GCOS
GLOBAL CLIMATE OBSERVING SYSTEM

GCOS

Global Climate Observing System

Austrian Inventory Report 2017

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ZAMG

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www.gcos.at

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Local Observations for Global Understanding

The ultimate success of the Global Climate Observing System, GCOS, depends on effective coordination at the national level of the contributions of Member countries to the WMO Integrated Global Observing Systems (WIGOS), the IOC-led and co-sponsored Global Ocean Observing System (GOOS), the coordination of the various and very diverse terrestrial observing systems, and the many other in situ and space-based observing systems providing climate-related observation data.

The need for an effectively operating GCOS has recently assumed even greater importance with the Paris Agreement[1], which was adopted by the 21st Conference of Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) in December 2015 which addresses global efforts to limit climate change. Its central aim is to strengthen the global response to the threat of climate change by keeping the global temperature rise until the end of this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit it to 1.5 degrees Celsius. This is, however, not possible without a thorough and reliable systematic observations of the climate system.

The mechanism to address these observation needs is GCOS. Established in 1992 and co-sponsored by the World Meteorological Organization (WMO), the United Nations Educational, Scientific and Cultural Organization (UNESCO), the United Nations Environment Progamme (UNEP) and the International Council for Science (ICSU), GCOS promotes standardized, systematic and sustained climate observations in order to improve the understanding of our climate system and enhance climate services. One of GCOS most prominent tools to promote climate observations are the Essential Climate Variables (ECVs), a collection of currently 54 parameters that serve as a guideline for operators of climate observation systems.

GCOS guides climate observing systems through regular implementation plans. The recent plan was published in 2016[2] and responds to the needs identified in the GCOS status report from 2015[3] but also to the ambitious goals and expectations of the Paris Agreement. This 2016 plan includes many actions to improve the observing networks that will help to improve and adapt observations networks to the increasing needs of the climate community. In order to reach this goal, the 22nd COP in Marrakesh in 2016 invited “United Nations agencies and international organizations to support the full implementation of the [GCOS] implementation plan, as appropriate”.

This recognition and support by the United Nations and its members to address the big challenges laid out in the Paris agreement holds for all climate observing networks of which the GCOS consists.

The responsibility for GCOS implementation and operation at the national level in individual WMO, IOC, UNEP, and ICSU Member countries is thus usually distributed across many departments and agencies rather than being focused solely in a single agency, such as the National Meteorological Service (NMS). It is therefore useful, in order to ensure effective coordination across the GCOS contributing organizations at the national level and to maintain a coordinated overall channel of communication with the GCOS Secretariat in Geneva, that there be a jointly designated ‘GCOS National Coordinator’ in each country with responsibility for as many as possible of the following functions.

1 "Paris Agreement". United Nations Treaty Collection. 8 July 2016: https://treaties.un.org/pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-7-d&chapter=27&clang=_en

2 The Global Observing System for Climate: Implementation Needs. GCOS-200 (GOOS-214). Pub WMO, Geneva, 2016. https://library.wmo.int/opac/index.php?lvl=notice_display&id=19838.

3 The Global Observing System for Climate: Status of the Global Observing System for Climate. GCOS-195. Pub WMO, Geneva, 2015.

Many countries have appointed GCOS National Coordinators and National Committees that are able to cross-manage the observation requirements of the atmospheric, ocean and terrestrial domains. Many countries still need to establish such national coordination mechanisms.

I would like to thank Austria and the Zentralanstalt für Meteorologie und Geodynamik, ZAMG, for nominating in 2017 an Austrian GCOS Coordinator, Ms Silke Adler, whose efforts in facilitating climate observations will certainly serve as inspiration and motivation for all national experts in climate research and observation to prove that it will need "Local observations for Global Understanding" of our changing Earth`s climate.

Dr. Carolin Richter
Director of the GCOS Secretariat,
World Meteorological Organization

Foreword

Policy makers have to face changing climate conditions and their possible impact on various aspects of live. Long-term series of climate measurements are essential for our knowledge of the interactions between the climate, ecosystems and human activities. In Austria, we can count on long-standing meteorological data collections, the longest starting in 1767 at Kremsmünster, which builds the basis for research on climate change. Not only temporal, but also spatial continuity is the deciding factor for successful climate monitoring. Therefore supporting and promoting monitoring networks on an international level is a major task when dealing with climate change.

The Global Climate Observing System (GCOS) of the World Meteorological Organization (WMO) is such an effort. It was founded to identify and coordinate monitoring networks worldwide. It also supports countries in setting up monitoring networks especially when public funding is poor.

Although in Europe public funding of monitoring networks is relatively high, even in Austria important initiatives like glacier or permafrost monitoring are depending on third party funding. This creates not only financial uncertainties, but also possible discontinuations of valuable long time series.

This report is the result of the effort, taken on by Zentralanstalt für Meteorologie und Geodynamik (ZAMG) in its role as Austria's national GCOS coordinator, to provide an overview of various programs for collecting the main climate variables in Austria. The report may help to facilitate the access and interdisciplinary use of this data.

We want to thank all national partner institutions and organizations for their interest in and productive collaboration on the Austrian GCOS Report.

Dr. Michael Staudinger
Director of the Central Institute for Meteorology and Geodynamics

Introduction

Austria's landscape consists of high mountains and valleys in the west and lowlands in the eastern part of the country. While this composition may be perceived as quite idyllic, it poses a major challenge when measuring meteorological parameters and monitoring long term changes of the climate. For example, when observing meteorological parameters under the extreme conditions of an Alpine summit, one will be faced with higher demands to the instruments in use.

In Austria several institutions own observation networks designed for their specific needs. These networks build the fundamental basis to understand the impact of climate change.

Various aspects of the change need to be observed, covering rockslide due to melting permafrost as well as woods or plants facing infestation with vermin.

These changes and modifications in our environment make it increasingly important to document the changes and exchange experiences with other countries.

Global Climate Observing System (GCOS) is a Co-sponsored Program of the World Meteorological Organisation (WMO) for collecting and providing climate monitoring data records for improved management of the impacts and consequences of climate variability and current and future climate change. (https://public.wmo.int/en/programmes/global-climate-observing-system).

For a global climate monitoring system, national coordination is an essential factor. Therefore, in 2012 a national coordination GCOS office was set up in Austria (Austrian GCOS Secretariat) located at the national weather service, the Zentralanstalt für Meteorologie und Geodynamik (ZAMG). Periodic meetings have been established and attended by several institutions.

This Report is an overview of climate monitoring in Austria in collaboration with governmental institutes, universities and alpine organisations. The first part gives short introductions to the contributing institutes. The second part is structured into two climate monitoring domains, the atmospheric climate observing system and the terrestrial climate observing system. All institutions present their climate observation network and measurement methods. An information sheet summarizes where the data records can be found and lists the contact person appointed by the institution.

This document is a record of climate monitoring in Austria in accordance with the Implementation Plan of the WMO Global Climate Observing System (GCOS).

More information about the impact of climate change in Austria can be found in the Austrian Assessment Report 2014 - AAR14 which is based on the IPCC structure and process. In this extensive work, more than 200 scientists depict the state of knowledge on climate change in Austria and the impacts, mitigation and adaptation strategies, as well as the associated known political, economic and social issues. (http://www.ccca.ac.at/de/apcc/)

Contributing Institutes

Alpenverein

www.alpenverein.at

The monitoring of glacier length variations in Austria is traditionally organized and carried out by the Austrian Alpine Association (Österreichischer Alpenverein). This monitoring started as early as 1891 and is currently carried out at about 100 glaciers by research institutions or private persons who are responsible for defined mountain groups or regions. At a limited number of glaciers additional monitoring on surface velocities and height variations takes place. Data is collected by responsible persons appointed by the association (currently: A. Kellerer-Pirklbauer and Gerhard K. Lieb) and compiled to an annual report which is published in the association's journal "Bergauf" and in the internet. The association's special interest in glacier (and permafrost) variations is due to the fact that its network of marked trails in the Alps is prone to potentially hazardous processes triggered by these changes.

ARGE LWD

www.lawinen.at

The ARGE LWD is an informal consortium linking all regional avalanche warning services in Austria. The ARGE LWD includes the avalanche warning services of the Provinces Vorarlberg, Tyrol, Salzburg, Carinthia, Styria, Upper and Lower Austria. Most avalanche warning services were founded in the mid-1960s and provide since the early days public avalanche forecasting or warning products and safety advisories. The most prominent product is the avalanche bulletin, which is issued on a daily basis during winter season by the regional avalanche forecasting centres for their Province. In order to provide high-quality avalanche danger assessments throughout the warning products, the various regional Avalanche Warning Services established and continuously maintain an intensive network of observers and automated measurements. In total, the consortium obtains snow measurements from 186 automated weather stations, which represents one of the densest snow and weather station networks in mountainous terrain worldwide. ARGE LWD's experts represent Austria in numerous international organizations and associations such as e.g. the EAWS Technical Advisory Board and ISSW Steering Committee.

AUSTRO CONTROL GMBH

www.austrocontrol.at

The "AUSTRO CONTROL GMBH" was founded in 1994 as a privatized successor organization of the former "Bundesamt für Zivilluftfahrt" which had been founded in 1955. AUSTRO CONTROL is an air navigation service provider primarily responsible for Austria's air traffic control and therefore one part of it is the aviation meteorological department. AUSTRO CONTROL is an institution affiliated to the Federal Ministry of Traffic, Innovation and Technology (BMVIT). Until a new headquarter building is built in Schnirchgasse 11 the institution is temporary headquartered at Wagramer Straße 19 in Vienna and maintains air traffic control towers at Wien Schwechat, Linz, Salzburg, Innsbruck, Graz and Klagenfurt and an air traffic control centre at Wien Schnirchgasse. The meteorological operational service is located at each of the towers and the MET department with about 10

employees is located in Wagramer Straße. About 50 employees in shift work provide aviation meteorological reports, forecasts and warnings. Beside the observations at the six Austrian international airports AUSTRO CONTROL operates in close cooperation with ZAMG the full automatic VAMES AUTOMETAR network with 50 stations. AUSTRO CONTROL's experts represent Austria in numerous international organizations at ICAO.

Bundesforschungszentrum für Wald

www.bfw.ac.at

The Austrian Research Centre for Forests (BFW) is a multidisciplinary research and training institution and holds the legal status of an institution under public law. The BFW supports the economic, ecological and socially sustainable development of the society and its environment through the preparation of scientific guidelines and the dissemination of knowledge concerning the multi-functional utilisation of natural resources. In pursuance of research, monitoring and knowledge transfer the BFW focuses its work on the strategic and thematic fields of forest management, forest and climate, bioenergy, biodiversity and natural hazards. The BFW is organized in six Research Departments, two Forest Training Centres, and several internal service units. Currently the BFW employs approximately 280 people of which about 120 are researchers. At the European level, the BFW and its Departments provide leadership in fields of forest inventory, harmonization and monitoring issues, forest growth modelling and soil carbon and nitrogen cycling and modelling with a special focus on soil ecology.

University of Natural Resources and Life Sciences

www.boku.ac.at/en/

The University of Natural Resources and Life Sciences or BOKU, Vienna was founded in 1872. The first study programmes offered were Agricultural-, Forestry studies and Environmental Engineering. Today BOKU, sometimes called "Alma Mater Viridis", is a modern, international University of Life Sciences with 9 Bachelor and 25 Master programmes for more than 10,000 students. BOKU perceives itself as a teaching and research centre for renewable resources, which are necessary for human life. It is BOKU's objective to help make a considerable contribution to the conservation and protection of resources for future generations by providing diversity in its fields of study. Connecting natural sciences, engineering and economic sciences, we wish to increase knowledge of the ecologically and economically sustainable use of natural resources, to provide a harmoniously cultivated landscape. We at BOKU commit ourselves to international performance in research and teaching, cooperation on regional, national and international levels, and to receptiveness to new developments.

ENVEO

www.enveo.at

ENVEO (Environmental Earth Observation) IT GmbH, Innsbruck, is an engineering company founded in 2001 with main business activities in the field of remote sensing research and services in climate monitoring, hydrology, meteorology, and cryospheric studies. The scope of activities and expertise comprises the development of techniques for remote sensing data analysis and satellite data exploitation, including product generation and services for snow and glacier monitoring, hydrology and water management, polar research, and geo-hazard monitoring. From the beginning ENVEO has also contributed to the development of concepts and techniques for advanced satellite systems in environmental monitoring. Climate related products generated from satellite data within ESA and EC

contracts, made available to the public, include time series of snow cover extent with global and regional coverage, regional maps of glacier area extent and surface velocity, and maps of ice motion covering the Greenland and Antarctic ice sheets.

HYDRO graphie Österreich

MINISTERIUM FÜR EIN LEBENSWERTES ÖSTERREICH

http://ehyd.gv.at; www.bmlfuw.gv.at

The Division IV/4 – Water Balance (Hydrographical Central Office) is part of the Federal Ministry of Agriculture, Forestry, Environment and Water Management (BMLFUW http://www.bmlfuw.gv.at) and coordinates the work of the Hydrographical Services in the nine provincial governments. The Hydrographical Service in Austria operates a hydrometrical network for the quantification of the water cycle in Austria. The network consists of about 800 discharge, 900 precipitation and 3800 groundwater stations. Acquisition, processing and controlling of hydrological data is done consistent by the hydrological divisions in the nine provincial governments.

The results of the investigations on the water cycle are published currently in the Austrian Hydrographical Yearbook. This yearbook and hydrological data are available in the internet, published at https://wasser.umweltbundesamt.at/hydjb and http://ehyd.gv.at.

ÖAW IGF INTERDISZIPLINÄRE GEBIRGSFORSCHUNG INTERDISCIPLINARY MOUNTAIN RESEARCH

IGF

www.mountainresearch.at

The Institute for Interdisciplinary Mountain Research of the Austrian Academy of Sciences is investigating the effects of global change on mountain regions. Climate change and globalization in terms of the relations of humans with the environment in cultural landscapes, mountain cities and in protected mountain areas are the subject of disciplinary, but also inter- and transdisciplinary research. The disciplinary research in cryospheric sciences focusses on Alpine sites and on process studies which are often based on long time series and are aiming at developing and validating tools and methods for application to the world's mountain glaciers.

LUFTGÜTE BURGENLAND

Amt der Burgenländischen Landesregierung

www.luft-bgld.at

The Air Quality Network of Burgenland is a part of the department for natural reserve at the government of Burgenland and is located in Eisenstadt. The main task is to measure air pollution in Burgenland. The Basis for these measurements is the Austrian law for ambient air quality „Immissionsschutzgesetz – Luft" and the „Ozongesetz". Therefore the main aim is the control of the permanent protection of human health, animal and plant life, reduction of immissions and preservation of best air quality. The Air Quality Network of Burgenland started in 1994 and only for measure ozone and nitrogen dioxide and meteorological data at two measuring points. Since then the network was increased to three fixed stations and three mobile ones, which are now operated by 3 employees. Data are collected automatically throughout the day and year. The monitoring stations are located in urban agglomerations and also in rural regions. The collected data are freely available for both private and public institutions.

LAND KÄRNTEN Amt der Kärntner Landesregierung

www.ktn.gv.at

Meteorological measurements within the Provincial Government of Carinthia (Amt der Kärntner Landesregierung) are performed by the Department 8 – Environment, Water and Nature Protection, headquartered in Klagenfurt am Wörthersee, Flatschacher Straße 70. With its more than 400 employees the department is responsible for the protection of soil, water and air in the province of Carinthia. The spectrum of the department is broadly diversified with the areas of waste management and environmental remediation, energy management and grants, water rights, water management, hydrography, lakes research, climate protection and adaptation, sustainability, air quality improvement, geology and soil protection, strategic environmental assessment, nature protection, environmental control, acoustic and electrical engineering, safety and process engineering, radiation protection, shipping and motor and air traffic. Through the use of synergies of all these areas the department is the main contact point for all matters relating to environment, water, nature and energy in Carinthia.

NUMBIS - NÖ Luftgütemessnetz

www.numbis.at

The NÖ Luftgütemessnetz is affiliated to the Amt der NÖ Landesregierung and is headquartered in St. Pölten, Landhausplatz 1. The main task of the monitoring network is the execution of the "Immissionsschutzgesetz Luft" (law for ambient air quality). Therefore the main aim of the institution is the control of the permanent protection of human health, animal and plant life, reductions of immissions and preservation of best air quality.

The air quality network of Lower Austria started in 1984 with monitoring air quality. Since then a network of 42 fixed stations and 4 mobile stations has been built up, which is now operated by six employees. Data are collected automatically throughout the day and year. The monitoring stations are located in urban agglomerations, near hotspots like motorways and industries and also in rural regions. Because of a close cooperation with the Environment Agency Austria (Umweltbundesamt - UBA) concerning the quality management system the measurements are fully comparable. The collected data are freely available for both private and public institutions.

Das Land Steiermark LUIS – Steiermärkisches Luftgütemessnetz

www.umwelt.steiermerk.at

The Styrian Air Quality Network is part of the regional government of Styria/Austria. The main task of the monitoring network are measurements of ambient air quality due to the EU air Quality Directive (2008/50/EC) and the Austrian law for ambient air quality "Immissionsschutzgesetz Luft". Therefore the main aim of the institution is the control of the permanent protection of human health, animal and plant life, reductions of immissions and preservation of best air quality.

The air quality network of Styria started in the late 1970s with measurement of SO_2 at industrial hot spots. Since 1989 all data were stored in our Air Quality Database. Now a network of 38 fixed stations and 3 mobile stations has been built up, which is currently operated by five employees. The monitoring stations are located in urban agglomerations, near traffic routes and industrial sites but also in rural regions. Because of a close cooperation with the Environment Agency Austria (Umweltbundesamt - UBA) concerning the quality management system the air quality measurements are fully comparable. The collected data are freely available for both private and public institutions.

Oberösterreichisches Luftmessnetz

www.land-oberoesterreich.gv.at/657.htm

The Upper Austrian air-measuring network belongs to the office of the Upper Austrian government and is headquartered in Linz, Goethestraße 86. The main task of the monitoring network is the execution of the “Immissionsschutzgesetz Luft” (law for ambient air quality). Therefore the main aim of the institution is the control of the permanent protection of human health, animal and plant life, reductions of immissions and preservation of best air quality.

The air quality network of Upper Austria started in 1977 with monitoring air quality. Since then a network of 16 fixed stations and about 4 mobile stations has been built up, which is now operated by ten employees. Data of the main pollutants are collected automatically throughout the day and year. The connected calibration laboratory is a European reference laboratory in the Aquila network.

For other pollutants samples are collected and analysed in our laboratory. The monitoring stations are located in urban agglomerations, near hotspots like motorways and industries and also in rural regions. The collected data are freely available for both private and public institutions.

Air Quality Monitoring Network

www.salzburg.gv.at/themen/umwelt/luft

The air-measuring network of Salzburg as a part of the environmental department belongs to the local government of Salzburg and is headquartered in the City of Salzburg, Michael-Pacher-Straße 36. The main task of the monitoring network is the execution of the “Immissionsschutzgesetz-Luft” and the “Ozongesetz” (law for ambient air quality). Therefore the main aim of the institution is the control of the permanent protection of human health, animal and plant life, reductions of immissions and preservation of best air quality.

The air quality network of Salzburg started in 1978 with monitoring air quality. Since then a network of 13 fixed stations and about 3 mobile stations has been built up. Data of the main pollutants are collected automatically throughout the day and year. The connected calibration laboratory ensures the high quality of the measured data and is supplemented with the standards of the Environment Agency Austria (UBA).

All data are published daily, monthly and yearly in reports and can be accessed from the webpage.

Abteilung Waldschutz/Fachbereich Luftgüte

www.tirol.gv.at/umwelt/luft

The Tyrolean air-quality-monitoring network is affiliated to the Amt der Tiroler Landesregierung and is headquartered in Innsbruck Bürgerstraße 36 and Langer Weg 27. The main task of the monitoring network is the execution of the “Immissionsschutzgesetz-Luft” and “Ozongesetz” (law for ambient air quality). Therefore the main aim of the institution is the control of the permanent protection of human health, animal and plant life, reductions of immissions and preservation of best air quality.

The air quality network of Tyrol started in 1973 with monitoring air quality. Since then a network of at the moment 19 fixed stations has been built up, which is now operated by 7 employees. Data are collected automatically throughout the day and year. The monitoring stations are located in urban agglomerations, near hotspots like motorways and industries and also in rural regions. Because of a close cooperation with the Environment Agency Austria (Umweltbundesamt - UBA) concerning the

quality management system the measurements are fully comparable. The collected data are freely available for both private users and public institutions.

Graz University of Technology

www.tugraz.at

The Graz University of Technology (German: Technische Universität Graz, short TU Graz) is one of five universities in Styria, Austria. It was founded in 1811 by Archduke John of Austria and currently comprises seven faculties. The university is a public university. It offers 18 bachelor and 33 master study programmes (of which 14 are in English) across all technology and natural science disciplines. Doctoral training is organised in 14 English-speaking doctoral schools. The university has more than 13,000 students, and approximately 2,000 students graduate every year. Science study programmes are offered in the framework of NAWI Graz together with the University of Graz. The university has some 3,300 staff. Research areas are combined in five fields of expertise. The university is one of the universities with the highest third-party funding in Austria. In the competence centre programme COMET of the Austrian Research Promotion Agency, the university is the most strongly represented Austrian university. The university information system CAMPUSonline, which was developed at the university, is used by the majority of Austrian universities as well as by several other universities in the German-speaking area. Student teams from the university successfully participate in international student competitions in a variety of disciplines. The TU Graz, the Montanuniversität Leoben and the TU Wien form the network Austrian Universities of Technology (TU Austria) with approximately 47,000 students and 9,000 staff.

Vienna University of Technology

tuwien.ac.at/; http://rs.geo.tuwien.ac.at/

The Vienna University of Technology (TU Wien) was founded in 1815 as „k. k. polytechnisches Institut“, making it the first University of Technology of today’s German-speaking area. TU Wien staff comprises about 140 professors, 3300 scientific staff and 1300 non-scientific staff. Over 28,000 students are enrolled. With its eight faculties – mathematics and geo-information, physics, technical chemistry, informatics, civil engineering, architecture and regional planning, mechanical engineering and business science, electrical engineering and information technology – TU Wien covers the classic engineering disciplines.

The Remote Sensing unit of the Department of Geodesy and GeoInformation (GEO, Faculty of Mathematics and GeoInformation) is one of the leading research institutes in Europe in global monitoring of soil moisture and other land-surface variables (water surfaces, wetlands, freeze/thaw status) by microwave remote sensing. Many of the algorithms and products developed by the unit have been transferred into operational data services, including Copernicus Global Land and Climate Change Services, and EUMETSAT’s soil moisture services. The world’s largest database of global in situ soil moisture observations, the International Soil Moisture Network (ISMN), has been developed and operated by the GEO Remote Sensing research group since 2010.

ENVIRONMENT AGENCY AUSTRIA umweltbundesamt

www.umweltbundesamt.at

With more than 500 staff members from 55 scientific disciplines, the Environment Agency Austria is the largest organisation of experts in the environment sector in Austria and a leading adviser in environmental matters. The Environment Agency builds bridges between the economy, science and politics at national and international level and develops perspectives on the sustainable development of society.

The Environment Agency Austria has a demonstrable track record of successful projects in more than 60 countries – from the new EU Member States to the Western Balkans, the Middle East, the Maghreb countries and Asia. In its capacity as adviser the Environment Agency Austria advises UN and EU institutions and is active as a partner in more than 200 national, European and international networks, bodies, and working groups.

University of Graz

www.uni-graz.at

The University of Graz was founded in 1585 and is therefore Austria's second oldest university. Many excellent scientists, amongst them six Nobel laureates, have taught and researched at this university. With some 32,500 students and 4,300 employees this university is one of the largest in the country. The university consists of 6 faculties with a total number of 76 institutes and department. In particular one department of the University of Graz carries out research in the field of glaciology, namely the Department of Geography and Regional Science. This department focuses on a strong cooperation with a variety of national and international partners in the field of environmental issues including glaciers and permafrost, sustainable development and educational matters. In the field of glaciology several scientists at this department carry out field, remote sensing and modelling studies at different glacier and permafrost areas in the Austrian Alps but also the high Arctic.

University of Innsbruck

www.uibk.ac.at

Founded in 1669, the University of Innsbruck looks back to a long and variable history. It is currently the largest research and education institution in western Austria with more than 28,000 students and 4,500 staff. The 16 different faculties include social and natural sciences, economy, law and architecture. The research focus ‘Alpine space – man and environment’ is unique in Austria. This is based on a long tradition in mountain research at the University. The focus of the Research Centre ‘Climate - Cryosphere and Atmosphere’ is on the interactions between climate and cryosphere as well as any scientific research within any of these disciplines. The Alps and particularly our field sites in the “backyard” of the Innsbruck University (e.g. Hintereisferner) are an ideal laboratory for research, from which universal climate-relevant aspects of surface-atmosphere exchange in complex terrain can be inferred and transferred to other mountain ranges worldwide.

University of Salzburg

www.uni-salzburg.at

The University of Salzburg is proud of its long history in glaciology and high mountain research. Today the LTER site Oberes Stubachtal is a long-range research site with a main focus on the measurement of glacier front variation and annual mass balance, going along with water budget estimations within the catchment area of the lake Weißsee. The research site, including the Stubacher Sonnblickkees (SSK) is located in the Hohe Tauern Range (Eastern Alps) in the south of Salzburg Province. The mass balance record was the first one established in the Hohe Tauern region and is one of the two dozen longest series worldwide. For more than 20 years the Interfaculty Department of Geoinformatics (Z_GIS) has supported the research activities and monitoring programs at Sonnblickkees in many ways: Monitoring glaciers with various data capture and photogrammetric methods as well as geospatial analysis workflows are the key methods.

Vienna's Air Quality Monitoring Network

www.wien.gv.at/umweltschutz

Vienna´s air quality monitoring network is affiliated to the "Amt der Wiener Landesregierung" and is headquartered in Vienna, Dresdnerstraße 45. The main task of the monitoring network is the execution of the "Immissionsschutzgesetz Luft" (act for ambient air quality). Therefore, the main aim of the institution is to control the permanent protection of human and animal health and plant life, reductions of immissions and preservation of best air quality.

Vienna's Air Monitoring Network is a real-time system to primarily provide information on current values of air components (sulfur dioxide, nitrogen dioxide, carbon monoxide, ground-level ozone and particulate matter). Thus, the Environmental Protection in Vienna (Municipal Department 22) can inform and warn the population about the exceedance of thresholds. The evaluation of measures concerning the reduction of the amount of air pollutants is accomplished with long-term datasets. In addition to the acquisition of air pollutant values, meteorological parameters are also measured (wind direction, wind velocity, air temperature, air pressure, sunshine duration, precipitation). All datasets are based on half-hourly average values. The longest series extend back to 1986. Vienna's Air Quality Monitoring Network consists of 17 stationary measurement stations. The monitoring stations are located at roadside, in the urban background, in industrial zones and in the rural fringes of the city.

Quality control of the data is done by the data providers of the particular federate states of Austria. Because of a close cooperation with the Environment Agency Austria (Umweltbundesamt - UBA) concerning the quality management system the measurements are fully comparable. The collected data are freely available for both private users and public institutions.

Umweltinstitut Vorarlberg

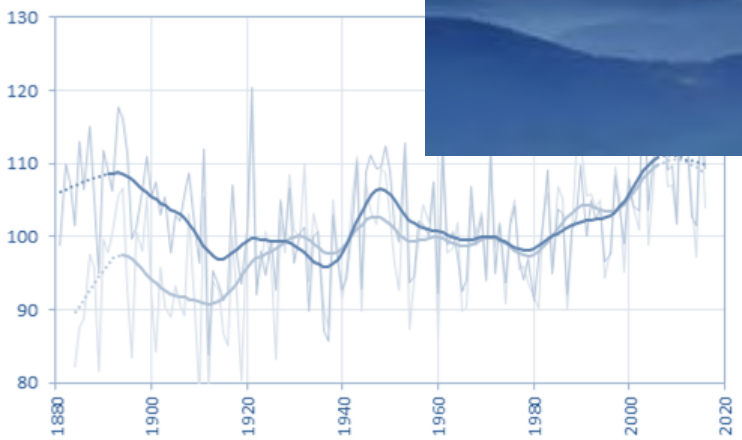
www.vorarlberg.at/vorarlberg/umwelt_zukunft/umwelt/umweltundlebensmittel/start.htm

Ambient air quality monitoring has been carried out in Vorarlberg since the 1970s. Initially, classical air pollutants like sulfur dioxide and carbon monoxide were our main concern. At the end of the 1980s the ozone problem was recognized and remains to this day, a central theme. Our interests further include a particular concern for traffic caused air pollution by nitrogen dioxides, particulate matter, carbon monoxide and benzene. Together with results from meteorological investigations, air quality data provide the essential basis for developing measures to maintain clean air. Data on ambient air concentrations are recorded at stationary and mobile measuring sites and analysed in the air-quality-monitoring information-centre of the Environmental Institute.

Activities:

- operating the ambient air-quality monitoring network and continuous monitoring and assessment of air-quality
- problem oriented air-quality investigations
- calculation of the dispersion of air pollutants
- determining the causes and consequences of air pollution
- documenting and publishing air quality data
- producing air quality assessment reports.

