BURNED AREA MAPPING USING SCATTERING SPECTRUM INFORMATION FROM FULL POLARIMETRIC ALOS-2 SAR DATA

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Dichotomies in Forest Fire Mapping

- Imaging RADAR data over Boreal forest (Bourgeau-Chavez et al., 2002)
- Modis active fire detection products (Schroeder et al., 2008)
- Sensitivity of X-, C- and L-band SAR over Mediterranean forest (Tanase et al., 2010)
- Ensemble projections of wildfire activity (Yue et al., 2013)

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Polarimetric Spectrum

- In full-polarimetric (FP) SAR, the 2 ×2 complex scattering matrix can be represented as,

$$\mathbf{S} = \begin{bmatrix} S_{\mathrm{HH}} & S_{\mathrm{HV}} \\ S_{\mathrm{VH}} & S_{\mathrm{VV}} \end{bmatrix} \Rightarrow \tilde{\mathbf{k}} = V([\mathbf{S}]) = \frac{1}{2}\mathrm{Tr}(\mathbf{S}\Psi)$$

k = Pauli basis vector

- V(.) is the vectorization operator on the scattering matrix, Tr is the trace operator
- The second-order information can be obtained as,

$$\mathbf{T} = \langle \tilde{\mathbf{k}}\,\tilde{\mathbf{k}}^{*T} \rangle$$

- Now let us define a 3 ×1 complex scattering vector,

$$\tilde{\omega} = \begin{bmatrix} Ae^{i\phi_1} \\ Be^{i\phi_2} \\ Ce^{i\phi_3} \end{bmatrix}$$

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Polarimetric Spectrum

- We then project the normalized complex vector $\tilde{\omega}_n = \tilde{\omega}/|\tilde{\omega}|$ by the coherency matrix, **T**

$$\tilde{\omega}_s = \mathbf{T}\tilde{\omega}_n$$

- $\tilde{\omega}_s$ allows us to project the data (**T**), onto any arbitrary scattering basis (by varying $\tilde{\omega}_n$)
- **T** is positive semi-definite, $\langle \tilde{\omega}_n^* \tilde{\omega}_s \rangle \geq 0$
- One can note that $\tilde{\omega}_s = \tilde{\omega}_n$ only when **T** represents a canonical target
- We utilize the projected scattering vector $\tilde{\omega}_s$ to obtain a higher-order coherency matrix,

$$\mathbf{T}_s = \langle \tilde{\omega}_s \tilde{\omega}_s^{*T} \rangle$$

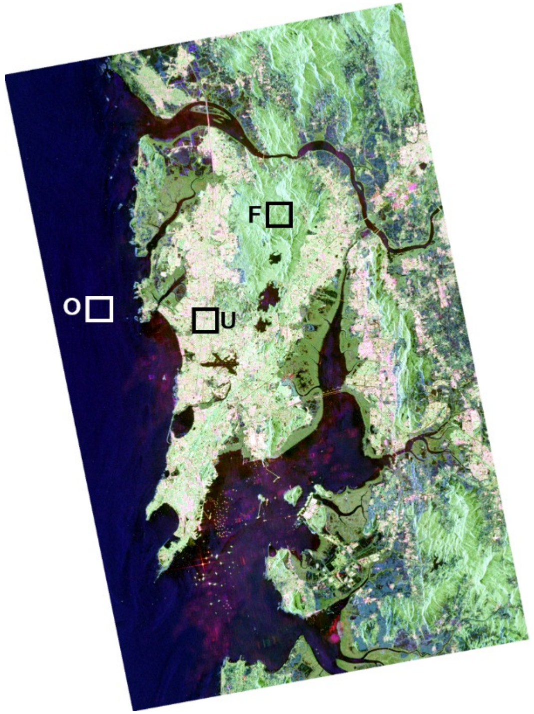
- $\mathbf{T}_s$ is Hermitian and positive semi-definite
- We then utilize Schur factorization to obtain the second order scattering information, $\mathbf{T}_p$
- The scattering-type parameter is derived as,

$$\tan\theta_{\text{FP}}^{p} = \frac{m_{\text{FP}}\,\text{Span}\,\left(T_{11} - T_{22} - T_{33}\right)}{T_{11}\left(T_{22} + T_{33}\right) + m_{\text{FP}}^2\,\text{Span}^2}$$

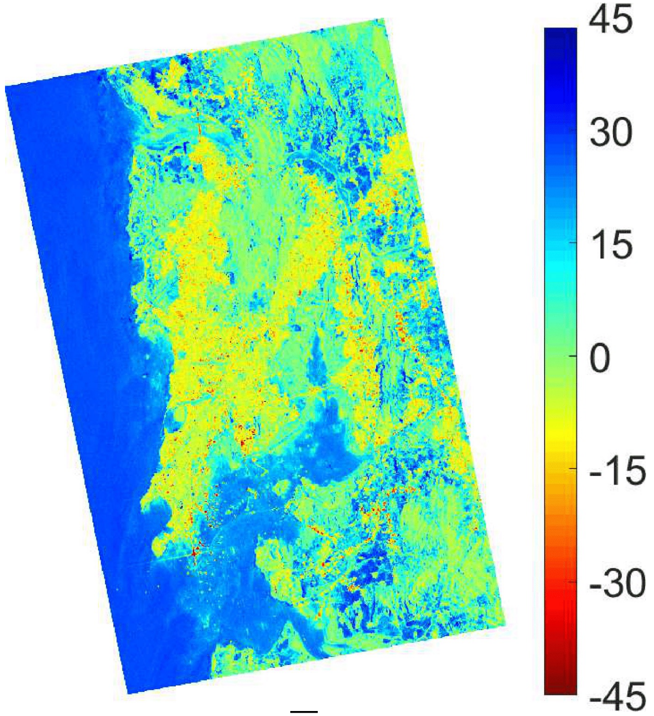
Target Characterization Parameter

$$\tan\theta_{FP} = \frac{m_{FP}\,\mathrm{Span}\,(T_{11} - T_{22} - T_{33})}{T_{11}(T_{22} + T_{33}) + m_{FP}^2\mathrm{Span}^2}$$

