Rapid Climate Change Science Plan

Science Plan

To improve our ability to quantify the probability and magnitude of future rapid change in climate

Executive Summary

Studies of past climate suggest that large and rapid (as fast as 10-20 years) changes have occurred and that changes in the ocean's thermohaline circulation (THC) are often a major factor. Modelling studies show that the THC and the heat that it transports northward in the Atlantic produces a substantially warmer climate in western Europe than would otherwise be the case. They also predict that under a global greenhouse-gas warming situation the THC might slow down, possibly leading to a cooling of western Europe, which could have significant socio-economic impacts. A limited number of observations of the North Atlantic THC are available and, of the few that are, some suggest that a slow down of the THC might be occurring now.

The programme therefore aims to investigate and understand the causes of rapid climate change, with a main (but not exclusive) focus on the role of the Atlantic Ocean's THC. Using a novel combination of present day observations, palaeo data and a hierarchy of models (from local process models to global general circulation models) the programme will improve our understanding of the roles of the THC and other processes in rapid climate change, and of the global and regional impacts of such change. As a result, our ability to monitor and predict future rapid climate change, particularly in the North Atlantic region, will be enhanced. This will be achieved by undertaking improved observations of the Atlantic THC and the processes that influence it; by using improved palaeo data to reconstruct past changes; by combining the present-day and palaeo observations with models, in order to test and improve them; and by using the understanding gained to assess the probability and magnitude of future rapid climate change.

The programme will deliver: an assessment of the probability and magnitude of future rapid climate change; an improved observing system for the THC; better understanding of the processes that "drive" the THC; improved palaeo-climate data and new methods for using these data with models; improved models for predicting rapid climate change, giving greater confidence in the predictions; and scenarios that can be used in risk assessments by those studying the impacts of climate change.

The programme has been funded by NERC at a level of £20M over a period of 6 years. The programme will bring together the diverse research communities that have the skills to address the problem, and will provide training and opportunities for new researchers. Given the scale of the problem, it will also actively seek international collaborations that complement and enhance the work being carried out.

Objectives

The purpose of the RAPID programme is to improve our ability to quantify the probability and magnitude of future rapid change in climate. The programme aims to investigate and understand the causes of rapid climate change, with a main (but not exclusive) focus on the role of the Atlantic Ocean's thermohaline circulation (THC).

Using a combination of observations (present day and palaeo) and modelling (atmospheric, oceanic, terrestrial, cryospheric) the programme will study rapid climate change, with a focus on the key role of the THC in such change. The programme will seek to observe the present operation of the THC, to infer its time evolution from palaeo data, to understand what processes might change or stabilise the THC, and to assess the climatic consequences (atmospheric, oceanic, terrestrial, cryospheric) of such changes. The aim is to quantify under what conditions a weakening of the THC would occur, as an essential precursor to predicting when this may happen. Observations will be made that are crucial for testing simulations of THC variability and climate change. Palaeo data will be used to reconstruct past changes of the climate system, with a particular focus on rapid changes and a geographical emphasis on the expression of such changes in the North Atlantic region. The programme will use palaeo-reconstructions of past climate and observations to test and improve models. This will include a focus on the individual and linked processes that are simulated in climate models, with the aim of improving prediction of potential future rapid climate change.

Specific objectives of the programme are:

- To establish a pre-operational prototype system to continuously observe the strength and structure of the Atlantic meridional overturning circulation (MOC).
- To support long-term direct observations of water, heat, salt, and ice transports at critical locations in the northern North Atlantic, to quantify the atmospheric and other (e.g. river run-off, ice sheet discharge) forcing of these transports, and to perform process studies of ocean mixing at northern high latitudes.
- To construct well-calibrated and time-resolved palaeo data records of past climate change, including error estimates, with a particular emphasis on the quantification of the timing and magnitude of rapid change at annual to centennial time-scales.
- To develop and use high-resolution physical models to synthesise observational data.
- To apply a hierarchy of modelling approaches to understand the processes that connect changes in ocean convection and its atmospheric forcing to the large-scale transports relevant to the modulation of climate.

