

**Vertical ground deformation monitored by precise leveling:
Ubaye, Southern Alps & geothermal exploitations
sites Soultz-sous-Forêts & Rittershoffen, Alsace.**

Gilbert Ferhat^{1,2}, Gilles Ménard³, Jean-Philippe Malet², Jacques Hinderer²

¹ Institut National des Sciences Appliquées de Strasbourg, France

² Institut de Physique du Globe de Strasbourg
UMR 7516 CNRS/Université de Strasbourg, France

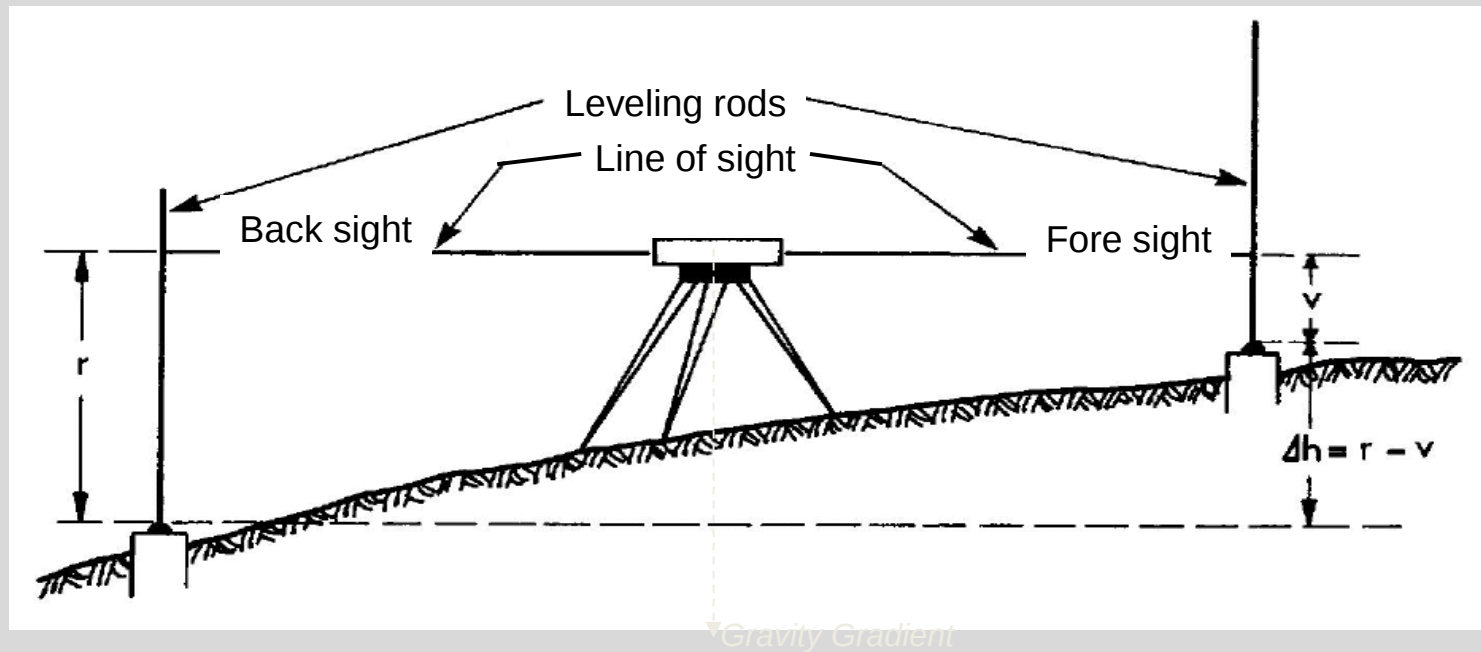
³ EDYTEM, Environnements, Dynamiques et Territoires de la Montagne
UMR52024 CNRS/ Université de Savoie, France

Outlines

- Vertical surface monitoring:
 - small deformation: few mm
 - Principle of leveling
 - Refraction error in leveling measurement
- Case study:
 - Ubaye, Southern Alps
 - Geothermal exploitation sites
(Soultz/Forêts & Rittershoffen, Alsace)

Technical background

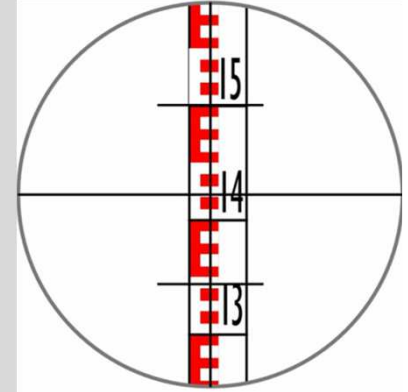
Fundamental principle of leveling:



Typical length 30 to 50 meters

Equipment: levels

- Automated levels
 - Easy to use
 - Needs experience
 - Robust even in hostile environment
- Digital levels
 - Push-button technique
 - No reading errors, special staff
 - Readings are stored and analyzed digitally



