USING MULTI-SOURCE DTM SUPER-RESOLUTION FOR IMPROVED INUNDATION DEPTH ESTIMATION

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ABSTRACT

Accurate digital terrain models (DTMs) are an essential component for reliable flood depth estimation from synthetic aperture radar (SAR) imagery. This study proposes a deep learning-based DTM super-resolution approach, integrating remote sensing data to enhance the resolution of globally available terrain information. A collaborative loss function is introduced to focus learning on key hydrologic features. Evaluations against real-world flood sites in Germany indicate that using high-resolution super-resolved DTMs can improve the estimation of water depth compared to traditionally interpolated counterparts.

DATASET

For super-resolution model training we leverage a set of both low- and high-resolution DTMs as well as optical satellite imagery. The low-resolution data include FABDEM (Uhe et al. 2022) tiles with 30 m spatial resolution as well as a cloud-free mosaic of Sentinel-2 imagery with 10 m spatial resolution, obtained from the Copernicus Dataspace Ecosystem STAC catalog. For high-resolution target DEM sources, openly available DTMs with spatial resolution ≤ 5 m, mainly derived from airborne LiDAR scanning, were collected. To showcase the preliminary results, we currently include the Bavarian Digital Terrain Model (BY-DGM5) (Bayerische Vermessungsverwaltung, 2025) as well the North-Rhine Westphalian Digital Terrain Model (NRW-DGM5) (GeoBasis NRW, 2025). More datasets are planned to be integrated during the further course of the study.

CONCLUSION & OUTLOOK

This study addresses the critical need for accurate terrain information to improve flood depth estimation. The proposed methodology offers a cost-effective and scalable approach to generate high-resolution elevation models in data-scarce regions using solely free, globally available input data. Preliminary results indicate, that super-resolved DTMs can improve the accuracy of flood inundation depth estimation. There is still potential for improvement in terms of preserving hydrologic features in predicted DTMs. In the further course of the study project, we will focus on proving the robustness and global applicability of the framework by expanding the training dataset.

References

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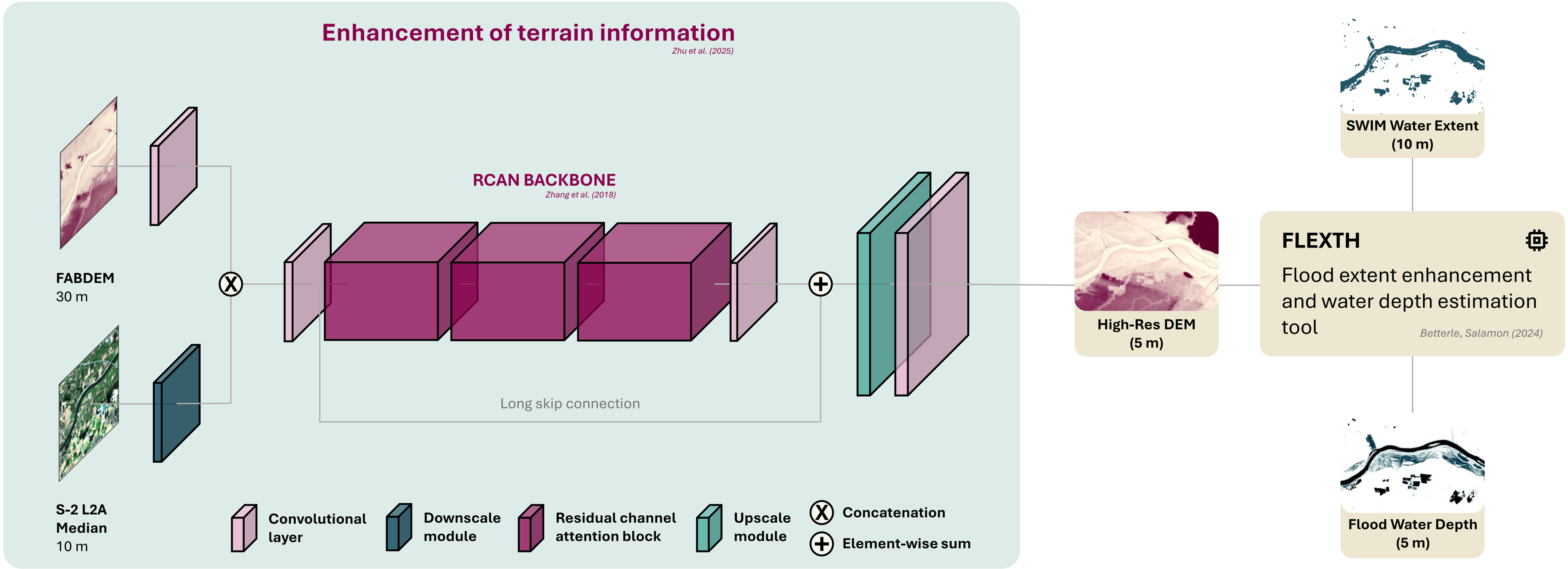
METHODS

