Koninklijk Nederlands
Meteorologisch Instituut
Ministerie van Infrastructuur en Milieu

Climate Observing Systems in the Netherlands

National Activities Contributing to GCOS

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Executive summary

Climate monitoring is a multidisciplinary and international activity. KNMI and partner institutes in the Netherlands contribute to climate monitoring and coordinate their actions based on a national implementation in accordance to the Implementation Plan of the WMO Global Climate Observing System (GCOS-IP, WMO/TD No. 1244, October 2004). Here we summarize the contribution of governmental institutes and universities in the Netherlands to climate monitoring activities.

This document consists of two parts. First, the various institutions and universities are introduced with a short statement describing their respective contributions to climate monitoring. Next follows a set of highlights in each of the three climate monitoring domains [atmospheric, oceanic and terrestrial]. The survey as shown here is by no means exhaustive; a representative selection is made of both in situ and satellite observations as a detailed description of all activities is beyond the scope of this summary document. The highlights are each supplemented by tables in which inventories are given of the relevant essential climate variables, the institution / university responsible for their collection and the appropriate websites or data collection centres where further description of the efforts can be found.

Climate monitoring can only exist as a continuous activity. The value of its output stands or falls with the ability of investigators to string together high quality data sets through the generations. After all, the 'life time' of a dedicated investigator is only 30 to 40 years, and that of funding programmes is much less than that. The inevitable result of the short life time of investigators is disruption of activities, loss of funding and most

importantly discontinuities in climate time series. And it is just these discontinuities, disruptions and questions about accuracy that are the root cause of many heated discussions about past and current climate change.

Climate monitoring data are used by policy makers in effective planning to deal with climate variations, trends and extremes, and to cope with their impacts. Since the beginning of this century many advances have been made in the observing technologies, in particular from satellites of which several examples are shown in this document. Yet, nationally the continuation of existing ground-based monitoring efforts is under pressure by limiting short-term funding cycles and budgetary constraints, a fact that has not escaped the attention of the UNFCCC in its review of the NC6 communication of the Netherlands on Research and Systematic Observations.

Climate monitoring is a wide-spread distributed activity. No one institution by itself is able to perform all complex tasks of monitoring all climate parameters. This is both a strength and a weakness. It is a strength because the specialized skills in developing and maintaining sophisticated monitoring equipment can only be developed in the institutional and university surroundings that are the most suitable to foster the excellence needed in order to perform this work. But it is also a weakness, because scattered monitoring efforts may lead to insufficient and uncoordinated outreach to policymakers, stakeholders or other end users. Reports like this may improve the outreach, strengthen cooperation and foster the usability of climate monitoring data sets.

Contributing authors

KNMI: Marc Allaart, Wouter Knap, Jan Fokke Meirink, Andreas Sterl, Gé Verver
ECN: Alex Vermeulen
IGRAC: Nienke Ansems
NIOZ: Laura de Steur
RIVM: Daan Swart
RWS: Peter Heinen
RUG: Huilin Chen, Harro Meijer
TNO: Bas Henzing
TUDelft: Herman Russchenberg
VU: Han Dolman, Guido van der Werf
WUR: Martin Herold, Brice Mora

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GCOS: Contributing Institutes in the Netherlands

GCOS activities are distributed activities. In the Netherlands a number of government institutes and universities contribute to the collection of climate data that are distributed to international GCOS-related networks. Here we briefly describe these institutes and their main GCOS activities.

KNMI

Koninklijk Nederlands Meteorologisch Instituut
Ministerie van Infrastructuur en Milieu

The Royal Netherlands Meteorological Institute [KNMI] is the main independent authority on atmospheric climate. KNMI controls an expansive network of stations for recording climatological data. Validated data are made available to national and international data centres. A climate services department is responsible for the collection, validation and distribution of data. KNMI is focal point for climate observations by satellite. These observations include trace gases, aerosols and clouds. Main satellite instruments are GOME, GOME2, OMI, SEVIRI and SCIAMACHY. To validate satellite observations profiles of ozone, NO_2 are regularly taken. KNMI supports the collection of oceanic observations by contributing to the ARGO buoy network and to the collection of oceanic data from more than 150 ships via the VOS network. KNMI maintains the climate observatory CESAR at the central location of Cabauw [51.97 N, 4.93 E], which includes a 200 m observing tower and remote sensing site.

Deltares

Deltares
Enabling Delta Life

Deltares is an independent institute for applied research in the field of water, subsurface and infrastructure. The main focus is on deltas, coastal regions and river basins. Deltares contributes to the Northwest European Shelf Operational Oceanic System [NOOS], in developing and implementing ocean observing and prediction systems for the Northwest Shelf area, with delivery of real time operational data products and services.

ECN

ECN
Your energy. Our passion.

The Energy Centre of the Netherlands [ECN] has established a long term monitoring program of trace gases, aerosols and radon at the 200 m tower of Cabauw. Through their involvement in ICOS and many European Research Programs they have been able to sustain a continuous observations program of more than 2 decades.

IGRAC

IGRAC is officially the UNESCO global groundwater centre, a legally independent foundation and the in-house partner of the UNESCO-IHE, in Delft, the Netherlands. The Global Groundwater Monitoring Network (GGMN) is a participative, web-based network of networks, set up to improve quality and accessibility of groundwater monitoring information and subsequently our knowledge on the state of groundwater resources. GGMN is a UNESCO programme, implemented by IGRAC and supported by many global and regional partners.

NIOZ

The National Institute for Research of the Sea [NIOZ] is a Dutch research institute in the field of oceanographic sciences. In order to do this research the NIOZ has a number of research vessels in service. The RV *Pelagia* is one of them. On board there are facilities to do field work such as fixed laboratoria and places for mobile laboratoria. The NIOZ is currently involved in several long-term oceanic subsurface mooring programs that collect ocean temperature, salinity and velocity data. A profiling mooring in the central Irminger Sea initiated by the Long-term Ocean Climate Observation program (LOCO) has been in place since 2003 to measure deep convection in the gyre.

RIVM

Rijksinstituut voor Volksgezondheid en Milieu
Ministerie van Volksgezondheid, Welzijn en Sport

The National Institute for Public Health and the Environment (RIVM) is a governmental research institute. RIVM operates the Dutch Air Quality Monitoring Network, with over 60 monitoring stations in the Netherlands. These stations are mainly focused on the continuous monitoring of the chemical composition of the atmosphere at ground level (air pollution). As many air pollutants also influence the radiation balance, most of them are on the list of Essential Climate Variables.

Apart from the regular reporting to the European Environmental Agency, these observations are also reported to the World Data Centre for Greenhouse Gases. RIVM operates one of the primary instruments of the NDACC site in Lauder, New Zealand, the RIVM Stratospheric Ozone Lidar which has been in operation there since 1994. Its data are reported to NDACC and WOUDC data centers, and are widely used in climate analyses and satellite validation studies. RIVM participates in CESAR, the Cabauw Experimental Site for Atmospheric Research with local surface air quality observations, and scientific studies involving profile measurements of NO_2, SO_2 and NH_3 with Lidar and DOAS. These studies mostly link to satellite validation. RIVM is also one of the founding fathers of iSpex, a Citizen Science project involving measurements of aerosols with a smart phone.

RWS

Rijkswaterstaat [RWS] controls an automatic observation network, the National Observation Network Water [LMW]. This network comprises over 400 locations which register water levels, waves, water temperature, river discharge and salt levels. This information serves multiple purposes such as operational water [level] control, shipping, research, model development, preparation and evaluation of [water] policy and detecting trends and characteristics of all water systems. A number of the 400 stations are attributable to the purpose of climate monitoring.

RUG

The Centre for Isotope Research [CIO] is part of the University of Groningen [RUG] and has been involved in programs concerning atmospheric greenhouse gases and the carbon cycle ever since the late 1970's. Started as an isotopic analysis laboratory, its activities have gradually expanded. In 2000, the CIO established the atmospheric monitoring station Lutjewad, and has operated the station continuously since then. Lutjewad is situated at the Wadden Sea Dike near the village of Hornhuizen in the north of the province of Groningen, 53° 23' N, 6° 22' E).

It consists of a 60 meters mast/tower with a multitude of air inlets and basic meteorological instrumentation.

The CIO also operates a greenhouse gas monitoring facility on the off-shore oil-and-gas platform F3 [owned by GdF Suez,54° 51' N, 4°44' E] in the North Sea, 200 km north of Den Helder . Here, CO_2 and oxygen are monitored, and there is an automatic air flask sampler installed, with remote control.

The CIO maintains the Dutch contribution to two large global datasets in the area of water isotopic abundances: it monitors the isotope ratios (^{2}H and ^{18}O, formerly also ^{3}H) of the rivers Rhine, Meuse and Scheldt at the locations where these rivers enter the Netherlands, as well as the monthly mean isotope ratios in precipitation for five stations in the Netherlands. The latter are part of the Global Network of Isotopes in Precipitation, a climate-relevant data collection maintained by the IAEA.

TNO

The Netherlands Organization for Apllied Scientific Research [TNO] is part of the CESAR consortium. It maintains aerosol measurement systems set up on the Cabauw mast which includes equipment to observe aerosol size spectra and composition. It also maintains equipment to measure aerosol optical thickness from surface remote sensing data.

