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

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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

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

**Land Surface Scheme**
SVS (Soil Vegetation and Snow)
- Multiple energy budgets for bare ground, low and high vegetation
- Single layer snowpack scheme

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

Gaborit et al. (2017)
Alavi et al. (2016) Husain et al. (2016)
Kouwen (2010)
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

**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**

Cumulated precipitation
19 June 12Z to 21 June 12Z
Precipitation analysis: evaluation

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

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

- Strong underestimation of precipitation over mountainous areas
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)
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 1 km No Insertion
SVS 1 km Insertion SNODAS

8 hydrological simulations 18-25 June

Region of interest

Calgary
Elbow River
Highwood River

Atmospheric forcing

Region of interest
• **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 precip. 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!

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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 (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**