Environnement et Changement climatique Canada
Environment and Climate Change Canada

# On the ongoing snow-related improvements in ECCC's land surface model and data assimilation system

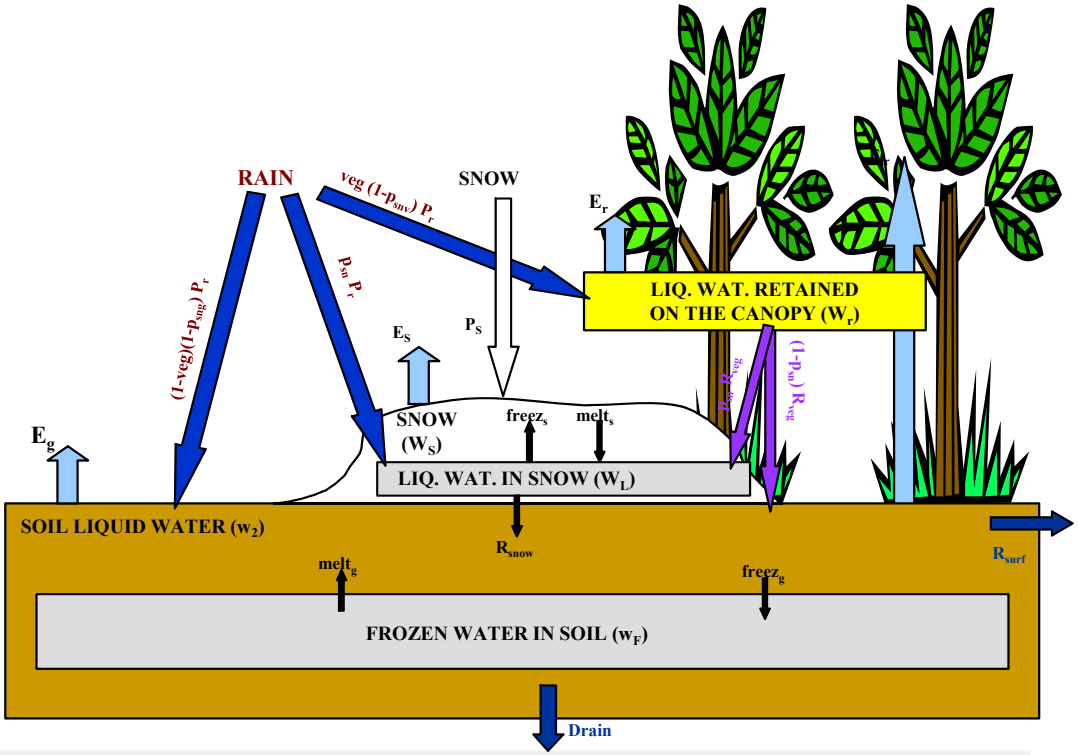
Camille Garnaud, Vincent Vionnet, Marco Carrera, Stéphane Bélair, Vincent Fortin, Étienne Gaborit, Bernard Bilodeau, Dorothée Charpentier, Maria Abrahamowicz, and many more