ZAMG as the Austrian National Weather and Geophysical Service is an institution affiliated to the Federal Ministry of Science, Research and Economy (BMWFW). ZAMG with its head office in Vienna maintains customer service centres in Graz, Innsbruck, Klagenfurt and Salzburg. Its nearly 300 employees provide weather forecasts and warnings, conduct meteorological, climatological and geophysical research, perform seismological measurements, and serve as environmental and climatological consultants. Founded in 1851, ZAMG operates a meteorological (about 270 stations) and a seismic monitoring network (about 40 stations) as well as the Conrad Observatory in Lower Austria, and the Sonnblick Observatory in Salzburg. ZAMG's experts represent Austria in numerous international organizations and associations such as WMO, ECMWF, and GEO. The leading meteorological institution in Austria, ZAMG, offers its services to clients such as public and private television and radio stations and newspapers as well as to insurance companies, energy providers, road services, construction companies and municipal authorities.



Atmospheric Observations

Surface

Climate Monitoring ZAMG

Silke Adler (ZAMG)

The Zentralanstalt für Meteorologie und Geodynamik (ZAMG) offers meteorological data from more than 250 semi-automatic weather stations (TAWES), 53 full automatic weather stations (VAMES) in cooperation with Austro Control (ACG) and about 176 climate stations, which additionally provide observer-based meteorological information.

The longest measurement period of climate data can be found in Kremsmünster (since 1767), in Vienna (since 1775) and in Innsbruck (since 1777). From about 20 observing stations in 1852 the meteorological service rose to more than 200 observing stations in 1896. Observations of the most important meteorological parameters such as temperature, pressure, precipitation and humidity were recorded daily by observers - initially at 07, 14 and 21 local mean time (LMT).

During the annexation of Austria the climate observation archive had been moved to the Reichswetterdienst in Berlin, where most of the hard-copies had been destroyed during World War II. Due to this break most climate observations in Austria do not start before 1948. Only a few data duplicates could be retained at ZAMG, building now the basis for long-term studies in Austria (Vienna, Salzburg, Graz, Innsbruck, Sonnblick). In 1980 the observing weather stations became semi-automatic weather stations (TAWES) and climate stations.

The semiautomatic weather stations (TAWES) take measurements of air temperature, wind speed, wind direction, pressure and relative humidity and transmit the data with a rate of 10 minutes. Information on precipitation is crucial for several applications and is therefore sent every minute. After thorough quality checks and corrections the measurement and observation data is stored at ZAMG's climate database.

Observations at the 176 climate stations are made three times a day, at 06 UTC, at 12 UTC and at 18 UTC (before 1972 at 07, 14 and 21 LMT). They include the current weather condition and development, (e.g. type of cloud, lower cloud limit, visibility, type of precipitation) which cannot be detected satisfactorily by an automatic sensor. Historically these daily records have been transmitted to ZAMG or the responsible regional office once a month by mail in the form of a climate sheet. At ZAMG these climate records where archived and entered into a database since 1984. Since 2012 a direct input of the observation to the database is possible using an online tool called KSE (Klima-Synop-Eingabe). This allows immediate access and quality control of the data.

Figure 1 TAWES and VAMES stations of Austria.

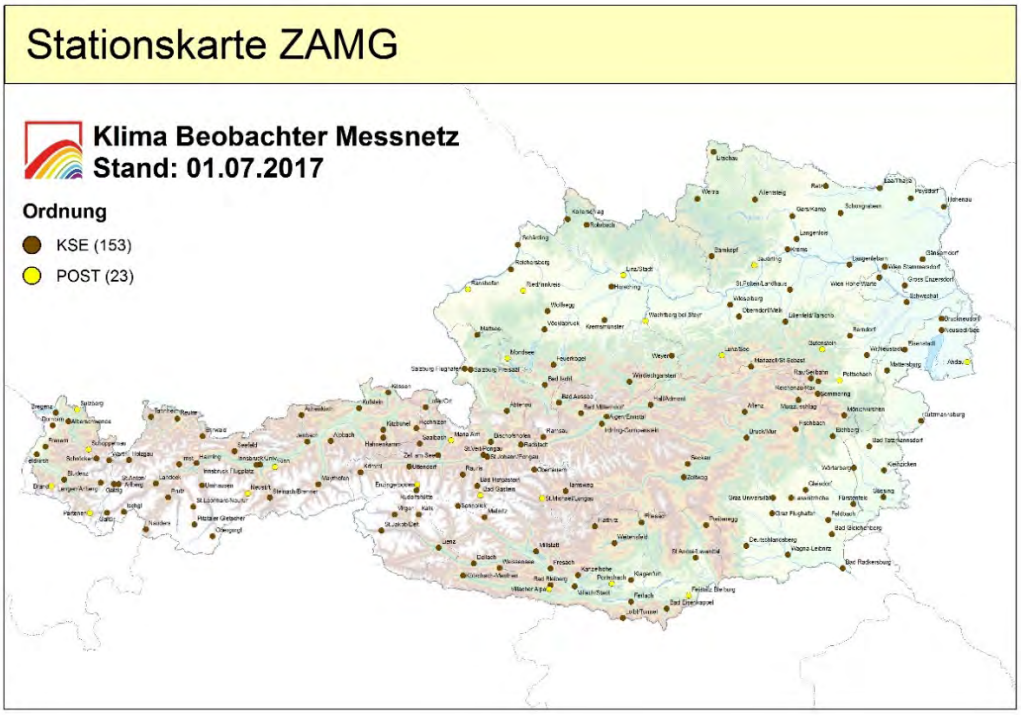


Figure 2 Manual observing stations of Austria.

The meteorological network also includes SYNOP stations, most of them are semiautomatic weather stations (TAWES) which are additionally supervised twice a day (at 6 a.m. and 6 p.m. UTC). At the synoptically main time 06 UTC and 18 UTC next to the automatic measurements of the TAWES stations 65 additional observations according to criteria of WMO are made by observers or supervisors. The data are transmitted in SYNOP code to the ZAMG in Vienna or to the respective regional office. The data set of these SYNOP stations can be found in the WMO Information System (WIS) Program of the World Meteorological Organisation (WMO).

Essential Climate Variables - Atmospheric Observations - Surface

Parameter measured/observed	air temperature, wind, relative humidity, pressure, clouds, sunshine duration, precipitation visibility, present weather, cloud base, cloud amount
Starting date	01.03.1767 Kremsmünster
Temporal Resolution	air temperature, wind speed, wind direction, relative humidity, pressure: 10-minute data. precipitation: 1-minute-data data are also available hourly, daily or monthly
Observational Network	Austrian TAWES network, about 250 stations
Stations	23 essential stations and 97 additional stations located throughout Austria (9.53 - 17.16 deg E, 46.37 - 49.02 deg N)
Data Portal	www.zamg.ac.at/cms/de/klima/klimauebersichten/jahrbuch www.wmo-sat.info/oscar/ https://gisc.dwd.de/wisportal/#PortalHomePlace:PortalHome
Supervising Organization	ZAMG
National and/or international Networks or Programs	WIGOS (WMO Integrated Global Observing System) WIS / OSCAR (WMO Information System / Observation Systems Capability Analysis and Review Tool) GCOS (Global Climate Observing System) EGOS (Evolution of Global Observing System)
Data Submission	data contribution once a year to the international data centres.
Licenses	general ZAMG data conditions, essential stations: CC-BY 3.0 AT
Use Limitation	no limitation but fee depending on usage conditions
Data Format	data download as ASCII File, PDF-File, HTML-File
Data Access	open access daily and monthly data: www.zamg.ac.at/cms/de/klima/klimauebersichten/jahrbuch access by registration is also available
Data Quality	quality control is done by ZAMG / Division for Data, Methods, Modelling / Section Quality Control System
Performance Monitoring	Continuously supervised by ZAMG.
Publications	Once a year the year book is produced and made public on ZAMG Homepage: www.zamg.ac.at/cms/de/klima/klimauebersichten/jahrbuch

Contact (National correspondent, focal point)	Focal Point: GCOS: Silke Adler, silke.adler@zamg.ac.at WIGOS: Lipa Wolfgang, wolfgang.lipa@zamg.ac.at WIS: Paul Anita, anita.paul@zamg.ac.at Pichler Michael, Michael.Pichler@austrocontrol.at OSCAR: Silke Adler, silke.adler@zamg.ac.at EGOS-IP: Lipa Wolfgang, wolfgang.lipa@zamg.ac.at TAWES: roland.potzmann@zamg.ac.at dpru@zamg.ac.at
Remarks	

VAMES

Gregor Mitternast (ACG)

VAMES (Voll_Automatisches_Meteorologisches_Erfassungs_System) has been established as an aviation weather observation network within Austria. It is a very successful cooperation project between the national weather service ZAMG and the aviation weather service which is a department of the air traffic services AUSTRO CONTROL. Based on the existing TAWES network from ZAMG with about 260 stations, 50 stations along valley flight tracks which are used by general aviation have been chosen to extend them with visibility/present weather detection sensors (VAISALA PWD22) and ceilometers with cloud coverage algorithm (VAISALA CL31). The extension began in 2011 with 10 stations per year and has been completed at the end of 2016. The performance of the availability lies at more than 98%. Raw data are collected by ZAMG and delivered to AUSTRO CONTROL where AUTOMETARs in the WMO No. 306 METAR format are produced after the information of a so called convection module (TS, VCTS and CB) has been integrated. AUTOMETARs are disseminated within Austria and Germany continuously every 10 minutes and used e.g. for GAFOR preparation and for aviation meteorological briefings.

Quality control is done by ZAMG with data monitoring software and by AUSTRO CONTROL in form of continuously supervising by the operational service at the meteorological watch office in Wien Schwechat.

Content of the AUTOMETAR reports:

- Wind speed (TAWES sensor)
- Wind direction (TAWES sensor)
- Meteorological visibility from VAISALA PWD 22
- Present weather:
    - from VAISALA PWD 22
    - TS and VCTS information from convection module (generated product of lightning and weather radar information)
- Height of cloud base from VAISALA CL31
- Cloud amount by algorithm from VAISALA CL31
- Type of cloud in case of CB from convection module (generated product of lightning and weather radar information)
- Temperature at 2 m above ground (TAWES sensor)
- Dew point (TAWES sensor)

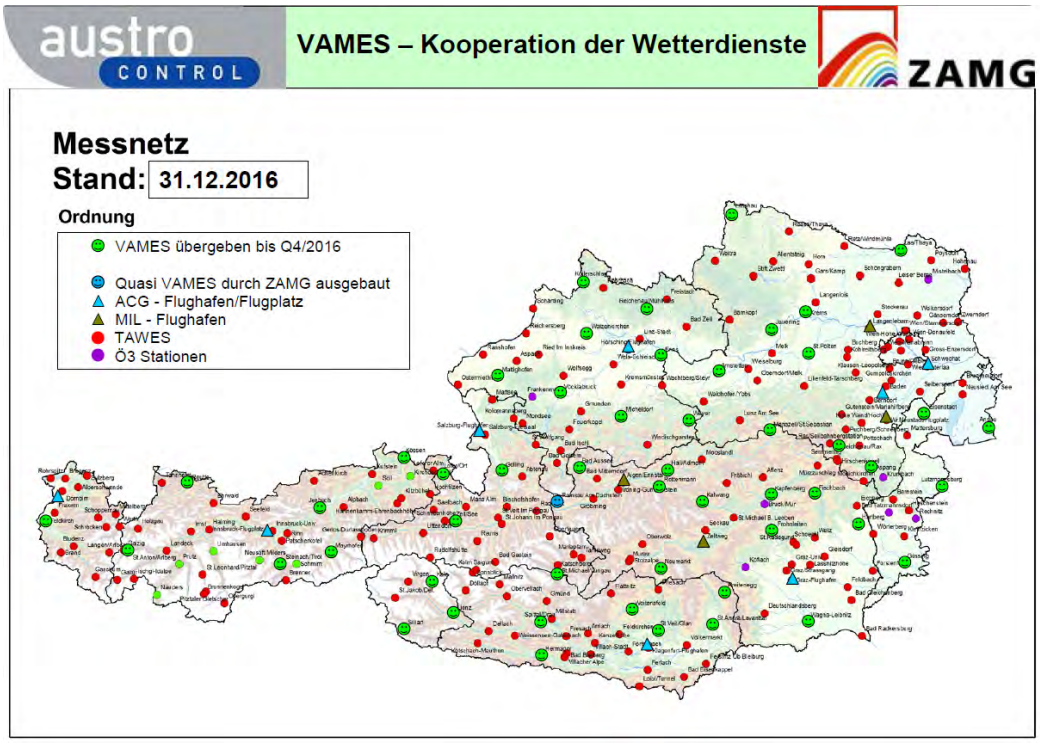


Figure 3 VAMES Stations.

List of stations:

11070 Krems
11171 Mariazell
11188 Aspang
11335 Laa/Thaya
11380 Reichenau/Rax
11389 St.Pölten
11393 Lutzmannsburg
11395 Andau
11190 Eisenstadt
11024 Jauerling
11063 Rottenmann
11167 Hall/Admont
11173 Fischbach
11198 Güssing
11249 Frohnleiten
11296 Leibnitz
11229 St.Andrä/Lavanttal
11362 Kalwang
11370 Kapfenberg
11390 Hartberg
11018 Amstetten
11200 Kals
11201 Sillian
11204 Lienz
11214 Preitenegg
11371 Golling
11220 Neumarkt
11225 Weitensfeld
11237 St.Veit an der Glan
11259 Hermagor
11272 Spittal an der Drau
11007 Kollerschlag
11021 Litschau
11050 Reichenau im Mühlkreis
11105 Feldkirch
11131 Kössen
11311 St.Anton am Arlberg
11314 Reutte
11325 Jenbach
11329 Steinach in Tirol
11330 Mayrhofen
11002 Enns
11049 Mattighofen
11056 Vöcklabruck
11058 Waizenkirchen
11140 Lofer
11144 Zell am See
11148 St.Michael im Lungau
11341 Weyer
11347 Micheldorf
11356 Bad Aussee

Essential Climate Variables - Atmospheric Observations - Surface

Parameter measured/observed	wind, visibility, present weather, cloud base, cloud amount (according ICAO 1-3-5), temperature, dew point are used to prepare AUTOMETARs
Starting date	Cooperation between AUSTRO CONTROL and ZAMG was started on 9th November 2011.
Temporal Resolution	10-minute data
Observational Network	Austrian TAWES network
Stations	50 stations as part of the TAWES network
Data Portal	AUTOMETARs are officially disseminated by AUSTRO CONTROL within Austria and Germany
Supervising Organization	Depends on the type of sensor: AUSTRO CONTROL: visibility, present weather and cloud information ZAMG: all other TAWES sensors
National and/or international Networks or Programs	TAWES
Data Submission	update every 10 minutes, 24 h a day
Licenses	AUTOMETARs are disseminated free of charge
Use Limitation	For use in Aviation Meteorology only
Data Format	METAR (according WMO No. 306)
Data Access	Access by registration with pilot license
Data Quality	Quality control is done by AUSTRO CONTROL and ZAMG
Performance Monitoring	Continuously supervised by AUSTRO CONTROL and ZAMG.
Publications	No publications available
Contact (National correspondent, focal point)	Met-info@austrocontrol.at
Remarks	

Aerodrome Met stations in Austria

Gregor Mitternast (ACG)

Aerodrome meteorological stations at Austrian international aerodromes have been established in 1955 with the foundation of the Bundesamt für Zivilluftfahrt called AUSTRO CONTROL since 1994. According to the established air space classes within Austria it is necessary to operate with air traffic controllers (ATCOs) at the international aerodromes Wien (LOWW), Linz (LOWL), Salzburg (LOWS), Innsbruck (LOWI), Graz (LOWG) and Klagenfurt (LOWK).

Following the international standards and recommendations of ICAO, it is required that each provide meteorological observations and standardized reports in the MET REPORT, SPECIAL and METAR format. SYNOPs are prepared at all of these stations hourly and climatological observations are made three times per day semi-manually at Wien (LOWW), Linz (LOWL), Salzburg (LOWS) and Graz (LOWG).

Quality control of SYNOPs is done by ZAMG with data monitoring software, while aviation meteorological reports are handled by AUSTRO CONTROL in the form of continuously supervising by the operational service at the meteorological office in Wien Schwechat.

Measured parameters at each station are:

- Wind speed
- Wind direction
- Prevailing visibility
- Visibility runway specific
- Runway Visual Range
- Present weather
- Height of cloud base
- Cloud amount
- Temperature at 2 m and 5 cm above ground
- Dew point
- Air pressure QNH
- Sunshine duration
- Snow depth

Routinely aerodrome relevant evaluations are prepared e.g. as frequencies of the occurrence of RVR and/or height of the base of the lowest cloud layer of BKN or OVC extent below specified values at specific times – see figure.

AERODROME CLIMATOLOGICAL SUMMARY
LOWW / MODEL A1

austro CONTROL

LAT / LONG: 48.11 N / 16.57 E ELEVATION: 183M RUNWAY: 16/34
PERIOD OF RECORD: 2004 - 2016 PERIOD: DECEMBER 01 - 31
TOTAL NUMBER OF OBSERVATIONS: 18844

FREQUENCIES (PER CENT) OF THE OCCURENCE OF RUNWAY VISUAL RANGE (IN METRES) AND/OR HEIGHT OF THE BASE OF THE LOWEST CLOUD LAYER (IN METRES) OF BKN OR OVC EXTENT BELOW SPECIFIED VALUES AT SPECIFIC TIMES

TIME (UTC)	RVR/Hs					#OBS.
	<50	<200	<350	<550	<1500	
	-	-	<30 (100 ft)	<60 (200 ft)	<90 (300 ft)	
0000			0.5	9.4	13.2	393
0030			0.5	9.2	13.3	391
0100			0.5	9.7	12.8	391
0130			0.5	9.2	13.8	391
0200			0.5	10.3	13.8	390
0230			0.5	10	15.1	391
0300			0.5	10.4	15.3	393
0330			0.5	10.4	14.8	393
0400			0.8	9.7	14.8	393
0430			0.3	11.2	15.5	393
0500			0.5	11	15.3	392
0530			1.3	11	15.6	392
0600			2	11	16.1	392
0630			1.5	11.7	16.8	393
0700			2.3	11	16.9	391
0730		0.3	2	10.5	16.1	392
0800			2.5	11.2	16.5	393
0830			2.8	10.2	15.7	394
0900			2.3	9.9	15.5	394
0930			1.3	9.7	14.8	393
1000			1.3	8.7	14	393
1030			1.3	7.6	13.2	395
1100		0.3	1	6.3	11.9	396
1130			1.3	5.8	10.4	396
1200			0.8	5.6	9.1	394
1230			0.5	5.1	8.4	394
1300			0.5	5.1	7.4	393
1330			0.8	4.9	7.2	391
1400			0.8	4.3	7.7	392
1430			0.5	4.6	7.6	393
1500			0.5	5.6	7.9	394
1530			0.8	5.6	7.4	392
1600			0.8	5.3	8.7	393
1630			0.5	6.4	9.2	391
1700			0.5	6.6	8.9	392
1730			0.3	6.4	9	391
1800			0.3	6.6	8.9	392
1830				7.1	10.4	393
1900			0.3	6.9	10.2	394
1930			0.5	5.9	9.9	393
2000			0.5	6.6	10.2	393
2030			0.5	7.4	11.5	391
2100			0.5	8	11.3	389
2130			0.5	8.9	11.5	393
2200			0.8	8.4	10.7	393
2230			0.3	8.1	11.5	393
2300			0.5	8.7	12.2	392
2330			0.8	8.7	13.2	393
TOTAL		0	0.9	8.2	12.1	18844

Page 1

Figure 4 Aerodrome Climatological Summary.

Essential Climate Variables - Atmospheric Observations - Surface

Parameter measured/observed	wind, visibility, RVR (Runway Visual Range), present weather, cloud base, cloud amount (according ICAO 1-3-5), temperature, dew point, QNH are used to prepare MET REPORT, SPECIAL, METAR and SYNOP
Starting date	since 1955
Temporal Resolution	Depending on the sensors between 1 to 10-minute data
Observational Network	AUSTRO CONTROL internal MEDAS and external via GTS (Global Telecommunication System)
Stations	6 stations at the Austrian international aerodromes
Data Portal	MET REPORT and SPECIAL are disseminated nationally to air traffic service units. METAR and SYNOP are disseminated internationally via GTS (Global Telecommunication System)
Supervising Organization	AUSTRO CONTROL
National and/or international Networks or Programs	MEDAS
Data Submission	Update every 30 minutes or depending on weather situation
Licenses	Free of charge for aviation use
Use Limitation	For use in Aviation Meteorology only
Data Format	MET REPORT, SPECIAL (according ICAO Annex 3) METAR, SYNOP (according WMO No. 306)
Data Access	METAR: Access by registration with pilot license or via VOLMET Austria MET REPORT, SPECIAL access for pilots via ATIS
Data Quality	Quality control is done by AUSTRO CONTROL
Performance Monitoring	Continuously supervised by AUSTRO CONTROL
Publications	No publications available
Contact (National correspondent, focal point)	Met-info@austrocontrol.at
Remarks	

Sunshine duration - Measurements Austria

Marc Olefs (ZAMG)

The earliest regular measurements of sunshine duration (SSD) in Austria date back to the 1880s. The longest SSD time-series are recorded at stations Bad Ischl, Wien, Kremsmünster, Klagenfurt, Villacher Alpe and Sonnblick (since 1880, 1881, 1884, 1884, 1884 and 1887 respectively). Until the 1980s, SSD was recorded using a Campbell-Stokes sunshine recorder (CS; using the burn method). Starting with the introduction of the semi-automatic TAWES measurement network in 1981, CS was successively replaced by an automated sensor: the Haenni/Luft Solar 111b, using the contrast method. Today, sunshine duration is measured at all 250 TAWES stations.

Figure 6 shows the time-series of sunshine duration since the late 19th century in the Alpine lowlands and summit regions using homogenized long-term measurements of the ZAMG project HISTALP (see page 37)

Figure 5 The Campbell-Stokes sunshine recorder at station Sonnblick.

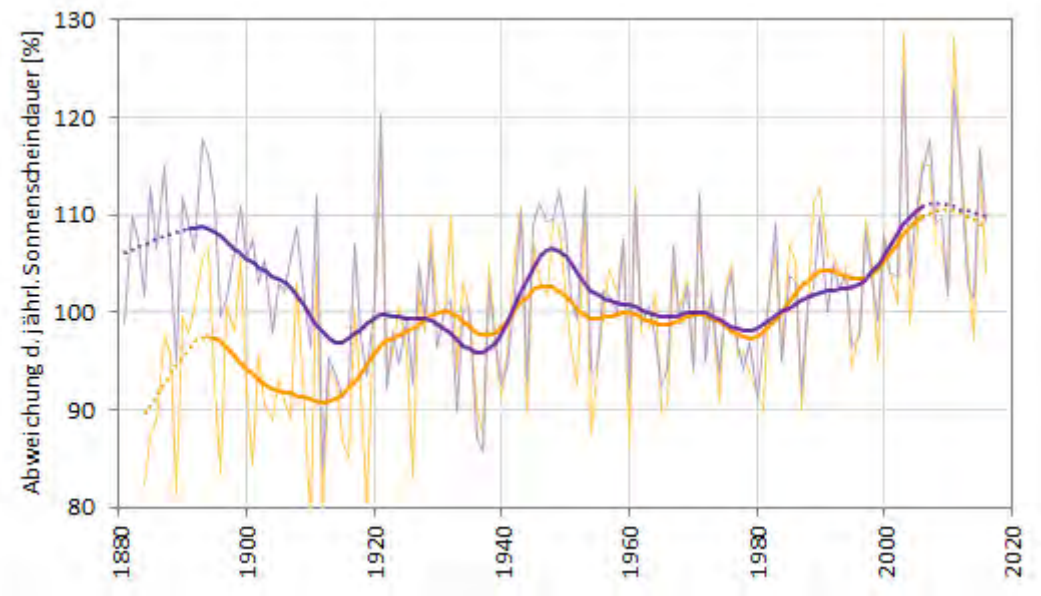


Figure 6 Time-series of annual sunshine duration anomalies in the Alpine lowlands (1881-2016, magenta) and summit regions (1884-2016; orange).

Essential Climate Variables - Atmospheric Observations - Surface

Parameter measured/observed	sunshine duration
Starting date	1880 (first station in Bad Ischl)
Temporal Resolution	Daily sums until around 1981 10-minute-averages since around 1981
Observational Network	Austrian TAWES network
Stations	about 250 TAWES stations
Data Portal	TAWES: klima@zamg.ac.at
Supervising Organization	ZAMG
National and/or international Networks or Programs	HISTALP project (www.zamg.ac.at/histalp)
Data Submission	TAWES: 10-min since around 1981
Licenses	general ZAMG data conditions
Use Limitation	no limitation but fee depending on usage conditions
Data Format	time-series in ZAMG data base
Data Access	restricted access, contact: klima@zamg.ac.at
Data Quality	Quality control is done by ZAMG / Division for Data, Methods, Modelling / Section Quality Control System
Performance Monitoring	Performance monitoring is done by ZAMG
Publications	
Contact (National correspondent, focal point)	TAWES: roland.potzmann@zamg.ac.at HISTALP: Barbara Chimani, Barbara.chimani@zamg.ac.at
Remarks	

UV Radiation

Stana Simic (BOKU)

Only about 5 % of the solar radiation reaching the earth's surface is in the ultraviolet spectrum. Although it's only a small portion, UV radiation has great impacts on the biosphere. Solar radiation with wavelengths shorter than 290 nm is entirely blocked by the Earth's ozone layer, whereas UV radiation with longer wavelengths is only partially absorbed. But it is this small portion in the UV-B range (290-315 nm) which is of great significance since it causes various chemical and physical reactions on molecular structures like life forms. While human exposure to UV radiation is very important and does have beneficial effects, it is a major risk factor for the development of skin cancer.

Measurements of UV Radiation in Austria

UV radiation is monitored at two stations in Austria: Hoher Sonnblick and Groß-Enzersdorf (see figure 7). The measurements have been carried out since 1994 and 1998 respectively by the Institute of Meteorology of the "University of Natural Resources and Life Sciences" (BOKU) and are financed by the "Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management" (BMLFUW). The datasets meet the high quality-standards of the "Network for the Detection of Atmospheric Composition Change" (NDACC) and are among the longest of all of Europe. Instrument comparisons and the dataset of previous years confirm that a high quality was reached. The gathered data help to better understand radiation transfer processes and ground insolation of UV radiation.

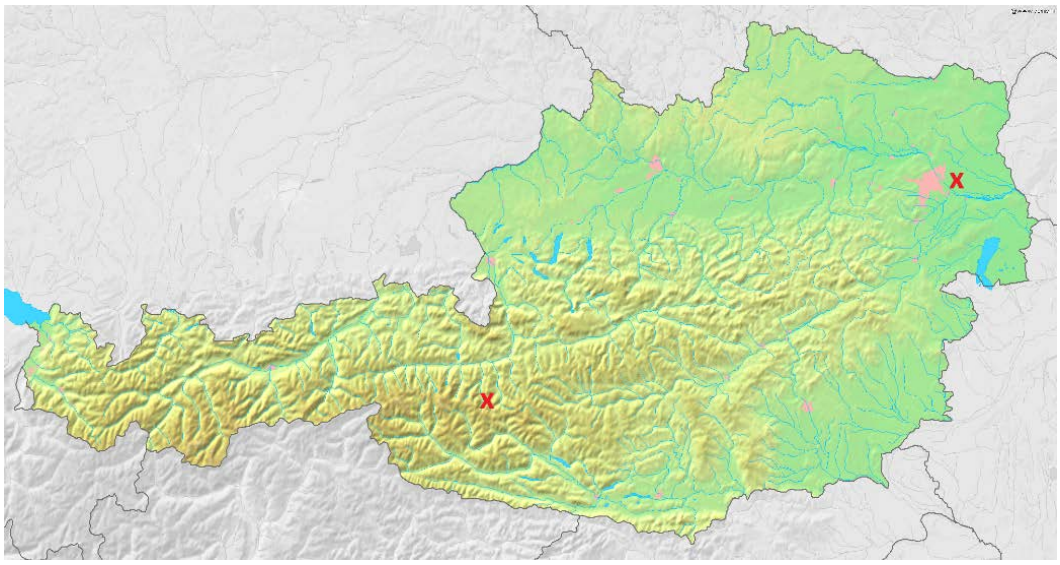


Figure 7 UV measurement sites in Austria: Groß-Enzersdorf (top-right) near the large city Vienna in a lowland basin at 156 m and Hoher Sonnblick (bottom-left) on a mountain peak at 3106 m elevation.

The knowledge of spectral UV-B irradiance and its dependence on various parameters is crucial to quantify and understand the consequences of increasing UV-B radiation. Evaluation of radiation transfer modelling, determination of a UV climatology and calculation of long-term UV-B trends all require exact measurements of spectral UV irradiance.

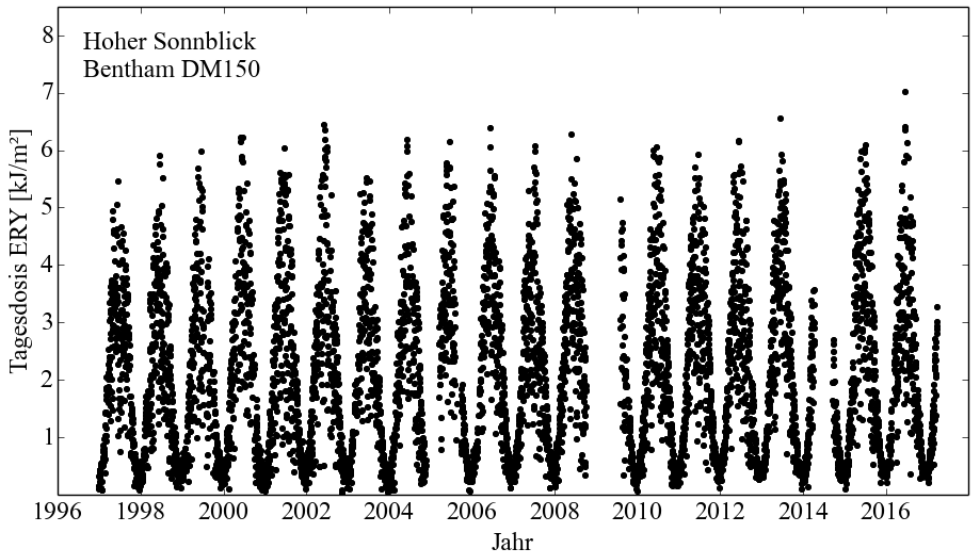


Figure 8 Daily sums of erythemally weighted UV irradiance measured at Hoher Sonnblick.

