Optimization of data exchange and energy consumption for dense networks of continuously operating GPS receivers

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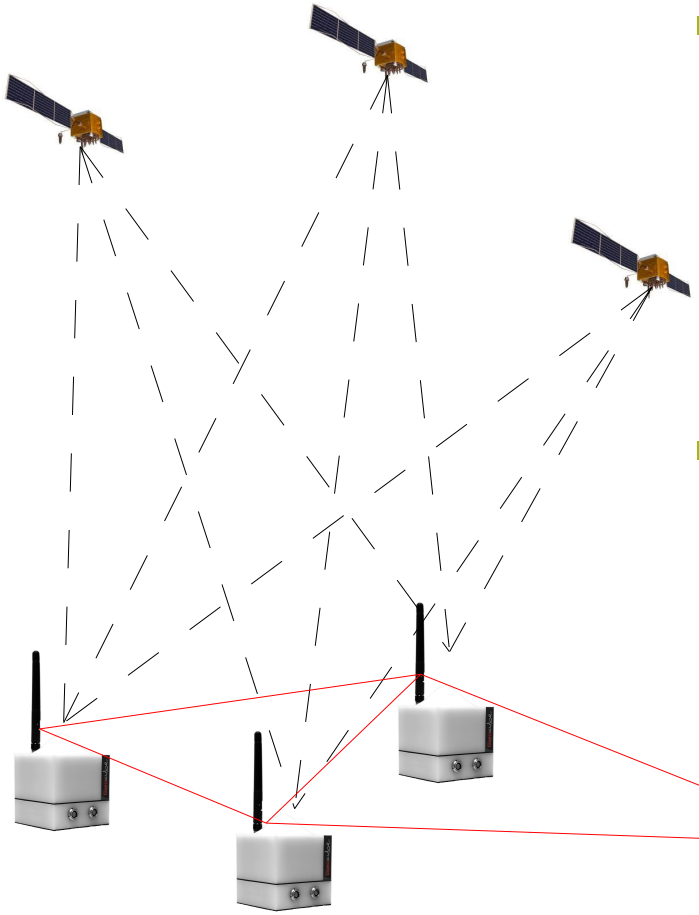
Introduction

- **Presentation of the Geocube.**
  - Geocube : wireless low-cost GPS
    developed by the French national mapping agency (IGN)

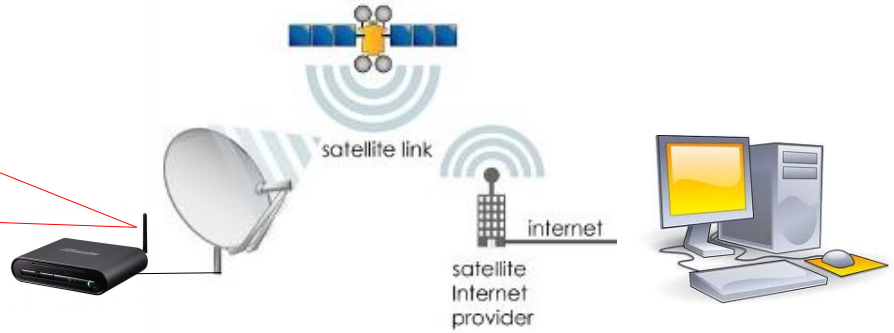
- **Results of a field test : landslide monitoring.**

- **Optimization of acquisition and processing in order to allow real-time monitoring under operational conditions:**
  - Data compression.
  - Processing of sparse data.

The Geocube : *A wireless low-cost GPS receiver*



- **A Geocube is equipped with :**
  - A mono-frequency GPS providing raw-carrier phase data.
  - A radio-module for communication and data exchange.
  - Batteries and solar panel for power supply.
  - Physical sensors modularly added.
- **Dense networks of small extend.**
  - Limitations : Ionosphere, radio range.