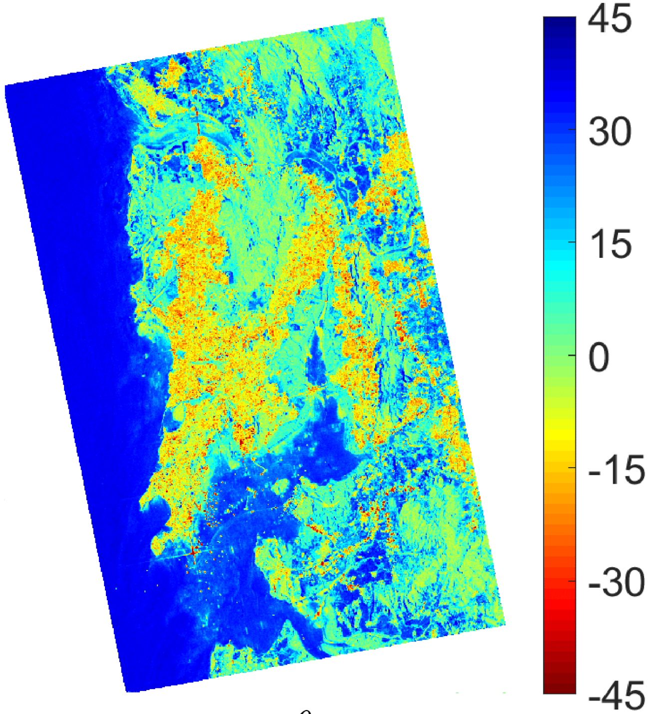
$$-45^\circ \le \theta_{FP} \le 45^\circ$$



ALOS-2 Mumbai (L-band)

