

DTU



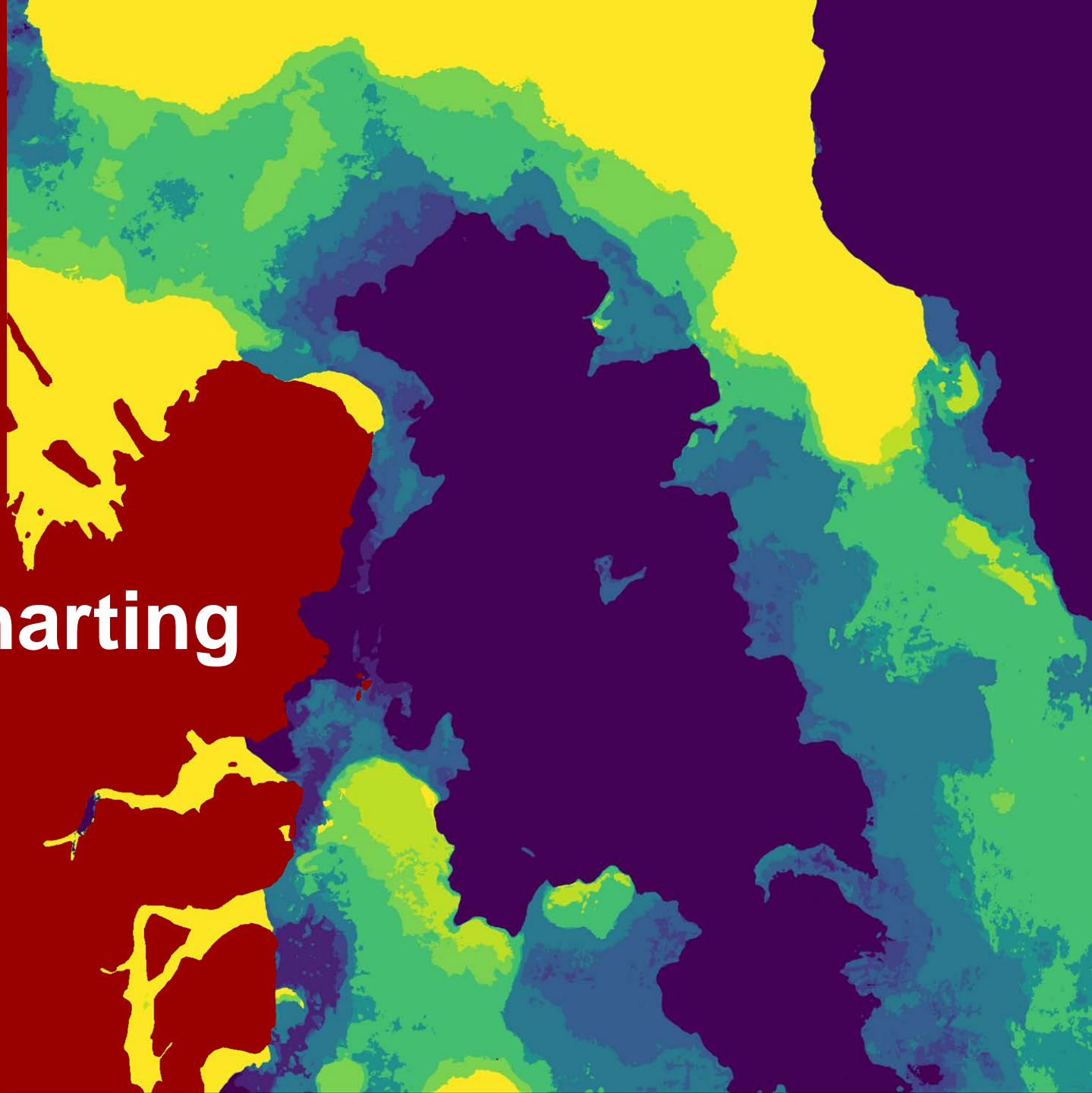


Automatic Sea Ice Charting with Sentinel-1 SAR

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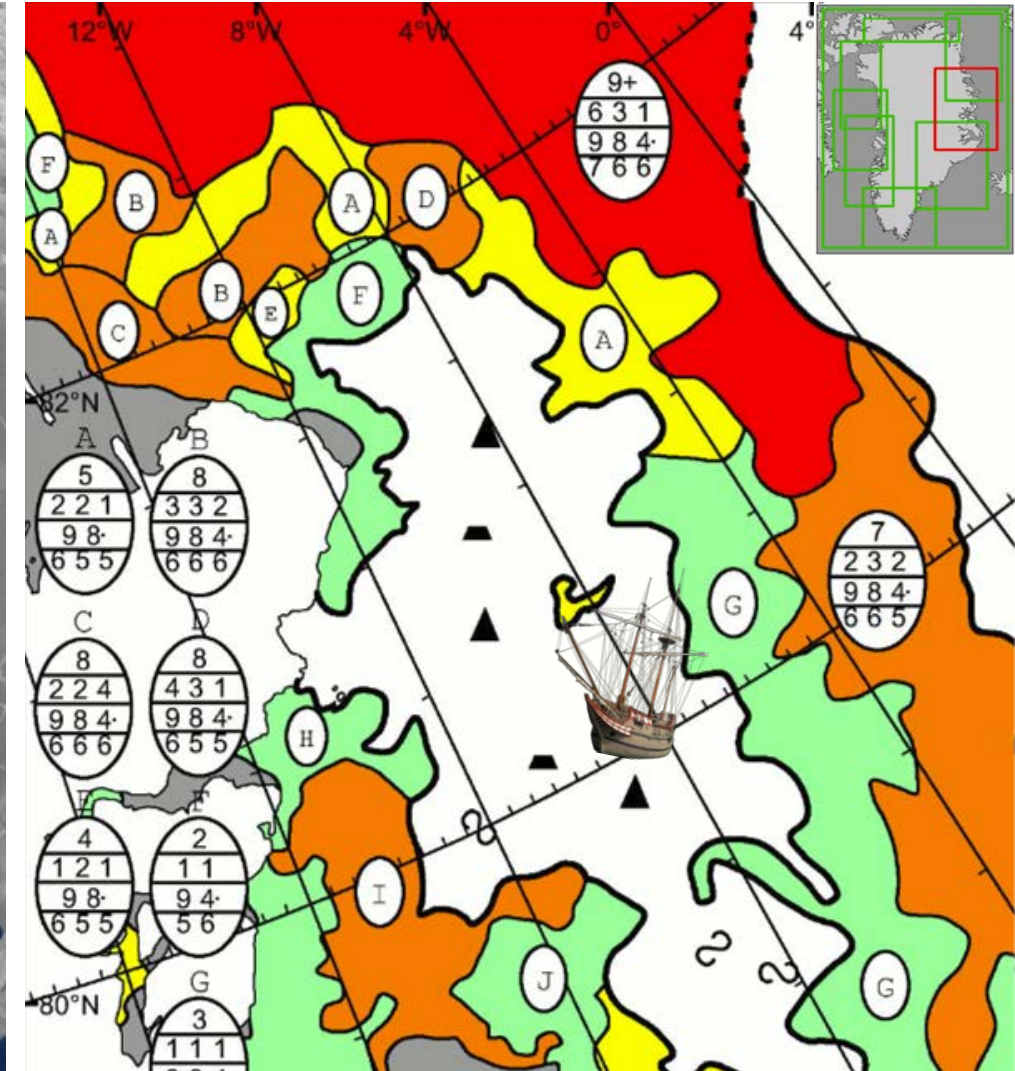
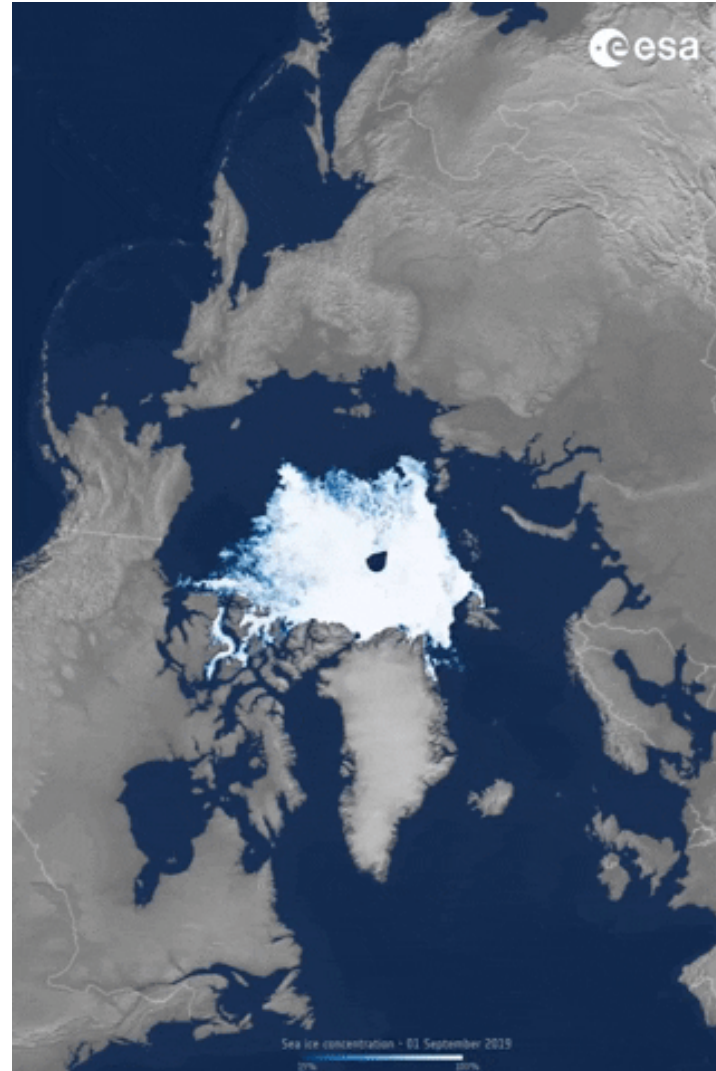


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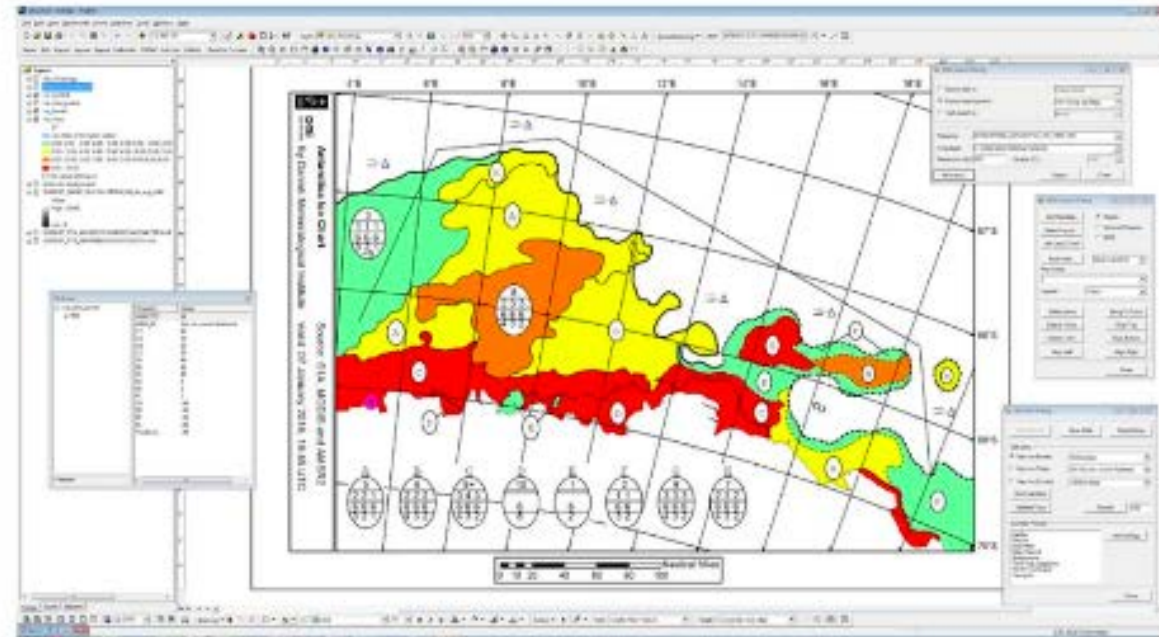
Sea ice charting



