Levee Protected Area Detection for Improved Flood Risk Assessment in Global Hydrology Models

Masato Ikegawa[1], Tristan Hascoet,[1] Victor Pellet,[2] Xudong Zhou,[3]

Tetsuya Takiguchi,[1] and Dai Yamazaki[3]

[1] Graduate School of System Informatics, Kobe University

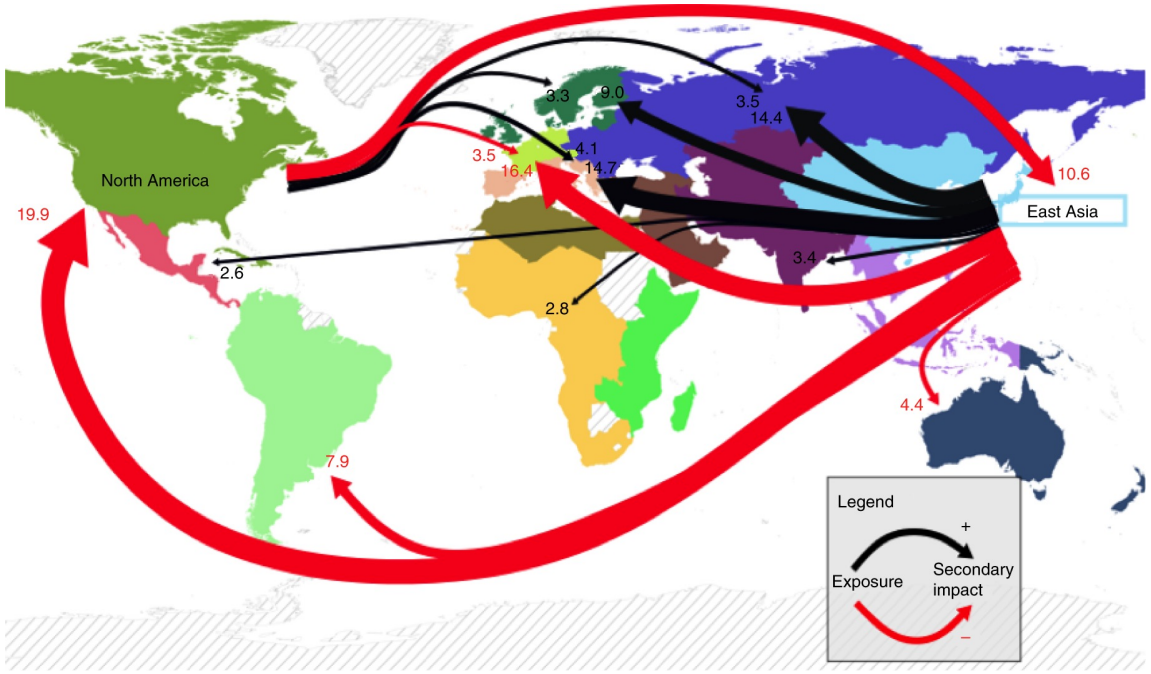
[2] LERMA, Observatoire de Paris, Paris, France

[3] Institute of Industrial Science, The University of Tokyo

NEURAL INFORMATION PROCESSING SYSTEMS

Global flood risk assessment

- Flood risk is defined as:
  - Hazard, exposure, and vulnerability.
- Protect people and goods from flood risks:
  - Levees and dams.
  - Early warning system.

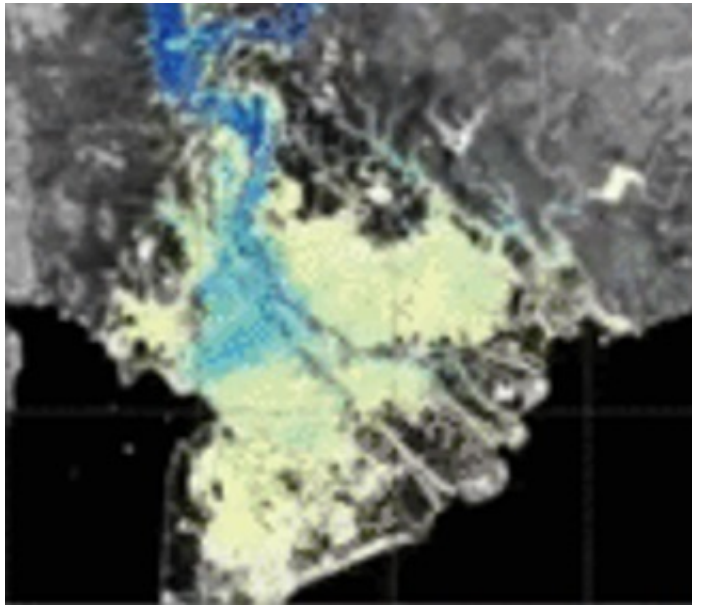


Red arrows: adverse secondary impact

Shughrue et al. 2020

Hydrological simulations

- Global hydrological models:
  - Reduce vulnerability for flood events.
  - Rely on global Digital Elevation Models (DEMs).
- Global hydrological models do not include man-made river-flow control infrastructure.

