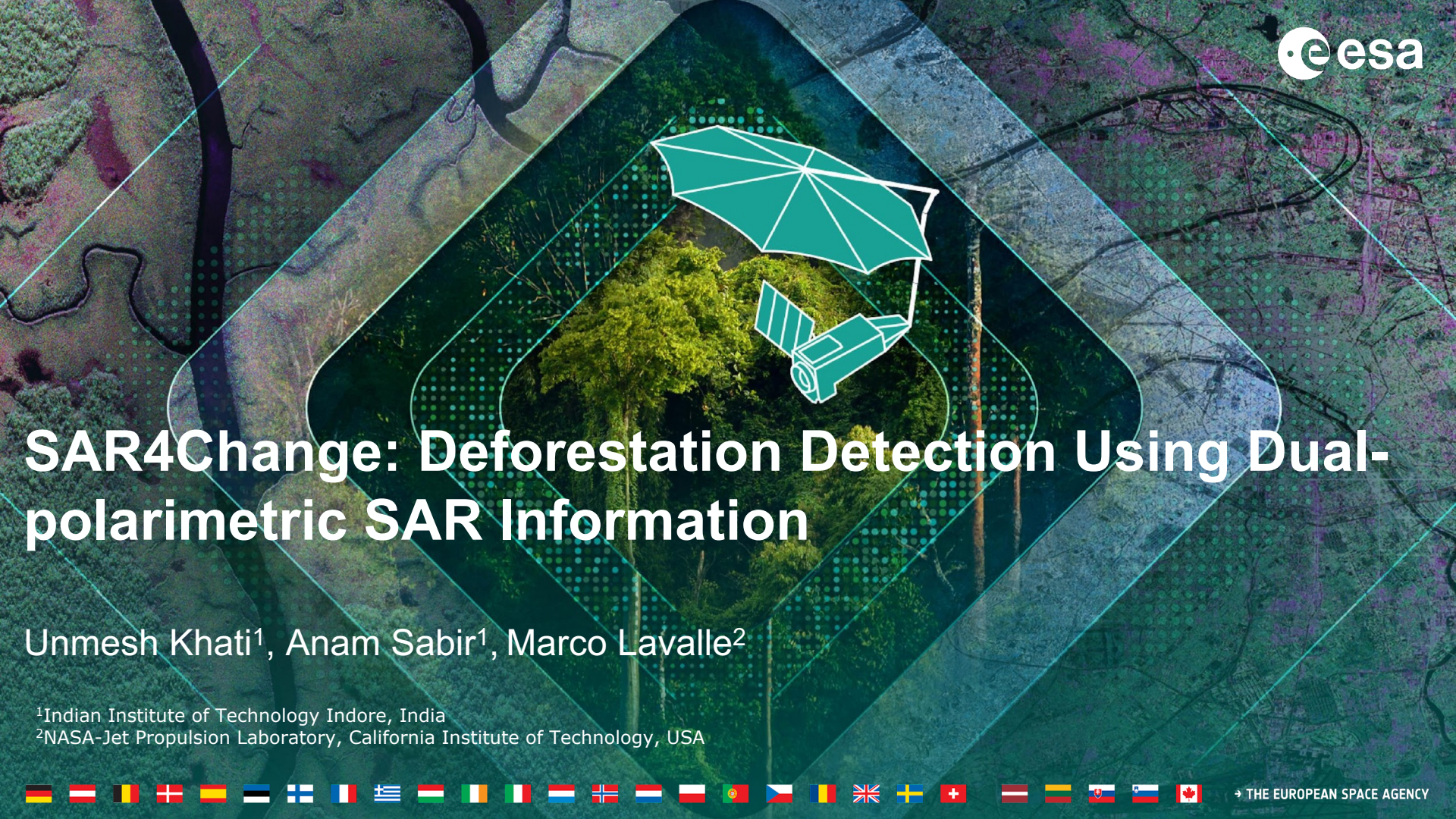


SAR4Change: Deforestation Detection Using Dual-polarimetric SAR Information

Unmesh Khati[1], Anam Sabir[1], Marco Lavalle[2]

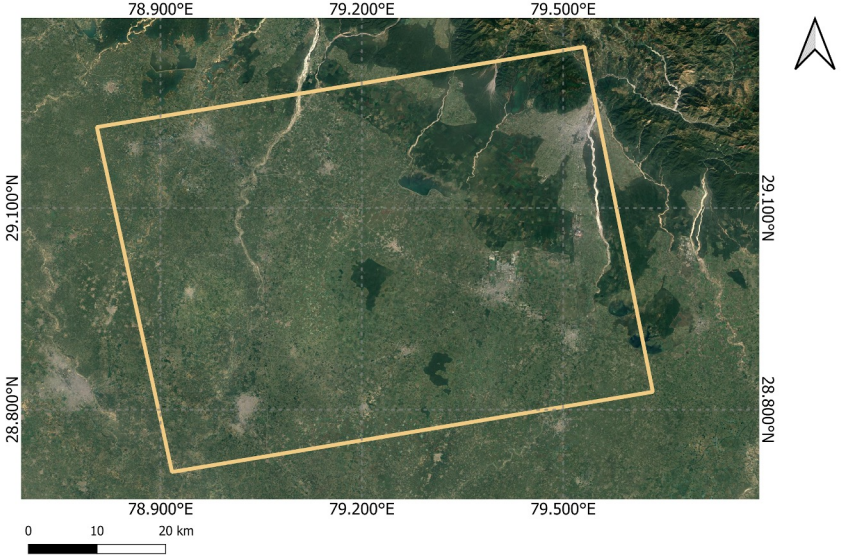
[1]Indian Institute of Technology Indore, India
[2]NASA-Jet Propulsion Laboratory, California Institute of Technology, USA

