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150 YEARS OF FRENCH "ANNALES HYDROGRAPHIQUES" (HYDROGRAPHIC ANNALS) (1848-1998)
FROM THE STUDY OF TYPHOONS IN 1848 TO THE PRODUCTION OF ELECTRONIC CHARTS

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Abstract

1998 marked the 150th anniversary of the first publication of "Annales hydrographiques" (Hydrographic Annals) by the French Hydrographic Service. After a description of the layout and contents of the five series which have been issued successively and without a break since 1848, this article sketches, through the studies and papers published in the Annals, a panorama of the sciences and techniques employed by French hydrographers during this period.

Introduction

1996: 75th anniversary of the International Hydrographic Bureau; 1998: 50th anniversary of the International Maritime Organization : the maritime world also has its share of commemorations, which sometimes irritate those who see in such events only nostalgia for a past which has no relevance with either the realities of today or the challenges of tomorrow. In deciding to publish a special issue for the 150th anniversary of the first publication in 1848 of the Hydrographic Annals of the French Hydrographic Service, Ingénieur Général François MILARD, Director of SHOM, expressed the wish *"that our young engineers and technicians should not be*

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unaware of either the heritage left by their elders nor the duties for which they will themselves be responsible vis à vis those who come after them" [MILARD, 1998]. This article aims to extend that hope and at the same time pay homage to those who made SHOM what it is today and who contributed, the most often in a very discreet manner, to the progress of hydrography, marine cartography and oceanography for the benefit of all seafarers.

SOME HISTORY

We will not hold it against historians if they attach more importance to those events of February 1848 which, in France, brought about the proclamation of the Second Republic and the final abolition of slavery, than to the decision by the Ministry of Marine to command, following a proposal by the General Naval Depot, the publication of *"Hydrographic Annals"*. Before that, since 1814, *"maritime and colonial annals"* had been issued twice yearly, with one issue containing *"laws and decrees"* and the other, labelled *"scientific and technical"*, containing accounts of voyages of hydrographic exploration and reconnaissance, extracts from navigation papers, notices to mariners, etc. This hydrographic component was published separately, from 1845 onwards, under the title of *"hydrographic miscellany"*. When, in 1847, the *"maritime and colonial annals"* and the *"hydrographic miscellany"* were discontinued, the *"hydrographic annals"* took the place of the latter publication.

In the first volume of the Annals, Ingénieur Hydrographe en Chef Pierre DAUSSY explained the aims of this new publication *"devoted particularly to hydrography and navigation"*. It was a matter of informing the mariner of recently discovered dangers, giving him a description of buoyage, publishing French sailing directions - or those coming from foreign navies - informing mariners of navigation by State vessels in little-known areas, reporting on scientific sea voyages, pointing out new publications, and publishing scientific papers on nautical sciences. He added that the best foreign publications would be called upon, notably the *"Nautical Magazine"*, the *"East and West Indies Monitor"* and the *"Portuguese Maritime Annals"*. Five series were to follow one another, without interruption, from 1848[4] to 1998. First placed under the responsibility of Ingénieur Hydrographe B. DARONDEAU, the Annals came under the Sailing Directions section in the new organization of the Naval Depot set up in 1860. The studies and documentation office (SHED) took over after 1945. In 1971, SHOM's head office in Paris retained the function of chief editor, but the material production of the Annals was then entrusted to the new establishment created in Brest.

THE LAYOUT OF THE ANNALS

The volumes of the first series (1848-1878) were divided into two parts. Part One, dealing with practical hydrography, contained three sections : Section 1: Notices to Mariners; Section 2: Sailing Directions, accounts of voyages, hydrographic papers; Section 3: various documents, miscellany, bibliography, cartography. Part Two consisted of memos and scientific notices concerning hydrography and navigation. Until 1861, the very voluminous Notices to Mariners

4. It was in fact in 1849 that the first volume appeared, dated 1848-1849.

appeared at the beginning; from 1861 onwards, they appeared after the table of contents. In practice, publication of the Annals being quarterly to facilitate their distribution, and the table of contents being unique for each volume, there resulted an apparent disorder when the work was thumbed through. It is relevant to point out that, in order to ensure better updating of nautical documents, Notices to Mariners became a separate publication as from 1865.

In the second series (1879-1916), the Notices to Mariners had disappeared and the themes of the first series were grouped under two headings : Section 1 : *"Sailing directions, accounts of voyages, information on hydrography and navigation"*; Section 2 : *"Scientific notes and observations; miscellany; bibliography"*. After the Notices to Mariners and the information on lighthouses, sailing directions were, in their turn, published separately as from 1887.

In the third series (1917-1949) and the fourth series (1950-1972), the themes did not change but they were no longer so detailed and priority in the table of contents was in principle given to reports from the hydrographic *missions* (units).

In the fifth series (1973-1998), the two parts of the table of contents, untitled, respectively concern scientific notes and reports by SHOM's hydrographic units.

The books of the first four series were in the format *"in-octavo-feuille de raisin"*; those of the fifth series are in A4 format. To reduce the time taken in distributing the articles, each volume was first published in three or four pamphlets, each with its own pagination and table of contents. With the exception of the first and fifth[5] series, there existed for each series recapitulative tables of the names of authors of articles and the titles of their works, as well as the subjects dealt with. Until 1911, the Annals had an alphabetic index of place names. These various tables made it possible, despite the vast amount of information contained in the Annals, to search quite rapidly for what one required, with effective results.

THE CONTENTS OF THE ANNALS

The one hundred and thirty six volumes of the Annals represent the life of the French Hydrographic Service over a hundred and fifty years. They constitute a collection in which French hydrographers record the major facts concerning themselves and their own work. An essential historical record of the sciences and techniques associated with navigation, hydrography and, to a lesser extent, oceanography, give the evidence of mariners and engineers concerning their evolution. They present a double aspect, clearly reflecting the Hydrographic Service's vocation of dialogue between mariners and hydrographers; they gather, on the one hand, a great variety of information useful to mariners and rigorously record, on the other hand, reports from hydrographic engineers' missions and their scientific products. They constitute, in the long term, a working tool and scientific and technical archives which few organizations may claim. However, beyond the

[5] As the fifth series ended in 1998, its recapitulative table will be published in the first issue of the sixth series in 1999.

personnel of the Hydrographic Service they are familiar only to a handful of the initiated.

The contents of the Annals have largely evolved in the course of time. Broadly speaking, whilst at the beginning the information coming from mariners or intended for them occupied the most important place, progressively one saw this being replaced by specific publications (sailing directions, lists of lights and radio signals, etc.) and at the present time, the whole of the contents are devoted to mission reports and scientific papers. A rapid review suggests some additional reflections. Running through the Annals is, to begin with, like sailing over the oceans and discovering the coasts of the world, meeting peoples and civilizations everywhere on Earth, living with history, experiencing the emotions, joys and sorrows of navigators and explorers. It is also, for hydrographic engineers, running through the sciences and techniques of *"hydrography"*. The early epoch of the Annals, up to about 1900, is rich in breathtaking stories written in literary French. The black slave trade, piracy, cannibalism, all are referred to, in an exotic environment. Naval officers, merchant navy officers, explorers and missionaries had a lot to recount to us. Their stories fill the transition period between the last wave of the great round-the-world voyages (1830-1840) which ended at the time of the birth of the Annals (1848), and the new era, when navigation was safer, thanks to them, and when maritime traffic existed which was to develop rapidly early in the 20th century.

From 1848 to 1916, the first two series of the Annals were thus characterized by a considerable amount of information on routes, approaches, moorings, meteorology, gathered at the time of ocean crossings (an average of five per year between 1880 and 1900), and hydrographic reconnaissance. Open-mindedness, exchanges with foreign services, the somewhat haphazard discovery of the coasts of the world, are clearly manifest during this pioneering phase. The result is an explosion of information in the form of Notices to Mariners but also the publication of numerous "*Route charts*" and "*Pilots*", translated into French, all of which alone justified the creation of a specific publication. Among the facts which specifically retain the attention, one notes :

- a vast quantity of meteorological observations and the interpretation of these. Violent phenomena (tempests, cyclones, typhoons) form the subject of numerous reports [(6)], intended to forecast them, which is a priority for shipping;
- the great interest in the comprehension and the use of the meteo-oceanographic work by M. F. MAURY (year 1850);
- the considerable number of determinations of geographic positions and longitudes, between 1880 and 1900, during a period involving various techniques: chronometers, lunar distances, the development of telegraphy (land and submarine), radio-telegraphy (from 1899 onwards);
- the interest aroused by magnetic observations (between 1880 and 1910);
- numerous hydrographic campaigns: coasts of Italy (1846-1858); west coast of Africa (1848-1851; 1908-1914); Spain, Morocco, Portugal, Gibraltar (1852-1855); Black Sea (1853-1855); Brazil (1857-1860);

[6] The paper "1848 Typhoons, Oblique Hurricanes and Fixed Gales, etc." by Ing. Hyd. F.A.E. KELLER, in the first volume of the Annals, began the series of scientific reports and notices.

