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SURVEILLANCE GRAVIMETRIQUE DE LA VARIATION DE LA NAPPE PHREATIQUE SUPERFICIELLE ASSOCIEE A LA GARONNE AU NIVEAU DE TOULOUSE

GRAVIMETRIC MONITORING OF THE GARONA WATER TABLE NEAR TOULOUSE

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GOAL: The UMR5562/BGI is starting a monitoring of the water table of the Garona River near Toulouse, at the Portet site, by microgravimetry and GPS. The goal is to be able to predict the piezometric level of this water table by only gravimetric and GPS surveys, and to study its balance.

The basic equation linking the gravimetric signal to the piezometric level is:

$$\Delta g = 42\ \Phi\ \Delta p - 308.6\ \Delta h$$

where Δg is in μGals, the piezometric level Δp is in meters, and the station altitude Δh with respect to some common reference is in meters. The porosity Φ of the aquifer usually ranges from 10 to 30 %.

The expected signals are small, of the order of 10 μGal, so we use repeated measurement loops for each data acquisition, with two different kinds of gravimeters: a Lacoste-Romberg model D and a Scintrex CG3.

FIG. 1 : GARONA RIVER HYDROGRAPHIC SYSTEM AND LOCATION OF OBSERVATION STATIONS (A, B, C, D)

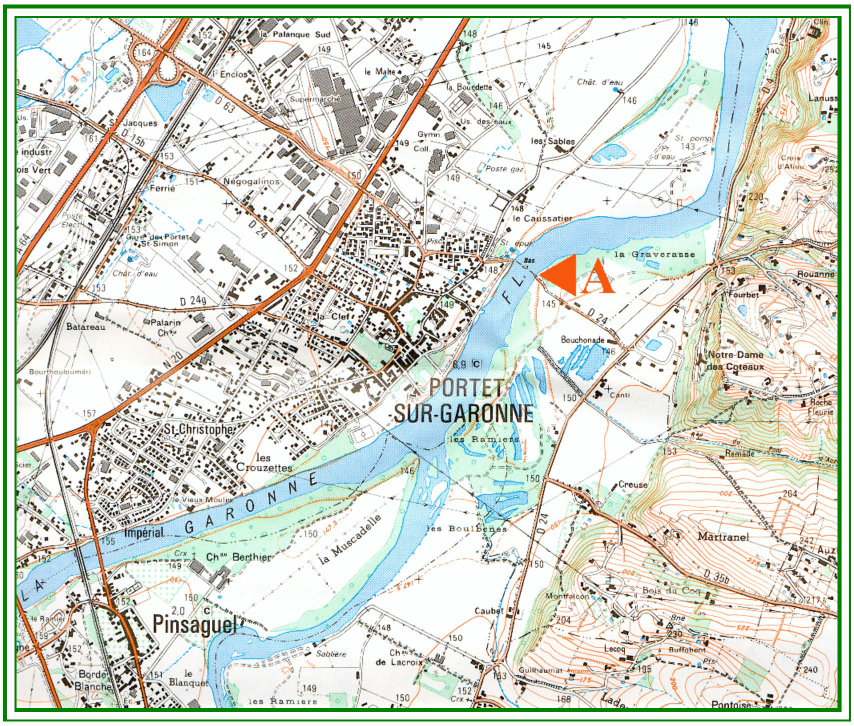


FIG. 2 : LOCATION OF THE PORTET-SUR-GARONNE GRAVIMETRIC , GPS AND RIVER FLOW OBSERVATION STATION (A), AT THE CONFLUENCE BETWEEN THE GARONA AND ARIEGE RIVERS (WILD AREA).

