European Geosciences Union
General Assembly 2011
Vienna | Austria | 03 – 08 April 2011
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Continuous monitoring and near-real time processing of GPS observations for landslide analysis: a methodological framework

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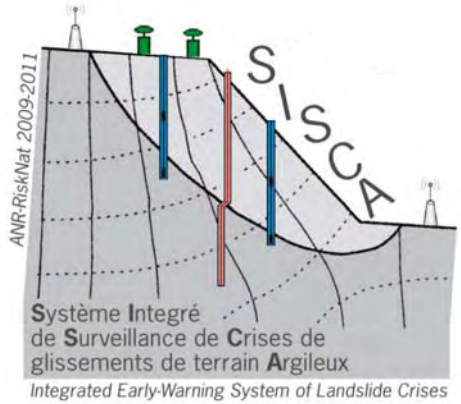
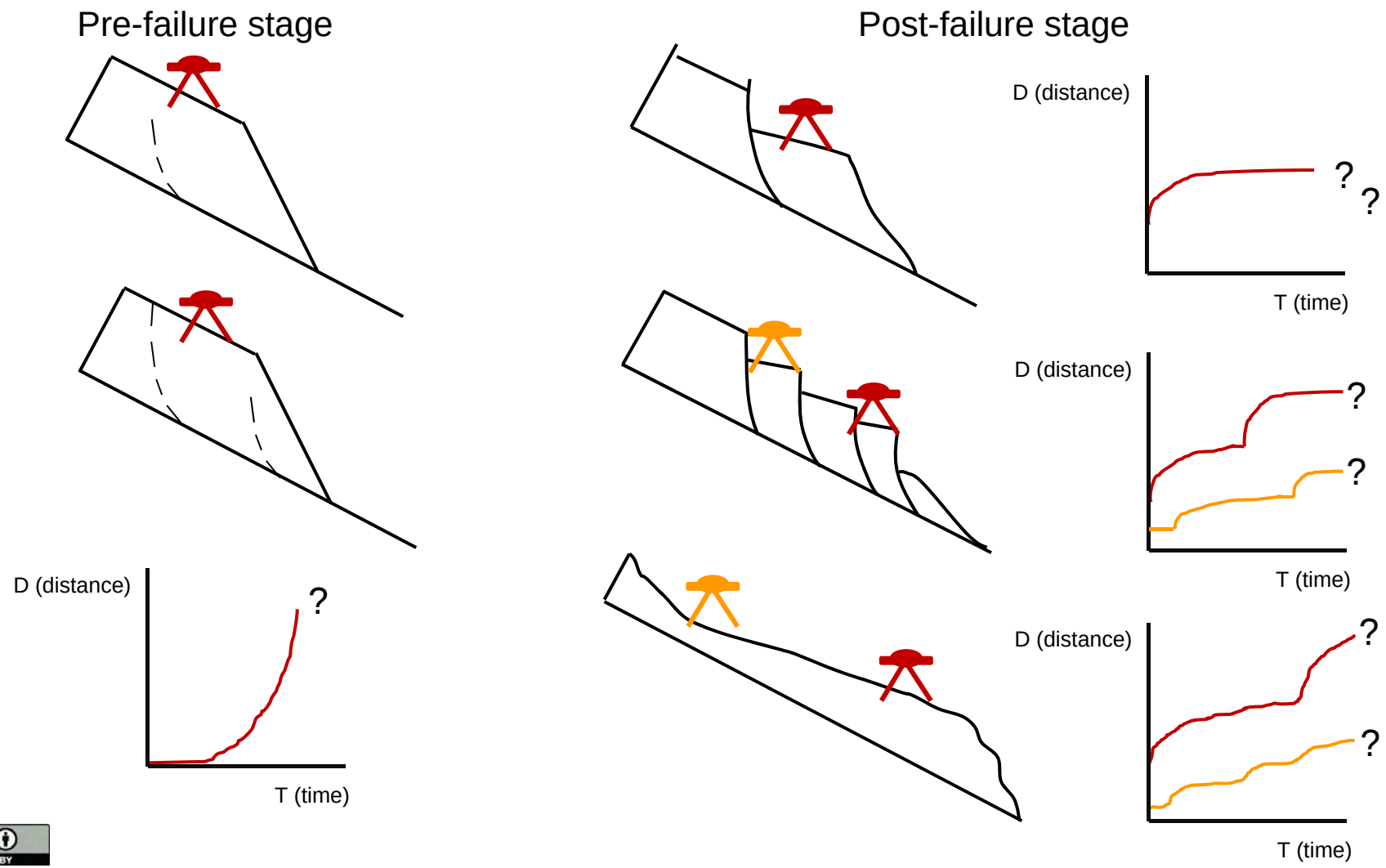


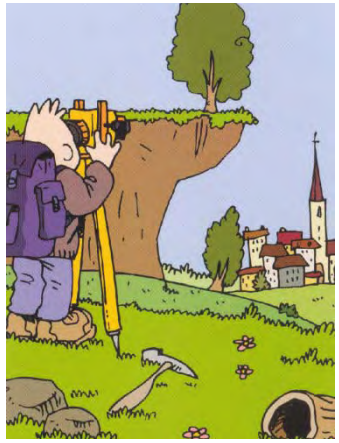
Motivation

1. Permanent monitoring of displacement in different regime



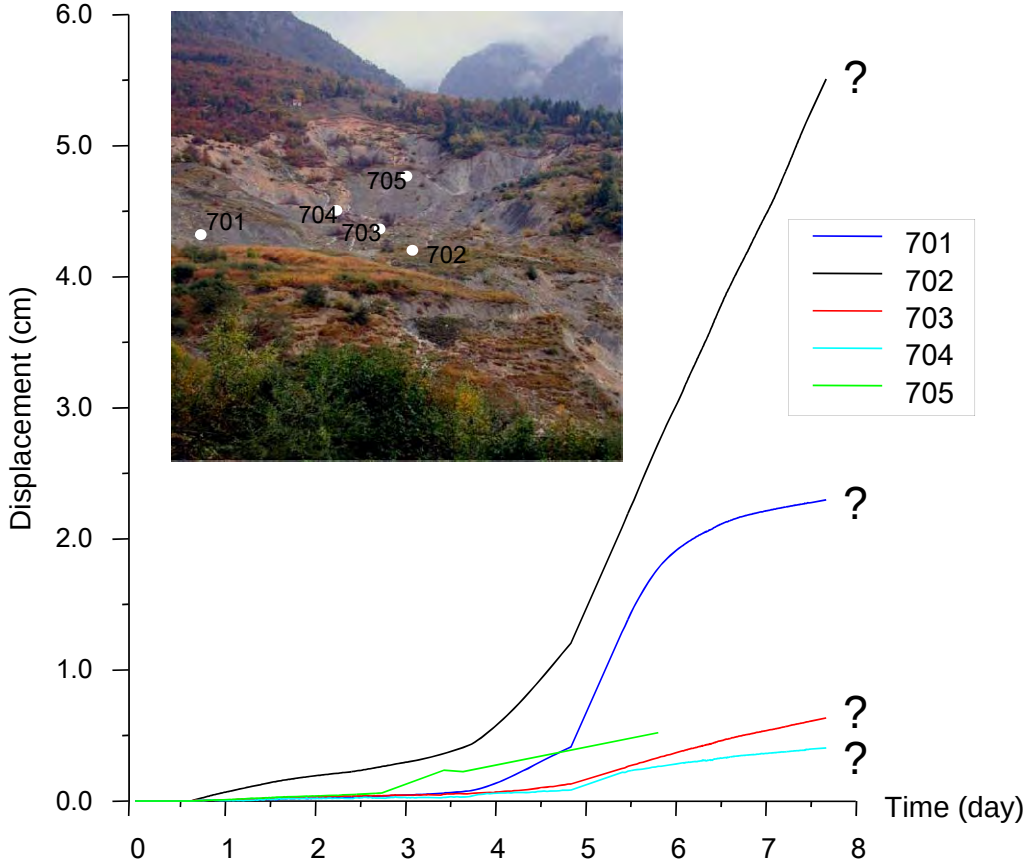
Motivation

2. Very-high accuracy (mm) on the displacement determination
   (absolute 3D coordinates)
3. Temporal forecast and definition of pre-alert / alert thresholds
   (EW: early-warning)



