DEVELOPPEMENT OF A REAL TIME IN SITU OBSERVING SYSEM

IN THE NORTH ATLANTIC OCEAN,

BY AN ARRAY OF LAGRANGIAN PROFILING FLOATS

GYROSCOPE

Prokect N° EVK2 – CT - 2000 - 00087

Key Action 2 “Global Change, Climate and Biodiversity”

2.4. European component of the global observing systems

2.4.2. Development of new long-term observing capacity

DESCRIPTION OF WORK

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1. Project summary

Development of a real time in situ observing system in the North Altantic ocean, by an array of Lagrangian profiling floats.

1.1 Problem to be solved

Progress in numerical modelling, the availability of satellite-borne sensors, and global ocean observation programmes, have led to the understanding of large fluctuations in the coupled ocean-atmosphere system. The possibility of seasonal forecasting of the coupled ocean-atmosphere system could have considerable economic benefits, but it cannot be done without appropriate ocean models and observations. In several countries, operational ocean–atmosphere models are being developed to enable nowcasting and forecasting.

Ocean observing systems are required in support of those operational objectives, as well as for ocean models assessment and validation; for understanding and modelling the ocean role in climate; monitoring ocean changes; and enabling long-term trends prediction.

GyroScope aims to develop a key component of such a system, that will provide, for the first time, basin-wide in situ ocean observations with a sampling appropriate to resolve seasonal and inter-annual variability. The detection of longer time scale climate signals will require that such observing systems be maintained permanently.

1.2 Scientific objectives and approach

The overarching objective of the GyroScope project is to develop a European component of a global *in situ* observing system of ocean variability in the North Atlantic, based on autonomous, freely drifting profiling floats, which can measure vertical profiles of temperature and conductivity (from which salinity can be deduced) at regular intervals. The data are transmitted by satellite to a receiving station.

The first objective is to deploy a pilot array of about 80 autonomous profiling floats, as a contribution to the international ARGO programme. This array will transmit in real time data to Data Centre Ifremer, that will quality control, and distribute it on the Global Telecommunication System for use by National Weather Services, and operational agencies. The data will be used to estimate the time varying ocean circulation, temperature and salinity fields, and the balance of heat in the North Atlantic. Some of the estimations will be done in real time ; other will include complementary data sets (satellite altimetry) to obtain the most accurate estimates and assess the information content of the float data (resolution, accuracy). Recommendations will be made for future implementation of an in situ ocean observing system.

This project involves a combination of field work, data processing and evaluation, numerical modelling of ocean circulation, and studies of ocean circulation and ocean-atmosphere interactions on large scales.

1.3 Expected impacts

The project goal is to develop a fully operational, low resolution array of profiling floats in the North Atlantic. A real time data stream operating continuously will deliver quality controlled data to operational meteorological and oceanographic services. Data synthesis obtained at two week intervals will give for the first time an opportunity to monitor the state of the ocean in real time. The data provided by this project will allow, in combination with satellite data and numerical models, improved long range weather forecasts by the National Weather Services, as well as more realistic ocean models for operational users, and a much improved understanding of the role of the ocean in climate. The data will contribute to a unique data base for future climate research.

It is hoped that the results of the project will enable the implementation of permanent in situ ocean observing systems for operational and scientific needs, much as those that have been in place for decades in the atmosphere.

2. Scientific/Technical objectives and innovation

2.1 Objectives

Introduction

Progress in numerical modelling, the availability of satellite-borne sensors, and global ocean observation programmes, have led to the understanding of large fluctuations in the coupled ocean-atmosphere system. The possibility of seasonal forecasting of the coupled ocean-atmosphere system could have considerable economic benefits, but it cannot be done without appropriate ocean models and observations. In several countries, operational ocean–atmosphere models are being developed to enable nowcasting and forecasting (the ECMWF seasonal forecasting unit, the FOAM model of the UK Meteorological Office, or the MERCATOR model, for instance). Ocean observing systems are required in support of those operational objectives, as well as for ocean models assessment and validation; for understanding and modelling the ocean role in climate; monitoring ocean changes; and enabling long-term trends prediction.

The overarching objective of the GyroScope project is to develop a European component of a global *in situ* observing system of ocean variability in the North Atlantic, based on autonomous, freely drifting profiling floats, which can be programmed to settle at a pre-set *parking* depth, where they drift with the ocean currents. At regular intervals, they dive to depth (nominally 2000 m) and then rise to the surface while measuring pressure, temperature and conductivity (from which salinity can be deduced). The vertical profile is transmitted by satellite to a receiving station, before another identical cycle is started (Fig. 1).

The project is a contribution to the international ARGO programme, with which it is coordinated (see Section B5). The international Global Ocean Data Assimilation Experiment (GODAE), planned to start in 2003, aims to demonstrate the feasibility of data assimilation on a global scale. Recognizing the need for appropriate in situ data, GODAE has strongly endorsed the ARGO programme as a key component of ocean observing systems. One of GyroScope's objectives is to address a number of outstanding issues in preparation to the full deployment of the ARGO array in support of GODAE. EuroGOOS and the EuroGOOS Atlantic Task Team (Le Provost and Flemming, 1998) have recommended that steps be taken for intensive European preparation to GODAE.

The research and development plan of the GyroScope proposal cover the different components of an ocean observing system, from its technical and engineering aspects, to the investigation of its information content and the study of ocean processes as observed by the array. We plan to design and deploy a pilot array of the order of 80 floats in the North East and sub-polar Atlantic Ocean (Fig. 2). The area has been chosen for its impact on European climate : the sampling frequency will allow the resolution, on a large scale, of the seasonal cycle, and to quantify the winter release of heat stored in the ocean during summer. The North Atlantic ocean plays also a critical role in the global ocean circulation, since variability in the subpolar gyre has the potential to affect catastrophically the thermohaline overturning pattern. It has been described by Broecker (1997) as *"the Achilles heel of our climate system"* that could be significantly affected by green house gases increases. During the time frame of the proposal, we will investigate and quantify the variability of ocean circulation, the water mass characteristics and the budgets of heat and fresh water, including large scale ocean–atmosphere interaction.

The GyroScope project will deliver data in real time to users in the national weather and oceanographic services (FOAM, MERCATOR, operational agencies, navies), to fisheries managers, and the scientific community.

Objective 1 : Deploy an initial array providing real-time data to users

The ARGO Science team has recommended a low resolution (order 300 km) deployment strategy, which we adopt as a base line. An array at least 80 floats will cover the area indicated on Fig. 2. They will be deployed to initiate the ARGO network, and to address the relevant scientific and technical challenges posed by this novel type of observing system. Array design studies are required to evaluate the pertinence of, and to qualify, the general ARGO recommendation for the specific case of the North Atlantic. Simulations in a high resolution ocean circulation model, will be performed to investigate the resolving power of various array configurations. The actual deployment strategy will be based on the results, with adjustments made according to constraints of ships available for deployment. The floats will be acquired, prepared for deployment, and deployed at sea.

A Data Centre will collect, quality control, validate, format, and distribute the data, which will be available, through the Global Telecommunications System, to the national weather services, other operational users (FOAM, MERCATOR), and the scientific community. After validation the data will be archived and made available to the scientific community as a legacy of the project. The life time of the floats will exceed the duration of the project, which will thus contribute to initiate a new cost-effective observation component for the North Atlantic Ocean. The data will then be handled by the ARGO infra-structure.

Objective 2 : Estimate the information content of the array.

We propose to investigate the information content of the system for its different applications. A novel feature of this array is that its geometry will be varying in a random fashion. The accuracy and resolution of the array will be investigated, not only for the observed variables (temperature, salinity, velocity), but also for derived quantities (for instance: heat and salt content, transports, surface fluxes, potential vorticity). Techniques of objective analysis and inverse modelling will be implemented for this purpose.

Profiling float data contains information complementary to that of satellite altimetre. We will use both data sets to inter-compare dynamic heights derived from altimetre and in situ profile data. Simple statistics and error covariance statistics of the data will be calculated, for the purpose of assimilating the float profiles in models of various resolutions. The inverse model, which combines altimetre, profiling float, and surface flux data will be used to assess the relative contributions of the data sources. This model will also provide an optimal estimation of the time varying field, for scientific investigations.

The potential value of profiling float data for detecting climate change will be assessed from long term simulations in a model field output from a coupled climate integration.

Objective 3 : Develop procedures for real time ocean state estimation.

Techniques for real time estimation of the ocean fields (circulation, temperature and salinity fields), based on inverse modelling of the float data will be developed and implemented on a pre-operational basis. They will provide quick-look synthesis of the data, useful for visualisation and interpretation of the data, and for monitoring of the progress of the experiment.

Another approach to real time estimates by an operational data user, is to combine satellite altimetre with float data into an ocean circulation model. During a two month test period the model will be serve in a now - and forecasting mode. Those approaches, which are incomparably less demanding on resources, provide an alternative to the full operational assimilations. Their skill will be evaluated.

Objective 4 : Estimate time varying ocean transports and structure

The time frame of the development phase covered by this proposal is too short to observe long term climate signals, but key underlying processes will be studied and quantified on seasonal and inter-annual scales. On the seasonal time scales, the ocean releases during autumn and winter the heat it has accumulated during summer, with a direct effect on the atmosphere and the European climate. On longer time scales, the ocean role in climate is the non linear cumulative effect of inter-annual processes.

We shall quantify, over a two year period, the upper ocean response to the wind variability, the large scale heat and fresh water budgets, the formation of the subpolar mode water, and the circulation and characteristics of the intermediate water masses. The contribution of float data to those calculations will be evaluated.

Objective 5 : Develop a cost effective sampling strategy to observe ocean variability in the North Atlantic.

The optimum strategy for implementation of an ocean observing system must take into account a wide range of factors : technical, economical, and scientific. We will review the results of the project and the initial array, and address such issues as the type of instruments and sensors to be used, the number of floats needed for the various applications (operational assimilation into models, scientific investigations, detection of large scale climate anomalies) ; platforms to be used for float deployment (ships or airplanes) ; and the institutional framework for implementation (national or international, public or private). Recommendations for future implementation of observing systems will be made at the end of the project.

2.2 Innovation

2.2.1 Introduction

In the last decades, the need has been growing for ocean observing systems in support of a wide range of human activities and concerns, such as fisheries, shipping, coastal forecasts, hydrographic surveys, or industrial and naval offshore exploration and operations. Increasing awareness and understanding of the role of the ocean in the global climate system has emphasized the requirement for further studies, modelling, and observations. In that context, several international panels (GOOS, GCOS, IOC, the OOPC,) the UNFCC, the Kyoto Protocol) have recommended and endorsed the development of enhanced ocean observing systems.

With respect to existing ocean observing systems, the ARGO array has the potential to increase significantly, on an operational mode, the quality and the number of in situ observations, with a much deeper and better spatial and temporal coverage, and with the addition of salinity and velocity observations.

2.2.2 Existing observing systems

Surface observations :

Most operational, global, in situ ocean data is presently obtained by Voluntary Observing Ships (VOS) and co-ordinated by National Weather Services (NWS). It is limited to sea surface temperature along shipping routes. The number of available observations has been decreasing in recent years, and the sampling is irregular in time and space.

Moored and drifting buoys are coordinated by the Data Buoy Cooperation Panel (DBCP) under sponsorship of the Intergovernmental Oceanographic Commission (IOC) and the World Meteorological Organization (WMO).

Satellite observations :

Remote sensing data provide the only real avenue to global coverage of the surface of the ocean at high space and time resolution. They can provide near real-time, long-term, repeated and global measurements of key parameters. The main remote sensing data sets include satellite altimetry (including geoid), wind vectors from scatterometry and sea surface temperature from infrared sensors. For the next five years, several missions are planned, that should ensure the continuity of those data : for SST (MODIS on EOS ; ATSR on ERS ; POES) ; for winds (Quickscat; ADEOS-2 ; Windsat), and for sea surface topography (JASON-1 ; DORIS-RA2) (Ratier, 1999).

The altimetre sensors (Topex-Poseidon) have spectacularly improved our view and understanding of global ocean circulation and variability. Their data have proven particularly efficient in combination with numerical models and in situ data.

