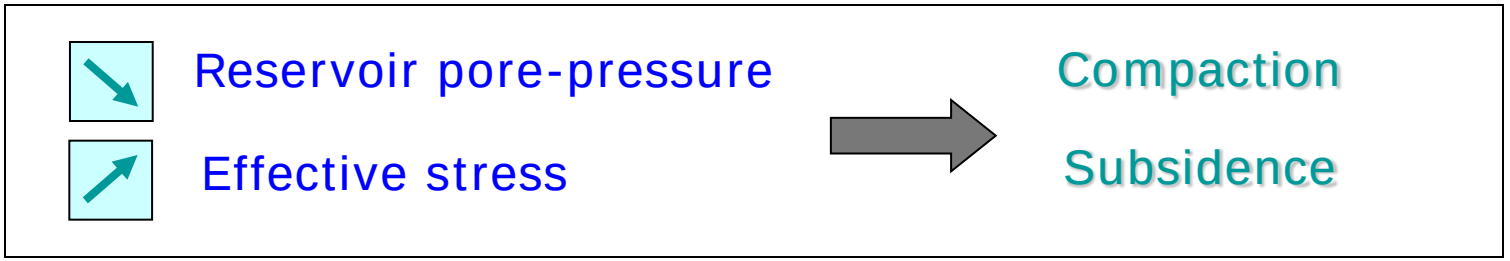
Terzaghi's principle of effective stress

$$\sigma' = \sigma - p$$

σ = totale vertical stress = overburden gradient x depth

σ' = effective vertical stress

p = pore pressure



"All measurable effects of a change of stress, such as compression, distorsion and a change of shearing resistance, are exclusively due to changes in the effective stress"

K. Terzaghi, 1936

TEAMS FOCUSED ON GEODYNAMICS IN ENI E&P

Geodynamics operations ITALIA 3 persons

Geomechanical models 10 persons

Geodynamic monitoring 8 persons

Mission:

prevention, mitigation and monitoring of geodynamic phenomena of the territory, with particular attention to issues of integration with the preservation and protection of territory, its economy and its environmental equilibrium.

UNIVERSITIES AND RESEARCH CENTERS

For all geodynamic subjects Eni collaborates with agencies, universities and research centers, national and international, to develop and maintain an excellent level of know-how and skills.

University of Bologna

University of Padua

University of Ferrara

University of Urbino

University of Torino

Deltares, Netherlands

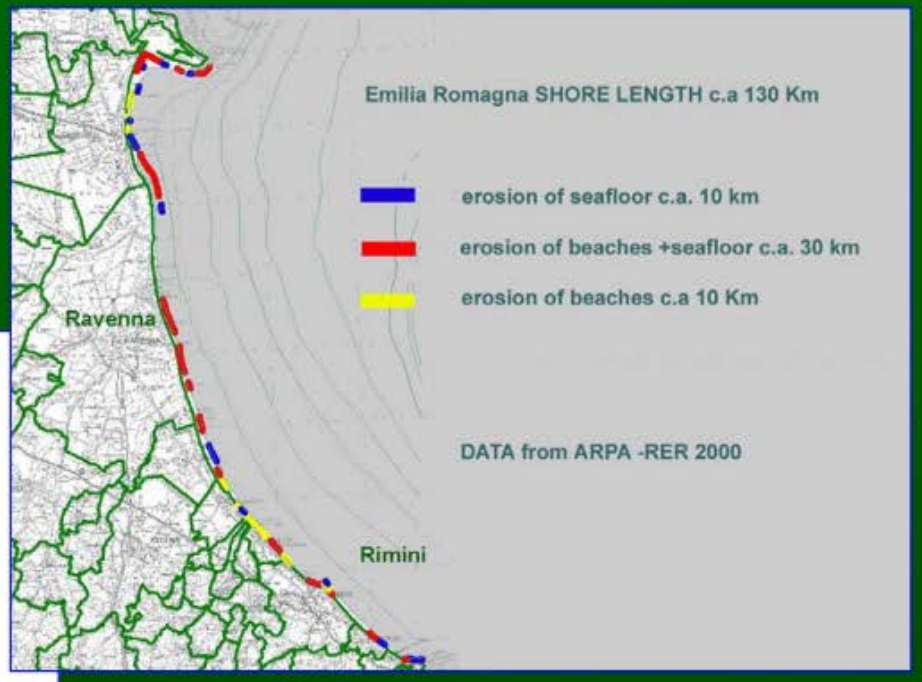
Tele-rilevemento Europa

Stanford University, USA

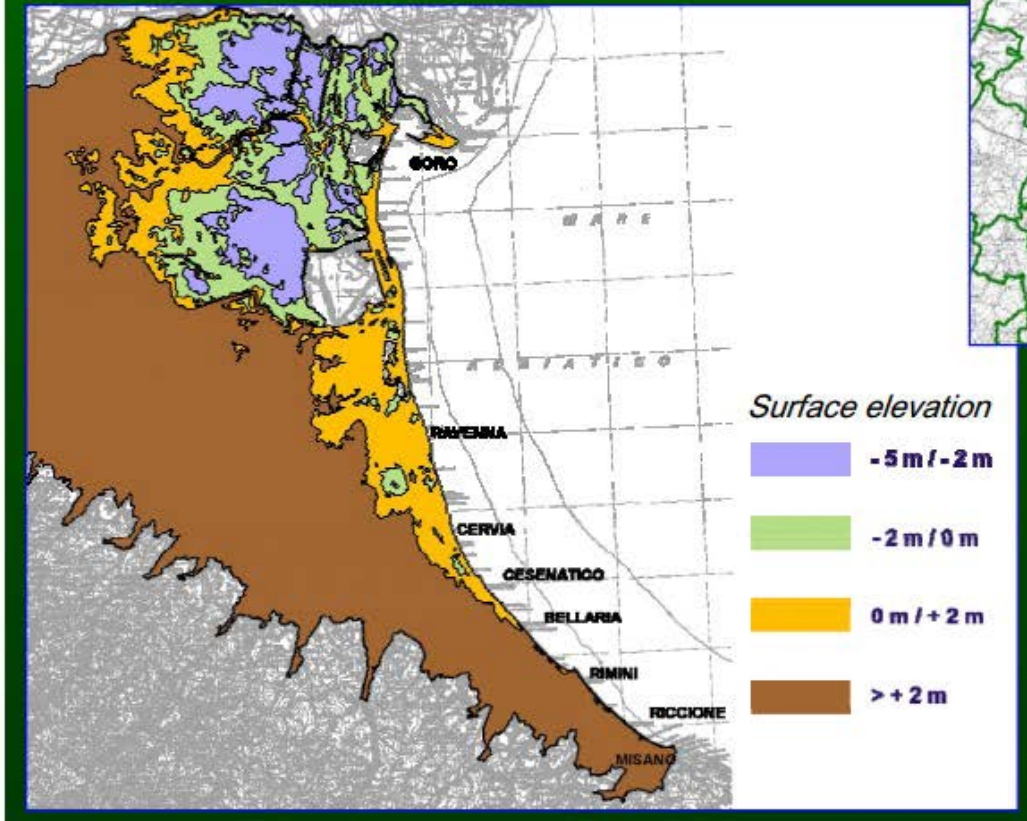
Italian National Institute of Geophysics and Volcanology

SUBSIDENCE IN THE COASTAL AREA: the risks

The 40 % of the coast line is affected by sea erosion

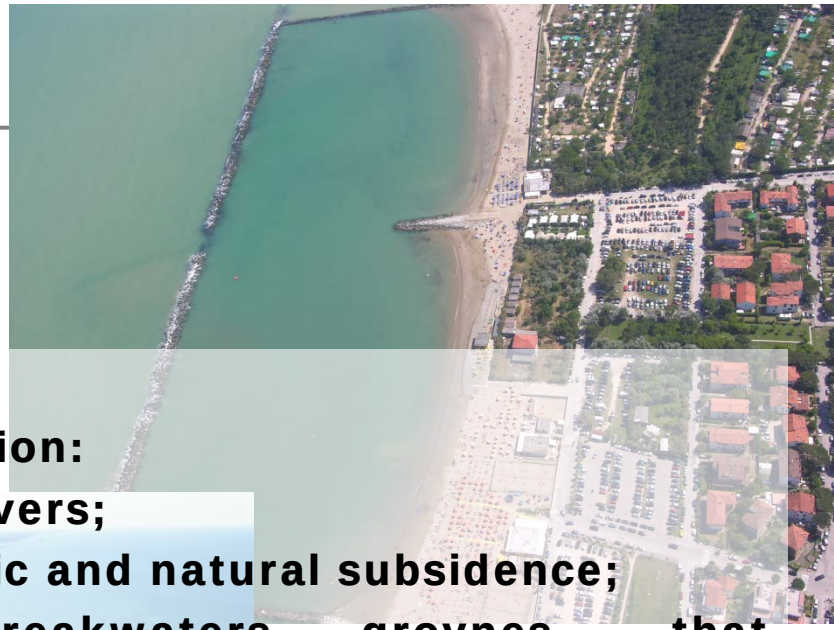


A great part of the coastal plain is below sea level and exposed to flooding and sea inundation



