Advanced SAR Descriptors for Land Cover Characterization

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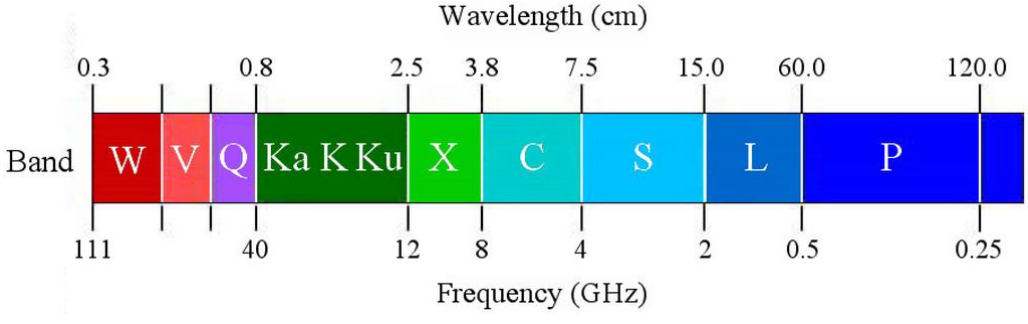
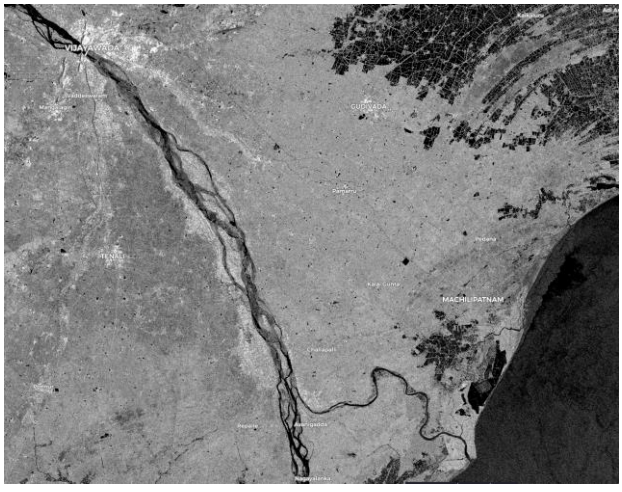
Remote Sensing Spectral Regions

- Microwave Remote Sensing
  - Microwave



Synthetic Aperture Radar (SAR) Imaging Satellites: Images



Sentinel-1 SAR image (VV Polarization)

Sentinel-2 Optical Image (FCC)

Advent of the south-west monsoon season

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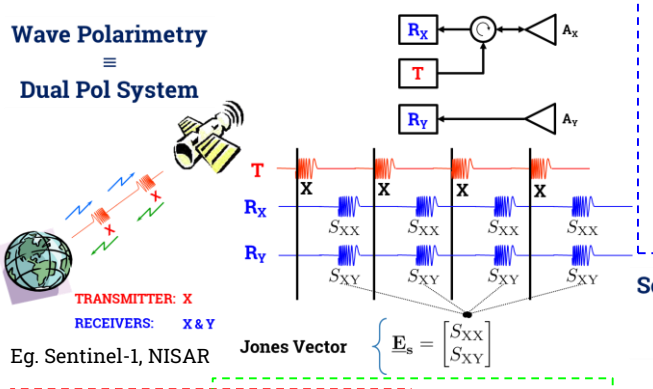
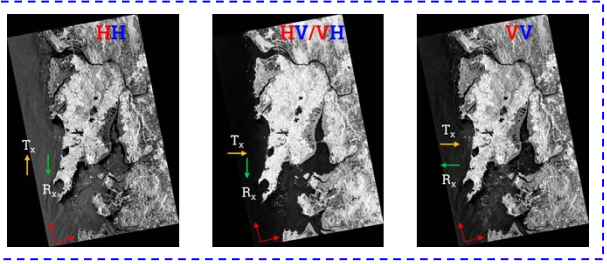
SAR Imaging Modalities

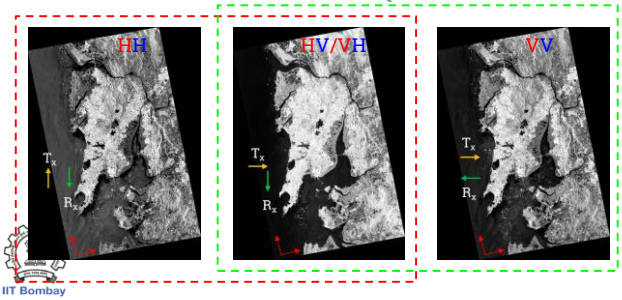
Wave Polarimetry
≡
Dual Pol System



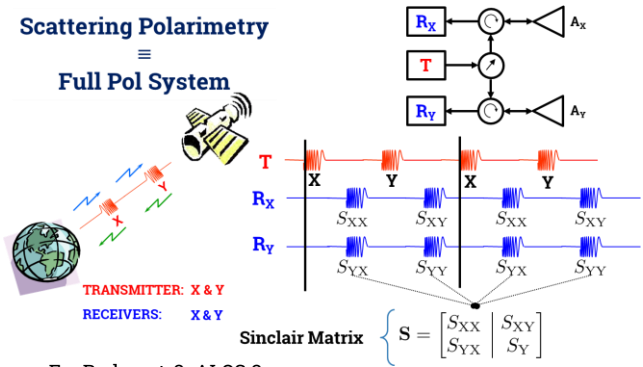
Eg. Sentinel-1, NISAR

Jones Vector $\underline{\mathbf{E}}_s = \begin{bmatrix} S_{XX} \\ S_{XY} \end{bmatrix}$





Scattering Polarimetry
≡
Full Pol System



Sinclair Matrix $\mathbf{S} = \begin{bmatrix} S_{XX} & S_{XY} \\ S_{YX} & S_Y \end{bmatrix}$

Eg. Radarsat-2, ALOS 2

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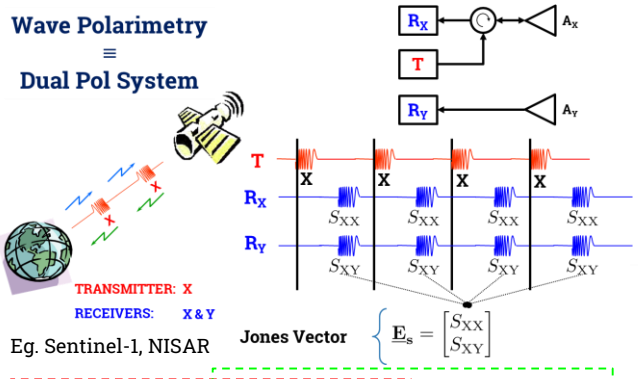
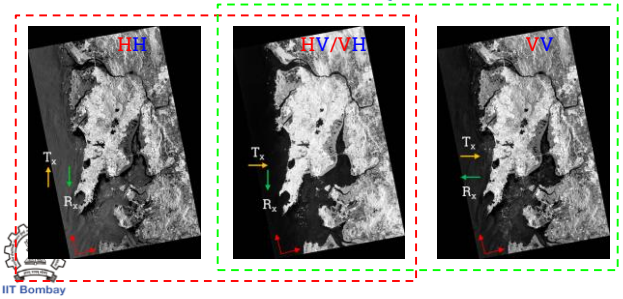
SAR Imaging Modalities

