WORKSHOP ON THE NUMERICAL-DYNAMICAL MODELING OF THE GREAT LAKES, CANADA CENTRE FOR INLAND WATERS, 1971

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ON THE

NUMERICAL-DYNAMICAL MODELING OF THE GREAT LAKES

Canada Centre for Inland Waters
August 23 - 24, 1971

Summary of Discussion

by

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1. *Objectives and agenda*

The workshop originated out of private communications of scientists involved in hydrodynamic lake modeling at the Great Lakes Conference held in Toronto April 19 - 21, 1971. In view of the recent explosion of numerical models of the Great Lakes it was felt that it would be desirable to organize the respective projects into a more coordinated modeling program. As a first step towards this goal a workshop on the numerical-dynamical modeling of the Great Lakes was planned for August 23 - 24, 1971, at the Canada Centre for Inland Waters in Burlington. Invitations were sent to scientists at a great number of U.S. and Canadian institutions actively engaged in this field or research. The objectives of the meeting were outlined to be:

(1) to consolidate the current status of knowledge on numerical modeling in geophysical hydrodynamics

(2) to evaluate current techniques and to consider the feasibility of developing and utilizing new methods

(3) to outline directions of future studies and to determine areas where applications of concepts and techniques of numerical modeling are most promising

(4) to determine the time-and-space-scales which at present are most relevant with regard to the study of the behavior and the properties of the Great Lakes

(5) to evaluate the time-and-space-density of meteorological and limnological standard observations and to make recommendations for improvements

(6) to plan a concentrated and well coordinated international modeling program on the Great Lakes Basin

(7) to issue a summary of discussion to inform the scientific community of the conclusions and recommendations of the workshop.

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The meeting was convened at 9:00 a.m. on August 23, 1971, with a welcoming address by Dr. Richard Vollenweider, Chief of the Lakes Division of the Canada Centre for Inland Waters. Each of the participants then presented a brief summary of his current modeling work. The afternoon session of August 23rd was devoted to a general discussion on the numerical and physical aspects of lake modeling. This exchange was continued on a more informal basis at the dinner in the evening. The next morning's discussion placed particular emphasis on recommendations for the future modeling program of the Great Lakes Basin. The discussion sessions were moderated by Professor George Platzman of the University of Chicago. A brief review of the entire proceedings follows and a list of participants is attached to this report.

The general consensus of the participants was that the meeting was fruitful and that such informal exchange of ideas could contribute substantially to the progress of the modeling program. The suggestion was therefore advanced to meet on an annual basis and it was decided to plan the next workshop for the later part of August 1972, at the Center for Great Lakes Studies, University of Wisconsin-Milwaukee.

2. *Review of current numerical-dynamical models*

A number of people are experimenting with steady state models, either homogeneous or stratified two-layer. The homogeneous models are found to be successful and apparently such models are available for all the Great Lakes. Current investigations in this field are directed towards improved treatment of bottom friction and shore configurations, including islands. Although the two-layer solutions have not yet reached a comparable level of success some preliminary work in this direction is now being done.

In the category of time dependent models a great amount of work has been done on vertically integrated one-layer configurations to simulate the behavior of a quasi-homogeneous lake. Most of these models are of the storm-surge type and they are used for various purposes such as the study of transient free surface phenomena including normal mode solutions as well as the longer term circulation patterns. The time dependent circulations are also being investigated with the help of rigid top models. Again the models vary widely with respect to mathematical techniques and parameterization of physical processes such as the effects of lateral boundary layers.

Recently progress is also being made in the development of three-dimensional time dependent lake models. Depending on the purpose of the investigation and the type of stratification to be simulated two alternative methods of approach are employed. One technique utilizes fixed permeable levels (or a three-dimensional

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grid) while the other tries to model the summer stratification of the Great Lakes by visualizing the thermocline as a material interface. Attention is focussed on such crucial matters as interfacial stresses and the intersection of the thermocline with the free surface and a sloping bottom.

To tie in with such three-dimensional circulation models numerical simulations of the annual lake stratification cycle are carried out. Initial attempts are made to consider the large-scale interactions generated by coupling of the thermodynamics with the hydrodynamics of the lakes.

At the same time parallel studies are being carried out on closely related topics such as laboratory modeling of rotating basins and numerical simulation of convective processes and the dispersion of thermal plumes. In order to study the interaction of the lakes and the atmosphere and to provide the necessary input for the hydrodynamic models, the numerical prediction of meteorological parameters for the Great Lakes Basin is being improved and attempts will be made to establish more accurate relationships between wind velocities and the transport of momentum to the water surface.

3. *Summary of discussion*

In the course of the discussion various aspects of the modeling problem were debated. A few topics in particular seemed to capture the interest of the attending scientists. An effort will be made to extract the essence of the exchange of opinions in the following.

