Semantic Enrichment of Sentinel-1 Data

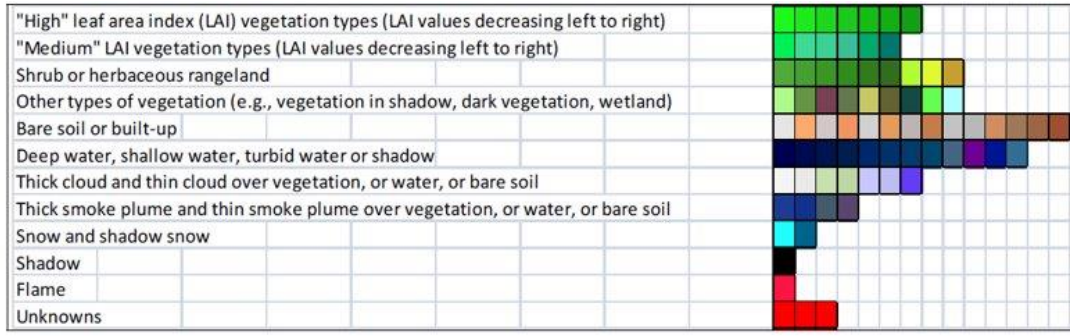
An Approach Suitable for Large-scale Analysis

17/06/2024 - EARSeL 2024, Manchester

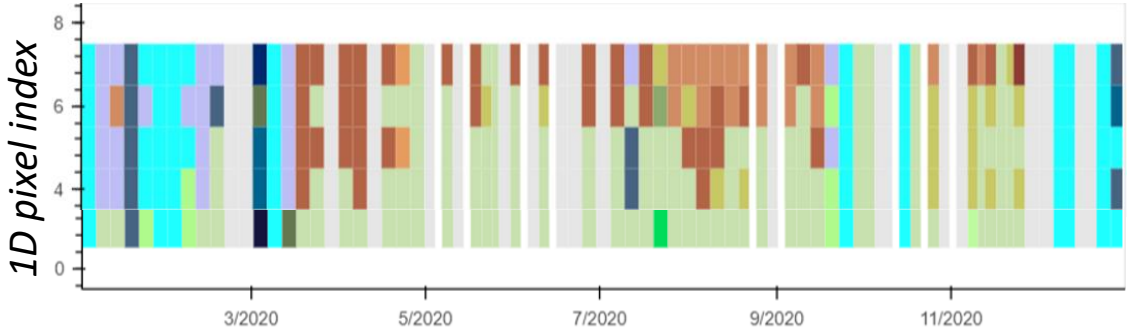
Luke McQuade, Dr. Martin Sudmanns, Assoc. Prof. Dirk Teide
@ EO Analytics, Dept. of Geoinformatics, PLUS

Semantic Enrichment – Sentinel-2

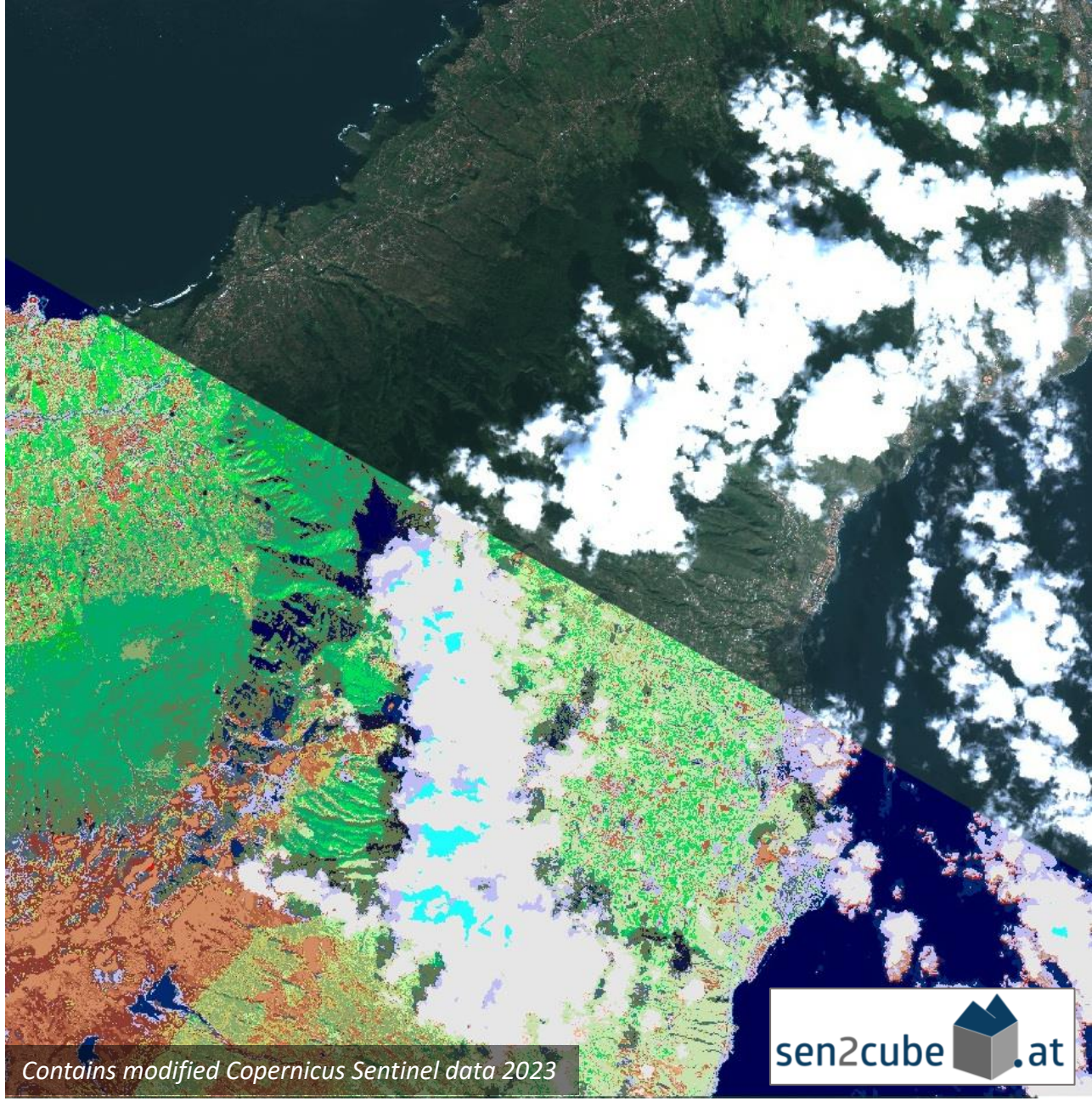
SIAM (Satellite Image Automatic Mapper) (*Baraldi et al 2018*): Spectral categories



+ Approx. 5-day revisit time => intuitive time-series analysis (Augustin et al, 2019)



But, problem: Clouds.
=> Can we do something like this with Sentinel-1 SAR imagery?

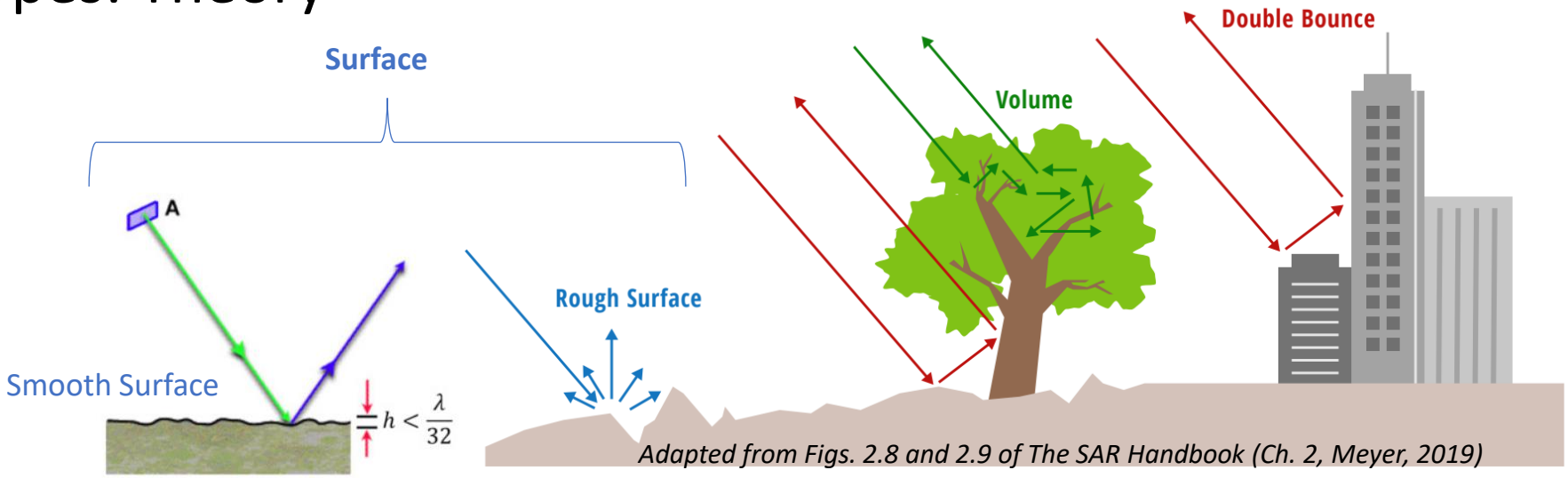


Tenerife, Jan. 2023, processed with SIAM

Sentinel-1

- C-band SAR, 5.55cm wavelength
  => Signals pass through clouds.
- Dual-polarimetric, typically VV and VH regularly captured over land.

