Retrieval of Ozone Column Content from Airborne Sun Photometer Measurements during SOLVE II: Comparison with SAGE III, POAM III, TOMS and GOME Measurements

J. Livingston[1], B. Schmid[2], P. Russell[3], J. Eilers[3], R. Kolyer[3], J. Redemann[2], S. Ramirez[2], J-H. Yee[4],C. Trepte[5], L. Thomason[5], M. Pitts[5], J. Zawodny[5], W. Chu[5], M. Avery[5], C. Randall[6], J. Lumpe[7], R. Bevilacqua[8], M. Bittner[9], T. Erbertseder[9], R. McPeters[10], R. Shetter[11], J. Kerr[12], K. Lamb[13], G. Diskin[5], J. Podolske[3]

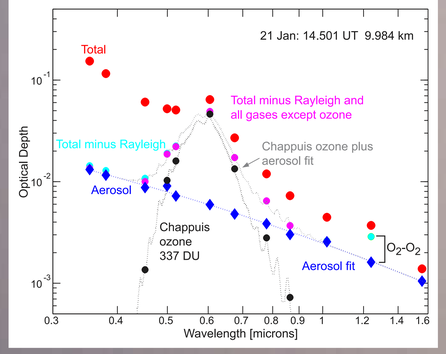
[1]SRI International, Menlo Park, CA [2]Bay Area Environmental Research Institute, Sonoma, CA [3]NASA Ames Research Center, Moffett Field, CA [4]Applied Physics Laboratory, Johns Hopkins University, Laurel, MD [5]NASA Langley Research Center, Hampton, VA [6]Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, CO [7]Computational Physics, Inc., Springfield, VA [8]Naval Research Laboratory, Washington, DC [9]DLR (German Aerospace Center), Oberpfaffenhofen, Germany [10]NASA Goddard Space Flight Center, Greenbelt, MD, [11]National Center for Atmospheric Research, Boulder, CO, [12]Environment Canada, Cobble Hill, BC [13]International Ozone Services, Inc., Toronto, ON

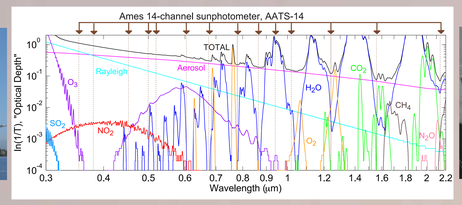
ABSTRACT

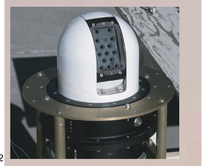
During the Second SAGE III Ozone Loss and Validation Experiment (SOLVE II), the 14-channel NASA Ames Airborne Tracking Sunphotometer (AATS-14) was mounted on the NASA DC-8 and successfully measured spectra of total and aerosol optical depth (TOD and AOD) during the sunlit portions of eight science flights. Values of ozone column content above the aircraft have been derived from the AATS-14 data by using a weighted linear least squares method (King and Byrne, 1976). For each AATS-14 measured TOD spectrum, this method iteratively finds the ozone column content that yields the best match between measured and calculated TOD. The calculations assume the known Chappuis ozone band shape (see below) and a three-parameter AOD shape (quadratic in log-log space). Seven of the AATS-14 channels (each employing an interference filter with a nominal full-width at half maximum bandpass of ~5 nm) are within the Chappuis band, with center wavelengths between 452.9 nm and 864.5 nm. One channel (604.4 nm) is near the peak, and three channels (499.4, 519.4 and 675.1 nm) have ozone absorption within 23-40% of that at the peak. For the typical DC-8 SOLVE II cruising altitudes of ~8-12 km and the background stratospheric aerosol conditions that prevailed during SOLVE II, absorption of incoming solar radiation by ozone comprised a significant fraction of the aerosol-plus-ozone optical depth measured in the four AATS-14 channels centered between 499.4 and 675.1 nm (see below). Typical AODs above the DC-8 ranged from 0.003-0.008 in these channels. For comparison, an ozone overburden of 0.3 atm-cm (300 DU) translates to ozone optical depths of 0.009, 0.014, 0.041, and 0.012, respectively, at these same wavelengths.

We compare AATS-14 values of ozone column content with temporally and spatially near-coincident values derived from measurements acquired by the Stratospheric Aerosol and Gas Experiment III (SAGE III) and the Polar Ozone and Aerosol Measurement III (POAM III) satellite sensors. We also compare AATS-14 ozone retrievals during selected DC-8 latitudinal and longitudinal transects with total column ozone data acquired by the Total Ozone Mapping Spectrometer (TOMS) and the Global Ozone Monitoring Experiment (GOME) satellite sensors. To enable this comparison, the amount of ozone in the column below the aircraft is estimated by combining SAGE and/or POAM data with high resolution, fast response in-situ ozone measurements acquired during the DC-8 ascent at the start or descent at the end of each science flight.

