Progress of the Maintenance of the French National Levelling Network (NGF) Using GPS

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ABSTRACT

The NGF, the French national vertical reference frame, is entering in a new step of complete maintenance. After a long phase of experimentation, the fieldwork has been defined and an experimental production has begun, using simultaneously classical digital levelling and GPS methodologies. At the end of the next 5-6 years, the NGF is expected to have been completely visited and refurbished, and to enter in a phase of cyclic maintenance. As an ancillary product, the same field data, along with new gravimetric observations, will allow the computation of a much higher precision national geoid, and will provide a considerable precision improvement of the monumented GPS network, the RGF 93.

RESUME

Evolution de l'entretien du réseau national français de nivellement (NGF) en utilisant le GPS

Le NGF, réseau national français de nivellement de précision, est entré dans une nouvelle phase d'entretien. Après une longue phase d'expérimentations, les méthodes de terrain ont été définies et une production expérimentale a commencé, utilisant simultanément des mesures GPS et du nivellement digital classique. A la fin d'une période de 5-6 ans, il est escompté que le NGF aura été complètement remis à neuf et pourra entrer dans une phase de maintenance en continu. Comme sous-produit, les mêmes données GPS, ainsi que de nouvelles mesures de gravimétrie, vont permettre de déterminer une nouvelle grille de correction de géoïde de très haute précision, et apporteront également une grande amélioration à la précision du réseau GPS borné, le RGF 93.

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1. INTRODUCTION

The NGF (Nivellement Général de France), composed of around 450 000 benchmarks (BMs) along the roads is still, 150 years after its creation, an extremely useful network. Reflections led within the CNIG (French national council for geographic information) in years 90 drove at that time the Government to disengage himself of the maintenance of the 4th order (75% of the network), expecting that the local authorities would finance by themselves the maintenance of these BMs. However one has observed that since then, this network is *de facto* no longer maintained at all. After new discussions it has been once again accepted that it is to the Government to fund the maintenance of this reference, since the synergism that results from its existence generates significant savings for many other public expenses, far beyond the directs costs it requires.

The descriptive documentation data of the BMs for the 90 000 sites of the planimetric networks - NTF (former triangulation) and of course of the RBF (new GPS monumented network with a very good accessibility, observed in 1993-94, one site every ~ 600 km^2) - were fully digitised and available on line (free of charge Web server since October 2001). The altimetric data base was already complete and available on line (Minitel data server) since 1995. But all these data had not been subject to any field visits, and thus the BMs were described with no realistic information since their initial observations, possibly up to 50 years ago. For that reason a systematic visit of the main part of these networks (NTF, RBF and NTF) was initiated in 2000, this phase being expected to end in 2005 (35 % completed at the fall of 2001). After 2005 a shorter cycle of visit / maintenance will be set up (probably 2 years), largely sub-contracted to local private surveyors.

2. THE MAINTENANCE OF THE NGF.

At the end the year 2000 the various research performed at IGN and in many other institutes, as well as the results of the systematic visit of marked networks permitted to redefine completely the politics that will be followed concerning the maintenance of the NGF. The initial structure of a national levelling network has always been heavily dimensioned by (1) the technique of spirit levelling and (2) by the former difficulties experienced to perform least squares adjustments before the availability of computers. Due to the technical reasons of (1) the BMs are traditionally along roads, with a linear density more or less stable. Due to (2) it was formerly necessary to adopt a hierarchical structure (1st, 2nd, 3rd, … orders). Today, the availability of GPS allows to re-evaluate these questions in a completely different way, and it was decided first to analyse without any technological considerations what where the needs of the customers regarding high precision altimetry.

After this analyse performed in 1998-2000 by consultation of all professional bodies involved in the use of NGF, we have strong bases to consider that still now, nearly all the needs for the NGF are linked to the gravity water flows, such as sewage, drainage, irrigation, etc… Many new environmental laws have recently been voted regarding the water in France and Europe, pushing ahead for considerable new sewage works. In large cities, the NGF is also more and more necessary as a legal base for 3D definitions of property subdivisions. In flat areas, the accuracy of the national network is directly in relation with the minimum allowed slope in sewage pipes, which in turn implies more or less deep trenches for them, and then more or less cubic meters of ground layers to remove : at the end the works are more or less expensive. In mountainous areas, the question is generally different as the natural slope is strong, so that one has not to look for a minimum slope in these sewage pipes, and thus one could accept a levelling network of lower quality.