Scatterer types: Theory

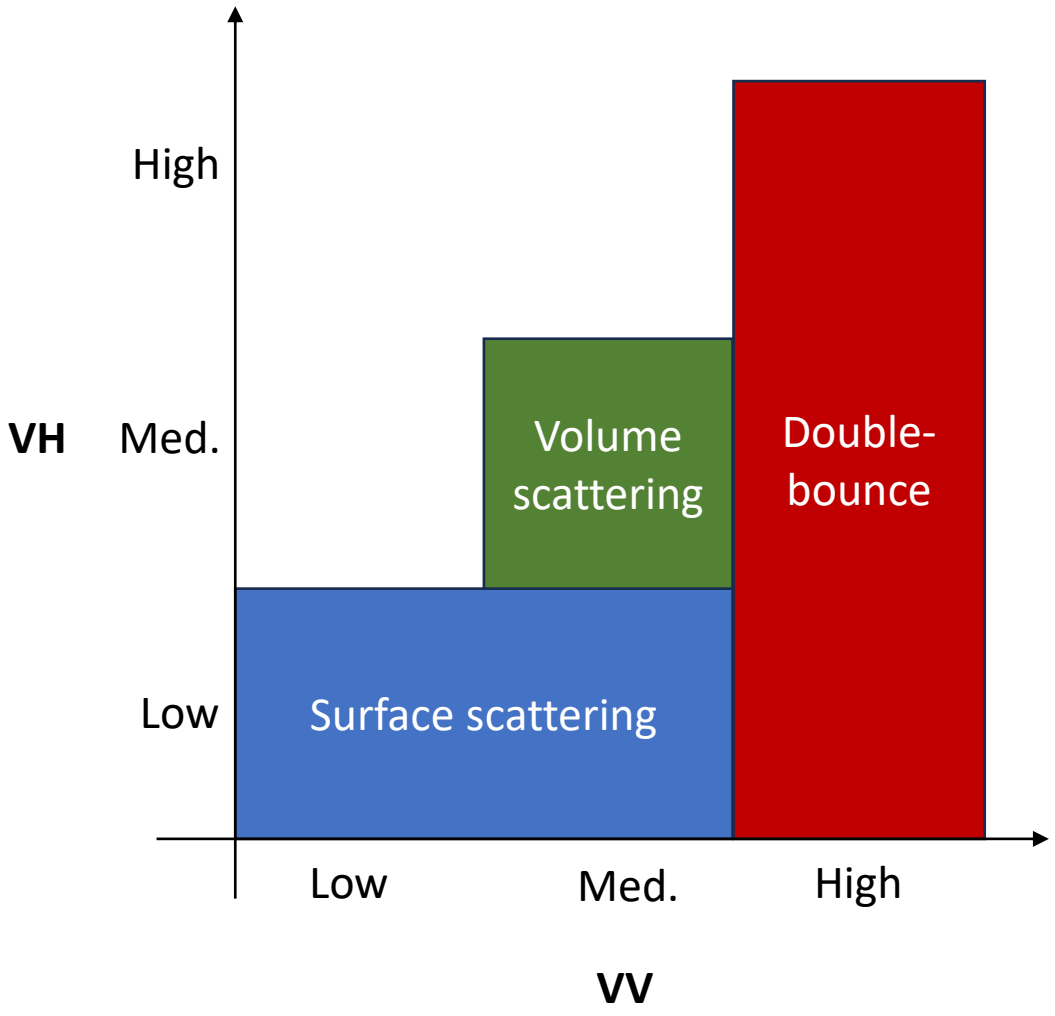


Adapted from Figs. 2.8 and 2.9 of The SAR Handbook (Ch. 2, Meyer, 2019)

Typical S1 Backscatter

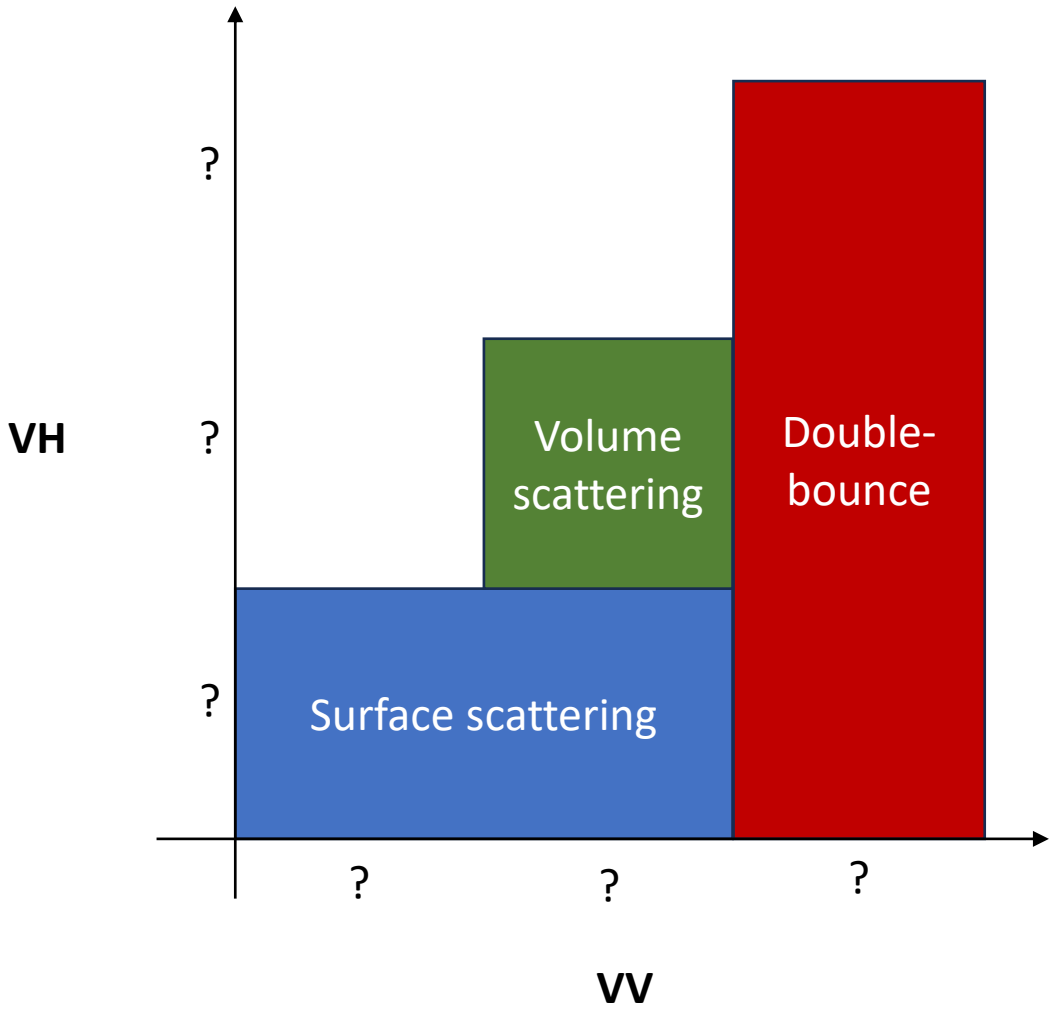
VV	Low	Medium	Medium	High
VH	Low	Low-Medium	Medium	[High]
E.g.	Calm water, tarmac	Ploughed field, lava field	Vegetation, snowpack	Buildings, cliffs

Semantic Enrichment for Sentinel-1?



Polarimetric categories.

What numbers to use?



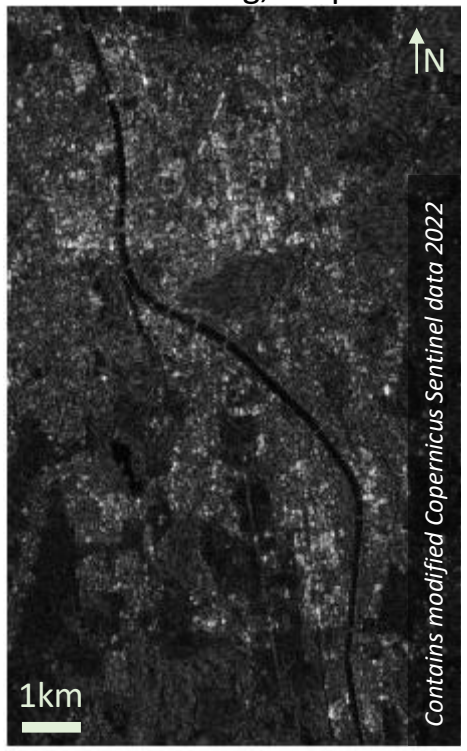
Backscatter dataset:

- Sentinel-1 RTC (Catalyst, Microsoft Planetary Computer) [*]
- IW, GRD
- Orthorectified
- 10m x 10m pixel grid
- Speckle-filtering applied

