UK- Environmental Observation Framework

GCOS IP10 – A UK Response
A summary of consultation responses from the UK
November 2011

CONTENTS

ACKNOWLEDGEMENTS

UK-EOF would like to thank all of the individuals who responded to the 2011 Consultation to the GCOS Implementation Plan (IP-10). Their input was invaluable and has ensured the content and quality of this summary report. Andrea Sharpe project managed the task, and was responsible for pulling everything together and creating coherence from the disparate input. Finally, thanks to Cathy Johnson (DECC) and colleagues on the UK-EOF Management Group, who supported the UK-EOF secretariat in their task of producing this document.

CITATION

UK-EOF (2011). GCOS IP10 – A UK Response: A summary of consultation responses from the UK. Available online: www.ukeof.org.uk.

EXECUTIVE SUMMARY

In August 2010 an updated version of the "Implementation Plan for the Global Observing System for Climate in support of the UNFCCC" was published by the GCOS (Global Climate Observing System) Secretariat. This Plan (IP10) was prepared in response to a request by Parties to the UNFCCC at the 30th session of the UNFCCC Subsidiary Body on Scientific and Technological Advice (SBSTA) in June 2009. This SBSTA request was affirmed by COP 15 in its Decision 9/CP.15.

The updated Plan recognises progress made since a similarly titled Plan (IP-04) was published in 2004. It takes account of the latest status of observing systems, recent progress in science and technology, the increased focus on adaptation, enhanced efforts to optimise mitigation measures, and the need for improved predictions of climate change.

IP-10, if fully implemented, will ensure that countries have the observational information needed to understand, predict, and manage their response to climate and climate change over the 21st century and beyond. It will address the commitments of the Parties under Articles 4 and 5[1] of the UNFCCC and support their needs for climate observations in fulfilment of the objectives of the Convention. It will provide observations of the Essential Climate Variables (ECVs) (see Table 1) needed to make significant progress in the generation of global climate products and derived information; it will also provide support for the research, modelling, analysis and capacity-building activities required by all Parties to the UNFCCC.

IP-10 identifies 26 "Key Needs" and specific recommendations are spelt out in 138 "Actions". The first two key needs summarise what is required:

Key Need 1: Urgent action and clear commitment by Parties to sustain, and build upon, the achievements in systematic observation of climate since 2004 are required to ensure that the Parties have the information they need to plan for, and manage effectively, their response to climate change.

Key Need 2: Parties need, both individually and collectively, to commit to the full implementation of the global observing system for climate; to sustain a mix of high-quality satellite, ground-based and airborne *in situ* measurements, and remote-sensing measurements; to sustain dedicated analysis infrastructure; and to undertake targeted capacity-building.

The increased resourcing required is estimated to be an additional US$ 2.5 billion, globally, compared with current expenditure of between US$ 5 and 7 billion.

[1] Through its articles 4 and 5, the UNFCCC commits Parties to support international efforts to strengthen systematic observation capacities and capabilities, particularly in developing countries, and to promote access to, and the exchange of, data and analysis of data from beyond national jurisdictions,

Table 1: Essential Climate Variables that are both currently feasible for global implementation and have a high impact on UNFCCC requirements

Domain	Essential Climate Variables	
Atmospheric (over land, sea and ice)	**Surface:**[8]	Air temperature, Wind speed and direction, Water vapour, Pressure, Precipitation, Surface radiation budget.
	Upper-air:[9]	Temperature, Wind speed and direction, Water vapour, Cloud properties, Earth radiation budget (including solar irradiance).
	Composition:	Carbon dioxide, Methane, and other long-lived greenhouse gases[10], Ozone and Aerosol, supported by their precursors[11]
Oceanic	**Surface:**[12]	Sea-surface temperature, Sea-surface salinity, Sea level, Sea state, Sea ice, Surface current, Ocean colour, Carbon dioxide partial pressure, Ocean acidity, Phytoplankton.
	Sub-surface:	Temperature, Salinity, Current, Nutrients, Carbon dioxide partial pressure, Ocean acidity, Oxygen, Tracers.
Terrestrial	River discharge, Water use, Groundwater, Lakes, Snow cover, Glaciers and ice caps, Ice sheets, Permafrost, Albedo, Land cover (including vegetation type), Fraction of absorbed photosynthetically active radiation (FAPAR), Leaf area index (LAI), Above-ground biomass, Soil carbon, Fire disturbance, Soil moisture.	

At COP 16 at Cancun, SBSTA urged Parties to work towards full implementation of the updated 2010 Implementation Plan and to consider, within the context of their national capabilities, what actions they can take at the national, regional and international levels to contribute to the implementation of the plan (http://unfccc.int/resource/docs/2010/sbsta/eng/l22.pdf).

This document is an attempt to produce a UK response to this request. It has drawn heavily on data contained in the Environmental Observation Activity Catalogue of the UK Environmental Observation Framework (UK-EOF), supplemented by responses to a questionnaire circulated to relevant UK bodies by the UK-EOF secretariat. It is likely that the information collected is incomplete; despite the best efforts of the secretariat, maintenance of the catalogue is acknowledged to be difficult. Nevertheless, it is clear that the UK is extremely active in climate observations; positive responses have been obtained against most of the 138 recommendations. What is not, clear, however, is whether or not the UK is doing "enough". Questionnaire respondents were strikingly reluctant to express opinions on this matter.

In the UK responsibility for observations of the climate system is widely dispersed and many different bodies are involved. GCOS have recommended that Parties designate national coordinators and/or committees, achieve national co-ordination, and produce national plans for contributions to the global observing system for climate in the context of this Plan (Recommendation C2). The reality in the UK is that some of the responsibilities of a national co-ordinator are undertaken by the Met Office and some by DECC, and that the UK-EOF secretariat has recently helped by providing resource to prepare this UK response. However, these arrangements fall short of "national co-ordination". This is evident in the difficulty in forming a UK view on "Is the UK doing enough?".

1. INTRODUCTION

In early 2011 DECC approached the UK-EOF asking for assistance with a consultation on the 137 recommendations in the GCOS Implementation Plan (IP-10). This was with a view to producing a UK response to the UNFCCC and answer the question "Is our existing support for climate observations adequate or should it change in the light of the IP's recommendations? If so, where should the UK be concentrating its efforts?" The recommendations were put out to consultation via the UK-EOF website and were sent to relevant UK-EOF contacts during summer 2011. For each recommendation, consultees were asked:

1. Does the UK do this?
2. If yes, who is the lead organisation?
3. What is the cost of the relevant activities/programmes? (If known)
4. Is the funding for the activities/programmes assured?
5. Is the recommendation complied with Fully, Partly, Not at all, or is it Not Applicable?
6. If the answer to (5) is Partly or Not at all, are we content with this situation or do we think the UK should do more?
7. If the UK were to do more – what exactly would this be?
8. Provide a short justification of any entries in 7.

Fifteen organisations sent responses (Appendix 1), some of which included input from several colleagues. Additional information was gathered directly from discussions with relevant experts and some background research which followed up leads. This document summarises the responses given for each of the recommendations.

2. OVER ARCHING / CROSS CUTTING ISSUES

This section of the Implementation Plan covers actions that are relevant to each of climate observing systems and includes national coordination, overarching plans, data quality, reporting, continuation of data/instruments, reanalysis and proxy climate observations as well as data management and stewardship.

Summary: Cross Cutting Actions

The UK has many experts involved in climate observations, research and modelling. It also has several centres of expertise and hosts organisations, such as ECWMF, which play a key role in climate research. Although responsibility for climate reporting (to the UNFCCC) lies with DECC, there is not however a central coordination point to oversee the UK's input to climate observations, nor is there a structured process to sustain long-term observations. Despite this UK researchers are successfully playing many key roles in the development, analysis and monitoring of ECV's, working both within the UK and in international collaborations.

UK activities relevant to each of the cross cutting recommendations are provided below.

2.1. Planning, Reporting and Oversight

2.1.1. International Planning

Action C1

Action: Participating international and intergovernmental organizations are invited to review and update their plans in light of this document in order to ensure they better serve the needs of the UNFCCC.
Who: International and intergovernmental organizations.
Time-Frame: Inclusion in plans by 2011 and continuing updates as appropriate.
Performance Indicator: Actions incorporated in plans.
Annual Cost Implications: <1M US$ (10% in non-Annex-I Parties).

This action is not applicable to a UK response.

2.1.2. National and Regional Planning

Action C2 *[IP-04 C2]*[51]

Action: Designate national coordinators and/or committees, achieve national coordination, and produce national plans for contributions to the global observing system for climate in the context of this Plan.
Who: Parties, through the national representatives to GCOS Sponsor Organizations and designated GCOS National Coordinators.
Time-Frame: Urgent and on-going.
Performance Indicator: Number of GCOS National Coordinators and/or national coordination committees in place.
Annual Cost Implications: 1-10M US$ (70% in non-Annex-I Parties).

At present the UK does not have one National Committee or a National Coordinator. Instead DECC, as the organisation responsible for reporting to the UNFCCC, encourages national co-ordination through the efforts of the Earth Observation Forum. Some of the roles of a National Coordinator are undertaken by the Met Office, others by the UK-EOF Secretariat and DECC. The number of bodies involved in funding and making observations is large and hence no-one organisation is charged with producing national plans.

Action C3

Action: Review the projects contained in RAPs for consistency with this Plan and update and revise the RAPs as necessary.
Who: Regional organizations and associations in cooperation with the GCOS Secretariat and the bodies responsible for the component observing systems.
Time-Frame: 2011.
Performance Indicator: Implementation strategy meetings held and number of RAP projects implemented.
Annual Cost Implications: 1-10M US$ (90% in non-Annex-I Parties).

The Met Office was involved in the writing of some of the RAPs (Eastern, Southern, Western and Central Africa). The RAPs were written between 2000 and 2005 and may need refreshing. These have been used to define priorities and needs and some action has taken place. At present there is no known work planned to revise the RAPs and it may be more practical to look at the priorities list drawn up by the AOPC for GCOS atmosphere observing, for which a number of projects have been and are in progress. The UK Met Office has been and still is involved in projects in Africa and the Indian Ocean (see Action C7).

2.1.3. National Reporting

Action C4 *[IP-04 C4]*

Action: Report to the UNFCCC on systematic climate observations using current guidelines.
Who: Parties with the UNFCCC.
Time-Frame: Conforming to UNFCCC guidelines.
Performance Indicator: Number of Parties reporting within specified timeframes.
Annual Cost Implications: 1-10M US$ (70% in non-Annex-I Parties).

Within the UK, DECC are responsible for reporting to the UNFCCC.

2.2. Toward Sustained Networks and Systems

Action C5 *[IP-04 C7]*

Action: Ensure an orderly process for sustained operation of research-based networks and systems for ECVs.
Who: All organizations operating networks contributing to GCOS.
Time-Frame: Continuous.
Performance Indicator: Number of sustained networks and systems.
Annual Cost Implications: Covered in domains.

Although the need for sustained observations is recognised by many organisations across the UK, there is not, at present, an orderly agreed process for sustained operations - this is generally done on an individual organisational basis to fulfil requirements. UK-EOF is working to encourage organisations to address the challenges surrounding the funding of long term sustained observational networks and to follow procedures in which decision making is transparent and holistically considers the observation needs of the UK.

Action C6 *[IP-04 C8]*

Action: Ensure all climate observing activities adhere to the GCMPs.
Who: Parties and agencies operating observing programmes, including calibration undertaken in collaboration with national metrology institutes.
Time-Frame: Continuous, urgent.
Performance Indicator: Extent to which GCMPs are applied.
Annual Cost Implications: Covered in domains. See Action C8 for satellite component.

This action is the responsibility of organisation's making the relevant observations of ECVs.

2.3. International Support for Critical Networks – Technical Cooperation

Action C7 *[IP-04 C9]*

Action: Support the implementation of the global observing system for climate in developing countries and countries with economies in transition through membership in the GCOS Cooperation Mechanism and contributions to the GCOS Cooperation Fund.
Who: Parties (Annex-I), through their participation in multinational and bilateral technical cooperation programmes, and the GCOS Cooperation Mechanism.
Time-Frame: Immediately and continuous.
Performance Indicator: Resources dedicated to climate observing system projects in developing countries and countries with economies in transition; number of Parties contributing to the GCM.
Annual Cost Implications: Covered in the domains.

Within the UK the main responsibility for supporting implementation in developing countries rests with the Department for International Development (Dfid). In the GCOS Cooperation Mechanism the UK is variously represented by DECC, the Met Office and Dfid. Dfid is planning to support observations in Africa through its ClimDev Africa programme, and in South Asia through a new programme supported by the International Climate Fund.

The Met Office supports some observations on remote islands through the World Meteorological Organisation's Voluntary Cooperation Programme (with funding coming from the Public Weather Service). Some of this support started in the 1950s and is mainly for upper air observations in St. Helena, Gough Island (in conjunction with the South African Weather Service), Pitcairn (with the New Zealand Weather Service). Partial support has also been provided in the Seychelles, Funafuti in Tuvalu, Tarawa in Kiribati and Rarotonga in the Cook Islands.

The Met Office also initiated a programme to support and develop climate data management systems in developing countries to implement and use climatology data management systems, improve recording and communication of observations, initiated in Africa this has since spread

to approximately 25 other countries and in cooperation with Kenya Meteorological Department (who have useful skills and people) is currently running in Uganda, Zambia and Rwanda. In addition the Met Office is involved in the installation and development of upper air stations in Yerevan, Armenia and Gan, Maldives. It should be noted that not all science priorities (as drawn up by the AOPC for GCOS atmosphere observing) are feasible, for example the AOPC would like to have a working upper air station in Angola but the chances of this happening are very small because the local support does not exist.

NOC (Liverpool) has been involved (through the IOC) in installing 12 new tide gauges in Africa (as part of the African GLOSS network – see Action O9). However it is proving difficult to find sustained resource required to maintain this African GLOSS network.

2.4. Earth Observation Satellites

Action C8 *[IP-04 C10]*

Action: Ensure continuity and over-lap of key satellite sensors; recording and archiving of all satellite metadata; maintaining appropriate data formats for all archived data; providing data service systems that ensure accessibility; undertaking reprocessing of all data relevant to climate for inclusion in integrated climate analyses and reanalyses, undertaking sustained generation of satellite-based ECV products.
Who: Space agencies and satellite data reprocessing centres.
Time-Frame: Continuing, of high priority.
Performance Indicator: Continuity and consistency of data records.
Annual Cost Implications: Covered in the domains.

With regard to continuity and overlap – the UKSA is leading on the ESA funded space and ground segments for the Envisat-Sentinel overlap and DECC on data continuity for SST measurements from the ATSR series and SLSTR. For SST, the overlap between AATSR and SLSTR is uncertain due to slippages in the Sentinel-3 launch date. However continuity can be provided using ship-borne radiometers (such as the Infrared Sea Surface Temperature Autonomous Radiometer (ISAR) deployed by NOC-Southampton on Voluntary Ships of Opportunity).

With regard to recording and archiving satellite metadata, NERC (and their data centres) supports the development of common standards for metadata description and data storage/services. This includes advice to data providers on formats, participation in the creation of EU INSPIRE standards (through thematic working groups) and joint coordination of the Climate Forecast–network of Common Data Forms (CF-netCDF) metadata conventions. This work partly fulfils this action. However greater support for the CF-netCDF metadata conventions, governance and management would enhance the usability of existing datasets and the interoperability and intercomparison between different areas of climate science (such as satellite observations versus model simulations).

2.5. Integrated Climate Products

2.5.1. Generation and Use of Products

Action C9

Action: Achieve adoption of the GCOS dataset and product guidelines; critical comparison of datasets/products and advice on product generation for all ECVs by the climate community.
Who: Parties' national agencies, working with key international coordination bodies, such as CEOS, GEO, IGBP, and IPCC Task Group on Data and Scenario Support for Impact and Climate Analysis (TGICA), and coordinated through GCOS and WCRP.
Time-Frame: Wide adoption by 2011 and on-going.
Performance Indicator: Level of adoption of guidelines; number of datasets stating adoption of guidelines; number of ECVs for which routine intercomparison arrangements are in place.
Annual Cost Implications: 1-10M US$ (20% in non-Annex-I Parties).

UK organisations were very successful in bidding for ESA Climate Change initiative research projects which aim to generate ECV's. Two UK organisations are leading projects, with a further eleven organisations contributing to ten projects (please note some of the eleven organisations are contributing to more than one of the ten projects).

In addition, the National Centre for Earth Observation, a NERC research centre, is working with a number of funding partners (ESA, EU Framework Programme, UK Space Agency and Technology Strategy Board) as well as industry and academia to develop a facility for Climate and Environmental Monitoring from Space (CEMS). This will form part of the suite of facilities/activities at International Space Innovation Centre (ISIC), in Harwell and build upon current NERC, NEODC and BADC functionality to provide an integrated system to facilitate model-data comparison. CEMS has two priority areas (in connection with ISIC's climate agenda):

a) To develop software and hardware facilities for the operational delivery of a wide range of "essential climate variables" stemming from ESA's Climate Change Initiative. At present individual groups are developing individual data sets from ESA satellites. Subsequent operational phases will fund one or two nodes in Europe to deliver comprehensive sets of products and synthesised data sets (e.g. re-analysed data sets) with an integrated systems engineering approach. The overall aim is to link NERC scientific expertise with industrial capability to be the leading operational node, and to extend the scope and value of the climate change initiative by incorporating satellite data from other space agencies, notably EUMETSAT and NASA.
b) To develop these facilities (including an enhanced data visualization facility) to enable the UK, to be a world leader in the provision of climate services.

In addition the UK Climate Community is actively participating in many FP7 projects from looking at how ECV's can be interfaced to models (MONARCH-A) to reanalysis of relevant observations (EURO4M).

