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STRATOSPHERIC PROCESSES AND THEIR ROLE IN CLIMATE

A Project of the World Climate Research Programme

# Report on the WCRP JSC Meeting

## Toulouse, France, March 11-16, 1996

The Joint Steering Committee (JSC) of the World Climate Research Programme (WCRP) met in Toulouse, France. M.-L. Chanin attended this meeting and presented the activities of the SPARC programme, as well as the recent major scientific results of concern for the SPARC community.

Extensive discussions were triggered by the release of the second full IPCC Assessment Report which concluded that « the balance of evidence suggests a discernible human influence on global change » but that there were still a number of uncertainties. Contribution of WCRP to help resolve the main uncertainties identified in the report was a subject of concern and discussion for the JSC.

One of the urgent needs is to better identify an anthropogenic climate change signal in the variability which could be partly explained by purely natural causes (solar, volcanic). In that line, and to complement near-surface parameters, a better knowledge of the change in the vertical profile of atmospheric temperature, which has been suggested for a long time as a possible « fingerprint » of greenhouse-gas induced climate change, was clearly stressed at this meeting. In one of the two lectures given during the meeting, B. D. Santer (LLNL) concluded that numerical simulation of such vertical changes needs to consider simultaneously change in $CO_2$, stratospheric ozone and anthropogenic sulphate aerosols, and that climate change detection investigations ignoring $O_3$ effects are likely to be unsuccessful. The contribution of SPARC on the stratospheric aspect of this issue is already approached by several SPARC initiatives from both the modelling aspect and the determination of trends in the vertical profiles of temperature, ozone and other minor species.

Liaison between SPARC and WGNE which could be achieved through GRIPS was highly praised, as well as a connection with CLIVAR which is focused on the identification of the source of variability in climate of both natural and anthropogenic nature.

A recommendation was again made for continuous monitoring of atmospheric concentrations of gases playing a main role in either the greenhouse problem or the ozone issue. The cooperation of SPARC with GAW and IGAC and a close connection with NDSC were encouraged.

A large WCRP Conference was announced to be held in 1997 aimed at considering WCRP priorities in the light of the IPCC 1995 Report. It would present the relevance of the research carried out by the different programmes to the expectation of society and set the priorities and objectives for the next 10-15 years. SPARC was asked to contribute to the preparation of this Conference.

● Marie-Lise Chanin
Co-chair of SPARC

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# SPARC STUDY-GROUP ACTIVITIES

## First GRIPS Workshop

Victoria, Canada, March 4-7, 1996
Conveners : S. Pawson, K. Kodera, T. Shepherd
Local convener : N. McFarlane

### Introduction

The GRIPS initiative (GCM-Reality Intercomparison Project for SPARC) aims at evaluation of the performance of GCMs that can resolve the stratospheric circulation. The initiative is open to all, but a model must include a realistic representation of the hydrological cycle and a full radiation scheme, so that it can be used as a fully interactive climate model. The workshop in Victoria provided the first opportunity to formally discuss the project structure/tasks. Of the 14 participating groups, 12 were represented. Expenses were covered by the Canadian AES, the WCRP and participating institutions.



### Scientific Objectives

The objectives were :

• For each group to make a presentation on their model, to bring standard documentation about their models, detailing the numerical, physical, and (where appropriate) chemical aspects of their code. A list of standard diagnostics were also requested in a form that should facilitate the intercomparison of the simulations.

• To discuss the GRIPS structure/objectives (a plan for 1-3 years and ideas for the longer term).

• To consider how GRIPS could liaise with other intercomparisons, particularly AMIP (Peter Gleckler represented AMIP at the workshop).

### Summary of presentations and posters

**S. Pawson** spoke on the objectives of GRIPS and how it may fit with other model intercomparison projects. **G. Boer** outlined his experience of model intercomparisons during the last two decades pointing out possible pitfalls as well as the successes.

Of the participating models, some have been reported in the literature for several years (e.g., NCAR CCM **[B. Boville]**, MRI/LRF [M. Chiba], UCLA **[J. Farrara]**, GFDL SKYHI **[J. Wilson]**) ; for a few models the first results are just becoming available (e.g., the Canadian Middle Atmosphere Model (MAM) **[S. Beagley]**, the UKMO model **[R. Swinbank]**), while others are of intermediate age. The location of the upper boundary varies between the models: both the UCLA and the MRI/CL **[K. Kodera]** models extend to 1 hPa, the highest tops being at 0.001 hPa in the Canadian MAM and the UGAMP model **[J. Thuburn]**. The treatment of physical processes differs considerably. The tropospheric physics varies in complexity, generally being more comprehensive in those models developed recently from tropospheric climate models, such as the FUB **[U. Langematz]** and MPI **[E. Manzini]** models. The differing histories of the models are also shown by their applications : two have been actively used for the problem of stratospheric data assimilation, at NASA-GSFC **[L. Coy]** and the UKMO, while others applied extensively for climate change research (notably the NASA-GISS model **[N. Balachandran]**). In most models the trace gas distributions are specified, but four of them -MAM, UCLA, NCAR **[B. Boville]**, and CNRM **[P. Simon]** models- include the option to transport ozone and other reactive trace gases and include chemistry modules of differing complexity. Chemistry-transport packages are being actively developed by several other groups. **P. Gleckler** summing up the AMIP status highlighted technical problems associated with such projects, and the need to tightly define any experiments and to ensure good quality control for all data was emphasised. Stratospheric aspects of the AMIP simulations **(J. Farrara** representing **R. Mechoso)** were presented (few of the AMIP models extend far into the middle atmosphere). **L. Gates**, the leader of the PCMDI where AMIP is coordinated, offered any help to GRIPS (storing data at PCMDI and the use of their comprehensive analysis and graphics packages). **P. Merilees (AES)** spoke about the Canadian middle atmosphere data assimilation initiative (modelling and observation). Some observational data available for model validation were discussed by **S. Pawson** (radiosonde, satellite), **R. Swinbank** (UKMO assimilations) and **L. Coy** (GSFC assimilations). **K. Kodera** studied recently the statistical links between stratosphere and troposphere in three different GCMs ; even with three models the results showed considerable variations (this type of study is an excellent example of how intercomparisons of the model output can be made and has direct relevance to the central themes of SPARC).

### Short-term aims

Much discussion was devoted to the first stage of the project, when existing runs should be analysed. The idea is to provide some overview of the current state of modelling to report to the SPARC SSG (which would then be used as a basis for future intercomparisons including dedicated integrations).

**Task 1.** 'Documentation of the models' is to ensure that all models are documented to the same standard (that produced by

Phillips, 1995, for the AMIP models, is a level to aim at) : numerical and physical aspects of the models, boundary conditions used in the integrations, and the storage of data. It should include references to published work and also allow for easy updates when the model is changed (while retaining the ability to cross-check the older integrations).

**Task 2.** 'Basic Climatology', is a documentation of the basic performance of the models. The quantities to be compared are (for 12 months, 10 years, at standard levels) : monthly means of *u, T, Z,* eddy fluxes of heat and momentum, meridional/vertical circulation, forcing for *u* and potential temperature, tracers ($O_3$, $H_2O$) and clouds, zonal wind at 60°N/S and $T_{NP/SP}$. These ought to be provided to FUB as ASCII files or SUN/UNIX-compatible binary files, along with a data description and routines to read them. An alternative form is input files for the GRADS plotting, along with the 'ctl' files. These data would only be used for an intercomparison of the models ; any publications which may use these data would include all contributors as co-authors. Groups are requested to provide data for each month of 10 years of their integration, or for the longest period possible. The levels are : 1 000, 850, 700, 500, 300, 200, 100, 70, 50, 30, 20, 10, 5, 3, 2, 1, 0.5, 0.3, 0.2, 0.1, 0.05, 0.03, 0.02, 0.01 hPa (some flexibility allowed).

'Optional' tasks are :

**Task 3** (K. Kodera) 'Statistical connections between the stratosphere and troposphere' can be performed using the zonal-mean fields and the monthly-mean temperature and height fields.

**Task 4** 'Stratospheric warmings' (synoptic evolution) is investigated individually for all models, with discussion at the next workshop.

**Tasks 5-8** are pilot studies with a small number of models. [**5**-'Travelling waves and tides' (J. Thuburn), **6**-'Tropical oscillations and waves' (J. Wilson), **7**-'Strat-trop exchange' (P. Simon), **8**-'Spatial wavenumber spectra' (J. Koshyk)].

## Medium-term aims

These involve some specific experiments within 1-2 years (some off-line tests of the radiative transfer schemes, diagnostics of GW drag, some GCM integrations).

### Radiation schemes

Many (but not all) schemes were validated in the WCRP/ICRCCM (InterComparison of Radiation Codes for Climate Models); further, the tests were for five profiles and concentrated on the troposphere. It is thus meaningful to perform some additional tests for the middle atmosphere :

• Zonal-mean (latitude-height) sections of radiative heating would be calculated using each radiation scheme, with identical temperature and trace gas distributions, surface albedo and emissivity, and incoming solar radiation. The calculations would first be performed for January, then for other months if motivated (coordinator U. Langematz).

• The possibility of obtaining reference line-by-line calculations for the same input data should be investigated. This would serve as a reference for the current study but also a unique opportunity to define a set of reference heating rates for the middle atmosphere.

### GW drag

GRIPS should coordinate activities with the SPARC GWPP Group. Also, two possible aspects of GRIPS concern the distribution of the drag in the atmosphere :

• From the assimilated data it may be possible to determine the required sub-gridscale drag by examining the 'correction' to the model fields introduced at the assimilation timesteps. L. Coy would investigate this using the DAO assimilated data.

• From the zonal net heating rates determined in the radiation calculations it is possible (often after some correction of the global thermal balance) to determine the diabatic circulation and thereby infer the total eddy forcing of the mean flow (see Shine, 1989, and others). If the large-scale wave drag can be determined from the eddy fields, some estimate of the drag can be made for the different radiation schemes. This approach could place some bounds on the estimates of GW drag in the upper stratosphere and mesosphere.

### GCM integrations

A set of dedicated experiments for GRIPS should be performed to give a directly comparable series of integrations with all the models, but also so that all participants obtain some useful results for their own work. The model integration should be for one winter season in the northern hemisphere. All model runs should use the same : incoming solar radiation, prescribed $CO_2$ concentration, zonal-mean $O_3$, prescribed stratospheric $H_2O$, and SST and sea-ice extents : then the boundary conditions and prescribed trace gases should not affect the results (also desirably the same initial conditions). All groups should then perform two integrations :

• The first should include no parameterisation of sub-gridscale drag on the zonal mean state but some artificial dissipation of waves at the upper model levels is permitted (to prevent spurious reflections from the upper boundary).

• The second is identical to the first, but an additional forcing is added at the top levels as a crude representation of sub-gridscale drag. All other forcing terms would be calculated interactively, using the usual model formulation. A prescribed body force should be applied imposed above 1 hPa in the models and tuned so that all models impose the same net force per unit mass, although the vertical distribution would be flexible to accommodate the different upper boundaries and positioning of the model levels.

These model integrations would be compared quite thoroughly. Some groups may perform a third

integration, using their usual formulation of sub-gridscale drag.

## Long-term aims

One of possible directions for GRIPS would be to perform long integrations for intercomparison ; a close liaison with the AMIP subproject directed towards the stratosphere may be possible.

One central issue may be the radiative forcing due to stratospheric trace gases, and the impact of ozone change (with potential coupling with dynamics) on climate. Important here is the ability of the GCMs to adequately transport the trace gases and the success of the chemical components of the models (e.g., the NCAR CCM recent results concerning transport show apparently severe numerical deficiencies in the formulation of the vertical advection). Chemical modules for the GCMs are in various stages of development. It is anticipated that GRIPS would eventually coordinate some aspects of modelling the stratospheric chemistry-climate feedbacks. Close liaisons with the SPARC initiatives for 'middle atmospheric water vapour' and 'UT/LS chemistry' are anticipated, with GRIPS concentrating on modelling aspects, possibly including long-term prediction and making attempts to put error bars on the certainty of the models.

## Other points

GRIPS should attempt to initiate a comprehensive home page system in Berlin, where all information would be available (documentation, reports). An attempt would be made to introduce a bulletin board for up to date discussion.

The second GRIPS workshop (a small, closed meeting) will be held in Berlin in the spring of 1997.

## Participants in GRIPS and Contact Scientists

CMAM, Canada (S. Beagley) ; CGAM, UK. (W. Lahoz) ; CNRM, France (P. Simon) ; FUB, Germany (U. Langematz) ; GFDL, USA (K. Hamilton) ; GISS, USA (D. Rind) ; GSFC, USA (L. Coy) ; JMA, Japan (T. Iwasaki) ; LaRC, USA (W. Grose) ; MPI, Germany (E. Manzini) ; MRI/LRF, Japan (M. Chiba) ; MRI/CL, Japan (A. Kitoh) ; NCAR, USA (B. Boville) ; UCLA, USA (R. Mechoso) ; UKMO, UK. (R. Swinbank).

● Steve Pawson



# STTA Meeting

## Berlin, Germany, December 18-19, 1995
## Convener : V.A. Ramaswamy

The Stratospheric Temperature Trends Assessment (STTA) group met in Berlin (Free Univ.) on December 18-19, 1995 to discuss further developments regarding this SPARC project. The meeting focused on two principal subjects : the data and time series, and trend determination strategies and analyses. Data has now been made available by 11 different groups. Not all the datasets are strictly independent. The datasets include those derived from instrumental measurements (e.g., satellite, radiosonde, lidar), and those obtained using, in addition, an analysis technique involving a model. In general, the time series from the different datasets show a reasonable coherence of the temperature anomalies, especially in the lower stratosphere. A deadline of July 1996 was established for receipt of additional new datasets that the STTA will consider in the present phase of the project. (Since the Berlin meeting, some data from the Russian radiosonde stations has been received).

Three different time periods were selected on a preliminary basis to examine the trends : 1979-1994, 1965-1994 and 1965-1979. The trends will be analysed in 10° latitude belts and at five height levels ranging from the lower to the upper stratosphere. Since different trend methods have been used in the literature in the past, it was decided that tests be conducted to identify differences between the various techniques. It was expected that an optimal technique will eventually be chosen for the project's objectives. Some preliminary determination of the trends and their significance using one of the techniques has been made. The possible influences of the QBO, volcanic aerosols, solar variations, and dynamical variability on the trends, and the need to consider these factors explicitly in the understanding of the trends, was reiterated.

Fixed Dynamical Heating (FDH) and General Circulation Model (GCM) simulations will be utilised in analysing the possible causes of the trends. Simulations include the stratospheric temperature changes expected due to increases in the well-mixed greenhouse gases, and due to the global decreases in ozone as reported by various satellite measurements. In the case of ozone, estimates will be made of the uncertainties in the calculated effects due to uncertainties in the

vertical profile of the ozone loss. In this regard, further calculations of temperature change in the stratosphere using the various ozone loss datasets were reported, and the relative roles of changes in different trace gases on the long-term trends were discussed. Models will also be employed to assess the extent of dynamical variability, which could prove to be a decisive factor in interpreting high latitude temperature trends. Discussions regarding the structure and contents of the report to be prepared by the group were also initiated.

● Vincent Ramaswamy

# Ozone, Aerosol and Climate of the Upper Troposphere and Lower Stratosphere (UT/LS)

The upper troposphere and the lower stratosphere are regions of the atmosphere where it is difficult to separate, in time scale, the chemistry and atmospheric motions. This is also the coldest region of the lower atmosphere, the pressures are still large, and condensable species are significant. Heterogeneous chemistry plays a critical role in this region. In addition, this is the region where the chemistry of ozone is least well understood but has the most impact in terms of climate. The current concerns are losses of ozone in the lower stratosphere and increases in the upper troposphere, both of which have important climate effects. Understanding the UT/LS region is also of immediate practical concern for issues such as the effects of subsonic and supersonic aircraft on the atmosphere.

Therefore, the SPARC Group on UT/LS will focus its efforts on better understanding of the chemistry in this region and facilitating inclusion of the chemistry in numerical models. The group will also bring the unique conditions of this region to the attention of laboratory chemists who need to make measurements under temperature and pressure conditions that are not normally used in the laboratory. Close interactions with the active field measurements community will be fostered. To this end, a working relationship with IGAC will be developed.

Composition of the SPARC group on UT/LS :

Co-Chairs : I. Isaksen (Norway) ivar.isaksen@geofysikk.uio.no, A. R. Ravishankara (USA) ravi@al.noaa.gov

Current Members : J. McConnell (Canada), M. Chipperfield (UK), S. Solomon (USA), A. Thompson (USA), A. Wahner (Germany).

During the last years there were many significant findings by individual PIs about the LS/UT (it clearly shows that our field is very active and good work is being done). Yet, it is important to bring to focus these activities and also foster free exchange of information between scientists who are from highly varied disciplines. These are the two main interests of the group.

