

The Cold Regions Hydrological Model: update to 2007 IP3 workshop

C. Ellis, J. Pomeroy, T. Brown and C. Spence

Purpose of CRHM

- Provide a flexible tool to describe the processes and flows in a basin and to assess the adequacy of current knowledge for various predictive tasks.
- Provide a modelling system by which new parameterisations can be rapidly tested in the context of existing parameterisations.
- Archive cold regions hydrology processes and basin algorithms that are not normally available in hydrological models
- Make field data analysis and modelling accessible to a larger community through a simple user interface and visualisation tools.

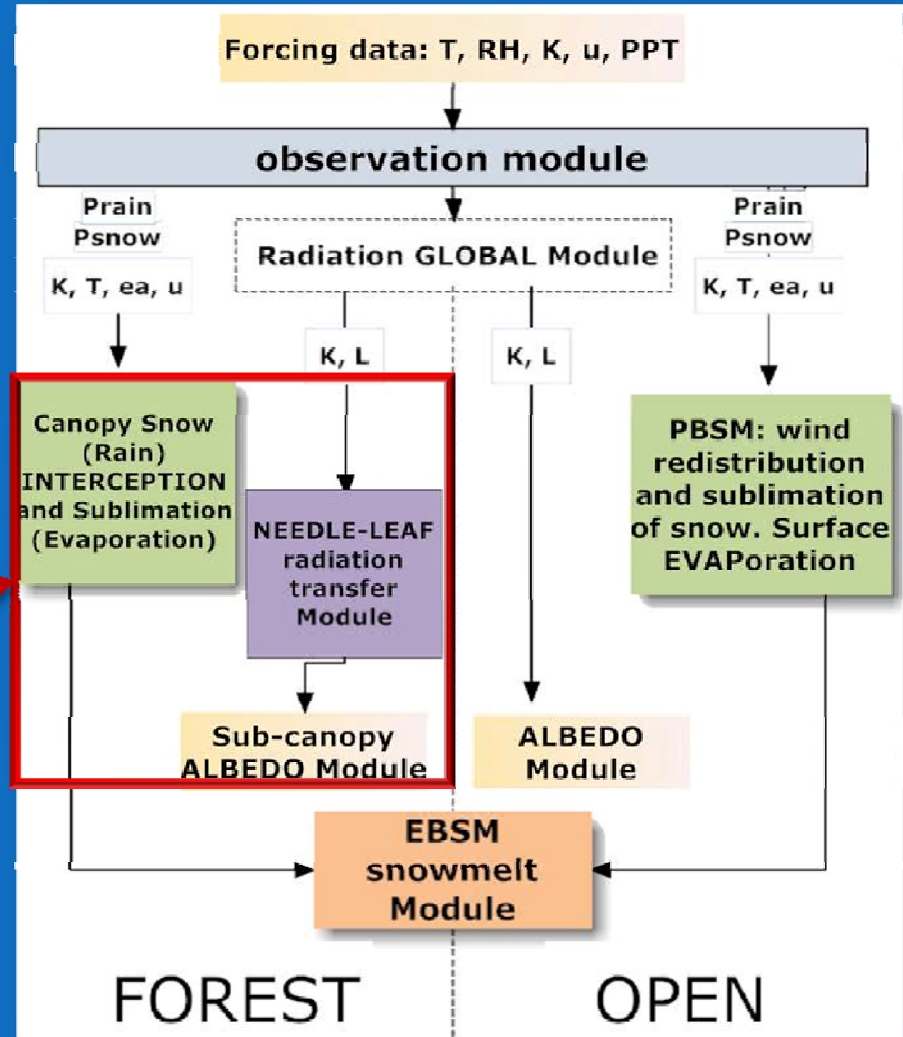
New Modules

- *Snobal*- layered physically based snow energy balance model (Marks et al. 1998) – unique linkage to *PBSM*.
- *Trees*- new forest energy and mass balance module.
 - Short and longwave radiation transfer
 - Snow interception, sublimation, unloading
 - Rainfall interception, drip, evaporation
 - Sub-canopy turbulent transfer parameterisation
- *Wamsley Wind*- wind speed correction for topography
- *Evap* - greater variety of evaporation models. Penman-Monteith, Bulk Transfer

