International Hydrographic Review, Monaco, LXX(2), September 1993

AN EXAMPLE OF THE USE OF DIFFERENTIAL GPS FOR HYDROGRAPHIC SURVEYING

by G. BESSERO [1]

SUMMARY

After reviewing the evolution of GPS equipment used by SHOM (Service Hydrographique et Océanographique de la Marine) since 1985, this article describes recent experience from a hydrographic survey off French Guiana, using differential GPS as a unique positioning system. This practical experience facilitates the development of an operation practice for a system which from now on covers most needs of the hydrographer.

INTRODUCTION

It did not take much risk in forecasting, in an article published in 1985 by NAVIGATION (Paris) (BESSERO, 1985), that GPS was going to change the hydrographers' habits before the turn of the next decade. Though the satellite deployment schedule announced at that time suffered significant setbacks, the experience gained in less than ten years now confirms that expected revolution. The Hydrographic and Oceanographic Service of the French Navy (SHOM - Service Hydrographique et Océanographique de la Marine) purchased its first GPS equipment as early as 1985. The growth of the number of GPS receivers and the build up of the GPS constellation permitted the progressive use of the system from oceanic transits to coastal surveys. The recent hydrographic survey off French Guiana with differential GPS, as a unique positioning system, highlighted the completion of this progression.

[1] Ingénieur en chef de l'armement, directeur de la mission océanographique de la Méditerranée, BP 700, 83800 Toulon Naval, France.

SHOM GPS EQUIPMENT

The first type of GPS equipment acquired by SHOM was the single frequency five-channel TR5S receiver of SERCEL, the first receiver being delivered at the end of 1985. With these first acquisitions, GPS was initially used to supplement conventional radio-positioning equipment for small scale surveys (scale less than 1:100,000). The purchase of adaptation kits for TR5S receivers, and then of two NR52 geodetic receivers, permitted the use of GPS in geodetic work, mainly in overseas territories.

The prospect of a degradation of the performance of the SPS standard natural mode and the uncertainty about practical access conditions to the PPS precise natural mode, prompted SHOM to take an interest in the differential mode. A preliminary experiment was conducted at sea in 1988, in collaboration with the SERCEL company (FOURGASSIE, NARD, BONIN, GOUNON, 1988). The results then obtained led to the acquisition in 1989 of a long range reference station and two correction receivers for TR5S receivers.

As more compact and advanced products appeared on the market, the renewal of the set of first generation equipment was undertaken with the acquisition, in 1990 of Ashtech LXIID geodetic receivers and then, in 1991-1992, of SERCEL NR103 navigation receivers, with integrated differential capability, and of one light short range NDS100 reference station.

Table 1 specifies the status of the SHOM inventory of GPS equipment as of 1 January 1993. Given the state of the GPS satellite constellation, which now provides almost continuous coverage, that inventory, supplemented with planned purchases up to 1995, should cover most of the needs of SHOM for ship and launch positioning, geodetic observations and aerial photographic surveys. Only very large scale port or coastal surveys (scale greater than 1:5,000) would theoretically require the use of more acurate systems (theodolites or AXYLE system).

THE USE OF GPS IN FRENCH GUIANA

Presentation of the survey

Located between Suriname and Brazil, French Guiana is one of the overseas Departments and Territories whose general hydrography is the responsibility of SHOM. In spite of frequent requests, SHOM was not able to devote important resources to the hydrography of this Department, until the first systematic survey of Guiana, which was undertaken in 1989.

Table 1
Inventory of SHOM GPS equipment
Status on 1 January 1993

Model	Manufacturer	Year of purchase	Nb	Main features	Application
1. Receivers					
TR5S	SERCEL	1985-89	5	L1 frequency, C/A code 5 parallel channels real time DGPS (with external HF receiver) adaptation kit	positioning H/OV (1) geodesy
NR52	SERCEL	1987	2	L1 frequency, C/A code 5 parallel channels	geodesy
CM015	MLR	1989-	5	L1 frequency, C/A code 4 sequential channels	navigation H/OV, HL (2)
LXIID	ASHTECH	1990	2	L1 and L2 frequencies C/A and P codes 12 parallel channels post-processing DGPS	geodesy aerial survey
NR103	SERCEL	1991-	11	L1 frequency, C/A code 10 parallel channels real time HF/UHF DGPS	positioning H/OV, HL
MXII	ASHTECH	1991-	2	L1 and L2 frequencies C/A and P codes 12 parallel channels post-processing DGPS	geodesy aerial survey
2. Reference stations					
LRDGPS	SERCEL	1989-	3	correction computation: L1 frequency C/A code 10 parallel channels correction broadcast: 2 adjustable HF frequencies operating range: 600 km	long range positioning H/OV, HL
PDGPS NDS100	SERCEL	1992-	1	correction computation: L1 frequency C/A code 10 parallel channels correction broadcast: 1 adjustable UHF frequency range: line of sight	short range positioning H/OV, HL

