

**DEFRA**

Department for  
**Environment,  
Food & Rural Affairs**

United Kingdom report on systematic  
observations for climate for the Global  
Climate Observation System (GCOS)

for

The Third National Communication to the  
Conference of the Parties to the  
United Nations Framework Convention on  
Climate Change (UNFCCC)



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Department for Environment, Food and Rural Affairs

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# EXECUTIVE SUMMARY

The Global Climate Observing System (GCOS) was established in 1992 to ensure that the observations and information needed to address climate-related issues are obtained and made available to all potential users. It is co-sponsored by the World Meteorological Organization (WMO), the Intergovernmental Oceanographic Commission (IOC) of UNESCO, the United Nations Environment Programme (UNEP) and the International Council for Science (ICSU). GCOS is intended to be a long-term, user-driven operational system capable of providing the comprehensive observations required for monitoring the climate system, for detecting and attributing climate change, for assessing the impacts of climate variability and change, and for supporting research toward improved understanding, modelling and prediction of the climate system. It addresses the total climate system including physical, chemical and biological properties, and atmospheric, oceanic, hydrologic, cryospheric and terrestrial processes.

Systematic observations in the UK and its overseas territories are made by a number of national agencies and organizations. For making and collecting meteorological and atmospheric observations the lead agency is the Met Office, but observations are also made by the Natural Environment Research Council's (NERC) Centres and Surveys, and the Environment Agency (EA) among others. Oceanographic (and marine) observing is widely distributed throughout the UK amongst many government departments and laboratories, universities and commercial companies, and is less well co-ordinated. Terrestrial observations are made or coordinated by NERC, the Forestry Commission and others; whilst the UK contributes to space-based observations through the European agencies ESA (European Space Agency) and EUMETSAT (the European Organization for the Exploitation of Meteorological Satellites).

This report describes the UK contribution to GCOS and covers observations made routinely, or regularly, across the different (meteorological and atmospheric, oceanographic, terrestrial and space-based) domains of GCOS. In addition, the report describes other national observational programmes which are not formally part of GCOS, but are considered relevant to national climate monitoring needs.

The report has been prepared as part of the UK's Third National Communication as a Party to the United Nations Framework Convention on Climate Change (UNFCCC). This report is the first compilation of information on UK systematic observations and monitoring across the different domains that make up the GCOS. As such it includes a wide spectrum of observing and monitoring systems for which information was made available. However, it is recognized that in some areas information provided was incomplete such that some details are missing and that some relevant observing/monitoring systems may be omitted. Notwithstanding this, the report provides the most complete inventory of UK systematic observing made to date.

## CHAPTER 1

# Introduction

Climate research and procurement of climate related observations are highly devolved activities in the UK. They are sponsored by various government departments in order for them to meet each of their responsibilities. The UK does not therefore have national plans for climate research and observations. Inter-agency coordination more generally on Global Environmental Change Research and Observations is undertaken by the GECC (Global Environmental Change Committee) chaired by the Chief Scientist of the Department for Environment, Food and Rural Affairs. The committee reports to the government's Chief Scientific Adviser. Within this framework the UK contributes to the GCOS, as described in Appendix I. GCOS activities in the UK are coordinated through the Met Office who have appointed a coordinator, Jon Turton. Paul Mason, Met Office Chief Scientist, is currently the chairman of the GCOS Steering Committee.

## Systematic Observations

Many agencies in the UK engage in the systematic observation of elements of the climate system. Invariably the capture, quality control and archiving of such data are designed to meet the integrated needs of these agencies, which derive from their overall missions. The UK has comprehensive observational coverage of its home territories and further contributes to the overall network through stations on its overseas territories. It contributes significantly to shared programmes involving ocean and space-based measurements, it has the longest instrumental temperature record in the world and pays considerable attention to quality control, data archiving, and the rescue of historic data both in the UK and elsewhere. It also provides the global database for sea levels.

Typically, the drivers for long-term systematic observation of environmental or ecological characteristics arise from an operational, regulatory or a research need. Examples of the former are to be found in the capture of meteorological data required for statistical and predictive services by the Met Office or hydrological data required for resource management purposes by the water industry. As a regulator, the EA needs to monitor compliance with its standards. The resulting observation programmes tend to be long term, but the resulting data may be seen as perishable and therefore not always subject to strict quality control procedures designed to maintain stability in the record; efforts to archive data and metadata may be perfunctory or dependent upon third parties. Systematic observations made for research purposes are generally made to test specific hypotheses under the direction of individual scientists and are time-limited as a result.

To meet the objectives of GCOS, the need to maintain stability in the record, for example by adhering to the published GCOS/GOOS/GTOS Climate Monitoring Principles (see Appendix II), is understood and increasingly accepted. As a result they have been adopted in some programmes and are being introduced elsewhere, as noted in the following sections which describe the individual programmes. A list of frequently used acronyms is given at Appendix III.

# Data Availability

## GOVERNMENT DATA POLICY

Material produced by Government qualifies for Crown copyright protection under the Copyright, Designs and Patents Act, 1988. A Review of Government Information was carried out during the Government's Spending Review 2000. The new Freedom of Information Act will provide a general right of access to government information, other than information which is exempt because, e.g. it is the subject of judicial proceedings, or is personal or commercial information supplied to government in confidence, etc. The general right of access is additional to information which a public authority publishes, or intends to make available to the public. All government bodies are tasked with the creation of "Information Asset Registers", registers that potential users of information can reference via web sites to see what information is held by individual departments. Further details are available at <http://www.hmso.gov.uk>.

The move by departments and agencies (other than trading funds) to a policy of marginal cost pricing for the licensing of basic "raw" data came into effect from 1 April 2001. Each relevant government trading fund, such as the Met Office, has been asked to prepare an action plan setting out where they are now, and how they propose to open access to their information further using the principles for improving its pricing and dissemination as set out in the report of the review.

## GCOS DATA

The UK position is that all national observations and data sets that have been declared as contributions to GCOS are submitted to the appropriate Data Centres. Additionally, all meteorological (and oceanographic) data and products that are produced by Members (national meteorological services) to support WMO programmes such as WWW (or co-sponsored programmes such as GOOS, WCRP, and IGOSS) are available under the terms of WMO Resolution 40 (WMO policy and practice for the exchange of meteorological and related data and products including guidelines on relationships in commercial meteorological activities, see <http://www.metoffice.com/corporate/international/res40.html>). Such data are "freely" available "without charge" (i.e. at no more than the cost of reproduction and delivery, without charge for the data and products themselves, and with no conditions on their use). Hydrological data and products are similarly covered under WMO Resolution 25 (<http://www.wmo.ch/web/homs/res25eng.html>). Similarly, IOC are expected to adopt a data policy which provides for free and open access to data that are collected, produced or exchanged as part of programmes conducted in association with IOC.

## MET OFFICE DATA

Met Office data policy is to encourage the widest possible use of data and products, for genuine research, in order to realize their potential value, whilst preserving the associated rights. Data requested by bona fide researchers for non-commercial activities will normally be subject to a charge covering only the cost of extraction, transmission and data handling.



## NERC DATA

Much environmental data in the UK is collected under the auspices of the NERC. It has delegated responsibility for its data, and implementation of its data policies, to seven designated Data Centres as follows.

**Antarctic Environmental Data Centre (AEDC)** at British Antarctic Survey (BAS): [www.antarctica.ac.uk/aedc](http://www.antarctica.ac.uk/aedc). Responsible for all NERC's data from the Antarctic, regardless of discipline. The AEDC is the UK National Antarctic Data Centre within the SCAR-COMNAP Antarctic Data Directory System.

**British Atmospheric Data Centre (BADC)** at Rutherford Appleton Laboratory (RAL): [www.badc.rl.ac.uk/index.html](http://www.badc.rl.ac.uk/index.html). Responsible for atmospheric sciences data.

**British Oceanographic Data Centre (BODC)** at Proudman Oceanographic Laboratory (POL): [www.bodc.ac.uk](http://www.bodc.ac.uk). Responsible for marine data.

**National Geosciences Information Service (NGIS)** at British Geological Survey (BGS): [www.bgs.ac.uk/geodata](http://www.bgs.ac.uk/geodata). Responsible for geosciences data.

**National Water Archive (NWA)** at Centre for Ecology and Hydrology (CEH): [www.ceh.ac.uk/data/nra.htm](http://www.ceh.ac.uk/data/nra.htm). Responsible for NERC's hydrological data and for the UK Government's National River Flow and Groundwater Level Archives.

**Environmental Information Centre (EIC)** at CEH: [www.ceh.ac.uk/data/eic.htm](http://www.ceh.ac.uk/data/eic.htm). Responsible for all other NERC terrestrial and freshwater data.

**NERC Earth Observation Data Centre (NEODC)** at RAL: [www.neodc.rl.ac.uk](http://www.neodc.rl.ac.uk). Responsible for Earth Observation data held by NERC, notably the satellite imagery archive at Dundee, imagery from NERC airborne surveys, and NERC's archive of imagery from commercial sources.

Details of NERC data policy are given in the NERC data policy handbook which can be found at <http://www.nerc.ac.uk/data/policy.shtml> and includes a charging policy. It differentiates between bona fide research for which data are provided free or at reduced rates, and operational or other commercial research for which higher charges are made, depending upon the data and reflecting the cost of compiling and maintaining the data set. (It defines bona fide research as "Academic research conducted solely to advance the state of knowledge. Results would be freely available, i.e. not used for commercial gain".) Access to basic catalogues and indexes is free to all.

## OTHER DATA SOURCES

NERC does not maintain a specialist data centre for Arctic regions, with data being dispersed amongst the discipline-related Data Centres. A catalogue to Arctic data held in UK universities is held by the Arctic Environmental Metadata Centre hosted by Scott Polar Research Institute (SPRI) within the University of Cambridge (<http://www.spri.cam.ac.uk/aemc/aemc.htm>). The ICSU World Data Centre for Glaciology (<http://www.spri.cam.ac.uk/wdcc/home.htm>) is funded by the Royal Society and is located in the Library of SPRI; it is part of the ICSU World Data Center System.

A number of other government agencies (e.g. EA, CEFAS (Centre for Environment, Fisheries and Aquaculture Science)), who have holdings of environmental data, also have data policies which permit charging for the commercial use of data.

## CHAPTER 2

# Meteorological and Atmospheric Observations

## 2.1 Contributing to GCOS

The UK fully participates in the GCOS Surface Network (GSN), the GCOS Upper Air Network (GUAN) and the Global Atmospheric Watch (GAW), as shown in Table 1 and described below.

Table 1: Participation in the global atmospheric observing systems			
	GSN	GUAN	GAW
How many stations are the responsibility of the Party	9	6*	3
How many of those are operating now	9	6	3
How many of those are operating to GCOS standards now	9	5	3
How many are expected to be operating in 2005	9	6	3
How many are providing data to international data centres now	9	6	3

\*In addition financial contributions are provided in support of 4 foreign GUAN stations. Regional GAW stations. In addition financial support is provided to the Global GAW station at Mace Head, Republic of Ireland.

### GCOS Surface Network (GSN) Stations

The GSN comprises, as far as possible, meteorological observing stations where the long series of data is unaffected by environmental changes, e.g. urbanization. The designated GSN stations in the UK run by the Met Office are Lerwick, Stornoway, Eskdalemuir, Valley, Waddington and Camborne (shown later in Figure 2). All of these currently meet the GCOS standard for surface observing.

The UK-run GSN designated stations overseas are St. Helena, Halley and Rothera. Halley and Rothera are run by BAS and St. Helena by the Met Office, all meet the GCOS standard.

### GCOS Upper Air Network (GUAN) Stations

The designated GUAN stations in the UK are Lerwick and Camborne. The Met Office has, in 2000, brought these stations up to the GCOS standard, by the provision of larger balloons to enable high altitude soundings to meet the GUAN requirement for data to at least 30 hPa.

Other UK-run GUAN designated stations include Gibraltar, St. Helena, Mt. Pleasant and Halley (run jointly with BAS). The Met Office stations at Gibraltar and Mt. Pleasant have also been brought up to GCOS standards this year by the use of larger balloons. Funding to upgrade St. Helena has not yet been identified.

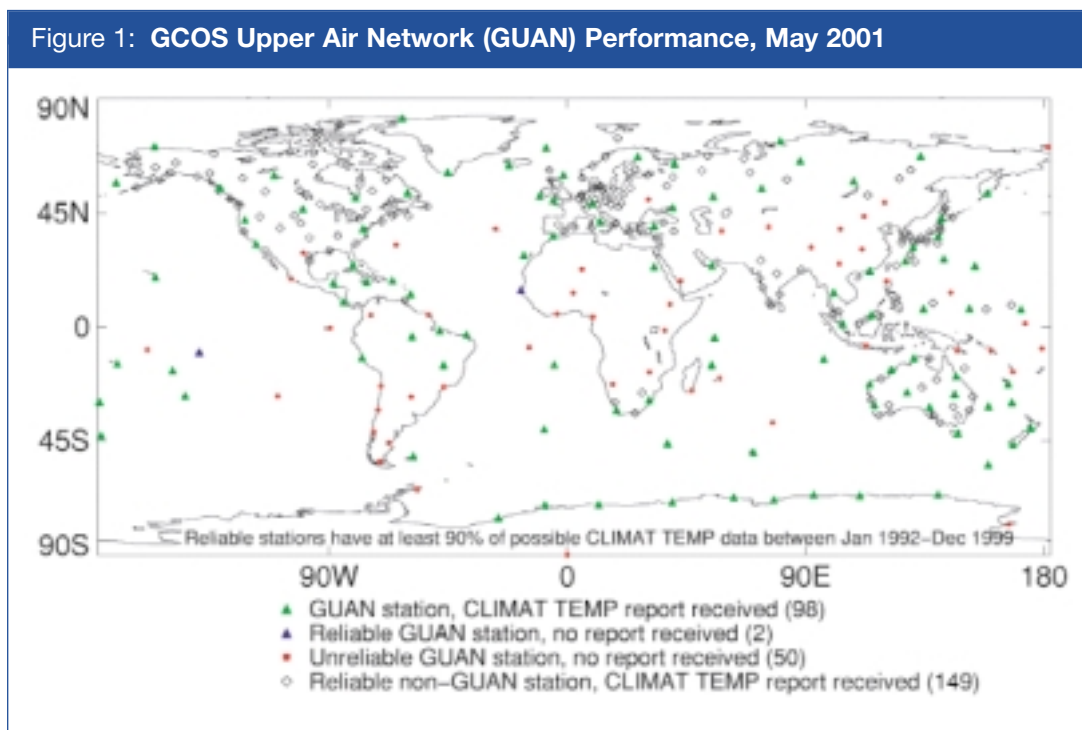
In addition, financial support is provided through the Met Office to the GUAN stations for Seychelles and for Tarawa, Funafuti and Penrhyn in the Pacific.

## GUAN Data Centre

The Met Office Hadley Centre (see <http://www.metoffice.com/research/hadleycentre/guan>) is responsible for one of the two GUAN Data Analysis Centres (the other centre is the NOAA/NCDC). The primary responsibilities of the Hadley Centre GUAN Data Analysis Centre are:

- to improve the monthly station data base,
- improve bias adjustments to monthly data,
- analyse monthly upper air data,
- provide gridded products with reduced biases, and
- to create global and regional monthly statistics.

At the Hadley Centre, CLIMAT TEMP monthly data are received regularly, but data from other sources (e.g. National Met Centres) and monthly statistics calculated by NCDC are also used. Products available from the Hadley Centre GUAN Data Analysis Centre include maps of GUAN stations, updated monthly, showing those stations for which a CLIMAT TEMP report has been received (as illustrated in Figure 1).



In addition various data sets (Hadley Centre Radiosonde Temperature, HadRT) are made available. These consist of monthly or seasonal temperature anomalies on a global grid, computed from data from about 200 radiosonde stations worldwide from 1958 to the present. Anomalies are available for 9 standard levels as well as tropospheric (850 – 300 hPa) and stratospheric (150 – 30 hPa) averages. In some versions bias corrections linked to instrumental or operational discontinuities have been applied to data, by weighting in the vertical to simulate Microwave Sounding Unit (MSU) retrievals. These data sets are available for use in the scientific community at no cost upon the signing of a short license agreement.

## Global Atmospheric Watch (GAW) Stations

In the UK, the Met Office runs Lerwick, Eskdalemuir and Camborne as Regional GAW stations, each making a limited set of atmospheric measurements. Work is undertaken at Lerwick and Camborne, under contract to the DEFRA to measure total column stratospheric ozone using ground-based Dobson spectrophotometers. The raw data are passed to an external organization, AEA Technology, who process the data to calculate the total ozone in the air column and report them to the World Ozone and Ultraviolet Radiation Data Centre in Toronto. During the winter/spring these measurements are forwarded to the WMO Ozone Mapping Centre in Greece.

Since March 1991 long-term monitoring of the thickness of the ozone layer has also been conducted with a SAOZ (Système D'Analyse par Observations Zénithales) spectrometer at Aberystwyth, by the University of Wales.

The DEFRA (Global Atmosphere Division) provides financial support for the monitoring of long lived trace gasses at the Mace Head Atmospheric Research Station on the west coast of Ireland as part of the NASA AGAGE network. Mace Head is also a Global GAW station and run by the National University of Ireland and so is not reported on here. In addition DEFRA also funds work on monitoring long lived trace gasses at the University of East Anglia (Weybourne Atmospheric Observatory on the north Norfolk coast), where work includes long-term measurements of a set of common pollutants suitable for trend analyses and the staging of intensive measurement campaigns.

## 2.2 Other National Meteorological and Atmospheric Observations

### Surface Climatological Networks

Climatological observations are needed to enable the climate of the UK to be determined and monitored and to serve as a National Weather Diary. Applied climatology is important to the national economy and requires a sufficiency of reliable climatological data. These data are collected by the Met Office for use in real-time (e.g. press reports) or in arrears (preparation of long-term averages or assessment of climate change).