New Modules: *Trees*

Basic model schematic

Trees



New Modules: *Trees*

Shortwave irradiance: The transmissivity (τ) of the canopy layer to above-canopy shortwave irradiance (K_{\downarrow}) is estimated as a function of the effective-leaf-area index (LAI^*) and solar elevation angle (θ) by:

$$\tau = \exp[-1.081 (\theta) \cos(\theta) LAI^* / \sin(\theta)]$$

Sub-canopy longwave irradiance ($L_{sc\downarrow}$) is determined as the sum of above-canopy longwave irradiance (L_{\downarrow}) and forest emissions weighted by the relative proportions of open sky (ν) and canopy-cover ($1 - \nu$) of the overhead forest scene:

$$L_{sc\downarrow} = L_{\downarrow} (\nu) + (1 - \nu)\varepsilon\sigma T^4$$

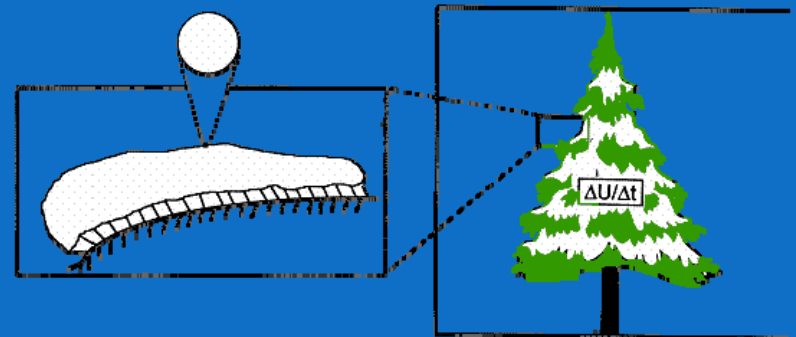
where ε is the emissivity of the forest (~ 0.98), σ is the Stephan-Boltzmann constant ($W m^{-2} K^{-4}$) and T is the physical temperature of the forest (K).

New Modules: *Trees*

Interception : Intercepted snow and rain by the canopy is subject to sublimation and evaporation back to the atmosphere, respectively. The amount of snowfall, P (kg m^{-2}) that may be intercepted by the canopy prior to unloading is related to the (i) antecedent intercepted load, L_o (ii) the maximum intercepted load, I^* (which is related to LAI and the density of falling snow) and the 'canopy-leaf' contact area, C_p via (Hedstrom and Pomeroy, 1998):

$$I = (I^* - L_o)(1 - \exp[-C_p P / I^*])$$

Sublimation: estimated by a multi-scale model approach: *ice-sphere to branch to canopy*





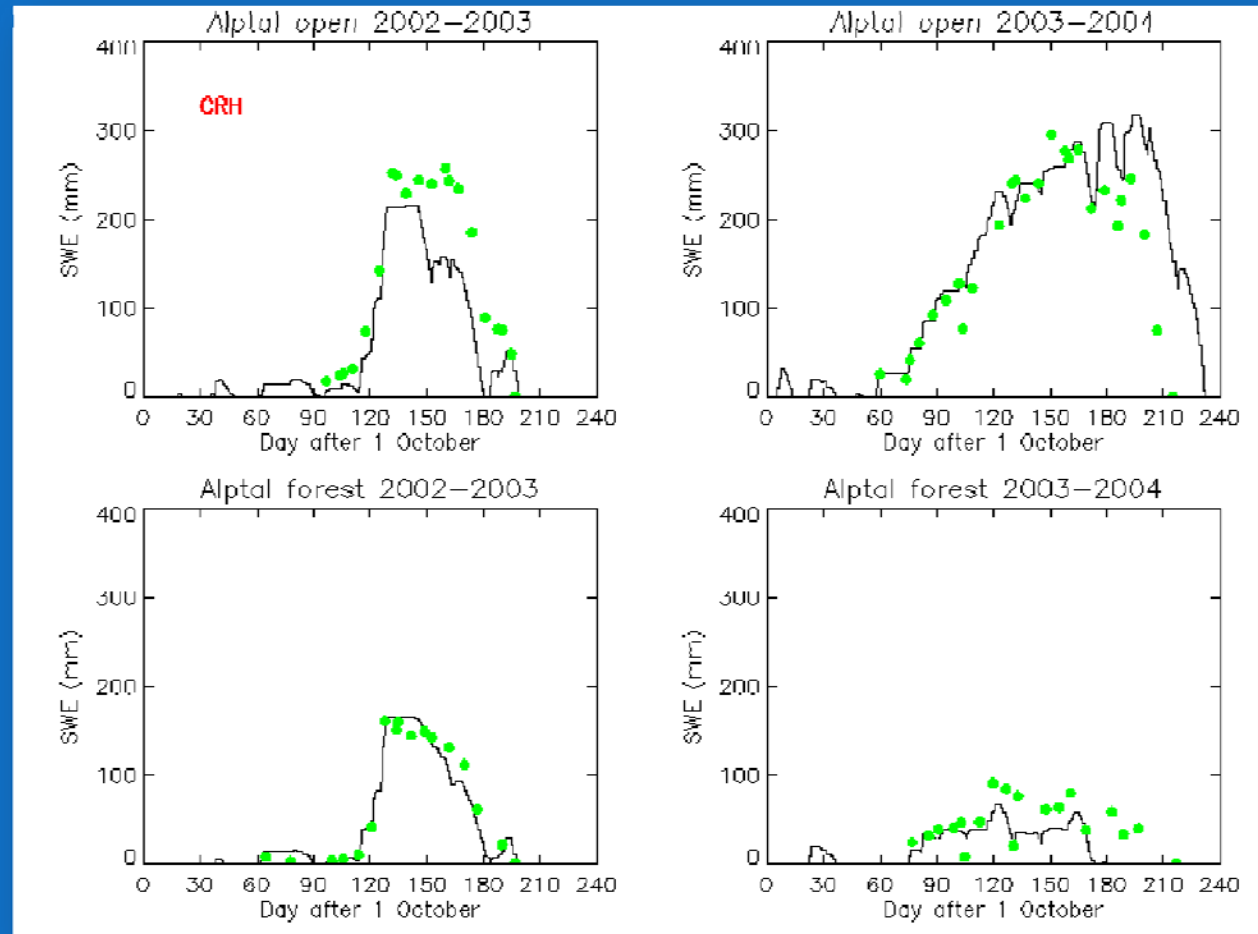
Effect of forest cover on snow accumulation and melt

