PROGRESS REPORT ON A GLOBAL SIMULATION OF A SLICE OF THE GLOBAL CLIMATE SYSTEM

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Abstract

A dynamic modelling program (DYNAMO) of the global meteorological system has been developed for the purpose of enhancing the understanding of the variables involved in estimating the probability of the polar ice caps either melting or swelling. This program takes into account about sixty climatological variables, which are incorporated into a matrix of equations that are solved simultaneously for evaluating possible increases or decreases of ice accumulation in the polar ice caps. The key parameter in this evaluation is the accumulation of carbon dioxide in the earth's atmosphere resulting from the burning of fossil fuels. The resulting greenhouse effect perturbs the heat balance of the earth's atmosphere, generating in the changes evaluated in this study.

Because of the great number of assumptions and limited amount of available data, it is not possible to make quantitiative predictions at this time. In this ongoing study, many iterations will be needed to narrow the margin of uncertainty.

Introduction

This study comprises a block simulation program intended to show trends that could later be investigated in finer detail with a general circulation model (GCM) simulation system.

Over the past few decades, the concentration of carbon dioxide in the earth's atmosphere has increased from about 300 to 350 parts per million, and this rate of concentration appears to be accelerating. One effect of this phenomenon is to induce the warming of the earth's atmosphere, thereby perturbing the global climatology. The purpose of the following study is to explore the potential effects upon the polar ice caps. If complete melting were to occur, for instance, the mean sea level would rise about 300 feet. Accompanying this melting, the seas would be warmed several degrees. For each degree of mean temperature increase, the seawater would expand by an increased depth of about five feet.

Before indulging in alarmist tactics, however, it is incumbent on us to explore alternative scenarios. The following alternatives should be considered:

1. Melting of the ice caps accompanied by warming of the seas.
2. Massive glaciation.
3. Partial melting of the ice caps followed by massive glaciation.
4. Glaciation followed by melting of the ice caps.
5. A dynamic balance, resulting in neither melting of the ice caps nor glaciation.

The following study shows that none of these alternatives can be ruled out until more data and a better understanding of the relationships is developed. The method of approach is to construct an analytic model for the purpose of evaluating the effect of each variable upon the ice pack and then perturbing these variables over their expected ranges to determine the sensitivity. An exact analysis is not possible, and only relative, qualitative results can be obtained.

Analysis

The accompanying diagram is a representation of the analytic model employed in this analysis. Circles in this diagram represent the input sources of data. Parallel lines in these circles represent tables of previously compiled data. The "tanks" represent the levels of accumulated masses of moisture. The "valves" are the rates of flow of this moisture. The small beads are the controlling constants associated with these flow rates. The "clouds" are the oceanic sources and sinks of the masses of moisture under study. Dashed lines represent the channels of information flow, and solid lines are the paths of moisture flow.

In the upper left-hand corner, the set of circles represent the time-related increases of carbon dioxide in the atmosphere, and the accompanying heating due to the greenhouse effect. Because of uncertainties in carbon dioxide concentrations, the lower range, normal range and upper range of variation are considered.

The northern hemisphere is considered to be comprised of three zones: equatorial, temperate, and polar. Geodesic convection cells, called Hadley cells, occupy these three zones. Significant quantities of moisture are transferred from cell to cell by air currents analogous to streams in the ocean. Massive quantities of water are evaporated from the oceans and carried aloft by the Hadley cells. There, the moisture condenses into clouds and returns to the seas via precipitation. The quantity of moisture transfer and precipitation is evaluated in the DYNAMO program shown in the appendix. Equations used in this program are based primarily upon the law of conservation of matter: that which goes in equals that which goes out plus that which remains behind. Flow rates are evaluated from the best available data in the literature. References are included in the DYNAMO program shown here.

A heat balance of the polar ice pack was conducted. This heat balance took into consideration (1)longwave radiation interchange between the ice/snow surface and the ambient air and clouds, (2)shortwave radiation received from the sun, (3)reflected solar radiation due to albedo of the snow, (4)heat carried to the ice/snow by precipitation, (5)latent heat of condensation due to condensation or evaporation of moisure from the ice/snow surface, (6)convective heat transfer between air and ice/snow, (7) the degree of cloud cover, and (8)heat of fusion of melting or freezing ice/snow. The resultant quantity is the rate of sensible and latent heat increase or decrease in the ice/snow. This quantity determines the rate of freezing or melting. For the present, evaluation of convective heat transfer was held in abeyance until suitable relationships are developed. Wind velocity data are not readily available.

Results of Evaluation

After considerable difficulties were encountered in debugging the accompanying DYNAMO program, a successful run for a complete year was obtained. The greatest difficulty proved to be instability. Icing/melting seemed to progress in unstable cycles due to inaccurate evaluation of transfer of moisture between the Hadley cells and inaccurate evaluation of the rates of evaporation from the ocean surface. By the time these problems were corrected, insufficient time remained to conduct the sensitivity evaluations.

The accompanying set of curves show the following:

1. The simulation accurately tracks the experimental data on carbon dioxide increase.
2. Moisture in the Hadley cells tends toward equilibrium values in about two weeks.
3. An inconsistency exists between the rate of ice increase and the evaporation rate. Therefore, a more precise method of evaluating the temperatures at the interface between sea and air is required. More temperature data is needed for cloud conditions.
4. Temperature data in the three zones are highly responsive to carbon dioxide concentration.
5. More data are needed on cloud cover in the polar zone.