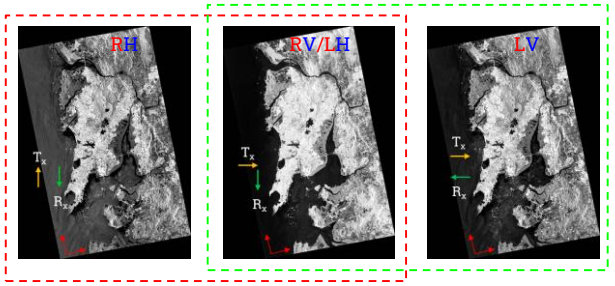
Wave Polarimetry
≡
Dual Pol System



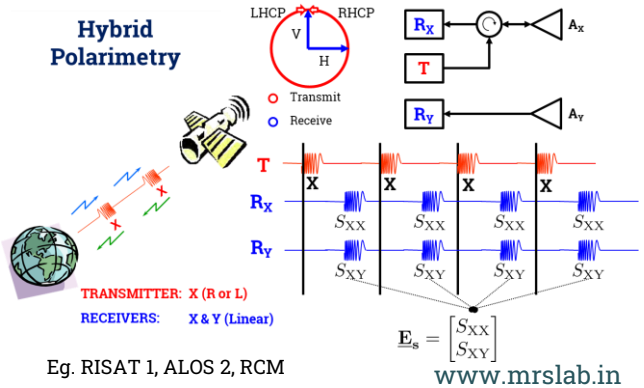
Eg. Sentinel-1, NISAR

Jones Vector $\underline{E}_s = \begin{bmatrix} S_{XX} \\ S_{XY} \end{bmatrix}$





Hybrid Polarimetry



Eg. RISAT 1, ALOS 2, RCM

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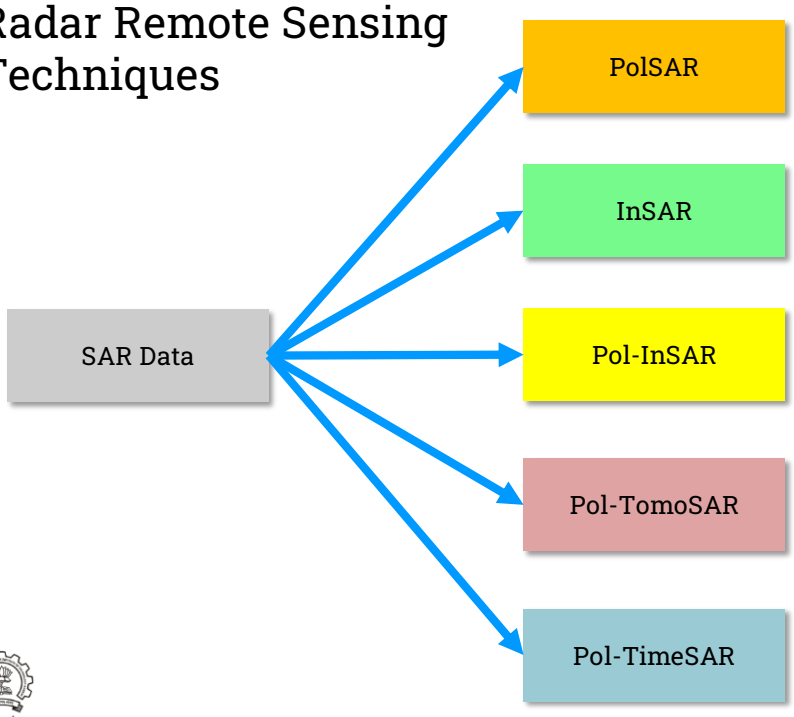
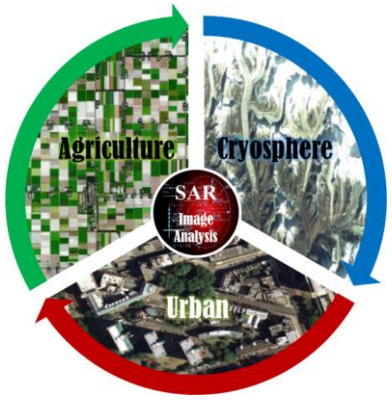
Radar Remote Sensing Techniques





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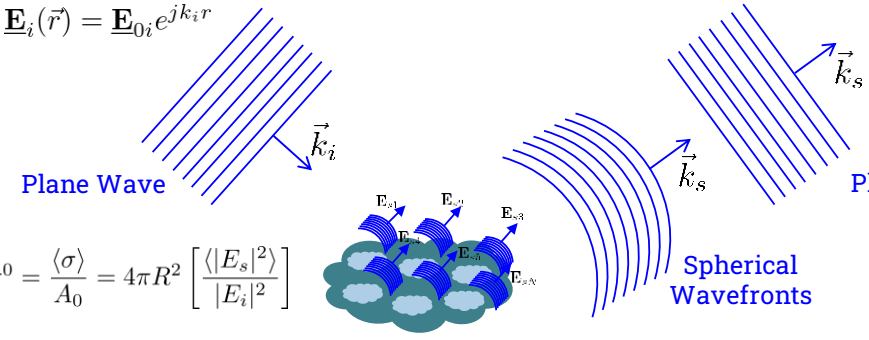
Scattering from an Extended Target

Far Field Approximation

$$\underline{\mathbf{E}}_i(\vec{r}) = \underline{\mathbf{E}}_{0i} e^{jk_i r}$$

$$\underline{\mathbf{E}}_s(\vec{r}) = \underline{\mathbf{E}}_{0s} e^{jk_s \cdot r}$$

$$|\vec{r}| \gg \lambda$$



$$\sigma^0 = \frac{\langle \sigma \rangle}{A_0} = 4\pi R^2 \left[\frac{\langle |E_s|^2 \rangle}{|E_i|^2} \right]$$

$$\underline{\mathbf{E}}_s(\vec{r}) = \frac{e^{jkr}}{r} [\mathbf{S}] \underline{\mathbf{E}}_i(\vec{r})$$

$$\begin{bmatrix} E_{s\perp}(\vec{r}) \\ E_{s\parallel}(\vec{r}) \end{bmatrix} = \frac{e^{jkr}}{r} \begin{bmatrix} S_{\perp\perp}(\vec{r}) & S_{\perp\parallel}(\vec{r}) \\ S_{\parallel\perp}(\vec{r}) & S_{\parallel\parallel}(\vec{r}) \end{bmatrix} \begin{bmatrix} E_{i\perp}(\vec{r}) \\ E_{i\parallel}(\vec{r}) \end{bmatrix}$$

2×2 Complex Scattering Matrix

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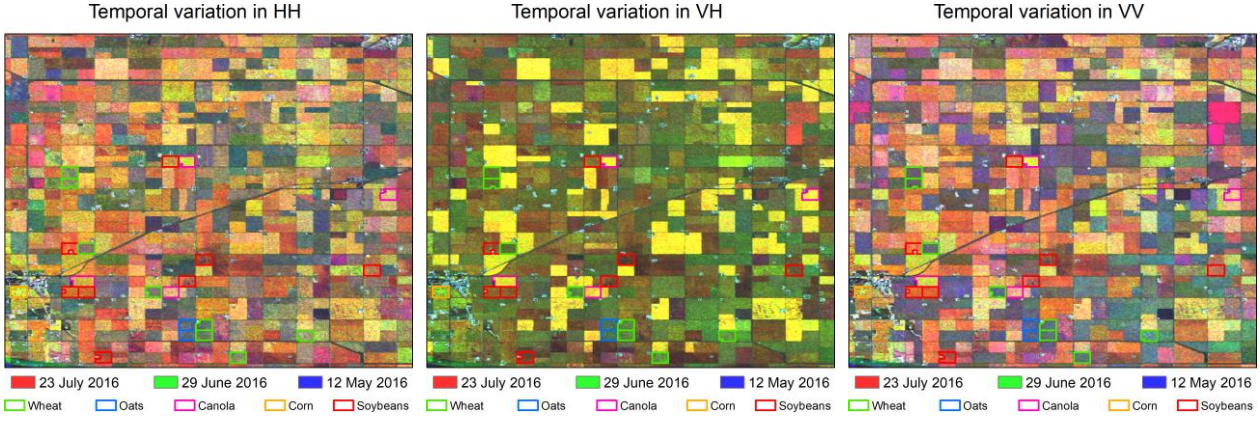
Temporal Variation in SAR Backscatter Intensity



