

# GEMS data and products for GMES

HALO  
report

Draft

Tuesday, 21 December 2004

Johannes Flemming  
J-N. Thepaut  
R.Engelen  
A.Dethof  
J-J.Morcrette  
A.Hollingsworth





## Content

1	Introduction.....	3
2	Project Overview .....	5
3	Observation data in GEMS .....	7
3.1	Satellite data to be used in GEMS .....	7
3.2	In-situ correlative data to be used in GEMS .....	12
4	Inventory of GEMS Products.....	16
4.1	GEMS production system.....	16
4.2	GEMS data products .....	17
4.3	Spatial and temporal resolution of global GEMS products .....	19
5	GEMS Infrastructure.....	20
5.1	Overview of GEMS system architecture .....	20
5.2	Access to GEMS products .....	21
6	Links to documentations on the web .....	22

## 1 Introduction

The report gives an overview on data requirements and production of the GEMS integrated project, which covers the atmosphere theme in GMES<sup>1</sup>. Prepared as part of the HALO<sup>2</sup> activities, the paper intends to meet the need for a description of GEMS data flow and dissemination relevant to the interaction between land, atmosphere and ocean IPs in GMES.

GEMS (Global and regional Earth-system Monitoring using Satellite and in-situ data) will be funded under FP 6 (Thematic Priority Space/GMES) and runs for 4-years (2005-2008). GEMS is devoted to monitoring of atmospheric composition from satellites and in-situ observations. GEMS priorities are global greenhouse gases, global reactive gases, global aerosol and regional air pollution. GEMS will establish a global operational modelling and assimilation system for greenhouse gases, reactive gases and aerosol which will be embedded in ECMWF operational forecast system.

The GEMS projects is currently (10/2004) in the final phase of contract negotiations. The start of the GMES-project is envisaged for the beginning of 2005. Given that the project has not started yet, the information supplied in this document is only based on the project proposal.

GEMS development activities are devoted to atmospheric composition and do not directly cover the typical meteorological parameters<sup>3</sup> known from weather forecast, re-analysis or climatology. However, due to the strong links between atmospheric composition and meteorological parameters, GEMS products will include meteorological the fields of the ECMWF production system.

The common demand of meteorological information from the GMES IPs will be included in the HALO work. A HALO- report on ECMWFs data and products provides a reference for available meteorological data. It can found at the following web address:

([http://www.ecmwf.int/research/EU\\_projects/HALO/details.html#Documents](http://www.ecmwf.int/research/EU_projects/HALO/details.html#Documents))

Many strong links exists between GEMS and Mersea as well as Geoland due to coupling of atmosphere, ocean and land & vegetation in the earth-system. Examples of interactions concerning atmospheric composition are:

- Carbon fluxes between atmosphere, ocean and land vegetation
- Aerosol and trace gases information is needed for retrieval of satellite observations
- Aerosol and trace gases control radiation input for photosynthetic activities in the ocean and on land

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<sup>1</sup> GMES is a joint initiative of the European Commission and the European Space Agency, designed to establish a European capacity for the provision and use of operational information for Global Monitoring of Environment and Security. Besides the ocean theme, GMES's thematic priorities are land & vegetation, atmosphere, water resources, natural risks and security.

<sup>2</sup> HALO is a GMES specific support action (SSA), which will be responsible for the harmonized coordination of the interaction between the atmosphere, land and ocean integrated projects of the GMES backbone. The objective of HALO is to enable an efficient and coherent data exchange between the relevant IP's of GMES. HALO will provide agreed recommendations for the data architecture of GMES in its operational phase starting in 2008.

<sup>3</sup> Temperature, wind, radiation



- Aerosol deposition data could provide information on iron input which controls maritime biological production

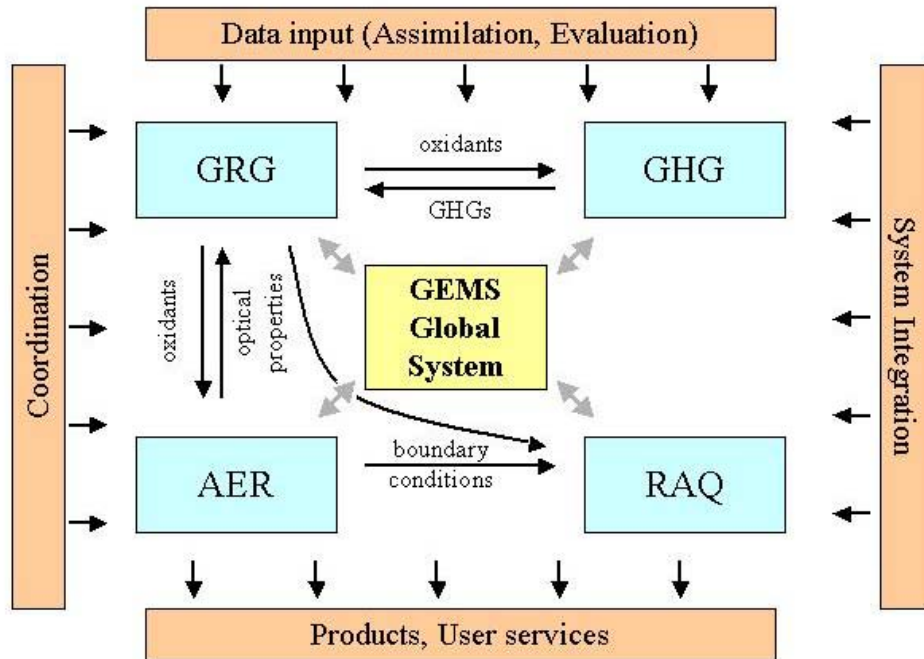
The report starts in chapter 2 with a general overview of the project compiled from the GEMS proposal. Satellite and in-situ observation, which are input in GEMS assimilation, modelling and validation activities are presented in chapter 3. The inventory of the GEMS products is content of chapter 4 and chapter 5 describes the GEMS system architecture and web-access to GEMS products.

