

RAPID-WATCH¹ Work Plan²

**THIS IS A “LIVING DOCUMENT” TO BE UPDATED, WHEN NECESSARY,
AS THE RAPID-WATCH PROGRAMME DEVELOPS**

Summary

This work plan details the implementation of the RAPID-WATCH research programme – the science of which was laid out in the RAPID-WATCH proposal – for which funding was earmarked in principle by NERC in November 2006. It addresses the requirements placed on the programme by both Council and SISB, and responds to the review of the RAPID MOC (meridional overturning circulation) observing system in 2007. The plan describes the implementation of the next stage of the MOC observing system, to deliver a decade of observations 2004-2014, the exploitation of the observations to gain further knowledge of the role of the Atlantic Ocean in rapid climate change and their possible utility in improving predictions of future changes, and the potential move to operational status beyond 2014.

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1. Introduction

In 2006 the RAPID-WATCH proposal (Bryden et al., 2006) was submitted to NERC. The proposal was peer-reviewed, evaluated by SISB and then accepted by NERC. Funding was earmarked in principle by Council; subject to two conditions³:

- a) the successful review of the existing RAPID MOC observing system by an independent group of international experts;

¹ RAPID-WATCH = Rapid Climate Change – Will the Atlantic Thermohaline Circulation Halt?

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³ A third condition – the availability of funds – is beyond our remit to address.

b) the production and approval by SISB of a work plan for the RAPID-WATCH programme, taking account of the recommendations of the review.

The first condition was met by the review of the MOC observing system that took place in February 2007. A review report (Church et al., 2007; see **Annexe B** for the executive summary) was submitted to and accepted by NERC in April 2007. The report highlighted the success of the MOC observing system to-date. Here the second condition is addressed by this plan. Responses to the review report by the teams carrying out the observations (26°N and WAVE) are incorporated into this plan (within the costs constraints, as the funding earmarked for RAPID-WATCH is tightly constrained).

In addition to the conditions laid down by Council, SISB required the plan to detail how partnership with the Hadley Centre would work. This too is addressed here (§7).

This plan draws on the original proposal (Bryden et al., 2006) and the recommendations of the MOC observing system review (Church et al., 2007). Before proceeding further the RAPID-WATCH objectives and deliverables are re-stated here (taken from Bryden et al., 2006), as these are the drivers for the plan.

2. RAPID-WATCH objectives

2.1 To deliver a decade-long time series of calibrated and quality-controlled measurements of the Atlantic MOC from the RAPID-WATCH arrays.⁴

The first objective will be addressed by continuing the RAPID MOC observations.

2.2 To exploit the data from the RAPID-WATCH arrays and elsewhere to determine and interpret recent changes in the Atlantic MOC, assess the risk of rapid climate change, and investigate the potential for predictions of the MOC and its impacts on climate.

The second objective will be addressed through answering four questions:

- 1. How can we exploit data from the RAPID-WATCH arrays to obtain estimates of the MOC and related variables?*
- 2. What do the observations from the RAPID-WATCH arrays and other sources tell us about the nature and causes of recent changes in the Atlantic Ocean?*
- 3. What are the implications of RAPID-WATCH array data and other recent observations for estimates of the risk due to rapid change in the MOC?*
- 4. Could we use RAPID-WATCH and other observations to help predict future changes in the MOC and climate?*

3. RAPID-WATCH deliverables

3.1 An observed time series of the MOC and associated variables from 2004-2014, and interpretation of the observations in the broader context of Atlantic and European climate.

3.2 A tested design for a cost-efficient and robust system suitable for operational monitoring of the MOC.

3.3 An assessment of the scientific (and in broad terms, socio-economic) benefits of an MOC monitoring system, including estimated timescales on which the full benefits would be realised. To include applications for: detection and attribution of unusual MOC change, reducing uncertainty in MOC projections, initialising MOC predictions (early warning system).

⁴ Rather than continually refer to the RAPID and RAPID-WATCH arrays, this is abbreviated to the RAPID-WATCH arrays here and in what follows.

3.4 A robust and scientifically credible assessment – specifically informed by the RAPID and RAPID-WATCH observations, modelling and synthesis – of the risk to the UK, Europe and other regions of a rapid change in the Atlantic MOC affecting our climate. This will address the probability, rate and expected magnitude of MOC-related rapid climate change, and associated uncertainties.

4. Science Plan

The RAPID-WATCH proposal (Bryden et al., 2007), having been accepted by NERC, will constitute the RAPID-WATCH science plan.

A key date in the science plan is 2011, when the MOC observing system will be evaluated and a decision made as to whether the system should move to operational status at the end of the programme in 2014.

