REGION-LEVEL LABELS IN ICE CHARTS CAN PRODUCE PIXEL-LEVEL SEGMENTATION FOR SEA ICE TYPES

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Introduction

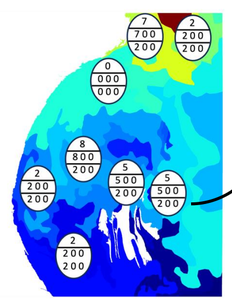
- Ice charts are crucial for Arctic ship navigation and climate research
- Ice analyst produces ice charts manually on a weekly basis
- They represent approximate ice concentration and types in polygonal regions
- Lack pixel-level annotations
- Auto ice competition [1] provides pseudo pixel level ground truth generated from Ice-charts and uses only dominant polygons (partial concentration > 65 %) to generate pixel-level labels

Can we design a learning scheme that directly learns from region-level labels (egg codes) to produce pixel level Ice types?

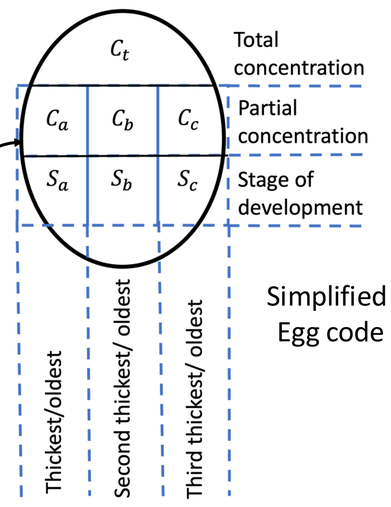
- Yes, we design a novel loss function to produce pixel level ice type (Stage of development) from polygon level labels
- The proposed scheme produces high resolution segmentations compared to benchmark model [2] (top solution of AutoIce competition) which is trained on pseudo pixel level ground truth

SAR imagery in HH channel

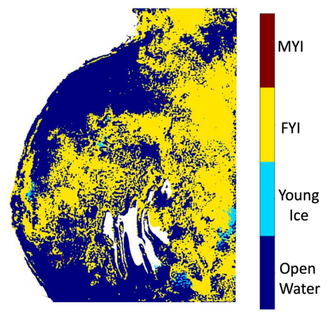
SAR imagery in HV channel



Manual ice charts



Pseudo pixel wise Ground-truth



Predicted pixel-wise Ice types

Entry number	Class representation	Description
0	Open water	Ice free regions identified in ice charts
1	Young ice	Ice with thickness no more than 30 cm
2	First year ice (FYI)	Ice of no more than one year's growth developing from young ice with thickness larger than 30 cm
3	Multiyear ice (MYI)	Ice survived at least one melt season

Label description

Method

Dataset

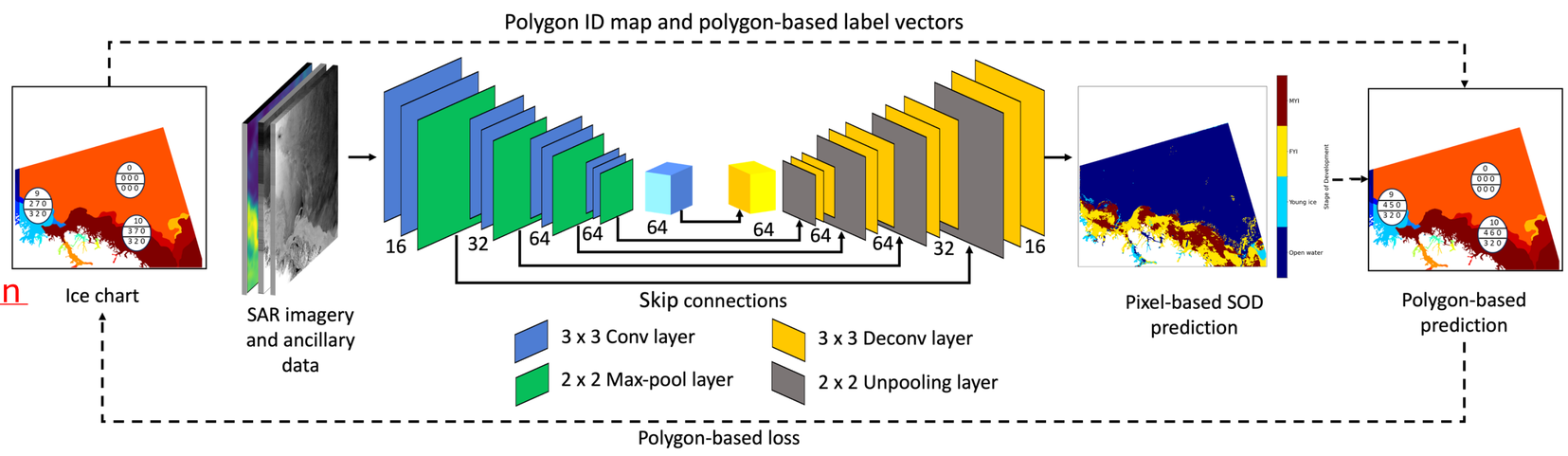
- We use AI4artic dataset and follow the same train-test split in the competition
- The input to the U-Net model is SAR images + Passive microwave + Spatial (lat, long) + Temporal Channels (month)

