Simulating coastal flooding in Lake Michigan with land-lake coupling

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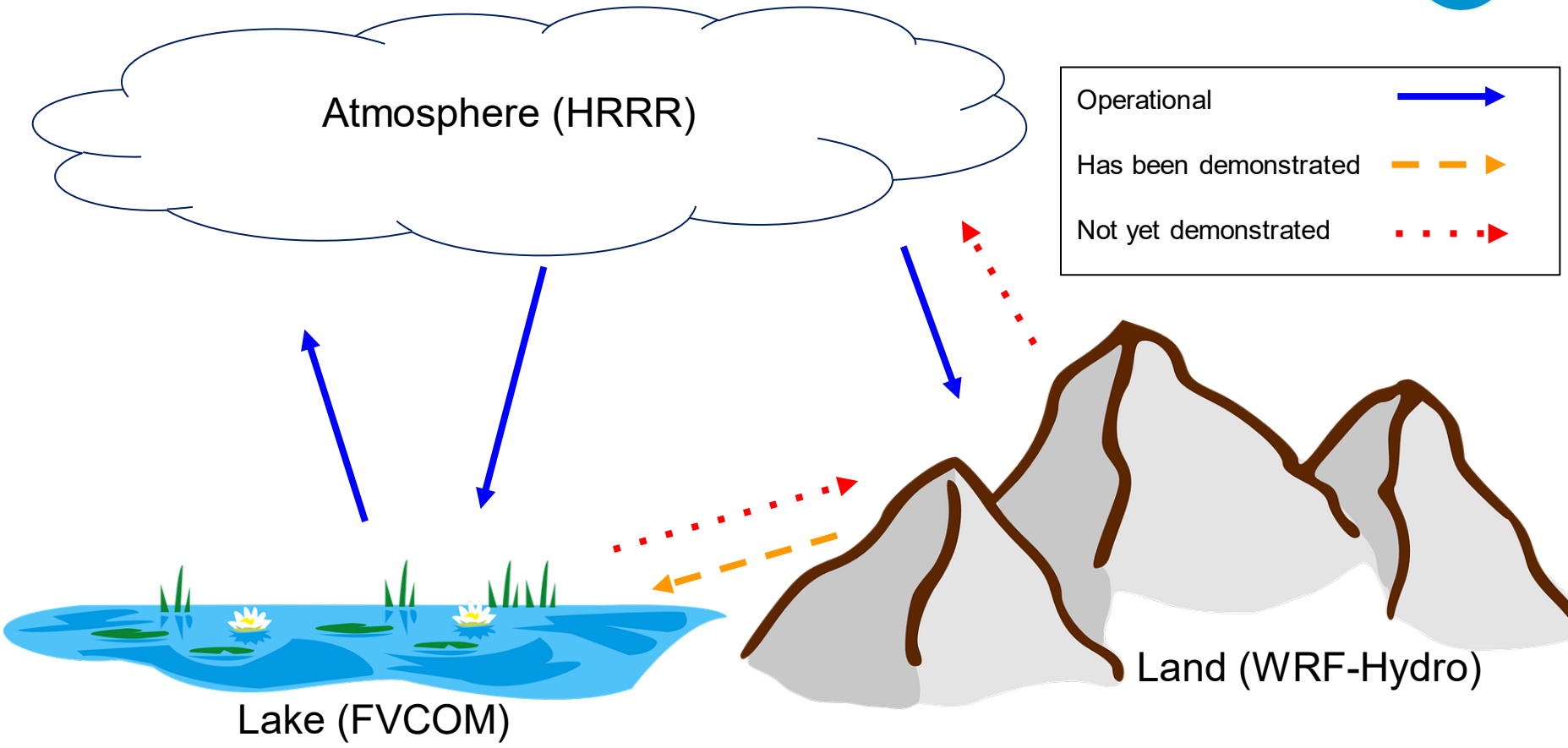
4. National Center for Atmospheric Research, Boulder, CO

Information Flow: Operational Models



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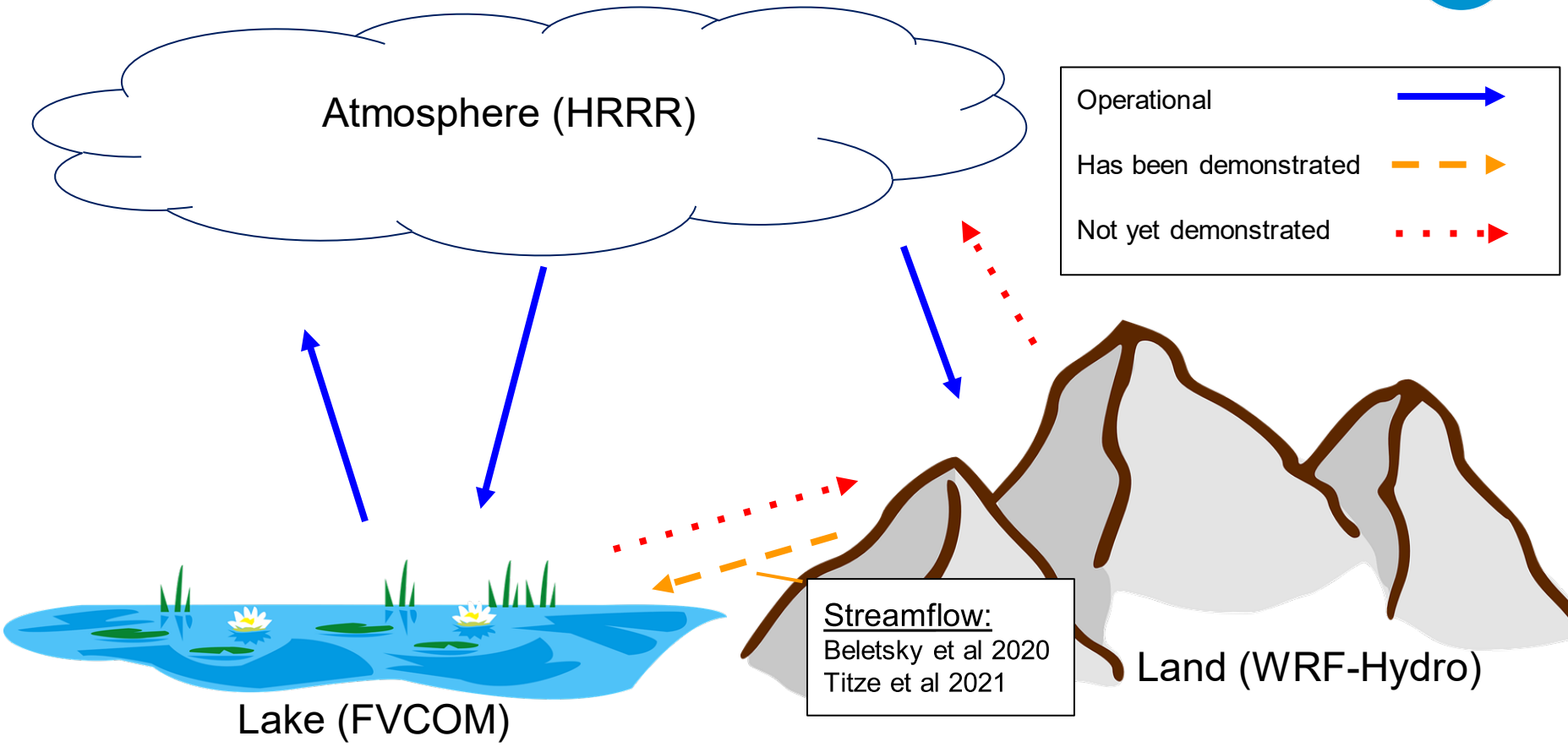

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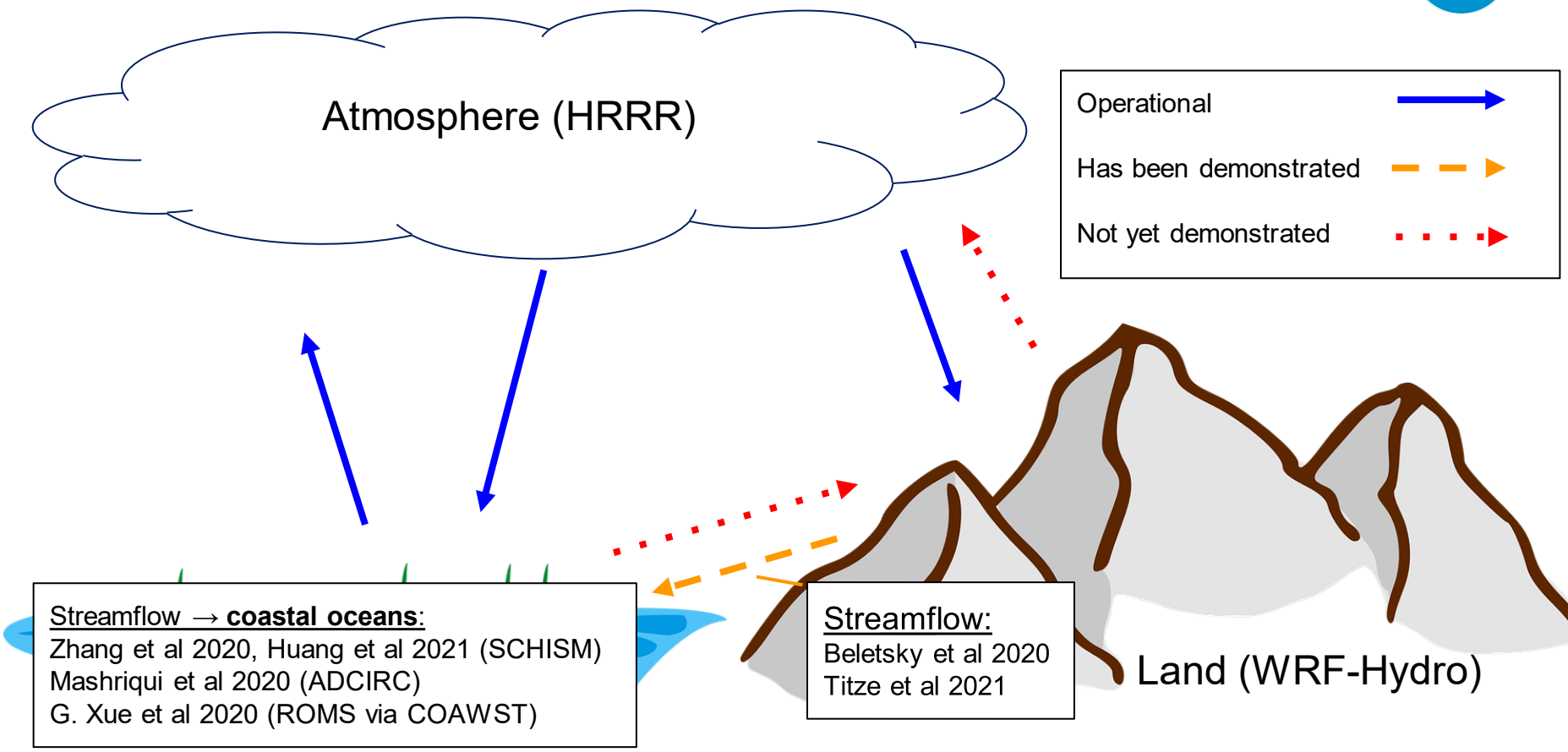


Information Flow: Operational Models

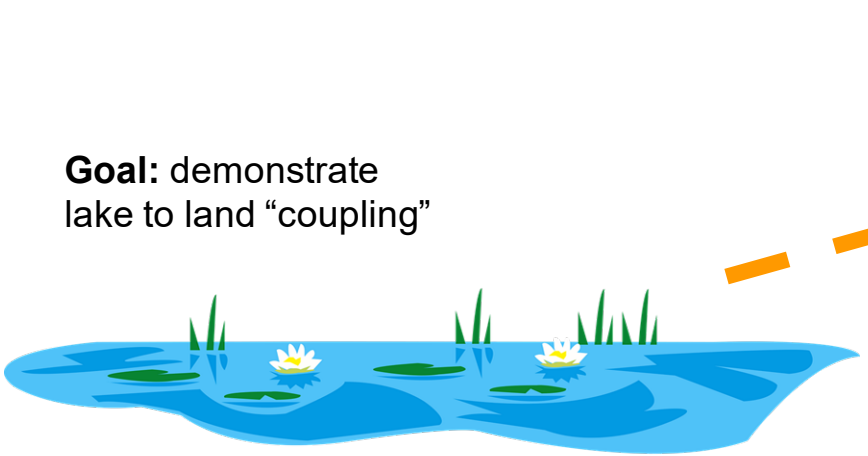
Atmosphere (HRRR)

