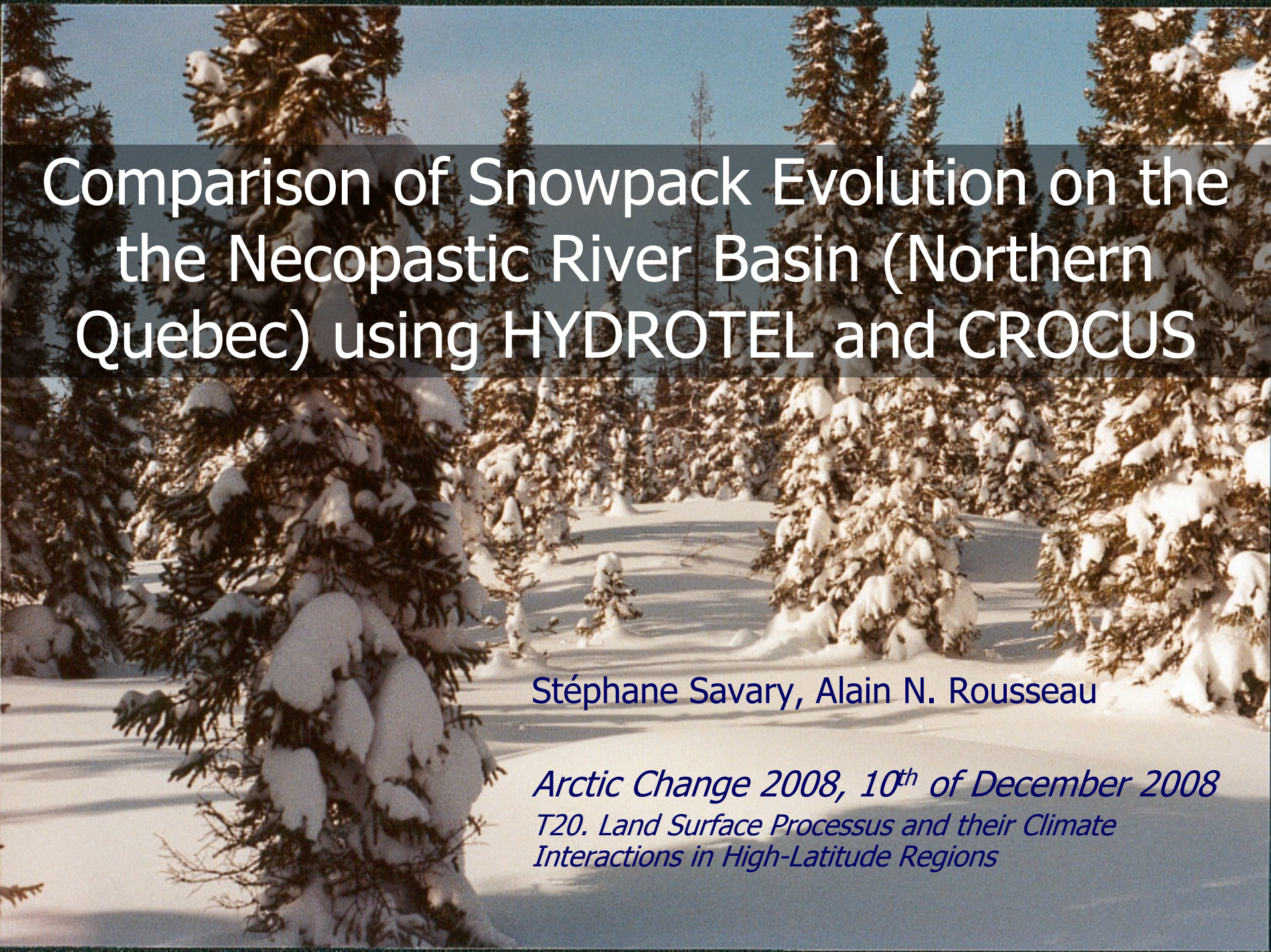


Comparison of Snowpack Evolution on the the Necopastic River Basin (Northern Quebec) using HYDROTEL and CROCUS

Stéphane Savary, Alain N. Rousseau

Arctic Change 2008, 10th of December 2008

T20. Land Surface Processus and their Climate Interactions in High-Latitude Regions