First there was a general category of questions relating to the details of the numerical techniques. The majority of the lake models employ conventional methods of finite differencing which have been developed to a high level of sophistication in closely related fields of science (e.g. numerical weather prediction). It became evident, however, that some models were constructed on the principles of the "finite-element-method" and a lively exchange followed on the relative merits of these methods. It was suggested that the finite-element-method becomes more convenient when a complicated irregularly shaped region is involved such as a natural lake basin. A few investigators hope to make more quantitative comparisons of these schemes in the near future.

In contrast to the above mathematical approach another more physical problem was raised, namely, the importance of the horizontal diffusion with particular reference to the coastal boundary layer. The opinion was advanced that the large scale circulation of the lakes might be computed without a detailed knowledge of the

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near-shore processes although considerable divergence of opinion on this matter was apparent. There was general consensus of opinion, however, that (a) our knowledge of the horizontal diffusion processes is at best inadequate to incorporate these with any degree of confidence, and (b) the degree of importance of the lateral diffusion depends on the character of the problem under investigation. It was also emphasized that the modeling of coastal phenomena would call for a variable mesh with high resolution near the shore along with the retention of non-linear acceleration terms, and the numerical problems associated with "grid-patching" were discussed.

Next the discussion moved towards the subject of verification of hydrodynamic models. Three possible alternatives were suggested. As a first step it might prove useful to run numerical models against ideal basin studies for which analytical solutions in closed form are available. It was recalled that similar studies were undertaken in the early days of numerical weather prediction. As a next step one should consider a few more realistic but at the same time fairly straight-forward problems such as the homogeneous circulation of one of the Great Lakes under idealized wind conditions. It was felt to be of great interest to compare the performance of the various models from the viewpoint of both accuracy and economy. As a final step it would then be possible to identify a number of past or future cases of record which are to be analyzed to the fullest extent and subsequently utilized for comparative testing of existing and future numerical models.

At this point the forthcoming IFYGL program was enthusiastically considered as an ideal opportunity for model verification. Various aspects of the measurement program were elaborated on by those among the participants who are involved in the IFYGL project. The attention then focussed on the ways and means of utilizing the output of the field program in the most profitable manner. A desirability was expressed to bridge the gap between the scientists involved in field work on the one hand and those engaged in modeling on the other. It was felt by several participants that there was a need for selective evaluation of the data by scientists who are familiar with analyzing and interpreting field data. The availability of detailed analyses of particularly interesting episodes instead of the raw data would not only prevent duplication of effort but also offer an opportunity for objective comparison of model performance.

As might be expected from the informal atmosphere at the meeting the proposed agenda of discussion was largely ignored and the primary train of thought was frequently interspersed with miscellaneous remarks. This added greatly to a free and lively exchange of scientific and other information. In retrospect it is concluded that certain clear lines of opinion emerged from this encounter resulting in a number of recommendations, the most significant of which follow.

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4. *Conclusions and recommendations*

In view of the informative character of this workshop it was agreed to try and continue the existence of this group on the present informal, non-organizational basis. Annual meetings of the group are visualized and the next workshop is planned for August, 1972, at the Center for Great Lakes Studies, The University of Wisconsin, Milwaukee. Scientists who did not attend this workshop but are interested in attending future meetings may contact D. B. Rao at the above address.

To further enhance the exchange of information it has been decided to distribute copies of manuscripts related to the Great Lakes modeling program to all participating scientists in order to offset the delay associated with reviewing and publication. In cases where it is not practical to distribute copies of the entire paper a detailed summary will be substituted. It is understood that this agreement will in no way interfere with the author's publication plans.

From the briefings by the individual scientists at the beginning of the workshop and the ensuing discussion it became apparent that a great diversity of lake models already exists. Consequently the view has been advanced that a need exists for a critical review of the current lake models. Such a study would not only benefit the modeling scientists but would also have tremendous informative value for the Great Lakes community at large.

Recognizing the vital importance of accurate information on meteorological parameters which constitute the input variables for the hydrodynamic models, it is urged that steps be taken to improve the weather analysis and prediction over the Great Lakes basin. In addition, a systematic study on the relationship between the stresses on the lake surface and the synoptic scale wind field is imperative.

It is clear that the hydrodynamical models of the Great Lakes still leave room for significant improvement. This can only be achieved by capturing the interests of both the theoretical fluid dynamicists and the observational limnologists. In view of the large spectrum of disciplines involved, no opportunities should be lost in improving communications between such diverse groups.

In the final analysis, it is understood that the hydrodynamic modeling is only one step towards the ultimate goal of modeling the ecological system of the Great Lakes. In order to achieve this goal, various steps should be taken. Foremost in this respect is the need to open a dialogue with chemical and biological limnologists to determine their requirements in this regard. It is, therefore, anticipated that future meetings will have sufficient input from these disciplines.

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The following people were not able to attend the workshop because of other commitments, but they have expressed their desire to be placed on the mailing list and to receive any information on future programs.

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