



Improved Processes & Parameterisation
for Prediction in Cold Regions

Cold Regions

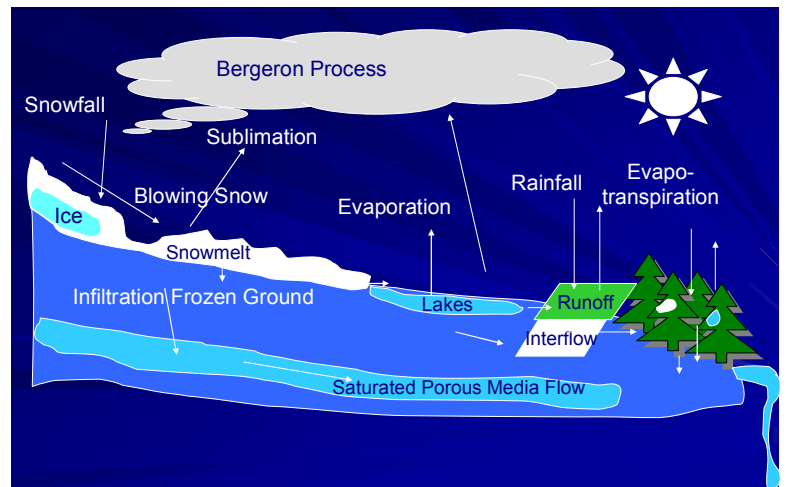
Hydrological Model

SUMMER 2009

The Cold Regions Hydrological Model (CRHM)

IP3 is a research network funded by the Canadian Foundation for Climate and Atmospheric Sciences (CFCAS) for 2006-2010. The network is comprised of investigators and collaborators from across Canada, the US and Europe and is headquartered at the University of Saskatchewan's Centre for Hydrology. IP3 is devoted to an improved understanding of the study of water and weather systems in cold regions, particularly Canada's Rocky Mountains and western Arctic.

The Cold Regions Hydrological Model (CRHM) is a software platform for building physically-based hydrological models over small to medium sized basins. CRHM models blowing snow, snow interception in forest canopies, sublimation, snowmelt, infiltration into frozen soils, hillslope water movement over permafrost, actual evaporation, and radiation exchange to complex surfaces. CRHM is a research and predictive tool that can rapidly incorporate new parameterisations and connect them over a basin to simulate the cold regions hydrological cycle. Landscape elements in CRHM can be linked episodically to mimic natural process sequences via blowing snow transport, overland flow, organic layer subsurface flow, mineral interflow, groundwater flow, and streamflow. CRHM has a simple user interface but no internal provision for calibration: parameters, observations, and model structure are selected to reproduce the fundamental behaviour of the particular hydrological system being studied.



Cold Regions Hydrological Cycle

CRHM Objectives

To develop a **hydrological cycle simulation** system that:

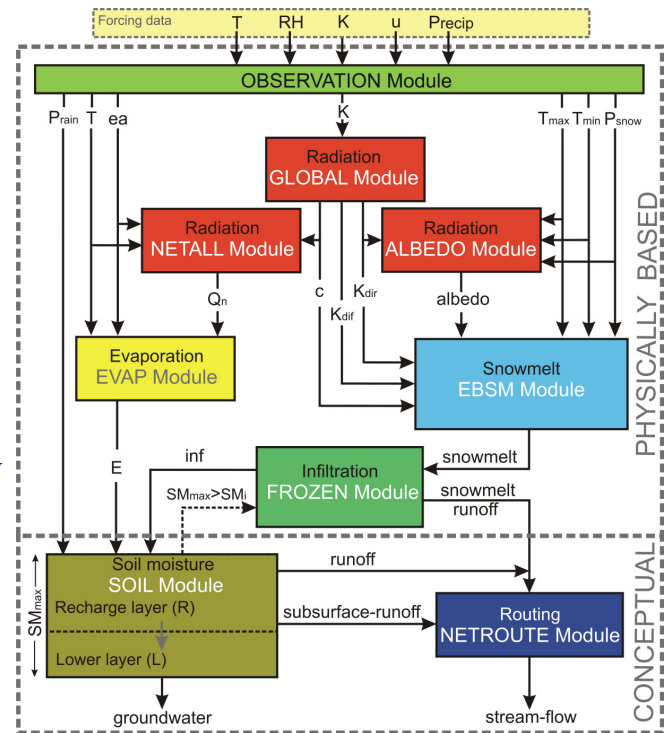
- Is spatially distributed such that the water balance for selected surface areas can be computed;
- Uses natural landscape units that have hydrological importance;
- Is physically based so that results contribute to a better understanding of basin hydrology and robust so that process parameters can be transferred regionally;
- Is sensitive to the impacts of land use and climate change;
- Reflects landscape sequencing in natural drainage basins;
- Does not require the presence of a stream in each land unit;
- Is flexible; can be compiled in various forms for specific needs;
- Is suitable for testing individual process algorithms;
- Is easy to use for all hydrologists and useful for teaching;
- **Is not dependent upon calibration.**



CRHM Modules and Structure

The complete set of CRHM modules can be classified into the following categories:

- Basin:** Basin and hydrologic response unit (HRU) physical, soil, and vegetation characteristics (reference definition for HRU in specifications below)
- Observation:** Interpolates meteorological data to HRU using adiabatic relationships and saturation vapour pressure calculations
- Snow Transport:** Blowing snow transport and sublimation
- Interception:** Rainfall interception, snowfall interception, snow interception in forest canopies and sublimation
- Radiation:** Shortwave direct and diffuse algorithms, slope corrections, snow albedo decay, longwave radiation, canopy transmissivity and net radiation
- Evaporation:** Several physically-based methods for unsaturated and saturated surfaces including transpiration
- Snowmelt:** Energy balance snowmelt, radiation index, temperature index, snow cover depletion and simple land surface scheme melt methods
- Infiltration:** Basic and parametric infiltration routines for frozen soils, frost depth calculation, Green-Ampt infiltration and redistribution for unfrozen soils
- Soil Moisture Balance:** Multiple flowpath 2-layer "bucket" model with sub-surface flow, groundwater, depositional storage and "pond" options
- Flow:** Organic layer flow, timing and storage control of overland flow, mineral interflow, and streamflow, using the lag and route hydrograph and Muskingum routing methods



CRHM Specifications

The CRHM interface consists of a native Microsoft Windows application written in C++ that can be run in XP, Vista, Linux and the Macintosh environment. The data are plotted as the model runs, and the results can either be exported to a text file, ArcGIS, or an EXCEL spreadsheet. The exported data can then be taken into other programs which are used for post-processing of the data, or the data can be used to drive other models. CRHM can be run in either spatially-distributed or aggregated modes to show the effect of differing model resolution. The basic unit of calculation in the model is the HRU (Hydrologic Response Unit), which is a spatial unit represented in the basin through three groups of attributes:

Biophysical structure: soils, vegetation, slope, elevation and area

Hydrological state: snow water equivalent, snow internal energy, intercepted snow load, soil moisture and water table

Hydrological flux: snow transport, sublimation, evaporation, melt discharge, infiltration, drainage and runoff

CRHM was developed and coded by Modeller Tom Brown based at the University of Saskatchewan's Centre for Hydrology.



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