1. Introduction

- Hydro-Québec/Ouranos are pursuing the development and adaptation to the boreal environnement of the distributed hydrological model HYDROTEL
- In Quebec, utilization and development of snow modeling tools have been widely focusing on:
  1. Snow cover evolution
  2. Melting of snow as a water resource which contributes to the hydrologic cycle of a large number of watersheds (hydroelectricity)
- **Inter-comparison between HYDROTEL snow model and the multi-layer, energy budget French model CROCUS (CEN/ Météo-France)**
- **Simulation of the snow cover evolution on the Necopastic River basin to improve simulation of spring runoff**

2. Background

- HYDROTEL ([1]Fortin *et al*. (2001). *J. of Hydrologic Engineering*, **6**(2): 91-99) is widely used in southern Quebec as an efficient tool for:
  1. Water reservoir management
  2. Hydrological forecasting
  3. Climate change impact on hydrology
- CROCUS model (Brun *et al*. (1992). *J. of Glaciology*, **35**(121): 333-342) was previously adapted for northern Quebec environmental conditions (Savary et al., *Revue des Sciences de l'Eau*, **17/3**(2004), p. 395-417)
- To integrate the CROCUS model into HYDROTEL as a full energy-budget approach instead of a mixed degree-day-energy-budget approach

3. HYDROTEL snow model

- HYDROTEL has a one-layer snow model developed within a hydrological forecasting context
- Using a mixed degree-day/energy-budget approach, the model accounts for (Turcotte *et al*. (2007). *Nordic Hydrology*, **38**(3): 211-234):

1. Freshly fallen snow or rain
2. Convection losses and calorific deficit adjustment
3. Heat transfer between snow and ground
4. Variation of snow cover albedo
5. Heat transfer from melting (modified degree-day equation)
   - Accounting for three possible land covers
6. Snow settling (Compaction off the snow-pack)
7. Calorific surplus and melting
8. Retained water through the snow-pack

3. CROCUS snow model

- CROCUS is a multi-layer, one-dimensional snow model developed for snow study and avalanche forecasting.
- Capacity to simulate the following major phenomena affecting the evolution of the snow cover:

1. Short and long-wave radiation effects
2. Turbulent exchanges between snow surface and atmosphere
3. Heat exchange due to precipitation
4. Heat conduction through snow-pack
5. Water movement through snow-pack
6. Snow settling (Compaction of snow-pack)
7. Heat transfer between snow and ground
8. Evolution of snow grain type and size (Avalanche Forecasting)

4. Research Site

Cold continental or sub-arctic climate; Short, mild summer and long, severe winter

Temp. ≈ -4°C/Year

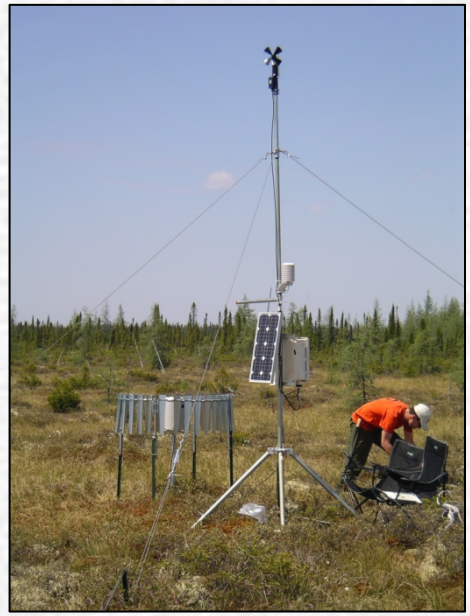
Precip. (WE) ≈ 765mm/Year

Snow depth ≈ 1.0m

Snow density ≈ (250kg/m³)

