

Flood Impact Maps

A standardized Approach of Understanding Vulnerable Landscapes

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2 | PRESENTATION

Outline

- Motivation
 - COP26
 - Publication of www.floodmapviewer.com
 - “Who is this loser?”
- Floodplain mapping project
 - Methodology
 - Implementation
- What are these maps for?
 - Overall understanding of the extent of flood hazard across the country
 - Identification of high risk areas for more detailed mapping
 - Investigation of regional impacts at the inundation level
 - Investigation of the changes in floodplain regimes for future climates
- Communication to the general public
- Remaining challenges

3 | MOTIVATION

COP26

- Climate change
 - IPCC (part of the AR6)
 - August report (Climate Change 2021 – The Physical Science Basis)
 - Review of 14,000 references
 - First time emphasized a much stronger connection between climate change and extreme weather
 - COP26 – Glasgow



4 | MOTIVATION

Canadian government



May 14 2021

THOMPSON'S WORLD INSURANCE NEWS

• CANADA'S INDEPENDENT NEWS SOURCE FOR INSURANCE PROFESSIONALS • SINCE 1988 •

May 10, 2021

Budget boosts action plan on flooding

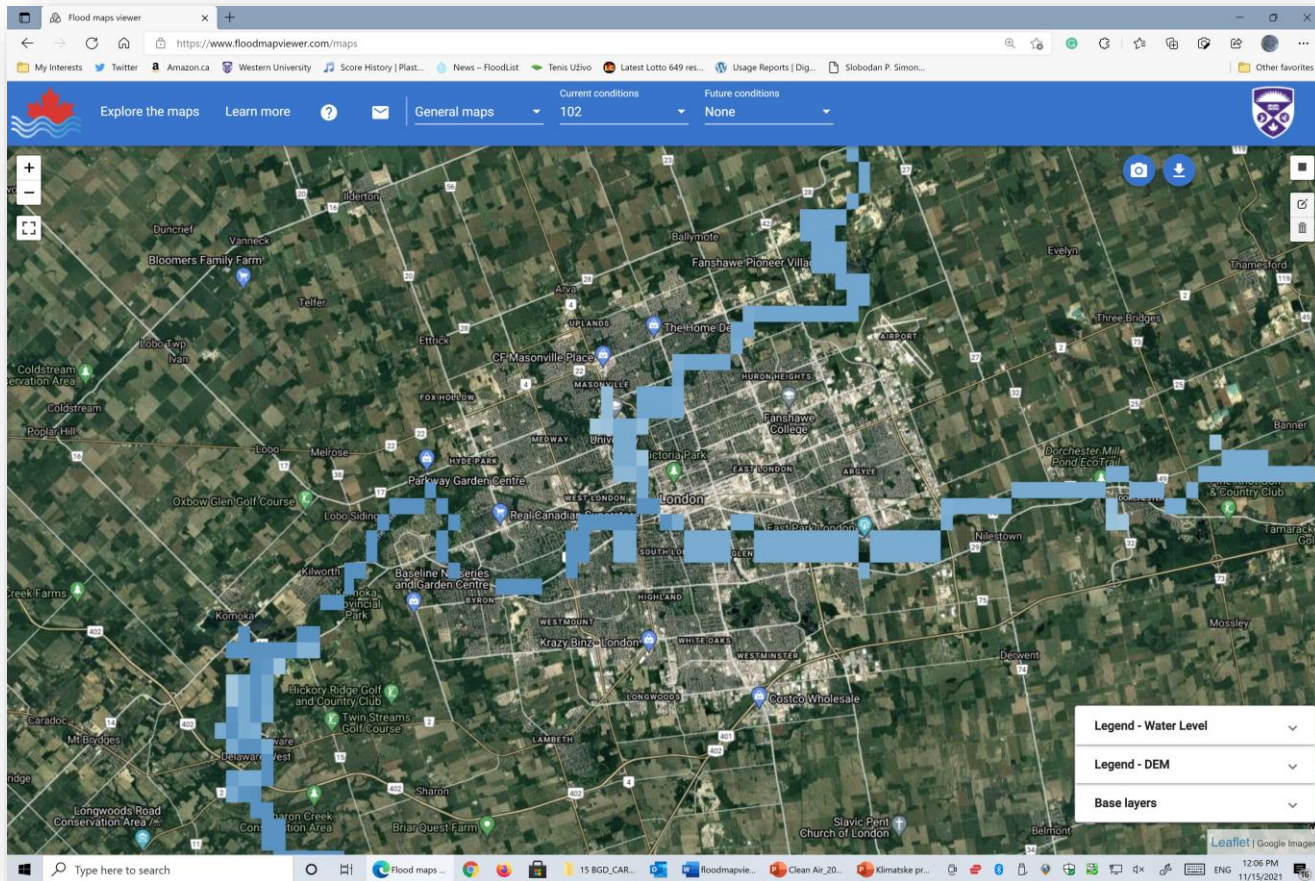
April 26 —THE FEDERAL government continued to implement its promised National Action Plan on Flooding with several measures in the recent spring budget announcement.

The Insurance Bureau of Canada noted that the government has now committed to spending \$1.4bn over 12 years to extend the Disaster Mitigation and Adaptation Fund with roughly half of the amount dedicated to smaller-scale projects.

Another \$63.8m will be allocated over three years to Natural Resources Canada, Environment and Climate Change Canada and Public Safety Canada to work with provinces and territories to finish flood maps for higher-risk areas.

5 | MOTIVATION

www.floodmapviewer.com



Response

- 8 newspaper articles
- 4 radio shows
- 6 TV shows



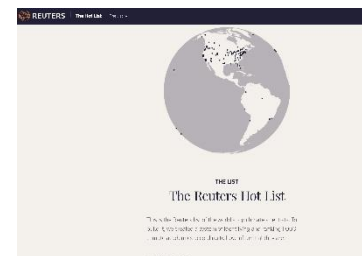
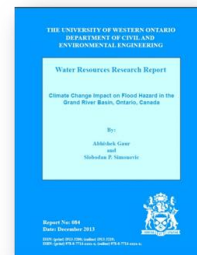
.....

Who is this loser?

6 | MOTIVATION

“Who is this loser?”

- Research:
 - *Subject Matter* - Systems modeling; Risk and reliability; Water resources and environmental systems analysis; Computer-based decision support systems development.
 - *Topical Area* - Reservoirs; Flood control; Hydropower energy; Operational hydrology; Climatic Change; Integrated water resources management.
- 77 research projects
- Completed: 12 visiting fellows, 21 PosDoc, 24 PhD and 45 MESC
 - ~ 600 professional publications
 - 260 in peer reviewed journals
 - 3 major textbooks
- Water Resources Research Reports 114 volumes – <https://ir.lib.uwo.ca/wrrr/>
- > 107,200 downloads since 2011
- One of 1,000 most influential climate scientists in the World



- Flood inundation analyses over large regions

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Project objectives

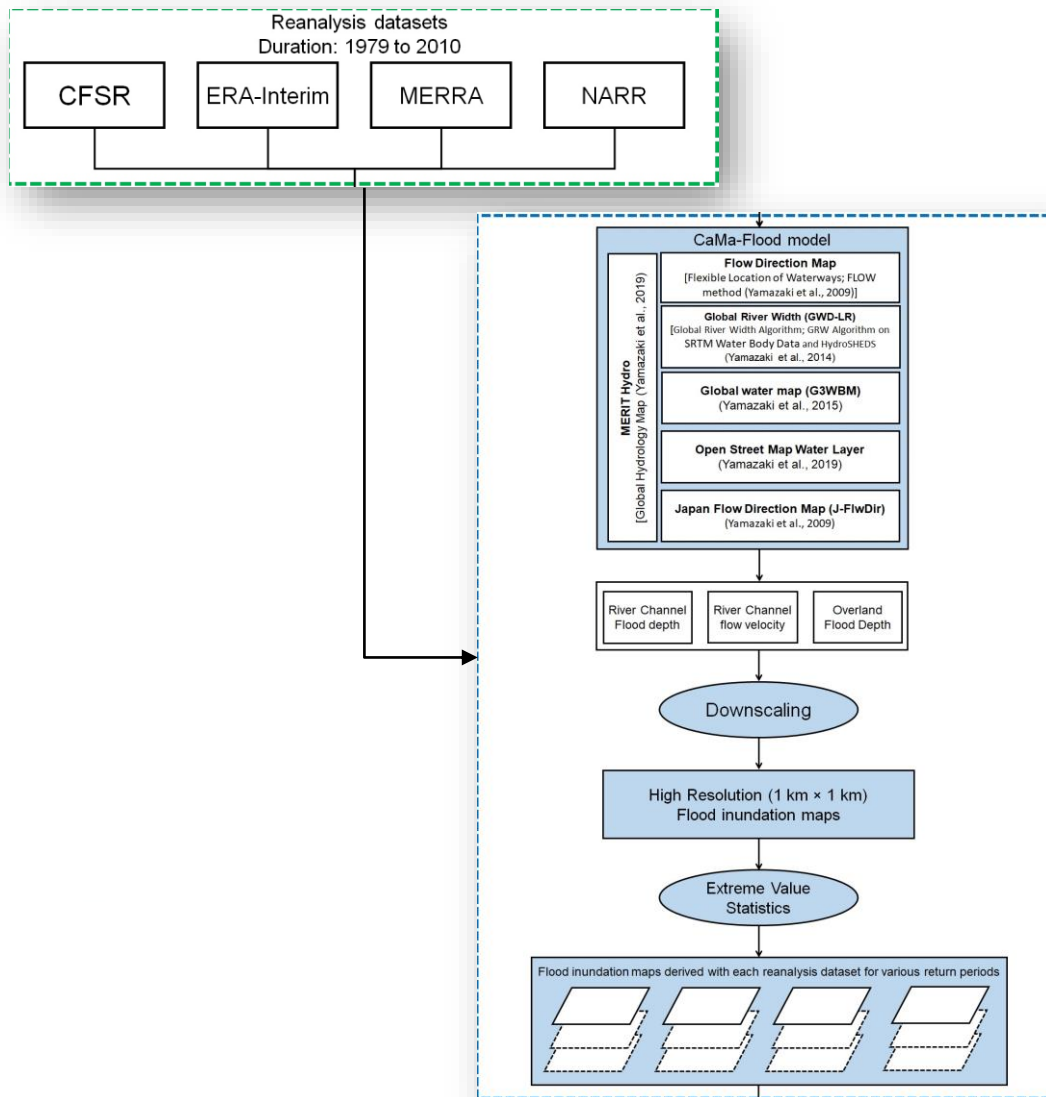
- Development of the methodology for high resolution flood inundation analyses over large regions
- Investigation of the fidelity of publicly available data
- Investigation of the changes in floodplain regimes for the future periods
 - (i) changes in flood inundation extents,
 - (ii) changes in flood hazards, and
 - (iii) changes in flood frequency.
- Funding: NSERC CRD with Chaucer Synd.: 2015-2022 \$1,375,600



