Preliminary Intercomparison Results from the NDSC Microwave Ozone Profiling Instrument at Mauna Loa Observatory

ALAN PARRISH
University of Massachusetts, Amherst, Massachusetts 01003

I. S. BOYD AND B. J. CONNOR
National Institute for Water and Atmospheric Research, Lauder, New Zealand

I. S. MCDERMID
Jet Propulsion Laboratory, Table Mountain Facility, Wrightwood, California 92397

S. OLTMANS
NOAA Climate Monitoring and Diagnostics Laboratory, Boulder, Colorado 80303

J. J. TSOU
Science Applications International Corporation, Hampton, Virginia 23666

J. M. ZAWODNY
National Aeronautics and Space Administration, Langley Research Center, Hampton, Virginia 23681

Since July 1995, the University of Massachusetts has operated a microwave instrument that measures vertical profiles of stratospheric ozone at the Climate Monitoring and Diagnostics Laboratory (CMDL) Mauna Loa Observatory (MLO). Results of intercomparisons with four other ozone profiling experiments using data recorded during 1995-1998 are reported here.

The microwave instrument measures a spectral line produced by a rotational transition of ozone at 110.836 GHz. Profiles covering an altitude range of 56-0.1 hPa (about 20-66 km) are retrieved from the details of the pressure-broadened line shape. The vertical resolution of the measurements is 8-10 km from about 20 to 40 km. At higher altitudes it smoothly degrades to a maximum of 17 km at about 60 km. Details regarding the instrument are given in *Parrish et al*. [1992], *Connor et al.* [1995] and *Tsou et al.* [1995].

The microwave instrument participated in the Network for Detection of Stratospheric Change (NDSC) sponsored MLO3 intercomparison campaign [*McPeters et al*., 1999] in July 1995. During that campaign the microwave instrument, two lidars, and Stratospheric Aerosol and Gas Experiment-II (SAGE-II) agreed within 5% from 22-43 km. Agreement at that level between microwave, SAGE-II, and one set of lidar measurements continued up to about 50 km. A further assessment, including a relative trend analysis, can now be made from intercomparisons using data obtained since the end of the MLO3 campaign through 1998.

Microwave data were recorded from July-September 1995, November 1995-March 1996, and from July 1996 on. Calibrated profiles were retrieved from these data through December 1998 and are considered preliminary because we are aware of two small, correctable defects in the data. First, the 1997 data were processed on a different implementation of the calibration and retrieval software. There is a slight difference between profiles produced by this algorithm and its predecessor in the 20-25 km region. Second, a small amount of 1995 and 1996 data may be affected by an occasional intermittent electronic fault that became apparent in 1997. Affected 1997 data were deleted from this dataset. While the microwave group intends to reprocess the data to eliminate the known defects, it is believed that the errors produced by these faults are small enough to make it worthwhile to proceed with the comparison described in the following text.

The previously described microwave data were compared with those produced by lidar, ozonesonde, SAGE-II [*Cunnold et al*., 1989], and Halogen Oscillation Experiment (HALOE) [*Bruhl et al*., 1996] instruments. The lidar was provided and operated by the Jet Propulsion Laboratory (JPL), California Institute of Technology [*McDermid et al*., 1990], and sondes were launched nearby at Hilo by CMDL personnel [*Oltmans et al*., 1998, and references therein]. Profiles in number density versus altitude format were converted to mixing ratio versus pressure assuming hydrostatic equilibrium with the NOAA National Center for Environment Prediction (NCEP) temperature profiles in the calculation. There are two points to note regarding the comparison datasets: The KI solution concentration in the sondes was increased from 1% to 2% in April 1998 for reasons discussed in *Oltmans et al*. [1998]. Data from earlier flights were adjusted to be consistent with those using the new solution. Problems with the lidar data that affect the profiles below 25 km have been found, and a revised dataset is being prepared. Therefore, the microwave-lidar comparison was cut off at 24 hPa (about 25 km.).