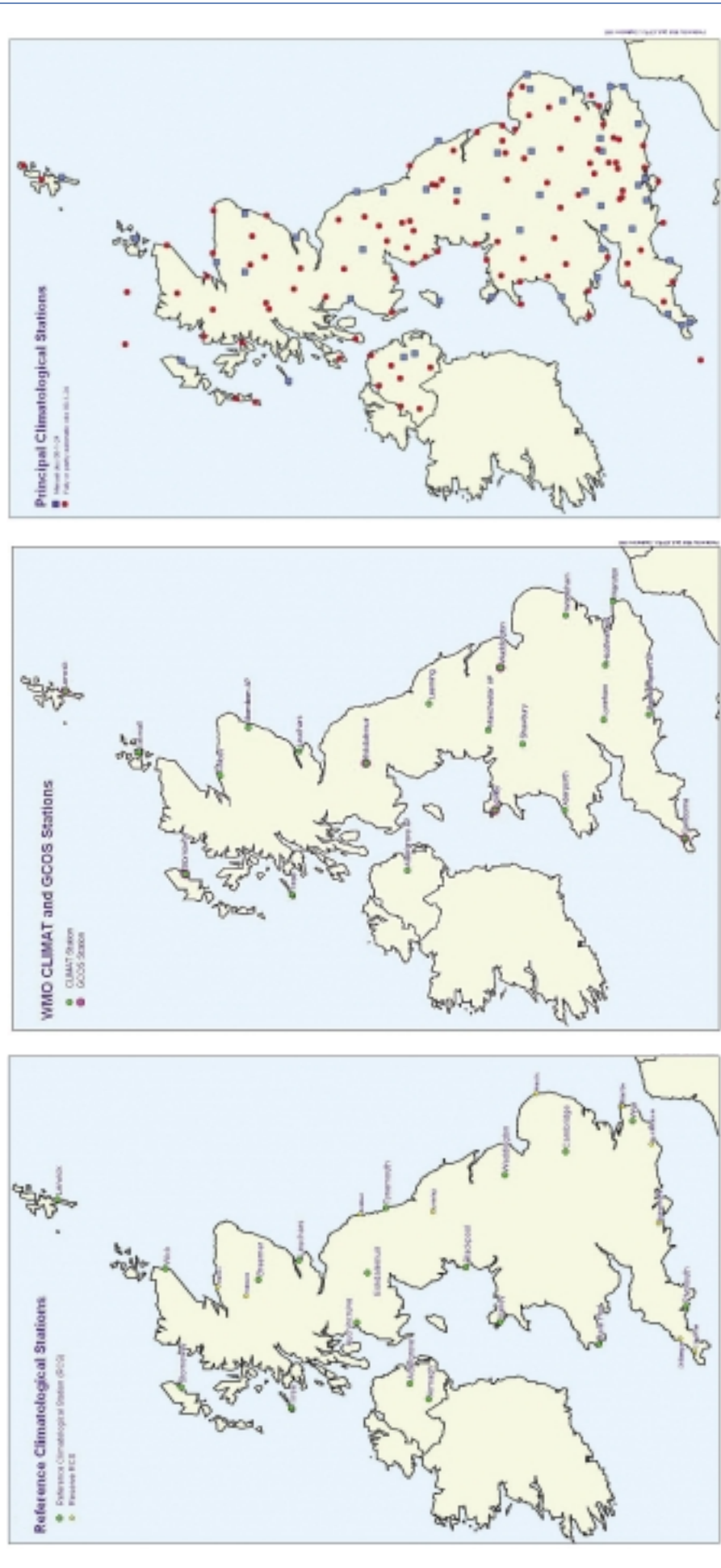
Core climatological data are collected to define the climate of the UK and to create a national database for a wide range of enquiries. Most climatological work involves the production of annual or monthly statistics including means, percentiles and standard deviations. Long records (of at least 30 years) are needed to establish reliable averages. Figure 2 (left) shows those stations that are designated as Reference Climatological Stations, each of these has a record longer than 30 years and is not subject to environmental changes (e.g. urbanization). The Climatological (CLIMAT) stations (see Figure 2 (centre)) are located with a spacing that reflects and accounts for the inherent spatial variability of different parameters, and are representative of the locality in terms of topography, aspect, land use and proximity to urban areas and the coast. Over 50% of the CLIMAT stations are at sites with an unchanging environment. However, with changes due to urbanization some stations are located in areas where the environment is changing.

Elements measured are in accordance with WMO requirements and soil temperatures are measured at 30 cm depth to maintain historical continuity. In addition soil temperature profiles (at 10 cm, 20 cm, 30 cm, 50 cm and 100 cm depths) are measured at some 30 stations across the UK to cover variations in climate and soil type; these stations also measure grass minimum temperature, air temperature, precipitation and solar radiation. Monthly means, exceedences, extremes, totals and departures from average for the GCOS and CLIMAT stations are routinely sent via GTS to the World Data Centre for Meteorology at Asheville, USA using the CLIMAT message. The data comprise statistics on atmospheric pressure, air temperature, vapour pressure, precipitation and sunshine and include days of hail and days of thunder.

In addition a network of Principal Climate Stations (Figure 2 (right)) in the UK has been defined which consists of around 145 stations where hourly readings are taken. This includes around 50 stations at which observations are made manually and from which data is transmitted via GTS every 3 hours; these include the subset of GCOS and CLIMAT stations. Monthly averages of maximum and minimum temperatures and rainfall from these stations are transmitted via the GTS.

A number of stations are designated as Ordinary Climatological Stations. The majority of these in the UK are voluntary, co-operating stations (e.g. agricultural stations, health resorts, organizations, local authorities and individuals). They are required to make one observation each day at 0900 UTC; the minimum requirement for daily measurement is maximum and minimum air temperature and daily total of rainfall although other elements may be measured. The Health Resort scheme was set up over a century ago to publicize the healthy benefits of coastal holiday resorts via daily weather reports for publication in the press and the scheme is now managed by the Met Office. The Health Resort report is an observation made at 1700 local time each day, the observation comprises temperature, sunshine and rainfall information.

Figure 2: Networks of (left) Reference Climatological Stations, (centre) UK GCOS and CLIMAT stations and (right) Principal Climatological Stations maintained by the Met Office



# Surface Radiation and Sunshine Observing Networks

## MET OFFICE NETWORKS

Networks also exist for the measurement of surface radiation (solar and terrestrial) and sunshine observing. These include the Climatological Radiation and Climatological Sunshine Networks which are established to maintain the climatology of radiation and sunshine in the UK. The Climatological Radiation Network (see Figure 3 (left)) comprises some 20 stations which make measurements of daily totals of global irradiation and sunshine. Quality controlled data is sent to the World Radiation Data Centre at St. Petersburg, Russia at monthly intervals. The Climatological Sunshine Network consists of a minimum of 150 stations which measure daily totals of sunshine. The data are archived by the Met Office.

The Reference Radiation Network of 3 Principal Radiation Stations (shown in Figure 3 (left)) provides high quality reference solar and terrestrial radiation measurements in support of research and development. These have a minimum programme of recording one minute mean values of global, direct and diffuse solar radiation, downward longwave radiation and hourly sums of bright sunshine. Hourly sums of global, diffuse downward longwave radiation and bright sunshine are passed to the World Radiation Centre. The measurement programmes are supported by a full manned meteorological observing programme and, where possible, a full upper air programme.

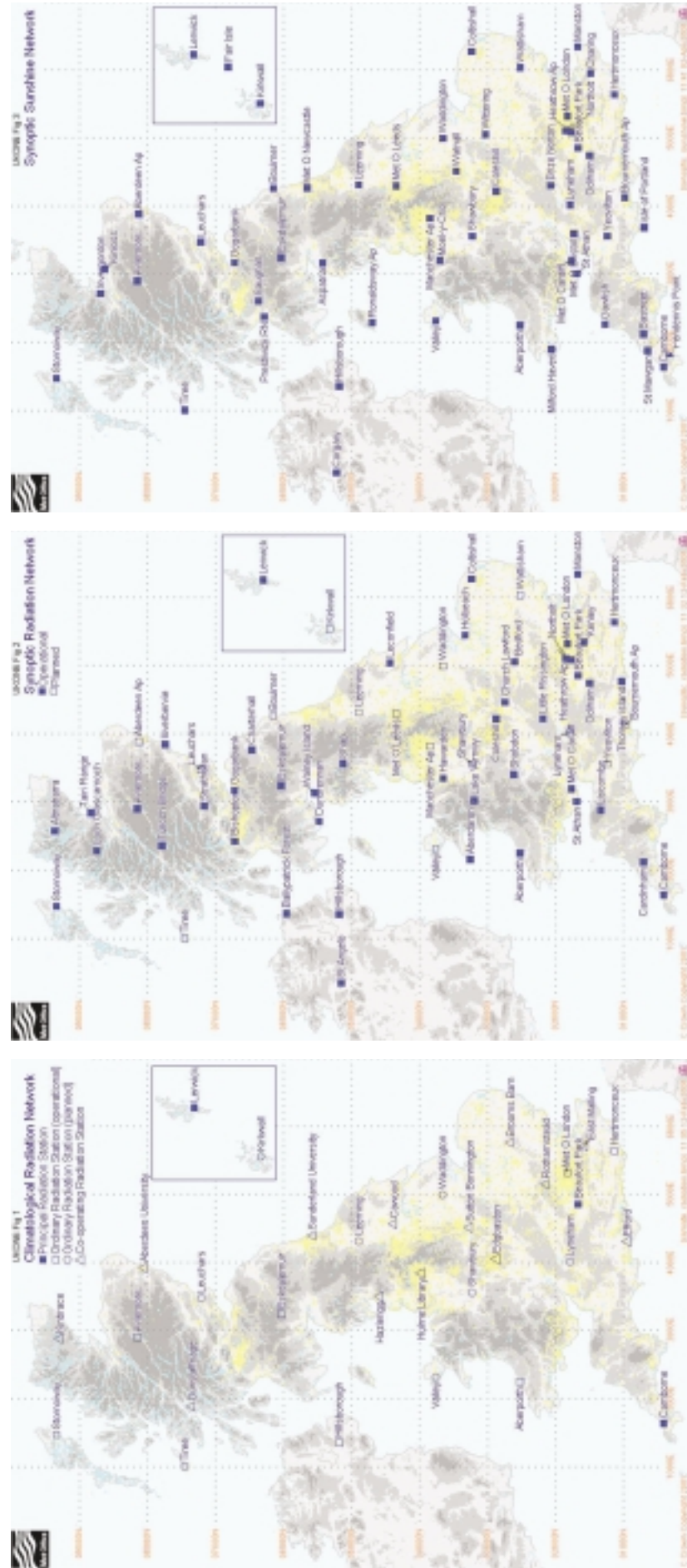
In addition there are Synoptic Radiation and Synoptic Sunshine Networks (Figure 3 (centre and right)) which provide radiation and sunshine data in support of routine forecasting, services and enquiries. The Synoptic Radiation Network comprises 40 sites evenly distributed throughout the UK which measure hourly totals of downward shortwave radiation (supported by full hourly meteorological observations). The data are archived by the Met Office. The Synoptic Sunshine Network consists of 55 of the Principal Climatological Stations (as shown in Figure 2 (right)) and 40 Health Resorts and provides daily totals of sunshine.

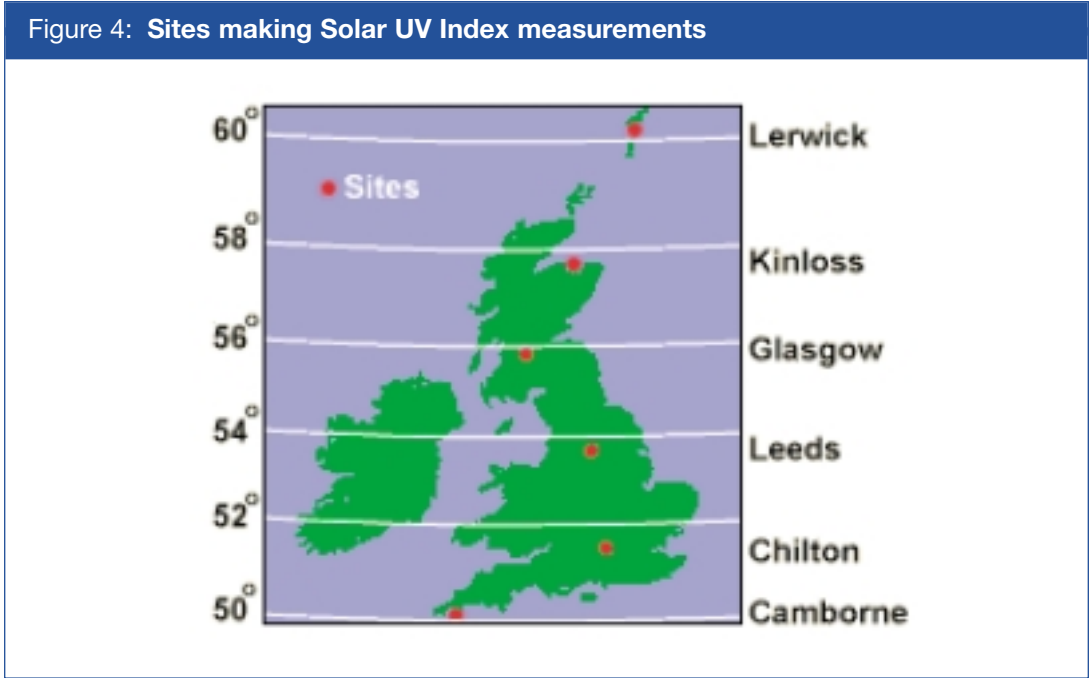
## SOLAR ULTRAVIOLET RADIATION NETWORKS

The Solar Ultraviolet (UV) index is measured by the National Radiological Protection Board (NRPB) at six sites around the UK as shown in Figure 4. The most recently established site is that at Kinloss. The sites at Camborne and Lerwick are Met Office locations and were established as network measurement sites in 1993. The longest running measurements are those made at the NRPB sites at Chilton, Leeds and Glasgow, established since 1988. The UK measurement sites are part of a wider solar radiation measurement network run by NRPB which includes two Irish and two Arctic measurement locations. The measurements made at all of these sites are those of the sunburn potential of solar UV radiation, of the UVA component of solar UV radiation and of visible radiation. Data are available from the NRPB.



Figure 3: Showing the (left) Climatological Radiation, (centre) Synoptic Radiation and (right) Synoptic Sunshine Networks maintained by the Met Office





The University of Manchester Institute of Science and Technology (UMIST) measure spectrally resolved solar UV at two sites in the UK, Reading University and UMIST. The monitoring site at Reading University has been in routine operation since December 1992, providing one spectrum per hour between sunrise and sunset in the range 280-500 nm at 1 nm wavelength step and 2 s per nm. The current data set has been measured with an Optronic 742 spectroradiometer but continuity with a Bentham DM150 spectroradiometer is currently being established before the latter becomes the main monitoring instrument. The instruments are calibrated in situ with a 200 W tungsten lamp, a transfer standard (at UMIST) from 1000 W NIST standards of spectral irradiance.

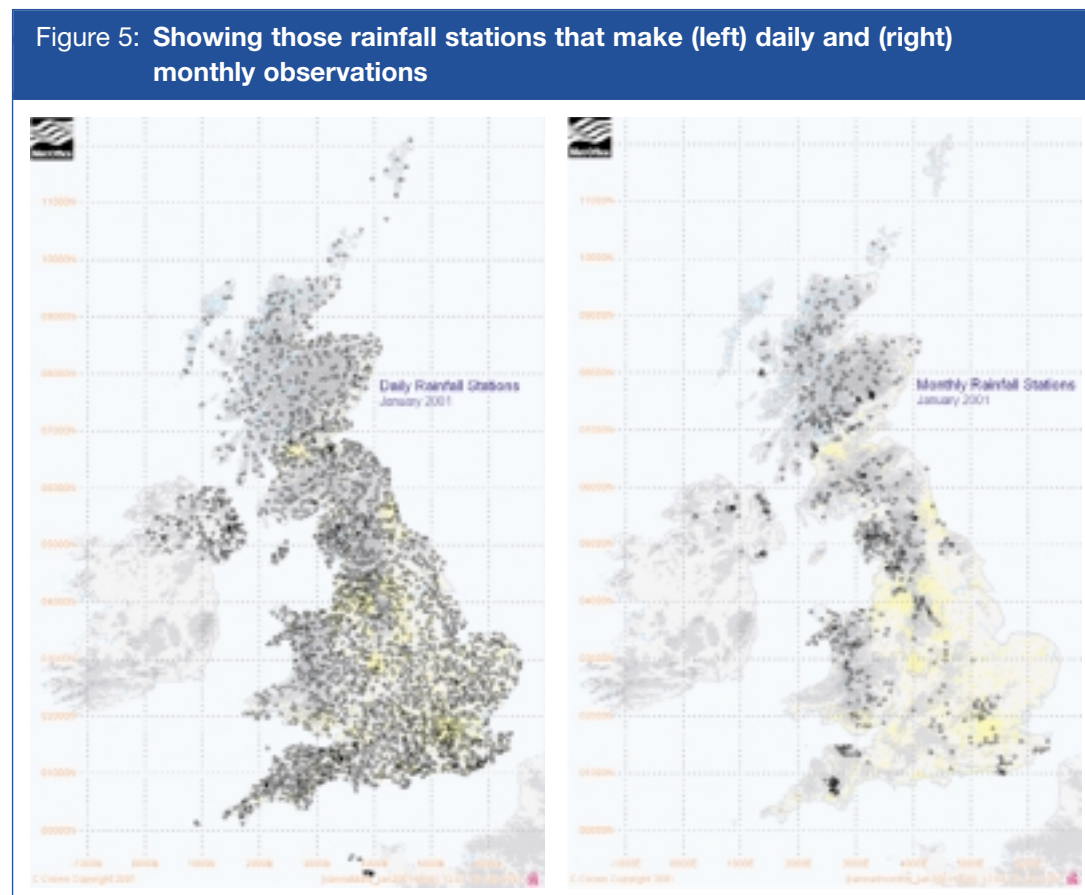
At UMIST, a Biospherical Instruments GUV-541 radiometer is employed to measure UV radiation in 5 narrow wavebands centred at 305, 313, 320, 340 and 380 nm and sampled at 2-3 Hz. Five-minute averages of the radiation in each band are recorded throughout the day. The instrument is mounted on top of an 11-storey building in the city centre, with a clear field of view. The instrument has been operating continuously since April 1997, with the exception of annual calibration periods.

The UV data is submitted to both the World Ozone and Ultraviolet Radiation Data Centre in Toronto (<http://www.msc-smc.ec.gc.ca/woudc/>), and the European UV database (<http://www.muk.uni-hannover.de/~martin/>) that is part of the EC EDUCE project. The spectroradiometers have also periodically participated in international intercomparisons, where results have been consistently good.

## Rainfall Observing Stations

The perceived need for rainfall data has always been greater than that served at public expense. The British Rainfall Organization (BRO) was formed as a privately funded organization in 1859 to collect daily data from rain gauges being set up by private persons and the water supply authorities. Within a few years the BRO was collecting data from several thousand sites across the UK. In 1919 the BRO was absorbed into the Meteorological Office who undertook (by deed of transfer) to continue and encourage the

voluntary system of observation, and the collection and quality control of data. Thus the Met Office has accepted most volunteers willing to make rainfall observations; however this has led to a rather uneven distribution of stations, too many in some areas too few in others. Nowadays, the number of private observers is much reduced with the majority of rainfall stations being owned and managed by the EA, the Scottish Environmental Protection Agency (SEPA) and water companies.



There are around 5,000 rainfall stations in the rainfall network. Data from a few hundred stations are received hourly or daily. For the remainder, daily or longer period totals are received as monthly collectives. Data from these stations are archived by the Met Office. In England and Wales the EA operate a network of telemetered rain gauges which report hourly data. (These, together with weather radar based products, are used for flood forecasting.) A similar network is operated in Scotland by the SEPA.