Monitoring

Early-warning

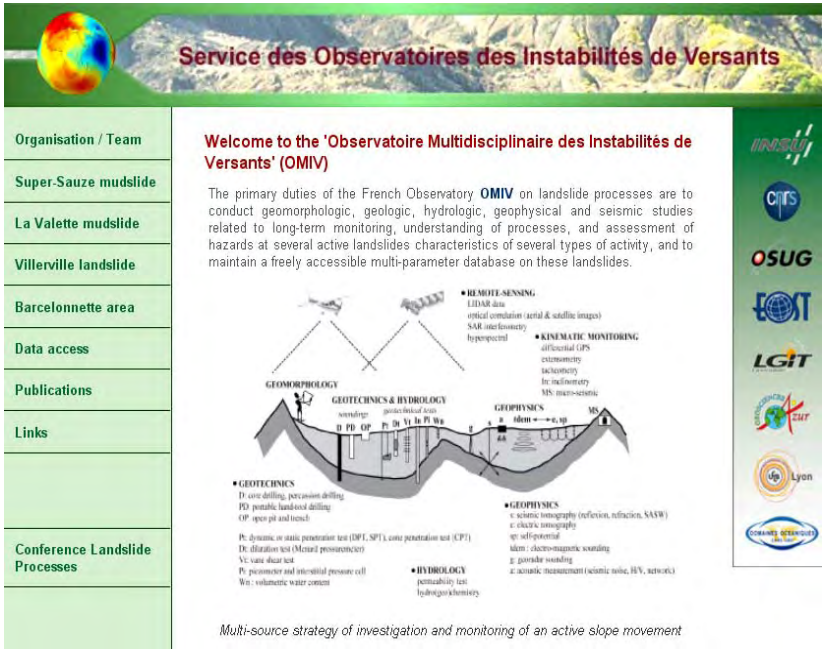


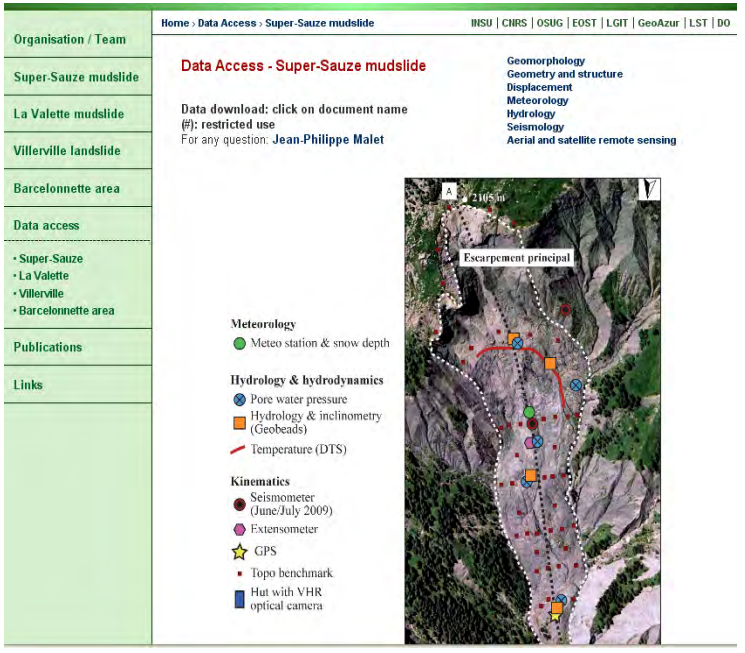
Motivation

4. Task of the French ‘Observatory on Landslides – OMIV’

Grenoble / OSUG
Nice / GeoAzur
Strasbourg / EOST

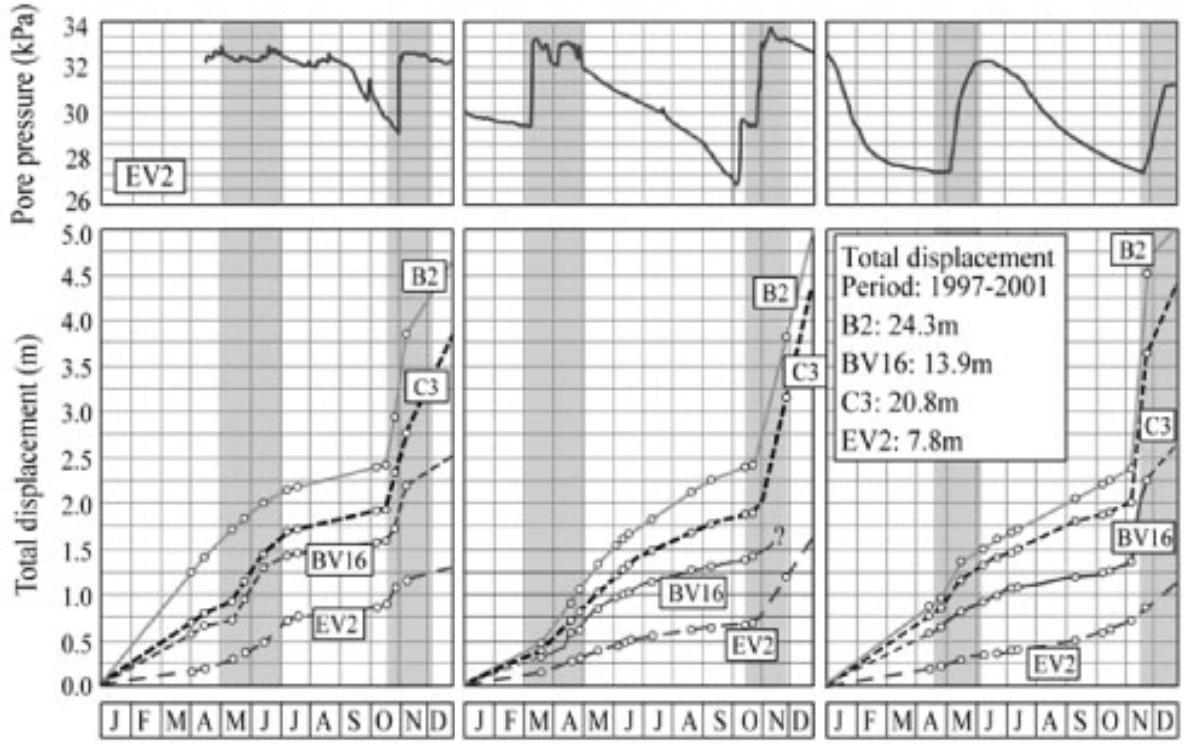
http://eost.u-strasbg.fr/omiv



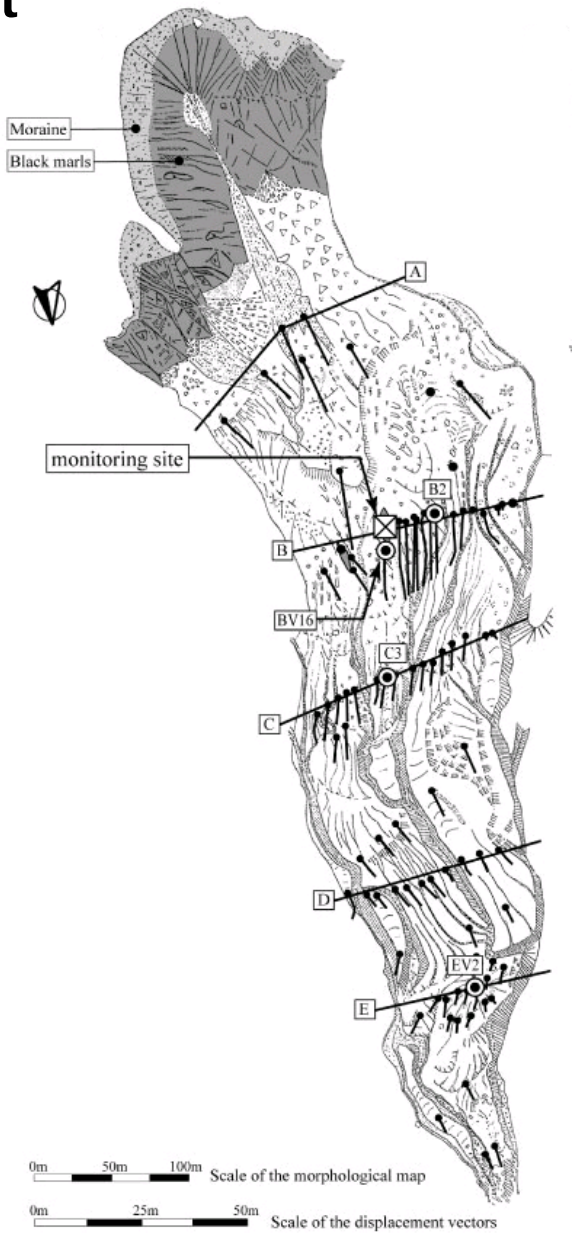


State-of-the-art: GPS & landslide displacement

+ Still mainly used through periodic (non continuous) determination of benchmark positions



