

INTRODUCTION TO DYNAMIC MODELLING WORKSHOP

A CCME Sponsored Workshop

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BACKGROUND

Canada and the U.S. have agreed to reduce emissions of sulphur dioxide and nitrogen oxides by the year 2010 and are working towards further reductions beyond that date. The goal of these emission reductions is to reduce acid deposition and, thereby, reduce impacts on lakes and forests resulting from exposure to acids. Dynamic acidification models are being utilized to forecast the effects of these reductions on ecosystems. Such projections allow politicians, managers and industry to understand how decisions regarding the production of acidifying emissions will affect the rate and extent of achievement of critical loads. Of the models available currently, the Model of Acidification of Groundwater in Catchments (MAGIC) developed by Dr. B.J. Cosby of the University of Virginia is one of the best.

WORKSHOP FORMAT AND OBJECTIVES

Acid rain experts from the federal and provincial governments and the university community participated in a CCME sponsored workshop on Dynamic Modelling. The workshop featured three experts: Dr. B.J. Cosby, from the University of Virginia, who developed MAGIC; Tom Clair, from Environment Canada (Atlantic Region), who has been applying MAGIC to watersheds in Nova Scotia; and Dr. P. Arp, from the University of New Brunswick, who developed a Dynamic Model for Forest Soil Geochemistry.

The objectives of the workshop were the following: 1) To transfer knowledge and expertise on the MAGIC model to watershed-based researchers across Canada; 2) To summarize our state of knowledge on nitrogen dynamics in watersheds; and, 3) Determine how our understanding of nitrogen dynamics can be better simulated by the MAGIC model.

KEY OUTCOMES

Why do we need dynamic models?

Dynamic models serve four key purposes; 1) they enable researchers to conceptualize the complex geochemical reactions that govern the acidification and recovery of ecosystems; 2) they facilitate the detection of knowledge and data gaps; 3) they enable researchers to make predictions regarding the response of ecosystems to changes in acid deposition and other environmental parameters, and; 4) they enable researchers to communicate the potential effects of changes in acidifying emissions on the rate and extent of ecosystem response. For these reasons, dynamic models are an excellent tool for furthering our understanding and communication of the interrelationships between emissions and ecosystem health.

What is MAGIC and how does it work?

MAGIC, developed by Dr. B.J. Cosby, stands for Model of Acidification of Groundwater in Catchments. It is a process oriented and lumped-parameter model of intermediate complexity that simulates short- and long-term geochemical and biological processes.

There are two types of geochemical reactions that are incorporated into MAGIC's mathematical structure. One type consists of equilibrium (short-term) reactions between the soil and the soil solution as well as rapid biological processes. The other type consists of input-output reactions (long-term) describing fluxes of acids, bases, and neutral salts into and out of the soil layers and watershed.

Applications of MAGIC

Analyses using MAGIC can be performed on a single site or over a region. The model is most frequently run on an annual time scale but is able to run on monthly, seasonal, decadal or centennial time scales. The model is usually calibrated for approximately 20 years worth of observations. Once calibrated, the model can be used to predict the affects of various emission scenarios on soil and watershed chemistry.

In some cases, there is a greater conceptual knowledge of certain processes than observations to accurately quantify these processes (e.g. nitrogen fluxes). One advantage of MAGIC is that it allows the user to turn conceptual cycles on or off in order to perform different analyses and observe how various processes affect ecosystem response.

One of the challenges of using MAGIC, and dynamic models in general, is presentation of results. Model outputs need to be conveyed to decision makers in a way that is easily understood and conducive to decision making. In some cases, decision makers may only need to know the past, current and future situation as opposed to the processes that govern these outcomes. In other cases, more detailed information is required in order to give decision makers flexibility in a complex decision-making situation.

Testing and Calibration

One way to test the validity of MAGIC's predictions is to compare results to actual observations. Other, less rigorous, validation techniques include the comparison of MAGIC's predictions to those of other models.

MAGIC can be calibrated through the input of observations (e.g., deposition chemistry, physical and chemical soil parameters, water balance), through a comparison of observations (e.g., chemistry of surface water and soil solution, soil base saturation), and by calibrating/optimizing physical and chemical parameters (e.g., weathering rates, soil and surface water organic content, etc.). A program called MAGIC Opt performs the optimization function in a relatively short period of time.

Dynamic Model for Forest Soil Geochemistry

A second dynamic model was also introduced to participants at the workshop. The Dynamic Model for Forest Soil Geochemistry, developed by Dr. P. Arp, uses a dynamic model for forest soil geochemistry to calculate critical loads for forest soils. Currently, the model has mostly been applied to calculate critical loads at steady state rather than forecasting the time to achieve (or exceed) critical loads under various emission scenarios. The model has been used to calculate critical loads for upland forests in the eastern Canadian provinces including Ontario.

ACCOMPLISHMENTS OF WORKSHOP

The workshop was very successful in transferring knowledge on dynamic models to the Canadian acid rain research community. The presentations led to energetic discussions on potential applications of the model in Canada. Many participants expressed interest in applying MAGIC to their study sites.