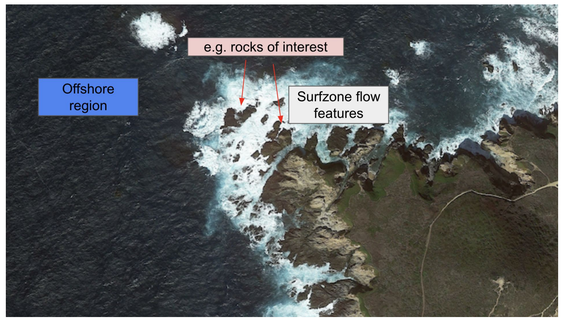
# Improving Segmentation Pipelines for Surfzone Rock Mapping

Alex Washburn, Ashton Pihl
Civil and Environmental Engineering, Stanford University

## Motivation

- Segmenting rocks in the surfzone (region of breaking waves) is important for understanding the hydrodynamics of rocky shorelines which are highly productive marine ecosystems and make up 75% of coastlines worldwide[1]
- High resolution aerial imagery exists in the public domain via Google Earth
- Accurate segmentation pipelines are needed to assess rock morphological statistics relevant to nearshore hydrodynamics



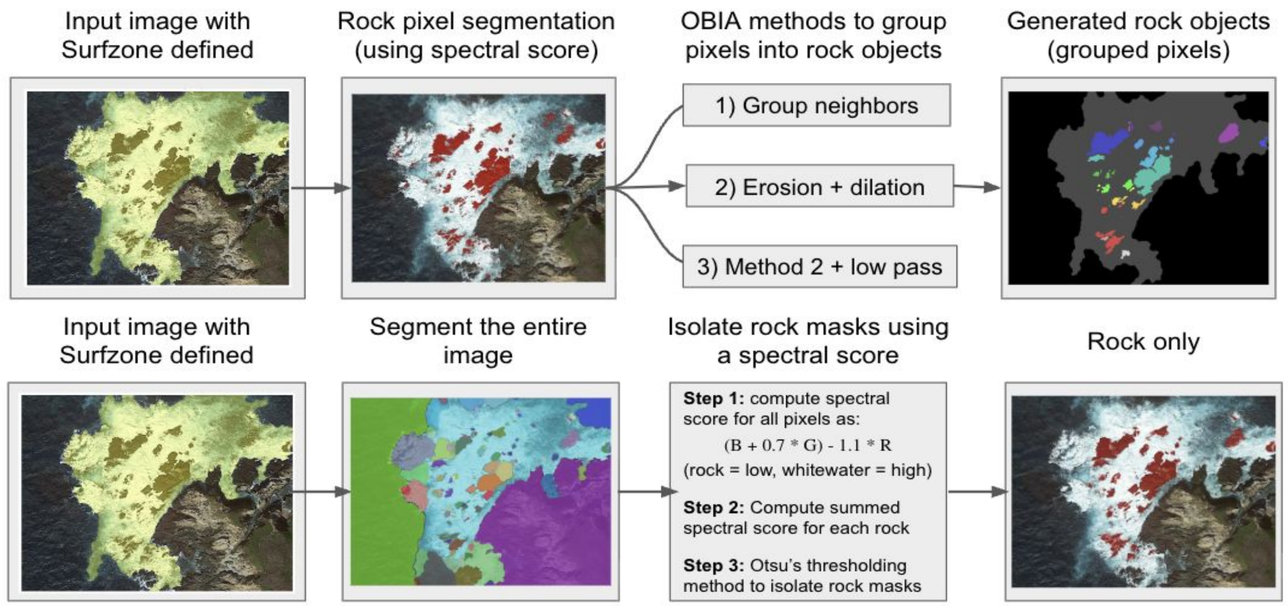

## Related Work

- Coastline segmentation pipelines exist for sandy beaches, but lack the ability to accurately segment the surfzone, rocky shorelines, or individual rocks[2]
- Object-Based Image Analysis (OBIA) groups like pixels as objects and is used in remote sensing[3]
- The Segment Anything Model is zero-shot transfer for any task though lacks the specificity to isolate rocks based on prompting[4]