Designing differentiable loss function

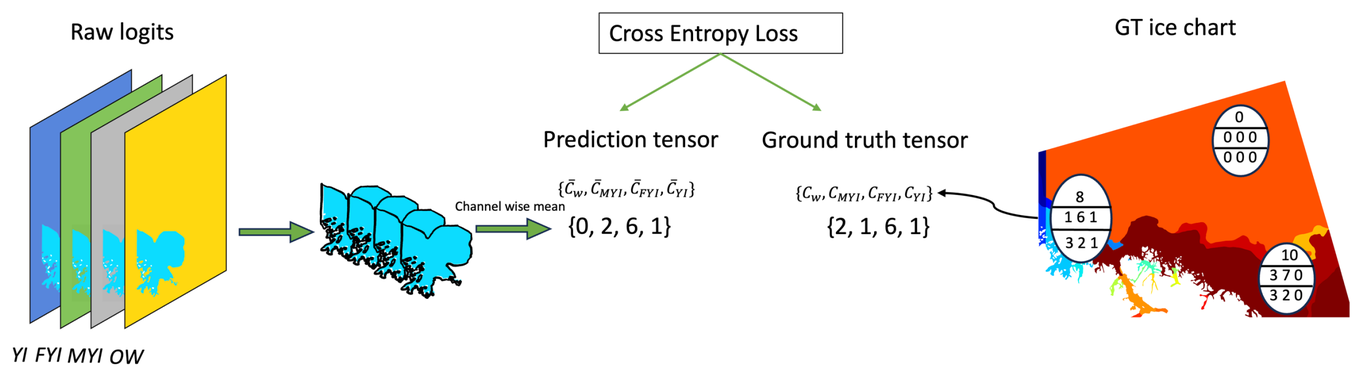
- U-Net produced raw logits can be passed through argmax to produce pixel-level ice types
- One can then count number of pixels belonging to each class to produce partial concentration of each ice-types in a polygon
- However, argmax and count operation are non-differentiable
- We introduce a differentiable approximate function for counting each ice type and obtain partial concentration

$$Y_i = \frac{1}{N_{pixel}} \sum_{j=1}^{N_{pixel}} y_i^j, \quad i = 1, \dots, 4$$

Overall learning Scheme



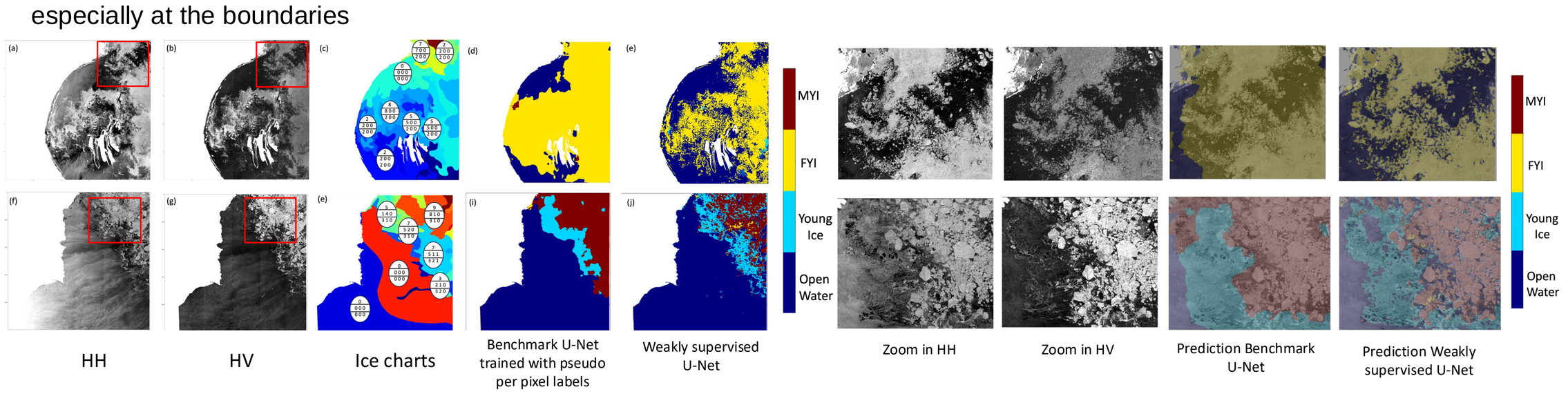
Differentiable loss function



Result

- Due to absence of pixel level ground-truth, we calculate R2 score between predicted and GT partial concentration at a polygon level
- The proposed methods outperforms the benchmark U-Net for all classes and produces high-resolution prediction especially at the boundaries

Models	Cross Validation				Test set			
	Open Water	Young Ice	First year ice	Multiyear ice	Open water	Young ice	First year ice	Multiyear ice
Benchmark U-Net trained with Psuedo per pixel labels [2]	93.95%	57.57%	75.54%	80.78%	91.37%	41.22%	75.52%	83.61%
Weakly supervised U-Net	97.45% **(+4.oo)**	68.16% **(+10.59)**	85.23% **(+9.69)**	95.73% **(+8.17)**	95.73% **(+4.36)**	58.83% **(+17.61)**	**83.09%** **(7.57)**	**86.04%** **(2.43)**



[1] Saldo, Roberto, et al. "AI4Arctic/ASIP Sea Ice Dataset-version 2." *AI4Arctic_ASIP_Sea_Ice_Dataset_-_version_2/13011134* (2020)
[2] Chen, Xinwei, et al. "MMSeaIce: a collection of techniques for improving sea ice mapping with a multi-task model." *The Cryosphere* 18.4 (2024): 1621-1632