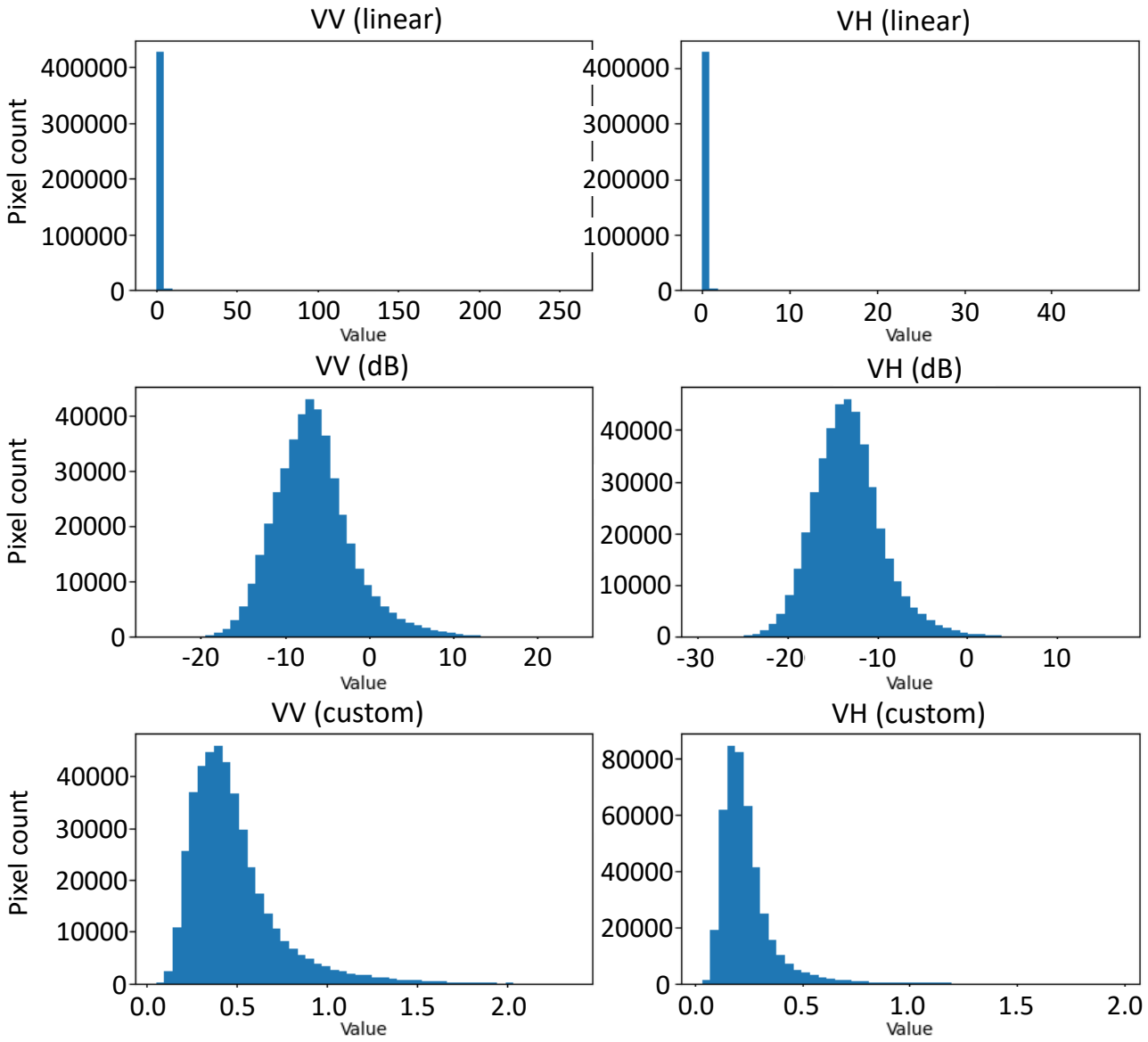
[*] https://planetarycomputer.microsoft.com/dataset/sentinel-1-rtc

What numbers to use?

S1 scene extract, VV:
Around Salzburg, 4-Apr-2022



$$y = \sqrt{\log(x+1)}$$



Hugely skewed.

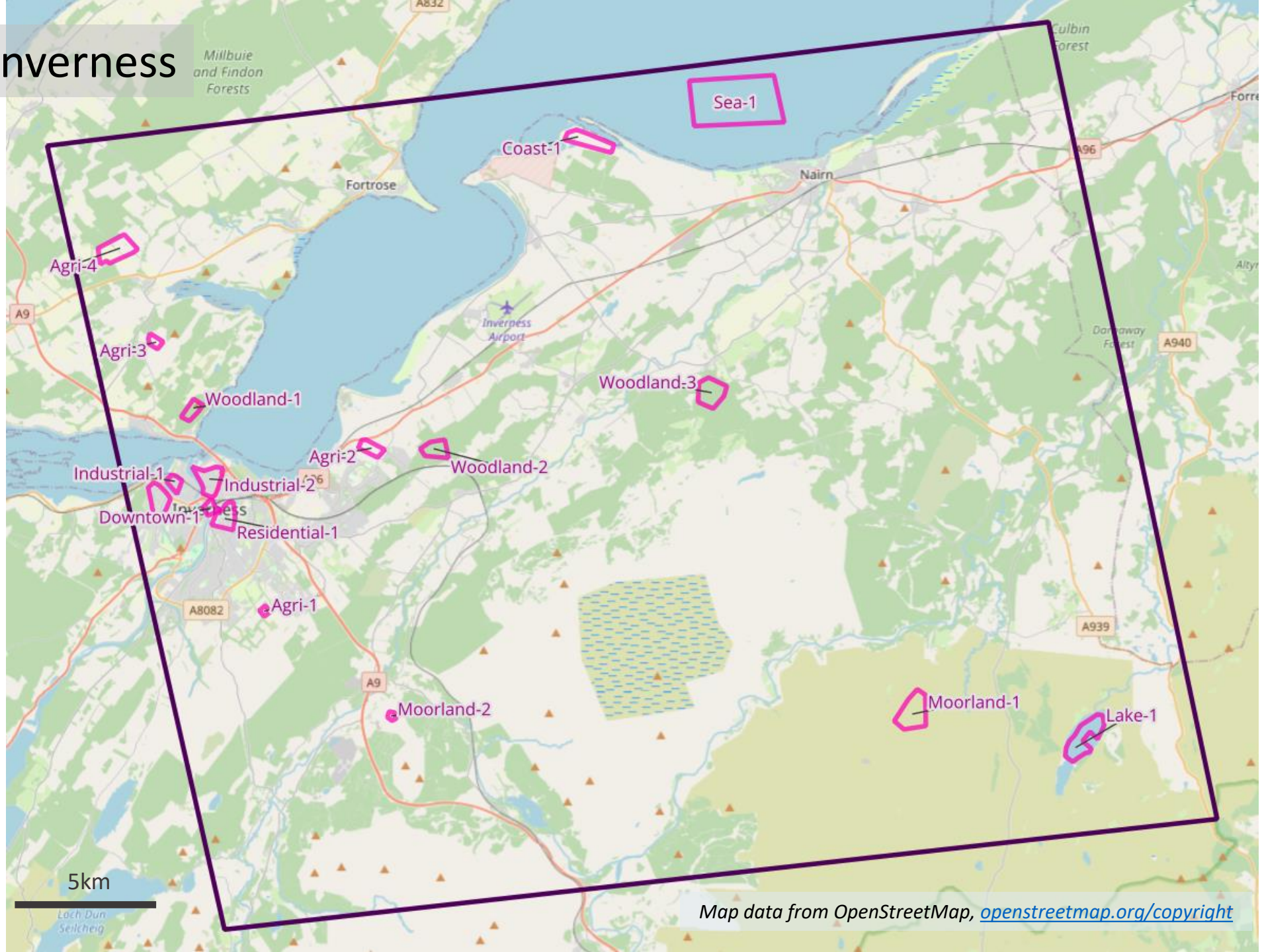
Inconvenient range,
varies between images?

Mostly between 0 and 1.
(Some additional skew.)