The main issue is thus the development of an appropriate in-situ observing system and the development of integration of in-situ and remote sensing data with model and dynamics. GyroScope will take into account the complementarity between the in situ and remote sensing data: subsurface information from in situ data, irregular and sparsely sampled, surface information from satellites with high space and time resolution and the need for calibration and validation data, particularly for altimetre data.

Subsurface observations from ships of opportunity :

Observations by expendable bathythermographs (XBT) from ships of opportunity have been implemented since the 70's, during the large ocean programmes of the WCRP, most notably TOGA and WOCE. These probes measure temperature with an accuracy of order 0.1°C down to a maximum of 1000 m, (only 400 or 700 m in most cases). Typical sampling, restricted to shipping routes, is about one profile every 150 km. Salinity measurements with this technology is still considered experimental. The data is available (albeit in degraded resolution) on the GTS. There is some concern that this system is not perennial.

2.2.3 The large oceanographic programmes

Most in situ observations are made during scientific research programmes, with the drawbacks of very uneven time and space distribution, and much delayed availability of the data. They provide data of the highest quality, on very specific locations. Repeat, systematic observations are very difficult to maintain in the research context.

Two major international oceanographic programmes TOGA (1985–1995) and WOCE (1990–1999), under the aegis of the World Climate Research Programme (WCRP), have collected valuable global data sets. They have contributed significantly to our understanding of the ocean role in climate.

Started with scientific objectives, TOGA has led to the design and eventual deployment of the operational TAO observing system in the Tropical Pacific ocean, consisting of moored surface buoys, tide gauges, surface drifters, and XBT lines on ships of opportunity. It is the only existing basin wide operational ocean observing system, albeit only for upper ocean processes. This network has supported the study, understanding, modelling, and prediction of the El Niño phenomenon.

During WOCE, the global oceans were systematically surveyed with hydrographic sections, subsurface floats, moorings, and satellite observations. The last major basin survey of WOCE, the Atlantic Circulation and Climate Experiment (ACCE) took place from 1996 to 1999. Profiling floats were launched, mostly in the Western part of the basin ; a few of those were equipped with conductivity cells to measure salinity. In many case the data remained proprietary to the principal investigators and is not readily available to the general community.

2.2.4 Observation of ocean climate variability

Because of the dearth of in situ data for long times, our understanding of ocean climate variability is still in its infancy. Even the seasonal signal over large scales is poorly observed. Although still inadequate, surface data sets are the most comprehensive. The Comprehensive Ocean Atmosphere Data Set (COADS) have enabled the detection of slowly propagating decadal SST anomalies in the North Atlantic (Hansen and Bezdek, 1996). Such data are so sparse that only the very lowest frequencies of variability, with very low resolution can be determined.

The situation is even worse with subsurface variability. Higher quality XBT or CTD data sets allow more detailed determination of ocean changes, but sampling has not been systematic. It is only with painstaking reconstruction of disparate data sets that large scale processes can be studied, with very low temporal resolution, such as the Great Salt Anomaly (Dickson et al., 1988), long term changes in convective activity related to the North Atlantic Oscillation (Dickson et al., 1996), or inter-pentadal deep variability (Levitus, 1989), or deep basin-wide changes.

An important question for understanding the effect of the ocean on the European weather and climate is to determine to what extent the atmosphere over the Atlantic responds to local oceanic feedbacks (as opposed to the ocean being entirely passive). To address this question, one must observe the upper boundary layer of the ocean ; the cycle of mixing and restratification; the manner in which SST and the associated thermal anomalies are created by air sea interactions ; and quantification of the role of the ocean in the advection and transfer of heat and fresh water to and from the surface. For the longer time-scale processes, the internal modes of ocean variability must be observed, with an emphasis on the thermohaline circulation and the mode waters.

2.2.5 The ARGO project

The Global Array of Profiling Floats (ARGO, 1999a, b) is planned as a major enhancement of upper ocean thermal networks (XBTs), by extending their geographical coverage, depth range and accuracy, frequency of sampling, and adding salinity and velocity measurements. Widespread salinity measurements will be a major innovation. Argo is based on the emerging technology of autonomous profiling floats, which were first deployed on a large scale during the ACCE.

In a typical mission, the float is launched and sinks to a pre-set *parking* depth where it drifts freely ; at a given time, it dives to 2000 m to initiate an ascent to the surface during which temperature, conductivity and pressure data are collected. At the surface, the position and the data are transmitted by satellite, for real-time processing and distribution on the Global Telecommunication System (GTS) ; after which another identical cycle is started (Fig 1). The design lifetime of the float is 100 cycles, i.e. 4 yrs for fortnightly cycles. This amounts to a cost of 170 Euro per profile, making it a very cost-effective technique.

The initial design of ARGO calls for a total of 3000 floats (average float separation of 300 km) to be progressively deployed starting in 2000. The goal is to have the full array in place by 2003, at the start of the Global Ocean Data Assimilation Experiment (GODAE).

2.2.6 GyroScope, towards a European contribution to ARGO

The proposed GyroScope project represents a significant contribution to the international ARGO project. It is proposed to deploy an array of the order of 80 floats, with the development of all the components necessary for an operational integrated system. The real-time aspect, including the anticipated possibility for data merging from satellites and numerical simulation results, will advance the state of the art in operational oceanography. Products derived from the experiment will substantially enhance our understanding of world's climate and its variability as a essential step towards its predictability.

In terms of ocean observations, the possibility of observing at a frequent rate (fortnightly) the temperature, salinity, and velocity of the upper 2000 m, is a very significant innovation. For the first time, one will be able to observe the in situ oceanic seasonal signal on the scale of a whole basin, and to derive budgets of heat and fresh water fluxes, storage, and transports.

During 1998, there were an average of 154 XBT profiles per month available over the area to be covered by GyroScope, with a monthly variance of 77, indicating uneven time distribution. The project would more than double that number, with deeper observations, including salinity and velocity information and regular time sampling. The real time data dissemination to users in the operational and scientific communities is a novel modus operandi in oceanography.

The area chosen, in co-ordination with the International ARGO Science Team, is most of the Eastern and Northern Atlantic Ocean (Fig. 2), an area of vigorous heat loss to the atmosphere in winter (Stommel, 1979).

In contrast to the situation for the atmosphere, where operational observing systems are taken for granted, the oceans are greatly under-sampled, and no systems exist for deep in situ observations. The development within an international context of a European capacity in this area is a major innovation. We will *not* actually *operate* such a system, but we will address the research and development issues which must be solved prior to a cost-effective implementation. At the end of the project we will make recommendations based on our experience and observations, which we hope will enable national and/or international agencies to set-up operational ocean observing systems for climate.

3. Project Work Plan

3.1 Introduction

The development of a large scale in situ observing system of ocean variability is a complex problem, owing to the vastness of the oceans, to the wide range of scales and the diversity of processes to be observed, and to the multiple purposes and clients the system must serve. Considerations must include technical issues related to instrumentation and data handling, scientific, operational, and economic aspects.

The strategy proposed to solve those problems, to investigate the accuracy, resolving power, and the cost-effectiveness of the observing array, and to build a European capacity in open ocean operational observations, is to design and deploy a pilot array in the North Atlantic. In the course of the project, all aspects of the development of an open ocean observing system will be considered.

The technical part of the proposal is included in work packages WP1-3, which cover the field work, instrumental evaluation, and the data stream. The deployment strategy will be defined in close co-operation with other ongoing or proposed experiments (either national programmes or EU funded). The in situ data will be delivered in real time to users (national weather services, operational oceanographic models, research teams), and validated in a delayed mode to build a unique data base on large scale variability of ocean state and circulation on seasonal to inter-annual scales.

WP4 will investigate the information on ocean circulation and processes that can be extracted from the GyroScope array of profilers, in combination with other ARGO floats and altimetry. The impact of float data in association with ocean assimilation models will be of particular interest.

We propose (WP5) to develop procedures for estimation in near real time maps of ocean circulation, and temperature structure from the profiler data, and combined with satellite altimetry data. The fields so derived will be useful data summaries to be filed on the project web site.

The region selected for float deployment covers a large part of the North Atlantic Ocean, where significant large scale ocean-atmosphere interactions occur. WP6 will investigate aspects of wind driven and thermohaline circulation relevant to understanding the role of the ocean on climate. For the duration of the project, only seasonal to inter-annual scales will be accessible – which is in itself quite novel.

The final work package (WP7) will review the whole observing system and make recommendations for future implementation of permanent operational observing systems.

WP1 : Design and deployment of a pilot array

This work package covers the activities leading to the actual deployment of the array in the North Atlantic. The base line strategy is that recommended by the ARGO science team : an average float separation of 300 km, tuned to the detection of large scale features. This amounts to about 80 floats for the area of interest. However, it will not be possible to deploy on a regular grid, because of ships availability, and ocean processes might require to adjust the sampling. These issues are reviewed in Task 1.1 ; the purchase and preparation of the instruments is the object of Task 2.2, while Task 3.3 covers the actual field work.

Task 1.1 - Array and experiment design

The objective of this task is to design an experimental configuration allowing resolution of the large scale seasonal signal of variability of the temperature, salinity and velocity fields.

CLS will provide realistic simulations of the contribution of different profiling float arrays to the description of the variations of the large scale 3-D thermohaline fields. CLS will use outputs and profiling float simulations from primitive equation models of the North Atlantic Ocean (1/3°, 1/6° and possibly 1/12°). The main objective will be to reconstruct the large scale and low frequency variability of the temperature and salinity fields at different depths, in the presence of mesoscale variability. Simulated T and S profiles corresponding to different types of arrays are sub-sampled from the model fields. An optimal interpolation method will then be used to reconstruct the large scale signal variations from these simulated data. Both covariance and noise-to-signal ratios will depend on the geographical position.

The analyses will be performed every ten days over a 4-year period at different depths. Several arrays with different resolutions will be tested. Sensitivity study to the model resolution (1/3° versus 1/6°) will also be conducted to better assess the impact of the mesoscale variability. The results will serve as a guide for the deployments and for the final recommendations on the implementation of the ARGO concept in the Atlantic (WP7).

The actual deployment strategy will be based on a compromise to fulfil the different requirements of extensive coverage, adequate spatial resolution, limitations due to availability of ships for deployment, and the number of floats affordable (for budgetary reasons). Additional evaluation will be made by LPO and IFM on the basis of available lagrangian data from previous experiments (EUROFLOAT, ACCE, and other national programmes).

We will of course take into account of, and coordinate with, other float programmes either decided, or pending approval in France, Germany, Canada, UK, USA. A meeting on ARGO Implementation for the Atlantic is planned in Paris in July 2000. Several of the GyroScope participants will attend.

LPO, CLS, IFM, and IEO will review the technical and scientific issues needed to determine all the mission parameters.

Task 1.2 - Preparing the floats

Floats will be purchased from different manufacturers, tested and prepared for deployment. LPO, SHOM, IFM, and IEO will be involved in those operations. They will be equipped with temperature, conductivity, and pressure sensors. They must have an active buoyancy control, and be able to transmit data at a high rate. As the instruments are autonomous, the mission parameters must be pre-programmed. They include data acquisition (reduction, storage, coding, formatting) and transmission. The parameters will be determined on a scientific and technical basis.

Task 1.3 - Field work

The actual planning and conduct of the field operations in a large segment of the North Atlantic is a complex task.

Several opportunities for deployment have been identified either from research vessels engaged in national projects, or during specific short cruises to be requested. We will aim to deploy as many of the floats as early as possible in order to have the full array in place as soon as feasible. The target date is late summer 2001, but depends on the start date of the project. Other contingencies include possible delays in delivery of floats from manufacturer, and ship scheduling.

IFM has several cruises planned in the Subpolar Gyre (North of 50°N) during the summer 2001. SHOM is involved in intensive field work (repeat hydrography) in the 30°N to 50°N area, during 2001. Ship-time for short dedicated cruises in the Fall of 2001, in the southern part of the GyroScope area (25°N to 40°N) has been requested by LPO (3 days), SHOM (15 days) and IEO (10 days). Opportunities for deployments West of the Azores are available on a Spanish fisheries ship surveying a Spain to Flemish Cap line in summer 2001. If necessary, opportunities will be sought on other ships or research vessels. The possibility to charter a small vessel for float release in specific areas that could not be reached with the previous assets will be considered.