## Near-Term Plans

It has been identified that one of the primary areas of uncertainty in dealing with UT/LS is the treatment of heterogeneous processes in numerical models. Laboratory data on heterogeneous processes have to be parameterised in a physically sound basis into forms that are easy to use in the models. Further, the growth in laboratory information is fast but its transfer to modellers is slow. Similarly, information from modellers is slow in reaching the laboratory scientists. To facilitate the transfer and explore the approaches that will be most fruitful in including heterogeneous and homogeneous processes in the models, the group is planning two workshops : (1) How to include heterogeneous processes in numerical models and (2) What are the kinetics and photochemical parameters that most affect UT/LS and how to obtain that information.

The first workshop will be held in Strasbourg, France during October 21-23, 1996 (close to the European Symposium on effects of aircraft, which will be held in Paris the week before) The local host has been identified (Prof. P. Mirabel) (see the announcement of the workshop in this newsletter). The workshop will include presentation of the latest results from laboratory scientists, field measurements scientists, and numerical modellers. A format for parameterisation, where heterogeneous reaction rates can be expressed as first order rate coefficients for removal from the gas phase, will be explored. The findings of the meeting will be documented as a report. The second workshop is still in its formative stages. It will most likely be held in Boulder CO, USA during the early part of 1997. In addition to the workshops, the group will expand the involvement of the very large group of atmospheric scientists who are making field measurements in UT/LS.

● A. R. Ravishankara

# SPARC-IOC Workshop on Trends in the Vertical Distribution of Ozone

## Observatoire de Haute Provence, July 8-11, 1996
## Conveners : Neil R. P. Harris, Robert D. Hudson

## Introduction

Proper understanding of the observed long term decrease in ozone is needed in order to be able to predict with confidence future changes in ozone and the implications of these changes on UV-B and climate. Accurate quantification of the observed changes is a pre-requisite for this understanding. The trends in ozone were last fully assessed in the WMO-UNEP Scientific Assessment of Ozone Depletion in 1994. Changes in total ozone are well characterised. At mid-latitudes in the northern hemisphere the trends from 1979 to 1994 found in the combined SBUV/SBUV-2 record (Hollandsworth et al., 1995) are significantly negative in all seasons and are larger in winter/spring (up to 7 %/decade) than in summer/autumn (about 3 %/decade). In the tropics there seems to have been no statistically significant change in total ozone. Trends in the southern mid-latitudes are significantly negative in all seasons (3-6 %/decade) and there is a smaller seasonal variation than in the north. From 1979 to 1991, the agreement between the trends derived from the SBUV, TOMS and the ground-based Dobson network records is better than 2 %/decade.

The bulk of the loss in total ozone at mid-latitudes has taken place at altitudes between 15 and 25km. The available long term records for this altitude region are sparse with nearly all of those longer than 10 years in the northern mid-latitudes. In this region there is good agreement between the ozonesonde and SAGE trends above 20km. However there has been considerable debate about the magnitude of the trends below 20km with SAGE giving considerably larger trends than the ozonesondes (-20±8 vs 7±3 %/decade). SAGE also reports large trends (-25 to -30 %/decade) in the very low stratosphere in the tropics, although it should be noted that there is very little ozone at these altitudes so that the effect on the total column is small.

A joint initiative to resolve these issues has been instigated by SPARC (Stratospheric Processes And their Role in Climate) and IOC (International Ozone Commission). A workshop was held at the Observatoire de Haute Provence from July 8-11 1996. 28 scientists from a number of countries attended to review the current state of knowledge about trends in the vertical distribution of ozone (see section 2). It was agreed that a report should be produced by the end of 1997, in time for use in the preparation of the next WMO-UNEP assessment planned for 1998 (see section 3). Successful completion of this report will involve a certain amount of work to be carried out in the next year.

## Workshop discussion

A large part of the meeting was dedicated to discussing the current status of the data quality of the different measurement systems. Particular attention was paid to any changes in instrument performance over long time periods which might affect the ability to determine the true trends. In addition the participants discussed the ability of each of the systems to measure ozone correctly in the presence of volcanic aerosol.

After an overview of the current status of the different ozone profile measurement techniques, presentations of the results from individual research studies were presented. The attendees then split into three working groups to discuss the outline of the chapters to appear in the SPARC/IOC report.

## Current status of the data from the different measurement systems

Four measurement techniques have records long enough for long term trend studies : SAGE, ozonesondes, SBUV and Umkehr. Other techniques have been used for shorter lengths of time and are planned for use in the future, e.g. in the Network for the Detection of Stratospheric Change (NDSC). Lidar, HALOE, MLS and ground-based microwave instruments were specifically discussed at this meeting.

### SAGE

The overview of the current status of the ozone measurements made by the Stratospheric Aerosol and Gas Experiment (SAGE) satellite instrument was presented by J. Zawodny (NASA/LRC, USA). The SAGE satellite data set comprises the longest term satellite measurements of the ozone profile including the lower stratosphere. The SAGE I instrument was operational from 1978 and 1981. SAGE II was launched in 1984 and is still working. SAGE is a solar occultation instrument making measurements at six wavelengths at sunrise and sunset.

There has been a long-recognised problem with the altitude determination of the SAGE I ozone measurements which has been recently examined by Wang and Cunnold (1996). They found empirical corrections through comparisons with SBUV and SAGE II which have a latitude dependence unlike previous adjustments.

With these corrections the agreement in the upper stratosphere with trends derived from SBUV for the same time period is now good at all latitudes. The biggest improvement in the agreement is in the tropics where both records now show no significant trend at about 40km. There are currently no plans to revise the SAGE I measurements

The SAGE II data is currently being revised. Comparisons with other measurement systems have allowed the identification of possible improvements of the SAGE II ozone profiles. The most important of these, with regards to ozone trend determination, is the correction of an aerosol artefact in the ozone measurement (to appear in version 5.95). Other improvements include a correction for an electronic transient (version 5.94) and a drift in the 448nm channel (version 5.96), both of which will improve the $NO_2$ measurements. In order to measure ozone in the upper troposphere, a correction for the water vapour interference (not needed in the much drier stratosphere) will be introduced to reduce the spectral interference on the ozone measurement in the 600nm channel. The vertical resolution of the transmission measurements (currently 1km) and the derived constituent mixing ratios will be increased to 500m. All these improvements will be implemented in version 6, due to appear late in 1996. A major reformatting of the data will occur, including a more elaborate error calculation and better indicators of quality assessment.

## Ozonesondes

The ozonesonde data set comprises the most extensive and longest ground-based measurements of the ozone profile. Numerous comparisons between different types of sondes and other measurement systems have been carried out in the past few years. As well as the overview by H. Smit (KFA-Jülich, Germany) of the current status of the ozonesonde measurements, other presentations on the quality of the data and derived trends from individual stations were presented. The discussion focused on error sources (instrumental and procedural) which could induce apparent changes over time in the ozone measurements. Other issues raised were the ability of the sondes to measure ozone correctly above 26km (the pump correction factor) and the possible change in the tropospheric response of the Brewer-Mast sonde.

Recent chamber simulations of the performance of different instrument types, carried out as part of the GAW/GLONET programme, have helped quantify the characteristics of the different types of sondes and the differences between them.

It was generally agreed that the pump corrections currently recommended by the WMO (to allow for the changing efficiency with ambient pressure) may need to be revised. The correction varies for different types of sondes and also over time as the sonde technology evolves. The pump correction used could thus influence the trends calculated using the sonde data sets, and so is to be well understood and quantified.

The procedure of normalising the profiles with a total ozone column correction was also discussed. If the pump efficiency is not well corrected, this procedure could introduce altitude dependent trends. These issues are currently being examined and it was felt that within the next year, the quality of the trends measured by sondes will have improved.

## SBUV

R. McPeters (NASA/GFDC, USA) presented an overview of the current status of the data sets of the two Solar Backscatter UltraViolet (SBUV) satellite nadir viewing instruments between 252 and 306nm. The SBUV instrument was operational from 1978 to 1990, and the first SBUV-2 instrument from 1989 to 1994. Two further SBUV-2 instruments are currently operating. The measurements from the original SBUV instrument will be revised into a version 7 using the experience gained in the revision of the TOMS v7 data.

The discussion centred on the accuracy of the profile retrieved at low altitudes. The vertical distribution of ozone is retrieved with a vertical resolution of 6-10km, and is constrained by the SBUV total ozone measurement. Since the vertical resolution is poor, the retrieval below the ozone maximum is sensitive to the error at higher altitudes and to tropospheric ozone. The 1994 WMO-UNEP assessment did not present SBUV trends at altitudes below about 25km (30mbar), but did give the trend in the column amount between the ground and 30mbar. A recent comparison of SBUV with CLAES and MLS has shown a longitudinal discrepancy which is thought to be due to differences in tropospheric ozone (Ziemke et al, 1996).

The combined SBUV/SBUV2 data set has been used to derive trends (Hollandsworth et al, 1995). The SBUV trends in total ozone are more negative than those calculated using the TOMS data by about 1 %/decade. Comparisons with the trends derived from the SAGE stratospheric ozone column (above 16km) have shown a very good agreement (within 2 %/decade) though the SBUV trend tends to be slightly smaller, especially in the tropics.

## Umkehr

M. Newchurch (Univ. of Alabama, USA) presented an overview of the Umkehr technique which was first described in the 1930s. Measurements have been made routinely at some stations since the 1960s. Zenith sky observations are made at high solar zenith angles by Dobson spectrophotometers. The vertical distribution of ozone is inferred from the effect of the changing path of the sunlight through the atmosphere as the mean height of the Rayleigh scattering changes. The inversion procedure (similar to that used in the SBUV measurement) currently used (Mateer and DeLuisi, 1992) was discussed in great detail.

The dependence of the different Umkehr layers on the a priori profile and the total ozone amount used was reviewed since this subsequently places a limitation on which of the Umkehr layers should be used for trend calculations. The effect of aerosol on the retrieval errors was also discussed in detail. It has been demonstrated that for trend calculations, the errors induced are important mainly in the lowest and highest Umkehr levels (e.g., Newchurch and Cunnold, 1994).

### Lidar

An overview of ozone measurements by DIAL Lidar was presented by S. Godin (SA/CNRS, France). This self calibrating technique is used to measure the stratospheric ozone profile under clear sky conditions with a resolution of 0.5km at 20km and 5km at 50km at a small number of stations. The ability of the lidar to measure ozone in the presence of aerosol was discussed. At the expense of vertical resolution and precision, the perturbation of the ozone profile due to aerosol can be reduced by measuring the Raman scattering of molecular nitrogen. Comparisons with satellite measurements and ozonesondes show good agreement. An intercomparison of retrieval algorithms is currently being carried out for the NDSC along with other quality control investigations as ozone lidar measurements are one of the core measurements. The data record is still too short for trend calculations, but the lidar measurements are currently valuable for comparison with other measurement techniques.

### HALOE

The current status of the HALOE ozone measurements was presented by Jim Russell. HALOE is an IR solar occultation instrument which has been in operation on UARS since 1991. Comparisons with other measurements (satellite, sondes and lidar) show good agreement in the upper stratosphere. As with SAGE, the ozone measurement is sensitive to the accuracy of the altitude determination and so is especially sensitive in the lower stratosphere. An improved altitude calculation is being introduced in the next version of the data.

### MLS

L. Froidevaux (JPL, USA) presented the current status of the MLS ozone measurements. MLS is also on board UARS and measures the atmospheric emission of millimetre radiation. This technique has the advantage of high sampling frequency and coverage and is not affected by the presence of aerosols, ice clouds or temperature. Intercomparisons have shown the MLS ozone measurements at pressures of 46hPa and below to be systematically higher than other measurements, although no changes over time in the data quality have been identified. Ozone measurements at 100 hPa are currently considered a research product but should be included in any intercomparisons performed for the SPARC-IOC report. A new version of the MLS ozone measurements will be available for assessment within a year.

The available ground-based microwave measurements and their suitability for intercomparisons was discussed, the main limitation being the sparse data record.

## Planned report

### Introduction

At the outset it was recognised that the principle focus of the report would be the derivation of global ozone trends between the tropopause and 25km. If one looks at the data sources that are currently available, only the SAGE data set could provide the temporal and spatial coverage to meet this objective. However, in order to be confident that the trends derived are correct, two questions need to be answered. The first is does SAGE measure ozone ? ». The answer would seem to be obvious, however if we rephrase the question as 'are there systematic errors in the SAGE instrument or retrieval algorithm which could bias the derived ozone product ? » then the answer is not so obvious. The second question is « can one derive true global trends given the SAGE data coverage ? ». The group considered both of these questions, and came up with the following broad strategy. This strategy can be broken up into two, one for the altitude region above 25km, and the other for below 25km. For the region above 25km we have other global long-term data sets which can also be used for trend analysis, these are from the SBUV/SBUV2 instruments, and to a lesser extent the Umkehr/Dobson network. There is also data from the LIDAR network, although this data set has sparse global coverage. It will, however, be used to verify the accuracy of individual profiles determined by the satellite instruments. In addition, data from the MLS and HALOE instruments on the UARS satellite, and from the LIMS instrument on Nimbus-7 will be compared with the SBUV, SAGE and Umkehr data over shorter intervals to examine any possible seasonal or latitude biases, which would indicate systematic errors in the instruments. The SBUV/SBUV2 data has good spatial coverage and will be used to test the effect of the poorer spatial coverage of SAGE on the derived trends. The overall strategy is to provide confidence that the derived trends above 25 km are correct.

For the region below 25km a different strategy has to be used, as the SBUV/SBUV2 and Umkehr instruments are not sensitive in this region. For this altitude interval we must now rely on the ozone sondes and LIDAR measurements for the long-term comparisons. We will again compare the ozone profiles derived from SAGE II with those from HALOE and MLS, as a function of season to ascertain any seasonal differences in the retrieved ozone data. Individual profiles from the sondes, LIDAR, etc., will provide further validity of the derived profiles.

Two additional results could come from the analysis discussed

above. If the comparisons above 25km are positive, then one could consider extending the Umkehr data to earlier years, which would increase the time period over which trends could be obtained. If the comparison below 25 km is successful, then one could consider extending the sonde data to earlier years, and to the derivation of tropospheric trends.

The SAGE I ozone measurements should play an important part in this assessment as their use potentially extends the SAGE measurement back an extra 5 years, even though the SAGE I instrument only operated for 2-3 years. The recently revised LIMS ozone measurements should used to help characterise the SAGE I measurements.

The quality of the SAGE data (and of the other satellite instruments) depends critically on the quality of the NMC temperature analyses. The NMC analyses are being revised which will improve their quality and consistency over time. It will be important to have access to these revised data sets to be available for use in this assessment.

## Contents

The report will be divided into four chapters. Chapter 1 will discuss the instruments to be used in the analysis, and their algorithms characteristics with the aim of developing error estimates for the ozone measurements. Chapter 2 will compare the different data sets, and provide estimates of the quality of the data products. Chapter 3 will discuss the trends in ozone that can be derived from the data. Chapter 4 will provide a synopsis of the lessons learned from the overall study.

A team will be organised to write each chapter, headed up by two or more co-chairman. The co-chairmen for Chapter 1 are C. Rodgers (Oxford University, UK) and D. Hoffman (NOAA/CMDL, USA) ; for Chapter 2, J. Russell (Hampton University, USA) and H. Smit (KFA-Jülich, Germany) ; and for Chapter 3, W. Randel (NCAR, USA), R Stolarski (NASA/GSFC, USA), and D. DeMuer (BMI, Belgium). The chairmen for Chapter 4 have not been designated, the responsibilities have currently been assumed by N. Harris (EORCU, UK) and R. Hudson (Univ. of Maryland, USA).

## Timetable/ assignments

At the end of the session, a tentative timetable was agreed to, and writing assignments were made within each chapter working group. The timetable calls for a draft of each chapter to be written prior to the full meeting next July, which might be held in Cambridge, UK. It was the opinion of the participants, that whereas some of the communication between the participants can be done by e-mail etc., a face-to-face meeting of each group will be necessary sometime in early 1997. Financial support will be required by some group members to attend these meetings.

There are two large scientific meetings before next July, the Quadrennial Ozone Symposium in Italy this September, and the First SPARC General Assembly in Melbourne, Australia this December. Only a small number of the group participants are attending these meetings, nevertheless subgroup meetings are being arranged.

It was decided to set up a password restricted home page for the study, which would not only contain the most up-to-date copy of the draft report, but which would also contain data sets which were peculiar to the study. It was also agreed that these data sets would be considered privileged and only for the use of the study, however, any data used in the final report would be made freely available on the release of the report. Access to the satellite data sets would be made through this home page. The draft report will be considered a living document. Representatives from NASA/GSFC and NASA/Langley, kindly agreed to provide the home page, and to organise the data base.