TUD

The Technical University of Delft is the leading entity in the CESAR consortium that runs a synergistic research program to measure atmospheric processes and parameters. It controls several radar facilities at Cabauw and serves as an important education institution for new observational talent.

VU

The Free University at Amsterdam [VU] is involved in setting up a distributed observation network to monitor the European carbon and net greenhouse gas balance. It consists of a large number of high precision observatories for greenhouse gas concentrations fluxes over Europe including central facilities that process and integrate all data. One of the locations is the research site of Cabauw.

In a separate program satellite information on fire activity and vegetation productivity is combined to estimate gridded monthly burned area and fire emissions, as well as scalars that can be used to calculate higher temporal resolution emissions.

WUR

At Wageningen University [WUR] a project office of GOFC/GOLD is established. The Global Observation for Forest Cover and Land Dynamics [GOFC/GOLD] is a coordinated international effort working to provide ongoing space-based and in site based information of the land surface for sustainable management of terrestrial resources to obtain an accurate, reliable, quantitative understanding of the terrestrial carbon budget.

WUR contributes to the overall maintenance and development of the CESAR site at Cabauw through their involvement in the measurement of precipitation and trace gases.

WUR also maintains a greenhouse gas / surface radiation monitoring site at Loobos [1996 onwards, 52.16 N, 5.75 E]. Observations at this station are on occasion supplemented by means of aircraft vertical profiling of turbulence fluxes of energy, momentum and CO_2.

Highlights in the Atmospheric Domain

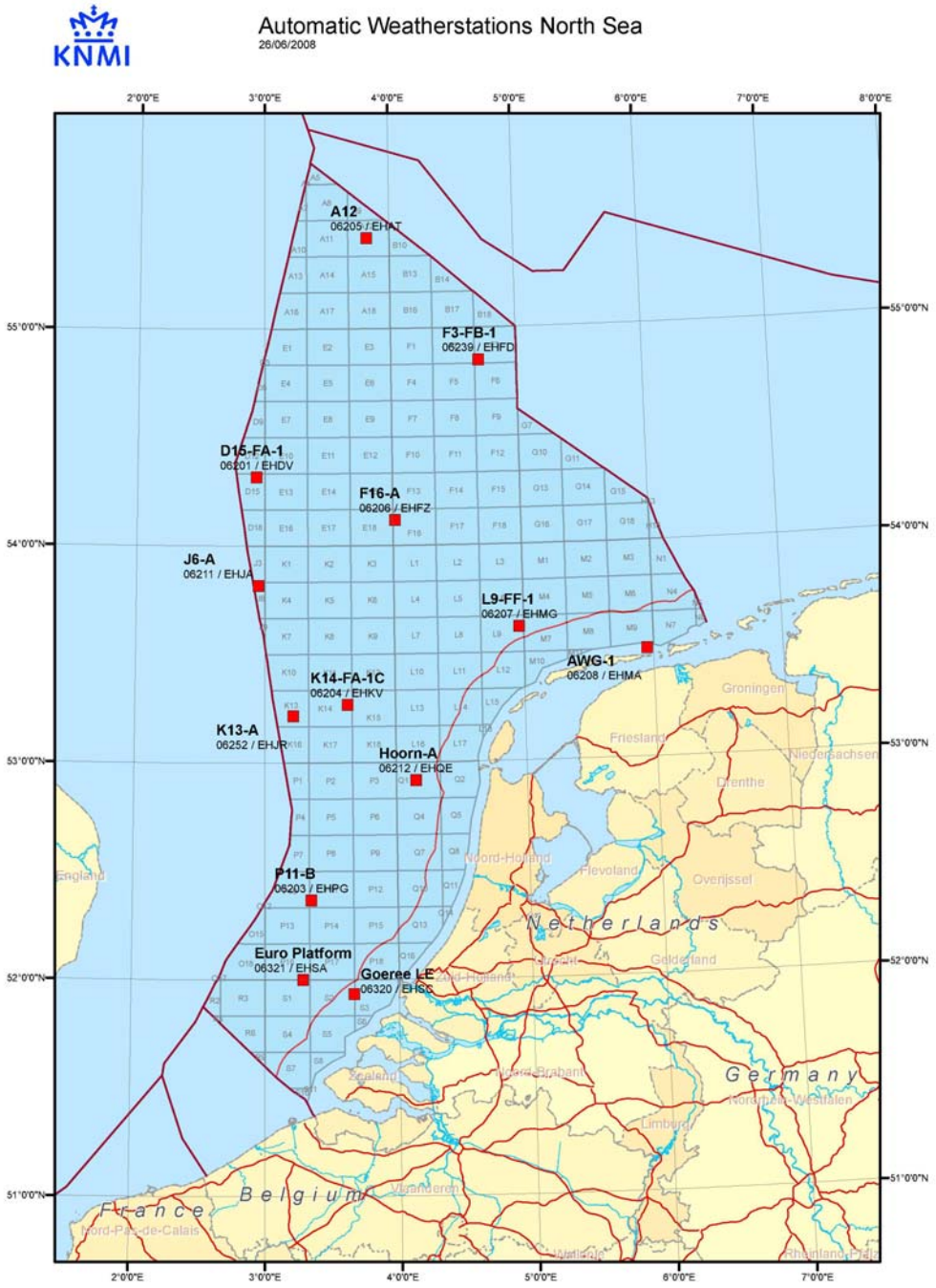
The land part of the synoptic network of the Netherlands. Red dots are the main stations. The large blue dots are the additional stations, and the small blue dots are wind mast.

The Synoptic Network of the Netherlands

In the past a unique situation has developed in the Netherlands whereby the positioning and instrumentation of observation sites evolved from requirements from several divergent interest groups The most important ones were weather / climate and air traffic management. In the last 20 years efforts have been made to optimize spatial coverage of the existing stations, which was made easier by the introduction of Automatic Weather Stations [AWS].

In comparison with our neighbour countries this situation is quite unique. In other countries there is often a separation of networks [such as synoptic, climate, air traffic, defense], each with their own users and modes of financing. In the Netherlands, the observation network had to adhere to a diffuse set of weather / climate requirements on the one hand. But on the other hand the network had to submit to other requirements from air traffic management, defense, local water authorities and even agricultural applications. This historical development has led to the current compromise which represents all users group more or less.

There are currently 42 observation sites over land maintained by KNMI, but of those 42 there are only 7 of which KNMI is their only user. Additionally, there are several coastal wind masts which are used by Water Authorities in support of water and dyke protection. Because of the different users observations were initiated at these stations at different times. There are five sites which are considered long term observation sites for climate purposes. They are De Bilt [260], De Kooy [235], Vlissingen [310], Eelde [280] and Beek [380]. All of them have recorded climate information going back into the 19th century, even though none of them have remained at exactly the same place over all these years. For example the Bilt [the oldest station] started its weather observations in the city of Utrecht in the year 1849, some 4 km away from its current location.



Location of automatic weather stations situated over the North Sea in the area controlled by the Netherlands.

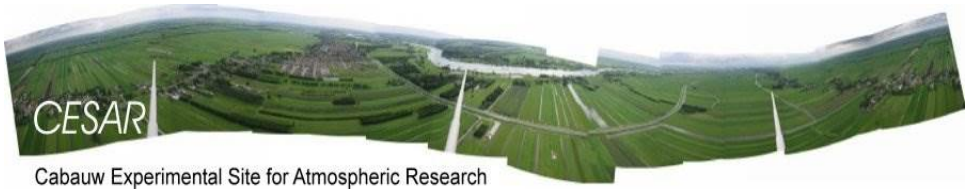
The offshore area over the North Sea attributable to control by authorities of the Netherlands is almost as large as its land mass and 13 additional AWS locations are operated by offshore industry and Water Authorities and maintained by KNMI.

The combined weather / climate and other weather observation sites on land and on water shown here is usually referred to as the Synoptic Network of the Netherlands, a vague term which derives from its unusual history. A number of the stations are assigned a special role as designated stations reporting to WMO's Regional Basic Climatological Network, or as special stations reporting to WMO's Regional Basic Synoptic Network.

The observation site of Eindhoven in the southern region of the Netherlands serves three purposes: a) as a KNMI station for climate and weather, b) in support of air traffic management and c) in support of the Defense Department which partially controls the airport.

Cabauw Experimental Site for Atmospheric Research.

Cabauw Site for Atmospheric Research [CESAR]



The Cabauw Experimental Site for Atmospheric Research (CESAR) is situated at 51.97 N, 4.93 E in a rural flat grassland region between the cities of Rotterdam and Utrecht in the Netherlands. Cabauw is the meteorological research site of KNMI and was originally established in 1974. In the first 20 years of its existence most work focused on exchange processes between the earth and atmosphere, using the 200m tower, which is instrumented with turbulence flux equipment at regular height intervals. In the mid – 1990's, the scope of the work was progressively expanded to include research on the interaction of clouds, aerosols and radiation, the evaluation of climate and weather models, the validation of satellite retrievals and the monitoring of climate. To this end additional remote sensing and radiation equipment were installed at the site.

