High-resolution hydrological forecasting of the June 2013 flood in the Canadian Rockies

V. Vionnet[1,2], E. Gaborit[2], V. Fortin[2], N. Gasset[2],
C. Garnaud[2], N. Gauthier[2] and J. W. Pomeroy[1]

[1] Centre for Hydrology, University of Saskatchewan, Saskatoon, Canada
[2] Environment and Climate Change Canada, Dorval, Canada

The 19-22 June 2013 Alberta Flood

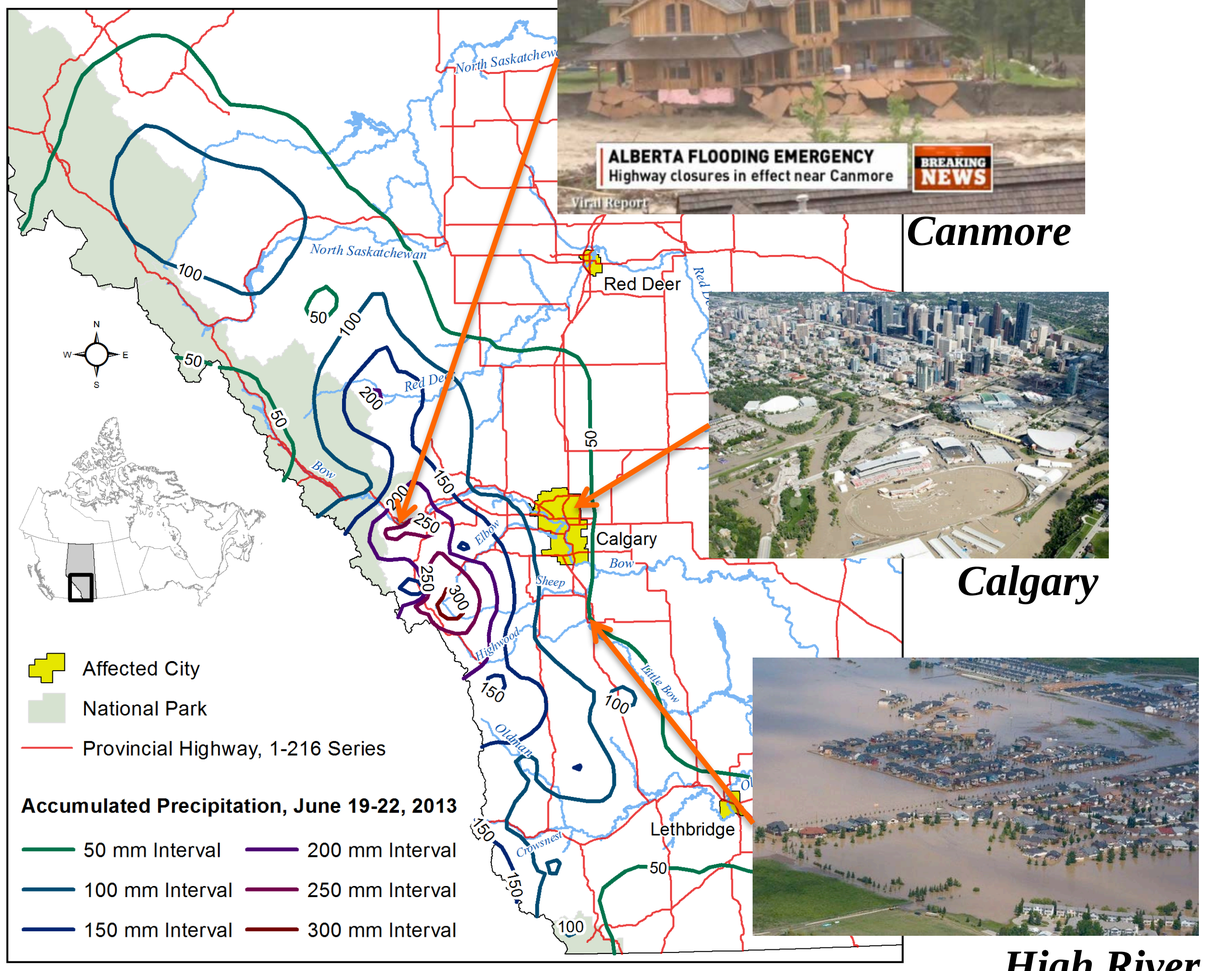
- **Major flood** in the Canadian Rockies and downstream areas

A complex hydrological event *(Pomeroy et al. 2015)*:

- **3-day heavy rainfall**
- **Rain-on-snow at high-altitude**

- **100 000 people evacuated** from many cities (Canmore, Calgary, High River, …)
- Total cost of **CAD$6 billions**

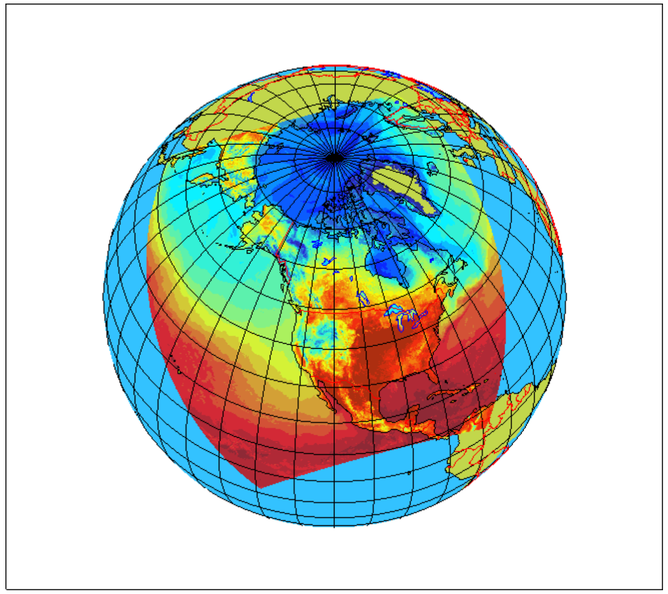
Q: What is the ability of the hydrological modelling system currently used at ECCC to simulate this event?



The GEM-Hydro modelling platform

Gaborit et al. (2017)

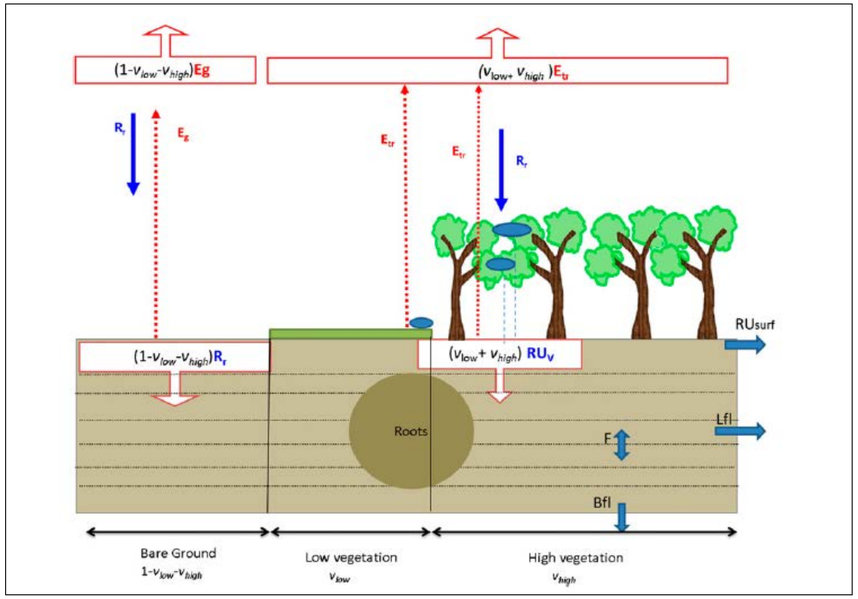
Atmospheric forcing



- Forecasts from the GEM model
- Canadian Precipitation Analysis (CaPA)

Land Surface Scheme
SVS (Soil Vegetation and Snow)

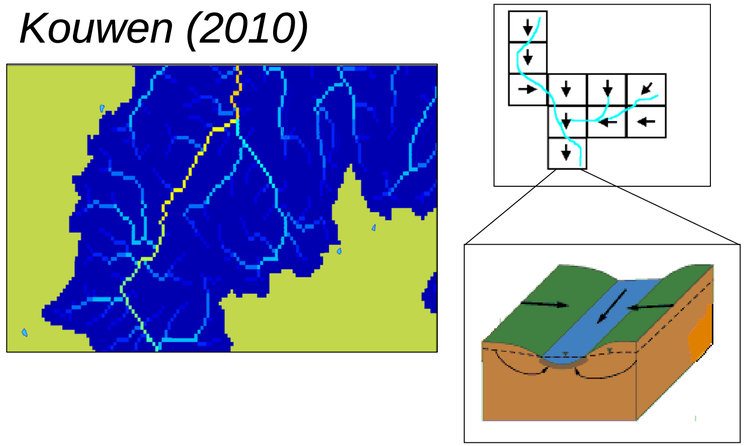
Alavi et al. (2016) Husain et al. (2016)