SnowMIP2 runs: Alptal, Switzerland:

open site

2002-03

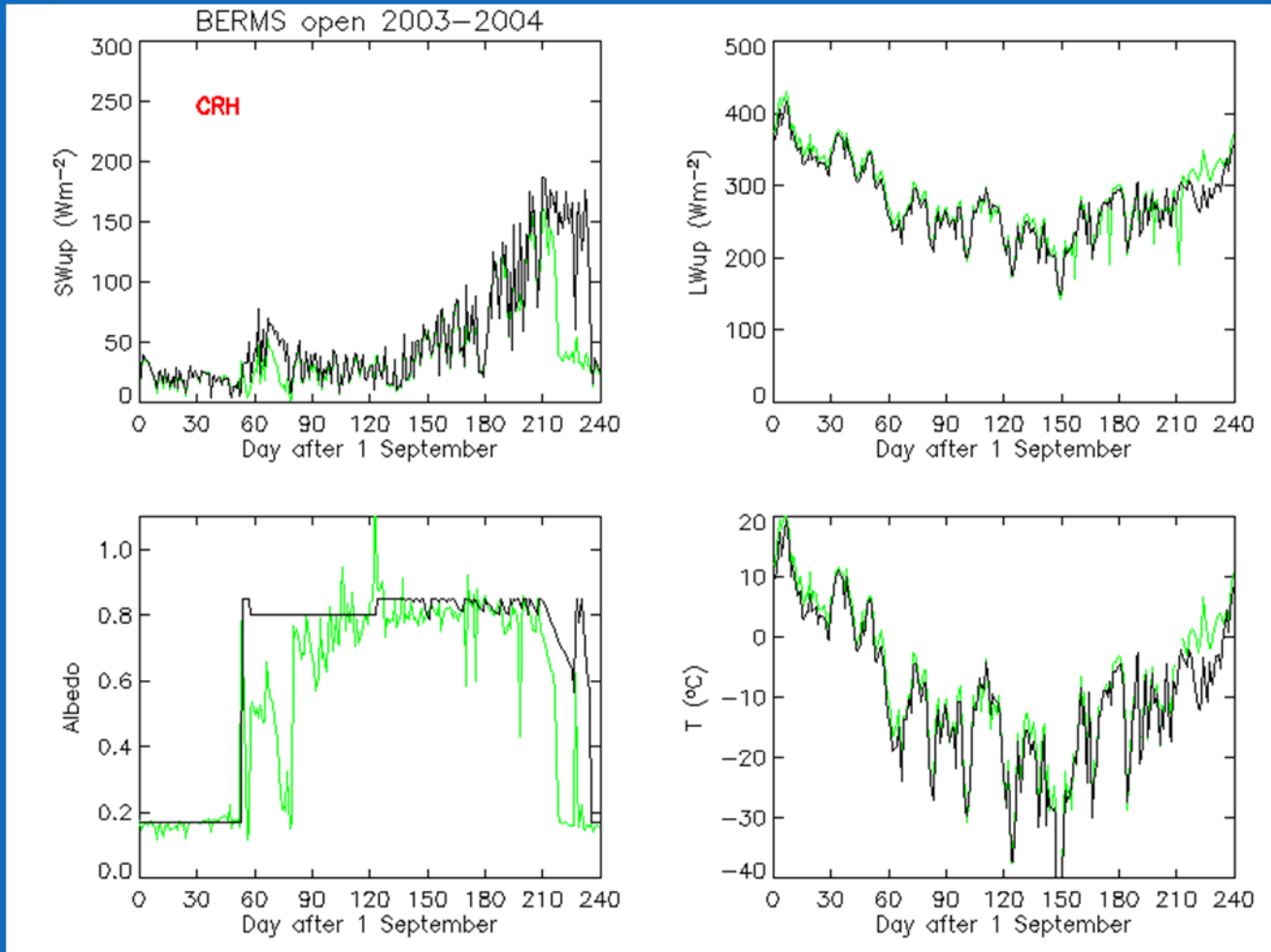
