Detecting and Monitoring of Water Hyacinth in Lake Victoria Using Radar Polarimetric Data

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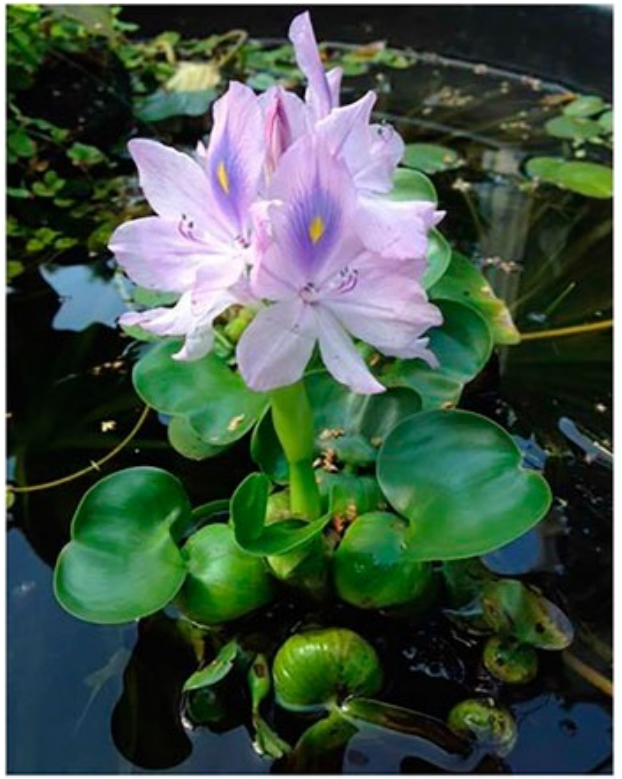
Introduction

- Water Hyacinth is an invasive species native to South America
- A single plant can produce 140,000,000 daughter plants in a year
- Introduced to lake Victoria in 1889
- It has formed mats that cover areas in hundreds of hectares
- Remote sensing offers a cheaper monitoring option compared to field measurements
- SAR offers any day, time and weather monitoring capability through microwave RS

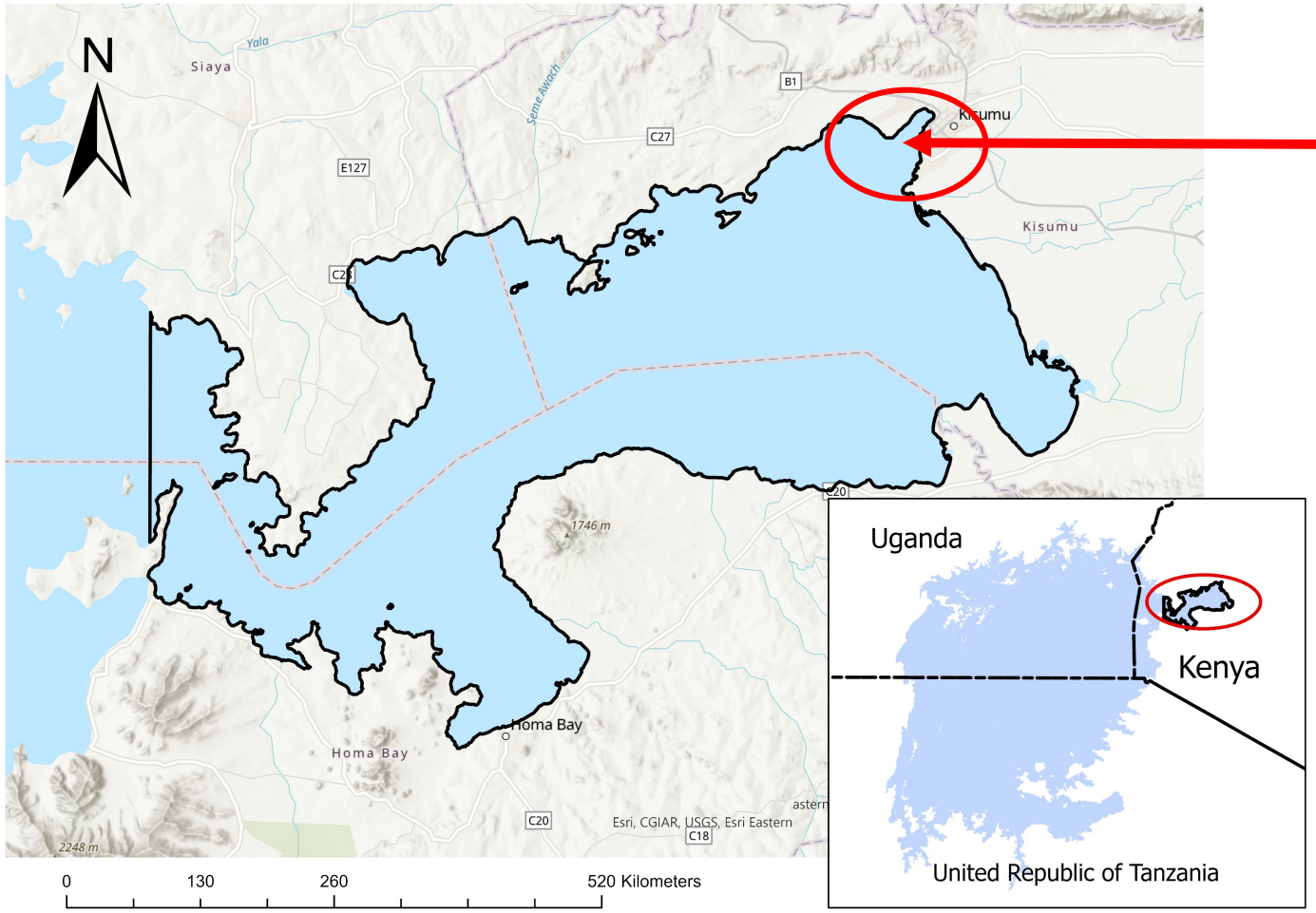
Karouach *et. al*.



- Scientific name: *Eichhornia Crassipes*
- Can extend up to 1m above the water

Study Area

Winam Gulf – Lake Victoria



Source: *https://www.theguardian.com/global-development/2019/aug/27/kenya-water-hyacinth-wonder-source-biofuel*

