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Evaluation of Depth Anything Models for Satellite-Derived Bathymetry

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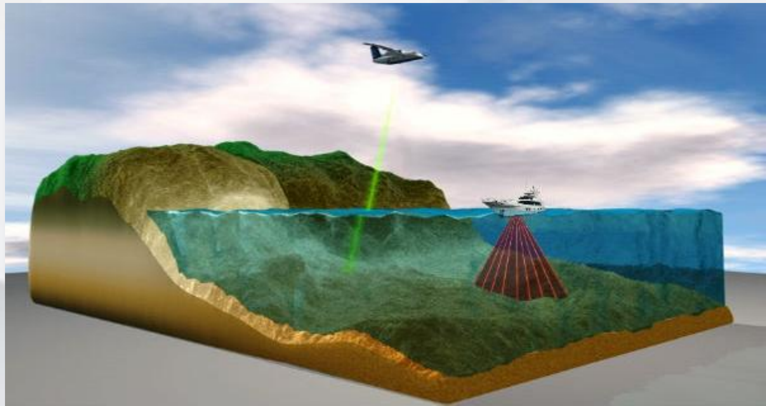
Sensor technology has advanced further with developments such as depth profilers, current profilers, bio-optical sensors, and increased data collection accuracy. However, the high cost and time-consuming nature of these traditional methods has increased the tendency towards alternative data sources in recent years; in this context, **satellite-derived bathymetry (SDB)** methods stand out as a remarkable solution.



Objective of This Study

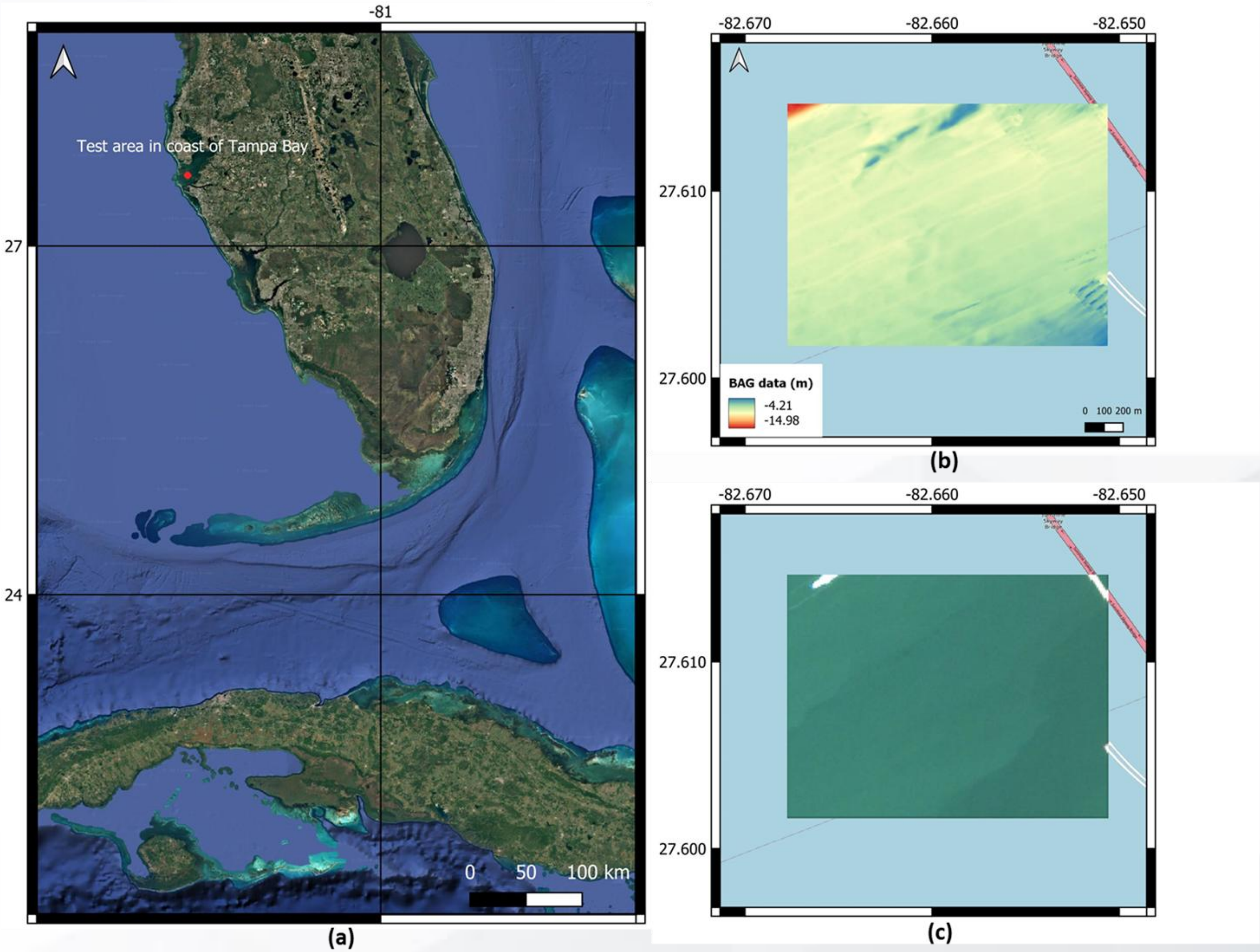
- This study evaluates the performance of Depth Anything V1 and V2 models in SDB estimation using Sentinel-2 optical imagery.

