

**Fourth Report of the Government of the
Federal Republic of Germany
on
Systematic Climate Observations in Germany
as a contribution to
Germany's 6th National Communication
under the
United Nations Framework Convention on Climate Change**



**Set up by the German GCOS Coordinator
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Images on front cover: The Zugspitz meteorological observation building of DWD (top, ©Claudia Hinz, DWD) and a pyranometer used to measure broadband solar irradiance (©DWD)

Germany's report on global observing systems for climate

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1 Common issues

The present report is the second official report based on the reporting guidelines contained in decision UNFCCC 11/CP.13, focussing on Essential Climate Variables. It is updating Germany's fourth such report published in early 2010. The purpose of this document is to inform Parties to the UNFCCC on the situation with regard to Essential Climate Variables (ECVs) and to support the Global Climate Observing System (GCOS) secretariat when compiling new reports on the status of the global observing systems for climate.

Further background information is contained in the Second Report of the Government of the Federal Republic of Germany on Systematic Climate Observation in Germany provided as part of Germany's 4th National Communication in 2006.

GCOS is a system of observing systems for climate and is the climate observing component of the Global Earth Observing System of Systems (GEOSS) implemented by the Group on Earth Observations (GEO), as well as the core element of the observations and monitoring pillar of the recently established Global Framework for Climate Services (GFCS). Many German institutions contribute to the GEO Work Plan, and thereby in many cases are also supporting GCOS' implementation.

In Germany, competences for systematic long-term observation of the various variables describing the climate system are distributed among a number of different Federal Ministries. These are the Federal Ministry of Transport and Digital Infrastructure Federal Ministry of Transport, Building and Urban Affairs (BMVI) and its subordinate authorities German Meteorological Service (Deutscher Wetterdienst, DWD), German Federal Institute of Hydrology (BfG), and German Maritime and Hydrographic Agency (BSH) as well as the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) and its subordinate authorities Federal Environmental Agency (UBA) and the Federal Agency for Nature Conservation (BfN). Research funded by the Federal Ministry of Education and Research (BMBF), and research institutions also play an important role.

Moreover, Germany delivers significant contributions to European satellite observation systems developed and operated by the European Space Agency (ESA) and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) aiming at the detection of global climate changes. The German Aerospace Center (DLR) also implements a national space-based earth observation programme that contributes to the global climate observation capacities.

In order to improve usability and accessibility of geographical data and information at Federal, Länder and Community levels a German Geodata Infrastructure (GDI-DE) was established. GDI-DE is also linked with the European INSPIRE and the Global Spatial Data Initiative. At Federal level an inter-ministerial committee (IMAGI) has been established as early as 1998. Access to geo-data is facilitated by the GeoPortal.Bund on the Internet¹.

In fall 1993, a national GCOS Secretariat was established at the DWD in Offenbach to coordinate the co-operation among the institutions involved on a national level in climate observing systems. Today this is the responsibility of the GCOS German Coordinator funded by the DWD. In January 2013 a brochure titled "German Climate Observing Systems – Inventory report on the Global Climate Observing System (GCOS)" had been published in German. An English version will be available by end of 2013.

The BSH serves as national point of contact for the Global Ocean Observing System (GOOS).

IMAGI, GDI-DE, GCOS, and GOOS Coordinators are also interlinked with the German GEO Experts Group (D-GEO).

¹ www.geoportal.bund.de

1.1 German contributions to capacity development

In Germany the overall responsibility for technical cooperation is with the Federal Ministry for Economic Cooperation and Development (BMZ), the responsibility for scientific and technological cooperation with developing countries is with the Federal Ministry of Education and Research (BMBF).

Germany's contributions to the World Meteorological Organisations (WMO's) Voluntary Co-operation Programme come from several governmental organizations, and more and more support climate related activities. In general, investments in climate change-related projects are increasingly used to combine them with cooperation projects for the National Meteorological Services of developing countries.

The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH works worldwide in the field of development cooperation. Together with DWD the GIZ inter alia supports the Indonesian Meteorological Service with the Project „Data and Information Management for Adaptation to Climate Change“ (DATACLIM). The project has the objective to significantly improve the climate services of the Indonesian Meteorological Service BMKG in the field of adaptation to climate change through the introduction of a web-based information system. One important step is the recovery and digitalization of historical climate data and the establishment of an IT-based data workflow for historical and real time data. Another GIZ project in Uganda is established in collaboration with the Department of Meteorology, Ministry of Water and Environment (UNMA) in the field of adaptation to climate change and improvement of monitoring systems.

DWD is involved in the German Initiative SASSCAL (“Southern African Science Service Centre for Climate Change and Adaptive Land Management”). SASSCAL is a joint initiative of Angola, Botswana, Namibia, South Africa, Zambia and Germany in response to the challenges of global change. DWD supports the National Meteorological Services in their climate data management activities and climate data rescue. Additional capacity development activities have been proposed like climate monitoring products and capacity building in the application of satellite products. Furthermore SASSCAL plans a network of automatic weather stations, the first stations are planned to be installed in Angola, Zambia and Botswana. Again Zambia: A Climate Monitoring and Early Warning System for Weather-related Disasters shall be established. German Development Cooperation has been requested by the Government of Zambia to support the establishment of an Integrated Water Resources Management Information System (IWRMIS).

The Global Atmosphere Watch (GAW) Training & Education Centre (GAWTEC) since 2001 provides scientific guidance and instructions to GAW station personnel worldwide from global and regional stations. GAWTEC, operated through funds from the UBA and the Bavarian State Ministry for Environment, Health and Consumer Protection, is based at the Environmental Research Station "Umweltforschungsstation Schneefernerhaus" (UFS), which accommodates the high-alpine platform of the GAW Global Station "Zugspitze/ Hohenpeissenberg". GAWTEC is part of Quality Assurance / Science Assessment Centre (QA/SAC) Germany and responsible for training and education of station personnel from global and regional GAW stations by teaching measurement techniques and data analysis. Teaching (introductory courses and advanced training) is done by experts from UBA, the Swiss materials science and technology research institution EMPA and DWD. Special topics are covered by experts from universities and other research facilities. Generally there are two GAWTEC courses per year to provide technical assistance and training to station personnel and central facilities.

DWD has no own budget for technical cooperation and only limited financial resources to support the GCOS Cooperation Mechanism (GCM). This governmental support will be continued and hopefully can be extended.

1.2 Atmospheric observations

Systematic and long term observation of meteorological variables in Germany is the responsibility of the Deutscher Wetterdienst (DWD), the National Meteorological Service of Germany. Some observations of atmospheric composition and aerosol properties are also the responsibility of DWD, but most of the atmospheric composition and aerosol properties' observations are the responsibility of the UBA and the Länder. In addition the AWI is contributing observations in the Arctic and Antarctic.

1.2.1 The Global Precipitation Climatology Centre (GPCC)

The Global Precipitation Climatology Centre (GPCC) provides global precipitation analyses for monitoring and research of the earth's climate. The GPCC provides free access to its monthly gridded precipitation data sets for climate monitoring purposes and related research. The centre is operated by DWD and is a German contribution to the World Climate Research Programme (WCRP) and to the Global Climate Observing System (GCOS).

1.2.2 The CBS Lead Centre for GCOS Data – Europe

The CBS Lead Centre for GCOS Data for WMO Regional Association Europe (WMO RA VI) is also operated by Deutscher Wetterdienst (DWD). The World Meteorological Organization (WMO) Commission for Basic Systems (CBS) has designated a regional network of nine CBS Lead Centres for GCOS. They are responsible for collecting and providing the Essential Climate Variables (ECVs) in their regions and to support any follow-up action.

1.2.3 The World Radiation Monitoring Centre (WRMC)

The Baseline Surface Radiation Network (BSRN) is a project of the World Climate Research Programme (WCRP), the Global Energy and Water Experiment (GEWEX) and the GCOS. It is aimed to detect important changes in the Earth's radiation field at the Earth's surface which may be related to climate changes. To fulfil these objectives a central BSRN data archive is essential. This archive - called World Radiation Monitoring Centre (WRMC) – was established in 1991 under the leadership of Prof. Atsumu Ohmura at the Division of Climate Sciences at the Institute for Atmospheric and Climate Science, ETH Zurich, Switzerland. After 16 years of nearly continuous operation at ETH, the WRMC went through a transition that resulted in the re-establishment of the archive at the AWI, Germany.

The WRMC at AWI² is based on the Publishing Network for Geoscientific & Environmental Data PANGAEA. At the moment data from more than 7,000 station-month provided from more than 50 stations are available. A Google-like interface is used for searching and distributing BSRN-data via web. Each dataset is identified, shared and published by a persistent Digital Object Identifier (DOI). The WRMC at AWI offers output formats separated into radiation data, upper air sounding data and synoptic observations readable for a variety of widely-used software. The datasets always include all necessary metadata and citation information. Additional, links to the ftp-server³, containing the original station-to-archive-files, are available.

1.2.4 The Network for the Detection of Mesopause Change

In cooperation with the Argentinean organisation CONICET (Consejo Nacional de Investigaciones Científicas y Técnicas) DLR is coordinating the recently established international

² <http://www.bsrn.awi.de/>

³ <ftp://ftp.bsrn.awi.de>

and global Network for the Detection of Mesopause Change (NDMC⁴) with the mission to promote international cooperation among research groups investigating the mesopause region (~80-100 km height). NDMC connects presently about 50 measurement sites worldwide addressing ground-based airglow observations to derive temperature variability at the mesopause level. The main climate-oriented goal of NDMC is the early identification of climate change signals (due to the low air density and the efficient infrared radiation cooling to space the mesosphere is working as a natural amplifier). NDMC is affiliated with the Global Atmosphere Watch (GAW)-program of the WMO and with the Network for the Detection of Atmospheric Composition Change (NDACC) and is officially registered with the GEOSS component dedicated to climate, research, monitoring and assessment. NDMC will be further developed within the next years to take care for the entire mesosphere.

1.3 Oceanographic observations

Oceanographic observations are mainly the responsibility of the BSH and several research institutions such as AWI, the GEOMAR Helmholtz Centre for Ocean Research Kiel, the Centre for Marine and Atmospheric Sciences (ZMAW), the Institute of Environmental Physics (IUP-Bremen) and others.

1.4 Terrestrial observations

Depending on the terrestrial variable different government and research institutions at the Federal and Länder level are responsible. In Germany many terrestrial Essential Climate Variables are being observed. Phenological observations provide additional terrestrial variables. For some terrestrial ECVs observing sites are also funded in foreign countries.

1.4.1 The Global Runoff Data Centre (GRDC)

The Global Runoff Data Centre (GRDC) was established in 1988 at the Federal Institute of Hydrology (BfG) under the auspices of the WMO. It is a contribution of Germany to the World Climate Programme (WCP) of the WMO. WMO mandates and directly supports GRDC through its Resolution 21 (Cg XII, 1995: Request to the member states to provide GRDC with river discharge data) and Resolution 25 (Cg XIII, 1999: Free and unrestricted exchange of hydrological data). The main objective of the GRDC is the world-wide acquisition, storage and dissemination of historical and near real-time river discharge data in support of the predominantly water and climate related programmes and projects of the United Nations (UN), their specialised agencies and the scientific research community.

The provision of hydrological data by National Hydrological Services to the GRDC is for the majority of the countries only happening sporadically, despite WMO resolutions. The GRDC is seeking to improve and operationalize the provision of data for the benefit of the research community.

⁴ <http://wdc.dlr.de/ndmc>

1.5 Space-based observations

For the identification and assessment of changes in the climate system, satellites offer unique advantages: they provide continuous, seamless and timely data for regions where there are no or only sparse other observation data available; the data relating to various regions come from one and the same observing system; some information, such as the radiation budget at the top of the atmosphere, can only be determined by means of a satellite system.

1.5.1 Participation to relevant European Satellite Programmes

Germany is the largest contributor to all European satellite programmes of ESA, EUMETSAT and the EU relevant for climate monitoring.

Of particular relevance for the investigation of the processes within the climate system are the experimental (the Earth Explorers) and pre-operational (such as ENVISAT with its multitude of land, atmosphere and ocean sensors and the Earth Explorer's series) ESA Earth observation programmes. Notably since 2009 three relevant Earth Explorer Missions has been launched. The Gravimetry Mission GOCE was launched in March 2009 and provided decisive and very precisely measurements of the Earth's geoid until November 2013. Combined with altimetry observations this will significantly help to constrain ocean surface currents. SMOS and CryoSat-2 continue to provide observations of soil moisture, ocean salinity (SMOS) and ice dynamics in Polar Regions (CryoSat-2), important information on the climate system. In addition, the mission SWARM which is dedicated to very precise measurements of the Earth's magnetic field and its variation over time is ready for launch. Two missions (ADM-Aeolus and EarthCARE) which will provide information about the atmosphere, e.g. three-dimensional wind fields and cloud and aerosol parameters, will complement the Earth Explorer mission suite in 2015 and 2016.

