Sodium Abundance Data Complied from the Maui Mesosphere and Lower Thermosphere Experiment

KECK ADAPTIVE OPTICS NOTE 417

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ABSTRACT

This note reports on averages for the Na layer altitude and the Na column density compiled from measurements with the Maui MALT experiment from 35 nights of data recorded over 3 years. Little to no seasonal variation is seen in the data. The largest variability is during the course of a single night of observation where the sodium abundance often varies by a factor of 2 or more in as little as a few hours. The histogram of sodium abundance measurements has a minimum value of about 2.0×10^9 atoms cm^{-2}. We adopt this value as reasonable for specification of laser flux return for future Keck laser guide star systems.

1. Introduction

The knowledge of the Na abundance is critical to determining the laser power needed to produce a given flux at entrance pupil of an adaptive optics system. Sodium abundance measurement campaigns have been undertaken at the sites of major astronomical observatories located at La Palma in the Canary Islands and at Cerro Tololo in Chile. At present, no systematic study of the sodium (Na) abundance and its variability has been undertaken at Mauna Kea where the Keck telescopes are located. However, the Na abundance has been extensively measured by lidar as part of the Maui Mesosphere and Lower Thermosphere (Maui MALT) experiment[1] at Haleakala. Haleakala is located approximately 130 km to the northwest of Mauna Kea. At any instant in time, the Na layer may be quiet different over Maui and the Island of Hawaii, but Maui is near enough to Mauna Kea to be considered in the same location from the standpoint of sodium layer climatology. As such, we would expect the sodium abundance averaged over long periods of time be similar for the two locations.

2. The Maui MALT University of Illinois Lidar

Maui-MALT is a consortium of scientific investigations studying the Mesosphere and Lower Thermosphere at the USAF AMOS facility on Haleakala in Maui, Hawaii. The infrastructure currently includes a Na wind/temperature lidar using the 3.7 m telescope. Remote sensing instrumentation includes an OH and O_2 band temperature mapper, an OH BB imager, a OH/O_2 band zenith photometer, multi-channel airglow imager, a 630 nm ‘spread F’ imager, an IR OH, narrow band imager, and a meteor radar. This infrastructure provides a basis for the study of equatorial dynamics (including small scale waves) and chemistry in the upper atmosphere

The Na wind/temperature lidar has successfully acquired data during the seven observing campaigns, each typically spanning 3-6 nights. Data were collected on a total of 35 nights since January 2002 with the last data collection campaign in March 2005. The results are summarized at the following web site[1]. The web site contains summary plots and processed data from each night of observation. The Na lidar photon count data is binned to 480 m resolution to derive temperature, wind, and Na density. The processed data is then smoothed with 1-km, 0.5 hr full-width Hamming window in both vertical and temporal dimensions. The smoothing is performed on a uniform grid with 100 m vertical resolution and 15 min temporal resolution. For each night, there is one file for each variable: Na density, temperature, vertical wind, and two horizontal wind components, if applicable. Altitude (above mean sea level) and universal time are also included in the data set. A typical set of summary plots for the night of August 9, 2004 are shown in **Figure 1**.

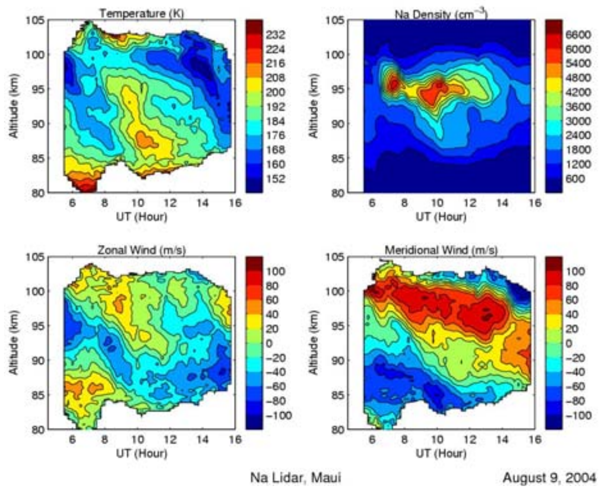

Figure 1. Typical Maui MALT lidar derived profiles for temperature, Na density, and wind speed. This data set is from the night of August 9, 2004**.**

3. Compilation of the University of Illinois Lidar data

The data provided by the University of Illinois were further analyzed in the following way: each individual Na density profile was integrated along the vertical direction resulting in a Na column density. The histogram over the entire 35 night data set is shown in Figure 2. The histogram includes 979 data values. The mean column density is 4.28×10^9 atoms cm^{-2} and the median column density is 3.602×10^9 atoms cm^{-2}. Based on the histogram, a value of 2×10^{-9} is adopted for specifying the lower bound on the Na column density for purposes of estimating laser power requirements for KPAO.

