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GCOS Switzerland
Progress Report 2008

Prepared for Submission to
the United Nations Framework
Convention on Climate Change
(UNFCCC)

Framework

This report was prepared in response to conclusions FCCC/SBSTA/2005/10, paragraph 95 (2005) and FCCC/SBSTA/2007/L.14 (2007) of the UN Framework Convention on Climate Change (UNFCCC) Subsidiary Body on Scientific and Technological Advice (SBSTA) and presents the progress in the implementation of GCOS in Switzerland. The progress reports on the national GCOS implementation activities are in close connection with the request from SBSTA-23 to the GCOS Secretariat to prepare a comprehensive report on progress with the GCOS implementation plan for SBSTA-30 (June 2009). The SBSTA noted that the GCOS report would be heavily dependent upon obtaining timely information on national implementation activities.

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Swiss GCOS Office

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Copies of the report are available for download from the Swiss GCOS website

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1 Common issues

Introduction

In recent decades – especially following the adoption of the Climate Convention in 1992 – the demand for observations of climate and climate change has steadily increased. For scientific conclusions on climate change, the attribution of anthropogenic influences and future climate scenarios, long-term, high-quality data series are essential.

Switzerland's climate in 2050

The recently published Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007) summarizes the current state of knowledge on climate change and its global impacts. From a global perspective, Switzerland is relatively seriously affected by climate change. By 2050, according to a recent report by the Swiss Advisory Body on Climate Change (OcCC, 2007), Switzerland will face autumn, winter and spring temperatures to increase by around 2 °C and summer temperatures by almost 3 °C. Precipitation levels are projected to rise by about 10% in winter and to fall by about 20% in summer. In addition, the frequency of extreme precipitation events is expected to increase, especially in the winter, possibly leading to more frequent floods and debris flows in certain regions. Climate change scenarios for Switzerland, however, are quantitatively still very uncertain. Early detection of long-term climate variations is therefore essential for the planning and management of climate change adaptation strategies.

UN Framework Convention on Climate Change and GCOS

To address these challenges, the Global Climate Observing System (GCOS) was established in 1992, parallel to the establishment of the UN Framework Convention on Climate Change (UNFCCC). The aims and requirements of systematic observation are specified in Article 4 and 5 of the UNFCCC and in Article 10 of the subsequent Kyoto Protocol. GCOS is designed to ensure that the observations and information needed to address climate-related issues are obtained and made available to all potential users. Building on existing networks and systems, GCOS encompasses the total climate system including observations of physical, chemical and biological properties of the atmosphere, the ocean and the land surface. The implementation of GCOS is based on the Second Adequacy Report (WMO, 2003) and the Implementation Plan (WMO, 2004). The GCOS Implementation Plan (GIP) thereby clearly highlights the role of every country to set up national coordination mechanisms and national plans for the provision of systematic observation of the climate system (→ GIP Action C2). Such mechanisms are usually best sustained when national coordinators or focal points are designated and assigned responsibility to coordinate planning and implementation of systematic climate observing systems across the many departments and agencies involved with their provision.

In response to conclusions FCCC/SBSTA/2005/10, paragraph 95 and FCCC/SBSTA/2007/L.14 of the UNFCCC Subsidiary Body on Scientific and Technological Advice (SBSTA), this report presents the progress in the implementation of GCOS in Switzerland, according to the guidelines adopted at the 13th UNFCCC Conference of the Parties (COP13; Decision 11/CP.13). The report is a short and updated version of the more comprehensive report "National Climate Observing System (GCOS Switzerland)" (Seiz and Foppa, 2007) compiled in 2007.

National GCOS implementation

Switzerland has a long tradition of climate observation. Temperature and precipitation series of more than 150 years, the world's longest total ozone series, glacier measurements dating back to the end of the 19th century and the 100-year anniversary of the Physical Meteorological Observatory Davos are only a few of the highlights of Switzerland's contribution to global and regional climate monitoring.

Swiss climatological time series in the IPCC report

The benefits of high-quality climate observations are substantial. Analyses of the climatological time series collected within the GCOS framework provide a key foundation for reports by international climate experts (e.g. IPCC Assessment Reports, WMO Scientific Assessments of Ozone Depletion). The Fourth IPCC Assessment Report makes reference to various papers concerning Swiss climatological time series, e.g. for precipitation (Schmidli and Frei, 2005), radiation (Philipona et al., 2005; Wild et al., 2005), snow (Scherrer et al., 2004), glaciers (Zemp et al., 2005), permafrost (Vonder Mühll et al., 2004) and phenology (Defila and Clot, 2001).

National coordination: Swiss GCOS Office

Following the ratification of the Kyoto Protocol by the Swiss Parliament in summer 2003, the national GCOS coordination was strengthened by the Federal Office of Meteorology and Climatology MeteoSwiss. On 1 February 2006, the Swiss GCOS Office was established, building on the former GCOS Focal Point at MeteoSwiss. The Swiss GCOS Office is responsible for coordinating climatological observations carried out in Switzerland by federal offices, research institutes and universities. Every 8 to 10 months, a so-called "Swiss GCOS Roundtable" is organized to foster a good information exchange between the different partners. The coordination also includes long-term planning to ensure continuous and representative observations, e.g. by identifying the risk of discontinuity ahead of time and engaging in remedial action. As far as possible, new measurement techniques are also considered in the integrated observation system. In addition, the Swiss GCOS Office identifies resource-related problems affecting the operation of international data and calibration centres in Switzerland and provides financial and technological support for selected observations abroad.

Switzerland's contribution to systematic observations with regard to GCOS has been reported in the Third National Communication (FOEN, 2001) and Fourth National Communication (FOEN, 2005) under the framework of UNFCCC. In 2006, the Swiss GCOS Office and ProClim performed a survey among Swiss universities, research institutes and federal offices with the aim of documenting climatological series and identifying risks to their continuation. The criteria were defined on the basis of similar studies for the selection of climatological stations (Müller, 1980; WMO, 1997). The main criteria specified were that a series should: (a) cover a period of more than 50 years, (b) be longer than comparable series abroad, or (c) concern recently introduced climate variables or observation methods. The secondary criteria included participation in international agreements or data centres, geographical representativeness, data quality and availability of metadata. Respondents were also asked to indicate their requirements for funding in order to ensure continued operation of stations.

First inventory of long-term climatological data series

Based on the survey results, a report about the National Climate Observing System (GCOS Switzerland) (Seiz and Foppa, 2007) has been completed by November 2007. The report is the first inventory of Switzerland's long-term climatological data series and international data centres, including an assessment of their future prospects. The inventory was compiled in cooperation with ProClim (the Forum for Climate and Global Change of the Swiss Academy of Sciences SCNAT) and the responsible federal offices, research institutes and universities advised by a steering committee consisting of scientists and policymakers.

Finally, at the request of the Federal Office of Meteorology and Climatology MeteoSwiss through the Federal Department of Home Affairs (FDHA), the Swiss Federal Council has agreed on 6 June 2008 on a long-term financial contribution to GCOS Switzerland, starting from 2010. This financial contribution will cover the operation costs of several long-term climatological data series of carbon dioxide, freeze dates of lakes, snow water equivalent, glaciers, permafrost and phenology, and of two international data centres in Switzerland (World Glacier Monitoring Service WGMS, palaeo-historic database Euro-Climhist), whose future were identified to be uncertain in the Swiss GCOS inventory report.

Quality assurance

Quality assurance of the climate observations is essential. The Swiss GCOS Office at MeteoSwiss is therefore paying continued and careful attention to the GCOS Climate Monitoring Principles, in particular to ensure that climate signals or artificial inhomogeneities can be distinguished from systematic biases (→ GIP Action C8). As measurement conditions are not generally constant for long time series, homogenization is necessarily required. Changes in measurement conditions (e.g. station relocations, environmental changes, new instruments) can lead to abrupt or gradual increases or decreases in readings, confounding trend analysis of time series.

Homogenization of ground-based meteorological data

At MeteoSwiss, statistical methods and assessments of station history are used since several years in an attempt to systematically identify and correct inhomogeneities in time series (Begert et al., 2003). In the NORM90 project, long time series of temperature and precipitation of selected stations were analyzed for artificial discontinuities and trends and homogenized. In order to increase the density of homogenized data series, particularly in the Central Alpine region, 16 additional stations were recently selected with time series from at least 1900 (exception: Jungfraujoch only from 1930). These stations of greatest climatological importance (28 in all) were then defined as the Swiss National Basic Climatological Network (NBCN) (Begert et al., 2007). Digitization and homogenization of the long temperature and precipitation series from these 28 stations is ongoing, in collaboration with ETH Zurich.

Homogenization of upper air and ozone data

Homogenization efforts of the time series of the Payerne soundings are undertaken by MeteoSwiss, in collaboration with different research institutions. With the inclusion of Payerne in the GCOS Upper Air Network (GUAN) since the beginning of 2008, MeteoSwiss will strengthen the historical documentation and homogenization of these upper-air measurements. Recently, the 36 years long (1966 - 2002) ozone sounding series with the Brewer-Mast sondes have been homogenized (Jeannet et al., 2007). Simultaneously, the replacement of the former sondes with another sonde type in 2002 has been carefully analyzed (Stübi et al., 2008). The Umkehr series from the Licht-Klimatisches Observatorium in Arosa have been recalculated due to instrument changes in 1988 and resubmitted to the World Ozone and Ultraviolet Radiation Data Centre (WOUDC) in Toronto.

Harmonization of forest ecosystem monitoring

Under the federal Long-term Forest Ecosystem Research (LWF) project, forest ecosystem monitoring has been run since 1994 at 18 monitoring sites in Switzerland, contributing to the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests). The aims of the project are in agreement with those of the ICP Forests. Efforts are undertaken by the ICP Forests to harmonize the approach to data sampling, gathering, monitoring, reporting and analysis of forest ecosystem parameters in over 40 countries. Switzerland as a participating country in the ICP Forests through the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) pursues the implementation of ICP Forests harmonization plans.

International centres

To determine state and variability of the climate system, measurements need to be globally standardized. The necessary activities of data collection, storage and redistribution are thereby guaranteed by international data and calibration centres around the world (→ GIP Actions C18, C19, C20, C21). International data centres have been established for many of the essential climate variables networks and systems (FCCC/CP/2007/6/Add.2, Appendix 4). In addition, international calibration centres – with their reference instruments and regular calibration activities – make a vital contribution to the quality of global observation programmes.

International data centres and databases

The Baseline Surface Radiation Network (BSRN) is the global baseline network for monitoring the radiation field at the Earth's surface; it currently includes 38 stations worldwide. The global BSRN measurements are stored at the BSRN archive based at ETH Zurich. As the long-term operation of the BSRN archive could not be assured at ETH Zurich, the BSRN archive has been transferred to the Alfred Wegener Institute (AWI) in Germany in early 2008, to be operational starting from 1 July 2008. In addition, the ETH Zurich maintains the Global Earth Balance Archive (GEBA) database, which provides quality controlled records of measured energy fluxes from 1'600 stations worldwide to the climate research community. Since November 1986, GEBA has been a World Climate Programme (WCP) project under the lead of the WMO, UNESCO and the International Council for Science (ICSU).

The collection of data on glacier variation worldwide was initiated in 1894 with the establishment of the International Glacier Commission at the 6th International Geological Congress in Zurich. Since 1986, the World Glacier Monitoring Service (WGMS) in Zurich has been coordinating the international collection and publication of glacier data, as well as being responsible for the Global Terrestrial Network for Glaciers (GTN-G) within GCOS/GTOS. Basic funding for WGMS is assured until March 2009 through the Swiss National Science Foundation and the University of Zurich. Thereafter, the already 110-year-old Swiss responsibility for worldwide glacier monitoring will be supported by long-term funding through the Swiss GCOS Office (→ GIP Action T13).

International calibration centres

The Physical Meteorological Observatory (PMOD) was founded at Davos in 1907 to carry out research in the field of solar radiometry and to study the effects of climate and weather conditions on humans, animals and plants. In 1971, the World Radiation Center (WRC) was established at the PMOD on the recommendation of the World Meteorological Organization (WMO). Since 2006, the WRC is divided into two sections (Solar Radiometry Section SRS and Infrared Radiometry Section IRS), with two additional new facilities (World Optical depth Research and Calibration Center WORCC and European Ultraviolet Radiometer Calibration Center EUVC).

The World Calibration Centre (WCC) for Surface Ozone, Carbon Monoxide and Methane (WCC-Empa) was established at Empa in 1996 at the request of the WMO. The goal of the WCC is to ensure that measurements carried out at different GAW stations are fully traceable to the designated reference.

