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Environmental Protection Agency
An Ghníomhaireacht um Chaomhnú Comhshaoil

Environmental Research Centre
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Current Status and Required Actions for National Climate Observing Systems

STRIVE

Environmental Protection Agency Programme

2007-2013

Met Éireann

Marine Institute
Foras na Mara

SSTI
Strategy for Science, Technology and Innovation

Comhshaol, Oidhreacht agus Rialtas Áitiúil
Environment, Heritage and Local Government

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Current Status and Required Actions for National Climate Observing Systems

Environmental Research Centre Report

Prepared for the Environmental Protection Agency

by

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Executive Summary

1 Introduction

This report identifies the strategic directions and sets out a 31-point action plan for Ireland for the establishment, maintenance and further development of an integrated national climate observing system. It is based on the outcomes of extensive consultation with Ireland's climate observation and research community. Furthermore, it documents the current observing capabilities in the atmospheric, oceanic, terrestrial and hydrological domains; it identifies critical gaps and it provides proposals on how to address these. It also highlights a number of institutional barriers and management issues and underlines shortcomings in data accessibility. Steps to address these are identified and resources and costs are provided in a prioritised action plan. Implementation of these recommendations will require a minimum capital investment of €3.8 million, with an estimated ongoing annual requirement of €1.1 million.

As part of the National Climate Change Strategy (2007)[1] the government expressed its commitment to ensuring "*that Ireland has an adequate and modern capability for climate observations*". Moreover, Met Éireann is identified as having a key role to play in the further development and enhancement of observation systems together with other State agencies, in particular the Marine Institute (MI) and the Environmental Protection Agency (EPA).

To date in Ireland only a limited number of studies have been carried out to estimate the costs to the economy of climate change. Efforts need to be made in this direction using the best possible scientific information to help reduce the large uncertainties in the potential cost to the national economy. Climate observations contribute to improving the information on how climate change will affect the country, help reduce the uncertainty about potential impacts and help in determining where best to focus resources for adaptation.

The development of appropriate climate observation and analysis systems is an essential part of the national response to climate change. Furthermore, these need to be linked to European and global networks. The overall aims of such systems are to: provide information for the assessment of environmental change, inform adaptation planning and improve risk analysis, and so provide a key information base for policy development.

Parties to the United Nations Framework Convention on Climate Change (UNFCCC) have agreed to develop the Global Climate Observation System (GCOS), which encompasses atmospheric, oceanic and terrestrial domains. A review of climate monitoring in Ireland, in accordance with the GCOS requirements, which was supported by the EPA, Met Éireann and the MI, has recently been published by the EPA[2]. However, the requirements identified at a global level do not address specific national requirements. Therefore, this work has been carried out to review the status of systematic observations in Ireland and their adequacy in relation to national requirements for responding to climate change.

This work provides a benchmark for the current status and requirements for climate observation systems in Ireland and will be reviewed annually with the first review taking place in January 2010.

2 Gaps in Ireland's Climate Observing Network

As things stand a range of climate-related observations are made for reasons other than climate monitoring. These include observations for operational requirements in weather forecasting and water

1. DoEHLG (Department of the Environment, Heritage and Local Government), 2007. *National Climate Strategy 2007–2012*. PRN:A7/0397, Custom House, Dublin, Ireland.

2. Dwyer, N., 2008, *Climate Change – Implementation of the Global Climate Observing System in Ireland*. Environmental Research Centre Report 8, Environmental Protection Agency, Johnstown Castle Estate, Wexford, Ireland. http://www.epa.ie/downloads/pubs/research/climate/name,24240,en.html

management; others have been initiated through short-term project activities.

The main issues that need to be addressed in order to upgrade Ireland's climate observing system in each of the thematic domains are shown in Table 1. It is important that the existing elements of the climate observation network are maintained and consolidated in addition to addressing key gaps. Additional resources will need to be allocated in order to initiate additional, and sustain existing, long-term observational programmes.

As noted in the National Climate Change Strategy (2007)[1], those organisations with responsibility for monitoring and measurement of the atmosphere, oceans, hydrology, soils and land use will need to work together to address the gaps that have been identified in the observation network and implement the required actions. These include but are not limited to Met Éireann, MI, the EPA, the Office of Public Works (OPW) and Teagasc.

Table 1. Gaps and issues to be addressed in order to upgrade Ireland's climate observing system.

Atmosphere

- Impact of move to automatic weather stations
- Effect of urban and related development on integrity of weather stations
- Planning controls and the establishment of new observation sites
- Need to review synoptic, climatological and rainfall network adequacy
- Requirements analysis for an enhanced evaporation and evapotranspiration network
- Implement recommendations of Global Atmosphere Watch (GAW) review[1]

Oceans

- Maintain long-term coastal sea-surface temperature observation sites at Malin Head and Castletownsend
- Sustain a long-term Argo float programme beyond 2010
- Ensure long-term Global Sea Level Observing System (GLOSS)-compatible sea-level measurements at two locations
- Review *in-situ* observation systems for climate monitoring adequacy
- Make use of remotely sensed data

Hydrology

- Determine a network of natural-flow and water-level stations on rivers and lakes for long-term climate monitoring purposes
- Select groundwater monitoring sites for long-term climate monitoring purposes
- Identify sites for the measurement of soil moisture as part of a long-term monitoring plan

Terrestrial

- Co-ordinate and consolidate land-cover mapping activities
- Establish a land-cover assessment capability
- Identify national reference sites for bogs
- Enhance forest ecosystem monitoring
- Set up long-term ground-truth sites for use in the calibration and validation of remotely sensed data
- Complete national soils map to underpin climate-related measurements in the terrestrial and hydrological domains

[1]Barrie, L. and Puckett, K., 2006. *Review of Global Atmospheric Watch Sites at Valentia and Mace Head, Ireland*. Environmental Research Centre Report 3, Environmental Protection Agency, Johnstown Castle Estate, Wexford, Ireland. http://www.epa.ie/downloads/pubs/research/air/name,12137,en.html

3 Strategic Directions

There is a need for a strategic and co-ordinated approach to respond to the specific issues raised above and also cross-cutting issues that concern climate monitoring in general. The main concerns that need to be addressed are listed below:

1. **Inclusion of climate monitoring in institutional mandates and budgets**: Statutory responsibility for data collection and management must be vested in the institutions best placed to carry them out.

2. **Network optimisation for climate monitoring:** It is vital that existing monitoring sites are optimised and protected for long-term climate monitoring purposes and that additional sites and programmes are established where necessary.

3. **Long-term data management:** Organisations that collect climate data need to ensure that data storage and management systems are appropriate for the long term.

4. **Data access policy**: The various climate data collection agencies need to put a consistent and coherent data access policy in place for all climate-relevant data.

5. **Facilitation of data access and exchange**: To improve data visibility and accessibility, a dedicated web-based climate data portal should be developed in order to facilitate access to comprehensive metadata and data sets in a harmonised way.

6. **Delivery of regular and relevant information**: The regular analysis and reporting of status, trends and projections for climate data are as important as the systematic collection and management of such data. Part of this reporting needs to be tailored to the needs of policy and decision makers in order to increase its effectiveness.

7. **Inter-institutional and national co-ordination:** As a number of organisations are involved in climate observation data collection, there should be co-ordination between them in order to avoid duplication and to maximise possibilities for synergy. An advisory committee should be set up to steer national climate observation requirements.

8. **Utilisation of remotely sensed products**: A number of barriers including lack of capacity, expertise, data costs and knowledge of data availability have all restricted the use of Earth Observation data and products. The development of expert thematic centres could help alleviate these problems.

9. **Meeting GCOS requirements:** National co-ordinators and institutions involved in climate data collection should ensure that all relevant actions are fully implemented by the end of the period covered by the GCOS Implementation Plan in 2013.

4 Action Plans

Tables 2–6 list the actions that need to be taken in order to ensure that a comprehensive, reliable and sufficient national climate observation system is put in place for Ireland. The actions are given for each thematic area as well as cross-cutting areas.

For each of the 31 actions:

- There is a link to the related overriding strategic area
- A lead agency is identified
- The resources required to implement it are listed
- Related costs are shown
- Priority is allocated, and
- An estimated start date is given.

Table 2. Atmospheric action plan.

Action	Observation	Strategic area	Tasks	Lead agencies	Priority	Resources	Capital cost	Recurrent cost	Preferred start
A1	Evaporation/ Evapotranspiration	Network optimisation	The existing evaporation and evapotranspiration network needs to be maintained, including the Class A pan network and the lysimeters located at Valentia Observatory and Johnstown Castle. Evapotranspiration measurements at Valentia Observatory are secure for the foreseeable future; however, those at Johnstown Castle cannot be guaranteed. Therefore the needs analysis mentioned below needs to be carried out as soon as possible.	Met Éireann, Teagasc	1	Existing and additional resources to facilitate weekend observations at Johnstown Castle		€20,000 pa	2009 – Q1
A2	Evaporation/ Evapotranspiration	Network optimisation	Carry out a comprehensive needs analysis for an enhanced evaporation and evapotranspiration network, which addresses the number and location of sites, the level of automation, the modelling/measurement mix, site responsibility, costs and overall co-ordination.	EPA	1	Consultancy	€7,000		2009 – Q1
A3	Meteorological observations	Network optimisation	A review group with international representation should assess the adequacy of the synoptic, climatic and precipitation network and recommend any changes required to meet current and future climate observation needs.	Met Éireann	1	Consultancy	€20,000		2009 – Q1
A4	Physical/Chemical observations: aerosols	Network optimisation	The World Meteorological Organisation's GAW report[1] needs to be implemented in full. In particular, sustainable, long-term operational support needs to be provided to Mace Head Observatory for aerosol analysis. Extra support needs to be provided to Met Éireann's chemical analytical laboratory to permit sustainable, long-term analysis of samples from the existing seven GAW and EMEP sites.	Met Éireann, NUI Galway, EPA	1	*Mace Head:* Instrument Scientist Data Systems and QC Scientist Equipment maintenance *Met Éireann:* Data Analysis Scientist *Equipment:* Aerosol/Chemical mass instrumentation	 €400,000	 €80,000 pa €80,000 pa €40,000 pa €80,000 pa	2009 – Q1

Table 2 *contd*.

Action	Observation	Strategic area	Tasks	Lead agencies	Priority	Resources	Capital cost	Recurrent cost	Preferred start
A5	Physical/Chemical observations: clouds	Network optimisation	Equipment support and data analysis related to the recently installed cloud radar and radiometer at Mace Head.	NUI Galway	1	*Mace Head:* Instrument Scientist Equipment maintenance		 €80,000 pa €20,000 pa	2009
A6	Evaporation/ Evapotranspiration	Inclusion of climate monitoring in institutional mandates	An agency needs to be assigned responsibility to lead on activities regarding evaporation/evapotranspiration observations.		2				2009
A7	Data access	Facilitation of data access and exchange	Streamline access to atmospheric climate observation data (including gridded data) and metadata. Promote the development of an online portal for access to climate observation data and metadata from all domains.	Met Éireann	2	Scoping study required to determine resources and costs			2009
							€427,000	**€400,000**	

[1]Barrie, L. and Puckett, K., 2006. *Review of Global Atmospheric Watch Sites at Valentia and Mace Head, Ireland*. Environmental Research Centre Report 3, Environmental Protection Agency, Johnstown Castle Estate, Wexford, Ireland. http://www.epa.ie/downloads/pubs/research/air/name,12137,en.html

EMEP, European Monitoring and Evaluation Programme; EPA, Environmental Protection Agency; GAW, Global Atmosphere Watch.

Table 3. Oceanic action plan.

Action	Observation	Strategic area	Tasks	Lead agencies	Priority	Resources	Capital cost	Recurrent cost	Preferred start
O1	Institutional mandate	Inclusion of climate monitoring in institutional mandates and budgets	The Marine Institute could be given a statutory role in undertaking and co-ordinating oceanic data collection for climate monitoring purposes. Appropriate resourcing should be put in place to allow it to fulfil this role.	DAFF/Marine Institute	1	Existing		Current budget	2009 – Q1
O2	Sea level	Network optimisation	The sea-level monitoring sites at Malin Head and Castletownsend should be brought up to GLOSS standard for long-term climate monitoring purposes. Ensure that these sites are maintained and resourced into the future.	Marine Institute	1	Network capital Network maintenance	€100,000	 €70,000 pa	2009
O3	Sea-surface temperature	Network optimisation	A minimum of two coastal (Malin Head and Castletownsend) and five offshore data buoy measurement sites need to be designated for climate monitoring purposes. Long-term maintenance and resourcing of these sites needs to be ensured.	Marine Institute	1	Existing		Current budget	2009
O4	Salinity	Network optimisation	Review the adequacy of current and planned *in-situ* salinity measurements and recommend if additional observational capacity is required.	Marine Institute	2	Existing		Current budget	2009
O5	Subsurface temperature, salinity, currents	Network optimisation	Ensure adequate funding and resourcing beyond 2010 for the deployment of a minimum of four Argo floats per year.	Marine Institute	2	Equipment and deployment		€60,000 pa	2009
O6	Inshore buoys for sea temperature, salinity, sea state and surface meteorological conditions	Network optimisation	Ensure that a minimum of three inshore buoys are deployed and can be adequately resourced into the future.	Marine Institute	2	Buoy and equipment per site Maintenance per site	€200,000 each	 €130,000 pa per site	2009

Table 3 *contd*.

Action	Observation	Strategic area	Tasks	Lead agencies	Priority	Resources	Capital cost	Recurrent cost	Preferred start
O7	Plankton	Network optimisation	The CPR programme should be extended to fill gaps in Irish near-shore waters. The utility of satellite ocean colour data for retrieving information on plankton should be explored.	Marine Institute	2	Equipment and deployment, personnel costs and analysis		€100,000 pa	2009
O8	Data access	Data access	Streamline access to oceanic climate observation data and metadata *via* the Marine Institute's web mapping services and marine data online facility. Promote the development of an online portal for access to all climate observation data and metadata.	Marine Institute	2	Existing		€30,000 pa	2009
							€700,000	**€650,000**	

CPR, continuous plankton recorder; DAFF, Department of Agriculture, Fisheries and Food; GLOSS, Global Sea Level Observing System.

Table 4. Hydrological action plan.

