Studies of Tropical/Mid-Latitude Exchange Using UARS Observations

Final Report for NAG5-6629

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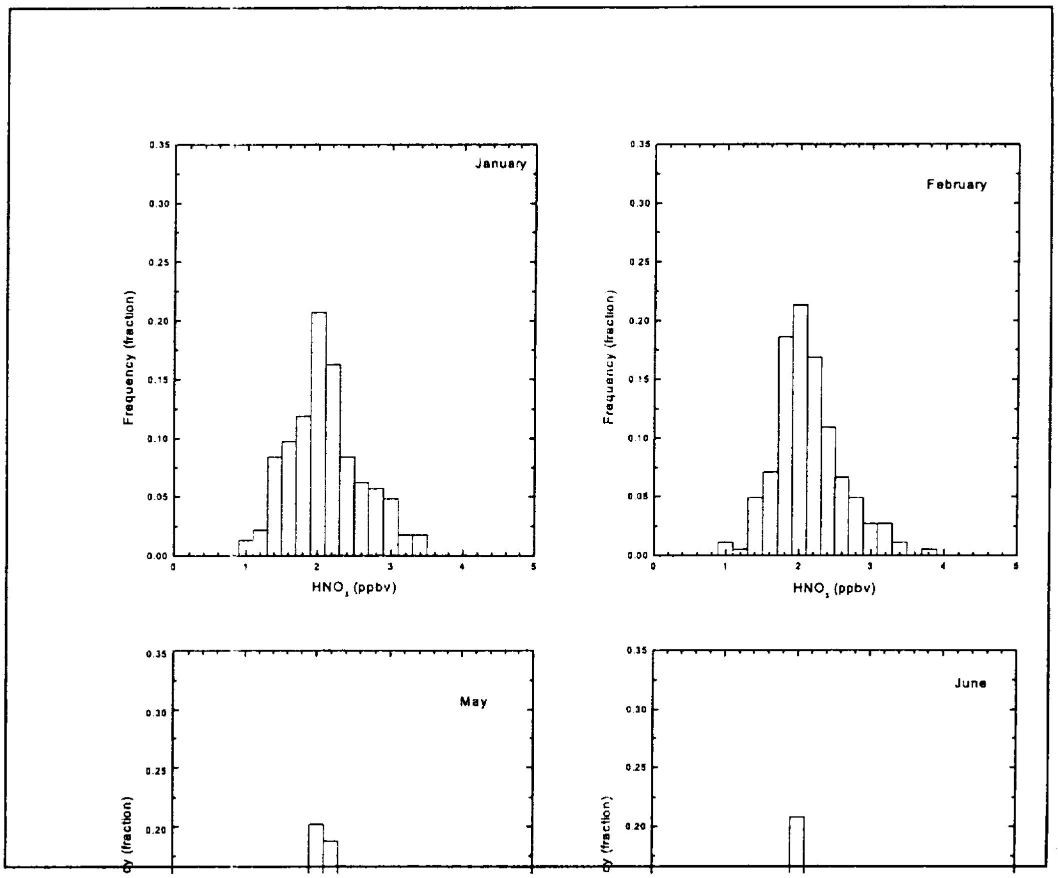
At the time this proposal was submitted, recent publications had suggested an important role for transport of midlatitude air into the tropical lower stratosphere. Most of these studies had employed data that gave only a time-averaged picture, making it difficult to determine the nature of the transport processes responsible for the observed behavior. We proposed to analyze observations of long-lived trace gases, such as nitric acid, methane, nitrous oxide, and chlorofluorocarbons, made from the Upper Atmosphere Research Satellite, to investigate the seasonal behavior of mixing between the midlatitudes and tropics. We planned to construct probability distributions of the concentrations of these species over small altitude ranges and to compare them to expectations based on modeled mean concentrations and knowledge of instrument precision. Differences from expectation were to be analyzed with respect to meteorological parameters to determine whether wave activity may have induced apparent mixing.

Over the funding period of this grant (three years, plus a fourth with no-cost extension), the work of several people on a variety of projects related to this proposal was supported. Dr. Leah Goldfarb (a postdoctoral researcher) was employed half-time for the months of March and April 1998. Dr. Goldfarb calculated ozone loss rates in a photochemical box model initialized with UARS observations of long-lived gases. This was a continuation of a study begun under a previous UARS Guest Investigator grant made to Profs. Darin Toohey and Michael Prather at the University of California at Irvine. The PI on the current project, Dr. Avallone, had been part of the UC Irvine team before taking a position at the University of Colorado. Dr. Goldfarb finished the modeling studies begun at UC Irvine and attended the UARS Science Team Meeting in March 1998, where she gave a poster presentation about her results.