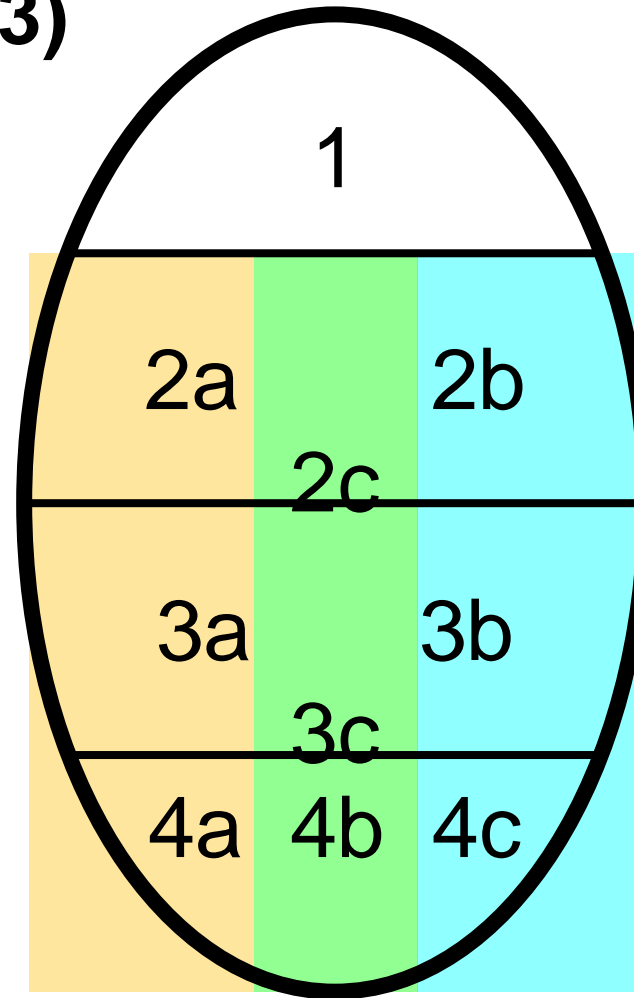
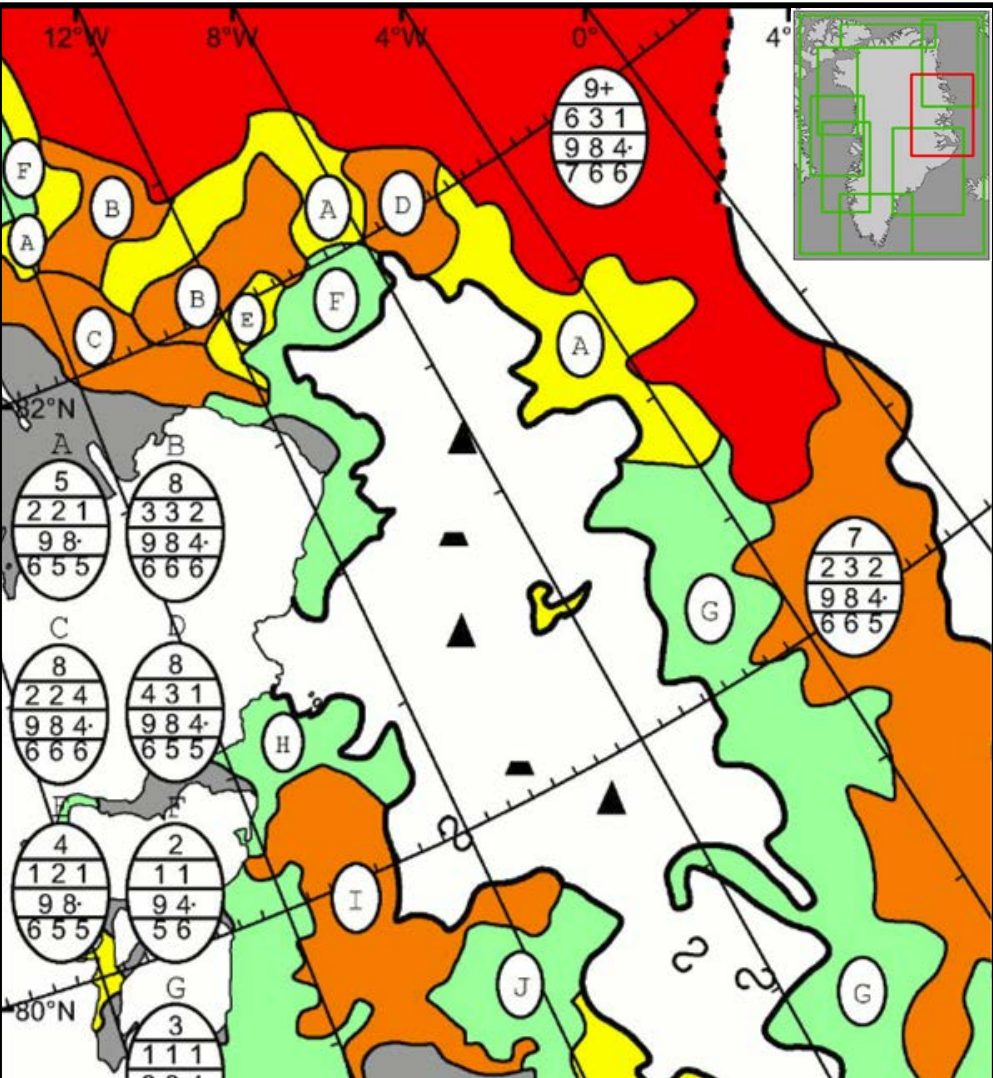
Charting in practice



Producing ice charts in ArcGis/SIKU



Egg code (SIGRID-3)



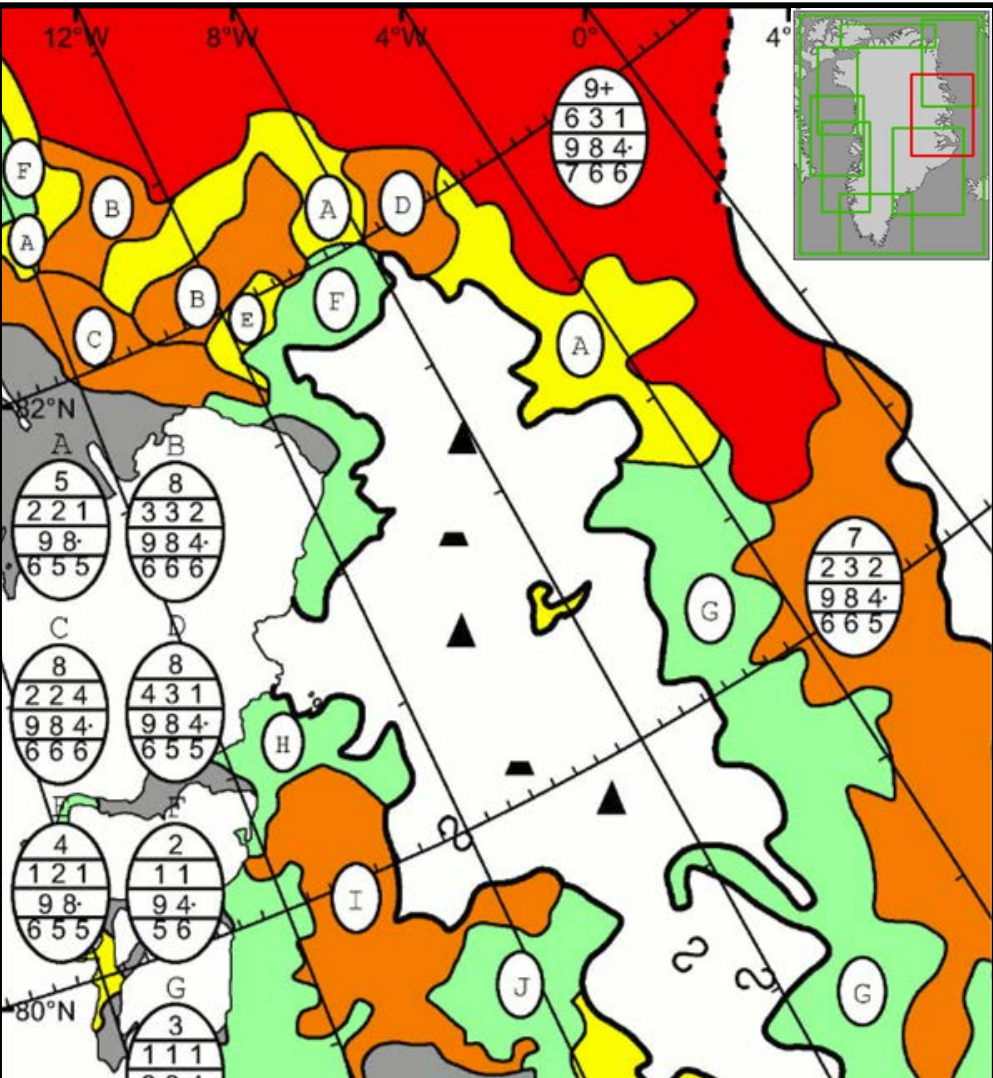
Total sea ice concentration

Partial sea ice concentration

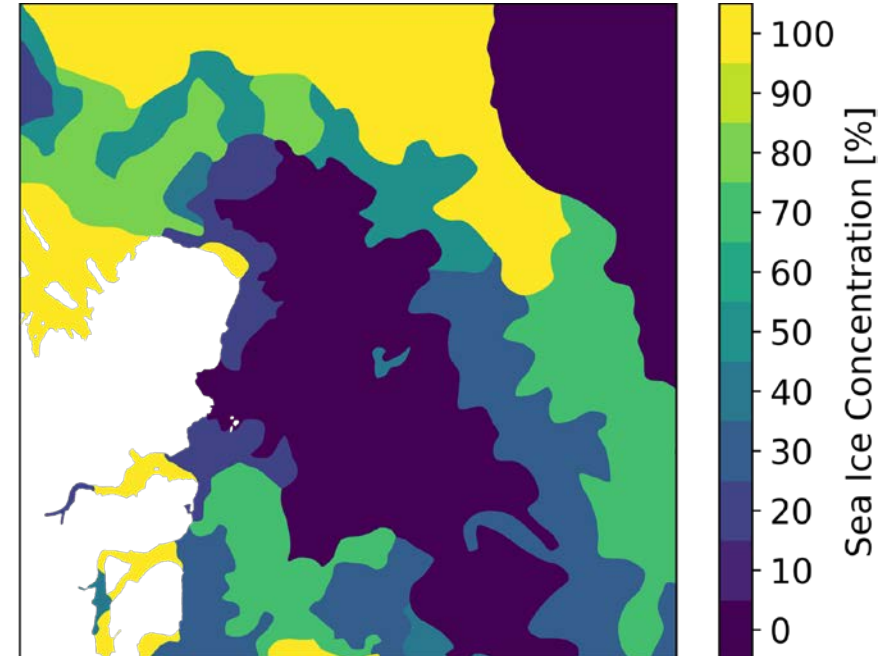
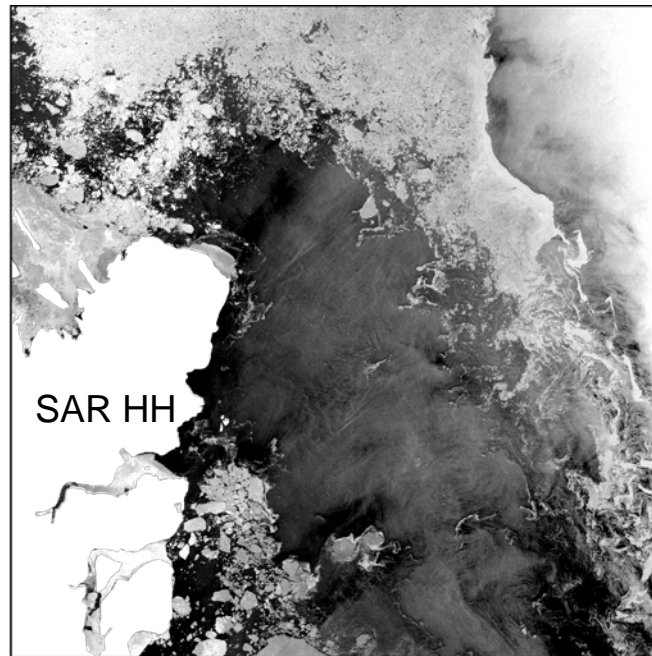
Stage of development

Form of ice

Ice analysts are currently regarded as the best approach to mapping sea ice in high resolution



- Polygons → regions of fairly homogenous ice
- Individual analysis of SAR
- Not one single solution
- High detail near edge
- Mean discrepancy for intermediate SIC: 20%

