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► **To cite this version:**

Florent Michenot, Israel Hinothroza, Regis Guinvarc'h, Laetitia Thirion-Lefevre. Road Detection in a Forest Using Sentinel-1 and FBR Time-Series Speckle Filtering. IGARSS 2023, Jul 2023, Pasadena, United States. IEEE, pp.6561-6563, 10.1109/IGARSS52108.2023.10281593 . hal-04424478

HAL Id: hal-04424478

<https://centralesupelec.hal.science/hal-04424478>

Submitted on 29 Jan 2024

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ROAD DETECTION IN A FOREST USING SENTINEL-1 AND FBR TIME-SERIES SPECKLE FILTERING



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IGARSS
Pasadena, California 2023
16-21 July 2023
IEEE International Geoscience and Remote Sensing Symposium
2023.ieeeigarss.org



Introduction

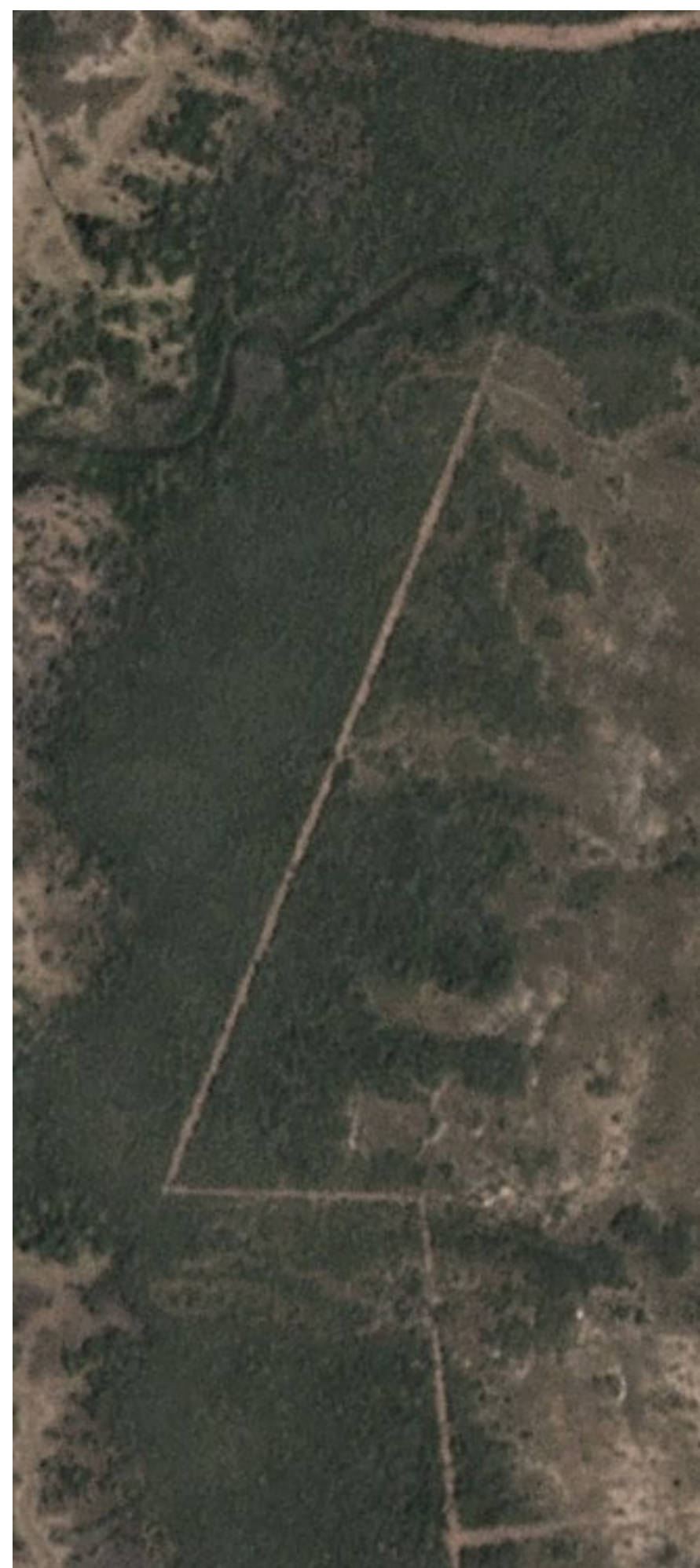
- **Objective:** Detect road in forest using SAR time-series
- Exploit information from two directions -> reduce false alarm rate
- Use a temporal speckle filter instead of a spatial one -> no loss of resolution
 - Added temporal information leveraged for better performance

