Hydrodynamic modelling of snowmelt flooding events and nutrient transport in the Canadian Prairies using the FLUXOS model

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INTRODUCTION

- Snowmelt can cause the flooding of agricultural fields and is a major period of nutrient transport.
- Snowmelt runoff is generally responsible for soil losses of N and P exceeding those from rainfall-induced runoff in the summer.
- Inundation of agricultural fields has a major impact on nutrient export.
- Predicting nutrient transport during snowmelt is important to support the development of effective land management practices, but it remains a major scientific challenge.
- Hydrodynamic simulations at high temporal and spatial resolution may be helpful to improve the prediction of field-scale streamflow and nutrient export during snowmelt events, as well as help advance theory on the dominant processes affecting nutrient release.

METHODS

- The FLUXOS model solves the dynamic wave - 2D shallow water PDEs - that accounts for inertial (local and convective), pressure, gravity and friction forces (momentum balance),
- Thus, the model can capture backwater effects (unlike the kinematic or diffusion waves). This is critical to simulate low-relief terrains.

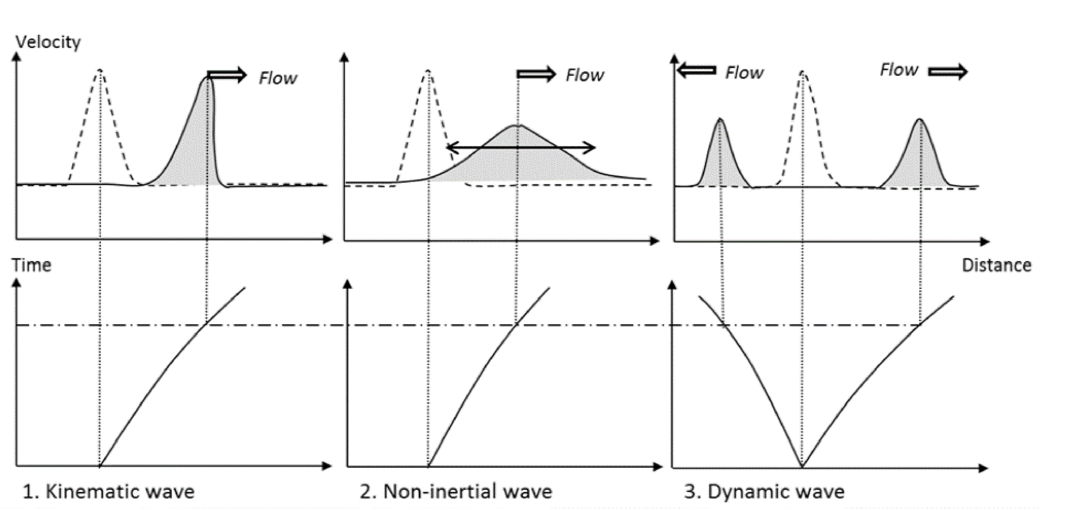


Fig. 1: Transformation of waves as per the different approximations of the Navier-Stokes Equation (Novak et al, 2010)

Can high resolution <u>2D hydrodynamic modelling of entire basins</u> help advance the theory and prediction of snowmelt runoff pathways and the associated nutrient export in the Canadian Prairies?

RESULTS:

