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

V. Vionnet^{1,2}, E. Gaborit², V. Fortin², N. Gasset²,
C. Garnaud², N. Gauthier² and J. W. Pomeroy¹
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)



- model
- **Canadian Precipitation** Analysis (CaPA)





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









Precipitation analysis

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



Cumulated precipitation 19 June 12Z to 21 June 12Z



First guess and observations







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









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



Evaluation against a network of independent stations (AB Env., USask, SHEF)

(mm)

precip.

cumul

Strong underestimation of precipitation over mountainous areas

Differences of cumulated precipitation(19-21 June)



New precipitation analysis Cumulated precipitation 19 June 12Z – 21 June 12 Z CaPA 10 km CaPA 2.5 km CaPA 1 km

New precipitation analysis:

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

- 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)





Differences with the initial 10 km analysis

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







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

Hydrological simulations



Region of interest



8 hydrological simulations 18-25 June







&a

Calgary

Elbow River

5

Highwood River

Said Loop

Anna and

12:00 ¥00

612

3

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





- 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**









- 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)

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





> Development of a new set of meteorological data at different resolutions for the

> A reliable estimation of snowpack conditions in the Canadian Rockies is needed





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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 (2)



- 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.



New precipitation analysis (3)

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