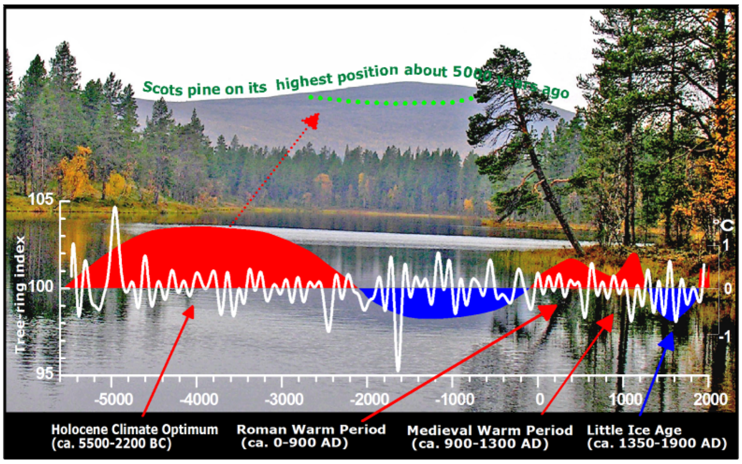
Finnish National Report on Systematic Observations for Climate

# National Activities with Respect to the Global Climate Observing System (GCOS) Implementation Plan

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





Compiled by the
Finnish Meteorological Institute



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## SUMMARY

*Finland has built up an archive of systematic atmospheric, oceanic and terrestrial observations based on the regulations of corresponding international organizations. Details of these observations are tabulated in this report made in accordance with the revised United Nations Framework Convention on Climate Change Reporting Guidelines on Global Climate Change Observing Systems (2007). - Since the foundation of the Global Climate Observing System the climate-related work in Finland has been directed gradually to follow the GCOS climate monitoring principles. The continuation and improvement of these activities are going on as well as climate change-related research.*

## Framework

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

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*Copies of the report are available for download from the Finnish IPCC Website:*
*http://www.fmi.fi/ilmastonmuutos/ipcc.html* *as well as*
*http://unfccc.int/methods_and_science/research_and_systematic_observation/items/4499.php*

*N.B. The acronyms used in this report are either explained in the text or can be found in* ***http://www.wmo.int/pages/themes/acronyms/index_en.html***

Cover figure: *The red and blue areas indicate Bradley's and Eddy's schematic temperature model (1991). Some modifications made by Mauri Timonen 2007. The white curve indicates a FFT smoothed 100-year average of Scots pine tree-ring index. Photo from Lake Pitkäjärvi in the Pallas-Yllästunturi National Park.*

*Contents*

# 1. COMMON ISSUES

## Introduction

The recently published Fourth Assessment Report of the Intergovernmental Panel on Climate Change summarizes the current state of knowledge on climate change and its global impacts. From a global perspective, Finland is relatively seriously affected by climate change because of its location in higher latitudes where the projected changes e.g. in temperature and precipitation are larger than in average globally. According to the recent national studies Finland would be faced annual mean temperatures to increase by around 2-4°C by the 2050s. Precipitation levels are projected to rise by about 20% in winter and 10% in summer. In addition, the frequency of extreme precipitation events is expected to increase, especially in winter, possibly leading to more frequent floods and debris flows in certain regions. Climate change scenarios, however, contain still large uncertainties due to unknown future emissions of radiative forcing agents and limitations of earth system models as well as natural climate variability. Understanding of long-term climate variations and early detection of signals is therefore essential for example in the planning and management of climate change adaptation strategies and in the validation of models.

The demand for observations of climate and climate change is increasing. For scientific basis on climate change, the attribution of anthropogenic influences and future climate scenarios, long-term and high-quality data series are essential. To address these challenges, the Global Climate Observing System (GCOS) was established in 1992, parallel to the establishment of the UN Framework Convention on Climate Change (UNFCCC).

The GCOS is designed to ensure that the observations and information needed to address climate-related issues are obtained and made available to all potential users. Building on existing networks and systems, GCOS encompasses the total climate system including observations of physical, chemical and biological properties of the atmosphere, the ocean and the land surface.

The implementation of GCOS is based on the Second Adequacy Report (2003) and the Implementation Plan (2004). The GCOS Implementation Plan thereby clearly highlights the role of every country to set up national coordination mechanisms and national plans for the provision of systematic observation of the climate system. Such mechanisms are usually best sustained when national coordinators or focal points are designated and assigned responsibility to coordinate planning and implementation of systematic climate observing systems across the many departments and agencies involved with their provision.

In response to conclusions FCCC/SBSTA/2005/10, and FCCC/SBSTA/2007/L.14, this report presents the progress in the implementation of GCOS in Finland, according to the guidelines adopted at the 13$^{th}$ UNFCCC Conference of the Parties (COP13; Decision 11/CP.13).

## National GCOS coordination

Finland's contribution to systematic observations with regard to GCOS has been reported in the National Communications under the framework of UNFCCC, cf. http://unfccc.int/national_reports/annex_i_natcom/submitted_natcom/items/3625.php

The national GCOS coordination is taken place by the Finnish Meteorological Institute (FMI), which represents operational and research activities in climatology including climate data-monitoring and applications-services (cf. Ch.2).

Climate-related observing activities in Finland are carried out also in the following institutions:

- Finnish Institute of Marine Research (cf. Ch.3)

- Finnish Environment Institute (cf. Ch.4)

Some climate-related observations are also made in the Finnish Forest Research Institute, MTT Agrifood Research, and at several universities.

National committees co-ordinate activities in Finland in relation to Intergovernmental Panel on Climate Change and International Geosphere-Biosphere Programme.

Finland is operationally taking part in the World Weather Watch (http://www.wmo.int) by the synoptic network of surface and upper-air stations. These stations constitute also the basis for the climatological services, applications and research. This station network is complemented nationally by climatological and precipitation stations. Finland is also contributing to the Global Atmospheric Watch (http://www.wmo.int).

Finland takes part in WMO climate activities mainly through the Commission for Climatology and its Open Programme Area Groups (OPAG), especially climate data and data management.