- Multiple energy budgets for bare ground, low and high vegetation
- Single layer snowpack scheme

Routing
WATROUTE

Kouwen (2010)



- Hydrological routing of surface/lateral flows and drainage simulated by SVS

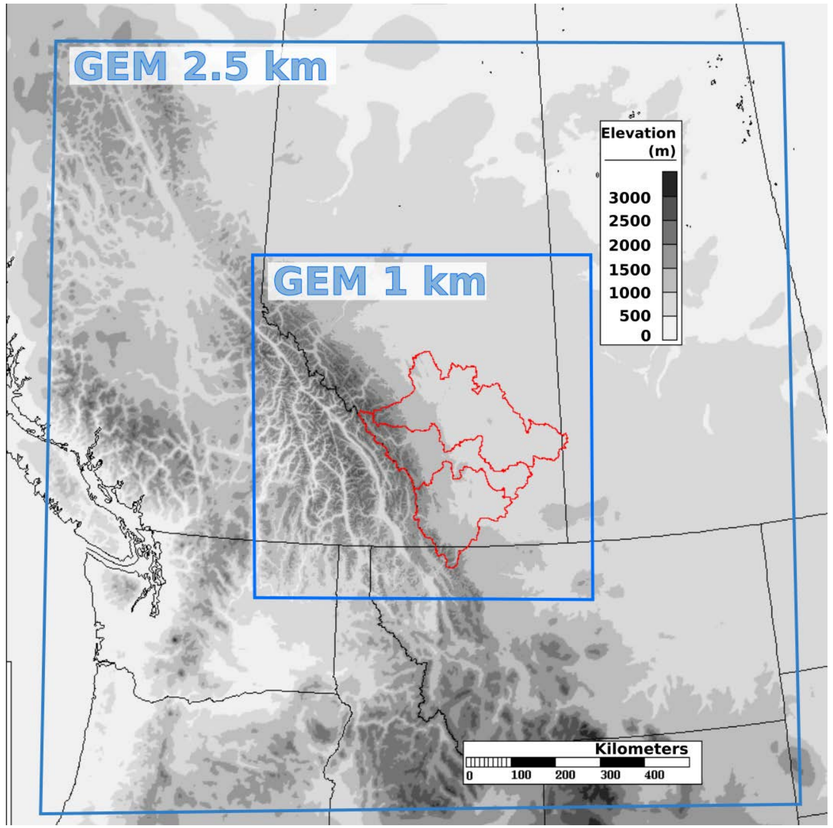
GEM-Hydro configuration

High resolution GEM and CaPA configurations

- 3 one-way nested grids: 10, 2.5 and 1km

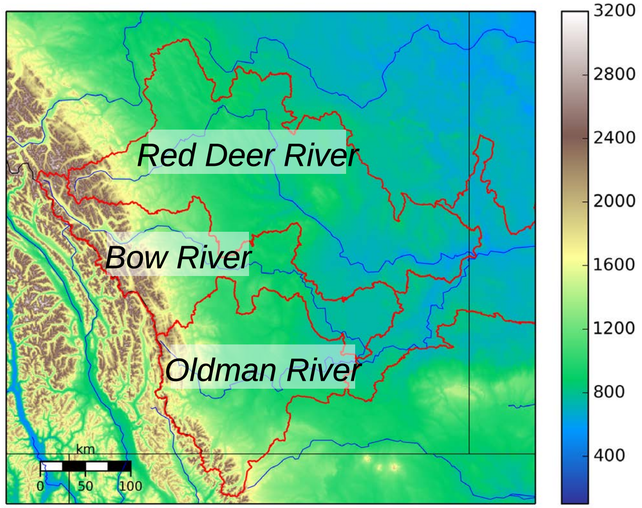
Model integration (18 to 22 June)**:**
- 4 cycles/day (0, 6, 12 & 18 UTC)
- 12-h forecasts
- Initial and boundary conditions: GEM 10 km operational in 2013

6-h **CaPA analysis**



SVS and WATROUTE

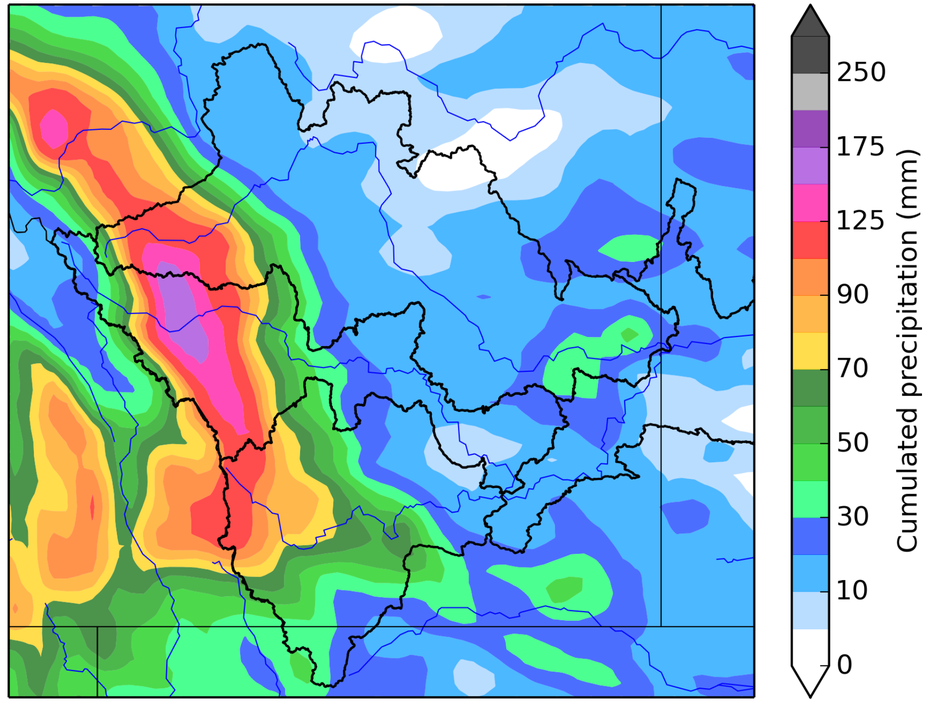
- **1-km grid** over the 3 main catchments of **Southern Alberta**



- **Atm. forcing:** Successive 6-12 GEM forecasts and CaPA at different resolutions
- **Simple downscaling** to the SVS 1km grid for GEM 10 and 2.5 km

Precipitation analysis

- Operational CaPA analysis at 10 km issued at the time of the event



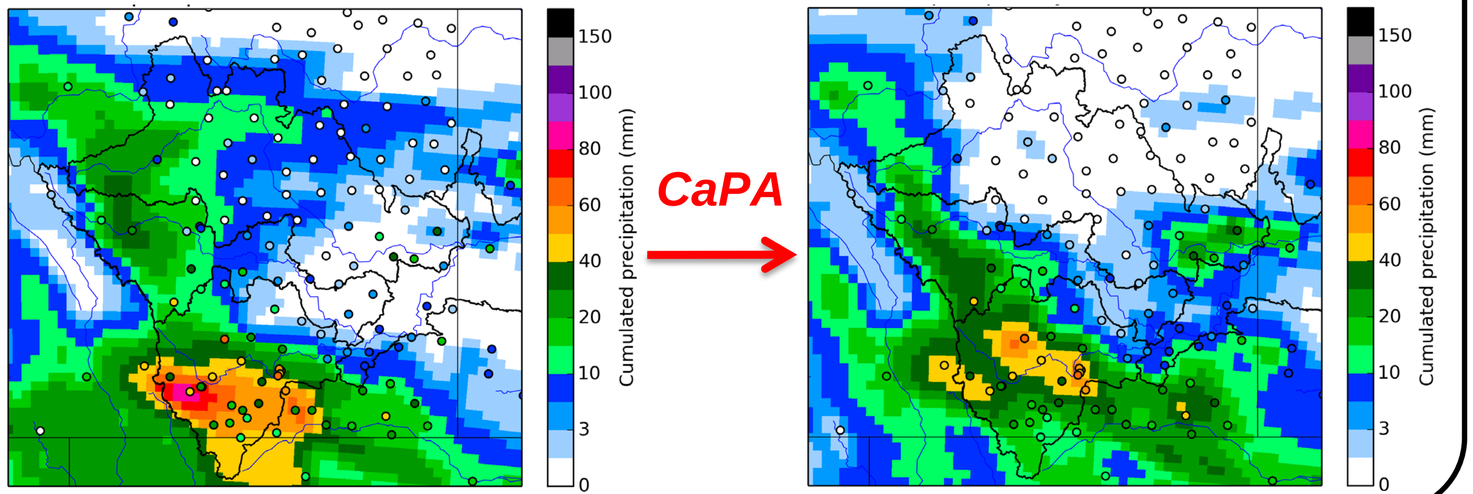
Cumulated precipitation
19 June 12Z to 21 June 12Z

