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Iceberg detection with SAR using the YOLO v8 deep learning model

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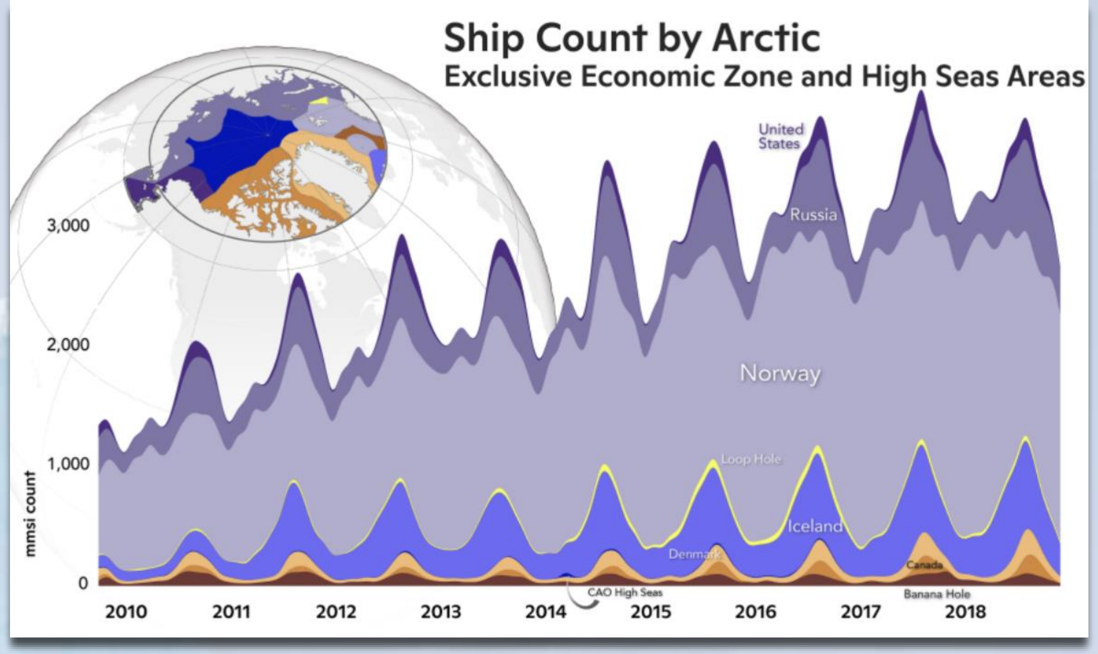
Context:

- By lowering the quantity of ice present, climate change is enabling increased Arctic shipping.
- Iceberg collisions cause extensive repair costs, environmental crises from spillages and/or even loss of life.
- 2-3 iceberg-ship incidents a year in the Northern Hemisphere, despite the modern radar technology on board ships.
- A new approach to detection is considered that utilises a state-of-the-art deep learning model.

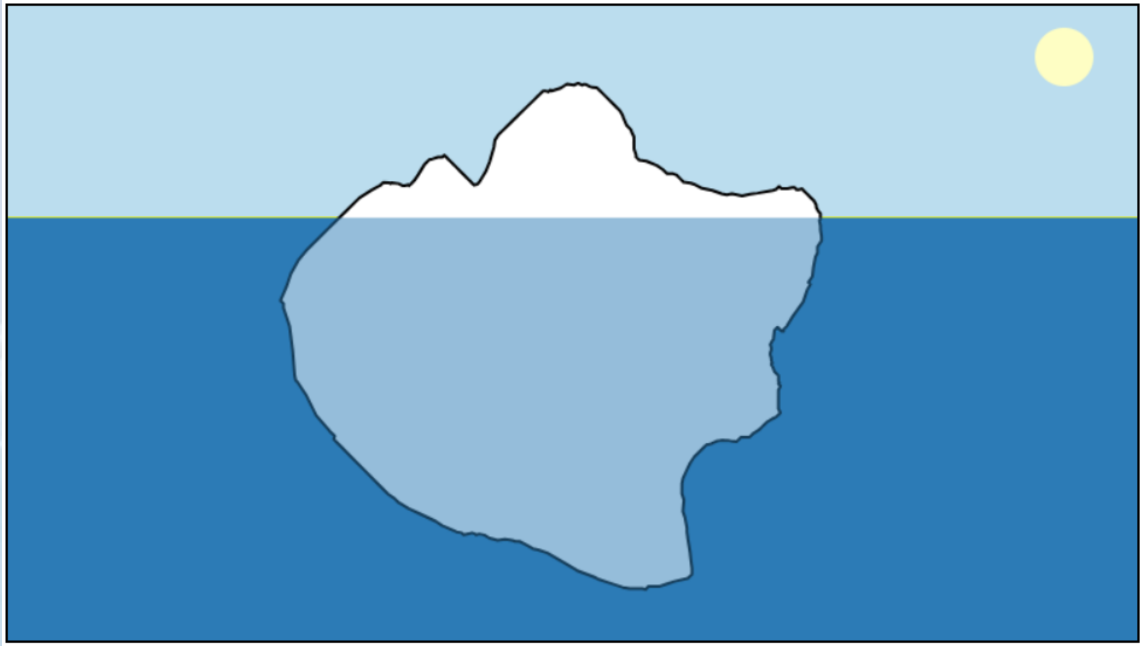


Sinking of MS Explorer, 2007

Icebergs are **hazards** to ocean activities. They are essential to monitor.

An introduction to icebergs:

- Icebergs are pieces of freshwater ice broken from a glacier tongue or an ice shelf.
- They can drift into open water, or become embedded within sea ice floes.
- They are classified by both size, and by shape, although this is based on in-situ observations.
- Iceberg detection is an important field, with importance raised due to Titanic.
- Only about 11% of an iceberg is visible above the ocean surface.



Iceberg physics can be fun!