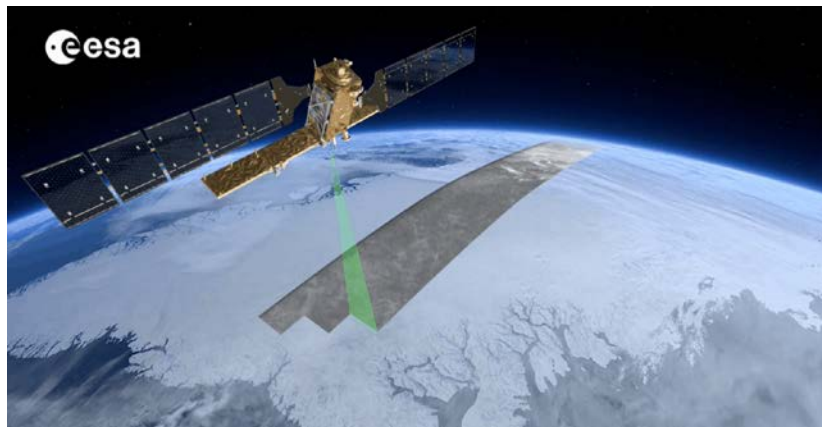
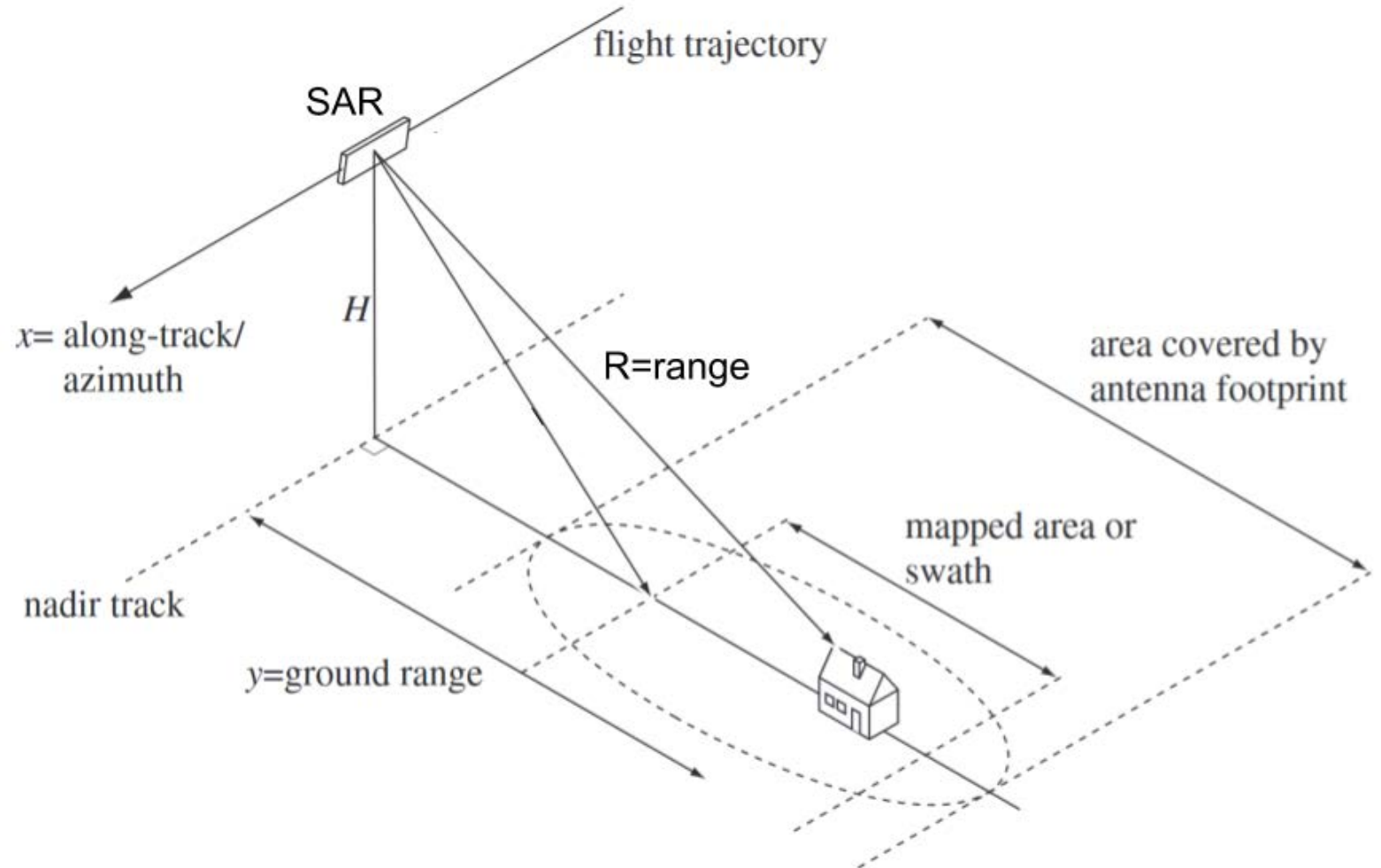


Synthetic Aperture Radar

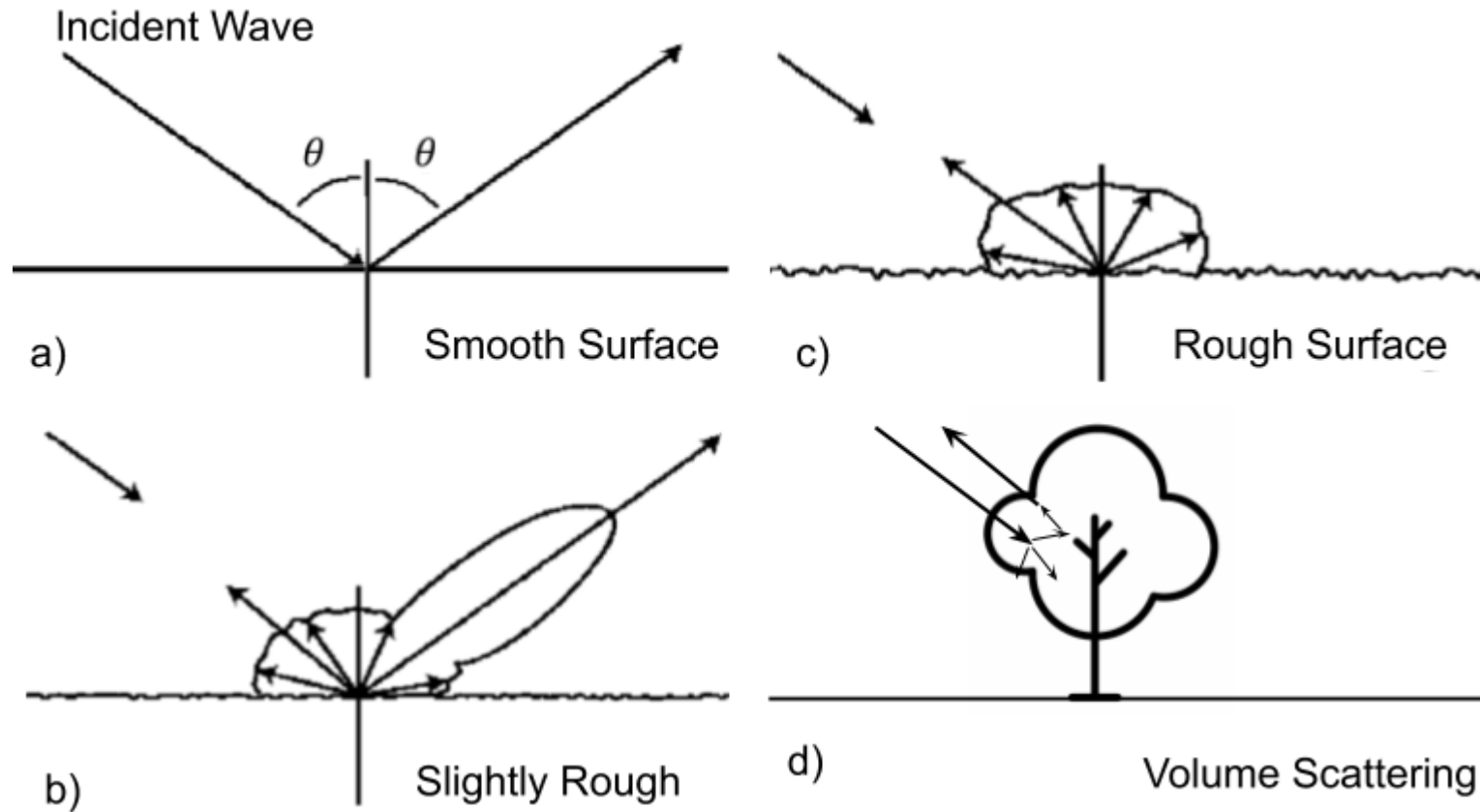
Advantages

- See through clouds
- Independent of sun
- High resolution

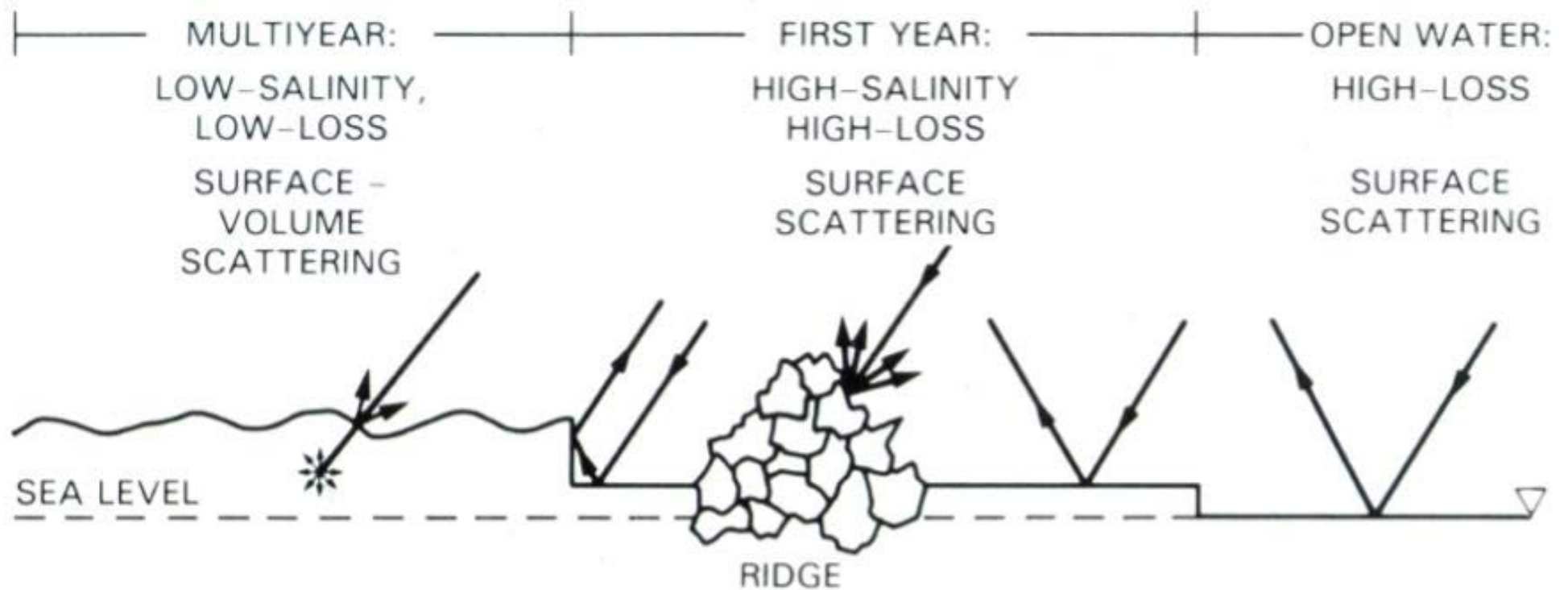
Also use Passive Radiometers, optical, infrared, when useful and available



SAR Scattering



Ice Scattering



Synthetic Aperture Radar - Sea ice

SAR (generally)

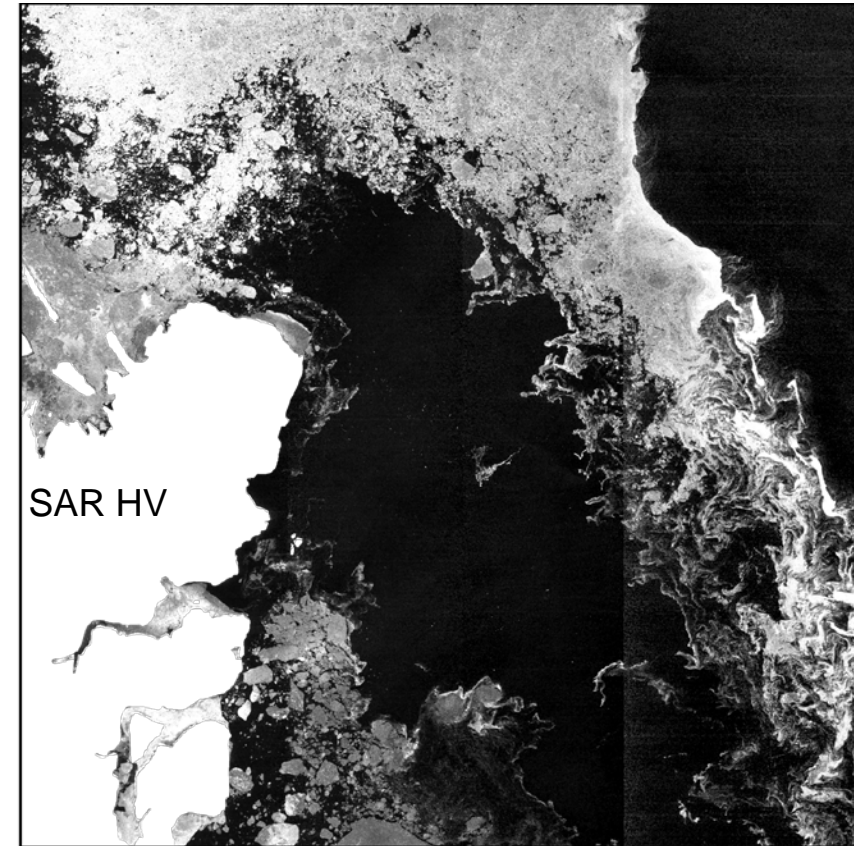
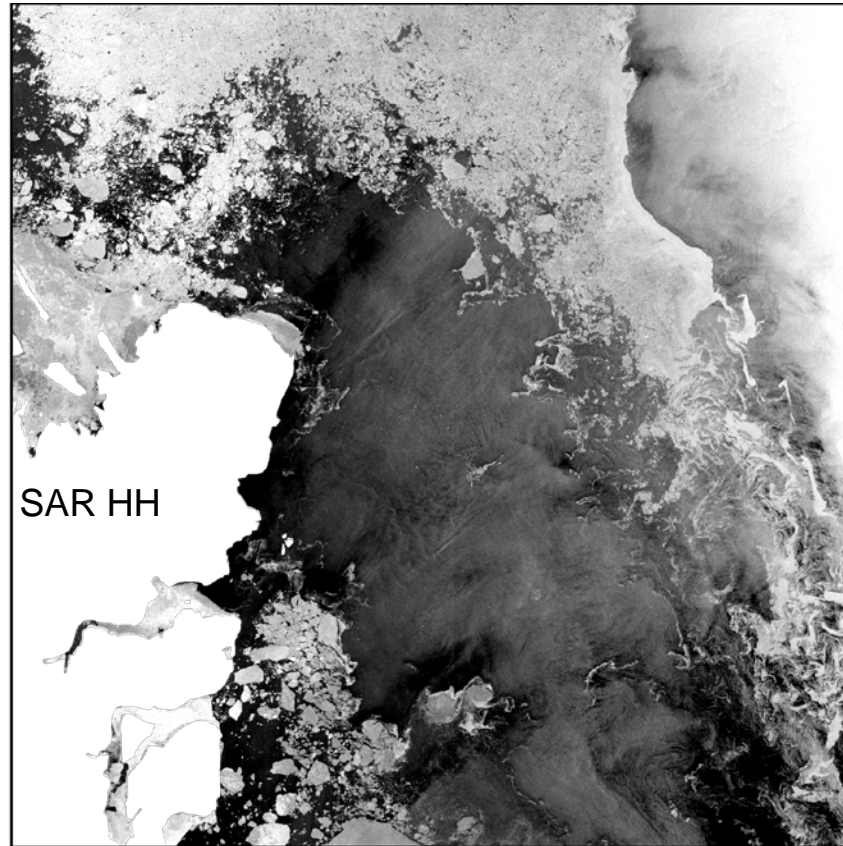
- Rough surface → bright
- Smooth surface → dark
- (most often) Ice → bright
- (calm) water → dark
- (windy) water → bright