The Met Office is playing a leading role in the International Surface Temperature Initiative (http://www.surfacetemperatures.org/). The initiative is working towards the creation of an international, in-situ, surface temperature data bank containing traceable information, starting with the original observations and related metadata, and progressing through the quality control and homogeneity processes to analysed gridded datasets and products. Homogeneity methods will be carefully benchmarked to assess and increase their reliability.

2.5.2. Reanalysis based on data assimilation

Action C10 *[IP-04 C11]*

Action: Prepare the atmospheric, oceanic, terrestrial and cryospheric datasets and metadata, including historic data records, for climate analyses and reanalyses.
Who: Parties with Data Centres (e.g., WDCs), working together with technical commissions and the scientific community, especially the joint WOAP/AOPC Working Group on Observational Datasets for Reanalysis and the ACRE collaborative initiative.
Time-Frame: Now and on-going.
Performance Indicator: New or improved datasets available for analysis or reanalysis.
Annual Cost Implications: Covered in domains.

The UK is already involved in many activities that contribute to this Action. NERC Data Centres manage data holdings including metadata collection and cataloguing, data preservation and curation; discovery, browse, extraction and visualisation services for use in research (analysis and re-analysis) across the various disciplines of environmental science. NCEO plays a particularly important role in producing and managing satellite-derived global datasets and is working to develop a facility for Climate and Environmental Monitoring from Space (CEMS) an aim of which is to deliver synthesised (reanalysed) datasets (see Action C9).

Although the NERC data centres are recognised as an essential part of the UK research infrastructure and contribute to this action, on-going and increased commitment is needed to achieve the goals of data access and interoperability required to respond to the scientific questions being asked about climate change.

ECWMF, an intergovernmental organisation supported by 34 European States, is based in Reading and are therefore included within the UK response. ECWMF are heavily involved in the reanalysis of historic climate records. Building upon previous EU Framework Programme funded work, ECWMF are conducting a 3 year EU funded project, ERACLIM (2011-2013), which is working on the Reanalysis of multi-decadal series of past observations. Both the Met Office Hadley Centre and the Climate Research Unit (CRU at the University of East Anglia) are also involved.

In addition to this CRU and the Met Office are also involved in another European project, EURO4M that is looking at reanalysing data for climate purposes and the Met Office in the ACRE initiative. The University of Edinburgh is leading on the ATSR Reprocessing Climate (ARC) project (funded by DECC, NERC and the MoD) which provides best quality SST data that is used by the Hadley Centre in their climate research. Continued funding for this project is therefore essential.

With regards for global mean sea level data – the preparation of metadata and historic data as requested under this action was done several years ago. The GCOS stations heavily overlap with the GLOSS network – PSMSL (at NOC Liverpool) are responsible for collecting this data from both networks (for climate purposes). For GCOS, more rapid changes are recorded by higher frequency datasets collected by British Oceanographic Data Centre (BODC, at NOC Liverpool) and the University of Hawaii. BODC has a formal commitment to collect and archive this information.

Historic bathymetric data for larger UK lakes (area, depth profile) are not currently prepared in an accessible data base. These paper based records could be readily transcribed to an interrogable online data archive, however resource is required to do this.

Action C11 *[IP-04 C12]*

Action: Establish sustainable systems for the routine and regular analysis of the ECVs, as appropriate and feasible, including measures of uncertainty.
Who: Parties sponsoring internationally-designated analysis activities, with guidance from WCRP, IGBP and IPCC.
Time-Frame: Now and on-going
Performance Indicator: Quality and range of analyses of the ECVs.
Annual Cost Implications: Covered in domains.

As mentioned above (Action C9) UK experts are involved in ESA CCI projects (N.B the Climate office of the CCI is also based at Harwell in the UK and feedback on the CCI projects are being fed back to the GCOS Secretariat with respect to GCOS requirements). The CCI itself is developing the system for the production of ECV's, but there is no current mandate to make these operational, nor does this extend to analysis therefore sustainability post the 6 year ESA programme is in question. The NCEO may address this to some extent with the development of their facility for Climate and Environmental Monitoring from Space (CEMS) which is looking towards operational delivery of a wide range of "essential climate variables" (stemming from ESA's CCI).

In addition to their involvement with the ESA CCI, the Met Office routinely produces datasets for climate monitoring, for example the HadCRUT dataset of global surface temperatures, which includes measures of uncertainty.

Action C12 *[IP-04 C13]*

Action: Establish a sustained capacity for global climate reanalysis and ensure coordination and collaboration among reanalysis centres.
Who: National and international agencies.
Time-Frame: Continue on-going activity but with climate trends better addressed by 2014, and expansion into coupled reanalysis by 2016.
Performance Indicator: Reanalysis centres endowed with long-term and coordinated programmes; cyclical flow of products of improving quality and widening range.
Annual Cost Implications: 10-30M (Mainly Annex-I Parties)

Through the ERA-Clim project the ECWMF is building on previous global climate reanalysis work. The reanalysis work is also supported by the two NERC centres (NCEO and NCAS), along with the Japan Meteorological Agency (JMA). NCEO is also working to develop (with external funding from academia and industry) a facility for Climate and Environmental Monitoring from Space (CEMS, see Action C9), which includes reanalysis.

2.6. Early Instrumental Data and Proxy Reconstructions of Past Climates

2.6.1. Early Instrumental Datasets

Action C13 *[IP-04 C14]*

Action: Collect, digitize and analyse the historical atmospheric, oceanic and terrestrial data records from the beginning of instrumental observations in a region and submit to International Data Centres.
Who: Parties, working through the WMO Commission on Climatology (CCl), the WMO Commission for Hydrology (CHy), other appropriate coordinating bodies (e.g., the GTOS Secretariat), the appropriate national agencies, and designated International Data Centres.
Time-Frame: Continuing.
Performance Indicator: Data receipt at designated International Data Centres.
Annual Cost Implications: 10-30M US$ (60% in non-Annex-I Parties).

Within the UK the digitisation and analysis of historic records is left to individual organisations themselves. Some data, such as lake depth profiles & area (Reading University) exist in paper

format and with appropriate resource could be transcribed into a digital format and submitted to Hydrolare (when the archive is fully functional). The Met Office is working to digitise historic marine records however progress is slow as funding and resources are limited. It is this lack of resource which restricts progression on this Action. EU funding sometimes enables the digitisation of data (e.g. EURO4M and ERACLIM in which UK researchers are involved) however emphasis is often placed on digitising data from regions that have gaps this does not generally include the UK itself.

If resource could be found to digitise all historical records held by the UK, these could provide useful information that could be included in the reanalysis of climate relevant data.

Action C14

Action: Improving data holdings in International Data Centres (IDCs).
Who: IDCs to send details of their data possessions to each of the Parties. The Parties to respond back to the IDCs about the quality and quantity of the data and ensure that the IDCs hold all available data.
Time-Frame: Complete by 2014.
Performance Indicator: Percentage of responses from Parties.
Annual Cost Implications: 10-30M US$ (60% in non-Annex-I Parties).

In the UK it is left to the organisations collecting and archiving the data to submit their information to International Data Centres. There is no coordination at National level.

2.6.2. Proxy Datasets for Climate Reconstruction

Action C15 *[IP-04 C15]*

Action: Undertake research initiatives to acquire high-resolution proxy climate data by extending spatial coverage into new regions, extending temporal coverage back in time and exploiting new sources.
Who: Parties' national research programmes in cooperation with WCRP and IGBP.
Time-Frame: Continuing.
Performance Indicator: Reports in scientific literature.
Annual Cost Implications: 10-30M US$ (60% in non-Annex-I Parties).

Several groups within the UK are undertaking research initiatives which look at proxy climate data, for example the University of Edinburgh have been investigating coral paleoclimatology (as part of the UK Integrated Ocean Drilling Programme, IODP), scientists at the Climate Research Unit (UEA) are looking at the reconstruction of temperature using tree rings, ice cores, sediments etc and at Edge Hill University a group are looking at past glacial activity in Papua New Guinea. At present there is no overarching National research programme - any activities are carried out by individual organisations or collaborations between organisations.

Action C16 *[IP-04 C16]*

Action: Improve synthesis of proxy climate and proxy environmental data on multi-decadal to millennial time scales, including better chronologies for existing records, particularly from the Tropics, Asia, the Southern Hemisphere and the Southern Ocean.
Who: Parties' national research programmes in cooperation with WCRP and IGBP.
Time-Frame: Continuing.
Performance Indicator: Reports in scientific literature.
Annual Cost Implications: 10-30M US$ (80% in non-Annex-I Parties).

Some researchers within the UK are looking at climate proxies using data from the tropics, for example Bristol University (Organic Geochemistry Unit) are using paleoenvironmental datasets, including oceanic sediments from Tanzania, the Benguela upwelling region and the Mediterranean.

Action C17 *[IP-04 C17]*

Action: Preserve proxy climate and proxy environmental data (both the original measurements as well as the final reconstructions) in archival databases.
Who: World Data Centre for Paleoclimatology in cooperation with national research programmes.
Time-Frame: Continuing.
Performance Indicator: Completeness of archival databases and availability of data to the research community through International Data Centres.
Annual Cost Implications: 1-10M US$ (30% in non-Annex-I Parties).

Through its data policy, NERC aims to enable long term accessibility to NERC funded data. Data is archived and accessible via the NERC Data Centres (see http://www.nerc.ac.uk/research/sites/data/policy.asp). This includes data that is produced by NERC-funded research, as well as some non NERC datasets that are deemed to be 'at risk'.

2.7. Data Management and Stewardship

Action C18

Action: Apply standards and procedures for metadata and its storage and exchange.
Who: Operators of GCOS related systems, including data centres.
Time-Frame: Initial implementation of the operational WIS and GEOSS systems is occurring in 2010, implementations will be on-going thereafter.
Performance Indicator: Number of ECV related datasets accessible through standard mechanisms.
Annual Cost Implications: <1M US$ (20 k US$ per data centre) (10% in non-Annex-I Parties).

With regard to the application of standards and procedures the UK is active in national and international arenas. Contributions come from academic, commercial and public sectors with the National Physical Laboratory leading on some projects.

The standards for metadata/data description and exchange are still being developed.

Much work has been done by the Weather/Climate/Ocean science communities to bridge the gap between 4-dimensional spatial-temporal datasets and the pre-existing GIS standards. It is important that the UK play a role to ensure that the standards developed by the international community are appropriate and fit for purpose.

Data specifications for the EU INSPIRE directive are currently under review. The UK contribution involves many organisations that take part in the thematic working groups (it should however be noted that although this includes UK expertise, some of the funding for these activities is via the European Framework Programme). The Centre for Environmental Data Archival (CEDA: http://ceda.ac.uk) and the UK Met Office has representatives on the Thematic Working Group on Atmospheric conditions and Meteorological Geographical Features. Both organisations also contribute to the MetOcean Domain Working Group of the World Meteorological Organisation (WMO) which aims to align the metadata/data models used in those communities with those being developed by INSPIRE.

The Met Office is also leading the implementation of a WMO Information System (WIS) which is underpinned by the same metadata standards being pursued by the other groups listed above.

Action C19

Action: Ensure national data centres are supported to enable timely, efficient and quality-controlled flow of all ECV data to International Data Centres (other than the very large satellite datasets that are usually managed by the responsible space agency). Ensure timely flow of feedback from monitoring centres to observing network operators.
Who: Parties with coordination by appropriate technical commissions and international programmes.
Time-Frame: Continuing, of high priority.
Performance Indicator: Data receipt at centres and archives.
Annual Cost Implications: 10-30M US$ (70% in non-Annex-I Parties).

The UK has several data centres in place, for example the NERC data centres. As specified in the Action, BADC do not generally transfer data to other datacentres (but do make archived data accessible for reuse) due to the size of the datasets, however BODC (The British Oceanographic Data Centre), who are a key player within the IODE (International Oceanographic Data Exchange, see http://www.iode.org/) programme, regularly submit UK oceanographic data (mainly collected from NERC activities) to NODC (in the States).

The UK Met Office makes gridded climate data available via the Hadley Centre Observations Centre (HadObs). However Climate model data is distributed via the Climate links Impact project, which is hosted by BADC. Some model runs are also available on the WCRP CMIP3 Multi Model data Archive (also at BADC).

Depending on the ECV in question some data is submitted to International Data centres by the responsible organisation e.g. river flow data is submitted to the Global Runoff Data Centre by CEH and GCOS surface and upper-air network information (GSN & GUAN) to the relevant data centres by the Met Office.

The National Oceanography Centre (NOC) – Liverpool, on behalf of ICSU hosts the Permanent Service for Mean Sea Level. BODC also hosts the GLOSS delayed mode centre.

Action C20 *[IP-04 C20]*

Action: Ensure that data policies facilitate the exchange and archiving of all ECV data.
Who: Parties and international agencies, appropriate technical commissions, and international programmes.
Time-Frame: Continuing, of high priority.
Performance Indicator: Number of countries adhering to data policies favouring free and open exchange of ECV data.
Annual Cost Implications: 1-10M US$ (70% in non-Annex-I Parties).

Within the UK data policy and archiving is the responsibility of individual organisations.

As mentioned under Action C17, NERC has a data policy (see: http://www.nerc.ac.uk/research/sites/data/policy.asp) that details its commitment to support the long-term management of environmental data and also outlines the roles and responsibilities of all those involved in collecting and managing environmental data. At present NERC metadata does not include an ECV flag, however this is something that could be included in the future.
The Met Office prepares monthly climate statistics for 20 UK sites (CLIMAT or RBCN, Regional Basic Climate Network stations - including 6 GCOS ones), which are exchanged through the WMO CLIMAT message mechanism. Daily climate statistics (for approximately 100 sites, including GCOS ones) are sent to the Dutch weather service (KNMI) who manage the European Climate Assessment and Dataset (ECA&D) project (http://eca.knmi.nl/). Data batches are sent, 12-18 months in arrears and are used by KNMI to over-write the data collected from the daily synoptic message exchanges. GCOS site data is available for public download (data from other sites is only available upon application to the Met Office).

Wider compliance with data and metadata standards and services, by all organisations, would facilitate greater interoperability and intercomparison. This may be facilitated by the enforcement of EU INSPIRE compliance, however the UK needs to ensure that INSPIRE data specifications are fit for purpose and are consistent across different domains of environmental science.

Action C21

Action: Implement modern distributed data services, drawing on the experiences of the WIS as it develops, with emphasis on building capacity in developing countries and countries with economies in transition, both to enable these countries to benefit from the large volumes of data available world-wide and to enable these countries to more readily provide their data to the rest of the world.
Who: Parties' national services and space agencies for implementation in general, and Parties through their support of multinational and bilateral technical cooperation programmes, and the GCOS Cooperation Mechanism.
Time-Frame: Continuing, with particular focus on the 2011-2014 time period.
Performance Indicator: Volumes of data transmitted and received by countries and agencies.
Annual Cost Implications: 30-100M US$ (90% in non-Annex-I Parties).

Many parts of the UK community, including the Met Office & research organisations, are adopting data services that allow interoperability with the global research community. Cataloguing and data delivery services are slowly converging towards the ISO19100 standards series and the Open Geospatial Consortium (OGC) web service standards specifications. Much NERC-funded development in the area of data service tools is developed using Open Source software that has the potential to be re-used for free in other parts of the world.

Compliance with this action will become easier once the standards have been converged and more clearly defined.

2.8. The Need for Information on Climate Impacts

Action C22

Action: Develop and publish guidelines for undertaking observational studies in support of impact assessments and to ensure that data policies facilitate the exchange and archiving of all impact-relevant observational data.
Who: IPCC TGICA, GTOS and IGBP.
Time-Frame: 2011.
Performance Indicator: Guideline published.
Annual Cost Implications: <1M US$ (10% in non-Annex-I Parties).

CEH is connected to international actions that align well with this action, largely through work under the GEO Global Earth Observation System of Systems (GEOSS). CEH is taking the initial lead (in collaboration with International Long-term Ecological Research Network (ILTER)) to develop a Global Network of Ecosystem Observatories (as part of the Global Biodiversity Observation Network (GEO BON)). GEO BON is also developing a set of Essential Biodiversity Variables which should complement the Essential Climate Variables that have already been developed for GCOS. The end result will be a global network of ecosystem observatories where co-located measurements of biological, hydrological, geochemical and climate measurements are undertaken and data made available through linked systems to contribute to global scale assessments of the effects of climate change impacts on ecosystems and ecosystem services.

In Phase 1 of the development of this network, CEH is working with ILTER to develop a database of existing sites and to establish the global partnership of organisations that could contribute to the network. Guidelines for producing site meta-data would be one of the main

outputs of this phase. CEH would like to retain a leading role in the later, design and implementation, phases of this network but this will depend on securing significant additional funding from UK or European sources.

Action C23

Action: Encourage recognition by scientific funding bodies of the need to consider guidelines for the conduct of observational impact studies, and encourage the definition of new impact-related ECVs. **Who:** Parties and ICSU **Time-Frame:** 2011 (Achieve improved recognition). **Performance Indicator:** Availability of supporting data; proposals for new ECVs. **Annual Cost Implications:** 1-10M US$ (50% in non-Annex-I Parties).

Within the UK the responsible scientific funding body is NERC. NERC are already involved in much related ECV work (through NCEO, BADC, BAS etc), however to fully fulfil this action encouragement and recognition would need to come from their parent body the Department for Business and Innovation (BIS).

3. ATMOSPHERIC CLIMATE OBSERVING SYSTEM

The Atmospheric Climate Observing System covers surface and upper air (atmospheric/meteorological) ECV observations, for both in-situ and satellite measurements. There is some cross over with the Oceanic observing system with respect to meteorological instrumentation on oceanic drifting buoys. The section also covers the observation networks infrastructure and data management/exchange.