# Presently operational

# Land surface model

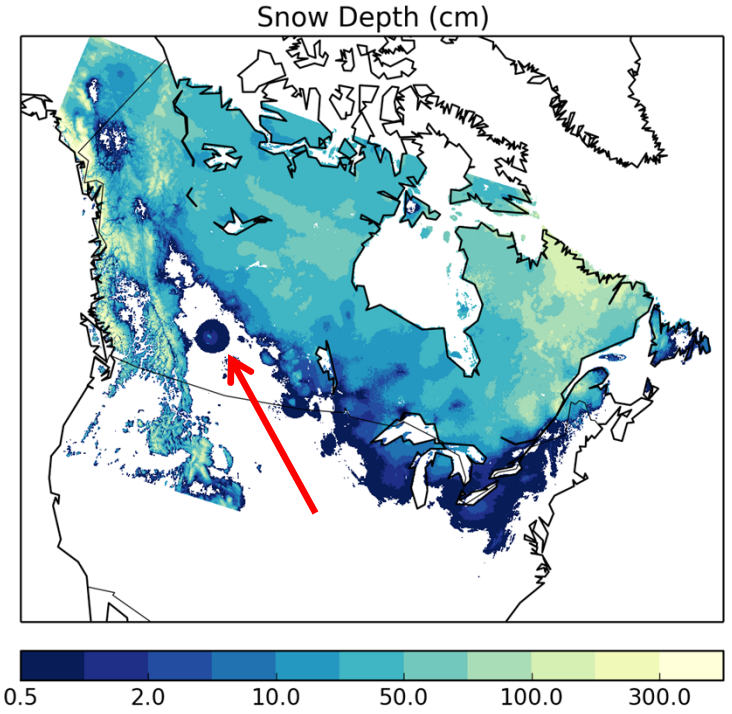
- Canadian version of Interactions-Sol-Biosphere-Atmosphere (ISBA) in our operational models (Belair et al. 2003a, Belair et al. 2003b)

- Single-layer snow module



# Land data assimilation system

- Canadian Land Data Assimilation System (CaLDAS; Carrera et al. 2015)
- Snow data assimilation
  - In situ snow depth observations
  - Ensemble Optimal Interpolation (OI)
- Problematic:
  - Snow cover: isolated patches (associated with isolated stations)
  - Snow line positionning
  - Timing and volume of snowpack melting
- Hydrology is impacted



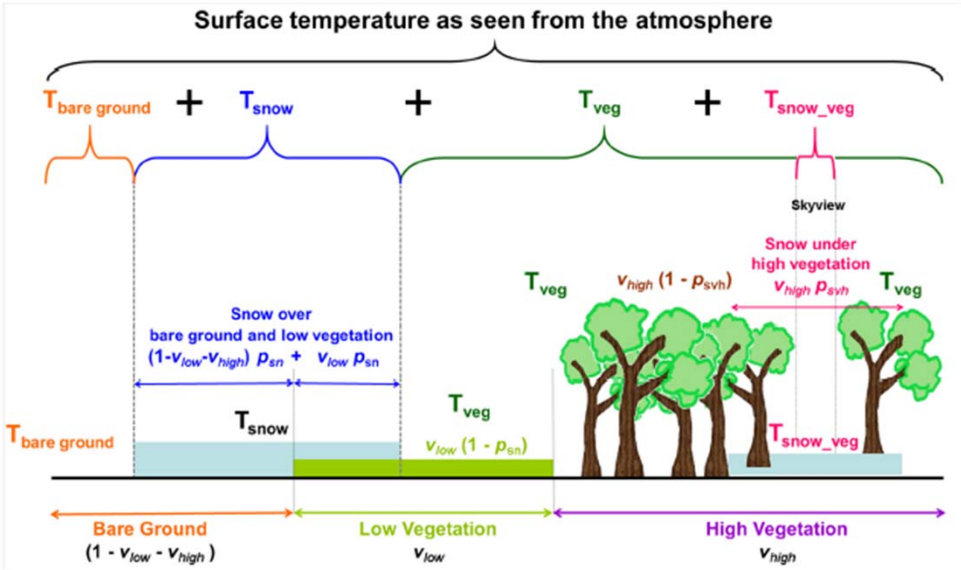
# Hydrology vs. Meteorology

- Until now, snow data assimilation was designed to improve weather forecasting
  - Snow cover, snow depth
  - For albedo, heat and water exchanges between the surface and the atmosphere
  - Assimilation technique may remove/add snow mass daily
- Now, ECCC also has the mandate to produce hydrological forecasts
  - Snow water equivalent (SWE)
  - For amount of water stored at the surface, amount/timing of snow melt
  - Needs water to be conserved