## Satellite information

Satellite observations are needed to obtain necessary observations of the climate system. Thus, a detailed global climate record for the future depends much on the satellite component within GCOS. Finland is not a satellite operator, but does have significant activity in satellite applications as well as development of remote sensing sensors. However, following the report of the systematic observation requirements for satellite-based products for climate, compiled by the WMO GCOS Secretariat in 2006 as a supplement to GCOS Implementation Plan (GIP-SS; WMO, 2006), these activities with involvement of Finnish institutions are described in Chapters 2-4 for relevant Essential Climate Variables (ECV, cf. Annex 1).

## Paleoclimatology

In Finland, there is an active research community working with reconstruction of past climate based on various sources of proxy records. The main research areas are dendroclimatology, including isotopic analyses of growth rings; lake sediments analysis of microfossils, geochemistry and magnetic susceptibility; and bog sediments.

Climate conditions can be reconstructed utilizing tree-rings. The growth of Scots pine (Pinus sylvestris L.) is highly sensitive to June-July temperatures at the Finnish pine timberline. Exceptional preservation of pine wood and its accumulation in non-oxygen muddy bottoms of ice-cold lakes have made it possible to build a 7641 years long continuous tree-ring chronology. The characteristics of this chronology, the distribution of the samples (on both sides of the present timberline) and the strong June-July temperature connection have provided exceptional tools for dendroclimatic analysis and reconstructions.

***These megafossils of Scots pine have preserved several thousands of years in ice-cold water. This small lake is located beyond the present pine timberline, north of Näkkälä village, Northern Finland (close to the Norwegian border).Photo by Mauri Timonen.***

According to Kultti et al. *) pine in Finland reached its maximum distribution between 8300 and 4000 cal. yr BP (Fig.). The inferred minimum shift in mean July temperature was at that time about 2.5 °C. Until 3000 cal. yr BP, the results indicate a shift of ca. 1 °C. Between 2538 and 1721 cal. yr BP, evidence for a wider distribution of pine in Finnish Lapland is lacking. During the Medieval Warm Period (MWP) the reconstructed minimum shift in mean July temperature was 0.5 °C. The record of subfossil pines beyond the present pine treeline breaks during the initiation of the Little Ice Age (LIA) about 700 years ago.

*) *Kultti, S., Mikkola, K., Virtanen, T., Timonen, M., Eronen, M. (2006): Past changes in the Scots pine forest line and climate in Finnish Lapland: a study based on megafossils, lake sediments, and GIS-based vegetation and climate data. The Holocene **16**(3) 381-391*.

## Capacity building

During the years Finland has had extensive capacity building programs around the world. Through the Finnish international development agencies climate data management systems have been implemented in several developing countries with considerable financial and personnel support. - The institutional support of the developing programs is channeled mainly through technical aid to strengthen the meteorological observing networks and weather services as well as climatological data bases, expert services and training programs.

Since the early 1970s, the Ministry for Foreign Affairs of Finland (MFAF) has within its development cooperation programme financially supported the strengthening of the WMO Global Observing System. - In 1980s and 1990s major Finnish development cooperation programmes to assist the NMSs of developing countries were implemented in cooperation with WMO and with the assistance of FMI expert services.

FMI published for the 21st Century a brochure "Finland and development cooperation in the field of meteorology". It describes inter alia the significance of weather and climate for agriculture, NMSs national commitments to UN conventions and achievements and the results of the cooperation projects in Central America, Sudan and SADC countries.

An advantage in the implementation of Finnish development co-operation programmes strengthening the NMSs of developing countries is the use of the expertise of such NMS which have updated expert services in the operational fields of instruments and observing methods, weather satellite receiving systems and weather radars, telecommunication and work stations, aeronautical and agrometeorological weather services, climatological statistics and applications, wind and solar energy, numerical models and data management systems, air quality laboratory instrumentation and education and training.

FMIs references in development cooperation consist of

- the expert services in project formulation, design, implementation, appraisal, evaluation, monitoring, review, management and training,
- the updated expertise related to the responsibilities of NMS of Finland,
- the global cooperation within the intergovernmental organizations WMO, EUMETSAT and ECMWF.

These references of FMI give a solid foundation for the challenges of the 21st Century.

One capacity building program of the recent years was the SIDS-Caribbean Project "Preparedness to Climate Variability and Global Change in Small Island Developing States, Caribbean Region". The overall objective of the program was to provide tools for better planning for sustainable development in the Caribbean region. The Project included 18 countries and had a budget of USD 3.5 million provided by the Government of Finland. The Project was implemented by the WMO, relied partly on the expertise of FMI and comprised the following components:

- improvement of the telecommunications systems at national and regional levels
- rehabilitation and upgrading of the observing networks
- renovation of the regional technical laboratory for the calibration and maintenance of instruments
- upgrading of the database management systems
- implementation of data rescue programs and
- training and awareness building

Similar project with the Small Island Development States of the Pacific Region is in the pipeline during compilation of this report. Further capacity building projects are aimed at Peru, Nepal and Vietnam among others.

# 2. ATMOSPHERE ESSENTIAL CLIMATE VARIABLES

## Introduction

In Finland, the prime source of atmospheric observations relevant to climate change is the routine surface and upper air weather observations undertaken by the Finnish Meteorological Institute (FMI). The observations are archived in the data bases. The FMI plays also an important role in air chemistry observations.

Arrangements and conditions for data provision are consistent with WMO Resolution 40 (Cg-XII) on policy and practice for the exchange of meteorological and related data and products. Appropriate weather observations are forwarded to other countries in real time, through the WMO networks. Finland provides also climate and greenhouse gas monitoring data to international data centers under the WMO/ICSU programs.

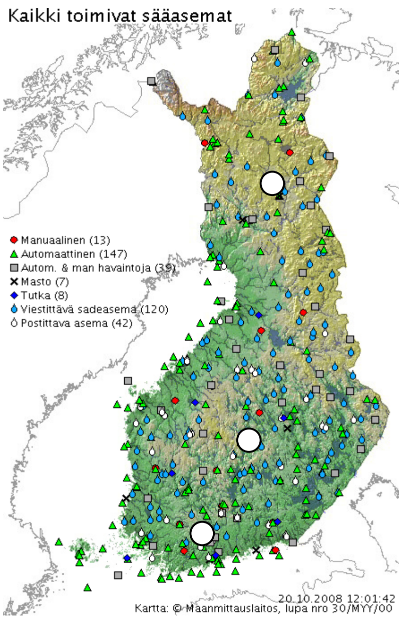
Finland has three stations providing data to international data centers as part of the Global Surface Network (GSN), and one station which reports as part of the Global Upper Air Network (GUAN).

