

The Changing Water Cycle Programme

Specification

NERC Themes: Climate System, Sustainable Use of Natural Resources, Natural Hazards

1. Summary

The **Changing Water Cycle** programme will develop an integrated, quantitative understanding of the changes taking place in the global water cycle, involving all components of the earth system, improving predictions for the next few decades of regional precipitation, evapotranspiration, soil moisture, hydrological storage and fluxes. The programme will work to understand how local to regional scale hydrological and biogeochemical processes are responding and will respond to changing climate and land use, together with their consequent impacts on the sustainable use of soil and water and investigate the consequences of the changing water cycle for water-related natural hazards, including floods and droughts, improving prediction and mitigation of these hazards. This programme will address the urgent needs to understand the changes taking place now; predict changes that will take place over the next few decades; and, through the Living With Environmental Change programme (LWEC), work with partners to build resilience, mitigate problems, and develop adaptive solutions.

The programme will work with partners to build resilience, mitigate problems, and develop adaptive solutions. The programme will have global dimensions and dimensions that focus both on the UK/European region and overseas regions and take advantage of international collaboration opportunities. It will foster interdisciplinary research that links applied water resources issues seamlessly to fundamental climate system science.

It is proposed that this Research Programme will run initially for four years with NERC funding of £10.1 million (£5million from the Climate System Theme; £2.3M from Natural Hazards Theme, £2.8M from SUNR Theme). The programme will be highly multidisciplinary, aiming to bring science understanding across the three NERC Strategic themes in a fully integrated way.

A key aim of this programme is to bring together a diverse community of scientists from wide-ranging backgrounds including (palaeo-)climatology, hydrology, biogeochemistry, and natural hazards to address the multi-disciplinary scientific questions and deliver truly ground-breaking science to address the needs of a broad range of users who require a better understanding of the changing water cycle and the future of hydrological resources.

2. Background, Rationale and Objectives

Changes in the hydrological cycle as a consequence of climate and land use drivers are expected to play a central role in governing a vast range of environmental impacts. At the same time, predictions of water-related variables show very high uncertainty: for example, as shown in the recent Intergovernmental Panel on Climate Change fourth assessment report (IPCC AR4). Throughout much of the tropics there is no consensus amongst existing climate models about

whether greenhouse gas induced warming will lead to more or less rain – i.e. there is no consensus on the sign of the change, let alone the magnitude. Even when the sign is clear, the nature of changes in rainfall characteristics (i.e. frequency, intensity) is not, and these characteristics are critical for many impacts, such as those affecting hydrology and ecosystems. The very high levels of uncertainty in predictions of water-related variables, and the importance of these variables for climate impacts, suggests that this problem should be afforded comparable importance to the goal of constraining climate sensitivity. Progress is essential, and urgent, to provide decision makers with the information they need to anticipate and respond to the changes taking place.

The water-related challenges presented by climate change were recently summarized (April 2008) in a dedicated IPCC technical paper. Headlines from this paper include:

- “Increased precipitation intensity and variability is projected to increase the risks of flooding and drought in many areas.”
- “Climate change challenges the traditional assumption that past hydrological experience provides a good guide to future conditions.”
- “Changes in water quantity and quality due to climate change are expected to affect food availability, stability, access and utilization.”

Adapting to the changing water cycle will present enormous challenges.

In order to develop long-term adaptation and mitigation measures to minimise loss, not only of direct hazards, such as floods and droughts, but also indirect hazards, such as wildfires, subsidence and the triggering of landslides, it is essential to improve the prediction of changes in precipitation, and the distribution and nature of future impacts, at a regional scale.

Over the next 80 years, climate change and demographic and economic drivers will add further pressure to the water and soil life support systems on which we depend. Mitigation and adaptation measures linked to the forecast changes in water availability tend to focus on the demand end of the water balance. Sustainable solutions to climate change impacts on the water cycle mean getting to grips with changes in water supply, at scales from catchment to regional, and with the contingent changes in soil physical and biogeochemical processes. Clear signals of human induced impact on river flows are beginning to emerge. There is evidence to suggest that changes in weathering rates over the past 50 years due to changes in climate and land use are changing the chemistry of rivers. The challenge is to predict where the freshwater will land, when and in what volume. We also need to understand the implications for terrestrial and freshwater systems of measures designed to manipulate water availability such as large-scale water treatment movements (e.g. Ebro river, Spain), mixing raw water of different origin, and pumping water underground for storage.