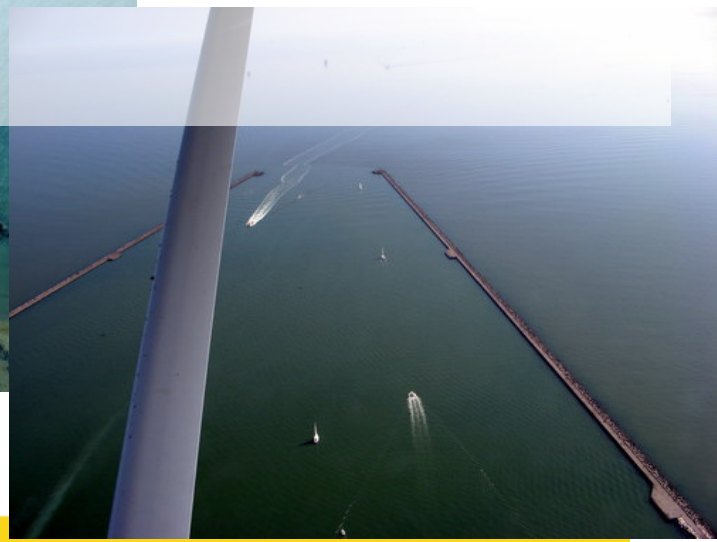
RegioneEmiliaRomagna

servizio geologico sismico e dei suoli



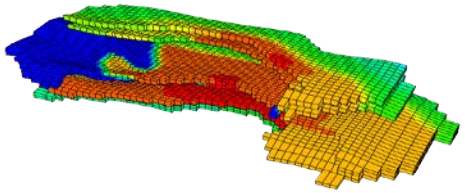
Main causes of erosion and marine ingression:

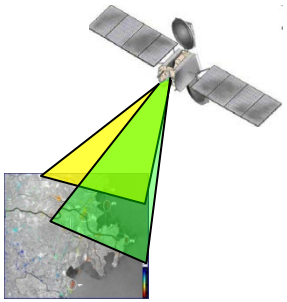
1. **decrease in sand transportation from rivers;**
2. **lowering of ground due to anthropogenic and natural subsidence;**
3. **presence of harbors, jetties, breakwaters, groynes… that modify sediment transport along the coast;**
4. **destruction of coastal dunes that formed, as well as a natural protection, the natural reservoir of sand.**



PREVISION AND CONTROL OF SUBSIDENCE

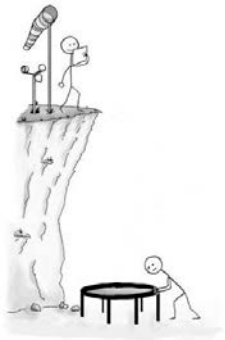
In a program of prevision and control of subsidence, three basic actions of intervention can be defined :

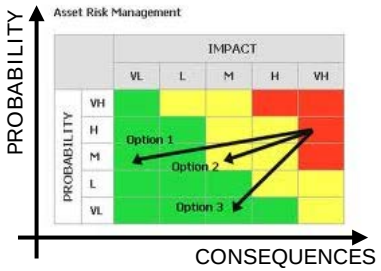




1. prediction of subsidence in the area affected by the phenomenon using mathematical and numerical models;

2. establishment of a monitoring program;





3. prevention of the expected subsidence or mitigation of observed subsidence during field production.

GUIDELINES PUBLISHED BY UNIVERSITY OF PADUA

LINEE GUIDA
PER LO STUDIO DEI FENOMENI DI SUBSIDENZA
NELL'AMBITO DI PROGETTI DI
SVILUPPO SOSTENIBILE DI CAMPI AD OLIO O GAS

Rapporto Tecnico 1/2007

Giuseppe Gambolati
Pietro Teatini
Massimiliano Ferronato

Padova, Gennaio 2007

MONITORINGS

Shallow:

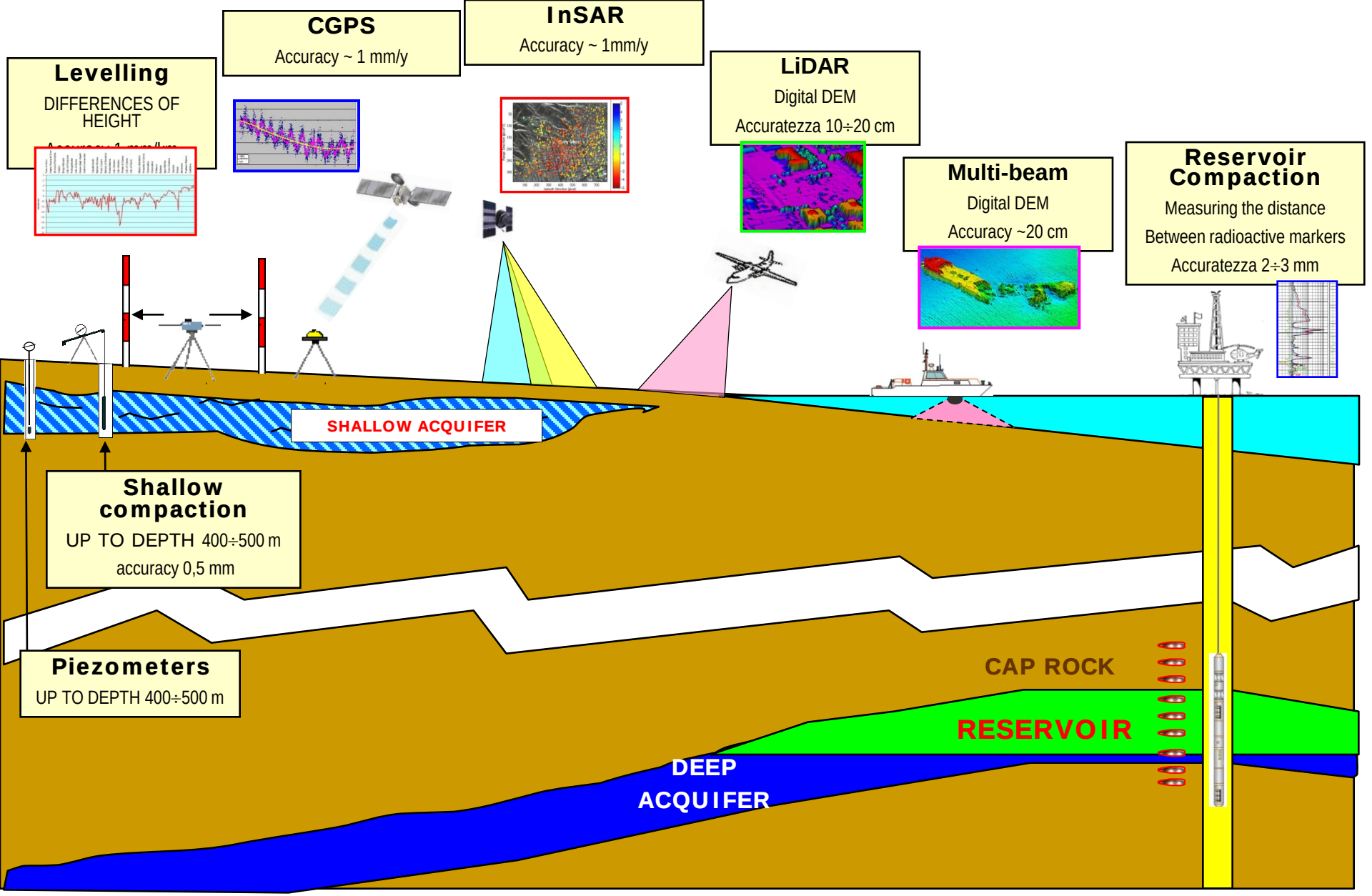
- optical levelling;
- permanent installations of continuos GPS;
- interferometry on SAR satellite images;
- extensimeters;
- piezometers;
- LiDAR survey (Laser Imaging Detection And Ranging);
- batymetric surveys (transepts, multibeam, LADS, etc.).

Deep:

- deep compaction survey with radioactive markers;
- deep monitoring of static pression in the reservoir;
- microsismic monitoring.

Validation of the metodologies and results:

- levelling -> University of Bologna – Civil Engineering Dpt.;
- CGPS -> University of Bologna – Phisic Dpt.