Jointly with other Nordic countries Finland is aiming at best possible long-term climatological data records for the study, monitoring and detection of past and future climatic changes in the northern areas. In this work the reliability and homogeneity of the data records and the station records (metadata) are in key roles.

Finland has a few stations providing atmospheric constituent data to international data centers as part of the Global Atmospheric Watch (GAW). Concentrations of carbon dioxide, methane and nitrous oxide, and ozone as well as aerosol properties and non-methane hydrocarbons, are monitored at the Sodankylä/Pallas GAW station.

## Weather observations

In addition to locations spotted on the map, weather observations are made at solar measurement stations, aviation weather stations, Jokioinen observatory, Arctic Research Centre in Sodankylä, and with the help of lightning detection systems, weather radars and satellites. The most common methods of observation, observation stations and observed parameters are introduced in the following.




***Finnish climate-related observing stations and the three GCOS stations.***

Synoptic weather messages are transmitted from weather and automated weather stations every three hours. Automated measurements are obtained also more frequently depending on the station in question. Nowadays, many of the weather stations are semi-automated, which means human observers make some but not all of the observations.

At climate stations it has traditionally been made three manual observations per day. Compared to synoptic messages, in particular the observations on clouds and weather phenomena are narrowed. Observations specially related to rainfall and snow are made once a day at precipitation stations.

Mast stations are used for the observation of the vertical profiles of several meteorological parameters. These are being used e.g. when exploring temperature inversions, low clouds and wind shear.

At solar radiation stations several different measurements are made, although some of these stations measure the duration of sunshine hours only. The most common other solar measurements include ultraviolet, global and diffuse radiation.

Radiosondes reveal important information also from the upper levels of the troposphere. This information is vital for both the forecast models and meteorologists. In addition to daily soundings, special ozone soundings are made e.g. weekly in Arctic Research Centre in Sodankylä. Radioactivity soundings may be also carried out if needed.

Lightning detection system consists of several sensors around the country. The system detects the time of arrival and the direction of an incoming electromagnetic pulse generated by a lightning, and then automatically calculates the location of the lightning,

The observations obtained with the help of weather radars and satellites are very important, because they give information on weather conditions from geographically large areas. These data are extensively used in the operational detection of rain and clouds, but also in research activities.

Other measurements include special research observations, testing new methods of observation, other more seldom used measurement techniques and observations obtained from co-operative agencies.

Meteorological observations have been made at several stations in Finland for more than a hundred years. In October 2008, observations were made at three meteorological observatory stations incl. upper-air observations, 188 synoptic stations, 9 climatological stations, 153 precipitation stations and 179 automatic stations. The national climate network includes continuing automation as finances permit.

Under the GCOS programs, stations in Jokioinen, Jyväskylä, and Sodankylä (cf. Fig) are included in the GCOS Surface Network (GSN) and Sodankylä in the GCOS Upper-Air Network (GUAN).

Long climatological time series form a necessary basis not only for the climatological research itself but also for estimates on the impacts of climate change. Finnish climate observations have been included for example in the international NkDS and ECA&D datasets, which are Nordic and European collections of reliable long-term climatic observations for climate change research.

The Finnish Meteorological Institute maintains the climatological database of the following components:
_ Station metadata register
_ Daily values
_ Synop data
_ Hourly values for solar radiation and sunshine hours
_ Rawinsonde data
_ Normal values
_ Automatic weather station data since 1996
_ Automatic synop data since 1998
_ Mast data since 1986.

The archives are full of observations which only exist in analogue form and would need to be digitized. Digitizing efforts are going on by the FMI with a focus on temperature and precipitation, but the same work remains to be done for other variables such as air pressure, wind, snow cover, or additional precipitation stations. Compiling long, daily meteorological series is important for impact studies of extreme events. Moreover, in parallel with global efforts in this direction, such data are needed to produce global historical reanalysis data sets.

The EUMETNET was established to promote European co-operation in the development of the meteorological observing network and the basic weather services. The FMI has hosted the programme, which was established to improve the observation technology for severe weather conditions, and been actively involved in the work of the European Climate Support Network (ECSN).

## Atmospheric composition

Finland participates in the Global Atmosphere Watch (GAW) programme of the World Meteorological Organization (WMO) with objection to observe greenhouse gas concentrations and long-range transport of pollutants in the atmosphere.

***The Pallas station in Lapland is the northernmost GAW-station in continental Europe. It offers unique possibilities for carrying out measurements on atmosphere-biosphere exchange and background air composition.***

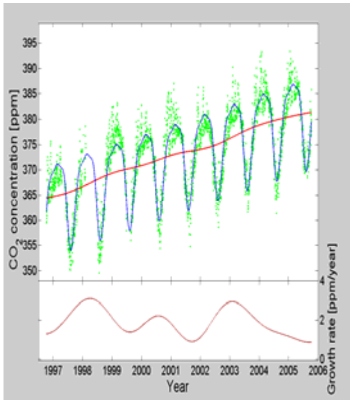
## Greenhouse gas monitoring

Concentrations of greenhouse gases in the atmosphere have increased significantly from preindustrial era causing global warming. Estimates of source strengths to the atmosphere from anthropogenic sources, based on emission factors and statistics of activity, have high uncertainties. Atmospheric observations are essential in determining trends and they provide the vital information for estimates of sources and sinks by natural processes and for allocating sinks and sources to marine and terrestrial environments.

Highly accurate and inter-calibrated global measurement networks are the basis for monitoring the global trends. The main network is the Global Atmosphere Watch (GAW) network co-ordinated by the World Meteorological Organization. It consists of 25 continuously monitoring sites around the world. The other important network is the cooperative sampling network by The Carbon Cycle Greenhouse Gases Group of the Earth System Research Laboratory (ESRL) of the U.S. National Oceanic and Atmospheric Administration for which weekly flask samples are collected at the sites and analysed in the central laboratory in Boulder (U.S.).