Stacey McIlwaine, a CU undergraduate student (majoring in Math, with a minor in Atmospheric and Oceanic Sciences) worked on this project from May 1998 through January 2000. Ms. McIlwaine was initially interested in a summer research project in which she could apply her knowledge of atmospheric dynamics. However, she quickly became engrossed in the project and made it the basis of her Honors Thesis (for which she received summa cum laude honors). Ms. McIlwaine developing a series of computer programs to transform and analyze the UARS data, primarily ozone, nitric acid, and CFC-12 measurements made by CLAES. She also developed an algorithm for better determining the boundaries of the tropics, based on gradients in chemical constituents or meteorological parameters, rather than simple latitude coordinates.

The original premise of this proposal was that transport into the tropics from midlatitudes occurs to some extent on an unknown timescale. Through an analysis of CLAES nitric acid, ozone, and CFC-12, we have sought to determine whether this transport happens episodically, in large bursts , or at a slow trickle all of the time. We began by investigating probability distributions (histograms) of nitric acid on constant ozone surfaces. As a photochemical clock whose abundance increases monotonically with altitude in the lower tropical stratosphere, ozone serves as a surrogate vertical coordinate. Monthly histograms of nitric acid abundance at altitudes ranging from 68 to

22 mbar (500 to 6000 ppbv) often show long, non-Gaussian tails of large mixing ratios. These higher concentrations are typical of midlatitudes, suggesting that air was recently transported into the tropics from higher latitudes. These tails are not seen all of the time, further suggesting that transport may be episodic in nature. There are no obvious seasonal patterns, as we might have expected based on the relative strengths of the winter and summer subtropical jets. The example shown below comes from a manuscript, written by Ms. McIlwaine, that is undergoing revisions for *J. Geophys. Res.*



Distributions of HNO_3 on the 2000-2500 ppbv O_3 surface (19 km).

Our research into the mixing of air into the tropics in the stratosphere led to curiosity about how similar transport processes might affect the uppermost tropical troposphere (now commonly referred to as the tropical transition layer, or TTL). Kristi Hines, a graduate student in the Program in Atmospheric and Oceanic Sciences, was supported under this grant to investigate this problem. Most UARS instruments are incapable of retrieving good information in the upper troposphere (with the exception of the MLS UT water product), so most of the work was performed using ozonesonde and radiosonde data from tropical sites, including Fiji, American Samoa, Tahiti, etc. Ms. Hines' research, employing probability distribution functions of ozone on various potential temperature surfaces, showed clear signatures of transport into the TTL from the lower midlatitude stratosphere during certain times of year and at particular locations. We are hopeful that this study will result in a journal publication in the near future.

Finally, Laura Patrick, a professional research assistant (formerly a masters' degree student) received support from this grant. Ms. Patrick carried out a study for her degree in which she investigated the representativeness of the zonal mean for describing distributions of atmospheric observations. This study included UARS observations of species such as CFC-11, methane, and NO_2. Ms. Patrick showed that, in most cases, distributions of the abundances of these compounds - in a given latitude band and at a given altitude - were not normally distributed. Hence, the mean of the distribution is not the most probable value, nor is the standard deviation a true measure of the width of the distribution. We are currently working on a manuscript that incorporates some of these results and that investigates the consequences of using the zonal mean (rather than a more representative metric) in atmospheric chemical models.

Presentations:

S.K. McIlwaine, L. Patrick, and L.M. Avallone, *Investigations of stratospheric variability and circulation using UARS data*, poster presented at the UARS Science Team Meeting, Virginia Beach, Virginia, October 1999.

S.K. McIlwaine and L.M. Avallone, *Studies of stratospheric tropical-midlatitude transport using UARS data*, poster presented at the American Meteorological Society Middle Atmospheres Meeting, Long Beach, California, January 2000.

K.M. Hines, D. Toohey and L. Avallone, *Seasonal patterns of ozone variability in the lower stratosphere and upper troposphere*, talk presented at the Fall American Geophysical Union Meeting, San Francisco, CA, December 2000.

L.C. Patrick and L.M. Avallone, *Suitability of the zonal mean for use in climatologies and atmospheric chemistry models*, poster presented at the Fall American Geophysical Union Meeting, San Francisco, CA, December 2000.

L.M. Avallone and S.K. McIlwaine, *An investigation of mixing into the tropical stratosphere using UARS data*, poster presented at the UARS Science Team Meeting, Greenbelt, MD, September 2001.

Publications:

S. K. McIlwaine, *Stratospheric Transport of Midlatitude Air into the Tropics*, Honors thesis, University of Colorado at Boulder, April 1999.

S. K. McIlwaine and L. M. Avallone, A study on the entrainment of midlatitude air into the tropical lower stratosphere, submitted to *J. Geophys. Res.* and undergoing revisions.

K. M. Hines, *Seasonal Patterns of Ozone Variability in the Upper Troposphere and Lower Stratosphere*, M.S. Thesis, University of Colorado at Boulder, December 2000.