Action	Observation	Strategic area	Tasks	Lead agencies	Priority	Resources	Capital cost	Recurrent cost	Preferred start
H1	River flows	Network optimisation	A number of high-quality hydrometric stations (with good rating curves, non-impacted flows, different physical settings and, preferably, long records) will be chosen from the EPA/local authority and OPW networks where long-term monitoring for climate purposes can be undertaken.	EPA/OPW	1	Existing		Current Budget	2009 – Q1
H2	Lake levels	Network optimisation	Lake levels need to be monitored on up to five representative lakes where a natural flow regime exists and where water is not abstracted. A set of appropriate lakes and monitoring sites needs to be identified.	EPA	1	Existing		Current Budget	2009 – Q1
H3	Groundwater	Network optimisation	The EPA is currently creating a groundwater monitoring network at up to 150 sites which should be completed by 2009. The most appropriate long-term monitoring sites for climate change purposes are in the process of being identified.	EPA	1	Existing		Current Budget	2009 – Q1
H4	Soil moisture	Network optimisation	Identify sites for the measurement of soil moisture as part of a long-term monitoring plan. In some cases these may be co-located with evaporation/evapotranspiration measurement sites. This task should form part of the needs analysis presented in Table 2 in relation to evaporation/evapotranspiration measurements.	Teagasc	1	Existing			2009- Q1
H5	Abstraction	Network optimisation	Collection of data on water abstractions is in the process of being rationalised as part of the Water Framework Directive. Requirements for long-term climate monitoring purposes should be included in the determination of the measures to be adopted.	EPA	2	Existing		Current Budget	2009

EPA, Environmental Protection Agency; OPW, Office of Public Works.

Table 5. Terrestrial action plan.

Action	Observation	Strategic area	Tasks	Lead agencies	Priority	Resources	Capital cost	Recurrent cost	Preferred start
T1	Land cover	Network optimisation	A long-term central facility to co-ordinate activities related to land-cover mapping and related data analysis needs to be established. This facility also needs to determine standard land-cover classification schemes that take into account the needs of different sectors and users. The EPA, Teagasc and third-level research organisations will have a key role to play in the establishment of such a facility	EPA/Teagasc	1	Establishment and running costs of facility including employment of core staff	€1.8M over 5 years		2009 – Q1
T2	Land cover	Network optimisation	Carry out an assessment in order to select a number of key long-term reference or ground-truth sites primarily for use in the calibration and validation of remotely sensed data for land-cover mapping. All key habitats (e.g. grassland, wetlands, forest) need to be taken into account.	Teagasc/EPA	1	Study	€700,000 over 3 years		2009 – Q1
T3	Land cover	Network Optimisation	Assess the need to establish one or more national reference sites for peatlands to facilitate co-ordinated monitoring of this extensive Irish habitat.	NPWS/EPA	2	Existing		Current Budget	2009
T4	Data access	Facilitation of data access and exchange	Co-ordinate approach to provision of metadata and data products from the various relevant data collection and supply organisations in the terrestrial area. The central land facility may be able to assume this role.	EPA/Teagasc	2	Existing		Current Budget	2009
							€2,500,000		

EPA, Environmental Protection Agency; NPWS, National Parks and Wildlife Services.

Table 6. Cross-cutting action plan.

Action	Observation	Strategic area	Tasks	Lead agencies	Priority	Resources	Capital cost	Recurrent cost	Preferred start
C1	Monitoring site integrity	Network optimisation	Establish a clear and coherent policy to protect the integrity of long-term climate monitoring stations.	DoEHLG	1	Existing		Current Budget	2009 – Q1
C2	Data policy	Data access policy	Establish a consistent and coherent climate data access policy across all agencies collecting observational data that is in line with the requirements of the INSPIRE Directive.	DoEHLG	1	Existing		Current Budget	2009 – Q1
C3	Analyses and reporting	Delivery of regular and relevant information	Carry out analyses of climate observations and report on the status, trends and projections of climate as part of regular *State of the Irish Climate* reports. A report every 4/5 years would be appropriate, to alternate with the EPA *State of the Environment* report.	Met Éireann	1	Existing		Current Budget	2009 – Q1
C4	Data portal	Facilitation of data access and exchange	An online climate data portal should be established to facilitate access to all relevant observational metadata and data. This will require co-ordination between data supply organisations. Sufficient resources will need to be allocated for the long-term maintenance of such a facility.	EPA	2	Capital set-up and design cost 1 full-time staff member	€200,000	€100,000 pa	2009
C5	Co-ordination	Inter-institutional and national co-ordination	An advisory committee with members drawn from the key observation agencies and data user communities should be set up to steer and co-ordinate national climate observation requirements.	Met Éireann/ DoEHLG	2	Existing		Current Budget	2009
C6	Remote sensing	Utilisation of remotely sensed products	Establish a structure that (i) facilitates the use of remotely sensed derived information in analyses of climate variability, (ii) promotes and supports capacity building, and (iii) promotes active participation in relevant ESA, EUMETSAT, EU and other international activities in this area.	Enterprise Ireland	2	Existing		Current Budget	2009

Table 6 *contd.*

Action	Observation	Strategic area	Tasks	Lead agencies	Priority	Resources	Capital cost	Recurrent cost	Preferred start
C7	Remote sensing	Utilisation of remotely sensed products	A comprehensive inventory of relevant satellite data and derived products along with portal and access details should be compiled. Information on relevant research programmes should also be included.	EPA	2	Existing		Current Budget	2009
C8	UNFCCC reporting	Meeting GCOS requirements	Ensure that climate data collection, management and archiving activities are compatible with and in support of the GCOS Implementation Plan. All relevant data should be supplied to the appropriate world data centres in a timely manner.	DoEHLG	2	Existing		Current Budget	Ongoing
							€200,000	**€100,000**	

DoEHLG, Department of the Environment Heritage and Local Government; EPA, Environmental Protection Agency; ESA, European Space Agency; EU, European Union; EUMETSAT, European Organisation for the Exploitation of Meteorological Satellites; GCOS, Global Climate Observing System; INSPIRE, Infrastructure for Spatial Information in Europe; UNFCCC, United Nations Framework Convention on Climate Change.

1 Introduction

1.1 The Need for a National Climate Observing System Plan

1.1.1 International commitments

In 1992, Ireland was one of the over 180 signatories of the United Nations Framework Convention on Climate Change (UNFCCC). Systematic, high-quality observations of the atmosphere, oceans and terrestrial environments are required to improve understanding of climate characteristics and to assist in understanding the consequences of climate change. To support issues related to systematic observations, the Global Climate Observing System (GCOS) Secretariat was established within the World Meteorological Organisation (WMO) in 1992 to ensure that the observations and information needed to address climate-related issues are obtained and made available to all potential users.

Given limited progress throughout the 1990s in the establishment of adequate observing systems globally, the UNFCCC charged GCOS to deliver a 10-year implementation plan to address the gaps. This plan became available in October 2004 and presents over 130 separate actions to be taken by the parties to the Convention. It also identified a minimum set of essential climate variables (ECVs) for the atmosphere, ocean and terrestrial environments that require systematic observation.

In 2008, the Environmental Protection Agency (EPA) published a review of Ireland's progress in implementing the plan (Dwyer, 2008). It concluded that the country is partly fulfilling its climate observation commitments in regard to the UNFCCC. However, there are a number of areas in which additional funding and resources are required to augment existing programmes or to put in place new monitoring programmes in order to meet the GCOS requirements fully.

1.1.2 National policy

The first climate change strategy document for Ireland was published in 2000. This set out targets for the reduction of greenhouse gases (GHGs) with respect to Kyoto commitments and also outlined the measures and policy options that could be used to achieve the targets in different sectors of the economy.

A review of progress was published in 2002 and in April 2007 a strategy for the period 2007–2012 was published (DoEHLG, 2007). This new strategy looks at what additional measures are required in the period in order to meet Kyoto requirements. In summary, 80% of the requirements will be met by domestic measures while the remaining 20% will be met by the government investing in emission-reduction projects in developing countries.

The 2007 strategy document also addresses the role of climate observations. It states that there is a commitment "*to ensure that Ireland has an adequate and modern capability for climate observations*". Moreover, Met Éireann is identified as having a key role to play in the further development and enhancement of observation systems together with other State agencies, in particular the Marine Institute and the EPA.

1.1.3 The need for a specific national plan

International climate monitoring requirements as specified in the GCOS plan provide a global framework for development of national observations in support of analysis of signals of climate change. However, such global systems do not capture adequately the full observational needs for smaller countries and local areas. There is a need to review Ireland's existing observational infrastructure, data accessibility and analysis capacity. This will help to identify the status of existing observation systems, highlight shortcomings and ascertain where gaps exist. Based on this analysis, a set of recommendations can be made and an action plan put in place to address the needs for the collection and provision of the data and information that are required to improve understanding of climate change and its effects on Ireland.

1.1.4 The economic case for climate monitoring

There are huge uncertainties as to the cost implications of climate change for the national economy. According to the Stern report (2007), the costs and risks are the equivalent of between 5% and 20% of global gross domestic product (GDP) *per annum*, whereas mitigation efforts can be limited to around 1% of global GDP *per annum*. To date, in Ireland, only a limited number of studies have been carried out to estimate the costs to the economy of climate change. Efforts need to be made in this direction using the best possible scientific information to help reduce the large uncertainties in the potential cost to the national economy. Climate observations contribute to improving the information on how climate change will affect the country, help reduce the uncertainty about potential impacts and help in determining where best to focus resources for adaptation. Any information that aids mitigation efforts and appropriate adaptation planning can improve cost-effectiveness and potentially avoid some of the more catastrophic effects of climate change and hence major costs to the economy. The investments needed to enhance and maintain an appropriate climate monitoring system for the country need to be considered in the light of such potential impacts.

1.1.5 Participants in the planning process

Under the Climate Change Strategy (DoEHLG, 2007), Met Éireann has been charged with leading the development of further observation systems and is expected to work together with other State agencies including the Marine Institute and the EPA.

A number of additional interested parties have been consulted in order to provide input for this national plan. A 1-day workshop held on 28 May 2008 saw 35 participants from a wide range of organisations (Appendix 1) contribute to the formulation of this plan. Moreover, draft versions have been circulated for comment to a number of bodies; therefore this plan represents the views of all those involved in climate observations.

Climate scientists and end-users of data for climate studies at the national and local levels have also been consulted in order to understand their specific needs, not only in terms of historical and current observations, but also in terms of data access and requirements for analysis and modelling.

The Department of the Environment, Heritage and Local Government, which has responsibility for overseeing the implementation of the Climate Change Strategy, has a key role in the planning process

1.2 The Irish GCOS Planning Process

1.2.1 Interactions with GCOS

As a signatory to the UNFCCC, Ireland is obliged to provide national communications at regular intervals detailing what measures are being taken to implement the Convention. These are compiled and submitted by the Department of the Environment, Heritage and Local Government and may be accessed on the UNFCCC website (http://unfccc.int/national_reports/annex_i_natcom/submitted_natcom/items/3625.php). One chapter in these reports is dedicated to research and systematic observations, where observation systems contributing to GCOS are outlined.

As a response to the GCOS Implementation Plan (GIP), the EPA set up an advisory committee comprising members from the EPA, the Marine Institute and Met Éireann to oversee the compilation of a report in response to the plan. This document evaluates Ireland's position in relation to the GIP and provides recommendations on further steps considered necessary in order to complete fulfilment of the plan. Input and comments on the plan also came from experts in climate observations in a number of third-level institutions, while an external review was carried out by the Royal Dutch Meteorological Institute.

Implementation of those recommendations will be undertaken in light of that report, the National Climate Change Strategy 2007 and this national requirements document in order to achieve coherence and synergy between the different elements in the process.

1.2.2 Organisations participating in GCOS activities

Met Éireann is the key national agency charged with climate observation systems and their development. Moreover, it holds long historical records of climate observations. These are being digitised and their access is being facilitated. Other agencies that

manage climate observation systems and provide information to GCOS include the EPA, the Marine Institute and the National University of Ireland (NUI) Galway, *via* its management and operation of the Mace Head Global Atmospheric Watch (GAW) facility.

2 The Rationale for Climate Monitoring

2.1 Reasons for Climate Monitoring

Systematic, high-quality observations for the atmospheric, oceanic and terrestrial environments are required to improve understanding of climate characteristics and assist in understanding the consequences of climate change. The reasons for making climate observations as set out in the GCOS Second Adequacy Report (2003) are to:

- Characterise the state of the global climate system and its variability
- Monitor the forcing of the climate system, including both natural and anthropogenic contributions
- Support the attribution of the causes of climate change
- Support the prediction of global climate change
- Project global climate change information down to regional and national scales, and
- Characterise extreme events important in impact assessment and adaptation, and to assess risk and vulnerability.

From a national perspective these goals can be applied at regional and local levels. Data observations should therefore help with the understanding, management, adaptation to and mitigation of climate change.

2.2 Key Aspects of the System to be Monitored

It is imperative that sufficient information is gathered in order to help build a comprehensive understanding of the climate system. Observations therefore need to be collected in the three main domains affecting the climate system, namely the atmospheric, oceanic and terrestrial environments. Within each of these domains a further refinement can be specified:

- **Atmospheric:** surface, upper-air and composition variables
- **Oceanic:** surface and subsurface variables, including sea ice
- **Terrestrial:** hydrological cycle and land-cover variables.

The GIP lists a number of "*essential climate variables*" that need to be monitored in order to achieve a comprehensive understanding of the climate system. This list is provided in Table 2.1. Not all of these are applicable to Ireland. However, they provide a good basis on which to build a national observation system.

2.3 Minimum General Requirements for Monitoring

There are a number of general requirements that must be considered a minimum in order to collect quality climate data:

1. Within each environmental domain it is important that all significant variables regarding the climate system are observed.
2. The measurement networks must be sufficiently dense both spatially and temporally to capture the key scales of variability in the system.
3. Climate data measurements must be stable and accurate. Stability is the measure of repeatability and reproducibility of the meteorological characteristic of an instrument with time. High accuracy of a measurement is needed to understand climate processes and changes (Tett *et al*., 2006).
4. Observations must be of a long-term nature. Appropriate resources need to be put in place to support observations over long timescales.
5. Collected data need to be archived and managed according to the best international standards.
6. Data should be easy to find and made readily available to users for analysis.

Table 2.1. The Global Climate Observing System essential climate variables.

Domain	Essential climate variables
Atmospheric (over land, sea and ice)	**Surface:** Air temperature, Precipitation, Air pressure, Surface radiation budget, Wind speed and direction, Water vapour **Upper-air:** Earth radiation budget (including solar irradiance), Upper-air temperature (including Microwave Sounding Unit (MSU) radiances), Wind speed and direction, Water vapour, Cloud properties **Composition:** Carbon dioxide, Methane, Ozone, Other long-lived greenhouse gases[1], Aerosol properties
Oceanic	**Surface:** Sea-surface temperature, Sea-surface salinity, Sea level, Sea state, Sea ice, Current, Ocean colour (for biological activity), Carbon dioxide partial pressure **Subsurface:** Temperature, Salinity, Current, Nutrients, Carbon, Ocean tracers, Phytoplankton
Terrestrial	River discharge, Water use, Ground water, Lake levels, Snow cover, Glaciers and ice caps, Permafrost and seasonally frozen ground, Albedo, Land cover (including vegetation type), Fraction of absorbed photosynthetically active radiation (fAPAR), Leaf area index (LAI), Biomass, Fire disturbance

[1]Including nitrous oxide (N_2O), chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), sulphur hexafluoride (SF_6) and perfluorocarbons (PFCs).

