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Brazil Report on Physical Oceanography

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Breaking News . The Institute of Oceanography of University of Sao Paulo (Brazil),has recently acquired from NOAA (National Oceanographic and Atmospheric Administration)-USA. the "NOc Alpha Crucis", which will boost research on open waters of the Southern Tropical Atlantic.

Introduction

First participation of Brazil in International research programs on Physical Oceanography occurred during the Geophysical Year from years 1957 to 1958 of the past century. At that time, research in Physical Oceanography was mostly performed by the Brazilian Navy and many oceanographic cruises were pioneered by Admiral Paulo Moreira da Silva (FIG 1), to the Equatorial Atlantic and also to the Brazilian Southeastern coast.. With the advent of the Institute of Oceanography of the University of Sao Paulo in 1946, other scientists, as Dr Ingvar Emilsson (FIG 2),organized cruises, (1956), yet with the help of the Brazilian Navy, who provided the necessary ship time for the field work. First cruises were also directed to the Southern part of the coast and later, in the sixties, to the Western Equatorial Atlantic, in cruises organized by the International research program of EQUALANT,

Since then, many Educational Institutions were created in cities along the Brazilian coast and the number of graduated students in Physical Oceanography has increased significantly. Several government owned institutions as UERJ (Universidade Federal do Rio de Janeiro), State of Rio de Janeiro, other already existing military organizations, as the DHN (Directory of Hydrography and Navigation) of the Brazilian Navy and also recent private Institutions as the FURG, (Fundação Universidade Federal do Rio Grande), State of Rio Grande do Sul and UNIVALI (Universidade do Vale do Itajaí), State of Santa Catarina, among many others, produced then the oceanographic knowledge up to the present. .In this revised report, only the oldest academic oceanographic institution of the country is covered. in a retrospect.

Academic Research

The Institute of Oceanography of the University of São Paulo was created in the Department of Animal Production of the Secretary of Agriculture of the State of São Paulo, Brazil, in December 31st, 1946 as per State Decree number 16 685. The "Instituto Paulista de Oceanografia" was a section of the Division of Fishes and Animals of the Forests of the Department of Animal Production. Three months later, as per Decree number 16919, March 13th, 1947, its subordination was transferred to the Directory of Animal Production of the Secretary. The first attribution of the Institute of Oceanography was: "to study the physical, chemical and biological factors that influence the productivity of the sea aiming, mainly, at its economical aspect".

Four years later on December 4th, 1951 the "Instituto Paulista de Oceanografia" was incorporated to the University of São Paulo as per Law number1 310, as a Research Unity of the University, under the new name of "Instituto Oceanográfico", a position that gave it greater research autonomy.

As a Research Unit of the University, as per State Law number 5470, the Instituto acquired the possibility of offering Courses of Oceanography leading to the post-graduation of Oceanographers and training of Technical staff .In 1975 the Instituto was raised to the "status" of a Teaching Unit of the University of São Paulo and started to have ample teaching and research autonomy. In 2001, a general 5 year-undergraduate course in Oceanography started with disciplines in all (Physical, Chemical, Geological and Biological) branches of the Ocean Science.

The research work in Oceanography is carried out by means of Oceanographic Research Vessels, when sea material is collected for laboratory analysis and also *in situ* measurements of all oceanic physical, biological, chemical and geological processes. The first oceanic cruise with the participation of scientists of the "Instituto Paulista de Oceanografia" was organized to the Island of Trindade in the South Atlantic. In the early days, there were intense participation of the University people in Vessels of the Brazilian Navy such as the Solimões and Baependi. The first research vessel of the Instituto of Oceanography was the NOc Ungava, a sailing vessel adapted to the research work at sea.

The teaching activities began in 1963 and in 1968 with the post-graduate courses in Oceanography to Biologists, Physicists, Chemists and Geologists leading to Master's and Doctor's degrees, respectively.

