METEO-FRANCE
D2I
Department Environment

FRANCE REPORT ON SYSTEMATIC OBSERVATIONS FOR CLIMATE FOR THE GLOBAL CLIMATE OBSERVING SYSTEM (GCOS)

FOR

THE THIRD NATIONAL COMMUNICATION TO THE CONFERENCE OF THE PARTIES TO THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE

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This document is an extract of the French Third National Communication for the United Nations Framework Convention on Climate Changes concerning “Research and Systematic observation”. It includes two parts. First, there is an executive summary on the research programmes on climate change and the systematic observation of climate. In a second part it presents the detailed description of the different components of the Global Climate Observing System (GCOS), along the UNFCC Guidelines. It must be noticed that the French contribution of the GCOS system is presented for the first time.

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Executive Summary on Research and Systematic Observation

Physical Sciences Research

French research on climate is centred on the National Research Programme on Climate Dynamics (PNEDC), in which the following organisations participate: CEA, CEMAGREF, IFREMER, IFRTP, INSU, the Ministry of Research, Météo-France, the Ministry for the Environment and IRD. The PNEDC responds to the need to look at the interaction between the various components of the climate system – atmosphere, ocean, geosphere, biosphere – interactively. It answers to the CNRS National Institute of Sciences of the Universe (INSU).

The PNEDC's interests to a large extent correspond to those defined internationally by the World Climate Research Programme (WCRP).

However, some of its components also correspond to the concerns of other international programmes, such as SPARC (Stratospheric Processes and their Role in Climate), GEWEX (Global Energy and Water Cycle Experiment) and the International Geosphere Biosphere Programme (IGBP), as regards, in particular, paleoclimatology (Pages programme), atmospheric chemistry (IGAC) and atmospheric modelling (GAM). Finally, two non-specific projects – the use of WOCE data and the Clipper modelling project – work in parallel with the PNEDC. Moreover, this programme also provides specialist elements for defining and putting in place future space missions and climate observation and monitoring networks (GCOS and the climate component of GOOS) and for communicating with the socio-economic sector in the field of long-term forecasting and that of man-made climate changes.

The ECLIPSE programme (Climate Environment of the Past: History and Evolution) was created more recently as a complement to the PNEDC. It deals with analysis of glacier and sediment archives (lake or marine) and with paleoclimatology from a multi-disciplinary point of view (universe sciences, Human and Social Sciences, life sciences). It documents natural climate variability, making it possible to understand its mechanisms and the way it operates during key periods in the history of the Earth. Each community in ECLIPSE contributes to the development of consistent and quantifiable scenarios linking major changes in the terrestrial environment to the various possible causes (external or internal forcing).

Other programmes deal with the water cycle (GEWEX-radiation balance), the world ocean dynamic (WOCE) and the tropical ocean-atmosphere coupling (TOGA-Coare). Moreover, some complementary aspects or aspects situated on the borders of climatology are dealt with by the four other INSU programmes - PNCA, PATOM, PROOF and PNTS – presented below.

- The PNCA (National Atmospheric Chemistry Programme) deals with various issues related to the problem of atmospheric chemistry and climate interactions, following complementary approaches – experiments in the field, laboratory tests and modelling.
- The PATOM (Multi-Scale Atmosphere Ocean Programme) concerns the understanding and parameterisation of physical processes, which transform energy in the atmosphere and in the ocean, using experimental, theoretical and numerical methods. The priority themes are atmospheric and ocean variations in time scales lower than the season. The emphasis is

placed on coupling dynamics and chemistry or hydrology for the atmosphere, dynamics and biogeochemistry for oceanography with the various areas (offshore, coasts, shore).

- The PROOF (Bio-chemical Processes in the Ocean and Fluxes) replaced the JGOFS-France programme in 1998. It is based on the study of the processes governing the fluxes of chemical and biochemical elements exchanged between the atmosphere, the ocean and the marine biosphere, with special attention being paid to the improvement of coupled physical and bio-geochemical models. These models will also make it possible to describe the functioning of the climate system, past and present, more accurately and will be useful in assessing future systems.
- The PNTS is the National Programme for Space Remote Sensing. This involves satellite observation, for improved observation, and therefore understanding, of how the climate system works.

Research Pertaining to Adaptation, Mitigation and Related Technologies

This research is mainly carried out as part of the GICC programme (Ministry of the Environment). The general issues address the world of international negotiations, greenhouse gas (and aerosol) emission reductions, potential effects and strategies for adapting to climate risk. This programme is original in that it links up pure science and human science teams and works on three principal dates (2010, 2030, 2100). Various economic models are used: macro-economic or growth models, general balance models and sector models (optimisation of energy, agriculture etc.). In the long term, it is planned to develop economy-climate coupled models to analyse costs-profits that are proper expert-systems to optimise the level of greenhouse gas reduction to be determined and negotiated internationally.

Technological Research Programme

ADEME is carrying out a technological research programme on the greenhouse effect, including five key actions:

- reducing energy carbon content;
- improving energy efficiency and management of demand in transport, housing, the services sector and industry;
- reducing emissions of specific greenhouse gases (CO_2, N_2O, HCFC, SF_6) in industrial processes;
- CO_2 storage;
- control of the effects of specific greenhouse gases (CH_4, CO_2, N_2O) in agriculture and in the channels for recycling organic waste.

There is also a socio-economic aspect relating to behaviours and lifestyles, and the legal and financial framework of the CO_2 market.

European Research Prospects

European research is carried out under the 5th RTDFP (Research and Technical Development Framework Programme), which has a budget of EUR 14.96 billions.

It consists of six key projects, one of which is called «Planetary Change, Climate and Biodiversity». Its budget is EUR 301 millions. The 6th RTDFP, which is currently being negotiated, should include a priority issue on sustainable development and planetary change.

Systematic Observation

France is participating fully in the Global Climate Observing System (GCOS). It incorporates the following four components: meteorological and atmospheric, oceanic, terrestrial, spatial.

Meteorological observation refers to Météo-France's general observation mission; its policy is governed by the framework programme on meteorological observation (1999) and the framework programme dedicated on climatology (2001). However, the composite aspect of GCOS makes it a system in which some operators come from other institutions – laboratories dependent on the Ministry of Research, the Ministry for the Environment, Oceanography and Overseas institutions. The general policy for distributing data is contained in Resolution 40 of the WMO, regarding the distribution of meteorological data. They are looking into the issue of long series of data and continuation of the observation networks within the framework of the GCOS. The concept of Environment Observatories (operational or research) tries to address this question.

