CLIMATE CHANGE

## Scientific Assessment and Policy Analysis

**WAB 500102 011**

# Climate Change Monitoring in the Netherlands

# A Proposal based on the GCOS Implementation Plan in Support of the United Nations Framework Convention on Climate Change

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## A Proposal based on the GCOS Implementation Plan in Support of the United Nations Framework Convention on Climate Change

**Report**
500102 011


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**September 2009**


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This study has been performed within the framework of the Netherlands Research Programme on Scientific Assessment and Policy Analysis for Climate Change (WAB), project Climate monitoring: What to measure, Where and Why; Optimising the Netherlands' contribution.

**Wetenschappelijke Assessment en Beleidsanalyse (WAB) Klimaatverandering**

Het programma Wetenschappelijke Assessment en Beleidsanalyse Klimaatverandering in opdracht van het ministerie van VROM heeft tot doel:

- Het bijeenbrengen en evalueren van relevante wetenschappelijke informatie ten behoeve van beleidsontwikkeling en besluitvorming op het terrein van klimaatverandering;
- Het analyseren van voornemens en besluiten in het kader van de internationale klimaatonderhandelingen op hun consequenties.

De analyses en assessments beogen een gebalanceerde beoordeling te geven van de stand van de kennis ten behoeve van de onderbouwing van beleidsmatige keuzes. De activiteiten hebben een looptijd van enkele maanden tot maximaal ca. een jaar, afhankelijk van de complexiteit en de urgentie van de beleidsvraag. Per onderwerp wordt een assessment team samengesteld bestaande uit de beste Nederlandse en zonodig buitenlandse experts. Het gaat om incidenteel en additioneel gefinancierde werkzaamheden, te onderscheiden van de reguliere, structureel gefinancierde activiteiten van de deelnemers van het consortium op het gebied van klimaatonderzoek. Er dient steeds te worden uitgegaan van de actuele stand der wetenschap. Doelgroepen zijn de NMP-departementen, met VROM in een coördinerende rol, maar tevens maatschappelijke groeperingen die een belangrijke rol spelen bij de besluitvorming over en uitvoering van het klimaatbeleid. De verantwoordelijkheid voor de uitvoering berust bij een consortium bestaande uit PBL, KNMI, CCB Wageningen-UR, ECN, Vrije Universiteit/CCVUA, UM/ICIS en UU/Copernicus Instituut. Het PBL is hoofdaannemer en fungeert als voorzitter van de Stuurgroep.

**Scientific Assessment and Policy Analysis (WAB) Climate Change**

The Netherlands Programme on Scientific Assessment and Policy Analysis Climate Change (WAB) has the following objectives:

- Collection and evaluation of relevant scientific information for policy development and decision–making in the field of climate change;
- Analysis of resolutions and decisions in the framework of international climate negotiations and their implications.

WAB conducts analyses and assessments intended for a balanced evaluation of the state-of-the-art for underpinning policy choices. These analyses and assessment activities are carried out in periods of several months to a maximum of one year, depending on the complexity and the urgency of the policy issue. Assessment teams organised to handle the various topics consist of the best Dutch experts in their fields. Teams work on incidental and additionally financed activities, as opposed to the regular, structurally financed activities of the climate research consortium. The work should reflect the current state of science on the relevant topic.

The main commissioning bodies are the National Environmental Policy Plan departments, with the Ministry of Housing, Spatial Planning and the Environment assuming a coordinating role. Work is also commissioned by organisations in society playing an important role in the decision-making process concerned with and the implementation of the climate policy. A consortium consisting of the Netherlands Environmental Assessment Agency (PBL), the Royal Dutch Meteorological Institute, the Climate Change and Biosphere Research Centre (CCB) of Wageningen University and Research Centre (WUR), the Energy research Centre of the Netherlands (ECN), the Netherlands Research Programme on Climate Change Centre at the VU University of Amsterdam (CCVUA), the International Centre for Integrative Studies of the University of Maastricht (UM/ICIS) and the Copernicus Institute at Utrecht University (UU) is responsible for the implementation. The Netherlands Environmental Assessment Agency (PBL), as the main contracting body, is chairing the Steering Committee.

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# Samenvatting


## De relevantie van monitoring van klimaatverandering

Ons klimaat verandert. De concentraties van broeikasgassen zijn in miljoenen jaren niet zo hoog geweest. Dat is het gevolg van de wereldwijd toenemende uitstoot van broeikasgassen door industrialisatie, energieproductie, verkeer en vervoer, huishoudens en kantoren en het veranderende landgebruik. Het aardsysteem reageert op deze veranderingen. Alleen door goed te volgen hoe het aardsysteem zich ontwikkelt kan de toekomst zekerder worden. Daarvoor zijn observaties nodig.

Op verzoek van het Klimaatverdrag (UNFCCC) heeft de World Meteorological Organisation (WMO) geïnventariseerd welke Essential Climate Variables (ECVs) wereldwijd moeten worden gemeten om een Global Climate Observing System te realiseren. Samen geven deze waarnemingen een beeld van het gedrag van het wereldwijde klimaatsysteem. We onderscheiden daarin de domeinen atmosfeer, oceaan en landoppervlak. Niet alleen binnen deze domeinen worden fysische processen gevolgd. Ook interacties tussen deze domeinen zijn van groot belang.

Lange tijdreeksen van waarnemingen van deze ECVs geven een beeld van langzame veranderingen, van variabiliteit en van het optreden van extremen. Continuïteit van waarnemingen is daarbij cruciaal. Deze waarnemingen worden geïnterpreteerd in het kader van fysische wetmatigheden die zijn samengebracht in klimaatmodellen. Ze worden tevens gebruikt voor onderzoek om deze modellen verder te ontwikkelen en te testen. En tenslotte worden deze modellen gebruikt om uitspraken te doen over de toekomstige ontwikkeling van het mondiale en regionale klimaat.

*“Adequate high-quality observations of climate and climate-related variables are essential if adaptation to climate change is to be based on deliberate planning leading to better adaptation policies. Good observations acquired over extended periods make possible an understanding of the frequency of extreme events as well as average climate conditions. They thereby contribute to better planning and decision making related to agriculture, coastal zone management, water resources management, health, tourism, and disaster risk management”.*

*“At the present time, in many countries neither the quality nor quantity of observations needed by global and regional models is adequate to support and verify climate models so as to allow the reliable projections needed for adaptation purposes. In order to meet adaptation needs, models will need to be improved and observation networks and data use will need to be strengthened, especially in vulnerable areas”.*

Met deze uitspraken onderstreepte de World Meteorological Organisation (WMO) tijdens de Klimaatconferentie in Bali in 2007 dat goede metingen van groot belang zijn voor adaptatie aan klimaatverandering.

## Beleids samenvatting

***Aanleiding***
Na het verschijnen van het Vierde Assessment Report (AR4) van het IPCC in 2007, de overtuigende presentaties van Al Gore (The Inconvenient Truth) en het verschijnen van het advies van de Deltacommissie, is het belang van klimaatobservaties (monitoring) eens te meer duidelijk geworden. Daarnaast heeft het kabinet zich gecommitteerd aan de Millennium Development Goals en daarmee aan steun aan ontwikkelingslanden om zich te beschermen tegen klimaatverandering. Nederland heeft zich gecommitteerd bij te dragen aan mondiale inspanningen op het gebied van klimaatwaarnemingen via het zogenaamde Global Climate Observing System (GCOS), en op grond van het Klimaatverdrag (UNFCCC).

Deze ontwikkelingen en afspraken motiveerden het Ministerie van Volkshuisvesting Ruimtelijke Ordening en Milieu (VROM) om te laten inventariseren op welke manier klimaatwaarnemingen door Nederland kunnen worden verbeterd, zowel in het nationaal als internationaal belang. Het KNMI is gevraagd deze inventarisatie uit te voeren vanuit een door VROM gefinancierd programma Wetenschappelijke Assessment en Beleidsanalyse Klimaatverandering (WAB).

Aan dit project is meegewerkt door CESAR[1], Deltares, ECN, KNMI, NIOZ, Rijkswaterstaat Waterdienst, RIVM, RUG-CIO, TNO Built Environment and Geosciences/IGRAC, UU-IMAU, VU en WUR-ALTERRA.

*Het rapport constateert:*
1. Er is onvoldoende lange termijn financiële ondersteuning van klimaatmonitoring programma's waardoor de noodzakelijke continuïteit ervan in gevaar komt;
2. Klimaatmonitoring leent zich uitstekend voor structurele steun aan ontwikkelingslanden, waarmee Nederland haar commitments kan invullen, maar deze steun ontbreekt momenteel;
3. Verantwoorde klimaatmonitoring kan uitgevoerd worden tegen kosten die gering zijn ten opzichte van de kosten van adequaat beleid rond klimaatverandering.

***Het belang van betrouwbare financiering***
De inventarisatie betreft enerzijds de klassieke meteorologische waarnemingen zoals die al vele jaren door o.a. het KNMI worden verzorgd, en relatief nieuwe waarnemingen van vele andere parameters die nodig zijn om klimaatverandering te begrijpen en klimaatprojecties te kunnen ontwikkelen. Het blijkt dat de financiering van deze nieuwe klimaatwaarnemingen in Nederland voornamelijk ad-hoc plaatsvindt vanuit kortlopende nationale en internationale programma's. Dit is een ongewenste situatie omdat door deze wijze de continuïteit in gevaar komt. Klimaatmonitoring *moet* een langlopende en ononderbroken activiteit zijn. Kortlopende projecten zijn meer geschikt voor de ontwikkeling van waarneemtechnieken, niet voor waarnemingen zelf. De traagheid van klimaatveranderingen en aanwezigheid van natuurlijke variabiliteit vereisen lange doorlopende waarnemingsreeksen van hoge kwaliteit en daarmee continuïteit in de financiering. Daarom worden hier aanbevelingen gedaan om structureel te investeren in de continuïteit en kwaliteit van langlopende waarneemprogramma's. Daarnaast worden enkele uitbreidingen voorgesteld.

Satellietmetingen zijn een belangrijk onderdeel van klimaatmonitoring. De financiering en besluitvorming van satellietprogramma's loopt vaak anders dan voor waarnemingen vanaf de grond. Zo is onlangs besloten tot de bouw van een nieuwe satellietmissie, TROPOMI, met een grote Nederlandse bijdrage. Deze missie zal een belangrijke bijdrage leveren aan monitoring van de samenstelling van de atmosfeer. Voor satellietprogramma's is vaak het probleem dat de hardware wel is gefinancierd, maar het bewerken van de metingen tot bruikbare klimaatreeksen nauwelijks. Daarom wordt ook daarvoor een voorstel gedaan.

[1] Een samenwerkingsverband dat m.b.v. een 200 m. hoge meteorologische mast (Cabauw) de toestand van de atmosfeer meet. Deelnemers zijn TU Delft, KNMI, RIVM, WUR, ECN, ESA-ESTEC, TNO en IMAU.

***Kansen en commitments***
Klimaatmonitoring biedt goede kansen om te voldoen aan de internationale afspraken en nationale commitments. Nederland kan haar Millennium doelen vorm geven door ontwikkelingslanden structureel te steunen bij de operationalisering van meetsystemen, de analyse van de gegevens en opbouw van kennis en instituties (capacity building). Deze steun is nodig omdat adequate klimaatmonitoring werelddekkend moet zijn en er juist in ontwikkelingslanden grote lacunes zijn. Betere waarnemingen helpen deze landen in de ontwikkeling van nationaal en regionaal beleid, en dragen tevens bij aan de verbetering van onze kennis van klimaatverandering en aan klimaatprojecties in onze regio. Door de United Nations Framework Convention on Climate Change (UNFCCC) is bij herhaling aangedrongen op dergelijke steun. Daarnaast draagt Nederland hiermee bij aan de internationale afspraken om bij te dragen aan mondiale waarnemingsystemen.

***Klimaatmonitoring tegen geringe kosten***
Het rapport stelt dat additionele financiering van 2 à 3 M€ en 14 fte per jaar plus een éénmalige investering van 4 M€ de minimale omvang is om klimaatmonitoring op een adequate manier uit te voeren die voldoet aan alle afspraken en adviezen en bijdraagt aan een veiliger en duurzamer Nederland. Deze kosten zijn gering in vergelijking met andere klimaatopgaven waar de regering voor staat.

Het rapport geeft tevens aan hoe bovenstaande aanbevelingen uit te voeren. Hieronder volgen de hoofdpunten.

***Hoofdpunten van uitvoering***
1. Organiseren van een rondetafelbijeenkomst met belanghebbende partijen (wetenschappelijk instituten, klimaatonderzoeksprogramma's, NWO en RMNO, en departementen als VROM, VenW, EZ, LNV en OCW) over hoe klimaatmonitoring vanuit Nederland kan worden versterkt.
2. Oprichten van een nationaal platform voor de coördinatie van klimaatmonitoring in Nederland.
3. Uitwerken en voorbereiden van de aanbevelingen voor het optimaliseren en veiligstellen van klimaatmonitoring door een op te zetten werkgroep vanuit de wetenschappelijke organisaties en de betrokken departementen.

In de volgende technische samenvatting worden de noodzaak voor klimaatmonitoring en de aanbevelingen kort toegelicht.

## Technische samenvatting

***De noodzaak voor het continueren van klimaatmonitoring***

*"The Global Climate Observing System (GCOS) assessment of climate observations needs has pointed out the large gaps that require strengthening. Governments need to urgently consider strategic support for the National Meteorological and Hydrological Services, research institutions and environmental agencies. There is also a need for supporting developing countries to adapt through such programmes as the Climate for Development in Africa Programme".*

*WMO Position Paper for the UNFCCC 14th Conference of the Parties (COP14), Poznan, Poland, December 2008.*

*1. Inzicht en beleidsondersteuning*

Het vierde Assessment Report van het Intergovernmental Panel on Climate Change (IPCC) van eind 2007 stelt ondubbelzinnig de opwarming van de aarde vast op basis van een stijgende luchttemperatuur, stijgende zeespiegel, en afnemende bedekking van sneeuw en ijs. Het grootste deel van de waargenomen toename van de mondiaal gemiddelde temperatuur sinds het midden van de twintigste eeuw wordt zeer waarschijnlijk veroorzaakt door de mens.

Daarmee verschuift de aandacht van de vraag óf het klimaat verandert naar de vraag wat voor klimaat wij kunnen verwachten in deze eeuw en daarna. Dat is immers essentieel voor hoe wij ons kunnen aanpassen en hoeveel we klimaatverandering moeten beperken (adaptatie en mitigatie).

Vaak wordt vergeten dat onze kennis over het klimaat is gebaseerd op metingen die decennialang zijn uitgevoerd door weerdiensten en wetenschappelijke instellingen in bijna alle uithoeken van de aarde. Al deze informatie samen vormden de basis van de conclusies van het IPCC. Voor toekomstige assessments is continuering van de metingen dus essentieel.

Het voortzetten en gericht uitbreiden van deze waarnemingen is ook noodzakelijk om betrouwbare projecties van het toekomstige klimaat te kunnen maken. Voor het Nederlandse klimaatbeleid is dit van groot belang. Het nationale klimaatadaptatiebeleid steunt namelijk volledig op recentelijk ontwikkelde regionale klimaatscenario's. Bovendien staat lange-termijn klimaatmonitoring centraal in het recente advies van de Delta Commissie.

Zonder waarnemingen kunnen klimaatscenario's niet worden geconstrueerd. Klimaat-waarnemingen sturen niet alleen modellen aan, maar worden ook gebruikt om de modellen te testen waarmee klimaatscenario's worden berekend. Deze tests versterken het vertrouwen in en de betrouwbaarheid van scenarioberekeningen. Daarnaast registeren deze waarnemingen structurele veranderingen van het klimaat en kunnen ze eventuele klimaatsprongen tijdig signaleren.

Omdat het klimaat op verschillende plaatsen op aarde op verschillende manieren verandert, is er voor een adequaat adaptatiebeleid bovendien in toenemende mate behoefte aan meer fijnmazige waarnemingen dan in het verleden. Deze zouden de basis moeten vormen voor nationale klimaatkennisprogramma's als Kennis voor Klimaat, Klimaat voor Ruimte en Leven met Water.

*2. Internationale verplichtingen*

Het Global Climate Observing System (GCOS) van de World Meteorological Organisation (WMO) coördineert op verzoek van de United Nations Framework Convention on Climate Change (UNFCCC) de mondiale inspanningen op het gebied van klimaatwaarnemingen en het monitoren van het klimaat, en doet aanbevelingen voor te verrichten waarnemingen. De aangesloten landen waaronder Nederland hebben zich op ministerieel nivo gecommitteerd bij te dragen. Diverse instituten en organisaties in Nederland dragen bij aan deze mondiale inspanning. De kwaliteit en continuïteit van deze metingen is echter onvoldoende gewaarborgd. CESAR, Deltares, ECN, KNMI, NIOZ, Rijkswaterstaat Waterdienst, RIVM, RUG-CIO, TNO Built Environment and Geosciences/IGRAC, UU-IMAU, VU en WUR-ALTERRA hebben het stelsel van klimaatwaarnemingen in Nederland geanalyseerd en doen in dit rapport voorstellen voor verbeteringen, om tegemoet te komen aan de aanbevelingen van GCOS.

***Aanbevelingen:***

De aanbevelingen sluiten aan bij de bestaande, internationaal erkende expertise van Nederlandse instituten die het potentieel hebben de continuïteit van de waarnemingen te waarborgen.

*Investeringen*

| | | |
|---|---|---|
| Uitbreiding klimaatmeetnet: | 500 k€ | (KNMI, zie a.1) |
| Atmosferisch station Paramaribo: | 250 k€ | (KNMI, zie a.2) |
| Uitbreiding/upgrading CESAR: | 1.2 M€ | (CESAR, zie b) |
| Bijdrage aan ESFRI project ICOS: | 2 M€ | (ICOS-NL, zie d) |
| *Totaal:* | 3.95 M€ | |

*Jaarlijkse materiële kosten aan onderhoud en vervanging, uitgaande van een periode van 10 jaar*

| | | |
|---|---|---|
| Atmosferisch station Paramaribo: | 100 k€ | (KNMI, zie a.2.) |
| ARGO floats: | 150 k€ | (KNMI; NIOZ, zie a.3) |
| CESAR supersite Cabauw: | 1.3 M€ | (CESAR, zie b) |
| NL en Lauder LIDAR station: | 135 k€ | (RIVM, zie c) |
| Bijdrage aan ESFRI project ICOS: | 400 k€ | (ICOS-NL, zie d) |
| Capacity building: | 300 k€ | (zie e) |
| *Totaal* | 2.385 M€ | |

*FTE's*

| | | |
|---|---|---|
| Atmosferisch station Paramaribo: | 1 fte | (KNMI, zie a.2) |
| Ozon sonde verticale profielen: | 1 fte | (KNMI, 4 jaar, zie a.4) |
| CESAR supersite Cabauw: | 7 fte | (CESAR, zie b) |
| NL en Lauder LIDAR station: | 1.7 fte | (RIVM, zie c) |
| Bijdrage aan ESFRI project ICOS: | 3 fte | (ICOS-NL, zie d) |
| Support VU chair GCOS-GTOS: | 0.5 fte | (VU, zie f) |
| *Totaal* | 14.2 fte | |

***Toelichting:***

*a. KNMI*

Voorgesteld worden versterking van het nationale meetnet en van bijdragen aan internationale waarneemprogramma's, en voortzetting van steun aan ontwikkelingslanden. Deze voorstellen zijn in lijn met de in begin 2006 vastgestelde KNMI Meerjarenvisie Klimaatmonitoring en de recente Hoofdlijnen KNMI-strategie waarnemingen. Het betreft:

1. Uitbreiding van het nationale meetnet met 5 automatische weerstations i.v.m. lokale adaptatie; deze stations leveren tevens klimaatparameters. Kosten 500 k€.
2. Upgrading van het atmosferisch monitoring station Paramaribo van een regionaal station tot een niveau waarmee het bijdraagt aan het mondiale Global Atmospheric Watch (GAW) netwerk (meet chemische samenstelling van de atmosfeer). Dit station vult een gat in het wereldwijde GAW net. Kosten 150 à 250 k€ aan materieel; operationele kosten 50 à 100 k€ + 1 fte per jaar.
3. Vergroting van de nationale bijdrage aan het ARGO float netwerk op zee (onderwater metende boeien) door bij te dragen aan het door de EU gestarte EU-ARGO programma. NIOZ zet deze boeien uit. Kosten 100 à 150 k€ per jaar.
4. Productie van lange tijdreeks van mondiale ozonprofielen met satelliet en grondwaarnemingen. Kosten 1 fte voor vier jaar (80 k€ per jaar).