## 2 Project Overview

The GEMS project (Global and regional Earth-system Monitoring using Satellite and in-situ data) consists of sub-projects covering the following aspects of atmospheric composition monitoring (see Figure 1).

- Global greenhouse gases
- Global reactive gases
- Global aerosols
- Regional air pollution

The thematic sub-projects are accomplished by a subproject about the implementation of an operational production system and a sub-project on validation.



**Figure 1** Schematic of GEMS building blocks, GHG - Greenhouse gases, GRG - Global reactive gases, AER - Aerosol, RAQ - Regional air quality.

GEMS is going to provide fields of the atmospheric composition and will improve knowledge about sources and sinks. GEMS uses satellite data and applies atmospheric models to obtain information about the atmospheric composition in global and regional scales. Satellite data are exploited either by assimilation in atmospheric models or by independent retrieval algorithms. Ground based and airborne in-situ measurements will be used mainly for validation purposes but for assimilation and inverse modeling as well.

As part of the ECMWF forecast system, GEMS will develop and implement a comprehensive, validated, and novel operational global data assimilation / forecast system for atmospheric dynamics and composition, which combines all available remotely sensed and in-situ data to achieve global monitoring of the dynamics and

composition of the atmosphere from global to regional scales (50 km) and covering the troposphere and stratosphere. The deliverables will include current and forecast three-dimensional global distributions (four times daily with a horizontal resolution of 50 km) of greenhouse gases, global reactive gases, and global aerosols.

The global assimilation / forecast system will provide initial and boundary conditions for nine operational regional air-quality and 'chemical weather' forecast systems. This will provide improved operational real-time air-quality forecasts. It will also provide a methodology for assessing the impact of global climate changes on regional air quality.

The GEMS project will run for four years, 2005-2008. For the ENVISAT-EOS era (1999-2007) GEMS will provide a retrospective analysis of all accessible in-situ and remotely sensed data on atmospheric dynamics and composition, as validation material for the project itself, and as a service to the wider science community on which the project relies.

GEMS will develop operational state-of-the-art variational estimates of the sources/sinks, plus inter-continental transports, of many trace gases and aerosols; these estimates will be designed to meet, on a monthly or quarterly basis, policy makers' key information requirements relevant to the Kyoto and Montreal protocols and to the UN Convention on Long-Range Trans-boundary Air Pollution.

The GEMS project wishes to use a great deal of satellite data in building and testing a global 4D-Var data assimilation system to be run operationally at ECMWF from late 2008. In addition the satellite data will be used for an extended reanalysis of atmospheric dynamics and composition for the ENVISAT-EOS epoch. The satellite data of interest are listed chapter 3.1. The results of the reanalysis will be readily available on the web for researchers worldwide.

The GEMS global assimilation system will have three strands, Greenhouse gases, Reactive gases and Aerosol. The GEMS project will meet many of the atmospheric assimilation requirements of the GCOS 2nd Adequacy Report, and the assimilation recommendations of the IGOS\_P Themes on the Carbon cycle (IGCO) and on Atmospheric Chemistry (IGACO). GEMS will also benefit from parallel ECMWF work on implementing the recommendations of the IGOS\_P Integrated Global Water Cycle Observations Theme (IGWCO).

### 3 Observation data in GEMS

Satellite data as well as ground based and airborne in-situ observation will be used within GEMS (i) to provide fields of atmospheric trace gases (ii) to estimate sources and (iii) for validation purposes.

Effective management of the large satellite datasets to be transferred is going to be a challenge within GEMS. The data has to be transferred for GEMS operational systems in a timely manner. The time schedule for the operational data stream has not been set up yet.

The in-situ data are small in terms of data volume. The main problem will be to receive quality controlled data from the diverse providers in an organized way within an acceptable time frame.

#### 3.1 Satellite data to be used in GEMS

Satellite data are provided either as **radiances**, which are more or less the measurements of the instruments after calibration and quality checking, or as retrieved **products**, which are already direct data about atmospheric composition. Raw radiances tend to have bigger data volumes but can be used for retrieval of more than one parameter. At E.C.M.W.F, the raw radiances are converted into atmospheric state variables, i.e. in concentration data in the GEMS context, by means of 4D-VAR data assimilation techniques.

GEMS uses satellite data listed in Table 1 for Greenhouse Gases (GHG), in Table 2 for Reactive Gases (GRG) and in Table 3 for Aerosols (AER). The tables list retrievable species, respective instrument, missions and their duration and an estimate of daily data volumes. Figure 2 shows in summary the estimated daily transfer rates of satellite radiance data needed for GEMS. Figure 3 shows the transfers summed up for retrieved products used in the GEMS subprojects.

