A11B-11 1145h

ACE-Asia In-Situ Airborne Aerosol Measurements by PMS Probes on the NCAR C-130

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During the ACE-Asia project, the NCAR C-130 research aircraft carried a large scientific payload of instrumentation. Four probes made by PMS (Particle Measuring Systems, Inc.) that measure the sizes of single particles based on light scattering were mounted on the outside of the aircraft. They covered the size range 0.1 to 600 um diameter and were sampled at 10Hz. These probes included the FSSP-300, PCASP, 260-X and two FSSP-100. Calibrations were done before, during, and after the project with mono-disperse size spherical particles of glass (n=1.51) and poly-styrene latex (PSL, n=1.58).

Each probe covered a different size range and had different resolution. There was overlap in the size ranges. Agreement in measurements was often observed in the overlap regions, although systematic differences were also observed. Some of these differences resulted from sampling effects, such as particle size changes during sampling that caused drying and shrinkage of hydrated particles (haze droplets). Another source of differences resulted from using calibrations, that are based on homogeneous spherical particles, to real atmospheric particles of complex shape, different refractive index, and mixed composition. For most of the measurements during ACE-Asia, the particle shapes and complex indexes of refraction are not known. This results in uncertainty about particle sizing.

This paper describes the measurements made by the PMS probes during the ACE-Asia project. Examples of data will be presented along with caveats about quantitative limits to interpreting the data.

A11C MC: 123 Monday 0830h

New Insights Into Stratospheric Chemistry, Dynamics, and Transport I

Presiding: **E Shuckburgh,** Ecole Normale Superieure**; W Norton,** Clarendon Laboratory

A11C-01 0830h INVITED

Changes in the Residual Circulation in Climate-Chemistry Simulations

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A number of simulations have been performed with the MA-ECHAM4-CHEM climate chemistry model of the middle atmosphere for present, past and future conditions, including changes in greenhouse gases and organic total chlorine. Here the model results are revisited, with the focus on the changes occurred in the residual circulation and their possible role for providing either positive or negative dynamical feedbacks to the radiative heating changes related to greenhouse gases and chemistry. In particular, the changes in residual circulation related to changes in the dynamical tropospheric forcing of the stratosphere - and interannual variability of the stability of the polar vortex - are discussed. From past to present conditions, an increase in the frequency of major sudden stratospheric warmings is found in early winter. The role of mesospheric gravity waves in the reported changes of the stratospheric circulation are also evaluated.

A11C-02 0855h

Stratospheric Circulation and Tracer/Ozone Changes in Response to Alternative Doubled CO2 Climate Depictions

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The effect of alternative representations of the doubled CO2 climate on the stratospheric circulation and tracer transport is presented with the GISS 4x5, 53 layer Global Climate/Middle Atmosphere Model. In addition to doubled atmospheric CO2, two sets of sea surface temperature changes are used, one with greater low latitude and overall warming; the differences are associated primarily with different high cloud cover optical thickness responses. While both result in an intensified subtropical circulation in the lower stratosphere, they have opposite effects on the high latitude residual circulation and the Arctic Oscillation phase.

The effect each representation has on tracer transport is discussed, with primary emphasis on ozone distributions, utilizing the Linoz (linearized ozone) scheme. The corresponding effect the ozone changes have on the resulting doubled CO2 stratospheric circulation will also be discussed.

A11C-03 0910h

Interactive Chemistry-Climate Modelling of the Middle Atmosphere: Changes From the Near Past to the Present

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The middle atmosphere GCM with interactive photochemistry MA-ECHAM4-CHEM extending from surface to 80km was used for four 20 years 'time-slice' simulations applying the physical and chemical lower boundary conditions for the sixties, the early nineties and the present. To separate processes, also a sensitivity run with sea surface temperatures (SST) of the sixties and greenhouse gases and chemistry of the early nineties is analysed, including the implications of changes in the tropical SST for stratospheric water vapor. We focus also on feedback processes between chemistry and dynamics in high latitude spring involving polar stratospheric clouds, ozone depletion, and changes in dynamical and radiative heating. A short comparison with observed temperature changes in the lower stratosphere of the northern hemisphere is included, as well as a comparison of calculated interannual variability of ozone and water vapor with data of the Upper Atmosphere Research Satellite (UARS). We show that the model is able to reproduce the main features of global temperature and ozone distributions in the sixties and the nineties.

