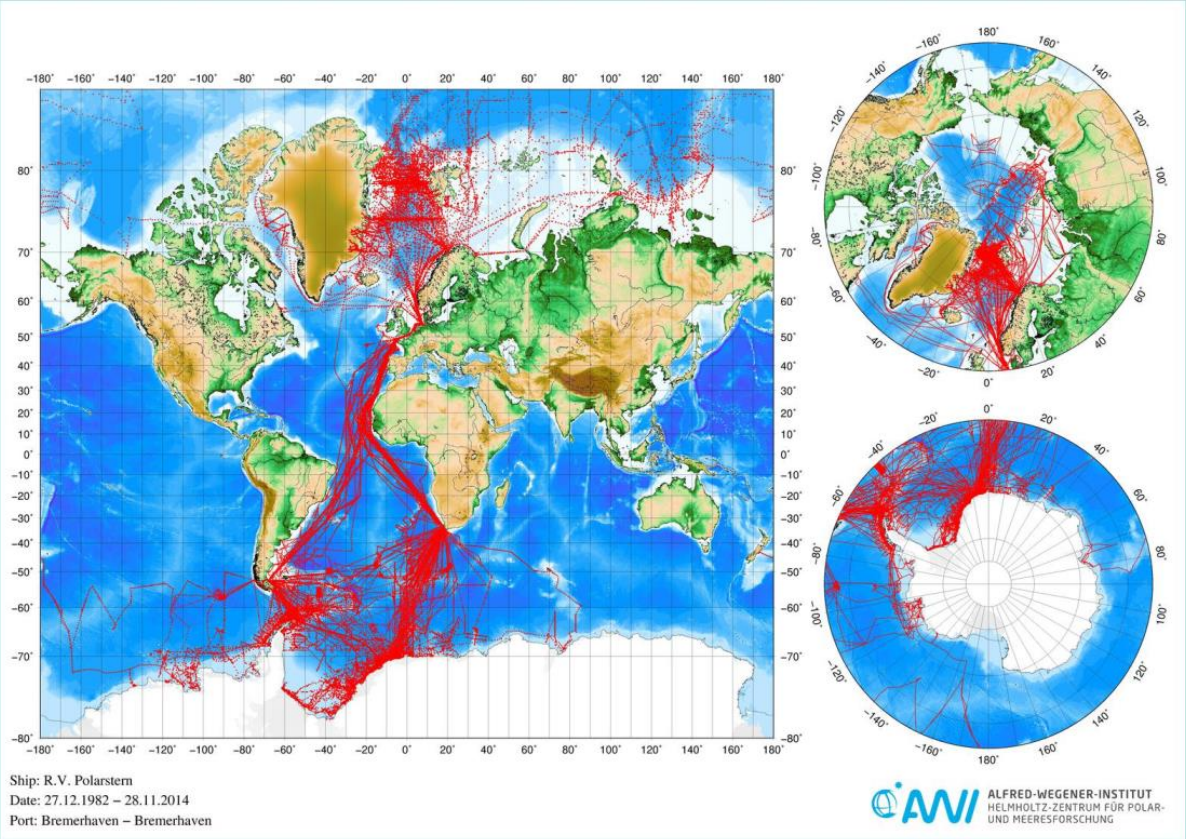
Fifth Report of the Government of the Federal Republic of Germany on Systematic Climate Observations in Germany as a contribution to Germany's 7th National Communication under the United Nations Framework Convention on Climate Change



Set up by the German GCOS Coordinator Deutscher Wetterdienst

Editor

Stefan Rösner
Deutscher Wetterdienst
Division Regional Climate Monitoring
Deputy GCOS German Coodinator
Frankfurter Strasse 135
63067 Offenbach am Main
Germany
E-mail: gcos@dwd.de

Contributing institutions

Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung (AWI)
Bayerische Akademie der Wissenschaften (BAdW)
Bayerisches Landesamt für Umwelt (LfU)
Bundesamt für Seeschifffahrt und Hydrographie (BSH)
Bundesanstalt für Gewässerkunde (BfG)
Deutscher Wetterdienst (DWD)
Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR)
GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel (GEOMAR)
Umweltbundesamt (UBA)
Institut für Umweltphysik, Universität Bremen (IUP-Bremen)
Zentrum für Marine und Atmosphärische Wissenschaften (ZMAW)

03.05.2017

Image on front cover: Course Plot 1982 - 2014 based on 75.000 synoptic observations from the research vessel Polarstern (Graphic: Wolfgang Cohrs) © AWI, Bremerhaven

Germany's report on global observing systems for climate

Content

1 Common issues

The present report is 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 2014. 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.
More detailed information is contained in the 2013 "German Climate Observing Systems – Inventory report on the Global Climate Observing System (GCOS)"[1].