In the presentations given at the meeting, a number of improvements to the SAGE I and SAGE II algorithms were identified, which should lead to a significant change in the quality of the retrieved ozone densities. Given the central nature of the SAGE data in the report, it is considered vital that these data be made available to the study in the near term in order that these improvements can be validated and documented prior to the final version of the report.

● N. R. P. Harris,
R. D. Hudson and C. Phillips

# Progress Report on SPARC 96

The First General Assembly of SPARC will be held in Melbourne on 2-6 December 1996. Sessions on the following themes have been organised :

- Troposphere-stratosphere GCMs
- Stratospheric climatology
- Trends in temperature, ozone and water vapour
- Gravity wave processes and parameterisation
- Stratosphere-troposphere transport
- Chemistry-climate interaction
- UV radiation and its impacts
- Other aspects of stratospheric processes

Preparation for the upcoming Assembly is in full swing. The second circular and call for papers was sent out in January 1996. The response was overwhelming with over 330 people from more than 20 countries having expressed interest in attending the Assembly. Over 280 abstracts have been received from about 240 people. Decisions on abstracts accepted for the Assembly were made in July 1996, with 272 abstracts accepted.

**Prof. Mario Molina,** joint recipient of the 1995 Nobel Prize for Chemistry, has accepted an invitation to participate in the Assembly. He will give a public lecture during one of the evenings. There are several other scientific activities planned around the Assembly. A short course for graduate students on « Atmospheric Chemistry and Transport » will be held in the week 26-30 November by the CRC for Southern Hemisphere Meteorology at Monash University. A number of short meetings of SPARC Working Groups will also be held around the time of the Assembly.

The registration brochure together with other Assembly information were sent out in July to the paper authors and others who have expressed interest in participation.

***For further information, contact Ms Meki Wong, fax: +61 3 9905 9689 or e-mail: sparc96@vortex.shm.monash.edu.au or see the SPARC96 WWW site at http://www.shm.monash.edu.au/sparc96/sparc96.html.***

David Karoly



# Symposium on the Global Atmospheric Effects of Aviation

## Virginia Beach, VA, USA, April 14-19, 1996

The sponsors for this symposium were the Association of European Research Establishment in Aeronautics, EC, IPCC, ICAO, NASA, NOAA, UNEP, and WMO. The objective was to bring scientific, technology and policy leaders together to review the status of relevant atmospheric research, for discussion of potential mitigation measures, and to consider what policy-relevant information may be available to decision makers in the next few years. Such a meeting had never been held and it was believed that the time had come for the scientific community to inform the various policy making bodies of the world of the status of the science with respect to the possible effects of aviation on the atmosphere. It was also felt that it is important for scientists and technologists to hear about the workings and concerns of decision makers. The meeting was hosted by H. Wesoky, the manager of the Atmospheric Effects of Aviation Project within NASA's Advanced Subsonic Technology and High-Speed Research Programs. The technology and scientific program of the symposium was coordinated by D. Lister of DRA, UK and A. R. Ravishankara of NOAA, USA, with guidance from the organising committee, which comprised representatives of the sponsoring organisations. A total of 150 attendees participated in the meeting. The symposium was organised into daily tutorials, each followed by reports on special topics of major concern.

The discussions were centred around the following themes :

- Aircraft, Engines, and Emissions, Including Current and Forecast Emission Inventories
- Stratospheric Ozone : the Original Issue
- Tropospheric Ozone : the Newer Issue
- Greenhouse Gases and Climate : the Emerging Issue
- Aerosols, Chemistry, and Climate : A New Focus
- The Overall Effect of Aviation on the Atmosphere
- Control of Emissions
- Where Do We Go from Here ?

Prior to the meeting, the speakers were presented with a position paper written by Dr. D. L. Albritton of NOAA, which brought out the likely question that will be asked of the scientists by the policy making community.

One of the important aspects of the meeting was that all the science was presented in a format that was user-friendly to the decision makers. Attempts were made to paint broad pictures of the state of science and hierarchical order of what is known and what is not known. Participants appreciated the opportunity for the different,

often non-interacting, communities to interact, and greatly assisted each other in better understanding of the complexities in the relevant science, technology and policy issues.

There were many findings of importance from the symposium. The most important findings were : Aviation is a significant source of the $CO_2$ and its fractional contribution to transportation related greenhouse gas emissions was likely to increase. Aerosols or particulates, which may contribute to global climate change, may be influenced by aviation. The earlier concern about the NOx emission still remains, though its importance relative to the other two influences appears to be less.

Based on many discussions, it was concluded that not enough was known to make definitive predictions of the effects of aviation on the atmosphere, but enough was known to start an assessment process. Based on this finding, the stage was set and a timeline established for focused international assessments of aviation's environmental impact which could serve as a basis for future aircraft emission standards.

A report of the symposium proceedings will be prepared by the organisers and published before the end of 1996.

● A. R. Ravishankara

# WORKSHOP ANNOUNCEMENTS

## International Workshop on Modelling Heterogeneous Chemistry of the Lower Stratosphere/Upper Troposphere, October 21-23, 1996. Strasbourg, France.

Heterogeneous reactions in the atmosphere play critical roles in many environmental issues of today. Unfortunately, however, heterogeneous reactions are still not represented in atmospheric models in a realistic manner. Information needed to comprehensively include such processes is either lacking or is not being communicated between scientists involved in various disciplines of atmospheric chemistry. To hasten the communication of information between the scientists in all the major disciplines -laboratory measurements, microphysics, field measurements, and modelling- and to take stock of where we are in realistically including heterogeneous processes in modelling activities, a workshop is being organised in Strasbourg under the auspices of SPARC. Other sponsors include NASA and NOAA from the US. To a first approximation, this meeting will pick up where the 1993 Boulder meeting left off. The proceedings of the Boulder workshop (entitled « Heterogeneous Chemistry of the Atmosphere : An Assessment of Current Status ») are published as a part of the NASA Ref. Publ. 1359, 1995.

The workshop in Strasbourg will cover heterogeneous chemistry of the stratosphere and upper troposphere : (1) microphysics of particles (PSCs, sulphuric acid aerosols, and cirrus clouds), (2) laboratory measurements of reactive/ non-reactive uptake, (3) atmospheric measurements of surface area, volume, composition, etc. and (4) modelling of these processes.

Discussions are of primary importance. Forms will be provided for presentation of various talks, but they will be centred around common themes. Because of the nature of the meeting and logistics, the attendance is limited to 75 people, and poster sessions are believed to be unnecessary.

***Organising committee : Ivar Isaksen (Univ. of Oslo, Norway), Jack Kaye (NASA HQ, USA), Philippe Mirabel (Louis Pasteur Univ., France), A. R. Ravishankara (NOAA, USA), Thomas Peter (MPI-Mainz, Germany).***

● A.R. Ravishankara



## Second Workshop on « Solar Activity Effects the Middle Atmosphere » 18-22 August 1997, Prague, Czech Republic

The workshop will cover the effects of solar electromagnetic radiation (solar cycle, solar rotation, longer as well as shorter time scales), solar wind (including geomagnetic storms), and high energy particles on the middle atmosphere (including ozone) and to some extent on the troposphere and lower ionosphere. A session on « How to distinguish between long-term solar and anthropogenic effects » will be included. Related invited papers about solar radiation, particles, geomagnetic storms, etc. are foreseen.

The Prague Workshop will be complementary to the Uppsala IAGA-ICMA-SCOSTEP'97 programme.

***Programme Committee : J. Lastovicka (Chair, <jla@ufa.cas.cz>), S. Chandra, L.L. Hood, H. Ranta.***

# The MOZAIC Programme

## Purpose

The goal of MOZAIC (Measurement of OZone by Airbus In-service airCraft) is to help understand the atmosphere, how it is changing and how it will change, with particular interest in the aircraft impact on the atmosphere. Scientists and aircraft manufacturers are closely associated in this programme. MOZAIC involves automatic measuring (ozone, water vapour) equipment installed on five Airbus A340 aircraft in normal airline service. The data are gathered in a data bank and used for scientific interpretations. MOZAIC aims to help improve the basic knowledge of atmospheric composition and its evolution as well as the future impact of aviation. The MOZAIC data, associated with meteorological data (e, g., from the ECMWF) allow to : establish an accurate climatology of ozone and water vapour at flight levels ; determine the importance, location and frequency of exchange phenomena between the stratosphere and troposphere ; validate 3D models, using the spatial and temporal variation of ozone and water vapour. In particular, the climatology is essential for studying the impact of subsonic aircraft. It is necessary to describe precisely the environment into which the NOx and $H_2O$ (from the engine exhaust) are emitted : either tropospheric air (low ozone, higher water vapour content ; formation of ozone from NOx emissions) or stratospheric air (high ozone, lower water vapour ; formation or destruction of ozone from NOx emissions).

The study of ozone variations during cruise shows that aircraft are successively crossing very different circulation cells of tropospheric/stratospheric origin (see fig.1). Such successions of cells have to be introduced into the aircraft impact assessment models, because it is clearly not correct to make calculations with an intermediate « mixed layer » (8-13 km) or a tropopause at fixed altitude as it is generally done.

## Organisation

The programme started in January 1993 and was planned for a duration of 3.5 years. The project is funded by the EC (APAS initiative ; Area 3 Aeronautics ; Brite Euram II RTD programme) and by the scientific and industrial participants. Seventeen organisations from 6 countries are participating in the programme (see tasks in table 1) which is coordinated by Laboratoire d'Aérologie (LA/CNRS - Toulouse, France).

The instruments and their control system were developed by LA/CNRS (ozone, control) and KFA/Julich (water vapour, temperature). Five aircraft have been equipped by AI partners, LA & KFA and flown (free of charge) by Air France (1 aircraft), Sabena/Air France (1), Lufthansa (2) and Austrian Airlines (1).

## Unit Description

The unit uses the aircraft's power supply and is driven by a computer which controls the instruments, receives the aircraft parameters and stores the data on high capacity disks. The system automatically detects various phases of the flight and provides maintenance information on the ground. The airline's routine maintenance is only to replace the data disk and water vapour sensor every month. Measurements are taken every 4 seconds, starting after take-off of the aircraft and continuing up to landing. Besides ozone, water vapour and temperature, flight parameters and wind direction and speed are recorded.

The ozone analyser is a Dasibi UV absorption Thermo-Electron Model 49-103. Automatic in-flight calibrations (internal ozone generator) and periodical absolute calibrations are performed in order to maintain the quality of measurements. For water vapour and temperature measurement, a Humidity Sensor AD-FS-88 from AERODATA is installed in a Rosemount housing near the ozone pitot tube; after about 500 hours of flight operation (« A check »), each water vapour sensing unit is calibrated against a Lyman $\alpha$ fluorescence hygrometer in the environmental simulation chamber in KFA. An electronic interface has been developed for communication between the different devices of the MOZAIC system.

## Data Processing

The data are stored on 230 Mbyte removable data disks (storage capacity of about 2000

| | | |
|---|---|---|
| Scientists | Laboratoire d'Aérologie<br>KFA / Julich<br>UPS / Toulouse | Development of 6 sets of automatic units (ozone, water vapour) |
| Manufacturers | Airbus Industrie<br>Aérospatiale<br>British Aerospace<br>Deutsche Aerospace | Integration aboard aircraft & certification |
| Airlines | Air France (/Sabena)<br>Lufthansa<br>Austrian Airlines | Flights, disks replacements |
| Scientists | Laboratoire d'Aérologie<br>KFA / Julich<br>Météo-France / Toulouse<br>Cambridge University<br>MPI / Mainz | Data handling & analysis |

*Table 1 : MOZAIC partners and tasks*

flight hours). These disks replaced every « A check » of the aircraft are sent to LA. Data processing and control (numerical and visual) are performed for each flight's data, prior to sending the flight files to KFA for water vapour and temperature calculation. Finally, data are returned to LA for organisation in definitive files which are then sent, after final control, to CNRM (Météo-France, Toulouse).

## Data Bank

The MOZAIC data bank is managed by the CNRM and is accessible through Internet to the partners of MOZAIC programme and co-investigators associated to interpretations. The up to date structure of the data bank contains 6 main directories (raw data, low resolution data, graphics files, standard statistical codes, simultaneous Earth observation data : satellite data, meteorological fields). CNRM is also producing and diffusing in the MOZAIC community the monthly edition of two quick-look booklets : « Atlas of MOZAIC measurements » ; « Atlas of Meteorological data ». The conversion of the MOZAIC data bank into a data base with modern extraction facilities, tailored to user selected rules, will be achieved soon by MEDIAS France using ORACLE software.

A decision was taken to open the data base to external scientists, acting as co-investigators, through the signing of the MOZAIC Data Protocol. A certain number of PIs were identified to conduct the programme. Various European institutes are now associated with the MOZAIC evaluation phase. (Scientists interested in joining the MOZAIC Programme may contact Dr Alain Marenco).

## Status

The MOZAIC Programme was divided in three main tasks :

1 - **Development** (from development to ground test of the first unit (January-October 1993).

2 - **Aircraft programme** (from installation of the first unit (November 1993) to the beginning of regular in-service flight (August 1994).

3 - **Scientific programme** (recovery, calculation, validation, storage of data in the data bank and the beginning of scientific interpretations (since September 1994).

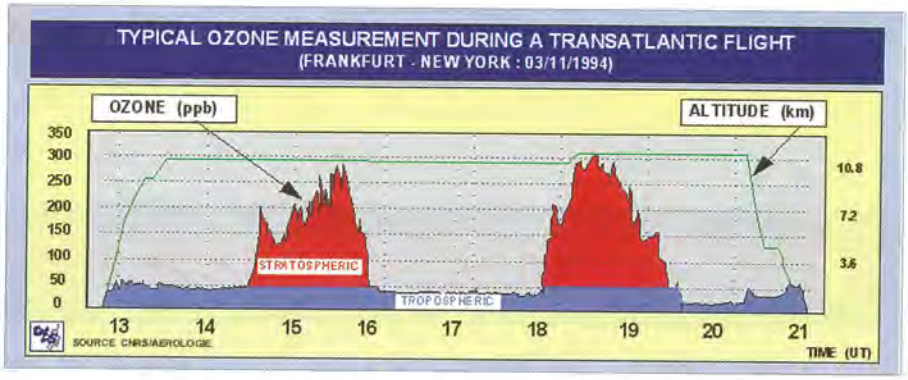


*Figure 1. Typical ozone measurement during a flight from Frankfurt to New York on 3 Nov. 1994.*

Five MOZAIC aircraft were delivered to participating airlines between April 1994 (Air France) and March 1995 (Austrian Airlines). By May 31 1996, the MOZAIC systems had recorded 3402 flights or 27000 flight hours. The distribution of the coverage between the continents for the period of July 1994-May 1996 was : Europe (42 %), North America (26 %), South America (15%), Asia (15 %), Africa (2 %).

## Strategy - Use of data

Preliminary studies confirmed the high quality and reliability of measurements and their usefulness for studies relevant of atmospheric chemistry. The evaluation of data is now under way and will extend with the development of the data base. At the moment, about 25 PIs and co-investigators are working on MOZAIC data for studies on the following topics.

• **Ozone and Water vapour climatology** : From the vertical profiles and variations at cruise altitude, the large scale spatial and temporal distributions of $O_3$ and $H_2O$ can be established. Of particular interest are : (1) horizontal distributions at various altitudes (8-10, 10-11, 11-12 km) and their seasonal variations ; (2) meridional and vertical distributions over the main continents and their seasonal variations ; (3) zonal and vertical distributions at various latitudes ; (4) vertical and temporal evolution in representative places of the world. An example is given in Figure 2 showing the horizontal ozone distribution in layer 10-11 km for the summer of 1995 ; the highest ozone values (>100 ppb) observed north of 45°N are mainly representative of stratospheric air and correspond fairly well with the position of the polar front and tropopause altitude

• **Study of processes** : The MOZAIC measurements at the 8-12 km altitude are valuable in studying the exchange between stratosphere and troposphere by both case studies and statistical evaluations. As an example, Figure 3 presents the percentage of air (sampled by the MOZAIC aircraft at the 10-11 km altitude in Jan-March 1995) that was from the stratosphere (in this, the 100 ppb $O_3$ level has been chosen to discriminate between tropospheric and stratospheric air mass, with values

greater than 100 ppb considered as the stratospheric air). In agreement with the latitudinal variation of the tropopause, no stratospheric air is found south of 30°N, and its percentage comes almost to 100% north of 60°N.

The nature of the mechanisms causing transport across the tropopause can be investigated using the high density of MOZAIC data, in particular over the North Atlantic, including transverse secondary circulation associated with subtropical and polar-front jet streams ; tropopause folding caused by upper-level frontogenesis and subsequent mixing in shear-zones ; impact of the diffusion (over long residence times) of stratospheric tracers in dynamically-confined systems like cut-off lows ; fast « stalactite » descent of stratospheric air in the equatorial band, associated with strong convective systems, as detected during MOZAIC flights.