Indo-China (1857-1914); Madagascar (1846-1914); renewal of surveys of French coasts (1864-1895); triangulation from Isle of Ushant to Bordeaux (1816-1825);
- numerous studies in geodesy and in the field of tides;
- strong interest in polar expeditions: although France was not taking part in polar enterprises, except for Lieutenant Bellot, the Annals faithfully record the reports concerning them. They give over eleven years (1848-1859) accounts of research expeditions (about forty) by the ships of Franklin, the *Erebus* and the *Terror*, en route for the North West Passage. One also finds echoes of the exploration by the *Polaris* (1871-1873) and the death of captain HALL; the voyage by the Norwegians to Novaya Zemlya and in the Kara Sea; the fifth Swedish expedition to the North Pole (1872-1873) by Professor Nordenskjöld; the Austro-Hungarian expedition to the North Pole (1872-1874). One will also note, during the first international polar year (1881-1882), that Commander MARTIAL took part in the mission in the Cape Horn archipelago (1883-1884).

From 1917 to the present day, the third, fourth and fifth series form a group, distinct from the preceding ones, in which one recognizes easily that the Hydrographic Service has attained its 'cruising speed', divided between hydrographic - then hydro-oceanographic - units, on the one hand, and their exploitation in the form of mission reports, on the other hand. Intense activity was evident overseas (Indo-China, Equatorial and West Africa, Djibouti, French Polynesia, New Caledonia) and along the coasts of France throughout this period. The work in black Africa and Madagascar, which ended in 1965 by the dissolving of the relevant units, has been relayed by work undertaken in the West Indies and Guyana, since 1976. One also notes:

- a considerable effort in the determination of (overseas) geographic positions between 1918 and 1948;
- multiple magnetic observations between 1918 and 1936, and from 1950 to 1972;
- numerous studies of toponymy (Brittany, Polynesia, Madagascar, Comores, French coasts of the Somalis, Gabon) between 1950 and 1972;
- very varied scientific studies: about two dozens in astronomy, geodesy, gravimetry, cartography and another two dozens in tides, sounding, tide gauges, oceanography.

SCIENTIFIC AND TECHNICAL DEVELOPMENTS IN HYDROGRAPHY AND OCEANOGRAPHY

Hydrography is a technical field which involves a good number of scientific subjects. To carry it through successfully, it is essential to guarantee for those benefitting from it a quality of knowledge superior to what they can themselves attain with the means at their disposal. Because of this, the hydrographer has always been led to seek the continual improvement of this methods and his means so as to preserve his mastery in satisfying the needs of users of the sea and if possible in anticipating such needs. In doing so, he has contributed extensively to scientific developments linked with knowledge of the ocean, whether as regards instrumentation, understanding or modelling. The Annals thus retrace 150 years of evolution - and sometimes of revolution - in the various disciplines of hydrography.

Land Geodesy

In his report on the geodetic work carried out by the Hydrographic Service of the (French) Navy, E. FICHOT [1921] outlined perfectly and in a way that is still true today the contribution made by hydrographic engineers to geodetic knowledge:

"The (geodetic) operations were conceived and executed, not in seeking a result directly concerning geodesy itself, but above all to serve as a solid basis for the soundings which constitute the essential part of any hydrographic campaign. Subsequently, it was not possible to devote to them a length of time disproportionate with the principal objective to be attained, and their execution necessarily depended on a perpetual compromise between the concern to achieve the maximum accuracy possible and the limited time and means available to the hydrographic engineers."

For determining the geographic position of the fundamental point of the geodetic networks necessary for their work, hydrographic engineers first used the theodolite and chronometers. From 1850 to 1901, they used the portable meridian circle. The prismatic astrolabe, the first example of which was constructed in 1901 under the instigation of CLAUDE and DRIENCOURT, remained in use, with some improvements, until 1970, after which the satellite systems Transit (1970) then GPS (1985) and DORIS (1994) permitted the precise determination of positions in a world geodetic system [LE GOUIC, 1993]. Until the generalisation of time signals, many were the hydrographic engineers who studied, following LIEUSSOU [1853], the important question of how chronometers worked. Once the network was fixed, for a long time its direction was determined by a third measurement, a fix taken by theodolite on the stars. It was only in 1951 that a simultaneous determination of the position, of an azimuth and of the local sideral time was established by GOUGENHEIM [1951a], who solved equations of spherical trigonometry by the method called 'azimuth straight lines method'.

Direct or indirect measuring of the length of the base to enable the scale of the network to be fixed was difficult for a long time because of the means of observation available. Early in the 20th century, devices with invar tapes subjected to a constant tension (Swedish geologist JÄDERIN's process) made a considerable improvement in accuracy. But the real progress, both in speed of execution and accuracy, only appeared after the second world war with the arrival of distance-measuring equipment in hydrographic campaigns in 1958 [BOURGOIN, 1959-60 ; ROUBERTOU, 1959-60].

With the advent of distance-measuring equipment, traverse then trilateration operations were regularly applied. The work of hydrographic engineers then consisted in establishing rigorous calculation procedures, taking into account the environment (effects of temperature, pressure and hygrometry) and facilities for calculation in projection (reductions at the ellipsoid, projection correction). In the latter field, the "esprit de géométrie" of hydrographic engineers had been particularly productive [HATT, 1886; COURTIER, 1912; GOUGENHEIM, 1950; 1951b]. For a long time - until after the second world war - hydrographers used a mode of plane representation consisting in successively laying down all the triangles on the plane of one of them after having corrected the observed angles of one third of the spherical excess defined by HATT [1886, op. cit.]. This process had the advantage of simplicity but could only be applied to narrow strips of land in a relatively straight line, which explained its popularity with hydrographers. The various geodetic system created formed independent stretches, with internal heterogeneousness and discontinuities at the junctions with other neighbouring systems. To set up long-range radio positioning systems, it was necessary to have homogenic geodetic control. The computer made it possible to process observations globally and to eliminate most of the abusive simplifications associated with projection calculations.

Marine geodesy

In continuing the methods developed by BEAUTEMPS-BEAUPRÉ at the dawn of the 19th century, the precise determination of the position at sea was for a long time exclusively done by observing angles between signals already placed, first with the help of BORDA's reflection circle and the sextant, then with a simplified reflection circle giving the minute of the angle, which was called a "*hydrographic circle*". After the second world war, progress in radiocommunications made possible radio-guiding by precise fix with the theodolite. Because of the functioning problems of the first portable transmitter-receivers and the increased manpower required to man earth stations, the circle continued nevertheless to be used for sounding from sounding boats until the early 1970s. When hydrographic work had to be extended out to sea, out of sight of the shore, networks of beacons had to be anchored whose positions were determined from one to the next. The process was an extremely cumbersome one, the behaviors of the beacons uncertain, and the accuracy of positions fixed in this way soon became mediocre. The problem of position-fixing beyond the optical horizon had been causing concern to hydrographic engineers for a long time. BOUQUET DE LA GRYE's method [1859], based on the propagation of sound through the air, supported by theodolite readings, was interesting but not very flexible and it was difficult to establish the temporal concordance of measurements. Such concordance, even for simply using a theodolite taking a fix on a light at the top of the mast of the sounding vessel, could not be obtained in a satisfactory way until after the second world war, with the use of radiocommunications. But even with this new flexibility, the range remained limited to the optical horizon. MARTI, who studied the possibility of submarine sound waves for determining depths, took an interest, in the period between the two wars, in the horizontal propagation of such waves so as to determine positions at sea over large distances. The sound range obtained was variable depending more on the stratification of the seawater layers than the quantity of explosives used. The studies carried out made it possible to study the velocity of sound in sea water [MARTI, 1919-20], and were extremely useful for measuring depths acoustically. Even with its limitations, this process was quite widely used and rendered great service to hydrography.

After the second world war, the propagation of radio-electric waves through the air was used. Industry, stimulated by the needs of oil companies, rapidly proposed a large variety of systems, some furnishing distances directly to a transmitter, the others the difference in distance between two land stations. These systems gave rise to many problems in use: propagation conditions, reflection, calibration, calculation of the position, etc. ALLARD [1947] specified a new geometric problem related to the generalisation of the ellipsoid of "geodetic" ellipses and hyperboles, until then limited to the plane. The first trials of the Decca system were carried out under the direction of CHATEL, by ALLARD and hydrographic professor-in-chief HUGON [CHATEL, 1950]. From then on, earth-based radio position-fixing systems were the subject of regular studies by hydrographers - studies intended to specify the optimum conditions for their use and the objective limits of their accuracy [LACOMBE, 1957; COMOLET-TIRMAN, 1963-64; BRIE, 1969; GUYON, 1984; LE GOUIC and LE VISAGE, 1991]. Le Trident circular system was conceived under the impulsion of the Hydrographic Service which had had the Derveaux Laboratories build a short-range position-fixing system, tried out and used as from 1959 by ORTAIS [1963-64]. The firm COTELEC took up the principle of Derveaux to create Trident I, before being taken over by the firm Thomson-CSF which developed a Trident series [DEMERLIAC, 1967-68; BONNOT, 1978] the fourth and final version of which was used aboard all SHOM's ships and boats until 1995. Here, as in geodesy, the arrival of satellite systems was a turning point. With the satellites of the Transit system, positions were obtained by integrating the signals transmitted on a long arc of orbit. The position-fixing was not continuous and, as the number of satellites was limited, the system had to be coupled with another continuous method, but one which was not well-calibrated (LORAN) or one which was relative (acoustic beacons) [SCHRUMPF, 1978]).

