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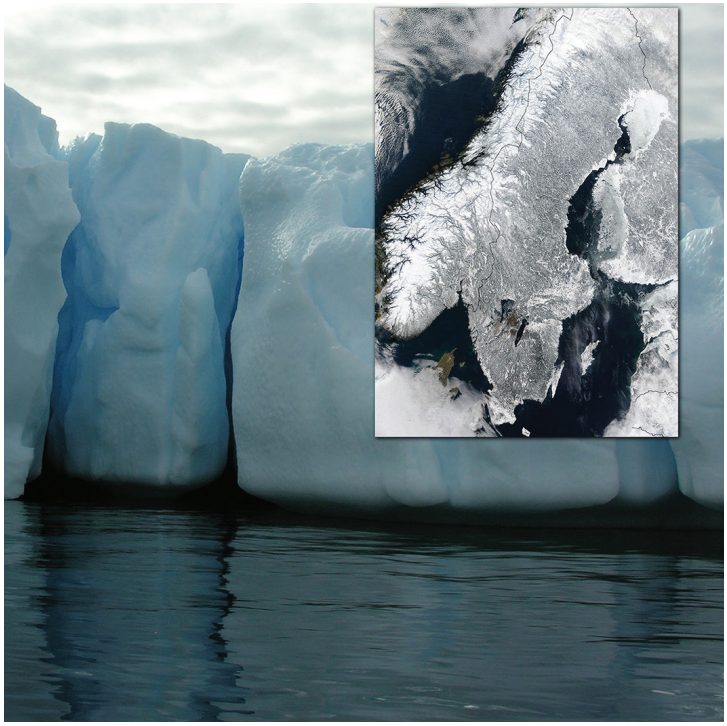

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The GEMS project – making a contribution to the environmental monitoring mission of ECMWF

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The EU's initiative on "Global Monitoring for Environment and Security" (GMES, www.gmes.info) aims to make environmental information more readily available to both providers and users. In addition it will lead to the creation of a "European Shared Information System" for exchanging a wide range of information. The reason for the GMES initiative is that scientists, policy-makers and industry are confronted with volumes of data so large and varied that extracting information for a specific need is very difficult. Something needed to be done to rectify the situation.

As a contribution to the GMES initiative, an EU-funded project, GEMS (Global Earth-system Monitoring using Satellite and in-situ data) has been established to develop a real-time operational assimilation and forecast capability of aerosols, greenhouse gases and reactive gases. The new European operational system will be an extension of current data assimilation and forecast capabilities for Numerical Weather Prediction. It will be used to monitor the composition, dynamics and thermodynamics of the atmosphere and produce medium-range and short-range air-chemistry forecasts.

Satellite data will be a major source of information, and ground-based observations will be used initially for validation and evaluation. The inclusion of these new parameters in data assimilation systems will improve the retrieval of temperature and moisture from infrared sounders. Also the explicit representation of ozone and aerosols in the models will have a positive impact on weather forecasts. The GEMS Project should provide a good step towards fulfilling the new environmental monitoring mission of ECMWF. The main beneficiaries of the GEMS Project will be high-level policy users, operational regional air-quality and environmental forecasters, users of the GMES, and the scientific community.

Objectives and participants

The GEMS forecast capabilities will require sophisticated operational models. In addition global and regional data assimilation systems will be needed to exploit satellite and in-situ data so as to provide initial data ('status assessments') for the forecasts. These operational 'status assessments' are also invaluable for documenting sources, sinks and transports of atmospheric trace constituents. The specific objectives of the GEMS Project are to:

- Develop and implement at ECMWF a validated, comprehensive, and operational global data assimilation/forecast system for atmospheric composition and dynamics, which combines all available remotely sensed and in-situ data. Operational deliverables will include current and forecast three-dimensional global distributions (four times daily with a horizontal resolution of 50–100 km, and vertical resolution of 60 levels between the surface and 65 km) of key atmospheric trace constituents including greenhouse gases, reactive gases and aerosols.
- Provide initial and boundary conditions for operational regional air-quality and 'chemical weather' forecast systems across Europe. This will provide a methodology for assessing the impact of global climate changes on regional air quality. It will also provide improved operational real-time air-quality forecasts.
- Provide a retrospective analysis of all accessible in-situ and remotely sensed data on atmospheric dynamics and composition as validation material for the ENVISAT-EOS era (1999–2007).
- Develop 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 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 consortium consists of four categories of participants.