The Austrian UV-B Measurement Network

It is known that exposure to UV radiation has beneficial as well as detrimental effects on the human body. While it is absolutely crucial for endogenous vitamin D photosynthesis, overexposure can acutely lead to sunburn and chronically induce skin cancer development. Therefore it is a high priority to provide the public with high-quality UV measurement data. The Austrian UV-B measurement Network is financed by the "Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management" (BMLFUW) and was established in 1998. Since 1999 it consists of 13 stations, equipped with UV biometers, spread throughout Austria. The Section for Biomedical Physics (https://www.i-med.ac.at/dpmp/bmp/) at the Medical University of Innsbruck and the CMS Ing. Dr. Schreder Company together maintain the UV-B measurement grid continuously. The UV index data is continuously published in 10-minute intervals at http://www.uv-index.at.

Figure 9 The Bentham spectrophotometer at sunset at the High Alpine Observatory Hoher Sonnblick (3106 m).

Essential Climate Variables - Atmospheric Observations - Surface

Parameter measured/observed	spectral UV irradiance
Starting date	01.01.1997
Temporal Resolution	10-minute intervals for UV biometer data 30-minute intervals for spectral UV radiation
Observational Network	Two spectrophotometers and two UV biometers
Stations	Two spectrophotometers and two UV biometers, one of each located in Groß-Enzersdorf, near Vienna and the high Alpine observatory Hoher Sonnblick (3106 m)
Data Portal	UV-B data: http://www2.i-med.ac.at/uv-index/de/graphs_hoehe_eu_de.html Spectral UV radiation data: NDACC
Supervising Organization	BOKU, BMLFUW
National and/or international Networks or Programs	NDACC (international Network for the Detection of Atmospheric Composition Change)
Data Submission	Via FTP to a Server located at BOKU
Licenses	general BOKU data conditions
Use Limitation	For research only
Data Format	ASCII
Data Access	Downloadable data at NDACC data centre
Data Quality	Data quality control is done by NDACC and is a very high standard
Performance Monitoring	The instruments and data availability are supervised by the work group „UV Radiation and Ozone“ at the Institute of Meteorology at University of Natural Resources and Life Sciences, Vienna (BOKU).
Publications	Annual publications at NDACC newsletter Further publications are listed here: www.wau.boku.ac.at/en/met/forschungsthemen/atmosphaerische-strahlung/forschungsbereich-uv-strahlung-und-gesamtozon/publikationen/
Contact (National correspondent, focal point)	Dr. Stana Simic BOKU Wien, Institut für Meteorologie, Department für Wasser-Atmosphäre-Umwelt Gregor-Mendel-Straße 33, 1180 Wien Telefon: (+43) (0)1 47654-81430, www.wau.boku.ac.at/met.html
Remarks	

Solar and terrestrial radiation monitoring networks (TAWES, ARAD)

Marc Olefs (ZAMG)

10-minute average values of global radiation are currently measured at 254 TAWES stations of ZAMG using a Schenk Star Pyranometer (black dots in figure 10). Beside this routine measurement network, ZAMG and Austrian University partners operate a high accuracy radiation measurement network (ARAD; red dots in figure 10). ARAD ("**A**ustrian **Rad**iation") is a long term measurement project for solar radiation and thermal radiation of the atmosphere in Austria. Currently, the temporal and spatial variations of the radiative components (global, direct and diffuse incoming solar radiation and incoming longwave radiation are recorded at six sites (Vienna, Sonnblick, Graz, Innsbruck, Kanzelhöhe, Klagenfurt) using very high quality instruments.

ARAD is a scientific research project lead by the ZAMG in collaboration with the University of Innsbruck, the Karl-Franzens-University Graz and the University of Natural Resources and Life Sciences (BOKU) in Vienna. ARAD provides very accurate data of the temporal and spatial changes of the radiation components of the sun and atmosphere. Besides a continuous survey of our climate, these data can also be used to verify and improve regional climate models and weather forecasting models. More information can be found at zamg.ac.at/strahlung.

Integration in international networks

Since 2013 the ARAD Station Sonnblick is part of the baseline surface radiation measurement network BSRN (see separate chapter). Data of the TAWES Stations Grossenzersdorf, Salzburg/Freisaal, Bregenz, Innsbruck/Flughafen, Sonnblick (ARAD Station), Klagenfurt/Flughafen, Graz/Universität and Wien Hohe Warte is regularly transmitted to the World Radiation Data Center (WRDC) in St. Petersburg. BSRN and ARAD measurements are used at the European Centre for Medium Range Weather Forecasts (ECMWF) to evaluate forecasts of downward fluxes of shortwave and longwave radiation.

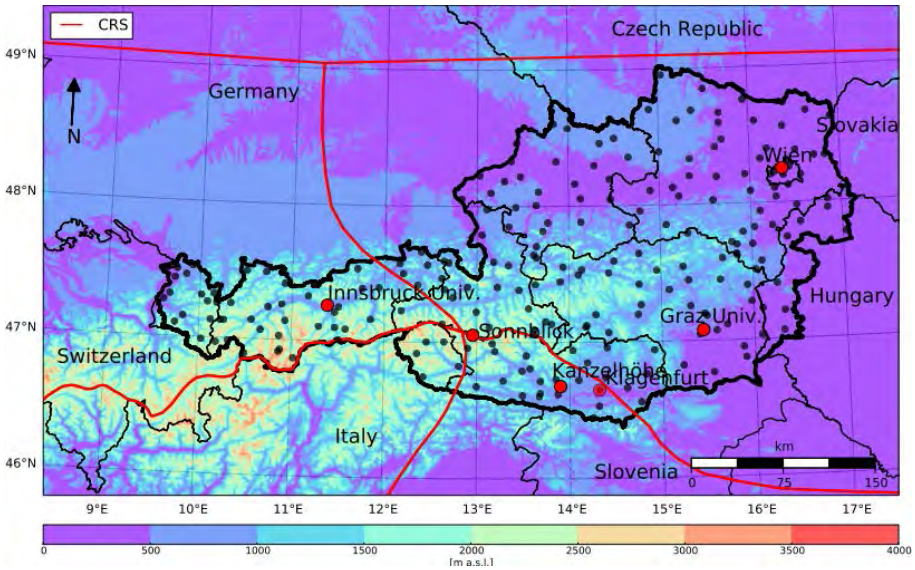


Figure 10: Topographic map (colour-coded elevations) with ARAD stations (red points), TAWES stations measuring GLO (black points) and the coarse resolution subregions (CRSs) defined as regions with common climatic variability.

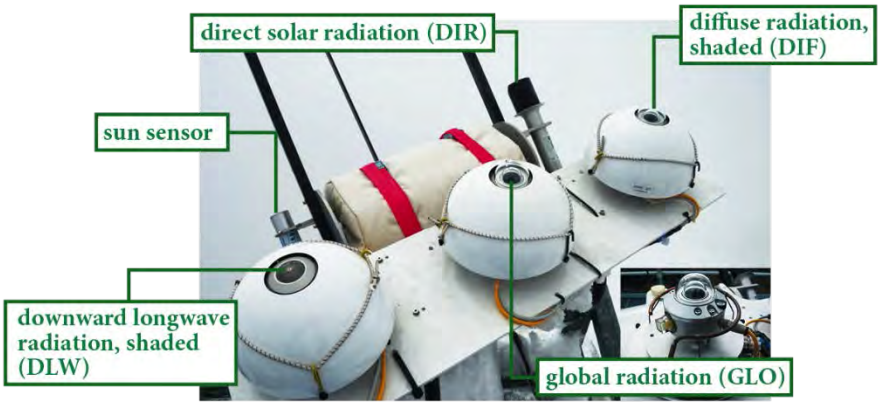


Figure 11: Typical ARAD station: suntracker with different radiation sensors. The picture in the lower right corner shows a pyranometer without radiation shield exposing the heating and ventilation system (PMOD-VHS).

ZAMG ARAD Partners

Essential Climate Variables - Atmospheric Observations - Surface

Parameter measured/observed	ARAD Network: global radiation, diffuse radiation, direct solar radiation, longwave incoming radiation TAWES Network: global radiation
Starting date	1953 (first station Vienna Hohe Warte)
Temporal Resolution	ARAD Network: 1-min averages (based on 1 Hz sampling), min/max (1 Hz) TAWES Network: 10-min average values (based on 1-minute averages based on 0,1 Hz samplings)
Observational Network	TAWES, ARAD
Stations	TAWES: 254 stations; ARAD: 6 stations
Data Portal	TAWES: klima@zamg.ac.at; ARAD: www.zamg.ac.at/strahlung
Supervising Organization	ZAMG
National and/or international Networks or Programs	The ARAD network is a collaborative effort of ZAMG together with the following national partners: University of Innsbruck, Graz and BOKU (see www.zamg.ac.at/strahlung) 6 stations: ARAD (national), station Sonnblick: BSRN (international)
Data Submission	TAWES: 10-min, ARAD: 1-min, ZAMG internal data transfer

Licenses	TAWES: general ZAMG data conditions, ARAD: ZAMG and partner conditions
Use Limitation	TAWES, ARAD: no limitation but fee depending on usage conditions
Data Format	Time-series in ZAMG data base
Data Access	restricted access, contact: klima@zamg.ac.at
Data Quality	TAWES: Quality control is done by ZAMG / Division for Data, Methods, Modelling / Section Quality Control System. ARAD: strict data quality management following BSRN guidelines www.zamg.ac.at/strahlung
Performance Monitoring	ZAMG
Publications	Olefs, M., Baumgartner, D. J., Obleitner, F., Bichler, C., Foelsche, U., Pietsch, H., Rieder, H. E., Weihs, P., Geyer, F., Haiden, T., and Schöner, W.: The Austrian radiation monitoring network ARAD – best practice and added value, Atmos. Meas. Tech., 9, 1513-1531, doi:10.5194/amt-9-1513-2016, 2016.
Contact (National correspondent, focal point)	ARAD: Marc Olefs (marc.olefs@zamg.ac.at) ZAMG: dpru@zamg.ac.at
Remarks	

BSRN - Baseline Surface Radiation Network

Marc Olefs (ZAMG)

The Baseline Surface Radiation Network (BSRN) is the most prominent, worldwide observational ground-based network for surface radiation fluxes and was established in the early 1990s (Ohmura et al., 1998) by the World Climate Research Programme (WCRP). BSRN provides measurements with high accuracy and high temporal resolution, and comprises currently 48 sites in different climate regimes (König-Langlo et al., 2013; bsrn.awi.de; figure 30 and figure 31). In Austria, the ARAD station Sonnblick (3106 m a.s.l.), is also included in the BSRN network (SON; since January 2013; http://bsrn.awi.de/stations/listings.html).

The objectives of BSRN are:

- monitor the background (least influenced by immediate human activities which are regionally concentrated) short-wave and long-wave radiative components and their changes with the best methods currently available
- provide data for the validation and evaluation of satellite-based estimates of the surface radiative fluxes and
- produce high-quality observational data for comparison to climate model (GCM) calculations and for the development of local regionally representative radiation climatologies.
- to serve as a baseline for national radiation monitoring networks (e.g. TAWES in Austria).

The sites are equipped with four broadband radiation sensors, which are suitable to BSRN requirements, mounted on a suntracker, for measurements of global (GLO), direct (DIR) and diffuse (DIF) solar radiation and downward longwave radiation (DLW). The suntracker allows correct tracking of the solar path, guarantees the continuous alignment of the pyrheliometer to record DIR and ensures continuous shading of the pyranometer for measurements of DIF and the pyrgeometer for measurements of DLW. All radiation sensors used within ARAD are state-of-the-art thermopile instruments with specifications well within the limits recommended and accepted by BSRN. Following the ISO 9060 classification, all pyranometers used within ARAD are secondary standard instruments and all pyrheliometers are first-class instruments.

Figure 12 Map of the BSRN stations (world).

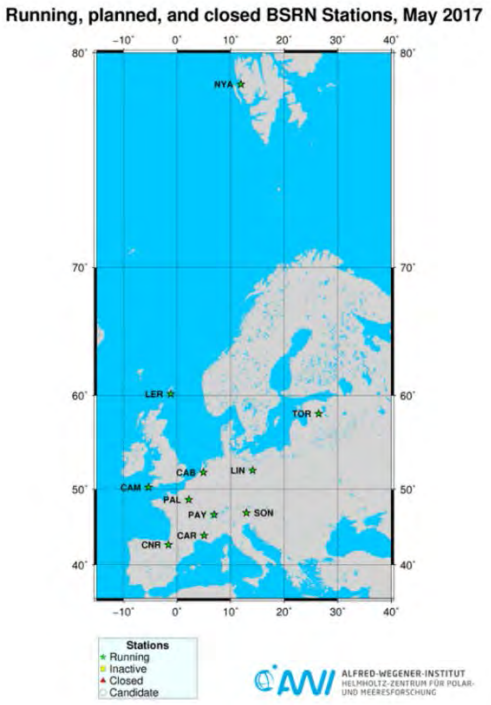


Figure 13: Map of the BSRN stations (Europe).

Essential Climate Variables – Atmospheric Observations - Surface

Parameter measured/observed	shortwave solar radiation: global radiation, diffuse radiation, direct solar radiation longwave radiation: longwave incoming radiation
Starting date	1.1.2011
Temporal Resolution	1-Min averages (based on 1 Hz sampling), Min/Max (1 Hz)
Observational Network	BSRN
Stations	Sonnblick
Data Portal	bsrn.awi.de
Supervising Organization	Word Radiation Monitoring Center (WRMC – data management), GEWEX
National and/or international Networks or Programs	ARAD (national)
Data Submission	monthly, ftp
Licenses	Specific license details: http://bsrn.awi.de/data/data-retrieval-via-pangaea/
Use Limitation	Data can be made available for bona fide research purposes at no cost.
Data Format	
Data Access	Free after acceptance of data release guidelines https://dataportals.pangaea.de/bsrn/
Data Quality	Each station scientist is responsible for his station (strict BSRN quality standard/guidelines).
Performance Monitoring	ZAMG und WRMC (bsrn.awi.de)
Publications	data are citable via PANGAEA (DOI)
Contact (National correspondent, focal point)	Amelie Driemel (amelie.driemel@awi.de) – WRMC Marc Olefs (marc.olefs@zamg.ac.at) - Station Scientist Sonnblick (SON)
Remarks	

HISTALP - Homogenized monthly long-term climate dataset

Barbara Chimani (ZAMG)

HISTALP is an international dataset to provide information on the long-term climate evolution in the Alpine region. The dataset consists of monthly homogenised temperature, pressure, precipitation, sunshine and cloudiness records for about 150 station located in the „Greater Alpine Region“ (GAR, 4-19 deg E, 43-49 deg N, 0-3500 m asl). The longest temperature and air pressure series extend back to 1760, precipitation to 1800, cloudiness to the 1840s and sunshine to the 1880s. Such long term datasets are essential to estimate the significance of current climate evolutions. But due to the length of those series they are subject to changes like improvements in the instrumentation, necessary relocations due to improved knowledge on e.g. impact of buildings or due to changes in the surrounding, changes in the observation times, etc. In order to get a realistic climate signal from those time series, those effects have to be removed. This process is called homogenisation.

Quality control of the data is done by the national data providers. Homogenisation of the time series is done afterwards to remove artificial “climate signals” that are solely caused by effects on the measurement like the relocation of the stations or changes in the instrumentation. Additionally, corrections for the early instrumental bias have been applied.

Homogenisation is redone in about 10 year cycles. Updates of the time series are done annually, depending on the availability of the data.

In addition to the stations data, gridded datasets of temperature and precipitation are available.

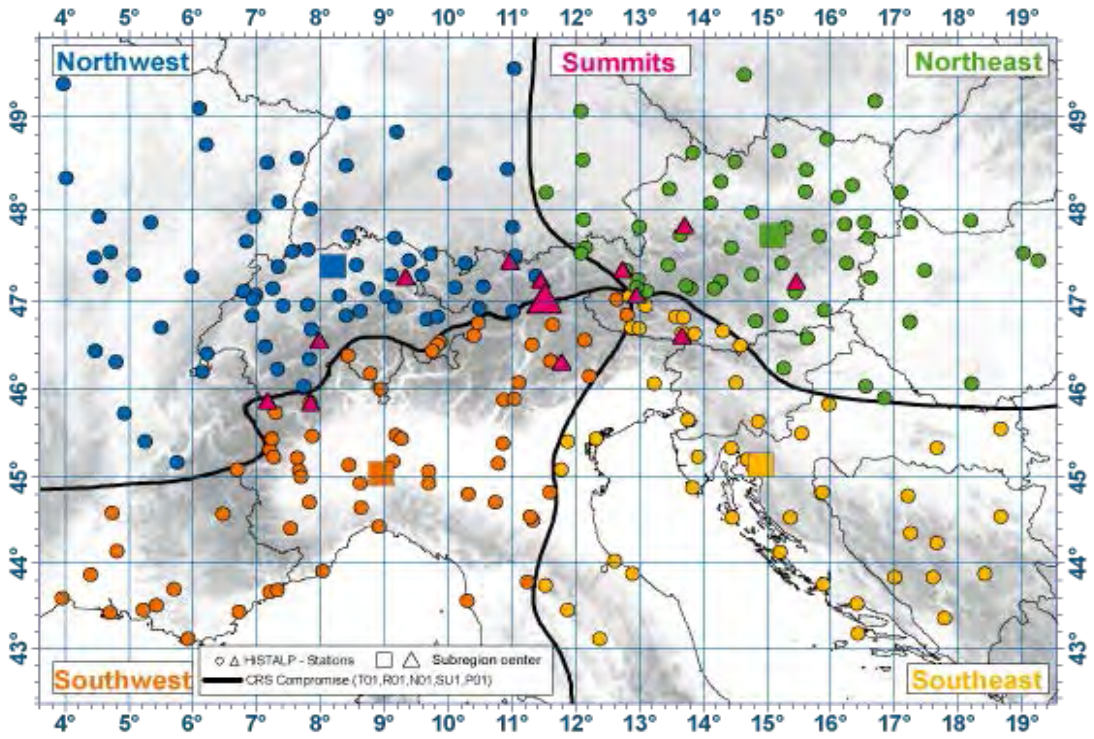


Figure 14 Network of HISTALP stations and regionalisation into different climate regions (colours). Small points and triangles represent the stations, big symbols the centre of the subregions. Triangles represent mountain stations. (Due to data restrictions data of France and Switzerland can not be downloaded via the HISTALP-data centre)

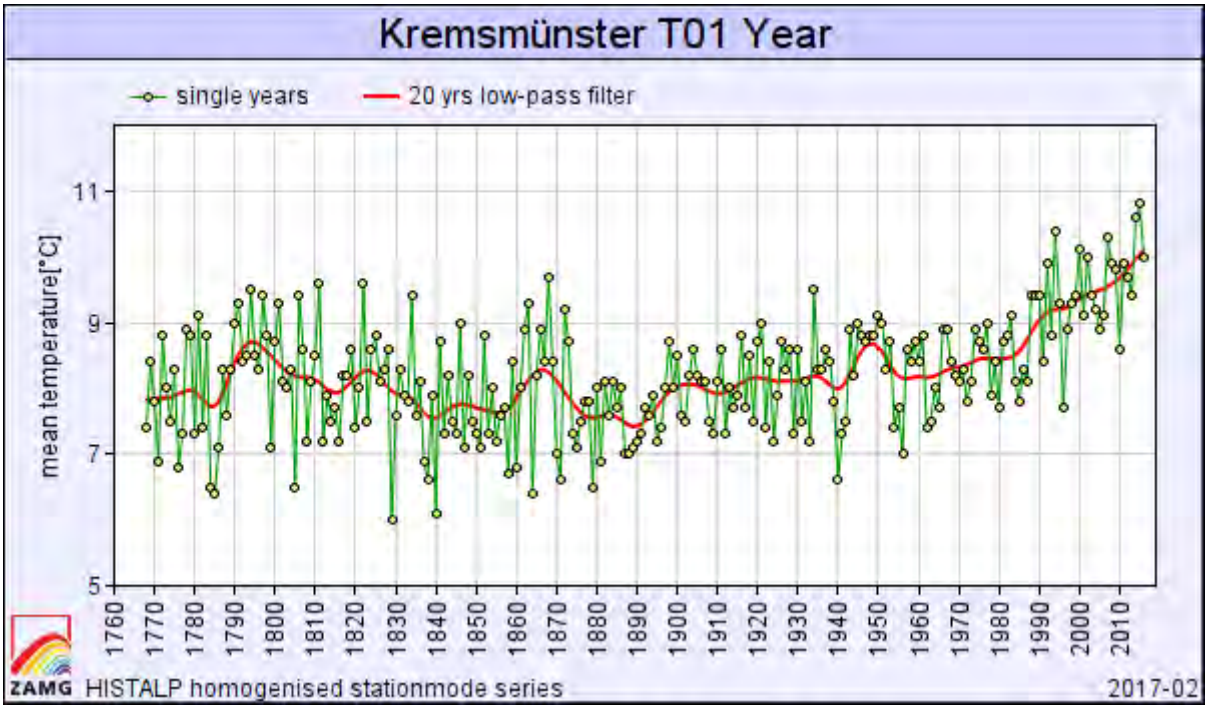
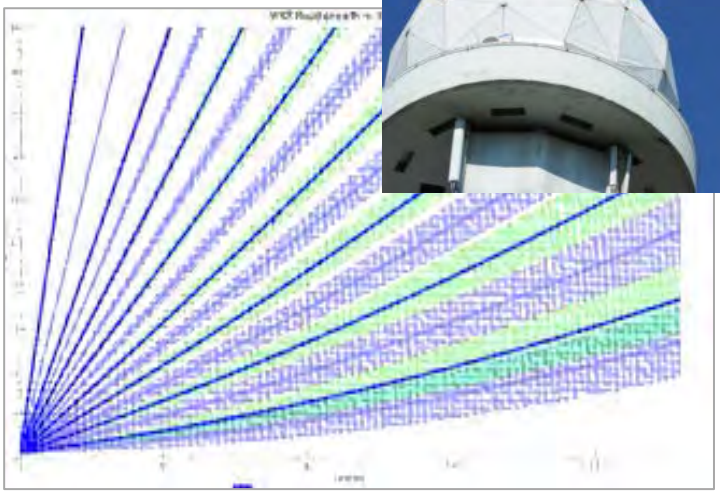


Figure 15 Homogenised time series of annual homogenised temperature of Kremsmünster (Austria).

Essential Climate Variables - Atmospheric Observations - Surface

Parameter measured/observed	homogenized monthly data of temperature, precipitation, mean station level pressure and sunshine duration
Starting date	earliest time series in 1760
Temporal Resolution	monthly data
Observational Network	Long term time series of the Alpine region from the national observation networks of the participating countries
Stations	About 150 stations located in the Greater Alpine region (4-19 deg E, 43-49 deg N)
Data Portal	www.zamg.ac.at/histalp partly national data centre of the participating countries
Supervising Organization	ZAMG
National and/or international Networks or Programs	HISTALP

Data Submission	Most of the stations are updated once a year
Licenses	free of charge, provided the sources are acknowledged
Use Limitation	for non-profit research
Data Format	Download of the data as csv
Data Access	Download via the HISTALP-homepage (www.zamg.ac.at/histalp) Open access
Data Quality	Data quality control is done by the national data providers. The data is homogenized afterwards.
Performance Monitoring	Data availability is supervised by ZAMG, but depends on the national data providers.
Publications	Regular newsletters (3 times a year) on the long term climate evolution in Austria Further publications on the dataset can be found on the HISTALP-webpage: www.zamg.ac.at/histalp
Contact (National correspondent, focal point)	Contact: histalp@zamg.ac.at
Remarks	



Atmospheric Observations

Upper Air

Radiosonde ZAMG

Silke Adler (ZAMG), Roland Potzmann (ZAMG)

Since 1952 radiosonde ascents have been carried out twice a day (0 UTC, 12 UTC) at the ZAMG. A probe is transported by a weather balloon to heights of 30 to almost 40 km. This probe continuously measures air temperature, humidity and air pressure and transmits the recorded data to the ground station with a radio signal in cycle only seconds long. From 1956, a radar was used to determine the position of the balloon, and since the end of the 1990s GPS has also been available for this purpose. The wind speed and wind direction are calculated from the change in the position between two (or more) time steps.

Despite new measurement methods being available, such as the installation of sensors on commercial aircraft (AMDAR), the radiosonde data remain an indispensable basis for weather models. Apart from the limited number of airports, too few AMDAR system data is available, especially during the night (0 UTC) due to take-off and landing prohibitions. Radiosonde data provide important information for the meteorologist for short-term forecasts and for the estimation of thunderstorm probability (stability of the atmospheric stratification). In winter the knowledge of the temperature and humidity profile helps to forecast fog.

The temporal homogeneity of this measuring system can only be ensured with a certain effort, which poses a problem when using it for monitoring climate (changes). While instruments for ground based measurements at a station are usually used over many years or even decades, radiosonde devices can only be used for one ascent. High demands are also placed on the sensors, which are intended to measure accurately over a temperature range of 40° C to -90° C and a pressure range of less than 5 hPa to 1000 hPa. Particularly at low pressure with simultaneous solar irradiation, the sensors will be heated up by the solar radiation and therefore the temperature is measured systematically too high compared to the actual air temperature. During the observation period of more than 50 years, various radiosonde models with different systematic measurement errors were used at the radio probe station in Vienna.

Modern radio probes show only slight systematic measurement errors and GCOS explicitly recommends the use of radio probes with very well-known measuring characteristics.

Essential Climate Variables - Atmospheric Observations – Upper Air

Parameter measured/observed	wind, temperature, dew point, pressure.
Starting date	1.1.1952
Temporal Resolution	2 RASO ascents per day
Observational Network	GUAN (Global Upper Air Network) RASO of ZAMG
Stations	11035 Wien Hohe Warte
Data Portal	ZAMG: drpu@zamg.ac.at, roland.potzmann@zamg.ac.at GUAN: https://www.ncdc.noaa.gov/gosic/global-climate-observing-system-gcos/development-gcos-networks/gcos-upper-air-network-guan-data-access
Supervising Organization	ZAMG
National and/or international Networks or Programs	GUAN (Global Upper Air Network)
Data Submission	GTS (Global Telecommunication System). Two times a day
Licenses	TEMP Data are disseminated free of charge
Use Limitation	no limitation but fee depending on usage conditions
Data Format	TEMP (according WMO No. 306) Bufr (since 2016)
Data Access	
Data Quality	Quality control is done by ZAMG / Division for Data, Methods, Modelling / Section Quality Control System
Performance Monitoring	Performance monitoring is done by ZAMG.
Publications	No publications available
Contact (National correspondent, focal point)	dpru@zamg.ac.at, roland.potzmann@zamg.ac.at
Remarks	

Radiosonde AUSTRO CONTROL

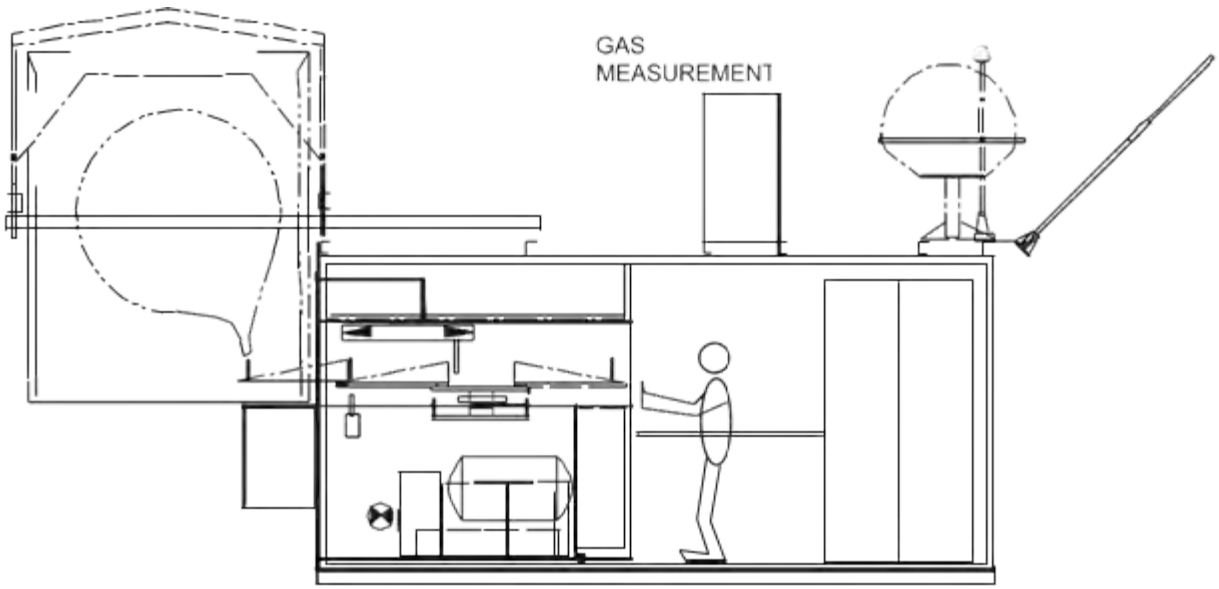
Gregor Mitternast (ACG)

Radiosoundings are made by AUSTRO CONTROL since 1994 after a government decision. They have to be made for military use with cost refund at the aerodromes in Linz (LOWL), Graz (LOWG) and Innsbruck (LOWI) once per day at published early morning times. Since 2016 all three stations are equipped with VAISALA AUTOSONDE AS14 systems which are full automatic operating systems each with maximum load of 24 radiosondes on a carousel launcher. VAISALA RS92 sondes are used with parachutes and TOTEX balloons filled with hydrogen.

