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COMPARISONS OF DOWNWELLING RADIATION TO MODEL PREDICTIONS BASED ON GROUNDBASED MEASUREMENTS DURING FIRE'91

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ABSTRACT. Surface radiation measurements and simultaneous ground-based measurements of the atmosphere during the FIRE'91 cirrus field experiment provided an opportunity to identify crucial measurements and parameterization deficiencies in current cloud-radiation models.

Comparisons between measured and calculated broadband surface fluxes with only a small data subset already reveal these needs:
(1) accurate humidity and aerosol vertical profiles for clear cases,
(2) accurate vertical extinction profiles and dimensions for clouds,
(3) understanding of the (solar) scattering properties of cirrus.

1. INTRODUCTION

The recent FIRE'91 cirrus field experiment provided an unique opportunity to validate atmospheric models. Concentrating on the radiative transfer modeling aspect - by comparing measured downward fluxes at the surface to modeled fluxes - we like to address the questions: 'How well can simple models simulate radiative properties of the atmosphere?' and 'How well can models translate directly and indirectly measured atmospheric properties into radiative fluxes?'.

The radiative transfer model is described first. The employed data are introduced next. Finally, comparisons for cloud-free and cloudy cases, in particular cirrus clouds cases, are discussed.

2. MODEL

Radiative transfer calculations of hemispheric downward broadband fluxes are based on a four-stream code at eight solar wavelengths and on a two-stream code at twelve infrared wavelengths, as the entire spectrum has been subdivided into twenty bands. Absorption by atmospheric gases in these bands is expressed via exponential sum-fitting and based on the HITRAN-database. Although the selection of radiative method, spectral resolution and absorption approximation can notably affect calculated fluxes, the chosen model is found to be sufficiently accurate. Deviations of surface broadband fluxes to values based on more accurate models and/or spectral resolution (less than 4%) are found to be small compared to the measurement errors. In all these models horizontal homogeneity has been assumed. This assumption, which is particularly poor for many cloud conditions, can create significant deviations between measured and calculated fluxes. To reduce errors due to the observed inhomogeneity only average flux values for time-periods of at least five minutes are used.

3. DATA

In-situ measurements and simultaneous remote sensing methods during the FIRE'91 field experiment characterized the atmosphere. Only those measurements are listed that are used in our study:

(1) Vertical profiles of atmospheric variables (e.g. temperature, humidity) are defined by up to 3 hour frequent NOAA radiosonde launches. For times between launches interpolations are used.

(2) Cloud properties are based on remote sensing data from the ground, including the Penn State University 94 Ghz radar for cloud dimensions and 10-channel sunphotometer for cirrus cloud optical depths. Ice cloud particles from the FIRE'86 cirrus experiment are adopted, as FIRE'91 data were not available yet.

(3) Downward hemispheric broadband solar and infrared fluxes are provided by Eppley radiometers of the Penn State University, and also by NOAA radiometers, employed as part of SPRECTRE.

Measurements (1) and (2) provide the input to the model. Calculated downward broadband surface fluxes, are compared to measurement (4).

4. COMPARISONS

Comparisons between measured and calculated fluxes carry a combination of model related errors, which are generally small, and an uncertain contribution of data related errors. Flux comparisons for four clear and four cloudy days are given in Figures 1 and 2.