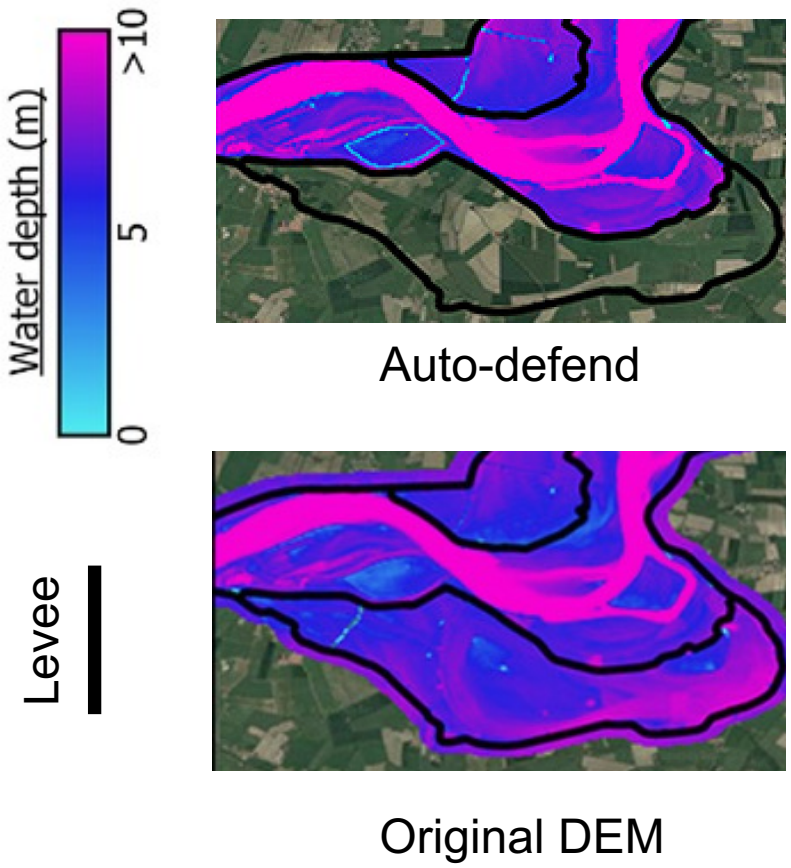


Simulation by Cama-flood

http://hydro.iis.u-tokyo.ac.jp/~yamadai/cama-flood/

Challenge

- Some works simulated the dam's impact on river discharge at global scale.
- But: Only case studies of levee impact on river discharge exist (not global scale).
- Main bottle neck: Non-availability of a global river control equipment dataset.

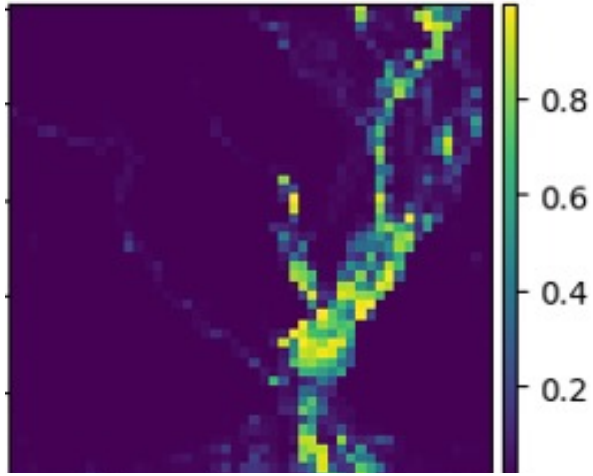


A New Automated Method for Improved Flood Defense Representation in Large-Scale Hydraulic Models, E.J.Wing et al. 2019

Machine Learning (ML)

- Expand our knowledge of levee locations using ML.
  - Learn locally and Infer levee locations at global scale.
- However: This is a very **challenging** because levees are too small to detect.