5. Observing system

The implementation of the MOC observing system, which addresses the first RAPID-WATCH objective (§2.1 above), shall be carried out by the 26°N and WAVE array teams that have been responsible for these observations under RAPID. In essence, this is a continuation of the existing RAPID MOC observing system, with some modifications that take account of the review of the system (Church et al., 2007). The funding for the 26°N and WAVE work, at NOCS and POL respectively, shall be handled through the usual NERC channels and mechanisms, so no special arrangements are required. The implementation shall be overseen by the RAPID-WATCH Programme Advisory Group (PAG – see below §11), working with the Science Coordinator and the NERC Programme Administrator and Superintending Officer, who shall regularly monitor progress and give guidance to NERC on changes to and developments of the system (see §11.3 below).

In particular, the PAG shall carry out the interim review of progress on WAVE in 2009 (see provisional timetable for RAPID-WATCH §12 below), as recommended by the review group (Church et al., 2007). The PAG shall also arrange for the 2011 evaluation of the MOC observing system by independent international experts (as per the science proposal; Bryden et al., 2006) and make the recommendation as to whether the MOC observing system could move to operational status in 2014. If such a recommendation is made, the PAG and NERC shall work together to ensure that funding from the appropriate government sources is available for an operational system and that a smooth transition can be made to operational status.

5.1 26°N array

Essentially the implementation of the 26°N array shall be as described in the RAPID-WATCH proposal (Bryden et al., 2006), but with one variation recommended by the MOC observing system review group (Church et al., 2007): for one year two extra deep moorings shall be deployed in the western basin to measure the flow of Antarctic Bottom Water (AABW) at depths below 4800m. This is to examine the variability of this deep flow and its effect on the estimation of the MOC at 26°N (which is thought to be minimal, but this needs to be confirmed).

5.2 WAVE array

In view of the recommendations made by the MOC observing system review group and the proposed revision of the WAVE array by the WAVE team (see Church et al., 2007, for details), the implementation of the WAVE array will differ significantly from the RAPID-WATCH proposal (Bryden et al., 2006). Previously WAVE had two lines of moorings on the eastern seaboard of North America, to the north of the Gulf

Stream, to measure the Deep Western Boundary Current (DWBC) – one off the Grand Banks and one off Halifax. The array will be reduced to one line of moorings off Halifax, and the work will be carried out in partnership with the Bedford Institute of Oceanography (BIO), Halifax, Canada (see §8.1 below). In particular, use of the BIO ship to service the moorings shall be both logistically simpler and less expensive.

In view of these changes and the moorings losses experienced during the first deployment of the WAVE array,⁵ the MOC observing system review group recommended that an interim review of the WAVE array be carried out in 2009. This review shall be done by the PAG (see §11 below), who shall make recommendations to NERC as to whether the WAVE project should continue for the full duration of the RAPID-WATCH programme.

5.3 Modelling

Following the recommendation of the MOC observing system review group (Church et al., 2007), RAPID-WATCH will fund a full-time modeller – for the period 2008-2011. This will ensure that good links are made to UK and international modelling groups. The modeller will help in the development of products from the 26°N and WAVE arrays that can then become routine products available to users (see §10.2 below).

6. Open call

To exploit the RAPID-WATCH data (objective 2.2 above) an open ‘Research Programme’ call shall be made for proposals to answer the associated questions. The primary mechanism for this shall be an announcement of opportunity (AO) for outline bids. The PAG and independent experts shall evaluate these, and a subset will be chosen to proceed to the full proposal stage. The full proposals shall be internationally peer-reviewed and final funding recommendations made by a moderating panel, consisting of the PAG plus independent experts. (PAG members directly involved in proposals being considered will be excluded from those parts of the moderating panel discussions that affect their proposal – to avoid vested interest issues.)

Proposals submitted to the open call shall be required, not only to address the objective and associated questions (§2.2 above), but also to detail how they shall contribute to the RAPID-WATCH deliverables (§3 above)

Proposals in response to question 1 and 2 under the second objective (§2.2 above) are expected to be innovative but of moderate size. It is anticipated that one-third of the open call funds shall be used for this aspect of RAPID-WATCH and international collaborations will be encouraged (n.b. international collaborators will benefit from access to data, but will not receive NERC funding). In contrast, proposals in response to questions 3 and 4 under the second objective (§2.2 above) are expected to be more naturally addressed by consortia (possibly including international partners) and will be required to demonstrate close partnership with the Hadley Centre in achieving their objectives and contributing to the RAPID-WATCH deliverables. It is anticipated that this work will be delivered through two consortium grants (each of up to one-third of the available open call funds). The AO shall be worded to reflect these priorities. Awards made by NERC shall have conditions attached that ensure that the funded projects contribute in a timely manner to the RAPID-WATCH deliverables.

⁵ The RAPID-WATCH proposal was submitted (April 2006) prior to the first recovery of the WAVE array (August 2006). The MOC review group recommendations (Church et al., 2007) take account of the mooring losses experienced by WAVE.

Specifically, funded proposals will not exceed 4 years in duration and shall contribute to the evaluation of RAPID-WATCH in 2011 (see §11 below).

A sum of money (sufficient for 1 FTE) will be kept to fund synthesis activities over the last 3 years of the programme, so that the transition to operational activities may proceed smoothly. The details of how this synthesis role will work shall be decided by the PAG as the programme develops.⁶ The PAG will oversee the progress of the funded open call projects and ensure that they deliver the programme science, re-directing resources if necessary to achieve this (see §11.4 below).