Quality control is done by ZAMG with data monitoring software and by AUSTRO CONTROL in form of continuously supervising by the operational service at the meteorological watch office in Wien Schwechat.

Main components are:

- Sounding converting system SPS311
- Local workstation including sounding software
- Remote workstation
- Logic controller and support facility
- Balloon launcher
- Carousel and support facility for RS92 radiosondes
- Gas cassettes
- Periphery tools including GC25 and UPS
- Antennas (Telemetrie, GPS und Navigationshilfe)
- RS92 Radiosondes with dry batteries)



Essential Climate Variables - Atmospheric Observations – Upper Air

Parameter measured/observed	wind, temperature, dew point, pressure
Starting date	Since 1994 after governmental decision AUSTRO CONTROL received order to take over the radiosoundings for military use at the aerodromes in Linz (LOWL), Graz (LOWG) and Innsbruck (LOWI).
Temporal Resolution	1 RASO ascent per day at each station
Observational Network	GTS (Global Telecommunication System)
Stations	3 stations at the aerodromes LOWL, LOWG, LOWI
Data Portal	GTS (Global Telecommunication System)
Supervising Organization	AUSTRO CONTROL
National and/or international Networks or Programs	National military network
Data Submission	Update once a day
Licenses	TEMP Data are disseminated free of charge
Use Limitation	For operational use in Military Aviation Meteorology
Data Format	TEMP (according WMO No. 306)
Data Access	Open access via international data bank
Data Quality	Quality control is done by AUSTRO CONTROL
Performance Monitoring	Continuously supervised by AUSTRO CONTROL.
Publications	No publications available
Contact (National correspondent, focal point)	Met-info@austrocontrol.at
Remarks	

Austrian Weather Radar Network

Gregor Mitternast (ACG)

The operational weather radar network in Austria consists of 5 stations (figures 14, 15), where 2 stations are situated at lower altitudes close to international airports and others are mountain sites above altitudes of 2000 m msl. All weather radars are manufactured by Enterprise Electronics Corporation (EEC) and operate at C band (5600-5650 MHz) fully polarized. Four weather radars have been renewed between 2010 and 2013. The new radar type is DWSR-5001C/SDP/CE (antenna pedestal mounted receiver) including 500 kW solid state modulator, Gamic Enigma III+ or EEC IQ2 signal processor, 4.2 m sandwich antenna and AFC 6 m stealth radome with hydrophobic coating. The Valluga radar, in the western part of Austria was upgraded in 2015 with new signal processor EEC IQ2, but still operating with 250 kW peak power and orange peel radome.

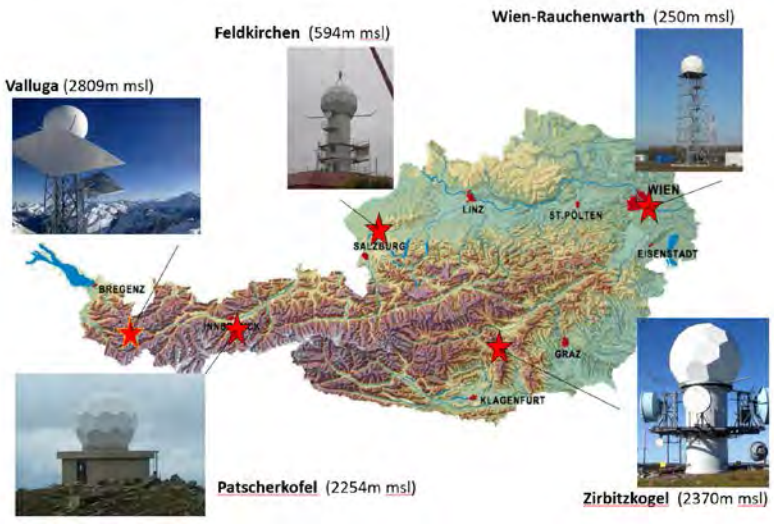


Figure 16 Austrian Weather Rada Network.

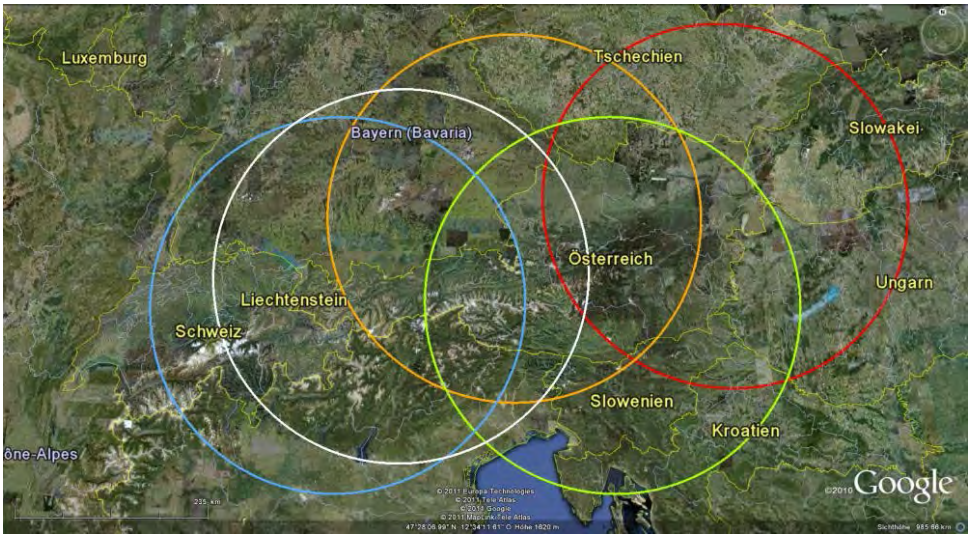


Figure 17 Weather radar data coverage using range of 220/224 km.

Two scan strategies are applied. For Valluga every 5 minutes 16 elevations are captued from bottom to top using elevation angles from -2 to 60 degrees. Other radars use two interleave scans (figure 16) with elevation angles from -1.5 to 65 degrees. Each half scan consists of 8 elevations (approx. duration of 2.5 min) by applying variable antenna rotation speeds. The latest two half scans are combined and updated every 2.5 min. Subsequent full volume scan covers 16 elevations, too. For each half scan the scan sequence is from top to bottom. To increase the unambiguous Doppler velocity, dual PRF sampling is applied on the second half scan and on all scans at Valluga. Spatial resolution is approximately 0.9 degree azimuthal and 250 m in radial. Cartesian composite products are created for 1 km resolution in 5 min resolution.

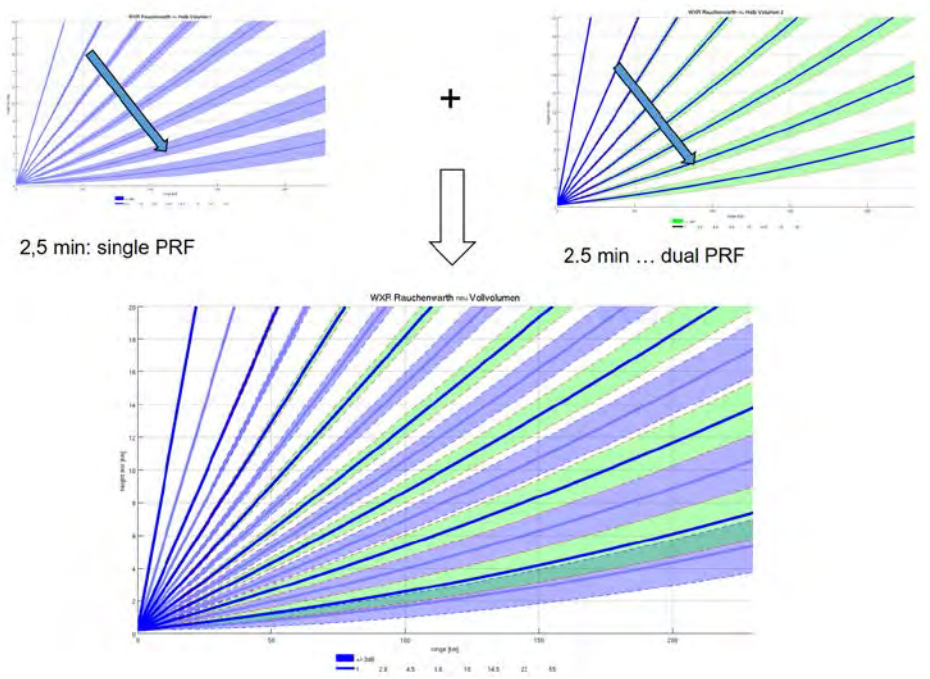


Figure 18 **Interleave scan strategy. Full volume scan consists of two half scans of different elevations (3dB beam width is colored in blue/green).**

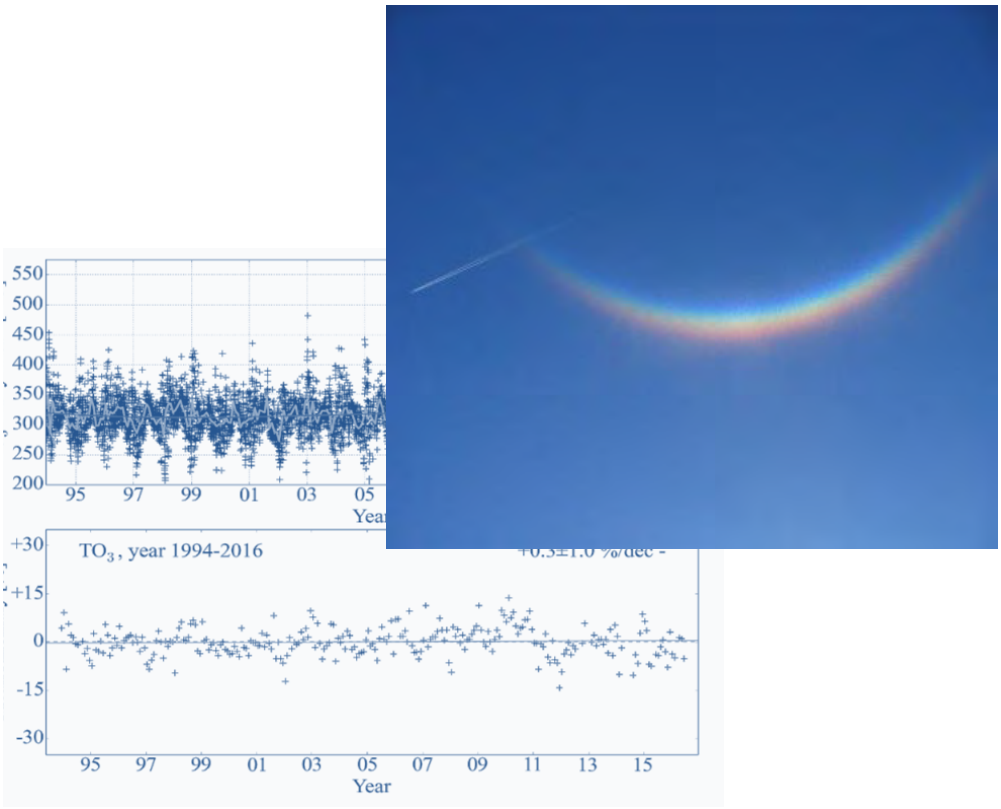
Austrian weather radars collect following moments: radar reflectivity, Doppler velocity, spectral width, and the polarimetric moments as differential reflectivity, copolar cross-correlation coefficient and differential phase.

References:

http://www.meteo.fr/cic/meetings/2012/ERAD/extended_abs/NET_166_ext_abs.pdf

http://www.meteorologie.at/docs/OEGM_bulletin_2012_2.pdf

http://eumetnet.eu/wp-content/themes/aeron-child/observations-programme/current-activities/opera/database/OPERA_Database/index.html



Atmospheric Observations

Composition

Stratospheric Ozone

Stana Simic (BOKU)

The major part of atmospheric ozone (about 90 %) is found in the stratosphere in heights of 15 to 55 km. The maximum concentration varies with latitude and season between heights of 20 and 25 km. Ozone has the ability to strongly absorb UV radiation. Therefore no radiation with wavelengths shorter than 290 nm (harmful UV-C radiation) reaches the Earth's surface and its lifeforms. Thus the ozone layer is an essential part for the wellbeing of life on Earth. Considering the heavy ozone depletion of the past decades it is of outermost importance to precisely and continuously monitor stratospheric ozone.

As scientists of the British Antarctic Survey (Farman et al, 1985) discovered the extremely low ozone values over Antarctica in 1985, anthropogenic Chlorofluorocarbons (CFCs) could be identified as the main cause. The following years a global depletion of ozone was found. These findings lead to the 1987 international Montreal Protocol to limit further emissions of CFCs. The protocol proved to be successful when research showed that the concentration of CFCs was decreasing since the mid-1990s.

Measurements of Stratospheric Ozone in Austria

Total ozone column has continuously been measured at the High-Alpine Observatory Hoher Sonnblick since 1994 and is the only ozone measurement station in Austria. Measurements are carried out by the Institute of Meteorology of "University of Natural Resources and Life Sciences" (BOKU) and are financed by the "Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management" (BMLFUW). The data fulfils the high-quality standards of the "Network for the Detection of Atmospheric Composition Change" (NDACC). Ozone is measured with a Brewer MkIV spectrophotometer which is maintained regularly by the Institute of Meteorology at BOKU.

Total Ozone Column

The long-term dataset of total ozone is one of the longest in all of Europe. It is a fundamental part in understanding the ozone layer above Austria in its present state and to predict its future development and changes. The Montreal Protocol proves successful because the reduction in the concentration of ozone-depleting substances has led to a slight recovery in total ozone which can be observed. At the same time, an increase in total ozone variability, caused by the changing meteorological parameters under the changing global climate, can be seen. Because of these climate-ozone interactions, it is very important to closely monitor the ozone layer under the influence of our future changing climate.

Vertically Resolved Ozone – Umkehr Layers

Vertical ozone profiles can be measured with the Brewer spectrophotometer too and are routinely produced since 1994, using the so called Umkehr-method. These profiles are interesting because the influencing factors on the top of the stratosphere are entirely different to the bottom. Near the tropopause (approx. 15 km) dynamic influences dominate ozone concentration while near the stratopause (approx. 50 km) photochemical processes prevail.

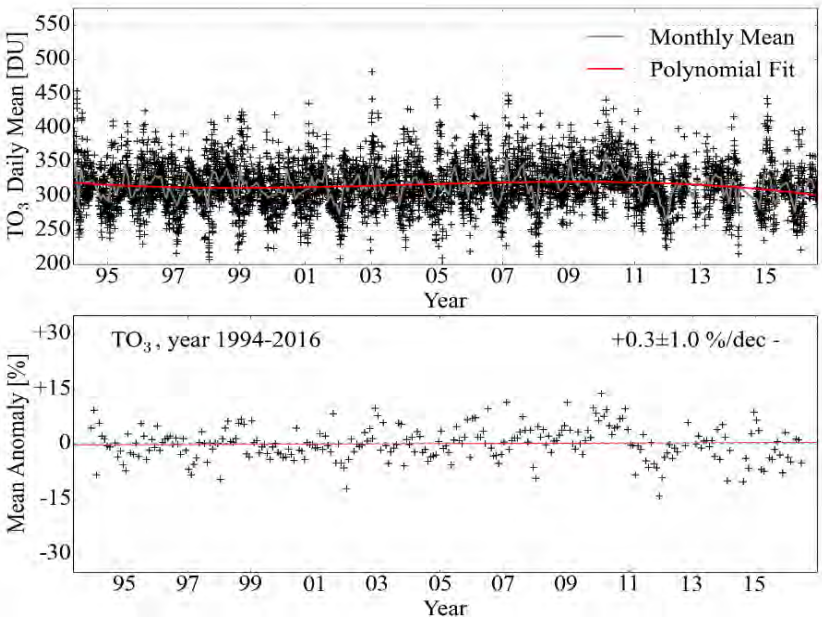


Figure 19 Daily Mean (upper graph) and trend in mean anomalies of total ozone measured at Hoher Sonnblick Observatory in 1994-2016.

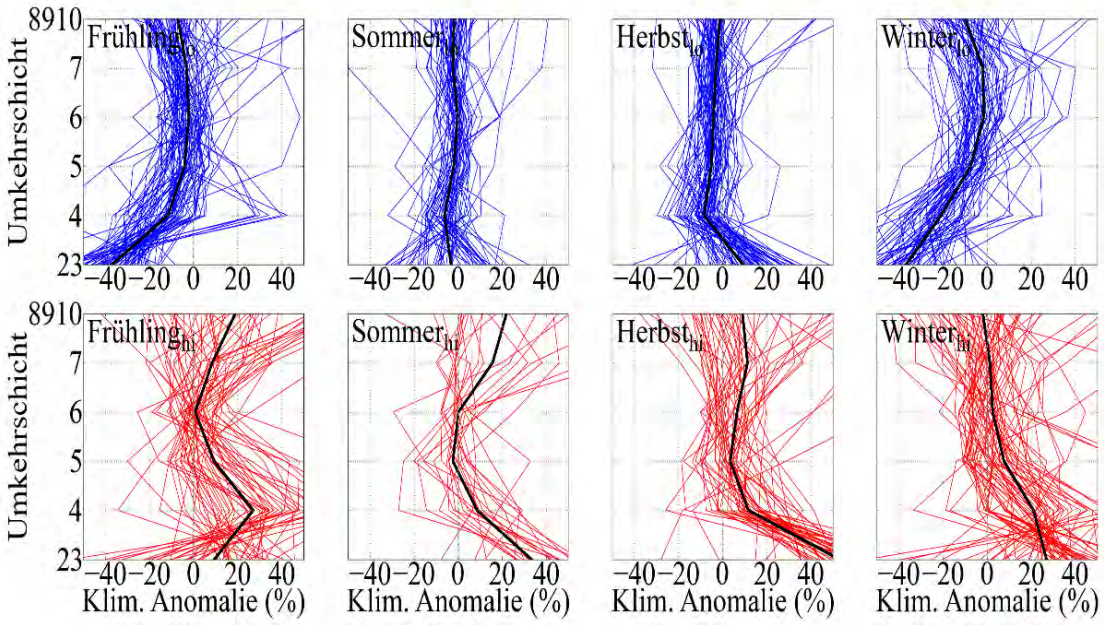


Figure 20 Seasonal anomalies of vertical ozone compared to the climatological mean. Red represents high-ozone and blue low-ozone events.

Essential Climate Variables – Atmospheric Observations - Composition

Parameter measured/observed	total ozone column and vertical ozone profiles
Starting date	01.01.1994
Temporal Resolution	Daily datasets of total ozone and vertically resolved ozone.
Observational Network	Sonnblick Observatory
Stations	A Brewer MkIV spectrophotometer located at High Alpine Observatory Hoher Sonnblick.
Data Portal	NDACC: http://www.ndsc.ncep.noaa.gov/data/ BOKU: https://imp.boku.ac.at/Strahlung/messwert.htm
Supervising Organization	BOKU, BMLFUW
National and/or international Networks or Programs	NDACC (Network for the Detection Atmospheric Composition Change)
Data Submission	The log Files of the Brewer instrument are transferred daily to a server at BOKU.
Licenses	general BOKU data conditions
Use Limitation	Use for research only
Data Format	ASCII
Data Access	Total ozone column is made publicly available at: https://imp.boku.ac.at/Strahlung/messwert.htm and http://teletext.orf.at/600/644_0006.htm
Data Quality	High-quality standard of NDACC
Performance Monitoring	The instrument and data availability are supervised by the work group „UV Radiation and Ozone“ at the Institute of Meteorology at University of Natural Resources and Life Sciences, Vienna (BOKU).
Publications	Publications are listed here: http://www.wau.boku.ac.at/en/met/forschungsthemen/atmosphaerische-strahlung/forschungsbereich-uv-strahlung-und-gesamtozon/publikationen/
Contact (National correspondent, focal point)	Dr. Stana Simic BOKU Wien, Institut für Meteorologie Department für Wasser-Atmosphäre-Umwelt Gregor-Mendel-Straße 33, 1180 Wien Telefon: (+43) (0)1 47654-81430, www.wau.boku.ac.at/met.html
Remarks	

Air quality monitoring network

Iris Buxbaum (UBA)

The Environment Agency Austria (Umweltbundesamt) operates the Austrian background monitoring network. Air pollutants and meteorological parameters are measured at seven stations (figure 19).

The objectives of the measurements are the assessment of

- the large-scale background levels,
- the trend of background levels,
- the long-range transport of air pollutants and
- the monitoring of compliance with limit and target values for the protection of human health and for the protection of ecosystems and vegetation according to the Ozone Act, the Ambient Air Quality Act and related ordinances.

Some of these stations are integrated into international measuring programs. Three of the sites (Illmitz, Vorhegg and Zöbelboden) are part of the European Monitoring and Evaluation Programme (EMEP) under the Convention on Long-range Transboundary Air Pollution (CLRTAP). The Zöbelboden site is also integrated into the Integrated Monitoring measurement program of the UNECE for long-term ecosystem monitoring. The monitoring site at Sonnblick is part of the "Global Atmosphere Watch" program (GAW) of the World Meteorological Organization (WMO). The measurements are used for the investigation of large-scale pollutant transports across Central Europe and the long-term monitoring of pollutant trends in the alpine region.

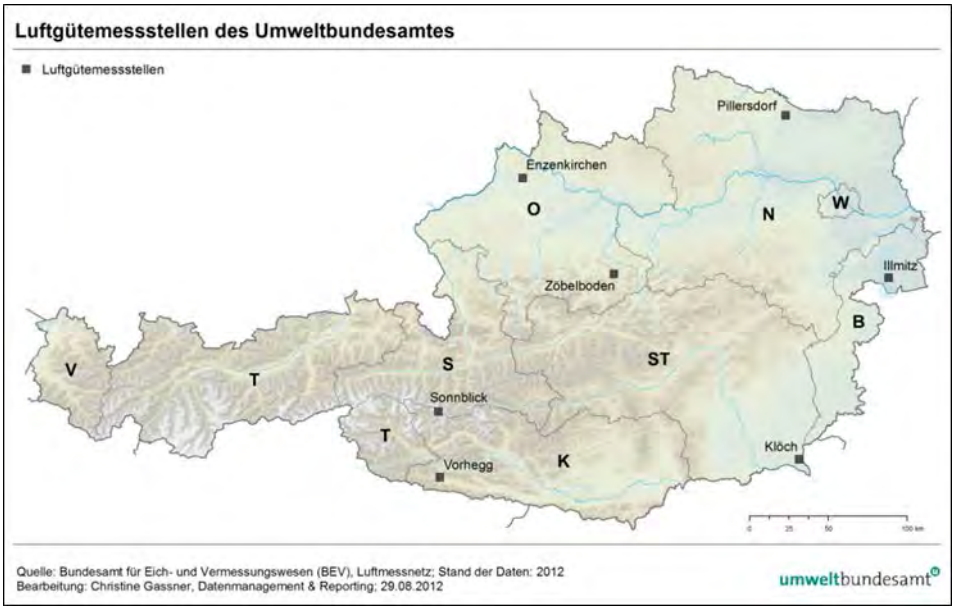


Figure 21 Network of air quality monitoring stations of the Environment Agency Austria.

Essential Climate Variables – Atmospheric Observations - Composition

Parameter measured/observed	ozone, sulfur dioxide, nitrogen oxides, carbon monoxide, carbon dioxide, methane, particulate matter (PM_{10}, $PM_{2,5}$, PM_1), heavy metals (As, Cd, Hg, Ni, Pb), PAH, VOC, EC/OC air temperature and humidity, wind speed and direction, pressure, precipitation, sunshine duration, global radiation, surface radiation budget
Starting date	Enzenkirchen since 03.06.1998 Illmitz since 01.01.1978 Klöch since 01.08.1995 Pillersdorf since 27.02.1992 Sonnblick since 01.01.1989 Vorhegg since 11.12.1990 Zöbelboden since 01.09.1993
Temporal Resolution	Half-hour mean values, daily mean values for gravimetric particulate matter measurements, monthly and yearly mean values for heavy metals, PAH, VOC, EC/OC
Observational Network	Austrian background air quality monitoring network according to the Austrian Ambient Air Quality Act and Ozone Act
Stations	Enzenkirchen, Illmitz, Klöch, Pillersdorf, Sonnblick, Vorhegg, Zöbelboden www.umweltbundesamt.at/messnetz_u/
Data Portal	Contact: luft@umweltbundesamt.at Webpage: www.umweltbundesamt.at/luftguete_aktuell/ Open Data Portal for Ozone: http://www.umweltbundesamt.at/umweltsituation/umweltinfo/opendata/oed_luft/ European Air Quality Portal (by EEA -European Environment Agency): http://eeadmz1-cws-wp-air.azurewebsites.net/ Data from Sonnblick site: GAW World Data Centre for Reactive Gases (WDCRG, http://www.gaw-wdcrg.org/) and World Data Centre for Greenhouse Gases (WDCGG, http://ds.data.jma.go.jp/gmd/wdcgg/) Data from EMEP-sites: http://ebas.nilu.no/
Supervising Organization	Umweltbundesamt (Environment Agency Austria) www.umweltbundesamt.at
National and/or international Networks or Programs	GAW - Global Atmosphere Watch Programme (http://www.wmo.int/pages/prog/arep/gaw/gaw_home_en.html) EMEP - European Monitoring and Evaluation Programme (http://www.emep.int/)

Data Submission	Up-to-date air quality data and yearly submission of validated data
Licenses	CC BY 3.0 AT http://creativecommons.org/licenses/by/3.0/at/deed.de
Use Limitation	No limitations, references to data sources are obligatory.
Data Format	Download of the data as csv (European Air Quality Portal, WDCGG), as NASA-Ames Files (EMEP, WDCRG) or as .json (OpenData Portal for Ozone) Contact luft@umweltbundesamt.at for data as .xlsx
Data Access	Download via various data portals (see Data Portal) or contact luft@umweltbundesamt.at Open access
Data Quality	Data quality control is done by the Environment Agency Austria according to the requirements of the Directive 2008/50/EC and Directive 2004/107/EC. Data quality objectives as laid down in Directive 2008/50/EC and Directive 2004/107/EC. Up-to-date data are not validated.
Performance Monitoring	Data availability is supervised by the Environment Agency Austria.
Publications	Monthly and yearly reports (in German, download via www.umweltbundesamt.at/monatsberichte/ and www.umweltbundesamt.at/jahresberichte/)
Contact (National correspondent, focal point)	Contact: luft@umweltbundesamt.at
Remarks	

Air quality monitoring of the federal states of Austria

Elisabeth Scheicher (Amt der NÖ Landesregierung)

Air pollution control in Austria is the responsibility of the individual countries.

At the air quality stations the parameters SO_2, NO_x, CO, O_3, PM_{10}, $PM_{2,5}$ are measured. Additionally the meteorological parameters wind speed, wind direction, temperature and at a few stations radiation balance, global radiation and relative humidity are observed. A detailed overview of the position of the measuring points and the measured parameters can be found in the report ” AIR QUALITY MONITORING SITES IN AUSTRIA 2017”

http://www.umweltbundesamt.at/fileadmin/site/publikationen/REP0607.pdf

The measured values are recorded and stored as half-hour values in the database. The quality assurance is carried out by the technicians of each office of the regional government. An annual comparison with the Umweltbundesamt ensures the comparability of the measurements in Austria.

Overview of the individual measuring networks:

Burgenland

Gabriele Wieger (Amt der Burgenländischen Landesregierung)

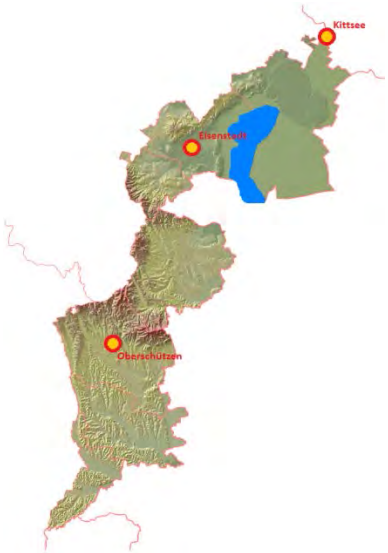


Figure 22 Monitoring stations, Burgenland.