2003-04



forest site

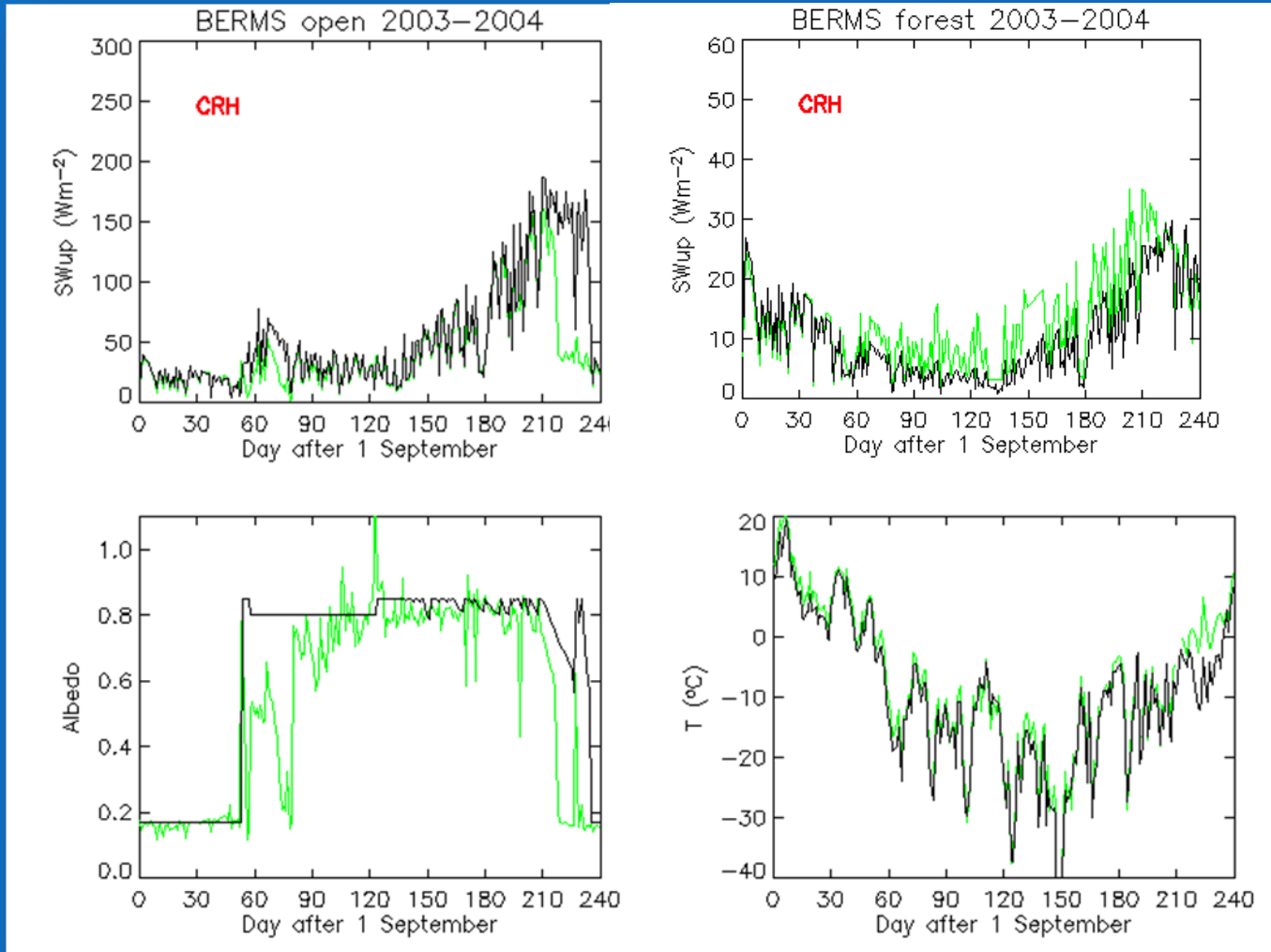


SnowMIP2 runs: BERMS, Sk.