The GAW Quality Assurance/Scientific Activity Centre (QA/SAC Switzerland) was established at Empa in 2000 and is one of four such facilities worldwide. Although it focuses on surface ozone, carbon monoxide and methane, the scope of its activities covers additional measurements as well. One major ongoing activity is the development and operation of the GAW Station Information System (GAWSIS), an interactive database application for integrating information on the GAW measurement programme.

Capacity building

Technology transfer and local training are important means of enhancing the quality of climate-related observations abroad, especially in developing and emerging countries (→ GIP Action C9). The observations currently carried out by Swiss institutions abroad cover the following climate variables: ozone (Kenya), trace gases (Algeria, Kenya, Indonesia) and glaciers (worldwide). In the future, additional financial resources will be required in particular for trace gases measurements at global GAW stations and for selected glacier observations worldwide.

The GCOS Cooperation Mechanism (GCM) was initiated in 2002 at SBSTA-17 and is implemented under the GCOS Memorandum of Understanding. It is a voluntary multi-governmental funding mechanism. The purpose of the GCM is to identify and make the most effective use of resources available for improving global observing systems for climate in developing countries, particularly in order "to enable them to collect, exchange, and utilize data on a continuing basis in pursuance of the UNFCCC" (Decision 5/CP.5). The GCOS Cooperation Mechanism consists of a Cooperation

Board and a Cooperation Fund. Switzerland has participated at the GCM Board meeting in June 2008.

Earth observation satellites

Satellite observations are essential to obtain observations of the climate system from a near-global perspective and to compare the behaviour of different parts of the globe. So, a detailed global climate record for the future critically depends upon a major satellite component within GCOS (→ GIP Action C10). Therefore, a report about the systematic observation requirements for satellite-based products for climate has been compiled by the WMO GCOS Secretariat in 2006 as a supplement to GCOS Implementation Plan (GIP-SS; WMO, 2006). To emphasize the role of space agencies in the implementation of GCOS, the SBSTA-25 invited the Parties that support space agencies to enable these agencies to implement, to the extent possible, the actions identified in the Committee on Earth Observation Satellites (CEOS) report (CEOS, 2006) and to continue responding in a coordinated manner through CEOS to the efforts to meet these needs.

Switzerland is member of the European Space Agency (ESA) and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT). ESA, focused on research and development projects, as well as EUMETSAT, more orientated towards pre-operational and operational projects, have activities in the field of climate monitoring. The most important of these activities with involvement of Swiss institutions are described in a one page summary in Chapter 2 (for atmospheric Essential Climate Variables) and in Chapter 4 (for terrestrial Essential Climate Variables). As high-quality surface and in-situ observations remain of central importance for calibration and validation of satellite data, Switzerland with its many unique observation systems and climate records can play a leading role in advancing the integration of satellite data into fundamental climate data records.

Palaeoclimate data

Euro-Climhist database

Euro-Climhist is a database developed at the Institute of History at the University of Bern, including records of early instrumental measurements, daily to seasonal weather reports and observations on lake and river freezing, snow cover, phenology and the impacts of natural disasters, as well as reports on perceptions of weather. The database is a valuable resource for analysis of the climate history of Switzerland (from the late 15th to the early 19th century) and Europe with a focus upon the Medieval Period. Altogether the database currently holds more than 1.2 million records, of which 620’000 are available in digital form. In addition, around 40’000 individual observations from pre-1500 Europe were processed in the EU Millennium project. The continuation of Euro-Climhist is assured until 2009 through funding from the Oeschger Centre for Climatic Change Research at the University of Bern and will then be continued with funding through the Swiss GCOS Office.

Submitting historical data

In spring 2008, Switzerland submitted daily values of precipitation, minimum and maximum temperature of the two GCOS Surface Network (GSN) stations Säntis and Grand St. Bernard from January 1864 to December 2006 to the National Climatic Data Center (NCDC) in Asheville, USA.

Difficulties

Baseline Surface Radiation Network

For more than 20 years, Switzerland hosted the archive of the BSRN network at the ETH Zurich. Unfortunately, as mentioned earlier, the long-term operation of the BSRN archive could not be assured at ETH Zurich, so that the BSRN archive has been transferred to the AWI institute in Germany in the first half-year of 2008.

EuroGCOS

The implementation of a regional coordination mechanism in Europe (EuroGCOS) proves to be difficult (→ GIP Action C3). EuroGCOS has been started with a regional workshop in April 2005 and a regional action plan for Eastern and Central Europe (WMO, 2005). A letter of the German GCOS Office at DWD and the Swiss GCOS office in 2007 to all European GCOS focal points has not been answered. In summary, the EuroGCOS regional action plan still remains largely unimplemented.

Data rescue

There are still many observations which only exist in analogue form and would need to be digitized (→ GIP Action C17). New digitizing efforts have started with a focus on temperature (and to some extent precipitation), but the same work remains to be done for other variables such as air pressure, wind, snow cover, or additional precipitation stations. Compiling long, daily-to-subdaily meteorological and hydro-meteorological series from Switzerland is extremely important for impact studies of extreme events. Moreover, in parallel with global efforts in this direction, such data are needed to produce global historical reanalysis data sets. For example for snow cover, the data collected before 1930 are often only available in the original analogue form and therefore require additional processing and digitization if they are to be used in analyses.

2 Atmospheric Essential Climate Variables

INTRODUCTION

SURFACE
Air temperature
Precipitation
Air pressure
Sunshine duration
Radiation

UPPER AIR
Clouds
Water vapour

COMPOSITION
Ozone
Carbon dioxide
Greenhouse gases
Air pollutants
Aerosols
Pollen

ROLE OF SATELLITES

Introduction

Switzerland has a long tradition in the observation of climate. Systematic observation programmes established by Swiss institutions make a significant contribution to the global climate observing system. The most important systematic observations of the atmospheric domain concern the surface and upper air climate, Earth radiation budget, atmospheric trace gases, aerosols and pollen. Pollen is no Essential Climate Variable (ECV) listed in the GCOS Second Adequacy Report, but its measurement has a long tradition in Switzerland and consequently, its series are an important part of the Swiss climate observing system.

Essential Climate Variables of the atmospheric domain

Surface	Air temperature, Precipitation, Air pressure, Surface radiation budget, Wind speed and direction, Water vapour
Upper Air	Earth radiation budget (including solar irradiance), Upper air temperature, Wind speed and direction, Water vapour, Cloud properties
Composition	Carbon dioxide, Methane, Ozone, Other long-lived greenhouse gases, Aerosols, *Pollen*

Table 1: Essential climate variables of the atmospheric domain as listed in the GCOS Second Adequacy Report (WMO, 2003), together with additional variables of relevance for Switzerland (in italics).

In the following the status of the Swiss GCOS contribution of the different essential climate variables is reported. In general, the paragraph structure corresponds to the list above. In some cases however, it made sense to combine several ECVs (i.e. some of the upper air ECVs) or to include additional ECVs (i.e. Pollen). For each climate variable the measurements in Switzerland, their long time series and their international integration are described.

Highlights

For the surface-based atmospheric observations, a Swiss National Basic Climatological Network (NBCN) has been designated, consisting of 28 stations of the greatest climatological importance. The NBCN includes the 2 GSN stations Säntis and Grand St. Bernard and further 5 RBCN stations.

Since January 2008 the Payerne aerological station is part of the GCOS Upper Air Network (GUAN), meeting higher quality requirements for long-term monitoring of the climate. Moreover, following a recommendation by the meeting on the implementation of the GCOS Reference Upper Air Network (GRUAN) in Lindenberg (Germany) in February 2008, Payerne has been invited to become part of the initial set of sites forming the GRUAN.

Since 1992, one of the 38 stations of the worldwide Baseline Surface Radiation Network (BSRN) is operated at Payerne by the Federal Office of Meteorology and Climatology MeteoSwiss. The BSRN network has been designated as the surface radiation observation arm of GCOS.

Ten years after its launch, an evaluation of the Swiss Global Atmosphere Watch programme (GAW-CH) by three international experts was organized in 2005. The experts concluded that the transition from the consolidation phase to the permanent phase in 2007 requires at least the same level of funding as successful monitoring needs continuous improvement from research and development. They also recommended to launch a Swiss GAW *Plus* programme which adds or extends components going beyond the current scope of GAW-CH. In the meantime, these recommendations have been fully implemented. In order to give the scientific Swiss GAW programme a strong impulse and enable the innovations necessary for the future, MeteoSwiss and the project partners (i.e. research institutes) provided extraordinary funds for the 2007-2009 period.

National Contributions

Contributing networks specified in the GCOS implementation plan	ECVs	No. of stations or platforms currently operating	No. of stations or platforms operating in accordance with the GCMPs[1]	No. of stations or platforms expected to be operating in 2010	No. of stations or platforms providing data to the international data centres	No. of stations or platforms with complete historical record available in international data centres
GCOS Surface Network (GSN)	**Air temperature**	2	2	2	2	2
	Precipitation	2	2	2	2	2
Full World Weather Watch/ Global Observing System (WWW/GOS) surface network	**Air temperature, air pressure, wind speed and direction, water vapour**	7	7	7	7	7
	Precipitation	7	7	7	7	7
Baseline Surface Radiation Network (BSRN)	**Surface radiation**	1	1	1	1	1
Solar radiation and radiation balance data	**Surface radiation**	73	73	126	10	10

Table 2a: National contributions to the surface-based atmospheric essential climate variables.

Contributing networks specified in the GCOS implementation plan	ECVs	No. of stations or platforms currently operating	No. of stations or platforms operating in accordance with the GCMPs	No. of stations or platforms expected to be operating in 2010	No. of stations or platforms providing data to the international data centres	No. of stations or platforms with complete historical record available in international data centres
GCOS Upper Air Network (GUAN)	**Upper-air-temperature, upper-air wind speed and direction, upper-air water vapour**	1	1	1	1	1
Full WWW/ GOS Upper Air Network	**Upper-air-temperature, upper-air wind speed and direction, upper-air water vapour**	1	1	1	1	1

Table 2b: National contributions to the upper-air atmospheric essential climate variables.

[1] GCOS Climate Monitoring Principles.

Contributing networks specified in the GCOS implementation plan	ECVs	No. of stations or platforms currently operating	No. of stations or platforms operating in accordance with the GCMPs[2]	No. of stations or platforms expected to be operating in 2010	No. of stations or platforms providing data to the international data centres	No. of stations or platforms with complete historical record available in international data centres
World Meteorological Organization/ Global Atmosphere Watch (WMO/GAW) Global Atmospheric CO2 & CH4 Monitoring Network	**Carbon dioxide**	1	1	1	0	0
	Methane	1	1	1	1	1
	Other greenhouse gases	3	3	3	3	3
WMO/GAW ozone sonde network	**Ozone**	1	1	1	1	1
WMO/GAW column ozone network	**Ozone**	1	1	1	1	1
WMO/GAW Aerosol Network	**Aerosol optical depth**	4	4	4	0	0
	Other aerosol properties	2	2	2	2	2

Table 2c: National contributions to the atmospheric composition.

[2] GCOS Climate Monitoring Principles.

Air temperature

Measurements

Temperature is a key indicator of changes in the climate. As long time series of measurements of ground-level temperature in Switzerland are available, dating back to the mid 19th century, long-term trends can be analyzed. At ground level, temperature is today measured by MeteoSwiss at almost 130 stations. In some cases, these systematic measurements extend as far back as December 1863, when Switzerland's first nationwide meteorological observation network came into operation. Monthly values are available from earlier periods, e.g. for Basel (from 1755), Geneva (1768) or Grand St. Bernard (1817), but the individual measurements have never been digitized. The network of stations has been continually reviewed on the basis of analyses of requirements and the distribution of stations across the country and various altitudes has been optimized.

Long time series and their importance for GCOS

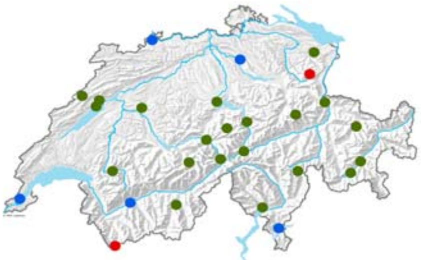

Figure 1: Swiss National Basic Climatological Network NBCN. 2 stations belong to the GCOS Surface Network GSN (red) and seven to the Regional Basic Climatological Network RBCN (red + blue).

At many of the sites chosen in 1863, stations are still in operation today. In the NORM90 project, for each of Switzerland's twelve major climate regions, a station was selected where measurement data have been collected since at least 1900. These long time series were analyzed for artificial discontinuities and trends caused, for example, by station relocation, change of instrumentation and calibrations, and homogenized. In order to increase the density of stations, particularly in the Central Alpine region characterized by large differences in altitude, 16 additional stations were selected with time series from at least 1900 (exception: Jungfraujoch only from 1930). These stations of the greatest climatological importance (28 in all) were designated as the Swiss National Basic Climatological Network (NBCN). The deviation of the annual mean temperature in Switzerland from the multiyear average (norm 1961–1990) offers a striking example of climate change. The linear trend of temperature in Switzerland between 1864 and 2005 is + 1.1°C per 100 years, yielding a total warming of +1.5 °C from 1864 to 2005 (Begert et al., 2005).