- Sixteen research institutes in seven countries providing expertise in satellite and in-situ observations for assessing/validating models, expertise in developing models and assimilations of tropospheric and stratospheric chemistry and aerosol, and expertise in inversion methods to estimate sources, sinks and transports.

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- Ten regional modelling centres in nine countries, most with operational responsibilities for national or regional air-quality forecasts.
- Two environmental protection agencies.
- Two international bodies: ECMWF with extensive experience in exploiting satellite and in-situ data to produce forecasts, and the Institute for Environment and Sustainability of the EU's Joint Research Centre.

The members of the consortium are listed in the Annex.

GEMS strategy

Figure 1 illustrates the main strands of the GEMS strategy to build an integrated operational system for monitoring and forecasting the atmospheric chemistry environment. The building blocks of the separate elements of the system already exist. The schematic also illustrates the scientific interactions between the strands of development, which will develop and mature as the integration of the system proceeds. In formulating the strategy, both scientific and practical considerations were taken into account. The primary scientific goal is to create an architecture which will provide a fully integrated treatment of all aspects of atmospheric composition and dynamics when it becomes operational in the first half of 2009. In doing this full use will be made of the existing infrastructure provided WMO's World Weather Watch and European resources in information technology.

The GEMS strategy is based on a step-wise approach.

- Establish in parallel, and validate, individual elements of the system in the first half of the period.
- Merge the individual components in an integrated system, and validate the integrated system.

The operational system for greenhouse gases and for the inference of surface fluxes will be the first such operational system. It will considerably strengthen the already strong European position in international negotiations, because of its transparency and sophistication.

Research systems for assimilation of reactive gases and aerosol have been developed in recent years, but none has the comprehensive use of satellite data, the comprehensive validation mechanisms and the high spatial resolution of the system proposed here. Again the operational global system will be a first, and will maintain and strengthen European leadership in these areas.

The GEMS assessments of the impact of the global composition changes on regional air quality will be based on a range of regional air-quality models using similar assessment protocols. The resulting assessments will be comprehensive and extensive, examining impacts on mean fields and on extreme events.

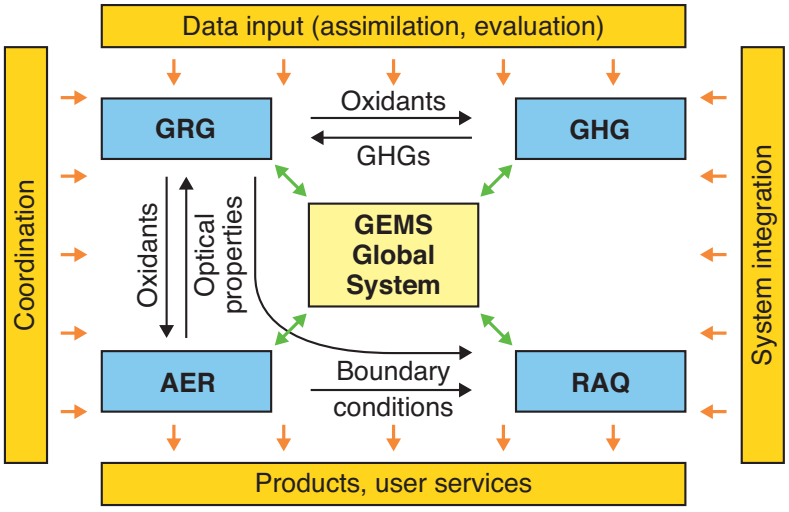

Figure 1 Schematic illustrating the links and the flow of data and information between the main elements of the GEMS system: Greenhouse Gases (GHG), Global Reactive Gases (GRG), Global Aerosol (AER), Regional Air Quality (RAQ) and the global atmospheric assimilation system at ECMWF.

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Links with other initiatives and operational implementation

The aim of the GEMS project is to be scientifically and technically ready to transition the global and regional GEMS systems to operational status by mid-2009, at the end of the project. To ensure successful transition it will be necessary to create institutional arrangements step-wise in the next four years. The actors will include the following.

- European Commission (e.g. GMES Advisory Committee), European Environment Agency (EEA) and European Space Agency (ESA).
- National Meteorological Services, together with ECMWF, EUMETSAT and EUMETNET.
- National Environment and Regional Environment Agencies.
- Other scientific and technical partners in GEMS and related GMES activities (see http://www.gse-promote.org/).