NLD: National Levee Database

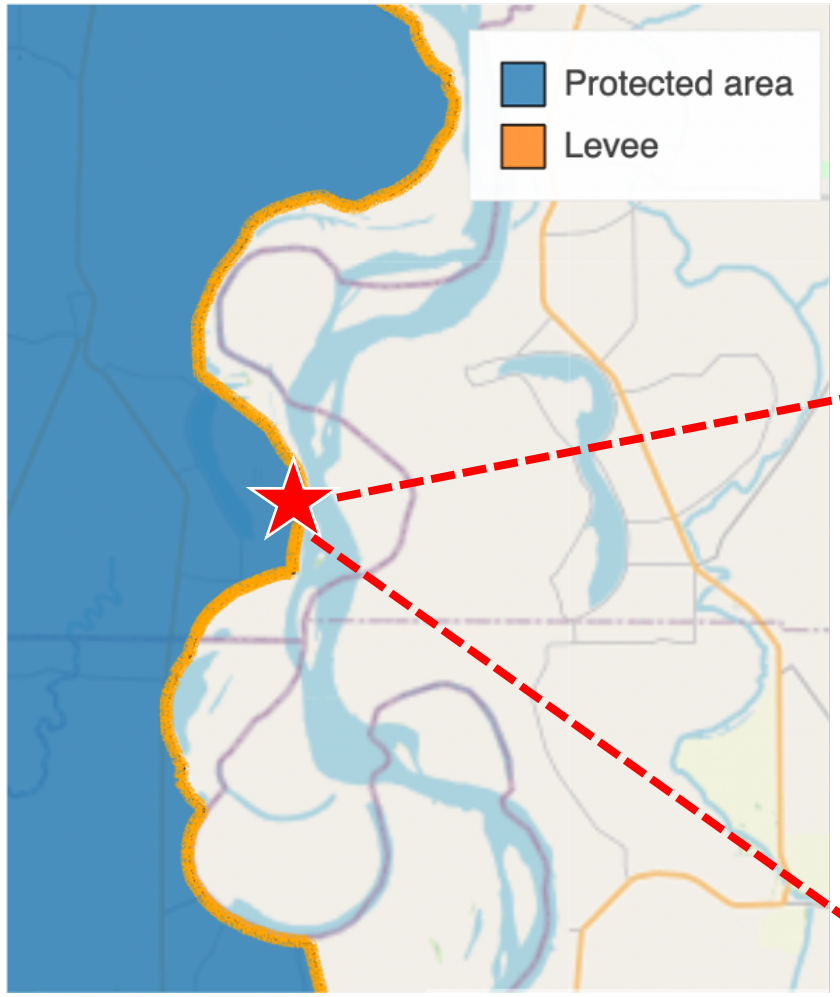


Probabilities of levees

1. https://levees.sec.usace.army.mil/#/

Where do humans build levees? A case study on the contiguous United States, M.Ikegawa et al. 2022

Levee Protected Area Detection



Around Mississippi river

Protected Area:

The areas protected from flooding by levees.