This task is one where there is some risk of partial failure. It is usual for field work in the ocean that some of the instruments will fail and will not perform their mission according to specifications. Every care will be taken in instrument preparation and testing to keep these mishaps to a minimum. If the array of floats becomes too sparse in some regions, we will endeavour to re-seed the area with floats obtained from national programmes, in co-ordination with the international ARGO team. Assessment of ocean state estimation from sparser arrays will also be made.

There is also a possibility that delays might occur in the delivery of floats by the manufacturers. If that should be the case, the fall-back position would be to delay some of the deployments to a later date in the project. The complete array might not be fully operational until the second year of the project, but we shall endeavour to ensure that some areas are properly sampled (subpolar gyre, and inter-gyre region of the NE Atlantic) for efficient ocean estimation.

WP2 : Instrumental monitoring and evaluation

This work package deals with technical aspects of the fleet of cycling floats. They include the float as a vehicle, and the sensors. The objective is to collect information from the experiments at sea, which will be assessed in respect to improvements of the equipment and methods. The evaluation and inter-comparison of different types of floats during their multi-year missions will be an essential element for the final recommendations for future ocean observations in an operational mode (WP7).

Task 2.1 - Monitoring float performance

Incoming data from floats will be handled and distributed by WP3. They comprise two types of data : scientific (pressure, temperature and conductivity) and technical information on float performance of engineering interest. LPO, NERC, IFM and IEO will look into the maintenance of mission parameters, sensor stability, noise level, energy budgets, transmit power, mortality rates and other technical properties of the sensors and their vehicle. The floats from different manufacturers will be inter-compared. Results from WP2 will accelerate the technical development of this type of instrumentation in Europe.

Task 2.2 - Sensor evaluation

Specific efforts are needed to evaluate the sensors in terms of accuracy, stability, and reliability of the hydrographic data obtained during the mission. It is anticipated that salinity measurements will require particular scrutiny because of sensitivity of the sensors to bio-fouling. Automatic correction procedures will be derived by LPO, based on climatology for the area (deep T/S relation), float history, or availability of other data in the area (cross validation of floats). The correction algorithms and information on sensor errors will be conveyed to the data centre to be taken into account in the validated data sets. For floats released from research vessels LPO, IFM, and IEO will make CTD casts at launch sites of floats to obtain reference profiles. Similar sensor comparisons, though on a larger scale, are envisaged with other floats from national sources. Selected sample pre-deployment profiles will be obtained as a check, with the float attached to a CTD rosette, for detailed determination of the sensor response characteristics.

WP3 : Data management and information centre

The objectives of the data management and information ARGO data Centre are to collect, quality control and disseminate the data transmitted from the floats to users. This distribution will be made in a real-time, and in a delayed mode in support of different applications. Complementary data collected in the course of the GyroScope project, or public data (other ARGO floats, for instance) from the GyroScope area will also be handled as part of WP3. A project web site will be established to provide information on all aspects of the project, and to provide easy access to the data.

Task 3.1 - Specification and design of data management structure

This task consists in the development and definition of the data formats and protocols required for implementation of the real-time processing. A data management protocol will be developed by TMSI-Ifremer, in order to insure the comparability, coherence and overall quality of the data collected from different types of floats in accordance with the international agreed standards and the best practise of the international programmes. It will include a data dictionary, formats description (existing formats and libraries will be considered), and description of the quality checks (QC). These QC will include automatic and visual checks. Qualification procedures will be defined for real time, delayed mode, and computed/analysed data. The project web site will be designed and set-up.

Task 3.2 - Real time data management

The float data will be processed in a pre-operational mode by LPO and SHOM. After automatic reception, decoding, and formatting, the data that pass automatic and visual quality checks will be transmitted, within one working day, on the Global Telecommunication System, for delivery to the National Weather Services and for assimilation into operational ocean assimilation models. Other users (such as the scientific community) can be served directly via a mailing list. A WEB site will be maintained to allow browsing and access to the data. Data that do not pass the quality check will be flagged for later scientific evaluation. Every profile flagged as doubtful, will be examined by a trained operator. Technical status of floats will be provided to the engineers and scientists involved in WP2 for evaluation.

All pertinent information on the progress of the experiment will be available on the WEB site, as well as simple data summaries in the form of maps and graphs. As they are developed and made available by the results of WP4, the real time products will be placed on the web site.

The web site will be linked to other servers, with a deliberate effort to connect to educational, or public service sites in order to reach the general public as well as the scientific community and the programme managers.

Task 3.3 - Assembly of integrated data set

After validation, the data set will be merged into a coherent data base with other available data. The data base will be progressively updated during the course of the experiment. The status of the data collection will be available on the web server, with free access on the information (meta-data) : cruises/deployments/data sets summary reports at standardised ROSCOP or other formats. An access to the qualified data will be offered with on line user interfaces.

A perennial archiving of the data will be made for long time exploitation, with merging of the data with long time series of data of the same type. A data product on user friendly media (CD-ROM or similar), will be edited at the end of the project for dissemination of the data to a wide range of users, scientists and non scientists.

A CD-ROM containing validated data synthesis will be released at the end of the project to the users and the scientific community.

WP4 : Information content of the float data

The objective of this work package is to investigate the information that can be extracted from the ARGO array of profilers. The first two tasks consider the combination of the ARGO data with altimetre data. The next two tasks investigate the impact of the ARGO data on inverse model and objective analyses in the Gyroscope area. The final task is an initial assessment of the timescale on which the ARGO system might be able to reveal anthropogenic climate change.

The ARGO system has been proposed as complementary to the altimetre satellite JASON : they should both provide global coverage, with a repeat frequency of the order of 10 days. JASON gives a high along-track spatial resolution of the surface sea level anomalies, while ARGO gives access to the vertical structure of the flow. The sea level anomalies are the sum of two contributions : the steric effect and the reference pressure contribution. The profiling floats measure both terms, through temperature and salinity profiles, and through the geostrophic velocity deduced from float drift and dynamic height differences. In regions where the steric contribution is dominant, the satellite primarily observes variability of heat and fresh water storage. The floats allow discrimination and quantification of the two terms.

Task 4.1 - Compare altimetre and in situ profile data

Studies will be conducted by CLS to better understand altimetre data information content (vertical structure, barotropic/baroclinic), *and* profiling float and altimetre data sampling error. This is a necessary step before combination and data assimilation and should be part of a routine data monitoring activity. The method will use a space/time objective analysis data to interpolate TOPEX/POSEIDON + ERS-2 (and/or GFO, Jason-1 and ENVISAT) altimetre Sea Level Anomaly (SLA) at the time/location of T and S profiles. We will then add a mean dynamic topography to the altimetre SLAs and compare the altimetre sea level with dynamic height derived from profiling float T and S data. Differences will allow to quantify the barotropic component of the flow and measurement (e.g. salinity) and sampling errors. The comparison could be performed in near real time. The analysis of altimetre maps superimposed on profiling float data will also allow us to characterize the flow field (provide the large scale and mesoscale context) around float positions.

Task 4.2 - Statistics and error covariance from assimilation models

OA/MO will assimilate a wide range of observation types, including altimetre and profile data, into models ranging in resolution from 1^o to $1/9^o$, and will examine how standard statistics of the differences between the profile observations and model fields depend on the model resolution and assimilation of altimetre data. In addition OA/MO will attempt to calculate improved statistics for its data assimilation system using the complementary nature of the profile and altimetre measurements. The ocean model fields produced by the system have their errors concentrated at two quite different horizontal scales : the ocean mesoscale (@ 50 km) and the atmospheric synoptic scale (@ 1000 km). These errors at ocean mesoscale and atmosphere synoptic scales have different vertical structures, and amplitudes which vary geographically in different ways. The assumptions a data assimilation system makes about the statistics of these errors determine how the observational increments to the model fields are distributed into mesoscale and synoptic scale structures, and have a large impact on the information extracted from the observations. The statistics can be estimated by comparing observational data and co-located model values. Profile data have an important role in determining the vertical structure of the errors and hence in how altimetre data should be projected in the vertical. Altimetre data give much more information on the horizontal scales and amplitudes of the mesoscale motions but no information on the vertical distribution.

Task 4.3 - Inverse modeling

The finite difference inverse model developed by LPO will be run to estimate the 3D temperature, salinity and velocity fields in the Gyroscope area by combining, in an optimal way, profiling float data (temperature and salinity profiles, velocity at parking depth) and sea surface height from altimetre mission with a dynamical model based on mass, heat, salt and potential vorticity conservations. Storage terms are included in the heat balance. The wind stresses and net heat flux, which are forcing the model, will be those estimated by ECMWF and will be obtained via the French National Weather Service. The spatial resolution will be 1° x 1° and time resolution will be 10 days. For the first year of data, outputs of the inverse model run with profiling float and altimetre data will be compared with those obtained without altimetre data to assess the contribution of each data set to the estimation of the fields.

Task 4.4 - Objective analysis

Univariate objective mapping is the most direct method for estimation of ocean fields on the basis of data alone. Inherent to the technique is the estimation of error maps. Different implementations of objective mapping will be explored by ICM for the observed parameters (temperature and salinity), and derived quantities (density, geostrophic velocity, stream function, vorticity, mixed layer depth). The spatial correlations of the errors in the fields before the introduction of data and the magnitude of errors in these fields and in the observations will be assessed and modelled. The sensitivity of the results to the analysis parameters used, the objective mapping technique (e.g. optimal interpolation and successive corrections) and the scales which the mapping seeks to resolve will be explored. The results will provide a reference against which output from the inverse model and data assimilation studies can be assessed.

Task 4.5 - Observing climate signals with an array of profiling floats

The ocean integrates highly variable surface forcing, and so ocean data potentially can give a high signal to noise ratio for detection of anthropogenic climate change. Recent work (Banks et al., 2000) suggests that changes to the salinity on isopycnal surfaces of mode waters may give an early indication of climate change. The ARGO array would be very well suited to monitoring such salinities. However historical data is limited. OA/MO shall generate synthetic ARGO data from existing integrations of a climate model, in order to assess the potential of ARGO to strengthen confidence in statements about the detection and attribution of climate change. In particular we shall address the question: for how long would we expect it to be necessary to maintain an ARGO system in order to detect anthropogenic climate change in the ocean ?

WP5 : Develop and implement methods for real time field estimation

Two aspects of real time, operational field estimation from the float data are developed in this work package. We seek efficient approaches which do not require the massive resources (man-power and computing) of a full assimilation operational model (such as FOAM, MERCATOR, or DIADEM). The objective is to develop procedures to be implemented in an operational system to estimate, validate, and interpret the data provided by the Gyroscope profilers. The results are valuable data to monitor the experiment, and to obtain quick look data summaries.

In the first approach (Task 5.1), the temperature, salinity and the velocity fields are obtained by inverse analysis. In the second (Task 5.2), SHOM (an operational user of ocean data) will combine float and altimeter data into a quasi-geostrophic and mixed layer operational model, in now- and forecasting modes. Evaluation of the efficiency and skill of those techniques are part of WP5. These tasks are closely related to the techniques developed under WP4, the emphasis being here on the real time implementation.

Task 5.1

LPO will produce 3D maps of the temperature and salinity fields for each cycle of the profilers by an objective mapping procedure. The goal is to go from an experimental phase to a pre-operational phase in which the maps are produced within one working day after delivery of the data by the Data Centre.

The objectively mapped temperature and salinity fields will then be used to obtain 3D velocity fields in the Gyroscope region for every cycle of the profilers using a version of the finite difference inverse model of ocean circulation adapted for real time implementation. Here again, the goal is to achieve a transition from an experimental approach to a near-real time approach. This transition is expected to take place 18 months after the beginning of the project. During the pre-operational phase, maps of the velocity field will be made available on the world wide web by the Data Centre one working day after data delivery.

Task 5.2

SHOM will investigate the potential of profiler data to improve operational analysis and forecast of the flow field in support of offshore activities. As a mission oriented participant, and a user of ocean data, SHOM runs a system coupling an upper ocean model and a QG circulation model constrained respectively with in-situ temperature profiles data and altimetre measurements. Estimates of the dynamical and thermal state of the ocean in real time are obtained.

A quantitative assessment of the improvements brought by assimilation of profilers temperature data to mixed layer prediction and skills of circulation models operated in real time will be given.

The methodology relies on two *predictive* models operated daily with real time forcing and data assimilation.