For monitoring globally and regionally representative trends, observatories should be located in clean, preferably elevated, sites to exclude effects of local pollution.

The Finnish Meteorological Institute maintains Pallas-Sodankylä GAW-station in Lapland. Greenhouse gas concentrations are measured on a mountain top in a national park. Carbon dioxide, methane, nitrous oxide, sulphur dioxide and ozone are measured continuously at Pallas. Continuous measurements of carbon dioxide started in 1996 and of methane in 2004.




***Measurements of $CO_2$ in Pallas GAW station.***

Flask samples are collected weekly and sent to Boulder to analyze by ESRL for $CO_2$, $CH_4$, CO, $H_2$, $N_2O$, and $SF_6$ concentration and by Stable Isotope Laboratory of the University of Colorado at Boulder for the concentrations of stable isotopes of $CO_2$ and $CH_4$. At Sodankylä, ozone soundings in the troposphere and stratosphere are conducted weekly. Regular ozone soundings have been also performed at Marambio (Antarctica) since 1988; the data has been used in scientific publications, and form a significant contribution to the WMO ozone bulletins.

For assessing global trends and regional sources and sinks, global data integration and earth system modelling are needed. The data is sent to relevant data banks including World Data Centre for Greenhouse Gases in Japan and European data banks of CARBOEUROPE and GEOMON projects.

Trend of atmospheric methane concentrations is a result of many anthropogenic and natural sources of which possible increases of terrestrial and marine sources in Arctic areas have recently raised lively discussion. Warming of the Arctic region will change patterns of methane emissions from wetlands. Huge reservoirs of organic carbon are stored in northern peatlands. According to some scenarios there is a high risk that warming will increase soil respiration turning these long-term sinks of atmospheric carbon dioxide to net sources. Measurements of ambient air concentrations in the high northern latitudes are essential to monitor the effects of environmental changes in this area and to act as early warning guards. The importance of the GAW-station of Pallas-Sodankylä is emphasized by the fact that it is the only continuously monitoring site in the northern parts of Eurasia.

Variations of ambient air concentrations have source areas of thousands of kilometres integrating various sources and sinks. For monitoring carbon dioxide and methane fluxes at ecosystem level, micrometeorological methods are available. Using high-tech instrumentation we can observe gas exchange of a forest or mire continuously, year round. Presently, the Finnish Meteorological Institute measures continuously methane emissions and carbon dioxide exchange from two subarctic *aapa* mires and carbon dioxide exchange of two forests in Northern Finland. These data are used to study the effect of climate on seasonal and annual patterns of carbon sink and methane emissions in northern boreal and subarctic regions. The sites belong to the European CARBOEUROPE flux measurement network and the observations are analysed together with other global flux networks.

## Air quality

Finnish Meteorological Institute is responsible for the national background air quality monitoring. The monitoring network consists of about twenty measurement stations in different parts of the country. Most of the measurements are part of the international monitoring and research programmes.

The background air quality monitoring started in the beginning of the 1970's. The longest time series from those days include sulphur dioxide and major ions in precipitation. Nowadays monitoring measurements include major ions, PAHs, heavy metals and mercury in air and in precipitation, ozone, sulphur- and nitrogen oxides, volatile organic compounds, and fine particles. Quality assurance procedures are an essential part of the monitoring routines.

The Global Atmosphere Watch (GAW) programme of the World Meteorological Organization (WMO) provides highly accurate measurement data on the atmospheric composition and other information related to physical characteristics of the background atmosphere from all parts of the globe. In addition to the GAW-functions the Pallas-Sodankylä station is also a part of Arctic Monitoring and Assessment Programme (AMAP) co-ordinated by the Arctic Council. Five stations (Pallas, Ähtäri, Virolahti, Oulanka and Utö) belong to the European Monitoring and Evaluation Programme (EMEP).

The Integrated Monitoring programme (IM co-ordinated by UN/ECE) refers to the simultaneous measurements of physical, chemical and biological properties of an ecosystem over time and across compartments at the same location. There are two IM measurement stations (Kotinen and Hietajärvi). HELCOM's (Helsinki Commission co-ordinated by the Baltic Marine Environment Protection Commission) objective is to protect the marine environment of the Baltic Sea. There is one HELCOM station; Hailuoto.

The FMI also maintains the monitoring and warning system of the tropospheric ozone concentrations according to the European Union's Ozone Directive (92/72/EEC). There are ten ozone monitoring stations (Utö, Virolahti, Evo, Jokioinen, Ähtäri, Oulanka, Ilomantsi, Pallas, Sodankylä ja Raja-Jooseppi). Air quality issues in European Union are co-ordinated by the European Environment Agency and in the European Topic Centre on Air Quality.

**Aerosols**

Aerosols have direct and indirect effects on the atmosphere. The magnitude of these effects, as regards warming or cooling, remains one of the most significant sources of uncertainty in climate models. As a Finland’s contribution to WMO GAW program, FMI runs Pallas-Sodankylä station. Sodankylä is the classical meteorological part of the twin site, homogenized data records date back to 1908. Pallas is a new clean air site for air chemistry and aerosol measurements established 1994. The variables measured there include the scattering, backscattering, absorption and size distribution. Aerosol optical depth (AOD) is measured with PFR sunphotometer at Sodankylä GAW station and Jokioinen Observatory as well as in Argentine Antarctic station Marambio. AOD results are regularly submitted to World Data Centre for Aerosols (WDCA). Furthermore, there are three AERONET stations in Finland, located at Hyytiälä (run by the University of Helsinki), Kuopio and Helsinki (both run by the FMI) for measuring AOD as well as microphysical and radiative properties of aerosols in atmospheric column. Related to FMI’s contribution to EUCAARI, fourth AERONET station is in Gual Pahari, India. Mass concentration monitoring (PM10, PM2.5) is performed in five stations by FMI. Chemical composition of aerosol (major ions and heavy metals) is analyzed.

Finland has also three field sites in ACCENT (Network of Excellence funded by EC, FP6, PRIORITY 1.1.6.3 Global Change and Ecosystems) and EUSAAR (European Supersites for Atmospheric Aerosol Research).