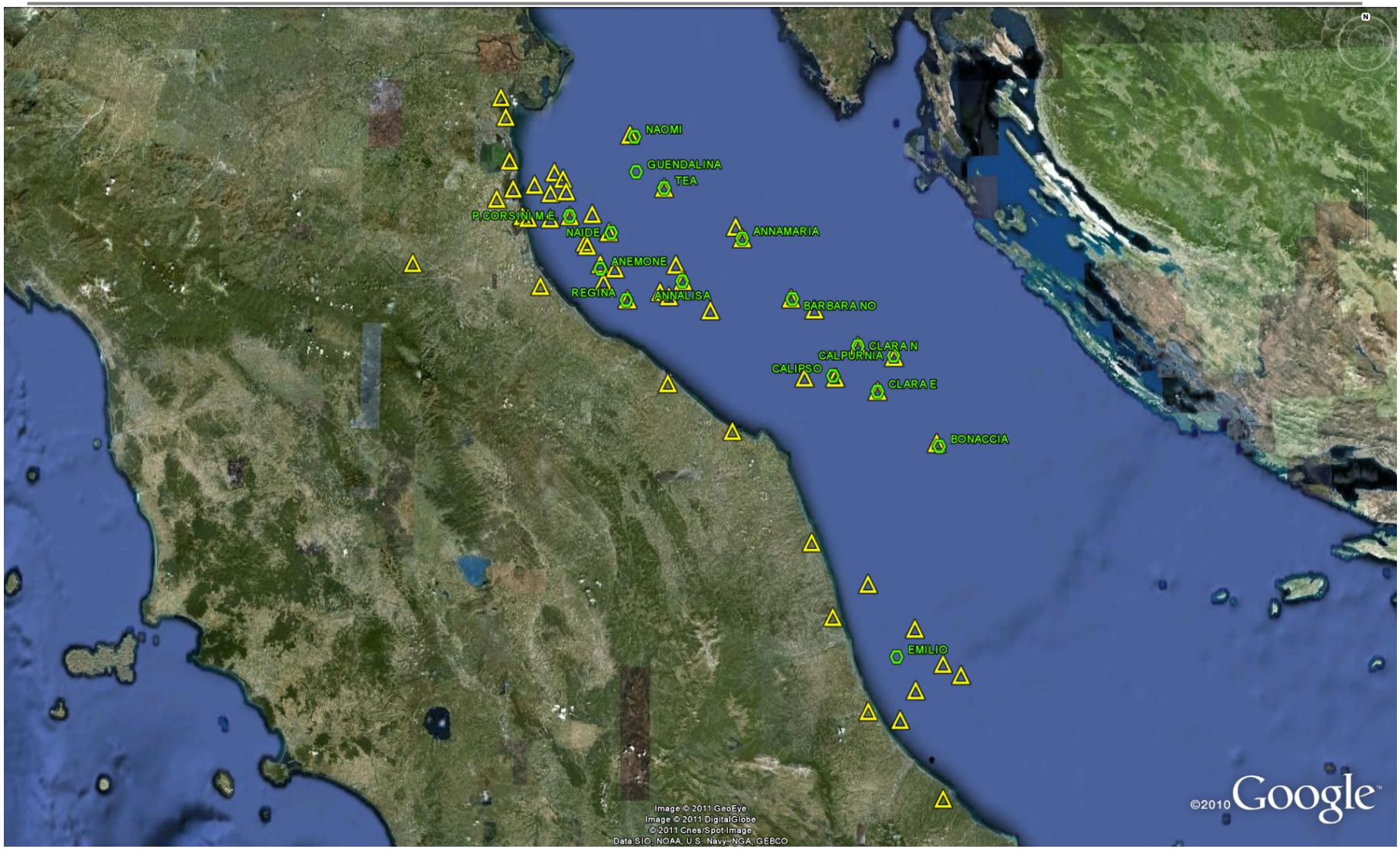

Levelling
DIFFERENCES OF HEIGHT
CGPS
Accuracy ~ 1 mm/y
InSAR
Accuracy ~ 1mm/y
LiDAR
Digital DEM
Accuratezza 10÷20 cm
Multi-beam
Digital DEM
Accuracy ~20 cm
Reservoir Compaction
Measuring the distance
Between radioactive markers
Accuratezza 2÷3 mm
SHALLOW ACQUIFER
Shallow compaction
UP TO DEPTH 400÷500 m
accuracy 0,5 mm
Piezometers
UP TO DEPTH 400÷500 m
CAP ROCK
RESERVOIR
DEEP ACQUIFER