Essential Climate Variables - Atmospheric Observations – Composition

Parameter measured/observed	SO_2, NO_x, NO, NO_2, CO, O_3, PM_{10}, $PM_{2,5}$, BTEX, wind, air temperature, global radiation, relative humidity
Starting date	1994 (only few stations), the development of the whole network was done in 1997
Temporal Resolution	Half-hour mean values , BTEX as yearly mean values, $PM_{2,5}$ as daily mean values
Observational Network	Burgenländisches Luftgütemessnetz
Stations	3 fix and 3 mobile stations
Data Portal	http://www.burgenland.at/natur-umwelt-agrar/umwelt/luftguete
Supervising Organization	Amt der Burgenländischen Landesregierung
National and/or international Networks or Programs	
Data Submission	Half-hourly
Licenses	none
Use Limitation	none

Data Format	MySQL-Datenbank
Data Access	Download via various data portals (see Data Portal) or contact post.a4-luft@bgld.gv.at Open access
Data Quality	Data quality control is done by Amt der Burgenländischen Landesregierung
Performance Monitoring	Data availability is supervised by the Amt der Burgenländischen Landesregierung
Publications	Monthly and yearly reports, and also reports of special measurements
Contact (National correspondent, focal point)	post.a4-luft@bgld.gv.at
Remarks	

Carinthia

Gerhard Heimburger (Amt der Kärntner Landesregierung)

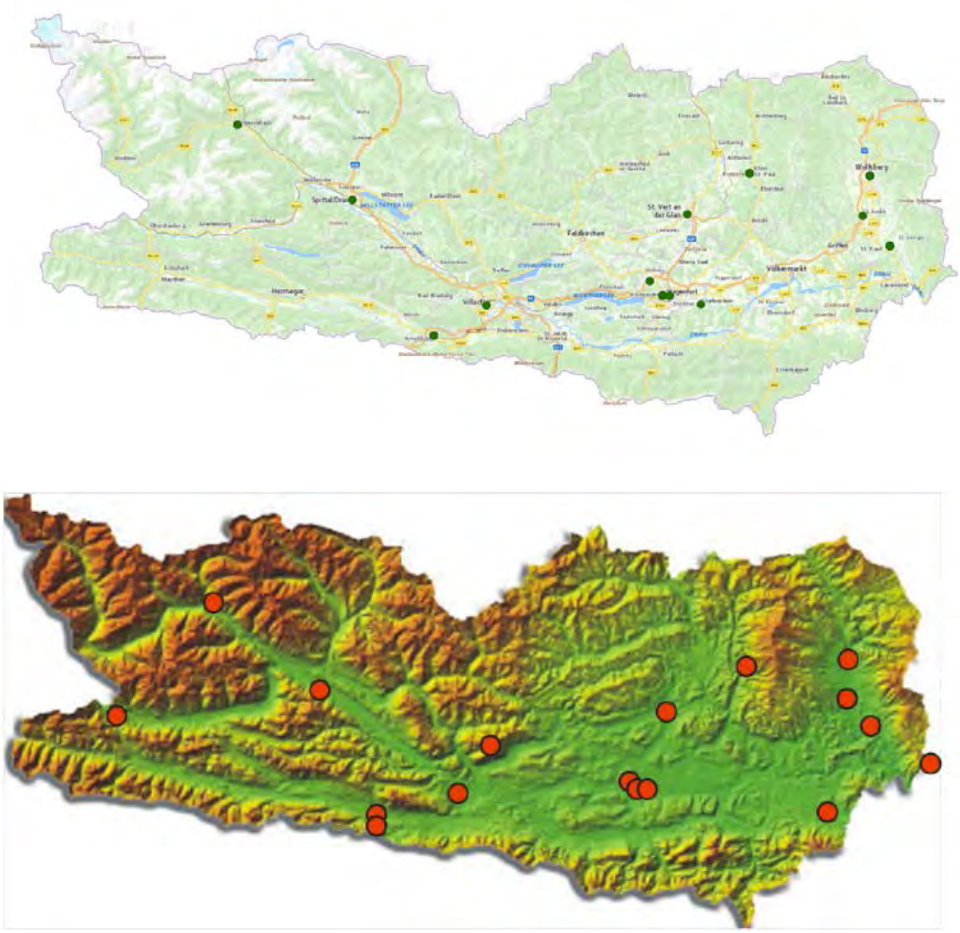


Figure 23 Monitoring stations, Carinthia.

Essential Climate Variable - Atmospheric Observation – Composition

Parameter measured/observed	Sulfur dioxide (SO_2), nitrogen oxides (NO_x, NO, NO_2), ozone (O_3), fine dust (PM_{10}, $PM_{2,5}$), carbon monoxide (CO), benzene, benzo(a)pyrene (B(a)P), heavy metals in PM_{10} (lead, cadmium), meteorological parameters (air temperature, relative humidity, wind direction, wind speed)
Starting date	From late 1990 onwards
Temporal Resolution	Half-hourly, daily, monthly and annual means
Observational Network	LGMK
Stations	Circa 25 air quality measurement stations in Carinthia
Data Portal	www.umwelt.ktn.gv.at/luft/ www.umweltbundesamt.at/umweltsituation/luft/ Meteorological data only on request since they are mainly used for the assessment of the recorded air pollutant concentrations or air pollutant dispersion conditions, and therefore generally neither published nor transmitted to other data networks
Supervising Organization	Provincial Government of Carinthia, Department 8 – Environment, Water and Nature Protection, Subdivision Ecology and Monitoring, Emission Control
National and/or international Networks or Programs	None
Data Submission	Half-year to annual mean values, transmission path of the continuously recorded measurement data is UMTS, the data are forwarded to the Austrian immission data network (IDV)
Licenses	None
Use Limitation	None
Data Format	ODV = Data format of the Austrian immission data network
Data Access	Generation of Austrian wide uniform time-series through the website of the Umweltbundesamt GmbH www.umweltbundesamt.at/umweltsituation/luft/ Region wide to a limited extent through www.umwelt.ktn.gv.at/luft/ Meteorological data only on request since they are mainly used for the assessment of the recorded air pollutant concentrations or air pollutant dispersion conditions, and therefore generally neither published nor transmitted to other data networks

Data Quality	Daily data checks are performed by the Provincial Government of Carinthia, Department 8 – Environment, Water and Nature Protection, Subdivision Ecology and Monitoring, Emission Control. From this point the data are considered as seen and are referred to as provisional data. Final inspection is carried out within the framework of the preparation of the annual report - from this point they are also available to fulfil the national reporting requirements (UBA-EU). The comparability and traceability of the measured data is ensured by at least one annual link to primary or reference standards of a reference laboratory and by the regular participation in ring tests.
Performance Monitoring	Provincial Government of Carinthia, Department 8 – Environment, Water and Nature Protection, Subdivision Ecology and Monitoring, Emission Control
Publications	According to the IG-L or Ozone Law, daily reports, monthly reports and annual reports are created and published www.umwelt.ktn.gv.at/luft/
Contact (National correspondent, focal point)	Provincial Government of Carinthia, Department 8 – Environment, Water and Nature Protection, Subdivision Ecology and Monitoring, Emission Control Abt8.post@ktn.gv.at Umweltbundesamt GmbH, Spittelauer Lände 5, 1090 Wien office@umweltbundesamt.at
Remarks	

Lower Austria

Elisabeth Scheicher (Amt der NÖ Landesregierung)

Figure 24 Monitoring stations, Lower Austria (NÖ).

Essential Climate Variable - Atmospheric Observation – Composition

Parameter measured/observed	SO_2, NO_x, NO, NO_2, CO, O_3, PM_{10}, $PM_{2,5}$, B(a)P, wind, temperature, radiation balance, global radiation, relative humidity
Starting date	01.10.1984 (only a few station) the development of the whole network was done in 1990
Temporal Resolution	30 minute values
Observational Network	NUMBIS (Niederösterreichisches Umwelt- Beobachtungs- und Informationssystem)
Stations	42 stations as part of the air quality network
Data Portal	https://www.data.gv.at/ post.bd4numbis@noel.gv.at
Supervising Organization	Amt der NÖ Landesregierung
National and/or international Networks or Programs	
Data Submission	Hourly, but only one complete day available
Licenses	Measurements are disseminated free of charge.
Use Limitation	none
Data Format	xls, csv, txt, ascii
Data Access	Open access for data.gv.at Access by contact via mail to numbis.at (post.bd4numbis@noel.gv.at)
Data Quality	Quality control is done by Amt der NÖ Landesregierung
Performance Monitoring	by Amt der NÖ Landesregierung
Publications	Monthly and annual report published at www.numbis.at/publikationen
Contact (National correspondent, focal point)	post.bd4numbis@noel.gv.at
Remarks	

Upper Austria

Elisabeth Danninger (Amt der OÖ Landesregierung)

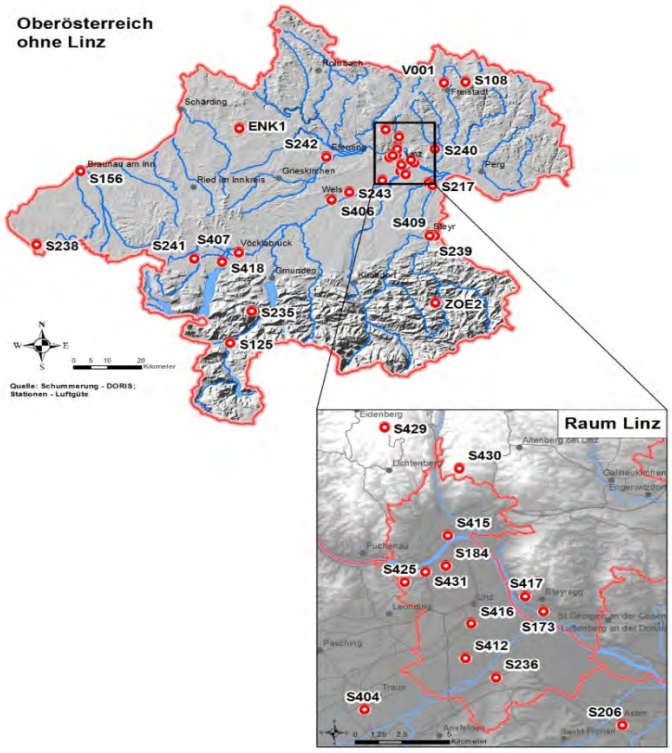


Figure 25 Monitoring stations, Upper Austria (OÖ).

Essential Climate Variable - Atmospheric Observation – Composition

Parameter measured/observed	SO_2, NO_x, NO, NO_2, CO, O_3, PM_{10}, $PM_{2,5}$, B(a)P, benzene, heavy metals, wind, temperature, radiation balance, global radiation, relative humidity, light pollution
Starting date	01.02.1977 (only a few stations) the development of the main network was done in 1984, but the locations of various stations have changed since then
Temporal Resolution	B(a)P and benzene monthly, heavy metals yearly, PM_{10} and $PM_{2,5}$ daily, other 30 minute values
Observational Network	OÖ Luftmessnetz
Stations	18 stations as part of the air quality network
Data Portal	www.land-oberoesterreich.gv.at/Luftgüte_und_Meteorologie www.land-oberoesterreich.gv.at/Lichtmessnetz www.land-oberoesterreich.gv.at/OpenData www.data.gv.at/ us-goethe.post@ooe.gv.at

Supervising Organization	Amt der OÖ Landesregierung
National and/or international Networks or Programs	
Data Submission	Half-Hourly, but only 5 years available
Licenses	Measurements are disseminated free of charge.
Use Limitation	none
Data Format	xls, csv, txt, ascii, json
Data Access	Open access for data.gv.at Access by contact via mail to Land Oberösterreich (us-goethe.post@ooe.gv.at)
Data Quality	Quality control is done by Amt der OÖ Landesregierung
Performance Monitoring	by Amt der OÖ Landesregierung
Publications	Monthly and annual report published at Luftgüteberichte und Messprogramme
Contact (National correspondent, focal point)	us-goethe.post@ooe.gv.at
Remark	

Salzburg

Alexander Kranabetter (Amt der Salzburger Landesregierung)

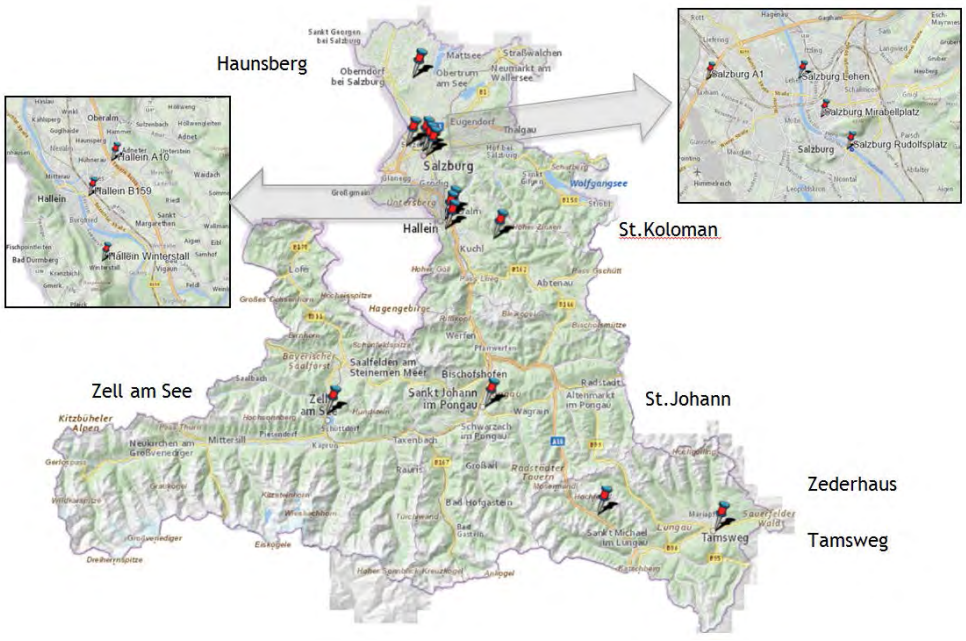


Figure 26 Monitoring stations, Salzburg.

Essential Climate Variable - Atmospheric Observation – Composition

Parameter measured/observed	SO_2, NO_x, NO, NO_2, CO, O_3, PM_{10}, $PM_{2,5}$, B(a)P, EC, particle number, benzene, heavy metals, wind, temperature, radiation balance, global radiation, relative humidity
Starting date	01.10.1978 (only a few stations) the development of the whole network was done in 1988
Temporal Resolution	B(a)P , EC, heavy metals yearly, PM_{10} and $PM_{2,5}$ daily, other 30 minutes value
Observational Network	Section 5, Salzburger Luftgütemessnetz
Stations	16 stations as part of the air quality network
Data Portal	https://www.salzburg.gv.at/themen/umwelt/luft http://service.salzburg.gv.at/ogd/client/ luftmessnetz@salzburg.gv.at
Supervising Organization	Amt der Salzburger Landesregierung
National and/or international Networks or Programs	
Data Submission	Half-Hourly
Licenses	Measurements are disseminated free of charge
Use Limitation	none
Data Format	csv
Data Access	Open access for data by http://service.salzburg.gv.at/ogd/client/
Data Quality	Quality control suits to Immissionsschutzgesetz & RL 2008/50/EG
Performance Monitoring	by Amt der Salzburger Landesregierung
Publications	Daily, monthly and annual reports: https://www.salzburg.gv.at/themen/umwelt/luft/luftberichte
Contact (National correspondent, focal point)	Land Salzburg Abteilung 5: Natur- und Umweltschutz, Gewerbe Referat 5/02: Immissionschutz Ulrich-Schreier-Straße 18, 5020 Salzburg Telefon: +43 662 8042-4592 Email: luftmessnetz@salzburg.gv.at
Remarks	

Styria

Thomas Pongratz (Amt der Steiermärkischen Landesregierung)

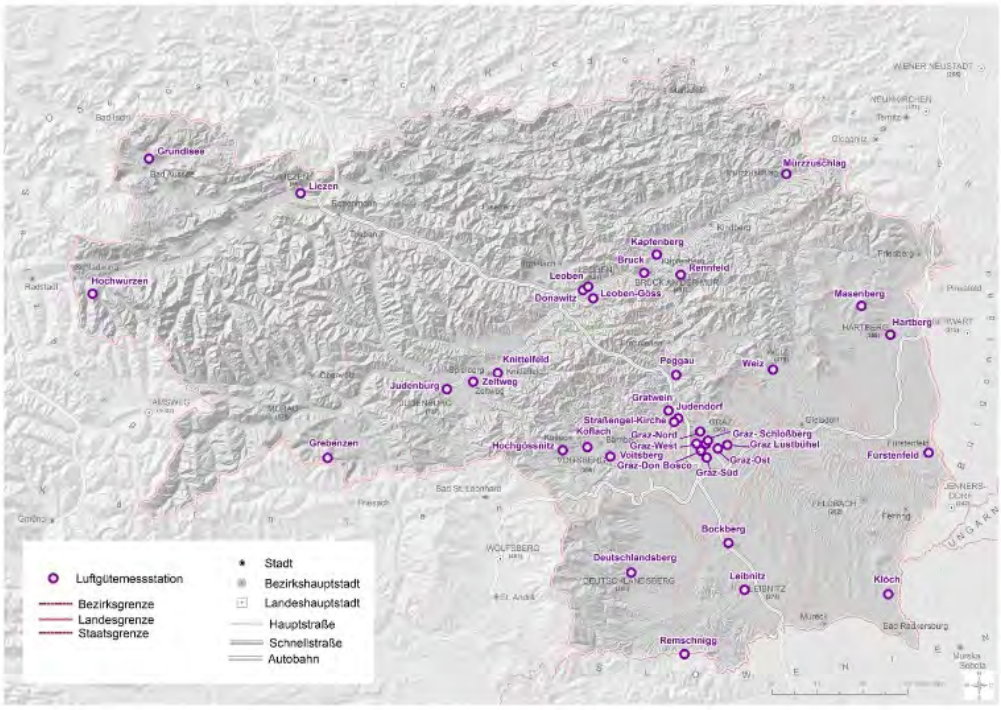


Figure 27 Monitoring stations, Styria.

Essential Climate Variable - Atmospheric Observations - Composition

Parameter measured/observed	SO_2, NO_x, NO, NO_2, CO, O_3, PM_{10}, $PM_{2,5}$, B(a)P, benzene wind speed and direction, temperature, , global radiation relative humidity
Starting date	Data since 1989 are stored in the Air quality database
Temporal Resolution	30 minute values
Observational Network	LUIS (Landesumweltinformation Steiermark)
Stations	38 air quality monitoring stations + 9 meteorological stations
Data Portal	Air quality measurements: www.umwelt.steiermark.at/cms/ziel/2061730/DE/ Meteorological measurements: www.umwelt.steiermark.at/cms/ziel/2061802/DE/ Online data portal: www.umwelt.steiermark.at/cms/ziel/2060750/DE/ luft@stmk.gv.at
Supervising Organization	Amt der Steiermärkischen Landesregierung
National and/or international Networks or Programs	

Data Submission	twice an hour (30 minutes mean values)
Licenses	Measurements are disseminated free of charge. Disclaimer and terms of use: www.umwelt.steiermark.at/cms/beitrag/10795434/2054533/
Use Limitation	none
Data Format	Data are available as xls File.
Data Access	Free access via online data portal: www.umwelt.steiermark.at/cms/ziel/2060750/DE/:
Data Quality	Quality control is done by Amt der Steiermärkischen Landesregierung
Performance Monitoring	Performance monitoring is done by Amt der Steiermärkischen Landesregierung.
Publications	⇨ Monthly and annual data reports ⇨ Air Quality plans and Programs ⇨ Reports of mobile air quality measurements. ⇨ Studies concerning Air Quality were published at www.umwelt.steiermark.at/cms/ziel/18437939/DE/
Contact (National correspondent, focal point)	luft@stmk.gv.at
Remarks	

Tyrol

Walter Egger (Amt der Tiroler Landesregierung)

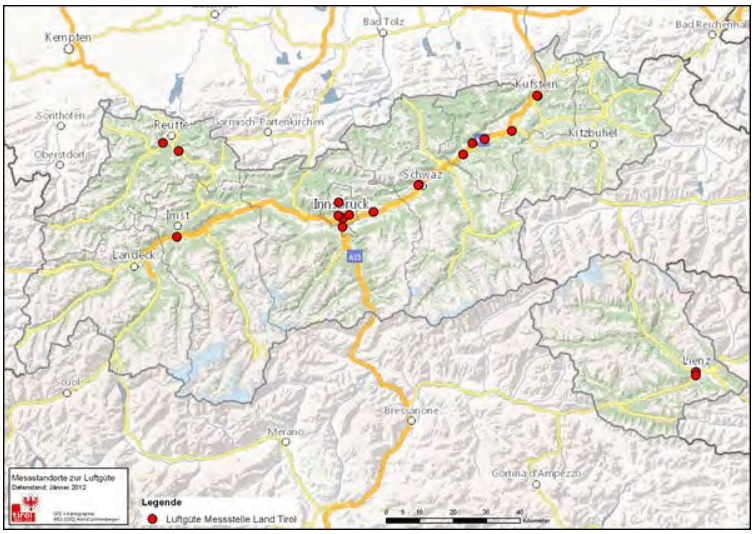


Figure 28 Monitoring stations, Tyrol.

Essential Climate Variable - Atmospheric Observations – Composition

Parameter measured/observed	SO_2, NO_x, NO, NO_2, CO, O_3, PM_{10}, $PM_{2,5}$, B(a)P, wind, temperature, global radiation, relative humidity
Starting date	1973 (only a few stations) most of the development of the actual network was done within 1995 and 2005.
Temporal Resolution	30 minute values except gravimetric PM_{10}-measurements (daily mean)
Observational Network	Tiroler Luftmessnetz
Stations	19 stations as part of the air quality network
Data Portal	Immissionsdatenverbund at the Umweltbundesamt Contact Person: Spangl Wolfgang wolfgang.spangl@umweltbundesamt.at +43 (1) 31304 5861 Metadata: www.tirol.gv.at/umwelt/luft/messnetz-galerie-webcams/
Supervising Organization	Amt der Tiroler Landesregierung
National and/or international Networks or Programs	Immissionsdatenverbund at the Umweltbundesamt
Data Submission	Half-hourly
Licenses	Measurements are free of charge.
Use Limitation	none
Data Format	Please Contact: Spangl Wolfgang wolfgang.spangl@umweltbundesamt.at +43 (1) 31304 5861
Data Access	Please Contact: Spangl Wolfgang wolfgang.spangl@umweltbundesamt.at +43 (1) 31304 5861
Data Quality	Quality control is done by Amt der Tiroler Landesregierung; The quality control is carried out according to the requirements of the IG-L Messkonzeptverordnung and the Ozonmesskonzeptverordnung.
Performance Monitoring	by Amt der Tiroler Landesregierung/Abt.Waldschutz/Fachbereich Luftgüte
Publications	Monthly and annual report published at www.tirol.gv.at/umwelt/luft/messwerte-berichte/

Contact (National correspondent, focal point)	Please Contact: Spangl Wolfgang wolfgang.spangl@umweltbundesamt.at +43 (1) 31304 5861
Remarks	

Vorarlberg

Bernhard Anwander (Institut für Umwelt und Lebensmittelsicherheit des Landes Vorarlberg)

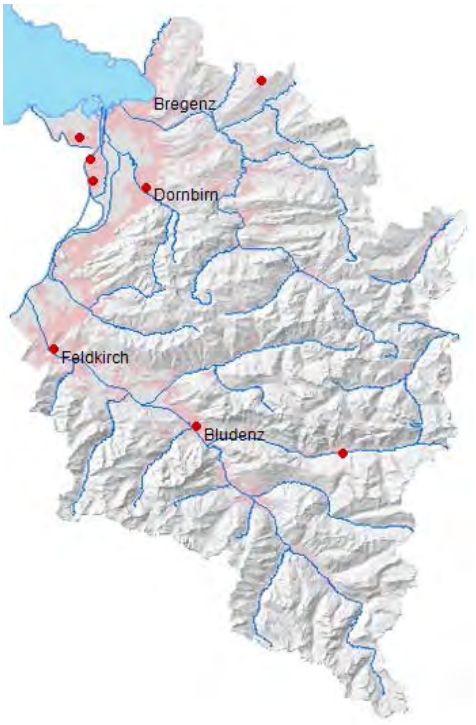


Figure 29 Monitoring stations, Vorarlberg.

Essential Climate Variable - Atmospheric Observation –Composition

Parameter measured/observed	SO_2, NO_x, NO, NO_2, CO, O_3, PM_{10}, $PM_{2,5}$, B(a)P, benzene, heavy metals, EC/OC, wind, temperature, radiation balance, global radiation, relative humidity
Starting date	some data time series begins in 1980, but stations may vary
Temporal Resolution	B(a)P, heavy metals , EC/OC, benzene every 4^{th} day, PM_{10} and $PM_{2,5}$ daily, other 30 minutes value
Observational Network	Air quality monitoring network
Stations	9 stations as part of the air quality network
Data Portal	http://www.vorarlberg.at/vorarlberg/umwelt_zukunft/umwelt/umweltundlebensmittel/weitereinformationen/luft/uebersicht.htm

Supervising Organization	Umweltinstitut des Landes Vorarlberg
National and/or international Networks or Programs	
Data Submission	
Licenses	Measurements are disseminated free of charge.
Use Limitation	none
Data Format	xls, csv
Data Access	Access by contact via mail to Umweltinstitut (umweltinstitut@vorarlberg.at)
Data Quality	Quality control is done by Umweltinstitut
Performance Monitoring	by Umweltinstitut
Publications	Daily, monthly and annual report published at http://www.vorarlberg.at/vorarlberg/umwelt_zukunft/umwelt/umweltundlebensmittel/weitereinformationen/luft/tages-_monats-jahresberic.htm
Contact (National correspondent, focal point)	umweltinstitut@vorarlberg.at
Remarks	

Vienna

Rainer Plank (MA22)

Figure 30 Monitoring stations, Vienna.

Essential Climate Variable – Atmospheric Observations - Composition

Parameter measured/observed	wind direction, wind speed, air temperature, air pressure, sunshine duration, precipitation sulfur dioxide, nitrogen monoxide, nitrogen dioxide, carbon monoxide, ground-level ozone and particulate matter (PM_{10}, $PM_{2,5}$)
Starting date	First monitoring sites in 1986
Temporal Resolution	Half-hourly averaged
Observational Network	City of Vienna Municipal Department 22 – Environmental Protection Air Quality Monitoring Network
Stations	17 measuring stations located in Vienna (urban environment, traffic-oriented locations, recreation area and industrial zone)
Data Portal	https://www.wien.gv.at/ma22-lgb/luftgi.htm
Supervising Organization	City of Vienna
National and/or international Networks or Programs	Environment Agency Austria (Umweltbundesamt) http://www.umweltbundesamt.at/
Data Submission	real-time
Licenses	CC BY-NC
Use Limitations	For non-profit research
Data Format	on request (cvs, Excel, …) or download
Data Access	Download via Municipal Department 22 – Environmental Protection in Vienna – homepage www.wien.gv.at/umwelt/luft/messwerte/berichte.html
Data Quality	Data quality control is done by Vienna's Municipal Department 22
Performance Monitoring	Data availability is supervised by Vienna's Municipal Department 22
Publications	daily, weekly, monthly and yearly reports Further publications on the dataset can be found at the web-site of Vienna's Municipal Department 22 www.wien.gv.at/ma22-lgb/luftgi.htm
Contact (National correspondent, focal point)	Contact: luft@ma22.wien.gv.at
Remarks	

Sonnblick Observatory - High-altitude research station

Elke Ludewig (ZAMG)

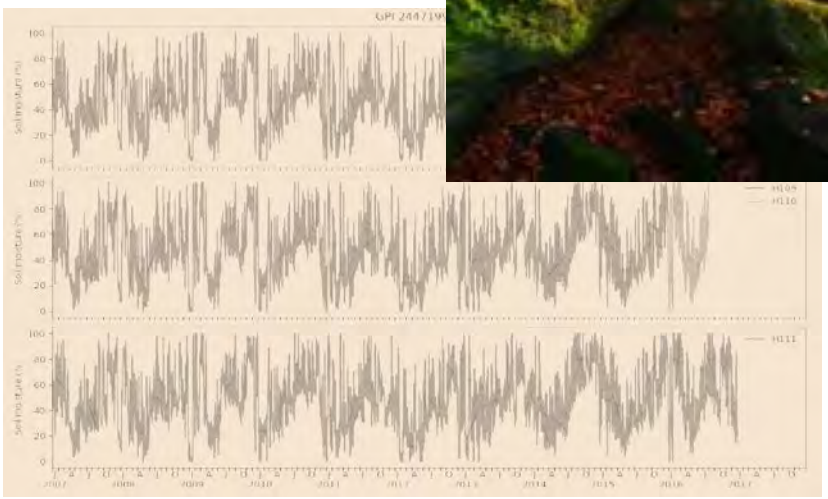
The Sonnblick Observatory is a high altitude research station at 3,106 m altitude and was established in 1886. Meteorological parameters have been retrieved since 1886, hence the Sonnblick Observatory provides climate time series of about 130 years. Measurements of greenhouse gases were added to the monitoring in 2012 in combination with aerosol measurements since 2010 and selected reactive gases since 2002. The Sonnblick Observatory is part of NDACC (Network for the Detection of Atmospheric Composition Change) since 1997, part of BSRN (Baseline Surface Radiation Network) since 2011 and since 2015 it was upgraded to a global GAW (Global Atmosphere Watch) station. Beside the atmosphere the Sonnblick Observatory also focuses on the biosphere and the cryosphere considering the WMO programme GCW (Global Crysophere Watch) and includes measurements from the glacier Pasterze. The Sonnblick Observatory operates constantly, around the clock, all year long. A minimum of two technicians works at the site on a routine basis which is one important step of the data quality control. The data quality control is done in different steps starting directly at the observatory. The Sonnblick Observatory has partner institutions taking measurements at the site that contributes to the Sonnblick Observatory data set. Hence a part of the quality control is also done by the national partners such as TU-Vienna, Umweltbundesamt or BOKU-Vienna. Data are uploaded yearly to the defined world data centres but can be also obtained via the Sonnblick Observatory and its partner institutions.

