25PF1 MEASUREMENTS OF UPPER TROPOSPHERIC MOISTURE WITH A RAMAN LIDAR

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1. INTRODUCTION

We describe water vapor profile measurements made with the Sandia Raman lidar during the April 1994 Intensive Observational Period at the U. S. Southern Great Plains Cloud and Radiation Testbed site. The goal of this study is to determine the effect of convection on the upper tropospheric moisture budget. At present, considerable controversy exists over the nature of the vertical redistribution of water vapor in a changing climate, and particularly the distribution of water vapor in the upper troposphere. Although upper tropospheric moisture concentrations are several orders of magnitude lower than those near the surface, upper tropospheric moisture exerts an important influence on climate. On a per-molecule basis, greenhouse absorption due to water vapor is about one hundred times more effective at high altitudes than at low altitudes. Several one-dimensional radiative convective models have been used to demonstrate the importance of upper tropospheric moisture on climate. What these models show is that for a given *fractional* increase in water vapor at a given altitude the response or change in surface temperature is qualitatively the same. Figure 1 (Arking 1993) shows the change in surface temperature for a 50% increase of the specific humidity in a 40 mbar layer in clear skies. Understanding upper tropospheric moistening processes are therefore of prime importance in addressing the water vapor feedback question. The goal of this study is to determine the upper tropospheric moisture budget associated with convective events, and in particular to extend process models to higher altitudes than have been achieved previously.

We are planning to use the Sandia Raman lidar system at the SGP (Southern Great Plains) CART (Cloud and Radiation Testbed) site in north central Oklahoma in April 1994 to investigate the effect of convection on the upper tropospheric moisture budget. The CART site is ideally suited to conduct such an investigation for several reasons. First, the frequency of convective events is very high in this region in the springtime. Meteorological data for nearby Ponca City, Oklahoma show that the frequency of thunderstorms is highest in the April-July period and averages about 9-10 storms per month. Furthermore, the diurnal cycle of thunderstorm activity in the SGP region peaks near midnight, when Raman lidar measurements are most accurate and extend to highest altitude. Finally, instruments are situated throughout the CART site which provide the data required for moisture and energy budget calculations on a GCM (General Circulation Model) scale.

2. SANDIA RAMAN LIDAR

Because minute amounts of upper tropospheric water vapor can have a potentially large effect on climate, it is important that accurate measurements be performed. Raman lidar is a powerful, proven technique for making nighttime water vapor measurements in clear skies (or up to the lowest cloud level). At Sandia, we have developed a Raman lidar which is capable of making accurate nighttime and *daytime* water vapor measurements. We are presently making several modifications to our system that will significantly enhance its performance. First, we will approximately double the laser energy by adding a second XeCl amplifier to the system. Second, we will enhance the throughput of the high-sensitivity water vapor channel in the detection system by replacing the narrowband interference filter in the channel with a higher-transmission filter; the accompanying increase in filter bandwidth will not degrade the nighttime performance of the system (the daytime performance can be recovered simply by swapping the existing filter back into the system). Third, we have installed a low-noise photomultiplier tube in the high-sensitivity water vapor channel, leading to a significant enhancement in low-signal (i.e. long range), long time averaged measurements.

We have recently made some preliminary lidar measurements with the wideband interference filter and low noise photomultiplier tube. Figure 2 shows these results for the 5-12 km region. The apparent discrepancy above 7 km is believed to be due to a systematic dry bias in the radiosonde at high altitudes. The data clearly shows that it is possible to obtain water vapor profiles up to 8.5 km with one minute averaging and 75 m range resolution. For increased range and accuracy, the averaging time would be increased to approximately 10 minutes and the vertical resolution reduced to 150 m. The ultimate range is limited by residual background, dark counts, signal induced noise, averaging time and spatial resolution. During the April 94 IOP (Intensive Observational Period) we will explore these effects and their potential impact on upper tropospheric water vapor measurements. Results of this study will be presented.

3. REFERENCES

Arking A. (1993): "Water vapor feedback and lapse rate feedback: Insight from a one-dimensional climate model." J. Climate (submitted).

Table 1.

Transmitter		Receiver	
Laser	XeCl Excimer Osc, 2 Amp	Telescope	Cassegrain (Dall-Kirkham)
Wavelength	308 nm (XeCl)	Diameter	0.76 m
Energy/pulse	200 mJ	f number	4.5
Repetition rate	200 Hz	Channel bandpass	2.0 nm, 60% transmission
Bandwidth	3 pm	Field of view	Dual (0.4 mr, 4 mr)
Divergence	~0.1 mr	Range resolution	150 m (1.0 μsec)
		Species	Rayleigh/aerosol (308 nm) Water vapor (347 nm) Nitrogen (332 nm)

This work was supported by the U. S. Department of Energy, Atmospheric Radiation Measurement (ARM) Program.

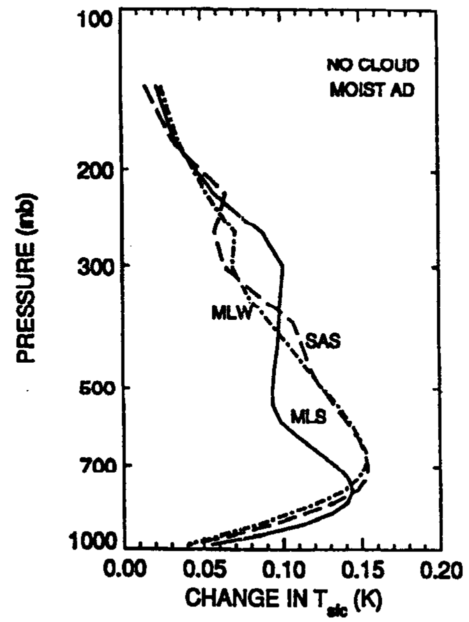

Figure 1. Change in the surface temperature for a 50% increase of the specific humidity in a 40 mbar layer under clear skies (Arking 1993). Regardless of latitude or season, [mid-latitude summer (MLS), mid-latitude winter (MLW), sub-arctic summer (SAS)] the effect of a fractional increase in water vapor on surface temperature is within a factor of 3 up to 150 mbar.

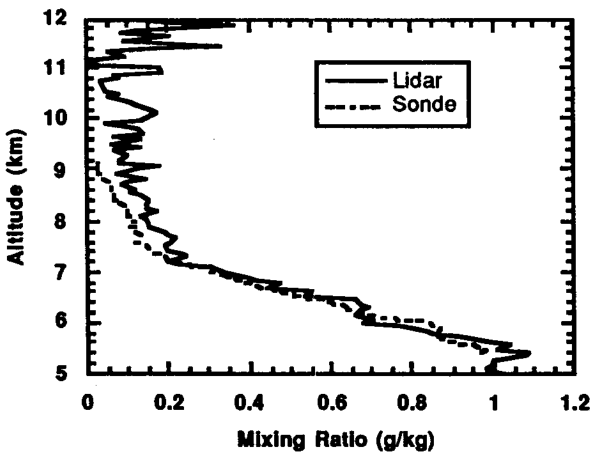

Figure 2. Comparison of the high altitude lidar performance and Vaisala radiosonde. The discrepancy above 7 km is believed to be due to a dry bias of the radiosonde at high altitudes. The lidar data is a one-minute average with 75 m vertical range resolution and a laser energy of 65 mJ. We anticipate that with further spatial (150 m) and temporal averaging (10 min) and increased laser energy (150-200 mJ) the maximum nighttime range could be extended to 10-12 km.