As for the water vapour, up to now it is unknown whether deep convection moistens or dries the atmosphere, particularly the upper troposphere. MOZAIC data will allow the investigation of the (upper) tropospheric water vapour distribution in the tropical and extra-tropical regions, in relation to motion systems like deep convection and subsidence, its link to sea surface temperature (SST), etc... A striking feature observed more often in the aircraft corridor between Europe and USA is that the measured humidity can sometimes show values higher than 100 % (fig. 4) which most likely is caused by the evaporation of hydrometeors due to adiabatic heating of the sampled airflow in the sensor housing.

• **Model validation** : It is essential to validate the 2D and 3D photochemical and transport models which are available now for troposphere. Using the climatology and processes studies, the MOZAIC data bank at the moment seems to be one of the best existing data sets useful for such a purpose. Model validation plays a central role in all programmes related to the study of global atmospheric chemistry and aircraft impact, and tight coordination is under development with other EC programmes to accelerate the exchange of information and prevent overlapping.

From the whole data set obtained over several annual cycles, the geographical and vertical distributions and the seasonal variability of $O_3$ and $H_2O$ can be obtained and compared with the outputs of 3D models, such as those developed at Cambridge University, MPI (Frankfurt), ONERA (France) and Oslo University.



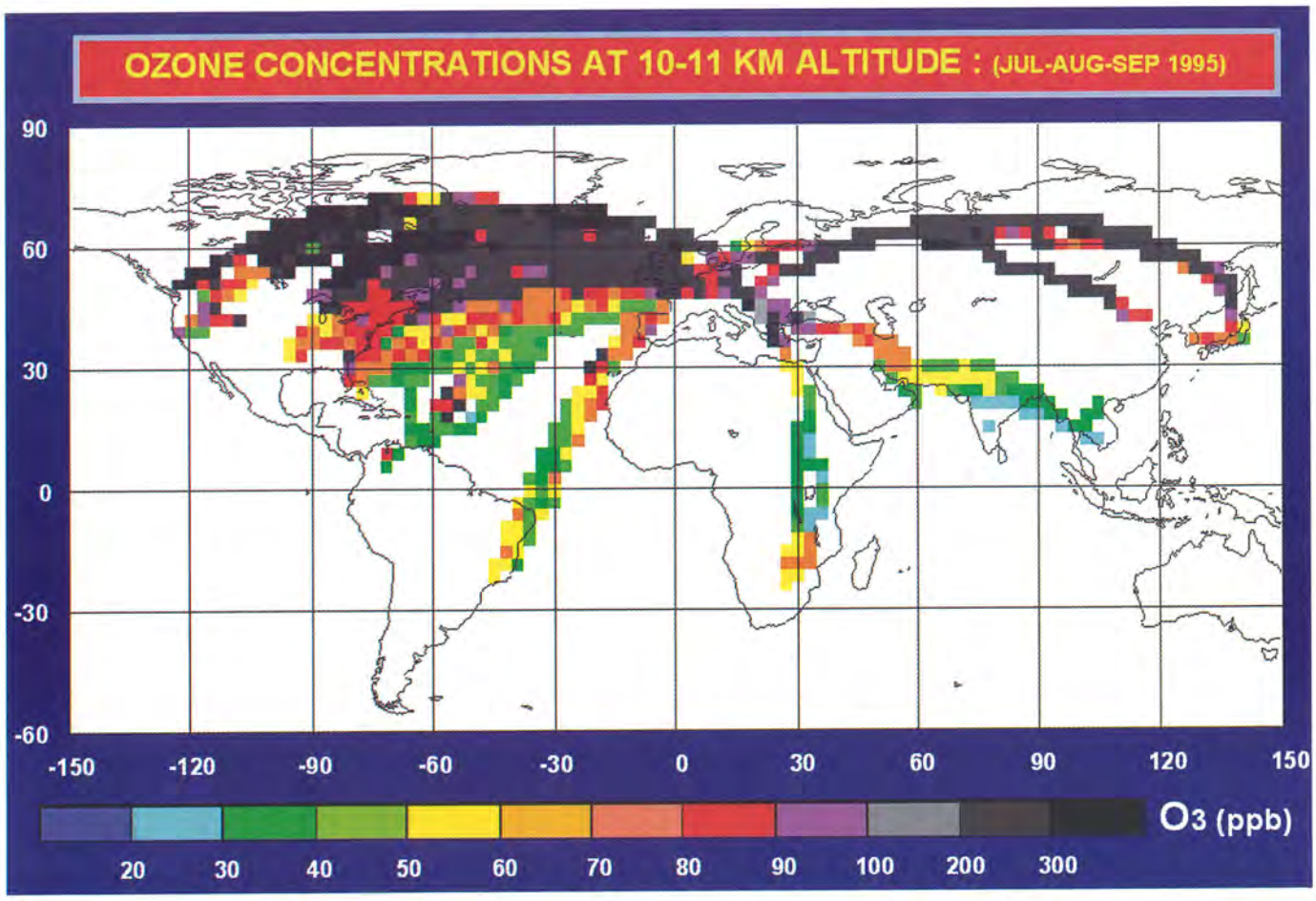


*Figure 2. Mean ozone concentration (ppb) at 10-11 km altitude in July to Sept. 1995.*

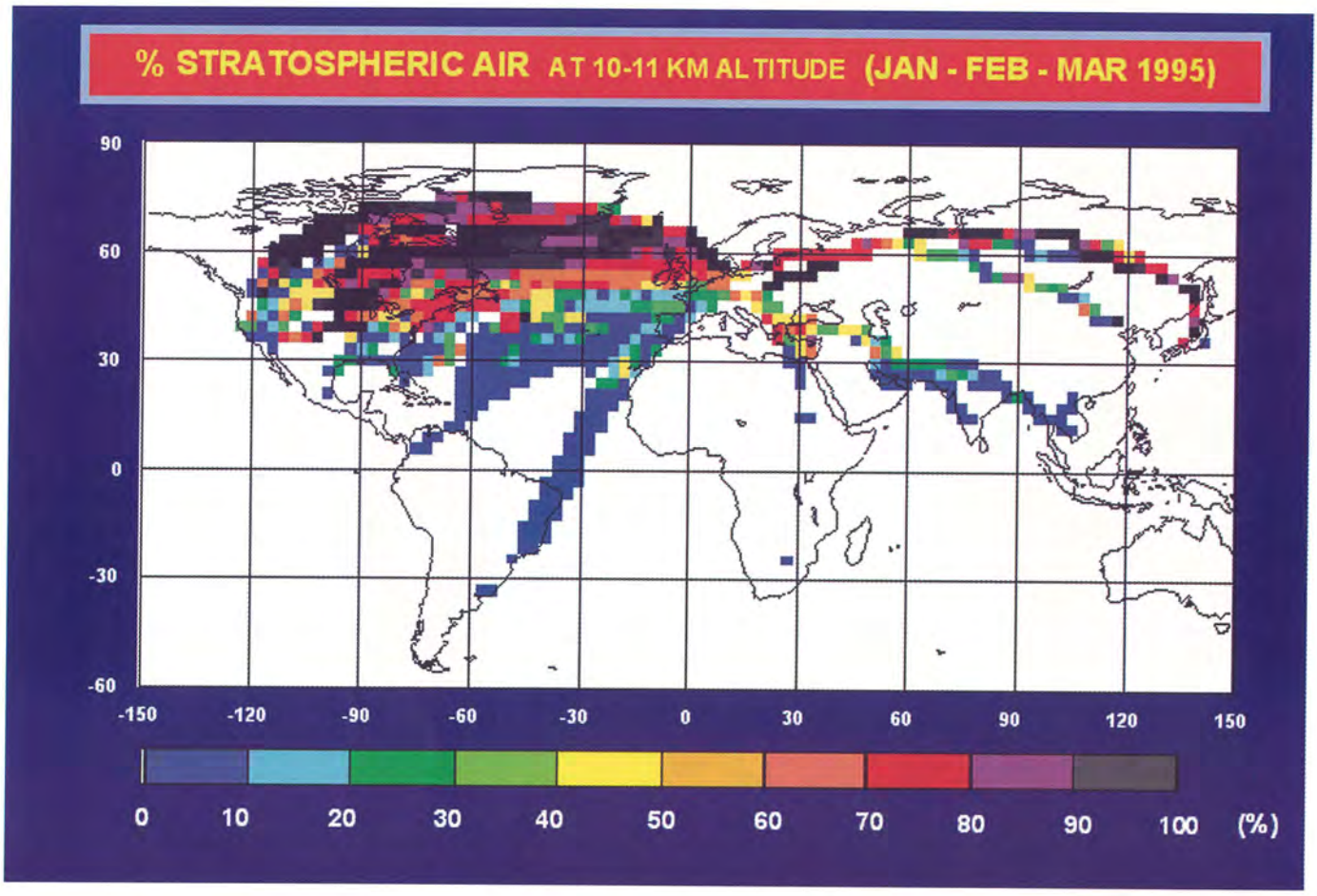


*Figure 3. Percentage of air of stratospheric origin, at 10-11 km, in January to March 1995.*



## MOZAIC II

The first phase (MOZAIC I) is ending in June 1996. A second 2 year phase (MOZAIC II) is expected to start in autumn 1996, with three main objectives :

- continuation of the MOZAIC I project (5 aircraft, $O_3$ and $H_2O$ measurements, constitution of data bank) ;
- feasibility study of new airborne devices : NOy (chemiluminescence), CO (resonance fluorescence) and light compact computer (central unit), following critical requirements for an automatic and prolonged functioning aboard commercial aircraft (these new devices will be installed and operated aboard MOZAIC aircraft in a third phase) ;
- interpretation of the MOZAIC data to gain a better understanding of atmospheric chemistry and dynamics.

MOZAIC is part of EC global activities with the cooperation of various institutions and intensive research programmes.

***Contact : A. Marenco : MOZAIC Programme Co-ordinator, Laboratoire d'Aérologie [UMR CNRS/ UPS 5560], Toulouse - France), Fax : 33-61-33-27-33, E-mail : mara@aero.obs-mip.fr***

Alain Marenco

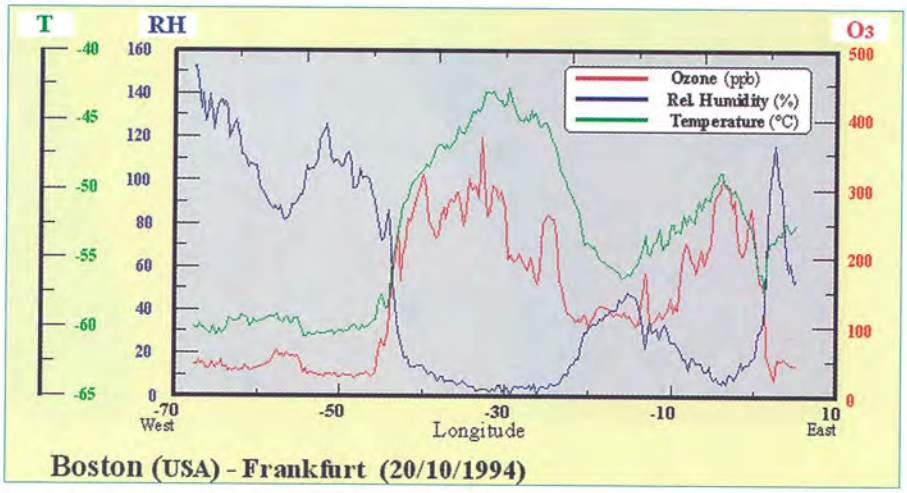


*Figure 4. Distribution of air temperature, relative humidity, and ozone during a flight at 35000 feet.*

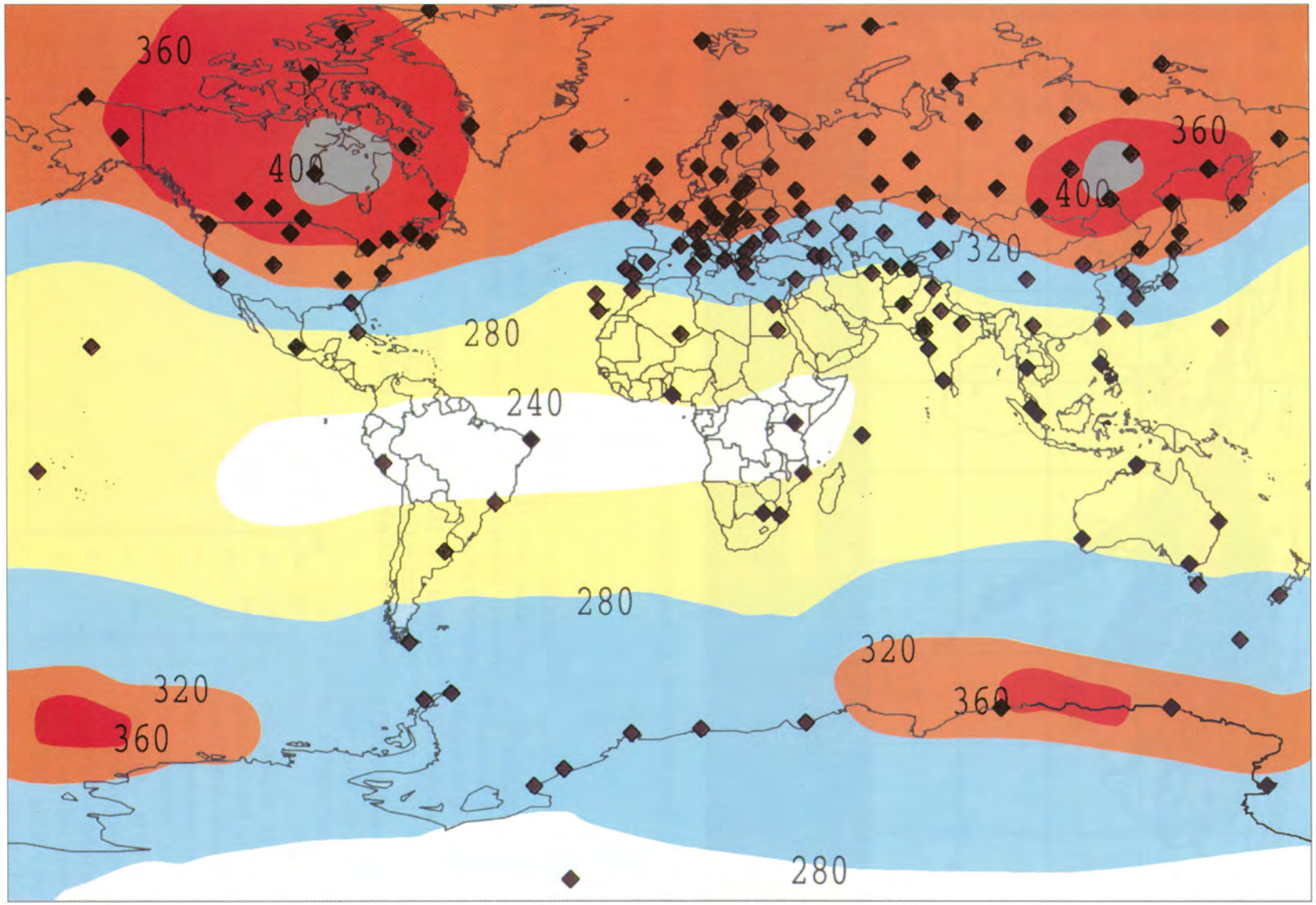


*Figure 5. The Global Atmospheric Watch $GO_3OS$ Network*

# Global Atmosphere Watch : A long history of coordinating atmospheric ozone measurements and research

The WMO Global Atmosphere Watch (GAW) system was established in 1989 and has integrated a number of WMO's research and monitoring activities in the field of the atmospheric environment including the WMO Background Air Pollution Monitoring Network (BAPMoN) and the WMO Global Ozone Observing System ($GO_3OS$), established respectively in the 1960s and in the 1950s. The $GO_3OS$ network is shown in Figure 5.

The WMO/GAW programme has two main objectives : 1) To coordinate long-term monitoring of the chemical composition of the atmosphere and related physical parameters, 2) To provide regular scientific assessments of the state of the atmosphere. Thus the data collected at the GAW monitoring stations are essential in contributing to understanding the relationship between atmospheric composition and global and regional climate changes, the long-range atmospheric transport and deposition of potentially harmful substances over terrestrial, freshwater and marine ecosystems, and the natural cycling of chemical elements in the global atmosphere/ocean/biosphere system, and anthropogenic impacts thereon.

WMO/GAW, in cooperation with other international organisations and the scientific community, has the leading role in the regular assessment of the state and trends of stratospheric ozone as requested by the Vienna Convention for the Protection of the Ozone Layer.