Area of interest

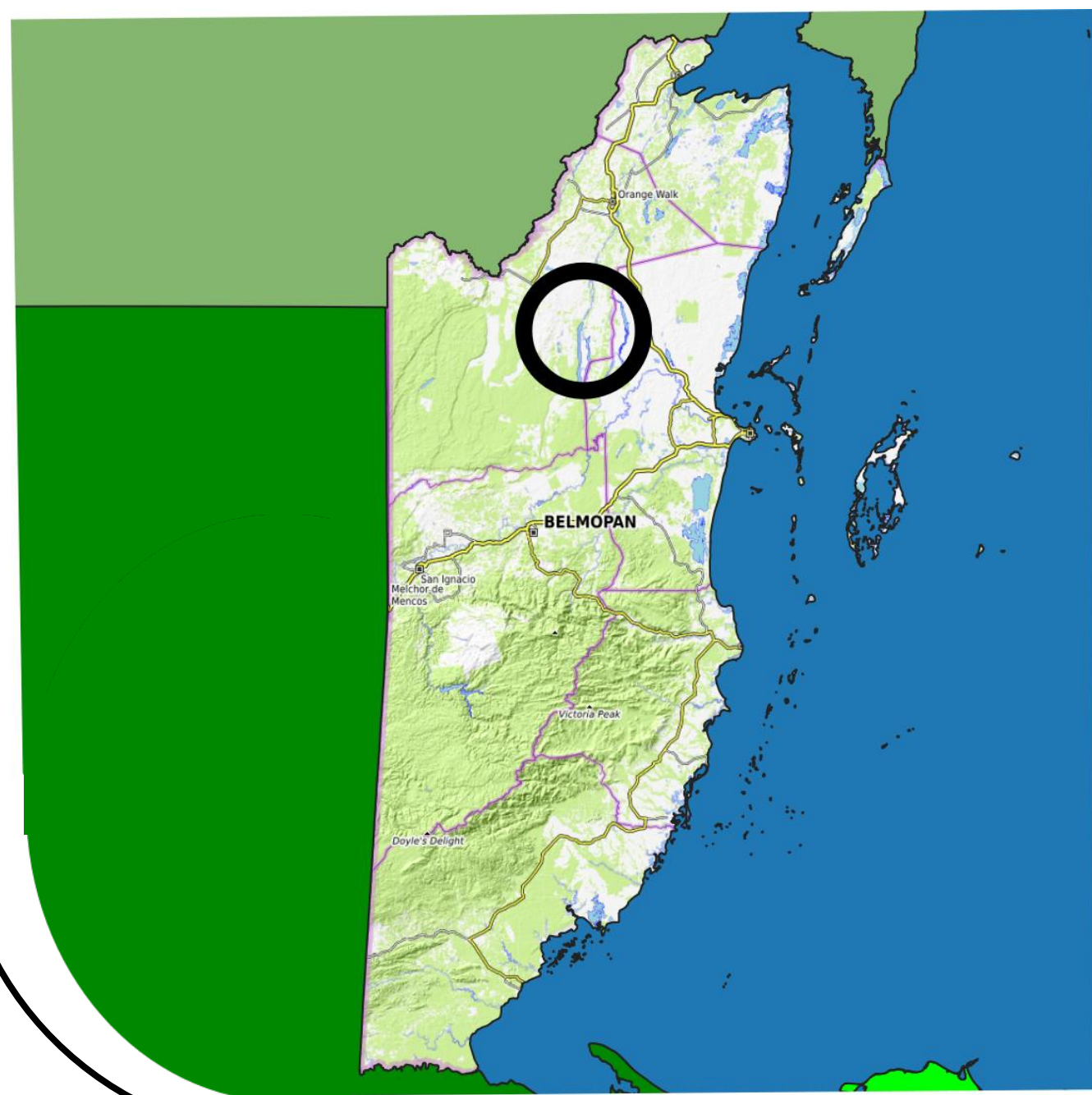
- Small forest on the Eastern shore of the New River Lake, opposite the town of Indian Church in Belize.

