KINEMATIC GPS PROFILES AND NAVIGATION IN ANTARCTICA

A.Capra*, F.Radicioni **, L.Vittuari*

* D.I.S.T.A.R.T. (Topografia), Università di Bologna. Italy
** Istituto di Ingegneria Ambientale, Università di Perugia. Italy

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Abstract
GPS data collection started at Terra Nova Bay Station (Antarctica) since the 1988-89 in the framework of the Italian Antarctic Research Program (PNRA). During the past expeditions a number of tests of GPS kinematic were made.
The GPS data were collected under various operational conditions and for different targets, such as glacier movements monitoring, kinematic GPS controlled aerophotogrammetry, execution of long range Antarctic traverses, ship navigation tracking control, etc.
Those GPS kinematic applications showed peculiar aspects by the point of view of data processing, due to ionospheric disturbances and satellite configuration at high latitude.
Here are described the different kinematic GPS experiences and are presented some results.

1. Introduction

The very high ionospheric disturbance and the NAVSTAR GPS constellation characterised by low satellite elevation, create serious problems in signal acquisition and data processing.
The strong influence of the severe ionospheric conditions became evident during GPS static data elaboration. This effect has been overcame through the employment of idoneous post processing strategies, and receivers development. On the contrary, the problem, still maintains problematic aspects for kinematic applications, so in order to obtained the required precision it is not possible to apply an automatic procedure, but it is necessary to analyse step by step limited block of data.
Various applications required different levels of accuracy and precision, ranging from different tens of metres for navigation purposes to few centimetres for glacier bodies monitoring through profiles comparison.
Precision of few metres level are achievable without serious problems using code smoothing techniques also in Antarctica, the critical aspects pointed out for high accuracy applications where the presence of ionospheric cycle slips often invalidate fixed ambiguities determination. This aspect becomes evident already after a distance of 5 km between master and rover receiver (Vittuari, 1994).

2. Airborne kinematic GPS positioning

Different application for GPS assisted aerophotogrammetry and geophysical survey purposes were made in Antarctica. In this case the required accuracy is related to the purposes of the survey and ranging from few metres to few decimetres.
During the 1993-94 expedition eleven missions

of GPS assisted aerophotogrammetry were performed in the framework of a co-operative project between U.S.G.S. and the Dept. of Survey and Land Information (New Zealand).
On the aircraft were installed two receivers and were used up to 5 reference stations on ground. The day 326 the operations were co-ordinated by Terra Nova Bay Station on different Italian projects characterised by photo scale ranging from 1 :20000 to 1 :50000 for mapping purposes and 1 :3000 for biological aims (Hothem et al., 1994).
During the 1994-95 expedition various RES (Radio Echo Sounding) profiles were made with a GPS antenna installed on the top of a Twin-Otter plane. In Fig.1 is shown a trajectory of the vehicle obtained from a continuos kinematic survey. The master receiver was located at about 1 Km far from the starting point. The plane travel was made through an automatic data processing without any interruption and obtaining the required precision. In Fig. 2 is presented the altymetric profile of the fly referred to same RES survey.