- To understand, using model experimentation and data (palaeo and present day), the atmosphere's response to large changes in Atlantic northward heat transport, in particular changes in storm tracks, storm frequency, storm strengths, and energy and moisture transports.
- To use both instrumental and palaeo data (see 1-3) for the quantitative testing of models' abilities to reproduce climate variability and rapid changes on annual to centennial time-scales. To explore the extent to which these data can provide direct information about the THC and other possible rapid changes in the climate system and their impact.
- To quantify the probability and magnitude of potential future rapid climate change, and the uncertainties in these estimates.

The above objectives are clearly inter-linked. Thus our ability to predict future climate change (8), rapid or otherwise, is predicated on understanding the current state of the climate (particularly a key component like the THC; 1-2) and past changes in climate (3), on developing models necessary to investigate the THC and climate (4), on using the models to investigate how the climate system works (5-6) and to test the response of the whole system (7). It is the novel combination of present day observations, palaeo data and a hierarchy of models (from local process models to global general circulation models - GCMs) that will improve our understanding of the roles of the THC and other factors in the processes leading to rapid climate change. It will also improve our understanding of the global and regional impacts of such change and our ability to monitor and predict potential future rapid climate change.

Deliverables

The primary deliverable will be a quantitative assessment of the probability and magnitude of potential future rapid climate change, and the uncertainties in these estimates. A key deliverable will be the identification of the critical observations that will eventually be part of an operational long-term Atlantic MOC observing system. Moreover, the programme will produce recommendations for future climate model development, to increase confidence in projections of THC and climate change. Specific deliverables are:

- A proven, field-tested and cost-effective design for an operational monitoring system for the Atlantic MOC.
- Identification of main drivers of THC variability.
- Identification of consequences for climate of rapid change of the THC, including scenarios for use in risk assessments.
- Improved palaeo-climate data sets with associated error estimates and sufficient temporal resolution to identify variability and rapid change on annual to centennial time-scales.
- Improved methods for using palaeo-climate data for quantitative testing of models.
- An assessment of the ability of climate models to simulate rapid change and the role of the THC variability in such change, and recommendations for model development to reduce uncertainty in projections of THC and other rapid changes in climate and their impacts.

Background

A wide range of model studies unanimously show that the presence of the THC and its associated heat transport produces a substantially warmer climate in western

Europe than would otherwise be the case (Manabe and Souffer 1988, Schiller et al. 1997, Vellinga and Wood 2001, Seager et al. 2001). The THC consists of deep convection induced by surface cooling at high latitudes, sinking to depth, and upwelling of deep waters at lower latitudes, with horizontal shallow and deep currents feeding these vertical flows. The deep convection and sinking in the North Atlantic (in the Labrador and Greenland Seas) have no counterpart in the North Pacific Ocean, where northward heat transport is consequently much weaker. However, the Atlantic THC has not always been like today's. Palaeo climate records prove that massive and abrupt climate change has occurred in the Northern Hemisphere, especially during and just after the last cold stage (Broecker and Denton, 1989, Dansgaard et al., 1993, Broecker, 2000b), with THC change as the most plausible mechanism. Similar change might occur in the future. Model results suggest that the human-induced increase in the atmospheric concentration of CO2 and other greenhouse gases will lead to a significant reduction in THC strength in the Atlantic (e.g., Manabe and Stouffer, 1993; Wood et al., 1999). This in turn will modify substantially the projected rate of climate change over western Europe. Furthermore, it is possible that the changes in the strength of the THC could occur rapidly, perhaps over just 10-20 years. Such large, rapid climate change would make adaptation to, and mitigation of, the impacts exceedingly difficult for the affected countries. Therefore, it would be useful to estimate the probability of such changes. However, while most climate models indicate that there will be THC weakening, there is considerable spread between their projections (Cubasch et al, 2001), and at least two models show no change at all (Latif et al., 2000, Gent 2001). Hence, the climate research community is faced with both a challenge and an opportunity.