Furthermore, the GCOS principles for climate monitoring (Appendix 3) should be observed in the design and implementation of national observation systems.

2.4 Key Elements of a National Climate Monitoring Plan

There are a number of elements that must be addressed in the conception and development of a coherent plan:

1. Review the current climate monitoring systems and list the variables being observed and the observation mechanisms.

2. Determine if there are significant shortcomings or gaps in terms of (a) improving the collection of current variables, and (b) additional variables that should be collected.

3. Determine the role, if any, of satellites in providing climate information.

4. Outline requirements for any enhancements of national climate data collection systems and prioritise them.

5. Review the current data archiving, management and distribution systems and outline any modifications/enhancements required.

6. Review current institutional arrangements, roles and responsibilities and highlight those areas where adaptation or reorganisation is required.

7. Outline requirements for the resources necessary for existing and new systems and timescales for implementation.

2.5 Relationship to International Requirements

As a signatory of the UNFCCC, Ireland is committed to implementing the GCOS climate monitoring plan. However, this plan has been conceived from a global perspective and does not reflect the entire climate monitoring requirements of a small island nation. In essence, the requirements are a subset of what is needed at a national level. Nevertheless, Ireland's participation in the GCOS, the Global Ocean Observing System (GOOS), the Global Terrestrial Observing System (GTOS), the GAW, etc., is invaluable as it allows participation in international projects. This provides access to overseas expertise in the field, enhances collaboration and sharing of resources and allows the transfer and adoption of international methods and standards in climate monitoring.

The Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR)

requires that signatories make a range of oceanic environmental and atmospheric observations. Nutrients and phytoplankton are two of the aspects to be monitored. The potential for synergistic use of measurement platforms and sites for these and other observations required for climate monitoring should be explored.

In the hydrological sphere, the EU's Water Framework Directive (WFD) requires a range of observations to be made including river flow and lake levels. Taking advantage of such requirements can allow fulfilment of climate observation needs with minimum additional resource allocation.

3 The Current Status of Irish Climate Monitoring Networks and Programmes

This section reviews the current status of Irish *in-situ* networks (e.g. spatial extent, gaps, automation, partners) with respect to all climate variables that are or should be monitored. It also presents the plans of the key monitoring agencies with respect to future observations, examines the contribution of remote sensing and identifies issues related to historical information and data accessibility.

3.1 Atmosphere

3.1.1 Surface networks

The surface network operated by Met Éireann (Fig. 3.1) takes measurements of the standard meteorological variables, namely temperature, rainfall, surface pressure, humidity, sunshine, wind speed and direction. The following description of the surface network has been extracted from Ireland's response to

Figure 3.1. Location of hourly reporting synoptic and automatic (Tucson) stations in Ireland (source: Met Éireann).

the invitation of the Subsidiary Body for Scientific and Technological Advice (SBSTA) to submit additional information regarding the implementation of the GCOS plan (DoEHLG, 2008):

"*Ireland has three main groupings of meteorological observing stations:*

- *25 Synoptic or real-time automatic weather stations (AWS)*
- *67 Climate stations*
- *537 Rainfall stations including the Synoptic, AWS and Climate stations*

The synoptic and AWS stations operated by Met Éireann provide observations of the standard meteorological parameters at hourly or better time resolution. In the case of 14 stations, data is collected at one-minute resolution. This network consists of 8 fully manned stations, including 5 airports, one partially manned station with co-located AWS and 16 unmanned AWS.

All climate stations return daily values of Dry, Wet, Max and Min temperatures and rainfall. 17 of these also report daily sunshine. Twenty two report soil temperatures at 3 depths while 10 report some soil temperature data. Thirteen report earth temperatures at 3 depths while 8 report some earth temperature data. The daily readings are taken at 0900 UTC[1]. Readings are taken by private individuals, government bodies, local authorities, schools and colleges, etc.

A total of 509 stations report daily rainfall at 0900 UTC and 28 stations report monthly falls. Readings are provided by a variety of bodies and private individuals in the same way as for climate stations.

In addition, there are 34 daily and 3 weekly Dines Tilting Syphon Rain Recorders in operation at various locations. There are also 11 evaporation stations using Class A pan evaporimeters."

In addition to the evaporation stations, evapotranspiration is an important variable for the understanding of climate change. Lysimeter measurements of potential evapotranspiration are currently made at Johnstown Castle and Valentia Observatory, with monthly reporting of the daily readings. The Irish Hydrology Working Group recommends that the number of measurement sites be increased to eight in locations where readings can be continued indefinitely.

The synoptic weather stations at Valentia Observatory and Malin Head are part of the GCOS Surface Network (GSN) and have been submitting data to world data centres since October 1939 and May 1955, respectively. Additionally, stations at Cork Airport, Johnstown Castle, Shannon Airport, Dublin Airport, Connaught Airport and Belmullet are part of the WMO Region VI Regional Climate Basic Network (RCBN) and submit data to appropriate data centres

3.1.1.1 Future plans

Met Éireann is in the process of implementing a number of changes to the synoptic network. The human observer presence is being wound down and fully automatic weather stations (AWSs) are being deployed. In addition, the synoptic stations at Rosslare, Kilkenny, Clones and Birr are in the course of being abandoned. Nearby stations are taking over the synoptic role.

The station at Belmullet suffers from poor exposure. A new site is being sought in an area which is part of a Special Area of Conservation. Planning and acquisition of the land remains to be resolved.

At the Mullingar station there are fears that development may encroach on the site. This would compromise the ability of the station to provide reliable long-term measurements. Other weather stations may face similar problems in the future. There is a need to address this issue and draw up guidelines regarding development in the vicinity of weather stations.

With the removal of manual observations, variables such as visibility, cloud and weather type will still be available with the data coming from automated sensors. However, those requiring manual intervention such as sunshine and evaporation will not be available.

All 14 of the new generation AWS systems being installed measure global radiation and wind parameters. This is a significant increase on existing

1. UTC, Coordinated Universal Time.

capacity. Surface radiation is probably a more useful and more consistently measurable quantity than sunshine duration. Sunshine measurements will probably decrease unless/until a good automated sensor becomes available and is incorporated into automatic stations.

Met Éireann is committed to maintaining lysimeter measurements at Valentia Observatory. The measurements at Johnstown Castle are made on weekdays only and there are no plans to resume weekend readings. Clear evidence of ongoing use and the necessity for lysimeter measurements would help to guarantee the future of measurements at Johnstown Castle. In addition, automation of the measurements could help facilitate future weekend observations.

3.1.2 Upper air network

One station located at Valentia Observatory in Co. Kerry carries out a full range of upper air measurements using radiosondes. These are launched four times daily and measure pressure, temperature, humidity, wind speed and direction at a range of altitudes.

Solar radiation is also measured at Valentia Observatory, to WMO standards and data are submitted to the world radiation data centre in St Petersburg (http://www.mgo.rssi.ru/).

The Atmospheric Science Research group at NUI Galway participated in the European Framework Programme 5 (FP5)-funded Cloudnet project (2001–2005) (http://www.cloud-net.org/) which attempted to derive cloud profiles using remote sensing techniques. The group has recently installed a cloud radar and radiometer at Mace Head, funded by the EPA, which will help with cloud characterisation. However, it is vital that resources are put in place to support staff to operate and maintain the equipment and carry out data quality control and analysis.

Air and precipitation chemistry are monitored at seven sites. Both background and trans-boundary air pollution levels are measured.

3.1.3 Aerosols and greenhouse gases

Aerosol and GHG parameters are measured at two locations, namely Valentia Observatory, Co. Kerry, and Mace Head, Co. Galway (Fig. 3.2). Both stations are part of the GAW network and the data collected are submitted to the relevant world data centres. Valentia Observatory is managed by Met Éireann, while the Mace Head Observatory is managed by NUI Galway (http://macehead.nuigalway.ie/). In 2005, a WMO-appointed group carried out a thorough review of these two stations (Barrie and Puckett, 2006).

Continuous measurements of surface and total column ozone and weekly ozonesonde ascents are performed at Valentia Observatory. Following a recommendation from the 2005 GAW review, ozonesonde ascents were extended to a once weekly, all year round programme in 2007 as part of a 3-year Environmental Research Centre (ERC) research project. The potential to ensure that these are continued on a long-term basis should be explored. Spectral ultraviolet (UV) radiation, aerosol chemistry and bulk precipitation chemistry variables are also being collected. However, the GAW review noted that five core aerosol variables (aerosol optical depth (AOD), scattering, absorption, mass in two size ranges and chemistry in two size ranges) are not being measured at Valentia.

Other recommendations made by the review team were:

- "*the installation of automated sun-tracking sunphotometer AOD measurements, to complement those in place at Mace Head, and in addition, to extend chemical analyses of existing samples to describe levels of MSA*[2]*, using well-developed ion chromatographic techniques.*

- *It is suggested that the current "bulk" precipitation collector be replaced by a wet-only precipitation chemistry collector conforming to the recently released measurement guidelines in GAW Report No. 160.*"

Following on from these recommendations:

- Met Éireann commenced AOD measurements at Valentia in 2007.

- Analysis for MSA of samples from Valentia Observatory and Mace Head commenced at Met

2. MSA, methane sulphonic acid.

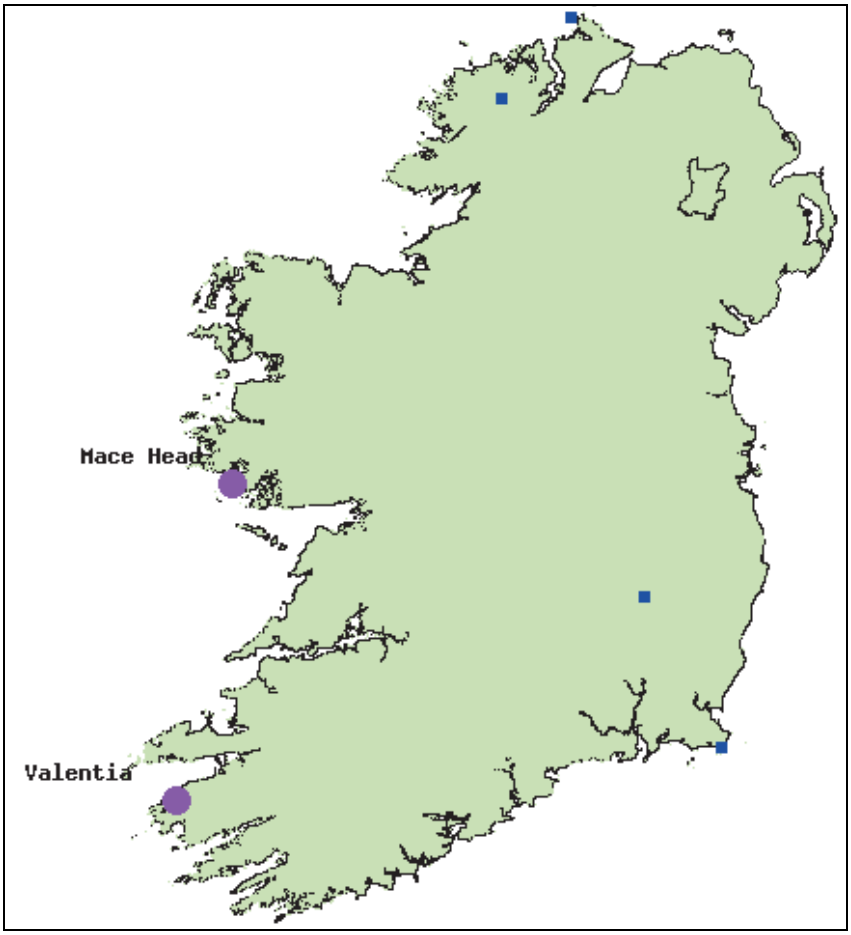

Figure 3.2. Location of the two Irish stations contributing to the Global Atmospheric Watch observatory (source: Barrie and Puckett, 2006).

Éireann's chemical analytical laboratory in January 2008.

- A wet-only precipitation collector was installed at Valentia Observatory in August 2008.
- Met Éireann's chemical analytical laboratory commenced routine chemical analysis of aerosol samples from Mace Head in 2007.

Mace Head station measures GHGs, aerosols, carbon monoxide, surface ozone and UV radiation. Currently, it does not measure the total column or vertical profile of ozone, the vertical profile of aerosols, or precipitation chemistry on a routine basis. Although it measures AOD, scattering and absorption, it is currently not measuring mass and chemistry variables. The GAW review therefore recommended that "*routine mass and aerosol chemistry in two size ranges are added to the surface measurement programme*". Regarding aerosol chemistry the review states: "*It is recommended that the EPA considers the initiation of a size-fractionated aerosol chemistry programme at Mace Head, possibly by upgrading the funding to Met Éireann's analytical laboratory and the sampling system*". Furthermore, regarding the lack of vertical aerosol measurements, it recommends that: "*vertical profiling alternatives for clouds and aerosols are considered and implemented at Mace Head. Possibilities include LIDAR*[3] *(several alternatives from simple micro-pulse to heavy-duty Raman aerosol systems) and routine light aircraft profiling*". The review group also expressed its concern about the lack of solid institutional support for the Mace Head facility and recommended that "*the EPA, Met Éireann and NUI, Galway develop a memorandum of understanding for the technical support and life-cycle*

3. LIDAR, light detection and ranging.

management of observational equipment and facilities at Mace Head".

For operational purposes Mace Head would need ongoing resources for the employment of two full-time scientists, one to oversee the equipment and the other to manage the data for both national and international requirements.

3.1.4 Use of remotely sensed information

Ground-based radar is used for rainfall measurements. There are two radar installations based at Dublin and Shannon airports. Images have been archived every 15 min since April 1997. Although they have a theoretical range of up to 240 km, their accuracy drops significantly above 100 km.

Ireland is a member of the European Organisation for the Exploitation of Satellites (EUMETSAT), which owns, controls and operates a number of meteorological satellites. It receives, processes and archives data and makes them available to interested parties such as Met Éireann, where they are routinely used in weather forecasting. For example, imagery and data from the Meteosat-8 satellite are collected with a frequency of up to 15 min for some products and the radar altimeters onboard the Jason satellite series provide data of use in marine meteorology, operational oceanography, seasonal prediction and climate monitoring. Furthermore, Met Éireann participates in the EUMETSAT co-ordinated Satellite Application Facility (SAF) for Climate Monitoring which generates and archives high-quality data sets on a continuous basis for the monitoring of climate state and variability.

The GIP identifies the role and status of various satellite sensors in contributing information for all the ECVs. In certain cases semi-operational systems are in place (e.g. scatterometers for wind speed and direction over oceans) while in others systems are still very much in the research domain (e.g. infrared sounders for GHGs).

NUI Galway has been involved in research to improve cloud property observations in three dimensions, using remote sensing instruments, *via* the FP5-funded Cloudnet project (http://www.cloud-net.org/). The recent allocation of funds to install a cloud radar and radiometer at Mace Head will aid further research in this area.