Methodology

Steps

Pre-Processing → **Co-registration** → **Change Detection**

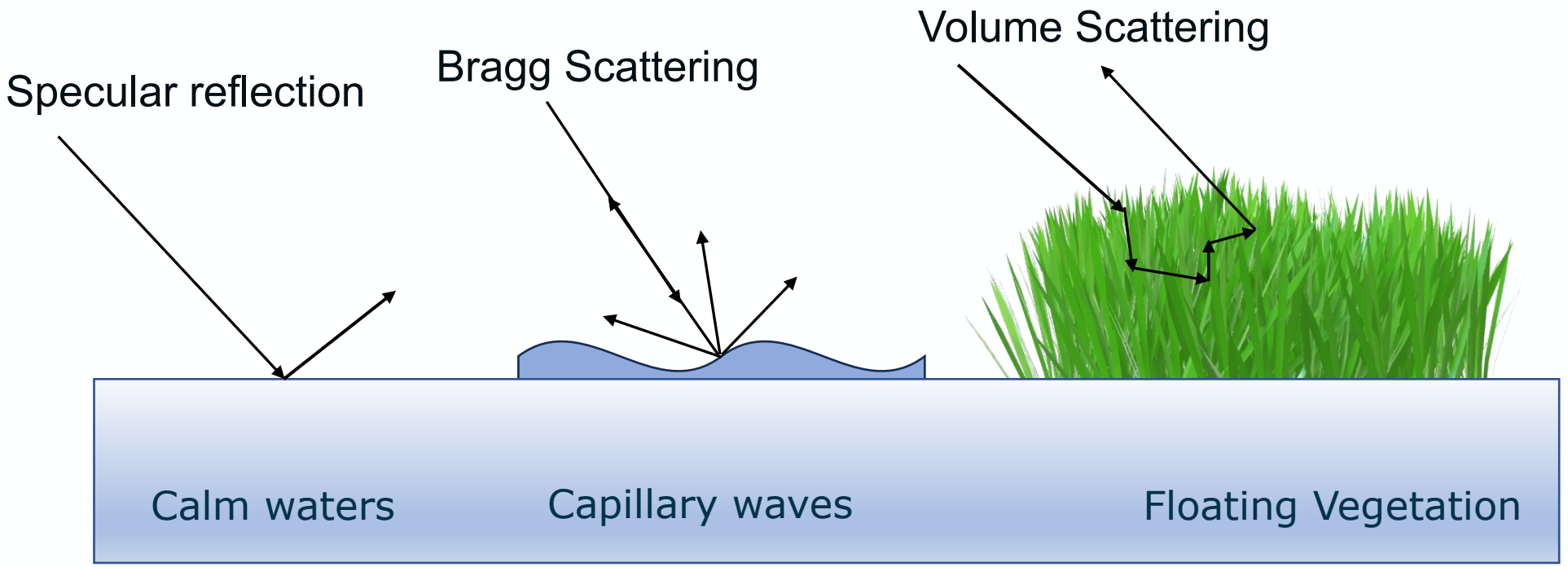
- ESA SNAP GPT(graph builder)
- Calibration of data
- Polarimetric covariance matrix (CM) (VV, VH & VV*VH)
- Multi-looking
- Filtering and terrain correction

- Creation of stacks
- Cross-correlation and Warp
- Aligns all images for time series comparison

- Optimization of Power Difference(OPDiff)
- Use of eigen-decomposition
- Subtraction of two CM of two dates
- Resulting change matrix shows mechanisms with max. and Min. change
- Reference without WH against image with WH

WH Scattering

- **WH** will exhibit **volume** scattering due to its properties
- The surrounding **waters** will experience surface or **Bragg scattering** depending on wind speeds
- Smooth water will appear darker, WH waters will appear brighter



Change detection: OPDiff

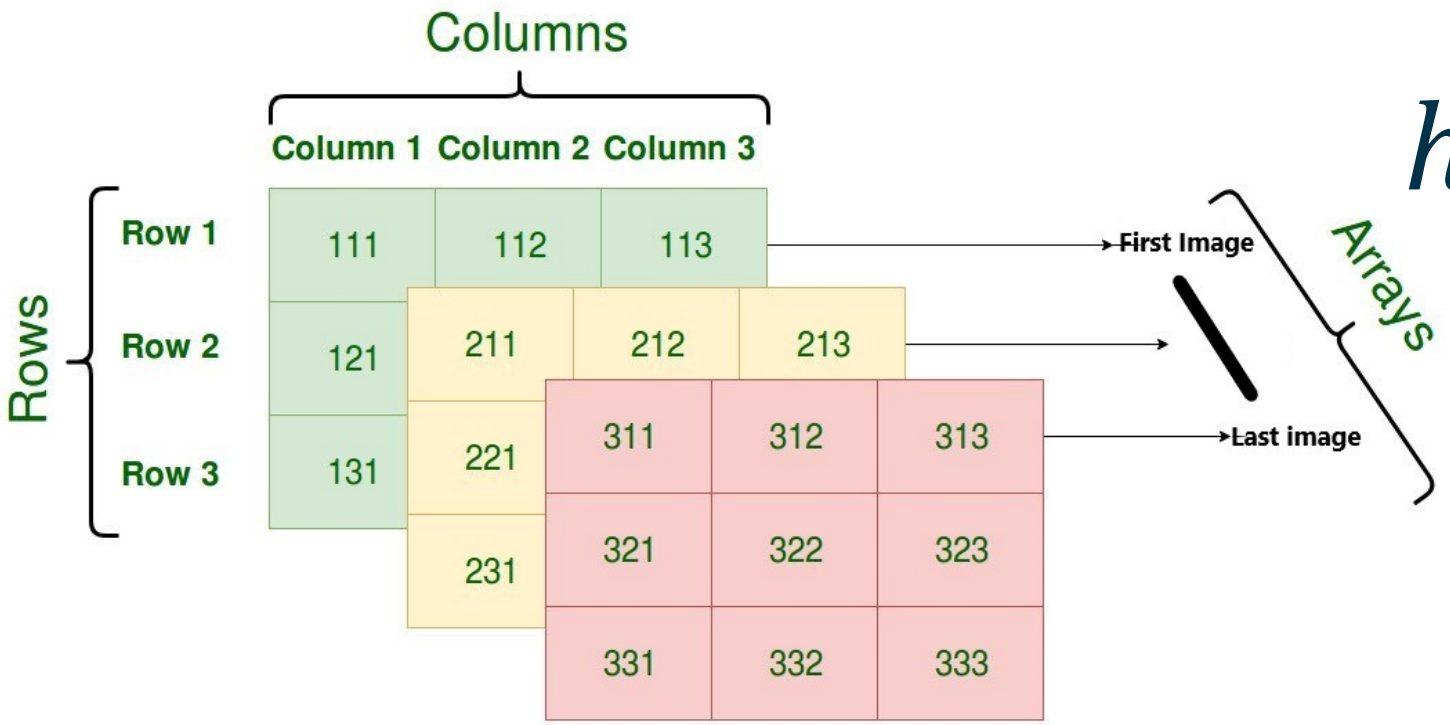
- Optimisation of Power Difference (Referred to as OPDiff) *(Marino, 2022)* was applied for change detection

$$\Delta = \underline{\omega}^{*T}([T_{22}] - [T_{11}])\underline{\omega} = \underline{\omega}^{*T}[T_c]\underline{\omega}$$

$$[T_c]\underline{\omega} = \lambda\underline{\omega}$$

- The OPDiff was the best performing algorithm for WH in an evaluation by *Simpson et al.,*
  - the accuracy of the *VH_Intensity_Difference* detector was 30% for medium density, 70/75% for high density and 5% for low density WH. The OPDiff detector performance was 85% for medium density, 98% for high density, and 35% for low density.
- Unlike in *Simpson et al*., where maximum eigenvalues were used, in this research, **minimum eigenvalues** were utilized in change detection.
- **The second changing scattering mechanism (SM) detects increases in volume, but it rejects increases in surface scattering e.g. wind, which only excite one SM.**