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 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 (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 Internet[2].

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.

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.gcos.de
[2] www.geoportal.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 Cooperation 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 and Hydrological Services (NMHS) of developing countries.
The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH works worldwide in the field of development cooperation.
The GIZ und DWD started the project: "Improved Climate Services for infrastructure investment (CSI)" International Climate Initiative, financed by the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB):
The project goal is to enable government agencies and decision-makers in developing countries to use climate services for planning resilient infrastructure. In the selected countries (Brazil, Costa Rica, Vietnam and Riparian countries of the Nil), the project strengthens supply and demand in the climate services market. It aims to improve climate services of NMHS's and government agencies for better integration of climate risks into infrastructure planning.

DWD contributed to 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 supported the National Meteorological Services in their climate data management activities and climate data rescue. Furthermore SASSCAL installed a network of automatic weather stations, in Angola, Botswana, Namibia and Zambia.
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). Meanwhile the practical rehabilitation of a hydrological network has been finished as well as the creation of data transmission facilities at the stations.

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.

As a special activity in the framework of the StratoClim project (Stratospheric and upper tropospheric processes for better climate predictions), a Swiss / German / Indian team conducted a sounding campaign in Nainital in India. The main objective of the StratoClim project is to produce more reliable projections of climate change and stratospheric ozone by improving the understanding of key processes in the upper troposphere and stratosphere.

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 providing the Essential Climate Variables (ECVs) by supporting the collection of the World Weather Records as well as improving the availability and correctness of the monthly disseminated CLIMAT reports in their regions.

1.2.3 The World Radiation Monitoring Center (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 Center (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 AWI[3] is based on the Publishing Network for Geoscientific & Environmental Data PANGAEA. At the moment data from about 10,000 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-server[4], containing the original station-to-archive-files, are available.

[3] http://www.bsrn.awi.de/
[4] ftp://ftp.bsrn.awi.de

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 and global Network for the Detection of Mesopause Change (NDMC[5]) 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 constantly improve and operationalize the provision of data for the benefit of the research community.

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 re-

[5] http://wdc.dlr.de/ndmc

gions 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 one of 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 has been launched in November 2013 providing an excellent insight into the Earth's magnetic field. 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 extent the Earth Explorer mission suite in 2017 and 2019. Since 2013 and 2015, the Earth Explorers BIOMASS and FLEX are under implementation, respectively. BIOMASS is dedicated to monitor the biomass at the globe's land surface to be launched in 2022. FLEX will provide insight into the vegetation growth and health status (stress).

ESA has also launched a major programme line under the Earth Watch programme umbrella dedicated explicitly to the generation of a number of Thematic Climate Records of ECVs, the ESA Climate Change Initiative (ESA-CCI) to which the GCOS Implementation Plan 2016 (GCOS-200) is also referring to. Germany is contributing over one third to the programme, much more than any other participating state. The first part of the programme (GMECV) has been successfully carried out encompassing about 13 ECV oriented projects including a phase to 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. The second part of the programme (GMECV+) will provide an extension of further 10 ECV projects including permafrost, water vapour, biomass, sea surface temperature, and others. One focus will be also the synergy of the outcome from different ECV projects.

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 2022 through to 2035. Also implementation for a Metop-Follow-on system has

started which will provide data from about 2022 for the following 15 to 20 years. Furthermore, since the successful launch of the Jason-2 satellite in mid 2008, EUMETSAT, as partner in the French-US JASON satellite ocean altimetry programme, provides operational near-real-time data to European users. The Jason programme had been complemented with the launch of the NASA-EUMETSAT collaboration Jason-3 at the beginning of 2016. Jason will find its follow-up in Copernicus Sentinel-6.