Equipment: invar staff (*mire*)



1-meter long staff (Ubaye, June 2014)



Leveling plate (*crapaud*)



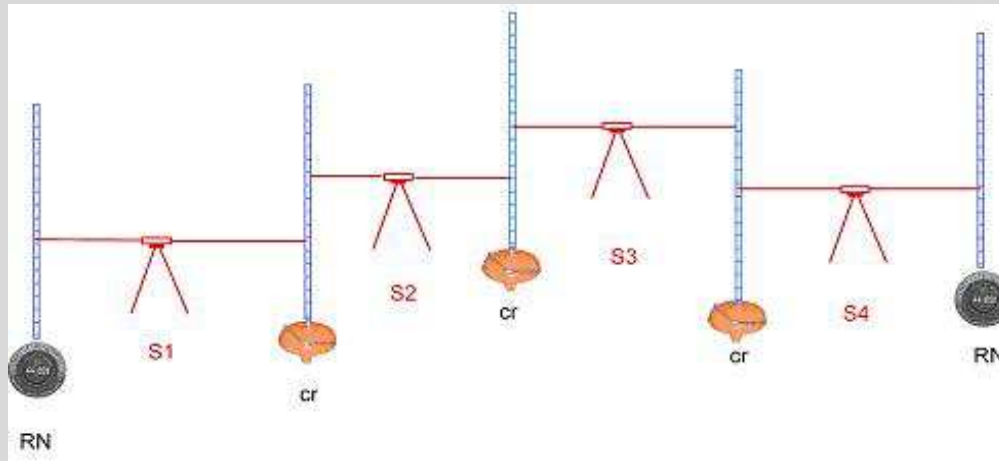
Bubble



3-meter long staff (Alsace, June 2014)

Technical background

Fundamental principle of leveling:



Accuracy : 0.3 mm/km to few mm/km (double run)



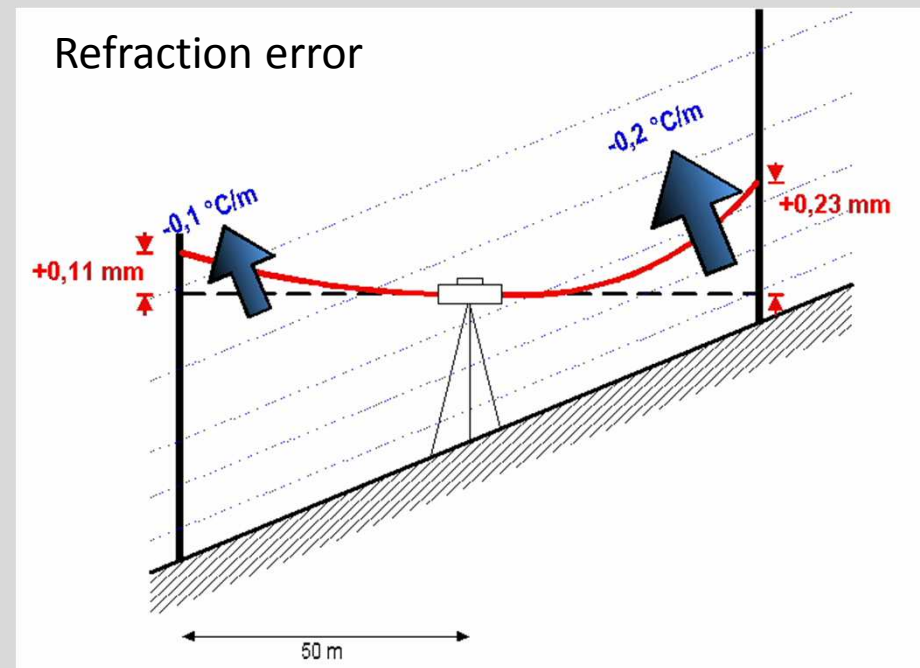
Leveling benchmarks (BM)

Repères de nivellement (RN)

RN IGN

Systematic and random errors

- Earth curvature
 - Refraction
 - Collimation errors
 - ...
 - Solution:
1. The instrument must be set up in the middle between two staffs
 2. Readings must be taken 30-50 cm above the ground
 - Surface refractions
 - Beware also of temperature gradients
 3. Leveling must be done in two opposite directions but the same line (beware of gravity gradients)
 4. Staff should be calibrated, especially if INVAR
 5. ...