(1) Snowmelt flood maps and water depths

South Tobacco Creek, MB (2011 snowmelt event) Smith Creek, SK

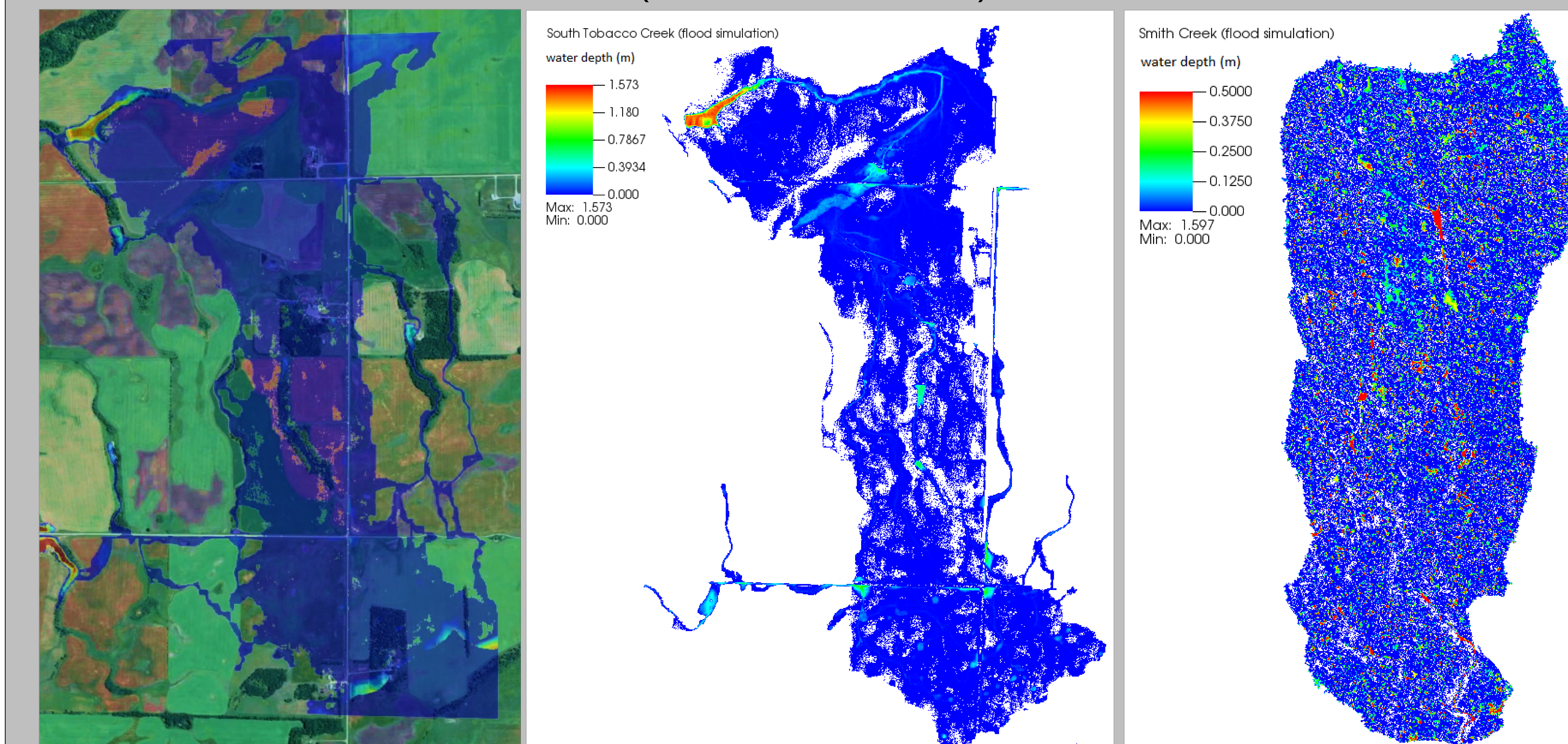
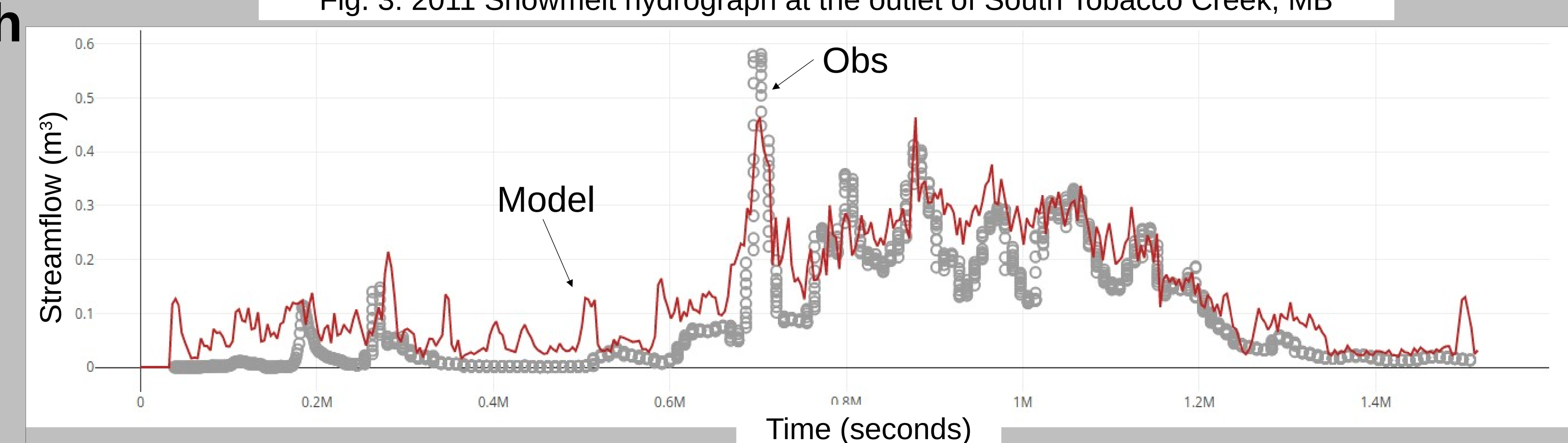


Fig. 2: Flood maps of snowmelt events at South Tobacco Creek (SK) and Smith Creek (SK)