Item	Width
4 straight segments	10m
Curved path	30m
River	10m to 20m
Sentinel-1 pixel size	10m

Optical image of the Aoi (14/03/2019)
© Planet Labs PBC [1]



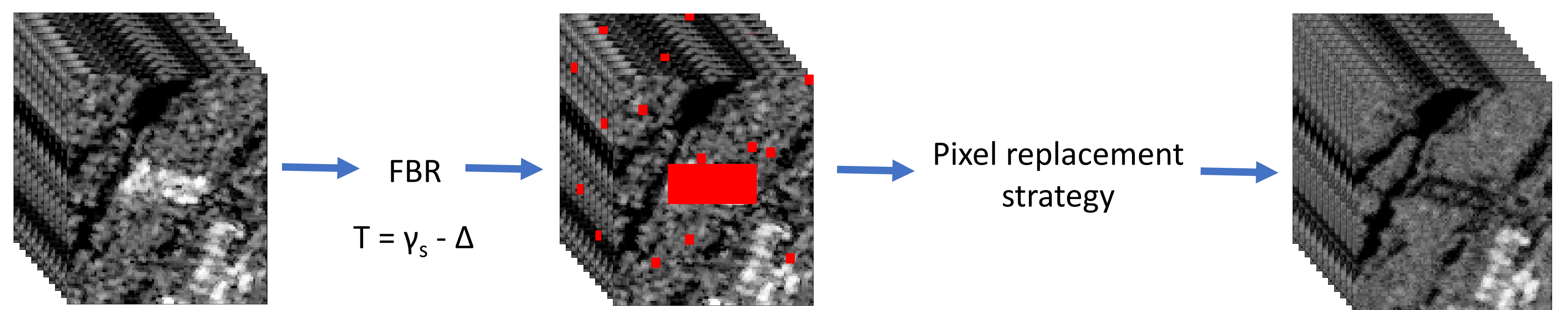
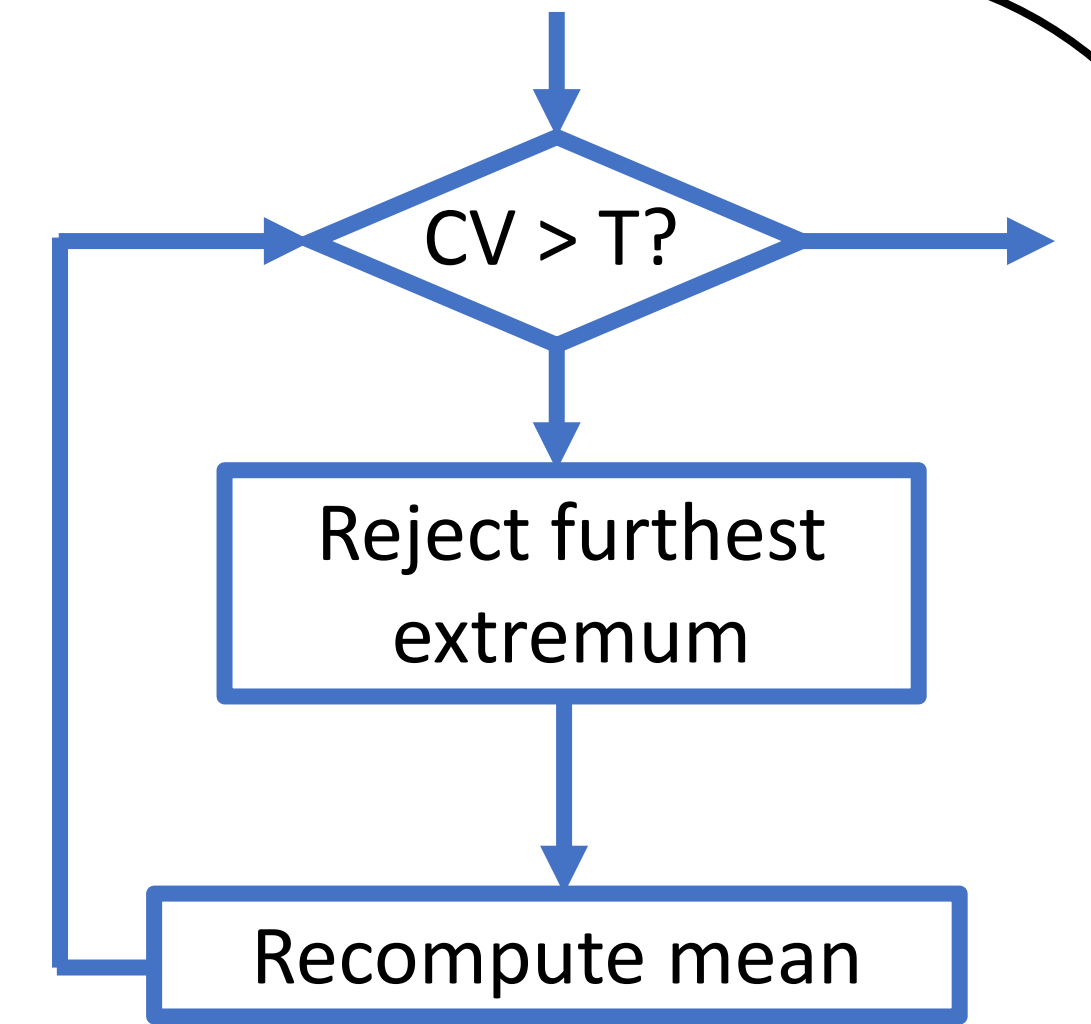
Map of Belize, with the approximate location of the Aoi circled.