RETRIEVAL METHODOLOGY





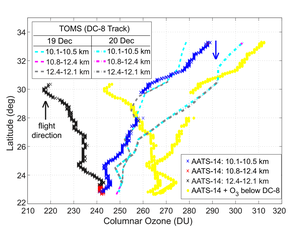


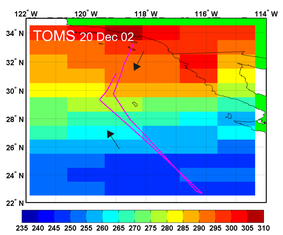
SUMMARY and CONCLUSIONS

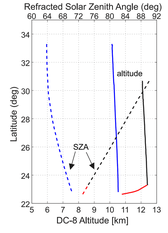
- AATS-14 measurements on the DC-8 during SOLVE II have been analyzed using least squares methodology to retrieve values of columnar ozone above aircraft altitude. The technique exploits the differential absorption of AATS-14 channels located within the Chappuis ozone absorption band and assumes a known AOD spectral shape.
- Values of overlying columnar ozone retrieved from AATS-14 measurements acquired during extended horizontal transects during three flights (19-20 Dec, 21 Jan, 6 Feb) have been compared with corresponding TOMS and GOME total ozone column retrievals. When the amount of ozone below the aircraft is estimated from a model or from data obtained by a fast response in-situ ozone sensor (FASTOZ) during aircraft ascent or descent results are found to be mutually consistent for two of the cases (21 Jan, 6 Feb). AATS retrievals depart significantly from the satellite retrievals for the third case (19-20 Dec). These differences are attributed to spatial and temporal variability on this day, but analysis is ongoing.
- AATS-14 columnar ozone retrievals have been compared with measurements by SAGE III and POAM III for four coincident occultation events, each. RMS differences are 18 DU (6%) for AATS/SAGE and 10 DU (3%) for AATS/POAM.
- AATS-14 ozone retrievals have been found to agree to better than 5% with corresponding values derived from coincident measurements acquired by two other DC-8 based solar occultation instruments — GAMS (the NASA Langley Gas & Aerosol Monitoring System) and DIAS (the NCAR Direct Beam Solar Irradiance Spectroradiometer).
- AATS-14 ozone retrievals have been compared directly with high resolution in-situ ozone measurements (the NASA Langley FASTOZ instrument) during the DC-8 descent into Edwards AFB on 6 Feb. Corresponding layer ozone values agree to with ~12 DU for the layer between 12.4 and 1.1 km altitude. Differentiation of a spline fit to the AATS-14 columnar ozone values yields a coarse vertical profile of ozone number density that, not surprisingly, is unable to reproduce the fine structure seen by FASTOZ.
- For the 6 Feb DC-8 descent, measurements in the AATS-14 941-nm channel have been analyzed to yield a vertical profile of water vapor columnar overburden and then, by differentiation, water vapor density. These results are in excellent agreement with independent measurements from aboard the DC-8 by the NASA Langley Diode Laser Hygrometer (DLH) and with nearby radiosonde measurements acquired ~1.5 hr earlier.