*b. CESAR consortium (Cabauwmeetstation met als consortiumpartners, TUDelft, KNMI, RIVM, WUR, ECN, ESA-ESTEC, TNO, IMAU)*

Een moderne ontwikkeling op het gebied van klimaatmonitoring is de opkomst van stations die verticale atmosferische profielen meten. Deze zijn uitgerust met geavanceerde remote sensing apparatuur die het klimaat in de atmosferische kolom boven het grondpunt kan waarnemen. Er zijn slechts een handvol profielstations in de wereld, maar vanwege de grote meetnauwkeurigheid en het verticaal hoogoplossende vermogen van de instrumenten spelen zij een belangrijke rol in het monitoren van het klimaat. De Cabauw metingen worden ook gebruikt bij het evalueren van weer- en klimaatmodellen, en bij het valideren van satellietwaarnemingen. Cabauw is wereldwijd het langst metende observatorium voor hoge precisie waarnemingen van diverse broeikasgassen. Als één van slechts elf internationale onderzoeksstations is Cabauw via de site- en onderzoeksmanager KNMI door GCOS onlangs gevraagd om toe te treden tot het WMO GCOS Reference Upper-Air Network (WMO-GRUAN) vanwege de hoge kwaliteit van de metingen. Tevens is CESAR ingebed in een reeks andere globale monitoringsnetwerken wat in belangrijke mate bijdraagt aan de vooraanstaande rol van het station. Op dit moment is de continuïteit van monitoren te Cabauw afhankelijk van kortdurende meetprojecten. Bovendien is er te weinig staf voor management en analyse. Daarnaast zijn de capaciteit van datatransport en -opslag onvoldoende, en is ter completering van het instrumentarium aanschaf van een Fourier Transform Interferometer nodig (meet samenstelling van de atmosfeer). Voorgesteld

wordt vanuit structurele financiering Cabauw verder op te zetten en te onderhouden als monitoren/ankerstation voor klimaat en milieu voor een periode van tenminste tien jaar. Daarvoor zijn nodig:
1. 4 fte's (data manager en onderzoeksanalisten, 320 k€ per jaar)
2. 1.5 fte's (RAMAN-lidar, 120 k€ per jaar)
3. 0.5 fte (Fourier Transform Interferometer, 40 k€ per jaar)
4. 1 fte (GRUAN, k€ 80 per jaar)
5. Onderhoud, vervanging, vernieuwing van apparatuur, 1.3 M€ per jaar
6. Investeringen éénmalig, 1.2 M€ (Fourier Transform Interferometer (600 k€), verbetering datatransport en -opslag (500 k€) en verbetering stroomvoorziening (100 k€))

*c. RIVM*

Naast de input in het CESAR consortium meet het RIVM op diverse locaties ultraviolette straling, en fijnstof/aërosolen. Bovendien worden verticale profielen van stratosferisch ozon gemeten op het meetstation Lauder in Nieuw-Zeeland (primary site van het Network for the Detection of Atmospheric Composition Change (NDACC)), met het oog op detectie van veranderingen in de stratosfeer en kwaliteits- en continuïteitsborging van satellietinstrumenten. In Nederland worden verticale profielen van troposferisch ozon gemeten. Deze metingen zijn of worden in internationale monitoringprogramma's ingebracht en data worden in vrij toegankelijke databases ingebracht. Deze activiteiten worden momenteel bekostigd uit kortlopende projecten. Het is noodzakelijk deze activiteiten steviger te verankeren door middel van structurele financiering. Voor het voortzetten van de metingen inclusief bijdragen aan de databases is nodig:
1. 0.2 fte + 25 k€ materiaal per jaar (Aërosolen)
2. 0.5 fte + 50 k€ materiaal per jaar (Stratosferisch ozon, NDACC Lauder/NZ)
3. 0.5 fte + 30 k€ materiaal per jaar (Troposferisch ozon)
4. 0.5 fte + 30 k€ materiaal per jaar (UV straling)

*d. Het ICOS-NL consortium (VU, WUR-ALTERRA, ECN, RUG-CIO, KNMI)*

Het Integrated Carbon Observation System (ICOS) is een Europees (ESFRI) initiatief dat in Europa de wetenschappelijke infrastructuur bouwt m.b.t. de benodigde gestandaardiseerde, hoge precisie lange termijn observaties van concentraties en verticale transporten (fluxen) van broeikasgassen nabij het oppervlak van de aarde. Het is erop gericht de continuïteit te van deze waarnemingen te garanderen aangezien die op dit moment afhankelijk is van projectfinanciering (CarboEurope, KvR). ICOS-NL zal de unieke Nederlandse bijdrage aan ICOS zijn, gebaseerd op de kennis, ervaring en faciliteiten van de betrokken Nederlandse groepen, zich daarbij richtend op de dichtbewoonde complexe situatie in Nederland. In ICOS-NL werken de VU, Alterra, ECN, SRON, RUG-CIO, UU, KNMI en WU samen. Het ECN is het ICOS focal point in Nederland. Het ICOS-NL voorstel bevat naast de baseline monitoring een uitbreiding met 3 flux- en 2 concentratie sites specifiek gericht op de vaststelling van het Nederlands broeikasgasbudget en hoge resolutie (inverse) modellering. Dat laatste is hier niet meegenomen; gekozen is hier alleen de minimale omvang op te nemen. ICOS-NL vergt in deze minimale versie (3 flux en 2 concentratie stations) een investering van ca. 8 M€ voor de periode t/m 2011. De kern van het op te bouwen netwerk bestaat uit drie sites voor metingen van verticale transporten van broeikasgassen (VU+ECN/KNMI+Alterra) plus twee hoge precisie sites voor concentratie metingen (ECN+RUG-CIO). De kosten hiervan bedragen:
*Investering t/m 2011*
1. 800 k€ (verticale broeikasgas transporten)
2. 1200 k€ (broeikasgas concentraties)

*Operationele kosten per jaar*
1. 200 k€ + 1.5 fte (verticale broeikasgas transporten)
2. 200 k€ + 1.5 fte (broeikasgas concentraties)

*e. KNMI, WUR-ALTERRA*

Steun aan ontwikkelingslanden voor de installatie van meetsystemen en capacity building t.b.v. goed operationeel gebruik en data management is nodig om het wereldwijde netwerk van klimaatmonitoring stations waar de UNFCCC om heeft gevraagd te helpen realiseren. Voorgesteld wordt de bestaande tijdelijke steun vanuit Nederland structureel voort te zetten. Dit betreft:

1. Gecoördineerd door KNMI
   200 K€ per jaar aan ontwikkelingslanden via het GCOS Cooperation Mechanism als voortzetting van wat nu voor een periode van 4 jaar wordt bijgedragen (2007-2010, 50% VenW, 50% VROM).
2. Gecoördineerd door WUR-ALTERRA
   100 K€ per jaar voor capacity building en infrastructuur op het gebied van terrestrische waarnemingen, in samenwerking met LNV.

*f. VU Amsterdam*

0.5 fte (50 k€) per jaar voor ondersteuning van het voorzitterschap van VU Amsterdam van het Terrestrial Observation Panel for Climate Change van GCOS-GTOS i.v.m. internationale inbreng in programmering en activiteiten van GCOS en GTOS.

*Indicatie van wat thans aan apparatuur en mankracht voor operationele klimaatmonitoring wordt ingezet (maar waarvan in een aantal gevallen financiering op langere termijn of nu al niet verzekerd is). De ontwikkeling van nieuwe technieken voor monitoring is hier niet bij inbegrepen.*

| Uitvoeringsorganisatie | Materiaal, k€ per jaar | Menskracht, fte per jaar |
|---|---|---|
| **CESAR - consortium** | 200 | 2 |
| **Deltares zie 6.2** | - | - |
| **ECN** | 50 (niet structureel) | 1 (niet structureel) |
| **KNMI** | 1000 | 15 |
| **NIOZ** | 400 | 2 |
| **Rijkswaterstaat**[2] | 2000 | 15 |
| **RIVM** | 135 (niet structureel) | 2 (niet structureel) |
| **RUG** | 50 | 1 |
| **TNO Built/IGRAC** | 50 | 1 |
| **UU-IMAU** | 250 | 3 |
| **VU** | 25 | 0.4 |
| **WUR** | 50 (niet structureel) | 2 (niet structureel) |

[2] Klimaat gerelateerde monitoring van het watersysteem door Rijkswaterstaat is deel van het Landelijk meetnet water. Informatie over de kosten van het klimaat gerelateerde deel kan slechts globaal worden gegeven.

# Executive Summary

## The relevance of monitoring climate change

Our climate is changing. The concentrations of greenhouse gasses are higher than they have been in millions of years. This is the result of the increase in the global emissions of greenhouse gasses by industries, energy production, traffic and transport, housekeeping and offices and changing land use. The earth system reacts to these changes. Our future can only become more secure by carefully monitoring how the earth system develops. We therefore need observations.

The World Meteorological Organisation (WMO) has, on request by the Convention on Climate Change (UNFCCC), made an inventory of Essential Climate Variables (ECVs) that must be monitored worldwide to realise a Global Climate Observing System. Together, these observations provide a picture of the behaviour of the global climate system. In this system we distinguish the atmospheric, oceanic and terrestrial domains. Not only are the processes within these domains monitored, but also the interactions between these domains, which are very important.

The long time series of observations of these ECVs give an indication of slow changes, variability and the occurrence of extremes. Here the continuity of the observations is crucial. These observations are interpreted in climate models that obey physical laws. They are also used for research to further develop and test these models. These models are finally used to formulate opinions on the future development of the global and regional climate.

*“Adequate high-quality observations of climate and climate-related variables are essential if adaptation to climate change is to be based on deliberate planning leading to better adaptation policies. Good observations acquired over extended periods make possible an understanding of the frequency of extreme events as well as average climate conditions. They thereby contribute to better planning and decision making related to agriculture, coastal zone management, water resources management, health, tourism, and disaster risk management”.*

*“At the present time, in many countries neither the quality nor quantity of observations needed by global and regional models is adequate to support and verify climate models so as to allow the reliable projections needed for adaptation purposes. In order to meet adaptation needs, models will need to be improved and observation networks and data use will need to be strengthened, especially in vulnerable areas”.*

At the climate conference in Bali in 2007, the World Meteorological Organisation (WMO) emphasized the importance of good observations for adaptation to climate change with this statement.

## Policy summary

***Motivation***

With the publication of the IPCC Fourth Assessment Report in 2007, the convincing presentation by Al Gore (The Inconvenient Truth) and the publication of the advice of the Deltacommissie (Delta committee), the importance of climate observations (monitoring) became all the more evident. Additionally, the cabinet has expressed its commitment to the Millennium Development Goals, and thus to supporting developing countries in their protection against climate change. The Netherlands have expressed commitment to contribute to the global efforts in the field of climate monitoring through the Global Climate Observing System (GCOS) and the Convention on Climate Change (UNFCCC).

These developments and agreements motivated the Ministry of Spatial Planning, Housing and the Environment into an inventory on ways to improve climate monitoring by the Netherlands, in view of both national and international interests. The VROM programme Scientific Assessment and Policy Analysis Climate Change (WAB) asked KNMI to carry out this inventory.

Contributions to this project were made by CESAR[3], Deltares, ECN, KNMI, NIOZ, Rijkswaterstaat Waterdienst, RIVM, RUG-CIO, TNO Built Environment and Geosciences/IGRAC, UU-IMAU, VU and WUR-ALTERRA.

*The report concludes:*

4. There is insufficient long term financial support for climate monitoring programmes, which endangers the necessary continuity;
5. Climate monitoring is well suited as structural support to developing countries, with which The Netherlands could fulfil her commitments, but at the moment this support is missing;
6. Sound climate monitoring is feasible against costs that are small compared to the costs of adequate climate change policies.

***The importance of reliable financing***

The inventory concerns on one hand the classical meteorological observations as carried out for many years by e.g. KNMI, and on the other hand relatively new observations of many other parameters needed to understand climate change and to develop climate projections. It turned out these new climate observations are mainly financed on an ad-hoc basis through short term national and international programmes. This is an undesirable situation because it endangers the continuity. Climate monitoring *must* be a long term uninterrupted activity. Short term projects are more suitable for the development of observation techniques, not for the observations themselves. The relatively slow speed at which climate change is occurring and the existence of natural variability require high quality continuous time series of observations and, thus, continuous financial support. Recommendations are therefore made here for structural investments in the continuity and quality of long term observation programmes. In addition some extensions are proposed.

Satellite observations are an important component of climate monitoring. The financing and decision making processes of satellite programmes often differ from those for ground based observations. Recently it was decided to build a new satellite mission, TROPOMI, to which the Netherlands will contribute substantially. This mission will constitute an important contribution to monitoring of the composition of the atmosphere. As for satellite programmes the problem often is that the hardware is financed, whereas that of the necessary time series is often neglected. Therefore a proposal in this field is also made here.

[3] A consortium which monitors the state of the atmosphere by means of a 200 m high meteorological tower (Cabauw). Participants are TU Delft, KNMI, RIVM, WUR, ECN, ESA-ESTEC, TNO and IMAU.

***Opportunities and commitments***
Climate monitoring offers opportunities to comply with international agreements and national commitments. The Netherlands can shape her Millennium goals by structurally supporting developing countries in their efforts to make such measurement systems operational, in analysing the data and in the development of knowledge and institutions (capacity building). This support is necessary because global coverage is needed for adequate climate monitoring and major deficiencies are found in developing countries. Improved observations will support these countries in the development of national and regional policies, and also contribute to the improvement of our knowledge of climate change, as well as to future climate projections for our region. The United Nations Framework Convention on Climate Change (UNFCCC) has repeatedly insisted on such support. In addition, the Netherlands would contribute to the international agreements on the support of global monitoring systems.

***Climate monitoring at petty costs***
The report states that additional financing of 2 to 3 M€ and 14 fte per year, plus an initial investment of 4 M€, is the minimum needed for adequate climate monitoring that complies with all agreements and advices, and contributes to a safer and sustainable Netherlands. These costs are small compared to the costs of other climate related tasks that the government is facing.

The report also indicates how to implement the above mentioned recommendations. The key elements are given below.

***Key elements of implementation***
4. Organisation of a round-table meeting with interested parties (scientific institutes, programmes on climate research, NWO and RMNO, and ministries such as VROM, VenW, EZ, LNV and OCW) on how to strengthen climate monitoring in and by the Netherlands.
5. Formation of a national platform for the coordination of climate monitoring in the Netherlands.
6. Elaboration and preparation of the recommendations for the optimization and the provision for the future of climate monitoring by a working group to be established with input from scientific organisations and ministries involved.

The need for climate monitoring and the recommendations are explained briefly in the technical summary below.

## Technical summary

***The need for the continuation of climate monitoring***

*"The Global Climate Observing System (GCOS) assessment of climate observations needs has pointed out the large gaps that require strengthening. Governments need to urgently consider strategic support for the National Meteorological and Hydrological Services, research institutions and environmental agencies. There is also a need for supporting developing countries to adapt through such programmes as the Climate for Development in Africa Programme".*

*WMO Position Paper for the UNFCCC 14th Conference of the Parties (COP14), Poznan, Poland, December 2008.*

*1. Insight and policy support*

The fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) states that "warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level". Most of the observed increase in global average temperatures since the mid-20th century is very likely due to anthropogenic influences. Therefore the focus shifts from the question *if* climate changes to the question what climate can

be expected in this century and beyond. After all, this is essential for how we can adapt and to what extent we must mitigate climate change.

It is often forgotten that our knowledge of the climate is based on measurements that were carried out for decades by weather services and scientific institutes almost all over the world. Together, all this information provides the basis for the conclusions of the IPCC. Therefore continuation of the measurements is essential for future assessments.

Continuation and targeted extensions of these measurements are also necessary for the production of reliable projections of the future climate. This is very important for climate change policies in the Netherlands, as the national climate adaptation policy leans fully on recently developed regional climate scenarios. Moreover, long-term climate monitoring is a key issue in the recent advice of the Deltacommissie (Delta committee).

Climate scenarios cannot be constructed without observations. They act not only as input for models, but are also used to test the models that are used to calculate climate scenarios. These tests increase the confidence in scenario calculations as well as their reliability. In addition, these observations register structural changes of the climate and can timely point to possible discontinuities.

Because the climate changes in different ways in various regions of the earth, a denser network of observations relative to the past is increasingly needed for adequate adaptation policies. These networks should be the basis for national programmes on climate knowledge such as Kennis voor Klimaat (Knowledge for Climate), Klimaat voor Ruimte (Climate Changes Spatial Planning) and Leven met Water (Living with Water).

*2. International obligations*

The Global Climate Observing System (GCOS) of the World Meteorological Organisation (WMO) coordinates, on request by the United Nations Framework Convention on Climate Change (UNFCCC), the global efforts on climate measurements and climate monitoring, and makes recommendations for measurements to be carried out. The member countries, which includes the Netherlands, committed themselves on a ministerial level to contribute to this goal. Various institutes and organisations in the Netherlands contribute to this global effort. However, the quality and continuity of these measurements is insufficiently guaranteed. CESAR, Deltares, ECN, KNMI, NIOZ, Rijkswaterstaat Waterdienst, RIVM, RUG-CIO, TNO Built Environment and Geosciences/IGRAC, UU-IMAU, VU and WUR-ALTERRA have analysed the system of climate measurements in the Netherlands and propose in this report improvements in view of the GCOS recommendations.

***Recommendations:***

The recommendations comply with the existing internationally recognised expertise of the Netherlands' institutes that have the potential to guarantee the continuity of the observations.

*Investments*

| | | |
|---|---|---|
| Extension climate observation network: | 500 k€ | (KNMI, see a.1) |
| Atmospheric station Paramaribo: | 250 k€ | (KNMI, see a.2) |
| Extension/upgrading CESAR: | 1.2 M€ | (CESAR, see b) |
| Contribution to ESFRI project ICOS: | 2 M€ | (ICOS-NL, see d) |
| *Total:* | 3.95 M€ | |

*Yearly costs of materials for maintenance and replacements, assuming a period of 10 years*

| | | |
|---|---|---|
| Atmospheric station Paramaribo: | 100 k€ | (KNMI, see a.2.) |
| ARGO floats: | 150 k€ | (KNMI; NIOZ, see a.3) |
| CESAR supersite Cabauw: | 1.3 M€ | (CESAR, see b) |
| NL and Lauder LIDAR station: | 135 k€ | (RIVM, see c) |
| Contribution to ESFRI project ICOS: | 400 k€ | (ICOS-NL, see d) |
| Capacity building: | 300 k€ | (see e) |
| *Total* | *2*.385 M€ | |

*FTE's*

| | | |
|---|---|---|
| Atmospheric station Paramaribo: | 1 fte | (KNMI, see a.2) |
| Ozone sonde vertical profiles: | 1 fte | (KNMI, 4 years, see a.4) |
| CESAR supersite Cabauw: | 7 fte | (CESAR, see b) |
| NL and Lauder LIDAR station: | 1.7 fte | (RIVM, see c) |
| Contribution to ESFRI project ICOS: | 3 fte | (ICOS-NL, see d) |
| Support VU chair GCOS-GTOS: | 0.5 fte | (VU, see f) |
| *Total* | 14.2 fte | |

***Explanation:***

*a. KNMI*

What is Proposed is a strengthening of the national observation network and of the contributions to international observation programmes, as well as a continuation of the support to developing countries. These proposals are in line with the KNMI Meerjarenvisie Klimaatmonitoring which was endorsed early 2006, and with the recent Hoofdlijnen KNMI-strategie waarnemingen (Main principles for KNMI's observation strategy). These proposals concern:

5. Extension of the national observation network with 5 automatic weather stations in view of local adaptation; these stations also provide climate parameters. Costs 500 k€.
6. Upgrading of the atmospheric profiling station Paramaribo from a regional station to a level at which it can contribute to the Global Atmospheric Watch (GAW) network (which measures the chemical composition of the atmosphere). This station fills a gap in the worldwide GAW network. Material costs 150 to 250 k€; operational costs 50 to 100 k€ + 1 fte per year.
7. Enlargement of the national contribution to the ARGO float network over sea (underwater measuring buoys) by contributing to the EU-ARGO programme, recently started by the EU. NIOZ will deploy these buoys. Costs 100 to 150 k€ per year.
8. Production of long time-series of global ozone profiles using satellite and ground-based observations. Costs 1 fte for four years (80 k€ per year).

*b. CESAR consortium (Cabauw observatory with consortium partners TUDelft, KNMI, RIVM, WUR, ECN, ESA-ESTEC, TNO, IMAU)*

A modern development in the field of climate monitoring is the emergence of stations that measure vertical atmospheric profiles. These stations are equipped with advanced remote sensing equipment that can observe the climate in the atmospheric column above the ground location. There are only a handful of profiling stations around the world, but they play an important role in monitoring the climate because of the high measuring accuracy and the high vertical resolution. The Cabauw measurements are also used for the evaluation of weather and climate models, and for the validation of satellite observations.

Worldwide, Cabauw is the observatory with the longest record of high precision observations of a number of greenhouse gasses. As Cabauw is one of only eleven international research stations, GCOS recently asked KNMI, via the site and research manager, to join the WMO GCOS Reference Upper-Air Network (WMO-GRUAN) because of the high quality of the measurements. Moreover, CESAR is embedded in various other global monitoring networks, which contributes significantly to the prominent role of the station. At present the continuity of monitoring at Cabauw depends on short-term measurement projects. Moreover, there is insufficient staff for management and analysis. In addition, the capacity of data transport and

data storage is currently insufficient, and, in order to complete the set of instruments, the purchase of a Fourier Transform Interferometer (measuring atmospheric composition) is needed. Further set up and maintenance of Cabauw for monitoring and as anchor station for climate and environment is also proposed, based on structural financing for a period of at least ten years. Needed for that purpose are:

7. 4 fte (data manager and research analysts, 320 k€ per year)
8. 1.5 fte (RAMAN-lidar, 120 k€ per year)
9. 0.5 fte (Fourier Transform Interferometer, 40 k€ per year)
10. 1 fte (GRUAN, k€ 80 per year)
11. Maintenance, replacements, renewal of instrumentation, 1.3 M€ per year
12. Investments once-only, 1.2 M€ (Fourier Transform Interferometer (600 k€), improvement of data transport and data storage (500 k€) and improvement of power supply (100 k€))

*c. RIVM*

In addition to contributing to the CESAR consortium, RIVM measures ultraviolet radiation and particulate matter / aerosols at various locations. Moreover, vertical profiles of stratospheric ozone are measured at station Lauder in New Zealand (primary site of the Network for the Detection of Atmospheric Composition Change (NDACC)), in view of the detection of changes in the stratosphere and to secure the quality and continuity of satellite instruments. Vertical profiles of tropospheric ozone are measured in the Netherlands. These measurements contribute, or will contribute, to international monitoring programmes and the resulting data submitted to freely accessible databases. At present these activities are financed via short-term projects. A more firm provision must be made for the future of these activities via structural financing. For the continuation of the measurements including contributions to the databases are needed:

5. 0.2 fte + 25 k€ material per year (Aerosols)
6. 0.5 fte + 50 k€ material per year (Stratospheric ozone, NDACC Lauder/NZ)
7. 0.5 fte + 30 k€ material per year (Troposphere ozone)
8. 0.5 fte + 30 k€ material per year (UV radiation)

*d. The ICOS-NL consortium (VU, WUR-ALTERRA, ECN, RUG-CIO, KNMI)*

The Integrated Carbon Observation System (ICOS) is a European (ESFRI) initiative which builds the scientific infrastructure for the standardized high precision long-term observations near the earth surface of concentrations and vertical transports (fluxes) of greenhouse gasses, needed in Europe. It aims at guaranteeing the continuity of these observations because they currently depend on project based financing (CarboEurope, Klimaat voor Ruimte (Climate Changes Spatial Planning)). ICOS-NL will be the unique Netherlands' contribution to ICOS, based on knowledge, experience and facilities of the groups involved in the Netherlands, aimed at the complex situation introduced by the dense population in the Netherlands. In ICOS-NL VU, Alterra, ECN, SRON, RUG-CIO, UU, KNMI and WU cooperate. ECN is ICOS focal point in the Netherlands. In addition to baseline monitoring, the ICOS-NL proposal contains an extension with 3 flux sites and 2 concentration sites, specifically aiming at the determination of the greenhouse gas budget in the Netherlands and at high resolution (inverse) modelling. The latter is not taken into account here, where only the the minimal scope is chosen. This minimal version of ICOS-NL (3 flux and 2 concentration stations) requires an investment of about 8 M€ for the period upto and including 2011. The core of the network which is to be built consists of three sites for measurements of vertical transports of greenhouse gasses (VU+ECN/KNMI+Alterra) plus two high precision sites for concentration measurements (ECN+RUG-CIO). The costs of these are:

*Investments upto and including 2011*

3. 800 k€ (vertical transports of greenhouse gasses)
4. 1200 k€ (greenhouse gas concentrations)

*Operational costs per year*

3. 200 k€ + 1.5 fte (vertical transports of greenhouse gasses)
4. 200 k€ + 1.5 fte (greenhouse gas concentrations)

*e. KNMI, WUR-ALTERRA*

Support to developing countries for the installation of measuring systems and capacity building in view of proper operational use and data management is needed to support the realisation of the global network of climate monitoring stations as requested by UNFCCC. It is proposed to continue the existing temporary support by the Netherlands in a structural way. This concerns:

3. Coordinated by KNMI
   200 K€ per year to developing countries via the GCOS Cooperation Mechanism as a continuation of the current contribution for 4 years (2007-2010, 50% VenW, 50% VROM).
4. Coordinated by WUR-ALTERRA
   100 K€ per year for capacity building and infrastructure in the field of terrestrial observations, in cooperation with LNV.