Since 1999, the Global Surface Network (GSN) has had six stations in mainland France. In France's dominions, the GSN network has the following fourteen stations. Cayenne-Rochambeau (Guyana), Le Raizet (Guadeloupe), Dzaoudzi-Pamanzi (Mayotte), Martin de Vivies (Amsterdam Island), Port-aux-Français (Kuergelen Islands), Dumont d'Urville (Adelia Land), Koumac and Nouméa (New Caledonia), Hififo (Wallis Island) and for French Polynesia, Atuona, Tahiti-Faa, Rikitea, Tubuai and Rapa.

The French contribution to oceanographic observation for climate comes under the GOOS system (Global Ocean Observation System) and contains the following: voluntary and occasional observation ships, ocean gauges, floating and anchored weather buoys and, finally, sub-surface floaters (Coriolis Project). We would like to emphasise the pre-operational direction of ocean observation, with Mercator modelling projects, the Coriolis observation project and the future data assimilation experiment, GODAE (2002-2004). The seven French agencies involved in oceanography (CNES, CNRS, IFREMER, IFRTP, IRD, Météo-France and SHOM) are joining forces to develop a complete and coherent system of operational oceanography based on three focal points: satellite altimetry (JASON), global numerical modelling with assimilation (MERCATOR) and *in situ* measures (Coriolis). The Coriolis project aims to construct a pre-operational structure for acquiring, collecting, validating and distributing world ocean data (temperature, salininity and current profiles) responding to the needs of modellers (MERCATOR) and of the scientific community (under CLIVAR).

The Global Terrestrial Network (GTN) deals with observation of mountain glaciers, long-term monitoring of greenhouse gases (RAMCES) and, finally, measurements of carbon fluxes linked to terrestrial ecosystems (FLUXNET). Mountain glaciers are thus studied in numerous parts of France and abroad, in particular by LGGE, IRD and CEMAGREF. The RAMCES network aims to understand greenhouse gas cycles and to provide a regional balance. France is also actively participating in measuring carbon flows in terrestrial ecosystems carried out under the international programme Fluxnet, and the various programmes connected with the Carboeurope project group. Forest ecosystems have also been systematically observed by the National Forestry Inventory (IFN) every ten years for almost forty years. A mechanism for

monitoring environmental influences was also put in place after the damage caused by acid rain.

In the area of space observation, the CNES was one of the pioneer organisations in observing the earth from space. The programme takes up almost a third of its budget. It works with international cooperation, in a bilateral framework, and it also participates to a large extent in European Space Agency projects. This programme is organised in «sectors» – a series of projects in response to common objectives or requiring specific techniques, with a concern for innovation, satisfaction of scientific needs and development of applications. The three sectors – terrestrial observation, meteorological observation and research – have increasingly contributed to our understanding of climate. France has also contributed significantly to EUMETSAT (European Agency for Meteorological Satellites), which manages Météosat and the future polar orbiting platform, METOP.

Report on Systematic Observation for the Climate

The Global Climate Observing System (GCOS) is a composite system designed to monitor the climate. It is made up of the four following components: meteorological and atmospheric, oceanic, terrestrial and spatial. They will be elaborated upon below, after the section on Generalities. Note that this is the first time that France is issuing a National Overview on Systematic Observation of the Climate.

1. Generalities

Meteorological observation is one of the basic responsibilities of Météo-France, whose policy is defined by the framework programme on meteorological observation (1999) and the framework programme dedicated to climatology (2001). However, as a result of its composite aspect, GCOS is a system where operators can also come from other institutions, including laboratories under the aegis of the Ministry of Research or the Ministry for the Environment, oceanographic institutions and overseas institutions. The general policy about dissemination of data is concerned is defined by WMO's Resolution 40, relative to the dissemination of meteorological data. Concerning the global climate observing system, the issues of how to disseminate long series of data and how to ensure the permanence of observation networks will have to be addressed. Environment Observatories (operational or research) are presently trying to answer these questions.

2. Meteorological and Atmospheric Observation

Meteorological and atmospheric observation includes the following aspects: surface observation (GSN), upper air observation (GUAN) and physico-chemical measurements (GAW).

Global Surface Network (GSN)

Since 1999, the meteorological surface network GSN has been made up of the six following stations in continental France: Rennes, Strasbourg-Entzheim, Bourges, Toulouse-Blagnac, Marseille-Marignane, and Mont-Aigoual. The latter was selected as a mountain-based station. These six stations belong to the basic synoptic network at the WMO level, for the dissemination of data. As a result, the previous data series (monthly and daily averages), along with the meta-data and the daily observations, presented as Climate messages, are sent on a regular basis to the National Climatic Data Center in Asheville (United States). As regards overseas french stations, the GSN network includes the following sites:

- In Guyana: Cayenne-Rochambeau;
- In Guadeloupe: Le Raizet;
- In the Indian Ocean and Austral regions : Dzaoudzi-Pamanzi (Mayotte), Martin de Vivies (Amsterdam Island), Port-aux-Français (Kerguelen Islands);
- In Antarctica: Dumont d'Urville;
- In New Caledonia: Koumac, Nouméa, Hififo (Wallis Island);
- In French Polynesia: Atuona, Tahiti-Faaa, Rikitea, Tubuai, Rapa.

Global Upper Air Network (GUAN)

This network is devoted to measurements taken in altitude. In continental France, there is no station. However, overseas, the following stations are used:

- Guyana: Cayenne-Rochambeau;
- In the Indian Ocean and Austral regions : Serge Frolow (Tromelin Island), Martin de Vivies (Amsterdam Island), Port-aux-Français (Kerguelen Islands);
- In Antarctica: Dumont d'Urville;
- In New Caledonia: Nouméa;
- In French Polynesia: Atuona, Tahiti-Faaa, Rapa.

GAW: Physico-Chemical Network

This network is responsible for physico-chemical measurements of the atmosphere. It is made up of four observation stations on the continent, located in Abbeville, Gourdon, Carpentras and at the National Observatory of Haute-Provence. The acidity of precipitation (BAPMON programme) is measured in Abbeville and Gourdon, while radiation is measured in Carpentras.

Measurements of ozone (profiles and/or total columns) are performed on a regular basis by CNRS' Aeronomics Department at the National Observatory of Haute-Provence, in Dumont d'Urville (Antarctica), in Saint-Denis de la Réunion (in collaboration with the University) and in the Kerguelen Islands, as part of the NDSC (Network for Detection of Stratospheric Changes). Lastly, CO2 is measured in Amsterdam Island (see also section 4, below).

