EUROPEAN UNION

European research on stratospheric ozone and UV radiation

INTRODUCTION AND OVERVIEW

Stratospheric research was a priority of the European Framework Programmes for Research and Technological Development (FPs) from the very beginning and has been coordinated at European level since the late 1980s. The early European stratospheric research programmes (FP1-FP3, 1982-1994), focused on the investigation of potential severe Arctic ozone losses and increased UV radiation across Europe and the populated northern mid-latitudes. Results from a series of national and international programmes including the European Arctic Stratospheric Ozone Experiment (EASOE, 1991-92) and the Second European Stratospheric Arctic and Mid-latitude Experiment (SESAME, 1994-95) concluded that the winter polar stratosphere over northern Europe was primed for severe ozone losses. Large ozone losses over the Northern Hemisphere have indeed been observed in some winters in the early 1990s. This trend has continued in the early 2000s, coincide with a stratospheric cooling trend and new record low temperatures. Low stratospheric temperatures favour the development of Polar Stratospheric Clouds (PSCs) which play a key role in the process of ozone destruction.

In the 4th Framework Programme for Research and Technological Development (FP4, 1994-1998) stratospheric research was focusing on basic processes affecting ozone depletion, in particular over Northern Europe. The Third European Stratospheric Experiment on Ozone (THESEO, 1998-2000) was a major component of this coordinated programme. Moreover, research addressed the mid-latitude lower stratosphere, the interaction with other layers of the atmosphere, the Arctic vortex, and exchanges processes between the Troposphere and the Stratosphere in the tropics and sub-tropics.

The 5th Framework Programme for Research and Technological Development (FP5, 1998-2002), Programme Energy, Environment and Sustainable Development (EESD) was designed to support environmental legislation and international commitments such as the Montreal Protocol, promoting interdisciplinary research. Research focused on understanding, quantification and prediction of stratospheric changes and changing of UV-radiation levels. The programme has been implemented through multitude projects organised in a number of research clusters addressing similar topics: UV radiation (ATUV), impact of aircraft emissions (CORSAIRE), ozone–climate interactions (OCLI), stratospheric ozone loss (SOLO).

The 6th Framework Programme for Research and Technological Development (FP6, 2002-2006) was designed to promote interdisciplinary research in a more integrated way. The newly designed funding instrument, called Integrated Project (IP), was a very effective implementation tool for stratospheric research at European level. Stratospheric topics of the Programme addressed future stratospheric ozone levels and physical and chemical processes affecting ozone depletion. Also ozone-climate interaction and the study of exchange process between the Troposphere and the Stratosphere received high priority. Projects funded under FP6 (still ongoing) are listed in Table 1.

Integrated and interdisciplinary UV and stratospheric research will continue in the 7th Framework Programme for Research and Technological Development (FP7, 2007-2013) under **Programme 6. Environment (including climate)**. In addition, the **GMES** (Global Monitoring for Environment and Security) initiative, part of **Programme 9. Space,** addresses some stratospheric research aspects (related to pre-operational services) under topic '**Pilot Services Atmosphere'.**

In the past effective links have been maintained with existing international observational programmes such as NDACC and the Global Atmosphere Watch programme of the World Meteorological Organisation (WMO-GAW). This collaboration will continue. The International Ozone Commission and the WCRP programme Stratospheric Processes And their Role in Climate (SPARC) should also be mentioned in this context.

Overall, European research has greatly benefited from the European research programmes which have provided an effective co-ordination mechanism and have helped European scientists to make major advances to the understanding of stratospheric ozone depletion, climate-stratospheric

interactions and changing UV levels. As a result, they have significantly contributed to the international Scientific Assessment of Ozone Depletion: 2006, basically concluding that the Montreal Protocol is on track.