The inventory of the satellite data needs is compiled from an ECMWF perspective. Much of the high volume sounding data required (IASI) is already being received in real-time, or will be received in real-time at ECMWF. The main challenge will be the transfer of MODIS and MERIS radiance data. Most of the satellite data to be used in GEMS will come from satellite agencies (ESA, EUMETSAT, NASA) and in the case of some products from research centres (KNMI) and universities (Universitaet of Bremen, Heidelberg).

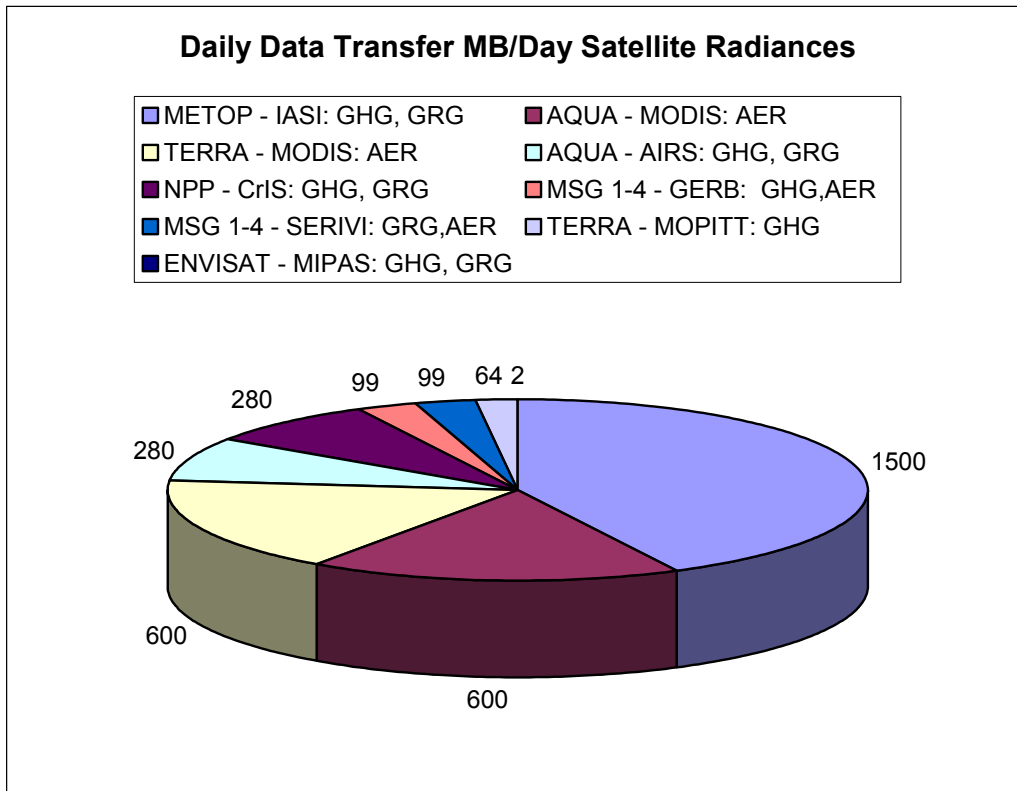


Figure 2 Estimated daily transfer in MB/day of satellite radiance data for GEMS.

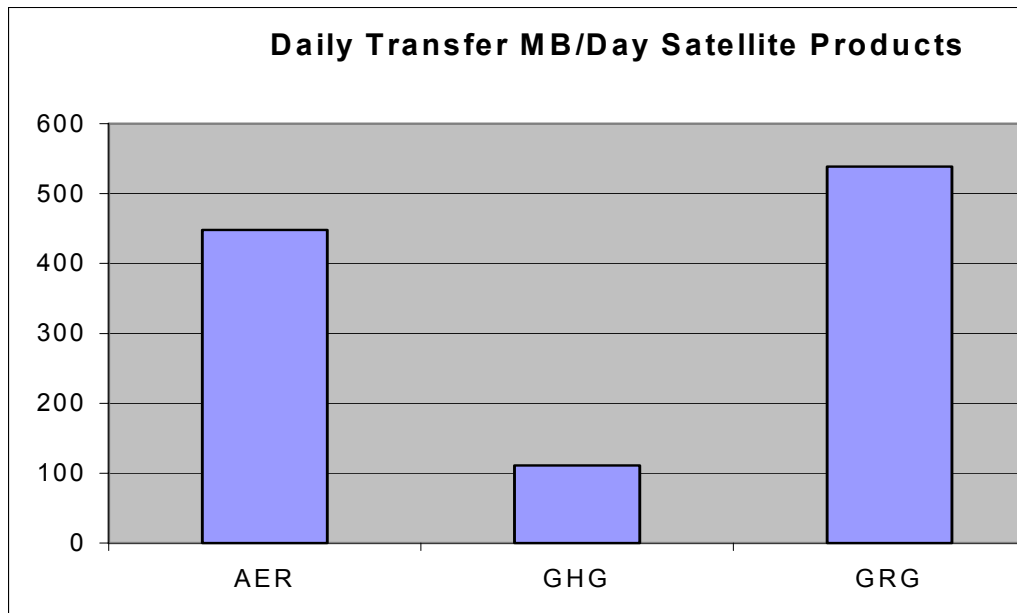


Figure 3 Estimated daily transfer in MB/day of satellite products need in GEMS subproject Aerosol (AER), Greenhouse gases (GHG) and Global Reactive Gases (GRG) .