Operational

Has been demonstrated

Not yet demonstrated

Goal: demonstrate lake to land “coupling”



Lake (FVCOM)

Land (WRF-Hydro)

Outline

- ❑ Description of flooding event: April 2020
- ❑ Coastal Coupling Methodology
- ❑ Preliminary results
- ❑ Summary

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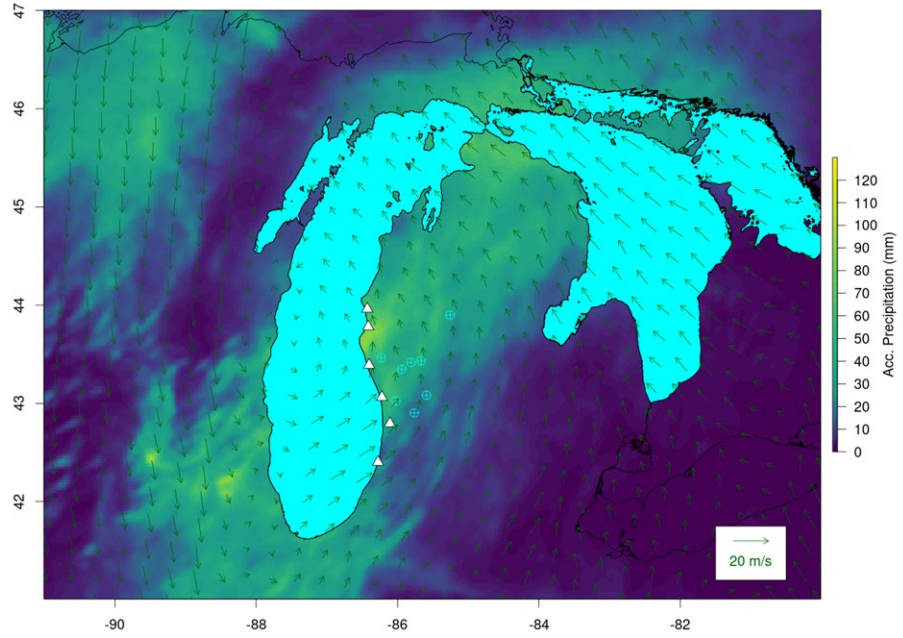
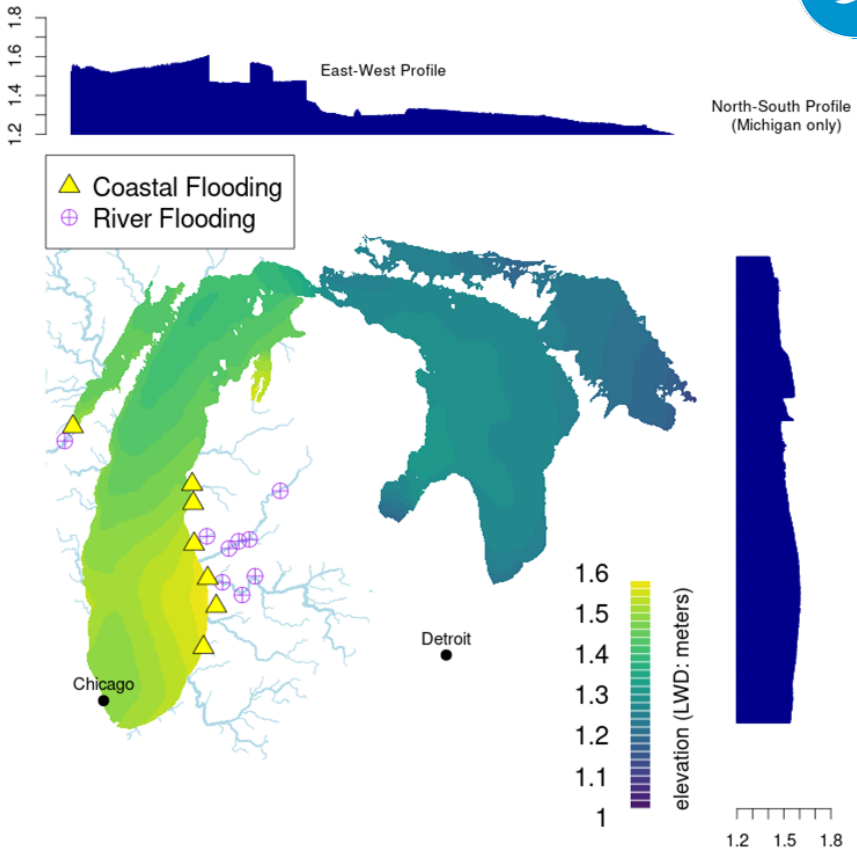
Lake Michigan: Apr 28-30, 2020

High water, flooding and coastal erosion cost an estimated $500M in damage to GL cities in 2019
[O' Connell 2020]

precip and winds @10m

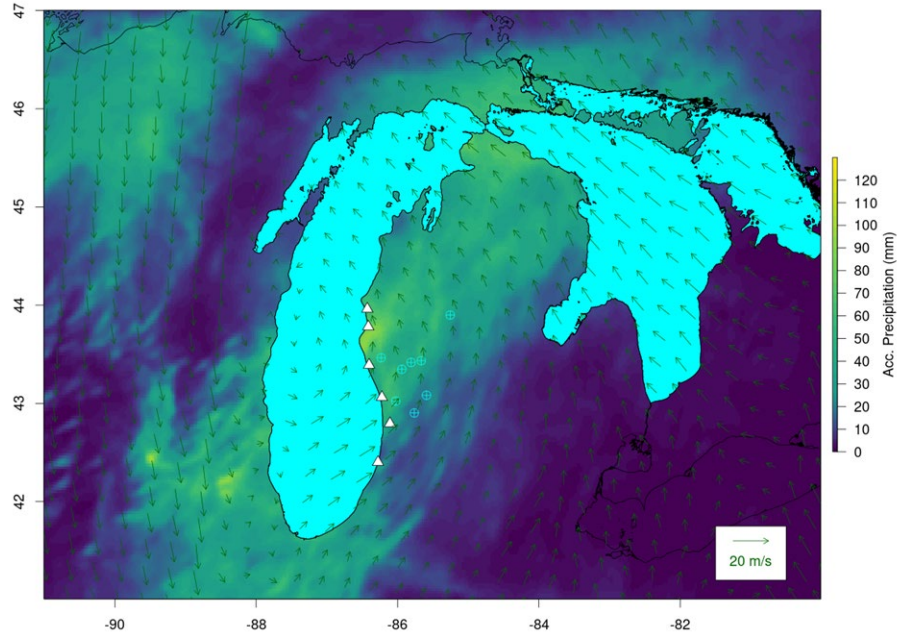


HRRR valid @ Apr 29, 22Z



LMHOFS valid @ Apr, 30 01Z

precip and winds @10m



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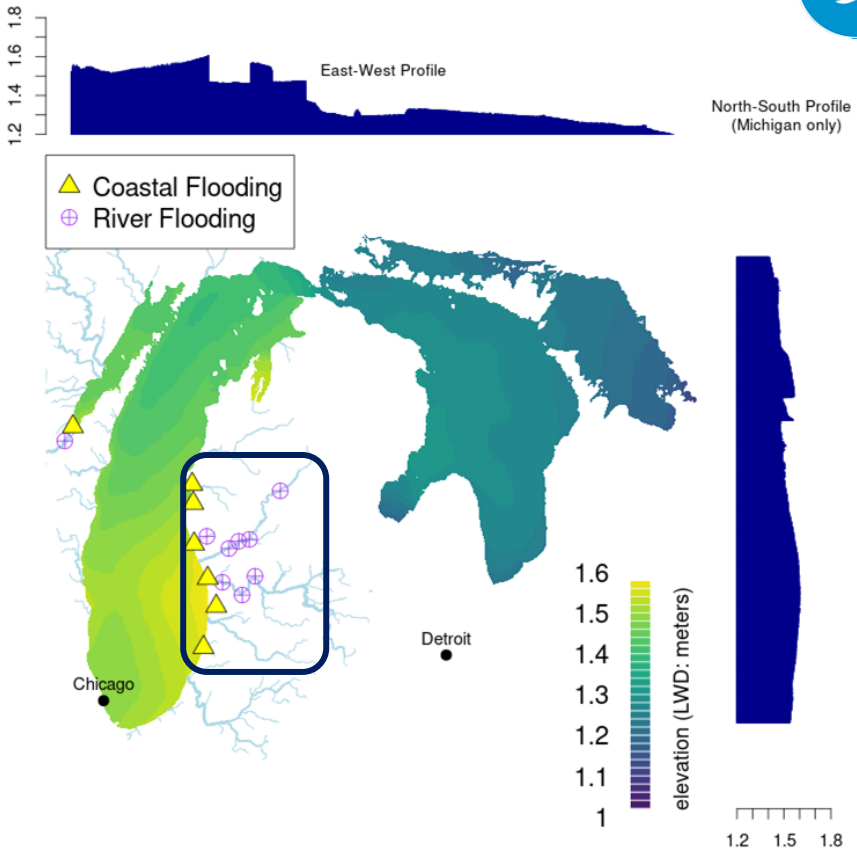
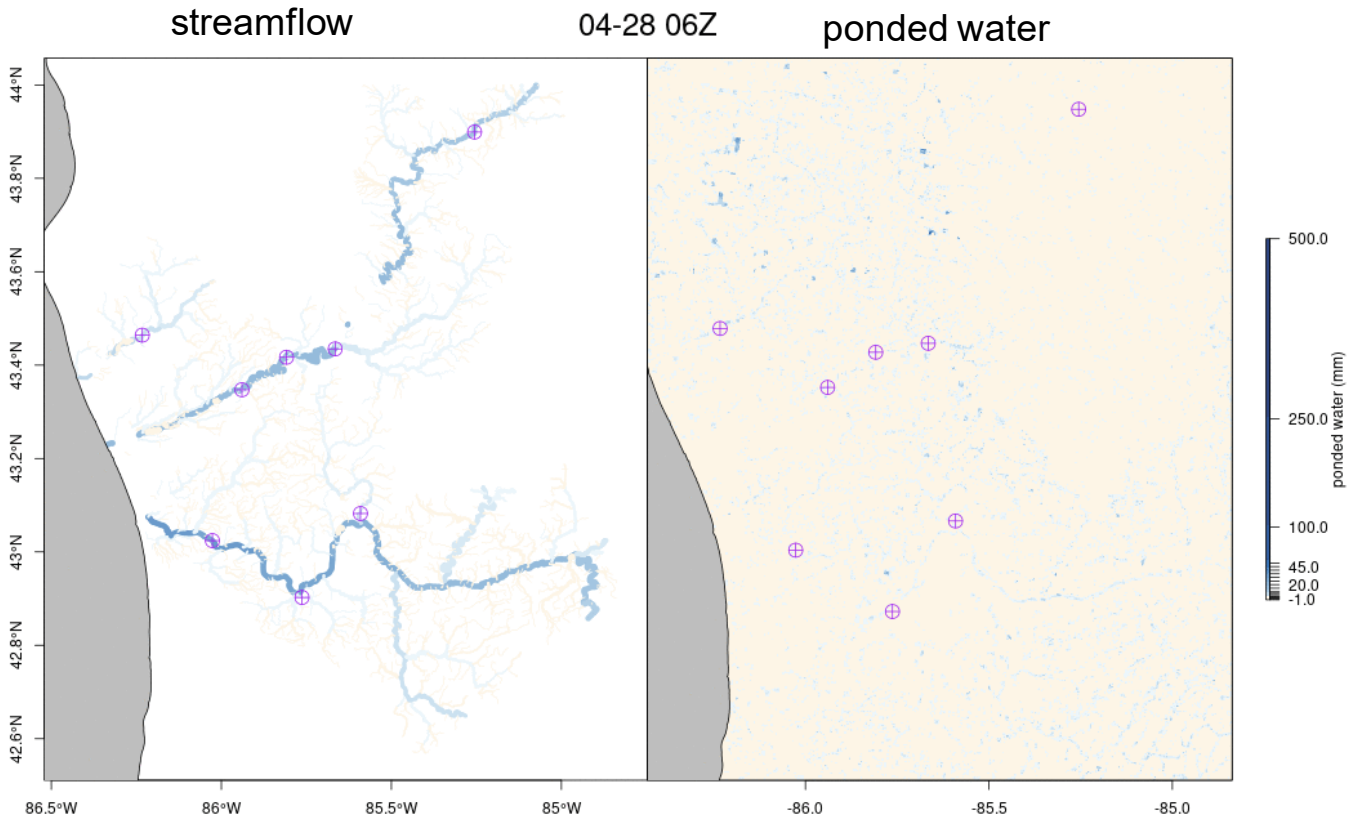
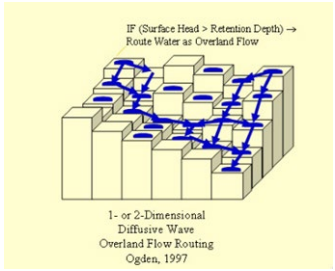