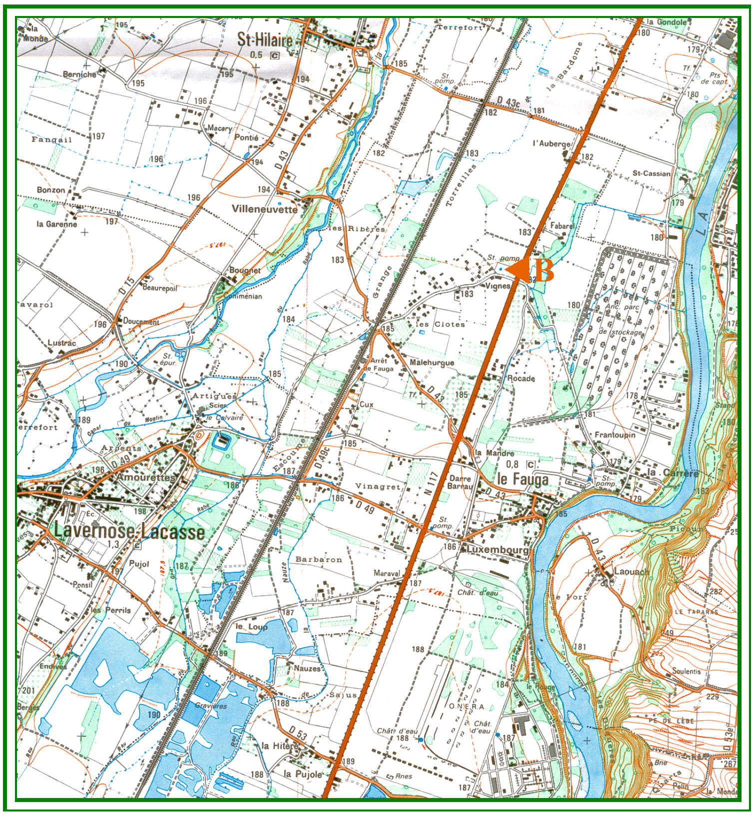


FIG. 3 : LOCATION OF LE FAUGA GRAVIMETRIC AND GPS OBSERVATION STATION (B)

FIG. 4 : PORTET SUR GARONNE GRAVIMETRIC AND GPS STATION. THE LIMNOGRAPH IS ON THE OPPOSITE BANK.

FIG. 5 : PORTET SUR GARONNE WILD AREA, SHOWING THE SUPERFICIAL WATER TABLE BEING MONITORED.

FIG. 6 : LE FAUGA PUMPING STATION (PIEZOMETER), COLLOCATED WITH A GRAVIMETRIC AND GPS STATION (B)

FIG. 7 : THE TOULOUSE-JOLIMONT REFERENCE GRAVIMETRIC STATION (C), USED FOR ABSOLUTE GRAVIMETRIC MEASUREMENTS (CONCRETE PILAR).