STRATOSPHERIC RESEARCH IN FP6 (2002-2006)

The following section gives a more detailed overview of the FP6 stratospheric research priorities and the objectives of the ongoing FP6 research projects supported by the European Commission (EC). Stratospheric research was mainly addressed under topic ***I.5. Stratospheric Ozone and Climate Interactions*** **in the Work programme of the Thematic Sub-Priority 1.1.3 Global Change and Ecosystems,** as indicated below:

> ***I.5. Stratospheric Ozone and Climate Interactions***
>
> *Research will focus on future stratospheric ozone levels affected by halogens, aerosols, water and greenhouse gas emissions and how physical, radiative and chemical changes in structure and circulation in the global stratosphere will be affected by climate change. UV radiation fluxes reaching the ground and the factors affecting their transfer in the atmosphere as well as the effects of surface pollution, aviation and natural factors on the upper troposphere and lower stratosphere will be studied in the context of ozone-climate interactions.*

Under FP6 European Commission supported 3 IPs focusing on ozone-climate interactions and UV radiation (**SCOUT-O3,** Stratospheric-Climate Links with Emphasis on the Upper Troposphere and Lower Stratosphere), on quantifying the impact of emissions from the transport sector on climate and ozone depletion (**QUANTIFY**, Quantifying the Climate Impact of Global and European Transport Systems) and on atmospheric observations (**GEOMON,** Global Earth Observation and Monitoring of the atmosphere), respectively. In addition, IP **GEMS** (Global and regional Earth-system (Atmosphere) Monitoring using Satellite and in-situ data) has a work package on the assimilation of gas-phase chemical species in the stratosphere and troposphere, and the project **DYNAMITE** (Understanding the Dynamics of the coupled Climate System) has a component which investigates the Troposphere/Stratosphere coupling. Please note that the financial volume of some IPs exceeds that of FP5 research cluster (for details see Table 1).

Furthermore, the European Commission funded a number of Specific Support Actions (SSAs) to underpin stratospheric research and relevant policies. **ATTICA** (European Assessment of Transport Impacts on Climate Change and Ozone Depletion) was designed to assess the impact of the transport sector (aviation, land traffic, shipping) on climate change and ozone depletion, and the **HCFC-Workshop** (5-6 April 2008, Montreal) should help to find ways to reduce and early phase-out HCFCs consumptions and emissions. Furthermore, the EC also contributed to the Quadrennial Ozone Symposium 2004 (Kos, Greece, 1-8 June, 2004).

Core objectives of SCOUT-03

The aim of this project is to study and predict the evolution of the coupled chemistry/climate system with emphasis on reliable prediction of the future evolution of the ozone layer and surface UV. Forecasts will be build on refined and improved models by exploiting existing data for model testing and validation and by provision of new data on fundamental processes. In order to meet these goals, 10 project activities have been defined:

- Determination of air residence time (with major field campaign)
- The influence of clouds on the tropical UTLS (with major field campaign)
- Understanding the stratospheric water vapour trend and its consequences
- The stratospheric aerosol layer – role of TTL and possible changes
- Past UV changes, variability and trends
- Ozone variability and past changes at mid-latitudes

- Inter-annual variability in polar processes and likely changes in a changing atmosphere
- Improved understanding of the Brewer-Dobson and general stratospheric circulation.
- Stratosphere/troposphere coupling – past and future.
- Predictions of ozone recovery, effect on climate change on recovery and the impact of the ozone changes on surface UV.

Campaigns

- Tropical aircraft campaign has been carried out November-December 2005, Darwin, Australia (Russian stratospheric research aircraft M55 Geophysica was contributing).
- Atmospheric research campaign with M55 Geophysica from July 31 to August 18, 2006 in Ouagadougou, Capital of Burkina Faso, West Africa.
- SCOUT-O3/AMMA tropical balloon campaign, Niger, July-August 2006.
- SCOUT-O3 UV radiation and aerosol campaign, Thessaloniki (Greece) July 2006 in Southern Europe.
- Balloon campaigns are planned for 2008.

Core objectives of QUANTIFY

The main goal of QUANTIFY is to quantify the impact of global and European transport systems on climate and ozone depletion for the present situation and for several scenarios of future development. The climate impact of various transport modes (land transport, shipping, and aviation) will be assessed, including those of long-lived greenhouse gases like CO_2 and N_2O, and in particular the effects of emissions of ozone precursors and particles, as well as of contrails and ship tracks.