**Satellite Data on Greenhouse Gases to be used in GEMS**

AGENCY	MISSION DURATION	INSTRUMENTS	SPECIES	TYP	ESTIMATED TRANSFER TO ECMWF PER DAY (MB)
ESA	ENVISAT 2002-2007	SCIAMACHY	CO <sub>2</sub> , N <sub>2</sub> O, CO, CH <sub>4</sub>	P	11
ESA	ENVISAT 2002-2007	MIPAS	CH <sub>4</sub> , N <sub>2</sub> O	raw	2
EUMET	METOP-2 2005- 2010,20	IASI	CO <sub>2</sub> , N <sub>2</sub> O, CO, CH <sub>4</sub>	raw	1500
NASA	AQUA 2002-2008	AIRS	CO <sub>2</sub> , N <sub>2</sub> O, CO, CH <sub>4</sub>	raw	280
NASA	TERRA 2000-2006	MOPITT	CO, CH <sub>4</sub>	raw	64
NASA	AURA 2004-2009	TES	CO, CH <sub>4</sub>	P	16
NASA	AURA 2004-2009	HIRDLS & MLS	CO, N <sub>2</sub> O, CH <sub>4</sub>	P	4
NASA	OCO 2007-2009	OCO	CO <sub>2</sub>	P	80
NESDIS	NPP	CrIS	CO <sub>2</sub> , N <sub>2</sub> O,CO, CH <sub>4</sub>	raw	280

**Table 1 Satellite Data on Greenhouse Gases to be used in GEMS**



<b>Satellite Data on Reactive Gases to be used in GEMS</b>
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Agency	Mission Duration	Instruments	Species	Typ	Estimated transfer to ECMWF per day (MB/day)
ESA	ENVISAT 2002-2007	SCIAMACHY	O <sub>3</sub> , NO <sub>2</sub> , SO <sub>2</sub> , CH <sub>2</sub> O	P	53
ESA	ENVISAT 2002-2007	GOMOS	O <sub>3</sub> , NO <sub>2</sub>	P	2
ESA	ENVISAT 2002-2007	MIPAS	O <sub>3</sub> , NO <sub>2</sub>	raw	2
ESA	ERS-2	GOME	O <sub>3</sub> , NO <sub>2</sub> , SO <sub>2</sub> , CH <sub>2</sub> O	P	19
EUMET	METOP-1 2005-2010,20	GOME-2	O <sub>3</sub> , NO <sub>2</sub>	P	152
EUMET	MSG 1-4 2002-2015	SEVIRI	O <sub>3</sub>	P	10
EUMET	METOP-1 2005-2010,20	IASI	O <sub>3</sub>	raw	1500
NASA	AQUA 2002-2008	AIRS	O <sub>3</sub>	raw	280
NASA	Earthprobe ADEOS Meteor-3 Nimbus-7	TOMS	O <sub>3</sub>	P	4
NASA	AURA 2004-2009	OMI	O <sub>3</sub> , NO <sub>2</sub> , SO <sub>2</sub> , CH <sub>2</sub> O	P	152
NASA	AURA 2004-2009	HIRDLS	O <sub>3</sub> , NO <sub>2</sub> ,	P	2
NASA	AURA 2004-2009	MLS	O <sub>3</sub> , SO <sub>2</sub> ,	P	2
NASA	AURA 2004-2009	TES		P	152
NESDIS	NOAA-16	SBUV-2	O <sub>3</sub>	P	1
NESDIS	NPP	CrIS	O <sub>3</sub>	P	280

**Table 2 Satellite Data on Reactive Gases to be used in GEMS**



<b>Satellite Data on Aerosols to be used in GEMS</b>
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AGENCY	MISSION	INSTRUMENTS	SPECIES	TYP	ESTIMATED TRANSFER TO ECMWF PER DAY (MB/DAY)
ESA	ENVISAT 2002-2007	MERIS	Aerosol Optical Depth at 865 nm Aerosol Epsilon Factor Radiances	P	TBD (target ~250MB/day maximum)
ESA	ERS-2 1995-2005 ENVISAT 2002-2007	ATSR AATSR	Radiances used in GLOBAER project	P	TBD
EUMET	MSG 1-4 2002-2015	SEVIRI	Radiation budget Radiances for inversion	raw	TBD low-moderate volume
	MSG 1-4 2002-2015	GERB	Radiation budget Radiances for inversion	raw	TBD low-moderate volume
NASA	TERRA 2000-2006	MODIS	Aerosol optical depth / Type / Size Distribution Radiances	raw	600
NASA	AQUA 2002-2008	MODIS	AsTERRA	raw	600
NASA	AURA 2004-2009	HIRDLS	Aerosol Optical Depth (4 wavelengths)	P	TBD low-moderate volume
NASA	ERBS 1984-present	SAGE-II	Aerosol optical depth (8 wavelengths)	P	low volume, available on web
NASA	Meteor-3 2001 ISS 2004	SAGE-III	Aerosol optical depth (8 wavelengths)	P	low volume, available on web
NASA	Seastar	SeaWifs	Aerosol products	p	?
NASA	VIIRS	NPP, NPOES	Aerosol	p	?

**Table 3 Satellite Data on Aerosols to be used in GEMS**

### 3.2 In-situ correlative data to be used in GEMS

The in-situ data to be used in GEMS (described below) will come from many streams: ground-based, satellite-based, aircraft, and balloon. GEMS will use

- The in-situ data listed Table 4 for Greenhouse Gases, GHG
- The in-situ data listed Table 5 for Reactive Gases, GRG
- The in-situ data listed Table 6 for Aerosols, AER.
- The in-situ data listed Table 7 for Regional Air Quality, RAQ.