7. Partnership with the Met Office Hadley Centre

The new Hadley Centre programme (2007-2012; see **Annexe A** for more details) has been developed with the expectation that RAPID and RAPID-WATCH will deliver substantial scientific advances that can be pulled through to the policy arena by effective collaboration. In practice, this means that there will be close collaboration in those areas laid out in the RAPID-WATCH proposal (Bryden et al., 2006) and in the letter of support for the RAPID-WATCH proposal sent by the Met Office. The primary (but not the only) mechanism to ensure collaboration will be the requirement that proposals in response to the AO seeking to address questions 3 and 4 of the second objective (see §§2.2 and 6 above) will have to demonstrate close partnership with the Hadley Centre in achieving their objectives and contributing to the RAPID-WATCH deliverables (§3 above). More details of the partnership are given in Annexe A (§A.1 below). The Hadley Centre work represents a contribution of the order of £••• per year. This partnership with the Hadley Centre builds on the initial collaborations in RAPID, including the involvement Dr. Richard Wood in preparing both the RAPID and RAPID-WATCH proposals and his membership of the RAPID steering committee.

To facilitate interactions between RAPID-WATCH and the Hadley Centre a jointly funded post (50:50) may be possible (discussion are in progress – following the precedent established by the NERC COAPEC directed programme). This would be focussed on ensuring effective knowledge transfer from RAPID-WATCH to the Hadley Centre and then through to policy. Such a post would also contribute significantly to addressing the deliverable 3.3 (see above).

8. International collaboration

8.1 USA (NSF and NOAA) and Canadian (BIO) partnerships

NSF – At the time of writing (July, 2007) NSF have funded the proposal led by Johns (University of Miami) that contributes to the 26°N array. The Toole (WHOI) proposal that contributes to the WAVE array (Line W) is still *sub judice*. If both proposals are fully funded this would represent a contribution of around \$•••. Therefore, NSF will contribute significant funding for science and for shiptime over the period 2008-2014.

NOAA – NOAA's commitment to the continuation of the critical Florida Strait undersea cable measurements, by AOML, was expressed in a letter of support for the RAPID-WATCH proposal and is unchanged. This work includes the calibration cruises for the cable measurements and processing and analysis of the cable data, so represents a substantial investment. NOAA scientists will also contribute to the monitoring of the DWBC, most notably through the provision of shiptime and

⁶ This springs out of experience in RAPID, and is aimed at ensuring that synthesis of programme results can be funded towards the end of the programme.

mooring operations on an annual basis. The total NOAA contribution is approximately \$••• for science and 86 days shiptime per annum.

Recently the USA announced increased funding in the area of ocean science (see news article in Science, vol. 315, pp.585-6, 2nd Feb. 2007) with four near-term priorities, one of which focuses on studies of the role of Atlantic Ocean currents in rapid climate change.⁷ No firm plans yet exist on how the money will be spent, but a science planning team has been formed (NOAA, personal communication). Potentially, this provides an opportunity for further cooperation with the USA in this area of science under RAPID-WATCH.

Bedford Institute of Oceanography (BIO), Halifax, Canada – BIO have agreed to become partners in the WAVE project. In particular, the RAPID-WATCH programme will be able to make use of the BIO ship to service the WAVE Halifax line of moorings and will work with BIO scientists on analysing the data in the context of other BIO observations in the region.

8.2 European partnerships

FP7 – The EU 7th Framework Programme (FP7) issued a 10M€ call for studies of the MOC / thermohaline circulation. Several consortia submitted proposals, some involving UK RAPID scientists. The THOR (Thermohaline Overturning – at Risk?) was funded and there are clear opportunities for synergy with the RAPID-WATCH programme.

MarinERA – A meeting in St Feliu, Spain in October 2006 explored the possibilities of a joint international call under MarinERA for research on the thermohaline circulation, with a partnership between nine countries (UK, Germany, France, Spain, The Netherlands, Norway, Portugal, Belgium, and Ireland). If agreement is reached, a call for proposals may be issued in 2008 and would facilitate further use of RAPID-WATCH data and products by members of the European science community. To this end the RAPID-WATCH programme will set aside £0.5M to contribute to this call. If all countries contributed equal amounts this would amount to £4.5M.

Max Planck Institute for Meteorology (MPI-M), Hamburg, Germany – The involvement of Prof. Jochem Marotzke (Director, MPI-M) in the original pre-RAPID proposal (called ABRUPT) and his subsequent leadership of the 26°N MOC observing system project while at Southampton (prior to his move to MPI-M) means that there are close links already in existence here. These will continue under the RAPID-WATCH programme, with MPI-M contributing effort at the level of at least 1.5FTE of modelling effort (plus HPC), as well as Prof. Marotzke's personal involvement in the 26°N project (see §A.2 below), with additional effort from MPI-M Ph.D. students. (In total an effort of approximately •••M€ per annum).