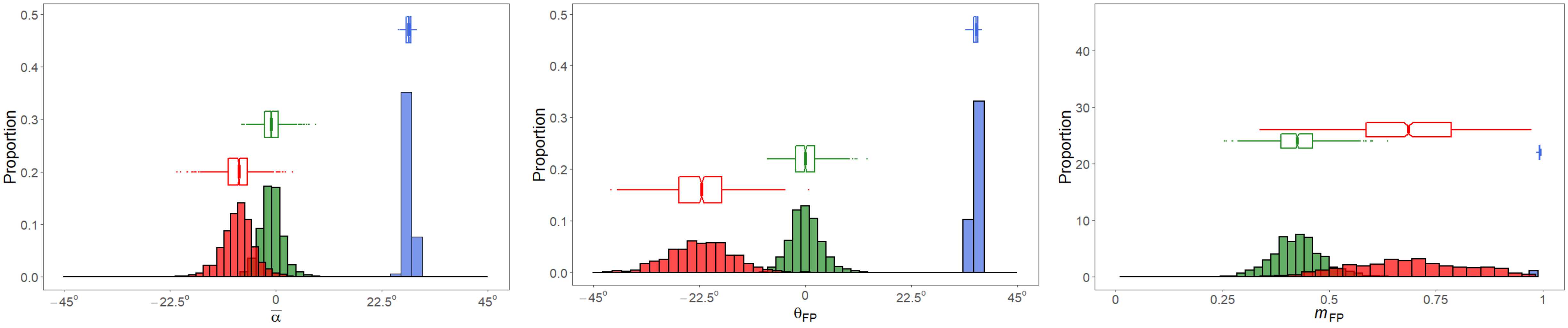


$\overline{\alpha}$



θ_{FP}

Target Characterization Parameter

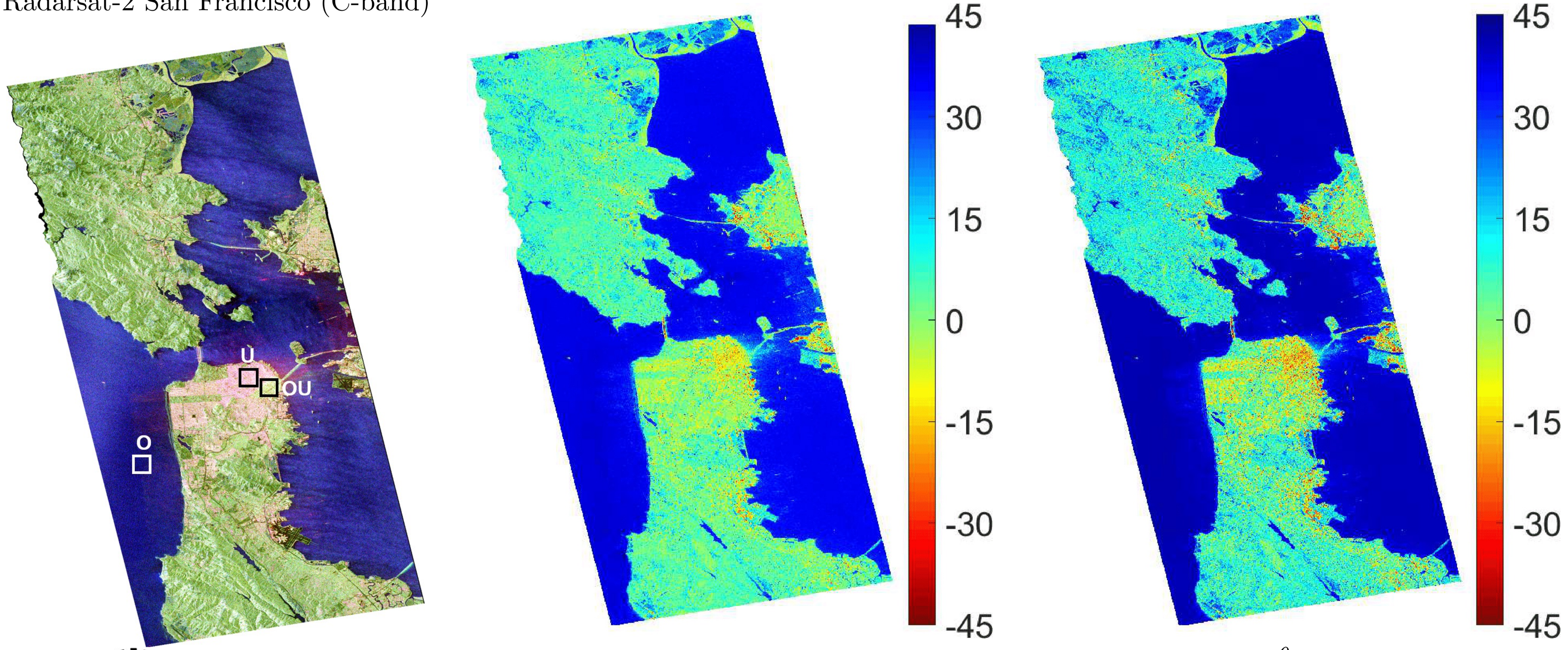


$\overline{\alpha}$ θ_{FP} m_{FP}

Comparison of θ_{FP} with $\overline{\alpha}$ and m_{FP} for "U" (red), "F" (green) and "O" (blue) over FP ALOS-2 L-band data.

Target Characterization Parameter

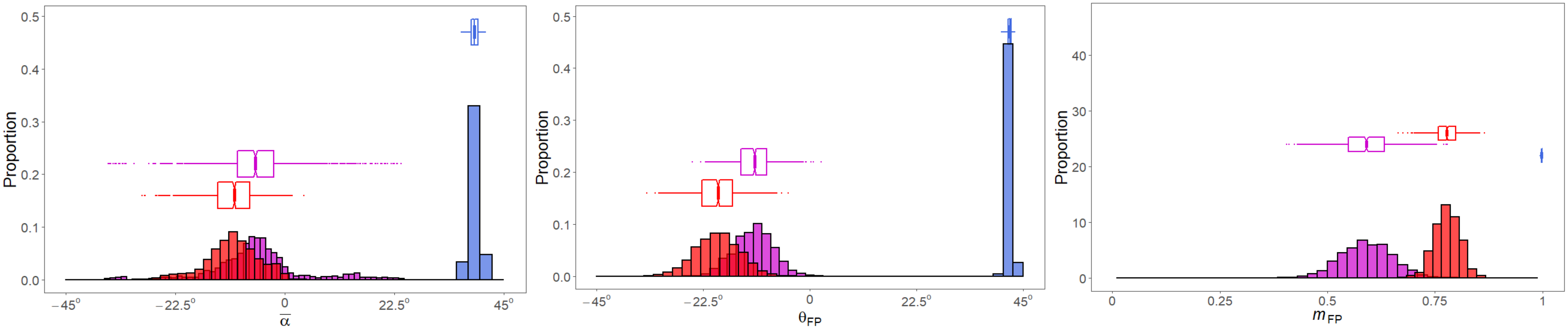
Radarsat-2 San Francisco (C-band)



$\overline{\alpha}$

θ_{FP}

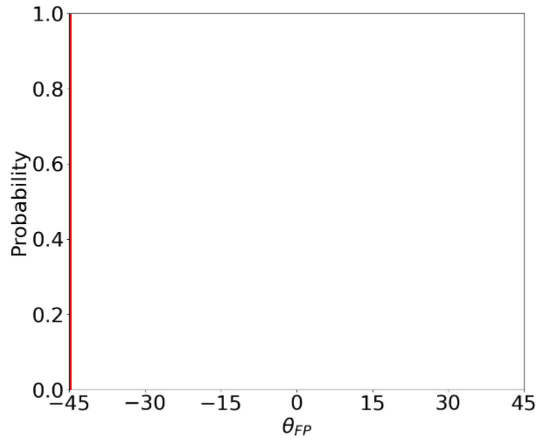
Target Characterization Parameter



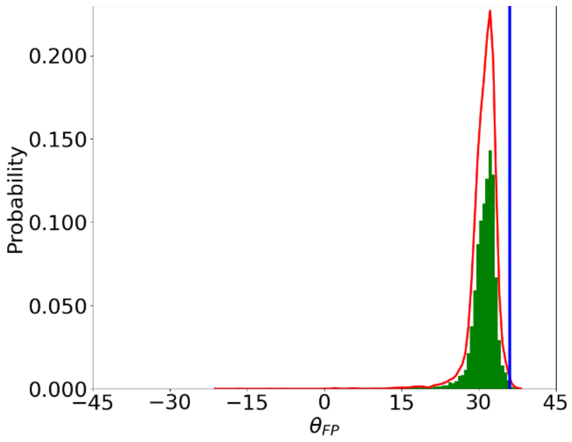
$\overline{\alpha}$ θ_{FP} m_{FP}

Comparison of θ_{FP} with $\overline{\alpha}$ and m_{FP} for "U" (red), "OU" (magenta) and "O" (blue) over FP RS-2 C-band data.