Motivation

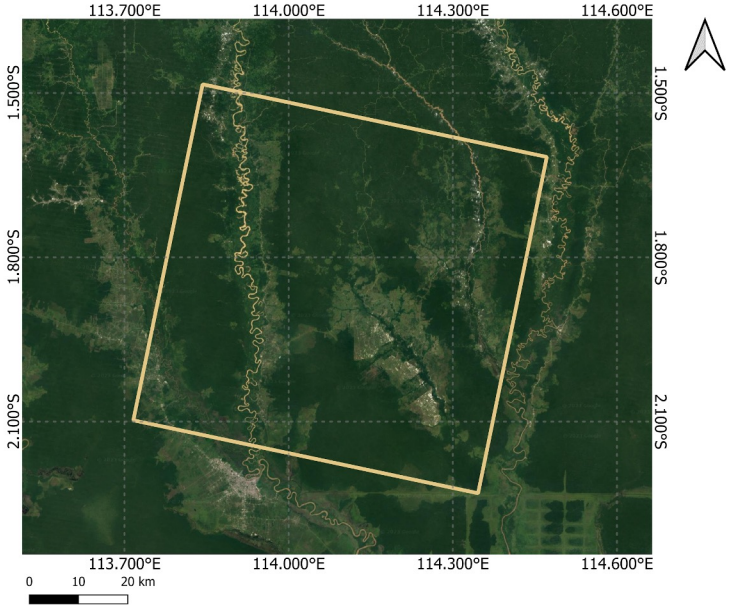
- Deforestation detection using SAR time-series is important
- Focus on Sentinel-1 and NISAR missions, we aim to study the impact of
  - Frequency
  - Polarization
  - Resolution
  - Forest eco-regions

Deforestation Sites

Haldwani, India



Kalimantan, Indonesia



Data Used

- C-band
  - Sentinel-1, Dual-pol, SLC
  - Timeline: 2016-2020
  - Number of acquisitions
    - Haldwani: 71
    - Kalimantan: 134
- L-band
  - ALOS-2, Dual-pol, Stripmap SLC
  - Timeline: 2016-2020
  - Number of acquisitions
    - Haldwani: 23
    - Kalimantan: 28

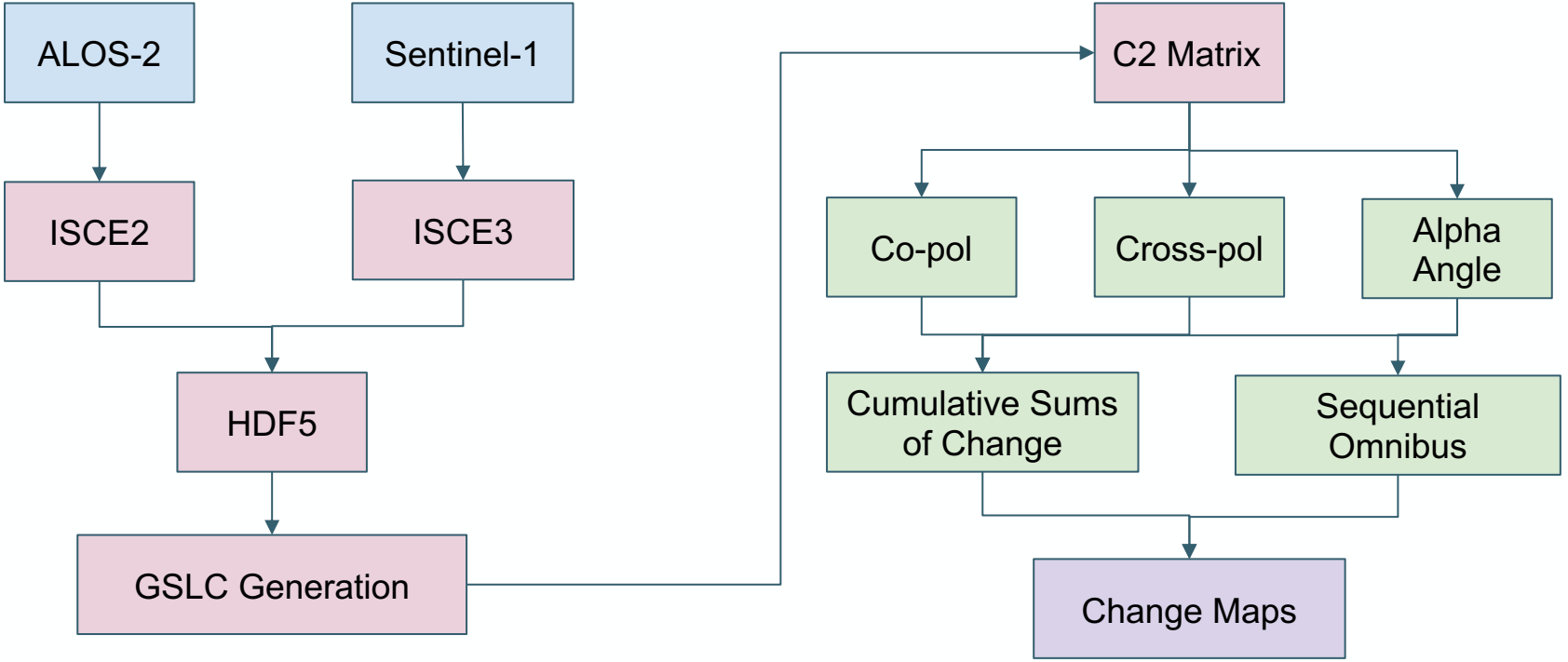
Kalimantan

2016	2017	2018	2019	2020
14	29	29	28	24

Haldwani

2016	2017	2018	2019
8	27	26	10

Processing Workflow



Change detection algorithms

Cumulative Sums of Change

Initialize cumulative sum
$S_o=0$

Calculate cumulative sums
$S_I = S_{i-1} + (I_i - I_{mean})$

Calculate
$S_{max} = max_{i=0,1,....n}\ S_i$

Calculate
$S_{min} = min_{i=0,1,....n}\ S_i$

Calculate
$S_{diff} = S_{max} - S_{min}$

Bootstrapping
Generate a bootstrap sample by randomly reordering the original values

