First general Assembly of the WCRP-SPARC project « Stratospheric Processes and their Role in Climate »

Melbourne, 2-6 December 1996

The First SPARC Assembly, sponsored by numerous Australian and International Sponsors, was opened on 2 December 1996 by Prof. M. Geller, Chairman of the Assembly Scientific Programme Committee. The participants were welcomed by Dr. J. Zillman, the WMO President and Director of the Australian Bureau of Meteorology, and by Prof. D. Karoly, Chairman of the Local Organising Committee for the Assembly. Dr. Marie-Lise Chanin presented the scientific goals of SPARC and its main activities.

More than 220 people attended the Assembly (plus about 10 local people who came for a day or two), and 21 countries were represented. Of a total of 211 papers presented, 75 were oral and the remaining 136 were poster presentations. An abstract volume has been prepared by the LOC and issued before the assembly. In 1997, the extended (4-page) abstracts of the assembly will be published as a WRCP report.

Dr. J. Zillman, the WMO President and Director of the Australian Bureau of Meteorology, during his welcome speech at the SPARC 96 General Assembly. Courtesy of CRC for Southern Hemisphere Meteorology.

Below follows the summary of the main results as prepared by the SPARC co-chairs and SPARC Study Group chairmen and edited by the SPARC Office.

Session 1. Troposphere-strastosphere general circulation models

Rapporteur : S. Pawson

Many of the presentations at the meeting included results from comprehensive numerical models of the troposphere and middle atmosphere. These were supplemented by a range of studies using simpler numerical models. The various models included some or all of the dynamical, radiative, and chemical processes in the atmosphere.

Several of the studies examined the success with which the comprehensive models currently simulate the climatic structure of the atmosphere. Although the dominant features of the circulation are captured, there are important systematic errors in the strength and location of, say, the polar night jet in the winter stratosphere. In this sense, the use of some parameterisation of small-scale gravity wave drag was shown to be an essential feature, although the models can react quite strongly to changes in some of the « unknown » parameters. Topics such as the seasonal evolution of the atmosphere were addressed : some models display a reasonably accurate progression through the year. The use of these models as an integral part of data assimilation systems was also a theme.

The dynamics of the tropical middle atmosphere were discussed in several presentations. These studies concentrated on the propagation of tropical waves in the middle atmosphere, as well as the sensitivity of the wave spectra to some numerical aspects (resolution) of the models. Mechanisms of wave excitation in the stratosphere were discussed, as were the propagation of waves from tropospheric sources. These tropical waves are, of course, a potential forcing mechanism for the dominant vacillations of the tropical stratosphere : the semi-annual and quasi-biennial oscillations (QBO). This latter feature, which dominates the low-frequency dynamics of the tropical lower stratosphere, has until recently proved elusive in GCMs, so it is of considerable interest that some simulations can produce analogues of the observed QBO : these point the way towards its simulation in more models, which will facilitate studies of its potential climatic impact.

As precursors to fully coupled chemistry-dynamics studies, some presentations examined the effects of imposed ozone perturbations, which disturb the radiative balance, on the circulation of models.

Chemical transport models (CTMs), which use observed or modelled winds to advect trace gases and the corresponding temperatures in the chemistry calculations were the basis of several presentations. These studies examined the transport of long-lived tracers, the contributions of dynamics and chemistry to certain situations.

Further studies examined the coupled chemistry-circulation problem. The seasonal evolution of various chemically active trace gases with and without heterogeneous chemical processes was discussed. Several studies examined the 3D structure of such coupled models, showing successes and problems with the ozone distribution, as well as examining the distributions and importance of other trace gases.

All in all, the modelling studies gave a representative overview of current research interests and showed how comprehensive 3D models have evolved over the past years. Many of the models were used in later presentations in the meeting, to examine trends and variability in the atmosphere.

Session 2. Stratospheric climatology studies

Rapporteur : W. Randel

Stratospheric climatology studies focused on analyses of global data sets to study aspects of stratospheric dynamics and trace constituent behaviour in the middle atmosphere. Long time records of stratospheric circulation statistics from the National Centres for Environmental Prediction (NCEP), the United Kingdom Meteorological Office (UKMO) and the NASA Goddard Earth Observing System/ Data Assimilation System (GEOS/ DAS) were analysed by a number of groups. These data sets form the basis for the SPARC Reference Climatology program, which will compile statistics and also make systematic comparisons between the analyses to highlight uncertainties. Aspects of stratospheric variability based on analyses of these data sets were presented by a number of researchers, including troposphere-stratosphere coupling, stratospheric variations associated with the quasi-biennial oscillation (QBO) and the 11-year solar cycle, and « natural » internal stratospheric variability. Among the more novel results was the use of « elliptical diagnostics » to study behaviour of the stratospheric polar vortices (presented by D. Waugh of Monash Univ. in Melbourne) ; these diagnostics describe the position of the vortex centre, its orientation and elongation in a set of compact statistics that are complimentary to the usual zonal Fourier wave decomposition. Other climatological data sets used for studies of long-term variability included tropical winds from Singapore (to study the QBO), NCEP re-analyses, and direct measurements of stratospheric winds from the High Resolution Doppler Imager (HRDI) instrument on the Upper Atmosphere Research Satellite (UARS) (figs. 1 and 2). The analyses of temperature and geopotential heights and total ozone variations with a period close to that of the solar cycle were presented by K. Labitzke and H. van Loon (fig. 3) ; the results for ozone are based on only a 15-year series of TOMS observations and may thus be not representative of a longer period.