Nota: (1): H/OV: hydrographic or oceanographic vessel
(2): HL : hydrographic launch

The area to study (Fig. 1) extends out 200 km from the coast to the 1,000 m depth contour and coastwise 300 km between the Oyapock and Maroni entrances. The coastline is low and bordered with mangroves; except for some river mouths, it is rather straight and boat refuges are scarce. The sites, needed for establishing radio-positioning beacons, are not high and very often are already occupied by telecommunication towers or facilities belonging to the Guiana Space Center (CSG - Centre Spatial Guyanais), based at Kourou.

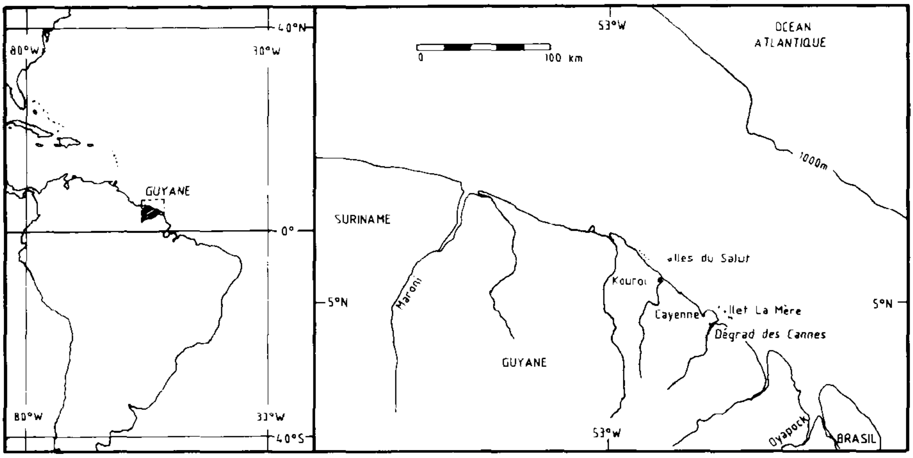

FIG. 1.- Geographical situation of French Guiana.

As with all hydrographic cruises in overseas areas with no permanent hydrographic unit, the Guiana survey was the responsibility of the Mission Océanographique de la Méditerranée (MOM) to which the oceanographic vessel D'ENTRECASTEAUX is assigned. D'ENTRECASTEAUX of 2,400 tons, has a crew of 90 men and a hydrographic detachment of 40. It is the only multipurpose vessel in the hydrographic fleet. The vessel is capable of deploying most of the modern positioning, hydrographic and oceanographic equipement in all waters, both in the open sea or coastal areas The three 9 m hydrographic launches and the Alouette III helicopter permit stand-alone operations far from the vessel's homeport and in areas of difficult access.

The first cruise of MOM in Guiana took place in May and June 1989, and provided a survey of part of the continental shelf between Kourou and Cayenne, the waiting area of the harbour of Dégrad des Cannes (sole important harbour of the Department) and the coastal route between Kourou and the Iles du Salut. The primary objectives of the second cruise, as scheduled in the MOM 1992-programme, were the exhaustive survey of the access route to Dégrad des Cannes waiting area, the 1:10,000-scale survey of Cayenne island approaches and the 1:500,000-scale exploratory survey of the entire continental shelf -except the part already surveyed in 1989 - to determine the 20, 30 and 50 m depth contours. Figure 2 shows the actual work done during D'ENTRECASTEAUX's stay in Guiana from 20 October to 24 November.

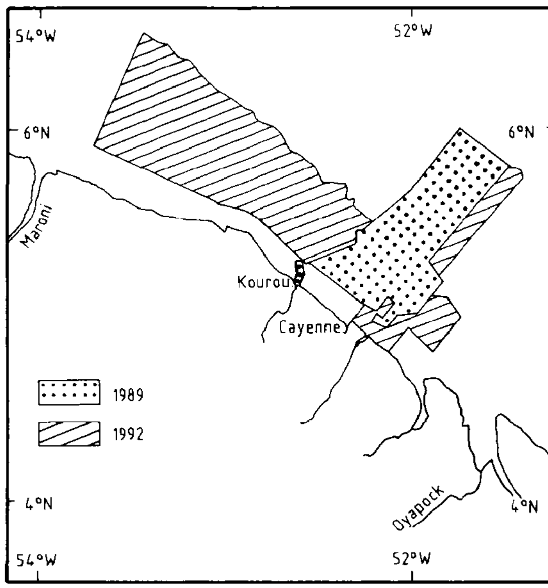

FIG. 2.- Hydrographic survey off French Guiana.