- Unlike earlier approaches that relied heavily on labeled datasets with limited scene diversity, recent models leverage large-scale, unlabeled monocular images for pretraining.

- **Depth Anything**, a foundational model trained in this context, demonstrates strong zero-shot performance across diverse scenarios.

- The improved version, **Depth Anything V2**, offers enhanced depth prediction accuracy.

- To assess their effectiveness, the predicted depth maps were compared with ground-truth bathymetric data obtained from the National Centers for Environmental Information (NCEI/NOAA).



(a)
(b)
(c)

📍 The selected study area lies off the coast of Tampa Bay, Florida (27.60°N, 82.66°W),

Workflow

Satellite Images from Sentinel-2

- Bands: 4, 3, and 2 (RGB), Spatial resolution: 10 m, Date: between January 2025 and March 2025, Cloud coverage: below approximately 10%.

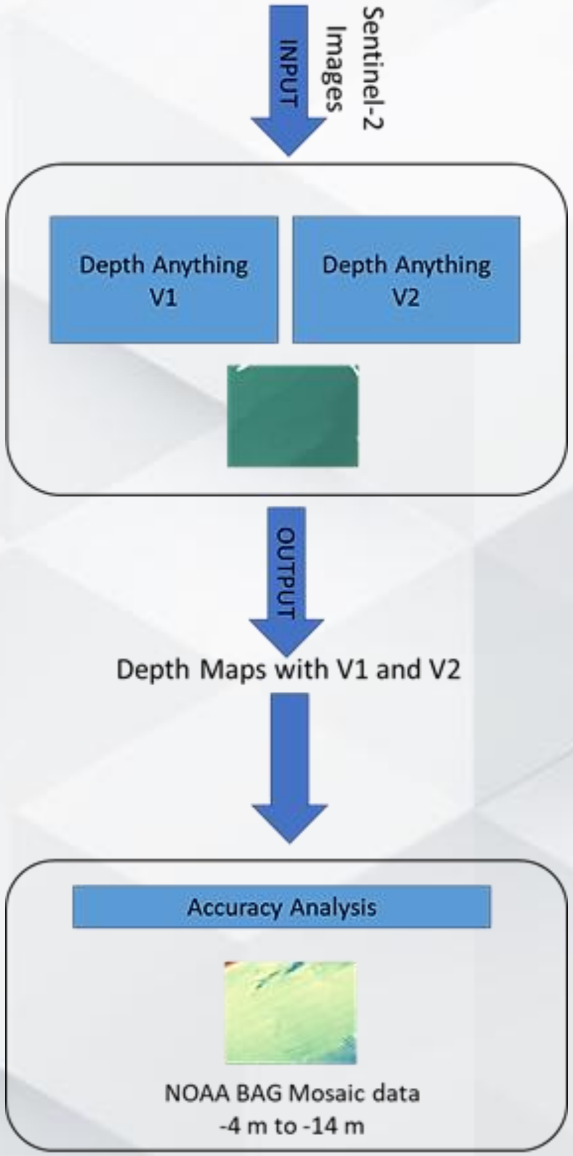
The Depth Anything V1 and V2 models

- Generated depth maps range between 0-1 normalized values.