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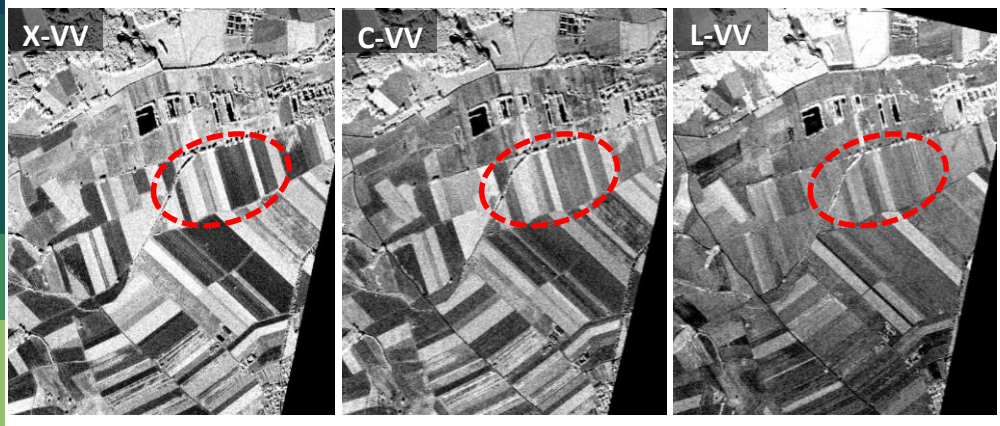
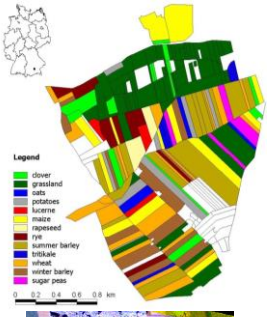
Dependence of Frequency on Target

Airborne E-SAR data, June 14, 2000: Bavaria, Germany





Adapted from EO-college lecture notes https://eo-college.org/resource-spectrum/radar/

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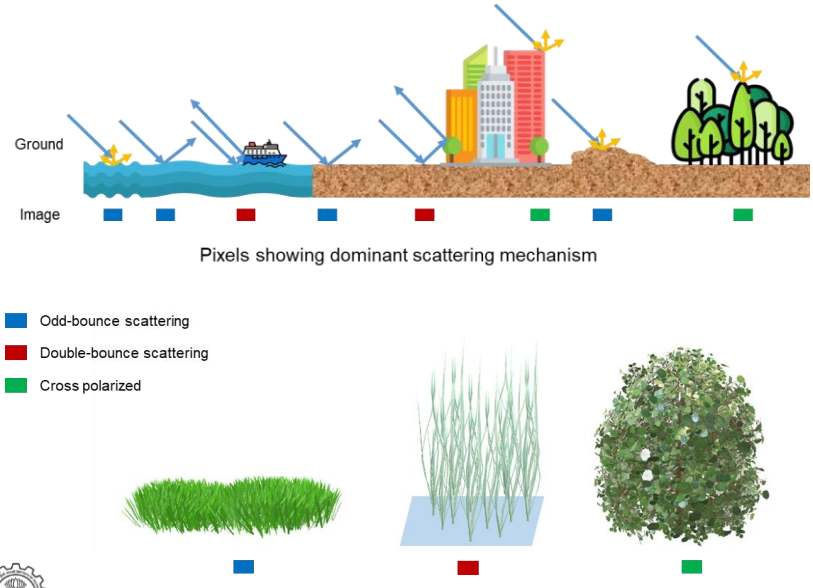
Sensitivity to Target Geometry & Polarization



Pauli RGB

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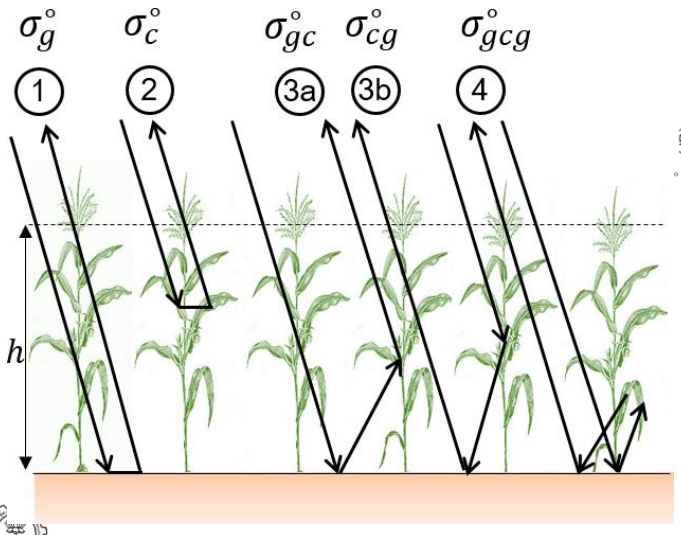
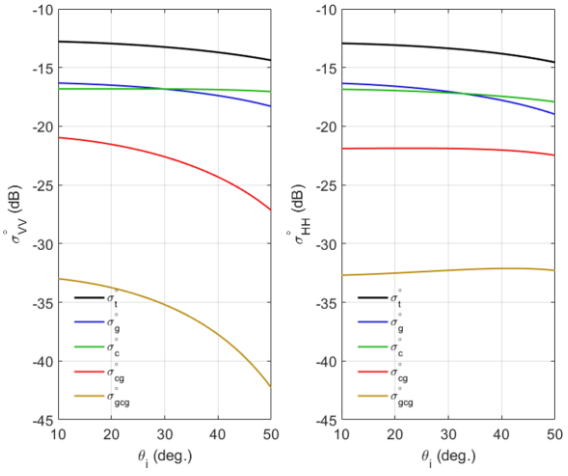
Dependence of Target Geometry & Polarization

Soil-Vegetation Interaction using a physical model





$$\sigma^\circ_{t_{pq}} = \sigma^\circ_{g_{pq}} + \sigma^\circ_{c_{pq}} + \sigma^\circ_{gc_{pq}} + \sigma^\circ_{cg_{pq}} + \sigma^\circ_{gcg_{pq}}$$

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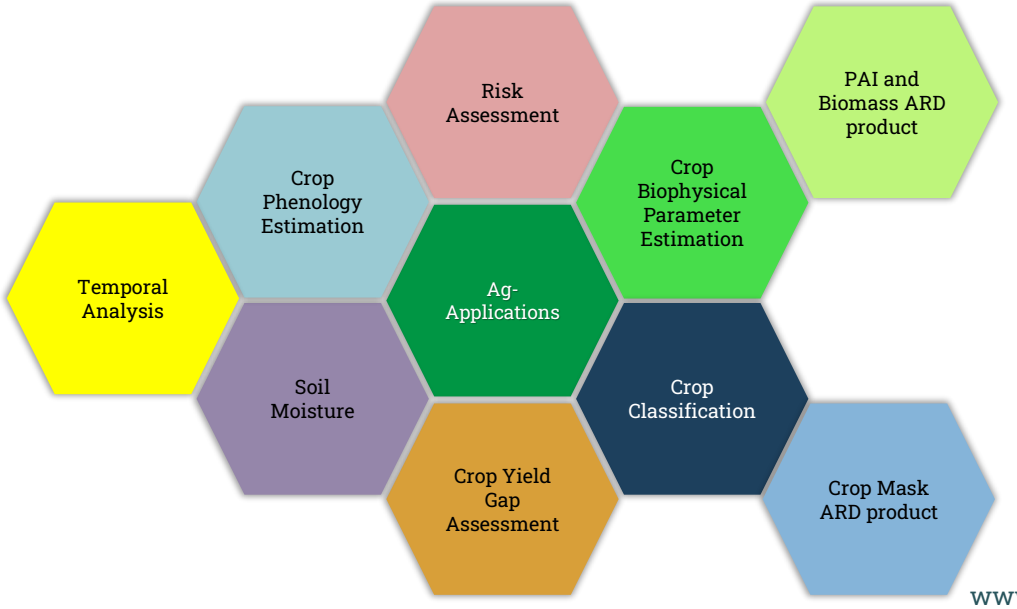
Research Components in SAR Agriculture