International integration

In Switzerland, two NBCN stations were selected as GCOS Surface Network (GSN) stations – Säntis and Grand St. Bernard. Seven NBCN stations (Säntis, Grand St. Bernard, Geneva, Sion, Basel, Zurich and Lugano) belong to the WMO Regional Basic Climatological Network (RBCN).

Precipitation

Measurements

Precipitation, together with temperature, is a key indicator of changes in the climate. Its long time series are particularly valuable for assessing the effects of climate change on the water cycle, glacier mass balance and the frequency of flooding events. Precipitation is now measured by MeteoSwiss at more than 400 stations, some of which have been in operation since December 1863. In a number of cases, the measurements go back to the 18th century, although there are considerable gaps in some of the time series. Since 1980, a number of these stations have been converted to automatic operation (ANETZ). The roughly 70 ANETZ stations are currently being upgraded, and about 60 other stations (KLIMA, ENET) are also being automated (SwissMetNet project). While the remaining precipitation stations (NIME, totalizers) are not to be automated at present, the distribution of these stations is to be investigated in detail and reviewed in the coming years under a Precipitation Concept. At each automatic MeteoSwiss station, precipitation is collected and measured at 10-minute intervals. At the NIME stations, the amount of precipitation is recorded once a day by the station operator, and records are sent in by post once a month. To measure precipitation in mountainous areas, so-called totalizers are used. A totalizer generally measures precipitation for the hydrological year (October 1 to September 30). Additional readings are sometimes taken during the year. In addition to in-situ measurements, precipitation is also calculated indirectly on the basis of radar reflectivity with 3 precipitation radars (La Dôle, Albis and Monte Lema). These stations have been in operation since 1961 (La Dôle, Albis) or 1993 (Monte Lema), and the data have been systematically archived in digital form since 1991.

Long time series and their importance for GCOS

Systematic recording of precipitation in Switzerland began in 1864 with the operation of, initially, about 70 weather stations equipped with a precipitation gauge. The total number of stations subsequently rose sharply, and by around 1900 precipitation was being measured daily at more than 300 locations. The most important sites are 27 of the 28 Swiss NBCN stations; only at the Jungfraujoch NBCN station is precipitation not recorded. To complement the Swiss NBCN stations, the most important NIME stations (about 46 sites) with daily measurements are to be defined under the precipitation concept. In mountainous areas, the totalizer data represent important additional precipitation series with a low temporal resolution. From a climatological perspective, 8 of the totalizers are to be protected with priority 1 and another 27 with priority 2.

International integration

The precipitation data from all MeteoSwiss stations are transmitted to the precipitation data centre of the DWD in Offenbach (→ GIP Action A6). Precipitation radar networks in Europe are coordinated by the EUMETNET operational programme for the exchange of weather radar information (OPERA). All three Swiss precipitation radars are integrated into the OPERA programme. In addition, the INTERREG projects VERBANO and Franche-Comté are improving precipitation radar coverage in the border regions with Italy and France respectively.

Air pressure

Measurements

Air pressure is an important component of the climate system, characterizing both local and large-scale atmospheric circulation. Surface pressure is now measured by MeteoSwiss at 90 stations. Systematic measurements began in 1864, when Switzerland's nationwide meteorological observation network came into operation. Early records for individual sites such as Basel or Geneva go back to the 18th century. However, as these data have never been processed, they are either not available in digital form or only as monthly averages.

Long time series and their importance for GCOS

From the Swiss meteorological network developed since 1864, 28 stations of climatological significance were selected so that Switzerland's climate would be represented and characterized as well as possible. These Swiss National Basic Climatological Network (NBCN) stations also provide the most important long series of air pressure measurements, as most of the stations have recorded air pressure data continuously since 1863. It is not planned to homogenize all of the 28 time series, since air pressure shows strong regional correlations.

International integration

Of the Swiss NBCN stations, Säntis, Grand St. Bernard, Geneva, Sion, Basel, Zurich and Lugano are also RBCN stations; additionally, two of them (Säntis, Grand St. Bernard) are GSN stations. At the WMO, efforts are also under way to establish an international surface pressure database. In an initial global dataset, measurements of surface pressure (including Swiss RBCN data) have been processed for the years 1850–2004. This dataset comprises global data on a monthly basis with a spatial resolution of about 500km. Air pressure, i.e., the distribution of atmospheric mass, is the most fundamental input for historical reanalysis projects, delivering high-resolution, 3-dimensional fields of the global atmosphere.

Sunshine duration

Measurements

In addition to temperature, precipitation and air pressure data, other meteorological measurements are required as indicators of changes in the climate. Among the most important additional variables recorded at weather stations are wind speed and direction, humidity, sunshine duration, global radiation, cloud cover and snow. The variables of greatest climatological importance are now measured by MeteoSwiss at almost 130 stations. In some cases, these systematic measurements extend as far back as December 1863, when Switzerland's first nationwide meteorological observation network came into operation. Since 1980, a number of these stations have been automated (ANETZ). The roughly 70 ANETZ stations are currently being upgraded in line with the latest technological developments, and the other stations in the network are also to be converted to automatic operation by 2012 (SwissMetNet project). The surface measurements of wind speed/direction and humidity are supplemented by in-situ observations (soundings, airborne measurements) and increasingly also by measurements from ground- and satellite-based remote sensing instruments.

Long time series and their importance for GCOS

A permanent Swiss monitoring network was established in the second half of the 19th century. Recently, the 28 stations of the greatest climatological significance have been designated as the Swiss NBCN. In most cases, time series for humidity go back to 1864. Measurements of sunshine duration began some years later, and only at selected locations. Before the network was automated (starting in 1981), wind speed and direction were measured three times a day. For this reason, wind data have only been systematically analyzed since the 1980s. In addition to the 12 homogeneous temperature and precipitation series dating back to 1864, homogeneous time series are now available from 1959 for air pressure, sunshine duration, vapour pressure and cloud cover, and from 1981 for global radiation and wind speed.

International integration

Of the Swiss NBCN stations, Säntis, Grand St. Bernard, Geneva, Sion, Basel, Zurich and Lugano belong to the RBCN. As part of the EU ENSEMBLES project, a European dataset has been compiled for various observational series (minimum, maximum and mean temperature, precipitation, air pressure, snow depth, sunshine duration, relative humidity and cloud cover) from around 2000 stations and checked for inhomogeneities.

Radiation

Measurements

Radiation is the main factor in the climate system, accounting for seasonal and regional differences in climate. The effects of greenhouse gases and anthropogenic aerosols on the climate are directly manifested as changes in the radiation budget. In addition to the monitoring of global radiation at the automatic network (ANETZ, now SwissMetNet) stations, MeteoSwiss operates four dedicated stations for the measurement of radiation fluxes from the ultraviolet through the visible to the infrared portion of the electromagnetic spectrum. The Jungfraujoch and Davos stations are situated in the Alps, while the Payerne station is on the Central Plateau and Locarno-Monti lies south of the Alps. This network, known as CHARM (Swiss Atmospheric Radiation Monitoring), was supplemented in 1995 by another 10 stations of the Alpine Surface Radiation Budget (ASRB) network. Four CHARM stations and two ASRB stations are located at ANETZ (now SwissMetNet) sites, permitting comparison with other variables. At all the CHARM and ASRB stations, global radiation and longwave downward radiation are recorded. At three of these sites, shortwave upward radiation and longwave upward radiation are additionally recorded. UV radiation has been measured at CHARM stations since 1995. CHARM and ASRB are attached to the WMO GAW programme. The Payerne station also belongs to the BSRN network. To this end, shortwave (direct, diffuse and global) and longwave radiation fluxes are measured in accordance with BSRN and GAW guidelines. In addition, individual spectral radiation fluxes are measured continuously with the greatest precision and at a high temporal resolution in order to determine the aerosol optical depth and water vapour content of the atmosphere. Various institutions are involved in the CHARM network: MeteoSwiss, the PMOD/WRC, the ETH Zurich and the University of Bern.

Long time series and their importance for GCOS

Under the CHARM programme, radiation measurements were initiated at Davos in 1991 and at the Payerne BSRN station in 1992. The Jungfraujoch and Locarno-Monti sites were established in 1996 and 2001 respectively. In addition, radiation measurements have been carried out at ten ASRB stations since 1995. The CHARM and ASRB networks are designed for long-term monitoring and provide reliable radiation data, making it possible to study trends in the radiation budget specifically for the Alps. Philipona et al. (2004) found an increase in the measured longwave downward radiation at the surface of +5.2 Wm^{-2} over the period from 1995 to 2002 at eight ASRB stations over the central Alps.

International integration

Data are supplied to the World Radiation Data Centre (WRDC) in St. Petersburg, one of five GAW World Data Centres, and to the BSRN archive at the Alfred Wegener Institute in Bremerhaven. Under COST Action 726, the climatology of UV radiation over Europe is being studied in a European initiative with the participation of MeteoSwiss and the PMOD/WRC. Payerne is one of 38 BSRN stations.

Clouds

Measurements

The interaction between radiation and clouds remains one of the major sources of uncertainty in climate models. High priority is therefore accorded to measurement of the spatial distribution and microphysical properties of clouds. At the MeteoSwiss monitoring stations (except for airports), cloud variables are not measured instrumentally, but estimated by observers at regular intervals. Currently, 54 stations belong to the visual observation network (OBS). The variables recorded include cloud cover, cloud type, cloud height, visibility, and present and past weather. At the airports, in addition to human observers, present weather sensors are used to measure a number of cloud variables (e.g. ceilometer for cloud-base height) and visibility (transmissometer).

Long time series and their importance for GCOS

Visual observations from the 28 Swiss NBCN stations go back to the 19^{th} century, as do meteorological measurements at many stations. However, in most cases the data have not yet been homogenized; i.e. they may contain inhomogeneities resulting from different observers, changing observation times or station relocations. In the NORM90 project, in addition to sunshine duration, cloud data from eight conventional NBCN stations were homogenized from 1961 onwards. At certain NBCN stations the continuation of visual observations is not guaranteed.

International integration

The visual observations of the seven RBCN stations are submitted to the WMO within the standard CLIMAT bulletin format.

Water vapour

Measurements

As well as surface measurements, vertical profiles of key atmospheric variables (air temperature, air pressure, wind, water vapour) are of crucial importance for climate monitoring. They make it possible to investigate climate signals in various layers of the atmosphere. As a natural greenhouse gas, water vapour is of particular interest in this context. Since 1942, Switzerland has a permanent aerological station at Payerne operated by MeteoSwiss. Operations involving two soundings per day were commenced in 1954. Today, with four radiosondes launched per day, there are twice-daily continuous measurements of air pressure, temperature, relative humidity and wind speed/direction, and twice daily measurements of wind speed/direction alone, up to an altitude of approx. 33km, humidity only up to approx. 12 km. In addition, ozone soundings are carried out three times per week. Since 2000, a wind profiler installed at Payerne has continuously recorded vertical wind conditions up to an altitude of approx. 5km. This system is part of the European Wind Profiler Network (CWINDE). For continuous recording of the vertical distribution of temperature and water vapour, other passive and active remote sensing systems (microwave radiometer, lidar) are currently being tested for subsequent installation on an operational basis. At the observatory of the Institute of Applied Physics (IAP) of the University of Bern in Zimmerwald, microwave radiometers, GPS receivers and spectrophotometers are used for water vapour measurements since 2006. Measurements of wind, temperature and, in some cases, humidity are also carried out on most commercial aircraft under the Aircraft Meteorological Data Reporting (AMDAR) programme.

Long time series and their importance for GCOS

Analysis of the long and high-quality Payerne sounding time series is possible from 1948 (one sounding per day) and 1954 (two soundings per day). The University of Bern holds a globally unique data series on integrated water vapour content since 1994. Since 2003, water vapour profiles in the stratosphere have been determined operationally under the GAW programme with the middle atmospheric water vapour radiometer MIAWARA, operated by the University of Berne at Zimmerwald observatory. Data are provided on a regular basis to the Network for the Detection of Atmospheric Composition Change (NDACC). Water vapour measurements from across Switzerland are made available in a dedicated database (STARTWAVE) as part of an NCCR Climate work package. Total water vapour content has been estimated by analysis of GPS radio signals, initially (from 1999) on an experimental basis under the COST-716 programme, and since 2006 operationally at the swisstopo AGNES stations.