LMHOFS valid @ Apr, 30 01Z

National Water Model





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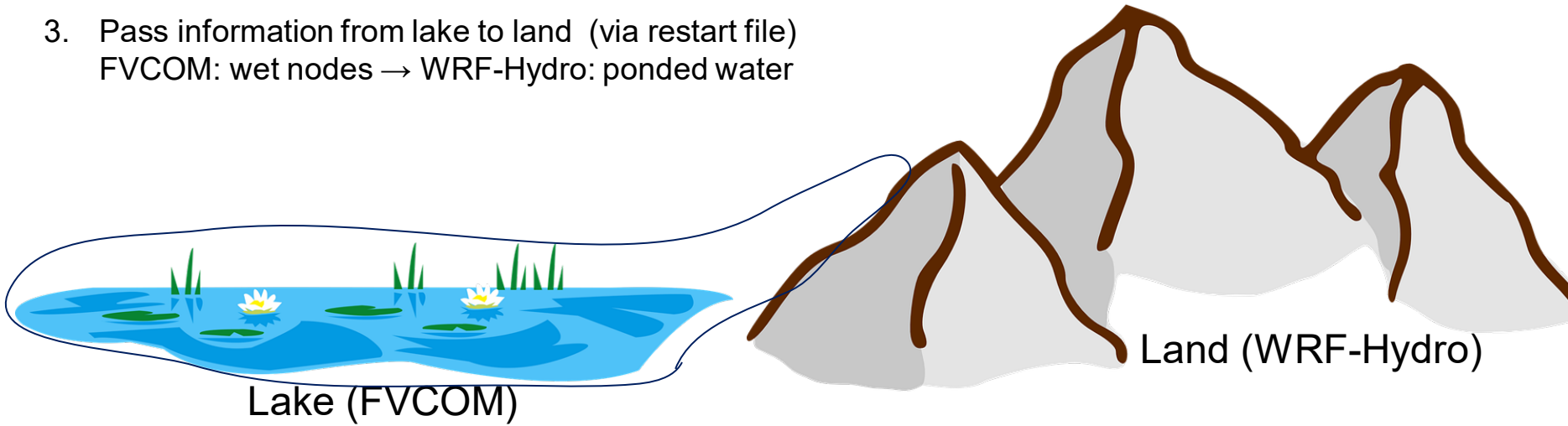
Method Overview

1. Extend operational FVCOM grid onto land
2. Simulate storm surge
3. Pass information from lake to land (via restart file)
   FVCOM: wet nodes → WRF-Hydro: ponded water



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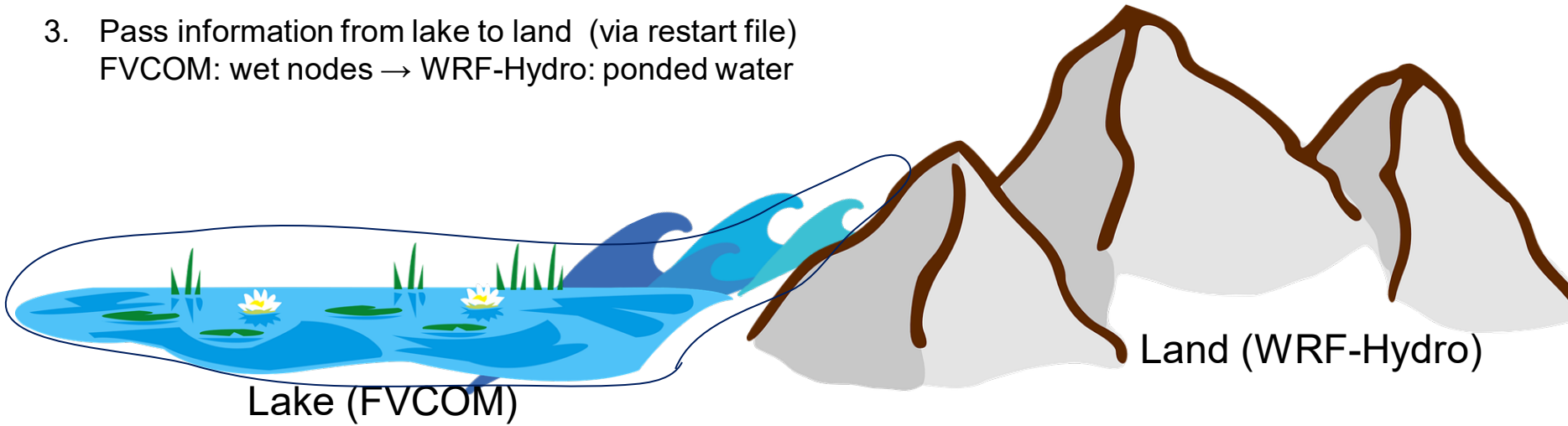

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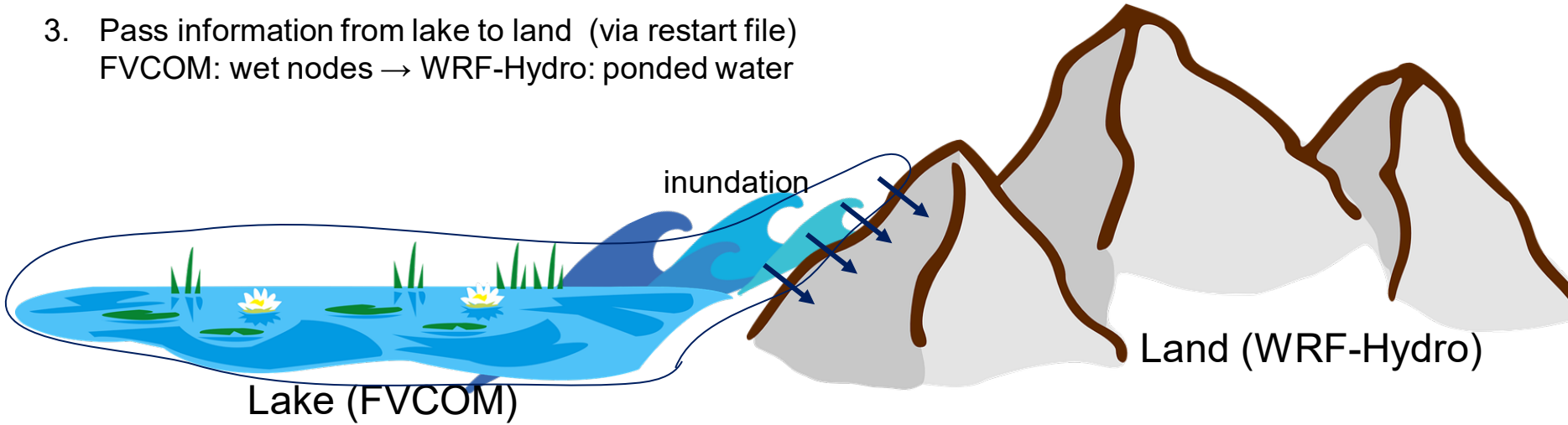
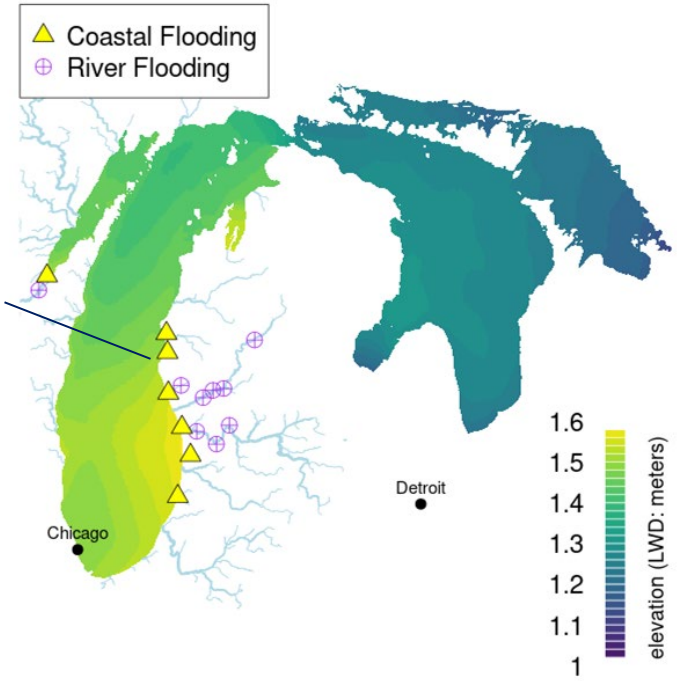
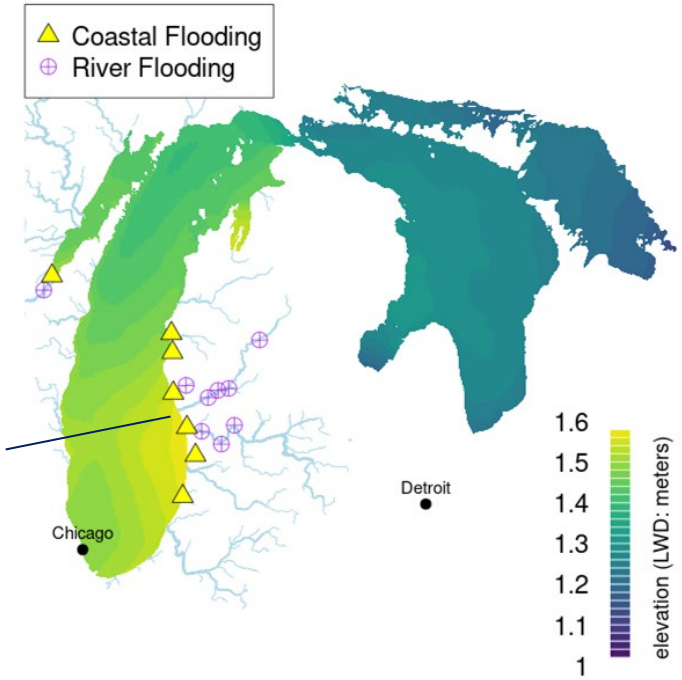


