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APPLICATIONS OF KINEMATIC GPS AT SHOM

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Abstract

The GPS in kinematic mode has now been in use at SHOM for several years in geodetic work. During the past year, these applications have been extended to include position-fixing during hydrographic surveys, thanks to the real-time function. Today, exploitation of the vertical component offers new perspectives, notably for tidal observations.

Introduction

SHOM has been interested in the GPS since the mid-1980s. Its equipment as regards receivers has followed the evolution of techniques, from GPS in natural mode offering absolute positioning with accuracy to within a hundred metres or so, to geodetic GPS, making possible relative measurements accurate to within millimetres or centimetres. After modes called 'static' then 'rapid static' requiring observation sessions ranging from ten minutes to several hours, the kinematic mode has opened the way towards new applications. The use of kinematic GPS in geodesy, now current, will not be dealt with here. After a summary description of the equipment, an example is given illustrating its use in hydrographic and topographic surveying, along with a study on tidal observation using GPS.

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EQUIPMENT

SHOM's hydro-oceanographic units use Dassault Sercel NP NR103 GPS receivers, generally in differential mode, for most of their positioning work at sea. For geodesy, on the other hand, work is carried out using bi-frequency Ashtech (Z12, ...) receivers. Use of kinematic mode only appeared progressively, as a function of needs and processing capacity. Real-time capacity was obtained by synchronizing a pair of Ashtech Z12 receivers and adding modems ensuring the transmission of information between the base and the mobile at a frequency that can be regulated between 445 and 449 MHz, and with a range of about 5 km. The minimum configuration of the mobile equipment, consisting of a GPS receiver and a corrections receiver with their antennas and power supply, can be supplemented, as required, with a portable computer and other sensors (a sounder, for example).

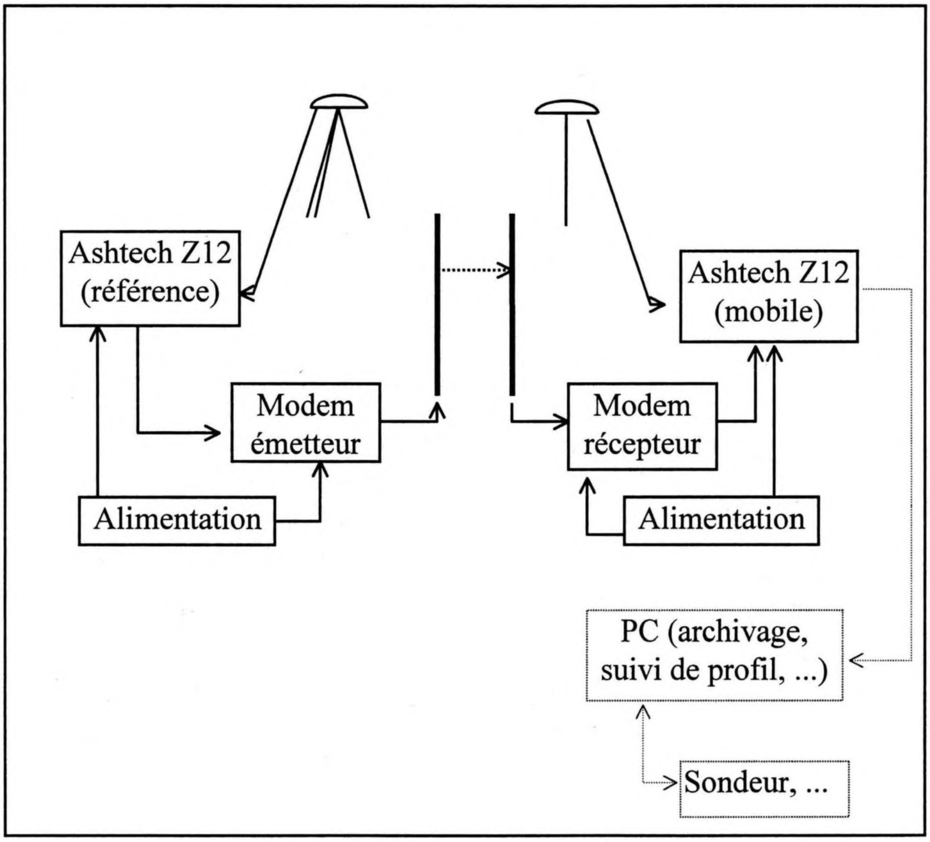


FIG. 1.- Configuration of equipment.