1. The upper ocean model is a one-dimensional finite difference mixed layer model, using as input meteorological analyses *and forecasts* of surface heat fluxes, net radiative fluxes and wind stress in order *to predict* evolution of temperature profile up to 3 days ahead within the 0-400 m upper layer of the ocean. *In-situ* data contribute to the model initialization.

2. *Circulation of the ocean interior* is given by a quasi geostrophic (QG) circulation model assimilating sea surface height measurements in real time from altimetre missions. A full 3D description of the thermal ocean state is achieved by building up the mixed layer on top of the QG-derived profiles.

Temperature profiles will be obtained daily from the data centre to correct a 3D-temperature first guess of the ocean state. The correction of the first guess (assimilation phase or nowcasting) is performed using an optimal interpolation scheme. Now-cast estimation are then propagated in time using the forecasted atmospheric forcing to predict mixed layer evolution. The system shall be run daily, in real time, for a 2 evaluation month period during the winter 2001-02. The impact of the float data on the skill of the forecasts will be evaluated.

WP6 : Ocean processes

The objective of this workpackage is to use the profiling float data and the outputs of the analysis performed in WP4 to better document the variability of the ocean circulation, the water mass characteristics and the mass, heat and fresh water budgets.

The cyclonic subpolar gyre of the North Atlantic represents a region where the thermohaline circulation has its most distinct vertical component. The warm and saline subtropical waters, imported and advected by the Gulf Stream and its extensions, are transformed in the subpolar basins into intermediate and deep water masses. The pertinent local exchange of heat and fresh water at the surface of the subpolar gyre directly influences the atmosphere, making fluctuations of water mass transformations highly relevant to climate variations in Europe. A monitoring of this conversion on a seasonal basis including careful flux budgets and local circulation observations are essential as input variables for numerical predictions of climatic changes.

Task 6.1 - The upper ocean response to wind variability

LPO will survey and analyze, from the data collected by the floats and the outputs of the inverse model (WP4), the three dimensional structure of the upper main pycnocline. Its evolution with time, the locations of convective and mode water regions will be extracted and related to the realistic wind-driven large scale ocean circulation theories (Pedlosky, 1996). The variability of the upper ocean cross-gyre transports related to the meridional overturning cell will be studied. By analyzing water mass properties from objective mapping and the circulation schemes produced by the inverse model, IEO will study the origin of the surface waters flowing eastward into the Gulf of Cadiz. Are they a small residual from a clockwise circulation including the Azores and Canaries Currents ? IEO and ULPGC will document the variability of the circulation in the Canaries Basin and estimate any relation with the wind forcing. The profiling float data will provide useful measurements to validate prognostic models. NERC will work closely with the numerical modelling group at his institution. The results of a high resolution run forced with ECMWF surface fluxes for the period of the float measurements will be compared with direct observations.

Task 6.2 - The heat and fresh water budget

One of the most vigorous heat transfers from ocean to atmosphere occurs as the North Atlantic Current progressively yields its heat during its progression North-eastward. LPO will use the inverse model results to estimate the respective contribution to the heat balance of local storage, advection by Ekman and geostrophic currents. Time and spatial averaging will be performed to obtain stable estimates over regions of uniform dynamical regimes. LPO will study the compatibility of the sum of the storage and advective contributions to the heat balance with the ECMWF air-sea heat. NERC will compare the variability of the various contributions to the heat balance quantified by LPO with that diagnosed from the prognostic high resolution model and will examine the compatibility of the time-mean of these terms with a climatology of air-sea heat flux. Thus, the capability of the float data to assess the errors and possible bias in both ECMWF air-sea heat fluxes and climatologies will be tested. The fresh water budget is also of major importance for Europe climate. Given the anticipated poor signal to noise ratio, we will concentrate on assessing the capability of the float array and estimation methods to lead to significant estimates.

Task 6.3 - The formation of the Subpolar Mode Water

From the time the warm water enters the advective loop by the North Atlantic Current to the time when it reaches the convection and subduction areas and is transformed into subpolar mode waters, this water mass undergoes a lost of buoyancy (McCartney and Talley, 1982, 1984) which varies according to seasonal and inter-annual fluctuations of surface forcing. In Winter, thermocline water is entrained into the surface mixed layer, which becomes re-stratified the following Spring and Summer by the formation of the seasonal pycnocline. In Autumn, this seasonal thermocline is eroded until winter convection sets in again. This memory effect from one winter to the next, can be one of the processes whereby the ocean sets long time scales into the North Atlantic climate. IFM will investigate the mode water formation, mixed-layer depths, their regional distribution and the relation to forcing mechanisms. NERC will document the occurrence of deep convection from the float profiles. LPO will study the impact of the seasonal cycle on the formation of the subpolar mode waters. These results are important for understanding physical and climatic variability and its impact on the ocean biochemical system.

Task 6.4 - The circulation and characteristics of the intermediate water masses

The intermediate water masses of the ocean provide the long term memory in the climate system. They must be considered in the global budgets of heat and salt, in particular for their contribution to the meridional overturning circulation. The GyroScope array affords the unique opportunity to obtain a synoptic view of the variability of those water masses.

The Labrador Sea Water, which is an end member of the subpolar mode waters, circulates as an intermediate water in the subpolar gyre. Its traces can be identified in the Irminger and Iceland Seas. It contributes as a mixing agent to the formation of North Atlantic Deep Water by blending Overflow Waters from the Greenland and Norwegian Seas and Mediterranean Water from the northeastern Atlantic. IFM aims at the observation of mode and intermediate waters in the Iceland and Irminger Basins with cycling floats. Their profiling capabilities enable the observation of the hydrographic stratification with sufficient resolution in time. The pertinent underwater drift of the floats will reveal the propagation of Labrador Sea Water while spreading from its source region. The Mediterranean outflow is the other important contribution to the intermediate water in the North Atlantic Ocean, and to the overall salt balance of the Atlantic. IEO proposes to study the characteristics of the Mediterranean Water in the eastern Atlantic and to assess the capability of the profiling float of revealing any variability of those characteristics. IEO and ULPGC will study the mixing of the Mediterranean Water with the surrounding water masses and the northward spreading of the Antarctic Intermediate Water in the Canary Basin. The Antarctic Intermediate Water is an important contributor of the meridional overturning cell and is believed to spread northward as an eastern boundary current. The ability of the floats to monitor this current will be assessed by ULPGC.

WP7 – Management, Assessment, and reporting

All aspects of project management and co-ordination are included in this workpackage. Section 9 describes the management approach. The deliverables include the six-monthly managements reports, annual interim reports, and the final report. Additional deliverables include a short glossy brochure to be issued six months into the project, and an updated version at the end of the project. We will also produce a User Requirements Document, which identifies and characterises the main user groups and specifies the sort of results they would find useful.

The final report will review the project and summarize key findings. The approach taken is of an observing *system*, which includes several components : instrumentation, field operations, data stream, real time validation and delivery of data and value-added products, and observation of ocean processes. Results from all the work packages will be synthesized and form the basis for assessment of the strengths and weaknesses of the ARGO concept, as applied to the North Atlantic ocean and European interests.

We believe there is a definite need for the development of operational oceanography in Europe. We shall make recommendations for future implementation of a European capability in that area. Thus we shall consider the issues involved. On a technical level, the types of instruments to be used and recommendations for further technological development ; the cost-effective procedures for deployment and maintenance of an in situ array (ships, air deployments) ; the operation of a data centre. On a scientific level, the impact of in situ float data on ocean modelling, and their complementarity with other in situ or remote sensing data; the accuracy and resolution with which ocean processes can be observed; the strategy required to observe climate signals. We shall include economics considerations, and the institutional framework (private or public) within which an operational ocean observing system could be implemented in Europe.

The final report will contain a Technical Implementation Plan setting out how the consortium will exploit the work after the end of funding (exploitation plan, dissemination, and technology transfer).

WPL Workpackage list						
Workpackage No	**Workpackage title**	**Lead Participant**	**Person months**	**Start month**	**End month**	**Deliverable No**
1	Design and deploy array	LPO	65	1	36	4, 6, 8
2	Monitoring and evaluation	IFM	27	6	33	18, 19
3	Data management	LPO	41	1	36	5, 21, 22
4	Information content	Met Office	88	1	36	11, 13, 15, 16, 17, 25
5	Real time estimation	LPO	13	1	36	9, 23, 24
6	Ocean processes	LPO	184	15	36	26, 27, 28, 29
7	Management and reporting	LPO	15	1	36	1, 2, 3, 7, 10, 12, 14, 20, 30
Total			**433**			

Note on cost of work packages : A significant part of the budget is necessary for the field work: purchase of floats, and ship time. A budget of 1 320 000 Euro is necessary to acquire a minimum of 80 floats (depending on best offer from manufacturers), i.e. about 1/3 of the total cost of the project. Identified ship-time amounts to 252 600 Euro ; but it must be noted that most of the deployments will take place from research cruises organized by the participants (or other opportunities) at no added cost to the project. Short cruises to fill in gaps not covered with the previous assets might be organized on small chartered vessels, the cost of which would be taken from the float budget.

Deliverable list

Deliverable Nr	Deliverable title	Delivery date	Nature	Dissemination level
1	User Requirements Document	3	Re	PU
2	Management Report N°1	6	Re	Co
3	Glossy brochure	6	Pu	PU
4	Array and experiment design	6	Re	PU
5	Design of data management strucure	6	Me	PU
6	Preparation of equipement	9	Eq	RE
7	Annual Interim Report N°1	12	Re	Co
8	Array deployed and transmitting data	12	Da	Pu
9	Real time QG + mixed layer model	14	Da	Co
10	Management Report N°2	18	Re	Co
11	Report on error covariance statistics	21	Re	Pu
12	Annual Interim Report N°2	24	Re	Co
13	Potential for ARGO to detect climate change	24	Re	Pu
14	Management Report N°3	30		
15	Inter-comparison of altimeter and profile data	30	Re	Pu
16	Assessment of contribution of float and altimeter data to inverse model	30	Re	Pu
17	Conclusions of objective analysis study	33	Re	Pu
18	Report on technical behaviour of floats	33	Re	Co
19	Report on sensors behaviour	33	Re	Co
20	Glossy brochure, final version	36	Pu	PU
21	Real time data dissemination	36	Da	Pu
22	Final validated data set	36	Da	Pu
23	Real time temperature and salinity fields	36	Da	Pu
24	Real time velocity fields	36	Da	Pu
25	Inverse model fields every 10 days	36	Da	Co
26	Evolution of upper layers	36	Re	Pu
27	Heat and fresh water budgets	36	Re	Pu
28	Subpolar mode waters characteristics and dynamics	36	Re	Pu
29	Intermediate waters characteristics and circulation	36	Re	Pu
30	Final report, recommendations, Technical Implementation Plan	36	Re	Co

Workpackage number : **WP1**
Start date : **Start of project**
Lead contract : **LPO**
Participants : **LPO, SHOM, CLS, IFM, IEO**
Man-months : **21 (LPO) ; 7 (SHOM) ; 9 (CLS) ; 17 (IFM) ; 8 (IEO)** **Total : 62**

OBJECTIVES AND INPUT

Definition of experimental strategy, and deployment of pilot array.

DESCRIPTION OF WORK

Task 1.1 : Array and experiment design
Perform simulation of different arrays in high resolution circulation model. Review previous data on ocean circulation and lagrangian float trajectories to study dispersion by ocean currents. Define all experimental parameters.

Task 1.2 : Preparing the floats
Purchase, test and prepare floats for deployment. Programme all mission parameters, including data acquisition (reduction, coding, formatting) and transmission.

Task 1.3 : Field work
Organize and prepare cruises, go to sea, and deploy the floats

DELIVERABLES

D4 - Deployment strategy and field work planning .... (Mo 6)

D6 – All equipment ready for deployment .... (Mo 17)

D8 - Array deployed and transmitting data. Output to WP2 and WP3 .... Mo 18)

MILESTONES AND EXPECTED RESULTS

- Definition of optimal sampling grid ....(Mo 6)
- Definition of all experimental parameters...(Mo 6)
- Deployments begin...(Mo 6)
- Different cruises for deployments .... (Mo 6 to 18)
- An ocean observing array is in place and transmits data at regular intervals.
- Quantification of the time evolving accuracy and resolving power of different float arrays

Workpackage number :	**WP2**
Start date :	**First floats deployment, i.e. 6 Mo after start of project**
Lead contract :	**IFM**
Participant:	**LPO, NERC, IFM, IEO**
Person-Mo per partner :	**6 (LPO) ; 2 (NERC) ; 16 (IFM) ; 3 (IEO) Total : 27**

OBJECTIVES AND INPUT

Instrumental monitoring and evaluation of sensors from cycling gyroscope floats.
Input : From WP1 and WP3

DESCRIPTION OF WORK

The WP is structured in two tasks :

Task 2.1 : Evaluate technical aspects of float performance.