The GPS system revolutionised the problematic aspects of position-fixing on the high seas. Henceforward, one had a system offering continuous, very satisfactory accuracy of position-fixing without complex and costly installation. Right from the trial stage, GPS was used operationally by SHOM, both for calibrating land-based systems [LE GOUIC and LE VISAGE, 1991, op. cit.] and for carrying out surveys programmed in the French mainland [BESSERO, 1996] from 1987, and overseas from 1989 [LE GOUIC, 1993, op. cit.]. With the possibilities offered by differential mode, use of GPS has become almost systematic because of the accuracy available.

Bathymetric sounding

Up until the first world war, hydrographers were only exceptionally required to carry out sounding in deep waters, their aim being to study in detail and with precision the vicinity of the coasts. The limit of depths to be investigated was governed by depths the knowledge of which might be useful only for surface navigation by ships of small draught. Hydrographers used graduated lines and sounding leads which they were led to perfect in various ways [LESAGE, 1913; COT and CATHENOD, 1922; MARTI 1925-26; GOUGENHEIM, 1937].

The first world war had led to the taking up again of Leonardo de VINCI's idea of listening to the sound made by vessels in order to detect their presence. When peace was restored, MARTI had the idea of provoking the acoustic noise by means of an explosion and measuring the time of propagation of the echoing sound wave reflected from the seabed. His work [MARTI, 1923-24] is at the origin of the principle that has been used for seventy years in vertical echo sounders. Certainly, the means of provoking the sound transmitted is no longer the "*military rifle firing the ordinary cartridge shot*", or the "*37mm gun firing salute munitions, e.g. 60g of black powder, without shell*", and the methods of analogic recording have been perfected. But the development of echo sounders materialised MARTI's amazeingly realistic forecast: "*one may, without being taxed with optimism, predict that we will one day see aboard all ships instruments constantly indicating the depth of the sea*". During the cruises of the *Pourquoi-Pas*, after A. CHATTON in 1927, CHARCOT used the MARTI sounder in 1929, up to a speed of 10 knots, with complete satisfaction [CHARCOT, 1930]. Thanks to the use of the LANGEVIN-FLORISSON processes, MARTI also created a sounder - ultra-sonic, this time - that was used in hydrographic missions aboard quite large-size vessels [MARTI, 1927-28; 1930].

From 1940, the Hydrographic Service used Hughes MS 26 F and G sounders; then, during the 1970s, Atlas sounders in shallow water and Edo, then Raytheon, sounders in deep water. Though those sounders were produced by industry, the expertise of hydrographers enabled them to be used with the real limits of their performance and precision. The operational precautions both in their use in the field and in the exploitation and archiving of the data collected, were complex, as shown by the fact that outside Hydrographic Offices, few quality soundings were carried out with these instruments. Thus SHOM took part in the Famous mission of 1973-74 [SCHRUMPF, 1978, op. cit.] so as to determine the fine characteristics of the mid-Atlantic ridge, over which a dive by diving saucer was to be made later. An Edo narrow-beam sounder with stabilised base was therefore employed in order to guarantee safe conditions for the navigation of the saucer as close to the seabed as possible. Another important improvement was made from 1980 with the entry into service of the Anschütz heave compensator to correct the vertical movements of hydrographic vessels due to swell. Development of the performances of 'motion sensors' was only able to result in a satisfactory solution to the more difficult problem of the heave of hydrographic launches in 1996.

It was in the mid-1970s that a new concept was born: the multi-beam sounder. SHOM rapidly studied the possibility of equipping one of its ships with this new type of sounder, but the focus at that time was on shallow-waters, and it was subsequently decided to develop a multi-beam sounder adapted to that range of depths. The Thomson company therefore constructed, in 1987, based on specifications by SHOM, a sounder called Lennermor which was able to produce, between 20 and 300 m depth, a swath of 90° by a set of 20 elementary beams scanning either side of the route of the sounding vessel. Despite the extreme rigour imposed by the standards recommended by the International Hydrographic Organization, this sounder remained for a long time the only shallow-water multi-beam sounder qualified as hydrographic [KERLÉGUER, 1993]. The relative priority given to shallow waters was counterbalanced, at the end of the 1980s, by an increased need for precise deep-water data and, in 1993, SHOM acquired a sounder intended to describe deep waters, developed by the Simrad company. This sounder was installed aboard *L'Espérance* and its performance was the subject of detailed studies [TONCHIA, 1996].

Detection of obstructions

The primary aim of hydrography is to guarantee the safety of conditions for navigation. It is not the morphology of the seabed which is essential, but in fact the determination of the highest points, whether natural (rock, coral needle, ...) or artificial (obstacles, wrecks, ...). For the former, a knowledge of the conditions of geological continuity may be useful to anticipate certain bottom rise, but in the latter case their accidental nature in no way allows one to have any indication of their existence by sounding (apart from a lucky 'direct hit').

For such searches for obstructions, referred to as "*search for obstructions*", hydrographers for a long time used floating drags, the first model of which was made by Renaud in 1884 and the type of which was constantly perfected and simplified [RENAUD, 1902]. In addition, to obtain a precise estimate of the object detected by the drag, FICHOT [1908-09-10] employed as from 1908 underwater divers to find the summits of rocks in the Cherbourg passes, but that process, extremely demanding in material and personnel, remained exceptional, until the arrival of autonomous wet-suits and aqua-lungs after the second world war. Different types of drags were, on the other hand, used with success by the hydrographic units until the end of the 1960s. Several hydrographic engineers adapted or invented mechanical devices enabling a 'cleared depth' to be checked [BRUNEL, 1935-36]. Use of the drag called "*American*" became general. Even the hydrographic wreck-seeking unit (1949-69) which had at its disposal a sonar (asdic) resorted to its use systematically [ROLLAND de CHAMBAUDOIN d'ERCEVILLE, 1951].

In 1969, the Service acquired first, a prototype of a side-scan sonar echo sounder developed by the French Petroleum Institute, trials of which proved to be disappointing [ROUBERTOU, 1973-75], before opting for a series of items of equipment of smaller size but whose performance was at once judged promising: the side-scan sounders of EG&G [BONNOT, 1978, op. cit.]. Certainly, the service was not at the origin of the development of this equipment, but very numerous studies were made to qualify it, define a doctrine for its use, and estimate its performance [CAILLIAU, 1988; CHIMOT and DUPUY, 1990]. In 1988, a hydrographic sonar derived, as specified by SHOM, from a Thomson mine-hunting sounder, was installed by that firm aboard the *Lapérouse* [CHIMOT, 1992].

While at the same time diversifying its acoustic means of detection, SHOM rapidly took advantage of the development of nuclear resonance magnetometers for the observation of magnetic anomalies resulting from the induced magnetising of metallic objects such as wrecks or cables and the study of theoretical conditions of detection, in particular according to the depth and the size of such objects [COMOLET-TIRMAN, 1976; SCHRUMPF, 1980].

Remote sensing

To prepare this essential hydrographic task which is the search for obstructions, RENAUD [1902, op. cit.] proposed the use of captive balloons for detecting obstructions by sight, so as to carry out a general reconnaissance of the area to be surveyed: "*if one rose in a balloon to a certain height, the shots taken from the nacelle [...] would give an initial idea of practicable channels, would facilitate the preparation of sounding, and would subsequently provide the means of checking regular surveying*". This idea was taken up again after the first world war had shown the very effective use that could be made of reconnaissance planes equipped with a camera. One issue of the Hydrographic Annals was devoted in 1917 to the theoretic study of the exploitation of photographs taken from the air. But such work essentially concerned what was above water and shown on the picture. VOLMAT [1919-20] considered the conditions of use of photographs for hydrographic work in shallow water. In his remarkable report on the photo-hydrographic unit that he directed in the approaches to Brest, he noted practical facts such as the right flight altitude, the optimal height of the sun, or the fitting out of the seaplanes to carry a camera, as well as considerations on the possibilities of detecting bottom rise of the seabed: practical depth, appearance of the seabed, presence of tide rips, swell diffraction. Stereoscopic examining is mentioned but, as he notes: "*in the* *region explored, the rock shelves [...] do not give any clear sense of relief*". It was necessary to wait for another sixty years before obtaining such "*sensing*", when analytic stereocompilation made it possible to take into account refraction at the passage of the air-sea diopter. The immediate consequence of VOLMAT's work was to double all hydrographic survey units with the addition of air-photography reconnaissance of the area to be surveyed, carried out by seaplanes of the maritime aeronautical service for the coasts of France or the military aeronautical service, for the "*colonies*" [COT, 1922].