9. Knowledge Transfer (KT)

Under RAPID KT has been successful in building links with the stakeholder/user community and, in particular, with the Hadley Centre, Defra, UKCIP and MCCIP. Results from RAPID are now routinely lodged in the Defra “knowledge bank” to help inform policy (following a short secondment of the RAPID KT manager to Defra).

⁷ RAPID provided input to NOAA in this area and is in close contact with US scientists as their plans develop. See: http://www.usclivar.org/science_status/AMOC/AMOC_Strategy_Document.pdf. RAPID has also provided information to a US senator and provision for abrupt climate change research was incorporated into a Senate energy bill (representing a possible investment of \$••• per annum over 6 years).

RAPID is represented on the MCCIP steering committee and has contributed to the Annual Report Card that brings together evidence of changes in the marine environment (see <http://www.mccip.org.uk/>). A joint RAPID/MCCIP KT workshop is scheduled for the autumn of 2007. RAPID will also contribute to the next UKCIP report on climate change impacts due in 2008. To ensure a smooth transition from RAPID to RAPID-WATCH the existing full-time KT post will be extended for 12 months (2008-9). The principal objective shall be to maintain and enhance the links with stakeholders and users that have been forged during RAPID – and also to manage KT activities orientated around RAPID results, some of which will only be available after the official end of the RAPID programme in March 2008. Thereafter the post shall be scaled-down to a part-time role, which should provide adequate resources to ensure that effective RAPID-WATCH KT activities are maintained throughout the programme's duration.

Note too that the proposed joint Hadley Centre / RAPID post (described above §7) will also make a significant contribution to RAPID-WATCH KT activities, but the focus there will be more on the technical aspects of knowledge transfer related to use of data, modelling and prediction.

10. Data management

As in RAPID, data management for RAPID-WATCH shall be handled by the two appropriate NERC designated data centres – BODC and BADC – through the standard NERC mechanisms. The Science Coordinator and PAG (see §11 below) shall be responsible for agreeing the data management plan with the data centres and overseeing data management for RAPID-WATCH, including regular meetings with, and annual reporting by, the data centres.

10.1 Data policy

A revised data policy⁸ will be developed by the PAG and Science Coordinator for data from the MOC observing system, in order to ensure timely availability of data to the open call projects in RAPID-WATCH and to other users. To raise the profile of RAPID-WATCH, and that of the funders of the MOC observing system, there will be a requirement on all scientists who use the data and/or products to acknowledge RAPID, and NERC, NSF, NOAA, in all presentations, papers, publications and so on (see below §11.6 on “branding”).

10.2 Observing system component

The major data management task will continue to be the processing, archiving and distribution of data from the MOC observing system as occurs under RAPID. However, as the aim is to move to an operational system in 2014, the process of going from the recovery of moorings and instruments at sea to making the data available to users will need to be streamlined (in comparison to RAPID). If real-time data are available from the MOC observing system these shall be made available on the web in near real-time (the feasibility of this has already been demonstrated by BODC under RAPID).

In addition, the MOC observing system review report (Church et al., 2007) recommended that standard products should be made available to the user community from the MOC observing system and that the production and distribution of these should be the responsibility of BODC. Therefore, working in conjunction with the 26°N and WAVE groups, who will seek to develop appropriate products required by

⁸ As compared to the existing RAPID data policy.

users (e.g. modellers for use in data assimilation or model initialisation or validation; see §5.3 above), BODC will be responsible for the routine production and distribution of products from the MOC observing system.

10.3 Open call component

Data management for this component shall follow the approach used in RAPID, with the additional requirement that data from the MOC observing system shall be made available to open call participants in a timely manner.

11. Programme management

11.1 Programme Advisory Group (PAG)

A Programme Advisory Group (PAG) will advise NERC on the delivery of the RAPID-WATCH programme. The PAG will consist of national and international experts, and be chaired by an independent UK scientist familiar with how RAPID and NERC operate. The PAG will work closely with the Science Coordinator, the Programme Administrator and the Superintending Officer (the latter two posts based at the NERC Swindon Office). The PAG shall be appointed by NERC by the end of 2007.

The **key responsibilities** of the PAG (working with the Science Coordinator) shall be to:

- advise on all aspects of the RAPID-WATCH programme to ensure that it is delivered effectively and within budget
- advise on the draft announcement of opportunity for the open call and, working with independent experts (including members of the NERC Peer Review College), evaluate the proposals and make funding recommendations to NERC
- report on progress with the WAVE array in 2009 (as recommended by Church et al., 2007) and make recommendations to NERC regarding continued funding
- organise an independent expert review of the MOC observing system in 2011 (following the model of the RAPID 2007 review)
- monitor the progress of projects against programme objectives and advise on the re-direction of resources as necessary to ensure delivery of the RAPID-WATCH programme
- ensure that there is timely delivery of data and products to the user community
- manage the risks to the programme

11.2 Science Coordinator

The Science Coordinator shall be a part-time role based outside the NERC Swindon Office. The post shall be at the level of 0.5FTE (at least) in the initial phase of the programme; that is, until the evaluation in 2011. Thereafter the PAG will review and recommend the level of effort required for the post, as this will depend critically on the decision whether the MOC observing system should transition to operational status in 2014. The Science Coordinator shall be responsible for the day-to-day management and coordination of the programme, working closely with the Programme Administrator based in the Swindon Office. The Programme Administrator shall be responsible for the administrative aspects of the programme. Both shall report to the NERC Superintending Officer, also based in the Swindon Office.

