N91-10472

ERBE AND AVHRR CIRRUS CLOUD FIRE STUDY

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1. Introduction

Understanding the impact of cirrus clouds on the global radiation budget is essential to determining the role of clouds in the process of climate change. The ongoing Earth Radiation Budget Experiment (ERBE) is charged with measuring the global radiation balance at the top of the atmosphere. The International Satellite Cloud Climatology Project (ISCCP) is measuring global cloud amounts and properties over a time frame similar to ERBE. Specific cloud properties are absent from the ERBE program, while ISCCP lacks the broadband radiances necessary to determine the total radiation fields. Together, results from these two global programs have the potential for improving the knowledge of the relationship between cirrus clouds and the Earth radiation balance. The First ISCCP Regional Experiment (FIRE), especially its cirrus Intensive Field Observations (IFO), provides opportunities for studying radiation measurements from the ERBE taken over areas with known cirrus cloud properties (Starr, 1987 and Cox et al., 1987). In this paper, satellite measurements taken during the IFO are used to determine the broadband radiation fields over cirrus clouds and to examine the relationship between narrowband and broadband radiances over various known scenes. The latter constitutes the link between the ERBE and the ISCCP.

2. Analysis

The analysis presented here concentrates on the ERBE and AVHRR (Advanced Very High Resolution Radiometer) data from the NOAA-9 satellite. Both of these instruments are cross-track scanners which allows simultaneous and coincident comparisons. The 4-km AVHRR pixel data can be spatially averaged to match the 40-km ERBE resolution. The other significant difference in these two instruments is their spectral bands. ERBE has broadband channels of 0.2 to 5.0 μm for shortwave, 5.0 to 50 μm for longwave, and 0.2 to 50 μm for total radiation. The three channels allow for spectral consistency checks to be made between channels. The AVHRR has five narrowband channels, three of which were used in this study: the 0.58 to 0.68 μm window for visible radiation and a combination of the 10.3 to 11.3 μm window and the 11.5 to 12.5 μm window for infrared radiation. In this study, the IFO region is defined as a 5^{o} box between 42^{o}N and 47^{o}N and 87^{o}W and 92^{o}W. It is analyzed using a 0.5^{o} grid.

The ERBE broadband radiances are inverted to fluxes at the top of the atmosphere by applying angular directional models for scenes identified using a maximum likelihood estimator technique (Wielicki and Green, 1988). Geographical scenes are classified as ocean, land, desert, coast, or snow with cloud cover categories of clear (0-5%), partly cloudy (5-50%), mostly cloudy (50-95%), or overcast (95-100%). The hybrid bispectral threshold method (HBTM) developed by Minnis et al. (1987) was used to determine cloud amount at low (0-2 km), middle (2-6 km), and high (>6 km) altitudes from the AVHRR visible and infrared measurements.

In order to perform the HBTM analyses, the AVHRR narrowband radiances were converted to broadband fluxes following the approach of Minnis and Harrison (1984). Figure 1 presents the correlations between the ERBE and AVHRR data taken over Wisconsin during seven overpasses within the IFO period. The AVHRR data were averaged to match the larger ERBE footprints. A linear least-squares fit yielded a root-mean-square (RMS) difference of 4.5% in the longwave radiances predicted from the infrared (IR) radiances. An RMS difference of 14.5% was found for the shortwave data using a quadratic fit in visible counts. These results are consistent with Minnis and Harrison (1984) narrowband-broadband correlations of GOES and Nimbus-7 ERB data. The longwave correlations also agree with the narrowband-broadband correlations of Yang et al. (1987). Clear-sky visible reflectance, necessary for application of the HBTM, was predicted for the AVHRR using the clear-sky albedo map given by Heck et al. (1988).