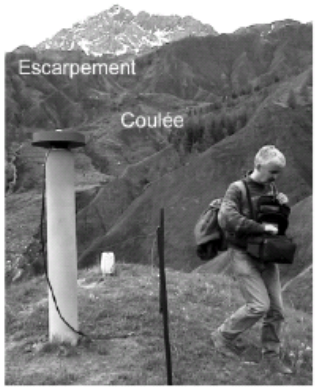
Malet et al. (2000)



State-of-the-art: GPS & landslide displacement

+ Very few examples of permanent (continuous) monitoring

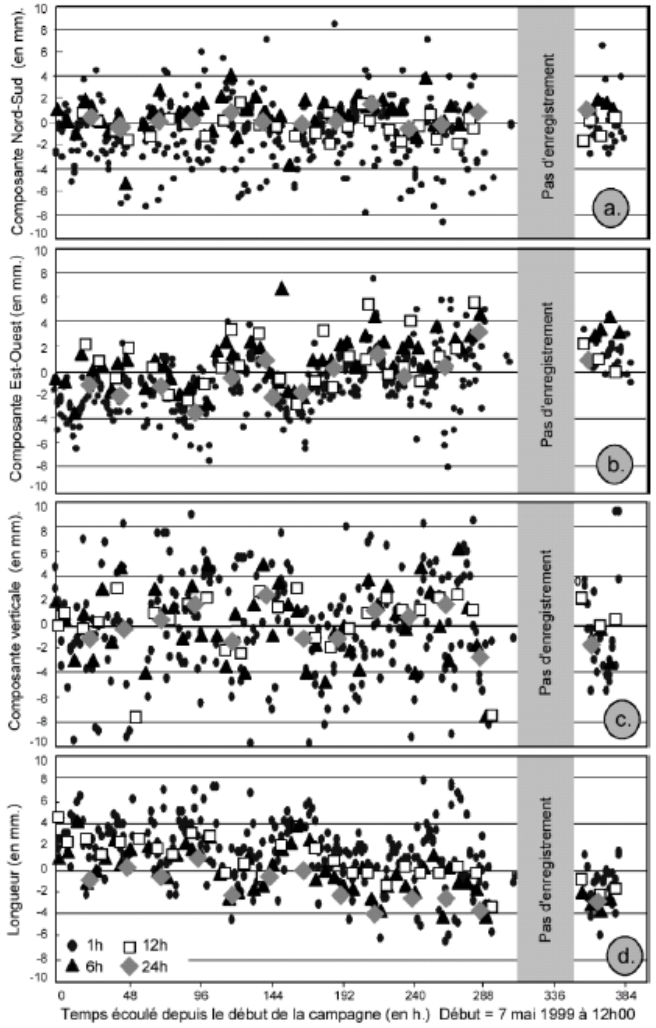
S.-Sauze landslide

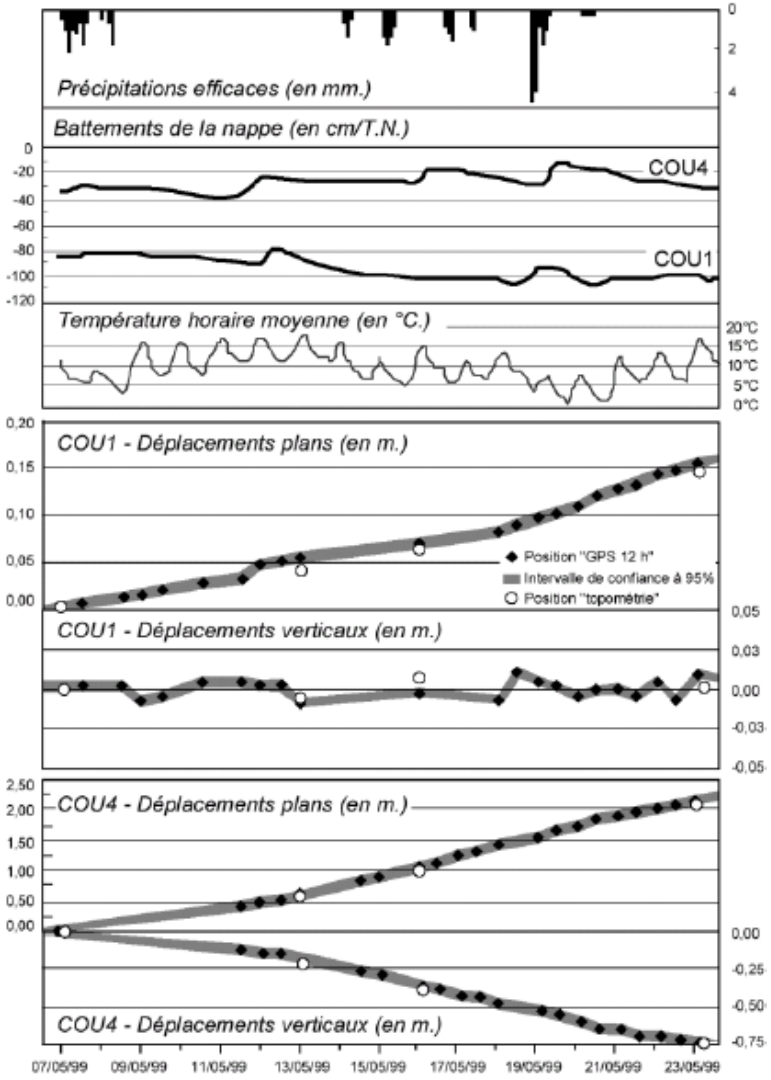


Reference GPS

'Moving' GPS

Malet et al. (2002)



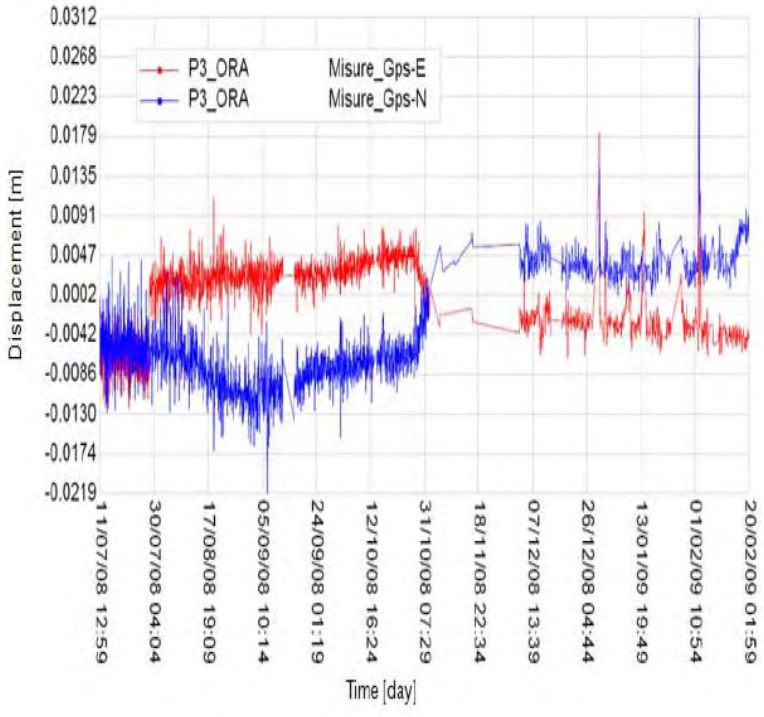


State-of-the-art: GPS & landslide displacement

+ Some commercial solutions, but (still) expensive and no ‘advanced’ or black-box processing

Leica L1/L2 GRX1200 receiver

Valoria landslide
Ancona landslide, Italy



Bertacchini et al. (2010)

Objective

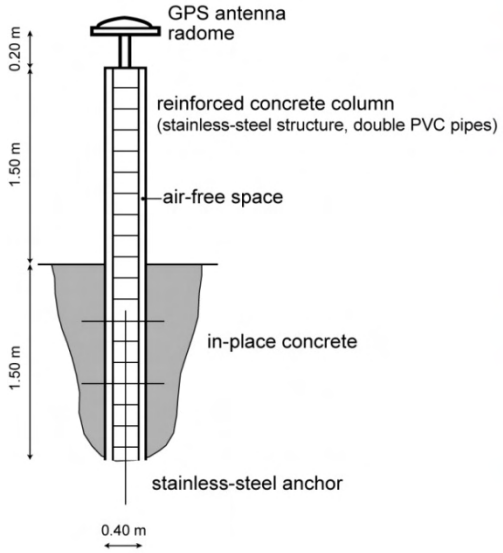
- **Propose a workflow for the automated processing of GPS observations**
  - with an accuracy adapted to the displacement rate of the landslide
  - with a baseline determination at day+1
  - with the possibility to analyse the observations over a range of temporal sequence (from 1-h session to 24-h session duration)
  - with the possibility to send graphs, maps and warning messages in case of change in the displacement regime
  - with the possibility of processing a large serie of observations
  - with the possibility of controlling all the processing steps

- **Analysis of the influence of:**
  - the combination of L1/L2 observations
  - the geometry of the GPS network used in the processing
  - the duration of the observation session
  - ….