A11C-04 0925h

Detecting Recovery in Vertically-resolved Ozone Records

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Current estimates for the recovery rates of the ozone layer are very small: at mid-latitudes, recovery is expected to be only a few Dobson Units per decade over the next 50 years. Detecting this gradual recovery in the total column ozone record could take 15 to 35 years, even under the best of circumstances. Variations in the seasonal and altitudinal distributions of ozone suggest that evidence of recovery may be easier to detect during the local springtime, or at a single vertical layer in the atmosphere.

This work investigates the length of time necessary to detect expected ozone recovery in geographically, seaonally, and vertically resolved records. The studies are based on our understanding of the magnitude of the trends expected for different seasons and locations, as well as on the variability and autocorrelation at those locations. Both factors–the size of the trend and the noise characteristics–are likely to influence where it will be easiest to detect future recovery. Estimates of past ozone variability are derived primarily from TOMS and SBUV-SBUV/2 observations, with intercomparisons to Dobson Umkehr, SAGE II and ozonesonde data. Chemical and coupled chemical-climate models, including the GSFC 2-D model and the GISS abbreviated 3-D model, provide estimates of expected recovery rates.

Results include estimates of most optimal locations in terms of latitude, longitude and altitude for detecting future ozone recovery. The results also indicate at which times of year recovery can be expected to be resolved earliest. These findings can be useful for prioritizing future monitoring efforts to detect the expected recovery as early as possible. Estimates of recovery times produced now, early in the recovery phase, will be useful in explaining the complexity of the situation to all interested parties and may help ensure that future monitoring continues with the high levels of quality assurance necessary to detect recovery.

A11C-05 0940h

Analysis of Long-Term Trends in Tropospheric Ozone at Northern Hemisphere Midlatitudes with the GEOS-CHEM Model

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Trends in tropospheric ozone at northern midlatitudes over the past 30 years are investigated with the GEOS-CHEM model, a global three-dimensional model of the troposphere driven by assimilated meteorological observations from the Goddard Earth Observing System (GEOS), and with the Harvard-GISS model, a global model driven by winds from the general circulation model of the Goddard Institute for Space Studies (GISS). The sensitivity of tropospheric ozone is investigated with respect to changes in the anthropogenic emission of nitrogen oxides (NO_x) and non-methane hydrocarbons (NMHCs), increases in methane concentrations, variations in the stratospheric source of ozone, and finally increases in tropospheric temperatures and solar irradiation related to global warming and stratospheric ozone depletion. Model results indicate that local increases in NO_x emissions have caused most of the increases seen in lower tropospheric ozone in Europe and Japan. Increases in methane concentrations are responsible for roughly one fourth of the anthropogenically-induced increase in tropospheric ozone on a global scale. Still, anthropogenic factors do not adequately explain the wide variability in observed ozone trends across midlatitudes, and fail to simulate observed decreases in the upper troposphere. Ozone depletion in the lowermost stratosphere is likely to have reduced the stratospheric source significantly - perhaps by more than 30% over the past 30 years. Model simulations that also account for this expected reduction show steep declines in the upper troposphere and variable increases in the lower troposphere that are more consisitent with observations. Differential temperature increases in summer between North America and Europe may account for at least some of the remaining variability in ozone trends. Increases in ultraviolet (UV) radiation due to stratsoheric ozone depletion do not appear to significantly reduce tropospheric ozone, except perhaps at midlatitudes in the Southern Hemisphere following the breakup of the ozone hole.