Summary of Atmospheric Climate Observing System

The UK undertakes measurements which contribute to the majority of the GCOS observation networks (the exception being the GRUAN). Relevant observations are made in the UK, in UK overseas territories and the British Antarctic. The UK also supports some developing nations, both in training, analysis and making climate observations. Key organisations in the monitoring include the Met Office, NERC organisations (e.g. BAS, NCEO, CEH) and university research groups. Within this area the British Atmospheric Data Centre (BADC) archive and manage the vast majority of relevant data, with some being sent directly to International Data Centres by the responsible organisation.

In addition to undertaking direct measurements for GCOS networks the UK also takes climate measurements for other initiatives which contribute to International Data Centres that are used by GCOS, for example GAW and the EMEP.

The UK does not own or launch satellites *per se* but contributes and collaborates via the European Space Agency, who also works in collaboration with other nations such as the USA and Japan. UK experts often use satellite information and several groups conduct primary processing and analysis to produce relevant products and datasets. Despite this there is not however a sustainable funding line within the UK for contributions to these platforms.

Details on the UK's involvement with each of the recommendations for the Atmospheric Climate Observing System are given below.

3.1. Atmospheric Domain – Surface

Action A1

Action: Improve the availability of near real-time and historical GSN data.
Who: National Meteorological Services, in coordination/cooperation with WMO CBS, and with advice from the AOPC.
Time-Frame: Continuous for monitoring GSN performance and receipt of data at Archive Centre.
Performance Indicator: Data archive statistics at WDC Asheville and National Communications to UNFCCC.
Annual Cost Implications:[63] 10-30M US$ (70% in non-Annex-I Parties).

The UK contributes to the Global Surface Network (GSN) with information from a number of sites under the Regional Basic Climate Network (RBCN) and the UK's Reference Climate Network. There are 6 designated GSN stations in the UK (run by the Met Office - Lerwick, Stornoway Airport, Eskdalemuir, Valley, Waddington, Camborne); and several in overseas territories (run either directly by the met office, in collaboration or by the relevant overseas government). BAS are responsible for GSN stations (as part of their Long term Monitoring & Survey) in the British Antarctic.

The UK also has a meteorology component to the Environmental Change Network, these AWS collect data using UK Met Office standards. Although not designated GSN sites, this monitoring provides additional local information. ECN data are archived and readily available through the ECN Data Centre (a constituent part of the CEH Environmental Information Data Centre - a NERC designated Data Centre).

Action A2 *[IP-04 A2]*

Action: Obtain further progress in the systematic international exchange of both hourly SYNOP reports and monthly CLIMAT reports from the WWW/GOS RBSN.
Who: National Meteorological Services, in cooperation/coordination with WMO CBS, WMO CCl, WMO RAs, and WMO WWW.
Time-Frame: Continuous, with significant improvement in receipt of RBSN synoptic and CLIMAT data by 2014.
Performance Indicator: Data archive statistics at WDC Asheville.
Annual Cost Implications: 1-10M US$ (60% in non-Annex-I Parties).

As part of their Land Surface Weather Observations Programme the Met Office runs approximately 200 Automatic Weather Stations (AWS), which have recently been upgraded to a uniform system known as the "Meteorological Monitoring System" (MMS). The University of East Anglia also run an Automatic Weather Station – the Weybourne Atmospheric Observatory.

The BAS Automatic Weather stations in Antarctica transmit data every 3 hours rather than hourly.

Action A3

Action: Ensure sustained operation of surface meteorological stations addressing national and sub-national needs, and implement additional stations where necessary; and exchange hourly SYNOP reports and monthly CLIMAT reports from all stations internationally.
Who: National Meteorological Services, in cooperation/coordination with WMO CBS, WMO CCl, WMO RAs, and WMO WWW.
Time-Frame: Full operation of all stations globally by 2015.
Performance Indicator: Data archive statistics at WDC Asheville.
Annual Cost Implications: 100-300M US$ (90% in non-Annex-I Parties).

The Met Office has a Land Surface Weather Observation Programme which includes both Automatic Weather Stations (approx. 200) and Manual Observing Stations (approx. 300). In addition an Automatic Weather station is located at the Weybourne Atmospheric Observatory

(UEA), with data deposited in BADC and Meteorological information is collected as part of the ECN (however this does not produce SYNOP reports).

BAS is responsible for servicing a small network of AWS on the Antarctic peninsula as well as at Halley and Rothera. The Antarctic and Southern Ocean areas are remarkably data sparse and the distribution of observatories is generally greater than 200km (UK and other nation stations combined). ARGO floats have helped significantly to fill data gaps, however the floats do not operate in ice infested areas (which for Antarctica is an area bigger than Europe).

Although logistically challenging, more remote long term observation stations with a larger suite of calibrated instruments, are needed in this climatically sensitive area. This would enable the determination of seasonal and inter-annual variability of Antarctic bottom water that drives much of the global circulation. Due to the logistical challenge of implementing this, the high cost of instruments and the limited availability of ship time to service instruments, this is unlikely to happen in the foreseeable future. NERC (BAS) does have a Southern Ocean Observing system (SOOS) which aims to collect long term observations to improve understanding of climate change and variability as well as biogeochemical cycles and coupling of climate and marine ecosystems, however this is also resource limited.

Action A4 *[IP-04 A3]*

Action: Apply the GCMPs to all measurements relevant for climate from surface networks.
Who: National Meteorological Services, in coordination with WMO CBS, WMO CCl, WMO RAs, and GCOS Secretariat.
Time-Frame: Continuous.
Performance Indicator: Quality and homogeneity of data and metadata submitted to International Data Centres.
Annual Cost Implications: 10-30M US$ (70% in non-Annex-I Parties).

The Met Office complies with GCOS Climate Monitoring Principles, e.g. side-by-side comparisons were undertaken when new infrastructure was put in place, such as between old and new equipment at Central England and GCOS stations when the Meteorological Monitoring System was introduced.

BAS is the nominated WMO CBS (Commission for Basic Systems) for Antarctica and therefore collates the monitoring performance of all those working in the Antarctic for GCOS.

Action A5 *[IP-04 A4]*

Action: Implement guidelines and procedures for the transition from manual to automatic surface observing stations. Conduct expert review of the impact of increasing use of automatic stations on the surface climate data record.
Who: Parties operating GSN stations for implementation. WMO CCl, in cooperation with the WMO CIMO, WMO CBS for review.
Time-Frame: On-going for implementation. Review by 2014.
Performance Indicator: Implementation noted in National Communication.
Annual Cost Implications: 1-10M US$ (60% in non-Annex-I Parties).

As mentioned under Action A4 the Met Office ensured that comparisons were made between old and new equipment at Central England and GCOS stations when the Meteorological Monitoring System was introduced.

BAS are also trying to move steadily towards automation of meteorological observations; no analysis of intercomparisons has been undertaken, however this information exists in available literature. There are issues associated with automation in polar regions, primarily instruments being covered in freezing rain, ice, snow, rime[2] etc which results in no or erroneous data.

3.1.1. Specific Issues – Surface ECVs

ECV Pressure

Action A6 *[IP-04 A5] [also see action on O8]*

Action: Seek cooperation from organizations operating drifting buoy programmes to incorporate atmospheric pressure sensors as a matter of routine.
Who: Parties deploying drifting buoys and buoy-operating organizations, coordinated through JCOMM, with advice from OOPC and AOPC.
Time-Frame: Complete by 2014.
Performance Indicator: Percentage of buoys with sea-level pressure (SLP) sensors.
Annual Cost Implications: <1M US$ (Mainly by Annex-I Parties).

The Met Office releases approx. 5-10 drifting buoys a year in the south Atlantic / Southern Ocean. Buoys are often released by BAS vessels, sometimes in collaboration with Plymouth Marine Laboratory (PML) and National Oceanography Centre (NOC). All buoys deployed are equipped with pressure sensors.

ECV Precipitation

Action A7 *[IP-04 A6]*

Action: Submit all precipitation data, including hourly totals where possible and radar-derived precipitation products, from national networks to the International Data Centres.
Who: National Meteorological Services, with coordination through the WMO CCl.
Time-Frame: Continuous.
Performance Indicator: Percentage of nations providing all precipitation data to the International Data Centres. Percentage of stations for which hourly data available.
Annual Cost Implications: 1-10M US$ (60% in non-Annex-I Parties).

The Met Office runs both the Weather Radar Network which primarily measures precipitation and the Rainfall Collection Sites Programme in conjunction with the Environment Agency. The Met Office also derives satellite precipitation from AMSU-A globally and Meteosat over Europe BAS also provides data from its Antarctic observatories.

The UK does have other activities which collect precipitation data, such as the ECN and Environmental Change Biodiversity Network (ECBN) (England), this more local collection of data is archived within the NERC data centre and not submitted to IDCs.

Action A8

Action: Ensure continuity of satellite precipitation products.
Who: Space agencies.
Time-Frame: Continuous.
Performance Indicator: Long-term homogeneous satellite-based global precipitation products.
Annual Cost Implications: 10-30M US$ (for generation of climate products, assuming missions funded for other operational purposes) (Mainly by Annex-I Parties).

[2] Rime is white ice which forms on the surfaces when water within fog freezes.

The UK Met Office represents the UK on EUMetSat, a programme of which is the JASON 2 mission (Ocean Altimetry Satellite programme) that provides rain rates over the oceans.

Action A9 *[IP-04 A8]*

Action: Equip all buoys in the Ocean Reference Mooring Network with precipitation-measuring instruments.
Who: Parties deploying moorings, in cooperation with JCOMM and OOPC.
Time-Frame: Complete by 2014.
Performance Indicator: Number of instruments deployed and data submitted to International Data Centres.
Annual Cost Implications: <1M US$ (Mainly by Annex-I Parties).

This action has strong links with Ocean Actions (O5). The UK Met Office and NOCS collaborate to operate a surface moored buoy at the Porcupine Abyssal Plain ocean reference mooring site. It does not have a precipitation sensor and there are no current plans to add one. Although instruments do exist, for example on the Tropical Atmospheric Ocean Array (TAO/TRITON), precipitation measurements from ships and / or buoys are subject to error. Therefore if (in the future) precipitation instruments were added to UK buoys (and as mentioned there is no current plan to do so) extensive testing would be needed before reliable data could be gathered.

Action A10 *[IP-04 A9]*

Action: Develop and implement improved methods for observing precipitation and deriving global precipitation products that take into account advances in technology and fulfil GCOS requirements.
Who: Parties' national research programmes through WCRP, in cooperation with GCOS.
Time-Frame: Continuous.
Performance Indicator: Implemented methods; improved (in resolution, accuracy, time/space coverage) analyses of global precipitation.
Annual Cost Implications: 10-30M US$ (40% in non-Annex-I Parties).

Global precipitation products are being developed from satellite data. The Met Office has not been involved in this action, however the TRMM (Tropical Rainfall Measuring Mission, NASA/Japan National Space Development Agency) and CloudSAT (NASA) both provide new technology to refine global satellite precipitation estimates.

BAS stations are already operating to GCOS standards.

ECV Wind Direction & Speed
Action A11 *[IP-04 A11]*

Action: Ensure continuous generation of wind-related products from AM and PM satellite scatterometers or equivalent observations.
Who: Space agencies.
Time-Frame: Continuous.
Performance Indicator: Long-term satellite observations of surface winds every six hours.
Annual Cost Implications: 1-10M US$ (Mainly by Annex-I Parties).

Currently wind is only available from AM orbit through ASCAT on METOP. The Met Office is attempting to use Indian Oceansat-2 scatterometer to cover the PM orbit.

ECV Water Vapour
Action A12 *[IP-04 A12]*

Action: Submit water vapour data from national networks to the International Data Centres.
Who: National Meteorological Services, through WMO CBS and International Data Centres, with input from AOPC.
Time-Frame: Continuing.
Performance Indicator: Data availability in analysis centres and archive, and scientific reports on the use of these data.
Annual Cost Implications: <1M US$ (60% in non-Annex-I Parties).

The UK has several programmes that measure water vapour. The Met Office runs a GPS Water Vapour programme.

NERC funded programmes also collect relevant data: The Mesosphere-Stratosphere-Troposphere Radar Facility at Aberystwyth measures the water vapour column, The EMEP Supersite at Auchencorth Moss takes measurements of water vapour fluxes and the Chilbolton Facility for Atmospheric and Radio Research (CFARR[*]) conducts water vapour studies. These programmes submit data to the NERC British Atmospheric Data Centre. BADC does not submit the data to the International Data Centre however the archived data is accessible upon request.

BAS provides relevant data from its Antarctic observatories (BAS is the WMO CBS for Antarctica).

ECV Surface Radiation Budget
Action A13 *[IP-04 A13]*

Action: Submit surface radiation data with quality indicators from national networks to the World Radiation Data Centre (WRDC), and expand deployment of net radiometers at WWW/GOS surface synoptic stations.
Who: National Meteorological Services and others, in collaboration with the WRDC.
Time-Frame: On-going.
Performance Indicator: Data availability in WRDC.
Annual Cost Implications: 1-10M US$ (70% in non-Annex-I Parties).

Solar radiation is measured by the Met Office and information from 14 surface synoptic stations including, Lerwick and Camborne) are submitted to the WRDC. BAS Antarctic Observatories also provide data.

The ECBN (Climate), ECN (meteorology) and the Weybourne Atmospheric Observatory collect and submit data to NERC data centres, where the archived datasets are accessible.

Action A14 *[IP-04 A14]*

Action: Ensure continued long-term operation of the BSRN and expand the network to obtain globally more representative coverage. Establish formal analysis infrastructure.
Who: Parties' national services and research programmes operating BSRN sites in cooperation with AOPC and the WCRP GEWEX Radiation Panel.
Time-Frame: On-going (network operation and extension); by 2012 (analysis infrastructure).
Performance Indicator: The number of BSRN stations regularly submitting data to International Data Centres; analysis infrastructure in place.
Annual Cost Implications: 1-10M US$ (20% in non-Annex-I Parties).

The Met office contributes to the BSRN with measurements from Lerwick & Camborne.

[*] N.B. The Chilbolton Facility for Atmospheric and Radio Research is part of the Science and Technology Facilities Council

3.2. Atmospheric Domain – Upper-air

3.2.1. General

Action A15 *[IP-04 A15]*

Action: Improve operation of the GUAN, including infrastructure and data management.
Who: Parties operating GUAN stations, in cooperation with GCOS Secretariat and WMO CBS.
Time-Frame: On-going.
Performance Indicator: Percentage of data archived in WDC Asheville.
Annual Cost Implications: 10-30M US$ (80% in non-Annex-I Parties).

The Met Office maintains operations at UK GUAN radiosonde stations at Lerwick and Camborne. Other GUAN stations are located in British Overseas Territories: Gibraltar, Mt Pleasant (both run by Met Office Staff on RAF bases); St. Helena (Met Office funded, but run by St. Helena government), Gough Island (in conjunction with the South African Weather surface, SAWS) & Bermuda (run by Bermuda Met Service, for Bermuda Government). UK support of St. Helena and Gough Island is from the Met Office PWS through the WMO Voluntary Co-operation Programme, which also provides long-term support of GUAN stations in, Seychelles and in the South Pacific (with the Met. Service of New Zealand) at Funafuti in Tuvalu, Tarawa in Kiribati and Rarotonga in the Cook Islands. A GUAN (and SHADOZ ozone) station on Ascension Island ran until the beginning of 2011, when American funding (from their shuttle programme) was removed. The Met Office is currently in negotiation with the US to reinstate this station, using US funding but UK MO Staff.

BAS also operate a GUAN station at Halley; expansion of this network (to include Rothera) is limited due to resource availability.

Action A16

Action: Continue implementation of the GRUAN of high-quality radiosondes and other supporting observations, including operational requirements and data management, archiving and analysis.
Who: National Meteorological Services and research agencies, in cooperation with AOPC, WMO CBS, and the Lead Centre for GRUAN.
Time-Frame: Implementation largely complete by 2013.
Performance Indicator: Number of sites contributing reference-quality data for archive and analysis.
Annual Cost Implications: 30-100M US$ (20% in non-Annex-I Parties).

At present there are 15 GRUAN stations, none of which are run by the UK.

The Met Office has contributed to GRUAN via the scientific planning led by Peter Thorne, previously based at the Met Office, but now at NOAA/NCDC in the USA. The National Physical Laboratory (NPL) has also had involvement in the scientific planning.

Action A17 *[IP-04 A17]*

Action: Improve implementation of the WWW/GOS radiosonde network compatible with the GCMPs and provide data in full compliance with the BUFR coding convention.
Who: National Meteorological Services, in cooperation with WMO CBS and WMO RAs.
Time-Frame: Continuing.
Performance Indicator: Percentage of real-time upper-air data received in BUFR code with no quality problems.
Annual Cost Implications: 10-30M US$ (60% in non-Annex-I Parties).

As mentioned under A15, the Met Office has through the WMO Voluntary Cooperation Programme provided support for GUAN stations in both British Overseas Territories and the South Pacific. All stations with Met Office VCP (with the exception of St. Helena) are reporting in BUFR. The stations directly on the Met Office network use a conversion of the TEMP code

(and are therefore missing the extra time/location data from the full BUFR code). The WMO has set the deadline for withdrawal of TEMP code to November 2012.

Within the UK Lerwick and Camborne are designated GCOS radiosonde stations. The UK Met Office is planning to implement BUFR coding from these sites. The UK has other radiosonde stations however these are automated and follow different practices (such as using smaller balloons that affect the height reached) and are therefore not compatible. The cost of operating radiosonde stations restricts the expansion of this component of the UK Met Office's network.

Action A18 *[IP-04 A18*]

Action: Submit metadata records and inter-comparisons for radiosonde observations to International Data Centres.
Who: National Meteorological Services, in cooperation with WMO CBS, WMO CIMO, and AOPC.
Time-Frame: On-going.
Performance Indicator: Percentage of sites giving metadata to WDC Asheville.
Annual Cost Implications: <1M US$ (50% in non-Annex-I Parties).

Data from all the Met Office and BAS run GUAN stations are submitted to the International Data Centres.