The Tables include identified European and international research data streams, together with all operational atmospheric, ocean, and land data available under WMO auspices. The GEMS - partners have access to and will use the identified data sets for scientific validation of the work of individual GEMS sub-projects, and then for validating the products of the integrated GEMS system. The GEMS assimilation system will play a role as a transfer standard between the diverse satellite and in-situ data sources.

CORRELATIVE IN-SITU DATA ON GREENHOUSE GASES TO BE USED BY GEMS			
Agency / network / institute	Species	Instruments	Provider within GEMS
Network of flask monitoring stations	CO <sub>2</sub>	in-situ CO <sub>2</sub> monitoring stations	Carboeurope IP
Network of tall towers (CarboEurope IP)	CO <sub>2</sub> , CH <sub>4</sub> , N <sub>2</sub> O	in-situ measurements from tall towers	Carboeurope IP
Aircraft measurement campaigns (CarboEurope IP)	CO <sub>2</sub> , CH <sub>4</sub> , CO	aircraft in-situ	Carboeurope IP
FLUXNET Network of eddy flux towers	CO <sub>2</sub> fluxes, surface energy balance	eddy flux towers	FLUXNET-DIS
NOAA-CMDL air-sampling network	CH <sub>4</sub> , CO, H <sub>2</sub> , N <sub>2</sub> O, SF <sub>6</sub> , isotopes of CO <sub>2</sub> and CH <sub>4</sub> .	flask	CMDL
ALE-GAGE-AGAGE	methane, nitrous oxide, chlorofluorocarbons CFCl <sub>3</sub> , CF <sub>2</sub> Cl <sub>2</sub> , and CF <sub>2</sub> ClCFCl <sub>2</sub> , methyl chloroform, CH <sub>3</sub> CCl <sub>3</sub> ; chloroform, CHCl <sub>3</sub> ; and carbon tetrachloride, CCl <sub>4</sub> . Additional: H <sub>2</sub> , CO, HFC-134a, HCFC-141b, and HCFC-142b.	gas chromatographs	NUIG
WDCGG data centre, WMO/GAW	CO <sub>2</sub> , CH <sub>4</sub> , CFCs, N <sub>2</sub> O, water vapour etc.	various	WDCGG

**Table 4 Correlative in-situ data on Greenhouse Gases to be used by GEMS**



CORRELATIVE IN-SITU DATA ON GLOBAL REACTIVE GASES TO BE USED BY GEMS			
Agency / network / institute	Species	Instruments	Provider within GEMS
WMO/GAW global stations (WOUDC)	total ozone, ozone profile	Brewer, Dobson, filter ozonometers (M-124), ozone sonde	NKUA
WMO/GAW global stations	UV, solar radiation		FMI
WMO/GAW global stations	reactive gases (carbon monoxide, sulphur dioxide, nitrogen oxides, volatile organic compounds), chemical composition of rain	various	DWD
CMDL stations	ozone, CO, NO <sub>x</sub> ...	various	SA
selected "super sites", e.g. Hohenpeissenberg	O <sub>3</sub> , NO <sub>x</sub> , PAN, CO, peroxides, VOC, OH, etc.	various	DWD
SHADOZ	O <sub>3</sub> profiles, H <sub>2</sub> O profiles	ozone sonde	LA
MOZAIC	ozone profiles, water vapor, carbon monoxide and nitrogen oxides	aircraft	LA
DLR, IPSL	in-situ data of trace gases (NO <sub>x</sub> , NO <sub>y</sub> , ozone, water vapour, CO) and aerosol properties (number concentration, size distribution)	Falcon research aircraft	SA
Research aircraft field campaigns	O <sub>3</sub> , NO <sub>x</sub> , PAN, CO, peroxides, VOC, OH, etc	various	SA
NILU	ozone profiles (ca. 1980-now), near-real time delivery	ozone sondes	BIRA
NDSC	ozone profile (stratosphere)	Brewer, Dobson, SAOZ, DOAS, FTIR	BIRA
NDSC	ozone profile (stratosphere)	ozone sonde, lidar (DIAL), microwave	DWD
WDCGG data centre (WMO/GAW)	CO, NO <sub>x</sub> , SO <sub>2</sub> , VOC, etc. and surface ozone	various	DWD
EMEP	CO, NO <sub>x</sub> , N <sub>2</sub> O, NHHCs/VOCs	various	Meteo-FR
ALE/GAGE/AGAGE global stations	CH <sub>4</sub> , CFCs, N <sub>2</sub> O, CO, ...	gas chromatographs	NUIG
WMO/GAW regional stations	surface ozone, precipitation chemistry, solar radiation (visible and UV), CH <sub>4</sub> , CO, aerosol composition, black carbon, total column ozone, and meteorological parameters		DWD
ENVISAT cal/val data base hosted by NILU	Atmospheric composition measurements	various	KNMI/U. Bremen