Canadian Precipitation Analysis (CaPA)

- 24-h and 6-h precipitation product on a **regular grid**
- Combination of **precip. observations** with a **first guess** obtained from a **short-term forecast** using optimal interpolation
- Radar data in CaPA since Nov. 2014

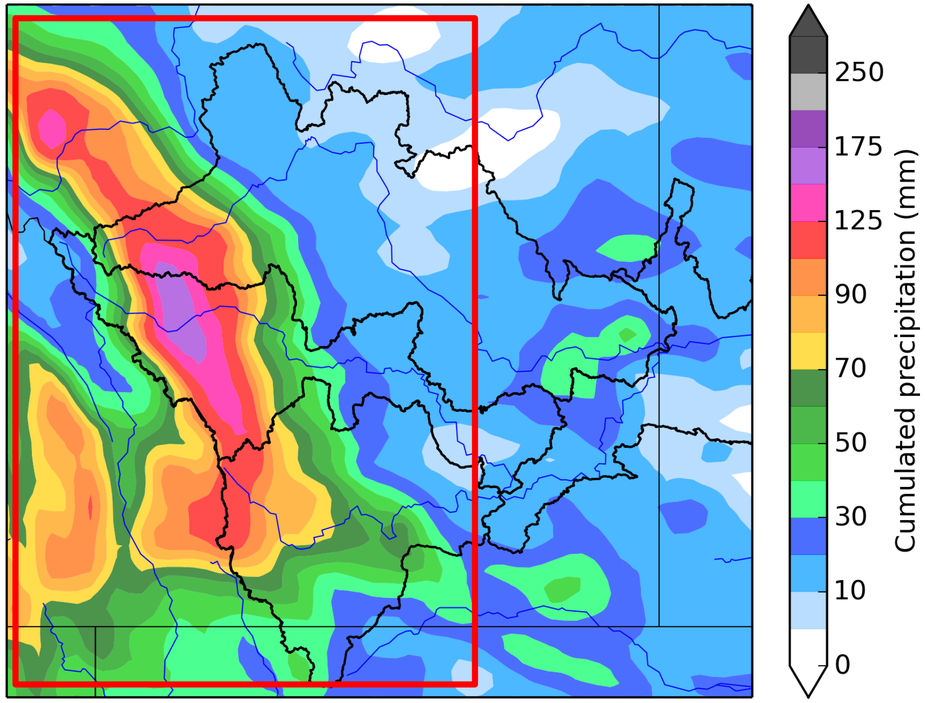
First guess and observations

Analysis

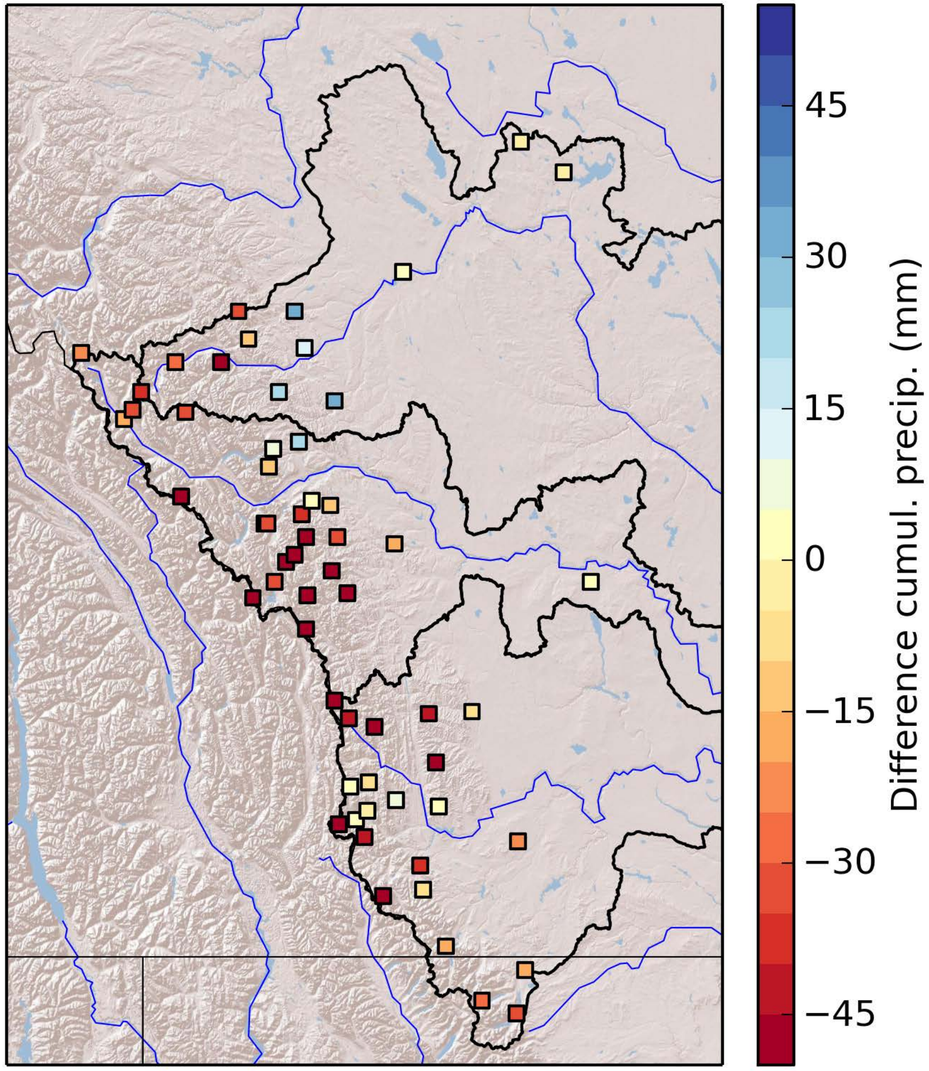


Precipitation analysis: evaluation

- Operational CaPA analysis at 10 km issued at the time of the event



Cumulated precipitation
19 June 12Z to 21 June 12Z



Differences of cumulated precipitation(19-21 June)

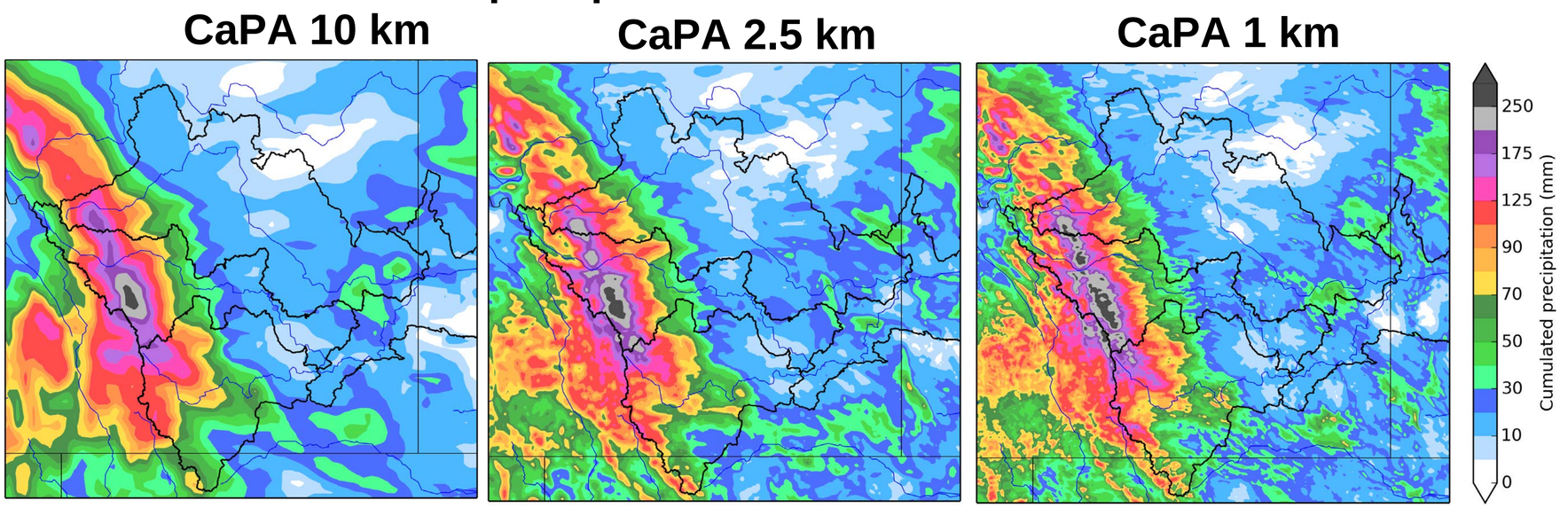
- Evaluation against a network of **independen**t stations (AB Env., USask, SHEF)
- Strong **underestimation** of precipitation over mountainous areas