Action A19

Action: Implement and evaluate a satellite climate calibration mission, e.g., CLARREO.
Who: Space agencies (e.g., NOAA, NASA, etc).
Time-Frame: On-going.
Performance Indicator: Improved quality of satellite radiance data for climate monitoring.
Annual Cost Implications: 100-300M US$ (Mainly by Annex-I Parties).

The NPL have a proposal (called TRUTHS) to provide a component of CLARREO to cover the SW part of the spectrum. However CLARREO is currently on hold due to a lack of funding.

3.2.2. Specific Issues – Upper-air ECVs

ECV – Upper-air Temperature
Action A20 *[A19 IP-04]*

Action: Ensure the continued derivation of MSU-like radiance data, and establish FCDRs from the high-resolution IR sounders, following the GCMPs.
Who: Space agencies.
Time-Frame: Continuing.
Performance Indicator: Quality and quantity of data; availability of data and products.
Annual Cost Implications: 1-10M US$ (for generation of datasets, assuming missions, including overlap and launch-on-failure policies, are funded for other operational purposes) (Mainly by Annex-I Parties).

EUMETSAT EPS programme provides AMSU-A and IASI radiances to provide continuity in the AM orbit. The Met Office is the UK representative for EUMETSAT. NOAA with the JPSS programme (ATMS, CrIS) provides continuity in the PM orbit.

Action A21 *[A20 IP-04]*

Action: Ensure the continuity of the constellation of GNSS RO satellites.
Who: Space agencies.
Time-Frame: On-going; replacement for current COSMIC constellation needs to be approved urgently to avoid or minimise a data gap.
Performance Indicator: Volume of data available and percentage of data exchanged.
Annual Cost Implications: 10-30M US$ (Mainly by Annex-I Parties).

US-Taiwan COSMIC-2 programme will ensure continuity along with GPS receivers on other platforms (e.g. METOP).

ECV Upper Air Wind Speed and Direction; Upper Air Water Vapour
Action A22 *[IP-04 A21]*

Action: Finalise standard and implement exchange of data globally from the networks of ground-based GPS receivers.
Who: WMO CIMO and WMO CBS, in cooperation with national agencies.
Time-Frame: Finalisation of standard urgent, implementation by 2012.
Performance Indicator: Number of sites providing data.
Annual Cost Implications: <1M US$ (20% in non-Annex-I Parties).

Data from across Europe is well co-ordinated via the EUMETNET E-GVAP Programme – a collaborative activity set up at a European level to coordinate the activities of European Met Services (htto://egvap.dmi.dk/).

For global GPS Total Zenith Delay, the Met Office has lobbied for real time availability in WMO BUFR format in various fora, most recently at NAEDEX meeting in Boulder in May 2011.

ECV – Cloud Properties
Action A23 *[IP-04 A22]*

Action: Continue the climate data record of visible and infrared radiances, e.g., from the International Satellite Cloud Climatology Project, and include additional data streams as they become available; pursue reprocessing as a continuous activity taking into account lessons learnt from preceding research.
Who: Space agencies, for processing.
Time-Frame: Continuous.
Performance Indicator: Long-term availability of global homogeneous data at high frequency.
Annual Cost Implications: 10-30M US$ (for generation of datasets and products) (Mainly by Annex-I Parties).

The UK contributes to EUMetSat (1st and 2nd Generation) through the Met Office.

Chilbolton Facility for Atmospheric and Radio Research (CFARR) also have radar facilities (for cloud measurement), this information is archived with the NERC Data Centre BADC.

Action A24 *[IP-04 A23]*

Action: Research to improve observations of the three-dimensional spatial and temporal distribution of cloud properties.
Who: Parties' national research and space agencies, in cooperation with the WCRP.
Time-Frame: Continuous.
Performance Indicator: New cloud products.
Annual Cost Implications: 30-100M US$ (Mainly by Annex-I Parties).

Cloud research is on-going within the UK. There is a cloud group in the Dept. Meteorology at Reading University, this group works closely with scientists at Chilbolton (CFARR) (using cloud radar). The Met Office also conducts research through the use of satellite data.

ECV- Earth Radiation Budget
Action A25 *[IP-04 A24]*

Action: Ensure continuation of Earth Radiation Budget observations, with at least one dedicated satellite mission operating at any one time.
Who: Space agencies.
Time-Frame: On-going.
Performance Indicator: Long-term data availability at archives.
Annual Cost Implications: 30-100M US$ (Mainly by Annex-I Parties).

NOAA JPSS programme has committed to continue these measurements from space using CERES. ESA will contribute with its forthcoming EarthCARE mission[3], which is being carried out in conjunction with the Japanese Space Agency and is due to launch in 2013.

3.3. Atmospheric Domain – Composition

3.3.1. General

Action A26

Action: Establish long-term limb-scanning satellite measurement of profiles of water vapour, ozone and other important species from the UT/LS up to 50 km.
Who: Space agencies, in conjunction with WMO GAW.
Time-Frame: On-going, with urgency in initial planning to minimize data gap.
Performance Indicator: Continuity of UT/LS and upper stratospheric data records.
Annual Cost Implications: 100-300M US$ (including mission costs) (Mainly by Annex-I Parties).

ESA Envisat and NASA Aura satellites provide this capability. For the future there are no firm plans for an operational limb sounding instrument (at least from Europe).

Action A27

Action: Establish a network of ground stations (MAXDOAS, lidar, FTIR) capable of validating satellite remote sensing of the troposphere.
Who: Space agencies, working with existing networks and environmental protection agencies.
Time-Frame: Urgent.
Performance Indicator: Availability of comprehensive validation reports and near real-time monitoring based on the data from the network.
Annual Cost Implications: 10-30M US$ (30% in non-Annex-I Parties).

Chilbolton (CFARR) operates meteorological radar instruments along with other facilities including lidar (although this is only one site it could be included in any network).

3.3.2. Specific Issues – Composition ECVs

ECVs – Carbon Dioxide, Methane, & other GHGs *(including N_2O, CFCs, HCFCs, HFCs, SF_6 & PFCs)*
Action A28 *[IP-04 A27]*

Action: Maintain and enhance the WMO GAW Global Atmospheric CO_2 and CH_4 Monitoring Networks as major contributions to the GCOS Comprehensive Networks for CO_2 and CH_4.
Who: Parties' national services, research agencies, and space agencies, under the guidance of WMO GAW and its Scientific Advisory Group for Greenhouse Gases, in cooperation with the AOPC.
Time-Frame: On-going.
Performance Indicator: Dataflow to archive and analyses centres.
Annual Cost Implications: 10-30M US$ (50% in non-Annex-I Parties).

The UK contributes to the GAW monitoring network with contributing and regional stations across the UK. DECC also contributes to the long term atmospheric trace gas monitoring at Mace Head, which is a GAW site in the Republic of Ireland.

GAW stations are located in British overseas territories (Bermuda, South Georgia, and British Antarctica). Grant applications have been submitted to extend GAW type measurements at British Antarctic stations. In addition a GAW station, measuring a wide range of greenhouse gases is operated by NCAS, on Cape Verde. The GAW station on Ascension is currently

[3] The ESA/JAXA EarthCARE Mission aims to improve the representation of the Earth's radiative balance in climate and numerical weather forecast models by using vertical profiles of clouds and aerosols, as well as the radiances at the top of the atmosphere.

silent, the vacuum flasks programme is in operation (CO_2 / CH_4) but negotiations to reopen the SHADOZ ozone are in process with the USA (see Action 15).

Other sites within the UK, which contribute to the World Data Centre for Greenhouse Gases via the EMEP (European Monitoring and Evaluation Programme) include Auchencorth Moss and Harwell. UEA's trace gas observatory at Weybourne measures ozone, CO, oxides of Oxygen, VOCs and GHGs, data is archived at BADC.

An EU Framework 6 programme, CarboEurope used flux towers in the UK this programme finished in 2009 however it may be picked up again under the ICOS (Integrated Carbon observing System) in which the UK is involved. In addition NOC-Southampton ran a weather ship (polarfront) at Station Mike, investigating air-sea exchanges of CO_2 amongst other parameters. These measurements are continuing on RRS James Clark Ross until 2012.

Action A29

Action: Assess the value of the data provided by current space-based measurements of CO_2 and CH_4, and develop and implement proposals for follow-on missions accordingly.
Who: Parties' research institutions and space agencies.
Time-Frame: Urgent, to minimise data gap following GOSAT.
Performance Indicator: Assessment and proposal documents; approval of consequent missions.
Annual Cost Implications: 1-10M US$ initially, increasing with implementation (10% in non-Annex-I Parties).

ESA Satellites Envisat (Sciamachy) & MetOp (IASI) currently provide these measurements. In the future Sentinel-4 and 5 will provide this from Europe.

Action A30 *[IP-04 A29]*

Action: Maintain networks for halocarbon and N_2O and SF_6 measurements.
Who: Parties' national research agencies and national services, through WMO GAW.
Time-Frame: On-going.
Performance Indicator: Data flow to archive and analyses centres.
Annual Cost Implications: 1-10M US$ (20% in non-Annex-I Parties).

Again the UK contributes to the GAW network. Nitrous oxide (N_20) is measured at Lerwick (by CSIRO) and at Cape Verde. It is also measured at Weybourne Observatory (although this is not part of the GAW network). DECC supports measurements of N_2O and SF_6 at Mace Head; these data are contributed to the GAW network. DECC is also beginning to support measurements of N_2O and SF_6 at Angus and Talcolnston and of N_2O at Ridge Hill, but these are not part of the GAW network.

ECV Ozone

Action A31 *[IP-04 A30]*

Action: Maintain the quality of the GCOS Global Baseline (Profile and Total) Ozone Networks coordinated by the WMO GAW and seek to increase coverage in the Tropics and Southern Hemisphere. Improve timeliness of provision of data to users and promote adoption of a single code standard.
Who: Parties' national research agencies and services, through WMO GAW and partners, in consultation with AOPC.
Time-Frame: On-going.
Performance Indicator: Network coverage and operating statistics.
Annual Cost Implications: 1-10M US$ (50% in non-Annex-I Parties).

As mentioned above the UK does contribute to the GAW network and has stations within the UK that do so for ozone (Eskdalemuir, Cambourne, Lerwick, Manchester & Reading). Within the

tropics, the NCEO contribute to the Cape Verde station. The British Antarctic Survey has submitted grant applications to extend GAW type measurements at Antarctic stations.

The UK Met Office also owns a Dobson Ozone Spectrophotometer which is on long term loan in South Africa.

Action A32

Action: Continue production of satellite ozone data records (column, tropospheric ozone and ozone profiles) suitable for studies of interannual variability and trend analysis. Reconcile residual differences between ozone datasets produced by different satellite systems.
Who: Space agencies.
Time-Frame: On-going.
Performance Indicator: Statistics on availability and quality of data.
Annual Cost Implications: 10-30M US$ (Mainly by Annex-I Parties).

Envisat Sciamachy, GOMOS and METOP GOME-2, IASI and JPSS OMPS, CrIS all provide these data.

ECV – Aerosol Properties
Action A33 *[IP-04 A31]*

Action: Develop and implement a coordinated strategy to monitor and analyse the distribution of aerosols and aerosol properties. The strategy should address the definition of a GCOS baseline network or networks for *in situ* measurements, assess the needs and capabilities for operational and research satellite missions for the next two decades, and propose arrangements for coordinated mission planning.
Who: Parties' national services, research agencies and space agencies, with guidance from AOPC and in cooperation with WMO GAW and AERONET.
Time-Frame: On-going, with definition of baseline *in situ* components and satellite strategy by 2011.
Performance Indicator: Designation of GCOS baseline network(s). Strategy document, followed by implementation of strategy.
Annual Cost Implications: 10-30M US$ (20% in non-Annex-I Parties).

The assimilation of satellite aerosol products are being developed at the Met Office.

UK in-situ measurements (currently from CFARR, Wytham Woods and UCL) are included in AERONET.

With additional resource, measurements at UK managed GAW stations could be extended to include routine aerosol observations. With the appropriate resource (approximately ~£400k capital plus £60k p.a would be needed) this could be done at Cape Verde relatively easily.

Action A34

Action: Ensure continuity of products based on space-based measurement of the precursors (NO_2, SO_2, HCHO and CO in particular) of ozone and aerosols and derive consistent emission databases, seeking to improve temporal and spatial resolution.
Who: Space agencies, in collaboration with national environmental agencies and meteorological services.
Time-Frame: Requirement has to be taken into account now in mission planning, to avoid a gap in the 2020 timeframe.
Performance Indicator: Availability of the necessary measurements, appropriate plans for future missions, and derived emission data bases.
Annual Cost Implications: 10-30M US$ (10% in non-Annex-I Parties).

ESA Sentinel 4 and 5 missions will contribute to this Action.

4. OCEANIC CLIMATE OBSERVING SYSTEM

The Oceanic Climate Observing System refers to surface and subsurface oceanic ECVs (that cover physical, chemical and biological parameters), using a range of platforms for example, in-situ Voluntary Observing Ships (VOS), drifting or moored buoys, profiling floats and satellites etc. The need for coastal monitoring is also mentioned.

Summary of Oceanic Climate Observing System
Again there are many UK experts and organisations undertaking relevant monitoring, research, analysis and data management - key organisations being the Met Office, NERC (BAS & NOC), NERC associated centres, PML, Cefas, CPOM and university research groups. The UK is also home to the Continuous Plankton Recorder at SAHFOS and hosts the Permanent Service for Mean Sea Level (PSMSL) at NOC (Liverpool) alongside British Oceanographic Data Centre (BODC), which is one of the designated International Data Centres. The UK is also hoping to jointly host the Integrated Carbon Observation System (ICOS), Oceanic Theme, which will address some of the action listed within the Implementation Plan.

The UK contributes in some way to the majority of the actions listed however some gaps exist, for example with regard to sea surface salinity and the UK does not support the Tropical Moored Buoy array. The UK is also struggling to identify sustained funding streams to make secure contributions to long term ocean observations.

The majority of UK marine data is archived and managed by BODC (who sit on the International Oceanographic Data Exchange). The Marine Environment Data Information Network (MEDIN), along with the UK Marine Monitoring and Assessment Strategy (UKMMAS) are also working to establish National data archiving centres, encouraging adherence to common standards and coordination of data.

UK activities and collaborative work, relevant to each of the Oceanic Actions are given below.

4.1. Agents for Implementation

Action O1 *[IP-04 O1]*[76]

Action: Analyse the ocean section of national reports on systematic observation for climate to the UNFCCC, and encourage non-Annex-I Parties to contribute reports.
Who: IOC and I-GOOS JCOMM, in consultation with GOOS.
Time-Frame: Conforming to UNFCCC guidelines.
Performance Indicators: Number of Parties providing reports on their ocean observing activities.
Annual Cost Implications:[77] <1M US$ (10% in non-Annex-I Parties).

NERC takes the lead on behalf of the UK for IOC matters, NERC and Met Office share the lead to JCOMM.

Implementation in Coastal Regions
Action O2 *[IP-04 O5]*

Action: Establish prioritized national and regional plans that address the needs to monitor the coastal regions and support adaptation and understanding of vulnerabilities.
Who: All coastal Parties, in consultation with PICO and OOPC.
Time-Frame: Continuing.
Performance Indicator: Publications by regions (e.g., GRAs) and nations of their plans for coastal climate observing systems, and reporting their progress against performance measures established by technical advisory bodies, including PICO and OOPC.
Annual Cost Implications: 1-10M US$ (Mainly by Annex-I Parties).

NERC has future plans to study this. A priority of the Belmont Forum is Coastal vulnerability, therefore research coordination on this areas is planned through the Belmont Forum.

Within the UK, Marine and Coastal monitoring is coordinated by the MSCC (which is supported by Evidence Groups made up of representatives from across the UK including, Defra, NERC, Met Office, the Marine Management Organisation, Cefas, Marine Scotland etc).

There is a need to determine the drivers for ECV's on the NW European shelf, the EU Marine Strategy Framework Directive may be one such driver - indicators of state need to be agreed with other EU states bordering the NW European shelf and sustained monitoring rationalised relative to existing measurements and drivers of observations.

4.2. Oceanic Domain – Surface

4.2.1. General

Action O3 *[IP-04 O6]*

Action: Improve number and quality of climate-relevant marine surface observations from the VOS. Improve metadata acquisition and management for as many VOS as possible through VOSClim, together with improved measurement systems.
Who: National meteorological agencies and climate services, with the commercial shipping companies.
Time-Frame: Continuous.
Performance Indicator: Increased quantity and quality of VOS reports.
Annual Cost Implications: 1-10M US$ (10% in non-Annex-I Parties).

As part of their Marine Surface Programme the Met Office works with approximately 350 Voluntary Observing Ships, at a cost of approximately £350K per year (including a contribution to the EUMETNET surface marine (E-SURFMAR) programme) to measure meteorological observations. A small subset these ships report to VOSClim standards (the number reporting has increased from 51 (in January 2010) to 119 (April 2011). The Met Office aims to increase this number to 200 over the coming years). In addition to VOS, measurements are received from approximately 30 offshore rigs and platforms.

Although not currently reporting to VOSClim several UK research projects also use VOS. ISAR operated by NOCS (funded by DECC) and SISTeR operated by RAL, provide ship-borne radiometer measurements of SST. A limited VOS programme is run for SST and SSS by the Centre for Environment, Fisheries and Aquaculture Science (Cefas - currently a single vessel in the Southern North Sea). UEA use a VOS to tow an autonomous CO_2 instrument between the UK and the Caribbean.