Figure 31 **The Sonnblick Observatory in June 2016. The observatory is located in Austria at the alpine ridge between the provinces Salzburg and Carinthia at 3,106m altitude. It was established in 1886 having the focus on atmosphere, cryosphere and bisophere. Research and monitoring is defined within the programme ENVISON (Enviromental Research and Monitoring SONNBLICK).**

Essential Climate Variables – Atmospheric Observations - Composition

Parameter measured/observed	Meteorological parameters: air temperature, relative humidity resp. dew point temperature, precipitation, snow depth, air pressure, global radiation, direct beam solar radiation, wind speed, wind direction, sun shine duration, electrical field strength, cloud cover, visibility, direct radiation, diffuse radiation, longwave radiation form the atmosphere, spectral UV, total column ozone, UV-B Greenhouse gases: CH_4, CO_2 Ozone: surface ozone Selected reactive gases: CO, NO, NO_x, NO_2, SO_2 Aerosols: particulate mass concentration, mass concentration of major chemical components, particle number concentration, particle number size distribution, light absorption coefficient, light scattering coefficient Radioactivity: ambient dose rate, Radon-222, BE-7 Precipitation Chemistry: Hydrogen ion (H+) or pH in precipitation, electrical conductivity, inorganic anions, inorganic cations Permafrost: temperature in different layers Glaciology: mass change, meteorological data, outflow rate, snow coverage
Starting date	Main periods of measurements: Meteorological parameters: 1886 – ongoing Greenhouse gases: 2012 - ongoing Ozone: 1989 - ongoing Selected reactive gases: 2002 - ongoing Aerosols: 2010 - ongoing Radioactivity: 1984 - ongoing Precipitation Chemistry: 1987 - ongoing Permafrost: 2007 - ongoing Glaciology: 1896 - ongoing
Temporal Resolution	Different temporal resolution depending on the global data centre in the frame of GAW, mostly 10 min and monthly
Observational Network	Long term series of the Alpine region
Stations	One station, Sonnblick Observatory, also includes glacier observations from Pasterze
Data Portal	Not yet, data can be retrieved via the world data centre, PANGAEA or via the Sonnblick Observatory
Supervising Organization	ZAMG

National and/or international Networks or Programs	NDACC, WMO-GAW, WMO-GCW, BSRN, ARAD, WMO-GTS, LTER, HISTALP
Data Submission	Yearly submission to the world data centre in the frame of GAW
Licenses	No, free of charge for research, DOI (digital object identifier) is planned
Use Limitation	for non-profit research only
Data Format	Different data formats possible, mostly csv
Data Access	Access by registration planned so far no open access, only via personal contact or via the global data centre in the frame of GAW
Data Quality	The data quality control is done by the ZAMG and also directly at the Sonnblick Observatory and its partner institutions like TU-Vienna, Umweltbundesamt or BOKU-Vienna. The data quality control also follows restriction of GAW, NDACC and BSRN.
Performance Monitoring	data availability is supervised by ZAMG, but also depends on the partner institutions
Publications	online-data at www.sonnblick.net report of the association Sonnblick Verein every second year yearly data report planned from 2018 on
Contact (National correspondent, focal point)	Common contact: dion@zamg.ac.at Direct Contact to the Sonnblick Observatory: elke.ludewig@zamg.ac.at
Remarks	The Sonnblick Observatory is organized by the ZAMG but a couple of national institutions having instruments at the Sonnblick Observatory for long-term measurements contributing the Sonnblick Observatory data set.



Terrestrial Observations

Hydrosphere

eHYD

Viktor Weilguni (BMLFUW)

The hydrological service ("Hydrographischer Dienst") in Austria operates a modern hydrometrical network for the quantification of the water cycle in Austria. The monitoring network consists of about 800 discharge, 900 precipitation and 3800 groundwater stations. All data on the water cycle in Austria are collected, quality checked and disseminated by the hydrological service. The data accessibility is guaranteed by the platform eHYD.

eHYD is a platform to provide data for all interested users http://ehyd.gv.at/. The data are free of charge - provided the sources are acknowledged – and for non-profit research.

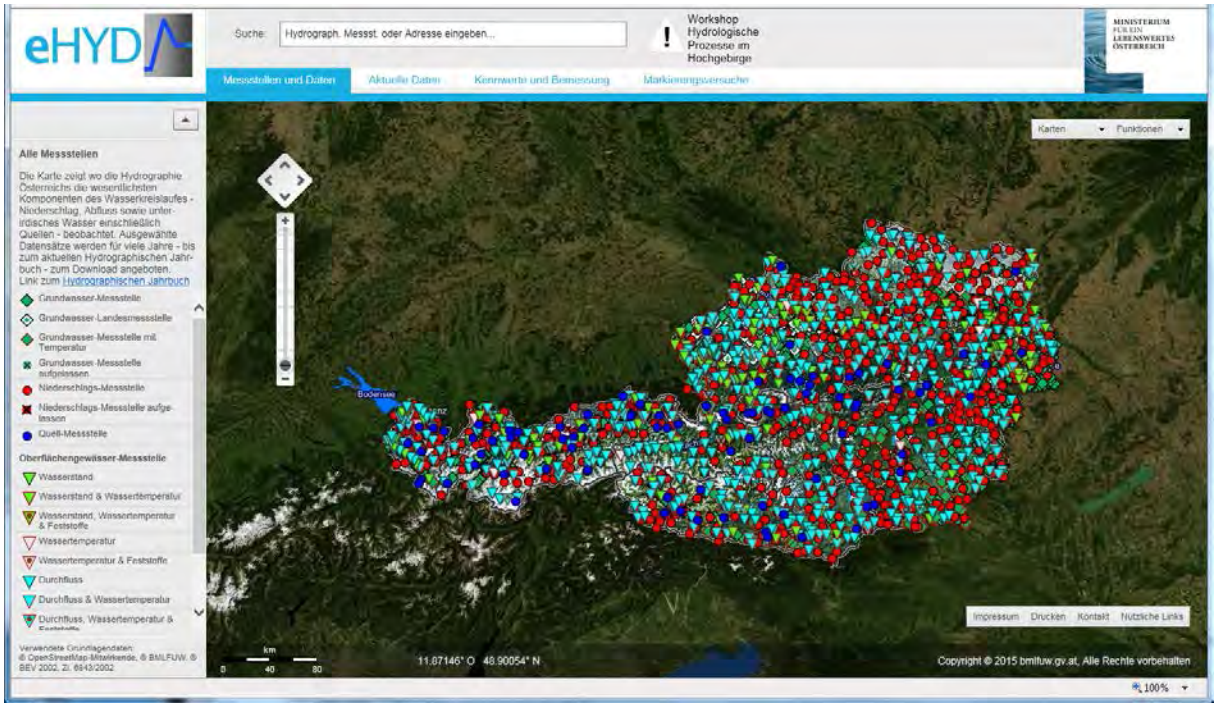


Figure 32 Overview of the stations

Essential Climate Variables - Terrestrial Observations - Hydrosphere

Parameter measured/observed	precipitation, new snow depth, snow depth discharge, water level groundwater level, groundwater temperature
Starting date	precipitation, new snow depth, snow depth: 1971 discharge, water level: earliest time series 1950 groundwater level, groundwater temperature: earliest time series 1966
Temporal Resolution	precipitation, new snow depth, snow depth and discharge, water level: daily data groundwater level, groundwater temperature: monthly data

Observational Network	Hydrological service (“Hydrographischer Dienst”) and other national data providers. precipitation, new snow depth, snow depth: without the ZAMG-network
Stations	precipitation, new snow depth, snow depth about 900 stations in Austria discharge, water level: about 800 stations in Austria groundwater level, groundwater temperature: about 3800 stations in Austria
Data Portal	http://ehyd.gv.at/ “Messstellen und Daten” precipitation, new snow depth, snow depth: “Niederschlag” discharge, water level: “Oberflächengewässer“ groundwater level, groundwater temperature: ”Grundwasser”
Supervising Organization	Federal Ministry of Agriculture, Forestry, Environment and Water Management Division IV/4, Water Balance
National and/or international Networks or Programs	
Data Submission	The data are updated once a year
Licenses	Free of charge, provided the sources are acknowledged CC-BY-NC
Use Limitation	For non-profit research
Data Format	Download of the data as ASCII csv
Data Access	Download via the eHYD-homepage http://ehyd.gv.at/ Open access
Data Quality	Data quality control is done by the hydrological service (“Hydrographischer Dienst”)
Performance Monitoring	Data availability is supervised by the Federal Ministry of Agriculture, Forestry, Environment and Water Management Division IV/4, Water Balance
Publications	Yearbook (once a year) – an overview of the behaviour of the data in the (yearbook) year in relation to the long term mean values
Contact (National correspondent, focal point)	Contact: Division IV/4, Water Balance: wasserhaushalt@bmlfuw.gv.at
Remarks	

Tuxer Alps

Reinhard Fromm (BFW)

The units 'Snow and Avalanches' and 'Torrent Processes and Hydrology' of the Department of Natural Hazards operate 6 stations in the Tuxer Alps with different configurations. The main objectives are investigations of the hydrological processes in the catchment and themes concerning the snowpack and snow avalanches. Depending on research questions of projects the configurations of the stations changed and they will be adapted to fit the requirements in future. In this context additional data acquisitions were performed (automated terrestrial laser scanning – spatial distribution of snow; photogrammetry with images taken by remotely piloted systems – snow depth maps and orthophotos).

Essential Climate Variables - Terrestrial Observations - Hydrosphere

Parameter measured/observed	air temperature, humidity, wind speed and direction, gusts, global radiation, reflected shortwave radiation, incoming outgoing longwave radiation precipitation, river discharge, snow height, snow water equivalent, snow temperatures, snow surface temperature, soil temperatures
Starting date	different, first data February 2006
Temporal Resolution	1 min, 10 min It depends on the station and parameter.
Observational Network	long term data acquisition of the Institute of Natural Hazards
Stations	Tarntalerboden, Lizumerboden, Snowpillow, Lizumbach, Mölsbach, Finkenberg
Data Portal	no
Supervising Organization	Department of Natural Hazards, Austrian Research Centre for Forests (BFW)
National and/or international Networks or Programs	Hydrological data are used by the Hydrological Service. Snow and weather data are used by the Avalanche Warning Service.
Data Submission	automatic data collection: intervals 2 - 4 hours
Licenses	different, depending on work contracts
Use Limitation	different, depending on work contracts
Data Format	csv
Data Access	restricted
Data Quality	simple automatic quality check
Performance Monitoring	Data availability is supervised by BFW.

Publications	Data were used in several publications concerning snow avalanche research and hydrological investigations.
Contact (National correspondent, focal point)	reinhard.fromm@bfw.gv.at gerhard.markart@bfw.gv.at
Remarks	Additional data acquisitions were carried out in the test site. This includes terrestrial laser scanning and photogrammetry which uses images taken with remotely piloted systems. Results are snow depth maps, spatial snow depth changes, depositions of snow avalanches, orthophotos, landslides, etc.

Torrent Research Areas – Monitoring data

Ulrike Stary (BFW)

Since the beginning of settlements in the alpine space, natural hazards such as torrents have been a major threat to human beings. Increasing conflicts between natural geophysical processes and increasing human demands on natural resources require improved protection strategies and protection measures. Occurrence probability and potential impacts of this risk in terms of damages to property define the degree of the risk. Natural hazards cannot be totally avoided through targeted countermeasures but certain risk management strategies and actions may be derived thereof: prevention before, reaction during and rebuilding after the disaster.

Data for process analyses are collected within monitoring systems implemented in torrent research areas. These are equipped with a large number of measuring instruments. For nearly 50 years the Department of Natural Hazards of the BFW has been engaged in research in the Alpine region recording measuring data at extreme sites. Data series of this duration provide also a good insight into the evolution of climate parameters. Extrapolations derived from it are suitable for comparison with results from climate change models or supplement them with regard to their informative value. This is useful because climate change models describe a simplified picture of reality based on the size of the data grid they use.

Figure 33 Location of the Torrent Research Areas (TORA)

Essential Climate Variables - Terrestrial Observations - Hydrosphere

Parameter measured/observed	precipitation, air temperature, wind speed and direction, humidity, snow height and water equivalent, global radiation river discharge, groundwater (level and temperature)
Starting date	earliest time series in 1969
Temporal Resolution	5 min, 15 min, 1 hour, daily, weekly, depending on parameters
Observational Network	long term series of the Alpine region and Alpine lowland from BFW
Stations	about 20 stations located in Lower Austria and Carinthia
Data Portal	no
Supervising Organization	Department of Natural Hazards, Austrian Research Centre for Forests (BFW)
National and/or international Networks or Programs	no
Data Submission	daily GSM calls, weekly data transmissions of Excel files
Licenses	different, depending on work contracts
Use Limitation	different, depending on work contracts
Data Format	text, .mis, .xlsx, access, ascii
Data Access	restricted
Data Quality	Data quality control is done by employees of BFW.
Performance Monitoring	Data availability is supervised by BFW.
Publications	BFW reports, (former: FBVA reports)
Contact (National correspondent, focal point)	Contact: erich.lang@bfw.gv.at
Remarks	

ISMN - In situ soil moisture observations

Wouter Dorigo (TU Wien), Angelika Xaver (TU Wien)

Since 2010, the International Soil Moisture Network (ISMN; http://ismn.geo.tuwien.ac.at) is being developed, hosted, and operated by TU Wien. It acts as a data repository for ground-based soil moisture observations. Soil moisture measurements are collected from individual networks and data providers distributed all over the globe. The collected observations are highly diverse. They result not only from different measurement principles, but also their format, structure and means of provision are inhomogeneous. Within a fully automated processing chain the datasets are harmonized with respect to measurement unit, temporal resolution, and data format. Advanced quality control procedures are an essential part of the processing algorithms, assigning quality indicators to each single observation. The harmonized observations are visualized in a web portal where they become available for download to registered users.

At present, 57 networks consisting of 2260 stations are part of the ISMN (Figure 32). Due to the fact that each network is organised individually the datasets vary in observation depth, ancillary metadata and available time span. Data availability ranges from historical observations starting in 1952 to recent measurements measured only a few days ago. In addition to soil moisture, other climate variables such as air temperature, soil temperature, precipitation, snow depth, and snow water equivalent are provided through the ISMN (Figure 33).

The primary goal of the ISMN is to provide reference data for satellite product validation, e.g. for the operational Copernicus Climate Change Service (C3S; http://climate.copernicus.eu/) and Copernicus Global Land Service (http://land.copernicus.eu/global/index.html), the Climate Change Initiative (http://www.esa-soilmoisture-cci.org/) and SMOS mission (http://www.catds.fr/) of the European Space Agency (ESA), and the operational soil moisture products produced by EUMETSAT (http://hsaf.meteoam.it/; https://www.eumetsat.int/website/home/Data/Products/Land/). For many years, these services have had a strong involvement of Austrian research institutes, public services, universities, and private companies.

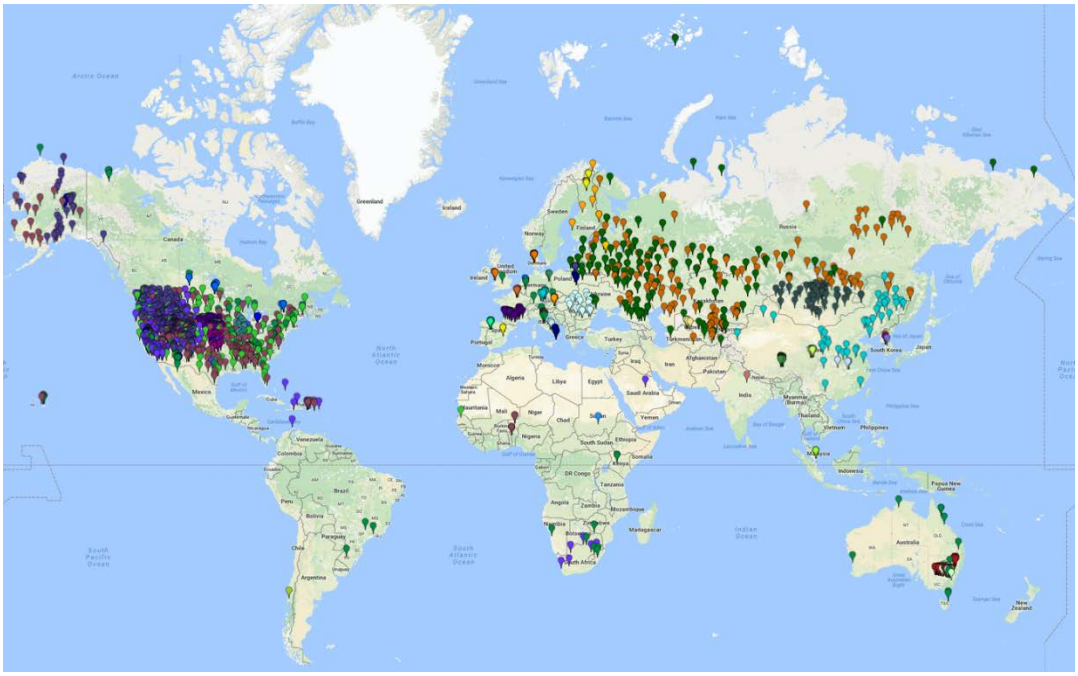


Figure 34 Overview of stations contained in the ISMN.

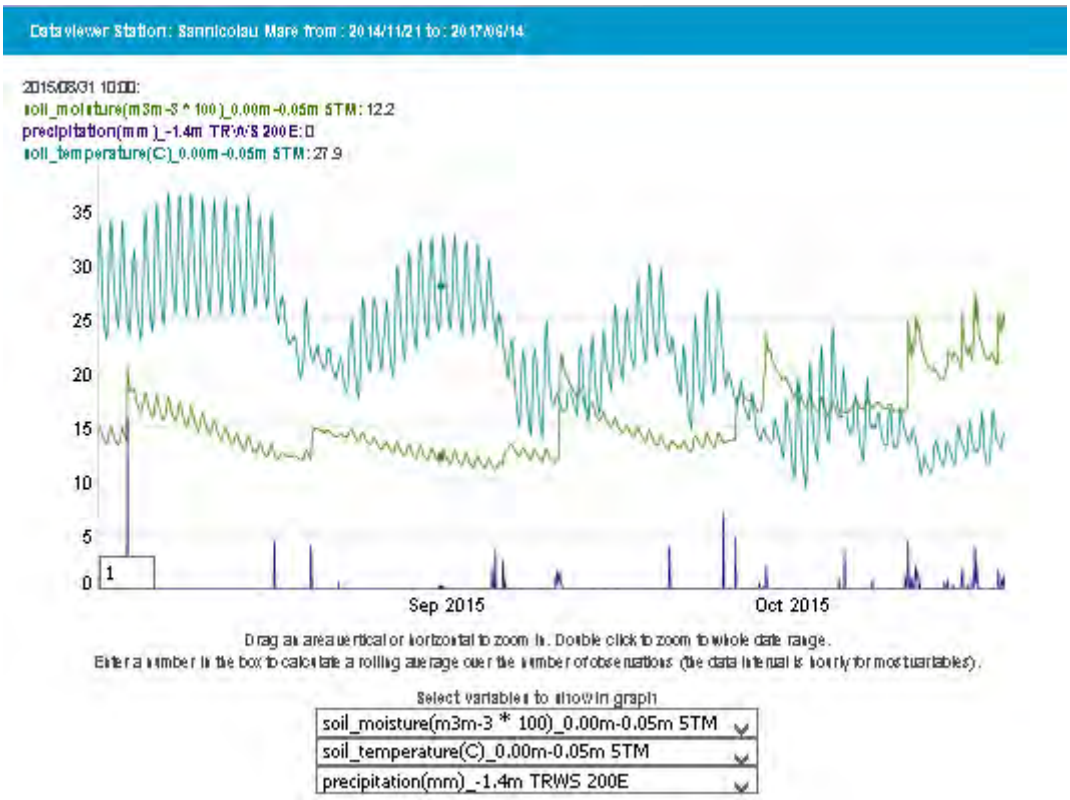


Figure 35 **Example of soil moisture, soil temperature and precipitation data of a Romanian station, visualized through the ISMN data viewer.**

Essential Climate Variables - Terrestrial Observations - Hydrosphere

Parameter measured/observed	Soil moisture
Starting date	Earliest observations from 1952
Temporal Resolution	1 hour (~1 week for earliest observations)
Observational Network	Various individual data providers and networks (>50)
Stations	2260 (globally distributed)
Data Portal	http://ismn.geo.tuwien.ac.at/
Supervising Organization	TU Wien
National and/or international Networks or Programs	ISMN, currently sponsored by ESA Earth Observation Program SMOS (funding guaranteed until December 31st 2017)
Data Submission	Variable, ranging from irregular updates approximately once a year to automated daily updates, using various data exchange protocols (email, ftp, https, etc.)

Licences	Free of charge, data origin shall be acknowledged and referenced (see http://ismn.geo.tuwien.ac.at/terms-and-conditions/)
Use Limitation	For scientific use only
Data Format	Downloaded datasets are provided in text format
Data Access	Access by registration
Data Quality	All datasets implemented in the ISMN have to run through a series of automated quality control procedures. Each observation is then associated by a quality indicator (see also http://ismn.geo.tuwien.ac.at/data-access/quality-flags/).
Performance Monitoring	Supervised by TU Wien, although data availability depends on the individual data providers.
Publications	A list of relevant publications can be found online: http://ismn.geo.tuwien.ac.at/publications/
Contact (National correspondent, focal point)	Wouter Dorigo: wouter.dorigo@tuwien.ac.at
Remarks	

ASCAT surface soil moisture data records

Alexander Jann (ZAMG)

In the framework of the Satellite Application Facility on Support to Operational Hydrology and Water Management (http: //hsaf.meteoam.it), several soil moisture products are generated on a regular basis and distributed to users. Among them are Climate Data Records (CDR) of Surface Soil Moisture (i.e. in the topmost soil layer, < 5 cm). These soil moisture CDRs are derived from Level 1b data provided by the Advanced Scatterometer (ASCAT) on-board the series of Metop satellites. ASCAT is a radar instrument operating in C-band and measuring the backscatter coefficient. Two Metop satellites (Metop-A and Metop-B) are currently in the same sun-synchronous 29-day repeat cycle orbit, shifted by half an orbital period (approximately 51 minutes). The third and last Metop satellite (Metop-C) is planned to be launched in 2018, which will replace Metop-A.

The TU Wien soil moisture retrieval algorithm (TUW-SMR) [1, 2] is used to derive relative surface soil moisture information from the Metop ASCAT backscatter measurements. The retrieval represents a physically-based change detection method. The TUW-SMR uses long-term backscatter measurements (> 10 years) to model the incidence angle dependency of backscatter, which allows to normalize backscatter to be normalized to a common reference incidence angle. The relative surface soil moisture estimates range between 0 % (completely dry) and 100 % (completely saturated) and are derived by scaling the normalized backscatter between the lowest/highest backscatter values corresponding to the driest/wettest soil conditions.

Metop ASCAT Level 1b products with a spatial sampling of 12.5 km are used as input. A new soil moisture CDR is processed each year containing the complete soil moisture history. One of the main

differences between two consecutive CDRs is one year of additional data in the latest CDR. Depending on the version of the algorithm and the version of the level-1 input data, soil moisture in the time period covered by both CDRs can also be different. In general, CDRs are never exactly the same, because empirical model parameters (as part of the soil moisture retrieval algorithm) are derived from the complete history of level 1 input data and therefore change from one CDR to the next.

Offline products CDR-EXT are extending the soil moisture CDRs: Since a CDR is a self-contained data set and it is not foreseen to manipulate the data retrospectively, an offline product is generated and extends the original CDR. It is important to use the same version of soil moisture retrieval algorithm and level-1 input data to get a compliant offline product. Therefore, offline products have to be based on the same empirical model parameters as the respective CDR. The processing of an offline product is maintained until a new CDR release supersedes the extension. Figure 34 illustrates the relationships between the CDR variants.

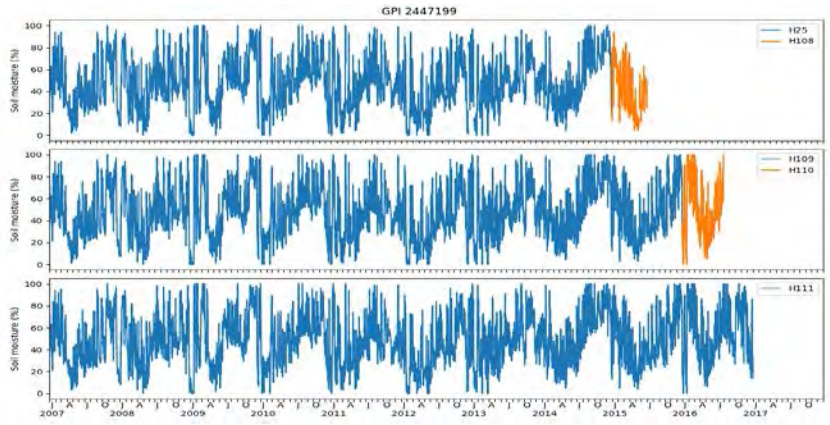


Figure 36 Soil moisture time series for CDR (blue) and CDR-EXT(orange) products for the same grid point at three different points in time.

References:

[1] W. Wagner, G. Lemoine, and H. Rott, "A method for estimating soil moisture from ERS scatterometer and soil data," *Rem.Sens.Environ.*, **70,** 191–207 (2009).

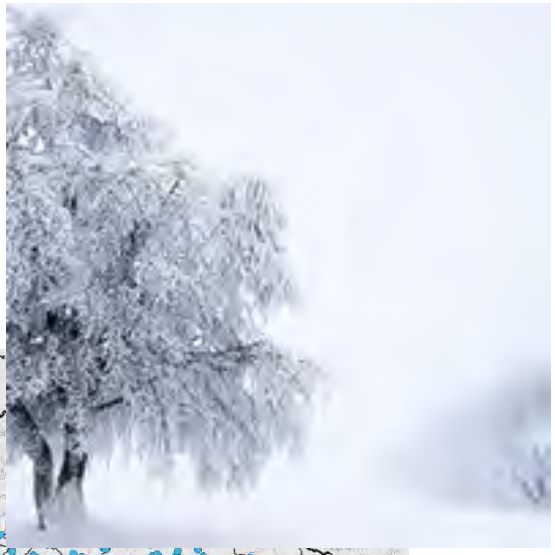
[2] V. Naeimi, K. Scipal, Z. Bartalis, S. Hasenauer, and W. Wagner, "An Improved Soil Moisture Retrieval Algorithm for ERS and METOP Scatterometer Observations," *IEEE Trans. Geosci. Remote Sensing*, **47,** 1999–2013 (2009).

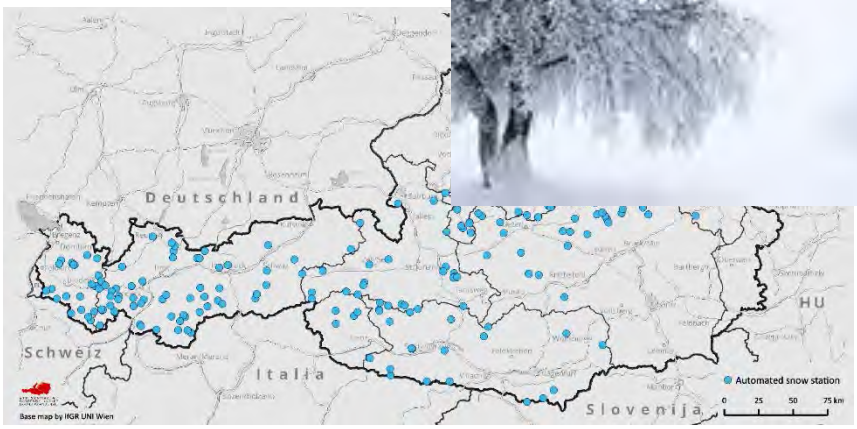
Source: S. Hahn, T. Melzer, S. Elefante (2017): „Product User Manual (PUM): Metop ASCAT Soil Moisture CDR and offline products". Project documentation, EUMETSAT Satellite Application Facility on Support to Operational Hydrology and Water Management, revision 0.6.

Essential Climate Variables - Terrestrial Observations - Hydrosphere

Parameter measured/observed	surface soil moisture
Starting date	1.1.2007
Temporal Resolution	variable, depending on satellite orbit geometry and location on the earth
Observational Network	Metop satellites
Stations	

Data Portal	http: //hsaf.meteoam.it
Supervising Organization	TU Wien
National and/or international Networks or Programs	EUMETSAT Satellite Application Facility on Support to Operational Hydrology and Water Management
Data Submission	yearly via ftp.
Licenses	
Use Limitation	
Data Format	netCDF
Data Access	Access by registration
Data Format	netCDF
Data Access	Access by registration
Data Quality	
Performance Monitoring	
Publications	
Contact (National correspondent, focal point)	
Remarks	





Terrestrial Observations

Cryosphere

SNOW

Annett Bartsch (ZAMG, b.geos GmbH), Helmut Rott (ENVEO),
Gabriele Schwaizer (ENVEO), Koch Roland (ZAMG)

Snow parameters which are regularly obtained are snow height, snow water equivalent and snow covered area. The first two are obtained in situ, the latter by remote sensing methods. Snow height measurements are available since the end of the 19th century for several stations.

Standard measurements include snow depth, while advanced records also provide Snow water equivalent (SWE) and snow temperature. Based on the existing TAWES network from ZAMG with about 260 stations, 74 stations contribute to regular, quality controlled snow monitoring of snow depth. Measurements are available from 723 further sites which are maintained by local authorities (HD – Hydrografischer Dienst) and distributed via the eHyd portal on a federal level. Additional records are collected by the avalanche services. This comprises additional parameters and locations.