3. Results

The following results were derived from NOAA-9 data taken during the November 2, 1986 overpass of the IFO region. This occurred at approximately 1405 LT. Solar zenith angles ranged from 65° to 70° with satellite viewing zenith angles between 1° and 31°. Figure 2 shows the contours of IR temperature and visible reflectance from the AVHRR. Total and high cloud amounts derived from these data are plotted in Fig. 3. A large area of overcast clouds extends from the northwestern corner to the Green Bay area. Since no emissivity corrections were applied to the results, only the thickest clouds are classified as high-level clouds. Tops of many of the other clouds probably extended above 6 km, but apparently were not dense enough to radiate as blackbodies above the 6-km level. The corresponding broadband shortwave albedos and longwave fluxes derived from the ERBE (Fig. 4) follow the same basic patterns as their narrowband counterparts. IR temperatures from AVHRR range from about 282K over clear areas to 236K over the thickest clouds. Longwave flux varies from about 155 Wm^{-2} to 260 Wm^{-2}. Shortwave albedos generally exceed the visible reflectances.

The inferred broadband shortwave albedos and longwave fluxes derived from the AVHRR data are given in Fig. 5. Although the AVHRR reveals much more structure in the radiation fields than seen in Fig. 4, the large-scale patterns are very similar. On average for this figure, the AVHRR albedos are 1% $\pm$ 4% less than the ERBE values. AVHRR longwave fluxes are 7 Wm^{-2} greater than the ERBE values. The standard deviation of the flux difference is 7 Wm^{-2}. These differences may be the result of several factors, such as uncertainties in the correlations, in the scene-type selection, and in the bidirectional models. It appears that the AVHRR albedos are greater over the areas of thick cirrus while they are lower over clear areas and relatively thin cirrus. AVHRR longwave fluxes are much higher than ERBE's over areas with the thickest cirrus. Since the correlations represent average conditions, such differences are to be expected in the resultant fluxes for a given day.

4. Concluding Remarks

The apparent geographical variations of the differences in the fluxes derived from the two different instruments provide encouragement that they are scene-type dependent. Thus it may be possible to improve the methods for inferring broadband radiance from narrowband data by accounting for the scene identification differences. This may be accomplished with additional case studies in combination with radiation measurements taken from other platforms during the IFO.

5. References

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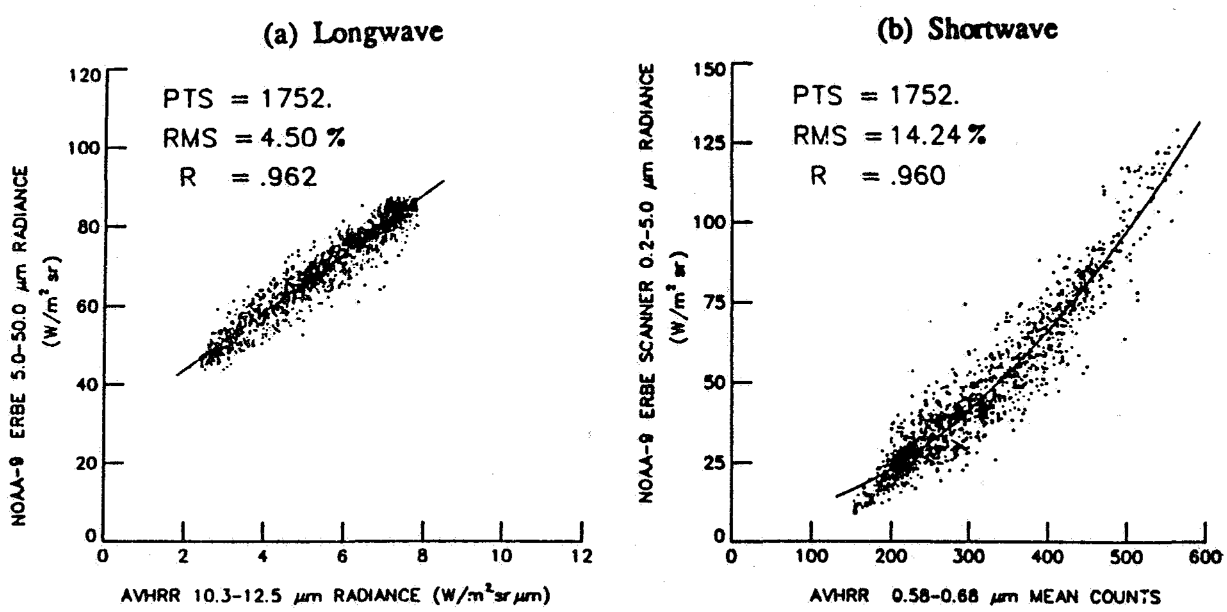

Figure 1. Correlation of ERBE broadband and AVHRR narrowband data for FIRE during October 22 - November 2, 1986.