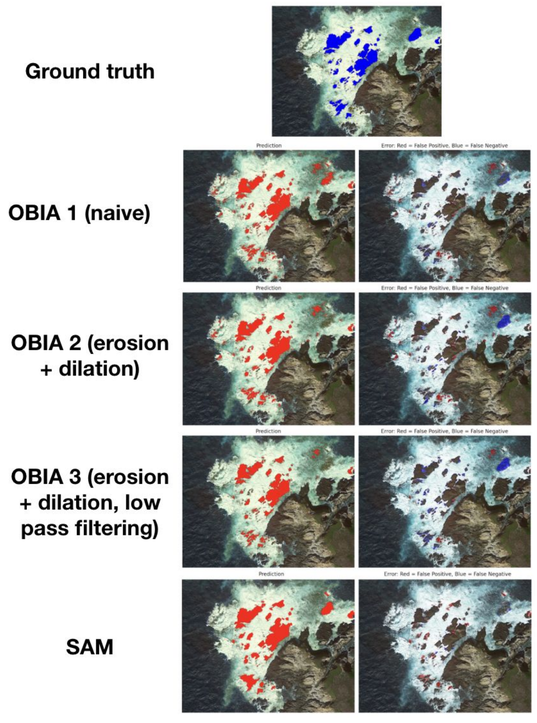
## References

[1] *MacMahan et al., Rip Currents Off Rocky-Shore Surge Channels, Journal of Geophysical Research: Oceans, 2023*
[2] *Vos et al., CoastSat: A Google Earth Engine-enabled Python toolkit to extract shorelines from publicly available satellite imagery, Environmental Modelling & Software, 2019*
[3] Hossain and Chen, *Segmentation for Object-Based Image Analysis (OBIA): A review of algorithms and challenges from remote sensing perspective, ISPRS Journal of Photogrammetry and Remote Sensing, 2019*
[4] *Kirillov et al., Segment anything, Proceedings of the IEEE/CVF international conference on computer vision, 2023*

## Pipelines




## Experimental Results

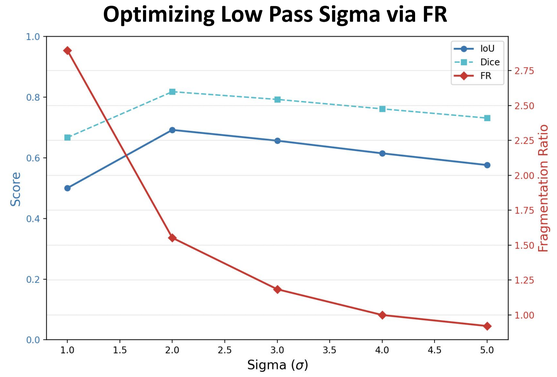



$$\mathbf{DSC} = \frac{2|P \cap G|}{|P| + |G|} \quad \mathbf{IoU} = \frac{|P \cap G|}{|P \cup G|}$$

$$\mathbf{ASD} = \frac{1}{|\partial P|} \sum_{p \in \partial P} d(p, \partial G) \quad \mathbf{FR} = \frac{N(P)}{N(G)}$$

Dice Similarity Coefficient (DSC)
Intersection over Union (IoU)
Average Surface Distance (ASD)
Fragmentation Ratio (FR)
$P$ : Set of predicted rock pixels
$G$ : Set of ground truth rock pixels
$d(p, \partial G)$ : Euclidean distance from point $p$ to the boundary of $G$
$N(\cdot)$ : Number of disjoint connected components (individual rock fragments)

| Pipeline | DSC | IoU | ASD | FR |
|---|---|---|---|---|
| OBIA 1 | 0.822 | 0.698 | 1.96 pix | 26.0 |
| OBIA 2 | 0.812 | 0.683 | 1.85 pix | 1.37 |
| OBIA 3 | 0.762 | 0.615 | 2.87 pix | 1.00 |
| SAM | 0.889 | 0.800 | 3.33 pix | 0.76 |




### Findings

- OBIA 1 (thresholding only) performs relatively well on area and spatial dilation metrics, but over-estimates rock cardinality due to whitewater intrusion
- OBIA 2 improves on cardinality while preserving area and dilation metrics
- OBIA 3 exactly produces cardinality due to optimization, but sacrifices area and dilation performance
- SAM performs the best on area metrics, but poorly on dilation and cardinality