The current infrastructure of the Institute include the Department of Biological Oceanography, the Department of Physical, Chemical and Geological Oceanography, a Library, the Oceanographic Museum , the Research Stations of Cananeia and Ubatuba, two boats for coastal work and the Noc Prof. W. Besnard for the open sea.

The NOc Prof W Besnard (FIG 3), was projected in the Department of Naval Engineering of the Polytechnic School of the University of São Paulo. She was built in Norway in 1968 weighing 700 tons, with a length of 49.35 m. She can carry 16 scientists, 23 crew members and has an autonomy of 20 days. The smaller fishing boats, the Velliger and the Albacora, both 14m long, are used for coastal research work based on the Research Stations of Cananeia and Ubatuba, in the Coast of the State of São Paulo.

In order to better carry out its purposes, the Institute developed the capacity to measure *in situ* the oceanic (physical, chemical, geological and biological) processes by using research ships. A laboratory for instrumentation with the capability of calibrating thermometers, salinity and pressure sensors was established. There was the development of oceanographic/meteorological buoys for measuring surface meteorology parameters, ocean properties, T, S, currents etc, together with the development of bottom pressure devices with acoustic recovery and several other modern devices.

A library holding 11.000 books and about 800 current scientific periodicals gives support to the work and the publication of results of the scientific staff is made through the Brazilian Journal of Oceanography, that is the substitute of the originally named "Boletim do Instituto Oceanográfico" and the Technical Reports, that substituted the previous publications under the titles: "Climatológico Boletim"(Climatological Bulletin), "Relatório Interno" (Internal Report) and "Relatórios de Cruzeiros" (Cruise Reports).

The Geophysical Year

The research activities of the Geophysical Year were an incentive for the development of the climatological measurements that started in the Research Stations of Cananeia, in the Southern part and Ubatuba in the Northern part of the State of Sao Paulo. In response to this incentive the first oceanographic-meteorological field work in the "Mar Virado" in the Bay of Ubatuba occurred in the years of 1958 and 1960.

As a follow-up, in the year 1963, there was an intense participation of scientists in International programs of research such as the Equalant I. This participation was entirely possible with the help of the Vessels of the Brazilian Navy.

Soon after the incorporation of the NOc Prof W. Besnard to the University of Sao Paulo in 1967, Physical Oceanography there was her first cruise from Norway to Brasil, the VICKINDIO

(Vickings and Indians) expedition and later she played a key rule in the in multi-disciplinary research programs, such as the GEDIP (Executive Group for the Development of Fish Industry of the State of Rio Grande do Sul) that occurred in the Southern Part of the Brazilian coast.

Started in 1969 the Program for Marine Geology and Geophysics (PGGM) for the continental margins, which produced the first geological charts of the Brazilian coast. With similar objectives was the Global Reckoning of the Continental Brazilian Margins (REMAC) with the important participation of the Noc Prof W Besnard, in collaboration with PETROBRAS (Brazilian Petrol Company), DNPM (National Directory of Mineral Research) – CPRM (Company of Research of Mineral Resources) and of CNPq (National Council for Scientific Research and Technology).

GATE and FGGE International Programs

In the years 1974 and 1979 global International programs for measuring the meteorological and oceanographic processes of the air-sea interface were organized by WMO (World Meteorological Organization) and ICSU (International Council of Scientific Unions), which involved several research oceanographic ships, land and sea meteorological stations for upper soundings and then, the newly developed satellite technology for globally measuring several physical variables of the atmosphere and the oceans.

The participation of scientists of the Institute of Oceanography of the University of São Paulo came through the NOc Almt Saldanha and the NHi Sirius, from the DHN (Directory of Hydrography and Navigation), in the Southern winter months of 1974, during GATE (GARP [Global Atmospheric Research Program] Atlantic Tropical Experiment). In the year 1979, their participation was on board the NOc Prof W Besnard, during the FGGE (First Global GARP Experiment) simultaneously measuring, for the first time on a global scale, the oceans and the atmosphere.