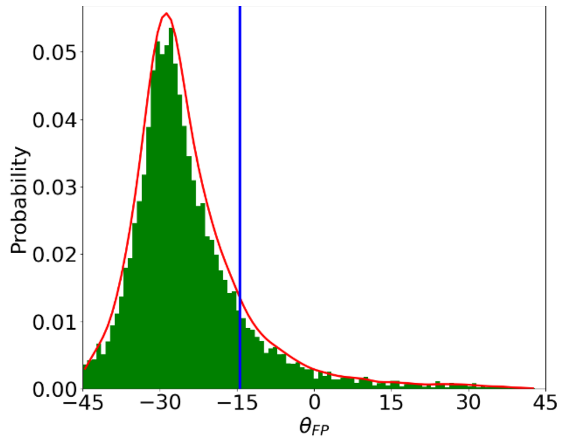
Analysis Over Different Targets (θ_{FP}^{p})



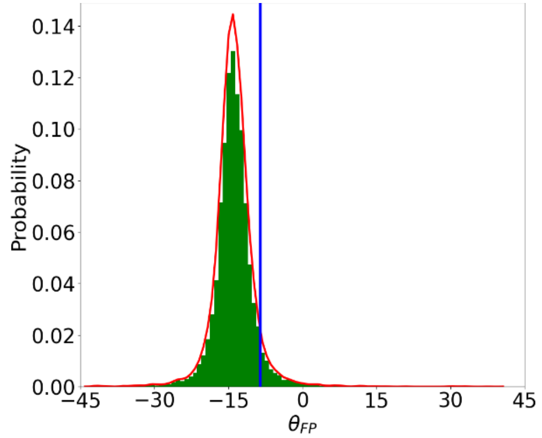
Dihedral



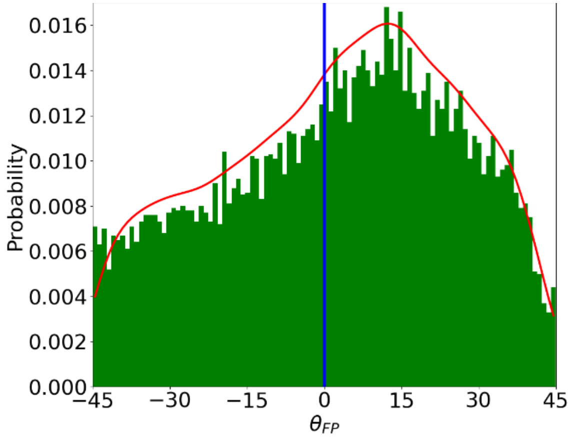
Ocean



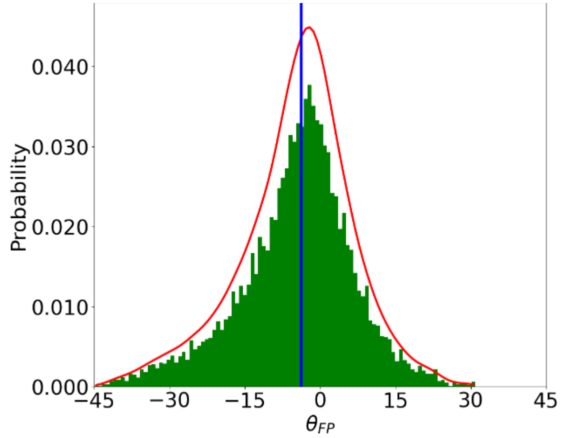