SnowMIP2 runs: BERMS, Sk.

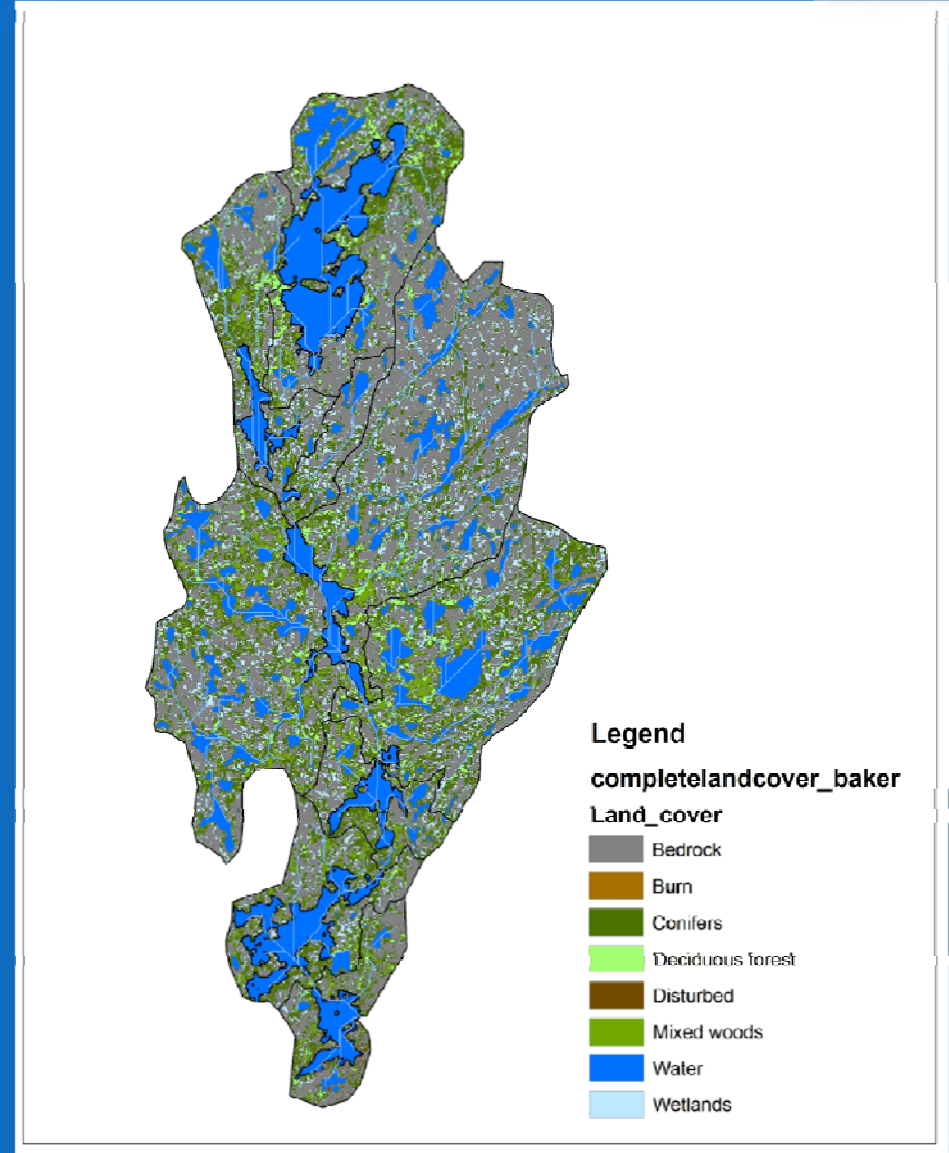


New Modules: *Soil*

- Depression storage
 - sub-HRU
 - can form subsurface runoff, ground water recharge or fill and spill.
 - transfer of flows between HRUs
- Pond storage
 - all of HRU water covered.
 - parameterization of maximum pond storage.
 - possible to: (i) fill and spill (ii) leak to subsurface flow or groundwater recharge.
- Interflow between HRUs
 - subsurface flow can enter downhill HRU as surface or subsurface flow.

