A DISCUSSION ON THE PREDICTABILITY OF GLOBAL CHANGE

The International Geosphere-Biosphere Programme (IGBP) has come into its new phase, since the First Meeting of the Scientific Advisory Council for the IGBP, Stockholm, October, 1988. A plan for action is being worked out by each Coordinating Panel and Working group of IGBP. The implementation phase of the IGBP is scheduled to begin in 1991.

In the procession of designing the core projects of IGBP and selecting the key areas for priority in the IGBP, some fundamental problems of philosophy and methodology of global changes need to be discussed further. In this note we shall address only the predictability of global change.

As described in the Report No. 4 of IGBP (1988) 'a primary goal of the programme is to advance our capability to predict changes in the global environment'. This is a scientifically exciting problem as well as being immensely significant in charting the future of our species. To discuss this extremely challenging scientific problem, we would like to raise the following points:

I. The Clarification of What We Want to Predict

To address this problem one has to clarify first what we are going to predict in the sense of global change.

Of course we hope to be able to predict the change of earth as a whole system rather than its individual components which are studied by many other existing programmes. But since the earth system is such a complex one, how do we define the whole system? What are the most important elements of the system which we are going to predict? These are fundamental questions that need to be studied.

There may be many different choices for prediction. For instance, one may like to predict the renewable resources of earth system in the future (i.e., from decade to century) which consists of water resources, soil resources, climate resources and biota resources, their quantity and quality. These are the four fundamental conditions for human life. One may want to predict the changes of global landscape, which is also crucial for human life such as the vegetation zones (natural forests, grassland and agricultural distribution), deserts, lake areas, glaciers and so on. Or we may want to predict some other things which are of global nature.

Is it a good strategy that at the very beginning we are entangled in such a complex problem to predict changes in global environment as a whole? Would it not be a good idea to start from a simpler problem, but still very complex and highly important to human beings?
We would like to suggest that two steps should be undertaken to address the issue of predicting global change. The first step may deal individually with several main components of global change, such as the changes of renewable earth resources in the future, the global landscape changes and so on. And then the second step is to address an integrated prediction of global change, i.e. the change of the earth system as a whole. In this second step, the method of system dynamic analysis should be applied to aggregate our knowledge from the first step.

II. Predictability

After choosing the objectives of prediction, then comes the predictability problem: Whether the potential changes of these individual components are predictable scientifically.

To what extent (how long? how accurate?) the future of a system can be predicted depends mainly on three factors: memory of the system, external forcing and our scientific capabilities. Of these three factors we shall only discuss the first two. For different systems, the memory and the external forcing are different. Since the final aims of prediction are not clear yet, we are going to discuss this matter in general, i.e., the prediction of the change of the whole earth system as our aim.

1. Memory

Since the time-scale of IGBP has been set to be decade to century, any components of the earth system which can memorize things longer than this time-scale may be said to have a good memory. Due to its slow motion, its huge heat capacity and its power to absorb CO$_2$, deep ocean has a good memory. Some components which may not possess good memory individually may become so when they interact nonlinearly with others. As was discussed by Lorenz, a system of three simple components which interact nonlinearly with each other may produce changes in state with certain recurrent features to some extent. This is highly useful for prediction. We may call this 'nonlinear memory'. The GCMs may simulate the variability of climate elements (as temperature or precipitation) which agrees fairly well with the observed one. This may be attributed to its 'nonlinear memory'. The earth system, when left alone without any external forcing, may also possess 'nonlinear memory'. To explore the predictability of the earth system, the problem of memory needs to be studied.

2. Forcing Factors

Forcing factors may be classified into two kinds. One is from exterior, chiefly the sun. It may be called external forcing. Because the sun is an obvious source of external forcing we shall not discuss it. Another kind of forcing which comes from