The Future GSN Network

The European Climate Support Network (ECSN), which encompasses the climatological centres of EUMETNET's member countries, is coordinating the development of a bank of daily climatological data, under the co-leadership of The Netherlands and Norway. France's planned contribution will involve the 14 following stations, all located in the plains: Besançon, Bordeaux, Bourges, Brest, Clermont-Ferrand, Lille, Lyon, Marseille, Paris, Perpignan, Poitiers, Rennes, Strasbourg and Toulouse.

14 additional stations will be brought in to enrich the network and to offer a more representative view of France's topo-climates.

The selection process was based on long series of existing data on temperature and precipitation observations, and taking into account the recommendations issued by EUROCLIVAR. The data generally goes back to 1945, but on certain sites, can go back to approximately 1880, either at the same observation site or at a nearby one.
The network will be managed as part of an European Climatological Databank (ECD). Access will be available via CD-ROM, ftp or Internet.

3. Oceanographic Observation

The French contribution to oceanographic observation of the climate was developed within the framework of the GOOS programme and includes the following components: voluntary observation ships (VOS), ships of opportunity (SOOP), tide gauges, drifting and anchored meteorological buoys and, lastly, sub-surface floaters (CORIOLIS project). Note the pre-operational nature of this ocean observation system, which includes the modelling project Mercator, the observation project Coriolis and the future data assimilation experiment GODAE (2002-2004).

Voluntary Observation Ships (VOS)

The VOS are part of the WMO's observation programme. There are approximately 80 vessels, all of which will eventually be equipped with the BATOS system, developed by Météo-France. They perform atmospheric observation, but sometimes oceanic observation too.

Ships of Opportunity (SOOP)

Here, measurements of the upper layers of the ocean are made using XBT probes launched by ships of opportunity. Four ships operate in the Atlantic Tropics, while eight are present in the West Pacific. The means for the programme were provided by IRD, with the support of NOAA, which provided the probes. Nearly 300 profiles are disseminated each year through the ARGOS system, then inserted in the GTS in Toulouse. The data are archived in the TOGA/WOCE database at the Brest branch of IRD (www.brest.ird.fr/goos). IRD has also equipped twelve ships with thermo-salinographs to measure surface salinity. The data is disseminated post-time, but will soon be available in real time. The corresponding databases are managed by IRD (Brest and Nouméa). The data collected in the Pacific are available on CD-ROM, as well as on IRD's Nouméa server.

Tide Gauge Network (GLOSS)

Tide gauges provide data on sea level, which are used to determine the general circulation patterns of the ocean and to monitor the climate. In addition, these data can be used as a basis for analysing the data gathered via altimetric satellite (ERS-1, Topex/Poseidon, Jason). The GLOSS network of tide gauges includes 12 stations under France's responsibility: Brest, Marseille, Nouméa, Nuku Hiva (Marquise Islands), Rikitea (Gambier), Matavai (Tahiti), Kerguelen, Amsterdam, Crozet, Dumont d'Urville, Clipperton, Fort-de-France, Pointe-des-Galets (La Réunion), Cayenne and Dzaouzi (Mayotte).

A databank including daily, monthly and annual average levels recorded by SHOM over the past 40 years, has been made available to the Permanent Service for Mean Sea Level (Proudman Oceanographic Laboratory, Great Britain). In 2002, SHOM will develop a server to make these data available on Internet.

Drifting Meteorological Buoys

Météo-France regularly deploys drifting meteorological buoys as part of its work within the Data Buoy Cooperation Panel (DBCP), which itself reports to WMO and IOC. Météo-France contributes to the studies of two groups within the DBCP: the European Group on Oceanic Stations (EGOS) and the International Buoy Programme in the Indian Ocean (IBPIO). These groups are responsible for verifying the quality of the measurements and the dissemination of information via the GTS, for allowing the exchange of information on the topic, and for defining new techniques.

The buoys measure atmospheric pressure, sea surface temperature (Marisonde B or SVP-B) and, in some cases, wind (Marisonde G or SVP-BW) and deep-sea temperature up to 200 metres (Marisonde GT). The ARGOS system is used to locate the probes and transmit the data they gather (hourly observations).

Each year, Météo-France deploys 15 buoys in the North Atlantic for EGOS. As part of IBPIO, Météo-France contributes to observation in the Indian Ocean by equipping 10 american SVP floaters per year with atmospheric pressure gauges, and by providing around five buoys. Météo-France takes responsibility for the coordination of the two drifting buoy networks at the international level.

Anchored Meteorological Buoys

In addition to the oceanic stations, Brittany and Gascogne, which are run in the Near Atlantic with the cooperation of the United Kingdom Meteorological Office, Météo-France has set up anchored oceanic buoys on three other sites since 1999: two off of the Caribbean coast, at a depth of 5 500 metres, and another off of Nice's coast, at a depth of 2 300 metres. A fourth site will be equipped in the Mediterranean's Golfe du Lion in 2001.

Every hour, each of the acquisition systems makes observations, recording atmospheric pressure, temperature and humidity, surface wind and sea temperature at 1 metre below. The data are sent via Météosat. The localisation of the buoys is performed using GPS and an ARGOS beacon. Lastly, a buoy-beacon was set up in June 2000 in the Mer d'Iroise and anchored to the «rail d'Ouessant» (Lighthouse and Beacon Department). Two directional swell gauges are anchored near the Caribbean Islands, one in Guadeloupe and the other in Martinique. They observe significant heights, the period and spectrum of the swell, as well as the sea temperature every half hour and send them via the ARGOS system. The buoys anchored off the coast regularly send messages, which travel over the GTS and enrich the data exchanged throughout the world as part of the World Weather Watch.

The PIRATA Observatory

The PIRATA Observatory is an international meteo-oceanic real-time monitoring system, which was established in a vast sector of the Atlantic Tropics. The observatory, coordinated by IRD-Brest since late 1997, is part of the International CLIVAR Programme, but has a strong operational emphasis. PIRATA-France is one of the components of the French programme, ECLAT. Within this context, the Pirata Observatory is associated with the Equalant programme, but is also equipped with a current-measuring interface and sub-surface anchorages along the Equator. Over 30 ATLAS systems have been released at 12 key

locations, through eight campaigns carried out between September 1997 and December 2000, using a number of oceanographic ships: Antea (five) Le Suroît (one), La Thalassa (one) and L'Atalante (one). Most of these launch trips departed from the Pirata-France base, in Abidjan. Today, the whole of the global climate community can reap the benefits of the information gathered by this observatory.