*f. VU Amsterdam*

0.5 fte (50 k€) per year in support of the chairmanship of VU Amsterdam of the GCOS-GTOS Terrestrial Observation Panel for Climate Change in view of international contributions to the programming and activities of GCOS and GTOS.

*Indication of equipment and manpower currently deployed for operational climate monitoring (but of which in a number of cases long-term financing already is not secured at present). The development of new monitoring techniques is not included here.*

| Organisation | Material, k€ per year | Manpower, fte per year |
|---|---|---|
| **CESAR - consortium** | 200 | 2 |
| **Deltares see 6.2** | - | - |
| **ECN** | 50 (not structural) | 1 (not structural) |
| **KNMI** | 1000 | 15 |
| **NIOZ** | 400 | 2 |
| **Rijkswaterstaat**[4] | 2000 | 15 |
| **RIVM** | 135 (not structural) | 2 (not structural) |
| **RUG** | 50 | 1 |
| **TNO Built/IGRAC** | 50 | 1 |
| **UU-IMAU** | 250 | 3 |
| **VU** | 25 | 0.4 |
| **WUR** | 50 (not structural) | 2 (not structural) |

[4] The climate related monitoring of the water system by Rijkswaterstaat is part of the “landelijk meetnet water” National Measuring Network Water. The information on the cost of the climate related part can only be given globally.

# 1 Introduction

The development of knowledge based climate policies depends on the further improvement of our understanding of the global climate system. In this respect, Climate monitoring yields the data that are fundamental for answering questions like:

- What are the changes in the global climate system?
- What causes global change?
- How will climate change develop in the future?

Therefore, climate monitoring is essential for the development of climate scenarios. Climate monitoring comprises global monitoring of all sub-systems of the global climate system, i.e. atmosphere, ocean, land surface and cryosphere. Both satellite based and in-situ observations, that are complementary, are needed.

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) which was endorsed in 2004 by the tenth Conference of Parties (CoP) to the UN Framework Convention on Climate Change (UNFCCC). At CoP 11 (2005) the need for actual national and regional implementations in accordance to the GCOS-IP was stressed. Background information on climate monitoring in the Netherlands can be found in Annex 8.1 of the Fourth Netherlands' National Communication under the UNFCCC, edited and published by the Netherlands Ministry of Housing, Spatial Planning and the Environment (VROM 5313, December 2005, for copies see www.vrom.nl). It is an inventory on national observations for international use, but does not aim at improving national observations.

On request by the Netherlands Environmental Assessment Agency (PBL) we summarize in this report the investments of governmental institutes and universities in climate monitoring activities to inform policy makers on the contribution of the Netherlands in the field of climate monitoring and GCOS. It became clear that many of the programmes that are mentioned here are under continuous threat of termination because presently no mechanism exists to assure their funding support over time scales relevant for climate studies. Because the continuity of climate monitoring is essential, it is recommended that proper funding mechanisms be put in place.

Below, chapters on the nature and relevance of climate monitoring, on existing national activities and on financing lead to the core of this report, the recommendations. References are presented in the form of a list of relevant literature, acronyms and internet links and a glossary. Information on climate monitoring principles, on international climate monitoring programmes and on national activities in several European countries is given in annexes. The last annex is an inventory of the actual Dutch contribution to GCOS in view of the specific Actions to be undertaken in accordance with the GCOS Implementation Plan.

# 2 What is climate monitoring?

Climate monitoring is: ‘Long term uninterrupted measurement, archiving and value adding of all relevant parameters of the global climate system’.
To obtain useful high quality time-series of observations one has to obey specific global climate monitoring principles (GCMPs), as defined by GCOS (see Annex 1). Some essential elements are:

- No interruptions in the measurements
- Fixed representative location
- No discontinuities when measurement methods are changed
- Archiving of metadata
- Quality control
- Free and unrestricted exchange of data

To understand global change one has to study the physics and chemistry of all components of the global climate system with all their complicated interactions. Therefore global observations of all atmospheric phenomena are needed, such as the mean values, fluctuations and extreme values of all weather parameters, of all elements of the atmospheric composition, of oceans, land surface, ice caps and of biomass. Also, to handle the variety of measurable earth parameters a diverse spectrum of observation systems is necessary, including ground-based, satellite-based and in situ observation systems.

Satellite remote-sensing and in-situ observations are complementary because of differences in spatial coverage, and in temporal and spatial resolution. Some parameters can only be measured by one of the methods. Satellite remote sensing is earth-covering but by its nature less accurate than in situ observation of the same parameter. Therefore, in-situ observations are also essential for calibration and validation of satellite observations. On the other hand, some of the in-situ observational networks have very poor coverage in important climate zones, so that satellite systems can compensate for that lack of coverage.

In the GCOS IP a number of Essential Climate Variables (ECV) are identified that should be monitored worldwide in order to meet the needs of the UNFCCC for climate information. It was stressed in the GCOS Second Adequacy Report (WMO/TD No. 1143) that: **'Without urgent action and clear commitment of additional resources by the Parties, the UNFCCC and intergovernmental and international agencies, the Parties will lack the information necessary to effectively plan for and manage their response to climate change'**. The variables that should be monitored are listed in Table 1.

*Table 1. Essential Climate Variables as identified in the GCOS Implementation Plan*

| Domain | Essential Climate Variables |
|---|---|
| **Atmospheric** (over land, sea and ice) | **Surface:** Air temperature, Precipitation, Air pressure, Surface radiation budget, Wind speed and direction, Water vapour.<br>**Upper-air:** Earth radiation budget (including solar irradiance), Upper-air temperature (including MSU radiances), Wind speed and direction, Water vapour, Cloud properties.<br>**Composition:** Carbon dioxide, Methane, Ozone, Other long-lived greenhouse gases, 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>**Sub-surface:** Temperature, Salinity, Current, Nutrients, Carbon, Ocean tracers, Phytoplankton. |
| **Terrestrial** | 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. |

# 3 Why climate monitoring?

Climate monitoring yields data that are essential for:
- the description of the climate
- the detection of climate change
- improvements of climate models and the development of climate scenarios, both on global and regional scales
- adaptation measures
- process studies, and
- fundamental research

To enable high quality scientific interpretation, e.g. for trend analysis, the climate observations are often assimilated in (combined with) state-of-the-art numerical climate models. In this way spatial and temporal interpolation of the data is possible, obeying fundamental laws of physics. This process (Re-analysis) is carried out at e.g. the European Centre for Medium-Range Weather Forecast (ECMWF, Reading, UK) but also at KNMI.

Adequate monitoring of the global climate system is only feasible when virtually all countries make observations to realise the spatial coverage that is needed. In addition, more detailed national observations are needed for the verification of models that are used for the development of regional climate scenarios, for tailored scenarios for the Netherlands, for reference climatologies with high spatial resolution, especially for extremes, to support studies of climatological processes, and for advice in view of national security and economic development. Therefore climate monitoring supports the development of national and international global change policies.

The importance of climate monitoring has been stressed in several publications in Nature (Vol 450, Issue no. 7171, 6.12.2007). Here we quote some phrases from the Editorial on this topic.

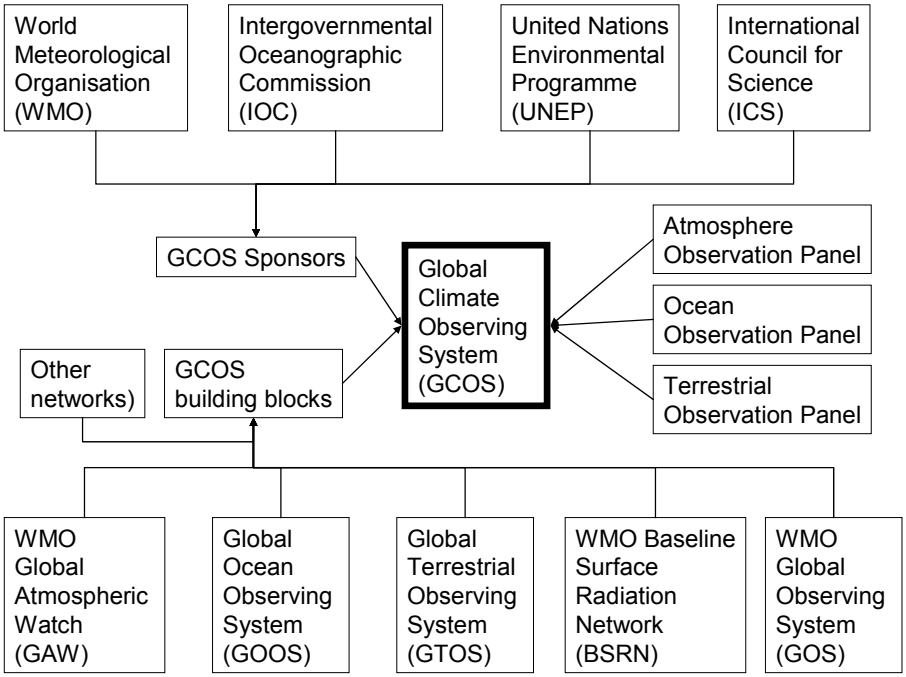
“Monitoring the Earth system requires great expertise, not just to build the instruments but to use them properly and interpret their output. Testing hypotheses about how the world works requires not just information on the current state of the three-dimensional globe, but on its progress through the fourth dimension of time. And continuous data sets are going to be vital to the validation of the ever more informative models of the Earth system that we need. This is why operational systems for data collection in which scientists play key roles are so important”.

# 4 The international context

The Global Climate Observing System GCOS was created in 1992 and is sponsored by the World Meteorological Organization (WMO), the Intergovernmental Oceanographic Commission (IOC), The United Nations Environmental Programme (UNEP) and the International Council for Science (ICSU). The GCOS programme stimulates, encourages, coordinates and otherwise facilitates the undertaking of observations by national or international organizations in support of their own requirements as well as of common goals. It provides an operational framework for integrating, and enhancing as needed, observational systems of participating countries and organizations into a comprehensive system focussed on the requirements for climate issues. The GCOS programme does not directly make observations nor generate data products.

GCOS builds upon, and works in partnership with, other existing and developing observing systems such as the WMO Global Observing System (GOS) and Global Atmosphere Watch (GAW), the Global Ocean Observing System (GOOS), and the Global Terrestrial Observing System (GTOS). It includes in situ, airborne and space-based observational components.

The GCOS principles are developed, supported and maintained by three science panels, that together encompass the entire domain of Earth Observations, namely the Atmospheric Observation Panel, the Ocean Observation Panel and the Terrestrial Observation Panel.




GCOS has been requested by the United Nations Framework Convention on Climate Change (UNFCCC) to write the Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (GCOS-IP, WMO/TD No. 1244, October 2004). As mentioned above, this report contains an extensive list of all parameters that should be monitored globally, scientific arguments and specific actions. Essential Climate Variables (ECVs) are listed, as well as Climate Monitoring Principles. The GCOS IP is worldwide accepted as guidance for the efforts to improve climate change monitoring. Other relevant reports are: Analysis of Data Exchange Problems in Global Atmospheric and Hydrological Networks (WMO/TD No. 1255, February 2005) and Systematic Observation Requirements for Satellite-based products for Climate (WMO/TD No. 1338, September 2006). The latter report specifically calls for a

coordinated effort to generate Fundamental Climate Data Records, i.e. long-term homogeneous records of ECVs spanning several satellite missions.

Since 2001 GCOS organised ten Regional Workshops, covering all regions of the world where improvement of observations is necessary. All these workshops led to Regional Action Plans. GCOS and CoP emphasize that countries that lack funding or knowledge should be supported by countries in the position to do so. Here we mention especially ClimDev Africa (Climate Information for Development Needs, an Action Plan for Africa WMO/TD No. 1358, November 2006). In this plan the need for better observations is linked to socio-economic development strategies. At CoP12 (Nairobi, November 2006) the Netherlands announced a substantial financial contribution for this plan, generated by the Ministry of Transport, Public Works and Water Management (VenW) and the Ministry of Housing, Spatial Planning and the Environment (VROM). This is in line with GCOS Key Action 7 (see Annex 4).

See for GCOS reports: http://www.wmo.ch/web/gcos/gcoshome.html.

Actual implementations of measurement systems are coordinated on international level by the ‘Group on Earth Observations’ (GEO), the ‘Global Monitoring for Environment and Security’ (GMES) programme of the EU, the Committee on Earth Observation Satellites (CEOS), and the ‘Integrated Global Observing Strategy’ (IGOS) (see Annex 2).

In Europe several countries deploy climate monitoring activities on a national scale. Moreover, there are two regional action plans. Details are given in Annex 3.

# 5 Why contribute?

In view of the responsibilities of the institutes involved, and given the global context of climate monitoring, there are several reasons to contribute:

- Global coverage can only be achieved when the developed countries contribute substantially
- Climate change is a global problem: local emissions have global impacts
- The existence of teleconnections in the climate system implies global common interest
- Participation is essential to obtain access to large global datasets
- Active participation stimulates the development of expertise needed for the interpretation of the data
- The necessary continuity can only be guaranteed by governmental organisations
- Global solidarity implies capacity building activities by developed countries

Contribution by the Netherlands underpins GCOS activities and recommendations by GCOS to articulate and identify on a national level the contribution to climate monitoring.

# 6 Overview of national activities

This chapter gives an overview in general terms of the national activities in the field of climate monitoring. The institutes and consortia that are involved are:

CESAR[5]; Cabauw Experimental Site for Atmospheric Research
Deltares; Dutch institute for Delta Technology
ECN; Energy research Centre of the Netherlands
KNMI; Royal Netherlands Meteorological Institute
NIOZ; NIOZ Royal Netherlands Institute for Sea Research
Rijkswaterstaat Waterdienst; Rijkswaterstaat Centre for Water Management
RIVM; National Institute for Public Health and the Environment
RUG-CIO; University of Groningen, Center for Isotope Research
TNO Built Environment and Geosciences/IGRAC; International Groundwater Resources Assessment Centre
UU-IMAU; Utrecht University, Institute for Marine and Atmospheric Research
VU; VU University Amsterdam
WUR; Wageningen University and Research Centre - ALTERRA

Here we follow the division in the three domains that are used by GCOS.

## 6.1 Atmospheric Domain

CESAR (Cabauw Experimental Site for Atmospheric Research) is an observational facility with a comprehensive set of remote sensing and in-situ equipment to characterize the state of the atmosphere, its radiative properties and interaction with the land surface, for the study of physical and chemical processes, climate monitoring and validation studies. It is a co-operation between TUD, KNMI, RIVM, WUR, ECN, ESA-ESTEC, TNO and IMAU. A database is being operated, and new technologies are being developed for atmospheric observation to reduce gaps in climate knowledge, including space and ground based instruments, improving representation of physical processes in climate models.

ECN (Energy Research Centre of the Netherlands) is monitoring atmospheric composition at the Cabauw tower since 1992 (continuous vertical gradients of $CO_2$, $CH_4$, $N_2O$, SF6, H2 and 222Rn; continuous concentrations of halocarbons, Rn and H2, event sampling for isotopic analysis in collaboration with RUG-CIO), and aerosols (size distribution, size resolved chemical composition, cloud forming properties, radiative properties). It is a partner in international projects such as CarboEurope IP, NitroEurope IP, and ICOS (Integrated Carbon Observing System). It is national focal point for ICOS. Specific activities focus on network optimisation, capacity building in Eastern Europe, higher network density, data quality, emission verification for greenhouse gases and concentration data submission to bodies like EMEP (European Monitoring and Evaluation Programme) and GAW.

KNMI (Royal Netherlands Meteorological Institute) is responsible for the operation of national networks for weather and climate monitoring, especially in the Atmospheric and Oceanic Domains. It is contributing to the global aircraft monitoring system AMDAR, as well as to the development of satellite instruments and retrieval techniques for atmospheric composition, aerosol and cloud monitoring. KNMI is also contributing to observations at the Cabauw 200 m

[5] A consortium that has set up and operates at the Cabauw site an observational research facility with a comprehensive set of remote-sensing and in-situ equipment to characterise the state of the atmosphere, its radiative properties and interaction with the land surface for the study of physical and chemical processes, monitoring of the atmosphere and validation studies. Members are: TUD, KNMI, RIVM, WUR, ECN, ESA-ESTEC, TNO and IMAU.

tower observatory, including a BSRN station. At a wider scope than the Atmospheric Domain, KNMI is responsible for collecting, quality controlling and identifying and filling gaps of observational time series and subsequent sustainable archiving in the National Observational Database. Twice daily upper air observations and weekly ozone soundings are performed in De Bilt as well as continuous ozone measurements by Brewer, which are submitted regularly to WMO databases. KNMI is the principal investigator institute of the Ozone Monitoring Instrument (OMI) on board the NASA EOS AURA satellite and is responsible for the generation and distribution of the OMI observations on atmospheric composition. KNMI is also principle investigator for the recently approved TROPOMI instrument, planned to be launched in 2015. Other activities on climate monitoring by satellites include cloud, aerosol and ozone observations through the EUMETSAT Satellite Application Facilities (SAF) and a strong involvement in future ESA missions Sentinel 5 Precursor, ADM, EarthCare and TRAQ. KNMI is digitizing and archiving national and a selected set of international historical observations. It is also co-organizer of a WMO workshop on data rescue for the Mediterranean area (RAVI and RAI). It contributes to national and international research to the reconstruction of instrumental and proxy series into high quality paleoclimate observational time series. Homogenisation of data sets and individual time series is done in cooperation with COST-ES0601. KNMI is also operating a measurement station in Paramaribo, Surinam together with the Meteorological Service of Surinam. KNMI participates in the GCOS Cooperation Mechanism. At CoP12 in Nairobi, the Netherlands announced a contribution of 800 k€ in total for 4 years (2007-2010) to the GCOS Action Plans for Africa, generated by the Ministries of V&W and VROM. Currently it is planned to start a digitizing project of historical data in cooperation with the Indonesian Weather Service.

RIVM (National Institute for Public Health and the Environment) is operating the National Air Quality Monitoring Network, monitoring atmospheric composition (greenhouse gases, aerosols/particulate matter and other air quality parameters). On national level RIVM collaborates with partners in CESAR contributing with measurements of vertical profiles of water vapour, aerosols and clouds, and ground based measurements of aerosols/particulate matter (mass, size distribution and optical properties), UV radiation, and tropospheric ozone. RIVM is also contributing to international observation networks for ground based remote sensing of atmospheric composition, in particular EARLINET (European Aerosol Research Lidar Network) and NDACC (Network for Detection of Atmospheric Composition Change) and GALION (GAW Aerosol Lidar Observation Network). In NDACC RIVM operates a stratospheric ozone lidar in Lauder, New Zealand.

RUG-CIO is operating a 60m tower observation point at Lutjewad (north-east coast) for greenhouse gas concentrations and fluxes of $CO_2$. Besides continuous high precision concentration measurements of the gases $CO_2$, $CH_4$, CO, SF6 and $N_2O$ the concentrations of O2/N2 and 222Rn are measured. Also integrated samples of $14CO_2$ are taken. CIO-RUG also takes part in the CarboEurope-IP and ICOS project.

## 6.2 Oceanic Domain

Deltares is a new and independent institute in the Netherlands building on knowledge and expertise concerning water, soil, and the subsurface, and is playing a role in providing the government and private sector with applied research and specialist advice. Concerning Climate monitoring Deltares provides feedback to monitoring programmes based on analysis and integration of information sources into decision making where climate relevant aspects play a role. (i.e.spatial planning, EU-Directive on Marine Water Quality).

KNMI (Royal Netherlands Meteorological Institute) is responsible for the operation of national networks for weather and climate monitoring, especially in the Atmospheric and Oceanic Domains. As for the Oceanic Domain KNMI contributes to the international VOS, VOSClim and ARGO networks. KNMI also contributes to the quality control of the US Maury Collection.

NIOZ (Royal Netherlands Institute for Sea Research) is an institute for fundamental multidisciplinary research in coastal seas and oceans. In the framework of that research a number of climatic monitoring programmes are maintained. In the western Wadden Sea the benthic ecosystem is monitored since over 30 years, while continuous observations of sea surface temperature and salinity extend a time series, started in 1860. Moored profiling CTDs (Conductivity-Temperature-Depth) in the Irminger Sea monitor the hydrography of the Irminger Sea since 2003. A moored current meter array in the Mozambique Channel determines the ocean transport at the tropical-subtropical connection in the western Indian Ocean. NIOZ intends to submit its vast archive of sea surface temperature and salinity data to the appropriate GCOS data centre.

Rijkswaterstaat is operating the North Sea Monitoring Network covering the Dutch Continental Shelf (wave buoys, fixed sea level monitoring stations, water temperature). It also runs a chemical monitoring programme (22 offshore ship based stations (32x/year temperature, salinity, nutrients, micro pollutants etc.) and combined biological monitoring programme (phytoplankton, zoo-plankton, ((shell-) fish, birds etc.). Rijkswaterstaat Centre for Water Management also carries out a coastal research programme (local and large scale coastal dynamics related to sea level rise).

Under the National Offshore Mining Act oil and gas exploration production platforms monitor and distribute data on waves, sea level, temperature, wind etc. A yearly morphological survey and coastline monitoring (dune height and bathymetry up-to 20 m) is carried out as well. Other activities are SEPRISE (Sustained, Efficient Production of Required information Services) for real time oceanographic data, SeaDataNet (Pan-European infrastructure for Ocean & Marine Data Management) for historical data, and NOOS (North West Shelf Operational Oceanographic System) for North Sea monitoring and modelling capacity.