Ludington, MI



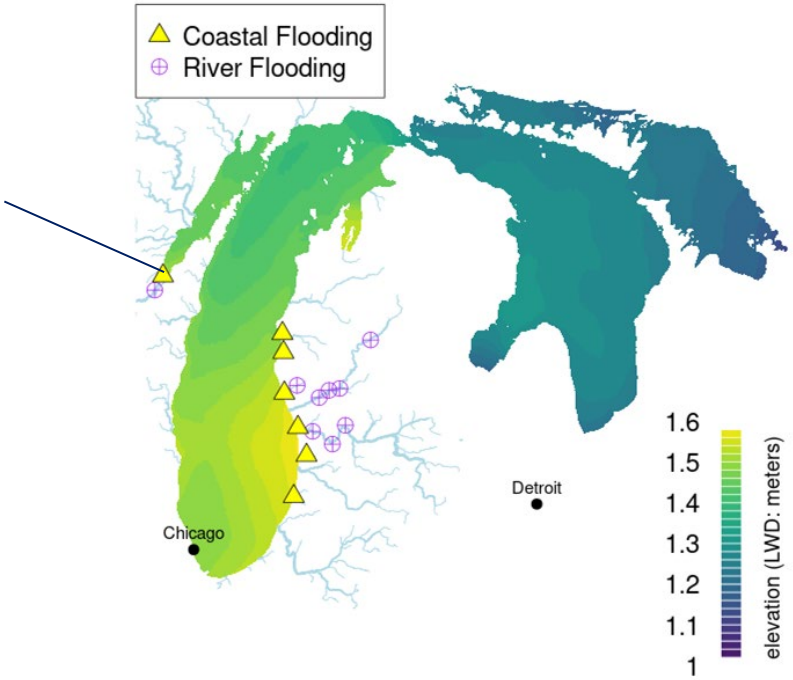
Muskegon, MI


5 km


Coastal Flooding
River Flooding
Chicago
Detroit
1.6
1.5
1.4
1.3
1.2
1.1
1
elevation (LWD: meters)

Green Bay, WI


2 km


Coastal Flooding
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Chicago
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1.6
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1
elevation (LWD: meters)

Experiment Design

- **Control:** run models independently
- **Experiment:** pass flood depth from FVCOM to WRF-Hydro **once** (at storm surge peak)

	Domain	**Resolution**	**forcing**	**notes:**	**Version**
WRF-Hydro	Michigan Basin	250m / 1km 30K features	HRRR	reach-based channel routing, **no DA**	Hydro 5.1.3 (NWM 2.1)
FVCOM	LMHOFS extended	50m - 3 km	HRRR (no precip)	no river inflows	4.3.1

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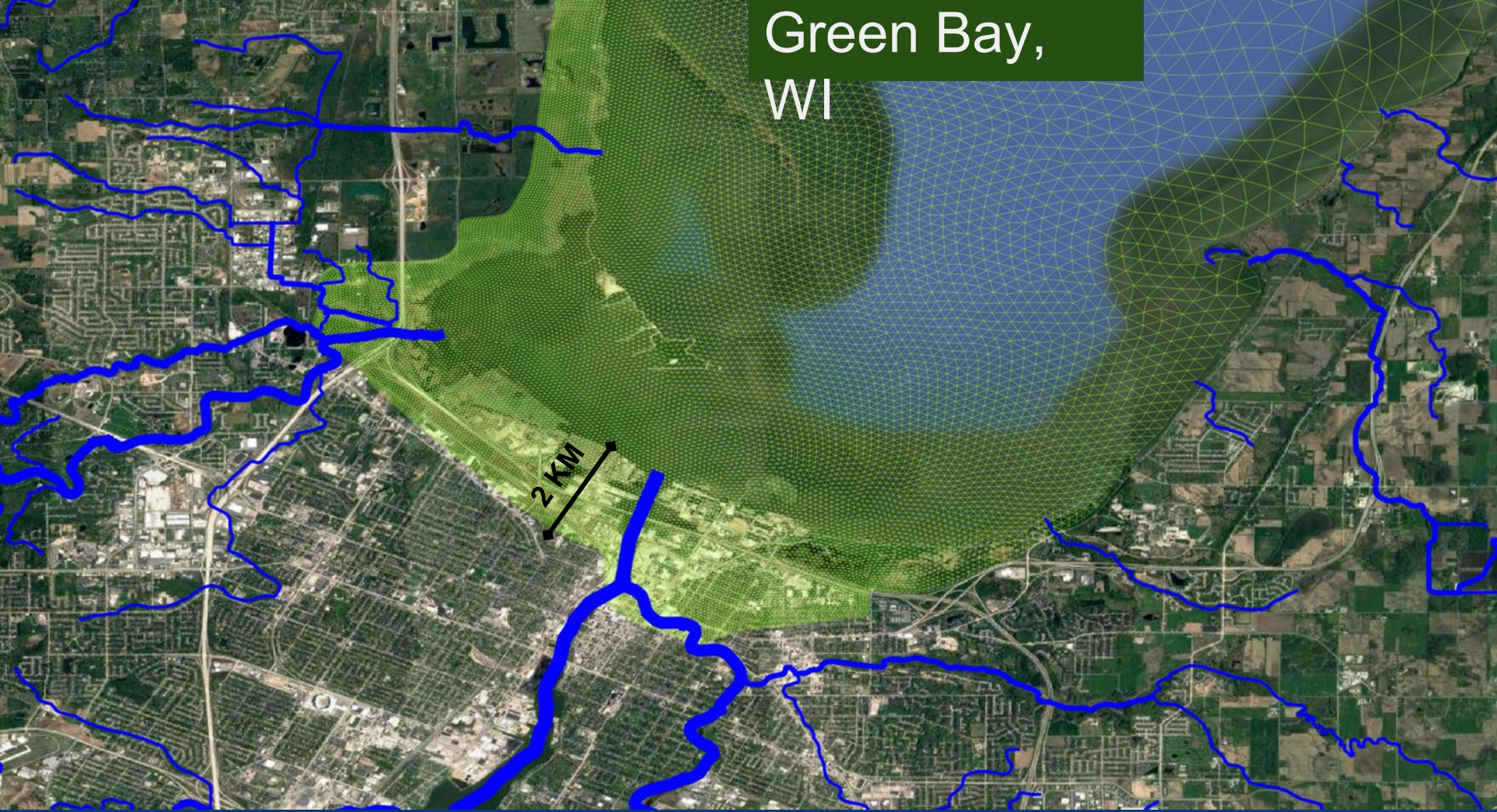
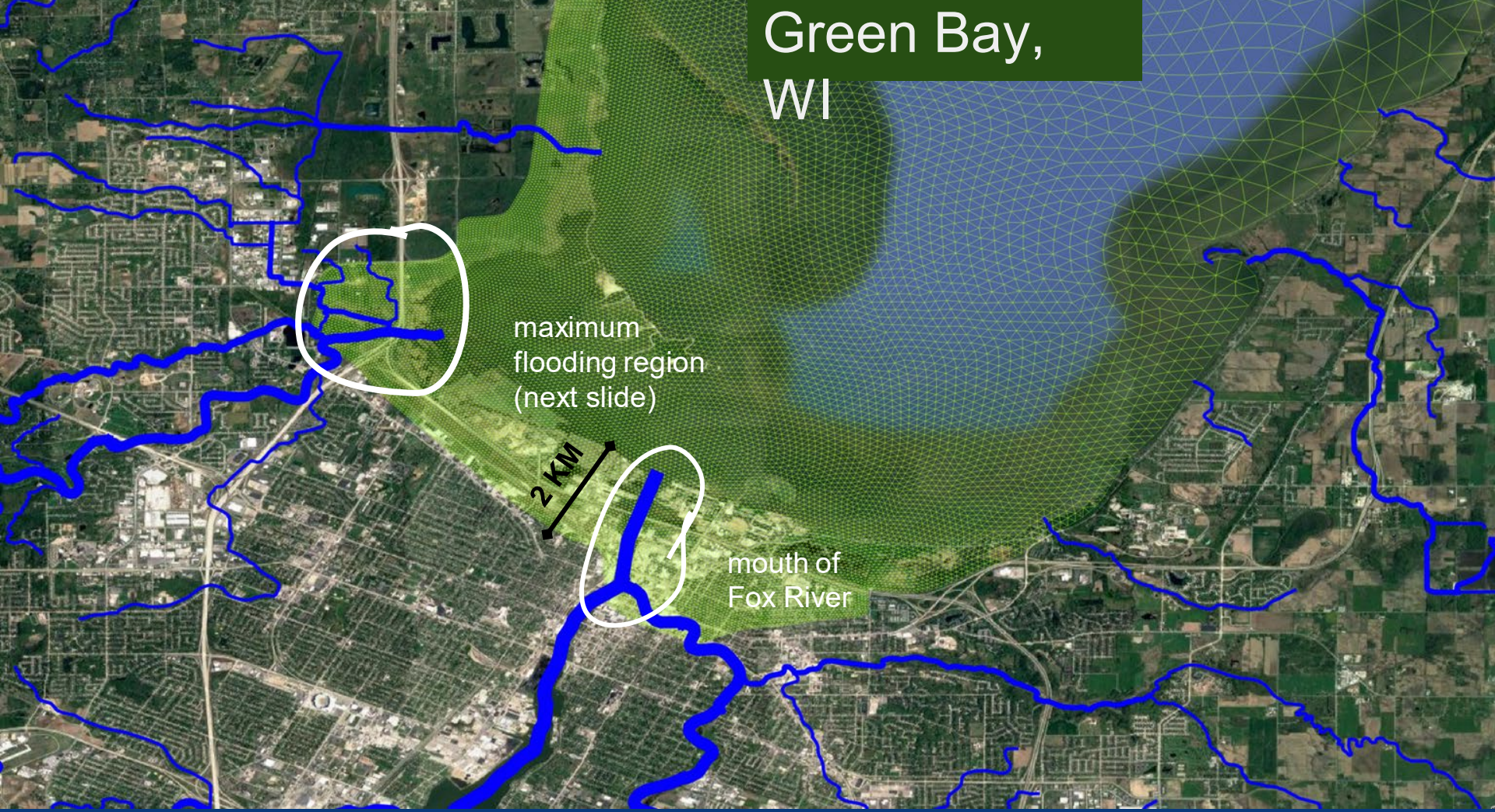
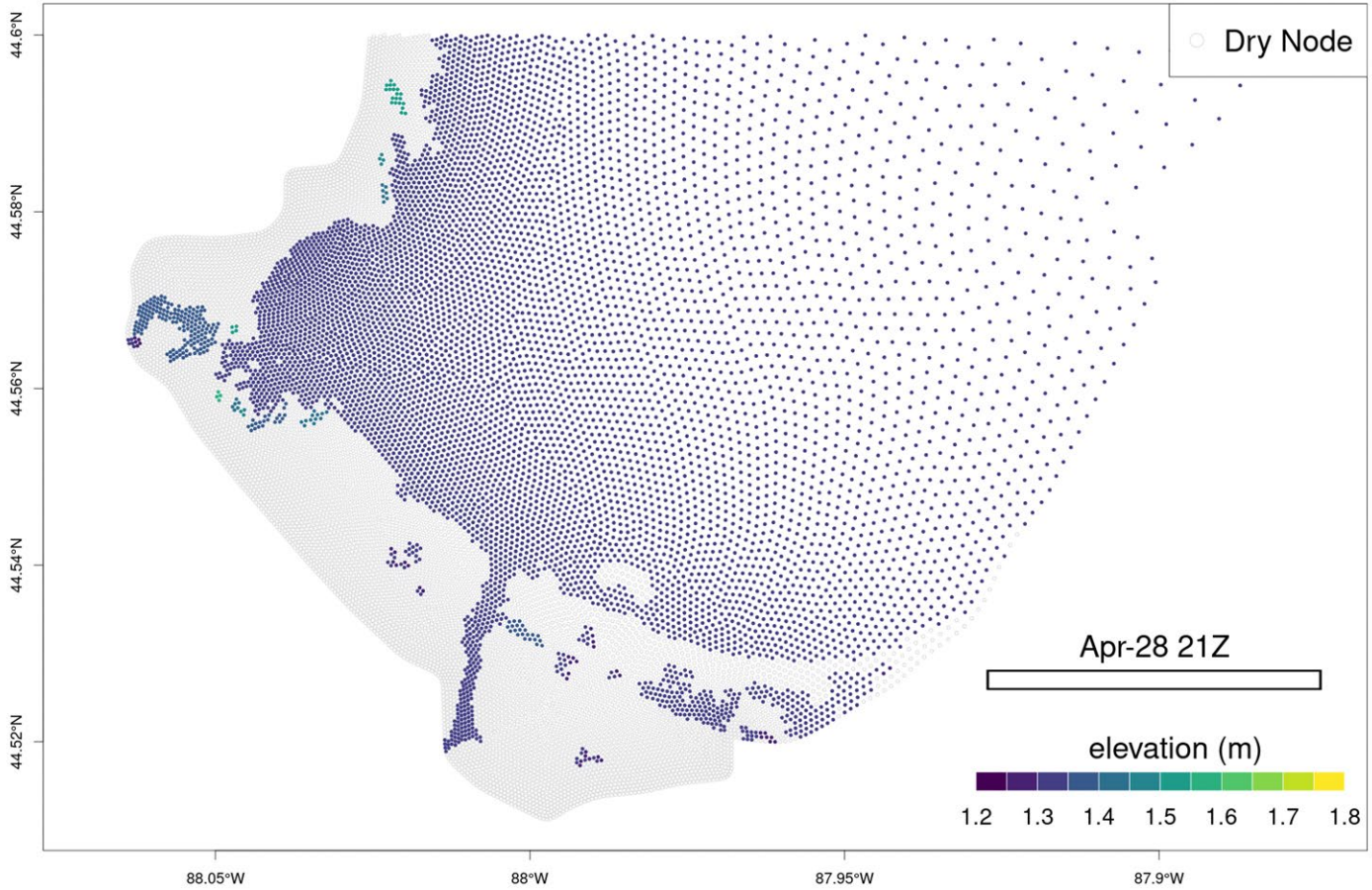
    b. WRF-Hydro results
- ❑ Summary