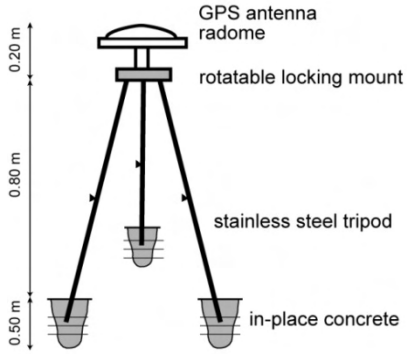
- **Several permanent GPS receivers installed on landslides in FR since 3 yrs**
  - *Avignonet, Super-Sauze, La Valette, Villerville (clayey landslides)*
  - *La Clapière (rockslide)*

Field installation: Example of La Valette & Villerville landslides

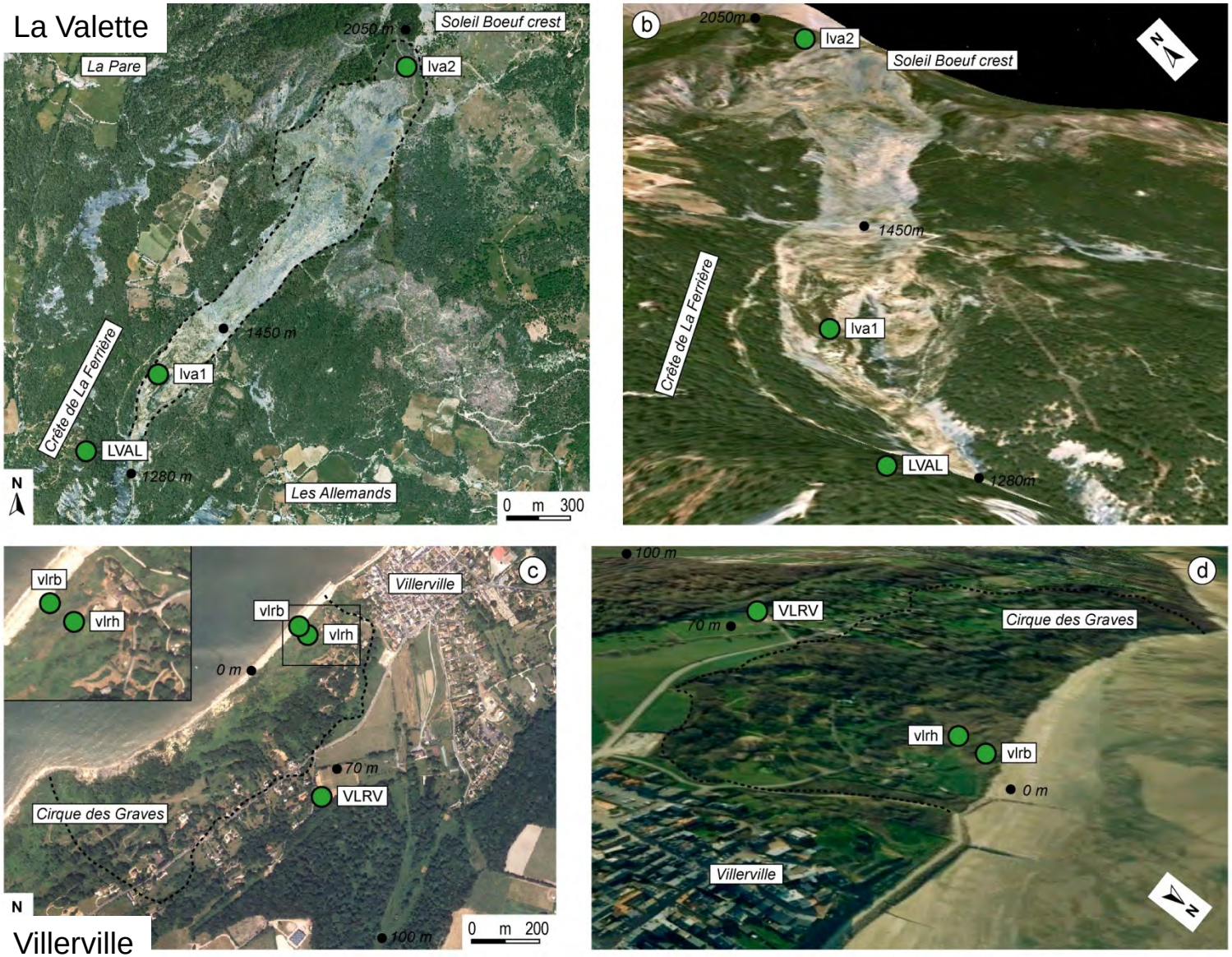