4. Research Site

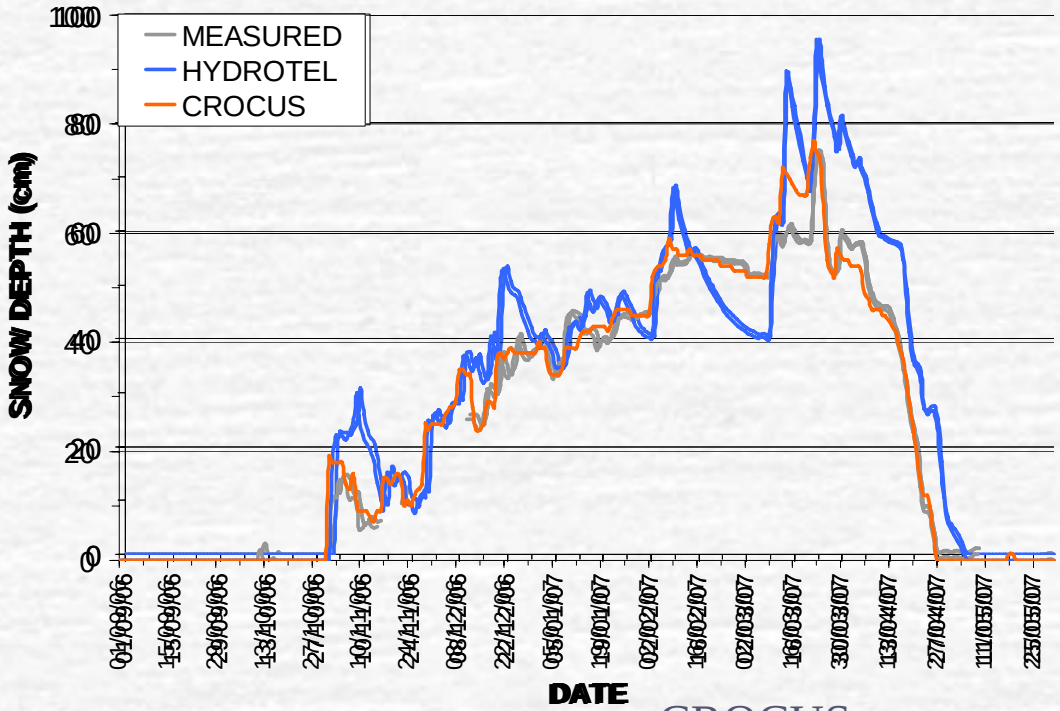
		LG2	NECO-1	NECO-2	T.YVES
Model entry data	**Meteorological Data**				
	Air temperature (°C)	√	√	√	√
	Wind speed (m/s)	√	√	√	√
	Precipitation (SWE) (mm)	√	√	√*	√*
	Air humidity (%)	√	√	√	√
	Long wave radiation (W/m^2) ("IR")		√		
	Short wave radiation (W/m^2) ("SR")		√		√
	Cloudiness (0.0 to 1.0)				
Validation	**Continuous measurements**				
	Snow depth (cm)		√	√	
	SWE (GMON) (mm)		√		



- Missing input meteorological data at the NÉCO-1 site are completed with recorded data at the NÉCO-2, T. YVES or LG2 sites.
- Remaining missing data are calculated (Long wave or short wave radiation) based on measured data and site characteristics.
- Cloudiness is attributed from statistical monthly values available for northern Quebec.

5. Comparison of CROCUS and HYDROTEL snow model (NECO-1)

- Open area (neglecting effects of forest)

