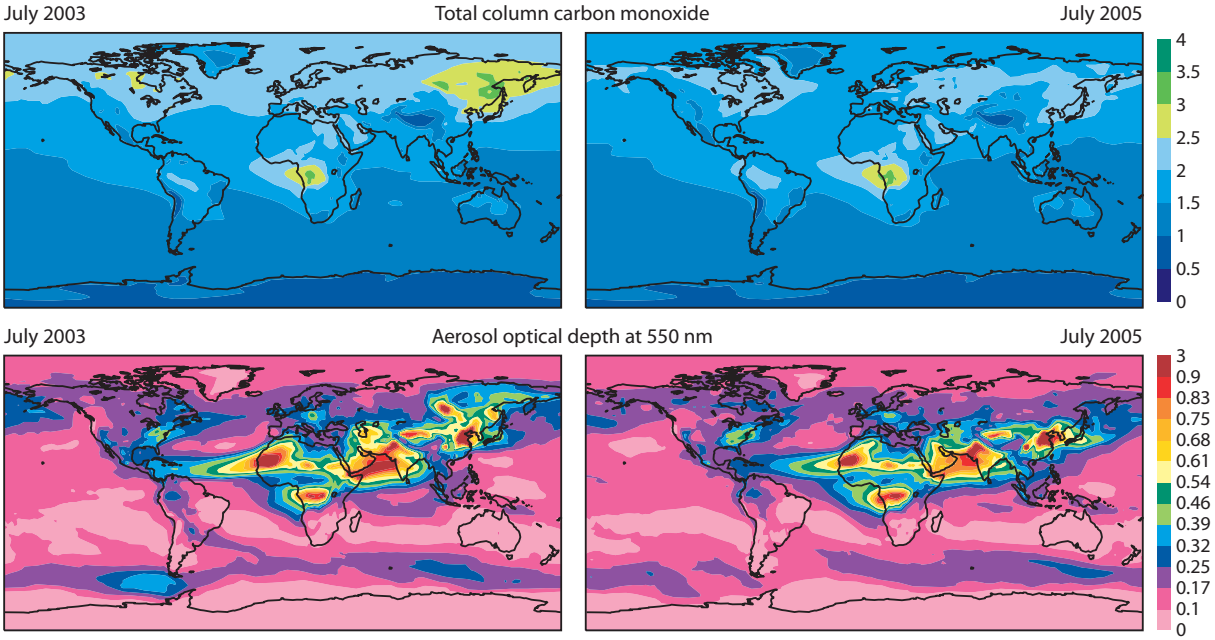
Monitoring Atmospheric Composition and Climate (MACC)

MACC combines computer model simulations with world-wide observations to monitor the composition of the Earth's atmosphere and predict air quality with a focus on Europe. MACC provides data that are important for understanding climate and validating and improving the computer models used to predict climate change. It also provides information important for the protecting health and efficiently exploiting sources of renewable energy.

MACC is developing core operational atmospheric environmental services for Europe's GMES (Global Monitoring for Environment and Security) initiative. MACC is a project funded under the European Union's Seventh Framework Programme and began on 1 June 2009. It is undertaken by a 45-partner consortium drawn largely from the participants in earlier projects (GEMS and PROMOTE) funded by the European Union and European Space Agency, and builds on the systems and service lines developed by these projects. MACC is coordinated by the European Centre for Medium-Range Weather Forecasts (ECMWF).

Variations in emissions and transport

Wildfires emit large amounts of greenhouse gases and other gases that affect air quality. Dust blown up into the atmosphere affects air quality and visibility, as does the smoke from fires. The emissions and long-range transport by winds of these pollutants change from day-to-day, month-to-month and year-to-year. They are monitored in MACC because of their long-term effect on climate, and forecasted daily because of their more immediate effect on public well-being.



Aerosol and carbon monoxide analyses show large differences over north-eastern Asia between July 2003 and July 2005, due to much greater fire activity over Siberia in 2003. The aerosol analyses also show stronger transport of Saharan dust westward to the Caribbean in 2003.

GMES Observing our planet for a safer world

SEVENTH FRAMEWORK PROGRAMME

ECMWF

Input data

MACC utilises data from the many satellites that supply information on atmospheric dynamics, thermodynamics and composition. The data are provided either by space agencies or by other institutions that extract or "retrieve" data on physical or chemical variables from the raw satellite measurements. MACC itself undertakes some of the required satellite data retrieval. The satellite data are complemented by extensive in situ data from ground-based and airborne meteorological instruments and by a more limited amount of in situ data on atmospheric composition.