n = index of refraction

$n = f(\text{temperature, pressure, humidity})$

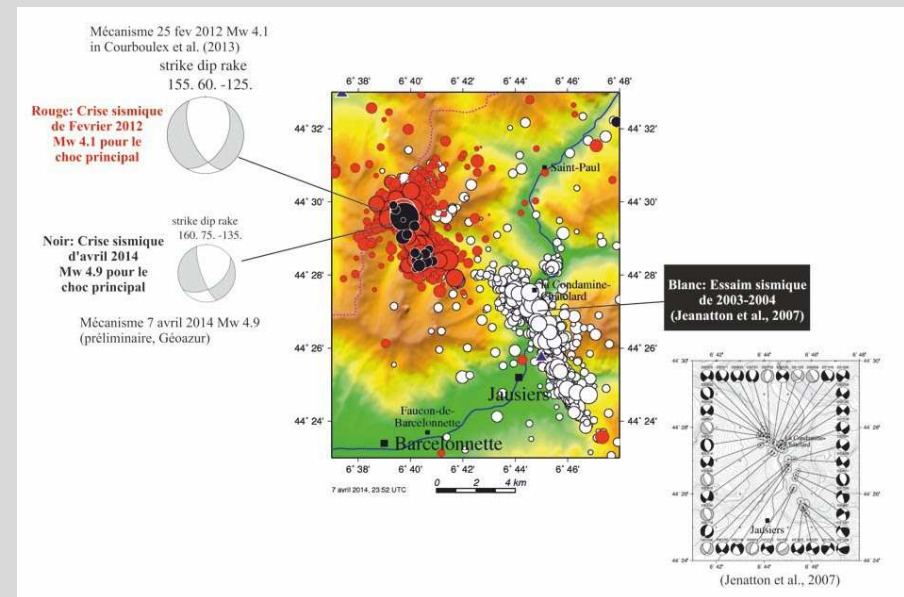
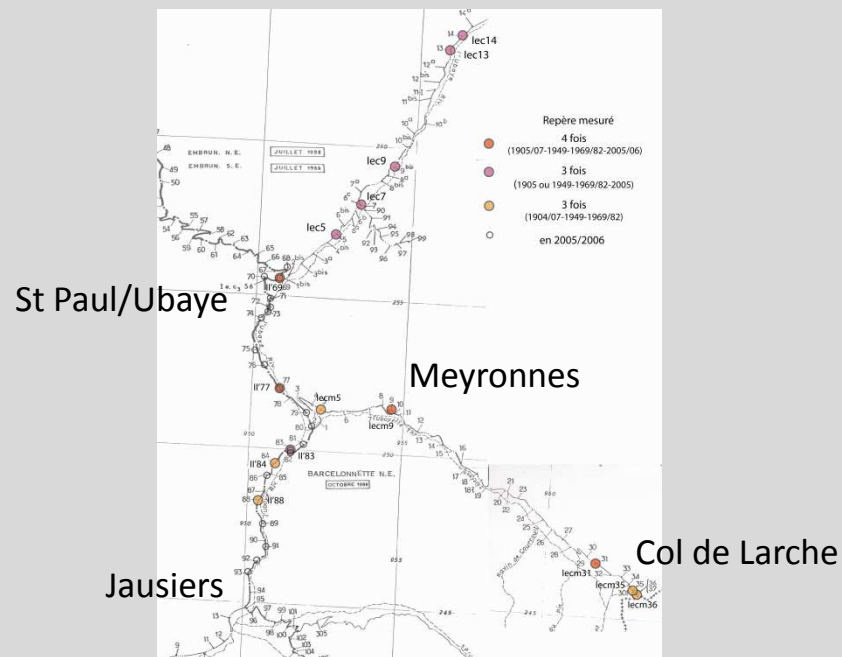
Haute Ubaye, Southern Alps

Old data : IGN leveling profiles

Profile N-S: Jausiers –St Paul/Ubaye IGN:1969-GM2005

Profile NW-SE: Gleizolles-Meyronnes-Col de Larche

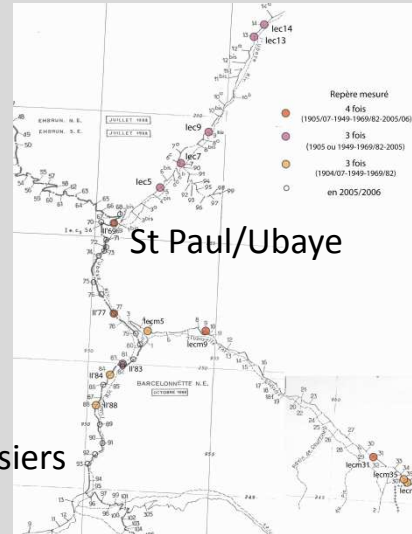
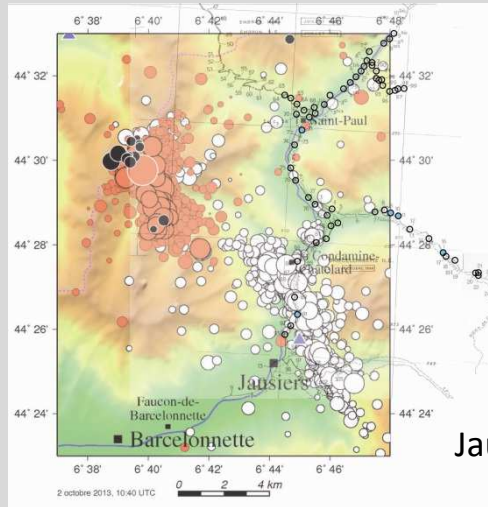
IGN: 1909 – 1949 + GM:2006