New precipitation analysis

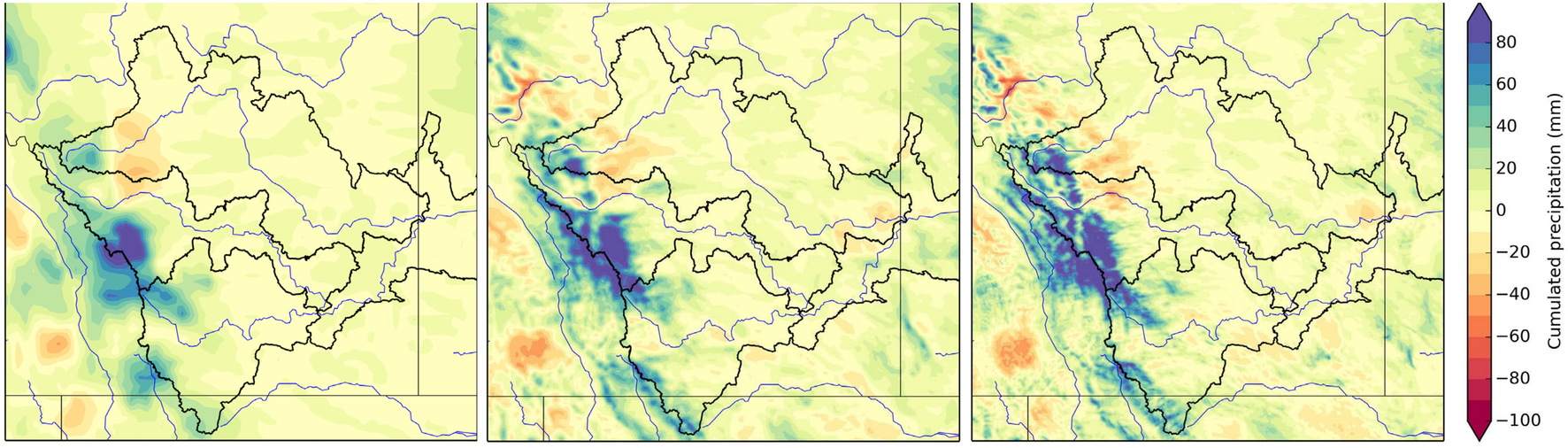
New precipitation analysis:

- Guess from 6-12 GEM forecasts at 10, 2.5 and 1 km
- Stations from AB Env., USask and SHEF included

Cumulated precipitation 19 June 12Z – 21 June 12 Z



Differences with the initial 10 km analysis



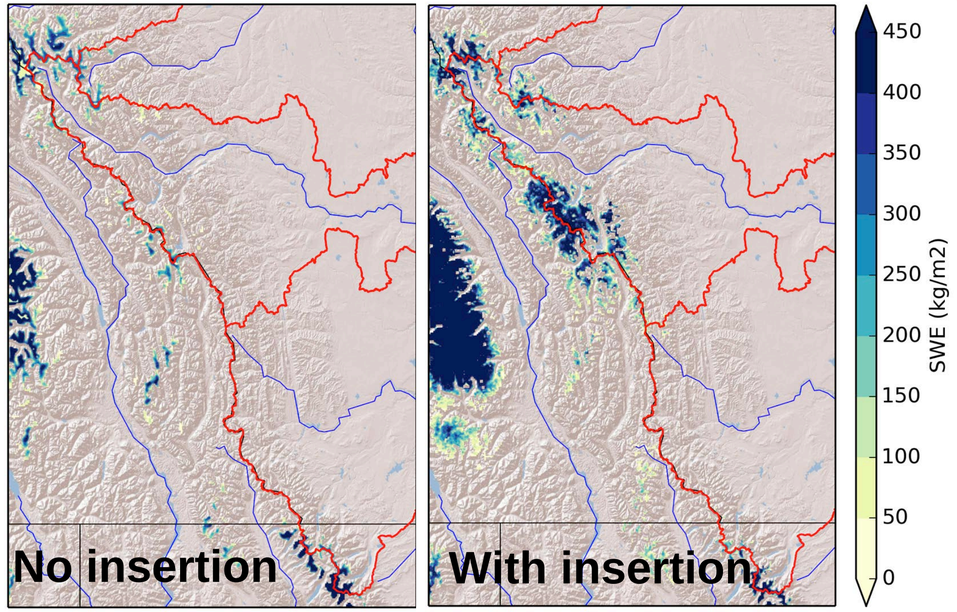
- **Additional stations** strongly affect the analysis **at all resolutions**.
- Additional features due to the **topography** are present at **2.5 and 1 km.**
- **Overall:** best analysis at 2.5 and 1 km (not shown)

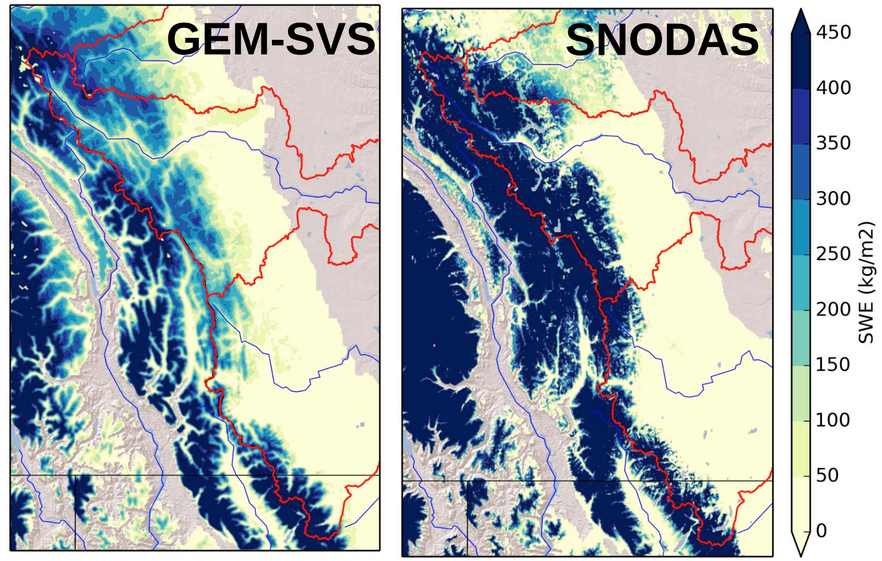
Initial snowpack conditions

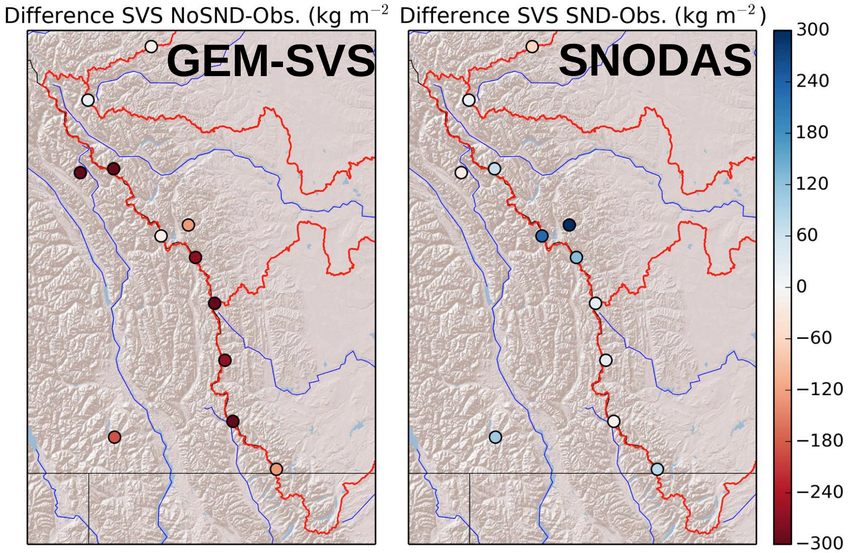
- SVS 1 km driven by GEM 10 km from 01/06/12 to 18/06/13
- **Underestimation of SWE** close to maximal accumulation