The WMO's $GO_3OS$ under GAW is now in its fifth decade and has been the key international programme to collect and evaluate the measurements of atmospheric ozone. $GO_3OS$ includes the following activities :

- Coordination of the uniform world-wide total column ozone measurements from Dobson, Brewer, and filter instruments.
- Provision for inter-calibrations of total ozone instruments on a routine basis.
- Coordination of surface ozone measurements for selected regional and global locations.
- Organisation of numerous scientific meetings and workshops on stratospheric ozone depletion.
- Archiving of total column, vertical and surface ozone data through the WMO World Data for Ozone and UV-B in Toronto, Canada.
- Publication of numerous scientific and technical reports on atmospheric/tropospheric ozone.
- Issuing of routine advisories on the state of the stratospheric ozone layer.
- Provision of information on the state of the science to member governments.

Since SPARC was founded, GAW has continued to maintain its active role in coordinating stratospheric ozone and other related activities. Particularly more emphasis has been placed on the increase of UV-B as a result of stratospheric ozone depletion and the role of tropospheric ozone in climate change. The establishment of calibration of ozone and UV-B measurements (see SPARC Newsletter No. 5) has been given priority. Activities over the last three years include :

- Several Dobson intercomparisons (Spain 1994, Switzerland 1995, Japan 1996).
- Intercomparison of all types of ozone sondes used globally (Germany 1996).
- Distribution of ozone advisory bulletins for both northern and southern hemisphere.
- Publication of the popular brochure, « The Changing Ozone Layer ».
- Co-sponsorship of the IGAC Global Tropospheric Ozone Network (GLONET).

One of the most important new aspects of GAW is the establishment of Quality Assurance Science Activity Centres (QA/SAC) to oversee the quality of the data produced under GAW. Three centres have been established in Germany, United States and Japan. The centres are playing a major role in training, quality control and establishing protocols for measurements. The first important step has been the establishment of a QA protocol for surface ozone measurements.

Assessment activities, in which the GAW programme has played a major role, included the Scientific Assessment of Ozone 1994 and the Assessment of Global Acid Deposition 1996 (in print).

Since its establishment, the GAW system has promoted cooperation with the scientific community represented by ICSU. Particularly strong ties have been strengthened with IGAC in which a number of projects (GLONET, ACEed) are being implemented in partnership with the WMO. Since much of the activities under SPARC would use GAW measurements and assessments, it is suggested that closer coordination be developed between the two programmes.

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***Fax: 41 22 7400984.***
***E-mail : john-milton.miller@itu.ch***

John M. Miller

# Gravity Wave Processes and Their Parameterisation in Global Climate Models

## A NATO Advanced Research Workshop, Santa Fe, USA, April 1-5, 1996
## Director : Kevin Hamilton

## Introduction

Gravity waves (GW) can act to transfer mean horizontal momentum from the ground to levels aloft in the atmosphere or from one layer of the atmosphere to another. Comprehensive numerical models of the atmosphere are known to produce unrealistic simulations of the extratropical stratospheric/mesospheric circulation unless some account is taken of the effects of these GW. If credible simulations of climate (and predictions of climate response to anthropogenic forcing) are to be obtained, some physically justifiable parameterisation of the momentum transport due to unresolvable GW needs to be formulated. This issue is now recognised as one of the most important challenges in dynamical meteorology.

In order to begin addressing this problem, a NATO ASI was held in Santa Fe from April 1-5. The meeting was cosponsored by SPARC and STEP and was attended by 36 scientists from 10 countries. The meeting was notable in bringing together experts in observations and theory of GW along with representatives of several climate modelling groups. The proceedings of this workshop will be published later this year by Springer-Verlag.

## Some Background on Currently Proposed Parameterisations

This meeting included the first widespread discussion of the performance of currently proposed parameterisation schemes. There are three main schemes now being tested. Each is essentially one-dimensional and explicitly considers only statistically-steady conditions. Each makes some assumption concerning the spectrum of upward-propagating GW at the lowest level considered (typically taken near the tropopause) and then uses a simplified treatment of the dynamics to compute the propagation and dissipation of the waves throughout the middle atmosphere (and hence the mean flow modifications induced by the waves). The « Lindzen » scheme is based on a quasi-linear treatment of a discrete set of waves (each with prescribed frequency and horizontal phase velocity relative to the ground). The waves are treated independently and are assumed to grow linearly until an instability criterion (typically characterised by some Richardson number criterion) is exceeded at some height. Then the growth of the wave is assumed to be limited to just maintain the saturation of the instability condition. The « Hines » scheme treats a continuous spectrum of waves. Again each component of the spectrum is assumed to grow linearly until some nonlinearity condition is met, but Hines explicitly involves the entire spectrum in the determination of this condition. In particular, he imagines that the high vertical wavenumber (denoted here as $m$) end of the spectrum is controlled by nonlinearity and that the break between the linear and nonlinear $m$ regimes occurs at lower wavenumber as the total horizontal wind variance in the spectrum increases. The third approach advocated by Fritts and Lu also treats the entire spectrum, but uses empirical evidence to guide the imposition of the saturation of the wave amplitudes. Both the Lindzen and Hines schemes predict little wave forcing of the mean flow below heights at which their proposed saturation mechanisms become important. The stronger the imposed waves at the lower boundary, the lower down the significant nonlinearities (and consequent wave driving of the mean flow) will occur. This observation has led many modellers to a particular modification of these schemes, which can be described as follows. Imagine first a standard application of, say, the Lindzen scheme with a single prescribed wave with momentum flux $F_0$ imposed at the lower boundary. Then one could imagine another application based on the assumption that the wave is present for a fraction $\alpha$ of the time and completely absent for the remaining time. If the wave flux at the lower boundary is multiplied by $1/\alpha$, then the time-average wave flux imposed in the two cases is the same, but the region of significant forcing of the mean flow will extend lower down in the second case. The factor $\alpha$ has been referred to by many investigators as the « efficiency factor », but might be better termed an « intermittancy factor ». Typically in the Lindzen scheme the same efficiency factor is assumed to apply to each of the waves considered. The same kind of modification could be introduced into the Hines scheme.

## Summary of Presentations

**I. Hirota** (Kyoto Univ.) opened the meeting with a historical review of our observational knowledge of the GW field in the middle atmosphere (MA). He emphasised the value of single station data in characterising the details of the GW field. Hirota also reported on recent work concerning the relation between observed stratosphe-

ric waves and localised tropospheric sources such as jet streaks.

**R. Vincent** (Univ. of Adelaide) discussed the use of high-resolution radiosondes to investigate the GW field in the lower stratosphere. He reviewed his earlier work with temperature data for several Australian stations and then noted that the geographical and seasonal variations in wave activity have been found to be more complicated as data from more stations has become available. Vincent described an analysis of the simultaneous temperature and horizontal wind observations at some Australian stations designed to determine the intrinsic frequencies and dominant directions of propagation of lower stratospheric GW. He ended with a description of some calculations he has conducted using idealised random wave spectra to produce wind and temperature fields that were then sampled in the same manner as a radiosonde. This allowed him to test the limitations of using single station for determination of GW properties.

**R. Sica** (Univ. of West. Ontario) discussed observations of the vertical temperature structure in the upper stratosphere and mesosphere obtained with the Purple Crow Rayleigh lidar located near London, Canada. One of his striking results was a high vertical and temporal resolution determination of the regions of negative static stability. An example for one night is shown here as Fig. 6. It appears that very thin regions (~100 m) of unstable lapse rate appear rather randomly, and typically persist for an hour or less. In general about 5 % of the measured column (30-70 km) is found to be statically-unstable at any time, with the incidence of unstable situations observed to increase with height.

**N. Gavrilov** (St. Petersburg Univ.) reviewed observations of GW climatology focusing particularly on radar observations of the horizontal wind in the upper mesosphere and lower thermosphere. He pointed out a number of interesting features of the analysis that has been conducted on the MF radar data from Saskatoon, Canada. In particular, both the seasonal amplitude behaviour and dominant wind orientations of the highest frequency variations (periods less than 30 minutes) were found to differ from those of lower frequency waves.

**K. Sato** (Kyoto Univ.) discussed the analysis of radiosonde data to examine the equatorial waves in the lower stratosphere. She found prominent peaks in zonal wind and temperature variance at periods near 10 days during the westerly shear phase of the QBO and in the 1-3 day period range throughout the entire QBO cycle. She discussed different approaches to estimating the vertical flux of zonal momentum associated with these prominent waves. The result for the 10 day wave suggested that this spectral peak is largely associated with eastward-propagating Kelvin waves. For the 1-3 day waves there was a clear indication of a rough balance between eastward and westward propagating components. Sato also discussed observations of higher frequency GW made with the Kyoto MU radar during the passage of a typhoon within 100 km of the facility.

**C. Gardner** (Univ. of Illinois) discussed Na lidar observations of wind and temperature in the ~80-105 km altitude range obtained near Albuquerque, New Mexico during several nights. Temperature, vertical and horizontal wind measurements were to be obtained with 24 m vertical resolution and 3, 6 and 12 minute time resolution, respectively. This high quality data allowed a very detailed picture of the vertical wavenumber and temporal spectra to be obtained. Gardner found that the temperature variance spectrum varies like $m^{-2}$ and $\omega^{-2}$. The horizontal and vertical power spectra vary roughly as $m^{-3}$ and $m^{-1}$, respectively. Gardner pointed out that the shallowness of the spectrum of vertical velocity relative to that of horizontal velocity invalidates the usual assumption of a spectrum of wave separable in vertical wavenumber and frequency.

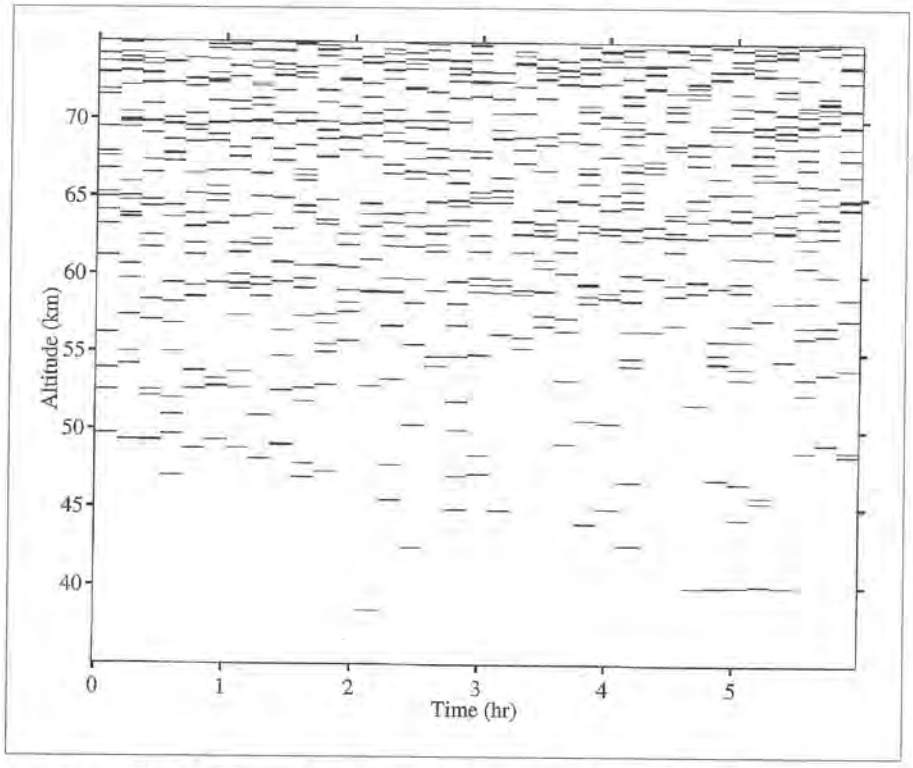


*Fig. 6. Height-time distribution of regions in which the lapse rate is unstable, based on high-resolution Rayleigh-lidar observations of temperature taken at London, Canada, during the night of August 30, 1994. Figure provided by R. Sica*

**F.-J. Lübken** (Univ. of Bonn) described results from a large number of rocket-borne falling sphere profiles taken in the mesosphere near 70°N over the period 1983-95. The spheres were instrumented with ion probes that allowed a very high-resolution determination of the density and temperature profiles. The profiles display considerable small-scale temperature variability and thin regions with statically-unstable lapse rate are found to occupy about 4 % of the region. In summer turbulent layers were found to be largely restricted to 80-95 km, while in winter significant turbulence was observed throughout the mesosphere.

**J. Bacmeister** (Naval Res. Lab.) discussed horizontal spectra of wind and temperature in the lower stratosphere determined from ER-2 flights in the AASE and SPADE as well as the ASHOE/MAESA campaigns. The total data set consists of about 70 flights of ~6-8 hours each and analysis focused on the 1-100 km wavelength range. The wind and temperature spectra differ significantly from the $k^{-5/3}$ power law often taken as a reference for the mesoscale regime. At wavelengths shorter than about 3 km the observed spectra are steeper than $k^{-5/3}$, while at wavelengths longer than about 6 km the spectra are shallower than $k^{-5/3}$. By contrast, the ozone and nitrous oxide spectra appear to follow a simple $k^{-5/3}$ power law over the entire range considered.

**L. Pfister** (NASA Ames) described both in situ and microwave profiling observations from the ER-2 aircraft in the ASHOE/MAESA campaign. He discussed a particular case of a flight south from New Zealand which passed directly over a rather localised tropospheric storm. Over the storm region there was a clear maximum in the variance in both temperature and vertical wind. The temperature and wind perturbations were consistent with the lower stratospheric response being mainly in linear, vertically-trapped waves. The largest displacements of isentropic surfaces seen above the extratropical storms in the ASHOE/MAESA campaign were ~250 m, which Pfister points out is smaller by a factor of ~2 than the largest displacements seen above tropical convective events.

**D. Wu** (Jet Propulsion Lab.) discussed the horizontal variations seen in limb-scanning microwave measurements of atmospheric temperature from the UARS satellite. The observations are particularly sensitive to those waves with vertical wavelengths greater than ~10 km and horizontal wavelengths less than ~100 km. The variance in this wavelength range is found to increase with height throughout the middle atmosphere and also shows strong geographic modulation. Particularly striking are maxima in variance seen over the continental areas in low latitudes and over the midlatitude jet streams. Wu pointed out that this is consistent with the possibility of a strong geographical modulation of tropospheric wave sources.

**F. Sassi** (Univ. of L'Aquilia and NCAR) discussed a simple mechanistic equatorial β- plane model stretching from the ground to the lower thermosphere and truncated to zonal wavenumber 15. This was forced by a random tropospheric heating meant to account for the effects of tropical convection. The spectral form for this heating was chosen with guidance from time series of satellite observations of tropical cloudiness. The model also included a zonal-mean forcing in the middle atmosphere designed to account for the easterly drag connected with cross-equatorial flow and planetary waves in the real atmosphere. Sassi was able to produce a quite realistic semiannual oscillation (SAO) near the stratopause in this model. He showed that the intermediate scale waves (zonal waves 4-15) account for a very significant fraction of the mean flow forcing in the westerly acceleration phase of the stratopause SAO.

**J. Holton** (Univ. of Washington) discussed calculations of convectively-forced GW in a 2D, nonlinear, moist, limited-area model. The model was initialised with tropical ambient conditions and a localised disturbance. This led to a rather realistic simulation of a squall line which involves the modulation of a series of propagating precipitation cells of brief duration. This squall line also produced GW radiating into the model stratosphere. Holton repeated his calculations with stratospheric mean winds characteristic of the easterly and westerly phases of the QBO. The tropospheric simulation was largely unaffected by the stratospheric winds, but the GW field within the stratosphere itself was found to be strongly dependent on the mean wind distribution employed. When averaged over the limited area of the model (800 km in the zonal direction) Holton found that the mean flow forcing from his simulated GW in the lower stratosphere can be ~5 m-s-day$^{-1}$. He argued that the small horizontal scale, high-frequency GW produced by such tropical weather systems could make a significant contribution to the global forcing of the QBO.

**M. Reeder** (Monash Univ.) described some calculations of the stratospheric wave response to tropospheric mesoscale systems in the context of a dry 2D anelastic model. He initialised his model with a large-scale confluent wind field taken from the classic semi-geostrophic frontogenesis solutions, but with an added perturbation. The integration produced a very well-developed tropopause fold and cross-frontal circulation in the troposphere, and a train of inertia-gravity waves radiating into the stratosphere (see Fig. 7 which shows the horizontal and vertical wind fields after 36 hours of integration).

**J. Alexander** (Univ. of Wash.) began by reviewing attempts that have been made to use large-scale data and radiative transfer calculations to make a residual calculation of the required GW drag. She then went on to discuss calculations of the GW field and mean flow forcing from a somewhat

modified version of the Lindzen parameterisation with an input spectrum consisting of 60 discrete waves widely distributed in horizontal wavelength (6 to 800 km) and period (7 minutes to 4 hours). The waves were assumed to have a globally-uniform source, but then propagated through a mean state based on the full 3D monthly-mean UKMO observational analyses. Alexander was able to show that in the stratosphere and mesosphere the filtering effects of the mean flow were able to produce very significant geographical variations in the computed wave activity. With her choice of parameters and an efficiency factor ~0.001 she was able to produce a distribution of zonal-mean drag that is comparable to that estimated in the residual calculations.

