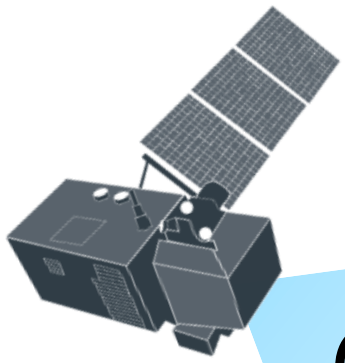




Quantifying walrus aggregations in Sentinel-2 satellite imagery using sub-pixel spectral unmixing

Ellie Bowler, Hannah Cubaynes, Peter Fretwell



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Walrus monitoring

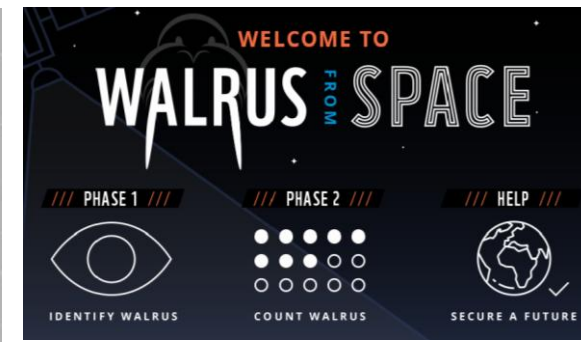
Very wide distribution and summer haul-outs in remote locations

Surveys expensive, cannot be conducted very regularly

BAS/WWF “Walrus from Space” project using 30-50cm resolution data and citizen science to monitor all sites over 5 years



[Cubaynes et al. \(2026\)](#)



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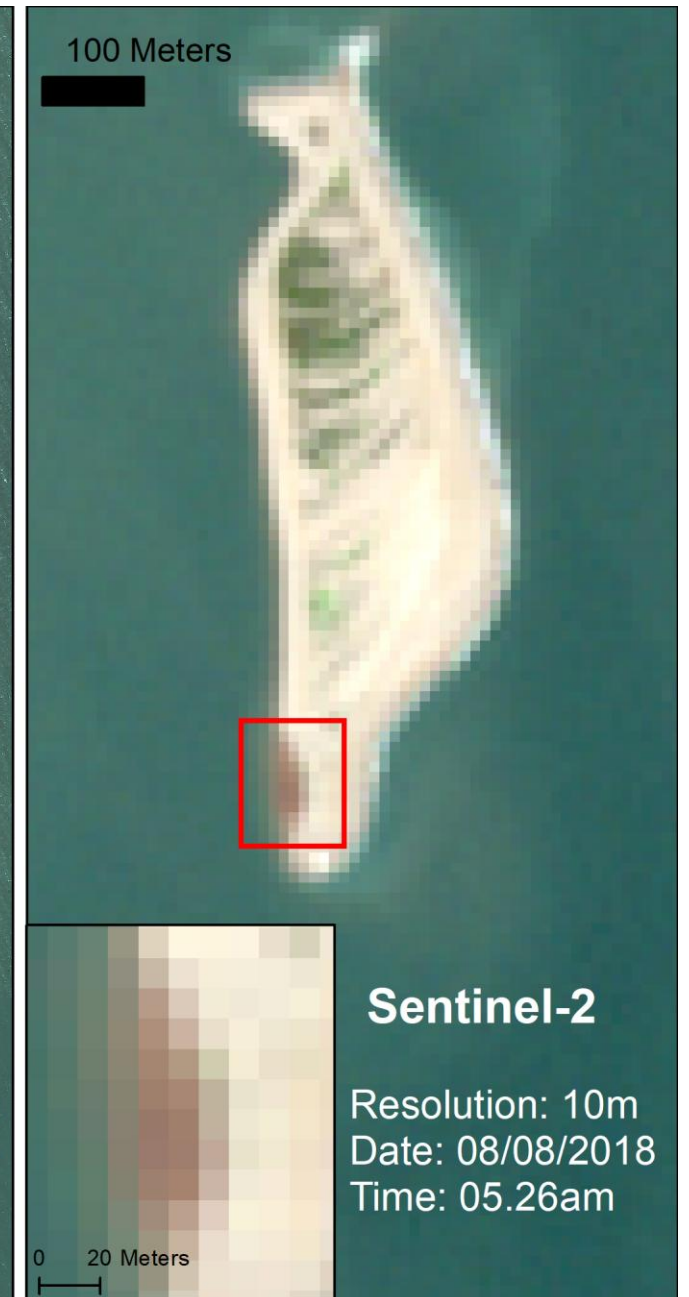
Potential of sentinel-2

Larger haul-outs are visible in Sentinel-2 imagery

10m spatial resolution and 12 spectral bands

More frequent revisit times (5 days at the equator, more at the poles)