Within the UK there is an integrated network of weather radar's for defining the location and intensity of near surface precipitation. Weather radar data (precipitation type, rate and rainfall) are used in support of operational forecasting and, in particular, for flood forecasting. The weather radar network is operated by the Met Office jointly with the EA (in England and Wales), and in the Regions with the Scottish and Northern Ireland Executives.

# Upper Air Measurements

## **RADIOSONDE AND WIND PROFILER OBSERVATIONS**

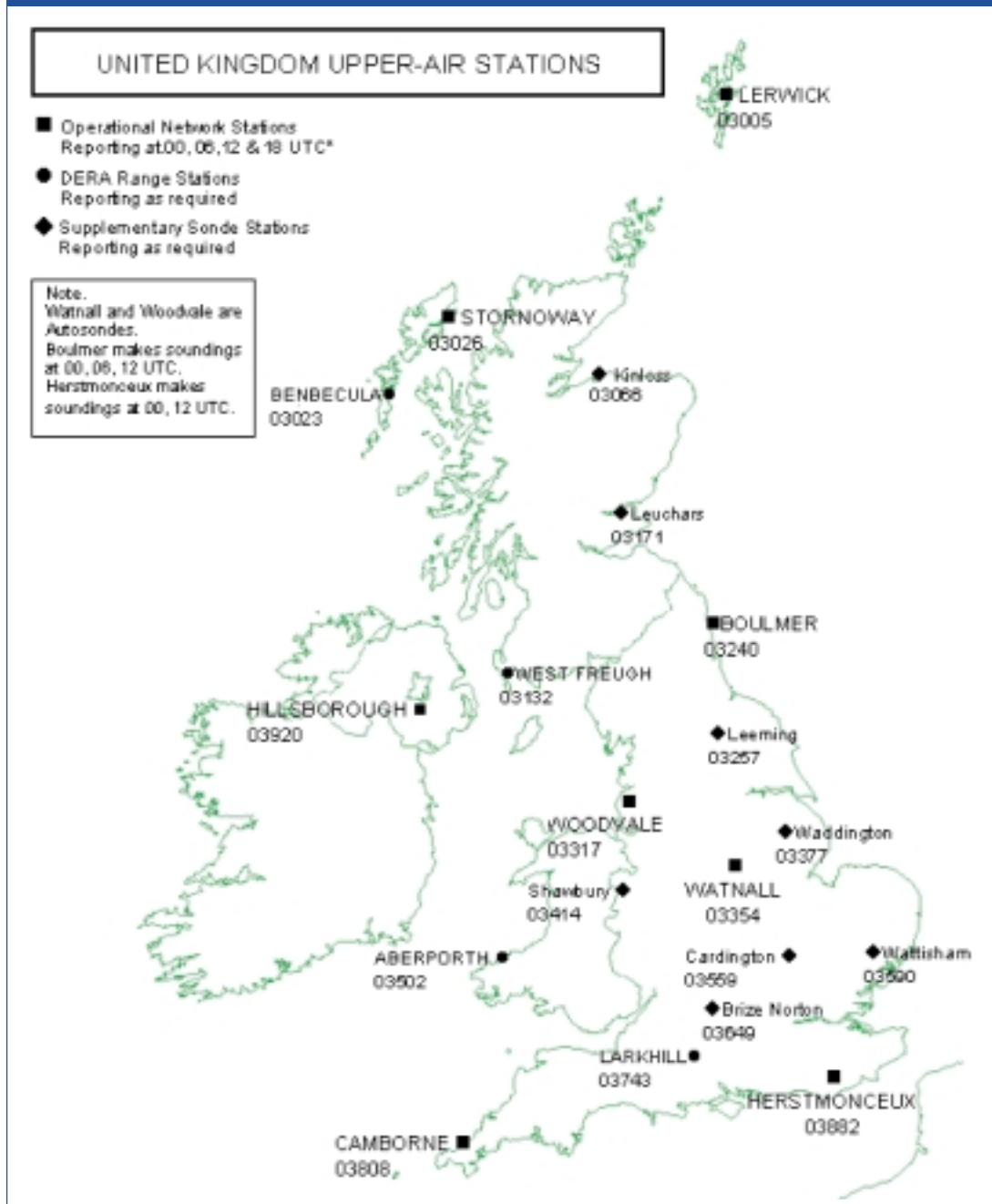
The Met Office will have moved from an observation network dominated by manual observations to a highly automated observation network by 2002. As a consequence, almost all the operational systems in the UK upper air network will be changed and some radiosonde stations will close or be moved. There will be a move away from a group of 8 conventional radiosonde stations to a mixture of 2 conventional sites, 4 unmanned sites with automatic launch systems, and at least 4 other sites using wind profilers and other remote sensing devices. This observing system will be supported by measurements from commercial aircraft landing at (among others) Heathrow/Gatwick, Manchester, Glasgow, Edinburgh and Belfast airports and in transit across the country at heights between 9 and 12 km. Conventional radiosonde stations will be retained at the overseas sites in the Falklands, Halley, St. Helena and Gibraltar.

The radiosonde network is shown in Figure 6. The station at Hemsby closed recently in March 2001, having operated for the past 50 years. Currently there are 8 upper-air stations reporting at main synoptic intervals, 6 of these (Stornoway, Hillsborough, Boulmer and Herstmonceux plus the 2 GCOS stations at Lerwick and Camborne) are manned and 2 (Nottingham and Woodvale) are Vaisala autosonde stations. There are plans for autosondes to replace the manned systems at Boulmer, Hillsborough and Herstmonceux, the autosonde at Woodvale being removed. In addition there are 4 stations on military ranges which typically make several radiosonde ascents during daytime hours as required locally and 7 radiosonde systems (some reporting PTU only) which make occasional ascents as required to meet forecasting needs. Upper air data are also recorded by wind profilers at Capel Dewi, near Aberystwyth (not shown on the figure), Camborne and Wattisham. At Stornoway there will be a manned radiosonde system until March 02 and a tropospheric wind profiler will be installed by December 02.

## **GPS TOTAL COLUMN WATER VAPOUR**

A Met Office network of 8 GPS receivers is being developed to facilitate initial studies into the potential of GPS for (total column) water vapour estimation. The network centres on Southern England with the aim of demonstrating the viability of a network with 50 km spacing, although one site is maintained at Lerwick to provide long baseline information. In addition to the Met Office sites, GPS ground stations are operated (on an hourly or daily basis) by other organizations such as Ordnance Survey, EA, DEFRA, universities and the National Physical Laboratory. The site at Herstmonceux is part of the International GPS Service European Reference Network.

Figure 6: Showing the Met Office Upper Air Network comprising radiosonde stations, profiler sites and supplementary aircraft (AMDAR) reports



## Climatological Data Sets

There are several long term climatological series (e.g. Central England Temperature, England & Wales precipitation) which have become established (see <http://www.metoffice.com/research/hadleycentre/obsdata>). The Central England Temperature (CET) is representative of a roughly triangular area of the UK enclosed by Bristol, Manchester and London. The monthly series began in 1659, and to date is the longest available instrumental record of temperature in the world. Since 1974 the data have been adjusted by 1-2 tenths °C to allow for urban warming. The monthly time-series of England and Wales total precipitation begins in 1766. The series is currently based on weighted averages of daily observations from a network of stations in five regions. It is the longest instrumental series of this kind in the world.

In addition a variety of observationally based Met Office global climate data sets are available through the British Atmospheric Data Centre (BADC) for bona fide research purposes. These include (i) monthly surface air temperature (prepared in collaboration with the Climatic Research Unit (CRU) of the University of East Anglia), (ii) sea surface temperature and sea-ice concentration (with missing data filled in to give global coverage), (iii) sea level pressure, (iii) nighttime marine air temperature and (iv) sea surface temperature; as well as recent (last three months) climatological surface and upper air data.

## Air Quality Monitoring

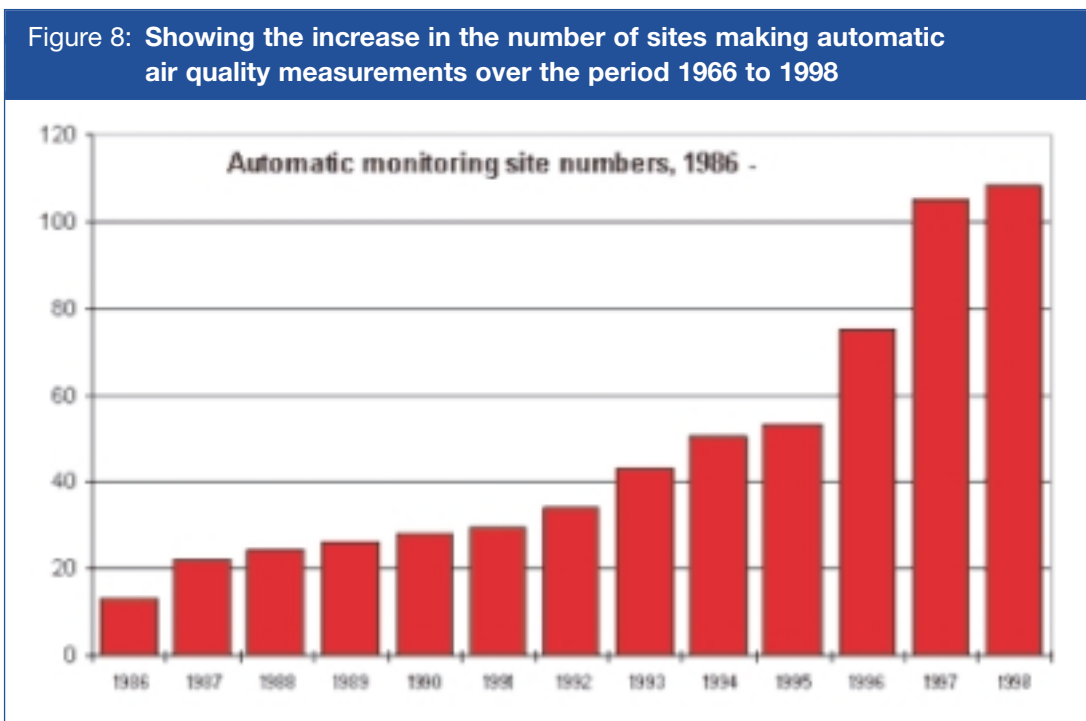
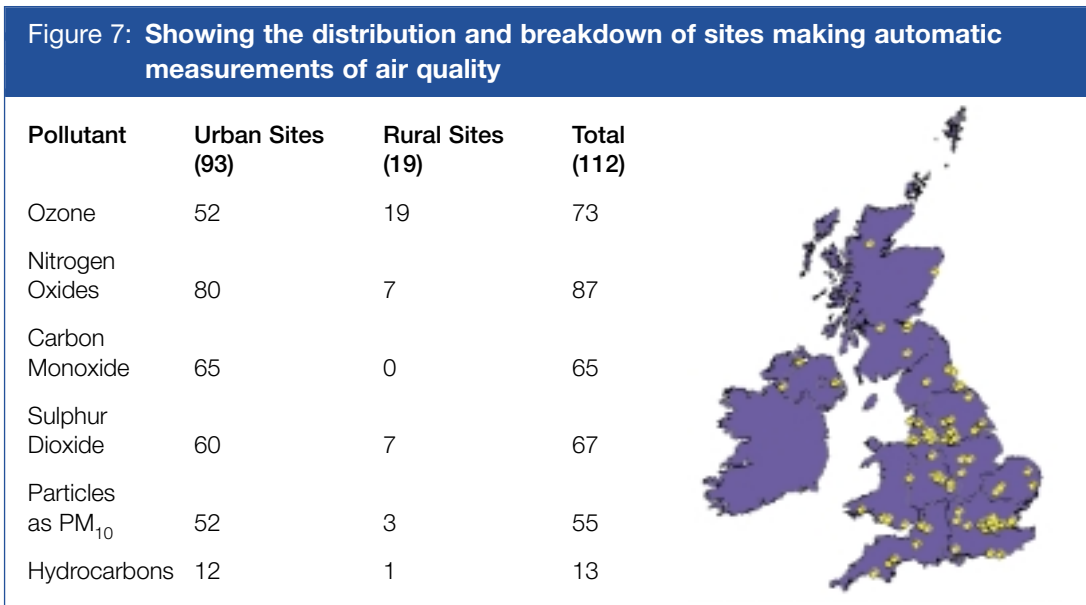
### **AUTOMATIC NETWORKS**

Automatic monitoring takes place near ground level in both urban and rural locations across the UK in a network known as the Automatic Urban and Rural Network (AURN). A wide range of pollutant species are measured:

- Ozone ( $O_3$ )
- Nitrogen dioxide ( $NO_2$ )
- Nitric oxide (NO)
- Oxides of nitrogen ( $NO_x$ )
- Carbon monoxide (CO)
- Sulphur dioxide ( $SO_2$ )
- Particulates ( $PM_{10}$ )
- And 25 hydrocarbon species.

Great care is taken over the QA/QC of data from the AURN and the resultant data are of very high quality.

Figure 7 shows the number and type of air quality monitoring stations and how they are distributed across the UK. The numbers of sites that monitor air quality automatically in the UK has expanded rapidly, and continues to do so, as Local Authority (local government in the UK) sites have been affiliated into the network and new centrally funded sites have been established. This is illustrated by Figure 8 below, showing how automatic site numbers have increased over recent years.



Stanger Science and Environment are responsible for the management and operation of the UK Automatic Monitoring Networks on behalf of DEFRA. Detailed information on each monitoring location can be found at <http://www.stanger.co.uk/siteinfo/>.

### NON-AUTOMATIC NETWORKS

A number of non-automatic monitoring networks have also been set up to achieve specific goals. The techniques employed, species measured and time scale of measurement all differ from network to network. The networks currently in operation are:

**Lead and other trace elements.** Since 1976, lead and other important trace elements have been measured at a number of sites across the UK. The network is set up to monitor the UK's compliance with the EC Directive on lead in air, to monitor the effect of the reduction of lead in petrol and the introduction of unleaded petrol, and to monitor the lead content of air in specific industrial areas.

**Diffusion Tube Nitrogen Dioxide Monitoring Network.** Over 300 Local Authorities in the UK participate in this network, which provides a nationwide picture of concentrations of this combustion-related pollutant. Monthly means of nitrogen dioxide are measured at over 1,100 urban sites, to assess the distribution of NO<sub>2</sub> concentrations over time and space in the urban environment in the UK and highlight areas where elevated concentrations of NO<sub>2</sub> occur, which may need further investigation by automatic monitoring.

**Smoke and Sulphur Dioxide Monitoring Networks.** This network has been in operation for over 30 years. There are currently around 165 sites monitoring black smoke and SO<sub>2</sub> on a daily basis, using the so-called bubbler technique. The aims of the programme are to provide information on long-term trends and to calculate a national average concentration on a consistent basis and to monitor for compliance with an EC Directive on SO<sub>2</sub> and Suspended Particulate Matter.

**Toxic Organic Micro Pollutants.** The objective of this network is to monitor a range of toxic organic micro-pollutants, such as dioxins, PAHs and PCBs at selected sites around the UK. Data are available from 17 sites although 3 of these are no longer operating.

**UK Acid Deposition Monitoring Network.** Acid deposition is currently measured at 32 weekly sites across the UK. Wet deposition is calculated from the concentration of the specified ion in bulk precipitation collectors and the Met Office rainfall field. Sulphur dioxide is measured at approximately 38 sites across the UK and the interpolated concentration field is combined with a process-based model to estimate the dry deposition of sulphur to the UK. Daily data from 5 primary network sites are provided to EMEP (UNECE European Monitoring and Evaluation Programme), Norwegian Institute for Air Research and the data for one site (Eskdalemuir) are made available to GAW.

Further information on both the automatic and non-automatic networks, and archived air quality data, is available from the UK National Air Quality Archive prepared by the National Environmental Technology Centre (part of AEA Technology Environment) on behalf of the DEFRA, see <http://www.aeat.co.uk/netcen/airqual/>.

## UK Ammonia and Nitric Acid Monitoring Networks

CEH (Centre for Ecology and Hydrology) runs the National Ammonia Monitoring Network (see <http://www.nbu.ac.uk/cara/UKNAMN/uknamn.htm>) for DEFRA. The objectives are to quantify the spatial patterns and temporal trends in air concentrations of ammonia gas and ammonium aerosol. These measurements are important to provide estimates of atmospheric nitrogen deposition on ecosystems which are vulnerable to excess nitrogen. Sampling is conducted with a monthly frequency using low cost methods developed by CEH. This allows sampling to be conducted at many locations, which is essential given the high degree of spatial variability.

The network (Figure 9) was established using two measurement methods: an active sampling “denuder” (DELTA system) and a sensitive passive method (ALPHA sampler), with the ALPHA results calibrated against the DELTA reference. Sampling with the DELTA system provides spatial coverage across the UK (59 sites), as well as measuring ammonium aerosol, while the ALPHA samplers are applied to explore spatial variability in



ammonia concentrations (49 sites), with 10 reference sites using both methods. The network includes the 5 primary Sites of the DEFRA rural air quality network, the 12 terrestrial sites in the Environmental Change Network and the 10 Level II Forest Health sites (see Section 4, Figures 16 and 17). A number of the sites are also co-located with sites of the DEFRA rural SO<sub>2</sub>, NO<sub>x</sub> and O<sub>3</sub> monitoring networks. Monitoring began at the start of September 1996.



A related network (run by AEA Technology and CEH) is the UK National Nitric Acid Monitoring Network. This includes monthly measurements of nitric acid and aerosol nitrate at 12 sites, plus daily measurements at 1 site (Barcombe Mills). The measurements are made using DELTA denuders for the monthly sites and an annular denuder system for the daily site. The measurements were started in 1999 and also include determinations of other acid gas and inorganic aerosol chemistry.

## Observations in the Antarctic

### METEOROLOGICAL MEASUREMENTS

Automatic data loggers are often used to monitor environmental variables such as temperature (of air and soil), humidity, wind speed and radiation in microclimates where experimental or ecological studies are being carried out. Some loggers are only in operation for a few weeks or months while others have been run for several years. Loggers have been sited in a wide variety of locations from the sub-Antarctic (South Georgia), South Orkney Islands (Signy), various Peninsula sites (as far south as Alexander Island – 70°S), and some continental localities (e.g. Victoria Land). These form an important data resource to the climate conditions experienced by Antarctic terrestrial organisms.

The Physical Sciences Division of BAS has holdings of meteorological data for the stations operated by BAS. They are available for the following locations and periods:

- Halley: 01 January 1957 to present
- Rothera: 08 March 1976 to present
- Signy: 01 January 1956 to 1995
- Faraday/Vernadsky: 01 January 1947 to present
- Grytviken (South Georgia): 1905 to present
- Bird Island (South Georgia): 2000 to present.