Task 2.2 : Sensor evaluation and monitoring. Cross-reference observations from floats and other available instruments ; consideration of climatology to evaluate and calibrate sensors. Special emphasis on salinity measurements. Develop algorithms for automatic correction of sensor drift.

DELIVERABLES

D18 - Report on technical behaviour of floats during course of the project .... (Mo 33)
Output to WP3, WP7.

D19 - Report on sensors behaviour. Output to WP3, WP5, and WP7... (Mo 33)

MILESTONES AND EXCEPTED RESULTS

- Automatic corrections procedures delivered to Data Centre... (Mo 9)
- Interim description and evaluation of floats technical performance for first year of experiment........ (Mo 24)
- Interim report on sensors performance after first year of experiment.. (Mo 24)

Workpackage number :	**WP3**	
Start date or starting event :	**Mo 0**	
Lead contract :	**LPO**	
Participant:	**LPO, SHOM, NERC**	
Person-months per partner :	**35 (LPO) ; 3 (SHOM) ; 3 (NERC)**	**Total : 41**

Objectives and input to workpackage

The objective of the data centre is to collect, quality control, and disseminate in real-time to users the data transmitted by the floats. Within one working day of reception the data will be put on the WMO-GTS network. In a delayed mode, after full validation, data sets will be archived and made available to the scientific community. A GyroScope web site will be established, containing data server, and information on the progress of the project and its results. Diverse data synthesis products will be displayed and retrievable on the web site, for scientific use and general public information.

Input from WP1, WP2, and WP5.

DESCRIPTION OF WORK

Task 3.1 : Specification and design of data management structure

Elaboration and dissemination of the project data management protocol including definition of file formats. Adaptation of the data centre software to take in account the data management protocol requirements of different types of floats. Development and maintenance of the internet catalogues of float deployments. Incorporate sensor correction procedures provided by WP2.

Task 3.2 : Real time data management

Real time management includes : automatic reception of data sets from telecommunication operator, decoding, formatting, qualification, dissemination on WMO-GTS, WEB server, and mailing lists.
Qualification by both automatic and visual checks. In a routine mode, qualified data will be disseminated within 24 hours after complete reception of raw data.
Technical status of floats and deployments will be delivered to WP2 for assessment.
Display synthesis products provided by WP5.

Task 3.3 : Assembly of integrated data set

Delayed mode data management : additional checks for quality including estimation of the sensor drifts are done (WP2). Include data from other sources : data obtained from within the project, and from XBT and other ARGO floats in the GyroScope area are merged with float data in order to aggregate a comprehensive data set. Final archiving and dissemination : Preparations and edition of the data products on CD-ROM. Maintenance of the catalogue in the data centre catalogue

DELIVERABLES

D5 Data centre ready to handle data in real time...(Mo 6)
D21 Data delivered continuously in real time to users Output to WP2, WP4, WP5, WP6, WP7......... (Mo 6 to 36)
D22 Complete validated GyroScope data set available. Output to WP7 .... (Mo 36)

MILESTONES AND EXPECTED RESULTS

- Web server designed, including catalogues of float deployments, continuously updated until the end of the project...(Mo 6)
- First float data transmitted on the WMO-GTS...(Mo6)
- Delayed mode data sets available on the web site, ftp, or e-mail subscription................................(Mo 12 to 36)
- Beta-test version of final CD-ROM including float data sets and results of the project ....(Mo 33)
- Final version at the end of the project...(Mo36)

MILESTONES AND EXPECTED RESULTS

- Start routine comparison of profiling float and altimetry..(CLS Mo 12)
- Provide seasonal estimates of temperature, salinity and circulation in the Gyroscope area by running the inverse model using a climatology. Output to WP5.......................(LPO Mo 12)
- Provide field estimates from the inverse model for the first year of the field experiment. Output to WP6...(LPO Mo 24)

Workpackage number : **WP4**
Start date or starting event : **+0 months**
Lead contract : **UKMO**
Participants : **UKMO, LPO, CLS, ICM**
Person-months per partner : **26 (UKMO) ; 38 (LPO) ; 10 (CLS) ; 14 (ICM)** **Total : 88**

OBJECTIVES AND INPUT TO WORKPACKAGE

The main objective of this workpackage is to explore techniques for extracting valuable information from arrays of profiling floats. Some techniques seek to exploit complementarity between the float data and altimeter data. Others assess the impact of the float data on results from objective or inverse model analyses. An initial assessment will also be made of the value of profiling floats for detecting climate change.

DESCRIPTION OF WORK

The first two tasks explore how to use low resolution profiling float data in combination with altimeter data in high resolution ocean model data assimilation systems. Relatively simple intercomparisons and novel calculations of statistics will be explored. Tasks T3 and T4 aim to provide lower resolution analysis fields which will exclude the mesoscale component. They will focus specifically on the Gyroscope area. T3 will combine the profiling float data with altimeter data using dynamical constraints whilst T4 will provide more direct estimates with a greater focus on error estimates.

T5 will sample output from a coupled climate model to assess how long it would take various global arrays of floats to detect changes in mode water.

Task 4.1 : Intercompare dynamic heights calculated from altimeter and in situ profile data.

Task 4.2 : Calculate simple statistics and error covariance statistics using output from a set of data assimilation experiments, with models of various resolutions, and interpret the results.

Task 4.3 : Use an inverse model to combine altimeter and profiling float data with surface flux data and assess the relative contributions of the data sources.

Task 4.4 : Develop statistics and investigate techniques suitable for objective mapping of profiling float data.

Task 4.5 : Use model field output from a coupled climate integration to make an initial assessment of the potential value of profiling float data for detecting a particular signal of climate change

Deliverables

D15 Report on inter-comparisons of altimeter and profile data. Output to WP6............................ (CLS Mo 30)

D11 Report describing new error covariance statistics. Output to WP7....................................(UKMO Mo 21)

D16 Assessment of the respective contribution of the float and altimeter data to the estimation of the fields using the inverse model. Output to WP7 .... (LPO Mo 30)

D25 Provide estimates of the 3D velocity, salinity, and temperature fields from the inverse model grid every 10 days for the duration of the project. Output to WP7............. (LPO Mo 36)

D17 Report on conclusions on objective analysis and provide best estimate univariate analyzed fields. Output to WP7..(ICM Mo 33)

D13 Report on use of climate model output to assess timescales on which ARGO might provide detection/attribution of anthropogenic climate change. Output to WP7.......(UKMO Mo 24)

Workpackage number : **WP5**
Start date: **+ 0 month**
Lead contract: **LPO**
Participants : **LPO, SHOM**
Work Package Participants : **10 (LPO) ; 3 (SHOM)** **Total : 13**

Objectives

To produce a near real time analysis of the data provided by lagrangian profilers, maps of these data, and maps of the associated ocean circulation. This analysis, which will prepare the combination of profiler data with other data sources and subsequent data assimilation, should be part of a routine data monitoring activity.

Input

Float displacements, temperature and salinity data provided by Data Center (WP3).
Objective mapping techniques from WP5.
Reynaud's atlas of the temperature, salinity and density fields in the Atlantic.
Topex/Poseidon or JASON altimetre data.

Description of work

Task 1 : Develop and implement procedures for real time estimates of temperature, salinity and velocity fields by objective mapping and inverse analysis of temperature and salinity fields observed by the Gyroscope profilers

Task 3 : Combination of altimeter data and profiler data in a QG and mixed layer circulation model

Deliverables

(will be put on the web on a near real time basis towards the end of the project)

D23 - 3-D fields of temperature and salinity derived from profiler data in real time.
Output to WP3(Mo 6 to 36)

D24 - Maps of the velocity field calculated by the inverse model. Output to WP3, WP7.(Mo 18 to 36)

D9 - Maps of surface temperature ; mixed layer depth (analysis and forecast) ; and stream-function for intermediate layers for two months test period.
Output to WP7 (Mo 13 to 14)

MILESTONES AND EXPECTED RESULTS

- Procedure for near real time objective analysis of temperature and salinity fields set-up........................ (Mo 6)

- Procedure for near real time mapping of velocity field by inverse analysis set-up............................... (Mo 18)

- Combined QG assimilation and mixed layer model set up for now- and forecasting............................ (Mo 12)

Workpackage number : **WP6**
Start date or starting event : **Mo 15**
Lead contract : **LPO**
Participant : **LPO, NERC, IFM, IEO, ULPGC**
Person-months per partner : **71 (LPO) ; 30 (NERC) ; 31 (IEO)**
18 (IFM) ; 34 (ULPGC) **Total : 184**

OBJECTIVES

The main objective of this workpackage is to use the profiling float data to gain scientific insight on the large scale variability of the mass and heat and fresh water budgets and water mass distribution in the Gyroscope area.
Inputs : data from WP3 and analyses from WP5.

METHODOLOGY/WORK DESCRIPTION

We will use the float data (WP3), the optimal estimates of the temperature, salinity and velocity fields (WP5), the ouputs of a prognostic model, and theory to characterize the state of the ocean and its variability during the field experiment. We identify 4 tasks :

Task 6.1 : Describe the upper layer variability on seasonal time scales, understand its relationship to forcing variability using a theoretical model, evalute the ability of a prognostic model to reproduce it.

Task 6.2 : Study the heat budget and assess the accuracy of independant estimates of surface fluxes. Assess the capability of the float array to diagnose the fresh water budget.

Task 6.3 : Study the impact of the seasonal cycle on the formation of the subpolar mode waters.

Task 6.4 : Study the circulation at the Labrador Sea, Mediterannean and Antarctic Intermediate Water levels, determine these water mass characteristics, estimate variability.

DELIVERABLES

D26 - Seasonal evolution of the thermohaline structure of upper waters in the eastern subpolar gyre in form of yearly isotherm and isohaline plots (IFM). Assessment of the relationship between the evolution of the upper layer transports and the wind forcing variability (LPO, IEO, ULPGC). Assessment of the ability of a GCM to reproduce the seasonal variability observed in the upper layers (NERC). Output to WP7....................... (Mo 36)

D27 - Estimates of the respective contribution of local storage, advection and air-sea heat flux in the heat budget on seasonal time scales (LPO, NERC). Assessment of the capability of the float array to diagnose the fresh water budget and to estimate the accuracy of independent estimates of surface fluxes (LPO, NERC).
Output to WP7.. (Mo 36)

D28 - Estimate the characteristics of the subpolar mode water in the form of mixed-layer depth, temperature and salinity plots on seasonal time scales and assessment of the role of the seasonal cycle in the formation of the Subpolar Mode Water (LPO, NERC, IFM). Output to WP7. .... (Mo 36)

D29 - Spreading of Labrador Sea Water in the eastern subpolar gyre in form of fortnightly vectors as the base for yearly low-passes trajectory estimates (IFM). Seasonal maps of the circulation of the Mediterranean and Antarctic Intermediate Waters and potential temperature – salinity diagrams analysis (IEO, ULPGC).
Output to WP7.. (Mo 36)

Workpackage number : **WP7**
Start date or starting event : **Mo 0**
Lead contract : **LPO**
Participant : **LPO, NERC, UKMO, IFM, IEO**
Person-months per partner : **9 (LPO) ; 1 (NERC) ; 3 (IFM) ; 1 (IEO) ; 1 (UKMO)** **Total : 15**

OBJECTIVES

This workpackage covers the management, co-ordination, and reporting for the project.
It includes the User Requirements Document, the Technical Implementation Plan, and other reports required by the Commission.

A key objective of this workpackage is to review the whole project, produce the final report, and make recommendations for future implementation of an ocean observing system component based on profiling floats. Input from WP1, WP2, WP3, WP4, WP5, WP6.