Along with the dynamical climatology studies, results based on analyses of stratospheric trace constituents provided novel insight into stratospheric transport issues. Seasonal and interannual variations in ozone and water vapour were discussed in a number of presentations. Novel results from the Halogen Occultation Experiment (HALOE) on UARS were presented by K. Rosenlof of NOAA, addressing the asymmetry in lower stratospheric water vapor between the NH and SH, and aspects of transport between the tropics and middle latitude. A new climatology of stratospheric aerosol parameters (including surface area and volume density) derived from several satellite data sets was presented by L. Thomason of NASA Langley ; this promises to be a valuable resource for the research community. The combination of climatological constituent data sets with stratospheric circulation diagnostics promises to refine our understanding of stratospheric transport behaviour, and provide concise tools for model validation.

Session 3. Trends in temperature, ozone and water vapour

Temperature

Rapporteur : V. Ramaswamy

Presentations were made concerning the impact of changes in radiative constituents, which included both modelling and observational studies. Progress was reported on the intercomparison of trends in the lower stratospheric temperature over the last decade as inferred from a variety of datasets. It is found that the midlatitude Northern Hemisphere lower stratosphere has undergone a statistically significant cooling. Problems were noted concerning the inhomogeneity in the radiosonde records due to changes in instrumentation and methods of observation, and radiation-related errors that can occur in the temperature sensors, all of which affect the quantitative trends analyses.

Temperature trends inferred from aerological stations located in the Arctic suggest an amplification of the lower stratospheric cooling in recent years in late winter ; however, the trends in this season are not statistically significant. From modelling studies, the loss of ozone in the global lower stratosphere is estimated to be largely responsible for the cooling trends in this altitude region over the past one-and-a-half decades. Fig. 4 compares the satellite-based and GFDL-modelled trends. Additionally, model simulations show that there also occurs a slight cooling of the upper troposphere.

Rocketsonde data based on launches by the United States since 1969 have been systematically analysed and a cooling of the upper stratosphere is evidenced.

Russian rocketsonde data have also been analysed and a negative trend is seen in most of the stratosphere and particularly in the mesosphere. The prospective launch of the SAGE III instrument offers a hope for continuous measurements of the vertical temperature profile and thus of trends in the future. Diagnostic analyses of observations reveal a more substantial cooling of the Antarctic lower stratosphere in southern spring and summer over the past 15 years than before 1980. A simulation of the impacts of the Antarctic springtime ozone depletion has been carried out which reveals the occurrence of a strong cooling accompanied by a delay of the springtime warming, consistent with observations. Another diagnostic study indicates that there may be a dynamical contribution to the cooling in the wintertime Northern Hemisphere polar stratosphere (European and Siberian sectors) in recent years, which could be conducive for the formation of PSCs and thus holds potential implications for ozone depletion.

In contrast to the traditional Fixed Dynamical Heating method and its results, a new method employing observed stratospheric ozone and temperature changes finds the resulting change in the irradiance at the tropopause to be substantially less. Modelled dynamical adjustments in the stratosphere in response to ozone losses are seen to be non-negligible.

In another paper, concurrent ozone and temperature measurements are analysed and it is inferred that both vertical displacement and radiative adjustment to changes in trace gas concentrations need to be considered in order to explain observed ozone and temperature variations. The impacts on stratospheric temperatures and surface-troposphere forcing due to uncertainties in the vertical profile of ozone were presented ; the influence of ozone losses relative to other trace gases on temperature trends in the middle/upper stratosphere was also discussed. A series of GCM experiments related to increases in trace gases (e.g., doubling of CO_2) reveal that the stratospheric circulation and the tropospheric climate changes are strongly linked.

Ozone

Rapporteur : Neil Harris

The trends in ozone were fully assessed in the last WMO-UNEP Scientific Assessment of Ozone Depletion (WMO, 1995). There have been no major changes in our knowledge of the trends since that time, although a number of studies have been made which have either added to our picture or changed certain features. The information given in WMO (1995) is briefly summarised, before the new findings discussed at the SPARC General Assembly are presented.

The changes in total ozone were found to be relatively well characterised. At mid-latitudes in the northern hemisphere the trends from 1979 to 1994 found in the combined SBUV/SBUV-2 record 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.

WMO (1995) also reported that the bulk of the loss in total ozone at mid-latitudes has taken place at altitudes between 15 and 25 km. The available long term records 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 20 km. However there has been considerable debate about the magnitude of the trends below 20 km 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 there so that the effect on the total column is small.

Re-analysis of the TOMS measurements has produced a continuous record of total ozone from 1979-1994 by producing version 7 level data from the

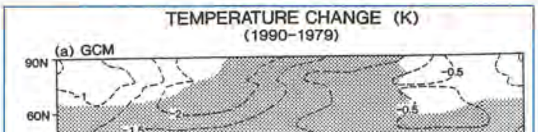

Figure 4 . (Ramaswamy et al., Nature, Vol. 382, pp. 616-618, 1996, fig. 2). Zonal, monthly-mean pattern of the lower stratosphere change over the past decade (1979-1990)
a - As simulated by the GCM due to the observed ozone depletion (Stolarski et al, GRL, 1991; McCormick et al. GRL, 1992) for the altitude region of the model where ozone concentration changes occur.
b - as inferred from satellite observations for a layer comprising the lower stratosphere.
Shaded areas denote the statistical significance at the 95 % level.