International integration

Payerne is one of the RBCN stations that transmit data from soundings on a daily and monthly basis to the WMO (→ GIP Action A12). About 150 of the 800 aerological stations worldwide are part of the GCOS Upper Air Network (GUAN), meeting higher quality requirements for long-term monitoring of the climate. Since January 2008, the Payerne station also belongs to GUAN (→ GIP Action A15). In addition, Payerne has been listed as a potential GRUAN station. The Payerne soundings are transmitted to the GUAN Monitoring Centre at the ECMWF in Reading (UK) and the Hadley Centre in Exeter (UK). The data are archived at the Integrated Global Radiosonde Archive of the National Climatic Data Center (NCDC) in Asheville (US). The stratospheric water vapour profiles of the IAP are integrated in the global NDACC dataset with measurements from more than 70 research stations.

Ozone

Measurements

The ozone layer in the stratosphere filters out a large proportion of the sun's harmful ultraviolet rays. Monitoring of stratospheric ozone is therefore extremely important, especially in view of the rate of ozone depletion – which has however been reduced in recent years thanks to international agreements. MeteoSwiss uses a variety of instruments to monitor ozone concentrations in the atmosphere over Switzerland. At the Light Climatic Observatory (LKO) in Arosa, total ozone has been measured continuously since 1926 using Dobson and Brewer (since 1988) spectrophotometers. In addition, ozone profiles are derived using various methods of measurement and analysis.

Total ozone: Long time series and their importance for GCOS

Switzerland has a long history of ozone monitoring, going back to the first measurements at Arosa in 1926. Total ozone over Arosa has been determined on every sunny day virtually without interruption down to the present. Almost from the beginning of the time series, measurements have been carried out using the same type of instrument (Dobson). Total ozone over Arosa is currently measured by two Dobson and three Brewer spectrophotometers. To date, the global networks of Dobson and Brewer instruments have maintained independent calibration procedures. Both networks produce almost identical results, with minor differences (1-3%)

depending on the season and latitude. These differences remain a subject of current research, and the 20-year parallel measurements carried out with Dobson and Brewer instruments at Arosa are of great importance in this regard.

Ozone profile 0-33 km: Long time series and their importance for GCOS

Information on the vertical distribution of ozone is important since the processes of ozone production and destruction differ markedly in the troposphere and the stratosphere. The first estimates of the ozone profile were obtained by means of special Dobson measurements in the 1930s. This so-called Umkehr method yields only 6–9 layers, at altitudes between approx. 5 and 50km. The Arosa Umkehr measurement series is the world's longest and at the same time one of the few sources of information on vertical ozone distribution in the years 1955–1970, before the start of satellite observations. In the late 1960s, ozone profiles were also determined in situ for the first time using small ozone sondes. Measurements were first performed for two years at Thalwil (1966/67), and since 1968 the ozone sondes have been combined three times a week with the meteorological radiosonde balloon activity at Payerne. The ozone profiles obtained exhibit a high vertical resolution (currently about 50m) between the Earth's surface and an altitude of 30–35km.

Ozone profile 20-70 km: Long time series and their importance for GCOS

In the early 1990s, a microwave radiometer known as the Ground-Based Millimeter Wave Ozone Spectrometer (GROMOS) was developed at the Bern University Institute of Applied Physics (IAP). Since 1994, it has been used to determine the ozone profile about every 30 minutes. The second-generation Stratospheric Ozone Monitoring Radiometer (SOMORA) was tested in parallel to the GROMOS instrument at Bern from January 2000, and it has been used operationally by MeteoSwiss at Payerne since 2002. Covering an altitude range of 20–70km, this more than 10 years high temporal resolution time series extends the sounding data over the balloon burst height and allows the detection of short-lived processes in the stratosphere.

International integration

Measurements from Arosa (Dobson and Brewer) and Payerne (ozone soundings) are routinely supplied to the World Ozone and UV Radiation Data Center (WOUDC) in Toronto. These data together with data from the two microwave radiometers (GROMOS and SOMORA) are also fed into the NDACC. The multi-sites constellation "Jungfraujoch – Payerne – Berne – Arosa" is considered as a primary alpine station for the NDACC and WOUDC/GAW networks.

Carbon dioxide

Measurements

Anthropogenic greenhouse gases are the main cause of global warming. Concentrations of greenhouse gases in the atmosphere have risen markedly since the industrial revolution. Levels of carbon dioxide CO_2 – the most important greenhouse gas apart from water vapour – are now at least 35% higher than in the preindustrial era. Emissions are not measured directly, but determined by the FOEN, partly on the basis of statistics on the consumption of heating and motor fuels (overall energy statistics, Swiss Federal Office of Energy). The CO_2 emissions arising from the burning of fossil fuels are calculated by multiplying the total consumption of each fuel by the relevant emission factor. In Switzerland, atmospheric concentrations of CO_2 have been measured by the Bern University Physics Institute on the Jungfraujoch since the end of 2000 and in Bern since October 2003. In addition to measurements of the CO_2 mixing ratio, the ^{13}C fraction of CO_2 and the O_2/N_2 ratio of the samples are determined. The accuracy of the CO_2 measurements is better than ±0.5 parts per million (ppm).

Long time series and their importance for GCOS

The Jungfraujoch and Bern stations are of great global importance. Despite the existence of various CO_2 monitoring stations around the world, additional, particularly continental, stations are required to reduce uncertainties in terrestrial carbon fluxes. Carbon absorption by the terrestrial biosphere and the oceans can be determined by combined measurements of O_2 (or O_2/N_2) and CO_2. The series of CO_2 and O_2 measurements initiated at the Jungfraujoch station in 2000 are thus of major importance for GCOS. Furthermore, there is a lack of concurrent atmospheric O_2 measurements over Europe.

International integration

Within CarboEurope IP European wide efforts have been undertaken to continue or newly setup a CO_2 measuring program at 24 flask sampling sites and 12 continuous ground level sites. The Jungfraujoch station is one of these flask sampling as well as one of these continuous ground level sites.

Greenhouse gases

Measurements

Apart from carbon dioxide, also methane, nitrous oxide and various synthetic gases contribute to the greenhouse effect. Concentrations of these gases are also steadily rising, further intensifying global warming. Long-term monitoring of greenhouse gases is therefore of major importance under international and national climate change legislation. Since February 2005, atmospheric concentrations of the greenhouse gases methane (CH_4), nitrous oxide (N_2O) and sulphur hexafluoride (SF_6) have been measured by Empa and the Federal Office for the Environment (FOEN) at the Jungfraujoch station, which is part of the National Air Pollution Monitoring Network (NABEL). In addition, since 2000, Empa and the FOEN have also measured halogenated greenhouse gases such as hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) at the Jungfraujoch station as part of the System for Observation of Halogenated Greenhouse Gases in Europe (SOGE). Other greenhouse gases measured at the Jungfraujoch station are certain (hydro)fluorochlorocarbons (CFCs, HCFCs) responsible for the depletion of stratospheric ozone. The measurements carried out at the Jungfraujoch also make it possible to detect the use of these banned substances in Europe and identify sources. Halogenated greenhouse gases (CFCs, HCFCs, HFCs) are also measured at Dübendorf in campaigns carried out at intervals of several years in order to track emission trends. Here, it is possible to estimate emissions at a site close to the source and to compare the results with measurements from the Jungfraujoch station.

Long time series and their importance for GCOS

Thanks to its high-altitude alpine location in the centre of the heavily industrialized European continent and the low levels of local pollution, the Jungfraujoch is particularly suitable as a site for research on emissions of air pollutants. Although measurements of greenhouse gases (CH_4, N_2O) were only initiated at the Jungfraujoch station at the beginning of 2005, they represent extremely important future time series for GCOS. Likewise, measurements of the synthetic greenhouse gases have only been carried out operationally at this site under the SOGE programme since 2000, but they already provide an initial signal reflecting international efforts to phase out ozone-depleting substances in compliance with the Montreal Protocol.

International integration

Since 2006, the Jungfraujoch site is one of the 25 global GAW stations. All GAW carbon dioxide and methane measurement stations are also part of GCOS. The data are transmitted regularly to the World Data Centre for Greenhouse Gases (WDCGG) in Japan. In addition, there is close cooperation between the Jungfraujoch station and the renowned Advanced Global Atmospheric Gases Experiment (AGAGE) network. As measurements are based on the same calibration scale and a similar method, the results are comparable and exhibit well known and very small uncertainties, with the same temporal resolution.

Air pollutants

Measurements

Trace gases with indirect effects on the climate (known as precursor gases) – such as carbon monoxide (CO), nitrogen oxides (NO_x) and volatile organic compounds (VOCs excluding methane) – only absorb infrared radiation to a limited extent, but they are chemically active in the atmosphere. They thus promote the formation and prolong the lifetime of climate-relevant trace gases. The National Air Pollution Monitoring Network (NABEL), a joint FOEN/Empa project measures air pollution at 16 sites, representing key types of pollution situations. The NABEL monitoring programme covers gaseous pollutants (ozone O_3, nitrogen monoxide NO, nitrogen dioxide NO_2, nitrogen oxides NO_x, sulphur dioxide SO_2, carbon monoxide CO, volatile organic compounds VOCs, ammonia NH_3), particulate matter (PM10, PM2.5, PM1, particle number, particle size distribution and key constituents), as well as dust deposition and constituents in precipitation. The long-term, precise and internationally comparable time series make it possible to assess air quality trends and to review the effectiveness of air pollution control measures. The time series can be used to estimate the impacts of gaseous air pollutants and aerosol particles on human health and the environment. From the data collected, knowledge of sources, sinks and atmospheric chemical processes can also be obtained.

Long time series and their importance for GCOS

In 1969, monitoring of air pollutants was initiated by Empa at three stations in Switzerland (Dübendorf, Payerne, Locarno-Monti) under a joint international programme involving 11 countries. In subsequent years, measurements were also performed at the Jungfraujoch station. The NABEL network came into operation in stages from 1979. From 1989 to 1991, the network was modernized and expanded from 8 to 16 stations. The longest ongoing time series is that for SO_2 at Payerne (since 1969). Other long series include those for suspended particulates at the Dübendorf and Payerne stations (since 1973), and for SO_2 and suspended particulates at the high-altitude Jungfraujoch station (since 1973).

International integration

The NABEL network regularly exchanges data with several international monitoring programmes. Since the start of monitoring operations, the rural Payerne and Rigi stations have been part of the European Monitoring and Evaluation Programme (EMEP). The NABEL measurements also contribute to the WMO GAW programme: the Jungfraujoch site is a global, Rigi and Payerne are both regional GAW stations. The NABEL network also supplies data to the European Air Quality Monitoring Network (EuroAirnet).

Aerosols

Measurements

Aerosols have direct and indirect effects on the atmosphere. The magnitude of these effects, as regards warming or cooling, remains one of the most significant sources of uncertainty in climate models. As part of Switzerland's contribution to the GAW programme, continuous aerosol measurements are carried out by the Paul Scherrer Institute (PSI), on behalf of MeteoSwiss, at the High Altitude Research Station Jungfraujoch. The variables measured include the scattering, backscattering, absorption and extinction coefficients at various wavelengths, together with the number concentration, mass concentration (TSP, PM10, PM1) and size-resolved chemical composition. In some cases (TSP, PM10), aerosol measurements at the Jungfraujoch site are carried out under the NABEL programme. In addition, at the 4 CHARM stations aerosol optical depth (AOD) is measured by spectrophotometers. A further category consists of the AErosol RObotic NETwork (AERONET) stations. The AERONET programme, jointly established by NASA and the Centre National de la Recherche Scientifique (CNRS), currently coordinates a network of approx. 400 ground-based aerosol remote sensing stations, operated by national agencies, research institutes or universities. Two AERONET stations are located in Switzerland, at Lägeren (since 2003; run by the University of Bern) and Davos (since 2005; run by the PMOD/WRC). The

Federal Institute of Technology, Lausanne (EPFL), and the University of Neuchâtel are involved in the groundbased aerosol monitoring activities of the European Aerosol Research Lidar Network (EARLINET).

Long time series and their importance for GCOS

From 1973, TSP mass concentrations were measured continuously at the Jungfraujoch station as part of the NABEL programme. In 2006, this series was succeeded by measurements of PM10 concentrations. The PSI has carried out continuous measurements of aerosol variables at the Jungfraujoch site since 1988. The first variable measured by the PSI from the outset was the surface concentration of aerosol particles. In 1995, PSI monitoring was expanded to cover all other optical variables and integrated into the GAW programme. Chemical composition has been additionally measured since 1998.