METHODOLOGY/WORK DESCRIPTION

The technical and scientific results of the project will be reviewed and summarized. Conclusions drawn on all aspects : instrumental, field work, data management, performance of the array for operational models, and its ability to detect ocean processes, and to monitor climate signals. Aspects related to cost, organization and international context will be included in the recommendations for operational implementation.

DELIVERABLES

D1 User Requirement Document .... (Mo 3)

D2 Management Report N°1 .... (Mo 6)

D3 Glossy brochure.. (Mo 12)

D7 Annual interim report N° 1 .... (Mo 12)

D10 Management report N°2.. (Mo 18)

D12 Annual interim report N°2 .... (Mo 24)

D14 Management report N°3.. (Mo 30)

D20 Glossy brochure, final version.. (Mo 36)

D30 Final report, recommendations, Technical Implementation Plan. .... (Mo 36)

4. Contribution to objectives of programme call

The GyroScope project is proposed in direct response to the Research and Technological Development priority *2.4.2 Development of new long-term observing capacity.* It aims to develop a cost-effective array of in situ observations in most of the North Atlantic ocean. The array to be deployed (WP1) while contribute to the global array within Argo. The management and validation of the data and their timely distribution to a wide community of users (WP2, WP3, WP4) are essential aspects of an integrated observing system. Those are seen as necessary steps in the development of a long term observing capacity.

The final recommendations of WP7 will consider various options and scenarios for implementation, on technical (WP2), scientific (WP5 and 6), and economic grounds. Our project (WP6) will contribute directly to the Key action 2.1, *to assess global change processes*, by providing, for the first time, synoptic observations and estimations of seasonal to inter-annual variability in large scale heat transports and fluxes. This will be a step towards *Quantification of natural variability in the climate system*. Our studies will contribute directly to a "*better understanding of the role of the ocean in the climate system, in particular thermohaline circulation, deep water formation and its links to the hydrological cycle*". The salinity observations from the floats should provide data on the hydrological cycle, but with an accuracy that remains to be evaluated.

The GyroScope array is a natural complement to satellite altimetry. Our project will fulfil partly the objectives of key action 2.4.1 : a "*better exploitation of existing data and observing systems"*. WP5 addresses specifically this issue. Existing systems include satellites (altimetry and surface fluxes) and XBT. The information content of each of those components will be assessed, with a particular emphasis on the altimetre data. The extent to which existing operational ocean and atmosphere forecasting systems (and those under development) are enhanced by the data provided by GyroScope is also considered in WP5.

Other programmes

The system to be developed as part of this project will provide large scale coverage of the North Atlantic ; its implementation will be coordinated with other national contributions to ARGO (Canada, France, Germany, UK, USA). We shall work closely also with various data assimilation projects in the UK, Germany, France, and Norway.

Our project is also a contribution to CLIVAR (CLIVAR, 1998), which has identified two principal research areas directly relevant to European climate : the North Atlantic Oscillation and the Thermohaline Circulation. CLIVAR will rely heavily on Global Ocean Observing Systems that have been designed and recommended by GOOS, GCOS, and the Ocean Observations Panel for Climate (OOPC), who have endorsed ARGO as one of the key elements for in situ global observations. GYROSCOPE is one component of the EuroGoos Atlantic Task Team.

5. Community added value and contribution to EU policies

5.1 The UNFCC context

The steady increase of greenhouse gases and the resulting global climate changes are undoubtedly some of the most severe problems facing mankind for the next century. The international implementation of restrictive measures on greenhouse gases emissions can be done equitably, and a consensus can be reached, only on the basis of indisputable evidence on the state of the global environment and on the basis of reliable predictive models. The GyroScope project aims to develop an essential component of an ocean observing system, that will provide the data necessary to initialise and to validate ocean predictive models. The observing system will be designed with an operational objective in mind, that is to make recommendations for future implementation of a permanent array.

The United Nations Framework Convention on Climate Change (UNFCC) states the following objective in the Article 2 of the treaty (our emphasis) :

The ultimate objective of this Convention ... is to achieve ... stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a timeframe sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.

Considering the socio-economic impact that restrictive measures on green house gas emissions will have on society, there will be considerable debate on what constitutes *dangerous* interference (the problem of forecasting), and on the *timeframe* for the change (the problem of predicting the rate of change). On both counts the answers can come only from the scientific community, through programmes such as CLIVAR. The international political and scientific organizations have endorsed programmes to develop ocean observing systems. The UNFCC was particularly sensitive to this need, since preamble to the convention recognized : "*that steps required to understand and address climate change will be environmentally, socially and economically most effective if they are based on relevant scientific, technical and economic considerations and continually re-evaluated in the light of new findings in these areas*.

The Article 4 and 5 emphasize repeatedly the need for "more research" ; development of data archives ; systematic observation ; international and intergovernmental programmes and networks aimed at defining, conducting, assessing and financing research, data collection and systematic observation, taking into account the need to minimize duplication of effort ; international and intergovernmental efforts to strengthen systematic observation and national scientific and technical research capacities and capabilities.

The need for enhancing observing systems was further re-iterated by the Conference of Parties in Kyoto (Decision 8/CP.3, 1997) and Buenos Aires (Decision 14/CP.4, 1998). The UNFCC is by now internationally binding, since it has received 181 instruments of ratification. The UE has ratified the UNFCC in 1993, as well as the Kyoto protocol, in 1998 (to which there are presently 84 signatories).

The present proposal will contribute to fulfil the obligations of the EU in this framework.

5.2 Fisheries

Many interests (European, national, professional, etc.) collide at the time of establishing fishing quotas, allotting fishing permits, restructuring industries, etc. with ensuing serious socio-economic problems involving the lay-off of many workers, disappearance of industries, political conflicts within the EU and other countries, etc.

Frequently, the absolute standardised catch rate is used as an abundance estimator of these species, but it is a very crude estimation. It is becoming more and more evident that oceanic environmental conditions on different time scales (seasonal to climatic) affect strongly the abundance and recruitment of fish, sometimes blurring the over-fishing effect. Efficient planning of surveys requires to take the variability into account.

Information supplied by a ocean observing system could provide a better understanding of the fisheries, its trends and evolution enabling the EU to exercise a better founded common fisheries policy. It will also provide the fishery scientists with the data needed to define the environmental conditions of the fish habitats, enabling researchers to have a better knowledge and understanding of the fish biology and its relationship with oceanic and climate changes.

The Gyroscope region includes important fishing grounds. Several EC countries (France, Ireland, Portugal, Spain and UK) plus others as Taiwan and Japan catch albacore, tropical tuna and swordfish there. Ocean circulation and hydrographic conditions of the area (temperature gradient, depth of the thermocline, currents) affect also the medium and small pelagic fisheries in W. Europe slope and coastal waters, in particular those of the Iberian Peninsula. As a sample of the magnitude of this socio-economic sector, the total value of catch of the pelagic fish (first prize) for the EC countries involved is of the order of 170 millions of Euro per year.

5.3 A problem of European dimension

In contrast to meteorological observing networks that have been operating for several decades, and are now taken for granted, there are no equivalent systems for observing the oceans on an operational basis. The state of the art in this domain has been reviewed briefly in Section 4 above. Because of their interest in ocean surface data, the Meteorological Services coordinate the acquisition of sea surface temperature data, mostly from voluntary observing ships. But it is relatively recently that the need for, and the possibility of, operational oceanography has emerged. The need for in situ data in real time is inherent to such models. No national services are mandated to collect systematically subsurface data.

Subsurface data are collected mostly by the Navies (and their associated Hydrographic Services), or within the context of scientific programmes. In neither case is the data available widely, in real time. The spatial coverage is often limited, as it is in time. In most countries, ocean research and development agencies are mostly concerned with fisheries and coastal management. There are no structures charged with systematic observation of the oceans.

The European Union involvement is needed to fill this gap during the research and development phase. Since it is a costly project, as is any activity involving open ocean operations, to be efficient one must define an optimum strategy, and pool resources of several countries. Trans-national support is required since the data must be obtained from areas beyond national jurisdiction. The magnitude of the task at hand requires co-ordination for float deployments, and data handling to avoid duplication of efforts.

Support from the EU will enable to develop and federate expertise in several countries. The consortium for the GyroScope project brings diverse and complementary expertise in field oceanography, numerical modelling, data management, operational ocean and atmosphere forecasting, and climate modelling. At the end of the project, recommendations will be made for implementation of permanent ocean observing systems; it is likely that direct EU involvement will be required to coordinate and phase in such networks.

6. Contribution to community social objectives

The ocean observing system component proposed here will serve several purposes. It will provide data which will feed into operational ocean models ; which will in turn allow more reliable extended weather forecasts, on a seasonal basis or more. In situ observations will also improve our understanding of the climate system, by monitoring ocean variability, and enabling more skilful predictive models. The long range information on the evolution of the climate system is essential to the decision making process of governments and international organizations. Thus we shall assess the type of array necessary to monitor natural variability and detect anthropogenic climate change.

Shorter range forecasts on the ocean state (velocity, temperature), or statistical information on mean state and variability, are useful to a number of industrial sectors : essentially deep ocean offshore oil exploration and operations, shipping, and fisheries. Coastal circulation models used in pollution studies and coastal management, need open ocean models as boundary conditions. The development of operational ocean models will benefit from the data and the results of GyroScope.

A better understanding of the fishing ground location, fisheries trends, etc could help to predict the abundance of fish population, allowing for a better and effective use of a natural resource, a better planning of the fishing industry and optimisation of investments.

Several essential economic sectors are strongly dependent on weather forecasting : transportation (air, sea, and land), agricultural (frost protection, forage preservation, irrigation, crop choice, fertilization, forestry), the energy sector, water management, the leisure industry, defence, to name a few. All those activities would benefit from more accurate, longer range forecasts. It is difficult to put a monetary value on weather information, which is generally generated (data and forecasts) by the public sector (although special forecasts are made by private companies) ; but there are a number of studies that demonstrate clear benefits either in a decision making or in a social context (Johnson and Holt, 1997).

The El Niño-Southern Oscillation phenomenon provides a good case in point. The operational TAO observing system has allowed better seasonal forecasts for precipitation and temperature which have been used in the USA for disaster mitigation and economic benefit. For the 1982 event, Adams et al. (1995) estimated the value of perfect forecasts to be $145M, while the value of imperfect but improved forecasts was $96 million.

During the 1997-98 ENSO, the State of California took mitigation actions which might have saved as much as $500M-$1B (Leetma et al., 1999). (It is estimated that the weather related global impact of the 97-98 event was of $34B in damage (NOAA-OGP, 1999)).

Beyond the purely economic aspects of improved forecasts, there is a general demand by society for improved forecasts and understanding of the global environment. The public wants to be informed, expects predictions, not only of extreme catastrophic events, but also of seasonal and climatic trends. There are great educational and public awareness benefits to be derived from an observing system such as GYROSCOPE. Part of the project is devoted to establishing a WEB site with an educational outreach component towards schools and the general public.

The activities generated by the operation and maintenance of an in situ ocean observing system do not represent a large industrial sector, but rather a high technology specialized market. The manufacture of the instruments required for a global network would represent a recurrent production, as the instruments are expendable. Comparisons can be made with manufacturers of XBT probes, or atmospheric radiosondes whose output is in thousands of units. European companies, some of which already have expertise in this market, will benefit from the global development of observing systems.

ARGO floats and the environment.

The European Community is dedicated to sound environmental practices and the potential impact of the floats on the environment is a legitimate concern. ARGO floats are meant to be expendable, so that at the end of their mission they are not recovered. Floats have very little residual value for re-use at the end of their mission. Nearly all floats will end their mission at depth, gradually sinking to the sea bottom, where they will be crushed by the ambient pressure. (If 600 floats are released in the Atlantic ocean, and ¼ sink every year, this is equivalent to one float over an area the size of France or Spain). Most (nearly 90%) of the float mass is aluminium, which will eventually corrode to form harmless, soluble, aluminium oxide.

A very small percentage will find their way ashore. Floats do not present a hazard or risk of pollution. Being rather small (typically 1.80 m, weighing about 35 kg), they do not present any danger to navigation. Any reaching the coast may be picked up easily for proper disposal in any town dump. A sticker will be affixed on the float to advise on the procedure.