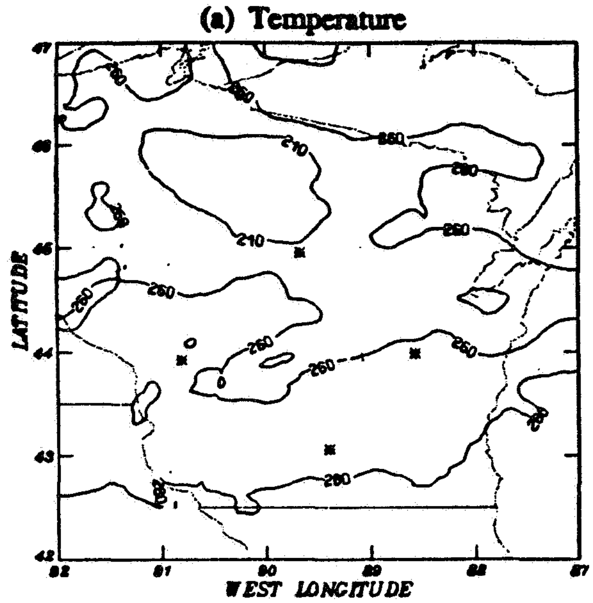

Figure 2. AVHRR temperature (K) and reflectance (%) results for November 2, 1986.

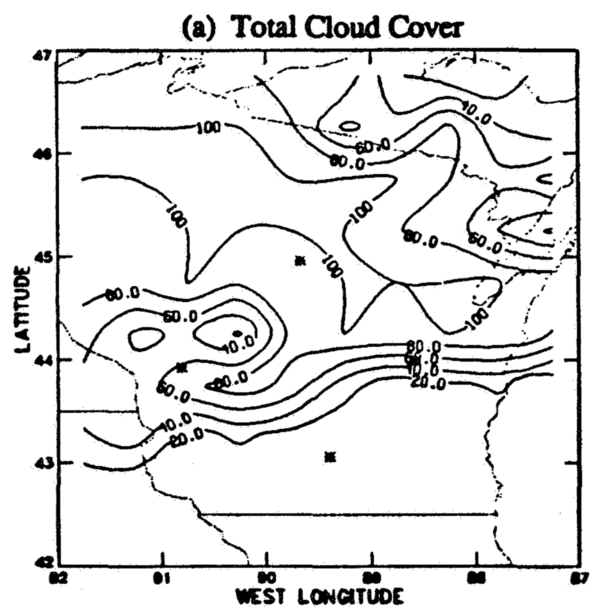

Figure 3. Cloud cover (%) derived from AVHRR for November 2, 1986.