**Table 1a. National contributions to the surface-based atmospheric essential climate**

| Contributing networks specified in the GCOS implementation plan | ECVs | Number of stations or platforms currently operating | Number of stations or platforms operating in accordance with the GCMPs | Number of stations or platforms expected to be operating in 2010 | Number of stations or platforms providing data to the international data centres | Number of stations or platforms with complete historical record available in international data centres |
|---|---|---|---|---|---|---|
| **GCOS Surface Network (GSN)** | Air temperature | 3 | 3 | 3 | 3 | - |
| | Precipitation | 3 | 3 | 3 | 3 | - |
| **Full World Weather Watch/Global Observing System (WWW/GOS) surface network** | Air temperature, air pressure, wind speed and direction, water vapour | 160 | - | 160 | 160 | |
| | Precipitation | 160 | - | 160 | 160 | - |
| **Baseline Surface Radiation Network (BSRN)** | Surface radiation | 0 | - | 0 | - | - |
| **Solar radiation and radiation balance data** | Surface radiation | 8 | - | 8 | - | - |
| **Ocean drifting buoys** | Air temperature, air pressure | | | | | |
| **Moored buoys** | Air temperature, air pressure | | | | | |
| **Voluntary Observing Ship Climate Project (VOSClim)** | Air temperature, air pressure, wind speed and direction, water vapour | | | | | |
| **Ocean Reference Mooring Network and sites on small isolated islands** | Air temperature, wind speed and direction, air pressure | | | | | |
| | Precipitation | | | | | |

**Table 1b. National contributions to the upper-air atmospheric essential climate variables**

| Contributing networks specified in the GCOS implementation plan | ECVs | Number of stations or platforms currently operating | Number of stations or platforms operating in accordance with the GCMPs | Number of stations or platforms expected to be operating in 2010 | Number of stations or platforms providing data to the international data centres | Number of stations or platforms with complete historical record available in international data centres |
|---|---|---|---|---|---|---|
| **GCOS Upper Air Network (GUAN)** | Upper-air temperature, upper-air wind speed direction, upper-air water vapour | 1 | 1 | 1 | 1 | 1 |
| **Full WWW/GOS Upper Air Network** | Upper-air temperature, upper-air wind speed direction, upper-air water vapour | 3 | 3 | 3 | 3 | |

**Table 1c. National contributions to the atmospheric composition**

| Contributing networks specified in the GCOS implementation plan | ECVs | Number of Stations or platforms currently operating | Number of stations or platforms operating in accordance with the GCMPs | Number of stations or platforms expected to be operating in 2010 | Number of stations or platforms providing data to the international data centres | Number of stations or platforms with complete historical record available in international data centres |
|---|---|---|---|---|---|---|
| **World Meteorological Organization/ Global Atmosphere Watch (WMO/GAW) Global Atmospheric CO2 & CH4 Monitoring Network** | Carbon dioxide | 1 | 1 | 1 | 1 | 1 |
| | Methane | 1 | 1 | 1 | 1 | 1 |
| | Other greenhouse gases | 1 | 1 | 1 | 1 | 1 |
| **WMO/GAW ozone sonde network** | Ozone | 1 | 1 | 1 | 1 | 1 |
| **WMO/GAW column ozone network** | Ozone | 1 | 1 | 1 | 1 | 1 |
| **WMO/GAW Aerosol Network** | Aerosol optical depth | 5 | 5 | 5 | 5 | 5 |
| | Other aerosol properties | 7 | 5 | 7 | 5 | 5 |

## Role of satellites

Finland is the member of the European Space Agency (ESA) and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT). ESA, focused on research and development projects, as well as EUMETSAT, more orientated towards pre-operational and operational projects, have activities in the field of climate monitoring. The Finnish Meteorological Institute hosts the ozone research programme and participates in the satellite climate data programme.

### Ozone

Several satellite instruments provide global distributions of ozone columns and profiles. Finnish Meteorological Institute (FMI) has a major contribution in four of these: GOMOS, OSIRIS, OMI and GOME-2. High resolution (2-3 km) ozone profiles are obtained from GOMOS onboard ESA's Envisat satellite and OSIRIS onboard Swedish Odin satellite. Total ozone columns are measured operationally by Dutch- Finnish OMI instrument on-board NASA's EOS-Aura satellite. In addition, Finnish Meteorological Institute is leading EUMETSAT's Satellite application Facility on ozone and atmospheric chemistry monitoring. This project aims for processing and archiving several trace gases from Metop satellite, including ozone from GOME-2 and IASI. By combining the measurements from several instruments better understanding of the geographical, vertical and temporal distribution can be obtained. The tropospheric ozone is one of the products that can benefit from combining data. FMI is also offering a Very Fast Delivery service for distributing OMI total ozone maps of Northern-Europe within 30 min of the measurement time.

### Greenhouse gases and air pollutants

Dutch-Finnish Ozone Monitoring Instrument OMI measures ozone, $NO_2$, $SO_2$ and HCHO daily with 24 x 13 km ground resolution at nadir. This is presently the best resolution that is available for such measurements from space and it allows studies of greenhouse gases and air pollutants on city level. FMI is also contributing to satellite measurements by providing validation data (e.g. ozone and $CO_2$) from Sodankylä-Pallas validation site in Northern-Finland.

### Aerosols

Retrieval of aerosol properties using satellite measurements enables the observation of the spatial distribution of the properties. Since the spatial and temporal variation of aerosol loading is highly varied in troposphere, satellite data gives opportunity to detect these variations. Aerosol optical depth (AOD) spectrum is the main retrieved property. In addition, information about the physical properties of aerosols can be derived. At FMI, aerosol properties are retrieved using two satellite instruments: the European Advanced Along-Track Satellite Radiometer (AATSR) and the Dutch-Finnish Ozone Monitoring Instrument (OMI). Purpose of these retrievals is to provide global information for the climate change research, and for other research purposes. Also, operational aerosol retrieval using the AATSR is under development.

## Snow cover

FMI is responsible for the snow cover (SC) product development of the Land surface analysis Satellite Application Facility project financially supported by EUMETSAT. The SC product is computed within the area covered by the MSG disk, over 4 specific geographical regions (Europe, Africa - N_Africa and S_Africa- and South America), every 15 minutes. For each day and geographical region, the SC field and respective Quality Control (QC) data are disseminated in HDF5 format; the relevant information concerning the data fields is included in the HDF5 attributes. Also the SC field for each time slot is available.