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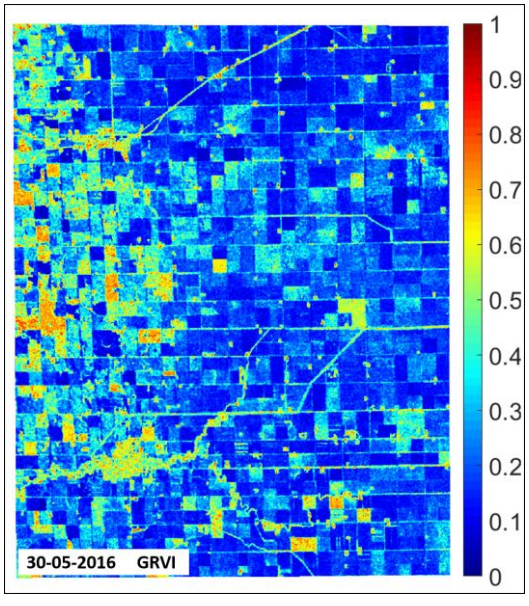
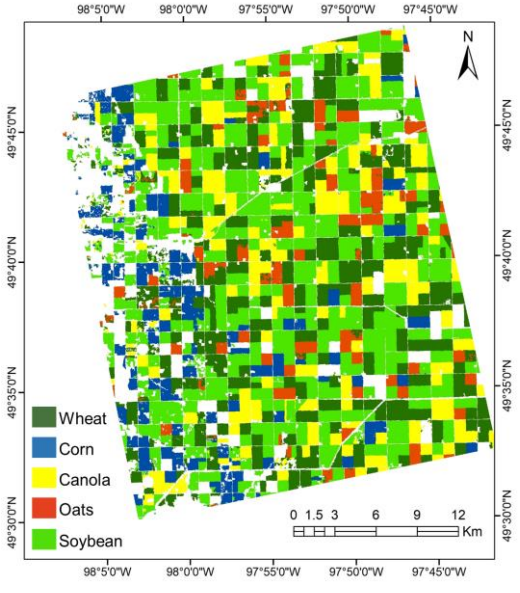
Crop Characterization with Full-Pol SAR

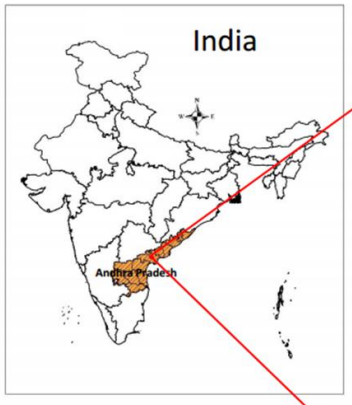
Radar Vegetation Index: Temporal Variation



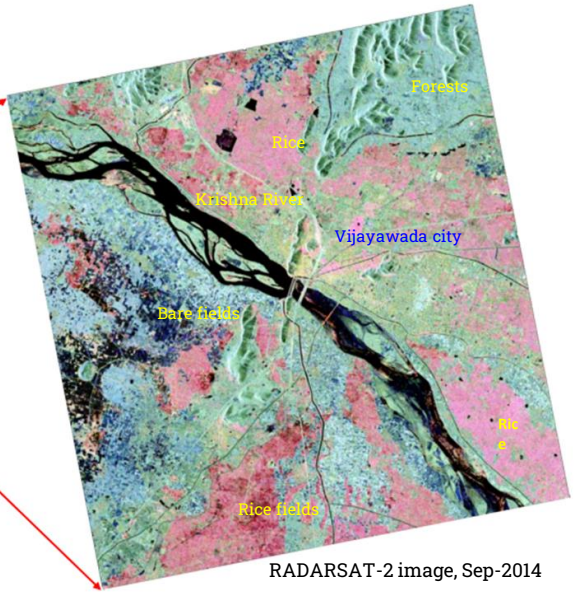


A Generalized Volume Scattering Model Based Vegetation Index from Polarimetric SAR Data,
D. Ratha, D. Mandal, V. Kumar, H. McNairn, A. Bhattacharya and A. C. Frery, *IEEE Geoscience and Remote Sensing Letters*, 2019

Vijayawada, India: SAR Image Visualization



$|HH+VV|$ $|HV|$ $|HH-VV|$



RADARSAT-2 image, Sep-2014

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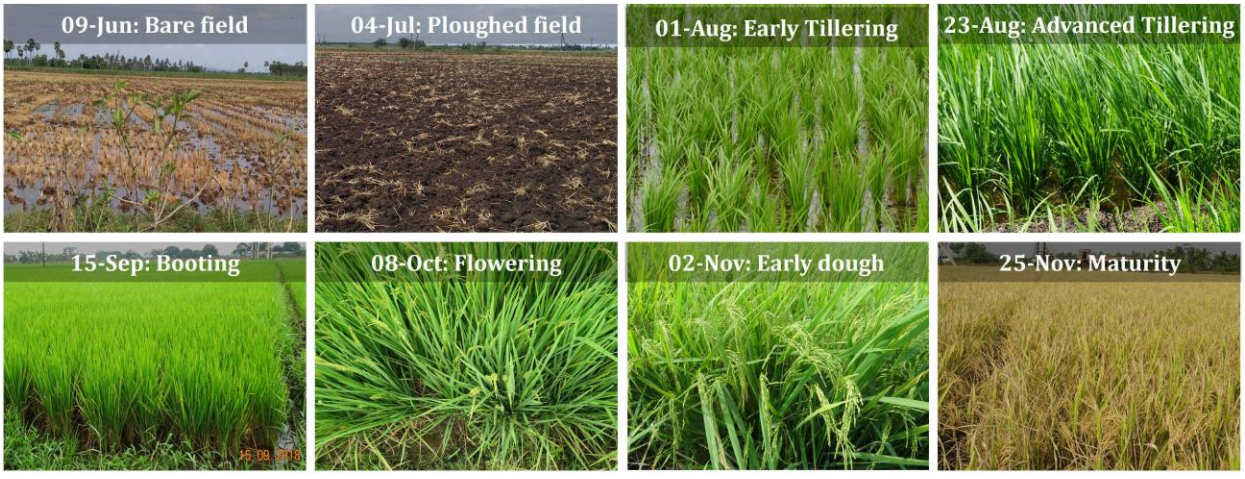
Transplanted Rice (TR)



- In traditional farming, rice is primarily grown by transplanting seedlings into flooded puddled fields.
- The TR cultivation requires a high amount of water (150 cm) for puddling and further maintenance of standing-water conditions

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Direct Seeded Rice (DSR)

- DSR cultivation includes alternate wetting and drying instead of standing-water condition.
- The DSR method of cultivation reduces water consumption by ~30% by eliminating the nursery raising, puddling, transplanting, and initial standing-water condition during early tillering stage

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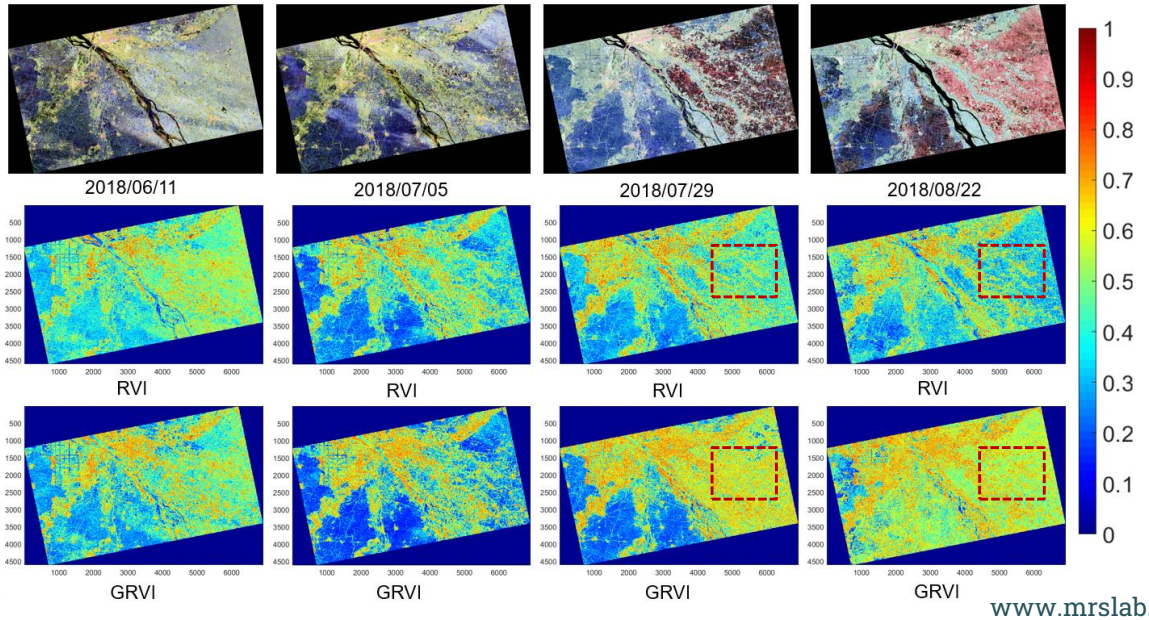
Vegetation Index: Temporal Variation