Implemented means of positioning

The coastal surveys of the 1989 cruise had been carried out with a Trident radioelectric circular system. The range of the beacons installed on the available summits did not much exceed 50 km, and GPS was used in natural standard mode to position D'ENTRECASTEAUX surveying outside the 50 m depth contour. The usable interval of the system in 2D+T mode (altitude-hold, at least three satellites simultaneously visible), was then limited to about 7 hours each night.

As the status of the GPS satellite constellation in mid-1992 (4 block 1- and 13 block 2-satellites) provided continuous coverage, the exclusive use of GPS could be considered for the 1992 cruise. The accuracy of the natural standard mode (100 m at 95% confidence level) being incompatible with the required accuracy for coastal surveying (10 m), the use of the differential standard mode was a definite requirement.

For the 1992 cruise, MOM had the following GPS equipment:

- one DGPS/HF long range reference station,

- one DGPS/UHF short range reference station,

- one TR5S GPS-receiver with HF differential capability,

- one NR103 GPS-receiver with HF differential capability,

- three NR103 GPS-receivers with combined HF/UHF differential capability.

Installation of differential stations

The SERCEL LRDGPS reference station (Fig. 3) consists of one transmitting and receiving rack, one non-interruptible 2.5 kW inverter, one receiving antenna for GPS signals and two 14 m transmitting antennas. The whole station, when packaged for transportation, weighs 1.5 ton and takes up 6 m^3. The transmitting and receiving rack consists of:

- one modified NR103 GPS receiver, which receives and processes satellite signals,

- one formatting unit, which elaborates correction messages and drives the transmitters,

- two transmitters of 150 W maximum power each,

- one 220 V AC / 24 V DC power supply and one ventilation unit.

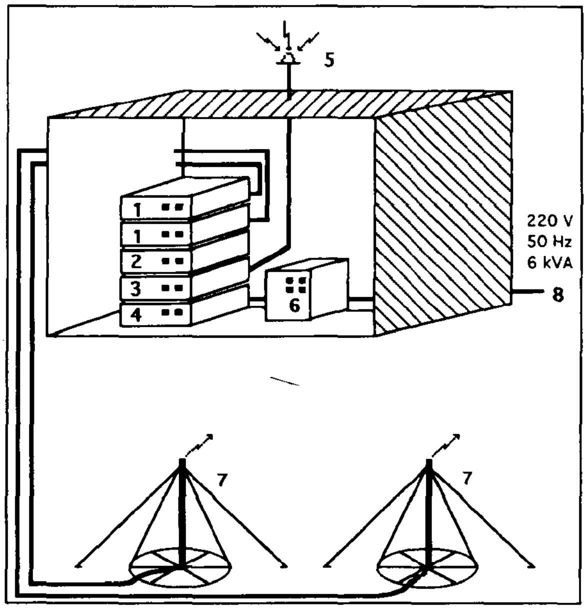

FIG. 3.- SERCEL DGPS/HF station

1. HF transmitter 2. Formatter unit 3. GPS receiver
2. Power supply 5. GPS antenna 6. Inverter
3. HF antenna 8. External power

A specific control and display unit, or a PC (personal computer) is necessary to switch on the station and for operation control. After one initialization, starting up after a power outage is automatic.

Both transmitting frequencies can be adjusted. They must be separated at least 1 MHz and chosen between 1.6 and 2.4 MHz, on the one hand, and between

2.4 and 3 MHz on the other hand, to ensure the reception aboard mobiles of at least one of the two frequencies, night and day, up to 600 km away from the reference station, with 100 W radiated power. The two frequencies allocated to MOM were 1,897 and 3,154.6 kHz.

The format of the correction messages is close to the one recommended by RTCM 104. With a transmission rate of 50 baud, 6 seconds are needed to transmit up to 8 corrections.

The installation of a DGPS/HF station is a fairly major operation. The primary criteria that must be taken into account when selecting a site are as follows:

- fair propagation conditions towards the survey area for HF frequencies: land path must be limited, and above all, free of any significant obstacle.

- enough clearance to set up the transmitting antennas: a 30 m diameter level surface is necessary for each antenna, with a 30 m minimum distance between antennas. The length of the coaxial cable between each antenna and the emission rack is normally 30 m but it can be increased to 100 m without any major drawback.

- enough clearance to install the GPS receiving antenna; no mask must have an elevation angle greater than 10°.

- few interference and multipath risks within the HF and GPS frequency bands. The absence of any disturbing frequency must be checked with a spectrum analyzer prior to installing the station.

- availability of a closed-in and air-conditioned shelter for electronics. This shelter must be situated less than 100 m from the transmitting antennas and have reliable 220V - 50 Hz electric power, if possible protected against failure. The required power is 6 kVA.