3.1.5 Historical records

Historical observations, as digitised hourly values, are available from Met Éireann for the Valentia Observatory and Malin Head GSN stations from October 1939 and May 1955, respectively. The data from all other stations and the upper air network are archived by Met Éireann. These data are quality controlled and kept under continuous scrutiny by the Climatology and Observations Division.

There are disparate sources on historical climate and extreme events in Ireland. However, no broad-scale survey of extreme events, climatic change, and the impacts thereof has been undertaken. A project currently under way at University College Cork (http://wiki.ucc.ie/extreme-weather/) seeks to combine knowledge from the direct observational record, the proxy record and the historical record.

3.1.6 Data integrity, archive and retrieval

Changes in observing site location, site exposure, local land use, instrumentation, observing methods, observing times and data processing methodologies can all compromise the integrity of long-term observations. Statistical methods are used to find inhomogeneities in the data, which can then be corrected. However, these need to be used carefully to avoid removing data points that show real climate events. The European-funded COST[4] action ES0601 (2007–2011) is currently looking to establish a co-ordinated approach to homogenisation methodologies.

Most of the data collected from the Met Éireann network since 1941 are archived in electronic databases. Much of the data prior to that date are in paper format only.

Met Éireann is committed to maximising availability of climate data to the research and other communities and providing it in a timely manner insofar as commercial and cost-recovery policy allows.

Meteorological data from Mace Head may be acquired free of charge. Micro-meteorological, gas, aerosol and

4. COST, Cooperation in the Field of Scientific and Technical Research.

aerosol property research data may be made available to external scientific investigators in certain cases and under certain conditions.

Much of Mace Head's hourly data are now available through the EU-funded CREATE project database located at the Norwegian Institute for Air Research (NILU) (http://www.nilu.no/projects/ccc/create). These data are also converted to a format for archiving at the World Data Centre for Aerosols (http://wdca.jrc.ec.europa.eu/).

3.2 Oceans

3.2.1 Surface variables

A number of ocean-surface variables are measured by the fixed weather buoy network. The first buoy was installed in 2000. Since then five more have been deployed. Figure 3.3 shows the current location of these buoys. The weather buoys return hourly information on:

- Wind speed and direction
- Atmospheric pressure and tendency
- Air temperature
- Relative humidity
- Sea-surface temperature
- Wave height and period.

New instrumentation is being installed on the buoys. M1 has the capacity to record sea-water conductivity and salinity from 1 m below the surface. It is planned to install similar instrumentation on the other buoys over the coming years. Near real-time measurement values can be accessed at http://www.marine.ie/home/publicationsdata/data/buoys.

The buoys are being upgraded and sea trials are taking place at present. A replacement programme will then be initiated subject to available resources.

It is planned to install coastal buoys over the coming years at a number of locations surrounding the coast subject to available funding. These buoys will support instrumentation to measure water conductivity and temperature, partial CO_2, current, waves, meteorological parameters and water quality.

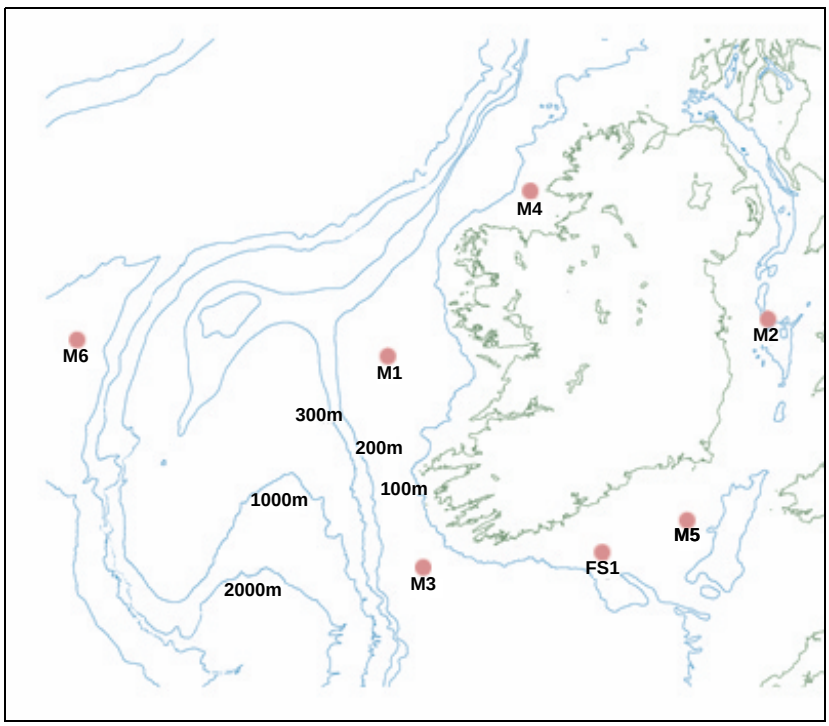

Figure 3.3. Location of the six fixed buoys and the one located at the Marathon Oil platform (FS1) (source: Marine Institute).

The following sections present the current status regarding measurement of some of the ECVs as identified in the GIP.

3.2.1.1 *Sea-surface temperature*

Sea-surface temperature measurements around Ireland are quite sparse (Boelens *et al.*, 2005). The longest measurement record is at Malin Head where observations have been made since 1957. Sea-surface temperature is also measured by the buoy network discussed above at a depth of approximately 1 m. The values are considered accurate to 0.005°C. These data can be accessed in near real time over the Internet. Historical values are archived by the Marine Institute.

3.2.1.2 *Sea-surface salinity*

Conductivity, and hence salinity, is currently recorded on M1, with recording devices planned for deployment on the other buoys.

Measurements of salinity are also made systematically at 10-s intervals by the two research vessels, namely the *RV Celtic Explorer* and *RV Celtic Voyager*. These vessels spend over 300 and 200 days at sea, respectively, each year. The collected salinity data are quality controlled, gridded and archived in monthly data files by the Marine Institute.

3.2.1.3 *Sea level*

Two stations in Ireland (Malin Head and Castletownsend) are part of the Global Sea Level Observing System (GLOSS) network. The Castletownsend site was established in December 2004 and has been part of the network since then. The Malin Head gauge has been operational since 1958. Work is ongoing to upgrade this station with an additional gauge and a Global Positioning System (GPS) in order to integrate it fully into the GLOSS network (Murphy and Westbrook, 2007). Data are submitted to the international data centre of the permanent service for sea level housed at the Proudman Oceanographic Laboratory (http://www.pol.ac.uk/psmsl/).

It is anticipated that high-frequency sea-level data from at least eight gauges will be delivered to the European Sea Level Service (ESEAS). ESEAS is an element of GLOSS. Information on current tidal heights can be accessed *via* the Irish National Tide Gauge Network which has 17 active nodes (http://www.marine.ie/home/services/operational/oceanography/TideGauge.htm) as of September 2008 (Fig. 3.4). It is planned that up to 40 nodes will be operational by 2010 (subject to funding).

Many port authorities record tidal levels for operational purposes. Some of these report the data to the Proudman Oceanographic Laboratory on an ongoing basis.

3.2.1.4 *Sea state and currents*

Sea-state parameters include wave height, direction, length, and period. Monitoring of such parameters on a long-term basis is required to help characterise storminess, the occurrence of extreme events and to aid in the quantification of impacts on coastal environments. Systematic measurements of wave period and wave height are made by the fixed-buoy network. In addition, wave direction is currently measured by one of the buoys (M1). It is hoped to recover directional wave data from all buoys by 2011.

There is currently no routine measurement of surface currents; however, the Marine Institute plans to retrieve full water column currents at three inshore buoy locations by 2009.

3.2.1.5 *Ocean colour*

Ocean colour is a measure of the quantity of chlorophyll, and hence phytoplankton, in the water. In certain cases overproduction of particular phytoplankton species can lead to the formation of harmful algal blooms, which can compromise the health of many ocean dwellers as well as having consequences for humans. Ocean colour measurements have been made by satellite for many years. Global data are archived by the international ocean-colour co-ordinating group (http://www.ioccg.org/), but no specific archive for Ireland currently exists. The Marine Institute initiated a programme of work in 2008 on the retrieval of ocean colour information from satellite data requested under the European Space Agency's (ESA's) Announcement of Opportunity (AO) specifically published for Irish research institutions in 2007.

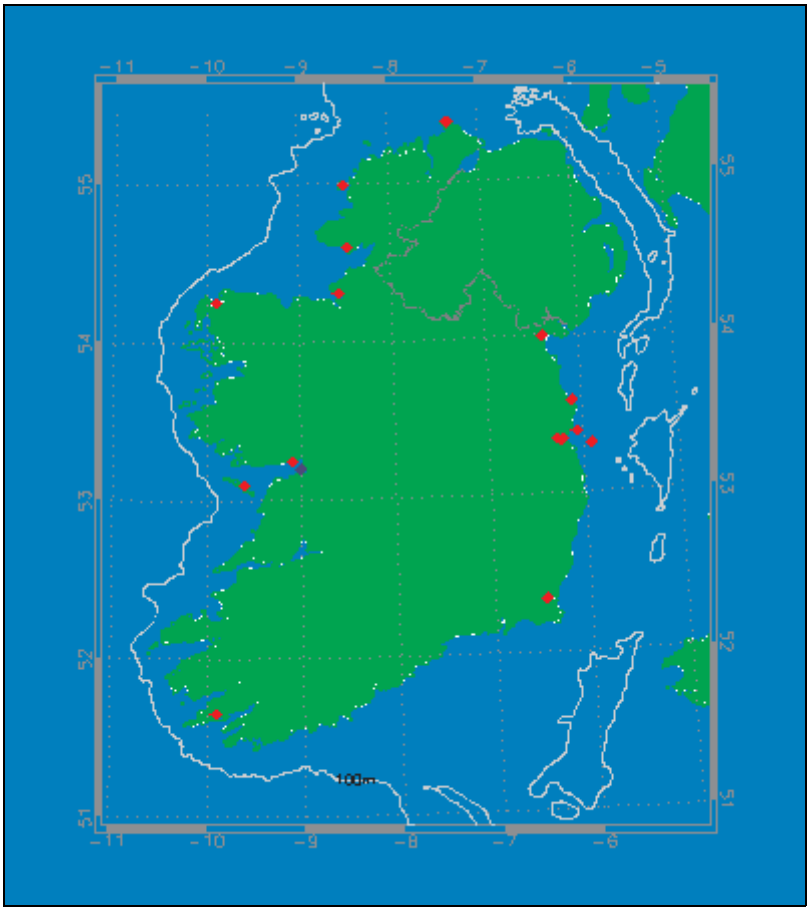

Figure 3.4. Location of gauges within the Irish National Tide Gauge Network as of September 2008 (source: Marine Institute).

3.2.1.6 CO_2 partial pressure

Ocean-surface carbon dioxide partial pressure (pCO_2) measurements help quantify CO_2 air–sea fluxes. Global measurement networks are still sparse and no specific programme for such measurements exists in Ireland. Research activities in this area are co-ordinated under the Surface Ocean Lower Atmosphere Study (SOLAS) group, with Irish activities being co-ordinated from NUI Galway. During 2007, NUI Galway deployed a pCO_2 device on the *RV Celtic Explorer* on a trial basis. There are plans to measure *p*CO2 from a buoy offshore of Mace Head (Co. Galway) in 2009. Discussions are ongoing regarding the use of pCO_2 sensors on the national meteorological buoys described above (dependent on future resource availability).

3.2.2 Subsurface variables

A number of subsurface variables are measured by the two national research vessels annually. Four Argo floats have been deployed (Fig. 3.5) and funding is in place to deploy an additional four each year until 2010. Argo floats typically measure conductivity (from which salinity can be derived), temperature and pressure. The latest ones being developed can measure fluorescence, dissolved oxygen and pCO_2. The following sections provide details on specific ECV measurements.

3.2.2.1 Temperature and salinity

These are measured on an annual basis in a number of transects by research vessels deploying conductivity, temperature, depth (CTD) meters. The data may be accessed *via* the Marine Institute's Marine Data Online Catalogue. The four Argo floats currently deployed measure temperature and salinity at depths up to 1,000 m. Instrumentation is being deployed on buoy M6 to make measurements of temperature and salinity at five depths.

Figure 3.5. An Argo float being readied for deployment (source: Marine Institute).

Temperature is measured at hourly intervals at 18 locations along the west coast at a range of depths using Tidbit data loggers.

3.2.2.2 Current

The currently deployed and planned Argo floats can provide information on subsurface currents by examination of the floats' drift trajectories.

3.2.2.3 Nutrients

Water samples are collected on an ongoing basis by the Marine Institute and analysed for nutrient content, specifically dissolved nitrate and nitrite, phosphate, silicate, and ammonium. Winter sampling has been carried out in the Irish Sea since 1991. In recent years, the measurements have been extended to cover more of the Celtic Sea and the western Irish Shelf.

3.2.2.4 Carbon and ocean tracers

Oceans act as important carbon sinks. The net amount of carbon that can be absorbed depends on biological as well as chemical activity. Other constituents such as oxygen and chlorofluorocarbons (CFCs) can affect carbon uptake, storage and transport. Globally these variables and their change with time are not adequately sampled (GCOS, 2003). A number of global and regional initiatives have been put in place to address this. The International Ocean Carbon Coordination Project (IOCCP) promotes the development of a global ocean carbon monitoring network. Within Europe, the Sixth Framework Programme CarbOcean integrated project is one initiative that aims to improve understanding of the role of oceans in the carbon cycle. The SOLAS group, in which Ireland participates, also carries out research of relevance to this area.

3.2.2.5 Phytoplankton

Ship-towed continuous plankton recorders (CPRs) have been used to measure phytoplankton in the North Atlantic since the 1940s. This monitoring is important to detect ecosystem changes to climate. Boelens *et al.* (2005) recommend that the CPR programme be extended to fill gaps in Irish near-shore waters.

As part of a pilot project, a CPR has been installed by the Marine Institute on a ship that makes a monthly journey between Ireland and Iceland. Moreover, the Marine Institute monitors phytoplankton under a national programme which has been in place since the 1980s. Samples are taken at a number of designated sites and the various species present are analysed. If any harmful species are detected these are reported via the Institute's website.

3.2.3 Use of remotely sensed data

Remote sensing is not used in an operational fashion in Ireland for the determination of any of the oceanic ECVs. However, satellite data from altimeter missions such as Jason (EUMETSAT) are used in the determination of sea level and in weather and climate forecasting by meteorological services. Remotely sensed data are also used on a project basis. As part of a collaboration between the Marine Institute and the National Oceanic and Atmospheric Administration (NOAA USA), remote sensing has been used to look at factors that influence fisheries recruitment and the forecasting of harmful algal blooms.

As mentioned above, a new programme to examine the potential use of satellite data for the retrieval of ocean colour information was initiated in 2008.

