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MOVEMENT OF WATER VAPOR IN THE ATMOSPHERE MEASURED BY AN IMAGING SPECTROMETER AT ROGERS DRY LAKE, CA

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1. INTRODUCTION

Movement of water as vapor in the atmosphere is a fundamental process in the Earth's hydrological cycle. Investigations of spatial and time scales of water vapor transport in the atmosphere are important areas of research.

Water vapor transmits energy as a function of its abundance across the spectrum. This is shown in the 400- to 2500-nm spectral region where the transmission of the terrestrial atmosphere has been modeled using the MODTRAN radiative transfer code (Berk et al., 1989) for a range of water vapor abundances (Figure 1). Based on these model results, spectra measured by the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) have been used to investigate the movement of water vapor at 20-m spatial resolution over an 11-by-30-km area at approximately 15-minute time intervals (1.25 hours total). AVIRIS measures the upwelling spectral radiance from 400 to 2500 nm at 10-nm spectral intervals and collects images of 11-by-up-to-1000 km at 20-m spatial resolution. Data are collected at a rate of 1 km of flight line per 4.5 seconds. A set of five AVIRIS flight lines was acquired in rapid succession over Rogers Dry Lake, CA on May 18, 1993 at 18:59, 19:13, 19:29, 19:47, and 19:59 UTC (Figure 2). Rogers Dry Lake is located 2 hours north of Los Angeles, California at 34.84 degrees north latitude and 117.83 degrees west longitude in the Mojave Desert.

2. MEASUREMENT OF ATMOSPHERIC WATER VAPOR

AVIRIS measures the upwelling spectral radiance that has been reflected by the surface and transmitted and scattered by the atmosphere. The change in radiance as a function of the abundance of water vapor in the atmosphere has been modeled with MODTRAN for a terrestrial atmosphere ranging from 0 to 36.5 precipitable mm of water vapor (Figure 3). This plot shows that the water absorption bands at 940 nm and 1140 nm are strongly sensitive to water vapor over the range of abundances encountered in the terrestrial atmosphere. Absorption bands at shorter wavelengths are less sensitive and those at longer wavelengths saturate for this range of water vapor. A model (Green et al., 1991 and 1993) of the upwelling radiance at AVIRIS in the 940-nm region as a function of water vapor has been developed incorporating MODTRAN. This model was inverted using a nonlinear least squares spectral fitting approach to determine the water vapor abundance for the spectrum of each AVIRIS spatial element. A sample spectral fit from the first spatial element in the first flight line is used to derive a water vapor column abundance of 14.39 precipitable mm (Figure 4). The average residual radiance error across the spectral fit is 1.1 percent.

This algorithm has been applied to the five AVIRIS flight lines over Rogers Dry Lake (Figure 5). The spatial coverage of these images is the same as presented in the radiance images. In each image the water vapor varies from approximately 12 mm to 16 mm precipitable water vapor, which represents a 25-percent variation in water vapor throughout the image. Spatial patchiness and lateral variation of water vapor are shown at scales from less than 200 m to greater than 5000 m. Through these five images, the spatial distribution of water vapor changes significantly between each 15-minute observation. However, several dominant features are observed to persist and drift from image to image. Overall, there is a trend towards decreasing water vapor through the observation time interval. For this test case at Rogers Dry Lake, CA, these images demonstrate the high spatial and temporal variability of water vapor in the terrestrial atmosphere.

3. CONCLUSION

Water vapor in the atmosphere has been derived from the AVIRIS spectra measured in five overpasses above Rogers Dry Lake, CA. The abundance of water vapor in these data is shown to be spatially heterogeneous at the 25-percent level over a range of spatial scales. Temporal variation is also shown through the changing water vapor distribution in the five data sets acquired at 15-minute intervals. Imaging spectrometer data provide a unique means of rapidly measuring quantitatively the spatial distribution and movement of water vapor in the terrestrial atmosphere at high spatial resolution and over large areas.

4. FUTURE WORK

A future water vapor mass balance calculation will be performed to characterize the rate of change in water vapor in the atmosphere in this data set. Mapping features in the water vapor between overpasses will be used to investigate water vapor diffusion rates from the data themselves.

5. ACKNOWLEDGMENTS

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6. REFERENCES

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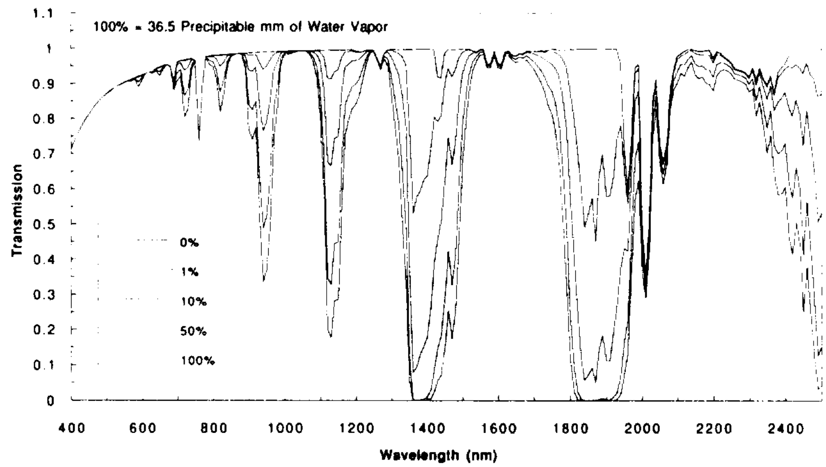

Figure 1. Decrease in transmittance of the atmosphere as a function of increase in the abundance of water vapor.