Reference GPS



'Moving' GPS

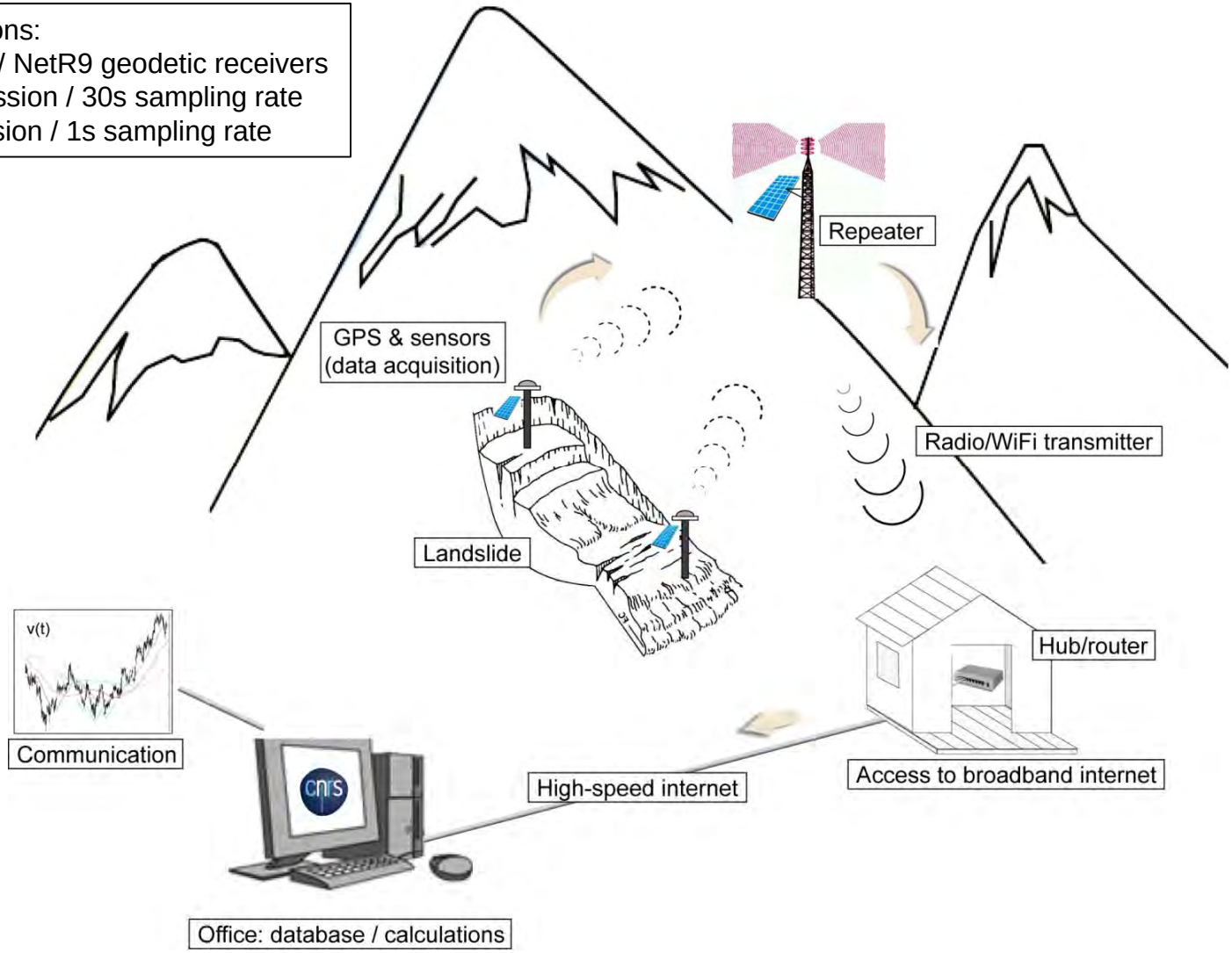


Field installation: Example of La Valette & Villerville landslides



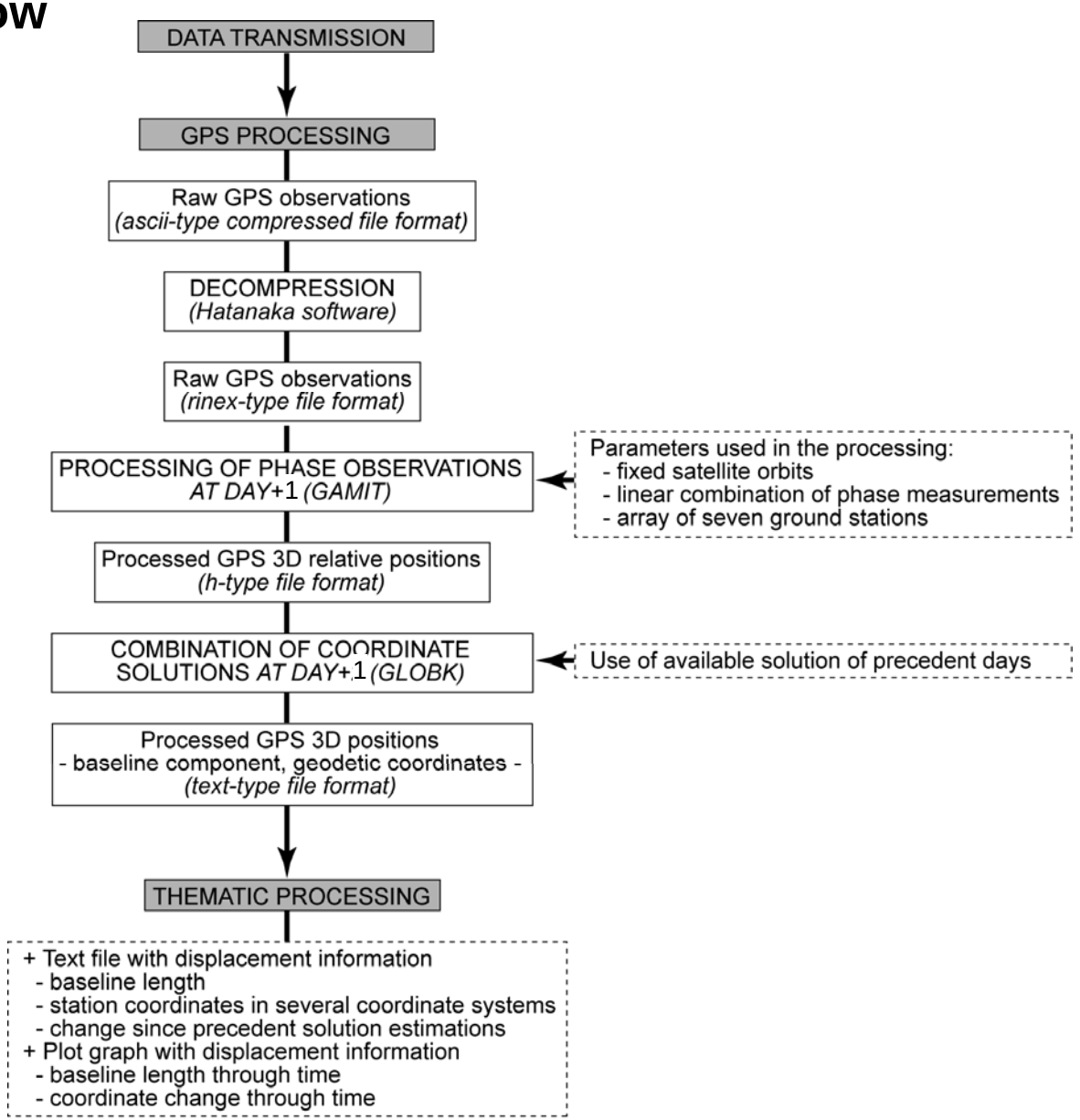
Data transmission and storage

GPS observations:
Trimble NetRS / NetR9 geodetic receivers
- 24h session / 30s sampling rate
- 1h session / 1s sampling rate