Several transport scenarios and potential mitigation options will be assessed on a sound common basis to identify the most effective combination of short and long-term measures as input for policy- and industrial decisions. The project aims to provide such guidance by focused field measurements, exploitation of existing data, a range of numerical models, and new policy-relevant metrics of climate change. The project will focus on the following activities:

- Establishment of transport Scenarios and emission inventories.
- Regional dilution and processing (with emphasis on chemical conversion of ship emissions).
- Large –scale chemistry effects (impact of transport emissions on chemical composition for past and present day conditions).
- Long-term measurements of UTLS compounds.
- Aviation, shipping and clouds (generation and modification of clouds by emissions of different traffic modes, with emphasis on cirrus clouds).
- Radiative forcing and climate change (contribution from different modes of transport)
- Development of improved metrics of climate change.
- Synthesis of the results.

Campaigns

- CIRCLE-1 aircraft campaign ship emissions, Brest, June 2007.

Core objectives of GEOMON

The goal of GEOMON is to sustain and analyze European ground-based observations of atmospheric composition complimentary with satellite measurements. It is a first step to build a future integrated European atmospheric observing system dealing with observations of long-lived greenhouse gases, reactive gases, aerosols, and stratospheric ozone. GEMON is a European contribution to GEOSS (Global Earth Observation System of Systems) helping to optimize the European strategy of environmental monitoring in the field of atmospheric composition observations. Furthermore, the project is also relevant for the European GMES (Global Monitoring for Environment and Security) initiative integrating in-situ and satellite measurements. Main activities:

- Unify and harmonise the main European networks of surface and aircraft-based atmospheric measurements.
- Support data gathering at existing networks.
- Co-ordinate and access to data and data-products at a common data centre.
- Integrate surface measurements with those of satellites with emphasis on data gathered by NDACC stations.
- Develop new methodologies to use these data for satellite validation.
- Enable new ground based measurements complementary to satellites.
- Deduce biases and random errors in satellite observations, to identify long-term trends in tropospheric and stratospheric composition related to climate change.

Core objectives of GEMS

The GEMS project will create the first-ever system for operational global monitoring and medium & short range forecasts of atmospheric chemistry and dynamics. Much improved exploitation of the best available satellite and in-situ data will be achieved through assimilation into numerical models. By 2008, GEMS will produce near-real-time & retrospective analyses of greenhouse gases, reactive gases and aerosols in the troposphere and in the stratosphere on the regional and on the global scale. GEMS covers the atmospheric theme within the GMES initiative of the EC, and GEMS data products will provide valuable new analysis & forecast products for the GMES Service Element. Focus is on:

- Global Greenhouse Gases.
- Global Reactive Gases.
- Aerosols.
- Regional air quality.
- Data assimilation and production.
- Data validation.

Core objectives of DYNAMITE

The aim of the project is deepen the understanding of strongly and weakly coupled processes underlying the natural variability of ENSO and NAO/AO. It will evaluate the representation of the coupled processes underlying ENSO and the NAO in state-of-the-art models used to predict climate change. Furthermore, it will advance understanding of the response of ENSO and NAO/AO to climate change and will assess the role of ocean biology in the variability of the tropical coupled climate system, including ENSO. The coupling between the Troposphere and Stratosphere forms part of the modelling activity as indicated below:

- To quantify strongly and weakly coupled processes underlying the natural variability of ENSO and NAO/AO.
- To evaluate the representation of the coupled processes underlying ENSO and the NAO in state-of-art models used to predict climate change including tropospheric/stratospheric coupling.
- To identify the response of ENSO and NAO/AO to climate change.
- To quantify the role of ocean biology in the variability of the coupled climate system, including ENSO.