The average difference between the microwave profiles and those from the other instruments is mostly less than 5% (Figure 1). The spread of differences in the several comparisons is largest in the lower stratosphere (~40 hPa), from -8 to +12%. The difference would be slightly positive when averaged over the SAGE, HALOE, and ozonesonde comparisons, suggesting that the microwave measurements may be biased slightly high. However, the large spread makes this result inconclusive. In the middle stratosphere (~10 hPa), the microwave values are generally a few percent smaller than the others. For both the SAGE-II and HALOE comparisons, the average differences stay below 5-6% up to 0.6 hPa, and the variability in individual difference profiles remains small. Although microwave-lidar differences grow rapidly above a few hPa, similar increases are seen between sets of measurements made with two lidar instruments during intercomparison campaigns (e.g., *McPeters et al*. [1999]). The variability in the microwave-lidar difference

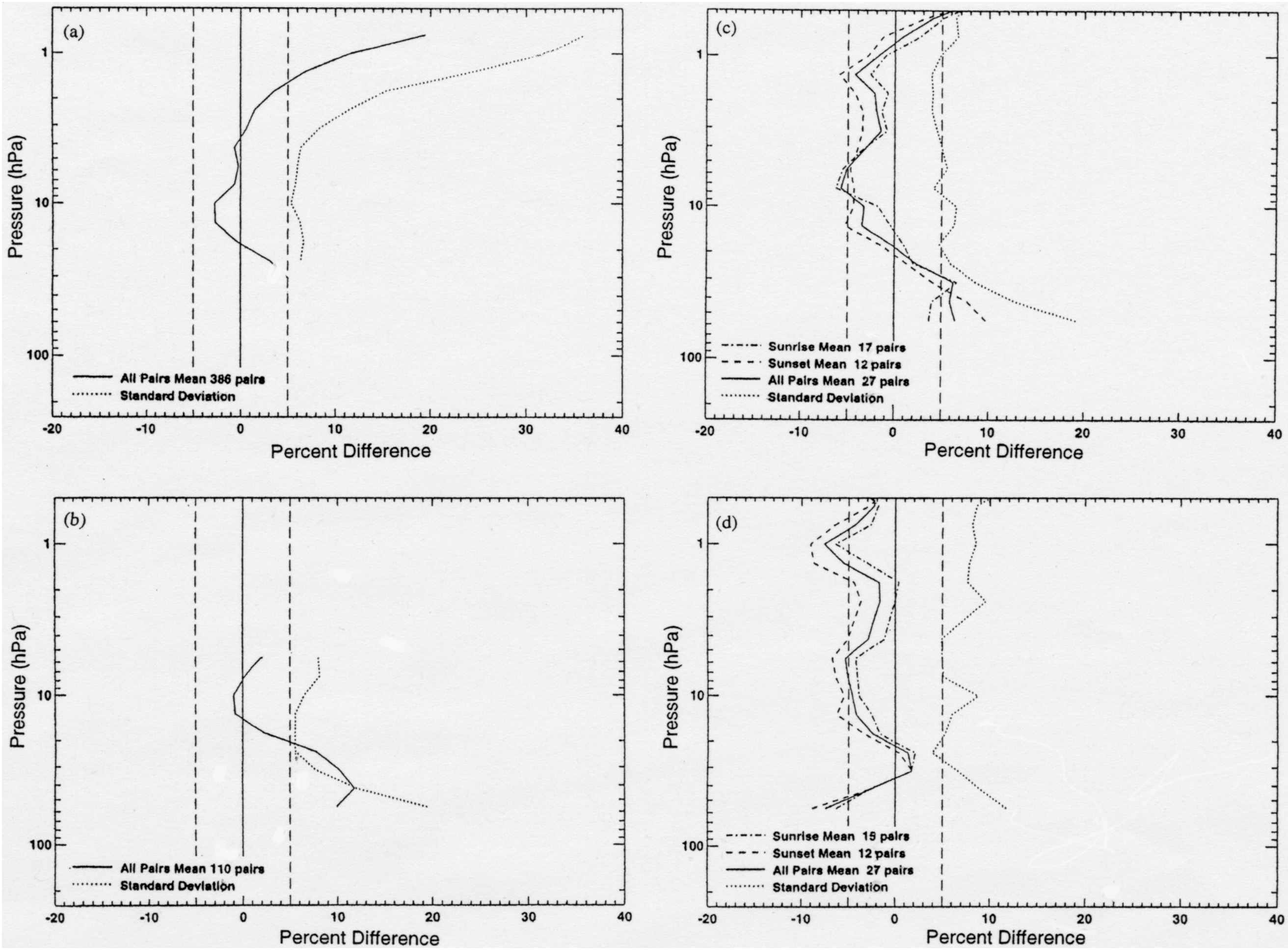

Fig. 1. Solid lines: Differences between ozone profiles recorded with the microwave instrument at Mauna Loa and those recorded with the co-located (a) JPL lidar, (b) NOAA ozonesondes, and during overpasses of the (c) HALOE (version 19), and (d) SAGE-II (version 5.96) instruments averaged from August 1995 through December 1998. Dotted lines: The root-mean-square of individual difference profiles. The percent difference is calculated by subtracting the specified instrument ozone amount from the microwave ozone amount, dividing by the sum of the ozone amount from the two instruments, and multiplying by 100.

profiles also increases rapidly above 4-5 hPa. These facts suggest that the increasing average difference between these lidar and microwave measurements with altitude above a few hPa is due to the decreasing intensities of the signals returned to the lidar. We have not extended comparisons to higher altitudes because of the difficulty in accounting for the effect of diurnal, photolysis-induced changes in ozone levels along the line of sight of the satellite-borne occultation type instruments.