## 6.3 Terrestrial Domain

Rijkswaterstaat monitors the physical, chemical and biological state of the main water system in the Netherlands. This includes water levels and discharge at the main inflow (e.g. river Rhine and Meuse) and the discharge to the seawater levels, temperature and some other physical parameters are measured on a continuous basis.
Rijkswaterstaat monitors and archives water related data as part of its legal task (MWTL - Monitoring Programme of the National Water Systems). This includes ECVs, the discharge of River Meuse and Rhine.

TNO Built Environment and Geosciences is monitoring groundwater levels and groundwater quality. Measurement series of groundwater levels and groundwater quality at approximately 20.000 sites in the Netherlands are stored in the DINO-system. The DINO-system is the central storage site for geo-scientific data on the shallow and deep Dutch subsurface and resorts under the DINO-programme, aimed at maintaining and improving the National Geological Database in the Netherlands. There is an on-going research programme to improve data acquisition, data storage and data distribution. The focus is on sensor networks and Sensor Web Enablement (SWE). Some initial research has been conducted investigating the relation between climate change and groundwater.

IGRAC (International Groundwater Resources Assessment Centre) has taken initiative to establish a Global Groundwater Monitoring Network (GGMN). The network has become operational in 2008, having a web-based application and people network as the main components. This network intends to gradually provide crucial data for the climate change - groundwater analyses. It uses aggregated information from existing networks in order to represent a regional change of groundwater resources at a scale relevant for the global assessment. The main challenge is setting up a people network (read further at http://www.igrac.nl/publications/281). With the GGMN, IGRAC is responsible for the global groundwater observations in the GEO (Group of Earth Observations) work plan for 2009-2011 and in the GCOS/WMO Global Terrestrial Network Hydrology (GTN-H). Besides, IGRAC is

involved in several projects and initiatives related to impact of climate change on groundwater such as Initiative with Cooperative Programme on Water and Climate (CPWC) and Groundwater Resources Assessment under the Pressures of Humanity and Climate Changes (GRAPHIC).

UU-IMAU (Utrecht University, Institute for Marine and Atmospheric Research) is monitoring ice-caps and glaciers. Automatic weather stations are operated on glaciers in the Alps, Norway, Greenland and Antarctica. Mass balance measurements are carried out on the Greenland ice sheet.

The VU Amsterdam operates a GHG observation site on a fen meadow Horstermeer, where energy balance and moisture fluxes are observed, next to $CO_2$ and $CH_4$ emissions. The VU coordinates the efforts of several Dutch Institutions in the Integrated Carbon Observing System, a European ESFRI infrastructure proposal. VUA is producing maps of soil moisture from microwave radiation satellites and is active in Groundwater Resources Assessment under the Pressures of Humanity and Climate Changes (GRAPHIC). VUA is a partner in several EU funded monitoring programs such as CarboEurope, IMMEC, and Watch. The VU also chairs the GCOS Terrestrial Observation Panel for Climate.

WUR- (Wageningen University and Research centre) is monitoring soil and soil moisture parameters, land-use (change) and land bound GHG emissions. Fluxes of $CO_2$, water vapour, sensible heat and momentum are continuously monitored at Loobos forest site since 1994. Additional flux monitoring sites (also including $N_2O$ and $CH_4$ fluxes) are being operated for shorter periods over a variety of other land cover types (crops, grasslands, peat lands, etc). This flux monitoring network is a collaborative action between WUR and a number of other universities and research centres (VU Amsterdam, ECN, TNO, RUG), largely initiated through the CarboEurope and NitroEurope projects. Data are managed and made accessible at national and European level. It also provides observations and archiving of phenological data (Nature's Calendar). WUR-ALTERRA also provides capacity building and incidental support for infrastructure in the field of terrestrial observations in cooperation with the Ministry of LNV.

The Netherlands Environmental Assessment Agency (PBL) coordinates the Emission Database for Global Atmospheric Research (EDGAR) information system. This is a joint project of research institutes in the Netherlands and Italy. It stores global emission inventories of direct and indirect greenhouse gases from anthropogenic sources including halocarbons and aerosols both on a per country and region basis as well as on a grid. The Netherlands Environmental Assessment Agency (PBL) also developed the History Database of the Global Environment (HYDE). It presents not only (gridded) time series for the last 12000 years of population and land use, but also various other indicators such as GDP, Value Added, Livestock, Private Consumption, GHG emissions, and Industrial production data.

# 7 Financing

Adaptations to climate change and mitigation measures require vast financial resources. Large national programmes such as Climate Changes Spatial Planning and Knowledge for Climate Research aim at getting climate change and climate variability one of the guiding principles for spatial planning in the Netherlands and develop knowledge that is necessary to be able to assess investments to make spatial planning and infrastructure climate-proof over the coming twenty years. Similarly, industries and government commit themselves to significant emission reduction targets to be realised at all sectoral and administrative levels of society, in order to make society more climate neutral. For these programmes the availability of climate monitoring products is essential. Furthermore, climate monitoring data are essential to further improve our understanding and attribution of climate change.

The operation of the monitoring systems listed in this document is funded by a mix of long term (service based) and short term (project based) commitments from various national and international sources. Because climate monitoring essentially is a long term uninterrupted measurement activity (see Annex 1 on GCOS Climate Monitoring Principles), guaranteed long term funding is a fundamental prerequisite. Project based funding is more appropriate for the development of monitoring systems and techniques. Where large scale monitoring activities such as CESAR and the fluxnet sites, based on a patchwork of funds, are scientifically successful, they are constantly threatened by discontinuity due to lack of long term funding commitments.

It is thus vital that a funding mechanism be brought into place to assure continuity of support for the national GCOS activities that are identified as ‘core’ activities. Therefore one of the principal recommendations of the project is to secure more long term funding commitments for existing core facilities and to support development and realisation of additional measurements where needed and feasible. The additional funding needed is small compared to the budget needed for the realisation of climate change policies.

# 8 Recommendations

The inventory of GCOS activities in the Netherlands in view of the GCOS Implementation Plan which can be found in Annex 4 revealed that core climate monitoring activities are mainly funded on an ad-hoc bases in relation to short-term national and international programmes. This implies that the required continuity, which is essential in view of the large timescales of climate change and the natural variability, is not guaranteed. Therefore structural investments are recommended to secure the continuity and quality of long term climate monitoring programmes.

Satellite observations are an important contribution to climate monitoring. Financing of these observations is usually secured in other ways than for ground-based and in-situ observations. Recently it was decided to build a new mission for the monitoring of the atmospheric composition, TROPOMI, with an important contribution from the Netherlands. For satellite programmes the financing of the hardware is often available. However, there is often a lack of financial means for the subsequent derival of time series of climate parameters. Therefore a proposal in that field of activities is made here.

The Workshop in Sydney 'Future Climate Change Research and Observations: GCOS, WCRP and IGB P Learning from the IPCC Fourth Assessment Report' WMO/TD No. 1418, January 2008, gives additional guidance. We quote:

“In situ reference observing networks leveraging on existing or partially completed networks of reference sites taking multiple measurements of many different variables will be an important element of any future observing network. Implementation of these reference networks is of high priority to ensure the value of future observations. For example, the GCOS Reference Upper-Air Network (GRUAN), aiming at reference atmospheric profile measurements of several ECVs, is now in the process of being established”.
A recommended activity is to 'continue to design and advocate the setting up of reference networks, and promote their widespread use in dataset construction and climate monitoring'. The recommendations below for strengthening the CESAR consortium comply with this ‘Sydney’ recommendation.

We also recommend structural support to developing countries for the implementation of measurement systems and capacity building in view of operations and data management as a substantial contribution to reducing existing gaps in global climate monitoring, which hamper a complete global picture of climate change. This will also support developing countries to develop national and regional climate change policies. This also is an opportunity to contribute to the Millennium Development Goals.

The core facilities we identified, and the responsible institutions are:

1. *KNMI*
   - National climate monitoring network
   - Contributions to international monitoring networks (Paramaribo observatory, ARGO, VOS, Ozone profiles)
2. *CESAR consortium*
   - Atmospheric profiling station Cabauw
3. *RIVM*
   - Observations of Greenhouse Gases, aerosol and radiation at various locations
4. *VU, WUR-ALTERRA, ECN, RUG-CIO, KNMI*
   (ICOS-NL *consortium*, Integrated Carbon Observation System)
   - Observations of GHG concentrations and fluxes near the earth surface
5. *KNMI, WUR-ALTERRA*
   - Support to developing countries
6. *VU Amstredam*
   - The VU chairs the GCOS Terrestrial Observation Panel for Climate Change

7. *Rijkswaterstaat*
   - National water monitoring network

## 8.1 Recommendations per institute:

1. *KNMI*
   - Extension of the national monitoring network with 5 automatic weather stations that also provide climate information, in view of data needs for local adaptation. Costs: 500 k€.
   - Upgrading of the Atmospheric Monitoring Station Paramaribo from a regional station to a global (background) Global Atmospheric Watch (GAW) station. This station fills a gap in the global GAW network. This requires an initial investment estimated between 150 and 250 k€ for equipment and infrastructure changes. Additional operational costs for the execution of the measurement programme will be between 50 and 100 k€ plus 1 fte per year. Remark: A BSRN station was recently established at Paramaribo. (Recommendation of 'KNMI Meerjarenvisie Klimaatmonitoring' January 2006).
   - Enlargement of the contribution to the global ARGO float network, buoys for global sub-surface sea observations. A recent development is the EURO-ARGO programme. In the framework of the ESFRI Roadmap preparations are being made for a European contribution to the ARGO network, aiming at a quarter of the global needs (FP7-211597). The operational phase will start in 2010. EU countries will than provide a yearly amount of floats to maintain operations. For the Netherlands it is estimated that a yearly budget of 100 to 150 k€ will be needed. In addition to general use for climate monitoring, NIOZ uses the ARGO data for research. (Recommendation of 'KNMI Meerjarenvisie Klimaat-monitoring' January 2006).
   - Generation of Fundamental Climate Data Records (FCDR) of vertical ozone distributions (with RIVM). Separate instrument records of ozone profiles exist since the early 1970ties (BUV, SBUV instruments) and are continued today with OMI and GOME2/METOP satellite instruments. There is a need for continuous en homogeneous data records of ozone, separating stratosphere from troposphere, conform the GCOS definition of FCDR. This work requires connecting the different instrument records, correcting for biases and other systematic errors. The use of ground truth from lidar, microwave instruments is essential for this work. This requires 1 fte for 4 years at postdoc level (80 k€/y).

2. *CESAR consortium*

   Atmospheric profiling stations are a modern development in the field of climate monitoring. They deploy advanced remote sensing systems that observe atmospheric climate parameters in a vertical column. There are only few of these stations in the world, but they play an important role in climate monitoring because of the accuracy and high vertical resolution of the instruments deployed. CESAR (Cabauw Experimental Site for Atmospheric Research) is an observational facility with a comprehensive set of remote sensing and in-situ equipment to characterize the state of the atmosphere, its radiative properties and interaction with the land surface, for the study of physical and chemical processes, climate monitoring and validation studies and the validation of satellite observations. It is a co-operation between Delft University of Technology, KNMI, RIVM, WUR, ECN, ESA-ESTEC, TNO and IMAU. Recently a request was received to participate in the WMO GCOS Upper-Air Reference Network (GRUAN). A BSRN station is also in operation. At present the continuity of the monitoring programmes at Cabauw depends on project based funding. It is proposed that structural funding is made available for the further development and continuous deployment of CESAR as monitoring and anchor station for climate and environment. Needed for that purpose is 1.3 M€/y and 7 fte's for 10 years plus an initial investment of 1.2 M€. More specified:
   1. 4 fte's (data manager and analysts, 320 k€/y)
   2. 1.5 fte's (RAMAN-lidar, 120 k€/y)
   3. 0.5 fte (Fourier Transform Interferometer, 40 k€/y)
   4. 1 fte (GRUAN, 80 k€/y)
   5. Large scale maintenance and replacements, 1.3 M€/y

6. Initial investments, 1.2 M€ (Fourier Transform Interferometer (600 k€), improvements of data-transport and data-storage capacities (500 k€) and enlarged power supply capacity (100 k€)).

3. *RIVM*
   In addition to its contribution to the CESAR consortium, RIVM monitors UV-radiation and aerosols at various locations. Moreover, vertical profiles of stratospheric ozone are measured at station Lauder (New Zealand), a primary site of the Network for the Detection of Atmospheric Composition Change (NDACC) in view of the detection of changes in the atmosphere and the validation of satellite observations. In the Netherlands vertical profiles of tropospheric ozone are also observed. These measurements are, or will be, submitted to freely accessible databases of international monitoring programmes. Most of these observations are funded on short-term project basis. To secure long-term funding of these observations and databases additional budget of 135 k€ and 1.7 fte is needed:
   - Aerosols, 25 k€ + 0.2 fte per year
   - Stratospheric ozone (Lauder, NZ), 50 k€ + 0.5 fte per year
   - Tropospheric ozone, 30 k€ + 0.5 fte per year
   - UV radiation, 30 k€ + 0.5 fte per year

4. *VU, WUR-ALTERRA, ECN, RUG-CIO, KNMI (ICOS-NL consortium)*
   The Integrated Carbon Observation System (ICOS) is a European (ESFRI) initiative that builds in Europe the scientific infrastructure needed for standardised, high precision long term observations of Greenhouse Gas (GHG) concentrations and fluxes near the earth surface. This will guarantee the continuity of an infrastructure based on project funding (CarboEurope, KvR). ICOS-NL will be the unique Netherlands' contribution to ICOS, based on knowledge, experience and facilities from the institutions involved in the Netherlands, taking into account the densely populated complex situation in the Netherlands. ICOS-NL sees cooperation between VU, ALTERRA, ECN, SRON, RUG-CIO, UU, KNMI and WU. In addition to baseline monitoring, the ICOS-NL proposal foresees an extension with 3 flux and 2 concentration sites, aiming at determining the greenhouse gas budget in the Netherlands, and at high resolution (inverse) modelling. Here it is decided to concentrate on the first essential needs. In this minimal version (3 flux and 2 concentration station), ICOS-NL needs an investment of approximately 8 M€ for the period until (incl) 2011. The core of the network will consist of 3 flux sites (VU, ALTERRA) and 2 high precision GHG monitoring sites (ECN, RUG-CIO). For this the following funding is needed:
   Investments until (incl) 2011
   1. 800 k€ (flux sites)
   2. 1200 k€ (GHG sites)

   Operational costs 900 k€/y, more specific
   3. 200 k€ + 1.5 fte (flux sites)
   4. 200 k€ + 1.5 fte (GHG sites)

5. *KNMI, WUR-ALTERRA*
   Support to developing countries for the implementation of measurement systems and capacity building in view of operations and data management is needed to help realise the global monitoring networks according to the needs of the UNFCCC. Existing contributions from the Netherlands should be continued, based on more structural funding.
   - KNMI coordinates national participation in the GCOS Cooperation Mechanism with a contribution of 800 k€ in total for 4 years (2007-2010) to the GCOS Action Plans for Africa, funded by the Ministries of V&W and VROM. It is unlikely that climate monitoring programmes can be operated continuously in developing countries in the coming 10 years without financial support. Structural support through the GCOS Cooperation Mechanism to developing countries of 200 k€/y is proposed for the coming 10 years.
   - WUR-ALTERRA provides capacity building and incidental support for infrastructure in the field of terrestrial observations in cooperation with the Ministry of LNV. It is proposed to continue this support by making available 100 k€/y on a structural basis.

6. *VU Amsterdam*
   - VU chairs the Terrestrial Observation Panel for Climate Change of GCOS-GTOS. To strengthen the international support to programmes and activities of GCOS and GTOS 0.5 fte (50 k€) per year is needed.

*7 Rijkswaterstaat*

Monitoring of the North Sea and of the main water systems in the Netherlands is an operational task of Rijkswaterstaat (see the description of the these activities in 6.2 and 6.3). No additional or structural investments are proposed to support the climate related part of the monitoring.

## 8.2 Additional general recommendations

- Contributions by research oriented institutes are recognized as valuable contributions to climate monitoring. Uninterrupted station operations and observing systems should be pursued where possible and conversion of research observing systems to long-term operations should be promoted and facilitated.
- All institutes are recommended to adhere to the GCOS Climate Monitoring Principles (GCOS Key Action 10) where possible.
- All institutes are recommended to archive metadata (GCOS Key Action 11).

## 8.3 The way forward

1. Organisation of a round-table meeting with parties involved (research institutes, climate research programme boards, NOW and RMNO, and ministries such as VROM, VenW, EZ, LNV and OCW) on how to enhance the Netherlands' contribution to climate monitoring.
2. Establishment of a national platform for the coordination of climate monitoring activities in the Netherlands.
3. Elaboration and implementation of these recommendations by a working group with representatives from scientific organisations and ministries involved.

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Regional Action Plan for Eastern and Central Europe; GCOS, December 2005; http://www.wmo.int/pages/prog/gcos/documents/GCOS_ECE_RAP_Dec05.pdf

Report of the GCOS Regional Workshop for Eastern and Central Europe on Improving Observing Systems for Climate, WMO/TD No. 1283, July 2005.

Report of the GCOS Regional Workshop for the Mediterranean Basin, WMO/TD N° 1337, July 2006.

Systematic Observation Requirements for Satellite-based products for Climate, WMO/TD No. 1338, September 2006.

The Second Report on the Adequacy of the Global Observing Systems for Climate in support of the UNFCCC, WMO/TD No. 1143, April 2003.

# 10 Acronyms and Internet links

- ADM; Atmospheric Dynamics Mission; http://www.esa.int/esaLP/LPadmaeolus.html
- ALTERRA; http://www.alterra.wur.nl/NL/
- AMDAR; Aircraft Meteorological Data Relay; http://amdar.wmo.int/
- APA; Agência Portuguesa do Ambiente; http://www.apambiente.pt/Paginas/default.aspx
- ARGO; http://www.argo.ucsd.edu/
- BSRN; Baseline Surface Radiation Network; http://www.gewex.org/bsrn.html
- BUV; Backscatter Ultraviolet
- CarboEurope IP; http://www.carboeurope.org/
- CESAR; Cabauw Experimental Site for Atmospheric Research; http://www.cesar-observatory.nl/
- COST-ES0601; http://www.cost.esf.org/index.php?id=1077
- CPWC; Co-operative Programme on Water and Climate; http://www.ihe.nl/Project-activities/Project-database/CPWC-Co-operative-Programme-on-Water-and-Climate
- Deltacommissie; http://www.deltacommissie.nl
- Deltares; http://www.deltares.nl/xmlpages/page/deltares
- DINO; Data en Informatie van de Nederlandse Ondergrond; http://dinoloket.nitg.tno.nl/nl/about/about.html/
- DWD; Deutscher Wetterdienst; http://www.dwd.de/
- EARLINET; European Aerosol Research Lidar Network to Establish an Aerosol Climatology; http://www.earlinet.org/
- EarthCare; http://www.esa.int/esaLP/LPearthcare.html
- ECMWF; European Centre for Medium-Range Weather Forecasts; http://www.ecmwf.int/
- ECN; Energieonderzoek Centrum Nederland; http://www.ecn.nl/
- EDGAR; Emission Database for Global Atmospheric Research, http://www.mnp.nl/edgar/
- EMEP; European Monitoring and Evaluation Programme; http://www.emep.int/
- EOS AURA; Earth Observing System AURA; http://www.nasa.gov/mission_pages/aura/main/index.html
- ESA; European Space Agency; http://www.esa.int/esaCP/index.html
- ESFRI; http://cordis.europa.eu/esfri/
- ESTEC; European Space Research and Technology Centre; http://www.esa.int/esaCP/SEMOMQ374OD_index_0.html
- EUMETSAT; European Organisation for the Exploitation of Meteorological Satellites; http://www.eumetsat.int/Home/index.htm
- EURO-ARGO; http://www.euro-argo.eu/
- FCDR; Fundamental Climate Data Records
- FTIR; Fourier Transform Interferometer
- GALION; GAW Aerosol Lidar Observation Network; http://www.igarss08.com/Abstracts/pdfs/1775.pdf
- GAW; Global Atmospheric Watch; http://www.wmo.int/pages/prog/arep/gaw/gaw_home_en.html
- GCOS; Global Climate Observing System; http://www.wmo.int/pages/prog/gcos/
- GEO; Group on Earth Observations; http://www.earthobservations.org/
- GEOSS; Global Earth Observation System of Systems; http://www.earthobservations.org/
- GGMN; Global Groundwater Monitoring Network; http://www.igrac.nl/publications/281
- GLACIO-CLIM; Les GLACIers, un Observatoire du CLIMat; http://www-lgge.ujf-grenoble.fr/ServiceObs/contexte.htm#glacioclim
- GMES; Global Monitoring for Environment and Security; http://www.gmes.info/
- GOME; Global Ozone Monitoring Experiment; http://earth.esa.int/ers/gome/
- GOOS; Global Ocean Observing System; http://www.ioc-goos.org/
- GOS; Global Observing System; http://www.wmo.int/pages/prog/www/OSY/GOS.html
- GPS; Global Positioning System