### OZONE MEASUREMENTS

A Bentham spectroradiometer was sited on the roof of the Bonner Laboratory at Rothera in February 1997. It measures spectral global irradiance between 280 and 600 nm with a step size of 0.5 nm and a resolution of 1 nm. Scans are recorded at various time intervals depending on the time of day and season peaking at every 30 minutes while the sun is above the horizon during the spring and summer. These scans can be used to measure the amount of solar radiation reaching the Earth's surface at Rothera. It provides particularly useful background data for studies on the effects of increased UV-B, due to the ozone hole, on the plants and microbes in regions around Rothera.

## **SOLAR ULTRAVIOLET MEASUREMENTS**

Ozone column measurements have also been measured by BAS at Halley, since 1956, using a Dobson spectrophotometer and at Rothera, since 1996, using a SAOZ spectrometer. The SAOZ instrument was transferred from Faraday to Rothera in January 1996. Faraday (now renamed Vernadsky) was transferred to Ukraine on 6 February 1996 and the long term monitoring is continued by Ukraine. Ozone information for Halley, Rothera and Vernadsky is available at <http://www.nerc-bas.ac.uk/public/icd/jds/ozone/>.

# Supplementary Tables

**Table S1. Atmospheric Observing Systems at the Land Surface (Surface Meteorological Observations)**

Systems	Climate Parameters	Total # Stations	Appropriate for Characterizing National Climate		Time Series			Adequate Quality Control Procedures		Metadata available	Continuity # expected operational in 2005		
			Fully	Partly	No	# stations/platforms (Data Digitized)	30-50y	50-100y	>100y			Fully	Partly
Reference Climatological Stations	Pressure, Temp, Precip, Radiation	18	☉			13 (13)	4 (4)		☉			all	18
Principal Climatological Stations	Pressure, Temp, Precip, Radiation	~145	☉						☉			all	~145
Ordinary Climatological Stations	Pressure, Temp, Precip, Radiation	~380	☉						☉			all	~380
Stations Reporting Internationally	Max/Min Temp, Daily Precip	48 (Total) incl 6 (GCOS), 15 (WMO CLIMAT)				5 (5)	26 (26)	1 (1)	☉			all	~26
Rainfall Network (in addition to Clim Stations)	Precip	~5,000		☉		1008	728	232		☉		1642	<5,000

**Table S2. Atmospheric Observing Systems at the Land Surface (Surface Radiation Observations)**

Systems	Climate Parameters	Total # Stations	Appropriate for Characterizing National Climate		Time Series # stations/platforms (Data Digitized)		Adequate Quality Control Procedures		Metadata available	Continuity # expected operational in 2005
			Fully	Partly	No	30-50y	50-100y	>100y		
Principal Clim Radiation Stations	Solar and Terrestrial Radiation	3	🌐					🌐	3	3
Ordinary Clim Radiation Stations	Daily Total of above	15 13 (cooperating)	🌐			25		🌐	all	~28
Synoptic Radiation Stations	Hourly Solar Radiation	61		🌐				🌐	all	~60
Synoptic Sunshine Network	Daily Totals of Sunshine	55 40 (HR)		🌐				🌐	all	~95
NRPB Ultraviolet Network	Solar UV Index	6 4 (overseas)		🌐		Earliest sites started 1988		🌐		~10
UMIST UV	Spectrally Resolved Solar UV	2	🌐			Since 1992, 1997		🌐	2	2
Stations Reporting Internationally		18 (clim radiation) 2 (UMIST UV)						🌐		~20

**Table S3. Available Homogeneous Data Sets for Meteorological Land Surface Observations**

Data Set Name	Climate Parameters	# Stations or Grid Resolution and Region covered	Time Period	References
HadCET	Temperature	Central England	1659 to present	<a href="http://www.metoffice.com/research/hadleycentre/obsdata">http://www.metoffice.com/research/hadleycentre/obsdata</a>
HadEWP	Precipitation	England and Wales	1766 to present	<a href="http://www.metoffice.com/research/hadleycentre/obsdata">http://www.metoffice.com/research/hadleycentre/obsdata</a>
HadCRUTV	Temperature	Global 5° gridded land surface air temperature with sea surface temperature	1856 to present	<a href="http://www.metoffice.com/research/hadleycentre/obsdata">http://www.metoffice.com/research/hadleycentre/obsdata</a> see also P. D. Jones et al. (2001), J Geophys Res, 106, 3371-3380.
HadSST (MOHSST)	Sea surface temperature	Global ocean on 5° grid	1871 to present (unrefined: 1856 to present)	<a href="http://www.metoffice.com/research/hadleycentre/obsdata">http://www.metoffice.com/research/hadleycentre/obsdata</a> see also P. D. Jones et al. (2001), J Geophys Res, 106, 3371-3380.
HadISST	Sea surface temperature	Global ocean on 1° grid	1871 to present	<a href="http://www.metoffice.com/research/hadleycentre/obsdata">http://www.metoffice.com/research/hadleycentre/obsdata</a>
HadMAT	Nighttime marine air temperature	Global ocean on 5° grid	1871 to present	<a href="http://www.metoffice.com/research/hadleycentre/obsdata">http://www.metoffice.com/research/hadleycentre/obsdata</a>
GMSLP/HadSLP	Sea level pressure	Global on 5° grid	1871 to 1998	<a href="http://www.metoffice.com/research/hadleycentre/obsdata">http://www.metoffice.com/research/hadleycentre/obsdata</a>
Met Office Land Stations Data	Surface Observations Hourly observations	Daily observations Hourly observations	1853 – July 2000 1983 – July 2000	<a href="http://www.badc.rl.ac.uk/data/surface/">http://www.badc.rl.ac.uk/data/surface/</a>
UK Raingauge Stations	Rainfall	Hourly Daily	1983 – July 2000 (hourly) 1900 – July 2000 (daily)	<a href="http://www.badc.rl.ac.uk/data/surface/">http://www.badc.rl.ac.uk/data/surface/</a>

Table S4. Atmospheric Observing Systems (Meteorological Upper Air Observations)												
Systems	Total # Stations or platforms	Appropriate for Characterizing National Climate			Time Series # stations/platforms (Data Digitized)			Adequate Quality Control Procedures		Metadata available	Continuity # expected operational in 2005	
		Fully	Partly	No	5-10y	10-30y	30-50y	>50y	Fully			Partly
Radiosonde Stations												
UK-based	8	☺						☺		8	7	
Overseas	4	☺						☺		4	4	
Range Radiosonde Stations	4		☺					☺			4	
Wind-only Stations	0											
PTU-only Stations	7			☺					☺		≤7	
CLIMAT TEMP Reporting Stations	6							☺				
Stations Reporting Internationally	12 (UK) 4 (Overseas) 2 (ASAP)							☺			~17	
ASAP Stations	2					0		☺			2	
Profilers	3 (wind) 1 (temp)					0			☺		~4	
GPS (Total Column Water Vapour)	8 1 (temp)					0			☺		~8	
Aircraft (Land & Locations)	9 (wind & temp)					0			☺		9	

Table S5. Available Homogeneous Data Sets for Meteorological Upper Air Observations					
Data Set Name	Climate Parameters	# Stations or Grid Resolution and Region covered	Time Period	References	
HadRT	Monthly temperature anomalies	Global on 5° grid	1958 to present	<a href="http://www.badc.rl.ac.uk/data/hadrt/">http://www.badc.rl.ac.uk/data/hadrt/</a>	
Radiosonde Data	Pressure, Temp, Humidity, Wind	Global UK and European (165) stations UK high resolution (10 stations)	1997 to present 1990 – June 1998 1990s to present	<a href="http://www.badc.rl.ac.uk/data/radioslobe/">http://www.badc.rl.ac.uk/data/radioslobe/</a> <a href="http://www.badc.rl.ac.uk/data/radiosonde/">http://www.badc.rl.ac.uk/data/radiosonde/</a> <a href="http://www.badc.rl.ac.uk/data/rad-highres/">http://www.badc.rl.ac.uk/data/rad-highres/</a>	

**Table S6. National Atmospheric Constituent Observing Systems**

Constituent	Total # Stations or platforms	Appropriate for Characterizing National Climate			Time Series # stations/platforms (Data Digitized)			Adequate Quality Control Procedures			Metadata available	Continuity # expected operational in 2005
		Fully	Partly	No	10-20y	20-30y	30-50y	>50y	Fully	Partly		
Carbon dioxide	0											
Ozone (surface)	73											≤73
Ozone (column)	2											2
Ozone (profile)	1											1
Atmospheric Water Vapor												
Radiosonde GPS	See Table S4											See Table S4
Other Greenhouse Gases	0											
Aerosols	0											
Other (Air Quality Monitoring)	See Figure 7											

**Table S7. Available Homogeneous Data Sets for Atmospheric Constituents**

Data Set Name	Constituent	# Stations or Grid Resolution and Region covered	Time Period	References
UGAMP Ozone Climatology	Ozone	4D global	1985 – 1989 (5 year)	<a href="http://www.badc.rl.ac.uk/data/ugamp-o3-climatology/">http://www.badc.rl.ac.uk/data/ugamp-o3-climatology/</a>
Radiosonde Data	Humidity (water vapour)	See Table S5		
Many other atmospheric chemistry and stratospheric data sets from experimental campaigns and satellite measurements are also available from the British Atmospheric Data Centre				
				<a href="http://www.badc.rl.ac.uk">http://www.badc.rl.ac.uk</a>



## CHAPTER 3

# Oceanographic Observations

### 3.1 Contributing to GCOS

For oceanographic observations GCOS is based upon the open ocean (climate) module of GOOS, which comprises the following programmes: drifting and moored buoy programmes managed by the DBCP (Data Buoy Co-operation Panel), the Ship of Opportunity Programme (SOOP), the Argo array of profiling floats, the Global Sea Level Observing System (GLOSS) and the Voluntary Observing Ships and Automated Shipboard Aerological Programmes (VOS and ASAP).

In the UK, the Inter-Agency Committee for Marine Science and Technology (IACMST) maintains an overview of marine activities across Government. During 2000 the IACMST GOOS Action Group (the UK national GOOS coordinating committee) prepared a report<sup>1</sup> to GOOS on national GOOS activities together with a report<sup>2</sup> on UK marine observations, from which much of the information in this section is taken.

The UK participates in the VOS programme, SOOP, GLOSS, the DBCP, Argo, and the ASAP, as summarized in Table 2.

Table 2: Participation in the global oceanographic observing systems							
	VOS	SOOP	TIDE GAUGES (GLOSS)	SFC DRIFTERS (DBCP)	SUB-SFC FLOATS (Argo)	MOORED BUOYS (DBCP)	ASAP
For how many platforms is the Party responsible	552	14	13	51	13 Argo 3 pre-Argo	14*	2
How many are providing data to international data centres	552	14	10	37	13	13*‡	2
How many are expected to be operating in 2005	<550	14	10	≥25	150-200	14*	2
* 2 buoys operated jointly with Météo-France. The number of VOS providing data at any one time will vary according to a variety of factors, e.g. ship trading patterns, ship crewing arrangements etc. ‡ One buoy (K7) has recently been lost and is not reporting.							

<sup>1</sup> see [http://www.ioc.unesco.org/goos/MS/rpts/uk\\_r00.htm](http://www.ioc.unesco.org/goos/MS/rpts/uk_r00.htm)

<sup>2</sup> Review of Current UK Marine Observations in Relation to Present and Future Needs. Report prepared for IACMST by Dr J E Portmann. IACMST Information Document No. 7 (will be available at <http://www.oceannet.org>)

## Voluntary Observing Ships (VOS)

VOS is an international scheme, first developed almost 150 years ago, by which ships plying the various oceans and seas of the world are recruited for taking and transmitting meteorological observations. VOS ships make a highly important contribution to the Global Observing System (GOS) of the World Weather Watch (WWW), and increasingly, through the VOS Climate Project (VOSCLim), to global climate studies. VOS data are disseminated on the GTS and are archived by many national meteorological services.

At the end of 2000 the UK Voluntary Observing Fleet (VOF) numbered 552 vessels reporting in WMO SHIP Code comprising: 454 'Selected' ships which are currently operating in all ocean regions; 39 'MARID' ships which operate in UK coastal or near continental areas; 24 'Auxiliary' ships which generally operate in areas where observational data is in short supply; and 35 Offshore units comprising both fixed and mobile rigs on the UK continental shelf.

Ships recruited to work in the 'Selected' category carry a precision aneroid barometer, a marine barograph and a marine screen containing dry and wet-bulb thermometers; for recording sea-water temperature they also carry a sea-water bucket with thermometer, or are fitted with distant reading equipment. 'MARID' ships are equipped with tested thermometers and their observations assist with the prediction of fog.

The 35 offshore units reporting in SHIP code comprise 17 fixed and 16 mobile offshore installations. In addition a further 16 offshore units host automatic weather systems. These units provide data from the North Sea oil fields and other areas of exploration on the UK continental shelf. Anemometers are not normally used by the UK VOF, the surface wind speed and direction being estimated from the sea state.

As the appointed lead centre for monitoring marine surface data the Met Office produces detailed statistics to monitor the quality of surface marine data. Such statistical reports are made available to other National Meteorological Services and WMO on a regular basis and identify those ships whose observations have been 'flagged' as being suspect.

### VOSCLim

The Met Office is actively involved in the VOSCLim project which aims to provide a high quality reference set of VOS data for satellite ground truth verification, climate change studies, research and climate prediction – and so is of particular importance for GCOS. The Met Office has agreed to host the Real Time Monitoring Centre (RTMC) for the project and plans to recruit some 30 participating vessels (of the overall target of 200 ships). Southampton Oceanography Centre (SOC) has also been closely involved and maintain VOSCLim project information at <http://www.soc.soton.ac.uk/JRD/MET/VOSCLIM>

## Ship of Opportunity Programme (SOOP)

The primary goal of the joint IOC/WMO SOOP is to fulfil upper ocean data requirements which have been established by GOOS and GCOS, and which can be met by measurements from ships of opportunity. The initial upper ocean thermal data requirements met by the SOOP are those which were developed by the TOGA and WOCE programmes for the low density expendable bathythermograph (XBT) network and endorsed by the WCRP Ocean Observing System Development Panel (OOSDP), who have emphasized the value of long-term monitoring of upper ocean heat content using XBT's from ships of opportunity for climate prediction. High resolution (profiles sampled at 1 or 2 m resolution) delayed mode data are routinely distributed to Regional National Oceanographic Data Centres (RNODC's) and forwarded to the World Data Centres

The UK is represented by the UK Hydrographic Office (UKHO) on the SOOP Implementation Panel. UKHO co-ordinates the provision, to UK SOOP vessels (mainly research ships), of around 1,000 XBT's per year, which are funded by the Ministry of Defence (MoD). In addition about half a dozen of the UK VOF currently undertake XBT operations on behalf of other countries.

## Tide Gauges (GLOSS)

The Permanent Service for Mean Sea Level (PSMSL) (see <http://www.pol.ac.uk/psmsl>) is hosted by the Proudman Oceanographic Laboratory (POL). The PSMSL was established in 1933, and is the global data bank for long-term sea level change information from tide gauges. As at February 2001, the database of the PSMSL contained over 47,000 station-years of monthly and annual mean values of sea level from over 1,800 tide gauge stations around the world received from almost 200 national authorities. On average, approximately 2,000 station-years of data are entered into the database each year.

GLOSS is an international programme coordinated by the IOC for the establishment of high quality global and regional sea level networks for application to climate, oceanographic and coastal sea level research. The main component of GLOSS is the Global Core Network (GCN) of 287 sea level stations around the world for long-term climate change and oceanographic sea level monitoring. For several years the PSMSL has provided a regular summary of the status of each of the 287 sites in the GCN which is available via the above web page. The UK maintains 3 GLOSS sea level stations in the UK at Lerwick, Stornoway and Newlyn, and is responsible for 10 GLOSS stations overseas: Ascension, Bermuda (St. George's Is), Diego Garcia Is, Faraday (Antarctica), Gibraltar, St. Helena, Stanley (Falklands), Edinburgh (Tristan Da Cunha), Signy (South Orkney Is) and South Caicos (the latter three are not operational and are unlikely to become so in the near future).

## Drifting Buoys

The UK participates in the WMO/IOC Data Buoy Co-operation Panel and its action groups: EGOS (European Group on Ocean Stations), IABP (International Arctic Buoy Programme), IPAB (International Programme for Antarctic Buoys), ISABP (International South Atlantic Buoy Programme) and the GDP (Global Drifter Programme). Participation involves the Met Office, the SPRI and BAS. The majority of drifters are capable of

measuring barometric pressure, air temperature and sea surface temperature; some drifters are fitted with additional sensors to measure wind speed and direction. At May 2001 there were 51 active UK drifting buoys (38 Met Office buoys and 13 others), 37 of these were reporting data on GTS.

The Met Office aims to maintain about 25 drifters in the water at any one time as a contribution to the global population. (The average lifetime of buoys in the EGOS programme is 375 days, and rises to 439 days if early failures and recoveries are excluded.) The majority of the Met Office drifters are deployed in the North Atlantic as part of EGOS, although 1 ice-buoy has been deployed on the polar ice cap as part of the IABP. In the year to September 2000 some 32 EGOS drifters, 1 IPAB ice-buoy and 1 ISABP drifter were deployed, all reported data on GTS.

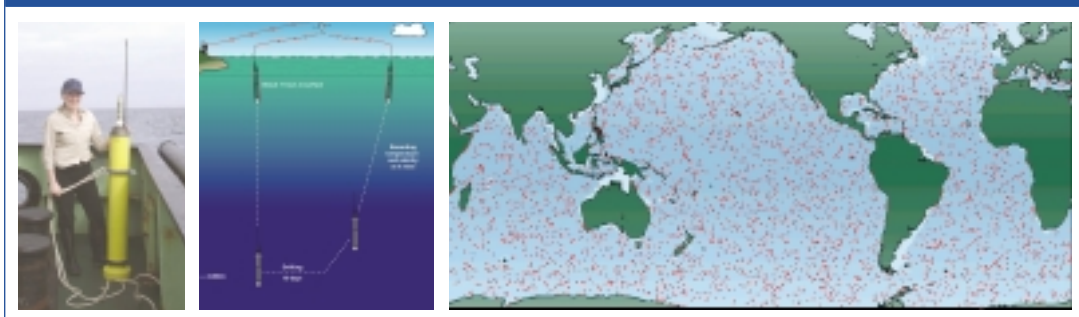
During the year to September 2000 some 24 drifting buoys were deployed by CEFAS (Centre for Environment, Fisheries and Aquaculture Science) in UK coastal waters. NERC has also deployed a number of drifters for research purposes: 6 by Dunstaffnage Marine Laboratory (DML) in the Weddell Sea, 2 by Plymouth Marine Laboratory (PML) in the Southern Ocean and 1 by SOC in a Scottish sea loch.

In 2001 all of the above programmes are continuing, with additional planned activities by British Antarctic Survey (4 ice drifters in the Bellingshausen Sea).