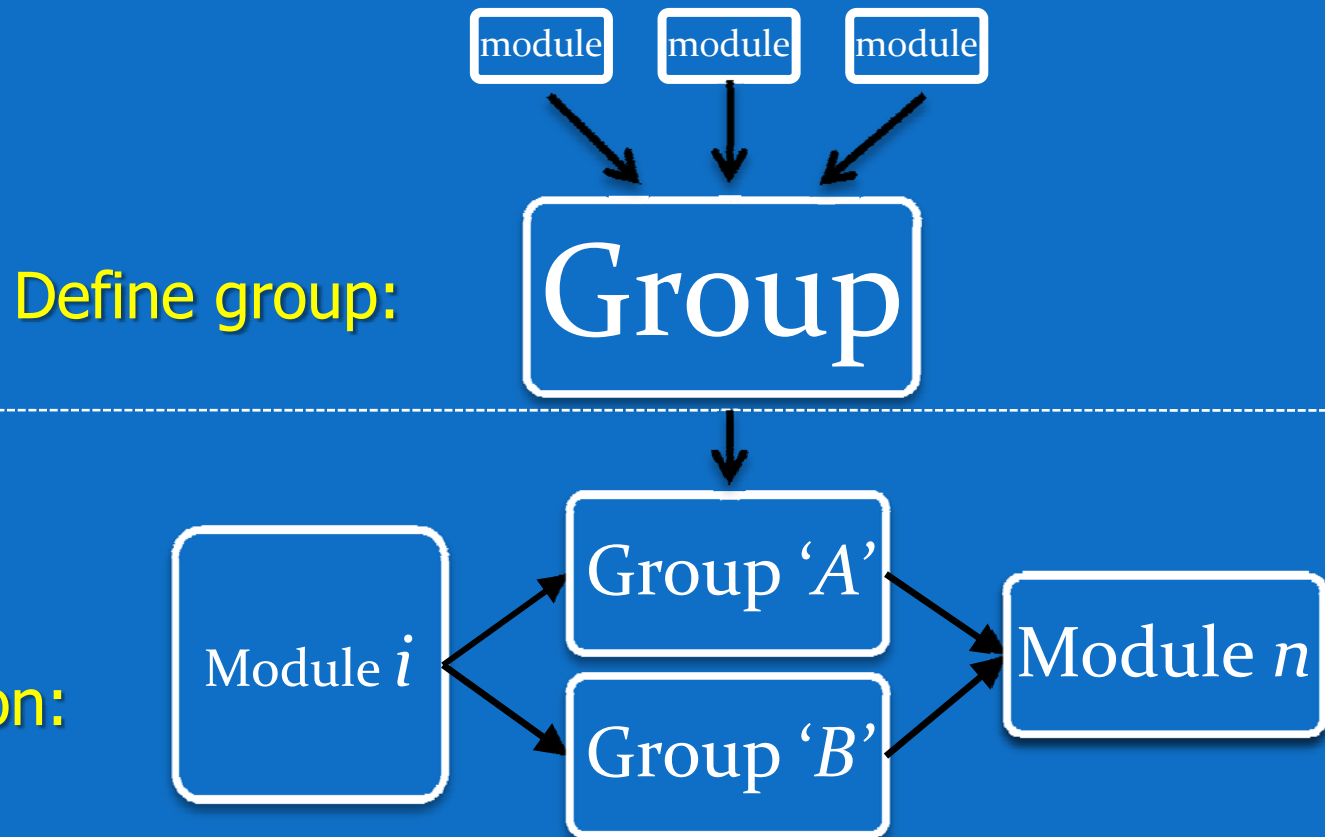
Baker Creek, NWT

- Sub-arctic shield lakes
- Parameterized CRHM with 16 HRU's - 8 trunk lakes and their contributing areas
- The storage interaction between HRU's was manipulated within the model to evaluate effect on water budget



New Capabilities: *Groups*

- A collection of modules executed in sequence for all HRUs.