SAR HH

- H = Horizontal
H polarized radar wave
- HH = transmitted and received
- Near-range → bright

SAR HV

- V = Horizontal
- HV = transmitted H and
received V polarized
- Less affected by near-range
- High contrast ice vs water

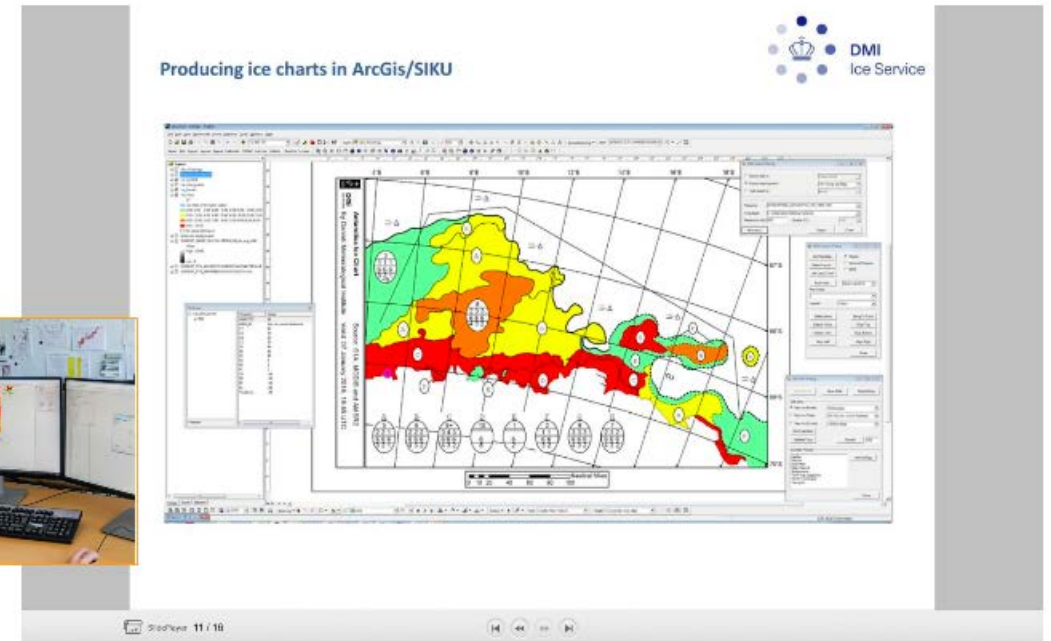


Limitations of current chart production

- Production time
 - Takes 1-3 hours to receive image from satellite
 - Drawing duration: 2-3 hours (less ice -> easier/shorter)
 - Total average production time:
 - Daytime: 4-5 hours
 - Night time: up to 11 hours
 - Ice moves -> information degrades

- Coverage
 - Confined to national interest
 - Constrained by number of analysts
 - Limited regional map updates

- Quality
 - Large polygons -> fewer details (low resolution)
 - Individual subjective interpretations (biases)
 - Slightly conservative interpretation (could also be positive)
 - Sea ice edge receive more attention
 - Human error



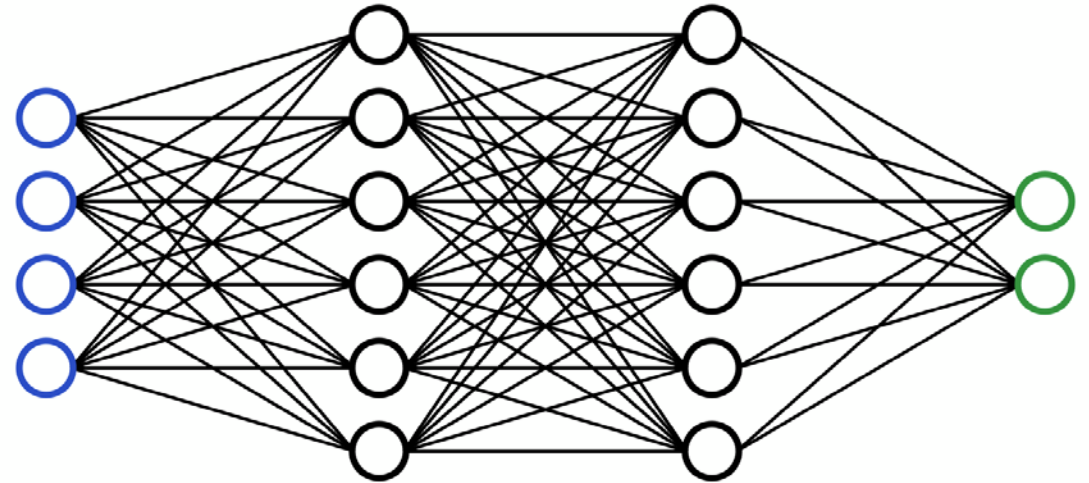
Neural Networks

$$f(x) = y$$

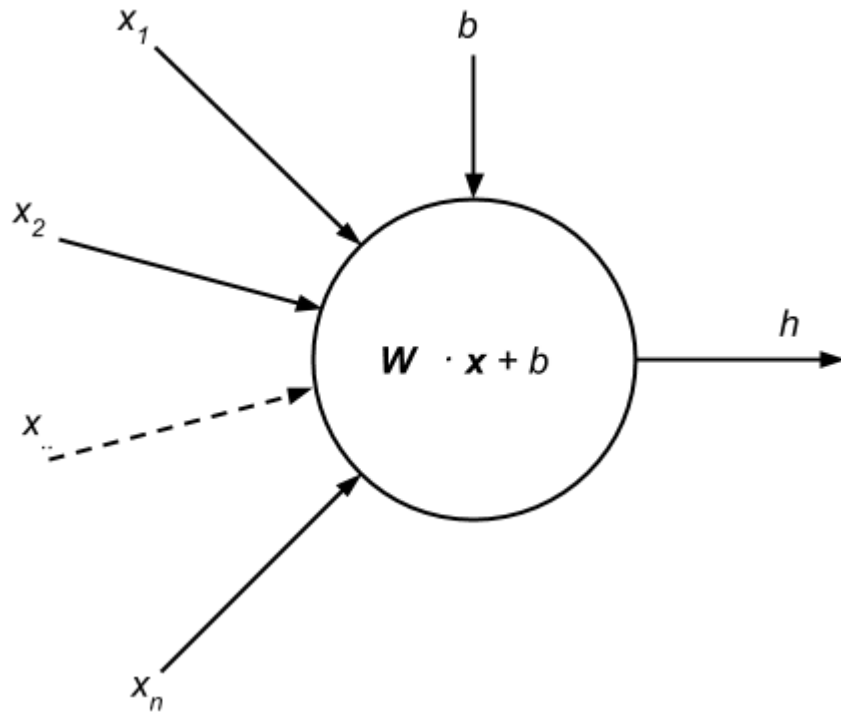
$x \rightarrow$ SAR data

$y \rightarrow$ sea ice charts

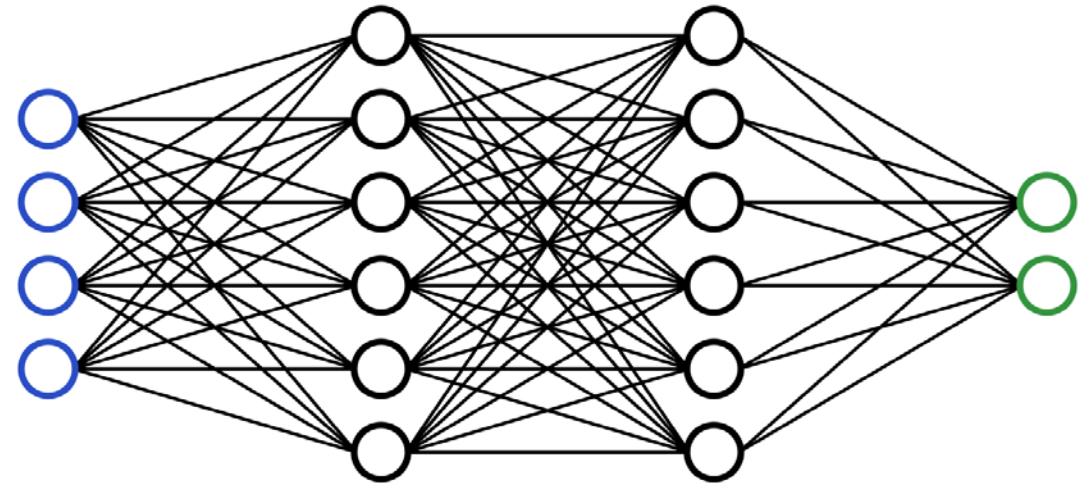
find $f()$



Neural Networks

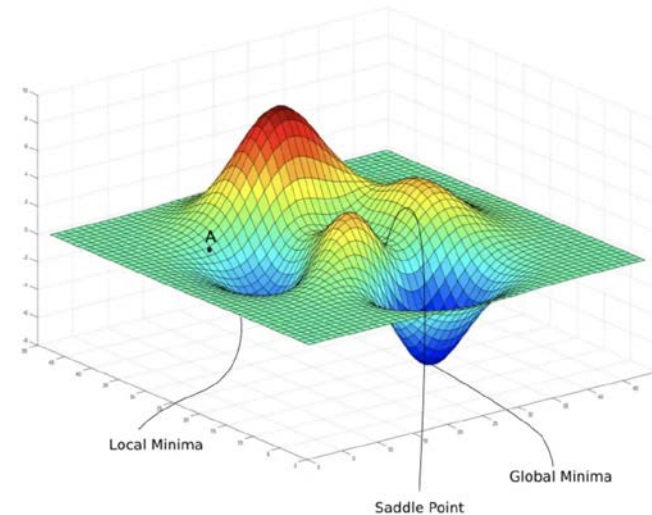
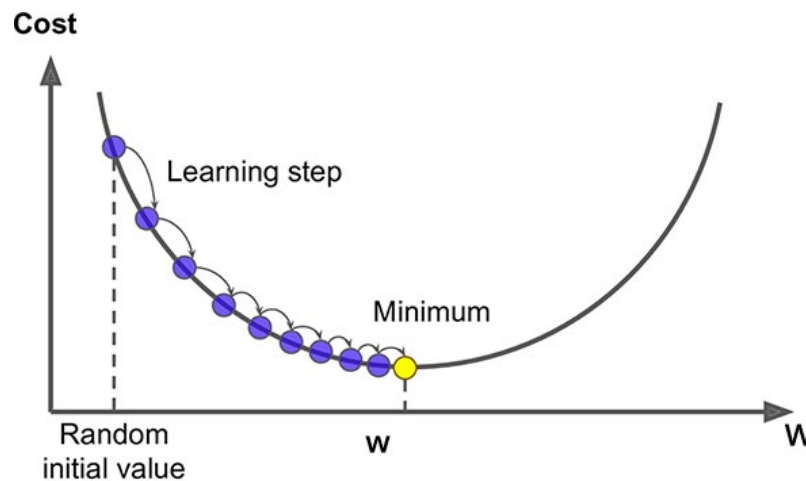
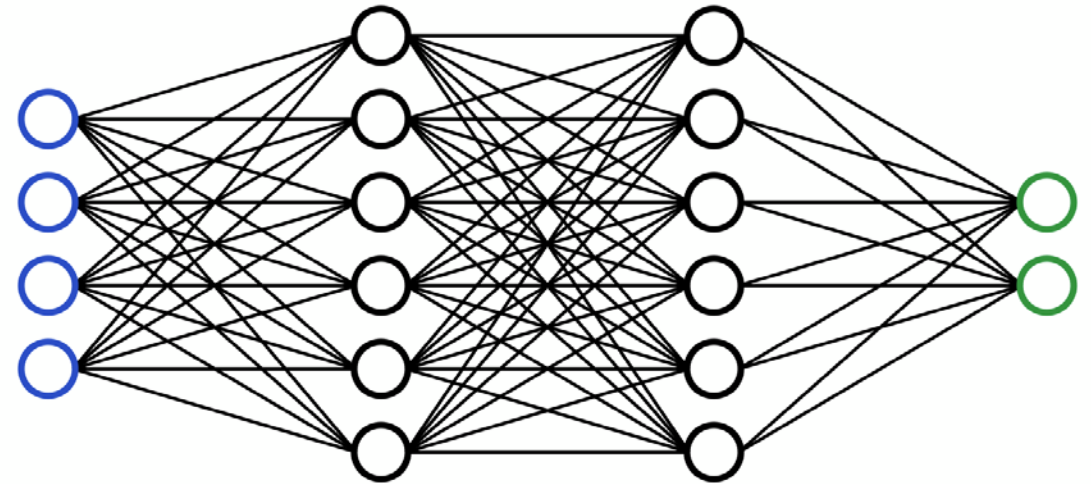