There is a possibility that the North Atlantic THC will undergo changes that will result in substantial and rapid climate change for western Europe and Scandinavia, but we cannot reliably quantify the probability of this occurring. In order to have a context in which to assess the probability of a future rapid change in the THC and climate, it is also necessary to understand other potential drivers of rapid change and the intrinsic variability of the climate system. Over recent years progress has been made in acquiring palaeo observations of past rapid climate change (Dansgaard et al., 1989; Alley et al., 1993; Koç Karpuz & Jansen, 1992) and Holocene climate variability (Mann et al 1998, 1999, Briffa et al 2001), and in developing climate models that might be used to predict such change. However, this work is currently largely disjointed and generally lacking in estimates of uncertainty. So a further challenge and opportunity exists in bringing together the palaeo data and the climate models, and also in developing estimates of uncertainty. (McAvaney et al. 2001 summarises the current state of climate models and the uses of palaeo data that have been made so far for model testing). This will aid understanding of rapid climate change and the intrinsic variability of the system, and test the climate models' abilities across a range of time scales that is greater than that for which instrumental records exist.

Research Programme

The programme will support research that addresses the objectives in the following areas:

1) Observing the Atlantic meridional overturning circulation (MOC):

Present observations of the Atlantic MOC (of which the THC is the dominant component) are insufficient to detect whether it is changing. Thus a significant weakening of the MOC may already be in progress, unnoticed. In order to detect such change and to develop predictive capabilities for the MOC it is necessary to monitor it, akin to the necessity of observing the equatorial Pacific if one wants to forecast El Niño. Therefore the programme will support work to develop and implement a prototype pre-operational system to observe the Atlantic MOC strength and structure. It is the ocean heat transport (and hence the MOC) around 25-35N that is most relevant for western European climate, because much of this heat is given off to the atmosphere between 35 and 50N, from where it is transported north-eastward towards Europe by the atmosphere. Therefore it will be necessary for the observing system to be able to monitor changes that affect this heat transport. As a minimum requirement the observing system should be able to monitor the strength and structure of the Atlantic MOC on time scales from months to decades, and collect about 3-4 years of continuous data during the course of the programme. The observations acquired by the system will need to be analysed to show that they provide the required information to an acceptable accuracy. A cost-effective design for an operational version of the monitoring system, and any technological and other developments necessary to its implementation, will be produced.

2) Northern high latitude observations, long-term transports and mixing processes:

In addition to observing change in the THC overturning rate the programme will support studies to learn more about which northern high latitude processes and regions are responsible for the observed changes. Observations show significant changes over the past few decades in the temperature of the warm Atlantic currents flowing towards the Arctic Ocean and in the outflows of fresh water and ice from the Arctic Ocean. Arctic sea ice volume has shrunk dramatically over the past decades (Vinnikov et al., 1999; Johannessen et al., 1999; Rothrock et al., 1999). These recent changes affect the characteristics of the cold deep overflows (Østerhus and Gammelsrod, 1999; Turrell et al., 1999; Hansen et al., 2001), which cross the Greenland-Scotland Ridge southwards to “drive” the THC. Modelling results suggest that an increase in the southward flux of freshwater through Fram Strait is able, in a few years, to reduce the intensity of the THC in the North Atlantic. However, the models are not necessarily reliable, since there are no direct measurements of some of the key ocean fluxes involved to test their results against. These include the net poleward flux of heat and salt to the Arctic Ocean through the three main gateways (Fram Strait, Barents Sea and Bering Strait) and the net equator-ward flux of ice and freshwater through the two main pathways (southward along the East Greenland shelf and through the Canadian Arctic Archipelago). Model improvement thus depends on obtaining these measurements, and on doing so over a long enough period to capture their variability. Since the most advanced models now suggest a link between the time-dependence of certain of the ocean fluxes at different Arctic gateways, these measurements ultimately need to be made simultaneously and for several decades. The programme will support work that contributes to this long-term measurement requirement.