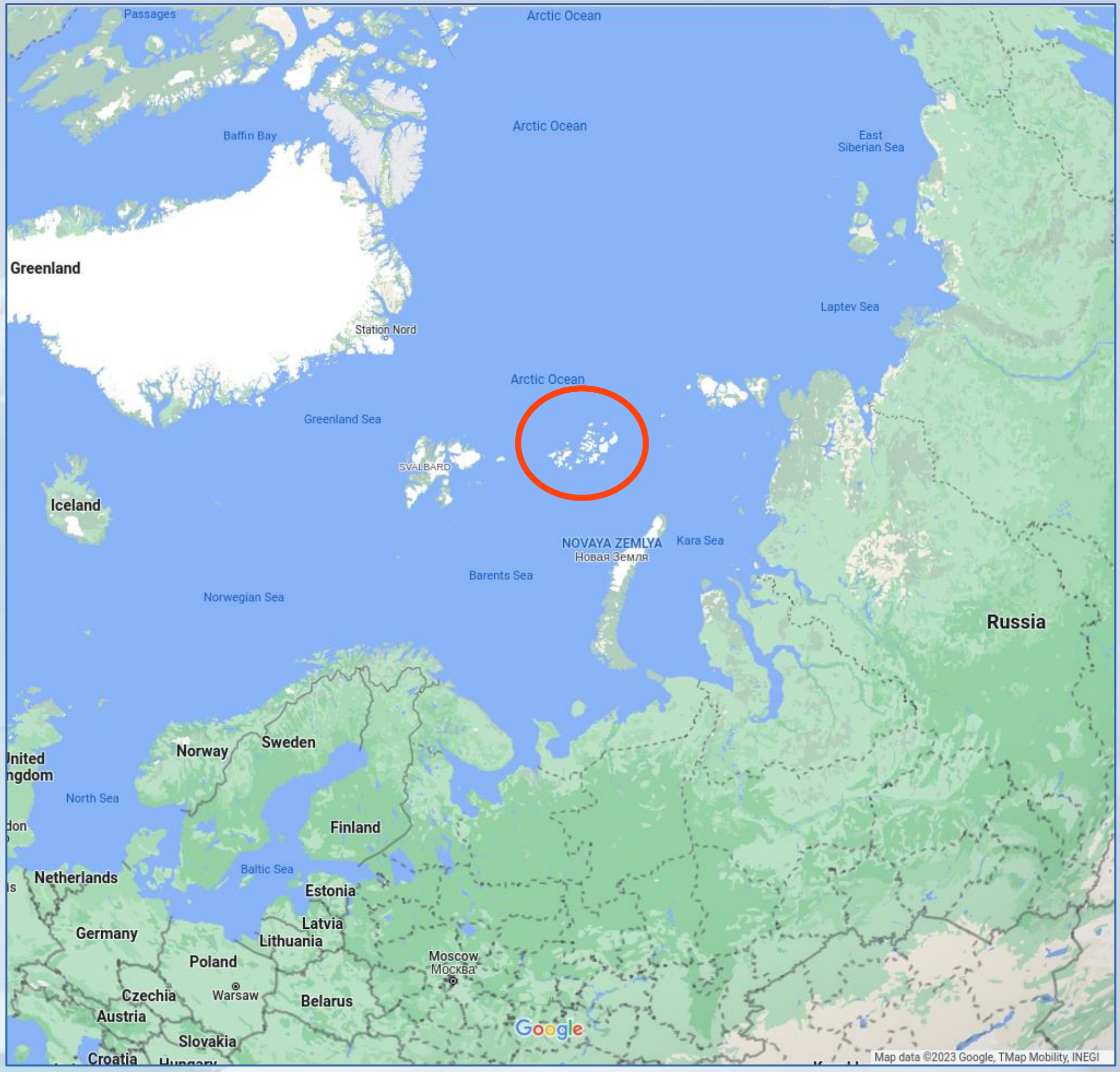
Icebergs can topple over as well as drift. Tracking and monitoring is essential.

Joshdata.me/iceberger.html

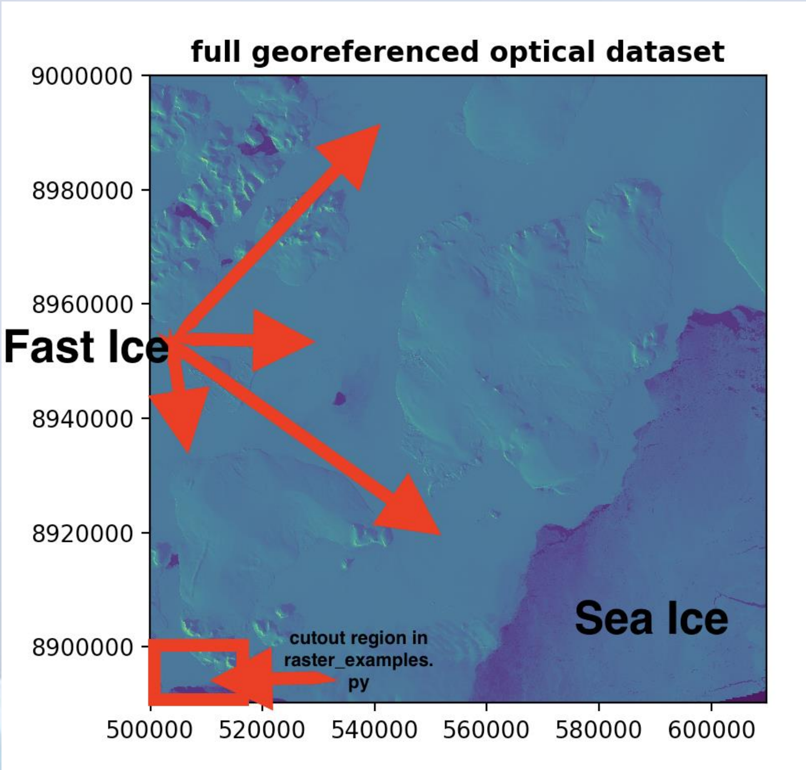
Aside:

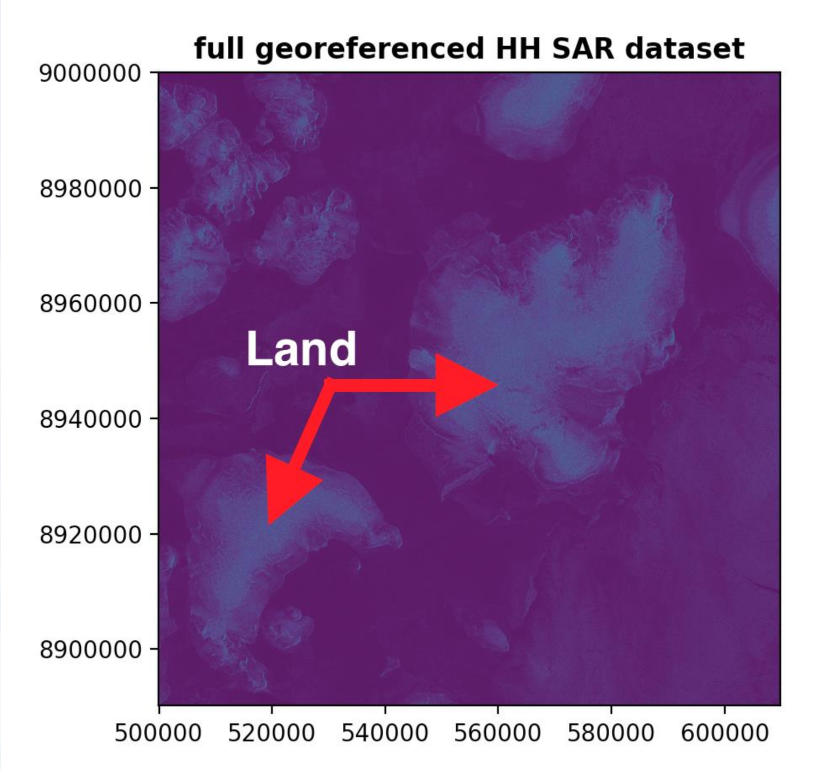
- This idea came from wanting to apply a machine learning algorithm we had developed for astrophysics to problems here on Earth.
- We were using it to find the most massive objects in the Universe: Galaxy Clusters.