1 General Workflow



2 Collaborative Loss

$$HYDLOSS = w_{mae} \times \boxed{L_{mae}} + w_{slope} \times \boxed{L_{slope}} + w_{flowdir} \times \boxed{L_{flowdir}}$$

$$L_{mae} = \frac{1}{N}\sum_{i=1}^{N} |\hat{z}_i - z_i|$$

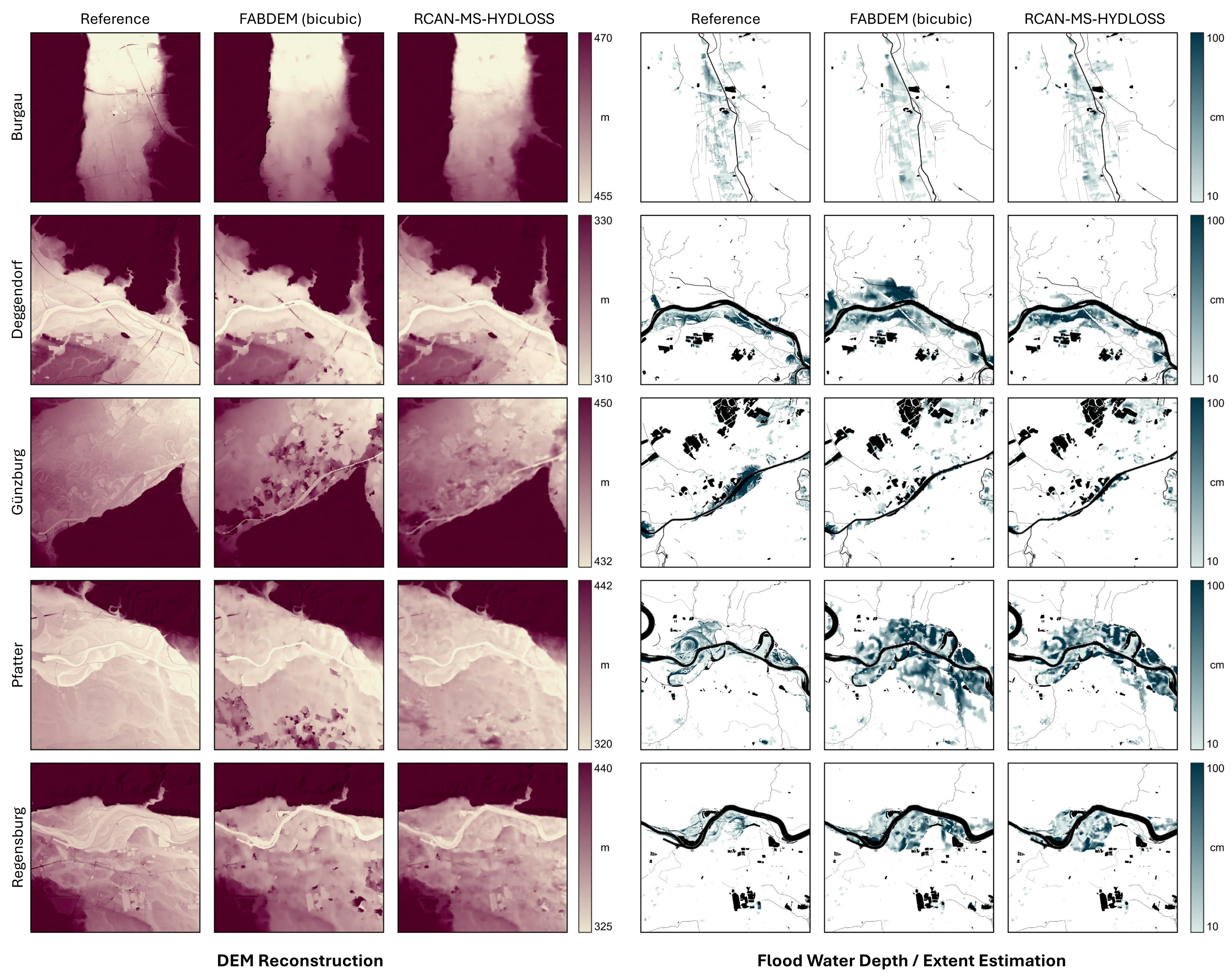
$$L_{slope} = \frac{1}{N}\sum_{i=1}^{N} |s(\hat{z}_i) - s(z_i)|$$

$$L_{flowdir} = \frac{1}{|V|}\sum_{i \in V} 1[\hat{d}_i \neq d_i]$$

N Number of pixels
z_i Reference elevation
V Valid set (direction defined)
$\hat{d}_i$ Predicted direction
$\hat{z}_i$ Predicted elevation
$s(\cdot)$ Slope computation
$1(\cdot)$ Indicator function
d_i Reference direction

PRELIMINARY RESULTS

1 DTM Reconstruction and Flood Inundation Depth Estimation



2 Loss Function Evaluation

Method	MAE in m	L_{slope}	$L_{flowdir}$
FABDEM (bicubic)	2.41	0.73	0.56
RCAN-MS	2.02	0.83	0.67
RCAN-MS-HYDLOSS	1.86	0.78	0.60

Method	MAE_{depth} in cm	IoU_{extent}
FABDEM (bicubic)	3.94	0.53
RCAN-MS	5.09	0.56
RCAN-MS-HYDLOSS	3.25	0.59

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