

WORLDWIDE CLOUD COVER MODEL

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ABSTRACT

This is a first study effort aimed at modelling, i. e. , classifying worldwide cloudiness into homogeneous regions, using a satellite data set containing Day IR, Night IR, Incoming, and Absorbed solar radiation measurements on a 2.5-degree latitude-longitude grid. The progress on the initial work to data and the methods of analysis are presented.

INTRODUCTION

The purpose of this investigation is to develop a model for worldwide cloud cover using a satellite data set containing infrared radiation measurements. Other cloud models exist [1 - 3]. These early cloud models used primarily ground-based cloud observations. The satellite data set containing Day IR, Night IR, Incoming, and Absorbed solar radiation measurements on a 2.5-degree latitude-longitude grid covering a 4-year period of record (with some missing months) has recently become available. There was originally a 2-year period of similar data on an NMC grid.¹ The first step is to convert these infrared data to estimates of cloud cover. The statistical analysis of classification of cloud region characteristics can then be performed.

There are several reasons for desiring a cloud model based on satellite data. The ground-based data are much more limited in scope. Some fairly large areas of the world have either no data or very sparse data, and models using ground-based observations necessitate a number of assumptions, including on occasion that a region is essentially like its antipodal location. A good worldwide cloud cover model is needed for the purpose of studying the relationship between cloudiness, precipitation, and the Earth radiation budget.

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CONVERSION OF SATELLITE IR MEASUREMENTS
TO CLOUD COVER

A major initial task is to derive cloud cover estimates from the satellite infrared data. The method used in this investigation follows the suggestions obtained through personal communications with Tom Gray, National Environmental Satellite Services [4].

Albedo is defined as the reflective power, or the fraction of incident light that is reflected by a surface or body. Included in the satellite data are the amount of incoming solar radiation, I_{in} , and the amount of absorbed solar radiation, I_{ab} . The satellite observed albedo, A_{so} , is estimated by

$$A_{so} = (I_{in} - I_{ab}) / I_{ab} \quad (1)$$

If the Earth's surface absorbed all solar radiation, then the cloud cover might be taken simply as 1 minus albedo (assuming also that clouds reflect all solar radiation). Different parts of the Earth's surface, however, have differing radiances. For example, the albedo of the ocean is approximately 5 percent (95 percent of the solar radiation being absorbed), while the Sahara desert reflects approximately 40 percent of the solar radiation reaching it.

To determine cloud cover, we need to obtain the background radiation of the region of the Earth of interest. To do this, for a given month and a specified location, we calculate A_{so} from equation (1) for every day of a month and observe the minimum value, $A_{so_{min}}$. This minimum value should occur on the day of least (hopefully near zero) cloud cover. If r is the reflectance of the clouds and n is the fraction of cloud cover, then the basic formula may be written as

$$A_{so} = n * r + (1 - n) * A_{so_{min}}$$

from which we have the fraction of cloud cover, n , as:

$$n = \frac{A_{so} - A_{so_{min}}}{r - A_{so_{min}}} \quad (2)$$

This formula requires a knowledge of \underline{r} which varies.

A way to estimate the cloud reflectance, r , is by observing the difference between the Earth's surface temperature and the temperature equivalent of the satellite-observed daytime infrared reading (denoted by IR_D). The radiance of the IR_D by Stefan's law is equal to $5.75 \times 10^{-8} T^4$ (watts/m²), where T is the temperature equivalent in degrees Kelvin. Putting $X = (\text{surface temperature} - T)$, (units degree Kelvin), the following relationship has been observed:

$$r = -0.000265 X^2 + 0.0295 X + 0.10 \quad . \quad (3)$$

We propose to use a surface temperature of 30° C for latitudes within 25 degrees of the equator and -5° C for latitudes within 25 degrees of the pole. Interpolations will be used for intermediate latitudes.

Because this investigation is based on derived cloud cover estimates and may be subject to criticism, it is noted that ground-based cloud observations are also estimates as well as cloud cover obtained by satellite photography. We make this conjecture: Those variables which are not well defined in the IR to cloud cover conversion procedure will have small contributions to climatic modelling of the clouds over the entire month. For a specific day and area the preceding procedure may not be entirely satisfactory for synoptic cloud cover analysis.

MODELING FOR CLOUD COVER

We propose to obtain for each grid point (2.5 × 2.5 latitude-longitude over the entire world to the extent the satellite infrared data are available) the mean and standard deviation of cloud cover for a specified month (beginning with the four January periods). Then we will use a nonparametric density estimate technique to estimate the joint probability density function of the mean and standard deviation of all the grid points so observed.

Visualize the following: A "plotted" joint probability density function will then show "hills" and "valleys." A discriminant method will be used to separate the hills, valleys, and plateaus in the joint probability density function. The grid locations corresponding to a particular region (e. g. , hill) of the joint probability density function will be a region on the Earth's surface of similar cloud cover characteristics. We will thus be able to model cloud cover over the world for the specific month (say, January).

Similar analyses will be made for other months—say, April, July, and October. The result will be a division of the globe into distinct

regions based on cloud cover characteristics for each month. The statistical methods of classification are objective. These statistical methods could be applied to the original satellite infrared data.

To make a good climatological model a reasonably long record length is required. The satellite data available for this study comprise approximately 44 months. This is sufficient for some model development, but a longer period of record would be desirable.

REFERENCES

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