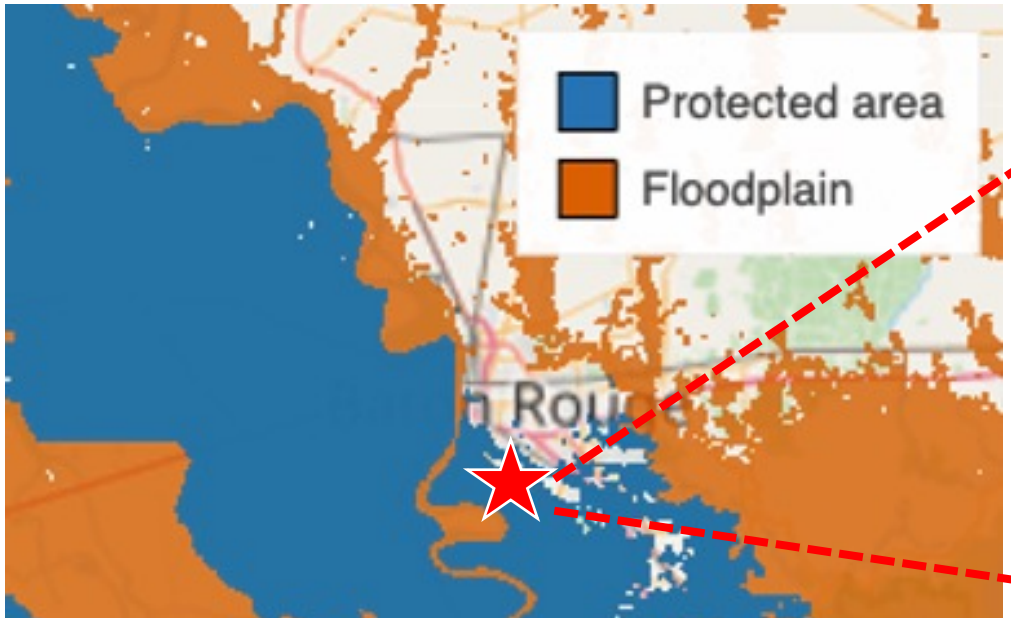
Levee

Levee Protected Area Detection

Formulation: $F(X) = P(protected|X), \quad F : R^{14} \longmapsto [0, 1]$

$P(protected)$: Probability of protected area

1: Protected area



Baton Rouge, Louisiana

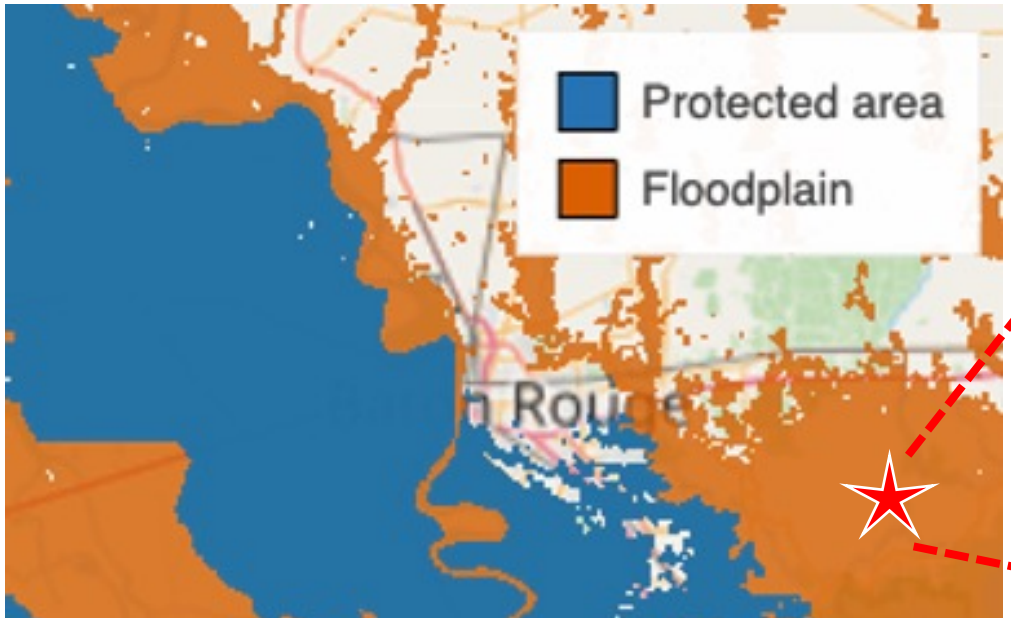
Human activities (residential area)

Levee Protected Area Detection

Formulation: $F(X) = P(protected|X), \quad F : R^{14} \longmapsto [\mathbf{0}, 1]$

