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CALCULATION OF CLEAR-SKY OUTGOING LONGWAVE RADIATION USING ECMWF GRIDDED FIELDS AND ISCCP C1 CLOUD DATA

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1. INTRODUCTION

Clear-Sky OLR has a variety of definitions. Clear-sky OLR can be measured from satellites by examining the data to detect clouds, eliminating those observations that are contaminated with clouds, and averaging the remaining data. The disadvantage of this method is that satellites do not provide time continuous coverage, requiring many observations and careful analysis to remove sampling biases.

Alternatively, clear-sky OLR can be found continuously using a radiative flux code, combined with analyzed fields of temperature, humidity and clouds, either from assimilated observations or a GCM simulation. The disadvantage is that the cloud field is typically very low resolution, on the order of 200 km, so they lack important small scale cloud detail. Even if fractional clouds data is available, it is not obvious how GCM and ERBE results should be compared. At least four methods have been used in published studies to calculate long-term average clear-sky OLR based on a series of observations (Cess, *et al.*, 1992, Potter *et al.*, 1992). They are summarized in Table 1. Also described is a modification to one of the methods based on fractional coverage.

The purpose of this study is to assess clear-sky OLR calculated from these methods using available data. Cloud data from ISCCP provides the fractional cloud coverage data necessary to test these methods against calculations based on observed data. Clear-sky OLR is calculated using the ECMWF/TOGA archive. Monthly averages are made in the manner of the several methods listed above and compared to each other and to ERBE.

Table 1. Five types of clear-sky OLR algorithms

Name, Ref	Algorithm
Ia, Cess, *et al.*, 1992	$F_{cs} = \frac{\Sigma F_i^{clear}\delta_i}{\Sigma\delta_i}$ $\delta_i = \begin{cases} 1, \text{Box Totally Clear} \\ 0, \text{Otherwise} \end{cases}$
Ib Potter, *et al.*, 1992	$F_{cs} = \frac{\Sigma F_i^{clear}(1-c_i)}{\Sigma(1-c_i)}$ c_i=Cloud Fraction
II Cess, *et al.*, 1992	$F_{cs} = \frac{\Sigma F_i^{clear}\delta_i}{\delta_i}$ $\delta_i = 1$
III Cess, *et al.*, 1992	$F_{cs} = \frac{\Sigma F_i^{clear}\delta_i}{\Sigma\delta_i}$ $\delta_i = \begin{cases} 1, \text{Box Clear During Day} \\ 0, \text{Otherwise} \end{cases}$
Iaf, This work	$F_{cs,x} = \frac{\Sigma F_i^{clear}\delta_i}{\Sigma\delta_i}$ $\delta_i = \begin{cases} 1, \text{Box} > x\% \text{ Clear} \\ 0, \text{Otherwise} \end{cases}$

2. PROCEDURE

2.1. Atmospheric Data

The atmospheric state is derived from the WCRP/TOGA Archive II version of the ECMWF global scale upper air analyses. This data set contains upper air and surface data twice-daily on a 2.5° x 2.5° grid.

2.2. Cloud Data

The International Satellite Cloud Climatology Program (ISCCP) C1 data set contains, among other things, summaries of cloud top pressures on a 2.5° x 2.5° grid at three hour intervals. A complete description is in Rossow, *et al.* (1988). For this study, the only cloudiness data used were the number of IR-cloudy pixels and the available pixels. Because this value is based on IR observations, data are available every three hours, except when data are missing.

2.3. ERBE Clear-Sky Data

The data used in this project are the ERBE scanner data from the GEDEX (Greenhouse Effect

Detection Experiment) CD-ROM disk. It is a 2.5°x2.5° gridded product.

2.4. Longwave Model

The longwave model is an emittance-type wide band model as described in Harshvardhan, *et al.* (1987). This model includes two water vapor bands, one carbon dioxide and one ozone band.

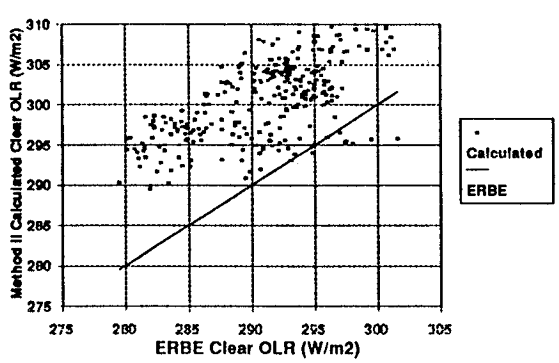
The model as used has 16 layers corresponding to two model layers per ISCCP layers, with two stratospheric layers. The division was made on these levels in order to accommodate the multi-layer ISCCP data, though that data is not explicitly used in this study

2.5. Analyses

The Method II analysis consisted of simply taking the mean of the twice daily OLR calculations made using the ECMWF temperature and humidity data with no clouds in the model. This was done for January, May, June, and July, 1986. The analysis domain is the equatorial Pacific Ocean, from 150°E to 120°W and from 10°N to 10°S. For calculation of other averages, the twice daily OLR values were linearly interpolated to create a three-hourly clear-sky OLR data set compatible with the ISCCP three-hourly observations.