Calculate bootstrap CuSum
S^o_i for i=1,2,.....,n (S^o_0, S^o_1,....,S^o_n)

Calculate max, min and difference of bootstrap CuSum denoted S^o_{max}, S^o_{min} and S^o_{diff}

Calculate number of samples X where $S^o_{diff} < S_{diff}$
Total number of sample = N

Calculate Confidence Level = 100 * X/N %

Sequential Omnibus

Test for equality of several complex covariance matrices
Null Hypothesis:
$H_0=\sum_1=\sum_2.....=\sum_k$

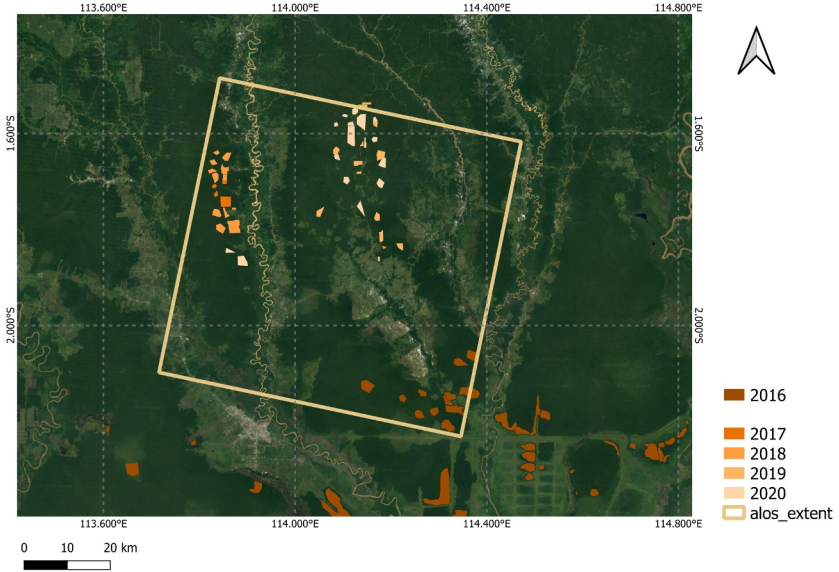
Omnibus Test Statistic
$Q = \{k^{pk}\pi^k_{i=1}|X_i|/|X|^k\}^n$

Complex Wishart Distribution followed by
$X_i = n\sum_i = n\ \langle C \rangle_i$
N = equivalent number of looks
$X = \pi^k_{i=1}X_i$

p = 3: full pol
2: dual pol
1: single pol

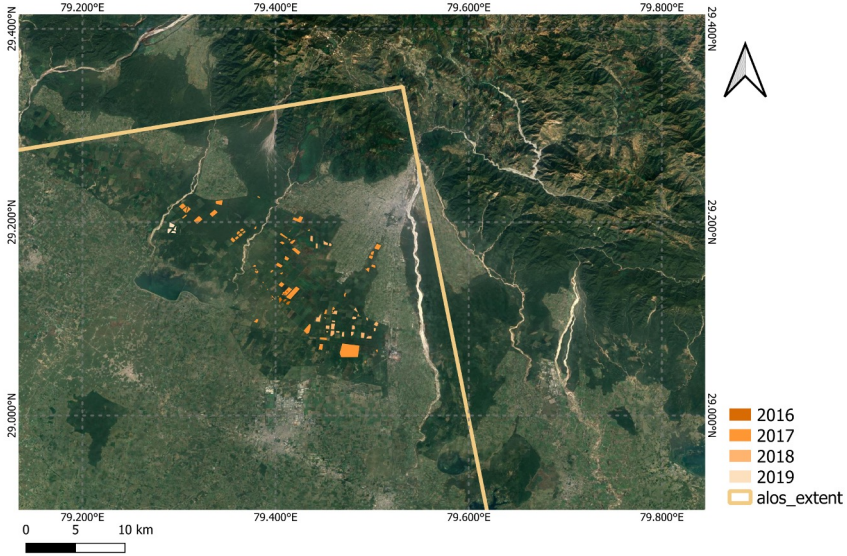
Validation Plots

Kalimantan



Minimum Area: 4 ha
Maximum Area: 79 ha

Haldwani



Minimum Area: 1 ha
Maximum Area: 220 ha

Accuracy Assessment Parameters

- **Overall Accuracy**: Proportion of correctly classified instances over the total number of instances.

  Overall Accuracy = (TP + TN) / (TP + TN + FP + FN)

- **User's accuracy**: Proportion of correctly classified positive instances out of all actual positive instances.

  User's Accuracy = TP / (TP + FN)

- **Producer's Accuracy (Precision)**: Proportion of correctly classified positive instances out of all predicted positive instances.

  Producer's Accuracy = TP / (TP + FP)

- **F1 Score**: Harmonic mean of precision and recall, providing a single metric that balances both metrics.

  F1 Score = 2 * (Producer's Accuracy * User's Accuracy) / (Producer's Accuracy + User's Accuracy)

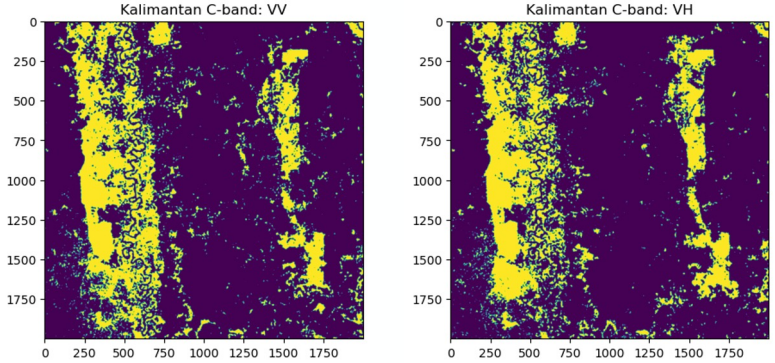
- **Kappa Coefficient**: Agreement between the predicted and actual labels, adjusted for the agreement occurring by chance.