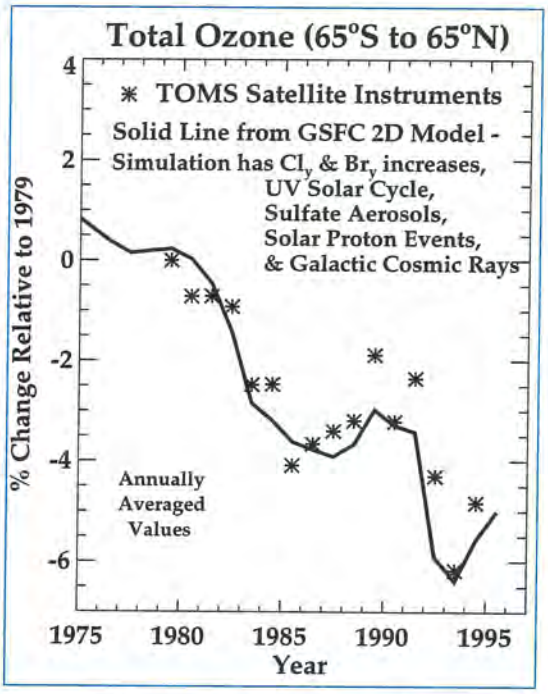

Figure 5. Percentage total ozone changes between 1975 and 1995 for annually averaged values integrated between 65°S and 65°N for TOMS version 7 (stars) and a GSFC 2-D model simulation (solid line). (adapted from fig. 15 of Jackman et al., Past, present, and future modelled ozone trends with comparisons to observed trends, JGR, 101, 28753-28767, [1996], copyright AGU).

instruments on the Nimbus 7 and Meteor 3 satellites. The losses calculated from this record are about 1 % per decade smaller than those found in the SBUV record, and so some of the smaller losses which were previously statistically significant by a small amount are found in TOMS v.7 to be just insignificant. This effect is most obvious in summer in northern mid-latitudes and in the tropics where the TOMS v.7 trend is found to be about -1% per decade and not statistically significant. The TOMS v.7 data has not been widely available for long and further close examination will be of great interest.

The correction made in the SAGE algorithm for the presence of stratospheric aerosol changes has been known to induce an uncertainty into the ozone measurement at low altitudes. Any change in aerosol loading could induce an artificial trend. The influence of changes in size distribution of aerosols on the SAGE measurements was examined (Steele et al.). They concluded that any change in size distribution over the SAGE observational period could lead to artefacts in ozone trends below about 20 km.

The BUV instrument on Nimbus-4 was operational from 1970-77. The number of measurements decreased through this period. During the first two years, near-global coverage was achieved. These data have been re-examined by Stolarski et al. and compared to the available ground-based measurements and are found to be consistent to within about 5 %, although it should be noted that the BUV measurements were calibrated using the World Standard Dobson Instrument. It is hoped that the BUV data can be re-analysed to version 7 standard using the experience gained from TOMS and SBUV.

The evolution of ozone levels as atmospheric chlorine amounts fall and the possibility of early detection of a recovery was discussed by Hofmann et al. The ozonesonde data collected at the South Pole from 1967-71 and since 1985 indicate that ozone loss at altitudes above 20 km have accelerated in recent years and so could be reasonably expected to show early signs of recovery. The globally averaged (65°S-65°N) total ozone from TOMS has been compared by Jackman et al. (see JGR, 1996) with the output from the Goddard 2-D model (fig. 5). According to this model, most of the ozone changes (4 %) are driven by halocarbon increases, UV radiation variations (1.2 % difference in ozone between solar maximum and minimum) and changes in sulphate aerosol (ozone decrease -2.8 % in 1992 due to Pinatubo).

The effect of aerosol on model calculated ozone trends has been investigated in more detail by Solomon et al. They conclude, among other things, that the effect of the solar cycle on total ozone could be much less than currently thought as the eleven year solar cycle could have acted as a proxy variable for volcanic aerosol loading over the last 20 years. More study of the time evolution of ozone changes as a function of season, altitude and latitude before cause and effect can be quantitatively ascribed. The effects of global warming on the stratosphere are not well enough understood to do this at the current time.

Water vapour

Rapporteur : John Gille

There was no session devoted specifically to Upper Troposphere/ Lower Stratosphere (UT/LS) water vapour, although a number of papers bearing on this subject were presented in sessions on trends and climatology, and in the posters. These are reviewed here; because of the overlap, some of the papers will be mentioned in other sections as well.

A number of advances in knowledge of the UT/LS were reported, and plans for further activities were presented. K. Rosenlof reported analyses of satellite data showing that the effects of Antarctic dehydration extend to about 50° S at the 46 hPa level. They also displayed significant longitudinal variations, explaining differences in earlier aircraft observations. She also showed that mixing from the dehydrated region above the tropical tropopause is more effective toward the northern hemisphere than the southern hemisphere. For this and other reasons, the southern hemisphere lower stratosphere is slightly drier than the northern hemisphere. P. Mote and T. Dunkerton extended Mote's earlier analysis of the tropical tape recorder, deriving an estimate of the upward velocity in the tropics. They found a minimum near 50 hPa, in agreement with Rosenlof's results. D. Jackson presented maps of UT/LS water vapour derived from HALOE data. These showed large longitudinal variations, with higher water vapor concentrations in regions characterised by more active convection. In a related paper, G. Reid showed that short term variations of tropical tropopause height and temperature are quite large, especially during the northern summer. The vapour pressure associated with these temperatures correspond to water vapour mixing ratios that are larger than observed. The observed values can be understood if air only enters the stratosphere when the tropopause is highest and coldest, i.e. when vertical motions are largest. Tropical water vapour content also varies strongly in response to the QBO, according to results based on SAGE and HALOE data presented by E.W. Chiou.