FMI is also responsible for the development of the snow cover, snow moisture content, snow water equivalent and partial snow cover products in the project Satellite Application Facility of Operational Hydrology and Water Management financially supported by EUMETSAT. SYKE and Helsinki University of Technology are partners within the project. The products are delivered for non-mountaineous areas of Europe. For the time being the products are pre-operational.

## Albedo

FMI is responsible for the surface albedo product (SAL) development of the Satellite Application Facility on Climate Monitoring project financially supported by EUMETSAT. The SAL product is computed within the area covered by the MSG disk every 15 minutes and for the area covering Europe with Arctic extension for all Metop/AVHRR and NOAA/AVHRR images received by DWD. The Arctic area with the North Pole as the image center will be operationally processed beginning 2009. The official albedo products are the weekly and monthly means, but also daily means and instantaneous products are delivered on request. The surface albedo products contain currently also the sea ice and water albedo values besides the land cover albedo values.

# 3. OCEAN ESSENTIAL CLIMATE VARIABLES

## Introduction

The Finnish Institute of Marine Research (FIMR) maintains networks of water level and water temperature observations in the marine areas of Finland. The FIMR has also developed the Baltic Sea Database (Algaline), which provides real-time information on the state of the Baltic Sea for the general public, media and authorities.

The FIMR has recently participated in the development of operational sea ice monitoring by satellites, integrated use of new microwave satellite data for sea ice observations and improvement of measurement technologies for marine near-surface fluxes. All three studies were EU projects. The EURONODIM programme in 1998–2000 created a European network for oceanographic data and information management.

**Table 3a. National contributions to the oceanic essential climate variables – surface**

| Contributing networks specified in the GCOS implementation plan | ECVs | Number of stations or platforms currently operating | Number of stations or platforms operating in accordance with the GCMPs | Number of stations or platforms expected to be operating in 2010 | Number of stations or platforms providing data to the international data centres | Number of stations or platforms with complete historical record available in international data centres |
|---|---|---|---|---|---|---|
| **Global surface drifting buoy array on 5x5 degree resolution** | Sea surface temperature, sea level pressure, position-change based current | | | | | |
| **GLOSS Core Sea-level Network** | Sea level | 13 | | 13 | 6 | 13 |
| **Voluntary observing ships (VOS)** | All feasible surface ECVs | | | | | |
| **Ships of Opportunity** | All feasible surface ECVs | 3 | | 4 | | |

FIMR's Algaline-project utilises so-called ship-of-opportunity (SOOP) monitoring system, which uses merchant ships as operating platforms. The data collection and water sampling for analytical measurements are carried out with autonomous flow-through measuring systems. Recently, the SOOP-systems of this kind have been increasingly adopted for routine use all over the world as the most cost-effective environmental monitoring system. Algaline is a forerunner in the field of unattended SOOP-monitoring, and currently forms a state-of-the-art environmental monitoring system from data collection and assimilation to Internet applications and products.
http://www.fimr.fi/en/tietoa/algaline_seuranta/en_GB/algaline_seuranta

FIMR-Algaline has collaboration with several research institutes, local environmental instances, military, non-governmental entities and shipping companies. The monitored oceanographic data is published through the Baltic Sea Portal within 2 days. Portal disseminates information concerning the Baltic Sea as follows: weekly algae newsletter, blue-green algal bloom maps, taxonomic reports, latest flow-through and analytical measurements as figures, as well as general information about the Baltic Sea, its environment, and its recent development.

**Table 3b. National contributions to the oceanic essential climate variables – water column**

| **Contributing networks specified in the GCOS implementation plan** | **ECVs** | **Number of stations or platforms currently operating** | **Number of stations or platforms operating in accordance with the GCMPs** | **Number of stations or platforms expected to be operating in 2010** | **Number of stations or platforms providing data to the international data centres** | **Number of stations or platforms with complete historical record available in international data centres** |
|---|---|---|---|---|---|---|
| **Global reference mooring network** | All feasible surface and subsurface ECVs | - | - | - | - | - |
| **Global tropical moored buoy network** | All feasible surface and subsurface ECVs | - | - | - | - | - |
| **Argo network** | Temperature, salinity, current | - | - | - | - | - |
| **Carbon inventory survey lines** | Temperature, salinity, ocean tracers, biogeochemistry variables | - | - | - | - | - |

## Role of satellites

Finnish Ice Service is responsible to collect, analyse and distribute sea ice data in the Baltic Sea. The input data consists of ground truth, visual air-borne data, and space-borne data of various satellites. Satellite data from RADARSAT 1, ENVISAT, AMSR, NOAA/AUHRR and MODIS is or has been used. Space borne synthetic aperture radar (SAR) has been used operationally by the icebreakers in the Baltic Sea since 1992. Today, both RADARSAT and ENVISAT advanced synthetic aperture radar (ASAR) data are delivered to end-users. Ice Thickness Charts are operationally produced from a SAR image received, using the latest available ice chart as an input. The algorithm, which combines SAR data and ground truth, provides ice thickness information in 500 m resolution. The products are provided operationally and are available for users shortly after the SAR data is available. The sea surface temperature in the Baltic Sea is monitored using NOAA/AVVHRR and MODIS satellite images.

MODIS-Aqua L1β-data from NASA server is used for Baltic Sea chlorophyll-a research.

Analysing sea state wave height data from JASON 1 is used to compare the models.

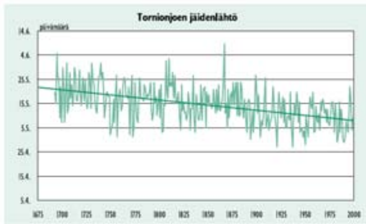
# 4. TERRESTRIAL ESSENTIAL CLIMATE VARIABLES

## Introduction

The Finnish Environment Institute (SYKE) is a national centre for monitoring the physical, chemical and biological state of inland waters in Finland. Terrestrial ECVs and relevant metadata are included in the following registers:

- Hydrology and Water Resources Management Data System (HYDRO)
- Groundwater Database (POVET)
- State of Finland's Surface Waters (PIVET)
- Lake Register
- Information System for Monitoring Land Use Planning.

