How can we make Polarimetry Analysis Ready?

“As easy as possible to the users”

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Motivation

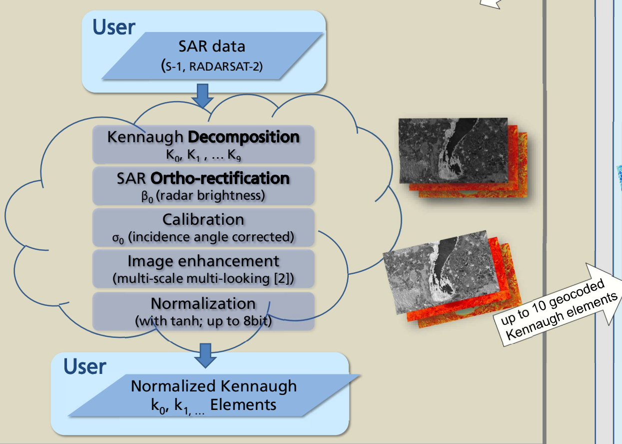
The Committee on Earth Observation Satellites (CEOS) has set up the CEOS Analysis Ready Data for Land initiative (CARD4L) that aims for the standardization of SAR products. The standardization of Analysis Ready Data (ARD) for polarimetric SAR data is still in progress. Here, we propose a decomposition as well as a storage scheme for polarimetric data based on the Kennaugh decomposition.

Polarimetric SAR data need to be fully geocoded for user application!

We need a paradigma change from providing complex data to easy-to-use GeoTIFF data.

SAR expert

Proposed pol-SAR Data Processing Workflow



Equations of Kennaugh decomposition [1]

The Kennaugh decomposition describes the polarimetric information comparable to the covariance and the coherence matrix. In contrast to other matrix representations, every Kennaugh element is a real number. Its elements are all intensity differences, only the first element represents the total intensity. K_1, K_2 and K_3 describes the absorption, K_4, K_5 and K_6 the diattenuation and K_7, K_8 and K_9 the retardance. In the case of quad-pol, all ten Kennaugh elements hold individual information, less input channels lead to linear dependencies.

Input Sinclair matrix

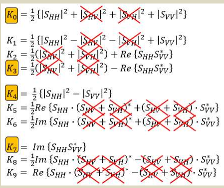
$$K_0 = \tfrac{1}{2}\{|S_{HH}|^2 + |S_{HV}|^2 + |S_{VH}|^2 + |S_{VV}|^2\}$$ **Total intensity**

$$K_1 = \tfrac{1}{2}\{|S_{HH}|^2 - |S_{HV}|^2 - |S_{VH}|^2 + |S_{VV}|^2\}$$
$$K_2 = \tfrac{1}{2}(|S_{HV}|^2 + |S_{VH}|^2) + Re\{S_{HH}S_{VV}^*\}$$
$$K_3 = \tfrac{1}{2}(|S_{HV}|^2 + |S_{VH}|^2) - Re\{S_{HH}S_{VV}^*\}$$

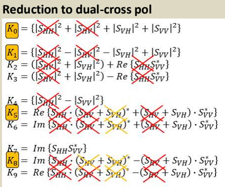
$$K_4 = \tfrac{1}{2}\{|S_{HH}|^2 - |S_{VV}|^2\}$$
$$K_5 = \tfrac{1}{2}Re\{S_{HH}\cdot(S_{HV}+S_{VH})^* + (S_{HV}+S_{VH})\cdot S_{VV}^*\}$$
$$K_6 = \tfrac{1}{2}Im\{S_{HH}\cdot(S_{HV}+S_{VH})^* + (S_{HV}+S_{VH})\cdot S_{VV}^*\}$$

$$K_7 = Im\{S_{HH}S_{VV}^*\}$$
$$K_8 = \tfrac{1}{2}Im\{S_{HH}\cdot(S_{HV}+S_{VH})^* - (S_{HV}+S_{VH})\cdot S_{VV}^*\}$$
$$K_9 = \tfrac{1}{2}Re\{S_{HH}\cdot(S_{HV}+S_{VH})^* - (S_{HV}+S_{VH})\cdot S_{VV}^*\}$$

Reduction to dual-copol



Reduction to dual-cross pol



Pros

- ✓ For dual- and quad-polarization one framework; even for single and hybrid-compact pol
- ✓ Full polarimetric information in geocoded image elements
- ✓ storage in uniform scale]-1; 1[allows compression
- ✓ Further decompositions still supported
- ✓ Enables multi-sensor data fusion ([3])
- ✓ Processing in a cloud possible – realized at DLR

Cons

- – Loss of absolute phase
- – Varying number of looks in one image

References

[1] Schmitt, A., Wendleder, A. and Hinz, S.: The Kennaugh element framework for multi-scale, multi-polarized, multi-temporal and multi-frequency SAR image preparation. ISPRS J Photogramm and Remote Sens, 102, pp. 122-139, 2015

[2] Schmitt, A.: Multiscale and Multidirectional Multilooking for SAR Image Enhancement. IEEE Transactions on Geoscience and Remote Sensing, 54 (9), pp. 5117-5134, 2016

[3] Schmitt, A.; Wendleder, A.; Kleynmans, R.; Hell, M.; Roth, A.; Hinz, S.: Multi-Source and Multi-Temporal Image Fusion on Hypercomplex Bases. Remote Sens. 2020, 12, 943.