- Research team
 - Prof. Slobodan P. SIMONOVIC
 - Prof. Mohit Mohanty
 - Ms. Bogdana Sredojevic
 - Dr. Andre Schardong

9 | METHODOLOGY

Floodplain mapping



The runoff data:

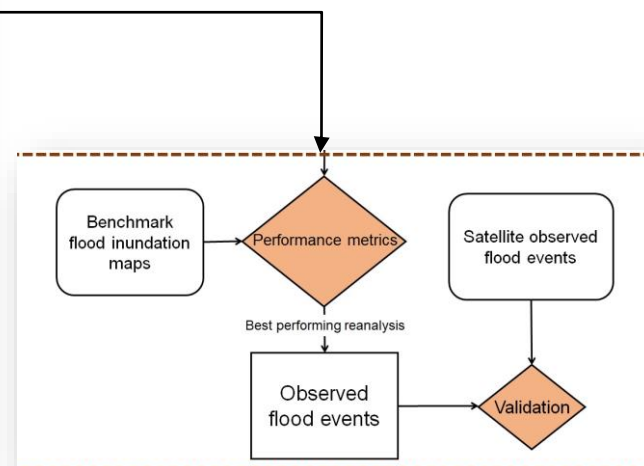
CFSR every 6 h, 1979-2010 at a surface grid resolution of 0.3°.

ERA 3 h, 1979- present, 0.75°.

MERRA 1 h, 1979- present, 2/3° × 1/2°.

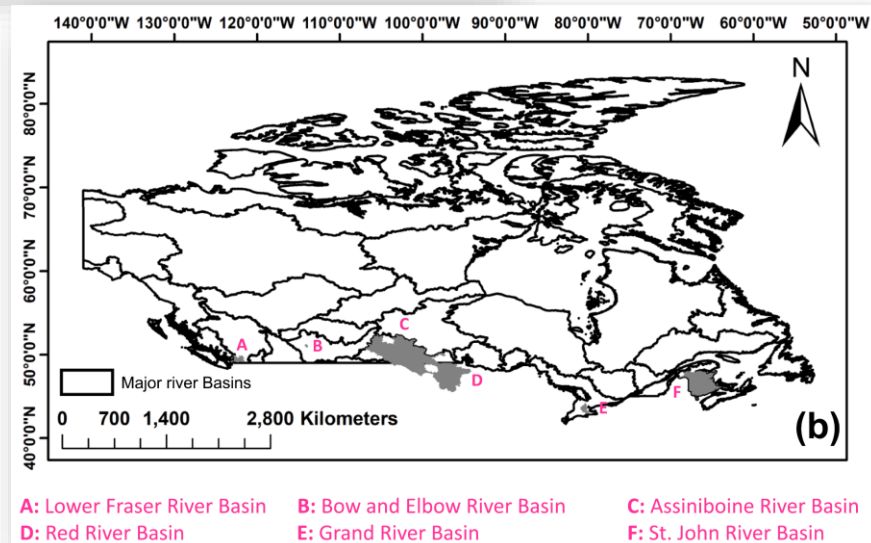
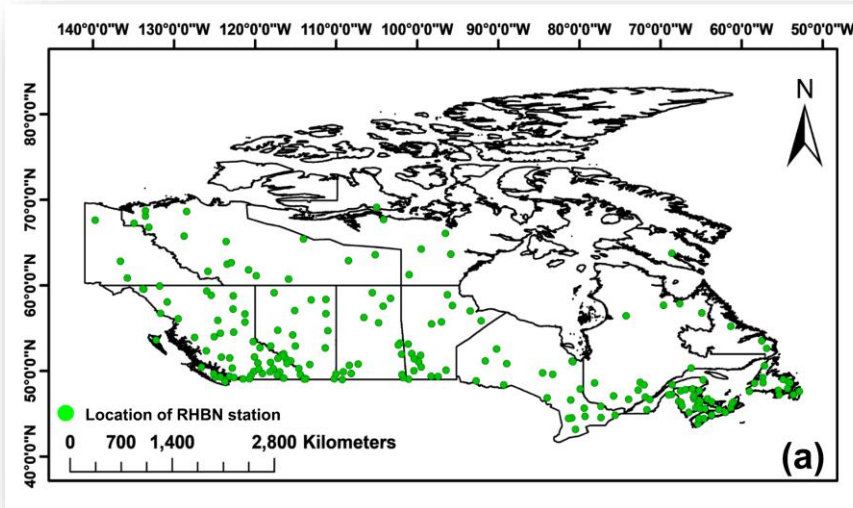
NARR 3 h, 1979 –present, 0.3°.

MODIS – near real-time global flood mapping project: a few historic flood events.



10 | METHODOLOGY

Data



11 | METHODOLOGY

Implementation steps

- Download runoff data for each reanalysis product
- At station locations – comparison between observed and reanalysis runoff values (correlation coefficient)
- Fitting GEV distribution to the data – extracting 100 year and 200 year
- Use gridded 100 and 200-yr runoffs with the CaMa-Flood model to derive maximum flood depth (m) and inundation extents (km²) for entire Canada
- Downscaling maps to 1 km x 1 km spatial resolution
- Discretization of water depths into five classes based on the degree of severity to humans and economic losses
- Clip the maps for six selected basins
- Compare the maps using four common performance statistics

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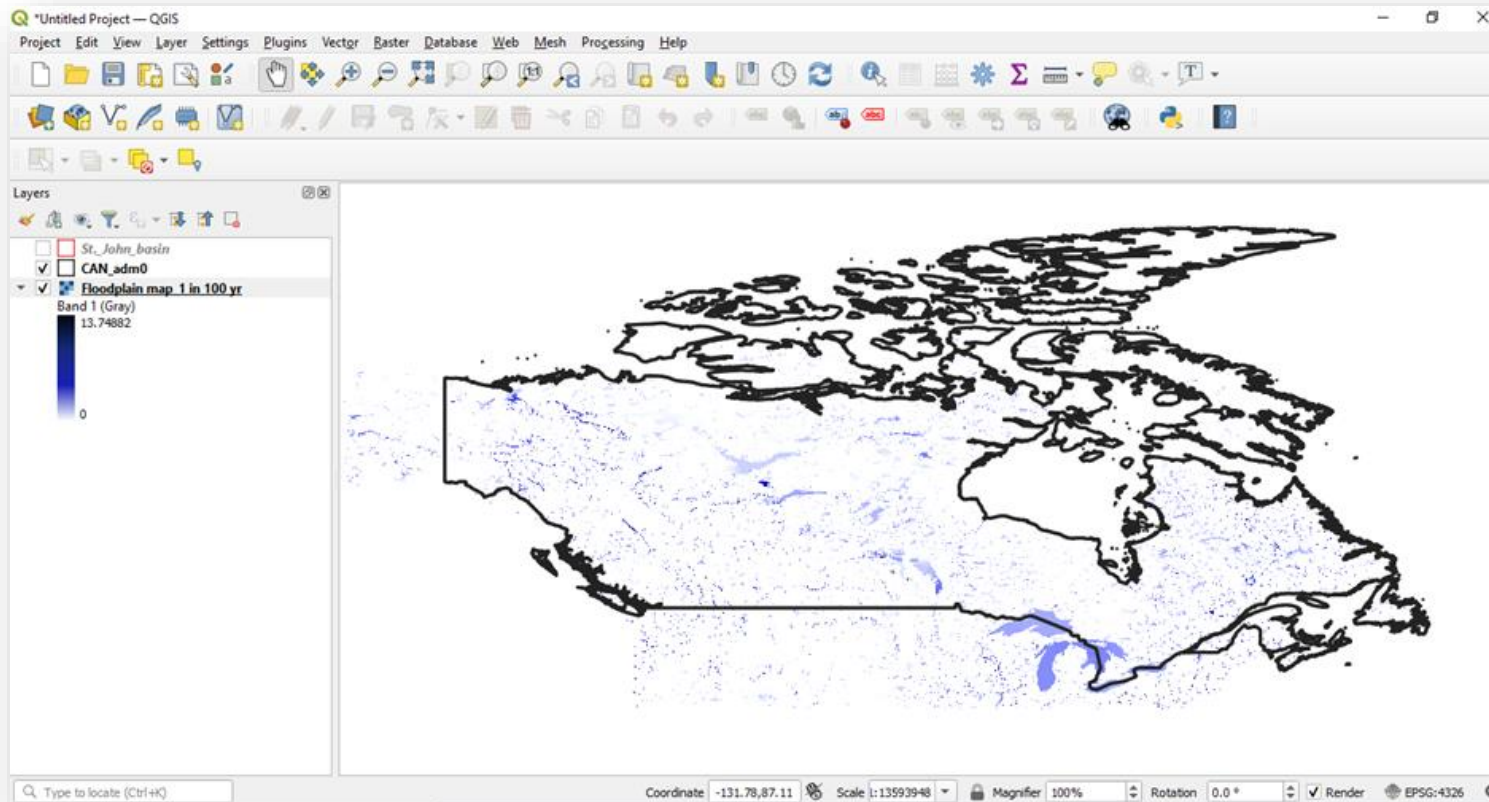
Implementation steps

$$h_z = \begin{cases} 1, 0 \leq h \leq 0.2 \\ 2, 0.2 < h \leq 0.6 \\ 3, 0.6 < h \leq 1.5 \\ 4, 1.5 < h \leq 3.5 \\ 5, h > 3.5 \end{cases}$$

Performance statistic	Description	Range	Remarks
H	$\frac{IA_s \cap IA_b}{IA_b}$	0 to 1	The Hit Rate (H) also referred to as the probability of detection, indicates how well the model result replicates the benchmark data without penalizing for over-prediction. A score of '1' indicates that all flooded cells in the simulated floodplain map are also wet in the benchmark floodplain map.
F	$\frac{IA_s/IA_b}{(IA_s \cap IA_b + IA_s/IA_b)}$	0 to 1	The False Alarm Ratio (F) is a measure of model over prediction. A value of '0' indicates no false alarms (overpredicted cells), while '1' indicates false alarms
C	$\frac{IA_s \cap IA_b}{IA_s \cup IA_b}$	0 to 1	The Critical Success Index (CSI) combines both H and F to account for both underpredicted and overpredicted grids. A value of '0' indicates no match between the simulated and benchmark floodplain map, while '1' indicates perfect match between simulated and benchmark floodplain map.
B	$\frac{IA_s/IA_b}{IA_b/IA_s}$	0 to ∞	The Error Bias (B) indicates the tendency of the model to underpredict or overpredict. A value between '0 and 1' indicates a tendency of the model to underpredict and a value between '1 and ∞ ' indicates a tendency of the model to overpredict.