3.2.4 *Use of models*

Modelling can underpin basic oceanographic studies in a range of ways. One of the most useful is to use a model to look at a particular process in the ocean (e.g. transport pathways or upwelling) where *in-situ* observations are sparse. A well-validated model will allow researchers to extend the spatial coverage of their observations so that a larger area can be considered.

Models are often used to forecast sea state, currents, temperature and salinity. These outputs can also be used operationally to allow marine users to improve planning of ocean activities. For example as part of the INTERREG IIIA project PRISM (2000–2006), in which the Department of Communications, Marine and Natural Resources and NUI Galway were involved, models of conditions in the Irish sea were provided in near real time *via* a web GIS http://www.prism.ie/.

Quality observations are essential in modelling in order to set realistic forcing conditions and to validate model outputs.

3.2.5 *Historical records*

A range of measurements is made by research vessels operated by the Marine Institute. The data collected are quality controlled and archived in digital format and are publicly available. Due to occasional operational problems with computer equipment, fouling and sensor malfunction, there are some missing data from cruise tracks.

3.2.6 *Data archive and retrieval*

Near real-time access to data from the fixed-buoy network and tide gauges is possible. The availability of other data depends on the organisation collecting the data, processing concerns and policies regarding data release.

The Marine Institute is the key agency for the archiving of oceanographic data. Other agencies and research institutes collect data on a mainly project basis but the archiving, ongoing maintenance and ability to provide the data to third parties vary. The Marine Institute has an open data policy and provides its data as public information. The Marine Data online catalogue www.marinedataonline.ie allows the searching of the Marine Institute's data holdings, while a number of map viewers allow the browsing of oceanographic and other data sets https://www.marine.ie/home/publicationsdata/data/WebMapServices/. The Marine Institute intends to improve access to its climate data *via* a web-accessible server in 2009.

The Irish Spatial Data Exchange (http://www.isde.ie) provides access to data catalogues held by the Marine Institute, the Geological Survey of Ireland (GSI), the EPA and the Coastal and Marine Resources Centre (CMRC) of University College Cork. Some of the data holdings are of relevance to climate studies.

3.3 Terrestrial

Terrestrial measurements for climate change include those related to both hydrology and the land surface.

3.3.1 *Hydrological variables*

The EPA has a statutory role to prepare a national programme for the collection, analysis and publication of levels, volumes and flows in rivers, lakes and groundwater. This hydrometric network is maintained with the assistance of local authorities. The Office of Public Works (OPW) is the lead agency for flood risk management and flood relief in Ireland. Its Hydrometric Section provides hydrometric data and hydrological analysis for flood relief and arterial drainage services in the OPW. The data are also provided on request to a range of external sources. The OPW has recently completed a strategic review of the hydro-meteorological monitoring programme required for flood risk management.

3.3.1.1 *River discharge*

River discharge or flow is measured and data collected by a number of agencies including the EPA, the OPW, local authorities and the Electricity Supply Board (ESB). There are over 900 active river flow meter stations in the country. The locations of these measurement stations have not been chosen with climate change in mind but for a variety of operational reasons such as flood warning and control, drought warning, or electricity generation. A copy of the register of hydrometric stations can be found at

http://www.epa.ie/whatwedo/monitoring/water/hydrometrics/network/, while their locations may be viewed on the EPA's EnVision website (http://maps.epa.ie). A range of hydrometric data types is available, including water levels, flows and summary statistics, from over 200 locations on rivers and lakes on the EPA's Hydronet website (http://hydronet.epa.ie/). Information on flows at stations operated by the OPW may be accessed at http://www.opw.ie/hydro. The EPA is co-ordinating a selection process of flow measurement stations in a number of the hydrometric areas in order to determine an appropriate network for long-term climate monitoring purposes.

3.3.1.2 Lake level/area

Lake level is measured at 86 locations on lakes across the country. Again these levels are monitored for primarily operational reasons and the locations of the meters have not been chosen using climate change considerations. The EPA has started a process in order to identify the most appropriate lakes and measurement locations for long-term climate monitoring purposes. It is expected that up to five locations will be chosen.

The hydrometric gauges on lakes and rivers consist of a mix of digital data loggers and staff gauges. Staff gauges are maintained by local authorities on a needs basis. Should a local authority consider that there is no further need for a particular staff gauge, its use may be discontinued.

3.3.1.3 Groundwater

Under the WFD, there is an obligation to monitor groundwater quality and flows. The EPA co-ordinates this monitoring programme. The focus is on the monitoring of groundwater bodies that are considered 'at risk' from over-abstraction. 'Not at risk' areas are monitored with the objective of improving understanding of groundwater flows from areas of recharge to discharge. Review of the water monitoring network will be ongoing in order to meet WFD requirements. There is a plan to have 150 groundwater-level monitoring sites established by the end of 2009. A small number of these sites will be identified for long-term climate monitoring purposes.

The GSI also monitors groundwater levels, and long-term records are available for a number of wells in Counties Cork, Kerry, Kildare, Laois, Louth, Roscommon and Tipperary. Digital map information related to groundwater may be found at http://www.gsi.ie/Programmes/Groundwater/Groundwater+web+mapping.htm.

3.3.1.4 Soil moisture

Although soil moisture is not currently identified as an ECV by GCOS, there are indications that it will be adopted as one in the coming years. At the moment, there is no long-term systematic soil moisture monitoring programme in place in Ireland. It is often measured as part of small-scale research projects (e.g. Barrett *et al.*, 2007) or as an element in other initiatives. For example the mini-catchments programme being conducted by Teagasc and which runs until 2012, measures soil moisture as part of its investigation into water quality in a number of intensively farmed areas.

Soil moisture deficit information is provided by Met Éireann. This is calculated using a model which takes rainfall measurements and actual evapotranspiration into account.

3.3.1.5 Water use

Water finds a variety of uses in the agricultural, industrial, recreational and domestic sectors. Some of the key water-using sub-sectors within these areas, excluding domestic use, as identified in the report on the characterisation of Ireland's River Basin Districts (EPA, 2005) are shown in Table 3.1.

As one of the actions regarding implementation of the WFD, each River Basin District has collated information on abstractions in its district. The Eastern River Basin District completed preparation of a Programme of Measures relating to abstractions, which was published in the draft River Basin Plans in December 2008 (ERBD, 2008).

3.3.2 Land-cover variables

3.3.2.1 Land-cover maps

Land cover is mapped using satellite imagery on a regular basis as part of the European CORINE (Coordination of Information on the Environment) initiative, which is co-ordinated in Ireland by the EPA (http://www.epa.ie/whatwedo/assessment/land/).

Table 3.1. Key water-using sub-sectors.

Agricultural sub-sectors	Industrial sub-sectors	Miscellaneous sub-sectors
• Potatoes	• Mining and quarrying	• Forestry
• Cattle and cattle products	• Food product and beverage manufacturing	• Inland commercial fishing
• Sheep and sheep products	• Pulp, paper, and paper products manufacturing	• Seaweed harvesting
	• Chemical and chemical products manufacturing	• Aquaculture
	• Basic metals manufacturing	• Water-based leisure
	• Machinery and equipment n.e.c. manufacturing	
	• Electrical and optical equipment manufacturing	
	• Transport equipment manufacturing	
	• Thermoelectric power generation	
	• Hydroelectric power generation	

n.e.c., not elsewhere classified.

Maps for 1990 and 2000 are currently available and a map based on 2006 imagery will become available during the second half of 2009. The minimum mapping unit for the CORINE maps is 25 ha. Land-cover change maps are also produced, showing areas of change of 5 ha or greater. The land-cover categories used are standardised across Europe.

A related project called Monitoring Land Use/Cover Dynamics (MOLAND) (http://moland.jrc.it/index.htm), co-ordinated by the Joint Research Centre of the European Commission, has seen the generation of land-cover maps for the greater Dublin region and the five border counties. Again satellite imagery is the main base data set; however, the spatial resolution of the maps is 1 ha in urban areas and 3 ha in rural areas. Maps of the Dublin area exist for 1998, 1986, 1968, 1956, with non-satellite information being used for the latter two. The land-cover map of the border counties is based on 2000 data.

The Forest Inventory and Planning System (FIPS), which was created in 1998 by the Forest Service from satellite imagery and aerial photographs, maps all forested areas over 1 ha. Information is stored in a GIS which allows queries on a large number of forest-related parameters. An update to FIPS known as Forest07 has been completed and is now available (DAFF, 2009).

Teagasc has compiled a land-cover map known as TLC95, based mainly on supervised classification of Landsat imagery from 1995, using a minimum mapping unit of 1 ha. The main reason for its production was as an input to pedological models. Derived from this using spatial modelling, in conjunction with other data sets, is a habitat indicator map (THIM95) using a minimum mapping unit of 1 ha. It refines the TLC95 map both spatially and thematically, with more detail especially on wetland habitats.

Boglands, comprising raised bogs, blanket bogs and fenlands, are a significant land-cover type in Ireland, occupying up to 1,200,000 ha or 17% of the land area (Feehan and McIlveen, 1997). They store large quantities of carbon in peat deposits. Their ongoing growth is very sensitive to the hydrology regime and there may be significant impacts from climate change. Current research on bogs is project based and short term in nature. Long-term observation systems should be put in place to provide a time series of data to support research on the effects of decadal-scale change on the structure, function and ability of a

peatland ecosystem to provide goods and services to people. This is necessary to understand the causes and effects of ecosystem change and for practical management purposes.

3.3.2.2 Albedo, fAPAR, LAI, biomass

These variables are predominantly related to vegetated land cover, except for Albedo which can also be measured over bare and artificial surfaces. Currently, none of these variables is measured on a consistent, ongoing basis in Ireland, with the exception of biomass, where estimates have been made. The National Inventory (McGettigan *et al.*, 2007) gives a value of 19.9 Mt C as the total carbon stock in forests for 2005 whilst Byrne and Milne (2006) have quoted a figure of 9.3% forest cover in Ireland in 2002, representing a total forest carbon stock of 19.1 Mt C. The National Forest Inventory carried out in 2005–2006 estimated forest cover at 10% (Forest Service, 2007). Forest cover is expected to increase in coming years with a consequent increase in biomass and carbon stock.

Satellite techniques are under development internationally to derive these parameters, but fully operational systems will not be available for some time.

3.3.3 Use of remotely sensed data

Remotely sensed data are the main source for the production of national-scale land-cover maps. They have been used in the generation of CORINE, MOLAND, FIPS, TLC95 and THIM95 products. They are also used by various research centres to study a range of land-cover processes for local study areas.

Remote sensing methods are currently not used in the collection of hydrological data for climate change purposes.

3.3.4 Use of models

Met Éireann, as part of the Community Climate Change Consortium for Ireland (C4I) project (http://www.c4i.ie/), has carried out future climate projections for Ireland under a number of scenarios (Dunne *et al.*, 2008). As part of this work it has also simulated river flooding and low flow conditions up to 2060 using hydrological models for a number of river basins. In general, these simulations indicate enhanced river flows in winter and significantly reduced flows in the summer period.

The Irish Climate Analysis and Research Units (ICARUS) based in NUI Maynooth also carry out hydrological modelling under future climate scenarios (http://geography.nuim.ie/ICARUS/index.html). The climate modelling approach is somewhat different to that employed at Met Éireann, but the general trends in terms of future hydrological patterns are similar.

Land-cover/use and change data are required in order to calculate and model GHG exchanges to the atmosphere. These include methane from livestock, nitrous oxide from fertiliser usage (both waste and artificial), carbon exchange to/from soils due to land use and land-use change, carbon sequestration by biomass due to afforestation, methane from undrained peatlands and carbon release from drained, exploited or degraded peatlands. While non-spatial data can be used to estimate the first two items, the assessment of the other activities is hampered by poor data on the spatial extent of land cover/usage and especially in determination of the dynamics of land-cover/use change. Whilst a range of spatial data exists for urban and peatland areas, e.g. MOLAND, CORINE, FIPS, etc., integration of these disparate data sets is a challenge.

3.3.5 Historical records

The OPW has collated historical materials, including photographs, newspaper articles, and other information about reported floods as part of the work in compiling the national floods hazard mapping website (http://www.floodmaps.ie).

River flows at many of the gauging stations operated by the OPW going back many decades may be accessed on the http://www.opw.ie/hydro website.

Prof. James Dooge, in his article *The Flow of Irish Rivers* (1991), presents materials from medieval annals and later publications documenting both floods and droughts. Floods on the Shannon at Clonmacnoise are reported to have occurred on a number of occasions. Severe flooding in Kilkenny is recorded for a year late in the 14th century. Reports in the 18th and 19th centuries become more precise and

less anecdotal as measurement instrumentation was developed.

Micheál MacCárthaigh of the EPA has extracted information on weather, including flood events, from a number of historical documents including the *Annals of the Four Masters*, the *Annals of Innisfallen*, the *Annals of Connaught* and a book called *Miscellaneous Annals* (personal communication).

3.3.6 Data archive and retrieval

The current register of hydrometric stations can be downloaded from the EPA website at http://www.epa.ie/downloads/pubs/water/flows/#d.en.12977.

The OPW maintains hydrometric records from over 300 stations which can be accessed online at http://www.opw.ie/hydro/. Qualitative quality codes are provided which are indicative of data reliability.

Furthermore, the EPA provides water-level and flow data for over 200 stations *via* a public website (http://hydronet.epa.ie/). These data will require further verification and quality checks before being archived. All historical data are available free of charge from the Hydrology Section of the EPA.

Long-term groundwater-level data are available for wells in several aquifer types in Counties Cork, Kerry, Kildare, Laois, Louth, Roscommon and Tipperary from the GSI: http://www.gsi.ie/Programmes/Groundwater/.

Digital copies of the CORINE land-cover maps are available from the EPA at the cost of reproduction. They can be viewed on the EnVision website (http://maps.epa.ie). The classification of the base satellite data follows a set of standards set by the European Environmental Agency. The TLC95 land-cover map can also be sourced *via* the EPA.

The Spatial Analysis Unit within the Rural Economy Research Centre of Teagasc provides free digital versions of the habitat indicator map (THIM95) along with ISO-standard metadata.

4 Overarching Requirements and Strategic Directions

4.1 Overall Requirements for Climate Monitoring

Parties to the UNFCCC are committed to developing and sustaining climate observations. The required observations have been identified in the GCOS adequacy and implementation reports. An analysis of Ireland's contribution to the GCOS has been published (Dwyer, 2008). However, the information identified as being essential at a global level by the GCOS Secretariat does not address specific requirements existing at a national level. Nonetheless, the GCOS framework and approach provides a useful template for development of national observation systems that complement and interact with regional and global efforts.

The following sections highlight areas and issues that require attention in order to consolidate and enhance Ireland's climate monitoring capability for national requirements.

4.1.1 Atmospheric observations

4.1.1.1 Upgrade to automatic weather stations

In the atmospheric arena ongoing observation of all essential climate surface and upper-air variables must be maintained. Met Éireann's move to AWSs at all its synoptic stations will enhance its ability to observe global radiation and wind parameters. The implications of this move to AWSs need to be assessed with respect to climate observation requirements.