## Sub-Surface Floats (Argo)

Argo will be a global array of 3,000 free-drifting profiling floats (see Figure 10) that will measure the temperature and salinity of the upper ocean. Argo floats drift at a parking depth of typically 2,000 metres, rising to the surface every 10 days to record a temperature and salinity profile and transmit these data back via satellite before returning to depth and continuing another cycle. Each Argo float is expected to be capable of making as many as 150 cycles, and operate for 4 to 5 years.

Figure 10: (Left) an Argo float, (centre) illustration of a float cycle and (right) the projected global coverage of 3,000 Argo floats



The global observations from Argo will provide significant benefits for climate studies (detecting changes in the temperature and salinity of the oceans that are related to climate change), seasonal forecasting (improved long-term forecasts of warm/cold or wet/dry seasons and better warning of the likelihood of floods and drought) and operational oceanography (predictions of the ocean conditions for use by the oceanographic and marine research and industry communities). Argo is an important international programme to which the UK is making a significant contribution. Funding for the UK contribution to Argo is being provided by the DEFRA, MoD and NERC. The UK

contribution to Argo is being co-ordinated and managed by the Met Office and involves SOC, the British Oceanographic Data Centre (BODC) and the UKHO. Details are at <http://www.metoffice.gov.uk/research/ocean/argo>.

The aim of the UK Argo project is to establish by March 2003 an operational capacity to deploy about 50 floats each year, thus maintaining about 150 to 200 UK Argo floats in the water at any one time as a contribution to the global array, and to capture all Argo data in real time for operational ocean forecasting, as well as processing UK float data in delayed mode for climatological and hydrographic purposes. Additional NERC funding has been approved to host a regional Argo Data Centre for the Southern Ocean at BODC, starting autumn 2001. Long term funding, post-March 2003, has yet to be established.

A pilot UK Argo array of 10 floats in the North Atlantic is being established. This includes 5 Apex floats which were deployed in the Irminger Basin in January, together with 5 PROVOR floats which will be deployed autumn 2001. In addition, in May 2001 3 floats were deployed in the north-east Atlantic (Iceland Basin and Rockall Trough) and in July/August 5 floats were deployed in the south-west Indian Ocean; all of these are contributing to Argo. These, together with the delayed-mode data from the 7 SOC floats successfully deployed in 1996, provide the initial UK contributions to the international Argo programme.

During 2001 a further 25 floats will be deployed. 10 of these will be deployed from RRS *Charles Darwin* in the Arabian Sea in November/December. The other 15 floats will be deployed in the Norwegian Sea and Irminger Basin regions. Recent climate simulations made by the Hadley Centre suggest that freshening (decrease in salinity) in the Arabian Sea and southern Indian Ocean intermediate waters is a signal of anthropogenic climate change. In 2002 plans are to deploy a further 25 or so floats along the 32° S section in the southern Indian Ocean (supplementing the 5 in the south-west Indian Ocean). Other areas where UK plans to deploy floats in 2002/03 are the South Atlantic, eastern Mediterranean and Southern Ocean.

## Moored Buoys

The Met Office maintains an offshore array of 10 fixed open ocean and 2 inshore buoys supplying observations mostly from sea areas to the west of the UK. In addition 2 buoys are operated jointly with Meteo-France in the Bay of Biscay. These moored buoys also contribute to DBCP through EGOS and their data are broadcast on GTS. Together with 8 automatic observational systems on lightships and lighthouses, they make up the UK Marine Automatic Weather Station (MAWS) network, as shown in Figure 11. Data from these systems are used for routine weather forecasting, to monitor developing weather conditions, to provide information on the climatology of oceanic and coastal areas and ground truth for satellite observations. The network is supplemented by some 20 Shell Metnet stations funded and maintained by the Shell UK oil company.

Figure 11: The UK Met Office Marine Automatic Weather Station Network, showing the locations of moored buoys around the UK



## Automated Shipboard Aerological Programme (ASAP)

The ASAP in its present form began in the mid-1980s. It involves the generation of upper air profile data from data sparse ocean areas using automated sounding systems carried on board merchant ships plying regular ocean routes. Several National Meteorological Services operate ASAP units and the profile data are made available in real time on the GTS. ASAP data are archived alongside other radiosonde data by many national meteorological services. ASAP is an important contribution to both the WWW and GCOS. Most of the soundings are presently from the North Atlantic and North West Pacific Oceans, but the programme is expanding into other ocean basins, through a new, co-operative World-wide Recurring ASAP Project (WRAP).

Of the 21 ASAP units operated in 2000, about 13 of these operate in the European/N Atlantic area, including 1 UK operated ASAP on a UK VOS merchant ship (*CanMar Pride*) on the London to Montreal route. During 2000, 220 sondes were launched from *CanMar Pride*, see Figure 12, and 159 messages were transmitted, 97.5% of these were received over GTS. In 2001 a portable balloon launcher has been procured to reduce the sounding failure rate.

Figure 12: Radiosonde launch from the UK ASAP ship *CanMar Pride*



In addition the Met Office has been closely involved with setting up the WRAP on the UK voluntary observing ship *Palliser Bay*. This system was installed in March 2001 and upper air soundings commenced, as planned, on 20 April 2001. Of the 20 launches performed during the initial passage 16 were successful. At this stage of the project soundings are only being taken in the Indian and Southern oceans and in the Tasman Sea using a dedicated deck launcher. Soundings are also, on occasion, made by the British Antarctic Survey from the research ship RRS *James Clark Ross* and disseminated on GTS.

## 3.2 Other National Oceanographic and Marine Observations

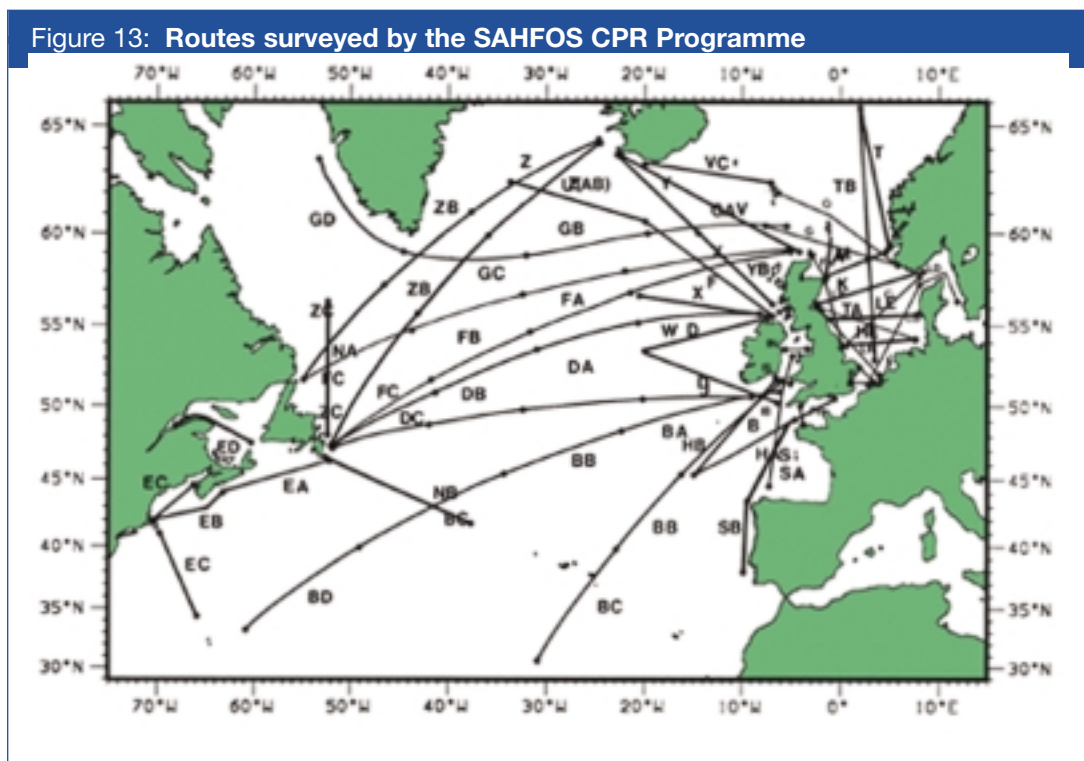
### Hydrographic Surveys

The Scottish Executive, Fisheries Research Services (FRS) undertakes routine hydrographic surveys between Faeroes and Shetland and the Ellett Line between the west coast of Scotland and Rockall. The north-east Atlantic surveys maintain continuous records stretching back over a century. DML and SOC are contributing to the occupation of the Ellett Line on an approximately annual basis and SOC has recently extended the line from Rockall to Iceland (see <http://www.soc.soton.ac.uk/GDD/hydro/nph/rockall/rockall.html>). The major objective is to monitor seasonal to decadal changes in the transport of water that makes important contributions to the global thermohaline circulation and whose variability is an issue for climate change. In addition FRS and the Norwegian Institute for Marine Research regularly survey (up to 5 times a year) the North Sea JONSSIS section.

POL has a continuing programme of observations (involving routine recording of sea level, bottom pressure and inverted echo soundings) in the Antarctic Drake Passage, the passage is one of the important 'choke points' between Antarctica and the other southern hemisphere continents at which to observe changes in the transport of properties from the Pacific to Atlantic Ocean and of the Antarctic Circumpolar Current. In most years since 1993 SOC has carried out repeat hydrographic sections across the Drake Passage (<http://www.soc.soton.ac.uk/JRD/HYDRO/scu/dp/index.html>)

## SAHFOS CPR Programme

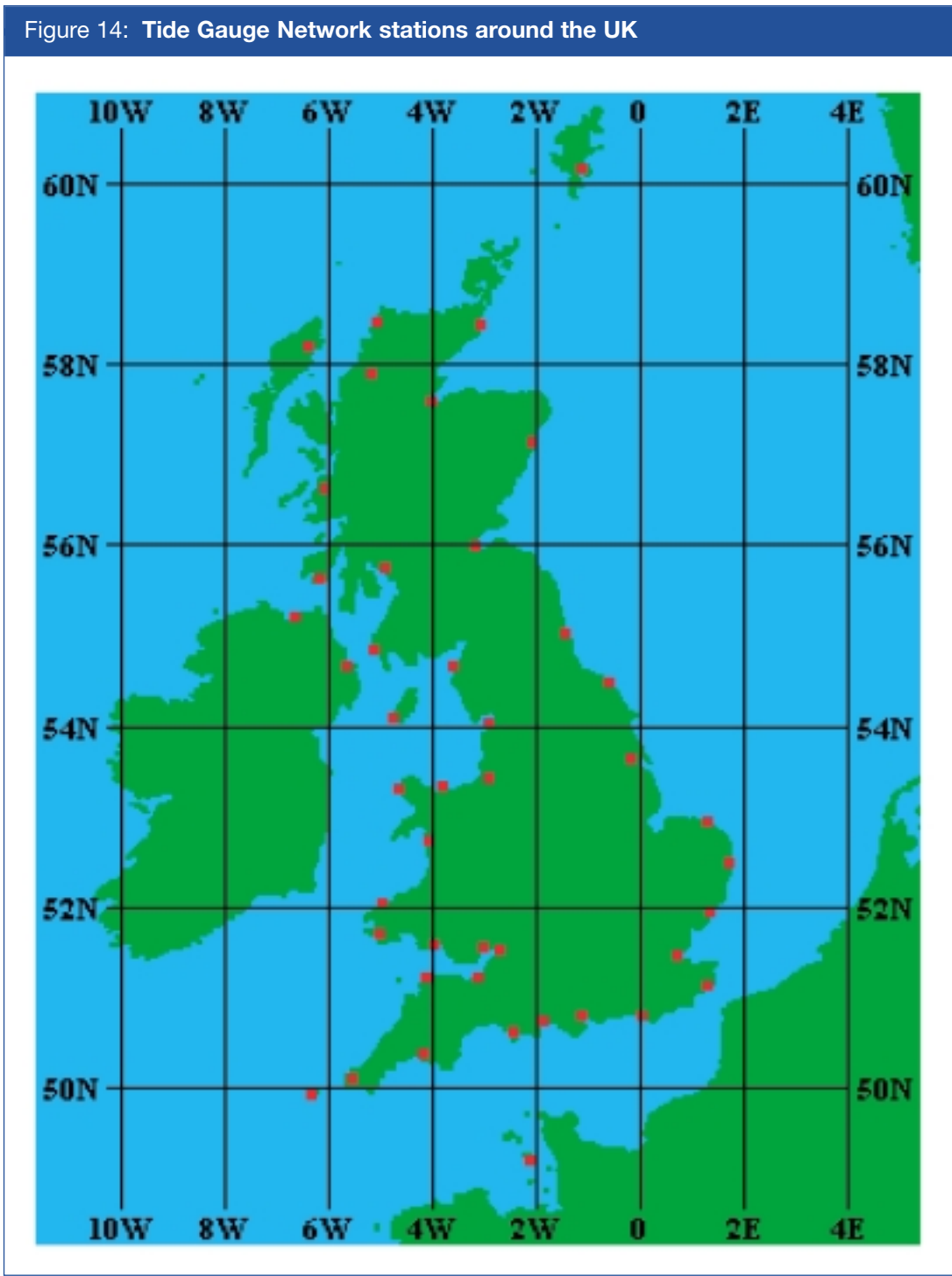
The Sir Alister Hardy Foundation for Ocean Science (SAHFOS), which operates the CPR (Continuous Plankton Recorder) programme (see <http://www.npm.ac.uk/sahfos/sahfos.html>), is based in the UK and funded largely by DEFRA and by NERC, although it receives essential financial backing from a number of other countries. Its database contains over 2 million records of plankton taxa covering the period 1946-1998 and a further 50,000 data records, from the year 1999, were added during 2000. The aims of the CPR Survey are to monitor the near-surface plankton of the North Atlantic and North Sea on a monthly basis, using Continuous Plankton Recorders on a network of routes to cover the area. Figure 13 shows the full network of routes that have been towed over the last 60 years, each with two-letter route identifier. (These routes were not all used at the same time.) Although in recent years CTD and fluorescence measurements have been added on some routes, the procedures used for both sample collection and analysis have changed little since the programme started in 1932, therefore long-term data comparability is assured.



## UK National Tide Gauge Network

Figure 14 shows the 44 sites of the UK National Tide Gauge Network, operated by the POL, where sea level data are collected, these include the 3 UK GLOSS sites previously mentioned. The British Oceanographic Data Centre (BODC) (see <http://www.bodc.ac.uk>) archives the 15-minute or hourly values of sea surface elevation collected by this network. Data collected from 1993 onwards have been quality controlled to modern standards; data collected prior to this are currently under review. These data are available from BODC under the conditions of the NERC Data Policy. Monthly and annual values of sea level are held by the PSMSL and can be downloaded from their web site (given earlier).





Based on the coherent variability in sea level changes around the British Isles (BI) a ‘BI sea level index’ has been derived as a guide to the ‘average state’ of mean sea level (MSL) in UK waters. The index is computed from the five longest UK MSL records at Aberdeen, North Shields, Sheerness, Newlyn and Liverpool. All five stations show a positive trend (i.e. an increase) in MSL, relative to the land, as do the majority of the other shorter records.

Further afield, the POL also operates a network of seven sea level stations in the South Atlantic and Antarctic Peninsula, of which most are part of the IOC GLOSS network. In addition, the UK Hydrographic Office operates a gauge at Gibraltar, while cooperation with US agencies provides gauges at Diego Ramirez and Bermuda.

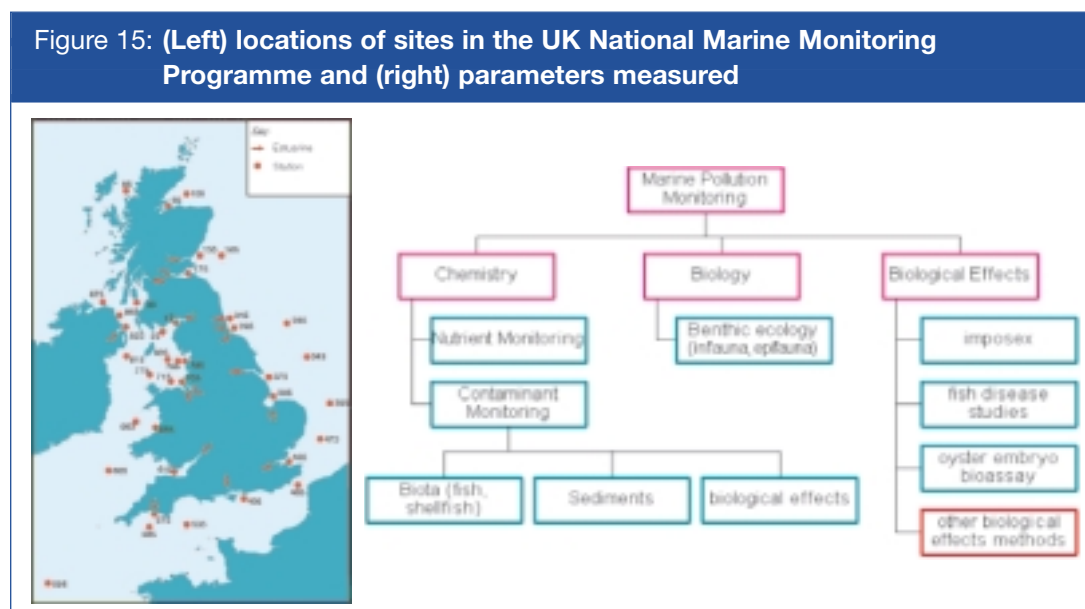
## CEFAS/FRS Coastal Temperature Network

CEFAS currently co-ordinates the collection of daily sea surface temperatures at 16 stations around England and Wales and FRS collate temperature data from 5 coastal stations around Scotland. Although these data are not available on GTS in real-time the data sets are available to GOOS (and hence GCOS) if required. The CEFAS/FRS coastal temperature records provide a good picture of the impact of the North Atlantic Oscillation (NAO) in UK coastal waters.

## UK National Marine Monitoring Programme (NMMP)

The National Monitoring Plan (now called the National Marine Monitoring Programme) was initiated in the late 1980s to co-ordinate marine monitoring in the UK between a number of organisations, see <http://www.cefasdirect.co.uk/monitoring/page-b3.asp> for further details. The NMMP aims to detect long-term trends in the quality of the marine environment, to ensure consistent standards in monitoring, to establish appropriate protective regulatory measures, to co-ordinate and optimise marine monitoring in the UK, and to provide a high quality data set for key variables. DEFRA is a major funder of the NMMP which involves CEFAS, FRS, DARDNI (Department of Agriculture and Rural Development Northern Ireland), EA and SEPA.

The objectives of the NMMP are: to establish as precisely as practicable the spatial distribution of contaminants in UK waters and to identify their biological impact, thus identifying any areas of specific concern; to detect trends in contaminant concentrations and biological well-being in those areas identified as being of concern; and to measure long-term natural trends in physical, biological and chemical parameters in selected areas. An initial spatial study was undertaken to achieve the first of these objectives. Figure 15 shows the locations of estuarine (16 sites) and intermediate/ offshore (38) sites in the UK National Marine Monitoring Programme and parameters measured.