It may prove difficult to partition the northern high latitude influences on the THC of all heat, ice, and freshwater fluxes (including terrestrial run-off) into their separate components in a quantitative way, but establishing their relative importance is crucial. Many of the transformation processes at high latitudes take place at small spatial scales, but the integral properties of the mixing probably depend on regional scale patterns of surface buoyancy flux and on the underlying stratification. Hence there is a need to determine the heat and water budgets (mean and variability). Given the existing work of the Labrador Sea Group (1998), this programme will primarily support studies that concentrate on the Nordic Seas. Establishing budgets will involve all the direct measurements in the Nordic Seas, including the mixing processes discussed below, and the model-data synthesis efforts (see 4 below).

The programme will also support studies of mixing processes such as convective and non-convective vertical mixing, interaction with topography (boundary mixing), sea-ice interactions, and the dynamics of overflows. These are known to be important for the THC but are poorly understood. The processes all have short space and time scales, making it impossible to model them from first principles in coupled GCMs. The effects of these processes must be parameterised in models, but the processes need to be well understood if the models are to have predictive skill. The programme will support experiments to increase the understanding of the key mixing processes in the Nordic Seas and their influence on the circulation in the Nordic Seas and the overflows. Possible approaches are tracer and direct turbulence measurements, which are powerful and mutually supporting techniques, and the integration of data with models (see 4 below).

3) Constructing well-calibrated and time-resolved palaeo data records:

There exists a wealth of indicators of past climate, which indicate that rapid changes have taken place and could be used to estimate the range of “normal” climate variability. The programme will support investigations into components of the climate system that have the potential for future rapid change, that would have major regional or global climatic repercussions. These studies will involve a combination of palaeo-climate reconstructions (using instrumental records and high-resolution natural archives, preferably with annual temporal resolution) and modelling (see 7 below). The palaeo studies are generally expected to focus on periods of rapid change (e.g. Dansgaard-Oeschger and Bond cycles, Heinrich events, possible abrupt cooling during interglacials) and the recent Holocene, and to obtain data with accurate dating and improved temporal resolution.

To enable the data to be used with models (see 7 below) it will be necessary to develop methods of integrating and characterising the diverse palaeo indicators on regional (e.g. the North Atlantic Ocean and surrounding land areas) or larger (up to global) spatial scales. Additionally, it will be necessary to quantify the uncertainties associated with both the palaeo data and any resulting climate re-constructions. Therefore, the programme will support work on new and more robust methods of reconstructing past climatic changes. This includes the assembly of data with higher temporal and spatial resolution than have previously been available, and the provision of data in a manner suitable for use in model validation. It also includes attempts to calibrate palaeo data against data from existing instrumental records. Highly resolved temporal data that can be precisely correlated between land, sea and ice records will be required to determine whether the atmospheric changes drive the THC changes or vice versa. This inference is of importance to the present-day situation where we are driving the system through anthropogenic changes in atmospheric composition.

Direct palaeo-information about ocean circulation is harder to obtain. Progress has been made recently in a number of areas (e.g. use of isotopic composition of foraminifera as a density proxy, Lynch-Stieglitz et al., 1999; grain size as a flow speed proxy, McCave et al., 1995, Bianchi and McCave, 1999), but generally the oceanic sediment palaeo-record has much lower temporal resolution than that obtained from ice cores and other palaeo sources (e.g. tree rings, coral bands). Therefore the programme will support the acquisition of better palaeo data on the ocean circulation. Using multi-proxy palaeo-records (terrestrial and marine) of high-resolution sites will allow the study of the interplay between decadal and longer time-scale climate variability and the THC.