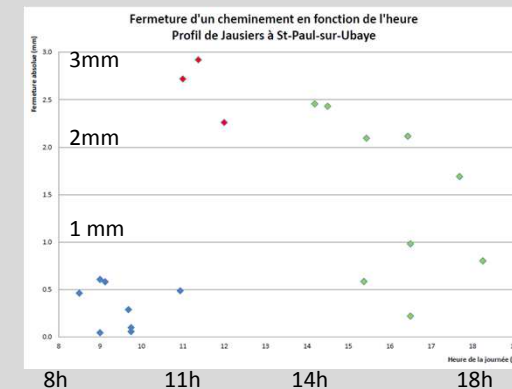
June 2014 (2 teams, 6 pers., 5 days)

Seismicity in Ubaye & focal mechanisms of 2012 et April 7, 2014 (NE of Barcelonnette) (after Thouvenot, 2014)

Profile NS: Jausiers-St Paul/Ubaye

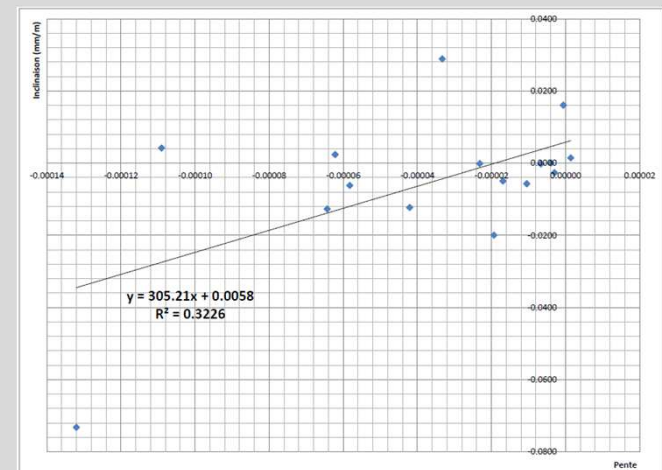
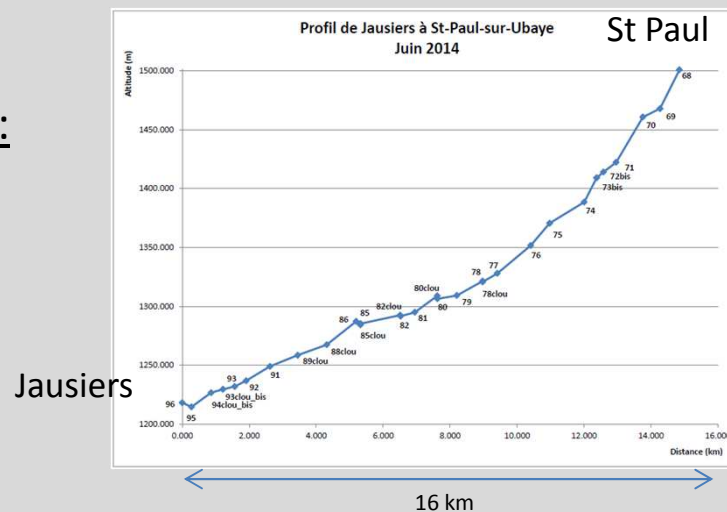


2014 data: misclosures



Instruments in 2014:

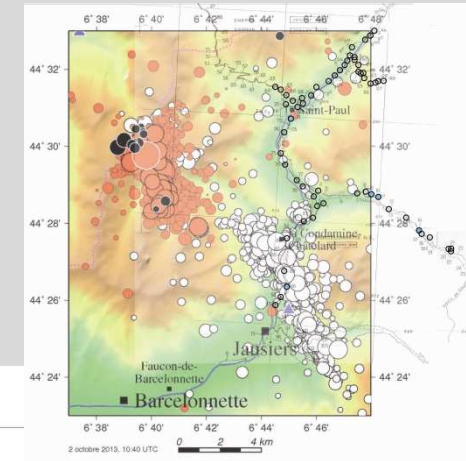
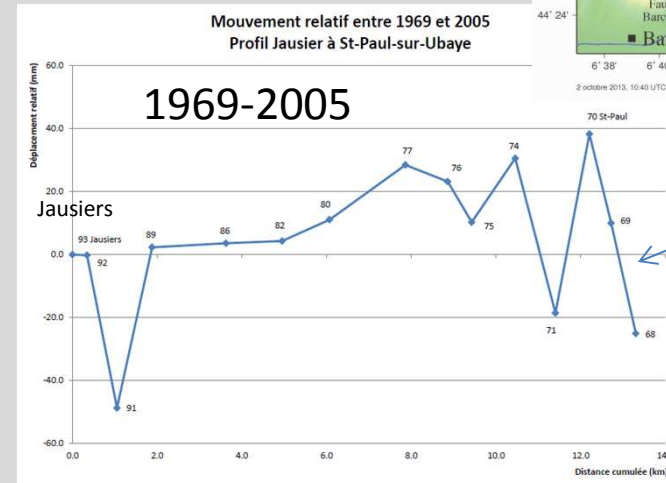
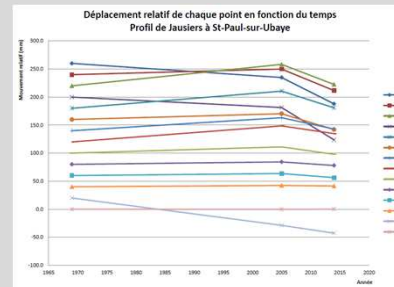
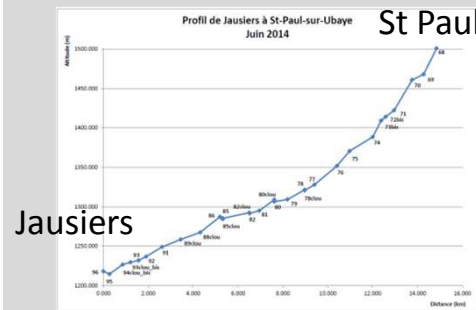
- Digital level: Leica
- DNA03 & NA3000
- invar rods
- Double run



