EUGENE

CLIMATE

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1 INTRODUCTION

1.1 Background

The EUGENE project is an FP7-funded support action. Its major goal is to contribute to the establishment of a coordinated and sustained European Earth observing system component as part of the Global Earth Observation System of Systems (GEOSS).

The establishment of a coordinated GEOSS has been initiated by the inter-governmental Group on Earth Observations (GEO). GEO was launched in response to calls for action by the 2002 World Summit on Sustainable Development and by the G8 (Group of Eight) leading industrialised countries. These high-level meetings recognised that international collaboration is essential for exploiting the growing potential of Earth observations to support decision making in an increasingly complex and environmentally stressed world. GEO is a voluntary partnership of governments and international organisations. As of November 2009, GEO's members include 80 governments and the European Commission. In addition, 58 intergovernmental, international, and regional organisations with a mandate in Earth observation or related issues have been recognised as participating organisations.

The development of GEOSS is supposed to qualitatively improve our understanding of the Earth system, enhancing global policy- and decision-making abilities to promote the environment, human health, safety, and welfare. GEOSS is expected to generate societal benefits in the following nine areas, the so-called Societal Benefit Areas (SBA):

- **Disasters:** reducing loss of life and property from natural disasters
- **Human health:** increasing the understanding of environmental factors affecting human health and well-being
- **Energy:** improving the sustainable management of energy resources
- **Climate:** improving the understanding and the prediction of climate variability and change as well as the adaptation to altered environmental conditions
- **Water:** improving sustainable water resource management through better understanding of the water cycle
- **Weather:** improving the information base with respect to meteorological parameters, weather forecasting and warning
- **Ecosystems:** improving the management and protection of terrestrial, coastal and marine ecosystems
- **Agriculture:** supporting sustainable agriculture and combating desertification
- **Biodiversity:** improving the understanding, monitoring and conserving of biodiversity

A GEOSS 10-Year Implementation Plan (TYIP, 2005-2015) was adopted during the Third Earth Observation Summit 2005 in Brussels to develop GEOSS. The plan defines a vision statement for GEOSS, its purpose and scope, expected benefits, and the nine SBAs. The implementation of GEOSS is realised through a number of dedicated tasks that are defined in the GEO Work Plan. This document (the current version being the 2009-2011 Work Plan) is updated annually.

GEO is governed by a plenary consisting of all member states and participating organisations. It meets at least once a year at the level of senior officials and periodically at the ministerial level. An Executive Committee oversees GEO activities when the plenary is not in session. Additionally, GEO established four permanent bodies to guide the implementation of the TYIP. These committees are organised around four transverse areas which cut across, and are relevant to, each of the nine SBAs:

- Architecture & Data Committee
- Science & Technology Committee
- User Interface Committee
- Capacity Building Committee

1.2 Scope and Objectives of the EUGENE Project

The objective of the EUGENE project is to foster collaboration between pan-European organisations in the field of Earth observation and to strengthen the coordination of national and regional programmes and organisations in their work towards GEO by establishing an appropriate coordination process. The ultimate goal is to contribute to the establishment of a coordinated and sustained European component as part of GEOSS.

The EUGENE project aims at further developing a comprehensive European GEO strategy by proposing a structured European approach for selected GEO Societal Benefit Areas (SBAs). This will also encompass intrinsic cross-cutting issues, such as data sharing, with special attention to the relationship between relevant European frameworks and GEOSS.

EUGENE addresses European activities and actors in three selected GEO SBAs, which correspond to European political priorities:

- Climate
- Disasters
- Water

The project work plan is intentionally limited to these three areas as a subset to start with and to allow working at a sufficient level of detail. For each of the three SBAs, a consolidated status-quo report will be provided. These reports provide information on relevant European activities and contributions to GEO. They form the basis for further considerations on a European GEO approach, with the goal to establish a coordinated and sustained European Earth observing system component as part of the GEOSS, maximizing both the GEO added value and the European benefit from GEOSS

1.3 Scope and Objectives of this Document

The scope of this document is defined by the relevant GEO target. According to the recent strategic targets document (Document 12, Revision 1, accepted by GEO VI, GEO 2009), the strategic target for the Climate SBA is defined as follows:

Before 2015, GEO aims to:

> ***Achieve effective and sustained operation of the global climate observing system and reliable delivery of climate information of a quality needed for predicting, mitigating and adapting to climate variability and change, including for better understanding of the global carbon cycle.***

In order to address the objectives of EUGENE, within in the overall context of this GEO Climate SBA target, this document is structured in 6 sections:

- Section 1 - this introduction;
- Section 2 - provides the user requirements context;
- Section 3 - describes the international coordination and cooperation frameworks;
- Section 4 - outlines the existing and planned European systems and programmes;
- Section 5 - analyses Europe's strengths, gaps, challenges and opportunities;
- Section 6 - draws conclusions on the possible way forward.

1.4 Applicable Documents

[AD.1]: EUGENE Description of Work, 8 September 2009.

[AD.2]: EUGENE Project Implementation Plan, EUGENE-01, 20 October 2009.

1.5 Reference Documents

[RD.1]: European Capacity for Monitoring and Assimilating Space-based Climate Change Observations - Status and Prospects, Final report.

[RD.2]: Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC.

[RD.3]: The Role of Observations in Support of Adaptation: The GCOS Contribution to the Nairobi Work Programme (in cooperation with the WCRP and WMO).

[RD.4]: GEO Carbon Strategy, Version 1.0, 17 November 2009.

[RD.5]: Critical Earth Observation Priorities, GEO Task US-09-01a, Climate Societal Benefit Area, Revised Report to the GEO User Interface Committee, 31 August 2009.

[RD.6]: Systematic Observation Requirements for Satellite-based Products for Climate - Supplemental Details to the Satellite-based Component of the "Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC", September 2006, GCOS-107.

[RD.7]: GEO 2009-2011 Work Plan, Rev 2.

[RD.8]: GEOSS 10-year Implementation Plan Reference Document.

[RD.9]: EUMETSAT Council Resolution on EUMETSAT Activities in Support to Climate Monitoring; EUM/C/67/09/Res. VIII.

[RD.10]: IPCC Fourth Assessment Report (AR4).

[RD.11]: GTOS submission to UNFCCC SBSTA 30, June 2009: Terrestrial framework mechanisms and assessment of available standards and guides to terrestrial ECVs, GTOS-71.

[RD.12]: GCOS Regional Action Plan for Eastern and Central Europe, December 2005.

[RD.13]: GCOS Regional Action Plan for the Mediterranean Basin, Sept 2006.

[RD.14]: The Second Report on the Adequacy of the Global Observing Systems for Climate in Support of the UNFCCC, April 2003, GCOS-82.

[RD.15]: Progress report on the Implementation of the Global Observing System for Climate in Support of the UNFCCC 2004-2008, GCOS-129.

2 USER REQUIREMENTS

This section addresses the:

- requirements basis;
- overall context (particularly in terms of the relationship between observations and applications).

2.1 Requirements Basis

A key commitment of the UNFCCC relates to the long-term[1], systematic observation and development of data archives, related to the climate system.

The Global Climate Observing System (GCOS) established in 1992 has become the recognised mechanism for facilitating this commitment. The GEO Climate SBA Strategic Target also recognises the GCOS as the climate-observing component of GEOSS.

The GCOS Steering Committee has issued two Reports to the UNFCCC on the adequacy of the global climate observing systems to meet the needs for climate data of the Convention. In its second report in 2003, GCOS established a list of Essential Climate Variables (ECVs) - see Table 1 - that are both feasible to measure and have a high impact on the UNFCCC requirements as well as on Intergovernmental Panel on Climate Change (IPCC) assessments (these independent, scientific, assessments are widely used by governments to shape their policy response to the challenge of climate change).

The GCOS ECVs are thus the consensus view from the international scientific community on a priority list of indispensable climate data sets. [RD.2] and its recommendations on resolution, accuracy, precision, etc. of such data sets and ECV products have been extensively reviewed and revised by the science community through open review, and dedicated workshops with the IPCC.

It is also recognised however, that the current ECVs are not the sole type of climate observation required and should be viewed as the absolute minimum.

In this respect it is noted that the list of ECVs given in Table 1 is currently under review[2] and it is expected that, in the near future, there will be some small-scale changes both to terminology, and to the number of variables, to reflect scientific and technological developments and the conclusions of the debate as to whether the set of ECVs adequately capture all the needs of the climate science community (e.g. in the areas of Energy and the Water Cycle).

As the modifications to this list of ECVs are still under review, the list of ECVs described in Table 1 is used as the requirements basis for the EUGENE project.

[1] Depending on the ECV under consideration, and the particular climate application, minimum record lengths typically vary from 10 to 30 years

[2] The 2010 Update of [RD.2] will be published in August 2010 on http://gcos.wmo.int , including an updated list of ECVs

Domain		Essential Climate Variable
Atmosphere[3]	**Surface**	Air temperature, Precipitation, Air pressure, Surface radiation budget, Wind speed and direction, Water vapour
	Upper Air	Earth radiation budget (including solar irradiance), Upper-air temperature (including MSU radiances), Wind speed and direction, Water vapour, Cloud properties
	Composition	Carbon dioxide, Ozone, Methane, Other long-lived greenhouse gases[4], Aerosol properties
Oceanic	**Surface**	Sea-surface temperature, Sea-surface salinity, Sea level, Sea state, Sea ice, Current, Ocean colour (for biological activity), Carbon dioxide partial pressure
	Sub-surface	Temperature, Salinity, Current, Nutrients, Carbon, Ocean tracers, Phytoplankton
Terrestrial[5]		River discharge, Water use, Ground water, Lake levels, Snow cover, Glaciers and ice caps, Permafrost and seasonally-frozen ground, Albedo, Land cover (including vegetation type), Fraction of absorbed photosynthetically active radiation (fAPAR), Leaf area index (LAI), Biomass, Fire disturbance, Soil moisture[6]

Table 1: List of Essential Climate Variables[7]

[3] Over land, sea and ice
[4] Including nitrous oxide (N_2O), chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), sulphur hexafluoride (SF_6), and perfluorocarbons (PFCs).
[5] Includes runoff ($m^3\ s^{-1}$), ground water extraction rates ($m^3\ yr^{-1}$) and location, snow cover extent (km^2) and duration, snow depth (cm), glacier/ice cap inventory and mass balance ($kg\ m^{-2}\ yr^{-1}$), glacier length (m), ice sheet mass balance ($kg\ m^{-2}\ yr^{-1}$) and extent (km^2), permafrost extent (km^2), temperature profiles and active layer thickness, above ground biomass (t/ha), burnt area (ha), date and location of active fire, burn efficiency (%vegetation burned/unit area).
[6] Recognized as an emerging Essential Climate Variable (not part of the 44).
[7] As extracted from [RD.2].

2.2 Overall Context

The ECVs identified in section 2.1, after suitable processing, are used by a variety of climate applications, and Figure 1 provides a schematic overview of some of the main processing paths for observational data, together with their links to a set of climate applications.

Before describing some of the various data types, processing functions and applications, some general features about the structure of Figure 1 are noted:

i) The focus of Figure 1 is observational data.

ii) The dataflows are simplified (for example reanalysis can make use of level 1 data as well as level 2 data);

iii) The upper part of Figure 1 addresses the main observational data flows, whereas the lower part lists some of the common applications that rely on observational data.

iv) For the observational data part of Figure 1, there is a trend, in terms of both data latency and time span of the data, as one moves from the left hand side to the right hand side. For example:

- on the left hand side the data can be/is provided in Real Time or Near Real Time (typically with a latency of around 24 hours);
- as one moves to the right hand side of figure 1, both the latency and the time span of the data increases (as the focus shifts progressively from products to records).

v) There is not a strict correlation between the order that applications are listed at the bottom of Figure 1 and their needs in terms of data latency and data time span (i.e. the order does not always mirror the trend for observations in the upper part of Figure 1 - see point iv) above).

2.2.1 Observations

This section describes some of the main data types and processing activities identified within the observations part of Figure 1.

2.2.1.1 Data Types

Some of the main data types identified in Figure 1 are described below.

Environmental Data Record (EDR): typically a data record that is generated directly from archived Near Real Time Level 2 data.

Climate Data Records (CDRs): a time series of measurements of sufficient length, consistency and continuity to determine climate variability and change.

Fundamental Climate Data Record (FCDR): is a long-term data record (radiances for satellites), involving a series of instruments, with potentially changing measurement approaches, but with overlaps and calibrations sufficient to allow the generation of homogeneous products providing a measure of the intended variable that is accurate and stable enough for climate monitoring.

Thematic Climate Data Record (TCDR): consists of values or fields of geophysical variables derived from FCDRs. Satellite derived data sets, that address Essential Climate Variables (ECVs) based on Fundamental Data Records eventually become Thematic Climate Data Records (TCDR) which are extremely valuable for higher level climate applications such as variability and trend analysis.

Climate Information Records (CIRs): are higher-level information that can be derived from the TCDRs, such as drought indices or hurricane intensities, probability of extreme events etc.

2.2.1.2 Data Processing

Inter-calibration and Recalibration: intercalibration and recalibration are usually combined together within an overall calibration regime in order to:

- ensure consistency of satellite measurements from different instruments and programmes;
- tie these measurements to absolute references and SI standards;
- enable the recalibration of archived data.

Inter-calibration of satellite instruments involves relating the measurements of one instrument to those of another and can be achieved when the instruments are viewing the same scenes at the same time and from the same viewing angle. Or, for time series of archived satellite data, the overlapping records of two satellite instruments can be compared. The result of an inter-calibration is consistency, and the absence of any bias of one instrument's measurements with respect to the others.

To ensure in-situ data comparability and compatibility within observational networks, in-situ measurements also need proper calibration. As a first step, calibration establishes a relationship between the quantity values with measurement uncertainties provided by measurement standards, and corresponding quantity values provided by a measuring instrument or a measuring system with associated measurement uncertainties. As a second step, this information is used to establish a relationship in order to obtain a measurement result from the measuring system. In-situ calibration pre-supposes that the accepted standard and a scale are propagated to in-situ measurements. In this way it is ensured that all obtained data are on the same/known scale and can be compared to each other.

Assimilation and Reanalysis: reanalyses are produced using fixed, modern versions of the data assimilation systems developed for numerical weather prediction (in the case of ECMWF). Reanalysis products are more suitable than operational analyses for use in studies of long-term variability in climate and are used increasingly in fields that require an observational record of the state of either the atmosphere or its underlying land and ocean surfaces.

Re-processing: the re-processing of satellite data is normally synchronised with reanalysis cycles and involves the re-processing of satellite data to generate a coherent set of products that have been derived from the most recent product generation system.

2.2.2 Applications and Related Observational Needs

This section describes some of the four main application areas identified in Figure 1 and provides an indication of the related observational data needs (principally in terms of data type) with the exception of the policy-related applications described in section 2.2.2.4 (which tend to require more processed information - such as reports produced by the other application areas).

2.2.2.1 Climate Research

Process Studies: are studies on processes that influence the climate and are essential for the understanding of the physics of the climate system in general, and to improve climate models and climate prediction.

Process Studies have strong requirements with respect to spatial and temporal resolution as well as accuracy, but less stringent requirements on coverage (spatial and temporal) and stability. In principle, the instantaneous (NRT and offline) satellite products, from advanced research satellites, may be used for such activities. Also, dedicated science satellite missions that measure geophysical parameters typically not available from operational missions can be used to increase our understanding of climate processes. This application does not rely on long-duration climate data records and so there is no requirement for sensor continuity.

2.2.2.2 Climate Monitoring

Operational Climate Monitoring: involves the routine, statistical characterisation of parameters for a given period and region in relation to long-term averages. This information is widely used for the climate reports of the national weather services and for different application areas (e.g. solar power consultancy, model validation, parameterisation improvement).

Temporal and spatial averages of Near Real Time products make significant contributions to operational climate monitoring. As this is an operational activity, long-term observation programmes are best-placed to contribute to this application.

Detection of Climate Change [RD.10]: Detection of climate change is the process of demonstrating that climate has changed in some defined statistical sense, without providing a reason for that change.

The detection of changes and trends in the climate system require observations of global trends in the range of decades, and transient changes in variability in climate variables and extreme value statistics. Spatial and temporal coverage requirements are extremely demanding (global coverage over more than 30 years). The generation of reliable data sets has to be based on the careful assessment of the stability of all involved sensors and perfective inter-calibration is fundamental. Climate Data Records make a fundamental contribution to this application.

Attribution [RD.10]: Attribution of causes of climate change is the process of establishing the most likely causes for the detected change with some defined level of confidence.

Attribution requires (i.a.) access to global, long-term CDRs that are closely coupled to the candidate mechanisms responsible for climate change (e.g. Greenhouse Gases, Land Use, Aerosols…).

Variability [RD.10]: Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all spatial and temporal scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability).

The observational needs of climate variability are similar (in terms of data type) to those of climate change detection.

2.2.2.3 Climate Prediction and Projection

Climate Prediction [RD.10]: A climate prediction or climate forecast is the result of an attempt to produce an estimate of the actual evolution of the climate in the future, for example, from seasonal to decadal time scales. Since the future evolution of the climate system at such timescales may be highly sensitive to initial conditions, such predictions are usually probabilistic in nature.

Climate prediction requires Climate Data Records and reanalysis datasets (atmosphere and more recently ocean) for model validation purposes. Instantaneous data is required, in varying degrees, for the initialisation of models - analyses (involving the merging of in-situ and satellite observations) are sometimes used to initialise the atmospheric and oceanic components.

Climate Projection [RD.10]: A projection of the response of the climate system to emission or concentration scenarios of greenhouse gases and aerosols, or radiative forcing scenarios, often based upon simulations by climate models. Climate projections are distinguished from climate predictions in order to emphasise that climate projections depend upon the emission/concentration/radiative forcing scenario used, which are based on assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realised and are therefore subject to substantial uncertainty.

The observational needs of climate projection are similar (in terms of data type) to those of climate prediction. Although the required data characteristics (e.g.spatial resolution, time sampling, etc), and the relative importance of particular variables, can differ between prediction and projection.

2.2.2.4 Policy-Related Applications

Impact Assessment [RD.10]: The practice of identifying and evaluating, in monetary and/or non-monetary terms, the effects of climate change on natural and human systems.

Vulnerability [RD.10]: Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity.

Adaptation [RD.10]: Initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects. Various types of adaptation exist, e.g. anticipatory and reactive, private and public, and autonomous and planned. Examples are raising river or coastal dikes, the substitution of more temperature-shock resistant plants for sensitive ones, etc.

Mitigation [RD.10]: Technological change and substitution that reduce resource inputs and emissions per unit of output. Although several social, economic and technological policies would produce an emission reduction, with respect to Climate Change, mitigation means implementing policies to reduce greenhouse gas emissions and enhance sinks.

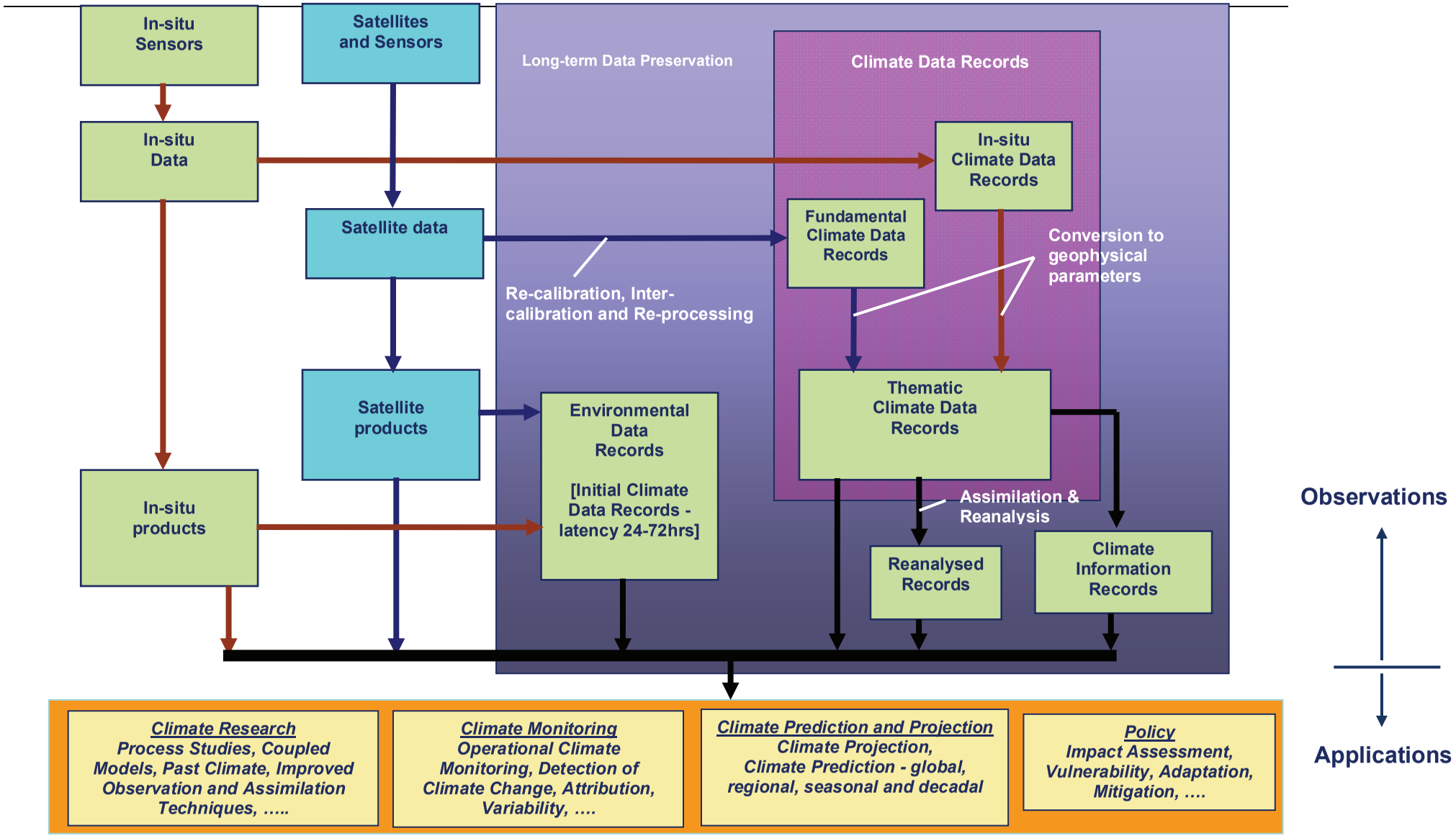

Figure 1: Climate Observations and Applications

3 INTERNATIONAL COORDINATION AND COOPERATION

This section firstly summarises the main "over-arching" frameworks and, secondly, the relevant international coordination frameworks in the areas of:

- Data Provision;
- Climate Research.

Where relevant, the contributions and links to GEO activities are noted in "text boxes".

3.1 Over-arching Frameworks

Figure 2 illustrates the main over-arching frameworks (UNFCCC, IPCC and GCOS) which are described in more detail in the following sections. In addition, the initiative to develop a Global Framework for Climate Services (GFCS) is also described (but not illustrated in Figure 2 as its final shape is still under discussion).

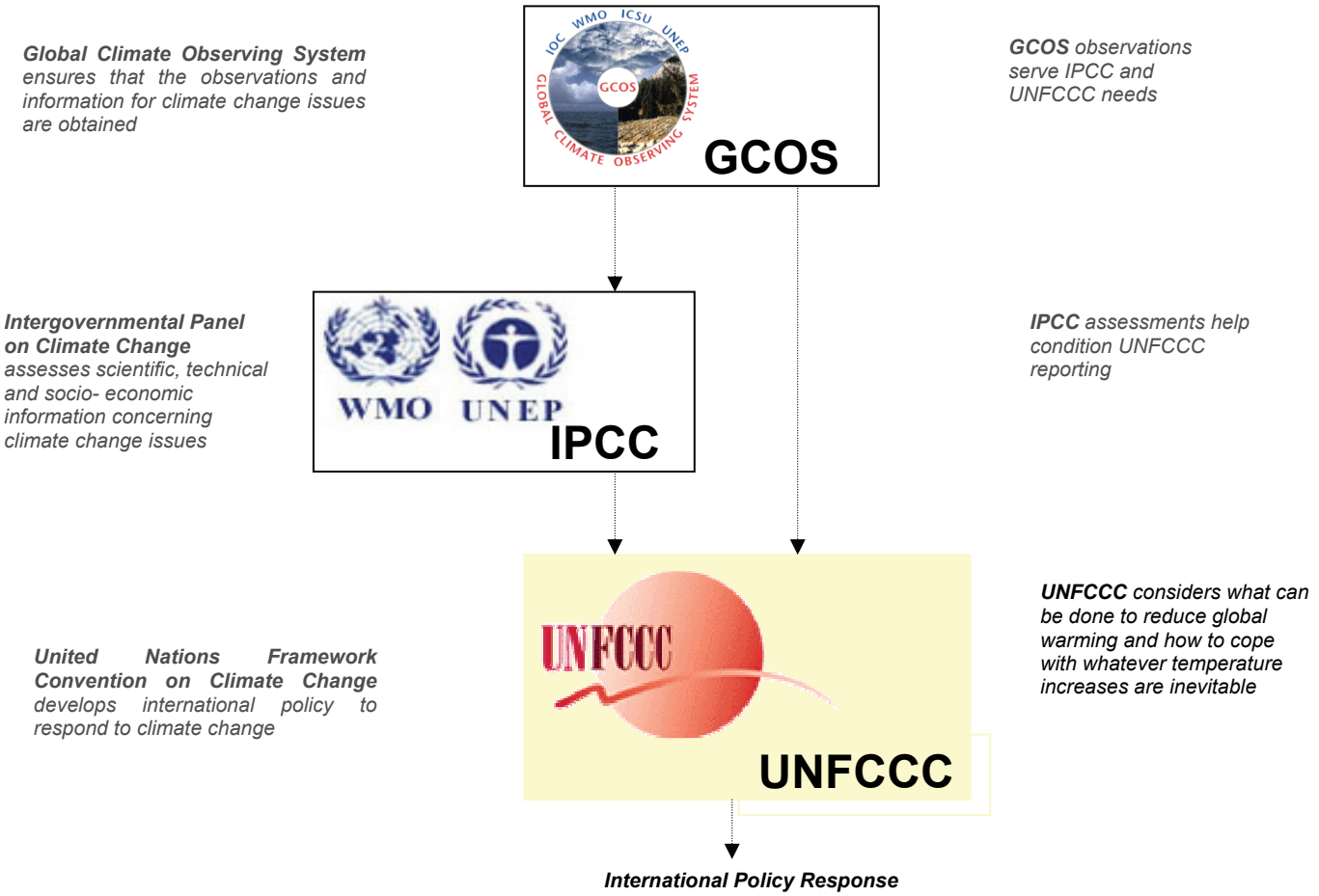

Figure 2: Over-arching Frameworks

3.1.1 UNFCCC

The **United Nations Framework Convention on Climate Change** (**UNFCCC**) is an international environmental treaty produced at the United Nations Conference on Environment and Development (UNCED), informally known as the Earth Summit, held in Rio de Janeiro from 3 to 14 June 1992. The objective of the treaty is to stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.

The treaty itself sets no mandatory limits on greenhouse gas emissions for individual countries and contains no enforcement mechanisms. In that sense, the treaty is considered legally non-binding. Instead, the treaty provides for updates (called "protocols") that would set mandatory emission limits. The principal update is the Kyoto Protocol , which has become much better known than the UNFCCC itself.

One of its first tasks was to establish national greenhouse gas inventories of greenhouse emissions and removals, which were used to create the 1990 benchmark levels for accession of Annex I countries to the Kyoto Protocol and for the commitment of those countries to GHG reductions. Updated inventories must be regularly submitted by Annex I countries.