- GRAPHIC; Groundwater Resources Assessment under the Pressures of Humanity and Climate Changes; http://unesdoc.unesco.org/images/0015/001507/150730e.pdf
- GRUAN; GCOS Reference Upper-Air Network; http://www.wmo.ch/pages/prog/gcos/Publications/gcos-121.pdf
- GTN-H; Global Terrestrial Network for Hydrology; http://www.wmo.int/pages/prog/gcos/Publications/gcos-63.pdf
- GTOS; Global Terrestrial Observing System; http://www.fao.org/gtos/
- GWEX; Global Energy and Water Cycle Experiment; http://wcrp.wmo.int/AP_GEWEX.html
- HYDE; History Database of the Global Environment; http://www.mnp.nl/en/themasites/hyde/index.html
- ICOS; Integrated Carbon Observing System; http://icos-infrastructure.ipsl.jussieu.fr/
- ICSU; International Council for Science; http://www.icsu.org/index.php
- IGOS; Integrated Global Observing Strategy; http://www.igospartners.org/
- IGRAC; International Groundwater Resources Assessment Centre; http://www.igrac.nl/
- IM; Instituto de Meteorologia, Portugal; http://www.meteo.pt/en/index.html
- INAG; Instituto de Água, Portugal; http://www.inag.pt/
- IOC; Intergovernmental Oceanographic Commission; http://ioc-unesco.org/
- Kennis voor Klimaat; http://www.kennisvoorklimaat.nl/templates/dispatcher.asp?page_id=25222734
- KNMI; Koninklijk Nederlands Meteorologisch Instituut; http://www.knmi.nl/
- KvR; Klimaat voor Ruimte; http://www.klimaatvoorruimte.nl/pro1/general/start.asp?i=0&j=0&k=0&p=0
- Leven met Water; http://www.levenmetwater.nl
- MEDARE; Mediterranean Data Rescue; www.omm.urv.cat/MEDARE
- METOP; Meteorological Operational satellite programme; http://www.esa.int/esaLP/LPmetop.html
- MWTL; Monitoring Programme of the National Water Systems; http://www.waterbase.nl/
- NASA; National Aeronautics and Space Administration; http://www.nasa.gov/
- NDACC; Network for the Detection of Atmospheric Composition Change; http://www.ndsc.ncep.noaa.gov/
- NIOZ; Royal Netherlands Institute for Sea Research; http://www.nioz.nl/
- NitroEuropeIP; http://www.nitroeurope.eu/
- NODC; National Oceanographic Data Committee of the Netherlands; http://www.nodc.nl/
- NOOS; North West Shelf Operational Oceanographic System; http://www.noos.cc/
- OMI; Ozone Monitoring Instrument; http://aura.gsfc.nasa.gov/instruments/omi/index.html
- ORE; Observatories for the Research on Environment; http://www2.clermont.inra.fr/discover/experiments/ore.htm
- PBL; Planbureau voor de Leefomgeving; http://www.pbl.nl/en/index.html
- RAMCES; Résau Atmosphérique de Mesure des Composés à Effet de Serre; http://soon.ipsl.jussieu.fr/en/RAMCES/Organization.htm
- Rijkswaterstaat Waterdienst; http://www.rijkswaterstaat.nl/rws/riza/home/waterdienst/index.html
- RIVM; Rijksinstituut voor Volksgezondheid en Milieu; http://www.rivm.nl/
- RUG-CIO; Rijksuniversiteit Groningen - Center for Isotope Research; http://www.rug.nl/ees/onderzoek/cio/index?lang=en
- SAF; Satellite Application Facility
- SBUV; Solar Backscatter Ultraviolet; http://www.ozonelayer.noaa.gov/action/sbuv2.htm
- SeaDataNet; Pan-European infrastructure for Ocean & Marine Data Management; www.seadatanet.org
- Sentinel; http://www.esa.int/esaLP/SEMZHM0DU8E_LPgmes_0.html
- SEPRISE; Sustained, Efficient Production of Required information Services; http://www.coriolis.eu.org/english/news/seprise.htm
- SMHI; Sveriges meteorologiska och hydrologiska institut; http://www.smhi.se/
- SWE; Sensor Web Enablement; http://www.opengeospatial.org/projects/groups/sensorweb
- TNO; http://www.tno.nl/
- TNO Built Environment and Geosciences; http://www.tno.nl/content.cfm?context=overtno&content=overtnosub&laag1=32&item_id=62&Taal=2

- TRAQ; TRopospheric composition and Air Quality; http://www.acd.ucar.edu/Events/Meetings/Air_Quality_Remote_Sensing/Presentations/Posters/Phulpinv2.pdf
- UNEP; United Nations Environment Programme; http://www.unep.org/
- UNFCCC; United Nations Framework Convention on Climate Change; http://unfccc.int/2860.php
- US Maury Collection; http://icoads.noaa.gov/maury.html
- UU-IMAU; Utrecht University - Institute for Marine and Atmospheric research Utrecht; http://www.phys.uu.nl/~wwwimau/
- VOS; Voluntary Observing Ship; http://www.vos.noaa.gov/
- VOSClim; Voluntary Observing Ship Climate; http://www.ncdc.noaa.gov/oa/climate/vosclim/vosclim.html
- VU; Vrije Universiteit Amsterdam; http://www.vu.nl/nl/index.asp
- WGMS; World Glacier Monitoring Service; http://www.geo.unizh.ch/wgms/
- WMO; World Meteorological Organisation; http://www.wmo.int/pages/index_en.html
- WUR; Wageningen Universiteit en Researchcentrum; http://www.wur.nl/NL/

# 11 Glossary[6]

***Aerosols***
A collection of airborne solid or liquid particles, with a typical size between 0.01 and 10 µm that reside in the *atmosphere* for at least several hours. Aerosols may be of either natural or *anthropogenic* origin. Aerosols may influence *climate* in several ways: directly through scattering and absorbing radiation, and indirectly by acting as cloud condensation nuclei or modifying the optical properties and lifetime of clouds.

***Albedo***
The fraction of solar radiation reflected by a surface or object, often expressed as a percentage. Snow-covered surfaces have a high albedo, the surface albedo of soils ranges from high to low, and vegetation-covered surfaces and oceans have a low albedo. The Earth's planetary albedo varies mainly through varying cloudiness, snow, ice, leaf area and land cover changes.

***AMDAR***
Aircraft Meteorological Data Relay (AMDAR) is a programme initiated by the *World Meteorological Organization*. AMDAR is used to collect meteorological data worldwide by using commercial aircraft. Data are collected by the aircraft navigation systems and the onboard standard temperature and static pressure probes. The data are then preprocessed before linking them down to the ground.

***Anthropogenic***
Resulting from or produced by human beings.

***ARGO***
Argo is a global array of free-drifting profiling floats that measures the temperature and salinity of the upper 2000 m of the ocean. This allows, for the first time, continuous monitoring of the temperature, salinity, and velocity of the upper ocean, with all data being relayed and made publicly available within hours after collection. Argo deployments began in 2000 and by November 2007 the array was complete. To be maintained at that level, national commitments need to provide about 800 floats per year.

***Atmosphere***
The gaseous envelope surrounding the Earth. The dry atmosphere consists almost entirely of nitrogen (78.1% volume mixing ratio) and oxygen (20.9% volume mixing ratio), together with a number of trace gases, such as argon (0.93% volume mixing ratio), helium and radiatively active greenhouse gases such as carbon dioxide (0.035% volume mixing ratio) and ozone. In addition, the atmosphere contains the greenhouse gas water vapour, whose amounts are highly variable but typically around 1% volume mixing ratio. The atmosphere also contains clouds and aerosols.

***Baseline Surface Radiation Network (BSRN)***
BSRN is a project of the *World Climate Research Programme (WCRP)* and the *Global Energy and Water Experiment (GEWEX)* and as such is aimed at detecting important changes in the Earth's radiation field at the Earth's surface which may be related to climate changes. The data are of primary importance in supporting the validation and confirmation of satellite and computer model estimates of these quantities. At a small number of stations (about 45) in contrasting climatic zones, covering a latitude range from 80°N to 90°S, solar and atmospheric radiation is measured with instruments of the highest available accuracy and with high time resolution (1 to 3 minutes). The BSRN was designated as the global baseline network for surface radiation for

[6] Partly based on the Glossary in: Climate Change 2007 - The Physical Science Basis Contribution of Working Group I to the Fourth Assessment Report of the IPCC (ISBN 978 0521 88009-1 Hardback; 978 0521 70596-7 Paperback)

the *Global Climate Observing System (GCOS)*. The BSRN stations contribute to the *Global Atmospheric Watch (GAW)*.

***Biomass***
The total mass of living organisms in a given area or volume; dead plant material can be included as dead biomass.

***Biosphere (terrestrial and marine)***
The part of the Earth system comprising all ecosystems and living organisms, in the atmosphere, on land (terrestrial biosphere) or in the oceans (marine biosphere), including derived dead organic matter, such as litter, soil organic matter and oceanic detritus.

***Carbon cycle***
The term used to describe the flow of carbon (in various forms, e.g., as carbon dioxide) through the atmosphere, ocean, terrestrial biosphere and lithosphere.

***Carbon dioxide ($CO_2$)***
A naturally occurring gas, also a by-product of burning fossil fuels from fossil carbon deposits, such as oil, gas and coal, of burning *biomass* and of *land use* changes and other industrial processes. It is the principal anthropogenic greenhouse gas that affects the Earth's radiative balance. It is the reference gas against which other greenhouse gases are measured.

***CESAR***
A consortium that has set up and operates at the Cabauw site of the Royal Netherlands Meteorological Institute (KNMI) an observational research facility with a comprehensive set of remote-sensing and in-situ equipment to characterise the state of the *atmosphere*, its radiative properties and interaction with the land surface for the study of physical and chemical processes, monitoring of the atmosphere and validation studies. Members are: Technical University Delft, KNMI, RIVM, WUR, ECN, ESA-ESTEC, TNO and IMAU.

***Climate***
Climate in a narrow sense is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the *World Meteorological Organization.* The relevant quantities are most often surface variables such as temperature, precipitation and wind. Climate in a wider sense is the state, including a statistical description, of the climate system.

***Climate change***
Climate change refers to a change in the state of the *climate* that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or *external forcings*, or to persistent *anthropogenic* changes in the composition of the *atmosphere* or in *land use*. Note that the *United Nations Framework Convention on Climate Change* (UNFCCC), in its Article 1, defines *climate change* as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods'. The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition, and *climate variability* attributable to natural causes. See also *Climate variability; Detection and Attribution*.

***Climate model (spectrum or hierarchy)***
A numerical representation of the *climate system* based on the physical, chemical and biological properties of its components, their interactions and *feedback* processes, and accounting for all or some of its known properties. The climate system can be represented by models of varying complexity, that is, for any one component or combination of components a *spectrum* or *hierarchy* of models can be identified, differing in such aspects as the number of spatial

dimensions, the extent to which physical, chemical or biological processes are explicitly represented, or the level at which empirical parametrizations are involved. Coupled Atmosphere-Ocean General Circulation Models (AOGCMs) provide a representation of the climate system that is near the most comprehensive end of the spectrum currently available. There is an evolution towards more complex models with interactive chemistry and biology. Climate models are applied as a research tool to study and simulate the climate, and for operational purposes, including monthly, seasonal and interannual *climate predictions*.

***Climate monitoring***
Climate monitoring is: 'Long term uninterrupted measurement, archiving and value adding of all relevant parameters of the global *climate system*', covering the atmospheric, the oceanic and the terrestrial domains. To obtain useful high quality time-series of observations one has to obey specific global climate monitoring principles (GCMPs), as defined by GCOS (see Annex 1). Some essential elements are:

- No interruptions in the measurements
- Fixed representative location
- No discontinuities when measurement methods are changed
- Archiving of metadata
- Quality control
- Free and unrestricted exchange of data

***Climate prediction***
A climate prediction or *climate forecast* is the result of an attempt to produce an estimate of the actual evolution of the *climate* in the future, for example, at seasonal, interannual or long-term time scales. Since the future evolution of the *climate system* may be highly sensitive to initial conditions, such predictions are usually probabilistic in nature. See also *Climate projection*; *Climate scenario*.

***Climate projection***
A projection of the response of the *climate system* to emission or concentration scenarios of *greenhouse gases* and *aerosols*, or radiative forcing scenarios, often based
upon simulations by *climate models*. Climate projections are distinguished from *climate predictions* in order to emphasize that climate projections depend upon the emission/concentration/ radiative forcing scenario used, which are based on assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realised and are therefore subject to substantial uncertainty.

***Climate scenario***
A plausible and often simplified representation of the future *climate*, based on an internally consistent set of climatological relationships that has been constructed for explicit use in investigating the potential consequences of anthropogenic climate change, often serving as input to impact models. *Climate projections* often serve as the raw material for constructing climate scenarios, but climate scenarios usually require additional information such as about the observed current climate. A *climate change scenario* is the difference between a climate scenario and the current climate.

***Climate system***
The climate system is the highly complex system consisting of five major components: the *atmosphere*, the *hydrosphere*, the *cryosphere*, the land surface and the *biosphere*, and the interactions between them. The climate system evolves in time under the influence of its own internal dynamics and because of external forcings such as volcanic eruptions, solar variations and *anthropogenic* forcings such as the changing composition of the atmosphere and *land use* change.

***Climate variability***
Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the *climate* on all spatial and temporal scales beyond that of individual weather events. Variability may be due to natural internal processes

within the *climate system* (internal variability), or to variations in natural or *anthropogenic* external forcing (external variability). See also *Climate change*.

***Committee on Earth Observation Satellites (CEOS)***
Established in 1984, CEOS coordinates civil space-borne observations of the Earth. Participating agencies strive to enhance international coordination and data exchange and to optimize societal benefit. Currently 28 space agencies along with 20 other national and international organizations participate in CEOS planning and activities.

***Conference of the Parties (COP)***
The Conference of the Parties is the governing body of the *United Nations Framework Convention on Climate Change (UNFCCC)*, and advances implementation of the Convention through the decisions it takes at its periodic meetings.

***Cryosphere***
The component of the *climate system* consisting of all snow, ice and frozen ground (including permafrost) on and beneath the surface of the Earth and ocean.

***Detection and attribution***
*Climate* varies continually on all time scales. *Detection* of *climate change* is the process of demonstrating that climate has changed in some defi ned statistical sense, without providing a reason for that change. *Attribution* of causes of climate change is the process of establishing the most likely causes for the detected change with some defined level of confidence.

***ESFRI (European Strategy Forum on Research Infrastructures)***
ESFRI is a strategic instrument to develop the scientific integration of Europe and to strengthen its international outreach. The competitive and open access to high quality Research Infrastructures supports and benchmarks the quality of the activities of European scientists, and attracts the best researchers from around the world. The mission of ESFRI is to support a coherent and strategy-led approach to policy-making on research infrastructures in Europe, and to facilitate multilateral initiatives leading to the better use and development of research infrastructures, at EU and international level.

***Essential Climate Variables***
The Essential Climate Variables (ECVs) are required to support the work of the *UNFCCC* and the *IPCC*. They were selected by the *Global Climate Observing System (GCOS)*. Together they provide monitoring of the global *Climate System*. 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.

***External forcing***
External forcing refers to a forcing agent outside the *climate system* causing a change in the climate system. Volcanic eruptions, solar variations and *anthropogenic* changes in the composition of the *atmosphere* and *land use change* are external forcings.

***Feedback***
An interaction mechanism between processes in the *climate system* is called a climate feedback when the result of an initial process triggers changes in a second process that in turn influences the initial one. A positive feedback intensifies the original process, and a negative feedback reduces it.

***GAW (Global Atmospheric Watch)***
GAW is a programme of the *World Meteorological Organisation (WMO)*. Its mission is to:
- Make reliable, comprehensive observations of the chemical composition and selected physical characteristics of the atmosphere on global and regional scales
- Provide the scientific community with the means to predict future atmospheric states
- Organize assessments in support of formulating environmental policy

GAW is considered the atmospheric chemistry component of the *Global Climate Observing System (GCOS)*.

***GCOS IP***

The Global *Climate Observing System (GCOS)*, in consultation with its partners, has prepared an implementation plan (the Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC) that addresses the requirements identified in the Second Report on the Adequacy of Global Observing Systems for Climate in Support of the United Nations Framework Convention on Climate Change (UNFCCC). This plan specifically responds to the request of the *Conference of the Parties (COP)* to the UNFCCC in its decision 11/CP.9 to develop a 5- to 10-year implementation plan.

***Global Climate Observing System (GCOS)***

The Global Climate Observing System (GCOS), established in 1992, is an internationally coordinated
system of observing systems and networks for meeting national and international needs for climate observations. It consists of the climaterelevant components of all established environmental observing networks and systems, and it serves as the climate observation component of the *Global Earth Observation System of Systems (GEOSS)*. It is co-sponsored by the *World Meteorological Organization (WMO)*, the *Intergovernmental Oceanographic Commission (IOC)* of UNESCO, the *United Nations Environment Programme (UNEP)*, and the *International Council for Science (ICSU)*.

The purpose of GCOS is to ensure that the observations required to meet the totality of national and international needs for climate and climate-related data and information are identified, obtained and made widely available. Its goal is to provide continuous, reliable, comprehensive data and information on the state and behaviour of the global climate system, including its physical, chemical and biological properties and its atmospheric, oceanic, hydrological, terrestrial and cryospheric processes.

The objectives of GCOS are to support all components of the *World Climate Programme*, the assessment role of the *Intergovernmental Panel on Climate Change (IPCC)* and the international policy development role of the *United Nations Framework Convention on Climate Change (UNFCCC)*; and, in participation, to provide the comprehensive, continuous climate and climate-related observations needed for:

- Climate system monitoring;
- Climate change detection and attribution;
- Operational climate prediction on seasonal-tointerannual timescales;
- Research to improve understanding, modelling and prediction of the climate system;
- Applications and services for sustainable economic development;
- Assessment of the impacts of, and vulnerability and adaptation to, natural climate variability and human-induced climate change;
- Meeting the requirements of the UNFCCC and other international conventions and agreements.

***Global Earth Observation System of Systems (GEOSS)***

In July 2003, the Earth Observation Summit brought together 33 nations plus the European Commission and many International Organizations to adopt a declaration that signified a political commitment toward the development of a comprehensive, coordinated and sustained Earth Observation System to collect and disseminate improved data, information, and models to stakeholders and decision makers.

An ad-hoc group of senior political officials from all participating Countries and Organizations *(Group on Earth Observations (GEO))*, developed a 'Framework Document' plus a more comprehensive report describing how the collective effort could be organized to continuously monitor the state of our environment, increase understanding of dynamic Earth processes, and enhance forecasts on our environmental conditions. GEO also addressed potential societal benefits if timely, high quality, and long-term data and models were available to aid decision-makers at every level, from intergovernmental organizations to local government and to individuals. In April 2004 the Framework Document for a ten-year implementation plan for a Global Earth Observation System of Systems (GEOSS) was adopted by more than 50 nations.

GEOSS is envisioned as a large national and international cooperative effort to bring together existing and new hardware and software, making it all compatible in order to supply data and information at no cost. The U.S. and developed nations have a unique role in developing and maintaining the system, collecting data, enhancing data distribution, and providing models to help all of the world's nations.

***Global Energy and Water Experiment (GEWEX)***
GEWEX is an integrated programme of research, observations, and science activities ultimately leading to the prediction of global and regional climate change. It is a core programme of the *World Climate Research Programme (WCRP)*. The goal of GEWEX is to reproduce and predict, by means of suitable models, the variations of the global hydrological regime, its impact on atmospheric and surface dynamics, and variations in regional hydrological processes and water resources and their response to changes in the environment, such as the increase in *greenhouse gases*. GEWEX will provide an order of magnitude improvement in the ability to model global precipitation and evaporation, as well as accurate assessment of the sensitivity of atmospheric radiation and clouds to climate change.

***Global Ocean Observing System (GOOS)***
GOOS is a system of programmes, each of which is working on different and complementary aspects of establishing an operational ocean observation capability for all of the world's nations. UN sponsorship and UNESCO assemblies assure that international cooperation is always the first priority of the Global Ocean Observing Sytem. GOOS is the oceanographic component of the *Global Earth Observing System of Systems (GEOSS)*.
GOOS is designed to:

- Monitor, understand and predict weather and climate
- Describe and forecast the state of the ocean, including living resources
- Improve management of marine and coastal ecosystems and resources
- Mitigate damage from natural hazards and pollution
- Protect life and property on coasts and at sea
- Enable scientific research

***Greenhouse effect***
*Greenhouse gases* effectively absorb thermal infrared radiation, emitted by the Earth's surface, by the *atmosphere* itself due to the same gases, and by clouds. Atmospheric radiation is emitted to all sides, including downward to the Earth's surface. Thus, greenhouse gases trap heat within the surface-*troposphere* system. This is called the *greenhouse effect*. Thermal infrared radiation in the troposphere is strongly coupled to the temperature of the atmosphere at the altitude at which it is emitted. In the troposphere, the temperature generally decreases with height. Effectively, infrared radiation emitted to space originates from an altitude with a temperature of, on average, –19°C, in balance with the net incoming solar radiation, whereas the Earth's surface is kept at a much higher temperature of, on average, +14°C. An increase in the concentration of greenhouse gases leads to an increased infrared opacity of the atmosphere, and therefore to an effective radiation into space from a higher altitude at a lower temperature. This causes a radiative forcing that leads to an enhancement of the greenhouse effect, the so-called enhanced greenhouse effect.

***Greenhouse gas (GHG)***
Greenhouse gases are those gaseous constituents of the *atmosphere*, both natural and *anthropogenic*, that absorb and emit radiation at specifi c wavelengths within the spectrum of thermal infrared radiation emitted by the Earth's surface, the atmosphere itself, and by clouds. This property causes the *greenhouse effect.* Water vapour (H2O), *carbon dioxide* ($CO_2$), nitrous oxide ($N_2O$), methane ($CH_4$) and *ozone* (O3) are the primary greenhouse gases in the Earth's atmosphere. Moreover, there are a number of entirely humanmade greenhouse gases in the atmosphere, such as the halocarbons and other chlorine- and bromine-containing substances, dealt with under the *Montreal Protocol.* Beside $CO_2$, $N_2O$ and $CH_4$, the *Kyoto Protocol* deals with the greenhouse gases sulphur hexafl uoride (SF6), hydrofl uorocarbons (HFCs) and perfl uorocarbons (PFCs).

***Group on Earth Observations (GEO)***
The Group on Earth Observations is coordinating efforts to build a *Global Earth Observation System of Systems*, or GEOSS. GEO was launched in response to calls for action by the 2002 World Summit on Sustainable Development and by the G8 (Group of Eight) leading industrialized countries. These high-level meetings recognized that international collaboration is essential for exploiting the growing potential of Earth observations to support decision making in an increasingly complex and environmentally stressed world.
GEO is a voluntary partnership of governments and international organizations. It provides a framework within which these partners can develop new projects and coordinate their strategies and investments. As of March 2009, GEO's Members include 77 Governments and the European Commission. In addition, 56 intergovernmental, international, and regional organizations with a mandate in Earth observation or related issues have been recognized as Participating Organizations.
GEO is constructing the *Global Earth Observation System of Systems (GEOSS)* on the basis of a 10-Year Implementation Plan for the period 2005 to 2015. The Plan defines a vision statement for GEOSS, its purpose and scope, expected benefits, and the nine 'Societal Benefit Areas' of disasters, health, energy, climate, water, weather, ecosystems, agriculture and biodiversity.

***GRUAN (GCOS Reference Upper-Air Network)***
The GRUAN, a network for atmospheric reference observations, will form the high quality climate reference sites needed for many applications. This Network is required to provide the foundation for long-term datasets that can be used to reliably monitor and detect emerging signals of global and regional climate change. GRUAN is outlined in the *GCOS IP*, the Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC.

