N92-14511

ATLAS: Airborne Tunable Laser Absorption Spectrometer for Stratospheric Trace Gas Measurements

Max Loewenstein and James R. Podolske
NASA Ames Research Center
Earth System Science Division
Moffett Field, Ca. 94035

Susan E. Strahan
San Jose State University
San Jose, Ca. 95192

The ATLAS instrument is an advanced technology diode laser-based absorption spectrometer designed specifically for stratospheric tracer studies. It was first deployed with the Stratosphere Troposphere Exchange Project in 1987. The true fruition of this technique has come with the highly successful acquisition of N_2O tracer data sets on the Airborne Antarctic Ozone Experiment (AAOE, 1987) and the Airborne Arctic Stratospheric Expedition (AASE, 1989). These data sets have proved extremely valuable in themselves for comparison with atmospheric models, as well as in assisting in the interpretation of the entire ensemble of chemical and meteorological data acquired on these two important field campaigns.

During the period covered by this report two major thrusts were underway by the ATLAS research team: one was the analysis and interpretation of the rich data sets acquired during the AAOE field campaign in Punta Arenas, Chile in 1987, the other was preparation for the AASE field campaign to Stavanger, Norway in December-February 1989. The N_2O dynamical tracer data set analysis revealed several important ramifications concerning the polar atmosphere: the N_2O/NO_y correlation, which is now used as a tool to study denitrification in the polar vortex; the N_2O southern hemisphere morphology, showing extensive subsidence in the winter polar vortex; and the value of N_2O measurements in the interpretation of ClO, O_3 and NO_y measurements and of the derived dynamical tracer, potential vorticity. All of these implications of the N_2O data sets are explored in several papers appearing in the Journal of Geophysical Research special issues on AAOE slated to appear late in 1989. Various aspects of these N_2O results were reported by ATLAS team members at the Polar Ozone meeting, Snowmass, May 1988, the Quadrennial Ozone Symposium, Goettingen, FRG, August 1988 and the European Geophysical Society meeting, Paris, Sept. 1988.

The field campaign known as AASE produced an additional large and high quality N_2O data set which has fully occupied the ATLAS team with analysis and interpretation efforts since February 1989. Several papers are now in preparation for a special Geophysical Research Letters issue slated for early 1990 publication.

An intensive ATLAS instrument calibration effort during the first half of 1989 led to an improved characterization of the instrument under field conditions, and a well-based method for establishing the accuracy of the field data from the AAOE and AASE campaigns. The results are incorporated in a manuscript now being prepared for publication.

References

Loewenstein, M., J. R. Podolske, K. R. Chan and S. E. Strahan, Nitrous Oxide as a Dynamical Tracer in the 1987 Airborne Antarctic Ozone Experiment, J. Geophys. Res. D, Special Issue on AAOE, in press.

Podolske, J. R., M. Loewenstein, S. E. Strahan and K. R. Chan, Stratospheric Nitrous Oxide in the Southern Hemisphere, J. Geophys. Res. D, Special Issue on AAOE, in press.

Strahan, S. E., M. Loewenstein, J. R. Podolske, W. L. Starr, M. H. Proffitt, K. K. Kelly and K. R. Chan, Correlation of N_2O and Ozone in the Southern Polar Vortex During the Airborne Antarctic Ozone Experiment, J. Geophys. Res. D, Special Issue on AAOE, in press.

AIRBORNE MICROWAVE TEMPERATURE PROFILER INVESTIGATIONS OF ATMOSPHERIC DYNAMICS RELATED TO OZONE DEPLETION

Bruce L. Gary
Jet Propulsion Laboratory
Pasadena, CA 91109

Research Objectives

Airborne measurements are made of air temperature versus altitude using microwave radiometric remote sensing techniques. The Microwave Temperature Profiler, MTP, covers an altitude region that extends from approximately 2 km below to 3 km above aircraft flight level. Three atmospheric science objectives have been pursued using MTP data taken during flights into the Antarctic and Arctic stratospheric polar vortices: 1) mountain waves in the polar stratosphere have been detected and characterized, 2) calculations of potential vorticity versus latitude have been made possible using the instrument's measurements of air temperature lapse rate, and 3) a component of mesoscale vertical oscillations of air parcels have been identified and characterized for use by polar stratospheric cloud modelers needing realistic cooling rate simulations.