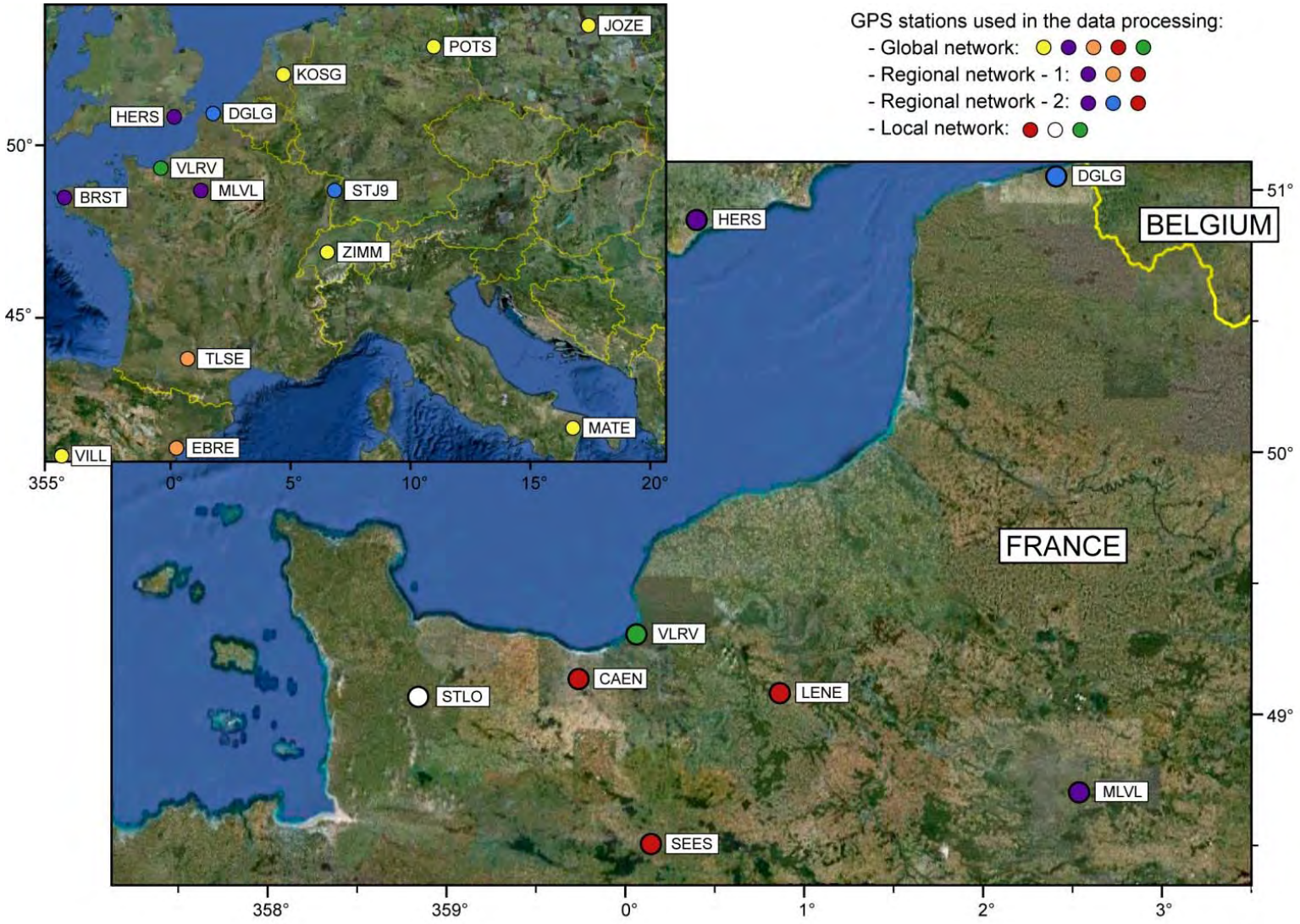


Data processing workflow

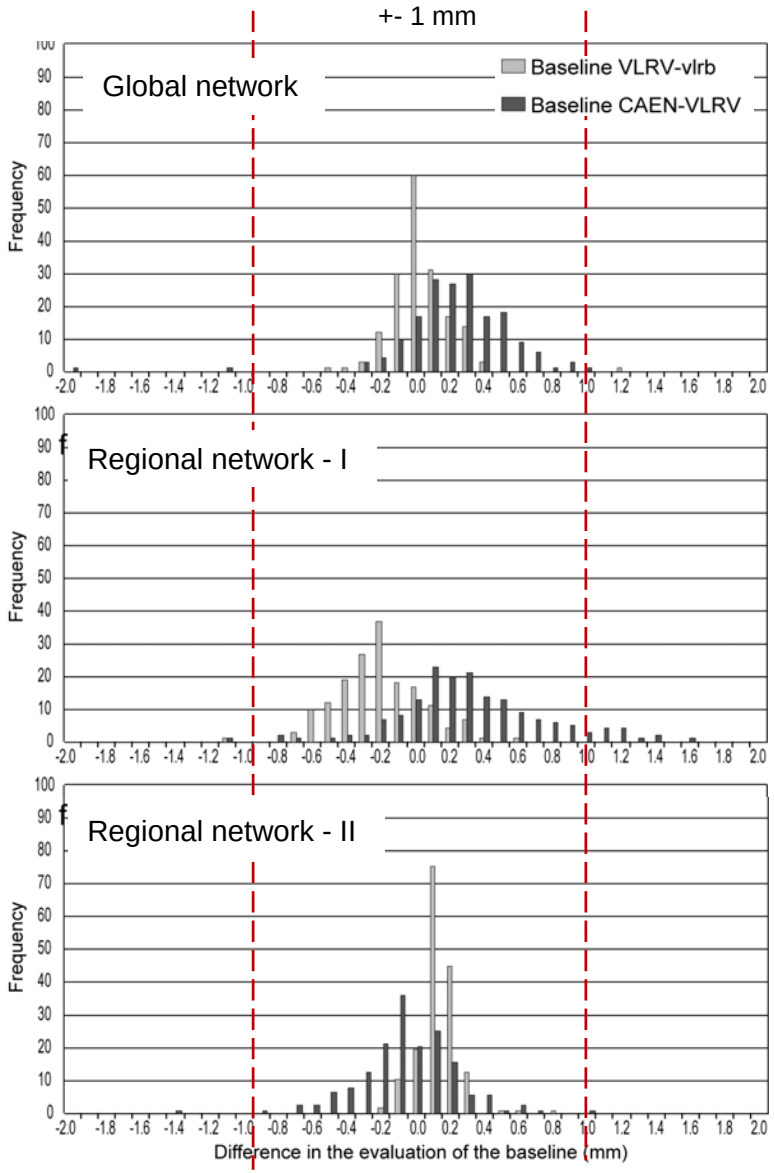
- C-Shell script for the workflow
- GPS observations processed with GAMIT/GLOBK (MIT)
- Use of the rapide/precise satellite orbites of IGS (at day+2, day+30)
- Conversion of coordinate system, creation of graphs, maps and messages



Effect of the geometry of the GPS station network



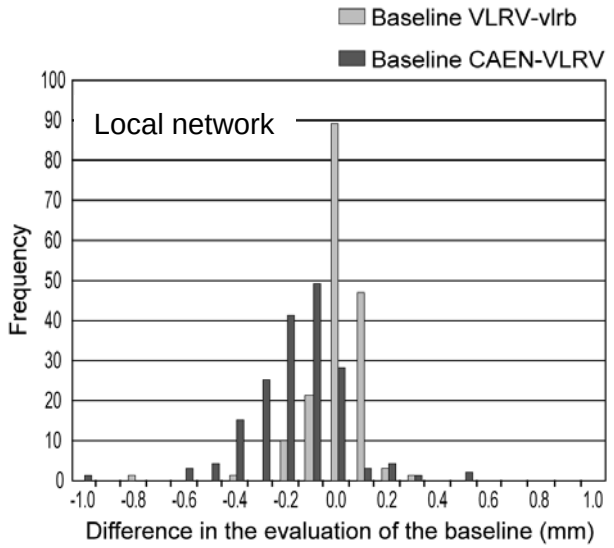
Effect of the geometry of the GPS station network



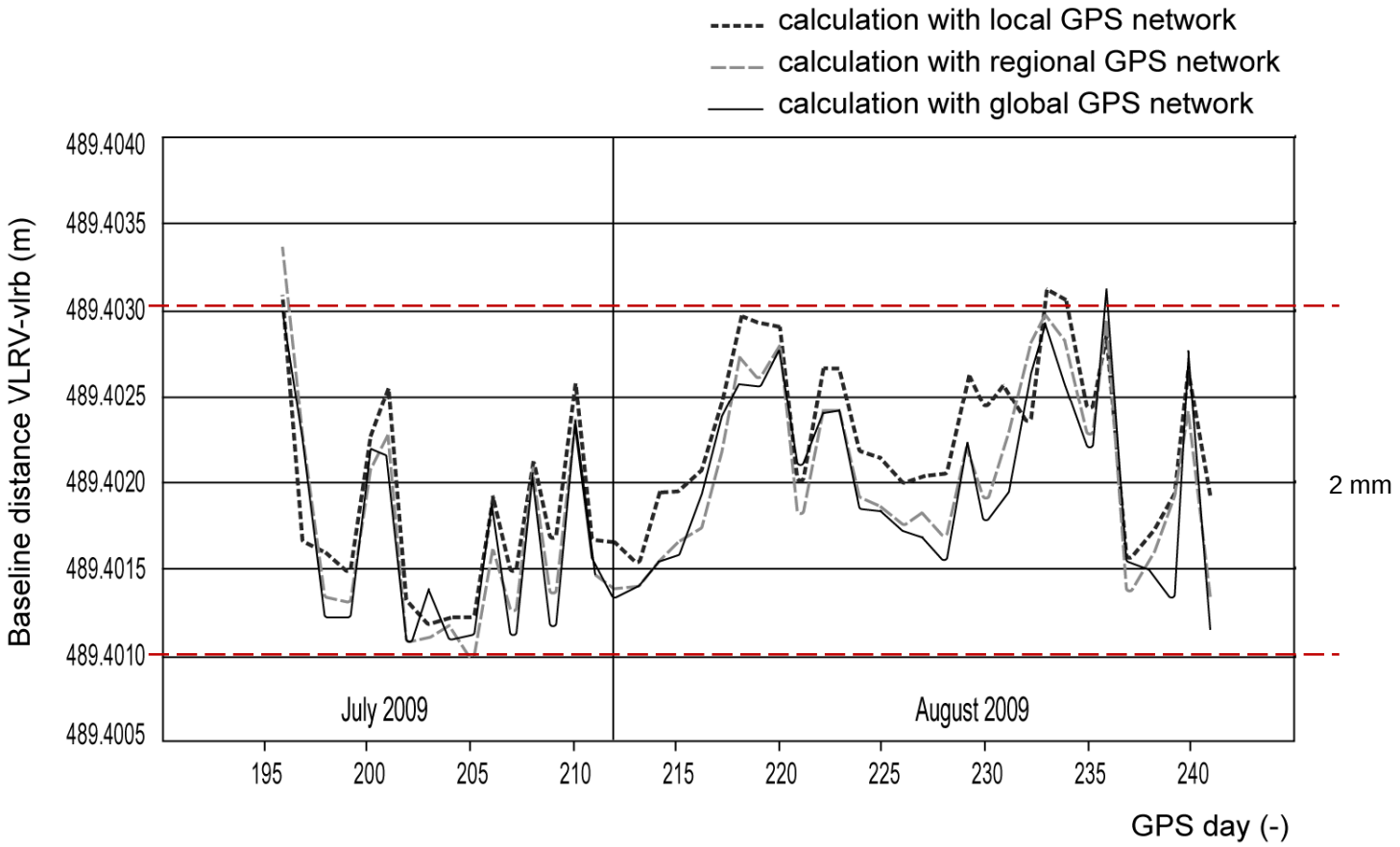
- Processing of a serie of 50 days of observations