Method

Temporal speckle filtering

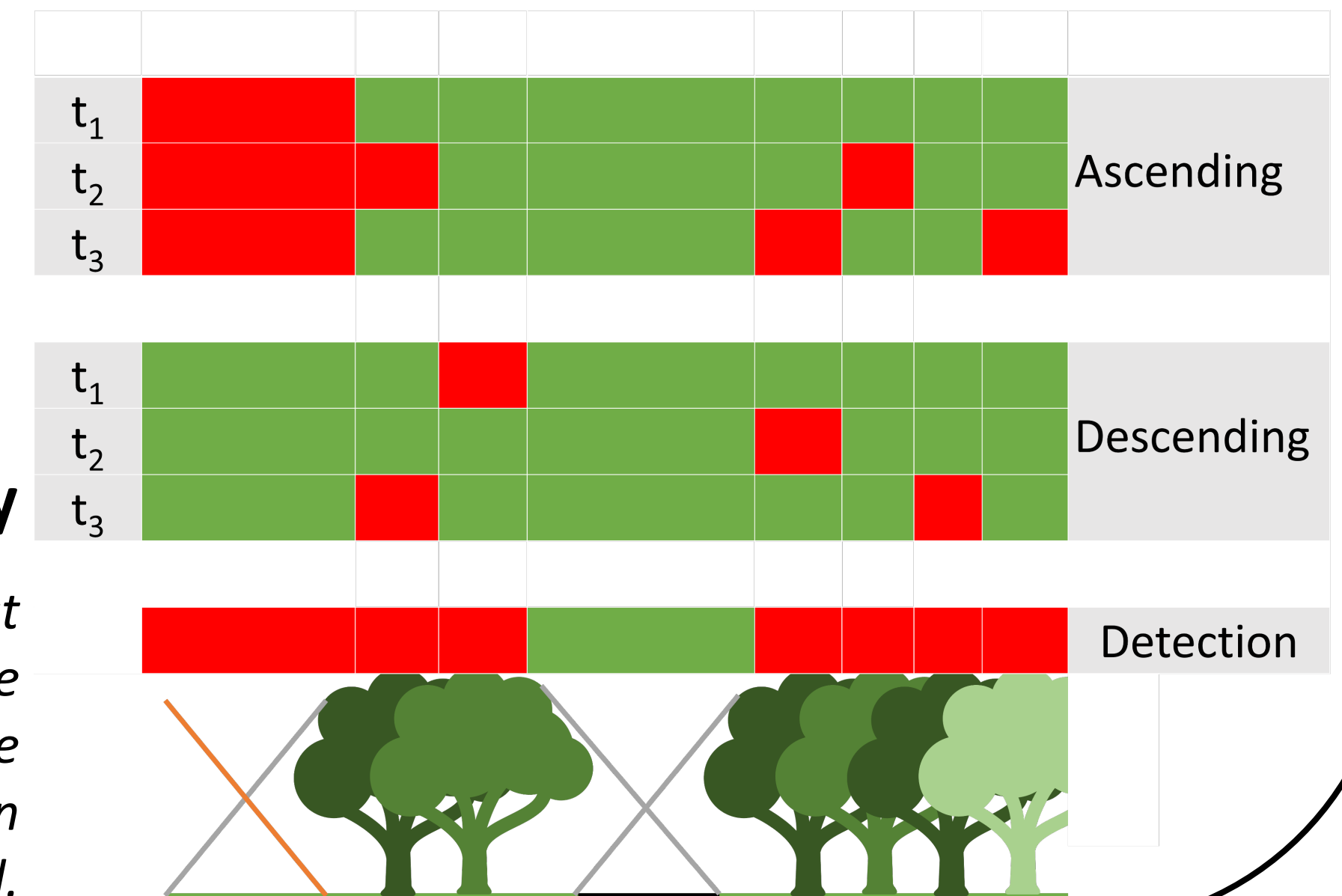
- Spatial speckle filtering degrades spatial resolution.
 - Detrimental to detection performance of targets of size smaller than the initial resolution.
- FBR-based time-series speckle filter [2] reduces speckle without loss of spatial resolution.
 - Uses the temporal Coefficient of Variation (CV)



The Frozen Background Reference (FBR) algorithm (top) and the process of the FBR-based time-series speckle filter (bottom). The input time series goes through the FBR algorithm with a threshold T equal to the theoretical CV of speckle (γ_s) minus an offset Δ , in order to reject both speckle and ephemeral targets. The pixel replacement strategy is then applied to fill in the blanks. The output is a complete time series devoid of speckle and ephemeral targets.