Other International Programs

Other major programs engaged by physical oceanographers of IOUSP were TOGA (Tropical Ocean Global Experiment), WOCE (World Ocean Circulation Experiment), the Brazilian Antarctic Program during the period of 1986 to 1990 financed by CIRM, the Mussel Watch Program covering the Brazilian Coast from 1992 to 1994, the ECOLAB program for mangroves of Suriname and the Northern States of Brazil, the SARP (Sardine- Anchovy Recruitment Project) program and IGBP (International Geosphere Biosphere Programme) the multidisciplinary international program of research for Global Changes resulting from the current economic activities of humanity.

First Local Research Programs

Other participation of the NOc Prof W Besnard in 1975 was for the lauching of a submarine cable for communications connecting the Virgin Islands in the Caribbean (USA) and Recife (Brazil). During the period 1976 to 1983, supported by FINEP (Funds for Studies and Projects) of the Presidency of the Republic, she was engaged in measurements for the “Integrated Project for the Rational Exploration of the Marine Environment”, covering the coastal area between Cabo Frio, State of Rio de Janeiro (RJ) and Cabo of Santa Marta, State of Santa Catarina (SC). Measurements in Physical Oceanography of currents, sea level, TS and surface meteorology were systematically taken following similar previous pioneering measurements taken at that time (in the 60s), on board the Navy ship NOc Almt Saldanha, with much simpler equipment, as for example, the use the Ekman current meters.

The program on Sea Level and Tides with the acronym PAVASAS (Anphidromic Points and

Seasonal Variations of the Equatorial and South Atlantic), financed by FAPESP and CNPq (National Council for Scientific and Technological Research) extended to the platform non permanent pelagic measurements of sea level bottom pressure.

Other programs involving Physical Oceanography participation in multidisciplinary studies were financed by CIRM (Inter-ministerial Commission for the Resources of the Sea) to study the sardines in the Southeastern coast. From 1985 to 1990, the OPIS (Oceanography of the Internal Platform of Sao Sebastiao, State of Sao Paulo), with funds by FAPESP (Sao Paulo State Foundation for Research). The COROAS (1992), (Oceanic Circulation in the Western Region of the South Atlantic) financed by FAPESP and CNPq aiming at studies of the Brazil current.

The REVIZEE (1994), (Living Resources in the Exclusive Economic Zone), program with the aims of cataloguing the live resources of the Brazilian shelf along the Exclusive Economic Zone in response to the United Nation´s Convention of the Law of the Sea (UNCLOS). The DEPROAS (2000), (Dynamics of the Shelf Ecosystem of South Atlantic Western Region), with aims of detailing the penetration of the South Atlantic Central Water (SACW) on the Southeastern continental platform.

Other Research Programs

Another recent program is the PIRATA (Pilot Research Moored Array in the Tropical Atlantic) an operational program with objectives of studying the air sea interactions ocean-atmosphere in the tropical Atlantic and its impacts in the climatic variability. The multinational effort involves measurements with moored buoys the sea surface meteorology and the oceanic currents of the tropical Atlantic. Another multinational program, the SACC (A Consortium for the Study of Climate Changes) involving scientists of various countries of the Americas for modeling the South Atlantic convergence zone is also in operation.

The GLOSS (Global Sea Level Observing System) of IOC/UNESCO (1993), involving sea level of all permanent sea level measuring systems of all countries of the globe has 9 (nine) sea level permanent stations along the Brazilian coast. The GLOSS sea level station of Cananeia holding the GLOSS number 194 has produced, since its installation in 1946, about 50 years of continuous measurement of the sea level in the tropical Atlantic.

The SIRGAS (2005), (Program for Geocentric Reference System for the Americas, measuring vertical and horizontal motions of the crust by GPS (Global Positioning System) and relative and absolute Gravity in the Research Stations of Cananeia and Ubatuba, State of Sao Paulo is the recently started program at the Research stations of Cananeia and Ubatuba..

