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SIMULTANEOUS LIDAR AND AIRGLOW TEMPERATURE MEASUREMENTS IN THE MESOPAUSE REGION

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Abstract. A scientific flight over Fort Collins CO (40.6°N,105°W) was conducted on the night of April 15-16, 1990, during the ALOHA-90 campaign. In this Colorado mission, a direct comparison between measured mesospheric O_2 and OH rotational temperatures with the airglow instruments on board the Electra and simultaneously measured Na temperatures by a ground-based narrowband Na lidar has been made. This first comparison resulted in general agreement in measured temperatures between different instruments.

Introduction

The Colorado flight of ALOHA-90 on the night of April 15-16, 1990 was design to study wave activity near the Rocky Mountains with both ground-based and airborne instrumentations. One of the scientific objectives is to compare the values of mesospheric temperatures simultaneously measured by the University of Michigan airglow instruments on the Electra and by the ground-based Colorado State Na temperature lidar. Although both ground-based and airborne instruments had recorded about 5 hrs of data each, as shown in Figure 1, only a little over 2 hrs of data overlapped. This is because the cloud coverage over a fixed location and the flight path occur at different times. Three triangular paths were flown [Gardner, 1991] and the times of closest approach to Fort Collins, as marked by X on the time scale, were 3.44, 6.24, 8.58 and 11.24 hr. UT, April 16, 1990. Simultaneous lidar and interferometry determination of mesospheric temperatures for two such times, 6.24 hr. and 8.58 hr. UT, were available.

On this night, the Colorado State Na temperature lidar [She et al.,1990] was setup to measure temperature profiles at 1 min interval with a range-bin length of 75 m. In order to reduce photon-noise and density variations, the photon-count profiles were spatially and temporally filtered to yield mesopause temperature profiles with 1 km vertical resolution in an integration period of 2.5 min. Consecutive profiles are then averaged and reduced to one temperature profile from 83 km to 103 km every 5 min with 1 km vertical resolution. The absolute temperature accuracies are estimated to be ± 3 K and ± 5K respectively at the peak and at ± 5 km from the peak of the Na layer. The detailed experimental and data analysis procedures have been given in a separate publication [She et al., 1991(a)].

The University of Michigan had two airglow instruments on board the Electra: an Ebert-Fastie spectrometer and a Michelson interferometer. On this night, the Ebert-Fastie spectrometer measures the intensities and rotational temperatures of the O_2 Atmospheric (0-1) and OH Meinel (7-3) bands. The Michelson interferometer measures the intensities and rotational temperatures of the OH Meinel (3-1) band.

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Experimental Results

Figure 1 shows the measured O_2 and OH airglow intensities along with Na abundance. Due to the difference in vibrational transitions used, the emission intensities of the two OH bands are different [Yee et al., 1991]. Rotational temperatures of the O_2 atmospheric (0-1) band, OH Meinel (7-3) band and OH Meinel (3-1) band taken by the University of Michigan airborne airglow instruments are compared in Figure 2. Except the narrow peak near 8.7 hr. UT measured by the Ebert-Fastie spectrometer, mesopause temperatures from 5 hr. to 10 hr. UT varied around 200 K with minor features masked by the error bars. Depending on

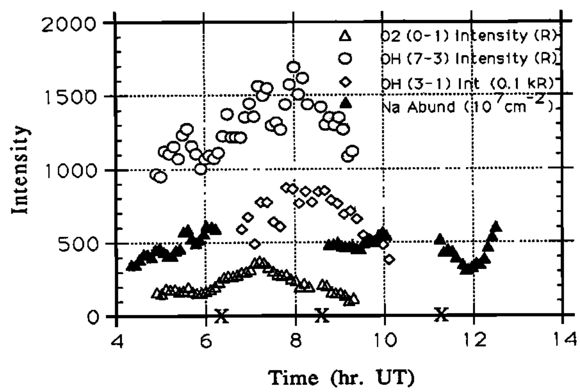

Fig. 1 Temporal distribution of intensities of O_2 and OH nightglow and Na aboundance for April 16, 1990, showing over 2 hrs of data overlap between lidar and airglow measurements. Times of closest approach to Fort Collins, 6.24, 8.58, and 11.24 hr. UT are marked by X on the time axis.