Franz Josef Land (FJL) in the Arctic:

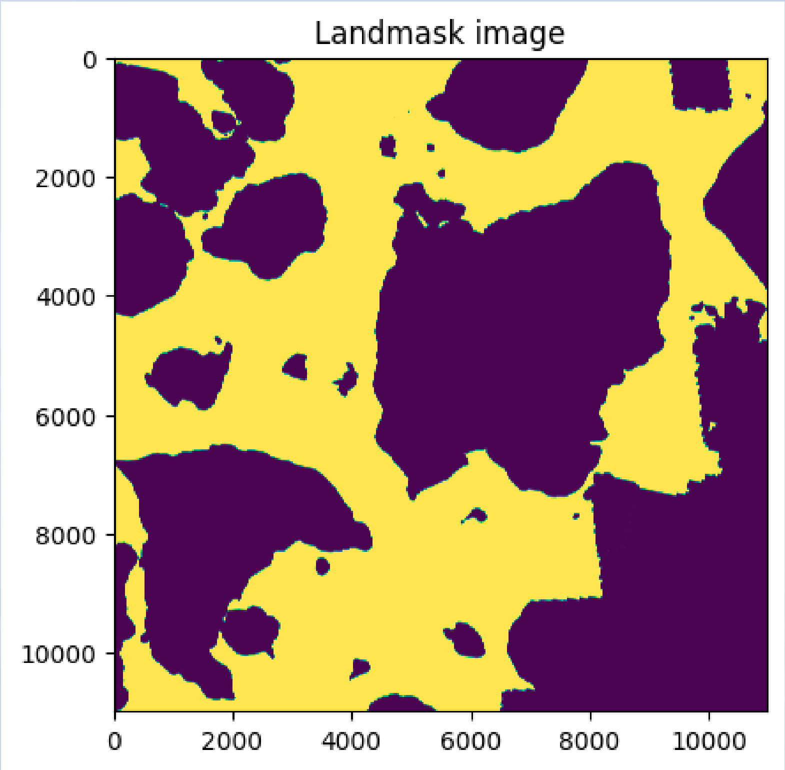


Fast ice, sea ice and land in FJL:





Synthetic-aperture radar (SAR) and optical image data from European Space Agency (ESA) Sentinel 1 & 2 satellites (~100km on the side)



Landmask image data from the Polar Geospatial Center

Problem:

We cannot easily separate icebergs from sea ice, due to similar SAR signatures.

We need an algorithm of some sort to discriminate such a target.

Solution:

The dual polarisation intensity ratio anomaly detector:

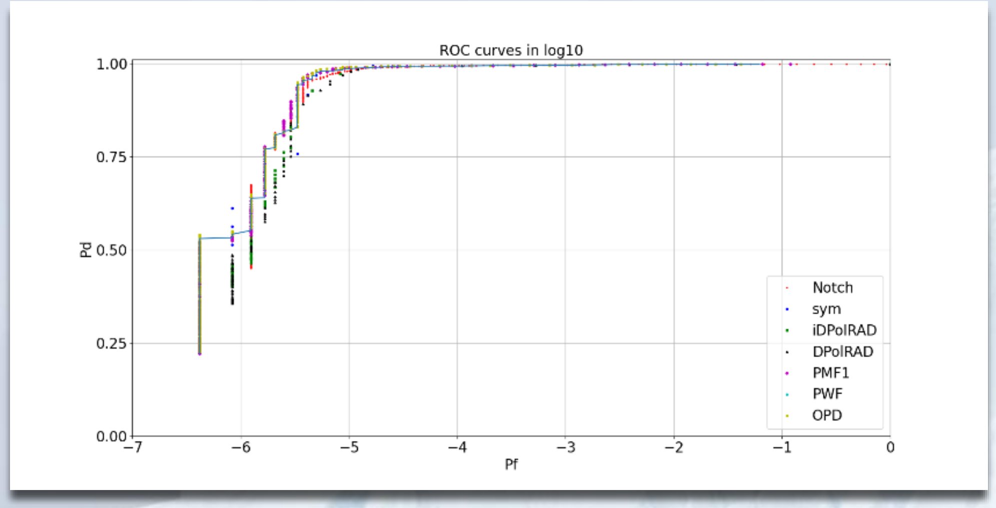
$$I = \frac{\langle |VH|^2 \rangle_{test} - \langle |VH|^2 \rangle_{train}}{\langle |VV|^2 \rangle_{train}} \sigma^0{}_{HV} = \Lambda \sigma^0{}_{HV} > T_{\Lambda}$$

We can utilise the cross polarised SAR image for stronger iceberg backscatter.

But after we have the final image, we need a way to quantify the performance.

We could:

Use ROC curves, with or without a Constant False Alarm Rate (CFAR) method to find the most optimal performance.



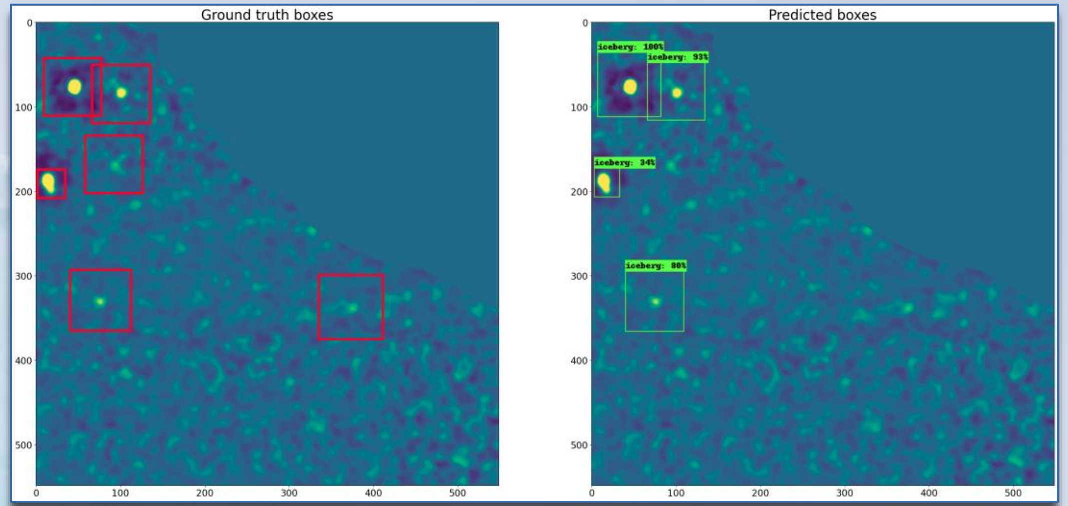
But:

CFAR requires a probability density function (pdf) representing the single intensity.