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. The first generation of the Sentinel fleet encompasses six types of missions

- Sentinel-1: a set of four C-band SAR satellites of which the first two had been launched (Sentinel-1 A/B: April 2014 and April 2016). The Sentinel-1 C/D units are planned to follow in the second half of 2020s;
- Sentinel-2: a set of four multispectral satellites of which the first two had also been launched (Sentinel-2 A/B: June 2015 and March 2017, respectively). C/D units are also planned to follow in the second half of the 2020s;
- Sentinel-3: a set of four medium resolution land and ocean monitoring satellites of which the first (Sentinel-3A) had been launched on February 16, 2016, the second (B-unit) will be launched in 2018; C/D units are also planned to follow in the second half of the 2020s;
- Sentinel-4 is a spectrometer instrument on the MTG sounder missions to be launched in 2022 and 2032, respectively. The monitoring of pollution and diurnal variations in the atmosphere is the main goal of that mission;
- Sentinel-5 is also a spectrometer instrument but based on the next generation polar orbiting MetOp-SG series which elements are planned to be launched in 2022, 2029, and 2036. Sentinel-5 will continue to monitor the atmospheric composition including greenhouse gases (CO and CH_4);
- Sentinel-6 was called before JASON-CS and will continue the altimetry missions to extend the insight on ocean surface knowledge. Two satellites will be implemented for launch foreseen in 2020 and 2025.

In order to fill the gap between the very successful ENVISAT mission and Sentinel-5, the member states of ESA had decided to implement a gap filler which is called Sentinel-5 Precursor. This self-standing mission will be launched in August 2016 and complements the time series from SCIAMACHY on board ENVISAT until Sentinel-5 for atmospheric composition targets.

Germany is the largest contributor to the Copernicus Space Component which is under implementation by ESA. Its operation is and will be shared by ESA and EUMETSAT on behalf of the EU. On behalf of the BMVI, DLR contracted a consortium of German entities to implement ab Collaborative Ground Segment which allows in a big data approach not only the data access but also the inclusion of higher-level processing units in order to derive information from the Sentinel data products,

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 pro-

ject 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 2017 the CM SAF, hosted by DWD, started its Third Continuous Development and Operations Phase (CDOP 3; 2017 - 2022). 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)

1.5.3.1Data 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
- D-PAC for Sentinel-1, Sentinel-2, and Sentinel-2 or parts of it.
- Ozone Monitoring (AC) 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 O_3 and NO_2, cloud information
- SCIAMACHY on ENVISAT: O_3 vertical columns and profiles, NO_2 vertical columns and profiles, cloud information
- GOME-2 on MetOp-1 and MetOp-2: vertical columns of O_3, NO_2 and SO_2, tropospheric columns of NO_2, 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 providers[6].

As pointed out above, the Sentinel Collaborative Ground Segment is also allocated at DLR in Oberpfaffenhofen in cooperation with several service companies. Aside the national access point for Sentinel data products, the Collaborative Ground Segment is the national facility to provide opportunities for the inclusion of exploitation services. Those will provide users and stakeholders higher-level and synergistic information from different Sentinels but also other missions.

1.5.3.2World 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 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.

1.5.3.3Retrieval 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

[6] https://centaurus.caf.dlr.de:8443/

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 Climate[7] in response to the GCOS implementation plan[8] 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 a delegate for the CEOS Working Group on climate. This Working Group has been implemented by CEOS in cooperation with CGMS as a joint working group. At DLR a delegate is working since the initialisation in contact with experts from different communities. The upcoming GCOS implementation plan revision (GCOS-200) is currently one of the focus areas aside the implementation of the Space-based Climate Data Architecture, originally initiated by WMO, Coordination Group for Meteorological Satellites (CGMS), and CEOS.
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.

[7] GCOS-154, 2011 at http://gcos.wmo.int
[8] 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 182 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 519 automated precipitation stations have the same measurement intervals. Furthermore, there is still an additional large number (724) 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.
Ten National Reference Stations (Aachen, Brocken, Frankfurt/Main, Görlitz, Hamburg-Fuhlsbüttel, Helgoland, Hohenpeissenberg, Lindenberg, Potsdam and Schleswig) are being operated in the national network. At six of 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.,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.
- GAW World Calibration Centres for VOC, N2O, NO2, and aerosol physics.

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, greenhouse gases, and a range of auxiliary data needed to interpret atmospheric chemistry data. In addition to the measurement program covering 6 focal areas of GAW, the site is WMO-CIMO test bed for GAW observations. Cur-

rently, the Hohenpeissenberg Observatory is one of the most comprehensive GAW stations in the world.

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, NO_2, NO_x, NO_y, PAN, VOCs, carbonyl samples) and trace gases relevant to climate (CO_2, CH_4, N_2O, SF_6, 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 Jungfraujoch 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.