In middle latitudes D. McKenna outlined the result of an aircraft study of a major tropopause fold event off the coast of France. In this case, because water vapour mixing ratios were altered by phase changes and sedimentation, he concluded that the negative correlation between ozone and water vapor may not be true after the exchange, and that air going through the fold could carry significant amounts of water vapour into the lower stratosphere.

J. Gille reviewed the global distribution of water vapour and presented the preliminary outline of plans for the SPARC UT/LS water vapour initiative. The activities are envisaged to fall under three major headings : determination of the present distribution of water vapour, understanding the mechanism that maintains that distribution, and developing a capability to model the distribution and predict its future evolution. While much progress can be made to determine the present distribution from satellite data, these need to be validated and have their absolute values confirmed through comparison with in situ measurements. In-situ measurements and ground-based remote sensing are likely to play a major role in understanding the smaller-scale mechanisms.

Session 4. Gravity wave processes and their parameterisation

Rapporteurs : K. Hamilton and R. Vincent

The session included a total of 22 presentations and posters. The use of single-station radiosonde horizontal wind and temperature measurements to determine dominant gravity wave characteristics was dealt with in five of these papers. R. Vincent reviewed the efforts of the SPARC Gravity Wave Initiative to gather and analyse high-resolution radiosonde data on a global basis. G. Roff et al. and F. Guest et al. discussed radiosonde data from the TOGA-COARE experiment in the tropics and at Macquarie Island (54°S), respectively. K. Sato and T. Dunkerton described their research on determining the momentum flux associated with equatorial modes using near-equatorial radiosonde data, while S. Ogino et al presented an analysis of radiosonde data from two research cruises that spanned a large meridional range in both the Northern and Southern Hemispheres.

Seven of the papers dealt with the inclusion of practical gravity wave drag parameterisations within global, three-dimensional models. K. Hamilton reviewed the status of such parameterisations in light of the recent SPARC workshop on this topic (Santa Fe, USA, April 1996, see SPARC Newsletter #7). B. Lawrence described some experiments with a mechanistic 3D model of the middle atmosphere incorporating a parameterisation of non-stationary gravity waves. Papers by E. Manzini and by N. McFarlane and C. McLandress described aspects of simulations obtained with general circulation models that included parameterisations of non-stationary wave drag. Three papers (Y. Chang et al. , Y.-J. Kim et al. , W. Min et al.) discussed the effects of inclusion of topographic drag parameterisations in GCMs. An overall theme emerging from all of these papers is the complicated nature of the interaction between the parameterised drag and other aspects of the model formulation.

Four papers dealt with simplified models of gravity wave generation and propagation. J. Alexander and J. Holton described simulations of the gravity wave field generated by a tropical squall line in a nonlinear, time-dependent, 2D mesoscale model. I. Mikkelsen and J. Thayer showed 3D simulations of topographic waves over Greenland which were compared with actual incoherent scatter radar measurements. S. Eckermann and J. Bacmeister described the application of ray tracing models to predict the gravity wave response to flow over Iceland. They were able to apply this to explain aircraft observations considerably downstream from the wave source. J. Alexander showed that a ray-tracing model with a simple saturation condition imposed could explain many of the observed geographical variations in upper stratospheric wave variance, even when a globally-uniform source is assumed.

There were also interesting papers describing the application of sophisticated statistical analysis techniques to isolate gravity wave properties in observations (X. Zhu et al., T. Shimomai et al., F. Chane-Ming and F. Molinaro) and model simulation (M. Charron and G. Brunet). Also discussed were simple models of the effect of adiabatic gravity wave displacements on observed ozone profiles (D. Gibson-Wilde et al.) and visualisation of gravity waves in laboratory experiments (S. Sakai et al.).

Session 5. Stratosphere-troposphere transport and mixing

Rapporteur : T. Shepherd

It is now widely accepted that the subject of stratosphere-troposphere exchange (STE) is best viewed within the broader context of transport and mixing and this viewpoint was reflected in the title of the session. Results presented in the session fell, for the most part, within one of the six following areas.

Brewer-Dobson circulation

The Brewer-Dobson circulation describes the equator-to-pole Lagrangian circulation in the stratosphere, and results from a combination of the residual circulation and (mainly quasi-isentropic) mixing. There have been many recent attempts to quantify the residual circulation through radiative calculations, though as T. Shepherd noted this calculation is subject to considerable uncertainties. In any case the effect of mixing is very far from negligible, and so there is much current interest in quantitatively characterising the Brewer-Dobson circulation through the « age » of stratospheric air (relative to when it passed through the tropical tropopause). This can be done using chemical tracers - either real or idealised - with simple time dependence, e.g. linear or seasonally varying (T. Hall, D. Rind, J. Bacmeister (presented by S. Eckermann)). Hall emphasised, however, that while « age » corresponds to periodic-signal phase lags (like in the tropical « Tape recorder » when the tracer motion is essentially advective, when there is significant mixing the two quantities can be very different. Thus one must be careful in interpreting time dependencies in tracer signals in regions such as the lower stratosphere - where there is strong mixing. In general one must consider an « age spectrum ». More effort is needed now to quantitatively interpret tracer information and relate it to mixing and transport properties.