OPTICAL LEVELLING

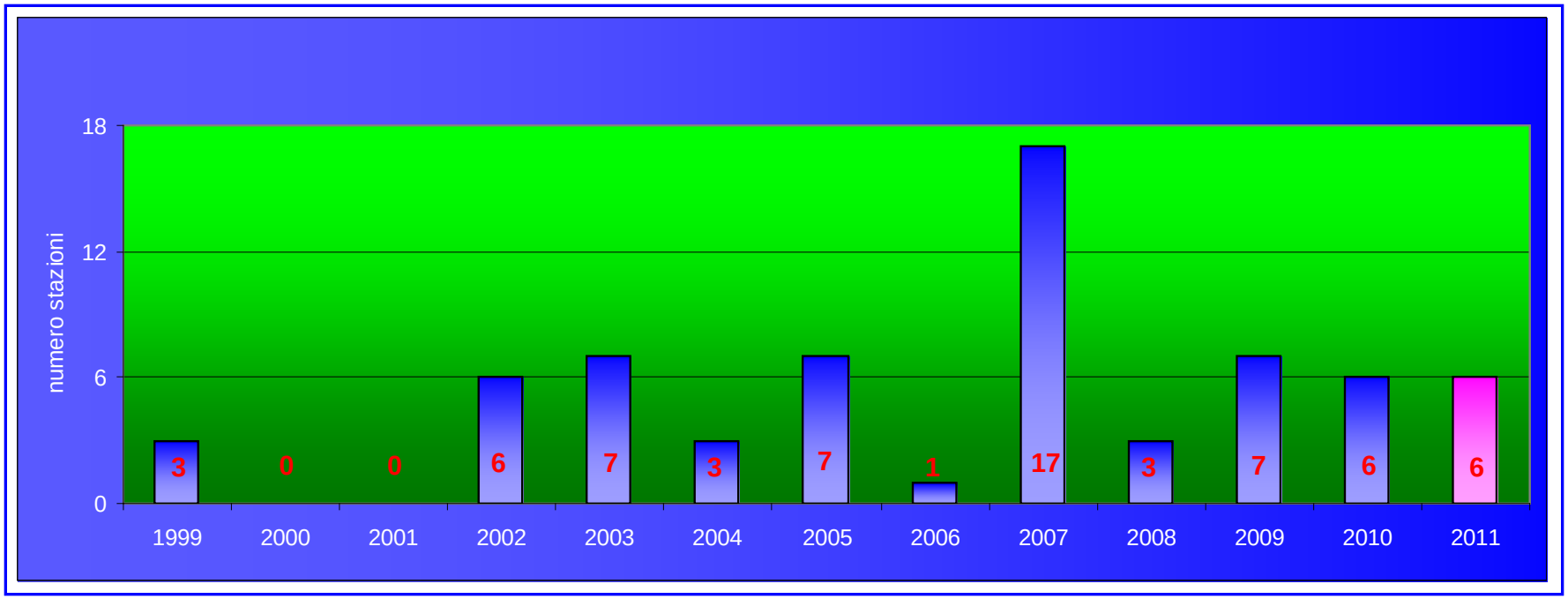
OPTICAL LEVELLING: ENI NETWORK

PERMANENT GPS

CGPS: ENI NETWORK

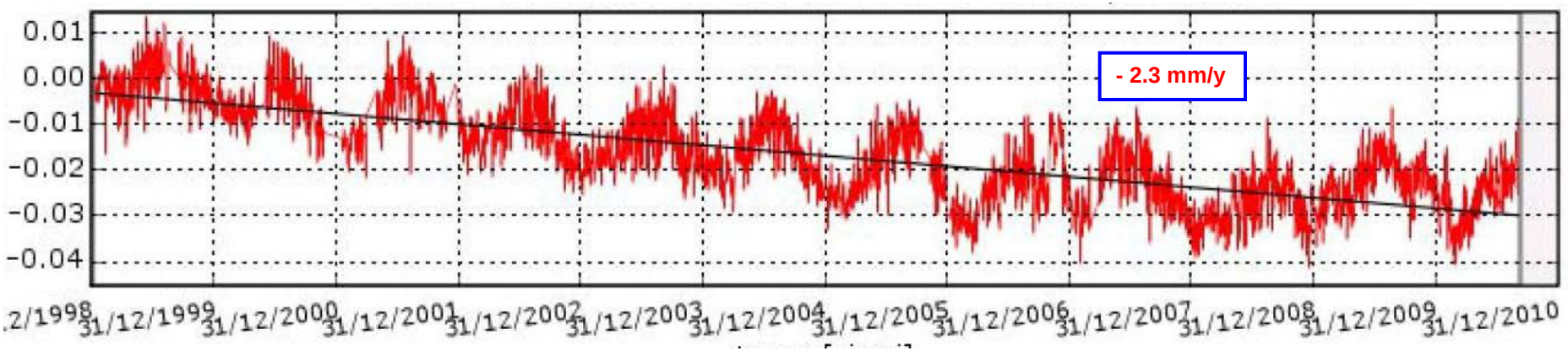


PERMANENT GPS: ENI NETWORK



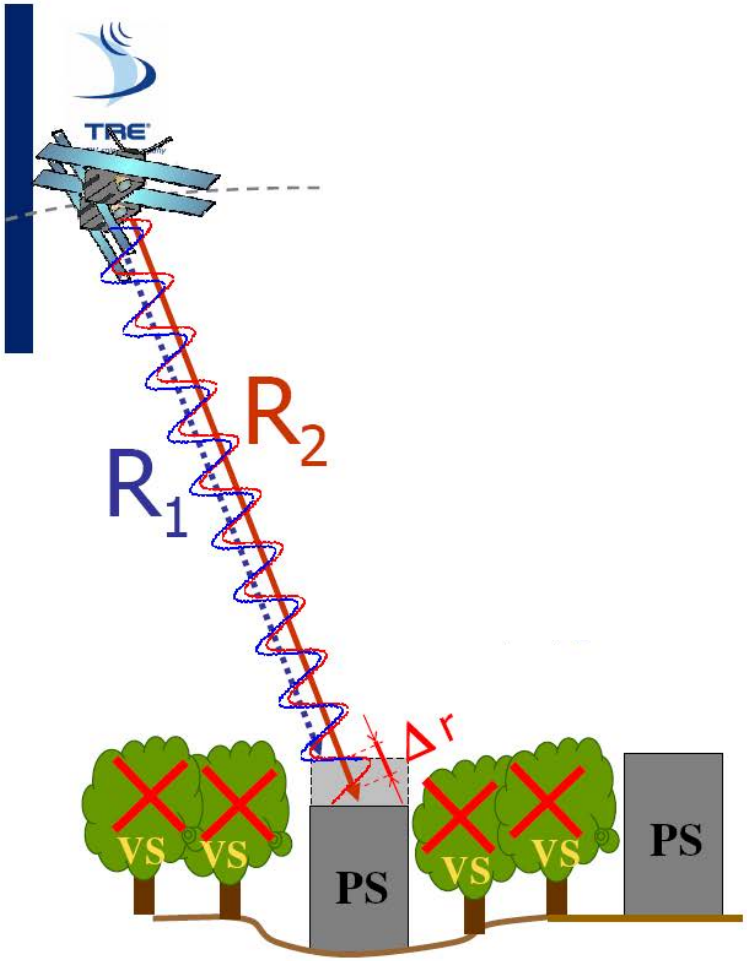
The GPS network is composed by 66 stations, 45 offshore e 21 onshore.

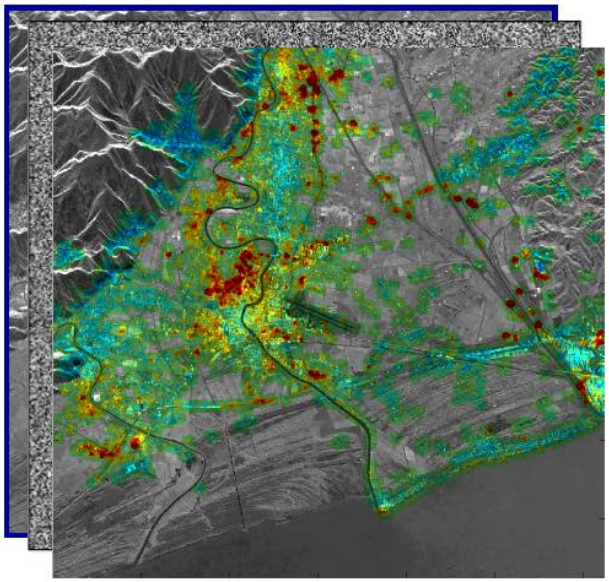
CGPS RECORDING



InSAR

INTERFEROMETRY ANALYSIS OF SAR SATELLITE IMAGES WITH PSINSAR™





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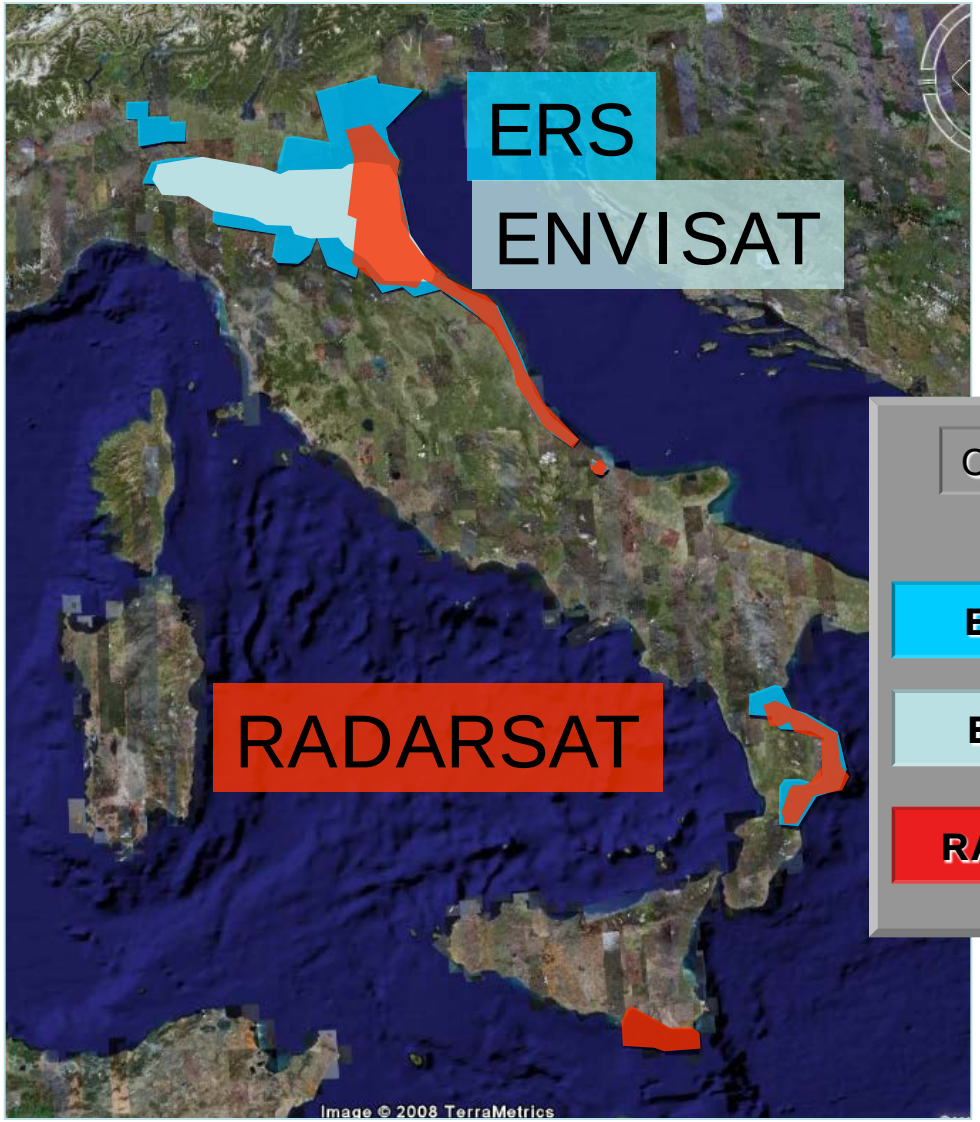
AREA COVERED