Heatmap generation



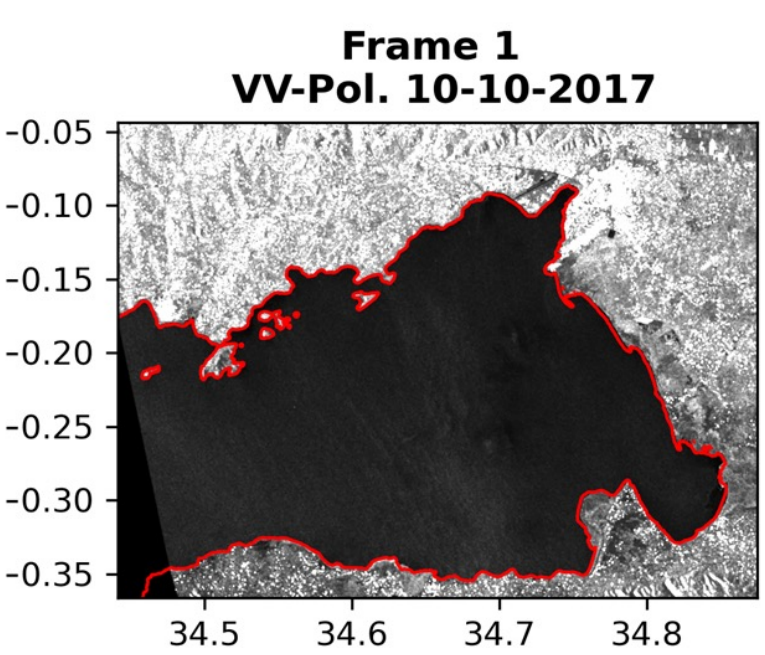
$$h = \frac{\sum binary\ map}{n}$$

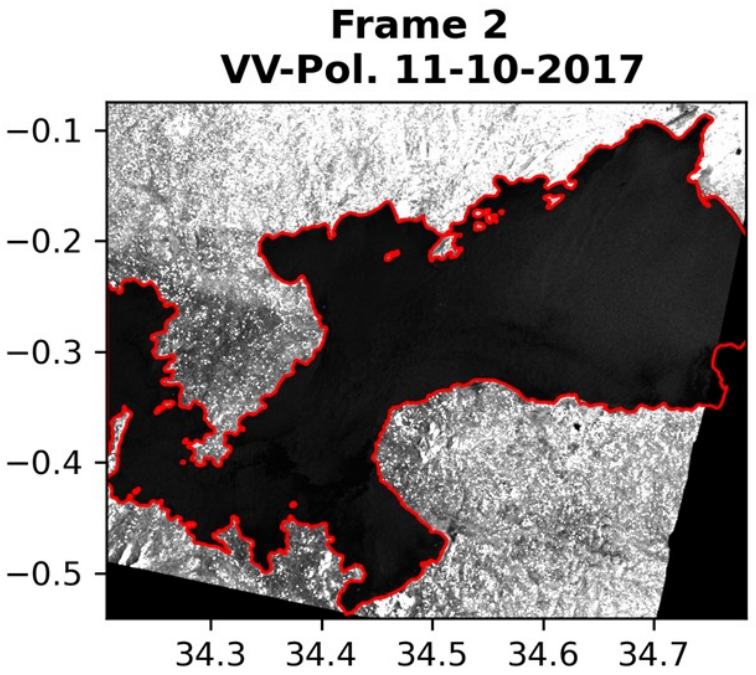
- ***h*** is the heatmap
- Where $\sum binary\ map$ is the sum of binary images with 1 for WH and 0 for clear water
- ***n*** is the total number of images in a stack

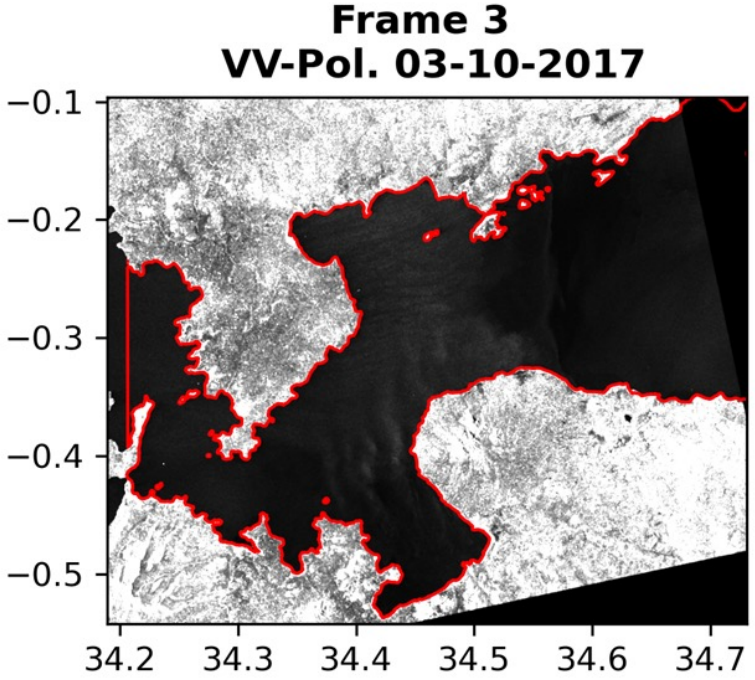
Data

- SAR Sentinel-1 IW SLC data
- Number of datasets - 438
- Data processing - SNAP-GPT, python

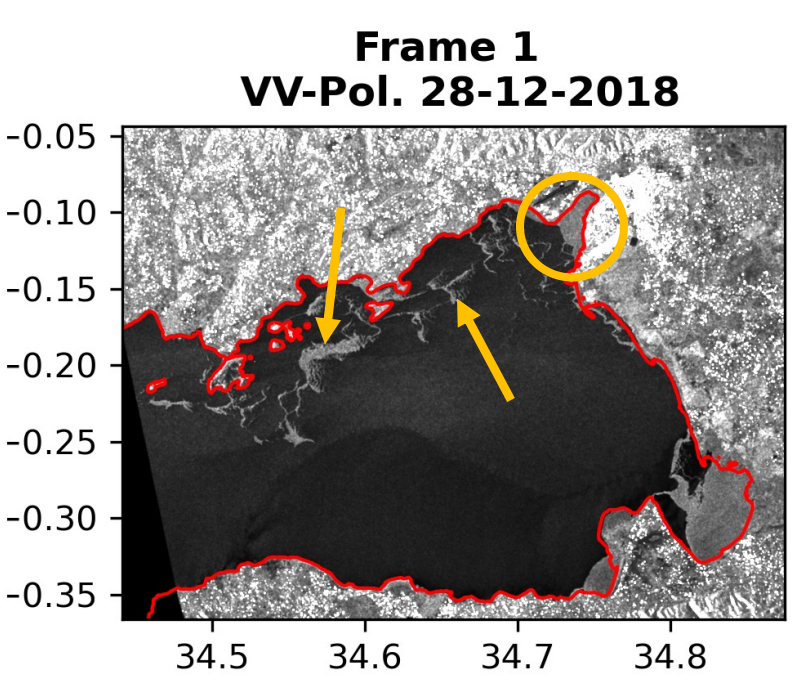
Frame	No. of images	Reference image	Orbit direction	Processing time(hrs)
Frame 1	174	10/10/2017	Ascending	23
Frame 2	114	29/09/2017	Descending	13
Frame 3	150	03/10/2017	Ascending	21