  Kappa = (Overall Accuracy - Expected Accuracy) / (1 - Expected Accuracy)

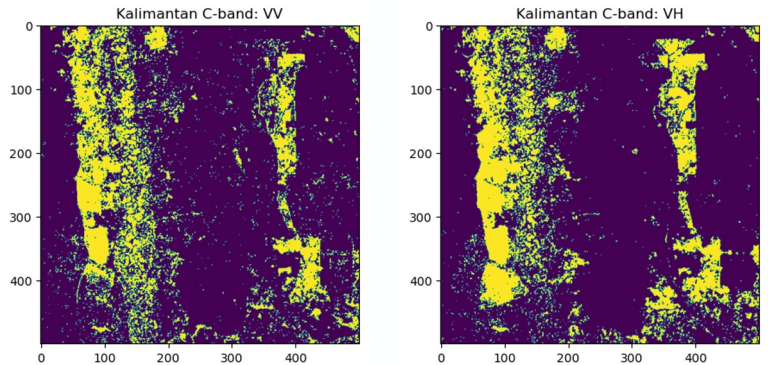
Change Maps

Cumulative Sums of Change
Kalimantan

25m



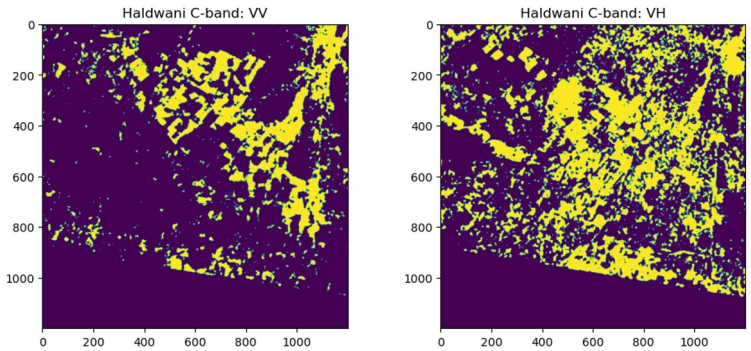
100m



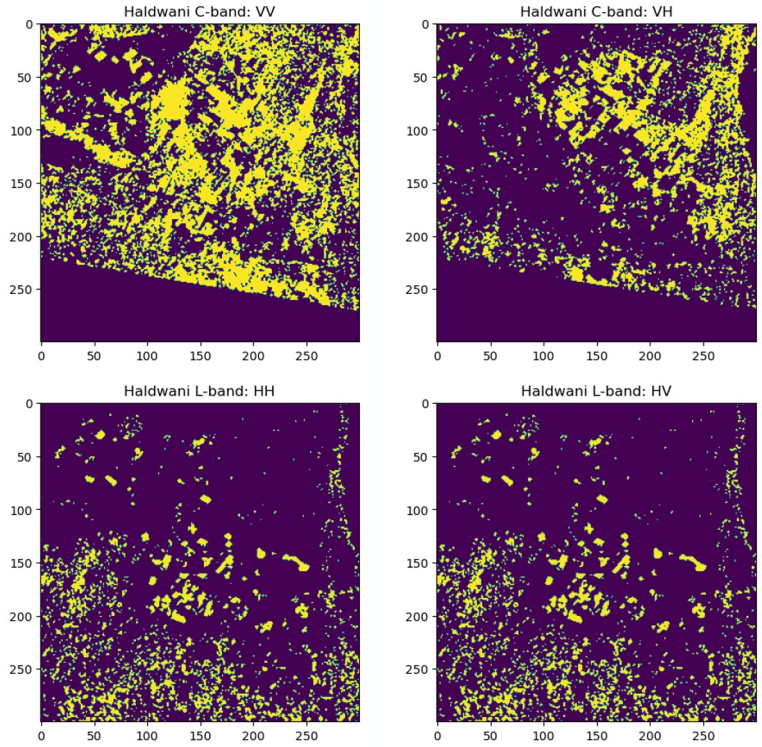
Change Maps

Cumulative Sums of Change
Haldwani

25m

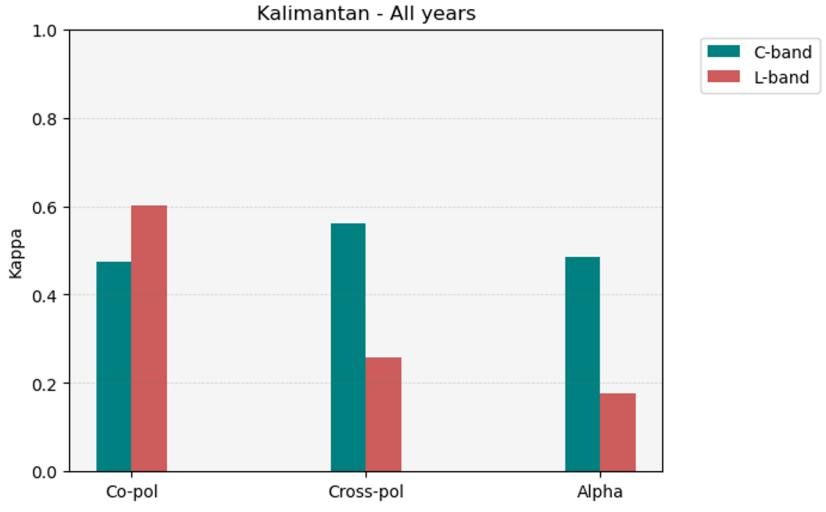


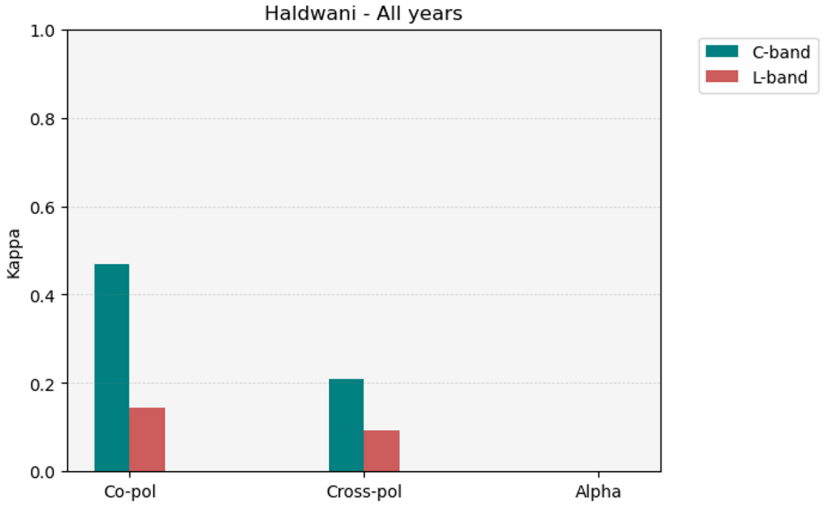
100m



Observations

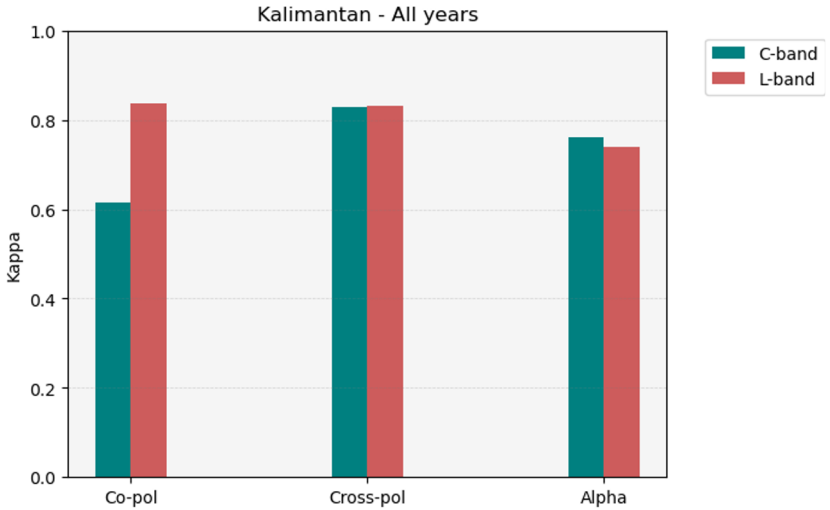