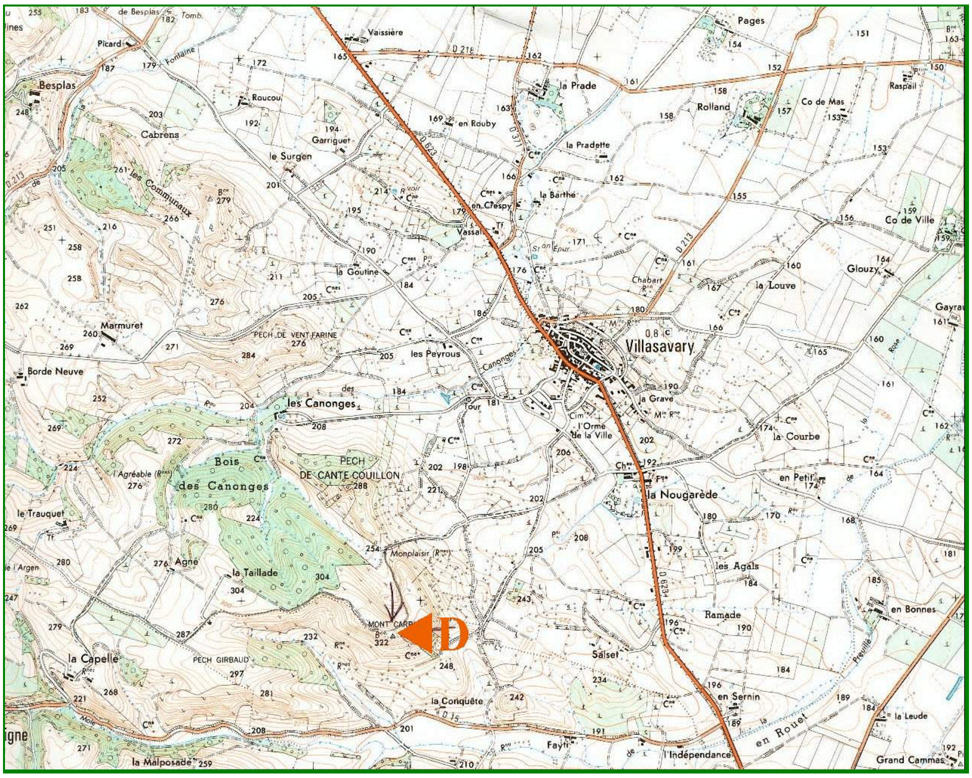


FIG. 8: LOCATION OF THE FANJEAUX GRAVIMETRIC AND GPS REFERENCE OBSERVATION STATION (D), AT THE WEST OF TOULOUSE

FIG. 9 : THE FANJEAUX GPS (AND GRAVIMETRIC) REFERENCE STATION (D).