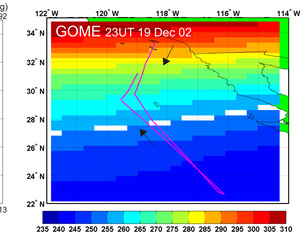
COMPARISONS WITH TOMS and GOME

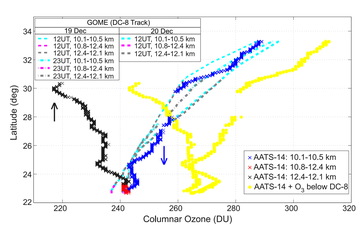
19-20 DEC 02



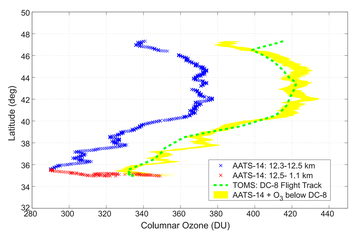


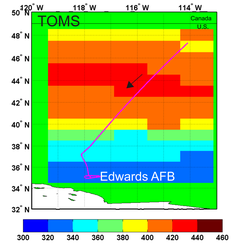


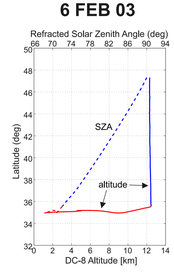


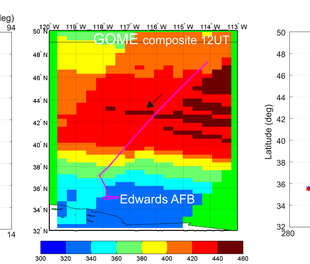


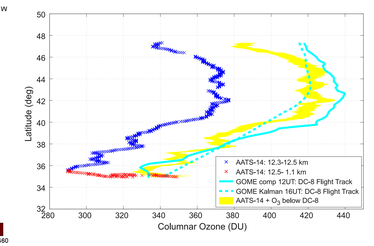
6 FEB 03



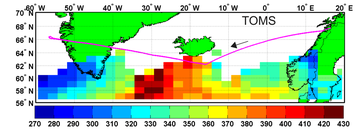


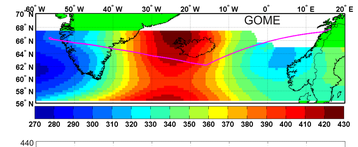


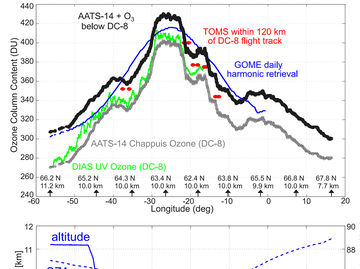


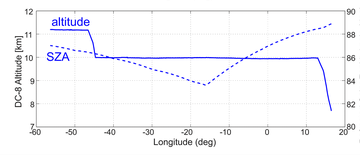


21 JAN 03

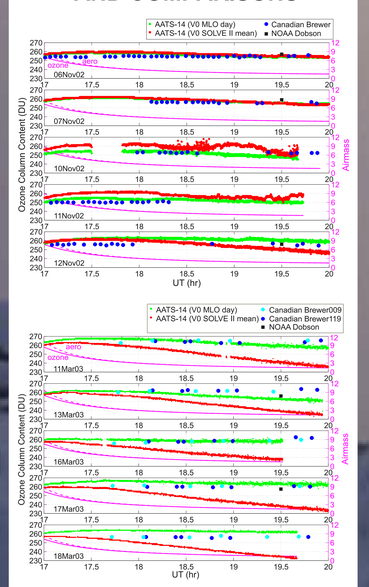








MAUNA LOA CALIBRATION AND COMPARISONS



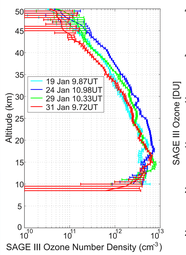
COMPARISONS WITH SAGE III and POAM III

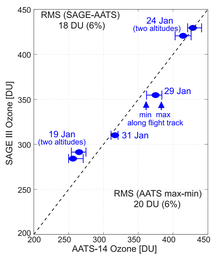
AATS-14/ SAGE III Coincidences

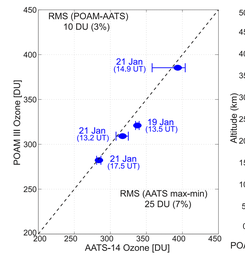
DATE	SAGE UT	SAGE Lat	SAGE Lon	AATS UT	Separation (km)
19 Jan	9.87	69.31 N	24.20 E	9.69-9.80	39-99
24 Jan	10.98	70.60 N	11.01 E	10.60-10.89	7-205
29 Jan	10.33	72.00 N	25.74 W	10.13-10.43	59-100
31 Jan	9.72	72.55 N	36.90 W	9.39-9.81	81-150

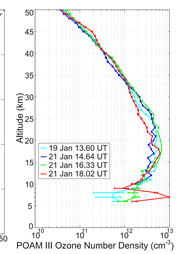
AATS-14/ POAM III Coincidences

DATE	POAM UT	POAM Lat	POAM Lon	AATS UT	Separation (km)
19 Jan	13.60	64.95 N	16.05 E	13.10-13.22	34-59
21 Jan	14.64	65.14 N	1.74 E	13.22-13.66	138-200
21 Jan	16.33	65.15 N	23.58 W	14.92-15.43	251-300
21 Jan	18.02	65.16 N	48.90 W	17.53-17.61	52-60

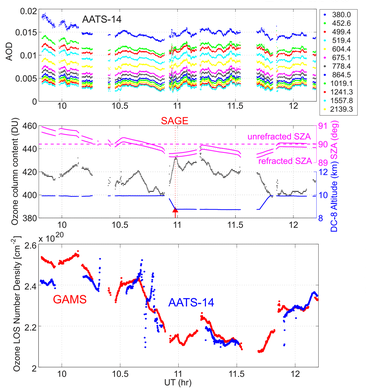


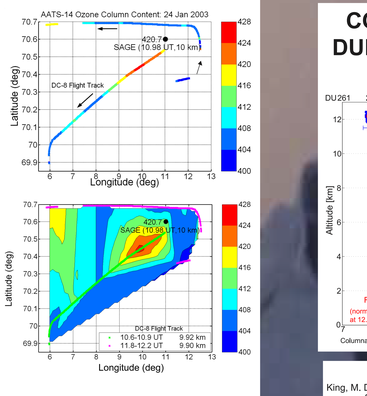




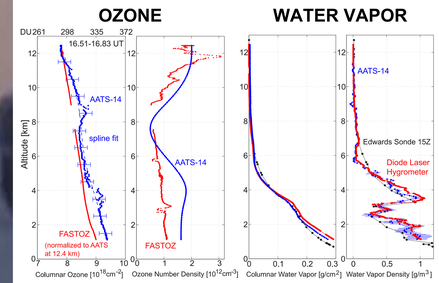


24 JAN 03





COMPARISON WITH IN-SITU DATA DURING DC-8 DESCENT ON 6 FEB 03



REFERENCE

King, M. D., and D. M. Byrne, A method for inferring total ozone content from the spectral variation of total optical depth obtained with a solar radiometer, *J. Atmos. Sci.*, 33, 2242-2251, 1976.