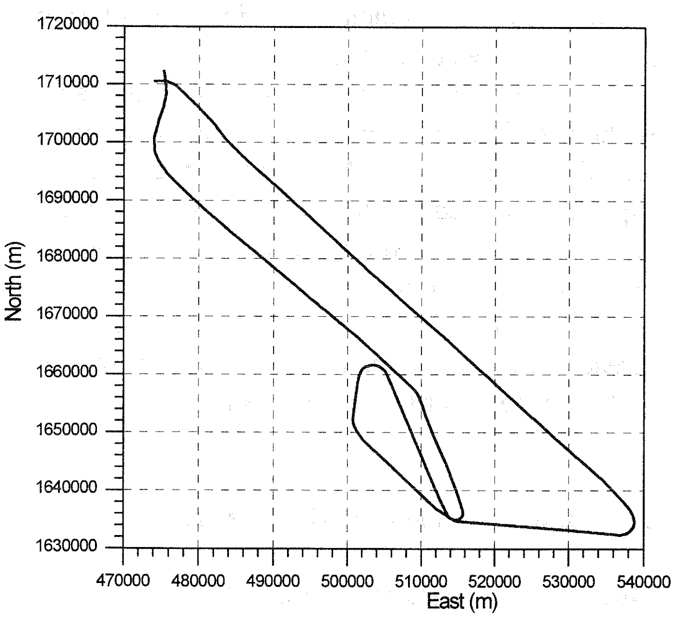

Fig.1- Planimetric track of airborne RES mission obtained by continuous kinematic GPS surveying.

Considering the required precision for this particular experiment, it did not appear necessary to use more receivers on board and more reference stations, that could permit to increase the control on the accuracy and repeatability of the survey but that introduce excessive costs for this purpose. The OTF solved automatically the phase integer ambiguities for the whole profile.

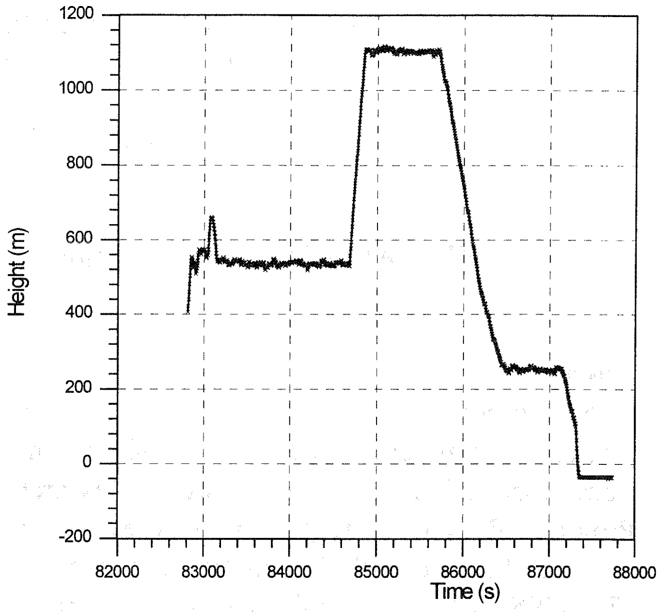

Fig. 2- Altimetric profile relative to the trajectory presented in figure 1.

3. International Trans Antarctic Scientific Expedition

A continuous kinematic survey was performed on the vehicles partecipating at the International Trans Antarctic Scientific Expeditions test, made during the 9th expedition. The survey was required for navigation purposes and for altimetric description for the ice surface monitoring. The first leg covered a distance of about 280 km from Terra Nova Bay Station towards the plateau with the purpose of investigating the accessibility of the plateau from Italian Base on the basis of the foreseen Traverse to Dome C (1997-98).
One of the main objectives of the Traverse Program is the development of a high resolution map in order to describe the climate change during the last 100-200 years on Dome C area.
In figures 3, 4 and 5 are reported the comparison between the obtained solutions from two different reference stations. The first

one located close to the vehicle while the second one located 200 km far away .
Different DGPS elaboration are presented and it is possible to observe the effect of ionospheric cycle slips.