(2) Snowmelt flood hydrograph

The prototype model is being tested in the South Tobacco Creek (MB) and Smith Creek (SK) Watersheds and shows promising results. It can predict both snowmelt flood maps and hydrographs, as well as wetland routing and drainage impact

Fig. 3: 2011 Snowmelt hydrograph at the outlet of South Tobacco Creek, MB



CONCLUSIONS

- Results show that FLUXOS can provide insights into the hydrodynamic response of low-relief terrains (e.g. expansion and contraction of wetlands/ potholes).
- The model allows investigating complex runoff pathways that can be key to predict nutrient sources and mobilization
- Currently being tested: nutrient transport modules and the coupling to CHM for integrated blowing snow, snowmelt and hydrodynamic simulations

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FLUXOS CHM

METHODS (cont.)

- The model was originally developed for river reach flood simulations, and therefore it was repurposed here to allow for field and catchment-scale simulations and snowmelt forcing.
- The topography (DEM) is used to capture snowmelt runoff pathways (there is no need to specify the location of the streams). This is important in regions with variable contributing areas such as the Canadian Prairies
- A module for drop inlet spillways and culverts was added. It is based on Bernoulli's Equation (assumes pressure dominated at this stage) and head losses computed from the implicit Colebrook-White equation for both laminar and turbulent pipe flows, which is solved interactively using the Raphson-Newton interaction method.
- Vegetation and other obstacles to the flow are included through distributed absolute roughness heights

DISCUSSION

- FLUXOS has been previously tested at river-reaches scales and has shown good prediction capacity (Costa et al., 2016)
- The model is currently being coupled to the Canadian Hydrological Model (CHM) for fully integrated blowing snow, snowmelt and hydrodynamic simulations
- CHM is a modular, multi-physics, spatially distributed modelling framework designed for representing cold-regions hydrological

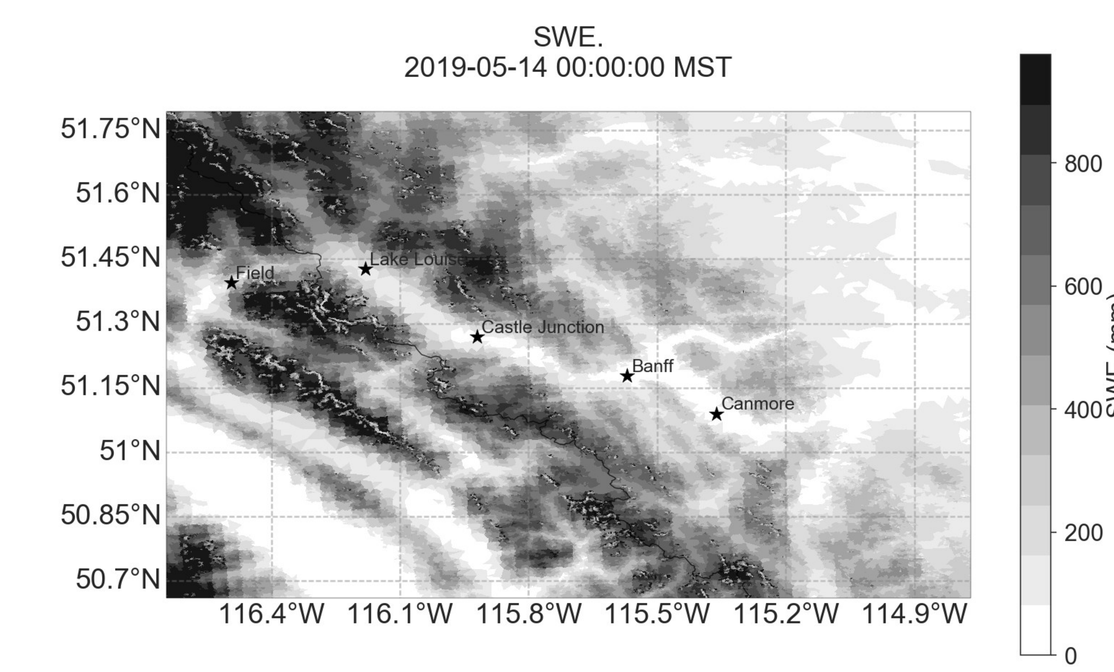

Fig. 4: Example of a simulation of snow water equivalent (SWE) at the Bow River Basin, centered over Banff, Canada (www.snowcast.ca)

REFERENCES

Costa, Diogo, Paolo Burlando, and Shie-Yui Liong. 2016. "Coupling Spatially Distributed River and Groundwater Transport Models to Investigate Contaminant Dynamics at River Corridor Scales." Environmental Modelling & Software 86: 91–110. https://doi.org/10.1016/j.envsoft.2016.09.009.

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