ESA has also launched a major new programme dedicated explicitly to the generation of a number of Thematic Climate Records of ECVs, according to the GCOS implementation plan (GCOS-138). Germany is contributing over one third to the programme, much more than any other participating state. The first phase of the programme has been successfully carried out including about 13 ECV oriented projects. A second three-year phase starting in 2014 will complete the preparation for a semi-operational time series generation of those ECV. DLR contributes prominently to atmospheric and some terrestrial ECV projects; DWD makes use of its experience from CM SAF to lead the cloud ECV project. Other German entities are key players for the generation of the greenhouse gases ECVs and oceanographic ECVs.

Due to the longevity needed, operational satellites play the major role in the detection of variations or changes in the climate system. In Europe, the operation of meteorological satellites and the planning of appropriate successor systems are in the responsibility of EUMETSAT with its headquarters in Darmstadt, Germany. EUMETSAT operates the geostationary Meteosat satellites (First and Second Generation) and the European polar-orbiting meteorological satellite Metop (complementary with the NOAA satellites), all 3 series developed by ESA. The first data transmitted from a Meteosat satellite dates from 1977. Meteosat has been operating since 1977 above Europe, Africa and the Atlantic and over the Indian Ocean since 2005. Since 2002 the Meteosat Second Generation (MSG) is the primary service, with altogether 4 MSG satellites being secured. It is delivering considerably improved data with planned continuity at least until 2019. The development of the Meteosat Third Generation (MTG) with again improved payload (completely new, additional instruments) is already entering the development phase. MTG will secure data continuity and many new observations from about 2016 through to 2030. Also preparations for a Metop-Follow-on system have started which will provide data from about 2018 for the following 15 to 20 years. Furthermore, in mid 2008 EUMETSAT with the successful launch of the Jason-2 satellite, EUMETSAT, as

partner in the Franco-US JASON satellite ocean altimetry programme, provides operational near-real-time data to European users.

With the joint ESA/EU Copernicus, the previous Global Monitoring for Environment and Security (GMES) initiative, Europe will secure long-term continuity for many of the required climate related satellite observations of oceans, atmospheric chemistry, land surfaces, that have been initiated particularly by ESA's ERS and ENVISAT, but also other European programmes. ESA is coordinating the Copernicus Space Component and implements a Space Component Programme to build a core capacity for operational space-based Earth observation for Copernicus. A constellation of operational satellites, called "Sentinels", will dramatically increase Europe's capacity to monitor global surface and atmospheric processes. They will be of utmost importance for global climate monitoring purposes. Currently approved and funded are two SAR satellites (Sentinel-1, launches 2011 and 2015), two multispectral satellites (Sentinel-2, launches 2015 and 2017), two medium resolution land and ocean monitoring satellites (Sentinel-3, launches 2015 and 2017), two spectrometer instruments on EUMETSAT's geostationary MTG mission (Sentinel-4, launches 2019 and 2027) and a polar-orbiting spectrometer (Sentinel-5 precursor, launch 2013) to monitor atmospheric composition, including greenhouse gases. Germany is the largest contributor to ESA's Copernicus Space Component Programme.

Within the Copernicus programme DLR is playing a key role in the atmosphere section. From 2006 – 2009 DLR has been leading the ESA GSE project PROMOTE (the GSE for atmosphere) which demonstrated and evaluated products and services together with more than 60 end users for stratospheric ozone, UV radiation, air quality, aviation support and climate study support. The air quality services will move into the FP7-Copernicus downstream project PASODOBLE, which is also coordinate by DLR. DLR is also involved in the FP7-Copernicus core project for the atmosphere MACC and its follow-on MACC-2 with satellite long-term data provision (vertical ozone profiles, aerosol composition, solar radiation) and by leading the interface to users and downstream services.

1.5.2 EUMETSAT Satellite Application Facility (SAF) on Climate Monitoring (CM SAF)

Within the so-called Satellite Application Facilities (SAF) operated by EUMETSAT, the functions of the lead institution has been assigned to DWD for the tasks of deriving climate relevant parameters from data transmitted by the MFG, MSG EPS/Metop and other satellites and of establishing, operating and further developing the 'SAF on Climate Monitoring'. Under the responsibility of EUMETSAT, the SAFs form a European network of specialised centres for the exploitation of satellite data. The Satellite Application Facility on Climate Monitoring (CM SAF) is one of presently 8 such competence centres. CM SAF provides more than 40 Essential Climate Variables mainly related to the energy and water cycle. The Climate Data Records cover the Meteosat-Disk and, for polar orbiting satellites, the whole globe for time periods of up to 30 years.

In March 2012 the CM SAF, hosted by DWD, started its Second Continuous Development and Operations Phase (CDOP 2). CM SAF will continue to provide products (cloud parameters, radiation at surface and top of atmosphere, humidity) in support to climate monitoring and analysis on a routine basis.

1.5.3 Contributions of the German Aerospace Centre (DLR)

DLR is Germany's national research centre for aeronautics and space. As Germany's Space Agency, DLR is also responsible for the planning and implementation of the German space programme as well as international representation of Germany's space interests.

DLR is involved in various activities related to the provision of ECVs in the atmospheric, oceanic and terrestrial domains. Main activities include:

- Data systems as part of EO mission ground segments
- The World Data Center for Remote Sensing of the Atmosphere (WDC-RSAT)
- algorithm development for the retrieval of ECV related parameters from EO data
- contributions to CEOS Implementation Plan for Climate actions
- participation in GEO Work Plan tasks (e.g. Forest Carbon Tracking)

1.5.3.1 Data systems at DLR

As part of the operational ground segments of relevant EO missions operated by ESA and EUMETSAT, DLR is responsible for the generation, archiving and dissemination of specific products:

- D-PAF for ERS-1 and ERS-2
- D-PAC for ENVISAT
- Ozone Monitoring (O3M) SAF for MetOp-1 and MetOp-2

D-PAF and D-PAC are hosted by DLR's Applied Remote Sensing Cluster, formed by the Remote Sensing Technology Institute (IMF) and the Remote Sensing Data Centre (DFD). In the consortium for the Ozone Monitoring SAF the Applied Remote Sensing Cluster is responsible for some of the specified ozone products. In addition EO data from other missions, acquired by national and international stations, are analysed to yield climate related information. ECV related parameters retrieved comprise:

- GOME on ERS-2: total columns of O₃ and NO₂, cloud information
- SCIAMACHY on ENVISAT: O₃ vertical columns and profiles, NO₂ vertical columns and profiles, cloud information
- GOME-2 on MetOp-1 and MetOp-2: vertical columns of O₃, NO₂ and SO₂, tropospheric columns of NO₂, cloud information
- MERIS: regional Value Added information concerning clouds and aerosol
- TerraSAR-X: high resolution maps of ice coverage (related to IPY)
- NOAA AVHRR: regional Sea Surface Temperature

Whenever applicable, the acquired datasets are subject to reprocessing aiming at applying the most up-to-date retrieval algorithms. Example is the reprocessing of the complete SCIAMACHY measurement dataset obtained not only since the start of routine operations in August 2002 but also yet after the end of operations in April 2012.

Users can access these data using either DLR's Earth Observation on the Web (EOWEB[®]) interface or the corresponding tools of other mission providers⁵.

1.5.3.2 World Data Center for Remote Sensing of the Atmosphere

The World Data Center for Remote Sensing of the Atmosphere (WDC-RSAT) is hosted by DLR-DFD with mandates by ICSU, WMO and CEOS. WDC-RSAT gives the research community simplified access to a wide collection of continuously generated satellite-based data on the chemical composition and dynamical state of the atmosphere as well as to data on radiation, cloud-physical parameters and to data on the ground (e.g. land surface data such as the NDVI etc. as well as land and sea surface temperatures). This is achieved either by giving access to data stored at the centre resulting of systematic operations of basic dataset retrieval and value adding processes at DLR or by acting as a portal that contains links to other satellite data providers. The Memorandum of Understanding between DLR and WMO has been signed on 22 July 2009. WDC-RSAT will provide a one-stop shop for access to globally distributed satellite-based data sets starting with ozone and aerosol products and

⁵ <https://centaurus.caf.dlr.de:8443/>

contributes its own climate-related long-term datasets (basic satellite retrieval products and value-added products). WDC-RSAT serves as foundation of the new CEOS Atmospheric Composition Constellation (ACC)-Portal responding to the GEO 2009-2011 work plan and also serves the GEOSS Societal Benefit Areas Climate, Health, Weather, Disasters, and Energy. WDC-RSAT is also making significant contributions with regard to INSPIRE (interoperability of data centres, common metadata); it is furthermore acting as data publication agent, where datasets can be archived and published with a registered digital object identifier.

1.5.3.3 Retrieval algorithm development

A major effort is required to develop retrieval and data analysis algorithms. This is not only true for new methodologies but also for existing code which has to be continuously adapted to reflect recent progress. Initial prototype algorithms are usually developed by DLR facilities in cooperation with scientific institutes and further on transferred to operational processor systems. The goal is to provide for a timely delivery of high quality data products even in missions generating permanently high data volumes. Those will be carried out in many fields of application and for different types of sensors as for example for SAR-type, optical and atmospheric missions. Specifically, one focus is the new development of new algorithm and new retrieval methods in the SAR domain to extent the product portfolio and applications for coming missions. The other focus is the development of operational production chains from level 0 until level 2 or 3 for atmospheric applications.

1.6 Participation in CEOS Implementation Plan for Climate actions

The CEOS Implementation Plan for Climate⁶ in response to the GCOS implementation plan⁷ is comprised of 53 actions addressing space-based observations. They cover the atmospheric (20 actions), oceanic (11) and terrestrial (22) domains. For each action a Climate Action Team was established, with one or two persons acting as lead and a group of others as contributors. Each CEOS space agency was expected to nominate individuals. At DLR a point of contact was established, coordinating a team of experts participating in 15 climate actions. DLR extended its WDC-RSAT to be the foundation of the CEOS portal for the Atmospheric Composition Virtual Constellation (ACC) in close cooperation with NASA. In addition, DLR is also present in the further development of the space-based climate architecture originally initiated by WMO, Coordination Group for Meteorological Satellites (CGMS), and CEOS.

⁶ GCOS-154, 2011 at <http://gcos.wmo.int>

⁷ GCOS-138, 2010 at <http://gcos.wmo.int>

2 Atmospheric Essential Climate Variables

All atmospheric Essential Climate Variables (ECVs) are being measured in Germany. There is a general distinction in the responsibility of the observation of physical and chemical atmospheric ECVs. Several German institutes and organization support observing atmospheric ECVs outside the borders of Germany.

Systematic and long term observation of meteorological variables in Germany is the responsibility of the Deutscher Wetterdienst (DWD), the National Meteorological Service of Germany. Some observations of atmospheric composition and aerosol properties are also in the responsibility of DWD, but most of the atmospheric composition and aerosol properties' observations are the responsibility of the UBA and the Länder. In addition the AWI is contributing observations in the Arctic and Antarctic.

2.1 General information

Meteorological observations have a long tradition in Europe. State-owned weather services in Germany started collecting climate data at the midst of the 19th century, but only after the reunification of Germany in 1990 the data have been recorded and processed according to unified standards. With the use of automated stations, the frequency of measurements considerably increased, such that nowadays 183 primary weather stations record and store the data in intervals of one to 10 minutes. In addition, about 320 automated secondary weather stations with voluntary observations also measure and store climate relevant data in intervals of 1 to 10 minutes. About 515 automated precipitation stations have the same measurement intervals. Furthermore, there is still an additional large number (910) of conventional precipitation stations, operated by voluntary observers, which record precipitation once a day.

Relevant climatological requirements – for example, relative to the networks operated by the DWD – have always been given careful attention, since both real-time and climate applications and services benefit from the precision required for climatological purposes. For this reason, DWD recognizes and respects the GCOS Climate Monitoring Principles (GCMP) contained in decision UNFCCC 11/CP.13 for its primary weather stations and with some restrictions also for its secondary weather stations.

Eleven National Reference Stations (Aachen, Brocken, Fichtelberg, Frankfurt/Main, Görlitz, Hamburg-Fuhlsbüttel, Hohenpeissenberg, Lindenberg, Potsdam and Schleswig) are being operated in the national network. At these sites, conventional and new automatic measuring devices are operated in parallel. All measured data have been and are subjected to thorough quality checks and are stored in digital form.