Data acquisition => Geocubes	Data collection Command sending => Coordinator
On the field	

Data processing User interface (command generation)
In the office

The Geocube : *processing strategy and typical use*

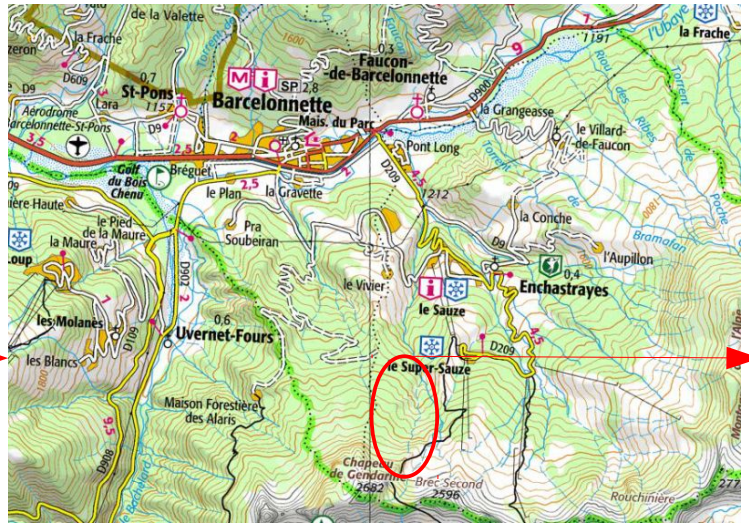
- **A dedicated processing software allows post as well as real-time processing.**

- **It is based on :**
  - Observations : double differences of raw carrier phase data.
  - Inversion : Extended Kalman filter.
  - Ambiguities : fixed from an approximated position (static positioning or triple differences).
  - Main error sources : multipath.

- **Typical use : monitoring of small objects.**
  - Landslides, glaciers, volcanoes...
  - Structures : Buildings, dams, bridges...

Field test : *the monitored area*

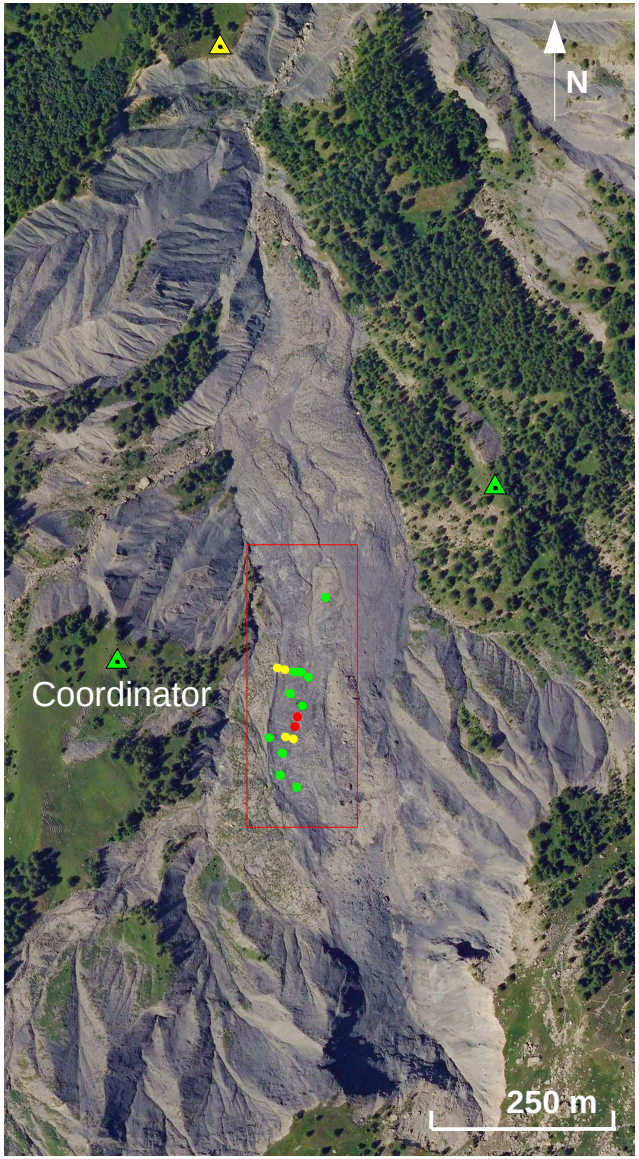
- **During the summer of 2012, a Geocube network was deployed on the Super-Sauze's landslide (French Alps, Ubbaye valley).**
  - Three month monitoring.
  - Focus on an active part of the landslide with a relatively high velocity.
  - Relatively small area (Baselines < 1km).