For sounding work, maximum configuration is used, whilst for topographic work it may be reduced to a minimum for reasons of bulk and weight. In such a case, two methods of acquisition are employed :

- for occasional tasks (checking positions on aerial photographs, fixing of particular positions, etc..) the positions obtained in real time are recorded in a notebook with other useful information (sketches, etc..);
- for high-rate observations (line-tracing), the real-time position only serves when following the pre-determined line or profile, the data acquired at the reference station and at the mobile being post-processed kinematically.

In all cases, an indicator furnished by the GPS receiver (or by the software when post-processed) indicates whether phase ambiguities are fixed or not. Only positions calculated with fixed ambiguities are retained as valid. Their accuracy is then estimated to be within a few centimetres (relative to the reference station).

BEACH SURVEY

Real-time kinematic GPS has been available to SHOM for less than a year and has so far been used for only two surveys carried out by the Oceanographic Unit of the Atlantic (MOA). In fact, for most surveys the quality of positioning sought does not require the use of a positioning system with accuracy greater than one metre. In such cases, differential GPS suffices (the reference article described one application). There almost always exists, among the various systems available, a solution to the problem raised : a simple differential station with transmission of corrections by UHF or HF, a network of real or virtual stations with corrections by satellites, and so on.

For certain surveys, however, the accuracy requirement is no longer fulfilled : this was the case for two beach surveys carried out in 1997 and 1998 in the context of NATO military exercises, "Rapid Response 97 & 98", in support of amphibious forces. The horizontal accuracy sought in such cases is to less than one metre, whether for bathymetry in shallow waters or for the topography of the beach. The applications are many - charting of the disembarkment zone, determination of the gradient of the beach, calculation of breaking waves, etc. In both cases, in addition to the requirement for quality there was the necessity for speed. Moreover, no geodesy was available. The most appropriate solution was therefore kinematic GPS, with three-dimensional accuracy to within a few centimetres and requiring only one reference station. The reference position was fixed by differential GPS with corrections promulgated by satellite (SeaStar system), taking a mean of one hour's observations. The standard deviations in latitude and longitude were less than one metre. The kinematic GPS reference station was therefore installed at this position with estimated absolute accuracy of about one metre. Kinematic GPS was then used as follows :

- aboard a boat carrying out bathymetric survey in very shallow waters (from the beach out to a few metres' depth) as a means of horizontal position-fixing;
- for the topography of the beach, in minimal configuration, as a means of three-dimensional positioning.

For topography, the antenna was fixed on a pole This was moved, following on the land the lines run by the boat. Measurements were taken continuously, the operator endeavouring to keep the pole vertical and its end lower than ground level. As far as possible, they were continued in the water, thus enabling some overlap with the sounding by boat or possibly a supplement to the latter.

The measurements taken by the mobile and reference receivers were post- processed by the PRISM (Ashtech) software. The heights and depths measured were then reduced for the height of the pole and the difference compared with the sounding datum so that they might be compatible. This difference was obtained by positioning a tidal benchmark by means of geodetic GPS. The sets of three measurements obtained (horizontal position, height or depth) could then be exploited in exactly the same way as bathymetric measurements for creating the products. The figure 2 shows a beach gradient, the maritime part of which was obtained by sounding and the land part by topography using kinematic GPS.

TIDAL OBSERVATION

The use of kinematic GPS for the positioning of a survey is of value because of the accuracy obtained and the ease of setting up (only one reference station required). However, up to present, the availability of vertical positioning accurate to within less than one metre had not been exploited. A study was therefore carried out during a hydrographic survey to try and obtain the tide from the vertical positioning of a survey launch when sounding. This survey launch surveyed an area of limited extent (500 x 1000m) in Brest harbour, in good weather (choppy sea). For this purpose, the launch was equipped with a real-time kinematic GPS. Throughout the sounding, the tide observed by this permanent digital tide gauge (considered hereafter to be the reference tide) was recorded every two minutes. The position of the survey launch antenna, obtained in real time by kinematic GPS, was also acquired every second during 5 days' sounding. The distance of the reference station (5 km) and masking often impaired the quality of the position-fixing. Only 20347 positions resulting from a calculation with fixed ambiguities were retained.