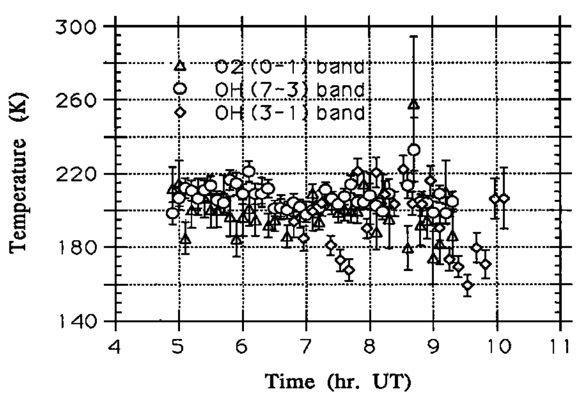

Fig. 2 Temporal mesospheric temperatures measured by airglow instruments via O_2 (0-1), OH (7-3) and OH (3-1) bands during the nightglow of April 16, 1990 near Fort Collins, CO.

the detected intensity, the temperature uncertainty for a 5 to 10 min. integration time is typically ± 10 K. In general, both the accuracy and agreement of the three rotational temperatures improved in the region of high airglow intensities near 7-8 hr. UT. Again, the rotational temperatures measured by the two OH bands differ somewhat, with higher temperatures being recorded for the (7-3) band [Niciejewski and Yee, 1991].

Figure 3 shows the temperatures measured by Colorado State Na temperature lidar. The averaged centroid height of the Na layer that night was 92.5 km. The temperatures at three altitudes of 97.5 km, 92.5 km and 87.5 km are the result of a moving average using a Gaussian weighting function of 10-km full-width at 92.5 km and of 5-km full-width at 97.5 km and 87.5 km, resulting in temperature uncertainties of ± 3 K and ± 5 K respectively. The three points near 8.8 hr. UT are exceptions where the errors are roughly doubled because of poorer signal due to partial cloud coverage. It is evident that the averaged temperatures of the two higher altitudes are relatively constant changing from 200 K between 4.0 to 6.0 hr. UT (9:00 to 11:00 p.m., MST) to slightly lower than 190 K after 9.0 hr. UT. The temperatures below the Na centroid was much colder (as low as 170 K) between 9:00 to 11:00 p.m., MST and then warmed up to the temperatures of the rest of the Na layer with somewhat bigger fluctuations. Although the temperature uncertainty near 8.8 hr. UT is larger, the anomalously high readings for all three altitudes at this time appear to be real.

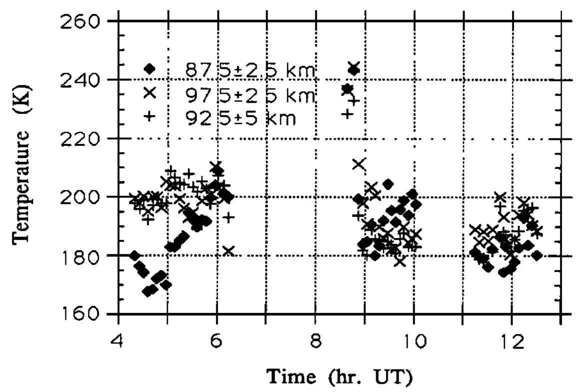

Fig. 3 Temporal mesospheric temperatures at altitudes of 87.5 km, 92.5 km and 97.5 km measured by narrowband Na lidar on April 16, 1990 at Fort Collins, CO.

Comparisons and Discussion

It is unfortunate that due to local cloud coverage, lidar data were not available form 6.3 hr. to 8.5 hr. UT when the airglow intensities were high. However, there are more than two hours of data overlap between the ground-based lidar and the airborne airglow instruments which form the basis of an viable first comparison.

It is well known that, on the average, the O_2 airglow originates from near 95 km altitude [McDade et al., 1986] and OH from near 87 km altitude [Baker and Stair, 1988], each with a layer thickness of about 10 km. We compare the airglow O_2 measurements with lidar temperatures at these altitudes averaged over a Gaussian weighting function with a 10-km full-width at 95 km and a 5-km full-width at 87.5 km. The reason for chosen a narrower width at 87.5 km is due to larger lidar temperature errors at altitudes below 83 km. Figure 4 compares these measurements between 5.0 and 10.0 hrs., UT, April 16, 1990. Within the experimental errors, the O_2 airglow temperatures seem to track the lidar