The Science Coordinator shall continue to develop the work plan and delivery strategy (this document), plus a data management plan and a knowledge transfer strategy. The Science Coordinator shall work to ensure coordination between the different science components of RAPID-WATCH, in particular ensuring that the open

call activities are closely coupled to the MOC observing system. The Science Coordinator, together with the PAG, shall organise workshops to facilitate this interaction across the programme as well as annual meetings. The Science Coordinator, together with the Programme Manager, shall administer the awards process, feeding back information to unsuccessful candidates and, where necessary, negotiating modifications to the work plan and/or finances of successful applications. The Science Coordinator shall also be responsible for the monitoring and reporting on behalf of the whole programme, including annual reporting and the completion of output performance measures (OPMs). In addition, the Science Coordinator shall maintain an overview of the scientific progress made against the RAPID-WATCH objectives (§2). The Science Coordinator shall liaise with all RAPID-WATCH participants and continue the development of the RAPID community under RAPID-WATCH.

The Science Coordinator shall be responsible for the maintenance of a RAPID-WATCH web site. It is anticipated that the research highlights from the programme shall be included on the web site.

The Science Coordinator shall be appointed by NERC by the end of 2007.

11.3 Observing system component

As the observing system components shall be carried out by NOCS and POL, the management of these aspects of the programme shall use the normal mechanisms in those centres. Oversight of the observing system shall lie with the PAG. The 26°N and WAVE teams shall report annually to the PAG. The PAG shall recommend to NERC any changes that need to be made to the MOC observing system to achieve the objectives of RAPID-WATCH.

The PAG shall have particular responsibility for carrying out the interim review of the WAVE array in 2009, as recommended by the review group (Church et al., 2007). It shall also be responsible, together with the Science Coordinator, for organising the 2011 review of the MOC observing system and making the recommendation as to whether or not to move to operational status in 2014 (following the model of the RAPID MOC observing system review in 2007). If the recommendation is to move to operational status, then the PAG and Science Coordinator shall work with NERC and other relevant government bodies to ensure that this occurs effectively.

11.4 Open call component

The open call component of RAPID-WATCH shall be overseen by the PAG and projects shall report regularly (at a minimum annually but probably every six-month) on progress. The reports shall be discussed by the PAG at their meetings. Where clear problems are identified the Science Coordinator and members of the PAG will discuss with the PI how the problems can be rectified to ensure the delivery of the science over the lifetime of the programme. If necessary, and with the approval of the NERC Superintending Officer, resources will be re-directed to ensure delivery of the programme.

11.5 Risk management

Risk management – identified as a critical issue by the MOC observing system review group (Church et al., 2007) – shall be overseen by the PAG for the programme as a whole. For the 26°N and WAVE projects each group shall be responsible for implementing appropriate risk management (as recommended by Church et al., 2007). In addition, the RAPID-WATCH programme will support activities (for example,

workshops and exchange visits) that will allow the UK mooring teams to learn from the experience of members of the international community. Additional resource for the risk management of the RAPID-WATCH arrays was provided by NERC through Theme 8 of Oceans 2025 and this will provide for the development of a risk management process for the RAPID-WATCH array by 2011 (i.e. in time for the re-evaluation of the MOC observing system) The PAG, together with the Science Coordinator, shall be responsible for managing the risks to the overall programme.

11.6 “Branding”

With regard to “branding” – all partners and NERC will fully acknowledge the contribution each makes to the joint work being pursued (for example, by suitable acknowledgements in published papers). RAPID⁹ is and will remain the internationally recognised “brand name” and should be used in promoting the work being done (e.g. through appropriate use of the logo). As appropriate, other logos would be included in any material following the example of the international science conference branding in 2006, where the conference was sponsored by a number of organisations (see <http://www.noc.soton.ac.uk/rapid/rapid2006/>).

⁹ In terms of branding it seems better to continue with RAPID than try to move to RAPID-WATCH. RAPID is an internationally recognised and respected programme, so changing the branding at this stage would be counter-productive.