$P(protected)$: Probability of protected area

0: Non-protected area

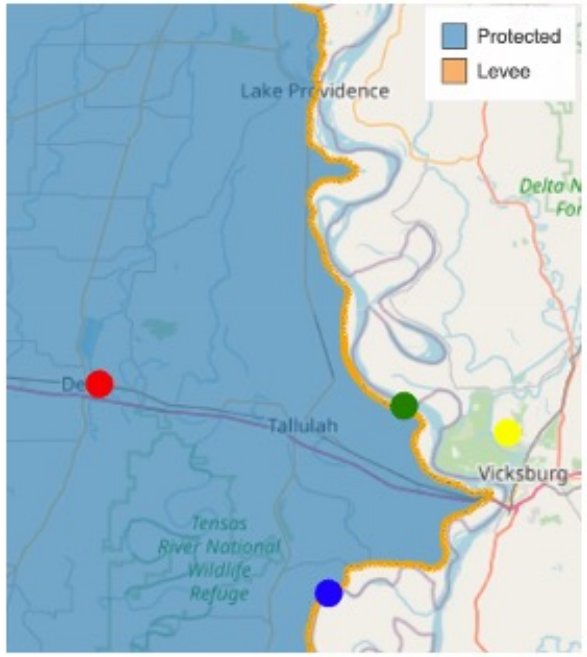


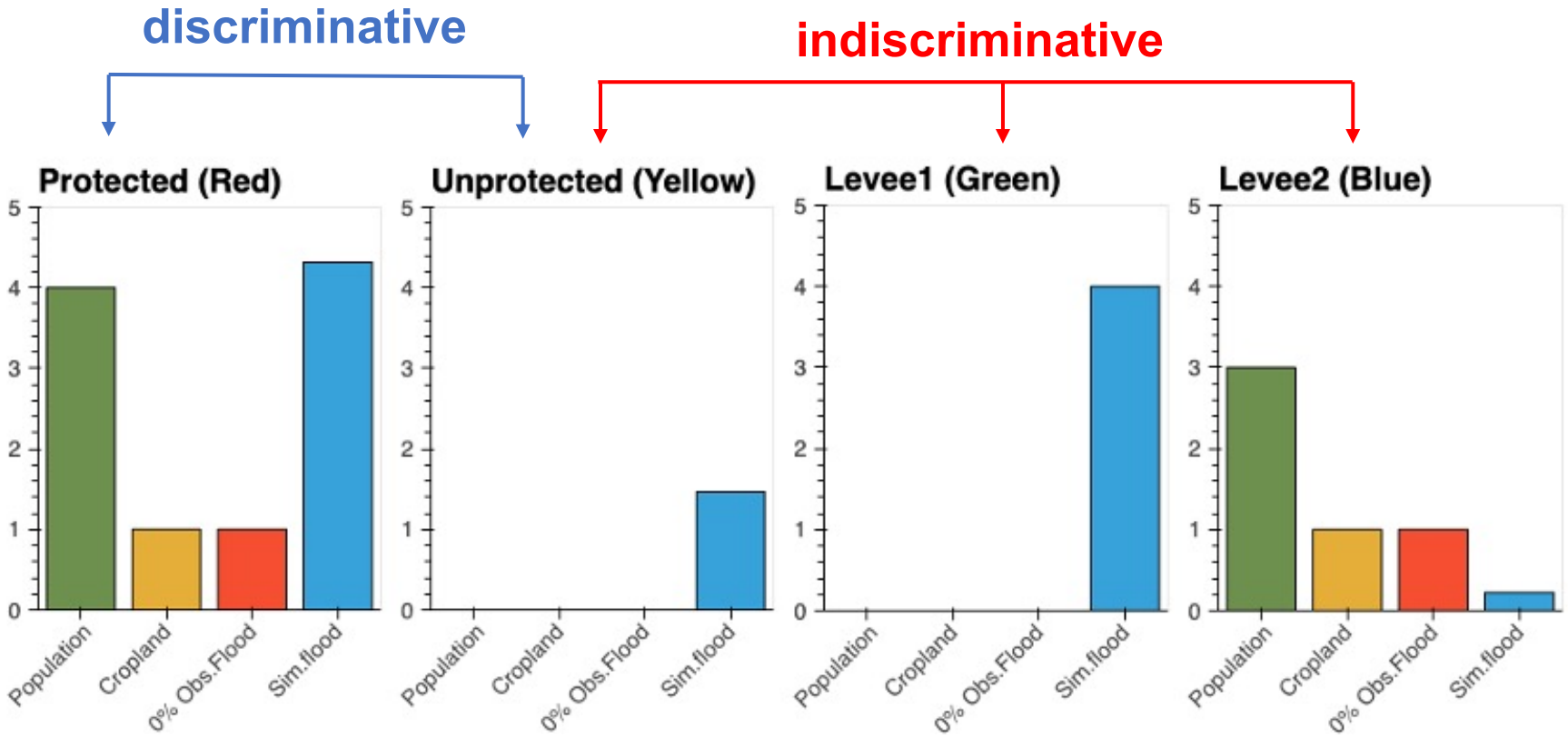
Baton Rouge, Louisiana

Forest roads

Merit

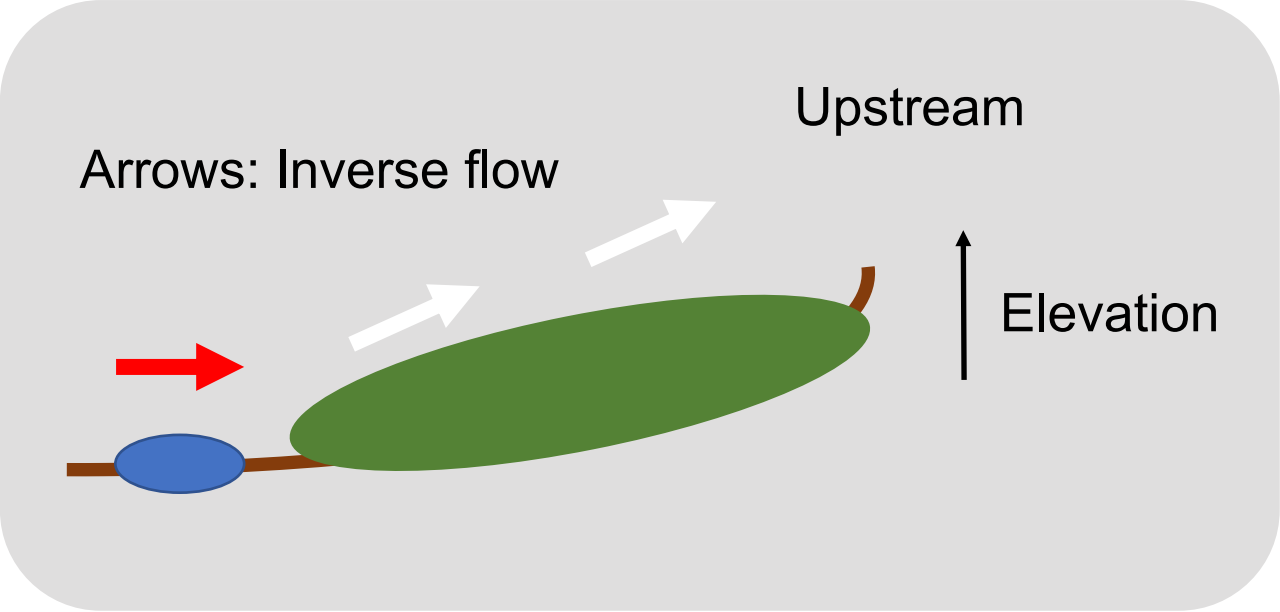
- Protected areas have more **discriminative** feature distributions.