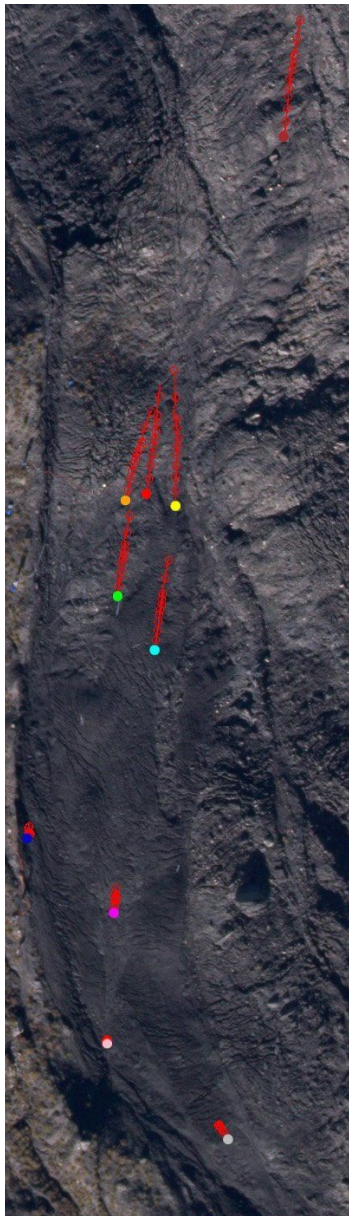
Field test : *the deployed network*

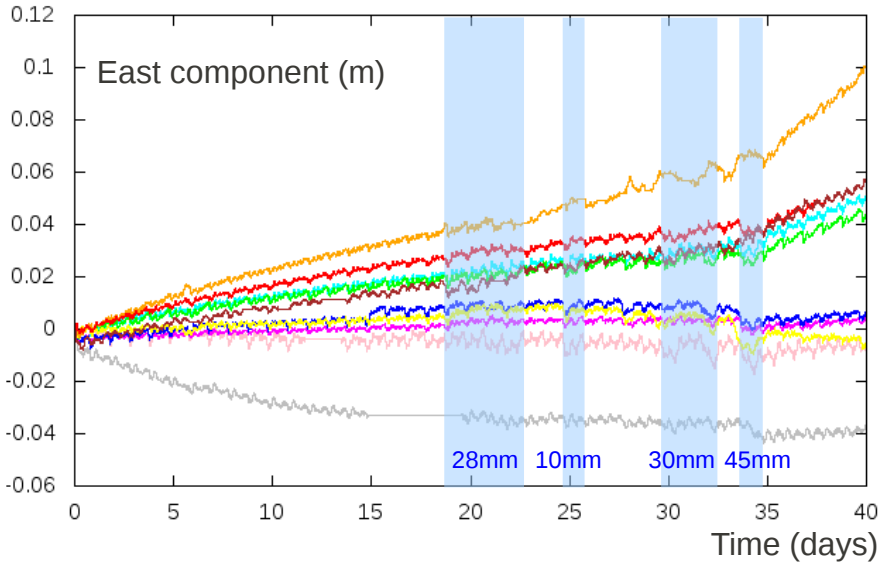
- **19 Geocubes were deployed (3 fixed, 16 mobiles)**
  - 2 did not ran (red).
  - 5 ran with interruption (yellow).
    => *Malfunctions were due to a sealing defect.*
  - 12 worked well (green).
- **Meteorological sensors and ground pressure and humidity sensor were added on some receivers.**

