CHANGE DETECTION IN SPATIOTEMPORAL SAR DATA FOR DEFORESTATION MONITORING

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1 Abstract

SAR data is a valuable resource for deforestation monitoring as it is not affected by the highly prevailing cloud cover in the tropics. However, unlike longer wavelengths, C-band SAR (as in Sentinel-1) does not penetrate the forest canopy and is thus less sensitive to changes in canopy height. We want to explore whether the high temporal frequency and public availability of Sentinel-1 data may still be exploited for applications in deforestation and forest degradation monitoring. A pixel-wise change detection algorithm proposed by Conradsen et al (2016) using test statistics based on the complex Wishart distribution is found to capture 60.7% of loss pixels with a 2.5% commission error. Enhancement of the algorithm by using spatial context is ongoing research.

2 Study Area

The study area shown below is located in Rondônia, Brazil (9.3S/63.8W to 9.5S/63.55W). However, as the research is focused on algorithm development, there is no inherent focus on any particular geographic area. The dominant deforestation driver in this area is conversion to agriculture and pasture by large scale clearances.

3 Background

The **complex covariance matrix representation** of dual-polarized SAR data is given by

$$\langle C \rangle_{\text{dual}} = \begin{bmatrix} \langle S_{hh} S_{hh}^* \rangle & \langle S_{hh} S_{hv}^* \rangle \\ \langle S_{hv} S_{hh}^* \rangle & \langle S_{hv} S_{hv}^* \rangle \end{bmatrix}$$

where S_{hh} and S_{hv} are the complex HH and HV backscatter, respectively. These covariance matrices follow a complex Wishart distribution as follows:

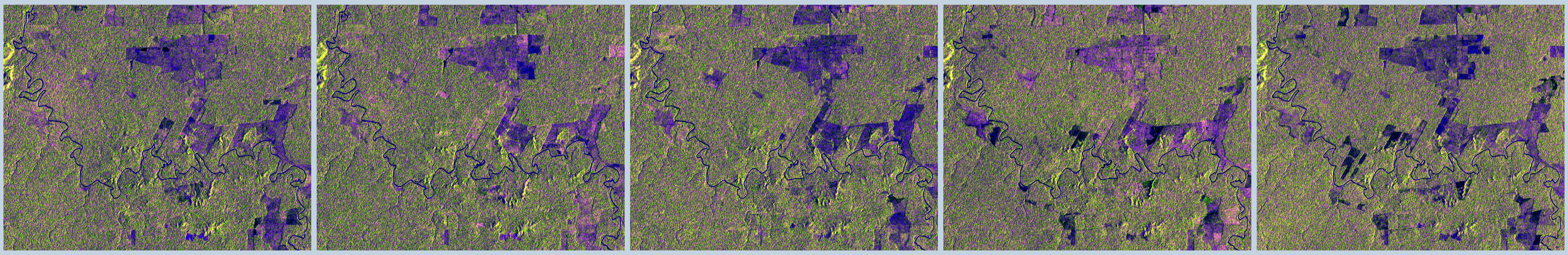
$$n \langle C_i \rangle \sim W_C(p, n, \Sigma_i), \quad i = 1, \dots, k$$

where p is the rank of $\langle C \rangle$, n is the number of looks, and $\Sigma_i = E[C_i]$. Change detection is done by repeatedly testing the null hypothesis (omnibus test)

$$H_0 : \Sigma_1 = \Sigma_2 = \ldots = \Sigma_k$$

4 Dataset

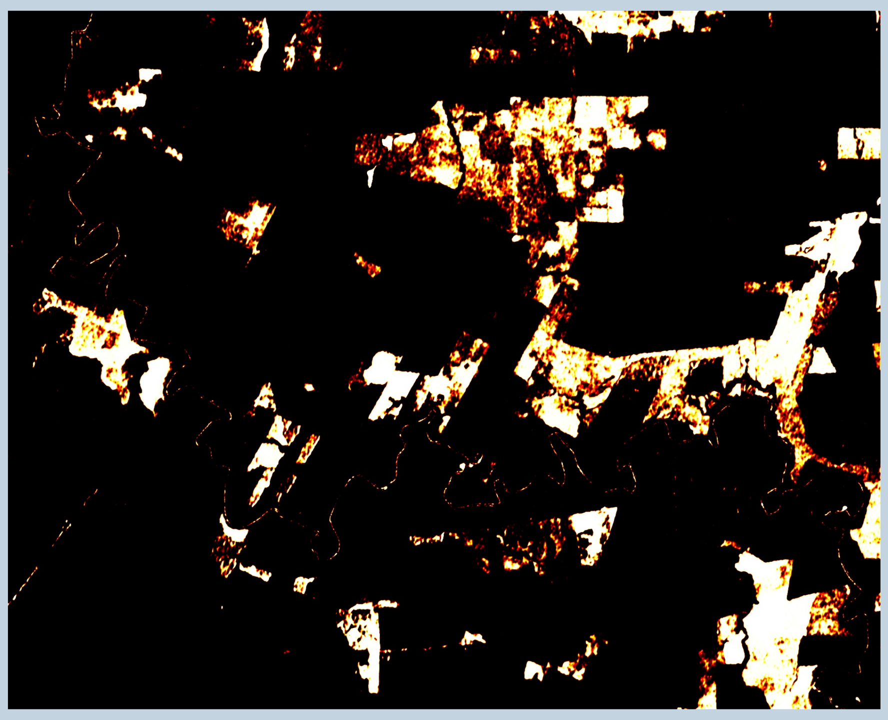
The following sequence of images shows a time series of SAR data over the study area for the year 2017 (red: C_{11}, green: C_{22}, blue: C_{11}/C_{22}).