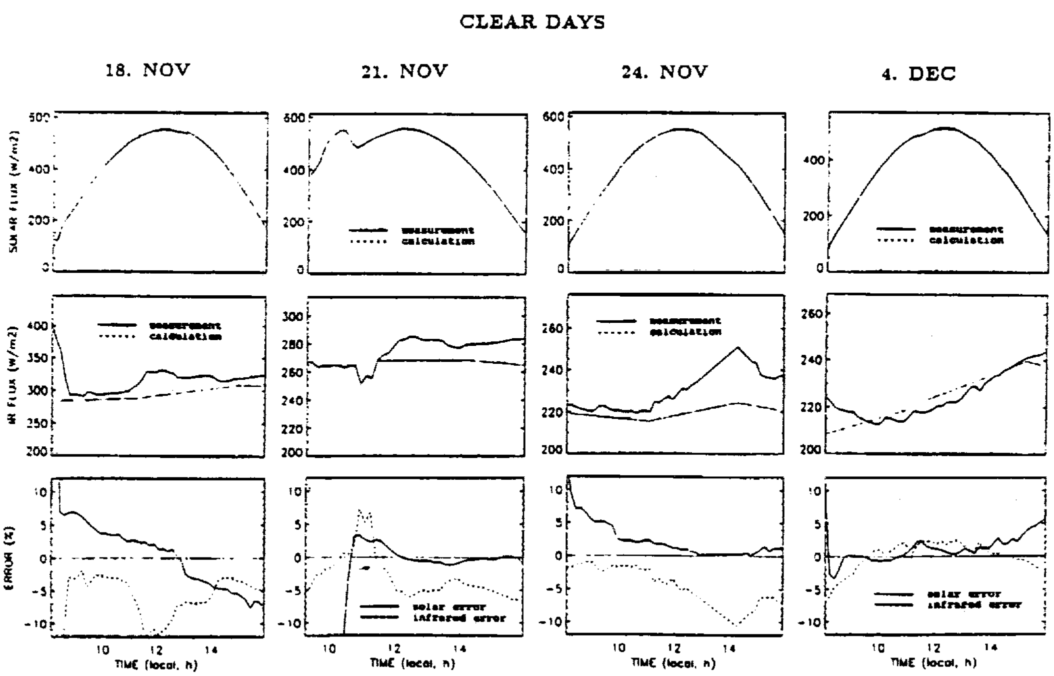

Figure 1. Comparison of measured and modeled hemispheric broadband downward solar and infrared fluxes on four cloud-free days. Errors (in %) for solar and infrared fluxes are given in the lower panels.

Clear sky flux comparisons are based on ten minute averages. For the solar spectral region, deviations of less than 5% are even smaller than expected from instrumental error analysis. For the infrared spectral region clear-sky deviations are larger, in part due to inaccurate humidity data, as radiosonde launches are sparse.

Cloudy sky flux comparisons are based on five minute averages. Average values reduce effects from often observed cloud horizontal inhomogeneities and from the lack of instrumental co-location. For the solar spectral region large deviations are found for situations involving optically thick clouds, as optical depths are uncertain. Under cirrus conditions (e.g. Dec.5), systematically higher modelled transmissions indicate solar asymmetry-factors smaller than 0.75. For the infrared region the good agreement of less than 10 W/m2 mainly reflects an accurate height positioning for the clouds base.

5. CONCLUSION

Simple radiation models can reasonably well reproduce surface fluxes under clear-sky conditions. However, the schemes frequently fail to reproduce surface fluxes for cloudy conditions, mostly due to insufficient information about cloud microphysics and structure.