After the second world war, the use of air photographs was limited to the description of the coastline from photos taken by the (French) National Geographic Institute - or simply to the maps of that Institute - and it was only in the 1980s that the photogrammetric activity of the Service assumed new importance [BONNOT, 1982]. The piloting of analytic stereoplotters by a computer enabled one, firstly, to take advantage of the precise radio-electric positioning system of the plane taking the photographs for the setting up of models [CHIMOT and LE GOUIC, 1986; 1988], and secondly, to take into account the refraction at the passage of air-sea diopter for the stereoscopic evaluation of spot heights under the water. The precision of this evaluation was studied, based on various photogrammetric flights carried out under very strict conditions: position-fixing of the plane, local modelling of the tide, precise time slots resulting from the height of the water and that of the sun, flight profiles minimising specular reflection effects, etc. [EVEN, 1997]. As is very often the case in hydrography, the result shows favourable situations where the bathymetry is well compiled and other situations where distortions are not negligible. Nevertheless, from 1984, resorting to photogrammetric compilation, if only to describe the intertidal zone in fine detail, became systematic again for the preparation of hydrographic surveys, the creation of cartographic compilations or the preparation of military operations in coastal areas.

The American Landsat satellites made it possible at the end of the 1970s to rise higher than Renaud's captive balloons. The mediocre spatial resolution of the first three Landsat satellites only permitted the exploitation of the following generation of satellites to be prepared. The Hydrographic Service took part in 1984 in the campaign for pre-evaluation of the French SPOT satellites by airlifted simulation, then rapidly integrated the techniques developed to exploit the first operational images in its portfolio of marine charts. The methods were original for two reasons. From a technical point of view, the exploitation of the images furnished by the observation satellites was normally done according to a logic of ground coverage, whereas at SHOM there was an estimated quantification of the bathymetry in shallow-water areas. Moreover SHOM was (and remains) the only Hydrographic Service to include in its portfolio of original charts, information very directly derived from satellite imagery: certainly, a note on the reliability and the accuracy of the information invites the mariner to be cautious, but it was a step difficult to take because of the special nature of marine charts - official documents where the reliability of information is of prime importance.

Geophysics

In the 19th century, hydrographers' geodetic work was generally adapted to the local needs of a survey. However, the fact that the local figures were based on astronomical observations resulted in a lack of homogeneity over long distances.

In 1885, GERMAIN [1886] considered that the differences between the relative astronomical positions of Nice and Toulon and those deduced from the triangulation carried out in 1842 by BEGAT on the south coasts of France were largely due to the shape of the geoid and therefore to the fact that the physical verticals did not coincide with those of a model based on an ellipsoid. If PIROT [1923-24] took up Germain's work again between 1921 and 1923, it was as much to study the amazing possibilities of the prismatic astrolabe as for dealing with the deviation of the verticals. It was necessary to wait until GOUGENHEIM [1940-45] had stressed the significant deviations of the verticals in the islands of the Pacific before the Hydrographic Service endeavoured to make the systematic corrections to the vertical necessary for homogeneity between the astronomical positions of the islands in French Polynesia [NAY, 1951; VALLAUX, 1954].

Knowledge of the geoid, more generally, supposed that one had access to observations regularly distributed over the earth and therefore that it was possible to carry out measurements of the intensity of the gravity field at sea. The Hydrographic Service quickly became associated with the work of the International Union of Geodesy and Geophysics, in particular with two campaigns carried out aboard the submarines *Fresnel* (1933-34) and *Espoir* (1936) in the course of which, under the direction of the tireless MARTI, the device developed by Vening-Meinesz [ANTHOINE, 1947] was put to use. Early in the 1960s, instruments derived from land gravimeters appeared, in which the action of gravity on a mass was balanced by a spring. The Hydrographic Service acquired an Askania gravimeter in 1962 which was installed aboard the *Amiral Mouchez*. Performances and sources of error were studied in detail [COMOLET-TIRMAN, 1967-68], which enabled good quality measurements to be rapidly obtained.

Tides

Whether it is a question of observing them or predicting them, tides in France have always been a key feature of the Hydrographic Service. A chronological extract from the list of papers published in the Hydrographic Annals gives an idea of the considerable effort devoted by the Service to the analysis and prediction of tides over 150 years: *determination of the various waves, the whole of which constitute the tide* [CHAZALLON, 1852], *report on the tides in Cochinchine* [HÉRAUD, 1872], *decomposition of the tide into elementary waves* [HATT, 1878], *harmonic analysis of tidal observations* [HATT, 1893], *harmonic analysis of a short period of observation and calculation of tidal prediction tables* [ROLLET DE L'ISLE, 1896], *note on tidal prediction by calculation using the harmonic formula* [COURTIER, 1908-09-10], *on the application of Laplace's formula to the calculation of tides at Brest* [GOUGENHEIM, 1949], *determination of tides on the high seas based on tidal currents - application to tides in the Channel (between Cherbourg and Fécamp)* [LACOMBE, 1949], *charts of cotidal lines in the oceans* [VILLAIN, 1952], *the method of concordances and harmonic analysis by approximate constants* [EYRIÈS, 1956], *the tide rips of a construction in a tidal sea* [VANTROYS, 1957], *mean sea level - calculations of the daily mean level* [DEMERLIAC, 1974], *noise in tidal analyses* [DESNOËS, 1977], *tidal analysis and prediction - application to the tides of Le Havre and Brest* [DESNOËS and SIMON, 1977], *properties of continuous and invariant systems by translation subjected to periodical component entries - application to a global tidal prediction formula* [DESNOËS, 1978], *principles applied and methods used to draw up permanent tables of water levels* [PASQUAY, 1978a], *study of the variation of the mean level in the Channel* [SIMON, 1979], *analysis of 19 years' tidal observations at Brest* [SIMON, 1980], *prediction of the tides at Brest* [SIMON, 1982], *determination of extreme water levels for the delimitation of the public maritime zone* [SIMON, 1996]. This theme was also the subject of close cooperation with research bodies, notably the Mechanics' Institute of the University of Grenoble, to which the Hydrographic Annals opened wide their columns from 1976 to 1991.

The first series of tidal observations made early in the 19th century were done by reading a carefully levelled tide pole. CHAZALLON made a notable addition by the exactitude of data in bringing the water to record its own height and thus shielding against forgetfulness or possible errors on the part of observers. The first tide gauge imagined by CHAZALLON was installed at Brest in 1846: it served as a model for those quickly installed in ports along the west coast: Cherbourg, Le Havre, Saint Nazaire, Saint Malo, La Rochelle, Rochefort, etc. These installations meant that the tide was studied only close to the coasts. Considering the scientific value of observation on the high seas, removed from the influence of the shape of the coastline and variations in depth in approaching the shore, FAVÉ imagined, as early as 1887, a tide gauge which might be submerged at a particular depth and record the variations in sea level [FAVÉ, 1908-09-10; 1921]. The equipment was intended to study tides out at sea, but also to take the place of readings on tidal poles when the profile of the coastline made that difficult, or when continuous observations at night were deemed necessary. Unfortunately, recovery of the instruments was rather uncertain and they were frequently lost, which resulted in restricting their use and a diminution of the stock being used. Early in the 1960s, interest was renewed in the study of ocean tides, which it had not been possible to observe until then. A description of the problem and the characteristics of its solutions were presented by EYRIÈS in 1967 after the first operational instrument, the AFEGPO tide gauge, built to the specifications of the Hydrographic Service by the Telemac company, had made it possible to carry out the world's first measuring of the tide in very deep waters.

After the second world war, portable tide gauges appeared, recording on a continuous graph. These tide gauges equipped the stations of the Service's permanent observation network. Since 1990, they have been progressively replaced by digital equipment, the observations from which are transmitted to the establishment at Brest by telematic liaison. Portable tide gauges were also installed by survey units for the reduction of bathymetric soundings. However, as FAVÉ had sensed, the accuracy sought today for depth measurement led to observation of the tide close to areas where work was taking place, and therefore with the help of submerged tide gauges. The first modern instruments of this type used analogic recording on paper of the pressures observed. The most recent ones have digital memories which can be consulted by computer liaison. SHOM's hydrographic engineers largely helped the industry to master the various parameters influencing measurement [BATANY et al., 1991; LEBRETON et al., 1991]. Today, the combination of digital tide models and measurements effected out at sea by submerged pressure recording tide gauges makes it possible to calculate the astronomical tide at any point of the continental shelf of the French mainland with an accuracy at least satisfactory for the needs of hydrography [SIMON, 1990].

Coastal hydrodynamics

Knowledge of currents is necessary for navigation. Until the second world war, most of the observations were taken on the surface, either by observing from a mooring the length and the course of a streamed line for a precisely determined length to time [CASPARI, 1888], or by following the movement of slightly submerged parachute drogues [RENAUD, 1895]. Sometimes recourse was made to throwing floating bottles into the sea with a note inside for the person who found them: exploitation of integrated current observations was limited to a mere recapitulation of the points of departure and arrival(7) [Anonymous, 1894; 1902], Finally, much information was gathered by ships' captains themselves, who noted differences between the route prescribed and that really observed. Such information enabled great ocean currents to be described, but sometimes also certain effects of tidal streams [SALOMON, 1915].