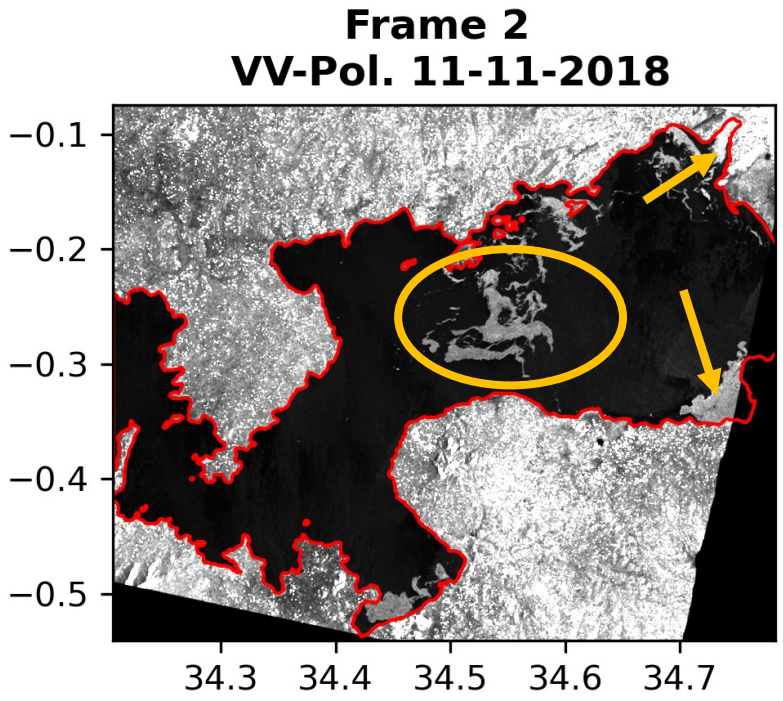


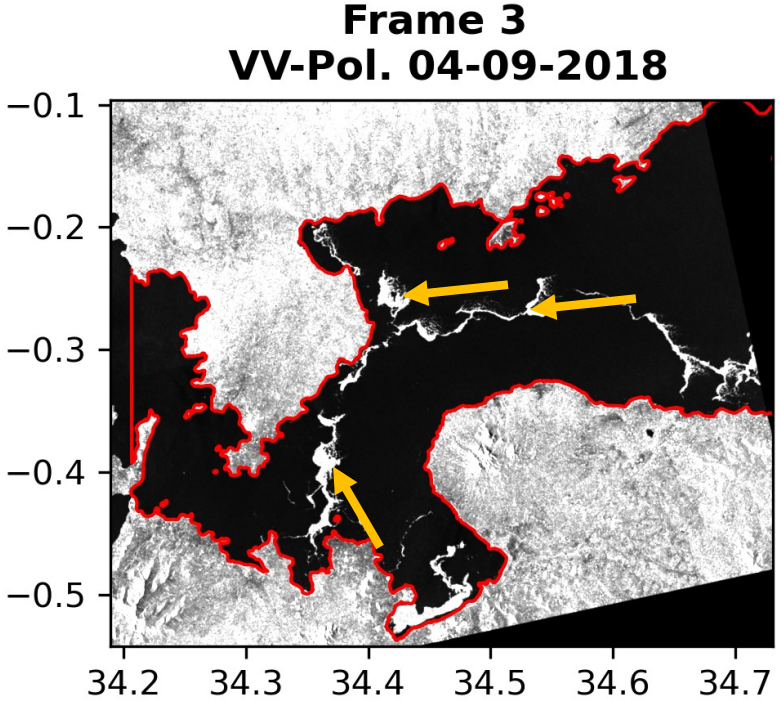




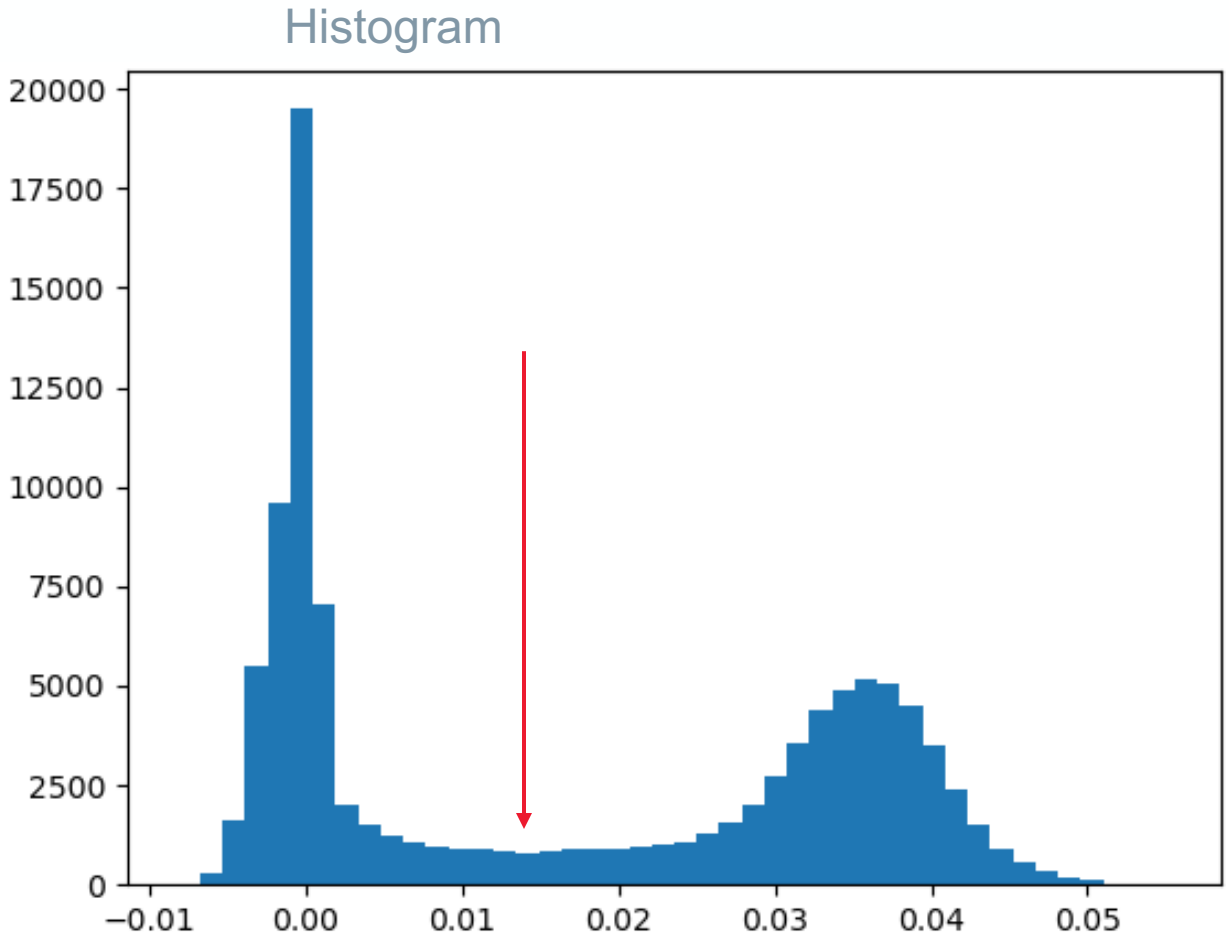
Data cont' (with WH)