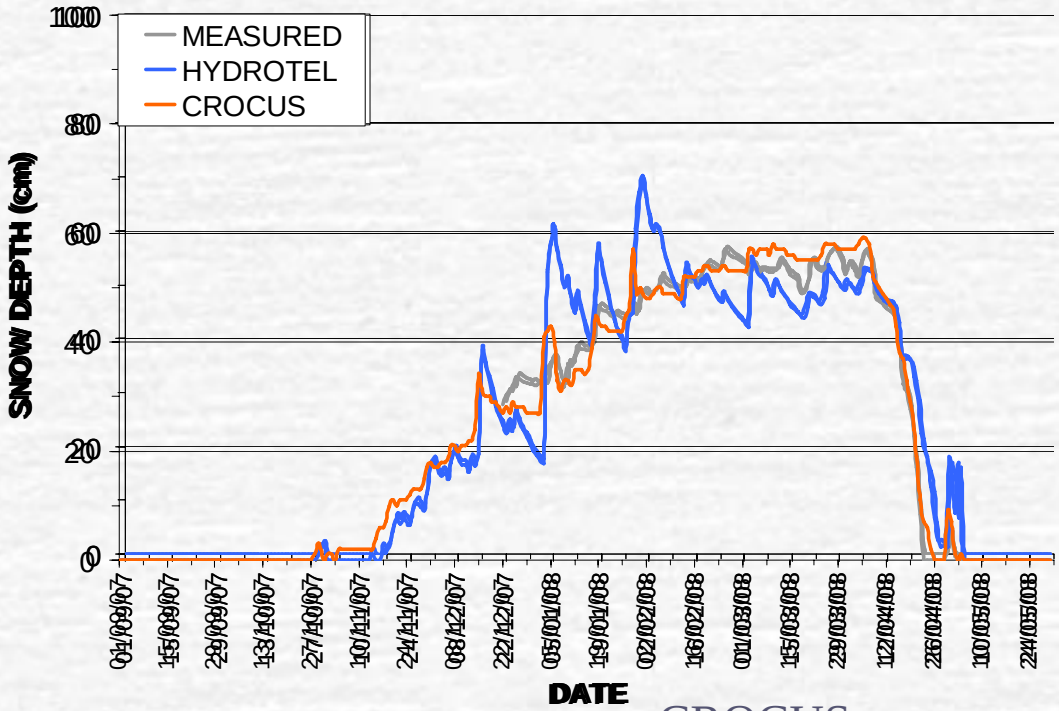


HYDROTEL
(R^2=0.82; N-S=0.70; PBIAS= 29%)

CROCUS
(R^2=0.97; N-S=0.97; PBIAS= -7%)

5. Comparison of CROCUS and HYDROTEL snow model (NECO-1)

- Open area (neglecting effects of forest)

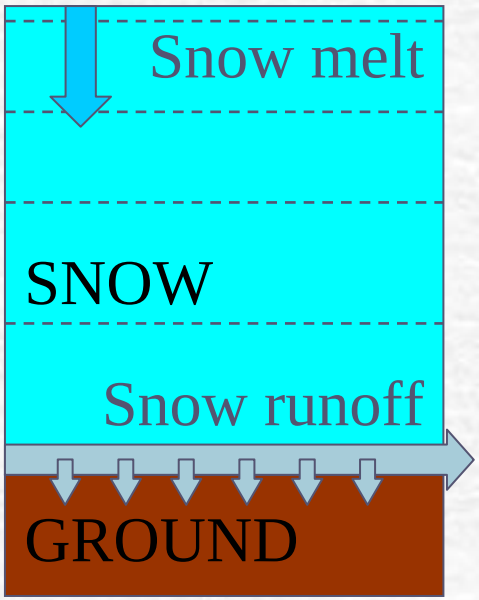


HYDROTEL
(R^2=0.50; N-S=0.42; PBIAS= 28%)

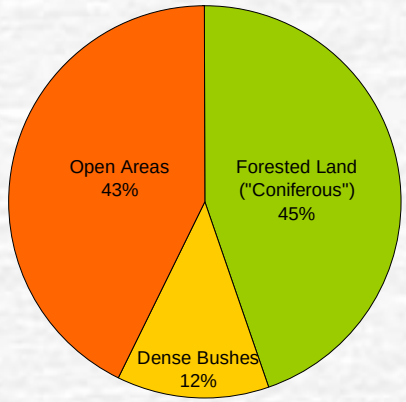
CROCUS
(R^2=0.94; N-S=0.93; PBIAS= 4%)

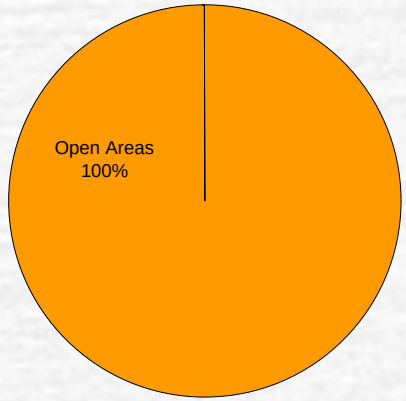
6. From snow pack to river runoff

- Snow model distribution of land cover (Nécopastic)