The UNFCCC Secretariat, with offices in Bonn, Germany, is charged with supporting the operation of the Convention. The Intergovernmental Panel on Climate Change (see Section 3.1.2) assessment reports are a major scientific input to inform the negotiations under the UNFCCC (organised by the UNFCCC Secretariat).

The parties to the convention have met annually from 1995 in Conferences of the Parties (COP) to assess progress in dealing with climate change. In 1997, the Kyoto Protocol was concluded and established legally binding obligations for developed countries to reduce their greenhouse gas emissions.

3.1.2 IPCC

The Intergovernmental Panel on Climate Change (IPCC) is the leading body for the assessment of climate change, established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) to provide the world with a clear scientific view on the current state of climate change and its potential environmental and socio-economic consequences.

The IPCC is a scientific body. It reviews and assesses the most recent scientific, technical and socio-economic information produced worldwide relevant to the understanding of climate change. It does not conduct any research nor does it monitor climate related data or parameters. Thousands of scientists from all over the world contribute to the work of the IPCC on a voluntary basis. Review is an essential part of the IPCC process, to ensure an objective and complete assessment of current information. Differing viewpoints existing within the scientific community are reflected in the IPCC reports.

The IPCC is an intergovernmental body, and it is open to all member countries of UN and WMO. Governments are involved in the IPCC work as they can participate in the review process and in the IPCC plenary sessions, where the main decisions about the IPCC workprogramme are taken and reports are accepted, adopted and approved. The IPCC Bureau and Chairperson are also elected in the plenary sessions.

Because of its scientific and intergovernmental nature, the IPCC embodies a unique opportunity to provide rigorous and balanced scientific information to decision makers. By endorsing the IPCC reports, governments acknowledge the authority of their scientific content. The work of the organization is therefore both policy-relevant and policy-neutral, but not policy-prescriptive.

The IPCC Assessment Reports are key inputs to the negotiations under the UNFCCC.

3.1.3 GCOS

The Global Climate Observing System (GCOS), established in 1992, is an internationally coordinated system of observing systems and networks for meeting national and international needs for climate observations. It consists of the climate-relevant components of all established environmental observing networks and systems, and it serves as the climate observation component of the Global Earth Observation System of Systems (GEOSS). It is co-sponsored by the:

- World Meteorological Organization (WMO);
- Intergovernmental Oceanographic Commission (IOC) of UNESCO;
- United Nations Environment Programme (UNEP);
- International Council for Science (ICSU).

The purpose of GCOS is to ensure that the observations required to meet the majority of national and international needs for climate and climate-related data and information are identified, obtained and made widely available. Its goal is to provide continuous, reliable, comprehensive data and information on the state and behaviour of the global climate system, including its physical, chemical and biological properties and its atmospheric, oceanic, hydrological, terrestrial and cryospheric processes.

The objectives of GCOS are to support all components of the World Climate Programme, the assessment role of the IPCC (see section 3.1.2) and the international policy development role of the UNFCCC (see section 3.1.1); and, in participation with other entities, to provide the comprehensive, continuous climate and climate-related observations needed for:

- Climate system monitoring;
- Climate change detection and attribution;
- Operational climate prediction on seasonal to inter-annual timescales;
- Research to improve understanding, modeling and prediction of the climate system;
- Applications and services for sustainable economic development;
- Assessment of the impacts of, and vulnerability and adaptation to, natural climate variability and human-induced climate change;
- Meeting the requirements of the UNFCCC and other international conventions and agreements.

The specific role of GCOS in data provision is described in section 3.2.1.1.

3.1.4 Global Framework for Climate Services (GFCS)

In 2009 the WMO organised the third World Climate Conference in order to initiate the establishment of an international framework to guide the development of climate services which will link science-based climate predictions and information with climate-risk management and adaptation to climate variability and change throughout the world.

As an outcome of this conference, a path has been mapped out to put in place a Global Framework for Climate Services that is expected to have a strong focus on climate prediction (and its implications for adaptation).

It is expected that the WMO Regional Climate Centres (see section 3.2.2.3) will form an integral component of this framework.

3.2 Data Provision

Three types of international framework exist for data provision:

- frameworks that coordinate data provision;
- frameworks that provide data;
- frameworks for inter-calibration and standardisation.

3.2.1 Coordination of Data Provision

3.2.1.1 Global Climate Observing System (GCOS)

GCOS is a system of observing systems built on the climate-relevant components of the established global observing systems (listed below) for the atmosphere, ocean, land and surface water. The main contributing observing systems on which it is based are:

- WWW Global Observing System (GOS) for atmospheric physical and dynamical properties;
- WMO Global Atmospheric Watch (GAW) for atmospheric constituent and chemical properties, and other WMO climate related observing systems;
- IOC/WMO/UNEP/ICSU Global Ocean Observing System (GOOS) for physical, chemical and biological properties of the ocean;
- FAO/UNEP/UNESCO/WMO/ICSU Global Terrestrial Observing System (GTOS) for land surface ecosystem, hydrosphere, and cryosphere measurements; and
- IGBP and WCRP and other research observing networks.

A number of climate-orientated observation panels work within joint frameworks that include GCOS:

- the Atmospheric Observation Panel for Climate (AOPC) was established by the GCOS Steering Committee in recognition of the need for specific scientific and technical input concerning atmospheric observations for climate. The Joint Scientific Committee of the World Climate Research Programme, recognizing the benefits of the AOPC, agreed in 1995 to co-sponsor the panel, which was therefore renamed as the GCOS/WCRP Atmospheric Observation Panel for Climate. The AOPC initiated the GCOS Reference Upper-Air Network (GRUAN) - see section 3.2.2.2.7);

- the Ocean Observations Panel for Climate (OOPC) is a scientific expert advisory group charged with making recommendations for a sustained global ocean observing system for climate. The Panel is sponsored by the Global Climate Observing System, the Global Ocean Observing System (GOOS), and the World Climate Research Programme (WCRP). The Panel also aids in the development of strategies for evaluation and evolution of the system and of its recommendations, and supports global ocean observing activities by interested parties through liaison and advocacy for the agreed observing plans;

- the Terrestrial Observation Panel for Climate (TOPC) was set up to develop a balanced and integrated system of in-situ and satellite observations of the terrestrial ecosystem. The Panel focuses on the identification of terrestrial observation requirements, assisting the establishment of observing networks for climate, providing guidance on observation standards and norms, facilitating access to climate data and information and its assimilation, and promoting climate studies and assessments. TOPC is jointly sponsored by GCOS and the Global Terrestrial Observing System (GTOS) of FAO.

CEOS, together with CGMS, acts as the principal coordinating entity for the provision of space-data for the generation of ECVs (see sections 3.2.1.7 and 3.2.1.8 for further details). A number of in-situ data provision networks have been recognized as contributions to GCOS (see section 3.2.2.2) through agreements between GCOS and the entities owning and coordinating these networks. Where needed and possible, additional coordination of and support to those networks is provided by GCOS.

*Accelerated implementation of all systems contributing to GCOS has been recognized as a priority in the GEO 2009-2011 Work Plan (Task **CL-09-02**).*

3.2.1.2 Global Terrestrial Observing System (GTOS)

As part of GTOS, the Global Terrestrial Observing Network (GT-NET) is envisaged as a master network system. It has been in development since June 1997, when a meeting of experts on ecological networks established that GT-NET should generate complete and coherent data sets on global terrestrial ecosystems through international research collaboration. These networks provide support to gather the required global data on the terrestrial Essential Climatic Variables.

GTOS also has the potential to support of REDD+[8] as measurement and monitoring is required at the international level to provide independent checks on the health of the climate, and progress towards the emissions reduction target.

*From Europe, the EEA, ESA, JRC, Germany, Italy, Portugal, Switzerland and the UK contribute to the GEO Task **AR-09-03a**: Global Terrestrial Observations.*

3.2.1.3 Global Ocean Observing System (GOOS)

GOOS is a permanent global system for observations, modelling and analysis of marine and ocean variables to support operational ocean services worldwide. GOOS provides accurate descriptions of the present state of the oceans, including living resources; continuous forecasts of the future conditions of the sea for as far ahead as possible, and the basis for forecasts of climate change.

The Argo array, which provides sub-surface ocean data, is separately described in section 3.2.2.4.

EuroGOOS (see section 4.1.1.2.2.3) is one of a number of regional alliances of GOOS.

*From Europe the EC (via HYPOX and EuroSITES), Germany, Greece, Norway and Spain contribute to the GEO Task **AR-09-03c**: Global Ocean Observation System*

3.2.1.4 Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM)

The aims of JCOMM include:

- To develop the observing networks under the guidance of GOOS, GCOS, the World Weather Watch (WWW) and other operational programmes, and cooperation with these bodies in seeking commitments for all components of an operational programme in the global oceans;
- Implementation of integrated end-to-end data management systems to meet the real-time operational needs of the present operational systems and the global observing systems.

3.2.1.5 Global Atmosphere Watch (GAW)

The Global Atmosphere Watch programme of WMO is a partnership involving 80 countries, which provides reliable scientific data and information on the chemical composition of the atmosphere, its natural and anthropogenic change, and helps to improve the understanding of interactions between the atmosphere, the oceans and the biosphere.

GAW focuses on global networks for GHGs, Ozone, UV, aerosols, selected reactive gases and precipitation chemistry.

[8] Reducing Emissions from Deforestation and Forest Degradation (REDD) - is an effort to create a financial value for the carbon stored in forests, offering incentives for developing countries to reduce emissions from forested lands and invest in low-carbon paths to sustainable development. “REDD+” goes beyond deforestation and forest degradation, and includes the role of conservation, sustainable management of forests and enhancement of forest carbon stocks.

The GAW programme coordinates the activities of the observational network, and includes a Central Calibration Laboratory maintaining primary standards and the WMO World Reference Scales for ECVs connected with atmospheric composition.

Chemical ECVs are measured worldwide. In particular CO_2 measurements are performed in 54 countries around the globe, including 19 European countries.

The main European contribution to the GAW programme is provided by the European Monitoring and Evaluation Programme (EMEP).

3.2.1.6 World Weather Watch (WWW)

The World Weather Watch - the core of the WMO Programmes - combines observing systems, telecommunication facilities, data-processing and forecasting centres (operated by Members) to make available meteorological and related environmental information needed to provide efficient services in all countries.

A component of the WWW is the WMO Global Observing System (GOS) - the coordinated system of methods and facilities for making meteorological and other environmental observations on a global scale in support of all WMO Programmes. The system is comprised of operationally reliable surface-based and space-based subsystems (the coordination of the space component is caried out by the WMO Space Programme - see section 3.2.1.9). The GOS comprises observing facilities on land, at sea, in the air and in outer space. These facilities are owned and operated by the Member countries of WMO each of which undertakes to meet certain responsibilities in the agreed global scheme so that all countries can benefit from the consolidated efforts.

The international exchange of meteorological data and products is governed by WMO Resolution 40 which *inter alia* ensures that Members provide access, on a free and unrestricted basis, to essential meteorological data and products to other Members. Access to such data is generally arranged through the relevant NMHS.

3.2.1.7 Coordination Group for Meteorological Satellites (CGMS)

CGMS provides an international forum for the exchange of information and coordination on geostationary and polar-orbiting meteorological systems and addresses issues such as future plans, telecommunications, operations, inter-calibration of sensors, product validation and back-up.

Its participants include operators of both research and operational Earth-observation satellites.

CGMS also coordinates its activities with those of CEOS (CGMS could be viewed as the coordinator of the international meteorological satellite constellation).

CGMS is of direct relevance to climate because the requirement for long-term, sustained atmospheric observations is common to both climate monitoring and meteorology.

CGMS has four Working Groups (ITWG[9], IROWG[10], IPWG[11] and IWWG[12]) that consider climate applications.

EUMETSAT, ESA and CNES are members of CGMS - with EUMETSAT providing the CGMS Secretariat.

[9] International ATOVS Working Group
[10] International Radio Occultation Working Group
[11] International Precipitation Working Group
[12] International Satellite Winds Working Group

3.2.1.8 Committee on Earth Observation Satellites (CEOS)

CEOS provides an international framework for coordination across its member space agencies; with a particular focus on the international coordination of Earth observation programmes, and the maximum utilization of their data.

In 2005, the CEOS annual Plenary decided that priority must be given to actions that support GEO, the GEOSS 10-Year Implementation Plan and the associated Work Plans.

This new focus and sense of purpose have given CEOS a new relevance and importance in the field of earth observation and made it one of the main engines behind the development of GEO.

CEOS uses a "theme-orientated" virtual constellation mechanism to coordinate international activities.

Currently there are 6 constellations defined:

- Atmospheric Composition;
- Land Surface Imaging;
- Ocean Surface Topography;
- Precipitation;
- Ocean Colour Radiometry;
- Ocean Surface Vector Winds.

All these virtual constellations are directly relevant to the ECV observational requirements noted in section 2.1 and CEOS has embedded the relevant GCOS Implementation Plan actions within its overall work plan (which, in turn, sits within the framework of GEO Work Plan tasks).

The Ocean Surface Topography constellation has proved to be a key mechanism in the process to secure continuity of altimetry observations from space which are fundamental for the generation of the sea level ECV. Recently, CEOS has placed a strong emphasis on tasks that directly relate to the monitoring of the carbon cycle {see [RD.4] for further background on the Carbon Cycle observational requirements}.

In view of the importance of the GOSAT data JAXA leads a GHG task force, which is closely-related to the CEOS Atmospheric Composition Constellation, and includes the participation of ESA and EUMETSAT (as the IASI and SCIAMACHY instruments also provide useful information about GHG concentrations).

Currently there are three CEOS Working Groups i) the Working Group on Calibration and Validation (WGCV), ii) the Working Group on Information Systems and Services (WGISS), and iii) the Working Group on Education (WGEdu).

Of these Working Groups, the WGCV is the most relevant for climate applications. Recently, one of its main activities has been the creation of the QA4EO Guidelines (proposed standards to be followed by EO data providers). These guidelines are further discussed in Section 3.2.3.2).

Also, in order to coordinate CEOS's climate response, CEOS has appointed a Climate SBA Coordinator (e.g. to coordinate the CEOS Response to the GCOS IP - as recognised by the COP).

Furthermore CEOS is in the process of establishing a Climate Advisory Group to ensure *inter alia* that the contribution of space data to ECV generation is optimised.

European Member States generally rely on ESA and EUMETSAT to represent their interests within CEOS, although some Member States with national space agencies participate directly (i.e. ASI, BNSC, CNES and DLR). The EC is also a member of CEOS.

Japan, the United States and Europe provide the permanent CEOS Secretariat:

- EUMETSAT jointly with ESA from Europe;
- NASA jointly with NOAA from the United States;
- MEXT jointly with JAXA from Japan.

ESA also currently provides the CEOS Executive Officer.

European institutions are active contributors to the key GEO tasks that involve CEOS:

*a) ESA, EUMETSAT, ECMWF, Germany, JRC, Norway and Portugal contribute to **CL-06-01a**: Sustained Reprocessing and Reanalysis of Climate Data;*
*b) ESA, CEOS agencies, Cyprus, France, Germany, Italy, Netherlands, Norway and Portugal contribute to **CL-09-02b**: Key Climate Data from Satellite Systems;*
*c) ESA, EC (HYPOX, EuroSITES, GEOmon), France, Germany, Italy, Netherlands, Norway, UK contribute to **CL-09-03a**: Integrated Global Carbon Observation (IGCO);*
*d) ESA, JRC, Italy, Netherlands, Norway, Spain and UK contribute to **CL-09-03b**: Forest Carbon Tracking;*
*e) ECMWF, ESA, EUMETSAT, EC (COCOS), France, Germany, Netherlands, Norway, Portugal, Spain contribute to **CL-09-03c**: Global Monitoring of Greenhouse Gases from Space.*

3.2.1.9 WMO Space Programme

The role of the WMO Space programme is to:

- coordinating environmental satellite matters within WMO;
- develop the WMO space-based Global Observing System (GOS);
- promote satellite data use for weather, water, climate and related applications.

In more detail, the WMO Space Programme coordinates environmental satellite matters and activities throughout all WMO Programmes and provides guidance on the potential of remote-sensing techniques in meteorology, hydrology and related disciplines and applications. It also aims at continuously improving the provision of data, products and services from operational and R&D satellites contributing to the WMO GOS, as well as facilitating and promoting the wider availability and meaningful use of these data, products and services around the globe.

The WMO Space Programme had a central role in the establishment of GSICS and SCOPE-CM (see sections 3.2.3.1 and 3.2.2.1).

3.2.2 Data Provision

3.2.2.1 Sustained Coordinated Processing of Environmental Satellite Data for Climate Monitoring (SCOPE-CM)

The Sustained and Coordinated Processing of Environmental Satellite Data for Climate Monitoring (SCOPE-CM) initiative of WMO addresses the requirements of GCOS in a cost-effective, coordinated manner, capitalising upon the existing expertise and infrastructures. The overall objective is the continuous and sustained provision of high-quality Essential Climate Variables satellite products on a **global** scale.

SCOPE-CM also addresses the problematic issue of objective quality assessment of ECV records by considering the development of data set maturity measures.

SCOPE-CM is seen by WCRP, and in particular by GEWEX, as the main partner in sustaining mature research data sets within operational environments.

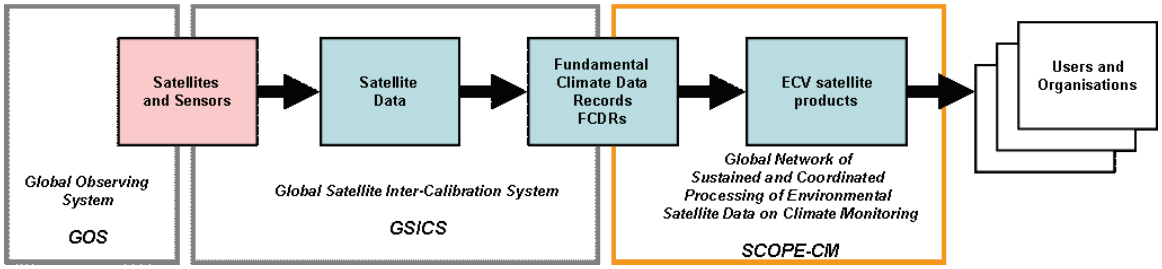

Figure 3: Relationship Between GSICS and SCOPE-CM

The participating organisations have decided to initially focus on five Thematic Climate Data Records and their associated FCDRs:

- AVHRR based data set of cloud and aerosol properties;
- SSM/I total column water vapour, precipitation and liquid water path;
- Surface albedo, clouds and aerosols from geostationary satellites;
- Atmospheric motion vectors and clear sky radiances;
- Upper tropospheric humidity.

SCOPE-CM is a real data provider (and not just a coordinating entity) and generates multi-mission and global satellite climate data records (FCDRs and TCDRs). As such, SCOPE-CM provides an ideal framework for building upon European activities such as the Climate Monitoring SAF (which has similar objectives in terms of the sustained generation of Climate Data Records). SCOPE-CM is also a good example of a mechanism that combines data from both R&D and operational satellites to generate Climate Data Records.

EUMETSAT participates in SCOPE-CM, supports WMO in the Secretariat function, and coordinates any relevant EUMETSAT SAF contributions.

3.2.2.2 In-situ Networks/Data Centres Contributing to GCOS

Table 2 summarises the in-situ networks and data centres that contribute to GCOS, together with their relationship to the ECVs listed in section 2.1.

In the subsequent sections, some of the main data centres associated with the following GCOS-affiliated networks are described:

- GCOS Surface Network (GSN);
- Baseline Surface Radiation Network (BSRN);

- WMO GAW GCOS Global Baseline Total Ozone and Profile Ozone Networks;
- GCOS-affiliated WMO GAW Comprehensive Global Atmospheric Network for CO_2 and CH_4 Monitoring;
- GCOS Reference Upper-Air Network (GRUAN);
- GCOS Upper-Air Network (GUAN);
- GCOS/GTOS Global Terrestrial Network - Rivers;
- GCOS/GTOS Baseline Global Lake Network;
- GCOS/GTOS Global Terrestrial Network - Glaciers.

Networks Contributing to GCOS	International Data Centres and Archives	Domain/Essential Climate Variables (ECVs)
GCOS Surface Network (GSN) (subset of the full WMO World Weather Watch Global Observing System surface synoptic network)	❑ GSN Monitoring Centres (DWD, JMA) - see section 3.2.2.2.1 ❑ GSN Analysis Centre (NCDC) - see section 3.2.2.2.2 ❑ GSN Archive (WDC Asheville) ❑ CBS Lead Centres for GCOS (BAS, BOM, DMC, DMN, DWD, INM, IRIMO, JMA, NCDC) ❑ Global Precipitation Climatology Centre (GPCC, DWD) - see section 3.2.2.2.3	Atmosphere (surface): ❑ Air Temperature ❑ Precipitation
Baseline Surface Radiation Network (BSRN)	❑ World Radiation Monitoring Centre - see section 3.2.2.2.4	Atmosphere (surface): ❑ Surface Radiation Budget
Full WWW/GOS Surface Network	❑ GDPFS World Centres ❑ GDPFS Regional/Specialized Meteorological Centres ❑ WDC Asheville	Atmosphere (surface): ❑ Air Temperature ❑ Precipitation
Global tropical moored buoy network	❑ NCDC ❑ WODC	Atmosphere (surface) and Oceans: ❑ All feasible surface and subsurface ECVs
Voluntary Observing Ships (VOS)	❑ VOSClim Data Centre ❑ NCDC	Atmosphere (surface) and Oceans: ❑ All feasible surface ECVs
Global reference mooring network	❑ NCDC ❑ WODC	Atmosphere (surface) and Oceans: ❑ All feasible surface and subsurface ECVs
GLOSS Core Sea-level Network	❑ Permanent Service for Mean Sea Level ❑ Proudman Laboratory	Oceans: ❑ Sea Level
Argo network - see section 3.2.2.4	❑ Argo Data Centres ❑ GTSPP ❑ WODC	Atmosphere (surface) and Oceans: ❑ Temperature ❑ Salinity ❑ Current
GCOS Reference Upper-air Network (GRUAN)	❑ GRUAN Lead Centre (DWD) - see section 3.2.2.2.7	Atmosphere (surface and upper-air): ❑ All feasible surface and

Networks Contributing to GCOS	International Data Centres and Archives	Domain/Essential Climate Variables (ECVs)
		upper-air ECVs
GCOS Upper-air Network (GUAN) (subset of full WMO World Weather Watch Global Observing System radiosondes network)	❑ GUAN Monitoring Centres (ECMWF) - see section 3.2.2.2.8 ❑ GUAN Analysis Centres (NCDC) ❑ GUAN Archive (WDC Asheville) ❑ CBS Lead Centres for GCOS (BAS, BOM, DMC, DMN, DWD, INM, IRIMO, JMA, NCDC)	Atmosphere (upper-air): ❑ Upper-Air-Temperature ❑ Upper-Air Wind Speed/Direction ❑ Upper-Air Water Vapour
Full WWW/GOS Upper Air Network	❑ GDPFS World Centres ❑ GDPFS Regional/Specialized Meteorological Centres ❑ WDC Asheville	Atmosphere (upper-air): ❑ Upper-Air-Temperature ❑ Upper-Air Wind Speed/Direction ❑ Upper-Air Water Vapour
Aircraft (ASDAR etc.)	❑ GDPFS World Centers ❑ GDPFS Regional/Specialized Meteorological Centers ❑ WDC Asheville	Atmosphere (upper-air): ❑ Upper-Air-Temperature ❑ Upper-Air Wind Speed/Direction ❑ Upper-Air Water Vapour
Profiler (radar) network	❑ GDPFS World Centers ❑ GDPFS Regional/Specialized Meteorological Centers ❑ WDC Asheville	Atmosphere (upper-air) ❑ Upper-Air-Temperature ❑ Upper-Air Wind Speed/Direction ❑ Upper-Air Water Vapour
Ground-based GPS receiver network		Atmosphere (upper-air): ❑ Upper-Air-Temperature ❑ Upper-Air Water Vapour (through atmospheric refractivity)
GCOS-affiliated WMO/GAW Global Atmospheric CO2 and CH4 Monitoring Networks (see section 3.2.2.2.6)	❑ WDC-GG (JMA) ❑ Carbon Dioxide Information Analysis Centre (Oak Ridge National Laboratory)	Atmospheric Composition: ❑ Carbon dioxide ❑ Methane
▪ WMO/GAW GCOS Global Baseline Total Ozone Network ▪ WMO/GAW GCOS Global Baseline Profile Ozone Network (see section 3.2.2.2.5)	❑ WOUDC (MSC) ❑ Network for Detection of Atmospheric Composition Change (NDACC) Archive ❑ Norwegian Institute for Air Research ❑ Southern Hemisphere Additional Ozonesondes (SHADOZ – NASA) Archive	Atmospheric Composition: ❑ Ozone
WMO/GAW Aerosol Network	❑ AERONET, SKYNET, BSRN and ❑ GAWPFR data centres ❑ World Data Centre for Aerosols (NILU)	Atmospheric Composition: ❑ Aerosol Properties

Networks Contributing to GCOS	International Data Centres and Archives	Domain/Essential Climate Variables (ECVs)
Global surface drifting buoy array on 5x5 degree resolution	❑ NCDC	Oceans: ❑ Sea-Surface Temperature ❑ Sea-Level Pressure ❑ Position-change-based Current
GCOS/GTOS Global Terrestrial Network - Rivers (GTN-R)	❑ Global Runoff Data Centre - see section 3.2.2.2.9	Terrestrial: ❑ River Discharge
GCOS/GTOS Baseline Global Lake Network	❑ International Data Centre on the Hydrology of Lakes and Reservoirs (HYDROLARE) - see section 3.2.2.2.10	Terrestrial: ❑ Lake Level/ Area/ Temperature
WWW/GOS synoptic network	❑ National Snow and Ice Data Center (NSIDC)	Terrestrial: ❑ Snow Cover
GCOS/GTOS Global Terrestrial Network - Glaciers (GTN-G)	❑ World Glacier Monitoring Service (WGMS) - see section 3.2.2.2.11 ❑ National Snow and Ice Data Center (NSIDC) - see section 3.2.2.2.12	Terrestrial: ❑ Glaciers mass balance and length, also Ice sheet mass balance
GCOS/GTOS Global Terrestrial Network - Permafrost (GTN-P)	❑ NCDC ❑ NSIDC	Terrestrial: ❑ Permafrost borehole-temperatures and active-layer thickness
Global Terrestrial Network Hydrology (GTN-H)	❑ Distributed	Terrestrial: ❑ All hydrological ECVs

Table 2: In-Situ Networks and Data Centres Contributing to GCOS

3.2.2.2.1 GCOS Surface Network - Monitoring Centre

Germany (DWD) and Japan provide the functions for the monitoring and quality control of GSN data.

3.2.2.2.2 GCOS Surface Network - Analysis Centre

The US National Climatic Data Center (NCDC) fulfils the role of the GSN Analysis Centre and provides higher-level quality control of both the daily and monthly GSN data.

3.2.2.2.3 GCOS Surface Network (and other WMO and National Networks) - Global Precipitation Climatology Centre (GPCC)

The GPCC operates under the auspices of WMO as a German contribution to the World Climate Research Programme (WCRP).

The main objective of the GPCC is the analysis of the spatial and temporal distribution of global precipitation on a monthly time-scale based on in-situ observation data.

The rain gauge observation database used for GPCC analyses comprises:

- near real-time weather and climate observation data continuously exchanged via the GTS;
- non-real-time precipitation data provided by NMHSes.

The GPCC holds the largest monthly in-situ precipitation database in the World.

The primary products of the GPCC are monthly gridded data sets of global land-surface precipitation, which are used as the "ground truth" within the complete global satellite-gauge combined data sets of the GEWEX Global Precipitation Climatology Project (GPCP).