In addition there is a joint UK-Netherlands monitoring programme in the southern North Sea designed to improve understanding of environmental variability and ecosystem functioning. It represents a further step towards creating a co-ordinated monitoring network for the North Sea.

## Other Biological and Chemical Observations

Since 1999 SOC has made detailed measurements of the dynamics of phytoplankton blooms in Southampton Water and the Solent using a continuously recording instrument package (Ferry-Box) on the Southampton Isle of Wight ferry (<http://www.soc.soton.ac.uk/GDD/Sonus/index.html>). In 2002, SOC work using Ferry-Boxes will be extended to making hydrographic and chemical measurements on the route between Portsmouth and Bilbao.

The Atlantic Meridional Transect (AMT) programme (see <http://www.pml.ac.uk/amt/index.html>) was initiated by the PML in 1995. The programme utilises the annual passage of the RRS *James Clark Ross* to Antarctica. Each year the ship sails from the UK to the Falkland Islands in September/October and from the Falkland Islands back to the UK in April/May. These voyages are used to collect biological, optical, physical and water quality data from a wide range of oceanographic provinces through the Atlantic Ocean. The AMT is currently suspended (for 2001) as PML can no longer support it financially alone. Recently, it has been submitted for funding under the NERC consortium project initiative with SOC and a number of Universities as co-partners. The proposal is under review at present with funding to start in 2002 if successful.

FRS has also been monitoring *Calanus fimarchius* and currents west of Scotland for at least 6 years in the Foinaven region where the current system is part of the Global Conveyor System. In addition to these studies FRS also collect weekly ecosystem data at Stonehaven (near Aberdeen) which permits phytoplankton numbers and community structure to be linked to environmental parameters.

In the last few years the Fisheries Departments have instituted a toxic algal blooms monitoring programme in shellfish fishing and harvesting areas in accordance with the requirements of the EU Shellfish Hygiene Directive. A pattern of toxic algal species occurrence is beginning to emerge from this programme, which is slowly expanding.

The Dove Marine Laboratory (University of Newcastle) currently operates a benthos, nutrient and plankton station and has undertaken long-term monitoring of plankton (since 1970) and benthic organisms (since 1965) off the local coast. Current work includes examining the relationship between changes in plankton and climate change.

Since 1954, the Port Erin Marine Laboratory has measured concentrations of various nutrients in the surface waters at its Cypris station, off the Isle of Man. Observations are also routinely made as part of the National Marine Monitoring Programme (NMMP), i.e. measurements of a variety of contaminants in water, sediments and biota, and of biological effects.

## Marine Coordination and Networking

As noted earlier the IACMST maintains an overview of marine activities across Government. It encourages links between Government and the national marine community, the wider application of marine science and technology, optimum use of major UK marine facilities, training and education and international links.

IACMST also has a Marine Environmental Data Action Group (MEDAG) which forms the UK Marine Environmental Data Network which has the following activities: to develop, maintain and make available inventories of data; to develop guidelines for data management; to improve mechanisms to facilitate data exchange (including contributing UK data to global databases) and maintains a web site **OceanNet** (<http://www.oceannet.org>) as a portal to data and information about the marine environment. The **OceanNet** web site provides links to various marine data catalogues (see Table S9). A recent initiative of the MEDAG is the compilation of a new UK Directory of Coastal Data Sets.

In addition DEFRA is supporting efforts to establish a UK Marine Environmental Change Network which will draw upon observations currently in progress or planned and assess the extent of change in recent time. In 2001 a report *Climate of UK Waters at the Millennium: Status and Trends*<sup>3</sup> was produced by the IACMST covering waters around the UK and builds on the annual *Ocean Climate Status Report*<sup>4</sup> for the waters around Scotland produced by the Scottish Executive FRS. The report presents the current (1999/2000) status and trends of marine parameters (marine weather, sea temperature, salinity, sea level, waves, plankton, nutrients, chlorophyll) in UK territorial waters. The intention is that an updated report for all UK coastal waters will be produced at intervals.

The Joint Nature Conservation Committee (JNCC) is responsible for coordinating the collection of a variety of information on the biota found around the UK coast. These data are available to the coastal module of GOOS. The JNCC's Marine Environmental Resource Mapping and Information Database (MERMAID) (see <http://www.jncc.gov.uk/mermaid/>) has been developed to provide wider access to information on marine sites, habitats and species around Britain and Ireland collected as part of the Marine Nature Conservation Review (MNCR) and originally held on the MNCR database. Use of Internet technology provides rapid access to the most up to date information held in JNCC's central data system, including map-based searches. The development of MERMAID also links closely with the National Biodiversity Network (NBN) (<http://www.nbn.org.uk>) and is being used as a demonstration project showing that delivery of database information over the Internet is both technically possible and advantageous.

The Marine Life Information Network for Britain and Ireland (MarLIN) (see <http://www.marlin.ac.uk>) is an initiative of the Marine Biological Association of the UK in collaboration with major holders and users of marine biological data. MarLIN will provide the most comprehensive and easily used source of information about marine habitats, communities and species around Britain and Ireland. MarLIN will develop a network for the location, cataloguing, collation and exchange of information on marine biodiversity in the coastal and shelf seas of Britain and Ireland and provide the marine node to the NBN.

<sup>3</sup> *Climate of UK Waters at the Millennium: Status and Trends*. Edited by Graham Alcock and Lesley Rickards. IACMST Information Document No. 9, (Also available at [www.oceannet.org/UKclimate-status](http://www.oceannet.org/UKclimate-status)).

<sup>4</sup> Turrell, W R, 2001. *Scottish Ocean Climate Status Report 1999*. Fisheries Research Services Report 06/00, Marine Laboratory, Aberdeen.

Table S8. National Oceanographic and Marine Observing Systems

System Component	Total # Stations	Appropriate for Characterizing National/Regional Climate		Time Series			Adequate Quality Control Procedures		Metadata available	Continuity # expected operational in 2005		
		Fully	Partly	No	# stations/platforms (#Data Digitized)	30-50y	50-100y	>100y			Fully	Partly
Sea Level (UK Tide Gauges)	44	☐	☐	☐	14	5	4	☐				44
Sea Level (Overseas, S Atlantic and Gibraltar Gauges)	8	☐	☐	☐	1	0	0	☐				8
Deep Sea Tide Gauges (bottom pressure recorders)	6	☐	☐	☐	0	0	0	☐				
Marine Automatic Weather Station (MAWS) Network	14 (Moored Buoys) 4 (Islands) 4 (Lightships)	☐	☐	☐				☐				22
Shell Metnet	22	☐	☐	☐				☐				
CEFAS/FRS Coastal Temperature Network	21	☐	☐	☐				☐				~20
Surface Drifters	51	☐	☐	☐				☐				~25+
Sub-Surface Profiles (floats)	13 (Argo) 7 (pre Argo)	☐	☐	☐				☐				150-200 (operating at any time)
Hydrographic Surveys	Ellett Line and extension to Iceland JONSSIS Section (North Sea) Drake Passage (Antarctic)											
SAHFOS CPR Surveys Plankton CTD/fluorescence	300-400 40-50	☐	☐	☐				☐				300-400
National Marine Monitoring Programme (Chemical/Biological)	16 (Estuarine) 38 (coastal and offshore)	☐	☐	☐				☐				16+38
Note, more complete summary tables for physical, chemical and biological observations are given in <sup>2</sup> IACMST Information Document No. 7.												

Table S9. Available Homogeneous Data Sets for Oceanographic Observations

Data Set Name	Date Published	Brief Description
North Sea Project CD-ROM	1992	Containing data collected on 38 cruises of RRS Challenger in the southern North Sea during the NERC North Sea Project (see <a href="http://www.bodc.ac.uk">http://www.bodc.ac.uk</a> )
BOFS North Atlantic Data Set CD-ROM	1994	Data collected on 11 deep-sea cruises to the Northeast Atlantic during the NERC Biogeochemical Ocean Flux Study (see <a href="http://www.bodc.ac.uk">http://www.bodc.ac.uk</a> )
OMEX-I Project Data Set CD-ROM	1997	Covering over 550 data sets collected on 47 cruise legs during the First Phase of the EU Ocean Margin Exchange Project (see <a href="http://www.bodc.ac.uk">http://www.bodc.ac.uk</a> )
ARABESQUE Project Data Set CD-ROM	1998	Upper ocean microbial biogeochemistry data from 2 cruises of RRS Discovery to the Arabian Sea (see <a href="http://www.bodc.ac.uk">http://www.bodc.ac.uk</a> )
WOCE Global Sea Level Data Set CD-ROM	1998	1st release of the hourly sea level data from over 160 sites worldwide that comprise the WOCE global tide gauge network (see <a href="http://www.bodc.ac.uk">http://www.bodc.ac.uk</a> )
UK Digital Marine Atlas (3rd Edition) CD-ROM	1998	Updated Windows version containing over 1,600 thematic charts of the seas around the British Isles (see <a href="http://www.bodc.ac.uk">http://www.bodc.ac.uk</a> )
LOIS Shelf Edge Study Data Set CD-ROM	1999	Data from moorings, drifters, cores and shipboard operations on 19 cruise legs on the Hebridean shelf during the NERC LOIS Project (see <a href="http://www.bodc.ac.uk">http://www.bodc.ac.uk</a> )
PRIME Project Data Set CD-ROM	1999	Mesocosm experiment and cruise data collected during the NERC Plankton Reactivity in the Marine Environment Project (see <a href="http://www.bodc.ac.uk">http://www.bodc.ac.uk</a> )
<b>Catalogues/Metadata Sets</b>		
GLOSS Station Handbook CD-ROM		Describing the 300 tide gauge sites worldwide that comprise the IOC GLOSS
International Current Meter Inventory		Covering over 29,000 moored current meter series collected by laboratories in 16 countries worldwide (see <a href="http://www.oceannet.org">http://www.oceannet.org</a> )
European Directory of Marine Environmental Data (EDMED)		Directory describing over 2,300 data sets from 500 organizations across Europe (see <a href="http://www.oceannet.org">http://www.oceannet.org</a> )
UK Directory of Marine Environmental Data Sets		A component of EDMED (above), over 500 data sets collected by 90 UK laboratories, covering a wide spectrum of marine data types, are described (see <a href="http://www.oceannet.org">http://www.oceannet.org</a> )
UK Moored Current Meter Inventory		Includes 10,000 entries relating to current meter records collected by 75 organizations in both the public and private sectors. Most of the data have been collected in the shelf seas around the British Isles and the eastern North Atlantic (see <a href="http://www.oceannet.org">http://www.oceannet.org</a> )
UK Inventory of Marine Monitoring Observations		Includes information relating to on-going measuring programmes from 10 organizations (see <a href="http://www.oceannet.org">http://www.oceannet.org</a> )
UK Cruise Inventory		Includes information on over 4,000 research cruises and summaries of the data collected, carried out by 73 organizations over the past 30 years (see <a href="http://www.oceannet.org">http://www.oceannet.org</a> )
MERMAID		Marine Environmental Resource Mapping and Information Database (see <a href="http://www.jncc.gov.uk/mermaid">http://www.jncc.gov.uk/mermaid</a> )
NBN		National Biodiversity Network ( <a href="http://www.nbn.org.uk">http://www.nbn.org.uk</a> )
MARLIN		Marine life information datasets (see <a href="http://www.marlin.ac.uk">http://www.marlin.ac.uk</a> )

## CHAPTER 4

# Terrestrial Observations

### 4.1 Contributing to GCOS

For terrestrial observations GCOS works with the Global Terrestrial Observing System (GTOS), which is being developed for land surface ecosystem, hydrosphere, and cryosphere measurements. The initial observing system for GTOS (and GCOS) is being developed around a series of existing networks, pilot and demonstration projects, and IGOS (Integrated Global Observing Strategy) themes. GTOS is developing various networks including the Permafrost Network (GTN-P), the Glacier Network (GTN-G) and the Global Flux Tower Network (FLUXNET). In addition there is the Ecology Network (GTN-E) and the Hydrology Network (GTN-H). These elements are being organized under the umbrella of the Global Terrestrial Observing Network (GT-Net). GT-Net is a “system of networks”, formed by linking existing monitoring sites and networks with the aim of better understanding global and regional change. GT-Net includes both thematic and regional networks.

Table 3: Participation in the global terrestrial observing systems				
	GTN-P	GTN-G	FLUXNET	GT-Net
How many sites are the responsibility of the Party	0	0	3	60*
How many of those are operating now	0	0	3	60
How many are providing data to international data centres now	0	0	1	60
How many are expected to be operating in 2005	0	0	3	60
* Includes 47 ECN sites and 13 (contributing to World Network of Biosphere Reserves, International Co-operative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems) others.				

### Environmental Change Network (ECN)

The ECN programme (see <http://www.ecn.ac.uk>) operates a network of 12 terrestrial and 42 freshwater sites throughout the UK. Sites range from upland to lowland, moorland to chalk grassland, small ponds and streams to large rivers and lakes. A consortium of 14 UK government departments and agencies sponsor the ECN. These organizations contribute to the programme by funding either site monitoring and/or network co-ordination activities. 3 ECN sites (Alice Holt, Moor House/Upper Teesdale and Wytham) are part of the GTOS GT-Net demonstration project, and 47 are designated as GT-Net sites.

At the terrestrial sites measurements are made, at appropriate intervals, of: the local meteorology; atmospheric chemistry; precipitation chemistry; surface water discharge, chemistry and quality; soil solution chemistry; soil properties; vegetation; vertebrates and invertebrates. Records of management activities at the sites are maintained.

At the freshwater sites measurements are made, at appropriate intervals, of: surface water chemistry and quality; surface water discharge; macro-invertebrates; aquatic macrophytes; zooplankton; phytoplankton and epilithic diatoms.

The objectives of the Environmental Change Network are:

- To establish and maintain a selected network of sites within the UK from which to obtain comparable long-term data sets through the monitoring of a range of variables identified as being of major environmental importance.
- To provide for the integration and analysis of these data, so as to identify natural and man-induced environmental changes and improve understanding of the causes of change.
- To distinguish short-term fluctuations from long-term trends, and predict future changes.
- To provide, for research purposes, a range of representative sites with good instrumentation and reliable environmental information.

Figure 16: Monitoring sites in the Environmental Change Network





The ECN is a founder member of the GTOS GT-Net and provides metadata about its sites and measurements to the GTOS-TEMS meta-database (<http://www.fao.org/gtos/tems/index.jsp>). The Network is also in position to provide summary data although, until now, GTOS has not been able to make effective use of these.

ECN sites are contributing to two ongoing GTOS Global Demonstration Projects, both of which are relevant to climate change observing systems. These are: (i) the GTOS Demonstration Project on global mapping of Net Primary Productivity (NPP) (<http://www.fao.org/gtos/actthemanpp.html>), and (ii) the GTOS/IGOS-P Terrestrial Carbon Observation Programme (TCO) (<http://www.fao.org/gtos/Actthematco.html>).

The ECN encompasses the spirit of all the GCOS/GOOS/GTOS climate monitoring principles (see Appendix II) and relevant best practices, and is one of the leading national terrestrial observing networks in the world. It follows strict QC procedures from data collection through data management to data dissemination. Raw data are supplied under licence, but data products of the kind usually required by GTOS can be provided free of charge and are available directly over the Internet. All data are maintained and disseminated through a central database at the CEH, Merlewood. Further information on ECN and access to data are available at <http://www.ecn.ac.uk>.

## Carbon Flux Monitoring

Long-term monitoring of the fluxes of carbon dioxide, water vapour and energy exchange is undertaken at 3 sites in the UK: Aberfeldy, Harwood Forest and Alice Holt.

One of these, at Aberfeldy in Griffin Forest, Scotland has been operating continuously since the end of 1996 as part of the EUROFLUX, then CarboEuroFlux, programmes and thus contributes to FLUXNET. Site details are at <http://daac.ornl.gov/FLUXNET/EUROFLUX/site11.html>. The site is operated by the Institute of Ecology and Resource Management at the University of Edinburgh. The data from the EUROFLUX programmes are sent after quality checks to the FLUXNET database (<http://www-eosdis.ornl.gov/FLUXNET/>) and UK data appear on the relevant CD-ROM archives as and when they are produced for the wider community. The University has also contributed to instrumentation development and standardization and data quality, analysis and archiving procedures in FLUXNET. Other support is provided in the form of free-of-charge software which can log and re-process eddy covariance data (<http://www.ierm.ed.ac.uk/research/edisol/index.html>). The software is in widespread use (about 35 sites) in FLUXNET.

The University of Edinburgh (UoE) has operated two sites in Harwood Forest, Northumberland since 2000 and at which measurements are being made in a 30-year old Sitka spruce stand and a clearfell site. This is part of the CarboAge project (which UoE co-ordinates) funded by the EC (<http://www.bgc-jena.mpg.de/public/carboeur/projects/cag.html>). Data from Harwood are processed according to the FLUXNET protocols and will be submitted to FLUXNET for inclusion in the database and its subsequent publication on CD-ROM. In addition, the CarboAge consortium plan to produce a series of 'briefing notes' for policy makers on the subject of carbon budgeting for post-Kyoto scenarios.

The Forestry Commission operates the third site at one of its Level II plots – see the section on Forest Health. This is located at Alice Holt and is in lowland oak woodland. Arrangements are being made to incorporate the site in the EUROFLUX network, although to date data and information transfer has not taken place. The site has been running since 1998 and uses the UoE's system (*EdiSol*) referred to above.

Within the CarboEurope consortium, which includes CarboEuroFlux and Carbo-Age, there is another research project which has established a network of sites across Europe at which air samples are taken at various heights to 3,000 m above sea level. The project is AeroCarb (<http://www.aerocarb.cnrs-gif.fr/project.html>) and the objectives are to provide sufficient information on the latitudinal and altitudinal variation in CO<sub>2</sub>, CH<sub>4</sub> O<sub>2</sub> and their appropriate isotopes, so that inverse modelling studies can monitor the C balance of Europe and ascertain the size of sources and sinks for C at this scale. The UK contributor to this programme is UoE which operates a bi-weekly series of air sampling campaigns from Perth airport. Samples are taken at 6 flight levels above the University's Griffin field site at which the CarboEuroFlux measurements are being made. The project started in 2001 and will run for two years.

UK scientists from the CEH and the Institute for Ecology and Resource Management (UoE), are also active in monitoring carbon fluxes from tropical rainforest in Amazonia through participation in the Large-scale Biosphere-Atmosphere Experiment in Amazonia (LBA), an international experiment led by Brazil. In collaboration with scientists from Brazil and the Netherlands the fluxes at five sites over Amazonia are being routinely monitored.