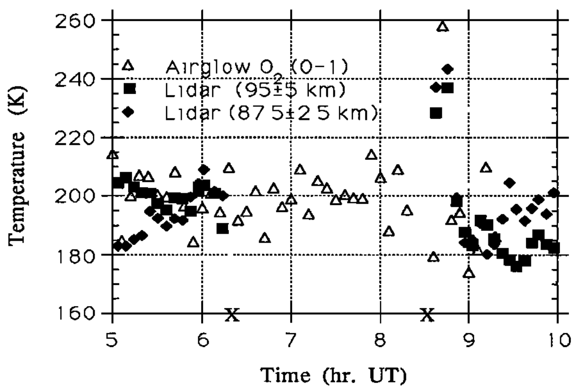

Fig. 4 Rotational temperatures of the O_2 (0-1) band compared with Na lidar temperatures at 95 km and 87.5 km. Times of closest approach to Fort Collins, 6.24 and 8.58 hr. UT are marked by X on the time axis.

temperatures at 95 km. We note that this general agreement includes the sharp temperature rise near 8.7 hr. UT, and that one of the Electra's closest approach to Fort Collins, as marked by a X on the time axis, took place at 8.58 hr.UT. As shown in Figure 2, airglow OH (7-3) temperatures are comparable to the O_2 temperatures within the error bars. Compared to the airglow data, the available lidar temperatures at 87.5 km are clearly colder before 5.5 hr. UT and somewhat warmer after 9.5 hr. UT, suggesting that the OH layer this night might have been higher than usual. A comparison between OH data from both airglow instruments and Na temperatures at 95 km and 87.5 km altitudes averaged over a Gaussion weighting function with 5-km full-width is shown in Figure 5. Compared to the available OH (3-1) band data, the OH (7-3) band temperatures are in general higher [Niciejewski and Yee, 1991]. The OH (3-1) band temperatures between 9-10 hr. UT are closer to the lidar values at 95 km than those at 87.5 km, again suggesting a higher OH layer.

In summary, the first comparison of simultaneous mesopause temperature measurements between Na temperature lidar and airglow instruments have been made near Fort Collins, CO (40.6ºN,105ºW) as a part of ALOHA-90 campaign. Despite the differences in angular views between ground-based lidar (1 mrad.) and airborne airglow instruments (30 mrad.), the measured temperatures agreed within the error bars of the instruments. A narrow high temperature feature near a time of closest approach to Fort

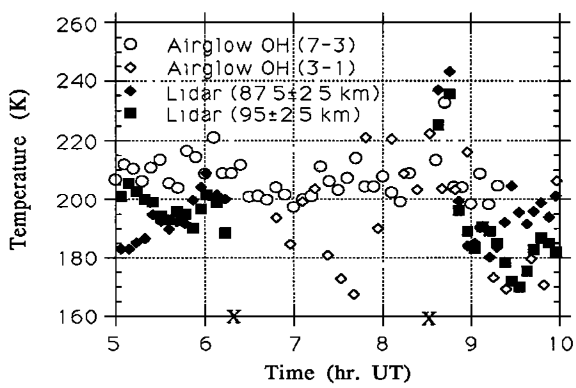

Fig. 5 Rotational temperatures of the OH (7-3) and OH (3-1) bands compared with Na lidar temperatures at 95 km and 87.5 km. Times of closest approach to Fort Collins, 6.24 and 8.58 hr. UT are marked by X on the time axis.

Collins (8.58 hr. UT) were detected by both the lidar and the Ebert-Fastie spectrometer at 8.7 hr. UT, April 16, 1990. Lidar measurements show temperature differences between Na layers centered at 95 km and 87.5 km. This difference coupled with the lack of gross differences between O_2 and OH temperatures suggests that the OH layer might have been much higher that night than its known average. This is consistent with rocket data which showed a mean half-width of 12 km [Baker and Stair, 1988]. Indeed, compared to the available lidar temperatures on March 3, 1990, the measured lidar temperatures at 87.5 km, on the average, were much colder on April 16, 1990 [She et al., 1991(b)]. Continued simultaneous and co-located mesopause temperature measurements between lidar and airglow instruments with lower measurement uncertainty will not only permit studies of temperature variations within 5-K range but also permit investigations of the layer heights of mesopause radicals, such as O_2 and OH, and their variabilities. In fact, such a campaign using Western Ontario's Michelson interferometer which has a temperature error of ± 1 K [Turnbull and Lowe, 1991] and Colorado State's Na temperature lidar already took place in March 1991.

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