3.2.2.2.4 Baseline Surface Radiation Network - World Radiation Monitoring Centre

The World Climate Research Programme (WCRP) Radiative Fluxes Working Group initiated a Baseline Surface Radiation Network (BSRN) to support the research projects of the WCRP and other scientific programmes and was subsequently incorporated into the WCRP Global Energy and Water Cycle Experiment (GEWEX) Radiation Panel - see section 3.3.1.

The World Radiation Monitoring Center is the central archive of all BSRN measurements and is hosted by the Alfred Wegner Institute in Germany.

The radiation data are stored together with collocated surface and upper-air meteorological observations and station metadata in an integrated database. High accuracy BSRN radiation measurements have been used to validate the radiation schemes in global climate models and satellite algorithms and are beginning to develop into an extensively documented and widely representative surface radiation data set.

3.2.2.2.5 WMO GAW GCOS Global Baseline Total Ozone and Profile Ozone Networks - World Ozone and Ultraviolet Radiation Data Centre

The World Ozone and Ultraviolet Radiation Data Centre (WOUDC) is operated by the Experimental Studies Division of the Meteorological Service of Canada (MSC), until recently known as the Atmospheric Environment Service, Environment Canada. The Data Centre began as the World Ozone Data Centre (WODC) in 1960 and in June 1992, the MSC agreed to a request from the WMO to add ultraviolet radiation data to the WODC. The Data Centre has since been renamed the World Ozone and Ultraviolet Radiation Data Centre (WOUDC) with the two component parts: the WODC and the World Ultraviolet Radiation Data Centre (WUDC).

The WODC operates a scientific archive and database providing a variety of ozone data sets to the international scientific community, including data from the WMO GAW GCOS Global Baseline Total Ozone and Profile Ozone Networks. Some data records date back more than 40 years. Data sets include total column ozone and vertical profile data from ozonesonde flights, lidar measurements and the Umkehr technique.

3.2.2.2.6 GCOS-affiliated WMO GAW Comprehensive Global Atmospheric Network for CO_2 and CH_4 Monitoring - World Data Centre for Greenhouse Gases

The World Data Centre for Greenhouse Gases (WDCGG) was established at the Japan Meteorological Agency (JMA) in October 1990 and collects and distributes data on the mixing ratios of greenhouse (CO_2, CH_4, CFCs, N_2O, etc.) and related reactive (O_3, CO, NOx, SO_2, VOC, etc.) gases in the atmosphere and the ocean. Simultaneously measured meteorological parameters are also recorded at WDCGG. Under an agreement between the Global Climate Observing System (GCOS) and WMO/GAW that considers the WMO/GAW global atmospheric CO_2 and CH_4 monitoring network as a comprehensive network of GCOS, the WDCGG is charged with data management and dissemination of value-added products on these species in order to facilitate more reliable monitoring and data analysis.

3.2.2.2.7 GCOS Reference Upper-air Network (GRUAN) - Lead Centre

GCOS is in the process of establishing a reference network for upper-air climate observations (GRUAN).

GRUAN is expected to provide long-term, highly accurate measurements of the atmospheric profile, complemented by ground-based state of the art instrumentation, to constrain and calibrate data from more spatially-comprehensive global observing systems (including satellites and current radiosonde networks), in order to fully characterize the properties of the atmospheric column and their changes.

GRUAN is envisaged as a network of 30-40 high-quality, long-term, upper-air observing stations, building on existing observational networks, such as NDACC, ARM, GUAN, GAW, BSRN and GSN. GRUAN builds on, but is not confined to, the larger GCOS Upper Air Network (GUAN).

In 2007, the GRUAN Lead Centre was assigned to the Richard-Assmann-Observatory at DWD, Lindenberg, Germany. The GRUAN Lead Centre is responsible for the coordination among stations, including training, education and research, and ensuring the archival and dissemination of GRUAN Data

3.2.2.2.8 GCOS Upper-Air Network (GUAN) - Monitoring centre

The European Centre for Medium-Range Weather Forecasts (ECMWF) and the Hadley Centre (UK) are responsible for the routine monitoring of daily temperature information from all GUAN stations, including the provision of station performance indicators.

3.2.2.2.9 GCOS/GTOS Global Terrestrial Network - Rivers - Global Run-off Data Centre

The GRDC is an international archive of data up to 200 years old, and is a unique collection of river discharge data collected at daily or monthly intervals from more than 7300 stations in 156 countries. This adds up to around 280,000 station-years with an average record length of 38 years. The GRDC provides discharge data and data products for non-commercial applications.

The German Federal Institute of Hydrology (Bundesanstalt für Gewässerkunde or BfG) hosts the GRDC which operates under the auspices of the World Meteorological Organisation (WMO) and supports research on global climate change and integrated water resources management.

3.2.2.2.10 GCOS/GTOS Global Lake Network - International Data Centre on the Hydrology of Lakes and Reservoirs (HYDROLARE)

This Data Centre, currently being established by Russia under the auspices of WMO, will provide information for decision-making, on regional and global scales, concerning the water resources of inland lakes and reservoirs. A priority list of globally-distributed lakes to be monitored systematically for climate is currently being established, the future Global Terrestrial Network – Lakes.

3.2.2.2.11 GCOS/GTOS Global Terrestrial Network - Glaciers - World Glacier Monitoring Service

The world-wide collection of information about ongoing glacier changes was initiated in 1894 with the foundation of the International Glacier Commission at the 6th International Geological Congress in Zurich, Switzerland. In 1986 the World Glacier Monitoring Service (WGMS) was started to maintain and continue the collection of information on ongoing glacier changes, and collects standardised observations on changes in mass, volume, area and length of glaciers with time (glacier fluctuations), as well as statistical information on the distribution of perennial surface ice in space (glacier inventories).

Such glacier fluctuation and inventory data are high priority key variables in climate system monitoring; they form a basis for hydrological modelling with respect to possible effects of atmospheric warming, and provide fundamental information in glaciology, glacial geomorphology and quaternary geology. The highest information density is found for the Alps and Scandinavia, where long and uninterrupted records are available.

Switzerland hosts the WGMS and provides the bulk of its funding.

3.2.2.2.12 GCOS/GTOS Global Terrestrial Network - Glaciers - National Snow and Ice Data Centre

The National Snow and Ice Data Centre (in the United States) complements the data holdings of the WGMS with information about snow, ice, glaciers and frozen ground.

3.2.2.3 WMO Regional Climate Centres (RCCs)

WMO RCCs are centres of excellence that create regional products, including long-range forecasts, that support regional and national climate activities and thereby strengthen capacity of WMO Members in a given region to deliver better climate services to national users. Also, as noted in Section 3.1.4, it is envisaged that the RCCs will form an integral component of the Global Framework for Climate Services.

WMO is currently in the process of "designating" RCCs and currently two pilot projects have been identified in WMO Regional Association II (Asia) and WMO Regional Association VI (Europe).

The European Pilot RCC is a network of centres that is coordinated by DWD. There are three distinct application areas (nodes) within this network:

- **Climate Data** (led by KNMI and supported by Meteo-France, Meteorological Service (OMSZ) Hungary, Norwegian Meteorological Institute, Republic Hydrometeorological Service of Serbia (RHMS), Swedish Meteorological and Hydrological Institute (SMHI) and the Turkish State Meteorological Service (TSMS);

- **Climate Monitoring** (led by DWD and supported by Armstatehydromet Armenia, Meteo-France, KNMI, Republic Hydrometeorological Service of Serbia (RHMS) and the Turkish State Meteorological Service (TSMS);

- **Long-Range Forecasting** (co-led by Meteo-France and Roshydromet and supported by Norwegian Meteorological Institute, Republic Hydrometeorological Service of Serbia (RHMS) and the Turkish State Meteorological Service (TSMS).

Japan and China are taking a leading role in the development of the Asian RCC.

3.2.2.4 Argo Project

Argo is a major contributor to the WCRP's Climate Variability and Predictability Experiment (CLIVAR) project and to the Global Ocean Data Assimilation Experiment (GODAE). The Argo array is part of the Global Climate Observing System/Global Ocean Observing System GCOS/ GOOS) - see section 3.2.1.1.

The Argo Project is supported by a large number of countries, including European contributions from the European Union, France, Germany, Greece, Ireland, Netherlands, Norway, Poland, Spain and the UK.

The global array of temperature/salinity profiling floats, provided by Argo, is a major component of the ocean observing system. It complements surface ocean observing systems with the measurement of subsurface temperature, salinity, and velocity, with sufficient coverage and resolution to permit interpretation of altimetric sea surface height variability. Argo is not confined to major shipping routes, which can vary with season, and the Argo array of 3,000 floats is distributed roughly every 3 degrees (300km) - see Figure 4.

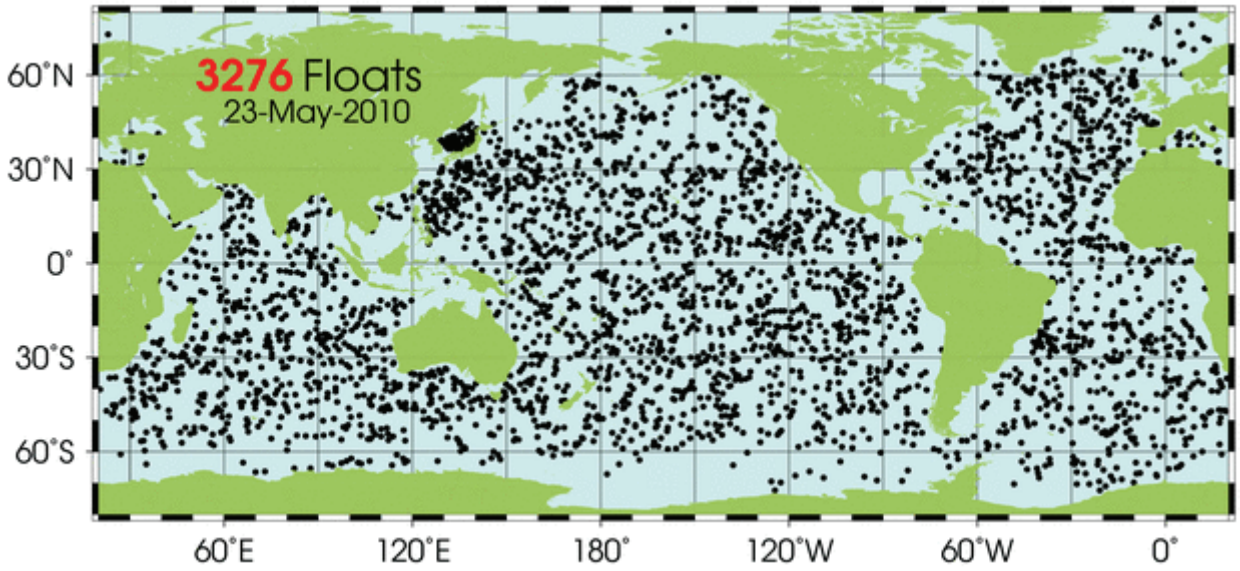

Figure 4: Argo Array

Argo data is used for initialising ocean and coupled ocean-atmosphere forecast models, for data assimilation and for model testing. A primary focus of Argo is to document seasonal to decadal climate variability and to aid our understanding of its predictability.

All Argo data are publicly available in near real-time via the Global Data Assembly Centres (GDACs) in Brest, France and Monterey, California after an automated quality control (QC), and in scientifically quality controlled form, delayed mode data, via the GDACs within six months of collection. The Argo Information Centre is located in Toulouse.

3.2.3 Inter-calibration and Standards

3.2.3.1 Global Space-Based Inter-Calibration System (GSICS)

High, stable measurement accuracy is essential for climate monitoring. High precision is also needed for Numerical Weather Prediction.

GSICS was launched in 2005 by WMO and CGMS in order to meet these requirements. Within GSICS, participating agencies develop and implement a comprehensive calibration strategy for space-based instruments with the aim of:

- Ensuring consistency of satellite measurements from different instruments and programmes,
- Tying these measurements to absolute references and SI standards,
- Enabling recalibration of archived data.

GSICS coordinates activities for pre-launch instrument characterisation, on-board routine calibration, sensor intercomparison by collocation of individual scenes or overlap between time series, use of Earth-based or celestial references, as well as field campaigns.

The GSICS activities are closely-coupled to those of SCOPE-CM (see section 3.2.2.1) and are also coordinated with the Cal/Val activities of CEOS - see section 3.2.1.8.

From Europe, EUMETSAT and CNES are members of GSICS.

3.2.3.2 Standards

In order to ensure that Earth observation data is usable for climate applications, GCOS has developed the GCOS Climate Monitoring Principles (see Appendix D). These Principles apply to both in-situ and satellite data (albeit with some additional constraints on satellite data).

The CEOS Working Group on Calibration and Validation (WGCV) - see section 3.2.1.8 - is also developing the QA4EO Guidelines, which have been coordinated with GSICS (see section 3.2.3.1). This initiative has also been adopted within the framework of the GEO WP (covering both in situ and satellite data) and builds upon the standards that already exist and are compliant with the QA4EO guidelines (e.g. standards followed by the WMO GAW programme).

GTOS is also in the process of developing standards for Terrestrial ECVs see [RD.11].

*Europe (initially via ESA through CEOS) has taken the lead in extending the QA4EO approach within GEO via GEO task **DA-09-01a**: GEOSS Quality Assurance Strategy.*

3.3 Climate Research

3.3.1 World Climate Research Programme (WCRP)

The aim of the WCRP is to improve climate predictions and the understanding of human influence on climate through observations and modelling of the Earth system and policy-relevant assessment of climate conditions. Within the framework of WCRP the WCRP/CLIVAR Working Group on Coupled Modelling (WGCM) facilitates and fosters the development of coupled climate models, including organization of model intercomparison as a basis for model validation and diagnosis of shortcomings (e.g. the Coupled Model Intercomparison Project, CMIP). WGCM also promotes co-ordinated studies of, and experimentation with, coupled models aiming to achieve more confident projections of the response of the climate system to changes in natural and anthropogenic forcing, as a basis for the IPCC Assessments.

The World Climate Research Programme (WCRP) organization has many partners and stakeholders. Each of these contributes services, information, solutions or funds. The overarching objectives of all members of this network are to contribute to improved understanding of the climate system, climatic change and the interactions between climate, people and the environment.

Together with the International Geosphere-Biosphere Programme (IGBP), the International Human Dimensions Programme on Global Environmental Change (IHDP) and DIVERSITAS, WCRP provides the international framework for scientific cooperation in the study of global environmental change through the Earth System Science Partnership (ESSP).

The World Climate Research Programme (WCRP) initiated the Global Energy and Water Cycle Experiment (GEWEX) in 1988. GEWEX is an integrated program of research, observations, and science activities ultimately leading to the prediction of global and regional climate which is directed by four objectives: 1) To determine the hydrological cycle and energy fluxes by means of global measurements of atmospheric and surface properties. 2) To model the global hydrological cycle and its impact on the atmosphere, oceans and land surfaces. 3) To develop the ability to predict the variations of regional and global hydrological processes and water resources, and their response to environmental change. 4) To advance the development of observing techniques, data management and assimilation systems for operational application to long-range weather forecasts, hydrology, and climate predictions.

The GEWEX Radiation Panel (GRP) guides GEWEX data set projects in determining global water and energy fluxes in the atmosphere and at the surface, as an element of seasonal-to-interannual climate variability, and the response of the climate systems on decadal-to-interannual time scales to changes in anthropogenic forcing.

The GEWEX Modelling and Prediction Panel (GMPP) develops accurate global model information on the energy and water budget and demonstrates predictability of their variability and response to climate forcing.

The GEWEX Coordinated Energy and Water Cycle Observations Project (CEOP) demonstrates skill in predicting changes in water resources and soil moisture on time scales up to seasonal and annual as an integral part of the climate system.

The WCRP Observation and Assimilation Panel (WOAP) is co-sponsored by the GCOS (Global Climate Observation System) - see section 3.2.1.1. WOAP consists of a panel of representatives from all of the other activities in WCRP (projects and working groups) and GCOS to deal with cross cutting issues related to global observations, their analysis and assimilation, and the resulting products from a research perspective on behalf of WCRP and GCOS.

WOAP is complementary to the GCOS Panels (further described in section 3.2.1.1) and it includes representatives from the WCRP/GCOS co-sponsored panels AOPC (Atmospheric Observation Panel for Climate), OOPC (Ocean Observation Panel for Climate) and Terrestrial Observation Panel for Climate (TOPC) to establish requirements of climate researchers for in-situ as well as satellite observation networks and systems.

WOAP, AOPC, OOPC and TOPC also serve the research community in the collection and reanalysis of climate observations in order to better describe the structure and variability of the climate system, as well as climate change. WCRP exploits observations and re-analyses in its input to the Intergovernmental Panel on Climate Change (IPCC) assessment reports and other wide-ranging policy advice.

WOAP also has representatives from the WCRP modelling working groups, as models are essential to analyse observations, and assimilation of observations provides fields for initializing climate predictions with models. It therefore also provides a forum for exploring modelling and prediction observational needs.

*The WCRP is co-lead with WMO/THORPEX on GEO Task **CL-07-01**: Seamless Weather and Climate Prediction System. Europe (particularly France, Germany Norway and UK) is an important contributor to THORPEX.*

*Greece and Norway are also involved in GEO Task **CL-06-01b**: Extending the Record of Climate Variability at Global Scale*

4 EXISTING AND PLANNED EUROPEAN SYSTEMS AND PROGRAMMES

4.1 Status Quo Assessment

Within the context of the requirements noted in section 2.1, an assessment of the European climate capabilities is made in the following areas:

- Data Provision:
  - Space Data Provision;
  - In-situ Data Provision;
- Modelling (including reanalysis).

This assessment is based on a combination of published material and questionnaire responses.

4.1.1 Data Provision

In order to be able to generate the ECVs listed in section 2.1, two types of data are required:

- Space Data;
- In-situ Data (including airborne, balloon-based measurements as well as ground-based remote-sensing, and floating buouys).

For space-based data provision, the following assessment relies heavily upon the work described in the recent JRC report {see [RD.1]}.

4.1.1.1 Space Data Provision - Current Capabilities and Plans

A resolution on “Space and Climate Change” of the 5th Space Council (a concomitant meeting of the European Union (EU) Competitiveness Council and the European Space Agency (ESA) Ministerial Council) in September 2008 invited the commission to conduct a study to "*assess the needs for full access to standardised data and for increased computing power, and the means to fulfil them taking into account existing capacities and networking in Europe*".

Furthermore this resolution called for the scientific community, in conjunction with the EC, ESA and EUMETSAT to define how the range of GMES (Global Monitoring for Environment and Security) services and European space observation archives can contribute most effectively to the provision of data including Essential Climate Variables (ECVs) for scientific research.

The implementation of this resolution resulted in [RD.1] which provides a recent view of the capabilities and plans of the European Space data providers for climate applications and, in line with the envisaged scope of the EUGENE project, reliance is placed on [RD.1] for the current capabilities and plans for space data provision.

From [RD.1] it can be seen that Europe has a rich tapestry of satellite observing systems and associated processing capabilities:

- EUMETSAT Operational Meteorological Satellite Systems {e.g. MTP, MSG, MTG, EPS, Post-EPS - see section 5.1.2 of [RD.1]);
- ESA Research and Development Satellites {e.g. Envisat, Earth Explorer Missions and Sentinels - see section 5.1 of [RD.1]};
- Multi-agency programmes such as Jason;
- National Satellite Programmes (e.g. CALISPSO, PARASOL, DEMETE, SPOT, …..)
- EUMETSAT Satellite Application Facilities {e.g. CM-SAF, GRAS-SAF, O3M-SAF, OSI-SAF, LSA-SAF… see section 5.1.2 of [RD.1] for further details};
- the ESA Climate Change Initiative (see section 5.2.1 of [RD.1]).

Based on these satellite observing and processing systems, the current capabilities, and future plans, (within an ECV reference frame) are summarised in Appendix A. This appendix is a subset of the information provided in [RD.1].

From this Appendix it can be seen that, with the existing European space segment, Europe has the potential to make a significant contribution from space to 26 ECVs.

However, the summary nature of this table masks a number of factors which affect the value of these space segment activities for climate applications. These factors include:

a) the availability of suitable satellite products;
b) the availability of suitable Climate Data Records;
c) the relative contribution of space data to the ECV under consideration.

Concerning a), it should be noted that the availability of a suitable sensor does not necessarily imply the availability of a suitable satellite product. Without a suitable satellite product, the contribution to all the climate application areas identified in Figure 1 will be correspondingly limited.

Concerning b), some of the climate applications summarised in section 2.2.2 rely on the availability of appropriate Climate Data Records. Some satellite operators do not implement all the range of activities required to generate appropriate records for exploitation by these climate applications.

There is also the issue of the varying degree of adherence, by Satellite Operators, to the GCOS Climate Monitoring Principles (see Appendix D) which have been defined to ensure that systems provide effective climate monitoring support.

In addition, if one assumes that a Climate Data Record needs to span more than 10 years to be useful, then the landscape becomes rather sparse, with atmospheric records generally dominating (primarily due to the long-term continuity offered by operational meteorological satellite programmes).

Concerning c), it is noteworthy that, for some ECVs, space sensors provide the principal source of data (e.g. Cloud Properties, Earth Radiation Budget, Albedo) whilst for others (e.g. surface air temperature) the contribution of space data is much less significant, with in-situ data being of much more relevance.

4.1.1.2 In-situ Data Provision

4.1.1.2.1 Questionnaires

In order to determine the status in the area of In-situ data provision, questionnaires were released in January 2010 to 3 entities/centres involved in the provision of in-situ observations (EUMETNET-EIG, EEA and EUROGOOS). As of 26 March 2010, responses had been received from EUMETNET-EIG and EEA.

The in-situ questionnaire addressed the following topics for each Centre:

- the particular **strengths** of the Centre;
- the biggest **challenges** (e.g. gaps, opportunities) for *in-situ* data provision for climate applications during the next decade, and how these challenges should be best approached;
- the **main partners** of the Centre in the field of climate;
- the envisaged **evolution in the Centre's climate role** during the next decade;
- the **Centre's role in the maintenance of Climate Data Records (CDRs)** and their relationship to ECVs;
- the **information that is passed to other Centres** involved in climate monitoring.

4.1.1.2.2 Summary of Responses

A summary of the responses to this questionnaire is provided in Appendix B.

4.1.1.2.2.1 EUMETNET-EIG Response

From the responses it can be seen that, within the framework of European Climate Support Network (ECSN) - a EUMETNET-EIG programme, there is a long-term ("*permanent*") commitment to the maintenance of European surface records of:

- Air Temperature;
- Precipitation;
- Air Pressure;
- Snow Depth;
- Sunshine Duration;
- Relative Air Humidity;
- Cloud Cover Ratio.

Operational access is provided to these quality-controlled in-situ climate data sets, which are aimed at climate monitoring and modelling applications. The record lengths for this meteorological data, in general, greatly exceeds that of space data records with, in some cases, record lengths spanning more than 100 years.

It is stressed that the ECSN programme is built upon, and is dependent on, the climate monitoring activities of Europe's NHMSes. These national climate monitoring activities are of a mandatory nature and involve regular reporting in accordance with WMO recommendations. The datasets resulting from these national activities provide the source material for the ECSN records, which are generally at a lower temporal and geographical resolution than the nationally-held datasets.

4.1.1.2.2.2 EEA Response

In addition, EEA and EIONET[13] (European Environment Information and Observation Network) collect, from data providers, environmental information according to the reporting obligations of the EU (e.g., greenhouse gas emissions, air, water quality, biodiversity[14]) and voluntary data flows as agreed with member countries (e.g., CORINE land cover data[15]). EIONET is a European contribution to GAW.

The EEA has an important role in coordinating GMES in-situ data. GISC[16] (GMES In-Situ Coordination) project is a key element of this EEA coordination role. The goal of the GISC action is to stimulate open access to all relevant in-situ data for operational GMES service provision by resolving the issues which are barriers for cost effective and sustainable data provision and thus ensuring an operational framework for in-situ for all GMES services.

4.1.1.2.2.3 EuroGOOS Response

The EuroGOOS questionnaire was forwarded (by EuroGOOS) to the National Oceanography Centre, UK who provided a partial response (Excel sheet only) which described the contributions of the Voluntary Observing Ship (VOS) Programme to in-situ ECVs, principally:

- Air Temperature;
- Precipitation;

[13] http://eea.europa.eu; http://www.eionet.europa.eu/;
[14] http://dataservice.eea.europa.eu/dataservice/; http://www.eea.europa.eu/themes/climate/data-viewers; http://www.eea.europa.eu/themes/air/airbase; http://www.water.europa.eu/; http://www.eea.europa.eu/themes/biodiversity/eea-activities
[15] http://www.eea.europa.eu/publications/COR0-landcover
[16] http://gisc.ew.eea.europa.eu/gisc-project

- Air Pressure;
- Radiation Budget;
- Wind Speed and Direction;
- Water Vapour;
- Sea Surface Temperature.

The questionnaire response did not cover the Argo network which is built on national funding and, although international in nature, involves a significant European contribution, i.e.:

- individual contributions (mostly array contributions) from the European Union, France, Germany, Greece, Ireland, Netherlands, Norway, Poland, Spain and the UK;
- hosting of one of the two Global Data Assembly Centres (GDACs) in Brest, France;
- hosting of the Argo Information Centre in Toulouse, France.

4.1.1.2.3 European Contributions to Global In-Situ Frameworks

As is evident from section 3, Europe also makes a substantial contribution to in-situ data provision via global frameworks. Such contributions are "over and above" the normal national contributions to the collection networks. Table 3 highlights some of these "over and above" contributions.

Framework	European Contribution	Section Reference
GAW	The World Data Centre for Aerosols is hosted by Norway The World Data Centre for Remote Sensing of the Atmosphere is hosted by DLR (Germany)	3.2.1.5
GSN	Germany (DWD) and Japan provide the functions for the monitoring and quality control of GSN data. - Germany (DWD) hosts and operates the GPCC (as a contribution to the WCRP)	3.2.2.2
BSRN	Germany (AWI) hosts the World Radiation Monitoring Centre	3.2.2.2.4
GRUAN	Germany (DWD) provides the Lead Centre for the GRUAN	3.2.2.2.7
GUAN	ECMWF and the Hadley Centre (UK) provide the Monitoring Centre for the GUAN	3.2.2.2.8
GRDC	Germany (BfG) hosts the GRDC	3.2.2.2.9
WGMS	Switzerland hosts the WGMS and provides the bulk of its funding	3.2.2.2.11

Table 3: **European Contributions to Global In-situ Frameworks** (beyond "routine" national contributions)

4.1.2 Climate Modelling

4.1.2.1 Questionnaires

In order to determine the status in the area of Climate Modelling, questionnaires were released in December 2009 and January 2010 to 15 entities/centres involved in Climate Modelling[17] [Alfred-Wegener-Institut (AWI), Centro Nazionale di Meteorologia e Climatologia Aeronautica (CNMCA), Deutscher Wetterdienst (DWD), European Centre for Medium Range Weather Forecasting (ECMWF), Forschungszentrum Jülich (Jülich), Hadley Centre, Koninklijk Nederlands Meteorologisch Instituut (KNMI), Laboratoire de Meteorologie Dynamique (LMD), Météo-France, Météo-Swiss, Max Planck Institute for Meteorology (MPI-M), National

[17] In view of the limited scope of the EUGENE project, it was not possible to send questionnaires to all European Centres that have a climate modelling capability, and the selection was based upon the list of major Centres given in the approved EUGENE Description of Work - see [AD.1]. So, the responses described in section 4.1.2.2 may not fully capture the diversity of climate modelling activities within Europe.

Centre for Earth Observations (NCEO), Potsdam Institute for Climate Impact Research (PIK), GKSS, World Climate Research Programme (WCRP)].

As of 26 March 2010, 14 responses had been received.