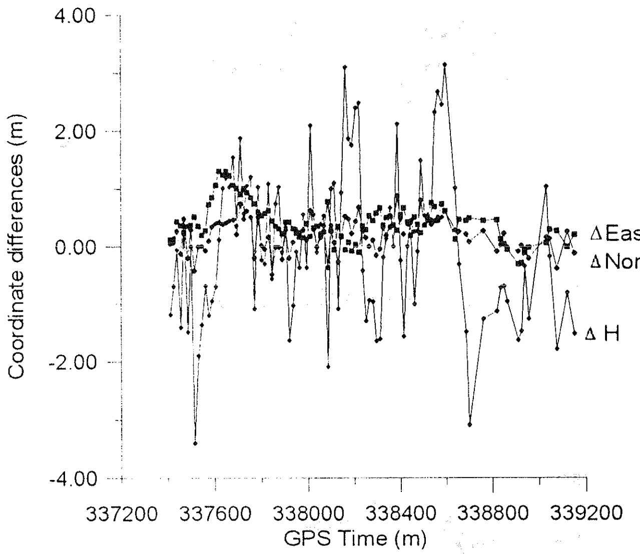

Fig.3 - Rover antenna coordinate differences obtained through DGPS solution from two reference stations located at 5 and 200 km .

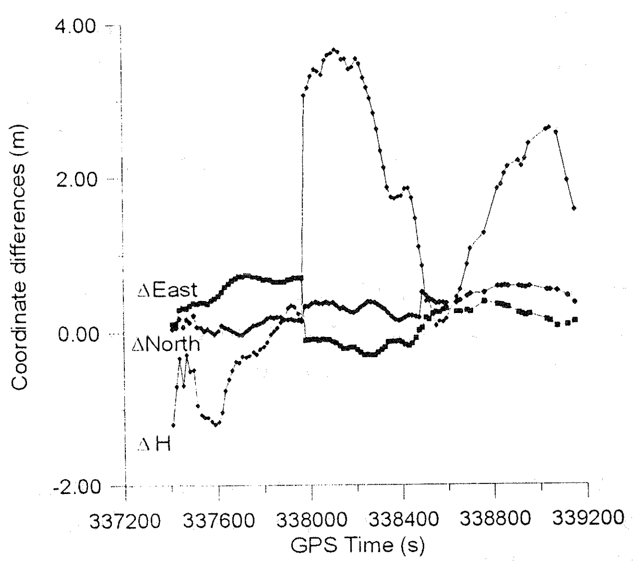

Fig.4 - Rover antenna coordinate differences obtained through Code Smoothed solution from two reference stations located at 5 and 200 km .

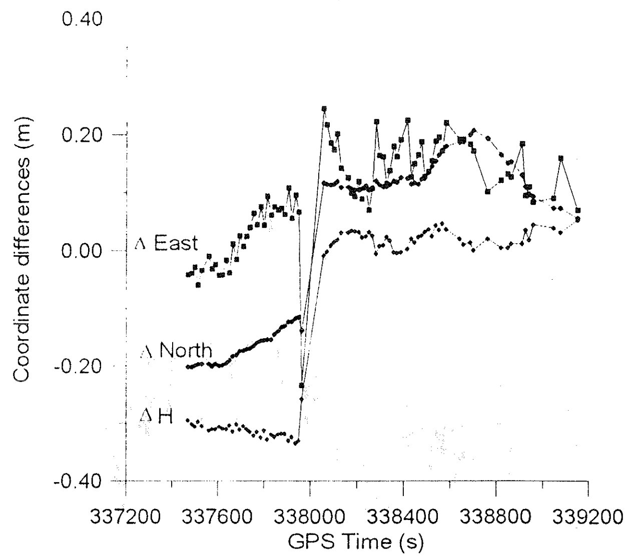

Fig.5 - Rover antenna coordinate differences obtained through kinematic solution from two reference stations located at 5 and 200 km .

4. Hells Gate Ice Shelf grounding line determination

Fast static GPS measurements were made to study the effect of tidal undulation on the Hells Gate Ice Shelf platform and to locate the presence of eventual grounding zones (Bondesan A., 1994).
The results of GPS measurements showed that the vertical movement curves of the platform are show a similar pattern with the sea tidal curves provided by the tide-gauge recordings according.
Limited number of stations allows to cover a small investigated area for grounding line detection, so a continuous kinematic GPS survey was designed with the aim to cover a wide range area.
The first operation was the continuous survey of 40 hours on some points to build a tidal response curve of the ice shelf floating platform (Fig. 6).
After an accurate determination of the time relative to the maximum and minimum amplitude, kinematic profiles (long till to 30 km) were made in maximum and minimum sea tidal amplitude. The GPS antennas were located on two skidoos (fig.7), while the two reference

stations were situated at a distance ranging from 5 to 30 km.