In order to understand rapid, or indeed other changes, in climate and to be able to run model simulations it is important to know the forcing that is being applied to the system. Therefore the programme will support studies to establish the climate forcing that has occurred over different time-scales up to millennial ones. This includes forcing due to Milankovich cycles, solar and volcanic activity, iceberg discharges from the Greenland and Laurentide ice sheets, greenhouse gases, atmospheric dust, and sea ice and vegetation cover changes. These studies will need to link clearly with the model ones described below (see 7) and focus on periods of rapid change and the recent Holocene (see above).

4) High resolution physical model-observation synthesis:

Even the most intensive observational campaign in oceanography provides insufficient sampling to extract all the information one needs to understand processes and budgets. Observational data must be augmented with information from numerical models, which express the conservation laws governing ocean circulation. This programme will support work that provides model-observation syntheses based on the intensive field campaigns (see 1 - 2 above), and which contribute to understanding and quantifying the key processes and budgets which control THC stability. The emphasis is on models with high spatial resolution. Although the basic principles of data assimilation are relatively well understood (Bennett, 1992; Wunsch, 1996), and mesoscale ice-ocean models are available (e.g. Backhaus and Kämpf, 1999), model-observation synthesis of this type has not been performed routinely. An important and fundamental aspect of regional modelling arises through the need to specify lateral boundary conditions. In the data assimilation mode, these conditions can be estimated from the model and the observations. Such an approach has been implemented in a low-resolution model (Zhang and Marotzke, 1999), but considerable further exploration is required.

5) Atmospheric forcing of ocean convection, and large-scale ocean transports:

Though a range of climate models suggests that greenhouse warming can lead to THC weakening, these models all have relatively crude spatial resolution in their oceanic and atmospheric components. It has never been demonstrated that the THC can undergo dramatic weakening in ocean and atmospheric climate models of the resolution and sophistication that is needed to reproduce quantitatively observed features of ocean circulation, such as the narrowness of fronts and boundary currents. Many fundamental questions remain unanswered concerning the physics that controls the stability of the THC. Coupled GCMs are important tools to address this problem, but their computational expense limits both the physics that can be resolved and the number of sensitivity studies that can be performed. Two recent studies of the THC response to increasing atmospheric greenhouse gases with the

HadCM3 coupled model illustrate this. Wood et al. (1999) emphasise the importance of poorly resolved processes, such as Labrador Sea convection and sill overflows, in controlling the model response. In contrast, Thorpe et al. (2001) note the importance of large-scale atmospheric feedbacks (inter-basin water transport) in stabilising the model THC, in agreement with Latif et al. (2000). The two views are not necessarily contradictory, but the first implies a need for high resolution modelling of the overflows to assess the robustness of the HadCM3 results. In contrast, the second suggests a need to examine the robustness (e.g. sensitivity to poorly known model parameters) of the basin-scale processes. For the latter, both high resolution GCMs and low resolution, parameterised models may be necessary. Particular processes which may be important include: the adjustment of the THC to forcing of the deep water source (possibly in response to the NAO), through boundary waves and currents (Kawase, 1987; Marotzke and Klinger, 2000); the response of the THC to variations in the two deep water sources (Labrador and Greenland-Iceland-Norwegian Seas; Döscher and Redler 1997); the inhomogeneity of interior mixing (Polzin et al., 1997; Marotzke, 1997). Low-resolution models have been used to propose some large scale parameters which may be critical controllers of the THC and its stability, e.g. large-scale dynamic height contrasts or deep density differences between North and South Atlantic (Hughes and Weaver, 1994; Rahmstorf, 1996; Marotzke and Klinger, 2000; Thorpe et al., 2000), or the integrated fresh water budget of the Atlantic basin (Wang et al., 1999). The programme will support a range of modelling approaches, of appropriate degrees of complexity, that assess the robustness of the representation of such processes in the present generation of climate models.