The climate modelling questionnaire addressed the following topics for each centre:

- the **contributions** and objectives of the Centre to Climate Monitoring, Climate Prediction and Climate Research;
- the **particular strengths** of the Centre in Climate Monitoring, Climate Prediction and Climate Research;
- the biggest **challenges** (e.g. gaps, opportunities) in Climate Monitoring, Climate Prediction and Climate Research during the next decade, and how these challenges should be best approached;
- the **main partners** of the Centre in the field of climate;
- the **envisaged evolution in the Centre's climate role** during the next decade;
- the Centre's **role in the generation of ECVs**;
- the Centre's **role in the maintenance of CDRs**;
- the **information that is passed to other Centres** involved in climate monitoring;
- any **unfulfilled requirements for CDRs** for modelling purposes.

4.1.2.2 Summary of Responses

A summary of the responses to the questionnaire is provided in Appendix C and Table 4 identifies the main contributions to climate monitoring, climate prediction and climate research[18].

4.1.2.2.1 Reanalysis

As reanalysis is an important activity that feeds a number of climate applications, it merits particular consideration.

Reanalyses of multi-decadal series of past observations have become an important and widely-utilised resource for the study of atmospheric and oceanic processes and predictability. Since reanalyses are produced using fixed, modern versions of the data assimilation systems developed for numerical weather prediction, they are more suitable than operational analyses for use in studies of long-term variability in climate. Europe is fortunate in having a world-leading centre (ECMWF) that has pioneered reanalysis, and makes available the resultant datasets (on a project basis) particularly to Climate Monitoring applications - see the ECMWF response in Appendix C.4 for further details.

*Europe (via ESA, EUMETSAT, ECMWF, Germany, JRC, Norway and Portugal) makes an important contribution to the GEO Task **CL-06-01a**: Sustained Reprocessing and Reanalysis of Climate Data.*

[18] Excluding the GAW input as it is a global capability (rather than European) and is addressed in section 3.2.1.5

Centre	Climate Monitoring	Climate Prediction and Projections	Climate Research
AWI	The most important monitoring activities are the meteorological measurements at both polar stations: Neumayer Station in Antarctica and Koldewey Station in Ny-Alesund (Spitsbergen). In addition, standard meteorological measurements are taken on our Research Ice Breaker Polarstern. Monitoring of the ocean is conducted through a long-term mooring programme in Fram Strait (between Spitsbergen and Greenland), in the Lena Delta, and in the Weddell Sea (Antarctica). Sea ice observations are performed during Polarstern expeditions and aircraft missions. Our specialty is the observation of sea ice thickness. These measurements are generally done as a process study, rather than as a monitoring activity.	Prediction is a small part of research activities - predictive capabilities are currently being developed on the basis of optimised coupled regional climate and earth system models, especially for polar regions.	Focus is on the coupled ocean-ice-atmosphere system and its importance for the global climate. Studies are regionally- confined (polar) but collaboration allows results to be interpreted in a global context
CNMCA	The main contribution is the construction of time series of weather parameters in appropriate data-sets, developing of catalogues and meta-data collections, monthly issue of statistical analysis on conventional and non-conventional observational data, comparison with Climate Normals and updating of outliers data recorded during extreme events, co-operation in the European Climate Support Network and European Climate System Monitoring activities.	At present there is no contribution in the field of Climate Prediction.	The main contribution is studies on simplified GFD dynamical systems for a better understanding of climate processors.

Centre	Climate Monitoring	Climate Prediction and Projections	Climate Research
DWD	Main contribution in the area of climate monitoring is: - operation of in-situ and remote sensing observation networks for atmospheric and some near surface oceanic Essential Climate Variables. Details are given in http://unfccc.int/resource/docs/gcos/deugcos.pdf; - operation of the WMO Regional Association VI Regional Centre on Climate Monitoring (RCC-CM), - the EUMETSAT Satellite Application Facility on Climate Monitoring (CM-SAF) and the - Global Precipitation Climatology Centre (GPCC).	Operation of a regional climate model (started recently). Operation of high resolution climate impact models in support of urban and spatial planning, Agriculture and Hydrology. Operational assessment of seasonal weather forecasts for Germany. Assessment of regional climate simulations for Germany. DWD aims to become one of the major European meteorological services with operational climate consultancy services for temporal scales from seasonal forecasts via decadal forecasts up to 100 years regional climate simulations.	Climate Research is carried out within the activities of Climate Monitoring and Climate Prediction supporting the development of climate consultancy services contributing to climate change adaptation strategies.
ECMWF	The reanalysis activities at ECMWF (ERA-15, ERA-40, ERA-Interim and the planned ERA-CLIM) all contribute to climate monitoring. We also contribute to monitoring of atmospheric composition through the MACC (former GEMS) activities connected to the GMES programme. ECMWF will be a partner of the Climate Modelling User Group (CMUG) within the ESA Climate Change Initiative (CCI). Strong interactions have been established between ECMWF and the Global Space Based Intercalibration System (GSICS), coordinated by NOAA. ECMWF contributes within this framework by documenting satellite data biases, with the aim of ensuring consistency of satellite measurements from different instruments and programmes, and tie these measurements to absolute references and SI standards.	ECMWF is currently not involved in climate prediction - longest prediction time scale is seasons - as ECMWF have a model system that is well suited also for climate prediction ECMWF foresee an increased interaction with European research groups that wish to use the ECMWF system for climate prediction purposes	ECMWF scientists have contributed with papers in the scientific literature in the field of climate modelling and have been actively involved in EU projects. The reanalysis group have contributed with results from climate monitoring. The most widely cited paper in geophysics over the last years was written by the reanalysis group at ECMWF. These climate research activities directly contribute to climate monitoring by providing the time history of basic climate parameters. Our atmospheric modelling research directly benefits climate modelling.

Centre	Climate Monitoring	Climate Prediction and Projections	Climate Research
Jülich	Currently **Jülich** does not have a mandate for operational climate monitoring but makes a contribution through the European research infrastructure (ESFRI) project IAGOS (http://www.fz-juelich.de/icg/icg-2/iagos). The prototype system for monitoring ozone and water vapour on commercial airliners has been installed in the MOZAIC project. IAGOS is building up a more sustainable infrastructure for these observations and expanding the number of observed compounds to include CO_2 and aerosols, amongst others.		Jülich is involved in research activities related to climate (with a focus on energy technologies and chemistry climate interactions). Jülich is involved in chemistry climate assessment work (WMO, IPCC, TFHTAP) and operates various global and regional scale climate models (ECHAM5-HAMMOZ, MOZART, CLAMS, EURAD).
GKSS	Our CoastDat Database comprises a compilaton of coastal analyses (that is hindcasts and reconstructions) and scenarios for the future obtained from numerical models for the Northern Sea. The objective is to provide a consistent meteorological-marine data set that best represents past conditions in order to complement the existing but limited observations. Based on model results CoastDat may thus provide information over long time spans, at high spatial and temporal detail, and at places and for variables for which no observations have been taken.	GKSS focuses on coastal seas and storm activities. Our CoastDat Database comprises a compilaton of coastal analyses (that is hindcasts and reconstructions) and scenarios for the future obtained from numerical models for the Northern Sea.	The objective of our CoastDat database is to provide a consistent meteorological-marine data set that best represents past conditions in order to complement the existing but limited observations.
Hadley Centre	Main contribution is production of gridded data sets of marine and land temperatures, sea-level pressure, upper air temperatures and of climate extremes (e.g. surface temperatures); specific UK data sets of temperature and precipitation; development of long-term record of infrared radiances from the HIRS instruments. Full details of the Hadley Centre observational data sets can be found at http://www-hc/~hadobs/www.hadobs.org/. Historically we have focused on conventional observations from the global network, although there is now an increasing amount of work using satellite data, either to augment the conventional data (e.g. SSTs) or as the basis for new data sets (IR radiances).	Development of climate models incorporating state-of-the-art representations of the most important physical processes. The primary model for climate prediction is the Hadley Centre Global Environmental Model (HadGEM). Aim to provide predictions on timescales ranging from seasonal to centennial in response to our customer requirements. ECVs are used primarily to evaluate model performance but are also likely to become increasingly important for initialising decadal predictions.	Fundamental research into the key processes and feedbacks operating in the climate system in support of the requirements for climate prediction, i.e. development of better climate models.

Centre	Climate Monitoring	Climate Prediction and Projections	Climate Research
KNMI	**National** KNMI is responsible for the meteorological basis observations within the Netherlands (40 meteorological and climatological stations and 320 precipitation stations: see http://www.knmi.nl/klimatologie/). More activities on climate observations are: • Extensive atmospheric measurements at the Cabauw site, including mast measurements, radiation and remote sensing. See http://www.cesar-database.nl/ • Satellite data: retrieval and delivery (e.g. www.temis.nl , http://www.knmi.nl/scatterometer/) • Contribution to Argo floats programme • Twice daily radio sonde at De Bilt • Weekly ozone sonde at De Bilt • Continuous Brewer measurement of total column over De Bilt Regular ozone sonde and Brewer measurements at Paramaribo station, Surinam. HISCLIM project: recovering, digitizing and archiving daily historical meteorological observations back to 1700 AD (www.knmi.nl/research/climate_services/hisklim.html) **International** Operation of the WMO Regional Association VI Regional Centre on Climate Data (RCC-CD) Operation of ECA&D: the European Climate Assessment and Data Set (http://eca.knmi.nl), giving access to > 12000 climate meteorological observational series and related assessments from > > 3200 stations in > 60 (Europe and bordering) countries The DIDAH project aims at data rescue and data access for the Indonesian Archipelago	KNMI issues about every 6 years the climate scenarios for The Netherlands. KNMI leads the development of the EC Earth climate prediction model to be used for IPCC AR5 and further and the national scenarios. KNMI uses and develops the regional climate model RACMO2 for use in AR5 and national scenarios.	KNMI research staff produces about 80 peer-review papers on climate research per year. Main research subjects are future climate for The Netherlands, predictability, feedbacks, atmospheric chemistry, boundary layer.

Centre	Climate Monitoring	Climate Prediction and Projections	Climate Research
LMD	Analysis of long time series of satellite observations from meteorological satellites, both GEO and LEO satellites, including calibration and retrievals as well as climate studies (variability and trends) and physical interpretation (relationship between different ECV's). Hereby it is difficult to separate climate monitoring and climate research.		Analysis of long time series of satellite observations from meteorological satellites, both GEO and LEO satellites, including climate studies (variability and trends) and physical interpretation (relationship between different ECV's). LMD leads the cloud assessment initiated by the GEWEX Radiation Panel. Participation in CMIP5 and other modeling activities coordinated by the WCRP Working Group on Coupled Models (WGCM). LMD is also involved in the FP7 european project EUCLIPSE

Centre	Climate Monitoring	Climate Prediction and Projections	Climate Research
Météo-France	Climate Monitoring is performed for France and its overseas territories. Daily, Monthly, Seasonal and annual reports are delivered on a routine basis. Ad hoc reports are published in case of special events (e.g. the winter current cold wave). Seasonal Forecasting is delivered each month for the next trimester, with a public bulletin put on Météo-France's public web site, a full monitoring and analysis report, and special products tailored to various user's need, especially in the industry and research. Seasonal forecasting applications are also in operations or in development, in a wide range of sectors, from hydrology and water resource, to energy or health. They are namely used for overseas territories and Africa (eg Support to OMVS for the regulation of the river Senegal flows at the Manantali dam; Rift Valley Fever for cattle in Senegal…).	Climate Prediction is an operational activity that provides seasonal forecasts for public, applications and specific end-users. The climate model used is a coupled ocean-atmosphere general circulation model Arpege/ORCA. The ocean initial conditions are prepared by MERCATOR in Toulouse. Input variables are those of the atmospheric and oceanic data assimilation systems. This includes data from meteorological satellites and satellite altimetry. An earth system model is used to participate to the CMIP simulation exercises resulting in centennial projections and decadal predictions that serve as a basis of the GIEC assessment reports. Regional climate projections covering this century are also performed to contribute to impact and adaptation studies over some regions including Europe and the Mediterranean area. Re-analysis is used to perform hindcast predictions that are used to calibrate seasonal predictions. The ECV link is through these re-analyses that might include these variables in the assimilation systems. The outputs of the predictions are seasonal anomalies of some parameters (mainly temperature and precipitations) that are classified in a very limited number of classes (typically 3). The combination of several predictions for the same season (ensembles) and of different models (multi-model) allows to generate probabilistic forecasts in the context of the EUROSIP project.	Climate Research is carried out in the Météo-France climate research group. The general main scientific objectives are the study of climate variability and of the impact of human activities on climate, the study of climate predictability, the study of the interactions between climate and atmospheric chemistry and the study of the interactions between ocean and atmosphere. The methodology relies mainly on modelling both at the global and at the regional scales.

Centre	Climate Monitoring	Climate Prediction and Projections	Climate Research
Météo-Swiss	• Coordination of GCOS activities in Switzerland (GCOS Switzerland) • Observation of surface and upper-air Atmosphere ECVs including quality control and homogenization of time series • Observation of atmospheric composition ECVs (ozone, aerosols, trace gases, pollen, etc.) and coordination of the Swiss activities within the WMO GAW programme (GAW-CH) • Provision of calibration services, maintenance of international calibration centres in the framework of GCOS (eg. World Glacier Monitoring Service WGMS) and of WMO GAW (eg. World Radiation Centre PMOD/WRC Davos) • Member of EUMETSAT CM SAF consortium	Climate prediction services for industry and governmental offices from monthly, seasonal, decadal and centennial time scales.	Climate research in the Framework of the Swiss National Centre of Competence in Research on Climate (NCCR Climate)
MPI-M	MPI-M is not involved in Climate Monitoring activities as such, as these include an operational component. Climate observations at MPI-M focus on: the long-term analysis and homogenization of existing observational records with a strong emphasis on satellite data (e.g. HOAPS climatology of ocean surface fluxes) and observations related to a better understanding of relevant processes in the Earth System	MPI-M is also not a climate prediction centre in the operational sense. However we are deeply involved in climate prediction as part of community protocols such as CMIP, which underlies the IPCC assessments. We are also playing a leading role in developing a decadal prediction capacity within Europe. Our center maintains and develops a comprehensive Earth-system model, which is comprised of a coupled ocean, atmosphere, terrestrial biosphere and biogeochemical model. This model is used to develop our understanding of the climate system and provides an essential basis for the periodic assessments lead by the IPCC.	MPI-M is a leading centre in the development of climate models and climate theory. Our research focuses on climate sensitivity and feedbacks, and controls on predictability of the climate system. The focal point of MPI-M's work is the integration of observations and climate modelling, particularly in relation to controls on the radiation budget (mostly clouds and water vapour, and to a lesser extent chemistry or aerosol).

Centre	Climate Monitoring	Climate Prediction and Projections	Climate Research
NCEO	The NCEO supports a number of projects which involve contributions to climate monitoring although these all have a research focus. The centre does not support observation programs of its own. Specific projects supported include: -construction of long land surface and SST records from overlapping satellite observations; -ocean reanalyses using all available ocean data over past decades; -analysis of atmospheric water vapour and precipitation records from EO data; -analysis of sea ice thickness records based on altimeter-derived freeboard.	A strong focus of the NCEO is to see EO data used more widely in weather and climate predictions and so a strong partnership with the Met Office is being built with the aim of embedding use of EO data in operations using improved retrieval and data assimilation methods Projects are recently underway to examine the use of EO data for assessment and initialisation of climate models used for decadal prediction.	The NCEO has a Climate theme with activities particularly in atmospheric radiation, the water cycle, ocean circulation, long term EO records from SST sensors, ocean reanalysis for climate studies, ocean colour assimilation, the cryosphere, including land and sea ice, and role in the climate system, the land surface, water cycle and carbon cycle. Atmospheric work focuses on comparing and combining satellite and ground-based observations, atmospheric reanalysis products and climate model simulations to improve knowledge of physical processes by analyzing the Earth's radiative energy balance and its links to the global water cycle. In particular understanding current changes in precipitation, understanding the role of ice and water in clouds, and implications for future changes.

Table 4: European Contributions to Climate Monitoring Prediction, Projection and Climate Research

5 STRENGTHS, GAPS, CHALLENGES AND OPPORTUNITIES

Based on the material gathered during the status quo assessment, the following sections analyse the strengths, gaps, challenges and opportunities for Europe (in sections 5.1 and 5.2).

Europe's contributions to GEO are also summarised in section 5.3.

5.1 Strengths

5.1.1 European Contributions to International Frameworks

Europe is very well positioned in the international context with the active participation of ESA, EUMETSAT, ECMWF, EC and national agencies in key frameworks (e.g. IPCC, GCOS, CEOS, CGMS, GSICS, SCOPE-CM, WCRP….). These key frameworks are, in turn, closely connected to the implementation of the relevant GEO Climate tasks and targets.

The European involvement in international frameworks is summarised in Table 5 (based on the information contained in section 3) and illustrates the strong contribution of Europe at all levels (i.e. from the over-arching frameworks of UNFCCC, IPCC and GCOS through to the provision of data, and the hosting of data centres).

This strategic participation by European organisations in international frameworks is underpinned by strong, individual, contributions from European Countries. For example, a large number of national institutions are engaged in international cooperation (e.g. meteorological services, oceanographic services, modelling centres and in-situ data centres). The role of national institutions is particularly significant in the provision of in-situ data, due to the strong dependence on national infrastructures for in-situ data collection, and a significant number of the international in-situ data centres are hosted by national institutions within Europe.

In addition, comprehensive bilateral and multi-lateral arrangements exist between Europe and international partners (e.g. Initial Joint Polar System (IJPS) between NOAA and EUMETSAT, Jason, etc) resulting in the coordinated implementation of selected Satellite-based Earth Observing Systems.

Area	Framework	Section Ref.	Summary of Main European Contributions
Over-arching	UNFCCC	3.1.1	Active participation at both national level and the European Union (signatories to the Convention)
	IPCC	3.1.2	The IPCC Secretariat is located in Switzerland. Of the three Working Groups that provide inputs to the Assessment Reports, Switzerland and Germany provide the co-chairs for 2 of these Working Groups as well as the Working Group Secretariats (WGs on Physical Science Basis and the Mitigation of Climate Change). In addition, Europe provides members of all three Working Groups.
	GCOS	3.1.3	The GCOS Secretariat is located in Switzerland. Both the Director of the GCOS Secretariat and the GCOS Steering Committee Chair are from Europe (and 6 of the 16 Steering Committee members are also from Europe). European and national institutions also make significant financial contributions to support the Secretariat.
	GFCS	3.1.4	In addition to a widespread European involvement in WCC-3 which initiated the GFCS, Europe is also at the forefront in the WMO Regional Climate Centres which will be one of the main components of the GFCS - so far two pilot RCCs are under development - one in Europe and one in Asia. The European RCC is being coordinated by DWD - see section 3.2.2.3 for further details
Data Provision (including coordination)	GTOS	3.2.1.2	GTOS is supported by a number of international organisations and Italy is the main financial donor of GTOS. There is a strong European involvement in the GTOS Steering Committee
	GOOS	3.2.1.3	Individual national contributions with EuroGOOS being a regional alliance of GOOS
	JCOMM	3.2.1.4	Mainly individual national contributions
	GAW	3.2.1.5	As noted in section 3.2.1.5, the main European contribution to the GAW programme is provided by the European Monitoring and Evaluation Programme (EMEP). Also, as well as individual national observing system contributions, two of the six GAW data centres are hosted within Europe (World Data Centre for Aerosols is hosted by Norway and the World Data Centre for Remote Sensing of the Atmosphere is hosted by Germany). Although not directy linked to the GAW framework, the EC FP7-funded ICOS[19] Project provides long-term observations in order to understand the present state and predict future behaviour of the global carbon cycle and greenhouse gas emissions.
	WWW	3.2.1.6	The World Weather Watch lies at the core of WMO's programmes and is built upon national contributions to its main elements [e.g. Global Observing System (both space and in situ), Global Telecommunications System (GTS), Global Data Processing and Forecasting System……]. Europe, principally via its national meteorological and hydrological services, makes an important contribution to the WWW.
	CGMS	3.2.1.7	European space agencies play a major role in CGMS - with EUMETSAT fulfilling the permanent secretariat role of CGMS.

[19] Integrated Carbon Observation System

Area	Framework	Section Ref.	Summary of Main European Contributions
Data Provision (including coordination)	CEOS	3.2.1.8	As noted in section 3.2.1.8, Europe plays a major role in CEOS through its permanent role within the CEOS Secretariat, the provision of the CEOS Executive Officer and its active participation in the CEOS Working Groups
	WMO SP	3.2.1.9	European organisations and individual members play an active role in both WMO SP and the associated Consultative Meetings. EUMETSAT also contributes to the WMO Trust Fund that supports the WMO SP.
	SCOPE-CM	3.2.2.1	EUMETSAT serves as the SCOPE-CM Secretariat and leads 2 of the 5 pilot projects (CMA, JMA, NOAA and USGS lead the others) Europe also played a key role in the formation of SCOPE-CM.
	GSN	3.2.2.2	Individual national contributions, plus: - Germany (DWD) and Japan provide the functions for the monitoring and quality control of GSN data. - Germany (DWD) hosts and operates the GPCC (as a contribution to the WCRP)
	BSRN	3.2.2.2.4	Individual national contributions and Germany (AWI) hosts the World Radiation Monitoring Centre
	GRUAN	3.2.2.2.7	Individual national contributions and Germany (DWD) provides the Lead Centre for the GRUAN
	GUAN	3.2.2.2.8	Individual national contributions. ECMWF and the Hadley Centre (UK) provide the Monitoring Centre for the GUAN
	GBRDN/GRDC	3.2.2.2.9	Germany (BfG) hosts the GRDC
	WGMS	3.2.2.2.11	Switzerland hosts the WGMS and provides the bulk of its funding
	WMO RCCs	3.2.2.3	Europe provides one of the 2 Pilot RCCs so far identified
	Argo	3.2.2.4	Individual national contributions to the array with France providing one of the 2 Global Data Assembly Centres and hosting the Argo Information Centre
	GSICS	3.2.3.1	Europe provides 2 (of the 10) GSICS members - EUMETSAT and CNES. Europe also played a key role in the formation of GSICS.
	Standards	3.2.3.2	Europe is taking a leading role in the development of the QA4EO guidelines (through ESA and the WGCV Chair)
Climate Research	WCRP	3.3.1	Individual national contributions. Europe hosts 3 of the 5 International Project Offices (CliC: Norway; CLIVAR and SOLAS: UK). Europe (particularly France, Germany Norway and UK) is also an important contributor to THORPEX.

Table 5: European Involvement in International Frameworks

5.1.2 European Capacity

Within Europe there is a strong "political will", at the highest levels, to address climate issues. This "political will" provides a solid backdrop to exploit Europe's considerable strengths in climate, including:

a) Systematic meteorological observation networks (both in-situ and space) together with the associated long-term archives [with in-situ record lengths of over one hundred years in some cases (EUMETNET-EIG and EIONET[20]) and satellite record lengths spanning over 30 years (EUMETSAT)];

b) Long-term, operational programmes designed to ensure continuity of meteorological satellite observations (e.g. MTP, MSG, MTG, EPS and Post-EPS);

c) Extensive modelling capabilities addressing *inter alia* Earth system processes, Reanalysis and Climate Prediction and Projections. In many cases these capabilities are work-leading (e.g. ECMWF for Reanalysis);

d) The long-term commitment of EUMETSAT to generate Fundamental Climate Data Records (FCDRs) and Thematic Climate Data Records(s) at EUMETSAT's Central Facility and through its Satellite Application Facility Network to support climate monitoring, as reflected in a EUMETSAT Council Resolution - see [RD.9];

e) The research and development investment by ESA, and national space agencies, in observing systems (which in some cases are the forerunners of operational missions);

f) The ESA Climate Change Initiative - with the first phase focussing on the generation of 11 space-related ECVs;

g) Specific, diverse, expertise (e.g. polar monitoring, coastal seas and storms, energy technologies, cloud assessment…) that complement general capabilities.

h) The commitment of the European Community to address climate issues through the use of the Research Funding. This is consistent with the Europe 20:20 strategy which focuses on knowledge and innovation (with more investment in Research and Development).

5.2 Gaps, Challenges and Opportunities

5.2.1 Sustained Framework for Climate Activities

As noted in section 3.1.4, the 3rd World Climate Conference has embarked on a process to establish a systematic framework for climate services.

Implicit in this approach, which is also evident as a general trend within European meteorological services, is the need to put climate activities on a more sustainable, long-term footing that is based on commitments (rather than "best efforts").

Although Europe has extensive, and in some cases world-leading, capabilities that are well-integrated within the key international frameworks, the overall contribution could be strengthened by the targeting of some specific activities with secure, long-term, funding.

During the workshop[21] discussions, it was debated as to whether there was a need to introduce a sustained framework to cover such activities and it was concluded that such a framework should only be introduced if it:

a) adds value;
b) is compatible with existing frameworks.

[20] In the strict sense EIONET is not yet related to meteorological observation networks and some parameters collected via EIONET are not strictly meteorological (e.g.GHG emissions, Air quality, Water Quality and quantity,…).
[21] EUGENE Climate Experts Workshop 26-27 April held at the EUMETSAT Headquarters in Darmstadt

Concerning a) it was noted that the factors affecting "added value" could typically include:

i) the degree to which the framework targets activities that require strengthening e.g.:

- o the essential role of in-situ data networks in the generation of ECVs and the need to address:
  - data availability from the GCOS Surface and Upper-Air Observing Networks in Eastern and Central Europe and North Africa - see section 5.2.2.1.1;
  - sparseness of ocean data - see section 5.2.2.1.1;
  - sustainability - see section 5.2.2.1.2;
- o creation of long time-series CDRs - Data Rescue and Homogenisation - see section 5.2.2.2;
- o unfulfilled requirements for CDRs - see section 5.2.2.3;
- o construction of long time-series of ECVs based on satellite data (TCDRs) - see section 5.2.2.4;
- o creation of metadata - see section 5.2.2.5;
- o access to data - see section 5.2.2.6;
- o assimilation and reanalysis - see section 5.2.3.1.

ii) the degree to which the framework results in formal commitments (rather than "best efforts");
iii) the adherence of the related activities with the relevant standards (e.g. GCOS Climate Monitoring Principles - see Appendix D).

Concerning b) it was noted that such a framework would need to complement, and be compatible with, other relevant frameworks such as:

i) the Global Framework for Climate Services (see section 3.1.4);
ii) EU, ESA and EUMETSAT programmes and initiatives, e.g.:
  - the operational programmes implemented by the meteorological community (including the EUMETSAT SAF Network);
  - the ESA Climate Change Initiative;
iii) National programmes and initiatives.

It was also noted that, if such a framework was felt to be advantageous, a future GMES Climate Core Service could be a potential candidate.

5.2.2 Data Issues

Based on the information contained in the questionnaires and issues noted in [RD.12], [RD.13], [RD.14] and [RD.15] issues have been identified in the following areas.

- In-situ networks;
- Creation of long time-series CDRs - Data Rescue and Homogenisation;
- Unfulfilled Requirements for CDRs;
- Construction of long time-series of ECVs based on satellite data (TCDRs);
- Creation of Metadata;
- Access to In-situ Data.

5.2.2.1 In-situ networks

Most in situ meteorological observations are implemented by European NMHSes. There is a tendency, due to budget constraints, to reduce the number of observing stations and/or a deterioriation of the network as a result of decreasing maintenance activities. Such networks generally struggle to find resources as funding agencies/programmes generally consider observational networks to be (national) infrastructure. This situation is, in turn, reflected in the often restrictive national data policies (see section 5.2.2.6) which hamper open and free access, as income from in situ data is needed for network maintenance.

The need to maintain a high quality global network of conventional observations needs to be continually emphasised. This includes, for example, the requirement for quality control and all appropriate metadata in accordance with the GCOS Climate Monitoring Principles - see Appendix C.7.3.

Two major issues have been identified with in-situ networks:

- data gaps;
- sustainability.