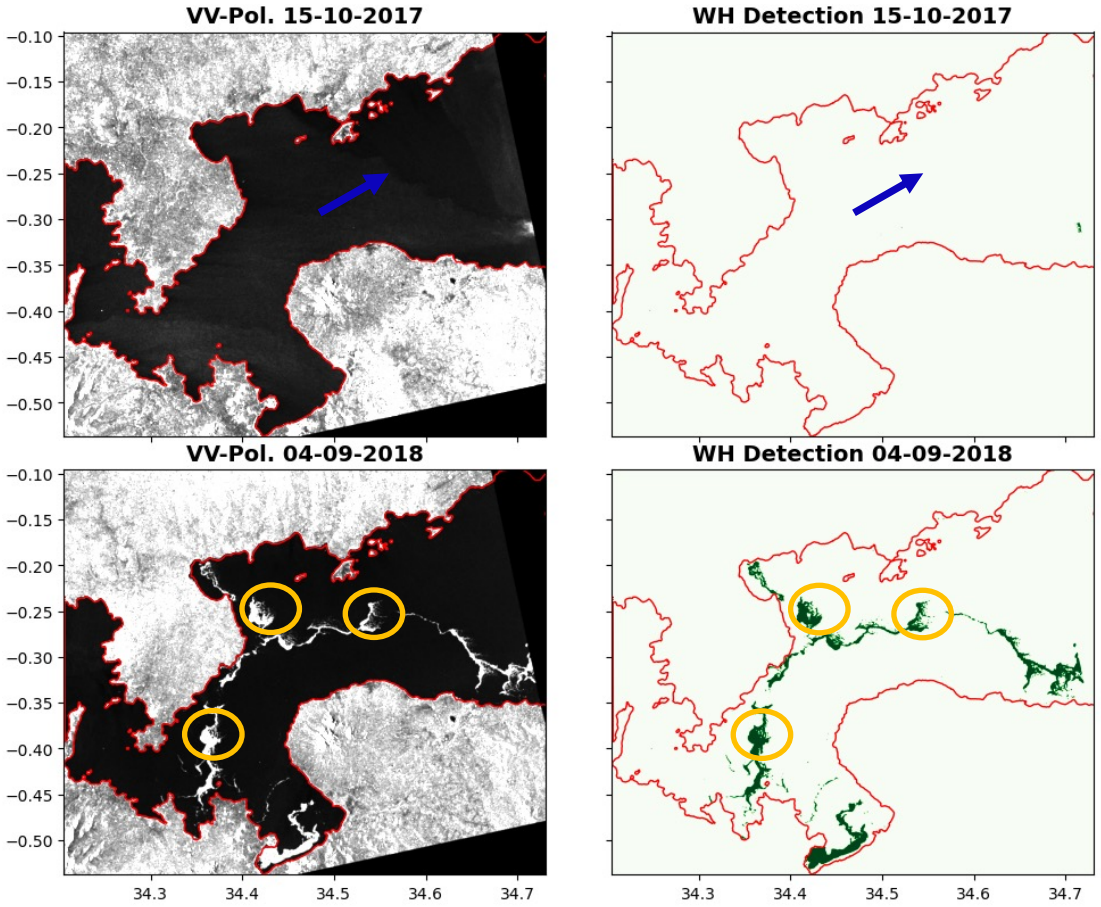


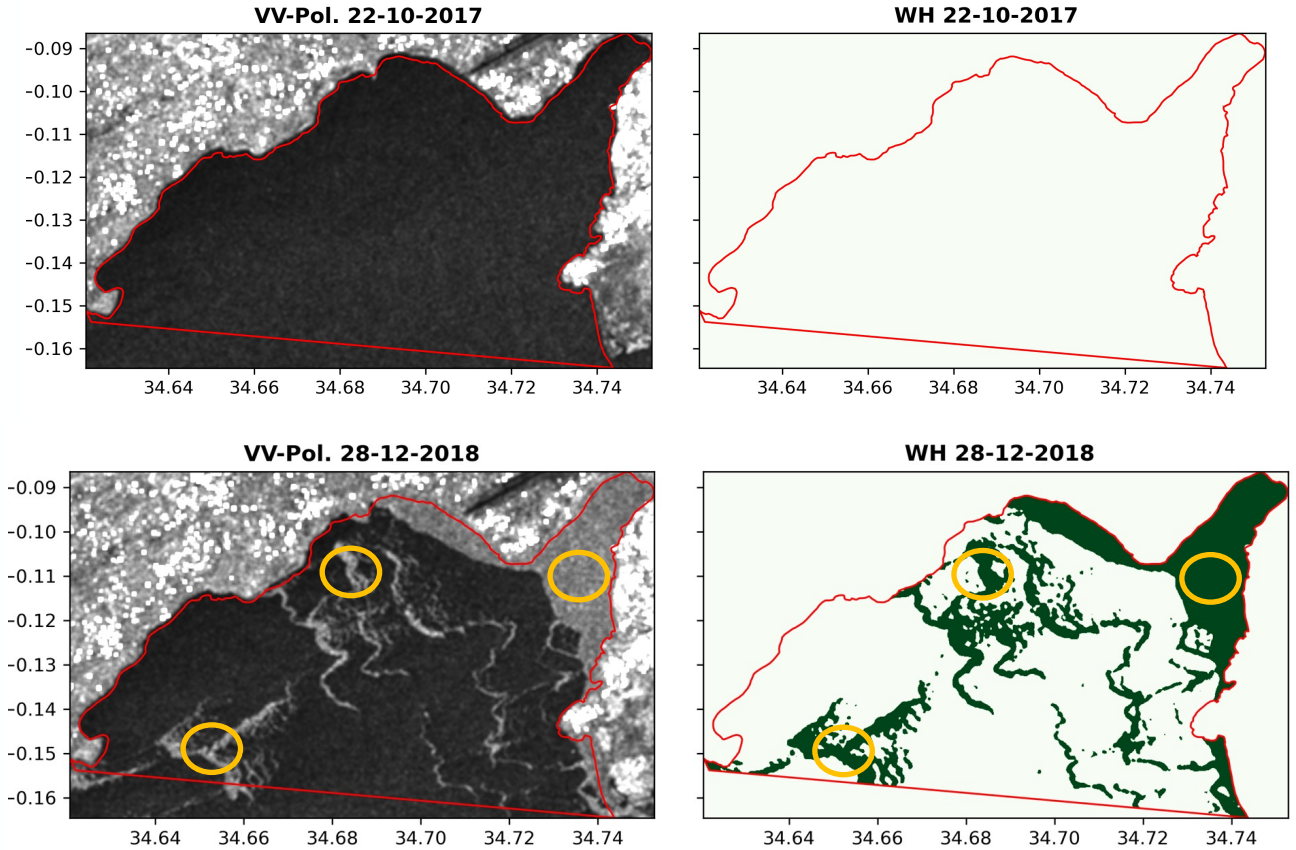
After application of detector



- Selection of threshold for positive values
- The values indicate changes that were added (WH) when compared with reference image(clear of WH)