For real world detection, ideally we want a more automated process with lots of data.

This is where deep learning comes in:

Computer vision can be used to identify icebergs. This would involve training a model to draw bounding boxes around icebergs.

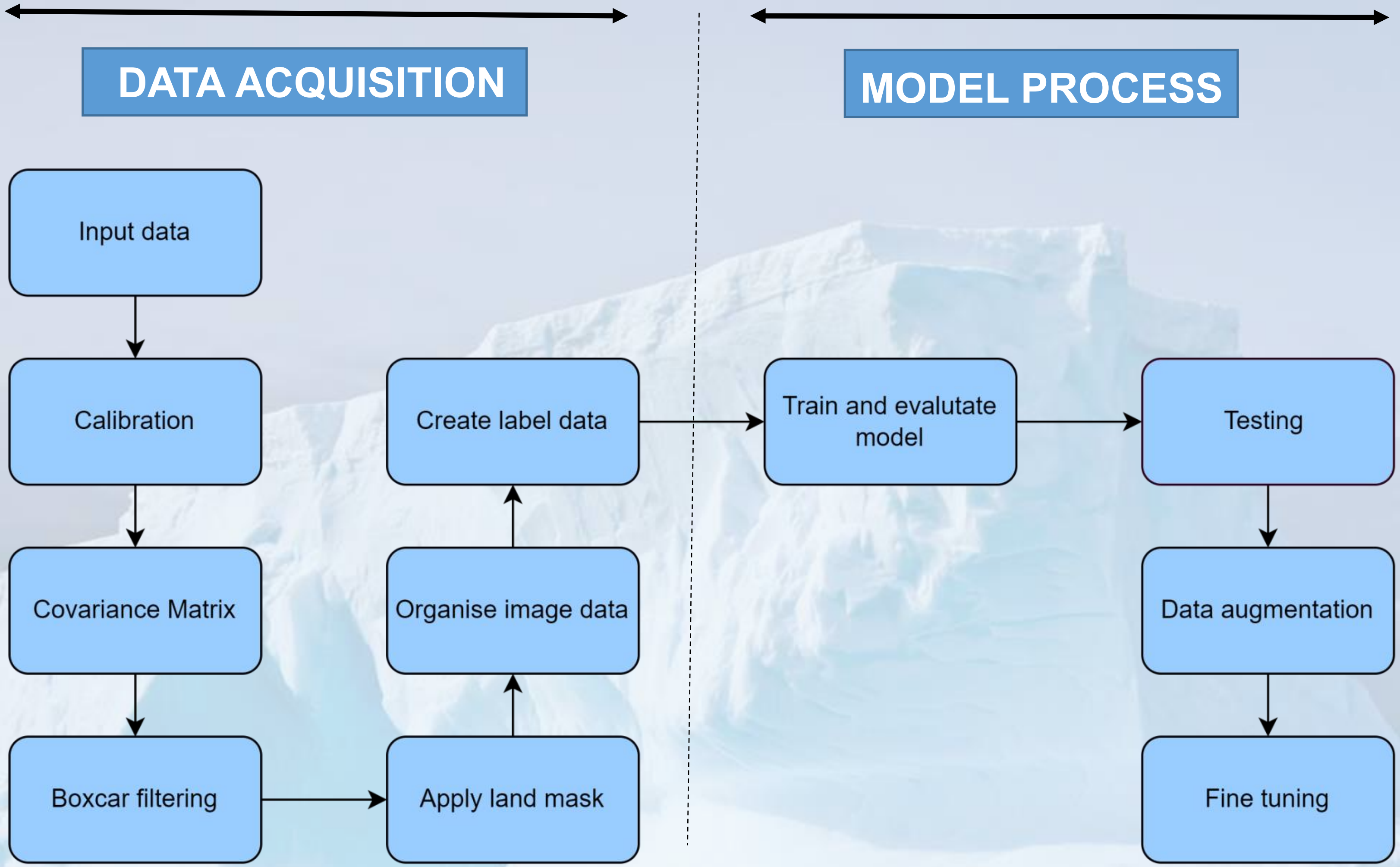


Past work:

Faster RCNN model was used to perform object detection in land-masked Sentinel-1 images of icebergs in Franz-Josef Land.

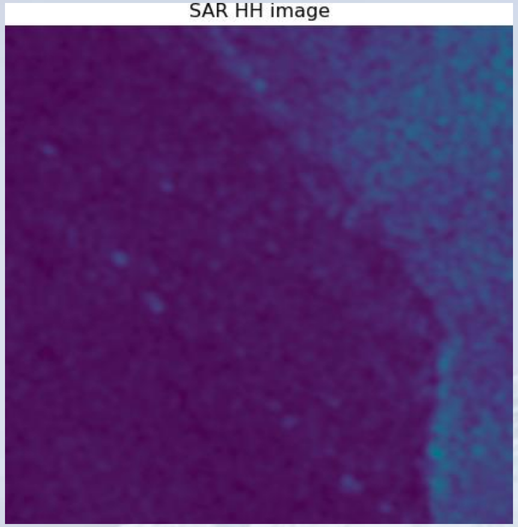
My project has expanded upon this using YOLO v8.

Methodology of current work:



- The previous model only used 104 images each with icebergs.
- This work has utilised data augmentation to produce more data for the model.
- The next step is tweaking the hyperparameters and then evaluating the subsequent performance.
- This required multiple trainings and tests.