At 25m resolution, Cumulative Sums of Change

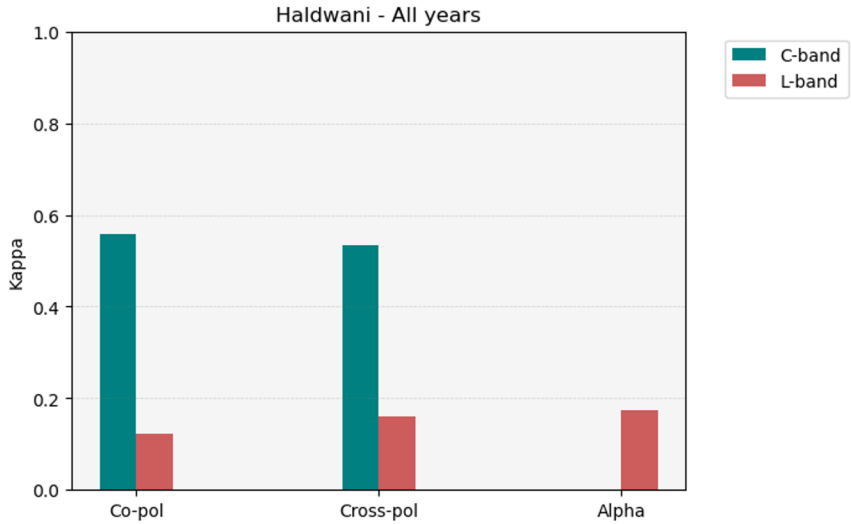




Observations

At 100m resolution, Cumulative Sums of Change





Accuracy Parameters

Overall Accuracy

Kalimantan

		25m	100m
Sentinel-1	Co-pol	0.737	0.802
	Cross-pol	0.783	0.915
ALOS-2	Co-pol	0.796	0.919
	Cross-pol	0.635	0.915

Haldwani

		25m	100m
Sentinel-1	Co-pol	0.745	0.782
	Cross-pol	0.608	0.770
ALOS-2	Co-pol	0.625	0.577
	Cross-pol	0.563	0.585