Scene ID: S1A_IW_GRDH_1SDV_20220604T165923_20220604T165948_043516_05321B_rtc

Around Inverness

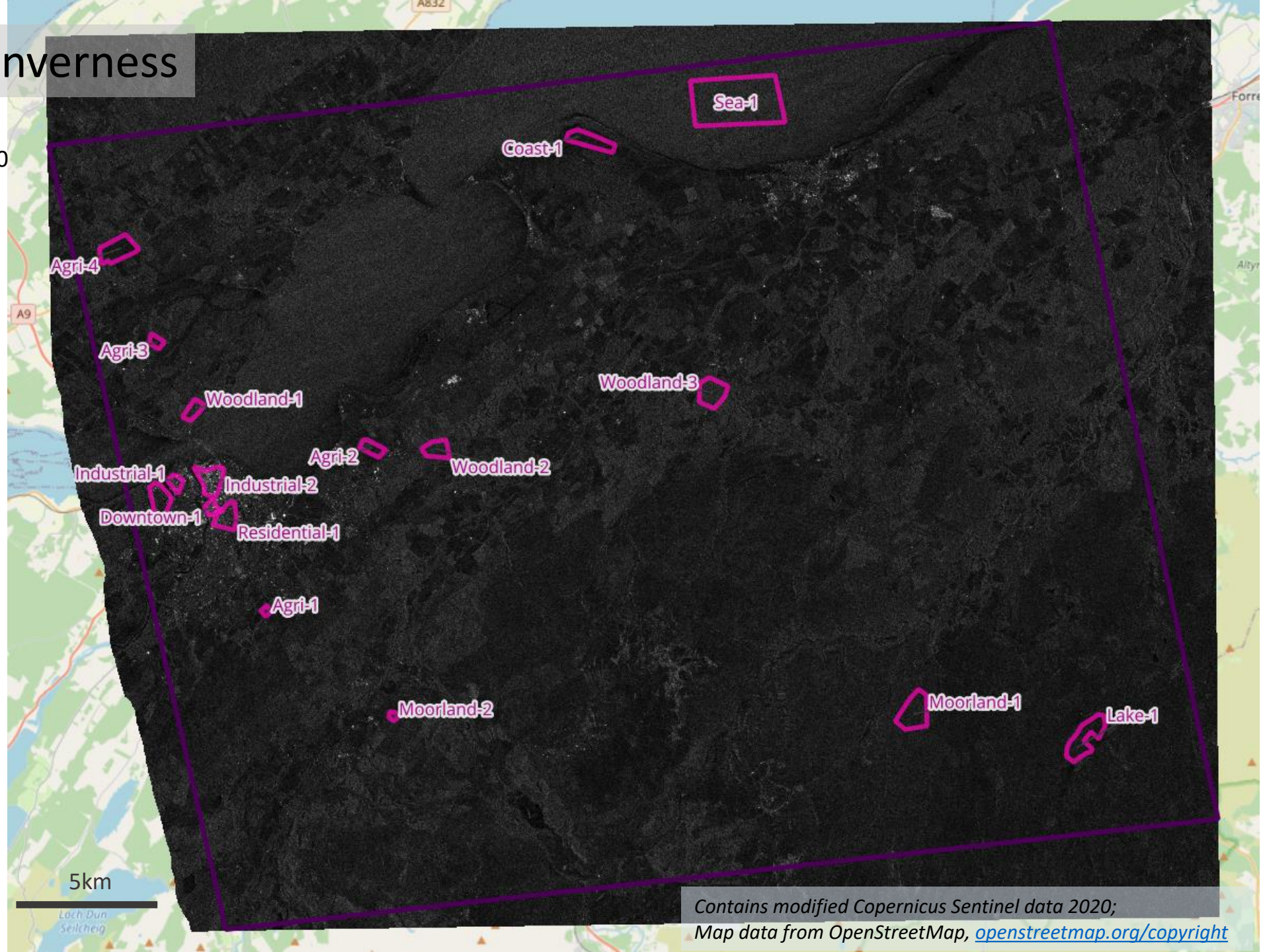
Sample area



Around Inverness

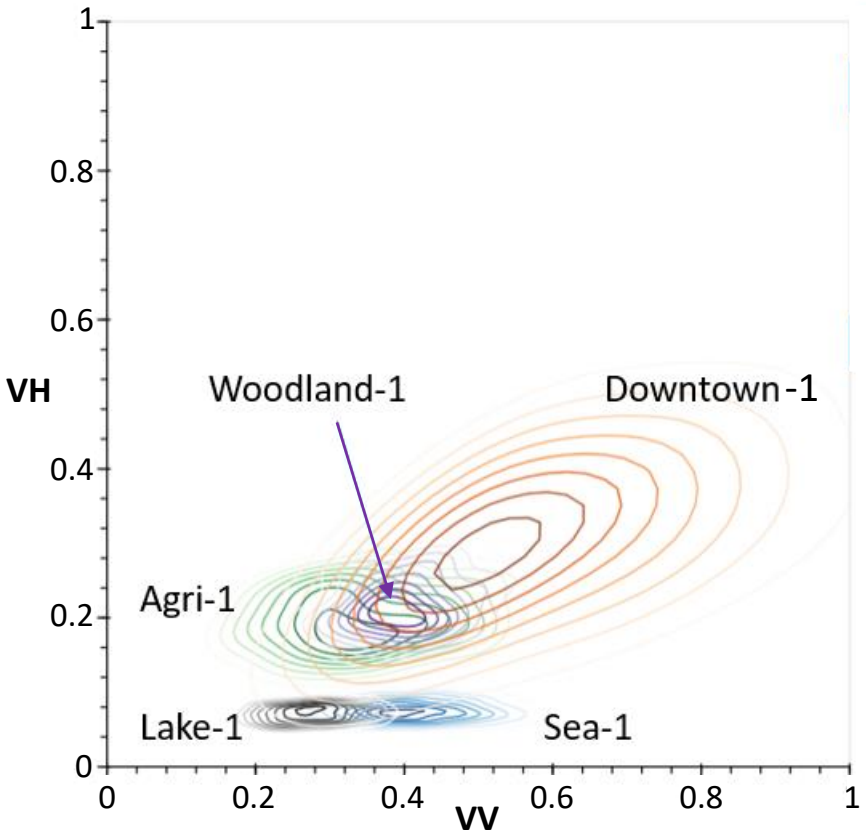
S1, VV, 25-Aug-2020

Sample area

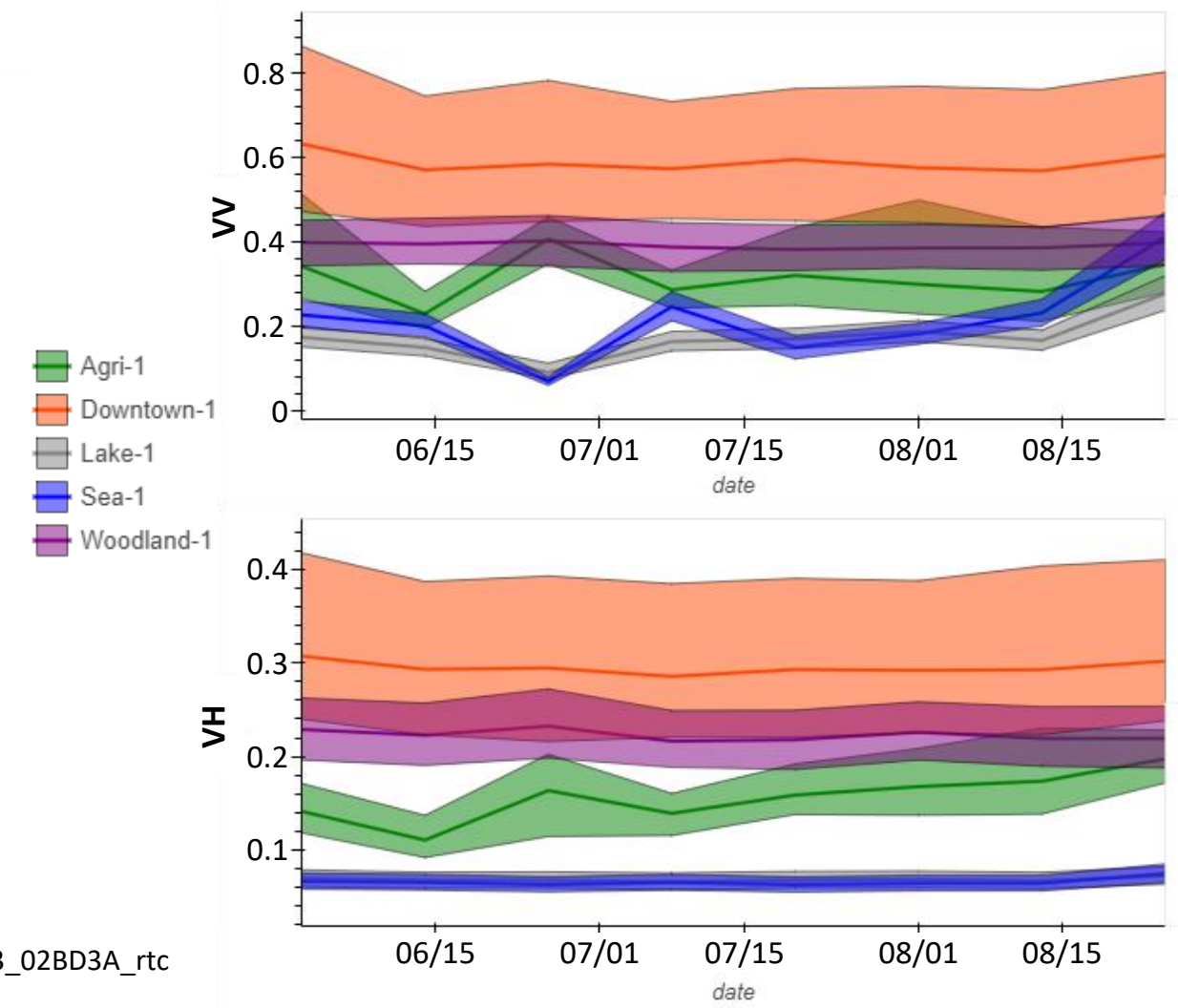


Around Inverness