With the Method II data, the monthly mean clear-sky OLR based on Method Iaf was calculated. From ISCCP, the total cloud fraction (cloudy pixels/total pixels) was found. Then OLR results were included in the monthly average depending on whether or not the clear fraction exceeded 0%, 1% (not more than 99% cloudy), 5%, 10%, 20%, 50%, and 90%. The Method Ib and Method II averages were calculated according to the criteria contained in Table 1.

Figure 1. Scatter Plot of Calculated Method II Clear-Sky OLR vs. ERBE January, 1986.



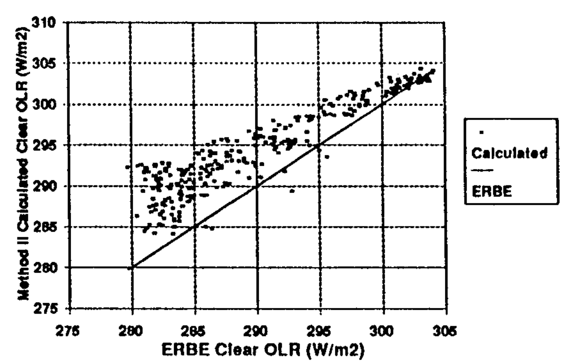
3. RESULTS

3.1. Method II Clear-Sky

Figure 1 shows a scatter plot comparing the ERBE and calculated clear sky OLR's for January 1986. The variability in the calculated values is quite high, indicating that the calculated values are not a good approximation to observations.

Figure 2 (July 1986) shows much better results. The absolute differences between the Method II calculated values and the ERBE results are considerably smaller in magnitude, around 5 - 8 W m^{-2}. Brigleib (1992) indicates that this is the correct magnitude for a model without trace gasses. The differences in slope are possibly attributable to cloud contamination (Kiehl and Briglieb, 1992). Similar results were obtained for other months after May 1986. From these results, it is concluded that the ECMWF data is inadequate for radiation calculations prior to March 1986, but that after that date probably have utility.

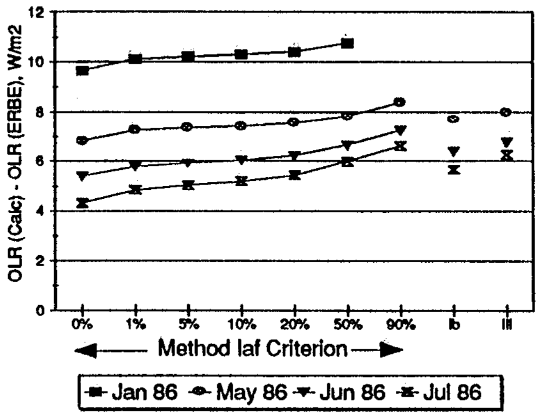
Figure 2. Scatter Plot of Calculated Method II Clear-Sky OLR vs. ERBE July, 1986.



3.2. Calculation using Other Methods

Figure 3 shows the difference between the calculated clear sky OLR and ERBE for the various clear thresholding conditions. Zero percent clouds means that all calculations are included in the average, corresponding to method II . One percent means that at least 1% of the box must be clear for the calculated value to be included in the average. The 90% value is considered to be the best possible approximation of Method Ia. Method Ib and Method III are also shown. In all cases, the methods that are more selective

Figure 3. Monthly Mean Calculated (Calculated - ERBE) Clear-Sky OLR July, 1986.



showed higher clear-sky OLR than less selective methods. This is expected because the cloudy areas tend to be colder and wetter than clear areas, so their inclusion should reduce the mean.

Figure 4 shows the correlation between the monthly mean calculated clear-sky averages and ERBE for the several methods. In all cases, the Method II correlation was the best; Method Ia was the worst. It is generally true that the more selective the method, the worse the correlation between the calculated means and ERBE.

4. CONCLUSIONS

Clear-sky OLR was calculated from ECMWF/TOGA archive using a wide band longwave model. Results for January, 1986 were poor, both in terms of absolute error and variability relative to ERBE monthly averages. Results for May, June, and July were much better. There is a residual bias, which is attributed to lack of trace gasses in the longwave model.

Several methods for evaluating clear-sky OLR were used. All were found to produce quite similar results for the region in question, though the simplest method produced the best correlation with ERBE. This implies that the additional complexity of other methods does not necessarily lead to better results.

5. ACKNOWLEDGMENTS

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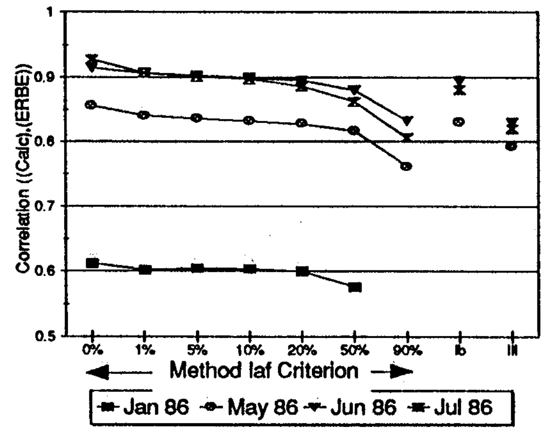
Figure 4. Correlation Between Clear-Sky OLR as Calculated by the Various Methods and ERBE



NCAR. The ISCCP data was provided by NSSDC. The calculations for this project were made on an IBM RISC/6000-320 workstation provided to Purdue under a shared study grant.

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