Core objectives of ATTICA

The SSP ATTICA will provide a coherent series of assessments of the impact of transport emissions on climate change and ozone depletion. Three assessments will cover the emissions of single transport sectors (aviation, shipping, land traffic). Another assessment will deal with metrics that describe, quantify, and compare in an objective way the effects of the transport emissions in the atmosphere. Finally, the synthesis will summarise the key results of the individual reports in a coherent way, considered as a reference document for stake holders and environmental policy makers.

Core objectives the HCFC workshop
The international HCFC workshop, scheduled for 5-6 April 2008, Montreal, Canada, is focusing on the reduction of HCFC consumption in developing countries between now and 2015. Furthermore, it will identify ways to further reduce consumption and dependence on HCFCs between 2016 and 2040. Specifically, the workshop will provide developing country stakeholders with the technical tools and needed to phase-out HCFCs (e.g., information on viable alternatives, technology transfer, funding opportunities) and to build consensus among stakeholders on next steps for this important issue that faces all of the Parties to the Montreal Protocol.

STRATOSPHERIC AND UV RESEARCH IN THE 7TH FRAMEWORK PROGRAMME (FP7, 2007-2013)

UV and stratospheric research will remain a priority in FP7, mainly implemented under **Theme 6: Environment (including Climate).** More general speaking**,** research under the Environment theme **6.1 Climate Change, Pollution and Risks** will support the implementation of relevant international environmental commitments, protocols, and initiatives concluded by the European Union and its Member States, such as the UN Framework Convention on Climate Change (UNFCCC) and the Kyoto and Montreal Protocols, respectively. Research is considered as an essential component in the increasing efforts of the European Commission to combat climate change and stratospheric ozone depletion. Furthermore, health risks associated with changing UV radiation levels will be investigated under **Activity 6.2 Environment and Health**.

Please note that **Programme 9. Space** under the **GMES** initiative also supports a topic on '**pilot services atmosphere in new application fields'** which includes stratospheric aspects.

In preparation of FP7 the European Commission had established a Science Panel on Atmospheric Research to discuss and prioritize research needs. As a results a report has been prepared and was published, entitled “Atmospheric Change and Earth Science AIRES III: Research challenges” (EUR 21465). The report indicates a number of topics (given below) which should receive high priority in FP7. Most of them include UV and stratospheric research aspects:

1. **Bio-geochemical cycles and climate**
2. **Atmospheric self-cleansing capacity**
3. **Lower-middle atmosphere interactions**
4. **Aerosols, clouds and water cycle**
5. **Global change and radiation transfer**
6. **Air quality, megacities and global change**

Consequently, in the **first call of FP7, Programme 6. Environment (2006/2007)**, the European Commission has opened a topic on **megacities, air quality and climate.** As a result of this call two projects will be funded. Furthermore, in response of the first call of **Programme 9. Space**, one project on atmospheric data services, closely linked to IP GEMS will be supported.

The second FP7 call (**Programme Environment)** has been launched end of November 2007, deadline 25 February. It included two topics which are directly relevant for UV and stratospheric research. It is expected that for each topic at least one project will be funded. Headlines and research objectives are described below:

Area 6.1.1.2 Emissions and Pressures: Natural and anthropogenic

ENV.2008.1.1.2.1. Climate-chemistry interactions in the stratosphere related to ozone depletion

Anthropogenic emissions of chemical species have altered the atmospheric composition with long lasting impacts and consequences such as changing air quality, the forcing of climate change and stratospheric ozone depletion. Climate change in turn is affecting atmospheric chemistry with many unknown feed-back mechanisms and may further delay ozone recovery. Changes in stratospheric composition need to be detected. Research should help to better understand stratospheric dynamics, trends and processes of stratospheric composition changes, the role of climate-chemistry interactions, including the dynamical response of the stratosphere to the chemical composition changes, and its impact on stratospheric ozone depletion. Feed-back mechanisms between climate change and stratospheric processes need to be better understood in order to predict the future evolution of ozone abundance. Standard climate change scenarios should be applied to assess the impact on the future evolution of stratospheric composition and its impacts on the climate.