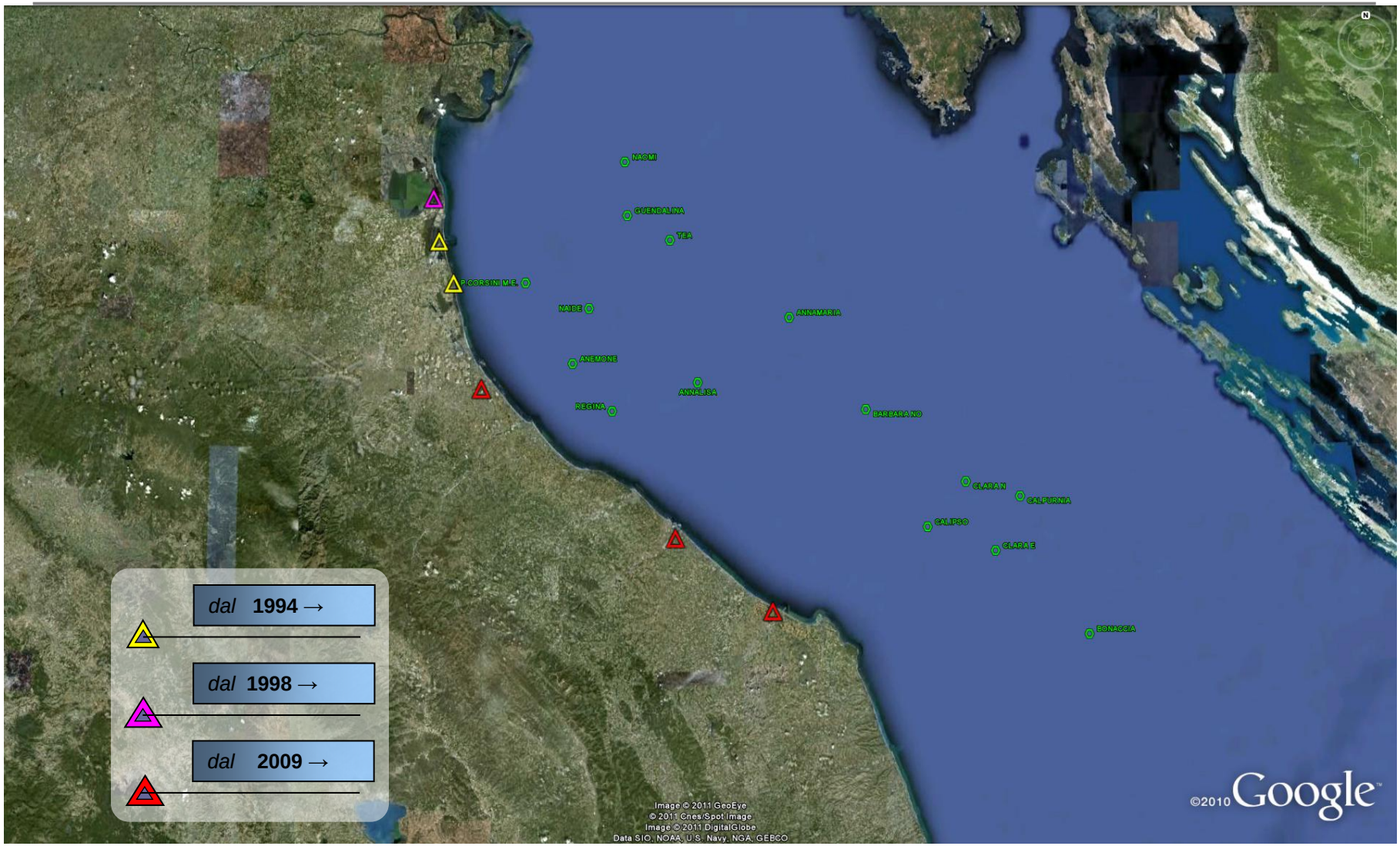


COPERTURA IMMAGINI

ERS	156000 km²
ENVISAT	41000 km²
RADARSAT	96000 km²

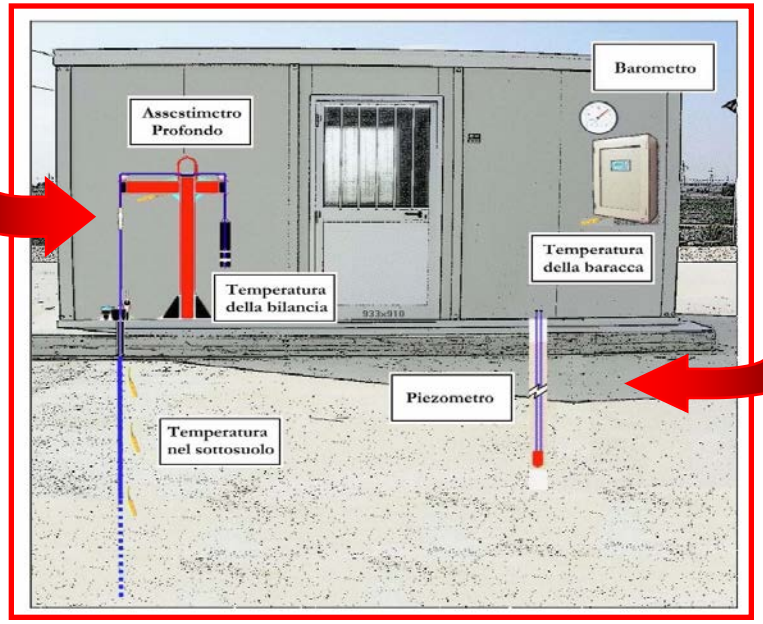
ESTENSIMETERS AND PIEZOMETERS

EXTENSIMETER / PIEZOMETER STATIONS



EXTENSIMETER / PIEZOMETER STATIONS

To obtain informations necessary for the determination of the shallow compaction.



DATA MONITORING INTEGRATION

Reliability and quality of subsidence monitoring is strongly improved combining the three technique:

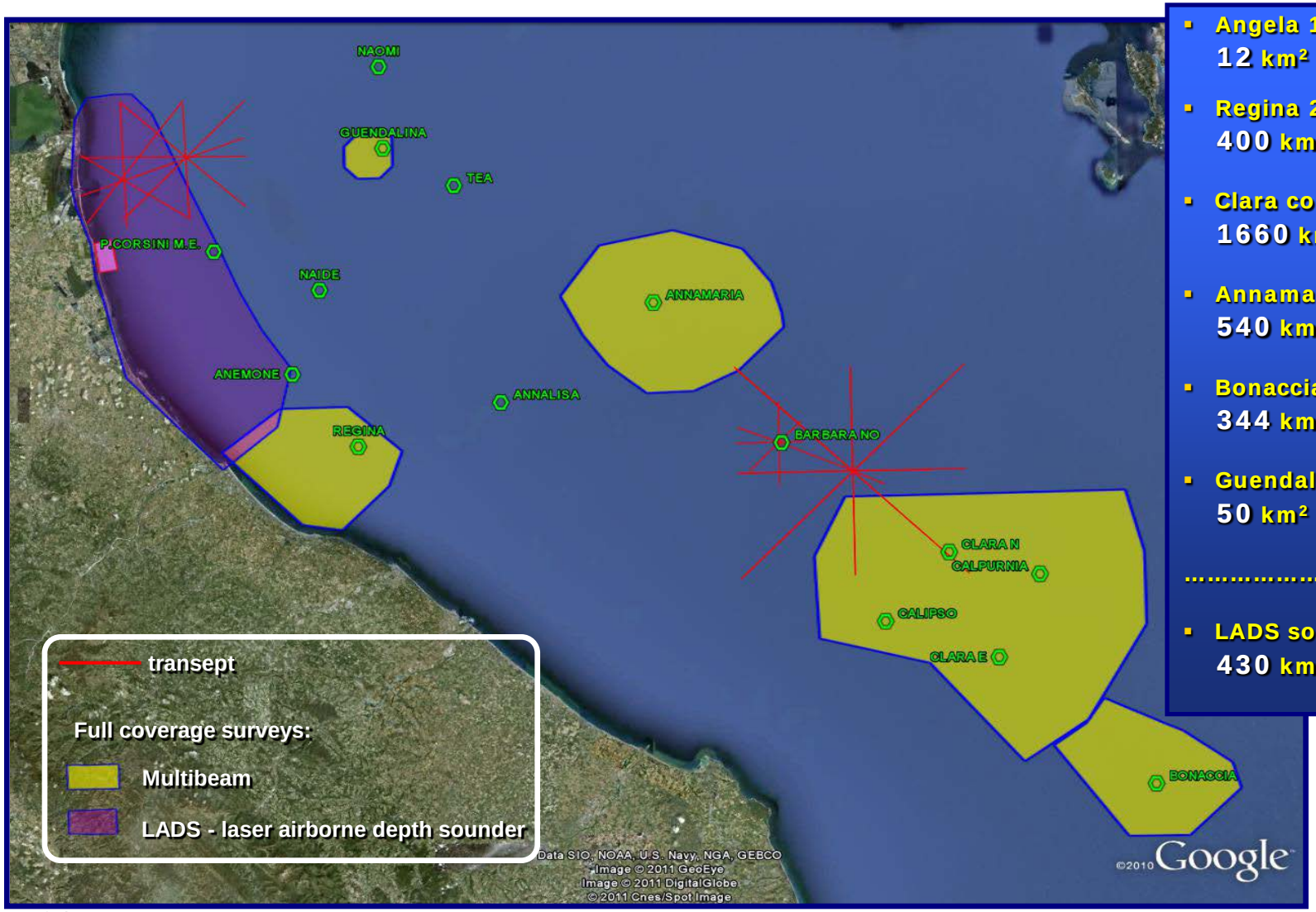
1. **optical levelling;**
2. **permanent GPS;**
3. **InSAR.**

Data collected by extensimeter / piezometer help to evaluate different components of the recorded subsidence:

1. **natural subsidence;**
2. **subsidence due to water pumping.**

BATHYMETRIC SURVEYS

BATHYMETRIC SURVEYS



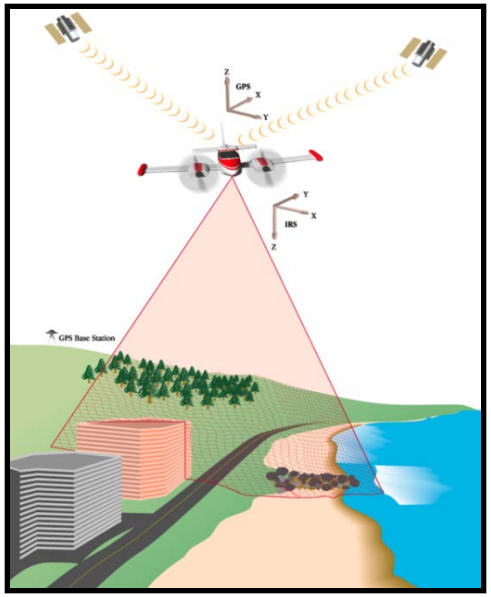
- **Angela 1993-2003**
  12 km²
- **Regina 2007**
  400 km²
- **Clara complex 2008**
  1660 km²
- **Annamaria 2009**
  540 km²
- **Bonaccia 2010**
  344 km²
- **Guendalina 2010**
  50 km²

