EUROPEAN UNION

European Research on Stratospheric Ozone and UV Radiation

INTRODUCTION

Stratospheric research has been coordinated at European level since the late 1980s, building on a number of trans-national collaborative initiatives and EC projects supported by the research Framework Programmes (FPs) of the European Commission. 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 steady stratospheric cooling trend and new record low temperatures.

Research priorities within the 4th Framework Programme (FP4, 1994-1998) have shifted towards improving our understanding of the processes affecting stratospheric ozone over Northern Europe. The Third European Stratospheric Experiment on Ozone (THESEO 1998-2000) was a major component of this coordinated programme. At that time research focused on the mid-latitude lower stratosphere, the interaction with other layers of the atmosphere, the Arctic vortex, the tropics and sub-tropics.

Stratospheric research carried out under FP5 (1998-2002) was building on FP4 achievements with the emphasis to understand, quantify and predict stratospheric changes. This interdisciplinary research has been implemented through individual projects organised in research clusters addressing similar topics (details below).

The ongoing 6th Framework Programme (FP6, 2002-2006) is focusing on stratospheric climate interactions and on the impact of the transport modes on the upper troposphere/lower stratosphere (UTLS). Research is organised and implemented by 2 large Integrated Projects (IPs): SCOUT-O3 (Stratosphere-Climate links with emphasis On The UTLS) and QUANTIFY (Quantifying the Climate impact of Global and European Transport Systems), respectively.

Stratospheric research at European level was effectively co-ordinated by the EU Science Panel on Atmospheric Research and the European Ozone Research Coordination Unit (EORCU). The Science Panel has provided advice to the EC regarding future direction and priorities of atmospheric research for the currently running 6th Framework Programme (2002-2006) and to establish the coming 7th Framework Programme (beyond 2006). EORCU was responsible for the co-ordination of research clusters formed in the course of the 5th Framework Programme (see Table 1). EORCU also serves as the project office/co-ordination unit of the SCOUT-O3 IP funded under the 6th Framework Programme.

Effective links are maintained with existing international observational programmes such as the Network for the Detection of Stratospheric Change (NDSC) and the Global Atmosphere Watch programme of the World Meteorological Organisation (WMO-GAW) which already provides a large degree of coordination for a large number of European groups. 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 has provided an effective co-ordination mechanism and has helped European scientists to make major advances to the understanding of the stratospheric ozone and UVB issue. As a result, they have significantly contributed to international assessments and research experiments carried out in support of the Montreal and Kyoto Protocols.

Stratospheric Research under the 5th Framework Programme (1998-2002)

The scientific objectives of stratospheric research were addressed under ***Area 2.1.2 Stratospheric Ozone Depletion*** **in the work programme Global Change, Climate and Biodiversity, Key Action of the EC's Environment and Sustainable Development Programme:**

2.1.2 Stratospheric ozone depletion, in support of the Montreal Protocol

The target is the quantification and prediction of ozone depletion in the stratosphere and the increase of UV-radiation levels at the Earth's surface. This focuses on the quantification of anthropogenic and natural emissions of ozone depleting substances and their transformations; reduction of the uncertainties in stratospheric-tropospheric exchange processes and the impacts of aircraft emissions; quantification of ozone loss in the stratosphere over Europe and the linkages with the polar, tropical regions and the upper troposphere; understanding of stratospheric cooling and its links to tropospheric global warming, and better quantification of its impacts; accurate determination of the atmospheric UV radiation field and its changes in the European region."

During FP5 overall 32 research projects on stratospheric ozone and UV radiation were supported by the EC (see Table 1). They include the CRUSOE concerted actions entitled "Coordination of Research into Understanding of Stratospheric Ozone over Europe" which supports EORCU. These projects together with national activities were coordinated by the following five clusters:

1. Stratospheric ozone loss (SOLO)

The central objective was to quantify the ozone depletion in the northern and middle latitudes throughout the year. The research involved measurements made by balloons, aircraft, ground-based and satellite instruments which were used to understand the causes of chemical ozone loss under various atmospheric conditions. The analysis of THESEO data continued after contract extension. These studies helped to improve our understanding of the long term trends observed over polar and mid-latitudes.

2. Coordination of Research for the Study of Aircraft impact on the Environment (CORSAIRE)

The basic objective was to address persisting uncertainties concerning the upper tropospheric and lower stratospheric processes in the tropopause region related to aviation emissions. Research focused on the formation and evolution of contrails and particles and the ozone budget in the upper troposphere and lower stratosphere region. This work also included improved predictions and scenario calculations of aviation-induced future changes in climate. It has provided the aviation-aeronautics communities and decision-makers with options to mitigate climate impact from aircraft emissions.

3. Atmospheric UV radiation (ATUV)

The main objective was to study the evolution of the UV radiation at the earth's surface and in the atmosphere over the last ten years. Existing databases were extended and further developed to provide additional products, such as a European UV climatology using spectral UV irradiance measurements from 26 stations in Europe including actinic flux data suitable for use by a wide user community.