12. Programme timetable (2007-2014)¹⁰

<i>February 2007</i>	<i>MOC observing system evaluation (completed)</i>
<i>April 2007</i>	<i>MOC observing system review report submitted to and accepted by NERC (completed)</i>
<i>July 2007</i>	<i>Work plan (completed)</i>
<i>Sept. 2007</i>	<i>Work plan to SISB for approval</i>
<i>Nov. 2007</i>	<i>Council approval / allocation of funding</i>
<i>Feb. 2008</i>	<i>Appointment of Programme Advisory Group (PAG) and Science Coordinator</i>
<i>Mar. 2007</i>	<i>Announcement of opportunity (open call)</i>
<i>Apr. 2008</i>	<i>Deadline for submission of outline bids</i>
<i>Apr. / May 2008</i>	<i>Evaluation of outline bids, plus feedback to proposers</i>
<i>Summer 2008</i>	<i>Deadline for submission of full bids</i>
<i>Summer 2008</i>	<i>Review of full proposals</i>
<i>Autumn 2008</i>	<i>Evaluation of full bids</i>
<i>End of 2008</i>	<i>Open call projects start</i>
<i>2009</i>	<i>Trans-Atlantic hydrographic section (Oceans 2025)</i>
<i>2009</i>	<i>Interim review of WAVE array by PAG, with recommendation to NERC as to whether to continue for duration of RAPID-WATCH</i>
<i>Early 2011</i>	<i>Initial results from programme available to feed into decision about move to full operational status</i>
<i>2011</i>	<i>Evaluation of MOC observing system by independent international experts (modelled on 2007 review) and recommendation to NERC on whether to move to full operational status in 2014</i>
<i>2014</i>	<i>Trans-Atlantic hydrographic section (post-Oceans 2025 core / strategic programme)</i>
<i>March 2014</i>	<i>Formal end of RAPID-WATCH programme</i>
<i>Mid-2014</i>	<i>RAPID-WATCH finale event</i>

Note that this timetable is indicative and will be updated as the programme develops.

¹⁰ To be updated as RAPID-WATCH programme develops.

13. Cruise timetable

Significant effort will be expended in work at sea during the lifetime of RAPID-WATCH and the following is indicative of the cruise schedule planned through to 2014.

26°N cruises

Schedule of cruises for the refurbishment of the *western boundary array* from spring 2008 to spring 2014. The Sponsor provides ship-time and leads the cruise.

Approximately 50 CTD stations (Hydro) will be occupied on each cruise. During Rapid-MOC cruises mobilised from a variety of ports on the eastern US and in the Caribbean. (n.b. hydro = hydrography)

Year	Season	Sponsor	Activity
2008	spring	NSF US+UK	moorings, Hydro
2008	autumn	NOAA	Hydro
2009	spring	NERC	UK moorings, Hydro
2009	autumn	NOAA	US moorings, Hydro
2010	spring	NOAA	UK moorings, Hydro
2010	autumn	NOAA	Hydro
2011	spring	NSF	UK+US moorings, Hydro
2011	autumn	NOAA	Hydro
2012	spring	NOAA	UK moorings, Hydro
2012	autumn	NSF	US moorings, Hydro
2013	spring	NOAA	UK moorings, Hydro
2013	autumn	NOAA	Hydro
2014	spring	NERC	US+UK moorings (recover only), Hydro

Schedule of cruises for the refurbishment of the *eastern boundary and mid-Atlantic Ridge array* from spring 2008 to spring 2014. The Sponsor provides shiptime and leads the cruise. Approximately 12 CTD stations (Hydro) will be occupied on each cruise. During Rapid-MOC these cruises usually mobilised from Santa Cruz de Tenerife, but occasionally mobilised directly from the UK.

Year	Season	Sponsor	Activity
2008	autumn	NERC	UK moorings, Hydro
2009	autumn	NERC	UK moorings, Hydro
2010	autumn	NERC	UK moorings, Hydro
2011	autumn	NERC	UK moorings, Hydro
2012	autumn	NERC	UK moorings, Hydro
2013	autumn	NERC	UK moorings, Hydro
2014	spring	NERC	UK moorings (recovery only), Hydro

13.2 WAVE cruises

Year	Line	Ship	BPR moorings	BPR/CTD moorings	ADCP moorings	Moorings operations	Sampling stations
2009	Halifax	Hudson (AZMP-BIO)	0	6	5	Deployment	6
2009	W	Oceanus (W-WHOI)	6	0	0	Recovery/ redeployment	0
2010	Halifax	Hudson (AZMP-BIO)	0	6	5	Recovery/ redeployment	6
2010	W	Oceanus (W-WHOI)	6	0	0	Recovery/ redeployment	0
2011	Halifax	Hudson (AZMP-BIO)	0	6	5	Recovery/ redeployment	6
2011	W	Oceanus (W-WHOI)	6	0	0	Recovery/ redeployment	0
2012	Halifax	Hudson (AZMP-BIO)	0	6	5	Recovery/ redeployment	6
2012	W	Oceanus (W-WHOI)	6	0	0	Recovery/ redeployment	0
2013	Halifax	Hudson (AZMP-BIO)	0	6	5	Recovery	6
2013	W	Oceanus (W-WHOI)	6	0	0	Recovery	0

Note that the WAVE cruises will be in the summer so the final cruises will be in 2013, as RAPID-WATCH will end in spring 2014.

