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Validation of Aura Microwave Limb Sounder Ozone by ozonesonde and lidar measurements

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[1] We present validation studies of MLS version 2.2 upper tropospheric and stratospheric ozone profiles using ozonesonde and lidar data as well as climatological data. Ozone measurements from over 60 ozonesonde stations worldwide and three lidar stations are compared with coincident MLS data. The MLS ozone stratospheric data between 150 and 3 hPa agree well with ozonesonde measurements, within 8% for the global average. MLS values at 215 hPa are biased high compared to ozonesondes by ∼20% at middle to high latitude, although there is a lot of variability in this altitude region. Comparisons between MLS and ground-based lidar measurements from Mauna Loa, Hawaii, from the Table Mountain Facility, California, and from the Observatoire de Haute-Provence, France, give very good agreement, within ∼5%, for the stratospheric values. The comparisons between MLS and the Table Mountain Facility tropospheric ozone lidar show that MLS data are biased high by ∼30% at 215 hPa, consistent with that indicated by the ozonesonde data. We obtain better global average agreement between MLS and ozonesonde partial column values down to 215 hPa, although the average MLS values at low to middle latitudes are higher than the ozonesonde values by up to a few percent. MLS

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v2.2 ozone data agree better than the MLS v1.5 data with ozonesonde and lidar measurements. MLS tropical data show the wave one longitudinal pattern in the upper troposphere, with similarities to the average distribution from ozonesondes. High upper tropospheric ozone values are also observed by MLS in the tropical Pacific from June to November.

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1. Introduction

[2] The Microwave Limb Sounder (MLS) is one of four instruments on the Earth Observing System (EOS) Aura satellite which was launched on 15 July 2004 and placed into a near-polar orbit at ~705 km altitude, with a ~1:45 p.m. ascending equatorial crossing time. The Aura mission objectives are to study the Earth's ozone, air quality, and climate [*Schoeberl et al.*, 2006a, 2006b]. MLS [*Waters et al.*, 1999, 2006] contributes to this objective by measuring atmospheric temperature profiles from the troposphere to the thermosphere, and more than a dozen atmospheric constituent profiles, as well as cloud ice water content [*Wu et al.*, 2006] from millimeter- and submillimeter-wavelength thermal emission of Earth's limb with seven radiometers covering five broad spectral regions.

[3] Initial ozone validation results using MLS v1.5 data include the early work of *Froidevaux et al.* [2006], as well as results of comparisons between MLS and ground-based microwave profiles [*Hocke et al.*, 2006], and the analyses of *Ziemke et al.* [2006] and D. Yang et al. (Midlatitude tropospheric ozone columns derived from Aura OMI and MLS data using the TOR approach and mapping techniques, submitted to *Journal of Geophysical Research*, 2007, hereinafter referred to as Yang et al., submitted manuscript, 2007), focusing on stratospheric columns and resulting tropospheric ozone residual column abundances, using a combination of MLS and OMI data.

[4] In this paper, we present validation results of the newly released MLS version 2.2 (or v2.2) ozone product from the upper troposphere to the upper stratosphere through comparisons with global ozonesonde and ground-based lidar measurements. Although MLS measures ozone in several spectral bands [*Waters et al.*, 1999, 2006], this paper focuses on the "MLS standard product" for ozone, which is obtained from radiance measurements near 240 GHz and provides the best overall precision for the widest vertical range. There are related papers focusing on validation of the 240 GHz MLS ozone (and CO) data in the upper troposphere and lower stratosphere [*Livesey et al.*, 2007], mainly for pressures of 100 hPa and larger, and in the stratosphere and lower mesosphere (L. Froidevaux et al., Validation of Aura Microwave Limb Sounder Stratospheric ozone measurements, submitted to *Journal of Geophysical Research*, 2007, hereinafter referred to as Froidevaux et al., submitted manuscript, 2007), using satellite, aircraft and ground-based ozone measurements. Version 2.2 is currently in the early stages of reprocessing and is therefore more limited in terms of available days than version 1.5, with about 3 months of v2.2 reprocessed data, covering selected days in 2004, 2005, and 2006. A recent minor software patch has led to version 2.21, with results that are essentially identical to v2.20 results for the vast majority of days.

[5] In section 2, we summarize the data usage and screening recommendations for MLS v2.2 ozone profiles. Section 2 also provides a brief description of the estimated MLS ozone uncertainties, both random and systematic, which we generally refer to as precision and accuracy. We provide the comparisons between MLS ozone and ozonesonde profiles in section 3, followed by section 4 on ground-based lidar measurement comparisons. Section 5 summarizes the results and suggests improvements needed in future versions.

5. Summary and Conclusions

[30] This paper presents the validation results of newly released Aura MLS v2.2 ozone in the upper troposphere and lower stratosphere using worldwide ozonesonde and ground-based lidar measurements. In the upper troposphere and lower stratosphere, MLS ozone is generally biased high at middle to high latitudes, as compared to ozonesondes, but within 20% or 20 ppbv, on average, in the tropics. In the middle stratosphere, MLS is within 7% of the global ozonesonde measurements. Averaged over each ozonesonde station, the column ozone comparisons against MLS show better than 10% agreement, but there is no significant bias globally.

[31] Comparisons to three sets of lidar measurements from Hawaii, Table Mountain, and Haute Provence in France show excellent agreement (within about 5%) in the stratosphere and MLS ozone biases higher by 35% at 215 hPa level. This study also shows that the temporal variations in MLS ozone and in midlatitude ozone from the Boulder, CO, ozonesondes and the Table Mountain Facility, CA, lidar track each other very well. The global results of comparisons between ozonesondes and lidars are listed in Tables 3 and 4. The results from the lidar comparisons are consistent with that from the ozonesonde comparisons in the lower altitude range. However, the comparisons between MLS ozone and aircraft in situ and lidar data do not give strong evidence for a high MLS bias at 215 hPa of more than 15% [*Livesey et al.*, 2007; Froidevaux et al., submitted manuscript, 2007]. Because of the somewhat inconsistent evidence of a high MLS bias at 215 hPa, the accuracy estimate for MLS v2.2 ozone at 215 hPa has been set at about 20 ppbv + 20% (see the above references), rather than the somewhat lower estimate of 20 ppbv + 10% expected from simulations and sensitivity studies (see the above two references). Further detailed investigations using more reprocessed MLS v2.2 data may shed more light on these issues.