Azimuthal diversity

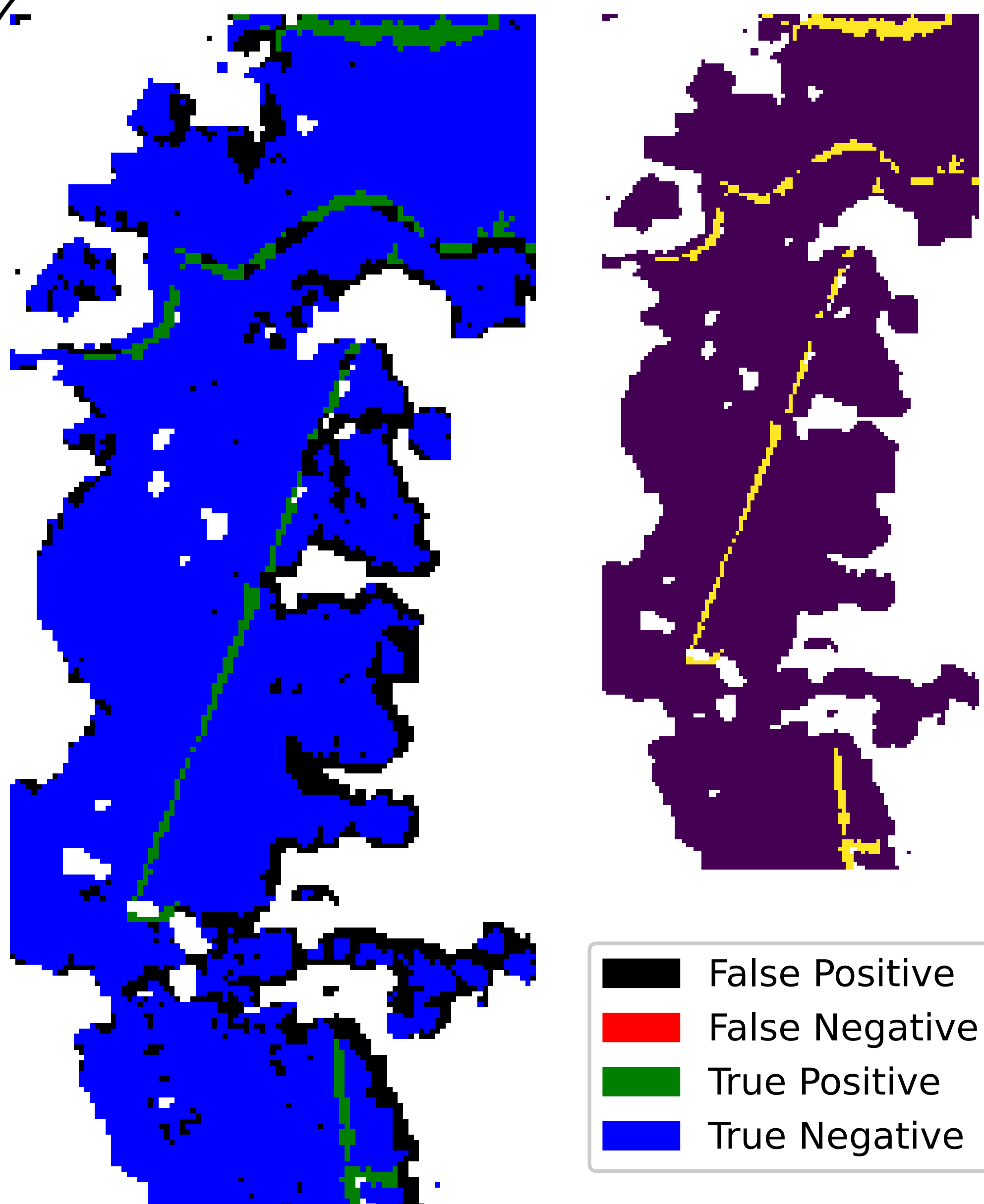
- Diversity of directions of acquisition already used to improve road detection performance [3].
- Easy for spaceborne SAR sensors: ascending and descending orbital directions.