6) Atmospheric response to large changes in ocean heat transport:

Ultimately, it is the atmosphere's response to THC changes – changes in climate and weather patterns – that influences societies, more so than oceanic changes (with the important exceptions of sea level change and influence on ocean ecosystems). In particular, changes in North Atlantic storm tracks, storm frequency, storm strengths, and energy and moisture transports are crucial for western European climate. Furthermore, many of the key processes which control the stability of the THC involve atmospheric heat and water transports, and are subject to large modelling uncertainty (e.g. Rahmstorf and Ganopolski 1999, Wood et al 1999, Latif et al. 2000, Thorpe et al. 2001, Vellinga et al 2001). Therefore, this programme will support studies that assess the impact of a THC weakening on atmospheric climate. Previous work with coupled models (e.g. Manabe and Stouffer, 1988;Vellinga and Wood, 2001,) showed a large-scale cooling of the Northern Hemisphere, a possible Southern Hemisphere warming, and changes to the main precipitation zones in the tropics. Atmosphere-only GCMs have been used to study the atmospheric response to large changes in North Atlantic sea surface temperature (SST, e.g., Rind et al., 1986; Venzke at al., 1999). The programme will support work to confirm these results with higher-resolution atmospheric models, having much more realistic storm track representations, and for different scenarios (e.g. changes in North Atlantic heat transport rather than in SST). Studies aiming to quantitatively estimate the impact of changes on the terrestrial environment using palaeo-reconstructions alone or in conjunction with modelling (see 3 and 7) will also be supported.

7) Use of palaeo data in ocean and climate models:

Past occurrences of rapid climate change predate the beginnings of instrumental climate records (with the possible exception of the early 20th century warming), so present understanding of these must be tested against palaeo data of all types (from continental, marine and ice sources). A major effort is needed to confront ocean and climate models with these observations quantitatively. As noted above (3), direct palaeo-information about ocean circulations is hard to obtain, but is becoming available. Even though palaeo-proxy data are often point measurements whereas models mostly have large grid-boxes, palaeo-time series offer anchor points to test and evaluate models. Implementation of widely used palaeo-proxies, such as oxygen isotopes, into model simulations already has produced a series of meridional ocean palaeo-circulation transects (e.g., Rohling and Bigg, 1998; Schmidt, 1998). The addition of atmospheric components will help reconcile, in a fully quantitative sense, the ocean data with the ice core record of rapid climate change. Extra tracers, such as carbon isotopes and ocean nutrient cycles, will go further towards producing true quantitative comparisons between the climate models and the palaeo-proxies. This will allow for an improved interpretation of the palaeo-records and help in the design of algorithms for relating palaeo-data to meteorological variables. Palaeo-oceanographic and palaeo-climatic modelling and palaeo data assimilation, including direct model simulation of oceanographic and climatic palaeo proxies, are therefore important elements that the programme will support. Rapid climate change events, such as the 8.2kyr event and the LIA (Little Ice Age), will serve as a more accessible test-bed for understanding possible large THC-climate interactions during and at the end of the glacial. Studies of recent Holocene variability will allow an assessment of "normal" climate variability.

The unusual combination of present day observations, palaeo data and hierarchy of models (local process models to GCMs) represents an important aspect of the work of the programme and provides a unique opportunity to test and improve GCMs (including those used at the Hadley Centre). In particular, the programme will support the development of a scientific basis for using palaeo data for testing and improving the individual and linked processes that are used in climate models. Techniques, such as sensitivity analysis and data assimilation, allow the testing of various components of the models, focused on their ability to simulate the processes that are important for THC and other rapid climate change. This should lead to improvements in the models and reduced uncertainty in prediction of future rapid change.