Green Bay, WI
2 KM

Green Bay, WI



Green Bay Flooding: **FVCOM**



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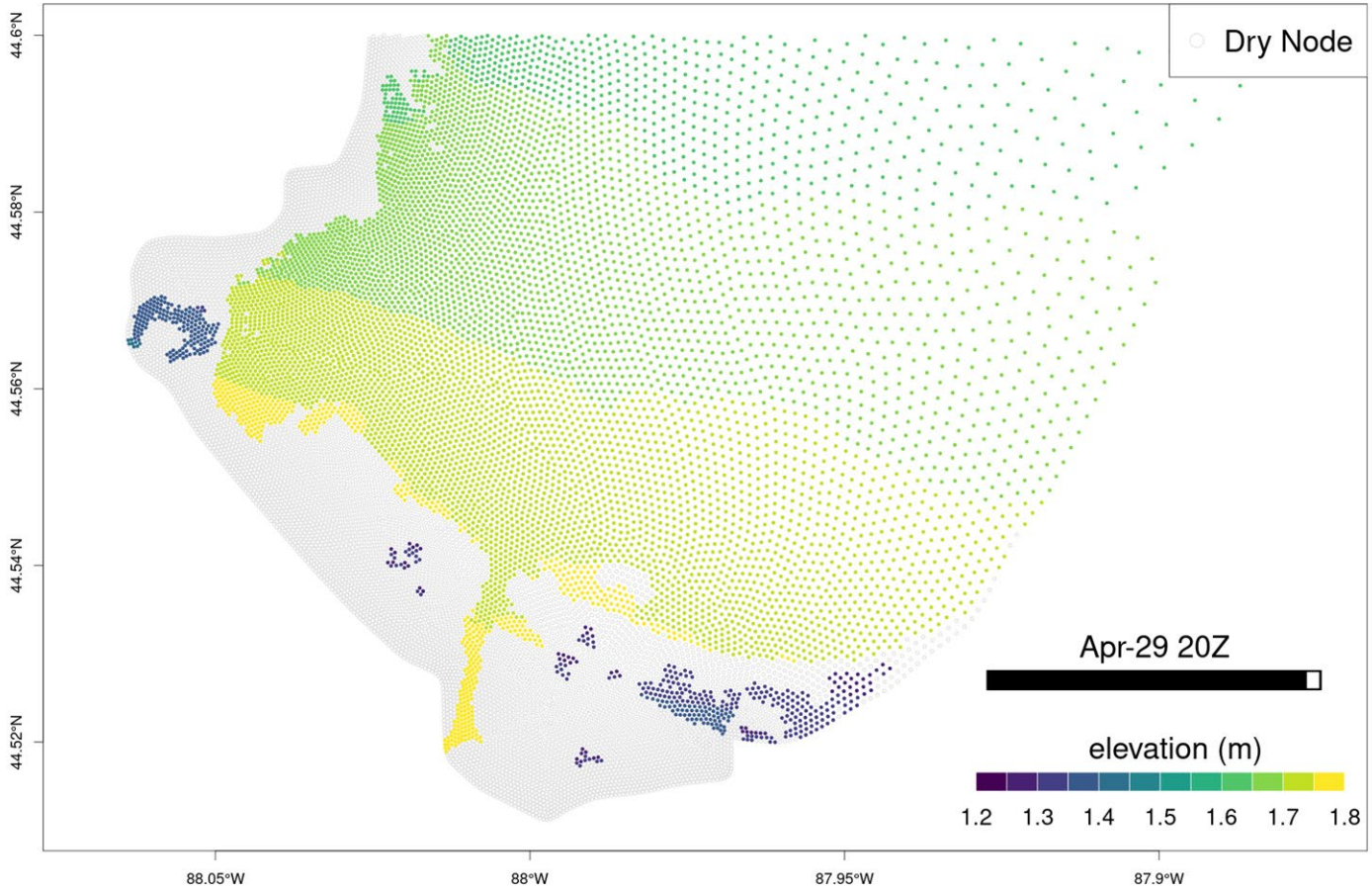
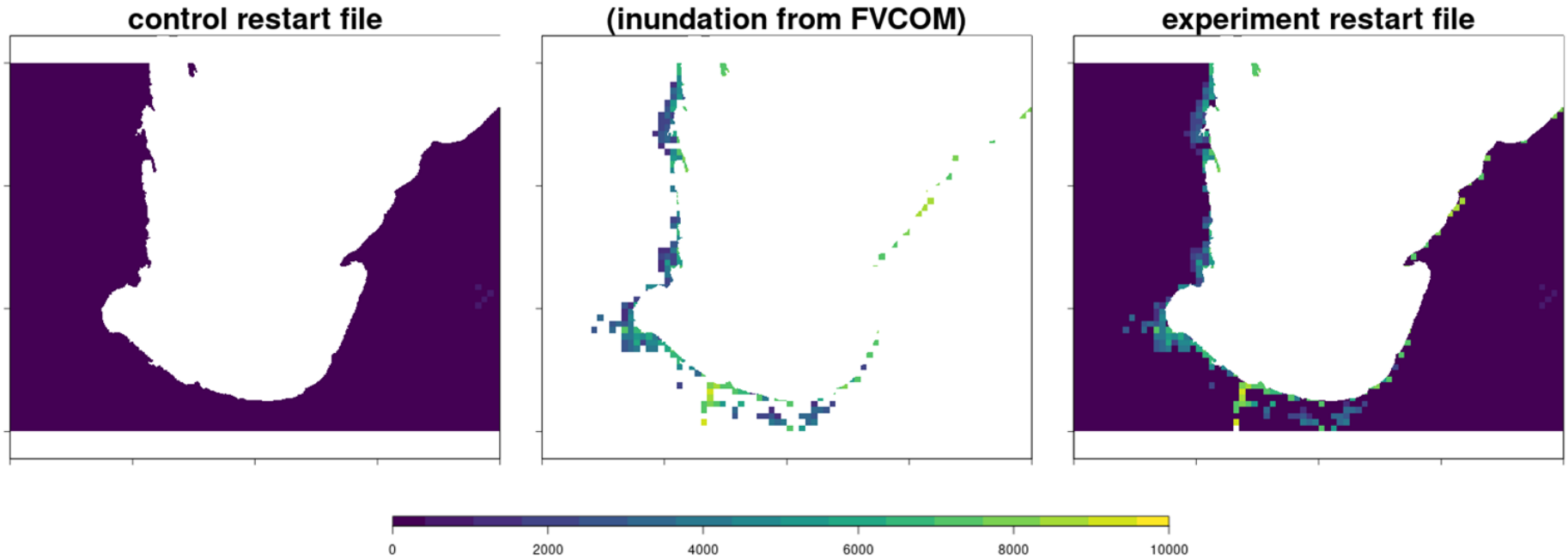


valid: Apr 29, 20Z



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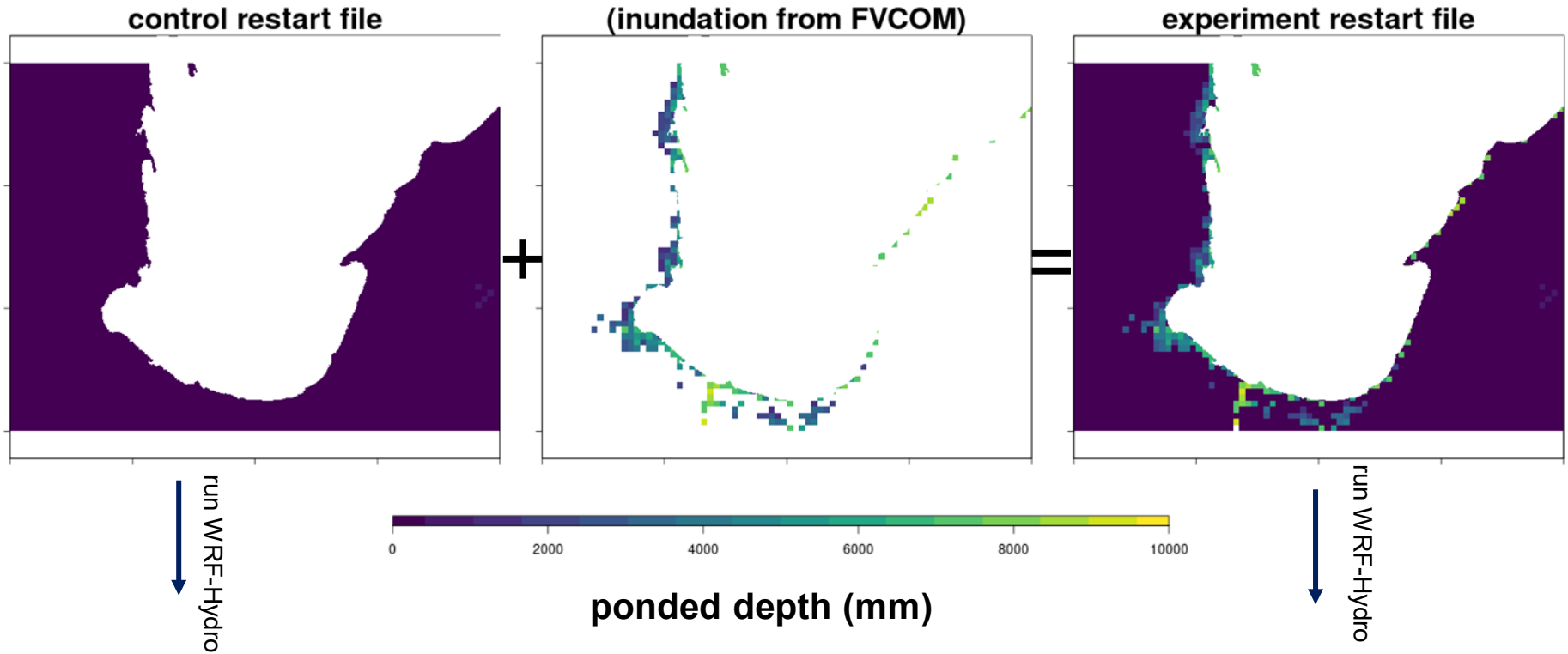

