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Progress with the GEMS Project

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Progress with the GEMS Project

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The GEMS project (Global Earth-system Modelling using Space and in-situ data) is an Integrated Project funded under the EU's initiative for Global Monitoring for Environment. The aim of the project is to extend the modelling, forecasting and data assimilation capabilities used in numerical prediction to problems of atmospheric composition. This will deliver improved services and products in near-real time (e.g. global air quality forecasts to provide boundary conditions for more detailed regional air-quality forecasts). In addition the operational analyses and retrospective reanalyses will support treaty assessments (e.g. the Kyoto protocol on greenhouse gases and the Montreal protocol on the ozone layer) while the joint use of satellite and in-situ data will enable sources, sinks and transports of atmospheric constituents to be estimated. The project involves about thirty institutes in fourteen European countries and has an EU contribution of 12.5 million Euro. It will run for four years from spring 2005 to spring 2009 with coordination carried out by ECMWF.

The objectives of GEMS fall into two categories.

- The global elements of GEMS are to produce by 2009 a validated, comprehensive, and operational global data assimilation/forecast system for atmospheric composition and dynamics.
- The regional elements in GEMS are to assess the value of information on long-range trans-boundary air pollution for operational air-quality forecasts in Europe.

The core operational products of GEMS will be gridded data assimilation and forecast fields of key atmospheric trace constituents with high spatial and temporal resolution. These will include greenhouse gases (initially including CO_2, and progressively adding CH_4, N_2O, plus SF_6 and Radon to check advection accuracy), reactive gases (initially including O_3, NO_2, SO_2, CO, HCHO, and gradually widening the suite of species) and aerosols (initially a 15-parameter representation, later ~30).

The GEMS Annual Assembly convened at ECMWF on 6–10 February 2006 to review progress since the start of the project, and to make plans for the coming 18-months. The Assembly was organised by Olivier Boucher (Met Office), Guy Brasseur (Max-Plank Institut für Meteorologie), Henk Eskes (KNMI), Anthony Hollingsworth (ECMWF), Vincent-Henri Peuch (Météo-France), Peter Rayner (LSCE/IPSL) and Adrian Simmons (ECMWF).

Based on discussions at the Assembly, we describe some of the developments which have occurred in the first year of GEMS and outline future plans.

Progress in the first year of GEMS

Progress on data issues

The GEMS project has had considerable help from major Space Agencies, including ESA EUMETSAT, NASA and NESDIS, in the acquisition of the very large amounts of satellite observations needed by the project. As the data are acquired the observations are reformatted in BUFR and archived at ECMWF.

Within the GEMS project, considerable work has been done to reconcile the differing data format requirements of the operational partners, who prefer BUFR and GRIB formats, and the research partners who prefer netCDF. A means to accommodate the needs of both communities is being developed.

Early in 2005 the Canadian Meteorological Service circulated for comment a draft proposal on extension of the BUFR format to encompass atmospheric chemistry observations. A revised proposal was discussed by the relevant WMO technical committee in December 2005. After further revision it is expected to be adopted as the WMO format for real-time international exchange of air chemistry measurements.

Progress on global modelling and data assimilation

Substantial efforts have been devoted to extending the modelling needs of the project. ECMWF's Integrated Forecast System (IFS) has introduced the generic capability to advect many (~100) trace species by the model's dynamics, and to transport them in the parametrizations, such as the convection parametrization. In-line parametrizations have been implemented for greenhouse gases and aerosols, with surface fluxes specified climatologically (CO_2) or dynamically (aerosols). Year-long test runs with specified meteorology and free-running chemistry have provided valuable checks on the models (see Figure 1).

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For reactive gases it is essential that the assimilating model has the benefit of an advanced chemistry scheme. Since it is believed premature to introduce a full-blown chemistry representation into the IFS, the IFS model has been coupled to the three participating Chemistry Transport Models (CTMs). At the time of writing the coupling has been achieved technically for two of the three CTMs, so attention is moving from technical issues of the coupling to assessing the scientific issues raised by the possible mis-matches or dislocations introduced by the coupling.

A key requirement of the GEMS modelling and assimilation capability is an accurate representation of the stratospheric Brewer-Dobson circulation, which is involved in the control of the stratospheric distribution of many stratospheric constituents, and in key aspects of tropospheric-stratospheric exchange. There is evidence that there have been important improvements in this regard since the completion of the ERA-40 reanalyses in 2002. Consequently the meteorological components of the preliminary GEMS system have been used to reanalyse 2003–2004. Preliminary results are encouraging.

The IFS's 4D-Var system has been adapted to provide three separate data assimilation systems for greenhouse gases, reactive gases and aerosols. Depending on which of the domains is addressed, the assimilation systems will use radiances via fast forward models and their adjoints (greenhouse gases initially, aerosols later), or retrieved profiles (aerosols, reactive gases) or total column amounts.

The specification of natural and anthropogenic emissions is a key issue for both the global and regional elements of the GEMS project. Agreement has been reached on the use by GEMS of the global anthropogenic emissions calculated by the RETRO project of the Fifth Framework Programme.