Although KNMI is Cabauw site manager, it is not solely responsible for running and maintaining all of the scientific instruments there. In fact, a number of Dutch universities and scientific and technological research institutes are organized in the CESAR – consortium with the specific aim to jointly plan and execute their research activities at Cabauw and to share responsibility in running field programs. CESAR provides an important platform for collaboration in the field.

GRUAN

Cabauw is one of the GCOS GRUAN sites and participates in ICOS, building a high resolution network to cover the large variability of emissions of GHG from the Dutch land surface.

An important question comes up with respect to the measurement of climate parameter by different measurement systems: For a given specified precision of the measurement system, how precise can we measure a climatic trend? This question poses not only a scientific but also an economic dilemma. In the Netherlands the recession of the last 4 years made money scarce which impedes the development of climate monitoring programs, so that investments in new systems are postponed.

The Baseline Surface Radiation Network site at
the Cabauw Experimental Site for Atmospheric Research.

Baseline Surface Radiation

The Baseline Surface Radiation Network (BSRN) was conceived and implemented in the late 1980s by the World Climate Research Program (WCRP) with the collected data intended to be used for climate research applications, in particular; satellite product validation, climate model comparisons, and establishment of regional radiation climatologies, all in support of Earth radiation budget studies. In the mid-1990s, BSRN was included under GEWEX. In the late 1990s, BSRN was designated as a contributing network to the the WMO Global Atmospheric Watch (GAW) Program, and in 2004 was designated as the Global Baseline Surface Radiation Network of the Global Climate Observing System (GCOS).

Because of the important role radiation plays in the climate system, the Baseline Surface Radiation Network (BSRN) was established to provide a worldwide network to continuously measure radiative fluxes at the Earth's surface. Many of these stations began operation in 1992 and each year more stations are added to the network. About 40 stations in contrasting climatic zones, covering a latitude range from 80°N to 90°S are providing data to the BSRN archive located at the Alfred Wegener Institute (AWI) in Bremerhaven, Germany. These stations provide data for the calibration of the GEWEX Surface Radiation Budget (SRB) Project and other satellite-based measurements of radiative fluxes. At Cabauw, construction of the BSRN site was completed in 2004 and installed as a formal site at the 9th BSRN Workshop and Scientific Review in 2006.

Station Lutjewad (53° 23' N, 6° 22' E) in the province of Groningen [above] and the laboratory facilities [below].

The Lutjewad Atmospheric Greenhouse Gas Monitoring Station

Station Lutjewad [53° 23' N, 6° 22' E] has been established by the university of Groningen in 2000. Station Lutjewad is ideally situated for quantifying the anthropogenic emissions of greenhouse gases from the Netherlands, and north-western Europe. Its direct surroundings are rural, but the big industrial and highly populated areas of the Randstad and even the Ruhrgebiet are close by. Therefore Lutjewad is able to capture the anthropogenic signals of these areas as a whole, without direct local disturbances: Lutjewad is near, but not in the middle of, the large anthropogenic emissions.

Air from the tower inlets is lead to the adjacent laboratory building in which a number of continuous measurements take place: concentrations of the greenhouse gases CO_2, CH_4, N_2O and SF_6, as well as of the "anthropogenic indicator" CO. Furthermore, the tracer gas Radon is monitored, which is an important measure for atmospheric mixing. Specialties of the station are the continuous high precision measurement of atmospheric oxygen, and the various ways of air sampling for ^{14}C (radiocarbon) analysis of atmospheric CO_2.

Thanks to the funding by the Dutch national "sector plans for Physics and Chemistry" an extensive restructuring of the space inside the Lutjewad laboratory could finally take place in 2013. At present the building contains a large state-of-the art laboratory of some 40 m^2, which can be kept at room temperature also during winter. About half of the space is even climatized to +/- 1°C, suited for the most temperature-sensitive equipment, such as the atmospheric oxygen measurements.

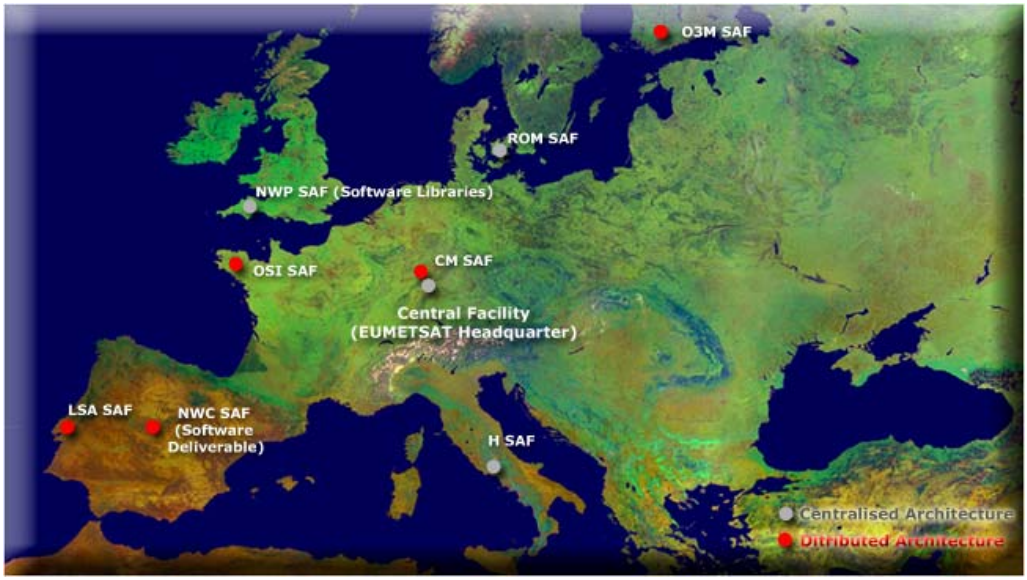
With this investment, and the extension of the atmospheric group of the University of Groningen, station Lutjewad can continue to produce high-quality data for the determination of the greenhouse gas balance. Furthermore, again thanks to the sector plans investments, the scientific program is being extended by new observations of important other atmospheric trace gases (such as COS), and of an aerosol programme.

On the longer run, systematic support for especially greenhouse gas monitoring is needed to let Lutjewad keep up with European and international initiatives .

Satellite Application Facitilities [SAF]

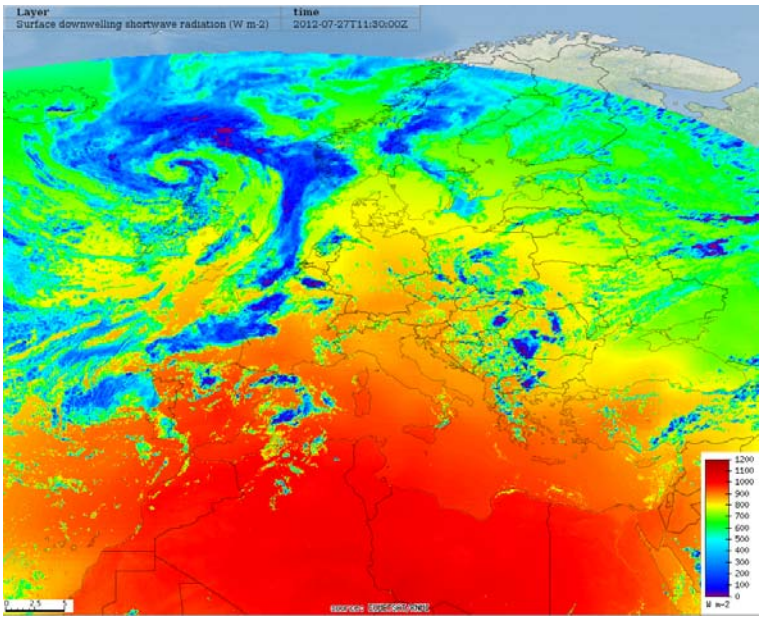
Utilising specialist expertise from the Member States, Satellite Application Facilities (SAFs) are dedicated centres of excellence for processing satellite data. They form an integral part of the distributed EUMETSAT Application Ground Segment. The eight EUMETSAT SAFs provide users with operational data and software products, each one for a dedicated user community and application area. EUMETSAT Secretariat supervises and coordinates the overall activities of the SAF network, ensuring that the SAFs in operations are providing reliable and timely operational services related to the meteorological and environmental issues. The SAF Network manages and coordinates interfaces between the SAFs themselves and between SAFs and other EUMETSAT systems, overseeing the integration and operations of SAFs into the overall ground segment infrastructure. During this process EUMETSAT ensures that services are delivered in the most reliable and cost-effective way. The SAFs help deliver a variety of benefits, but includes the preparation of data for climate monitoring.

The Netherlands participates in a number of SAF, namely the Climate Monitoring SAF, The Ocean, Sea - Ice SAF, the Ozone and Atmospheric Chemistry SAF, and the Numerical Weather Prediction SAF.