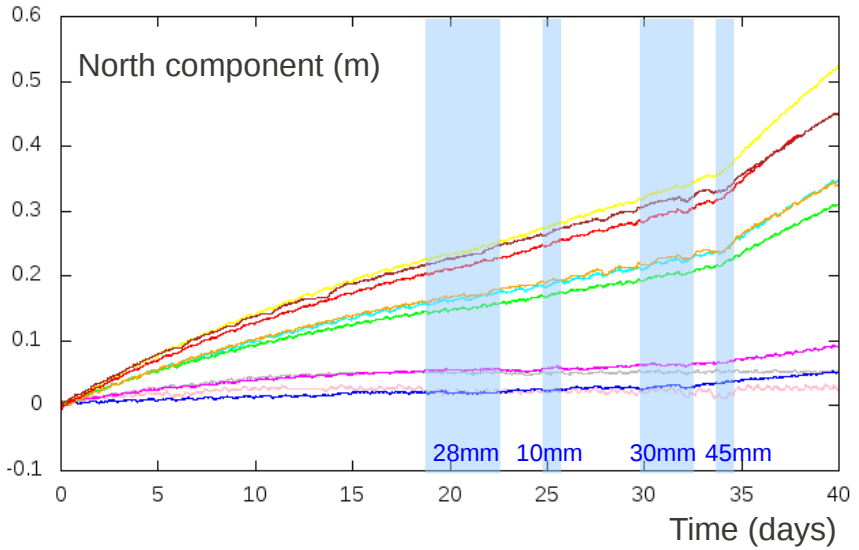
- **Difficult conditions for GPS :**
  - Multipath.
  - 40° mask on the South.



Field test : *results of a 40 days subset*

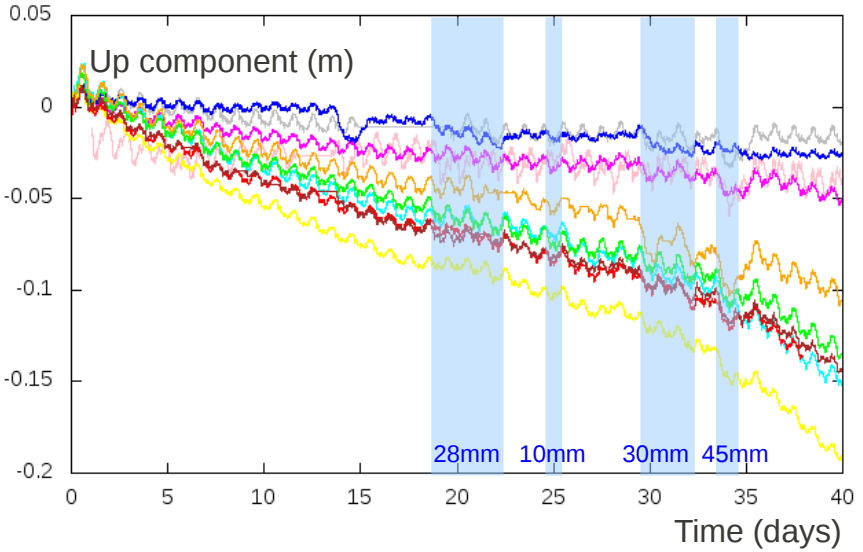






3D time series and correlation with rain.

Light blue : rainy period.
Blue text : rain accumulation.



Horizontal displacements of Geocubes.

Red circles : one every four days
Red lines : 30sec positions
Scale : — = 10cm displacement

- **Accuracy (1σ) < 1cm for all components.**

Field test : *conclusions*

- **Good results were obtained with post-processing.**
  - Difficult conditions for GPS.
  - Sub-centimetric accuracy.

- **In addition real-time deformation monitoring was successfully performed.**

- **However some limitations appear for real-time monitoring under operational conditions :**

  - The transfer of raw data needs a large bandwidth.

    => Radio bandwidth too small if densely populated networks are considered.

  - The data transfer is highly energy consuming.

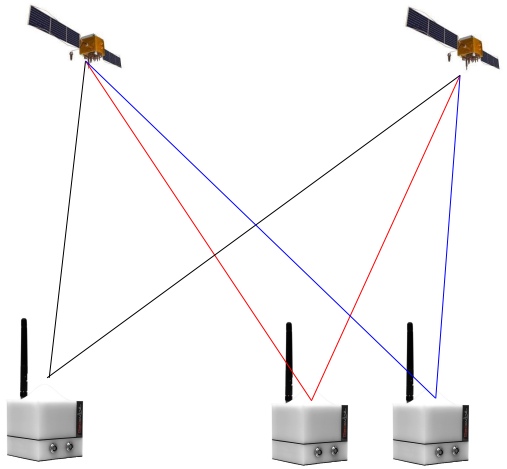
    => Too much energy needed in case of continuous monitoring.