5.2.2.1.1 Data Gaps

As noted in [RD.12], [RD.13] and [RD.15], there is a need to:

a) improve data availability from the GCOS Surface and Upper-Air Observing Networks in Eastern and Central Europe and North Africa [in compliance with the GCOS Climate Monitoring Principles (see Appendix D)];
b) address the sparseness of data from the Oceans.

Concerning a) specific actions were identified in [RD.12] and [RD.13] and further work is required in order to improve data availability.

Concerning b) the sparseness of ocean data is a problem for both the initialisation of climate prediction models and the reconstruction of past ocean behaviour (as part of the climate record). Also, as the oceans control the rate of climate change there is a need to get more out of the sparse observations using modelling and assimilation methods and through the bias correction of older data.

Also, as noted in [RD.4], there is a need for better information about methane concentrations, in general, in order to improve our understanding of the carbon cycle.

5.2.2.1.2 Sustainability

Concerning the oceanic domain, at a global level, [RD.15] notes "most *in situ* observing activities continue to be carried out under research agency support and on research programme time limits. A particular concern is the fragility of the financial arrangements that support most of the present effort; there has been very limited progress in the establishment of national ocean or climate institutions tasked with sustaining a climate-quality ocean observing system. Thus, the primary Agents for Implementation for ocean observations and analyses remain the national and regional research organisations, with their project-time-scale focus and emphasis on principal investigator-driven activities."

Also, the ice-free upper 1500 metres of the ocean are now being observed systematically for temperature and salinity for the first time in history, because both the Argo profiling float and surface drifting buoy arrays have reached global coverage at their target numbers. This data is critical for decadal prediction.

In contrast, the number of Volunteer Observing Ships reporting marine meteorological observations has declined.

Although not an in-situ issue, there is also a need to ensure the continuity of the Jason series in addition to the planned GMES altimeter missions (to ensure the continued availability of high-accuracy sea level data).

Therefore there is a need to strengthen these valuable in-situ networks and put these predominantly R&D-funded networks on a more sustained footing.

In terms of funding, it is noteworthy that the developed countries at COP-15 committed to "*provide to new and additional resources, including forestry and investments through international institutions, approaching USD 30 billion for the period 2010–2012 with balanced allocation between adaptation and mitigation*".

5.2.2.2 Creation of long time-series CDRs - Data Rescue and Homogenisation

Long time-series CDRs are very valuable for climate applications and the creation of such CDRs sometimes requires the rescue and homogenisation of long-term analogue data records.

The rescue and homogenisation of data requires significant resources and, as noted in [RD.15], there is a need to prioritise which datasets should be rescued first in order to fill record gaps in space and time quickly.

There are a number of initiatives underway addressing data rescue and homogenisation (e.g. RA VI initiative MEDARE[22] and the ACRE project).

However, as noted in Appendix C.10.3, more remains to be done in this area.

*Europe has taken an active role in a related GEO task, with ESA, France, Italy and Germany contributing to **DA-09-01c**: Long Term Preservation of Earth Observation Data.*

5.2.2.3 Unfulfilled Requirements for CDRs

Climate modelling centres, in their questionnaire responses, have identified the need for some additional CDRs (see Appendix C).

Also, apart from CDRs that are directly correlated to the GCOS ECVs, there are other areas that need climate information such as: solar energy consultancy; reinsurance industry; airline industry; etc.

5.2.2.4 Construction of long time-series of ECVs based on satellite data (TCDRs)

As noted in the responses from climate modelling centres (see Appendix C) the construction of consistent, long time-series of stable, good quality, inter-calibrated satellite-based ECVs remains a major challenge.

The mechanisms of SCOPE-CM, the SAF Network and the ESA CCI could be further used to foster the generation of consistent, high-quality data products across the different ECVs.

5.2.2.5 Creation of Metadata

In order to ensure that climate data can be "discovered" by the relevant applications, there is a need for the relevant entities to provide metadata describing the outputs of the data production and processing chains (applies to both satellite and in-situ data).

The WMO Information System (WIS) addresses (*inter alia*) the need for coherent metadata standards, the creation of metadata and the data delivery mechanism. Increased emphasis could be placed on WIS as a mechanism to address the problem of the creation of coherent metadata (and data discovery).

WIS is addressed under GEO WP Task AR-09-02b.

5.2.2.6 Access to In-Situ Data

Homogeneous access to climate-related in-situ data is currently not possible - mainly due to restrictive national data policies.

[22] MEDARE is a WMO initiative, coordinated by the University of Tarragona, focussing on DARE activities in the Mediterranean (Southern Europe, Middle East, North Africa) countries

For example, DWD collect monthly precipitation data from around the globe (see section 3.2.2.2.3) but are not allowed to redistribute it because of national data policy constraints.

There are similar constraints associated with the data holdings of the European Climate Support Network (a EUMETNET-EIG programme - see Appendix B.1.2). EUMETNET-EIG is in the process of developing a data policy to address this issue.

This important issue is being addressed by the EC (e.g. the INSPIRE Directive) and by GEO (through the implementation of the Data Sharing Principles - see GEO Task DA-06-01 and section 5.2.4) and further work is necessary in order to realise the objective of homogeneous access to data (on data policy, data infrastructure and maintenance of the datasets).

5.2.3 Modelling Issues

5.2.3.1 Reanalysis

Reanalysis enhances the value of historical observations for climate applications. Within Europe, this important activity is currently carried out on a project basis and is not covered by sustained funding.

As noted in [RD.15] this lack of sustained long-term funding inhibits coordination between centres over their production schedules for new reanalyses. All reanalyses need to have evaluation teams (e.g. to document the products and their quality) and in order to maintain technical competence between reanalysis cycles and to ensure the regular implementation of reanalysis, the funding of reanalysis activities should be put on a sustained footing.

Also, each centre's reanalysis cycle should ideally be timed to follow on from others so as to aid progressive improvement in both observational databases and data assimilation systems.

5.2.4 Building GEOSS

Once in place, GEOSS will provide many advantages to Earth observation data users (particularly in the areas of data discovery and data access).

In order to build GEOSS, and realise these advantages, a number of key "cross-cutting" tasks have been defined by GEO, which are aimed at:

a) Establishing the GEOSS Common Infrastructure (GCI):
   - AR-09-01a: Enabling Deployment of a GEOSS Architecture;
   - AR-09-01b: GEOSS Architecture Implementation Pilot;
   - AR-09-01c: GEOSS Best Practices Registry;
   - AR-09-01d: Ontology and Taxonomy Development.

b) Securing the full and open exchange of data, metadata, and products shared within GEOSS:
   - DA-06-01: GEOSS Data Sharing Principles

Concerning a), the GCI consists of three main building blocks: i) GEO web portal(s) ii) Clearinghouse(s) and iii) Registries. The GEO web portal(s) provide user access to information and services related to the nine societal benefit areas. Clearinghouse(s) provide facilities to search for data, information and services. Registries contain information about GEOSS components and associated standards and best practices.

In order to realise the GCI, a number of activities are currently underway, addressing (i.a.):

- interoperability issues;
- the population of the GEOSS Registries (component systems, services, resources, etc);
- integration issues.

Concerning b), in order to ensure that the GCI can meet the information needs of users, GEO has attached a very high importance to the full and open exchange of data, metadata and products shared within GEOSS (this has been a prominent discussion topic at all recent GEO Plenaries).

In terms of the involvement of the Climate community in these cross-cutting (non-SBA specific) tasks that are central to the realisation of the GEOSS vision, it is noted that:

i) Although the Global Climate Observing System is acknowledged to be the climate component of GEOSS, the owners of the constituent elements of this system (e.g. networks and data centres) have been somewhat reticent to register their contributions within the GEOSS component registry. In order to make this contribution to GEOSS more visible and effective, it is suggested that the GCOS programme facilitates the registration of the corresponding networks and data centres by their respective owners;

ii) The problems of access to in-situ data are highlighted in section 5.2.2.6 and the momentum behind the GEOSS Data Sharing Principles could be exploited/leveraged to make progress on this in-situ issue.

5.3 GEO Context

The following sections summarise how Europe contributes to climate tasks within the GEO Work Plan, and to the GEO targets {as described in [RD.7] and [RD.8]}. It should be noted that a lot of climate activities (particularly national) are conducted outside the framework of GEO, and hence do not explicitly appear in section 5.3.2. In addition, some countries make direct contributions to GCOS via the Voluntary Contribution programme (which also is not evident from section 5.3.2).

5.3.1 GEO Climate Target (*verbatim*)

The GEO climate target is given within the bordered text below and is strongly correlated with the successful implementation of the GCOS Implementation Plan - [RD.2] - and the better understanding of the global carbon cycle.

Before 2015, GEO aims to:

> ***Achieve effective and sustained operation of the global climate observing system and reliable delivery of climate information of a quality needed for predicting, mitigating and adapting to climate variability and change, including for better understanding of the global carbon cycle.***

This will be achieved through:

- the full implementation of the WMO-IOC-UNEP-ICSU Global Climate Observing System (GCOS) as the climate observing component of GEOSS, *and especially through strong support for the climate-relevant functions and activities of:*
  - the IOC-WMO-UNEP-ICSU Global Ocean Observing System (GOOS);
  - the FAO-WMO-UNESCO-UNEP-ICSU Global Terrestrial Observing System (GTOS);
  - the WMO Global Observing System (GOS) and Global Atmosphere Watch (GAW);
  - the research observing systems and observing systems research of the WMO-IOC-ICSU World Climate Research Programme (WCRP) and other climate-relevant international programs;
  - CEOS, as coordinator of the satellite components of GCOS;

and their enhancement and supplementation as necessary, including closure of critical gaps, to ensure the availability of all the climate and climate-related observations needed to support GEOSS;

- promotion of data sharing as well as coordination of data management and exchange systems;
- contributions to major advances in the monitoring and prediction of climate on seasonal, interannual and decadal time scales, including the occurrence of extreme events;
- strengthened GCOS support for the assessment role of the IPCC and the policy development role of the UNFCCC;
- enhanced efforts for data rescue and digitization.

This will be demonstrated by:

- Improved scientific understanding, modelling and prediction of climate.
- Accessibility of all the observational data needed for climate monitoring and services in support of adaptation to climate variability and change.
- Development and facilitation of a comprehensive (atmosphere, ocean, land) global carbon observation and analysis system in support of monitoring based decision-making and related environmental treaty obligations.
- Availability of all Essential Climate Variables needed by the WCRP, the IPCC and the UNFCCC.

5.3.2 GEO Work Plan Tasks

The GEO Work Plan, which covers a two-year period, is regularly updated with the aim of achieving the progressive implementation of the GEO 10-year Targets (including the GEO 10-year climate target noted in section 5.3.1).

The following table illustrates how Europe contributes to the current climate-related GEO Work Plan tasks.

GEO WP Task	Lead	European Contributors
AR-09-03a: Global Terrestrial Observations	FAO	EEA, ESA, JRC, Germany, Italy, Portugal, Switzerland, UK
AR-09-03c: Global Ocean Observation System	GOOS, IEEE, IOC	EC (HYPOX, EuroSITES), Germany, Greece, Norway, Spain
CL-06-01a: Sustained Reprocessing and Reanalysis of Climate Data	WOAP, NOAA, ESA, GCOS, NOAA	ESA, EUMETSAT, ECMWF, Germany, JRC, Norway, Portugal
CL-06-01b: Extending the Record of Climate Variability at Global Scale	IGBP	Greece, Norway
CL-09-02b: Key Climate Data from Satellite Systems	CEOS, ESA, GCOS, NASA, NOAA, WMO	Cyprus, France, Germany, Italy, Netherlands, Norway, Portugal
CL-09-03a: Integrated Global Carbon Observation (IGCO)	Australia, France, Netherlands, US, WMO	ESA, EC (HYPOX, EuroSITES, GEOmon), France, Germany, Italy, Netherlands, Norway, UK
CL-09-03b: Forest Carbon Tracking	Australia, Canada, CEOS, FAO, Japan, Norway	CEOS (ESA, Germany and Italy), JRC, Italy, Netherlands, Norway, Spain, UK
CL-09-03c: Global Monitoring of Greenhouse Gases from Space	Japan, CEOS, ESA, US	ECMWF, ESA, EUMETSAT, EC (COCOS), France, Germany, Netherlands, Norway, Portugal, Spain
DA-09-01a: GEOSS Quality Assurance Strategy	CEOS, IEEE	CEOS (UK and ESA), EC (HYPOX), Germany
DA-09-01c: Long Term Preservation of Earth Observation Data	ESA, Canada, France, Germany Italy	ESA, Italy

Table 6: European Contributions to GEO Work Plan Tasks

6 CONCLUSIONS

Following an in-depth review of European climate activities, undertaken by experts at the EUGENE Climate Workshop, the following general conclusions are drawn:

i) Europe has extensive and, in some cases, world-leading capabilities that are well integrated, at all levels, within the relevant international frameworks;

ii) The scope and degree of Europe's contribution to such international frameworks is prominent. This involvement embraces over-arching frameworks (such as the UNFCCC, IPCC, GCOS, etc) as well as data provision frameworks;

iii) This high level of European capability, combined with excellent integration within international frameworks, provides a strong platform to respond to the "political will" within Europe to address climate issues;

iv) In the GEO context, Europe's contribution to the fulfilment of the 10-year climate target (and the associated Work Plan Tasks) is comprehensive, and includes both National and European-level activities;

v) Some specific opportunities are identified in section 5.2 (e.g. strengthening of in-situ networks, improving climate data records, facilitating data access, regular reanalysis cycles, registering of climate observing system components within the GEOSS Common Infrastructure, etc) that could benefit from targeted actions to further enhance Europe's contribution to the GEO Climate Societal Benefit Area.

APPENDIX A SUMMARY OF EUROPEAN SPACE CONTRIBUTIONS TO ESSENTIAL CLIMATE VARIABLES

Domain	Essential Climate Variable (Contribution from Space)	Fundamental Climate Data Record	European Availability of Data	Lead EU Institutions	Contributing EU Institutions	GMES, ESA, EUMETSAT 'projects' (global, *limited area)*	Use of non-EU datasets	Contribution to International Initiatives - (GCOS/GEO in each)	Funding horizon commitment (20 years) - green, yellow, red, 2yr/cell										
									09-10	11-12	13-14	15-16	17-18	19-20	21-22	23-24	25-26	27-28
Atmospheric	*Precipitation*	Passive microwave radiances, High frequency geostationary IR, Active radar (for calibration)	AMSU-A, MHS, Meteosat	EUMETSAT	ECMWF	*CM SAF, Euro4M (EU area)*	SSM/I, SSMI/S	GPCP											
	Earth Radition Budget	Broadband radiances, Spectrally resolved solar irradiances, Geostationary multi-spectral imagery	GERB(MSG &MTG), EarthCare	EUMETSAT, ESA	ECMWF	*Euro4M, CM-SAF*	CERES	WCRP											
	Upper-air Temperature	Passive microwave radiances, GPS radio occultation, High spectral resolution IR radiances for reanalayses.	HIRS, AMSU, MHS, IASI, SSU, GRAS	EUMETSAT	ECMWF	*Euro4M, CM-SAF, GRAS-SAF*	AIRS, HIRS, AMSV												
	Upper-air Wind	VIS/IR imagery, Doppler wind lidar	METEOSAT, AVHRR, [*ADM*]	EUMETSAT/ESA	ECMWF	*Euro4M*	GOES, MTSAT	CGMS IWWS											
	Surface Wind Speed and Direction	Passive microwave radiances and scatterometry	ERS-1/2 SCAT, ASCAT	EUMETSAT/ESA	KNMI, ECMWF	*Euro4M, OSI SAF, Monarch-A*	SEAWINDS	NOAA ?											
	Water Vapour	Passive microwave radiances, UV/VIS Radiances, IR imagery/soundings in 6.7um band, Microwave soundings in 183 GHz band	HIRS, MHS, IASI, MERIS , GRAS, ATSR, GOME	EUMETSAT/ESA	ECMWF	MACC, *Euro4M, CM SAF*	SSM/I, AIRS, HIRS, AMSV-B												
	Cloud Properties	VIS/IR imagery, IR and microwave sundings	METEOSAT, ATSR, AVHRR, Meris [*Sentinel-3: OLCI, SLSTR*] ; Earthcasre	EUMETSAT/ESA	ECMWF	*Euro4M, CM SAF*	AVHRR, GOES, MTSAT	ISCCP											
	Carbon Dioxide	NIR/IR radiances	SCIAMACHY, IASI, Sentinel-5	ESA, EUMETSAT	ESRON, U BREMEN, LMD/CNRS, ECMWF	MACC, Carbones, *Monarch-A (arctic)*	AIRS, GOSAT												
	Methane	NIR/IR radiances	SCIAMACHY, IASI Sentinel-5 precursor, Sentinel-5	ESA, EUMETSAT	ESRON, BREMEN, LMD/CNRS, ECMWF	MACC	GOSAT												
	Other GHGs	NIR/IR radiances	IASI, Sentinel-5	ESA, EUMETSAT	ECMWF	MACC													
	Ozone (tropospheric)	UV/VIS radiances, IR/Microwave radiances	GOME-1, SCIAMACHY, GOME-2, OMI, IASI	ESA/NIVR/EUMETSAT	ECMWF	MACC, O3M-SAF													
	Ozone (stratospheric)	UV/VIS radiances, IR/Microwave radiances	GOME-1, MIPAS, GOMOS, SCIAMACHY, OMI, IASI	ESA/EUMETSAT	ECMWF	MACC, O3M-SAF													
	Aerosol Properties	VIS/NIR /SWIR radiances	SCIAMACHY, AATSR, ATSR-2, MERIS, POLDER, PARASOL, MSG, Sentinel-3 SLSTR, OLCI, Earthcare	ESA, CNES	ECMWF	MACC	AVHRR,SAGE, TOMS, MODIS, MISR												
Oceanic	*Sea-Surface Temperature*	Single & multi-view IR and microwave imagery	ATSR-1, ATSR-2, AATSR, Sentinel-3 SLSTR, MSG, METOP	ESA, EUMETSAT	EEA,IFREMER, Met Office Hadley Centre	MyOcean, *OSI SAF, Euro4M, Monarch-A*	AVHRR, AMSR-E, TRMM-TMI, GOES,	WMO, GEO, JCOMM												
	Sea Level	Altimetry	ERS/ENVISAT altimeter. Cryosat. Sentinel-3, JASON-2	ESA/CNES, EUMETSAT, EC	CLS	MyOcean, *Monarch-A*	ERS/ENVISAT Altimeter, GOCE	Wide ranging											
	Sea Ice	Passive Microwave imagery (DMSP, AMSRE), SAR, TIR & VIS imagery	ERS/ENVISAT SAR, Cryosat2, RA, ASCAT, ERS-scat, MERIS, (A)ATSR, Sentinel-1, Sentinel-3	ESA, EUMETSAT	EUMETSAT/Met.no, ECMWF	MyOcean, *OSI SAF, Monarch-A*	AMSRE, SSM/I, SMMR, AVHRR, SeaWifs, Qscat, NSCAT	JCOMM, WMO/IMO (GMDSS Arctic and antarctic Met Area responsibility)											
	Sea State	Altimetry, scatterometer, SAR	ERS/ENVISAT SAR, Cryosat2, RA, ASCAT, ERS-scat, MERIS, (A)ATSR Sentinel-1, Sentinel-3	ESA/EUMETSAT, EC	EUMETSAT	MyOcean, *Monarch-A*	RADARSAT, AMSRE, SSM/I, Qscat, NSCAT	WMO/IMO (GMDSS Arctic and antarctic Met Area responsibility)											
	Ocean Salinity	Microwave radiances	SMOS	ESA	IFREMER, ECMWF	MyOcean	Aquarius	Potentially many but immature at present.											
	Ocean Colour (IOP + Chl_a)	Multispectral VIS imagery	MERIS, Sentinel-3 OLCI	ESA, EC	JRC, PML, CNR, DLR	MyOcean, *Monarch-A*	SeaWiFS, MODIS	CEOS Virtual Constellation											
Terrestrial	*Snow Cover (Extent, Snow Water Equivalent)*	VIS/NIR/IR and passive microwave optical imagery	MSG. Envisat ASAR, Sentinel-1, Sentinel-3 OLCI	ESA	EUMETSAT	*Euro4M, Land SAF, ECMWF*	AVHRR												
	Glaciers and Ice Caps	VIS/NIR/SWIR optical imagery, Altimetry	ERS ENVISAT SAR, SPOT, Sentinel-1, Sentinel-2, ERS, ENVISAT Altimeter, Sentinel-3 RA	ESA		*Monarch-A (Arctic >65°N)*													
	Permafrost and seasonally -frozen ground					*Monarch-A*													
	River Discharge	Altimetry				*Monarch-A*													
	Lake levels	VIS/NIR imagery radar imagery, Altimetry, IR imagery	ERS/ENVISAT/Sentinel-3 RAs,	ESA		*Geoland2 (Africa)*													
	Albedo	Multispectral and broadband imagery	MSG, Meris, ATSR2, AATSR, Sentinel-3 OLCI	ESA, EUMETSAT		Geoland2, *Land SAF, ECMWF*	AVHRR												
	Land Cover	multispectral VIS/NIR imagery	MERIS, SPOT, Sentinel-2, Sentinel-3 OLCI, ATSR-2,AATSR,SLSTR, Sentinel-1,	ESA, CNES		*Geoland2*													
	fAPAR	VIS/NIR imagery	MERIS (300m-1.1km) , SEVIRI, VEGETATION, ATSR-2-AATSR-SLSTR,OLCI	ESA	JRC, EUMETSAT, VITO	Geoland2, *Land SAF*	SeaWiFS	GEO RE-analysis (Task ****)											
	Leaf Area Index	VIS/NIR imagery	MSG, Vegetation, , Meris, ATSR-2-AATSR-SLSTR, OLCI	ESA/EUMETSAT		Geoland2, *Land SAF, ECMWF*													
	Biomass	L Band / P Band SAR, Laser altimetry	[BIOMASS explorer: Phase-A study]	ESA															
	Fire Disturbance	VIS/NIR/SWIR/TIR multispectral imagery	MSG, ATSR-2, AATSR, MERIS, OLCI	ESA, EUMETSAT		Geoland2, *Land SAF, Monarch-A, ECMWF*													
	Soil Moisture (surface and root zone)	Active and Passive microwave (Scatterometer and SMOS)	ERS Scatt, ASCAT, ASAR, Sentinel-1	ESA, EUMETSAT	EUMETSAT/ECMWF, ECMWF, H-SAF, Univ Vienna	Geoland2	Scatterometer and Aquarius												

APPENDIX B IN-SITU QUESTIONNAIRE RESPONSES

B.1 EUMETNET-EIG

B.1.1 Strengths

The EUMETNET-EIG response is constructed from the viewpoint of the European Climate Support Network (ECSN) - a EUMETNET-EIG programme.

The activities associated with this programme are (implicitly) presented as the main strength of EUMETNET-EIG in the climate arena.

The objective of the ECSN is to support its 25 members in their climate practices in order to better serve the European user community with climate products and services for the benefit of environment, safety, economy and health.

ECSN see their role as: "*Liable and acknowledged providers of sustainable high quality and climate reference services, tailored to the users needs, thereby acting as interface between research and users and bridging the national to the European scope. We exploit our most important skill; the production of high quality observational climate data sets to be used for climate monitoring and modelling."*

The main features of the ECSN are:

- coordination framework covering a range of related projects that are connected to the overall ECSN objective;
- coordination and cooperation with EEA, ESA, WMO, ECMWF and EUCOS;
- participation is generally drawn from the climate services area of NMHSes;
- operational access is provided to in-situ data sets [daily quality-controlled time series of temperature, precipitation, air pressure, snow depth, relative humidity, cloud cover and sunshine duration from a network of more than 3000 stations (Europe Climate Assessment and Dataset (ECA&D)].

B.1.2 Challenges

The greatest challenge is that heterogeneous national data policies hamper uniform access to the observational datasets. Next a large number of (manual) precipitation stations cannot deliver “on line” data sets.

These challenges are tackled on a threefold approach: 1: by developing an appropriate common (EUMETNET-EIG) data (access) policy, 2: by redesigning the (terms of references of) observational in-situ network 3: by running and implementing projects that provide improved data access (ECA&D, EUMETGRID, EURO4M, etc.).

Recently a Working Group on Climate Change Services has been established that will make recommendations to EUMETNET-EIG about the role of the European NMHSes (EUMETNET-EIG and WMO-RAVI) in these services.

B.1.3 Main Partners

EUMETNET-EIG members (23) and ECA&D partners (53) as providers and as users EEA, EU (GMES), Research Community, and commercial users as Reassurance Companies.

B.1.4 Evolution in Centre's Climate Role

The climate data activities of ECSN, as embedded in ECA&D, will serve as baseline platform for the WMO-RAVI (~Europe) Regional Climate Centre on Data.

B.1.5 Centre's role in the maintenance of Climate Data Records (CDRs)

Within the framework of ECSN, there is a long-term ("*permanent*") commitment to the maintenance of European surface records of:

- Air Temperature;
- Precipitation;
- Air Pressure;
- Snow Depth;
- Sunshine Duration;
- Relative Air Humidity;
- Cloud Cover Ratio.

B.1.6 Information that is passed to other Centres

Data series, indices series, assessments (graphs, maps, texts) are made publicly available.

B.2 EEA

B.2.1 Strengths

EEA and the EIONET[23] (European Environment Information and Observation Network) are monitoring, holding and providing environmental information according to the reporting obligations of the EU (e.g., greenhouse gas emissions, air, water quality, biodiversity[24]) and voluntary data flows as agreed with member countries (e.g., CORINE land cover data[25]). In addition EEA provides access to air and bathing water quality data to citizens through Eye on Earth[26]. Data are either freely available or restricted in access in line with the data policies of the member countries. Furthermore EEA publishes indicators and assessment on many themes, including e.g. on biodiversity[27] and on climate change impacts, vulnerability and adaptation.[28]

B.2.2 Challenges

There is a need for enhanced monitoring, data collection and exchange and reducing uncertainties in projections, to improve climate change impacts, vulnerability and adaptation assessments. Especially in the key environmental areas of freshwater, marine and terrestrial biodiversity/ecosystems and land use/soil, there is a need for long-term data series (e.g. decades) to allow for trend analysis and extreme value analysis as well as a need for a higher spatial resolution.

The key information needs for climate change impacts, vulnerability and adaptation assessments are appropriate:

- geographical coverage (the impacts of climate change transcend the boundaries of individual countries, thus there is a need for alternative analysis units such as catchments, sea basins, bio-geographic regions),
- record length (allowing for the detection of significant trends/changes in the environment)
- consistency:
    - in time (homogeneity considerations, to allow for comparability of information)
    - in space (e.g. in the analysis across national boundaries to allow for pan-European comparability of assessments)
    - between variables/indicators (also for non-physical and non-chemical variables such as socio-economic variables)
- spatio-temporal resolution, (e.g. regional reanalysis)
- quality (fit-for-purpose)
- transparent format of data and accessible and available to stakeholders/users

EEA furthermore manages a project for the coordination of the in-situ component of GMES (GISC) which has started end of 2009.

[23] http://eea.europa.eu; http://www.eionet.europa.eu/;
[24] http://dataservice.eea.europa.eu/dataservice/; http://www.eea.europa.eu/themes/climate/data-viewers; http://www.eea.europa.eu/themes/air/airbase; http://www.water.europa.eu/; http://www.eea.europa.eu/themes/biodiversity/eea-activities
[25] http://www.eea.europa.eu/publications/COR0-landcover
[26] http://www.eea.europa.eu/data-and-maps/explore-interactive-maps/eye-on-earth
[27] http://www.eea.europa.eu/themes/biodiversity
[28] http://www.eea.europa.eu/themes/climate;

B.2.3 Main Partners

The main clients and partners are the EEA member countries[29] and European institutions (in particular the European Commission's DG Environment; DG Climate action and DG Joint Research Centre). Furthermore EEA cooperates with a number of relevant European organisations including ECMWF, EUMETNET-EIG, UNECE, OECD, WHO and also with various research organisations involved with EU FP7 projects.