NOC also has a number of projects aimed at improving quality of observations - see http://www.noc.soton.ac.uk/ooc/SURFACE/VOSerrors.php

Action O4 *[IP-04 O7]*

Action: Ensure coordination of contributions to CEOS Virtual Constellations for each ocean surface ECV, in relation to *in situ* ocean observing systems.
Who: Space agencies, in consultation with CEOS Virtual Constellation teams, JCOMM, and GCOS.
Time-Frame: Continuous.
Performance Indicators: Annually updated charts on adequacy of commitments to space-based ocean observing system from CEOS.
Annual Cost Implications: <1M US$ (Mainly by Annex-I Parties and implementation cost covered in Actions below).

Both the ISAR (funded by DECC and run by NOC-Southampton) and SISTer, operated by RAL, provide ship-borne radiometer measurements of SST that are being used to validate AATSR. (It should be noted that other UK experts at University of Leicester and RAL are involved in the calibration and validation of AATSR through CEOS).

Action O5 *[IP-04 O8]*

Action: Complete and maintain a globally-distributed network of 30-40 surface moorings as part of the OceanSITES Reference Mooring Network.
Who: Parties' national services and ocean research agencies responding to the OceanSITES plan.
Time-Frame: Network complete by 2014.
Performance Indicator: Moorings operational and reporting to archives.
Annual Cost Implications: 30-100M US$ (10% in non-Annex-I Parties).

The NOC-Southampton are coordinating the Framework 7 programme EuroSITES, which is the European contribution to the OceanSITES network. In addition NOC-S are running the Porcupine Abyssal Plain (PAP) Observatory (one of the EuroSITES, with funding from NERC National Capability), where the surface moored buoy is jointly operated with the Met Office (see Action A9).

The UK has 3 other mooring sites which contribute to OceanSITES - the RAPID array, Angmagssalik Denmark Strait Overflow array (jointly maintained by Cefas & German partners) and The Wyville Thomson Overflow moorings run by the Scottish Association for Marine Science (SAMS). With the exception of the SAMS site, these sites are funded as part of research programmes rather than via sustained observation budgets.

Action O6

Action: Develop and deploy a ship-based reference network of robust autonomous *in situ* instrumentation for biogeochemical and ecosystem variables.
Who: Parties' national ocean research agencies, supported by the IGBP and IOCCG.
Time-Frame: Plan published and pilot project deployed by 2014.
Performance Indicator: Pilot project implemented; progress towards global coverage with consistent measurements.
Annual Cost Implications: 10-30M US$ (10% in non-Annex-I Parties).

Although not fully autonomous, SAHFOS runs the Continuous Plankton recorder across several Atlantic routes. BAS also operates a continuous plankton recorder and $_{P}CO_2$ equipment on the James Clark Ross - in conjunction with SAHFOS and PML. Equipment is towed from the UK to locations in the South Atlantic in November and on the return journey in April/May the following year. Other NERC vessels, (RRS Discovery and RRS James Cook) also tow pCO2 instruments (however this is on an ad hoc basis).

With additional resource, many more parameters could be measured autonomously in transit and a more widespread deployment of autonomous instruments places on ships of opportunity. Atmosphere-ocean fluxes are severely under-sampled, therefore this could be one method to increase data which is essential for comprehensive earth system modelling.

4.2.2. Specific Issues – Oceanic Surface ECVs

ECV – Sea-surface Temperature

Action O7 *[IP-04 O9]*

Action: Continue the provision of best possible SST fields based on a continuous coverage-mix of polar orbiting IR and geostationary IR measurements, combined with passive microwave coverage, and appropriate linkage with the comprehensive *in situ* networks noted in O8.
Who: Space agencies, coordinated through CEOS, CGMS, and WMO Space Programme.
Time-Frame: Continuing.
Performance Indicator: Agreement of plans for maintaining a CEOS Virtual Constellation for SST.
Annual Cost Implications: 1-10M US$ (for generation of datasets) (Mainly by Annex-I Parties).

The UK contributes financially towards fulfilling this Action through Met Office contributions to the EUMETSAT (SST data from AVHRR & SEVIRI); UK funding of ESA (CCI programme) and DECC funding (jointly with the Australian Department of Innovation, Industry, Science and Research) of AATSR and ship borne radiometers for climate quality SST measurements.

UK expertise contributes via a combination of the data in the Met Office Hadley Centre HadISST and OSTIA systems as well as validation of ATSR products by the University of Leicester, and in-flight performance by RAL). Thus the UK provides the benchmark reference data set to the climate community through ATSR instruments.

To maintain IR measurements a high accuracy sensor of the ATSR class, supported by an international network of ship borne radiometers is required along with microwave SST to improve coverage and sampling under cloudy skies.

The SLSTR on Sentinel-3 is the successor to ATSR and will need UK support to ensure that the time series of SST is maintained in an accurate form. The UK has the expertise to do this however a funding plan to exploit SST data from SLSTR is required – at present a sustainable funding source is not assured.

Ship-borne radiometers are fundamental to GCOS as a traceable, reference standard for SST and can be used to both validate satellite radiometer performance and to inter-calibrate follow-on satellite missions. This is and will be particularly important where gaps in data exist between follow-on missions. The UK currently has two ship borne radiometer (research) projects measuring SST (see O4), however an international network, which works with the VOS and buoy communities is needed (and would need the support of the international community).

The UK therefore should therefore work to agree a sustainable source of funding potential through the UKSA and NERC, so that it is able to invest in understanding of microwave SST and future sensors.

Action O8 *[IP-04 O10] (Also see Action A6)*

Action: Sustain global coverage of the drifting buoy array (total array of 1250 drifting buoys equipped with ocean temperature sensors), obtain global coverage of atmospheric pressure sensors on the drifting buoys, and obtain improved ocean temperature from an enhanced VOS effort.
Who: Parties' national services and research programmes through JCOMM, Data Buoy Cooperation Panel (DBCP), and the Ship Observations Team (SOT).
Time-Frame: Continuing (sustain drifting buoy array and enhance VOS by 2014).
Performance Indicator: Data submitted to analysis centres and archives.
Annual Cost Implications: 1-10M US$ (10% in non-Annex-I Parties).

The Met Office makes an appropriate contribution to the global drifter array both in the North Atlantic (through E-SURFMAR) and the South Atlantic/Southern Ocean. These programmes

are funded via the Public Weather Service. The Met Office also contributes actively to various pilot projects (e.g. high resolution SST drifters) organised through the WMO-IOC Data Buoy Cooperation Panel (DBCP). All Met Office (and E-SURFMAR) drifters have pressure sensors.

The Met Office has a VOS programme see Action O3 for details. The UK Argo programme is also deploying floats with the capability to record temperatures within the top few metres and these data are being evaluated for accuracy and usefulness in conjunction with the GHRSST (Group for High Resolution SST) community.

Under this action a global network of ship borne (VOS) radiometers that are accurately calibrated against traceable internationally defined standards (before and after each deployment) should be included. Two UK research projects, ISAR and SISTer currently run ship borne radiometers (see O4).

ECV – Sea Level
Action O9 *[IP-04 O11]*

Action: Implement the GLOSS Core Network of about 300 tide gauges, with geocentrically-located high-accuracy gauges; ensure continuous acquisition, real-time exchange and archiving of high-frequency data; put all regional and local tide gauge measurements within the same global geodetic reference system; ensure historical sea-level records are recovered and exchanged; include sea-level objectives in the capacity-building programmes of GOOS, JCOMM, WMO, other related bodies, and the GCOS system improvement programme.
Who: Parties' national agencies, coordinated through GLOSS of JCOMM.
Time-Frame: Complete by 2014.
Performance Indicator: Data availability at International Data Centres, global coverage, number of capacity-building projects.
Annual Cost Implications: 1-10M US$ (70% in non-Annex-I Parties).

The UK contribution to GLOSS includes the Permanent Service for Mean Sea Level (PSMSL) at NOC-Liverpool (NOC-L hosts the PSMSL on behalf of International Council for Science, ICSU) and the GLOSS delayed mode centre at BODC.

NOC-L also run, with financial support from Defra and the EA, the National Tide and Sea Level Facility at NOC-L for data collection in the UK, South Atlantic, Antarctica and Gibraltar. NOC-L has also been involved (through the Intergovernmental Oceanographic Commission, IOC) in installing 12 new gauges in Africa (as part of the African GLOSS network). There is an on-going need to sustain and maintain this network as there is no regional maintenance service in place for this network. There is a further need to continue developing the local scientific human capacity to ensure the reliability of the data and broaden the use of the observations for local / regional products and coastal planning.

Although this action has been set a completion date of 2014, continued maintenance post installation, as found with the African network, is an issue that must be addressed.

Action O10 *[IP-04 O12]*

Action: Ensure continuous coverage from one higher-precision, medium-inclination altimeter and two medium-precision, higher-inclination altimeters.
Who: Space agencies, with coordination through the CEOS Constellation for Ocean Surface Topography, CGMS, and the WMO Space Programme.
Time-Frame: Continuous.
Performance Indicator: Satellites operating, and provision of data to analysis centres.
Annual Cost Implications: 30-100M US$ (Mainly by Annex-I Parties).

Several UK organisations contribute to this Action via various Satellite missions - JASON 2, ENVISAT, Jason-3 and GMES Sentinels 3A & 3B.

ECV – Sea-surface Salinity
Action O11 *[IP-04 O15]*

Action: Implement a programme to observe sea-surface salinity to include Argo profiling floats, surface drifting buoys, SOOP ships, tropical moorings, reference moorings, and research ships.
Who: Parties' national services and ocean research programmes, through IODE and JCOMM, in collaboration with CLIVAR.
Time-Frame: By 2014.
Performance Indicator: Data availability at International Data Centres.
Annual Cost Implications: 1-10M US$ (10% in non-Annex-I Parties).

The UK is involved in developing new sensor technology, for example NOCS have developed novel surface salinity micro-sensors that could be deployed, with appropriate funding, on Met Office (or other) moored and drifting buoys, or the EuroSITES mooring at Porcupine Abyssal Plain (PAP). Other programmes already collect salinity, however at present this is salinity in the water column, for example the Arctic Shelf Time Series and Cefas smartbuoys (salinity at 1m). Although information from some of these programmes is submitted to the British Oceanographic Data Centre, the data is not currently coordinated at a National level.

In addition to data collection, UK owned research vessels, such as BAS's James Clark Ross, are often used to deploy floats when requested.

Action O12 *[IP-04 O16]*

Action: Research programmes should investigate the feasibility of utilizing satellite data to help resolve global fields of SSS.
Who: Space agencies, in collaboration with the ocean research community.
Time-Frame: Feasibility studies complete by 2014.
Performance Indicator: Reports in literature and to OOPC.
Annual Cost Implications: 1-10M US$ (Mainly by Annex-I Parties).

No responses or comments were provided against this action.

ECV – Carbon Dioxide Partial Pressure
Action O13 *[IP-04 O17]*

Action: Develop and implement an internationally-agreed strategy for measuring surface pCO_2.
Who: IOCCP, in consultation with OOPC; implementation through national services and research programmes.
Time-Frame: Implementation strategy for end-2010; full implementation by 2014.
Performance Indicator: Flow of data into internationally-agreed data archives.
Annual Cost Implications: 1-10M US$ (Mainly Annex-I Parties).

UK scientists (from UEA) sit on the Scientific Steering Group of the IOCCP. These and other UK scientists (UEA, PML in conjunction with NOCS & BAS) are actively involved in measuring surface pCO_2 including autonomous measurements.

Although not focused on agreeing a measurement strategy, the SOCAT (Surface Ocean Carbon Atlas) project is collating surface fCO_2 (fugacity of carbon dioxide, which is the partial pressure of CO_2 (pCO_2) corrected for non-ideal behaviour of the gas) from researchers across the globe. UK researchers at UEA, NOCS and PML are heavily involved in this project, both in quality control and submission of their data holdings. In the future the project will produce two products, a quality controlled global surface ocean fCO_2 data set following agreed procedures

and regional review and gridded monthly surface water fCO_2 means (see http://www.socat.info/).

In addition, under the Integrated Carbon Observation System (ICOS) Europe an Ocean Thematic Centre is currently under consideration. The UK have submitted a bid to the NERC International Opportunities fund (with DECC backing), to enable the UK, along with Norway and Spain, to host the Ocean Thematic Centre. If successful this centre will play a key part in the implementation of a strategy for measuring pCO_2.

ECV – Ocean Acidity
Action O14

Action: Develop instrumentation for the autonomous measurement of either DIC, Alk, or pH with high accuracy and precision.
Who: Parties' national research programmes, coordinated through IOCCP.
Time-Frame: Strategy: 2010; technology: 2012; pilot project: 2014.
Performance Indicator: Development of instrumentation and strategy, demonstration in pilot project.
Annual Cost Implications: 1-10M US$ (Mainly by Annex-I Parties).

NOCS have been working on autonomous carbonate chemistry systems over the last 5 years. They recently deployed an operational autonomous pH system (on an Ocean Acidification cruise and a subsequent CLIVAR cruise). Precision is 0.001pH units with an accuracy of 0.002 pH units. It will be possible, in the future to incorporate this lab-on-a-chip design onto moorings, gliders etc.

Development of an autonomous alkalinity sensor is also underway, however further work is required (approx. 1-2 years development) before this will be operational. Work is also planned to develop an autonomous DIC instrument (based on the pH system), however it will be at least a year before any operational instrument will be available.

NOCS are also looking at developing a new approach to measuring pCO2 (using a fluorescent pCO2 foil, rather than licor IR detection, which is currently used.

ECV – Ocean Colour
Action O15 *[IP-04 O18]*

Action: Implement continuity of ocean colour radiance datasets through the plan for an Ocean Colour Radiometry Virtual Constellation.
Who: CEOS space agencies, in consultation with IOCCG and GEO.
Time-Frame: Implement plan as accepted by CEOS agencies in 2009.
Performance Indicator: Global coverage with consistent sensors operating according to the GCMPs; flow of data into agreed archives.
Annual Cost Implications: 30-100M US$ (10% in non-Annex-I Parties).

The UK via ESA supports Envisat and several UK groups are involved in the processing of data. In addition NEODAAS, a NERC funded facility have the capability to automatically receive, archive, process and map global data from multiple polar-orbiting sensors in near-real time, including MERIS, MODIS, SeaWiFS.

ECV – Sea State
Action O16 *[IP-04 O19]*

Action: Implement a wave measurement component as part of the Surface Reference Mooring Network.
Who: Parties operating moorings, coordinated through the JCOMM Expert Team on Waves and Surges.
Time-Frame: Deployed by 2014.
Performance Indicator: Sea state measurement in the International Data Centres.
Annual Cost Implications: 1-10M US$ (Mainly by Annex-I Parties).

With regards to the Surface Reference Mooring Network the UK has the PAP reference site mooring (operated jointly by the Met Office and NOCS); although the surface moored buoy has a wave measuring capability the wave sensor is not presently working and the buoy is due to be replaced in 2012.

The UK collects does collect wave data although this is generally in UK waters (e.g. The Met Office Marine Weather Station network of instrumented moored buoys (7 in deep water off the continental shelf, 2 near coast) and light vessels (5 along the Channel) record wave data and have long-term records of around 20 years. The Cefas' WaveNet programme operates a number of waveriders in near coastal locations and collects wave data from a number of operators (Met Office, Irish Marine Institute, CEFAS, EA, local authorities, the offshore oil and gas industry and from the BAS research vessel the James Clark Ross). Waves are also recorded in a national network of Strategic Regional Coastal Monitoring Programmes, such as the Channel Coastal Observatory which maintains a number of wave buoys along the English Channel coastline).

There is other wave information from around the globe that is not collected as part of the Surface Reference Mooring Network, which could contribute to this GCOS IP (GCOS-138) action. This includes the existence and climate relevance of moored buoy networks operated around the coasts of North America (NOAA, Environment Canada), Europe (Met Office, Meteo-France, Irish Marine Institute, Puertos del Estado) and elsewhere (India, Brazil etc). There is however a gap (as illustrated by JCOMM) in wave observations collected in the open ocean, this could be addressed by instrumenting not only the Surface Reference Mooring Buoys but also the Tropical Moored Buoys etc).

ECV – Surface Current
Action O17[80] *[IP-04 O20]*

Action: Establish an international group to assemble surface drifting buoy motion data, ship drift current estimates, current estimates based on wind stress and surface topography fields; prepare an integrated analysis of the surface current field.
Who: OOPC will work with JCOMM and WCRP.
Time-Frame: 2014.
Performance Indicator: Number of global current fields available routinely.
Annual Cost Implications: <1M US$ (10% in non-Annex-I Parties).

No responses or comments were provided for this action.

ECV – Sea Ice
Action O18 *[IP-04 O22]*

Action: Plan, establish and sustain systematic *in situ* observations from sea-ice buoys, visual surveys (SOOP and Aircraft), and ULS in the Arctic and Antarctic.
Who: Arctic Party research agencies, supported by the Arctic Council; Party research agencies, supported by CLIVAR Southern Ocean Panel; JCOMM, working with CliC and OOPC.
Time-Frame: Internationally-agreed plans published by end 2010, implementation build-up through 2014.
Performance Indicators: Publication of internationally-agreed plans, establishment of agreements/frameworks for coordination of sustained Arctic and Southern ocean observations, implementation according to plan.
Annual Cost Implications: Plan and agreement of frameworks: <1M US$; Implementation: 10-30M US$ (Mainly Annex-I Parties).

The UK contributes to planning for Ocean observations in the Arctic through involvement (via representatives from SAMS and NOCS) in the Marine Working Group (MWG) of the

International Arctic Science Committee[4] (IASC, formerly the Arctic Ocean Science Board), and leads on the drafting of the iAOOS (integrated Arctic Ocean Observing System) for the IASC MWG and CliC.

CPOM have recently been involved in gathering limited in-situ data on sea ice within the Arctic to validate satellite data. In addition CPOM scientists led a NERC (UK) funded consortium, the Arctic Synoptic Basin-wide Oceanography, this project contributed in-situ monitoring of sea ice using Systems supplied by SAMS (Scottish Association for Marine Science), these observations are not however sustained.