- Alternative: **SNODAS SWE analysis**
- Better agreement with obs. but **strong limitations** in open alpine terrain and in forested areas
- **Additional experiment: insertion of SNODAS SWE** on May 1st in GEM-SVS experiment

2 sets of **initial** soil and snow **conditions** on **18 June 2018**







SWE on May 1st 2013 (Top) and differences with snow pillows (Bottom)

Hydrological simulations

Atmospheric forcing

GEM 10 km
CaPA 10 km Old

GEM 10 km
CaPA 10 km New

GEM 2.5 km
CaPA 2.5 km New

GEM 1 km
CaPA 1 km New

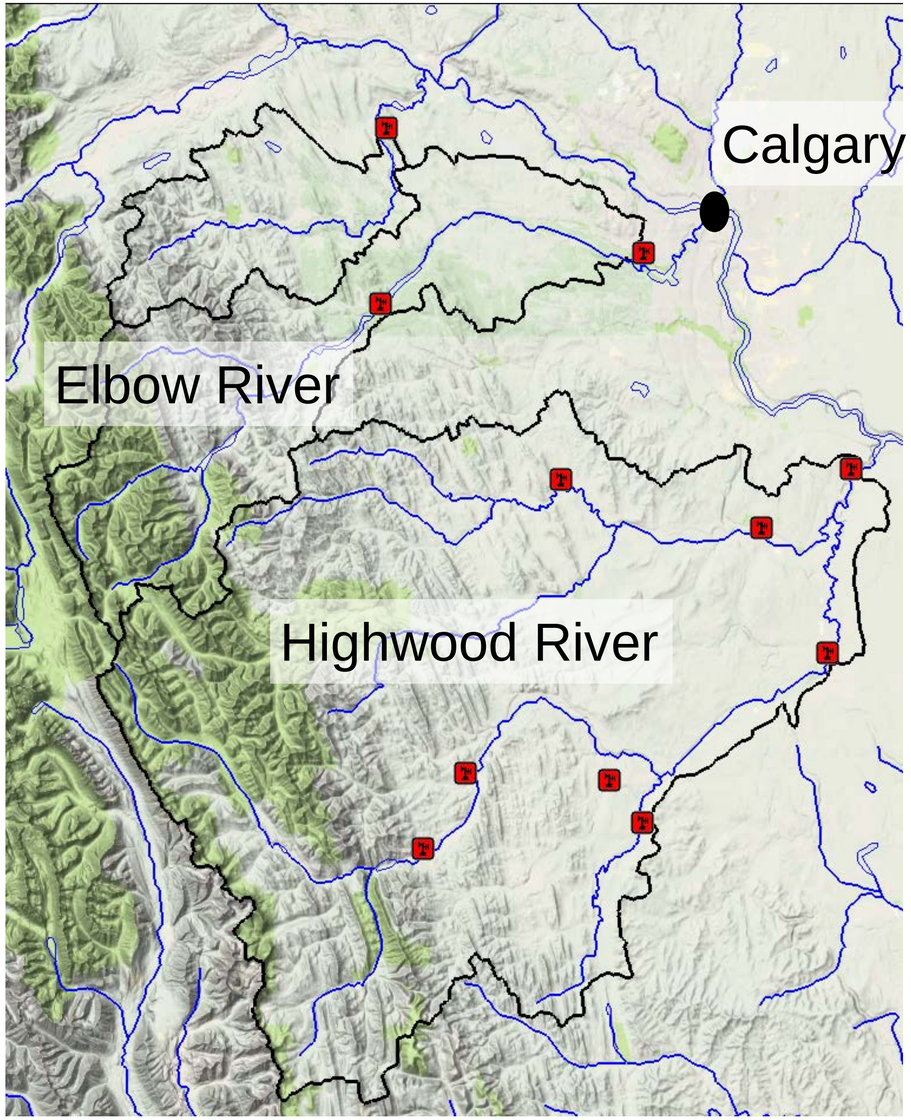
Initial surface conditions

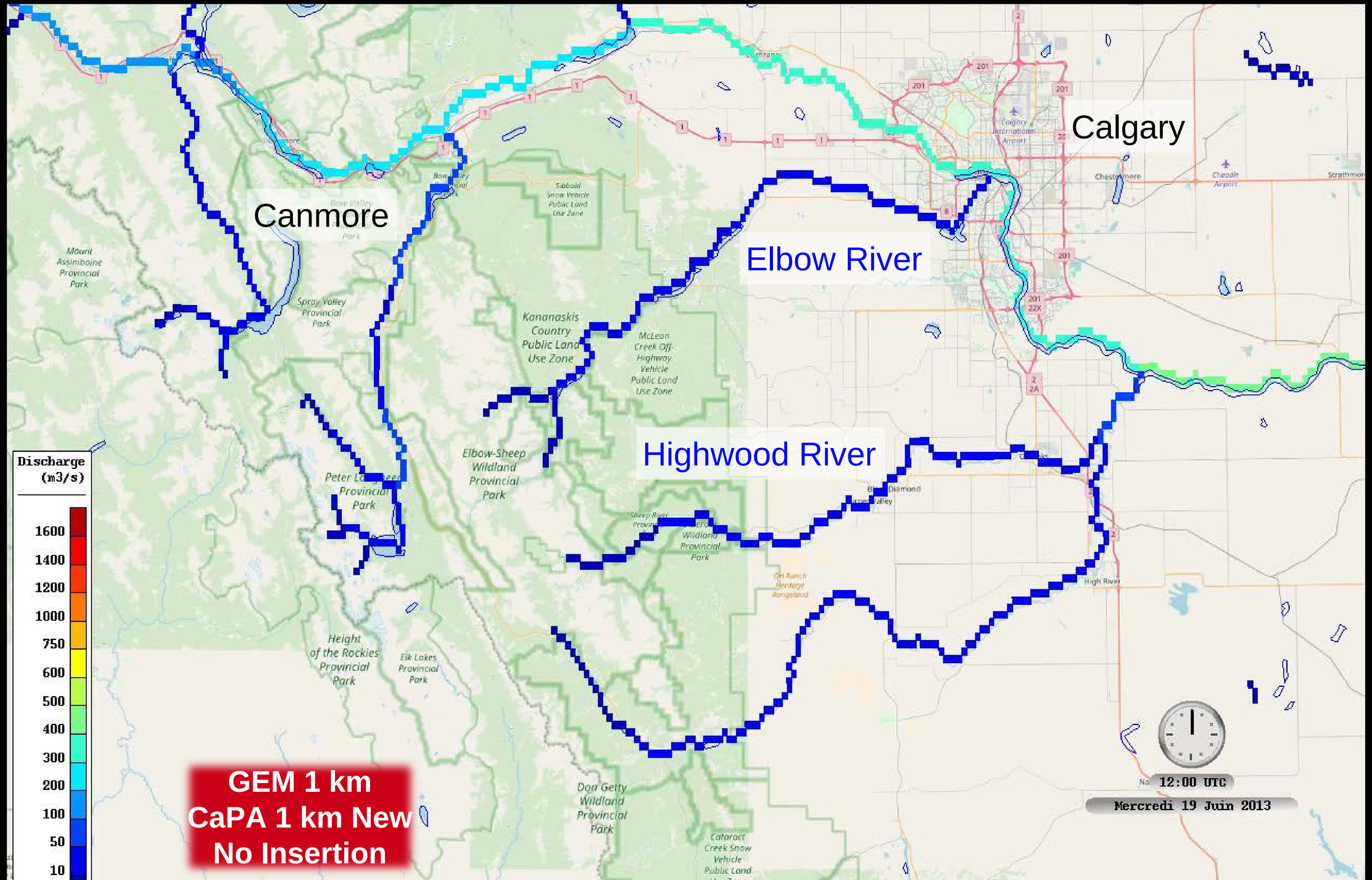
SVS 1km
No Insertion

SVS 1km
Insertion SNODAS

8 hydrological simulations
18-25 June

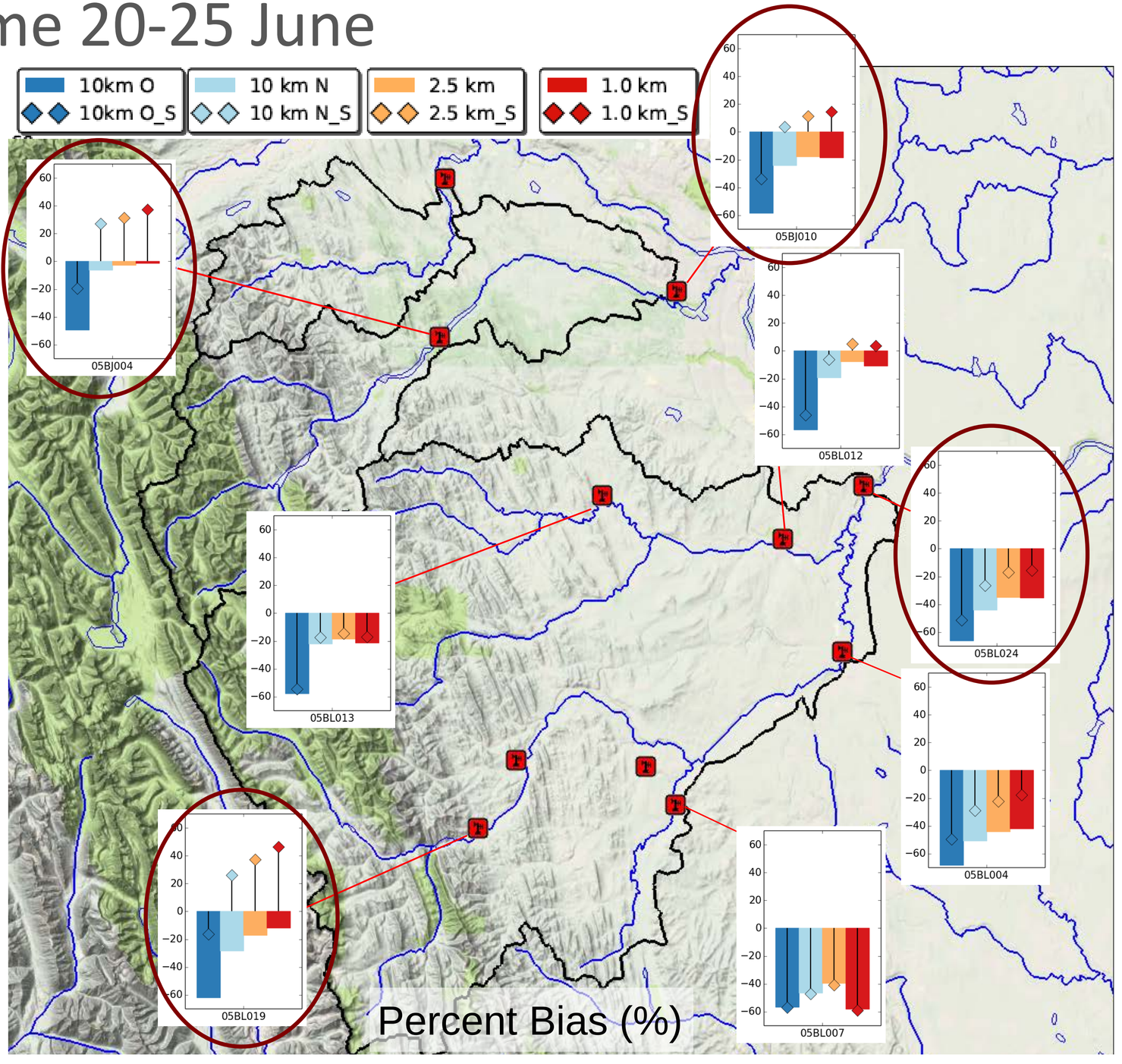
Region of interest



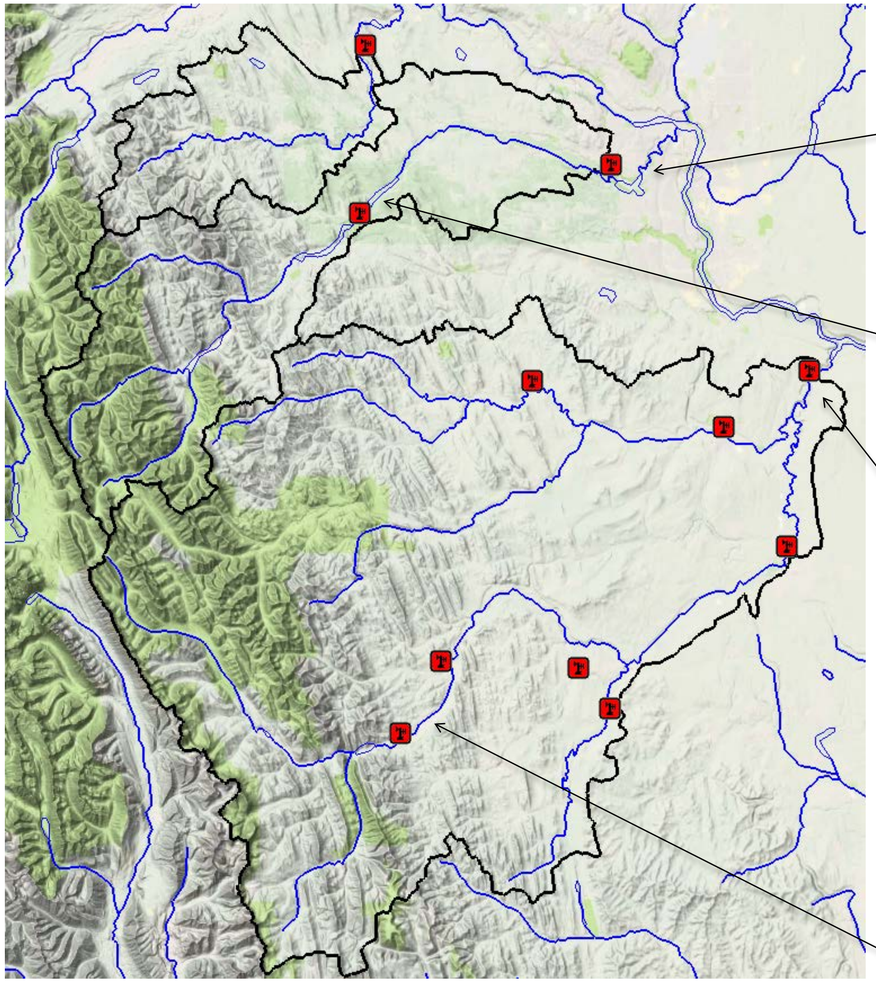

Canmore
Calgary
Elbow River
Highwood River
Discharge (m3/s)
1600
1400
1200
1000
750
600
500
400
300
200
100
50
10
GEM 1 km
CaPA 1 km New
No Insertion
12:00 UTC
Mercredi 19 Juin 2013