The amount of materials left in the sea will be minuscule compared to other, mostly military and commercial operations, using similar materials. Indeed, each 35 kg float will replace more than 100 kg of (presently deployed) Expendable Bathythermographs, hence resulting in a net savings of unrecoverable material.

The small footprint of Argo floats in the environment is greatly outweighed by their critical and irreplaceable benefits in observing the evolving physical state of the ocean.

7. Economic development and scientific and technological prospects

7.1 Real time data distribution

The most original and significant aspect of the GyroScope proposal is the distribution of the data in real time to a large number of users. Through the Data Centre, the quality controlled data will be broadcast on the Global Telecommunication System with a maximum delay of 48h. As such they will be used worldwide by all the national weather services for their atmospheric analysis and forecasts. The weather services do not use presently the subsurface information for their daily forecasts ; but the extended (seasonal) forecasts are very dependent on such data. The GyroScope data will be available for long range forecasts, for instance to the ECMWF, the Météo France, and the UK Met Office.

Operational ocean models require in situ data at regular intervals as input to the assimilation schemes. Models run by Météo France and the hydrographic and oceanographic service of the French navy (MERCATOR, SOPRANE) and the UK Met Office (FOAM) will be receiving and incorporating the GyroScope data at each surfacing of the floats. Through the GTS, the data will be available to other users (in the USA, for instance : National Centre for Environmental Prediction, NCEP, and Fleet Numerical Oceanographic Center, FNOC). Note that the UK Met Office and the French Navy are participants in the project.

The International GODAE Steering Team viewed the weakness of the in situ observing system as the principal area requiring urgent attention for conduct of a plausible experiment (mesoscale and seasonal forecasting) ; CLIVAR views ARGO as one of the corner stones of a long term observing system for the ocean's climate. Both the international and the USA ARGO principal scientists strongly support the GyroScope proposal (see letters in annex).

The real time data synthesis developed by the Project will have great educational value. They will be available to the general public and the media through the project WEB site ; links will be established with other sites for maximum exposure of our results.

7.2 Time delayed distribution

The scientific community is one of the principal users of the data. After validation the final data set will be archived at the Data Centre and distributed to other international data centres (NODC, BODC). Data summaries on CD ROMs will be distributed widely. It is hoped that the final recommendations of the GyroScope project will lead to implementation of the ARGO concept on a perennial basis. The data collected will be the legacy to the climate research community, which needs long time series with wide coverage. The availability of the data to the scientific community increases its usefulness and its valorisation.

7.3 Scientific exploitation

The life-time of many of the floats will exceed the duration of the project. The data will continue to be received, quality controlled, and distributed as part of the ARGO programme. The end of GyroScope (2003) will coincide with the beginning of the Global Ocean data assimilation experiment (GODAE). The various techniques for field estimation will continue to be implemented in that context.

The unique data set collected in the course of the project will be the basis for scientific analysis of ocean processes for years, not only by the contractors, but also by the larger scientific community. For those studies, the GyroScope data set will be combined with other data.

It is generally the case that ocean observations are so rare and valuable that what little there is, is used for years. Cases in point are the International Geophysical Year (1957-58), or the World Ocean Circulation Experiment (1990-98) data which form the basis of many climatologies. The GyroScope data, as a contribution to ARGO, will provide a reference on large scale oceanography, within which diverse process studies will be conducted.

7.4 Communication

The prime forum for presentation of the results of the project is the usual process of scientific publications, conferences and workshops. During the time span of the project the first preliminary and descriptive results will be submitted for publications in peer reviewed scientific journals and participation to international conferences will be active (the European Geophysical Society, for instance ; but also more focused workshops organized by CLIVAR or GOOS). Technical aspects of the project will be presented to appropriate journals (*Sea Technology*, or the *Journal of Ocean and Atmosphere Technology,* for instance) and at conferences (OSATES, the Oceanology International conferences).

Summary information and results obtained will be publicised and supplied to the fisheries, research institutes, fishermen and national and regional fisheries administration, at a minimum cost (just the physical support) by the IEO.

In order to increase public awareness of the role of the ocean in the global environment and global change, we will resort to other forms of communication through the media, conferences, participation in science fairs, etc.

7.5 Market opportunities

The development in Europe of ocean observations with expendable instruments will open new market opportunities for manufacturers. Mass production of large number of instruments will reduce the unit cost. The example of the radiosondes used in operational meteorology is instructive. There are about 430000 such soundings of the atmosphere every year ; over half of the instruments are produced by a Finnish company (Vaisala), at a cost of the order of 150 Euro. In 1996, some 70000 XBT probes were sold, representing a market value of 6.4 MEuro.

There are presently two potential manufacturers of autonomous profiling floats in Europe : (4H-JENA, in Germany ; MARTEC, in France). The cost of 15000 Euro per float yields a cost per profile of 150 Euro, for a 100 cycle mission. Decrease in price is expected, due to development of new technology and mass production. The development of operational oceanography in Europe is bound to create new markets for European companies.

8. Description of the consortium

Members of the consortium are a diverse group from academia, public research and development organizations, and service oriented consulting firm, devoted to oceanography and meteorology. Together they bring complementary expertise in the scientific and technical fields necessary for the successful completion of the project. Together they bring complementary, interdisciplinary expertise in the scientific and technical fields necessary for the successful completion of the project. Their active involvement in planning groups and scientific programmes related to climate and/or operational oceanography, such as the International ARGO Science Team, GODAE, Mercator, FOAM, GOOS, CLIVAR, ICES, or the OOPC, guarantees close integration of the GyroScope project in the international context. The table summarizes the partners and their involvement in the work-packages.

Part. N°	Role	Institution	Area of expertise	Work-packages
P1	CO	Ifremer CNRS*	Project management. Field work, instrumentation, data management, inverse modelling, physical oceanography	1, 2, 3, 4, 5, 6, 7
P2	AC	SHOM	**User** : field work, operational oceanography	1, 3, 5
P3	AC	CLS	**User** : operational oceanography, satellite altimetry	1, 4
P4	CR	NERC	Numerical modelling, physical oceanography	2,3,6, 7
P5	CR	UKMO	**User :** meteorology and oceanography, operational numerical modelling, coupled climate modelling	5, 7
P6	CR	IFM	Field work, instrumentation, physical oceanography	1, 2, 6, 7
P7	CR	IEO	Field work, instrumentation, physical oceanography, fisheries	1, 6, 7
P8	AC	ICM	Estimation theory, signal processing, physical oceanography	4
P9	AC	ULPGC	Physical oceanography	6

Partner 1. Ifremer – CNRS

This participant comprises two groups pooling their efforts for the GyroScope project : The Laboratoire de Physique des Océans (LPO) and SISMER. The Laboratoire de Physique des Océans is a joint research unit (*Unité Mixte de Recherche*), overseen jointly by Ifremer, the CNRS (Centre National de la Recherche Scientifique) and the University of Western Brittany, and operating under the terms of a memorandum of understanding. Personnel from Ifremer and CNRS will take part in the project. SISMER (Systèmes d'Informations Scientifiques pour la Mer) is a Department of Ifremer, created in 1990. It designs and operates scientific information systems and databases for national and international projects in the marine domain. Its activity includes compilation, safeguarding and dissemination of conventional data collected during national and international projects.

The LPO will manage the project and be involved in varying degree in all the work packages. The bulk of the field (WP1) work will be shared between LPO and IFM, with significant contributions from IEO and SHOM. LPO and SHOM will concentrate on the intergyre region of the NE Atlantic. The instrumental monitoring and evaluation of sensors (WP2) will be shared with IFM, IEO and SHOM. The data management (WP3) is the under the responsibility of SISMER, with contributions from LPO and other partners. The contribution of LPO to WP4 is the implementation of an inverse model combining altimetre and float data into a dynamical consistent model. A simplified version of that model, allowing real time estimation of temperature, salinity, and velocity will be developed by LPO , part of the technical work being subcontracted. The scientific analysis of LPO will focus (WP6) on the estimation of the heat, mass and fresh water balance over the North Atlantic. As co-ordinator, LPO will manage the project (WP7) and lead a number of related tasks, such as reports writing, liaison with the services of the Commission, communication and outreach initiatives.

Staff category	Number	Expertise	Tasks
Senior scientist	2	Physical oceanography	Project management and coordination, experiment planning, data analysis, inverse modelling, data interpretation, publication of reports and results
Scientists	3	Physical oceanography	Implementation of inverse models, scientific analysis, publication of results
Electronics engineer	1	Ocean instrumentation	Prepare and deploy the instruments; assessment of instrumental performance
Electronics technician	1	Ocean instrumentation	Laboratory and field testing, field work
Computer engineers	4	Data management, data processing, software design, signal processing	Develop software for data management and ocean modelling, design of web site, implement inverse modelling, assist in data interpretation
Computer technicians	5	Computer programming	Assist in analysis of data and model output; perform real time data quality control; assist in computer programming; maintain and update project web site.
Administrative staff	1	Administrative assistant	Assist in project management

HOCER

(Subcontractor to LPO)

HOCER is a small company that specializes in software development and consulting for research institutes and for the French Navy. Its staff of about ten employees is composed of technicians, software engineers, and research engineers who graduated from the Ph.D. program in physical oceanogaphy of the University of Brest.

HOCER's staff will adapt the finite difference inverse model of the ocean ciculation developed at LPO for use in an operational context. Il will develop a user-model interface, to allow the inverse model to be run in near real-time by operators. HOCER will automatize the procedures to objectively map the data provided by the gyroscope floats in near-real time, and to run the inverse model in a semi-automatic mode. During the test phase, the output of the model will be transferred to the data centre for display and distribution.

Times are expressed in weeks

Tasks	**Oceanographer**	**Software Engineer**	**Technician**
Preliminary	2	4	
Formation to the LPO finite difference model	2		
Interface development		4	
Inversion	12		
Acquisition of the Clipper model	2		
Objective Maps	4		
Inversion of the data	6		
Sensibility to atmospheric fluxes	3		
Documentation	1	1	
Exploitation	5		8
Objective maps and data inversion			8
Validation of the results	5		
WP Management	2		
Total	**25**	**5**	**8**

Partner 2. SHOM – CMO

SHOM is the national hydrographic and oceanographic service of the French Navy. Its oceanographic activities are led by the Centre Militaire d'Océanographie (CMO), located in Brest, inside EPSHOM (Etablissement Principal du SHOM).

Two laboratories of the Centre Militaire d'Océanographie (CMO), located in Toulouse and Brest, will contribute to the project. The Brest group will contribute to float prepararation and deployments and organize one dedicated cruise (WP1); it will also be involved in the real time data validation (WP3). The Toulouse group will combine (WP5) altimeter and profiler data into a mixed layer and quasi-geostrophic model (the operational SOPRANE model) to produce now- and forecasting of the temperature and velocity fields. SHOM is one of the users of GyroScope data for its operational missions.

Staff category	**Number**	**Expertise**	**Tasks**	**WPs**
Scientist	1	Physical oceanography	Combination of altimeter data and profiler data in a QG and mixed layer circulation model	5
Engineer	1	Physical oceanography, ocean instrumentation	Management & coordination	1, 3
Technician	1	Ocean instrumentation, data processing,	Field work, preparation of floats, float deployments, data processing	1, 3
Technician	3	Hydrography, Field work	Field work, float deployments	1

Partner 3. CLS

Collecte Localisation Satellites was established in early 1986 as a subsidiary of CNES (French Space Agency) and Ifremer. CLS started an activity in satellite altimetry in 1990 with the creation of the CLS Space Oceanography Division. About thirty engineers and scientists now work in this division.

CLS is in charge of the systematic validation of TOPEX/POSEIDON data distributed by AVISO and ERS data distributed by CERSAT. CLS developed the real-time regional altimeter data acquisition and processing module used by the French Navy Operational Ocean Forecasting System (SOAP and SOPRANE) since 1993.

CLS will contribute to the array design of GyroScope (WP1) by using the output of simulations in a numerical ocean circulation model (the CLIPPER model). It will also (WP4) compare dynamic heights calculated from altimeter and float data, in order to assess the relative information content of each data set.

CLS participants will be a senior scientist and a research engineer. The senior scientist has expertise in physical oceanography and project management. He will be in charge of coordinating CLS work for Gyroscope. The research engineer holds a degree in physical oceanography, and has expertise in inverse modeling. They will be both involved in the two CLS tasks (array simulation studies – WP1 task 1.1 and comparison of profiling float data with altimetry –WP4 task 4.1) .