4.1.1.2 Maintaining the integrity of weather stations

A number of synoptic weather stations are being relocated while others are in danger of being compromised because of encroaching development or changes in land use (e.g. forestation). It is imperative that the integrity of long-term weather stations be maintained. This should be taken into account in the formulation of county development plans. The designation of buffer zones around weather stations needs to be discussed with local authorities and with the relevant government departments.

4.1.1.3 Challenges facing new observation sites

The setting up of new observation sites faces a number of challenges. Many landowners are reluctant to give the long-term commitment required; planning permission is difficult to secure as preferred sites may be located in protected areas or may be subject to visual amenity restrictions, and it is hard to guarantee sufficient resources to maintain additional sites.

4.1.1.4 Review of station adequacy

Although there is an extensive network of synoptic, climate and precipitation stations, the adequacy of the network and the location of stations should be reviewed by a group with international representation to determine if improvements can be made. For example, upland areas are currently not well represented within the network.

4.1.1.5 Enhanced evaporation and evapotranspiration measurements

Evaporation and evapotranspiration are considered important variables that need to be monitored on a long-term basis. Recommendations of the hydrology group within the EPA include maintenance of existing recording stations, upgrade and extension of the network and improved quality control and analysis capacity. However, at the moment no agency has a mandate to co-ordinate collection and analysis of these measurements. There is an urgent need to carry out a comprehensive needs analysis in this area. Some of the issues that will need to be considered include establishing a business case for *in-situ* measurements, identifying the number and location of measurement sites, acquiring sites, selecting appropriate instrumentation and defining the data collection methodology, network supervision, role of modelling, data quality assurance and data provision, among others. As a result of this review process a lead agency for co-ordinating activities in the evaporation and evapotranspiration area needs to be identified.

4.1.1.6 Implementation of the GAW review

With regard to aerosols and GHGs, the recommendations in the GAW review of Valentia

Observatory and Mace Head (Barrie and Puckett, 2006) need to be implemented in full as soon as possible. In addition to enhancing and extending the suite of measurements, institutional support of Mace Head needs to be enhanced in order to secure its long-term viability. This includes additional full-time staff to allow the full recommended range of observation and analysis services. Extra staffing and support need to be provided to Met Éireann's chemical analysis laboratory to permit sustainable long-term analysis of samples from the existing seven GAW and European Monitoring and Evaluation Programme (EMEP) sites.

4.1.2 Oceanic observations

4.1.2.1 Maintaining Malin Head observations

Oceanic observation systems have been undergoing constant enhancement over the last number of years. One of the longest series of observations is sea-surface temperature at Malin Head, with a record going back to 1957. It is imperative that observations at this site are maintained and that the integrity of the measurement site itself is assured.

4.1.2.2 Development of a sustainable Argo float programme

The global Argo float network is vital for the collection of subsurface data such as salinity and temperature. Ireland has only recently started deploying floats as part of this network to the West of Ireland in an area that is poorly covered. Resources are in place to guarantee the deployment of four floats each year until 2010. It is important that Ireland's contribution to the float network can be guaranteed on a long-term basis.

4.1.2.3 Ensuring long-term sea-level measurements

The network of measurements of sea level using tide gauges has expanded dramatically in recent years. This is being co-ordinated by the Marine Institute and the programme is implemented by the participation of local stakeholders such as local authorities and port authorities. For climate change purposes, it is vital that the stations at Malin Head and Castletownsend are brought up to GLOSS standard as soon as possible and maintained for long-term monitoring. Institutional support is needed in order to guarantee the long-term integrity of such sites.

4.1.2.4 Climate monitoring review

Existing observational systems have been generally installed for operational purposes not linked to climate change. Since 2007, the Marine Institute is taking climate considerations into account when deciding on the location of observational equipment. Moreover, during the initial phase of its Climate Change Programme, a review of all existing *in-situ* observation systems is being carried out in order to determine if they are sufficient for climate monitoring purposes. A report on this is expected in 2009.

4.1.2.5 Enhancing the use of remotely sensed data

Remotely sensed data from satellite sensors have seen limited use in Ireland for the systematic monitoring of oceanic variables. The potential to take advantage of available sensors needs to be ascertained. Following on from the success of the ESA's Announcement of Opportunity, the Marine Institute will increase its research activity from 2008 to 2011. Other opportunities arising from Ireland's participation in the ESA's Earth Observation Envelope Programme and the EU's Framework Programme, among others, should be availed of.

4.1.3 Hydrological observations

4.1.3.1 River and lake measurements

Measurements of flows and levels of surface waters have been carried out for some time for operational reasons generally related to water supply. Under the WFD, there are specific requirements for the monitoring of both surface and groundwaters. To date monitoring for climate purposes has not been explicitly recognised. However, in future cycles of the WFD more climate-change-related actions are expected to be included. The EPA is currently in the process of identifying a number of high-quality hydrometric stations (with good rating curves, non-impacted flows, different physical settings and, preferably, long records) from the EPA/local authority and OPW networks where long-term monitoring for climate purposes can be undertaken. The location of these stations in relation to meteorological observation stations should also be taken into account. A report on the monitoring of lake levels is currently being compiled by the Eastern River Basin District. It is the

intention that four or five stations will be chosen for long-term monitoring purposes.

4.1.3.2 Monitoring for flood risk assessment

An international consultancy recently carried out a review for the OPW on the adequacy of monitoring for flood risk assessment. It identified 80 key river sites that need monitoring, only two of which require additional infrastructure and investment. This report should be taken into account in order to help select a sub-network of natural flow stations for climate change purposes.

4.1.3.3 Groundwater monitoring network

The EPA is currently creating a groundwater monitoring network at up to 150 sites, which should be completed by 2009. A subset of these will be designated for long-term climate monitoring purposes. It is important that such sites are not affected by groundwater abstraction or other factors which could bias the data.

4.1.3.4 Soil moisture monitoring

The long-term requirements for soil moisture observations need to be established. The appropriate mix between *in-situ* and remote measurements and modelling needs to be established. The relevance of ongoing work in this area nationally should be taken into account. Such a study should be carried out as part of the needs analysis for enhanced evaporation and evapotranspiration measurements discussed above.

4.1.4 Terrestrial observations

4.1.4.1 Consolidating land-cover mapping

Land-cover mapping to date has been carried out for individual institutional purposes or in response to European requirements. A number of maps have been generated using different methodologies and classification systems. This makes integration very difficult. There is a need to promote the use of standard classifications and to formulate agreed methodologies for 'translating' between different classifications. A key challenge relates to the design of an approach that satisfies the needs of ecologists, agronomists, planners and geographers. The outputs from any mapping exercises should respond firstly to Irish needs; however, they must be scalable and adaptable in order to meet international reporting requirements in regards to climate change.

4.1.4.2 Need for a land assessment capability

Land-cover/use and change maps form the basis for a range of applications related to climate change, including GHG exchanges. Assessment of this is hampered by poor data on the spatial extent of land cover/usage and especially in the determination of the dynamics of land-cover/use change. Moreover, good-quality land-cover/use data are required to assess the viability of existing land cover under conditions of changed climatic stresses/inputs and also the potential for adaptation and management to sustain threatened systems. A central land assessment capability needs to be put in place with a view to developing a coherent and consistent set of land-cover/use products which takes the needs of the various land-cover communities into account.

4.1.4.3 Research sites for bogs

With bogs covering almost 19% of the land area, and being important stores of carbon, their long-term monitoring is vital. Although many studies have been carried out on peatlands, their value is limited by the fact that they may have taken place on one site only and that other complementary studies were dealt with on other sites or even other peatland types altogether. The monitoring approach should thus embrace the idea of one or more national research sites or some other means of co-ordinating the monitoring, including the protocols, and the reasons for it. Potential for synergies with the monitoring requirements of the WFD regarding surface and groundwater should also be explored.

4.1.4.4 Forest ecosystem monitoring

A number of forest sites have been monitored since the early 1990s for atmospheric deposition and fluxes of biogeochemicals through the plots. Long-term monitoring of these and other key ecosystem sites for climate purposes should be considered.

4.1.4.5 Establishing long-term ground-truth reference sites

The selection of these sites should form part of a nationally co-ordinated activity to choose a number of ground-truth sites for use in the calibration and

validation of remotely sensed data that are used in the generation of national and regional land-cover products. In addition to the above land-cover types, other important habitats in this respect are grasslands (improved, semi-improved, rough grazing, natural) and wetlands. Teagasc would be in a position to operate three or four long-term grassland/wetland sites on its properties; however, an assessment needs to be carried out in order to characterise appropriately the variability within and between habitats and determine an appropriate number of ground-truth sites.

4.1.4.6 Improving the national soils map

A significant gap remains in the soil data for Ireland. A partial small-scale survey of a number of counties exists but it was decided to seek an alternative methodology in order to complete it. A detailed scoping study was carried out for the EPA by Daly and Fealy (2007) which recommends the use of a methodology based on that developed by the European Soils Data Bureau, at a scale of 1:250,000. The required resources, timescales and costs are presented in the study itself. Although soil properties themselves are not designated ECVs, high-quality information on soil is vital in relation to land cover, hydrology and other components of the climate monitoring system.

4.2 Strategic Directions for Climate Monitoring

- **Inclusion of climate monitoring in institutional mandates and budgets:** Collection and management of climate observations must be carried out in a systematic and comprehensive way and take place on an ongoing basis over decades. Statutory responsibility for data collection and management must be vested in the institutions best placed to carry them out and sufficient resources must be available in order to guarantee their long-term collection and maintenance. For certain observations, this mandate does not currently exist. A number of variables are observed as part of short-term projects and are supported by existing institutional budgets. In order to transform such projects into long-term programmes, additional resources and investment will be required.

- **Network optimisation for climate monitoring:** Much of the data collected across the *in-situ* atmospheric, oceanic, hydrological and terrestrial networks have been for reasons other than climate monitoring. It is vital that the utility of these networks for climate monitoring is ascertained and that an appropriate subset of sites and measurements is optimised or additional sites established for long-term climate monitoring purposes. Similarly, new infrastructure installed for climate change monitoring should also support Ireland's monitoring requirements in areas such as EU Directives, OSPAR requirements and other national and international monitoring requirements.

- **Long-term data management:** Climate data need to be archived, managed and maintained on an ongoing, long-term basis. Organisations that collect climate data need to ensure that data storage and management systems are appropriate for the long term. Data storage technology is constantly undergoing change, and the implications of this need to be taken into account. The costs associated with data archiving and management should be explicitly included in institutional budgets.

- **Data access policy:** The various climate data collection agencies operate different policies in regard to data accessibility: in certain cases data are released in near real time, in others the data are available only after rigorous quality control checks have been carried out, collectors may have preferential access to the data for long periods of time, applications for data access are considered by management committees, and charges and intellectual property restrictions apply. As public funds are used in the collection of these data, minimum access restrictions should apply and data should be released as soon as possible after collection. Nevertheless, collectors and providers need to be protected against problems arising from conclusions based on the use of raw data which are subsequently falsified by quality-assured data. A consistent and coherent data access policy should be put in place for all climate-relevant data that is in line with the requirements of the Infrastructure for Spatial Information in the

European Community (INSPIRE) Directive which is due for transposition into Irish law in 2009.

- **Facilitation of data access and exchange:** Usage of observations for climate studies is restricted by technical data access difficulties. A subset of observations is supplied to world data centres under international obligations; however, this represents only a fraction of potentially useful data. The difficulties encountered in accessing data limit Ireland's competitiveness in international funding efforts. Rather than centralising all climate observation data nationally, it is preferable that the agencies with climate observation remits manage and maintain their data. To improve data visibility and accessibility a dedicated, web-based climate data portal should be developed in order to facilitate access to comprehensive metadata and certain data sets, dependent on size, in a harmonised way. The Irish Spatial Data Exchange (ISDE) (http://www.isde.ie), co-ordinated by the Marine Institute, and the SAFER-Data Environmental Data Archive (http://erc.epa.ie/safer/), maintained by the ERC in the EPA, provide templates for the development of such a portal. Activities related to the development of a portal within the Central Statistics Office should also be kept under review.

- **Delivery of regular and relevant information:** The regular analysis and reporting of status, trends and projections for climate data are as important as the systematic collection and management of such data. Part of this reporting needs to be tailored to the needs of policy and decision makers in order to increase its effectiveness. Possible templates for such reporting include the 5-yearly *State of the Environment* reports issued by the EPA or the regular bulletins produced by the UK Climate Impacts Programme.

- **Inter-institutional and national co-ordination:** As a number of organisations are involved in climate observation data collection, there should be co-ordination between them in order to avoid duplication and to maximise possibilities for synergy. Research into appropriate and improved observational systems is vital and needs to be funded at the national level as well as through participation in international programmes. It is also important that there is overall national-level co-ordination of matters related to climate observations. An advisory committee should be set up to steer national climate observation requirements, including the need for extra resources to initiate additional and sustain existing long-term observational programmes. The Climate Change Research Co-Ordination Committee may be an appropriate forum from which to draw members of such a committee, as there is a wide representation across government departments and organisations involved in climate data collection.

- **Use of remotely sensed products:** Data and products from EUMETSAT are used regularly by Met Éireann as part of its weather and climate prediction work. However, a number of barriers, including lack of capacity, expertise, data cost and knowledge of data availability, have restricted the more widespread use of Earth Observation data and products. The development of expert thematic centres could help alleviate some of these problems. Moreover, Ireland's participation in the ESA's Earth Observation Envelope Programme since 2008 should provide an impetus for a more co-ordinated and strategic national approach to Earth Observation issues, with a view to participating more fully in space-related EU Framework Programme projects. In early 2009, the ESA commenced a focussed programme to deliver satellite-based information on a large number of the ECVs.

- **Meeting GCOS requirements:** As a signatory to the UNFCCC, Ireland is obliged to implement all relevant actions from the GIP. National co-ordinators and institutions involved in climate data collection should ensure that all relevant actions are fully implemented by the end of the period covered by the Plan in 2013.

5 Climate Monitoring Action Plans

Tables 5.1–5.5 list the practical actions that need to be taken in order to ensure that a comprehensive, reliable and sufficient national climate observation system is put in place. The actions are given for each thematic area as well as cross-cutting areas. For each of the 31 actions:

- There is a link to the related overriding strategic area
- A lead agency is identified
- The resources required to implement it are listed
- Related costs are shown
- Priority is allocated, and
- An estimated start date is given.

Table 5.1. Atmospheric action plan.