The Neumayer air chemistry observatory is one of only very few comparable clean air laboratories operated in Antarctica with an extensive scientific programme, partly established since 1982. There is a strong scientific cooperation with the meteorological observatory of the station. Both observatories are part of the GAW (Global Atmosphere Watch) global station network. For further information see: https://www.awi.de/en/science/long-term-observations/atmosphere/antarctic-neumayer/air-chemistry.html.

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.

Germany hosts important Quality Assurance components of GAW coordinated by the German QA-SAC at UBA-Germany. These comprise the GAW World Calibration Centres for VOC and N_2O and KIT-IMK-IFU (Karlsruhe Institute of Technology, Campus Alpine at Garmisch-Partenkirchen), NOx at FZ-Juelich (Institute for Energy- and Climate Research: Troposphere (IEK-8), Research Centre Juelich), and aerosol physics at TROPOS (Leibniz Institute for Tropospheric Research at Leipzig). All WCCs contribute to QA procedures, provide support to stations, perform audits and intercomparisons and thus contribute to high quality measurements of ECV within GAW.

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 (01.04.2017):

- **182** main meteorological watch offices and automatic weather stations, of which **25** are manned around the clock, **14** are manned part time and **143** are fully automatic weather stations;
- **28** surface weather stations run by the German Federal Armed Forces;

- **1767** voluntary weather stations carried out by non-professionals, of which **839** are automatic stations for 10-minute data (**62** stations measure only wind parameter and **519** only precipitation);
- **6** upper-air stations (**6** 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 (as of 01.04.2017):

- **502** stations measuring temperature and humidity;
- **209** stations measuring air pressure;
- **1910** stations measuring precipitation;
- **302** 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 observational networks. Presently DWD is receiving precipitation data from 513 stations from these observing networks.

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.

Hohenpeissenberg and MOL-RAO contribute to the European Research Infrastructures ICOS (Integrated Carbon Observation System) and ACTRIS (Aerosol, Clouds, reactive Trace gases Research Infrastructure Consortium) aiming at better greenhouse gases (GHG) and short lived climate forcer (SLCF) monitoring and research in Europe. The respective consortia include the relevant European research institutions and are coupled to GAW, GEO, GCOS, EMEP, etc. In particular, ICOS will feed data into IG_3IS (Integrated Global Greenhouse Gas Information System) and thus serve in service provision for science, society and politics.

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 research base in Ny Ålesund on Spitsbergen. This station contributes to NDACC and BSRN, and furthermore is a certified station of the GCOS Reference Upper-Air Network (GRUAN). The operational upper-air data of the station are transmitted to WMO's GTS under a Norwegian WMO station number in cooperation with the Norwegian Meteorological Institute.

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 InGOS[9]. 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 quantitative methods in physical geography, University Augsburg and Tropos Institute, Leipzig. Besides other topics essential themes are long term trend analysis of greenhouse gases and aerosols, methodical selection of representative data and quantification of the central European contribution to atmospheric carbon dioxide concentrations.

Station Zugspitze is part of the project group for aerosols, climate and health which has been initiated by the centre 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, mutual support for quality assurance 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. 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. The derived products are also used to provide monthly updates on the state of the climate in Germany (e.g. http://www.deutscher-klimaatlas.de).
Not all records of climate data generated before 1969 are yet digitized and imported into the database of the NKDZ. So DWD is continuously running data rescue activities 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 resources for digitizing these records are estimated to be in the order of 800 person 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 to provide the data for application and

[9] http://www.ingos-infrastructure.eu/

research. Since 2014 a large part of DWD's climate data is freely available. They are accessible via DWD's Climate Data Center homepage[10].

DWD also works on 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 including in the logbooks are digitized, scanned, quality controlled, stored and provided for purposes of climate research and climate modelling. 50% of these historical meteorological ship journals are already digitized. The complete digitization will take about 200 person years. Approximately 100 person years are estimated for digitizing the signal (along the North and Baltic Sea) and colonial, overseas stations.

2.4.1 Surface-Based Atmospheric ECV's

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

For 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:

- **182** 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
- **1767** secondary weather and precipitation stations with voluntary observers, of which 839 are automatic stations for 10-minute data (62 stations measured only wind parameter and 519 only precipitation)

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 Ny Ålesund on Spitsbergen. Data of these stations are included into the WRMC which includes all BSRN measurements and is managed by the AWI (see section 1.2.3).

Solar radiation and radiation balance data:
These parameters were measured at selected 119 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 including 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 to the international community.