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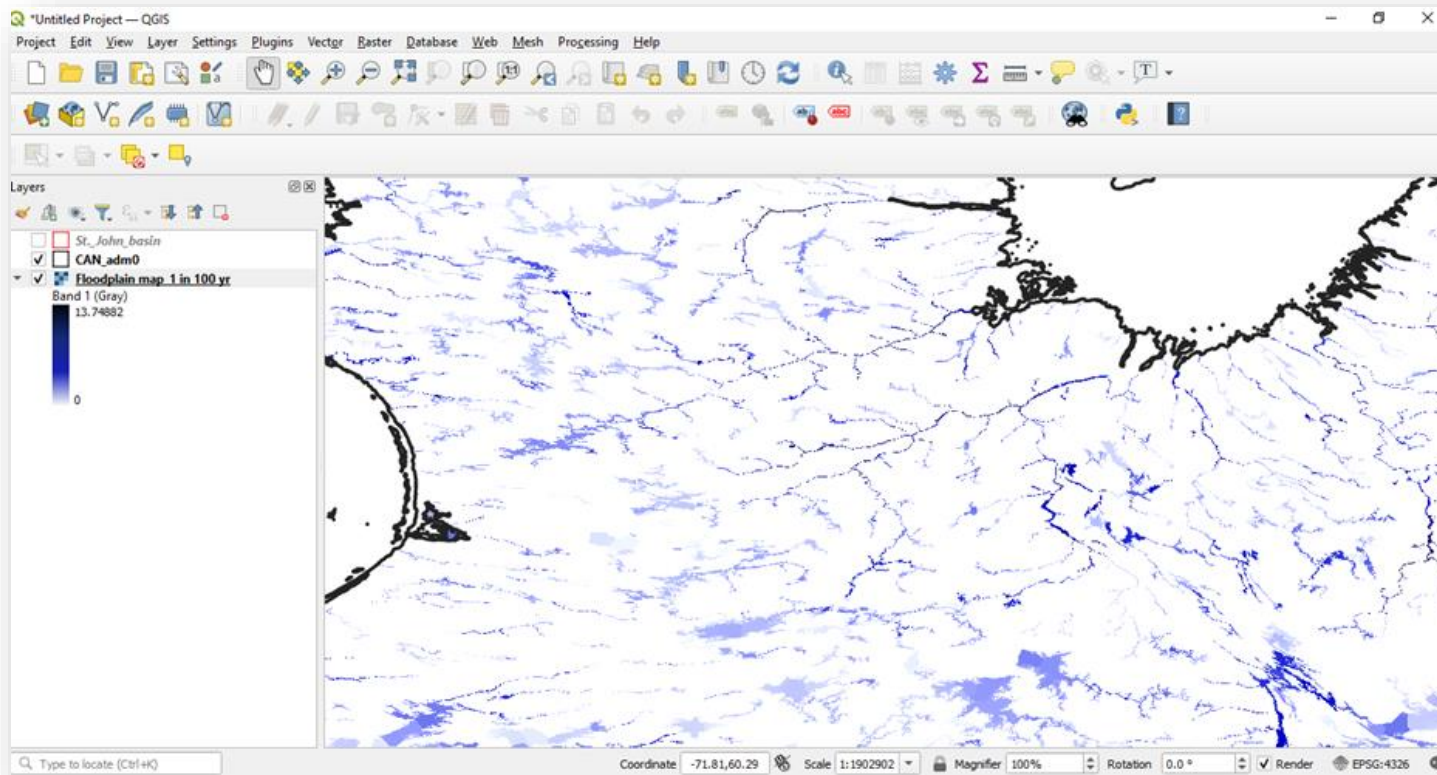
Representative floodplain map



100 yr floodplain map of Canada (opened in QGIS)

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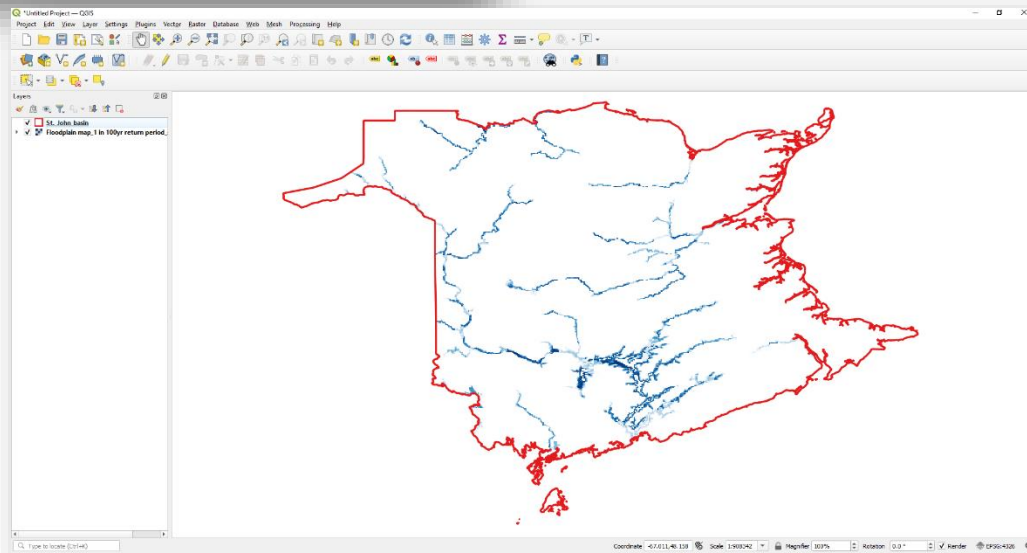
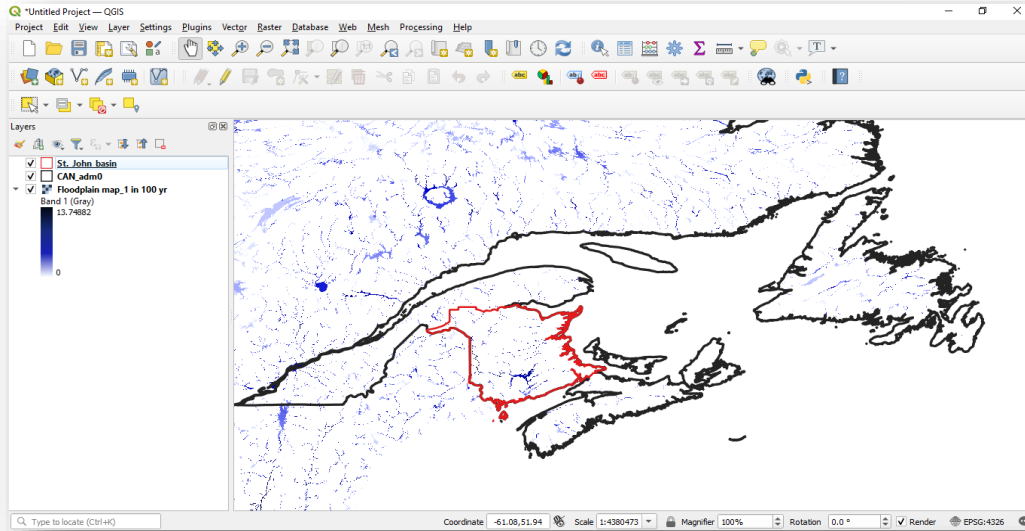
Representative floodplain map



100 yr floodplain map of Canada (zoomed illustration)

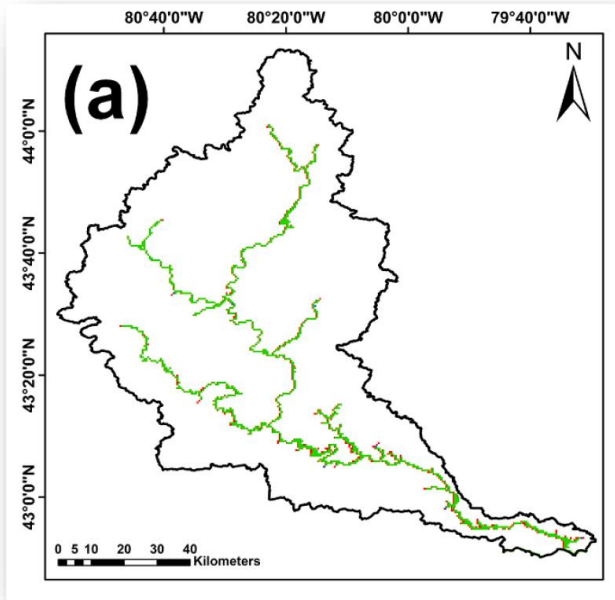
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Representative floodplain map