***GTOS***
GTOS is a programme for observations, modelling, and analysis of terrestrial ecosystems to support sustainable development. GTOS facilitates access to information on terrestrial ecosystems so that researchers and policy makers can detect and manage global and regional environmental change. The specific aim of GTOS is to improve the quality and coverage of terrestrial data, to integrate it into a worldwide base and to facilitate its access by scientists, policy makers and the public. GTOS has two sister observing systems, the *Global Climate Observing System (GCOS)*, and the *Global Oceanic Observing System (GOOS)*. Each system is part of the larger plan to provide comprehensive, global data on the biophysical environment, ecosystem processes and the socio-economic forces that influence them. This knowledge base is a prerequisite for effective planetary management.

***Hydrosphere***
The component of the *climate system* comprising liquid surface and subterranean water, such as oceans, seas, rivers, fresh water lakes, underground water, etc.

***ICOS (Integrated Carbon Observing System)***
An ESFRI research infrastructure to decipher the greenhouse gas balance of Europe and adjacent regions. The mission is:
- To provide the long-term observations required to understand the present state and predict future behavior of the global carbon cycle and greenhouse gas emissions.
- To monitor and assess the effectiveness of carbon sequestration and/or greenhouse gases emission reduction activities on global atmospheric composition levels, including attribution of sources and sinks by region and sector.

ICOS fulfils the monitoring obligations of Europe under the *United Nations Framework Convention on Climate Change (UNFCCC)*.

***Integrated Global Observing Strategy (IGOS)***
IGOS seeks to provide a comprehensive framework to harmonize the common interests of the major space-based and in-situ systems for global observation of the Earth. It is being developed as an over-arching strategy for conducting observations relating to climate and *atmosphere*, oceans and coasts, the land surface and the Earth's interior. IGOS strives to build upon the strategies of existing international global observing programmes, and upon current achievements. It seeks to improve observing capacity and deliver observations in a cost-effective and timely fashion. Additional efforts will be directed to those areas where satisfactory international arrangements and structures do not currently exist.

***Intergovernmental Oceanographic Commission (IOC)***
The IOC was created in 1960 to promote international cooperation and coordinate programmes in research, sustainable development, protection of the marine environment, capacity-building for improved management, and decision-making. It assists developing countries in strengthening their institutions to obtain self-driven sustainability in marine sciences. On a regional level, it is coordinating the development of tsunami early warning and mitigation systems in the Pacific, the Indian Ocean, the North-eastern Atlantic and the Mediterranean, and the Caribbean. It also facilitates interagency coordination through the UN-Oceans mechanism and works with the *United Nations Environment Programme (UNEP)* in establishing a process for global reporting and assessment of the state of the marine environment. Through the *Global Ocean Observing System (GOOS)*—the ocean component of the *Global Climate Observing System (GCOS)*—the IOC helps improve operational oceanography, weather and climate forecasts and monitoring and support the sustained observing needs of the *UN Framework Convention on Climate Change (UNFCCC)*.

***Intergovernmental Panel on Climate Change (IPCC)***
The IPCC was established to provide the decision-makers and others interested in climate change with an objective source of information about climate change. The IPCC does not conduct any research nor does it monitor climate related data or parameters. Its role is to assess on a comprehensive, objective, open and transparent basis the latest scientific, technical and socio-economic literature produced worldwide relevant to the understanding of the risk of human-induced climate change, its observed and projected impacts and options for adaptation and mitigation. IPCC reports should be neutral with respect to policy, although they need to deal objectively with policy relevant scientific, technical and socio economic factors. They should be of high scientific and technical standards, and aim to reflect a range of views, expertise and wide geographical coverage.
The IPCC is a scientific intergovernmental body set up by the *World Meteorological Organization (WMO)* and by the *United Nations Environment Programme (UNEP)*. Its constituency is made of :
- The governments: the IPCC is open to all member countries of WMO and UNEP. Governments of participate in plenary Sessions of the IPCC where main decisions about the IPCC workprogramme are taken and reports are accepted, adopted and approved. They also participate the review of IPCC Reports.

- The scientists: hundreds of scientists all over the world contribute to the work of the IPCC as authors, contributors and reviewers.
- The people: as United Nations body, the IPCC work aims at the promotion of the United Nations human development goals.

***International Council for Science (ICSU)***
The International Council for Science (ICSU) is a non-governmental organization representing a global membership that includes both national scientific bodies (116 members) and international scientific unions (30 members).
Through this extensive international network, ICSU provides a forum for discussion of issues relevant to policy for international science and the importance of international science for policy issues and undertakes the following core activities:

- Planning and coordinating interdisciplinary research to address major issues of relevance in both science and society;
- Actively advocating for freedom in the conduct of science, promoting equitable access to scientific data and information, and facilitating science education and capacity building;
- Acting as a focus for the exchange of ideas, the communication of scientific information and the development of scientific standards;
- Supporting in excess of 600 scientific conferences, congresses and symposia per year all around the world, as well as the production of a wide range of newsletters, handbooks, learned journals and proceedings.

***Kyoto Protocol***
The Kyoto Protocol to the *United Nations Framework Convention on Climate Change* (UNFCCC) was adopted in 1997 in Kyoto, Japan, at the Third Session of the *Conference of the Parties (COP)* to the UNFCCC. It contains legally binding commitments, in addition to those included in the UNFCCC. Countries included in Annex B of the Protocol (most Organisation for Economic Cooperation and Development countries and countries with economies in transition) agreed to reduce their *anthropogenic greenhouse gas* emissions (*carbon dioxide*, methane, nitrous oxide, hydrofl uorocarbons, perfl uorocarbons, and sulphur hexafl uoride) by at least 5% below 1990 levels in the commitment period 2008 to 2012. The Kyoto Protocol entered into force on 16 February 2005.

***Land use and Land use change***
*Land use* refers to the total of arrangements, activities and inputs undertaken in a certain land cover type (a set of human actions). The term land use is also used in the sense of the social and economic purposes for which land is managed (e.g., grazing, timber extraction and conservation). *Land use change* refers to a change in the use or management of land by humans, which may lead to a change in land cover. Land cover and land use change may have an impact on the surface *albedo*, evapotranspiration, sources and sinks of *greenhouse gases*, or other properties of the *climate system* and may thus have a radiative forcing and/or other impacts on *climate*, locally or globally. See also the IPCC Report on Land Use, Land-Use Change, and Forestry (IPCC, 2000).

***Lithosphere***
The upper layer of the solid Earth, both continental and oceanic, which comprises all crustal rocks and the cold, mainly elastic part of the uppermost mantle. Volcanic activity, although part of the lithosphere, is not considered as part of the *climate system*, but acts as an external forcing factor.

***Montreal Protocol***
The Montreal Protocol on Substances that Deplete the Ozone Layer was adopted in Montreal in 1987, and subsequently adjusted and amended in London (1990), Copenhagen (1992), Vienna (1995), Montreal (1997) and Beijing (1999). It controls the consumption and production of chlorine- and brominecontaining chemicals that destroy stratospheric *ozone*, such as chlorofluorocarbons, methyl chloroform, carbon tetrachloride and many others.

***OMI***
The Ozone Monitoring Instrument (OMI) is a contribution of the Netherlands' Agency for Aerospace Programs (NIVR) in collaboration with the Netherlands Meteorological Institute KNMI and the Finnish Meteorological Institute (FMI) to a NASA satellite mission. It monitors total *ozone* and other atmospheric parameters related to *ozone* chemistry and *climate*. OMI is in orbit since July 2004 and delivers daily measurements.

***Ozone***
Ozone, the triatomic form of oxygen (O3), is a gaseous atmospheric constituent. In the *troposphere*, it is created both naturally and by photochemical reactions involving gases resulting from human activities (smog). Tropospheric ozone acts as a *greenhouse gas*. In the *stratosphere*, it is created by the interaction between solar ultraviolet radiation and molecular oxygen (O2). Stratospheric ozone plays a dominant role in the stratospheric radiative balance. Its concentration is highest in the ozone layer.

***Stratosphere***
The highly stratified region of the *atmosphere* above the *troposphere* extending from about 10 km (ranging from 9 km at high latitudes to 16 km in the tropics on average) to about 50 km altitude.

***TROPOMI***
TROPOMI (Tropospheric Ozone-Monitoring Instrument) is a joint development of KNMI, SRON, Dutch Space, TNO and the Netherlands Agency for Aerospace Programmes (NIVR) which will play a key role in future climate research and air quality measurements.

***Troposphere***
The lowest part of the *atmosphere*, from the surface to about 10 km in altitude at mid-latitudes (ranging from 9 km at high latitudes to 16 km in the tropics on average), where clouds and weather phenomena occur. In the troposphere, temperatures generally decrease with height.

***United Nations Environment Programme (UNEP)***
UNEP is the United Nations system’s designated entity for addressing environmental issues at the global and regional level. Its mandate is to coordinate the development of environmental policy consensus by keeping the global environment under review and bringing emerging issues to the attention of governments and the international community for action.

***United Nations Framework Convention on Climate Change (UNFCCC)***
The Convention was adopted on 9 May 1992 in New York and signed at the 1992 Earth Summit in Rio de Janeiro by more than 150 countries and the European Community. Its ultimate objective is the 'stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system'. It contains commitments for all Parties. Under the Convention, Parties included in Annex I (all OECD countries and countries with economies in transition) aim to return *greenhouse gas* emissions not controlled by the *Montreal Protocol* to 1990 levels by the year 2000. The convention entered in force in March 1994. See *Kyoto Protocol*.

***World Climate Programme (WCP)***
The World Climate Programme of the *World Meteorological Organisation (WMO)* is an authoritative international scientific programme whose goals are to improve understanding of the climate system and to apply that understanding for the benefit of societies coping with climate variability and change. The World Climate Programme was established following the staging of the First World Climate Conference in Geneva, Switzerland in February 1979.

***World Meteorological Organisation (WMO)***
The World Meteorological Organization is a specialized agency of the United Nations. It is the UN system's authoritative voice on the state and behaviour of the Earth's atmosphere, its interaction with the oceans, the climate it produces and the resulting distribution of water resources. WMO has a membership of 188 Member States and Territories (since 24 January

2007). It originated from the International Meteorological Organization (IMO), which was founded in 1873. Established in 1950, WMO became the specialized agency of the United Nations in 1951 for meteorology (weather and climate), operational hydrology and related geophysical sciences.

# Annex 1 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 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.

*Furthermore, 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.

# Annex 2 CEOS, GEOSS, GMES and IGOS

CEOS
Established in 1984, the 'Committee on Earth Observation Satellites' (CEOS, http://www.ceos.org/) coordinates civil space-borne observations of the Earth. Participating agencies strive to enhance international coordination and data exchange and to optimize societal benefit. Currently 28 space agencies along with 20 other national and international organizations participate in CEOS planning and activities.

The 'Global Earth Observation System of Systems' (GEOSS, http://www.epa.gov/geoss/) is envisioned as a large national and international cooperative effort to bring together existing and new hardware and software, making it all compatible in order to supply data and information. In February 2005 the GEOSS 10 year Implementation Plan was approved. However, the funding of this GEOSS implementation plan depends on national or supra-national (e.g. EU) commitments to take long-term responsibility for operational costs of parts of the Systems.

The 'Global Monitoring for Environment and Security' (GMES, http://www.gmes.info/) (http://ec.europa.eu/kopernikus/index_en.htm), a joint initiative of European Commission and European Space Agency, represents a concerted effort to bring data and information providers together with users, so they can better understand each other and make environmental and security-related information available to the people who need it through enhanced or new operational services. In its final operational phase GMES will again rely on national contributions; it does not replace existing observational networks. GMES is considered the European contribution to GEOSS. The scope of GEOSS and GMES is even wider than climate. As for climate, the GCOS IP is seen as guiding for the strategy of GMES.

The 'Integrated Global Observing Strategy' (IGOS, http://www.igospartners.org/) seeks to provide a comprehensive framework to harmonize the common interests of the major space-based and in-situ systems for global observation of the Earth. Monitoring strategies are established for the carbon cycle, ocean, water cycle and atmospheric chemistry. Strategies for more theme's are in preparation.

# Annex 3 Climate monitoring activities in Europe

In France the GCOS coordinator has compiled a document with the main information on the four networks that contribute to GCOS (atmosphere and chemical composition, ocean, terrestrial and space component) that complies with the new Reporting Guidelines. Also a short narrative paragraph was written to consider (i) the achieving and access of the data collected, (ii) the duration of the funding of these observation systems, (iii) the link of these observations with research programs and (iv) the insertion of these data in a reanalysis program. These considerations may help to comply with the GCOS Implementation Plan, for which the spatial component has given a diligent and precise answer. For the long term funding the Observatories for the Research on Environment (ORE) is an adequate structure. That is the case for the observation of mountain glaciers (GLACIO-CLIM Observatory) and for atmospheric composition (RAMCES Observatory).

Germany established a German GCOS Secretariat at the German Meteorological Service (Deutscher Wetterdienst, DWD) as early as 1993, and since then contributed through different means to the development of the international GCOS programme. At national level a GCOS German Coordinator and a German GCOS Focal Point are established at DWD. The German GCOS Programme is a virtual programme that comprises all climate observing components and data centres relevant to GCOS. The implementation of the GCOS Implementation Plan is being considered by relevant agencies and progress has been reported to the GCOS Secretariat. GCOS activities at national level are closely coordinated with the German GEO (Group on Earth Observations) working group.

Ireland established a GCOS project to assess national contributions to GCOS in accordance with the guidelines established in the GCOS implementation plan. The project was lead by the Environmental Protection Agency, Met Eireann (meteorological organisation) and the Marine Institute. Following a consultation and assessment process, which involved meetings with key groups involved in provision of relevant observations, a report on Ireland's contribution to GCOS was published. This can be downloaded from www.epa.ie. Ireland is now in the process of addressing issues raised in this report.

In Portugal GCOS activities are supported not only by the Meteorological Institute (IM, state authority responsible for meteorology and climate commitments, providing continuity of scientific and technical activities relating to climate observations, which have been carried out since 1856), but also by other State Laboratories and Agencies, such as the Portuguese Water Institute (INAG, lakes, rivers and precipitation gauges), the Hydrographic Institute (IH, ocean, coastal zones and estuarine regions) and the Agency for the Environment (APA, air quality). As climate monitoring is a multidisciplinary activity, the Meteorological Institute is working on the implementation of a plan that aims at the development of a better national coordination and planning of climate monitoring activities.

In Sweden the Swedish Meteorological and Hydrological Institute (SMHI) has a responsibility and clear commitments towards authorities to cover around 90% of the climate networks. However, with regard to 'chemical' networks and some terrestrial ones there is an unclear situation. It is planned to make a survey of what is in operation and then make a plan to establish sustained measurements. Sweden is also of the opinion that the development of GCOS networks has to be performed in international collaboration (European or Ra VI) in order to create a regionally harmonized network. In relation to (GMES) Sweden is of the opinion that this concept is also relevant for developing networks with the intention to optimize the blend of space and in situ measurements as well as meeting the needs on a European scale (for GCOS IP and its ECVs). Reanalysis is considered a supreme tool.

In Switzerland, the establishment of the Swiss GCOS Office enhanced dialog among the various institutions involved in climate observation and led to a well-received first inventory report on the national climate observing systems and their future prospects. The report subsequently helped leverage additional base funding by the national government for sustained

climate measurements and operation of international data centres (e.g. the World Glacier Monitoring Service WGMS at the University of Zurich).

In April 2005 the GCOS Regional Workshop for Eastern and Central Europe, co-sponsored by the German government, was held in Leipzig, Germany. More than 60 participants from 28 countries attended this meeting. See report WMO/TD No. 1283, July 2005. In a follow up meeting a Regional Action Plan for Eastern and Central Europe has been developed (December 2007, available on the GCOS Homepage:
http://www.wmo.int/pages/prog/gcos/documents/GCOS_ECE_RAP_Dec05.pdf). Progress so far has mainly been made with Project No. 9. 'Training in the Use of Satellite Data for Climate Monitoring Based on the Satellite Application Facility'.
The implementation of a regional coordination mechanism in Europe (EuroGCOS) proved to be difficult (Project 1). A letter of the German GCOS Office at DWD and the Swiss GCOS office in 2007 to all European GCOS focal points has not yet been answered. Only recently some activities within the GCOS Cooperation Mechanism started to improve the GCOS Surface Network in that region. In summary, the Regional Action Plan for Eastern and Central Europe still remains largely unimplemented.

The tenth GCOS regional workshop was held in Marrakech, Morocco from 22 to 24 November 2005 and involved the countries bordering the Mediterranean Sea (see report WMO/TD N° 1337). Participants at the workshop assessed climate observing networks and related programmes in the Mediterranean Basin and agreed on critical issues that should be addressed in a Regional GCOS Action Plan. That Action plan was subsequently defined at a follow-up meeting held in Tunis from 16 to 18 may 2006. It contains 16 projects aiming to integrate considerations of climate variability and change in that region, in relation with the development programmes. However, up to now, due to limited resources, these projects have not been developed, except for the Data Rescue theme. This has been developed under the MEDARE project (Mediterranean Data Rescue, www.omm.urv.cat/MEDARE). It has been considered during the International workshop on Rescue and Digitization of climatic records in the Mediterranean Basin (Tarragona, Spain, 28-30 Nov. 2007; report WMO TD N° 1432).

# Annex 4 Inventory of the Dutch contribution to GCOS (ground- and satellite based)

In order to trigger the implementation of all additional measurements identified in the GCOS IP and to guarantee the quality of the data, the IP lists over a hundred specific Actions to be undertaken in the period until 2014. Many of the proposed Actions are already underway, at the least as part of research activities. In this report we review the status of these Actions as far as relevant for the Netherlands. Contributions by the Institutes participating in this project are listed. In doing so we will follow the GCOS classification, i.e. Key Actions, Cross Cutting Actions and Atmospheric, Oceanic and Terrestrial Actions. Based on this inventory the needs for future actions in the Netherlands are identified.

## 1. Key Actions

### *1.1. National activities*

*Key Action 1*
Parties need, both individually and collectively, to commit to the full implementation of the global observing system for climate, sustained on the basis of a mix of high-quality satellite measurements, ground-based and airborne *in situ* and remote-sensing measurements, dedicated analysis infrastructure, and targeted capacity-building.

*Status*
The Netherlands is committed to the implementation of the observing system. The majority of the required systems is in place, funded by a mix of long term (service based) and short term (project based) commitments from various national and international sources. All institutes that participate in this WAB project contribute, and the aim of the project is to secure existing core facilities and to support realisation of additional measurements where needed and feasible.

*Key Action 2*
Parties need to provide support for an International Project Office to provide overall coordination, to monitor performance, to report regularly on implementation, to initiate corrective actions, and to oversee the GCOS Cooperation Mechanism.

*Status*
Financial support included in the Netherlands' contribution to WMO.

*Key Action 5*
Parties are requested to undertake national coordination and planning and produce national plans on their climate observing, archiving and analysis activities that address this Plan.

*Status*
At KNMI a Climate Monitoring Strategy was established early 2006. Climate monitoring was recognised as a key-activity, and various actions were identified. Realisation of the actions is at present frustrated because of planned reductions in budget and staff. In relation with other institutes involved in climate monitoring in the Netherlands, this WAB-project aims at national coordination and planning, and the development of a national plan. KNMI also established an archiving strategy.

*Key Action 6*
Parties are requested to submit information on their activities with respect to systematic observation of all ECVs as part of their national communications to the UNFCCC utilizing an updated Supplementary Reporting Format.

*Status*
Coordinated by the Ministry of VROM, the Netherlands submits regularly National Communications under the UNFCCC with an Annex on Systematic Observation, coordinated by KNMI, and contributes to improvements in the reporting format.

*Key Action 7*
Parties are requested to address the needs of least-developed countries, small island developing states and some countries with economies in transition for taking systematic climate observations by encouraging multilateral and bilateral technical cooperation programmes to support global observing systems for climate and by participating in the GCOS Cooperation Mechanism.

*Status*
KNMI participates in the GCOS Cooperation Mechanism. The Netherlands announced a contribution of 800 k€ in total for 4 years (2007-2010) to the GCOS Action Plans for Africa at CoP12 in Nairobi, generated by the Ministries of V&W and VROM, and called on other (EU) Parties to pay attention to this matter.
KNMI coordinates and supports (100 k€/y) the operation of a GAW and BSRN station at the Meteorological Service of Surinam in Paramaribo (see Key Action 15). The radiation measurements are being upgraded to BSRN standards.

### *1.2. General climate data aspects*

*Key Action 8*
Parties need to ensure that International Data Centres are established and/or strengthened for all ECVs.

*Status*
KNMI has been nominated to fulfil a Regional Climate Centre (ECC) function based on ECA&D (European Climate Assessment and Dataset) for 'classical' climatological networks in RAVI.
KNMI has established in cooperation with ESA a website (www.temis.nl) containing complete databases on satellite measurements of the ECV ozone.
IGRAC is hosted and staffed by TNO Built Environment and Geosciences and financially supported by the government of the Netherlands.
Global Groundwater Monitoring System (GGMS) of IGRAC will provide crucial data for the global groundwater change - climate change analyses.
Data acquired at the CESAR observatory, including ECVs, are all stored in the CESAR database.
GHG data collected by RIVM at Kollumerwaard are stored in WDCGG.
Discharge data collected by Rijkswaterstaat, including the ECVs, are stored in the GRDC database.
Land bound GHG emission data collected by various institutes (WUR, VU, ECN, TNO and RUG) are processed and stored in the CarboEurope flux database (http://gaia.agraria.unitus.it/database/). Similarly continuous atmospheric GHG concentration data are processed and archived through the. Both also are copied to the other topic data centres like CDIAC, etc.

*Key Action 10*
Parties need to ensure that their climate-observing activities which contribute to GCOS adhere to the GCMPs.

*Status*
Most ECV-observing activities adhere to the GCOS climate monitoring principles (GCMPs). The less operational observations (e.g. for research) adhere to the GCMPs as much as feasible. Inhomogeneities resulting from changes in technology and observing practices are kept to a minimum. More specifically:

- KNMI adheres to the GCMPs, as endorsed in the KNMI Climate Monitoring Strategy (see Key Action 5). A protocol is being developed to minimize discontinuities resulting from changes in measurement infrastructure, and to allow for the calculation of corrections in view of long-term climate records.
- Global Groundwater Monitoring System (GGMS) of IGRAC also adheres to GCMP, and those will be endorsed in the GGSM manual (that is under preparation).
- The Monitoring Programme of the National Water Systems done by Rijkswaterstaat adheres to the GCMP.
- ECN adheres to the GCMOs.