- Use of a combination of L1/L2 band, troposheric model, precise IGS orbits

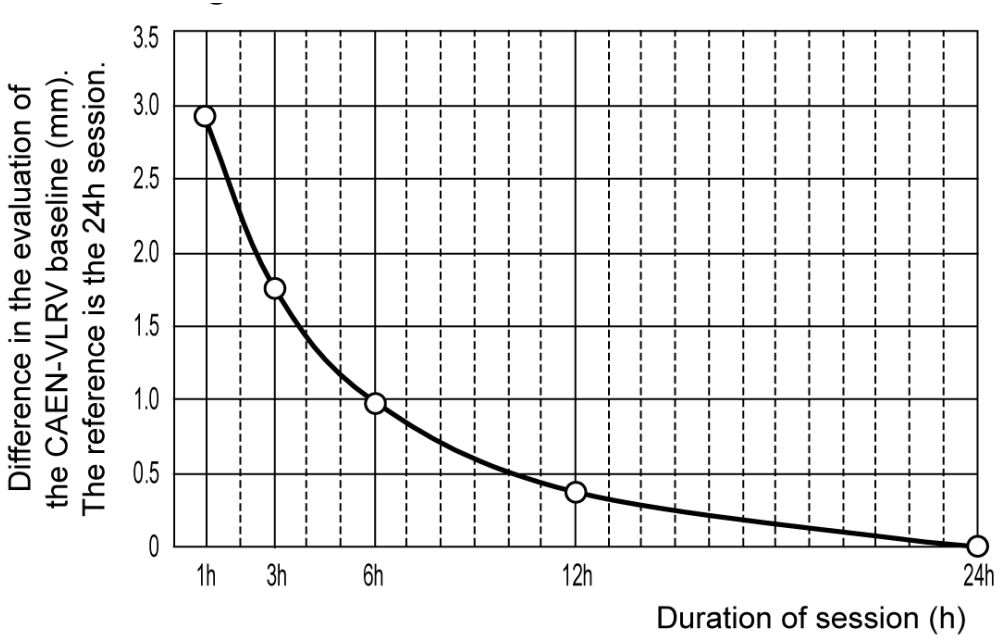
- Criteria: difference in the evaluation of the baseline CAEN-VLRV (50 km) and VLRV-vlrb (500 m)



Effect of the geometry of the GPS station network



Effect of the duration of the GPS observation session

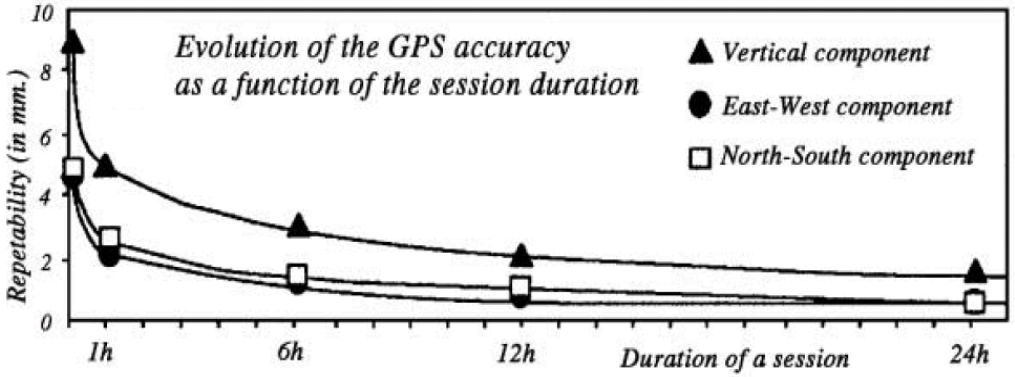


- Processing of a serie of 14 days of observations

- Use of a combination of L1/L2 band, precise IGS orbits

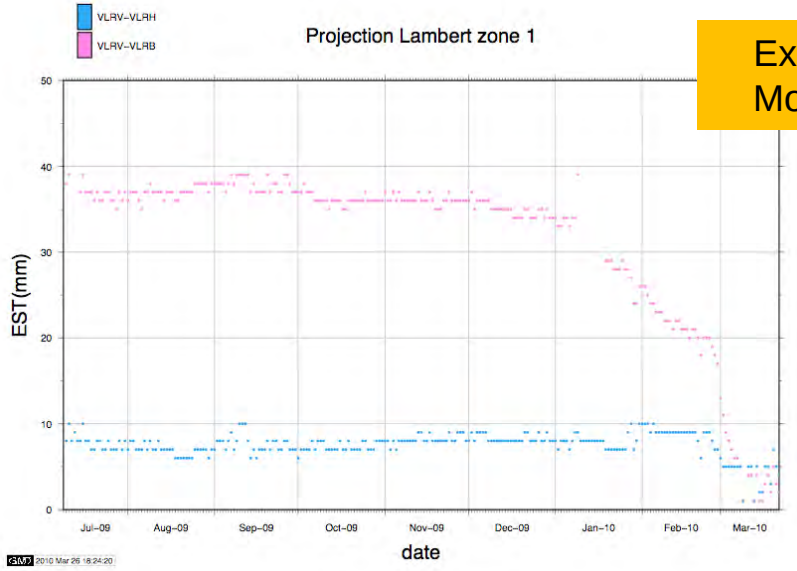
- Criteria: difference in the evaluation of the baseline CAEN-VLRV (50 km)

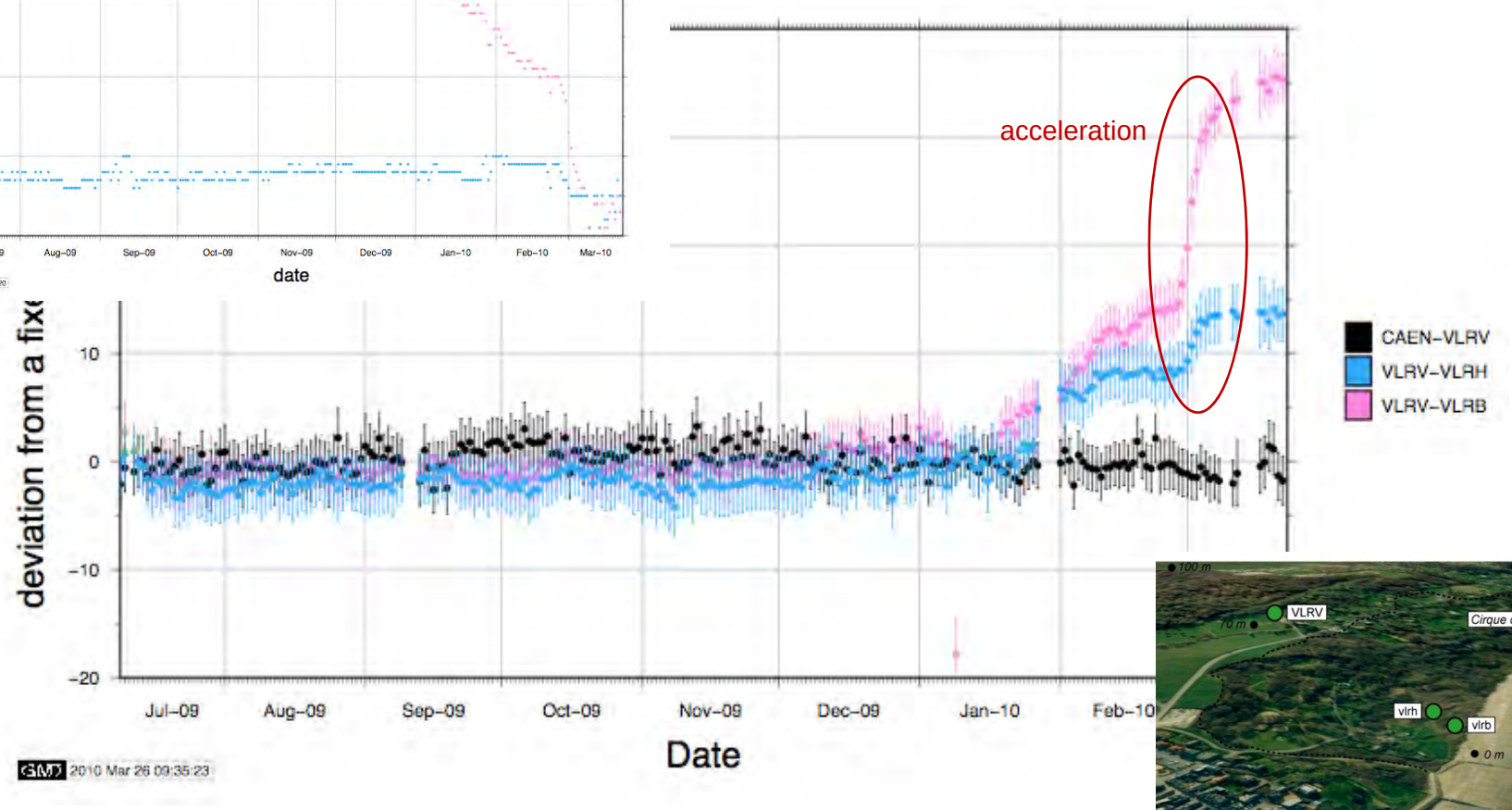
Results in agreement with previous studies (L1 phase processing; Malet et al., 2002)