Emissions by wildfires and biomass burning are a key issue for the GEMS project. A proposed approach to the issue was developed recently through discussions between the HALO, GEMS, GEOLAND and ACCENT projects. Efforts will be made to include the issue in the Work Programme of the Seventh Framework Programme.

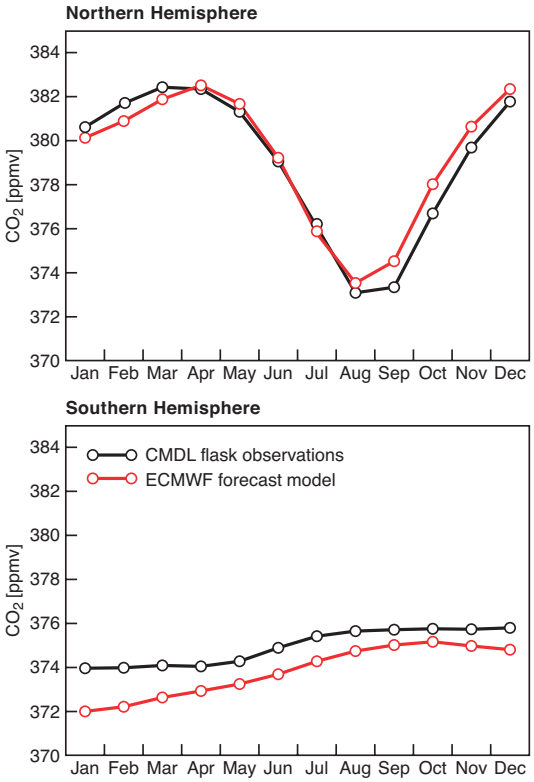

Figure 1 Comparisons between NOAA/CMDL surface flask measurements of CO_2 and a year-long run of the ECMWF model where the meteorology is corrected every 12 hours and the CO_2 is free-running, with specified climatological surface fluxes. The figure shows good qualitative agreement for the seasonal cycle. (Courtesy R.Engelen and S. Serrar).

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Progress on regional modelling and assimilation

The GEMS regional models will consider a common European domain (35°N–70°N; 15°W–35°E), or a larger area, for ensemble activities and inter-comparisons. Vertical and horizontal resolutions depend upon the model: many will start with 20–50 km resolution with a target resolution of 5–20 km. Nested domains at higher resolution will also be developed. The main goal of the regional activity is to enhance and improve Regional Air Quality (RAQ) forecasts, hindcasts and analyses across Europe through the use of information on long-range trans-boundary air pollution. All ten GEMS regional models (Figure 2) have demonstrated good progress in building-up their GEMS-RAQ configuration.

An area of common concern is surface emissions. The EMEP (Steering Body to the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe) inventory of anthropogenic emissions is the up-to-date reference in Europe, and is generally of good quality. For GEMS, the main limitation of the EMEP dataset is the resolution of ~50 km which does not meet all RAQ requirements in terms of a good temporal resolution (hourly, weekly, monthly and annual) over the GEMS European domain and at a 5 km resolution. The creation of a dataset of European emissions, shared and used by a large number of groups involved in regional air-quality forecasting, would represent an important step. The GEMS Management Board will arrange the preparation of such a dataset through a sub-contract.

An important goal for GEMS is to provide coordinated access to air quality verification data across Europe for near-real time operations and to exploit the hindcasts. Consequently efforts will be made to agree a Memorandum of Understanding on data and forecast exchange for purely scientific and technical objectives with air-quality agencies. Also there is a need for preparation of similar agreements for the post-2009 phase involving institutions such as regional and national agencies and the European Environment Agency (EEA).

In preparation for pre-operational near-real time daily forecasts, work is progressing on the definition of methodologies for meaningful evaluation and comparison of partner hindcasts and forecasts over the GEMS domain. Included will be metrics for assessing forecasts of basic chemical species and metrics specific to user communities (e.g. air quality indices for human health and crop damage, and metrics for city level forecasts). Plans are also in preparation for software development based on 'Verify/MetPy' system developed at ECMWF which will allow central verification and user-tailored metrics.

One of the goals of GEMS is to assess the value of the GEMS data in epidemiological studies of the public health effects of long-range aerosols and reactive gases. Preliminary studies are being planned to identify the types of health effects that can be meaningfully studied using GEMS-RAQ data.