Researchers[2] at higher latitude sites in the northern hemisphere have noted a seasonal variation in sodium abundance, with the highest abundance during the winter months. To look for seasonal variations in the Maui MALT data a plot of each sodium column density measured as a function of day number was produced, see Figure 3. The data from individual years are color coded. Each observation for a single night is plotted on the same day number resulting in a vertical scatter of data points above the days when observations were made. The data show a large variation in Na abundance during the course of individual nights (causing the vertical scatter). However the data show little seasonal variation. The observations on Oct 24, 2003, show a high sodium abundance, it should be noted that this date is close to the peak of the Orionid annual meteor shower which could be the cause of this higher than average sodium abundance. Sporadic Na abundance enhancements have been noted by other researchers[2] and can be caused by meteor events and geomagnetic activity.

The mean altitude of the sodium layer was estimated by calculating the density weighted centroid of all the profiles in the data set. The distribution of these centroids is shown in Figure 4. The Na layer often has several distinct peaks of Na concentration. At these times, the centroid will likely not reflect this structure. The reference level for the Na layer altitude is mean sea level not the summit of Haleakala.

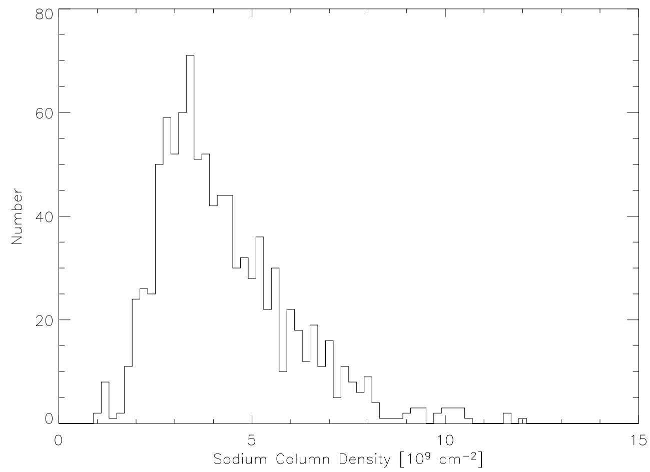

Figure 2. The histogram of Na abundance measurements from the 35 nights of the Maui MALT experiment, the histogram includes 979 data points. The median value of the Na density is 3.602×10^9 atoms cm^{-2} and average density is 4.28×10^9 atoms cm^{-2}.

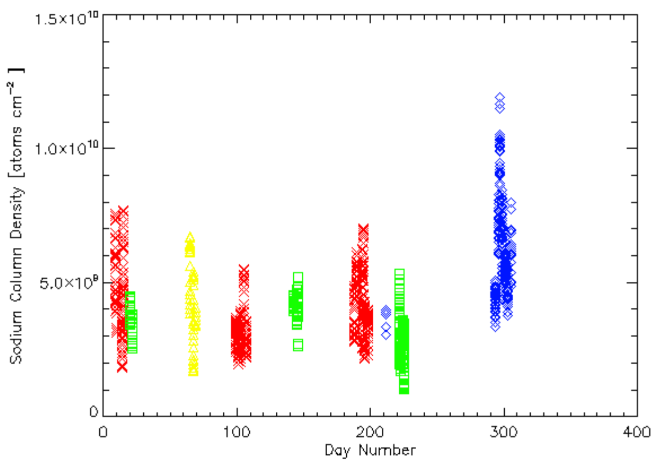

Figure 3. Yearly variation in Na column density: The data from each year are color coded as follows: red 2002, blue 2003, green 2004, and yellow 2005. The day number is equivalent to the days since Dec 31 of the previous year. For example Jan 1 is day number 1.

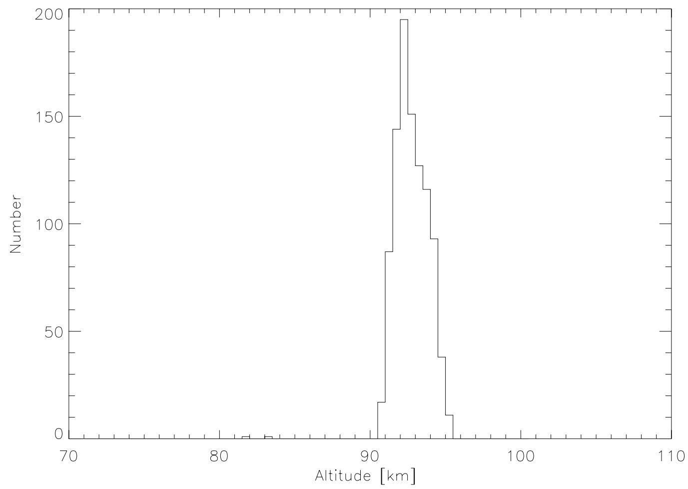

Figure 4. The histogram of sodium layer centroids: The centroid is calculated for each Na profile in the data set. The Na layer is known to often have several distinct peaks of Na concentration. At these times, the centroid will likely not reflect this structure. The reference level for the Na layer is mean sea level not the summit of Haleakala.

REFERENCES

1. Maui MALT web site, http://eoslserver.csl.uiuc.edu/Research/Maui/NaLidar/index.html.
2. Papen, G.C., Gardner, C.S. & Yu, J. , " 1996, in Adaptive Optics, Vol. 13, OSA Technical Digest Series (Optical Society of America, Washington DC), 1996.