**Table 5 Correlative in-situ data on Global Reactive Gases to be used by GEMS**

CORRELATIVE IN-SITU DATA ON AEROSOL TO BE USED BY GEMS			
Agency / network / institute	Species	Instruments	Provider within GEMS
EMEP	aerosol mass concentrations aerosol size distributions	PM samplers	NUIG (CEA-IPSL-LSCE, MPI-M)
IMPROVE	aerosol mass concentrations	PM samplers	NUIG (CEA-IPSL-LSCE, MPI-M)
AERONET/PHOTONS	AOD, SSA, aerosol size distribution	sunphotometer	CNRS-LOA
GAW/WMO (WDCA)	AOD	precision filter radiometer	DWD
Brewer network	AOD (UV)	UV-B spectrophotometer	RMIB
	profile of aerosol extinction coefficient	lidars	various
Mace Head	aerosol mass concentrations aerosol size distribution	various	NUIG
Hohenpeissenberg	aerosol mass concentrations aerosol size distribution	various	DWD
ARM sites	surface radiative fluxes	pyranometer, pyrgeometer	ECMWF, CNRS-LOA
SIRTA site	surface radiative fluxes	pyranometer, pyrgeometer	CEA-IPSL-LSCE, CNRS-LOA
NDSC	backscatter aerosol profiles	lidars (Observatoire de Haute Provence, Dumont d'Urville, Reunion Island)	SA_UPMC
BSRN (ETH), SURFRAD	radiation budget, surface irradiance, meteorological observations	pyranometer ...	ECMWF, CNRS-LOA
NASA, U.S. Navy	Aerosol extinction coefficient	HALOE, POAM	SA_UPMC

**Table 6 Correlative in-situ data on Global Aerosol to be used by GEMS**



CORRELATIVE IN-SITU DATA ON AIR QUALITY TO BE USED BY GEMS			
Agency / network / institute	Species	Instruments	Provider within GEMS
MOZAIC	O <sub>3</sub> , CO, NO <sub>y</sub> , H <sub>2</sub> O, profiles and cruise-level transects	aircraft	CNRS, Laboratoire d'Aérodologie
'New' EMEP, incorporating historical data from EMEP, HELCOM, OSPAR and GAW data	Air-quality data: ozone, NO, NO <sub>2</sub> , CO, PM, SO <sub>2</sub> , HNO <sub>3</sub> , NH <sub>3</sub> ... Deposition: rainfall analyses	various	met.no
CREATE	Air-quality data	various	
DAEDALUS	Air-quality data	various	CNRS-LOA
GMES-GATO	Air-quality data	various	Meteo-France
Met-Moniteur	Air-quality data	various	Meteo-France
AIRBASE air quality data	Air-quality data	various	met.no
Near-real-time data from regional and national agencies	Air-quality data	various	National partners responsible on a country by country basis (note that NRT data will necessarily be unvalidated at the time of transmission).

**Table 7 Correlative in-situ data on Air Quality to be used by GEMS**

## 4 Inventory of GEMS Products

This chapter (i) provides an overview of the development of GEMS operational services, (ii) list GMES products and (iii) presents detailed description of the spatial resolution of the global data on atmospheric composition.

The GEMS products will come from two main production streams:

- Forecast and analysis of the global and regional assimilation / forecast system for atmospheric dynamics and composition as well as regional air pollution (beyond 2007)
- Retrospective analysis atmospheric dynamics and composition and regional air pollution for the ENVISAT-EOS era (1999-2007)

Forecast and near-real-time analysis as well as retrospective analysis of atmospheric composition will be the majority of the GEMS products. These data will be accomplished by operational carbon flux estimates obtained by inverse modeling based on the analysed concentration fields and in-situ measurements.

Although GEMS is mainly concerned about atmospheric composition, the provision of meteorological data belongs to the obligations of an atmosphere IP in GMES. The operational provision of meteorological data is already well served by the Centers of numerical weather prediction.

The “added value” of GEMS meteorological products come from the fact that they are provided by a system which accounts to some extent for the interaction between atmospheric composition and atmospheric dynamics. The most important example of this interaction is the influence of aerosol on the atmospheric radiation fluxes.

Since meteorological data are a common data demand between the GMES IPs, HALO will covered this already well established link. The influence of aerosol on atmospheric radiation will provide valuable information for the ocean (Mersea) and land & vegetation (geoland) IP since it is needed to account for atmospheric correction during satellite data retrieval especially in the VIS range, and during the calculation of the photosynthetically active radiation (PAR). Further, iron input in the ocean, which controls biological production, could be derived from aerosol data.

### 4.1 GEMS production system

The GEMS final production system, combining the activities of the greenhouse gas (GHG), global reactive gas (GRG) and aerosol (AER) sub-projetcs, will consist of the following elements:

- An operational system to monitor and forecast concentrations of carbon dioxide in space and time, using the latest remote-sensing measurements
- A prototype system to monitor and forecast concentration of N<sub>2</sub>O, CO, SO<sub>2</sub>, and formaldehydeand CH<sub>4</sub> using novel remote-sensing retrievals
- A prototype system to monitor and forecast concentration of aerosols using novel remote-sensing retrievals



- An operational system to estimate surface carbon sources and sinks, by atmospheric inversions based on these 4d CO<sub>2</sub> fields
- A Carbon Cycle Data Assimilation System (CCDAS) to attribute land carbon sources and sinks to causes

The global operational system for forecast and monitoring will be part of ECMWFs integrated forecast system. The incorporation of the GEMS-system in to an already operational forecasting model will ensure its reliable operational service.

In addition to this global system, several regional air-pollution models will be run pre-operationally within the GEMS subproject on Regional air pollution (RAQ) using the data from the global system.