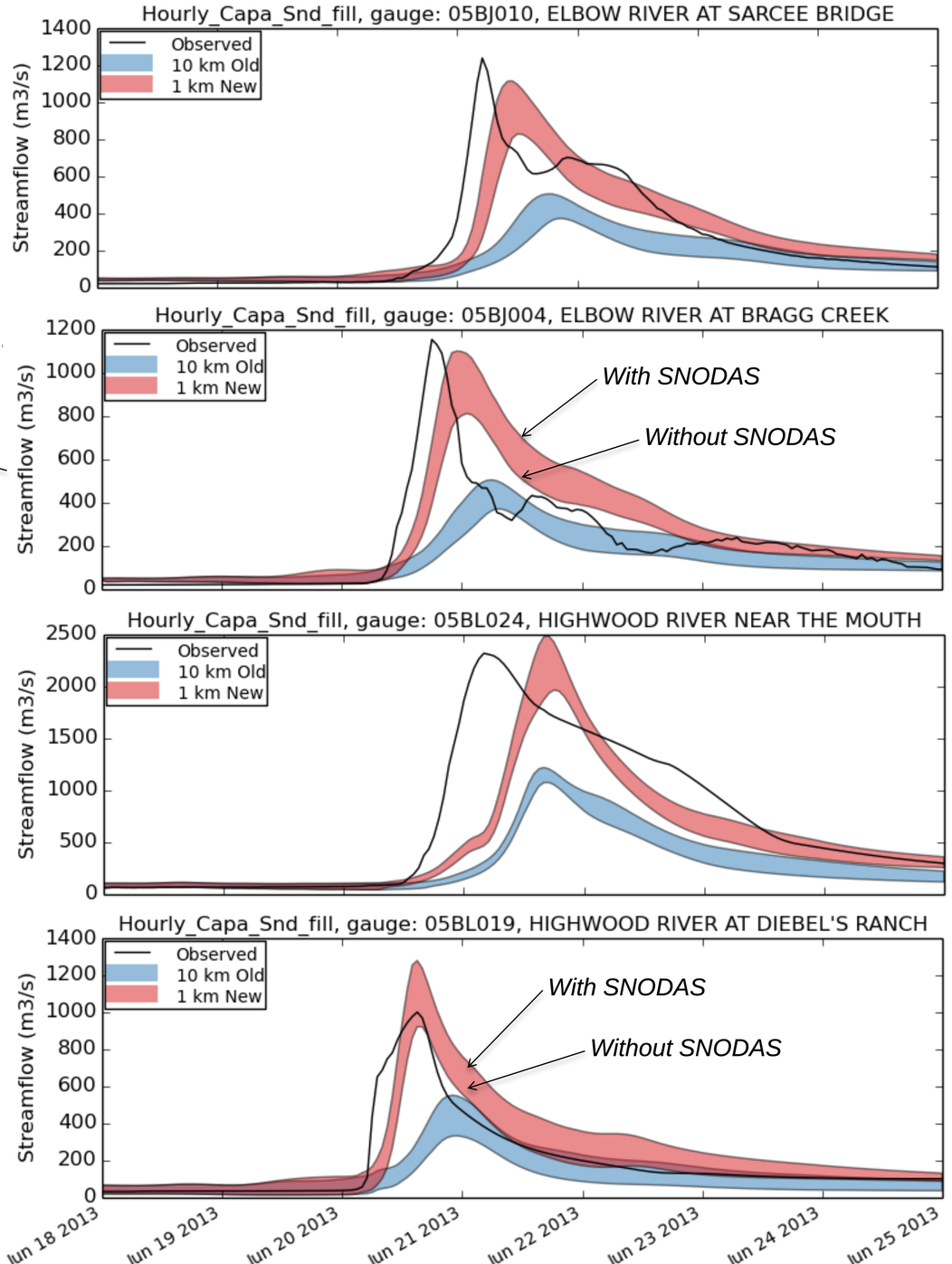
Flood Volume 20-25 June

- **Systematic underestimation** using the initial version of GEM-CaPA 10 km
- Large improvements with the new version of GEM-CaPA 10 km
- Similar results for GEM-CaPA 2.5 km and GEM-CaPA 1 km
- **Insertion of SNODAS** (◇): overestimation of flood volume for the upper part of the watersheds



Flood Dynamics





- **Better agreement** in terms **of peak flow** with GEM-CaPA 1km compared to GEM-CaPA 10km (Old)
- **Larger influence** of the **new pecip. analysis** than the insertion of **SNODAS**

Conclusions and perspectives

- Development of a **new set of meteorological data** at different resolutions for the **June 2013 flood**
- Clear **added value** of **the AB mountain stations** on **precipitation analysis** and **hydrology** (strong potential for the operational 2.5 km CaPA)
- **A reliable estimation** of **snowpack** conditions in the Canadian Rockies is **needed**

Perspectives:

- Test of **GEM-Hydro** in **forecast mode** (deterministic and ensemble) for the June 2013 flood and future **operational deployment**
- Collaboration between **GWF and ECCC** to propose a **new snowpack product** in the Canadian Rockies

Thank you for your attention!

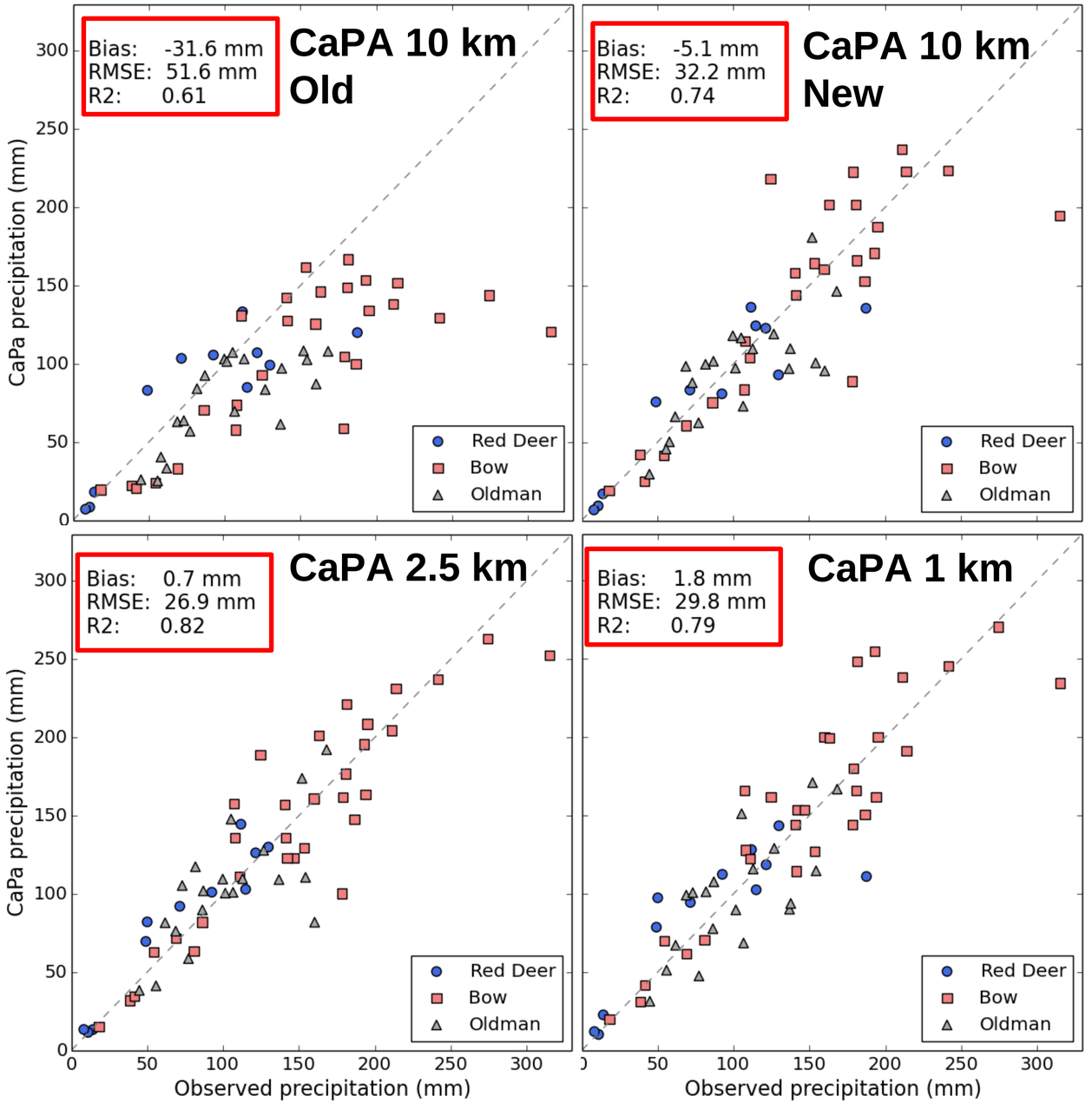
Acknowledgments: Nic Wayand (Usask), Manon Faucher (ECCC), Maria Abrahamowicz (ECCC), Milena Dimitrijevic (ECCC), Guy Roy (ECCC), Dorothy Durnford (ECCC)

New precipitation analysis (2)

Evaluation of the different analyses

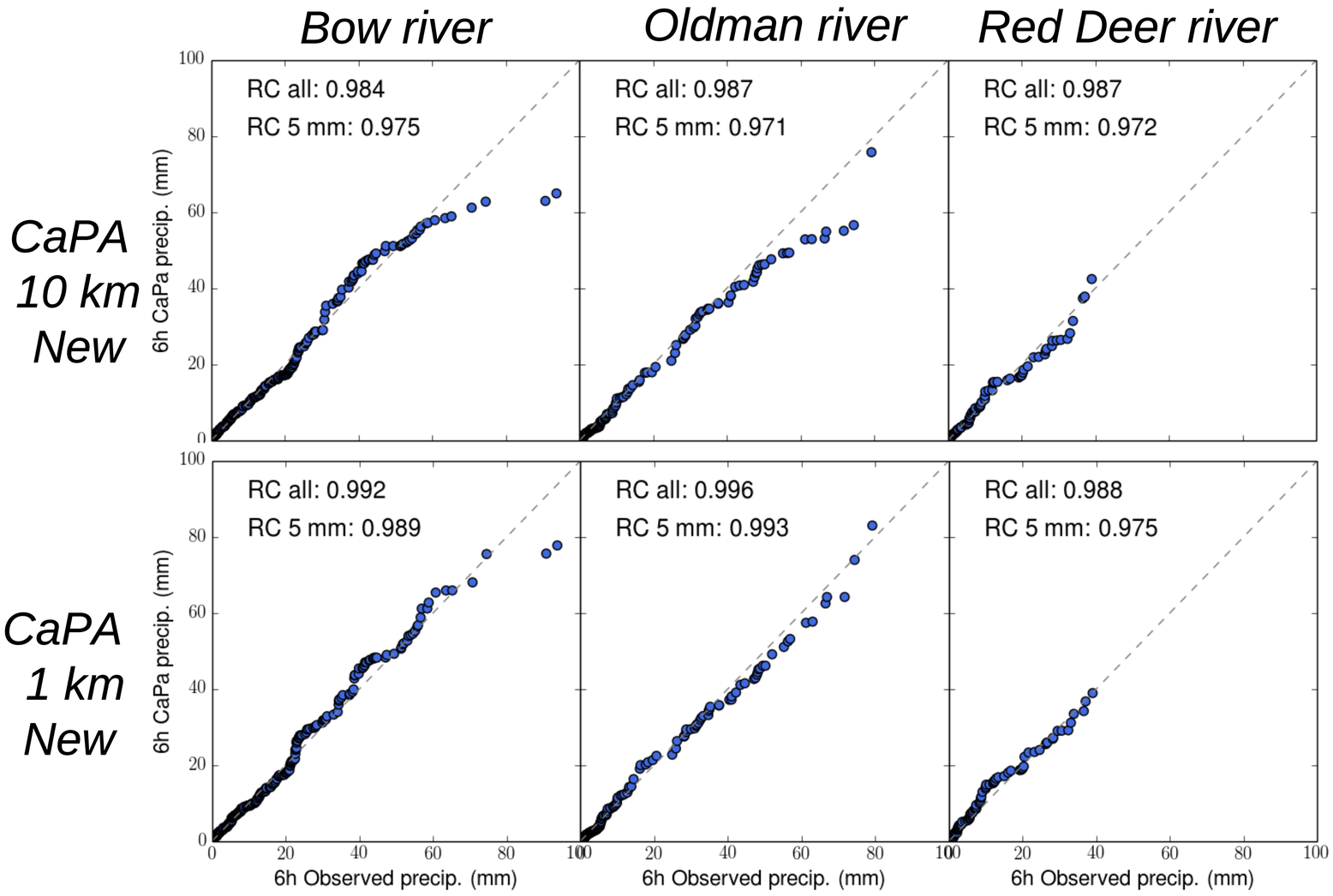
- Cumulated precip.: 19 -21 June
- Stations from AB Env., USask and SHEF
- Independent analysis for the initial version of CaPA 10 km
- Leave-One out cross validation for the other analyses