A11C-06 0955h

Effects of a Reduced Ozone Layer on the Lower Stratosphere and the Troposphere

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A possible mechanism for solar forcing of climate is being investigated. The mechanism couples changes in solar ultraviolet (UV) emission to those of ozone and temperature and circulation in the stratosphere and troposphere. This mechanism is an 'amplification mechanism' in the sense that it can magnify the effects of a small change in the UV emission to generate a significant climate effect and works as follows. At low solar activity, the ozone in the stratosphere becomes less abundant and the meridional temperature gradient there becomes smaller. This implies a weaker and warmer polar vortex and weaker planetary wave activity in the troposphere, resulting in a colder climate for the troposphere.

To investigate the interactions between the troposphere and stratosphere, which are integral to this 'amplification mechanism', we use a general circulation model of the atmosphere, the UCLA GCM. As it has been demonstrated that the response of the stratosphere to solar cycle variations is sensitive to the phase of the quasi-biennial oscillation (QBO) in tropical lower stratospheric zonal winds, we have performed two sets of experiments. In one set the QBO is in a perpetual east phase, in the other it is in a perpetual west phase. There are two GCM integrations in each set. One is a control, the other a 20% reduction in ozone mixing ratio imposed in the stratosphere. Preliminary analysis of these integrations will be presented to test the validity of this 'amplification mechanism'.

A11C-07 1025h INVITED

Assessing impact of stratospheric water vapor on climate

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It is now apparent that observed increases in stratospheric water vapor may have contributed significantly to both stratospheric cooling and tropospheric warming over the last few decades.

I show that if recent estimates for the observed water vapor trends are valid globally they could have contributed a radiative forcing of up to 0.3 Wm^{-2} and a lower-stratospheric cooling of more than 0.8 K over the past 20 years, with these values more than doubling if, as has been suggested, the trend has persisted for the last 40 years. I assess if such a large stratospheric cooling is consistent with observations.

A11C-08 1050h INVITED

Relationship Between Climate Variability and Total Ozone Change in the Northern Mid-Latitudes

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Traditionally, long-term changes (trends) in the total ozone amount at Northern mid-latitudes have been derived from zonal averages made over the latitude range from 25 to 60(N. We separate the total ozone field into four meteorological regimes, (1) a tropical regime south of the subtropical upper troposphere front; (2) a mid-latitude regime between the sub-tropical and the polar fronts; (3) a polar regime between the polar front and the arctic front (the polar vortex), (4) an arctic regime, north of the arctic front. The total ozone distribution within the first three regimes is quite narrow, with a width of about three per cent of the mean value. We also find that the mean value within these regimes is relatively constant from year to year. Thus the mean total ozone value that is observed between 25 to 60(N is mainly governed by the relative areas of the three regimes within these latitude limits. We find that during the period from 1978 to 1992 the area of the tropical regime increased while that of the polar regime decreased. We conclude that most of the northern mid-latitude trend in the total ozone record between 1978 and 1992 is the result of a northward movement of the mean latitude of both the subtropical and polar fronts. As there is a distinct tendency for the surface pressure systems to follow the flows aloft, e.g. the jet streams embedded in these fronts, any movement in the mean positions of the upper troposphere fronts will result in a change in the climate of the Northern hemisphere. Thus changes in climate, both short term and long-term, and the measured stratospheric ozone trends and variability at mid-latitudes are closely linked.

A11C-09 1115h

Evaluation of Tropical Transport in a Global Ghemistry and Transport Model

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Observations of constituents from satellite, aircraft and sondes can be utilized to develop diagnostics of various aspects of tropical transport. These include tropical midlatitude isolation, the seasonal transport from the upper tropical troposphere to the midlatitude lowermost stratosphere, the seasonal cycle of the tropical total ozone and its variability. These diagnostics will be applied to constituent fields from an off-line chemistry and transport model (CTM) driven by winds from two sources. These are the Finite Volume Community Climate Model (FV-CCM), a general circulation model that uses the NCAR CCM physics and the Lin and Rood dynamical core, and an assimilation system developed by the Data Assimilation Office at the Goddard Space Flight Center that uses the FV-CCM at its core. Signatures of interannual differences in the observations, related to the tropical winds and extratropical waves, will be emphasized to understand differences between the two model transports and the transport inferred from the observations.