# Recent developments

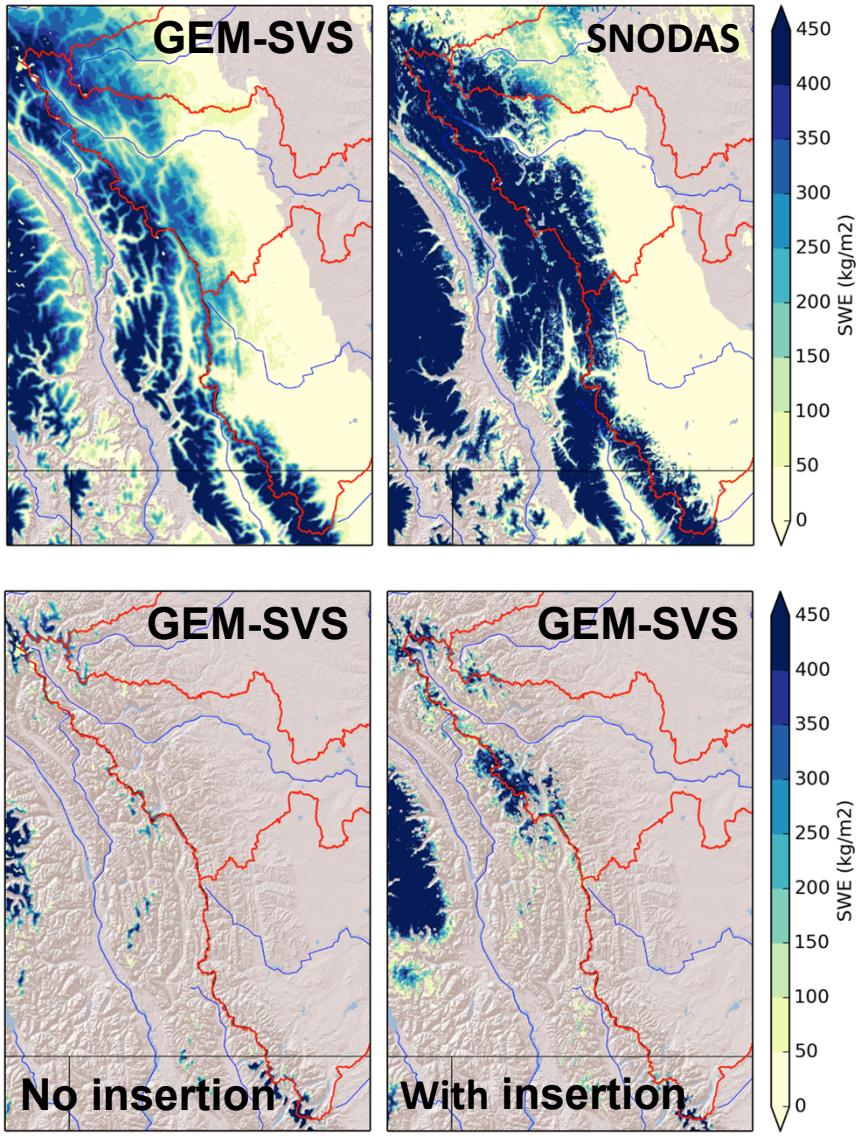
# Land surface model

- Soil, Vegetation and Snow (SVS; Husain et al., 2016, Alami et al., 2016)
- One-layer energy budget snowpack scheme
- Representation of:
  - Snow over bare ground and low vegetation
  - Snow under high vegetation
- Robust snowpack scheme for NWP applications with some potential limitations for hydrology