The NOC are leading on a (new) NERC Arctic Consortium (TEA-COSI: The Environment of the Arctic: Climate, Ocean and Sea Ice), which will measure the growth and decay of the ice throughout the year (using Ice Mass Balance array, IMB – built by the Scottish Association of Marine Science, SAMS) and profile the top 1000m of the ocean using Ice-Tethered Profilers (ITP), purchased from Woods Hole Oceanographic Institute. This purchase will enable the UK to buy into and join up with the on-going US ITP programme in the Arctic.

BAS also monitor sea ice through their Long Term Monitoring and Survey programme and the University of Cambridge map ice thickness using UK Submarines as platforms. With resource further observations of ice thickness could be obtained from Automatic Underwater Vehicles (AUV) from Antarctic ships and Arctic ships/ice camps (N.B. NOCS operated autosub under ice from 2003-5).

Action O19 *[IP-04 O23]*

Action: Ensure sustained satellite-based (microwave, SAR, visible and IR) sea-ice products.
Who: Parties' national services, research programmes and space agencies, coordinated through the WMO Space Programme and Global Cryosphere Watch, CGMS, and CEOS; National services for *in situ* systems, coordinated through WCRP CliC and JCOMM.
Time-Frame: Continuing.
Performance Indicator: Sea-ice data in International Data Centres.
Annual Cost Implications: 1-10M US$ (Mainly by Annex-I Parties).

ESA satellite Cryosat (Radar Altimeter) and NASA satellites including IceSat, Terra, Grace, Aqua provide relevant data. BAS produces operational maps of sea ice in near real time - See Polarview http://www.polarview.org/. Scientists at CPOM process satellite information and use it in the modelling of Arctic sea ice.

Action O20 *[IP-04 O21]*

Action: Document the status of global sea-ice analysis and reanalysis product uncertainty (via a quantitative summary comparison of sea-ice products) and to prepare a plan to improve the products.
Who: Parties' national agencies, supported by WCRP CliC and JCOMM Expert Team on Sea Ice (ETSI).
Time-Frame: By end of 2011.
Performance Indicators: Peer-reviewed articles on state of sea-ice analysis uncertainty; Publication of internationally-agreed strategy to reduce uncertainty.
Annual Cost Implications: <1M US$ (Mainly Annex-I Parties).

BAS carries out research using aircraft measurements to improve the sea ice products and derived parameters; this work has been progressed with the Met Office however it is not yet sufficiently developed to impact operational activities.

[4] N.B. The UK experts are also involved in the Terrestrial and Cryosphere Working Groups of the IASC.

ECV - Phytoplankton

Action O21

Action: Establish plan for, and implement, global Continuous Plankton Recorder surveys.
Who: Parties' national research agencies, working with SCOR and GOOS/OOPC.
Time-Frame: Internationally-agreed plans published by end 2010; implementation build-up through 2014.
Performance Indicators: Publication of internationally-agreed plans; establishment of agreements/frameworks for coordination of sustained global Continuous Plankton Recorder surveys; implementation according to plan.
Annual Cost Implications: 10-30M US$ (Mainly by Annex-I Parties).

The Sir Alistair Hardy Foundation for Ocean Science (SAHFOS) undertake Continuous Plankton Recorder (CPR) Surveys across the Atlantic. Partnerships with other organisations have extended these surveys into the Pacific and also in the Southern Ocean (via Australia CPR and also through BAS who operate a CPR on the James Clark Ross on behalf of SAHFOS). SAHFOS have recently announced a Global Alliance for plankton recording which will lead to further joining up of plankton recording across the globe.

Action O22

Action: Develop technology for underway plankton survey capabilities.
Who: Parties' national research agencies, working with SCOR and GOOS/OOPC.
Time-Frame: Continuous.
Performance Indicators: Successful pilot deployment of new technologies.
Annual Cost Implications: 1-10M US$ (Mainly by Annex-I Parties).

SAHFOS have already developed technology for underway plankton surveys. They are working to 'go global' and encourage the use across ships across the globe.

Monitoring of Marine Biodiversity and Habitat Properties

Action O23

Action: Establish a global network of long-term observation sites covering all major ocean habitats and encourage collocation of physical, biological and ecological measurements.
Who: Parties' national research and operational agencies, supported by GOOS/PICO, OOPC, GRAs, and other partners.
Time-Frame: 2014.
Performance Indicators: Reporting on implementation status of network.
Annual Cost Implications: 30-100M US$ (50% in non-Annex-I Parties).

The UK has some relevant sites for example within the BAS Long term Monitoring Survey which collects both physical and biological measurements.

4.3. Oceanic Domain – Sub-surface

4.3.1. General

Action O24 *[IP-04 O25]*

Action: Development of a plan for systematic global full-depth water column sampling for ocean physical and carbon variables in the coming decade; implementation of that plan.
Who: National research programmes supported by the GO-SHIP project and IOCCP.
Time-Frame: Continuing.
Performance Indicator: Published internationally-agreed plan from the GO-SHIP process, implementation tracked via data submitted to archives. Percentage coverage of the sections.
Annual Cost Implications: 10-30M US$ (Mainly by Annex-I Parties).

NOC-Southampton represents the UK on the GO-SHIP Committee, UK research vessels (James Cook and Discovery) have contributed to the GO-SHIP project to collect water column information. The UK could continue to contribute to the programme covering 3 sections (A05,

A10 & A21) per 5 year cycle. In addition information from UK Argo, the Drake Passage Repeat Hydrographic Section, moorings in the Drake Passage, at PAP, in the Antarctic (as part of the BAS LTMS), and for the Rapid Watch Programme are also contributing information. BAS also collect relevant information using CTD's etc around Bird Island, South Georgia.

In addition the UK is developing technologies that could contribute towards this action in the future for example long range Autosub, Gliders and additional sensors for Argo floats/moored buoys. These technologies could be used to increase the number of measurements made in the Southern Ocean as several of the largest uncertainties in the earth system science are associated with the Southern Ocean e.g. Movement of heat and trace elements around the world. However significant international coordination through the Southern Ocean Observing System (SOOS) is needed to achieve this.

Action O25 *[IP-04 O26]*

Action: Sustain the Ship-of-Opportunity XBT/XCTD transoceanic network of about 40 sections.
Who: Parties' national agencies, coordinated through the Ship Observations Team of JCOMM.
Time-Frame: Continuing.
Performance Indicator: Data submitted to archive. Percentage coverage of the sections.
Annual Cost Implications: 1-10M US$ (Mainly by Annex-I Parties).

BAS releases a number of XBT on a transect in the Weddell Sea about 10 degrees W.

Action O26 *[IP-04 O27]*

Action: Sustain the network of about 3000 Argo global profiling floats, reseeding the network with replacement floats to fill gaps, and maintain density (about 800 per year).
Who: Parties participating in the Argo Project and in cooperation with the Observations Coordination Group of JCOMM.
Time-Frame: Continuous.
Performance Indicator: Number of reporting floats. Percentage of network deployed.
Annual Cost Implications: 30-100M US$ (10% in non-Annex-I Parties).

The UK has been contributing to the international Argo float programme for the last 10 years or so. Over the last 3 years (2008-10) UK has deployed 74 floats and currently has around 100 active Argo floats contributing to Argo, which is around 3% of the global total. The UK Argo Programme has been managed by the Met Office and implemented in collaboration with NERC (NOCS and BODC). Presently funding for UK Argo is provided to the Met Office by DECC (from their climate science budget) and NERC funding covers the activities at NOCS and BODC. There is presently a shortfall in funding due to the withdrawal of MoD funding in 2010 and the UK is struggling to identify sustainable funding to enable it to make a secure, credible contribution to ARGO. This issue is however wider than just Argo, it is really about how to sustain (operationalize) new observational capabilities that have been developed and proven through research activities.

Action O27 *[IP-04 O28]*

Action: Complete implementation of the current Tropical Moored Buoy, a total network of about 120 moorings.
Who: Parties national agencies, coordinated through the Tropical Mooring Panel of JCOMM.
Time-Frame: Array complete by 2011.
Performance Indicator: Data acquisition at International Data Centres.
Annual Cost Implications: 30-100M US$[84] (20% in non-Annex-I Parties).

At present the UK is not involved in the Tropical Moored Buoy network.

Action O28 *[IP-04 O29]*

Action: Develop projects designed to assemble the *in situ* and satellite data into a composite reference reanalysis dataset, and to sustain projects to assimilate the data into models in ocean reanalysis projects.
Who: Parties' national ocean research programmes and space supported by WCRP.
Time-Frame: Continuous.
Performance Indicator: Project for data assembly launched, availability and scientific use of ocean reanalysis products.
Annual Cost Implications: 1-10M US$ (10% in non-Annex-I Parties).

In the UK the Met Office, Environment Systems Science Centre (University of Reading) and NCEO are involved in reanalysis via GMES, ESA CCI and nationally funded projects.

Action O29 *[IP-04 O30]*

Action: Work with research programmes to develop autonomous capability for biogeochemical and ecological variables, for deployment on OceanSITES and in other pilot project reference sites.
Who: Parties' national ocean research programmes, in cooperation with the Integrated Marine Biogeochemistry and Ecosystem Research, Surface Ocean – Lower Atmosphere Study, and Land-Oceans Interactions in the Coastal Zone of IGBP.
Time-Frame: Continuing.
Performance Indicators: Systems available for measuring pCO_2, ocean acidity, oxygen, nutrients, phytoplankton, marine biodiversity, habitats, with other ecosystem parameters available for use in reference network applications.
Annual Cost Implications: 1-10M US$ (50% in non-Annex-I Parties).

See Action O14 for details on autonomous carbonate chemistry systems. Autonomous oxygen sensors also exist (see Action O30).

4.3.2. Specific issues – Oceanic Sub-surface ECVs

ECV – Oxygen

Action O30

Action: Deploy a global pilot project of oxygen sensors on profiling floats.
Who: Parties, in cooperation with the Argo Project and the Observations Coordination Group of JCOMM.
Time-Frame: Continuous.
Performance Indicator: Number of floats reporting oxygen.
Annual Cost Implications: 1-10M US$ (10% in non-Annex-I Parties).

Instrumentation to measure dissolved oxygen is available and there are presently (September 2011) 176 active floats measuring dissolved oxygen. To date the UK has not purchased any floats with oxygen sensors however with funding this is an addition what could be added to UK Argo floats (see O26).

4.4. Oceanic Domain – Data Management

Action O31 *[IP-04 O32]*

Action: Monitoring the implementation of the IOC Data Policy.
Who: JCOMM.
Time-Frame: Continuous.
Performance Indicator: Reports by JCOMM and IODE to the IOC.
Annual Cost Implications: 1-10M US$ (10% in non-Annex-I Parties).

The British Oceanographic Data Centre (BODC) sits on the IODE.

Action O32 *[IP-04 O33]*

Action: Develop and implement comprehensive ocean data management procedures, building on the experience of the JCOMM Pilot Project for WIGOS.
Who: IODE and JCOMM.
Time-Frame: 2012.
Performance Indicator: Improved standards and accessibility of ocean data; Report of the 4th session of JCOMM.
Annual Cost Implications: 1-10M US$ (20% in non-Annex-I Parties).

Much of the ocean data generated by the UK is already managed and archived at BODC. In addition the Marine Environment Data Information Network (MEDIN), a partnership of public and private sector organisations, is committed to improving access to marine data. MEDIN is establishing a network of marine data archive centres (DACs), into which organisations can deposit data using agreed processes and standards. For ARGO data, through the FP7 SIDERI (Strengthening the International Dimension of the Euro-ARGO Research Infrastructure) project, the Met Office will be leading a task to determine how the ARGO data system should develop in order to be integrated in to the WIGOS.

Action O33 *[IP-04 O34]*

Action: Undertake a project to develop an international standard for ocean metadata.
Who: IODE and JCOMM in collaboration with WMO CBS and ISO.
Time-Frame: Standard developed by 2011.
Performance Indicator: Publication of standard for an agreed initial set of the ECVs. Plan to progress to further ECV.
Annual Cost Implications: 1-10M US$ (Mainly by Annex-I Parties).

Many organisations within the UK are involved in the development of common metadata standards. The Centre for Environmental Data Archival (CEDA: http://ceda.ac.uk) and the UK Met Office contribute to the MetOcean Domain Working Group of the World Meteorological Organisation (WMO) which aims to align the metadata/data models with those being developed by the EU metadata directive, INSPIRE.

NERC (including BODC) and MEDIN support the development of common standards for metadata description and data storage/services. This includes advice to data providers on formats, participation in the creation of EU INSPIRE standards (through thematic working groups) and joint coordination of the CF-netCDF metadata conventions.

UK organisations are also active in the European SeaDataNet projects

Interoperability and intercomparison between different domains will be an issue in the next 20 years. It is therefore essential that the standards used for Ocean systems are compatible with those developed for other domains so that in the future they can 'talk' to each other. This requires adherence to common standards at the data/metadata description level.

Action O34 *[IP-04 O35]*

Action: Undertake a project to apply the innovations emerging from the WMO Information System, and innovations such as OPeNDAP to develop an ocean data transport system for data exchange between centres and for open use by the ocean community generally.
Who: JCOMM.
Time-Frame: Report by 2012.
Performance Indicator: Report published.
Annual Cost Implications: <1M US$ (10% in non-Annex-I Parties).

There is much work going on internationally in providing data services. The UK is leading on some aspects of this work. The UK Met Office is leading the implementation of a WMO Information System (WIS) and the Centre for Environmental Data Archival (CEDA: http://ceda.ac.uk) runs OpenDAP servers for serving a number of datasets. CEDA also intends to serve the results of the multi-petabyte Coupled Model Intercomparison Project (CMIP5: http://cmip-pcmdi.llnl.gov/cmip5/) via OpenDAP.

Action O35 *[IP-04 O36]*

Action: Plan and implement a system of regional, specialized and global data and analysis centres for each ocean ECV.
Who: Parties' national services under guidance from IODE and JCOMM.
Time-Frame: Plan finished by 2012, implementation following.
Performance Indicator: Plan published; access to data streams by ECV
Annual Cost Implications: 10-30M US$ (30% in non-Annex-I Parties).

Within the UK, BODC, University of Edinburgh, University of Plymouth, NOC, Met Office and Imperial College are already doing this.

Action O36 *[IP-04 O37]*

Action: Support data rescue projects.
Who: Parties' national services with coordination by IODE through its GODAR project.
Time-Frame: Continuing.
Performance Indicator: Datasets in archive.
Annual Cost Implications: 1-10M US$ (30% in non-Annex-I Parties).

The Met Office leads the ACRE (Atmospheric Circulations Reconstructions over the Earth: http://www.met-acre.org/) project, which does much work towards the rescue of oceanic data. The NERC Data Centres support this work. NCAS & BADC archives digitised records for use by the research community.

As mentioned under Action O32 MEDIN is working to establish Data Archive Centres to store and archive marine data.

Action O37 *[IP-04 O38]*

Action: Develop enhanced and more cost-effective telecommunication capabilities, including two-way communications for dynamic control of systems, instruments and sensors.
Who: Parties, coordinated through JCOMM.
Time-Frame: Continuing.
Performance Indicator: Capacity to communicate data from ocean instrumentation to ocean data centres.
Annual Cost Implications: 1-10M US$ (50% in non-Annex-I Parties).

Several NERC centres/laboratories (NOCS & SAMS) are studying communication capabilities.

4.5. Oceanic Domain – Integrated Global Analysis Products

Action O38 *[IP-04 O39]*

Action: Develop plans for, and coordinate work on, data assembly and analyses.
Who: JCOMM and IODE, in collaboration with CLIVAR, CliC, WOAP, GODAE, and other relevant research and data management activities.
Time-Frame: 2013.
Performance Indicator: Number of ocean climatologies and integrated datasets available.
Annual Cost Implications: <1M US$ (Mainly by Annex-I Parties).

Coordination work on data assembly and analysis is being carried out by the Hadley Centre. The Evidence Groups of the UK Marine Monitoring and Assessment Strategy (UKMMAS), supported by MEDIN, are also coordinating data.

Action O39 *[IP-04 O40]*

Action: Develop plans and pilot projects for the production of global products based on data assimilation into models. All possible ECVs.
Who: Parties' national services and ocean research agencies, through CLIVAR, the CLIVAR GSOP, and GODAE.
Time-Frame: 2013.
Performance Indicator: Number of global oceanic climate analysis centres.
Annual Cost Implications: 1-10M US$ (10% in non-Annex-I Parties).

The National Centre for Ocean Forecasting (NCOF) is a participating member of GODAE and the associated data assimilation involves several UK research groups. NCOF are also working towards the EU project MyOcean, which involves a network of European organisations, who are monitoring, analysing and forecasting the oceans as part of a core Global Monitoring for Environment and Security (GMES) service. Although the GMES programme is not global this contribution is proportionate.

Action O40 *[IP-04 O41]*

Action: Undertake pilot projects of reanalysis of ocean data.
Who: Parties' national research programmes, coordinated through OOPC and WCRP.
Time-Frame: 2010.
Performance Indicator: Number of global ocean reanalyses available.
Annual Cost Implications: 1-10M US$ (Mainly by Annex-I Parties).

Within the UK both the Met Office and ESSC (at the University of Reading) are involved in the reanalysis of ocean data.

4.6. Oceanic Domain – Scientific and Technological Challenges

Action O41 *[IP-04 O3]*

Action: Promote and facilitate research and development (new improved technologies in particular), in support of the global ocean observing system for climate.
Who: Parties' national ocean research programmes and space agencies, in cooperation with GOOS, GCOS, and WCRP.
Time-Frame: Continuing.
Performance Indicator: More cost-effective and efficient methods and networks; strong research efforts related to the observing system; number of additional ECVs feasible for sustained observation; improved utility of ocean climate products.
Annual Cost Implications: 30-100M US$ (10% in non-Annex-I Parties).