2.2 Contributions to the GCOS Networks from international relevant stations

2.2.1 Contributions to the GCOS Surface Network (GSN)

In Germany five stations have been selected for the GCOS Surface Network i.e. four DWD stations and one station (Neumayer) is operated by the AWI in the Antarctic.

- Hamburg-Fuhlsbüttel (WMO-Nr. 10147)
- Lindenberg (WMO-Nr. 10393)
- Frankfurt/Main (WMO-Nr. 10637)
- Hohenpeissenberg (WMO-Nr. 10962)
- Neumayer (WMO-Nr. 89002)

The four DWD stations all belong to the network of National Reference Stations.

Hamburg-Fuhlsbüttel:

The Hamburg-Fuhlsbüttel station is an aeronautical meteorological office that was established in 1891 as an observatory. In 1938 the station was moved about 10 km from original location at the Deutsche Seewarte to the airport Hamburg-Fuhlsbüttel. In 1955, it was moved about 270 m to the west, and it is now located on the grounds of Hamburg Airport. In 1995, the station was moved again – this time, about 700 m to the south-west. In that same year, a transition was made to semiautomatic operation, and since then the station has automatically recorded air temperature (at heights of 2 m and 5 cm), ground temperature, humidity, air pressure, wind direction and wind speed, as well as precipitation and sunshine duration. In 2008 the instrumentation and data collection system on this station has been changed to a modern and homogeneous system, now generally used throughout Germany.

Due to its long term data records and its representativeness for the northern part of Germany Hamburg-Fuhlsbüttel has been selected as a National Reference Station in May 2008.

Lindenberg:

The Lindenberg Meteorological Observatory - Richard Assmann Observatory (MOL-RAO) was established in 1905 by Richard Assmann, the discoverer of the stratosphere, and it began taking measurements in the same year. In the years 1956 and 1971, the observation/measurement site has consecutively moved by around 200 m. Semi-automatic operation began already in 1992. Like the Hamburg-Fuhlsbüttel station, this station automatically measures air temperature at heights of 2 m and 5 cm, along with ground temperature, humidity, air pressure, wind direction and wind speed, precipitation and sunshine duration.

Due to its long term data records and its representativeness for the eastern part of Germany Lindenberg has been selected as a National Reference Station in May 2008.

Frankfurt/Main:

The meteorological station is located at Frankfurt airport, 12 km southwest of the city centre. The first meteorological measurements have been taken in December 1947. After nine years, in 1956 the station has been moved 800 m to the southeast. Since then, the station is located at the eastern part of the airport, between the two runways and the highway A5. The semi-automatic operation started already in 1984. Due to its long term data records and its representativeness for the centre of Germany, Frankfurt/Main has been selected as a National Reference Station in May 2008.

Hohenpeissenberg:

Measurements at the Hohenpeissenberg Meteorological Observatory started in 1781, within the framework of the Societas Meteorologica Palatina. This station has undergone the transition to semi-automatic operation in 1993. Since then, the station has automatically recorded air temperature at heights of 2 m and 5 cm, along with ground temperature, humidity, air pressure, wind direction and wind speed, precipitation and sunshine duration.

Due to its long term data records and its representation to the low mountain range of Germany Hohenpeissenberg has been selected as a National Reference Station in May 2008.

Neumayer:

Since March 1981 a meteorological observatory programme is carried out continuously at Neumayer Station (GvN, 70°37'S, 8°22'W). On March 16, 1992 the programme has been extended and transferred to the second Neumayer Station (NM II, 70°39'S, 8°15'W), in close proximity to the former one. The snow-covered Neumayer II station was located on an ice shelf of 200 metres thickness which is almost completely flat. Today, since February 20, 2009, the third station (Neumayer III, 70°40'S, 8°16'W) with the meteorological observatory is an integral part of many international networks, mostly associated with the World Meteorological Organization (WMO).

As far as possible, all stations within DWD and AWI network comply with the GCMPs. The effects of introducing new measuring systems and of changing existing systems are checked by DWD via parallel measurements at selected stations.

Continued operation of GSN and GUAN stations is guaranteed by virtue of their status as aeronautical meteorological office or meteorological observatory within the network of National Reference Stations.

2.2.2 Contributions to the GCOS Upper Air Network (GUAN)

One DWD station in Germany and one AWI-operated station in the Antarctic have been selected to contribute to the GCOS Upper Air Network (GUAN):

- Lindenberg (10393) and
- Neumayer (89002).

Lindenberg:

At Lindenberg station, radiosondes are launched at 00, 06, 12, and 18 UTC, which also include upper tropospheric and lower stratosphere wind measurements. Radiosounding in Lindenberg started in 1957, and since July 2004 they have been updated to GPS navigation. In February 2004, Lindenberg has replaced Stuttgart-Schnarrenberg (10739) as the GUAN station of Germany. The MOL-RAO focuses in a unique manner on calibrating humidity measuring instruments on a routine basis by means of radiosondes. The aim is to achieve highest quality standards for humidity profile measurements from radiosondes (with the accuracy being better than an uncertainty of 1 % in relative humidity). Due to the synergy of the high-temporal-resolution measurements (e.g. GEWEX / GvaP water vapour measurements) at the MOL-RAO, the radiosounding assumes even more importance as it also allows for cross-calibrations between the existing measuring systems.

Neumayer:

Three-hourly synoptic observations and daily upper air soundings (12 UTC) including weekly ozone profiling are the main part of the measurements at Neumayer station. Additional, intensive surface radiation measurements are performed in the framework of the "Baseline Surface Radiation Network BSRN".

2.2.3 Contributions to Global Atmosphere Watch (GAW)

Germany contributes to the Global Atmosphere Watch (GAW) with the following 4 stations:

- GAW Global Station at Zugspitze/Hohenpeissenberg,
- GAW Global Station at Neumayer (Antarctic, operated by AWI),
- GAW Regional Stations at Schauinsland and Neuglobsow.

Zugspitze/Hohenpeissenberg

The Zugspitze/Hohenpeissenberg GAW station consists of 2 platforms: one is based within the Zugspitze environmental research station and one is situated at the Hohenpeissenberg Meteorological Observatory of DWD.

The Hohenpeissenberg Meteorological Observatory has a long tradition of taking meteorological and atmospheric chemistry measurements. The beginning of its series of uninterrupted meteorological observations dates back to 1781. 1967 saw the start of the ozone measurement programme that has now developed into a vast and extensive programme. In 1994, the installation of the GAW station started, and the Observatory's measurement programme was considerably expanded. Pursuant to the GAW requirements for Global Stations, measured quantities include reactive trace gases, physical and chemical properties of aerosols,

substances contained in precipitation and a range of auxiliary data needed to interpret atmospheric chemistry data.

The Global Station at the Zugspitze is operated jointly by the UBA and DWD. Starting in 1999, UBA established the platform Zugspitze at the site Schneefernerhaus, situated at 2656 m asl, approximately 300 m below the Zugspitze summit. DWD measures meteorological components, aerosol concentrations and various radionuclides whereas the UBA deals with reactive (Ozone, CO, NO, NO₂, NO_x, NO_y, PAN, VOCs, carbonyl samples) and trace gases relevant to climate (CO₂, CH₄, N₂O, SF₆, halogenated carbons), as well as aerosol related data, e.g., size distributions of fine and ultrafine particles in the range of 10-800 nm and precipitation chemistry.

The Zugspitze/Hohenpeissenberg Global Station co-ordinates its activities and co-operates closely with the observatories at the Hoher Sonnblick in Austria and the Jungfrauoch in Switzerland. Its neighbouring stations are situated to the East in Tibet, to the North at the Arctic Circle, to the West on the Irish Isles and to the South on the Canary Islands. What makes the GAW network so unique is the fact that the concentration measurements are made in the free troposphere above a densely populated and comparatively high industrialised area. The Zugspitze/Hohenpeissenberg GAW station largely fulfils the 10 GCMP.

Schauinsland: (regional station)

The air quality measuring site exists since the middle of the sixties. It was founded by the German Research Foundation ('Deutsche Forschungsgemeinschaft', DFG) as part of a German monitoring network to investigate the composition of unpolluted air and background air pollution. In 1974 the network was integrated into the then newly established UBA. In the 1960s and early 1970s a lot of pioneering work concerning the development of methods to measure trace substances in air was necessary. Some measuring systems have been developed by the station staff themselves. Today, the site is one of seven stations of the German air monitoring network operated by the UBA. It serves for long-term monitoring of long-range transboundary air pollution within the scope of international programmes.

Over the years, the observational programme has changed according to new and emerging questions. While at the beginning sulphur dioxide was a main concern, its concentration in Germany today is very low. At the beginning of the 1990ies the tropospheric ozone became more important and a national ozone early warning system was installed. Recently one focus is on components having global effects, such as greenhouse gases.

Neuglobsow: (regional station)

From 1979 to 1991 the Stechlin Lake District station has been operated as a background site to monitor air pollutants and precipitation as well as their effects on ecosystems. In 1991 the monitoring site Neuglobsow was integrated into the German air monitoring network operated by the UBA.

The monitoring site Neuglobsow now serves as a regional GAW station as well as an EMEP site (European Monitoring and Evaluation Programme). In addition, Neuglobsow is one of two German Integrated Monitoring sites, the international cooperative programme of the Convention on Long-range Transboundary Air Pollution (CLRTAP) which investigates the effects of air pollutants on ecosystems.

DLR's WDC-RSAT is a contribution to GAW as one of the WMO-GAW world data centres. Additionally, WDC-RSAT serves the German Environmental Research Station Schneefernerhaus (UFS), which is also a WMO-GAW Global Station, with all aspects related to data management. WDC-RSAT allows the UFS access to satellite based data (often in near-real-time) and services as well as to related value added products.

2.3 Other networks for monitoring weather and atmospheric composition

2.3.1 DWD - National observing network

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 database 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 Länder 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 (10.03.2014):

- **183** main meteorological watch offices and automatic weather stations, of which **32** are manned around the clock, **28** are manned part time and **123** are fully automatic weather stations;
- **27** surface weather stations run by the German Federal Armed Forces;
- **1784** voluntary weather stations carried out by non-professionals, of which **835** are automatic stations for 10-minute data (**62** stations measure only wind parameter and **483** only precipitation);
- **9** upper-air stations (**5** stations are auto launcher and **2** stations measure additionally ozone);
- **4** upper-air stations run by the German Federal Armed Forces.

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

- **503** stations measuring temperature and humidity;
- **210** stations measuring air pressure;
- **1928** stations measuring precipitation;
- **297** stations measuring wind, of which **68** are part of the storm warning network;
- **299** stations measuring sunshine duration

At more than 500 stations two or more variables are measured. In addition the Länder are running their own observing networks. Presently DWD is receiving precipitation data from

about 250 stations from Bavaria, Rhineland-Palatinate, Baden-Wuerttemberg, and, North Rhine-Westphalia. It is estimated that in total the Länder could contribute about 500 additional precipitation stations.

2.3.2 DWD - cooperation with other organizations

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.

2.3.3 AWI - cooperation with other organizations

The data from Neumayer station helps to close significant gaps in the global weather and climate observing networks. The station is part of the GCOS-, GAW-, the Network for the Detection of Atmospheric Composition Change (NDACC, the formerly Network for Detection of Stratospheric Change, NDSC) and the Baseline Surface Radiation Network (BSRN). Its data are also exchanged via WMO's Global Telecommunication System (GTS).

Another important station with global monitoring is the AWIPEV station (former Koldewey station) in Ny Ålesund on Spitsbergen.

2.3.4 UBA - cooperation with other organizations

Data from GAW stations Zugspitze, Schauinsland and Neuglobsow also are integrated in the national UBA background air quality network which contributes to EMEP.

Schauinsland and Zugspitze are integrated in the EU Project Carbo Europe. Both stations serve with their data as platforms for other scientific research projects in cooperation with external partners. Schauinsland contributes its data to the EU Project ICOS. Within the framework of the environmental research station Schneefernerhaus, station Zugspitze cooperates for the accomplishment of masters and doctorates with Institute for Bioclimatology, Technical University Munich and Chair for atmospheric chemistry, University Bayreuth and institute for radiation research, Helmholtz Research Center, Munich.

Station Zugspitze is part of the project group for aerosols, climate and health which has been initiated by the center for environmental research of University Augsburg. Also there is a long term cooperation with the Bulgarian GAW regional station BEO MOUSALLA in 2925 m a.s.l. at Rila Mountain. Essential topics are: automation of data quality assurance and data processing and long term trend observation.

Schauinsland, Zugspitze and Neuglobsow are part of the German ultrafine aerosol network GUAN which measures ultrafine aerosols and black carbon in a selection of 14 representative measurement sites covering the area of Germany.