*Key Action 11*
International standards for meta-data for all ECVs need to be established and adopted by the Parties in creation and archiving of climate data records.

*Status*
KNMI adheres to ISO certified meta-data standards for the exchange of meteorological data.
KNMI contributes to the definition of standard names following the CF-convention. It leads the EU HYMN project where considerable effort is made to design uniform data and metadata for FTIR stations (FTIR=Fourier Transform Infrared Spectroscopy, measuring $CH_4$, $N_2O$, $CO_2$ etc.). It participates together with ECN and TNO in the EU GEOMON project where European surface atmospheric composition observations will be harmonised. KNMI also adheres to the standards for ozone soundings and total ozone observations from GAW/WOUDC.
TNO Built Environment and Geosciences adheres to the ISO meta-data standards for the exchange of groundwater level and groundwater quality data.
GGMS of IGRAC will be a network of networks, probably complying with various standards. IGRAC intends to harmonize these networks.
RIVM contributes GHG data to WDCGG. Participation in networks includes compliance with respective dataformats. Harmonisation is done at network level.
Rijkswaterstaat provides the data to the GRDC, complying with the meta-data standards.
ECN archives metadata.

### *1.3. Atmospheric Domain*

*Table 2. Existing atmospheric baseline networks and systems.*

| |
|---|
| • GCOS Surface Network (GSN).<br>• The atmospheric component of the composite surface ocean observation system including sea-level pressure (see Key Actions 17 and 18). GCOS Upper-Air Network (GUAN).<br>• Global Atmosphere Watch (GAW) global $CO_2$ network.<br>• MSU-like radiance satellite observations. |

*Key Action 12*
Parties need to: (a) ensure the implementation and full operation of the baseline networks and systems in accordance with the GCMPs, in order to specifically resolve reported problems, to ensure the exchange of these data with the international community, and to recover, homogenize and exchange historical records; (b) establish a high quality reference network of about 30 precision radiosonde stations and other collocated observations; and (c) exploit emerging new technology including the use of radio-occultation techniques and ground-based Global Positioning System (GPS) sensing of the total water column.

*Status*
a) KNMI Baseline Network Data are measured, freely available and exchanged (WMO Res 40). KNMI operates a dedicated programme on data rescue, homogenization and data exchange (HISKLIM).
b) KNMI is not involved.
c) KNMI estimates, at present primarily for weather forecasting applications, the GPS total water column on a routine basis for 35 stations in the Netherlands (incl. Cabauw). These data are archived at KNMI. See also 7.3.13.

KNMI is working on the upgrading of functional specifications of AWS, i.e. implementation of optical back scatter profile from LIDAR Based ceilometers, and on the introduction of humidity in temperature and wind profiles obtained via high frequent AMDAR observations (aircraft).
KNMI and CESAR (TU-Delft) participate in COST Action EG-CLIMET on the development of integrated ground-based remote sensing systems to provide key atmospheric variables.
CESAR includes a GPS system for observation of the water vapour column (TU-Delft). New lidar technologies to measure water vapour profiles are under development.

*Key Action 13*
Parties are urged to: (a) establish a reference network of precipitation stations on key islands and moored buoys around the globe and at high latitudes; (b) submit national precipitation data (preferably hourly data) to the International Data Centres; and (c) support the further refinement of satellite precipitation measurement techniques.

Status
a) KNMI is not involved.
b) KNMI national precipitation data are submitted to the Global Precipitation Climate Center (GPCC).
c) CESAR is involved in the validation programme of the Global Precipitation Mission.

*Key Action 14*
Parties need to: (a) ensure the continued operation of satellite measurements of the Earth radiation budget and solar irradiance (e.g., the NASA Earth Radiation Budget Experiment); and (b) support research to extend and improve current capabilities for monitoring clouds as a high priority.

*Status*
(b) KNMI contributes to the EUMETSAT Satellite Application Facility on Climate Monitoring, improving and validating cloud products from MSG. CESAR is involved in the definition of the future EarthCare mission, dedicated to clouds, aerosols and radiation, and the development of observation methodologies.

*Key Action 15*
Parties need to: (a) fully establish a baseline network for key greenhouse gases; (b) improve selected satellite observations of atmospheric constituents; and (c) extend existing networks to establish a global baseline network for atmospheric optical depth.

*Status*
a) KNMI coordinates the operation of a GAW station at the Meteorological Service of Surinam in Paramaribo. Ozone soundings, a Brewer ozone column measurement, a sun photo meter for aerosol optical depth measurements and several additional instruments are operated there. This station has recently been opened to (inter)national partners operating complementary instruments, such as FTIR, DOAS and lidar. For many of these observations Paramaribo is the only one or one of the few stations in the tropics or in South America included in the respective networks. Plans to expand the station to comply with GAW requirements are on hold.
KNMI also operates ozone soundings and a Brewer instrument in De Bilt.
It may be difficult to continue all these observations at De Bilt and Paramaribo due to reductions in KNMI personnel and funding.
RIVM operates a GAW station in Kollummerwaard for GHG. Operational lidar measurements of stratospheric ozone are done in Lauder, NZ.
CESAR is developing a comprehensive suite of observations that include ground based GHG concentrations and aerosols as well as their vertical distribution.
RUG-CIO monitors high precision GHG concentrations at Lutjewad station.
b) The Netherlands has built and currently operates in cooperation with NASA the satellite instrument OMI. OMI continues since 2004 the ozone time series of the TOMS instruments.

The Netherlands contributes to the development and distribution of good-quality measurements of the SCIAMACHY instrument on ESA ENVISAT.
One of CESAR's goals is to act as an anchor and validation station for current and upcoming satellite missions for climate research, so as to strengthen the quality and use of the satellite observations.
SRON develops algorithms for $CH_4$ and $CO_2$ profiling.

c) KNMI operates a BSRN station at the Cabauw Observatory and at Pararamaribo, Surinam. See also A 13.
RIVM participates in EARLINET for vertical profiles of aerosol optical properties, including optical depth.

### *1.4. Oceanic Domain*

*Table 3. Essential Ocean Satellite Systems*

- Sustained support for vector-wind (scatterometer), sea-ice, sea surface temperature (microwave and infra-red) and ocean-colour measurements.
- Continuous coverage from altimeters to provide high-precision and high-resolution sea-level measurements (1 high-precision and 2 lower-precision altimeters).

*Key Action 16*
Parties need to: (a) complete and sustain the initial oceanic observing system for climate; (b) designate and support national Agents for implementing this system; (c) establish effective partnerships between their ocean research and operational communities towards implementation; and (d) engage in timely, free and unrestricted data exchange.

*Status*

a) KNMI operates ~200 VOS (Voluntary Observing Ships) as part of the JCOMM-SOT. This number remained steady (between 180-200) for the last years. Of these 200 ships, 40 (and increasing) are registered as VOSClim ship.
KNMI is involved in EURO Argo, a proposal to achieve a sustained European Argo contribution. The intention is to deploy about 8 Argo floats per year.

d) VOS data are exchanged on a quarterly basis with other VOS operating countries under JCOMM-SOT agreements. In 2008 a publicly accessible website will offer the data from the Dutch VOS fleet at no costs.
Argo data are free.
Since 1999 NIOZ contributes to the annual reporting of the oceanic climate data, published in the ICES Report on Ocean Climate, published by the ICES Working Group on Ocean Hydrography.

*Key Action 17*
Parties need to ensure climate quality and continuity for essential ocean satellite observations.

*Status*
KNMI contributes to continuous observations of scatterometer wind over sea, the reprocessing of scatterometer observations and the development of a global 4D wind observation system.

*Key Action 18*
Parties need to provide global coverage of the surface network by implementing and sustaining: (a) the GCOS baseline network of tide gauges; (b) an enhanced drifting buoy array; (c) an enhanced Tropical Moored Buoy network; (d) an enhanced Voluntary Observing Ships Climatology (VOSClim) network; and (e) a globally-distributed reference mooring network.

*Status*

d) KNMI operates 40 VOSClim ships, including the NIOZ research vessel Pelagia NIOZ research vessel Pelagia.
e) The mooring arrays, maintained by NIOZ, are part of the Eulerian moorings coordinated by OceanSites.

*Key Action 19*

Parties need to provide global coverage of the sub-surface network by implementing and sustaining: (a) the Argo profiling float array; (b) the systematic sampling of the global ocean full-depth water column; (c) the Ship-of-Opportunity Expendable Bathythermograph (XBT) trans-oceanic sections; and (d) the Tropical Moored Buoy and reference mooring networks referred to in Key Action 18 above, as well as the satellite altimetry system.

*Status*

a) KNMI is involved in EURO Argo, a proposal to achieve a sustained European Argo contribution. The intention is to deploy about 8 Argo floats per year.
b) KNMI Argo floats contribute.
c) Since 1991 NIOZ is involved in the regular hydrographic survey of the former WOCE AR7E section between Ireland and Greenland. Observations involve full depth observations of temperature, salinity, oxygen and nutrients. On a more irregular basis observations of dissolved inorganic carbon are added.
d) Since 2003 NIOZ is involved in the deployment, recovery and maintenance of profiling CTD moorings in the central Irminger Sea. These moorings are part of the international OceanSITES programme of Eulerian ocean observatories.

### *1.5. Terrestrial Domain*

*Table 4. Priority terrestrial satellite products.*

| |
|---|
| • Daily global albedo from geostationary and polar orbiting satellites.<br>• LAI and fAPAR products to be made available as gridded products.<br>• Gridded fire and burnt area products through a single International Data Centre.<br>• Snow cover of both hemispheres.<br>• Digital elevation maps of the ice sheet surfaces and full glacier inventory from current spaceborne cryosphere missions.<br>• Specification and production of land-cover characterization data sets. |

*Key Action 20*

Parties are urged to support the operational continuation of the following priority terrestrial satellite-based products:

- Daily global albedo from geostationary and polar orbiting satellites.
- LAI and fAPAR products to be made available as gridded products.
- Gridded fire and burnt area products through a single International Data Centre.
- Snow cover of both hemispheres.
- Digital elevation maps of the ice sheet surfaces and full glacier inventory from current spaceborne cryosphere missions.
- Specification and production of land-cover characterization data sets.

*Status*

At national level land cover and land use change are monitored by WUR and compiled into the LGN database (www.lgn.nl).
VU University Amsterdam contributes to the development of the Global Fire Emissions Database (GFED).

*Key Action 21*
Parties are urged to develop a global network of at least 30 reference sites (collocated with atmospheric sites if possible) to monitor key biomes and to provide the observations required in the calibration and validation of satellite data.

*Status*

*Key Action 22*
Parties are urged to: (a) fill the identified gaps in the global networks for permafrost, glaciers, rivers and lakes; (b) provide support for the designated International Data Centres; and (c) submit current and historical data to the International Data Centres.

*Status*
a) Only the networks for Rivers applies to the Netherlands.
   1) There are no gaps for the Rivers Rhine and Meuse.
   2) Rijkswaterstaat supports the GRDC
   3) Rijkswaterstaat provides the river discharge data to GRDC

TNO Built Environment and Geosciences is a national focal point for all groundwater data in the Netherlands.
IGRAC is a designated International Data Centre that is in process of setting up a global groundwater monitoring network.

### *1.6. Availability of Climate Products*

*Key Action 23*
Parties are urged to adopt an internationally-coordinated approach to the development of integrated global climate products and to make them accessible to all Parties. As far as possible, these products should incorporate past data covering at least the last 30 years in order to serve as a reference for climate variability and change studies.

*Status*
As part of the EU-ENSEMBLES project, KNMI has developed high resolution gridded observational datasets of surface temperature and precipitation for climate model validation and impact analysis. KNMI also contributes information for Europe to the worldwide network of extremes studies that are based on historical station series (the European Climate Assessment & Dataset project).
KNMI is producing analyses end reanalyses of global atmospheric composition based on satellite observations (GOME, SCIAMACHY and OMI) and models, and makes these available on the internet.
KNMI participates in the Millennium project, aiming at climate reconstructions for Europe, and leads the workpackage on Instrumental Records AD 1700 to present.
TNO Built Environment and Geosciences provides analyses and measurements of groundwater level and quality covering more than the last 100 years at several sites.
Rijkwaterstaat is partner in the International Commission for the Hydrology of the Rhine (CHR). The CHR compiles meteo and hydrologic dataset for the Rhine basin and makes them available for research. The CHR analyses the available historical time series over last century.

*Key Action 24*
Parties are urged to give high priority to establishing a sustained capacity for global climate reanalysis, to develop improved methods for such reanalysis, and to ensure coordination and collaboration among centres conducting reanalyses.

*Status*
KNMI: see 23.

# 2. Over-Arching/Cross-Cutting Actions

## *2.1. National Planning and Reporting*

*Action C2*
Undertake national coordination and produce national plans for contributions to the global observing system for climate in the context of this Plan.

*Status*
This WAB Project aims at realising Action C2

*Action C4*
Report to the UNFCCC on systematic climate observations using an updated Supplementary Reporting Format and guidelines.

*Status*
See Key Action 6

## *2.2. Sustained Networks and Systems*

*Action C8*
Ensure all climate observing activities adhere to the GCMPs.

*Status*
The majority of the activities listed in this document adhere to GCMPs.

## *2.3. International Support*

*Action C9*
Support the implementation of the global observing system for climate in developing countries and countries with economies in transition.

*Status*
See Key Action 7.

## *2.4. Satellite Observations*

*Table 5. Variables largely dependent upon satellite observations.*

| Domain | Variables |
|---|---|
| **Atmospheric** (over land, sea and ice) | Precipitation, Earth radiation budget (including solar irradiance), Upper-air temperature (including MSU radiances), Wind speed and direction (especially over the oceans), Water vapour, Cloud properties, Ozone, Aerosol properties. |
| **Oceanic** | Sea-surface temperature, Sea level, Sea ice, Ocean colour (for biological activity). |
| **Terrestrial** | Snow cover, Glaciers and ice caps, Albedo, Land cover (including vegetation type), fAPAR, Fire disturbance. |

*Action C10*
Ensure continuity and over-lap of key satellite sensors; recording and archiving of all satellite meta-data; maintaining currently adopted data formats for all archived data; providing data service systems that ensure accessibility; undertaking reprocessing of all data relevant to climate for inclusion in integrated climate analyses and reanalyses.

*Status*

## *2.5. Integrated Climate Products*

*Action C11*
Prepare the data sets and meta-data, including historic data records, for climate analyses and reanalyses.

*Status*
KNMI is developing historical datasets of precipitation (daily sums, high-resolution and historical observations) in the framework of the national programme Investing in Knowledge Infrastructure (BSIK).
KNMI actively contributes to (future) reanalysis projects, by extending the reanalysis period (pushing the start date back in time), and by contributing to initiatives for higher resolution regional reanalysis for Europe (EUROGRID and READY projects).
KNMI provides daily ozone analyses and reanalyses based on assimilation of satellite observations from GOME, SCIAMACHY, OMI and GOME-2.
KNMI will become a WMO Regional Climate Centre (RCC) for RA VI on daily climate data and climate indices, based on the ECA&D dataset.
ECN archives are digitised.

## *2.6. Historical Data and Paleo-reconstructions*

*Table 6. ECVs targeted for special data archaeology efforts and the associated International Data Centres.*

| **ECVs** | **Data Archive** |
|---|---|
| Surface atmospheric variables | WDC Asheville |
| Oceanic variables | World Ocean Data Centres |
| **Sea-ice** (extent) | National Snow and Ice Data Center (NSIDC) |
| **River discharge** | Global Runoff Data Centre (GRDC) |
| **Lake level** (including freeze and break-up records) | Proposed GCOS lake data centre |
| Extent and mass balance of mountain **glaciers** and sub-polar **ice caps** | World Glacier Monitoring Service (WGMS) |
| **Biomass** | FAO's Forest Resources Assessment Project (FRA) |
| **Land cover** (and use) | Existing research networks |

*Action C14*
Collect, digitize and analyze the historical atmospheric, oceanic and terrestrial data records from the beginning of instrumental observations in a region and submit to International Data Centres.

*Status*
The KNMI project HISKLIM yields freely accessible large databases of historical Dutch meteorological observations, both land and marine based.
Rijkswaterstaat stores all the measurements in a central database called DONAR. This data can be accessed freely (www.waterbase.nl). Rijkwaterstaat has sent the historical discharge data to GRDC.
Groundwater related observations in the Netherlands are available in appropriate format at TNO Built Environment and Geosciences; these data are accessible to international data centres, including IGRAC.

*Action C15*
Undertake research initiatives to acquire high-resolution palaeo-climate data by extending spatial coverage into new regions, extending temporal coverage back in time and exploiting new sources.

*Status*
KNMI is involved in the 'Buisman' reconstruction of 1000 year temperature in the Low Countries based on documented data.
Paleoclimate reconstructions are carried out at several universities.
Paleo-oceanographic research in the Netherlands is carried out by universities and institutions for fundamental research.

*Action C16*
Improve synthesis of palaeo-climate and palaeo-environmental data on multidecadal to millennial timescales, including better chronologies for existing records, particularly from the tropics, Asia, the Southern Hemisphere and the Southern Ocean.

*Status*

### *2.7. Data Management*

*Action C19*
Ensure timely, efficient and quality-controlled flow of all ECV data to International Data Centres.

*Status*
KNMI meteorological data are freely exchanged according to all recommendations and standards.
KNMI provides quality controlled ozone soundings and Brewer ozone columns from Paramaribo and De Bilt to the WOUDC.
Groundwater related observations in the Netherlands are available in appropriate format at TNO Built Environment and Geosciences; these data are accessible to international data centres, including IGRAC.
CESAR observations are stored in CESAR database, which will be publicly accessible after agreement to the data protocol.
Rijkswaterstaat stores the measured data in DONAR, after the quality check it is freely accessible. The data is also sent to the GRDC.
Land bound GHG emission data are processed and stored in the CarboEurope flux database (http://gaia.agraria.unitus.it/database/), and continuous atmospheric GHG concentration data are processed and archived through the CarboEurope-IP database (Atmosphere component, URL: http://ce-atmosphere.lsce.ipsl.fr/database/index_database.html), with support from the ESF TTorch RNP (http://www.ttorch.org), chaired by ECN. Both also are copied to the other topic data centres like CDIAC, CarbonTracker, etc.
ECN measurements are available in the following databases: CarboEurope IP, CHIOTTO, CESAR, NOAA Globalview, GAW and WDCGGC.
NIOZ data are accessible via the website of the NIOZ Data Management Group. Project data (e.g. Clivar) are also submitted to the appropriate data centres.

*Action C20*
Ensure that data policies facilitate the exchange and archiving of all ECV data.

*Status*
A significant part of the data is freely available. The policy is to make all data freely available by 2012. More specifically:
CESAR observations are stored in CESAR database, which will be publicly accessible after agreement to the data protocol.
The data measured in the Monitoring Programme of the National Water Systems of Rijkswaterstaat is freely accessible, including the ECVs.

ECN climate data is freely accessible.
The NIOZ Data Management Group follows the policy to strife for easy overview and free access to marine and oceanographic data and data-products. Therefore it cooperates in the European SeaDataNet network.

*Action C21*
Develop modern distributed data services that can handle the increasing volumes of data and which can allow feedback to observing network management.

*Status*
IGRAC is developing a sophisticated web-based GGMS software application. DINO system is state of the art data (and information) storage and analyses system.
KNMI will become a WMO Regional Climate Centre (RCC) for RA VI on daily climate data and climate indices, based on the ECA&D dataset.
A National Oceanographic Data Commission performs the role of national oceanographic data centre. The data are distributed over data bases at different institutions, but will be accessible via a virtual data base at a single portal.
NIOZ cooperates nationally with other marine institutes in the NODCi project, and internationally in the European SeaDataNet project to ensure easy access and retrieval of distributed marine climate data, accessible via a single virtual data base.

## 3. Atmospheric Domain

### *3.1. Surface, General*

*Action A1*
Detailed analysis of causes of GSN faults, followed by full implementation of the GSN.

*Status*
KNMI operates GSN station De Bilt (06260).

*Action A2*
Obtain major progress in implementation and systematic operation of the full WWW/GOS RBSN in compliance with the GCMPs.

*Status*
KNMI operates all national RBSN surface stations, i.e. De Kooy (06235), Beek (06380), Schiphol (06240), Leeuwarden (06270), Twente (06290), Volkel )06375), and the North sea stations F3 (06239), K13 (06256) en EURO-platform (06321), in compliance with the GCMPs. De Kooy and Beek are also RBCN stations. Also, RBCN stations De Bilt (06260) and Vlissingen (06310) are operated.

*Action A3*
Apply the GCMPs to all surface climate networks.

*Status*
All ECV-observing activities adhere to the GCOS climate monitoring principles (GCMPs). Inhomogeneities resulting from changes in technology and observing practices are kept to a minimum. At KNMI a protocol is being developed to minimize discontinuities resulting from changes in measurement infrastructure, and to allow for the calculation of corrections in view of long-term climate records.

### *3.2. Surface, Air Pressure*

*Action A5*
Seek cooperation from organizations operating drifting buoy programmes to incorporate atmospheric pressure sensors.

*Status*
KNMI participates in DBCP and E-Surfmar.

### *3.3. Surface Precipitation*

*Action A6*
Submit precipitation data from national networks to the International Data Centres.

*Status*

*Action A8*
Develop and deploy precipitation-measuring instruments on the Ocean Reference Mooring Network.

*Status*

*Action A9*
Develop and implement improved methods for observing precipitation that take into account advances in technology and fulfil GCOS requirements.

*Status*
KNMI develops integrated in-situ measured and high frequent weather RADAR observation, providing both amount and intensity
CESAR has an active research program dedicated to the improvement of rainfall observations with radar.

### *3.4. Surface Wind Speed and Direction*

*Action A10*
Ensure availability of 3-hourly mean sea-level pressure and wind speed and direction data from GSN stations.

*Status*
These data are available.

### *3.5. Surface, Water Vapour*

*Action A12*
Submit water vapour data from national networks to the International Data Centres.

*Status*
The measurements of relative humidity (and of temperature) of the national network are submitted to the GTS.

### *3.6. Surface, Radiation Budget*

*Action A13*
Submit sunshine data from national networks to International Data Centres.

*Status*
At KNMI sunshine duration is derived from global radiation measurement. The algorithm used is tuned to represent Campbell Stokes measurements. The tuning is expected to be changed to represent the WMO criteria.
Monthly sums for five core stations are submitted to the GTS.