In order to install and switch on the station before the arrival of D'ENTRECASTEAUX the equipment and an advance team of 4 people were airlifted from France at the end of September. After a reconnaisance of the different possible sites, a CSG tracking station near Kourou (Fig. 1) was selected for the installation. The position of the receiving antenna was determined in WGS84 through GPS geodetic measurements, relative to one point of the DORIS network, which had been previously fixed by IGN (Institut Géographique National). It took less than one week to collect GPS measurements, process the data and install the station, but a fault on the formatting unit delayed the starting up of the station. The following failure of one of the two transmitters had no operational consequence: single-frequency operation was always satisfactory, as the maximum required range was less than 300 km.

A UHF differential station was delivered to MOM for evaluation, just before setting out for Guiana. This new station is markedly less bulky than the HF station: the different electronic units (GPS receiver, formatting board, modem, UHF transmitter) are integrated in a single 14 kg watertight case. Corrections are transmitted at 600 baud on a single frequency adjustable from 406 to 470 MHz.

Radiated power is 9 W. The case must be connected into an external 10/15 V DC power supply, the GPS receiving antenna and a 1.4 m UHF antenna. Range is limited to the radioelectric horizon.

The station was installed on La Mere islet, west of Cayenne, (Fig. 1) so that it could be used by launches during the coastal surveying of the approaches to Cayenne. Power was provided by a set of batteries charged by solar cells. To prevent the batteries from going flat overnight, the station was programmed to transmit only during launch surveys carried out exclusively by day. The GPS antenna position was determined, as was the HF station, by means of geodetic GPS measurements. Installing the station on the pre-determined site took only a few hours.

The watertight equipment case was initially set up in the open air without any protection. An unexplained outage was observed after two days of operation and the station could not be switched on again, probably because of the rather high ambient temperature. Trouble shooting aboard D'ENTRECASTEAUX did not reveal any anomaly. The case was put back on site under a makeshift shelter and the station operated correctly till the end of the cruise.

Operation of equipment aboard D'ENTRECASTEAUX

Figure 4 shows the configuration of equipment that has been used aboard D'ENTRECASTEAUX since the summer 1991. The equipment is installed in the main scientific room and consists of one TR5S receiver, one NR103 receiver, both with a HF differential capability and connected through a "Hydroboucle" local network (GAILLARD, FRACHON, ABGRALL, 1984) to a HP9000 series 200 or 300 computer which controls, processes and files data. The simultaneous use of two receivers allows the circumvention of possible failures (loss of signal, electronic fault).

At least one receiver is connected to a personal computer (PC) in order to check the differential station, either by editing correction or status messages or by visualizing the variation versus time of the pseudo-range corrections for each satellite in view (Fig. 5). The GPS receiver - PC link is also used to update the almanac file needed for the daily computation on the PC of satellite alert tables.

Table 2 lists the usual initialization parameters of both receivers. Fix computation mode (2D + T or 3D + T) can be selected on the TR5S receiver only; it is set according to the number of satellites in view, so as to guarantee at least one degree of freedom. The value of the pseudo-range residuals is then an element to assess fix quality.

The real time data collection software, running on the HP computer, offers the operator the possibility of setting up various validation criteria related to the accuracy of the fixes computed by each receiver. These criteria are as follows:

- criteria specific to each receiver connected to the network:
  * TR5S : maximum HDOP (DOPMAX)
  * NR103 : maximum GDOP (DOPMAX)
    minimum figure of merit (QUAMIN)

- accuracy criteria of the GPS fix computed by each receiver (these criteria are independent of the considered receiver):
* maximum circular standard deviation (DRMSMAX)
* fix computation mode: 3D+T only
  3D+T or 2D+T
  3D+T or 2D+T or 2D
  2D+T only
  2D+T or 2D
* pseudo-range correction mode:
  . natural : no validated satellite is corrected
  . differential : all validated satellites are corrected
  . mixed : there is at least one validated satellite that is corrected and one that is not
* activation or not of selective availability (SA)
* estimation of the accuracy of pseudo-ranges (UERE):
  . natural or mixed mode: with SA : 3 m
  without SA : 10 m
  . whole differential mode : 1 m