CORIOLIS: The Operational Oceanography Project

The seven French agencies involved in oceanography (CNES, CNRS, IFREMER, IFRTP, IRD, Météo-France and SHOM) have joined forces to develop a complete, coherent system for operational oceanography, designed along three lines: satellite altimetry (Jason), global numerical modelling with assimilation (Mercator) and in situ measurements (Coriolis).

The CORIOLIS project aims to build a pre-operational structure for the acquisition, gathering, validation and dissemination of global oceanic data (temperature and salinity profiles, current profiles) that fulfils the needs of modellers (such as Mercator) and the scientific community (as part of CLIVAR). The CORIOLIS project has four aims:

- To build a data management centre, which will be one of the two ARGO centres in the global experiment, GODAE, capable of supplying data in real- and post-time. The CORIOLIS Centre, currently being developed, centralises all of the temperature and salinity profiles, virtually in real time (three times per week and, in 2001, on a daily basis) that come from GTS and other sources. The data, which come from XBT probes, ATLAS, TAO and PIRATA buoys, floater-profilers and drifting buoys, can be found online (www.coriolis.eu.org).

- To contribute to the deployment of the ARGO network, especially in the Atlantic, with around 300 floater/profilers to be deployed between 2001 and 2003. 20 PROVOR floater-profilers were deployed in the North East Atlantic in 2000. 100 additional floaters will be purchased in 2001 and 140 will be purchased in 2002. These figures include the 40 floaters to be used as part of France's participation in the European programme Gyroscope (IFREMER), which calls for the deployment of 80 floaters in the North Atlantic to evaluate the need for a pre-operational measurement network at the oceanic basin scale and its working in real time;

- To develop and improve ARGO profilers. PROVOR is a self-ballasted floater, capable of remaining at a set drift depth, diving down 2000 metres and coming back up, and producing a precise temperature and salinity profile, which is then sent back on land via the ARGOS system. The PROVOR floater is capable of completing over 100 cycles during its life span of three years. A new generation of profilers, which would be smaller, less expensive and launchable from ships of opportunity or planes, is currently being studied, with a view to industrialisation in 2003;

- To acquire, validate and process in real time and using CORIOLIS, the other data that is routinely gathered by various French bodies, from surface floaters, anchored Pirata buoys, research ships (bathythermal XBT probes, thermosalinographs and ADCP current profilers).

In 2004, recommendations will be issued to turn the Coriolis pilot project into an operational activity that contributes to the permanent observation of oceans, depending on the progress of

the ARGO/GODAE experiments. The deployment of ARGO will then be complete, and the experience acquired will make it possible to gain a better understanding of the ocean circulation and, in so doing, contribute to the monitoring of the climate.

4. Terrestrial Observation

The Global Terrestrial Network (GTN) carries out observation of mountain glaciers, long-term monitoring of greenhouse gases (RAMCES), measurements of carbon flows as related to terrestrial ecosystems (FLUXNET) and, lastly, observation of forest ecosystems.

4.1 Observation of Mountain Glaciers

The Laboratory of Glaciology and Environmental Geophysics has been producing glaciological observations on alpine glaciers since 1956. These observations can be used to study the mass balance (accumulation versus ablation) of glaciers in the French Alps, and the modifications in the geometry and dynamics of these glaciers. These data serve as an indicator of climate change at high altitudes and are essential if we are to understand glaciary fluctuations (positions of fronts, thicknesses, speeds). In addition, they form the foundation for analysis of natural risk resulting from glacier activity. Since 1991, the Institute for Research and Development (IRD) has been operating a similar programme, but on tropical glaciers (Bolivia, Ecuador and Peru): it involves establishing mass balances and identifying modifications in geometry and dynamics, sometimes making use of a network of meteorological stations to calculate the energy balance at the surface.

LGGE Observation Network

Since 1995, the observation network of mass balances has been extended and the objective is now to ensure its livelihood. It involves the systematic determination of winter and summer mass balances, in both ablation and accumulation areas, on four glaciers (Argentière, the whole of the Mer de Glace, Gébroulaz and Saint-Sorlin). This network makes it possible to gather observations on most of the mountains in the French Alps, on an altitude range of over 1 500 meters and with varying exposure. The data, which results from direct observation of mass balances, taken on the glaciers (core samples, beaconed areas) can be used, if validated, to determine variations in volume of the glaciers on a 10- to 15-year scale. The analysis of mass balances over the last 50 years now proves that these observations are suitable for detecting changes in energy balance (summer fusion) and in winter precipitation (through accumulation) in high mountains. The network also produces observations of fluctuations on the four glaciers. Since 2000, the network has been part of the Universal Sciences Observatory in Grenoble (OSUG).

Aside from LGGE observations, CEMAGREF produces measurements of mass balance on the Sarennes Glacier since 1949. Lastly, the Parc national des écrins, in conjunction with LGGE, produces observations of mass balance in the accumulation zone of the Blanc Glacier.

IRD Observation Network

IRD's Glacier Study Programme first began in Bolivia (1991), with two glaciers: the Zongo Glacier (monthly monitoring of the mass balance and hydrological balance, annual monitoring

of variations in the glacier front and dynamics, and determination of surface energy balance since 1996) and the Chacaltaya Glacier (monthly monitoring of mass balance and annual monitoring of the position of the front). In 1995, a measurement system identical to that used on the Zongo Glacier, was installed on Glacier 15A of the Antizana Glacier, in Ecuador. The Carihuarazo Glacier is also monitored annually to check its mass balance. Lastly, since 1999, two glaciers in the Cordillera Blanca in Peru have been studied yearly for mass balance.

Prospective View: Observatory for Environment Research on Glaciers

In order to homogenise and preserve the network of measurements carried out on both alpine and tropical glaciers, LGGE and IRD launched a joint project in March 2001: the Observatory for Environment Research on Glaciers. Its purpose was to establish a data bank that can be used in the study of climate variations as well as for the validation of climate models. The glaciers selected for the ORE project represent a variety of climates and lie along a climatic meridian ranging from the Equator (Antizana) to the sub-tropics (Zongo) and the Alps (Argentière and Saint-Sorlin) and, finally, to the Poles (Dome C and coastal region near Dumont d'Urville). The polar portion of the project will be carried out in conjunction with the Polar Institute (IFRTP).