As a coordinated response to the multi-dimensional problem of the changing water cycle NERC will develop a major Research Programme across three themes: Climate System, Natural Hazards and Sustainable Use of Natural Resources. This programme will address the urgent needs to: understand the changes taking place now; predict changes that will take place over the next few decades; and, through LWEC, work with partners to build resilience, mitigate problems, and develop adaptive solutions. It will have global dimensions and dimensions that focus specifically on the UK/European region and certain overseas regions. The location of the overseas regions will be determined in consultation with potential partners.

The programme will foster interdisciplinary research that links applied water resources issues seamlessly to fundamental climate system science. The high level science goals are:

1. To develop an integrated, quantitative understanding of the changes taking place in the global water cycle, involving all components of the earth system – the atmosphere, ocean, land surface and geosphere, cryosphere and biosphere.
2. To improve predictions for the next few decades of regional precipitation, evapotranspiration, soil moisture, hydrological storage and fluxes, focusing on the requirement to quantify and narrow the uncertainty in predictions.
3. To understand how local to regional scale hydrological and biogeochemical processes are responding and will respond to changing climate and land use, together with their consequent impacts on the sustainable use of soil and water.
4. To understand the consequences of the changing water cycle for water-related natural hazards, including floods and droughts, and to improve prediction and mitigation of these hazards.

The first two goals are of central importance to the Climate System theme, the third goal to Sustainable Use of Natural Resources and the fourth goal to Natural Hazards. However, **the programme aims to build science understanding across the three themes in a fully integrated way** and not focus effort simply within each theme.

Recognising some parts of the programme will have global scope, in those parts that are more regionally focused there will be a particular geographical focus on a) UK/Europe and b) at least one other region; this is in line with the programme recommendations from the NERC Science and Innovation Strategy Board (SISB).

The first two science goals encompass a wide range of specific science challenges and opportunities. Particularly important is the need to observe and understand the wide range of processes that are shaping changes in water, and to test and improve the representation of these processes in predictive models. Key processes include those that control:

- generation of precipitation, including the roles of large-scale drivers such as sea surface temperatures and atmospheric dynamics, and smaller scale processes such as those involving clouds and aerosols;
- land-atmosphere interactions including local recycling, the movement of water through soils, and the role of vegetation;
- frozen water including glaciers, permafrost and seasonal snow.

Major new opportunities in this field are associated with exploiting new Earth Observations (e.g. SMOS, Cloudsat, GRACE), land-based observations and data sets (e.g. new run-off data sets being developed in the EU-WATCH project, observations of atmosphere-land interactions from AMMA, and new palaeodata syntheses), advances in land-surface modelling, and new tools for process modelling (e.g. CASCADE) and for confronting models with observational data. Understanding the interactions between processes occurring on different spatial scales, from global to catchment, and time scales from days to decades, is a key challenge.

The third science goal is particularly pertinent to the Sustainable Use of Natural Resources theme. The focus will be on experiment and prediction at catchment and regional scales to characterize the complexity of the water-soil system (from land surface to groundwater). The challenge is to understand the feedbacks from the water-soil system onto climate (e.g. coupling between soil moisture and precipitation; changes in water retention capacity and soils sealing) and the nature of scale interactions (upscaling and downscaling). We can no longer assume hydroclimatic stability as a foundation concept to quantify water resources. The recent IPCC Report states ‘Changes in water quantity and quality due to climate change are expected to affect food availability, stability,

access and utilization'. Consequently, we need new non-stationary models of relevant environmental variables to optimize water systems. This is a huge task: the patterns of change are complex; the uncertainties are large; and the knowledge base changes rapidly. The joint delivery of this action with the other goals will ensure better representation of surface and groundwater processes and water use (including agricultural and energy sectors) in climate models, and better treatment of the implications of land cover change and land use management on the ecological thresholds for different water body types.