Distribution density, 25-Aug-2020



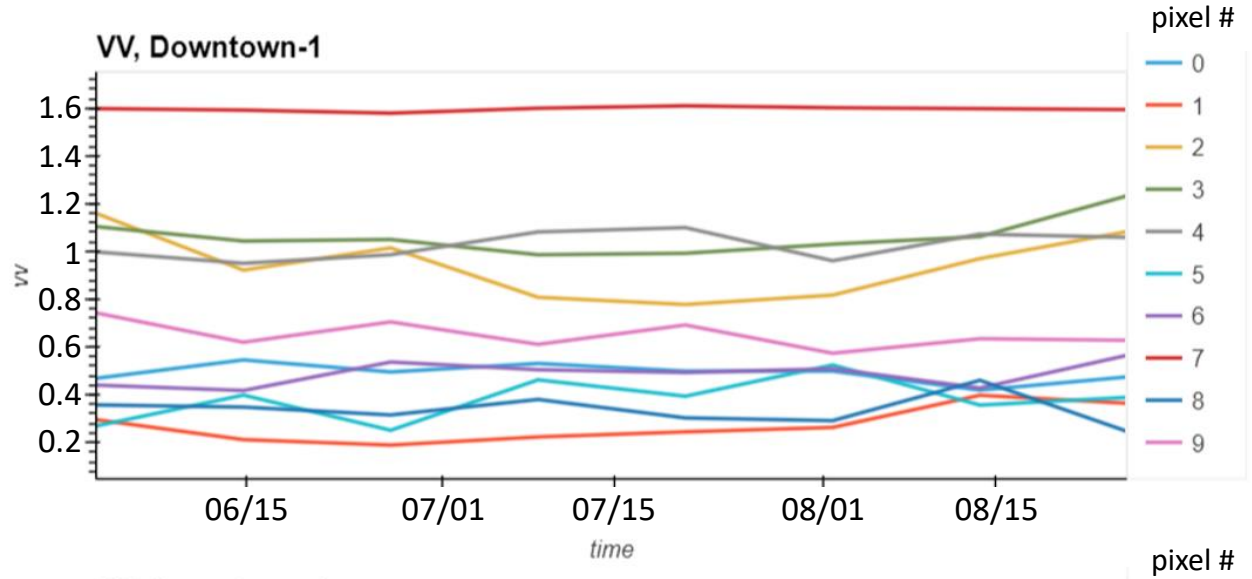
Time-series, sample medians and IQRs, Jun-2020 to Aug-2020

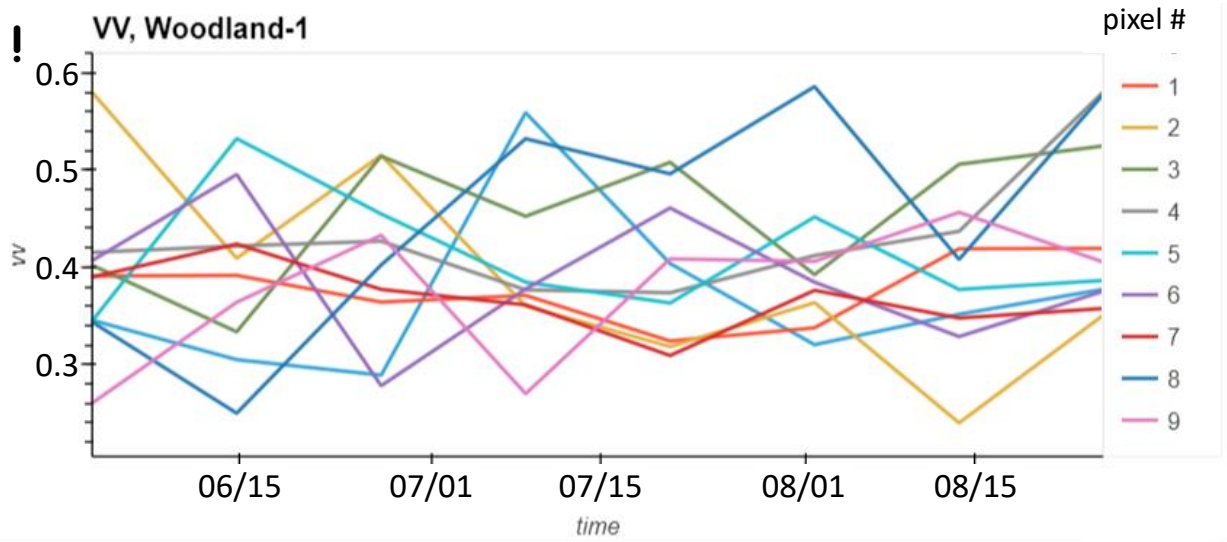


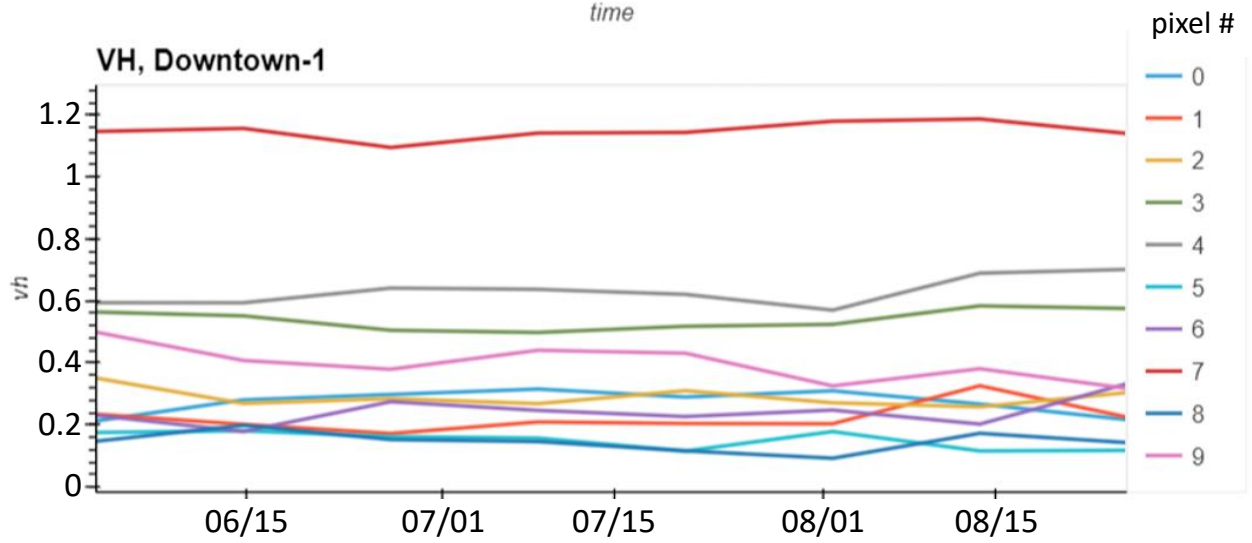
S1 scene/item ID:
S1B_IW_GRDH_1SDV_20200825T175046_20200825T175111_023083_02BD3A_rtc