*Action A14*
Expand the BSRN network to obtain global coverage and establish formal analysis infrastructure.

*Status*
KNMI/CESAR operates BSRN stations at Cabauw and Paramaribo, Surinam, and complies with the BSRN standards for radiation measurements.

### *3.7. Upper-air, General*

*Action A15*
Complete implementation of GUAN, including infrastructure and data management.

*Status*
There is no GUAN station in the Netherlands.

*Action A16*
Specify and implement a Reference Network of high-altitude, high-quality radiosondes, including operational requirements and data management, archiving and analysis.

*Status*
The Netherlands is not involved in the development of a Reference Network.
KNMI and CESAR are active in a related field: the Cabauw site is proposed to be part of GRUAN.

*Action A17*
Improve implementation of the WWW/GOS radiosonde network compatible with the GCMPs and in full compliance with coding conventions.

*Status*
KNMI operates a regular radiosonde station (2 flights per day) at De Bilt (06260), in full compliance with the GCMPs and coding conventions.
.
*Action A18*
Submit meta-data records and inter-comparisons for radiosonde observations to International Data Centres.

*Status*
Meta-data records are submitted. There are no specific intercomparisosns.

### *3.8. Upper-air, Cloud Properties*

*Action A21*
Developing a network of ground-based Global Positional System (GPS) receivers for measuring water vapour (A21).

*Status*
A network of 35 stations is in operation since 2005. The data are archived and available.

*Action A23*
Research to improve cloud property observations in three dimensions.

*Status*
CESAR has an extensive observational program to document the microphysical and geometrical properties of clouds, including the effect on radiation.

### *3.9. Atmospheric Composition, General*

*Action A25*
Establish a plan for and implement a consistent surface- and satellite-based global observing system for the atmospheric composition ECVs, based on common standards and procedures, and encourage data submission to WDCs.

*Status*
RIVM contributes to such initiatives. In particular, ground based data are used to improve consistency of satellite data.
CESAR contributes to such initiatives. In particular, ground based data are used to improve consistency of satellite data.

*Action A26*
Develop and implement a comprehensive plan to observe the vertical profiles of GHGs, ozone and aerosols utilizing commercial and research aircraft, pilotless aircraft, balloon systems, kites, ground-based lidars and satellites.

*Status*
RIVM is actively involved in observing vertical profiles of aerosols, water vapour and ozone using state of the art ground based lidar systems at Bilthoven, CESAR and Lauder (New Zealand). Using these instruments a comprehensive measurement plan is carried out. Collaboration in Networks is secured for all observations (EARLINET, NDACC and GALION). RIVM is also actively involved in satellite validation for aerosols and ozone, as well as the definition of new satellite missions for ECVs.
KNMI performs ozone soundings in De Bilt and Paramaribo, and it provides support to the CARIBIC project.

### *3.10. Atmospheric Composition, Carbon Dioxide and Methane and other GHGs*

*Action A27*
Establish the GCOS/GAW baseline network for $CO_2$ and $CH_4$, and fill the gaps.

*Status*
RIVM contributes GHG data collected at Kollummerwaard to WDCGG.
ECN will contribute the greenhouse gas observations at Cabauw to WDCGG, the CESAR database and the CarboEurope-IP and Geomon databases.

*Action A29*
Complete an International Halocarbon Inter-comparison Study, linking measurement scales for CFCs of major networks as an initial step in an ongoing quality assurance programme.

*Status*
ECN will start Halocarbon observations at Cabauw in 2008, linked to the concentration scales of the ALE-GAGE international network.

### *3.11. Atmospheric Composition, Ozone*

*Action A30*
Define and implement the Baseline Ozone Observing Network for balloon vertical profiles and total column ozone and initiate implementation.

*Status*
KNMI performs (at least) weekly ozone soundings in De Bilt and Paramaribo, Surinam.

### *3.12. Atmospheric Composition, Aerosol Properties*

*Action A31*
Develop and implement a coordinated strategy to monitor and analyze the distribution of aerosols and aerosol properties.

*Status*
RIVM contributes through advanced observations of vertical aerosol profiles by lidar. Also, RIVM is involved in further development of networks for such observations through improvement of quality and providing guidelines that will facilitate network expansion (EARLINET, GALION).
ECN contributes with aerosol composition observations using the MARGA aerosol analyser at Cabauw. TNO contributes through the EUSAAR I3 project with observations of aerosol and aerosol optical properties.

### *3.13. Atmospheric Domain, Challenges*

For some ECVs there remain outstanding issues requiring research, including:
- Representation of the 3D character of clouds.
- Global monitoring of the composition and distribution of aerosols.
- Global monitoring of water vapour especially at the surface and in the upper troposphere and lower stratosphere.
- Estimation of the spatial representation of surface wind speed and direction.
- Unbiased estimation of high temporal resolution precipitation amount and type, especially over the oceans and at high latitudes.
- Synthesis of quality-assured greenhouse gas and ozone data into a format suitable for reanalysis and inverse modelling.
- Development of consistent unbiased homogeneous reanalysis products for all ECVs.

To this GCOS list we can add:
- Representation of micro-physical properties of clouds.
- Representation of cloud-aerosol-radiation interaction.
- Development of GCOS Reference Upper-Air Network (GRUAN).
- KNMI and CESAR are active in these fields; the Cabauw site is proposed to be part of GRUAN.
- Build higher resolution network to cover the large variability of emissions of GHG from the Dutch land surface (ICOS-NL).

Further research is required to extend the range of ECVs to include other variables, such as soil moisture, and important reactive atmospheric constituents.

CESAR has the ambition to focus on reducing the uncertainty in climate models due to clouds-aerosols-radiation interaction mechanisms.

### *3.14. Atmospheric Domain, Specific five-year milestones include:*

- Establish centres to monitor and analyze all ECV data.
- Attain a fully operational GSN, including all relevant surface ECVs.
- Complete the archive of GSN historical data in the WDC.
- Attain a fully operational GUAN.
- Establish a GUAN-based reference network of high-quality, high-altitude (5 hPa) radiosondes.
- Extend BSRN to global coverage and consolidate data monitoring and analysis functions.
- Ensure atmospheric surface pressure is reported from all drifting buoys.
- Establish a homogeneous record of active and passive microwave observations to support the monitoring of precipitation and water vapour.
- Establish a global ground-based GPS total-column water monitoring system.
- Ensure sustained homogeneous ERB satellite observations.
- Establish a baseline network for key greenhouse gases based on WMO GAW.
- Consolidate coordinated long-term programmes for reanalysis.

CESAR has the ambition to set up a reference centre to monitor and analyze atmospheric ECVs.
KNMI and CESAR are planning the reprocessing of raw GPS data for climate applications on a routine basis.

## 4. Oceanic Domain

### *4.1. General*

*Action O3*
Promote and facilitate research and development (new improved technologies in particular), in support of the global ocean observing system for climate.

*Status*

### *4.2. Sea-surface, General*

*Action O6*
Improve meta-data acquisition and management for a selected, expanding subset of VOS (VOSClim) together with improved measurement systems.

*Status*
At KNMI data entry software (TurboWin) for VOS and VOSClim is developed and maintained. The software is kept up-to-date with the latest data and meta-data requirements according to JCOMM's SOT and ETMC advices. TurboWin complies completely with the latest VOSClim requirements.

*Action O8*
Complete and maintain a globally-distributed network of ~29 surface moorings as part of a Surface Reference Mooring Network. Including specific ECVs nutrients and tracers.

*Status*

### *4.3. Sea-surface, Temperature*

*Action O10*
Obtain global coverage, via an enhanced drifting buoy array (total array of 1250 drifting buoys equipped with atmospheric pressure sensors as well as ocean temperature sensors), a complete Tropical Moored Buoy network (~120 moorings) and the improved VOSClim ship fleet.

*Status*
At this moment (end 2007) KNMI recruited 30 VOSClim ships from the regular VOS fleet. The intention is to increase the number of VOSClim participants to at least 50 towards the end of 2008.

### *4.4. Sea-surface, Sea Level*

*Action O11*
Implement the GCOS subset of the GLOSS Core Network, with geocentrically-located high-accuracy gauges. Ensure real-time exchange and archiving of data. Ensure historical sea level records are recovered and exchanged.

*Status*

*Action O13*
Ensure high-frequency sea-level observations are available for all coastal regions (including historical records) and submitted to the international archive.

*Status*
Rijkswaterstaat is sharing sea level data of 5 coastal stations in the Dutch Coastal waters through EuroGOOS-NOOS. Historical SL-data is available through SeaDataNet on Pan-European scale.

*Action O14*
Include sea-level objectives in the capacity-building programmes of GOOS, JCOMM, WMO, other related bodies, and the system improvement programme of GCOS.

*Status*

### *4.5. Sea-surface, Salinity*

*Action O15*
Develop a robust programme to observe sea-surface salinity to include VOS ships, research ships, reference moorings, and drifting buoys.

*Status*
Rijkswaterstaat is maintaining an automatic monitoring programme (Ferrybox) on a freight Coaster-line IJmuiden-Bergen (N) and runs a undulating fish and Ferrybox monitoring programme on their survey vessel (Zirfea) during weekly cruises (T, S, DO, Nutrients, light, TSM, phytoplankton).

### *4.6. Sea-surface, Sea State*

*Action O19*
Implement a wave measurement component as part of the Surface Reference Mooring Network.

*Status*

### *4.7. Sea-surface, Sea Ice*

*Action O23*
Ensure sustained satellite (microwave, SAR, visible and IR) operations: improve the *in situ* observations from sea-ice buoys, visual surveys (SOOP and Aircraft) and ULS. Implement observations in the Arctic and Antarctic.

*Status*

### *4.8. Sub-surface, General*

*Action O25*
Perform the systematic global full-depth water column sampling of 30 sections repeated every 10 years. Including specific ECVs temperature, salinity, carbon and tracers.

*Status*
Since 2000 NIOZ performs a bi-annual hydrographic survey of the WOCE AR7E section between Ireland and Greenland, including temperature, salinity, dissolved oxygen, nutrients, and total dissolved carbon.

*Action O26*
Perform the 41 Ship-of-Opportunity XBT/XCTD trans-oceanic sections. Including specific ECVs temperature and salinity.

*Status*

*Action O27*
Deploy the planned 3000 Argo float array, reseeding the array with replacement floats to fill gaps and maintain density (estimated 800 per year). Including specific ECVs temperature, salinity and currents.

*Status*
KNMI contributes to the international ARGO network with 14 systems, and intends to increase this contribution. KNMI is national focal point for ARGO and for the Data Buoy Cooperation Panel.

*Action O28*
Maintain the current Tropical Moored Buoy arrays, expand the Atlantic array, and develop the Indian array – total array projected as ~120 moorings. Including specific ECVs temperature, salinity and currents.

*Status*
The NIOZ Eulerian moorings in the Mozambique Channel are part of the developing Indian Ocean array.

*Action O29*
Develop and implement a pilot project designed to assemble the *in situ* and satellite altimetry data into a composite data set and to assimilate the data into models and to create climate variability and trend analyses. Including specific ECVs temperature, salinity and currents.

*Status*

*Action O30*
Work with research programmes to develop autonomous capability for biogeochemical and ecological ECVs. Including specific ECVs currents and phytoplankton.

*Status*

*Action O31*
Develop and deploy in a reference network robust autonomous *in situ* instrumentation for biogeochemical and ecosystem variables. Including specific ECVs carbon, nutrients, currents and phytoplankton.

*Status*

### *4.9. Data Management*

*Action O36*
Plan and implement a system of regional, specialized and global data and analysis centres.

*Status*
At KNMI the HISKLIM project overarches different smaller projects in which data rescue is the main issue. Data from mainly Dutch, land based stations are keyed or scanned and made available to a larger audience. Special software is developed at KNMI to extract data from graphs (pluviographs, barographs, wind registrations, thermographs, etc.). In collaboration with NCDC (Asheville, NC, USA), several Dutch ship logbooks (1854-1880) will be keyed.

*Action O37*
Support data rescue projects**.**

*Status*
At KNMI the HISKLIM project overarches different smaller projects in which data rescue is the main issue. Data from mainly Dutch, land based stations are keyed or scanned and made available to a larger audience. Special software is developed at KNMI to extract data from graphs (pluviographs, barographs, wind registrations, thermographs, etc.). In collaboration with NCDC (Asheville, NC, USA), several Dutch ship logbooks (1854-1880) will be keyed.

*Action O38*
Develop enhanced and more cost-effective telecommunication capabilities, including two-way communications for dynamic control of systems, instruments and sensors**.**

*Status*

### *4.10. Integrated Global Analysis Products*

*Action O40*
Develop plans and pilot projects for the production of global products based on data assimilation into models. All possible ECVs**.**

*Status*

*Action O41*
Undertake pilot projects of reanalysis of ocean data.

*Status*

### *4.11. Oceanic Domain, Challenges*

Ocean climate product development will advance rapidly if adequately supported. Collaboration with ongoing global research programmes (e.g., WCRP, IGBP) and fishery/ecosystem programmes must be fostered. The following list is meant to be illustrative of areas requiring research and technology development:

- Satellite observations with higher resolution and accuracy and more spectral bands from geostationary satellites; improved capability for ocean colour observations in coastal and turbid waters; improved interpretation of sea-ice data from satellites; satellite measurements of salinity.
- Observing system evaluation and design, including improvements in air-sea flux parameterizations.
- Improvements in ocean platforms, including increased capabilities for Argo floats; improved 'Gliders' technology43 and mooring technology.
- New development in ocean sensors and systems, including improved bio-fouling protection, autonomous water sampling systems, optical and acoustic systems, airborne variable sensors, and two-way, low-cost, low-power telecommunications.
- New and improved capability to measure biogeochemical variables, nutrients, and dissolved oxygen and carbon dioxide, as well as to identify organisms.
- Improved instruments, including near-surface current meters, in-water radiometers, sensors for air-sea interface variables and turbulent fluxes, and VOS sensor systems.

### *4.12. Oceanic Domain, Specific five-year milestones include:*

- Completion of the initial oceanic climate observing system, including the composite surface networks and satellite systems (Table 14) and the composite sub-surface networks (Table 15).
- The designation and/or establishment of national and regional agents of implementation with responsibility to sustain the surface and sub-surface networks and satellite systems.
- Develop and implement an ocean data management and information system with agreed meta-data standards, effective quality control and data set assembly and maintenance, and efficient data transport systems.
- Obtain timely, free and unrestricted data exchange between Parties and International Data Centres for oceanic ECVs, including historical data.
- Complete a first set of global ocean climate reanalyses with uncertainty estimates and including the preparation of needed input data sets.
- Establish partnerships between the ocean and climate research and operational communities to provide scientific oversight and to recommend evolution needs of the observing system.
- Support development of new and/or more efficient technologies and observing methods for oceanic ECVs, including ecosystem and biogeochemical variables.
- Designation and/or establishment of Agents of Implementation to generate routinely ocean climate information products.
- Establish an Arctic GOOS Regional Alliance to plan, coordinate, implement and evaluate Arctic Ocean and sea-ice observing networks and systems.

# 5. Terrestrial Domain

## *5.1. General*

*Action T3*
Develop a global network of some 30 sites based on a progressive evolution of existing reference sites to monitor key biomes and provide the observations required for the calibration and validation of satellite data.

*Status*
(One of the) Sites covered by the ICOS infrastructure (see 4.2) could be part of this network, being very suited because of a long term monitoring history. International coordination to become part of this reference site network needs still to be initiated.

## *5.2. River Discharge*

*Action T4*
Confirm locations of GTN-R sites, determine operational status of gauges at all GTN-R sites, ensure that the GRDC receive daily river discharge data from all 380 sites within one year of their observation (including measurement and data transmission technology used).

*Status*
The Dutch GTN-R station in Borgharen on the river Meuse. The daily data is provided to the GRDC afterward on a yearly basis. Also the data for the station Lobith (River Rhine) is provided on the same basis.

## *5.3. Lake Level/Area*

*Action T6*
Submit weekly/monthly lake level/area data for the 150 GTN-L lakes to the International Data Centre; submission of weekly/monthly altimeter-derived lake levels by Space Agencies to the International Data Centre.

*Status*
In the Netherlands there is no GTN-L station.

*Action T7*
Submit weekly/monthly lake level and area data measured during the19th and 20th centuries for the 150 GTN-L lakes to International Data Centre.

*Status*
In the Netherlands there is no GTN-L station.

*Action T8*
Submit weekly surface and sub-surface water temperature, date of freeze-up and date of break-up of 150 priority lakes in GTN-L.

*Status*
In the Netherlands there is no GTN-L station

### *5.4. Ground Water and Water Use*

*Action T9*
Archive and disseminate information related to irrigation and water resources through FAO's on-line AQUASTAT database and other means.

*Status*
IGRAC has taken an initiative to develop a Global Groundwater Monitoring System. This system will provide data for analyses of climatic change impact on groundwater resources.
Special attention will be paid to recharge and salinisation in coastal aquifers. In October 2007 IGWCO/GARS/UNESCO groundwater working group has organized a high-profile international workshop at IGRAC to define the postulates of GGMS.
The data to be collected for GGMS at the territory of the Netherlands are readily available at TNO Built Environment and Geosciences.

### *5.5. Snow Cover*

*Action T10*
Strengthen and maintain existing snow-cover, snowfall observing sites and recover historical data.

*Status*
KNMI measures snowfall, snow cover and snow height on manned precipitation stations, on GOS stations only snowfall.

### *5.6. Glaciers and Ice Caps*

*Action T13*
Maintain current glacier observing sites and add additional sites and infrastructure in South America, Africa, the Himalayas and New Zealand; ensure continued functioning of WGMS.

*Status*
UU-IMAU is monitoring ice-caps and glaciers. Automatic weather stations are operated on glaciers in the Alps, Norway, Greenland and Antarctica. Mass balance measurements are carried out on the Greenland ice sheet.

### *5.7. Permafrost and seasonally-frozen ground*

*Action T15*
Define, publish and apply international observing standards and practices for borehole measurements.

*Status*

*Action T16*
Maintain the current 125 CALM sites, ensure that all the other 287 boreholes in the GTN-P are active and reporting; add 150 additional sites as identified by GTN-P including the high mountains of Asia, Europe, Southern Hemisphere and North American alpine and lowlands as part of the IPY Thermal State of Permafrost campaign, ensure that all use standards as defined by the IPA and provide data to the NSIDC.

*Status*

*Action T17*
Implement operational mapping of seasonal soil freeze/thaw.

*Status*

### *5.8. Albedo*

*Action T18*
Test prototype algorithms to retrieve the directional hemispherical reflectance factor (or black sky albedo) from geostationary satellites on a daily and global basis.

*Status*

*Action T19*
Obtain *in situ* calibration/validation measurements and collocated albedo products from all Space Agencies generating such products.

*Status*

*Action T20*
Identify the most appropriate satellite derived albedo for specific climate models.

*Status*

Action T21
Implement globally coordinated and linked data processing to retrieve the directional hemispherical reflectance factor (or black sky albedo) from geostationary satellites on a daily and global basis from archived (and current) satellite data.

*Status*

### *5.9. Land Cover*

*Action T25*
Develop an *in situ* reference network and apply CEOS WGCV validation protocols for land cover.

*Status*
At national level land cover and land use change are monitored by WUR and compiled into the LGN database (www.lgn.nl).

*Action T26*
Generate annual products documenting global land-cover characteristics at resolutions between 250m and 1km, according to internationally-agreed standards and accompanied by statistical descriptions of the maps' accuracy.

*Status*

### *5.10. Fraction of Absorbed Photosynthetically Active Radiation (FAPAR)*

*Action T29*
Establish a calibration/validation network of *in situ* observing sites for fAPAR and LAI (reference sites).

*Status*

### *5.11. Leaf Area Index*

*Action T30*
Evaluate the various LAI satellite products and benchmark against ground truth to arrive at an agreed operational product.

*Status*

### *5.12. Biomass*

*Action T31*
Develop methodology for forest inventory information and begin acquisition of data.

*Status*
WUR is responsible for national forest inventory data (Meetnet Functievervulling bos 2001-2005, Vijfde Nederlandse Bosstatistiek) which are also used to prepare annual NIR to UNFCCC and FAO-FRA. WUR also collaborates in the European Forestry Institute with the development of European and global forest data and model products.

### *5.13. Data Management*

*Action T36*
Expand TEMS to support the meta-data collection, collation and publication needs of the terrestrial ECVs and associated data centres.

*Status*

*Action T37*
Develop an experimental soil-moisture product from existing networks and satellite observations.

*Status*
The VU-Amsterdam (in collaboration with NASA) develops the Land Surface Parameters global database of Surface Soil Moisture, Land Surface Temperature and Vegetation Water Content. The parameters are derived from passive microwave remote sensing data, using the Land Parameter Retrieval Model (LPRM). The dataset covers the period of 1978 to present and has a 2-3 day revisit time at the equator for both day and night time overpasses.

### *5.14. Scientific and Technological Challenges*

### *5.15. Terrestrial Domain, Specific five-year milestones include:*

- Reporting from all nodes of the Global Terrestrial Network for Glaciers (GTN-G), including the Global Land Ice Measurements from Space (GLIMS).
- Reporting from all nodes of the Global Terrestrial Network – Rivers (GTN-R) 380 priority stations near the downstream end of the largest rivers of the world.
- Reporting from all nodes of the Global Terrestrial Network for Permafrost (GTN-P).
- Generation of Northern and Southern Hemisphere snow extent maps.
- Generation of digital elevation maps of the ice sheet surfaces.
- Characterization of land cover (the location and extent of inland water-bodies, vegetation type, snow and ice, barren, artificial surfaces, fractional tree cover) at 250-500m resolution.
- Production of global directional hemispherical reflectance factor (or black sky albedo).
- Generation of global measures of fraction of Absorbed Photosynthetically Active Radiation (fAPAR).
- Generation of global active fire and burnt area data sets at 250m-1km resolution.

In the longer term (5 to 10 years) all of the above will be sustained and

- GTN-R will be expanded to cover near real-time reporting of river discharge data from all significant rivers.
- A new baseline network recording lake level and area (GTN-L) will be established.
- A network for ground-water and aquifer monitoring will be designed.
- The contraction of the distribution and number of snow-depth monitoring stations will be reversed.
- Global land-cover change will be mapped at 30m resolution.
- Methods used to establish biomass in forest inventories will be harmonized and collected.
- A globally-representative network of reference sites measuring LAI (*in situ*) and above-ground biomass will be established.
- Representations of soil moisture from satellite and *in situ* measurements will be rationalized and global measures generated.