As is often the case, the capacity for current measurement was developed by industry after the second world war and the Hydrographic Service was generally content to use the products available without having been involved in their development, as was the case for tide gauges.

The processing of discrete current observations remained rudimentary for a long time. That was probably due to the fact that the information supplied to mariners consisted of an indication of speed and direction of currents at well-defined periods in relation to the tide, and the fact that this information was obtained quite directly by means of measurements taken to this effect. Computers revolutionised the manner of approaching the study of currents: it is now possible to envisage direct calculation based on hydrodynamic equations by digital modelling. Moreover, as from 1973, computer processing enabled surface currents to be determined by comparing the dead reckoning and the precise radio position-fixing of sounding vessels [PASQUAY, 1978b].

Nature of the seabed

When bathymetric soundings were carried out using a lead-line, the latter was covered in tallow so that the print in the tallow guaranteed that the bottom had been reached; the sediment adhering thereto was systematically described and its type, colour, and if possible the size of its granules, were noted. All this sediment data, obtained in great quantities (up to 400 samples per square kilometre close to the coast), made it possible to make plotting sheets of the nature of the seabed already by the mid-19th century. Few papers were published on the subject in the Annals, with the exception of a study by LAROUSSE [1871] on the mouths of the Nile.

The sedimentology activity of Hydrographic Service really began in the 1980s by reason of two circumstances. Firstly, with the increase in the draughts of commercial vessels, the sand dunes in the Straits of Dover and in the southern part of the North Sea became a danger, the mobility of which had to be checked. A strategy of periodic surveys was planned with the Hydrographic Services of the countries bordering the area (Belgium, Holland, United Kingdom) and various studies to understand and appreciate the extent of the movement of the dunes were undertaken and are still continuing today. Secondly, the national Navy expressed significant requirements as regards knowledge of sedimentology for mine-searching operations and for the mastery of the conditions of propagation of acoustic signals. This expressed need coincided with the appearance of new acoustic tools enabling

7 This observation strategy was re-launched in the 1970s using floating cards. This time, computers would have made processing possible, but too many aberrant observations led SHOM to give up the project.

the bottom surface to be described. The side-scan sounder, already referred to for its use in detecting rocks, furnished high quality imagery of the seabed, which permitted the delimitation of rocky areas, the differentiating of coarse and fine sand, and the description of sediment structures; such imagery is today also offered by multi-beam sounders [TONCHIA, 1996, op. cit.]. The RoxAnn system processes acoustic signals transmitted by vertical bathymetric sounders and reflected off the bottom; discrimination is made, after initiation, by analysing the roughness and hardness of the bottom. Low-frequency sounders (3.5 kHz or less) permit one to obtain very high resolution sismic profiles [CHIMOT et al., 1998].

Exploitation of data in the survey units

At the time of Beautemps-Beaupré, graphic construction by the subtense method of what was observed during a survey required a protractor and a compass. In 1885, BOUQUET DE LA GRYE made known and recommended a more precise process which consisted in constructing two points in the neighbourhood of the position sought and assimilating, in this neighbourhood, the segment arc with its chord. For a large number of stations, DRIENCOURT, in 1898 had recourse to the prior graduation of the perpendiculars on which were shown the centers of the curves, varying uniformly. The procedures of BOUQUET DE LA GRYE and DRIENCOURT were still employed after the second world war and only disappeared when radio-electric methods of position-fixing and calculators became generally used. Once the positions were determined, for a long time the sounding figures, corrected for the error arising from the lead line and the tide, were shown on sheets of paper stuck onto canvas to prevent them deteriorating too quickly. The aim was to conserve as many sounding figures as possible. Rocks and isolated dangers were shown on "*rock construction*" plotting sheets. All of these principles (redundant position-fixing, representation on non-perishable medium, reduction of instrument errors, reduction of tide, etc.) formed the basis of the "*data processing*" work at the Hydrographic Service.

Before the arrival of computer facilities in the 1980s, these manual methods were preserved, although developments were noted. Early in the 1970s, the points of radio-electric positions were traced beforehand by the computer and the hydrographer constructed an interpolation by hand between these points; the bathymetric details were next inserted, not in attempting to obtain as many soundings as possible, but in making a judicious choice among all those collected (analogic recording of sounders), taking into account the morphology of the seabed and the necessity of showing only real soundings and not interpolations. Sometimes the position-fixing was entirely processed by computer (after laborious filling up of printouts later entered onto punched cards), but manual intervention was preponderant. The first computer tool used to prepare this compilation was a system called SATAD (system of acquisition and automated processing of data) carried aboard the *D'Entrecasteaux* in January 1975 [DEMERLIAC, 1979]. This system met with strong reticence on the part of the directorate of SHOM and of users because it was not sufficiently reliable. It remained at the stage of an operational prototype used only by the Atlantic Oceanographic Unit, but it did prove the feasibility and above all the value of an entirely digital procedure for the piloting and editing of hydrographic surveys, and permitted the refining of various algorithms related to position-fixing, digitization, and the pursuit of sounder echoes, as well as the filtering of parasite movement such as heave. The experience acquired with SATAD gave rise to the conception, early in the 1980s, of a new generation of computer equipment, this time to equip all the units of SHOM. This system was called HYDRAC (for data acquisition) - HYTRAI (for data processing). A basic version was developed at the computer centre at SHOM's "Etablissement principal". It was subsequently optimised by users during campaigns [BOULARD, 1991; GAILLARD, 1992; BESSERO, 1992; 1996, op.cit.].

The SATAD and HYDRAC-HYTRAI systems, and now the new generation AQIDOC-TRADOC are intended for the exploiting and editing of hydrographic surveys carried out with the equipment commonly used by the hydro-oceanographic units. When specific sensors are used, pragmatism prevails and one does not seek to integrate the exploitation algorithms into the common chains. Several developments deserve mention, such as the "CTD" software perfected for hydrologic profiles [VENNEL et al., 1988] or the software for processing multi-beam sounding data [TONCHIA, 1996, op.cit.].

EXPLOITATION OF DATA IN NAUTICAL PRODUCTS

From the founding of the Service until the second world war, cartographic technology had practically not varied:

i. most of the symbols used were those adopted by Beautemps-Beaupré [ROLLET DE L'ISLE, 1950],
ii. the plotting sheets compiled after the work of hydrographic surveying were intended uniquely for the nautical chart; such surveys were, moreover, for the largest scales, often carried out at the scale of the future chart. Symbols, especially for topography, were therefore very similar to those of the nautical chart and the engraver often used the final plotting sheets directly, accompanied by an overlay on which were shown the sounding figures and isobaths selected.
iii. When the publications were not at the scale of the compilation, or for the assembling of documents at various scales (including foreign charts), a photographic reproduction whose details had become too small because of the reduction in scale and had been re-drawn by the draughtsman was handed to the engraver.
iv. These documents were accompanied by a projection with spot heights and by a publishing sheet containing the information necessary for publication (title, scale, tide, declination).
v. the copper plates were engraved by line-drawing specialists and by lettering specialists before printing, which was, moreover, very slow (about a dozen copies per hour).

The first important development which occurred after the second world war concerned point v): copper engraving. A resistant and little-warping medium of plastic material permitted, first, the transfer from the copper plate to zinc printing plates via a plastic film impregnated with the ink carried on the plate and obtained by pulversisation, and thus to attain printing speed greatly superior to that possible with line-engraving. Next, for publications, it permitted direct scribing of the lines into a prepared coating on the scribing medium and creating lettering by fixing stickers cut from sheets of thin plastic and printed beforehand according to the sizes desired. Masks of colour, flat or screened, could be reserved.

The second important development was that of computers. By piloting a plotter, it was rapidly possible to scribe various linear geometric features of the chart such as the border or the grids. To go further in the automatisation of line drawing, the service developed, in the mid-1970s, an original system of digitisation of depth curves called CARTAS (CARTographie ASsistée). The system was ambitious for the time because it was a matter of, on the one hand, piloting by computer the automatic movement of a photo-electric cell drawing curves on the negative of a document lit from behind, and, on the other hand, creating, maintaining and exploiting a base of vector data. The CARTAS system remained at the stage of a prototype, but it enabled the Hydrographic Service to enter the world of digital geographic information very early and to perceive its rich possibilities. This was extended during the 1980s by the setting up of digital data bases concerning a lot of information used on marine charts, an embryo of SHOM's geographic information system which was to be born in the early 1990s [LE FRANC, 1997].

Alongside this abundant creation of digital information it was necessary to develop the tools with which to manipulate, to supplement and to compile it. The aim was an ambitious one, because it meant that it was necessary to:

develop a veritable library of symbols and characters, coherent with the international standards adopted by the service in 1985,
perfect the associated software for graphic compiling,
develop a high-precision plotting table, capable of flashing directly onto film, with the aid of a cathodic head, any symbol, character, or depth curve previously defined in digital form,
develop software for digitising on a large-format table graphic data intended to supplement those already archived in digital files.

