REMOTE SENSING OF SMOKE, CLOUDS, AND FIRE USING AVIRIS DATA

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1. INTRODUCTION

Clouds remain the greatest element of uncertainty in predicting global climate change (Houghton et al., 1990). During deforestation and biomass burning processes, a variety of atmospheric gases, including CO^2 and SO^2, and smoke particles are released into the atmosphere. The smoke particles can have important effects on the formation of clouds because of the increased concentration of cloud condensation nuclei. They can also affect cloud albedo through changes in cloud microphysical properties (King et al., 1993). Recently, great interest has arisen in understanding the interaction between smoke particles and clouds (Kaufman et al., 1992).

In this paper, we describe our studies of smoke, clouds, and fire using the high spatial and spectral resolution data acquired with the NASA/JPL Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) (Vane, 1987; Vane et al., 1993).

2. THE AVIRIS DATA

AVIRIS collects spectral imaging data in the 0.4–2.5-µm wavelength range in 224 10-nm channels with a spatial resolution of 20 m from an ER-2 aircraft at 20-km altitude. An interesting data set was acquired on August 20, 1992, over an area near Stockton in northern California. The scene contains areas covered by active fire, burn scars, smoke, clouds, vegetation, and a small water pond. The data set offers an excellent opportunity to study the radiative properties of smoke, clouds, and fire. Our preliminary results are described in this paper.

3. RESULTS

3.1 Smoke

We have found that smoke is readily observable in images between 0.4 and 0.75 µm. The effects of smoke decrease with increasing wavelength. It is difficult to observe smoke from images beyond 1 µm. Figure 1(a) shows a 0.47-µm AVIRIS image. Smoke in the lower part of the image is clearly seen. The areas with active fires are located near the center (slightly upper) portion of the image. Most parts of the white areas in the image are clouds. Figure 1(b) shows a 2.13-µm image. Smoke disappears completely in this image.

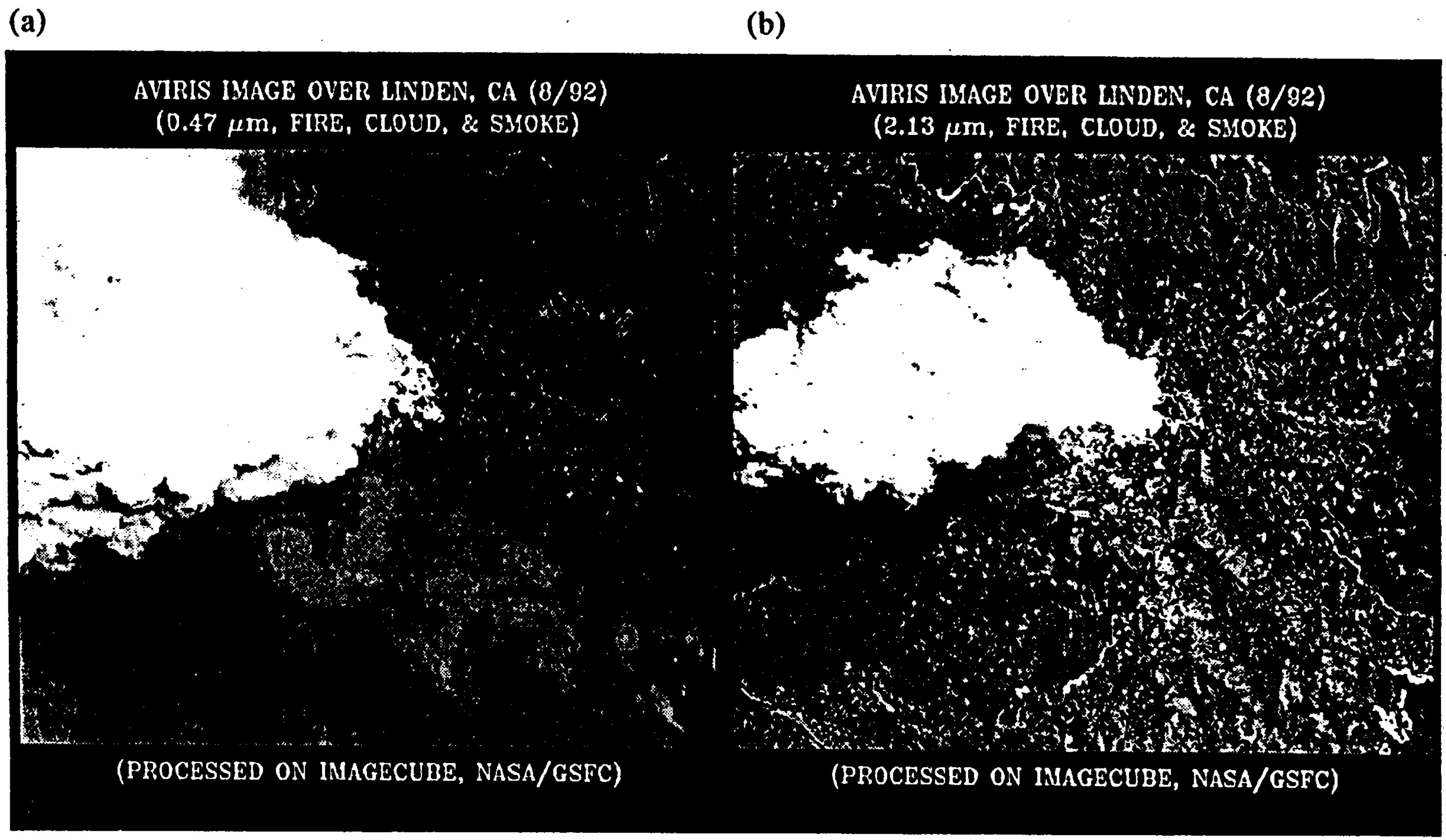

Fig. 1. A 0.47-μm AVIRIS image (a) and a 2.13-μm AVIRIS image (b). Smoke is clearly seen in the lower part of (a), but disappears completely in (b).