MSG-SEVIRI Satellite observations of clouds, precipitation and surface radiation

The Meteosat Second Generation (MSG) Spinning Enhanced Visible and Infrared Imager (SEVIRI) is EUMETSAT's geostationary weather satellite instrument. It roughly covers the domain of Europe, Africa, and the Atlantic Ocean, taking images at 12 visible to thermal infrared wavelengths with a repeat frequency of 15 minutes. Its spatial resolution is about 4x7 km^2 over the Netherlands.
At KNMI a range of cloud properties are routinely derived from MSG-SEVIRI observations using algorithms developed in the Climate Monitoring Satellite Application Facility (CM SAF) and other European and national projects. The cloud properties include the GCOS ECV's cloud amount, cloud-top height/ temperature, cloud optical thickness, cloud liquid and ice water path, and cloud effective particle radius. In addition, the GCOS ECV's surface solar irradiance – as well as its direct and diffuse components – and precipitation are retrieved. The satellite products have been extensively validated, and are available from 2004 onwards. Moreover, near-real time and archived products can be visualized at the dedicated website http://msgcpp.knmi.nl.



Example of surface solar irradiance retrieved from MSG-SEVIRI and visualized at the website http://msgcpp.knmi.nl.

Surface [Brewer] and Upper Air Ozone sondes

At the site "De Bilt" a Brewer Spectrophotometer is operated. The prime purpose of this instrument is to measure the total ozone column. Spin-off products of these measurements are the SO_2 column and the spectra of the solar irradiance and radiance. Measurements are continuous during daylight hours since 1994.

Ozonesondes are launched at weekly intervals. This instrument measures an ozone profile up to an altitude of 34 km. Spin-off products are temperature, humidity and wind profiles up to the same level. Additional sondes are launched if special conditions occur such as smog or polar stratospheric clouds. KNMI participates in the "Match" project, where launches of ozonesondes in the northern hemisphere polar area are coordinated in order to estimate the chemical depletion of stratospheric ozone in winter and early spring. Measurements in De Bilt have started in 1992.

KNMI also cooperates with the Meteorological Service of Suriname, where similar measurements (both Brewer and ozonesonde) are performed in Paramaribo.

All data are submitted to the WOUDC and NDACC databases after a quality check. Near real-time data of the De Bilt ozonsondes are available from the NILU database. Near-real-time data from the Brewer in De Bilt are available on the KNMI website. Ozonesonde data from the Paramaribo site are submitted to the SHADOZ database.

Brewer Ozone measurement system at the KNMI observation site at De Bilt.

CO_2/CH_4/CO Vertical Profile Measurements [AirCore]

Vertical profile measurements of greenhouse gases play a key role in improving our understanding of the sources and sinks of greenhouse gases (CO_2, CH_4), the main driver of ongoing climate change. Until recently, instrumentation aboard aircraft has been the major means to obtain such profiles.

AirCore, a long piece of stainless steel tube launched with a balloon, has been demonstrated to be a reliable sampling system for high-altitude profile measurements of CO_2 and CH_4. Compared to aircraft measurements, it is cost-effective, but covers a much larger altitude range of up to ~30 km, whereas aircraft usually reaches an altitude of ~10 km. These unique features made AirCore an ideal tool for validating observations from remote sensing techniques, e.g. Fourier Transform Spectroscopy (FTS) and satellites.

The CIO of the University of Groningen is a main hub for developing the AirCore technique in Europe, and in collaboration with the Finnish Meteorological Institute, has made the first AirCore launch in Europe. AirCore profiles of CO_2/CH_4/CO are regularly made near a FTS site at Sodankylä (67.368N, 26.633E), a total of 9 profiles from September 2013 to May 2014.

The launch(left), the recovery from the field (top right), and the analysis of AirCore in the laboratory (bottom right).

Tropospheric Monitoring Instrument [TROPOMI]

The TROPOspheric Monitoring Instrument (TROPOMI) is a spaceborne nadir viewing spectrometer with bands in the ultraviolet, the visible, the near infrared and the shortwave infrared. TROPOMI is the payload for the ESA/ GMES Sentinel 5 Precursor mission, planned for launch in 2015 with 7 years design lifetime. The objective of the mission is to provide high-quality and timely information on the global atmospheric composition for climate and air quality applications. TROPOMI will make daily global observations of key atmospheric constituents, including ozone, nitrogen dioxide, sulfur dioxide, carbon monoxide, methane, formaldehyde and aerosol properties. The Sentinel-5 Precursor mission will extent the current data records from OMI (Ozone Monitoring Instrument) on NASA EOS Aura and SCIAMACHY (SCanning Imaging Absorption spectroMeter for Atmospheric CartograpHY) on ESA Envisat and is the link between the current scientific missions and the operational Sentinel-4/-5 missions.

TROPOMI is an initiative from the Netherlands and is developed in cooperation with ESA. KNMI is the Principal Investigator institute for TROPOMI and SRON is the co-PI institute. The Netherlands Space Office (NSO) manages the TROPOMI project in the Netherlands.

At this stage [pre-launch] all efforts is geared towards technical completion of the instruments. The instrument is expected to go into orbit in 2015, and soon afterwards analysis will be initiated to extract ECV - parameters.

The ESA
Climate Change Initiative [CCI]

To respond to the need expressed by GCOS to provide Essential Climate Variables the European Space Agency (ESA) has initiated a new programme, Global Monitoring of Essential Climate Variables, (known as the ESA Climate Change Initiative) to provide an adequate, comprehensive, and timely response to the extremely challenging set of requirements for (highly stable) long-term satellite-based products for climate, that have been addressed to Space Agencies via GCOS and CEOS. It is exclusively concerned with addressing the explicit needs of UNFCCC.

Most of the effort will be focussed on activities related to ESA historical archives, and the contributions forthcoming ESA research (Earth Explorer e.g. GOCE, SMOS, Cryosat-2) missions will make to the ECVs but a very important component in this process is to ensure international collaboration and thus achieve global consistency in ECV product generation.

The initiative will implement a programme of work which ensures that the responsibilities and capabilities of ESA member states in addressing issues of climate change can be undertaken on a scale commensurate with the problem. It is based on the delivery of climate variable derived from satellite data sets (not just ESA but all sources via international collaboration) and includes all aspects of their availability including data acquisition, calibration and validation, long term algorithm maintenance, data curation, reprocessing as necessary, all within the context of an internationally agreed set of priorities.

The contributions to the CCI initiative of the Netherlands are though the themes Aerosol, Cloud and Ozone (all through KNMI), Greenhouse Gases (SRON), and Land Cover (WUR).

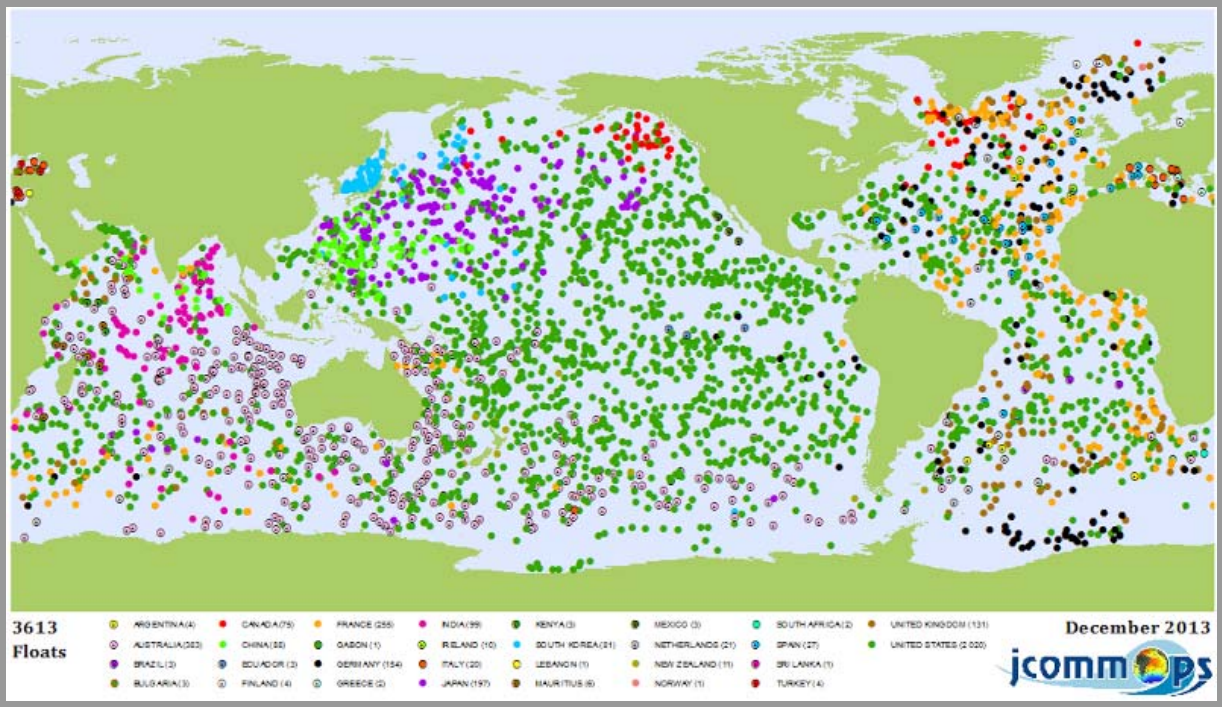
National contributions to the surface-based atmospheric essential climate variables