……

- **LADS sottocosta 2006**
  430 km²

LIDAR

AIRBORNE ALTIMETRIC LIDAR

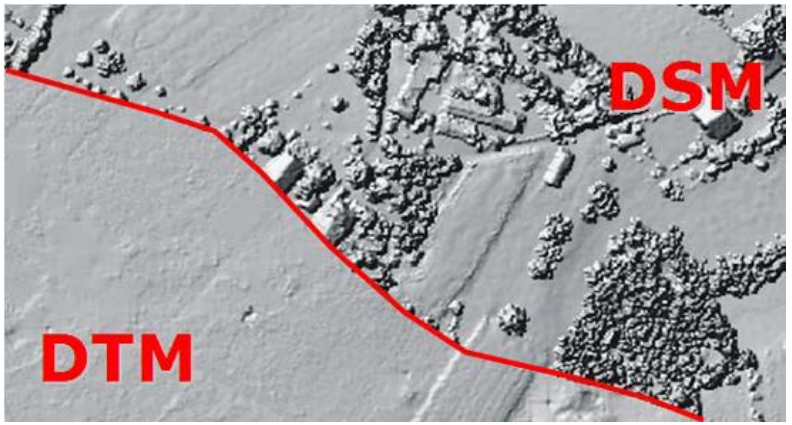


Area covered:

- **322 km² of coast from Rimini to mouth of Po river**

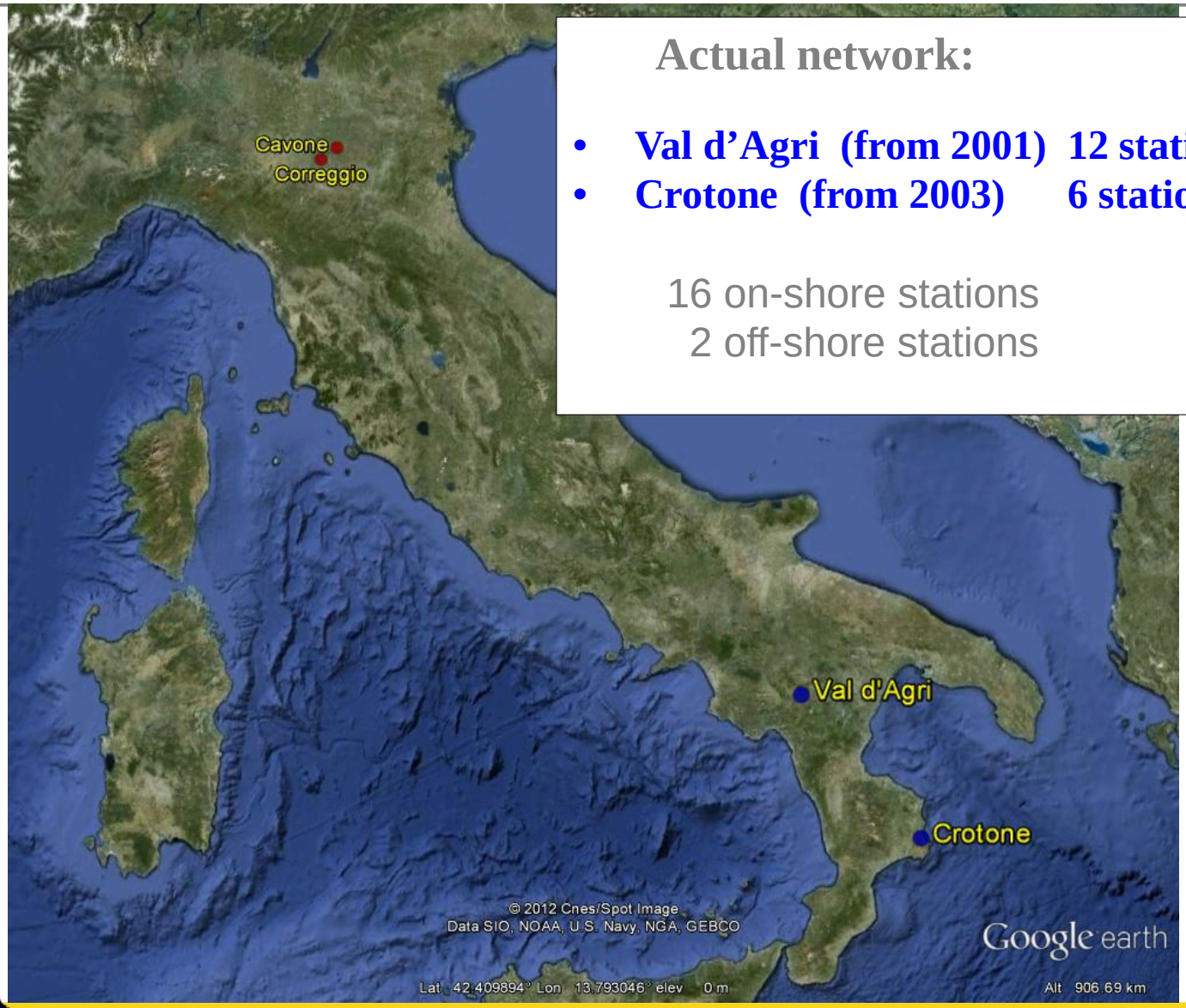
Goal:

- **build DSM and DTM to evaluate the soil compaction due to the presence of buildings.**



MICROSEISMIC

MICROSEISMIC MONITORING



Actual network:

- **Val d'Agri (from 2001) 12 stations**
- **Crotone (from 2003) 6 stations**

16 on-shore stations
2 off-shore stations

& production

MARINE METEOROLOGICAL MONITORING

MARINE METEOROLOGICAL MONITORING

5 STATIONS

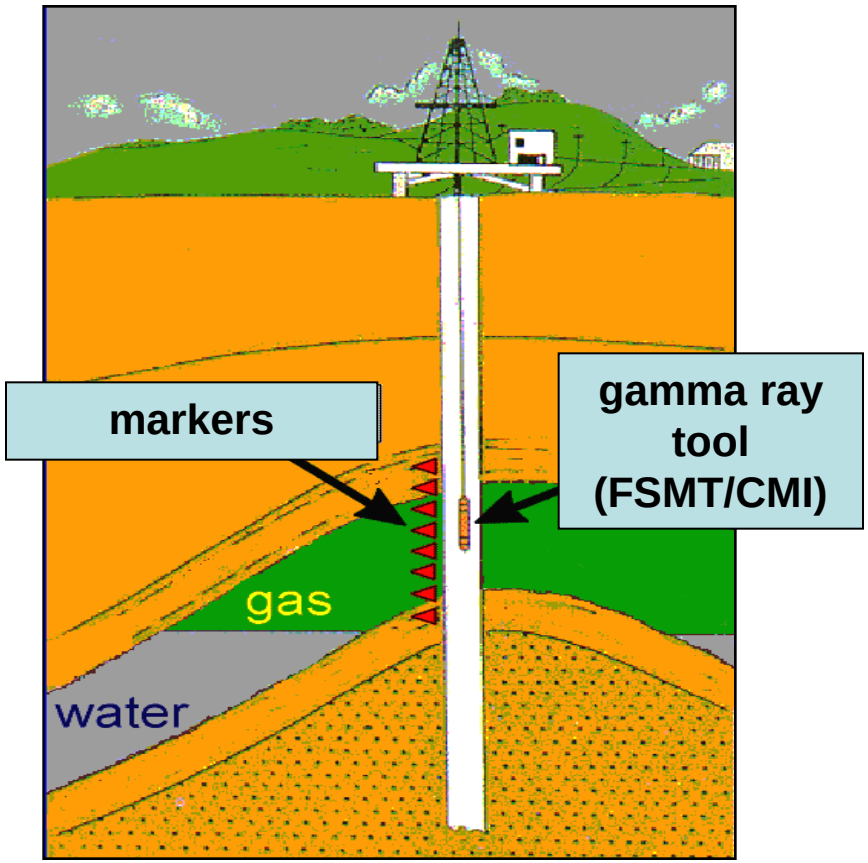
Variables acquired:

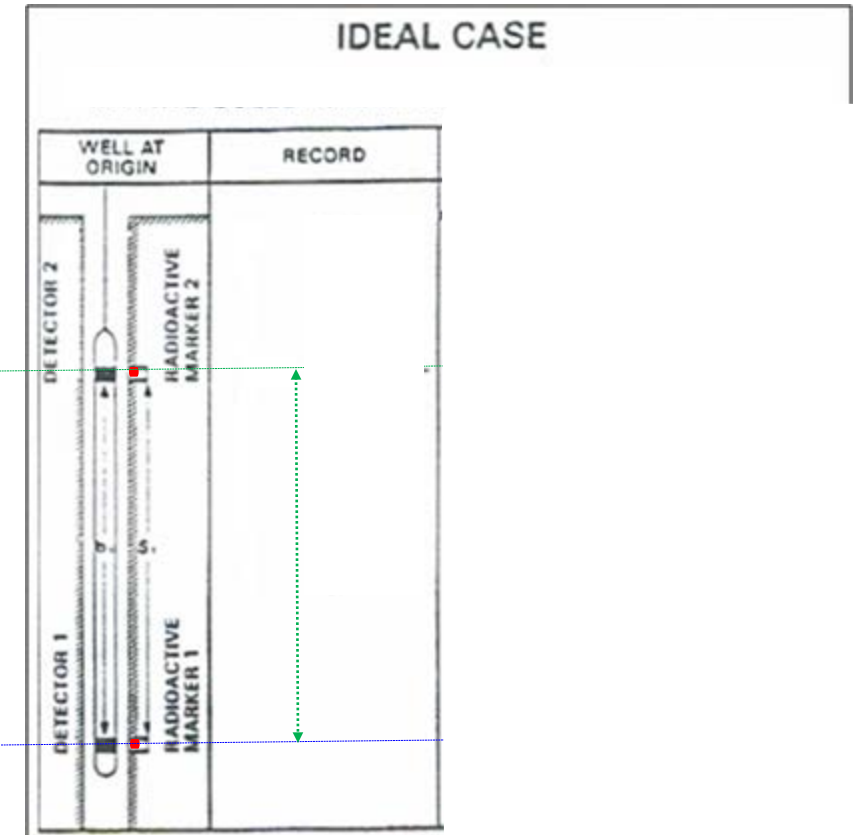
- current
- wave height
- sea temperature
- atmospheric temperature
- atmospheric pressure
- air humidity
- solar radiation
- wind direction
- wind speed

The measurements are sampled and stored every 30 minutes.