4. Ozone-climate interactions (OCLI)

The core objective was to study the physical and chemical impacts on climate in the past caused by variations in stratospheric ozone and to study to what extend these variations can be explained by natural and/or anthropogenic forcing. This includes scenario calculations of future

greenhouse gas emissions and halogen concentrations in order to investigate the impact of the Montreal and Kyoto Protocols.

5. Global atmospheric observations (GATO)

The main objective was to coordinate atmospheric measurements at European level to provide data at regional and global scale for ozone and related species. GATO aimed also to help ensure that all field and satellite measurements made within the European programme are available for validation and for scientific analysis. The work in GATO involved in-situ and satellite measurements, including data from new campaigns. This research contributed significantly to international observational programmes.

The clusters have been effectively co-ordinated by EORCU and the Research Directorate General. Results have been disseminated by specially organised workshops on particular topics, through special sessions at conferences (e.g. EGS) and international meetings such as the Quadrennial Ozone Symposia and the SPARC Assemblies.

VINTERSOL campaigns

VINTERSOL (Validation of INTERnational Satellites and study of Ozone Loss) was a series of major European field campaigns addressing stratospheric ozone and the natural sources of NO_x. VINTERSOL ('Winter sun' in the Scandinavian languages) has taken place from late 2002 until early 2005. Like the previous European campaigns, VINTERSOL relied on joint support from national funding agencies and from the EC's Environment and Sustainable Development programme.

The following VINTERSOL campaigns have been carried out:

- a small balloon campaign in the tropics in late 2002;
- intensive Arctic ozone loss studies in the 2002/03 winter/spring;
- ozone loss studies in the Antarctic winter and spring 2003; and
- balloon and aircraft studies in the tropics in early 2004
- balloon and aircraft studies in the tropics in early 2005.

Most of the research projects funded under FP5 already have or will finish by the end of 2005. Nevertheless, a number of measurement and modelling activities will run continuously yielding information on processes at longer time-scale in the stratosphere, partly supported by the FP6 IPs. For details please contact the EORCU web page http://www.ozone-sec.ch.cam.ac.uk/

Stratospheric Research under the 6th Framework Programme (2002-2006)

The scientific objectives of stratospheric research are 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**

1.5 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.

As a result of recent calls for proposals, 2 integrated research projects were selected focusing on ozone-climate interactions and UV radiation (SCOUT-O3), and on quantifying the impact of emissions from the transport sector on climate (QUANTIFY), respectively (see Table 2). SCOUT-O3 is a 5 years project which started May 1, 2004, supported by the EC with 15 Mill. €; QUANTIFY is a 5 years project which started March 1, 2005, supported by the EC with 8 Mill. €. Please note that the scientific ambition and financial support of these projects which adds up to 23 Mill. €, definitely exceeds that of individual FP5 research cluster.

In addition to the IPs, the Quadrennial Ozone Symposium 2004 (Kos, Greece, 1-8 June, 2004) has been supported through a Specific Support Action.

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 scheduled for November-December 2005, Darwin, Australia
- Tropical balloon campaigns planned for 2006/2007
- Age of air measurements planned for 2006
- UV-aerosol-cloud campaign, scheduled for spring/summer 2006 in Southern Europe

Core objectives of QUANTIFY

The main goal of QUANTIFY is to quantify the climate impact of global and European transport systems 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 planned for 2007 (Most of the modelling work carried out in QUANTIFY is based on existing data records)

The 4th (and last) call of FP6, which has been launched in July 2005 offers additional opportunities for stratospheric research. Among the priorities listed under Area 6.3.VI *Operational forecasting and modelling* a topic on *European atmospheric observation systems* (indicative budget 7 Mill. €) is included. It is designed to reinforce ground-based atmospheric measurements complementary to satellites to strengthen the European component of co-ordinated international observation networks such as NDAC. This should provide a good opportunity for the European stratospheric research community to safeguard continues long term measurements.

European Assessment

The EC has published its second assessment on European research in the stratosphere in late 2001. It took almost two years and over 100 scientists to prepare this assessment which is based on European research efforts during the last few decades and the analysis of 40 years of atmospheric data. It provides a thorough review of the progress of the European research programme on stratospheric ozone, UV radiation and aircraft impact on the atmosphere during 1996-2000, including THESEO. The results of the assessment endorse the position of the EU concerning the international agreements on ozone depletion (Montreal Protocol) and climate change (Kyoto Protocol), as well as the International Civil Aviation Organisation's regulation of the impact of aviation emissions. The assessment concludes among others that any ozone layer recovery could only become measurable around 2010 at the earliest.

The 4th FP6 call, launched in July 2005, includes under **Area IX** the following topic: **European assessment of the impact of transport on climate change and ozone depletion.** This assessment will, six years after the 1999 IPCC Special Report "Aviation and the Global Atmosphere", will provide an up-date of this report. The assessment will focus on atmospheric loading, impacts on climate change and stratospheric ozone depletion of gases and particulates from the air- and surface transport sectors, and will provide estimates of current and future trends based on FP5 project results. In case of successful application, first results are to be expected end of 2006.