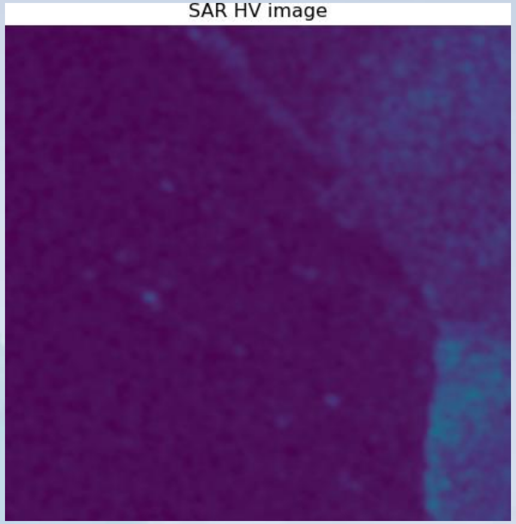
Image data processing:



1

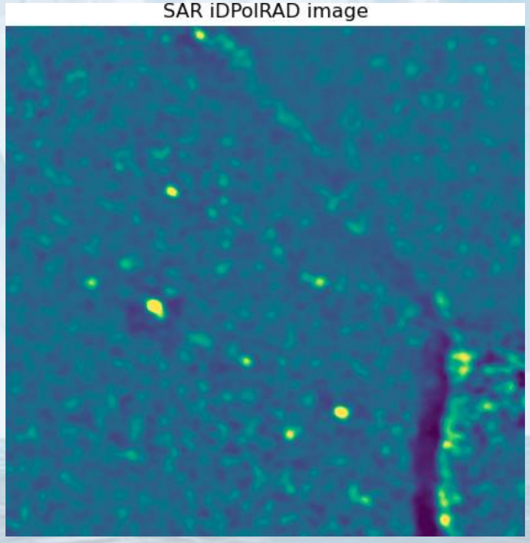
$$\frac{<|HV|^2>_{test} - <|HV|^2>_{train}}{<|HH|^2>_{train}}$$

From Marino et al. 2016 and Soldal et al. 2019

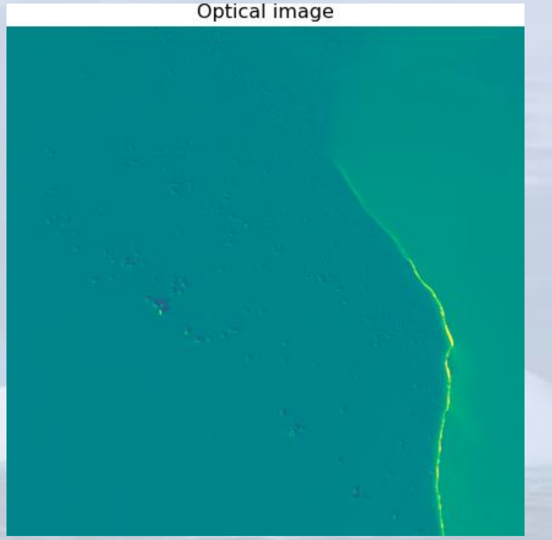


- 1) SAR HH means that a **horizontal** polarised radar wave is sent out and then a **horizontal** polarized radar wave is received back. SAR HV means that a **horizontal** polarised radar wave is sent out and then a **vertical** polarized radar wave is received back.