x: input
w: weight
b: bias
h: output



Optimisation of Neural Networks

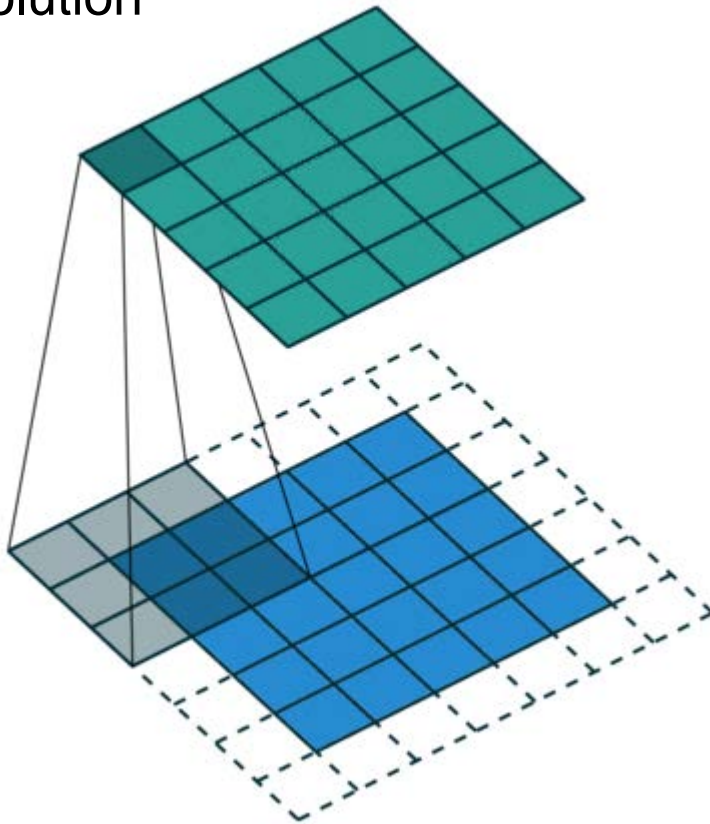
- Loss/cost function, e.g. $y - \hat{y}$
- Minimise loss
- Gradient descent
- Based on change of the loss, we change the weights in the network



The Building Blocks of Convolutional Neural Networks

$$\sum_m \sum_n I(i + m, j + n) K(m, n)$$

Convolution



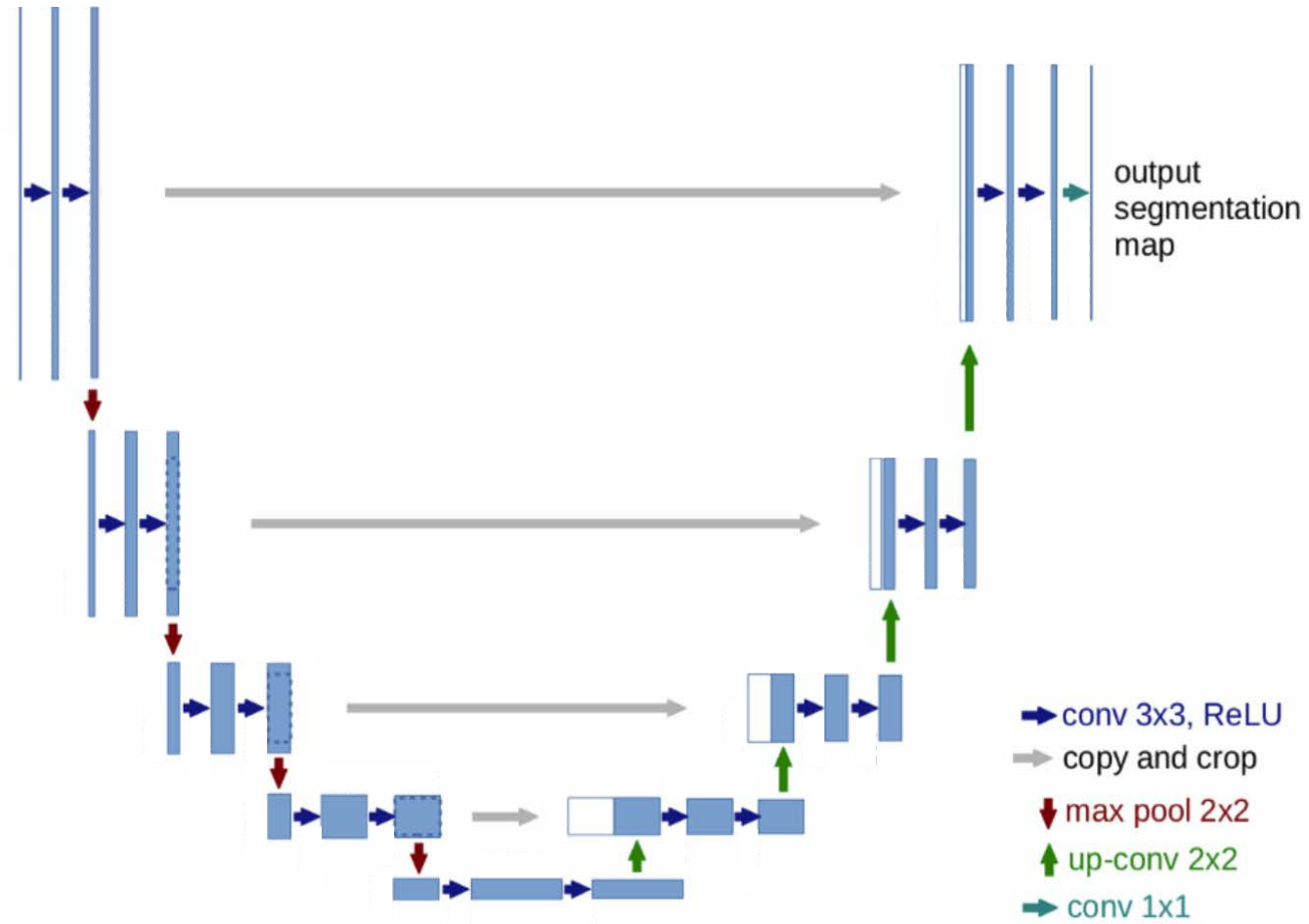
Max Pooling

3.0	3.0	3.0
3.0	3.0	3.0
3.0	2.0	3.0

3	3	2	1	0
0	0	1	3	1
3	1	2	2	3
2	0	0	2	2
2	0	0	0	1

Semantic Segmentation (labelling individual pixels)

Model, U-Net Levels

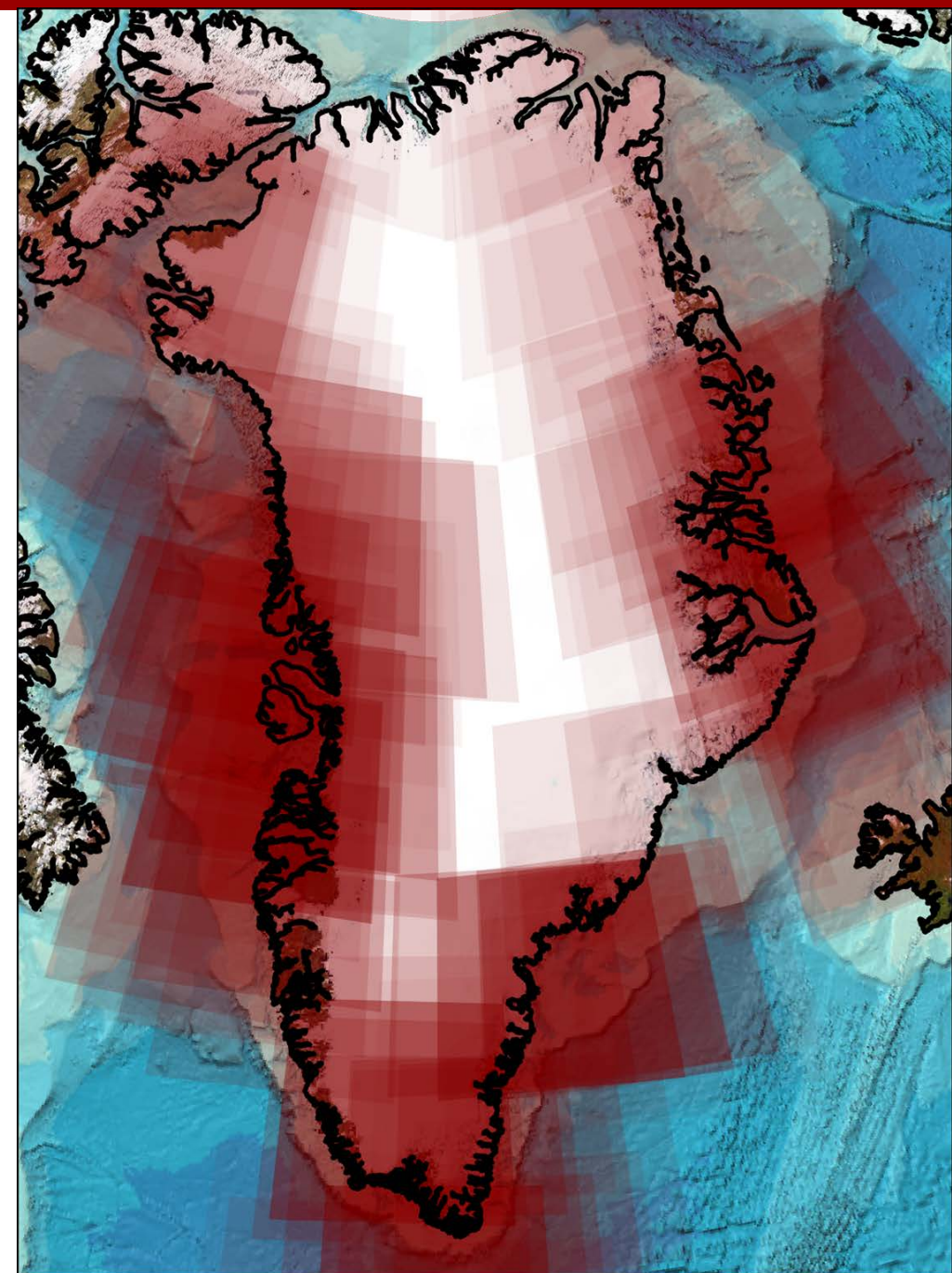


The AI4Arctic v2 Data Set

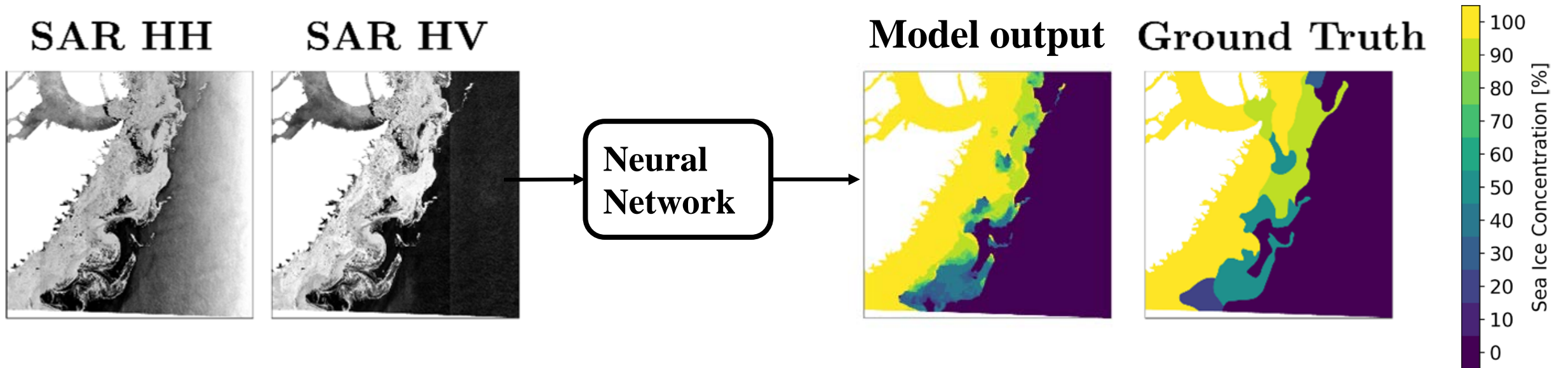
- 461 scenes, March 2018 - May 2019
- Scene contains (among others):
 - Sentinel-1 EW, HH + HV
 - DMI derived sea ice chart
 - + (other instruments and data types..)
- ~5000-10000² pixels per scene
- Training -> 306 scenes
- Testing -> 23 scenes

https://data.dtu.dk/articles/dataset/AI4Arctic_ASIP_Sea_Ice_Dataset_-_version_2/13011134/3