The operational system at ECMMWF, run within production (PRO) sub-project, will comprise assimilation systems, archived observation datasets, and gridded reanalysis datasets. Its gradual development follows the schedule

- 2005: Three independent assimilation systems for GHG, GRG and AER.
- 2006: Trial reanalyses for as much as possible of the period 2000-2005, for each of the three strands, GHG, GRG, AER.
- 2007: The integrated GEMS system assimilation system
- 2008: Extended reanalyses and daily forecasts with the Integrated GEMS system.

## 4.2 GEMS data products

The following products will be provided by GEMS. A more detailed description of the spatial resolution of the data is given in the next paragraph 4.3.

**Three-dimensional global atmospheric composition products** (four times daily with a horizontal resolution of 50 km, and vertical resolution of 60 levels between the surface and 65 km)

- Greenhouse gases (initially including CO<sub>2</sub>, and progressively adding CH<sub>4</sub>, N<sub>2</sub>O, plus SF<sub>6</sub> and Radon to check advection accuracy),
- Reactive gases (initially including O<sub>3</sub>, NO<sub>2</sub>, SO<sub>2</sub>, CO, formaldehyde, and gradually widening the suite of species),
- Aerosols (initially a 10-parameter representation, widening later to ~30 parameters).

### **Global atmospheric total column products:**

- Total column ozone
- Total column water and water vapour
- Total column amounts of CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, CO, O<sub>3</sub>, N<sub>2</sub>O, SO<sub>2</sub>, SF<sub>6</sub>, plus mixing ratios and other characteristics of up to 6 aerosol species (mineral / desert dust, marine aerosol, black carbon...)

### **Flux estimates**

- Global estimate of Carbon fluxes obtained by inverse modelling from the CO<sub>2</sub> concentration analysis and in-situ data

**Additional aerosol products**

- Aerosol properties for all sorts of atmospheric corrections
- Concentrations of PM for air pollution related issues
- Initial and boundary conditions for smaller-scale air quality models
- Visibility range (e.g., air traffic, tourism)
- Photosynthetically available radiation (for e.g. CO<sub>2</sub> cycle)
- Aerosol deposition flux (impact on vegetation, acid rain)

**Regional air pollution forecast:**

- O<sub>3</sub>, PM<sub>10</sub>, SO<sub>2</sub>, NO<sub>2</sub>, VOC and CO are typical species provided by air pollution forecast because they subjected to air quality standards set by EC framework directives on ambient air.

**Global atmospheric dynamics:**

- Mean sea level pressure,
- East-West & North-South components of 10 metre wind
- East-West & North-South surface stress,
- East-West & North-South components of orographic gravity wave stress,
- 2 meter temperature, and dewpoint temperature,
- Boundary layer height,
- Evaporation, Total precipitation, Convective precipitation, Stratiform precipitation (Large-scale precipitation), Runoff,
- Total cloud cover, Low cloud cover, Medium cloud cover, High cloud cover,
- Soil temperatures level 1-4,
- Volumetric soil water layers 1-4
- Ice surface temperature layers 1-4
- Snow depth, Snow evaporation, Snowfall (convective + stratiform), Snowmelt, Temperature of snow layer
- Significant ocean wave height, Mean wave direction, Mean wave period
- Sea-ice cover,
- Surface latent heat flux, Surface net solar radiation, clear sky, Surface net thermal radiation, clear sky, Surface sensible heat flux, Surface solar radiation, Surface solar radiation downwards, Surface thermal radiation, Surface thermal radiation downwards
- Top solar radiation, Top thermal radiation, Top net solar radiation, Clear sky, Top net thermal radiation, clear sky



### 4.3 Spatial and temporal resolution of global GEMS products

The GEMS from the operational system at ECMWF data will be provided and stored similar in format and availability to the ERA-40 reanalysis fields.

The ERA-40 project created an archive of re-analysed meteorological fields on a regular 2.5 degree latitude -longitude grid available four times daily (0000, 0600, 1200, 1800 UTC) for every days from September 1957 to August 2002. The GEMS reanalyses will cover a shorter period, but the GEMS data server will also provide global and regional analyses and forecasts, so that partners and interested researchers can make regional and global forecasts of atmospheric dynamics and composition.

The meteorological fields on the GEMS and ERA-40 web site comprise three-dimensional and two-dimensional fields. The three-dimensional fields at each time consist of divergence, geopotential, ozone mass mixing-ratio, potential vorticity, relative humidity, specific humidity, temperature, zonal velocity, meridional velocity, vertical velocity, and relative vorticity, all at the following standard pressure levels : 1000, 925, 850, 775, 700, 600, 500, 400, 300, 250, 200, 150, 100, 70, 50, 30, 20, 10, 7, 5, 3, 2, 1 hPa.

## 5 GEMS Infrastructure

### 5.1 Overview of GEMS system architecture

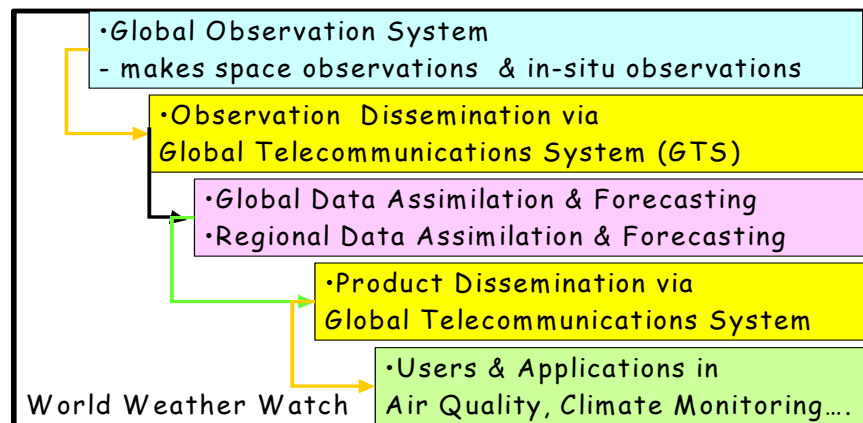
In this following sections section we outline the main elements of the GEMS system architecture, covering