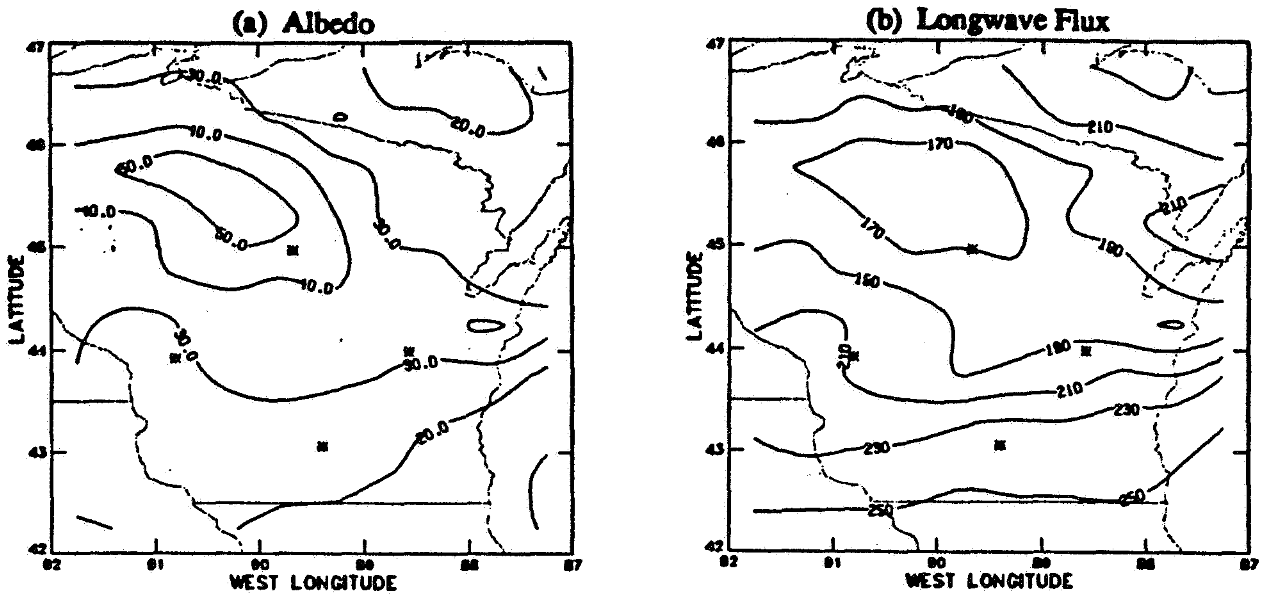

Figure 4. ERBE albedo (%) and longwave flux (Wm^{-2}) for November 2, 1986.

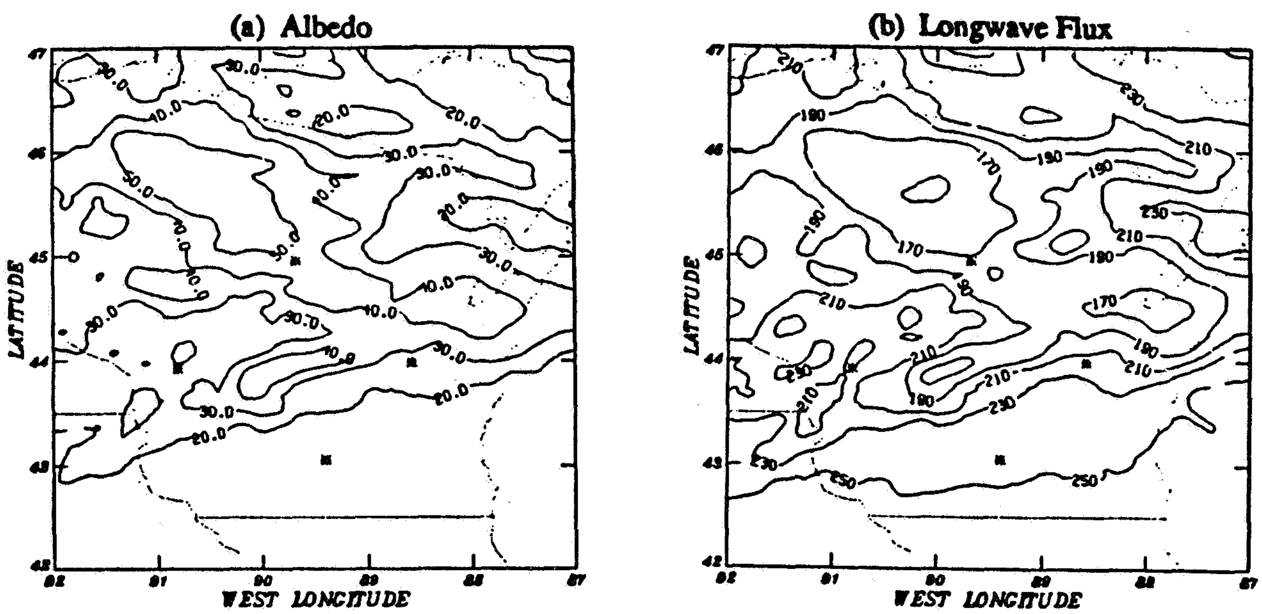

Figure 5. AVHRR albedo (%) and longwave flux (Wm^{-2}) for November 2, 1986.