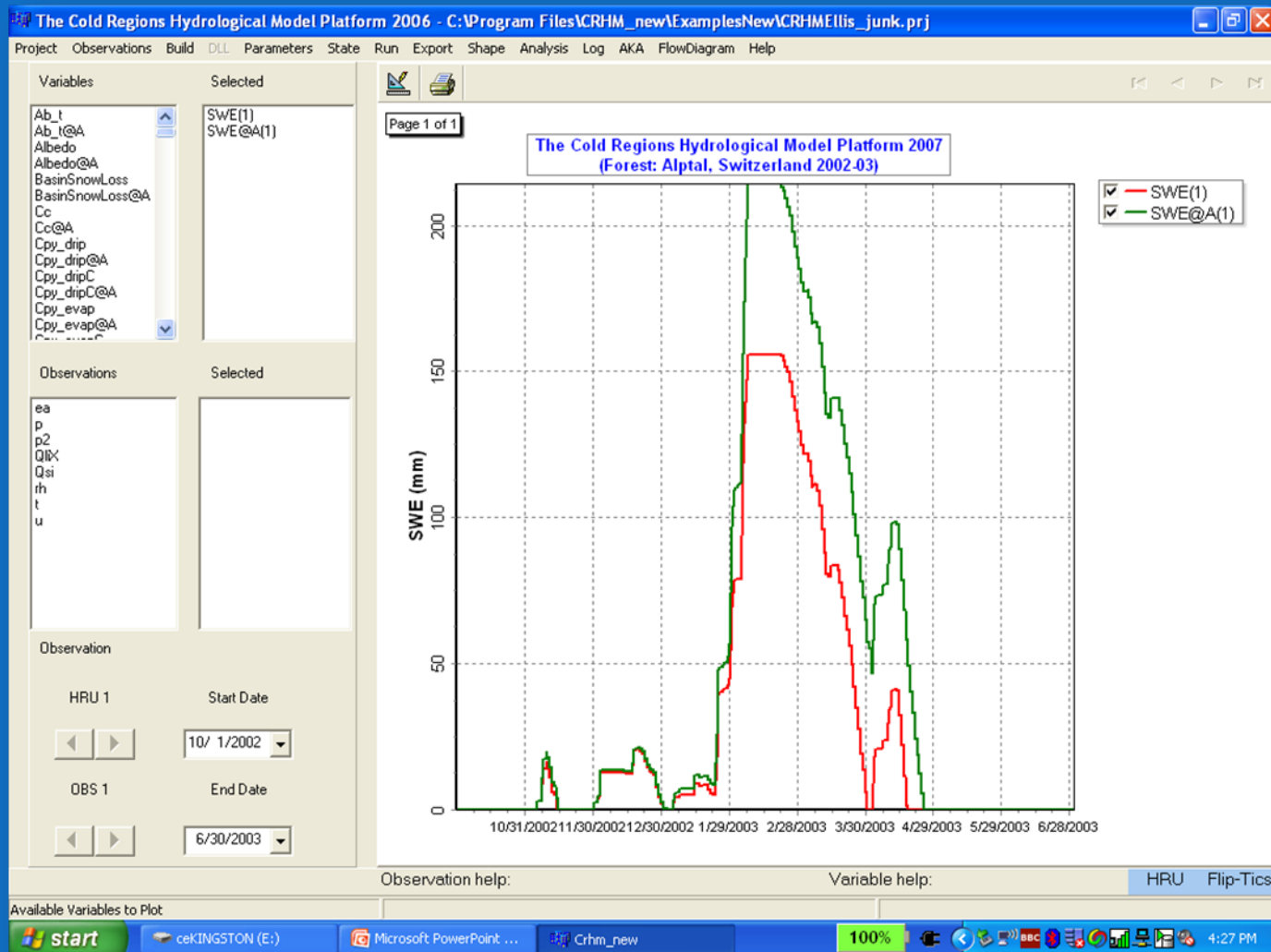
New Capabilities: *Groups*

Group application:

If groups are defined with the same modules, it is possible to execute the models in parallel using different parameters or driving observations.

New Capabilities: *Groups*

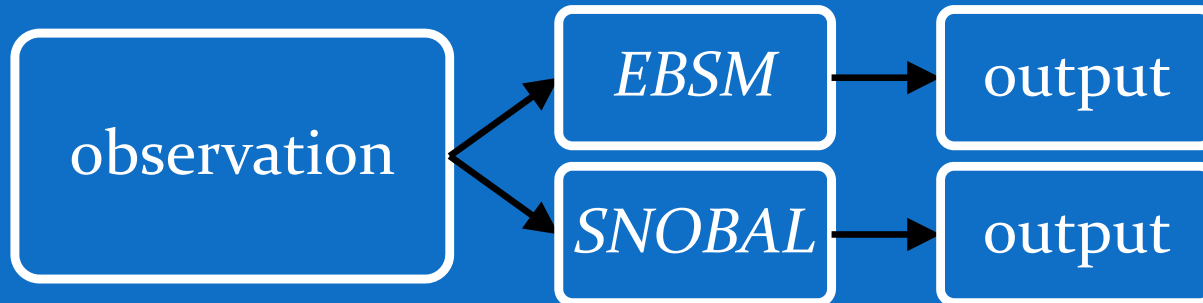
- E.g. estimate sub-canopy SWE for forests of differing leaf-area-index