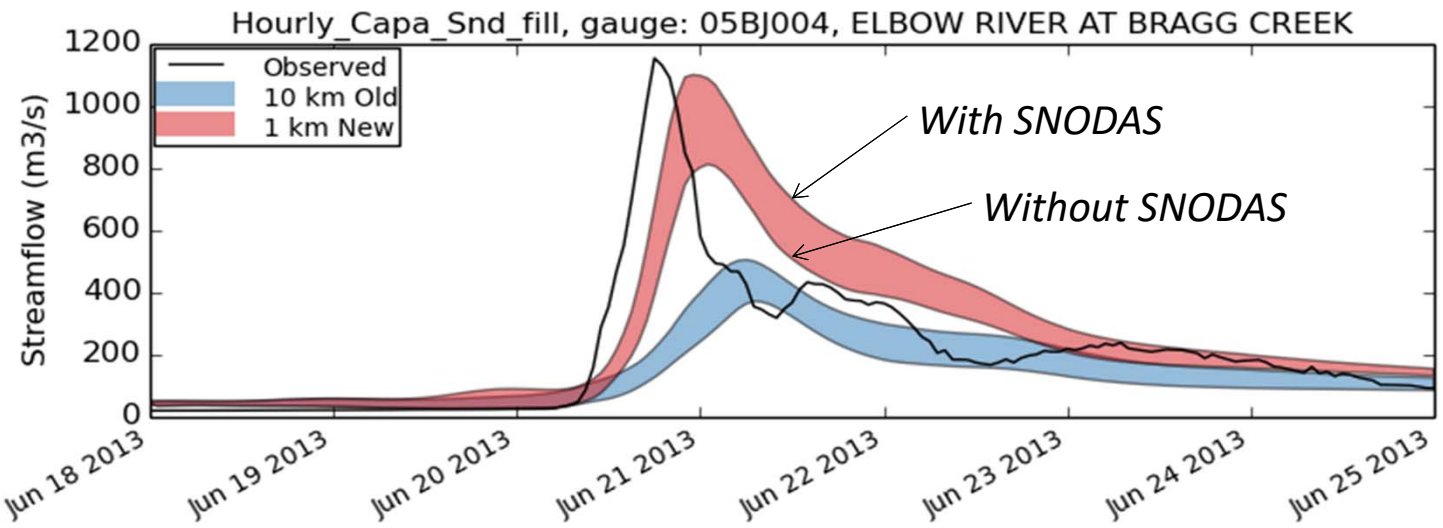
# SVS experiments

- Vionnet et al. 2019, in discussion.
- Domain: Canadian Rockies
- Context: June 2013 flood, complex hydrological event (heavy rainfall, rain-on-snow)
- SVS run at 1-km resolution forced by GEM and CaPA
- Top row: peak SWE
- Bottom row: two sets of intial conditions on 18 June 2013, including one with insertion of SNODAS SWE on May 1st



# SVS experiments

- Impact on streamflow as simulated by Watroute (Kouwen, 2010)