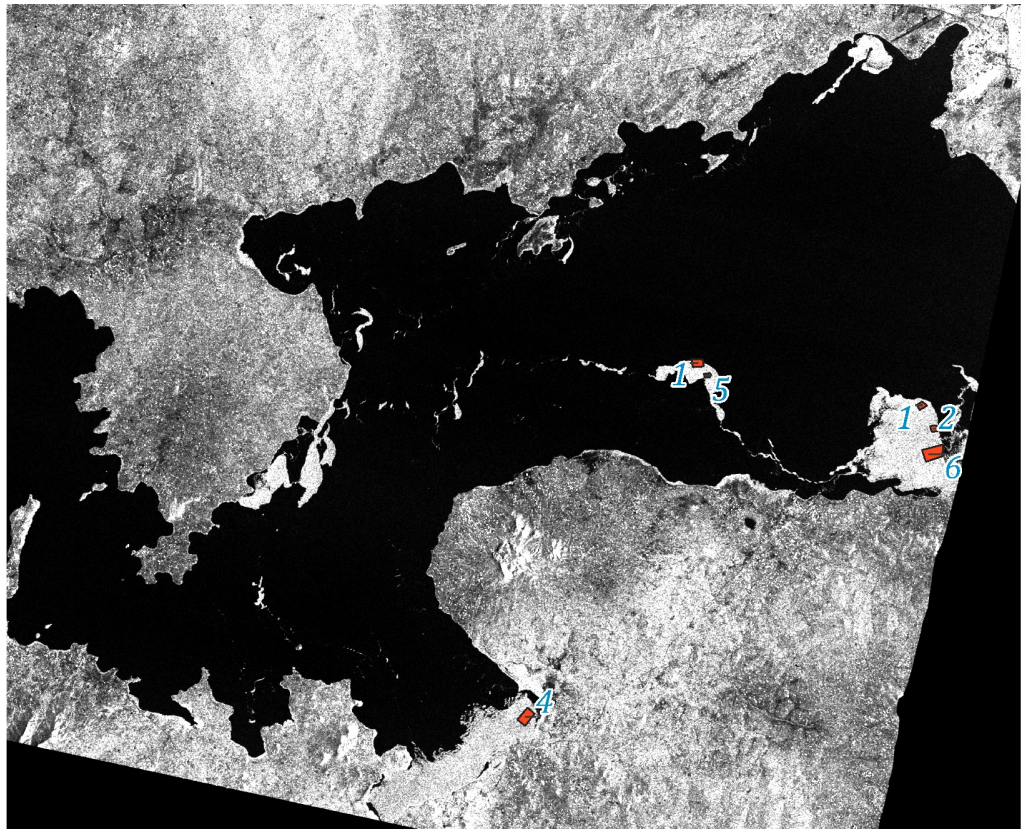
WH detection



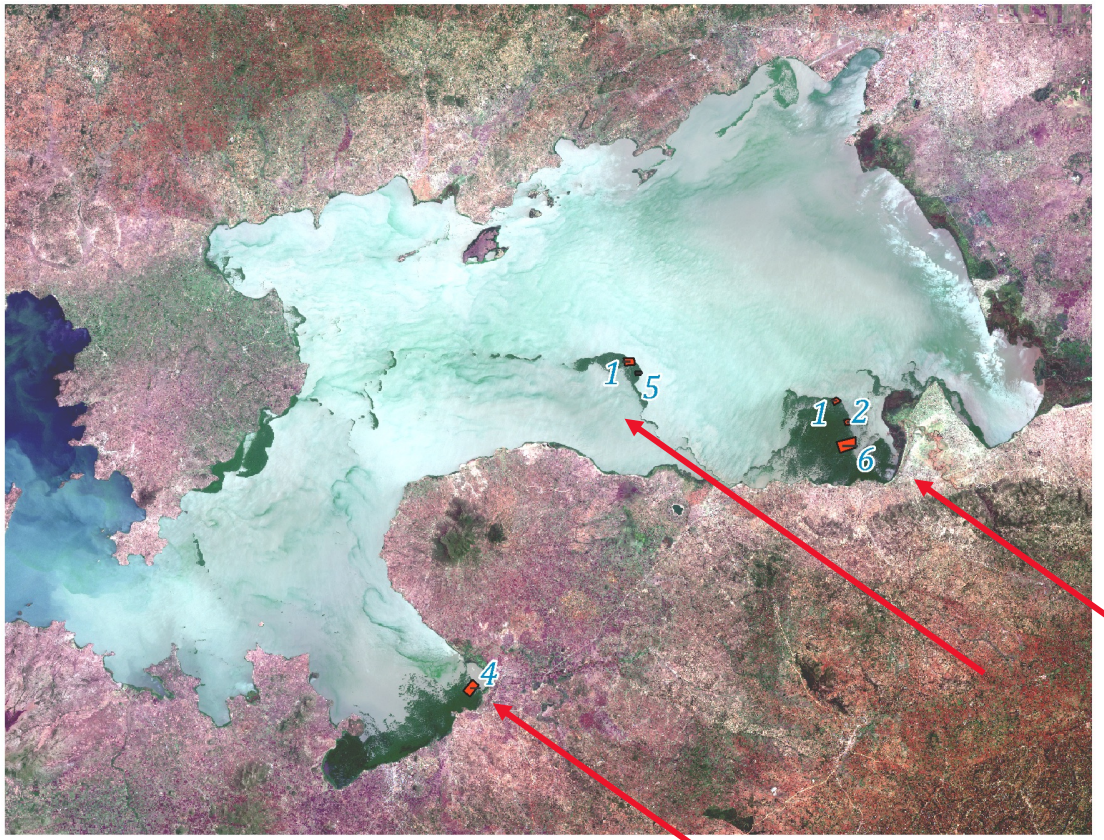


Validation data: 6 ROIs

Sentinel-1 VH Pol. 2018-09-24



Sentinel-2 2018-09-24

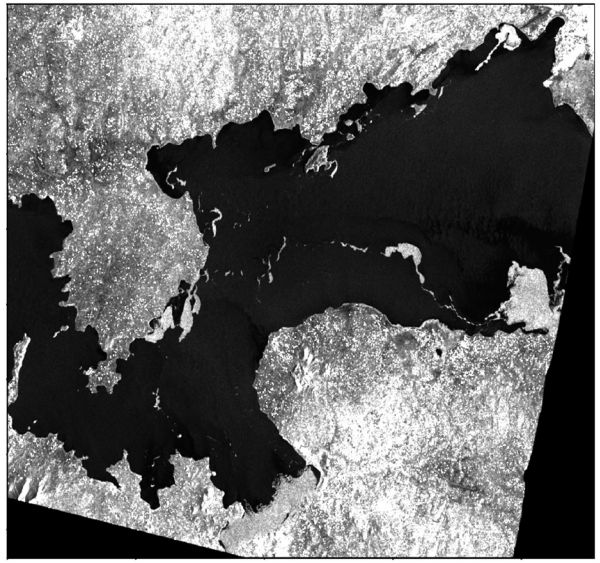


Validation ROI

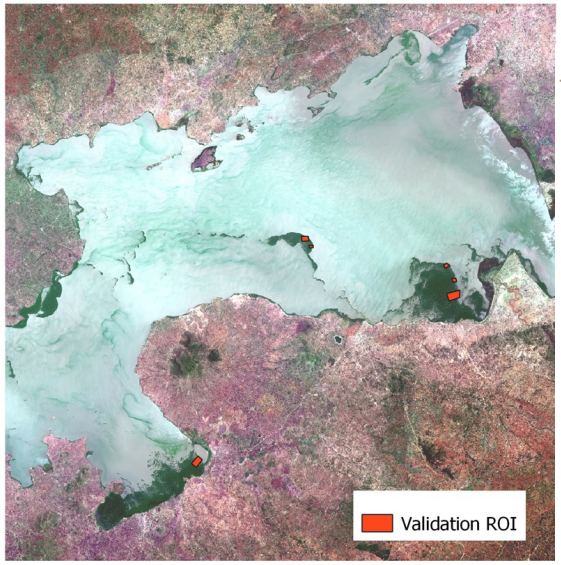
Accuracy of detector: 6 ROIs

Validation of detection

Sentinel-1 24-09-2018