Tropical tropopause

The tropical tropopause remains a region of great interest. Efforts continue to further refine the « tape recorder » model by including the effects of the QBO (P. Mote). Certainly the annual cycle in height and temperature of the tropical tropopause seems driven from above, as it is not well correlated with the middle troposphere (G. Reid). On the other hand, it seems quite clear that the monthly mean tropical tropopause temperatures are nowhere near cold enough to account for the low water vapour values (G. Reid). Reid suggested that this discrepancy could be resolved if air entered the stratosphere via intermittent injections in cold turrets, so that the tropopause temperature would be particularly cold when the air passed through.

Of course large-scale longitudinal asymmetries are also significant. D. Jackson et al. presented the global distribution of upper troposphere/lower stratospheric water vapour based on the HALOE observations (version 17) (figure 6). The map for Dec., Jan., Feb. shows that the moistest air is located over Indonesia, Africa, and South America, all regions of strong convective activity, and this suggests that the air here is being moistened by the tops of convective cloud systems. The Sept., Oct., Nov. plot shows these regions of moist air less clearly (by the way, this plot shows dehydration at southern high latitudes due to the cold temperatures there).

More complete measurements of the tropical tropopause region, especially of the water vapour distribution, are clearly needed to resolve this issue of what controls the water vapour values in the lower tropical stratosphere.

Extratropical downwelling

The Brewer-Dobson circulation ends in extratropical downwelling. T. Shepherd discussed the recent work of Appenzeller et al. (1996) which demonstrated a lag between the mass flux into and out of the Northern Hemisphere lowermost stratosphere, a result of its « seasonal breathing ». This lag explains the seasonal cycle of STE inferred from tracers ; insofar as this is distinct from the seasonal cycle of tropopause folds, this reinforces the global view of STE.

There remains an enormous discrepancy between the total mass flux across the tropopause and local estimates based on Wei's (1987) diagnostic (P. Siegmund, A. Ebel) ; clearly this must be clarified. Finally, a significant reason - especially within SPARC - for being interested in STE in the extratropics concerns the downward transport of ozone, and this is becoming the object of global budget analyses (A. Gettelman).

Tropical/ extratropical mixing

A major focus of recent studies has been mixing/exchange across the subtropical lower stratosphere « quasi-barrier » (manifested in a jump in tracer correlations). T. Shepherd reviewed the many recent papers that use dilution of chemical correlations with altitude to infer that, by 22 km, nearly half the air ascending in the « tropical pipe » is of extratropical origin. Presumably such significant entrainment should show up in the age spectrum. It is not clear whether further refinements of these calculations are possible, or sensible. This issue continues to be hampered by the lack of reliable wind data in the tropics, and by the apparent inability of all models to simulate a realistic subtropical transport barrier, i.e. to maintain a tracer edge (D. Cunnold).

Mixing and filamentation in the lowermost stratosphere

It is now clearly established, through a number of recent studies, that laminae seen in vertical profiles of ozone and other tracers, previously attributed to gravity waves, are in fact the result of filamentation of the vortex edge (M. Schoeberl, B. Legras, S. Reid). It was emphasised by T. Shepherd that this is in accord with the current picture of tracer motion being dominated by large-scale quasi-horizontal (2D) advection. The phenomenology of large eddies acting on sharp tracer gradients (the essence of the STE problem) is opposite to that assumed by classical diffusion (K-theory), and the fact that homogenisation occurs first on large-rather than small- scales is again opposite to diffusive behaviour.

T. Shepherd argued that large-scale filamentation of the vortex edge led to sharp « cliff-like » features in horizontal tracer profiles, and was thereby responsible for the k-2 horizontal wavenumber spectra seen in certain chemical tracers down to scales of 1 km or so (and previously attributed to gravity waves). M. Schoeberl made a similar point in conjunction with interpretation of recent data from the TOTE/VOTE campaign. Although large-scale advection is evidently dominant, there is nevertheless some evidence of small-scale gravity wave related activity in tracer structure (A. Langford). Note that gravity waves do seem to dominate the dynamical (as opposed to tracer) fields at these scales.

Mesoscale case studies of STE

There were a number of fairly traditional case studies of STE in tropopause folds (R. Rood, A. Ebel, D. McKenna, C. Schiller, E. Schuepbach). Rood showed a particularly clean case of rapid diabatic ascent of air from the boundary layer into the stratosphere, though it was notable that the ascent was capped in the very lowest layers of the stratosphere. This confirms the view that tropopause folds cannot