Regression analyses were performed to calculate relative trends between our measurements and the others used in the preceding difference profile discussion; results are shown as functions of altitude (Figure 2). There are 110 sonde-microwave coincidences, 386 lidar-microwave coincidences, 29 HALOE coincidences, and 27 SAGE coincidences. There are statistically significant altitude-dependent relative trends of 1-2% per year between the microwave and lidar measurements around 5 hPa. The relative trends in the other comparisons are more uncertain. Because they generally have the same sign and similar magnitude in this region, there may have been some form of systematic change in the microwave measurements during the 1995-1998 period. Because the present microwave dataset is known to have small defects that occur irregularly, it seems more likely that any systematic effect in the microwave data is quasi-random in nature than a steady drift. If so, the magnitude of the relative trends would decrease with increasing record length, even in the absence of an upgraded microwave data set.

A preliminary set of microwave ozone profiles (covering about 20-66 km) measured at MLO during 1995 through 1998 was compared with ozonesonde, lidar, SAGE-II, and HALOE profiles measured nearby. The average differences depend most strongly on the instrument being compared in the lower stratosphere. Above 30 hPa (about 24 km), the differences are generally less than 5% at altitudes where the comparison instruments are expected to work well. Relative trends of 1-2%

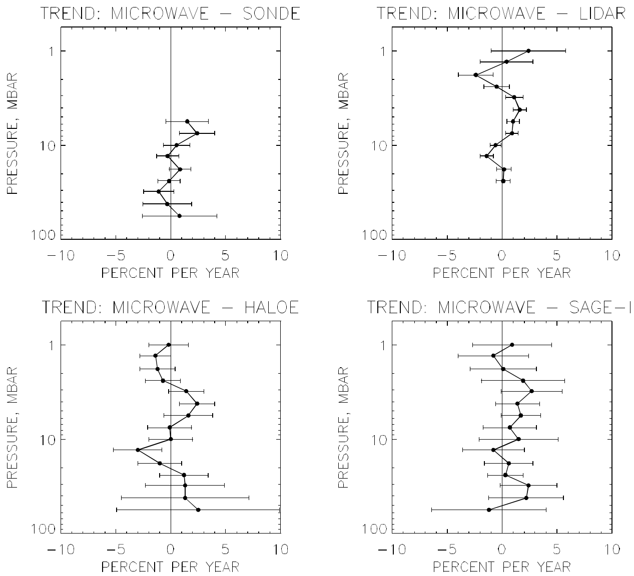

Fig. 2. Relative trends versus pressure calculated by linear regression from microwave profiles at Mauna Loa, those recorded by co-located JPL lidar, and NOAA sondes, and during overpasses of the SAGE-II and HALOE instruments. Error bars correspond to the 95% confidence interval. Trends are calculated from August 1995 through December 1998.

per year were found between time series of lidar and microwave measurements. The other three trend comparisons are less certain, but suggest that the lidar-microwave trends may be caused by flaws in the present microwave data. These trends are expected to integrate down as the record length increases. The relative trend also may be reduced when the microwave data are reviewed and uniformly reprocessed.

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