B.2.4 Evolution in Centre's Climate Role

See the EEA 5-year strategy for the general strategic development for the period 2009-2013[30].

On climate change impacts, vulnerability and adaptation the main objectives for 2009-2013 are:

- To contribute directly to EU policy developments on climate change impacts by refining relevant indicators[31], producing assessments, combined with socio-economic factors in Europe, using past trends, now-casting, spatial analysis, forward looking assessments, and policy effectiveness analysis including economic aspects.

- To support new EU and European Policy developments on vulnerability and adaptation and on disaster prevention and management by developing online access to relevant environmental information, observations for rapid spatial mapping and decision support tools, via SEIS and GMES services to help Member States' meet their objectives for dealing with climate change impacts, adaptation, vulnerability mapping, disaster prevention and management.

The Commission White Paper and accompanying Impact Assessment[32] underlined that information on climate change impacts and vulnerability and on the costs and benefits of adaptation measures in Europe remains scarce and fragmented and that more spatially detailed information is needed to develop adequate adaptation strategies. The Commission called therefore for a European Climate Change Impacts, Vulnerability and Adaptation Clearinghouse (CH) to be established by 2011. The CH will provide access to European climate change data and scenarios; information on climate change impacts and vulnerability, national and regional strategies, actions and measures and good practices, including economic costs. It will be an information system providing access to geospatial information and knowledge service, from multiple sources, for the development of adaptation policies, and a partnership between users and data providers for its development. EEA is much involved in the development of the CH and expects to host and maintain the CH after 2011.

B.2.5 Centre's role in the maintenance of Climate Data Records (CDRs)

The following data is collected from data providers:

- Ozone data from 700 air quality stations across Europe. Timestep: hourly (operational data), accuracy: 20 µg/m3;
- River discharge data from discharge measurements (planned activity in the frame of WISE)[33] ;
- Water Use - Water Exploitation Index - WEI (%); water abstraction for irrigation, public water supply, manufacturing industry and energy cooling (mio. m3 per year)[34]:

[29] http://www.eea.europa.eu/about-us/countries-and-eionet
[30] http://www.eea.europa.eu/publications/eea-strategy-2009852013-multi-annual-work-programme
[31] http://www.eea.europa.eu/publications/eea_report_2008_4;
http://www.eea.europa.eu/themes/climate/indicators
[32] http://ec.europa.eu/environment/climat/adaptation/index_en.htm
[33] Data collected under the Water Framework Directive along the line of the WISE data policies and the provisions of the INSPIRE initiative. http://www.water.europa.eu/en/welcome

- Land cover - Corine Land-cover map 1990 / 2000 / 2006 (Europe) to be operational as part of GMES land service from 2011 onwards[35]

It is also noted that other, possible relevant, data is maintained by EEA:

- AirBase air quality monitoring data submitted to EEA/Commission (SO2, TSP, PM10, PM2.5, black smoke, O3, NO2, NOx, CO, Pb, Hg, Cd, Ni, As, Benzene) under Council Decision 97/101/EC http://www.eea.europa.eu/themes/air/airbase;
- Greenhouse gas emission/removal data, submitted to EEA/Commission under UNFCCC and the EU Council Decision 280/2004/EC (CO_2, CH_4, N_2O, HFCs, PFCs, SF6) http://dataservice.eea.europa.eu/pivotapp/pivot.aspx?pivotid=475

B.2.6 Information that is passed to other Centres

Information is provided via a combination of web portals, internet (limited access) and EEA Reports to EIONET members and the general public.

[34] Data collected under the Water Framework Directive along the line of the WISE data policies and the provisions of the INSPIRE initiative.http://www.water.europa.eu/en/welcome
[35] Data processed as voluntary contribution of the EU and EEA member states (EIONET)

B.3 EUROGOOS

The EuroGOOS questionnaire was forwarded (by EuroGOOS) to the National Oceanography Centre, UK who provided a partial response (Excel sheet only) - a summary of this response is provided in section 4.1.1.2.2.3.

APPENDIX C CLIMATE MODELLING QUESTIONNAIRE RESPONSES

C.1 AWI

C.1.1 Main Contributions

Climate Research - studies in the Climate Science department of the Alfred Wegener Institute for Polar and Marine Research (AWI) focus on the coupled ocean-ice-atmosphere system and its importance for the global climate. AWI researchers conduct field measurements and numerical simulations related to oceanic circulation, transport of substances and energy in polar seas and the polar atmosphere, as well as related to the influence of these processes on the global climate system. Oceanographic studies concentrate on the modification of water masses in the Weddell and North Polar Seas and on the spreading of deep and bottom waters into the world ocean. Atmospheric studies focus on the investigation of climate relevant processes on different scales in space and time. In addition, variations in the concentration of climate-forcing trace gases and aerosols and their impact on the Earth's radiation balance are investigated. Although most studies are regionally confined, collaboration with scientists around the globe under the umbrella of international programmes, e.g. the International Polar Year, allows interpreting our results in a global context.

A more recent focus lies on the analysis of long-term climate oscillations as well as their interpretation with the aid of numerical models. Analysis of palaeoclimate variations shall broaden our view on the climate system and restructure our approach, in order to obtain a more complex theory on climate.

Climate Prediction - currently, climate prediction is only a small part of the research activities. Over the next four years more activities will focus on predictability in coupled regional climate (earth system) models.

Predictive capabilities are currently being developed on the basis of optimised coupled regional climate and earth system models, especially for polar regions. This optimisation is based on specific observations of important processes.

Climate Monitoring - the most important monitoring activities are the meteorological measurements at both polar stations: Neumayer Station in Antarctica and Koldewey Station in Ny-Alesund (Spitsbergen). In addition, standard meteorological measurements are take on our Research Ice Breaker Polarstern.

Monitoring of the ocean is conducted through a long-term mooring programme in Fram Strait (between Spitsbergen and Greenland), in the Lena Delta, and in the Weddell Sea (Antarctica).

Sea ice observations are performed during Polarstern expeditions and aircraft missions. Our specialty is the observation of sea ice thickness. These measurements are generally done as a process study, rather than as a monitoring activity.

C.1.2 Particular Strengths

Excellent infrastructure:

- Research Ice Breaker Polarstern (the best existing);
- Research Aircraft (Polar 5) for Arctic and Antarctic field-work;
- Research vessel (Heincke) for coastal and shelf seas;
- Two polar observatories with all-year-round operation: Neumayer (Antarctica) and Koldewey (Spitsbergen);
- Modelling infrastructure for regional and global climate modelling - this infrastructure is mostly used for regional process studies from which parameterisations are developed for regional and global coupled climate models.

C.1.3 Challenges

Climate Monitoring - ice sheet mass balance, sea ice thickness, sea level rise (approach through combined satellite and airborne measurements and modelling)

Climate Prediction - regional climate prediction and projection (approach through combined process observations, modelling and parameterisation).

Climate Research - process understanding (observations, modelling, especially in polar regions) and parameterisation of these processes in regional and global climate models.

C.1.4 Main Partners

Within the Helmholtz Climate Initiative: Regional Climate Change eight centres are involved (AWI, KIT, GKSS, GFZ, UFZ, HMGU, FZJ, DLR), in addition collaboration is planned with MPI for Meteorology, Hamburg.

Concerning polar processes, many polar research institutes in Europe, America, Russia, Japan and Australia are collaborating partners.

C.1.5 Envisaged Evolution in the Centre's Climate Role

We see our basic role in understanding the coupled climate and ecosystem in both polar regions and in the North Sea using observations and modelling studies. The focus is on the Changing Arctic and Antarctic, Coastal Change (North Sea and Laptev Sea), Lessons from the Past (paleoclimate) and the Synthesis in Coupled Earth System Models.

C.1.6 Role in the Generation of ECVs

Involved in the generation of ECVs related to the CDRs that are maintained by AWI (within the frameworks of GCOS, BSRN, NDACC and WOUDC)

C.1.7 Role in the maintenance of CDRs

Involved in the maintenance of CDRs related to atmospheric ECVs from the Arctic and Antarctic (Koldewey and Neumayer):

- Surface Air Temperature;
- Surface Air Pressure;
- Surface Radiation Budget;
- Surface Wind Speed and Direction;
- Upper Air Temperature;
- Upper Air Wind Speed and Direction;
- Upper Water Vapour;
- Ozone (tropospheric and stratospheric);
- Aerosol properties (Arctic only).

C.1.8 Information Passed to Other Centres

Nothing noted.

C.1.9 Unfulfilled Requirements for CDRs

None noted.

C.2 CNMCA

C.2.1 Main Contributions

In the field of **Climate Monitoring** the main contribution is the construction of time series of weather parameters in appropriate data-sets, developing of catalogues and meta-data collections, monthly issue of statistical analysis on conventional and non-conventional observational data, comparison with Climate Normals and updating of outliers data recorded during extreme events, co-operation in the European Climate Support Network and European Climate System Monitoring activities.

The objective is to improve and extend the set of parameters to be archived and analyzed, optimize integration of traditional observational data with numerical models and satellite products (including O3-SAF data).

In the field of **Climate Research** the main contribution are studies on simplified GFD dynamical systems for a better understanding of climate regime transitions and vacillation and identifications of a proper set of predictors; studies on statistics of extremes and return times of various variables; verification of a coupled regional climate model using a set of (observed) climate indices; application of clustering techniques to observational dataset to automatically characterize objective climate regions. Studies about teleconnections on our regions of large scale patterns of climate driving forcing, focusing on ocean-atmosphere and stratosphere-troposphere interactions.

At present there is no contribution in the field of **Climate Prediction**. Some projects are currently under development, concerning statistical and dynamical regional downscaling of global model fields, both on seasonal and decadal time scales. The objective is to set up a seasonal forecast system for our region.

C.2.2 Particular Strengths

Non-linear (neural network), EOF and wavelet techniques for analysis of data

C.2.3 Challenges

Seasonal and regional forecast, described in terms of gross projection in tercile ranges of main meteorological parameters (temperature, pressure, precipitation). This challenge should be approached by means of operating set-up of global and regional climate numerical model, massive use of re-analysis datasets and downscaling statistical techniques.

C.2.4 Main Partners

DWD, ENEA, CMCC

C.2.5 Envisaged Evolution in the Centre's Climate Role

Our Centre could have a coordination role in monitoring and analyzing climate trend over the Mediterranean Sea, together with other proper institutions

C.2.6 Role in the Generation of ECVs

The Centre is involved in the generation of the following ECVs:

- surface air temperature;
- surface precipitation;
- surface air pressure;
- surface radiation budget;
- surface wind speed and direction;
- surface water vapour;
- upper-air radiation budget;
- upper-air temperature;
- upper-air wind speed and direction;
- upper air water vapour;
- upper air cloud properties;
- CO2;
- tropospheric ozone;
- sea surface temperature;
- sea state.

C.2.7 Role in the maintenance of CDRs

The Centre is involved in the maintenance of the following regional CDRs:

- surface air temperature;
- surface precipitation;
- surface air pressure;
- surface radiation budget;
- surface wind speed and direction;
- surface water vapour;
- upper air cloud properties;
- CO2.

C.2.8 Information Passed to Other Centres

Nothing noted.

C.2.9 Unfulfilled Requirements for CDRs

None noted

C.3 DWD

C.3.1 Main Contributions

In the area of **Climate Monitoring**:

- operation of in-situ and remote sensing observation networks for atmospheric and some near surface oceanic Essential Climate Variables. Details are given in http://unfccc.int/resource/docs/gcos/deugcos.pdf;
- operation of the WMO Regional Association VI Regional Centre on Climate Monitoring (RCC-CM),
- the EUMETSAT Satellite Application Facility on Climate Monitoring (CM-SAF) and the
- Global Precipitation Climatology Centre (GPCC).

In the area of **Climate Prediction**:

- operation of a Regional Climate Model (CCLM) started recently;
- operation of High Resolution Climate Impact models in support of Urban and Spatial Planning, Agriculture, and Hydrology;
- operational assessment of ECMWF seasonal weather forecasts for Germany;
- in development phase: running our own regional climate model (CCLM) with simulation of the main atmospheric variables. Timeframe up to 2100;
- assessment of regional climate simulations for Germany analysing the results of deterministic (REMO) and statistical (STAR, WETTREG) downscaling models;
- in planning phase: research cooperation on the development of a German decadal climate forecast model

Climate Research is carried out within the activities of Climate Monitoring and Climate Prediction supporting the development of climate consultancy services contributing to climate change adaptation strategies.

C.3.2 Particular Strengths

Climate Monitoring - among the National Meteorological Services within Europe/ WMO RA VI a strong position or unique position as RCC-CM, CM-SAF and GPCC.

Climate Prediction and Research - very rapidly developing activity area, in which DWD is aiming to become one of the major European meteorological services with operational climate consultancy services for temporal scales from seasonal forecasts via decadal forecasts up to 100 years regional climate simulations.

C.3.3 Challenges

Climate Monitoring - making observing systems, operated in research mode, that demonstrated their value, sustainable, e.g. carbon fluxes, GHG monitoring – valid for both in-situ and remote sensing. User oriented climate monitoring services taking into account strengths and weaknesses of differing observing platforms. Generation of improved climate reference data sets as a basis for evaluations of the quality of climate simulations.

Climate Prediction - improvement of seasonal to decadal climate prediction models/ systems for the region of Europe as a basis for operationally applicable climate consultancy services. Improvements of high-resolution climate impact projections taking into account improved models as well improved emission and climate mitigation scenarios.

C.3.4 Main Partners

Other German ministries, agencies and Universities, like the Umweltbundesamt (UBA), MPI-M, PIK.

C.3.5 Envisaged Evolution in the Centre's Climate Role

Implementing and improving the Global Framework for Climate for Climate Services adopted by WCC-3 to deliver user oriented climate information for development planning, including adaptation. Support to monitoring, verifying and reporting mitigation activities and policies. Provide advice for decision makers.

C.3.6 Role in the Generation of ECVs

The role of DWD in the generation of ECVs is summarised in the 3rd Report of the Federal Republic of Germany on Systematic Climate Observations as a Contribution to Germany's 5th National Communication under the United Nations Framework Convention on Climate Change[36].

This role includes the generation of the following ECVs:

a) Atmospheric ECVs (surface)
- air temperature;
- precipitation;
- air pressure;
- wind speed and direction;
- water vapour;
- radiation.

b) Atmospheric ECVs (upper-air)
- air temperature;
- wind speed and direction;
- water vapour.

c) Atmospheric ECVs (composition)
- Carbon Dioxide, Methane and other GHGes;
- Ozone;
- Aerosol properties.

d) Oceanic ECVs (surface)
- Sea Surface Temperature;
- Sea Level Pressure;
- Currents;
- Sea Level.

e) Oceanic ECVs (water column)
- all feasible surface and sub-surface ECVs

[36] http://unfccc.int/resource/docs/gcos/deugcos.pdf

C.3.7 Role in the maintenance of CDRs

In addition to the stations in the global monitoring networks (GAW, GUAN, GSN), DWD operates a national observing network that regularly collects meteorological data in Germany. The data is subject to quality assurance measures and then chronologically archived in a climatological database. Most of these time series begin in the 1940s, although some date back to the 19th and 18th centuries.

Since the mid-1970s, DWD has regularly stored all meteorological data collected by its observing network on electronic media, checked the data for quality and then archived it on a routine basis. Furthermore, the data collected earlier in table form on paper or (since the 1950s) on punch cards, were registered, then archived in a standardised form on magnetic tape and later added to the climate database.

Data gathered by the Meteorological Service of the former German Democratic Republic (GDR), until 1990, has also been similarly processed (even though in some points in quite different ways) and compiled in a suitable data archive, the Standardised Meteorological Data-Storage Medium (EMDS). This data archive was integrated into the DWD climate data-base to the greatest possible extent with the work having been completed in 1992. Due to the different ways of data processing used in the old and new Federal Laender before 1990, the data sets differ in form and content.

Since 1997, new climate data has been stored within the DWD database application called MIRAKEL, which is based on a relational database system. The migration of the former data archive to the MIRAKEL database has largely been completed, with the result that the aforementioned climate data is now archived in a relational database system that greatly facilitates the use of the data.

The national observing network consists of (01.06.2009):

- 183 main meteorological watch offices and automatic weather stations, of which 50 are manned around the clock, 31 are manned part time and 102 are fully automatic weather stations;
- 34 surface weather stations run by the German Federal Armed Forces;
- 1839 voluntary weather stations carried out by non-professionals, of which 810 are automatic stations for 10-minute data (49 stations measure only wind parameter and 468 only precipitation);
- 9 upper-air stations (3 stations are auto launcher and 2 stations measure addition-ally ozone);
- 5 upper-air stations run by the German Federal Armed Forces.

DWD and the German Federal Armed Forces operate a combined network, the National Basic meteorological observing Network (NABAM). It consists of 183 main meteorological watch offices and automatic weather stations (DWD) and 19 surface weather stations operated by the German Federal Armed Forces.

The total network of DWD and the German Federal Armed Forces thus comprises:

- 525 stations measuring temperature und humidity;
- 221 stations measuring air pressure;
- 2008 stations measuring precipitation;
- 294 stations measuring wind, of which 56 are part of the storm warning network;
- 307 stations measuring sunshine duration

At more than 500 stations two or more variables are measured. In addition the Laender are running their own observing networks. Presently DWD is receiving precipitation data from about 400 stations from Bavaria, Rhineland-Palatinate, and Baden-Württemberg. It is estimated that in total the Laender could contribute about 1000 additional precipitation stations.

C.3.8 Information Passed to Other Centres

DWD also participates in other global observing networks. Its MOL-RAO is part of the BSRN (Baseline Surface Radiation Network) and thereby contributes to the global monitoring of atmospheric radiation. Furthermore, the MOL-RAO acts as a regional radiation centre of WMO RA VI in the aim of guaranteeing highest standards of atmospheric radiation measurements in WMO RA VI Europe.

The MOL-RAO actively contributes to several sub-projects of the Global Energy and Water Cycle Project (GEWEX) being part of the World Climate Research Programme of WMO. This includes participation in the Coordinated Enhanced Observation Period (CEOP), GEWEX Atmospheric Boundary Layer Studies (GABLS) and GVaP projects.

C.3.9 Unfulfilled Requirements for CDRs

None noted.

C.4 ECMWF

C.4.1 Main Contributions

Climate Monitoring - The reanalysis activities at ECMWF (ERA-15, ERA-40, ERA-Interim and the planned ERA-CLIM) all contribute to climate monitoring. We also contribute to monitoring of atmospheric composition through the MACC (former GEMS) activities connected to the GMES programme.

ECMWF will be a partner of the Climate Modelling User Group (CMUG) within the ESA Climate Change Initiative (CCI).

Strong interactions have been established between ECMWF and the Global Space Based Intercalibration System (GSICS), coordinated by NOAA. ECMWF contributes within this framework by documenting satellite data biases, with the aim of ensuring consistency of satellite measurements from different instruments and programmes, and tie these measurements to absolute references and SI standards.

Climate Prediction - ECMWF is currently not involved in climate prediction, our longest prediction time scale is seasons.

Climate Research - many ECMWF scientists have contributed with papers in the scientific literature in the field of climate modelling. Examples are physical processes in atmospheric models, medium range, monthly and seasonal prediction studies, predictability studies including ensemble prediction and numerical methods.

ECMWF have been actively involved in the EU project ENSEMBLE and its follow on THOR. We are also participating in the Athena Cray-4 initiative to run climate models at very high resolution.

The reanalysis group have contributed with results from climate monitoring, the most widely cited paper in geophysics over the last years was written by the reanalysis group at ECMWF.

These climate research activities directly contribute to climate monitoring by providing the time history of basic climate parameters. Our atmospheric modelling research directly benefits climate modelling.

C.4.2 Particular Strengths

Climate Monitoring - the use of variational bias correction in the most recent and future re-analyses makes it possible to determine climate trends despite changes in observational coverage, instrument drifts etc. ECMWF reanalyses rely on the world leading NWP assimilation and modelling system, which guarantees a higher quality product than from any other organisation. In addition the ECMWF reanalyses have a higher resolution and use larger observation data sets than many other similar reanalyses. Last but not least, ECMWF offers an unprecedented operational infrastructure, including operational and real time access to most input observations relevant to reanalyses as well as efficient feedback data archive and web service facilities that are invaluable resources to the scientific community.

Climate Research - Reanalysis, seasonal prediction and development of ensemble prediction methods.

C.4.3 Challenges

Climate Monitoring - one of the big challenges is to determine the accuracy with which 20th and early 21st century climate trends can be determined in the free atmosphere. We need to find historical observations hidden in various archives across the world and to assess how reanalysis techniques can be used to extract maximum information from the scarce observations. For future climate monitoring satellite data will dominate, a major challenge is to extract aerosol and other constituent information from visible and infrared radiances as well as lidar and radar information.

A second challenge will be to design the level of coupling between the atmosphere, land and ocean in future reanalyses to ensure an even better consistency between all ECVs.

Climate Prediction - to assess probability distributions of regional climate change, in particular to understand better how atmospheric modes of variability may be affected by global climate change. Most likely this will require high-resolution climate models, both of the atmosphere, the ocean and the land surface. A substantial increase in computing capacity is thus a necessary requirement.

Reanalysis data sets will be vital to assess the capabilities of future very high-resolution climate models. The reanalyses also need to be extended into the oceans through coupled ocean-atmosphere reanalyses. This will allow a more extensive verification of ocean model simulations. Such verifications are vital for the credibility of ocean climate predictions.

Climate Research - in addition to the areas listed under climate prediction:

- sensitivity of the climate system to greenhouse gas and aerosol forcing changes, in particular related to feedbacks involving cloud and water vapour;
- understanding of interactions between sea-ice, cloud and circulation changes in the Arctic and Antarctic regions.

C.4.4 Main Partners

Climate Monitoring - ESA, EUMETSAT, and the Met Office, the ERA-CLIM consortium at large, GSICS, NOAA, NASA, NCAR and JMA (as well as other reanalysis producers).

Climate Prediction - EC-Earth Consortium

Climate Research - Participation in EU framework programmes, EC-Earth.

C.4.5 Envisaged Evolution in the Centre's Climate Role

Climate Monitoring - ECMWF plans to extend and enhance the reanalysis activities. During the coming years we intend to expand the observational data base both in the time domain and in the space domain. Together with partners in a proposed EU project we will establish the observation data base needed for the next major reanalysis effort. We will also perform pilot reanalyses to evaluate the possibility of determining climate trends in the free atmosphere using the limited observational information available in the first half of the 20th century. Towards the end of the decade, it is hoped that ECMWF will provide an unprecedented climate quality global atmospheric reanalysis going back to the beginning of the 20th century and being continued in real time.

Another major area where ECMWF will contribute is monitoring of atmospheric composition. Using satellite data and re-analysis techniques we will contribute to the monitoring of carbon dioxide, aerosols and other climate relevant atmospheric constituents.

The involvement of ECMWF, via its reanalysis activities, in the above-mentioned CMUG will be an asset for the monitoring of a number of ESA ECVs, in particular ensuring their integration and consistency.

Using its reanalysis capability, ECMWF plans to contribute significantly to the activities that will emerge within the future GMES climate services.

Climate Prediction - as we have a model system that is well suited also for climate prediction we foresee an increased interaction with European research groups that wish to use the ECMWF system for climate prediction purposes.

Climate Research - we will continue with model development and exploit the benefits of higher resolution and improved descriptions of physical processes. Our research benefits both weather forecasting and climate research.

C.4.6 Role in the Generation of ECVs

ECMWF has no plans to produce ECVs as such. ECMWF can provide ancillary data (atmospheric forcing) for the production of ECVS, and can in return monitor some of the ECVs.

However, it could be argued that the production of a 20th century reanalysis continued in real time is in a way a generation of meteorological ECVs (temperature, moisture, wind, etc.) which will be fully physically and dynamically consistent through the reanalysis method.

C.4.7 Role in the maintenance of CDRs

No, apart from the operational satellite observations that are routinely assimilated in the system.

C.4.8 Information Passed to Other Centres

In collaboration with GSICS, ECMWF provides upon request the bias corrections for all satellite data that are assimilated or monitored in ERA-Interim. These corrections can then be assessed and compared by groups working on intercalibration of satellite instruments.

More generally, reanalysis products are freely available on a dedicated server to the science community and a heavy use of these resources is made by climate groups.

C.5 Forschungszentrum Jülich (Jülich)

JUELICH does not operationally produce any ECVs and is only involved in research activities related to climate (with a focus on energy technologies and chemistry climate interactions).

JUELICH coordinates the MOZAIC and IAGOS/ERI programmes which operate instruments to measure ozone, water vapour, CO, and several other variables on commercial airplane - this activitiy is bound to become operational but it is yet unclear under which institutional and funding framework.

JUELICH participates in field measurement campaigns with observations of chemical ECVs.

JUELICH is involved in chemistry climate assessment work (WMO, IPCC, TFHTAP) and operates various global and regional scale climate models (ECHAM5-HAMMOZ, MOZART, CLAMS, EURAD).

JUELICH is involved in emission inventory building for IPCC 5th assessment

JUELICH operates a WCS server for multi model results obtained in the framework of the TFHTAP initiative - this service is going to be registered as a GEOSS service in spring this year.

JUELICH coordinates one of the TERENO terrestrial observation networks.

C.6 GKSS

C.6.1 Main Contributions

Our CoastDat Database comprises a compilaton of coastal analyses (that is hindcasts and reconstructions) and scenarios for the future obtained from numerical models for the Northern Sea. The objective is to provide a consistent meteorological-marine data set that best represents past conditions in order to complement the existing but limited observations. Based on model results CoastDat may thus provide information over long time spans, at high spatial and temporal detail, and at places and for variables for which no observations have been taken. As an addition step, coastDat also provides consistent coastal scenarios for the near future allowing for an assessment of expected future changes relative to changes obsereved over the past few decades. In the CoastDat Dataset you will find implications of weather, wavesm currents and storms.

C.6.2 Particular Strengths

Coastal Seas and Storm activities.

C.6.3 Challenges

High resolution (barrier islands), long time series, more impact variables

C.6.4 Main Partners

In the PACES (Programme Marine, Coastal and Polar Systems: Polar Regions and Coasts in a changing Earth System)-Program: Alfred Wegener Institute Bremerhaven.

In the REKLIM (Regional Climate Change: From Observations and Modelling to Decision Support for Mitigation and Adaptation)-Program: he AWI is conducting investigations in the Arctic and Antarctic, Forschungszentrum Karlsruhe and Forschungszentrum Jülich are active in atmospheric research, and the GKSS Research Centre in Geesthacht carries out coastal research. The Helmholtz Centre Potsdam (GFZ), the Helmholtz Centre for Environmental Research (UFZ) and the Helmholtz Zentrum München- German Research Center for Environmental Health (HMGU) are also involved in climate research, as is the German Aerospace Center (DLR) with its earth observation activities.

In the CLISAP **(**Integrated Climate System Analysis and Prediction) - Program: Centre for Marine and Atmospheric Sciences, University of Hamburg**,** Max Planck Institute for Meteorology (MPI-M), Hamburg.

C.6.5 Envisaged Evolution in the Centre's Climate Role

Providing regional climate services, developing options and needs for adaptation

C.7 Hadley Centre

C.7.1 Main Contributions

Climate Monitoring - production of gridded data sets of marine and land temperatures, sea-level pressure, upper air temperatures and of climate extremes (e.g. surface temperatures); specific UK data sets of temperature and precipitation; development of long-term record of infrared radiances from the HIRS instruments. Full details of the Hadley Centre observational data sets can be found at http://www-hc/~hadobs/www.hadobs.org/. Historically we have focused on conventional observations from the global network, although there is now an increasing amount of work using satellite data, either to augment the conventional data (e.g. SSTs) or as the basis for new data sets (IR radiances).