The institutional arrangements will address issues such as long-term funding, data sharing, and product dissemination funding. There are further challenges in the availability of satellite data beyond 2010. The current ENVISAT/EOS era provides a wealth of observational capability from space, which GEMS will exploit. Beyond 2010, the operational METOP series will provide upper-troposphere measurements of ozone. In addition information about aerosols, land properties and ocean will come from the operational NPOESS series. The main gap in satellite provision is an effective atmospheric chemistry observing capability from space. No such missions are committed beyond the demise of ENVISAT and EOS-AURA. ESA's current priority for a chemistry mission is very low. Missions currently under study could not fly before 2015, even in a favourable funding environment.

A further institutional issue concerns the INSPIRE (Infrastructure for Spatial Information in Europe) initiative being developed by the European Commission. Discussions have begun between EUMETNET and the Commission on the scope of the draft INSPIRE directive in the domains of meteorology and oceanography. The outcome of those discussions will have a direct impact on important aspects of the operational transition.

Another component of GMES is the GEOLAND Integrated Project. This aims to provide products and services associated with the monitoring of land cover and vegetation. By 2009 it is expected that the elements of the GEMS and GEOLAND suites will be run operationally to provide:

- Real-time global air-quality products.
- Boundary and initial conditions for regional air-quality models.
- Quality control of satellite data in near-real-time.
- Four-dimensional Greenhouse gas fields needed by the inversion teams on a regular basis.
- Consequential quality control of flask data within a month or two of calibration.

Each individual element of the GEMS and GEOLAND suite may be useful for NWP, and so may be incorporated in the NWP assimilating model and/or in the deterministic and ensemble forecast models. Those elements of the GEMS suite not incorporated in the NWP suite will be run operationally as a stand-alone assimilation/forecast suite for the reasons just cited. From the viewpoint of GCOS (Global Climate Observing System) there may be arguments for operational running of all elements of the GEMS suite at a common resolution.

The initial post-2008 operational configuration of the GEMS assimilation system could have a 50–100 km resolution. The operational configuration will evolve thereafter to realise benefits for the NWP system. On the other hand, some elements of the GEMS suite (e.g. aerosol) could prove of sufficient value to justify implementation in the NWP suite by 2008.

The heat-wave of summer 2003 led to more than 18,000 excess deaths in Europe, partly due to heat-stress and partly due to high ozone levels. The operational GEMS system will provide a major improvement in European capabilities to forecast natural disasters, to monitor the global environment, and to advance the science of atmospheric dynamics and composition. Within the GEMS consortium ECMWF will undertake the global modelling and assimilation tasks. Other partners will use the global fields as boundary conditions for regional air-quality models as part of the regional air-quality forecast tasks. In addition the research partners will address the issues necessary to improve the system, and to assure the quality of the daily global analyses of greenhouse gases, monthly estimates of sources and sinks of carbon dioxide, daily global analyses and forecasts of reactive gases and aerosols, and the provision of boundary conditions for regional air-quality models. The availability of these data will be an important resource for the wider scientific community.

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Members of the GEMS Consortium

- European Centre for Medium-Range Weather Forecasts, UK
- Met Office, UK
- Centre National de la Recherche Scientifique, France
- Commissariat à l'Energie Atomique, France
- Max-Planck-Institute for Biogeochemistry, Germany
- Max Planck Institut für Meteorologie, Germany
- Royal Netherlands Meteorological Institute, Netherlands
- Institut d'Aeronomie Spatiale de Belgique, Belgium
- Finnish Meteorological Institute, Finland
- Danish Meteorological Institute, Denmark
- Deutscher Wetterdienst, Germany
- University of Bremen, Germany
- Universite Pierre et Marie Curie, France
- National and Kapodistrian University of Athens, Greece
- Météo-France
- Centre National de Recherches Météorologiques, France
- National University of Ireland, Galway, Ireland
- Koninklijk Meteorologisch Instituut – Institut Royal Météorologique, Belgium
- ARPA Emilia-Romagna, Italy
- Instituto di Scienze dell'Atmosfera e del Clima Consiglio Nazionale delle Ricerche, Italy
- Meteorologisk Institutt, Norway
- Rheinisches Institut für Umweltforschung Universität Köln, Germany
- Joint Research Centre, Institute for Environment and Sustainability, Italy
- Institut National de l'Environnement Industriel et des Risques, France
- Czech Hydrometeorological Institute, Czech Republic
- Irish Environmental Protection Agency, Ireland
- Polish Institute of Environmental Protection, Poland
- Imperial College of Science, Technology and Medicine, UK

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