Archive available to analyse past decade of haul-out dynamics



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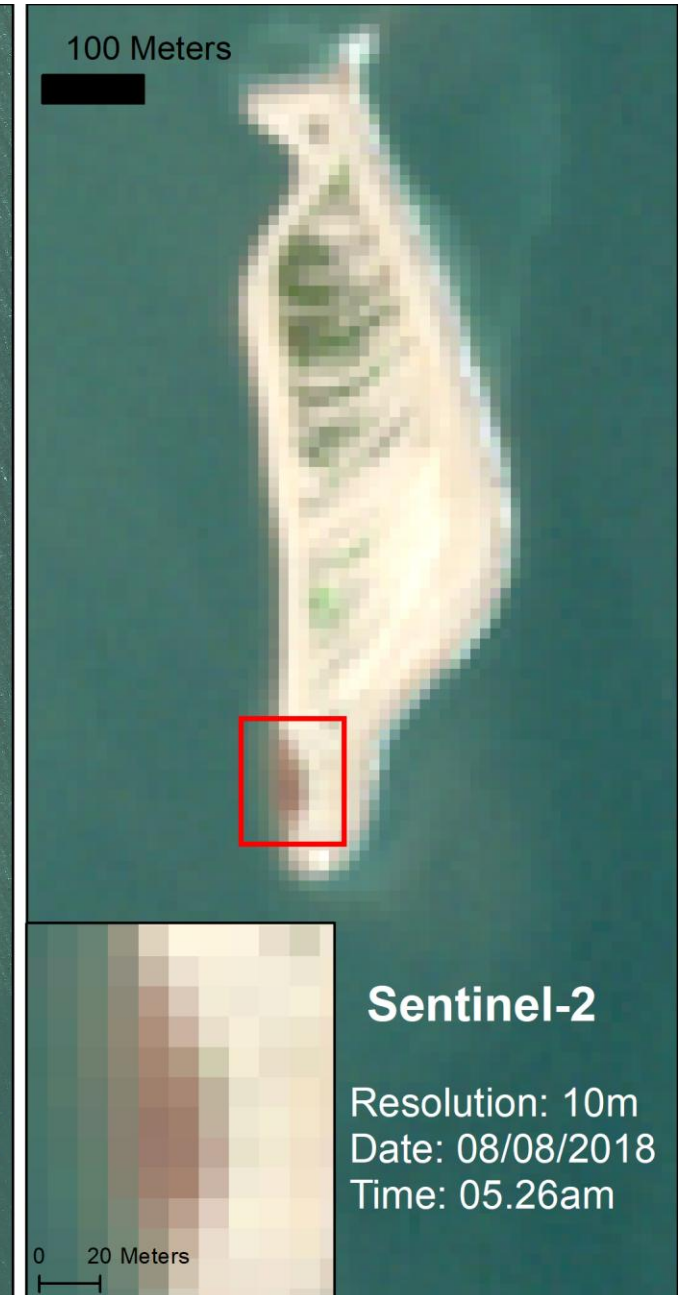
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Challenges of sentinel-2

Haul-outs difficult to delineate with binary segmentation – how to make ground truth?

Compromises the validation of binary classifiers

Detection of sub-pixel areas useful for determining presence for Atlantic walrus



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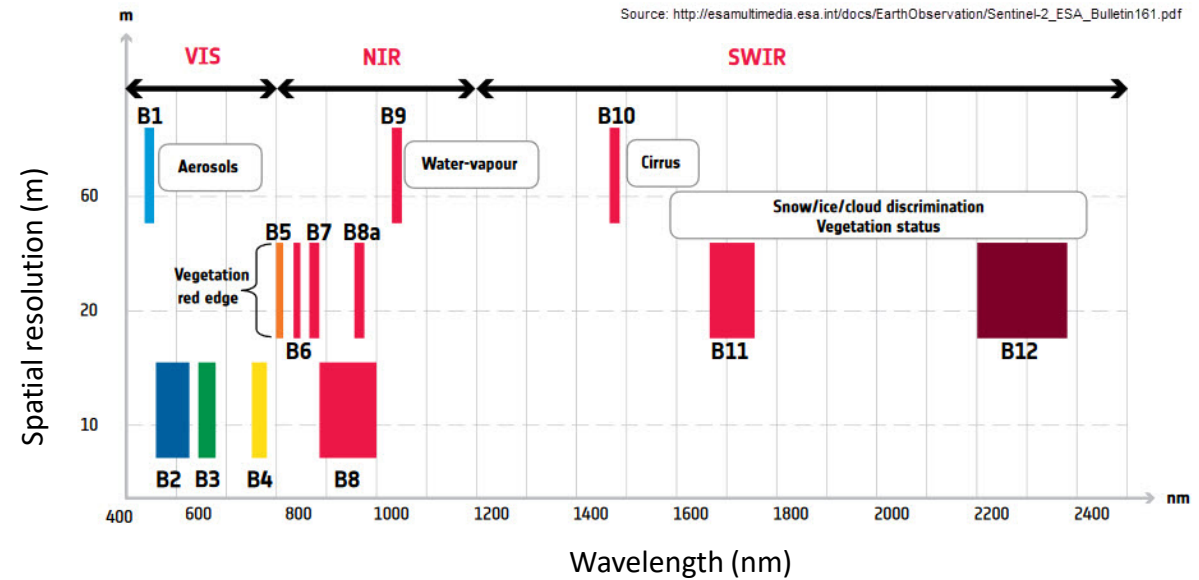
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Spectral unmixing

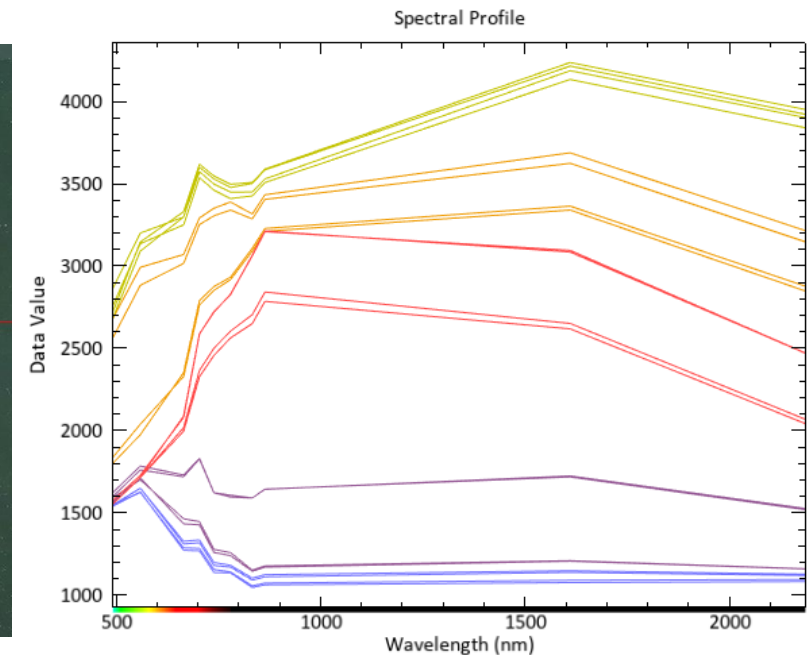
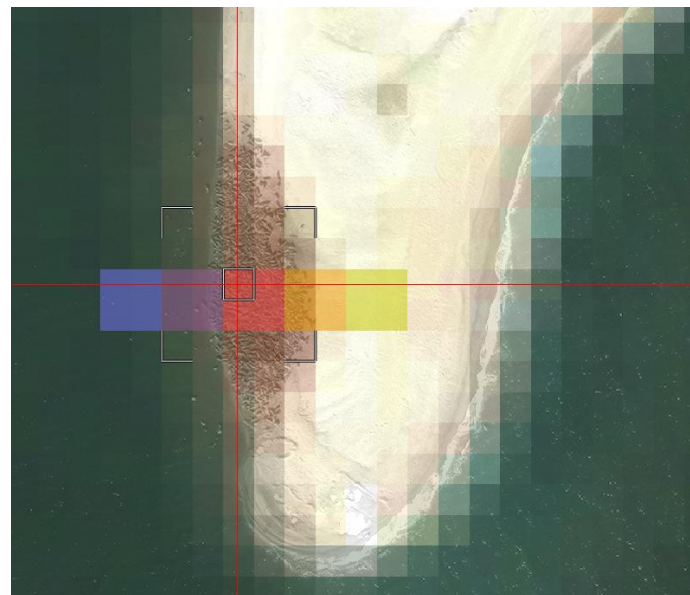
Estimate the presence or fractional cover of a material within an image pixel