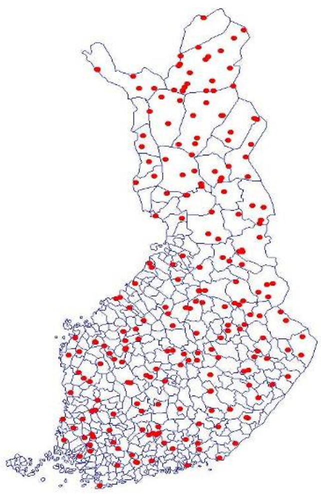
Of particular interest in climate change studies is HYDRO, because it contains a number of time series dating back to the 1800s. The series on the freezing and breakup dates of Finnish lakes and rivers are particularly long. The longest of them, breakup dates of River Tornio in northern Finland, starts as early as 1693 ***(cf. figure in the right).***




Indikaattori 1.3 Tornionjoen jäidenlähtö 1693-1999 (lineaarinen regressioanalyysi). Lähteet: Juha Kajander 1995. Cryophenological records from Tornio; Suomen ympäristökeskus, Vesivarayksikkö.

Finland is reporting to the Global Runoff Data Centre (GRDC), located in Koblenz, Germany. The number of stations reported is 50, out of the total of 280. Nordic runoff data centre at SMHI, Sweden, also contains a considerable amount of Finnish runoff data.

Finland has one of the densest snow survey network in the world. Snow depth is measured at 50-80 points and snow density at ten points on each survey line, which have a length of 2.5-4 km. Snow surveys have been made since the late 1940s, and areal water equivalents of snow have been calculated for all major river basins. In southern and central Finland, these data series are around 60 years long, in the north 30-50 years.



Cryospheric data from Finland have been reported to the National Snow and Ice Data Center (NSIDC) at Boulder, Colorado. These data include particularly the longest freezing and breakup data series.

There are no glaciers in Finland. Sporadic permafrost exists in the northernmost part of the country, but no regular observations have been made.

Finland has a network of 54 groundwater stations, also operated and maintained by the Finnish Environment Institute. In addition to groundwater levels, soil moisture and the depth of soil frost are measured. Most stations were established in the 1970s.

Information related to irrigation is not systematically collected, because this type of water use is rather limited in Finland. Sectoral water withdrawals are collected annually for municipal water supply, industry and agriculture.

As to land use, Statistics Finland maintains data registers. The Finnish Forest Research Institute (METLA) performs national forest inventories. The first inventory covering the entire Finland was carried out in 1921-24, the ninth one in 1996-2003.

Flood forecasting at the Finnish Environment Institute is based on the Watershed Simulation and Forecasting System (WSFS). Its main component is a hydrological model representing the circulation of water in a catchment. WSFS covers 100% of Finland and is used for forecasting over 85% of the total area of the country. The forecasts are made daily for 300 water level and discharge observation points. The WSFS is used for a number of purposes, including studies on climate change.

In 1998, the European Environment Agency issued instructions for building an observation network for monitoring the quality and quantity of water in EU member states. Together, the national networks form EUROWATERNET, which provides reliable and comparable data on the state of waters all over Europe. In Finland, the new monitoring system was implemented at the beginning of 2000. There are 195 observation points for rivers, 253 for lakes and 74 hydrological sampling stations.

**Table 5. National contributions to the terrestrial domain essential climate variables**

| **Contributing networks specified in the GCOS implementation plan** | **ECVs** | **Number of stations or platforms currently operating** | **Number of stations or platforms operating in accordance with the GCMPs** | **Number of stations or platforms expected to be operating in 2010** | **Number of stations or platforms providing data to the international data centres** | **Number of stations or platforms with complete historicalrecord available in international data centres** |
|---|---|---|---|---|---|---|
| **GCOS baseline river discharge network (GTN-R)** | River Discharge | 280 | | 280 | 50 | 50 |
| **GCOS Baseline Lake Level/ Area/Temperature Network (GTN-L)** | Lake level/area/ temperature | 310 - 35 | | 310 - 35 | | |
| **WWW/GOS synoptic network** | Snow cover | | | | | |
| **GCOS glacier monitoring network (GTN-G)** | Glaciers mass balance and length, also ice sheet mass balance | | | | | |
| **GCOS permafrost monitoring network (GTN-P)** | Permafrost Borehole temperatures and active-layerthickness | | | | | |

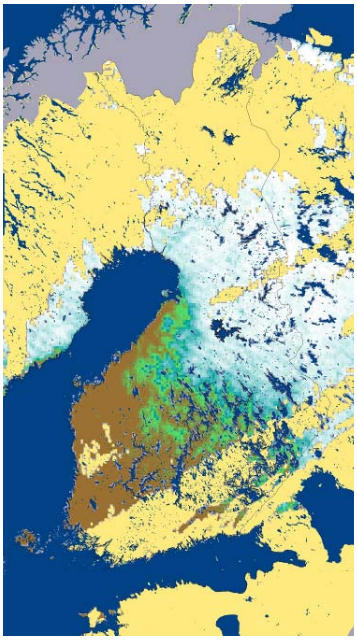
## Role of satellites

### Lakes and Coastal waters

The operational satellite-based surface water related products of SYKE are surface water temperature and surface algal blooms for Sea areas surrounding Finland. In addition, turbidity and chlorophyll a are reported seasonally. In lakes, water surface temperature is monitored annually for 12 large lakes in Finland. The satellite images used for water related products are NOAA/AVHRR and ENVISAT/MERIS. The operational products are available on SYKE's internet pages (www.environment.fi/syke/remotesensing).

### Snow

Satellite images by optical sensors have been used in the monitoring of snow melt since 1999. Remote sensing of snow is related to SYKE's nationwide hydrological monitoring and forecasting; its major task is to provide information for hydrological forecasting in order to improve the forecasts.



The remote sensing activity produces estimates on the regional fraction of Snow Covered Area (SCA) for 500m×500m grid cells as well as for all 3dr order drainage basins of Finland. The basin-wise product enables the practical use of SCA-estimates in the hydrological forecasting models. Currently, SCA-maps are produced with a specific SCA-method developed at SYKE. The method uses optical data provided by Terra/MODIS (other sensors such as NOAA/AVHRR can also be used). MODIS-imagery covering the Baltic Sea drainage area are delivered daily to SYKE from the Finnish Meteorological Institute. The results are presented as thematic maps in SYKE's internet pages (www.environment.fi/snowcover). Besides the thematic maps, the numerical information is delivered to the hydrological model.