[10] www.dwd.de/cdc

Voluntary Observing Ship Climate Project (VOSClim) ships
Germany currently operates 82 VOSClim ships having generated about 29.000 observations in 2016. It is part of 12 countries worldwide with about 350 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	**182 primary DWD** **320 secondary DWD** (some wind only; no pressure) **28 others**[a]	**502 DWD** **28 others**[a]	**182 DWD**	**182 DWD** **19 others**[a]	**182 DWD**
	precipitation	**182 primary DWD** **1739 secondary DWD (839 autom.)** **28 others**[a]	**182 DWD** **28 others**[a]	**182 DWD**	**182 DWD** **28 others**[a]	**182 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	**119 DWD**	**34 DWD**	**119 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	**82 DWD**	**82, as far as this is possible for a ship**	**120 DWD**	**82 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). All these five stations are involved in the national basic meteorological observing network.

The AWIPEV station in Ny Ålesund on Spitsbergen operated by AWI is part of the GRUAN network. The Neumayer station in Antarctica operated by AWI contributes to GUAN.

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) and GCOS Reference Upper-Air Network	Upper-Air-Temperature, Upper-Air Wind Speed/ Direction, Upper-Air Water Vapour	**1 DWD** **2 AWI**	**1 DWD** **2 AWI**	**1 DWD** **2 AWI**	**1 DWD** **2 AWI**	**1 DWD** **2 AWI**
Full WWW/GOS Upper Air Network	Upper-Air-Temperature, Upper-Air Wind Speed/ Direction, Upper-Air Water Vapour	**9 primary DWD** **5 Bw[a]** **2 AWI**	**9 DWD** **5 Bw[a]** **2 AWI**	**9 DWD** **5 Bw[a]** **2 AWI**	**9 DWD** **5 Bw[a]**	**9 DWD** **5 Bw[a]** **2 AWI**

[a]Bw – German Federal Armed Forces (Bundeswehr)

2.4.3 Atmospheric Composition

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

For the long-lived greenhouse gases CO_2 and CH_4, monitoring is performed in the frameworks of World Meteorological Organization / Global Atmospheric Watch (WMO/GAW) and within the European ICOS (Integrated Carbon Observation System) network.
In addition to four stations observing these variables since longer periods, i.e. the GAW regional stations Schauinsland and Neuglobsow, the global stations Zugspitze/ Schneefernerhaus and Neumayer, there have been set up 5 ICOS tall tower stations at Hohenpeissenberg, Lindenberg, Gartow, Ochsenkopf, and Karlsruhe. Furthermore, in 2017/18 ICOS tall tower stations will be installed at Torfhaus, Juelich, Steinkimmen, and a marine station at Helgoland.
Other long-lived greenhouse gases like nitrous oxide (N_2O), chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), sulphur hexafluoride (SF_6), and perfluorocarbons (PFCs) are measured at selected of the aforementioned stations.

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 measured at Hohenpeissenberg, Zugspitze/ Schneefernerhaus, Schauinsland, Neuglobsow, Neumayer and Ny Ålesund/AWIPEV.

Atmospheric precursor gases are measured at Hohenpeissenberg, Zugspitze/ Schneefernerhaus, Schauinsland, Neuglobsow, and Neumayer generally in the frameworks of GAW, EMEP and ACTRIS. Furthermore, such precursor, aerosol parameters and ozone measurements are performed at stations by regional environmental protections agencies in all areas of Germany in the framework of air quality networks but not listed in Table 1c.

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 CO_2 & CH_4 Monitoring Network, and ICOS Stations	Carbon Dioxide (CO_2)	**9**	**9**	**13**	**9**	**3**
	Methane (CH_4)	**9**	**9**	**13**	**9**	**3**
	Other greenhouse gases	**3**	**3**	**12**	**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**
WMO/GAW precursor network[d]	NO2, SO2, HCHO, CO	**5**	**5**	**5**	**5**	**5**

[a] Including SHADOZ, NDACC, remote sensing and ozone sondes.
[b] Including filter, Dobson and Brewer stations.
[c] Including AERONET, SKYNET, and BSRN.
[d] Including GAW, EMEP and ACTRIS.