Absolute Gravity (2007), measurements at the Research Stations of Cananeia and Ubatuba and at the (IAG), Institute of Astronomy, Geophysics and Atmospheric Sciences at the University campus are registered in the Fundamental Brazilian Gravimetric Net Work (Observatório Nacional/ Ministério da Ciência e Tecnologia) and the International Net Work of Stations of Absolute Gravity .

First Local Impacts

Among the various contributions to physical oceanographic knowledge of local relevance was the discovery of the upwelling phenomena in the Southeastern Brazilian coast, which has its maximum of occurrence during the summer months being more intense near the area of Cabo Frio State of Rio de Janeiro. The phenomenon is of great importance as it brings the bottom waters, which are fertile in nutrients to the surface fertilizing the area. It is governed by the seasonal winds, the planetary

vorticity and the water masses in the area. The seasonal behaviour of these Water Masses allowed the “seasonal thermal inversion” identification by showing that surface waters have a typical seasonal variation of the Southern Hemisphere, while the bottom water has a typical seasonal variation of the Northern Hemisphere.

The phenomenon is under study and various detailed local and general theories are being proposed for its understanding by means of computer solutions of the hydrodynamic nonlinear equations. Numerical models are also of importance to predict the tidal heights induced by the winds and currents in the Southeastern area and particularly in the channel of São Sebastião, where an important harbor for the PETROBRAS Brazilian petrol company is located.

Sea level studies lead to significative contributions in the field of analysis and predictions of the sea level. Sea level predictions are currently made for the ports of Cananeia in the Southern and Ubatuba in the Northern coast of the State of São Paulo, where the Institute maintains permanent stations for measuring the sea level and surface meteorology.

The border of the platform upwelling in the Western oceanic side was detected, that is the object of theoretical studies bearing in mind its scientific and practical nature, as well as, its relationship with the Brazil Current, which flows close and along the border. Brazil current, its meanders and vortices are the focuses of fertile studies, which are presently underway. The Malvinas Current and its influence, with waters of the River Plata in the Southeastern coast was detected and is another major physical phenomena currently under studies.

Contributions of global character related to the sea level called the attention of the public sector with regard to the increase of the rate of variation of the sea level and the grey perspectives that it shades to the coastal regions of the country, which may include the Amazon area via its major river and tributaries.

Coastal and estuarine studies of sea level and currents relative to the internal areas of the Cities of Cananeia, Santos, Ubatuba and Sao Sebastiao, State of S Paulo and Angra dos Reis, State of Rio de Janeiro describe in details the surface and bottom circulation patterns and are basic environmental elements to the rational use of these areas that have significant socio-economic relevance.

Contributions to the Northeastern (Nordeste) Brazilian area identified, for the first time, periodicities of the rainfall regime of meteorologically almost aleatory nature that showed unexpected interannual, decadal and longer periodicities. These periodicities in rainfall are of fundamental socio-economic value to the prediction of the draughts which are intense in the area. Further work, showed they are related and caused by the El Nino phenomenon that occurs in the Equatorial Pacific.

Equatorial research lead to the discoveries of large scale permanent vortices in the Western Atlantic near the Amazon River mouth; the seasonal variability of the equatorial system of current towards Africa and countercurrent towards Brazil; the Undercurrent that submerged at 100m depth, in the West, flows from the Brazilian coast to the East Africa continent; the Equatorial system of all sort of currents are trapped by the rotation of the Earth, inclusive forming great meanders around and along the Equatorial line and are reflected in the African coast.

Dissipation of energy via the phenomenon of internal waves, as internal tides, were determined as tidal components of higher order - open ocean non linear components - generated by the tides in the vast area of the abyssal Atlantic. The spectral characteristics of the Equatorial Atlantic measurements down to 500m, from hours to tenths of days, were heuristically estimated for the first time in the Western oceanic side of the Atlantic.

There was a great deal of pressure on the research projects towards the development of instrumentation for data collecting and several measuring artifacts to be used on board and at sea, such as met-oceanographic buoys, and others as current meters, CTDs, pressure gauges, that were built by local companies and soon were encompassed by larger international manufacturers.

