MULTIVARIATE SPECKLE CONTRAST FOR COHERENT POLARIMETRIC (RADAR) IMAGING

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Coherent imaging systems, whether optical or microwave, are fundamentally governed by wave interference. Speckle emerges as a natural consequence of coherence and encodes rich structural information, especially when polarization is involved. While extensively studied in optics, polarization has also been thoroughly investigated in radar imaging—but often along separate disciplinary lines, limiting the exchange of concepts across domains.

This work focuses on coherent polarimetric radar imaging, where polarization not only affects wave penetration—through vegetation or ice, for instance—but also reshapes the statistical properties of speckle. We introduce a new formalism centered on the **multivariate coefficient of variation**, a novel parameter that generalizes speckle contrast to fully polarimetric settings [1]. This descriptor captures the interaction between polarization diversity and speckle variability across scales, enabling the definition of a *polarimetric speckle contrast* that goes beyond classical intensity-based interpretations. Applied to real datasets (e.g., Sentinel-1, airborne campaigns like SETHI), the framework proves effective in detecting subtle changes and polarimetric anomalies in time series, including signals as weak as −30 dB on homogeneous sea surfaces [2], near the sensor's noise floor. These results illustrate the value of coherent polarimetric modeling, both for refining detection algorithms and enhancing physical insight into scattering under varying polarization states.

By bridging physical intuition from optical polarimetry with advances in radar imaging, this work advocates for a unified view of coherent imaging across the electromagnetic spectrum.

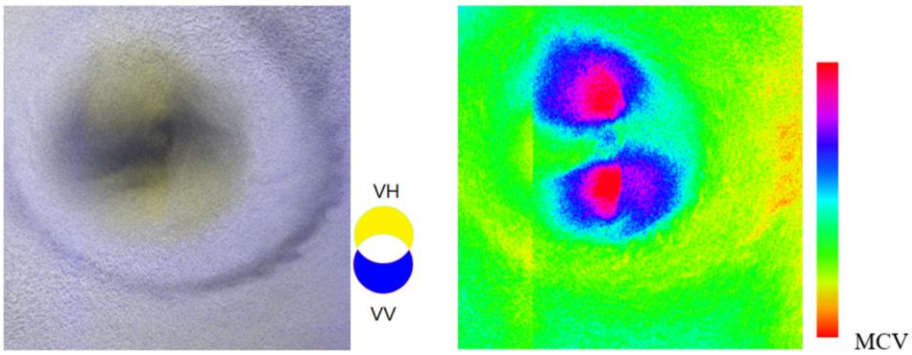

Fig. 1: *Polarimetric colored composition on the left / Multivariate Polarimetric Coefficient of variation on the right from a Sentinel-1 Image of hurricane*

[1]. E. Colin, R. Ossikovski (2024) Towards a Unified Formalism of Multivariate coefficients of Variation: Application to the analysis of polarimetric speckle time series. *Journal of the Indian Society of Remote Sensing,*
[2]. E. Colin, T. Taillade, L. Charrier, & R. Ossikovski (2025). Reactiv and Sentinel-1: Advances in Event-Based Alerts, Seasonal Adaptation, and Polarimetric Optimization for Large-Scale Change Detection. *Seasonal Adaptation, and Polarimetric Optimization for Large-Scale Change Detection*.