Progress and Results

Mountain waves were found to exist in the stratosphere over the Antarctica Peninsula during the 1987 Airborne Antarctic Ozone Experiment (AAOE). Vertical displacements as great as 600 meters (1200 meter peak-to-peak excursions) were observed in the potential temperature surfaces. The mountain waves were present approximately half the time during flight over the Peninsula and they were not found during flight over the open ocean. Wave amplitude was found to increase with altitude in the region 17 to 22 km in accordance with the predicted relation: $A_1=A_0/(P_1/P_0)^{0.5}$. The unexpected presence of mountain waves of such large amplitude in the stratosphere means that air parcels may frequently experience brief cloud forming episodes, which might influence ozone depletion through several possible routes.

Potential vorticity calculations require knowledge of air temperature lapse rate as well as horizontal wind shear. The MTP temperature profiles have provided lapse rate information for the AAOE and 1988/89 AASE (Airborne Arctic Stratospheric Expedition) flights. Penetrations of the polar vortex boundary show the expected changes in potential vorticity, which come entirely from the wind field. Temperature field changes are not noticeable.

Potential temperature surfaces reveal information about vertical displacements of air parcels. Cross-sections showing the altitudes of potential temperature surfaces in a plane parallel to the wind direction can be used to infer vertical velocities, which can be used to infer air parcel heating/cooling rates. MTP data has been used to determine the power spectral density of cooling rate versus frequency of oscillation. An apparently distinct "mesoscale component" of temperature fluctuations appears in such a spectrum. This component produces very large amplitudes of cooling that must be superimposed on simulations of parcel temperature versus time that are derived from synoptic scale weather data. When this is done cooling rates of 200 K/day are common, and during passage through regions disturbed by mountain waves parcels experience cooling rates as high as 2000 K/day. Brief as these cooling rates may be, it is important to determine their impact on polar stratospheric cloud particle size distributions, since only large particles have fall speeds sufficient to "denitrify" layers and thereby permit ClO chemical depletion of ozone.

Journal Publications

Gary, B. L., "Observational Results Using the Microwave Temperature Profiler During the Airborne Antarctic Ozone Experiment," J. Geophys. Res., *in press*

Denning, R. F., S. L. Guidero, G. S. Parks, B. L. Gary, "Instrument Description of the Airborne Microwave Temperature Profiler," J. Geophys. Res., *in press*

Hartmann, D. L., K. R. Chan, B. L. Gary, M. R. Schoeberl, P. A. Newman, R. L. Martin, M. Loewenstein, J. R. Podolske, S. E. Strahan, "Potential Vorticity and Mixing in the South Polar Vortex During Spring," J. Geophys. Res., *in press*

Proffitt, M. H., K. K. Kelly, J. A. Powell, M. R. Schoeberl, B. L. Gary, M. Loewenstein, J. R. Podolske, S. E. Strahan, K. R. Chan, "Evidence for Diabatic Cooling and Poleward Transport Within and Around the 1987 Antarctic Ozone Hole," J. Geophys. Res., *in press*

STRATOSPHERE-TROPOSPHERE EXCHANGE DURING HIGH LATITUDE CYCLOGENESIS AND LOWER ARCTIC STRATOSPHERE PROPERTIES

PI'S

Melvyn A. Shapiro
NOAA/WPL
R/E/WP
Boulder, CO 80303

Russell C. Schnell
CIRES, CB 449
University of Colorado
Boulder, CO 80309

CO-PI's

Patrick J. Sheridan
Mike Douglas
CIRES, CB 449
Boulder, CO 80309

Nick Bond
JISAO/NOAA
University of Washington
Seattle, WA 98115

Objectives

There are two main objectives to the research:

1) The quantification of stratospheric-tropospheric exchange from NOAA WP-3D measurements at higher latitudes and in the Arctic, and;

2) The measurement of aerosol properties in the lower Arctic stratosphere as calibrations for concurrent SAGE-II measurements.

This is accomplished through analysis of data collected during 500 WP-3D flight hours (1986-1989) in high latitude marine cyclogenesis systems and in Arctic basin tropopause folding events.

Results to Date

1) Results from the tropopause folding portion of the research are best summarized in graphical form. Figure 1 presents a vertical cross-section of potential temperature (K) and along-front wind component (ms^{-1}) for a NOAA WP-3D study of a marine cold front at 40°N in the North Pacific Ocean, December 9, 1987. Figure 2 shows the ozone concentrations measured in the same frontal structure. In this flight, the NOAA P-3 research aircraft documented the descent of ozone laden stratospheric air down into the eastern Pacific marine boundary layer. This stratospheric tropospheric exchange event occurred in association with a jet stream-frontal zone tropopause folding event.

2) Aerosol light scattering data from 11 NOAA WP-3D research flights into the Arctic spring tropopause and lower stratosphere have been compared to 28 corresponding SAGE-II extinction profiles. Results from this research show that:

A. There is excellent agreement between the aircraft nephelometer and the SAGE-II extinction measurements above 7 km in the Arctic stratosphere.