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 and incming update GCOS-161), facilitate the generation of ECV satellite products for climate monitoring purposes. The satellite systems have to be complemented by in-situ measurements for validationpurposes 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 page[11] or the information provided by EUMETSAT via CEOS. DWD as representative of 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), MetOp-SG (MetOpSecond Generation) and Jason-Follow-on (Jason-3, since 2016) and Jason Continuity of Service (Jason-CS) or named Sentinel 6 as part of the Copernicus programme (after 2020) as well as archiving aspects. The current satellite systems of EUMETSAT cover the period until around 2025 and the future EUMETSAT satellite systems will cover the period roughly from about 2020/21 till 2040 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 Atmospheric Composition (AC SAF) with major contributions from DLR. Detailed information on the CM SAF and the AC SAF can be retrieved from the Internet[12] (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 pages[13]. As host of the SAF on Climate Monitoring (CM SAF), DWD contributes directly to SCOPE-CM, DLR cooperates with GSICS via the CEOS Working Group on Calibration and Validation and both entities' subgroups.

[11] http://www.eumetsat.int
[12] http://www.cmsaf.eu, http://acsaf.org/
[13] 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)
Surface Wind Speed and Direction Surface vector winds analyses, particularly from reanalysis	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 around 2025; resulting products are archived; see also the web pages of the SAF on Ocean and Sea Ice (OSI SAF)[14].
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	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 around 2025; resulting data and products are archived.
Water Vapour Total column water vapour over the ocean and over land; Tropospheric and lower-stratospheric profiles of water vapour	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 Generation (ended 2017) and Meteosat Second Generation (MSG) and METOP; with all 4 MSG and all 3 METOP satellites data and product continuity can be expected until around 2025and longer; resulting products are archived.
Cloud Properties Cloud radiative properties (initially key ISCCP products)	VIS/IR imagery; IR and microwave soundings Requirement is fulfilled with Meteosat First Generation (ended 2017) and Meteosat Second Generation and METOP; with all 4 MSG and all 3 METOP satellites data continuity can be expected until around 2025and longer; resulting products are archived. See also the webpages from NWC SAF[15]
Precipitation Improved estimates of precipitation, both as derived from specific satellite instruments and as provided by composite products	Passive microwave radiances; High-frequency geostationary IR measurements; Active radar (for calibration) Requirement is fulfilled with Meteosat First Generation (ended 2017) and Meteosat 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 around 2025and longer; resulting products are archived.
Earth Radiation Budget Top-of-atmosphere Earth radiation budget on a continuous basis	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 around 2025 and longer; resulting products are archived.
Ozone Profiles and total column of ozone	UV/VIS and IR microwave radiances Requirement is fulfilled by GOME on ERS-2 (ended 2012), 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 around 2025 (from 2016 onwards with Sentinel 5 precursor); resulting products are archived; see also the

[14] http://www.osi-saf.org
[15] http://www.nwcsaf.org/

ECVs/ Global Products requiring Satellite Observations	Fundamental Climate Data Records required for Product Generation (from past, current and future missions)
	web pages of the SAF for Atmospheric Composition (AC SAF)[16]. Additionally, vertically resolved ozone products are provided through data assimilation within Coperrnicus projects like PASODOBLE and MACC (former GMES projects PROMOTE / MACC) using data of ENVISAT (ended 2012) and METOP satellites.
Aerosol Properties Aerosol optical depth and other aerosol properties	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 around 2025 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 / MACC-III and other based on ERS-2 (ended 2012), METOP and the Copernicus Sentinel family.
Carbon Dioxide, Methane and other GHG Distribution of greenhouse gases, such as CO_2 and CH_4 of sufficient quality to estimate regional sources and sinks	NIR/IR radiances The IASI and GOME-2 instrument on board of METOP and TROPOMI on Sentinel 5 Precursor (CO, CH4)contribute to the monitoring of the listed trace gases.
Upper-air Wind Upper-air wind reanalyses, particularly from reanalysis	VIS/IR imagery; Doppler wind lidar Wind vectors are derived from data of Meteosat First Generation (ended 2017) and Meteosat Second Generation; with MSG product continuity can be expected until around 2025and 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. The ESA ADM-Aeolus Mission will start 2017/18.
Atmospheric Reanalyses	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 (CM SAF[17]) continues to perform re-processing.
Soil moisture	Scatterometry, passive microwave radiances Requirement is fulfilled with MetOp ASCAT and ESA SMOS.

[16] http://acsaf.org/
[17] http://www.cmsaf.eu

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

The following statements refer to the GCOS implementation plan 2010 according to the reporting guidelines. A revision according to the 2016 update is planned.

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

To fulfil the GCMPs, DWD operates 6 Reference Stations throughout Germany. These are: Brocken, Frankfurt am Main, 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 GUAN 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/m^2.

(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 and through the implementation of Argo Programme.