Neuglobsow also serves as an EMEP site as well. In addition, the station is one of two German Integrated Monitoring sites within the international cooperative programme of the CLRTAP which investigates the effects of air pollutants on ecosystems.

All in all there exist two Regional GAW stations and one Global Station in Germany

2.4 National meteorological observations

The following tables (1a – 1c) give some detailed information on the contributions of the national observations.

General information for the historical data:

The National Climate Data Centre (Nationales Klimadatenzentrum, NKDZ) at DWD provides historical and current climate data observed in Germany. The database contains the data generated by the surface and upper air observational networks of DWD. The time resolution of the observations comprises minutes, hours, days and months: the number of stations differs according to observation time, time resolution and element. The length of time series may at some stations extend 100 years and more. The NKDZ provides products generated from the observational data like climate indices for months, seasons and years and produces grid fields with a 1-km-resolution as basis for more advanced products like time series of area means.

Not all records of climate data generated before 1969 are yet digitized and imported into the database of the NKDZ. So DWD is currently running a project for data rescue (KLIDADIGI) with the aim of saving and digitizing old, not yet digitized observation records and considerably enlarging the number of time series longer than 50 years.

The aim of the NKDZ is the archiving and documentation of the data, the establishment of quality control procedures to the historical data and the provision of access and distribution methods to make the data available for application and research. The current data of the NKDZ are distributed via the GTS. A web access to the historical database and a data catalogue according to ISO metadata standards is provided on the web⁸. All precipitation data are provided by the GPCC (Global Precipitation Climatology Centre).

Another project HISTOR, DWD aims in rescuing marine weather observations contained in 37.000 logbooks of sailing ships and steamer from the period of “Norddeutscher Lloyd” and “Deutsche Seewarte” from 1868 to 1945. The meteorological data and meta data included in the logbooks are digitized, quality controlled, stored and provided for purposes of climate research and climate modelling.

2.4.1 Surface-Based Atmospheric ECV's

The following gives some explanations for each row of Table 1a).

GCOS Surface Network (GSN):
see section 2.2.1

Full World Weather Watch / Global Observing System (WWW/GOS) surface network:
(see section 2.3.1)

The network of weather stations in Germany consists of:

- **193** main meteorological watch offices and automatic weather stations, including 10 surface weather stations run by the German Federal Armed Forces or other organizations with hourly measurements
- **17** surface weather stations run by the German Federal Armed Forces with temporarily measurements
- **1784** secondary weather and precipitation stations with voluntary observers, of which 835 are automatic stations for 10-minute data (62 stations measured only wind parameter and 483 only precipitation)

⁸ www.dwd.de/cdc

Baseline Surface Radiation Network (BSRN):

A total of three stations are involved in BSRN: the DWD station Lindenberg and the two AWI stations Neumayer and Spitsbergen.

The WRMC with all BSRN measurements is managed by the AWI.

Solar radiation and radiation balance data:

These parameters were measured at selected 121 stations. 34 stations are equipped with pyranometer (high level) and 85 stations with Scanning Pyrheliometer Pyranometer (SCAPPs, lower level).

Ocean drifting buoys:

Germany runs no drifting buoys on its own, but contributes to EUCOS/E-SURFMAR. More information is given in chapter 3.

Moored buoys:

The eight maritime stations currently consist of:

- 3 moored buoys Nordseeboje II
 Nordseeboje III
 Fehmarnbelt
- 1 navigation beacon Bake Zulu
- 2 lightvessels GW/EMS (TW Ems)
 G-Bight (Deutsche Bucht)
- 2 lighthouses Alte Weser
 Leuchtturm Kiel

The four lightvessels and lighthouses are equipped with DWD standard sensors and therefore assigned to DWD's primary observing network (see table 1a).

The data from the moored buoys, the lightvessels und the lighthouses are provided international.

Voluntary Observing Ship Climate Project (VOSCLim) ships

Germany currently operates 62 VOSCLim ships having generated about 20.000 observations in 2012. It is part of 10 countries worldwide with about 300 recruited VOSCLim ships. As for the entire VOS fleet (refer chapter 3), the German Meteorological Service funds the meteorological equipment for the merchant ships and research vessels taking part in the VOSCLim project.

Ocean reference Mooring Network and sites on small isolated islands:

Is not installed from Germany

Table 1a: National Contributions to the Surface-Based Atmospheric ECV's

Contributing Networks specified in the GCOS Implementation Plan	ECV's	Number of Stations or Platforms currently operating	Number of Stations or Platforms operating in accordance with the GCMPs	Number of Stations or Platforms expected to be operating in 2015	Number of Stations or Platforms providing data to the International Data Centres	Number of Stations or Platforms with complete historical record available in International Data Centres
GCOS Surface Network (GSN) see section 2.2.1	air temperature	4 DWD 1 AWI	4 DWD 1 AWI	4 DWD 1 AWI	4 DWD 1 AWI	4 DWD 1 AWI
	precipitation	4 DWD 1 AWI	4 DWD 1 AWI	4 DWD 1 AWI	4 DWD 1 AWI	4 DWD 1 AWI
Full World Weather Watch/Global Observing System (WWW/GOS) surface network see section 2.3.1	air temperature, air pressure, wind speed/ direction, water vapour	183 primary DWD 320 secondary DWD (some wind only; no pressure) 27 others ^a	503 DWD 27 others ^a	183 DWD	183 DWD 19 others ^a	183 DWD
	precipitation	183 primary DWD 1784 secondary DWD (835 autom.) 27 others ^a	183 DWD 27 others ^a	183 DWD	183 DWD 27 others ^a	183 DWD
Baseline Surface Radiation Network (BSRN)	surface radiation	1 DWD 2 AWI	1 DWD 2 AWI	1 DWD 2 AWI	1 DWD 2 AWI	1 DWD 2 AWI
Solar radiation and radiation balance data	surface radiation	121 DWD	34 DWD	121 DWD	8 DWD	8 DWD
Ocean drifting buoys	air temperature, air pressure	---	---	---	---	---
Moored buoys	Air temperature, air pressure	8 DWD	8 DWD	8 DWD	7 DWD	4 DWD
Voluntary Observing Ship Climate Project (VOSCLIM) ships	Air temperature, air pressure, wind speed/ direction, water vapour	62 DWD	62, as far as this is possible for a ship	90 DWD	62 DWD	---
Ocean reference Mooring Network and sites on small isolated islands	Air temperature, wind speed/ direction, air pressure	---	---	---	---	---
	precipitation	---	---	---	---	---

^a others = most of them operated by 'Bundeswehr' (German Federal Armed Forces)

2.4.2 Upper-Air Atmospheric ECV's

The following gives some explanations for each row of Table 1b).

GCOS Upper Air Network (GUAN):
see section 2.2.2

Full WWW/GOS Upper-Air Network:

DWD has 9 operating systems (Norderney [automated], Schleswig, Greifswald, Lindenberg, Meiningen [automated], Hohenpeissenberg, Essen [automated], Stuttgart [automated], München-Oberschleissheim [automated]) and 5 stations at the German Federal Armed Forces (Bergen, Meppen, Idar-Oberstein, Kümmersbruck and Altenstadt). Three stations (Bergen, Idar-Oberstein and Kümmersbruck) are involved in the national basic meteorological observing network.

The Neumayer station operated by AWI is also involved in the WWW/GOS upper-air network.

Table 1b: National Contributions to the Upper- Air Atmospheric ECVs

Contributing Networks specified in the GCOS Implementation Plan	ECVs	Number of Stations or Platforms currently operating	Number of Stations or Platforms operating in accordance with the GCMPs	Number of Stations or Platforms expected to be operating in 2015	Number of Stations or Platforms providing data to the International Data Centres	Number of Stations or Platforms with complete historical record available in International Data Centres
GCOS Upper Air Network (GUAN)	Upper-Air-Temperature, Upper-Air Wind Speed/ Direction, Upper-Air Water Vapour	1 DWD 1 AWI	1 DWD 1 AWI	1 DWD 1 AWI	1 DWD 1 AWI	1 DWD 1 AWI
Full WWW/GOS Upper Air Network	Upper-Air-Temperature, Upper-Air Wind Speed/ Direction, Upper-Air Water Vapour	9 primary DWD 3 Bw^a 1 AWI	9 DWD 3 Bw^a 1 AWI	9 DWD 3 Bw^a 1 AWI	9 DWD 3 Bw^a	9 DWD 3 Bw^a 1 AWI

^aBw – German Federal Armed Forces (Bundeswehr)

2.4.3 Atmospheric Composition

The following gives some explanation for each row of Table 1c).

World Meteorological Organization / Global Atmospheric Watch (WMO/GAW) Global Atmospheric CO₂ and CH₄ Monitoring Network:

Generally there are four stations observing these variables: the two GAW regional stations Schauinsland and Neuglobsow, Neumayer (also part of GSN and GUAN networks) and the station Zugspitze/ Schneefernerhaus.

Starting in 2014, additional CO₂ and CH₄ measurements will be performed at the tall tower station Hohenpeissenberg. The same measurements will start at Lindenberg in 2015.

WMO/GAW ozone sonde network:

The stations Lindenberg, Hohenpeissenberg, Neumayer and Ny Ålesund/AWIPEV measure ozone with ozone-sondes. At Hohenpeissenberg in addition an ozone-Lidar is used to detect ozone.

WMO/GAW column ozone network:

Lindenberg, Hohenpeissenberg, Neumayer and Ny Ålesund/ AWIPEV are involved in the WMO/GAW column ozone network.

WMO/GAW aerosol network:

The aerosol optical depth is detected at the four stations Lindenberg, Hohenpeissenberg, Zingst (a GAW contributing station), and Zugspitze/ Schneefernerhaus.

Other aerosol properties are additionally measured at Schauinsland, Neuglobsow, Neumayer and Ny Ålesund/AWIPEV. At Lindenberg only the optical depth is measured but no other components.

Table 1c: National contributions to the Atmospheric Composition

ECVs Contributing Networks specified in the GCOS Implementation Plan	ECVs	Number of Stations or Platforms currently operating	Number of Stations or Platforms operating in accordance with the GCMPs	Number of Stations or Platforms expected to be operating in 2015	Number of Stations or Platforms providing data to the International Data Centres	Number of Stations or Platforms with complete historical record available in International Data Centres
World Meteorological Organization/ Global Atmospheric Watch (WMO/GAW) Global Atmospheric CO₂ & CH₄ Monitoring Network	Carbon Dioxide (CO ₂)	4	4	6	4	3
	Methane (CH ₄)	4	4	6	4	3
	Other greenhouse gases	3	3	3	3	2
WMO/GAW ozone sonde network^a	Ozone	4	4	4	4	2
WMO/GAW column ozone network^b	Ozone	4	2	4	4	2
WMO/GAW Aerosol Network^c	Aerosol optical depth	4	4	4	4	4
	Other Aerosol Properties	7	7	7	7	7

^a Including SHADOZ, NDACC, remote sensing and ozone sondes.

^b Including filter, Dobson and Brewer stations.

^c Including AERONET, SKYNET, and BSRN.

2.5 Satellite observations

Satellite systems have become the major contribution to the global observing system for climate monitoring because of their global coverage, and uniform observing system for all parts of the globe. Long-term continuity of many satellite missions in combination with reprocessing of archived satellite data based on careful inter-sensor calibration, taking into account the GCOS systematic observing requirements for satellite-based products for climate (GCOS-107), facilitate the generation of ECV satellite products for climate monitoring purposes. The satellite systems have to be completed by in-situ measurements for calibration purposes and for the provision of ECVs which cannot be provided in sufficient quality from space data.

Like the other European meteorological services, DWD also coordinates its satellite matters via EUMETSAT, the European Organisation for the Exploitation of Meteorological Satellites. Therefore, all statements related to plans to ensure availability of past and future data and metadata records of satellite measurements for the atmospheric ECVs and associated global products contained in Table 2 are related to EUMETSAT. Some indications are directly introduced in Table 2 below. For more details it is recommended to visit the EUMETSAT home page⁹ or the information provided by EUMETSAT via CEOS. DWD as a major Member State is strongly involved in the planning and decision processes of EUMETSAT. This concerns the current satellite systems of EUMETSAT, the planning of future programmes such as Meteosat Third Generation (MTG), EPS-SG (EPS Second Generation) and Jason-Follow-on (Jason-3, from 2014 onwards) and Jason Continuity of Service (Jason-CS, after 2018) as well as archiving aspects. The current satellite systems of EUMETSAT cover the period up to 2015 till 2020 and the future EUMETSAT satellite systems will cover the period roughly from about 2015 till 2030 and beyond.