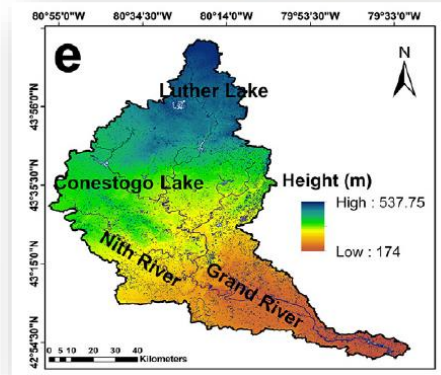


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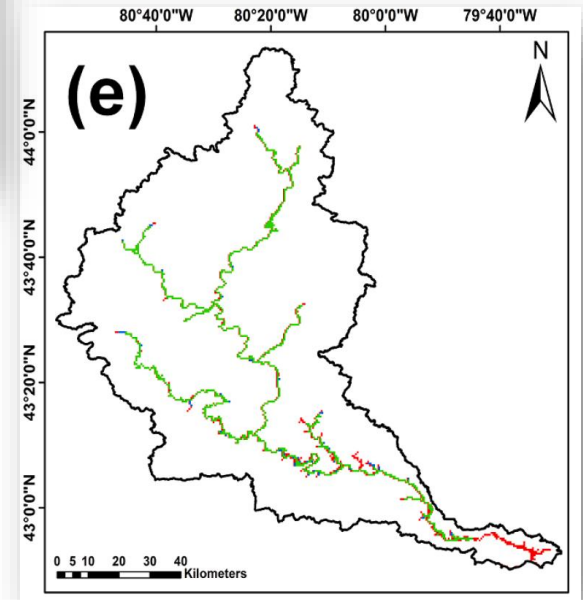
Verification



Grand River 100 yr



Grand River DEM



Grand River 200 yr

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Comparison of floodplain maps



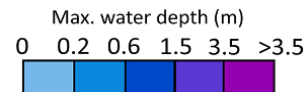
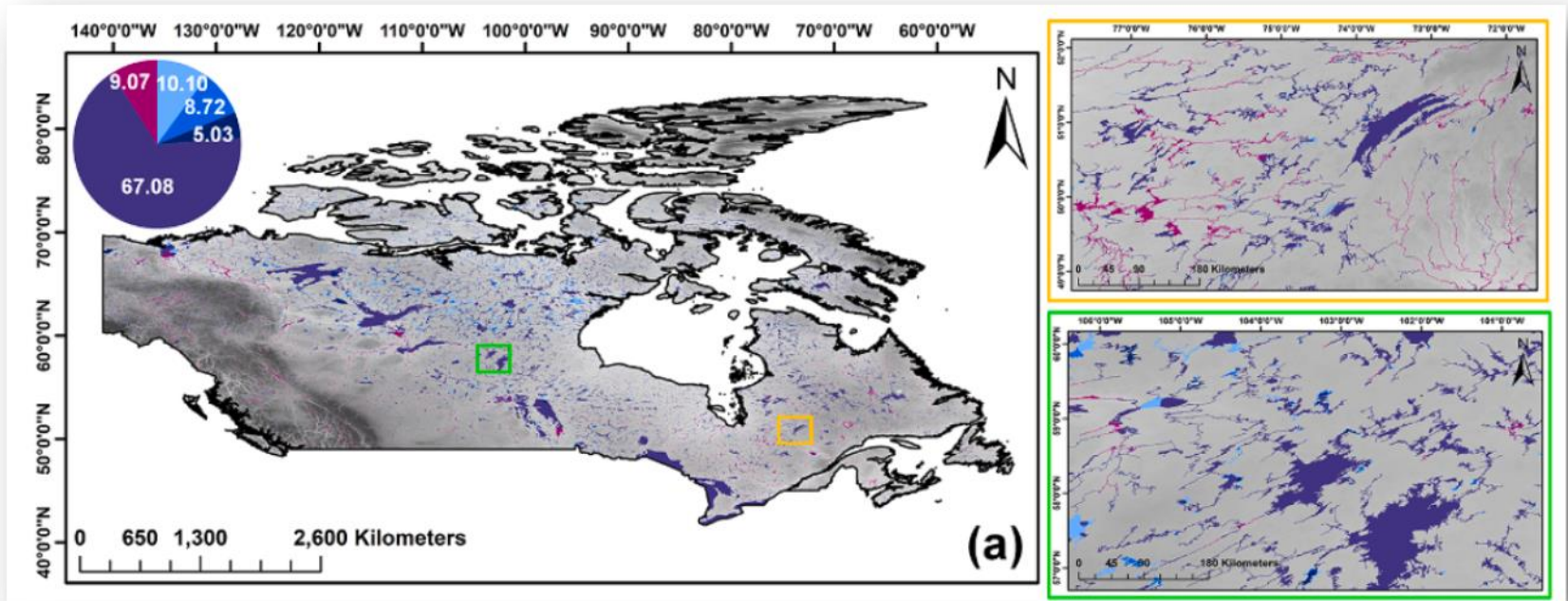
Test region	Performance metrics							
	Hit rate		False alarm ratio		Critical success index		Error bias	
	1 in 100-yr	1 in 200-yr	1 in 100-yr	1 in 200-yr	1 in 100-yr	1 in 200-yr	1 in 100-yr	1 in 200-yr
Bow and Elbow River Basin	0.83	0.82	0.27	0.30	0.81	0.80	0.84	0.82
Fraser River Basin	0.85	0.83	0.26	0.23	0.80	0.81	0.89	0.9
Assiniboine River Basin	0.80	0.81	0.28	0.26	0.75	0.78	1.10	0.92
Red River Basin	0.83	0.81	0.30	0.28	0.79	0.76	0.83	0.85
Grand river basin	0.82	0.83	0.26	0.23	0.80	0.82	0.86	0.82
St. John River Basin	0.81	0.84	0.25	0.24	0.78	0.78	0.80	0.82

- What are these maps for?

19 | IMPLEMENTATION

Understanding the overall flood hazard across the country

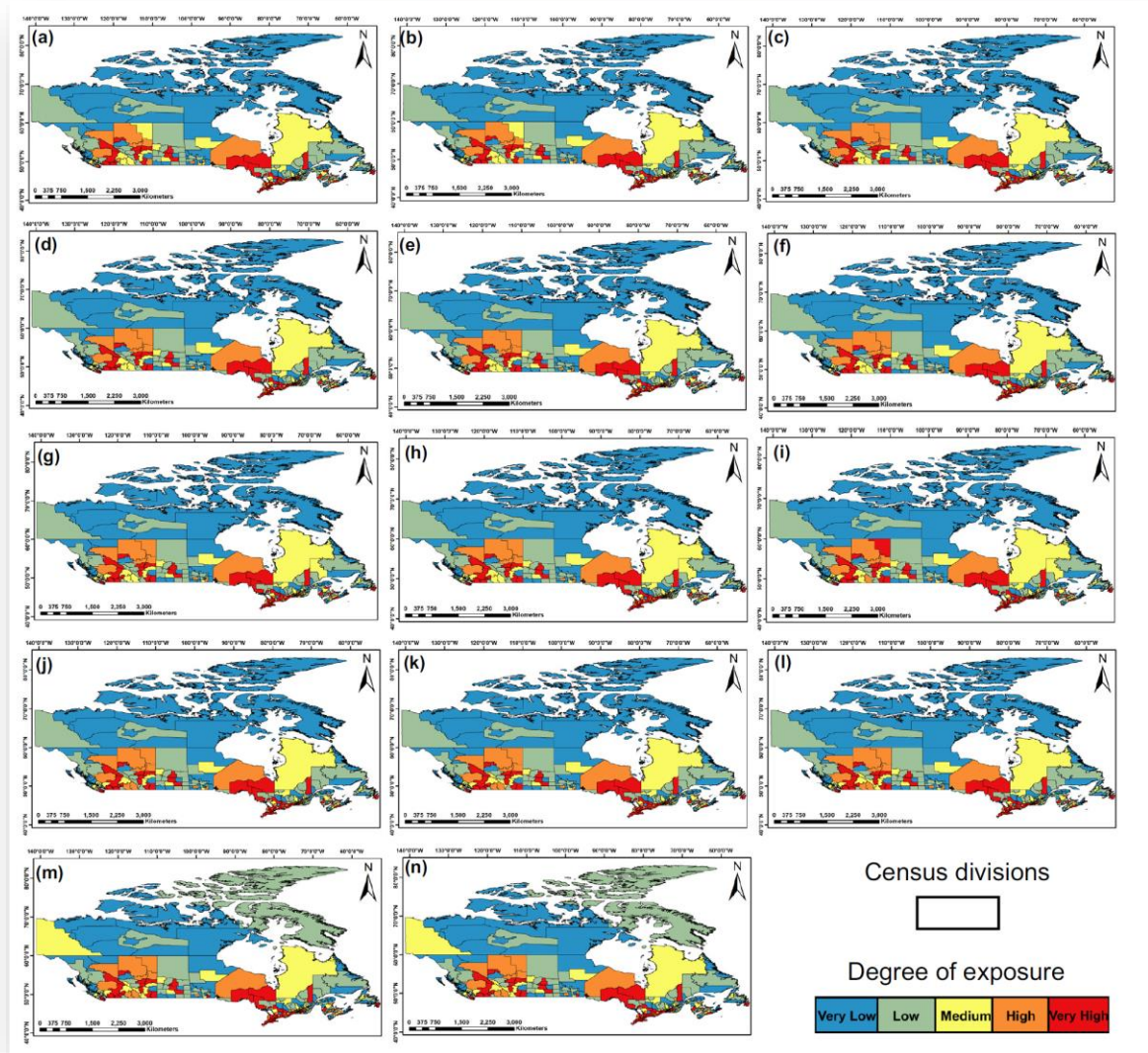
100-yr flood



20. IMPLEMENTATION

Identification of regional impacts - population exposure assessment

$$\epsilon_f = \begin{cases} \text{very-low, } 0 \leq (P_f/P_T) \leq 5\% \\ \text{low, } 5\% < (P_f/P_T) \leq 10\% \\ \text{moderate, } 10\% < (P_f/P_T) \leq 15\% \\ \text{high, } 15\% < (P_f/P_T) \leq 20\% \\ \text{very-high, } (P_f/P_T) > 20\% \end{cases}$$