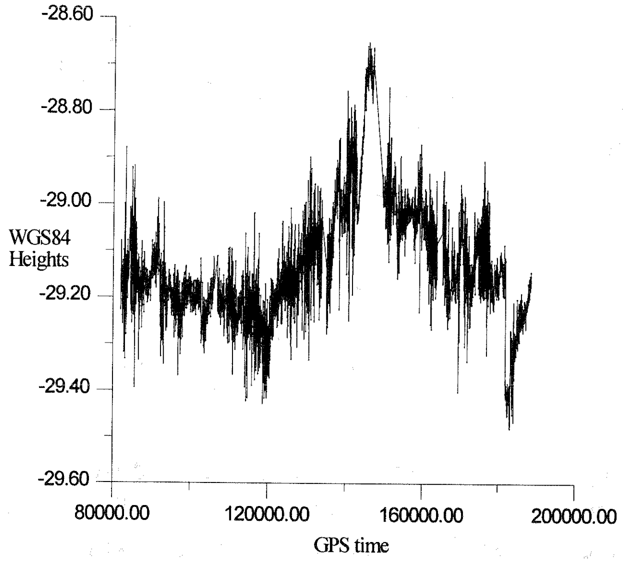

Fig.6 - Continuous vertical movement of GPS antenna located on Hells Gate floating platform under the effect of sea tidal undulation.

Through the comparison of the profiles, it could be possible to detect the eventual displacements between floating and grounding ice along the trajectories. In figure 8 is presented the comparison between two profiles for a length of about two kilometres, as can noted the showed portion of the trajectory is probably referred to a floating condition since the altimetric differences between the two profiles made in maximum and minimum sea tidal undulation are of about the same order of sea tide amplitude (40 cm) in the same span of time.
Another part of the experiment is reported in figure 9 and 10. In figure 9 the altimetric difference along the track, referred to a portion of other two continuous profiles made in an other area but in the same time of previous example is shown. In figure 10 the altimetric differences of homologous point of the profiles are reported.
The difference is scattered but the mean value is centred around zero, so, considering the expected differences due to the sea tidal effect, it could be hypothized that the profile was probably made on grounding zone.

Fig.7- GPS antenna on the skidoo.

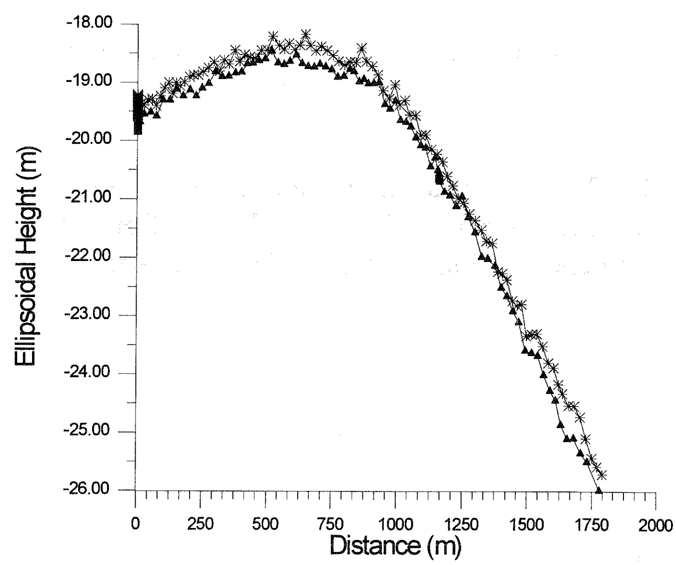

Fig. 8 - Comparison between two different GPS profiles made approximately in maximum and minimum sea tidal curve time.