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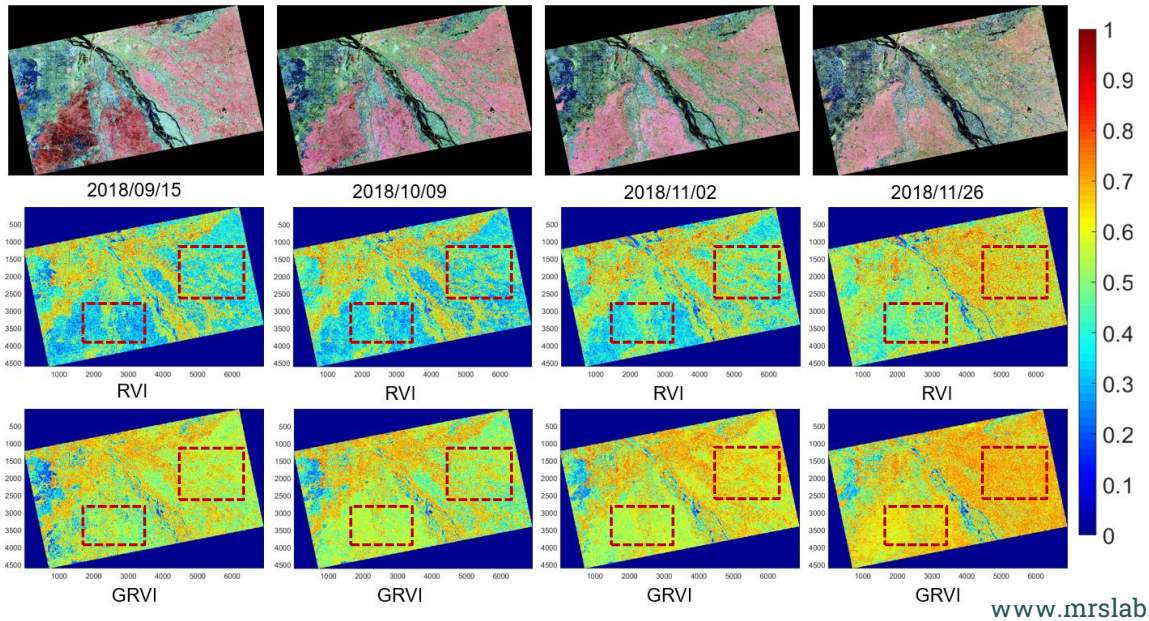
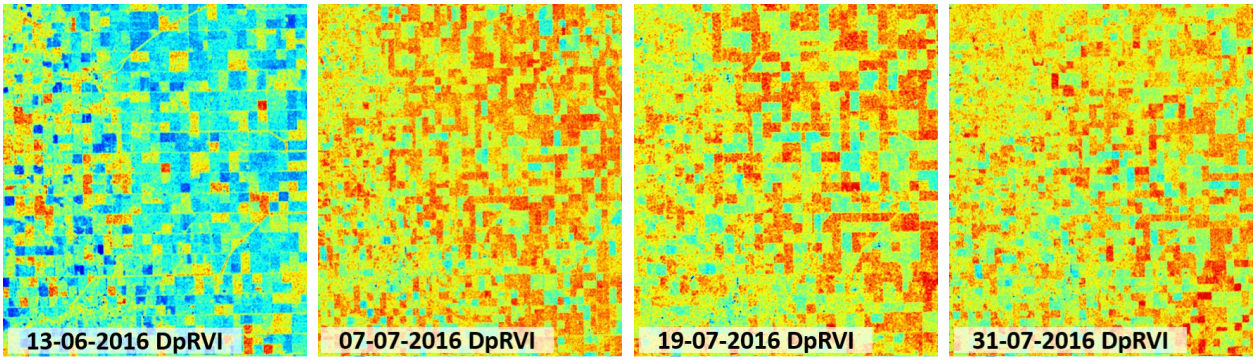
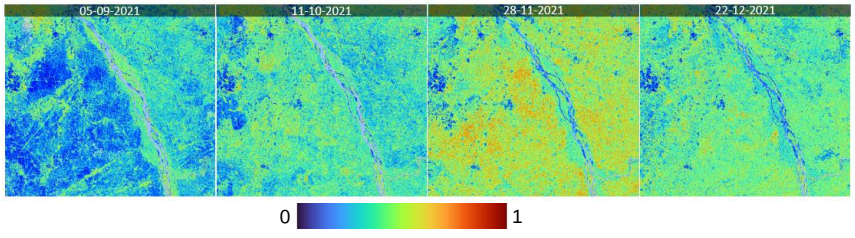
Vegetation Index: Temporal Variation



Crop Characterization with Dual-Pol SAR

Dual-pol Vegetation Index: DpRVI (SLC)





Available in SNAP

Dual polarimetric radar vegetation index for crop growth monitoring using sentinel-1 SAR data, D. Mandal, V. Kumar, D. Ratha, S. Dey, A. Bhattacharya, J. M. Lopez-Sanchez, H. McNairn, and Y. S. Rao, *Remote Sensing of Environment,* 247 (2020):111954.

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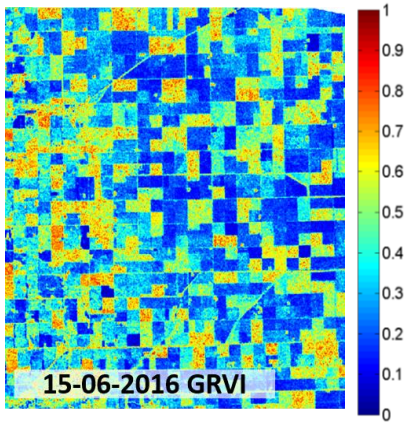
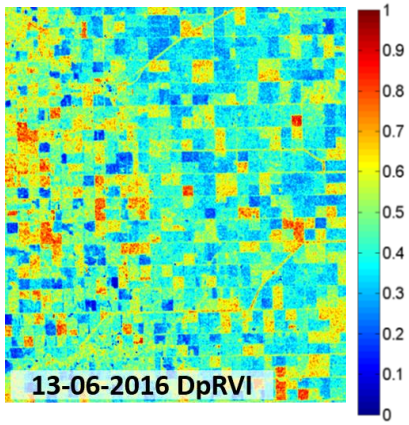
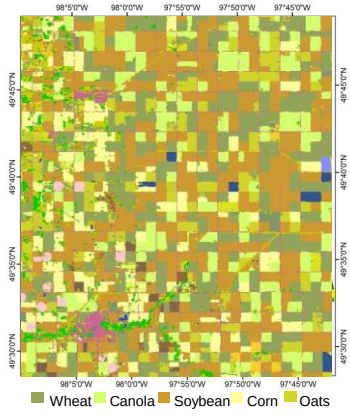
Full & Dual Polarimetric Radar Vegetation Indices



GRVI (RS-2 Dataset)



DpRVI (S1 Dataset)



Crop Map

A Generalized Volume Scattering Model-Based Vegetation Index From Polarimetric SAR Data,
D. Ratha, D. Mandal, V. Kumar, H. McNairn, A. Bhattacharya and A. C. Frery, *IEEE Geoscience and Remote Sensing Letters*, vol. 16, no. 11, pp. 1791-1795, 2019