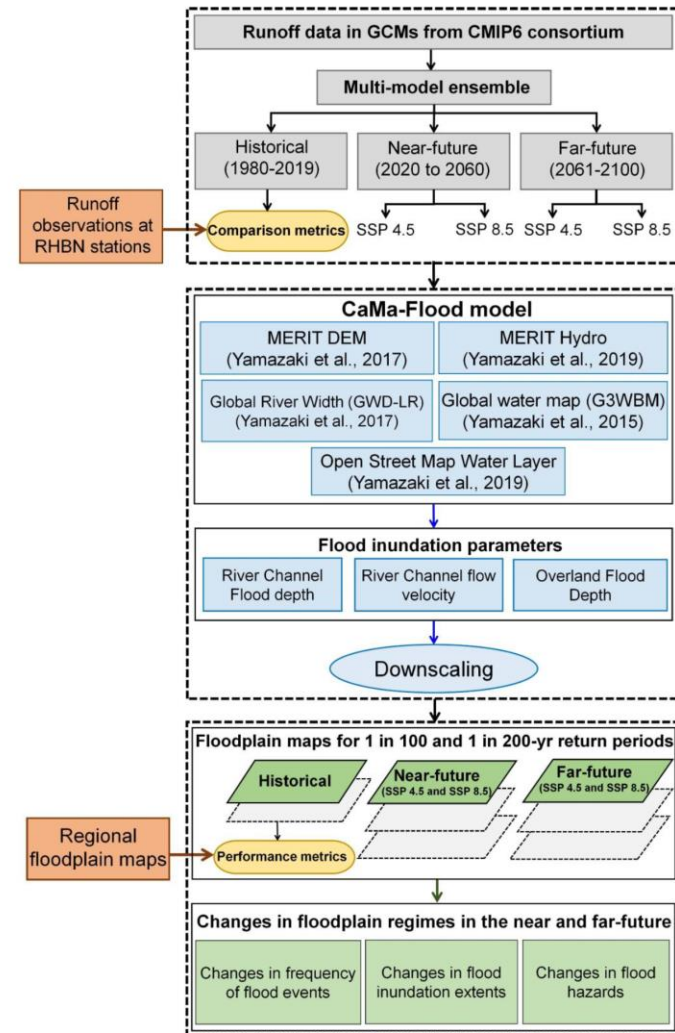


Divisions with various degrees of flood exposure from 2006 to 2019.

21. IMPLEMENTATION

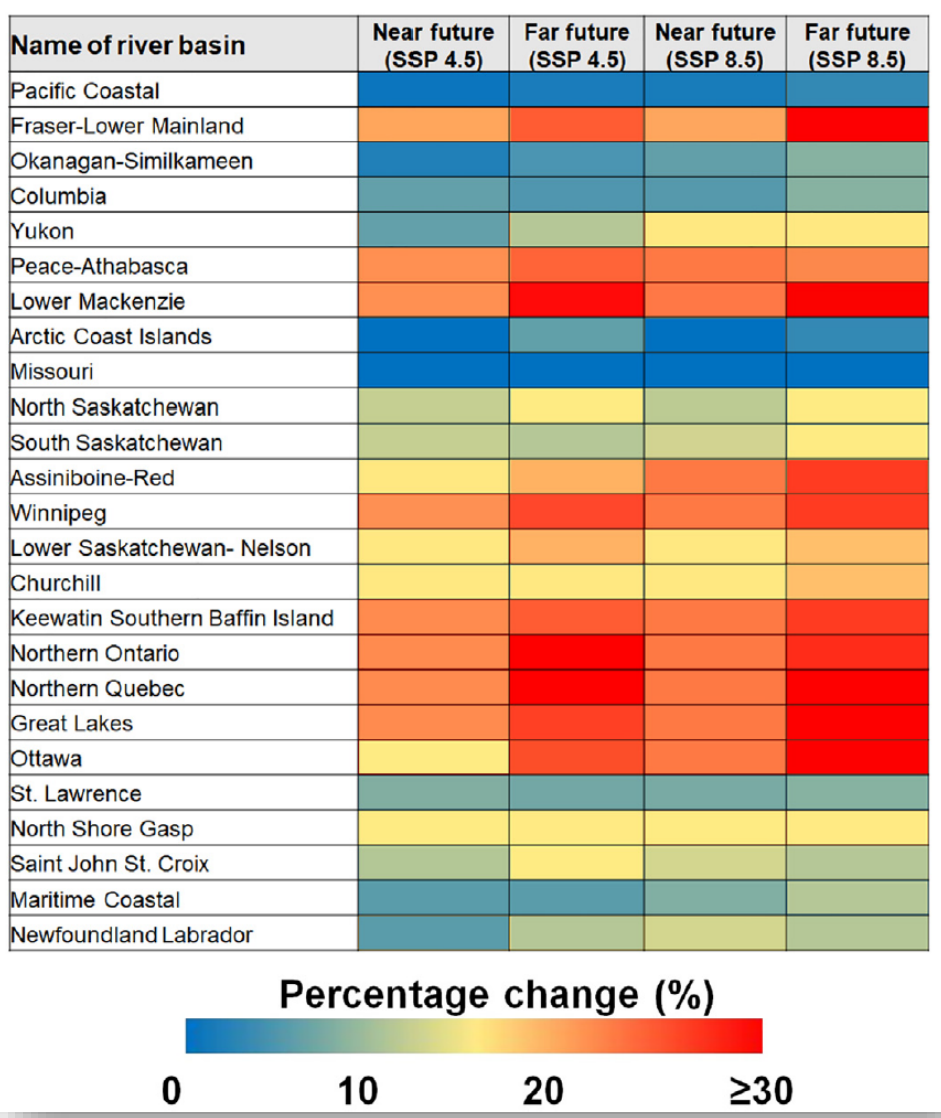
Climate change impacts

- Coupled Model Intercomparison Project 6 (CMIP6)
- 17 GCMs considered (runoff)
- SSP2 4.5 (medium range of future forcing pathway) and SSP5 8.5 (high range of future forcing pathway) scenarios used
- Three timeframes (historical, near future and far future)



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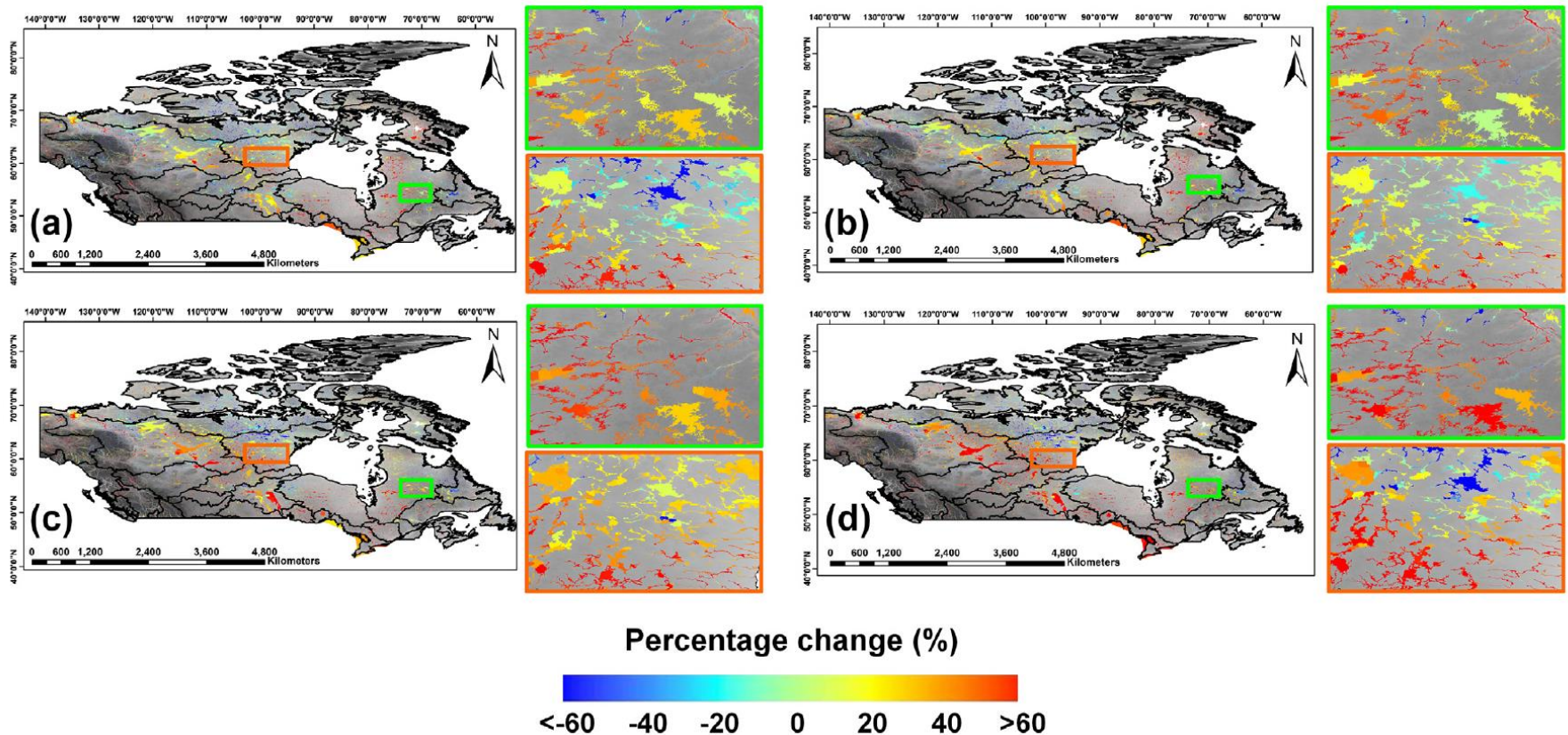
Climate change impacts - flood inundation



100 yr

23 | IMPLEMENTATION

Climate change impacts - flood depth (hazard)

