Hydrology models (Hydrology)

Table of Contents

Biophysical models: Hydrology **1/3**
- 1 Introduction 1/3
- 2 Methodology 1/3
- 3 Process 1/3
- 4 Review 1/3
  - 4.1 Evaluation results 1/3
  - 4.2 Experiences 1/3
  - 4.3 Combinations 2/3
  - 4.4 Strengths and weaknesses 2/3
  - 4.5 Further work 2/3
  - 4.6 References of the tool 2/3

Biophysical models: Hydrology

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1 Introduction

Hydrological models contain mathematical descriptions of the major elements of the water system, i.e. rivers, lakes, groundwater, soil, snow. Oceans and atmosphere are usually not considered. They area able to capture the impact of natural (e.g. climate change) and/or anthropogenic (e.g. water withdrawals) disturbances on the fluxes and states of elements in the water cycle, e.g. runoff, evapotranspiration, groundwater recharge and soil moisture. Hydrological models can be applied on different scales, ranging from local to global, with the degree of complexity usually being dependent on the scale for which they were designed. Some models cover water quality or other ecological aspects.

2 Methodology

Mathematical descriptions of the major water stores and water flows between the different compartments of the water system are the backbone of hydrology models. Deterministic hydrological models are based on the conservation equations of mass and energy or on simplifications thereof. They are driven by meteorological forcings like precipitation and radiation interacting with vegetation, land surface, soils and geological settings. Scenarios on natural and anthropogenic disturbances are fed into the models and the resulting changes in water flows and stocks are calculated. Results are usually presented based on Geographic Information Systems (GIS).

3 Process

The major elements of the water sub−system under investigation have to be identified (river basin, sub−basin, or hydrotope). A specific model type has to be selected, parameters have to be estimated and the model has to be calibrated and validated. Scenarios on relevant disturbances (e.g. climate change, irrigation needs) have to be derived from other models or other external sources. Modelling results have to be interpreted and related to their geographical location using GIS. Uncertainty analysis has to be conducted.

4 Review

4.1 Evaluation results

The water cycle provides an important link between human activities and environmental processes. Hence, hydrology models represent a very important tool in modelling the Earth system. They are very flexible with regard to spatial disaggregation, though sometimes suited for particular scales only (with respect to the detail of process representations). There are many important links to other natural and socio−economic phenomena. However, most hydrology models have a strong natural scientific bias, anthropogenic processes are often under−represented. Model coupling with socio−economic models has to be improved, but this is a huge challenge, as hydrology models in themselves are already very complex. The demand for computer power is high.

4.2 Experiences

Changes in the water cycle have been analysed on the global level, the river−basin level, and the sub−basin level. Aspects of global climate change, irrigation demand for food production, and river management options have been important research topics. Hydrology models could play an important role in analysing the impacts of increasing water demand for food, biofuels and nature services, especially in a regional context, i.e. for certain river basins.

4.3 Combinations

Various Integrated Assessment studies on the impact of climate change and population growth.

4.4 Strengths and weaknesses

Strengths:

- Consistent representations of the water cycle, one of the basic requirements of life
- Highly flexible in temporal and spatial scaling
- Strong relationship with many other natural and social processes
- Provide crucial links between environment and anthroposphere
- Validation on observed data, e.g. river flow, is often possible
- Requirements of a closed water balance provides good testing capability for programming errors

Weaknesses:

- Limited coverage of anthropogenic processes
- High complexity (except for some macro−scale models)
- Highly non−linear behaviour possible (though these are inherent to the water system)
- Potentially high demand for computer power
- Deterministic modelling requires good knowledge of hydrological processes and strong efforts for parameter estimation from physical basin characteristics

4.5 Further work

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4.6 References of the tool

Selected models:

WaterGAP

http://www.usf.uni−kassel.de/usf/forschung/projekte/watergap.en.htm

SWIM

http://www.pik−potsdam.de/~valen/swim_manual/

IRM−ABM

Valkering, P., J. Krywkow, et al. (forthcoming). “Simulating stakeholder support in a negotiation process: an application to river management.” Simulation: Transactions of The Society for Modeling and Simulation International.

Overview of other hydrology models:

Singh, V.P. and Frevert, D.K. (Editors), 2002a. Mathematical models of large watershed hydrology. Water Res. Publ., Chelsea, Michigan, 891 pp.

Singh, V.P. and Frevert, D.K. (Editors), 2002b. Mathematical models of small watershed hydrology and applications. Water Res. Publ., Chelsea, Michigan, 950 pp.

Server for mathematical models in ecology:

http://eco.wiz.uni–kassel.de/ecobas.html