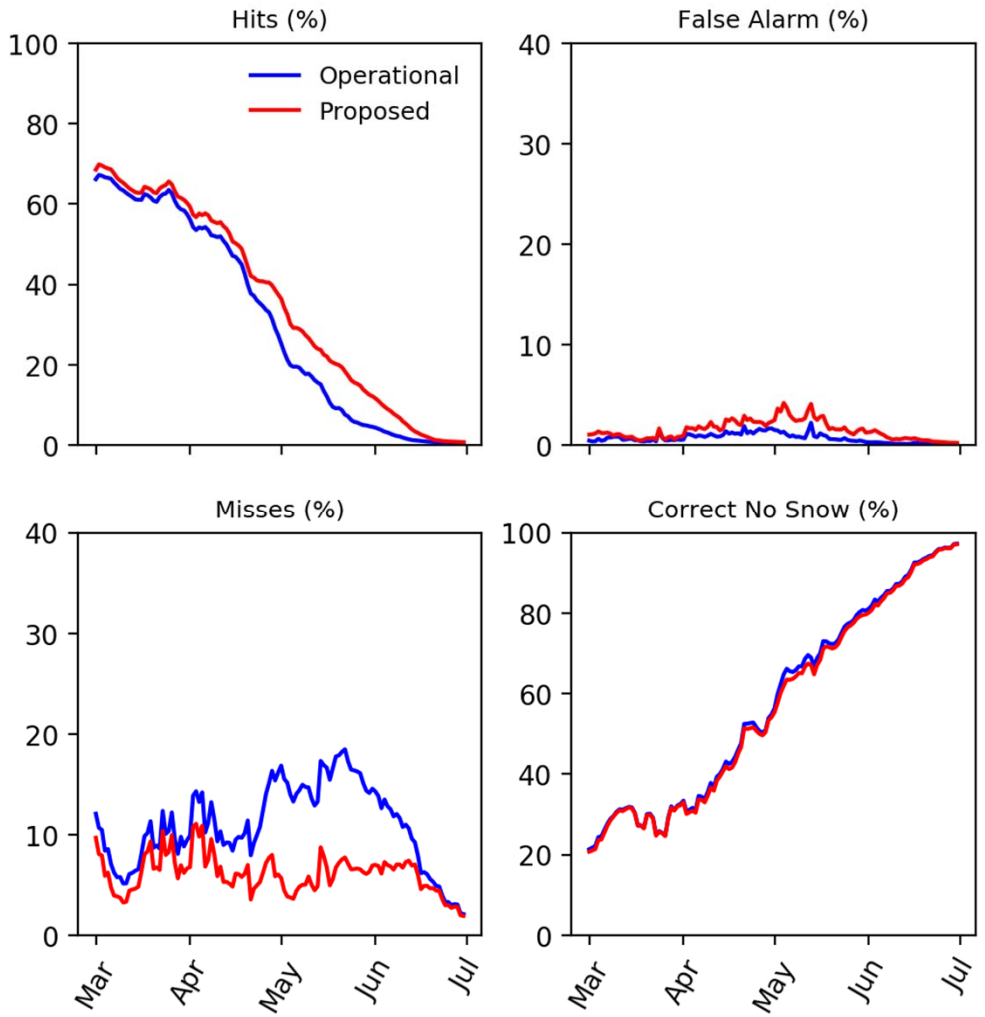


# Land data assimilation system

- CaLDAS-Sat: Emphasis on the assimilation of observations derived from space-based remote sensing platforms (SMOS, SMAP, GOES)
- Precipitation: ensemble Canadian Precipitation Analysis (CaPA)
- Based upon SVS and an offline land-surface data assimilation system:
  - Ensemble Kalman Filtering (EnKF) method for soil moisture and surface temperatures
  - Ensemble Optimal Interpolation (OI) for snow
- Forced by High Resolution Deterministic Prediction System (HRDPS), operational at ECCC

# CaLDAS-Sat

- **Snow presence:** Evaluated against IMS snow cover extent product
  - Contingency table
  - Spring 2016
- **Operational** = CaLDAS with no satellite data and with ISBA
- **Proposed** = CaLDAS-Sat with SVS