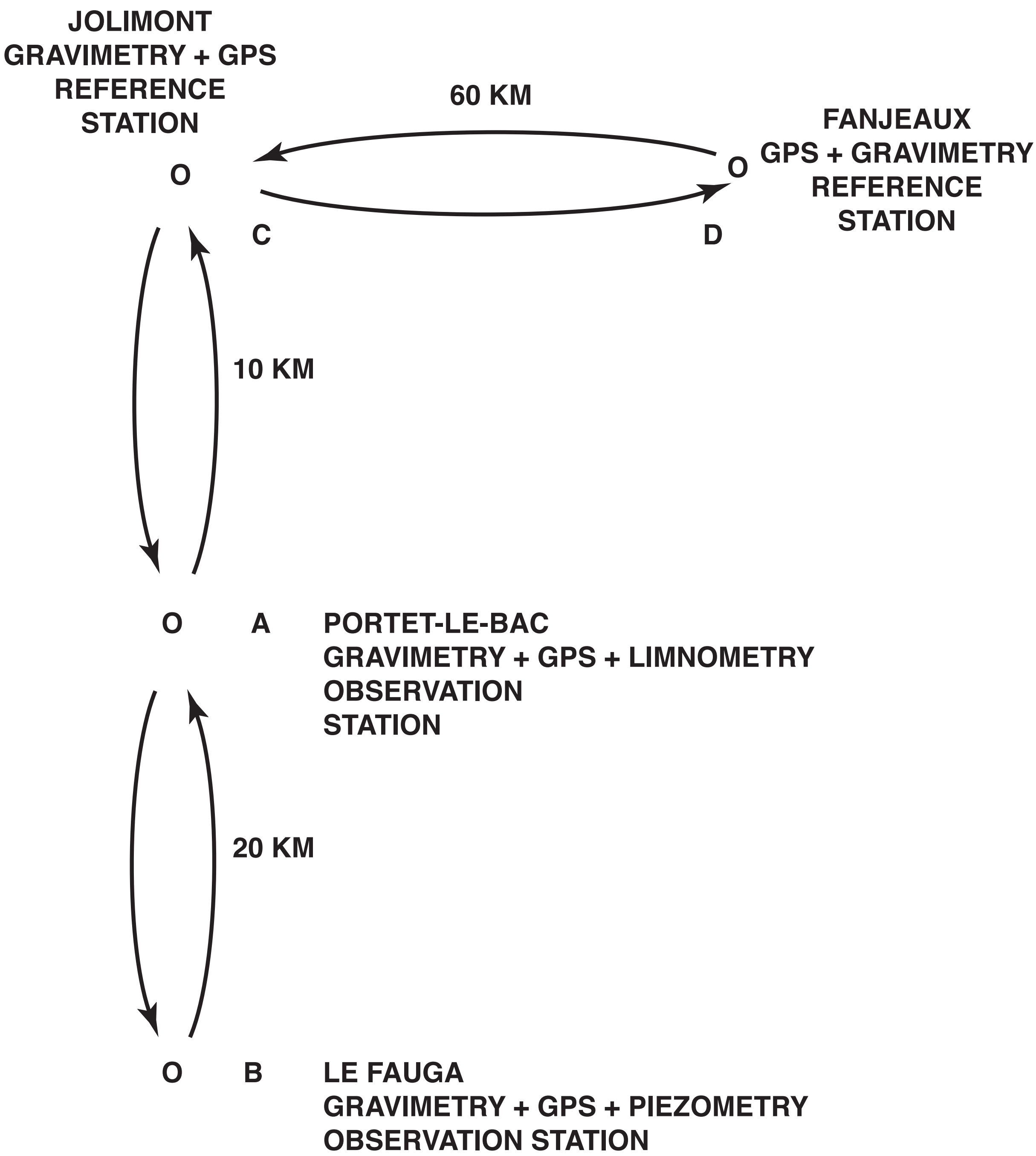
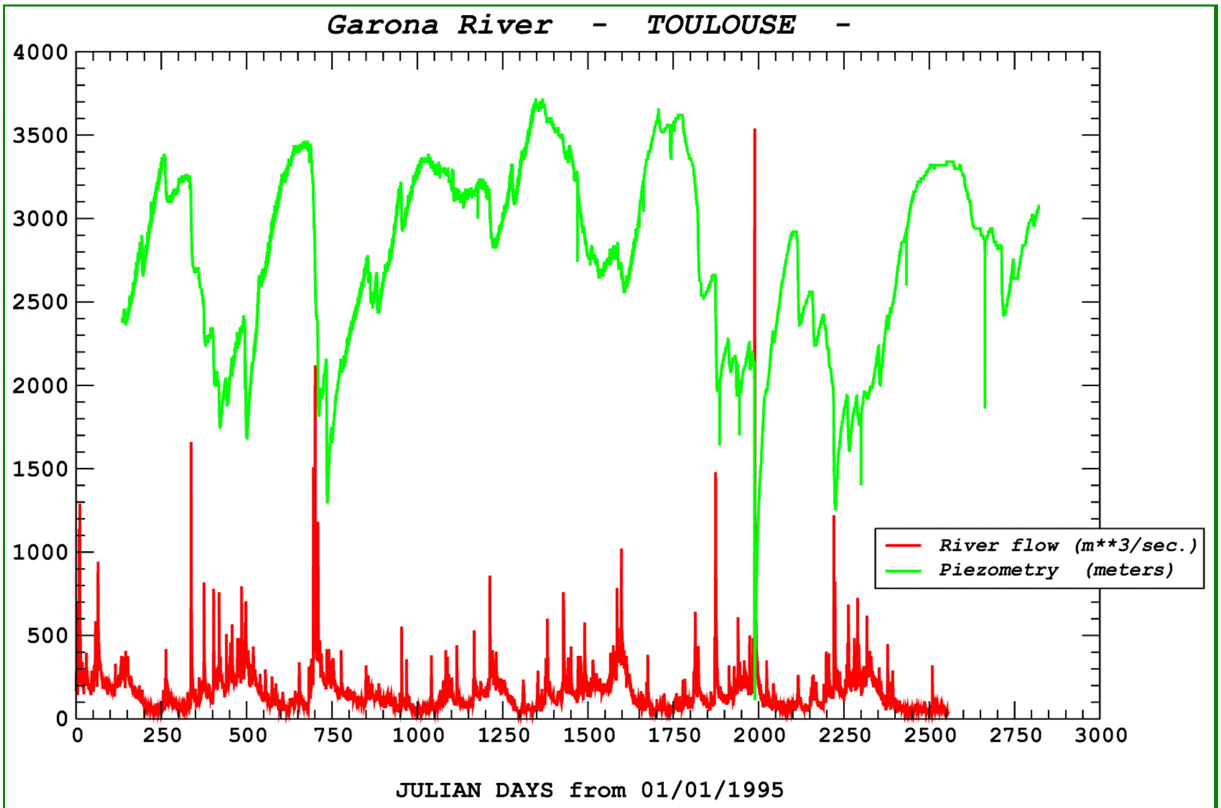