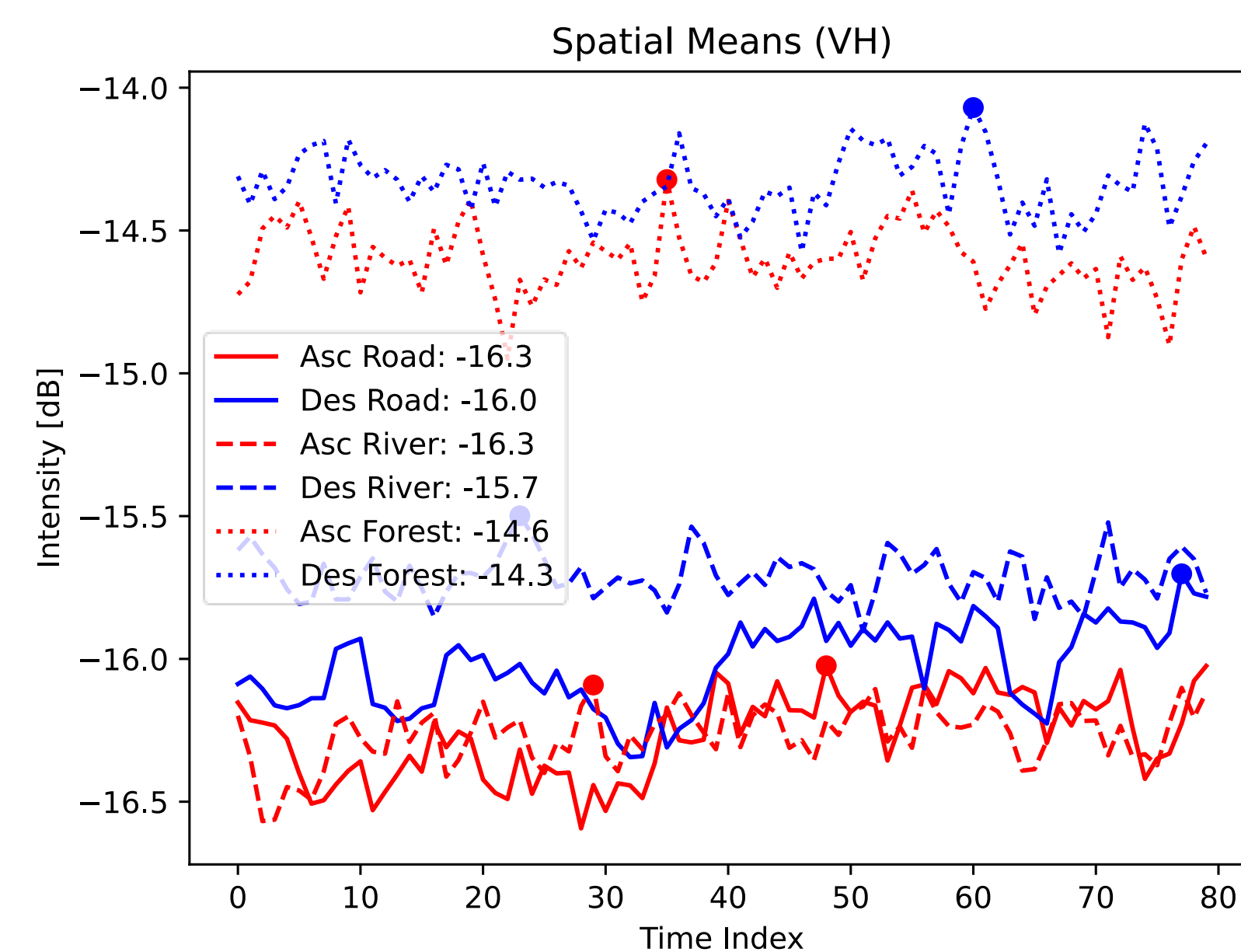
Detection criteria using VV or VH intensity

Each line corresponds to a single SAR image. The first block corresponds to the ascending direction and the second to the descending direction. The final line contains the detection result: red is not detected, green is detected.