Example of results

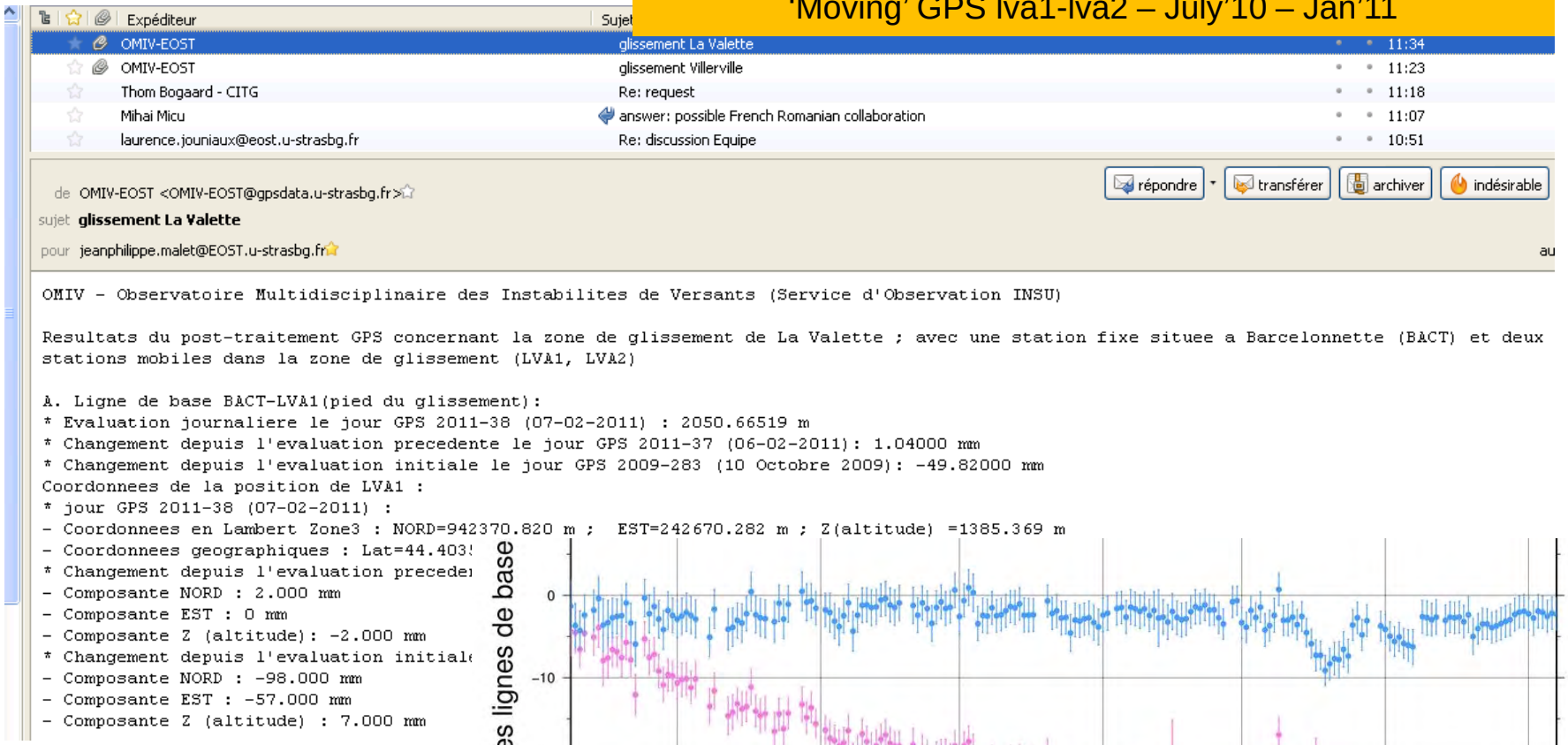
Example of the evolution of East component (Lambert I):
Moving GPS vlrh / vlrb at Villerville – July'09 – March'10





Example of results

Example of daily send messages with a synthesis of the calculations and associated graphs:
'Moving' GPS lva1-lva2 – July'10 – Jan'11



Expéditeur	Sujet	
OMIV-EOST	glissement La Valette	11:34
OMIV-EOST	glissement Villerville	11:23
Thom Bogaard - CITG	Re: request	11:18
Mihai Micu	answer: possible French Romanian collaboration	11:07
laurence.jouniaux@eost.u-strasbg.fr	Re: discussion Equipe	10:51

répondre | transférer | archiver | indésirable

de OMIV-EOST <OMIV-EOST@gpsdata.u-strasbg.fr>
sujet **glissement La Valette**
pour jeanphilippe.malet@EOST.u-strasbg.fr

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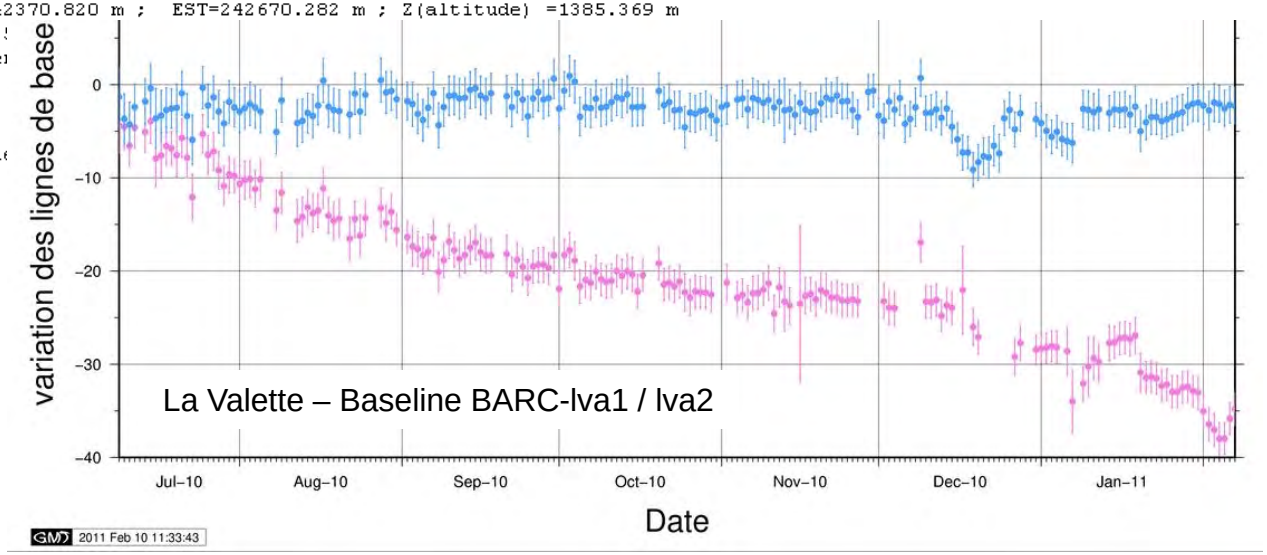
OMIV - Observatoire Multidisciplinaire des Instabilites de Versants (Service d'Observation INSU)

Resultats du post-traitement GPS concernant la zone de glissement de La Valette ; avec une station fixe situee a Barcelonnette (BACT) et deux
stations mobiles dans la zone de glissement (LVA1, LVA2)

A. Ligne de base BACT-LVA1(pied du glissement):
* Evaluation journaliere le jour GPS 2011-38 (07-02-2011) : 2050.66519 m
* Changement depuis l'evaluation precedente le jour GPS 2011-37 (06-02-2011): 1.04000 mm
* Changement depuis l'evaluation initiale le jour GPS 2009-283 (10 Octobre 2009): -49.82000 mm
Coordonnees de la position de LVA1 :
* jour GPS 2011-38 (07-02-2011) :
- Coordonnees en Lambert Zone3 : NORD=942370.820 m ;  EST=242670.282 m ; Z(altitude) =1385.369 m
- Coordonnees geographiques : Lat=44.403
* Changement depuis l'evaluation precede
- Composante NORD : 2.000 mm
- Composante EST : 0 mm
- Composante Z (altitude): -2.000 mm
* Changement depuis l'evaluation initial
- Composante NORD : -98.000 mm
- Composante EST : -57.000 mm
- Composante Z (altitude) : 7.000 mm
```



La Valette – Baseline BARC-lva1 / lva2

Conclusions and outlook

- **Precise determination of baselines can be estimated from GPS observations using Gamit/GlobK research software**
  - **3mm in plane coordinates, <5mm in elevation coordinate:**
    24-h session, ultra-precise satellite orbits of IGS, relevant geodetic monuments, calculation at day + 2
  - **5mm in plane coordinates, <10mm in elevation coordinate:**
    1-h session, estimated satellite orbits, relevant geodetic monuments, calculation at less than day+1

- **Complete automation of the script**
  data transmission, storage, quality control, processing, diffusion of results

- **Geometry of the GPS station network has to be studied carefully for each instrumented landslides**

➔ **On-going work:**
- Incorporation of new GPS observations in the script (Avignonet, La Clapière)
- Incorporation of pre-alert / alert thresholds based on displacement rate
- Incorporation of the results in .kml file format (Google Earth)