Stratospheric Ozone Climatology from Lidar Measurements at Mauna Loa

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INTRODUCTION

The Jet Propulsion Laboratory (JPL) lidar at Mauna Loa Observatory (MLO) continues to make regular measurements of ozone, temperature, and aerosol profiles for the Network for the Detection of Stratospheric Change (NDSC) program. This report describes the development of an ozone climatology from one aspect of the lidar results.

The routine measurement modes for the lidar are based upon the NDSC requirement for a long-term ozone survey. The usual measurements comprise an approximately 1.5-hour long data acquisition at the beginning of the night several times a week, weather and instrument permitting (the normal starting time is the end of astronomical twilight that ensures there is no sunlight falling on any part of the atmosphere sensed by the lidar). Additional full-night measurements have been made in the past 4 years at given periods of the year to study the tidal signature in the middle atmospheric temperature [*Leblanc et al.*, 1999]. However, to avoid any contamination by possible diurnal variations, only the profiles taken before 0930 UT were selected to build this climatology. The data set from the full-night campaigns will be used in the future for the study of the ozone diurnal variations. This temporal selection leaves more than 800 profiles between July 1, 1993, and June 30, 1999. The JPL lidars have participated in numerous intercomparison and validation exercises with nearly co-located and/or simultaneous measurements. The results of these campaigns have been extensively published and clearly indicate the quality of the lidar results [e.g., *McDermid et al*., 1995; *Tsou et al*., 1995; *Planet et al*., 1995; *Baily et al*., 1996; *Bruhl et al*., 1996; *Froidevaux et al*., 1996; *Grant et al*., 1998; *McPeters et al*., 1999].

OZONE PROFILES

In the present study the ozone concentration profiles were interpolated to a 1-km vertical interval in order to homogenize the entire data set. This operation reduces the magnitude of smaller vertical scale fluctuations, but these fluctuations are not needed for the climatological study presented. Figure 1 shows two typical profiles measured at MLO in late winter and midsummer. Unlike at more northern latitudes, such as the JPL Table Mountain Facility, there is no significant seasonal change in the altitude of the ozone peak. Also unlike northern midlatitudes, the ozone concentration in the lower stratosphere is not significantly higher in winter than in summer (5×10^{12} cm^{-3} in summer and 4-4.2 $\times 10^{12}$ cm^{-3} in winter near 24-26 km). Instead, the whole winter profile tends to have lower values than the summer profile. This is consistent with a more photochemically and/or radiatively driven tropical ozone abundance where the role of transport and mixing by the mid- and high-latitude planetary waves is much less significant. However, there remains a layer in the winter lower stratosphere where ozone is slightly more abundant than in summer. This feature, typical of the extra-tropical latitudes, is expected to disappear closer to the equator.

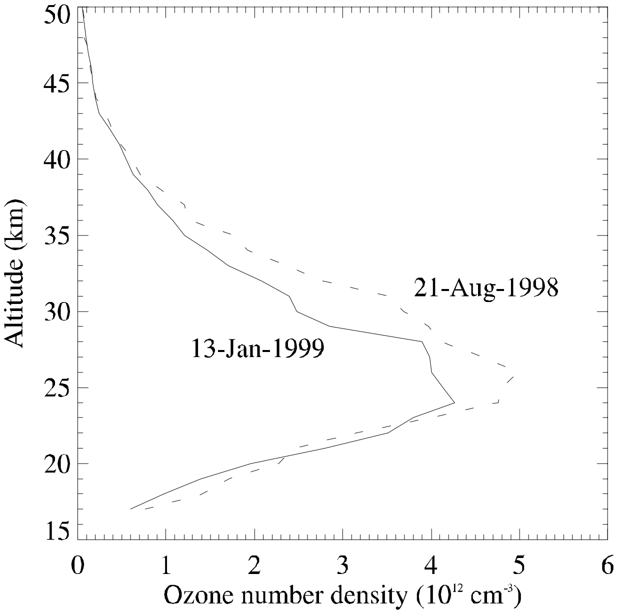

Fig. 1. Typical wintertime and summertime ozone profiles at MLO.

OZONE CLIMATOLOGY

The overall mean ozone number density was calculated as a function of altitude. The mean profile obtained is representative of an annual mean since the data distribution for each month is similar. Then, the deviations (in percent) from the quasi-annual mean were calculated for each day of measurement.

The two-dimensional contours of these filtered ozone deviations are shown in Figure 2. The color scale extends from –24% (violet) to +24% (red) with a 4% contour interval. The white solid line near 25 km represents the mean altitude of the ozone concentration peak. This altitude is nearly constant throughout the entire year. The seasonal variation of the ozone concentration at MLO is not as pronounced as for higher latitudes. Figure 2 nevertheless highlights a residual annual cycle at 30 km and above, similar to that observed at midlatitudes and related to the seasonal variation of the radiative balance of the upper stratosphere (more sunlight in summer). Figure 2 also reveals a springtime maximum near 19-20 km as the result of a residual contamination by the midlatitude planetary wave activity. No clear annual cycle is observed below 25 km. However, despite the strong variability at the bottom of the profiles (near the tropopause) persistent high ozone concentrations are observed during the summer months and persistent low concentrations are observed in December and January, indicating the dominant role of the photochemical and radiative effects over the dynamics. The annual cycles observed are in agreement within a few percent with previous climatologies such as that obtained from SAGE II data [*Shiotani and Hasebe,* 1994].