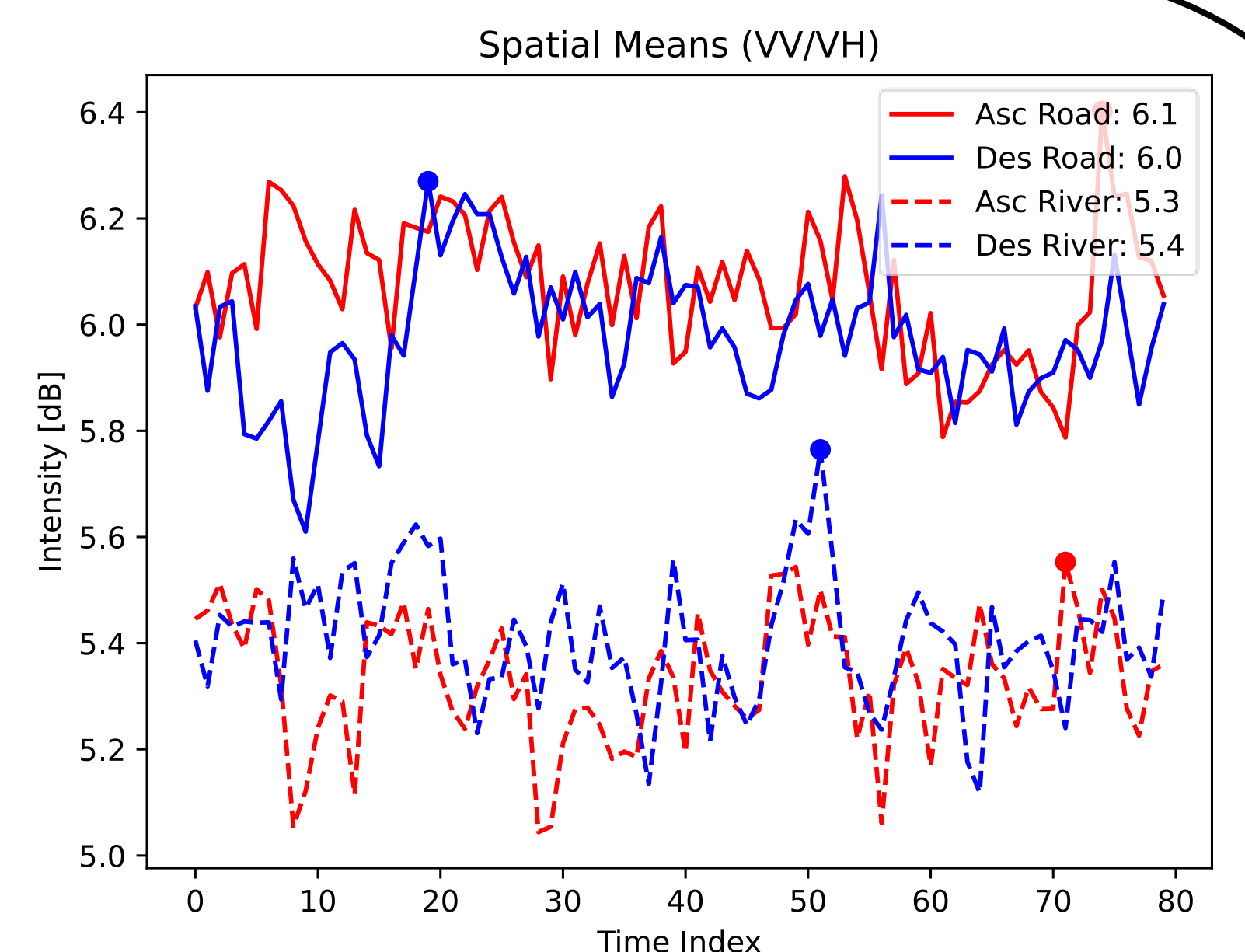
Results



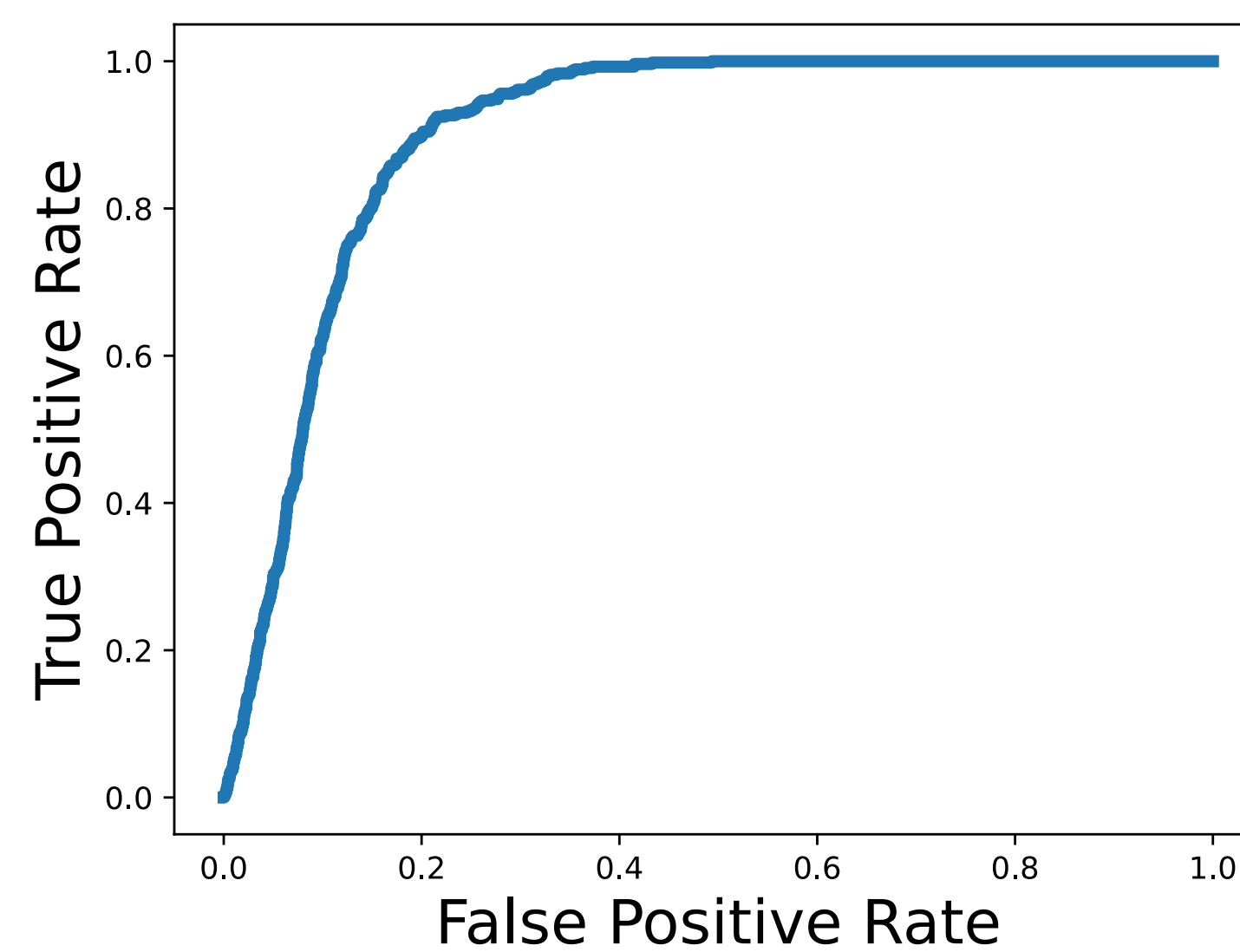
(left) Labeled output image for a threshold of -7.5 dB., after masking using WorldCover 2020 [4].
(right) Ground-truth: positive in yellow, negative in purple, masked in white.



Spatially-averaged temporal profile of VH intensity for the road, the river and a forest area of similar pixel-count. The behavior was similar in VV.



Spatially-averaged temporal profile of the ratio of VV and VH intensities for the road and the river, with similar pixel-counts.



ROC Curve using our VV dataset and ground-truth mask. The AUC score is 0.911.

N° of pixels	Predicted Positive	Predicted Negative
Actual Positive	544	0
Actual Negative	2028	11623

Confusion matrix for a threshold of -7.5 dB (values in number of pixels). No false negative whatsoever, most false positives due to deforestation/outdated mask.

Conclusion

- SAR intensity can be used to detect roads, even when pixel-sized
- **Assumptions:** temporal stability for roads in intensity, variability for forests
Azimuthal stability for roads, not for shadows.
- **Requirements:** despeckled SAR time-series
- **Perspectives:** separating rivers from roads

References

- [1] Planet Team, "Planet Application Program Interface: In Space for Life on Earth," 2017-.
- [2] F. Michenot, R. Guinvarc'h, and L. Thirion-Lefevre, "Temporal Stack Speckle and Target Filtering for Environmental Applications," presented at the IGARSS 2022, Jul. 2022.
- [3] F. Tupin, B. Houshmand, and M. Datcu, "Road detection in dense urban areas using SAR imagery and the usefulness of multiple views," IEEE Transactions on Geoscience and Remote Sensing, vol. 40, no. 11, pp. 2405-2414, 2002.
- [4] D. Zanaga, R. Van De Kerchove, W. De Keersmaecker, N. Souverijns, C. Brockmann, R. Quast, J. Wevers, A. Grosu, A. Paccini, S. Vergnaud, O. Cartus, M. Santoro, S. Fritz, I. Georgieva, M. Lesiv, S. Carter, M. Herold, Linlin Li, N.E. Tsendbazar, F. Ramoino, and O. Arino, "ESA WorldCover 10 m 2020 v100," 2020.