Conclusion

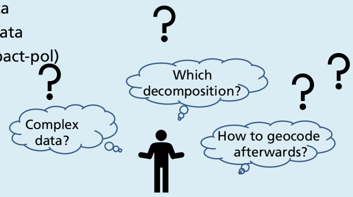
In order to facilitate the combination of multi-source SAR data an uniform framework for geometric and radiometric calibration as well as the combination of multi-polarised data is needed. For this purpose a Kennaugh decomposition is suggested which obtains the full polarimetric information in geocoded image layers that can directly be utilized e.g. in cloud computing environments without further pre-processing.

User

Data from multi-polarized SAR missions:

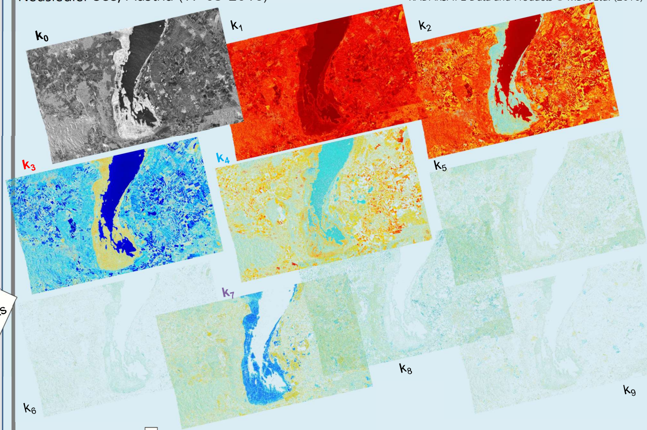
- Dual-pol Sentinel-1 (VV/VH) data
- Dual- or quad-pol TerraSAR-X data
- RADARSAT-2/RCM (hybrid-compact-pol)
- ALOS PALSAR/PALSAR-2
- NISAR

… leaves user with questions:

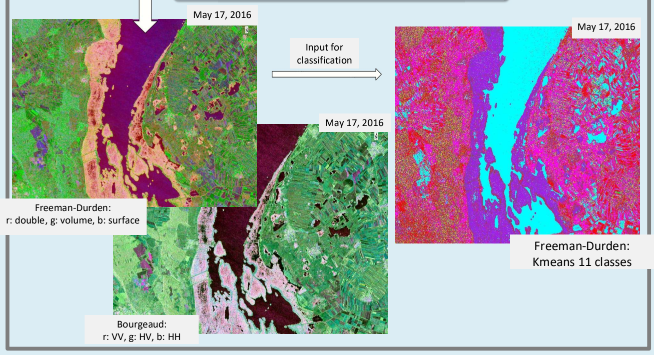


RADARSAT-2 full-pol (HH/HV/VH/VV): 10 Kennaugh elements

Neusiedler See, Austria (17-05-2016) RADARSAT-2 Data and Products © MDA Ltd. (2016)

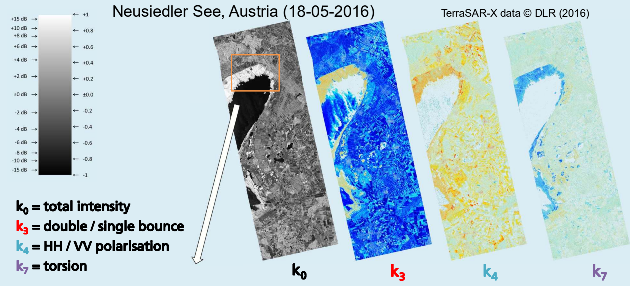


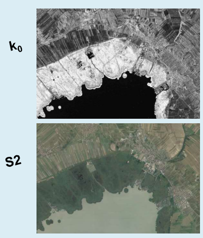
Further decompositions still possible



TerraSAR-X HH/VV Polarization: 4 Kennaugh elements

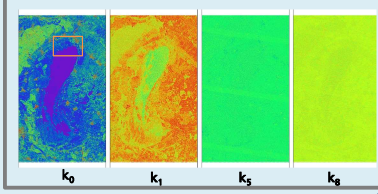
Neusiedler See, Austria (18-05-2016) TerraSAR-X data © DLR (2016)





Sentinel-1 VV/VH : 4 Kennaugh elements

Neusiedler See, Austria (05-03-2017) S1 data © ESA (2017)



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