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TYPE OF RADIATION MODEL NEEDED IN THE THERMODYNAMIC APPROACH TO LONG-RANGE PREDICTION

by

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1. INTRODUCTION

During the last few years a time-averaged thermodynamic model of the atmosphere-ocean-continent system has been developed. The model consists of an atmospheric layer of about 10 Km; a layer of about 50 meters in the ocean and a layer of negligible depth in the continents. The atmosphere includes a cloud layer.

Applying the conservation of thermal energy (first law of thermodynamics) to this system gives an equation for the integrated atmosphere, one for the oceanic layer and one for the surface of the continents. The equations allow computation of the mid-tropospheric temperature and the surface temperature, provided that we supply a parameterization of the different heating components.

The model predicts the temperature fields (in the troposphere and at the surface of oceans and continents) associated with the heating functions, most of which are also predicted variables. In particular, the radiation heating components are generated internally in the model.

The model has been described in a series of papers (ADEM, 1962, 1964a, 1965a, 1965b). It includes in some cases crude parameterizations of the heating functions and some very strong simplifying assumptions which are used for the lack of a better parameterization or for the purpose of making the problem mathematically tractable.

Despite the crudeness of the model its application has yielded surprisingly good results. First it was used to explain the climatological temperature distributions with good success (ADEM, 1964a, 1964b). Afterwards it was used to compute fluctuations from the computed climatological normal values, and since December 1965 it has been used to make predictions of departures from the normal values of temperature and precipitation for periods of a month. The preliminary results have been encouraging (ADEM & JACOB, 1968). The best skill of the current model is in predicting month-to-month changes in ocean temperatures.

While the current model is being tested operationally, attempts are being made to develop an improved model by refining the parameterization of the heating components, by using more realistic simplifying assumptions or by choosing better values of the parameters that enter in the current model.

2. RADIATION MODEL CURRENTLY USED

The radiation model used must adequately incorporate the interactions at the surface of the earth. This is due to the fact that, very frequently, the main sources of anomalous weather for periods of a month or a season are associated with anomalous conditions in the underlying surface (NAMIAS, 1957).

The best known factors are the anomalies of ocean temperature and surface albedo, which are responsible for important air temperature anomalies and which, therefore, have to be predicted together with the meteorological variables.

The present thermodynamic model uses a simplified radiation model, in which adequate parameterizations of variables are introduced (ADEM, 1962, 1964a). To illustrate the type of parameterizations and assumptions needed, we will mention some of the ones already used in the current model:

a) For the fractional absorption of short-wave radiation in the surface, the following formula is used:

$$\alpha_1^s = \frac{Q+q}{I}(1-\alpha)$$

where $Q+q$ is the total solar and sky radiation received by the surface of the earth, α is the fractional surface albedo and I is the insolation at the top of the atmosphere.

$Q+q$ is computed using the Savino-Ångström formula

$$Q+q = (Q+q)_0\left[1-(1-k)\epsilon\right] \qquad (1)$$

where $(Q+q)_c$ is the sum of solar and sky radiation received by the surface with clear sky, k is a function of latitude and ϵ is the fractional cloud cover.

b) We assume a single cloud layer whose horizontal extent is computed by

$$\epsilon = \epsilon_N + A(G_5 - G_{5N})$$

where A is a constant, ϵ_N is the normal cloudiness and $(G_5 - G_{5N})$ is the anomaly of the heat of condensation. The latter is computed from the anomalies of the temperature and the associated circulation.

c) To compute the effects of long-wave radiation we assume black-body emission from the surface of the earth and from the clouds. For the cloudless atmosphere, a radiation model is used with one single transparent window for wave-lengths from 8 to 13 microns, and with black body emission for all other wave-lengths. These assumptions were also used recently by KIKUCHI (1969) in a two-layer general circulation model.

3. POSSIBLE IMPROVEMENTS IN THE RADIATION MODEL

We would like to improve the simplified radiation functions and parameterizations used in the present model. In this report we will outline only a few of the possibilities for improvement.

a) At present we use LONDON'S (1957) climatological values for absorption of insolation by clear sky and by clouds, and we would like to incorporate these absorptions as variables, using adequate parameterizations.

b) The coupling of the extent of snow with temperature, precipitation and other variables must also be incorporated. CLAPP (1967) has developed a non-linear method for such coupling.

c) Satellite data can be used to improve the parameterizations. For example:

CLAPP (personal communication) is attempting to improve formula (1), for absorption of insolation at the surface, by expressing the cloud transmissivity R, as a function of cloudiness itself.

HANSON et al (1967) have derived a formula for the fractional absorption of insolation by the atmosphere ove the U. S.

d) A natural xtension of this simplified model is of course to develop a multiple-layer model, including a ratospheric layer with ozone absorption. However, we don't like to introduce sophistication unless it represents an essential addition to the physics of the model, resulting in an improvement in the skill of the predictions.

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