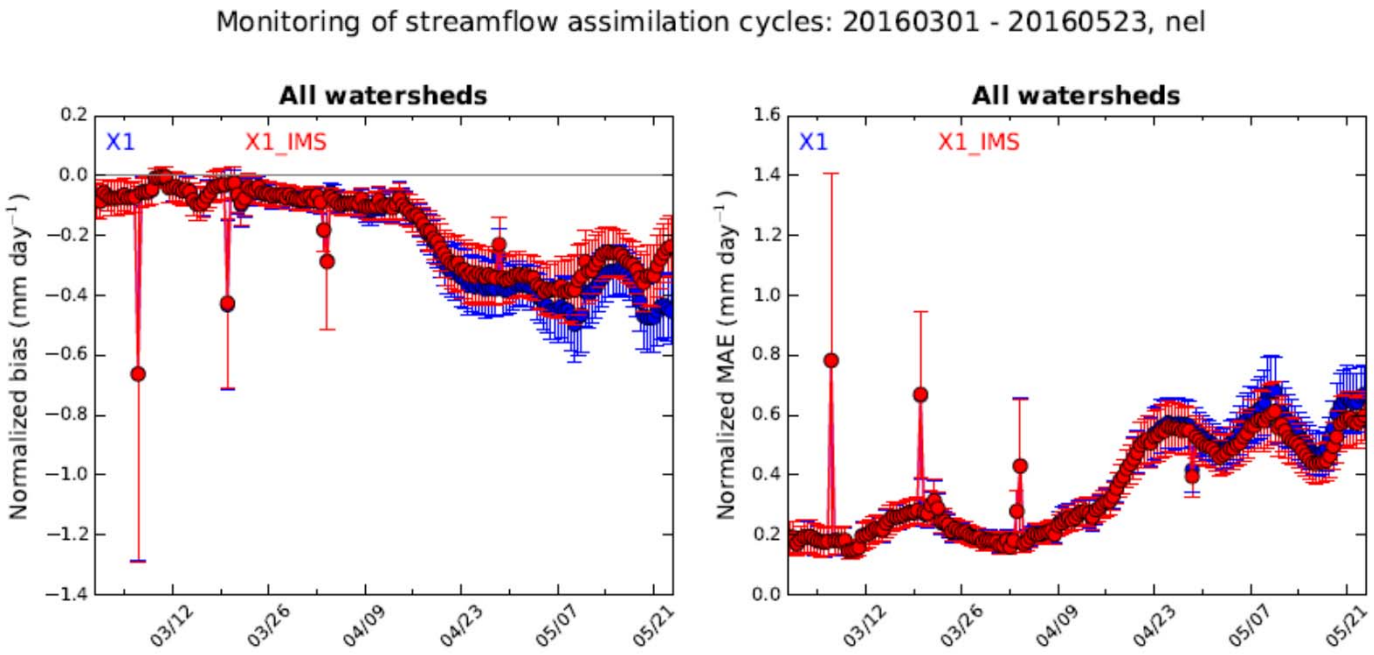


# CaLDAS-Sat

| | Operational | Proposed |
|---|---|---|
| Accuracy | 0.88 | **0.92** |
| Heidke Skill Score | 0.57 | **0.73** |
| Hit Rate | 0.56 | **0.74** |
| False Alarm Ratio | **0.06** | 0.08 |
| Threat Score | 0.55 | **0.71** |
| Equitable Threat Score | 0.43 | **0.59** |
| Frequency Bias Index | 0.59 | **0.79** |

# CaLDAS-Sat including IMS

- Preliminary tests of IMS SCE data assimilation in CaLDAS-Sat show improvements in simulated streamflows (Watroute; Kouwen, 2010) over Canada




**Nelson River basin, Spring 2016**

# Future developments

# Land surface model

- Soil, Vegetation and Snow, version 2
- Aims at improving some of the limitations identified in SVS-1, in particular for cold region hydrology:
  - **Multi-layer snowpack** scheme with improved snow physics and metamorphism
  - Improved representations of **snow/vegetation interactions**
  - **Multi-layer diffusion** scheme for **soil** temperature including freezing/thaw processes
- Essential for future satellite data assimilation of snow-related brightness temperatures and backscatters

# Land data assimilation system

- **Assimilated data**: IMS SCE, SWE in situ data, more SD in situ data, passive microwave data
- **Assimilation method for in situ data**:
  - Evolve from OI
  - Maintain water budget
  - Avoid non-realistic isolated patches
- **Assimilation method for satellite data**:
  - DA tests already performed using synthetic satellite snow mass retrievals through an EnKF (Garnaud et al., 2019).
  - Radiative transfer model: SMRT

# Summary

# Take home messages

- Recent events highlighted the importance of quality hydrological forecasts
- Current models are set up to satisfy the needs of NWP, not necessarily of Hydrology
- Work is underway to improve ECCC's snow analysis for both NWP and Hydrology
  - Land surface model: multi-layer snow scheme
  - Land data assimilation system: observed data and assimilation technique

# Many thanks!

- Acknowledgements to all the land surface group at ECCC
- Any questions or comments?
- camille.garnaud@canada.ca