<https://www.aireo.net/>



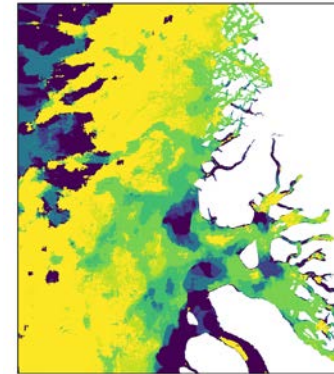
Results



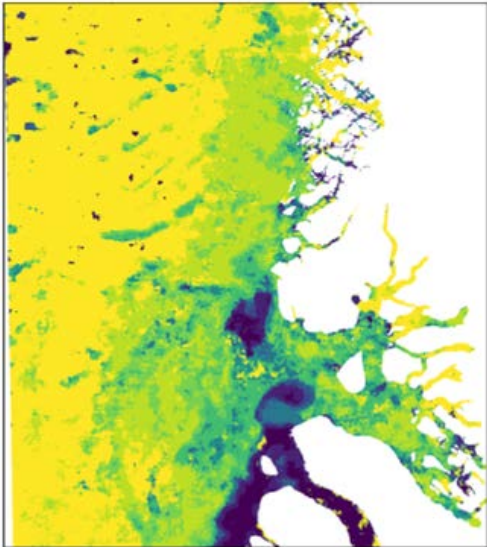
- We have shown with continuous development that we can create models that are:
 - Good at discriminating between water and ice
 - Robust
 - Has higher resolution

Robustness improvement

initial attempts

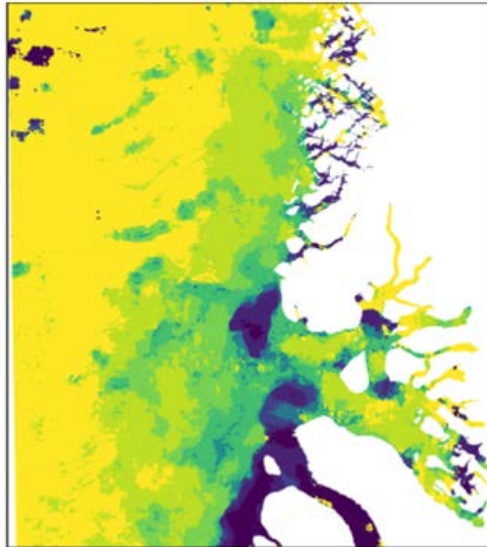


Level-3 U-Net



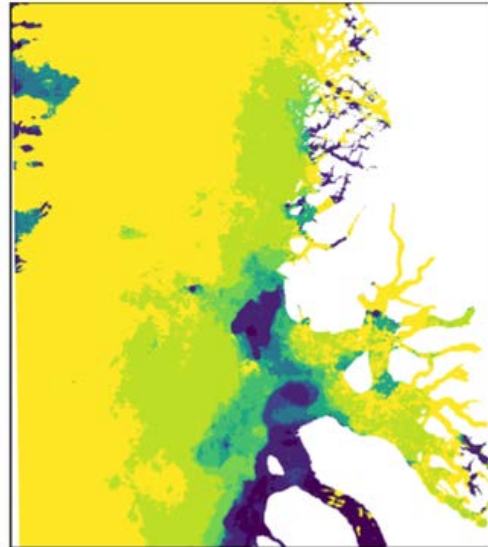
R^2 -score: 18.27%

Level-4 U-Net



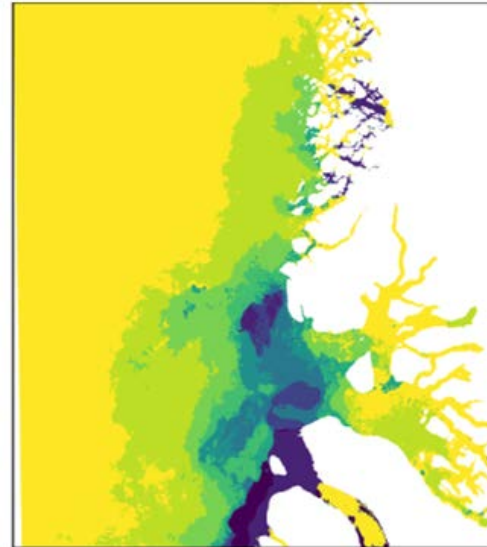
R^2 -score: 13.33%

Level-5 U-Net



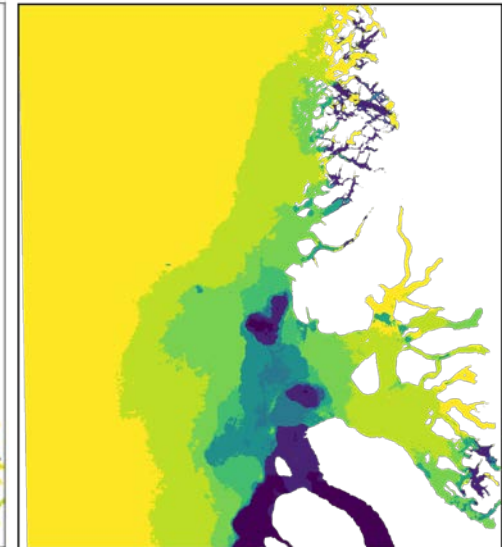
R^2 -score: 34.42%

Level-6 U-Net

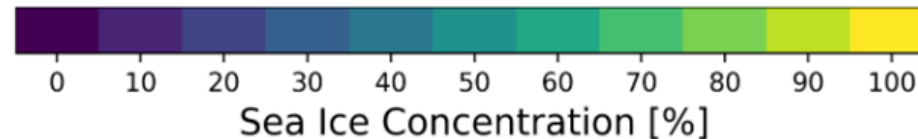


R^2 -score: 38.41%

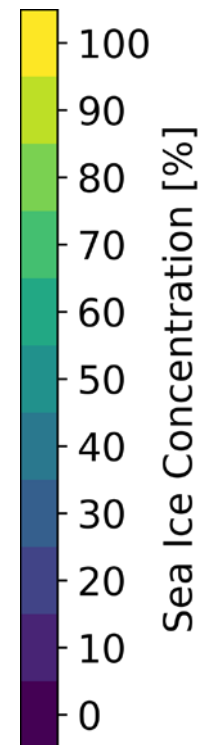
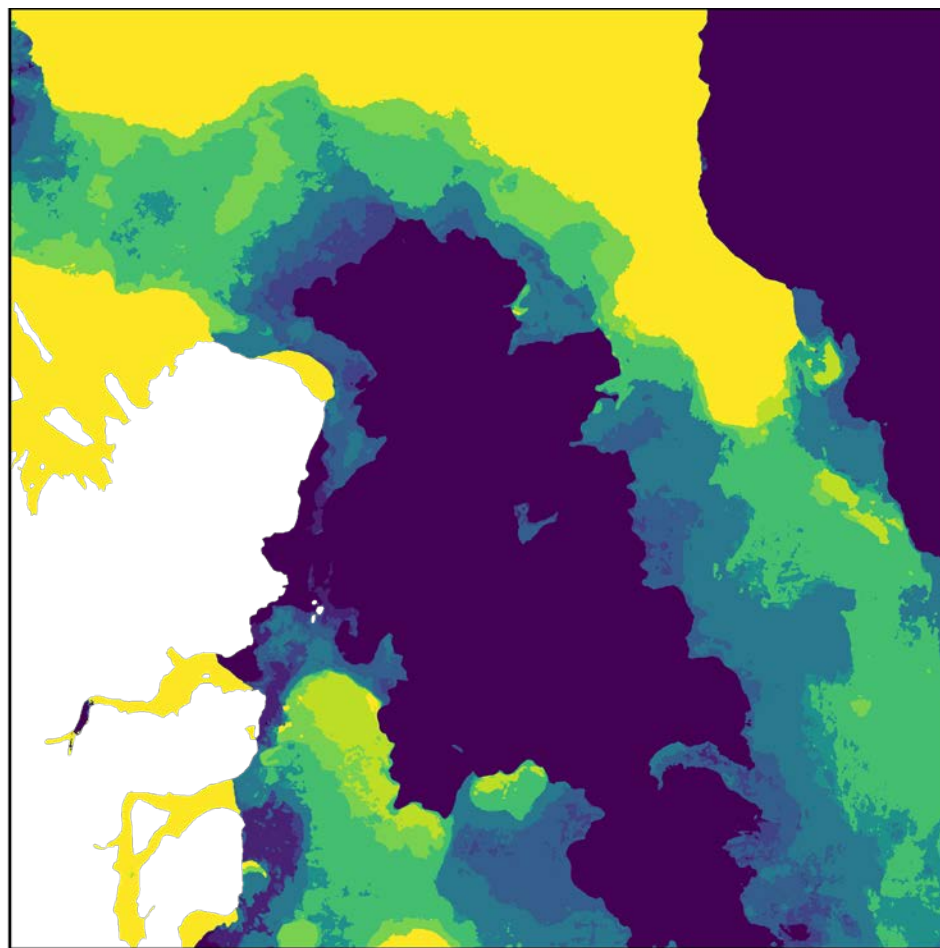
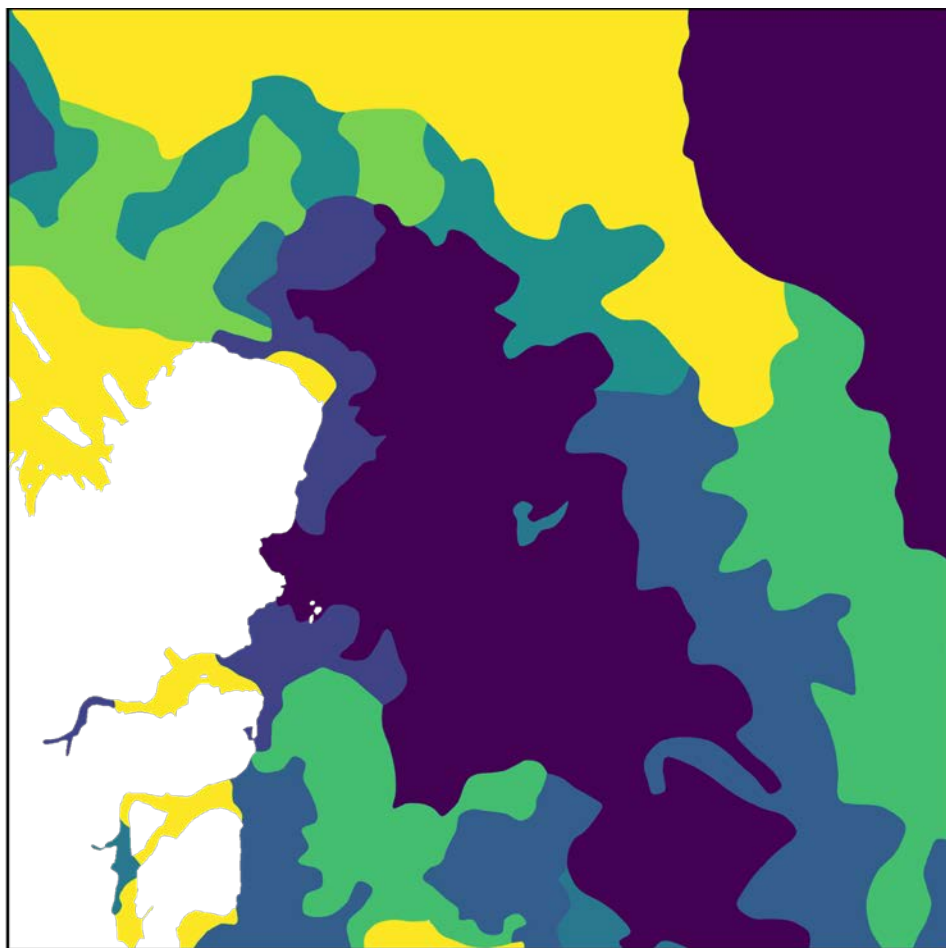
Level-8 U-Net