SWE measurements are obtained regularly at 54 sites. 48 are part of the HD network (weekly intervals), and four are maintained by the avalanche warning services (15 minutes intervals). In addition, a published record of SWE and snow temperatures by the TIWAG-Tiroler Wasserkraft AG is available for the Kühtai station in Tyrol, starting in 1990. The BFW (Bundesforschungszentrum für Wald) maintains an experimental site at Lizum/Walchen in Tyrol.

An annual summary of the records is published by the section 'Wasserhaushalt' (HZB) of the BMLFUW. This includes averages, maxima and snow cover duration.

Satellite snow coverage fraction maps are regularly available since 2000 and are updated as part of the Copernicus services. Daily maps with 1 km spatial resolution are disseminated via the CryoLand Portal. They are currently based on MODIS records and will soon be extended with records from Sentinel-3 SLSTR/OLCI.

Snow water equivalent records:

- Hydrographical Central Bureau (HD; since 01.12.1980)
- Avalanche warning services (Salzburg: since 07.10.2008, Styria: since 17.11.2010)
    - Hinterwildalpen
    - Maria Alm
    - Neukirchen/Wildkogel
    - Lawinenstein (2010-2012)
    - Wildalpen/Siebensee
- TIWAG: Kühtai, since 1990
- BFW: Lizum/Walchen
- Municipal Department 31 – Vienna Water (MA 31 Wiener Wasser): since 21.01.2016

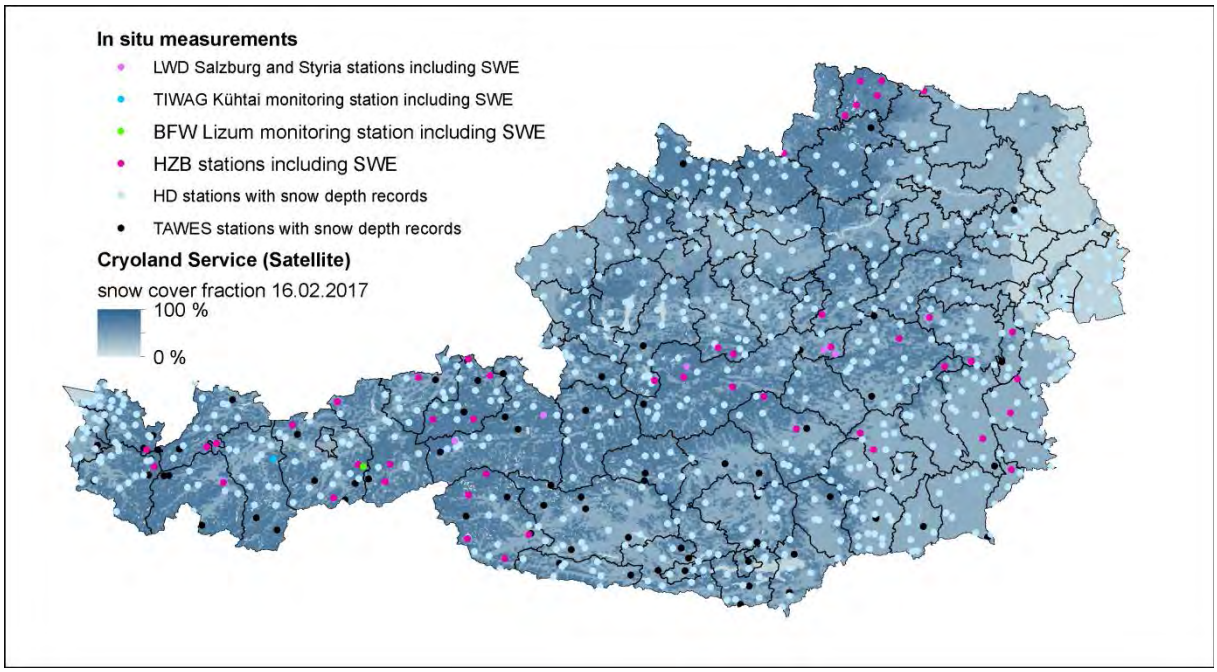


Figure 37 Overview of the stations.

Essential Climate Variables - Terrestrial Observations - Cryosphere

Parameter measured/observed	Snow height
Starting date	manual observation since 01.01.1911 at 13 stations automatic measurements since 3.11.2004
Temporal Resolution	daily
Observational Network	TAWES, eHYD
Stations	74 stations as part of the TAWES network. 723 HD – Hydrografischer Dienst
Data Portal	ehyd.gv.at www.zamg.ac.at/cms/de/klima/messnetze/wetterstationen
Supervising Organization	ZAMG BMLFUW – Abteilung VII/3 – Wasserhaushalt
National and/or international Networks or Programs	TAWES, eHYD
Data Submission	automatic
Licenses	eHYD: CC-BY-NC TAWES: general ZAMG data conditions
Use Limitation	Varying, partly for research only

Data Format	csv
Data Access	Varying, partially restricted
Data Quality	Data quality under the responsibility of the individual institutions providing the data.
Performance Monitoring	Regularity by ZAMG, regularity by HD
Publications	
Contact (National correspondent, focal point)	eHyd: wasserhaushalt@bmlfuw.gv.at TAWES: roland.potzmann@zamg.ac.at
Remarks	

Essential Climate Variables - Terrestrial Observations - Cryosphere

Parameter measured/observed	Fractional Snow Cover Extent
Starting date	01.11.2000
Temporal Resolution	Daily
Observational Network	Terra MODIS / NPP VIIRS (backup) in future: Sentinel-3 SLSTR/OLCI
Stations	
Data Portal	http://neso1.cryoland.enveo.at/cryoclient/ http://cryoportal.enveo.at/ in future: http://land.copernicus.eu/global/products/sce
Supervising Organization	ENVEO IT GmbH
National and/or international Networks or Programs	EU FP7 project CryoLand (No. 262925, 2011 – 2015, lead: ENVEO) Copernicus Land Monitoring Service – Cryosphere (snow cover extent under lead of ENVEO)
Data Submission	Automated daily product generation and upload on server via FTP
Licenses	CC BY ENVEO NC ND Further details: http://cryoportal.enveo.at/disclaimer/
Use Limitation	For research only Further details: http://cryoportal.enveo.at/disclaimer/
Data Format	GeoTIFF, NetCDF, JPEG2000, HDF-4

Data Access	Open Access
Data Quality	Intensive validation activities since the EU FP7 project CryoLand (2011 – 2015), where this product was developed. Product participated in the ESA QA4EO project SnowPEx - Satellite Snow Product Intercomparison and Evaluation Exercise (2014 – 2016, lead: ENVEO). Product Validation Report prepared by ENVEO for the Copernicus Global Land Monitoring Service is available at http://land.copernicus.eu/global/products/sce. Daily uncertainty layer, providing unbiased Root Mean Square Error per pixel (available at http://neso1.cryoland.enveo.at/cryoclient/)
Performance Monitoring	Daily, automated procedure
Publications	Project related reports and documents Scientific publications on snow and ice parameters retrieved by means of remote sensing
Contact (National correspondent, focal point)	Thomas Nagler: thomas.nagler@enveo.at Gabriele Schwaizer: gabriele.schwaizer@enveo.at Helmut Rott: helmut.rott@uibk.ac.at
Remarks	

Essential Climate Variables - Terrestrial Observations - Cryosphere

Parameter measured/observed	Snow water equivalent, Snow temperature
Starting date	TIWAG: Kühtai 1990 Avalanche warning service, Salzburg: since 07.10.2008 Avalanche warning service, Styria: since 17.11.2010 Municipal Department 31 – Vienna Water (MA 31 Wiener Wasser): since 21.01.2016 Hydrographical Central Bureau, Tyrol: since 01.12.1980 BFW: Lizum, since February 2006
Temporal Resolution	TIWAG: Kühtai 15 min Avalanche warning service /MA 31: 10 min Hydrographical Central Bureau, Tyrol: weekly
Observational Network	

Stations	TIWAG: Kühtai Avalanche warning service /MA 31: Hinterwildalpen, Maria Alm, Neukirchen/Wildkogel, Lawinenstein, Wildalpen/Siebensee Hydrographical Central Bureau, Tyrol: 24 stations in Tyrol BFW: Lizum
Data Portal	TIWAG: Kühtai http://onlinelibrary.wiley.com/store/10.1002/2017WR020445/asset/supinfo/wrcr22701-sup-0002-2017WR020445-ds01.txt?v=1&s=7df0aeb235e5329a292b92b12fcd8fc769e55c62
Supervising Organization	TIWAG-Tiroler Wasserkraft AG, Hydropower planning department, Innsbruck, Austria Avalanche warning service, Salzburg, Austria Avalanche warning service, Styria, Austria Municipal Department 31 – Vienna Water Hydrographical Central Bureau of Austria BFW-Austrian Research Center for Forests
National and/or international Networks or Programs	
Data Submission	Technical report, once
Licenses	CC BY, BFW: depending on work contracts
Use Limitation	BFW: depending on work contracts
Data Format	csv
Data Access	Open BFW: restricted
Data Quality	
Performance Monitoring	TIWAG Avalanche warning service, Salzburg, Austria Avalanche warning service, Styria, Austria Municipal Department 31 – Vienna Water Hydrographical Central Bureau of Austria BFW- Austrian Research Center for Forests
Publications	
Contact (National correspondent, focal point)	Global Cryosphere Watch - Focal Point Annett Bartsch: annett.bartsch@zamg.ac.at
Remarks	

Glaciers

Annett Bartsch (ZAMG, b.geos GmbH), Andrea Fischer (IGF),
Fabien Maussion (Universität Innsbruck), Helmut Rott (ENVEO), Gabriele Schwaizer (ENVEO),
Bernhard Zagel (Universität Salzburg)

More than 900 glaciers have been identified within the Austrian Alps. Their properties are continuously monitored by in situ observations as well as remote sensing methods. This is achieved by a combined effort on national level between a range of organizations including universities, research institutions, associations, companies and local authorities. These activities are embedded into international efforts such as the World Glacier Monitoring Service. In situ observations require a substantial amount of man power. The use of automatized methods is limited. Volunteers therefore substantially contribute to the glacier service of the Austrian Alpine Club. Currently, the length of 92 glaciers is measured. Length measurement started already in 1867. Data are reported to GTN-P and an annual report is published as part of the regular bulletins of the Alpine Club. Mass balance measurements have started on Hintereisferner in 1952/53, with a continuous increase of sites since the 1960s. All records demonstrate a declining trend in length, area and mass. Overall only 10 % of all glaciers in Austria are monitored by length measurements and 1 % by actual mass balance retrievals. An annual summary of length and mass balance records is published by the section 'Wasserhaushalt' (HZB) of the BMLFUW.

Satellite and airborne data complement the ground measurements. Glacier covered area is obtained at irregular intervals, depending on data availability. These inventories are part of international initiatives such as the Randolph glacier inventory and the Climate Change Initiative of the European Space Agency. Monitoring efforts expand beyond the boundaries of Austria due to the long history of glacier research in Austria. Austria contributes actively to Copernicus services, providing measurements also for Greenland and Antarctica. This includes additional parameters such as velocity and grounding lines where they terminate in water.

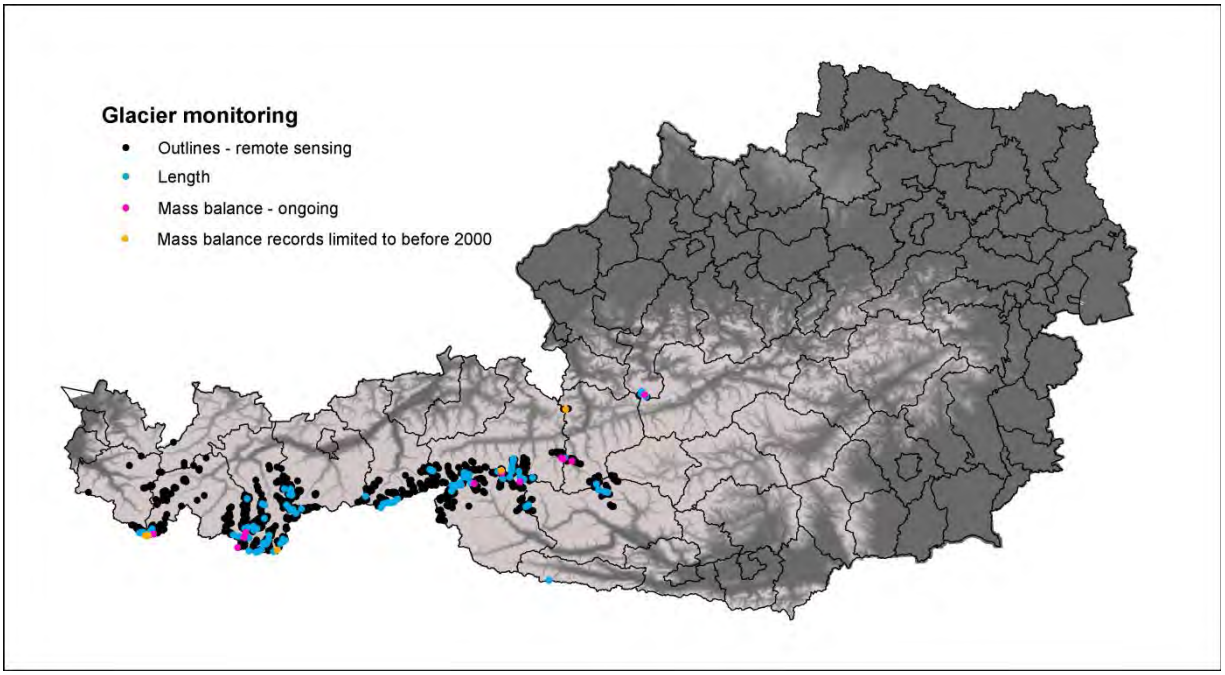


Figure 38 Overview of monitored glaciers

The role of terrestrial remote sensing methods by automatic cameras is increasing. Three glaciers in the Hohe Tauern Region (Kleinfleisskees, Goldbergkees, Pasterze) are currently included in an automatic monitoring network. Hintereisferner is, in addition to traditional methods, monitored by a fix Terrestrial Laser Scan system since autumn 2016.

Figure 39 Webcam photograph of Kleinfleisskees near the Sonnblick Observatory in the Hohe Tauern region.

List of glaciers with mass balance records

Hintereisferner (since 1952/53)
Kesselwandferner (since 1952/53, with change in method in 1966)
Stubacher Sonnblick Kees (since 1963/64), also LTER Oberes Stubachtal
Vernagtferner (since 1970/71)
Wurtenkees (since 1982/83)
Goldbergkees (since 1986/87)
Jamtal Ferner (since 1988/89), also LTSER Tyrolean Alps
Kleinfleiss Kees (since 1998/99)
Hallstätter Gletscher (since 2006/07)
Mullwitz Kees (since 2006/07)
Pasterze (since 2012/13)
Venediger Kees (since 2012/13)

Langtaler Ferner (1963-1970)
Übergossene Alm (1964-1975)
Filleck Kees(1964-1980)
Vermuntgletscher (1991-1999)
Ochsentaler Gletscher (1991-1999)

Essential Climate Variables - Terrestrial Observations - Cryosphere

Parameter measured/observed	Glacier mass balance
Starting date	varied
Temporal Resolution	Annual, seasonal
Observational Network	Worldwide network of monitored glaciers
Stations	Hintereisferner (since 1952/53) Kesselwandferner (since 1952/53, with change in method in 1966) Stubacher Sonnblick Kees (since 1963/64), also LTER Oberes Stubachtal Vernagtferner (since 1970/71) Wurtenkees (since 1982/83) Goldbergkees (since 1986/87) Jamtal Ferner (since 1988/89), also LTSER Tyrolean Alps Kleinfleiss Kees (since 1998/99) Hallstätter Gletscher (since 2006/07) Mullwitz Kees (since 2006/07) Pasterze (since 2012/13) Venediger Kees (since 2012/13) Langtaler Ferner (1963-1970) Übergossene Alm (1964-1975) Filleck Kees(1964-1980) Vermuntgletscher (1991-1999) Ochsentaler Gletscher (1991-1999)
Data Portal	www.gtn-g.ch
Supervising Organization	WGMS, http://wgms.ch/
National and/or international Networks or Programs	GTN-G WGMS
Data Submission	Annual, after the official WGMS “call for data”
Licenses	No formal license. Website says (citation): “Rights: Open access for scientific and educational purposes under requirement of correct citation” Source: http://wgms.ch/data_databaseversions
Use Limitation	For research only
Data Format	csv

Data Access	open access
Data Quality	Data quality under the responsibility of the individual institutions providing the data. Minimal quality check by the WGMS itself.
Performance Monitoring	NA
Publications	
Contact (National correspondent, focal point)	Andrea Fischer Institut für Interdisziplinäre Gebirgsforschung, Österreichische Akademie der Wissenschaften andrea.fischer@oeaw.ac.at
Remarks	

Essential Climate Variables - Terrestrial Observations - Cryosphere

Parameter measured/observed	Length of glaciers
Starting date	1969 (selected locations from 1867)
Temporal Resolution	Annual
Observational Network	Gletschermessdienst Alpenverein
Stations	92 glaciers
Data Portal	www.gtn-g.ch
Supervising Organization	Alpenverein
National and/or international Networks or Programs	World Glacier Monitoring service (WGMS), GTN-P Global terrestrial network on glaciers CCCA Ö-Kryonet
Data Submission	Annually by members of the association, via email)
Licenses	No formal license.
Use Limitation	
Data Format	Print and pdf copy of data table Csv via WGMS

Data Access	open access
Data Quality	Basic quality check by Gletschermessdienst
Performance Monitoring	NA
Publications	ÖAV-Gletscherbericht, als Teil des Magazins Bergauf http://www.alpenverein.at/portal/museum-archiv/gletschermessdienst/archiv-gletscherberichte/archiv-gletscherberichte.php
Contact (National correspondent, focal point)	Andreas Kellerer-Pirklbauer: andreas.kellerer@uni-graz.at
Remarks	

Essential Climate Variables - Terrestrial Observations - Cryosphere

Parameter measured/observed	Glacier outlines/extent, glacier facies, ice surface velocity, calving fronts, grounding lines
Starting date	Depends on parameter and available satellite data per region. Earliest products are from satellite images of the 1990s.
Temporal Resolution	Depends on the availability of satellite imagery. GLO/GLS/GLF/CF/GLL: (multi-)annually IV: 6-days since 2017, 12-days since 2014, monthly/seasonally/(multi-)annually before 2014 (depending on region).
Observational Network	NA
Stations	Satellite sensors: Sentinel-2 MSI, Landat 5 TM / 7 ETM+ / 8 OLI, SPOT-5 HRG, Sentinel-1 A/B C-SAR, TerraSAR-X, ERS-1/2
Data Portal	http://cryoportal.enveo.at/ http://neso1.cryoland.enveo.at/cryoclient/ (viewing service only for glacier outlines) Partially related: GLIMS Randolph Glacier Inventory, archived by the National Snow and Ice Data Center (NSIDC). https://www.glims.org/RGI/rgi60_dl.html
Supervising Organization	ENVEO IT GmbH for CryoPortal
National and/or international Networks or Programs	See remarks

Data Submission	Frequency of data submission depends on parameter and available data base (ranges between weekly and multi-annually updates). Upload on CryoPortal server via FTP
Licenses	CryoPortal :CC BY ENVEO NC ND Further details: http://cryoportal.enveo.at/disclaimer/
Use Limitation	CryoPortal: For research only Further-details: http://cryoportal.enveo.at/disclaimer/
Data Format	GeoTIFF, ESRI Shapefile (depending on parameter)
Data Access	open access
Data Quality	CryoPortal : Evaluation and intercomparison activities performed and documented within several ESA projects. GLIMS: Minimal quality check. Data quality under the responsibility of the individual institutions providing the data.
Performance Monitoring	Automated controlling of data on CryoPortal by ENVEO
Publications	CryoPortal : Project related reports and documents Scientific publications on snow and ice parameters retrieved by means of remote sensing
Contact (National correspondent, focal point)	CryoPortal : Thomas Nagler: thomas.nagler@enveo.at Gabriele Schwaizer: gabriele.schwaizer@enveo.at Helmut Rott: helmut.rott@uibk.ac.at GLIMS (Austrian Alps): Helmut Rott: helmut.rott@uibk.ac.at
Remarks	Related initiatives/funding sources: EU FP7 project CryoLand (No. 262925, 2011 – 2015, lead: ENVEO) ESA Glaciers CCI (Phase 1: 2010 – 2013; Phase: 2 2015 – 2018) ESA Greenland Ice Sheet CCI (Phase 1: 2012 – 2014; Phase 2: 2015 – 2018) ESA Antarctic Ice Sheet CCI (2015 – 2018)

Essential Climate Variables - Terrestrial Observations - Cryosphere

Parameter measured/observed	Rock glacier Surface motion, hydrology (well temperature, isotopes)
Starting date	1920
Temporal Resolution	Annual to multiannual
Observational Network	Austrian Rockglacier Measurement Network (ARGMN)
Stations	Comprehensive sites • Äußere Hochebenkar (since 1938) • Dösener • Hinteres Langtalkar • Weissenkar Basic sites • Tschadinhornblockgletscher • Leibnitzkopfblockgletscher Irregular monitoring • Innere Hochebenkar • Innere Ölgrube • Kaisersberg Krummgampen
Data Portal	No data portal yet
Supervising Organization	Uni Graz, TU Graz, ÖGM, University Innsbruck, ZAMG, Verein Gletscher Klima
National and/or international Networks or Programs	IPA – International Permafrost Association
Data Submission	Partially to pangaea (Äußeres Hochebenkar)
Licenses	
Use Limitation	
Data Format	csv
Data Access	open access
Data Quality	
Performance Monitoring	NA
Publications	ÖAV-Permafrostbericht, als Teil des Magazins Bergauf
Contact (National correspondent, focal point)	National correspondent Andreas Kellerer-Pirklbauer andreas.kellerer@uni-graz.ac.at
Remarks	

Permafrost

Annett Bartsch (ZAMG, b.geos GmbH), Viktor Kaufmann (TU Graz)
Andreas Kellerer-Pirklbauer (Universität Graz), Karl Krainer (Universität Innsbruck)

Approximately 2.5 % of Austria is characterized by permanently frozen ground which is overlain by a seasonally unfrozen layer (i.e. active layer). Such regions are addressed as permafrost areas. A further ca. 1.5 % of Austria is affected by deep seasonal frost which has similar impacts on weathering processes. 23 skiing resorts, 31 reservoirs and 42 mountain huts are directly or indirectly influenced by permafrost and associated processes. Ground stability and thus infrastructure (dams, supports, buildings) can be affected by temperature increases due to climate change. There are also substantial impacts on hydrology. The modification of permafrost affected regions is therefore of economic and ecological importance. A range of institutions are interested in systematic permafrost monitoring, e.g. Austrian universities, geological surveys at national and regional scale, the Austrian torrent and avalanche control agency, or several different alpine clubs. To date, no coordinated monitoring network has been established on a national level, and a strategy for long-term observations does not exist. This impedes the evaluation of the existing sparsely distributed measurements as well as the development of an understanding of underlying processes.

It is recommended to increase the number of monitoring sites based on the analyses of the current situation and exchange with stakeholders. This should include temperature measurements in deep boreholes and shallow boreholes close to the surface, geophysical surveys and ground movement measurements (rock glaciers, instable rock faces). In addition a spatially continuous observation of surface movements with remote sensing methods is required. Demand is highest for the entire Tirol, the district of Zell am See and south-eastern Vorarlberg.

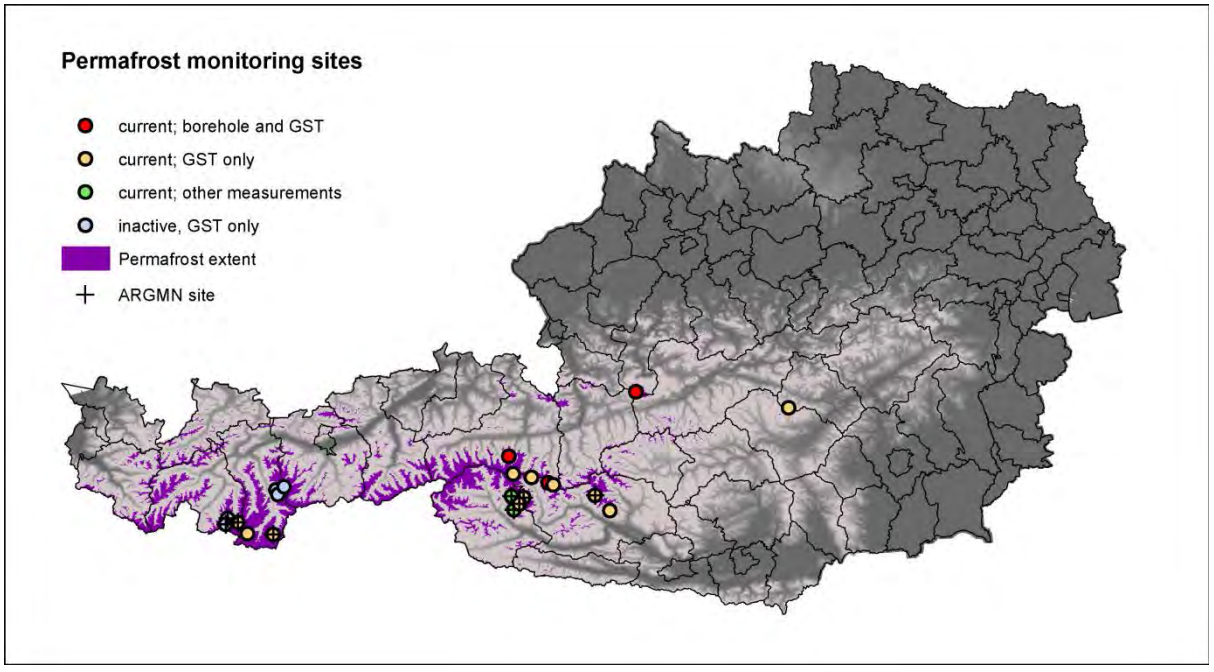


Figure 40 Permafrost monitoring sites

Currently, there are five boreholes at Kitzsteinhorn, three at Hoher Sonnblick (all sites are located in the Hohe Tauern Range) and one borehole at the Dachstein Massif (Northern Calcareous Alps). The records are submitted on an annual basis to GTN-P. Since 2016, a summary of the measurements is

published as part of the regular bulletins of the Alpine Club. Related permafrost/periglacial monitoring with other methods, including ground surface temperature (GST) measurements, geophysical observations, movements and hydrology has been conducted at 18 further sites in Austria. Nine rock glaciers are regularly monitored by four different institutions, six on an annual basis.

An Austrian Rock Glacier Monitoring network (ARGMN) is proposed. Time series from ten rock glaciers are available; six sites are continuously monitored with in situ and remote sensing methods. To date, no global database on rock glaciers exists, but there are efforts within the international community to establish it in the near future. The International Permafrost Association has recently formed an action group for the establishment of a geophysical measurements database. Two Austrian sites will contribute with continuous measurements and further eleven locations with sporadic data.

Table 1 List of sites (#=number of sites; d=maximum borehole depth in m; a=active monitoring; m=continuous monitoring; s=single measurements, * rock glacier of the ARGMN, † contributes to GTN-P).

Location	Borehole		GST/GT		Geophysics			Movements		Hydrology	
	#	d	a	#	a	m	s	a	m	a	m
Äußeres Hochebenkar *				2			X	X	X	X	X
Dachstein †	1	7	X	12			X				
Dösen *			X	12			X	X	X		
Hintereggen-graben			X	8							
Hinteres Langtalkar *			X	15			X	X	X		
Hochreichart-Schöneben			X	6			X				
Hochtor-Fallbichl			X	3				X			
Innere Ölgrube *							X		X	X	X
Kaiserberg *							X		X	X	X
Kitzsteinhorn †	5	29	X	29	X	X	X	X	X	X	X
Krummgampen *							X			X	X
Leibnitzkopf*								X	X		
Pasterze-Burgställe			X	7				X	X		
Reichenkar							X		X	X	X
Rofenberg			X	5			X	X	X		
Rosskar				≤1							
Schrankar				≤1							
Sonnblick †	3	20	X	15	X	X	X				
Tschadinalm *								X	X		
Weissenkar *			X	3			X	X	X		
Wintergasse			X	28							

Essential Climate Variables - Terrestrial Observations - Cryosphere

Parameter measured/observed	Ground temperature
Starting date	2007
Temporal Resolution	hourly (or at 10-minute intervals)
Observational Network	Sonnblick Observatory, Open Air Lab Kitzsteinhorn, GTN-P
Stations	Sonnblick Observatory (Hoher Sonnblick 1-3) Kitzsteinhorn (Kitzsteinhorn 1-5) Dachstein Massif (Koppenkarstein North Face)
Data Portal	Sonnblick.net, gtnpdatabase.org
Supervising Organization	Georesearch, Univercity of Graz, ZAMG
National and/or international Networks or Programs	AlpHaz, GTN-P
Data Submission	Sonnblick database, partially upload to GTN-P database
Licenses	CC BY-NC
Use Limitation	For research only
Data Format	csv
Data Access	restricted
Data Quality	raw data
Performance Monitoring	systematic check
Publications	National / International conferences and journals ÖAV-Permafrost-Report as part of the magazine “Bergauf”
Contact (National correspondent, focal point)	Claudia Riedl: claudia.riedl@zamg.ac.at Ingo Hartmeyer: ingo.hartmeyer@georesearch.at
Remarks	Satellite data based, modelled ground temperature data are made openly available through the ESA initiative DUE GlobPermafrost www.globpermafrost.info

ARGE LWD
Austrian snow station network

Christoph Mitterer (LWD-Tirol), Patrick Nairz (LWD-Tirol),
Michael Butschek (ZAMG), Alexander Podesser (ZAMG)

The consortium of regional avalanche warning services in Austria (ARGE LWD) operates an intensive automated snow and weather station network to record snow and weather parameters relevant for high-quality avalanche danger assessments. The network consists of 186 snow stations (Figure 39) and represents one of the most sophisticated and densest automated station networks worldwide.