FIG. 10 : GRAVIMETRY/GPS OBSERVATION LOOP



Flow: Min=28.2, Max=3540 m3/s; Piezometry: Min=1.06, Max=2.86 m

FIG. 11 : CORRELATION PIEZOMETRY/RIVER FLOW

Prediction methods for one channel (river flow, piezometric level, gravimetry):

$$h_i = \bar{h} + \sum_{j=1}^{N} \alpha_{ij}\, h_{i-j} + \sum_{k=1}^{M} a_k \cos\left(k\,\omega\, i\,\Delta t\right) + b_k \sin\left(k\,\omega\, i\,\Delta t\right)$$

where: h_i is the predicted value, $\bar{h}$ is the mean value of h, $h_{i-j}(j = 1 \text{ to } N)$ are the observed values, regularly sampled, α_{ij} are the filter coefficients, and a_k, b_k are the seasonal parameters (ω one-year pulsation). Or:

$$h(t) = \bar{h} + \left[C_{i1} \dots C_{iN}\right] \begin{bmatrix} C_{11} & \cdots & C_{1N} \\ \vdots & & \vdots \\ C_{N1} & \cdots & C_{NN} \end{bmatrix}^{-1} \begin{bmatrix} h(t_1) \\ \vdots \\ h(t_N) \end{bmatrix} + \sum_{k=1}^{M} a_k \cos\left(k\,\omega\, t\right) + b_k \sin\left(k\,\omega\, t\right)$$

where $h(t_1) \cdots h(t_N)$ are observed values unregularly sampled, at times $t > t_1 > t_2 > \cdots > t_N$ with the Gauss-Markov covariance model with correlation time α:

$$C_{ij} = C\left(t_i, t_j\right) = C_o \left(1 + \frac{\left| t_i - t_1 \right|}{\alpha}\right) e^{-\left| t_i - y_j \right| / \alpha}$$

FIRST GRAVIMETRIC MEASUREMENTS

We made two series of measurements at Site A, on February and June 2003 (see Figure 1), with a Scintrex CG3 gravimeter. Station 20 is on the left bank, station 50 at the foot of a molasses hill. They have been referred to site C, at the old Jolimont astronomical observatory in Toulouse(astronomical pillar).

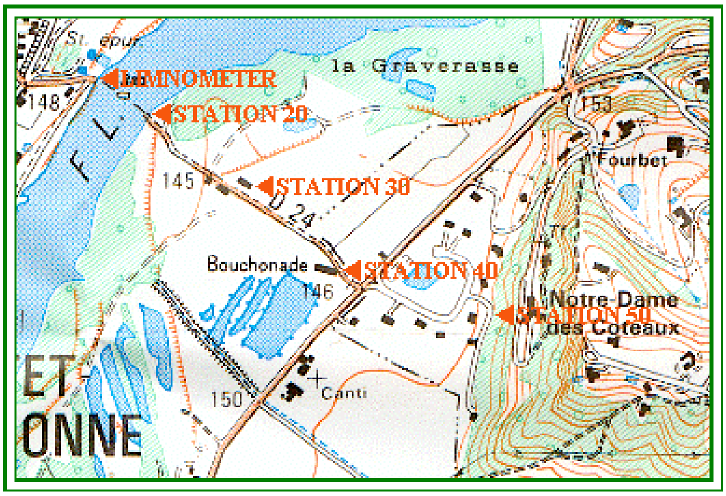


FIG 12: SITE A SKETCH: PORTET-LE-BAC, SHOWING STATIONS 20, 30, 40 AND 50.

