QUANTITATIVE IMPROVEMENT TO THE ESTIMATION OF NDVI VALUES FROM AVIRIS DATA BY CORRECTING THIN CIRRUS SCATTERING EFFECTS

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1. INTRODUCTION

The normalized difference vegetation index (NDVI) has been used for remote sensing of vegetation for many years. This index uses radiances or reflectances from a red channel around 0.66 μm and a near-IR channel around 0.86 μm. When cirrus clouds are present, both channels are affected by cirrus scattering effects. We have recently developed an empirical technique for removing thin cirrus scattering effects from remotely sensed data. In this paper, we demonstrate that the estimates of NDVI values can be improved quantitatively after the removal of thin cirrus effects. A pair of spectral imaging data with and nearly without thin cirrus contamination and acquired with the Airborne Visible Infrared Imaging Spectrometer (AVIRIS) is used in this study.

2. BACKGROUND

The Normalized Difference Vegetation Index (NDVI) (Deering, 1978) is the most widely used index for remote sensing of vegetation in the past two decades. It has been used in many applications, including estimates of green biomass and end-of-season above-ground dry biomass (Tucker et al., 1986). In this article, we use the definition

$$NDVI = (\rho^*_{NIR} - \rho^*_{RED}) / (\rho^*_{NIR} + \rho^*_{RED}), \quad (1)$$

where ρ^*_{RED} is the top-of-the-atmosphere apparent reflectance of a red channel near 0.66 μm, and ρ^*_{NIR} the apparent reflectance of a near-IR channel around 0.86 μm. The apparent reflectance ρ^* of a given channel is defined as

$$\rho^* = \pi L / (\mu_0 E_0), \quad (2)$$

where L is the radiance of the channel measured by a satellite, μ_0 the solar zenith angle, and E_0 the extra-terrestrial solar flux.

Because of their partial transparent nature, thin cirrus clouds are difficult to detect in satellite images, particularly over land, both in the visible and in the 10-12 μm IR atmospheric

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window regions. Thin cirrus clouds introduce additional path-scattered-radiances to the 0.66 and 0.86 μm channels. As a result, NDVI values calculated from data with cirrus contamination are different from those computed from data without any cirrus contamination. In order to obtain unbiased estimates of NDVI values from remotely sensed data, thin cirrus scattering effects must be removed. Previously, an empirical technique using scatter plots between the 1.38-μm cirrus detecting channel and another channel near 0.66 μm was developed (Gao et al., 1998). In this study, we use this technique to estimate thin cirrus scattering effects in the 0.66 and 0.86 μm channels.

3. THIN CIRRUS EFFECTS

In order to illustrate thin cirrus effects on remotely sensed data, we show in Figure 1 examples of AVIRIS images with and nearly without cirrus contamination acquired over a site in Gainsville, Florida on July 8, 1992 during the NASA sponsored Accelerated Canopy Chemistry Field Program. Several AVIRIS data acquisitions were made over the site when cirrus clouds were moving through. Figs. 1a and 1b show the 0.86-μm and 1.38-μm images from the second AVIRIS overpass. Due to strong water vapor absorption at 1.38 μm, the 1.38-μm channel is typically very sensitive in detecting upper level cirrus clouds (Gao et al., 1993) with little contamination from the surface and lower level clouds. Although the 1.38-μm image (Fig. 1b) shows the presence of cirrus clouds, the 0.86-μm image (Fig. 1a) looks perfectly clear. Figs. 1c-d, from the third AVIRIS overpass (about 15 minutes after the 2nd overpass), are similar to Figs. 1a-b, except, as seen from Fig. 1d, cirrus effects were less obvious during the 3rd overpass. NDVI values from the two overpasses in a few areas differ by more than 10%. Therefore, it is important to remove thin cirrus effects in order to obtain unbiased NDVI estimates.

4. IMPROVING NDVI ESTIMATES

We use a pair of AVIRIS images with and nearly without cirrus contamination to demonstrate the improvement in the estimates of NDVI values after the removal of thin cirrus scattering effects. As described in Section 3, the pair of AVIRIS data were measured over Gainsville, Florida on 8 July 1992. Figures 2a and 2b show the un-corrected and cirrus-corrected NDVI images calculated from the 2nd-pass AVIRIS data. NDVI values are generally increased after the correction of cirrus path radiances. By comparing Fig. 2a with Fig. 1b, it is seen that the areas with more cirrus clouds (upper left portion of Fig. 1b) have small NDVI values in the un-corrected NDVI image. Figures 2c and 2d show the un-corrected and cirrus-corrected NDVI images calculated from the 3rd-pass AVIRIS data. Again, NDVI values are increased after the correction of cirrus path radiances. The two un-corrected NDVI images (Figs 2a and 2c) do not look the same, while the two cirrus-corrected NDVI images (Figs 2b and 2d) appear to be nearly identical. The integrated NDVI values for both scenes differ by less than 1%. This demonstrate the success in recovering NDVI values from data contaminated by thin cirrus clouds after the removal of the thin cirrus scattering effects.