Data compression

- **Raw data are too large for radio bandwidth :**
  - Radio bandwidth limited to 1200 bytes/sec for the whole network.
  - Raw data for 1 receiver and 1 epoch : 300 bytes.

- **Compression method :**
  - Only useful data (phase, SNR and time) of sufficient quality are pre-processed on the receiver and transmitted.
  - Phase data are truncated and real double differences are reconstructed on the processing computer using a predicted receiver position.
  - Results :

UBX	300 bytes
RTCM 3.0	130 bytes
Compressed data	50 bytes



Predicted +++++++,+++ + Measured and transmitted **,***

Reconstructed double difference ++++**,***

Decreasing of energy consumption : *sparse data processing*

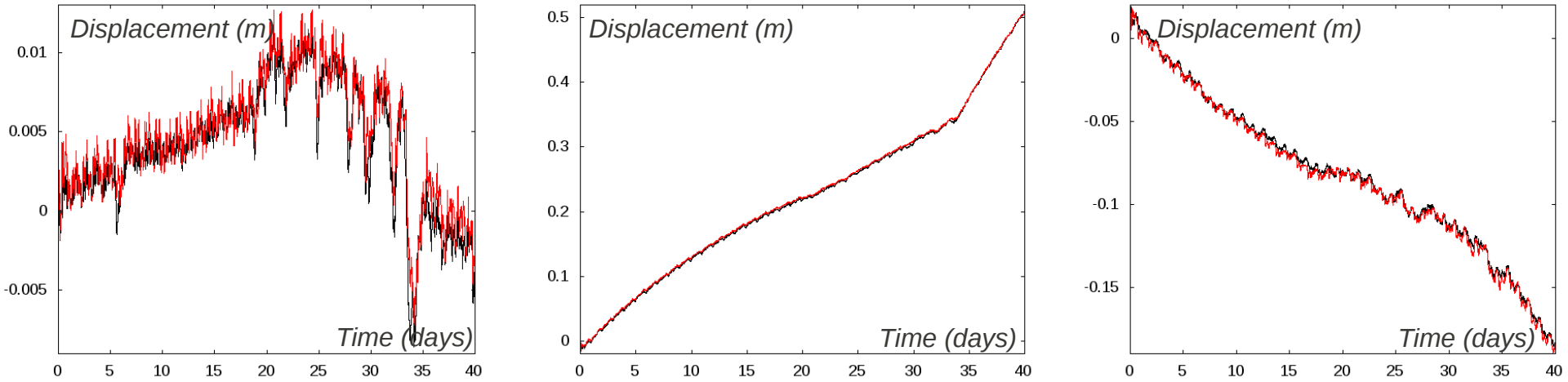
- **Reduce the daily acquisition time is the best solution to decrease energy consumption.**
  - 3mW in standby mode.
  - 650mW during data acquisition and transfer.
- **An acquisition span of 5min per 1/2h is chosen as trade-off between time resolution and energy saving.**
- **Other strategy (not tested): Acquire data during the most favorable periods (low multipath, low PDOP).**

Decreasing of energy consumption : *sparse data processing*

- **The processing software must be amended to support sparse data :**
  - The velocity is estimated in addition to the position in order to better fill the data gaps.
  - The ambiguities are recomputed after each gap from an approximated position predicted thanks to the Kalman filter.

    => Unexpected movements must be less than $\lambda_{L1}/2$ during the gap.
  - A sidereal mitigation of multipath remains possible moving the acquisition windows of 4min per day according to the repetition time of multipath.

- **The results are quite the same as with continuous data :**



Time series of a 40 days dataset (landslide of Super - Sauze); left : East, center : North, right : Up.
Black : continuous measurement, Red sparse measurement (sidereal).

Conclusion

About the concept of Geocube :

- Geocubes provide accurate (sub-centimetric) differential positioning on dense networks.
- Extra measurements are possible thanks to the modular adding of sensors.
- Well suited for the study of small but complex objects.

Current state :

- Post-processing fully operational.
- Real-time processing still under development.

Perspectives :

- New tests :
  - Post-processing on a glacier (Argentière, French Alps).
  - Real-time with a densely populated network on the site of IGN.
- New sensors : seismometer.

Thank you for your attention !