This system, prosaically named a first-generation interactive cartographic workstation (PCI 1), was to be rapidly disseminated within the cartographic section. It was doubly successful because it represented, of course, a complex development but above all it was the appropriation by all cartographers of a totally new approach to the nautical chart: the information is not a symbol but an object, in the computer sense of the term [SOUQUIÈRE AND FICHANT, 1989]. The PCI 2 (successor of PCI 1) pursued this essential evolution. It is no longer sufficient to use digital information for the creation of graphic documents but for the creation of products that are themselves digital - electronic charts.

From 1988, an electronic chart was developed to assist the hydrographic surveys conducted with the hydrographic exploration sonar aboard the hydrographic vessel *Lapérouse* [CHIMOT, 1992, op.cit.]. But the electronic chart that must now be considered is the result of intense international concertation, in which SHOM is engaged, with regard to the adoption of standards and the supply of data [LE FRANC, 1997, op.cit.], and also with regard to the implications concerning the responsibility of hydrographic offices [BESSERO, 1997].

OCEANOGRAPHY

Oceanography is a young discipline which grew rapidly after the second world war. In the case of the Hydrographic Service (which became SHOM in 1971 after the symbolic adding of the 'O' for *"oceanographic"*), the objective of oceanography is today military : that is, the physical knowledge and understanding of the ocean environment necessary for the conception and use of naval weapons systems.

Hydrographers have always been very directly concerned with the first aim, even if their primary objective is not knowledge for military use, but the application of such knowledge for the safety of navigation. MARTI's echo sounders were a considerable asset in the success of CHARCOT's campaigns [1930, op.cit.], the first French campaigns qualified as oceanographic [BOURGOIN, 1998].

In taking part in the developments in the various domains that we have spoken of - tides, hydrodynamics, nature of the seabed, bathymetry, gravimetry, topography, etc. - hydrographers have acquired considerable expertise to satisfy part of the military needs as regards acoustic applications, mine warfare, or amphibious operations. Part of the needs only, because if almost all the parameters necessary are covered by the field of hydrography, it is also necessary to interpret hydrographic information in *operational* terms.

Before the appearance of sonars, the study of water masses had only been approached in the Hydrographic Service essentially through navigation. As for meteorology, it was the subject of many articles published in the Hydrographic Annals and dealing principally with violent phenomena such as waterspouts, cyclones or hurricanes [KELLER, 1848-49]. After the second world war, the Hydrographic Service, perceiving the potential military interest of oceanography, and aware that no serious development was envisageable in France so long as physical oceanography was inexistent on a civilian level, contributed actively to its rapid development.

The creation of a bureau of oceanographic studies (BEO) in 1960 was an important turning point in the history of the Hydrographic Service, since the BEO represented, as it were, its first component devoted to oceanography. Its objectives were to ensure the correct carrying out of oceanographic observations, to sort and exploit the data collected with a view to forecasting the acoustic conditions, and to monitor the perfecting and evaluating of new measuring instruments [RIBET, 1972]. In this latter field, once again hydrographers quickly took advantage of equipment developed by industry [BONNOT, 1972] and developed their own tools when these did not yet exist, such as the SAMO (autonomous probe for oceanographic measurements), the MET (remote-controlled multi-sampler which was a precursor of the present *multiple sea sampler*) or a 'under water vehicle' towed at variable depths of immersion, an ancestor of the 'Sea Soar' of the 1990s. Apart from its 'routine' activity of collecting and processing hydrological and geophysical data, the BEO participated between 1962 and 1970 in about a dozen large international oceanographic campaigns both in the Mediterranean and in the Atlantic [VICARIOT, 1979].

The BEO was succeeded by an oceanographic unit for the Mediterranean in 1971 [BONNOT, 1978, op.cit.], marking, with the construction of the

D'Entrecasteaux [COMOLET-TIRMAN, 1976, op.cit.], the strengthened involvement of the Hydrographic Service in the field of oceanography. Certainly, the means available were not immediately on a level with the ambitions and in particular the rhythm of oceanographic campaigns was appreciably reduced. The noted insufficiency of the measurements obtained in the course of routine observations for evaluation of the models of evolution of the thermocline led SHOM to conduct, nevertheless, three oceanographic campaigns, increasing in extent and examplary because they foreshadowed the importance of means employed to approach the complexity of the ocean environment, even for specially pin-pointed phenomena. These three campaigns concerned, in fact, the autumnal behaviour of the seasonal thermocline in the Bay of Biscay : Thermocline 1977, the aim of which was to highlight the dissipation of this seasonal thermocline; ENVAT 1981, to study the oscillation of the thermocline and differentiate its structure between abyssal areas and those on the continental shelf; and ONDINE 1985, for the study of internal waves and tide [CHIMOT et al., 1998, op.cit.]. At the same time, a joint research office was developed between SHOM and the national meteorological office (BRESM) on the ocean-atmosphere link [SAUVEL, 1986].

It was, however, not until 1990 that means permitted a coherent ensemble of campaigns at sea, associations with civil research bodies and the development of study offices were put into place. A military oceanographic centre, responsible for the chain of military oceanography, was created at SHOM and allotted means in manpower and finance that were finally significant. Actions are carried out in close association with French civil oceanographers and in cooperation with foreign partners. The fields covered are vast, from research work on the modelling of ocean basins or phenomena such as internal waves to instrumentation and its deployment (acoustic tomography, lagrangian floats) or to the conducting of complex oceanographic campaigns [CHÉRUBIN et al., 1997; CHÉRUBIN, 1997; CHIMOT et al., 1998, op.cit.]. Satellites (which allow regular observation of the ocean surface) and computer science (algorithmic processing or data bases) are, here too, essential tools.

References

ALLARD M.-P. - Ellipses et hyperboles géodésiques. Annales hydrographiques, 3ème série, tome 19, 1947, p. 189 à 209.

ANONYME - Courants dans le Golfe de Gascogne. Annales hydrographiques, 2ème série, tome 16, 1894, p. 90 à 91.

ANONYME - Résultats d'expériences sur les courants au large d'Ouessant et du cap Finisterre et à l'entrée du détroit de Gibraltar. Annales hydrographiques, 2ème série, tome 24, 1902, p. 160 à 166.

ANTHOINE G. - Détermination de l'intensité de la pesanteur en mer. Annales hydrographiques, 3ème série, tome 19, 1947, p. 179 à 187.

BATANY C., HUET M., KERINEC J.C., LEBRETON B. - Évaluation des marégraphes SUBER en présence de courants forts. Annales hydrographiques, 5ème série, vol. 17, 1991, n° 764, p. 45 à 53.

BESSERO G. - Mission hydrographique de l'Atlantique (12 octobre 1987-7 septembre 1988). Annales hydrographiques, 5ème série, vol. 18, 1992, n° 765, p. 167 à 243.

BESSERO G. - Mission océanographique de l'Atlantique (janvier-septembre 1987). Annales hydrographiques, 5ème série, vol. 20, 1996, n° 767, p. 77 à 162.

BESSERO G. - La responsabilité des services hydrographiques. Annales hydrographiques, 5ème série, vol. 21, 1997, n° 768, p. 119 à 127.

BONNOT J. - Bathysonde Howald, utilisation, mise en œuvre et procédures d'étalonnage. Annales hydrographiques, 4ème série, tome 18, 1972, p. 333 à 381.

BONNOT J.F. - Mission hydrographique de dragage (février 1972 - août 1972) et Mission océanographique de Méditerranée (août 1972 - novembre 1975). Annales hydrographiques, 5ème série, vol. 6, fasc. 3, 1978, n°750, p. 79 à 183.

BONNOT J.F. - Contribution des aéronefs et de la photogrammétrie à la résolution de problèmes courants en hydrographie et cartographie marine. Revue hydrographique internationale, vol. LIX, n° 2, 1982, p. 133 à 152.

BOULARD M. - Mission océanographique de l'Atlantique (13 décembre 1980 - 13 juin 1982). Annales hydrographiques, 5ème série, vol. 17, 1991, n°764, p. 57 à 114.

BOUQUET DE LA GRYE A. - Exploration du plateau de Rochebonne. Annales hydrographiques, 1ère série, tome 16, 1859, p. 645 à 653.

BOURGOIN J. - Mission hydrographique de la côte ouest d'Afrique. Annales hydrographiques, 4ème série, tome 10, 1959-60, p. 127 à 193.

BOURGOIN J.-B. Les annales hydrographiques. Annales hydrographiques, 5ème série, vol. 22, 1998, n° 769, p. 35 à 51.

BRIE R. - Mission hydrographique de France et d'Algérie. Mission hydrographique des côtes de France (mars 1961-février 1963). Annales hydrographiques, 4ème série, tome 15, 1969, p. 1 à 81.

BRUNEL A. - La drague hydrographique M-1931. Annales hydrographiques, 3ème série, tome 14, 1935-36, p. 109 à 122.

CAILLIAU E. - Mission océanographique du Pacifique (mai 1978 – mai 1980). Annales hydrographiques, 5ème série, vol. 15, 1988, n° 762, p. 43 à 186.