The fourth goal will: develop and test probabilistic regional models to understand and predict key impacts of changes in water dynamics under a range of climate and land-use scenarios for the next few decades; determine the implications of change in climate for the assessment of water-related risks to human and natural systems, and; develop appropriate science-based mitigation strategies to respond to and minimise the risks to human and natural systems caused by changes to the water cycle through the development of adaptation options at the river basin scale.

To enable better prediction of the distribution and nature of natural hazards, research will be required on complex, non-linear, and multiple-component, interactions with between water and physical and living systems. This will need to address natural variability in physical properties, environmental tolerances, and rates of change (including histories and frequency of wetting and drying cycles). Increased understanding of these will lead to development of improved models of regional precipitation on natural hazards (for instance, groundwater controls on subsidence, landslides, or ecological susceptibility to wildfire).

Links with the Living With Environmental Change (LWEC) partnership

The Changing Water Cycle programme will deliver part of NERC's contribution to a major £1 billion investment in 'Living with Environmental Change (LWEC)', <http://www.nerc.ac.uk/research/programmes/lwec/> which brings together the UK research councils, government departments and stakeholders to provide decision makers with the best information to effectively manage and protect vital ecosystem services. It will improve our tools and knowledge needed to build resilience, mitigate problems, and adapt to environmental change. LWEC will meet many of the needs identified by the UK Stern Review, the United Nations' Millennium Ecosystem Assessment, and the recent reports by the Intergovernmental Panel on Climate Change. Promoting interdisciplinary working between different communities will be fundamental to the success of the Changing Water Cycle programme. The overarching applied science goal, to be addressed through appropriate LWEC partnerships, is:

To develop science-based strategies that respond to and minimise the risks to human and natural systems caused by changes to the water cycle and their consequent impacts on water and food security and ecosystem health, including development of appropriate adaptation and mitigation options applicable at the river basin scale.

The programme will have links to at least four of LWEC's strategic objectives. The principal objectives linking LWEC to the Changing Water Cycle programme being:

A: *To predict the impacts of climate change, mitigate or adapt to these and manage extreme events.*

B: *To manage ecosystems for human well-being and protect the natural environment as it changes.*

C: To promote human well-being, alleviate poverty and minimise waste by ensuring a sustainable supply of food and water.

D: To protect human, plant and animal health from diseases, pests and environmental hazards.

One key LWEC link is with the Ecosystem Services for Poverty Alleviation (ESPA) programme <http://www.nerc.ac.uk/research/programmes/espa/> which covers similar LWEC Objectives, but from the perspective of Developing Countries and with a clear focus on poverty reduction. ESPA and the Changing Water Cycle will be designed to be synergistic and complementary.

It is expected that several goals will be developed through actions within appropriate LWEC partnerships, and the programme will be actively seeking to foster such collaborations. These will:

- develop and test probabilistic regional models to understand and predict key impacts of changes in water dynamics under a range of climate and land-use scenarios for the next few decades;
- determine the implications of changes in climate and water availability/quality for the assessment of water-related risks to human and natural systems, and;
- develop appropriate science-based adaptation strategies to respond to and minimise the risks to human and natural systems caused by changes to the water cycle through the development of appropriate options at the river basin scale.

3. Programme Requirements

3.1 Science & Implementation Requirements

The potential outcomes and measures of success of this programme include:

- improved predictive capability for drought and flood and other water-related natural hazards;
- tools for visualisation of likely future scenarios as a consequence of adaptation or mitigation actions;
- development of early warning systems;
- quantitative assessment of changes in water resource availability with improved confidence and reduced uncertainty;
- identification of thresholds in terrestrial and freshwater system responses;
- advanced capacity for integrated monitoring of changes in the water cycle.

Applied outcomes might include tools for exploring future scenarios of water availability, and related variables, developed with partners, and advice to relevant users (e.g. EA, DEFRA, DFID) through partnership working.

It is anticipated that there will be a number of funding rounds, which would award the majority of the programme's science budget on consortium grants, research grants and studentships (excluding NERC Fellowships) in addition to programme-wide costs, such as science coordination, science meetings and data management, which will be included in the overall programme budget.

The programme will welcome and actively encourage interdisciplinary consortia and cross-theme grants that will enable science to be delivered across themes and scales. New consortia, particularly those involving younger scientists will be encouraged.