The gravimetric observations were processed in order to eliminate tides effects and apparatus drift. The observed amplitudes of the observed Δg variations are small, of the order of a few milligals. The gravimeter drift of the Scintrex gravimeter varies from 0,5 to 0,75 mgal/day;

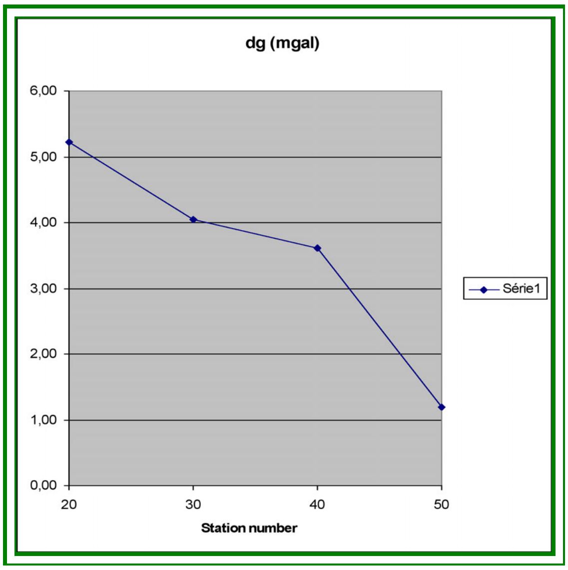


FIG 13 : GRAVITY PROFILE ACQUIRED DURING FEBRUARY 2003, FROM STATION 20 TO STATION 50

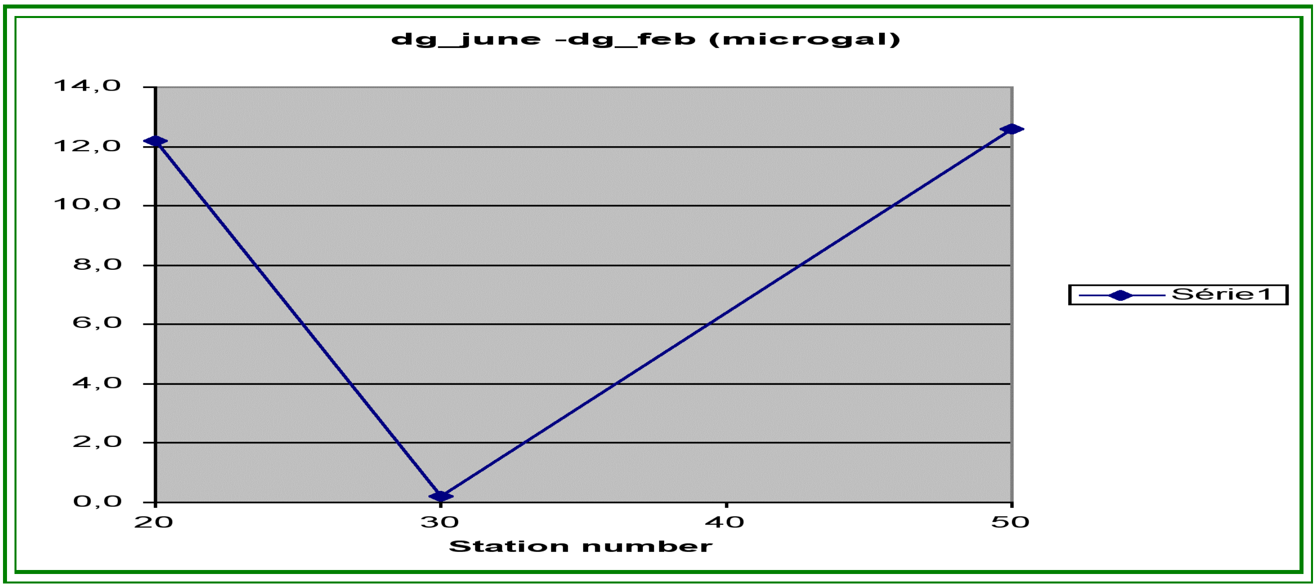


FIG 14: GRAVITY VARIATIONS AT STATIONS 20 TO 50, BETWEEN FEBRUARY AND JUNE 2003.