No correlation between topography & benchmark displacement (Rigo et al.)

Profile NS: Jausiers-St Paul/Ubaye

Topography



Changes in the trend:

1969 – 2005: trend +40 mm/14 km

2005 – 2014 : trend – 50 mm/14 km

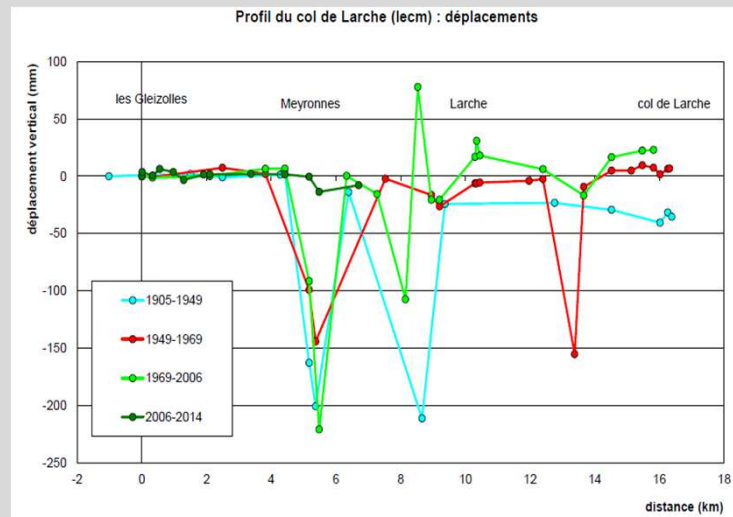
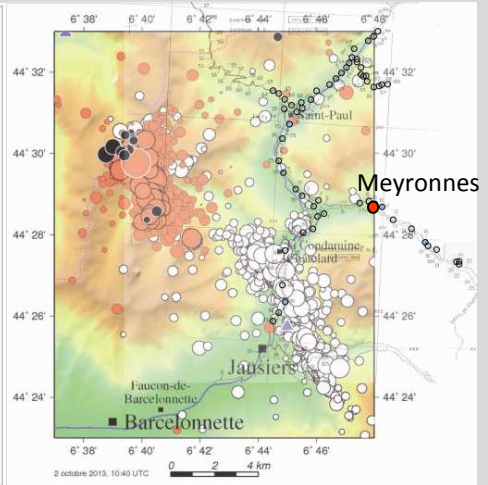
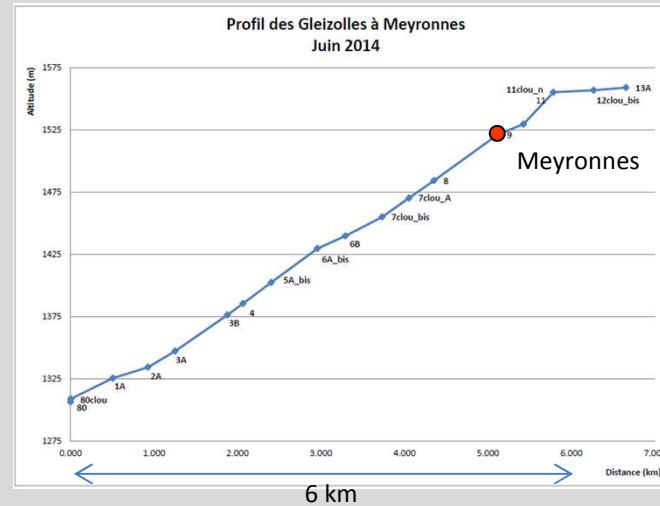
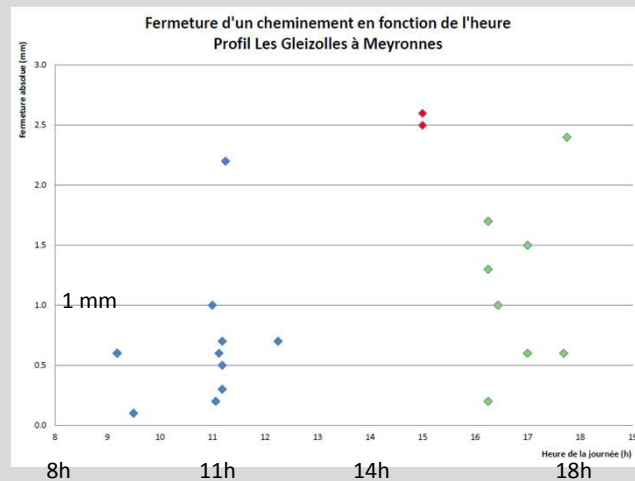
Causes:

- Systematic errors in measurements?
- Change linked to seismic crisis in 2003-2004?

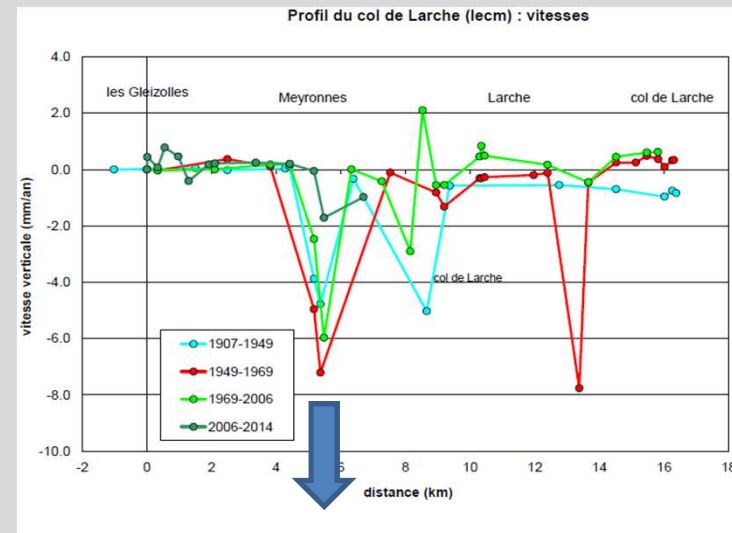


Meyronnes sector

1909—1949 —1969—2005—2014



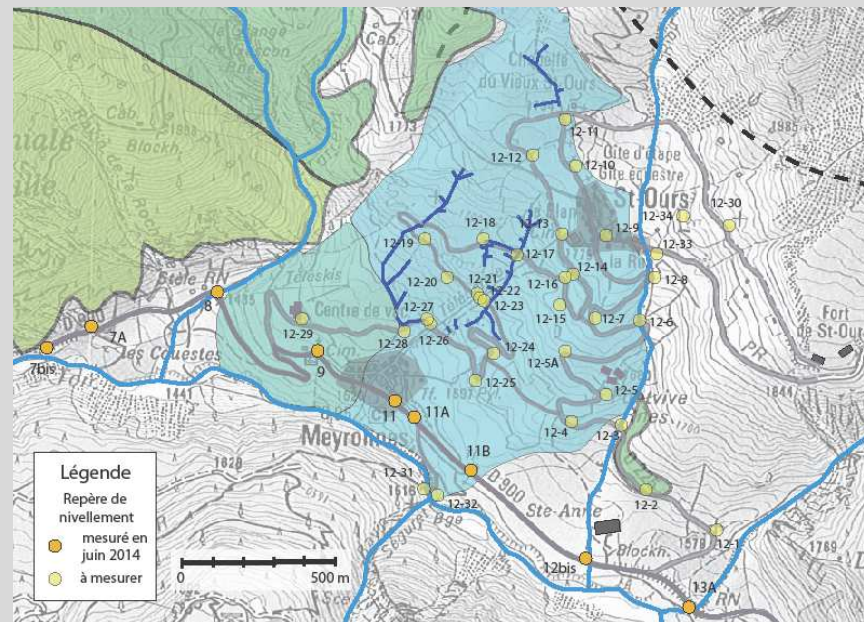
Displacements (mm)