New Capabilities: *Structures*

- Running similar modules in *parallel*

e.g. snowmelt



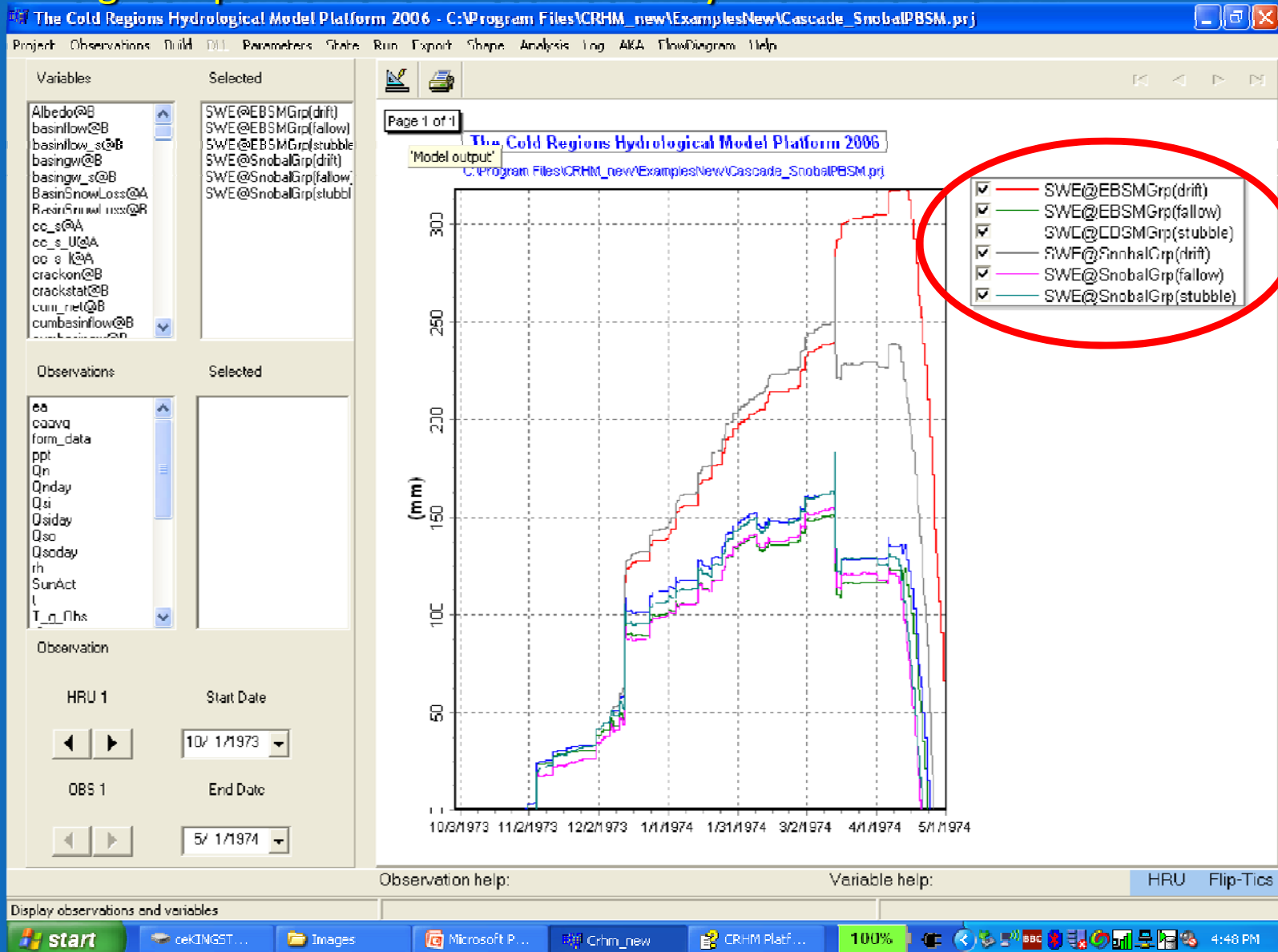
New Capabilities: *Structures*

Structure application:

1. Intercomparison of algorithms with similar driving data and parameters.
2. Mixed Land Use in Basin. Permits differing model structure for differing HRU (e.g. forest versus farmland).
3. Dynamical Structural Change. Permits change in model structure in response to changing hydrological state. The decision about which module to use would be made by a preceding module based upon the availability of moisture.

New Capabilities: Structures

e.g. comparison of SWE estimation by *EBSM* and *SNOBAL*:



Able to give structures meaningful names

www.usask.ca/hydrology

End