MACC also acquires and updates data related to the emissions of chemical species and particulate matter into the atmosphere. A special effort is devoted to the highly variable emissions from fires, whose location and intensity are identified from satellite observations.

Global and regional processing

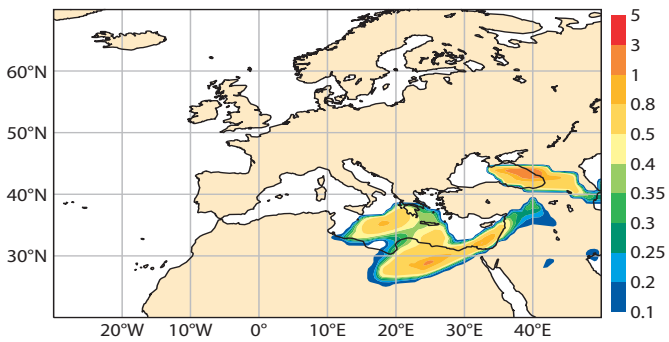
The global and regional components of MACC operate and refine processing systems that combine input data and modelling to provide basic monitoring and forecast products for atmospheric composition. They also provide derived products related to the radiative forcing of climate, inferred corrections to sources and sinks, surface UV radiation and resources for solar power generation. Additional observational data are used for validating products.

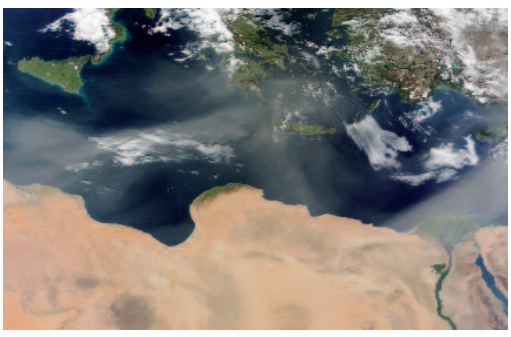
Central to MACC's global processing component is an integrated data assimilation and forecasting system for atmospheric composition and weather. The system incorporates greenhouse and reactive gases (including carbon dioxide, methane, carbon monoxide, ozone and nitrogen dioxide) and several types of aerosol (dust, sea-salt, organic and black carbon, and sulphate) into the Integrated Forecasting System (IFS) used routinely by ECMWF for its core global weather analysis and prediction. Chemical production and loss of the reactive gases are taken from one of three coupled chemistry transport models maintained by partners in the project. The system is run by ECMWF daily to provide monitoring and forecasting of the reactive gases and aerosols, some six months behind time for monitoring greenhouse gases, and retrospectively to analyze conditions over the past decade when satellite coverage has been at its best. Specialised systems for stratospheric ozone are run by partners to extend the data records established by PROMOTE and to provide reference points for the performance of the newer integrated MACC system.

MACC's regional processing component comprises an ensemble of higher resolution chemical analysis and forecasting systems run over a common European domain by seven partners. The core ECMWF system provides the meteorological fields required by the regional systems, and the global MACC system provides chemical and aerosol boundary conditions. Forecasts are produced daily for three days ahead. Retrospective analyses of validated air-quality measurements are also produced, providing a description of the background European levels of pollutants that are characterised by the influence of long-range transport. This enables evaluation of interannual variations in air quality and the effects of changes in emissions.

Dust forecasting

Determining the origin of air pollution episodes and distinguishing between natural and man-made sources of pollutants is important for establishing and implementing policies to improve air quality and protect health. Transport of dust from Africa is a significant factor causing European regulatory thresholds for particulate matter to be exceeded. Dust storms can cause major disruption to transport and other aspects of daily life, as well as a threat to health.





Jeff Schmaltz, MODIS Rapid Response Team, NASA GSFC

Dust outbreaks from North Africa into the eastern Mediterranean on 18 February 2010 captured in a 33-hour forecast (left) from the global MACC system and in an image from the MODIS instrument on NASA's Terra satellite (right). The forecast product is a prototype warning index based on scaling the dust aerosol optical depth by a measure of the deviation from climatological conditions.