The UK has a strong research base and the necessary expertise to develop new technologies for observing the oceans. Much research is funded either by the Government, NERC or EU Framework Programmes and is carried out by NERC research centres and associated groups, academic institutions, government agencies and contractors.

5. TERRESTRIAL CLIMATE OBSERVING SYSTEM

The Terrestrial Climate Observing System includes in-situ and satellite observations related to terrestrial networks for hydrology (rivers, lakes, groundwater), soil moisture/carbon, glaciers, ice, land cover, vegetation and fire disturbance.

Summary of Terrestrial Climate Observing System
Key organisations working in this area include NERC (CEH & BAS), the Environment Agency, SEPA, CPOM and university research groups.

CEH lead on much of the relevant monitoring and are also currently chairing the ILTER. The UK are contributing to the components of the Global Terrestrial Network to varying degrees, for example ecosystem monitoring networks exist in the form of the Environmental Change Network (ECN) and the Environmental Change Biodiversity Network (ECBN) and the UK has an extensive river gauge network, it does not however currently have any designated lakes under the GTN-Lakes. Information is also lacking for the permafrost ECV however, with the exception of British Antarctica, the UK does not have extensive regions that are subject to permafrost. Gaps also exist in several areas that involve satellite products and information, such as the development of experimental evaporation produce (T5) and validation of satellite soil moisture. It should however be noted that UK expertise has been used in the development and validation of some satellite products e.g. albedo and fire disturbance.

Details of relevant UK activities for each of the Terrestrial Climate Observing System recommendations are given below.

5.1. General

5.1.1. Standards

Action T1

Action: Ensure the development of observational standards and protocols for the each of the terrestrial ECVs; promote adoption of standards on a national level.
Who: GTOS, in conjunction with the sponsors of the UN/ISO terrestrial framework (WMO, FAO, ICSU, UNEP, and UNESCO).
Time-Frame: Develop a work plan for the development of standards by 2010; UN/ISO framework implemented by 2012; national-level adoption of standards by 2014
Performance Indicator: Number of terrestrial ECVs with international standards; uptake of standards by Parties (percentage of terrestrial ECV observations following standards).
Annual Cost Implications:[92] <1M US$, increasing to 1-10M US$ (Mainly by Annex-I Parties).

UK Measuring Authorities (Environment Agency, Scottish Environment Protection Agency, Rivers Agency Northern Ireland) conform to a range of national (British) and international standards on flow monitoring (e.g. ISO748) and rigorous QA/QC systems are used. In addition, when flow data are transferred to the National River Flow Archive at CEH (the primary archive of hydrometric data in the UK), further quality control is undertaken. CEH and the Measuring Authorities liaise closely on best practice for flow monitoring and hydrometric data management.

5.1.2. Exchange of Hydrological Data

Action T2

Action: Achieve national recognition of the need to exchange hydrological data of all networks encompassed by GTN-H, in particular the GCOS/GTOS baseline networks, and facilitate the development of integrated hydrological products to demonstrate the value of these coordinated and sustained global hydrological networks.
Who: GTN-H Coordinator, WMO, GCOS, GTOS, in consultation with GTN-H Partners.
Time-Frame: Continuing; 2011 (demonstration products).
Performance Indicator: Number of datasets available in International Data Centres; Number of available demonstration products.
Annual Cost Implications: <1M US$ (Mainly by Annex-I Parties).

CEH submit river flow data to the Global Runoff Data Centre (GRDC)

The WMO Global Framework of Climate Services outlines the need for Hydrological Outlooks within the UK, the National Hydrological Monitoring programme (held at CEH) provides assessments of current hydrological conditions but long-term outlooks are not produced systematically at present. However, the UK is in a unique position with regards to data and models, to lead in this area and could develop methodologies to provide hydrological outlooks at a range of spatial (catchment - globe) and temporal (now - 50 yrs) scales.

5.1.3. Monitoring at Terrestrial Reference Sites

Action T3 *[IP-04 T3, T29]*

Action: Development of a subset of current LTER and FLUXNET sites into a global terrestrial reference network for monitoring sites with sustained funding perspective, and collocated measurements of meteorological ECVs; seek linkage with Actions T4 and T29 as appropriate.
Who: Parties' national services and research agencies, FLUXNET organizations, the US National Ecological Observatory Network (NEON) and the European Integrated Carbon Observation System (ICOS), in association with CEOS WGCV, CGMS-GSICS, and GTOS (Terrestrial Carbon Observations Panel (TCO) and TOPC).
Time-frame: Implementation started by 2011, completed by 2014.
Performance Indicator: Plan for the development and application of standardised protocols for the measurements of fluxes and state variables.
Annual Cost Implications: 30-100M US$ (40% in non-Annex-I Parties).

The UK Environmental Change Network, run by 14 UK organisations, contributes 54 sites to the Global LTER network. The UK also has 14 FLUXNET sites. Despite this contribution, further work is required to align LTER sites and FLUXNET sites.

The UK is currently (through CEH) chairing ILTER (the International LTER network) and is in a good position to influence the development of a global terrestrial reference network. CEH are also involved in the EU Alter-NET programme, leading on both the communications/outreach and policy interaction.

5.2. Monitoring of Terrestrial Biodiversity and Habitats at Key Ecosystem Sites

Action T4

Action: Initiate an ecosystem monitoring network acquiring "Essential Ecosystem Records" (see section 3.8), by exploiting collocation opportunities with the global terrestrial reference network (Action T3) and the network of validation sites (T29).
Who: Parties' national services and research agencies, GTOS (Global Observation of Forest and Land Cover Dynamics (GOFC-GOLD)), TOPC, GEOBON, in association with the UNCBD.
Time-frame: Network concept and observation approach by 2011; Implementation by 2014.
Performance Indicator: Availability of essential ecosystem records, including proper documentation, from all designated sites in the network.
Annual Cost Implications: 30-100M US$ (50% in non-Annex-I Parties).

The UK's ECN and ECBN could provide relevant data as could a UK initiative, BICCO-net, which is working to collate, analyse and interpret key terrestrial and coastal biodiversity monitoring datasets with regards to climate change in the UK. It should however be noted that most UK ecosystem monitoring sites were not established for GCOS and do not align well with the ECV priority measurements therefore consolidation of UK observation sites may be needed to meet multiple requirements.

Action T5

Action: Develop an experimental evaporation product from existing networks and satellite observations.
Who: Parties, national services, research groups through GTN-H, the Integrated Global Water Cycle Observations (IGWCO) partners, TOPC, GEWEX Land Flux Panel and WCRP CliC.
Time frame: 2013-2015.
Performance indicator: Availability of a validated global satellite product of total evaporation.
Annual Cost Implications: 1-10M US$ (10% in non-Annex-I Parties).

No responses or comments were provided for this action.

5.3. Specific Issues – Terrestrial Domain ECVs

ECV – River Discharge

Action T6 *[IP-04 T4]*

Action: Confirm locations of GTN-R sites, determine operational status of gauges at all GTN-R sites, and ensure that the GRDC receive daily river discharge data from all priority reference sites within one year of their observation (including measurement and data transmission technology used).
Who: National Hydrological Services, through WMO CHy in cooperation with TOPC, GTOS, GRDC.
Time-Frame: 2011.
Performance Indicator: Reports to WMO CHy on the completeness of the GTN-R record held in the GRDC including the number of stations and nations submitting data to the GRDC, National Communication to UNFCCC.
Annual Cost Implications: 1-10M US$ (60% in non-Annex-I Parties).

Data for 200+ UK river gauging stations are routinely supplied to the GRDC by the National River Flow Archive (http://www.ceh.ac.uk/data/nrfa/index.html) which is hosted by CEH and holds flow data collected by the EA, SEPA and the Northern Ireland Rivers Agency.

Action T7

Action: Assess national needs for river gauges in support of impact assessments and adaptation, and consider the adequacy of those networks.
Who: National Hydrological Services, in collaboration with WMO CHy and TOPC.
Time-Frame: 2014.
Performance Indicator: National needs identified; options for implementation explored.
Annual Cost Implication: 10-30M US$ (80% in non-Annex-I Parties).

The UK has an extensive river gauge network with data archived in the National River Flow Archive. Due to budget reductions, networks in England and Scotland are under threat as a and could result in the closure of some sites: CEH is working closely with the Measuring Authorities to ensure that the strategic capabilities of the network are preserved.

ECV – Lakes

Action T8 *[IP-04 T6]*

Action: Submit weekly/monthly lake level/area data to the International Data Centre; submit weekly/monthly altimeter-derived lake levels by space agencies to HYDROLARE.
Who: National Hydrological Services through WMO CHy, and other institutions and agencies providing and holding data; space agencies; HYDROLARE.
Time-Frame: 90% coverage of available data from GTN-L by 2012.
Performance Indicator: Completeness of database.
Annual Cost Implications: 1-10M US$ (40% in non-Annex-I Parties).

The UK does not currently have any registered lakes with the GTN-L. Relevant data (lake level amongst other parameters) at is collected at 7 Cumbrian Lakes as part of a NERC sensor network grant, UKLEON (United Kingdom Lake Ecological Observatory Network) led by CEH. Further contributing information could be gathered from the Acid Waters Monitoring Network (lake levels at 2 sites) and The Northern Ireland Hydrometric Network under which lake levels have been measured since 2010 for WFD Surveillance purposes. Lakes are also monitored for the WFD in Scotland.

Action T9 *[IP-04 T7]*

Action: Submit weekly/monthly lake level and area data measured during the 19th and 20th centuries for the GTN-L lakes to HYDROLARE.
Who: National Hydrological Services and other agencies providing and holding data, in cooperation with WMO CHy and HYDROLARE.
Time-Frame: Completion of archive by 2012.
Performance Indicator: Completeness of database.
Annual Cost Implications: <1M US$ (40% in non-Annex-I Parties).

A series of bathymetric surveys of the larger (10 hectares plus) UK lakes (particularly the larger Scottish lochs and Welsh lakes) was undertaken in the early 20th Century which would provide historic lake area (and depth profile) data. The data is only available in a series of publications in paper form, but could readily be transcribed to an Excel spreadsheet form and submitted to HYDROLARE. The data could be provided, at a low cost, by the University of Reading through a review of literature previously accessed for an Environment Agency National R&D programme to develop a lake classification and monitoring scheme for England and Wales (Johnes, Moss, Phillips et al).

Historical data from the 1940's could also be provided for the Cumbrian Lakes. The data is currently archived and could be provided by CEH.

ECV – Groundwater

Action T11

Action: Establish prototype GTN-GW and a Global Groundwater Monitoring System (GGMS) as a web-portal for all GTN-GW datasets; deliver readily available data and products to the information system.
Who: IGRAC, in cooperation with TOPC.
Time-Frame: 2014.
Performance Indicator: Reports to WMO CHy on the completeness of the GTN-GW record held in the GGMS, including the number of records in, and nations submitting data to, the GGMS; web-based delivery of products to the community.
Annual Cost Implications: 1-10M US$ (40% in non-Annex-I Parties).

The UK could explore implementing this action through the current National Groundwater Level Archive (held by BGS/CEH at Wallingford), which holds groundwater level data for around 170 wells and boreholes throughout the United Kingdom.

ECV – Water Use
Action T12 *[IP-04 T9]*

Action: Archive and disseminate information related to irrigation and water resources through the FAO AQUASTAT database and other means; assure adequate quality control for all products.
Who: FAO, in collaboration with UN Statistics Division.
Time-Frame: Continuous.
Performance Indicator: Information contained in the AQUASTAT database.
Annual Cost Implications: <1M US$ (Mainly by Annex-I Parties).

Although the UK does not produce irrigation maps, UK information derived from Defra and Cranfield University data/statistics is available in the Aquastat database - see http://www.fao.org/nr/water/aquastat/irrigationmap/gb/index.stm.

ECV – Soil Moisture
Action T13

Action: Develop a record of validated globally-gridded near-surface soil moisture from satellites.
Who: Parties' national services and research programmes, through GEWEX and TOPC in collaboration with space agencies.
Time frame: 2014.
Performance indicator Availability of globally validated soil moisture products from the early satellites until now.
Annual Cost Implications: 1-10M US$ (10% in non-Annex-I Parties).

There is UK involvement through SMOS.

Action T14

Action: Develop Global Terrestrial Network for Soil Moisture (GTN-SM).
Who: Parties' national services and research programmes, through IGWCO, GEWEX and TOPC in collaboration with space agencies.
Time frame: 2014.
Performance indicator: Fully functional GTN-SM with a set of *in situ* observations (possibly collocated with reference network, cf. T3), with standard measurement protocol and data quality and archiving procedures.
Annual Cost Implications: 1-10M US$ (40% in non-Annex-I Parties).

Soil Moisture is currently monitored by several UK programmes; Environmental Change Network; Environmental Change Biodiversity Network (England); The Countryside Survey; at the Shelford Observatory and in Wetlands monitoring. This information is not currently coordinated within the UK. The UK could audit relevant sites, methods and data available and if deemed appropriate establish and initiative to determine how soil moisture data could be provided from a wide range of monitoring activities and networks. This would also require the development of transfer protocols and a process to formalise an arrangement.

ECV – Snow Cover

Action T15 *[IP-04 T10]*

Action: Strengthen and maintain existing snow-cover and snowfall observing sites; ensure that sites exchange snow data internationally; establish global monitoring of that data on the GTS; and recover historical data.
Who: National Meteorological and Hydrological Services and research agencies, in cooperation with WMO GCW and WCRP and with advice from TOPC, AOPC, and the GTN-H.
Time-Frame: Continuing; receipt of 90% of snow measurements in International Data Centres.
Performance Indicator: Data submission to national centres such as the National Snow and Ice Data Center (USA) and World Data Services.
Annual Cost Implications: 1-10M US$ (20% in non-Annex-I Parties).

Although the majority of the UK is not renowned for vast snow fall, the Met Office through their Automatic and Manual Weather Stations measure snow depth across the UK. Snow patch persistence is also measured in the Cairngorms, Scotland by CEH.

Action T16 *[IP-04 T11]*

Action: Obtain integrated analyses of snow cover over both hemispheres.
Who: Space agencies and research agencies in cooperation with WMO GCW and CliC, with advice from TOPC, AOPC and IACS.
Time-Frame: Continuous.
Performance Indicator: Availability of snow-cover products for both hemispheres.
Annual Cost Implications: 1-10M US$ (Mainly by Annex-I Parties).

No responses or comments were provided for this action. Global Cryosphere Watch is developing and will enter the implementation phase in 2012 (to 2019. It will become operational from 2020).

ECV – Glaciers and Ice Caps

Action T17 *[IP-04 T13]*

Action: Maintain current glacier observing sites and add additional sites and infrastructure in data-sparse regions, including South America, Africa, the Himalayas, and New Zealand; attribute quality levels to long-term mass balance measurements; complete satellite-based glacier inventories in key areas.
Who: Parties' national services and agencies coordinated by GTN-G partners, WGMS, GLIMS, and NSIDC.
Time-Frame: Continuing, new sites by 2015.
Performance Indicator: Completeness of database held at NSIDC from WGMS and GLIMS.
Annual Cost Implications: 10-30M US$ (80% in non-Annex-I Parties).

BAS monitors glaciers in British Antarctic Territory.

ECV – Ice Sheets

Action T18

Action: Ensure continuity of *in situ* ice sheet measurements and fill critical measurement gaps.
Who: Parties, working with WCRP CliC, IACS, and the Scientific Committee on Antarctic Research (SCAR).
Time-Frame: Ongoing.
Performance Indicator: Integrated assessment of ice sheet change supported by verifying observations.
Annual Cost Implications: 10-30M US$ (Mainly by Annex-I Parties).

As part of their Long Term Monitoring Strategy, BAS takes in situ ice sheet measurements in the British Antarctic Territory.

Action T19

Action: Research into ice sheet model improvement to assess future sea level rise.
Who: WCRP CliC sea level cross-cut, IACS, and SCAR.
Time-Frame: International initiative to asses sea level rise within 5+ years
Performance Indicator: Reduction of sea level rise uncertainty in future climate prediction from ice sheet contributions to within 20% of thermal expansion of the ocean.
Annual Cost Implications: 1-10M US$ (Mainly by Annex-I Parties).

There are several research groups within the UK which are looking at ice sheet melt related to climate change. Specifically the Centre for Polar Observations and Monitoring (CPOM) are using a suite of models to study the dynamics of ice sheets, ice caps and glaciers (see http://www.cpom.org/research.html) BAS also has an Ice Sheets Programme (see http://www.antarctica.ac.uk/bas_research/our_research/current/programmes/icesheets/index.php) and is leading a major EU initiative, Ice2sea, one of which is to develop and implement ice-sheet/glacier models to generate detailed projections of the contribution of continental ice to sea-level rise over the next 200 years (see: Ice2sea - http://www.ice2sea.eu/).

Action T20 *[IP-04 T14]*

Action: Ensure continuity of laser, altimetry, and gravity satellite missions adequate to monitor ice masses over decadal timeframes.
Who: Space agencies, in cooperation with WCRP CliC and TOPC.
Time-Frame: New sensors to be launched: 10-30 years.
Performance Indicator: Appropriate follow-on missions agreed.
Annual Cost Implications: 30-100M US$ (Mainly by Annex-I Parties).

The ESA satellite Cryosat-2 collects information on ice masses, CPOM is responsible for processing data from the satellite and has been involved in producing sea ice maps (using the data). Along with the Scott Polar Research Institute (SPRI, University of Cambridge), CPOM is involved in an exercise to validate data from the Cryosat mission. [SPRI is a member of the Cryosat Calibration, Validation and Retrieval Team (CVRT)].

ECV – Permafrost

Action T21 *[IP-04 T15]*

Action: Refine and implement international observing standards and practices for permafrost and combine with environmental variable measurements; establish national data centres.
Who: Parties' national services/research institutions and International Permafrost Association.
Time-Frame: Complete by 2010.
Performance Indicator: Implemented guidelines and establishment of national centres.
Annual Cost Implications: <1M US$ (10% in non-Annex-I Parties).