Mixture tuned matched filtering – target finding algorithm

Outputs matched filter (MF) score and infeasibility score



Spectral profiles for ocean (blue), walrus (red) and beach (yellow) – and mixed ocean/walrus (purple) and mixed walrus beach (orange).



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Image dataset

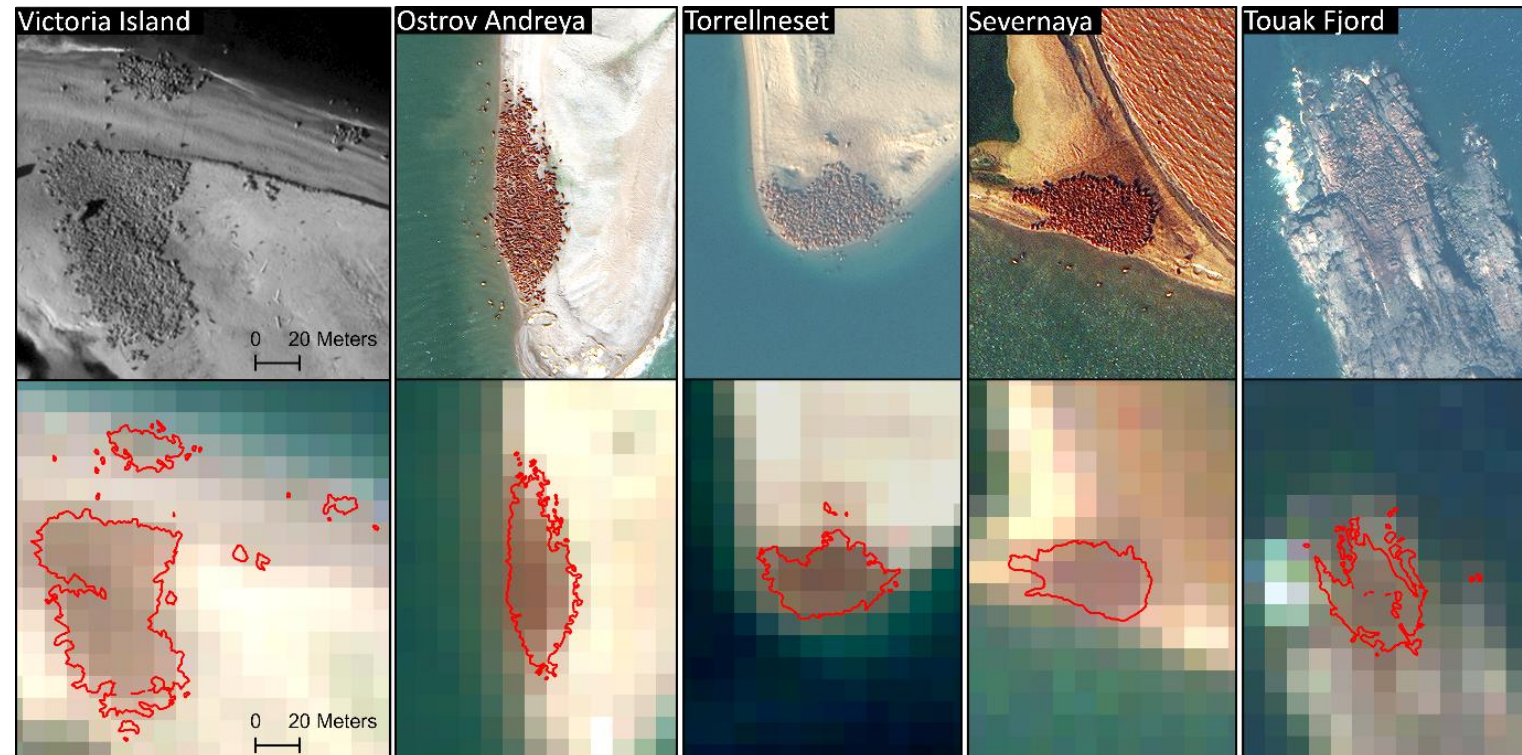
Looked for pairs in VHR image collection and Sentinel-2 archive