Climate Prediction - development of climate models incorporating state-of-the-art representations of the most important physical processes in order to respond to the requirements of our primary customers (e.g. UK government).

Our primary model for climate prediction is the Hadley Centre Global Environmental Model (HadGEM): HadGEM1 was submitted to IPCCC AR4, HadGEM2 will be submitted to AR5 and we are currently developing HadGEM3. We aim to provide predictions on timescales ranging from seasonal to centennial in response to our customer requirements. ECVs are used primarily to evaluate model performance but are also likely to become increasingly important for initialising decadal predictions.

Climate Research - fundamental research into the key processes and feedbacks operating in the climate system in support of the requirements for climate prediction, i.e. development of better climate models.

C.7.2 Particular Strengths

Climate Prediction and Research - as one of the leading climate modelling centres we participate in most of the major networks and initiatives in this field (e.g. WGCM, IPCC,…), often take a leading role. Two particular strengths of the Hadley Centre worth emphasising are:

- we use the same model for both climate prediction and weather forecasting. This has advantages for both model evaluation and development: it means that we can use information gained from evaluating our weather forecast model on a daily basis to inform our climate model development;

- our primary customers are UK government agencies, which means that our work is strongly focused on policy-relevant scientific research, e.g. providing scientific advice that can be used in the formulation of policies on adaptation to and mitigation of climate change.

C.7.3 Challenges

The need to maintain a high quality global network of conventional observations needs to be continually re-emphasised. This includes, for example, the requirement for quality control and all appropriate metadata in accordance with the GCOS principles.

There has been a joining up of effort in some communities to cover the gap between observations, small scale and large scale modelling. A good example is the CFMIP-GCSS link. Modelling efforts to produce diagnostics that allow acurate comparison to up-to-date EO or in-situ datasets has been very effective in highlighting model deficiences (e.g. COSP; Bodas-Salcedo et al, 2009). Mirroring this in other communities (e.g. hydrological modelling, …?) would enable greater progress to be made. There is also a gap between data assimilaton research for short to medium range weather prediction

and that used for initialising seasonal and decadal climate predictions.

Bridging the gap between observations, process studies and large-scale modelling also needs to happen in the field of Earth System modelling, especially in areas where parametrisations are still very crude (e.g. dynamic vegetation).

C.7.4 Main Partners

- The other major climate modelling centres worldwide
- Other NMSs and government agencies (e.g. NOAA, NCDC)
- The UK academic climate research community
- Organisations/agencies which use our climate/forecast models (e.g. Australia, Korea, Norway)

C.7.5 Envisaged Evolution in the Centre's Climate Role

- Increasing emphasis on seasonal-to-decadal, as opposed to longer-term, prediction
- Increasing emphasis on regional prediction and extremes
- Increasing interest in climate change impacts in many spheres, e.g. agriculture
- Inclusion of more so-called 'earth system' processes into climate models, e.g. carbon cycle, ocean biogeochemistry, etc
- Development of models with ever-increasing resolution, in particular to respond to the requirement for improved regional predictions
- A move to the provision of 'climate services'

C.7.6 Role in the Generation of ECVs

The Hadley Centre is involved in the generation of the following ECVs:
- surface air temperature;
- precipitation;
- surface air pressure;
- upper-air temperature;
- cloud properties (as part of the ESA CCI);
- sea surface temperature;
- sea level (as part of the ESA CCI);
- sea ice (as part of the ESA CCI);
- ocean colour (as part of the ESA CCI).

C.7.7 Unfulfilled Requirements for CDRs

In the Met Office we are utilising a seamless approach to model development and evaluation using the MetUM (Met Office Unified Model) framework. We will run the same physical model at all timescales from 1-5 day forecasts to centennial prediction. This allows study of errors at the shortest timescale (e.g. a few hours or less for fast physical processes such as clouds or seasonal timescales for coupled modes of variability such as ENSO). Hence we are able to evaluate processes in a strongly dynamically constrained environment focussing on errors in the physical mechanisms and compare in real-time to the most up-to-date observations.

However, observations of certain key quantities are still lacking across the range of timescales. For example, although there is a relatively large number of research stations around the world that make measurements of soil moisture, these are limited to certain areas of the globe and a reliable long-term global record is lacking. This is being addressed through the development of a number of satellite-based measurements such as ASCAT. Detailed information about cloud processes, ice and water contents and their conversion to precipitation is lacking - an area which experiments such as CloudSat are aiming to address. A number of global precipitation products exist which use multiple

sources of observations (rain gauges, radar, and multiple satellite measurements), but there is some disagreement between such products, both over land and sea. Thus, verification of global precipitation distribution on all timescales is problematic. This is being addressed through measurement projects such as the Tropical Rainfall Measuring Mission (TRMM; see http://trmm.gsfc.nasa.gov) and, in the future, the Global Precipitation Measurement mission (GPM; see http://gpm.gsfc.nasa.gov).

C.8 KNMI

C.8.1 Main Contributions

Climate Monitoring

National

KNMI is the national meteorological institute for The Netherlands and has the national and legal responsibility for the meteorological basis observations, including archiving and dissemination, within the Netherlands (40 meteorological stations and 320 precipitation stations: see http://www.knmi.nl/klimatologie/).

More activities on climate observations are:

- Extensive atmospheric measurements at the Cabauw site, including mast measurements, radiation and remote sensing. See http://www.cesar-database.nl/
- Satellite data: retrieval and delivery (e.g. www.temis.nl , http://www.knmi.nl/scatterometer/)
- Contribution to Argo floats programme
- Twice daily radio sonde at De Bilt
- Weekly ozone sonde at De Bilt
- Continuous Brewer measurement of total column over De Bilt
- Regular ozone sonde and Brewer measurements at Paramaribo station, Surinam.

HISCLIM project: recovering, digitizing and archiving daily historical meteorological observations back to 1700 AD (www.knmi.nl/research/climate_services/hisklim.html).

KNMI is national focal point of GCOS. In this role it coordinated the Scientific Assessment and Policy Analysis, Climate Change Monitoring in the Netherlands, addressing the national contribution to the GCOS Implementation Plan.

KNMI applies an open data policy: principally all meteorological observations, carried out by KNMI and processed for external use, are publicly available and without licence costs.

International

Operation of the WMO Regional Association VI Regional Centre on Climate Data (RCC-CD)

Operation of ECA&D: the European Climate Assessment and Data Set (http://eca.knmi.nl), giving access to > 12000 climate meteorological observational series and related assessments from > > 3200 stations in > 60 (Europe and bordering) countries

The DIDAH project: aims at data rescue and data access for the Indonesian Archipelago

Climate Prediction - KNMI issues every approx 6 years the climate scenarios for The Netherlands. Last one in 2006 (see http://www.knmi.nl/klimaatscenarios/knmi06/WR23mei2006.pdf), next one in 2012/13. KNMI leads the development of the EC Earth climate prediction model to be used for IPCC AR5 and further and the national scenarios.

KNMI uses and develops the regional climate model RACMO2 for use in AR5 and national scenarios.

Climate Research - KNMI research staff produces about 80 peer-review papers on climate research per year. (http://www.knmi.nl/research/climate_research.html). Main research subjects are future climate for The Netherlands, predictability, feedbacks, atmospheric chemistry, boundary layer.

C.8.2 Particular Strengths

Climate Monitoring

- Satellite remote sensing of atmospheric composition (e.g. OMI)
- Super site Cabauw for atmospheric research and monitoring

Climate Prediction

- Leading the development of EC Earth
- RACMO2 regional climate model

Climate Research

- Atmospheric composition
- Global climate feedbacks
- Boundary layer, clouds and radiation

C.8.3 Challenges

Climate Monitoring - construction of long, good quality time series of ECV based on satellite instruments. Continuation and better integration of ground (super) sites.
Suggested approach: programmes like the ESA CCI, more attention for instrument (cross) calibration, ensuring continuous availability of good quality ground data.

Climate Prediction - smaller scales, decadal time horizon (2030), organizing computing power

Suggested approach: Smaller scales: make non-hydrostatic models useable for climate runs.
Decadal: research on climate variability, good initialisation of models with observations.
Computing: funding, organisation, ECMWF for climate modelling?

Climate Research - the main climate feedbacks: clouds, chemistry, water vapour.

Suggested approach: bringing focus through research programmes, e.g. WCRP (is happening). Keep up funding levels (national, FP7).

C.8.4 Main Partners

Many meteo institutes, research centres and universities: ECMWF, UKMO, M-F, FMI, SMHI, MPI Ham, MPI Mainz, NASA GSFC, NASA JPL,…

C.8.5 Envisaged Evolution in the Centre's Climate Role

No major changes expected in research and monitoring. Prediction: more focus on climate services, better tailored climate information to users. Stronger coupling to climate policy.

C.8.6 Role in the Generation of ECVs

KNMI is involved in the generation of the following ECVs:

a) Atmospheric ECVs (surface)
   - air temperature
   - precipitation

- air pressure
- radiation budget
- wind speed and direction
- water vapour

b) Atmospheric ECVs (upper-air)
- air temperature
- wind speed and direction
- water vapour
- cloud properties

c) Atmospheric ECVs (composition)
- ozone (tropospheric and stratospheric)
- aerosol properties

d) Oceanic ECVs (surface)
- sea surface temperature
- sea surface salinity
- sea state
- current

e) Oceanic ECVs (sub-surface)
- temperature
- salinity
- current

f) Terrestrial ECVs
- ground water
- albedo
- soil moisture

C.8.7 Role in the maintenance of CDRs

All data is archived at KNMI and submitted to relevant databases (WMO/GCOS)

C.8.8 Information Passed to Other Centres

All data is archived at KNMI and submitted to relevant databases (WMO/GCOS)

C.8.9 Unfulfilled Requirements for CDRs

None noted

C.9 LMD

C.9.1 Main Contributions

Analysis of long time series of satellite observations from meteorological satellites, both GEO and LEO satellites, including calibration and retrievals as well as climate studies (variability and trends) and physical interpretation (relationship between different ECV's). Hereby it is difficult to separate climate monitoring and climate research. LMD/IPSL is leading the cloud assessment (http://climserv.ipsl.polytechnique.fr/gewexca), initiated by the GEWEX Radiation Panel. At present, ten cloud climate data records are participating and a data base (containing monthly means and variabilities as well as distributions) in a common format (netcdf) has been created and is under investigation. A WCRP report should be finished by the end of 2010.

Participation of the LMD/IPSL climate model in CMIP5 and other modeling activities coordinated by the WCRP Working Group on Coupled Models (WGCM). LMD/IPSL is also involved in the FP7 european project EUCLIPSE (EU CLoud Intercomparison, Process Studies and Evaluation"). As part of Cloud Feedback Model Intercomparison Project (CFMIP) and EUCLIPSE, we are developing methodologies of comparison of modeled and observed clouds (e.g. development of the lidar simulator included in COSP, the CFMIP Observations Simulator Package distributed to the different modeling groups participating in CMIP5), GCM-oriented satellite products (e.g. CALIPSO-GOCCP) designed for the evaluation of GCM outputs.

Analysis of climate change feedback processes using models and observations.
Development and conduction of new satellite projects (e.g., Megha-Tropiques, IASI-NG)

C.9.2 Particular Strengths

Modelling and satellite developments are performed in the same institute offering good conditions for facing the climate monitoring and prediction issues and for looking at climate research problems in a synergic way.

Synergistic retrieval of different atmospheric properties, on a global scale, allowing to study their relationship (e. g. temperature and humidity profiles, aerosol and cloud properties, as well as trace gas concentrations and surface properties using vertical sounders such as TOVS, AIRS, IASI).

C.9.3 Challenges

Physical understanding of climate change trends and projections with the emphasis on clouds and precipitation, in particular in the Tropics.

Climate model evaluation and improvement, in particular the improvement of the representation of moist processes (convection, clouds, turbulence) in the atmospheric component of climate models.

Encourage model development activities, collaborations between modelling, satellite and process communities around key scientific issues, support the analysis and the distribution of satellite data and in-situ observations in a coordinated manner (e.g. CMIP5).

On a practical point of view: distributing observations through a common portal, gridded, and in netcdf format would greatly help.

C.9.4 Main Partners

Hadley Centre (Exeter), Max-Planck Institute for Meteorology (Hamburg), KNMI (Netherlands), CNRM (Meteo-France), IPSL laboratories (LSCE, LOCEAN, LATMOS), CMS Lannion, ECMWF, NASA, NOAA, CNES

C.9.5 Role in the Generation of ECVs

LMD is involved in the generation of the following ECV-related variables:

a) Atmospheric (surface)
- skin temperature
- IR surface emissivity

b) Atmospheric (upper-air)
- Earth radiation budget
- temperature
- water vapour
- cloud properties

c) Atmospheric (composition)
- carbon dioxide
- methane
- aerosol properties

C.9.6 Role in the maintenance of CDRs

LMD is involved in the maintenance of CDRs related to:

a) Atmospheric (surface)
- skin temperature
- IR surface emissivity
- precipitation

b) Atmospheric (upper-air)
- Earth radiation budget
- temperature
- water vapour
- cloud properties

c) Atmospheric (composition)
- aerosol properties

C.9.7 Information Passed to Other Centres

Information is made available to a variety of centres (further information detailed in the Excel spreadsheet response).

C.9.8 Unfulfilled Requirements for CDRs

a) New observations that would be VERY useful for the study of the water cycle and a more constraining evaluation of climate models are observations of water isotopes (HDO, Oxygen18,

Oxygen17): global satellite data (as now available from a few platforms: MIPAS, IASII, TES, ODIN, etc) + global network of in-situ isotopic observations in precipitation, water vapor, rivers, vegetation (for the moment these observations are sparse, difficult to access, and not collocated).

b) The synergy of active and passive remote sensing instruments of the A-Train is unique, and agencies should plan such constellations also for the future

C.10 Météo-France

C.10.1 Main Contributions

Météo-France is covering the range of climate activities, daily monitoring and analysis of real-time climate, climate prediction on an operational basis with a seamless approach starting from short term ranges (hours, days) to 10 days, monthly, seasonal ranges. These reports are available on the web. Atmosphere and surface (soil moisture…) are addressed. Météo-France is responsible for the climate observation conservation (in the National Climatology Data Base: BDClim, quality control, homogeneization, dissemination. It is namely leading the European COST action on homogeneization, a key step in delivering validated climate data (see www.homogeneization.org). Data, as well as climatology products (eg return periods and all needed products for dimensioning criteria) are available via a web based application: Climathèque (http://climatheque.meteo.fr).

Climate Monitoring is performed for France and its overseas territories. Daily, Monthly, Seasonal and annual reports are delivered on a routine basis. Ad hoc reports are published in case of special events (e.g. the winter current cold wave).

Seasonal Forecasting is delivered each month for the next trimester, with a public bulletin put on Météo-France's public web site, a full monitoring and analysis report, and special products tailored to various user's need, especially in the industry and research. Seasonal forecasting applications are also in operations or in development, in a wide range of sectors, from hydrology and water resource, to energy or health. They are namely used for overseas territories and Africa (eg Support to OMVS for the regulation of the river Senegal flows at the Manantali dam; Rift Valley Fever for cattle in Senegal…).

Climate Prediction and Projections is at first an operational activity that provides seasonal forecasts for public, applications and specific end-users (see above). The climate model used is a coupled ocean-atmosphere general circulation model Arpege/ORCA. Arpege (the atmospheric component) has 91 vertical levels and a spatial resolution of about 300Km. ORCA (the oceanic component) is an ocean model developed at LOCEAN in Paris. The ocean initial conditions are prepared by MERCATOR in Toulouse. Input variables are those of the atmospheric and oceanic data assimilation systems. This includes data from meteorological satellites and satellite altimetry. Atmospheric and oceanic re-analysis are used to perform hindcast predictions that are used to calibrate seasonal predictions. The link with ECV is through these re-analyses that might include these variables in the assimilation systems. The outputs of the predictions are seasonal anomalies of some parameters (mainly temperature and precipitations) that are classified in a very limited number of classes (typically 3). The combination of several predictions for the same season (ensembles) and of different models (multi-model) allows to generate probabilistic forecasts in the context of the EUROSIP project.

An earth system model is used to participate to the CMIP simulation exercises resulting in centennial projections and decadal predictions that serve as a basis of the GIEC assessment reports. Regional climate projections covering this century are also performed to contribute to impact and adaptation studies over some regions including Europe and the Mediterranean area.

Climate Research is also carried on in the Météo-France climate research group. The general main scientific objectives are the study of climate variability and of the impact of human activities on climate, the study of climate predictability, the study of the interactions between climate and atmospheric chemistry and the study of the interactions between ocean and atmosphere. The methodology relies mainly on modelling both at the global and at the regional scales.

C.10.2 Particular Strengths

Climate Monitoring - a dense network of observations at the national level including some tropical islands, strong collaborations with some African countries in the field (Marocco, Tunisia, Western African countries, …), development of advanced method on data homogeneization with coordination of a COST project on this specific topic.
Climate Prediction - operational activity, part of European consortium EUROSIP, part of discussions at the international level (WGNE) and partner of main research past European projects on the subject (this includes PROVOST, DEMETE, ENSEMBLES/RT2A).

Climate Research - participation to CMIP climate change simulations contributing to IPCC assessment, partner of main research past or present European projects on climate variability and climate change at the global or regional level (this includes MERCURE, PRUDENCE, ENSEMBLES, IS-ENES, COMBINE, EUCLIPSE, …), advanced research on regional climate variability at the regional scale in particular over the Mediterranean area.

C.10.3 Challenges

Data Rescue is the first challenge to solve. Data are not digitized, and the length of series for analyzing climate, especially regarding extremes, is short for enabling a full and comprehensive detection, attribution, prediction of extremes of the climate (eg. Heat wave, droughts,… snow events, wind and storms…). Especially in France, a huge amount of data still need to be digitized, controlled and inserted in the data base. This requires financial support and human resources. Potential Data are covering France and former colonies (IndoChina, Africa, etc.). Data Rescue is also a major challenge in the Mediterranean area, where Météo-France plays a key role (eg MedDARE, CIRCE projects) and Africa. Extremes are the key challenge for the future, and data rescue (or reprocessing of satellite and radar data) do contribute to a better characterization and therefore understanding of extremes.

Homogeneization is next a challenge too. Météo-France is leading a COST action on this topic, giving free access to a world top-class tool (PRODIGE). Support has to find for spreading such tools, and know-how, which requires the organization of dedicated hands-on workshops.

Another major challenge is the realization of a long global reanalysis made with an excellent climate model, assimilating all available data until now. Such reanalysis have been made in the past, like ECMWF ERA-40 or continuing ERA-Interim. A major initiative should be supported by the EC to run a 1850-present major renalysis leaded by ECMWF, that would boost climate research but also enable a wide range of applications and climate services to be built (examples can be found at Météo-France on ERA-40 for aviation, building… etc. and various industrial sectors or ecosystems – eg water resource and drought monitoring – after application with local models eg for soil moisture enabling a comprehensive reanalysis, diagnosis and understanding of droughts in France after WWII).

On **Climate Prediction**, one main challenge is the development and the validation of decadal prediction. Decadal prediction is a very important societal demand in particular due its potential impact on economic activities that can adapt to the relevant time scale. But this remains an open scientific question since only very few studies have addressed this issue to drive definite conclusion on the predictability of the climate system at this time scale. One of the main difficulty come from the lack of ocean data to initialize the oceanic component of the system over several decades to develop and validate the prediction system. Research on this topic will be significantly promoted though the participation of several climate research group to the CMIP5 intercomparison exercise.

Concerning **Climate Research** there is of course a lot of challenging questions but we mention here only two of them that are related to research activities that develops in our Centre. The first one concerns the evaluation and reduction of uncertainties of climate change at the regional level. This is an important issue since a completed analysis of risks that are associated to climate change impacts,

ultimately requires a probabilistic approach of climate projections at the regional and even sub-regional scales. This implies the development, by specialist of different disciplines (atmospheric science, oceanography, biogeochemistry, …), of new modelling tools that describe the behaviour of the coupled climate system at the regional level as earth system models do it at the global one. This also implies the combination of results of climate change simulations from different research groups like those initiated within the framework of the CORDEX WCRP project. The second concerns the detection and attribution of climate change and climate change impacts also at the regional scale. This question is often a prerequisite to foster action in the field of adaptation or attenuation of climate change and remains a very open scientific question. It requires in particular the construction of homogenised long term data series, the development of regional climate and impact models and the development of suitable statistical methods to increase the detection of signals of change from the noise of climate and climate impact variability. Such researches need to be promoted in scientific programs and are encouraged by IPCC.

C.10.4 Main Partners

Météo-France collaborates closely with CERFACS and IPSL (LMD, LSCE, LOCEAN…) for climate variability studies and model development. The development of the atmospheric component of the climate model also implies a lot of collaborations within the French or European community (ECMWF, LA…). Within the framework of European project, the research group collaborates with the main climate research centres (Hadley Centre, MPI, …). As far as climate impact studies and applications of climate predictions are concerned, collaborations are extended to laboratories covering a wide range of disciplines (IRD, Ecole des Mines, LTHE, INRA, Cemagref, CSTB…).

C.10.5 Envisaged Evolution in the Centre's Climate Role

A strong emphasis will be put by Météo-France on climate issues, in a seamless approach, covering all weather and climate-related activities from the past to the future, at all ranges and scales.

C.10.6 Role in the Generation of ECVs

Météo-France is involved in the generation of the following ECVs:

a) Atmospheric ECVs (surface)
- air temperature
- precipitation
- air pressure
- radiation budget
- wind speed and direction
- water vapour (and humidity)

b) Atmospheric ECVs (upper-air)
- Earth radiation budget

c) Atmospheric ECVs (composition)
- carbon dioxide
- methane
- aerosol properties

d) Oceanic ECVs (surface)
- sea surface temperature

C.10.7 Role in the maintenance of CDRs

Data and metadata are available through web based services

C.10.8 Information Passed to Other Centres

Delivery of data within the EMI framework, namely EUMETNET-EIG/ECSN (eg ECA) or bilateral or for R&D purposes agreements

C.10.9 Unfulfilled Requirements for CDRs

Air Temperature (surface and upper-air): we need the longest CDR possible with a requirement of homogeneity and an estimate of associated errors in order to enter atmospheric reanalyses and thus help at evaluating climate models and initializing models for climate predictions. These homogenized CDR can also be used independently in detection/attribution studies.

Precipitation - we need the longest CDR possible with a requirement of homogeneity and an estimate of associated errors in order to validate models and possibly to perform detection/attribution studies.

Air Pressure (surface) - we need the longest CDR possible with a requirement of homogeneity and an estimate of associated errors in order to enter atmospheric reanalyses and thus help at evaluating climate models and initializing models for climate predictions. These homogenized CDR can also be used independently in detection/attribution studies.

Radiation Budget (surface and upper-air) - we need the longest CDR possible with a requirement of homogeneity and an estimate of associated errors in order to validate models.

Wind Speed and Direction (surface and upper-air) - we need the longest CDR possible with a requirement of homogeneity and an estimate of associated errors in order to enter atmospheric reanalyses and thus help at evaluating climate models and initializing models for climate predictions.

Water Vapour (surface and upper-air) - we need the longest CDR possible with a requirement of homogeneity and an estimate of associated errors in order to enter atmospheric reanalyses and thus help at evaluating climate models and initializing models for climate predictions. These homogenized CDR can also be used independently in detection/attribution studies.

Cloud Properties - we need the longest CDR possible with a requirement of homogeneity and an estimate of associated errors in order to validate models.

Carbon Dioxide, Ozone, Methane, Other GHGs, Aerosol Properties - we need the longest CDR possible with a requirement of homogeneity and an estimate of associated errors in order to enter atmospheric reanalyses and thus help at evaluating climate models and initializing models for climate predictions.

Sea Temperature (surface and sub-surface) - we need the longest CDR possible with a requirement of homogeneity and an estimate of associated errors in order to enter oceanic reanalyses and thus help at evaluating climate models and initializing models for climate predictions. These homogenized CDR can also be used independently in detection/attribution studies.

Sea Salinity (surface and sub-surface) , Sea Level, Sea Ice, Current (surface and sub-surface) - we need the longest CDR possible with a requirement of homogeneity and an estimate of associated errors in order to enter oceanic reanalyses and thus help at evaluating climate models and initializing models for climate predictions.

River Discharge, **Ground Water, Glaciers and Ice Caps, Permafrost, Albedo, Land Cover, fAPAR, LAI, Soil Moisture** - we need the longest CDR possible with a requirement of homogeneity and an estimate of associated errors in order to validate models.

Snow Cover - we need the longest CDR possible with a requirement of homogeneity and an estimate of associated errors in order to enter atmospheric reanalyses and thus help at evaluating climate models and initializing models for climate predictions.

C.11 Météo-Swiss

C.11.1 Main Contributions

Climate Monitoring:

- Coordination of GCOS activities in Switzerland (GCOS Switzerland)
- Observation of surface and upper-air Atmosphere ECVs including quality control and homogenization of time series
- Observation of atmospheric composition ECVs (ozone, aerosols, trace gases, pollen, etc.) and coordination of the Swiss activities within the WMO GAW programme (GAW-CH)
- Provision of calibration services, maintenance of international calibration centres in the framework of GCOS (eg. World Glacier Monitoring Service WGMS) and of WMO GAW (eg. World Radiation Centre PMOD/WRC Davos)
- Member of EUMETSAT CM SAF consortium

Climate Prediction:

- Climate prediction services for industry and governmental offices from monthly, seasonal, decadal and centennial time scales.
- For our research activities, seasonal and decadal forecasts and long term climate projection data from regional climate models are used from the EU FP6 ENSEMBLES project. Additionally, operational data from ECMWF is investigated. As output, the focus is on temperature and precipitation. We cover time scales from monthly forecasts up to 2050

Climate Research:

- Climate research in the Framework of the Swiss National Centre of Competence in Research on Climate (NCCR Climate)

C.11.2 Particular Strengths

- Centre of competence for Alpine meteorology and climatology
- Spatial interpolation of observations of various parameters and time scales in complex terrain such as the Alps for climate monitoring (e.g. in the framework of EU FP7 EURO4M).
- Homogenization of long time series from surface observations (e.g. within the COST-ES0601).
- Short term climate predictions (monthly and seasonal forecasts)
- Established coordination mechanism of climate observations in the atmospheric and terrestrial domain through the Swiss GCOS Office, including long-term sustainability of observations
- Expertise in the provision of calibration services

C.11.3 Challenges

- The provision of localized information on climate change on time scales of 10 to 40 years being relevant to climate adaption and political decisions.

- To maintain reliable operational sources for remote sensing and in-situ data, forecasts, hind casts, re-analysis data, ensemble prediction data etc. This can be achieved by strengthening the leading role of the ECMWF, EUMETSAT, EUMETNET-EIG and the national weather services.

- To maintain the high standards for the production of remote sensing and in-situ meteorological data and further essential climate variables. This should be done by well coordinated national activities, EUMETNET-EIG EUCOS and EUMETSAT under the coordination of the Global Climate Observing System (GCOS).

- The improvement of the skill of monthly, seasonal and decadal forecasts. This should be done by strengthening the research capacities coordinated by the World Meteorological Organization, the World Climate Programme and executed by the academia, the European Centre for Medium Range Weather Forecasts (ECMWF), the national weather services, the EUMETNET-EIG European Climate Support Network (ECSN) etc.

- The development of new and better user tailored climate services, coordinated by the evolving Global Framework on Climate Services.

C.11.4 Main Partners

- National: all Federal Offices, Research institutes and Universities with climate relevant measurements; Centre for Climate System Modelling (C2SM).

- International: World Meteorological Organization WMO, Global Climate Observing System GCOS, ECMWF, EUMETSAT, ESA, other NMHSs (eg. DWD, KNMI), FAO/GTOS, IPCC, UNFCCC

C.11.5 Envisaged Evolution in the Centre's Climate Role

- MeteoSwiss will remain an important player in the field of Climate research together with the partners from the Framework of the National Centre of Competence in Research on Climate

- MeteoSwiss will further strengthen the climate monitoring activities within GCOS Switzerland and GAW-CH

- MeteoSwiss will strengthen its leading role as national provider for tailor made climate services for industrial and governmental purposes.