EUMETSAT has a decentralised network of Satellite Application Facilities (SAFs) for the generation of products from EUMETSAT satellite data. Of special relevance to GCOS is the Satellite Application Facility on Climate Monitoring (CM SAF) which is hosted by DWD, and the Satellite Application Facility for Ozone (O3M SAF) with major contributions from DLR. Detailed information on the CM SAF and the O3M SAF can be retrieved from the Internet⁷ (see also 1.5.2).

The GCOS climate monitoring requirements for satellite based products (GCOS-107) are taken into account when the future satellite systems of EUMETSAT are planned. According to Article 2 of its convention one of the objectives of EUMETSAT is to contribute to the operational monitoring of the climate system and the detection of global climatic changes. In fulfilling its objectives EUMETSAT has also to take into account, as far as possible, the recommendations of WMO, which are corresponding to GCOS requirements. Of particular importance for fulfilling GCOS requirements by means of space-based observations are two WMO initiatives: GSICS (Global Space-based Inter-calibration System) and SCOPE-CM (Sustained Coordinated Processing of Satellite Data for Climate Monitoring [SCOPE-CM, formerly named R/SSC-CM]). Detailed information on both initiatives are available via the WMO Internet pages⁶. As host of the SAF on Climate Monitoring (CM SAF), DWD contributes directly to SCOPE-CM.

⁹ <http://www.eumetsat.int>

⁷ <http://www.cmsaf.eu>

⁶ <http://www.wmo.int>

Table 2. Global products requiring satellite observations – atmospheric essential climate variables

ECVs/ Global Products requiring Satellite Observations	Fundamental Climate Data Records required for Product Generation (from past, current and future missions)
<p>Surface Wind Speed and Direction Surface vector winds analyses, particularly from reanalysis</p>	<p>Passive microwave radiances and scatterometry Requirement is fulfilled: The METOP satellites of EUMETSAT have the ASCAT instrument on board providing sea surface wind speed and direction; with all 3 METOP satellites data continuity can be expected until about 2018; resulting products are archived; see also the web pages of the SAF on Ocean and Sea Ice⁹.</p>
<p>Upper-Air Temperature Homogenized upper-air temperature analyses; Extended MSU-equivalent temperature record; New record for upper-troposphere and lower-stratosphere temperature using data from radio occultation; Temperature analyses obtained from reanalyses</p>	<p>Passive microwave radiances; GPS radio occultation; High-spectral resolution IR radiances for use in reanalysis Requirement is fulfilled: The METOP satellites have the IASI, AMSU-A and GRAS instruments on board; with all 3 METOP satellites data continuity can be expected until about 2018; resulting data and products are archived.</p>
<p>Water Vapour Total column water vapour over the ocean and over land; Tropospheric and lower-stratospheric profiles of water vapour</p>	<p>Passive microwave radiances; UV/VIS radiances; IR imagery and soundings in the 6.7µm band; Microwave soundings in the 183 GHz band Requirement is fulfilled with Meteosat First and Second Generation (MSG) and METOP; with all 4 MSG and all 3 METOP satellites data and product continuity can be expected until about 2018 and longer; resulting products are archived.</p>
<p>Cloud Properties Cloud radiative properties (initially key ISCCP products)</p>	<p>VIS/IR imagery; IR and microwave soundings Requirement is fulfilled with Meteosat First and Second Generation and METOP; with all 4 MSG and all 3 METOP satellites data continuity can be expected until about 2018 and longer; resulting products are archived.</p>
<p>Precipitation Improved estimates of precipitation, both as derived from specific satellite instruments and as provided by composite products</p>	<p>Passive microwave radiances; High-frequency geostationary IR measurements; Active radar (for calibration) Requirement is fulfilled with Meteosat First and Second Generation and the MHS instrument on board of METOP; with all 4 MSG and all 3 METOP satellites product continuity can be expected until about 2018 and longer; resulting products are archived.</p>
<p>Earth Radiation Budget Top-of-atmosphere Earth radiation budget on a continuous basis</p>	<p>Broadband radiances; Spectrally-resolved solar irradiances; Geostationary multi-spectral imagery Requirement is fulfilled with GERB on all 4 MSG satellites and the imaging instruments SEVIRI and AVHRR on board of MSG resp. METOP; with all 4 MSG and all 3 METOP satellites product continuity can be expected until about 2018 and longer; resulting products are archived.</p>
<p>Ozone Profiles and total column of ozone</p>	<p>UV/VIS and IR microwave radiances Requirement is fulfilled by GOME on ERS-2, SCIAMACHY on ENVISAT (ended in 2012) and GOME-2 and IASI on board of the METOP satellites; with all 3 METOP satellites product and data continuity can be expected until about 2018; resulting products are archived; see also the web pages of the SAF on Ozone and Atmospheric Chemistry Monitoring¹³. Additionally, vertically resolved ozone products are provided through data assimilation within GMES projects PROMOTE / MACC using data of ENVISAT and METOP satellites.</p>

⁹ <http://www.osi-saf.org>

¹³ <http://o3msaf.fmi.fi>

<p align="center">ECVs/ Global Products requiring Satellite Observations</p>	<p align="center">Fundamental Climate Data Records required for Product Generation (from past, current and future missions)</p>
<p>Aerosol Properties Aerosol optical depth and other aerosol properties</p>	<p>VIS/NIR/SWIR radiances Requirement was fulfilled with MERIS (ended with ENVISAT in 2012) providing regional value added information concerning clouds and aerosols and with Meteosat Second Generation and METOP; with all 4 MSG and all 3 METOP satellites product continuity can be expected until about 2018 and longer; resulting products are archived. Additional information on aerosol composition is provided by the synergy of a radiometer and a spectrometer through Copernicus projects PROMOTE / MACC / MACC-2 based on ERS-2, METOP and the SENTINEL family.</p>
<p>Carbon Dioxide, Methane and other GHG Distribution of greenhouse gases, such as CO₂ and CH₄ of sufficient quality to estimate regional sources and sinks</p>	<p>NIR/IR radiances The IASI and GOME-2 instrument on board of METOP contribute to the monitoring of the listed trace gases.</p>
<p>Upper-air Wind Upper-air wind reanalyses, particularly from reanalysis</p>	<p>VIS/IR imagery; Doppler wind lidar Wind vectors are derived from data of Meteosat First and Second Generation; with MSG product continuity can be expected until about 2018 and longer; resulting products are archived; reanalysis is an issue to which EUMETSAT has to respond. Space-based Doppler wind lidar is an issue for the future, the relevant mission is not yet demonstrated and the expected data are probably not from the beginning on suitable for climate monitoring purposes.</p>
<p>Atmospheric Reanalyses</p>	<p>Key Fundamental Climate Data Records (FCDRs) and products identified in this report, and other data of value to the analyses The SAF on Climate Monitoring continues to perform re-processing.</p>
<p>Soil moisture</p>	<p>Scatterometry, passive microwave radiances Requirement is fulfilled with MetOp ASCAT and ESA SMOS.</p>

2.6 Responses to the actions recommended in the GCOS implementation plan 2010 update

- (a) Applying the GCMPs to all measurements relevant for climate from surface networks (A4);

To fulfil the GCMPs, DWD operates 10 Reference Stations throughout Germany. These are: Aachen, Brocken, Fichtelberg, Frankfurt am Main, Görlitz, , Hamburg-Fuhlsbüttel, Hohenpeissenberg, , Lindenberg, Potsdam and Schleswig. At these sites, conventional and new automatic measuring devices are operated in parallel. All measured data have been and are subjected to thorough quality checks and are stored in digital form (which also applies to all past records).

Before new instruments are installed and used operationally, they are tested at special test facilities (e.g. at Hamburg) to ensure that they comply with all requirements to replace the previous instrumentation (precision, accuracy, availability, and so on).

With this procedure, it is ensured that all primary weather stations (Wst I [meteorological watch office], Wst II [automatic weather office]) mostly comply with GCMPs and the secondary weather station which are operated by voluntary observers with some restrictions (Wst III [voluntary weather station], Nst(A) [automatic precipitation station] and Nst(k) [conventional precipitation station]).

- (b) Seek cooperation from organizations operating drifting buoy programmes to incorporate atmospheric pressure sensors as a matter of routine (A6)

Germany runs no drifting buoys on its own, but contributes to EUCOS/ E-SURFMAR.

- (c) Ensuring availability of three-hourly mean sea level pressure and wind speed and direction data from GSN stations (A10 in IP 2004, no longer included in IP 2010)

The German GSN stations are equipped with automatic sensors. These data (e.g. mean pressure at sea level, wind speed and direction) are hourly exchanged on the GTS. However, wind speed and direction is still not included in GSN.

- (d) Implementing a reference network of high-altitude, high-quality radiosondes (A16)

In 2007, WMO assigned the Lead centre of the GCOS Reference Upper-air Network (GRUAN) to the MOL-RAO. Over the last three years the GRUAN Manual and Guide have been developed in a strong community effort and have now been endorsed by all GRUAN participants. These documents are now published as joint GCOS-WIGOS documents (GCOS-170 and GCOS-171) and outline what is expected from GRUAN stakeholders such as the Lead Centre, the Working Group on GRUAN (WG-GRUAN) and participating sites to achieve the goals of this network.

- (e) Operating the WWW/GOS radiosonde network in full compliance with the GCMPs and coding conventions (A17)

Being a GRUAN station, MOL-RAO complies with the GCMPs and coding conventions. All other stations use routinely the same radio-sondes for at least two soundings a day (till 30 km).

- (f) Submitting metadata records and inter-comparisons for radiosonde observations to the specified international data centres (A18)

Currently, a database is installed at MOL-RAO that will contain all metadata of GRUAN stations as well as the data from radiosondes (and other) inter-comparison campaigns.

- (g) Developing a network of ground-based Global Positional System (GPS) receivers for measuring water vapour (A22)

Germany is operating a ground-based network of Global Positional System (GPS) receivers since 2000. The responsible and processing centre is located at the GeoForschung Zentrum (GFZ), Potsdam. At present the network consists of approximately 200 stations delivering measurements of integrated water vapour every 15 minutes and with an accuracy of circa 2 kg/m².

- (h) Sustained measurements of the atmospheric composition ECVs, supplementary to those activities implicit in table 1c.

In Germany, the environmental agencies of the Länder all run monitoring programmes dedicated to characterizing aerosol mass concentrations (PM₁₀, PM_{2.5}, soot, etc.) and ozone levels on regional scales. Thus, they contribute to “other aerosol parameters” and “other greenhouse gases”.

3 Oceanic Essential Climate Variables

3.1 Description of national contribution to oceanographic ECV

The German contribution to international networks and co-operation on climate research in the ocean is distributed over a wide range of centres of expertise at joint institutes, universities and operational agencies. Among the partners in this field are the AWI, the Centre for Marine and Atmospheric Sciences (ZMAW), the Federal Maritime and Hydrographic Agency (BSH), the German Meteorological Service (DWD), the GEOMAR, the Institute of Environmental Physics (IUP-Bremen) and others. Most of the contributions are achieved within research projects and lack sustained funding.

Suitable measuring instrumentation for field observations has been developed and used under German environmental research assistance measures. The measuring platforms available include aircrafts, research vessels (e.g. ‚Polarstern‘), merchant vessels, drifting buoys, moorings and remotely operated vehicles (ROVs).

The BSH has funded equipment for 2 merchant vessels conducting temperature measurements along 2 Atlantic XBT sections (AX03, AX11) until the end of 2012. These were part of the set of sections selected by the GCOS/GOOS/WCRP Ocean Observations Panel for Climate (OOPC) and CLIVAR as Ship of Opportunity Programme (SOOP) lines to fulfil the upper ocean data requirements which have been established by GOOS and GCOS. The contribution to the SOOP programme was terminated because of personnel and financial constraints at BSH. The XBT data were transmitted in near real-time to the Global Telecommunication network (GTS) of the World Meteorological Organization (WMO). The Federal Maritime Agency exchanges the data also to the Global Temperature and Salinity Profile Project (GTSP). About 550 observations have been generated by German SOOP ships each year.

The BSH operates the German contribution to the international Array for real-time geostrophic oceanography (Argo) network. Long-term funding will be provided by the Federal Ministry of Transport and Digital Infrastructure (BMVI) to deploy 30-40 Argo floats each year. The focus of deployments will be the Atlantic Ocean, but if necessary other oceans could be selected to maintain the global array. Deployment of the instruments is achieved in co-operation with the research community using deployment opportunities during research cruises. Data are transmitted in real-time to the international data centre CORIOLIS¹⁴. The BSH provides quality control on the collected data according to the data management procedures developed in the Argo programme and distributes the quality controlled data sets to the international data centres.