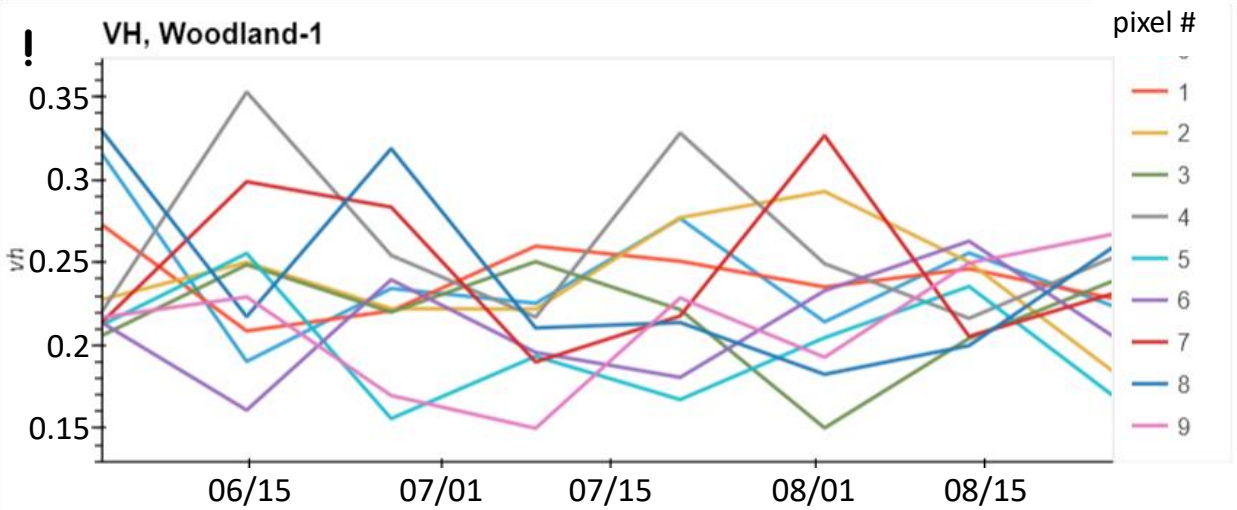
Around Inverness

Time-series, 10-pixel subsamples, Jun-2020 to Aug-2020





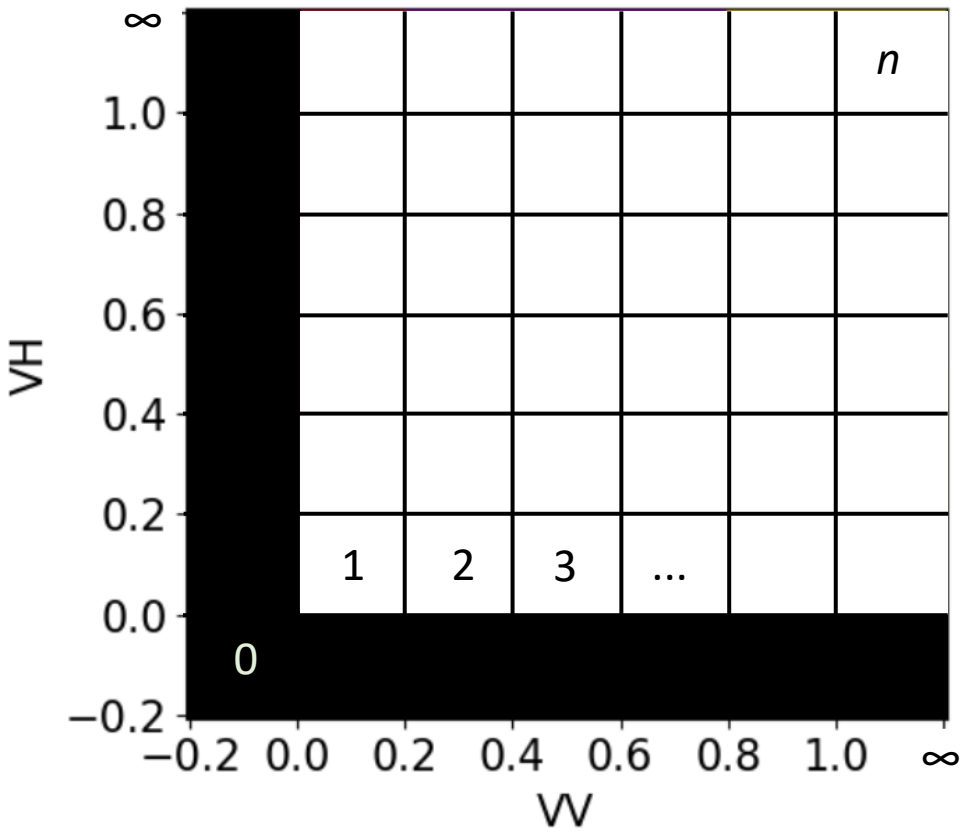




! = Note different axis limits

Revised Categories

Starting point: Regular binning



Revised Categories

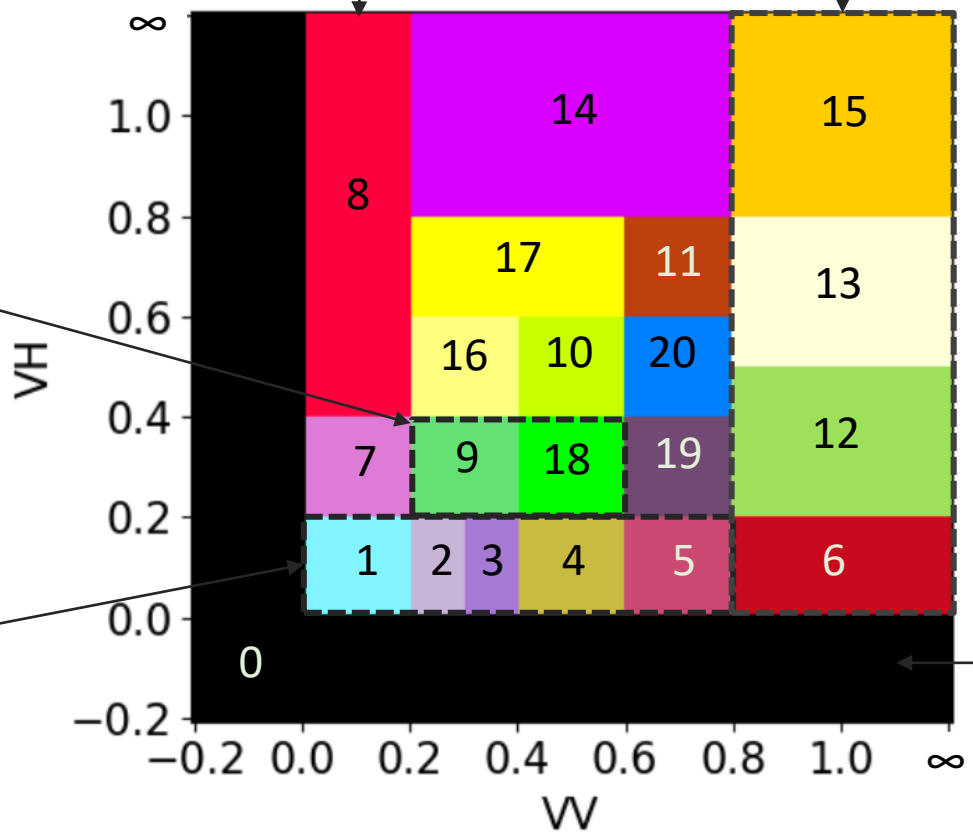
After several more experiments...

8: Physically ill-defined

6,12,13,15:
Mostly double-bounce

9,18:
Mostly volume scattering

1,2,3,4,5:
Mostly surface scattering
(smooth to rough)