Area 6.1.2.1 Health effects of exposures to environmental stressors

ENV.2008.1.2.1.5. Quantification of changing surface UV radiation levels and its impact on human health

The overall aim is to better characterise changing UV exposure in relation to important leisure (skiing, beach) and working activities in Europe and to assess its impact on human health (e.g. immune response) including risk/ benefit estimations. Furthermore, improved measurement techniques and radiative transfer models should be developed to better represent radiation in climate models and for prediction of future UV levels. Spectral radiance distribution at ground level under changing climate and atmospheric composition condition should be quantified, taking into account e.g. the role and interference of clouds and atmospheric pollution at ground level.

Projects finally supported under these topics will ensure continuation of UV and stratospheric research at European level, also maintaining a critical mass essential for future contributions to international ozone and UV assessments.

FUTURE ACTIVITIES

The complexity of the atmospheric processes, the scale of the scientific problems and the potential devastating impact on humans and the ecosystems caused by climate change, stratospheric ozone depletion and changing UV radiation require real interdisciplinary research collaboration. This has already started under the 5th and 6th Framework Programmes and, as indicated above, and will continue in the 7th Framework Programme. The AIRES III report points to the need to consolidate and strengthen these efforts to establish a solid scientific basis for developing policy options to protect the stratospheric ozone layer and the climate system. The European Commission will largely follow the suggestions as indicated in the AIRES report and will implement these topics in the cause of FP7.

Moreover, the European Commission is prepared to take new challenges onboard. In particular, the ongoing discussions regarding new laboratory measurements and (contradicting) results related to chlorine monoxide dimer absorption cross section are of concern. If the new laboratory results proof to be correct, than there is a serve lack of understanding of the polar stratospheric ozone loss rate. In 2007 a number of consultations and meetings have taken place on this pending issue. In any case, depending on the outcome of these discussions, the European Commissions is prepared to address this scientific problem in a coming call.

Table 1 : Relevant research projects supported under FP6

SCOUT-O3 ***(Stratosphere-Climate Links With Emphasis On The UTLS)***
Co-ordinator: Prof. John Pyle, University of Cambridge, UK
Budget: 15.000.000 €
Starting date: 1 May 2005 Duration: 5 years
Web-link: http://www.ozone-sec.ch.cam.ac.uk/scout_o3/index.html

QUANTIFY ***(Quantifying the Climate impact of Global and European Transport Systems)***
Co-ordinator: Prof. Robert Sausen, DLR, DE
Budget: 8.388.172 €
Starting date: 1 March 2006 Duration: 5 years
Web-link: http://www.pa.op.dlr.de/quantify/

GEOMON ***(Global Earth observation and monitoring of the Atmosphere)***
Co-ordinator: Prof. Philippe Ciais, CEA, FR
Budget: 6.621.740 €
Starting date: 1 February 2007 Duration: 4 years
Web-link: http://geomon.ipsl.jussieu.fr/

GEMS ***(Global and regional Earth-system (Atmosphere) Monitoring using Satellite and in-situ data)***
Co-ordinator: Dr. Adrian Simmons, ECMWF, UK
Budget: 12.450.000 €
Starting date: 1 March 2005 Duration: 4 years
http://www.ecmwf.int/research/EU_projects/GEMS/
DYNAMITE ***(Understanding the Dynamics of the Coupled Climate System)***
Co-ordinator: Prof. Helge Drange, NERSC, NO
Budget: 2.000.000 €
Starting date: 1 March 2005 Duration: 3 years
Web-link: http://dynamite.nersc.no

ATTICA ***(European Assessment of the Transport impacts on Climate and Ozone Depletion)***
Co-ordinator: Prof. Robert Sausen, DLR, DE
Budget: 680.000 €
Starting date: 1 June 2006 Duration: 3 years 6 months
Web-link: http://www.pa.op.dlr.de/attica/

HCFC workshop
Co-ordinator: ICF international
Budget: 300.000 €
Starting date: 1 January 2007 Duration: 1 year 6 months
The HCFC workshop is scheduled for 5-6 April 2008, Montreal, Canada

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