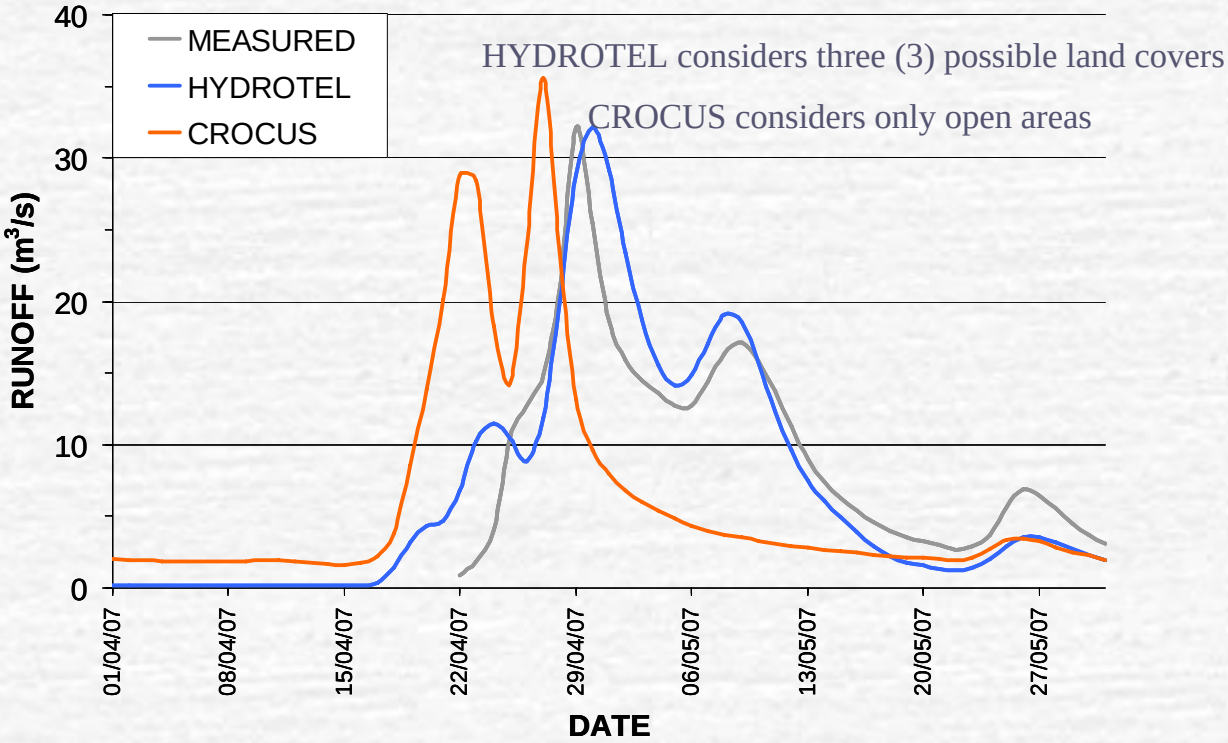


- **HYDROTEL** snow model accounts for three land covers (through the melt coefficient of the degree-day approach)
- Better representation of river spring runoff
- CROCUS snow model considers all land cover as open areas (not adapted to forest land cover)
- Restrained representation of river spring runoff





7. Impact of snow model on spring runoff simulation (Necopastic sub-watershed outlet)



HYDROTEL
(S. Runoff; Obs.=180mm, Sim.=186mm)

CROCUS
(S. Runoff; Obs.=180mm, Sim.=160mm)