Network	Essential Climate Variables (ECVs)	# stations [if applicable]	Years of continuous operation	Data Archiving Centre	Netherlands Institution responsible
Atmospheric Surface					
GCOS Surface Network (GSN)	T, precip.	1	>100	http://gosic.org/content/gcos-surface-network-gsn-data-access	KNMI
BSRN	Surface radiation	1	6	WRMC http://www.bsrn.awi.de/	KNMI
Full WWW/GOS Surface RBSN	T, precip	11	>40 some > 100	http://www.wmo.int/pages/prog/www/ois/rbsn-rbcn/rbsn-rbcn-home.htm	KNMI
Full WWW/GOS Surface RBCN	T, precip.	6	>100	http://www.wmo.int/pages/prog/www/ois/rbsn-rbcn/rbsn-rbcn-home.htm	KNMI
Voluntary Observing Ships (VOS)	All feasible surface ECVs	>100 ships	Since 1854	http://www.bom.gov.au/jcomm/vos/	KNMI
Global reference mooring network	All feasible surface and subsurface ECVs (T, S, and velocities)	one profiling mooring + one mooring array of 5 moorings	11	www.nioz.nl/dmg http://www.seadatanet.org/ NODC www.OceanSITES.org	NIOZ
Atmospheric Upper-Air					
GRUAN	All feasible surface and upper-air ECVs	1 [CESAR]	8	http://www.wmo.int/pages/prog/gcos/index.php?name=GRUAN	CESAR
Aircraft [ASDAR, AMDAR]	Upper-air T, w, q	X [aircraft]	14	http://www.knmi.nl/samenw/geoss/eumetnet/E-Amdar/QEvC/loc5939/index.htm	KNMI
Ground-based GPS	Water vapor	35	22	http://adn.agi.com/GNSSWeb/Default.aspx	KNMI

Network	Essential Climate Variables (ECVs)	# stations [if applicable]	Years of continuous operation	Data Archiving Centre	Netherlands Institution responsible
Atmospheric Composition					
GCOS affiliated WMO/GAW N20, CO2, CH4 monitoring networks	CO2, CH4, N20	Cabauw [51.97 N, 4.93 E], Hostermeer, Loobos [52.16 N, 5.75 E]	>20		VU, ECN, KNMI
Greenhouse gas monitoring	CO2, CH4, N20, CO, SF6, O2, Radon [all continuous), 13CO2, 14CO2 [flasks]	Lutjewad (53° 23' N, 6° 22' E)	14; 8 in present configuration	RUG, CDIAC, ICOS-EU	RUG
Atmospheric greenhouse gas monitoring site	CO2 and atm. Oxygen (continuous) CH4, CO, 13CO2, 14CO2 (flasks)	F3 (54° 51' N, 4° 44' E)	5; presently interrupted	RUG	RUG
WMO/GAW baseline total O3 Network	O3	1	20	http://www.woudc.org/ http://www.ndsc.ncep.noaa.gov/data/	KNMI
WMO/GAW GCOS O3Profiling network	O3	1	20	http://www.woudc.org/ http://www.ndsc.ncep.noaa.gov/data/	KNMI
AERONET	Aerosol optical thickness	1	10	http://aeronet.gsfc.nasa.gov/	KNMI, TNO

Network	ECV	stati-ons	Years of continued operation	Data Archiving Centre	Netherlands Institution responsible
Atmospheric Composition [continued]					
LML Dutch Air Quality Monitoring Network	Surface O3	36	20+	RIVM, EEA,EMEP, WDCGG	RIVM
LML Dutch Air Quality Monitoring Network	Surface NO and NO2	47	20+	RIVM, EEA,EMEP, WDCGG	RIVM
LML Dutch Air Quality Monitoring Network	Surface SO2	6	20+	RIVM, EEA,EMEP, WDCGG	RIVM
LML Dutch Air Quality Monitoring Network	Surface CO	4	20+	RIVM, EEA,EMEP, WDCGG	RIVM
LML Dutch Air Quality Monitoring Network	Surface aerosol PM10	46	20+	RIVM, EEA, EMEP	RIVM
LML Dutch Air Quality Monitoring Network	Surface aerosol PM2.5	26	Since 2009	RIVM, EEA, EMEP	RIVM
LML Dutch Air Quality Monitoring Network	Surface aerosol Black Smoke BS	13	20+	RIVM, EEA, EMEP	RIVM
LML Dutch Air Quality Monitoring Network	Surface aerosol BC/EC	13	to start 2015	RIVM, EEA, EMEP	RIVM
LML Dutch Air Quality Monitoring Network	Surface aerosol EC/OC	1	Since 2010	RIVM, EEA, EMEP	RIVM
LML Dutch Air Quality Monitoring Network	Precipitation: composition	8	20+	RIVM, EEA, EMEP	RIVM
LML Dutch Air Quality Monitoring Network	Precipitation: quantity	8	to start 2014	RIVM, EEA, EMEP	RIVM
NDACC	O3 profile (Lidar 18-45 km) NDACC station Lauder, New Zea-land	1	19+	NDACC, WODC, RIVM	RIVM, NIWA
NDACC	T profile (Lidar 18-65 km) NDACC station Lauder, New Zea-land (to come soon)	1	(19+)	NDACC, RIVM	RIVM, NIWA

Highlights in the Oceanic Domain



Global Distribution of the ARGO floats. Floats contributed by the Netherlands are continually changing position. Currently most of them reside in the Southern Atlantic Ocean.

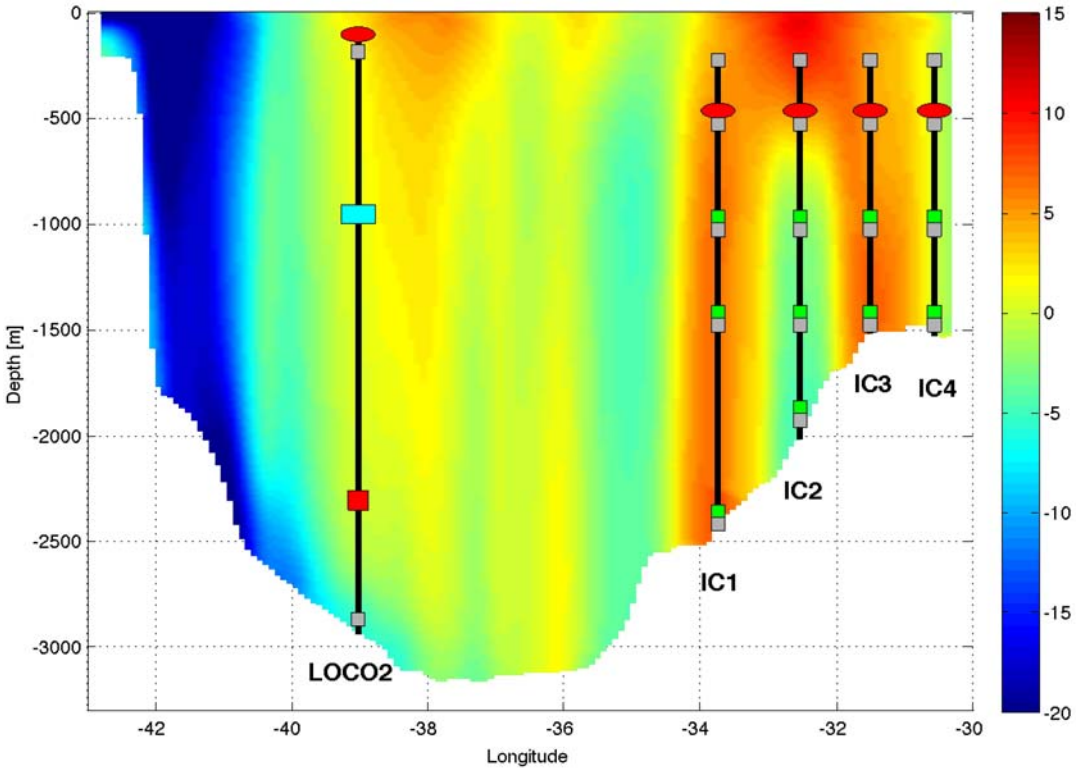
ARGO floats

ARGO is an observation system for the oceans that delivers real-time data for use in climate, weather, ocean fisheries research. Argo consists of a set of robot sondes that are transported by ocean currents all over the world. The sondes traverse in a continuous manner the upper ocean from the surface downwards to a depth of 2 km, and then upwards again. They measure conductivity, temperature and water pressure. At the times when they reach the surface they determine their geographical position. These data are then used to compute salinity, density and track. Every 10 days, data are transmitted via satellite to shore to be used by scientific investigators. However, all data can be accessed by everyone without restriction. The original purpose was to have 3000 sondes in operation at the same time; and a carefully-planned conversion of research observing systems to long-term operations is being promoted. Data management systems that facilitate access, use and interpretation are included as essential elements of GCOS climate monitoring systems.

The Netherlands contribute to the ARGO-project since 2004 when the first three floats where deployed in the Bay of Biscay. Since then 58 more floats have been deployed, all but one in the Atlantic and south-western Indian Oceans. Deployment has been done from several ships, including commercial vessels.