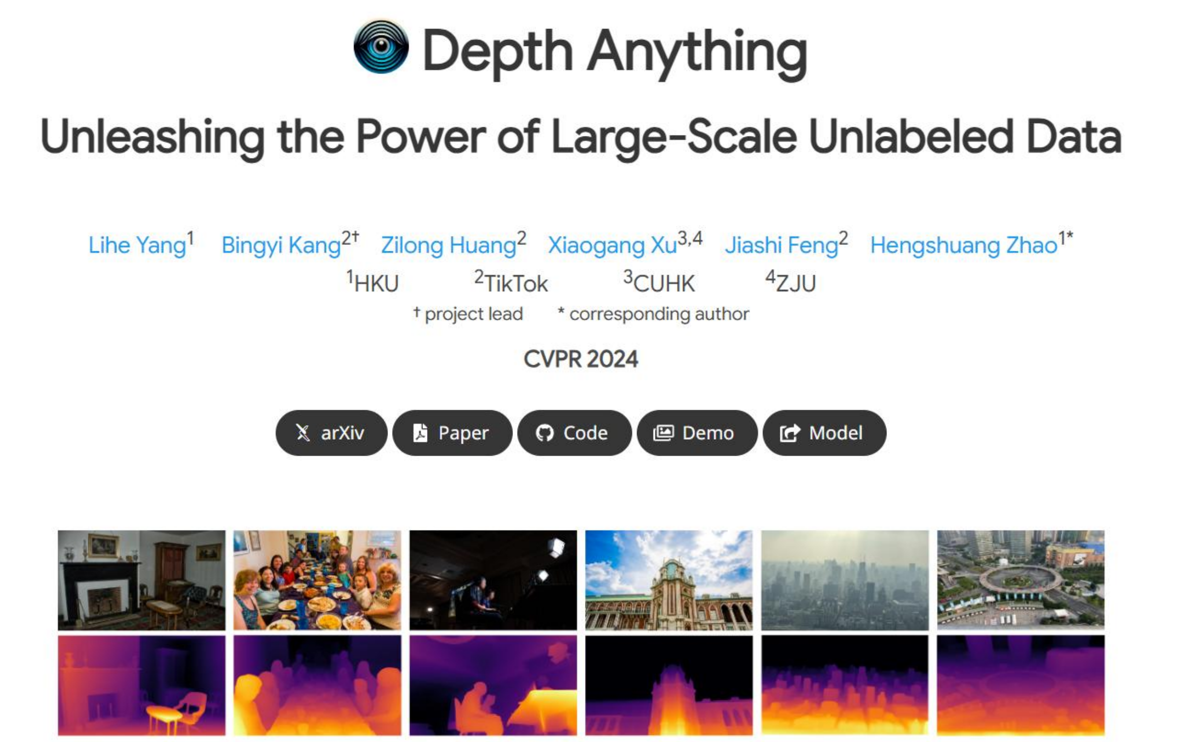
As the reference bathymetric data for validation purposes