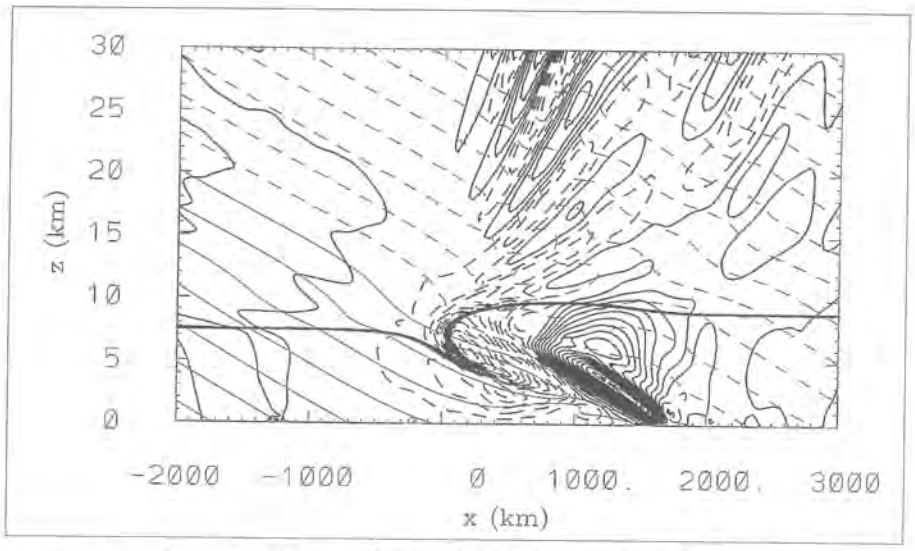


*Fig. 7. Isotachs of vertical velocity (thick lines) and isotachs of cross-frontal velocity (thin lines) after 36 hours of integration of a frontogenesis experiment with a dry mesoscale model. Contour intervals are 6 mms$^{-1}$ for vertical velocity and 5 ms$^{-1}$ for cross-frontal velocity. The thickest black line represents the location of the tropopause. Figure provided by M. Reeder.*

**C. Hines** (Toronto) described his work on formulating a parameterisation scheme for the GW field that considers the Doppler-shifting of the high vertical wavenumber waves by the wind fluctuations from the entire spectrum of waves. He began with a very basic justification of his approach in the simple case of no mean flow. He imagined a spectrum initially nonzero only in a restricted region of m space. As the waves propagate upward the horizontal winds associated with the waves increase and it is reasonable to expect that nonlinearities will begin to fill in the tail of the spectrum. Hines noted that he has performed detailed calculations that indicate that the asymptotic form of the tail should be roughly $m^{-3}$, but that this expectation is also consistent with the simplest similitude arguments. Hines suggested that the break between the linear low $m$ part of the spectrum and the saturated tail should occur at a wavenumber proportional to the Brunt-Vaisala frequency divided by the rms horizontal wind in the entire spectrum. Hines then went on to consider the implications of this picture of the spectral propagation for practical parameterisation schemes and to outline his specific proposal in this regard.

**H. Mayr** (NASA GSFC) described the incorporation of the Hines GW parameterisation scheme into a 2D nonlinear model of the middle atmosphere (forced also by a diabatic heating computed from a realistic radiative transfer model). The incorporation of the GW drag led to a number of realistic features in the simulation. The winter and summer mesospheric jets closed off in the upper mesosphere and reverse in the thermosphere, in basic agreement with observations. The imposed GW drag also generates a quite reasonable SAO in the equatorial mesosphere. There is even a QBO (though with unrealistically weak amplitude) appearing in the equatorial stratosphere of the model.

**M. McIntyre** (Cambridge Univ.) reviewed some recent work on the maintenance of the large-scale mean circulation in the middle atmosphere, which forms the basic background to the GW parameterisation problem. He then went on to consider some simple ray theory calculations for nonhydrostatic, inertia-gravity waves, noting that the usual ray theory fails near critical lines and near caustics (loci of ray crossings). McIntyre noted that ray theory provides an interesting view of some wave-wave interactions. For example, he showed that the propagation of a large m wave through a larger-scale wave packet can actually lead to its transformation into a wave with smaller vertical wavenumber. This represents a counterexample to the simplest notions that suggest that sufficiently large $m$ waves will inevitably be shifted to larger wavenumber and ultimately obliterated.

**A. Medvedev** (St. Petersburg Univ. and York Univ.) described his modification of the Hines scheme to account for the effects of the high $m$ end of the spectrum on the lower $m$ waves. The damping of low frequency waves in his scheme is accomplished by an effective diffusion due to the motions associated with the high frequency waves. He presented some preliminary results from the inclusion of his scheme into a version of the NCAR CCM.

**C. Warner** (Cambridge Univ.) reported on calculations of the propagation of a spectrum of waves with a very detailed quasi-linear model. The model considered a continuous spectrum (treated

numerically by a high-resolution discretisation) and allowed the waves to propagate conservatively except for absorption near critical surfaces, back-reflection when appropriate, and a nonlinear chopping of the spectrum at high $m$ and high frequency to impose a broadband saturation criterion. Warner investigated the decay of total wave energy with height and its sensitivity to the shape of the spectrum imposed at the lower boundary.

**M. Geller** (Univ. of New York at Stony Brook) discussed the use of a tidal model in conjunction with recent UARS satellite observations of tidal winds to estimate dissipation rates in the upper mesosphere and lower thermosphere. The procedure started with a linear calculation of the sun-synchronous tidal fields. The results then were adjusted to fit the UARS observations. Consideration of the energy equation then determined the implied dissipation. When regarded as a second order vertical diffusion, the implied dissipation would require a peak diffusion coefficient of ~200 $m^2s^{-1}$.

**O. Andreassen** (Norwegian Def. Res. Est.) described some very detailed calculations of the flow associated with GW breaking. He considered a 2D upward-propagating GW that is allowed to grow until the lapse rate becomes unstable. In a pure 2D calculation the wave will achieve considerable supersaturation before breaking. He showed, however, that if a small amount of 3D noise is added to the calculation the breaking occurs much more rapidly and involves development of very strong 3D circulation. He presented impressive flow visualisations for his simulations.

**F. Lott** (LMD-CNRS) reviewed the treatment of subgrid-scale topography in GCMs. He then described work with a new scheme for the effects of topography now being incorporated into the ECMWF model. This scheme considers both the blocking effects of the topography on the low-level flow as well as the generation of subgrid-scale GW by the flow over the topography. Tests of this scheme in the ECMWF model were promising.

**J. Vanneste** (LMD-CNRS and Univ. of Toronto) described his work on the nonlinear interaction among GW in the presence of strong mean flow shear. He was able to show that the usual criterion for instability (any wave is unstable if it can be the highest frequency wave of a resonant triad) can be generalised to the strong shear case. He also discussed the case of very strong wave growth (« explosive interactions ») that is possible in the resonant triads in mean shear.

**C. McLandress** (York Univ.) began with a review of the Hines scheme and a discussion of some practical issues involved in its implementation. He noted that the predicted drag from the Hines scheme at high levels depends strongly on the low $m$ behaviour of the assumed input spectrum. McLandress then compared the performance of a simple 2D model of the zonally-averaged flow when the Lindzen, Hines, and Fritts and Lu schemes are used to compute the wave drag. He found that the Lindzen and Hines schemes produced qualitatively quite similar results and could easily account for the mean wind reversals in the extratropical lower thermosphere. He then considered the same comparison but now for a model of the diurnal tide. He found that inclusion of either the Hines or Lindzen scheme results in an increase in the tidal amplitude, while the Fritts and Lu scheme acts to damp the diurnal tide.

**B. Lawrence** (Oxford Univ.) discussed some simulations that were conducted with a mechanistic model based on the UKMO stratosphere-mesosphere model. This was forced both by a realistic radiation and by an imposed planetary wave geopotential perturbation at the lower boundary (~16 km) taken from observations. The boundary forcing for the simulations discussed by Lawrence were for the winter of 1991/92 and the results were compared with observations of the middle atmospheric temperature field during that winter from the ISAMS instrument on the UARS satellite. The simulations were conducted with different parameterisations of GW drag. A simple Rayleigh friction, the Fritts and Lu schemes and the Hines scheme were all tested.

**D. Fritts** (Univ. of Colorado) began with a brief review of earlier work on using aircraft observations to characterise the relative importance of topographic, convective, and jet stream sources for the near-tropopause GW field. He then went on to describe the Fritts and Lu GW drag parameterisation. Fritts discussed the application of this parameterisation to the NCAR TIME model of the MA and thermosphere. While many features of the mean flow simulation are quite realistic, there was a strong sensitivity to the low $m$ part of the assumed spectrum. Fritts also noted that the inclusion of the GW parameterisation strongly affected the tidal amplitudes in the model.

**S. Pawson** (Free Univ. Berlin) described some simulations conducted with the Berlin troposphere-stratosphere-mesosphere GCM with different imposed Rayleigh drag distributions. Major changes were found between simulations with drag confined near the mesopause and those including drag distributed throughout the mesosphere. The differences extend into the troposphere and involve the planetary waves as well as the zonal-mean state.

**B. Boville** (NCAR) began with a review of the practical parameterisation problem for GCMs and emphasised the need for physically-based schemes. He discussed his own experience with incorporating a version of the Lindzen scheme into the NCAR Community Climate Model MA GCM. The scheme he adopted had 9 separate waves each with a prescribed phase speed varying from 0 to 40 $ms^{-1}$. The waves are launched upwards from the upper troposphere and the stress vector associated with each of the waves is aligned with the horizontal wind

at the source level. Boville found that with judicious tuning of his input parameters he could quite closely reproduce the observed climatological seasonal cycle throughout the MA. He needed a fairly small efficiency factor in order to produce these realistic simulations, however. Boville noted that it was interesting that the efficiency factor needed in the full GCM was about the same as that required in an earlier calculation he had performed with a zonally-averaged model.

**R. Garcia** (NCAR) discussed high-resolution 2D calculations of the propagation and breaking of GW. The waves were forced by flow over a transient deflection of the lower boundary imposed over a limited horizontal extent. This excited a localised wavepacket, but Garcia showed that by the time the waves had reached breaking heights the dispersion had transformed the disturbance into a rather monochromatic wavetrain. The details of the wave breaking itself were found to depend strongly on the horizontal wavelength involved.

**E. Manzini** (Max Planck Inst. Hamburg) described simulations obtained with the 39-level ECHAM GCM when a version of the Hines scheme was included. Two different experiments were discussed. In both runs the parameterised wave spectrum was introduced near the 15 km level. In one case the spectrum was assumed to have an rms wind velocity of 1.75 $m\text{-}s^{-1}$ everywhere at this level, while in the second case included an enhancement to this rms with a term dependent on the precipitation rate. The results obtained for the NH winter season were fairly realistic, but the SH winter polar region was still found to be too cold in both simulations.

**N. McFarlane** (Canadian Clim. Centre) discussed results obtained with the Canadian MA Model when the Hines scheme is included. In this approach the waves are introduced at the ground with a globally-uniform rms wind speed of 1 $ms^{-1}$. He also examined the sensitivity of the results to the form of the input spectrum assumed and to the characteristic horizontal wavelength for the input spectrum. He found that he could obtain realistic results in the upper mesosphere and lower thermosphere as long as the imposed spectrum at low $m$ was not too weak. He found also that the SH winter simulation was characterised by an unrealistically cold polar region even with the inclusion of the Hines scheme. The SH winter polar simulation improved somewhat when a longer characteristic horizontal wavelength was used for the input spectrum.

**W. Norton** (Oxford Univ.) discussed simulations obtained using the UGAMP MA GCM with a version of the Lindzen parameterisation included. The parameterisation was tuned to allow the model to produce a realistic zonal-mean state. This required a rather small (~0.01 to 0.1) efficiency factor for the parameterisation. Norton found that when the model was run at fairly high resolution (triangular 42 truncation) and the parameterised drag was included, a quite realistic « two-day wave » is produced in the summer mesosphere. The GW drag seems to be crucial in producing the two day wave in the simulation, and Norton noted that when the drag is included a region of negative meridional gradient of zonal mean potential vorticity is created in the summer mesosphere. This then presumably leads to the excitation of the two-day wave by baroclinic instability.

**S. Webster** (UKMO) described the topographic GW drag scheme now being developed for the UKMO operational model. This parameterisation considers three distinct regimes. At sufficiently large Froude number the surface drag is taken to be proportional to the surface wind and the usual saturation condition for the eddy momentum fluxes is used. For lower Froude numbers the flow is assumed to be affected by hydraulic jumps and low-level blocking.

**K. Hamilton** (GFDL/NOAA) described a preliminary experiment using the GFDL « SKYHI » GCM with a simple Lindzen parameterisation of nonstationary GW drag included. The inclusion of the drag resulted in an improved simulation, particularly in the SH winter upper mesosphere. He then described a numerical simulation with the SKYHI GCM when the zonal-mean zonal flow was constrained to agree with climatological observations. This was used to diagnose the drag needed to obtain realistic mean states. While this approach has some important limitations (notably in suppressing the day-to-day and interannual variability in the model), the results may still be a useful guide to formulating a detailed drag parameterisation.

## Discussion of the Parameterisation Problem

There was lively discussion of several aspects of the currently proposed parameterisations. One problem apparent in the Lindzen and Hines schemes is a tendency for the waves to break significantly only at high altitudes (near and above the mesopause). This leads to a predicted GW drag that has a distribution that is centred at higher altitudes than that required by numerical simulation models in order to obtain realistic results for the global circulation. There are two obvious approaches to dealing with this. One is to impose an efficiency factor as described earlier. The other is to adjust the horizontal wavenumber spectrum assumed for the input waves. In general, a longer horizontal wavelength wave will break lower down than a shorter wavelength wave (given the same horizontal phase velocity and momentum flux). The adjustment of the input wavelengths is very straightforward for the Lindzen scheme, of course. The Hines scheme requires some specification of the horizontal spectrum of the input waves and this involves a characteristic horizontal wavelength that can be adjusted (thus scaling the whole spectrum). In practice, in order to get realistic results, modellers

have been forced both to impose a fairly small efficiency factor and to consider quite long horizontal scale waves (typically at least several hundred km). The use of small efficiency factors raises the issue of whether such a degree of intermittancy is plausible. The use of long horizontal scales for the (allegedly) subgrid-scale waves begs the question of why such waves are not explicitly resolved in current GCMs.

Further discussion focused on some basic observational requirements for the formulation of realistic MA GW drag parameterisations. Notable was the issue of the horizontal spectrum of waves near the tropopause (needed as input to any parameterisation). There is currently a lack of detailed observations to characterise the spectrum and its relation to possible wave sources. Another important question arose concerning the very longest vertical wavelength components of the spectrum emerging into the MA. This end of the spectrum is extremely hard to characterise from observations, but (as was seen in numerous presentations) it is very important high in the atmosphere, since the longest vertical wavelengths correspond to the highest phase speeds and vertical group velocities.

There was discussion of some practical initiatives for advancing research on the GW parameterisation problem. **R. Vincent** described plans for a project to compare the GW statistics determined from radiosondes at as many stations as possible worldwide. At the meeting it was possible to identify at least 7 nations that have taken some regular high-resolution soundings for a long period. The project will involve the joint efforts of groups led by a « principal investigator » for each of the participating nations. **N. McFarlane** proposed an informal project to compare the predictions of various simplified GW models for a set of standard 1D cases. There was general support for this initiative and a number of individual researchers were identified as potential participants.

The possibility of a large field program to examine MA GW in relation to their sources was also discussed. **C. Gardner** briefly described his experience with the ALOHA-93 experiment in Hawaii and his views on how an even larger experiment might be organised. There seemed to be considerable support for the notion of an experiment to examine the MA response to tropical convection. Two possible sites suggested were Hawaii and Darwin, Australia. There was general agreement on a number of points that would need to be considered in a detailed plan for such an experiment. The necessity of numerical 3D simulations for both planning and interpretation of the field experiment was emphasised. It was also felt that the presence of a state-of-the-art Doppler meteorological radar would be crucial for adequate observational coverage of the tropospheric convection. There was an overall concern that the scientific issues to be addressed and hypotheses to be tested be described very clearly as part of the planning procedure. The possible role of SPARC in such a field program will be discussed again in December 96 at the SPARC General Assembly and the SPARC SSG meeting.