Urban



Oriented urban

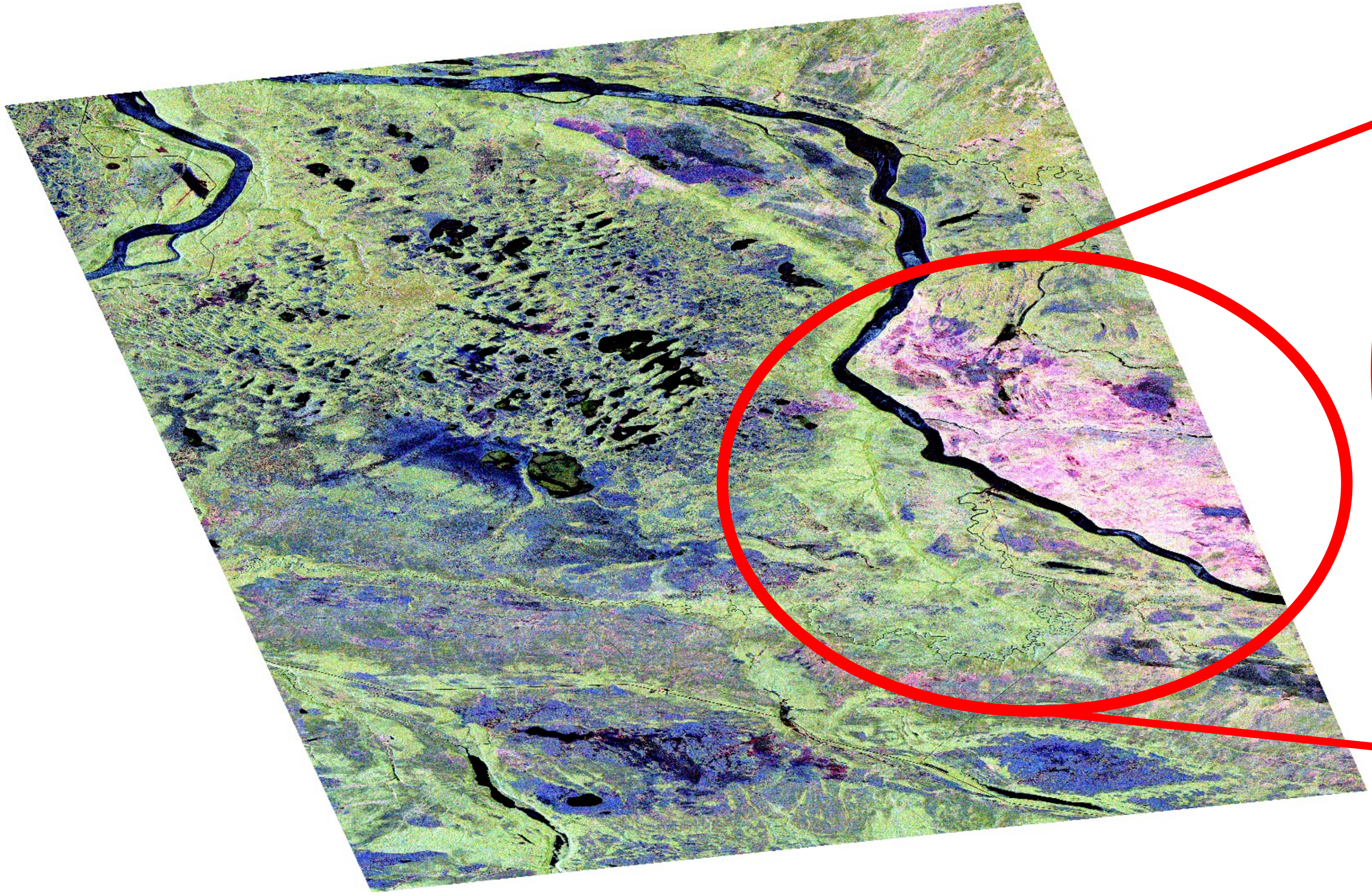


Random volume

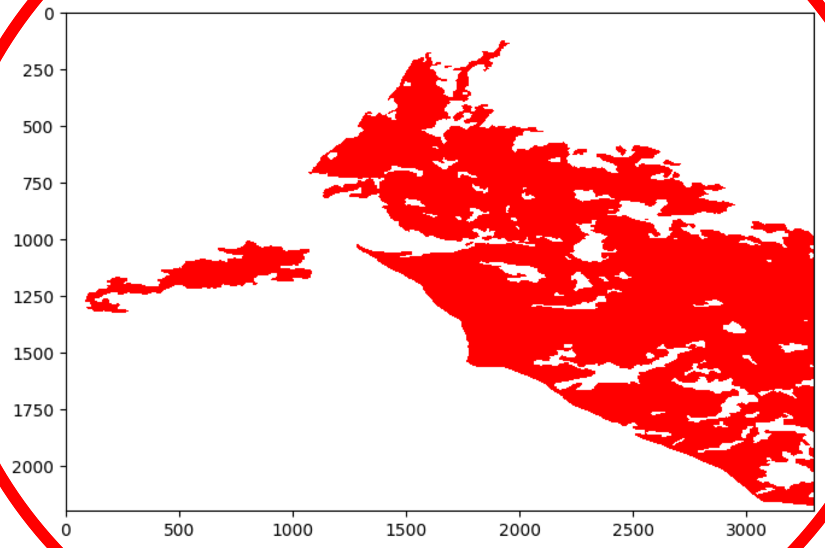


Yamaguchi volume

Study Area and *in-situ* Data

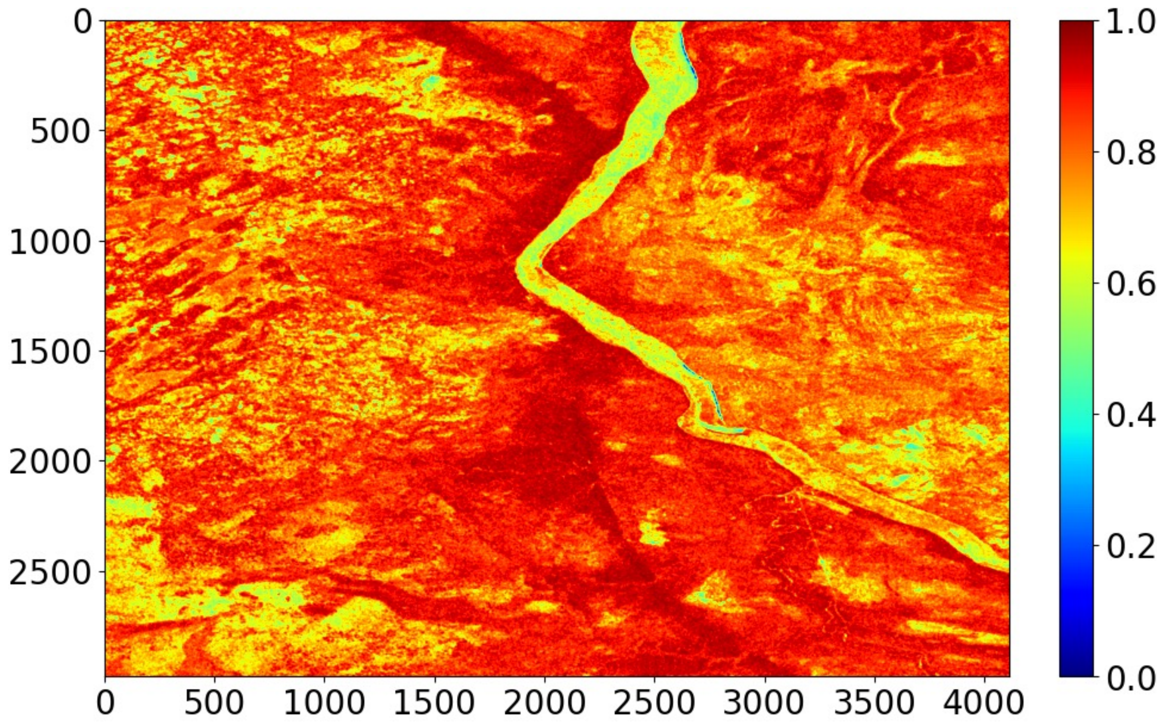


ALOS-2 data over BC, Canada