Action	Observation	Strategic area	Tasks	Lead agencies	Priority	Resources	Capital cost	Recurrent cost	Preferred start
A1	Evaporation/ Evapotranspiration	Network optimisation	The existing evaporation and evapotranspiration network needs to be maintained, including the Class A pan network and the lysimeters located at Valentia Observatory and Johnstown Castle. Evapotranspiration measurements at Valentia Observatory are secure for the foreseeable future; however, those at Johnstown Castle cannot be guaranteed. Therefore the needs analysis mentioned below needs to be carried out as soon as possible.	Met Éireann, Teagasc	1	Existing and additional resources to facilitate weekend observations at Johnstown Castle		€20,000 pa	2009 – Q1
A2	Evaporation/ Evapotranspiration	Network optimisation	Carry out a comprehensive needs analysis for an enhanced evaporation and evapotranspiration network, which addresses the number and location of sites, the level of automation, the modelling/measurement mix, site responsibility, costs and overall co-ordination.	EPA	1	Consultancy	€7,000		2009 – Q1
A3	Meteorological observations	Network optimisation	A review group with international representation should assess the adequacy of the synoptic, climatic and precipitation network and recommend any changes required to meet current and future climate observation needs.	Met Éireann	1	Consultancy	€20,000		2009 – Q1
A4	Physical/Chemical observations: aerosols	Network optimisation	The World Meteorological Organisation's GAW report[1] needs to be implemented in full. In particular, sustainable, long-term operational support needs to be provided to Mace Head Observatory for aerosol analysis. Extra support needs to be provided to Met Éireann's chemical analytical laboratory to permit sustainable, long-term analysis of samples from the existing seven GAW and EMEP sites.	Met Éireann, NUI Galway, EPA	1	*Mace Head:* Instrument Scientist Data Systems and QC Scientist Equipment maintenance *Met Éireann:* Data Analysis Scientist *Equipment:* Aerosol/Chemical mass instrumentation	 €400,000	 €80,000 pa €80,000 pa €40,000 pa €80,000 pa	2009 – Q1

Table 5.1 *contd.*

Action	Observation	Strategic area	Tasks	Lead agencies	Priority	Resources	Capital cost	Recurrent cost	Preferred start
A5	Physical/Chemical observations: clouds	Network optimisation	Equipment support and data analysis related to the recently installed cloud radar and radiometer at Mace Head.	NUI Galway	1	*Mace Head:* Instrument Scientist Equipment maintenance		 €80,000 pa €20,000 pa	2009
A6	Evaporation/ Evapotranspiration	Inclusion of climate monitoring in institutional mandates	An agency needs to be assigned responsibility to lead on activities regarding evaporation/evapotranspiration observations.		2				2009
A7	Data access	Facilitation of data access and exchange	Streamline access to atmospheric climate observation data (including gridded data) and metadata. Promote the development of an online portal for access to climate observation data and metadata from all domains.	Met Éireann	2	Scoping study required to determine resources and costs			2009
							€427,000	**€400,000**	

[1]Barrie, L. and Puckett, K., 2006. *Review of Global Atmospheric Watch Sites at Valentia and Mace Head, Ireland*. Environmental Research Centre Report 3, Environmental Protection Agency, Johnstown Castle Estate, Wexford, Ireland. http://www.epa.ie/downloads/pubs/research/air/name,12137,en.html

EMEP, European Monitoring and Evaluation Programme; EPA, Environmental Protection Agency; GAW, Global Atmosphere Watch.

Table 5.2. Oceanic action plan.

Action	Observation	Strategic area	Tasks	Lead agencies	Priority	Resources	Capital cost	Recurrent cost	Preferred start
O1	Institutional mandate	Inclusion of climate monitoring in institutional mandates and budgets	The Marine Institute could be given a statutory role in undertaking and co-ordinating oceanic data collection for climate monitoring purposes. Appropriate resourcing should be put in place to allow it to fulfil this role.	DAFF/Marine Institute	1	Existing		Current budget	2009 – Q1
O2	Sea level	Network optimisation	The sea-level monitoring sites at Malin Head and Castletownsend should be brought up to GLOSS standard for long-term climate monitoring purposes. Ensure that these sites are maintained and resourced into the future.	Marine Institute	1	Network capital Network maintenance	€100,000	 €70,000 pa	2009
O3	Sea-surface temperature	Network optimisation	A minimum of two coastal (Malin Head and Castletownsend) and five offshore data buoy measurement sites need to be designated for climate monitoring purposes. Long-term maintenance and resourcing of these sites needs to be ensured.	Marine Institute	1	Existing		Current budget	2009
O4	Salinity	Network optimisation	Review the adequacy of current and planned *in-situ* salinity measurements and recommend if additional observational capacity is required.	Marine Institute	2	Existing		Current budget	2009
O5	Subsurface temperature, salinity, currents	Network optimisation	Ensure adequate funding and resourcing beyond 2010 for the deployment of a minimum of four Argo floats per year.	Marine Institute	2	Equipment and deployment		€60,000 pa	2009
O6	Inshore buoys for sea temperature, salinity, sea state and surface meteorological conditions	Network optimisation	Ensure that a minimum of three inshore buoys are deployed and can be adequately resourced into the future.	Marine Institute	2	Buoy and equipment per site Maintenance per site	€200,000 each	 €130,000 pa per site	2009

Table 5.2 *contd*.

Action	Observation	Strategic area	Tasks	Lead agencies	Priority	Resources	Capital cost	Recurrent cost	Preferred start
O7	Plankton	Network optimisation	The CPR programme should be extended to fill gaps in Irish near-shore waters. The utility of satellite ocean colour data for retrieving information on plankton should be explored.	Marine Institute	2	Equipment and deployment, personnel costs and analysis		€100,000 pa	2009
O8	Data access	Data access	Streamline access to oceanic climate observation data and metadata *via* the Marine Institute's web mapping services and marine data online facility. Promote the development of an online portal for access to all climate observation data and metadata.	Marine Institute	2	Existing		€30,000 pa	2009
							€700,000	**€650,000**	

CPR, continuous plankton recorder; DAFF, Department of Agriculture, Fisheries and Food; GLOSS, Global Sea Level Observing System.

Table 5.3. Hydrological action plan.

Action	Observation	Strategic area	Tasks	Lead agencies	Priority	Resources	Capital cost	Recurrent cost	Preferred start
H1	River flows	Network optimisation	A number of high-quality hydrometric stations (with good rating curves, non-impacted flows, different physical settings and, preferably, long records) will be chosen from the EPA/local authority and OPW networks where long-term monitoring for climate purposes can be undertaken.	EPA/OPW	1	Existing		Current Budget	2009 – Q1
H2	Lake levels	Network optimisation	Lake levels need to be monitored on up to five representative lakes where a natural flow regime exists and where water is not abstracted. A set of appropriate lakes and monitoring sites needs to be identified.	EPA	1	Existing		Current Budget	2009 – Q1
H3	Groundwater	Network optimisation	The EPA is currently creating a groundwater monitoring network at up to 150 sites which should be completed by 2009. The most appropriate long-term monitoring sites for climate change purposes are in the process of being identified.	EPA	1	Existing		Current Budget	2009 – Q1
H4	Soil moisture	Network optimisation	Identify sites for the measurement of soil moisture as part of a long-term monitoring plan. In some cases these may be co-located with evaporation/evapotranspiration measurement sites. This task should form part of the needs analysis presented in Table 5.1 in relation to evaporation/evapotranspiration measurements.	Teagasc	1	Existing			2009- Q1
H5	Abstraction	Network optimisation	Collection of data on water abstractions is in the process of being rationalised as part of the Water Framework Directive. Requirements for long-term climate monitoring purposes should be included in the determination of the measures to be adopted.	EPA	2	Existing		Current Budget	2009

EPA, Environmental Protection Agency; OPW, Office of Public Works.

Table 5.4. Terrestrial action plan.

Action	Observation	Strategic area	Tasks	Lead agencies	Priority	Resources	Capital cost	Recurrent cost	Preferred start
T1	Land cover	Network optimisation	A long-term central facility to co-ordinate activities related to land-cover mapping and related data analysis needs to be established. This facility also needs to determine standard land-cover classification schemes that take into account the needs of different sectors and users. The EPA, Teagasc and third-level research organisations will have a key role to play in the establishment of such a facility	EPA/Teagasc	1	Establishment and running costs of facility including employment of core staff	€1.8M over 5 years		2009 – Q1
T2	Land cover	Network optimisation	Carry out an assessment in order to select a number of key long-term reference or ground-truth sites primarily for use in the calibration and validation of remotely sensed data for land-cover mapping. All key habitats (e.g. grassland, wetlands, forest) need to be taken into account.	Teagasc/EPA	1	Study	€700,000 over 3 years		2009 – Q1
T3	Land cover	Network Optimisation	Assess the need to establish one or more national reference sites for peatlands to facilitate co-ordinated monitoring of this extensive Irish habitat.	NPWS/EPA	2	Existing		Current Budget	2009
T4	Data access	Facilitation of data access and exchange	Co-ordinate approach to provision of metadata and data products from the various relevant data collection and supply organisations in the terrestrial area. The central land facility may be able to assume this role.	EPA/Teagasc	2	Existing		Current Budget	2009
							€2,500,000		

EPA, Environmental Protection Agency; NPWS, National Parks and Wildlife Service.

Table 5.5. Cross-cutting action plan.

Action	Observation	Strategic area	Tasks	Lead agencies	Priority	Resources	Capital cost	Recurrent cost	Preferred start
C1	Monitoring site integrity	Network optimisation	Establish a clear and coherent policy to protect the integrity of long-term climate monitoring stations.	DoEHLG	1	Existing		Current Budget	2009 – Q1
C2	Data policy	Data access policy	Establish a consistent and coherent climate data access policy across all agencies collecting observational data that is in line with the requirements of the INSPIRE Directive.	DoEHLG	1	Existing		Current Budget	2009 – Q1
C3	Analyses and reporting	Delivery of regular and relevant information	Carry out analyses of climate observations and report on the status, trends and projections of climate as part of regular *State of the Irish Climate* reports. A report every 4/5 years would be appropriate, to alternate with the EPA *State of the Environment* report.	Met Éireann	1	Existing		Current Budget	2009 – Q1
C4	Data portal	Facilitation of data access and exchange	An online climate data portal should be established to facilitate access to all relevant observational metadata and data. This will require co-ordination between data supply organisations. Sufficient resources will need to be allocated for the long-term maintenance of such a facility.	EPA	2	Capital set-up and design cost 1 full-time staff member	€200,000	€100,000 pa	2009
C5	Co-ordination	Inter-institutional and national co-ordination	An advisory committee with members drawn from the key observation agencies and data user communities should be set up to steer and co-ordinate national climate observation requirements.	Met Éireann/ DoEHLG	2	Existing		Current Budget	2009
C6	Remote sensing	Utilisation of remotely sensed products	Establish a structure that (i) facilitates the use of remotely sensed derived information in analyses of climate variability, (ii) promotes and supports capacity building, and (iii) promotes active participation in relevant ESA, EUMETSAT, EU and other international activities in this area.	Enterprise Ireland	2	Existing		Current Budget	2009

Table 5.5 ***contd.***

Action	Observation	Strategic area	Tasks	Lead agencies	Priority	Resources	Capital cost	Recurrent cost	Preferred start
C7	Remote sensing	Utilisation of remotely sensed products	A comprehensive inventory of relevant satellite data and derived products along with portal and access details should be compiled. Information on relevant research programmes should also be included.	EPA	2	Existing		Current Budget	2009
C8	UNFCCC reporting	Meeting GCOS requirements	Ensure that climate data collection, management and archiving activities are compatible with and in support of the GCOS Implementation Plan. All relevant data should be supplied to the appropriate world data centres in a timely manner.	DoEHLG	2	Existing		Current Budget	Ongoing
							€200,000	**€100,000**	

DoEHLG, Department of the Environment Heritage and Local Government; EPA, Environmental Protection Agency; ESA, European Space Agency; EU, European Union; EUMETSAT, European Organisation for the Exploitation of Meteorological Satellites; GCOS, Global Climate Observing System; INSPIRE, Infrastructure for Spatial Information in Europe; UNFCCC, United Nations Framework Convention on Climate Change.

6 Conclusions

This report documents the current climate observing capabilities in the atmospheric, oceanic, terrestrial and hydrological domains. It identifies critical gaps and provides proposals on how to address these. It furthermore sets out the strategic directions for climate monitoring and details a 31-point action plan for Ireland for the establishment, maintenance and further development of an integrated national climate observing system. It is based on the outcomes of extensive consultation with Ireland's climate observation and research community.

Although many elements of a climate monitoring system are in place, there are a number of issues that need to be addressed in order to make it more robust and capable of addressing the country's long-term needs in regard to climate monitoring. The most important of these focus on:

- The need to carry out a comprehensive needs analysis for an enhanced evaporation and evapotranspiration network, which addresses the number and location of sites, level of automation, modelling/measurement mix, site responsibility, costs and overall co-ordination, as well as the identification of an agency that will have overall responsibility for leading activities in this domain.

- Consolidating and securing long-term measurements of surface and subsurface variables in the oceanic domain as well as assigning a statutory role and appropriating resourcing to the Marine Institute in undertaking and co-ordinating oceanic data collection for climate monitoring purposes.

- Designating and securing a number of existing hydrological measurement stations on rivers and lakes as well as a number within the groundwater network for long-term climate observations.

- Establishing a long-term central facility to co-ordinate activities related to land-cover mapping and related data analysis. Reference sites for long-term research needs and ground-truthing in relation to the calibration and validation of remotely sensed data for land-cover mapping also need to be selected.

- Formulating a consistent and coherent climate data access policy across all agencies collecting observational data, as well as streamlining access to all relevant observational metadata and data by setting up an online climate data portal.

- Devising a clear and coherent policy to protect the integrity of long-term climate monitoring stations.

- Establishing a structure that facilitates the use of remotely sensed derived information in analyses of climate variability and promotes and supports capacity building, including active participation in relevant ESA EUMETSAT, EU and other international activities in this area.

- Co-ordinating national climate observation requirements by setting up a committee with members drawn from the key observation agencies and data user communities. Moreover, regular reporting on the status, trends and projections of climate should be carried out.

These issues must be addressed if Ireland is to ensure that it has a comprehensive, reliable and sufficient national climate observation system to help answer questions on climate change in a national context and meet its international obligations under the UNFCCC. The implementation of the action plans presented in this document will strengthen the country's ability to respond to these requirements.

Critically, the government must recognise the need for, and appropriately resource, sustained, long-term observations and data analysis in order to meet Ireland's climate change monitoring commitments at national and international level.