## Permafrost Monitoring

As a low-lying temperate country, the UK operates no GTN-P sites. However, UK scientists played active roles in the EU 4<sup>th</sup> Framework Permafrost and Climate in Europe (PACE) project, which was completed in March 2001. They continue to participate in the work of the International Permafrost Association <http://www.geodata.soton.ac.uk/ip>.

The PACE permafrost borehole monitoring network has been established and data are being collected, analysed and archived. Efforts are being made to continue this international research programme into the 21st Century, to foster a regional-scale approach to permafrost research, and in particular, long-term permafrost monitoring within the GTN-P programme of the Global Climate Observing System.

## 4.2 Other Terrestrial Observations

Within the UK there are a wide range of terrestrial observations that are made and which are of relevance to GCOS; some (but not all) of these monitoring programmes are described below.

## Forest Health Monitoring

In the UK, the Forestry Commission embarked on the first national survey of tree health in 1984. It has been repeated annually, and currently assesses a total of 8,471 trees of five species in 355 plots<sup>5</sup>. The results are in the public domain, in the form of Notes issued by the Forestry Commission.

Under initiatives by the United Nations Economic Commission for Europe (UNECE), various national surveys were incorporated into a large-scale pan-European survey of forest condition in 1987. This became known as the 'Level I' programme, with the major aim of monitoring crown condition changes over a long period of time in a large number of forest plots. There are now 15 EU and 19 non-EU country participants in the Level I programme. The UK has assigned approximately 90 of its national forest health plots to this European network. In total, the crown condition of almost 100,000 trees is assessed annually in around 5,400 plots, representing almost 200 million hectares of forest in Europe.

The Level I network provides accurate information on the extent and spatial distribution of crown condition in Britain and Europe, and a database for analysis of changes over time. However, it cannot identify cause-effect relationships. In particular, it does not determine the extent to which air pollution and other stress factors are responsible for the health of forest systems. To achieve this, a second series of plots for intensive monitoring of forest growth and condition, and the environmental conditions that cause them, was initiated under European legislation in 1994. This is known as the 'Level II' programme.

EU legislation for the Level II programme requires each country to nominate and finance a National Focal Centre responsible for the following tasks:

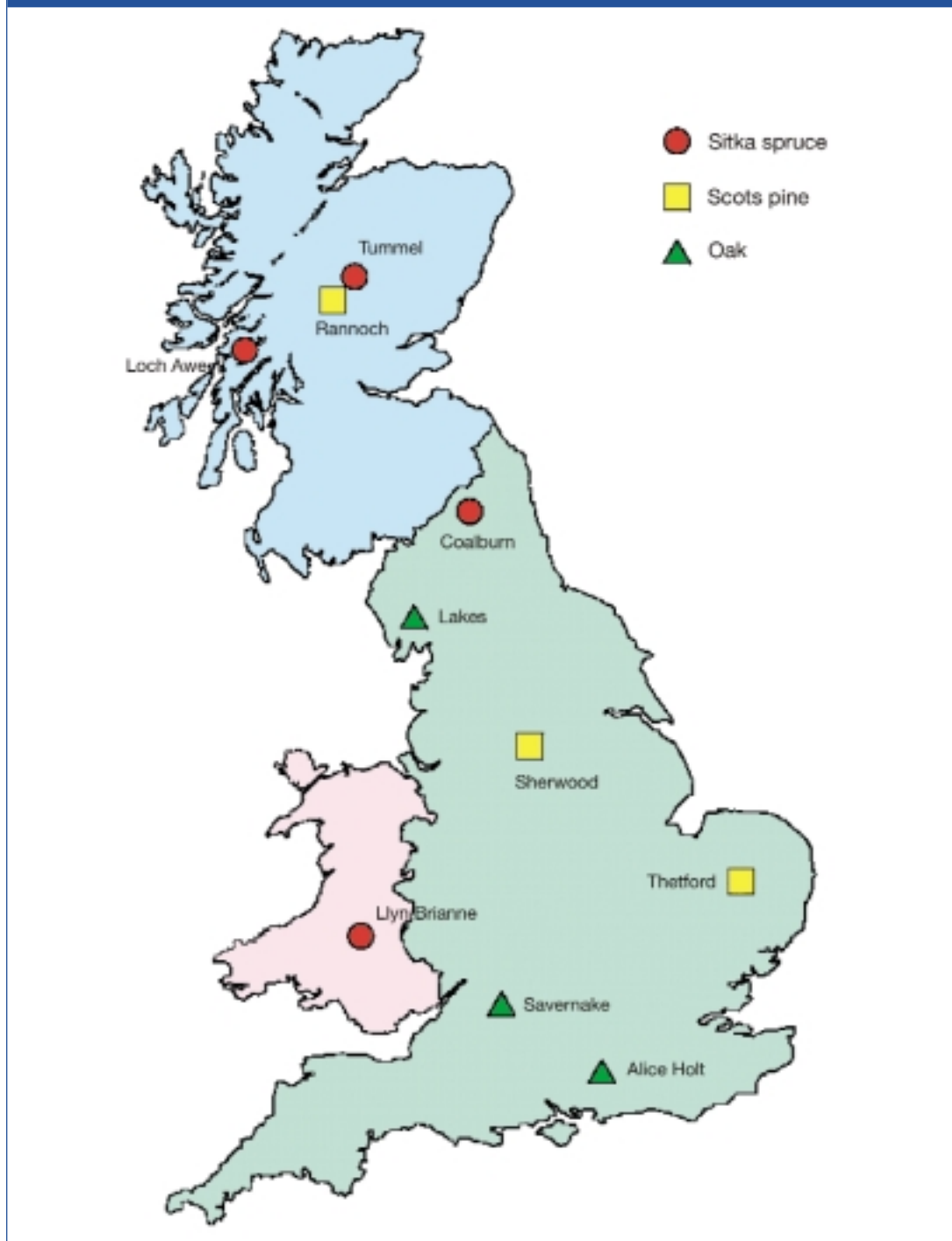
- the establishment of a network of permanent intensive monitoring plots;
- collection, validation and storage of national data;
- data analysis and evaluation at the national level;
- data submission to the European Commission;
- participation in evaluation and interpretation of data at the European level.

The UK National Focal Centre is based in Forest Research (an agency of the Forestry Commission). Since 1995, 10 permanent intensive monitoring Level II plots have been installed in Britain in accordance with EU protocols – see<sup>6</sup> for details. The 10 level II sites are shown in Figure 17, a number of these sites also have automatic weather stations. Each plot is 0.3 ha in area and contains a permanent mensuration sample plot of 0.1 ha for growth studies. These are monitoring three important forest species: Sitka spruce, Scots pine and oak; whilst there is an intention to also monitor beech in the near future. Monitoring is expected to take place for a minimum of 20 years.

<sup>5</sup> Redfern, D., Boswell, R. and Proudfoot, J. (2000). *Forest condition 1999*. Forestry Commission Information Note 33. Forestry Commission, Edinburgh.

<sup>6</sup> Durrant, D. (2000) *Environmental Monitoring in British Forests*. Forestry Commission Information Note 37. Forestry Commission, Edinburgh.

Figure 17: The UK network of Level II Forest Health Monitoring sites



The European Level II network comprises some 600 plots and is a valuable platform for atmospheric pollution research. The programme has been reviewed in depth recently and its aims have been broadened to reflect the growing co-operation with other European environmental interests and programmes, including biodiversity, sustainability, climate change and carbon sequestration.

## Land Cover and Ecological Mapping

### THE LAND COVER MAP OF GREAT BRITAIN

The Land Cover Map ([http://www.ceh.ac.uk/products\\_services/data/lcm/index.html](http://www.ceh.ac.uk/products_services/data/lcm/index.html)) of Great Britain was mapped in detail by the CEH using Landsat Thematic Mapper data from 1989 to 1990. It is a raster or grid-based product which records 25 cover-types, on a 25 m grid, with minimum mappable units of 0.125 ha, showing landscape patterns at the field-by-field scale. A similar map is being produced from satellite data captured in 1998 to 1999 to form LCM2000.

Using methods developed within the CORINE (Co-ordinating Information on the European Environment) experimental programme, a land cover data base <http://etc.satellus.se> is available operationally for the greater part of the 3.5 million km<sup>2</sup> covered by the European Union and progress is being made in the production of maps to CORINE standards for Central and Eastern Europe. The CORINE Land Cover map has generally been produced by visual interpretation of hard copy satellite images followed by manual digitising to give computer maps which show 44 cover types, as digital map outlines, in vector format at 1:100000 scale, with minimum mappable units of 25 ha. A project to convert the Land Cover map of Great Britain to CORINE Land Cover format has been carried out successfully by the CEH.

### COUNTRYSIDE SURVEY 2000

Countryside Survey 2000 (CS2000) is a major audit of the British countryside. It has involved both detailed field observations and analysis of LCM2000 to provide a complete land cover census for Great Britain and Northern Ireland. Detailed field observations have been made in a random sample of 1 km grid squares across Great Britain. Collection of data such as habitat types, hedgerows, plant species and freshwater invertebrates complements the powerful satellite imagery and enables a deeper level of ecological understanding. Many of the sample sites were first visited in 1978 and subsequently in 1984 and 1990 providing a time series of changes in the countryside.

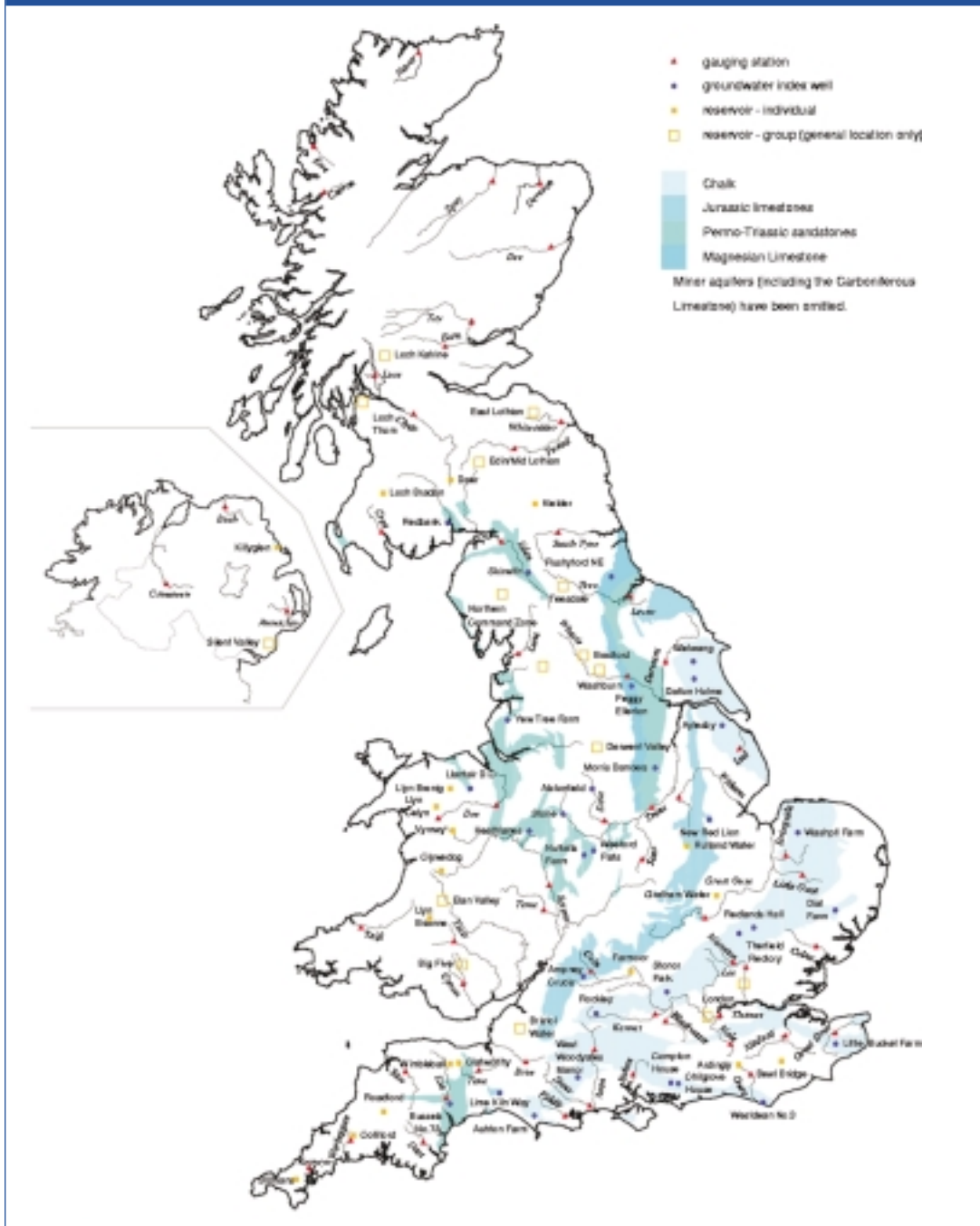
Countryside survey is co-sponsored by NERC and DEFRA and supported by several other agencies. Further information is available on <http://www.cs2000.org.uk>. Data availability and access policy are described on the web site.

## Hydrological Monitoring

To service a very broadly based need for river flow data, the UK maintains a network of over 1,300 gauging stations. Responsibility for these stations rests principally with the EA in England and Wales, the SEPA in Scotland and in Northern Ireland, the Rivers Agency. These measuring authorities maintain their own regional hydrometric databases and routinely forward processed data to the National River Flow Archive (NRFA), <http://www.nwl.ac.uk/ih/nrfa/index.htm> at CEH, Wallingford. Currently the archive holds more than 35,000 station years of daily and monthly flow data.

The British Geological Survey, also at Wallingford, maintains a National Groundwater Level Archive (NGLA), <http://www.nwl.ac.uk/ih/nrfa/groundwater/index.htm>. This contains water level data from a representative subset of around 170 wells and boreholes throughout the UK; in total there are 4 to 5,000 groundwater level monitoring sites in the UK.

Figure 18: The UK network of National Hydrological Monitoring sites



Hydrometric data entering the archives are subject to careful quality control and made available through a comprehensive data retrieval service. A subset of the monitoring sites, for which provisional data are submitted at monthly intervals, are used in the UK National Hydrological Monitoring Programme (see Figure 18); outputs from this programme include monthly and annual status reports, briefing material, and summary information routinely posted on the WWW.

The NRFA and NGLA holdings, together with the ability to analyse and interpret them – provide a capability to report regularly on hydrological conditions throughout the UK. Wide dissemination of such information – including regular provision of data to the Global Runoff Data Centre (Koblenz, Germany) – helps to increase public understanding of hydrological and water resource issues. The data are released in accordance with NERC policy on these matters, as described earlier.

The framework for hydrometric monitoring in the UK was largely established in the 1960s when the adequacy of water resources was the principal concern. The network grew rapidly up to the 1980s – a necessary response to the heterogeneity of the UK (in terms of its climate, geology, land use and patterns of water utilisation), but subsequent regional reviews, often driven by cost considerations and reflecting operational and regulatory imperatives rather than national strategic needs, made inadequate provision for the identification and attribution of trends. Most UK rivers are mere streams in a global context and their modest flows make them vulnerable to the impact of climate change. But the impact of artificial influences on river flow regimes is very pervasive; there are few pristine catchments where long term monitoring has been maintained. In order to improve the national capability to identify and interpret hydrological trends, a national network of benchmark catchments (around 80) is currently being designated. Holdings of reference and spatial data relating to these catchments will be extended to help in distinguishing between climate-driven trends and those due to anthropogenic factors. A parallel initiative will examine the homogeneity of nominated river flow (and groundwater level) records to establish whether they provide a suitable historical perspective against which to assess any trends identified in future years.

## UK Acid Waters Monitoring Network (UKAWMN)

The network was established in 1988 to monitor the ecological impact of acid deposition in areas of the UK believed to be sensitive to acidification and is funded by DEFRA and the Department of the Environment Northern Ireland. Over a decade on, its database provides a long-term record of water chemistry and biology that is unique for upland freshwater systems in the UK.

The network consists of 11 lakes and 11 streams which are monitored chemically and biologically, <http://www.geog.ucl.ac.uk/ukawmn/map.htm>. At all sites, regular spot samples are taken for laboratory analysis of an extensive range of chemical determinands, including pH, conductivity, and a standard suite of base cations, anions and metals. At a subset of streams, pH, conductivity and stream flow are also continuously monitored to provide a more detailed record of acid episodes. Epilithic diatoms, aquatic macrophytes and benthic invertebrates are sampled annually in the spring/summer and fish surveys for stream sites and the outflow streams of lakes are conducted each autumn.

At the lake sites, a full palaeoecological investigation has been conducted during the first five years of the project (1988-1992). This involved diatom, geochemical and carbonaceous particle analysis of <sup>210</sup>Pb dated sediment cores and diatom-based reconstruction of lake water pH for the past 100 or so years. These historical reconstruction techniques allow observations of more recent change to be placed in a longer-term context. Fresh sediment is now recovered annually from sediment traps in each lake and analysed for diatoms and carbonaceous particles.

Data generated at UKAWMN sites underpin the UK contribution to the two UNECE International Co-operative programmes: 'Integrated Monitoring' and the 'Assessment and Monitoring of Acidification of Rivers and Lakes', and thereby contribute to the requirement under the Second Sulphur Protocol to monitor the extent and impact of acid deposition. Four UKAWMN sites are integrated in the Environmental Change Network (Lochnagar, Scoat Tarn, Llyn Llagi and Old Lodge) and Lochnagar is the representative site in the UK on the EU funded Mountain Lakes Research project EMERGE (and formally MOLAR).

## Observations in the Antarctic

The NERC Antarctic Environmental Data Centre hosts the British Antarctic Survey (BAS) data catalogue that can be used to search for information on BAS's data holdings. It is also the UK National Antarctic Data Centre within the SCAR-COMNAP Antarctic Data Directory System. This is an international network of data centres within countries active in Antarctic research that are developing a common gateway to their data holdings – the Antarctic Master Directory.

The long term monitoring of water chemistry in Signy Island lakes is unique in polar limnology, in its duration (30 plus years), detail, and range of sites. It details seasonal patterns of snow and ice cover, inorganic nutrient status and chlorophyll-a and includes vertical profiles of various physical and chemical parameters. There are detailed data for several study lakes and twice/thrice yearly analyses for all the Signy Island lakes. Temperature and light climate has been studied in certain lakes using automatic data loggers. Micrometeorological monitoring with additional data loggers are providing data on solar radiation, air temperature, humidity and wind conditions. The data sets are entirely located in the Terrestrial and Freshwater Resource Centre ORACLE database system and summary information on them can be found in the BAS Data Catalogue.

The Biological Sciences Division of BAS holds a wealth of biological material collected from Antarctic and sub-Antarctic marine and terrestrial environments. The herbarium, for example, holds over 40,000 dried plant specimens representing over 2,000 species. In addition to the biological material, there are a number of long-term data sets that are now proving particularly useful for looking at the effects of recent climate change on the biological environment. Details can be found on the BAS Data Catalogue, and data sets include information from the Bentham spectroradiometer at Rothera and automatic data loggers monitoring environmental variables (discussed in Section 2.2 earlier).