Dual polarimetric radar vegetation index for crop growth monitoring using sentinel-1 SAR data,
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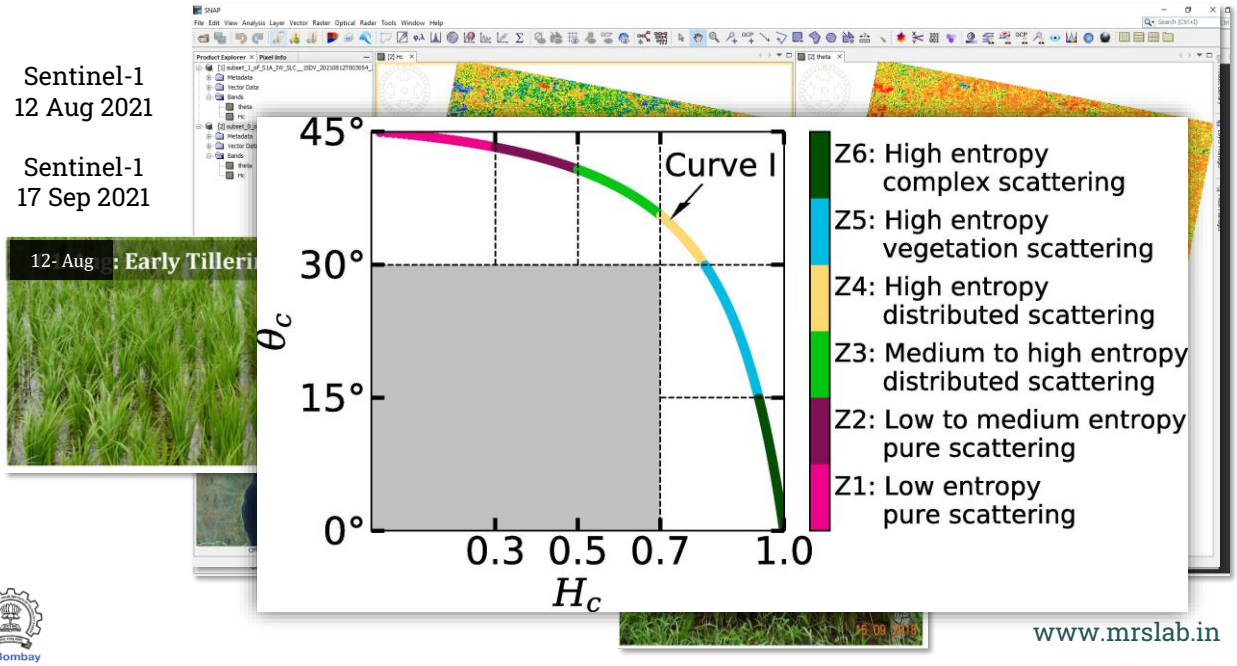
Crop Phenology Mapping Using Advanced Descriptors II

Sentinel-1
12 Aug 2021

Sentinel-1
17 Sep 2021



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Built-up Area Characterization with Dual-Pol SAR

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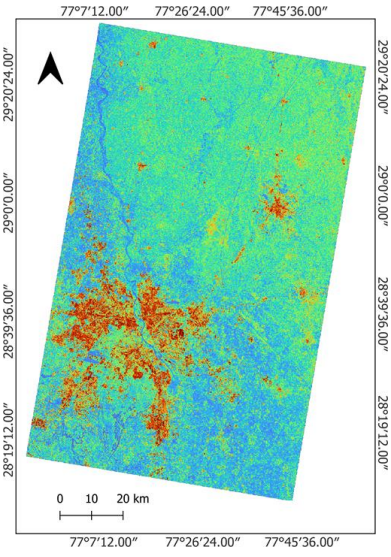
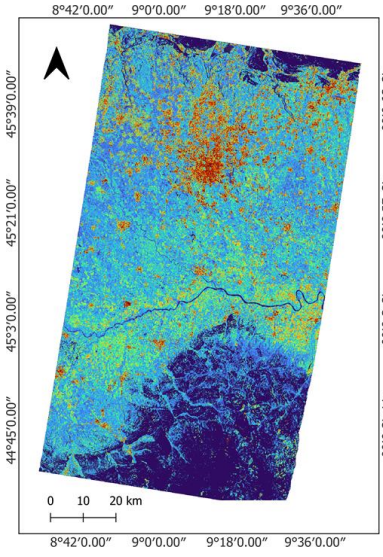
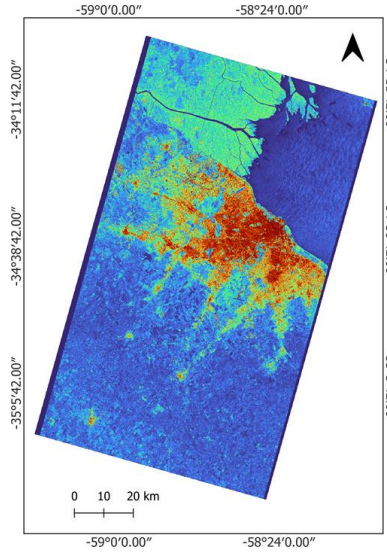
Dual-pol Radar Built-up Index (DpRBI)



Delhi, India



Milan, Italy



Buenos Aires, Argentina

1 0

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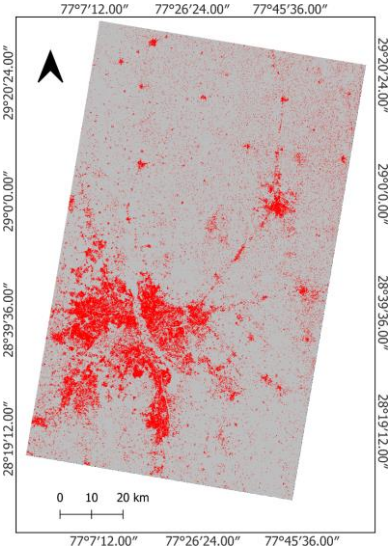
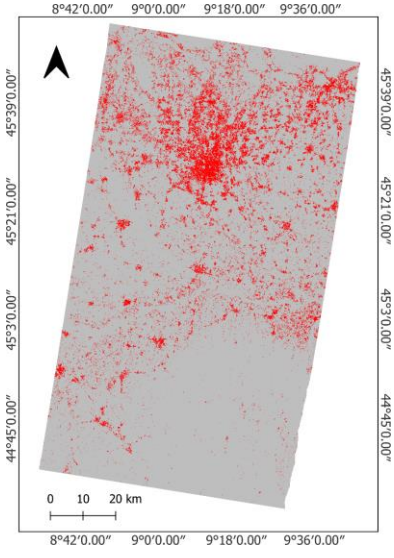
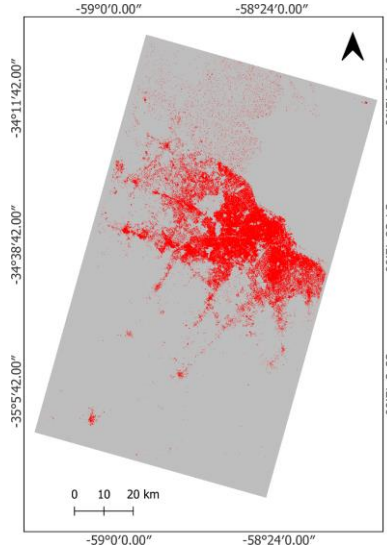
Built-up map using DpRBI



Delhi, India



Milan, Italy



Buenos Aires, Argentina

Built-up Non-Built-up

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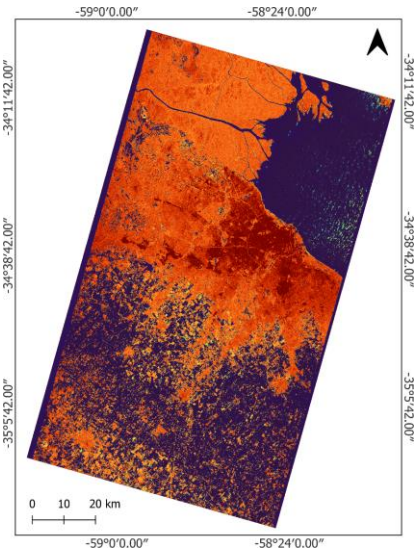
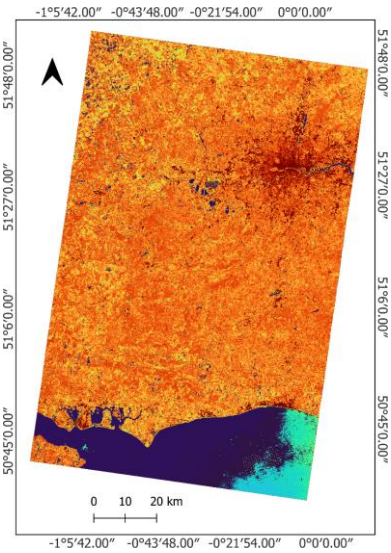
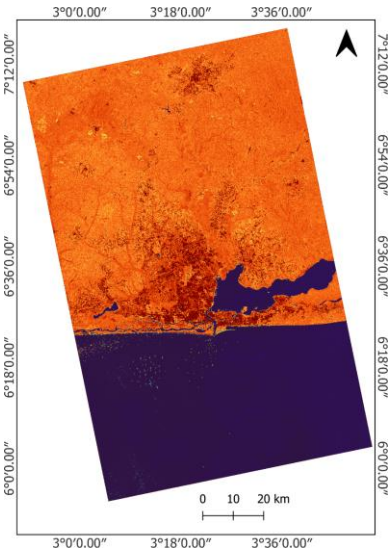
Dual-pol Radar Surface Index