Partner 4. NERC

The Southampton Oceanography Centre (NERC) is a centre of excellence in marine sciences, earth sciences and marine technology. The SOC was completed in 1995, creating a purpose built centre for over 450 research scientists, lecturing and support staff, as well as over 600 undergraduate and postgraduate students. The SOC has taken, and is taking, a leading role in many international scientific programs. For example, it hosts the International Project Offices of the World Ocean Circulation Experiment (WOCE) and the Climate Variability and Predictability initiative (CLIVAR).

Although it will contribute to the technical evaluation of the floats (WP2) and to the specifications for data quality control (WP3), NERC's main contribution will be in WP6. NERC will use the data to assess the OCCAM global ocean circulation model to reproduce the seasonal variability in the upper layers. It will work also on the heat and fresh water budgets and the validation of surface fluxes. NERC is a member of the Project Steering Committee (WP7).

Category	Expertise	Task
UG7	Physical Oc.: Numerical modelling, Hydrography	Real time data management; mass, heat and freshwater budget from floats and comparison with model; report.
HSO	Physical Oc.: Hydrography	Mass, heat and freshwater budget from floats and comparison with model
PDRA	Physical Oc.: Profiling Floats, Hydrography	Real time data management; mass, heat and freshwater budget from floats and comparison with model. Evaluation of instrument's performance.

Partner 5. The Met Office

The Met. Office is a national meteorological service, with large computing facilities and extensive activities in weather and ocean forecasting and in climate research and prediction. The Hadley Centre for Climate Prediction and Research, part of the Met Office, is one of the world's leading centres for climate research; its staff includes leading researchers in ocean climate modelling. The Forecasting Ocean Assimilation Model (FOAM) system at the Met. Office was the first global ocean forecasting system to be run daily on an operational basis.

The Met. Office will be a direct user of data from the GyroScope project, since the data will be assimilated into the FOAM model. The contribution to the project will be essentially to WP4, with participation in the Project Steering Committee (WP7). UKMO will calculate simple statistics and error covariance statistics using output from a set of assimilation experiments with FOAM, at various resolution. In the context of climate change detection, UKMO will use model output from a coupled climate integration to make assessment of the potential value of float data for detecting a particular signal of climate change.

Category	Expertise	Task
Scientist	Physical oceanography	Model diagnostics and validation
Scientist	Ocean modelling and data assimilation	Management ; data assimilation, information content evaluation
Scientist	Physical oceanography	Ocean modelling

Partner 6. IFM

Institut für Meereskunde an der Universität Kiel (IFM) is one of the leading institutes in the fields of marine research and training in marine science in Germany. In the field of physical oceanography and biogeochemical cycles, IFM significantly contributes to many national and international programmes. These include several EU-programmes (Eurofloat, CANIGO), the World Ocean Circulation Experiment (WOCE) and the Joint Global Ocean Flux Study (JGOFS). A major national programme focuses on the investigation of thermohaline circulation variability. IFM contributes also on a national basis to the ocean component of the international CLIVAR programme.

IFM will take a significant part in the field work, procuring and preparing floats, and deploying them during several cruises planned in the subpolar gyre (WP1). The technical monitoring and assessment will be lead by IFM (WP2). The scientific focus of IFM (WP6) will be in the water mass characteristics and dynamics in the subpolar gyre. As a member of the steering Project Steering Committee, IFM will contribute to the various reports (WP7).

	Function/Task	**Expertise**
Scientists	Principal Investigator	Long-standing expertise in ocean observation including acoustic tomography, experience in EC projects, PI of ALACE project in the Med Sea, member of ARGO Science Team.
	Co-principal Investigator	Long-standing expertise in ocean observations including mooring technology and RAFOS methodology, ex-partner of Eurofloat, PI in SFB 460 with RAFOS float observations in the Iceland Basin, member of the Ocean Observations Panel for Climate (OOPC). Chief scientist on METEOR deployment cruise 2001.
	Assistant to PI	Considerations of launching strategy in close cooperation with partners, administrative and in purchasing phase of floats, development of test procedures and protocols, pre-deployment tests, programming of floats, watch-going person at sea, evaluation of technical performance, scientific analyses of float trajectories, exchange of watermasses across internal fronts between Labrador Sea and Mediterranean Water, watermass formation studies at the northern end of the Gyroscope array, book keeping affairs, contact keeping with partners in Brest and Las Palmas.
Technicians	Technical Assistance on a day-by-day base	Preparation of floats, performance of tests, preparation and conductance of sea-going experiments, including help of CTD profile checks at sea, watch-going person at sea, collection of items for book keeping, maintenance of sea-going equipment, if appropriate assistance in presentations of results.
	System Manager	Experience with systems ARGOS, PC etc.
	Electronics Specialist	Experience with computer data acquisition, down- and up-loading needs etc.
	Engineer	Experience with RAFOS floats, CTD and rosette equipment, mechanical tasks.

Partner 7. IEO

Instituto Español de Oceanografia (IEO), established in 1914, is the largest marine research institution in Spain. It includes the headquarters in Madrid and seven laboratories distributed along the mainland coast and the archipelagos. The IEO has a wide expertise in the fields of physical and chemical oceanography and marine ecology, as well as fisheries research. It is the advisory body to the government in marine affairs, particularly in fisheries matters. Its staff is involved in many European and other international programmes. Presently, IEO has been ascribed to the new Ministerio de Ciencia y Tecnología, together with most of the Spanish public research agencies, including the Consejo Superior de Investigaciones Científicas.

IEO will organize one cruise in the Southern part of the region of interest, and participate in float deployment in close cooperation with LPO and ULPGC (WP1). IEO will also contribute to the technical assessment (WP2). The scientific contribution of IEO will focus in the Iberian Basin, the Gulf of Cadiz and the Canary basin, with investigations in the mass and heat budgets, as well as investigations related to water mass characteristics (Mediterranean, Antarctic Intermediate, Labrador Sea, Subpolar Mode waters) (WP6). As a member of the steering Project Steering Committee, IEO will contribute to the various reports (WP7)

Gyroscope will involved 6 scientists (grades A-1, A-2, A-3 and A-4) and 4 technicians from the IEO. All of them with long experience in sea work, familiarity with the region of study and frequent cooperation in international and European projects.

category	**expertise**	**task in the project**	**WPs**
Scientist	Physical Oceanography	Field work, data validation, water masses circulation, final report	1,6,7
Scientist	Physical Oceanography	Field work, data validation, Flux and heat budget calculations	1,2,6
Scientist	Chemical & Physical Oceanography	Field work, water masses circulation	6
Scientist	Physical Oceanography	Field work, data validation	6
Scientist	Physical Oceanography	Field work, objetive mapping	1,2,6
Scientist	Physical Oceanography	Objetive mapping	1,6
Technician	Computer programming, software development	Equipment preparation, data validation	1,2
	Data collection & processing	Field work, data processing	1,6
	Data collection & processing	Field work, data processing	1,6
	Data collection & processing	Field work	1

Partner 8. ICM-CSIC

The Physical Oceanography Group at the ICM (Institute of Marine Sciences) in Barcelona, one of the major marine laboratories in the Mediterranean region, is part of the Consejo Superior de Investigaciones Científicas. The Physical Oceanography Group (POG) has a long experience on marine circulation studies in the Western Mediterranean. Since 1986, it has been managing several research projects on surface layer mesoscale variability and frontal dynamics, including both experimental (ship cruises, Eulerian and Lagrangian current measurements, remote sensing) and numerical work.

ICM will apply its expertise in statistical estimation to the various techniques of objective analysis, with the goal to determine the impact of float data on the mapping of various ocean fields of interest (WP5).

Category	**Expertise**	**Task in the project**
Scientist	Physical oceanography	Data analysis and interpretation
Scientist	Physical oceanography	Objective analysis techniques

Partner 9. ULPGC

The physical Oceanographic group at the Universidad de Las Palmas de Gran Canaria (ULPGC**)** has been active since 1992; it has collaborated with different national and international research institutions with strong emphasis on interdisciplinary topics.

ULPGC will contribute essentially to the WP6, with studies of the relationship between the upper layers transports and the wind forcing variability, and the contribution of various water masses to the budgets of mass, heat and salt (in collaboration with IEO).

Four Scientists, and one junior scientist, with expertise in Physical Oceanography, will contribute to the project , with participation in the field work (WP1), and the data analysis and interpretation of WP6.

9. Project Management

9.1 Decision making and project coordination

The overall management of the project will be the responsibility of the coordinator. Y. Desaubies is a senior scientist at Ifremer, where he has been Director of the LPO.

A Project Steering Committee, headed by the coordinator, will comprise the work package coordinators. They are senior scientists and team leaders with experience in project management and past involvement in several EU- funded programmes. For administrative and contract matters, the coordinator refers to the Principal Contractors in each country.

The coordinator is responsible for the overall project, which he oversees and organizes. He ensures the flow of communication within and without the project. He liaises with the participants, their institutions, and the EU programme managers. He edits the reports, convenes and plans the meetings of the participants. He is responsible for timely production of the reports and the deliverables.

The coordinator also interacts with other projects related to GyroScope : either EU – funded, or international (ARGO, CLIVAR). Several of the participants are members of the ARGO science team (Desaubies, King, Le Traon, Send), so that close integration in the international programme is guaranteed.

The coordinator is assisted by the Steering Committee which reviews regularly the progress of the project, and makes recommendations whenever adjustments in the planning have to be made.

The work package coordinators will stimulate scientific and technical information exchange within their area and report to the project coordinator on progress and on any difficulty encountered.

Day to day communication will be primarily by e-mail, and by the project web site where all technical data and information on the project will be available (some of which password-protected for participants use only).

9.2 Meetings and Reports

Meetings of the participants are an important part of the life of the project. They will be held at key turning points in its development :

Mo 0 : kick off meeting at the start of the project

Mo 6 : review and final decision on deployment strategy

Mo 15 : first assessment of performance of array and of data exchange procedures

Mo 21 : review of first year of data collection, field estimations and scientific analysis

Mo 33 : final review of the whole project, report writing planning

It will not be necessary that all participants attend all meetings ; they will take part according to the agenda and to their involvement at each stage of the project. When possible the meetings will be held on the occasion of scientific conferences, interested parties will be invited to maintain good coordination with other related projects, and with users outside the project. After each meeting, a meeting report, including Action Items, will be distributed to the participants.

Comprehensive project reports will be produced yearly, and short interim managements progress reports every six months. Specific technical reports on the various developments will be written as appropriate. Scientific publications will be submitted to leading peer-reviewed scientific journals.

9.3 Quality assurance

Before the start of work on each deliverable, a list of the aspects of it which are most important to the objectives of the overall project will be agreed between the work package co-ordinators and the deliverer. They will also agree on a short assessment of each point on the list before the deliverable is accepted as complete.

Quality assurance is particularly important for the instrumentation and the data. Receiving, testing and checking procedures for the floats will be defined, from purchase to deployment at sea. Each instrument life profile will be recorded on individual files, including calibration results and deployment circumstances. The WP2 is devoted specifically to providing detailed evaluation of all aspects of instrumental performance.

Quality assurance is at the core of the activities and tasks of the WP3, on data management, quality control and validation. In conformity with the IOC, ICES and MAST international standards for data banking, SISMER performs Quality Control (QC) on the data and meta-data. Quality checks are performed for archiving the vertical profiles, according to the most up to date international standards and with automatic and visual procedures. Feedback from WP4 and 5 will ensure that archived data is of the highest quality.

9.4 Manpower table

Participants	WP1	WP2	WP3	WP4	WP5	WP6	WP7	Total
Ifremer-CNRS	21	6	35	38	10	71	9	190
SHOM	7		3		3			13
CLS	12			10				22
NERC		2	3			30	1	36
MetOffice				26			1	27
IFM : Project	17	16				18	3	54
IFM : Staff	5	5				18	2	30
IFM Total	22	31				36	5	94
IEO	8	3				31	1	43
ICM-CSCI				14				14
ULPGC : Project						34		34
ULPGC : Staff	1					28	1	30
ULPGC Total	1					62	2	65
Total (Project)	65	27	41	88	13	184	15	433

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