5 collected within approximately 2 hours of each other

Orthorectified, pansharpened, and performed geographic alignment

3 experts annotated WorldView data using polygon outlines

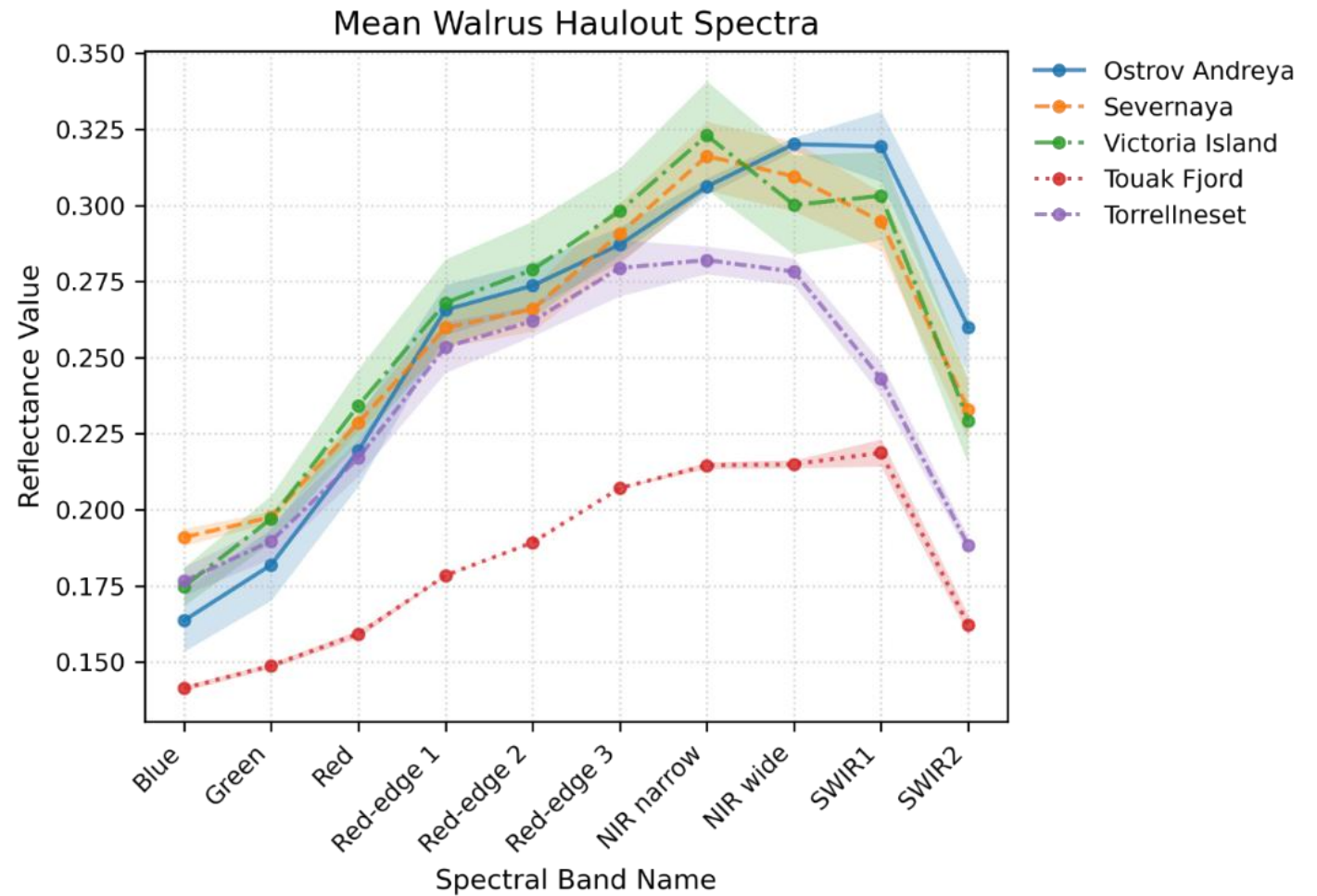
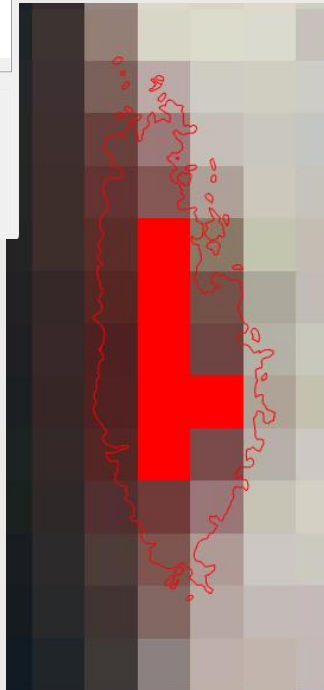
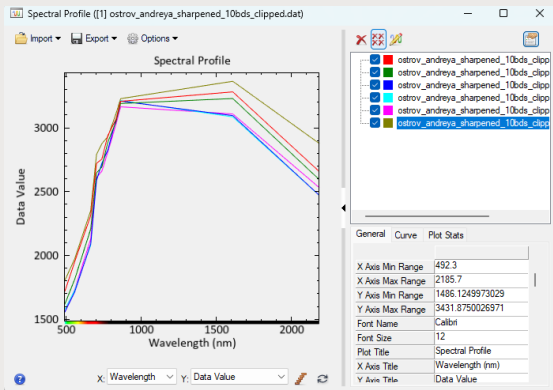
Haulout	VHR image	VHR image time	Sentinel image time	Time diff
Touak fjord (Canada)	WV3 MS (30cm)	2019-08-14 T15:56:46.834165Z	2019-08-14 T15:49:11.024000Z	00:07:35
Severnaya (Russia)	WV3 MS (40cm)	2019-08-26 T09:13:52.344427Z	2019-08-26 T08:55:59.024000Z	00:17:53
Ostrov Andrey a (Russia)	WV3 MS (30cm)	2018-08-08 T06:05:51.294777Z	2018-08-08 T05:26:39.024000Z	00:39:12
Victoria Island (Russia)	WV1 Pan (50cm)	2022-08-16 T14:52:28.784806Z	2022-08-16 T13:27:31.024000Z	01:24:57
Torrellneset (Svalbard)	WV3 MS (40cm)	2023-08-24 T14:50:06.027096Z	2023-08-24 T12:47:09.024000Z	02:02:57



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Extracting spectral signatures



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Ground truth fractional cover