3.2 Governance Requirements

The NERC Theme Leaders have had a key role in bringing this action forward and will continue to keep an overview of the related science and research areas but will have a more general advisory role within the ongoing programme. The direction, science implementation planning and management will be taken on by the various programme boards and groups.

Programme Executive Board (PEB):

This Research Programme will be managed by NERC Swindon Office, through a Programme Executive Board and the Programme Executive Board will appoint a Programme Manager and Knowledge Exchange Facilitator.

The Programme must adhere to the principles of the NERC Governing and Managing Investments Policy and to adopt appropriate practices.

www.nerc.ac.uk/about/delivery/processes/investments.asp

Terms of Reference for the PEB will include the following clauses:

- set up and manage input from any Advisory Body that the Programme Executive Board consider necessary;
- agree on the Science and Implementation Plan based on programme specification or proposal and TAP and ensure their execution.;
- advise on and foster the development of international collaborative activities;
- advise on and foster the development of user engagement;
- allocate resources including financial, e.g. profiling of funds within the programme budget, and awards for research and procurement for services;
- monitor the progress, and evaluate the results of individual projects and of the programme as a whole.

The PEB will be supported and advised by the Programme Advisory Group and Moderating Panels:

Programme Advisory Group (PAG):

Membership to be agreed, but it will include representatives of any co-funders and user groups. The PAG will be appointed via an open call for (self-)nominations with representation including but not limited to the following groups: the UK and international academic community (covering all programme's remit), relevant government departments and development agencies, NERC research and collaborative centres, UK and international water industry, Water aid charities, independent consultants.

The final decision for the composition of the advisory group lies with the PEB.

A writing group will be appointed following the Launch Event via the above call for nominations and meet initially on 25/26th March 2009. The writing group will evolve into the full PAG which can be added to throughout the duration of the programme. Terms of Reference for the PAG will include the following clauses:

- Advise on setting out of programme objectives in the Science and Implementation Plan and how to ensure their execution;
- Advise on the strategic direction of the programme, including specification of the scientific content of published announcements of opportunity;

- Advise on the development of international collaborative activities including emerging and future opportunities;
- Advise on the development of user engagement;
- Report as required to the PEB

Moderating Panels:

Membership will be agreed for each funding round as required composed of appropriate academic representatives (potentially including international), but it can include a representative of co-funders, the programme advisory group chair, programme executive board members and at least one member of the NERC Peer Review College. The moderating panel will advise the PEB on funding recommendations but final jurisdiction and decision always lies with the PEB.

3.2 Other Requirements

It is anticipated that research grants will (where appropriate) have Terms and Conditions that include milestones and deliverables to ensure that the Research Programme effectively delivers its research outputs and meets the requirements of stakeholders. The programme will employ a Knowledge Exchange facilitator to integrate stakeholder needs and build effective partnerships from the start of the programme although individually funded projects will be required to incorporate Knowledge Exchange activities and demonstrate the wider (economic) impacts of the work. Programme Knowledge Exchange activities will be developed and implemented via a dedicated and approved Knowledge Exchange Plan to provide effective advice to policy makers on the potential magnitude and timescale of risks and to allow for development of appropriate mitigation and adaptation strategies.

The Programme will build on and complement activities within NERC Research and Collaborative Centres e.g. CEH, BGS, NCAS.

The Research Programme will explore opportunities for international partnerships for example including links to and/or collaboration with the Global Water System Project (across WCRP, IGBP, IHDP, DIVERSITAS), Capability for Drought Prediction and Early Warning (US), NSF WATERS NETWORK (US), International Association of Hydrological Sciences programme on Prediction in Ungauged Basins (PUB), UNESCO – HELP (Hydrology Environment and Life Programme) and others.

In addition to the above, the Programme will:

- support activities that contribute to the RCUK Science in Society Strategy;
- comply with NERC policy on data management and access;
- develop and implement an approved Data Management Plan;
- take account of all IP issues;
- hold a public end of programme event;
- comply with standard NERC reporting requirements, including:
 - quarterly progress reports against the schedule for deliverables
 - NERC Output and Performance Measures (OPMs) and Final Report for the programme grants and awards
 - programme Annual Reports
 - other performance management information as required by NERC, and any co-funders.