One effort that lead to the development and construction of the first Brazilian Batiscaf, aimed at recovering lost equipment at S Pedro and S Paulo rocks during the FGGE program. The development of the BATIUSP was the starter of the Brazilian industry of encapsulated divers for deep sea exploration that has successfully been developed from that time on, under the Navy stimulus and the PETROBRAS petrol company.

Physical Oceanography during the Antarctic expeditions of the NOc Prof W Besnard was planned to support the biological activities, so that to help the first national expedition effort to that continental area. The national impact of her first presence in the icy continent was great and a very significant event in the history of the University of Sao Paulo.

Further Studies

In the last quarter of the 20th century there was a great deal of development coming from technology based on space research and the field of computation producing huge global cultural and economic interchange among the nations. The launching of several satellites to measure the sea surface physical variables gave new boost to synoptic, as well as, to time series of Physical Oceanography measurements, on a global scale.

Several solutions of the hydrodynamic non linear equations by new and fast computers involving the physical variables of the oceans were developed global wise. Following these lines, the first numerical model of the equatorial waters was developed at the Institute based on satellite altimetry data, actually measured currents and actual sea level heights in order to study the Equatorial Atlantic system of trapped currents.

There were fruitful studies on the meso scale dynamics associated to currents of western boundary, as the Brazil Current, with emphasis in the dynamic instability and vortices generation. The air sea interaction was intensively analyzed via several solutions of the hydrodynamic air–sea coupled equations. Sea satellites measurements as by scatterometers and altimeters were applied to the studies of Rossby waves and the phenomenon of Ekman pumping over the South Atlantic ocean.

Estuaries, Bays, Tidal Channels and Coastal areas, were fully scrutinized by highly instrumented mooring programs, aided with very fine computing grids for interdisciplinary studies covering biology, (coastal farming) chemistry, (pollution control) and geology, (sediment transport), funded by several local agencies as FAPESP, CNPq and PETROBRAS.

The sea level that has been measured since 1956 at the research station of Cananeia produced the first reliable estimate (40/cty) of the sea level increase of the Brazilian coast. Measurements are studied in conjunction with the Gravity and GPS measurements at stations of Cananeia, Ubatuba and the University Campus.

Courses on Oceanography

Courses of the Institute of Oceanography in the University of Sao Paulo are offered to the community as a Citizen´s Right, not as a Service to the Citizens and so, they are all free of charge. The University welcomes all interested students of the International community to make their application to the courses.

- The five-year undergraduate course of Oceanography covers the scientific areas of Biology,

Geology, Chemistry and Physics, leading to the Bachelor Degree in Oceanography. The Physical Oceanography part of the Course is lectured by lecturers with vast research experience from American, European and Asian Universities, in theory and in measuring the oceanic motions of all physical causes, in the oceans basins, continental platforms and in estuaries.

- The Institute also offers Courses of Extension such as the one-year course on: Measurement, Analysis, Prediction and Numerical Modeling of the Sea Level, aimed at graduates in Oceanography, Meteorology, Engineering, Physics, Statistics and others.

- An Open Course of Basic Concepts on Oceanography is also offered, on Sunday's mornings, to the community of Sao Paulo and of the cities of Cananeia and Ubatuba on the Coast of the State of São Paulo..

Divulged and Published Articles

1 – BJO – (Brazilian Journal of Oceanography)
The research staff of the Institute publishes regularly in the Brazilian Journal of Oceanography , (former "Boletim do Instituto Oceanografico"), as well as in the Technical Reports, (former "Cruise Reports), (Relatorio de Cruzeiro) and Internal Reports (Relatorio Interno) of the Institution, as well as in other international journals of the community. Their full curriculum can be accessed in the address: http://cnpq.lattes.br from where the references below were selected.

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Figure Captions
FIG 1 – Admiral Paulo Moreira da Silva
FIG 2 – Dr Ingvar Emilsson
FIG 3 – The NOc Prof W Besnard - Photo by Francisco Vicentini