8. Conclusion

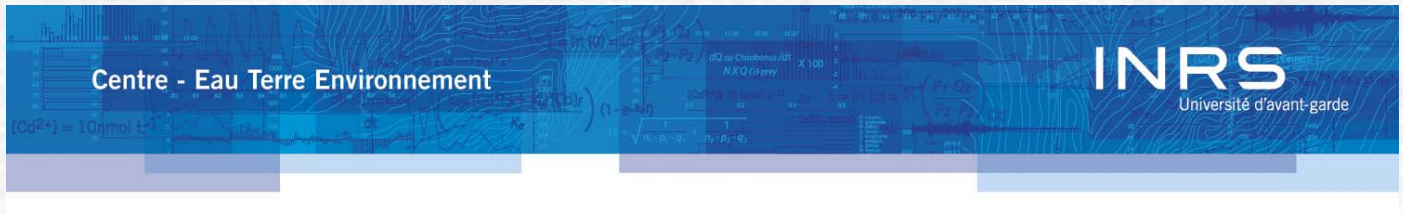
- Based on available field measurements, simulations show good agreement:
  1. **Snow depth**
  2. *SWE (GMON automatic measurements)*
- CROCUS constitutes an efficient tool for the simulation of snow cover for northern Quebec.
- HYDROTEL remains efficient to predict spring runoff on the Necopastic watershed but for snow depth simulation shows poor performance when compared to CROCUS.

9. next steps …

- *Complete integration of CROCUS to take into account for the separate land covers considered by HYDROTEL (Deciduous Forest, Evergreen Forest and Open Area).*
- *Distinct land use parameters highly contributed to a better spring runoff representation.*

Questions?

INRS-ETE:

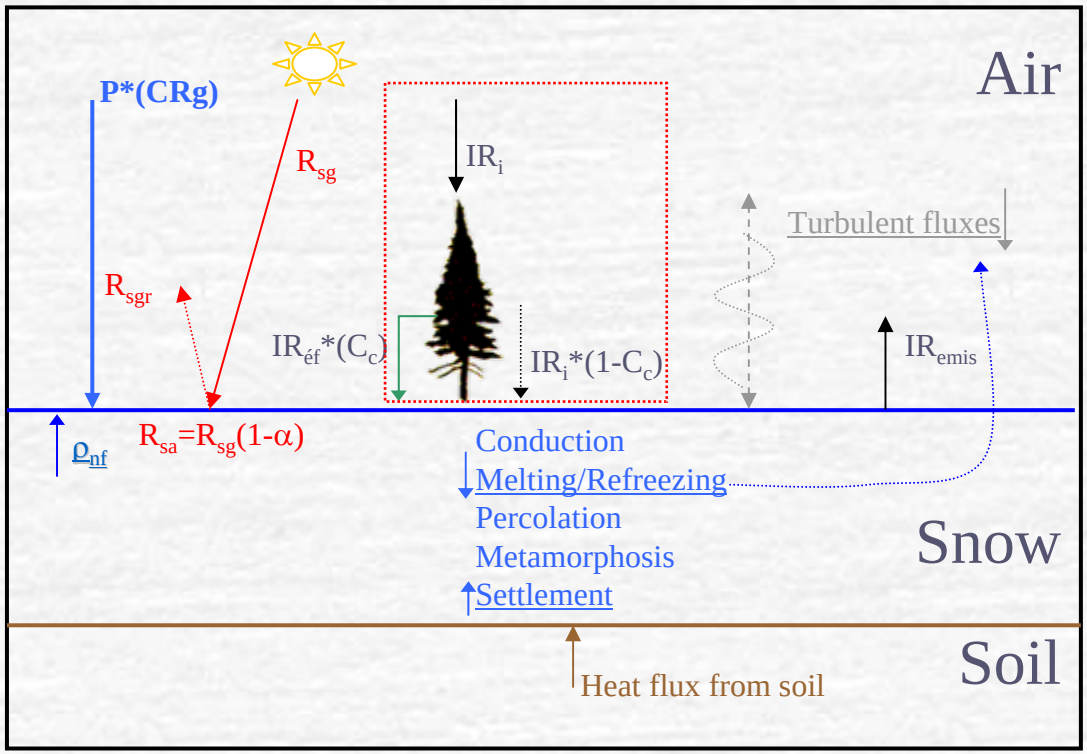


Stéphane Savary, Alain N. Rousseau, Sylvain Jutras, Alain Royer

Hydro Québec Institut de recherche

OURANOS

Adjustment of CROCUS and input data



Modifications made to CROCUS and the input data

- Snow settling
- Fresh snow density
- Spring melt
- Regional precipitation adjustment
- Infrared radiation calculation
- Introduction of forest effects on the radiation budget at the snow surface