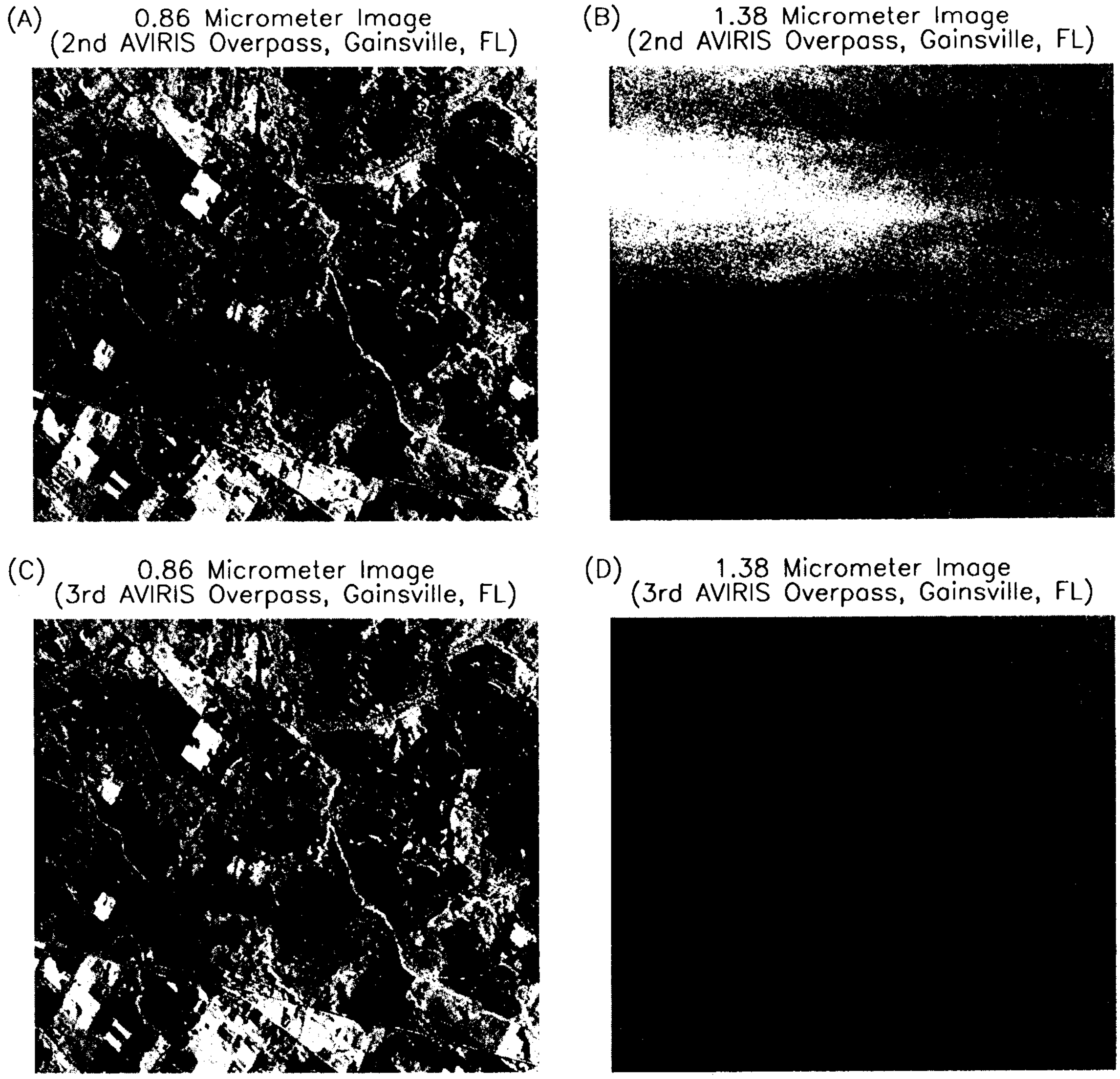

Fig. 1. (a) and (b) - the 0.86 μm and 1.38 μm images acquired with AVIRIS on July 8, 1992 during the 2nd overpass over an area in Gainsville, Florida, and (c) and (d) - similar to (a) and (b), except acquired during the 3rd overpass 20 minutes later over approximately the same area. The change in solar zenith angles between the two ER-2 overpasses was two degrees. The 0.86 μm images (a and c) appear to be very clear, but the 1.38 μm images (b and d) show variable thin cirrus effects.