A second gravimeter, a Lacoste-Romberg model D, with a smaller drift, will be used, to obtain independent measurements and control possible non-linear drifts of the instruments.

A data acquisition card, connected to the analogic output of the Lacoste-Romberg gravimeter, and using a USB port to transfer the data, is currently under development (Fig.4) to increase the accuracy of data acquisition.

The digital acquisition will allow to filter the long periods of the signal, due to industrial noise or wind effects, and also to identify the stabilization of the gravimeter beam, after its release.
To improve the reading accuracy, we use the following procedure:
1) we define the nearest rounded value of the vernier near the beam equilibrium and register the mean output voltage,
2) we then apply a rotation of the vernier of one revolution clockwise, registering the corresponding voltage,
3) we turn the vernier anticlockwise (2 revolutions),
4) we come back to the first rounded value of the vernier.

So we are able to determine, using a least square adjustment, the reading which corresponds to a null voltage and to the equilibrium position of the beam.

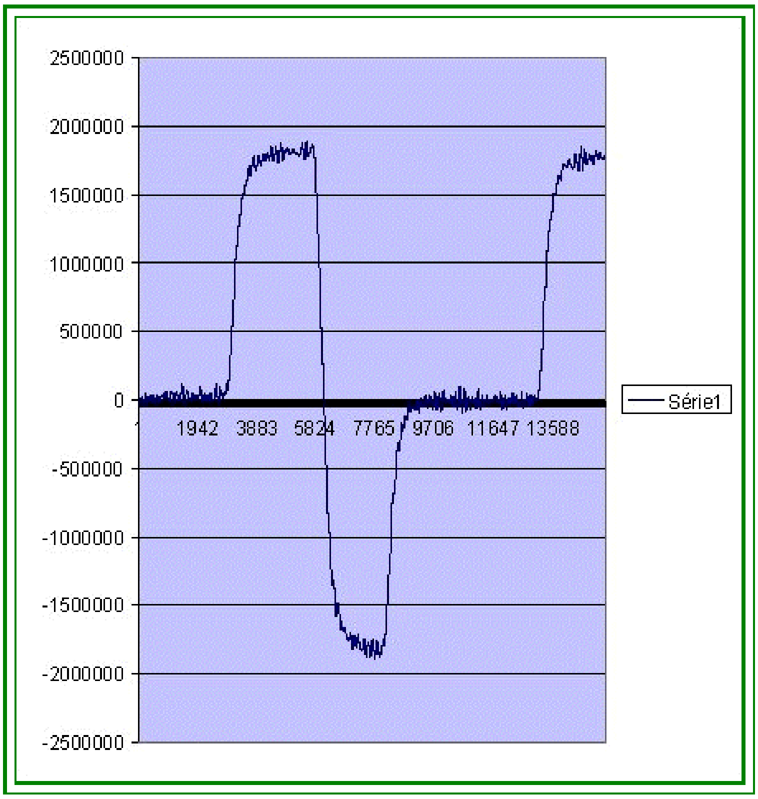


FIG. 15 : 32 Hz sampling during 8 minutes, with rotation of one or two revolutions of the gravimeter vernier. Each time the vernier is turned, we observe a transitional period of at least one-minute to reach the equilibrium position.

CONCLUSIONS AND FUTURE PROSPECTS

- The GPS complement, to separate altitude offsets (uplift, subsidence), is under development.
- The correlation and multiprediction of the piezometric level from different sources (gravimetry, past river flow, pluviometry, atmospheric pressure,…) is also under study.
- We plan to perform the survey for at least two years, with bimonthly gravity measurements.