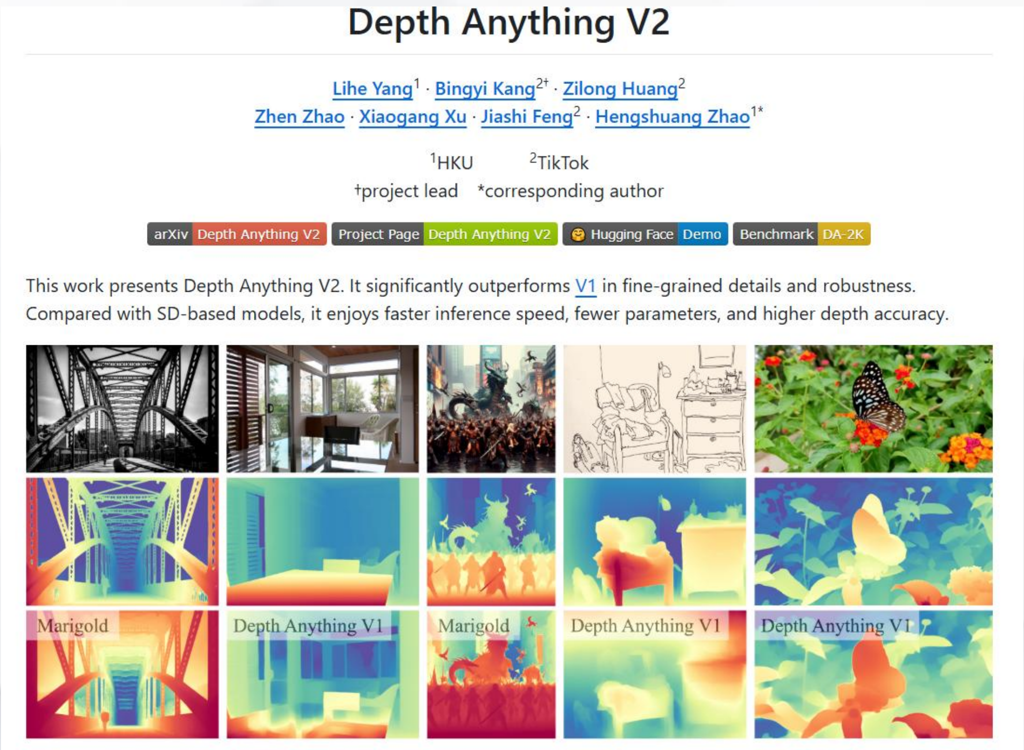
- The BAG Mosaic dataset provided by NOAA NCEI (NCEI Bathymetric Data Viewer, 2025), **approximate cell size:** 10 meters (1/3 arc-second)

The depth maps obtained from Sentinel-2 satellite images were compared with this reference bathymetry data, and their accuracy was tested.



Implementation of Depth Anything Models





Depth Anything is a transformer-based monocular depth estimation model trained on a large-scale dataset comprising 1.5 million labeled and 62 million unlabeled images.

Depth Anything V2 model:

- Over 10× faster and more efficient than diffusion-based depth models,
- Provided in multiple sizes (from 25M to 1.3B parameters) to support various application scales,
- Fine-tuned to produce highly accurate metric depth estimates, and
- Accompanied by a new benchmark dataset with diverse scenes