On the basis of the sea tidal undulation amplitude, with a maximum value of about 60 cm, it was necessary to obtain the higher accuracy in order to compare the profiles. For the presence of high ionospheric disturbance, it was not possible to solve the whole profile and only the OTF algorithm permitted to recover partial portions.

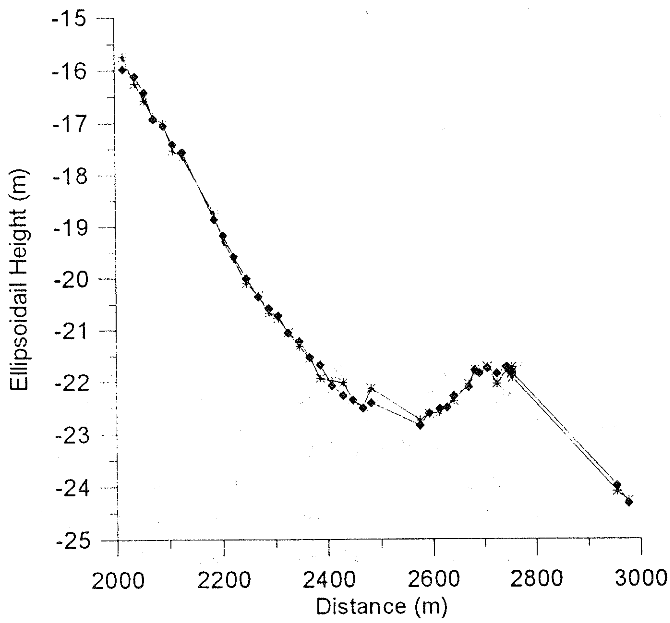

Fig. 9 - Comparison between two different GPS profiles made approximately in maximum and minimum sea tidal curve time.

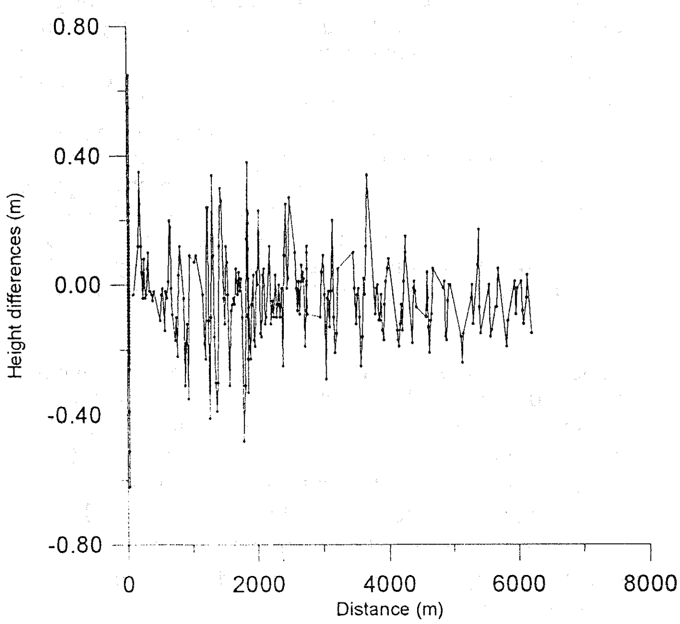

Fig.10 - Altimetric difference for homologous points along the profile.

5. Conclusion

A wide range of positioning problems relative to moving sensors and vehicles can be solved through GPS also in Antarctica.

The solution of trajectory can be easy solved when the required precision does not need for the phase ambiguities solution. Also in the case of high accuracy requirements the solution can be easily obtained for relatively short distances (less than 4-5 km).

For medium and long distances and for high accuracy surveying in Antarctica, it is very helpful the use of advanced post processing software (complete with OTF algorithms), dual code and frequencies GPS receivers. Moreover the frequent presence of ionospheric noise, recognised as a cycle slips from the software, requires an analysis of reduced portion of data.

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