The BSH operates the German contribution to the international Array for real-time geostrophic oceanography (Argo) network. Long-term funding is provided by the Federal Ministry of Transport and Digital Infrastructure (BMVI) to deploy 30-40 Argo floats each year. The focus of deployments is the Atlantic Ocean, but if necessary other oceans could be selected to maintain the global array. Currently (February 10th, 2017) 143 German floats are active and the total number of German floats deployed within the Argo program increased to 853. 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 CORIOLIS[18]. 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. BSH is the German representative in the European Research Infrastructure Consortium ERIC EuroArgo which coordinates the European contribution to the UN Argo programme.

The BSH maintains a net of 12 autonomous observation platforms in the North Sea and Baltic Sea (MARNET). 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 (3 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 are 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

[18] 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 29 individual long-term moorings which are part of the OceanSites programme. The locations of the moorings are in the Fram Strait (16), the Weddell Gyre along the Greenwich Meridian (8) and the Weddell Gyre proper (5). The GEOMAR operates 4 moorings in the Labrador and 2 moorings in the Irminger Sea and as well as 2 moorings off the Cape Verde Islands which are all integrated into the OceanSites programme. Additional mooring activities of the GEOMAR had focused on the tropical Atlantic where several moorings had been deployed for a long-term period. These moorings were 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 University of Hamburg (ZMAW) operates three moorings within the OceanSites program, 2 of them in Denmark Strait and 1 in the Greenland Sea. The IOW operates a long-term mooring near the Azores which is part of OceanSites. The IUP Bremen operates 3 integral moorings in the sub-polar North Atlantic to estimate the Gulf Stream transport, 2 of the mooring are located at the western boundary and 1 at the eastern. BSH is contributing 2 moorings to this 47/48 °N array at the eastern margin. Data from these moorings will be available for climate research. A multidisciplinary mooring has been established near the Cape Verde Islands (MARUM) and will contribute data to GEOSS.

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, but 37 surface buoys equipped with temperature sensors have been deployed by ZMAW in 2016 in the upwelling area of Namibia. The drifters are still active and have been adopted into the international surface drifter program after the end of the research project.

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. The BSH is digitizing older paper gauges from the Baltic sea coast dating back to about 1900.

DWD funds the meteorological equipment for 457 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 5×5 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	457	457	800	457	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	46	46	46	46	46
Global tropical moored buoy network	All feasible surface and subsurface ECVs	None	None	None	None	None
Argo network	Temperature, Salinity, Current	143	143	200	143	853
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[19]. TerraSAR-X, TanDEM-X and Sentinel-1 (launch 2014 and 2016) 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 Copernicus Sentinel-3 and Copernicus Sentinel-6.
Sea Surface Temperature Sea surface temperature	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. EUMETSAT will operate marine part of Copernicus 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 Copernicus 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 Copernicus 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

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).

[19] http://www.osi-saf.org

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*CO2. **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 pCO2 measurements on RV Polarstern and moored pCO2 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, reseeding the network with replacement floats to fill gaps, and maintain density (about 800 per year). **Who:** Parties participating in the Argo Project and in cooperation with the Observations Coordination Group of JCOMM.

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 ¼ 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 countries[20].

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.

[20] http://www.euro-argo.eu/

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 (GTOS[21]), 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-H[22] 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 and the GEMStat database are operational in Germany and are part of the GTN-H Panel and represent their respective networks on precipitation, river discharge and water quality.

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 258 stations in 22 countries. 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 since 1964/65, including the separation into winter and summer series. Since 2010, gravi-

[21] http://www.fao.org/gtos/
[22] http://www.gtn-h.info/

metric 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 (WGMS[23]) and National Snow and Ice Data Center (NSIDC[24]). Hydrological and meteorological data are published in the Open Access library Pangaea[25], 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 DWD[26], 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 are designed to collect temperature data for at least 15 years (planned up to 2022). The results contribute to a permafrost monitoring network for all of the Alps. The data are placed at disposal for the GTN-P. In addition, German permafrost working groups from AWI take care about several long-term permafrost temperature and active layer thickness observations in Northern Siberia (Lena Delta: Samoylov Island, Kurugnakh Island, Sardakh Island; Northern Yakutia: Mamontovy Klyk; Chukotka: El'gygytyn Crater), on Spitsbergen (Bayelva site, close to Ny Ålesund), in Alaska (Seward Peninsula), and in NW Canada (Herschel Island). Over the past six years, the GTN-P (Global Terrestrial Network for Permafrost) has developed considerably. It developed a Data Management System for the two ECVs permafrost temperature and active layer thickness with funding and coordination from AWI, the EU project PAGE21 and ESKP (eskp.de). The GTN-P Secretariat and its executive director are located at the AWI in Potsdam.