● Kevin Hamilton



# EGS ASSEMBLY REPORTS

## Session on Stratosphere-Troposphere Exchange
## The Hague, 6-10 May 1996
## Conveners : Peter Haynes, Volkmar Wirth

The session on stratosphere-troposphere exchange (STE) held at the recent EGS Assembly attracted scientists working on a whole range of problems in dynamics, transport, radiation and chemistry in the upper troposphere and lower stratosphere. This wide interest reflects the perceived scientific importance of the STE problem (see reports on the SPARC SSG meeting and on the Pointe-du-Lac meeting both in Newsletter-6).

At a large meeting such as EGS there is a danger that a session on an 'interdisciplinary' subject such as STE will fragment, as specialists in different areas are attracted away to parallel sessions in their own speciality. In the event, there seemed to be a substantial core of participants who stayed for most of the session. Over 45 papers and posters were presented during the session and there is space here to record only some of them.

**Dynamics and transport (extratropics). J. Thuburn** (Univ. of Reading) began the session by describing his work with G. Craig on a GCM investigation of the factors determining the height of the tropopause. This has been identified as one of the key issues in STE, given that the characteristics of the 'reservoir' in the lowermost stratosphere depend on the position of the tropopause, its time variation, and its effectiveness as a transport

barrier. This theme continued as first **M. Ambaum** (KNMI) and then **P. Haynes** (Univ. of Cambridge) described investigations of the formation and maintenance of the tropopause by the isentropic stirring action of baroclinic eddies. **C. Appenzeller** (Univ. of Washington) described the observed seasonal evolution of the reservoir and showed that it was consistent with the springtime maximum in radioactive debris observed during the period of stratospheric bomb tests (figure 8).

**Dynamics and transport (tropics).** Moving the focus to low latitude, **P. Mote** (Univ. of Edinburgh) discussed satellite observations of the annual cycle in water vapour and comparison with observational estimates of upwelling velocities. This work has been important in supporting the idea of a tropical tape-recorder that leads to the upward propagation of the annual water vapour signal from the tropopause into the middle stratosphere. **E. Highwood** (Univ. of Reading) discussed the basic question of defining the tropopause at low latitudes. Certainly there seems to be a clear distinction between the height to which convection penetrates and that, for example, at which the temperature is minimum. **D. Jackson** (Imperial College) showed the upper tropospheric/lower stratospheric water vapour distribution revealed by the HALOE instrument, with, for example, striking differences at low latitudes between northern hemisphere summer and northern hemisphere winter. **G. Reid** (NOAA, Boulder) discussed further the observed annual cycle in tropopause temperatures, noting a number of aspects that still require explanation. Transport out of low latitudes (another key STE issue) was considered by **C. Rogers** (Univ. of Oxford), using ISAMS aerosol observations. Associated transport calculations using observed winds highlighted interesting sensitivities to the particular wind dataset used.

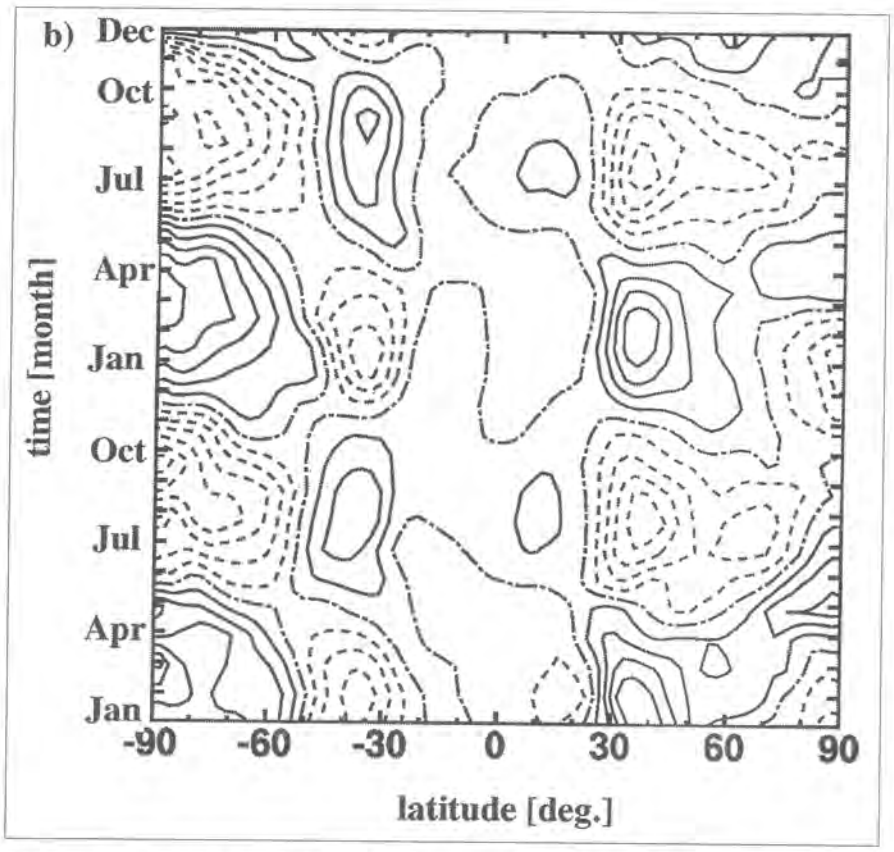


*Figure 8. Annual variation of the zonal and monthly mean relative pressure on the tropopause (defined by the PV=2PVU surface) for the years 1992 and 1993, derived from UKMO analyses. The pressure is given relative to the annual zonal mean, with a contour interval of 10 hPa, negative values dashed, zero line dash-dotted. The see-saw nature of the pattern in pressure in the SH means that the annual variation in the hemispheric average pressure is far smaller in the SH than in the NH. This leads to corresponding inter-hemispheric differences in the annual variation of the mass flux across the tropopause (Figure supplied by Dr. C. Appenzeller, Univ. of Washington).*

**Radiation and chemistry.** **K. Shine** (Univ. of Reading) reminded the session of the radiative processes that are important in the neighbourhood of the tropopause and the implications of changes in this region for e.g. tropospheric temperatures. He noted in particular the large trend in lower stratospheric ozone and its implications for the radiative forcing of the climate system. **B. Christiansen** (Danish Met. Inst.) described a GCM investigation of the effect of idealised perturbations in ozone on the circulation. **J. Lelieveld** (Univ. of Wageningen) then reviewed the chemistry of the lowermost stratosphere, identifying a number of important general issues before focusing on recent observations of carbon monoxide and other trace gases during the STREAM campaign.

**Observations.** **G. Vaughan** (Univ. College of Wales, Aberystwyth) discussed many recent observations from the TOASTE-B campaign, including the identification of air with stratospheric chemical characteristics, but tropospheric dynamical characteristics (i.e. PV values). Trajectory calculations supported the idea that this air had entered

the troposphere many days earlier. **A. Tuck** (NOAA, Boulder) noted a number of features seen in the recent ASHOE/MAESA campaigns that remind us that the division between troposphere and stratosphere is, at best, only a convenient conceptual simplification. Air with high water vapour content had been observed above the sub-tropical tropopause, whilst there was evidence from CFCs of air of stratospheric origin in the tropical upper troposphere. **B. Belloul** (Service d'Aéronomie-CNRS) described a new method for satellite temperature measurement using radio occultation. The combination of good vertical resolution (about 1 km) and global coverage gives this technique considerable potential for observing the tropopause region. **A. Hertzog** (Service d'Aéronomie-CNRS) presented an approach for distinguishing, in vertical profiles of ozone observed using lidar, between vertical structure due to gravity wave activity and vertical structure due to filamentation (i.e. differential advection by the large-scale flow). **F. Bertin** (CETP, St Maur) discussed the capability of ST radars to estimate the vertical diffusivities, via measurements of the turbulent energy dissipation rate, and reminded the audience of the range of very different physical models on which such estimates have been based.

**Mesoscale and small scale.** **U. Schumann** (DLR Oberpfaffenhofen) reviewed the observational constraints on small-scale turbulence in the tropopause region. He noted the inconsistency of assumptions concerning inertial ranges and gave observational evidence that, at least over oceans, small-scale turbulence may often be entirely absent. He also noted a possible association between the occurrence of cirrus and turbulence in the tropopause region. **J. F. Lamarque** (NCAR) described a numerical investigation of mixing between tropospheric and stratospheric air due to topographic waves, motivated by DIAL observations in the neighbourhood of Fritts Peak. **H. Davies** (ETH Zurich) reviewed observations of mesoscale features at tropopause levels and concluded that the tropopause was 'awash' with such features. He discussed the various different models that might capture some of the relevant dynamics and described numerical investigation of the evolution of simple vortex structures within a primitive-equation model. **H. Wernli** (ETH Zurich) continued by describing a quantitative analysis, based on high resolution ECMWF data, of the contribution of different types of feature such as streamers and cut-offs to STE. **V. Wirth** (Univ. Munchen) noted the need for a theoretical model to predict the quantitative relation between water vapour satellite images on one hand and PV maps on the other hand and presented a first attempt at such a model. **M. Bithell** (Rutherford Appleton Lab.) described simulations of tropopause folds and the occurrence of tube-like PV structures in a high resolution GCM and discussed the role of model dissipation in the evolution of such structures. Finally, **Y. Yamazaki** (Univ. of Toronto) described very-high resolution simulations of tropopause folds in a non-hydrostatic model and discussed sensitivity to resolution.

● Peter Haynes, Volkmar Wirth



## Open Session on the Middle Atmosphere The Hague, Netherlands, 6-10. May 1996

An open session on the Middle Atmosphere was organised by Dr. M. Dameris and Prof. Dr. P. Fabian. The session was very well attended. 38 oral and 14 poster papers were presented during this two day event covering various aspects of Middle Atmosphere dynamics and chemistry, investigations of atmospheric waves, new measurements of chemical tracers, aerosols, etc. in the whole middle atmosphere (10-120 km), modelling studies of atmospheric processes, comparison of model results and observations.

The abstracts are published in Annales Geophysicae, Supplement III to Volume 14, C701-C713, 1996.

***For more information, contact martin.dameris@dlr.de.***

● Martin Dameris

# COSPAR Session A1.1 - Middle Atmosphere-Satellite Observations, Interpretation and Validation, Models and Processes, and their Role in Global Change

## July 19-20, 1996, Birmingham, UK
## Convener : John J. Barnett

This symposium was one of more than seventy held during the 31st Scientific Assembly of COSPAR that took place in Birmingham, England. Other sessions included C1.2 (« Horizontal and vertical small scale structures in the middle atmosphere »), C4.3 (« CIRA Part III Reference Atmospheres -Trace Constituent Models- Comparison with Latest Data »), and sessions on measurement techniques, retrieval methods and instrument calibration. The Assembly was held over six days in July 1996. Being more compressed than the previous two week assemblies, there were inevitably more parallel sessions, and session C1.2 unfortunately took place at the same time as session A1.1. A total of 35 oral papers and 11 posters were scheduled, although a small number were withdrawn.

The session was dominated by UARS, with the Upper Atmosphere Research Satellite data probably accounting for more than half of those shown. **C. Jackman** gave an overview of the UARS data, adding to material which he had already presented in Session C4.3. Several authors gave papers about specific UARS instruments and their data sets, and for a number of studies data sets from various instruments were combined with each other and with other analyses such as from the NMC. Now that the UARS record exceeds five years, questions of year-to-year variability can be seriously addressed, and the first year which was affected by Mt. Pinatubo aerosol can be contrasted with the later years. Many of us never expected to see any meaningful temporal trends in the UARS data, but the increase of HCl and HF are clearly seen in the HALOE data.

The wind data, which are directly measured from Doppler shifts by WINDII and HRDI, are impressive, and values are obtained continuously from 10 to 200 km altitude apart from a gap between about 42 and 50 km. Such features as the Quasi-Biennial Oscillation are clearly revealed, and it seems likely that these measurements will be particularly valuable in the tropics where derivation of dynamical quantities from the temperature and geopotential height is inaccurate. Several instruments are showing high quality tracer latitude/height cross sections that point to patterns of meridional circulation indicating upwelling in the tropics. These patterns were seen in methane and nitrous oxide in the Nimbus 7 SAMS data 15 years ago as single or double humped structures that peaked in the tropics and varied with season. They are now seen much more clearly and also in CFC12 (from CLAES) and water vapour (from several instruments), and subtle variations in the pattern (« rabbit ears », subtropical steepening of the latitudinal gradients, etc.) are observed and found to depend on the phase of the QBO.

The behaviour of the winter vortex, particularly in relation to ozone depletion is still a major issue with most attention now being focused on the Northern Hemisphere. **L. Hood** (using TOMS and MSU data) and **S. Pawson** addressed the question of to what extent stratospheric ozone changes are induced by changes in the dynamics, and it appears that in the tropics dynamics could account for all of the changes observed, with dynamics also being a major cause at mid latitudes.

**R. Rood** described the assimilation work of the NASA/GSFC Data Assimilation Office. He showed comparisons between his own and the UK Meteorological Office assimilation for identical data input. They showed near perfect agreement in the troposphere where the data was a strong constraint, but much more marked differences in the stratosphere. He showed results for an event on 10 September 1992 when a tongue of tracers in the tropical stratosphere was seen to be extruded towards the Southern Polar vortex (data for this event were also shown in a number of other papers). In this case he found that using just HALOE data for a few days (i.e. with very few profiles, mainly in the tropics) gave very good results, apparently implying that the structures were mainly generated by the dynamics and that a low resolution tracer field was adequate to give the initial field. A simple form of assimilation was used for validation of the ERS2 GOME total column ozone data by **A. Piters** and **P. Levelt** from KNMI in the Netherlands. They advected column amounts as if at a single level using 200 hPa ECMWF winds (this level was found to give the best results) as a way of mapping the column amounts for internal consistency checks and comparison with other measurements.

**S. Pawson** described the SPARC GRIPS modelling intercomparison project in some detail and went on to give some results of comparisons with the Berlin data sets. He also expressed a considered desire for observations of temperature, height, winds and ozone at 500km x 500km x 2km resolution over a decade or more for long term studies, and better for process studies. **J. Gille** described the HIRDLS instrument due for launch on EOS-Chem that goes some way to addressing these needs.

Several papers (by **Y. J. Orsolini, T. Hirooka, D. Ortland**) were about free travelling Rossby waves, such as the 2-day and the 5-day waves, again using mainly UARS data. **Orsolini's** waves (seen in the UK Met. Office UARS assimilation fields for January 1992) seemed to be in lower latitudes than previous studies ; it was concluded that they were caused by inertial instabilities. **Hirooka** saw 5-day waves in ISAMS data with for example a global structure in May 1992 at about 1hPa.

The UARS orbit is not sun synchronous, which allows solar tides to be studied provided their effects can be separated from other, often much bigger, temporal changes. **M. Gelman** studied differences between 1hPa MLS and NMC temperatures and found patterns that varied over the orbit precession cycle in a repeatable manner that appeared to be tidal. This demonstrated that diurnal variations need to be allowed for, certainly in the upper stratosphere and above, when data for different local times are gridded or merged. Differences were up to about 4K. Similar results were reported by **P. Keckhut** when comparing between MLS and French lidars.

**D. Rees** described the ALOMAR lidar being installed at Andoya in northern Norway. It uses two steerable 2m diameter telescopes and is able to measure winds, temperature and PSC/aerosol reflections both by day and night. He made the point that the presence of polar stratospheric clouds or noctilucent clouds enabled much more accurate wind measurements.

A number of other papers addressed PSCs. **A. Lambert** showed how UARS ISAMS data could be used to map PSCs and determine their composition from measurements at different infra red wavelengths, while **S. Pawson** presented a study of northern winter temperatures (which are critical to PSC formation) as obtained from the SSU operational sounders over the last 17 years and from Berlin radiosonde analyses over the last 40 years.

**M. Lopez-Valverde** presented CO measurements from ISAMS and compared them with data from the March/April 1992 Space Shuttle flight of the ATMOS solar occultation interferometer. Although both are infra red measurements, they rely on different physics (ATMOS is not affected by non LTE; ISAMS relies on NLTE effects). They give similar results below 40km, but at 60km ATMOS is lower by two orders of magnitude, and then displays a very rapid increase to come back into agreement. The speaker believed that the ATMOS results were too low. **M. Summers** reported OH measurements from the MAHRSI instrument carried on the ATLAS-3 Shuttle mission along with MAS and CRISTA (CRISTA papers, which were presented in a parallel session, will be the subject of an article in the SPARC Newsletter 8). The measurements are consistent with models in the upper mesosphere but less with models in the lower mesosphere. He suggested that this is part of the larger problem whereby theory underpredicts ozone at 50km. Given that they have simultaneous CRISTA data for ozone and other species they now have a good chance of making some progress.

**M. Coffey** showed some results from four aircraft campaigns (three in the Arctic, one in the Antarctic) which measured column amounts of stratospheric species using a Fourier Transform Spectrometer looking up at the Sun. He addressed the problem of how to inter-relate them and found that they were well correlated with potential vorticity derived from meteorological analyses, such that PV fields could possibly be used to extrapolate the results of individual flights to much larger regions.