ECHAM3/CHEM (on-line) Aircraft - Control

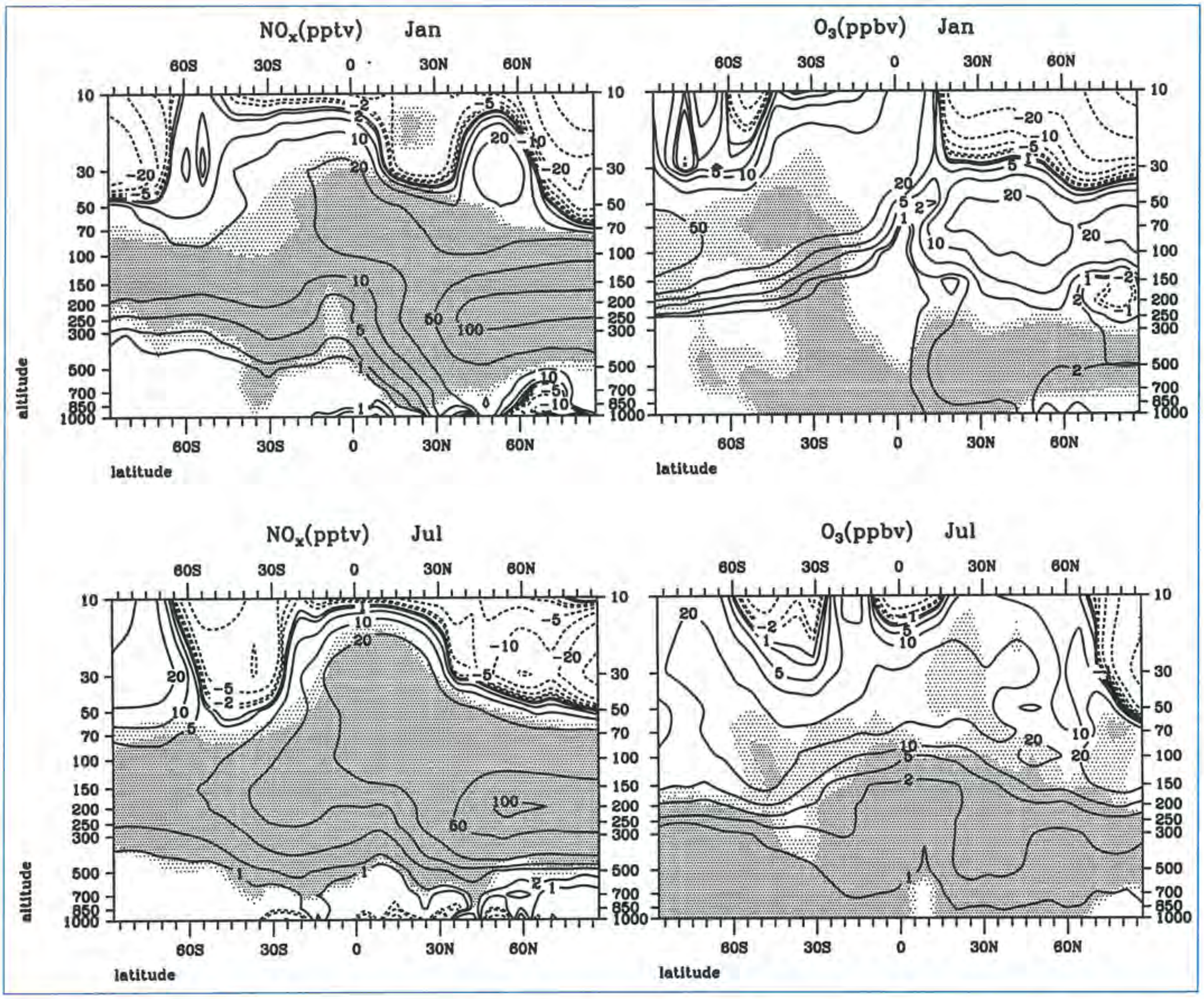

Figure 7. (from M. Dameris et al. « Impact of Aircraft Emissions on Atmospheric Chemistry », Inst. f. Physik d. Atmosphare, Report n° 6 ; Contributions on the topic of impact of aircraft emissions upon the atmosphere, edit. by U. Schumann, fig. 2). Differences in NOx (left column, in pptv) and O3 (right column, in ppbv) volume mixing ratio between a perturbed on-line integration with aircraft emissions and an on-line control integration without aircraft emissions for January (top) and July (bottom), using the GCM ECHAM3 coupled with a comprehensive chemistry module CHEM. Positive values indicate increase due to air traffic. Light (heavy) shaded areas denote regions of significance on the 95 % (99 %) level.

get air very deep into the stratosphere; they are strongly asymmetric in this respect. D. McKenna showed evidence of a fold having both tropospheric and stratospheric chemical characteristics, suggesting that simple distinctions between stratosphere and troposphere are inadequate. The issue remains of how to fit these illuminating case studies into a broader quantitative framework.

Session 6. Chemistry-climate interaction

Rapporteur : A.R. Ravishankara

The session on the UT/LS chemistry was rather small. However, it has to be combined with papers and posters from other sessions to form an image of the current research in this area. Almost all the presentations in this session dealt with the abundance of ozone and its changes in the UT/LS. A few papers also dealt with other atmospheric constituents, their variations and their optical/radiative properties.

Most emphasis of the session was on the lower stratospheric ozone depletion. From the talks and discussions of the Trends Group, it was clear that there is a downward change in the column ozone abundance from 1970s to 1990s. Even though this depletion is small, ~5 % in integrated ozone abundance between 60° N and 60° S, compared to the polar ozone depletion, the signature for the loss is unquestionable. The vertical distribution of the ozone shows a depletion in the lower stratosphere. Theoretical studies presented at the meeting could account for the observed yearly trends in the column ozone loss when satellite-measured sulphate aerosol loading were incorporated in models along with the most up-to-date chemistry. In addition, the findings clearly suggested that volcanic eruptions have modulated the ozone loss rates. It was also clear that these modulations could have been previously attributed to solar cycles. One of the major highlights of the meeting was the ability of current models (mostly 2D) to near-quantitatively account for the observed decadal trend in the stratospheric column ozone abundance. All these analyses show that the increasing anthropogenic chlorine is responsible for the observed stratospheric ozone loss. This is particularly important because it strongly links the stratospheric ozone depletion on the global scale with anthropogenic chlorine, as in the case of the Antarctic ozone hole.