The height of the antenna above the surface of the water - unknown - was determined by comparison between the GPS height and the reference tide. The average difference between the 20347 measurements and the tide was 2.147 m, with a standard deviation of 6 cm. This result was therefore adopted to calibrate the GPS observations. This method of calibration is identical to that used with submerged tide gauges (the reference is then obtained by measurements on the graduated staff tide gauge), and makes it possible to ignore any possible errors of levelling or antenna height at the reference station. The considerable standard error deviation to the movements of the launch shows that a smoothing of the GPS observations is necessary. This smoothing was carried out by taking the mean of the observations over 2 minutes. The figure 3 shows the result for the afternoon of 9 April :

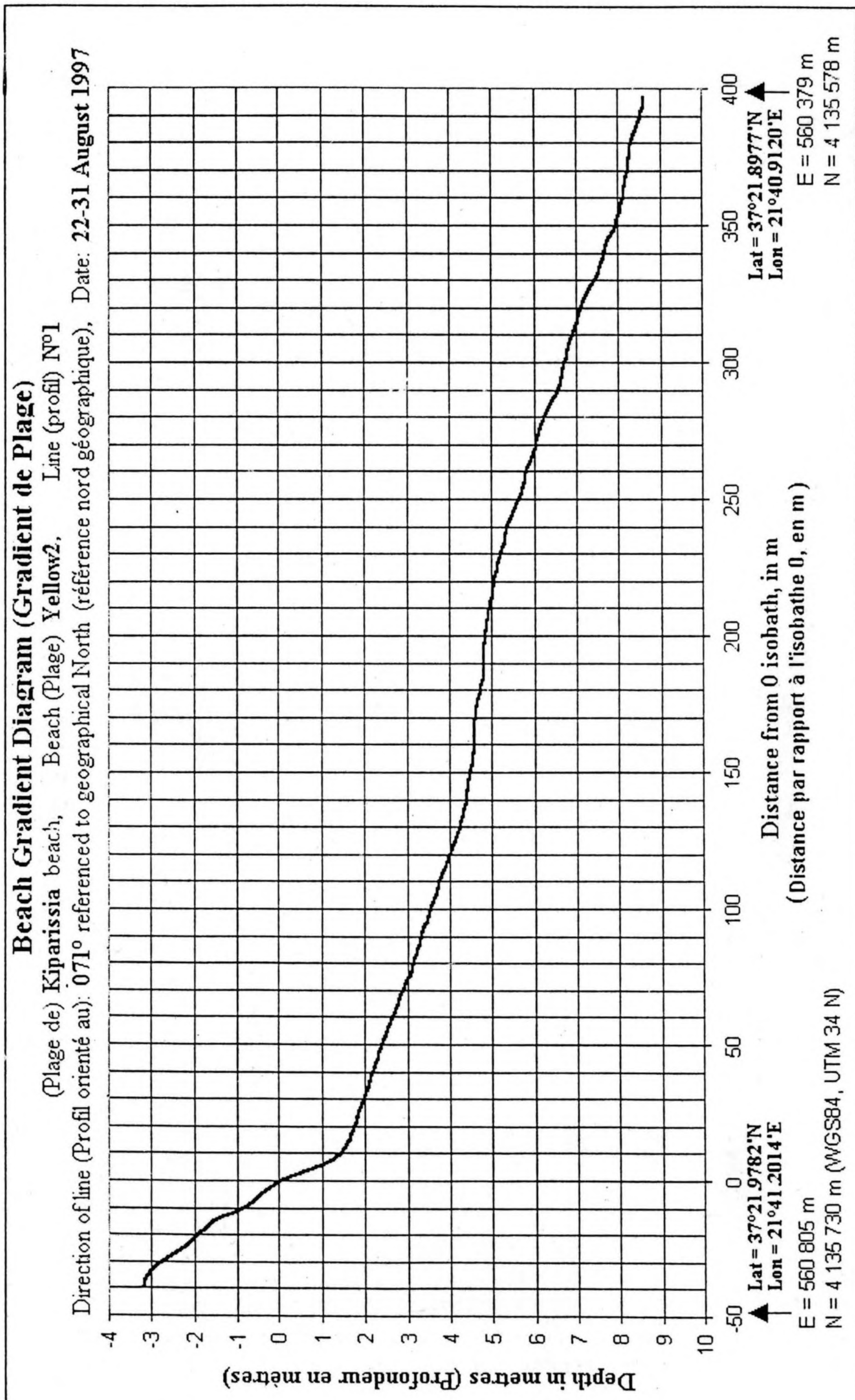


FIG. 2.- Beach gradient diagram.

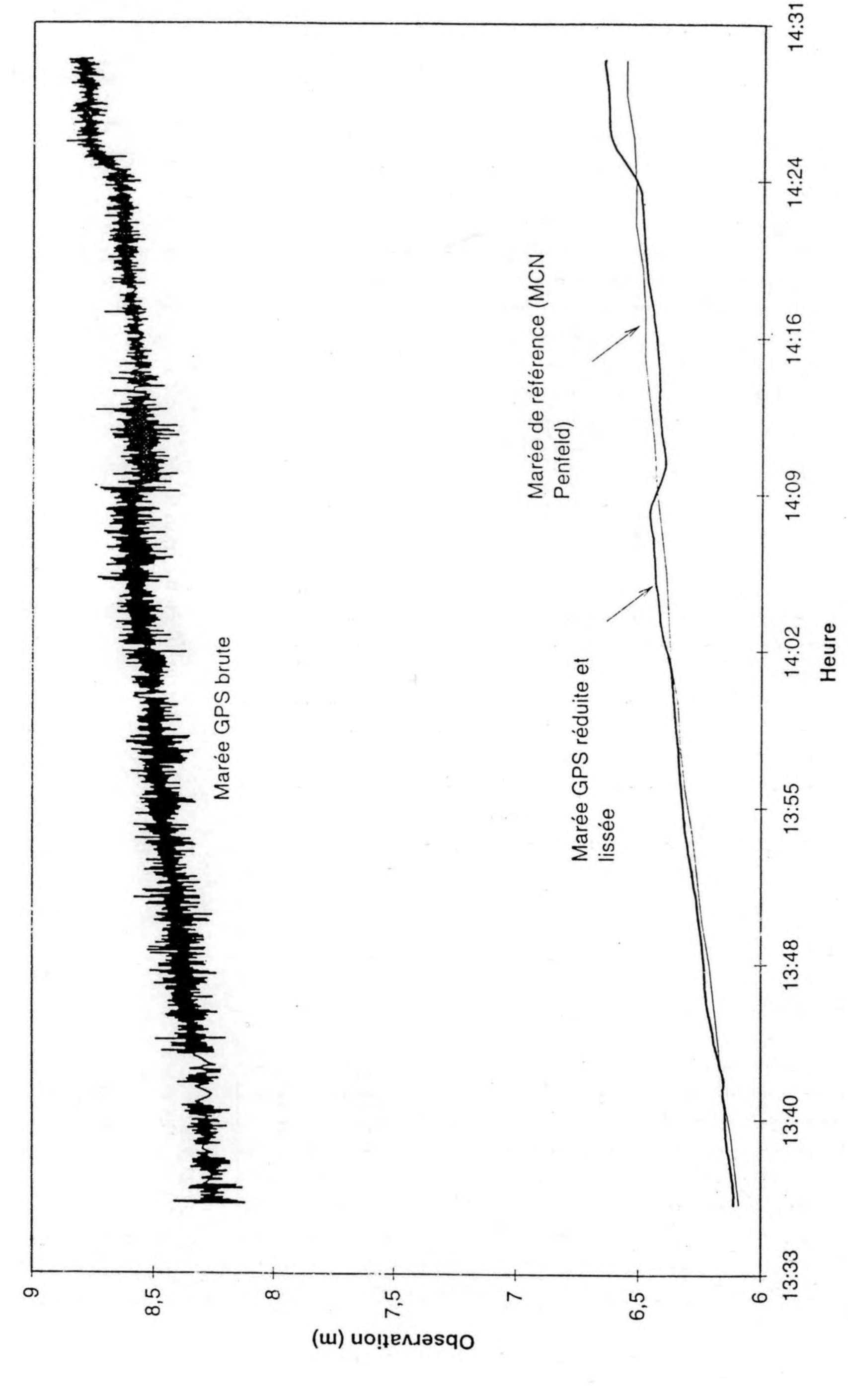


FIG. 3.- GPS and reference tides.