Accuracy Parameters

Kappa

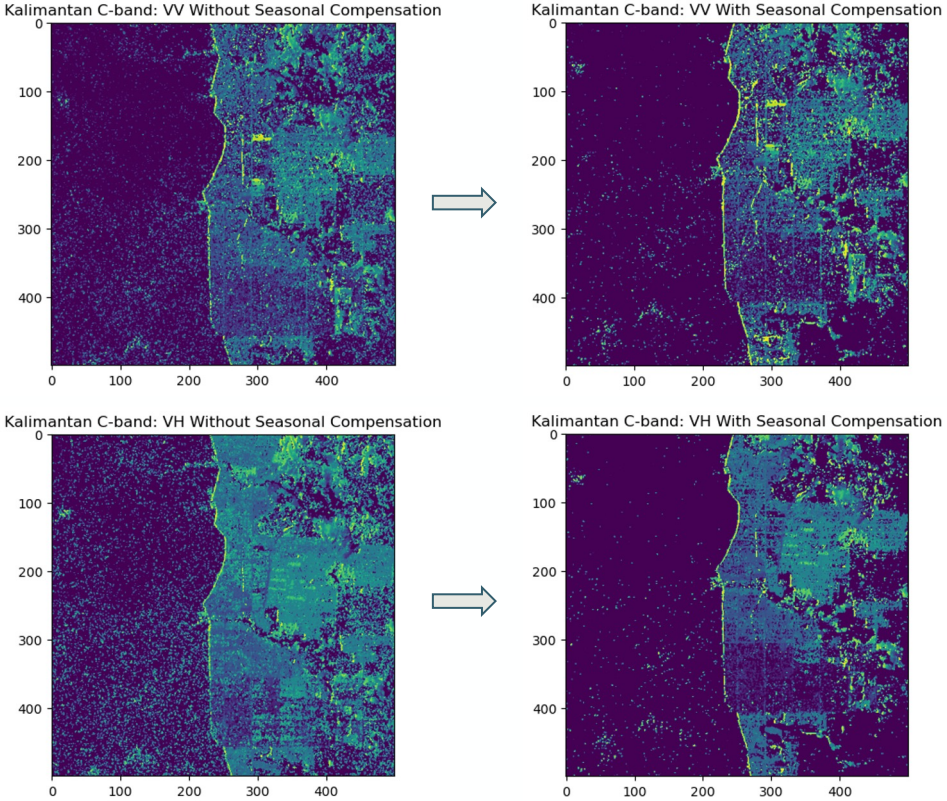
Kalimantan

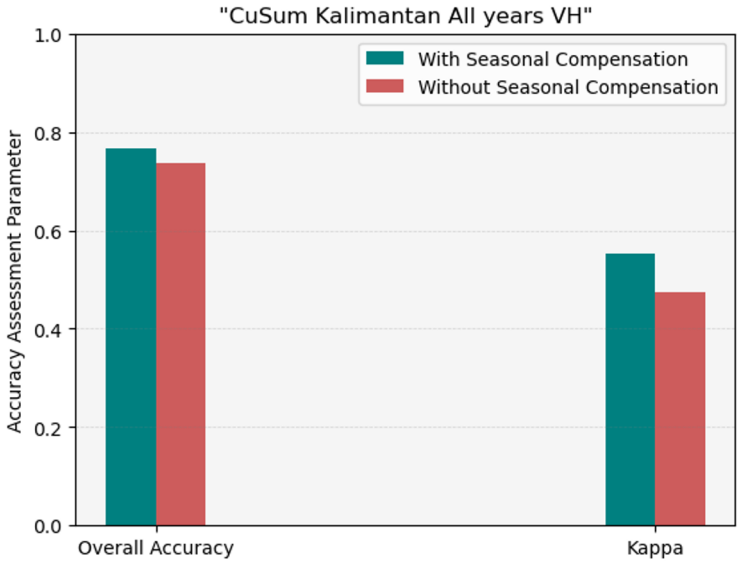
		25m	100m
Sentinel-1	Co-pol	0.474	0.614
	Cross-pol	0.561	0.828
ALOS-2	Co-pol	0.602	0.837
	Cross-pol	0.258	0.830

Haldwani

		25m	100m
Sentinel-1	Co-pol	0.745	0.559
	Cross-pol	0.608	0.533
ALOS-2	Co-pol	0.144	0.122
	Cross-pol	0.093	0.161