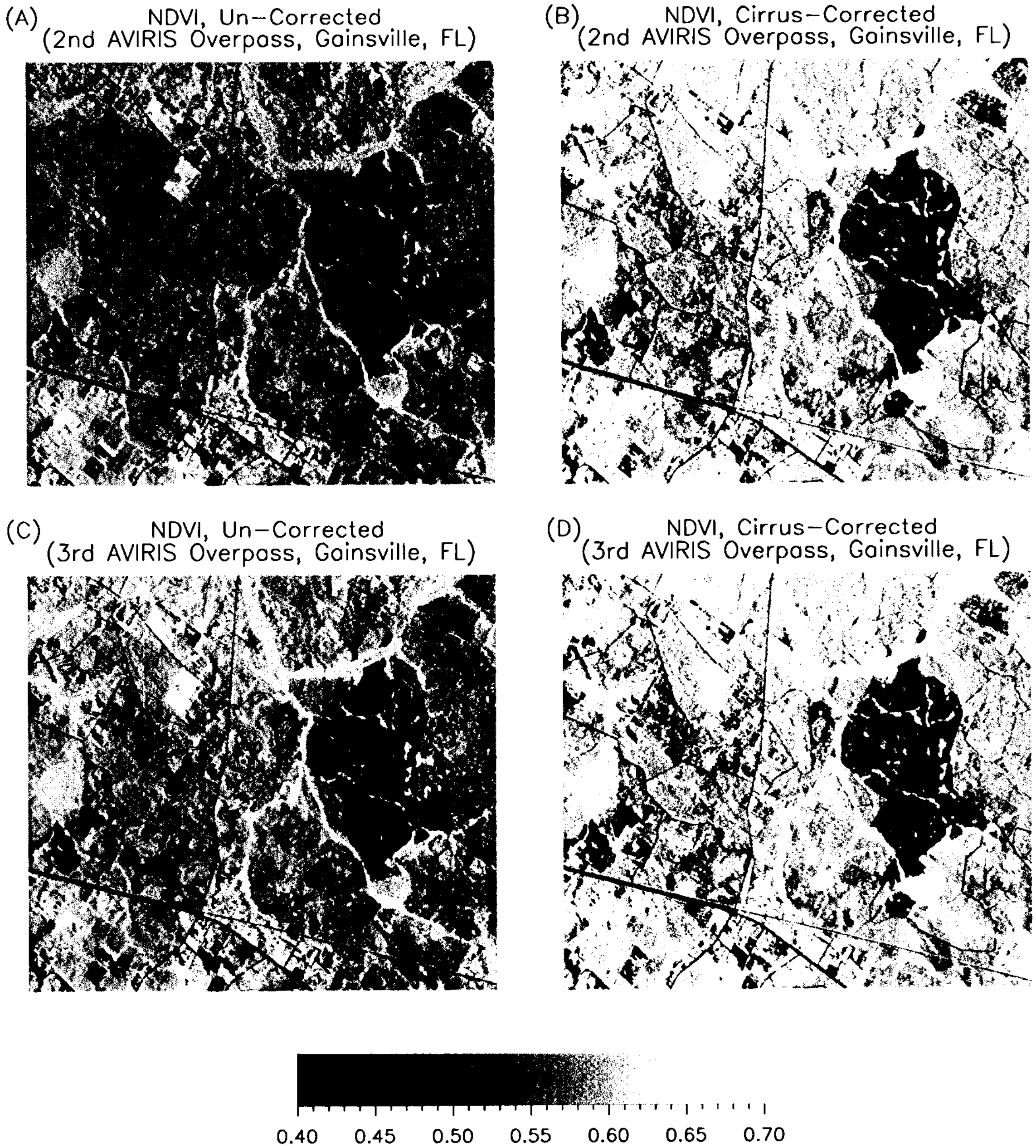

Fig. 2. (a) and (b) - un-corrected and cirrus-corrected NDVI images obtained from the 2nd-pass AVIRIS data over Gainsville, FL on July 8, 1992, and (c) and (d) - similar to (a) and (b), except obtained from the 3rd-pass AVIRIS data. The two cirrus-corrected NDVI images (b and d) are quite similar.

5. DISCUSSION AND SUMMARY

We have shown, using a pair of AVIRIS data sets with and nearly without thin cirrus contamination, that the estimates of NDVI values can be improved quantitatively after the removal of thin cirrus scattering effects from remotely sensed data. A special channel centered at 1.375 μm with a width of 30 nm (Gao and Kaufman, 1995) has been implemented on the Moderate Resolution Imaging Spectrometer (MODIS) (Salomonson et al., 1989; King et al., 1992; Asrar and Greenstone, 1995) for detecting thin cirrus clouds from space. It is possible to remove thin cirrus effects from MODIS data for improved estimates of NDVI values globally.

6. ACKNOWLEDGMENTS

The authors are grateful to R. O. Green of the Jet Propulsion Laboratory, to Kathleen B. Heidebrecht of University of Colorado in Boulder, Colorado for providing AVIRIS data, to Alexander F. H. Goetz of University of Colorado at Boulder for useful discussions, and to Curtiss O. Davis and Marry Kappus both at Naval Research Laboratory in Washington, DC for helpful comments on this article. This research was partially supported by a contract from NASA Goddard Space Flight Center to Naval Research Laboratory in Washington, DC.

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