Took intersection of expert
WorldView haul-out polygons

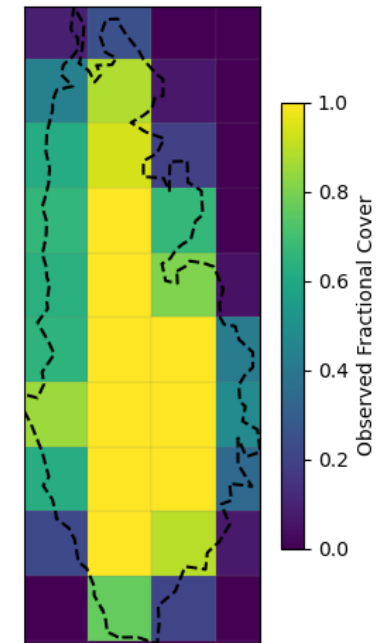
Made estimated fractional cover
by overlaying WorldView polygon
on Sentinel-2 pixel grid

Can then compare with MF-scores
output by MTMF

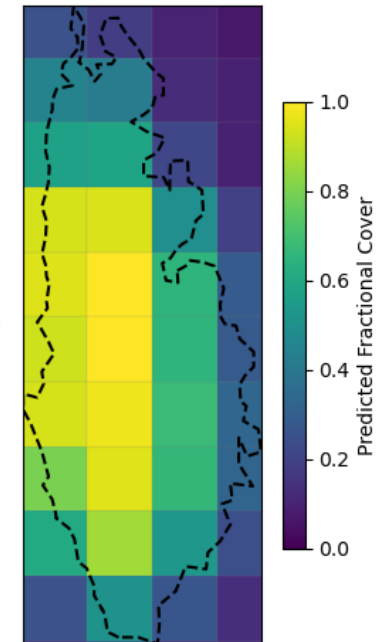
Polygon + fishnet



Observed Fractional Cover

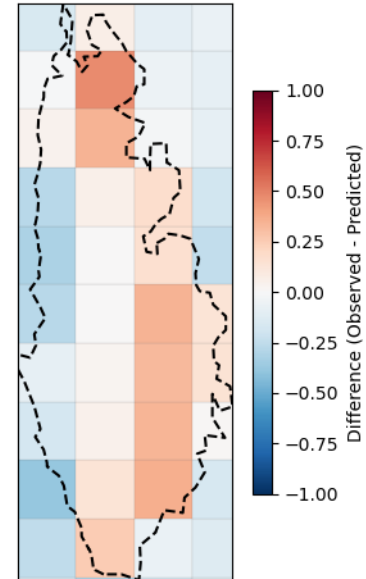


Predicted Fractional Cover



Compare

Difference in Fractional Cover



Mixture
tuned
matched filter



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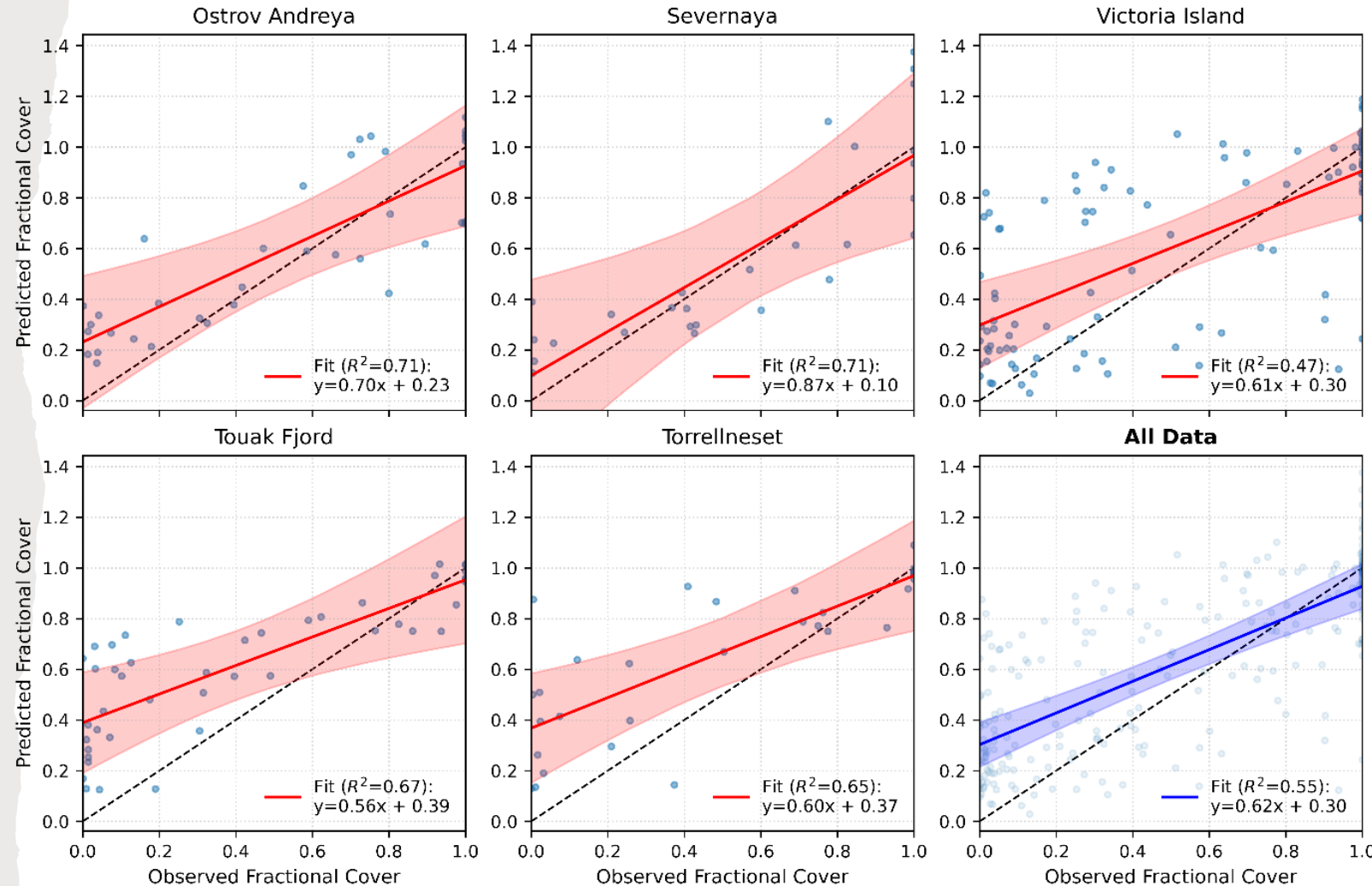
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Fractional cover relationship