KNMI represents the Netherlands in the international Argo Project, and, since its founding in May 2014, in the Euro Argo ERIC. The latter is a body under European Law that coordinates the European Argo contributions and collects EU funding for an operational continuation of the Argo network.

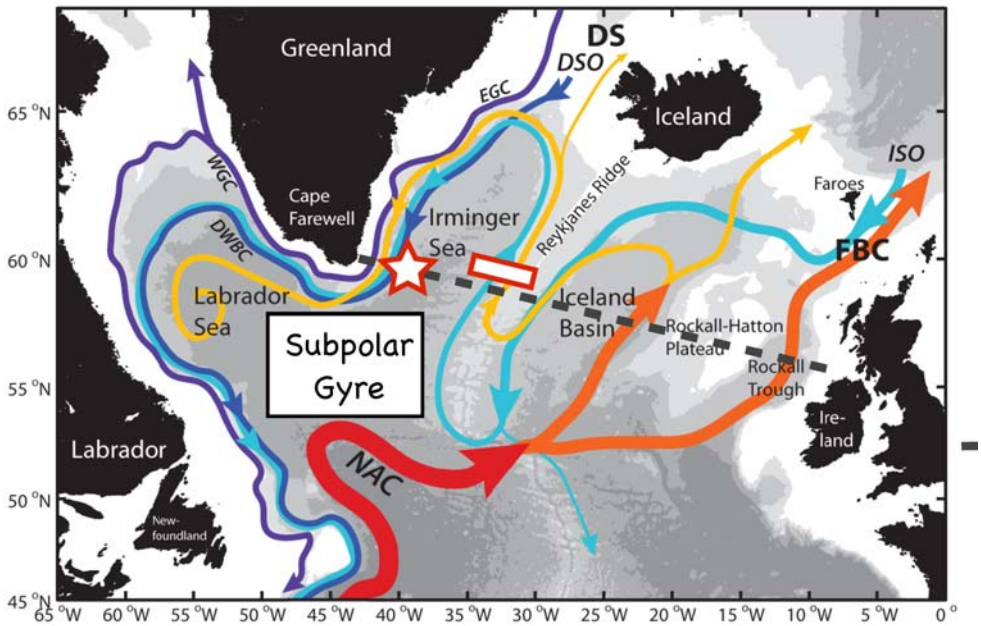
The NIOZ Research vessel RV. Pelagia.



Cross section of the NIOZ moorings in the Irminger Sea: the profiling mooring LOCO2 (left) and the Irminger Current (IC) moorings (on the slope of the Reykjanes Ridge). The background color illustrates the mean absolute geostrophic velocity [cm/s] in the gyre between 2000-2005 (Våge et al., 2011).

Subsurface mooring program

The NIOZ is currently involved in several long-term oceanic subsurface mooring programs that collect ocean temperature, salinity and velocity data. A profiling mooring in the central Irminger Sea initiated by the Long-term Ocean Climate Observation program (LOCO) has been in place since 2003 to measure deep convection in the gyre. A set of five tall moorings will be deployed in the subpolar gyre in 2014 to measure northward volume and heat transports as part of the EU FP7 project North Atlantic CLIMate (NACLIM). This array is also part of the international, basin-wide Overturning in the Subpolar North Atlantic Program (OSNAP). Other mooring programs of NIOZ in the Indian Ocean (East Madagascar Current and Mozambique Channel) have come to an end in 2013, however, plans are developed to contribute to an international array in the Agulhas Current near South Africa. In addition to collecting fixed point time series the NIOZ contributes to long-term ocean observations by carrying out repeat hydrographic stations on the former WOCE section AR7E in the Irminger Sea and Iceland Basin. The data obtained from these long-term (> 3 years) ocean programs feed into the marine data base SeaDataNet (www.seadatanet.org) and the OceanSITES network of open-ocean observatories (www.OceanSITES.org).



National contributions to the surface-based oceanic essential climate variables

Network	Essential Climate Variables (ECVs)	# stations [if applicable]	Years of continuous operation	Data Archiving Centre	Netherlands Institution responsible
Global reference mooring network	All feasible surface and subsurface ECVs	one profiling mooring + one mooring array of 5 moorings	11	www.nioz.nl/dmg http://www.seadatanet.org/ NODC www.OceanSITES.org	NIOZ
GLOSS Core Sea-level network		6	>50	RWS	RWS
ARGO network	T, S	58 floats	10	CORIOLIS [c/o Ifremer, Brest]	KNMI
VOS		>150 ships	> 100		KNMI http://www.vos.noaa.gov/
	SST	> 20	>40	LMW	RWS
	Wave height	5	>40	RWS [LMW]	RWS

Highlights in the Terrestrial Domain

Integrated Carbon Observing System [ICOS-NL]

ICOS is a distributed observation network to monitor the European carbon and net greenhouse gas balance. It consists of a large number of high precision observatories for greenhouse gas concentrations and exchange fluxes all over Europe and central facilities that process and integrate all data. Following the progress of emission reductions and changes in the (semi)natural fluxes of greenhouse gases is essential to improve Earth System science and to evaluate and develop climate change abatement policies. The proposed network in the Netherlands will have unprecedented resolution, needed to handle the complex and intense flux densities in this region. ICOS-nl will test and contribute unique data assimilation tools to provide higher level data products essential to the ICOS stakeholders and society

An emission rich and energy intensive region like the Netherlands requires a dedicated and local network of observations and very high resolution modeling. ICOS-nl will provide exactly this.

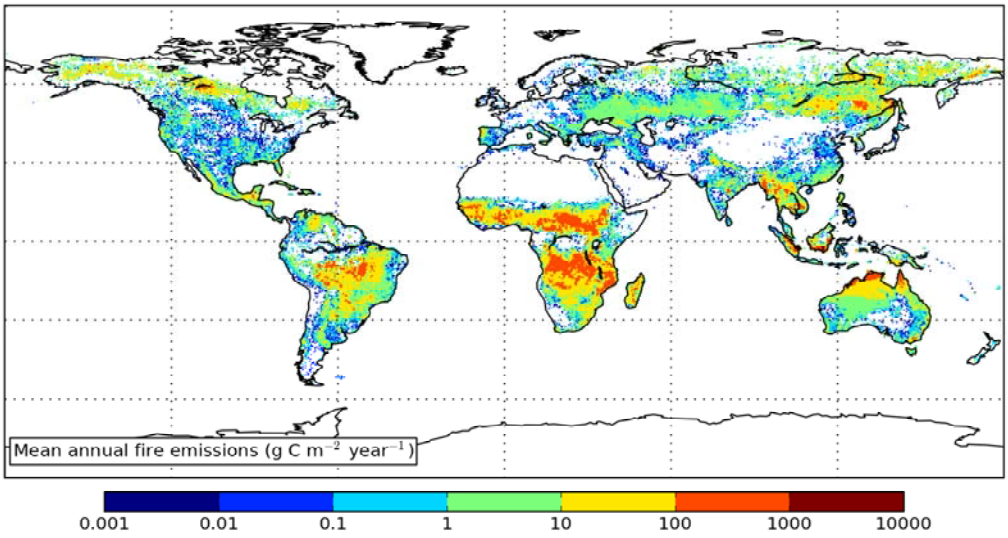
The ICOS products will reduce the uncertainties of current and future emission estimates of greenhouse gases and will allow better design of energy and agricultural systems. Clear visual products showing the development carbon and greenhouse budgets of cities, regions, nations and Europe as a whole will raise public awareness to our responsibility towards a sustainable society and allow early warning for future changes e.g. due to emerging climate change.

One of the tower measurement booms at the Cabauw .

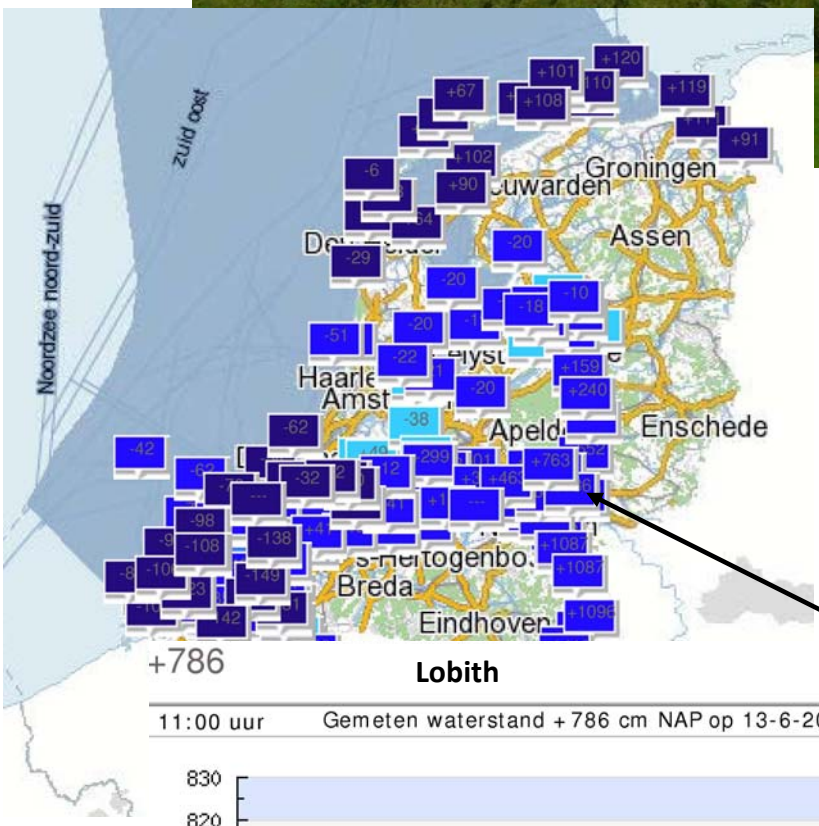
Global Fire Data [GFED]

Fires are an important source of atmospheric trace gases and aerosols and are the most important disturbance agent on a global scale. In addition, de-forestation and tropical peatland fires and areas that see an increase in the frequency of fires add to the build-up of atmospheric CO_2.