Buenos Aires, Argentina



London, United Kingdom



Lagos, Nigeria

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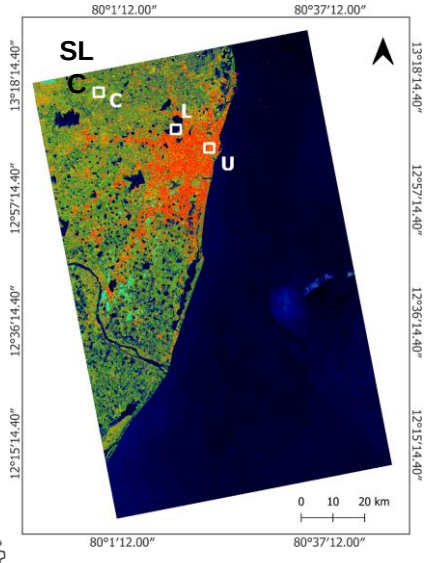
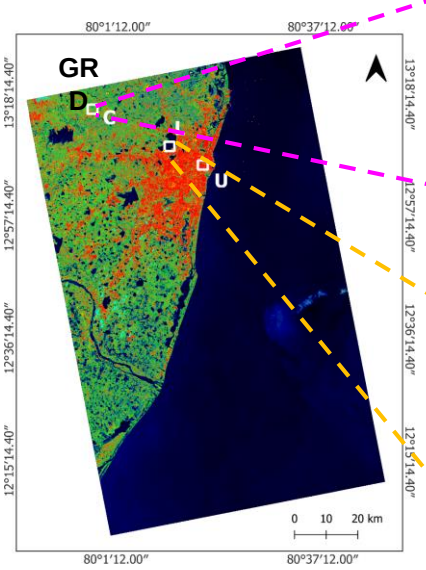
Scattering Power Components Over Land Cover

Chennai, India





Cropland (C): GE Image

Lake (L): GE Image

P_{d-l} P_r P_{s-l}

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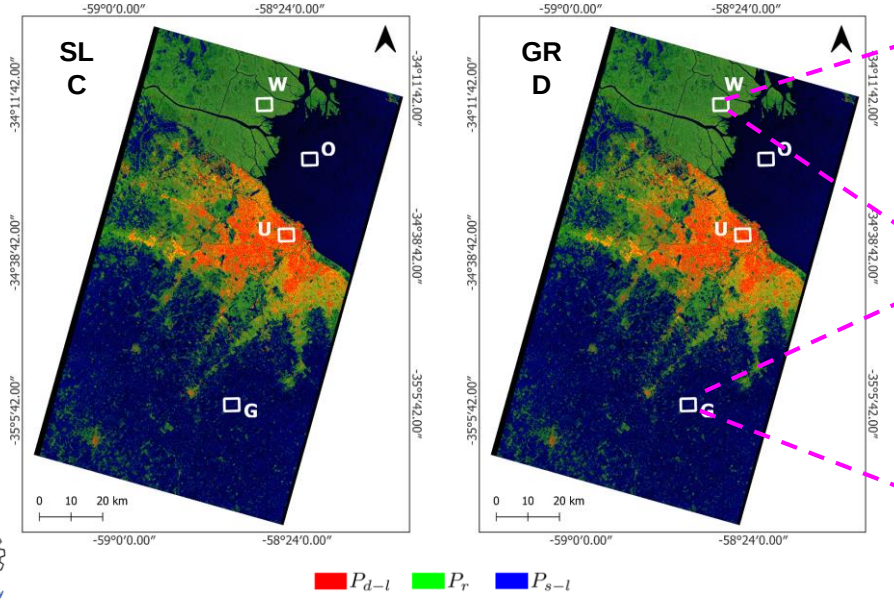
Scattering Power Components Over Land Cover

Buenos Aires, Argentina



Wetland (W): GE Image

Grassland (G): GE Image

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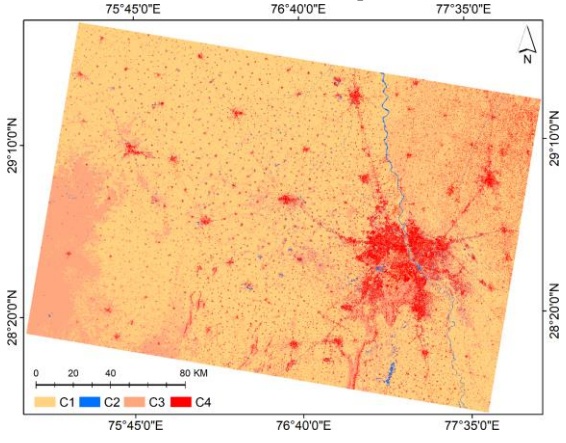
A Cloud-Based Clustering Framework for Urban Area Segmentation

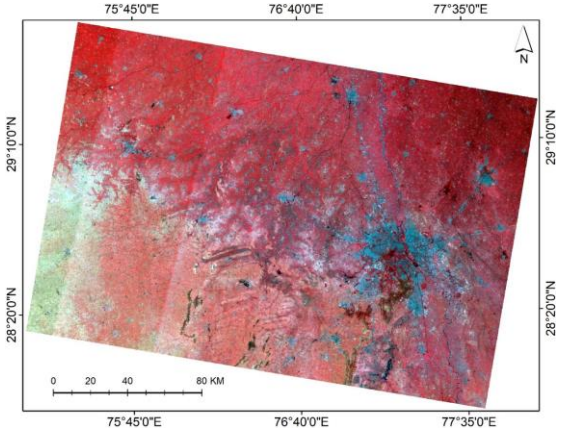
Delhi, India

Classified Map



C1 → Cropland
C2 → Waterbody
C3 → Shrubland/Bare/Sparse Vegetation
C4 → Built-up

Sentinel-2 Standard FCC



Dominant Land Cover

- Cropland
- Built-up areas
- Shrubland
- Bare/Sparse Vegetation
- Water body

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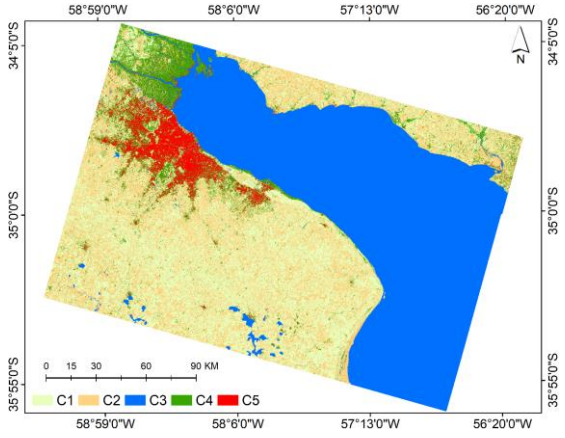
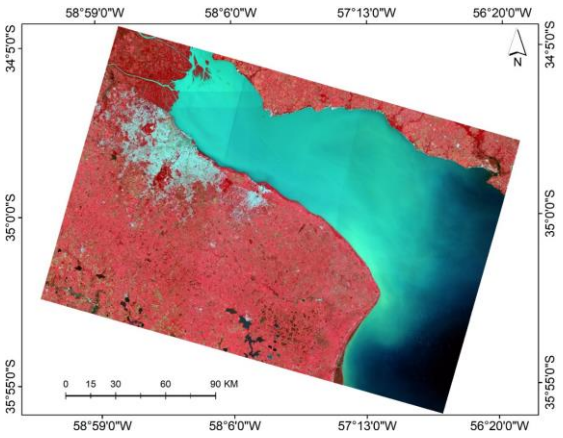
A Cloud-Based Clustering Framework for Urban Area Segmentation