Compensating for seasonality





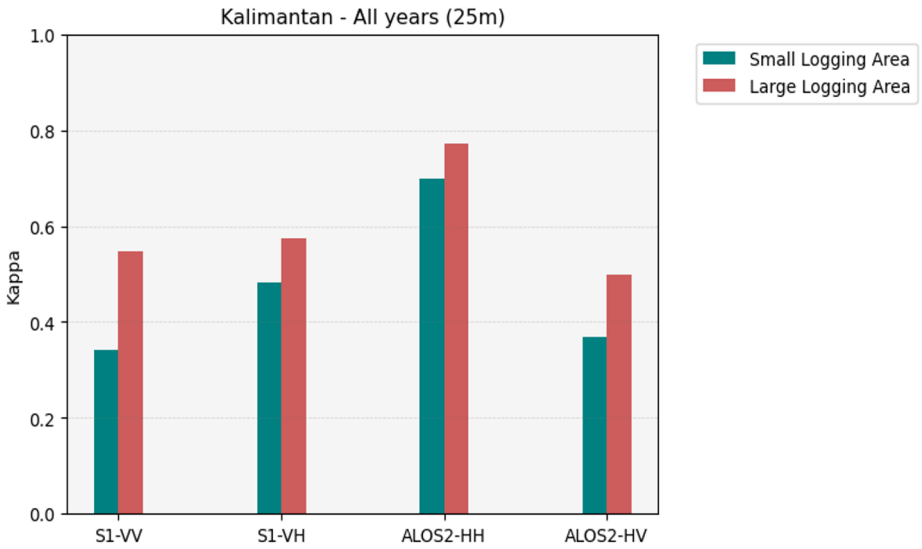
Effect of logged area size

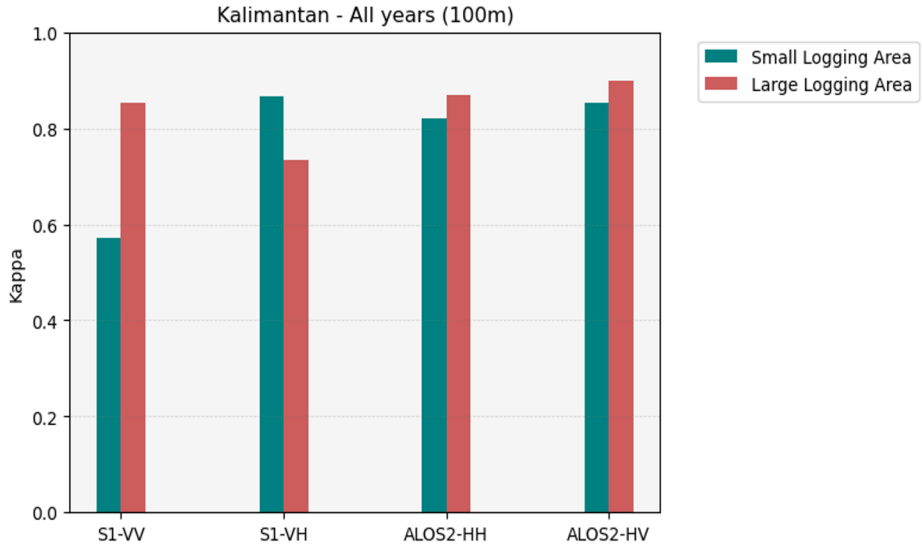
Kalimantan

Two subsets chosen with different sizes of logged area:

Small logging areas: 4 ha to 20 ha

Large logging areas: 52 ha to 796 ha





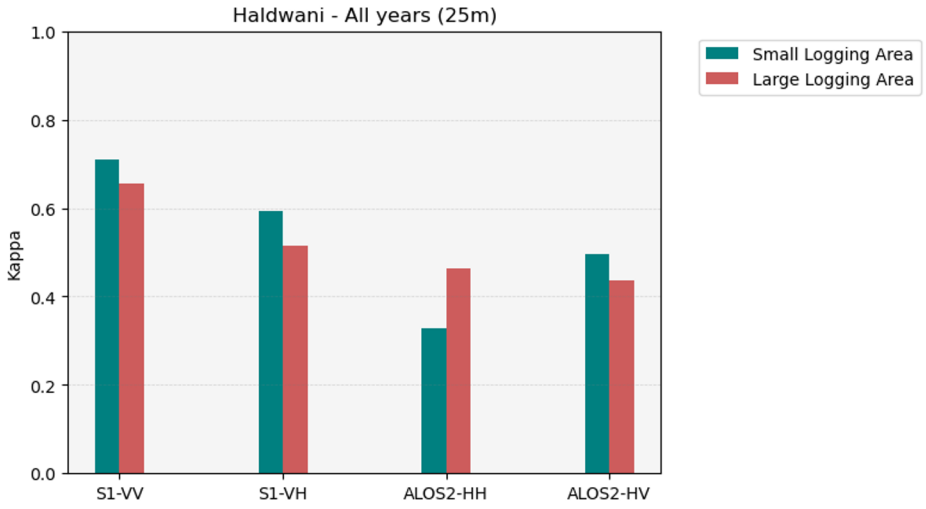
Effect of logged area size

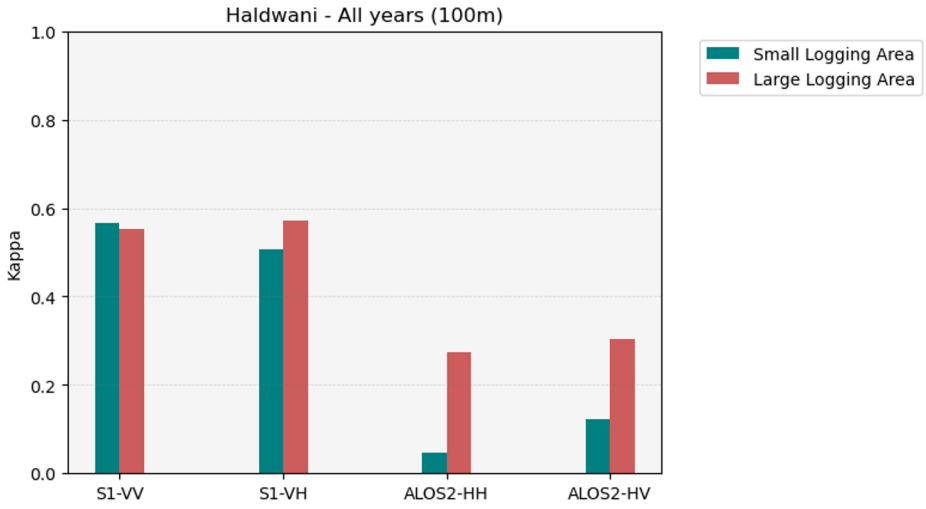
Haldwani

Two subsets chosen with different sizes of logged area

Small logging areas: 1 ha to 20 ha

Large logging areas: 30 ha to 90 ha





Take Away Message

- Forest- and management-type affects the detection of deforestation/logging
  - Logged area size
  - Frequency of logging activity
- Smaller logged regions are not captured (Haldwani)
- Impact of logged area much higher in case of L-band than at C-band
- Both polarizations perform equally in case of Kalimantan
- Cross-pol backscatter performs better in managed forests

2023 IEEE India Geoscience and Remote Sensing Symposium

Hosted at the International Institute of Information Technology, Bangalore (IIITB)

