DAYTIME LIDAR MEASUREMENTS OF TIDAL WINDS IN THE MESOSPHERIC SODIUM LAYER AT URBANA, ILLINOIS

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SUMMARY

For more than 15 years lidar systems have been used to study the chemistry and dynamics of the mesospheric sodium layer. Because the layer is an excellent tracer of atmospheric wave motions, sodium lidar has proven to be particularly useful for studying the influence of gravity waves and tides on mesospheric dynamics. These waves, which originate in the troposphere and stratosphere, propagate through the mesosphere and dissipate their energy near the mesopause making important contributions to the momentum and turbulence budget in this region of the atmosphere. Recently, the UIUC sodium lidar was modified for daytime operation so that wave phenomena and chemical effects could be monitored throughout the complete diurnal cycle. This paper describes the results of continuous 24 hour lidar observations of the sodium layer structure and presents measurements of the semidiurnal tidal winds.

The first daytime sodium lidar measurements were reported by Gibson and Sandford [1972] at Winkfield, UK (51°N, 1°W). Their measurements were obtained on a total of 7 days in 1971 and 1972 and revealed no pronounced change in sodium abundance between day and night. Granier and Megie [1982] reported daytime observations at Haute Provence, France (44°N,6°E) which also showed no consistent diurnal or semidiurnal variations in the layer. The most extensive set of daytime lidar measurements was reported by Clemesha et al. [1982] and Batista et al. [1985]. Their data were obtained at Sao Paulo, Brazil (23°S, 46°W) during 10 days in May 1981 and included one period of 100 hours of continuous measurements. Significant semidiurnal variations in the column abundance and centroid height were observed and attributed to the semidiurnal tide. The measured peak-to-peak abundance variation was approximately 30% and the peak-to-peak centroid displacement was approximately 2 km. Tidal perturbations of the nocturnal sodium layer are often observed at Urbana (40°N, 88°W) [Gardner et al., 1986] where vertical wind velocities due to the semidiurnal tide of up to 30 cms^{-1} with vertical wavelengths of the order of 50 km have been measured.

During the late summer and early fall 1985, the UIUC lidar system was modified for daytime operation. The modifications were required to reduce the high background photocount level from the bright daytime sky. The 1.22 m diameter Fresnel lens telescope was replaced by a diffraction limited 0.35 m diameter astronomical telescope (Celestron 14). The planar field of view of the telescope was reduced to 0.7 mrad and a pressure-tuned etalon filter was added to reduce the bandwidth to 33 pm FWHM. The laser divergence was also reduced to about 0.7 mrad (FW @ e^{-2}) by expanding the beam by a factor of 22.

The first daytime measurements were obtained at Urbana on October 5, 1985. Continuous 24 hour measurements were first made on January 15 and 16, 1986. Figure 1 is a summary of the profiles collected during these two days. The layer column abundance, centroid height and rms width are plotted versus time in Figure 2. Notice the strong semidiurnal oscillations in these parameters. The abundance varied by almost a factor of 3 reaching a maximum value of 2.5×10^{10} cm^{-2} at 1545 LST and a minimum value of 1×10^{10} cm^{-2} at 1050 LST and 2230 LST. The vertical wind velocity associated with these tidal perturbations can be inferred from the data by measuring the movement of the layer bottomside. The vertical wind velocity at 85 km altitude and the column abundance are plotted in Figure 3. A strong semidiurnal oscillation in the wind velocity is clearly evident. The 30 cms^{-1} wind amplitude is typical of the semidiurnal tide and is consistent with recent tidal models.