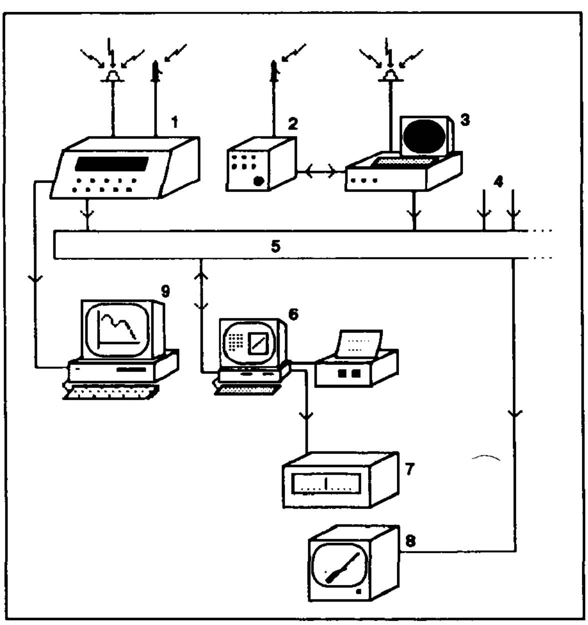

FIG. 4.- Configuration of equipment aboard D'ENTRECASTEAUX

1. NR103 receiver
2. Correction receiver
3. TR5S receiver
4. Other sensors
5. Hydroboucle network
6. HP9000 computer
7. Left-right indicator
8. Video monitor
9. Personal computer

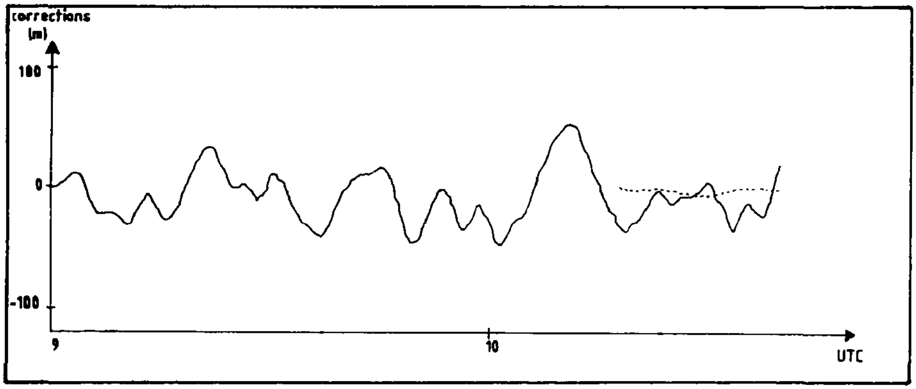

FIG. 5.- Example of variation of pseudo-range corrections
_______ PRN26 (block 2-satellite, SA on)
--------- PRN12 (block 1-satellite, no SA)

Table 2
Initialization parameters for GPS receivers

	NR103	TR5S
minimum elevation	8°	8°
	(0° if less than 3 SVs)	
maximum HDOP or GDOP	not adjustable	6
geodetic system	WGS84	not adjustable
geoid height	not adjustable	internal model
fix computation mode	not adjustable	(1)
differential transit	OFF or ON	MIXED DIFF
survey	ON	WHOLE DIFF
computation parameters	none	(2)

Notes: (1): AUTO 3D+T with 5 satellites and whole differential mode available
AUTO 2D+T otherwise
(2): 1st order filters parameters:
* pseudo-ranges : 600 s
* speed : 6 s
drift computation parameters:
* minimum elevation threshold : 14 °
* integration timespan : 3,600 s

The software carries out in real time various checks on the elements of the computed data messages sent to the Hydroboucle network:

- control of the residual of each satellite used in fix computation, from elements of the NSV block: the ratio residual/UERE must be less than, or equal to 2. If this condition is not met, an alarm flag is output on the screen and on the printer. The receiver fix remains valid. In case of persistent anomaly, one must look for one or more faulty satellite and manually cancel the selection on the concerned receiver.

- control of the computed height: the difference between the computed height and the known antenna height above the sea level must not exceed 100 m, in natural or mixed mode, and 10 m in differential mode. If this condition is not met, an alarm flag is output on the screen and on the printer and the computed fix is invalidated.

- control of the conformity of the fix-computation and correction modes with the requested modes. If this condition is not met, then the fix is invalidated.

- evaluation of the accuracy of each receiver-fix through the formula:

DRMS = HDOP (or GDOP for NR103) . SIG
where SIG = maximum {LPME, UERE}, if the quadratic mean of the observed residuals (LPME) is available (at least one degree of freedom in fix computation)
SIG = UERE otherwise

When the value of HDOP or GDOP is above the DOPMAX level selected by the operator, or when the figure of merit is below the QUAMIN level (NR103) receiver), the fix is invalidated. When the circular standard deviation DRMS is above the DRMSMAX level, an alarm flag is output, but the fix remains valid.

The final position is computed by the least square method, from the simultaneous validated GPS fixes converted to a reference antenna. The circular standard deviation associated with the computed position is the minimum DRMS value of the simultaneous validated GPS fixes. If the final DRMS value is greater than the limit derived from the survey scale, the position is invalidated and an alarm flag is output. The interval between two successive computations is 2 or 3 seconds, depending on the number of sensors connected to the Hydroboucle network. The recording rate is set by the operator according to survey scale. The elements needed to keep on track are transmitted to the wheelhouse through the Hydroboucle network and shown on a video monitor and a left-right indicator installed in front of the helmsman. The maximum deviation away from the intended track is computed and output after each interval between two successive recorded positions and at the end of the track.