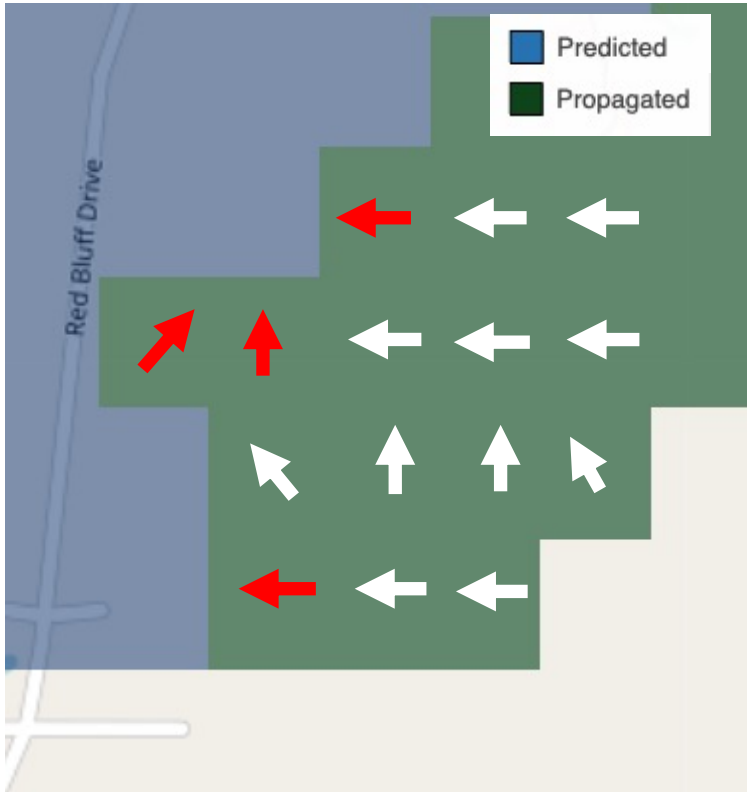


Merit

- **Inverse Flow Propagation (I.P.)**



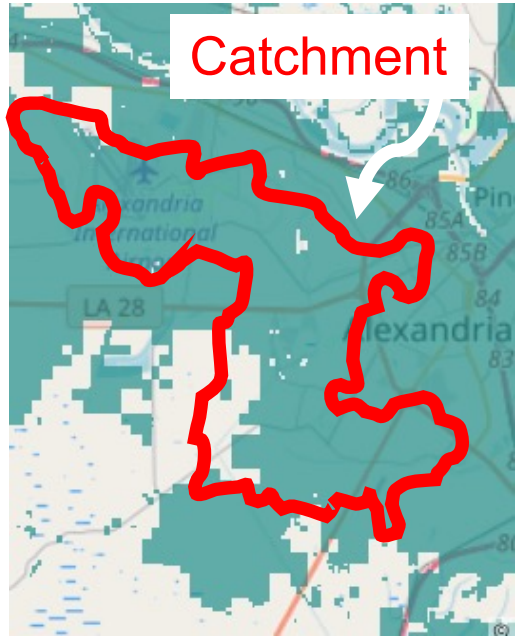
Protected areas are propagated from the model output (blue), starting from the red arrows.



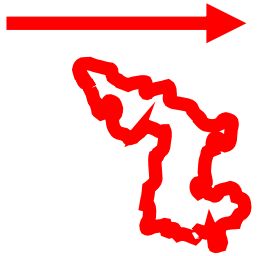
Arrows: Forward flow

Merit

- **Seamless integration** to existing global catchment level hydrological models.