8) Quantifying the probability and magnitude of rapid change:
A key component of the programme is the integration of the results from 1-7 above, in order to quantify the probability and magnitude of rapid climate change, and estimate the associated uncertainty. Work supported under this aspect of the programme includes measuring the statistical variations of the different component systems that go to make up a climate regime, including the characteristics of extreme climatic events. This encompasses time-scales from annual to centennial and space scales from regional to global, with a necessary requirement for firm palaeo dating control and high and accurate temporal resolution, ideally better than annual (see 3 above). Currently detection and attribution studies use model simulations to estimate natural climatic variability. Palaeo-data should allow comparison of these estimates with the variability of the natural system in order to validate these critical assumptions. The programme will support studies that attempt to quantify (probabilistically) the likelihood of rapid climate change, and to develop scenarios

that can be used in risk assessments.

Training

Researchers investigating rapid climate change require a broad range of interdisciplinary skills in palaeo studies, climate, meteorology, oceanography, numerical modelling, data assimilation, statistics, and computer science. There is a serious lack of scientists with the required breadth of knowledge and skill to pursue this scientific “grand-challenge”. The programme will therefore seek to attract talented scientists from related disciplines and will aim to provide training as appropriate. It is anticipated that a significant number of Ph.D. studentships will be allocated.

The Community

A major aim of the programme is to bring together the diverse research communities, which have the skills to address the problem of rapid climate change. These include researchers working in physical and tracer oceanography, meteorology, palaeo studies, sea ice research and atmospheric, oceanic, ice (sea and land) and climate modelling. In order to break down some of the disciplinary boundaries, proposals that involve researchers from a variety of disciplines will be particularly encouraged. Users will be policy makers and the climate community at large, including those dealing with climate predictability and prediction, and those dealing with the impacts of, and responses to, climate change. The programme will provide an underpinning for future climate predictability work and will provide scenarios for use in risk and impact assessments by social and policy analysts. In particular, this programme will feed interactively into the recently funded Tyndall Centre for Climate Change Research, whose focus is on prevention, mitigation, and adaptation strategies. There will be a strong involvement of the Hadley Centre, which focuses on climate prediction using GCMs. Collaborative links will be developed with organisations such as DEFRA, the Environment Agency and the UK Climate Impact Programme (including identification of their specific needs).

Collaboration and Links with other Programmes

An important aim of the programme is to develop the necessary international collaborations that will complement and so enhance and extend the NERC and UK work on rapid climate change. A key collaboration, arising from discussions between the Prime Ministers of the UK and Norway, will be with the Norwegian Ocean Climate project (NOClim; http://www.noclim.org). A high priority will be given to developing the UK–Norway initiative into a genuine scientific collaboration of mutual benefit. The RAPID has natural links with a number of NERC, UK and international programmes – either existing or planned. These include COAPEC, AUTOSUB\ICE, UGAMP (all NERC), CONVECTION, TRACTOR, VEINS, MAIA, OPEC2, PREDICATE (all EU), Clic, CLIVAR (GOALS, DecCen, ACC), IGBP (PAGES), HOLIVAR, ODP, IODP, IMAGES, ARGO, ERS-2, ENVISAT, GOCE, SMOS, CRYOSAT, TOPEX, JASON-1, ICESAT, GRACE, Florida Straits monitoring, ASOF (all international) and various modelling ventures, particularly (as noted above) those at the Hadley Centre.

Resources

The NERC Science and Technology Board (STB) has allocated £20M to RAPID over six years. The funding profile of the programme will be decided by the Scientific Steering Committee.

Project Management

The programme has a steering committee appointed by NERC to provide scientific direction. The NERC Superintending Officer is Dr. Phil Newton and the Programme Co-ordinator is Dr. Andy Parsons. An RAPID programme office has been established at the Southampton Oceanography Centre under the Scientific Co-ordinator Dr. Meric Srokosz.

Data Management

It is NERC policy that thematic programmes ensure the long-term availability of data collected, to maximise the application and exploitation of the results. In most cases, it is expected that NERC Designated Data Centres will be used for quality control and archiving, with costs covered from programme funds. After a period of sole access by PIs for publication preparation, data are made available to other programme participants and the wider community.

Appendix A: References

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