**Table S10. National Terrestrial Observing Systems**

Systems	Total # Stations	Appropriate for National/Regional Climate		Time Series			Adequate Quality Control Procedures	Metadata available	Continuity		
		Fully	Partly	No	# stations/platforms (#Data Digitized)	30-50y				50-100y	>100y
River Discharge (Streamflow Gauges)	> 1,300		☉							See text	
Ground Water Storage (e.g., Boreholes)	NGLA ~170 4 – 5,000 (All)		☉								~170
State of Ground (soil temps, snow cover, frozen)	See Climatological Stations in Table S1										
State of Ground (soil temps, snow cover, frozen)	At 12 terrestrial ECN sites		☉				☉				12
Radiation	See Table S2										
Carbon Flux (EuroFlux)	3		☉								
Carbon (AeroCarb)	1 (6 heights)						☉			2001-2003	
UK Acid Waters Monitoring Network	11 lakes 11 streams									Established 1998	22
Permafrost/Glaciers	0										

Table S11. National Ecological Observing Systems

Systems	Total # Stations	Appropriate for Characterizing National Climate		Time Series # stations/platforms (Data Digitized)	Adequate Quality Control Procedures		Metadata available	Continuity # expected operational in 2005
		Fully	Partly		No	Fully		
Environmental Change Network	12 (land) 42 (freshwater)	☉	☉	30-50y 50-100y 100-300y >300y	☉	☉		~50
Forest Health	355 (All) 90 (Level I) 10 (Level II)	☉	☉		☉	☉		~100 ~10

Table S12. Available Homogeneous Data Sets for Terrestrial and Ecological Observations

Data Set Name	Climate Parameter	# Stations or Grid Resolution and Region covered	Time Period	References
Land Cover Map of Great Britain	25 cover types	25 m grid	1989 – 1990	<a href="http://www.ceh.ac.uk/products_services/data/lcm/index.html">http://www.ceh.ac.uk/products_services/data/lcm/index.html</a>
LCM2000	25 cover types	25 m grid	1989 – 1999	<a href="http://www.ceh.ac.uk/data/lcm/LCM2000.shtml">http://www.ceh.ac.uk/data/lcm/LCM2000.shtml</a>
Countryside Survey 2000		Random selection of 1 km grid squares	1978, 1984 and 1990	<a href="http://www.cs2000.org.uk">http://www.cs2000.org.uk</a>

## CHAPTER 5

# Space-based Observing

The UK contributes to space-based observations through the European agencies ESA (a partnership of 15 European Member Governments, with Canada affiliated) and EUMETSAT (a partnership of 17 European Governments, with 3 Cooperating States). As such, details of the platforms and sensors are not given in this section, which focuses on UK specific needs and efforts. Many drivers for future Earth Observation (EO) missions are expected to originate in policies responding to, or created by, international fora. Others will address international science questions such as climate change. The UK strategy for EO is therefore delivered, largely, through participation in international programmes.

## The British National Space Centre (BNSC)

BNSC ([www.bnsc.gov.uk](http://www.bnsc.gov.uk)), which is Britain's space agency, represents the UK in ESA. BNSC advises and acts on behalf of Government and the Research Councils, to provide a focus for UK civil space policies, and help win the best possible scientific, economic and social benefits from putting space to work. BNSC's principal objectives include the improvement of knowledge of the environment and its resources through Earth Observation. The organisations, which have come together to form BNSC on a voluntary basis, are:

- Department of Trade and Industry (where BNSC is located),
- Office of Science and Technology,
- Department of the Environment, Food and Rural Affairs,
- Department of Transport, Local Government and the Regions,
- Foreign and Commonwealth Office,
- Natural Environmental Research Council,
- Particle Physics and Astronomy Research Council,
- Ministry of Defence,
- QinetiQ (formerly the Defence Evaluation and Research Agency)
- Rutherford Appleton Laboratory,
- Met Office.

BNSC has published a UK Space Strategy<sup>7</sup> which includes the following objectives relevant to GCOS: to carry out excellent basic research into the working of the Earth system through measurements from space and to maintain the UK as a world leader in scientific understanding of the planet and its environment; and to contribute to an independent knowledge base for developing effective, long term environmental policies and monitoring their implementation.

The UK science base and engineering base in EO is spread across a number of agencies. While NERC has lead responsibility, there are important contributions from the Hadley Centre (Met Office), from other Research Councils, from collateral funding of the

<sup>7</sup> UK Space Strategy 1999-2000 – New Frontiers. Available at <http://www.bnsc.gov.uk>.

university sector and from industry. In particular, NERC maintains a high quality programme of user-driven EO research in support of its environmental science objectives. It focuses on increasing our understanding of the interactions between atmosphere and land/sea surfaces, and of global environmental change. This will improve our ability to predict, monitor and mitigate the effect of natural environment hazards.

Many applications currently at the research stage involve the measurement of change over a period of time. There is currently no agreed plan for the long-term maintenance of archives of data sets enabling such change to be measured. BNSC are promoting an international strategy to resolve this issue.

## ESA and EUMETSAT Platforms and Programmes

ESA EO platforms that are either operational now or due for launch before the end of 2004, include:

- ERS-2. Launched in 1995. Follow-on to ERS-1 in examining the Earth by radar, microwaves and infrared radiation, carries an additional instrument to observe the ozone hole.
- ENVISAT. Launched planned for November 2001. European environmental satellite to succeed ERS series with advanced versions of instruments used in ERS-2, and several important new ones.
- MSG-1 (ESA & EUMETSAT) 2002 and MSG-2 about 18 months later. The Meteosat Second Generation geostationary satellites will give far sharper weather information than that from the Meteosat's, which have operated over the Equator since 1977.
- Cryosat 2003. The first low cost opportunity mission, led by University College, London, in ESA's new Earth Explorer series. Cryosat will use twin radar's to chart changes in the world's ice sheets and sea ice more accurately than before.
- METOP-1 (ESA & EUMETSAT) 2005. While Meteosat and MSG observe the weather from above the Equator, METOP will fly over the poles, with advanced instruments for sounding the atmosphere.

ENVISAT (see <http://envisat.esa.int/> for details) will provide measurements of the atmosphere, ocean, land, and ice over a five year period. ENVISAT will ensure the continuity of the data measurements of the ESA ERS satellites. The ENVISAT data will support Earth science research and allow monitoring of the evolution of environmental and climatic changes. Monitoring sensors include ASAR (Advanced Synthetic Aperture Radar), GOMOS (Global Ozone Monitoring by Occultation of Stars), MIPAS (Michelson Interferometer for Passive Atmospheric Sounding), MERIS (MEdium Resolution Imaging Spectrometer Instrument), MWR (microwave radiometer), RA-2 (Radar Altimeter), AATSR (Advanced Along Track Scanning Radiometer), DORIS (Doppler Orbitography and Radiopositioning Integrated by Satellite) and SCIAMACHY (SCanning Imaging Absorption SpectroMeter for Atmospheric CHartography).

In particular the prime purpose of AATSR is to establish continuity of the (ERS) ATSR-1 and ATSR-2 data sets of SST to ensure the production of a unique 15 year near-continuous data set at the levels of accuracy required (0.3 K or better) for climate research. As part of the DEFRA-funded Climate Prediction Programme the Met Office are involved in a project to investigate techniques for cloud clearing the satellite data to obtain the maximum amount of data with the minimum amount of cloud contamination; improve techniques for retrieving skin SST from satellite-measured brightness temperatures (elimination of residual erroneous trends and improvement of r.m.s.); convert AATSR retrievals of skin SST to form bulk SST (which is both compatible with in situ measurements and a better diagnostic for climate models), and develop improved techniques for this. A second project aims to develop retrieval algorithms for the generation of cloud products from ATSR-2 and AATSR and to contribute to the development of parametrizations of cloud radiative properties for use in the climate model.

The Met Office represents the UK on EUMETSAT, which has the following current programmes:

- MTP (Meteosat Transition Programme). Operation of Meteosat's-7, -6 (standby), -5 (Indian Ocean) in geostationary orbit.
- MSG (Meteosat Second Generation). Future operation of MSG-1, -2 and -3 in geostationary orbit.
- EPS (European Polar System). Future operation of METOP-1 (launch scheduled for December 2005), -2 and -3 in morning polar orbit.

As part of its distributed Application Ground Segment EUMETSAT has a network of Satellite Application Facilities (SAF's), as specialised development and processing centres; see <http://www.eumetsat.de/>. These utilise the specific expertise available in EUMETSAT's Member States, and complement the production of standard meteorological products derived from satellite data at EUMETSAT's Central Facilities in Darmstadt. Seven SAF projects are undergoing development, focusing on the following applications:

- Support to nowcasting and very short range forecasting
- Ocean and sea ice
- Ozone monitoring
- Numerical Weather Prediction
- Climate monitoring
- GRAS meteorology
- Land surface analysis.

A number of these are directly relevant to aspects of GCOS monitoring. The Met Office hosts the SAF for NWP and also contributes to the SAF on GRAS (atmospheric limb sounding for indirect measurement of temperature, pressure and water vapour in the stratosphere and the troposphere, based on utilising the radio signals continuously broadcast by the GNSS satellites).

## Oceanographic Sensing

Since the 1970s a variety of oceanographic sensors have been flown on satellites. These include infra red radiometers for SST, passive microwave radiometers for sea ice extent and concentration, microwave scatterometers for surface wind, radar altimeters for sea surface height and wave height, SAR for ocean wave spectrum and detailed sea ice conditions and motion, and sensors for measuring ocean colour (phytoplankton). Data sets from some of these now extend for one or several decades. However, there has been no guarantee of continuity of missions and for some sensors there have been large time gaps. Remote sensing satellites have been identified as being part of the GOOS on both global and regional scales. A recent conference<sup>8</sup> organized by the EuroGOOS Space Panel identified the need to establish a mechanism for funding and operating oceanographic satellites, and for JASON-2 to be partly funded as an Optional Programme within EUMETSAT. (EuroGOOS is an Association of Agencies, founded in 1994, to further the goals of GOOS, see <http://www.EuroGOOS.org>).

<sup>8</sup> Operational Ocean Observations from Space. EuroGOOS Publication No. 16, May 2001. Available at <http://www.EuroGOOS.org/Activities/Publications/Publications.html>.

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Environment Agency  
Fisheries Research Services, Marine Laboratory  
Forestry Commission (Forest Research)  
Inter Agency Committee on Marine Science and Technology  
The Met Office  
National Environmental Technology Centre  
National Radiological Protection Board  
Permanent Service for Mean Sea Level  
Plymouth Marine Laboratory  
Proudman Oceanographic Laboratory  
Sir Alister Hardy Foundation for Ocean Science  
Southampton Oceanography Centre  
UK Hydrographic Office  
University of Edinburgh, Institute of Ecology and Resource Management  
University of Wales, Aberystwyth  
University of the West of England

# APPENDIX I

## GCOS – the Global Climate Observing System

The GCOS is co-sponsored by three UN bodies, the WMO, IOC, UNEP and by the non-governmental organization, the ICSU. The GCOS Joint Planning Office is based with the WMO Secretariat. GCOS is intended to be a long-term, user-driven operational system capable of providing the comprehensive observations required for monitoring the climate system, for detecting and attributing climate change, for assessing the impacts of climate variability and change, and for supporting research toward improved understanding, modelling and prediction of the climate system. It addresses the total climate system including physical, chemical and biological properties, and atmospheric, oceanic, hydrologic, cryospheric and terrestrial processes. The scope and aims of GCOS are succinctly defined by the following, extracted from the Summary of the GCOS Plan<sup>9</sup>:

When fully operational, GCOS will meet the comprehensive scientific requirements for monitoring the climate, and provide the observational basis for detecting climate change, for predicting climate variations and change on a variety of time and space scales, and for observing the impacts of climate change. The GCOS will not typically make observations or generate data products, but will rather encourage, coordinate and otherwise facilitate observations which should be made by national or international organizations in support of their own requirements and common goals. However, the GCOS will provide an operational framework for integrating national and international operational and research observational components of the participating countries into a comprehensive end-to-end system.

Other globally coordinated observing and processing systems exist or are being set up to provide related information on the basis of a particular focus, source of expertise or need. The WWW of the WMO and the GTOS have a focus that is primarily concerned with the atmosphere and land surface respectively. The GAW is a WMO Programme designed to monitor the well mixed constituents of the atmosphere. The GOOS is conceived as a system for capturing data about the oceans and seas and for processing them, with other data, to provide beneficial services. GOOS is co-sponsored by the same organizations as GCOS, while the GTOS is co-sponsored by the FAO, ICSU, UNESCO, UNEP and WMO.

GCOS will build, to the extent possible, on these existing operational and research observing, data management and information distribution systems, and further enhancements of these systems. The GCOS will be based upon, inter alia:

- existing and enhanced WWW systems;
- the GAW and related atmospheric constituent observing systems;
- the GOOS physical, chemical and biological measurements;
- the GTOS for land surface ecosystem, hydrosphere, and cryosphere measurements.

<sup>9</sup> Plan for the Global Climate Observing System (GCOS), Version 1.0, May 1995, Report GCOS-14.



## APPENDIX II

### GCOS/GOOS/GTOS Climate Monitoring Principles

Effective monitoring systems for climate should adhere as closely as possible 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 of 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 capability 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 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.

# APPENDIX III

## Definition of Acronyms Used

AEDC	Antarctic Environmental Data Centre
AGAGE	Advanced Global Atmospheric Gases Experiment
AMT	Atlantic Meridional Transect
Argo	The global array of profiling floats
ASAP	Automated Shipboard Aerological Programme
AURN	Automatic Urban and Rural Network (for air quality)
BADC	British Atmospheric Data Centre
BAS	British Antarctic Survey
BI	British Isles
BNSC	British National Space Centre
BODC	British Oceanographic Data Centre
BRO	British Rainfall Organization
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
CEH	Centre for Ecology and Hydrology
CLIMAT	Climate messages encoded for the WMO network
COMNAP	Council of Managers of National Antarctic Programmes
CORINE	Co-ordinating Information on the European Environment)
CPR	Continuous Plankton Recorder
CTD	Conductivity Temperature Depth
DARDNI	Department of Agriculture and Rural Development Northern Ireland
DBCP	Data Buoy Cupertino Panel
DEFRA	Department for Environment, Food and Rural Affairs
DML	Dunstaffnage Marine Laboratory
EA	Environment Agency
EC	European Commission
ECN	Environmental Change Network
EDMED	European Directory of Marine Environmental Data Sets
EDUCE	European Dataset for UV Climatology and Evaluation
EGOS	European Group on Ocean Stations
EIC	Environmental Information Centre
ENVISAT	European Environment Satellite
EPS	European Polar Satellite
ERS	European Research Satellite
EU	European Union
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
ESA	European Space Agency
FAO	Food and Agriculture Organization (of the United Nations)
FLUXNET	Global Terrestrial Network (of CO <sub>2</sub> flux measurements)
FRS	Fisheries Research Services
GAW	Global Atmosphere Watch of WMO
GCN	Global Core Network (of GLOSS)
GCOS	Global Climate Observing System
GDP	Global Drifter Programme
GECC	Global Environmental Change Committee

GLOSS	Global Sea Level Observing System
GOOS	Global Ocean Observing System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GRAS	GNSS Receiver for Atmospheric Sounding
GSN	GCOS Surface Network
GTN-G	Global Terrestrial Network – Glaciers
GTN-P	Global Terrestrial Network – Permafrost
GTOS	Global Terrestrial Observation System
GTS	Global Telecommunications System
GUAN	GCOS Upper Air Network
IACMST	Inter Agency Committee for Marine Science and Technology
IAPB	International Arctic Buoy Programme
ICSU	International Council for Science
IERM	Institute for Ecology and Resource Management
IGBP	International Geosphere-Biosphere Programme
IGOS	Integrated Global Observing Strategy
IGOSS	Integrated Global Ocean Services System
IOC	Intergovernmental Oceanographic Commission (of UNESCO)
IPAB	International Programme for Antarctic Buoys
ISABP	International South Atlantic Buoy Programme
JNCC	Joint Nature Conservation Committee
JONSIS	Joint North Sea Information System
LCM	Land Cover Map
MarLIN	Marine Life Information Network
MAWS	Marine Automatic Weather Station
MEDAG	Marine Environmental Data Action Group
MERMAID	Marine Environmental Resource Mapping and Information Database
MNCR	Marine Nature Conservation Review
MoD	Ministry of Defence
MSG	Meteosat Second Generation
MSL	Mean Sea Level
MSU	Microwave Sounding Unit
MTP	Meteosat Transition Programme
MSL	Mean Sea Level
NAO	North Atlantic Oscillation
NASA	(US) National Aeronautics and Space Administration
NBN	National Biodiversity Network
NCDC	(US) National Climate Data Centre (Asheville)
NCM	National Climate Message
NEODC	NERC Earth Observation Data Centre
NERC	Natural Environment Research Council
NGIS	National Geosciences Information Service
NGLA	National Groundwater Level Archive
NIST	National Institute of Standards and Technology
NMMP	National Marine Monitoring Programme
NOAA	(US) National Oceanic and Atmospheric Administration
NRFA	National River Flow Archive
NRPB	National Radiological Protection Board
NWA	National Water Archive
NWP	Numerical Weather Prediction
OOSDP	Ocean Observation System Development Panel

PACE	Permafrost and Climate in Europe
PML	Plymouth Marine Laboratory
POL	Proudman Oceanographic Laboratory
PSMSL	Permanent Service for Mean Sea Level
RAL	Rutherford Appleton Laboratory
RNODC	Regional National Oceanographic Data Centre
RRS	Royal Research Ship
RTMC	Real Time Monitoring Centre
SAHFOS	Sir Alister Hardy Foundation for Ocean Science
SAOZ	Système D'Analyse par Observations Zénithales
SAF	Satellite Application Facility
SAR	Synthetic Aperture Radar
SCAR	Scientific Committee on Antarctic Research
SEPA	Scottish Environmental Protection Agency
SFC	Drifters Surface Drifters
SOC	Southampton Oceanography Centre
SOOP	Ship of Opportunity Programme
SPRI	Scott Polar Research Institute
SST	Sea Surface Temperature
SUB-SFC	Sub-surface
TOGA	Tropical Ocean and Global Atmosphere programme
UK	United Kingdom
UKAWMN	UK Acid Waters Monitoring Network
UKHO	UK Hydrographic Office
UNECE	UN Economic Commission for Europe
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UoE	University of Edinburgh
US	United States of America
UV	Ultraviolet
VOS	Voluntary Observing Ships
VOF	Voluntary Observing Fleet
WCRP	World Climate Research Programme
WHYCOS	World Hydrological Cycle Observing System
WMO	World Meteorological Organization
WOCE	World Ocean Circulation Experiment
WRAP	World-wide Recurring ASAP Project
WWW	World Weather Watch (of WMO) or World Wide Web