Crop



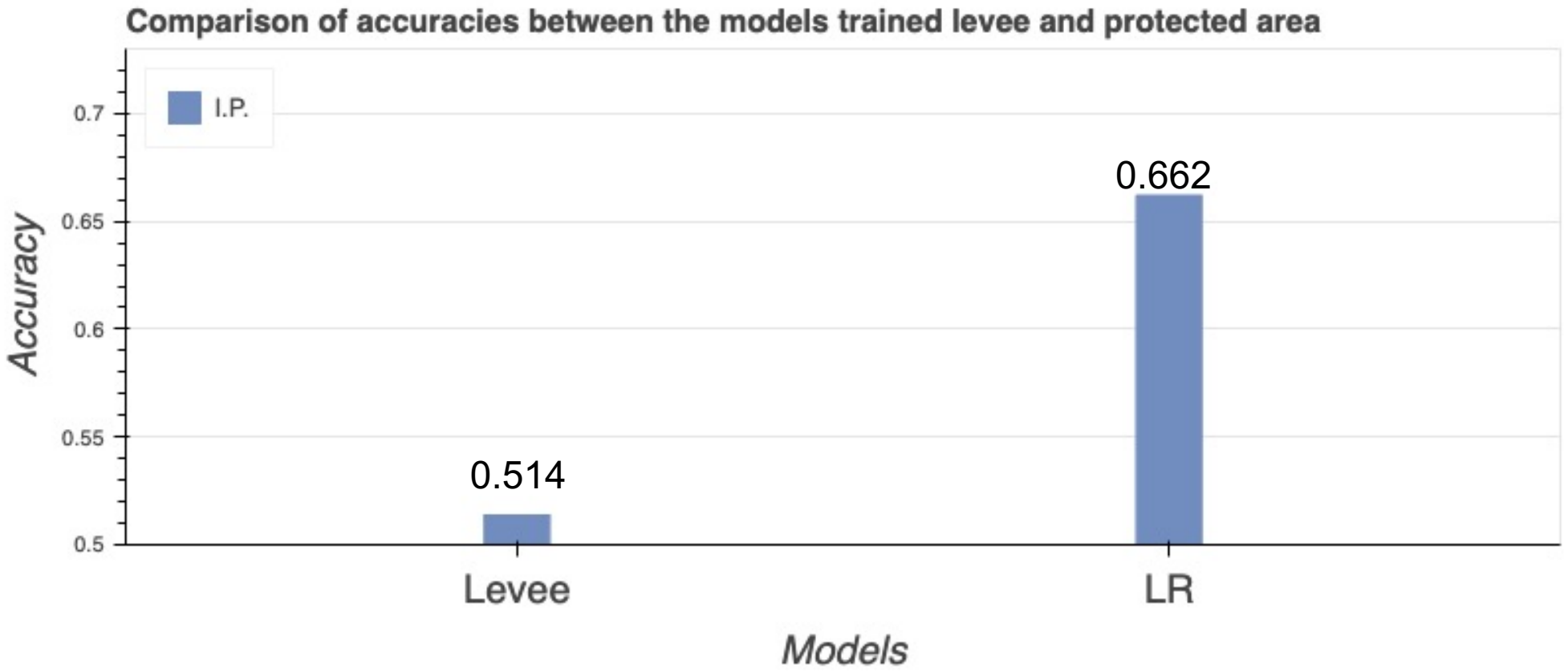
Ratio of protected area per catchment

Parameter

Hydrological Models

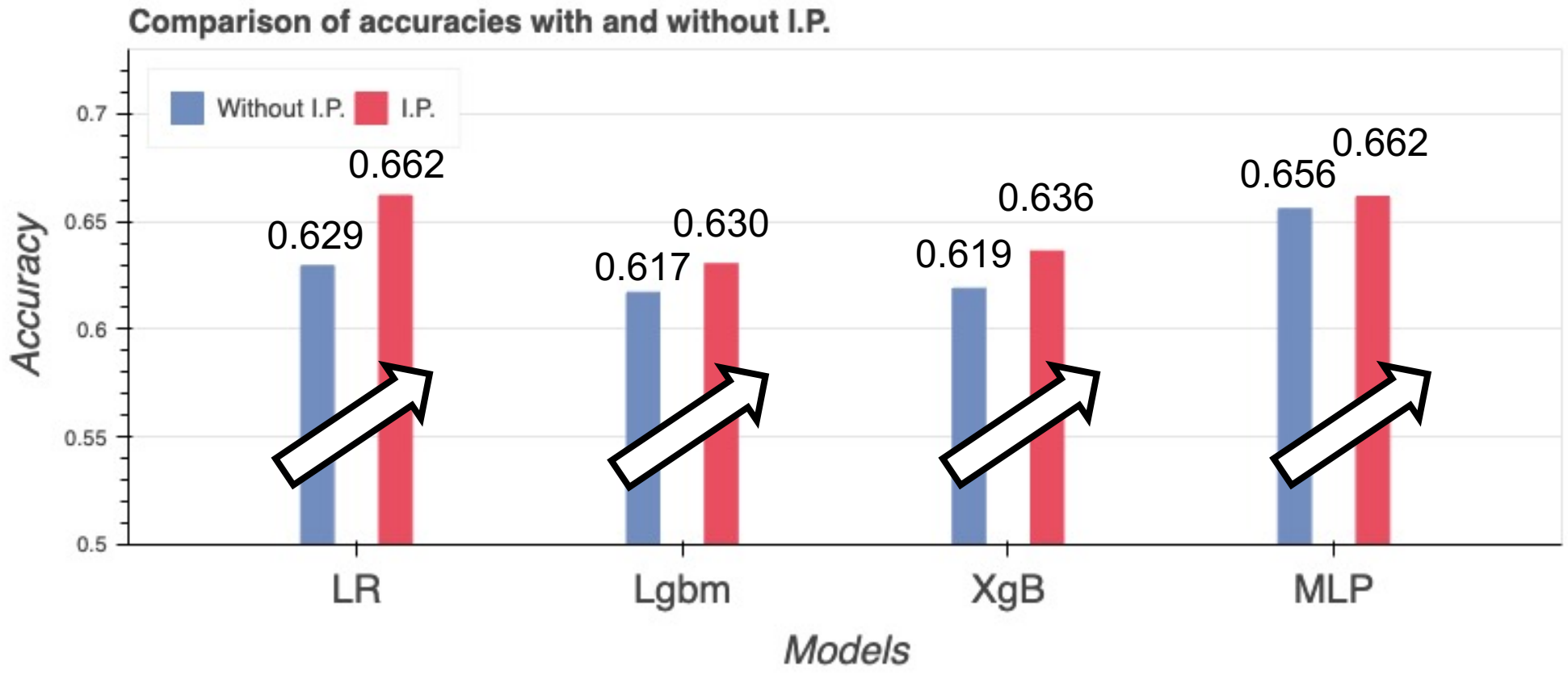
Comparison with levee detection model

- “Levee” refers to a linear model trained to classify levee locations.
- Logistic regression (LR) trained to classify protected area has better accuracy.



