

Flood Inundation Mapping using Remote Sensing and Deep Learning

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Introduction: Flood disasters are increasing in both frequency and societal impact across the United States and globally. Despite advances in hydrologic monitoring, reliable and high-resolution flood inundation maps remain sparse, particularly in ungauged or poorly instrumented river reaches. Traditional physics-based hydrodynamic models, while accurate, are often computationally intensive and difficult to scale for rapid, large-area applications. This study introduces a framework that leverages deep learning and remote sensing to learn the relationships between hydrologic forcing, terrain controls, and observed flood extent. By integrating multi-source geospatial data, the spatial deep learning framework aims to generate high-resolution (10 m), probabilistic flood inundation maps that are both scalable and computationally efficient.

Methodology:

- A Feature-wise Linear Modulation (FiLM)-conditioned U-Net Deep Learning (DL) framework consisting of encoder, bottleneck, and decoder.
- The framework learns relationship between terrain, hydrologic forcing, and flood extent from Dynamic World Map.
- The model predicts pixel-wise flood probability for a reach of the river by combining static spatial features (digital elevation model) and dynamic conditioning variables (discharge and season)

Results and Conclusions:

- The framework demonstrates rapid flood-inundation mapping using a FiLM-conditioned U-Net that integrates remote-sensing and hydrologic inputs.
- The predicted masks were compared with the available reference masks using the Intersection over Union (IoU) metric. IoU values ranged from 0.6 to 0.9 across different flood discharge levels, demonstrating the model's potential for rapid flood-inundation mapping.

FOR FURTHER READING:

Perez, E., Strub, F., de Vries, H., Dumoulin, V., and Courville, A. (2018). FiLM: Visual reasoning with a general conditioning layer. Proceedings of the AAAI Conference on Artificial Intelligence, 32(1).

Brown, C.F., Brumby, S.P., Guzder-Williams, B. et al. (2022). Dynamic World, Near real-time global 10 m land use land cover mapping. Sci Data 9, 251.

Joseph, Jibin & Merwade, Venkatesh (2026). Probabilistic Flood Inundation Mapping using Physics-Aware Spatial AI. <https://platform.i-guide.io/notebooks/05269a1a-ce6e-4e87-8b43-74490a986c09>.

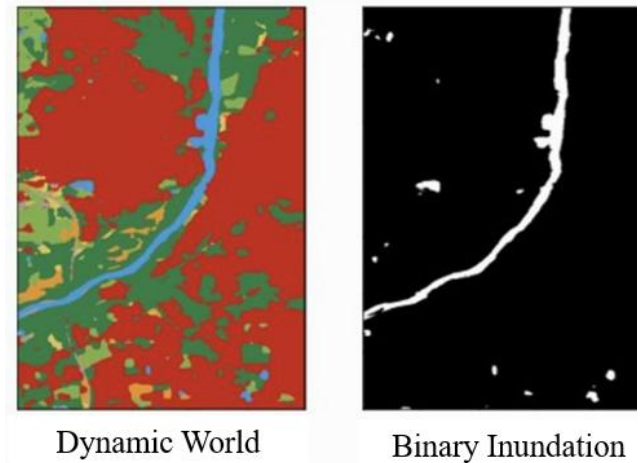


Figure 1. Binary Inundation masks are created from cloud-free Dynamic World Map available at ~5-day temporal scale for a reach near Wabash River at Lafayette, Indiana. White indicates inundated (water) pixels and black indicates non-inundated (land) pixel. A total of 234 masks were obtained from 2015 to 2025 along with corresponding discharges and were used in deep learning model.

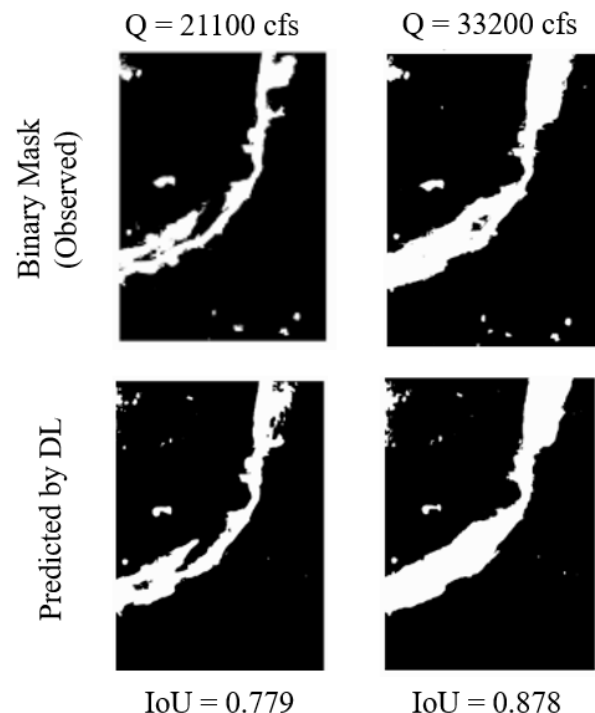


Figure 2. Comparison of the binary inundation mask from Dynamic World and the predicted inundation mask using spatial deep learning.