Velocities: -5 → -7 → -6 → -1.8 mm/yr

New leveling network in Meyronnes

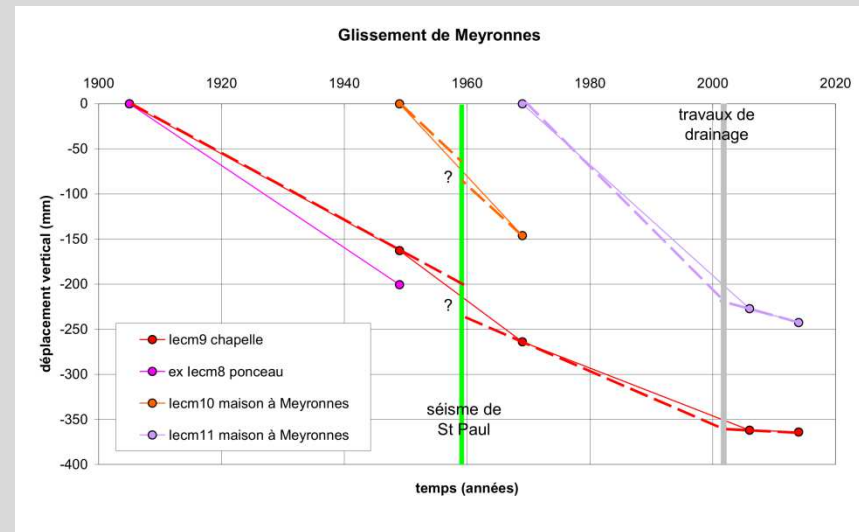
35 new benchmarks partially observed
in September & October 2014



-2.5 mm /yr (St Roch Chapel)

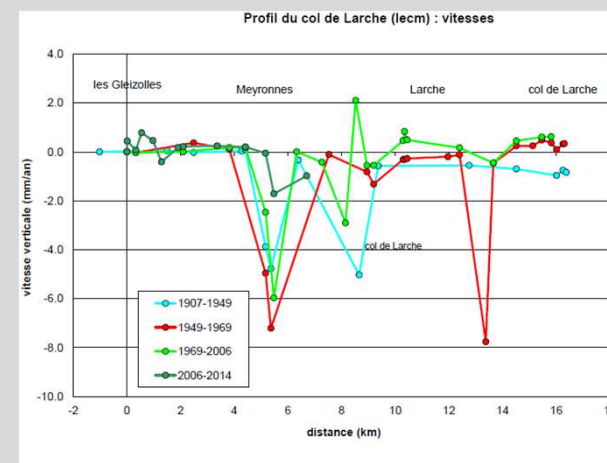
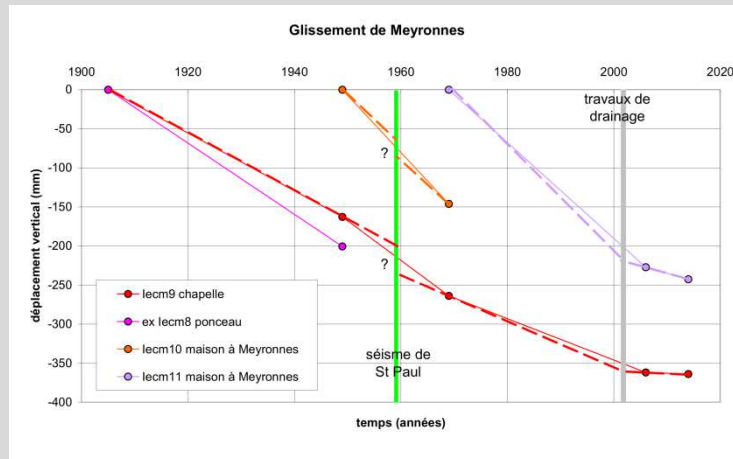
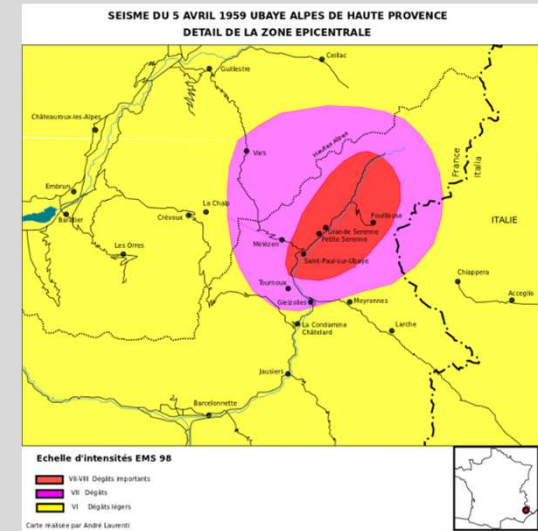
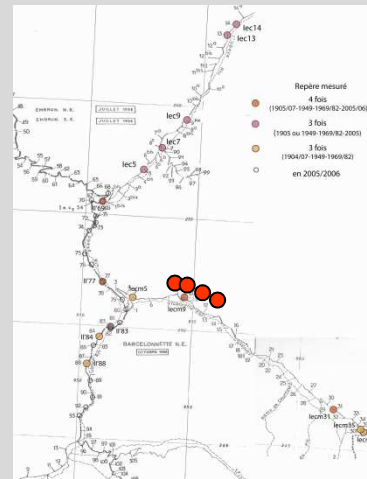
-6 mm/yr (BM village)

Changes in velocities after 2002 :
Linked to drainage works?



Route du col de la Larche

- Reactivation of the landslide by the 1959 Ubaye seism (Intensité VII-VIII)?