User interface and policy support

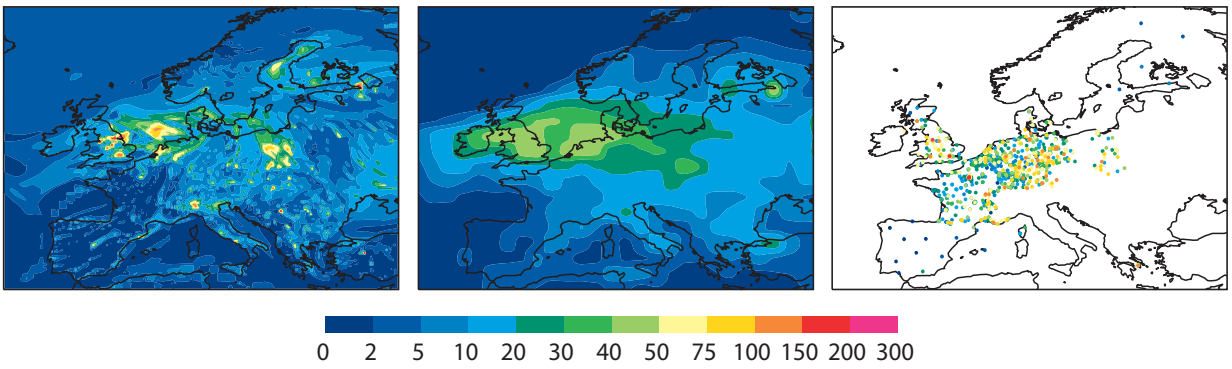
A further component of MACC provides the interface to intermediate service providers and end users, runs service-chain test cases and supports the development of policy for the control of atmospheric pollution. Boundary conditions from the global system may be used not only to support MACC's regional component, but also to drive other European models or models for other regions of the world. MACC includes a service-chain test case that uses regional modelling to study links between dust outbreaks and the occurrence of meningitis in the Sahel region of Africa. Other test cases evaluate the capability of MACC's core service lines to support downstream services for urban air-quality forecasting and other types of health warning. Policy support is undertaken in liaison with the European Environment Agency, national and regional environment agencies and other interested bodies. It includes agreements on data exchanges, preparation of scenarios and predictive tools to be run on demand in extreme situations and provision of agreed input to assessment reports.

Access to products

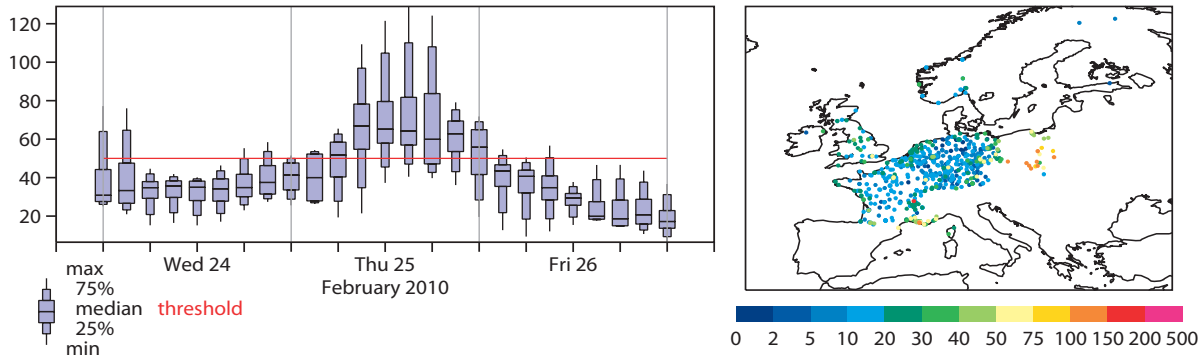
MACC's products relating to atmospheric composition are made freely available. Graphical products, datasets and reports can be downloaded from the project's main website (www.gmes-atmosphere.eu) or from partner websites for which the main site acts as a portal. Other dissemination services are under development. Training can be provided and user feedback is encouraged.

Focus on Europe for air quality

The global MACC system provides broad-scale distributions of reactive gases and aerosols. The higher-resolution regional models run over Europe provide enhanced detail. An indication of uncertainty is provided by running an ensemble of regional models.



Nitrogen dioxide distributions for 18 UTC 25 February 2010. 42h forecasts from 00 UTC on 24 February are shown from the MOCAGE regional model (left) and from the coarse-resolution global IFS coupled with the MOZART chemical transport model (centre). The right-hand panel shows measured values.