Dissemination of Information

The data stored in computer form have been available to the public since May 2001, on the LGGE server. Part of the data pertaining to mass balances and fluctuations in length appear in *Fluctuations of Glaciers*, a document published every five years by the Standing Committee on Fluctuations of Glaciers of the International Union of Geodesy and Geophysics (IUGG). Six volumes have been published since 1959. The annual mass balances of the Saint-Sorlin and Sarennes glaciers have been published since 1988 in the World Glacier Monitoring Service's bi-yearly publication, *The Glacier Mass Balance Bulletin.* Those of the Zongo, Chacaltaya and Antizana glaciers have been published since 1995.

Cooperation

The cooperation carried out between LGGE, CEMAGREF and IRD are part of the European Glaciorisk programme on natural risks resulting from glaciers. At the international level, an engineer from LGGE is a correspondent at the World Glacier Monitoring Service. In the Alps, LGGE maintains close relations with its Swiss counterpart, VAW, in Zurich. Co-operation also takes place with Italian and Spanish colleagues for the implementation of their observation networks in the Grand Paradis mountains and the Maladeta mountains. IRD also works with Andean partners in the countries where it operates. A researcher from IRD is a correspondent at the World Glacier Monitoring Service.

4.2 RAMCES Network

The long-term monitoring of greenhouse gases by the RAMCES network of atmospheric observatories fulfils two objectives:

- Understanding the cycle of the main greenhouse gases (CO_2, CH_4, N_2O) and their role within the climate system. By becoming familiar with these flows, we will be able to validate bio-geochemical models and socio-economic emissions scenarios, which can be used to predict the devolution of these sources and sinks in the future;
- Quantifying the carbon balance of a large region, along with its variability, as part of the verification of inspection policies or policies designed to reduce greenhouse gas emissions.

In order to achieve these objectives, it is necessary to regionalise CO_2 flows. CO_2, the leading greenhouse gas effecting climate change, is given priority, as it has increased by 30% over the last 100 years, in response to industrial emissions and changes in the way land is used.

It is not easy to convert CO_2 emissions (or CH_4 or N_2O) into different atmospheric concentrations, as these gases have natural cycles that regulate their abundance in the air. Anthropogenic disturbances must therefore be quantified separately from the natural sources and sinks that are sometimes much higher.

As concerns the carbon cycle, two reservoirs – the ocean and the continental biosphere – determine the air's CO_2 content, with very different response times. The objective is thus to regionalise CO_2 sources and sinks, in other words, determine which ecosystems and oceanic basins store or emit carbon.

The methodological approach developed by LSCE consists of measuring CO_2 regularly and very precisely using a global network of observatories to deduct the spatio-temporal distribution of the sources and sinks. This is because variations in concentration at a given point result from flows exchanged at the regional and global scale, and integrated by the circulation of masses of air. Using methods that invert atmospheric transport, it is then possible to translate the gradients in atmospheric concentration in terms of surface flows. Inversions are currently the most effective method for quantifying flows at the continental or oceanic basin scale.

An additional priority is the study of the balance of CH_4 and N_2O species. These two gases have a sufficiently long life span to be dispersed in the atmosphere at the global scale. Measurements of their concentration in the lower atmosphere, far from the sources, like those of CO_2, are thus just as appropriate for deducing flow patterns.
This will allow the long-term monitoring of these gases, a process that is justified by both physical and industrial reasons.

RAMCES for the Monitoring of the Background Composition of the Atmosphere

The first observatory for the continuous measurement of CO_2 was established in Amsterdam Island in 1981 (TAAF). A second observatory for the continuous monitoring of CO_2 was initiated in 1992, in Mace Head, on the West coast of Ireland. These two observatories of the troposphere were integrated into the WMO's GAW network and received labelling in 1995. In addition to CO_2, several other atmospheric compounds are measured in these observatories (radon 222, soot carbon, CO, CH_4), thus making it possible to carry out studies on the sources

of these species, using a multi-tracer approach, and to trace back the origins of the air masses. The monitoring of N_20, the third leading greenhouse gas, began in 2000. CO, in particular, is very useful for separate deduction of CO_2 of fossil origin. In addition, LSCE regularly takes a set of samples from each of the observatories in order to quantify regional variability.

Since 1996, in order to have access to representative measurements of the lower atmosphere in the continental region, LSCE has established regular sampling from 0 to 3 000 metres above Orléans. This set of data is one of the first series of measurements on the continental atmosphere, and will make it possible to quantify the seasonal variability of CO_2 in the lower troposphere.

Future RAMCES Measures

The Indian Ocean was chosen to enrich the network in key regions. The new project involves the OISO observation system, based on the ocean-faring ship Marion-Dufresne, with three air sampling stations to be used in La Réunion, Tromelin (in operation since 1997) and the Maldives Islands. These stations, which will be complemented by the Amsterdam (continuous) and Crozet (collaboration with NOAA) stations, are expected to enable good characterisation of the role of this region in the carbon cycle within three to five years.

The European Project «Aerocarb»

The second key region studied by Ramces is Europe. LSCE is co-ordinating the work of 13 laboratories in the Aerocarb project, which aims to raise the number of observatories of CO_2 above the European continent from 14 to 30 within three years. The programme was intended to demonstrate the feasibility of an integrated approach and to estimate and check the net carbon balance in Europe from the monthly to the decennial scale. This true pan-European network on greenhouse gas monitoring aims to unify CO_2 measurement networks in Europe (to be completed with measurements taken from planes), and use extremely precise measurement techniques. The objective is to implement a new approach using a variety of tracers so as to separate the various origins of carbon flows: O_2 and CO_2 concentrations (land-ocean interaction), CO_2 (contribution to fossil fuels) and CO measurements (validation as a less costly alternative for CO_2).

4.3 Fluxnet

Measurements of carbon flows in land ecosystems are carried out under the Fluxnet international programme and the various programmes associated with the Carboeurope group of projects described below.

Carboeuroflux

The aim of this programme is to improve our knowledge of the significance, location and evolution in time of carbon sinks and sources in terrestrial ecosystems and to understand their causes. This should make it possible to improve the European Community's ability to negotiate under the Kyoto Protocol. All these sites have similar equipment: a measurement mast (or tower) with several rapid sensors to measure movement quantity flows, sensitive heat, water vapour, CO_2 . Measurements are carried out at 20 Hz, constantly over periods of

several consecutive years. Microclimatic measurements are also made (spread, temperature, humidity, wind, precipitation etc.) and eco-physiological (sap flows, photosynthesis, ground aeration, biomass, lead rate etc.).