Over the 5 days, the average difference between the reduced and smoothed GPS tide and the reference tide is then nil, with a standard deviation of 4.1 cm and extreme values of +9.3 and -9.9 cm.

However, this deviation does not seem uncertain and rather of long wave length. If this difference really exists (and is not due simply to imprecise measurement), it corresponds :

- either to a local variation in the water level in relation to the level of the tide gauge, which could be taken into account by a model, but whose temporal wave lengths would probably be longer than those observed;

- or to a variation in the level of the antenna in relation to the water level (i.e. a 'squatting' or 'rising' of the launch).

The measurements available only allowed the second hypothesis to be considered and the possible causes of the launch's squat. The figure 4 shows - also for the afternoon of 9 April - the difference between the GPS tide and the reference tide, as well as the horizontal speed of the launch.

The correlation appears obvious : at high speed, the launch squats deeper in the water (the difference becomes negative). This correlation is also found in the figure 5, containing the observations over the 5 days:

The line of linear regression calculated from these observations is defined by the Equation :

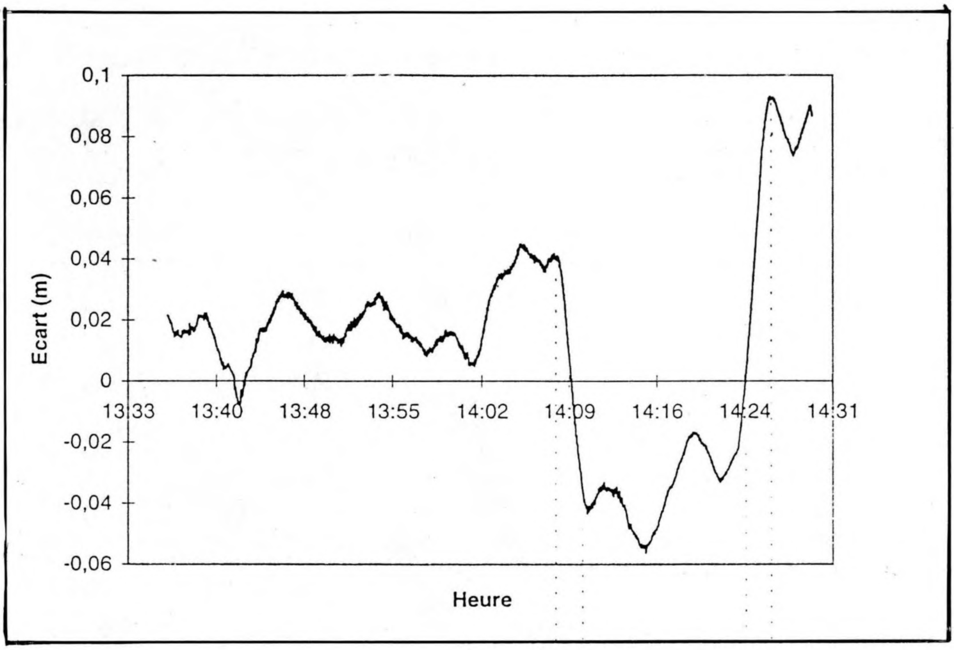
$$\text{Difference (m)} = -0.23 * \text{speed (m/s)} + 0.058$$

and corresponds, therefore, to a squat of 10 cm when the launch speed increases from 0 to 8 knots.

The dispersion of positions around the line of regression also shows that the influence of the speed does not explain all the differences noted. Thus, for a given speed, the difference may vary within a range of several centimetres. One might also think that acceleration is an influencing factor - at identical speeds the launch probably squats differently when slowing down than it does when accelerating.