[23] http://wgms.ch/
[24] http://nsidc.org/index.html
[25] http:/www.pangaea.de
[26] https://www.dwd.de/

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	1649 (180 primary + 1469 secondary DWD stations)	180 DWD	180 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 1100 sites in Germany (01.04.2017).

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 is still going on. 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 Berlin[27].

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 and TanDEM-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.

[27] https://www.agrar.hu-berlin.de/de/institut/departments/dntw/agrarmet/phenology/standardseite

ECVs/ Global Products requiring Satellite Observations	Fundamental Climate Data Records required for Product Generation (from past, current and future missions)
fAPAR Maps of fAPAR	VIS/NIR imagery Sentinel-2
LAI Maps of LAI	VIS/NIR imagery Sentinel-2
Biomass Research towards global, above ground forest biomass and forest biomass change	L band/ P band SAR; Laser altimetry University Jena: Regional biomass classification products in boreal areas (Siberia, China), derived from ERS interferometry and of hyper-temporal analysis of ENVISAT-ASAR time series
Fire Disturbance Burnt area, supplemented by active fire maps and fire radiated power	VIS/NIR/SWIR/TIR moderate-resolution multi-spectral imagery Sentinel-2 and Sentinel-3
Soil Moisture Research towards global near-surface soil moisture map (up to 10cm soil depth)	Active and passive microwave ESA's SMOS launched in November 2009, providing observations of this emerging ECV.

List of abbreviations

ACC	Atmospheric Composition Constellation
AC SAF	Satellite Application Facility for Atmospheric Composition
ACTRIS	Aerosol, Clouds, reactive Trace gases Research Infrastructure Consortium
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 **P**aul **E**mile **V**ictor
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)
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
CH4	Methane
CLIMAT	code for reporting monthly climatological data observed at land-based meteorological surface stationes
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 GMES)
CORIOLIS	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
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) – terminated 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
GTSPP	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
IG_3IS	Integrated Global Greenhouse Gas Information System

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)
InGOS	Integrated non-CO_2 Greenhous gas Observing System
INSPIRE	Infrastructure for Spatial Information in Europe
IOC	Intergovernmental Oceanographic Commission of UNESCO
IOCCP	International Ocean Carbon. Coordination Project
IOW	The Leibniz Institute for Baltic Sea Research (Leibniz-Institut für Ostseeforschung Warnemünde)
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
KIT-IMK-IFU	Karlsruhe Institute of Technology, Campus Alpine at Garmisch-Partenkirchen
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
MARNET	Marinen Umweltmessnetz in Nord- und Ostsee (Marine Environmental Monitoring Network in the North Sea and Baltic Sea)
MARUM	Center for marine research University of Bremen (Zentrum für Meeresforschung Universität Bremen)
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
NMHS	National Meteorological and Hydrological Services
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	now AC SAF (Satellite Application Facility on Ozone and Atmospheric Chemistry Monitoring)
Pan	Peroxyacyl nitrates
PANGAEA	Data Publisher for Earth & Environmental Science
PASODOBLE	**P**romote **A**ir Quality **S**ervices integrating **O**bservations – **D**evelopment **O**f **B**asic **L**ocalised Information for **E**urope
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	Quality Assurance
QA/SAC	Quality Assurance / Science Activity 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 Subsidary 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
SLCF	short lived climate forcer
SMOS	Soil Moisture and Ocean Salinity satellite
SOCAT	Surface Ocean Carbon Atlas
SOOP	Ship of Opportunity Programme
StratoClim	Stratospheric and upper tropospheric processes for better climate predictions
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
TROPOS	Leibniz Institute for Tropospheric Research at Leipzig

UBA	Umweltbundesamt (Federal Environmental Agency)
UFS	Umweltforschungsstation Schneefernerhaus (Environmental Research Station Schneefernerhaus)
UN	United Nations
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UTC	Coordinated Universal Time
UV	Ultraviolet
VIS	Visible light
VOC	Volatile organic compounds
VOS	Voluntary Observing Ships
VOSClim	Voluntary Observing Ship Climate Project
WCC	GAW World Calibration Centres
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
WMO-CIMO	Commission for Instruments and Methods of Observation
WOCE	World Ocean Circulation Experiment
WODC	World Ocean Data Centre
WRMC	World Radiation Monitoring Center
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