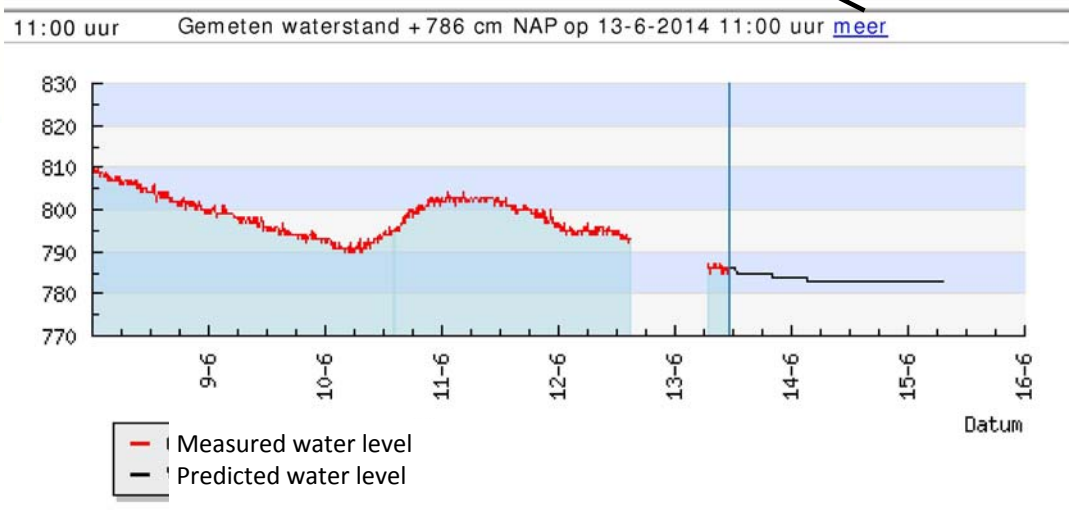
At VU University Amsterdam satellite information on fire activity (developed at NASA), and vegetation productivity is combined in a biogeochemical modeling framework to estimate gridded fire emissions of numerous trace gases and aerosol species. The resulting datasets are downloadable for use in large-scale atmospheric and biogeochemical studies. The emissions dataset is used in IPCC and Global Carbon Project assessments and is the default fire emissions dataset used in the GEOS-Chem and TM5 atmospheric modeling frameworks. The dataset receives over 200 citations annually.



Mean annual fire carbon emissions based on satellite-derived burned area and biogeochemical modeling. Averaged over 1997-2011 .



The River Rhine near Lobith . and the manner in which the water level near that location can be obtained from the web site http:// www.rijkswaterstaat.nl/ geotool/ waterhoogte_tov_nap.aspx? cookieload=true



Coastal and inland water properties

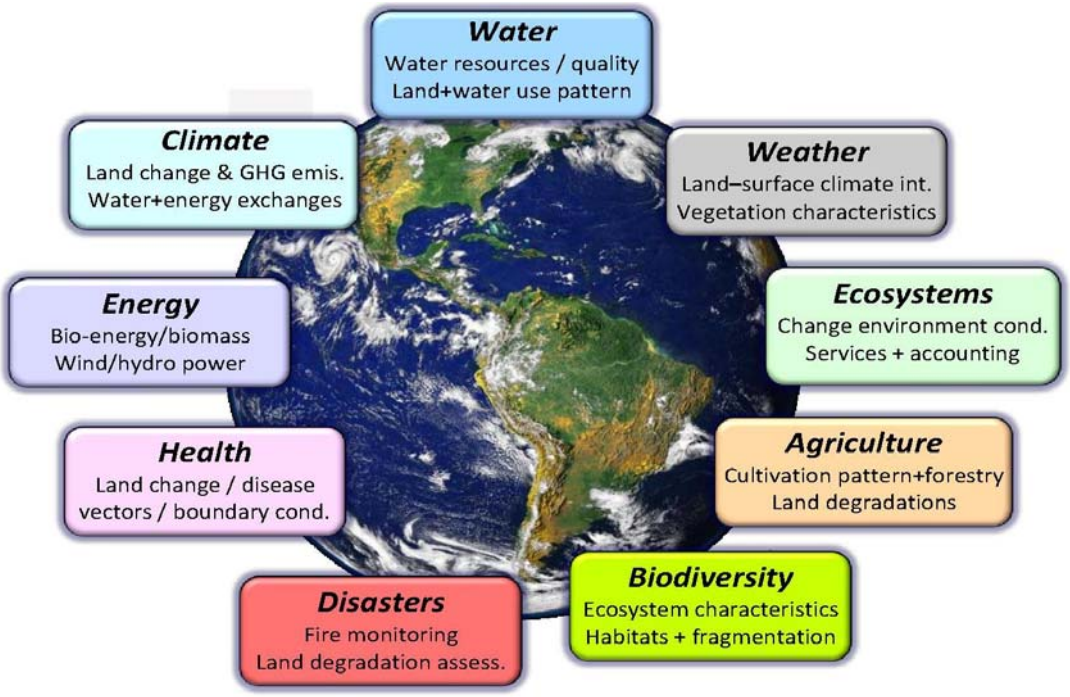
Rijkswaterstaat [RWS] controls an automatic observation network, the National Observation Network Water [LMW]. This network comprises over 400 locations which register water levels, waves, water temperature, river discharge and salt levels. This information serves multiple purposes such as operational water [level] control, shipping, research, model development, preparation and evaluation of [water] policy and detecting trends and characteristics of all water systems. Trend detection is part of climate monitoring and a number of the 400 stations are attributable to the purpose of climate monitoring.

Water levels: Monitoring of water levels is performed to detect trends in sea level. For all locations along the Dutch coast, long term time series of yearly averaged sea levels, high and low water level marks are derived. In particular the six main locations of Vlissingen, Hoek v Holland, Ijmuiden, Den Helder, Harlingen and Delfzijl are important to obtain a good impression of sea level rise.

Waves: Waves are measured at about 20 locations on the North Sea. The importance for climate monitoring is the detection of trends in the wave climate. As with water levels, only a small number of stations have a long history so that trends can be reliably be determined. These stations are: K13, Eierlandse Gat, Schiermonnikoog Noord, Europlatform and Schouwenbank.

River discharge: Monitoring is performed for the River Rhine [at Lobith] and the Rive Meuse [at Sint Pieter].

Water temperature: Sea surface temperature is determined at most mooring locations on the North Sea, and also at five locations along the coast [Vlissingen, Hoek v Holland, IJmuiden, Kornwerderzand and Eemshaven]. Long time series are used to detect possible changes in sea water temperature as a result of climate change.



The importance of land cover area information for society at large. [from Land Cover project Office Annual Report 2012]

Global Observation and Forest Cover Land Dynamics [GOFC-GOLD]

The role of GOFC-GOLD is to establish the link between space agencies, science community and the users of earth observation data and data products. The primary function of the Land Cover Implementation Team (LC-IT) is to develop and evaluate methods, tools and products for land cover measurements and monitoring using space-borne and in-situ observations. The LC-IT assesses current needs and deficiencies for global and regional monitoring to support Global Change research, national and regional forest inventories and international policy (i.e. through working with the UN Conventions).

Essential aim is the monitoring of land cover as an essential climate variable, and is actively involved in GCOS. The Project Office is established in Wageningen. It leads a GEO-task to provide a global land cover data base.

The GOFC-GOLD LC PO has been an active contributor to the GCOS activities, via the Terrestrial Observation Panel for Climate (TOPC). Here the essential contribution is the identification of terrestrial observation requirements, assisting the establishment of observing networks for climate, providing guidance on observation standards and norms, facilitating access to climate data and information and its assimilation, and promoting climate studies and assessments.

A joint GOFC-GOLD LC PO - GCOS workshop,was organized in May in Geneva, to consider the climate observation requirements for supporting mitigation of climate change. A GCOS report released in June 2014, summarizes the outcomes of the workshop and provides recommendations to key stakeholders (e.g., GCOS, CEOS, UNFCCC).