A11C-10 1130h

Maximum Path Height Distributions: a Measurable Quantity Independent of Mean Age and Age Distributions for Model Comparisons

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The stratospheric lifetimes of the halocarbons and nitrous oxide measured by the LACE in situ GC are dominated by simple photolysis. Between these species, local lifetimes span two orders of magnitude at any given altitude. Similarly, for each species the local photolytic lifetimes decrease by more than two orders of magnitude in going from the tropopause to 32 km. This range in lifetimes cover the dynamic time scales of stratospheric transport, making these halocarbons extremely sensitive to the altitude degree of freedom in the stratosphere and a powerful tool for studying stratospheric dynamics.

Tagging an irreducible air parcel (air particle) in terms of the maximum height encountered during its path to a final location, takes advantage of this logarithmic decrease with altitude in the local photolytic lifetimes. In particular, maximum path height identifies the molecular species that will have undergone substantial loss ($\approx$ 100 %). A measurement of these simple photolytic species at a given location in the stratosphere can then be used to calculate the distribution of maximum path heights corresponding to the distribution of irreducible air particles that make up the particular air parcel measured.

We will demonstrate a measured maximum path height distribution using LACE midlatitude data. Comparison of measured maximum path height distributions to model estimates will represent a check that would be independent from those obtained via. comparisons to mean age, and age distributions (calculated from SF_6 and CO_2 measurements). A short discussion of the interplay between maximum path height, time scales for transport, and the vertical resolution of models will be given to demonstrate the usefulness of the maximum path height concept. We hope to convince modelers to included maximum path height as an effective tracer for comparisons with measurements.

A11C-11 1145h

On the Relation Between Kinematic Boundaries, Stirring and Barriers for the Antarctic Polar Vortex

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Maximum stretching lines in the lower stratosphere around the Antarctic polar vortex are diagnosed using a method based on finite-size Lyapunov exponents. By analogy with the mathematical results known for simple dynamical systems, these curves are identified as stable and unstable manifolds of the underlying hyperbolic structure of the flow. For the first time, the exchange mechanism associated with lobe dynamics is characterized using atmospheric analyzed winds. The tangling manifolds form a stochastic layer around the vortex. It is found that fluid is not only expelled from this layer towards the surf zone, but also is injected inward from the surf zone, through a process similar to the turnstile mechanism in lobe dynamics. The vortex edge, defined as the location of the maximum gradient in potential vorticity or tracer, is found to be the southward (poleward) envelope of this stochastic layer. Exchanges with the inside of the vortex are therefore largely decoupled from those, possibly intense exchanges, between the stochastic layer and the surf zone. We stress that using the kinematic boundary defined by the hyperbolic points and the manifolds as an operational definition of vortex boundary is not only unpractical but also leads to spurious estimates of exchanges. We also present preliminary results of diagnostics based on rigorous theory of finite-time hyperbolicity.

A12A MC: Hall D Monday 1330h

General Atmospheric Sciences Contributions

Presiding: **M Avery,** NASA Langley Research Center

A12A-0034 1330h POSTER

Internal Wave Generation in the Lee of Periodic Topography

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Laboratory experiments are performed to examine the generation of internal waves in uniformly salt-stratified fluid by towed two-dimensional periodic topography of finite extent. Linear theory predicts that vertically propagating internal waves are generated if the Froude number $\mathrm{Fr} = U/N\lambda < 1/2\pi$. (Here U is the towing speed, N is the buoyancy frequency, and λ is the distance between successive hill crests.) As found by Baines and Hoinka (1985), when Fr is moderately smaller than this value, a large amplitude lee wave is generated downstream of the topography. This horizontally propagating wave is characterised by spatially decaying, periodic vertical displacements of near-surface isopycnals on the order of the hill amplitude immediately in the lee of the topography. The flow is laminar.

The lee wave itself excites vertically propagating internal waves which have amplitude approximately twice that of internal waves generated directly above the topography. That is, larger waves are excited after the topographic forcing is turned off! This occurs because the internal waves resonantly interact with the lee waves acting both to establish the pattern of lee waves and to extract energy efficiently away from them.