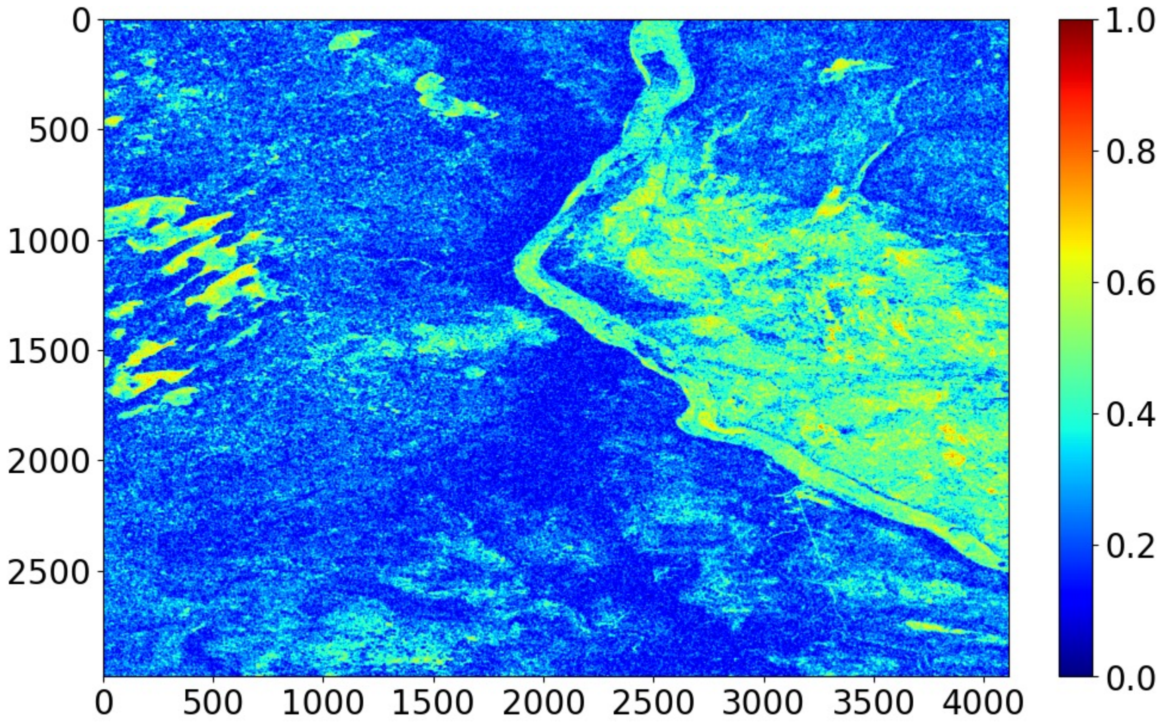


Ground truth

Different parameters



Entropy



Anisotropy

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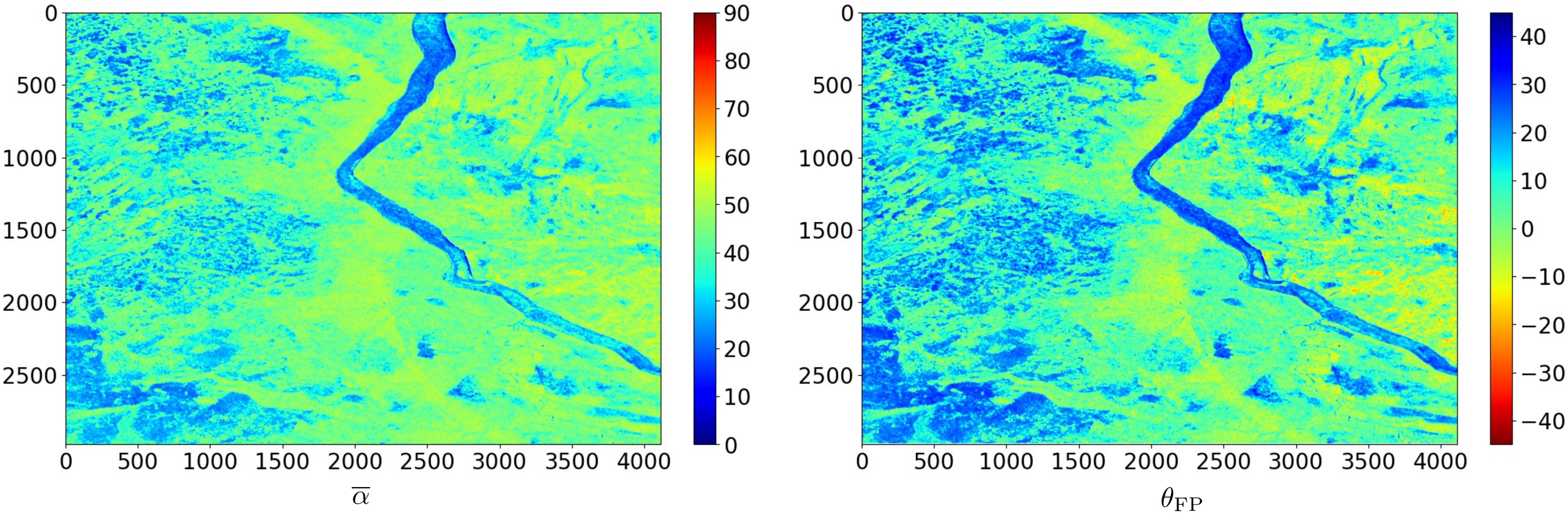
Different parameters