- **Improvements with the new versions** of the analysis compared to the initial one.
- **Improved results** at **2.5 and 1 km** compared to 10 km (also found for the distribution of 6h precip.)

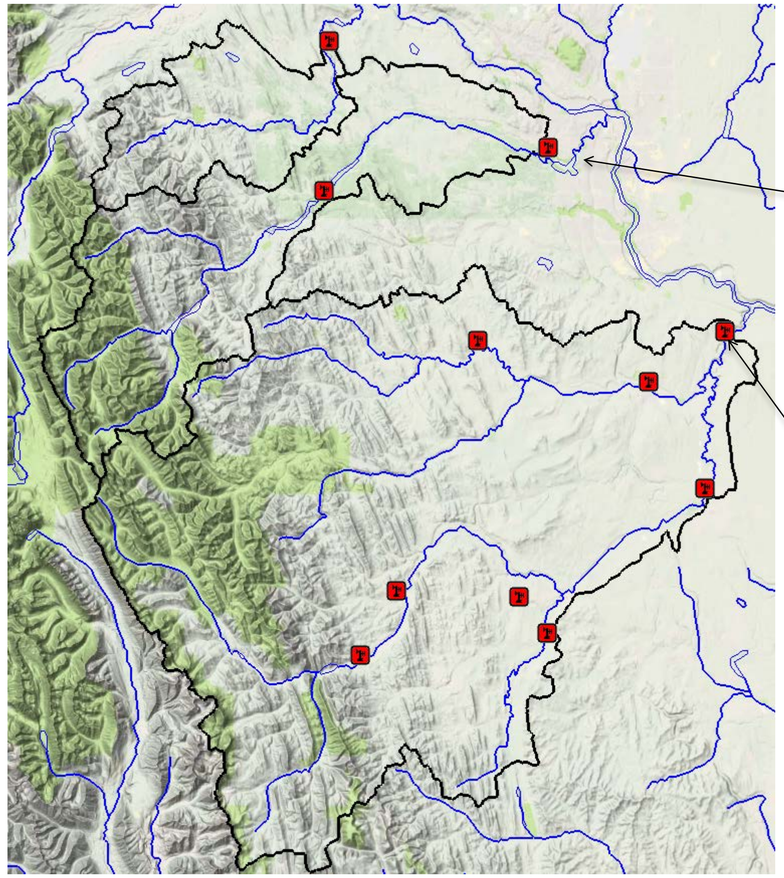


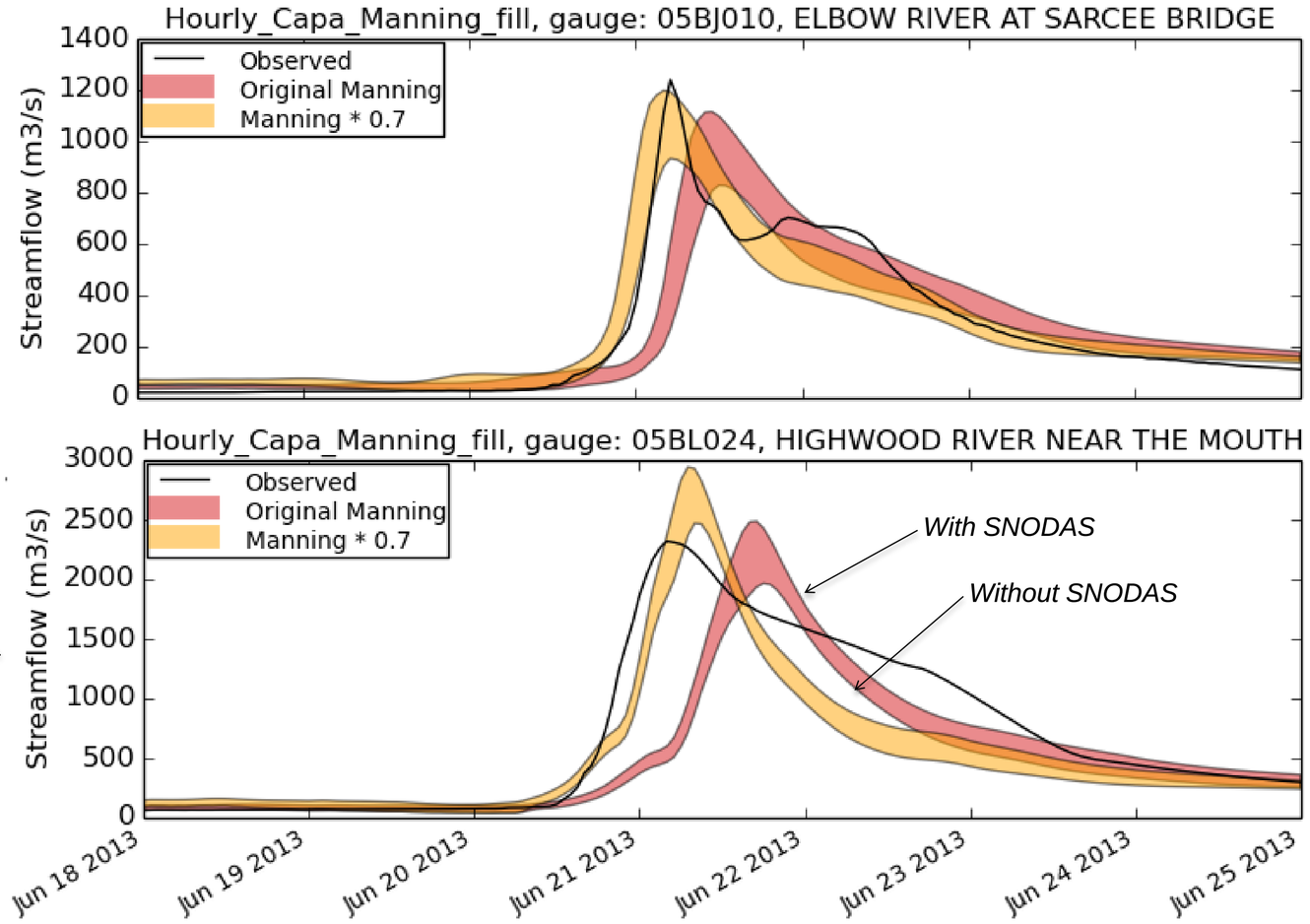
New precipitation analysis (3)

- Quantile-quantile plot of 6h precip. estimated by the leave-one out method for the different precip analysis.
- Concordance correlation coefficient computed for all precip. and precip > 5 mm
- CaPA 1-km (and 2.5 km) better captures the distribution of 6-h precip than CaPA 10 km.



Flood Dynamics: influence of river routing





- Major **changes** in **river geometry** during the flood (Ex. : Elbow River at Bragg Creek)
- Adjusting the **Manning's coefficients** modifies the **timing of peak flow and its values**