The objectives of the measurements:

- Provide information on snow and weather properties at a high temporal resolution to local and regional avalanche warning services and avalanche commissions.
- Provide the basis for daily local and regional avalanche danger assessments and/or forecast throughout various warning products and advisories.
- Provide the input for operational snow cover modelling.
- Provide the background for long-term statistical tools based on nearest-neighbor methods (e.g. NxD).

The network is partly owned by the Provincial Governments, communities and/or third party NGO's or companies such as e.g. the Austrian Railways (OEBB). Most measurement sites include two automated stations: a snow station and a wind station (not shown on the map below). While the wind station is mostly placed on exposed ridges or summits, snow stations are build in wind sheltered areas such as e.g. bowls. The name of the station speaks for its sensor equipment: Wind stations record parameters of wind and air temperature, while snow station focus on recording snow height, snow surface temperature and other relevant snow parameters (e.g. snow temperature and liquid water content).

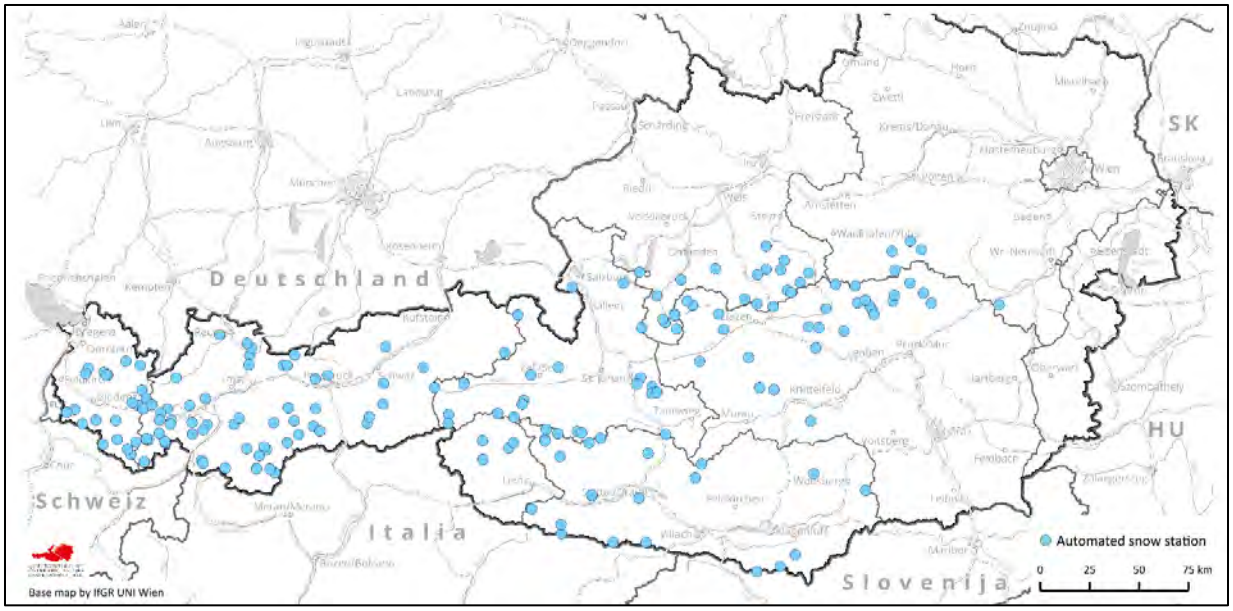
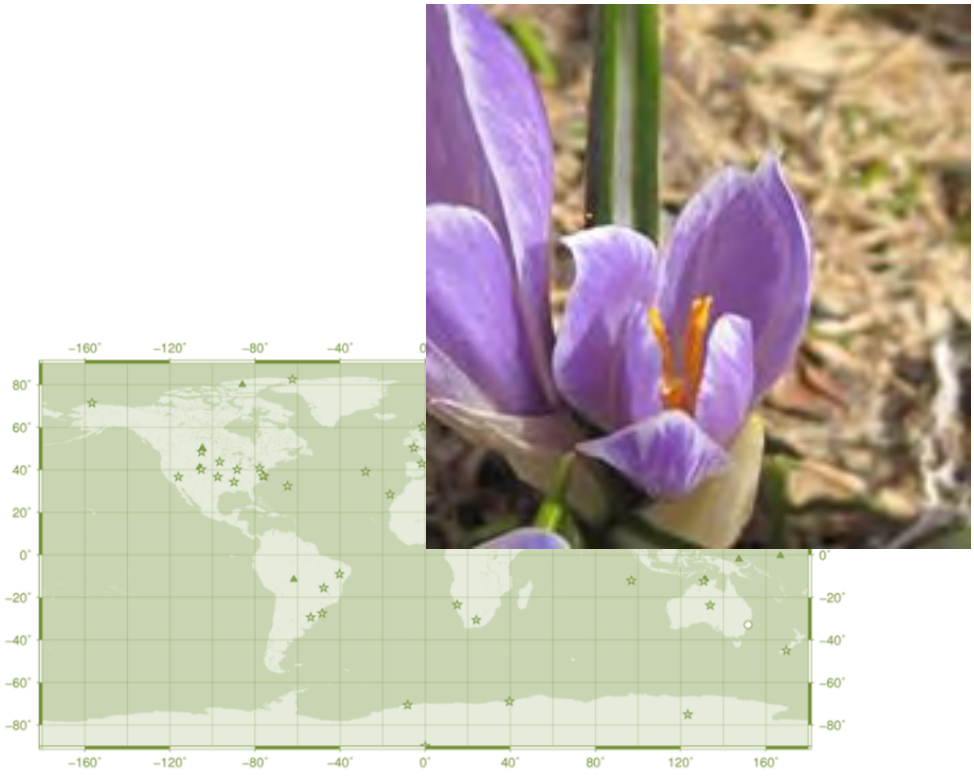


Figure 41 Network of snow stations operated by the consortium of regional Avalanche Warning Services in Austria (N = 186)

Essential Climate Variables - Terrestrial Observations - Cryosphere

Parameter measured/observed	10-minute-mean: air temperature, relative humidity, wind speed, wind direction, global radiation, snow height, snow temperature, snow surface temperature 10-minute-maximum: wind speed, wind direction 10-minute-total: precipitation Actual value: snow water equivalent, snow liquid water content, snow ice content
Starting date	Considerable variation within the various avalanche warning services, but mostly starting from mid to end 1990s.
Temporal Resolution	10 minute
Observational Network	Observational network of the corresponding regional avalanche warning service grouped within the ARGE Lawinenwarndienste Österreich
Stations	Vorarlberg: N = 23 Tyrol: N = 65 Salzburg: N = 23 Upper Austria: N = 19 Styria: N = 27 Carinthia: N = 35 Lower Austria: N = 10
Data Portal	No explicit and uniform data portal available, but data can be obtained upon request or through various OGD interfaces of the Provincial Governments.
Supervising Organization	The Provincial Governments of the correspondent regional avalanche warning service.
National and/or international Networks or Programs	ARGE Lawinenwarndienste Österreich
Data Submission	Automatic data transfer via HTTP
Licenses	Free raw data
Limitation of Use	For research purposes and operational warning only, non-commercial
Data Format	CSV, ASCII, ZRXP
Data Access	Open access on request or OGD interfaces

Data Quality	Data quality is evaluated by the correspondent regional avalanche warning service
Performance Monitoring	Data availability is monitored by the correspondent regional avalanche warning service
Publications	Vorarlberg: Various graphs on www.lawis.at Tyrol: Various graphs on www.lawis.at Salzburg: Various graphs on www.lawis.at Upper Austria: Current 3-day graphs www.land-oberoesterreich.gv.at/was_lnw.htm Styria: Various graphs on www.lawis.at Carinthia: Current 3-day graphs on ww.lawine.ktn.gv.at Lower Austria: Various graphs on www.lawis.at
Contact (National correspondent, focal point)	lawine@tirol.gv.at, lawine@lawine-steiermark.at lawine@ktn.gv.at
Remarks	



Terrestrial Observations

Biosphere

National Forest Inventory of Austria

Alexandra Freudenschuß (BFW)

The National Forest Inventory (NFI) of Austria is a large-scale forest monitoring programme covering the federal territory of Austria. The Austrian NFI is the main data provider for national and international reporting on Austria's forest resources. The results serve as basis for decisions in forest and environmental policy and are a valuable data source for numerous scientific projects. The planning, execution and evaluation is carried out by the Department of Forest Inventory of the Federal Research and Training Centre for Forests, Natural Hazards and Landscape (BFW).

Until today, seven sample-based inventories have been carried out. The field assessments of the most recent inventory are ongoing and cover the sampling period 2016 to 2021. The first inventory was conducted in the years 1961 - 1970, and was followed by the assessments in 1971 - 1980, 1981 - 1985, 1986 - 1990, 1992 - 1996, 2000 - 2002 and 2007 - 2009. While the first two NFIs were based on a temporary sampling grid, the subsequent inventories were carried out on a permanent grid consisting of approximately 5,500 clusters and 11,000 forest plots. The distance between the clusters is 3.89 km. The clusters have the shape of a square with 200 m side-length where the sample plots are located at the corners. At the sample plots numerous stand-, site- and tree-specific variables are assessed and form the basis for the periodic results of the Austrian NFI (bfw.ac.at/rz/wi.home)

Essential Climate Variables – Terrestrial Observations - Biosphere

Parameter measured/observed	Terrestrial data – 200 different stand-, site- and tree-specific parameters like e.g. land use, tree species, forest structure, above-ground biomass, elevation, slope, soil type, forest vegetation type, tree diameter and height.
Starting date	Inventory cycles started in 1961, since then seven NFIs had been conducted, the most recent NFI started in 2016.
Temporal Resolution	periodical assessments in 1961-1970, 1971-1980, 1981-1985, 1986-1990, 1992-1996, 2000-2002, 2007-2009 and 2016-2021.
Observational Network	Large-scale inventory with a sampling grid of 3.89 km x 3.89 km covering all federal territory.
Stations	5,500 clusters with approximately 11,000 plots located on forest land.
Data Portal	Results are available at the homepage https://bfw.ac.at/rz/wi.home for national and sub-national levels for different topics (e.g. forest area, standing volume, increment, harvest). Plot data accessibility restricted.
Supervising Organization	Federal Research and Training Centre for Forests, Natural Hazards and Landscape (BFW), Department of Forest Inventory
National and/or	The Austrian NFIs represents large-scale forest monitoring at

international Networks or Programs	national level. It is member of ENFIN – the European National Forest Inventory Network which promotes the harmonisation of forest information (http://enfin.info/).
Data Submission	Periodical update following each inventory cycle.
Licenses	Credits and attribution to BFW. No data sharing with others. No commercial use. No modification of data and results.
Use Limitation	Research projects and non-commercial uses.
Data Format	Stored in an Oracle® database. Data excerpts as xls or csv. Download of results as xls files.
Data Access	Open access download of results at the BFW homepage https://bfw.ac.at/rz/wi.home. Availability of plot data is restricted.
Data Quality	Data undergo comprehensive quality checking in several steps. Data quality checks are performed by the BFW.
Performance Monitoring	Data availability is supervised by BFW.
Publications	The Department of Forest Inventory publishes and contributes to publications within the thematic frames: inventory methods, harmonization of NFIs, use of remote sensing, uncertainty, climate change, biodiversity, and wood availability.
Contact (National correspondent, focal point)	klemens.schadauer@bfw.gv.at richard.buechsenmeister@bfw.gv.at
Remarks	

Monitoring hydrological data of forest ecosystems

Karl Gartner (BFW)

The web portal WALDÖKODATEN was developed by the department of Forest Ecology and Soils of the Federal Research and Training Centre for Forests, Natural Hazards and Landscape (BFW). It provides - daily updated - a large part of the ongoing ecological relevant measurements of the department, which belong to different ongoing projects of the department.

The web portal includes data, which come from the stations via remote access. The data are roughly checked and imported into a POSTGRESQL data base system. The data are aggregated to daily values and exported from this database to be shown in form of graphical form or to be downloaded in the form of CSV-files. Except for the data on changing stem circumferences, all data are shown and available online only for the last thirty days. A Google-map with the exact position of the measurement station completes the web site.

A simple quality control of the data is done before the data come into the data base. For this reason the data available from the web-portal are not final data sets. They can be changed by data analysis

which is done to get the corresponding results for the different projects. The use of the data for commercial use is not permitted.

The data comprise meteorological data of open field stations, air temperature and air humidity within the stand, soil temperature and soil moisture and measurements of changing stem circumference with the help of electronic girth bands.

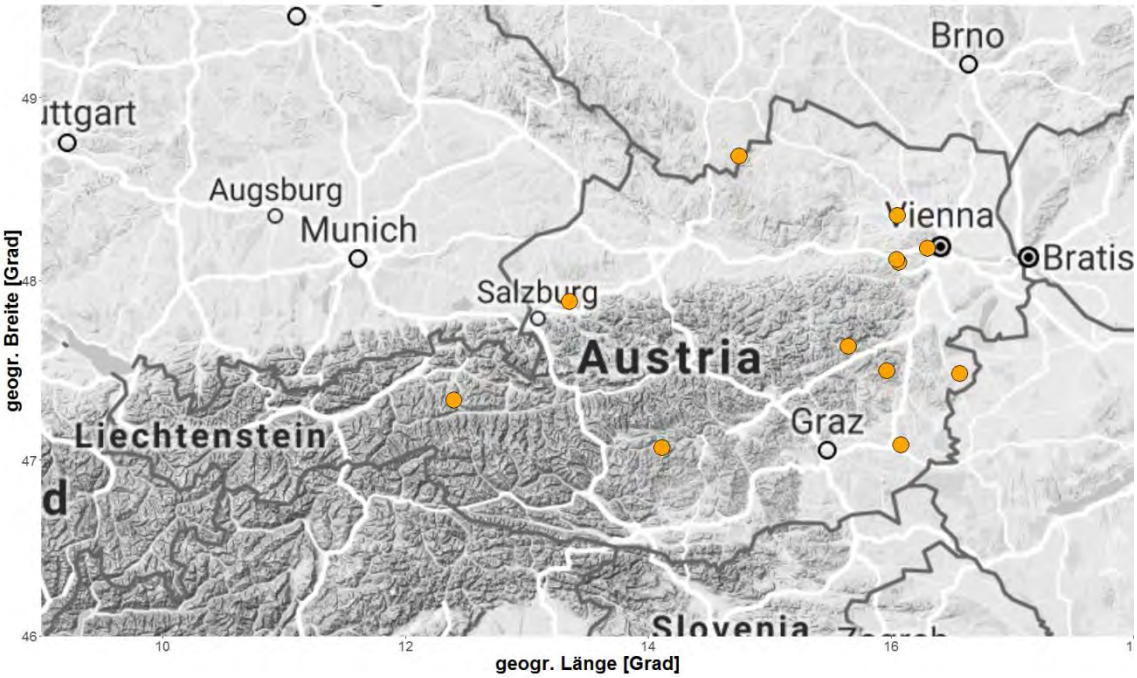


Figure 42 Location of the WALDÖKODATEN - stations.
Also shown are the stations in Tulln and Weitra, which are at the moment not part of the WALDÖKODATEN-portal.

Essential Climate Variables – Terrestrial Observations - Biosphere

Parameter measured/observed	meteorological data (air temperature, air humidity, global radiation, wind speed, wind direction, precipitation) together with soil temperature and soil moisture
Starting date	earliest dataset starts at 06/1998
Temporal Resolution	differs from 15 to 60 minutes
Observational Network	long term monitoring of forest sites
Stations	about 10 stations distributed across Austria
Data Portal	http://bfw.ac.at/rz/bfwcms2.web?dok=8658 partly national data centres of the participating countries
Supervising Organization	Federal Research and Training Centre for Forests, Natural Hazards and Landscape (BFW)
National and/or international Networks or	ICP Forests

Programs	
Data Submission	daily update
Licenses	CC BY-NC-SA
Use Limitation	for non-profit research
Data Format	Download of the data as csv
Data Access	Download via the Waldökodaten-homepage (http://bfw.ac.at/rz/bfwcms2.web?dok=8658) Open access to the last 30 days of data (otherwise see contact below)
Data Quality	Data quality is done by BFW.
Performance Monitoring	Data availability is supervised by BFW (see contact).
Publications	
Contact (National correspondent, focal point)	Contact: karl.gartner@bfw.gv.at
Remarks	

Phenology ZAMG

Thomas Hübner (ZAMG)

Insight Phenology

The roots of the Phenological Observation Network of Austria reach back to 1851 when ZAMG was founded. An uninterrupted series of phenological observations extend back to 1946. The start of the longest observation series dates back to 1457, which is the date of grape harvest in the vineyards of Klosterneuburg (NÖ). Digitized data of phenological development of crop, vine, fruit plants, trees, shrubs, herbaceous and some animals is available from 1926 until today. Earlier years are still under digitization.

Phenological observations are done by volunteering Citizen Scientists. By now there are about 100 observers per year who either enter their observations online on www.phenowatch.at or still use the traditional paper pen method and mail the completed form to ZAMG.

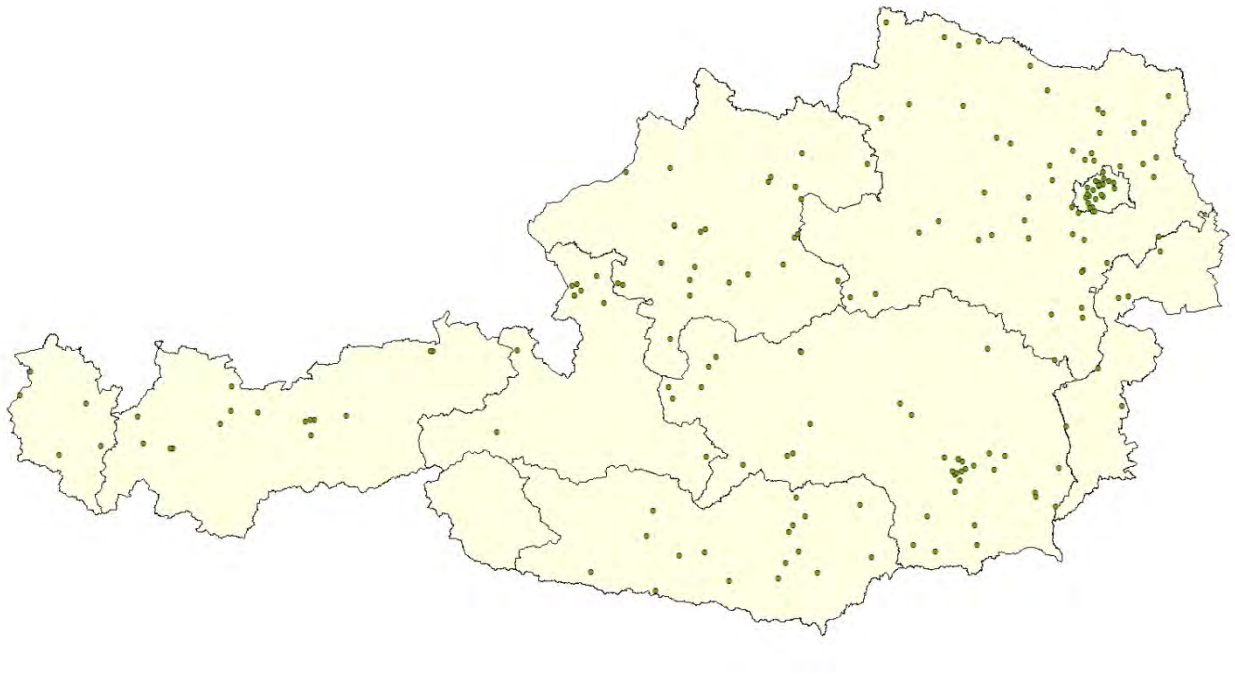


Figure 43 Active stations for phenological observation between 2014 and 2017.

National networks

Besides the National Observer Network of ZAMG there are regional projects which were founded to reach out for new long term observers. These projects called “Naturkalender Steiermark” and “Naturkalender Niederösterreich” involve schools and nature parks to spread the use and necessity for phenology to the general public.

Within these projects, a new tool was created - The Naturkalender smartphone app, which is freely available for Android and iOS.

Europe-wide network

ZAMG is the host of the Pan European Phenological database (PEP725) where all major phenological networks in Europe store their data for scientific research. The access is open to all interested parties and the download or support by ZAMG is free. www.pep725.eu.

ZAMG is also a partner of the international Plant Gardens (IPG). This phenological network works with cloned plants to avoid influences of genetic predetermination. In Austria there are two locations for observation which are the only institutionalized sites for phenological observation in general: ZAMG Wien und ZAMG Salzburg.

Essential Climate Variables – Terrestrial Observations - Biosphere

Parameter measured/observed	occurrence of certain states of development of plants, like first flowering or leaf colouring in DOY (day of year)
Starting date	1926 with interruptions and changing number of observation stations (not digitised before 1926, extend back to 1851)
Temporal Resolution	yearly occurrence per species, phase and location
Observational Network	National phenological network of Austria including their collaborations
Stations	all phenological stations in Austria (number species and phases may vary yearly)
Data Portal	portal for data entry and meta data www.phenowatch.at and www.naturkalender.at (starting in 2018) data portal for download etc. www.pep725.eu
Supervising Organization	Zentralanstalt für Meteorologie und Geodynamik (ZAMG)
National and/or international Networks or Programs	Paneuropean Phenological Database - PEP725 National Phenological Network of Austria (Phenowatch, Naturverrückt, Naturkalender Steiermark, etc.) GCOS

Data Submission	Online submission via website continuously (50 %) Annual data submission on posted paper form (50 %)
Licenses	CC-BY-NC
Use Limitation	Non-commercial, non-profit research
Data Format	download of the data as csv
Data Access	download via www.pep725.eu access by registration
Data Quality	First data quality control is done by boundary values during data entry and by review of the members of the phenology team at ZAMG. Other mechanisms are under development.
Performance Monitoring	Data availability is supervised by ZAMG.
Publications	annual report of ZAMG
Contact (National correspondent, focal point)	Paneuropean Phenological Database - PEP725 Markus Ungersböck markus.ungersboeck@zamg.ac.at National Phenological Network of Austria (Phenowatch, Naturverrückt, etc.) Elisabeth Koch elisabeth.koch@zamg.ac.at Helfried Scheifinger helfried.scheifinger@zamg.ac.at Thomas Hübner thomas.huebner@zamg.ac.at GCOS Silke Adler silke.adler@zamg.ac.at
Remarks	

Continuation of the measurements ensured for the next years:

□ < 5 years □ 5-10 years □ > 10 years

Atmospheric Observations – Surface	
Climate monitoring ZAMG	
VAMES	
Aerodrome Met stations	
Sunshine duration	
UV Radiation	
Solar and terrestrial radiation	
BSRN	
HISTALP	
Atmospheric Observations – Upper Air	
RASO ZAMG	
RASO AUSTRO CONTROL	
Austrian Weather Radar Network	
Atmospheric Observations - Composition	
Stratospheric Ozone	
Air Quality Monitoring Network	
Air Quality Monitoring of federal states of Austria	
Sonnblick Observatory	
Terrestrial Observations - Hydrosphere	
eHYD	
Tuxer Alps	
Torrent Research Areas	
ISMN - In situ soil moisture observations	
ASCAT surface soil moisture	
Terrestrial Observations - Cryosphere	
Snow	
Glaciers	
Permafrost	
Regional avalanche warning services in Austria	
Terrestrial Observations - Biosphere	
National Forest Inventory of Austria	
Monitoring hydrological data of forest ecosystems	
Phenology ZAMG (sustained through citizen science)	

Annex
Essential Climate Variables from the Global Observing System for Climate: Implementation Needs 2016 (WMO)

	Essential Climate Variables (ECVs)	WMO Programmes	WMO Co-Sponsored	CEOS & CGMS[1]	Other
Atmospheric	Surface:				
	Wind speed and direction, Precipitation,	WIGOS		WGClimate	
	Air temperature, Water vapour, Pressure, Surface radiation budget.	WIGOS			
	Upper-air:				
	Lightning	WIGOS			
	Temperature, Wind speed and direction, Water vapour, Cloud properties, Earth radiation budget.	WIGOS		WGClimate	
	Composition				
	Carbon Dioxide (CO_2), Methane (CH_4), Other long-lived greenhouse gases (GHGs), Ozone, Aerosol, Precursors for aerosol and ozone.	GAW		WGClimate	
Oceanic	Physics:				
	Subsurface Temperature, Subsurface Salinity, Subsurface Currents, Ocean Surface Stress, Ocean Surface heat Flux		GOOS/JCOMM		
	Sea Surface Temperature, Surface Currents, Sea Surface Salinity, Sea Level, Sea State, Sea Ice		GOOS/JCOMM	WGClimate	
	Biogeochemistry:				
	Inorganic Carbon, Oxygen, Nutrients, Transient Tracers, Nitrous Oxide (N_2O),		GOOS		IOCCP
	Ocean Colour		GOOS	WGClimate	IOCCG
	Biology/ecosystems:				
	Plankton, Marine habitat properties		GOOS		GEOBON
Terrestrial	Hydrology:				
	River discharge, Groundwater, Soil Moisture	WHYCOS	GTN-H		
	Lakes	WHYCOS	HYDROLARE	WGClimate	
	Cryosphere:				
	Snow, Glaciers, Ice sheets and Ice shelves,	GCW		WGClimate	
	Permafrost	GCW			GTN-G, GTN-P
	Biosphere:				
	Albedo, Land cover, Fraction of absorbed photosynthetically active radiation, Leaf area index, Above-ground biomass, Fire, Land Surface Temperature		BSRN	WGClimate	FluxNet, Others
	Soil carbon,				
	Human use of natural resources:				
	Water use,				AQUASTAT
	GHG fluxes	GAW		WGClimate	TBD, GCP

Notes: [1)] The WG-Climate works on satellite derived data products

Stakeholders:

AQUASTAT	FAO database and data collection system on water use
GAW	WMO's Global Atmosphere Watch
GCP	Global Caron Project
GCW	WMO's Global Cryosphere Watch
GOOS	Global Ocean Observing System Sponsored by WMO, IOC of UNESCO, …
GTN-G	Global Terrestrial Network – Glaciers
GTN-H	Global Terrestrial Network – Hydrology
GTN-P	Global terrestrial Network – Permafrost
HYDROLARE	International Data Centre on Hydrology of Lakes and Reservoirs
JCOMM	WMO-IOC Joint Technical Commission for Oceanography and Marine Meteorology
IOCCG	International Ocean Color Coordination Group
IOCCP	International Ocean Carbon Coordination Project
TBD	To be determined
WGClimate	The Joint CEOS/CGMS working group on climate
WHYCOS	World Hydrological Cycle Observing System (a WMO programme)

GCOS CLIMATE MONITORING PRINCIPLES

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

1. The impact of new systems or changes to existing systems should be assessed prior to implementation.
2. A suitable period of overlap for new and old observing systems is required.
3. The details and history of local conditions, instruments, operating procedures, data processing algorithms and other factors pertinent to interpreting data (i.e., metadata) should be documented and treated with the same care as the data themselves.
4. The quality and homogeneity of data should be regularly assessed as a part of routine operations.
5. Consideration of the needs for environmental and climate-monitoring products and assessments, such as IPCC assessments, should be integrated into national, regional and global observing priorities.
6. Operation of historically-uninterrupted stations and observing systems should be maintained.
7. High priority for additional observations should be focused on data-poor regions, poorly observed parameters, regions sensitive to change, and key measurements with inadequate temporal resolution.
8. Long-term requirements, including appropriate sampling frequencies, should be specified to network designers, operators and instrument engineers at the outset of system design and implementation.
9. The conversion of research observing systems to long-term operations in a carefully-planned manner should be promoted.
10. Data management systems that facilitate access, use and interpretation of data and products should be included as essential elements of climate monitoring systems.

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

(a) Take steps to make radiance calibration, calibration-monitoring and satellite-to-satellite cross-calibration of the full operational constellation a part of the operational satellite system; and
(b) Take steps to sample the Earth system in such a way that climate-relevant (diurnal, seasonal, and long-term interannual) changes can be resolved.

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

11. Constant sampling within the diurnal cycle (minimizing the effects of orbital decay and orbit drift) should be maintained.
12. A suitable period of overlap for new and old satellite systems should be ensured for a period adequate to determine inter-satellite biases and maintain the homogeneity and consistency of time-series observations.
13. Continuity of satellite measurements (i.e. elimination of gaps in the long-term record) through appropriate launch and orbital strategies should be ensured.
14. Rigorous pre-launch instrument characterization and calibration, including radiance confirmation against an international radiance scale provided by a national metrology institute, should be ensured.

15. On-board calibration adequate for climate system observations should be ensured and associated instrument characteristics monitored.
16. Operational production of priority climate products should be sustained and peer-reviewed new products should be introduced as appropriate.
17. Data systems needed to facilitate user access to climate products, metadata and raw data, including key data for delayed-mode analysis, should be established and maintained.
18. Use of functioning baseline instruments that meet the calibration and stability requirements stated above should be maintained for as long as possible, even when these exist on decommissioned satellites.
19. Complementary in situ baseline observations for satellite measurements should be maintained through appropriate activities and cooperation.
20. Random errors and time-dependent biases in satellite observations and derived products should be identified.

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