In applying the velocity correction defined by the line of regression to the smoothed and reduced GPS tide, the mean difference compared with the reference tide remains nil, but the standard deviation diminishes to 2.7 cm. The maximum and minimum values over the 5 days of observations are then 8.2 and -6.4 cm.

With the smoothings and the corrections applied in this study, the tide obtained by GPS does not have the quality of that supplied by a tide gauge but differs by only a few centimetres. It seems, moreover, impossible to obtain better results with observations carried out from a mobile floating object without good knowledge of the latter's behaviour at sea.



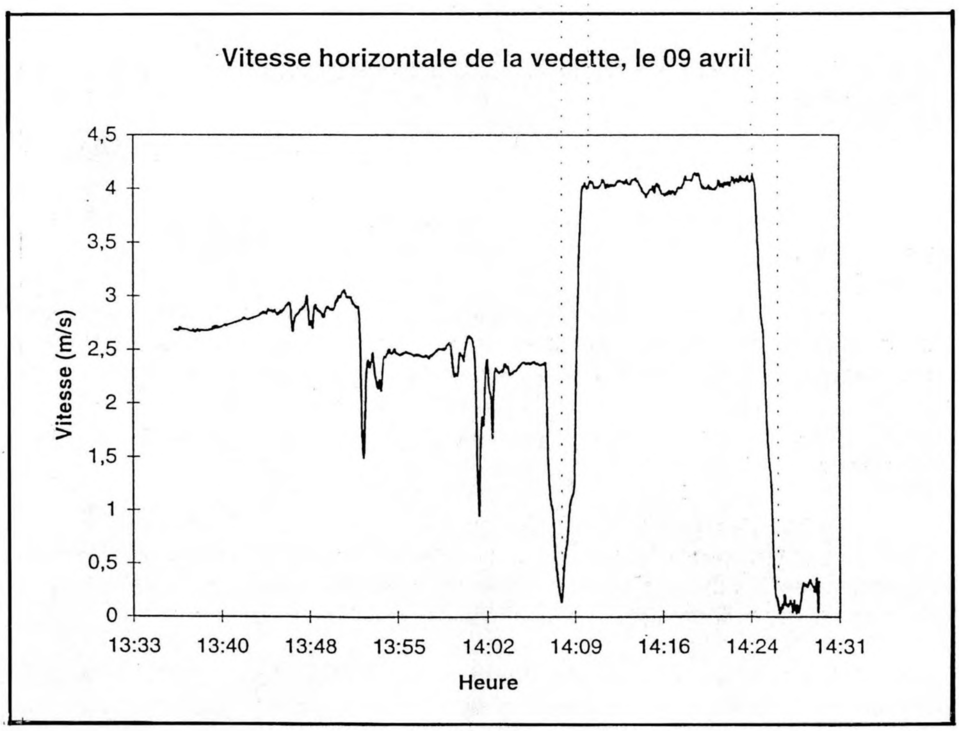


FIG. 4.- Difference between the smoothed and reduced GPS tide and the reference tide, 9 April and horizontal speed of the launch; 9 April.