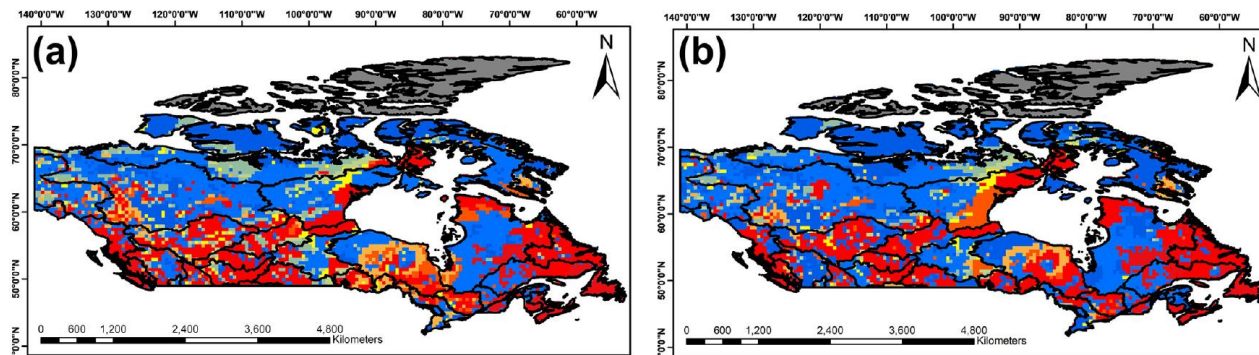


100 yr (near future SSP 4.5; near future 8.5; far future SSP 4.5 far future SSP 8.5)

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Climate change impacts - flood frequency

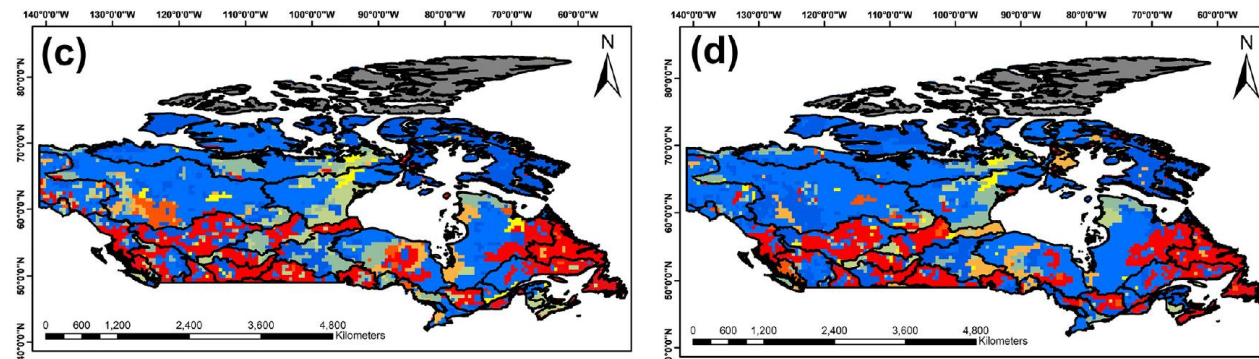
100 yr
far future
SSP 4.5



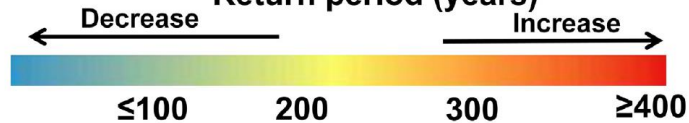
Return period (years)



200 yr
far future
SSP 8.5

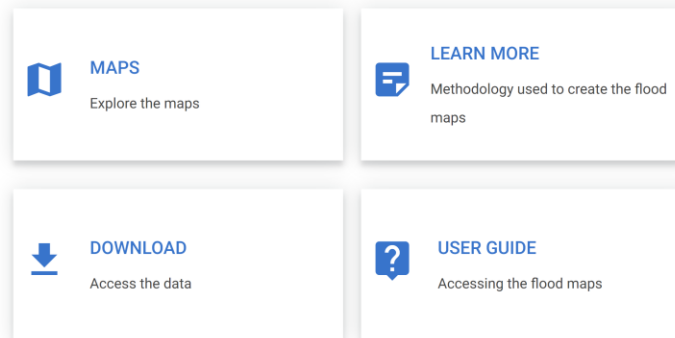
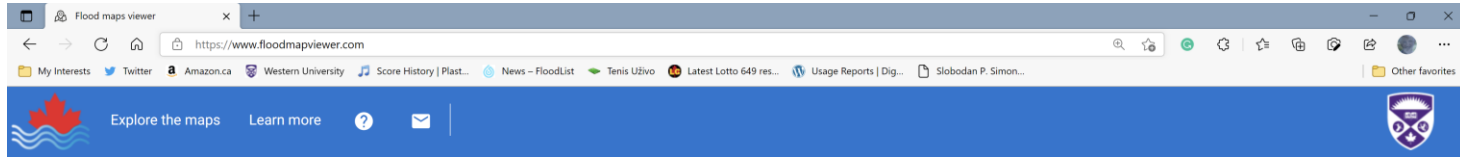


Return period (years)



- Communication of results to general public

26 | RESULTS COMMUNICATION



www.floodmapviewer.com

27 | RESULTS COMMUNICATION



Flood maps viewer

https://www.floodmapviewer.com/maps

My Interests Twitter Amazon.ca Western University Score History | Plast... News - FloodList Tennis Uživo Latest Lotto 649 res... Usage Reports | Dig... Slobodan P. Simon... Other favorites

Explore the maps Learn more ?

General maps Current conditions Future conditions

Canada

Hudson Bay

Legend - Water Level

Legend - DEM

Base layers

Leaflet | Google Imagery

Type here to search

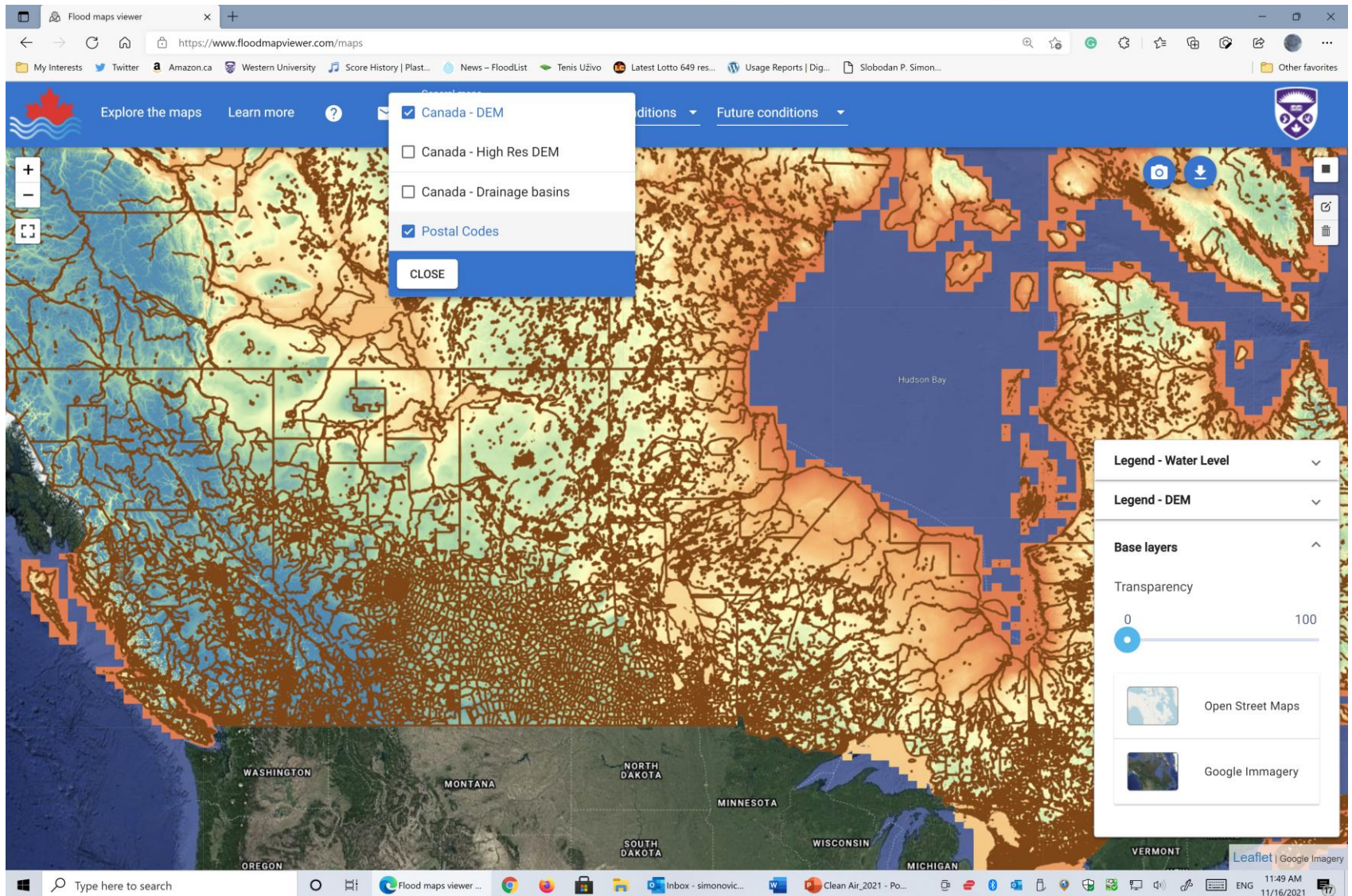
Flood maps viewer ...

Inbox - simonovic...

Clean Air_2021 - Po...

11:48 AM 11/16/2021

28 | RESULTS COMMUNICATION



The screenshot displays the 'Flood maps viewer' web application. The browser address bar shows the URL <https://www.floodmapviewer.com/maps>. The application interface includes a navigation bar with 'Explore the maps' and 'Learn more' links, and a header with the Western University logo. A map of Canada is shown with a color-coded overlay representing flood risk. A legend overlay is visible on the right side of the map, containing the following sections:

- Legend - Water Level** (dropdown menu)
- Legend - DEM** (dropdown menu)
- Base layers** (dropdown menu)
- Transparency** (slider control, currently set to 0)
- Open Street Maps** (base layer option)
- Google Imagery** (base layer option)

A secondary legend overlay is also visible in the upper left quadrant of the map, listing the following layers:

- Canada - DEM
- Canada - High Res DEM
- Canada - Drainage basins
- Postal Codes
- CLOSE** (button)

The map shows a color gradient from blue (low risk) to red (high risk) across the landmass. The bottom of the screen shows a Windows taskbar with the search bar and several open applications, including 'Flood maps viewer', 'Inbox - simonovic...', and 'Clean Air_2021 - Po...'. The system clock indicates the time is 11:49 AM on 11/16/2021.