Sentinel-2 24-09-2018

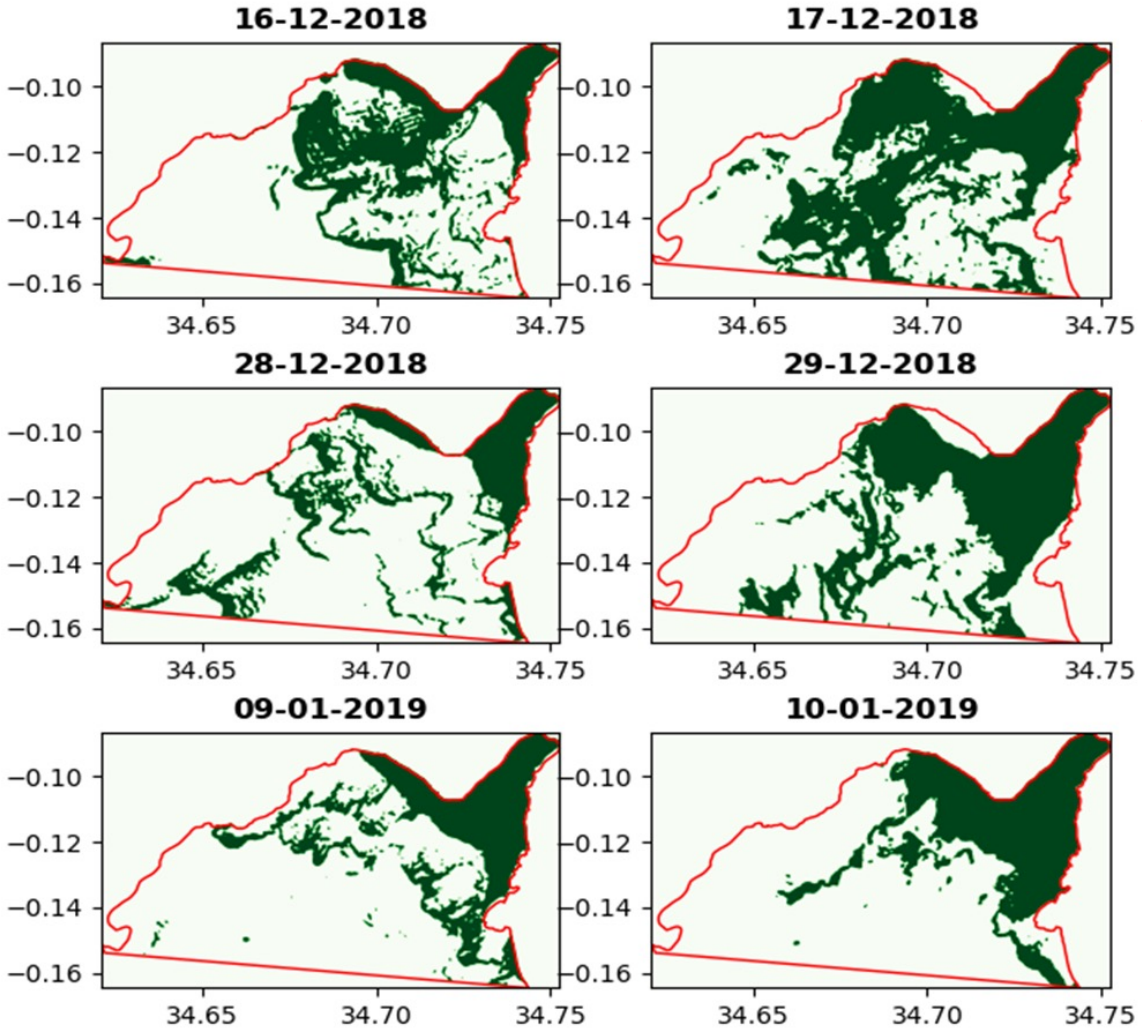


ACCURACY ASSESSMENT OF WH DETECTION USING SENTINEL-2 DATA

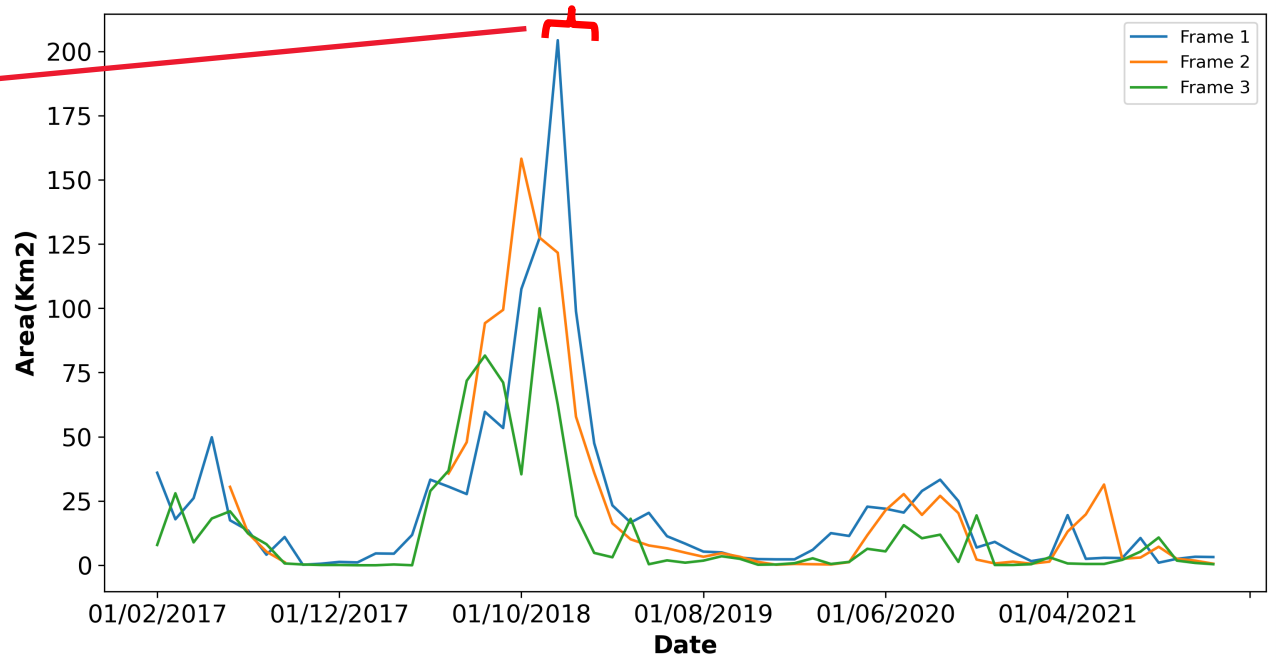
ROI	Area (Ha)	Precision %	Accuracy (%)	Miscalculation rate
1	38.7	91.3	87.9	0.05
2	19.91	91.7	89	0.02
3	17.17	87	82.2	0.03
4	68.04	95.9	94.5	0.04
5	11.22	94	91.6	0.01
6	104.06	95.4	94	0.06

Detection cont’