Moderate to strong correlation at all sites ($R^2=0.47-0.71$)

Tends to over-estimate at low fractional cover

MTMF can output predictions greater than one



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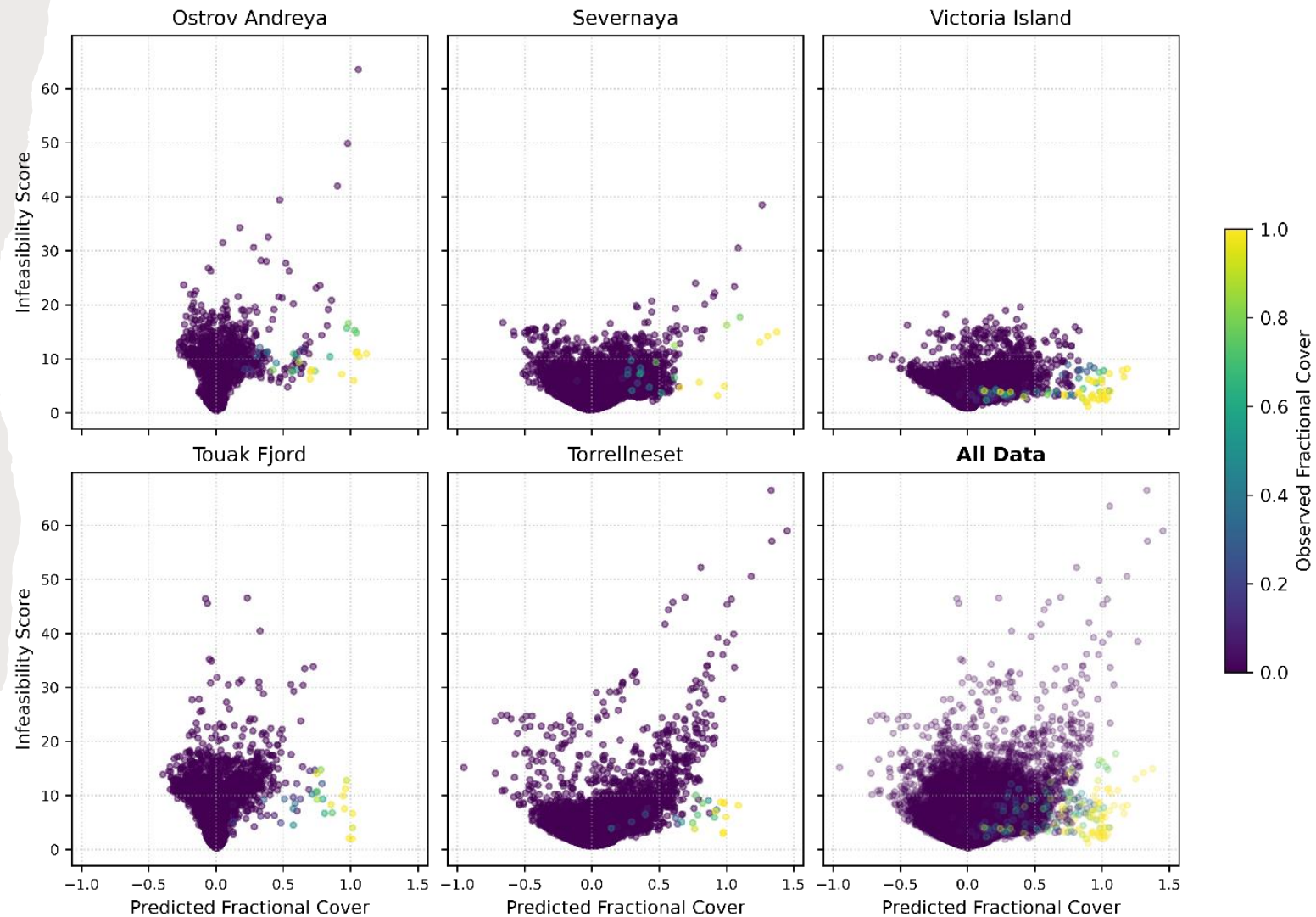
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MTMF classification

Combining MF and infeasibility score

Points coloured by observed fractional cover – can see good separation of yellow clusters