International integration

Since 2006, the Jungfraujoch site is one of the 25 global GAW stations. Aerosol measurements from the Jungfraujoch station are therefore regularly transmitted to the World Data Centre for Aerosols (WDCA) at the Joint Research Centre (JRC) in Ispra (Italy). In addition, the data are supplied to the Chemical Coordinating Centre of the European Monitoring and Evaluation Programme (EMEP) under the UNECE Convention on Long-Range Transboundary Air Pollution at the Norwegian Institute for Air Research (NILU) in Lillestrom. The research and monitoring activities at Jungfraujoch are also integrated into various ongoing EU projects (e.g. ACCENT, EUSAAR, GEOMON).

Pollen

Measurements

Pollen release and dispersal are controlled by meteorological conditions such as temperature, sunshine duration, humidity, precipitation and wind. Changes in airborne pollen levels, which may affect the prevalence of allergies or indicate the spread of new allergenic plant species, can be detected in good time by monitoring. From the late 1960s, airborne pollen was analyzed at individual stations in Switzerland on a private basis. From 1982, pollen counts in Switzerland were coordinated by the Working Group on Aerobiology. Since 1993, MeteoSwiss assumes responsibility for operating the National Pollen Monitoring Network (NAPOL). This network comprises a total of 14 stations, covering the country's major climate and vegetation regions. The stations operate during the vegetation period each year, from 1 January to 30 September and are equipped with volumetric pollen traps. Each week, the pollen types are identified under the microscope at the MeteoSwiss laboratories, and daily pollen counts are determined, expressed as the number of pollen grains per m^3 air.

Long time series and their importance for GCOS

Switzerland's first pollen analyses were carried out in Basel in 1969. Since the 1980s, pollen counts have been determined at the Neuchâtel, Davos and Lugano stations for the most important allergenic plants in Central Europe: hazel, alder, birch, ash, grasses, mugwort and the highly allergenic invasive species ragweed. In Switzerland, these pollen types are responsible for about 95% of pollen allergies. The selected four NAPOL sites represent different types of climate and vegetation.

International integration

As pollen dispersal is independent of national borders, it calls for international data exchanges. To this end, the European Aeroallergen Network (EAN) database was established in 1988. The EAN pollen database now has 152 users from 48 countries including Switzerland and incorporates pollen count data for 170 pollen types from 557 stations across Europe.

Role of satellites

Radiation

The Eumetsat Satellite Application Facilities for Climate Monitoring (CM-SAF), a joint project involving several European meteorological services, has the objective to monitor climate variables using satellite data. A variety of radiation products are derived from European satellite data and validated specifically for the Alps. The shortwave and longwave radiation components measured by the Swiss BSRN, CHARM and ASRB stations as well as global radiation measured by SwissMetNet stations have been essential for the development of algorithms for deriving surface radiation from satellites. The Payerne station is also an official station for routine validation of CM-SAF products. Ground-based radiation networks guarantee a stable validation source for the development of long-term data records from multiple platforms over several decades. Satellite-based radiation data on the other hand has shown to enhance ground-based measurements (Dürr and Zelenka, 2008).

Clouds and Water vapour

Satellite measurements can be used to determine several macroscopic and microphysical properties. A number of sensors such as MODIS, MISR, AIRS, and geostationary satellites are used to derive global cloud products (e.g. cloud height, cloud cover, cloud characteristics). Combining measurements from both imagers and sounders (e.g. CLOUDSAT, CALIPSO) offer promising cloud records. The European Cloud Climatology (ECC) project included different variables of cloud properties for the period 1989–2003 across Europe with a spatial resolution of approximately 1 km, based on NOAA AVHRR data and evaluated climatologically (Meerkötter et al., 2004). Globally, the results of the International Satellite Cloud Climatology Project (ISCCP) represent the most comprehensive cloud climatology analysis based on satellite data collected since 1983.

Ozone

For the application of satellite-based ozone data in Switzerland, good spatial resolution is crucial. For example, the total ozone product derived from Ozone Monitoring Instrument (OMI) data offers a horizontal resolution of 13 x 24 km. Swiss ozone monitoring data (Dobson/Brewer at Arosa, soundings at Payerne, microwave radiometry at Payerne and Bern) can make a decisive contribution to the validation of these satellite-based products. Under the joint EU/ESA environmental monitoring initiative – Global Monitoring for Environment and Security (GMES) – global and regional ozone maps are generated daily by the ESA on a pre-operational basis in the GMES Service Element PROMOTE (PROtocol MOniToring for the GMES Service Element on Atmospheric Composition).

Greenhouse gases, Air pollutants, Carbon dioxide

Measurements of air pollutants from satellite-based sensors (e.g. SCIAMACHY onboard Envisat, OMI onboard Aura, GOME-2 onboard Metop) will become increasingly important. First results of validation experiments involving surface monitoring stations are highly promising. In Switzerland, satellite data have been used for air pollution transport studies, for air pollutant emission mapping and assessment as well as for validation of chemical transport models. OMI data are used to retrieve the vertical tropospheric NO_2 columns over Switzerland and first inter-annual distributions (2005-2007). The high horizontal resolution of OMI allows for the first time to detect concentrations within the largest valleys of the Alps.

Aerosols

Aerosol data (e.g. Aerosol Optical Depth) are provided by passive satellite sensors such as AVHRR, SEVIRI, MERIS, MODIS and MISR, as well as by active satellite sensors such as CALIPSO (i.e. lidar) or CLOUDSAT (i.e. cloud profiling radar). At the University of Bern, Aerosol Optical Depth (AOD) is retrieved over land and maps of AOD are generated over Europe operationally using NOAA AVHRR and Meteosat SEVIRI data. Such products will further be empirically linked to air pollutants like particulate matter and can provide high resolution temporal and spatial air pollution maps.

3 Oceanic Essential Climate Variables

INTRODUCTION

Introduction

Table 3 lists the essential climate variables for the oceanic domain.

Essential Climate Variables of the Oceanic Domain

Surface	Sea-surface temperature, Sea-surface salinity, Sea level, Sea state, Sea ice, Current, Ocean colour, Carbon dioxide partial pressure
Sub-surface	Temperature, Salinity, Current, Nutrients, Carbon, Ocean tracers, Phytoplankton

Table 3: Essential climate variables of the oceanic domain as listed in the GCOS Second Adequacy Report (WMO, 2003).

Switzerland maintains measurements of Essential Climate Variables of the atmospheric and terrestrial domain, but no oceanic observations.

4 Terrestrial Essential Climate Variables

Introduction

Switzerland's most important systematic climate observations in the terrestrial domain concern the hydrosphere (river discharge, water temperature, lake ice phenology, water use, isotopes), the cryosphere (snow, glaciers and permafrost) and the biosphere (land use, forest ecosystem, forest fires, phenology). Table 4 lists the essential climate variables for the terrestrial domain.

Essential Climate Variables of the terrestrial domain

Hydrosphere	River discharge, Water use, Ground water, *Isotopes*, Lake levels
Cryosphere	Snow cover, Glaciers and ice caps, Permafrost and seasonally-frozen ground
Biosphere	Albedo, Land cover (including vegetation type), Fraction of absorbed photosynthetically active radiation (fAPAR), Leaf area index (LAI), Biomass, Fire disturbance, *Phenology*

Table 4: Essential climate variables of the terrestrial domain as listed in the GCOS Second Adequacy Report (WMO, 2003), together with additional variables of relevance for Switzerland (in italics).

Highlights GCOS Switzerland

Within the terrestrial domain, additional ECVs are of great importance for Switzerland such as isotopes and phenology, which are not explicitly listed by GCOS as ECVs in the Implementation Plan (WMO, 2004) but stated as an emerging ECV (isotopes).

The ongoing establishment of PERMOS (Permafrost Monitoring Switzerland) as a national baseline network will be funded on a sustained level from 2010 onwards. PERMOS will contribute systematically and on a long-term to the global network of permafrost GTN-P providing valuable information on alpine permafrost.

National Contributions

Contributing networks specified in the GCOS implementation plan	ECVs	No. of stations or platforms currently operating	No. of stations or platforms operating in accordance with the GCMPs[3]	No. of stations or platforms expected to be operating in 2010	No. of stations or platforms providing data to the international data centres	No. of stations or platforms with complete historical record available in international data centres
GCOS baseline river discharge network (GTN-R)	**River discharge**	197	197	197	26	22
GCOS Baseline Lake Level/Area /Temperature Network (GTN-L)	**Lake level/area/ temperature**	31	31	31	3	3
WWW/GOS synoptic network	**Snow cover**	7	7	7	7	7
GCOS glacier monitoring network (GTN-G)	**Glaciers mass balance and length, also ice sheet mass balance**	100	100	100	100	100
GCOS permafrost network (GTN-P)	**Permafrost borehole temperatures and active layer thickness**	12[4]	12[4]	20	3	3

Table 5: National contributions to the terrestrial domain ECVs.

[3] GCOS Climate Monitoring Principles.

[4] 12 sites fully approved and 8 sites approved under reserve.

River discharge

Measurements

Changes in climate affect the water cycle in various ways and have consequences for various aspects of water management. The Swiss river discharge monitoring networks currently consist of around 200 federal stations, about 300 cantonal stations on smaller surface waters and a number of privately operated stations. The FOEN monitors water flows and – in cooperation with the Swiss Federal Institute of Aquatic Science and Technology (Eawag) and the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) – water quality in Swiss waterbodies. Data collection takes the form of continuous measurements at permanent hydrometric stations and individual measurements at temporary sites. Surface water measurements fall into the following categories: the basic monitoring network, the National River Monitoring and Survey Programme (NADUF), water temperature and sediment transport. The basic monitoring network, which records water levels and discharge, goes back to the mid-nineteenth century. It now comprises some 260 gauging stations on surface waters (rivers and lakes). In this network, 90% of all stations have automatic remote retrieval facilities. Under the NADUF programme, which is designed to assess the state of Swiss watercourses, concentrations of nutrients and pollutants have been continuously measured at selected stations since the mid-1970s. In the 1950s, hydrological study areas (HUG) were first designated in Switzerland; over the years, further catchment areas have been added. The gauging stations in these areas are part of the basic monitoring network. The aim of the HUG studies is to observe long-term changes in the water regime in near-natural catchment areas across the country's various climatic regions. They therefore cover runoff depth and area precipitation for about 50 catchment areas.

Long time series and their importance for GCOS

In the Hydrological Yearbook of Switzerland, data (including discharge) from all the gauging stations operated by the FOEN has been published since 1917. The longest continuous daily discharge series come from stations on the Rhine (1891 Basel), the Thur (1904 Andelfingen) and the Birs (1917 Münchenstein). Among the oldest gauging stations are four border stations (Rhine-Basel, Rhône-Chancy, Ticino-Bellinzona, Inn-Martinsbruck), which record discharge from Switzerland and, in some cases, belong to the NADUF programme. The HUG gauging stations belonging to the basic monitoring network have an average time series length of 40 years. The HUG areas were selected with a view to covering all types of hydrological regime in Switzerland

International integration

A selection of stations (12) with long discharge series participate in the Global Runoff Data Centre (GRDC). Daily river discharge data from a total of 26 Swiss stations is supplied to the GRDC, representing an important contribution to international data exchange and meeting GIP Action T4. The GRDC is part of the Global Terrestrial Network for Hydrology (GTN-H), which is supported by GCOS, GTOS and the WMO Hydrology and Water Resources programme. The European Terrestrial Network for River Discharge (ETN-R) is a GRDC contribution to the European Flood Alert System (EFAS), facilitating medium- to long-term flood forecasts.

Lakes

Measurements

Lakes may react sensitively to changes in climate, depending on the type and size of waterbody concerned. The basic monitoring network operated by the FOEN Hydrology Division, comprising a total of around 260 hydrometric stations, includes more than 30 stations on Swiss lakes. These lake stations measure water levels and discharge. Measurements of other relevant lake-specific variables are requested in GIP Action T8 including surface and sub-surface water temperatures as well as the date of freeze-up and break-up of lakes. The vertical and horizontal differences in temperature occurring in the lakes are not, however, recorded by the FOEN temperature monitoring network. Measurements of lake water temperatures are carried out as part of comprehensive water quality studies by cantonal water protection agencies, international commissions and the Eawag. For example, Lakes Murten, Neuchâtel and Biel are monitored in a joint project by the competent authorities of Cantons Bern, Fribourg and Neuchâtel. Monitoring of Lake Constance is coordinated by the International Commission for the Protection of Lake Constance (IGKB). The lakes of Canton Ticino are monitored by the Joint Commission for the Protection of Italian-Swiss Waters (CIPAIS), and Lake Geneva by the International Commission for the Protection of Lake Geneva (CIPEL). Lake water temperature profiles are determined, in some cases, from boats at a high resolution, with the aid of probes. Temperatures are usually measured once or twice a month at various depths between the lake surface and bottom. Monthly measurements are required for an understanding of the development of lake temperatures over time.