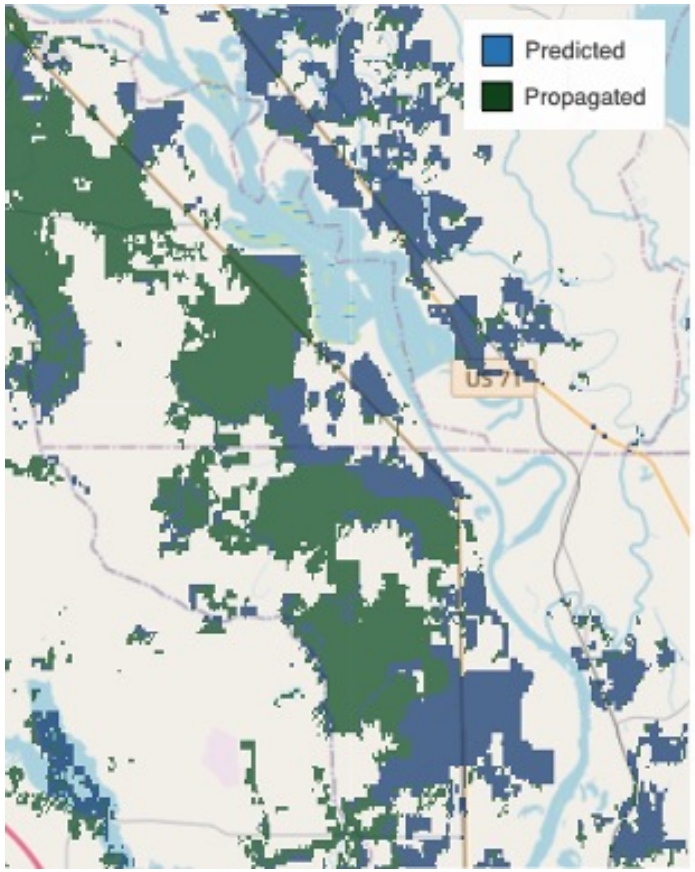
Effectiveness of inverse flow propagation

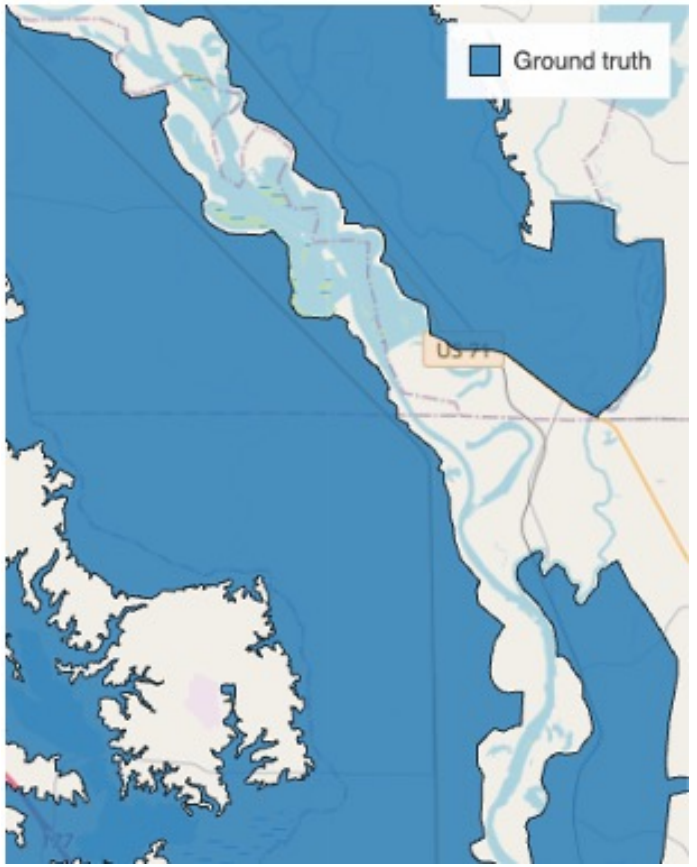
- Inverse flow propagation (I.P.) improves accuracy.



Visualization of protected areas outputted by models

- Flow propagation seems to appropriately fill some wholes of the floodplain area to be protected.





Conclusion

- Knowledge of man-made structures impacting global surface water processes is critical for flood risk assessment.
- We proposed a new formulation to the problem of levee detection.
- Our preliminary experiments have shown the merits of our formulation.
- Future work:
  - Improve detection by optimization of the ML model.
  - Generalize the application of our model on a global scale.

Thank you