Carboage

The aim of this programme is to analyse the role of forests in Europe as carbon sinks during their life cycle. Here we measure CO_2 flows on a certain number of sites (as in the case of Carboeuroflux), which will be used to estimate these flows on a higher scale. This will enable us to develop new options for managing carbon sequestration. We expect that disturbances in the soil resulting from tree cultivation (planting, maintenance, harvesting) produce carbon flows from the ground, which can have a significant effect on the development of these flows over time.

As regards these two programmes, France has six operational experimental sites that supply the databases. They can be seen in the following table:

Site	Place	Type	Manager	Programme	Start date
Bray	Gironde	Marine pine	Berbigier (INRA)	Carboeuroflux	1996
Hesse	Lorraine	Beech	Granier (INRA)	Carboeuroflux	1996
Puechabon	Hérault	Green oak	Rambal (CNRS)	Carboeuroflux	1998
Bilos	Gironde	Heath	Loustau (INRA)	Carboage	2000
Laqueuille	Puy-de-Dôme	Meadow	Soussana (INRA)	Greengrass	2000

Carbodata

These sites provide two types of data:

- unprocessed data (20 Hz), stored on CD for each participant;
- processed data (1/2 h), transmitted to the Carbodata programme, responsible for maintaining quality and storage. This is a database that supplies information on the carbon cycle for a broad range of ecosystems and places. It has to allow for day-to-day estimates of changes on various sites for studies of ecosystems. It can also validate remote sensing products. Eventually all this will make it possible to provide higher range carbon balances or supply European carbon flow maps. The final aim is to supply estimates of carbon sinks from models, in response to demand from users or Member States of the European Union.

4.4 Observation of Forest Ecosystems

Forest ecosystems, which occupy 27% of land in France, are regularly observed using two systems: over a period of ten-twelve years, the national forest index assesses – as it has done for almost forty years - forest resources and productivity; for about ten years it has been gathering environmental data, mainly on forest flora and soil. For ten-twelve years, a regular monitoring mechanism (annual or infra-annual data), originally introduced to investigate acid rain, has been developed towards an universal system covering all environmental influences. These two systems periodically evaluate carbon deposits in the forest biomass and soils and will, in the long term, enable us to quantify the influences of environmental changes, especially climate change.

5. Space Observation

CNES was one of the pioneer organisations to observe the Earth from space. Its programme takes up almost one third of the budget. It cooperates internationally, under a bilateral framework, and also by participating significantly (22% to 25%, depending on the programme) in European Space Agency programmes. This programme is organised in «sectors» – series of projects with common objectives or requiring specific techniques, with a concern for innovation, fulfilling scientific needs and developing applications.

Earth Surface Imaging Programme

The high-resolution imaging sector, supported by CNES, contains a Spot optical imaging system (4 satellites launched between 1991 and 1995; Spot-5 will be launched in October 2001) and the ESA radar satellites (ERS-1 and 2 launched in 1991 and 1995; Envisat will be launched in October 2001), whose images are used for various applications. Apart from the Spot project, the CNES is preparing the Pléiades system with European cooperation; it will contain various optical imaging and spectral and spatial resolution radar projects to respond to the various needs of European users.

Without directly supplying data on climate, the observations acquired over a long period by Spot satellites, and especially by the Végétation sensor, which ensures global cover of the earth on a daily basis, will act as a reference basis for long-term monitoring of ground cover.

Distributed on a commercial basis, Spot and Végétation data are placed at the disposal of the European scientific community at a discounted price, and sometimes completely free.

Meteorological Programme

In the 1970s, the CNES set up a meteorological programme, Météosat, transferred to the ESA and then to Eumestat. Since then, it has focused on improving remits for operational forecasting of the weather, using new sensors, such as IASI, to be installed on the series of three European meteorological satellites in the polar orbit, METOP (to be launched in 2005) and the preparation of future missions, beyond MSG and METOP.

Data from the meteorological satellites and improvements in performance, especially for atmosphere sounding, are of direct use for climate.

Research Programme

Research programmes for understanding the Planet Earth system are a very important item in the CNES programme. Firstly, they aim to acquire global data sets needed for world research programmes on climate and global change and have other objectives, such as improvements in our knowledge of geodynamics and forecasting or reducing geophysical parameters. The measured parameters refer to:

- clouds, water vapour, radiation, aerosols, plant cover, water colour: this is the aim of the wide field system, with Polder-1 and 2, Végétation-1 and 2, ScaRaB-1 and 2, Meris;

- ocean circulation with the altimetric project series, including Topex / Poséidon, Jason 1, RA / ERS and Envisat, Cryosat;
- physical chemistry of the atmosphere, with the balloon and airborne instrument sector (Theseo, Strateole, Map campaigns) and the atmosphere-sounding sector (Wind II, Odin, Iasi, Envisat, Alissa, Picasso-Cena etc.);
- measurement of the field of gravity, the magnetic field, determination of the geoid; this is the subject of the geophysical programme, in which the Doris series (on Spot, Topex / Poseidon, Envisat, Cryosat) plays a role, and the Oersted, Champ, Grace and Goce missions. The data thus acquired help to determine ocean circulation derived from the data measuring the dynamic topography of the ocean through altimetry. All these programmes are equipped with data use support, in partnership with other bodies and at European level, especially thematic data production centres, such as Mercator for oceanography. Satellite data in the research sector is made available free to the scientific community. Processing, standardisation, validation and storage of data is managed by international research teams.

To guarantee the continuity of spatial observations on climate, in partnership with other organisations and at European level, CNES is entering into discussions to ensure that data remain operational. This is the case of NASA, with Topex / Poséidon and Jason-1 on the one hand, and of NOAA and Eumetsat on the other, with a view to transferring responsibility for the altimetry sector to these two bodies (Jason-2).

Participation in ESA Programmes

ESA, for its part, is developing an Earth Observation Envelope Progamme (EOEP), to which France will make a 22% contribution. The first phase (1999-2001) includes «Earth Explorer» research missions that are all of direct use for climate study: fine resolution of the geoid (GOCE), ice cartography (CRYOSAT), experimental determination of ground humidity and of the surface salinity of the ocean (SMOS).

The second phase (2002-2007) of EOEP will be decided at the end of 2001. An Earth Watch programme may be introduced for this, with an application aim, including optical imaging and radar missions and an ocean surveillance mission in the polar orbit, expanding the ERS and Envisat missions.

National Programme for Space Remote Sensing

The National Programme for Space Remote Sensing (PNTS) illustrates the use of the satellite instrument for climate study and its research themes are presented along the different components of the environment (cryosphere, biosphere, atmosphere, ocean).

