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SEPARATION OF CIRRUS CLOUD FROM CLEAR SURFACE FROM AVIRIS DATA USING THE 1.38-μm WATER VAPOR BAND

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1. INTRODUCTION

Cirrus clouds play an important role in climate systems because of their large area coverage, persistence and radiative effects (Starr 1987). Thin cirrus clouds are difficult to detect in visible images and infrared images in the 10-12 μm atmospheric window region, particularly over land, because these clouds are partially transparent. Ackerman et al. (1990) have recently developed a method for detecting cirrus clouds using three narrow channels centered near 8, 11, and 12 μm, respectively, based on the analysis of IR emission spectra measured with a high spectral resolution interferometer. Barton (1983) has also described a method for estimating cirrus cloud height and amount from measurements with two narrow channel radiometers of the Selective Chopper Radiometer on Nimbus 5. Both channels are located within the strong 2.7 μm water vapor band absorption region. One of the channels includes additional carbon dioxide absorption. A differential absorption technique with sets of empirical coefficients has been used in the estimation of cirrus cloud heights and amounts.

In this paper a technique using narrow channels in the strong 1.38 μm water vapor band absorption region for detecting cirrus clouds from spectral imaging data acquired by the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) (Vane 1987) on December 5, 1991 during the FIRE (The First International Satellite Cloud Climatology Project (ISCCP) Regional Experiment) Phase II Field Experiment (Starr 1987) is described.

2. METHOD

The method for the detection of cirrus clouds using channels near the center of the strong 1.38 μm water vapor band is straight forward. Cirrus clouds are typically located at altitudes greater than 6 km. Most of the atmospheric water vapor is located below 6 km. AVIRIS channels near 1.38 μm receive little radiance resulting from scattering of solar radiation by the surface, because the solar radiation is mostly absorbed by water vapor in the lower atmosphere. When cirrus clouds are present, however, the AVIRIS channels near 1.38 μm receive a large amount of radiance resulting from scattering of solar radiation by the cirrus clouds. The radiance contrast in AVIRIS images near 1.38 μm allows the detection of cirrus clouds.

3. RESULTS

The method described above has been applied to AVIRIS data measured over Coffeyville in the southeastern part of Kansas and over the Gulf of Mexico on December 5, 1991 during the FIRE Phase II Field Experiment. Figure 1 shows a 0.56 μm AVIRIS image over Coffeyville. The surface area covered by the image is approximately 12x17 km. Various types of surface features are seen. For example, the town of Coffeyville in the upper left, triangular runways of the Coffeyville Airport in the middle left, and roads and rivers in several parts of the image are all seen. At the time of the AVIRIS overflight, thin cirrus clouds were seen from the ground. Figure 2 shows a 1.37 μm

Fig. 1: A 0.56 µm AVIRIS image over Coffeyville, Kansas. Surface features are seen in this figure.

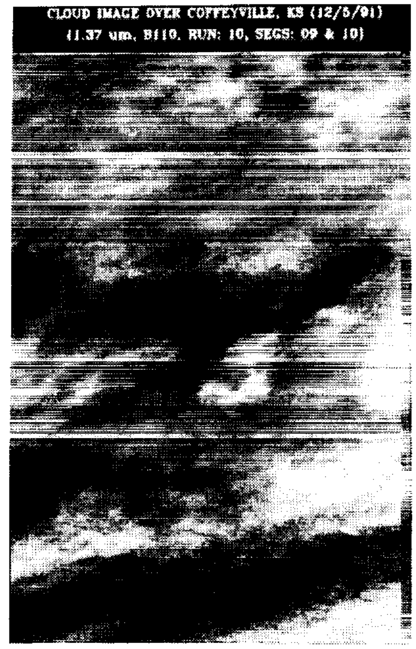

Fig. 2: A 1.37 µm AVIRIS image over the same area as that of Figure 1. Only cirrus clouds are seen in this figure.

Fig. 3: A 0.56 µm AVIRIS image over the Gulf of Mexico. Both the upper level extensive cirrus clouds and the lower level smaller cumulus clouds are seen.

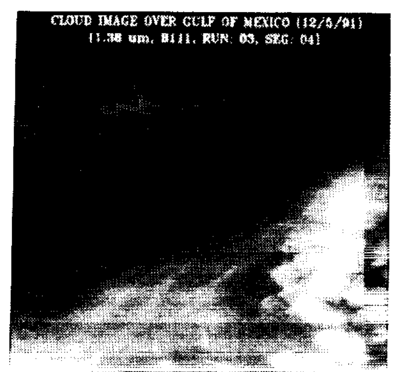

Fig. 4: A 1.38 µm AVIRIS image over the Gulf of Mexico. Only the upper level extensive cirrus clouds are seen.

AVIRIS image over the same area as that of Figure 1. Cirrus clouds are seen clearly in this figure. The surface features visible in Figure 1 disappear completely in this figure. This demonstrates that the 1.37 µm channel is useful for detecting thin cirrus clouds.

Figure 3 shows a 0.56 µm AVIRIS image over the Gulf of Mexico. Extensive cirrus clouds in the upper level and smaller cumulus clouds in the lower level are seen. Figure 4 shows a 1.38 µm AVIRIS image over the same area. The smaller cumulus clouds disappear completely in this figure. Only cirrus clouds are seen. This demonstrates again the usefulness of channels located near the center of the strong 1.38 µm water vapor band for detecting cirrus clouds.

4. DISCUSSION

Figures 1 and 3 show that the visible channels are contaminated by reflection from land surfaces and from lower level clouds when viewing thin cirrus clouds. This implies that it is difficult to derive accurate optical parameters of thin cirrus clouds from measurements with visible channels.

The availability of AVIRIS data allowed us to find the usefulness of detecting cirrus clouds using narrow spectral channels near the center of the strong 1.38 μm water vapor band, as demonstrated in Figures 2 and 4. These channels are also expected to have small sensitivity to mid-level clouds with top altitudes between approximately 4 and 6 km.

The 1.38 μm channel has some advantages over the 2.7 μm channels described by Barton (1983). The solar energy at 1.38 μm is 10 times as great as that at 2.7 μm. The ice particle absorption near 1.38 μm is significantly smaller than that near 2.7 μm. Also, the 1.38 μm region is not affected by emission from the Earth, while the 2.7 μm region is slightly contaminated by Earth's emission. The 8, 11, and 12 μm narrow IR channels described by Ackerman et al. (1990) have been proposed for a future polar-orbiting satellite for monitoring clouds. This IR emission technique has an advantage that it works both day and night. A disadvantage is that it requires a large field of view because of the weakness of the atmospheric and surface emission.

5. CONCLUSION

Narrow spectral channels near the center of the 1.38 μm strong water vapor band are useful for monitoring cirrus clouds. It is expected that our ability to determine cirrus cloud amounts using space-based remote sensing will be improved if channels near the center of the 1.38 μm water vapor band are added to future satellites.

6. ACKNOWLEDGMENTS

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7. REFERENCES

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