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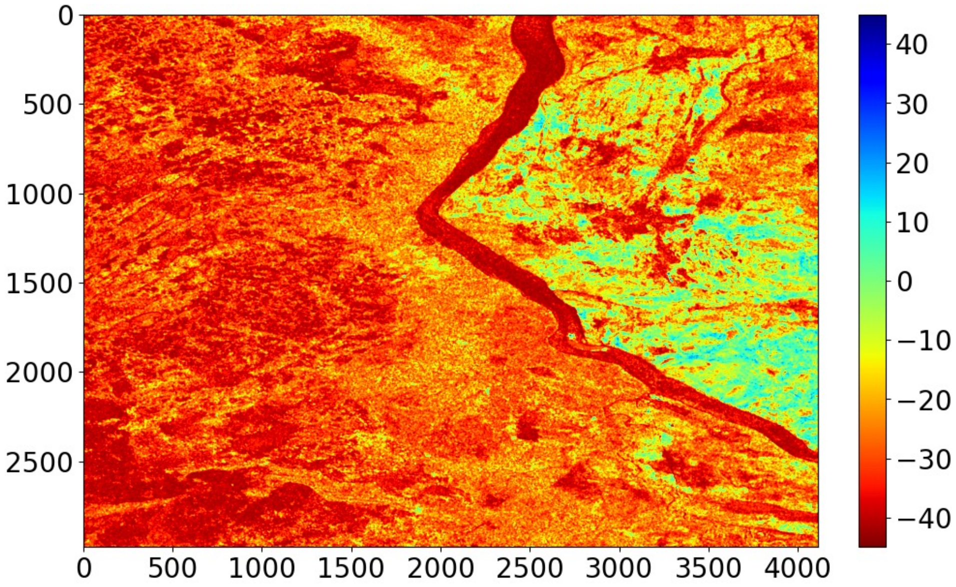
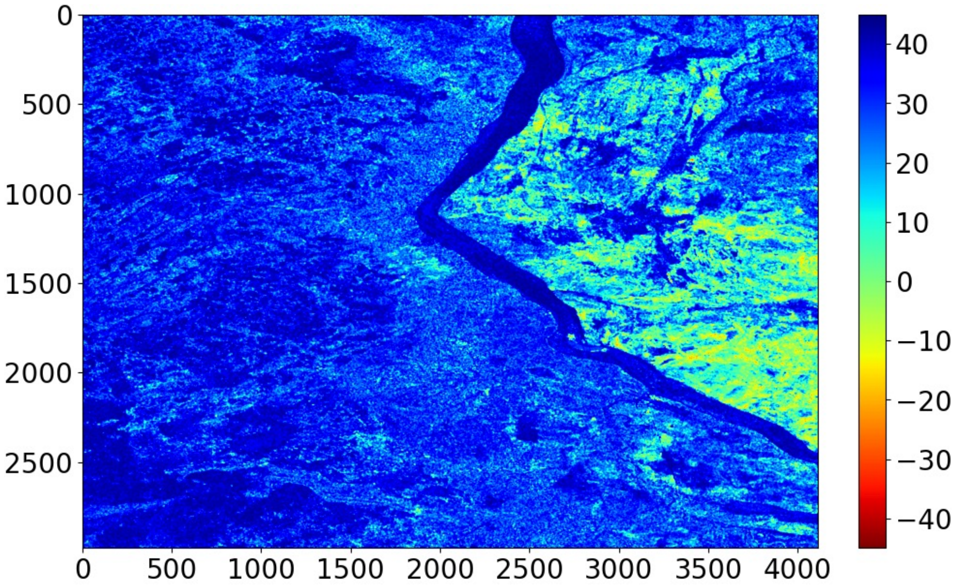
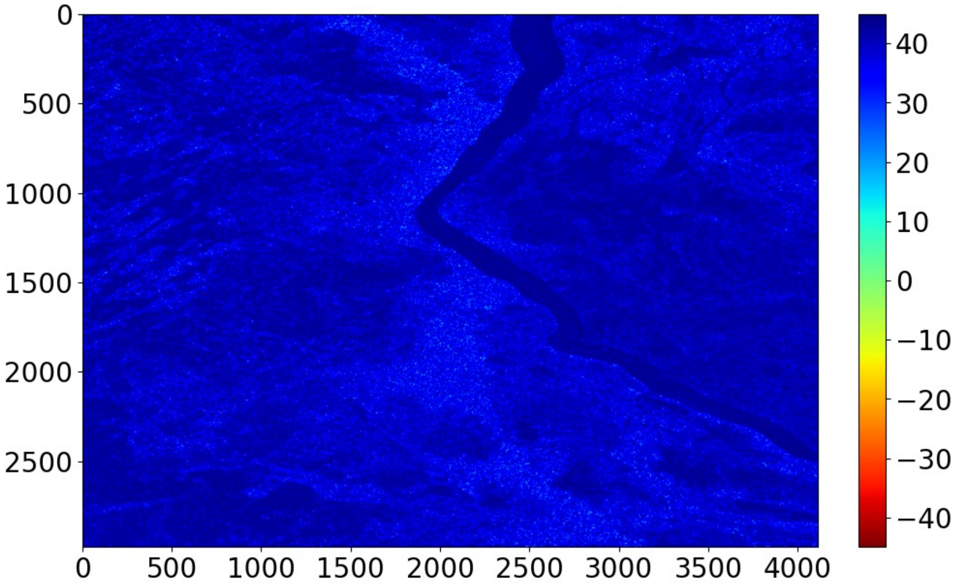
Dominant eigen parameters