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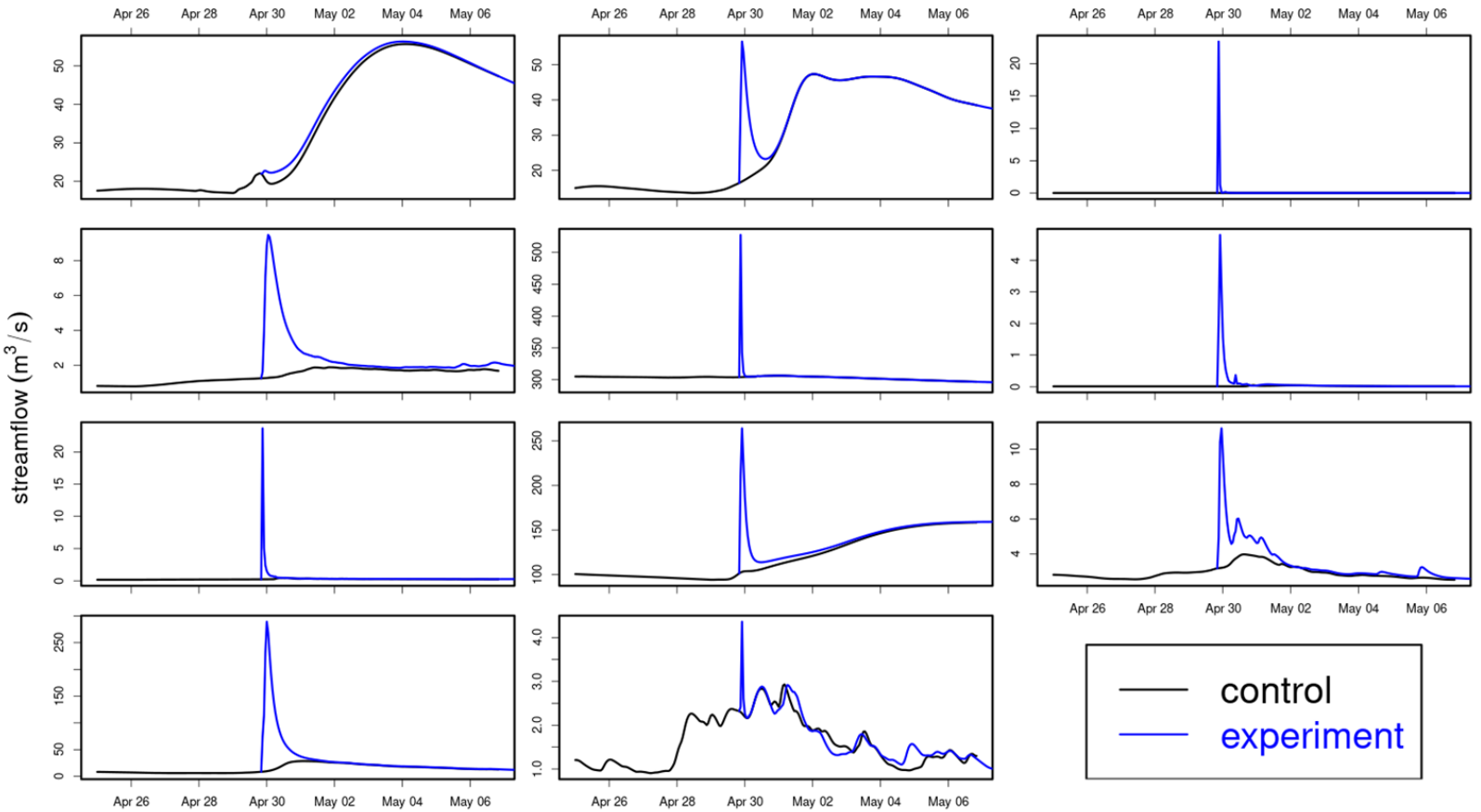
11 streams most impacted in experimental run:



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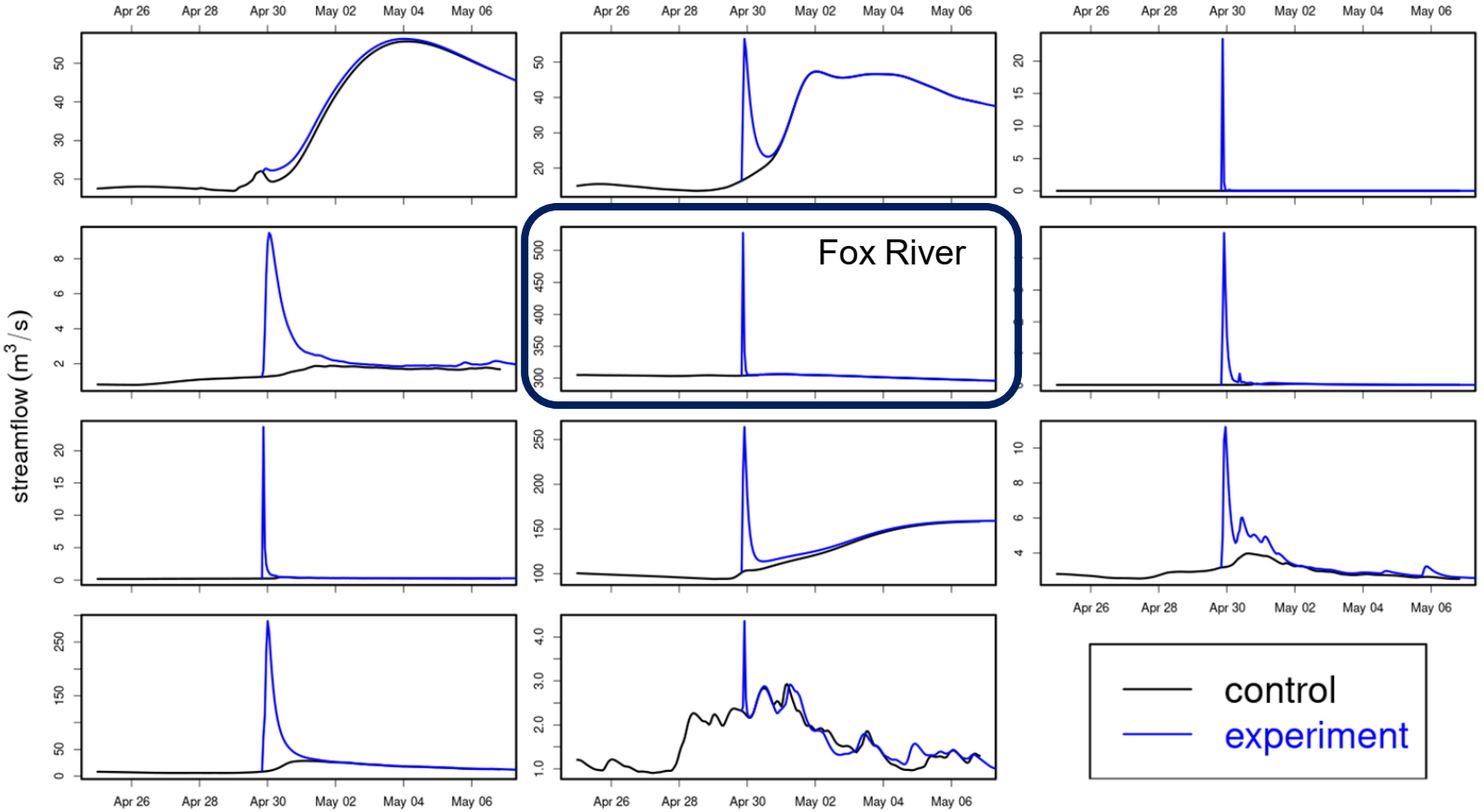
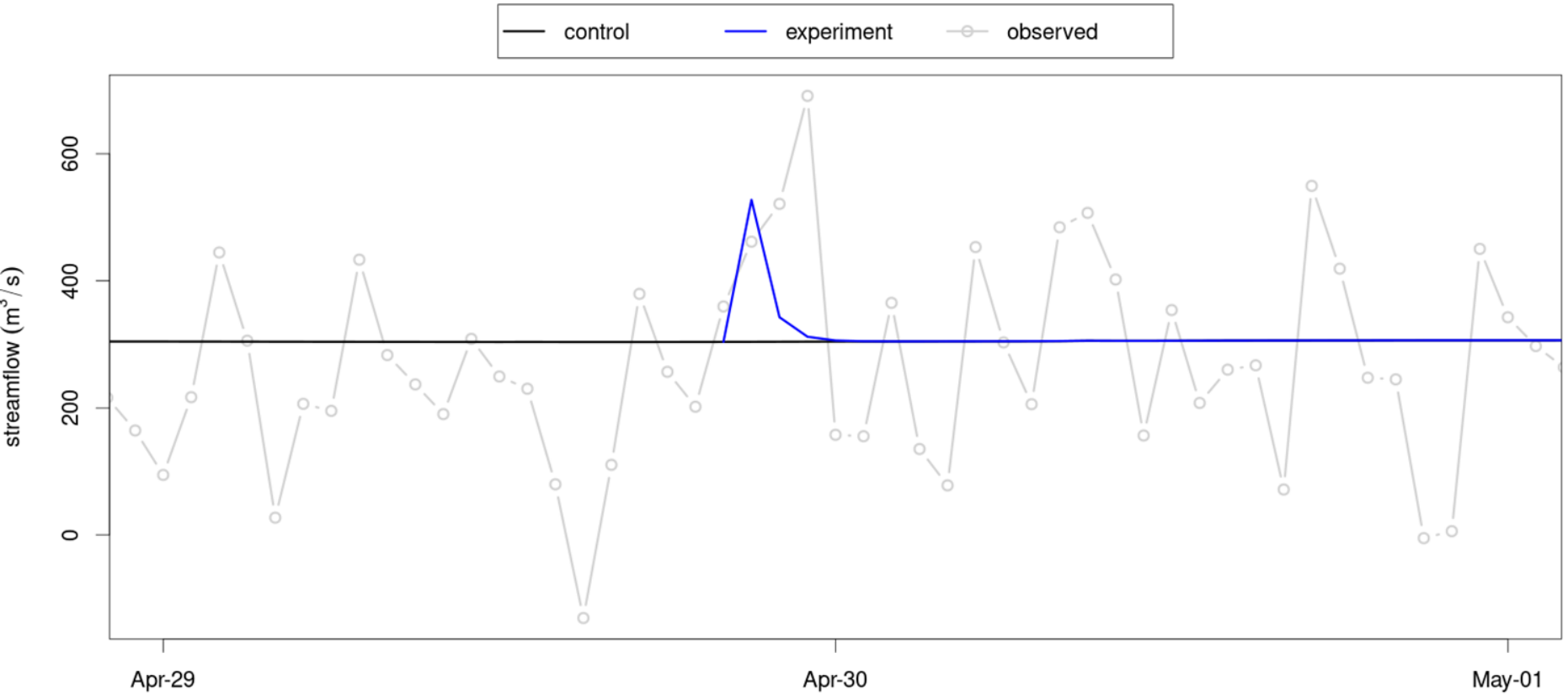
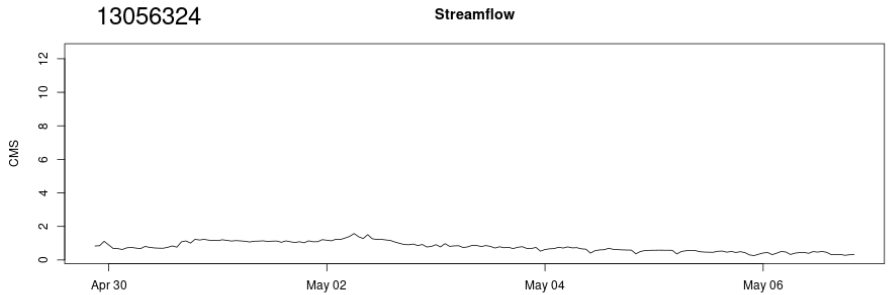


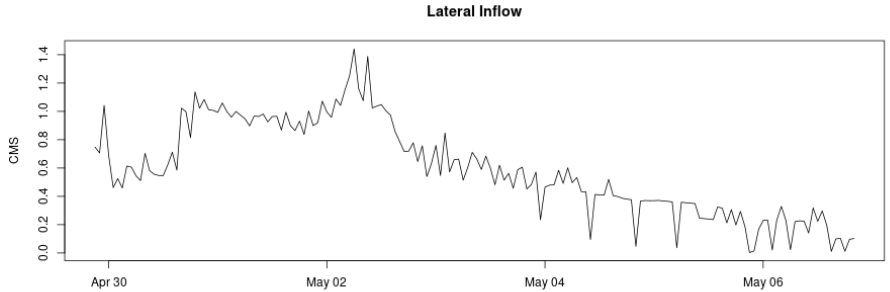
mouth of Fox River:



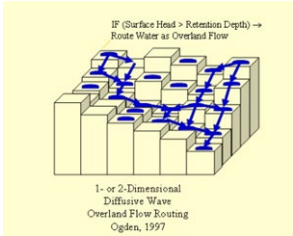
Streamflow component Plots: **lateral inflow** component of streamflow (from adjacent overland flow as opposed to upstream flow)



upstream flow + overland flow + groundwater



overland flow into chanel



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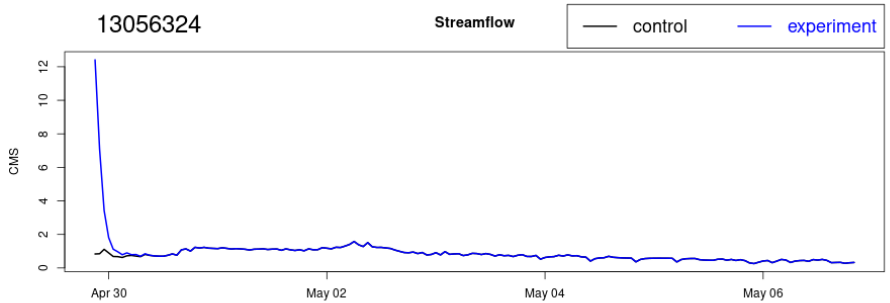

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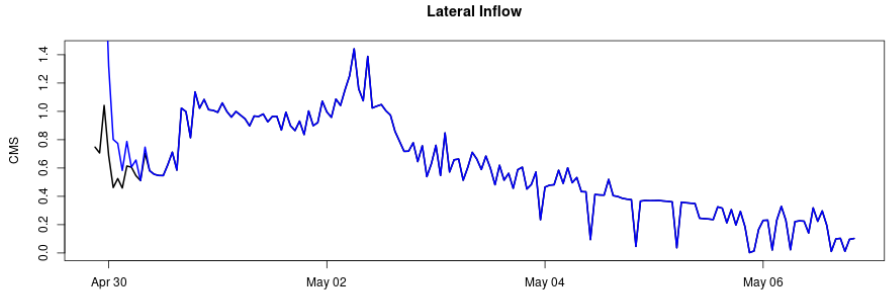
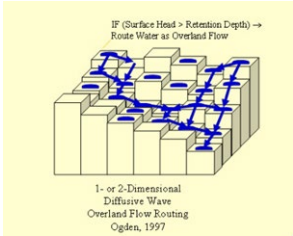
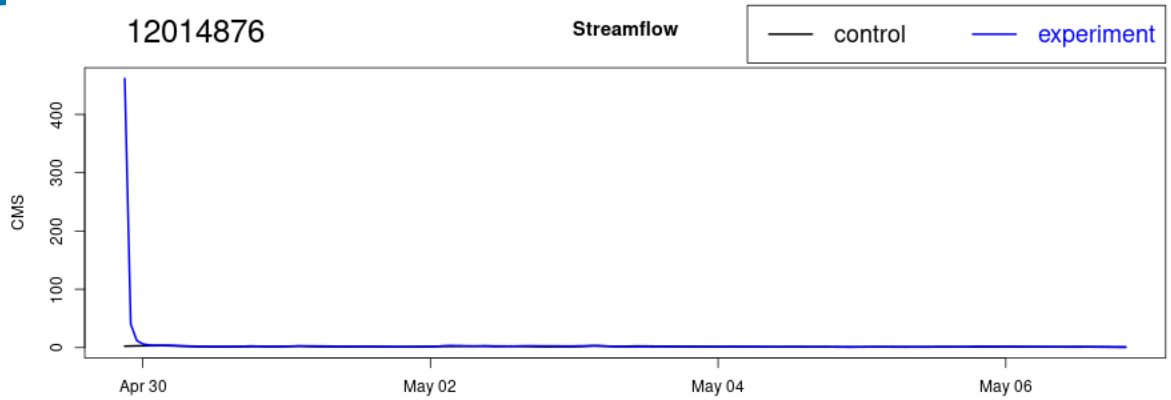
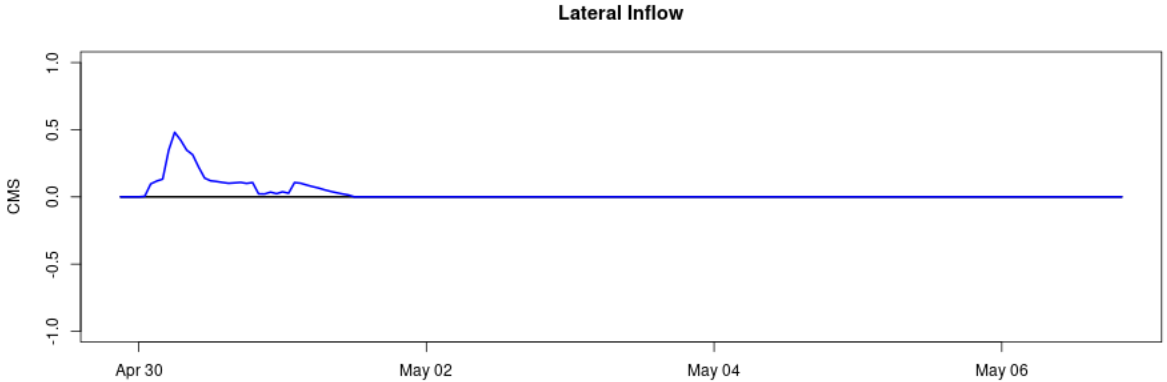
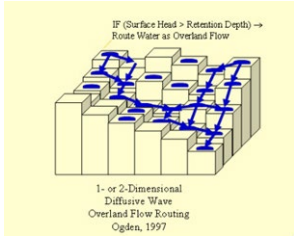


overland flow into chanel




12014876
Streamflow
control
experiment
CMS
0
100
200
300
400
Apr 30
May 02
May 04
May 06


Lateral Inflow
CMS
-1.0
-0.5
0.0
0.5
1.0
Apr 30
May 02
May 04
May 06


IF (Surface Head > Retention Depth) →
Route Water as Overland Flow
1- or 2-Dimensional
Diffusive Wave
Overland Flow Routing
Ogden, 1997

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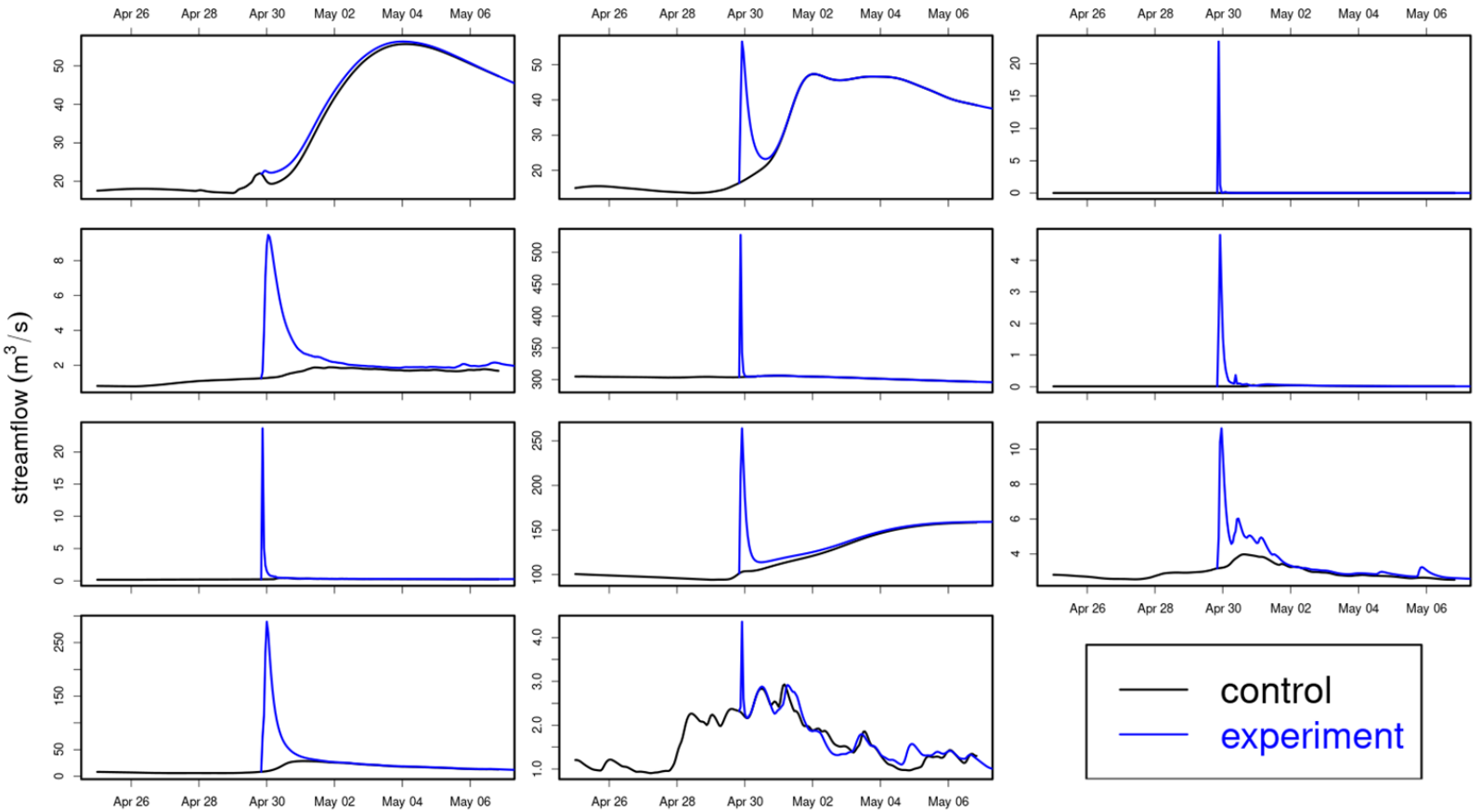
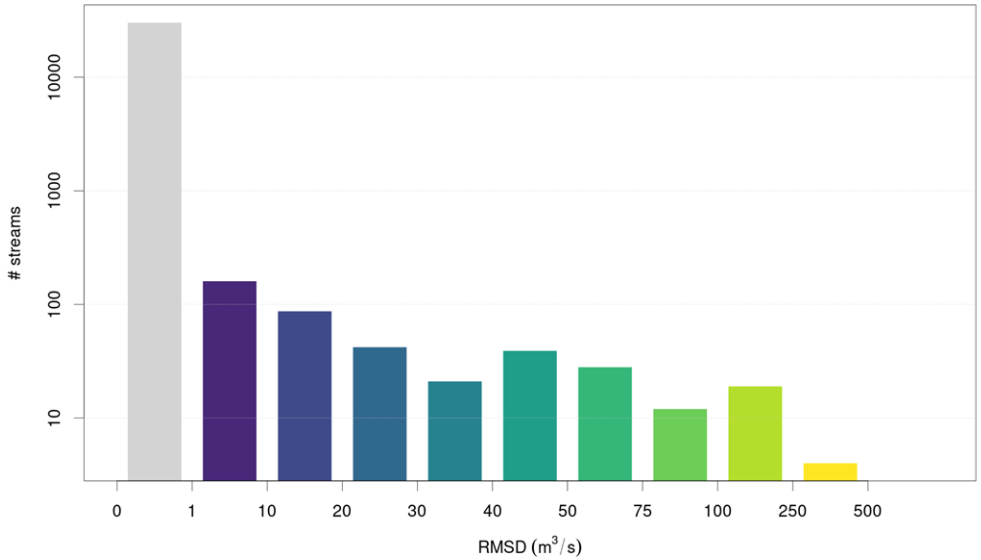
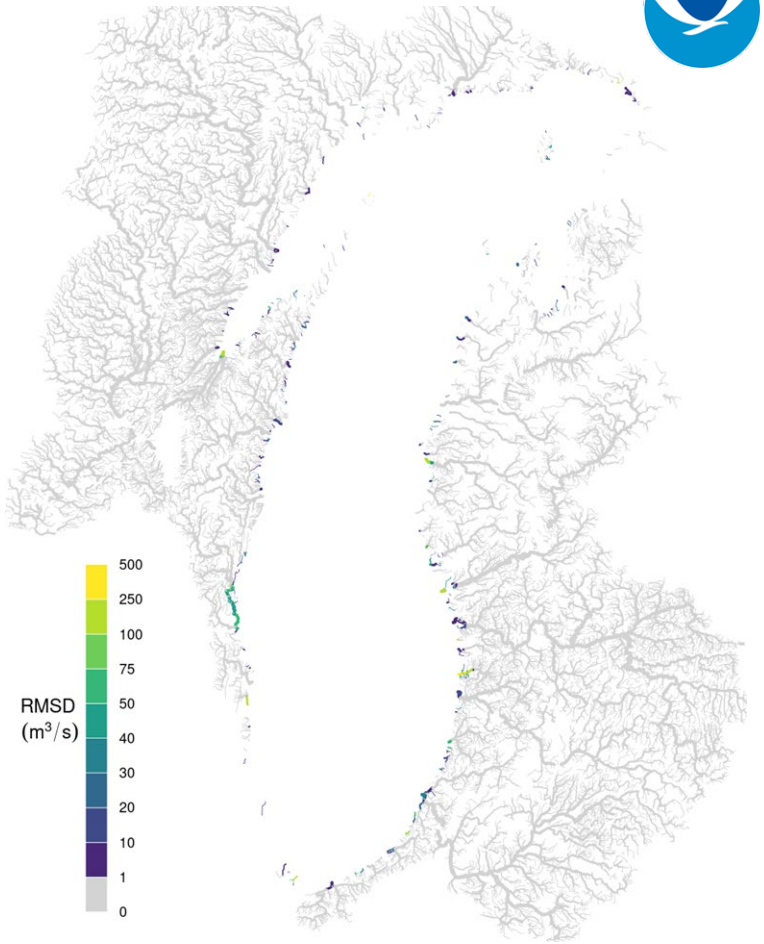