No responses or comments were provided for this action.

Action T22 *[IP-04 T16]*

Action: Ensure continuity of the existing GTN-P borehole and active layer networks, upgrade existing sites, and build "reference sites."
Who: Parties' national services/research institutions and International Permafrost Association. IGOS Cryosphere Theme team and WMO GCW to ensure continuity and associated Earth observation-derived variables.
Time-Frame: Continuing.
Performance Indicator: Number of sustained sites; completeness of database.
Annual Cost Implications: 10-30M US$ (20% in non-Annex-I Parties).

BAS works in conjunction with Italian Scientists in Antarctica taking measurements at Rothera and Signy Island. These measurements are sporadic within Antarctica, therefore the network could be extended. However funding for these measurements is not generally sustained - the majority are financed from research grants.

Action T23 *[IP-04 T17]*

Action: Implement operational mapping of seasonal soil freeze/thaw through an international initiative for monitoring seasonally-frozen ground in non-permafrost regions.
Who: Parties, space agencies, national services, and NSIDC, with guidance from International Permafrost Association, the IGOS Cryosphere Theme team, and WMO GCW.
Time-Frame: Complete by 2013.
Performance Indicator: Number and quality of mapping products published.
Annual Cost Implications: 1-10M US$ (10% in non-Annex-I Parties).

No responses or comments were provided for this action.

ECV – Albedo

Action T24 *[IP-04 T19]*

Action: Obtain, archive and make available *in situ* calibration/validation measurements and collocated albedo products from all space agencies generating such products; promote benchmarking activities to assess the quality and reliability of albedo products.
Who: Space agencies in cooperation with CEOS WGCV.
Time-Frame: Full benchmarking/intercomparison by 2012.
Performance Indicator: Publication of inter-comparison/validation reports.
Annual Cost Implications: 1-10M US$ (20% in non-Annex-I Parties).

ESA through their GlobAlbedo project are aiming to develop a 15 year time series of land surface albedo using operational European satellites. UK Scientists at both UCL and Swansea University are involved in this project, in which the broadband albedo products will be validated against both in-situ and earth observation data. In situ sources of data are from long term monitoring programmes including the Baseline Surface Radiation Network (BSRN, to which the UK has 2 contributory sites), SURFRAD (Surface Radiation Network, USA), Atmospheric Radiation Measurement (ARM, US Department of Energy), AErosol RObotic NETwork (AERONET, a NOAA project) and FLUXNET (to which the UK has 14 contributory sites). The final products from GlobAlbedo will be freely available for users and linked to the ESA Cal/Val portal.

Action T25 *[IP-04 T21]*

Action: Implement globally coordinated and linked data processing to retrieve land surface albedo from a range of sensors on a daily and global basis using both archived and current Earth Observation systems.
Who: Space agencies, through the CGMS and WMO Space Programme.
Time-Frame: Reprocess archived data by 2012, then generate continuously.
Performance Indicator: Completeness of archive.
Annual Cost Implications: 1-10M US$ (Mainly by Annex-I Parties)

Through the ESA GlobAlbedo project, UK scientists will contribute to the creation of a 15 year time series of land surface albedo using data from ATSR2, SPOT4-VEGETATION and SPOT5-VEGETATION2 as well as AATSR and MERIS. The dataset has potential to be sustained into the future using data from operational European satellites, such as the GMES Sentinels.

ECV – Land Cover

Action T26 *[IP-04 T23]*

Action: Produce reliable accepted methods for land-cover map accuracy assessment.
Who: CEOS WGCV, in collaboration with GOFC-GOLD and GLCN.
Time-Frame: By 2010 then continuously.
Performance Indicator: Protocol availability.
Annual Cost Implications: <1M US$ (10% in non-Annex-I Parties).

There are standard procedures for reporting land cover map accuracy. They examine the areal correspondences / confusion matrices between in-situ observations and satellite derived maps.

(N.B there are no generally accepted methods for accuracy assessment of change in land cover / land use).

The UK Land Cover Map (at 25m resolution) is produced by CEH (with the Countryside Survey Partnership) approximately every 7 years (1990, 2000, 2007), using established and operational methods for accuracy assessment (see Action T28).

Action T27 *[IP-04 T26]*

Action: Generate annual products documenting global land-cover characteristics and dynamics at resolutions between 250 m and 1 km, according to internationally-agreed standards and accompanied by statistical descriptions of their accuracy.
Who: Parties' national services, research institutes and space agencies in collaboration with GLCN and GOFC-GOLD research partners and the GEO Forest Carbon Tracking task team.
Time-Frame: By 2011, then continuously.
Performance Indicator: Dataset availability.
Annual Cost Implications: 1-10M US$ (20% in non-Annex-I Parties).

The UK contributes to EU CORINE Land Cover (CLC, an EU initiative). However this mapping of the UK is at a coarser scale to Land cover map (see Action T28). The accuracy assessment for CLC 2006 used a subjective technique due to limited availability of ground based in-situ datasets. The accuracy was therefore assessed by visual inspection of the thematic product against the satellite data and ordnance survey maps; random quality checks were made and where necessary adjustments made.

CLC is generated on a long repeat cycle and not annually as specified under this action. Correspondence analysis of CLC2000 was carried out in 2006, against LUCAS ground reference data. It was concluded that CLC2000 was greater than 85% accurate. No such analysis has been carried out for CLC2006.

Action T28 *[IP-04 T27]*

Action: Generate maps documenting global land cover based on continuous 10-30 m land surface imagery every 5 years, according to internationally-agreed standards and accompanied by statistical descriptions of their accuracy.
Who: Space agencies, in cooperation with GCOS, GTOS, GOFC-GOLD, GLCN, and other members of CEOS.
Time-Frame: First by 2012, then continuously.
Performance Indicator: Availability of operational plans, funding mechanisms, eventually maps.
Annual Cost Implications: 10-30M US$ (20% in non-Annex-I Parties).

Through the Countryside Survey Partnership, CEH produces a Land Cover Map (with 25m resolution) approximately every 7 years. LCM2007 map was developed using a combination of satellite images and national scale digital mapping data, a detailed report of the correspondence analysis, including confusion / correspondence matrices is given in the final report [for LCM2007].

CEH is currently assessing whether a rolling update programme is practical.

Within the GMES initiative land services are being defined and preoperational development are occurring under several projects one of which is the EU-funded Geoland2 project. Within this, core mapping services include land cover change monitoring with layers for grasslands, soil sealing etc, which are intended to be updated every 3 years.

ECV – Fraction of Absorbed Photosynthetically Active Radiation (FAPAR)
Action T29 *[IP-04 T29]*[98]

Action: Establish a calibration/validation network of *in situ* reference sites for FAPAR and LAI and conduct systematic, comprehensive evaluation campaigns to understand and resolve differences between the products and increase their accuracy.
Who: Parties' national and regional research centres, in cooperation with space agencies coordinated by CEOS WGCV, GCOS and GTOS.
Time-Frame: Network operational by 2012.
Performance Indicator: Data available to analysis centres.
Annual Cost Implications: 1-10M US$ (40% in non-Annex-I Parties).

A small number of site across the UK make these measurements routinely (e.g. CEH, Forest research) however these are not coordinated nor is the data held in a common database.

ESA (Harwell) are currently involved in the Working Group on CalVal and co-chair the Biophysical subgroup of the Land Product Validation Group (CEOS-WGCV-LPV-Biophysical). Protocols are currently being put together for both for LAI and FAPAR observations.

ECV – Leaf Area Index (LAI)
Action T30 *[IP-04 T30]*

Action: Evaluate the various LAI satellite products and benchmark them against *in situ* measurements to arrive at an agreed operational product.
Who: Parties' national and regional research centres, in cooperation with space agencies and CEOS WGCV, TOPC, and GTOS.
Time-Frame: Benchmark by 2012.
Performance Indicator: Agreement on operational product.
Annual Cost Implications: 1-10M US$ (10% in non-Annex-I Parties).

ESA Harwell are currently putting together protocols for LAI observations.

UK scientists have also been and continue to be involved in research projects to validate and assess satellite projects[5], however this research is not a long term core activity as long term monitoring sites are not being used. Other validation work is using earth observing system core sites and components of some scientific networks e.g. Fluxnet, to provide relevant in-situ information[6]

[5] For example see: De Kauwe, M. G., Disney, M. I., Quaife, T., Lewis, P., and Williams, M. (2011) An assessment of the MODIS collection 5 Leaf Area Index product for a region of mixed coniferous forest, Remote Sensing of Environment, 115(2), 767-780. doI:10.1016/j.rse.2010.11.004
Widlowski, J-L., Taberner, M., Pinty, B., Bruniquel-Pinel, V., Disney, M. , Fernandes, R., Gastellu-Etchegorry, J-P., Gobron, N., Kuusk, A., Lavergne, T., Leblanc, S., Lewis, P. E., Martin, E., Mottus, M., North, P. R. J., Qin, W., Robustelli, M., Rochdi, N., Ruiloba, R., Soler, C., Thompson, R., Verhoef, W., Verstraete, M. M., Xie, (2007), D. The third RAdiation transfer Model Intercomparison (RAMI) exercise: Documenting progress in canopy reflectance models, Journal of Geophysical Research, 112, D09111, doi:10.1029/2006JD007821.
Justice, C., Belward, A., Morisette, J., Lewis, P., Privette, J., Baret, F. Developments in the validation of satellite products for the study of the land surface. *International Journal of Remote Sensing* 21(17) 3383-3390

[6] See Nightingale, J., Nickeson, J., Justice, C., Baret, F., Garigues, S., Wolfe R., Masuoka, E. Global validation of EOS land products, lessons learned and future challenges: A MODIS case study.

Action T31 *[IP-04 T28]*

Action: Operationalize the generation of FAPAR and LAI products as gridded global products at spatial resolution of 2 km or better over time periods as long as possible.
Who: Space agencies, coordinated through CEOS WGCV, with advice from GCOS and GTOS.
Time-Frame: 2012.
Performance Indicator: One or more countries or operational data providers accept the charge of generating, maintaining, and distributing global FAPAR products.
Annual Cost Implications: 10-30M US$ (10% in non-Annex-I Parties).

As mentioned under Action T29 ESA (Harwell) are currently developing protocols for LAI and FAPAR observations.

UK researchers are currently working with Bernard Pinty (JRC Ispra) to provide a form of fAPAR product to associate with albedo (using the ESA GlobAlbedo product, for which the UK researchers designed the algorithm – see Action T24 & T25).

ECV – Above-ground Biomass
Action T32

Action: Develop demonstration datasets of above ground biomass across all biomes.
Who: Parties, space agencies, national institutes, research organizations, FAO in association with GTOS, TOPC, and the GOFC-GOLD Biomass Working Group.
Time frame: 2012.
Performance Indicator: Availability of global gridded estimates of above ground biomass and associated carbon content.
Annual Cost Implications: 1-10M US$ (20% in non-Annex-I Parties).

The Forestry Commission / Forest Research have an extensive forest database, based on an inventory for the whole of the UK. This is not widely available; however it is accessible to researchers.

ECV - Soil Carbon
Action T33

Action: Develop a global database of soil carbon measurements and techniques for extrapolation to global gridded products of soil carbon.
Who: Parties, national institutes, research organisations, and FAO, in association with GTOS and TOPC.
Time frame 2012-2014.
Performance Indicator: Completeness of database and availability of prototype soil carbon maps.
Annual Cost Implications: 1-10M US$ (10% in non-Annex-I Parties).

Within the UK soil carbon is measured via the Countryside Survey and also at Environmental Change Network sites. The precise mapping of Countryside Survey data is not possible due to some monitoring sites being on private land and subsequent restrictions on the use of the geospatial data. The National Soils Inventory Scotland has surveyed soil carbon in Scotland. Therefore some information could be available however the data is not held in one central location.

A soil Carbon database was produced by Defra in 2003. This was based on data from the National Soils Inventory (NSI) of England and Wales, the National Soils Inventory Scotland (NSIS) and data from Northern Ireland and produced with respect to compiling the UK Greenhouse Gas Inventory. There are no plans to update this database.

Action T34

Action: Develop globally gridded estimates of terrestrial carbon flux from *in situ* observations and satellite products and assimilation/inversions models.
Who: Reanalysis centres and research organisations, in association with national institutes, space agencies, and FAO/GTOS (TCO and TOPC).
Time Frame: 2014-2019.
Performance indicator: Availability of data assimilation systems and global time series of maps of various terrestrial components of carbon exchange (e.g., Gross Primary Production (GPP), Net Ecosystem Production (NEP), and Net Biome Production (NBP)).
Annual Cost Implications: 10-30M US$ (Mainly by Annex-I Parties).

CEH run 12 flux sites within the UK (although a few of these run discontinuously), in addition a few other sites (run by the University of Edinburgh, the University of Leicester and Forest Research) also measure CO_2. The UK also supports the Long Term Atmospheric Trace Gas monitoring at Mace Head in Ireland and up until 2009 the UK was part of the CarboEurope project which had 16 flux towers across the UK.

UK scientists are also involved in ICOS (the Integrated Carbon Observation System), which builds upon (amongst other initiatives) the work of CarboEurope and aims to build a network of standardised, long-term high precision integrated monitoring of atmospheric greenhouse gas concentrations including CO_2, CH_4 and CO.

The Monitoring Atmospheric Composition and Climate (MACC) system, is a preoperational service of GMES, run at ECWMF. It combines atmospheric modelling with Earth Observation data to produce estimates of GHG emission and concentrations (with a six month lag). NERC are in the process of launching a new GHG research programme, outputs of which will include improving scientific constraints that limit the use of outputs from MACC.

ECV – Fire Disturbance
Action T35 *[IP-04 T32]*

Action: Reanalyse the historical fire disturbance satellite data (1982 to present).
Who: Space agencies, working with research groups coordinated by GOFC-GOLD.
Time-Frame: By 2012.
Performance Indicator: Establishment of a consistent dataset, including the globally available 1 km AVHRR data record.
Annual Cost Implications: 1-10M US$ (Mainly by Annex-I Parties).

No comments or responses were received against this action.

Action T36 *[IP-04 T33]*

Action: Continue generation of consistent burnt area, active fire, and FRP products from low orbit satellites, including version intercomparisons to allow un-biased, long-term record development.
Who: Space agencies, in collaboration with GOFC-GOLD.
Time-Frame: Continuous.
Performance Indicator: Availability of data.
Annual Cost Implications: 1-10M US$ (Mainly by Annex-I Parties).

GMES through an EU funded project SAFER (Services and Applications for Emergency Response) has a fire theme as part of its Emergency Management Service. Within this burnt scar maps are being developed using satellite imagery along with mapping of burnt areas for monitoring incidents (as they happen).

Kings College London have been instrumental in the development of Fire Radiative Products (FPR) using information from Meteosat Second Generation Satellites. These are available,

free and in real time from the EUMetSat Land Satellite Applications Facility (LandSat) - http://landsaf.meteo.pt/algorithms.jsp?seltab=9&starttab=5).

Action T37 *[IP-04 T34]*

Action: Develop and apply validation protocol to fire disturbance data.
Who: Space agencies and research organizations.
Time-Frame: By 2012.
Performance Indicator: Publication of accuracy statistics.
Annual Cost Implications: 1-10M US$ (Mainly by Annex-I Parties

No comments or responses were received against this action.

Action T38 *[IP-04 T35]*

Action: Make gridded burnt area, active fire, and FRP products available through links from a single International Data Portal.
Who: Coordinated through GOFC-GOLD.
Time-Frame: Continuous.
Performance Indicator: Continued operation of the GFMC and the development of the Data Portal.
Annual Cost Implications: <1M US$ (Mainly by Annex-I Parties).

Some of the products being developed under the Emergency Management Service of GMES may be relevant to this action. Through the EU SAFER project, the ability to access both active fire maps and burned area maps are being developed (along with fire forecasting. See http://safer.emergencyresponse.eu/site/FO/scripts/myFO_contenu.php?noeu_id=48&lang=EN).

The Kings College London's Fire Radiative Products (FPR) is available, free and in real time from the EUMetSat Land Satellite Applications Facility (LandSat) - http://landsaf.meteo.pt/algorithms.jsp?seltab=9&starttab=5).

5.4. Terrestrial Domain – Data Management and Reanalysis

5.4.1. Terrestrial Reanalysis

Action T40 *[IP-04 T36]*

Action: Revision of TEMS with improved focus on the monitoring of terrestrial ECVs.
Who: Parties' national services and research programmes contributing to TEMS, in cooperation with GTOS, GOSIC, and the Global Change Master Directory (GCMD), and in consultation with the GCOS Secretariat.
Time-Frame: By 2012.
Performance Indicator: Improvement of site coverage measuring terrestrial ECVs.
Annual Cost Implications: 1-10M US$ (Mainly by Annex-I Parties).

Information about some UK in situ measurement sites (ECN, Field Study Centres, International Cooperative Programme Forests and International Long Term Eco. Research) are already available on TEMS, however more information could probably be added.

APPENDIX 1

The following 15 organisations provided responses to the UK-EOF 2011 Consultation on the GCOS Implementation Plan (IP-10):

- British Antarctic Survey (BAS)
- Countryside Commission for Wales (CCW)
- Centre for Ecology and Hydrology (CEH)
- Joint Nature Conservancy Council (JNCC)
- Met Office
- National Centre for Atmospheric Science (NCAS)
- National Centre for Earth Observations (NCEO)
- Northern Ireland Environment Agency (NIEA)
- National Oceanographic Centre (NOC), Plymouth
- National Oceanographic Centre Liverpool (NOCL)
- Ocean Processes Evidence Group, Defra (OPEG)
- Reading University
- Space Connexions
- Science and Technology Facilities Council (STFC)
- Welsh Government (WG)