InGARSS

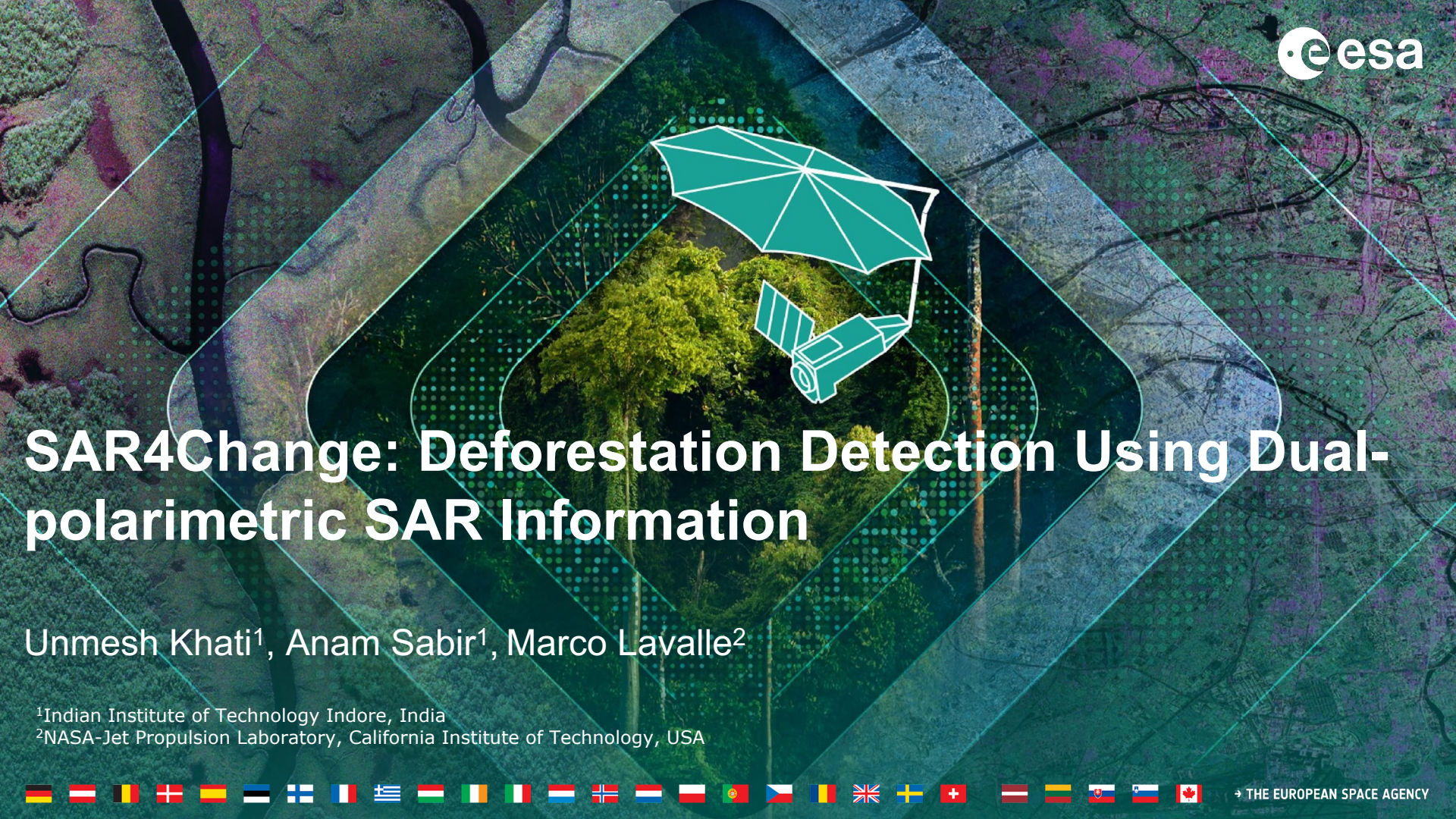
Bengaluru, India

December 10-13, 2023

10 – 13 December 2023, Bengaluru

Abstract Submission Deadline: 15th August 2023

https://ingarss.org/

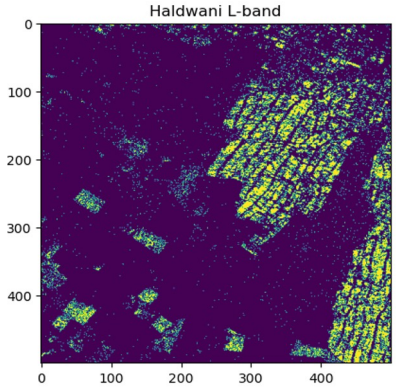


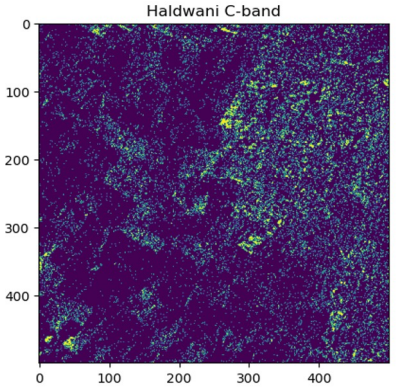
SAR4Change: Deforestation Detection Using Dual-polarimetric SAR Information

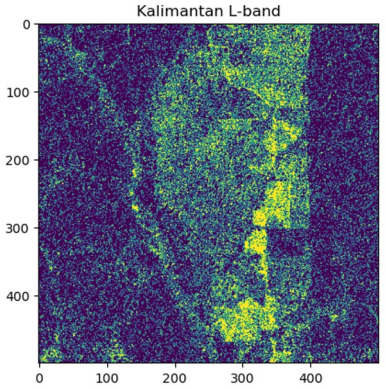
Unmesh Khati[1], Anam Sabir[1], Marco Lavalle[2]

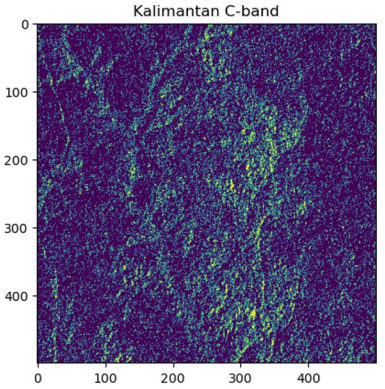
[1]Indian Institute of Technology Indore, India
[2]NASA-Jet Propulsion Laboratory, California Institute of Technology, USA

Sequential Omnibus









Observations

Sequential Omnibus