These points induce the following considerations :

- BMs are the more useful when the density of population is high : more generally, their density should be in accordance to the population density. We have considered that any village with more than 200 habitants should have its BMs, but that in the open countryside there is no need to maintain existing BMs, as their users are extremely scarce, and their requirement for precision is compatible even with a modest-quality use of GPS, which is now quite cheap. In large cities, the densification of the NGF is directly supported by their own technical services, so that no new work performed on governmental funds is necessary as soon as enough BMs are available to allow for this local densification.

- BMs must be maintained by groups of 3 (so that even when a BM is destroyed, the indispensable internal control of stability is still possible),

- The users of the NGF can accept relative errors of the order of one centimetre between BMs distant of 5 km or more (this point is well verified because of the actual movements of BM supports lie within this range a few tens of years after their observation, and such an error is widely accepted), but these users would certainly prefer no more than one or two millimetres of discrepancy between close BMs.

- The users wish to find BMs where the data base signals their existence.

- More and more surveyors use the GPS to make altimetric works, but to be precise enough such an altimetry is costly in time of measure beyond a few km of distance between the BMs. We have considered here the distance of 5 km as a limit between available BMs : if two villages of more than 200 habitants are closer than 5 km there is no need for one triplet of BMs in each of them.

- In order to allow to perform altimetric works using GPS, the national altimetric geoidal correction grid should be as precise as possible, its error should ideally be lower than the common vertical GPS errors. In France, the RAF98 grid shows an error around 1 cm rms (excepted in mountains where it may be slightly larger), and these errors are mainly due

to the bias in the gravity data and the errors on the vertical component of GPS determinations on the RBF (2 sessions of only 2 hours). The correction grid should ideally be provided within 5 mm in any flat areas (in mountains a lower requested accuracy may be accepted), and thus an improvement of the RAF98 is mostly advisable.

3. NEW SPECIFICATIONS FOR THE MAINTENANCE OF THE NGF

Thus we have adopted the following specifications:

- Any village with more than 200 habitants will have at least one BMs triplet maintained or even created if necessary, excepted if another BMs triplet is closer than 5 km.

- Within each triplet the observations are performed with digital levels, with one staff, double run backward and forward, as with such methodology any blunders are nearly impossible.

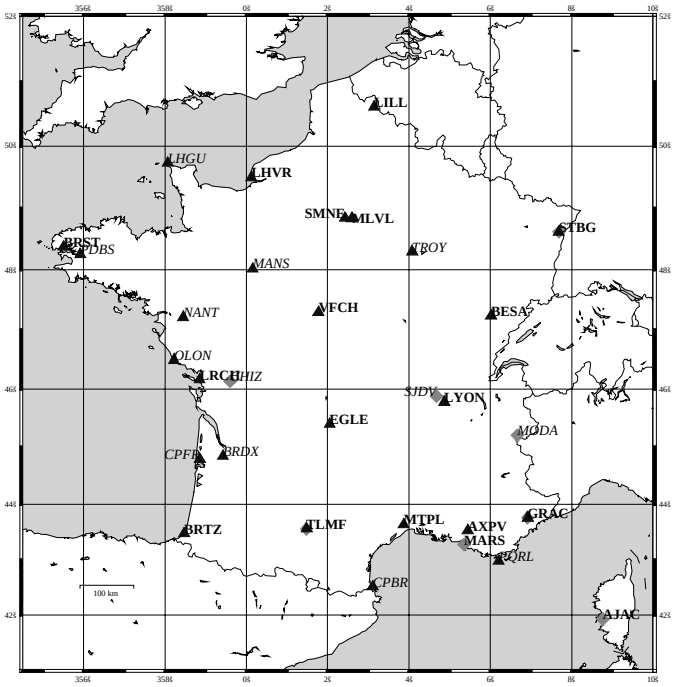
- The levelling of each triplet includes the measurement of the antenna of a GPS receiver, installed provisionally at the best place close to these BMs for the few hours necessary to perform the work (installation and description of the BMs and levelling work). A 1 metre section of staff is fixed directly to the antenna for this purpose.

- A pivot GPS receiver is installed close to the nearest RBF site (less than 2 km), in a place that will not pose any risk of theft or displacement, with the simplest and most cost-effective possible direct levelling link with the NGF. It must be continuously operational for a few days (typically 3).