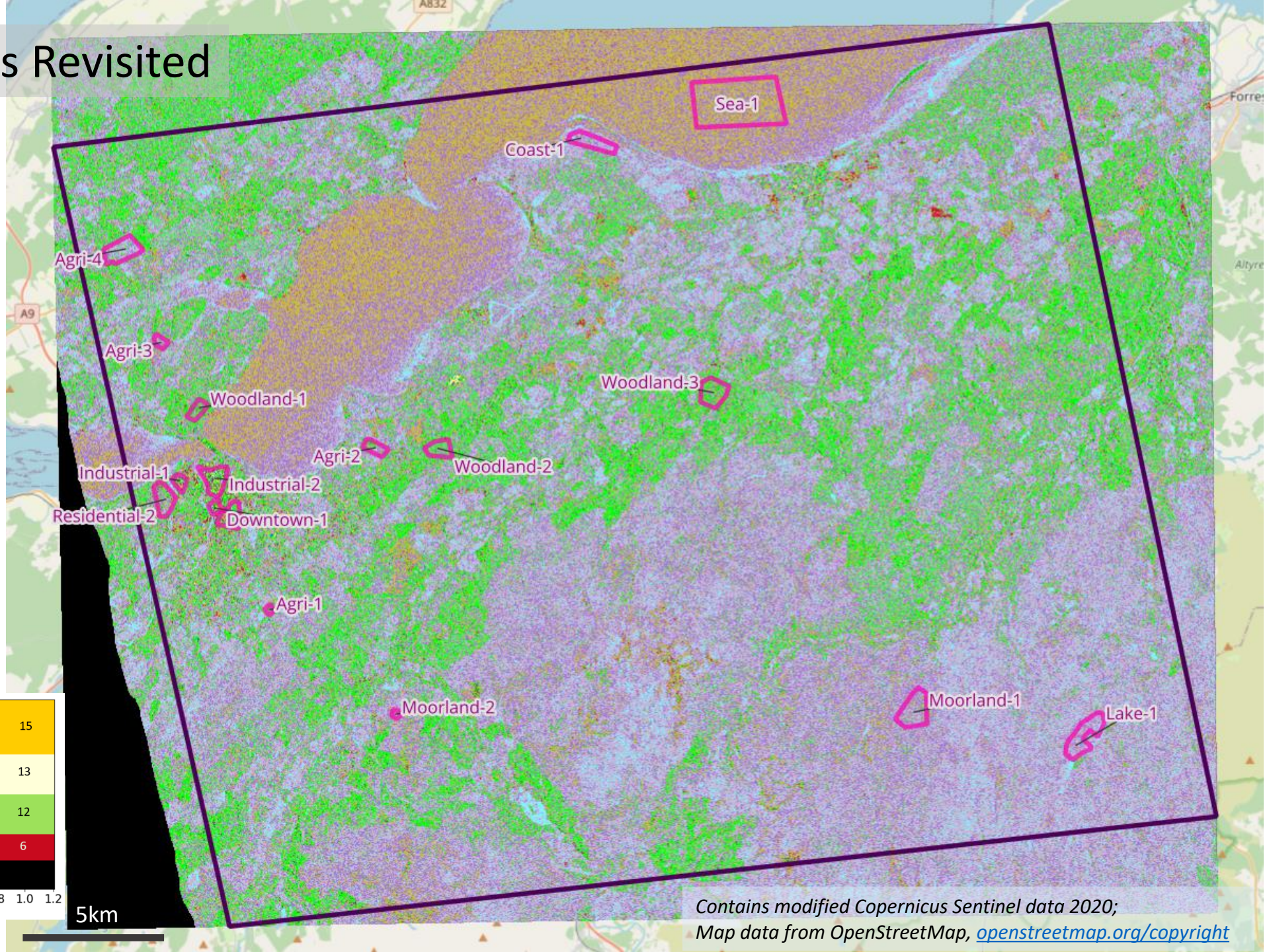
0: NoData/Invalid

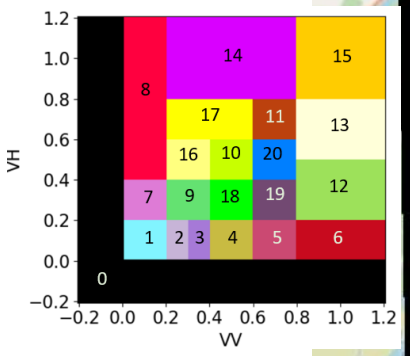
Others:
Mixed or complex interactions

Inverness Revisited

Pol. categories,
25-Aug-2020

Sample area





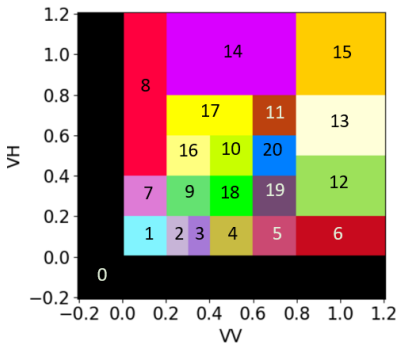
Inverness Revisited

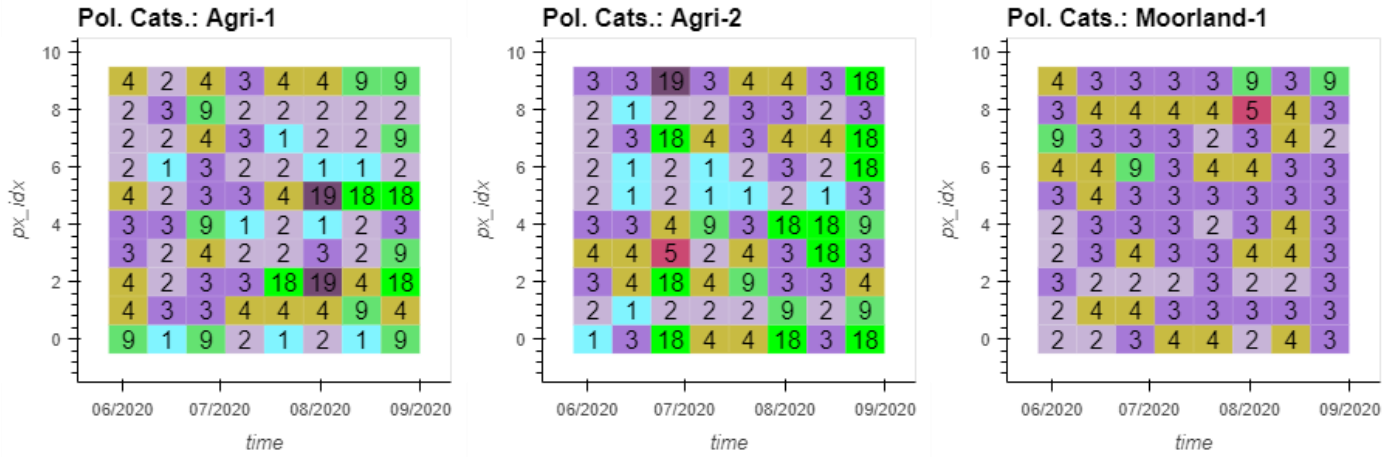
Category time-series

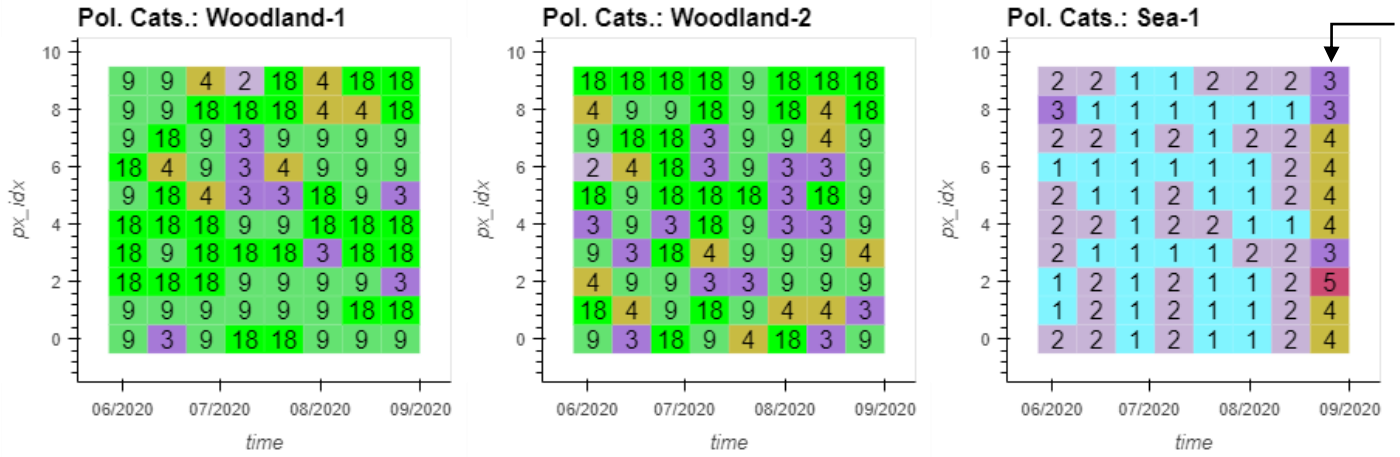
Clear differences:

- Composition
- Behaviour over time

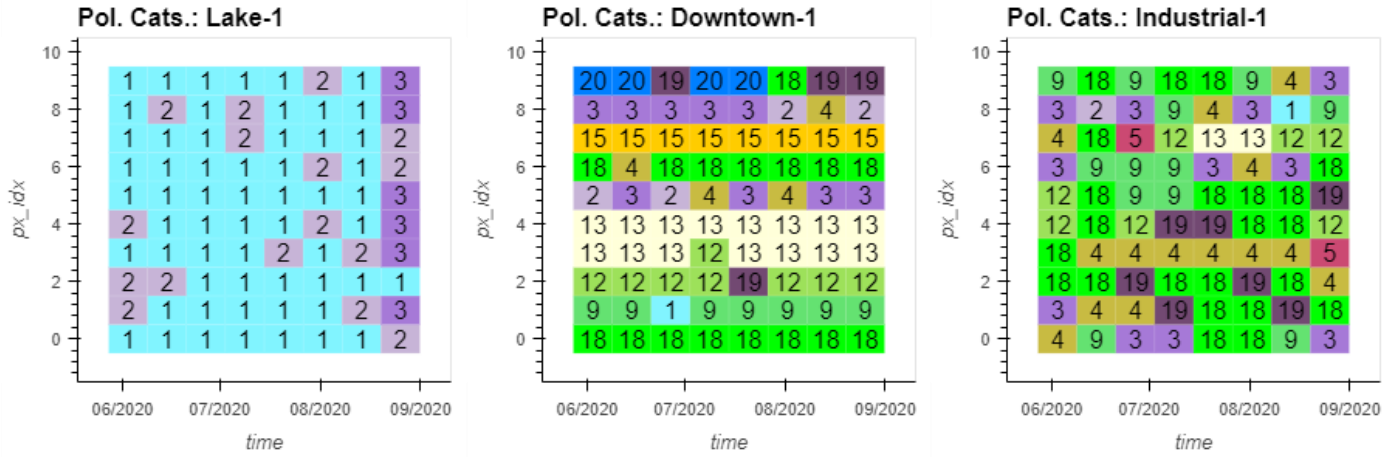
Categorical stability.





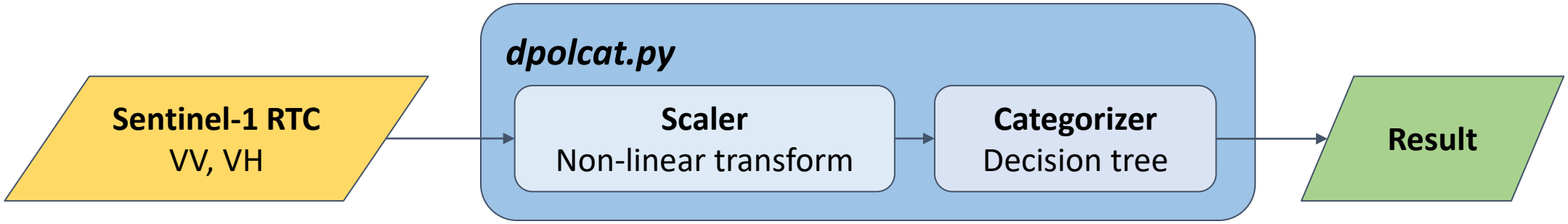


Notice change to rougher surface categories here. It was windy then! (https://www.timeanddate.com/weather/uk/inverness/historic?month=8&year=2020).



Implementation

https://github.com/lukesdm/dpolcat



Suitable for Big Earth Data Analytics?

- Pixelwise processing => Embarrassingly parallel
- Parameter-free => Use on any scene, across slices
- ~4 minutes to process a Sentinel-1 scene (single core).

