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NA WIND/TEMPERATURE LIDAR OBSERVATIONS OF THE MESOSPHERIC REGION TEMPERATURES AND WINDS

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INTRODUCTION

Recently, sodium Doppler lidar techniques have been used to measure fine scale structure of both temperatures [1-3] and winds [4] near the mesopause region of the atmosphere (~80-105 km). Na Doppler lidars have the potential for making extremely high resolution measurements on the order a few tens of meters and a few tens of seconds. Currently, Na lidars are the only instruments that provide high spatial and temporal wind and temperature data in this region of the atmosphere that has historically been one of the most difficult to study experimentally. This data is vital to understanding overall global energy transport and upper atmospheric chemistry. We present a brief overview of the technique and show some recent results highlighting the unique measurement capabilities of these systems.

EXPERIMENTAL TECHNIQUE

Narrowband Doppler lidar techniques using sodium resonance fluorescence have been described in several references [1,5]. The technique was developed through collaboration between Colorado State University and the University of Illinois at Urbana-Champaign. The technique relies on the frequency dependence of the resonant backscatter from the mesospheric sodium layer which is a function of both temperature T and radial wind velocity V_R. The narrowband method uses a pulsed laser to probe the sodium layer at four frequencies referenced to a Na vapor cell. The four measurements are then combined to produce temperature ratio R_T and a wind ratio R_w. The temperature frequencies are chosen to minimize the effect of wind on R_T and conversely, the frequencies used for R_w are chosen to be insensitive to T. A complete wind/temperature measurement cycle consists of sequentially tuning the laser through all four frequencies. An example of a single wind, temperature and density profile from one measurement cycle is shown in Figure 1. Note the strong correlation between a sporadic layer that formed at 90 km and a temperature enhancement of near 40 K at the same altitude.

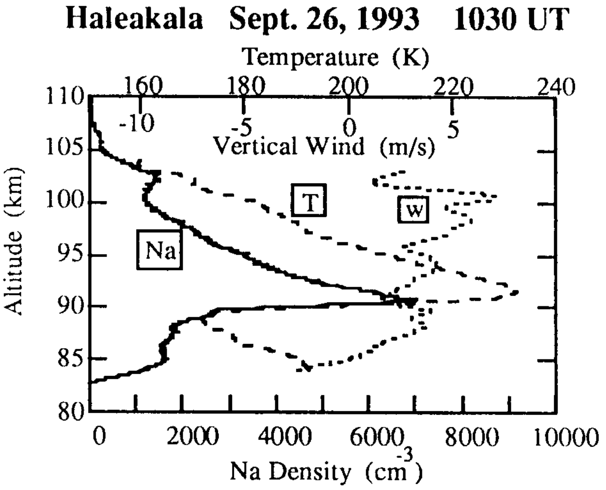

Figure 1. Density Na, temperature T, and vertical wind w at 10:30 UT on Sept. 26, 1993 at Haleakala, Maui (20 N 156 W). The total time to measure these profiles was 5 minutes.

TEMPERATURE MEASUREMENTS

Atmospheric temperatures in the region between 80 and 105 km altitudes are characterized by strong seasonal variability due to adiabatic heating and cooling associated with the mean meridional circulation system. Near the poles at mesopause heights temperatures can range from ~280 K in winter to ~120 K during summer. Although less extreme at lower latitudes, variations as large as 100 K have been observed at mid-latitudes by several groups [1, 6]. The predicted increases of atmospheric CO_2 and CH_4 during the next century and the accompanying increases on radiative cooling are likely to have major effects on the composition and thermal structure of the upper mesosphere and lower thermosphere [7].

A recent single night temperature and density profile recorded at Haleakala Maui (20 N 156 W) is shown in Figures 2 and 3. Note the strong phase progression downward over the course of the observation period.