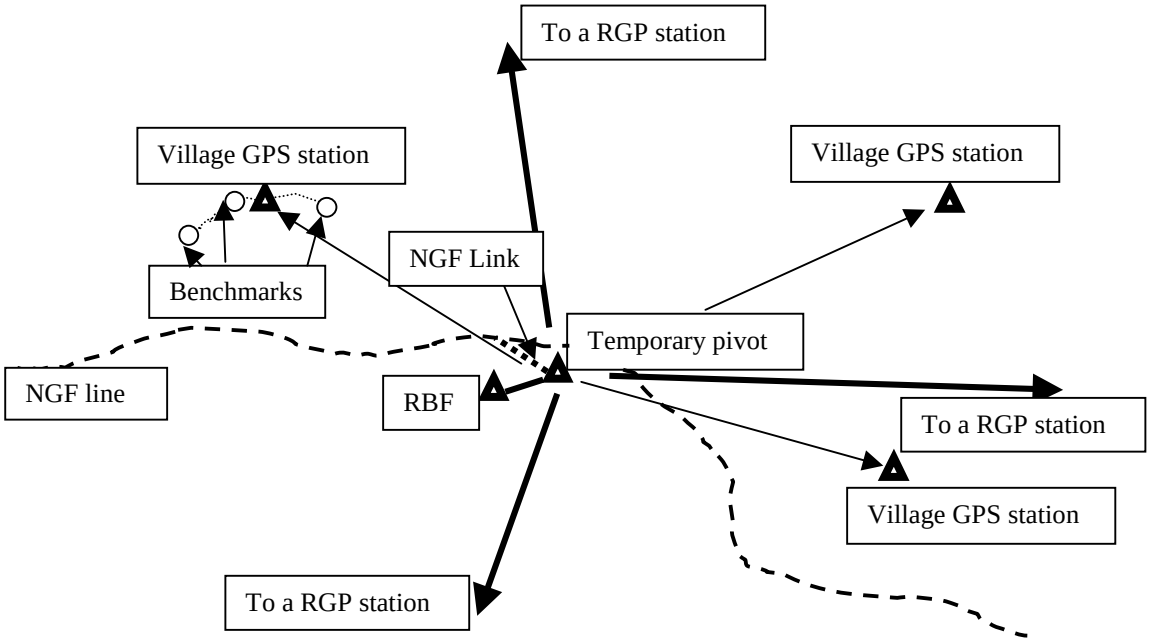
The pivot GPS have a good NGF altimetry, and the computation of its data with regard to the permanent GPS national network (the "RGP", Réseau GPS Permanent) will provide a new set of very high quality coordinates for the nearest RBF mark. Using the high precision altimetric geoid grid RAF98, the GPS link between the pivot and the receiver close to the new BMs provides an altitude determination with a standard deviation expected to stay around one centimetre. If in the BMs triplet one or two BMs are old, these altitudes are compared with the new one obtained through GPS, so that it is possible to decide whether the old altitudes are satisfying or not, and what are the definitive altitudes considered for the BMs of the triplet.

4. PRACTICAL ORGANISATION OF THE WORK

The campaigns during the next years will be planned in that way : The zones having made the object of a systematic visit the previous year will receive maintenance missions for the NGF whatever their order. The visit previously performed allows to define in an optimal way the interventions to carry out.



The RGP, French permanent GPS network



As the visit will cover all the France in about 5 years, it means that toward 2006 we will have all of the following elements:

– A very up to date levelling data base, where most BMs will be validated at worst 5 years before, with planimetric coordinates precise to about ten meters (which will allow to interrogate the data base with coordinates, instead of the classical cumbersome numbering).

– A density of maintained BMs that follows the density of the population, without any consideration to their order.

– A set of complementary measures on the RBF (altimetric links with the NGF, gravimetric measurements, and much better GPS measures) permitting to improve the quality of the national altimetric correction grid (currently RAF 98), which will in turn improve any new altimetric measurements by GPS. These data will also be used to improve the planimetric coordinates of the RBF too, from 2 cm rms today to around 5 mm rms

This production, extremely economic if one compares to the traditional levelling, will be coherent with the allocated present public funding for these operations, and appears as a much better public service for the users.