All the equipment functioned satisfactorily during the whole cruise.

Operation of equipment aboard hydrographic launches

Because of the limited available room and the harsh environmental conditions of temperature, humidity and vibrations, aboard the survey launches their configuration is limited to the bare minimum (Fig. 6). It consists of a NR103 receiver, with HF or UHF differential capability, directly connected to a laptop PC. A portable printer, a left-right indicator and the sounder are also connected to the computer. The whole set is powered by 24 V DC.

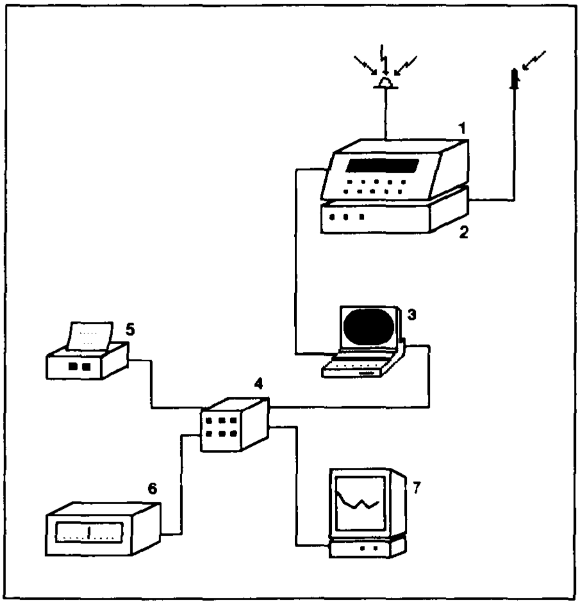

FIG. 6.- Configuration of equipment aboard a hydrographic launch.

1. NR103 receiver
2. UHF modem
3. Laptop computer
4. Interface box
5. Printer
6. Left-right indicator
7. Echosounder

The real time data collection software only allows the elaboration of the information needed to keep on track and the recording of computed data messages from the receiver. A validation procedure, similar to the one described in the preceding section is applied in post-processing when the data are transfered on to a HP9000 computer.

After correcting a few functional problems discovered during various tests conducted before leaving for Guiana and then during the crossing, the new configuration did not cause any particular trouble. Its straightforward operation was much appreciated by the users.

DGPS PERFORMANCE

The Guiana survey experience confirms the advantages of DGPS over conventional radio-positioning systems:

- the system is relatively insensitive to land paths,
- a single site is needed for the ground installation,
- it is not necessary to implement a thorough position post-processing routine, e.g. to account for variations in propagation corrections. Post-processing is restricted to the cancellation of a few erroneous fixes.

Yet, it is necessary to take into account some specific constraints:

- installing a HF station is a fairly major operation which calls for careful preparation. A temporary equipment shelter is absolutely needed.
- the inner redundancy of the system is limited: an error in the initialization of station coordinates is not easily detectable.
- GPS is not yet declared operational. Unexpected perturbations due to experiments or constellation changes are always to be feared. In practice, the interruptions of surveys due to such hitches have been rare up to now. A procedure providing regular access to information about the status of the system, limits the risks of such unpleasant surprises.

In Guiana, as well as during different surveys done with DGPS since the summer 1991, MOM tried to check the real performances of the system. These checks were based either on the analysis of static scatter plots or on comparisons with other systems said to be more accurate.

Table 3 sums up the performances which have been observed in port under various configurations. The following conclusions can been drawn from the analysis of the dispersion of scatter plots:

- the horizontal accuracy in natural mode, with SA on, is sufficient to carry out a survey at 1:100,000 scale (90% precision - 1.6 drms - better than 60 m);
- the horizontal accuracy in natural mode, with SA off, is sufficient to carry out a survey at 1:20,000 scale (90% precision better than 16 m);
- the horizontal accuracy in differential mode is sufficient to carry out a survey at 1:5,000 scale (90% precision better than 6 m). Neither the range to the reference station nor the transmission mode (UHF or HF) seems to have a significant effect on the observed accuracy (Fig. 7 and 8).