Buenos Aires, Argentina

Classified Map



Sentinel-2 Standard FCC



C1 → Grassland
C2 → Cropland
C3 → Waterbody
C4 → Tree Cover (Forest)
C5 → Built-up

Dominant Land Cover

- Waterbody
- Cropland
- Grassland
- Tree Cover (Forest)
- Built-up

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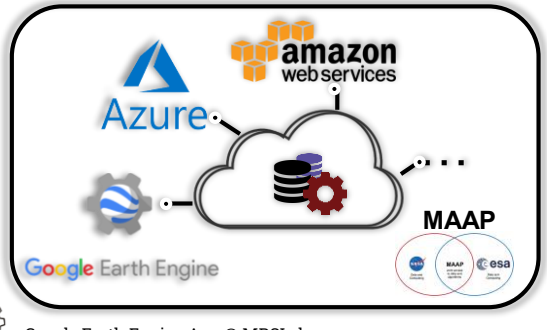
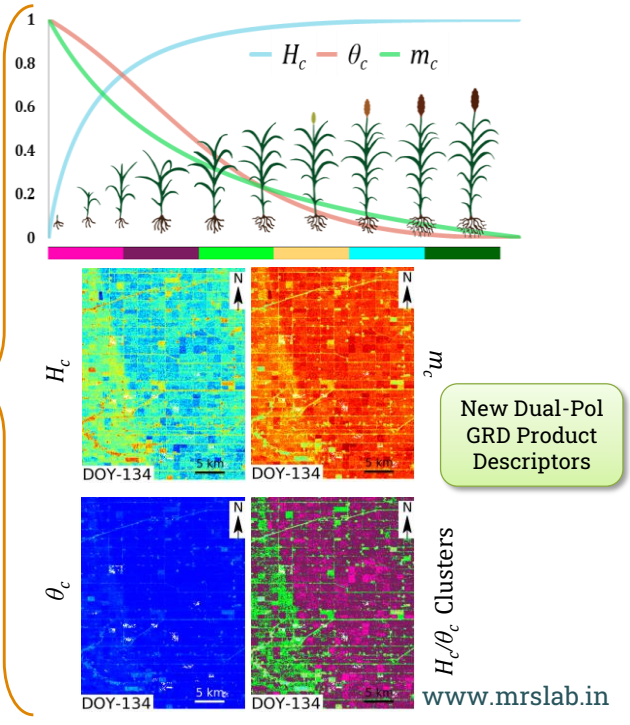


Google Earth Engine App @ MRSLab
URL: https://bnarayanarao.users.earthengine.app/view/dpgrd



New Dual-Pol GRD Product Descriptors

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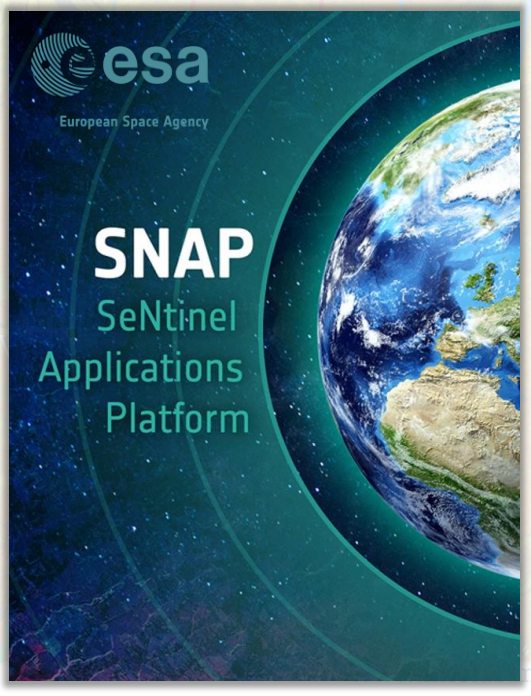
The functionalities are now available in version 9.0.0

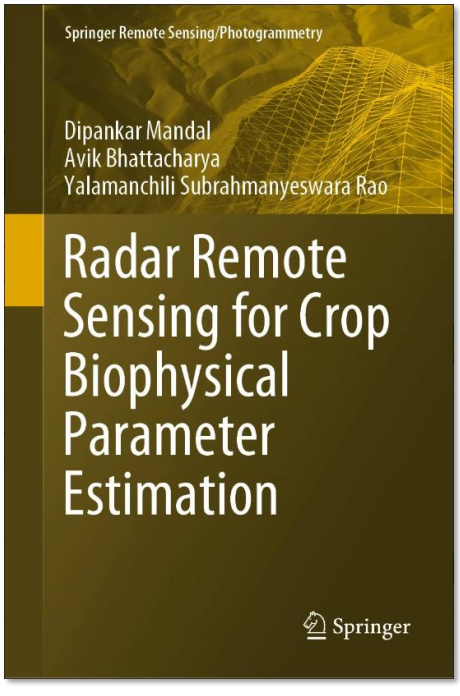
A Generalized Volume Scattering Model Based Vegetation Index from Polarimetric SAR Data,
D. Ratha, D. Mandal, V. Kumar, H. McNairn, A. Bhattacharya, A. C. Frery,
IEEE Geoscience and Remote Sensing Letters, vol. 16, no. 11, pp. 1791-1795, 2019

Dual polarimetric radar vegetation index for crop growth monitoring using sentinel-1 SAR data,
D. Mandal, V. Kumar, D. Ratha, S. Dey, A. Bhattacharya, J. M. Lopez-Sanchez, H. McNairn, Y. S. Rao,
Remote Sensing of Environment, vol. 247, 2020

A radar vegetation index for crop monitoring using compact polarimetric SAR data,
D. Mandal, D. Ratha, A. Bhattacharya, V. Kumar, H. McNairn, Y. S. Rao, A. C. Frery,
IEEE Transactions on Geoscience and Remote Sensing, vol. 58, 2020

Dual-polarimetric descriptors from Sentinel-1 GRD SAR data for crop growth assessment,
N. Bhogapurapu, S. Dey, A. Bhattacharya, D. Mandal, J. M. Lopez-Sanchez, H. McNairn, C. López-Martínez, Y. S. Rao,
ISPRS Journal of Photogrammetry and Remote Sensing, vol. 178, 2021





About this book :

This book presents a timely investigation of :

- Basic Theory of Radar Polarimetry
- Vegetation Models: Empirical and Theoretical Approaches
- Evolution of Semi-empirical Approach: Modeling and Inversion
- Biophysical Parameter Retrieval Using Full- and Dual-Pol SAR Data
- Biophysical Parameter Retrieval Using Compact-Pol SAR Data
- Radar Vegetation Indices for Crop Growth Monitoring

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Reproducibility and Replicability

PyPI packages

The codes are available through this link:

https://github.com/mrslab-iitb

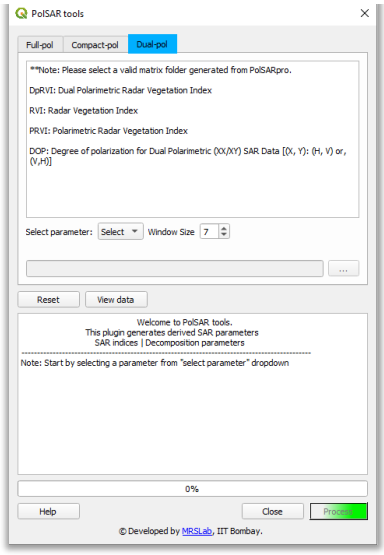
https://plugins.qgis.org/plugins/polsar_tools/

https://bnarayanarao.users.earthengine.app/view/dpgrd

Vegetation Indices
Generalized Radar Vegetation Index (GRVI)
Dual-pol Radar Vegetation Index (DpRVI)
Compact-pol Radar Vegetation Index (CpRVI)

Model-free (MF#Components) Decomposition Techniques
MF3CF, MF4CF for full-pol SAR data
MF3CC for compact-pol SAR data

MF3CF: https://pypi.org/project/mf3cf/
MF3CC: https://pypi.org/project/mf3cc/



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Our Collaborators :

Research Collaborators:

Satellite Data Access and Projects:

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