R^2 -score: 47.12%

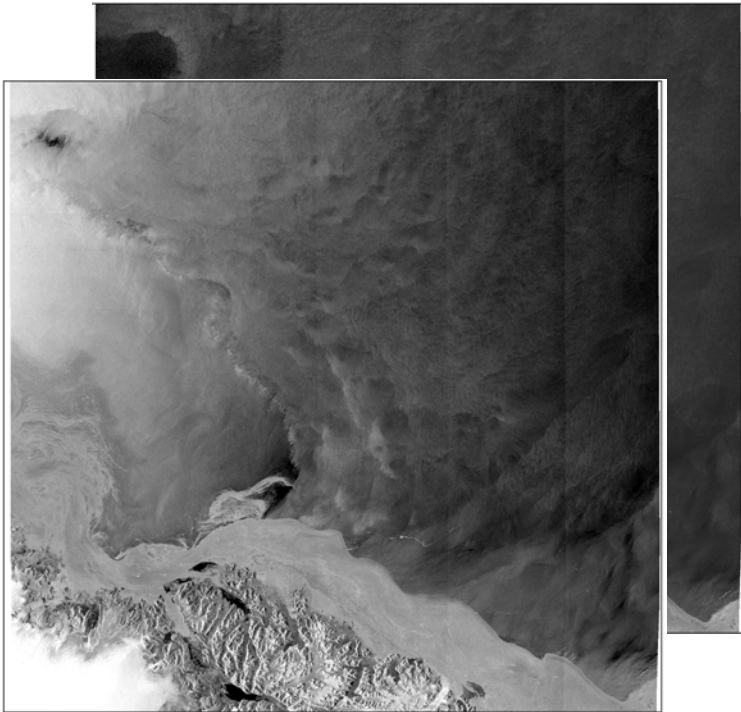


Higher resolution

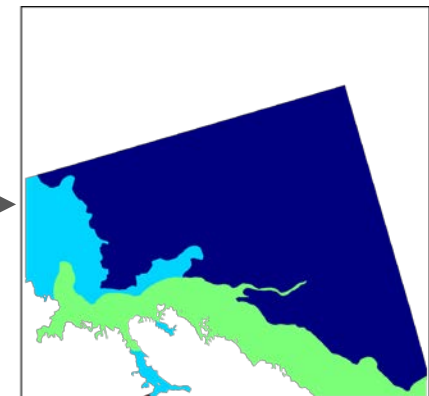
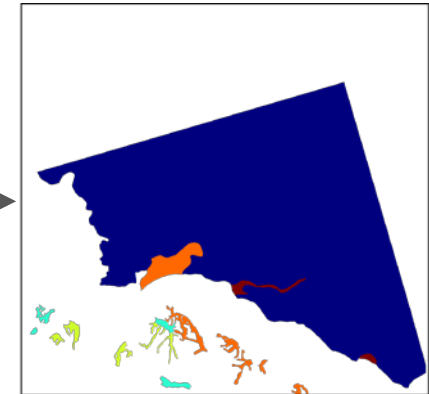
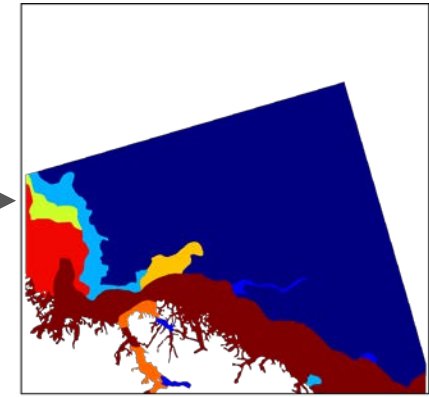


Current state-of-the-art

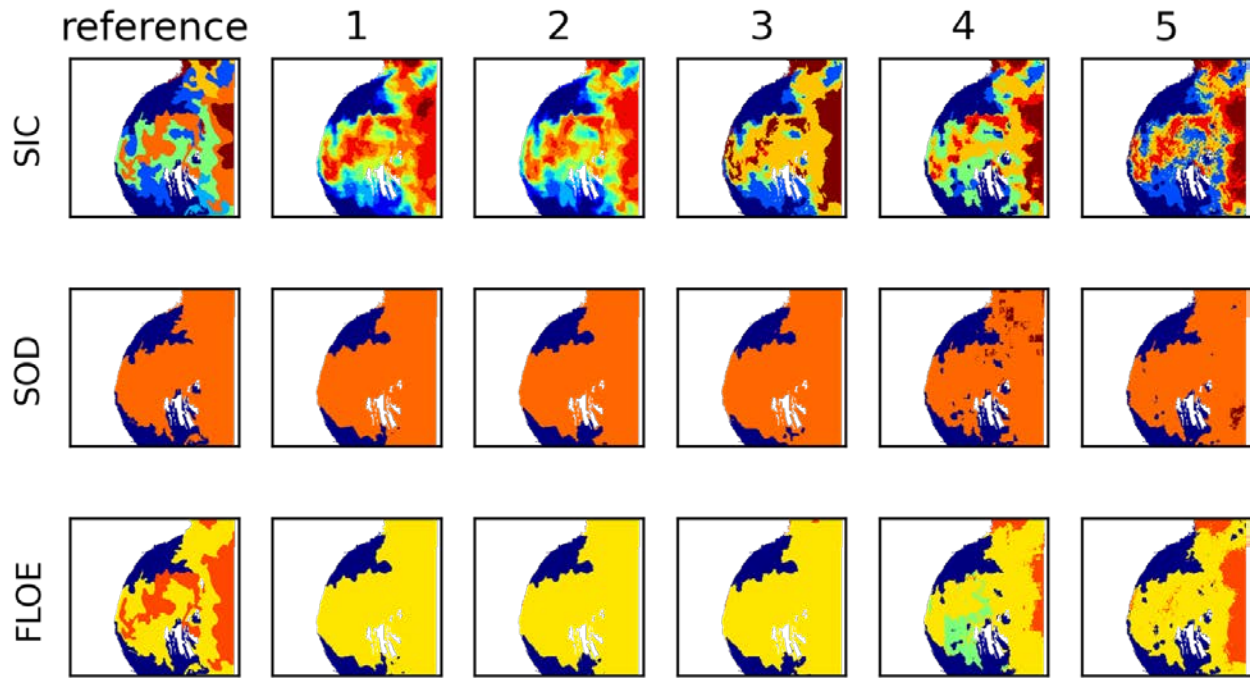
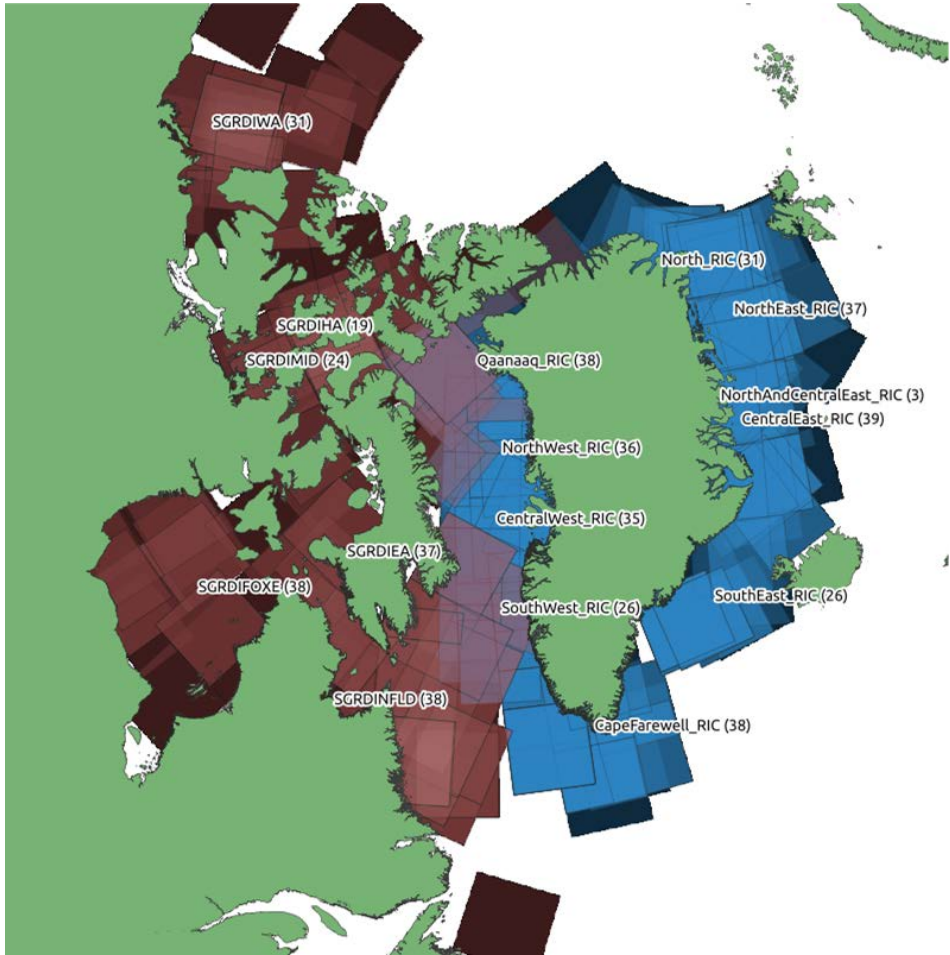
Sentinel-1 SAR HH, HV



Deep Learning Model

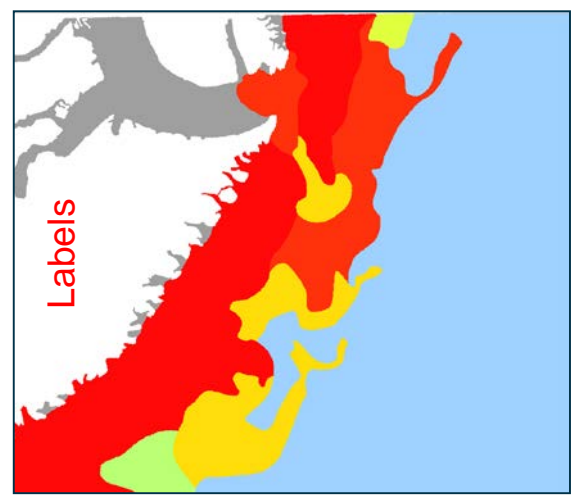
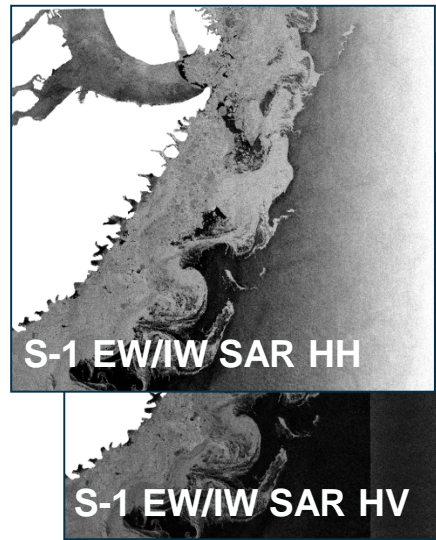


Multi ice-parameter retrieval



The next data set - AI4Arctic v3

(Fall 2023)



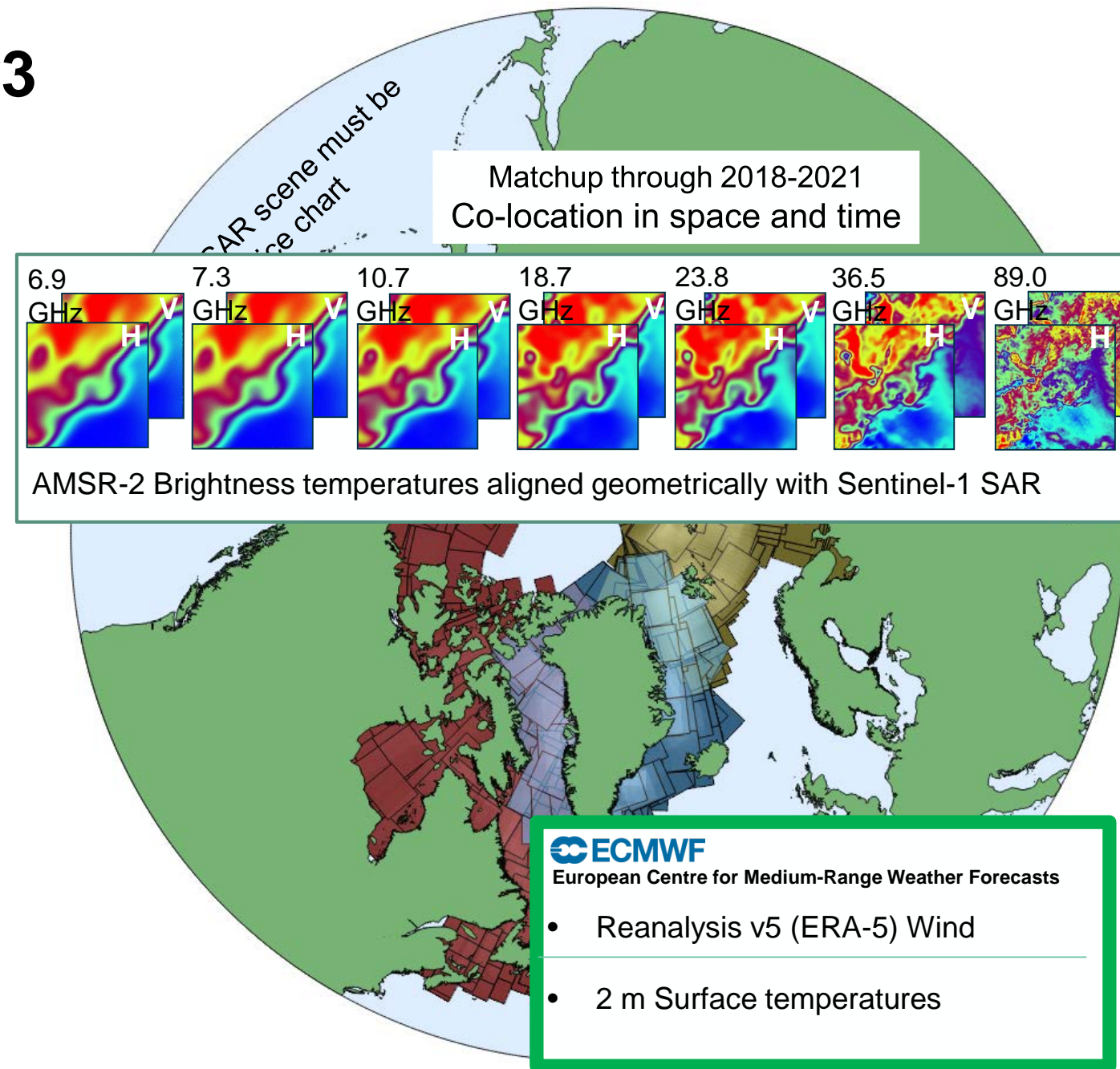
- CIS – 2599 matchups (SAR scenes/corresp. ice charts)
- DMI – 3387 matchups (SAR scenes/corresp. ice charts)
- MetNo – 2251 matchups (SAR scenes/corresp. ice charts)

Total matchups: **8237**

18 times larger than the previous dataset!