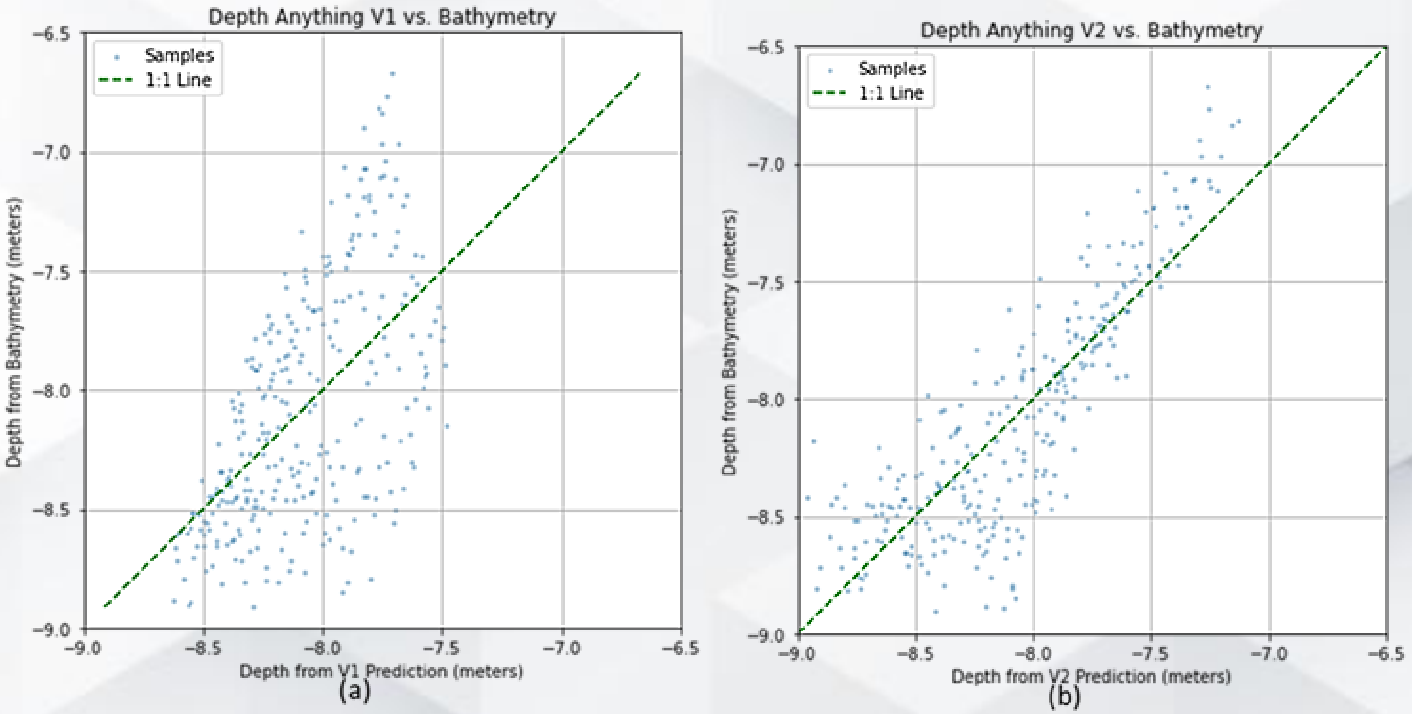
The Band Ratio Method (BRM) allows depth estimation by comparing the reflectance ratios between specific spectral bands with in-situ measurements. This method focuses on the blue and green bands, particularly by leveraging the intrinsic optical properties of water. In this context, the Z (depth) value can be calculated using a regression formula based on band ratios (Stumpf et al., 2003):

$$Z = m_1 \frac{\ln(n * \rho_w(\lambda_i))}{\ln(n * \rho_w(\lambda_j))} - m_0$$

Here,

- The coefficient m_1 is the constant used to scale the depth ratio.
- n is a value that is kept constant throughout the study area to ensure that the logarithm remains positive.
- m_0 is the depth offset representing the point $Z = 0$.
- ρ_w represents the magnitude of the radiation (reflectance value) reflected from the water surface.
- λ_i and λ_j represent two different spectral bands.

Method	R	RMSE (m)	MAE (m)
Band Ratio	38.20%	0.4639	0.3746
Depth Anything V1	56.69%	0.4135	0.3400
Depth Anything V2	84.54%	0.2681	0.2089