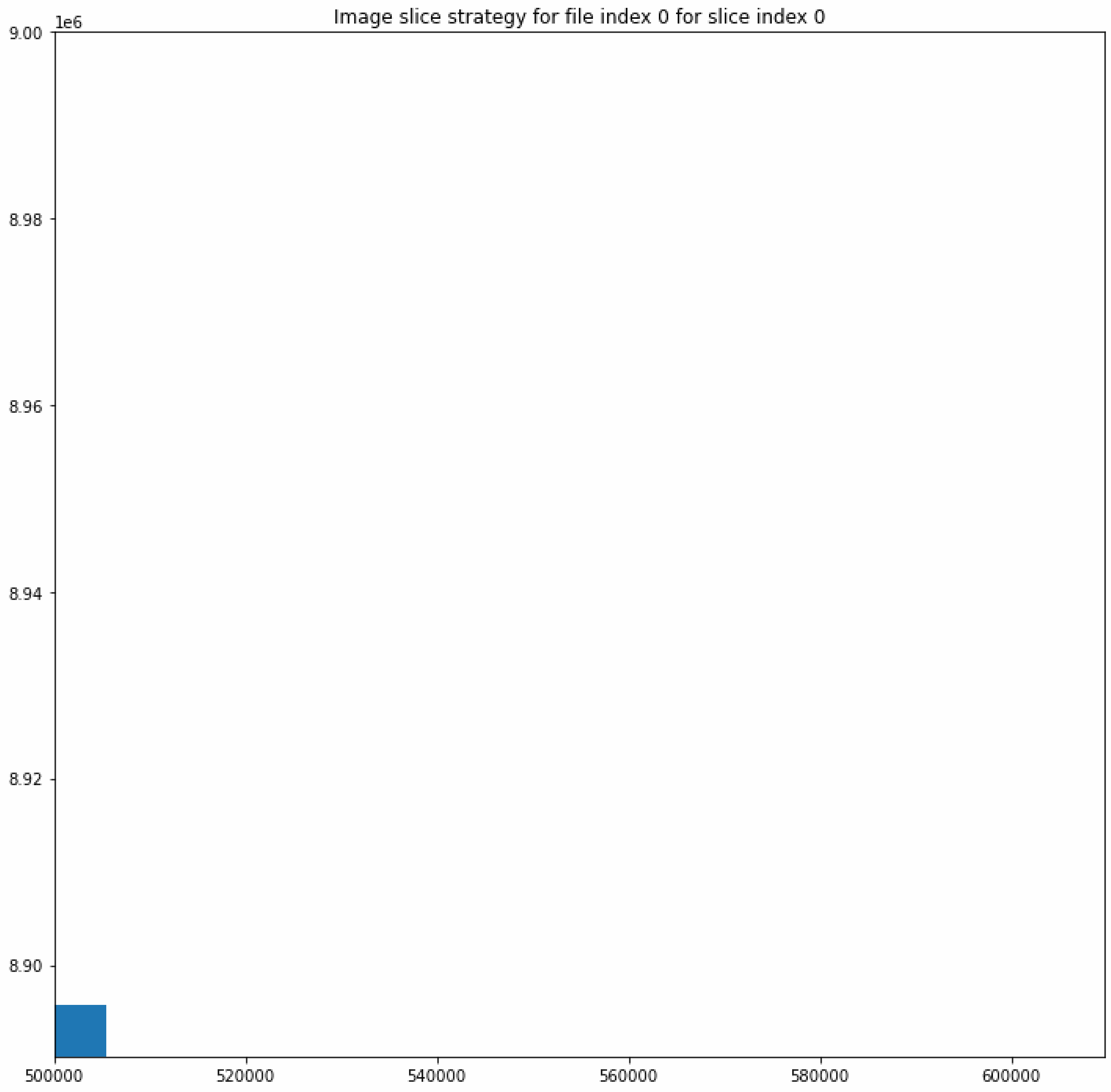
2



3



- 2) The SAR HH and SAR HV images can be combined to form SAR **intensity Dual-Polarization Ratio Anomaly Detector** (iDPolRAD) images.
- 3) This technique enhances icebergs relative to the background (e.g. fast ice, sea ice, open water) in the SAR iDPolRAD images.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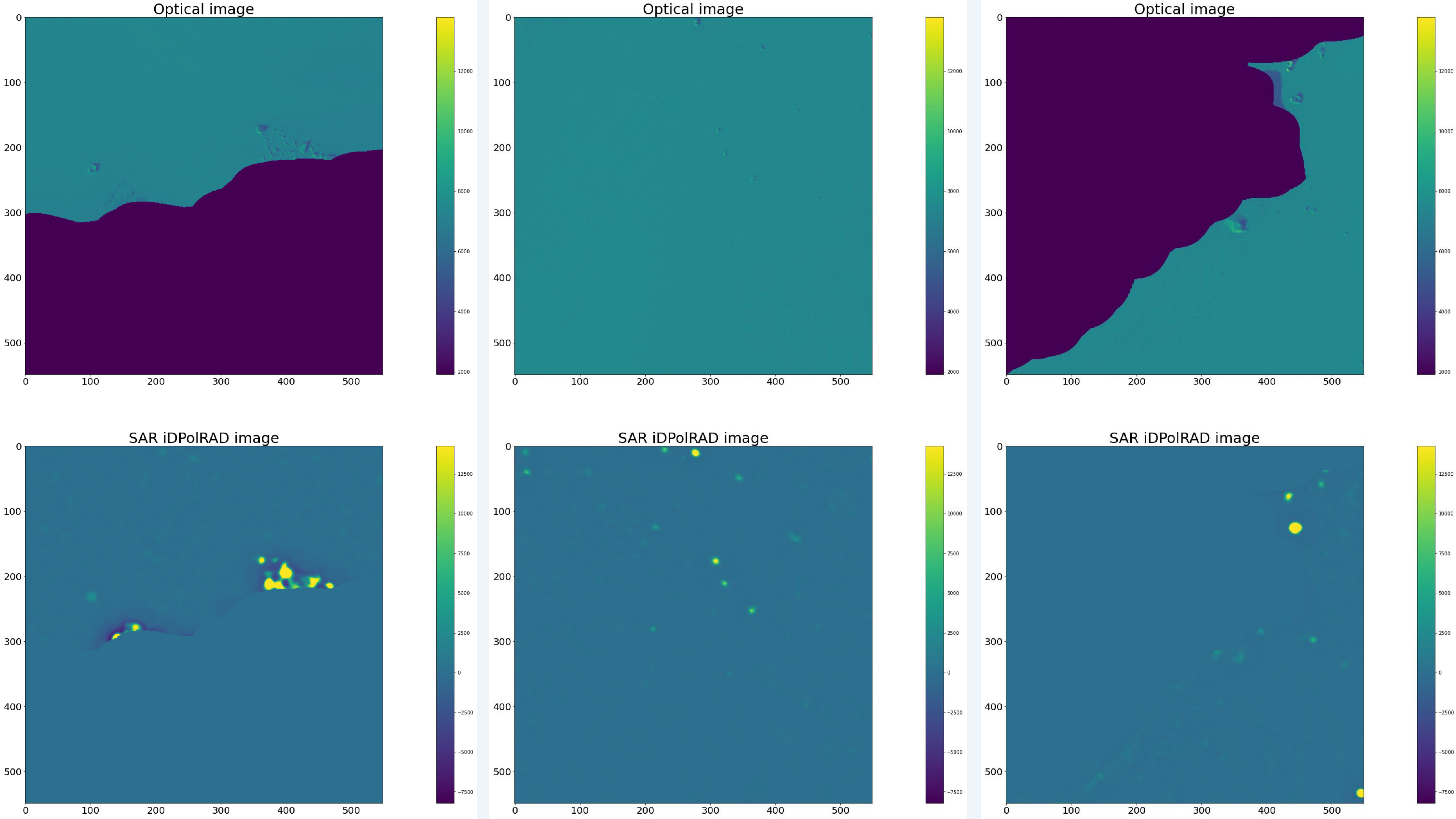