Using radiative transfer modeling techniques, we have retrieved optical depths and the mean particle radius of smoke particles. The derived optical depths vary with spatial locations. The derived mean particle radius is approximately 0.5 μm. As wavelength increases, the ratio of wavelength to the mean particle radius increases, and the scattering of solar radiation by smoke particles decreases. This is the reason that smoke is difficult to detect in images beyond 1 μm.

3.2 Clouds

The active fire produced hot air and smoke. As a result, strong convection was induced. As the lower air that contained a lot of water vapor was lifted to upper levels, the air was cooled down and clouds were formed. We have examined in detail the cloud spectra from the AVIRIS data. The shapes of the spectra around 1.6 and 2.2 μm show that the clouds are water clouds, not ice clouds. The reflectances of the clouds in the 0.8–1.6 μm region are greater than theoretical predictions, contrary to the belief of anomalous water cloud absorption in the near-IR spectral region (Stephens and Tsay, 1990).

We have also found that the depths of the oxygen band near 0.76 μm in cloud spectra are sensitive to cloud height variations. It may be possible to derive "effective" cloud heights using the oxygen band. The "true" cloud heights are difficult to obtain because of the complicated absorption and scattering processes inside the clouds (Wu, 1985).

3.3 Fires and Hot Surfaces

The temperatures of active fire-burning areas are several hundred degrees higher than non-burning areas. The emitted radiation from the fire-burning area is easily observable in images between 2.0 and 2.5 μm. The emission effect is also detectable in images around 1.6 μm. Below 1.2 μm, the emission effect is difficult to detect. The hot smoldering surface areas can be identified in images between 2.0 and 2.5 μm if appropriate stretches are applied to the images. Figure 2 shows such an example. The bright areas in this figure are hot surfaces.

4. Summary

Using AVIRIS data, we have discovered important radiative properties of smoke, clouds, and fire, as described in Section 3.

5. References

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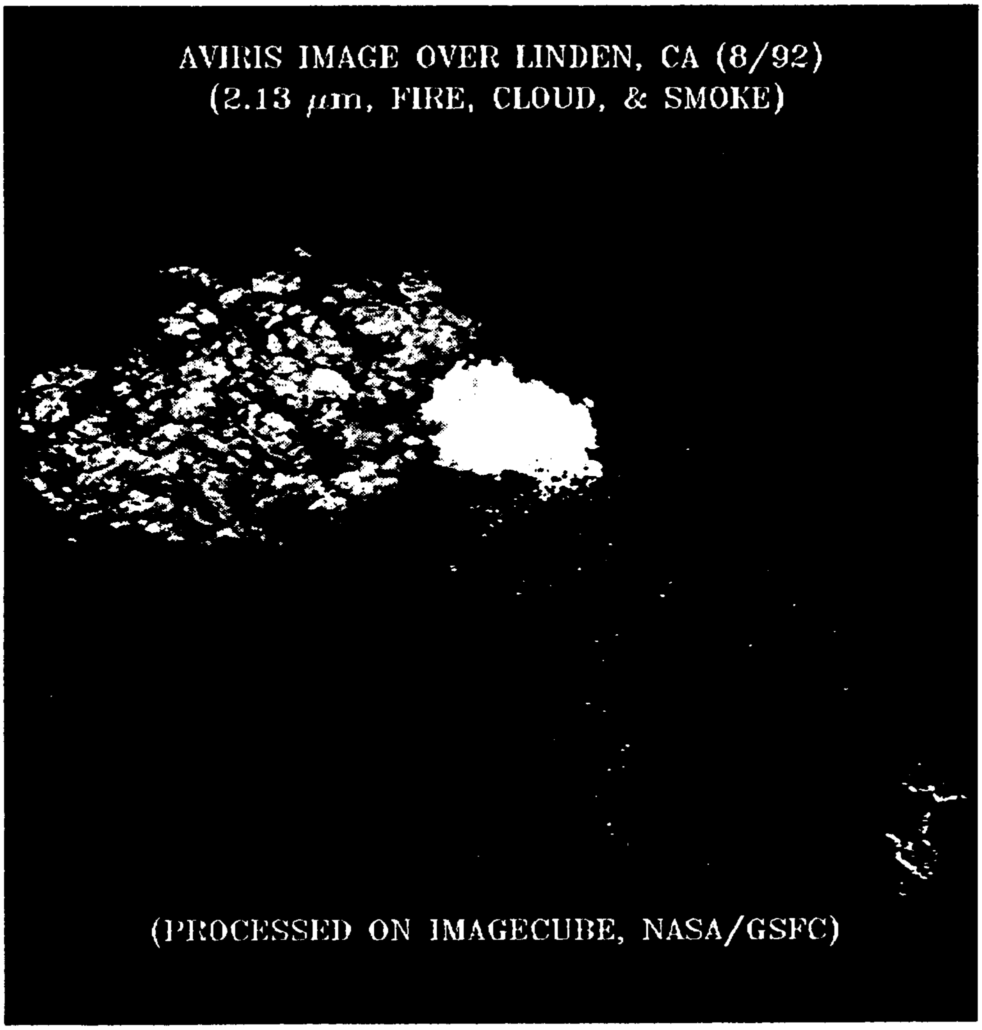

Fig. 2. A 2.13-μm AVIRIS image stretched to show hot surfaces (bright areas).