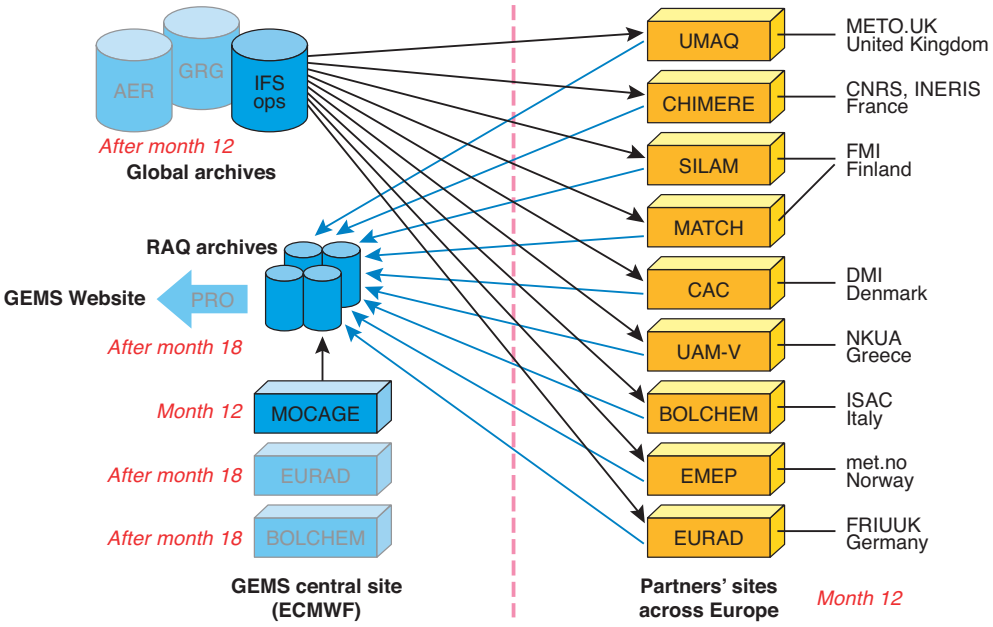

Figure 2 Illustration of the data flows between the central site and the GEMS regional modelling partners.

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Next steps in the development of GEMS

Plans for research and development

Table 1 illustrates the main phases of the work of the production team, based on the plans of the global modelling and assimilation partners, and of the regional partners. After further validation in the course of 2006, three separate global reanalyses of the study period 2003–2004 will begin later in 2006 with separate assimilation systems for greenhouse gases, reactive gases and aerosols. With completion expected in mid-2007, the reanalyses will be subjected to elaborate validation and check-out before being exploited in a number of ways.

The validation of the first reanalyses will lead to preparation of a second integrated reanalysis of the same period and scheduled to begin in late 2007. At the same time the integrated system will be the basis for development of a pre-operational system which will be designed to be ready for operational implementation in the first half of 2009.

Institutional arrangements needed for a transition to operations in 2009

Institutional arrangements are not yet in place for a transition of GEMS to operational status in 2009. Discussions with the EU are expected to begin in 2006 in the context of the preparation of an atmospheric service for implementation in 2009 as part of Global Monitoring for Environment and Security (GMES). The EU has already begun work on three GMES services for implementation in 2008, and it is expected that the atmospheric service preparation will follow a similar template. Issues to be considered include governance and definition of service level agreements for core services; for down-stream services consideration needs to be given to issues such as data policy and data access.

Satellite data provision in 2009–2019

The availability of adequate satellite data provision is a key issue in planning the first decade of operational GEMS activity. In terms of security and adequacy of satellite provision, the greenhouse gas project probably has the most secure provision with operational advanced sounders (IASI in 2006 plus GOME_2 on METOP, CrIS on NPP in 2009) for upper-tropospheric measurements and the research OCO and GOSAT missions from 2009 onwards. The least secure provision is probably the air-quality (lower-tropospheric chemistry), as no missions are planned beyond the demise of ENVISAT and AQUA. The satellite provision for aerosols and UTLS (upper troposphere-lower stratosphere) are comparable, with aerosols relying mainly on the VIIRS instrument on NPP and NPOESS and the UTLS chemistry relying on GOME-2 on METOP and OMPS on NPOESS (from 2012).

Period	Activity
Year 1 May 2005–Aug 2006	• Build and validate three separate assimilation systems for greenhouse gases, reactive gases and aerosols. • Acquire data; build web-site.
Year 2 Aug 2006–Aug 2007	• Produce three different reanalyses for greenhouse gases, reactive gases and aerosols. • Make reanalyses available for validation by all partners. • Provide feedback to data providers.
Year 2–2.5 Aug 2007–Jan 2008	• Merge the three assimilation systems into a unified system. • Upgrade the models and algorithms based on experience.
Year 2.5–3.5 Jan 2008–Nov 2008	• Build operational system and interfaces to partners. • Produce unified reanalyses for greenhouse gases, reactive gases and aerosols.
Year 3.5–4 Nov 2008–May 2009	• Carry out final pre-operational trials. • Prepare documentation and scientific papers.

Table 1 Main phases of the work of the GEMS production team, based on the plans of the global modelling and assimilation partners, and of the regional partners.

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Final thoughts

The GEMS Assembly showed that significant progress has been made with the project since spring 2005. This is due to the high level of expertise and commitment amongst the partners coupled with effective international collaboration between various research groups and project teams. There is every reason to be confident that by May 2009 the GEMS project will deliver a new European operational system which can monitor the composition, dynamics and thermodynamic of the atmosphere and produce forecasts of greenhouse gases, reactive gases and aerosols.

More information about the GEMS project can be found via the ECMWF web site at:
www.ecmwf.int/research/EU_projects/GEMS

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