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, stratostospheric ozone depletion and UV radiation require real interdisciplinary research collaboration. This has already started under the 5th and 6th Framework Programme and most probably, will continue in the 7th Framework Programme. The Science Panel on Atmospheric Research in a recent report, entitled "Atmospheric Change and Earth Science AIRES III: Research challenges", 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 report has identified a number of atmospheric research priorities within Earth System Science that will be most relevant for the future implementation of the 7th Framework Programme (2007-2013). In parallel, the proposal of the European Commission for the 7th Framework Programme under priority ***6. Environment (including climate change)*** is referencing the importance of changes in the atmospheric component of the Earth System in relation to

international commitments such as the Montreal Protocol. Therefore it is likely that stratospheric research remains a EC research priority. The 7th Framework Programme is expected to be adopted by the European Council and the European Parliament in 2006.

Table 1 : Research projects and clusters in FP5.

Stratospheric Ozone Loss (SOLO) cluster

CIPA (*Comprehensive investigations of polar stratospheric aerosols)*

THESEO 2000 – EUROSOLVE (*Improved understanding of stratospheric ozone loss by measurements and modelling contributing to THESEO and SOLVE)*

SAMMOA (*Spring-to-Autumn Measurements and Modelling of Ozone and Active species)*

TOPOZ III *(Towards the Prediction of Stratospheric Ozone III: The Partitioning of the NOy Components)*

QUOBI *(Quantitative Understanding of Ozone losses by Bipolar Investigations)*

EUPLEX *(European Polar Stratospheric Cloud and Lee Wave Experiment)*

Atmospheric UV radiation (ATUV) cluster

ADMIRA (*Actinic flux determination from measurements of irradiance)*

EDUCE (*European database for Ultraviolet Radiation Climatology and Evaluation)*

INSPECTRO *(Influence of clouds on the spectral actinic flux in the lower troposphere)*

Ozone-Climate Interactions (OCLI) cluster

SOLICE (*Solar influences on climate and the environment)*

DETECT (*Detection of changing radiative forcing over the recent decades)*

EUROSPICE (*European project on stratospheric processes and their impact on climate and the environment)*

PARTS (*Particles in the upper troposphere and lower stratosphere and their role in the climate system)*

CANDIDOZ *(Chemical and Dynamical Influences on Decadal Ozone Change)*

Global Atmospheric Observations (GATO) cluster

AMIL2DA *(Advanced MIPAS-Level-2 Data Analysis)*

GOA (*GOME Assimilated and Validated Ozone and Nitrogen Dioxide Fields for Scientific Users and for Model Validation)*

MAPSCORE (*Mapping of Polar Stratospheric Clouds and Ozone levels relevant to the Region of Europe*)

QUILT (*Quantification and Interpretation of Long-Term UV-Visible Observations of the Stratosphere)*

SOGE (*System for Observation of Greenhouse Gases in Europe)*

Coordination of Research for the Study of Aircraft impact on the Environment (CORSAIRE) cluster

MOZAIC-III (*Measurement of Ozone, Water vapour, Carbon monoxide and Nitrogen oxides by Airbus in-service aircraft (MOZAIC-III) - O_3 and H_20 budgets in the UT/LS)*

TRADEOFF (*Aircraft emissions: Contribution of different climate components to changes in radiative forcing-tradeoff to reduce atmospheric impact)*

INCA (*Interhemispheric differences in cirrus properties from anthropogenic emissions*

STACCATO (*Influence of Stratosphere-Troposphere Exchange in a Changing Climate on Atmospheric Transport and Oxidation Capacity)*

UTOPIHAN-ACT(*Upper tropospheric ozone : processes involving HOx and NOx. The impact of aviation and convectively transported pollutants in the tropopause region)*

CARIBIC 3 (*Civil aircraft for regular investigation of the atmosphere based on an instrument container)*

HIBISCUS (*Impact of tropical convection on the upper troposphere and lower stratosphere at global scale)*

SCENIC (*Scenario of aircraft emissions and impact studies on chemistry and climate)*

TROCCINOX (*Tropical convection, cirrus and nitrogen oxides experiment)*

Concerted actions

CRUSOE (*Coordination of Research into and Understanding of Stratospheric Ozone over Europe)*

CRUSOE II *(Coordination of Research into Understanding of Stratospheric Ozone over Europe II)*

***Two projects supported under Area 7.2 Development of generic Earth observation technologies* in the Global Change, Climate and Biodiversity, Key Action of the EC's Environment and Sustainable Development Programme:**

RAMAS *(Radiometer for Atmospheric Measurements At Summit)*
UFTIR *(Time series of Upper Free Troposphere observations from a European ground-based FTIR network)*

Table 2: Research projects in FP6.

Integrated Projects (IP)

SCOUT-O3 *(Stratosphere-Climate Links With Emphasis On The UTLS)*

QUANTIFY *(Quantifying the Climate impact of Global and European Transport Systems)*

Specific Support Action (SSA)

QOS2004 *(Quadrennial Ozone Symposium 2004)*

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