Long time series and their importance for GCOS

Monthly water temperatures have been recorded by the Zurich water utility on Lake Zurich, with some interruptions, since 1936. Over this period, the number of depths per profile varies. Since 1977, weekly observations have been made by the University of Zurich (Limnological Station, Institute of Plant Biology) in the middle of the lake between Ruschlikon and Kusnacht. Measurements have been carried out at different temporal resolutions and at various depths on lakes located in the Swiss Central Plateau starting earliest in 1950 (Lake Zug). As the measurements in these lakes have been carried out differently over the years, a degree of inconsistency both within and between the time series is inevitable. Observations of the freeze and thaw dates for lakes are not carried out systematically across Switzerland and come from various sources (including newspapers and personal records). The longest time series available in Switzerland is for Lake St. Moritz; starting in 1832, it extends without interruption up to the present. This dataset is unique for central Europe. It is part of a compilation of time series of lake freeze-up and breakup records included in a publication by Magnuson et al. (2000), referenced in the IPCC AR4 report (WG I).

International integration

The freeze and thaw dates for alpine lakes are the only lake variables transmitted to an international data repository (→ GIP Action T8). The Global Lake and River Ice Phenology Database at the National Snow and Ice Data Center (NSIDC) in Boulder, Colorado, archives observations from Lakes St.Moritz, Silvaplana and Sils. Observations are no longer being updated for the latter two lakes.

Groundwater

Measurements

Groundwater recharge is influenced not only by precipitation and dry periods but also by human activities. The National Groundwater Observation Programme (NAQUA) operated by the FOEN is designed to provide a representative picture, in both qualitative and quantitative terms, of the state and development of Swiss groundwater resources. NAQUA provides reliable information on (a) the main types of aquifer relevant to groundwater use in Switzerland; (b) the main aquifers used as sources of drinking water in Switzerland; (c) aquifers in the various major climatic and landscape regions of Switzerland; and (d) the most important natural and anthropogenic factors influencing Switzerland's groundwaters. NAQUA comprises four modules: TREND for tracking long-term developments in groundwater quality (50 stations), SPEZ for studies of specific pollutants (500 stations), QUANT for observing groundwater quantity (100 stations), and ISOT for observing isotopes in the water cycle (23 stations). Groundwater quality and quantity is also monitored at numerous sites by various institutions (universities, water utilities, cantons). Altogether, groundwater levels and spring discharges are currently observed at around 900 stations. Measurements of groundwater levels are generally carried out manually or automatically in a perforated tube installed in the aquifer. Spring discharge is measured as close as possible to the spring using a natural cross-section or with the aid of an artificial overflow.

Long time series and their importance for GCOS

To better assess the possible consequences of climate change, NAQUA pursues an integrated approach, aimed at increasingly recording groundwater quality and quantity at the same stations over time. Under the NAQUA programme, the FOEN is therefore collaborating closely with the cantons. The longest groundwater level data series in Switzerland (from around 1900 to the present) are available from water utility pumping wells. Since the end of the 1970s, groundwater levels have been continuously monitored nationwide. The discharge of the Areuse spring in the Jura mountains has been measured continuously since 1959, representing one of Switzerland's longest spring discharge time series.

International integration

Groundwater observations are coordinated internationally by various networks. The International Groundwater Resources Assessment Centre (IGRAC), a joint UNESCO/WMO initiative for global information exchange, belongs to the Global Terrestrial Network Hydrology (GTN-H). The data and information network responsible at the European level is EUROWATERNET, which is operated by the European Environment Agency (EEA).

Water use

Measurements

With rising temperatures, longer dry periods and seasonal fluctuations, climate change affects water supplies and demand. A knowledge of water consumption is therefore of great importance. In Switzerland, water consumption data are collected by different agencies to different extents and with varying degrees of regularity. For example, data on the withdrawal, treatment and supply of drinking and process water are collected by the Swiss Gas and Water Industry Association (SVGW) and determined by utilities that supply water to about 50% of the population. The main source of drinking water in Switzerland is groundwater, which is accordingly of great importance and subject to systematic qualitative and quantitative monitoring. Water consumption associated with Swiss agriculture is confined to relatively small areas and essentially to extremely dry areas and vegetable farming. Scant information is available on the distribution and extent of agricultural irrigation. This is due to Switzerland's federalist structures, which explain the lack of uniform data. Quantitative values concerning irrigated areas are determined with the aid of surveys conducted by the Swiss Farmers' Union and the Federal Office for Agriculture (FOAG). In the spring of 2007, the FOAG carried out a survey on irrigation. Here, data were compiled at the cantonal level, providing an updated estimate of consumption compared with the previous survey (2002).

Long time series and their importance for GCOS

In Switzerland, estimates of agricultural water use have been prepared and transmitted to international organizations since the early 1990s. The estimated irrigated area rose from 25,000 ha in 1995 to 30,000 ha in 2000 and 38,000 ha in the 2007 survey. The total area of 38,000 ha refers to regularly irrigated land, two thirds of which is to be found in the cantons of Valais and Graubünden. In contrast, other cantons appear to lack precise data on irrigated areas. In addition to the areas irrigated regularly, another 12,000 ha of land is irrigated occasionally. There are major regional differences in the efficiency of water use, which depends on cultivation methods and irrigation technologies.

International integration

Per capita water consumption is a standard international environmental indicator used by the OECD and FAO in various studies to assess sustainability. The FAO maintains a global information system on agricultural water use, particularly in developing and emerging countries (AQUASTAT). AQUASTAT is part of the Global Terrestrial network for Hydrology (GTN-H), to which the global networks on river discharge (GRDC) and groundwater (IGRAC) also belong. The information on water consumption in Swiss agriculture supplied to the AQUASTAT database is based on FOAG estimates, contributing to a global dissemination of information related to water resources (→ GIP Action T9).

Isotopes

Measurements

Serving as natural tracers, isotopes of oxygen and hydrogen leave a "fingerprint" in numerous components of the climate system. In addition to their use in groundwater management and protection, long-term isotope data series provide reference values for climatological studies. The stable isotopes oxygen-18 (^{18}O) and deuterium (^{2}H) and the radioactive hydrogen isotope tritium (^{3}H) are constituents of the water molecule. They are measured by various institutions at about 135 stations across Switzerland in water samples from precipitation, rivers, lakes, glaciers, snow and groundwater. In 1992, as part of the NAQUA programme, a new module was established for the observation of isotopes in the water cycle (ISOT). The ISOT network currently comprises 23 sites distributed throughout Switzerland: 13 precipitation, 7 surface water and 3 groundwater stations. At these stations, the isotope ratios of oxygen-18, deuterium and tritium in water are measured. The FOEN operates the ISOT network in cooperation with the Climate and Environmental Physics division at the University of Bern. The ISOT precipitation stations are spread across the various climatic regions of Switzerland. Monthly composite samples from a precipitation gauge emptied daily are used for isotope measurement. Stations belonging to the discharge monitoring network (basic monitoring network) or the NADUF programme were selected as ISOT surface water stations. At these sites, composite samples are collected automatically each month or spot samples are taken manually. At the ISOT groundwater stations, spot samples are collected monthly for isotope analysis, and water temperature, electrical conductivity and spring discharge/groundwater levels are also determined.

Long time series and their importance for GCOS

At the monitoring stations in Bern, Meiringen, Guttannen, Grimsel and Locarno, monthly composites of daily precipitation samples have been used for isotope analysis since the early 1970s. Time series from these five sites are the longest available in Switzerland and together form a NW/SE profile through the Alps from Bern (541m a.s.l.) across the Alps (Grimsel Pass 1950m a.s.l.) to Locarno (379m a.s.l.). Most of the stations are located close to climatological stations operated by MeteoSwiss, where additional variables, such as temperature and relative humidity, are measured. Isotope observation in rivers dates back to the mid-1980s (Rhine, Rhône and Inn). These measurements thus cover Switzerland's major rivers.

International integration

Since 1992, data from selected ISOT stations have been transmitted to the database of the Global Network of Isotopes in Precipitation (GNIP) operated by the International Atomic Energy Agency (IAEA) and the WMO. The ISOT network thus makes an important contribution to internationally coordinated isotope programmes, with data being used in research as reference values or for calibration purposes. Together with Germany and Austria, Switzerland has a dense monitoring network with long time series, as compared with other countries. This makes the ISOT series particularly valuable, e.g. for international research programmes.

Snow cover

Measurements

Apart from playing a key role in the climate system, snow cover is a vital economic factor. The most important observations for snow climatology are snow depth, new snow, and snow water equivalent. Snow depth and new snow are recorded by measurement networks operated by the Swiss Federal Institute for Snow and Avalanche Research (SLF), MeteoSwiss and other cantonal and private institutions. The SLF network comprises both automatic and conventional stations. At the roughly 100 conventional stations, the variables are measured manually by observers each day. Most of the stations are located at medium altitudes between 1000 and 2000 m a.s.l. By contrast, the 39 automatic (ANETZ, now SwissMetNet) and 11 conventional (KLIMA) snow measurement stations operated by MeteoSwiss are evenly distributed across Switzerland, also covering altitudes below 1000 m a.s.l. Since 1996, the SLF and MeteoSwiss stations have been supplemented by the approx. 70 automatic stations of the Intercantonal Measurement and Information System (IMIS), located at altitudes between 2000 and 3000 m a.s.l. At the 10 mountain stations of the automatic ENET network, observations required for avalanche warnings are jointly carried out by MeteoSwiss and the SLF. At about 75% of the roughly 340 precipitation stations in the MeteoSwiss NIME network, daily measurements of total and new snow are carried out manually. Unlike at the conventional and automatic stations, these data are not recorded digitally (→ GIP Action T10). The SWE is recorded by various institutions and measurement networks across Switzerland. Compared with measurements of snow depth, SWE is determined at a lower temporal resolution. At present, the water equivalent of the snow depth is determined by observers twice monthly at about 40 SLF stations. Measurements are mainly performed between November and April, and the data are digitally archived.

Snow depth and new snow: Long time series and their importance for GCOS

In general, time series for new snow are longer than those for the total snow depth. This may be associated with the early initiation of precipitation measurements. At 14 stations new snow depth measurements have been started before 1908, whereas only isolated total snow depth observations date back to the 19^{th} century (e.g. Engelberg 1890). Based on snow depth measurements on 110 stations in the period 1958 – 1999, snow cover trends in the Swiss Alps have been documented. The results were included in the IPCC AR4 (WG I) report as an example of regional trends in days of winter snow cover (Scherrer et al. 2004).

Snow water equivalent: Long time series and their importance for GCOS

The first regular observations of SWE within a measurement network were carried out in 1943 by the ETH Zurich (Laboratory of Hydraulics, Hydrology and Glaciology VAW) in cooperation with the electricity sector. This network was subsequently largely integrated into the SLF network. The SLF operates 6 stations where measurements of SWE go back to the 1940s. Of particular importance with regard to total SWE are the various stations in the Wägital valley. They account for the world's longest SWE series for a catchment area (since 1943) and include 11 SWE and 28 snow depth sites where measurements are performed in the spring and the average SWE of the snowpack is determined for the catchment. This network is now being run by Meteodat GmbH with financial support from the SLF.

International integration

SWE values are determined at 14 sites in the subalpine Alptal valley in central Switzerland on a weekly to monthly basis. These measurements serve as reference data for the validation of numerical models in the international Snow Model Intercomparison Project (SnowMIP2) conducted on behalf of the International Association of Cryospheric Sciences (IACS).

Glaciers

Measurements

Long-term changes in mass balance and glacier length are taken as key indicators demonstrating changes in climate. The variables studied (mass balance / volume change, length change, glacier inventory, firn temperature and flow velocities) are currently being reviewed by the Cryospheric Commission (EKK) of the Swiss Academy of Sciences (SCNAT). The aims are to integrate existing measurements into the Global Terrestrial Network for Glaciers (GTN-G), to define a future strategy and to incorporate modern technologies into the monitoring programme. With regard to GCOS and the GTN-G tier system, data can be integrated as follows: mass balance in Tier 3, length change in Tier 4 and glacier inventories in Tier 5. These three glacier variables are described in detail below.

The mass balance is determined by the direct glaciological method; i.e. measurements are performed at least once a year using snow pits and a number of stakes drilled into the glacier surface. These in situ measurements need to be calibrated at intervals of about 10 years by the geodetic-photogrammetric method (production of a digital elevation model), in which changes in volume are determined on the basis of spatial changes across the surface of the glacier. The direct method is currently used to determine area-averaged mass balances for three glaciers, and long-term volume changes are determined for 25 glaciers. The mass balance measurements are carried out by the Laboratory of Hydraulics, Hydrology and Glaciology (VAW) of the ETH Zurich, with support from the EKK, federal offices, power generation companies and private bodies (→ GIP Action T13).