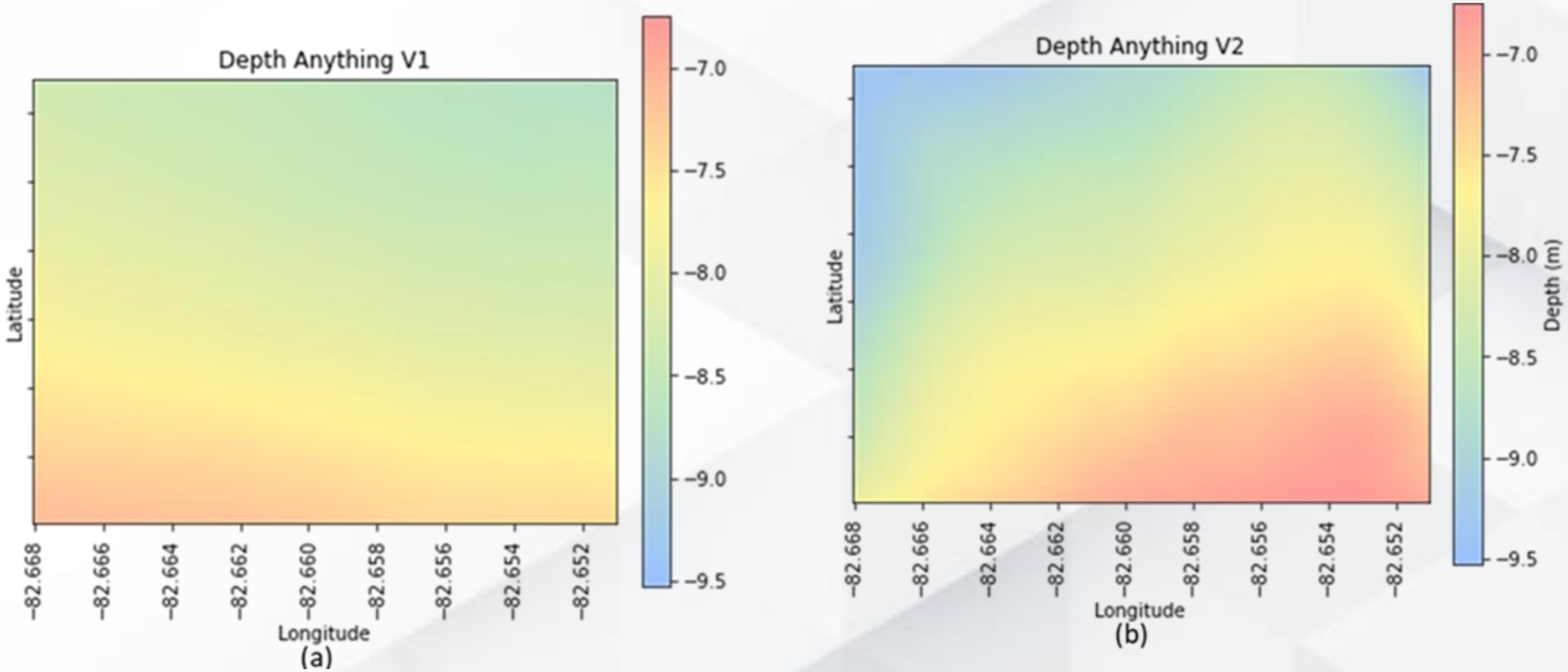


Figure: The depth maps generated with (a) Depth Anything V1 and (b) Depth Anything V2

Conclusion

- In this study, the performance of Depth Anything V1 and V2 models in the prediction of depths is evaluated using the Sentinel-2 satellite image.

- The results show that Depth Anything V1 provides 56.69% correlation with NOAA NCEI data, while Depth Anything V2 increases this value to 84.54%, demonstrating that the model provides a significant improvement in terms of correlation. In addition, the depth maps created by these models are measured with RMSE and MAE values, and are determined as 0.4135 m and 0.3400 m for V1, and 0.2681 m and 0.2089 m for V2, respectively. This improvement shows that Depth Anything V2 has further improved its ability to predict depth from monocular satellite images and offers great potential for cost-effective bathymetry mapping in remote sensing applications.

- A satellite-derived depth map was also generated using the classical band ratio method. Compared with reference bathymetric data, the correlation coefficient, RMSE, and MAE were found to be 38.20%, 0.4639 m, and 0.3746 m, respectively.

- In conclusion, this study highlights the effectiveness of deep learning-based approaches in the process of making bathymetry predictions from satellite images. The increased accuracy provided by Depth Anything V2 offers a potentially cost-effective method in areas such as underwater mapping and environmental monitoring.

- For future studies, it is recommended to further develop these models for larger geographic areas, diverse environmental conditions, and greater depth ranges in satellite-based bathymetry applications. Furthermore, this approach could potentially be used to freshwater environments like lakes and reservoirs, where bathymetric mapping is equally necessary for pollution prevention, ecosystem evaluation, and water resource management.

Thank You for Your Attention!

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