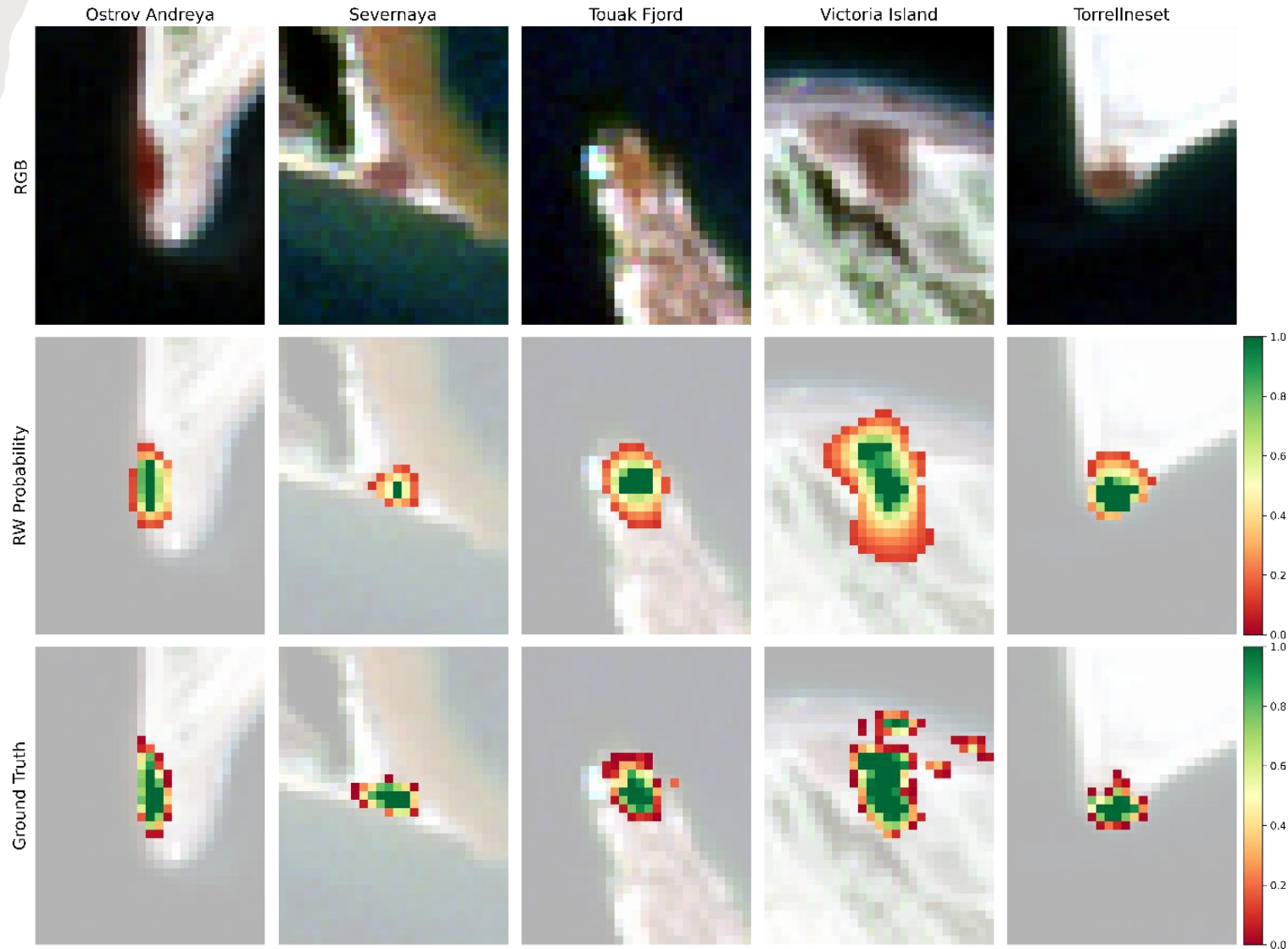
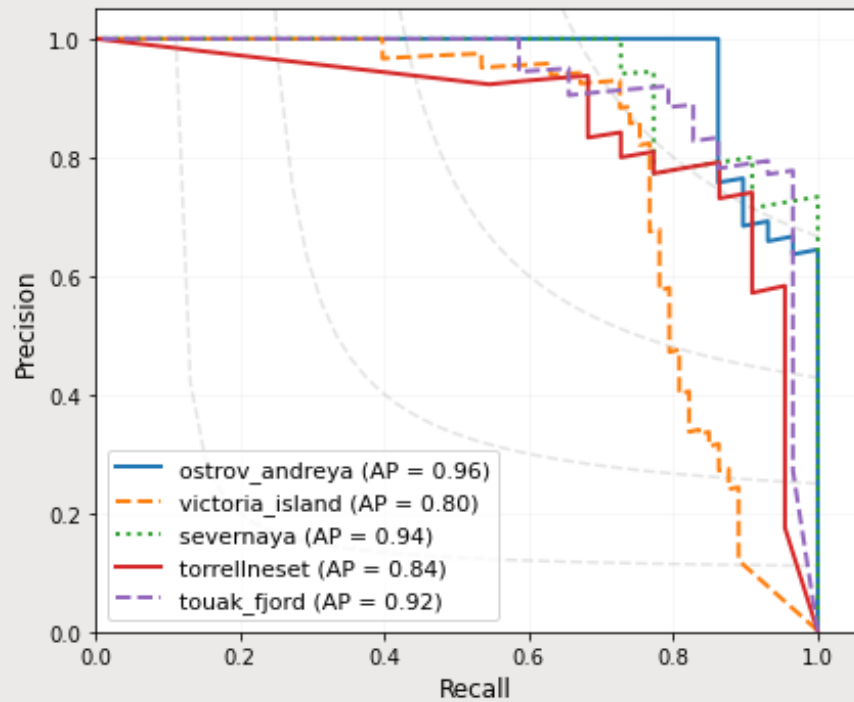
Look at clustering by factoring in spatial information as well