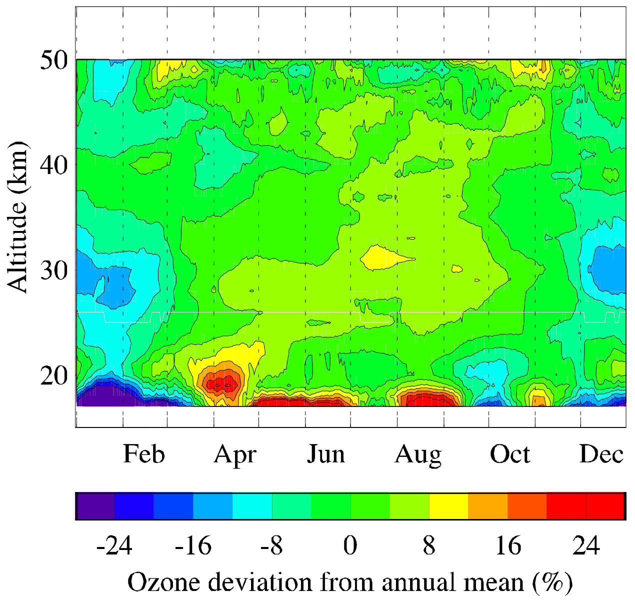

Fig. 2. Ozone number density deviation from the annual mean (%) as a function of altitude (km) and day-of-year at MLO. Contour interval is 4%.

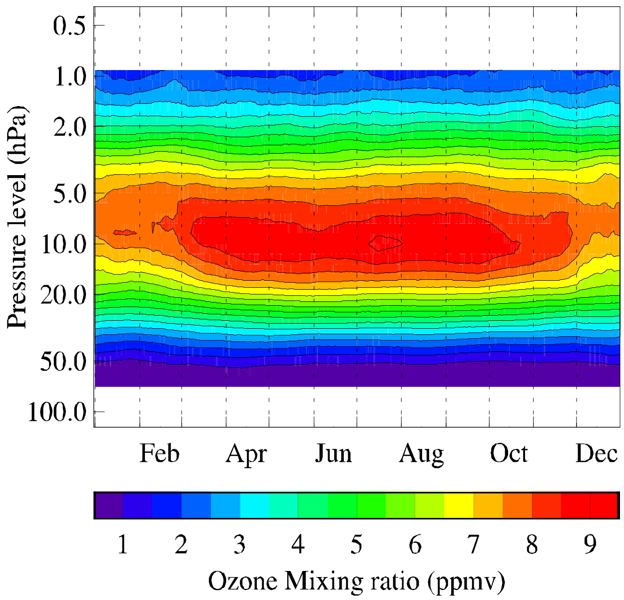

Fig. 3. Ozone mixing ratio (ppmv) at MLO, derived using the ozone results in Figure 2 and MSISE-90 density and temperature data, as a function of pressure altitude (hPa).

DERIVED QUANTITIES

For a convenient comparison with model results and other observations, the ozone number densities measured by the lidar were converted into ozone mixing ratios. The Mass Spectrometer Incoherent Scatter Extended-90 (MSISE) empirically modeled air densities and temperatures [*Hedin*, 1991] were used to calculate the ozone-mixing ratio as a function of pressure. Figure 3 shows the seasonal variations of the derived ozone mixing ratios for the periods. Since the densities and temperatures (i.e., pressures) used do not come from actual simultaneous measurements, a slight vertical distortion of the contours is expected, especially during the winter months. This distortion can lead to some 10-15% differences in the regions of sharp vertical gradient like in the late spring and summer lower stratosphere.

DISCUSSION AND CONCLUSION

A 6-year stratospheric ozone climatology obtained by the JPL DIAL instrument located at Mauna Loa Observatory (19.5ºN) has been described. The lidar provided high-resolution vertical profiles of nighttime ozone number density between ~15-50 km several nights a week since 1993. The climatology presented is typical of early night ozone values and includes a negligible fraction of Pinatubo-influenced ozone values [*Parrish et al.*, 1998]. It includes ozone values typical of a time of low solar activity since the measurement period is approximately centered on the 1996 11-year solar cycle minimum.

At MLO the ozone concentration tends to be higher during the summer months and lower during the winter months throughout the entire ozone layer. Only a weak signature of the extra-tropical latitudes is observed near 19-20 km with a secondary ozone maximum in late March-early April. As emphasized previously, the 1993-1999 measurement period at MLO is nearly centered on the 1996 11-year solar cycle minimum. Therefore, the upper stratospheric ozone values are expected to be slightly lower (~2-3%) than those obtained over a full solar cycle [*Chandra and McPeters*, 1994].

The current climatology will be complemented by ongoing detailed investigations of the day-to-day variability of the tropopause height, diurnal variations, interannual variability (Quasi-Biennial Oscillation, El Niño and the Southern Oscillation, solar cycle, etc.) and the long-term trends of ozone. The results from these investigations, combined with the present climatology, will eventually provide a comprehensive overview of the stratospheric ozone vertical distribution at MLO.

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