14. High Performance Computing (HPC)

Provision has been made for access to NERC HPC resources for the programme. Note that the partnerships with Met Office Hadley Centre and Max Planck Institute for Meteorology mean that they too will invest significant HPC resources into aspects of the programme.

15. References

- Bryden H., Marshall D., Sutton R., Wood R., Marotzke J. & Srokosz M. 2006
RAPID-WATCH – Will the Atlantic Thermohaline Circulation Halt? *proposal accepted by NERC*, 20pp.
- Church J., McPhaden M. & Quadfasel D. 2007 Review of and recommendations for the RAPID MOC observing system, *report to NERC*, 7pp.

Annexe A – details of Hadley Centre and MPI-M partnerships / links

A.1 Hadley Centre

RAPID-WATCH will make a unique contribution to a wider UK and international effort to assess and respond to the risks associated with major changes in the MOC. A key element of RAPID-WATCH will be its interaction and coordination with the Met Office Hadley Centre, which will facilitate the pull through of RAPID-WATCH science into the UK climate change policy arena. The Hadley Centre has recently agreed a new 5-year (April 2007- March 2012) research programme with Defra and MoD. The main focus of work on the MOC in this programme will be reduction of uncertainty in predictions of MOC change, on timescales from interannual to centennial. Specifically it is expected that the programme will:

- a) Extend the ‘perturbed physics’ AOGCM ensemble approach to identify key processes controlling MOC change, and to identify conditions under which abrupt MOC change is likely (‘early warning’ part 1)
- b) Contribute to the development of observational requirements that give tighter constraints on modelled MOC change, and feed these into the development of a case for observing system design
- c) Contribute to the development of a traceable model hierarchy suitable for building a scientifically robust risk assessment for rapid or irreversible MOC change, and produce such an assessment.
- d) Make decadal climate predictions, initialised using observations, using the DePreSys prediction system (and its successors; Smith et al., 2007), and assess the role of MOC in decadal climate prediction (‘early warning’ part 2).

Item 3 of the RAPID-WATCH ‘open call’ will require consortia to work with the Hadley Centre to deliver items (b-c), while item 4 of the open science call require consortia to work with the Hadley Centre to deliver specific assessments of MOC predictability and its link to climate, and improved initialisation for decadal MOC predictions (observing system and ensemble generation design), contributing to (d) above. Effective coordination and delivery plans with the Hadley Centre in these areas will be a key assessment criterion for proposals in ‘open science’ items 3 and 4. The joint research will contribute to the top-level deliverables of both RAPID-WATCH and the Hadley Centre programmes, namely robust risk assessment and improved decadal climate prediction/early warning capability.

‘Open call’ items 1 and 2 are more scientifically open, but coordination with the Met Office Hadley Centre and the National Centre for Ocean Forecasting is also encouraged in these areas. Specifically for item 1 the FOAM operational ocean analysis and forecasting system provides a potential test-bed for new state estimation methods at a range of model resolutions (1° global to 1/9° North Atlantic), and provides the potential of rapid pull through into operations, while for item 2 there is the potential for collaboration with wider work in the Hadley Centre programme on understanding and attribution of recent Atlantic climate change.

There is joint interest in building the scientific case for sustained observations to reduce uncertainty in MOC projections, to detect MOC change, and to initialise decadal MOC predictions. The Met Office will seek half funding to support a joint post focusing on delivery of that scientific case, the other half funding coming from RAPID-WATCH.

Reference

Smith D.M., Cusack S., Coleman A.W., Folland C.K., Harris G.R. & Murphy J.M. 2007 Improved surface temperature prediction for the coming decade from a global climate model, *Science*, **317**, 796-799.

A.2 Max Planck Institute for Meteorology (MPI-M)

The Max Planck Institute for Meteorology (MPI-M), through Prof. Marotzke's department "The Ocean in the Earth System", is committed to intensive participation in the RAPID-WATCH programme through its entire period. The MPI-M motivation stems from Prof. Marotzke's personal research interests, since the earliest RAPID discussions in late 1999, but also from MPI-M's strategic goals.

- 1) MPI-M is contributing to RAPID, and will continue to do so under RAPID-WATCH, through in-kind contributions. This includes Prof. Marotzke's annual participation in the mooring recovery and redeployment cruises, in the data analysis, in the publication of the results, and also through his contribution to the programmatic part of RAPID-WATCH. MPI-M's contribution includes the work of MPI-M-funded Ph.D. student Maria Paz Chidichimo, who participates in cruises and works on the contribution of eastern boundary variability to the MOC. In the future, MPI-M expects continued involvement through MPI-M funded Ph.D. students, for example on the comparison of the RAPID-WATCH data against coupled model integrations, such as in the proposed FP7 IP THOR (joint Work Package Cunningham-Marotzke). Additional costs arising from the participation of MPI-M researchers in RAPID and RAPID-WATCH are borne by MPI-M itself.
- 2) Strategically, MPI-M stands ready to make intensive use of the measurements taken in RAPID-WATCH, through MPI-M's recent involvement both in the ECMWF-led seasonal-to-interannual climate prediction project EUROSIP, and through the MPI-M project on decadal climate predictability. MOC predictability is a likely prerequisite for longer-term climate predictability, so the RAPID-WATCH measurements will be crucial in the initialisation and quality control of the coupled model predictability simulations. 1.5 FTE's are currently devoted to these predictability efforts and this level of involvement is very likely to increase.