The **cryosphere** is an important component of the earth's system; it incorporates water in its various solid forms, snow or ice: snow, sea, river and lake ice, polar ice caps and mountain glaciers. This important element in the earth's system is to be found from the tropics to the poles. Because of its albedo and positive retroaction effects, its role in the climate system is of vital importance. It is thought that some of the climate warming measured in the upper latitudes of the Northern Hemisphere, especially in Canada, is conditioned by these effects. Snow and ice, whether permanent or seasonal, also play a dominant role in the earth's hydrological system because of the amounts of potentially available water that they contain. The cryosphere is one of the main causes of rises in sea levels. These elements are sensitive

indicators of any climate change that can be detected and followed from the tropics to the poles. In the case of sea ice, since 1992, the space-time coverage of ERS diffusiometers has supplied seasonal and inter-annual changes in surface humidity and roughness (due to the type of sea ice). Launched in June 1999, the SeaWinds diffusiometer on QuickSCAT monitors retro-diffusion on a daily basis and its resolution makes it possible to follow sea ice drift for the first year or over three years. As regards alpine or tropical glaciers, thanks to optical images, we can now identify accumulation and ablation areas. We can therefore find the position of the line of equilibrium in order to determine the mass budget. Although the extent of snow cover is easy to detect, its thickness is not so easy to identify. The two radiometer channels, 19 and 37 GHz, gives an approximate thickness value that does not include changes in snow cover. Using the snow temperature gradient, we can correct algorithms (work done by CESBIO). As for the altimeter, it can measure vanishing snow cover, and therefore, potentially, thickness (work by LEGOS). Concerning the antarctic mass budget, seasonal variations in the accumulation rates have been estimated in terms of variations in sea level: these create a signal as to sea level of a maximum of 3 millimetres in magnitude at the end of december, which can be easily identified from the altimeter data (LEGOS).

For solid earth, we have explored new observation methods, such as airborne radar in band P, wide-field airborne laser telemetry and satellite altimetry in the continental area. These developments mean that we can, in particular, monitor lakes and medium-sized and major rivers. Similarly, we have extended the field of application of remote sensing to areas that have been little explored, such as the coastal dynamics with, for example, changes in coastlines and the emergence of rocky islets. Knowledge of them is vital for navigation. Finally, new approaches are directed at the urban environment, with combined use of optics and radar for integrated environmental studies of city environments.

Here are the respective studies for the **biosphere**, which includes the water cycle and the carbon cycle.

Water Cycle

Water is a vital element in the system because of the close coupling of its flows with those of energy, gas (including greenhouse gases, solutes, colloids, particles, genes etc.). Observation from space helps us to better understand how the soil works, the states of the ground surface in relation to run-off and erosion, hydrological conditions in the non-saturated area, and enables us to estimate water routes and, in particular, to study the major beds of the great rivers and to estimate flows at the outlet from the catchment basin by assessing balance terms. Microwave radiometry in band L enables us to characterise surface humidity. The development of the SMOS satellite programme is part of this framework. Interpreting radar data on rugged ground is progressing. We can thus estimate roughness and biomass in semi-arid areas in a dry ground situation.

Carbon Cycle

This concerns ecosystem productivity, dynamic and functioning, whether natural or developed by man. Important advances have been made in describing, understanding and using reflectance in the solar area. Inversion methods have been suggested to estimate biophysical surface characteristics (LAI, Fapar, albedo, soil humidity, biomass quantity), especially thanks to the use of directional variation to back up interpretation of Polder data. This work makes it possible to estimate variables that are part of the process for describing carbon and water flows at different levels: local, kilometric and global.

As regards the meteorological **atmosphere** and climate change, understanding of the cloud-aerosol-water of vapour-radiation naturally depends on observation. Space missions on this topic have played, and will continue to play, a predominant role in the future. We have to study clouds, look at their optical and physical features, examine aerosols, the intensity of their sources and their radiative and physical properties, estimate the radiation balance, arrive at a better understanding of the water cycle and quantify associated retroactions. We have obtained highly relevant results from the aerosol study. Firstly, the algorithms using Polder measurements have given us an excellent view from space of aerosols above the earth. Polder's polarised measurements are the first quantification of aerosols above the earth seen from space.

In the case of clouds, Polder's measurements enable us to analyse the anisotropy of reflected radiation. Observations mean that we can identify certain microphysical models. Moreover, with Polder's polarised measurements, we can unambiguously identify cloud phase. Finally, Polder's measurements provide a very precise measurement of the size of droplets at cloud summits.

For the **ocean**, methodological analyses on the same physical parameter from different satellite sensors (ERS, QSCAT, NSCAT for winds, ERS, SSMI for flows; ERS, Topex / Poseidon for sea level) improve signal release (work done by LODYC) and enable us to reconstruct ocean fields using the space-time capacities of each mission to their optimum (sea level). An inversion model for satellite surface temperatures, to produce high resolution fields of ocean surface current, has been developed and tested in the South Atlantic, together with an altimetry monitoring method of the vertically integrated transport of the current from the Falklands (work done by LEGOS and LODYC).

GENERAL CONCLUSION

These research and observation programmes for climate change cover a wide range of levels in space and time (past climate in particular), a large number of physical, chemical and biological processes and their interaction. Observation is carried out in various environments (earth, atmosphere, ocean) and gives us a better understanding of the way the whole system works, while ensuring comparison with former climates. The advances suggested for ocean observation, with operational connotations, will also provide us with a better understanding of the way the ocean machine works, which plays an important role in climate. Moreover, the question of ensuring constant observation, which is vital for observing the climate, has been clearly posed in recent years. For this purpose Observatories have been set up (operation and research) in the environments. Finally GMES (Global Monitoring for Environment and

Security) proposes to monitor the global environment within the framework of environmental treaties (Kyoto Protocol).