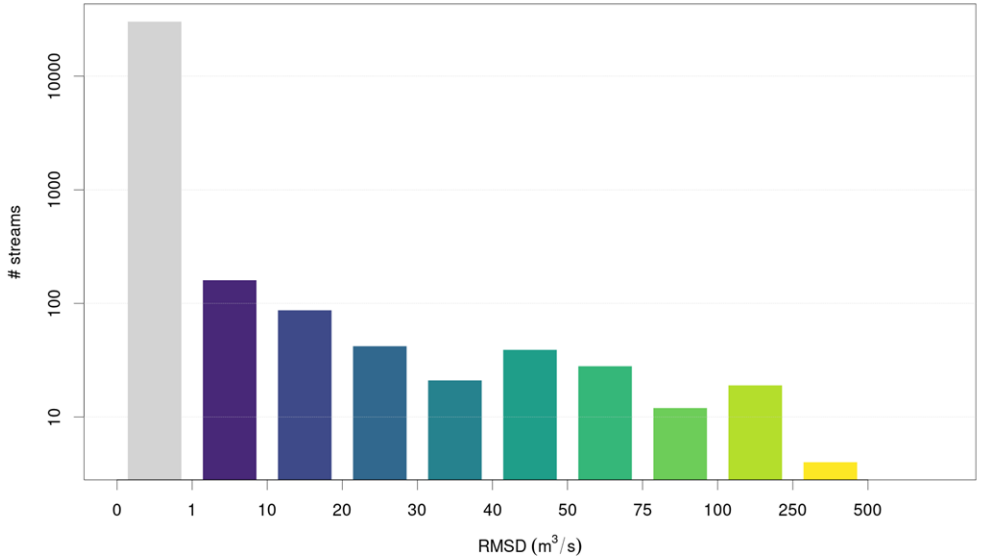
Impact on streamflow (RMSD: **control vs experiment**)

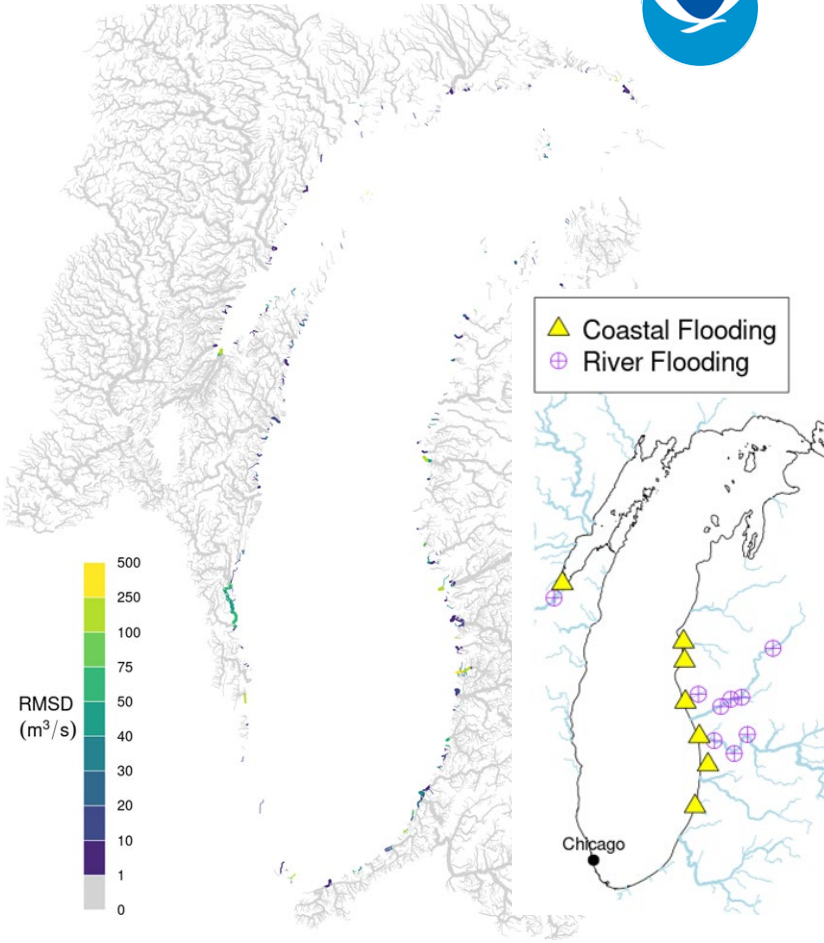




Impact on streamflow (RMSD: **control vs experiment**)

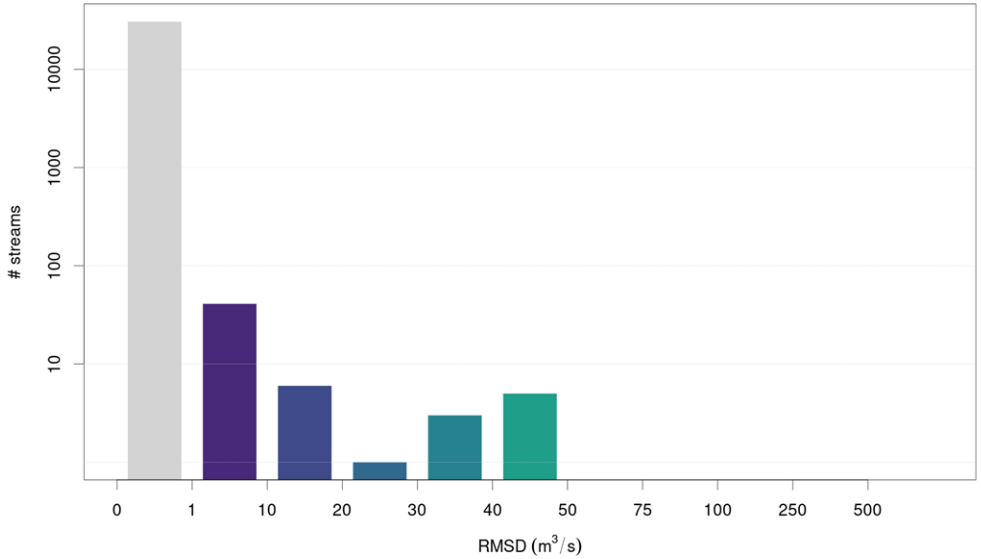
too much influence where flooding was not observed?

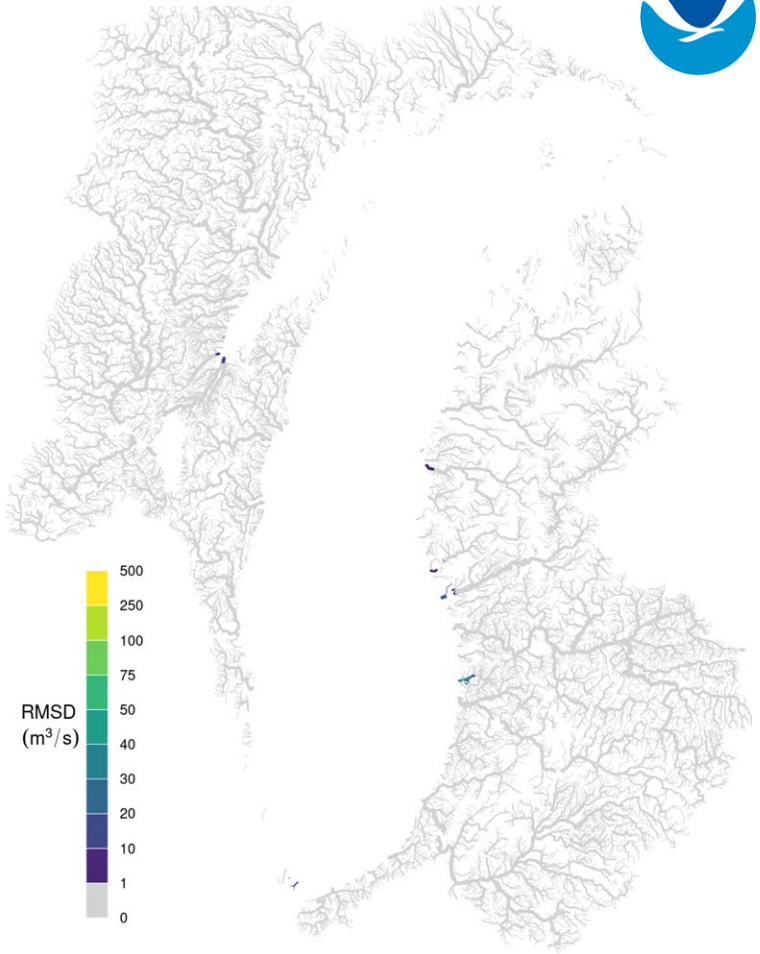




Impact on streamflow (RMSD: **control vs experiment**)

repeated experiment: exclude areas with depth < LWD





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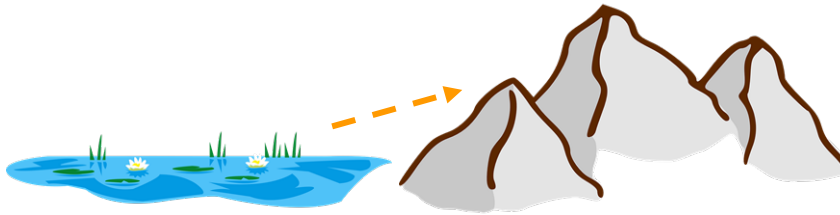
Summary:

- Demonstrated lake → land information flow:
  - ponded depth passed from FVCOM to WRF-Hydro via restart file
  - no modifications to model source code

- Pronounced impact on streamflow near coast
  - lack of observations near coast make validation difficult
  - no “upstream” impact (e.g. backwater effects)



Ongoing work:

- Iterative coupling
- River inflow in FVCOM and overlake precipitation
- Grid-based routing tests (backwater effects possible)

Key Questions and Issues:

1. Model domain overlap: which model is most “trustworthy” where?
2. Prescribing the location of river inflows in FVCOM
1. What timescale is appropriate for iterative coupling?