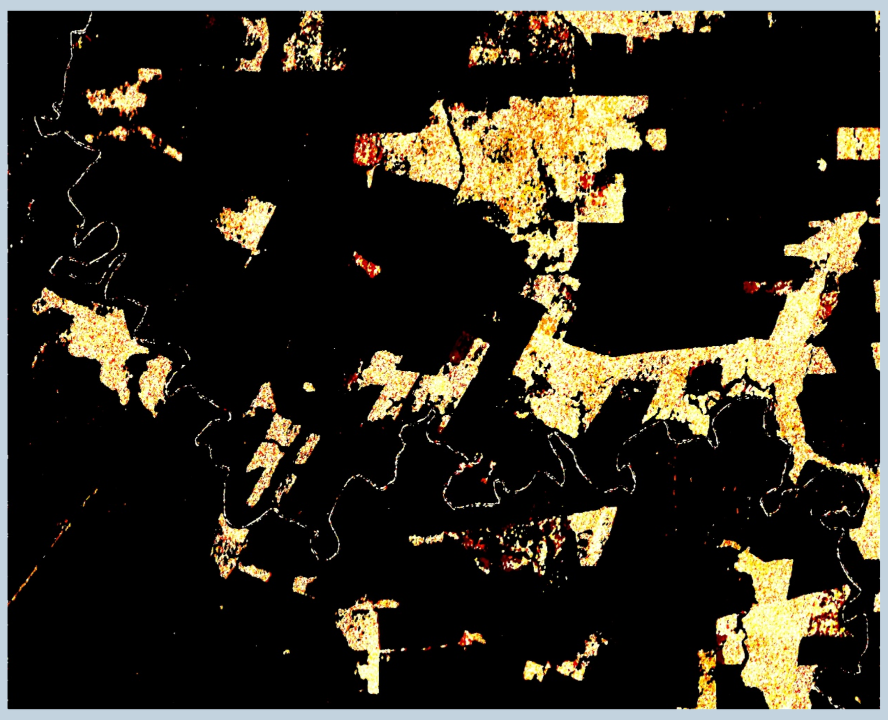
Jan 2017 **Mar 2017** **Jun 2017** **Sep 2017** **Dec 2017**

5 Results

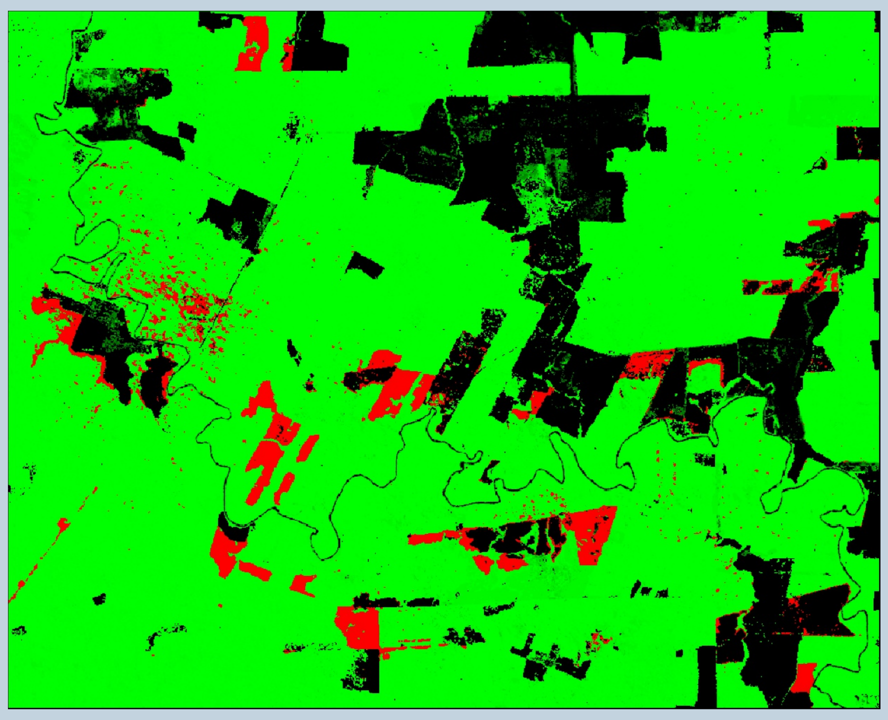
Based on the series of images above (a total of 30 time steps), a change detection result according to the algorithm by Conradsen et al. is presented here. **(a)** shows the overall probability of change, while **(b)** depicts the number of observed changes. Image **(c)** shows reference data for the study area taken from Global Forest Watch (Hansen et al.), and **(d)** is the result from (b) masked by forested area.
All images range from 0 (black) to high (white), except for the reference data which shows forest cover as green and forest loss as red.