CASPARI E. - Exploration hydrographique du chenal du Four en 1887. Annales hydrographiques, 2ème série, tome 10, 1888, p. 272 à 290.

CHARCOT J.-B. - Rapport sur l'utilisation du sondeur acoustique MARTI. Annales hydrographiques, 3ème série, tome 10, 1930, p. 15 à 20.

CHATEL G. - Mission hydrographique des côtes de France (1er mai 1947 - 31 décembre 1948). Annales hydrographiques, 4ème série, tome 1, 1950, p. 25 à 36.

CHAZALLON R. - Détermination des diverses ondes dont l'ensemble constitue la marée. Annales hydrographiques, 1ère série, tome 7, 1852, p. 163 à 176 et 315 à 338.

CHÉRUBIN L. - Processus de mélange dans l'écoulement d'eau méditerranéenne sur le talus ibérique. Annales hydrographiques, 5ème série, vol. 21, 1997, n° 768, p. 99 à 105.

CHÉRUBIN L., SERPETTE A., CARTON X., PAILLET J., CONNAN O., MORIN P., ROUSSELET R., LE CANN B., LE CORRE P. LABASQUE T., CORMAN D., POETE N. - Analyse descriptive de l'hydrologie et des courants sur le talus ibérique de Gibraltar au cap Finisterre. Annales hydrographiques, 5ème série, vol. 21, 1997, n° 768, p. 66 à 81.

CHIMOT J.M. - Étude de la doctrine d'emploi d'un sonar d'exploration hydrographique marine (SEHM). Annales hydrographiques, 5ème série, vol. 18, 1992, n° 765, p. 33 à 64.

CHIMOT J.-M., DUPUY P.-Y. - Évaluation du sondeur latéral numérique Edgerton 260. Rapport d'étude n° 7/90, SHOM, 1990.

CHIMOT J.M., LE GOUIC M. - Localisation d'un avion au cours de missions photoaériennes. Annales hydrographiques, 5ème série, vol. 14, 1986, n° 761, p. 33 à 40.

CHIMOT J.M., LE GOUIC M. - Localisation d'un avion de prise de vues aériennes (II). Annales hydrographiques, 5ème série, vol. 15, 1988, n° 762, p. 25 à 30.

CHIMOT J.-M., MOUSCARDÈS P., BISQUAY H., GRENARD P., GUILLAM Y. - Levés hydrographiques et campagnes océanographiques : évolution, état de l'art et perspectives. Annales hydrographiques, 5ème série, vol. 22, 1998, n° 769, p. 133 à 178.

COMOLET-TIRMAN A. - Mission hydrographique de l'Atlantique Sud (25 juin 1959-12 février 1961. Annales hydrographiques, 4ème série, tome 12, 1963-64, p. 155 à 300.

COMOLET-TIRMAN A. - Rapport sur l'étude du gravimètre marin Askania GSS 2, n° 15 (mai 1965). Annales hydrographiques, 4ème série, tome 14, 1967-68, p. 297 à 388.

COMOLET-TIRMAN A - Mission océanographique de l'Atlantique (avril 1971-octobre 1972), Annexe II : " note sur les anomalies du champ magnétique total créées par les épaves ". Annales hydrographiques, 5ème série, vol. 4, fasc. 1, 1976, n° 743, p. 80 à 93.

COT D. - Rapport au sujet de l'emploi des photographies aériennes par le service hydrographique de la marine française. Annales hydrographiques, 3ème série, tome 5, 1922, p. 185 à 195.

COT D., CATHENOD H. - Note sur quelques procédés de sondage. Annales hydrographiques, 3ème série, tome 5, 1922, p. 202 à 207.

COURTIER A. - Note sur la prédiction des marées par le calcul à l'aide de la formule harmonique. Annales hydrographiques, 2ème série, tome 30, 1908-09-10, p. 279 à 369.

COURTIER A. - Choix d'un système de représentation pour la rédaction des levés. Annales hydrographiques, 2ème série, tome 32, 1912, p. 19 à 88.

DEMERLIAC A. - Mission hydrographique de dragage (mars 1965 - septembre 1966). Annales hydrographiques, 4ème série, tome 14, 1967-68, p. 265 à 294.

DEMERLIAC A. - Le niveau moyen de la mer - calcul du niveau moyen journalier. Annales hydrographiques, 5ème série, vol. 2, fasc. 1, n° 741, 1974, p. 49 à 57.

DEMERLIAC A.. - Mission océanographique de l'Atlantique (octobre 1974 - septembre 1975). Annales hydrographiques, 5ème série, vol. 7, fasc. 3, n° 753, 1979, p. 67 à 82.

DESNOËS Y. - Le bruit dans les analyses de marée. Annales hydrographiques, 5ème série, vol. 5, fasc. 2, n° 747, 1977, p. 31 à 46.

DESNOËS Y. - Propriétés des systèmes continus et invariants par translation soumis à des entrées à composantes périodiques - application à une formule globale de prédiction de la marée. Annales hydrographiques, 5ème série, vol. 6, fasc. 1, n° 748, 1978, p. 15 à 17.

DESNOËS Y., SIMON B. - Analyse et prédiction de la marée - application aux marées du Havre et de Brest. Annales hydrographiques, 5ème série, vol. 5, fasc. 2, n° 747, 1977, p. 47 à 62.

EVEN M. - Bilan de l'évaluation des possibilités de la photobathymétrie. Annales hydrographiques, 5ème série, vol. 21, 1997, n° 768, p. 107 à 112.

EYRIÈS M. - La méthode des concordances et l'analyse harmonique par les constantes approchées. Annales hydrographiques, 4ème série, tome 7, 1956, p. 357 à 385.

FAVÉ L. - Marégraphe plongeur. Annales hydrographiques, 2ème série, tome 30, 1908-09-10, p. 383 à 415.

FAVÉ L. - Marégraphe plongeur - appareil enregistrant les marées sur les côtes . Annales hydrographiques, 3ème série, tome 4, 1921, p. 193 à 237.

FICHOT E. - Reconnaissance hydrographique de la passe ouest de la rade de Cherbourg en 1908. Annales hydrographiques, 2ème série, tome 30, 1908-09-10, p. 371 à 378.

FICHOT E. - Rapport sur les travaux géodésiques effectués par le service hydrographique de la marine. Annales hydrographiques, 3ème série, tome 4, 1921, p. 63 à 75.

GAILLARD J.-C. - Mission océanographique de la Méditerranée (6 octobre 1985 - 1er septembre 1988). Annales hydrographiques, 5ème série, vol. 18, 1992, n° 765, p. 89 à 166.

GERMAIN A. - Détermination de la déviation de la verticale sur les côtes sud de France. Annales hydrographiques, 2ème série, tome 8, 1886, p. 119 à 176.

GOUGENHEIM A. - Les corrections des sondages au plomb-poisson. Annales hydrographiques, 3ème série, tome 15, 1937, p. 77 à 96.

GOUGENHEIM A. - Sur la déviation de la verticale à Tahiti. Annales hydrographiques, 3ème série, tome 17, 1940-45, p. 205 à 208.

GOUGENHEIM A. - Sur l'application de la formule de Laplace au calcul des marées à Brest. Annales hydrographiques, 3ème série, tome 21, 1949, p. 321 à 324.

GOUGENHEIM A. - Sur une nouvelle famille de planisphères conformes. Annales hydrographiques, 4ème série, tome 1, 1950, p. 169 à 186.

GOUGENHEIM A. - Une nouvelle méthode d'astronomie géodésique : la méthode des droites d'azimut. Annales hydrographiques, 4ème série, tome 2, 1951a, p. 209 à 226.

GOUGENHEIM A. - Sur une généralisation des mappemondes. Annales hydrographiques, 4ème série, tome 2, 1951b, p. 177 à 188.

GUYON J.-C. - Évaluation du réseau Sylédis-Bretagne (1981-83). Annales hydrographiques, 5ème série, vol. 12, 1984, n° 759, p. 15 à 109.

HATT P. - Décomposition de la marée en ondes élémentaires. Annales hydrographiques, 1ère série, tome 41, 1878, p. 475 à 515.

HATT P. - Sur le choix à faire parmi les solutions multiples d'une détermination graphique de points trigonométriques. Annales hydrographiques, 2ème série, tome 8, 1886, p. 196 à 208.

HATT P. - Analyse harmonique des observations de marée. Annales hydrographiques, 2ème série, tome 15, 1893, p. 295 à 371.

HÉRAUD G. – Rapport sur le mémoire des marées de la Cochinchine. Annales hydrographiques, 1ère série, tome 35, 1872, p. 336 à 425.

KELLER F.-A.-E. – Des typhons de 1848, des ouragans obliques et des coups de vent fixe, etc. Annales hydrographiques, 1ère série, tome 1, 1848-49, p. 211 à 252.

KERLÉGUER L. - Évaluation et procédures d'exploitation du sondeur multifaisceaux Lennermor. Annales hydrographiques, 5ème série, vol. 19, 1993, n° 766, p. 37 à 49.