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Random walker outputs



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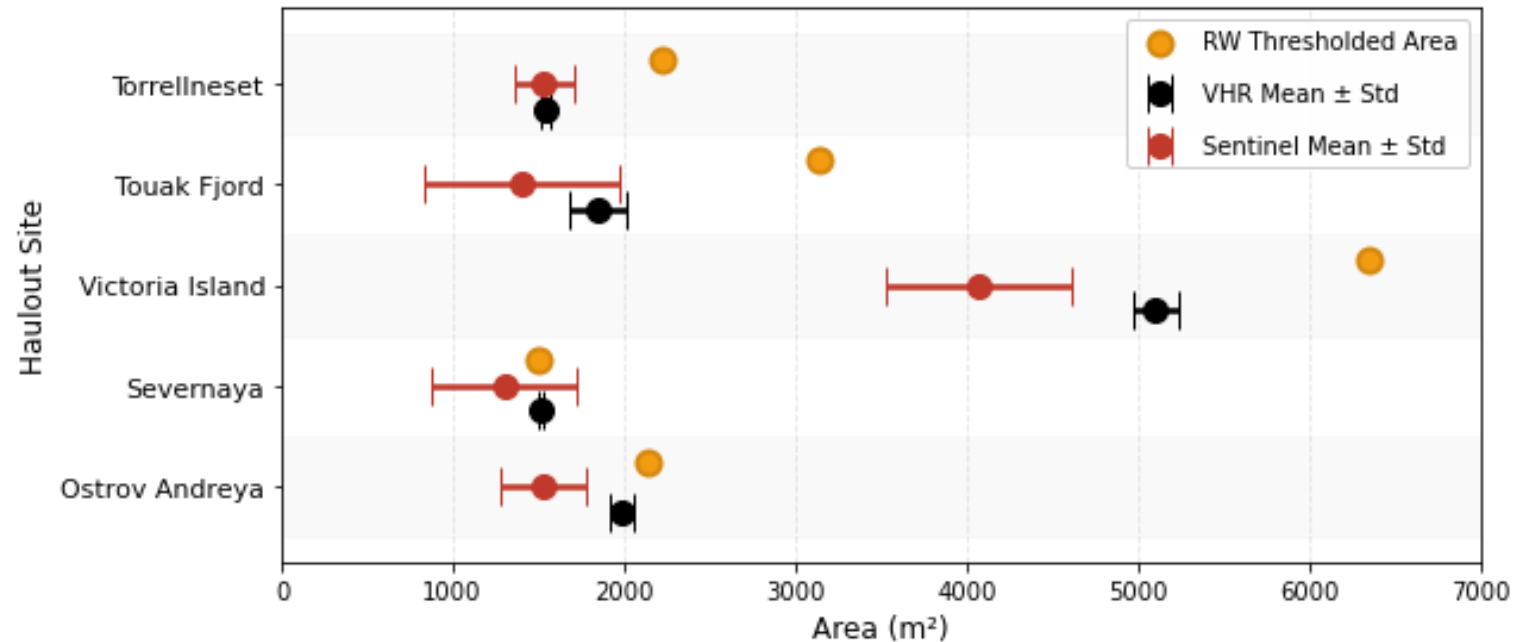
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Area estimates

Compare:

- VHR manual
- Sentinel-2 manual
- MTMF area

Haul-out	VHR manual	Sentinel-2 manual	MTMF
Torrellneset	1540 ± 31	1533 ± 170	2213
Touak fjord	1848 ± 161	1400 ± 572	3135
Victoria Island	5103 ± 130	4067 ± 544	6268
Severnaya	1515 ± 11	1300 ± 424	1393
Ostrov Andreyka	1985 ± 68	1533 ± 249	2097



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Future steps

Test how spectra transfer across sites

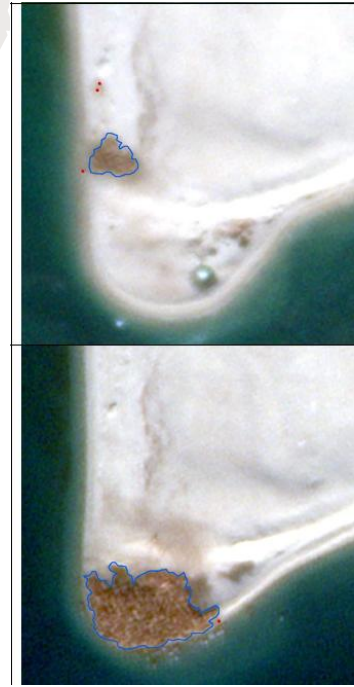
Test on smaller haul-out groups

Factor in timeseries information to improve results

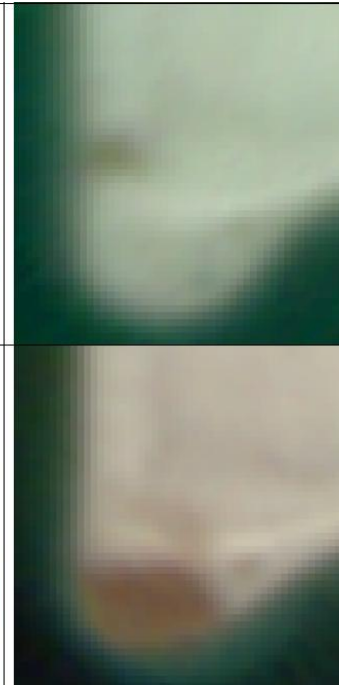
Explore PlanetScope data

Collect in-situ hyperspectral dataset

Skysat (~50cm)



PlanetScope (~3-4m)

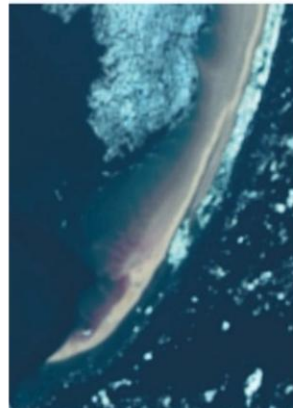


Project ideas

- Analyse whole sentinel-2 archive?
- Develop near real-time monitoring?
- Search for new haul-out sites?



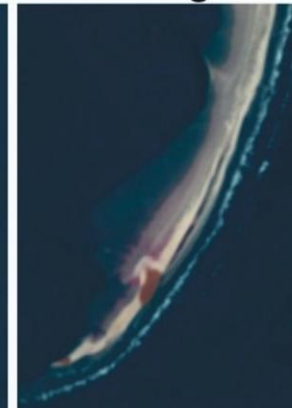
30th June



14th July



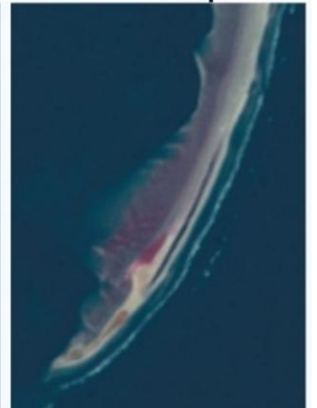
16th Aug



9th Sept

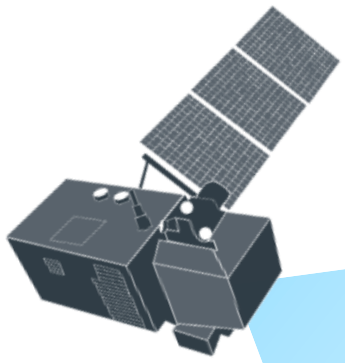


23rd Sept



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Thanks for listening! Any questions

Ellie Bowler, eller@bas.ac.uk



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