Adapted from Jørgen Buus-Hinkler, DMI

Size: 8-10 TB



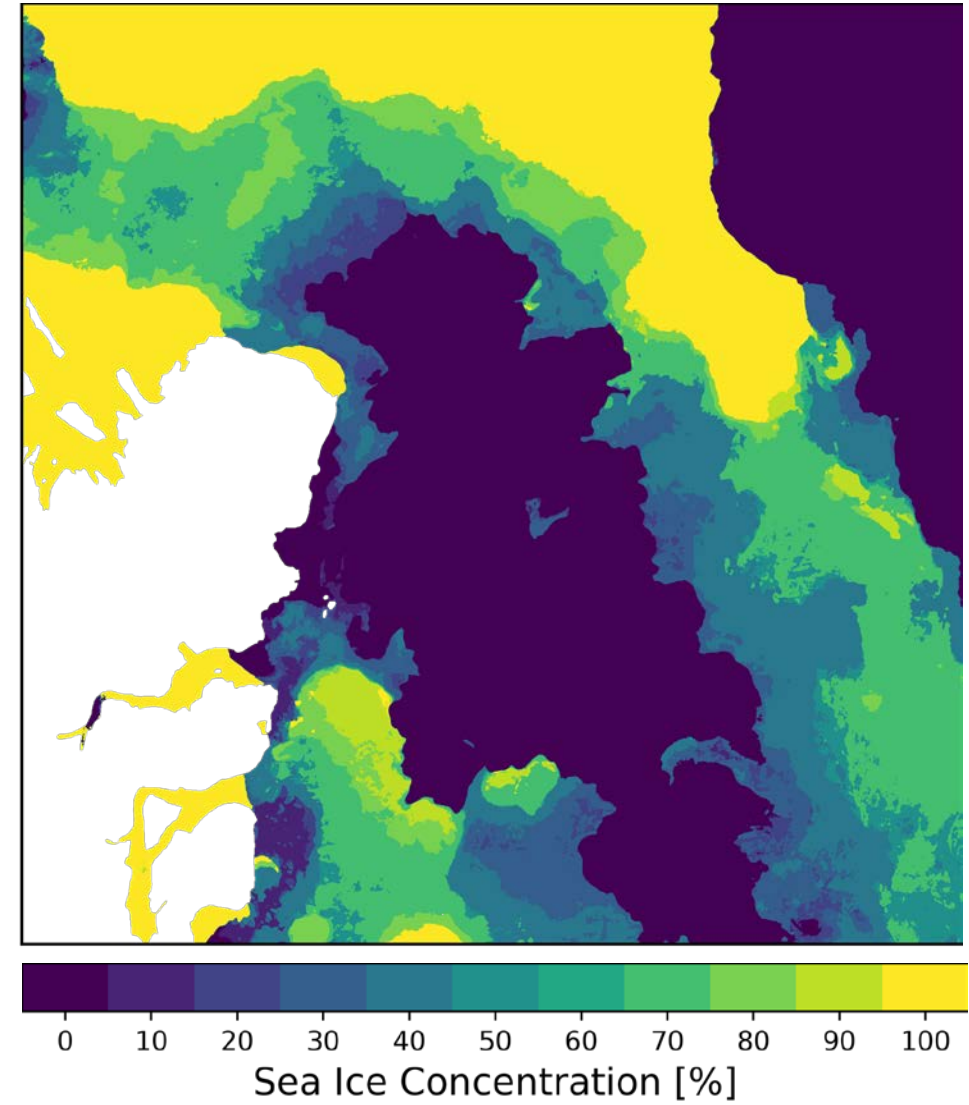
Impacts of automatic ice charts

- Production time
 - From hours to seconds

- Coverage
 - Could utilize all Sentinel-1 images
 - Maps across the Arctic
 - Limitation becomes the number of operational satellites
 - Independent of other ice services
 - More frequent map updates
 - More timely information -> improved situational awareness

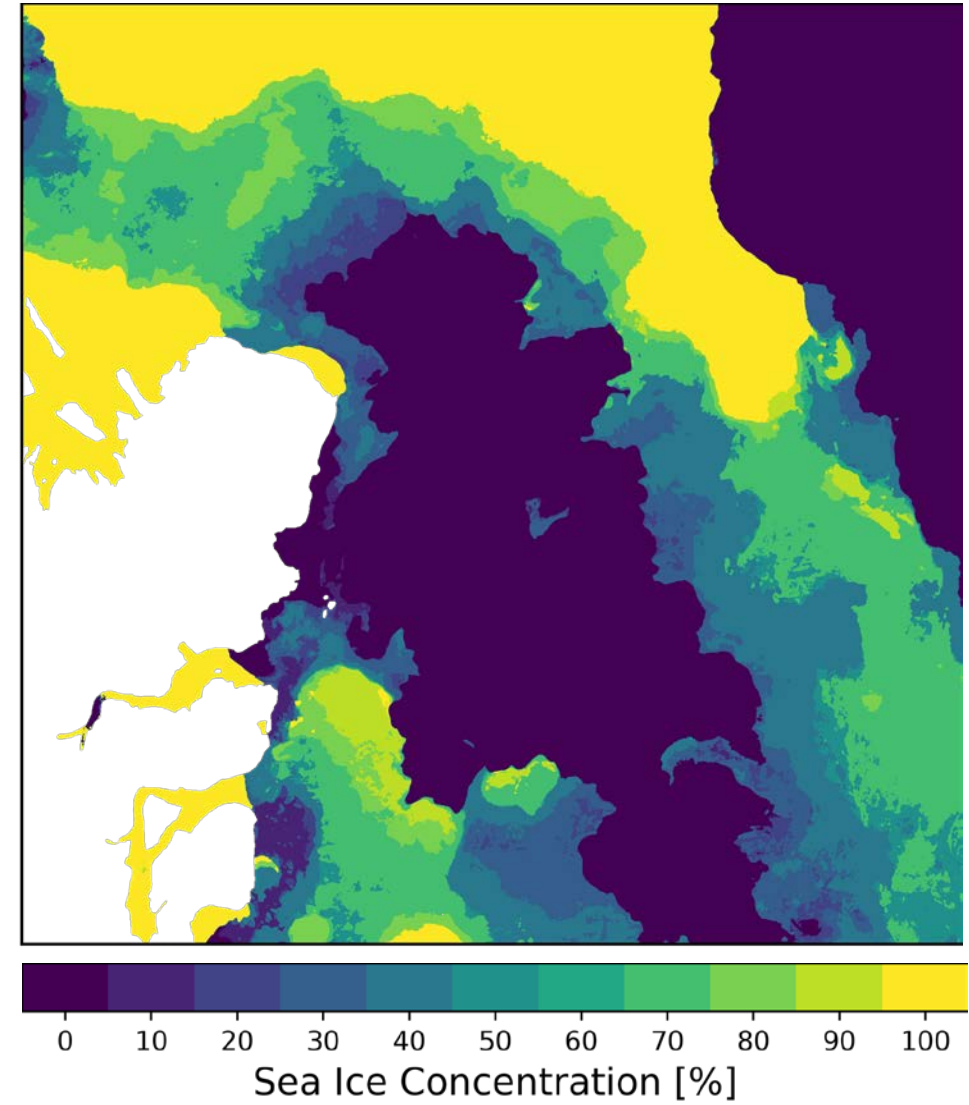
- Quality
 - Higher resolution
 - Different maps/models tailored to specific users
 - More focus on other areas than the ice edge

- High resolution products for climate and weather models



Conclusion

- We can produce robust ice charts
- Strong resemblance to human-labelled ice charts
- Potential for higher quality
- Products produced faster
- Produced more frequent
- Covering a larger area
- Multiple ice parameters
- New larger dataset should provide adequate training for even better models



Questions

Competition dataset



Dataset



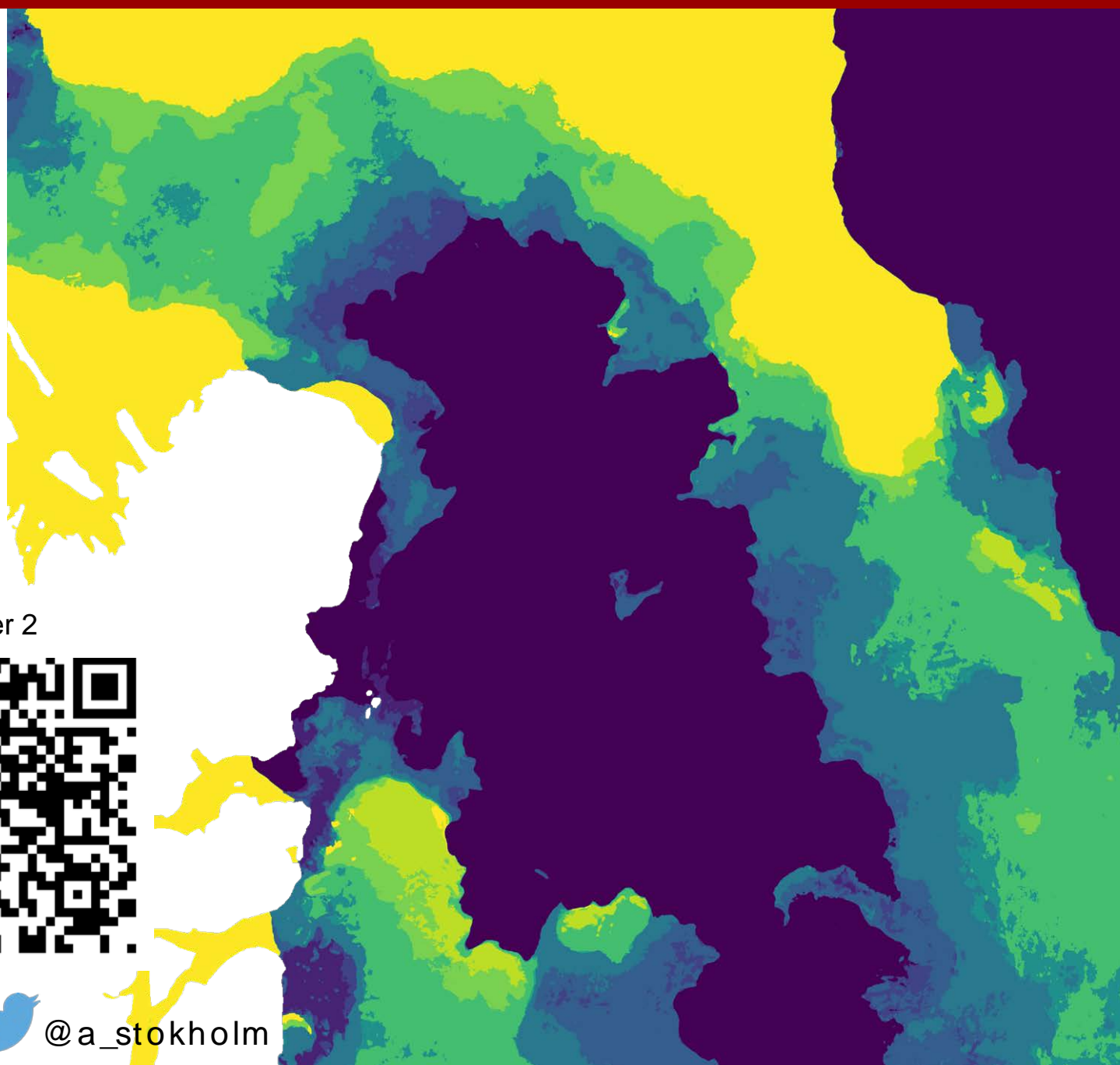
Competition gitHub



Paper 1



Paper 2



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