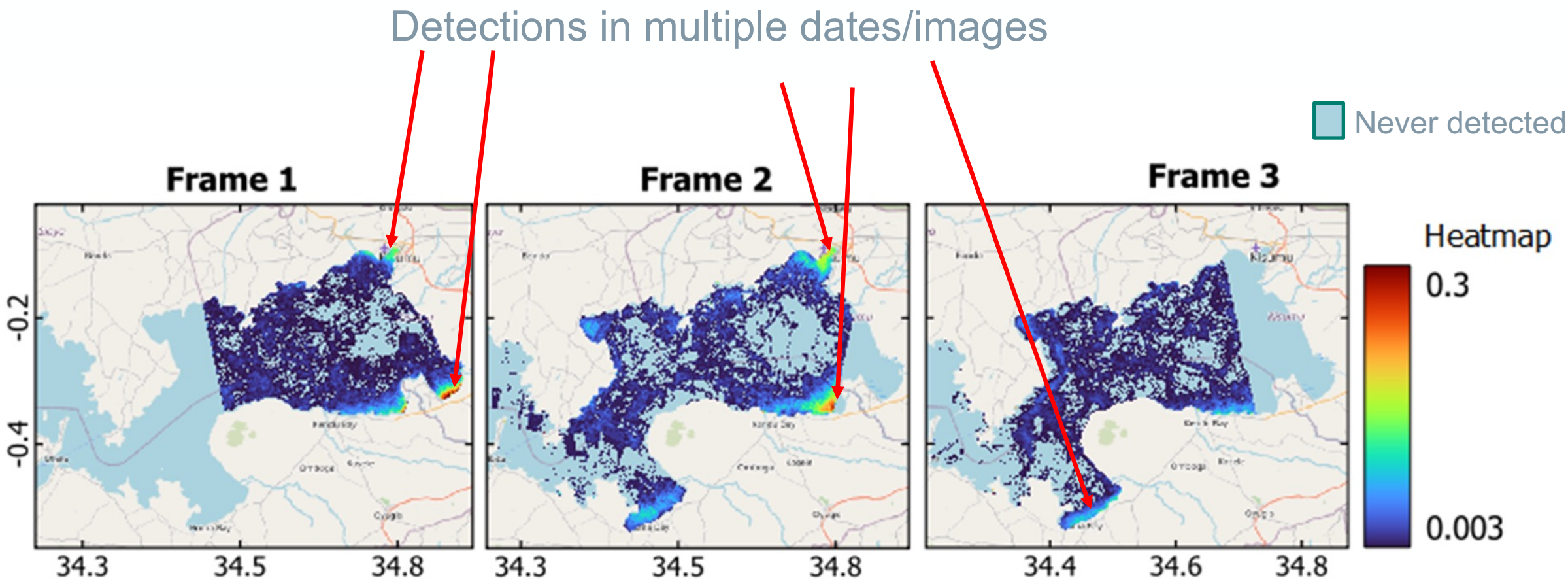
Kisumu Bay area



Time series of WH occurrence per frame



WH Heatmap


Detections in multiple dates/images
Never detected
Frame 1
Frame 2
Frame 3
-0.2
-0.4
34.3
34.5
34.8
34.3
34.5
34.8
34.4
34.6
34.8
Heatmap
0.3
0.003

Conclusion

- Demonstrated capability for RS monitoring of WH
- The detector performance is high
- Future studies to gear towards biomass estimation besides extent

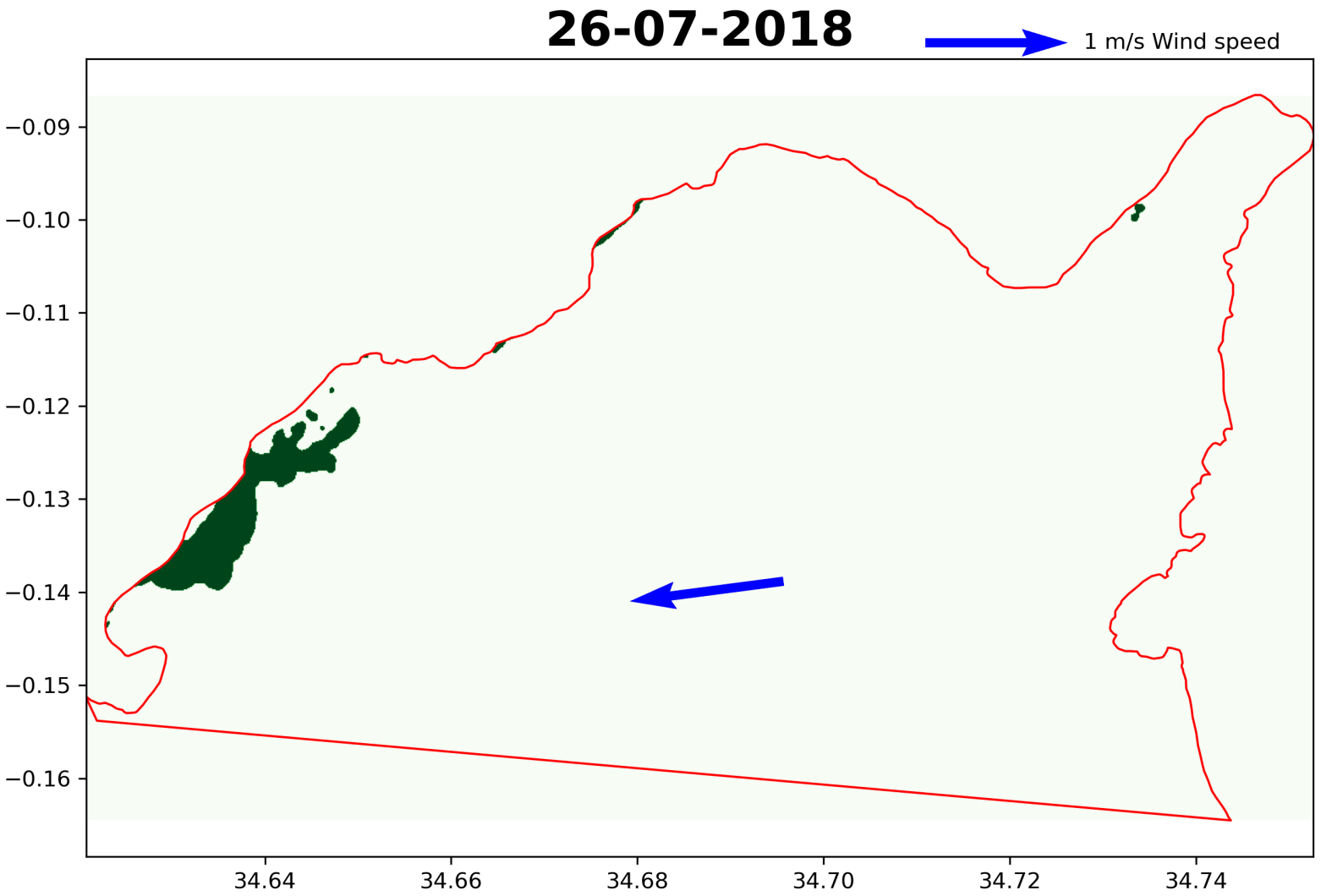
Reference

[1] Karouach F, Ben Bakrim W, Ezzariai A, Sobeh M, Kibret M, Yasri A, Hafidi M and Kouisni L (2022) A Comprehensive Evaluation of the Existing Approaches for Controlling and Managing the Proliferation of Water Hyacinth (*Eichhornia crassipes*): Review. *Front. Environ. Sci.* 9:767871. doi: 10.3389/fenvs.2021.767871

[2] A. Marino and M. Nannini, "Signal Models for Changes in Polarimetric SAR Data," in IEEE Transactions on Geoscience and Remote Sensing, vol. 60, pp. 1-18, 2022, Art no. 5212818, doi: 10.1109/TGRS.2021.3113182.

[3] M. D. Simpson et al., “Detecting Water Hyacinth Infestation in Kuttanad, India, Using Dual-Pol Sentinel-1 SAR Imagery,” Remote Sens., vol. 14, no. 12, 2022, doi: 10.3390/rs14122845.

Any Questions?



Thank You!