LACOMBE H. - Détermination de la marée au large à partir des courants de marée - application aux marées de la Manche (entre Cherbourg et Fécamp). Annales hydrographiques, 3ème série, tome 21, 1949, p. 203 à 239.

LACOMBE H. - Mission hydrographique des côtes de France et d'Afrique du Nord (1953-54). Annales hydrographiques, 4ème série, tome 8, 1957, p. 1 à 166.

LAROUSSE E. - Étude sur les embouchures du Nil et sur les changements qui s'y sont produits dans les derniers siècles. Annales hydrographiques, 1ère série, tome 34, 1871, p. 282 à 313.

LEBRETON B., DOLOU H., BATANY C., KERINEC J.C. - Évaluation des marégraphes SUBER en présence de courants forts : évaluation d'un atténuateur de dépression. Annales hydrographiques, 5ème série, vol. 17, 1991, n° 764, p. 37 à 43.

LE FRANC Y. - Production de documents et bases de données hydrographiques. Annales hydrographiques, 5ème série, vol. 21, 1997, n° 768, p. 113 à 117.

LE GOUIC M. - Mission océanographique du Pacifique, échelon de Polynésie (décembre 1988 - juillet 1990). Annales hydrographiques, 5ème série, vol. 19, 1993, n° 766, p. 77 à 124.

LE GOUIC M., LE VISAGE C. - Synthèse des résultats des campagnes de calibration du SNR LORAN C. Annales hydrographiques, 5ème série, vol. 17, 1991, n° 764, p. 31 à 36.

LESAGE G. - Mission hydrographique de Madagascar (1909). Annales hydrographiques, 2ème série, tome 33, 1913, p. 239 à 246.

LIEUSSOU J. - Recherches sur les variations de la marche des pendules et chronomètres. Annales hydrographiques, 1ère série, tome 9, 1853, p. 189 à 343.

MARTI P. - Note sur la vitesse de propagation du son dans l'eau de mer. Annales hydrographiques, 3ème série, tome 3, 1919-20, p. 165 à 178.

MARTI P. - Sondage en mer par le son aux grandes profondeurs au moyen de détonations. Annales hydrographiques, 3ème série, tome 6, 1923-24, p. 187 à 214.

MARTI P. - La sonde au plomb-poisson. Annales hydrographiques, 3ème série, tome 7, 1925-26, p. 313 à 334.

MARTI P. - Mission hydrographique sur les côtes d'Algérie et Tunisie en 1923, 1924 et 1925. Annales hydrographiques, 3ème série, tome 8, 1927-28, p. 213 à 306.

MARTI P. - Mission hydrographique de l'Indochine (juin 1928-mai 1929). Annales hydrographiques, 3ème série, tome 10, 1930, p. 153 à 193.

MILARD F. - Perspectives. Annales hydrographiques, 5ème série, vol. 22, 1998, n° 769, p. 239 et 240.

NAY G. - Mission géodésique des Tuamotu (janvier 1947 - juin 1950). Annales hydrographiques, 4ème série, tome 2, 1951, p. 1 à 31.

ORTAIS J. - Mission hydrographique de dragage des côtes de France et d'Afrique du Nord (décembre 1958-juin 1960). Annales hydrographiques, 4ème série, tome 12, 1963-64, p. 105 à 154.

PASQUAY J.-N. - Principes appliqués et méthodes utilisées pour l'établissement des tables permanentes des hauteurs d'eau. Annales hydrographiques, 5ème série, vol. 6, fasc. 1, n° 748, 1978a, p. 19 à 26.

PASQUAY J.-N. - Mission hydrographique de l'Atlantique (mai 1972 - septembre 1974). Annales hydrographiques, 5ème série, vol. 6, fasc. 1, n° 748, 1978b, p. 61 à 142.

PIROT L. - Deux années d'observations avec l'astrolabe à prisme sur la côte sud de France, en Corse, en Tunisie et en Algérie. Annales hydrographiques, 3ème série, tome 6, 1923-24, p. 111 à 167.

RENAUD J. - Note sur les courants observés aux abords de Dunkerque en 1894. Annales hydrographiques, 2ème série, tome 17, 1895, p. 109 à 110.

Renaud J. - Note au sujet de la recherche des roches sous l'eau. Annales hydrographiques, 2ème série, tome 24, 1902, p. 150 à 156.

RIBET M. - Bureau d'études océanographiques, juillet 1966-juillet 1969. Annales hydrographiques, 4ème série, tome 18, 1972, p. 1 à 40.

ROLLAND DE CHAMBAUDOIN D'ERCEVILLE I. - Mission de recherche d'épaves (1949-1950). Annales hydrographiques, 4ème série, tome 2, 1951, p. 121 à 157.

ROLLET DE L'ISLE M. - Analyse harmonique d'une courte période d'observation et calcul d'un annuaire de marée. Annales hydrographiques, 2ème série, tome 18, 1896, p. 196 à 248.

ROLLET DE L'ISLE M. - Étude historique sur les ingénieurs hydrographes et le service hydrographique de la marine. Annales hydrographiques, 4ème série, tome 1 bis, 1950, p. 1 à 378.

ROUBERTOU A. - Mission hydrographique de Madagascar (10 mai 1957 - 7 mai 1959). Annales hydrographiques, 4ème série, tome 10, 1959-60, p. 195 à 307.

ROUBERTOU A. - Rapport de la Mission hydrographique des côtes de France (octobre 1968-octobre 1970). Annales hydrographiques, 5ème série, vol. 1, fasc. 1, 1973-75, n° 740, p. 5 à 50.

SALOMON. M.L. - Étude des courants du Pas de Calais sur la ligne joignant Calais à Douvres. Annales hydrographiques, 2ème série, tome 35, 1915, p. 43 à 46.

SAUVEL J. - Partie 1. - Choix d'un modèle d'évolution à court terme de la couche de mélange océanique. Partie 2. - Test sur une utilisation opérationnelle simple d'un modèle d'évolution à court terme de la couche de mélange océanique. Partie 3. - Échelles temporelles et verticales pour la température et pour ses variations à court terme au point P (50°N, 145°W). Annales hydrographiques, 5ème série, vol. 14, 1986, n° 761, p. 41 à 65.

SCHRUMPF B. - Mission océanographique de l'Atlantique (octobre 1972-octobre 1974). Annales hydrographiques, 5ème série, vol. 6, fasc. 2, 1978, n° 749, p. 29 à 86.

SCHRUMPF B. - Recherche des épaves au magnétomètre, Annales hydrographiques, 5ème série, vol. 8, fasc. 2, 1980, n°755, p. 5 à 11.

SIMON B. - Étude de la variation du niveau moyen en Manche. Annales hydrographiques, 5ème série, vol. 7, fasc. 2, n° 752, 1979, p. 27 à 46.

SIMON B. - Analyse de 19 ans d'observations de marée à Brest. Annales hydrographiques, 5ème série, vol. 8, fasc. 1, n° 754, 1980, p. 5 à 13.

SIMON B. - Méthodes de prédiction de la marée en Gironde. Annales hydrographiques, 5ème série, vol. 9, 1981, n° 756, p. 25 à 37.

SIMON B. - Prédiction de la marée à Brest. Annales hydrographiques, 5ème série, vol. 10, n° 757, 1982, p. 33 à 50.

SIMON B. - Calculation of the tide offshore for sounding reduction. International Hydrographic Review, Vol. LXVII, No. 2, 1990, p. 149-166.

SIMON B. - Détermination des hauteurs d'eau extrêmes pour la délimitation du domaine public maritime. Annales hydrographiques, 5ème série, vol. 20, 1996, n° 767, p. 17 à 43.

SOUQUIERE P., FICHANT J. - Computer-Assisted Cartography: A Provisional but Promising Solution. International Hydrographic Review, Vol. LXVI, No. 2, 1989, p. 63-78.

TONCHIA H. - Évaluation d'un sondeur multifaisceaux grands fonds pour les levés hydrographiques. Annales hydrographiques, 5ème série, vol. 20, 1996, n° 767, p. 45 à 57.

VALLAUX F. - Mission géodésique des Tuamotu (juin 1950 - septembre 1953). Annales hydrographiques, 3ème série, tome 5, 1954, p. 89 à 116.

VANTROYS L. - Les remous d'un ouvrage dans une mer à marée. Annales hydrographiques, 4ème série, tome 8, 1957, p. 309 à 455.

VENNEL R., LE MAGUER F., LAUNO S. - ONDINE 85 : hydrologie et bathythermie réalisées à bord du bâtiment océanographique D'Entrecasteaux. Rapport d'étude n° 6/88, SHOM, 1988.

VICARIOT J. - Bureau d'études océanographiques (1er août 1969 - 15 décembre 1971). Annales hydrographiques, 5ème série, vol. 7, fasc. 2, 1979, n°752, p. 49 à 92.

VILLAIN C. - Cartes des lignes cotidales dans les océans. Annales hydrographiques, 4ème série, tome 3, 1952, p. 269 à 388.

VOLMAT J. - Rapport sur la mission photohydrographique de Brest (1919). Annales hydrographiques, 3ème série, tome 3, 1919-20, p. 191 à 220.