The GOFC-GOLD LC PO participates in the ESA Land Cover Climate Change initiative (CCI). The LC PO contributes to the acquisition of user requirements and the validation of the ECV global land cover maps of the CCI.

International Groundwater Resources Assessment Centre [IGRAC]

Groundwater is the largest readily available source of freshwater on our planet. Its utilization is of paramount importance for the social and economic development of society. The International Groundwater Resources Assessment Centre (IGRAC) contributes to the assessment of the groundwater resources of the world in order to encourage and enhance the conjunctive and sustainable utilisation of both groundwater and surface water and elucidate the impact of groundwater on other ecosystems of the Earth. The overall objective of IGRAC is derived from the Mission Statement and reads as follows: ''to include groundwater fully in the assessment of freshwater resources of the world in order to encourage and enhance the conjunctive and sustainable utilisation of both groundwater and surface water.''

IGRAC is officially the UNESCO global groundwater centre, a legally independent foundation and the in-house partner of the UNESCO-IHE, in Delft, the Netherlands. The Global Groundwater Monitoring Network (GGMN) is a participative, web-based network of networks, set up to improve quality and accessibility of groundwater monitoring information and subsequently our knowledge on the state of groundwater resources. GGMN is a UNESCO programme, implemented by IGRAC and supported by many global and regional partners.

National contributions to the terrestrial domain essential climate variables

Network	Essential Climate Variables (ECVs)	# stations [if applicable]	Years of continuous operation	Data Archiving Centre	Netherlands Institution responsible
GCOS/GTOS Baseline Global Terrestrial Network (GTN-R)	River discharge	2 [Lobith, S. Pieter]	>50	GRDC	RWS
GCOS/GTOS-Baseline Global Terrestria Network (GTN-H [hydrology]	Groundwater		6	GGMN (ggmn.unigrac.org	IGRAC
	Land cover	In situ and satellite-based			WUR/GOFC-GOLD Land Cover Office/ INFRAM
	Fire /burned area	Satellite-based	1996—present	VU	VU
	Snow cover				KNMI
GNIP (global network of isotopes in precipitation)	isotope ratios in precipitation in the Netherlands	5	≈50	WISER [IAEA]	RUG+ KNMI
GNIR (global network of isotopes in river water)	isotope ratios in three major rivers flowing into the Netherlands	3	>40	WISER [IAEA]	RUG + Rijkswaterstaat [RIZA]

Inventory of Satellite ECVs for GCOS Activities in the Netherlands

The Netherlands are at the forefront of developing new satellite observation technologies, retrieval algorithms and user applications.

Observations typically contribute to monitoring and research of Climate, Ozone, Air Quality and Land Surface characteristics. Some of the highlights have been shown in this document.

To validate the satellite observations and to provide local monitoring ground-based instruments are operated and used in validation campaign at f.e. the Cabauw Experimental Site for Atmospheric Research.

GCOS—related products derived from satellite observations are thus found at the end of a complex chain of research and development.

ECV	Satellite	Years of continuous operation	Data Archiving Centre	Netherlands Institution responsible
Wsurf, Wdir	ASCAT	10	http://www.eumetsat.int/website/home/Data/DataDelivery/EUMETSATDataCentre/index.html	KNMI
Cloud properties: amount, height/pressure, optical thickness, liquid/ice path and particle effective radius, precipitation	MSG SEVIRI	10	http://msgcpp.knmi.nl	KNMI
Surface radiation	MSG SEVIRI	10	http://msgcpp.knmi.nl	KNMI
Land cover	1. ENVISAT MERIS 2. Sentinel-2 3. Sentinel-3 4.Spot VGT 5. Proba-V 6. AVHRR	1. 2002-2012 2. launch expected 2015 3. launch expected 2015 4. 1986-2014 5. 2013 - 6. 1978 -	1. ESA 2. ESA 3. ESA 4. Centre National d'Eduted Spatiales 5. VITO 6. NOAA	WUR
Fires / Burned area	MODIS, ATSR	1996—present	VU	VU

Abbreviations

AERONET: Aerosol Robotic Network
AMDAR: Aircraft Meteorological Data Relay
ASDAR: Aircraft tot Satellite Data Relay
ATSR: Along-track Scanning Radiometer
AURA: [Latin for Breeze] Earth Observing Satellite
ARGO: [Greek mythical ship] Drifting Oceanic Profiling Floats
ARGO ERIC: European Contribution to the ARGO float
AVHRR: Advanced Very High Resolution Radiometer
BSRN: Baseline Surface Radiation Network
CCI: Climate Change Initiative
CEOS: Committee on Earth Observation Satellites
CESAR: Cabauw Experimental Site for Atmospheric Research
CIO: Centre for Isotope Research

DOAS: Differential Optical Absorption Spectroscopy

ECV: Essential Climate Variable ESA: European Space Agency
ENVISAT: Environmental Satellite
EOS: Earth Observing System
EUMETSAT: European Meteorological Satellite [name of agency]

FTS: Fourier Transform Spectroscopy

GAW: Global Atmospheric Watch
GCOS: Global Climate Observing Systems
GEWEX: Global Energy and Water Exchanges Project
GFED: Global Fire Emissions Database
GGMN: Global Groundwater Monitoring Network
GLOSS: Global Sea Level Observing System
GMES: Global Monitoring for Environment and Security
GNIP: Global Network for Isotopes in Precipitation
GOCE: Gravity field and steady-state Ocean Circulation Explorer
GOES-CHEM: Goddard Earth Observing System-Chemical Transport Model
GOFC/GOLD: Global Observation for Forest Cover and Land Dynamics
GOME: Global Ozone Monitoring Experiment

IAEA: International Atomic Energy Agency
ICOS: Integrated Carbon Observing System
IGRAC: International Groundwater Resources Assessment Centre
IPCC: Intergovernmental Panel on Climate Change
iSPEX: i Spectropolarimeter for Planetary Exploration

KNMI: Royal Netherlands Meteorological Institute
LMW: National Measurement Network Water
LOCO: Long term Ocean Climate Observations

MSG: Meteosat Second Generation
MODIS: Moderate Resolution Imaging Spectroradiometer
NASA: National Aeronautic and Space Administration
NDACC: Network for the Detection of Atmospheric Composition Change
NILU: Norwegian Institute for Air Research
NIOZ: Royal Netherlands Institute for Sea Research
NIWA: National Institute for Water and Atmospheric Research [NZ]
NOOS: Northwest Shelf Operational Oceanographic System
NSO: Netherlands Space Office

OMI: Ozone Monitoring Instrument NACLIM: North Atlantic Climate FP7 Collaborative Project
OSNAP: Subpolar North Atlantic Program
Proba: Project for On-board Autonomy [ESA mini-satellite mission]

RBCN: Regional Baseline Climate Network
RBSN: Regional Baseline Synoptic Network
RIVM: National Institute for Public Health and the Environment
RWS: Rijkswaterstaat
RUG: University of Groningen

SAF: Satellite Application Facility
SCIAMACHY: SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY
Sentinel: ESA Earth Observing Satellite
SEVIRI: Spinning Enhanced Visible and Infrared Imager
SHADOZ: Southern Hemisphere ADditional OZonesondes
SMOS: Soil Moisture and Ocean Salinity
SPOT: Satellite pour l'Observation de la Terre
SRON: Netherlands Institute for Space Research

TNO: Netherlands Organization of Applied Scientific Research
TROPOMI: Tropospheric Monitoring Instrument
TUDelft: Technical University of Delft
TM5: 5th version of Transport Model

UNESCO-IHE: UNESCO Institute for Water Education
UNFCCC: United Nations Federated Convention on Climate Change

VITO: Vision on Technology
VOS: Voluntary Observing Ships Scheme
VU: Free University at Amsterdam

WCRP: World Climate Research Programme
WISER: Water Isotope System for Data Analysis, Visualisation and Electronic Retrieval
WOUDC: The World Ozone and Ultraviolet Radiation Data Centre
WUR: Wageningen University

GCOS Monitoring Principles

The GCOS monitoring principles provide an important reference system for assuring that climate variables are collected to traceable standards. Data sets coming from satellites have now reached maturity and an additional set of principles have been formulated at the end that are particularly applicable for the satellite community.

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 should be required.
3. The results of calibration, validation and data homogeneity assessments, and assessments of algorithm changes, should be treated with the same care as data.
4. A capacity to routinely assess the quality and homogeneity of data on extreme events, including high-resolution data and related descriptive information, should be ensured.
5. Consideration of environmental climate-monitoring products and assessments, such as IPCC assessments, should be integrated into national, regional and global observing priorities.
6. Uninterrupted station operations and observing systems should be maintained.
7. A high priority should be given to additional observations in data-poor regions and regions sensitive to change.
8. Long-term requirements should be specified to network designers, operators and instrument engineers at the outset of new system design and implementation.
9. The carefully-planned conversion of research observing systems to long-term operations should be promoted.
10. Data management systems that facilitate access, use and interpretation should be included as essential elements of climate monitoring systems.

GCOS Monitoring Principles [continued]

Satellite systems for monitoring climate need to:

(a) Take steps to make radiance calibration, calibration-monitoring and satellite-to-satellite crosscalibration 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, meta-data 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 de-commissioned 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.