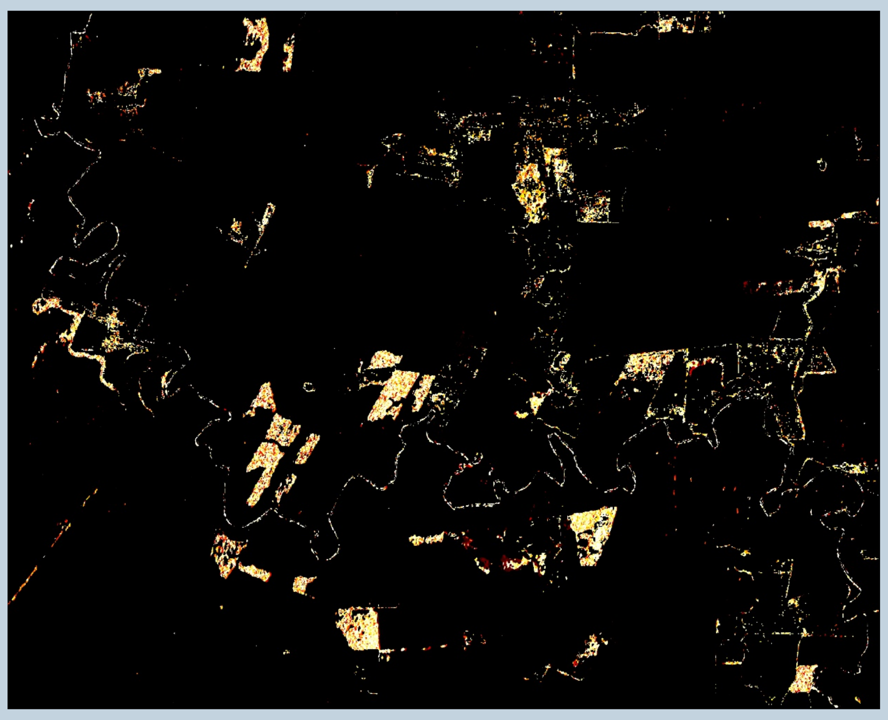
(a) **Overall probability of change**



(b) **Change frequency, $\alpha = 0.01$**



(c) **Reference data for forest cover and forest loss 2017 (Hansen et al)**



(d) **Change frequency masked by 2016 forest cover**

6 Discussion

For the selected area there was an omission error of 39.3% and a commission error of 2.5% compared to the reference data. However, the reference data itself cannot be assumed to be perfect and will thus have its own errors of commission and omission. Furthermore, the algorithm is a generic change detection algorithm and is not specifically tailored to forest loss. In general, stable forest is reliably classified as *no change*. Agricultural areas have lots of changes, such that the change frequency may be used to classify between land cover types. Nevertheless, the large omission error suggests that the majority of forest loss is either not captured by the C-band SAR or does not result in a statistically significant change point. One way of improving change detection is by taking into account collective trends within a land cover type. Removing these trends should enhance genuine change points.

7 Conclusion

The limitations of C-band SAR for forest monitoring are clear, particularly for small fragmented areas. Nevertheless, we are optimistic that the algorithm can be extended by incorporating spatial context and additional data sources.

8 Future Research

- Can the change signature be used to classify land cover type?
- How can spatial context improve the change detection algorithm?
- How can optical data be used in conjunction with C-band SAR?

9 References

K Conradsen, A A Nielsen, and H Skriver. "Determining the Points of Change in Time Series of Polarimetric SAR Data". *IEEE Transactions on Geoscience and Remote Sensing* 54.5 (2016), pp. 3007–3024. DOI: 10.1109/TGRS.2015.2510160.

M C Hansen et al. "High-Resolution Global Maps of 21st-Century Forest Cover Change". *Science* 342.November (2013), pp. 850–854. DOI: 10.1126/science.1244693.

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