Optical image
Optical image
Optical image
SAR iDPolRAD image
SAR iDPolRAD image
SAR iDPolRAD image
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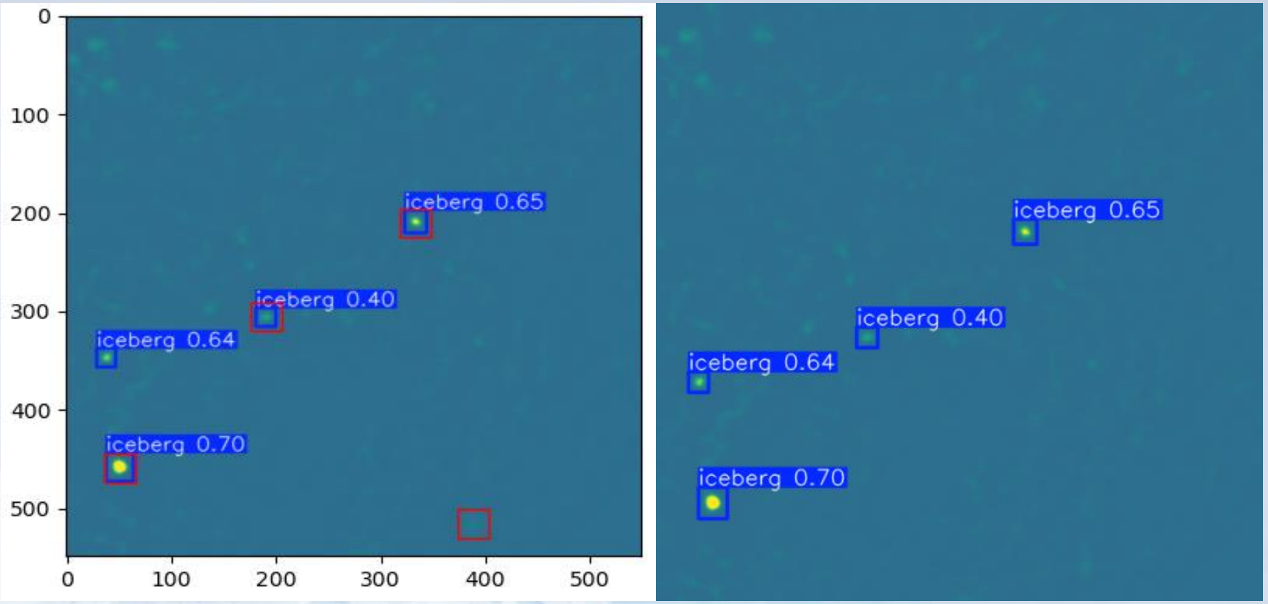
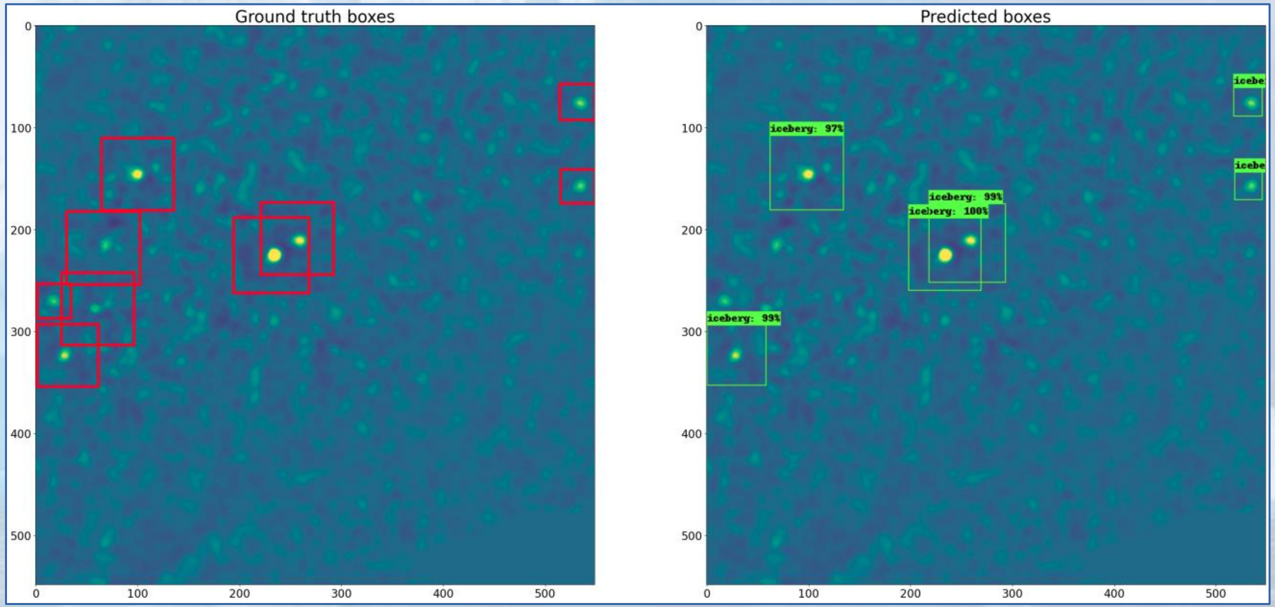
Example of predictions made by the models during testing:



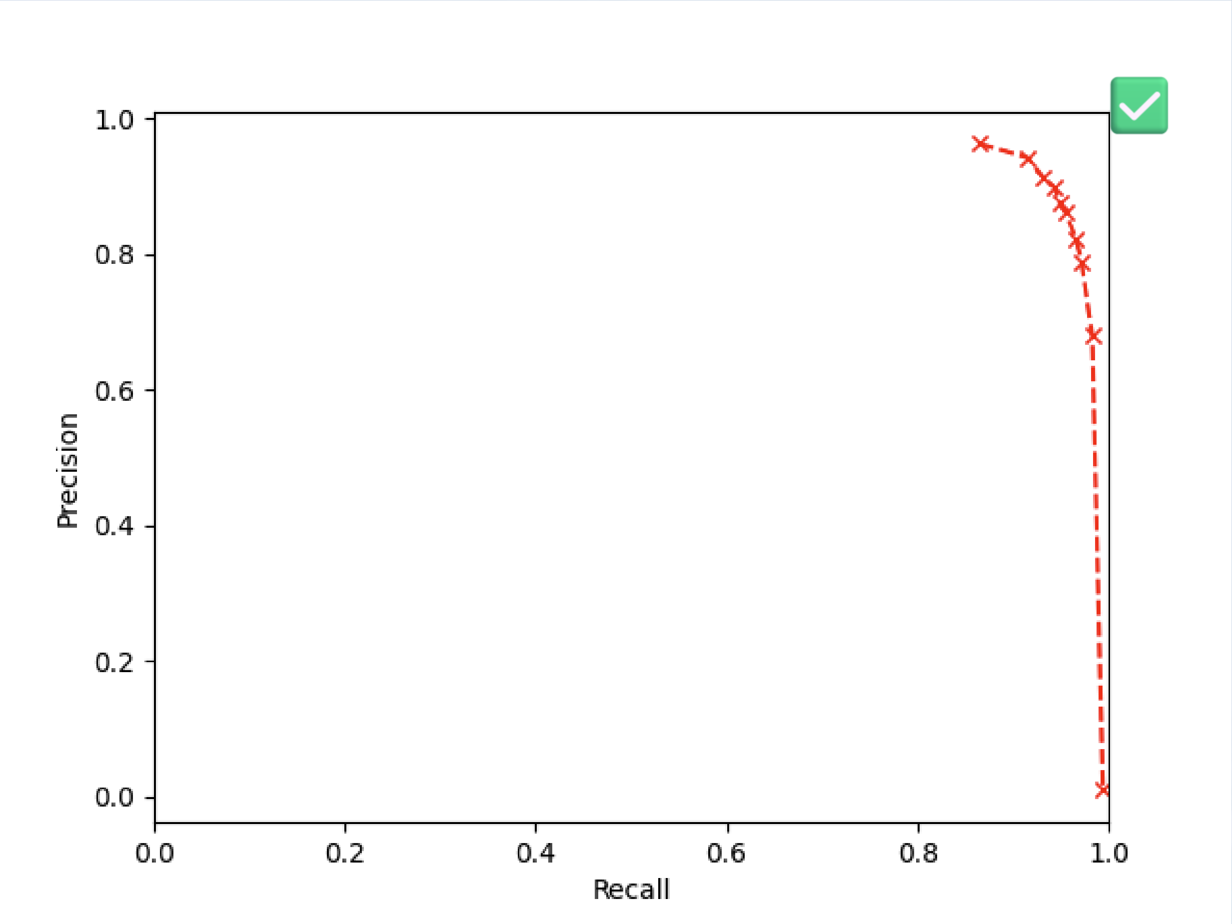


Performance:

$$Precision = \frac{TP}{TP + FP}$$

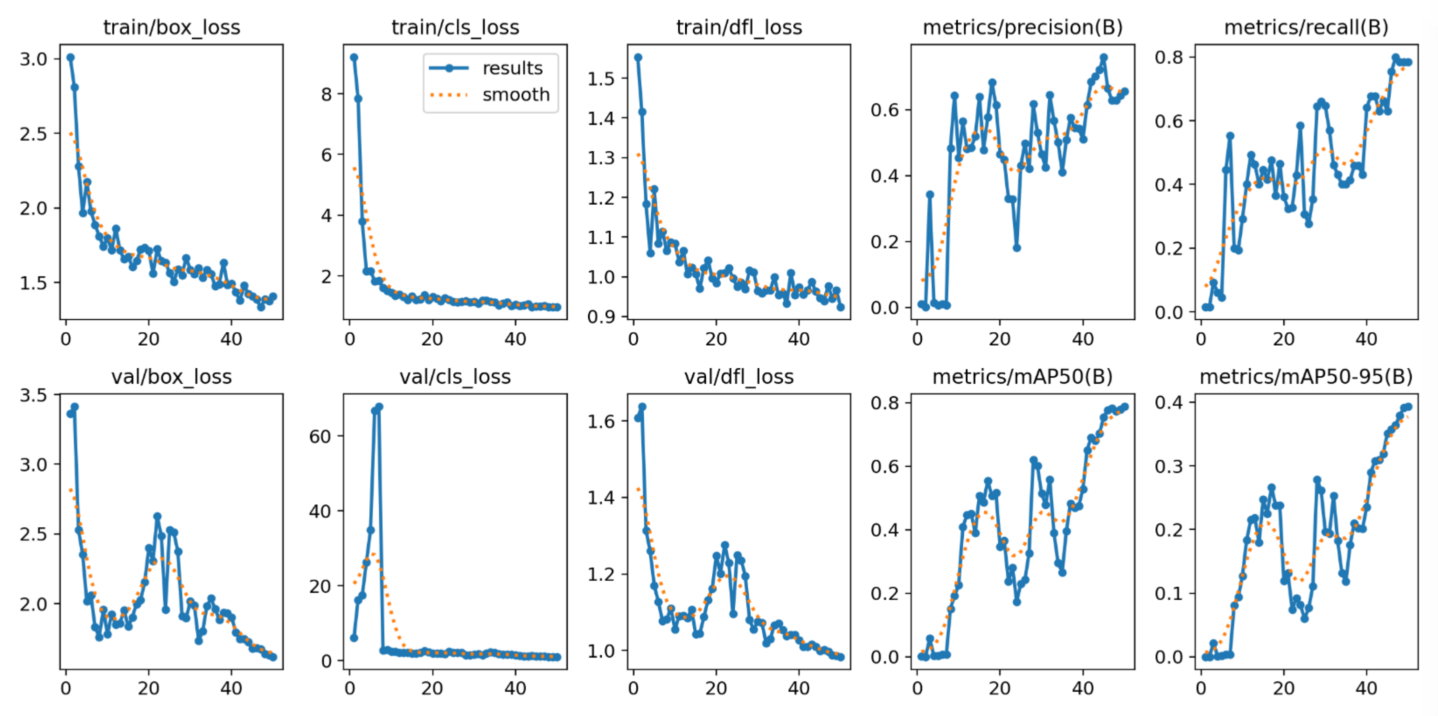
$$Recall = \frac{TP}{TP + FN}$$

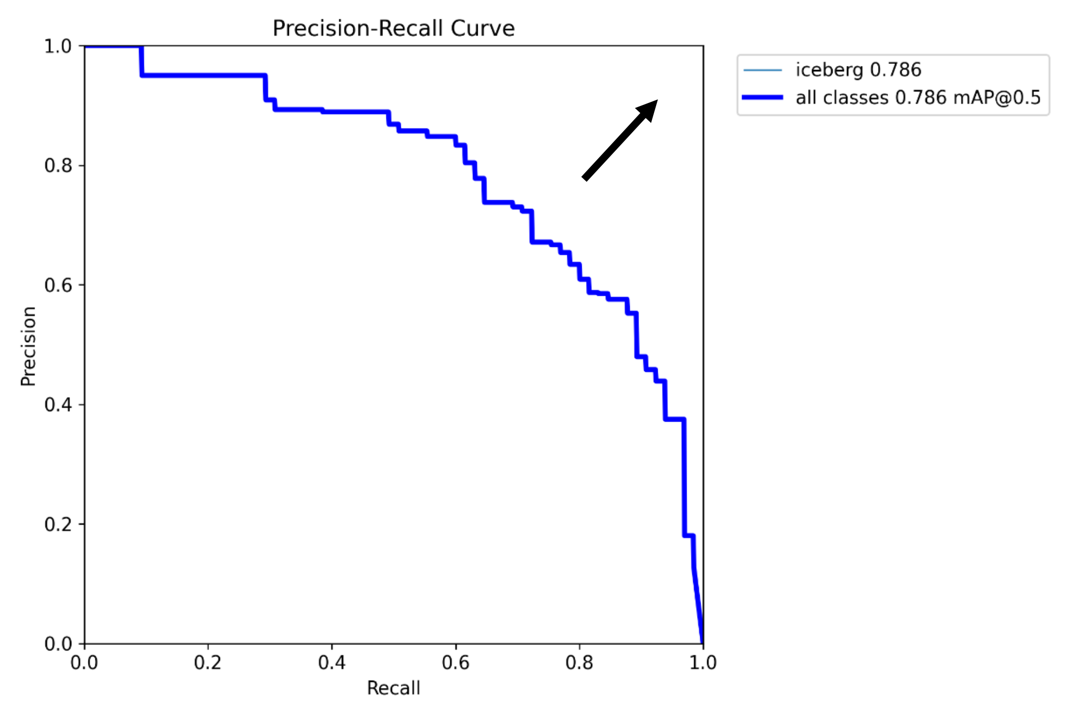
$$F1 - score = 2 \times \frac{Precision \times Recall}{Precision + Recall}$$



- Precision recall and F1 score, each point on graph represents a threshold of confidence in objects being icebergs.

Initial results of YOLO v8 model:





- Initial results suggest no overfitting.
- Model was trained for 50 epochs.
- A precision of ~0.8 with a Recall of ~0.8.
- Aim is to find the highest Precision and Recall (top right corner).

Conclusions:

- Given increased shipping near the poles and the increased presence of icebergs, there is a need for additional safety features.
- Our A.I. powered system appears to work well.
- Next step is to further develop the system in terms of speed and generality.
- Ultimate goal is to test it in a live situation – currently in conversations about this.