θ_{FP}^{1}



θ_{FP}^{2}



θ_{FP}^{3}

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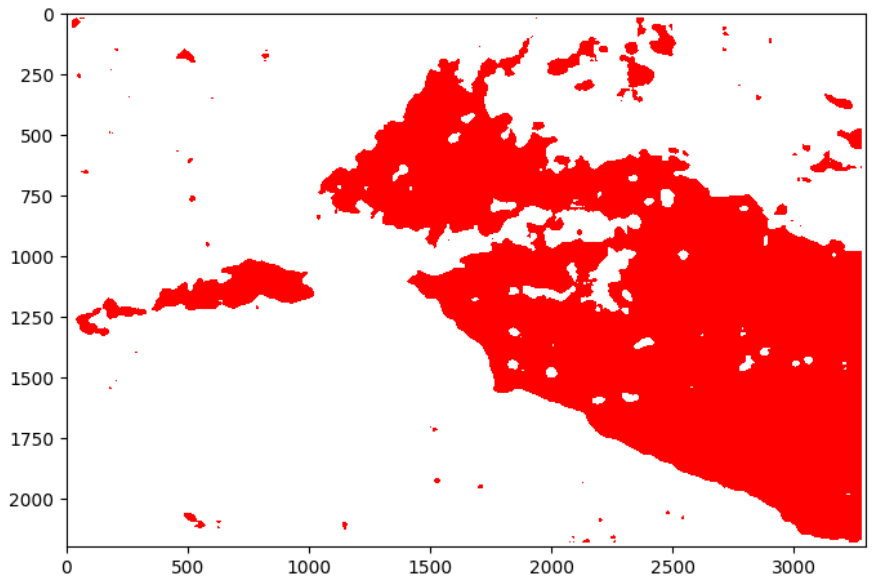
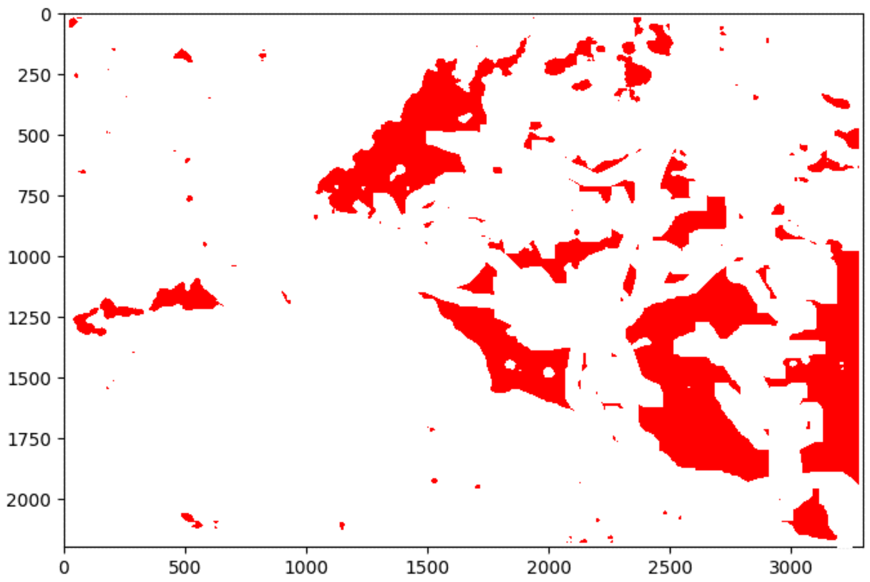
Classified Map



Classified map using spectrum



Classified map using eigen-based parameters

Features	Overall accuracy	Kappa score
θ_{FP} spectrum	85.12%	0.81
Eigen-based	74.91%	0.63
H-A-α	81.12%	0.73
H-A	79.34%	0.32
H	62.21%	0.36
A	76.02%	0.71

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Conclusions

- This work demonstrates an polarimetric spectrum based approach to identify the forest fire areas

- Polarimetric spectrum is sensitive to the geometry of the targets and can be a highly effective technique for target characterization and classification

- The classification accuracy using polarimetric spectrum is $\approx$10% higher than the Eigen-based technique

- In future, the S-band NISAR mission could enhance the overall forest-fire detection accuracy

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Thank You