B. The aerosol mininma at the Arctic tropopause, observed in SAGE-II data, is also present in the airborne measurements.

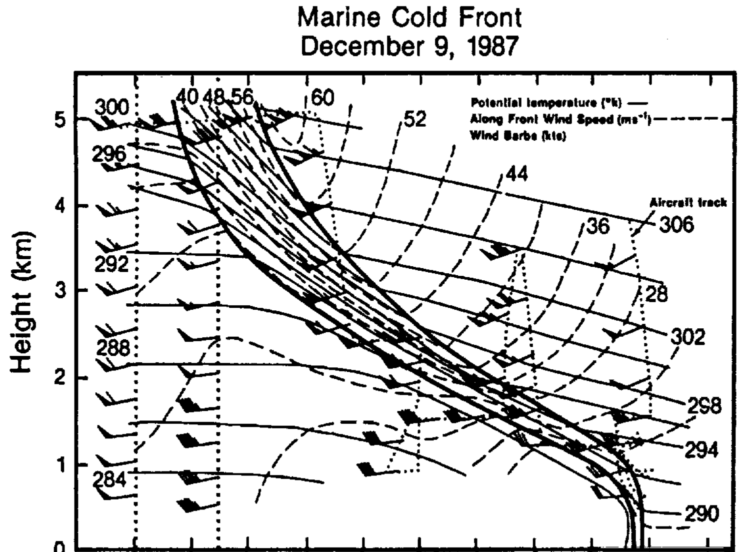

Figure 1. Vertical cross-section of potential temperature (K), along front wind components (ms^{-1}), selected wind barbs (kts) and frontal boundaries (heavy solid lines) for a North Pacific marine cold front tropopause folding event studied with the NOAA WP-3D (aircraft track, dotted line).

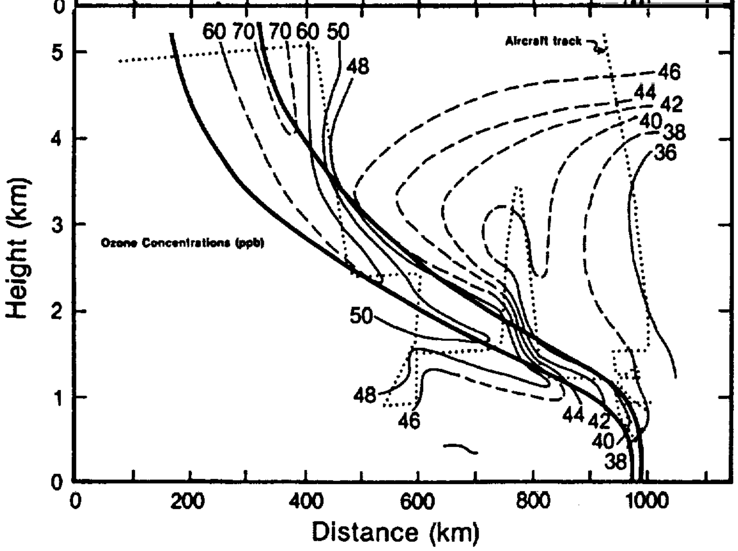

Figure 2. Ozone concentrations (ppb) measured in the fold (Figure 1) illustrating the downward intrusion of elevated concentration of ozone into the marine boundary layer.

Publications

Barrie, L.A., J.W. Bottenheim, R.C. Schnell, P.J. Crutzen, and R.A. Rasmussen, Ozone destruction and photochemical reactions at polar sunrise in the lower Arctic atmosphere, **Nature**, 334, 138-141, 1988.

Bridgman, H.A., R.C. Schnell, G.A. Herbert, B.A. Bodhaine, and S.J. Oltmans, Meteorology and haze structure during AGASP-II: Part 2, Canadian Arctic flights, April 13-16, 1986, **J. Atmos. Chem.** (Arctic Haze Issue), in press, 1989.

Oltmans, S.J., W.E. Raatz, and W.D. Komhyr, On the transfer of stratospheric ozone into the troposphere near the North Pole, **J. Atmos. Chem.** (Arctic Haze Issue), in press, 1989.

Oltmans, S.J., R.C. Schnell, P.J. Sheridan, R.E. Peterson, S.M. Li, J.W. Winchester, P.P. Tans, W.T. Sturges, J.D. Kahl, and L.A. Barrie, Seasonal surface ozone and filterable bromine relationship in the high Arctic, **Atmos. Environ.** (Arctic Haze Issue), in press, 1989.