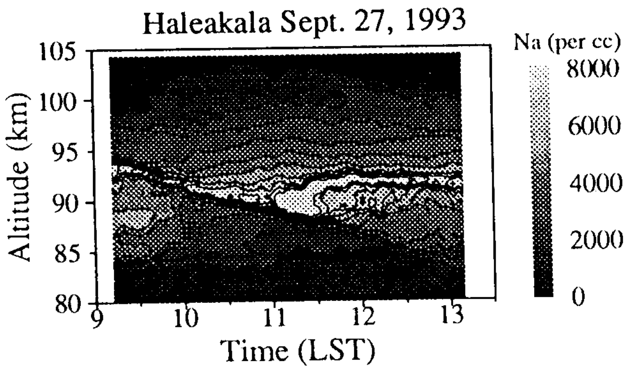

Figure 2. Contour plot of the nightly Na density in the mesopause region for the same night as in Fig. 1.

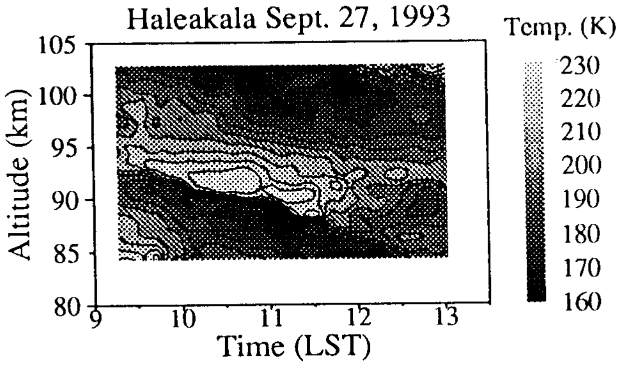

Figure 3. Contour plot of the temperature for the same night as Fig. 1 and Fig. 2.

Climatology studies have also been conducted. Figure 4 shows seasonal variation of the mesopause temperature at Urbana using 65 nights of data collected over a ~3 year interval.

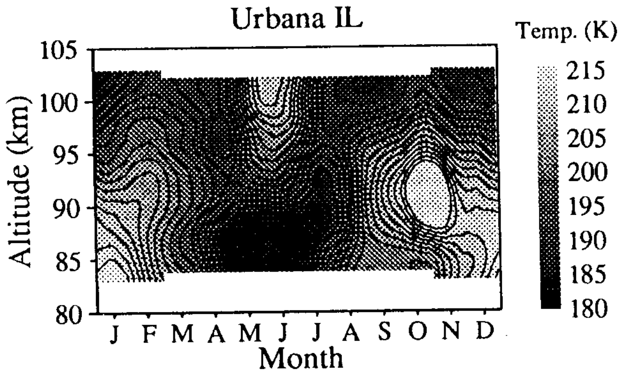

Figure 4. Contour plots of the seasonal variations on the mesopause region temperature structure at Urbana. The contour interval is 2K. Nightly mean data is smoothed from using a Hamming window of full widths 2 km and 45 days.

WIND MEASUREMENTS

Existing methods for measuring the upper mesospheric winds include incoherent scatter, MST radar. The measurement uncertainties associated with radar techniques are still subject to considerable debate.

The narrowband Doppler lidars offer several important advantages. These systems provide an direct measurement of winds and the can be pointed unambiguously at zenith, this eliminating a major source of error that characterizes MF radar measurement of vertical winds. Figure 6 is the vertical wave number power spectrum of vertical velocities measured at Haleakala during the ALOHA-93 campaign.

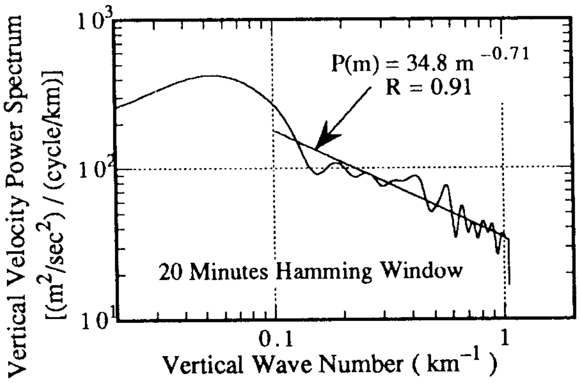

Figure 5. Power spectra of vertical winds for the same night as Figs. 1-3. The fit was done over a 1-10 km vertical scale.

CONCLUSIONS

Tunable laser technology has matured to the extent that measurement accuracies are now limited by signal levels, not tuning errors in the lasers. By coupling these modern Na Wind/Temperature lidars with large telescopes, resolutions of a few tens of meters of seconds are achievable.

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