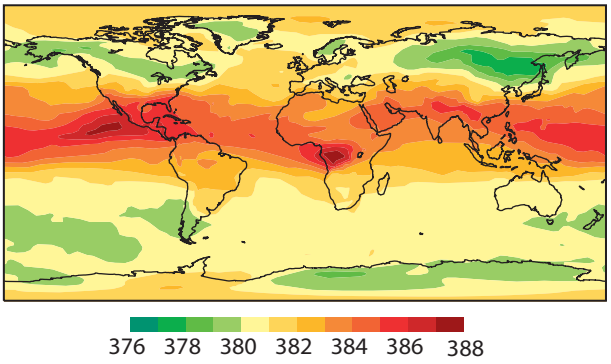


The spread in forecasts of PM10 (particulate matter with sizes up to 10 microns) for Warsaw over the three-day period commencing 00 UTC 24 February 2010 (left), and the measured values of PM10 at 12 UTC 25 February (right).

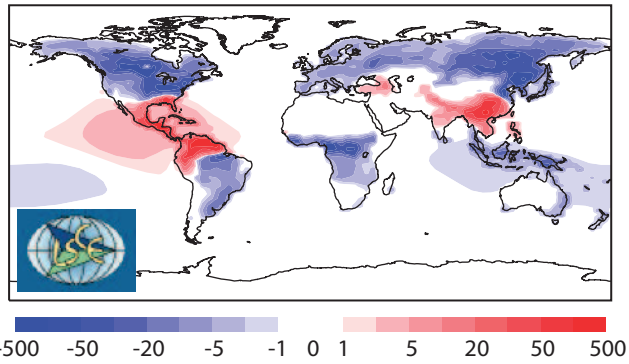
Monitoring aspects of the carbon cycle

Atmospheric concentrations of carbon dioxide and methane are increasing due to anthropogenic emissions. To understand the effects of these increases on climate, it is crucial to understand the full underlying carbon cycle in order to take effective emission reduction or mitigation decisions. MACC has built a system that can combine the observations from both satellites and in-situ networks to monitor the atmospheric concentrations of carbon dioxide and methane, and their net surface fluxes. While this is not sufficient to monitor anthropogenic emissions from individual countries, it is an important tool for monitoring the overall effectiveness of current and future policy decisions.

Mean Column CO_2 Mixing Ratio (ppm) July 2005



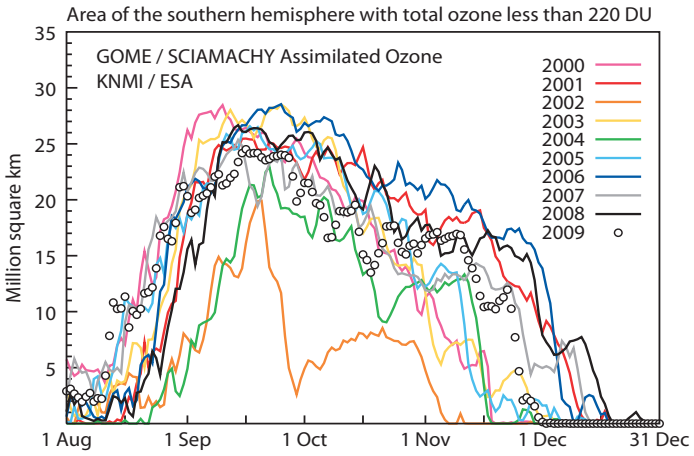
Mean CO_2 Flux Increments ($gCm^{-2}\ day^{-1}$) for July 2005



Analyses of CO_2 (left) representing a merge between model forecasts and satellite observations are used to estimate the adjustments (right) needed to correct the model's surface fluxes. While current satellite observations provide limited information about CO_2, this is expected to change in forthcoming years. Data from expanding in-situ observation networks will also be utilised.

Building records of stratospheric ozone

Long-term ozone records have been established using satellite data available from 1978 onwards. Records of gridded products are maintained by assimilating data from a series of satellites into chemical transport models.



The ozone hole that forms over the Antarctic each winter displays considerable variability from year to year. The records shown here for 2000 to 2009 are based on assimilating data from the GOME and SCIAMACHY instruments on ESA satellites.

ECMWF is an independent international organisation supported by more than 30 States. It provides weather services with medium-range forecasts of global weather and ocean waves to 15 days ahead and seasonal forecasts to six months ahead. ECMWF's computer system at its headquarters in Reading, United Kingdom, is one of the largest for meteorology worldwide and contains the world's largest archive of numerical weather prediction data. It runs the world's most sophisticated medium-range prediction model of the global atmosphere and oceans. The National Meteorological Services of Member States and Co-operating States use ECMWF's products for their own national duties, in particular to give early warning of potentially damaging severe weather.

European Centre for Medium-Range Weather Forecasts (ECMWF)

Shinfield Park, Reading RG2 9AX, United Kingdom

Tel: +44 (0) 118 949 9000

Fax: +44 (0) 118 986 9450

Website: www.ecmwf.int