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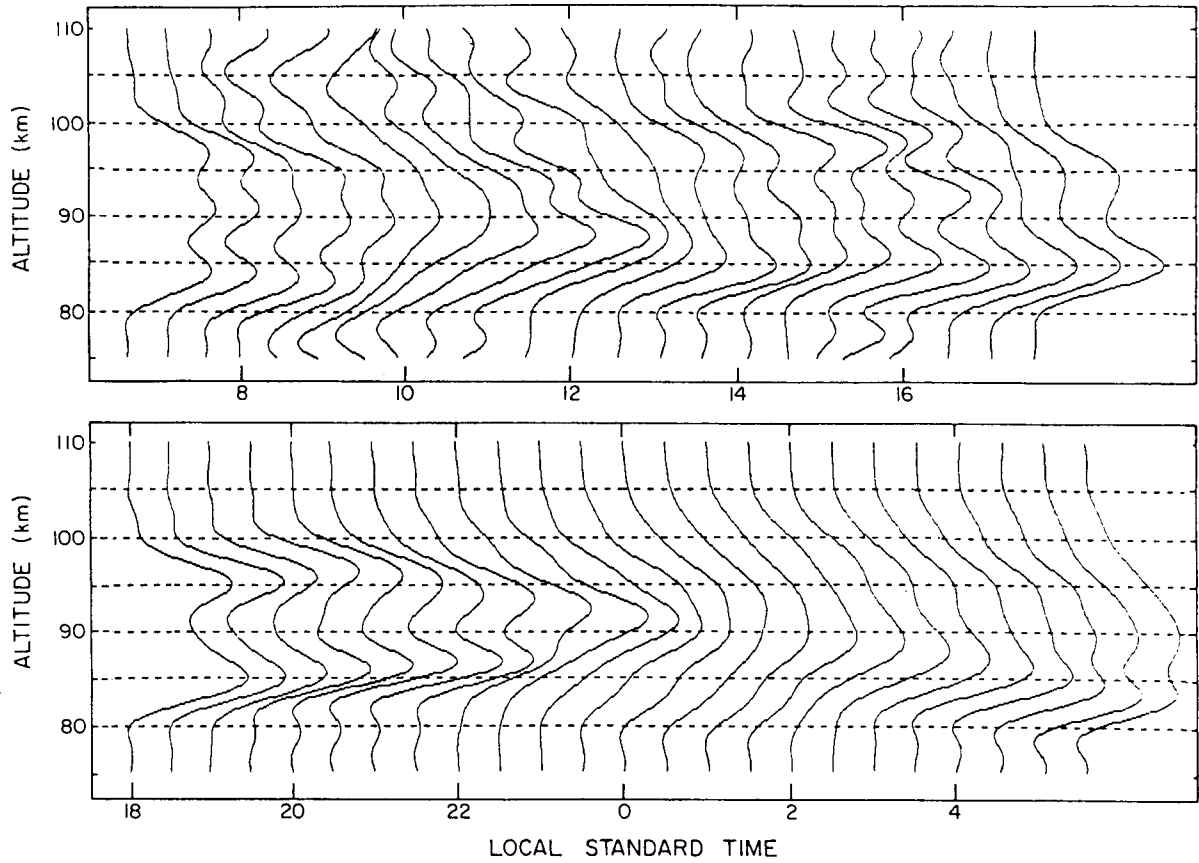
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Figure 1. Na density profiles measured during the 24 hour period starting at 0600 LST on January 15, 1985 and ending at 0600 LST on January 16, 1985. The profiles are plotted at 30 min intervals and have been low-pass spatially filtered with a cutoff frequency of 0.16 km^{-1}.