There was very little discussion of the polar ozone depletion observed during the past two decades. However, it was suggested at the meeting that one of the indicators for the recovery of the Antarctic ozone hole may be found in the changes in the vertical profiles measured in the polar regions. This insightful and interesting suggestion needs to be followed up.

Many of the papers dealt with the fundamental processes involved in the chemistry and physics of the UT/LS. This included free radical reaction kinetics, heterogeneous reactions, photochemical properties, and spectroscopic constants. It was suggested that formation of water clusters could change the transmission of the infrared radiation through clouds. Measurements of rate constants of certain free radical reactions down to 190 K were shown to deviate from those extrapolated from higher temperatures. The quantum yields for dissociation of atmospheric molecules were shown to vary with wavelength, temperature, and pressure. The heterogeneous reaction rates were suggested to vary with composition of the substrate, relative humidity, and temperature. Thus, the need for determinations of the basic parameters under conditions prevalent in the UT/LS was highlighted.

The heterogeneous hydrolysis of bromine nitrate on liquid stratospheric sulphuric acid aerosol was shown to be an important HOx source and a pathway for the conversion of NOx to NOy at high latitudes. Some field observations pertaining to the stratosphere were presented. This included observation of particles as well as gas-phase species.

Application of these laboratory and field observations to modelling studies aimed at explaining the field observations in the lower stratosphere were also discussed. Perturbations to lower stratospheric ozone due to various emissions, including those from aircraft, were presented (fig. 7 as an example).

The general impression was that there have been many recent successes in this field. A good example of the success is the explanation of the decadal ozone trend is one example. The lower stratospheric chemistry is maturing rapidly and has a large number of scientists working on it. Many of the practitioners of this field, however, were missing at the assembly. They need to be attracted into future SPARC activities.

Discussions of the upper tropospheric chemistry was very limited. The major questions for research in this area are : What determines the abundance of ozone in the UT ? How is this abundance affected by natural and anthropogenic emissions ? The area of UT chemistry has attracted significant current interest because of the possible environmental impact of subsonic aircraft. The transport of ozone from the stratosphere to UT was discussed in another session. It is clear that the estimated flux of ozone from the stratosphere to the UT is very uncertain. The in-situ photochemical production is also uncertain because of major uncertainties in the abundance of NOx in the UT. Further, the detailed chemistry in this region is not fully elucidated ; it is, indeed, far from complete. For example, the impact of recently observed high levels of acetone on the chemistry of this region is unclear. The role of heterogeneous chemistry in this region is very poorly understood. The lack of understanding about the heterogeneous reactions arises because of a lack of information about the composition of the particles as well as the reactivities of species on many substrates at warmer temperatures. The deficiency in the overall chemistry arises because of a lack of focused and coordinated field programs which can provide information on the composition of this region of the atmosphere. Thus, the UT chemistry is a field that is in its infancy and can be greatly aided by many SPARC activities.

Session 7. UV radiation and its impacts

Rapporteur : M.-L. Chanin

In this session, the papers presented could be classified into 4 categories: UV effects on human health, UV radiative transfer models, UV-Index calculation and forecast, and UV-B measurements (with the largest quantity of papers).

The introductory paper by B. Armstrong reviewed the potential effects of UV on human health, mostly the harmful ones: i.e. the effects on immunity, eye damage and skin cancer. The dose-response relationship was discussed as well as the question of accumulation versus occasional exposure, which could both lead to dangerous effects strongly dependent on the pattern of exposure. At least one fact seems to be well established: it is that recreational sun exposure is more dangerous than laborious one. Australia being the place with the largest incidence of melanoma in the world, numerous causal studies were attempted and we heard the results of a recent large study of trends in melanoma incidence which was conducted in a quite thorough manner, taking into account the seasonal and annual ozone trends, the geographical trends of UV radiation (UV-B, UV-A, MEDs) as well as the demography and its variation with time versus latitude and longitude and the characteristics of the population.

The sensitivity of UV-B calculations on atmospheric variables was the subject of several papers; it concerns clouds, aerosols, pollution, solar zenith angle, surface albedo and ozone concentration and vertical profile. Models taking into account those parameters were presented and as an example the STAR model (System for Transfer of Atmospheric Radiation, by A. Ruggaber) shows consistency with measurement within 10% under cloudless skies. The role of scattered clouds as an amplifier of UV radiation was stressed by R. L. McKenzie, and the mechanism of amplification does not seem to be understood and could be an issue that the SPARC scientific community should address. Most of the papers dealing with those radiative transfer calculations aimed towards a predictability in UV-B doses, based mostly on the ozone situation and the cloud forecasts. For example the Bureau of Meteorology in Brisbane issues a daily UV forecast map for all Australia, converted into an index which indicates the potential maximum UV-B intensity for the next day assuming cloud-free skies. The German Weather Service 48h-forecast was also presented. UV irradiance measurements have been the topics of the largest number of papers and they were introduced by an extensive review of the subject by R. L. McKenzie. The general goal of such UV monitoring programme was clearly stressed with 3 aims: understanding the causes of variability in UV radiation, relate UV variation at different sites in the world, and determining UV trends. Very interesting results of observations carried out from Lauder N.Z. (45° S, 170° E, 370m), Mauna Loa Observatory, Hawaii (19°5 N, 155°6 W, 3400m) and other Northern Hemisphere sites show that relatively high UV is observed in the South Hemisphere compared to the Northern Hemisphere due to the combined effects of less ozone, closer Earth-Sun separation in the summer and less tropospheric pollution. The difference can be as high as 15% but the peak UV can reach values obtained at the equator. The site of Mauna Loa Observatory due to its high altitude shows enhanced sensitivity to ozone change and seasonal effects. Results from other Southern Hemisphere sites as La Paz, Bolivia (16.3° S), Ushuaia, Argentina, (54.5° S) and Syowa Station in Antarctica confirm the enhanced level of UV in the Southern Hemisphere.