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Acronyms

AO	Announcement of Opportunity
AOD	Aerosol optical depth
Argo	Global array of profiling floats
AWS	Automatic weather station
C4I	Community Climate Change Consortium for Ireland
CFC	Chlorofluorocarbon
CMRC	Coastal and Marine Resources Centre
CORINE	Coordination of Information on the Environment
COST	Cooperation in the Field of Scientific and Technical Research
CPR	Continuous plankton recorders
CTD	Conductivity, temperature, depth
DAFF	Department of Agriculture, Fisheries and Food
DoEHLG	Department of the Environment, Heritage and Local Government
ECV	Essential climate variable (as defined by GCOS Second Adequacy Report (GCOS-82))
EMEP	European Monitoring and Evaluation Programme
EPA	Environmental Protection Agency
ERC	Environmental Research Centre
ESA	European Space Agency
ESB	Electricity Supply Board
ESEAS	European Sea Level Service
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
fAPAR	Fraction of absorbed photosynthetically active radiation
FIPS	Forest Inventory and Planning System
FP	Framework Programme
GAW	Global Atmosphere Watch (WMO)
GCMP	GCOS Climate Monitoring Principles
GCOS	Global Climate Observing System
GDP	Gross domestic product
GHG	Greenhouse gas
GIP	GCOS Implementation Plan
GIS	Geographical Information System
GLOSS	Global Sea Level Observing System
GOOS	Global Ocean Observing System

GPS	Global Positioning System
GSI	Geological Survey of Ireland
GSN	GCOS Surface Network
GTOS	Global Terrestrial Observing System
ICARUS	Irish Climate Analysis and Research Units
INSPIRE	Infrastructure for Spatial Information in Europe
IOCCP	International Ocean Carbon Coordination Project
IPCC	Intergovernmental Panel on Climate Change
ISDE	Irish Spatial Data Exchange
ISO	International Organisation for Standardisation
LAI	Leaf area index
LIDAR	Light detection and ranging
MOLAND	Monitoring Land Use/Cover Dynamics
MI	Marine Institute
MSA	Methane sulphonic acid
MSU	Microwave Sounding Unit
NILU	Norwegian Institute for Air Research
NOAA	National Oceanic and Atmospheric Administration
NPWS	National Parks and Wildlife Service
NUI	National University of Ireland
OPW	Office of Public Works
OSPAR	Convention for The Protection of the Marine Environment of the North-East Atlantic
PRISM	Predictive Irish Sea Models
RCBN	Regional Climate Basic Network
SAC	Special Area of Conservation
SAF	Satellite Application Facility
SBSTA	Subsidiary Body for Scientific and Technological Advice
SOLAS	Surface Ocean Lower Atmosphere Study
UCC	University College Cork
UCD	University College Dublin
UNFCCC	United Nations Framework Convention on Climate Change
UTC	Coordinated Universal Time
UV	Ultraviolet
WFD	Water Framework Directive
WMO	World Meteorology Office

Appendix 1 Organisations Represented at Climate Observations Workshop

Thirty-five people, representing the organisations listed below, attended a 1-day workshop entitled *Measuring and Monitoring Systems for Climate Variables – A Workshop on National Climate Observation Needs*, which took place in Dublin on 28 May 2008.

- Athlone Institute of Technology
- COFORD, National Council for Forest Research and Development
- Department of Agriculture, Fisheries and Food
- Department of the Environment, Heritage and Local Government
- Enterprise Ireland
- Environmental Protection Agency
- Electricity Supply Board International
- Galway County Council
- Marine Institute
- Met Éireann
- National University of Ireland, Maynooth
- National University of Ireland, Galway
- Office of Public Works
- Teagasc
- Techworks Marine
- Trinity College Dublin
- University College Cork.

Appendix 2 Websites Referenced in the Report

Website	Description
http://www.mgo.rssi.ru/	World Radiation Data Centre
http://www.cloud-net.org/	FP5-funded project for a European pilot network of stations for observing cloud profiles
http://wiki.ucc.ie/extreme-weather/	A UCC project on extreme weather events and climatic shifts
http://www.nilu.no/projects/ccc/create	FP5-funded project for a European aerosol database at the Norwegian Institute for Air Research
http://wdca.jrc.ec.europa.eu/	World Data Centre for Aerosols
http://www.marine.ie/home/publicationsdata/data/buoys	Irish Marine Weather Buoy Network
http://www.pol.ac.uk/psmsl/	Permanent service for mean sea level at the Proudman Oceanographic Laboratory
http://www.marine.ie/home/services/operational/oceanography/TideGauge.htm	Irish National Tide Gauge Network
http://www.ioccg.org/	International Ocean Colour Coordinating Group
http://www.prism.ie/	INTERREG IIIA-funded project to model conditions in the Irish Sea
http://www.marinedataonline.ie	The Marine Institute's marine data online catalogue
https://www.marine.ie/home/publicationsdata/data/WebMapServices/	The Marine Institute's web mapping services for a range of marine data
http://www.isde.ie	Irish Spatial Data Exchange
http://www.epa.ie/whatwedo/monitoring/water/hydrometrics/network/	Hydrometric network
http://maps.epa.ie	The EPA's web mapping service for environmental data
http://hydronet.epa.ie/	Online hydrometric data from the EPA
http://www.opw.ie/hydro/home.asp	Hydrometric information from the Office of Public Works
http://www.gsi.ie/Programmes/Groundwater/Groundwater+web+mapping.htm	The Geological Survey of Ireland's web mapping service for groundwater
http://www.epa.ie/whatwedo/assessment/land/	Information on the CORINE land-cover project
http://moland.jrc.it/index.htm	A Joint Research Centre project for land-use mapping and modelling in and around urban regions in Europe
http://www.c4i.ie/	The Community Climate Change Consortium for Ireland carries out work on climate modelling and prediction
http://icarus.nuim.ie/	Irish Climate Analysis and Research Units in NUI Maynooth
http://www.floodmaps.ie	National flood hazard mapping website
http://www.epa.ie/downloads/pubs/water/flows/name,12745,en.html	Register of Hydrometric Stations
http://erc.epa.ie/safer/	EPA's environmental research data archive

Appendix 3 GCOS Climate Monitoring Principles

Effective monitoring systems for climate should adhere to the following principles:

1. The impact of new systems or changes to existing systems should be assessed prior to implementation.
2. A suitable period of overlap for new and old observing systems should be required.
3. The results of calibration, validation and data homogeneity assessments, and assessments of algorithm changes, should be treated with the same care as data.
4. A capacity to routinely assess the quality and homogeneity of data on extreme events, including high-resolution data and related descriptive information, should be ensured.
5. Consideration of environmental climate monitoring products and assessments, such as Intergovernmental Panel on Climate Change (IPCC) assessments, should be integrated into national, regional and global observing priorities.
6. Uninterrupted station operations and observing systems should be maintained.
7. A high priority should be given to additional observations in data-poor regions and regions sensitive to change.
8. Long-term requirements should be specified to network designers, operators and instrument engineers at the outset of new system design and implementation.
9. The carefully planned conversion of research observing systems to long-term operations should be promoted.
10. Data management systems that facilitate access, use and interpretation should be included as essential elements of climate monitoring systems. *Furthermore, satellite systems for monitoring climate need to:*
    (a) Take steps to make radiance calibration, calibration monitoring and satellite-to-satellite cross-calibration of the full operational constellation a part of the operational satellite system; and
    (b) Take steps to sample the Earth system in such a way that climate-relevant (diurnal, seasonal, and long-term inter-annual) changes can be resolved. Thus, satellite systems for climate monitoring should adhere to the following specific principles:
11. Constant sampling within the diurnal cycle (minimising the effects of orbital decay and orbit drift) should be maintained.
12. A suitable period of overlap for new and old satellite systems should be ensured for a period adequate to determine inter-satellite biases and maintain the homogeneity and consistency of time-series observations.
13. Continuity of satellite measurements (i.e. elimination of gaps in the long-term record) through appropriate launch and orbital strategies should be ensured.
14. Rigorous pre-launch instrument characterisation and calibration, including radiance confirmation against an international radiance scale provided by a national metrology institute, should be ensured.
15. On-board calibration adequate for climate system observations should be ensured and associated instrument characteristics monitored.
16. Operational production of priority climate products should be sustained and peer-reviewed new products should be introduced as appropriate.
17. Data systems needed to facilitate user access to climate products, metadata and raw data, including key data for delayed-mode analysis, should be established and maintained.

18. Use of functioning baseline instruments that meet the calibration and stability requirements stated above should be maintained for as long as possible, even when these exist on decommissioned satellites.

19. Complementary *in-situ* baseline observations for satellite measurements should be maintained through appropriate activities and co-operation.

20. Random errors and time-dependent biases in satellite observations and derived products should be identified.

An Ghníomhaireacht um Chaomhnú Comhshaoil

Is í an Gníomhaireacht um Chaomhnú Comhshaoil (EPA) comhlachta reachtúil a chosnaíonn an comhshaol do mhuintir na tíre go léir. Rialaímid agus déanaimid maoirsiú ar ghníomhaíochtaí a d'fhéadfadh truailliú a chruthú murach sin. Cinntímid go bhfuil eolas cruinn ann ar threochtaí comhshaoil ionas go nglactar aon chéim is gá. Is iad na príomh-nithe a bhfuilimid gníomhach leo ná comhshaol na hÉireann a chosaint agus cinntiú go bhfuil forbairt inbhuanaithe.

Is comhlacht poiblí neamhspleách í an Ghníomhaireacht um Chaomhnú Comhshaoil (EPA) a bunaíodh i mí Iúil 1993 faoin Acht fán nGníomhaireacht um Chaomhnú Comhshaoil 1992. Ó thaobh an Rialtais, is í an Roinn Comhshaoil agus Rialtais Áitiúil a dhéanann urraíocht uirthi.

ÁR bhFREAGRACHTAÍ

CEADÚNÚ

Bíonn ceadúnais á n-eisiúint againn i gcomhair na nithe seo a leanas chun a chinntiú nach mbíonn astuithe uathu ag cur sláinte an phobail ná an comhshaol i mbaol:

- áiseanna dramhaíola (m.sh., líonadh talún, loisceoirí, stáisiúin aistrithe dramhaíola);
- gníomhaíochtaí tionsclaíocha ar scála mór (m.sh., déantúsaíocht cógaisíochta, déantúsaíocht stroighne, stáisiúin chumhachta);
- diantalmhaíocht;
- úsáid faoi shrian agus scaoileadh smachtaithe Orgánach Géinathraithe (GMO);
- mór-áiseanna stórais peitreail.
- Scardadh dramhuisce

FEIDHMIÚ COMHSHAOIL NÁISIÚNTA

- Stiúradh os cionn 2,000 iniúchadh agus cigireacht de áiseanna a fuair ceadúnas ón nGníomhaireacht gach bliain.
- Maoirsiú freagrachtaí cosanta comhshaoil údarás áitiúla thar sé earnáil - aer, fuaim, dramhaíl, dramhuisce agus caighdeán uisce.
- Obair le húdaráis áitiúla agus leis na Gardaí chun stop a chur le gníomhaíocht mhídhleathach dramhaíola trí comhordú a dhéanamh ar líonra forfheidhmithe náisiúnta, díriú isteach ar chiontóirí, stiúradh fiosrúcháin agus maoirsiú leigheas na bhfadhbanna.
- An dlí a chur orthu siúd a bhriseann dlí comhshaoil agus a dhéanann dochar don chomhshaol mar thoradh ar a ngníomhaíochtaí.

MONATÓIREACHT, ANAILÍS AGUS TUAIRISCIÚ AR AN GCOMHSHAOL

- Monatóireacht ar chaighdeán aeir agus caighdeáin aibhneacha, locha, uiscí taoide agus uiscí talaimh; leibhéil agus sruth aibhneacha a thomhas.
- Tuairisciú neamhspleách chun cabhrú le rialtais náisiúnta agus áitiúla cinntí a dhéanamh.

RIALÚ ASTUITHE GÁIS CEAPTHA TEASA NA HÉIREANN

- Cainníochtú astuithe gáis ceaptha teasa na hÉireann i gcomhthéacs ár dtiomantas Kyoto.
- Cur i bhfeidhm na Treorach um Thrádáil Astuithe, a bhfuil baint aige le hos cionn 100 cuideachta atá ina mór-ghineadóirí dé-ocsaíd charbóin in Éirinn.

TAIGHDE AGUS FORBAIRT COMHSHAOIL

- Taighde ar shaincheisteanna comhshaoil a chomhordú (cosúil le caighdéan aeir agus uisce, athrú aeráide, bithéagsúlacht, teicneolaíochtaí comhshaoil).

MEASÚNÚ STRAITÉISEACH COMHSHAOIL

- Ag déanamh measúnú ar thionchar phleananna agus chláracha ar chomhshaol na hÉireann (cosúil le pleananna bainistíochta dramhaíola agus forbartha).

PLEANÁIL, OIDEACHAS AGUS TREOIR CHOMHSHAOIL

- Treoir a thabhairt don phobal agus do thionscal ar cheisteanna comhshaoil éagsúla (m.sh., iarratais ar cheadúnais, seachaint dramhaíola agus rialacháin chomhshaoil).
- Eolas níos fearr ar an gcomhshaol a scaipeadh (trí cláracha teilifíse comhshaoil agus pacáistí acmhainne do bhunscoileanna agus do mheánscoileanna).

BAINISTÍOCHT DRAMHAÍOLA FHORGHNÍOMHACH

- Cur chun cinn seachaint agus laghdú dramhaíola trí chomhordú An Chláir Náisiúnta um Chosc Dramhaíola, lena n-áirítear cur i bhfeidhm na dTionscnamh Freagrachta Táirgeoirí.
- Cur i bhfeidhm Rialachán ar nós na treoracha maidir le Trealamh Leictreach agus Leictreonach Caite agus le Srianadh Substaintí Guaiseacha agus substaintí a dhéanann ídiú ar an gcrios ózóin.
- Plean Náisiúnta Bainistíochta um Dramhaíl Ghuaiseach a fhorbairt chun dramhaíl ghuaiseach a sheachaint agus a bhainistiú.

STRUCHTÚR NA GNÍOMHAIREACHTA

Bunaíodh an Ghníomhaireacht i 1993 chun comhshaol na hÉireann a chosaint. Tá an eagraíocht á bhainistiú ag Bord lánaimseartha, ar a bhfuil Príomhstiúrthóir agus ceithre Stiúrthóir.

Tá obair na Gníomhaireachta ar siúl trí ceithre Oifig:

- An Oifig Aeráide, Ceadúnaithe agus Úsáide Acmhainní
- An Oifig um Fhorfheidhmiúchán Comhshaoil
- An Oifig um Measúnacht Comhshaoil
- An Oifig Cumarsáide agus Seirbhísí Corparáide

Tá Coiste Comhairleach ag an nGníomhaireacht le cabhrú léi. Tá dáréag ball air agus tagann siad le chéile cúpla uair in aghaidh na bliana le plé a dhéanamh ar cheisteanna ar ábhar imní iad agus le comhairle a thabhairt don Bhord.

NDP
National Development Plan 2007 - 2013

The EPA's Environmental Research Centre (ERC) was established as a centre of excellence under the National Development Plan (NDP) to build capacity in environmental data handling, modelling, assessment and guidance. The objective of the ERC is to allow for a more structured approach to environmental research, through the development of advanced innovative techniques and systems to address priority environmental issues and thereby support environmentally sustainable development.

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Environment, Heritage and Local Government