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RMS WIDTH (km) | CENTROID HEIGHT (km) | COLUMN ABUNDANCE (10^9cm^{-2})
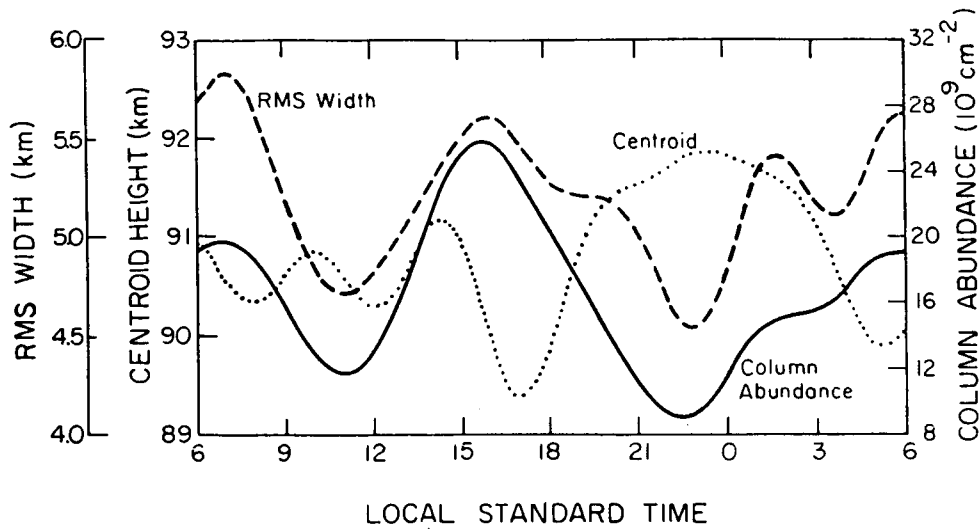
LOCAL STANDARD TIME

Figure 2. Temporal variations of the layer column abundance, centroid height and rms width measured during the 24 hr period starting at 0600 LST on January 15, 1986. The data were low-pass filtered with a spatial cutoff frequency of 0.05 km^{-1} and a temporal cutoff frequency of 0.25 hr^{-1}.

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COLUMN ABUNDANCE (10^9 cm^{-2}) | VERTICAL WIND VELOCITY (cm/sec)
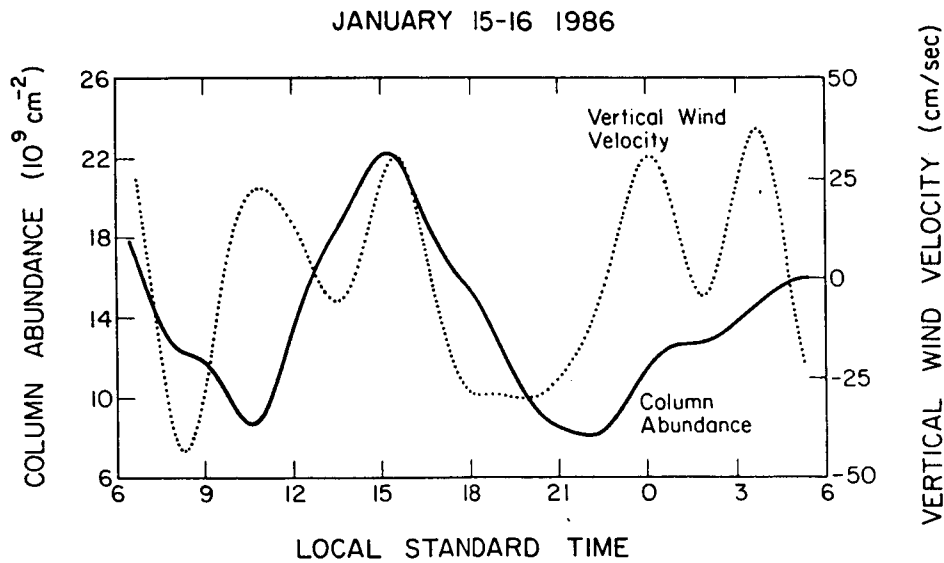
LOCAL STANDARD TIME

Figure 3. Comparison of the measured column abundance and vertical wind velocity (@ 85 km altitude). To eliminate shorter wavelength gravity wave perturbations the density profiles were initially low-pass spatially and temporally filtered with respective frequency cutoffs of 0.05 km^{-1} and 0.33 hr^{-1}. The wind velocity was then determined from the displacement of the bottomside of the filtered profiles.

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