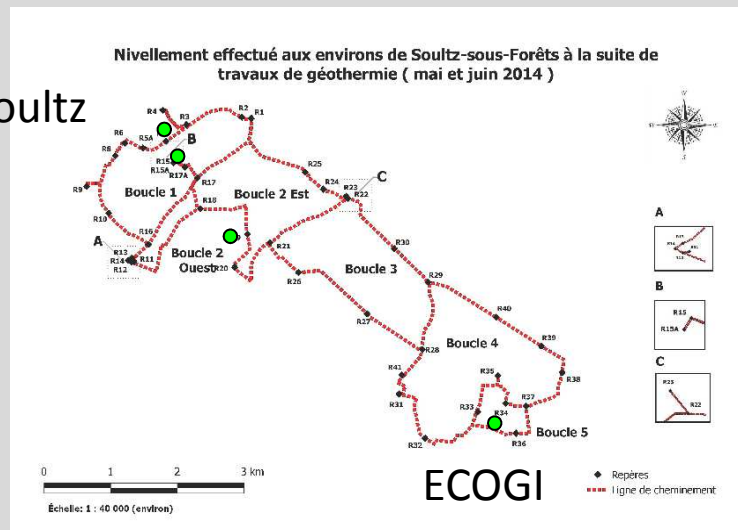


1909 – 1949 – 1969 – 2005 -2014

Geothermal exploitation sites Soultz-sous-Forêts & Rittershoffen

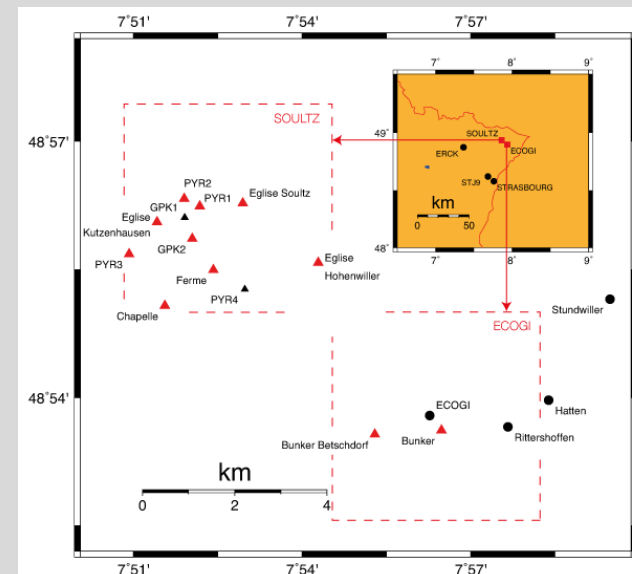


Soultz



Total length = 38 km (obs in 2014, in 2015)

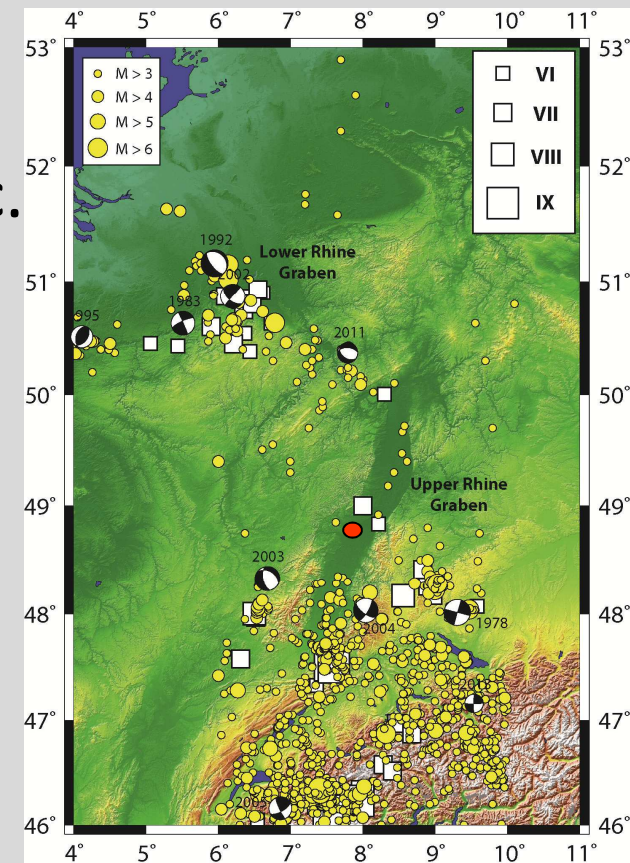
0.5 mm/km to 2.4 mm/km



Gravimetric sites (2013-2014) &
Continuous GPS stations.

Conclusion

- Leveling:
 - To monitor small vertical displac.
 - Old data : useful but
 - Complement other geodetic measurements:
 - cGPS, gravimetric, InSAR
 - Leveling helpful for some cases:
 - Annecy 1996 seism M4/5
 - Upper Rhine Graben: Serentz 1962



Meghraoui, 2013

Thanks to:

- IGN for providing old data
- students of INSA for field measurements



OMIV