The difficulties of trend detection and data quality insurance procedures were also discussed by R. L. McKenzie and the advantages of high resolution spectral distribution was demonstrated: a drift of 0.1nm could carry an error in the estimate of erythemal UV of 2%. Procedures to maintain the wavelengths shifts within 0.02nm based on the Fraunhofer lines spectral positions were suggested.

Session 8. Other aspects of stratospheric processes

Rapporteur : M. Geller

The section dealt with topics that were not covered by the previous seven sessions corresponding to the existing SPARC projects.

Some of the important points were that in-situ measurements were still to play a very important role even when satellites were making measurements of similar quantities. The in-situ observations have greater precision, in many instances, and they give more local time coverage at a given point in space than satellites, allowing one to infer, e. g., photolysis cross-sections and sunrise-sunset behaviour in a way that is not possible with satellites.

Another paper showed how TV imaging and lidar observations can be used to validate satellite images of contrails. The subject is of how aircraft contrails may be affecting climate by altering the earth's albedo directly and by altering the optical properties of existing clouds. Another paper showed the results of a 3-D isentropic dynamical-chemical modelling of the structure of the Brewer-Dobson circulation. This model reproduced the mean latitude-longitude TOMS O_3 structures. The trend in total ozone was found to be highly correlated with the trend in the vertical component of the Eliassen-Palm flux. However, two earlier papers had shown that their 2-D models reproduced observed O_3 trends well, not accounting for interannual variations in dynamics. Thus, it appears that there are conflicting results on the role of dynamics in producing observed O_3 trends.

Other papers dealt with the role of SST variations in producing the time variability of the length of the QBO cycle. Again, an earlier paper suggested that the variation of the periods of individual QBO cycles was probably due to variations in the tropical upwelling vertical velocity. The respective roles of these two processes remain to be determined. Some interesting results from the CRISTA instrument showed filamentary constituent structures that agreed quite well with trajectory calculations.

Yet other papers dealt with calculations of vertical velocities in the Antarctic derived from the UKMO analyses as well as those derived from HIS temperature measurements (the HIS-derived values were larger). In another paper, temperatures and aerosol concentrations were derived from lidar observations at Reunion Island. Another interesting paper used models and observations to study O_3 feedback effects on the QBO in stratospheric winds, and another one tried to understand what processes lead to the highest and coldest tropopause over NE India in the June-July period.

Some topics concerned interannual variations of stratospheric dynamics and O_3 behaviour; the excitation of planetary transient waves ; dynamically-induced changes in the Antarctic O_3 hole ; and an update of the previously noted relationships between stratospheric temperatures, the QBO, and the Sun. Other presentations dealt with the predictability of stratospheric flow ; Kelvin waves in the stratosphere as seen by the HRDI instrument ; the role of meridional and vertical motions in giving rise to O_3 structures; and the diurnal variations in stratospheric ClO as determined by balloon observations. Methods were presented how to determine PSCs from AVHRR measurements. New theoretical calculations of the factors that give rise to stratospheric sudden warmings were shown. GCM calculations of the Pinatubo effect on climate were presented and compared to observations. The predictive skill of the Australian BoM's Global Assimilation and Prediction scheme was demonstrated, and some potential vorticity diagnoses were shown illustrating the relationships between the stratospheric vortex and tropospheric circulation. Polarisation observations of the Pinatubo aerosol layer were shown, as was a diagnosis of the 1989 sudden stratospheric warming in terms of atmospheric angular momentum, and a new formulation for 2D middle atmospheric models was presented.

There were a couple of themes that emerged from this and previous sessions. One is that it is still unclear how much of the interannual variability in the ozone record is due to variabilities in dynamics. Another theme seen throughout the entire meeting is the effects of the stratospheric QBO in many different contexts.

The conference proceedings containing the 4-page extended abstracts will be published as a WCRP report. It will be available in limited quantity by applying to the SPARC Office.

International Workshop on Modelling Heterogeneous Chemistry of the Lower Stratosphere/Upper Troposphere

Strasbourg, France, October 21-23, 1996

It is now recognised that heterogeneous reactions play critical roles in the atmosphere. Unfortunately, however, these reactions are still not represented in atmospheric models in a completely realistic manner. Information needed to comprehensively include such processes is either lacking or 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 was organised in Strasbourg, France, under the auspices of SPARC of WCRP. Other sponsors of this workshop included NASA, NOAA , Meteo-France and the University of Strasbourg. This workshop also provided some of the information needed for the development of an implementation plan for the UT/LS initiative of SPARC.

This workshop covered heterogeneous chemistry of the LS/UT where such reactions play critical roles. The topics discussed were: (1) Abundance of stratospheric aerosols and PSCs, (2) Micro-physics of stratospheric aerosols and PSCs, (3) Heterogeneous chemistry in/on stratospheric aerosols and PSCs, (4) Heterogeneous chemistry of the UT, and (5) Particle formation, predictability, and their properties.