The monitoring network established in Switzerland over the years includes length change measurements for glaciers of all sizes and types, ranging from the small glacier patch through cirque and mountain glaciers to large valley glaciers. The length change measurements of glaciers are carried out – with financial support from the EKK – by the VAW in cooperation with the cantonal forest agencies, federal offices, hydropower companies and private bodies. Changes in length continue to be determined mainly by field measurements, carried out by local residents. In addition to ground-based measurements, remote sensing systems (aerial photography and satellite imagery) are increasingly being used. Efforts are now undertaken to integrate aerial photographs produced by swisstopo at regular intervals for several decades into the systematic analysis. Inventories of the glacierized area enable changes to be assessed nationwide (e.g. loss of ice volume).

Mass balance:
Long time series and their importance for GCOS

Measurements of mass balance were first carried out on the Rhône glacier in the period 1884 – 1910. Long-term in situ measurements of mass balance are currently still being carried out on the glaciers Silvretta (since 1914; since 1959 with a denser network), Gries (since 1961) and Basòdino (since 1991). Measurements from individual stakes are available for the Claridenfirn (since 1914) and Grosser Aletsch (since 1918) at seasonal resolution, and for four other glaciers (Giétro, Corbassière, Allalin and Schwarzberg) at annual resolution. For about 25 glaciers, data are available allowing long-term volume changes to be calculated for the past 100 years at intervals of 10–30 years. From a GTN-G perspective, measurements should be continued primarily on the three Tier 3 glaciers.

Length changes:
Long time series and their importance for GCOS

The first regular glacier observations in the Swiss Alps began in 1880 with annual measurements of length changes. Since 1894, these data have been systematically collected worldwide. Thanks to the continuous efforts of numerous observers, Switzerland has one of the world's most extensive monitoring networks. Monitoring is to be continued for at least 97 of the 120 glaciers currently surveyed (including 73 assigned priority 1).

Inventories:
Long time series and their importance for GCOS

A Swiss glacier inventory (SGI) was compiled from aerial photographs taken in the autumn of 1973. Supplementing this publication was an inventory from around 1850, reconstructed from contemporary plane-table sheets, surveys and analysis of aerial photographs. For the 1998/99 period, a new inventory (SGI 2000) was compiled from multispectral satellite data, covering about 85% of the remaining glacierized area. In various projects, the glacier outlines from 1850 and 1973 were digitized. According to inventory data, the total glacierized area was 1340 km^2 in 1973 and only 1050 km^2 in 2000.

International integration

The measurements at the three Tier 3 glaciers (Silvretta, Gries, Basòdino), the measurements of changes in volume (25 glaciers) and length (120 glaciers) and the glacier inventories (i.e. Tier 5 of GTN-G) represent Switzerland's contribution to the World Glacier Monitoring Service (WGMS). The SGI 2000 glacier outlines are also integrated into the Global Land Ice Measurements from Space (GLIMS) database.

Permafrost

Measurements

As a thermal subsurface phenomenon, permafrost reacts sensitively to changes in climate such as the rising air temperatures currently observed. Warming or thawing of alpine permafrost can influence the stability of steep mountain slopes and lead to problems with high-mountain infrastructure or natural hazards. Permafrost observations are coordinated by the network

PERMOS (Permafrost Monitoring Switzerland), which was established by a number of university-based partner institutes in the 1990s, is currently based at the University of Zurich and is funded by FOEN, SCNAT and MeteoSwiss. The monitoring predominantly relies on the measurement of ground temperatures, both at the surface and in the subsurface in boreholes. In addition, kinematics related to permafrost occurrence are quantified. PERMOS bases on established sites from research projects, namely equipped drillings, ground surface temperature measurement sites, and rockglaciers. The partner institutes carry out the field measurements and maintain the sites. In 2007, a sound evaluation of all potential PERMOS sites took place and the monitoring concept was updated based on experiences from the Pilot Phase (2000–2006). Starting in 2008, all approved sites are updated to a uniform technological and methodological standard in order to consolidate the network until 2010. So far, 10 borehole and 2 ground surface temperature sites have been approved. Additional 6 borehole and 2 ground surface temperature sites are subject to re-evaluation in 2009.

Long time series and their importance for GCOS

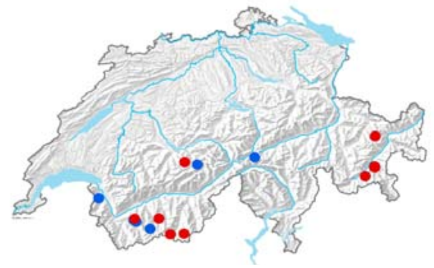

Figure 2: Permafrost monitoring network PERMOS (red: approved sites, blue: sites foreseen to be approved by 2010).

The Swiss permafrost temperature series are long compared to other international observation series of alpine permafrost. The temperature series from Corvatsch-Murtèl in the Upper Engadine is longer than 20 years. Analyses of time series of permafrost temperature measurements from selected PERMOS boreholes demonstrate their connection to climatic conditions and the seasonal variations in the uppermost meters (Vonder Mühll et al., 2007). Such measurements and analyses provide an important scientific basis for reports by international climate experts. The stations operated within the PERMOS network are of importance for GCOS Switzerland, as the quality and long-term continuation of measurements is assured at these sites. Expansion of the network is planned for the medium term to operate ideally at least two PERMOS stations in each alpine climate region.

International integration

PERMOS is a component of the Global Terrestrial Network for Permafrost (GTN-P), which is currently being established within GCOS/GTOS (→ GIP Actions T16 and T17). The EU Permafrost and Climate in Europe (PACE) project also contributed to GTN-P. This project involved studies at nine boreholes, including three Swiss sites.

Land use

Measurements

Information on historical and current land use conditions is needed to determine the effects of land use change on the climate. The FSO Land Use Statistics record changes in land use every 12 years on average. For this purpose, aerial photographs produced by the Federal Office of Topography (swisstopo) are analyzed. As of summer 2008, results of the third survey period (2004 –2009) are available for 33% of the total area of Switzerland. The latest survey employs 46 different categories of land use and 27 of land cover. Comparability with earlier data is assured by the definition of 72 basic categories. The first two surveys, conducted in 1979–1985 and 1992–1997, are being reviewed according to the current method and adapted to the new nomenclature. As transboundary environmental policy calls for a reliable, objective and comparable information base, the 1979/85 Swiss Land Use Statistics were integrated into the European CORINE (Coordinated Information on the Environment) Land Cover 1990 statistics. The datasets differ in the definition of land use types, nomenclature and spatial resolution. With the CORINE Land Cover 2000 project CLC2000, supported by the European Union and the European Environment Agency (EEA), an updated database on land use and land use changes across Europe is now available. The Swiss Land Use Statistics are currently integrated into the CLC2000 database. In order to preserve nationally protected ecosystems, landscape surveys are conducted by various project partners (e.g. WSL) on behalf of the FOEN.

Long time series and their importance for GCOS

Swiss land use surveys were previously carried out in 1912, 1923/24, 1952 and 1972. However, owing to inconsistencies in these surveys, changes in land use cannot be reliably determined over these periods. The reanalysis of the 1979/85 and 1992/97 Land Use Statistics according to the methodology used for the current survey makes all three datasets directly comparable with each other, permitting statistically based conclusions on land use changes over a lengthy period (1979–2009) (→ GIP Action T26). This also provides an excellent basis for determining carbon balances for the Greenhouse Gas Inventory. The greenhouse gas balances calculated show that, on average, land use has acted as a sink in Switzerland since 1990 (FOEN, 2008).

International integration

As a signatory to the UN Framework Convention on Climate Change (UNFCCC), Switzerland has a commitment to compile a national inventory of sources and sinks of greenhouse gases each year, taking 1990 as the base year. The FOEN is responsible for this task. A greenhouse gas balance for "Land Use, Land-Use Change and Forestry" (LULUCF) has to be prepared in the greatest possible detail according to guidelines issued by the IPCC. A particularly precise carbon balance of forests is important with regard to national reporting under the Kyoto Protocol (articles 3.3, 3.4). This is based on data from the Land Use Statistics and from three National Forest Inventory (NFI) surveys.

Forest ecosystem

Measurements

A changing climate affects forests by altering the length of the vegetation period – affecting the future distribution limits of individual tree species. Since 1985, the state of Switzerland's forests has been documented by the Sanasilva Inventory, which focuses on tree health. These surveys are carried out in July and August, using a 16 x 16km sampling grid (approx. 50 study sites). One of several main characteristics assessed, are growth rates, which are studied by the National Forest Inventory (NFI). Under the federal Long-term Forest Ecosystem Research (LWF) project, more intensive and wide-ranging studies have been pursued since 1994 as part of an integrated approach to forest monitoring. At 18 monitoring sites (LWF plots) in Switzerland, (a) external anthropogenic and natural influences (air pollution, climate) are evaluated, (b) changes in important components of the forest ecosystem are assessed, (c) forest health indicators are developed, and (d) comprehensive risk assessments are conducted under various stress scenarios. To this end, numerous site-specific variables are permanently monitored. On the LWF plots, meteorological measurements are carried out automatically according to international standards, with one station located in the stand and a second in a nearby unstocked area. In addition, stand, vegetation, soil and nutrient data are collected at varying temporal resolution (hourly to yearly). At the Seehornwald research station (Davos), microclimate and tree physiological data have been recorded for two decades. Covering a period of about 10 years, almost continuous records of gas exchange rates are available for a forest patch and for individual trees and branches. Over the same period, stem radius changes and sap flow rates have also been continuously measured. Other specific areas are being studied as part of forest fire ecology projects.

Long time series and their importance for GCOS

The systematic sampling grid of the Sanasilva Inventory has become less dense over the years. Around 8000 trees were surveyed at 700 points in a 4 x 4km grid in the period from 1985 to 1992; around 4000 trees in an 8 x 8 km grid in 1993, 1994 and 1997; and around 1'100 trees in a 16 x 16km grid in 1995, 1996 and from 1998 onwards. In addition to the measurements at these sites and the LWF plots, bioclimatological studies are carried out at the subalpine experimental afforestation site on the Stillberg mountain near Davos. Here, microclimatological variables have been studied at four plots since 1975. In larch stands in the Engadine and near Davos, measurements of needle growth have been performed since the 1960s.

International integration

The aims of the LWF are in agreement with those of the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests). This programme was launched in 1985 under the Convention on Long-range Transboundary Air Pollution (CLRTAP) of the United Nations Economic Commission for Europe (UNECE). The various measurements are submitted yearly to the Joint Research Centre (JRC) at Ispra (Italy) and to the ICP Forests Programme Co-ordinating Centre in Hamburg. Other data are used for reporting to the Ministerial Conference on the Protection of Forests in Europe (MCPFE) Criteria and Indicators. The LWF is part of the International Long-Term Ecological Research Network (ILTER).

Forest fires

Measurements

Forest fires may be caused either by human activities or by natural factors. With forest fire data going back years or even decades, analyses of various kinds can be carried out: (a) to identify areas or forest types particularly susceptible to forest fires, (b) to assess the forest fire ignition danger on the basis of meteorological conditions (Fire Weather Index) as an aid to decision-making concerning fire bans, (c) to optimize prevention measures, and (d) to assess the historical effectiveness of changes in forest fire control. In 1993, as part of the National Research Programme NRP 31, the WSL established a forest fire database for southern Switzerland. By 2006, information on more than 6600 forest fire events had been stored in this database, in some cases dating back to the 19th century. From 1980, forest fires were also systematically recorded by canton Graubünden (approx. 350 records by 2004). In other cantons (e.g. Valais, Uri), data on the most relevant forest fires since the beginning of the 20th century were compiled through archive research carried out by the forest and fire services. Since 2006 the database is extended nationwide and centrally managed by the WSL, so that data can be used in particular for research purposes.

Long time series and their importance for GCOS

The long-term forest fire statistics held in the central WSL database are valuable for analyzing forest fire trends for specific regions over lengthy periods. One such analysis, albeit restricted to 20 years, concerns the distribution of lighting-induced fires in the Alps. In a WSL project designed to study ecological resilience after fire in Central Alpine valleys, a forest fire patch in the canton Valais is the subject of a long-term monitoring study. Here, local weather conditions have been recorded since 2004, as in LWF monitoring, and vegetation and biodiversity have also been studied.

International integration

The Global Fire Monitoring Center (GFMC) provides early warnings and monitoring of fire events and archives global fire information. The GFMC is based at the Max Planck Institute for Chemistry at Freiburg i.B. and is supported by the German Federal Foreign Office, the Federal Ministry for Education and Research, and the UN International Strategy for Disaster Reduction (ISDR). The GFMC publication International Forest Fire News regularly includes reports from the WSL. In addition, the WSL is a new member of the European Commission's Forest Fire Expert Group. Data from the European Forest Fire Information System (EFFIS) are published by the European Commission.