- Observations,
- Telecommunications,
- Modelling and data assimilation (with the associated issues of high-performance computing and high-capacity data handling, data dissemination)
- Products and user access.
- Links with users and user access.
- GEMS Global Production team

The GEMS system will use as far as possible the existing infrastructure provided by (i) WMO's World Weather Watch and (ii) European resources in information technology.

By far the largest international flows of Earth Observation data (both in-situ data and space-based data on meteorology, oceanography, atmospheric composition and hydrology) are the daily operational global observation and forecast exchanges (and the corresponding monthly global exchanges of climate summaries). These exchanges are made under the aegis of the World Meteorological Organisation(WMO) and the International Ocean Commission of UNESCO, and involve about 200 countries and administrations. Extensive documentation on the legislative bases together with scientific technical / telecommunications / processing agreements for these exchanges is available from the WMO site ([www.wmo.int](http://www.wmo.int)) by selecting the topic 'WWW'.

Elements of WMO's World Weather Watch,  
Global Observing System takes observations (GOS)  
Global Telecommunications system disseminates observations & products (GTS)  
Global Data Processing System makes products (GDPS)



**Figure 4 The main elements of the WMO operational World Weather Watch System,**

## 5.2 Access to GEMS products

### **Global Analyses and Forecasts**

GEMS will provide a number of different access mechanisms for GEMS users, depending on user capabilities, user requirements, and the type of products needed. It is expected that most users will require access via the internet to the validated analysis and forecast datasets provided on the GEMS. Other users will require dissemination for pre-operational testing, in which case the distribution mechanism may be either the Internet or the dedicated meteorological circuits. Finally, researchers will need access for experimentation on the GEMS data assimilation and forecast systems, through user interfaces accessed over the Internet. The access and distribution mechanisms represent are based on considerable software investments made in earlier projects funded by the EU, and others funded by the meteorological community.

The ERA-40 Reanalysis project (<http://www.ecmwf.int/research/era/>) funded by the 5th Framework programme has built substantial software systems to undertake extended reanalyses of historical data and to provide access services to the validated results. These capabilities will be used in GEMS to produce the GEMS reanalyses and to provide access to the outputs and to visualise the outputs.

### **GEMS Regional Products**

Validated GEMS regional products will be archived and displayed on the GEMS web-site with a common graphics package and in a common format, for ease of comparison and to facilitate common verification protocols.

### **GEMS Diagnostic products**

Validated GEMS diagnostic will be archived and displayed on the GEMS web-site with a common graphics package and in a common format, for ease of comparison and to facilitate common verification protocols.

### **Management & Dissemination of Experimental NRT Global Runs**

In the last year of the GEMS project it is planned to undertake experimental Near-Real-Time (NRT) and pre-operational running of the full GEMS system including global analyses and forecasts and regional analyses and forecasts. National Institutes and Research Institutes of all EU Member States will be welcome to participate in this experimental work. GEMS will appoint a GEMS dissemination manager at the beginning of year 3 of the programme to prepare the real-time aspects of the experiment. The telecommunications means most appropriate for each participant will be used, either RMDCN or the Internet.

## 6 Links to documentations on the web

GMES:

- GMES general information: <http://www.gmes.info/>
- GMES and ESA <http://earth.esa.int/gmes/>
- GMES cross - cutting assessment team <http://www.gmes-cca.co.uk>
- Geoland project <http://www.gmes-geoland.info>
- MERSEA project <http://www.mersea.eu.org/>
- GEMS project [http://www.ecmwf.int/research/EU\\_projects/GEMS/](http://www.ecmwf.int/research/EU_projects/GEMS/)
- HALO specific support action  
[http://www.ecmwf.int/research/EU\\_projects/GEMS/](http://www.ecmwf.int/research/EU_projects/GEMS/)
- GSE PROMOTE <http://www.knmi.nl/promote/>

Satellite missions dedicated for monitoring of atmospheric composition

- OCO <http://oco.jpl.nasa.gov/>
- AURA <http://aura.gsfc.nasa.gov/>
- Envisat <http://envisat.esa.int>
- MSG and MetOp <http://www.eumetsat.de>

International Bodies and Programmes on the Land and Carbon theme

- WMO - Global atmospheric watch (GAW)  
[http://www.wmo.ch/web/arep/gaw/gaw\\_home.html](http://www.wmo.ch/web/arep/gaw/gaw_home.html)
- IGOS - Atmospheric chemistry theme  
<http://ioc.unesco.org/igospartners/atmosphere.htm>
- IGOS - Carbon Theme IGCO (Integrated Global Carbon Observation)  
<http://ioc.unesco.org/igospartners/Carbon.htm>
- CARBOEUROPE <http://www.bgc-jena.mpg.de/public/carboeur/>
- Global Carbon Project [http://www.globalcarbonproject.org/about\\_the\\_gcp.htm](http://www.globalcarbonproject.org/about_the_gcp.htm)