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ACRONYMS

ADCP : Acoustic Doppler Current Profiler

ADEME : Agence de l'Environnement et de la Maîtrise de l'Energie (Agency for the Environment and Energy Management)

ARGO : Array for Real time Geostrophic Oceanography

ARGOS : Système de localisation et de transmission de données par Satellite (System for Localising and Transmitting Data by Satellite)

BAPMON : Background Air Pollution MOnitoring Network

CEA : Commissariat à l'Energie Atomique (Atomic Energy Agency)

CEMAGREF : CEntre de Machinisme Agricole du Génie Rural et des Eaux et Forêts (Centre for Agricultural Machinery in Rural Affairs and Water and Forests)

CESBIO : Centre d'Etudes Spatiales de la BIOsphère (Centre for Spatial Studies of the biosphere)

CLIVAR : Climate Variability and Predictability (WCRP)

CNES : Centre National d'Études Spatiales

CNRM : Centre National de Recherches Météorologiques (National Research Centre of Météo-France)

CNRS : Centre National de la Recherche Scientifique

CRYOSAT : Cryogenic Satellite

DBCP : Data Buoy Cooperation Panel

ECD : ECSN Data Set

ECLAT : Etudes climatiques dans l'Atlantique tropical (Climate Studies in the Tropical Atlantic)

ECLIPSE : Environnement et CLImat du PasSE (Environment and Climate of the Past)

ECSN : European Climate Support Network

EGOS : European Group on Oceanic Stations

ENSO : El Niño Southern Oscillation

ENVISAT : ENVIronment SATellite

EOEP : Earth Observation Envelope Programme

EPS : Eumetsat Polar System

EQUALANT : étude de l'AtlaNTique EQUAtoriaL (study of the EQUAtorial AtlaNtic)

ERS : Earth Remote Sensing (Satellite ESA)

ESA : European Space Agency

EUMETNET : EUropean METeorological NETwork

EUMETSAT : organisation EUropéenne pour l'exploitation des SATellites METéorologiques (EUropean organisation for the Use of METeorological SATellites)

FAPAR: Fraction Absorbée du Rayonnement Photosynthétiquement Actif

GAM : Global Atmospheric Modelling

GAW : Global Atmosphere Watch

GCOS : Global Climate Observing System

GEWEX : Global Energy Water EXperiment

GICC : Gestion des Impacts du Changement Climatique (Management of Climate Change Impacts)

GLOSS : Global Sea Level Observing System

GMES : Global Monitoring for Environment and Security

GOCE : Gravity Field and Steady-State Ocean Circulation Mission

GODAE : Global Ocean Data Assimilation Experiment

GOOS : Global Ocean Observing System

GSN : GCOS Surface Network

GTN : Global Terrestrial Network

GTS : Global Telecommunication System

GUAN : GCOS Upper Air Network

IASI : Infrared Atmospheric Sounding Interferometer

IBPIO : International Buoy Program in Indian Ocean

IFN : Inventaire Forestier National (National Forestry Inventory)

IFREMER : Institut Français de Recherche pour l'Exploitation de la Mer

IFRTP : Institut Français pour la Recherche et la Technologie Polaires (French Institute for Polar Research and Technology)

IGAC : International Global Atmospheric Chemistry

IGBP : International Geosphere-Biosphere Programme

INRA : Institut National de Recherche Agronomique (National Institute for Agronomic Research)

INSU : Institut National des Sciences de l'Univers (National Institute for Universe Sciences)

IOC : Intergovernmental Oceanographic Commission

IUGG : International Union of Geodesy and Geophysics

IPSL : Institut Pierre-Simon Laplace

IPCC : Intergovernmental Panel for Climate Change

IRD: Institut de Recherche sur le Développement (Institute for Research overseas (formerly ORSTOM))

JASON : Altimetry Satellite (CNES/NASA), following TOPEX/POSEIDON

JGOFS : Joint Global Ocean Flux Study

LAI : Leaf Area Index

LEGOS : Laboratoire d'Etudes en Géophysique et Océanographie Spatiale (Laboratory for Geophysical and Space Oceanography Studies)

LGGE : Laboratoire de Glaciologie et de Géophysique de l'Environnement (Laboratory of Glaciology and Geophysics in the Environment)

LMD : Laboratoire de Météorologie Dynamique

LODYC : Laboratoire d'Océanographie Dynamique et du Climat

LSCE : Laboratoire des Sciences du Climat et de l'Environnement

MERCATOR : Projet français inter-organismes de Modélisation Océanique globale à haute Résolution avec Assimilation (Interorganisation French Project on High Resolution Global Ocean Modellisation with Assimilation)

METOP : METeorological Orbital Platform (EPS pour les européens)

MSG : Météosat Seconde Génération

NSCAT : NASA Scatterometer

OISO : Service d'Observation de l'Océan Indien (Indian Ocean Observation Service)

OSUG : Observatoire des Sciences de l'Univers de Grenoble (Grenoble Observatory of Universe Sciences)

PAGES : Past Global Changes

PATOM : Programme Atmosphère et Océan à Multi-échelles (Multi-Scale Atmosphere and Ocean Programme)

PIRATA : PIlot Research moored Array in the Tropical Atlantic

PlEIADES : Earth Observation Programme (optical sensors and radars)

PNCA : Programme National de Chimie Atmosphérique (National Programme for Atmospheric Chemistry)

PNEDC : Programme National d'Etude de la Dynamique du Climat (National Programme for Research into Climate Dynamics)

PNTS : Programme National de Télédétection Spatiale (National Programme for Space Remote Sensing)

POLDER : POLarization and Directionnality of Earth Reflectances

PRISM : PRogramme for Integrated earth System Modelling

PROOF : PROcessus bio-géochimiques dans l'Océan et Flux (Bio-geochemical Processes in the Ocean and Flows)

PROVOR: flotteur PROfileur français (IFREMER) (French Floater Profiler)

Quickscat : QUICK SCATterometer

RAMCES : Réseau Atmosphérique de Mesure de Composés à Effet de Serre (Atmospheric Network to Measure Components with Greenhouse effects)

RTDFP : Research and Technical Development Framework Programme

SHOM : Service Hydrographique et Océanographique de la Marine

SMOS: Salinity and Moisture Observation Satellite

SOOP : Ship Of OPportunity

SPOT : Satellite Pour l'Observation de la Terre (Earth Observation Satellite)

SSMI : Special Sensor Microwave Imager

SVP : Surface Velocity Program

TAAF : Terres Australes et Antarctiques Françaises (French Austral and Antartics Lands)

TAO : Tropical Atmosphere Ocean

TOGA : Tropical Ocean and Global Atmosphere

TOPEX/POSEIDON : Satellite franco-américain d'altimétrie Océanique (Franco-American Ocean altimetry Satellite)

UNFCC : United Nations Framework Convention on Climate Change

VAW : VersuchsAnstalt für Wasserbau, Hydrologie und Glaziologie der Eidgenössischen Technischen Hochschule (Research Institute for Hydraulic Engineering, Hydrology and Glaciology of the Federal Technical High School)

VOS : Voluntary Observing Ship

WAMP : Wet African Monsoon Project

WCRP : World Climate Research Programme

WOCE : World Ocean Circulation Experiment

WMO : World Meteorological Organisation

XBT : eXpendable BathyThermograph