The session included papers on variety of other topics including the mesosphere and thermosphere (notably from HRDI), on comparison with CIRA temperature and constituent climatologies, and calculation of UVB dose at the surface from stratospheric ozone fields.

Overall the session was well attended with an audience of typically about 40 despite overlapping sessions, and despite the last session being held on a Saturday morning during uncharacteristically hot and sunny weather!

John J. Barnett

# NATIONAL NEWS

## Austria

*Spectral measurements of Solar UV-A and UV-B Radiation in High Mountain Areas.* Records of erythemal effective irradiance over the year measured by Robertson-Berger UV-Biometers (models 500 and 501) are available in Innsbruck (577 m a.s.l., Austria) since 1980 and over seasonal intervals at Jungfraujoch (3576 m a.s.l, Switzerland) since 1980. The attenuation of erythemal effective irradiance and UV-A irradiance was investigated and the radiation amplification factor which describes the influence of ozone on erythemal effective irradiance was found to be 1.07 ±0.15 % between 20° and 60° solar elevations. From measurements in Western Austria, the increase of erythemal effective irradiance with altitude under cloudless sky was 15-20 % per 1000 m, depending on albedo and atmospheric aerosol content. With a high resolution double monochromator, spectra were measured between 290 and 500 nm. The spatial pattern of the diffuse sky radiation between 300 and 500 nm was measured and compared with the radiative transfer model given by K. Stamnes.

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## China

*China and Finland cooperate to study Quinghai-Tibet plateau ozone profiles.* Over the past several years, total ozone, Umkehr ozone profile and UV-B radiation measurements have been made in China Walinguan GAW station over Quinghai-Tibet plateau using #54 Brewer Ozone Spectrophotometer by the Chinese Academy of Meteorological Sciences. Now, an intercomparison campaign is on going near this station, at Xining meteorological sounding station from November 1995 to August 1996 in order to compare the vertical ozone profile made by balloon borne ECC ozonesonde and ground-based Brewer Umkehr measurements. This campaign, including a total of 50 ozonesondes, which is conducted in cooperation with Vaisala Oy of Finland, provides a good opportunity to investigate and evaluate the accuracy and precision of Brewer #54 Umkehr measurements serviced at Waliguan GAW station routinely.

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## Czech republic

*Ozone Laminae Studies.* The laminar structure of ozone profiles was studied. Investigations of occurrence frequency of ozone positive laminae and of ozone content in these laminae for two stations in Central Europe, Hohenpeissenberg (1968-1993) and Lindenberg (1975-1993) yielded pronounced negative linear trends. The laminae occurrence frequency (for laminae exceeding 30 mb) at these stations was decreasing by 18.6 ±1.7 %/dec. and 12.6 ±2.4 %/dec., respectively. The decrease of the overall ozone content inside the positive laminae was 21.8 ±2.6 %/dec. and 14.4 ±3.6 %/dec., respectively. Preliminary, a negative trend in laminae occurrence was found also for eastern part of Canada, but a positive trend in its western part. In Japan (near 40° N) the trend seems to be negative. The apparent regional dependence of the trends seems to correspond to their predominantly dynamic origin.

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## Greece

*An Extensive Study for the Measurement and Modelling of UV-B/Atmospheric Composition* Relations started as a joint venture of two EC projects on June 1-20, 1996. The specific is to model and measure how tropospheric ozone is affected by enhanced UV-B radiation in regions with a strong influx of UV-B radiation (Mediterranean region). (Similar studies of the UV-B/ozone relations will be performed in the Alps).

Investigations include observed and estimated variations in ozone column densities, solar fluxes and ozone photodissociation rates, measurements of tropospheric ozone, $NO_x$ and other key compounds, and related model calculations.

The overall project will study a sequence of events going from reduced stratospheric ozone through increased photochemical activity in the lower atmosphere to the evaluation of the impact on regulations which aim at reducing ozone levels in polluted regions. The project shall provide estimates and coupled UV-B fluxes/air quality measurements in urban and rural regions in Europe. Emphasis shall be given on height dependence of the tropospheric ozone oxidising capacity and UV changes.

67 scientists from Europe, USA and Canada are involved in PAUR (Photochemical Activity & Solar Ultraviolet Radiation Project) (Coordinator, C. Zerefos) for the campaign in Greece sponsored by EC DG XII and partly by the Min. of Environment. The instruments are deployed in central Aegean Is. and in the mainland of Greece. The measurements include ground-based and aircraft actinic fluxes (ATOP Project - A. Hofzumahaus, coordinator), ozone, trace constituents, lidar, meteorological and other measurements including monochromators.

Preliminary results have shown important transport and sources which maintain high values of lower tropospheric ozone. The role of UV-B fluxes in the upper troposphere is presently examined.

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## Japan

*International Cooperative Study on Stratospheric Change and its Role in Climate* (one of the Japanese programmes related to SPARC financed by the Sci. and Tech. Agen. of Japan-STAJ). A new lidar station is highly expected in the equatorial region considered to be the reservoir of stratospheric aerosols. Ground based sensing (lidar and FTIR) and balloon sounding give us precise distribution of minor constituents, and satellites provide their global distribution. Combining these observations to the objective analysis of the atmospheric circulation, spatial and temporal distributions of the constituents will be known. CTM is used to analyse observational data and to assess physical and chemical processes and the influence of the stratosphere on the troposphere.

**Monitoring of the Variability in the Stratosphere**

• *Observations of Stratospheric Aerosols* a) Lidar Observation of Stratospheric Aerosols in the Equatorial, Mid and High Latitude Region (T. Itabe, Communic. Res. Lab.- CRL ; M. Hirota, MRI). The lidar network comprises Eureka (80°N, 86°W), Tsukuba (36°N, 140°E, Naha (26°N, 127°E), Bandung (7°N, 107°E) and Lauder (45°S, 169°E). A polarisation sensitive Nd : YAG lidar system will be installed in Bandung. b) Observations of Stratospheric Aerosols by Balloon Sounding (M. Fujiwara, Fukuoka Univ.). To obtain the size distribution of aerosols and PSCs, optical particle counters are launched at Eureka, Bandung and Lauder.

• *Experimental Studies of Stratospheric Chemical Processes.* To understand the behaviour of minor constituents in the ozone layer chemistry, experimental studies by IR absorption and sub-millimetre emission spectroscopy are undertaken. a) FTIR Infrared Spectroscopy (Y. Makino, MRI) : Stratospheric minor constituents such as HCl, HF, $HNO_3$, $ClONO_2$, NO and $NO_2$ are studied with FTIR at Eureka, in cooperation with AES/Canada, and at Tsukuba. b) Sub-millimetre Spectrometer (H. Masuko, CRL : CRL has developed a sub-millimetre spectrometer system for observing stratospheric gases such as ClO with high sensitivity using superconducting technique. CRL constructs a modified version of the system and participates in the experiments to observe the upper atmosphere over the Arctic.

• *Development of New Lidar Technologies* (T. Nagai, MRI). New lidar technologies including the Raman method are developed to obtain the optical thickness of stratospheric aerosols and middle atmosphere temperature profiles with high precision.

**Chemical Process Studies**

• *Experimental and Modelling Study of Chemical and Transport Processes* (H. Akiyoshi, NIES ; M. Takahashi, Univ. of Tokyo ; T. Sasaki, MRI). To study the relation between stratospheric circulation changes and minor constituents through the radiation processes, 1- and 3-D CTMs are developed.

• *Photochemical Reaction Process Studies.* To establish more accurate chemical models and understand the change of tracer gases in the stratosphere, experimental, observational and modelling studies are performed. a) Laboratory Experiment of Heterogeneous Processes in the Stratosphere (T. Ibusuki, NIES) ; b) Observational Study of $CH_3Br$ Disturbing Ozone Distribution (Y. Yokouchi, NIES). c) Study of the Effect of Exhaust Gases from Aircraft on the Stratospheric Environment (S. Tamaru, STAJ).

**Observational and Numerical Studies of Stratospheric Change and its Effects on Tropospheric Climate**

• *Observational Studies.* a) Dynamical Analysis of the Structure of the Polar Vortex using Satellite and other Data (H. Kanzawa, NIES ; K. Kawahira, Toyama Nat. College and Tech.) b) Stratospheric Ozone (O. Uchino, JMA). To establish the harmonised data, mutual relationship among ozone data with ground based spectrophotometers, ozonesondes and satellite will be studied. c) Climatology of Gravity Waves (S. Konaga, Jap. Weather Ass.). GW climatology is investigated by using fine or raw data from operational radiosonde soundings. A special balloon campaign with very short time intervals is also planned.

• *General Circulation Model Studies* (M. Chiba, MRI; K. Kodera, MRI; K. Yamazaki (Hokkaido Univ.). By using a GCM, impacts of changes in stratospheric circulation on the troposphere and their mechanisms are investigated.

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## Netherlands

Recently a Centre for Climate Research has been established by the Royal Netherlands Meteorological Institute (KNMI), the Institute for Marine and Atmospheric Research at Utrecht (IMAU) and the Institute for Public Health and the Environment (RIVM). The objectives of the atmospheric part of the centre are to study physical and chemical processes that influence the atmospheric composition as well as the changes therein and the resulting climate responses. The Centre for Climate Research has modelling and measurement components.

**Measurements.** UV and ozone monitoring activities are performed at KNMI and RIVM. Spectral UV measurements are used for UV trend analysis, to test radiative transfer models and for studying the effects of atmospheric parameters (ozone, aerosols and clouds) on UV-B. An ozone and UV climatology for the Netherlands is constructed and used for the detection of regional trends in UV-B to support national UV policies. At the site of KNMI at De Bilt ozone soundings are made at least once per week. At RIVM several troposphere lidars are operational and measuring ozone in the free troposphere and boundary layer. As part of the NDSC, RIVM operates a lidar for measuring ozone, temperature and aerosol at Lauder in New Zealand. For three years IMAU and KNMI are involved in airborne measurements of the composition of the atmosphe-

re up to 14 km, with special emphasis to the study of stratosphere-troposphere exchange and composition of the lower stratosphere at mid-latitudes and in the Arctic vortex. The partners are also involved in remote sensing of the atmospheric composition from satellites (presently GOME on board the ERS-2, in the future also SCIAMACHY on board ENVISAT and OMI on board METOP). The airborne and satellite measurements are also directed towards mutual validation of measurements and models. Attention is being given to the assimilation of the satellite observations of the atmospheric composition in state-of-the-art models. Available satellite data (TOMS, TOVS, SBUV, UARS, GOME ; in future SCIAMACHY and OMI) are used to construct global climatologies. These should serve for model initialisation and assessment of global change.

**Modelling atmospheric transport, chemistry and radiation.** The strategy involves the development of a hierarchy of models, from simple process-oriented models such as a chemical box model coupled to trajectories, more elaborate off-line chemistry transport models, up to a GCM with fully coupled chemistry and radiation. The models are used to simulate measurement campaigns and historical and future changes. Presently, an important application area of the models is the effect of aircraft emissions on atmospheric composition and climate. Some recent results include :

• With a 2-D stratospheric model the effects of CFC and HCFC on the ozone layer have been studied. In combination with the satellite data, the budgets of chlorine and fluorine are studied and the roles of anthropogenic and natural sources are being determined.

• Changes in the formulation of the parent model, from which an off-line chemistry transport model derives its transport parameters, have been shown to affect the vertical transport characteristics profoundly (up to a factor of 2). This is a strong argument for the use of consistent meteorological input data sets, such as those from the reanalysis projects currently running at ECMWF and NMC.

• With a chemical box model coupled to trajectories the amount of ozone destruction during the 1993/1994 Arctic winter as observed from airborne measurements has been reproduced.

• Evidence has been found for the upward transport of polluted air through the tropopause at mid-latitudes. These observations are consistent with upward and downward fluxes of air through the tropopause that have been calculated using high resolution data from the ECMWF model.

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# NATO ASI « Solar UV Radiation Modelling, Measurements and Effects »

## October 2-11, 1995. Director : Ch. Zerefos (cosponsored by EC/DG XII). Halkidiki, Greece

The purpose of this NATO Advanced Study Institute was to provide the state of the art on the UV radiation transfer through the atmosphere and its biological and other photochemical consequences.

The UV-B chapter of the course included : a) Long-term trends : Lack of reliable measurements inhibits the detection of long-term trends. In addition, complicated processes occurring during the UV transmission through the atmosphere are possibly masking the expected ozone depletion. The atmospheric aerosol content, various natural or anthropogenic interfering gases and the cloud cover are potential sources of uncertainty in the trends. Only in the areas of major ozone losses (Arctic and Antarctic) there is strong evidence of UV radiation increases, so there is still an open question on « what is the situation in middle and low latitudes ». b) Biological consequences of increasing UV radiation : There are only a few occasions where atmospheric physicists and biologists join their expertise on this. It is essential that studies of the UV effects on man and on ecosystems be available to those concerned with the atmospheric science. Both categories of scientists should be aware of the needs and capabilities of each other. c) Modelling of UV transfer through the atmosphere : A variety of models are currently in use and their uncertainty is reduced as new and more reliable data become available. d) Measurements and calibration : There is an increasing demand for accurate UV measurements. Latest improvements on the quality of such measurements resulted in better understanding of both the UV transfer and its biological consequences. More accurate calibration methods have reduced the existing uncertainty.

In addition to tutorial lectures, several presentations on the atmospheric physics and UV-B transfer and UV measurements were given and the ASI students have presented their work. The ASI concluded with a visit to the Lab. of Atm. Phys. of the Aristotle Univ. of Thessaloniki.

A NATO ASI publication containing the lectures and reviewed presentations is planned to be published in early 1997 from Springer-Verlag.

● Christos Zerefos

# Future SPARC and Related Meeting

## Future SPARC meetings

**September 1996 :** SPARC Reference Climatology Study Group. Convener : W. Randel (NCAR), Stony Brook, N.Y., USA.

**October 1996 :** SPARC Stratospheric Temperature Trend Assessment Study Group. Convener : V. Ramaswamy (GFDL), London, UK.

**21-23 October 1996 :** International Workshop on modelling heterogeneous chemistry of the lower stratosphere/upper troposphere : I. Isaksen (Inst. for Geophysics, Univ. of Oslo, Blindern, Norway), A. R. Ravishankara (NOAA/ERL, Boulder, USA), Ph. Mirabel (Institut Louis Pasteur, Strasbourg, France), Strasbourg, France.

**2-6 December 1996 :** First SPARC General Assembly. Conveners : M. Geller (SUNY, Stony Brook, N.Y. 11794-5000, USA) and D. Karoly (CRC for SH Meteorology, Monash University, Clayton VIC. 3168, Australia), Melbourne, Australia.

**20-22 May 1997 :** IGAC/SPARC Conference on « Global Measurement Systems for Atmospheric Composition », Toronto, Canada. For more information, contact the SPARC Office or IGAC Office.

**August 1997 :** SPARC Session, IAGA-ICMA General Assembly, Conveners : D. Fritts (LASP, Univ. of Colorado, Boulder, CO 80309-0392, USA) and S. Pawson (IFM/FU, Berlin, Carl-Henrich-Becker-Weg 6-10, 12165 Berlin, Germany), Uppsala, Sweden.

## SPARC related meetings

**12-21 September 1996 :** XVIII Quadriennial Ozone Symposium-96. Conveners : G. Fiocco (Physics Department, University La Sapienza, Rome, I-00185, Italy) and G. Mégie (CNRS/SA, Université Paris VI, B. 102, 4 Place Jussieu, 75252 Paris Cedex 05, France), L'Aquila, Italy.

**15-18 October 1996 :** International Colloquium « Impact of Aircraft Emissions upon the Atmosphere » (Chairman : J. Carpentier, ONERA, 8, rue des Vertugadins, 92190 Meudon, France), Paris, France.

**4-8 August 1997 :** 9th Quadriennial SCOSTEP STP Symposium. (Chaiman: C. H. Liu, NCU, Chung-Li, Taiwan, Republic of China), Uppsala, Sweden.



**18-22 August 1997 :** Second Workshop « Solar Activity Effects on the Middle Atmosphere ». Chairman : J. Lastovicka (Geophys. Inst., Acad. of Sciences, Bocni 11, 141.),Prague, Czech Republic.

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## SPARC on the World Wide Web

### http://www.aero.jussieu.fr/~sparc/

The SPARC project now has a home page on the World Wide Web. The site includes up to date information on the general objectives and activities of the SPARC programme and the SPARC initiatives. A calendar of upcoming SPARC and SPARC-related meetings is available as well as a link to the SPARC 96 home page in Australia created for the First SPARC General Assembly. Reports from SPARC meetings are published on the home page as soon as they are available, as are articles intended for the SPARC newsletter. An e-mail link to the SPARC office has been included as well as links to other home pages relevant to SPARC, WCRP and WMO.

● Céline Phillips


## Edited by SPARC Office

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