The BSH maintains a net of 9 autonomous observation platforms in the North Sea and Baltic Sea. The stations are regularly serviced and calibrated and data are transmitted in real-time to the BSH. The parameters measured at the stations include sea state measurements (7 stations) and meteorological measurements, conducted by DWD. Data are exchanged within the framework of EuroGOOS, with its regional sections NOOS for the North Sea, and BOOS for the Baltic Sea. These bodies are part of the Global Ocean Observing System (GOOS), and contributing to GCOS.

Since 1998 the BSH carried out its annual North Sea Summer Surveys which cover the entire North Sea with seven coast to coast East-West sections between 54° and 60°N and additional stations between 54°N and the entrance of the English Channel. The surveys were realised at a time when thermal stratification is expected to be at its maximum and phytoplankton production has passed its maximum. Between a grid of fixed stations a towed CTD-system was deployed which oscillated between surface and bottom to record the distribution

¹⁴ <http://www.coriolis.eu.org>

of relevant oceanographic parameters with high resolution in space and time (24 Hz). This allows the calculation of basin wide heat and salt budgets. In order to sample the transition area between North Sea and Atlantic the survey was expanded to 62.5°N since 2010.

The German contribution to the global mooring network is distributed over several research institutes. The AWI operates 24 individual long-term moorings which are part of the OceanSites programme. The locations of the moorings are in the Greenland Sea (1), the Fram Strait (12), the Weddell Gyre along the Greenwich Meridian (5) and the Weddell Gyre proper (6). The GEOMAR operates 7 moorings in the Labrador and 1 mooring in the Irminger Sea and as well as 1 mooring off the Cape Verde Islands which are all integrated into the OceanSites programme. Additional mooring activities of the GEOMAR are focused on the tropical Atlantic where several moorings are deployed for a long-term period. These moorings are equipped with sensors that measure in high temporal resolution in-situ temperature, salinity, oxygen and currents. Two moorings (Irminger Sea and Cape Verde) are equipped with real-time data telemetry transmitting temperature/salinity data in real-time. The data flow is connected with the Coriolis data centre and distributed with the GTS system. The IUP Bremen operates 4 integral moorings in the sub-polar North Atlantic to estimate the Gulf Stream transport. Data from these moorings will be available for climate research. BSH contributes 4 moorings in the subpolar North Atlantic at the Mid-Atlantic Ridge between the Gibbs and Maxwell Fracture Zones, which will also contribute data to climate research. A multidisciplinary mooring has been established near the Cape Verde Islands and will contribute data to GEOSS. The ZMAW operates 3 moorings in the Nordic Seas as part of OceanSites.

Germany has played an important role in the World Ocean Circulation Experiment (WOCE) and has sampled several of the WOCE hydrographical sections. Although there is no special funding for these activities a repeated ship-based hydrographical network based on the formal WOCE lines is continued by the AWI and the IUP-Bremen. The AWI is repeating hydrographical surveys along SR03 and SR04 in the Southern Ocean and performs yearly measurements on a regular base in the Nordic Seas, in Fram Strait and in the Arctic Ocean. The IUP-Bremen is operating the A02 section every other year, including the measurements of the large scale tracer inventory changes to calculate the biennial change in the anthropogenic carbon inventory. Data are submitted to the WODC, GLODAP, and PANGAEA.

The AWI is also contributing to the global surface drifting buoy array with four buoys in the polar region. The ZMAW has started operation of 21 surface drifting buoys in 2010. The surface buoys are equipped with salinity sensors for validation/calibration purposes in connection with the SMOS satellite mission. Data have been reported to the international drifter data assembly centre. All drifter within this project have finished their lifetime and no further activities are planned.

The AWI is conducting underway pCO₂ and TCO₂ measurements in the water column from RV Polarstern along sections A13.5 and S04A in the southern ocean. The GEOMAR uses a VOS between Europe and North America to measure pCO₂ and TCO₂. Data are archived at the Carbon Dioxide Information Analysis Center (CDIAC).

The permanently installed pCO₂ system collects surface water data on all cruise legs of RV Polarstern in the Southern Ocean, the Arctic and Nordic Seas and in the Atlantic Ocean during transits. The data are part of the international SOCAT (Surface Ocean Carbon Atlas) effort.

Germany has increased its contribution to the Global Sea Level Observing System (GLOSS) and contributes data from 9 stations to the various programmes under the auspices of GLOSS. Data from these 9 stations are submitted on a yearly basis to PSMSL (Permanent Service for Mean Sea Level), quality checked and high-frequency data from 7 stations are delivered on an intermittent basis. Hourly data from one station are transmitted once a month and high-frequency near-real time data from 7 stations are made available to the IOC sea level station monitoring System by web services. Support to the operation of the sea level

stations is given by the Federal Waterways Directorate North (WSD Nord23) and the BfG. In the research community additional activities are maintained to provide long-term sea level data. The AWI is providing 15 PIES for validation of the Gravity Recovery And Climate Experiment (GRACE) mission, additional 47 PIES are provided by the IUP-Bremen for the same purpose.

DWD funds the meteorological equipment for 720 merchant ships and research vessels within the framework of the WMO programme VOS (Voluntary Observing Ship). Most of the observations are transmitted in real-time to the GTS. The total amount of observations is stored to electronic data medium or manual diaries that are fetched by the PMO (Port Meteorological Officer) during their visits on board. Then, the data sets are transferred for climatological processing. About 250.000 observations are generated by German VOS worldwide each year. The VOSclim contribution is also managed by DWD and reported under the meteorological section of this report.

Continuous ice observations are carried out along the German coasts since the end of the 19th century. Ice charts for the German coasts and the entire Baltic are provided at least weekly since the winter of 1927/1928. The observed parameters comprise mostly ice coverage and ice thickness, but additionally the form of the ice and the status of ship navigation are provided. The data and the resulting maps are archived at BSH, in part as digital files. Global coverage of ice conditions is available since the last few years from satellite measurements. Products based on the satellite data are made available continuously from the universities of Bremen (IUB) and Hamburg (ZMAW) via the internet and free of charge. ZMAW is contributing to the ESA Sea Ice CCI under the coordination of NERC as far as sea ice extent and sea ice concentration are concerned. Scientific analysis related to sea ice is carried out at the AWI and at German universities. Most of these studies are process oriented and lack continuity although they cover the entire globe. Long-term measurements from these scientific studies are mostly available for Fram Strait and the areas north of it.

3.2 Narrative of nominating national focal points and establishing partnerships between ocean research and operational communities

Due to the diversity of oceanic climate research in Germany contributions come from many different institutions. A high level national focal point for the oceanographic community is a member of the CLIVAR Steering committee (Prof. Visbeck, GEOMAR). The BSH serves as national point of contact for the Global Ocean Observing System (GOOS) and reports to GCOS. The Argo programme has provided a good link between the ocean research and operational communities. The German contribution to Argo has been developed from a joint research project and float deployment and technical development are advanced in close collaboration with the scientific community.

Table 3a: National contributions to the Oceanic ECVs – Surface

Contributing Networks specified in the GCOS Implementation Plan	ECVs	Number of Stations or Platforms currently operating	Number of Stations or Platforms operating in accordance with the GCMPs	Number of Stations or Platforms expected to be operating in 2015	Number of Stations or Platforms providing data to the International Data Centres	Number of Stations or Platforms with complete historical record available in International Data Centres
Global surface drifting buoy array on 5x5 degree resolution	Sea – Surface Temperature, Sea-Level Pressure, Position-change-based Current	0	0	0	0	0
GLOSS Core Sea-level Network	Sea level	9	9	9	9	9
Voluntary Observing Ships (VOS)	All feasible surface ECVs	720	720	800	~600	None
Ship of Oppor. Programme	All feasible surface ECVs	None	None	None	None	None

Table 3b: National contributions to the Oceanic ECVs – Water Column

Contributing Networks specified in the GCOS Implementation Plan	ECVs	Number of Stations or Platforms currently operating	Number of Stations or Platforms operating in accordance with the GCMPs	Number of Stations or Platforms expected to be operating in 2015	Number of Stations or Platforms providing data to the International Data Centres	Number of Stations or Platforms with complete historical record available in International Data Centres
OceanSites mooring network	All feasible surface and subsurface ECVs	43	43	43	43	43
Global tropical moored buoy network	All feasible surface and subsurface ECVs	None	None	None	None	None
Argo network	Temperature, Salinity, Current	155	155	237	155	602
Sustained and repeated ship-based hydrography network	All feasible ECVs including those that depend on obtaining water samples	6 sections with 50 stations each	6 sections with 50 stations each	6 sections with 50 stations each	6 sections with 50 stations each	6 sections with 50 stations each
Carbon inventory survey lines	Temperature, Salinity, Ocean Tracers, Biogeochemistry variables	3 sections with 50 stations	3 sections with 50 stations	3 sections with 50 stations	3 sections with 50 stations	3 sections with 50 stations

3.3 Satellite observations

Table 4: Global Products requiring Satellite Observations – Oceans

ECVs/ Global Products requiring Satellite Observations	Fundamental Climate Data Records required for Product Generation (from past, current and future missions)
Sea Ice Sea –ice concentration	Microwave and visible imagery. EUMETSAT: AVHRR on METOP contributes; data availability until 2018 and beyond; see also webpages of the Ocean and Sea Ice SAF ¹⁵ . TerraSAR-X and Sentinel-1 (launch 2011) provide SAR imagery for this purpose.
Sea Level Sea level and variability of its global mean	Altimetry. EUMETSAT is a partner in Jason-2 and plans to contribute to Jason-3. EUMETSAT will operate marine part of GMES Sentinel-3.
Sea Surface Temperature Sea surface temperature <ul style="list-style-type: none"> • 	Single and multi-view IR and microwave imagery DLR: NOAA AVHRR: regional Sea Surface Temperature EUMETSAT: AVHRR on METOP contributes, MSG contributes; data availability until 2018 and beyond; see also web pages of the Ocean and Sea Ice SAF ¹⁵ . EUMETSAT will operate marine part of GMES Sentinel-3.
Ocean Colour Ocean colour and oceanic chlorophyll-a concentration derived from ocean colour	Multi-spectral VIS imagery. EUMETSAT will operate marine part of GMES Sentinel-3.
Sea State Wave height and other measures of sea state (wave direction, wavelength, time period)	Altimetry. EUMETSAT is a partner in Jason-2 and plans to contribute to Jason-3. EUMETSAT will operate marine part of GMES Sentinel-3.
Ocean Salinity Research towards the measurements of changes in sea-surface salinity	Microwave radiances; ESA's SMOS mission was launched in November 2009, starting observations of this ECV. Cal/Val activities have been funded.
Ocean Reanalyses Altimeter and ocean surface satellite measurements	Key FCDRs and products identified in this report, and other data of value to the analyses

¹⁵ <http://www.osi-saf.org>

¹⁵ <http://www.osi-saf.org>

3.4 Response to recommended actions on oceanic ECV

In this paragraph Parties are invited to report on specific actions. Action numbers refer to the 2010 update of the GCOS implementation plan (GCOS-138).

O9 Action: Implement the GLOSS Core Network of about 300 tide gauges, with geocentrically-located high-accuracy gauges; ensure continuous acquisition, real-time exchange and archiving of high-frequency data; put all regional and local tide gauge measurements within the same global geodetic reference system; ensure historical sea-level records are recovered and exchanged; include sea-level objectives in the capacity-building programmes of GOOS, JCOMM, WMO, other related bodies, and the GCOS system improvement programme. **Who:** Parties' national agencies, coordinated through GLOSS of JCOMM.

BSH is now providing tide gauge information for 9 stations in the North and Baltic Sea and works continuously on increasing the exchange of high-frequency data as well as exchange of historical records under the coordination of GLOSS.

O13 Action: Develop and implement an internationally-agreed strategy for measuring surface $p\text{CO}_2$. **Who:** IOCCP, in consultation with OOPC; implementation through national services and research programmes.

The AWI contributes to this action through the BMBF funded project ICOS-D and carries out shipbased $p\text{CO}_2$ measurements on RV Polarstern and moored $p\text{CO}_2$ measurements at the 'Hausgarten' observatory.

O23 Action: Establish a global network of long-term observation sites covering all major ocean habitats and encourage collocation of physical, biological and ecological measurements. **Who:** Parties' national research and operational agencies, supported by GOOS/PICO, OOPC, GRAs, and other partners.

Various research institutes and operational agencies such as BSH are contributing long-term mooring observations from various research projects which are part of the OceanSites program.

O24 Action: Development of a plan for systematic global full-depth water column sampling for ocean physical and carbon variables in the coming decade; implementation of that plan. **Who:** National research programmes supported by the GO-SHIP project and IOCCP.

The AWI contributes to this goal with measurements on two repeat sections in the Weddell Gyre.