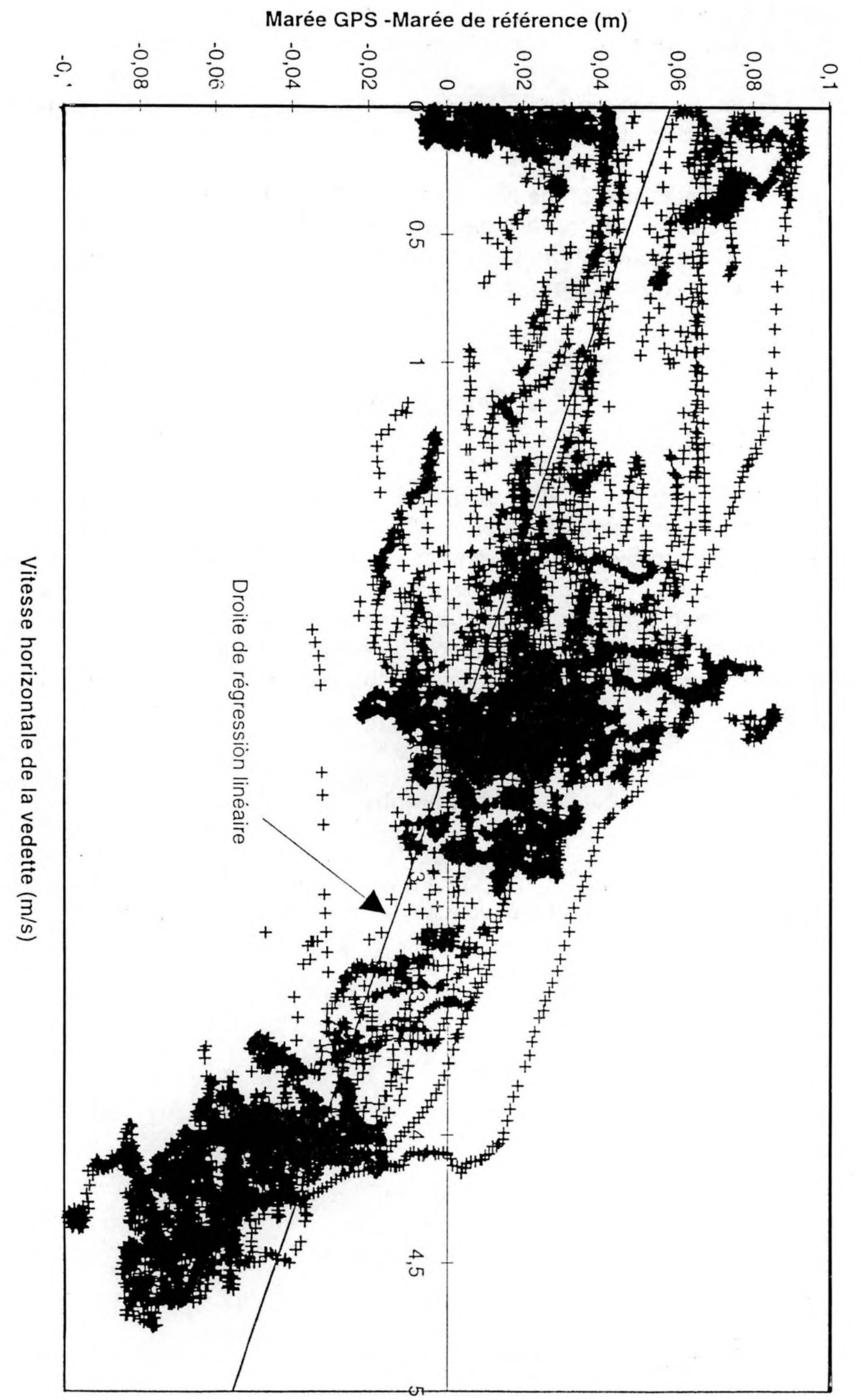


FIG. 5.- Correlation between the speed and the difference between the GPS tide and the reference tide.

On the other hand, for the correction of soundings from the vessel carrying the GPS, the tide obtained by GPS, reduced and smoothed, but not corrected for the vessel's squat, is of a quality at least equivalent to that of a tide gauge (in the case of this trial, i.e. in favourable sea conditions). Indeed :

- its accuracy is estimated to be within a few centimetres (compared with that of the tide gauge);

- the precision of the tide gauge is supposed to be perfect, but (unlike the GPS tide) this tide does not include the error on the sounding due to the squat of the launch and thus the lowering of the base of the sounder, which may be as much as ten centimetres.

CONCLUSION

The applications of kinematic GPS are being developed at SHOM. Its efficiency, without any great loss of quality compared with more conventional methods of measuring by GPS, has first of all rendered it a very practical tool for geodesy and topography. The availability of real-time positioning now enables it to be used as a very precise means of position-fixing for soundings. Finally, exploitation of the vertical composant opens up new perspectives with regard to tidal observation, with results which - as in the trial described - are sometimes unexpected.

Bibliography

BESSERO G. (1993) : «An example of use of differential GPS in hydrographic surveying", International Hydrographic Review, Vol. LXX, No. 2, September 1993, pp. 41-58.