Numba

numba.pydata.org/

dask

www.dask.org/

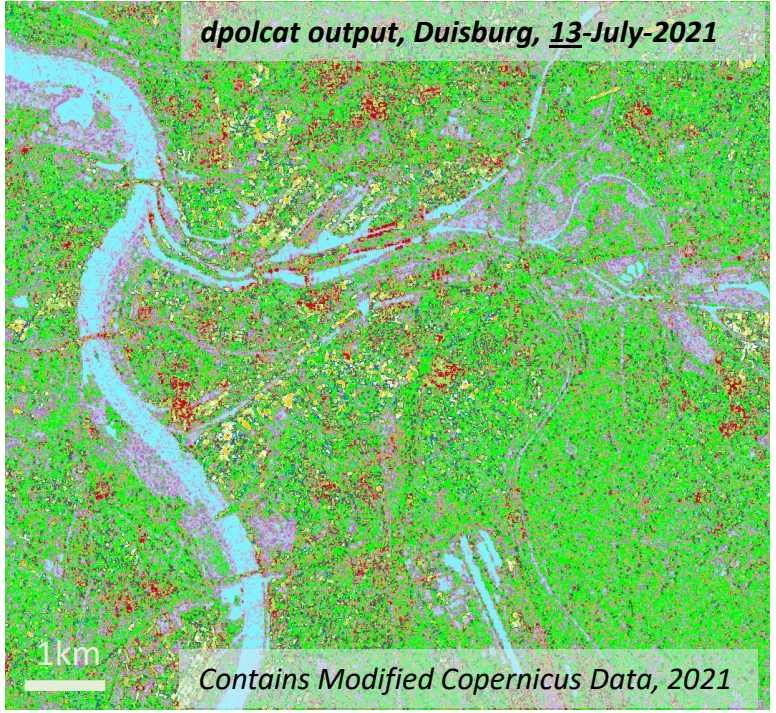
Microsoft | Planetary Computer

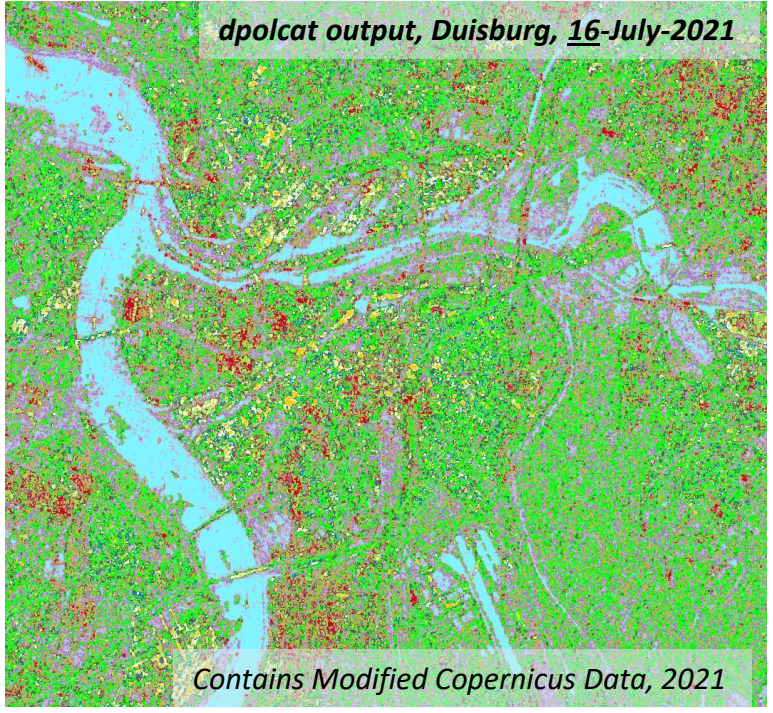
planetarycomputer.microsoft.com/

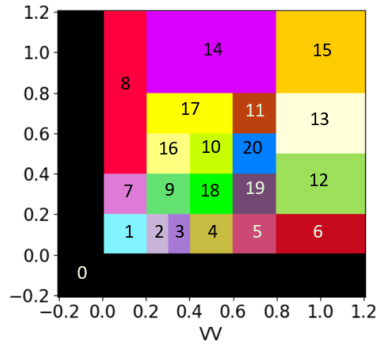
Usage Example: Flood Mapping

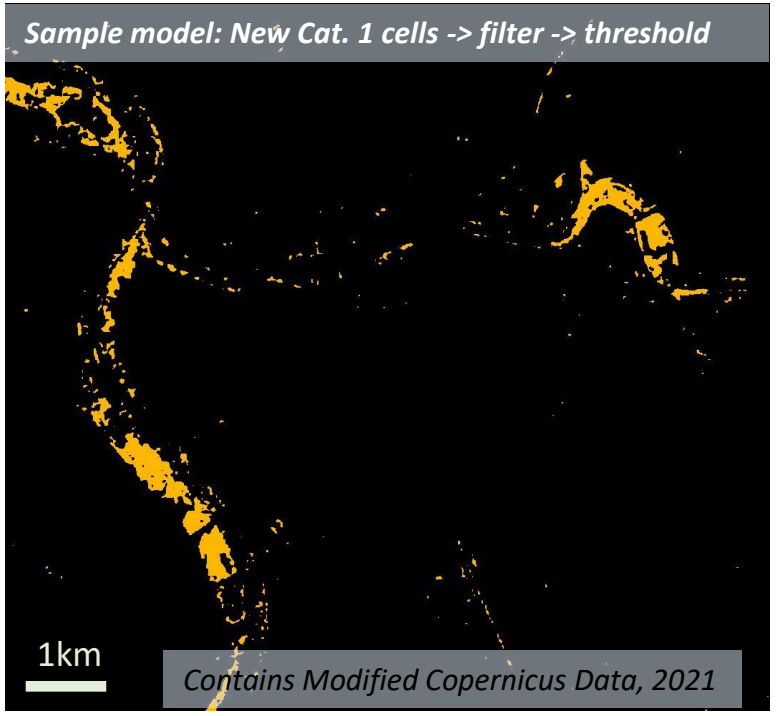
Floods around Duisburg, Germany, July 2021

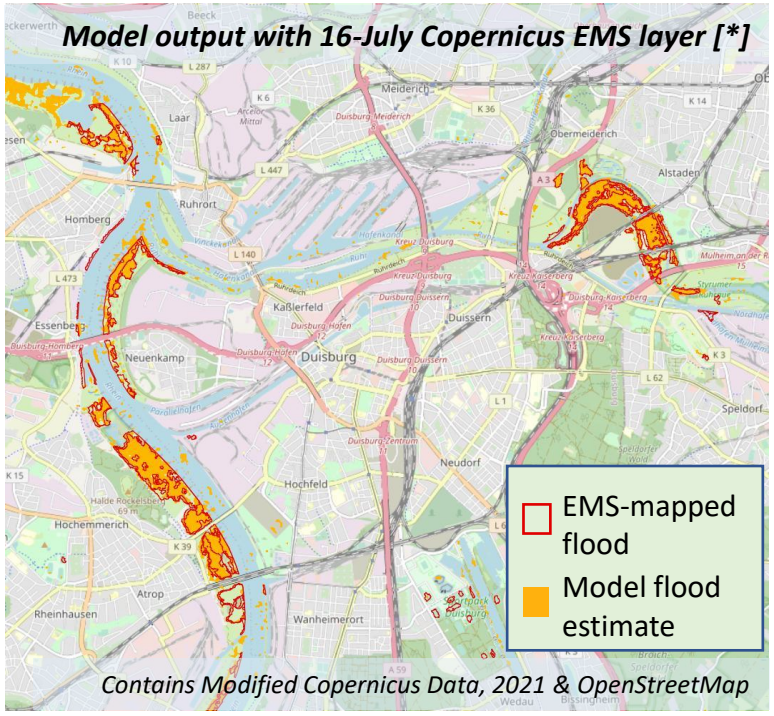
Model: New instances of smooth surface (cat. 1) pixels likely to be floodwater.











[*]: Copernicus EMSR517

Discussion

Key points:

- Landcover can consist of several different scatterer types.
- No 1:1 mapping of category to surface type.
- Considerable variation across space and time.
- *dpolcat* is not a robust classifier, on its own.

Possible next steps:

- Refine scaling function (less skew).
- Test on more areas, further refine categories.
- Integrate with Sentinel-2.
- Explore new applications.
- Your ideas?

Acknowledgements

Dr. Zahra Dabiri - Risk Hazard and Climate Lab, Z_GIS

Co-funded by Horizon Europe project LEONSEGS

Co-funded by the European Union

Microsoft | Planetary Computer

References

Augustin, H., Sudmanns, M., Tiede, D., Lang, S., & Baraldi, A. (2019). Semantic Earth observation data cubes. Data, 4(3), 102. DOI: 10.3390/data4030102

Baraldi, A., Humber, M.L., Tiede, D., Lang, S. (2018). GEO-CEOS stage 4 validation of the Satellite Image Automatic Mapper lightweight computer program for ESA Earth observation level 2 product generation – Part 2: Validation. Cogent Geosci. 4, 1–52. DOI: 10.1080/23312041.2018.1467254

Meyer, F. (2019), Ch. 2, The SAR Handbook: Comprehensive Methodologies for Forest Monitoring and Biomass Estimation. DOI: 10.25966/nr2c-s697

luke.mcquade@plus.ac.at

https://github.com/lukesdm/dpolcat