O25 Action: Sustain the Ship-of-Opportunity XBT/XCTD transoceanic network of about 40 sections. **Who:** Parties' national agencies, coordinated through the Ship Observations Team of JCOMM.

The operation of two transoceanic XBT sections in the Atlantic has been terminated at the end of 2012. The Ship Observation Team has been notified and is looking for a replacement.

O26 Action: Sustain the network of about 3000 Argo global profiling floats, reseeded the network with replacement floats to fill gaps, and maintain density (about 800 per year). **Who:** Parties participating in the Argo Project and in cooperation with the Observations Coordination Group of JCOMM.

BSH is continuing to operate the German contribution to the international Argo Program. On the European level the involved national agencies developed a European "infrastructure" for Argo to the level where the European partners have the capacity to support approximately 1/4 of the global array and provide an additional 50 floats per year for enhanced coverage in the European and marginal seas. A European Research Infrastructure Consortium (ERIC) has been established and involves 16 organizations from 13 countries¹⁰.

¹⁰ <http://www.euro-argo.eu/>

O28 Action: Develop projects designed to assemble the *in situ* and satellite data into a composite reference reanalysis dataset, and to sustain projects to assimilate the data into models in ocean reanalysis projects. **Who:** Parties' national ocean research programmes and space supported by WCRP.

A global reanalysis was constructed within the BMBF funded project 'Nordatlantik' which used the adjoint ECCO Model. The resulting GECCO reanalysis assimilated a large variety of in-situ data sets such as Argo float data, moored time series and satellite data.

O30 Action: Deploy a global pilot project of oxygen sensors on profiling floats. **Who:** Parties, in cooperation with the Argo Project and the Observations Coordination Group of JCOMM.

The European Research infrastructure consortium plans to implement a pilot project with oxygen sensors on profiling floats.

4 Terrestrial Essential Climate Variables

4.1 Global Terrestrial Network – Hydrology (GTN-H)

The GTN-H is a joint effort of the World Meteorological Organization / Climate and Water Department (WMO/CLW), the GCOS, and the Global Terrestrial Observing System (GTOS¹⁶), co-sponsored by WMO, UNESCO, ICSU, UNEP and FAO.

GTN-H represents the observational arm of the Group on Earth Observations / Integrated Global Water Cycle Observations Theme (GEO/IGWCO).

The following hydrological variables have been identified as essential for the GTN-H¹⁷ network: precipitation, river discharge, groundwater, water vapour, lake level/ area, isotopic composition, soil moisture, water use, snow cover, glaciers and ice caps, evapotranspiration, water quality/ biogeochemical fluxes. For most of the variables a global network is defined and a contact established. The GPCC and the GRDC, both operational in Germany, are part of the GTN-H Panel and represent their respective networks on precipitation and river discharge.

4.2 Global Terrestrial Network for River Discharge (GTN-R)

The GRDC has been tasked with the implementation of the GTN-R to address the growing need for a global runoff network monitoring freshwater surface water fluxes. Due to resource constraints only limited progress was achieved with this GCOS Baseline River Discharge Network during the reporting period. Currently near real-time hydrological data are received from 212 stations in 15 countries. 17 countries provided historical discharge data for 54 stations. The original objective was to include more than 450 stations from 81 countries, but only 40% of the approached countries responded to the WMO and GCOS supported requests to participate. The acquisition of external funding for the implementation of the GTN-R has been unsuccessful. The GRDC is continuing the implementation of the GTN-R with the limited resources available.

4.3 Global Terrestrial Network – Lakes (GTN-L)

Lake level data are being observed by different agencies at Länder or community level. Though some of these observations are available in environmental information systems of the Länder on the Internet, there is no nation wide database established and it is therefore not known to which degree such data is made available to international data centres.

4.4 Global Terrestrial Network – Glacier (GTN-G)

Since 2010, the newly formed Commission for Geodesy and Glaciology of the Bavarian Academy of Sciences and Humanities continued to maintain a substantial recording programme of the former Commission for Glaciology in the catchment of the Vernagtferner, Oetztal, Austria. Maps of the glacier are available since 1889 and were repeated in 1912, 1938, 1954, 1969, 1979, 1982, 1990, 1999, and 2006. Mass balance is determined annually

¹⁶ <http://www.fao.org/gtos/>

¹⁷ <http://gtn-h.net>

since 1964/65, including the separation into winter and summer series. Since 2010, gravimetric observations supplement the traditional mass balance determination. Runoff, precipitation, all radiation components, temperature, humidity, air pressure, and wind are recorded since 1974 on an hourly basis. The permanent observations at Vernagtferner are complemented/ extended by the repeated mapping of 15 glaciers in the Eastern Alps. The surveys are reiterated almost every 10 years and the last one has been completed in 2009. Volume changes are derived from the maps of these 15 glaciers in the Eastern Alps, which include the five German glaciers: Nördlicher and Südlicher Schneeferner, Höllentalferner, Watzmanngletscher and Blaueis. The longest mapping series starts in 1889 (Vernagtferner and Guslarferner), followed by (1892) the two Schneeferner on the Zugspitzplatt, the shortest series is provided for Watzmanngletscher (since 1959).

Glaciological data are regularly submitted to World Glacier Monitoring Service (WGMS¹¹) and National Snow and Ice Data Center (NSIDC¹²). Hydrological and meteorological data are published in the Open Access library Pangaea (www.pangaea.de), Analyses, results, and modelling approaches are presented in national and international Journals such as Zeitschrift für Gletscherkunde (Innsbruck), Journal of Glaciology, Annals of Glaciology (both: Cambridge), Geografiska Annaler (Stockholm), The Cryosphere (Online Journal, EGU), Climate Status Report 2007 of DWD¹³, Journal of Geodesy (Springer), Journal of Geodetic Science (de Gruyter), Kart og Plan (Norway), Geophysical Journal International (Wiley).

In addition, since many decades Germany is contributing to and supporting individual measurement campaigns in the Alps, in Central Asia, Greenland, Iceland and Antarctica.

4.5 Global Terrestrial Network for Permafrost (GTN-P)

Material of the lithosphere that is permanently at or below 0° C throughout the year is called permafrost. At high altitudes in the Alps a large portion of permafrost is in steep bedrock. At the Zugspitze Mountain for example, permafrost occurs mostly in the rock fissures. In steep mountain flanks, global warming causes slow but deep-seated degradation or thawing. Consequences could be settlement or rock fall. The Zugspitze Mountain was chosen as a representative location in the northern Alps for monitoring state and changes in bedrock permafrost. In 2007 the mountaintop ridge was drilled through, commissioned by the Bavarian Environment Agency. Along a 44 m long borehole 25 temperature sensors were installed. These will collect temperature data for at least the next 15 years (planned up to 2022). The results contribute to a permafrost monitoring network for all of the Alps. This site is not included into the GTN-P but data contribute to network created by the alpine wide EU-PermaNet-project¹⁴.

¹¹ <http://www.geo.unizh.ch/wgms/>

¹² <http://nsidc.org/index.html>

¹³ <http://www.dwd.de/>

¹⁴ <http://www.permanet-alpinespace.eu>

Table 5: National Contributions to the Terrestrial Domain ECVs

Contributing Networks specified in the GCOS Implementation Plan	ECVs	Number of Stations or Platforms currently operating	Number of Stations or Platforms operating in accordance with the GCMPs	Number of Stations or Platforms expected to be operating in 2015	Number of Stations or Platforms providing data to the International Data Centres	Number of Stations or Platforms with complete historical record available in International Data Centres
GCOS Baseline River Discharge Network (GTN-R)	River discharge	3	3	3	3 On request	3
GCOS Baseline Lake Level/ Area/ Temperature Network (GTN-L)	Lake Level/ Area/ Temperature					
WWW/ GOS Synoptic Network	Snow Cover	1484 (180 primary + 1204 secondary DWD stations)	180 DWD	185 DWD	180 DWD	180 DWD
GCOS Glacier Monitoring Network (GTN-G)	Glaciers mass balance and length, also Ice sheet mass balance	1 ^a	1 ^a	1 ^a	1 ^a	1 ^a
GCOS Permafrost Monitoring Network (GTN-P)	Permafrost borehole-temperatures and active - layer thickness	1 ^b	1 ^b	1 ^b	(1) ^b	0

^a – Vernagtferner

^b – Zugspitze established in 2007

4.6 Phenological monitoring network

A further important contribution to climatic change observations are the phenological observations which are also regularly conducted by DWD at currently about 1228 sites in Germany (10.03.2014).

Phenology at DWD deals with the periodically recurring growth and development phenomena of plants during the course of a year. The beginning of characteristic vegetation stages (phases) are observed and recorded. These are closely connected to the weather and cli-

mate and are thus suited for the most varied areas of application and for manifold scientific studies.

In parts the phenological monitoring data of DWD are provided to the Pan European Phenological Database (PEP), a project funded by the Austrian meteorological services ZAMG, the Austrian ministry for science & research and the network of European meteorological services EUMETNET, started in 2010 and will be running for 5 years. The main objective is to promote and facilitate phenological research by delivering a pan European phenological database with an open, unrestricted data access for science, research and education.

In 1957 a European network of International Phenological Gardens (IPGs) was established. This network was coached by DWD until 1995. Since then the responsibility is with the Humboldt-University in Berlin²¹.

4.7 Satellite observations

Table 6: Global Products requiring Satellite Observations – Terrestrial

ECVs/ Global Products requiring Satellite Observations	Fundamental Climate Data Records required for Product Generation (from past, current and future missions)
Lakes Maps of lakes, lake levels, and surface temperatures of lakes in the Global Terrestrial network for Lakes	VIS/NIR imagery and radar imagery TerraSAR-X for mapping lake extent Altimetry High-resolution IR imagery
Glaciers and Ice Caps Maps of the areas covered by glaciers other than ice sheets Ice sheet elevation changes for mass balance determination	High-resolution VIS/NIR/SWIR optical imagery Altimetry DLR: TerraSAR-X/ TanDEM-X: high resolution maps of ice coverage (related to IPY)
Snow Cover Snow areal extent	Moderate-resolution VIS/NIR/IR and passive microwave imagery Sentinel-3
Albedo Directional hemispherical (black sky) albedo	Multi-spectral and broadband imagery
Land Cover Moderate-resolution maps of land cover type; High-resolution maps of land cover type, for the detection of land cover change	Moderate-resolution multi-spectral VIS/NIR imagery High-resolution multi-spectral VIS/NIR imagery Copernicus Land Service will provide this in Europe and globally based on various satellite sensors, including Sentinel-2. High-resolution land cover map for Germany currently updated based on RapidEye imagery through contract by the German Federal Agency for Cartography and Geodesy (BKG). DLR: Contributions to the CEOS Space Data Coordination Group in support of the Global Forest Observation Initiative: TerraSAR-X data and application development projects.

²¹ <http://www.agrar.hu-berlin.de/struktur/institute/pfb/struktur/agrarmet/phaenologie/ipg>

<p style="text-align: center;">ECVs/ Global Products requiring Satellite Observations</p>	<p style="text-align: center;">Fundamental Climate Data Records required for Product Generation (from past, current and future missions)</p>
<p>fAPAR Maps of fAPAR</p>	<p>VIS/NIR imagery Sentinel-2</p>
<p>LAI Maps of LAI</p>	<p>VIS/NIR imagery Sentinel-2</p>
<p>Biomass Research towards global, above ground forest biomass and forest biomass change</p>	<p>L band/ P band SAR; Laser altimetry University Jena:</p> <ul style="list-style-type: none"> • Regional biomass classification products in boreal areas (Siberia, China), derived from ERS interferometry and of hyper-temporal analysis of ENVISAT-ASAR time series
<p>Fire Disturbance Burnt area, supplemented by active fire maps and fire radiated power</p>	<p>VIS/NIR/SWIR/TIR moderate-resolution multi-spectral imagery Sentinel-2 and Sentinel-3</p>
<p>Soil Moisture Research towards global near-surface soil moisture map (up to 10cm soil depth)</p>	<p>Active and passive microwave ESA's SMOS launched in November 2009, providing observations of this emerging ECV.</p>