Annexe B – Executive summary of MOC observing system review

Review group: John Church (CSIRO, Hobart, Tasmania & Chair of the Joint Scientific Committee of the WCRP), Michael McPhaden (PMEL, Seattle, USA), Detlef Quadfasel (IFM, Hamburg, Germany)

The international community has recognized the importance of the North Atlantic Meridional Overturning Circulation (MOC). Potential changes in the MOC are high profile in the science and policy maker communities and also amongst the general public. MOC changes have received significant attention within the IPCC Assessments. It is recognized that changes in the MOC may be a critical element of the science underpinning the definition of what is “dangerous” climate change and may also be vital for decadal climate prediction.

The review committee commends NERC for its international leadership, working in partnership with international collaborators, in taking on the challenging task of direct and continuous measurements of the MOC. This task has never been attempted previously and, if successful, would be a major step in designing an ongoing element of the climate observing system that would be critical in detecting climate change and allowing an early response to any change in the MOC.

The review committee agrees that the NERC RAPID-WATCH strategy of comprehensive measurements at one latitude, 26°N, supported by less comprehensive measurements at other latitudes, is an appropriate initial step in defining a comprehensive MOC Observing System.

The review committee were impressed by the new and exciting results that have already been produced from the 26° N array. These results, on their own, easily justify continuation of the array beyond the initial four-year observing period. Some variant of the 26°N array is likely to be an important element in any ongoing system to observe the MOC. The review committee strongly recommends continuation of the 26°N during the RAPID-WATCH Programme.

The WAVE array has had major technical problems, but the small initial amount of data available has been useful in re-designing the array. The review committee supports continuation of the re-designed WAVE array, subject to a further critical review at an appropriate time and before any ongoing long-term programme is supported.

The data return from both arrays (but particularly from WAVE) has been lower than expected. The review committee recognizes that a large project has been spun up over a very short period and that the two project teams have recognized that there have been significant technical difficulties and are moving to address these issues. The review committee strongly recommends that further efforts be pursued to ensure that the mooring program is conducted according to the highest professional standards. Essential elements of this include: ensuring that appropriate technical support is available in a timely and ongoing manner for the RAPID arrays; bringing international mooring experts to advise on the RAPID arrays and/or the RAPID mooring team visiting leading international institutes involved in mooring activities; and, ensuring that there is effective risk management for the RAPID arrays.

There is a need for an outreach/communication program providing data and data products to the broader scientific and policy communities and to the general public.

Glossary

AABW = Antarctic Bottom Water
ADCP = acoustic Doppler current profiler
AOML = NOAA Atlantic Oceanographic and Meteorological Laboratory, Miami
AZMP = Atlantic Zone Monitoring Programme
BADC = British Atmospheric Data Centre
BIO = Bedford Institute of Oceanography, Halifax, Canada
BPR = bottom pressure recorder
BODC = British Oceanographic Data Centre
CLIVAR = Climate Variability programme of the World Climate Research Programme
COAPEC = NERC Coupled Ocean-Atmosphere Processes and European Climate directed programme
CTD = conductivity, temperature and depth instrument
Defra = Department for the Environment, Food and Rural Affairs
DePreSys = Decadal Prediction System being developed at the Hadley Centre
DWBC = deep western boundary current
FP7 = European Union 7th Framework Programme
FTE = Full-time equivalent
HPC = high performance computing
KT = knowledge transfer
Line W = WHOI contribution to WAVE
MarinERA = European Research Area Network – for cooperation in and coordination of marine research activities
MCCIP = Marine Climate Change Impacts Partnership
MOC = meridional overturning circulation
MPI-M = Max Planck Institute for Meteorology, Hamburg, Germany
NADW = North Atlantic deep water
NERC = Natural Environment Research Council
NOAA = National Oceanic and Atmospheric Administration, USA
NOCS = National Oceanography Centre, Southampton
NSF = National Science Foundation, USA
Oceans 2025 = NERC Marine Laboratories research programme 2007-2012
OPMs = output performance measures
PI = principal investigator
POL = Proudman Oceanographic Laboratory
RAPID = NERC's Rapid Climate Change directed programme
RAPID-WATCH = Rapid Climate Change – Will the Atlantic Thermohaline Circulation Halt? – potential new NERC directed programme
SISB = NERC Science, Innovation and Strategy Board
THC = thermohaline circulation
THOR = Thermohaline Overturing – at Risk? European Union FP7 project
UKCIP = UK Climate Impacts Programme
WAVE = Western Atlantic Variability Experiment
WCRP = World Climate Research Programme
WHOI = Woods Hole Oceanographic Institution