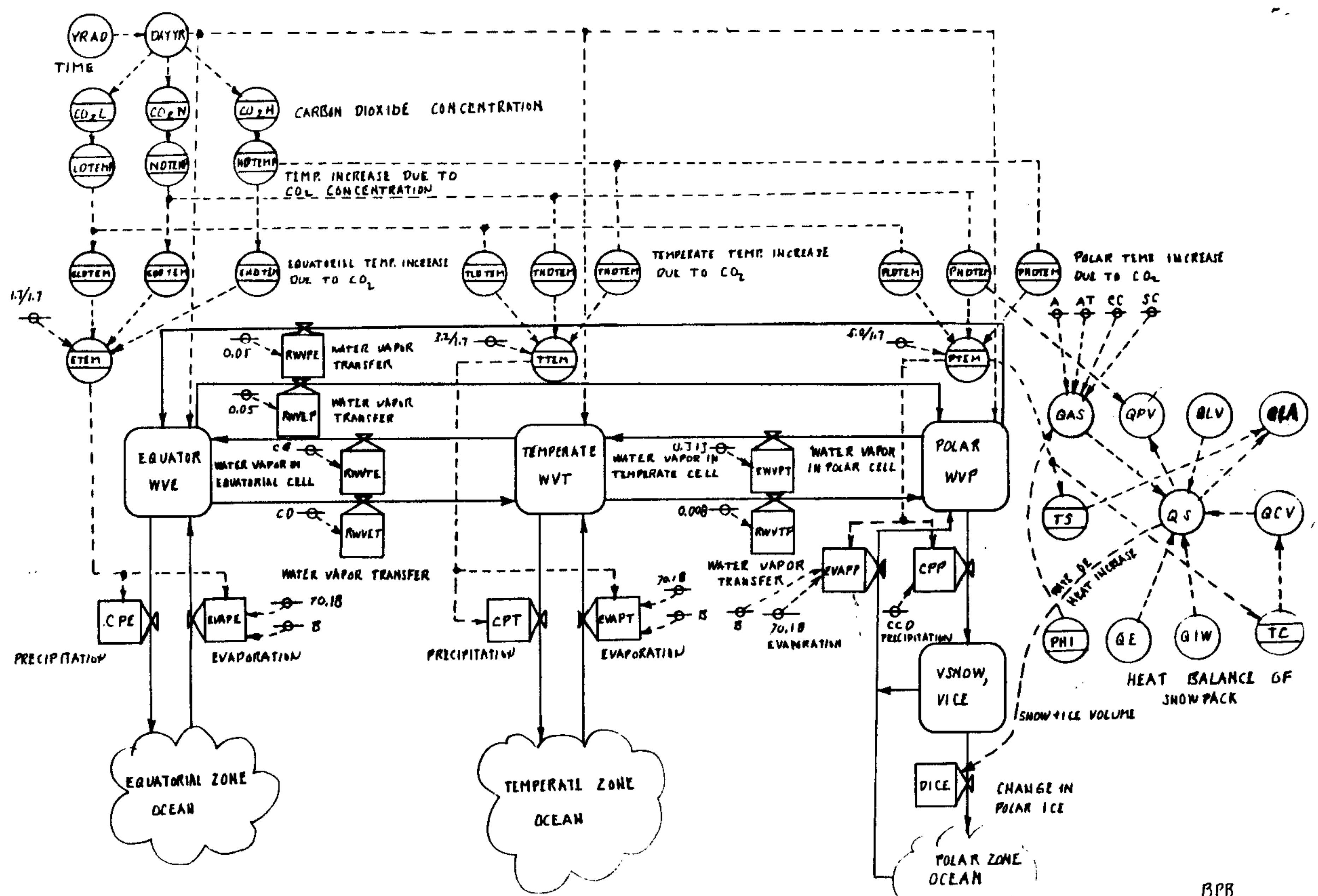
Discussion

The present approach is to prognosticate that, if the atmosphere is heated, the ice pack will melt. This is not necessarily the case, even if the temperature elevation due to carbon dioxide concentration in the polar zone is three times as great as it is in the equatorial zone. How can the heat be carried down to the ice? Warm air rises and cold air sinks down. The ice tends naturally to shield itself with a blanket of cold air. Measurements of heat balances of snow packs have shown that about 70% of the snow-melt results from direct sunlight, and 30% from all other sources combined. If the sky is overcast during the summer months, direct sunlight cannot reach the ice/snow surface.

The ratio of the total volume of the polar cells to the combined volumes of the equatorial and temperate cells can be shown to be 0.086. This means that about 12 times as much air is available for transfer to the polar zones as there is available to be carried away from the polar zones. A small increase of evaporation in the equatorial and temperate zones can result in a twelve-fold increase of precipitation in the polar zones. Increased transport of moisture to the polar zone will tend to increase the cloud cover there. Such a combination of circumstances could readily result in massive glaciation.

On the other hand, convective heat transfer and warm rains could conceivably negate this tendency toward galciation. Thus, a dynamic balance between glaciation and melting is possible.

The only conclusion that can be drawn at this time is the the results are inconclusive. More data are needed and more advanced analytic techniques need to be developed to resolve the key questions. Crude approximations have been shown to be inadequate. The value of this simulation program can be greatly enhanced by means of a constructive dialog between the interested parties. Specialists in climatology, metoerologists, generalists and cyberneticians can all contribute materially to this study by working together rather than by competing. Considering that the future of our earth might be at stake, such cooperation is imperative.



DYNAMO MODEL FOR EVALUATION OF POLAR ICE CAP MELTING OR GROWTH