Phenology

Measurements

Plant growth and development are strongly influenced by climatic conditions. The first phenological observation network in Switzerland was created in 1760 by the Economic Society of Bern. About 100 years later, from 1869 to 1882, the Forest Agency of canton Bern carried out a phenological observation programme in forests. A national phenological monitoring network was established by MeteoSwiss in 1951. This now comprises some 160 stations, distributed across various regions and elevations of Switzerland. Each year, observers record the dates of leaf unfolding (needle appearance), flowering, fruit ripening, leaf colouring and leaf fall for selected wild plants and crops. These observations cover 26 plant species and 69 phenophases. In 2001, MeteoSwiss also took over the forest phenology programme initiated by the FOEN. Trees, shrubs and herbs are taken as the most significant indicators of climatic changes: beech, hazel, larch, spruce, lime, wood anemone, dandelion and daisy. Observations are passed on to MeteoSwiss at the end of the year for use in studies on the long-term effects of the climate on plant development. To permit conclusions on the current state of vegetation, data are submitted immediately for certain phenophases providing a basis for reports on vegetation status.

Long time series and their importance for GCOS

Since 1808, the bud burst date for horse chestnut has been recorded in Geneva. This is Switzerland's longest phenological time series. Of equal importance is a second historical series – cherry tree flowering dates at the rural Liestal station (south of Basel) – which goes back to 1894. Observations from the stations of the national phenological monitoring network are more recent, going back to the beginning of the 1950s. The selection of the country's most important observation sites (12) includes a wide variety of regions and elevations, taking into account the quality of observations of tree, shrub and herb phenophases, preferably of long duration. The analysis of flowering and leaf-unfolding from several network stations between 1951 and 1998 were included in the latest IPCC AR4 report (WG II), highlighting changes in the phenology, particularly with altitude (Defila and Clot, 2001).

International integration

Switzerland is part of the European Phenology Network (EPN), and the Birmensdorf WSL site participates in the European International Phenological Gardens (IPG) observation programme. In addition, under COST-725, joint efforts are being undertaken to harmonize observation guidelines and to build a European reference data set. The Global Observation Research Initiative in Alpine Environments (GLORIA) aims to establish a worldwide long-term observation network of sites collecting data on vegetation in Alpine environments. Switzerland is contributing to this initiative with two sites – one in the National Park and one in the canton Valais.

Role of satellites

Lakes

Lake temperatures are usually measured at a specific site once or twice a month at various water depths. Thermal data from satellite sensors such as the AVHRR onboard the NOAA polar orbiting satellites are used to retrieve lake surface temperatures for larger lakes over the European Alps including Switzerland (Oesch et al., 2005). This is done for more than sixty lakes in near real-time at the University of Bern (→ GIP Action T8; GIP-SS Product T.1.3).

Snow cover

NOAA AVHRR data are used as well to determine operationally and in near real-time the snow cover extent over the European Alps (→ GIP-SS Product T.3) (Foppa et al., 2007). Snow areal extent from geostationary Meteosat Second Generation provides very high temporal information and is generated in near real-time by MeteoSwiss for assimilation in the mesoscale NWP model (De Ruyter de Wildt et al., 2007). This product is adapted for pilot studies on snow cover climatology for Europe within the Swiss GCOS activities at MeteoSwiss (Seiz et al., 2007).

Glaciers

For glacier inventories on a regional to global scale, satellite data provide comprehensive and uniform information. For the Swiss glacier inventory SGI 2000 (period 1998/99) an automated method for glacier classification based on satellite data has been developed. The methods developed for the inventory – automatic glacier classification based on multi-spectral satellite data and subsequent derivation of inventory data using geographical information systems – are applied worldwide, e.g. in the Global Land Ice Measurements from Space (GLIMS) initiative. The aim of the ESA Data User Element (DUE) GlobGlacier project is to apply these well established techniques for mapping glacier snow lines and indicators for mass balance to archived satellite data. To generate the required products, optical (ASTER/SPOT) as well as microwave and interferometric SAR data are used (e.g. ERS 1/2) (→ GIP-SS Products T.2.1 and T.2.2). Long time series of volume changes also provide a valuable data set for combining mass balance models with remote sensing data for spatio-temporal extrapolation of isolated measurements.

Land cover

With support from the European Space Agency (ESA), the European CORINE Land Cover statistics will be updated with satellite data from the GlobCover project, which is part of the DUE programme. At the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), CORINE data are compared with forest inventory data and moderate-resolution global land cover products based on satellite data (MODIS) (→ GIP Action T26; GIP-SS Product T.5.1).

Ecosystem

Time series of satellite-derived fractions of absorbed photosynthetically active radiation estimates (fAPAR) across the Alps are generated from MODIS data at WSL (Jolly et al., 2005). Mean fAPAR changes are produced for different elevation and vegetation zones in the Alps based on the full range of available data (2000-2004) (→ GIP-SS Product T.6). The resulting spatio-temporal patterns were verified with the Normalized Difference Vegetation Index (NDVI) from data sets of the Global Inventory Modeling and Mapping Studies (GIMMS). Time series (1982-2001) from NOAA AVHRR Pathfinder NDVI data sets were used for research purposes at the ETH Zurich to create a continuous European vegetation phenology dataset of a 10 day temporal and 0.1 degree spatial resolution. The resulting spatio-temporally consistent NDVI dataset is called European Fourier-Adjusted and Interpolated NDVI (EFAI NDVI) and has been processed at global scale.

Forest fires

Global forest fire maps are produced using satellite data and integrated into the World Fire Atlas. It is based on data from the radiometers ATSR-2 and AATSR onboard the ESA satellites ERS-2 and Envisat. The data set goes back to 1995 and documents local forest fires, which occurred mainly in the southern part of the Swiss Alps. The Standard Forest Fire Product based on MODIS data is a contribution to the GTOS programme Global Observation of Forest and Land Cover Dynamics (GOFC-GOLD) (→ GIP Action T33; GIP-SS Product T.9).

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Abbreviations

AERONET	Aerosol Robotic Network
AGNES	Automated GPS Network in Switzerland
AMDAR	Aircraft Meteorological Data Reporting
ANETZ	Automated Monitoring Network
AOD	Aerosol Optical Depth
ASRB	Alpine Surface Radiation Budget
(A)ATSR	(Advanced) Along Track Scanning Radiometer
AVHRR	Advanced Very High Resolution Radiometer
BSRN	Baseline Surface Radiation Network
CHARM	Swiss Atmospheric Radiation Monitoring
CIMO	Commission for Instruments and Methods of Observation
CM-SAF	Satellite Application Facility for Climate Monitoring
CNRS	Centre National de la Recherche Scientifique
COP	Conference of the Parties
CORINE	Coordinated Information on the Environment
COST	European Cooperation in the field of Scientific and Technical Research
CWINDE	European Windprofiler Network
DDPS	Federal Department of Defense, Civil Protection and Sport
DETEC	Federal Dep. of the Environment, Transport, Energy and Communications
DLR	German Aerospace Center
DWD	Deutscher Wetterdienst
EAN	European Aeroallergen Network
EARLINET	European Aerosol Research Lidar Network
Eawag	Swiss Federal Institute of Aquatic Science and Technology
ECC	European Cloud Climatology
ECMWF	European Center for Medium-Range Weather Forecasts
EEA	European Environment Agency
EKK	Cryospheric Commission of SCNAT
EMEP	European Monitoring and Evaluation Programme
Empa	Swiss Federal Laboratory for Materials Testing and Research
ENET	Supplementary Network
EPFL	Swiss Federal Institute of Technology Lausanne
EPN	European Phenology Network
ERS	European Remote Sensing Satellite
ESA	European Space Agency
ETH	Swiss Federal Institute of Technology Zurich (ETHZ)
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
EUVC	European Ultraviolet Radiometer Calibration Center
FAGS	Federation of Astronomical and Geophysical Data Analysis Services
FAO	Food and Agriculture Organization of the United Nations
FOAG	Federal Office for Agriculture
FOEN	Federal Office for the Environment
FoG	Fluctuations of Glaciers
FOPH	Federal Office of Public Health
FSO	Federal Statistical Office
GAW	Global Atmosphere Watch
GCOS	Global Climate Observing System
GEBA	Global Energy Balance Archive
GEWEX	Global Energy and Water Experiment
GFMC	Global Fire Monitoring Center
GIMMS	Global Inventory Modeling and Mapping Studies
GLIMS	Global Land Ice Measurements from Space
GLORIA	Global Observation Research Initiative in Alpine Environments
GMBB	Glacier Mass Balance Bulletin
GMES	Global Monitoring for Environment and Security
GNIP	Global Network of Isotopes in Precipitation
GOME	Global Ozone Monitoring Experiment
GPS	Global Positioning System
GRDC	Global Runoff Data Centre
GRUAN	GCOS Reference Upper Air Network
GSN	GCOS Surface Network
GTN	Global Terrestrial Network (-G: Glaciers; -H: Hydrology; -P: Permafrost)
GTOS	Global Terrestrial Observing System
GUAN	GCOS Upper Air Network
HFSJ	High Altitude Research Station Jungfraujoch
HUG	Hydrological Study Areas
IAC	Institute for Atmospheric and Climate Science
IACS	International Association of Cryospheric Sciences
IAEA	International Atomic Energy Agency
IAP	Institute of Applied Physics

ICP	International Co-operative Programme
ICSU	International Council for Science
IDNDR	International Decade for Natural Disaster Reduction
IGRA	Integrated Global Radiosonde Archive
IGRAC	International Groundwater Resources Assessment Centre
IMIS	Intercantonal Measurement and Information System
IPCC	Intergovernmental Panel on Climate Change
IPG	International Phenological Gardens
ISDR	International Strategy for Disaster Reduction
IUGG	International Union of Geodesy and Geophysics
JMA	Japanese Meteorological Agency
JRC	Joint Research Centre, Ispra
KLIMA	Conventional Monitoring Network
LKO	Licht-Klimatisches Observatorium Arosa
LULUCF	Land Use, Land-Use Change and Forestry
LWF	Longterm Forest Ecosystem Research
MERIS	Medium Resolution Imaging Spectrometer Instrument
MeteoSwiss	Federal Office of Meteorology and Climatology
MISR	Multiangle Imaging SpectroRadiometer
MODIS	Moderate Resolution Imaging Spectroradiometer
MVIRI	Meteosat Visible and Infrared Imager
NABEL	National Air Pollution Monitoring Network
NADUF	National River Monitoring and Survey Programme
NAPOL	National Pollen Monitoring Network
NAQUA	National Groundwater Observation Programme
NASA	National Aeronautics and Space Administration
NBCN	National Basic Climatological Network
NCCR	National Center of Competence in Research
NCDC	National Climatic Data Center
NDACC	Network for the Detection of Atmospheric Composition Change
NFI	National Forest Inventory
NILU	Norwegian Institute for Air Research
NIME	Precipitation Monitoring Network
NOAA	National Oceanic and Atmospheric Administration
NRP	National Research Programme
NSIDC	National Snow and Ice Data Center
OBS	Visual Observations Network
OcCC	Advisory Body on Climate Change
OECD	Organisation for Economic Cooperation and Development
OMI	Ozone Monitoring Instrument
OPERA	Operational Program for the Exchange of weather RAdar information
PERMOS	Permafrost Monitoring Switzerland
PMOD	Physical Meteorological Observatory Davos
PSI	Paul Scherrer Institute
QA/SAC	Quality Assurance/Scientific Activity Centre
RBCN	Regional Basic Climatological Network
SCNAT	Swiss Academy of Sciences
SEVIRI	Spinning Enhanced Visible and InfraRed Imager
SGI	Swiss Glacier Inventory
SLF	Swiss Federal Institute for Snow and Avalanche Research
SOGE	System for Observation of Halogenated Greenhouse Gases in Europe
SR	Systematische Sammlung des Bundesrechts
Swisstopo	Federal Office of Topography
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
VAW	Laboratory of Hydraulics, Hydrology and Glaciology
WCC	World Calibration Center
WCP	World Climate Programme
WCRP	World Climate Research Programme
WDCA	World Data Centre for Aerosols
WDCGG	World Data Centre for Greenhouse Gases
WGI	World Glacier Inventory
WGMS	World Glacier Monitoring Service
WMO	World Meteorological Organization
WORCC	World Optical depth Research and Calibration Center
WOUDC	World Ozone and Ultraviolet Radiation Data Center
WRC	World Radiation Center
WRC-IRS	World Radiation Center, Infrared Radiometry Section
WRC-SRS	World Radiation Center, Solar Radiometry Section
WRMC	World Radiation Monitoring Center
WSL	Swiss Federal Institute for Forest, Snow and Landscape Research