List of abbreviations

ACC	Atmospheric Composition Constellation
ADM-Aeolus	Atmospheric Dynamics Mission - Aeolus
AERONET	Aerosol Robotic Network
AMSU	Advanced Microwave Sounding Unit
Argo	Array for real-time geostrophic oceanography
ASAR	Advanced Synthetic Aperture Radar
ASCAT	Advanced Scatterometer
asl	Above sea level
AVHRR	Advanced Very High Resolution Radiometer
AWI	Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research
AWIPEV	French – German Arctic Research Base at Ny-Ålesund / Spitsbergen; AWI together with the Institut Polaire Francais Paul Emile Victor
BAdW	Bayerische Akademie der Wissenschaften (Bavarian Academy of Sciences and Humanities)
BfG	Bundesanstalt für Gewässerkunde (German Federal Institute of Hydrology)
BfN	Bundesamt für Naturschutz (Federal Agency for Nature Conservation)
BKG	German Federal Agency for Cartography and Geodesy
BMBF	Bundesministerium für Bildung und Forschung (Federal Ministry of Education and Research)
BMKG	Indonesian Meteorological Service (Badan Meteorologi, Klimatologi, dan Geofisika)
BMU	Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit (German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety)
BMVI	Bundesministerium für Verkehr und digitale Infrastruktur (German Federal Ministry of Transport and Digital Infrastructure)
BMZ	Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung (German Federal Ministry for Economic Cooperation and Development)
BOOS	Baltic Operational Oceanographic System
BSH	Bundesamt für Seeschifffahrt und Hydrografie (Federal Maritime and Hydrographic Agency)
BSRN	Baseline Surface Radiation Network of the WCRP
CBS	WMO Commission for Basic Systems
CCI	Climate Change Initiative of ESA
CDIAC	Carbon Dioxide Information Analysis Center
CDOP	Continuous Development and Operations Phase (SAF)
CEOP	Coordinated Enhanced Observation Period
CEOS	Committee on Earth Observation Satellites
CGMS	Coordination Group for Meteorological Satellites
CH ₄	Methane
CLIVAR	WCRP Programme on Climate Variability and Predictability
CLRTAP	UN/ECE Convention on Long-range Transboundary Air Pollution
CLW	Climate and Water Department (WMO)
CM SAF	EUMETSAT Satellite Application Facility on Climate Monitoring
CONICET	Consejo Nacional de Investigaciones Científicas y Técnicas
Copernicus	The European Earth Observation Programme (previously called GEMS)

CORIOLIS	an in-situ service for operational oceanography (international data centre)
CryoSat	satellite to measure changes in the extend and thickness of the ice sheets over Greenland and Antarctica
CTD	Conductivity Temperature Depth
DATACLIM	Data and Information Management for Adaptation to Climate Change
DFD	Deutsches Fernerkundungsdatenzentrum (Remote Sensing Data Centre)
DFG	Deutsche Forschungsgemeinschaft (German Research Foundation)
DLR	Deutsches Zentrum für Luft- und Raumfahrt e.V. (German Aerospace Center)
DOI	Digital Object Identifier
D-GEO	German GEO Experts Group
D-PAC	German Processing and Archiving Center at DLR
D-PAF	German Processing and Archiving Facility at DLR
DWD	Deutscher Wetterdienst (German Meteorological Service)
ECCO	Estimation of the Circulation and Climate of the Ocean
ECV	Essential Climate Variable
EarthCARE	Earth Clouds, Aerosols and Radiation Explorer
EMDS	Einheitlicher Meteorologischer Datenspeicher (Standardised meteorological data memory system)
EMEP	European Monitoring and Evaluation Programme
EMPA	Eidgenössische Materialprüfungs- und Forschungsanstalt (Swiss Federal Laboratories for Materials Science and Technology Research)
ENVISAT	European Environmental Satellite (ESA) – ended in 2012
EO	Earth Observation
EOWEB [®]	DLR's Earth Observation on the Web
EPS	EUMETSAT Polar System
ERIC	European Research Infrastructure Consortium
ERS	European Earth Remote Sensing Satellite (ESA)
ESA	European Space Agency
E-SURFMAR	EUCOS Surface Marine programme
ETH	Swiss Federal Institutes of Technology (Eidgenössische Technische Hochschule)
EU	European Union
EUCOS	EUMETNET Composite Observing System
EUMETNET	Network of European Meteorological Services
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
EuroGOOS	European Global Ocean Observing System
FAO	Food and Agriculture Organization
fAPAR	Fraction of Absorbed Photosynthetically Active Radiation
FCDR	Fundamental Climate Data Record (from satellites)
GABLS	GEWEX Atmospheric Boundary Layer Studies
GAW	Global Atmosphere Watch
GAWTEC	GAW Training and Education Centre
GCM	GCOS Cooperation Mechanism
GCMP	GCOS Climate Monitoring Principles
GCOS	Global Climate Observing System (co-sponsored by WMO, UNEP, IOC and ICSU)
GCOS IP	GCOS Implementation Plan
GDI-DE	Geodateninfrastruktur Deutschland
GDR	German Democratic Republic

GECCO	German contribution to Estimating the Circulation and Climate of the Ocean
GEO	Group on Earth Observations
GEOMAR	Helmholtz-Zentrum für Ozeanforschung (Helmholtz Centre for Ocean Research) Kiel
GEOSS	Global Earth Observation System of Systems
GERB	Geostationary Earth Radiation Budget
GEWEX	Global Energy and Water Cycle Experiment
GFCS	Global Framework for Climate Services
GFZ	Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum (GFZ German Research Centre for Geosciences)
GHG	greenhouse gas
GHz	Giga Herz (the unit of frequency)
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
GLODAP	Global Ocean Data Analysis Project
GLOSS	Global Sea Level Observing System
GMES	Global Monitoring for Environment and Security
GOCE	Gravity Field and Steady-State Ocean Circulation Explorer (satellite)
GOME	Global Ozone Monitoring Experiment (instrument to measure ozone profiles, ERS-2 and EPS satellites)
GOOS	Global Ocean Observing System
GO-SHIP	Global Ocean Ship-based Hydrographic Investigations Programme
GOS	WMO Global Observing System
GPCC	Global Precipitation Climatology Centre
GPS	Global Positioning System
GRACE	Gravity Recovery And Climate Experiment
GRA	GOOS Regional Alliances
GRAS	Global Navigation Satellite System Receiver for Atmospheric Sounding
GRDC	WMO Global Runoff Data Centre
GRUAN	GCOS Reference Upper-air Network
GSE	GMES Service Element
GSICS	Global Space-based Inter-calibration System
GSN	GCOS Surface Network
GTN-G	Global Terrestrial Network for Glaciers
GTN-H	Global Terrestrial Network for Hydrology
GTN-L	Global Terrestrial Network – Lakes
GTN-P	Global Terrestrial Network for Permafrost
GTN-R	Global Terrestrial Network for River Discharge
GTOS	Global Terrestrial Observing System (co-sponsored by WMO, UNESCO, ICSU, UNEP and FAO)
GTS	WMO Global Telecommunication System
GTSP	Global Temperature and Salinity Profile Project
GUAN	GCOS Upper Air Network
GUAN	German ultrafine aerosol network
GVaP	GEWEX Global water Vapor Project
HISTOR	Project for rescuing marine weather observations from ship logbooks
Hz	Herz (the unit of frequency)
IASI	Infrared Atmospheric Sounding Interferometer
ICOS	Integrated Carbon Observation System
ICSU	International Council for Science
IGWCO	Integrated Global Water Cycle Observations
IMAGI	Interministerieller Ausschuss für Geoinformation (Interministerial Committee for Geoinformation)

IMF	DLR Institut für Methodik der Fernerkundung (Remote Sensing Technology Institute)
INSPIRE	Infrastructure for Spatial Information in Europe
IOC	Intergovernmental Oceanographic Commission of UNESCO
IOCCP	International Ocean Carbon. Coordination Project
IP	Implementation Plan
IPG	International Phenological Garden
IPY	International Polar Year (March 2007 to March 2009)
IR	Infrared radiation
ISCCP	International Satellite Cloud Climatology Project
ISO	International Organization for Standardization
IUP	Institut für Umweltphysik (Institute of Environmental Physics), University Bremen
IWRMIS	Integrated Water Resources Management Information System, Zambia
Jason	a satellite oceanography mission to monitor global ocean circulation
JCOMM	WMO-IOC Joint Technical Commission for Oceanography and Marine Meteorology
KLIDADIGI	KLImaDATen DIGItalisierung (DWD project on the digitisation of climate data and data rescue for German land stations)
LAI	Leaf area index
Lidar	Light Detection And Ranging (a remote sensing technology that measures distance by illuminating a target with a laser and analyzing the reflected light)
MACC	Monitoring Atmospheric Composition and Climate
MERIS	Medium Resolution Imaging Spectrometer
Meteosat	Series of geostationary meteorological satellites operated by EUMETSAT under the Meteosat Transition Programme (MTP) and the Meteosat Second Generation (MSG) programme
MetOp	EUMETSAT Meteorological Operational Satellite programme
MFG	Meteosat First Generation
MHS	Microwave Humidity Sounder (an Earth-observing instrument)
MOL-RAO	Lindenberg Meteorological Observatory – Richard Assmann Observatory
MSG	Meteosat Second Generation
MSU	Microwave sounding unit
MTG	Meteosat Third Generation
N2O	Nitrous oxide, laughing gas
NASA	National Aeronautics and Space Administration
NDACC	Network for the Detection of Atmospheric Composition Change
NDMC	Network for the Detection of Mesopause Change
NDSC	Network for Detection of Stratospheric Change – now NDACC
NDVI	Normalized Differenced Vegetation Index
NERC	Natural Environment Research Council
NKDZ	Nationales Klimadatenzentrum (National Climate Data Centre)
NIR	Near Infrared
NOAA	National Oceanic and Atmospheric Administration, USA
NOOS	North-West Shelf Operational Oceanographic System
NSIDC	National Snow and Ice Data Center
OOPC	GCOS/GOOS/WCRP Ocean Observations Panel for Climate
O ₃	Ozone
O3M SAF	Satellite Application Facility on Ozone and Atmospheric Chemistry Monitoring
PANGAEA	Data Publisher for Earth & Environmental Science

PASODOBLE	Promote Air Quality Services integrating Observations – Development Of Basic Localised Information for Europe
pCO2	partial pressures of carbon dioxide
PEP	Pan European Phenological Database
PICO	GOOS Panel for Integrated Coastal Observations
PIES	Pressure Inverted Echo Sounders
PMO	Port Meteorological Officer
PROMOTE	PROtocol MONitoring for the GEMS Service Element AtmospherE
PSMSL	Permanent Service for Mean Sea Level
QA/SAC	Quality Assurance / Science Assessment Centre (within GAW)
RA	Regional Association (WMO)
ROV	Remotely operated vehicle
RV	research vessel
SAF	EUMETSAT Satellite Application Facility
SAR	Synthetic Aperture Radar
SASSCAL	Southern African Science Service Centre for Climate Change and Adaptive Land Management
SBSTA	UNFCCC Subsidiary Board on Scientific and Technological Advice
SCAPP	Scanning Pyrheliometer Pyranometer
SCIAMACHY	Scanning Imaging Absorption Spectrometer for Atmospheric Cartography
SCOPE-CM	Sustained Coordinated Processing of Satellite Data for Climate Monitoring
SEVIRI	Spinning Enhanced Visible and InfraRed Imager
SENTINEL	missions include satellite radar and super-spectral imaging for land, ocean and atmospheric monitoring
SHADOZ	Southern Hemisphere Additional Ozonesondes
SKYNET	observation network to understand aerosol -cloud-radiation interaction in the atmosphere
SMOS	Soil Moisture and Ocean Salinity satellite
SOCAT	Surface Ocean Carbon Atlas
SOOP	Ship of Opportunity Programme
SWARM	ESA mission to study the Earth's magnetic field .
SWIR	Short-wavelength infrared
TCO2	total carbon dioxide
TerraSAR	German radar satellite
TIR	thermal infrared
UBA	Umweltbundesamt (Federal Environmental Agency)
UFS	Umweltforschungsstation Schneefernerhaus (Environmental Research Station Schneefernerhaus)
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNMA	Department of Meteorology, Ministry of Water and Environment, Uganda
UTC	Coordinated Universal Time
UV	Ultraviolet
VIS	Visible light
VOS	Voluntary Observing Ships
VOSCLIM	Voluntary Observing Ship Climate Project
WCP	World Climate Programme (WMO)
WCRP	World Climate Research Programme
WDC-RSAT	ICSU/ WMO World Data Centre for Remote Sensing of the Atmosphere

WGMS	World Glacier Monitoring Service
WIGOS	WMO Integrated Global Observing System
WMO	World Meteorological Organization
WOCE	World Ocean Circulation Experiment
WODC	World Ocean Data Centre
WRMC	World Radiation Monitoring Centre
WSD	Waterways Directorate
WWW	World Weather Watch (of WMO)
XCTD	expendable CTD (Conductivity Temperature Depth)
XBT	Expendable Bathythermograph
ZAMG	Zentralanstalt für Meteorologie und Geodynamik (Austrian Central Institute for Meteorology and Geodynamics)
ZMAW	Zentrum für Marine und Atmosphärische Wissenschaften (Centre for Marine and Atmospheric Sciences), University of Hamburg