Table 3
Statistics of static GPS scatter plots

Harbour	Y.	Receiver	Mode (1)	Horizontal position errors (m)			Range to DGPS station km
				drms	r63%	r98%	
Horta (Azores)	91 92	TR5S NR103 TR5S NR103	3D+T DH 3D+T N 3D+T SA N 3D+T SA DH	3.4 5.8 36.1 1.6	2.8 5.2 33.9 1.1	7.3 11.4 79.2 4.5	250
Angra (Azores)	91	TR5S NR103	3D+T DH 3D+T N	2,8 7,1	2,5 6,8	6,7 15,7	360
Ponta Delgada (Azores)	91 92	TR5S NR103 TR5S NR103	3D+T DH 3D+T N 3D+T SA N 3D+T SA DH	3.5 6.1 35.0 1.1	2.8 5.3 31.9 1.0	9.3 14.8 80.8 3.7	520
Toulon	92 93	NR103 NR103	3D+T SA DU 3D+T SA DH	1.7 2.4	1.5 1.9	4.9 6.5	1 330
Dégrad des Cannes French Guiana	92	TR5S NR103 NR103 NR103	3D+T SA DH 3D+T SA DU 3D+T SA DH 3D+T SA DU	2.4 1.0 2.6 1.8	2.0 0.9 2.4 1.4	5.6 2.1 5.9 5.1	50 10 50 10

(1): 2D+T SA N : 2D+T mode, SA on, natural mode
3D+T DH: 3D+T mode, SA off, HF differential mode HF
3D+T SA DU: 3D+T mode, SA on, UHF differential mode

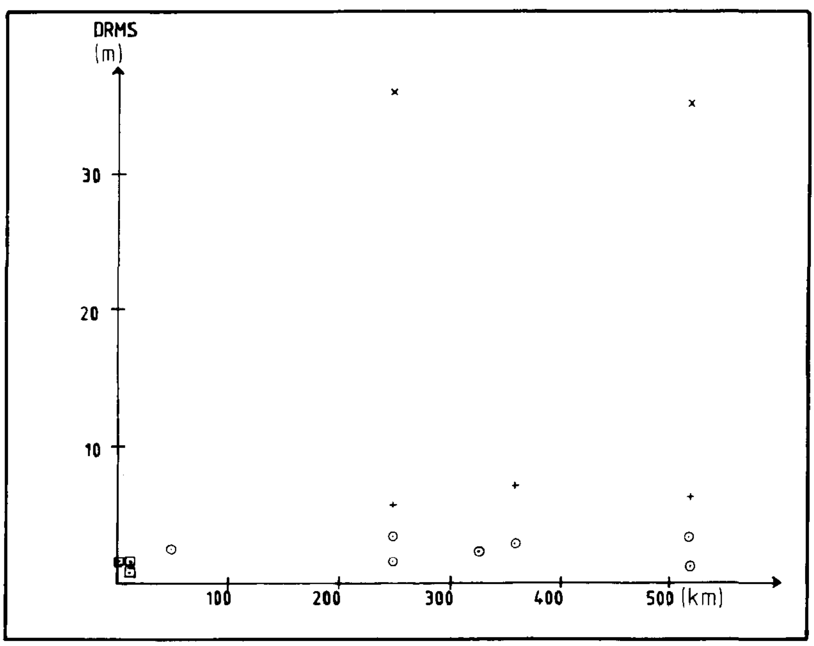

FIG. 7.- DRMS of GPS static scatter plots versus range to the reference station
□ DGPS/UHF
○ DGPS/HF
+ GPS NAT
x GPS NAT/SA

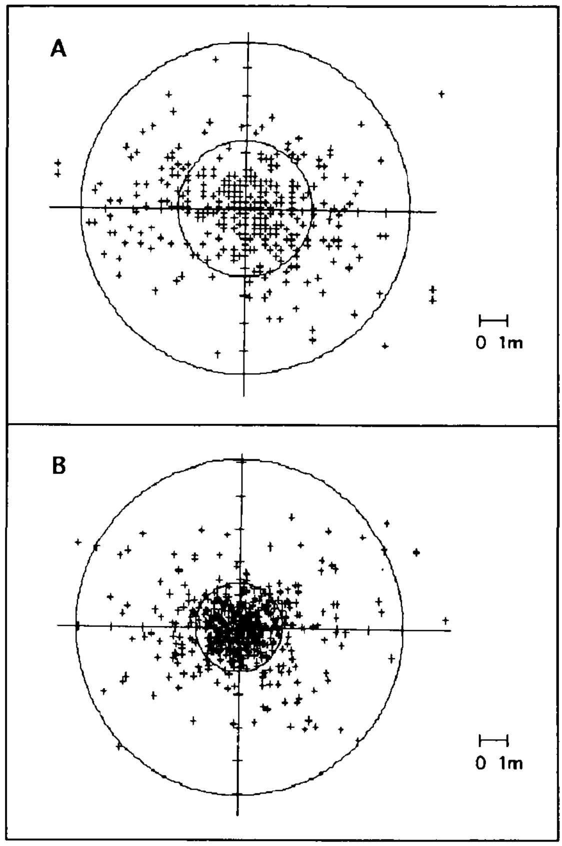

FIG. 8.- Static scatter plots at Dégrad des Cannes
(November 17 and 18, 1992)
A: HF mode - B: HF mode

Each time an independent determination of the WGS84 position of the GPS antenna could be obtained, it has been verified that the mean GPS position showed no significant bias, considering the accuracy of the connection process.