29 | RESULTS COMMUNICATION



The screenshot displays the 'Flood maps viewer' web application. The browser address bar shows the URL <https://www.floodmapviewer.com/maps>. The application interface includes a navigation bar with options for 'General maps', 'Canada - DEM', 'Current conditions', and 'Future conditions'. The main map area shows a street grid in London, Ontario, with the Thames River and its tributaries. A blue location pin is placed on the map, and an 'Info box' popup displays the following information:

Info box
Coordinates: 42° 58' 55.474" N 81° 15' 31.963" W
Low resolution DEM: 235.00 m

On the right side of the map, there is a legend and control panel with the following sections:

- Legend - Water Level** (dropdown menu)
- Legend - DEM** (dropdown menu)
- Base layers** (dropdown menu)
- Transparency**: A slider set to 53, with a range from 0 to 100.
- Open Street Maps** (selected layer)
- Google Imagery** (available layer)

The bottom of the screenshot shows the Windows taskbar with the system clock at 11:52 AM on 11/16/2021.

30 | RESULTS COMMUNICATION



Flood maps viewer

https://www.floodmapviewer.com/maps

My Interests Twitter Amazon.ca Western University Score History | Plast... News - FloodList Tennis Uživo Latest Lotto 649 res... Usage Reports | Dig... Slobodan P. Simon...

Explore the maps Learn more ?

General maps Current conditions 201 Future conditions None

Legend - Water Level

Legend - DEM

Base layers

Transparency 0 21 100

Open Street Maps

Google Imagery

Leaflet | Google Hybrid

Type here to search

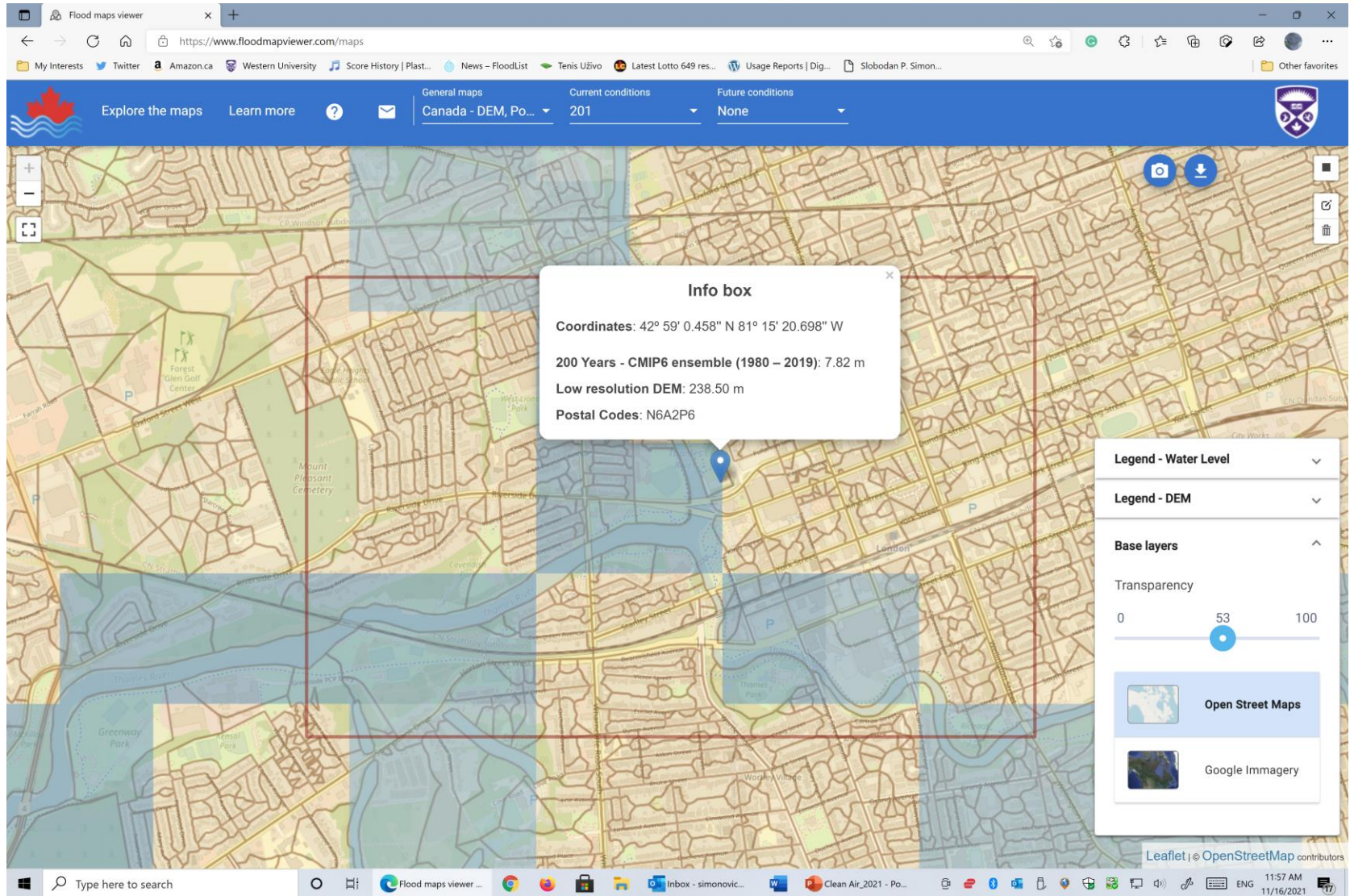
Flood maps viewer ...

Inbox - simonovic...

Clean Air_2021 - Po...

ENG 11:53 AM 11/16/2021

31 | RESULTS COMMUNICATION



The screenshot shows a web browser window displaying the Flood maps viewer application. The browser address bar shows the URL <https://www.floodmapviewer.com/maps>. The application interface includes a navigation bar with a search icon, a home icon, and a refresh icon. Below the navigation bar, there are tabs for "General maps", "Current conditions", and "Future conditions". The "General maps" tab is selected, showing "Canada - DEM, Po...". The "Current conditions" tab shows "201", and the "Future conditions" tab shows "None".

The main map area displays a satellite view of a residential area in London, Ontario, with a blue flood overlay. A red rectangular box highlights a specific area on the map. An "Info box" is open over this area, displaying the following information:

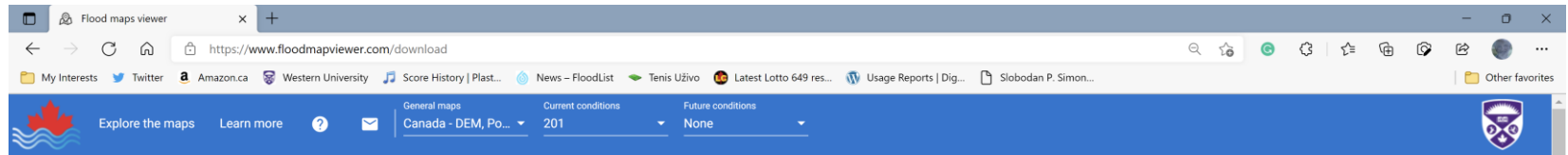
- Coordinates:** 42° 59' 0.458" N 81° 15' 20.698" W
- 200 Years - CMIP6 ensemble (1980 – 2019):** 7.82 m
- Low resolution DEM:** 238.50 m
- Postal Codes:** N6A2P6

On the right side of the map, there is a control panel with the following sections:

- Legend - Water Level** (dropdown menu)
- Legend - DEM** (dropdown menu)
- Base layers** (dropdown menu)
- Transparency** (slider control, currently set to 53)
- Open Street Maps** (button)
- Google Imagery** (button)

The bottom of the screenshot shows the Windows taskbar with the search bar and several open applications, including "Flood maps viewer...", "Inbox - simonovic...", and "Clean Air_2021 - Po...". The system tray shows the date and time as "11:57 AM 11/16/2021".

32 | RESULTS COMMUNICATION



Downloads

Downloading files

Please check the file size before starting your download.

We recommend installing [7-Zip](#) to decompress and open the full files. 7-Zip is free, open source software. You can use 7-Zip on any computer, including a computer in a commercial organization. You don't need to register or pay for 7-Zip.

To open the downloaded files, a Geographic Information System (GIS) processing tool should be used. The recommended software is Quantum GIS (QGIS), a free and open-source tool.

For more details on the files see the help section: [Help](#).

If you have questions or concerns contact us at simonovic@uwo.ca.

Area defined for clipping:

SW point: 42° 58' 25.515" N 81° 16' 38.157" W

NE point: 42° 59' 28.843" N 81° 14' 21.108" W

List of files

TITLE	DESCRIPTION	FILE NAME	DOWNLOAD	SIZE
101	100 Years - CMIP6 ensemble (1980 – 2019)	Map_100_yr_CMIP6_historical.7z	Full file Clipped file	9.96 MB
102	100 Years - NARR (1979 – 2010)	Map_100_yr_NARR.7z	Full file Clipped file	9.56 MB
103	100 Years - CMIP6 ensemble SSP2.45 (2020 - 2060)	Map_100_yr_near_future_ssp45.7z	Full file Clipped file	10.7 MB
104	100 Years - CMIP6 ensemble SSP5 8.5 (2020 - 2060)	Map_100_yr_near_future_ssp85.7z	Full file Clipped file	11.0 MB
105	100 Years - CMIP6 ensemble SSP2 4.5 (2061 - 2100)	Map_100_yr_far_future_ssp45.7z	Full file Clipped file	10.8 MB
106	100 Years - CMIP6 ensemble SSP5 8.5 (2061 - 2100)	Map_100_yr_far_future_ssp85.7z	Full file Clipped file	10.3 MB
201	200 Years - CMIP6 ensemble (1980 – 2019)	Map_200_yr_CMIP6_historical.7z	Full file Clipped file	9.16 MB
202	200 Years - NARR (1979 – 2010)	Map_200_yr_NARR.7z	Full file Clipped file	8.99 MB
203	200 Years - CMIP6 ensemble SSP2.45 (2020 - 2060)	Map_200_yr_near_future_ssp45.7z	Full file Clipped file	9.17 MB



33 | RESULTS COMMUNICATION



Flood maps viewer

https://www.floodmapviewer.com/learnmore

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Explore the maps Learn more ?

The data used in this work are publicly available.