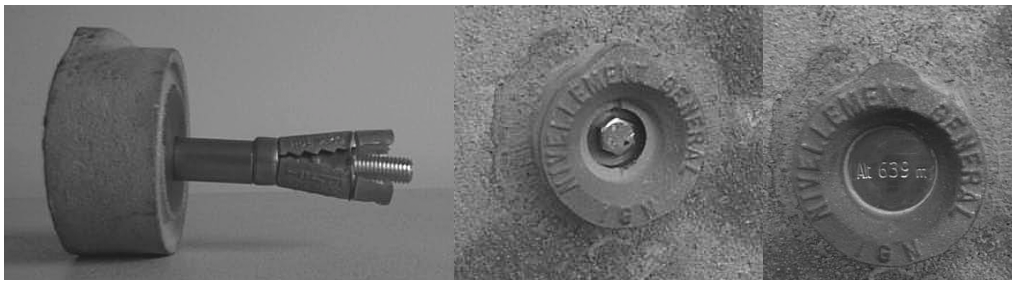
In 2001, we have performed two missions in the zones previously visited in 2000:

– The first one to check all the practical problems on a limited area (5000 km^2), without paying too much attention to the production costs. We have deduced from it the final production specifications.

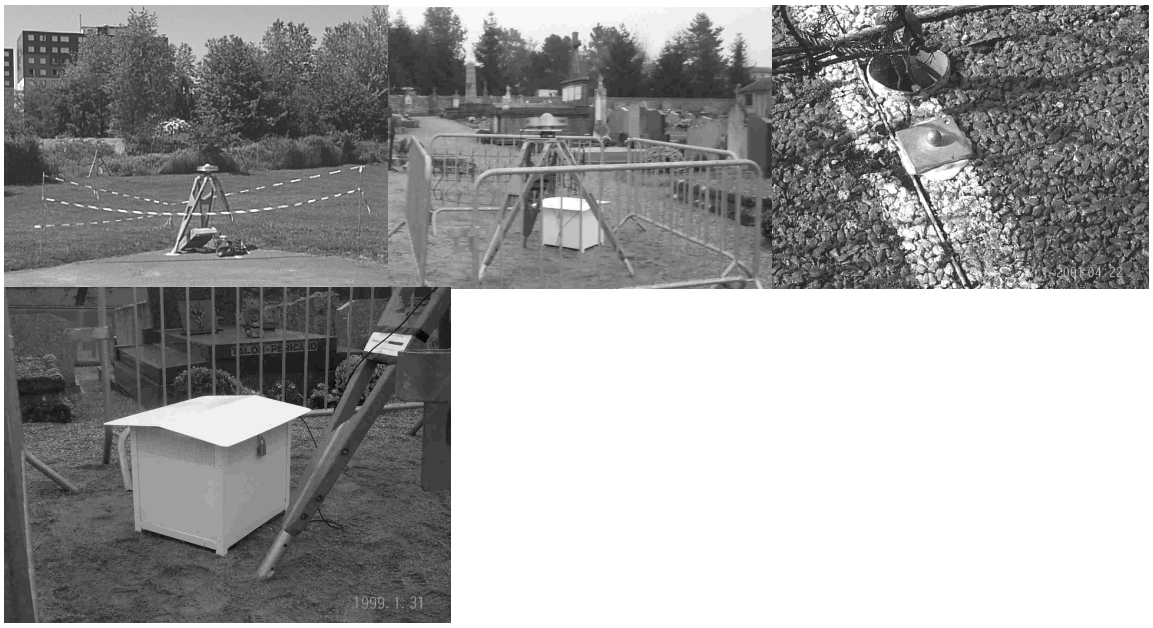
– The second one to optimise the production in various types of landscapes so as to reach the most cost-effective compromises, allowing also to plan as finely as possible the production of the next years.

The full-size production starts in 2002, with 3 teams of 2 people. It is expected that for one given 1/50 000^{th} base map sheet (1000 for the whole France), the necessary work time will be around 3 days. A few images are shown to explain how the equipment is designed and used.

Details of the car used for the mobile GPS (same car as used for motorised levelling), and of the antenna and staff section used to link the antenna altitude to the benchmarks.



Details of the benchmarks used before, during and after installation



Installation of the temporary pivot for 3 days, on a heavy tripod, with the GPS equipment in a specific box with its battery, and view of the temporary security benchmark.

5. CONCLUSION

The present status of activity on NGF does allow to conclude on most questions, either technical or economical, that arise around such a new production. Considering the present technical situation in France, it is expected to process the NGF on the base of 600 km^2 within 3 days, with a team of 2 people. This duration, estimated on zones where the levelling observations were done in the 1950^{ies}, should decrease when the zones reached will be more recently observed (and thus with significantly less BMs destruction). The new GPS data, levelling data and gravimetric data on the RBF points will allow for a new computation of the former geoid altimetric correction grid (RAF98) in 2005 that will definitively freeze the old NGF errors and allow for an easy inclusion of new GPS altimetric works in the NGF reference frame.