MARKERS

SURVEYS OF DEEP COMPACTION USING MARKERS

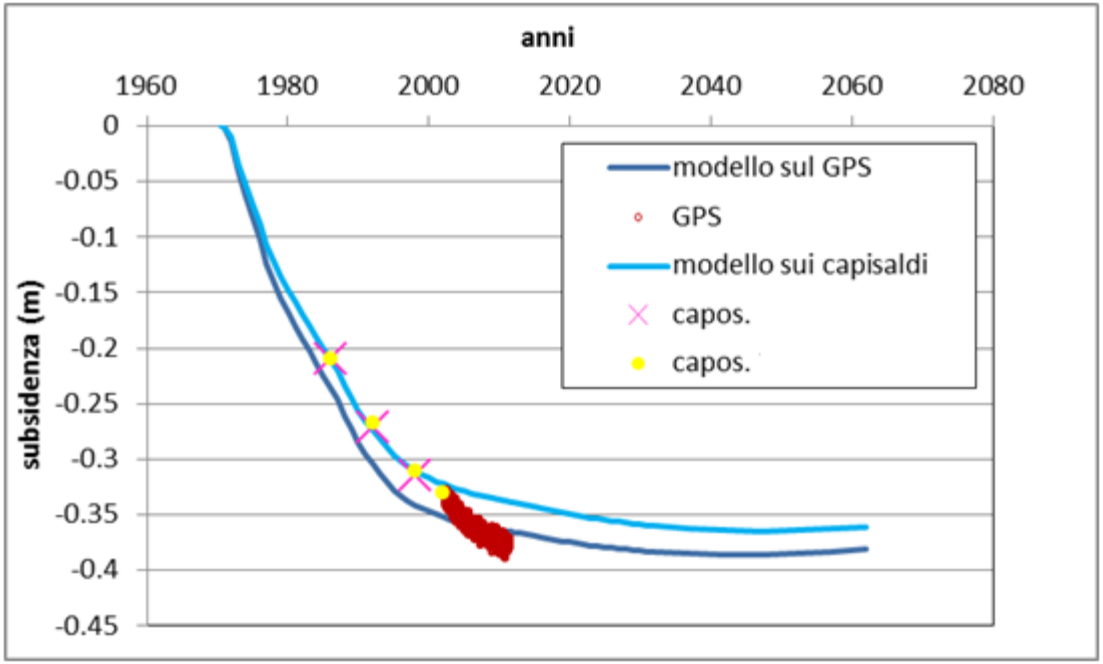


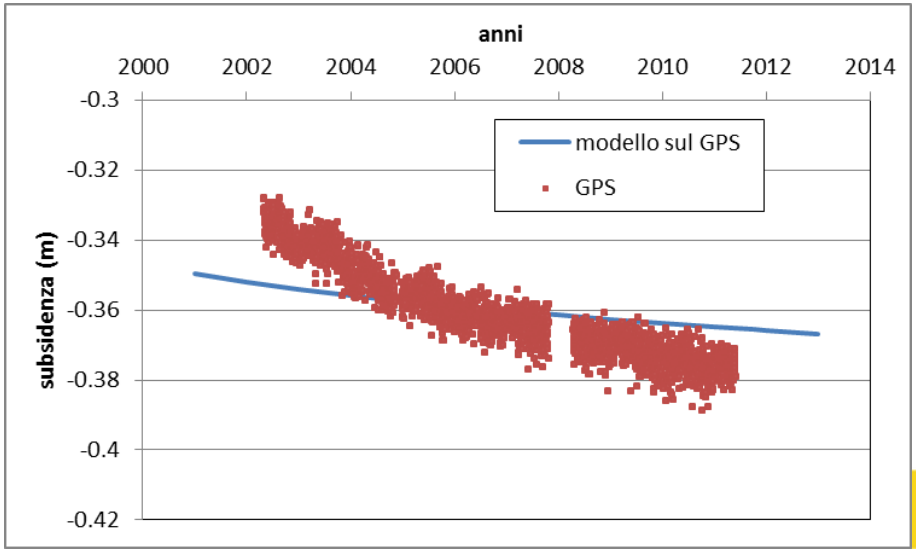


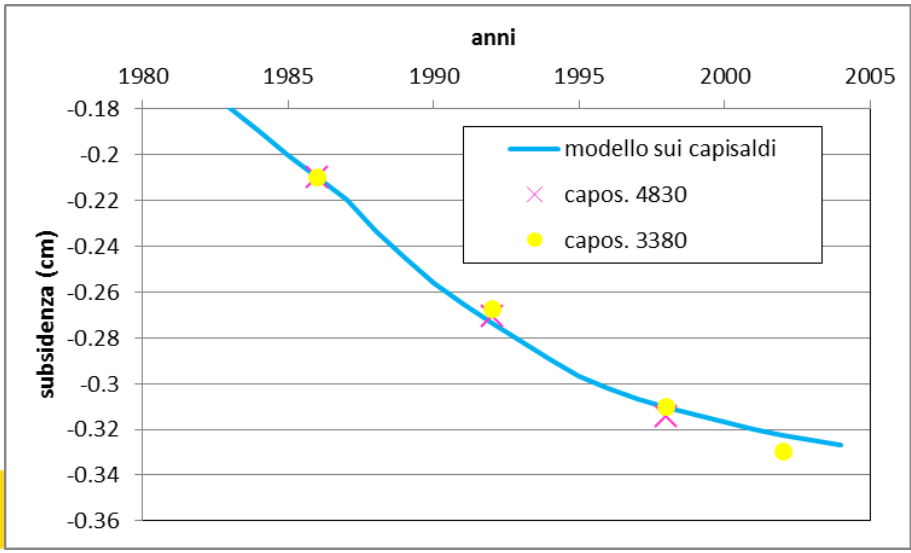
WELLS EQUIPPED WITH MARKER

SUBSIDENCE MODEL CALIBRATION

MODEL CALIBRATION WITH CGPS AND LEVELLING

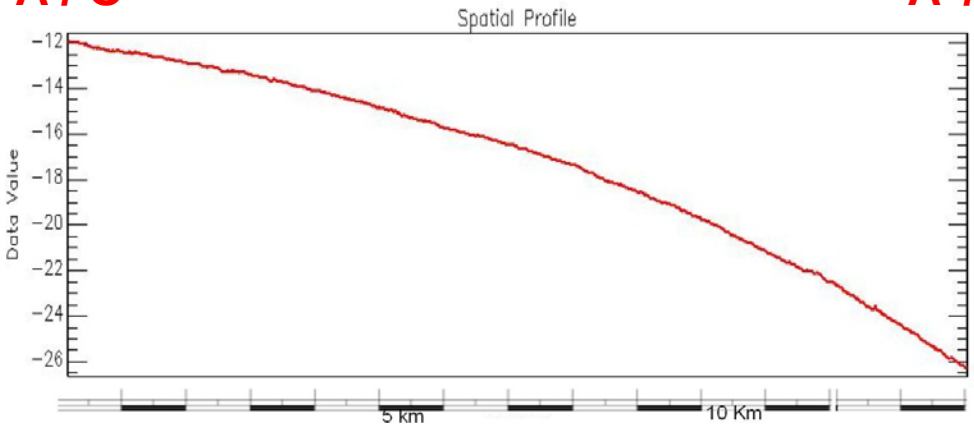




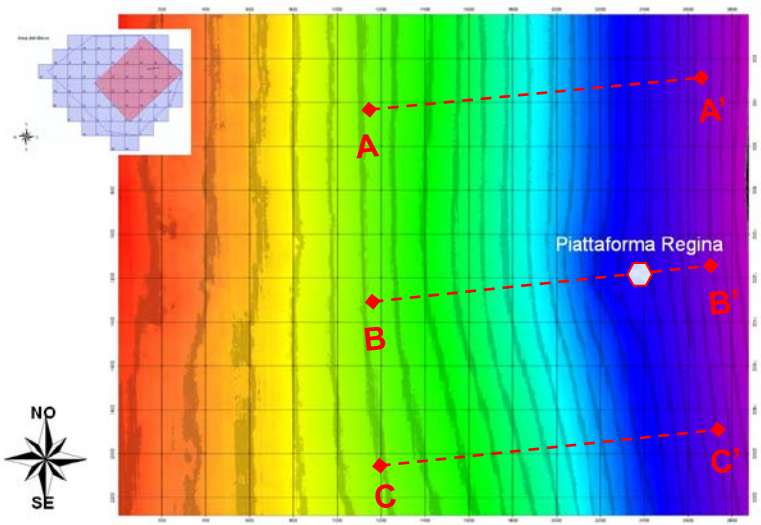


SUBSIDENCE MODEL CALIBRATION WITH BATHYMETRY

A / C

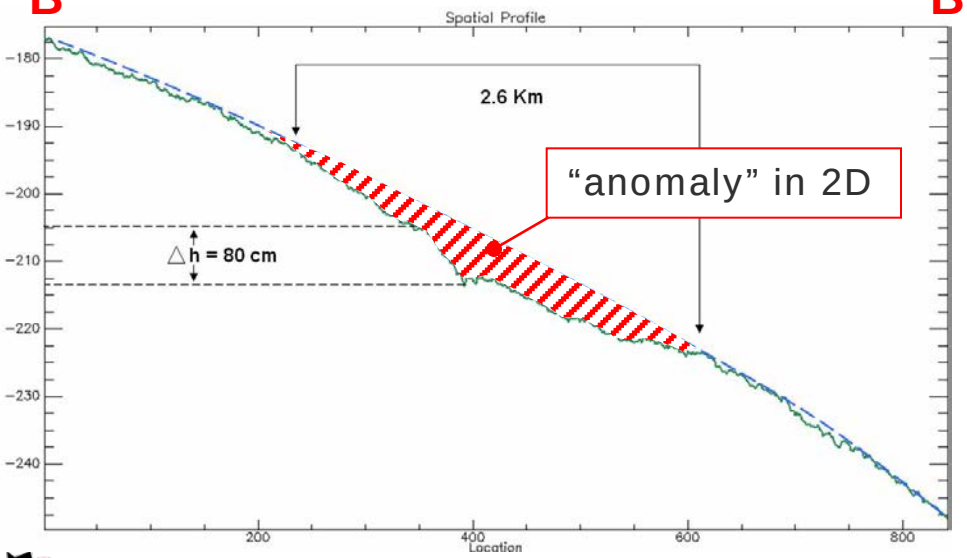


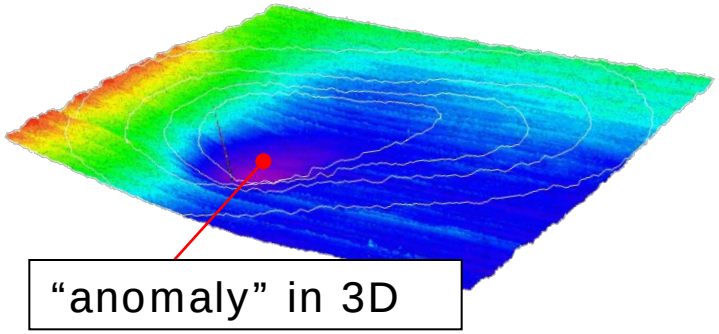
A' / C'



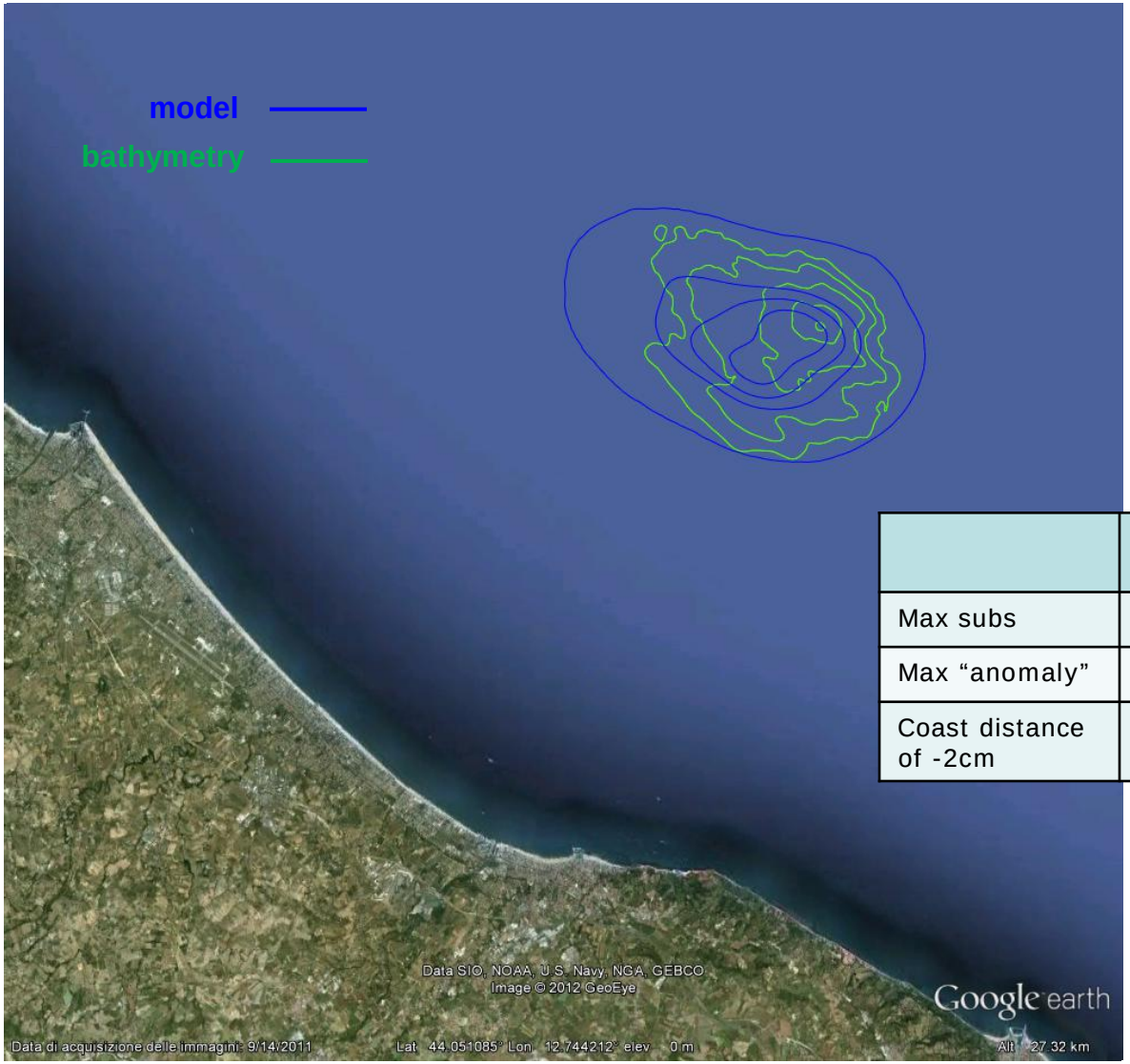
B

B'





SUBSIDENCE MODEL CALIBRATION WITH BATHYMETRY



	Previsional Model	bathymetry
Max subs	ca. 95 cm	
Max “anomaly”		ca. 80 cm
Coast distance of -2cm	ca. 11,5 km	ca. 11,5 km

CONCLUSIONS

MONITORING DATA COLLECTED DURING FIELD PRODUCTION ALLOW TO CALIBRATE AND UPDATE PREVISIONAL STUDIES OF SUBSIDENCE AND GIVE THE POSSIBILITY TO TAKE ANY NECESSARY ACTION OF CONTROL AND/OR MITIGATION OF THE PROBLEM TO PROTECT AND SAFEGUARD THE TERRITORY AND ITS ECONOMY.


MANY THANKS FOR YOUR ATTENTION