C.11.6 Role in the Generation of ECVs

Météo-Swiss is involved in the generation of the following ECVs:

a) Atmospheric ECVs (surface)
   - radiation budget

b) Atmospheric ECVs (upper-air)
   - water vapour
   - cloud properties

c) Atmospheric ECVs (composition)
- carbon dioxide
- ozone
- methane
- other long-lived GHGs
- aerosol properties

d) Terrestrial
- snow cover
- glaciers and ice caps
- fAPAR
- LAI
- fire disturbance
- soil moisture

C.11.7 Unfulfilled Requirements for CDRs

None noted.

C.12 MPI-M

C.12.1 Main Contributions

MPI-M is not involved in Climate Monitoring activities as such, as these include an operational component. Climate observations at MPI-M focus on:

a) the long-term analysis and homogenization of existing observational records with a strong emphasis on satellite data (e.g. HOAPS climatology of ocean surface fluxes) and
b) observations related to a better understanding of relevant processes in the Earth System

MPI-M is also not a climate prediction centre in the operational sense. However we are deeply involved in climate prediction as part of community protocols such as CMIP, which underlies the IPCC assessments. We are also playing a leading role in developing a decadal prediction capacity within Europe. Our center maintains and develops a comprehensive Earth-system model, which is comprised of a coupled ocean, atmosphere, terrestrial biosphere and biogeochemical model. This model is used to develop our understanding of the climate system and provides an essential basis for the periodic assessments lead by the IPCC.

MPI-M is a leading center in the development of climate models and climate theory. Our research focuses on climate sensitivity and feedbacks, and controls on predictability of the climate system.

The most important thing to note is that the integration of observations and climate modelling, particularly as relates to controls on the radiation budget (mostly clouds and water vapour, and to a lesser extent chemistry or aerosol) in the troposphere, is and will continue to be a focal point of our work. In particular we recently reconstituted one of our modelling groups as an observational group just for this purpose.

C.12.2 Particular Strengths

Climate monitoring - synergy between data from climate monitoring, modelling and theoretical understanding of the climate system. An example is the development by S. Kinne of a new aerosol climatology for use in our modelling, or the HOAPS data for evaluation of our coupled model.

Climate prediction - the development of a decadal prediction system, and a program to address model biases through an improved physical basis for the model.

Climate research - the development of theoretical concepts underpinning climate prediction, with a particular focus on an understanding of controls on climate sensitivity, and origins (or limits) of predictability within the climate system.

C.12.3 Challenges

Climate Monitoring - the biggest challenges for climate observations are:

- Generation of long-term stable (inter-calibrated) satellite data records at global scales (Level 1 data): homogenization and inter-calibration of different data records;
- Efficient availability of these data records;
- Provision of consistent ECV products. Consistent means, that all products share the same ancillary database and assumptions;
- Quantitative assessment of uncertainties in the observations on a grid cell basis;
- Combined estimation of energy and water fluxes in a consistent way.

The consistency of different data products might be the biggest challenge at the moment. There is currently no project or data set provides consistent data products accros the different ECVs. The ESA CCI and scope-CM initiatives could be major drivers to initiate the generation of consistent CDR's and especially ECV's.

An additional, or related challenge is in establishing synergies between models and observations, including: the exploitation of the synergies between climate models and observations is a challenging task and requires appropriate assessment of the uncertainties of models and observations; and Integrated analysis of satellite and climate model data e.g. through the use of satellite simulators for climate models.

Climate Prediction - the greatest challenge is to identify predictable elements of the system on moderate time- and regional spatial-scales, to better constrain principal feedbacks, particularly associated with clouds, and initial conditions (ocean data assimilation). On long-time scales (many decades or more) the chief challenges are in representing the dynamics of the cryosphere and the carbon cycle.

Climate Research - broadly speaking in climate research the biggest challenge is to advance our understanding of the climate system through the integrated use of models and data. Understanding is so critical because climate predictions rest more strongly on fundamental understanding than on practice (say as is the case for weather prediction). The careful integration of data is essential as climate scientists will be increasingly be called upon for explanations for "unusual" weather events as the publics consciousness about climate change is raised. Attribution will increasingly play a role in the climate discussion. These points are too often forgotten in the rush to apply our still rather primitive knowledge.

C.12.4 Main Partners

Modelling Centres: ECMWF, DWD

Observations: EUMETSAT Climate Monitoring SAF (CM-SAF); DWD; European Space Agency (ESA); NASA; DLR

Other Laboratories: Earth-System-Research Partnership of the Max Planck Society, including the Max Planck Institutes for Chemistry and Biogeochemistry and the Potsdam Institute for Climate Impacts Research.

Universities: Principally the University of Hamburg whose research is closely integrated with our own.

C.12.5 Envisaged Evolution in the Centre's Climate Role

Increasingly our focus will be developed toward advancing the conceptual foundations for the field as well as the tools required to synergize an increasing awareness of changes in the climate system (through monitoring) and the ideas that can help explain them.

C.12.6 Role in the Generation of ECVs

We are currently not engaged in generating new CDR's or ECV's as such, as they are defined by GCOS.

MPI-M is more focusing on the synergies and long-term analysis of ECV records. In general, MPI-M is focusing on the analysis and combination of different data sources to generate climatologies. These include

- HOAPS climatology of ocean surface fluxes (www.hoaps.org);
- Development of a climatology of land surface fluxes: This includes many aspects of different land ECV's (radiation budget, albedo, Leaf area index, precipitation …) and their combination;
- Aerosol climatology.

Additionally our centre is developing new observational stations to measure key climate processes and variables, particularly the connection between clouds, aerosol, precipitation and climate through the establishment of our Barbados observatory. This will be a state of the art facility, comparable to, or better than, the ARM stations of the US Department of Energy.

C.12.7 Unfulfilled Requirements for CDRs

None noted.

C.13 NCEO

C.13.1 Main Contributions

Increasing the use and usability of EO data in support of climate and other research in the UK. NCEO is a distributed body made up currently of 26 groups around the UK. The NCEO has a Climate theme with activities particularly in atmospheric radiation, the water cycle, ocean circulation, long term EO records from SST sensors, ocean reanalysis for climate studies, ocean colour assimilation, the cryosphere, including land and sea ice, and role in the climate system, the land surface, water cycle and carbon cycle.

The NCEO also has a Carbon theme which focuses on Monitoring and modelling Land and Ocean carbon reservoirs and exchanges with the atmosphere.

A strong focus of the NCEO is to see EO data used more widely in weather and climate predictions and so a strong partnership with the Met Office is being built with the aim of embedding use of EO data in operations using improved retrieval and data assimilation methods.

Ocean Reanalysis is also carried out for both **climate monitoring** and **climate prediction** purposes, with the climate prediction studies[37] being carried out in collaboration with the Hadley Centre and with the National Centre for Atmospheric Research group in Reading University.

SST retrieval from EO data for climate uses is carried out with a strong focus on physical retrieval algorithms and the use of dual view ATSR data. Newly developed methods are being used to upgrade historical retrievals from AVHRR instruments.

Atmospheric work focuses on comparing and combining satellite and ground-based observations, atmospheric reanalysis products and climate model simulations to improve knowledge of physical processes by analyzing the Earth's radiative energy balance and its links to the global water cycle. In particular understanding current changes in precipitation, understanding the role of ice and water in clouds, and implications for future changes.

C.13.2 Particular Strengths

The NCEO has strong expertise in climate and process modelling and in data assimilation for the purposes of monitoring climate.

In Climate predictions the close collaborations with the Hadley Centre and with the UK NCAS Climate program, including shared modelling and computational resources, give many opportunities for seeing EO data translated into operational activities and it is a strong ambition of the NCEO to see this take place more easily

In climate research the NCEO can call on the best EO Research groups across the UK academic sector. This expertise is very broad but perhaps the main strengths can be said to lie in quantitative interpretation of EO data for process understanding and for deriving long term data sets for assessing climate change rates and processes.

[37] Working with Hadley coupled models with focus on ocean initial conditions, particularly upper ocean heat content from in-situ data. We have a new project to explore scope of EO data for validating climate model hindcasts and for initialisation of climate models (interested in SST, Sea level (altimeter and Geoid), Sea Ice initially - later perhaps sea surface salinity, soil moisture….).

We also work with oceanography groups at Met Office (and more broadly in Europe) We expect to be involved in ocean reanalysis work using ECVs as collaborators of the Met Office in SST, Sea Ice, Sea level and ocean colour

C.13.3 Challenges

Climate Monitoring - reconstruction of past ocean behaviour from sparse observations. The oceans control the rate of climate change and we need to get more out of the sparse observations using modelling and assimilation methods and through bias correcting older data

Similarly we can improve satellite SST record by improved corrections of older instruments AHVRR using modern retrieval methods eg ATSR.

Improve estimates of water cycle changes using satellite and in-situ data.

Carbon cycle monitoring and derivation of sources and sinks is a huge challenge which will underpin global climate policy in future. Making best use of current satellite systems as well as rapid replacement for OCO is a key goal.

Measuring long-term changes in top of atmospheric net radiation and reconciling with SST, ocean heat content and sea level rise. Long-term, overlapping records are required with spectral sampling; this will aid the monitoring of climate and research into Earth's energy flows.

Climate Prediction - models need to be better tested against observations. Better climate predictions using assimilation methods for longer lead times, seasonal-interannual to decadal. Need to improve exploitation of observations in climate prediction. Higher resolution climate models versus ensemble methods in competition for development. Difficulty in allowing research community to work with huge data volumes. HPC centres not good at managing petabytes of data making diagnostics difficult as doing model runs. Need data centres with diagnostics capabilities.

Regional climate prediction is a huge challenge. Understanding regional feedback mechanisms and influences on circulation patterns through process studies with observations and models is vital in meeting this need.

Climate Research: improve understanding of coupling between the water cycle and the carbon cycle in land-atmosphere interactions and then represent in climate models.

Interpreting satellite estimates of precipitation and resolving discrepancies in terms of the probability distribution of precipitation events. Inter-comparisons of datasets combined with forward modelling of satellite radiances will help to improve agreement and understanding in relation to climate monitoring and research.

C.13.4 Main Partners

ESA, Hadley centre/Met Office, ECMWF, NERC National Centre for Atmospheric Research.

C.13.5 Envisaged Evolution in the Centre's Climate Role

More focus on modelling and prediction and studying and interpreting model-data errors at the process level.

Need to improve methods for downscaling climate space-time information (strong drive from government).

C.13.6 Role in the Generation of ECVs

In the HadIR project a homogenous set of microwave and infra-red radiances, will be generated applying cloud clearing and using coinciding, overlapping overpasses to set calibration, correct orbit drift.

Users: climate modellers interested in water vapour feedback and moist processes, project partners: Met Office, Edinburgh; funding until 2014.

More specifically NCEO is involved in the generation of the following ECVs:

a) Atmospheric ECVs (upper-air)
- temperature
- water vapour
- cloud properties

b) Atmospheric ECVs (composition)
- ozone
- methane
- other long-lived GHGs

c) Oceanic
- SST
- Sea Ice
- Ocean Colour
- Current

d) Terrestrial
- snow cover
- albedo
- leaf cover
- fAPAR
- LAI
- fire disturbance

C.13.7 Unfulfilled Requirements for CDRs

For climate model evaluation it would be valuable to have a CDR of air-sea fluxes of heat and freshwater. Similarly, air-sea fluxes of CO2.

Upper and deeper ocean heat content properly corrected to be accurate on climate timescales and properly adjusted for bias would be tremendously useful for validating climate models and for detection attribution studies. Both in-situ and satellite data could help in the construction, particularly in gap filling for sparse historical observations.

C.14 PIK

No response to questionnaire - summary information to be extracted from web-site material.

C.14.1 Main Contributions

C.14.2 Particular Strengths

C.14.3 Challenges

C.14.4 Main Partners

C.14.5 Envisaged Evolution in the Centre's Climate Role

C.14.6 Role in the Generation of ECVs

C.14.7 Role in the maintenance of CDRs

C.14.8 Information Passed to Other Centres

C.14.9 Unfulfilled Requirements for CDRs

C.15 WMO - GAW

C.15.1 Main Contributions

The WMO Global Atmosphere Watch (GAW[38]) programme (http://www.wmo.int/gaw) is the core of the GEO atmospheric carbon cycle and ozone observational framework. It is a unique international framework recognized by the Global Climate Observing System in its implementation plan to the UNFCCC. The GAW programme performs observation and analysis of the ECVs connected with atmospheric composition. Global ozone, carbon dioxide and methane observational networks are recognized by GCOS. Aerosol observations are also a part of the GAW programme.

Of all the climate related activities in the GAW programme, 60% is monitoring of the chemical ECVs and 40% is Climate Research.

GAW is not involved in climate prediction.

C.15.2 Particular Strengths

The GAW programme coordinates the activities of the observational network, and includes a Central Calibration Laboratory maintaining primary standards and the WMO World Reference Scales for ECVs connected with atmospheric composition. It includes World and Regional Calibration Centers maintained by WMO partners (three of them are situated in Europe), performs station audits, develops standard operational procedures and measurements guidelines and manages a rolling-review process for the data quality objectives and measurement requirements. Measurements data after quality control are submitted, archived and disseminated by the World Data Centers (for all chemical ECVs). These sets of data are used for global products and assessments preparation. In this way GAW implements the end-to-end approach.

C.15.3 Challenges

It is necessary to fill in the gaps in observations, to integrate different platforms including satellite and to adjust Data Quality Requirements and Central Facilities to the new measurement techniques. The latter two issues are addressed though regular expert meetings. The extension of the network can be reached by increasing the awareness and interest in different countries in GAW activities.

C.15.4 Main Partners

GAW is a global programme. Chemical ECVs are measured worldwide. In particular CO_2 measurements are performed in 54 countries around the globe, including 19 European countries.

C.15.5 Envisaged Evolution in the Centre's Climate Role

GAW will continue its activities providing reliable observations and analysis of chemical ECVs which help to further understand the reasons for the observed climate change.

[38] The questionnaire was originally sent to WCRP and was forwarded to the WMO GAW programme

C.15.6 Role in the Generation of ECVs

GAW is involved in the generation of the atmospheric composition ECVs (Carbon Dioxide, Ozone, Methane, Other long-lived GHGs and Aerosol Properties).

C.15.7 Unfulfilled Requirements for CDRs

None noted.

APPENDIX D GCOS CLIMATE MONITORING PRINCIPLES

Effective monitoring systems for climate should adhere to the following principles[39]*:*

1. The impact of new systems or changes to existing systems should be assessed prior to implementation.

2. A suitable period of overlap for new and old observing systems is required.

3. The details and history of local conditions, instruments, operating procedures, data processing algorithms and other factors pertinent to interpreting data (i.e., metadata) should be documented and treated with the same care as the data themselves.

4. The quality and homogeneity of data should be regularly assessed as a part of routine operations.

5. Consideration of the needs for environmental and climate-monitoring products and assessments, such as IPCC assessments, should be integrated into national, regional and global observing priorities.

6. Operation of historically-uninterrupted stations and observing systems should be maintained.

7. High priority for additional observations should be focused on data-poor regions, poorly-observed parameters, regions sensitive to change, and key measurements with inadequate temporal resolution.

8. Long-term requirements, including appropriate sampling frequencies, should be specified to network designers, operators and instrument engineers at the outset of system design and implementation.

9. The conversion of research observing systems to long-term operations in a carefully-planned manner should be promoted.

10. Data management systems that facilitate access, use and interpretation of data and products should be included as essential elements of climate monitoring systems.

Furthermore, operators of satellite systems for monitoring climate need to:

(a) Take steps to make radiance calibration, calibration-monitoring and satellite-to-satellite cross-calibration of the full operational constellation a part of the operational satellite system; and

(b) Take steps to sample the Earth system in such a way that climate-relevant (diurnal, seasonal, and long-term interannual) changes can be resolved.

[39] *The ten basic principles (in paraphrased form) were adopted by the Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) through decision 5/CP.5 at COP-5 in November 1999. This complete set of principles was adopted by the Congress of the World Meteorological Organization (WMO) through Resolution 9 (Cg-XIV) in May2003; agreed by the Committee on Earth Observation Satellites (CEOS) at its 17th Plenary in November 2003; and adopted by COP through decision 11/CP.9 at COP-9 in December 2003.*

Thus satellite systems for climate monitoring should adhere to the following specific principles:

11. Constant sampling within the diurnal cycle (minimizing the effects of orbital decay and orbit drift) should be maintained.

12. A suitable period of overlap for new and old satellite systems should be ensured for a period adequate to determine inter-satellite biases and maintain the homogeneity and consistency of time-series observations.

13. Continuity of satellite measurements (i.e. elimination of gaps in the long-term record) through appropriate launch and orbital strategies should be ensured.

14. Rigorous pre-launch instrument characterization and calibration, including radiance confirmation against an international radiance scale provided by a national metrology institute, should be ensured.

15. On-board calibration adequate for climate system observations should be ensured and associated instrument characteristics monitored.

16. Operational production of priority climate products should be sustained and peer-reviewed new products should be introduced as appropriate.

17. Data systems needed to facilitate user access to climate products, metadata and raw data, including key data for delayed-mode analysis, should be established and maintained.

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

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

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

APPENDIX E GLOSSARY OF TERMS

E.1 Records

Environmental Data Record (EDR): typically a data record that is generated directly from archived Near Real Time Level 2 data.

Climate Data Records (CDRs): a time series of measurements of sufficient length, consistency and continuity to determine climate variability and change.

Fundamental Climate Data Record (FCDR): is a long-term data record (radiances for satellites), involving a series of instruments, with potentially changing measurement approaches, but with overlaps and calibrations sufficient to allow the generation of homogeneous products providing a measure of the intended variable that is accurate and stable enough for climate monitoring.

Thematic Climate Data Record (TCDR): consists of values or fields of geophysical variables derived from FCDRs. Satellite derived data sets, that address Essential Climate Variables (ECVs) based on Fundamental Data Records eventually become Thematic Climate Data Records (TCDR) which are extremely valuable for higher level climate applications such as variability and trend analysis.

Climate Information Records (CIRs): are higher-level information that can be derived from the TCDRs, such as drought indices or hurricane intensities, probability of extreme events etc.

E.2 Processing

Assimilation and Reanalysis: reanalyses are produced using fixed, modern versions of the data assimilation systems developed for numerical weather prediction (in the case of ECMWF). Reanalysis products are more suitable than operational analyses for use in studies of long-term variability in climate and are used increasingly in fields that require an observational record of the state of either the atmosphere or its underlying land and ocean surfaces.

Inter-calibration and Recalibration: intercalibration and recalibration are usually combined together within an overall calibration regime in order to:

- ensure consistency of satellite measurements from different instruments and programmes;
- tie these measurements to absolute references and SI standards;
- enable the recalibration of archived data.

Inter-calibration of satellite instruments involves relating the measurements of one instrument to those of another and can be achieved when the instruments are viewing the same scenes at the same time and from the same viewing angle. Or, for time series of archived satellite data, the overlapping records of two satellite instruments can be compared. The result of an inter-calibration is consistency, and the absence of any bias of one instrument's measurements with respect to the others.

To ensure in-situ data comparability and compatibility within observational networks, in-situ measurements also need proper calibration. As a first step, calibration establishes a relationship between the quantity values with measurement uncertainties provided by measurement standards, and corresponding quantity values provided by a measuring instrument or a measuring system with associated measurement uncertainties. As a second step, this information is used to establish a relationship in order to obtain a measurement result from the measuring system. In-situ calibration pre-supposes that the accepted standard and a scale are propagated to in-situ measurements. In this way it is ensured that all obtained data are on the same/known scale and can be compared to each other.

Re-processing: the re-processing of satellite data is synchronised with reanalysis cycles and involves the re-processing of satellite data to generate a coherent set of products that have been derived from the most recent product generation system.

E.3 Applications

Process Studies: are studies on processes that influence the climate and are essential for the understanding of the physics of the climate system in general, and to improve climate models and climate prediction.

Operational Climate Monitoring: involves the routine, statistical characterisation of parameters for a given period and region in relation to long-term averages. This information is widely used for the climate reports of the national weather services and for different application areas (e.g. solar power consultancy, model validation, parameterisation improvement).
Detection of Climate Change [RD.10]: Detection of climate change is the process of demonstrating that climate has changed in some defined statistical sense, without providing a reason for that change.

Attribution [RD.10]: Attribution of causes of climate change is the process of establishing the most likely causes for the detected change with some defined level of confidence.

Variability [RD.10]: Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all spatial and temporal scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability).

Climate Prediction [RD.10]: A climate prediction or climate forecast is the result of an attempt to produce an estimate of the actual evolution of the climate in the future, for example, from seasonal to decadal time scales. Since the future evolution of the climate system at such timescales may be highly sensitive to initial conditions, such predictions are usually probabilistic in nature.

Climate Projection [RD.10]: A projection of the response of the climate system to emission or concentration scenarios of greenhouse gases and aerosols, or radiative forcing scenarios, often based upon simulations by climate models. Climate projections are distinguished from climate predictions in order to emphasise that climate projections depend upon the emission/concentration/radiative forcing scenario used, which are based on assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realised and are therefore subject to substantial uncertainty.

Impact Assessment [RD.10]: The practice of identifying and evaluating, in monetary and/or non-monetary terms, the effects of climate change on natural and human systems.

Vulnerability [RD.10]: Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity.

Adaptation [RD.10]: Initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects. Various types of adaptation exist, e.g. anticipatory and reactive, private and public, and autonomous and planned. Examples are raising river or coastal dikes, the substitution of more temperature-shock resistant plants for sensitive ones, etc.

Mitigation [RD.10]: Technological change and substitution that reduce resource inputs and emissions per unit of output. Although several social, economic and technological policies would produce an

emission reduction, with respect to Climate Change, mitigation means implementing policies to reduce greenhouse gas emissions and enhance sinks.

APPENDIX F LIST OF ABBREVIATIONS

ACRE: Atmospheric Circulation Reconstructions over the Earth
AOPC: Atmospheric Observation Panel for Climate
ARM: Atmospheric Radiation Measurement
ASI: Agenzia Spaziale Italiana
AVHRR: Advanced Very High Resolution Radiometer
AWI: Alfred-Wegener-Institut
BfG: Bundesanstalt für Gewässerkunde
BNSC: British National Space Centre
BSRN: Baseline Surface Radiation Network
CBS: Commission for Basic Systems
CCI: Climate Change Initiative
CDR: Climate Data Record
CEOP: GEWEX Coordinated Energy and Water Cycle Observations Project
CEOS: Committee on Earth Observation Satellites
CGMS: Coordination Group for Meteorological Satellites
CIR: Climate Information Record
CLIVAR: Climate Variability and Predictability Experiment
CMA: Chinese Meteorological Agency
CMIP: Coupled Model Intercomparison Project
CNES: Centre National d'Études Spatiales
CNMCA: Centro Nazionale di Meteorologia e Climatologia Aeronautica
COP: Conference of the Parties
DLR: Deutsches Zentrum für Luft- und Raumfahrt
DWD: Deutscher Wetterdienst
EC: European Commission
ECMWF: European Centre for Medium-Range Weather Forecasts
ECSN: European Climate Support Network
ECV: Essential Climate Variable
EDR: Environmental Data Record
EEA: European Environment Agency
EIG: Economic Interest Group
EIONET: European Environment Information and Observation Network
EMEP: European Monitoring and Evaluation Programme
EO: Earth Observation
EPS: EUMETSAT Polar System
ESA: European Space Agency
ESSP: Earth System Science Partnership
EU: European Union
EUGENE: Improving coordination, visibility and impact of European GEOSS contributions by establishing a EUropean GEo Network
EUMETNET: Network of European Meteorological Services
EUMETSAT: European Organisation for the Exploitation of Meteorological Satellites
FAO: Food and Agriculture Organisation
FCDR: Fundamental Climate Data Record
FCT: Forest Carbon Tracking
GAW: Global Atmosphere Watch
GBRDN: GCOS Baseline River Discharge Network
GCI: GEOSS Common Infrastructure
GCOS: Global Climate Observing System
GCMP: GCOS Climate Monitoring Principles
GDAC: Global Data Assembly Center
GEO: Group on Earth Observations
GEOSS: Global Earth Observation System of Systems
GEWEX: Global Energy and Water Cycle Experiment
GFCS: Global Framework for Climate Services

GHG: Greenhouse Gas
GMES: Global Monitoring for Environment and Security
GMPP: GEWEX Modelling and Prediction Panel
GODAE: Global Ocean Data Assimilation Experiment
GOOS: Global Ocean Observing System
GOS: Global Observing System
GPCC: Global Precipitation Climatology Centre
GPCP: Global Precipitation Climatology Project
GRDC: Global Run-off Data Centre
GRP: GEWEX Radiation Panel
GUAN: GCOS Upper-Air Network
GRUAN: GCOS Reference Upper-Air Network
GSICS: Global Space-based Inter-Calibration System
GSN: GCOS Surface Network
GT-NET: Global Terrestrial Observing Network
GTOS: Global Terrestrial Observing System
GTS: Global Telecommunication System
IASI: Infrared Atmospheric Sounding Interferometer
ICOS: Integrated Carbon Observation System
ICSU: International Council for Science
IGBP: International Geosphere-Biosphere Programme
IJPS: Initial Joint Polar System
IOC: Intergovernmental Oceanographic Commission
IP: Implementation Plan
IPCC: Intergovernmental Panel on Climate Change
JAXA: Japan Aerospace Exploration Agency
JCOMM: Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology
JMA: Japanese Meteorological Agency
KNMI: Koninklijk Nederlands Meteorologisch Instituut
LMD: Laboratoire de Meteorologie Dynamique
MEXT: Ministry of Education, Culture, Sports, Science and Technology
MPI-M: Max Planck Institute for Meteorology
MSG: Meteosat Second Generation
MTG: Meteosat Third Generation
MTP: Meteosat Transition Programme
NASA: National Aeronautics and Space Administration
NCDC: National Climatic Data Center
NCEO: National Centre for Earth Observations
NDACC: Network for the Detection of Atmospheric Composition Change
NOAA: National Oceanic and Atmospheric Administration
NMHS: National Meteorological and Hydrological Service
NRT: Near Real-Time
OOPC: Ocean Observations Panel for Climate
PIK: Potsdam Institute for Climate Impact Research
QA4EO: Quality Assurance Framework for Earth Observation
RA: Regional Association
RCC: Regional Climate Centre
SAF: Satellite Application Facility
SBA: Societal Benefit Area
SBSTA:
SCIAMACHY: SCanning Imaging Absorption SpectroMeter for Atmospheric CHartographY
SCOPE-CM: Sustained, Coordinated Processing of Environmental Satellite Data for Climate Monitoring
SI: International System of Units
SIT: Strategic Implementation Team
SSM/I: Special Sensor Microwave Imager

TCDR: Thematic Climate Data Record
THORPEX: The Observing System Research and Predictability Experiment
TOPC: Terrestrial Observation Panel for Climate
UNEP: United Nations Environment Programme
UNESCO: United Nations Educational, Scientific and Cultural Organisation
UNFCCC: United Nations Framework Convention on Climate Change
USGS: United States Geological Survey
VOS: Voluntary Observing Ship Programme
WCC: World Climate Conference
WCRP: World Climate Research Programme
WGCV: Working Group on Calibration and Validation
WGEdu: Working Group on Education
WGISS: Working Group on Information Systems and Services
WGMS: World Glacier Monitoring Service
WIGOS: WMO Integrated Global Observing System
WIS: WMO Information System
WMO: World Meteorological Organisation
WMO SP: WMO Space Programme
WOAP: WCRP Observation and Assimilation Panel
WRMC: World Radiation Monitoring Centre
WWW: World Weather Watch