- NARR data: <https://psl.noaa.gov/data/gridded/data.narr.html> ; and
- CMIP6 climate data: <https://pcmdi.llnl.gov/CMIP6/>

The information provided should be used at your own risk. By using this Tool you agree with these terms. Please check the Learn section for more information.

Third party software used to build the tool:

- Angular: Angular is a TypeScript-based free and open-source web application framework led by the Angular Team at Google and by a community of individuals and corporations. Angular is a complete rewrite from the same team that built AngularJ.
- Angular Material: Angular Material is a UI component library for Angular JS developers. Angular Material components help in constructing attractive, consistent, and functional web pages and web applications while adhering to modern web design principles like browser portability, device independence, and graceful degradation. It helps in creating faster, beautiful, and responsive websites. It is inspired by the Google Material Design
- Leaflet: Leaflet is the leading open-source JavaScript library for mobile-friendly interactive maps. The map information and photographic imagery contain trade names, trademarks, service marks, logos, domain names, and other distinctive brand features. (<http://leafletjs.com/>)
- Geoserver: GeoServer is an open-source server written in Java that allows users to share, process and edit geospatial data. Designed for interoperability, it publishes data from any major spatial data source using open standards.

Learn More

Project info

Disclaimer

Third party software used to build the tool:

Methodology

Data

Frequently Asked Questions - FAQ

References (all references are open access)

Methodology

The flood maps available for viewing and download were developed using an original methodology developed by Mohanty and Simonovic [1, 2, 3, 4]. Key elements of the methodology are presented here and the users are advised to consult available references for further details.

The provided floodplain maps are developed using globally available data. Four maps are developed to present current conditions, and eight maps are developed to capture changes in floodplain regimes over Canada due to climate change. All the generated maps have 1km by 1 km grid resolution. Table 1 lists the maps available with the tool.

Table 1. Floodplain maps available within the tool

RETURN PERIOD	MAP VERSION	TIME PERIOD	RUNOFF INPUT SOURCE
100 yr	101	1980 – 2019	CMIP6 ensemble
	102	1979 – 2010	NARR
	103	2020 - 2060	CMIP6 ensemble SSP2 4.5
	104	2020 - 2060	CMIP6 ensemble SSP5 8.5
	105	2061 - 2100	CMIP6 ensemble SSP2 4.5
	106	2061 - 2100	CMIP6 ensemble SSP5 8.5

Type here to search

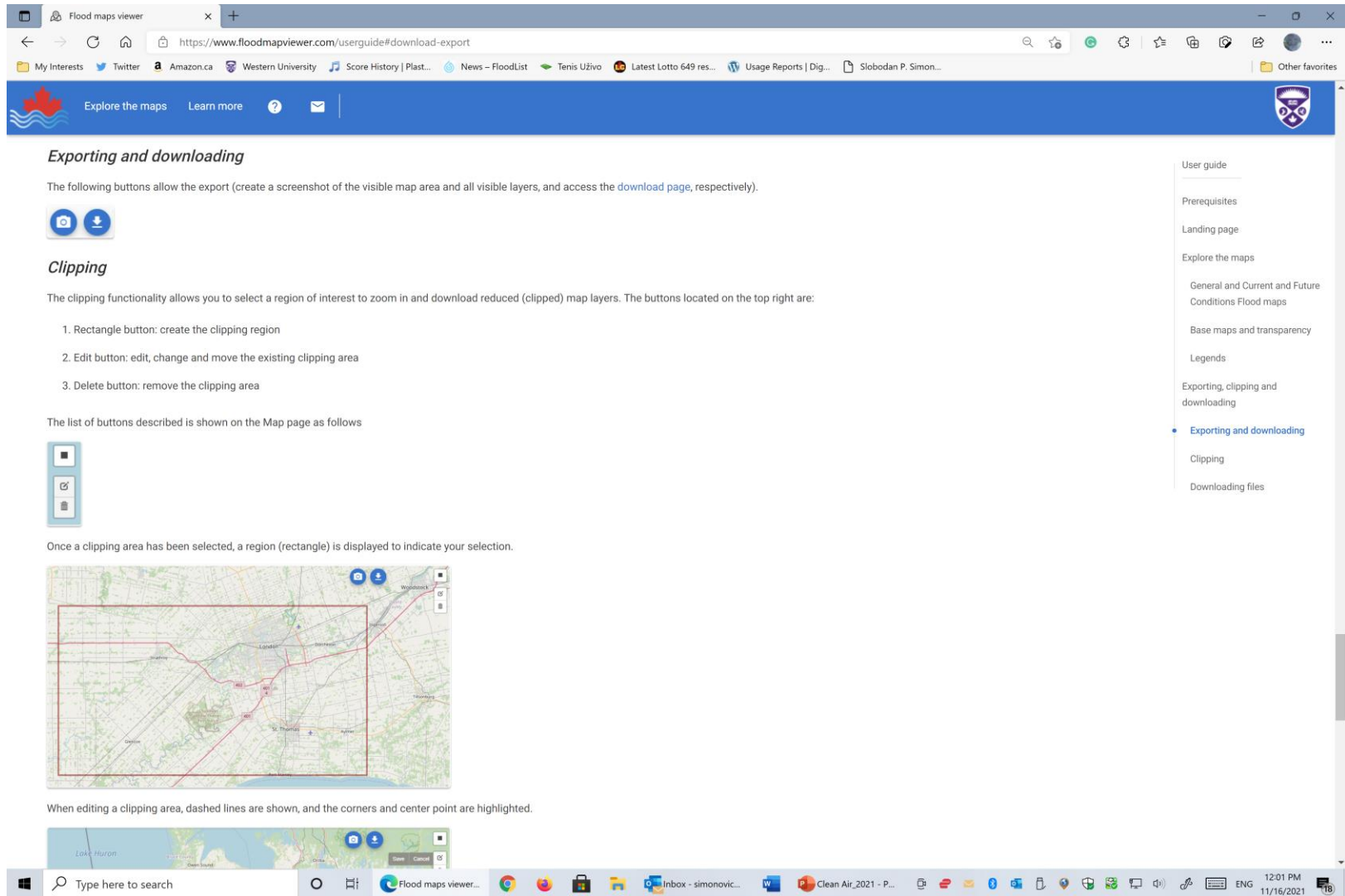
Flood maps viewer ...

Inbox - simonovic...

Clean Air_2021 - Po...


11:59 AM 11/16/2021

34 | RESULTS COMMUNICATION



Exporting and downloading

The following buttons allow the export (create a screenshot of the visible map area and all visible layers, and access the [download page](#), respectively).




Clipping

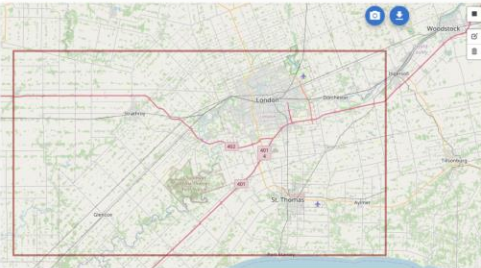
The clipping functionality allows you to select a region of interest to zoom in and download reduced (clipped) map layers. The buttons located on the top right are:

1. Rectangle button: create the clipping region
2. Edit button: edit, change and move the existing clipping area
3. Delete button: remove the clipping area


The list of buttons described is shown on the Map page as follows



Once a clipping area has been selected, a region (rectangle) is displayed to indicate your selection.



When editing a clipping area, dashed lines are shown, and the corners and center point are highlighted.



35 | SUMMARY

Floodplain mapping



- Specific aspects of the methodology
 - Consideration of the whole country (large region almost 10M km²) - standardized
 - Use of publicly available runoff data (runoff observations sparse – reanalysis products; future climate according to CMIP6 (Coupled Model Intercomparison Project) and 17 GCM models from that experiment)
 - Use of other public data required for hydrodynamic modelling (global DEM; global river width; global water; open street;....)
 - Modelling outcome: flood depth; flood inundation; and flow velocity in gridded form (1 km by 1 km)

36 | CONCLUSIONS

Climate change



- First time use of the latest CMIP6 project for understanding the changes in floodplain regimes in the future over a large country
- The near-and far-future 1 in 100-yr and 1 in 200-yr flood events will add to a rise in the high-, and very-high flood hazards
- Flood frequencies in the far future will increase in several regions (in the western, and northern parts and a few more in the eastern parts)

37 | RECOMMENDATIONS

- Using information from this study create a national flood hazard atlas for Canada
- Perform detailed exposure analyses for regions identified as highly affected
- Include coastal floods in the analyses

38 | REFERENCES



Mohanty, M. and S.P. Simonovic (2021) “Fidelity of Reanalysis Datasets in Floodplain Mapping: Investigating Performance at Inundation Level over Large Regions”, *Journal of Hydrology*, Vol.597, 125757, available online at <https://doi.org/10.1016/j.jhydrol.2020.125757>

Mohanty, M. and S.P. Simonovic (2021) “Changes in floodplain regimes over Canada due to climate change impacts: observations from CMIP6 models”, *The Science of Total Environment*, 792, 148323, open access <https://doi.org/10.1016/j.scitotenv.2021.148323> .

Mohanty, M. and S. P. Simonovic (2020). [A comprehensive framework for regional floodplain mapping](#). *Water Resources Research Report no. 109*, Facility for Intelligent Decision Support, Department of Civil and Environmental Engineering, The University of Western Ontario, London, Ontario, Canada, 58 pages. ISBN: (print) 978-0-7714-3147-0; (online) 978-0-7714-3148-7.

Sredojevic, B., M. P. Mohanty and S. P. Simonovic (2020). [Regional analysis of population exposure to flooding in Canada](#). *Water Resources Research Report no. 110*, Facility for Intelligent Decision Support, Department of Civil and Environmental Engineering, London, Ontario, Canada, 60 pages. ISBN: (print) 978-0-7714-3151-7; (online) 978-0-7714-3152-4.

Mohanti, M. and S.P. Simonovic (2021). [A generic framework to quantify changes in floodplain regimes by incorporating climate change impacts over large regions](#). *Water Resources Research Report no. 112*, Facility for Intelligent Decision Support, Department of Civil and Environmental Engineering, London, Ontario, Canada, 55 pages. ISBN: (print) 978-0-7714-3157-9; (online) 978-0-7714-3158-6.

Additional resources

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