Some comparisons between DGPS and optical positioning by theodolites were done from March to September 1992, first with a HF DGPS station installed in Corsica and then with a UHF DGPS station set up in Toulon. The GPS receiver was installed aboard a launch, or on a small vessel at MOM disposal. The measurements collected on the freely drifting mobile confirmed that there was no bias in DGPS (radial separation between simultaneous optical and DGPS positions less than one meter). The measurements done underway showed a delay in fix computation by the NR103 receiver. This delay is variable and can reach 1 second. Data collection through the Hydroboucle network introduces an additional delay, which depends on the load of the network and can also be as long as 1 second. The total error corresponding to these delays can be as much as 10 m at 10 knots.

The quality of track keeping is also an indicator of system stability. Figure 9 shows, as an example, a plot at 1:5,000 scale of some profiles surveyed by a launch in Guiana.

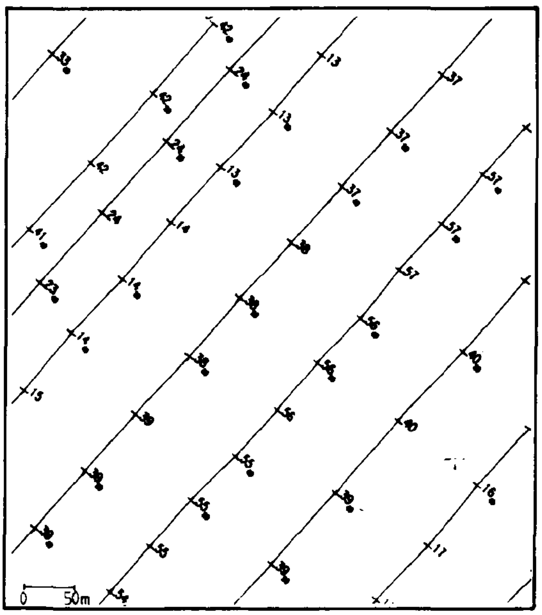

FIG. 9.- Extract from a plotting sheet with launch tracks.

ELEMENTS FOR DGPS OPERATION PRACTICE

From the experience gained by MOM since summer 1991, especially during the coastal survey off Guiana, it is possible to sketch a DGPS operation practice:

- working conditions:

DGPS can be used without any particular precaution for survey scale less than or equal to 1:20,000 (data collection through Hydroboucle network) or 1:10,000 (data collection through a PC). For larger survey scales, fix computation and collection delays must be taken into account.

- reference station operation:

If the area to cover is large enough to impose the use of a HF station, the selection of the station site must be carefully considered beforehand. One must make sure that a proper clearance is available around the transmitting antennas. It is essential to have on the site a protected power source and a shelter for electronics units.

The allocation of transmission frequencies must be requested early enough to the proper authorities.

The determination of the WGS84 position of the GPS antenna and the initialization of coordinates in the reference receiver must be done with care. An error at this stage will not be easily detected later on. The connection to a known WGS84 point must be direct if possible.

- positioning quality control:

In order to detect possible errors and control the proper working of the system, it is important to plan fixed point scatter plots within the surveyed area with an independent connection to WGS84 (through classical geodetic measurements).

Provisions must be made for a control procedure in real time, or at least in post-processing, of pseudo-range residuals and corrections broadcast by the reference station. This procedure can be associated in post-processing with an analysis of deviations from the theoretical routes. Fixes corresponding to anomalies which are not due to steering or to a speed change must be deleted. The recording rate must be fast enough, considering scale survey and surveying speed, so that this weeding out does not impair survey quality.

- control of system integrity:

Since GPS has not yet been declared operational, it is wise to plan a regular access to information about satellite status.

CONCLUSION

The experience gained by the Mission Océanographique de la Méditerranée in both coastal and oceanic surveys confirms that GPS used in differential standard mode covers most hydrographic needs in positioning. The straightforward operation of the system does not preclude however proper quality control procedures.

References

GAILLARD J.C., FRACHON B., ABGRALL F. (1984): "Automation of hydrographic surveys and of their processing at SHOM: present state and future prospects". Papers of the Second International Hydrographic Technical Conference, The Hydrographic Society, 1984, SP 14, pp. 25/1-7.

BESSERO, G. (1985): "GPS: une révolution en hydrographie", Navigation (Paris), 1985, vol. 33, n° 129, pp. 36-40.

FOURGASSIE A., NARD G., BONIN G., GOUNON R. (1988): "First experiment with the SERCEL real-time differential GPS system for hydrographic applications", Séminaire "Applications and experiences with GPS", The Hydrographic Society, London, 1988.