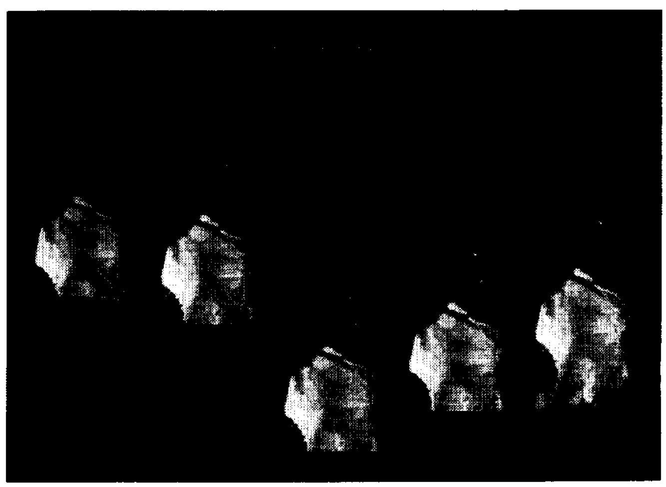

Figure 2. Radiance images of AVIRIS flight lines over Rogers Dry Lake, CA, acquired on May 18, 1993 (see AVIRIS Workshop Slide 2).

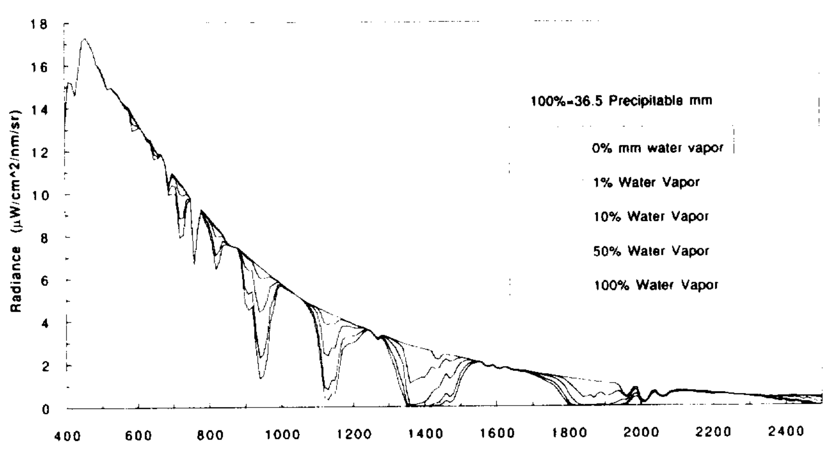

Figure 3. MODTRAN-modeled decrease in radiance with increase of water vapor over the range of abundances encountered in the terrestrial atmosphere.

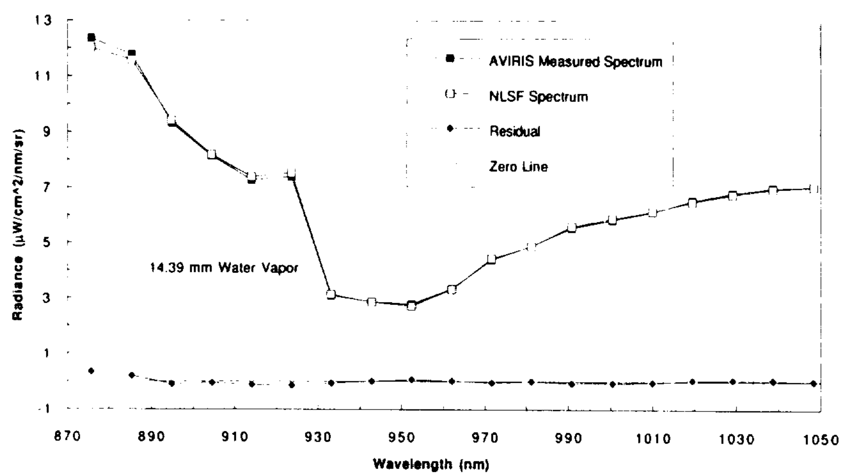

Figure 4. AVIRIS-measured spectrum and a model spectrum for determination of water vapor abundance.

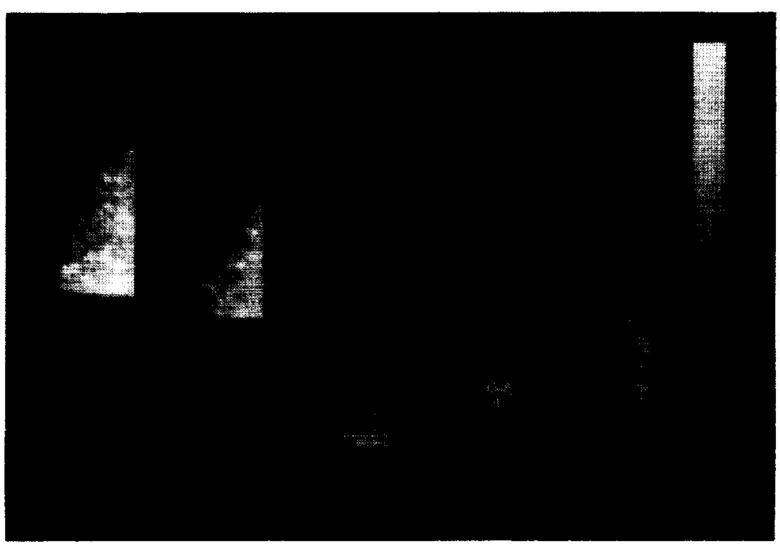

Figure 5. AVIRIS-derived water vapor for the five flight lines acquired over Rogers Dry Lake, CA (see AVIRIS Workshop Slide 2).