CLOUDY DAYS

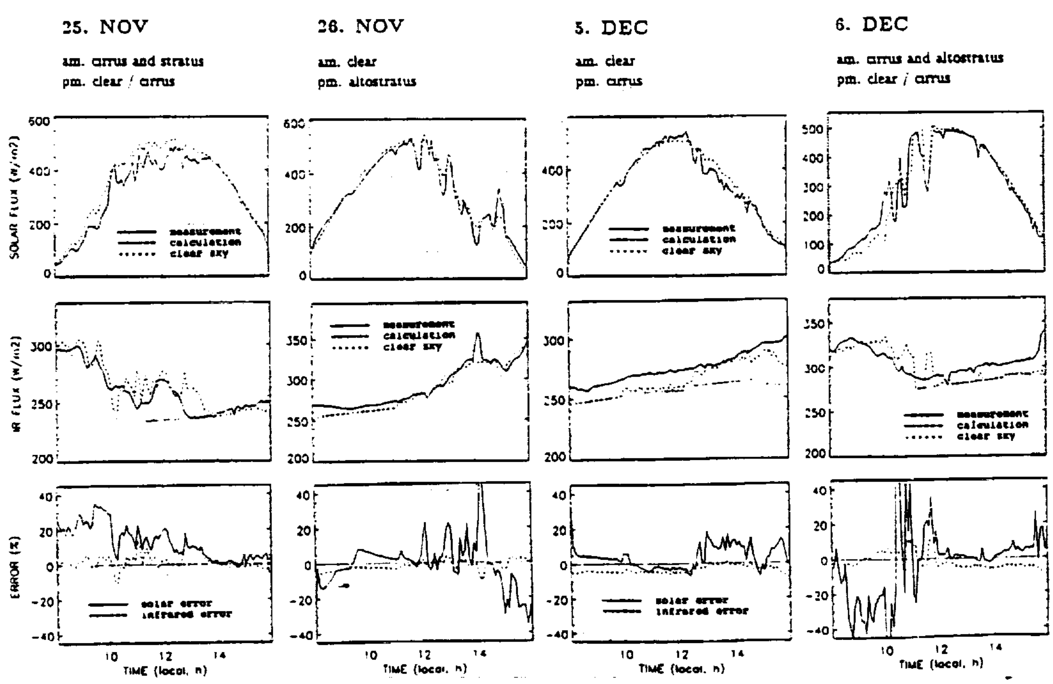

Figure 2. Comparison of measured and modeled hemispheric broadband downward solar and infrared fluxes on four (partly-) cloudy days. Corresponding flux errors and general cloud conditions are shown.

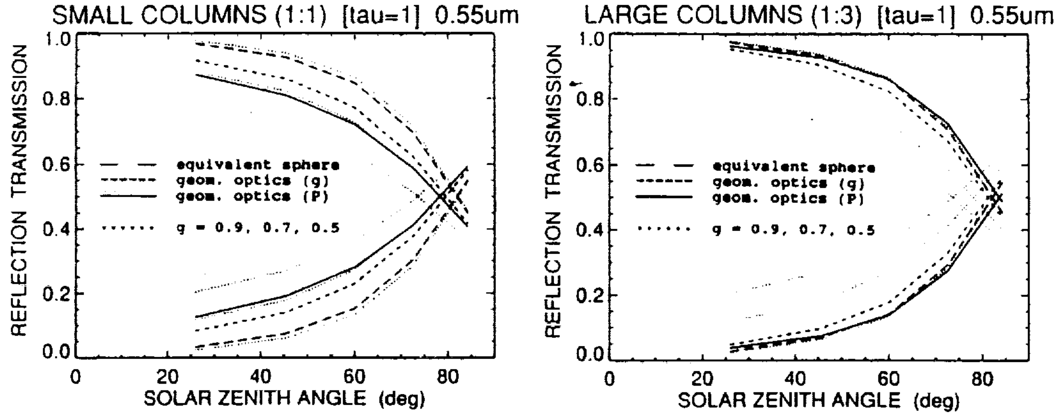

Figure 3. Comparison of reflection and transmission from different assumptions to single scattering properties of ice-crystal columns.

Particular disturbing is the current inability to model solar scattering of ice crystals. The results suggest asymmetry-factors of 0.70-0.75, which is lower than theoretical calculations on columns suggest (Takano et al., 1989). However, ice crystals are typically more complex, and often contain cavities (e.g., Milosevitch et al., 1992). New theoretical studies (e.g., Macke 1992) are encouraging. The use of asymmetry-factor in place of accurate phasefunctions in the model seems to lead to too much solar transmission, especially for smaller particles (Figure 3, also Fu et al., 1993) and may have contributed to the discrepancy in the flux comparison. Consequently, nonspherical single scattering corrections should be reevaluated.

This study reflects only an initial comparison with limited data-sets. The incorporation of more data, which were unavailable at this time for model calculations is in progress. This includes the use of in-situ cloud microphysical measurements (e.g. NCAR aircraft and balloon sondes) and additional ground based remote sensing data (e.g., NASA-Ames solar direct/diffuse and infrared radiometers, AFGL full sky camera, NOAA microwave radiometer and radar data).

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