Due to cloudy weather conditions in Finland during snow melt period a method for SCA-estimation using microwave radar data has been developed at Helsinki University of Technology and adapted to operational use at SYKE in 2006.

The snow water equivalent of snow (SWE) can be mapped using 25km×25km at-satellite microwave radiometer data combined with the at-ground observations on snow depth. The AMSR-E radiometer data are well suited for SWE-mapping with two daily overpasses over Finland are freely downloadable from NASA's web-portal. AMSR-E-based method is still under further development, this work mainly related to it accuracy- still providing feasible SWE data to be used in hydrological forecasts already in near future.

## Land Cover and vegetation

SYKE has participated in production of land cover data since the late 1980s. In the CORINE2000 program the land cover of Europe in the year 2000 (+/- 1 year) was mapped. SYKE produced the data covering Finland by combining satellite and map information with field measurements.

The CORINE Land Cover databases are updated on regular basis (every 5-10 years). Presently CLC2000 is updated to the reference year 2006 in Europe. In Finland the work will be completed year 2009 and a new land cover database including land cover changes between 2000-2006 will be produced. The update is based on national GIS data sets, environmental registers, in-situ measurements and IMAGE2006 satellite data (IRS P6 LISSIII and SPOT 4/5 XS). The Finnish Forest Research Institute produces the land cover information in forests using field measurements of National Forest Inventory and IMAGE2006 data.

Land use and land cover information are made available as regional statistics (drainage basins, municipalities, ground water areas) in environmental information system and as GIS data in data servers (see: www.environment.fi/syke/clc2000).

Daily TERRA/AQUA MODIS satellite data are used in the seasonal monitoring of vegetation status for different land cover categories. Parameters describing the seasonal changes in vegetation coverage are evaluated in dynamic modeling of diffuse nutrient loads into water bodies.

# 5. ADDITIONAL INFORMATION

Finland is working hard to maintain the best systematic observations program with the resources available. The process of automation is a great challenge in order to keep the continuity. However Finland will support global climate monitoring by applying GCOS Climate Monitoring Principles (cf. Annex 2) in all the observing work as far as possible. Finland will continue to keep high standards in its climate-related observing work, and will continue to support the GCOS and its programs in the future, too.

The relatively rapid advance of observation techniques and methods due to technical development in measurements and data processing has many effects on the observation network. Modern observation systems usually provide better temporal and/or spatial sampling than the old ones. Also new variables can be monitored. On the other hand introduction of new methods and techniques is a potential threat to the consistency of observations. It is of paramount importance that observation systems are developed in a balanced way.

**Annex 1**

# GCOS Essential Climate Variables

The Essential Climate Variables (ECVs; ) are required to support the work of the UNFCCC and the IPCC. All ECVs are technically and economically feasible for systematic observation. It is these variables for which international exchange is required for both current and historical observations. Additional variables required for research purposes are not included in this table. It is emphasized that the ordering within the table is simply for convenience and is not an indicator of relative priority. Currently, there are 44 ECVs plus soil moisture recognized as an emerging ECV.

| Domain | Essential Climate Variables |
|---|---|
| **Atmospheric**<br><br>(over land, sea and ice) | **Surface:** Air temperature, Precipitation, Air pressure, Surface radiation budget, Wind speed and direction, Water vapour.<br><br>**Upper-air:** Earth radiation budget (including solar irradiance), Upper-air temperature (including MSU radiances), Wind speed and direction, Water vapour, Cloud properties.<br><br>**Composition:** Carbon dioxide, Methane, Ozone, Other long-lived greenhouse gases[1], Aerosol properties. |
| **Oceanic** | **Surface:** Sea-surface temperature, Sea-surface salinity, Sea level, Sea state, Sea ice, Current, Ocean colour (for biological activity), Carbon dioxide partial pressure.<br><br>**Sub-surface:** Temperature, Salinity, Current, Nutrients, Carbon, Ocean tracers, Phytoplankton. |
| **Terrestrial**[2] | River discharge, Water use, Ground water, Lake levels, Snow cover, Glaciers and ice caps, Permafrost and seasonally-frozen ground, Albedo, Land cover (including vegetation type), Fraction of absorbed photosynthetically active radiation (fAPAR), Leaf area index (LAI), Biomass, Fire disturbance, Soil moisture[3]. |

[1] Including nitrous oxide ($N_2O$), chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), sulphur hexafluoride ($SF_6$), and perfluorocarbons (PFCs).

[2] Includes runoff ($m^3 s^{-1}$), ground water extraction rates ($m^3 yr^{-1}$) and location, snow cover extent ($km^2$) and duration, snow depth (cm), glacier/ice cap inventory and mass balance ($kg\ m^{-2} yr^{-1}$), glacier length (m), ice sheet mass balance ($kg\ m^{-2} yr^{-1}$) and extent ($km^2$), permafrost extent ($km^2$), temperature profiles and active layer thickness, above ground biomass (t/ha), burnt area (ha), date and location of active fire, burn efficiency (%vegetation burned/unit area).

[3] Recognized as an emerging Essential Climate Variable (not part of the 44).

**Annex 2**

# 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.

11. 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 inter-annual) changes can be resolved. Thus satellite systems for climate monitoring should adhere to the following specific principles:
12. Constant sampling within the diurnal cycle (minimizing the effects of orbital decay and orbit drift) should be maintained.
13. 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.
14. Continuity of satellite measurements (i.e. elimination of gaps in the long-term record) through appropriate launch and orbital strategies should be ensured.
15. Rigorous pre-launch instrument characterization and calibration, including radiance confirmation against an international radiance scale provided by a national metrology institute, should be ensured.
16. On-board calibration adequate for climate system observations should be ensured and associated instrument characteristics monitored.
17. Operational production of priority climate products should be sustained and peer-reviewed new products should be introduced as appropriate.
18. 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.
19. 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.
20. Complementary in situ baseline observations for satellite measurements should be maintained through appropriate activities and cooperation.
21. 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.)*