TerraSAR-X: Exploration of Polarimetric SAR

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Polarization Modes @ TerraSAR-X

**Single Polarization**
- 1 polarization channel, \{HH, VV\}
- stripmap, spotlight, ScanSAR

**Dual Polarization**
- 2 polarization channels, \{HH/VV, HH/HV, VV/HV\}
- stripmap, spotlight
- coherent pol. phase

**Twin Polarization**
- 2 polarization channels, \{HH/VV, HH/HV, VV/HV\}
- stripmap
- incoherent pol. phase
- full elevation beam

**Quad Polarization**
- All 4 pol. channels
- Stripmap
- coherent pol. Phase
- smaller elevation beam
- Experimental product
2-dim Polarimetry: 1st Order

\[
\begin{bmatrix}
E_H^R \\
E_V^R
\end{bmatrix} =
\begin{bmatrix}
S_{HH} & S_{HV} \\
S_{VH} & S_{VV}
\end{bmatrix}
\begin{bmatrix}
E_H^T \\
E_V^T
\end{bmatrix}
\]

Fully Polarimetric Scattering Matrix

**Quad-Pol:** Tx: H & V Rx: H & V  \[ S = \begin{bmatrix}
S_{HH} & S_{HV} \\
S_{VH} & S_{VV}
\end{bmatrix} \]

5 Parameters

**Dual-Pol:** Tx: V Rx: H & V  \[ [S] = \begin{bmatrix}
S_{HH} & S_{HV} \\
S_{VH} & S_{VV}
\end{bmatrix} \]

3 Parameters

**Case 1:**

Tx: H Rx: H & V  \[ [S] = \begin{bmatrix}
S_{HH} & S_{HV} \\
S_{VH} & S_{VV}
\end{bmatrix} \]

S_{HH} & S_{HV}

**Case 2:**

Dual-Pol: Tx: V Rx: H & V  \[ [S] = \begin{bmatrix}
S_{HH} & S_{HV} \\
S_{VH} & S_{VV}
\end{bmatrix} \]

S_{VH} & S_{VV}

**Case 3:**

Tx: H & V Rx: H & V  \[ [S] = \begin{bmatrix}
S_{HH} & S_{HV} \\
S_{VH} & S_{VV}
\end{bmatrix} \]

S_{HH} & S_{VV}
### 2-dim Polarimetry – 2\textsuperscript{nd} Order

\[
[T_3] = \begin{bmatrix} T_{11} & T_{12} & T_{13} \\ T_{21} & T_{22} & T_{23} \\ T_{31} & T_{32} & T_{33} \end{bmatrix}
\]

\[
[T_2] = [M][T_3][M]^T
\]

\[
[M] = \begin{bmatrix} m_{11} & m_{12} & m_{13} \\ m_{21} & m_{22} & m_{23} \end{bmatrix}
\]

\[
[T_2] = \begin{bmatrix} <|S_A|^2> & <S_A S_B^*> \\ <S_B S_A^*> & <|S_B|^2> \end{bmatrix}
\]

**9 Parameters**

**4 Parameters**

#### Case 1

\[
[M] = \begin{bmatrix} 1 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}
\]

\[
[T_2] = \begin{bmatrix} <|S_{HH}|^2> & <S_{HH} S_{VH}^*> \\ <S_{VH} S_{HH}^*> & <|S_{HH}|^2> \end{bmatrix}
\]

#### Case 2

\[
[M] = \begin{bmatrix} 1 & -1 & 0 \\ 0 & 0 & 0 \end{bmatrix}
\]

\[
[T_2] = \begin{bmatrix} <|S_{VV}|^2> & <S_{VV} S_{HV}^*> \\ <S_{HV} S_{VV}^*> & <|S_{HV}|^2> \end{bmatrix}
\]

#### Case 3

\[
[M] = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}
\]

\[
[T_2] = \begin{bmatrix} <(S_{HH} + S_{VV})^2> & <(S_{HH} + S_{VV})(S_{HH} - S_{VV})^*> \\ <(S_{HH} - S_{VV})(S_{HH} + S_{VV})^*> & <|S_{HH} - S_{VV}|^2> \end{bmatrix}
\]
2-dim Polarimetry: 2nd Order Statistical Parameters

\[ [T_3] := \langle \mathbf{k}_{3p} \cdot \mathbf{k}_{3p}^+ \rangle \quad \Rightarrow \quad [T_3] = [U_3][\mathbf{\bar{E}}_3][U_3]^{-1} \]

\[ [\mathbf{\bar{E}}_3] = \begin{bmatrix} \bar{e}_1 & 0 & 0 \\ 0 & \bar{e}_2 & 0 \\ 0 & 0 & \bar{e}_3 \end{bmatrix} \quad \Rightarrow \quad [U_3] = \begin{bmatrix} \bar{e}_1 & \bar{e}_2 & \bar{e}_3 \end{bmatrix} \]

\[ P_i := \frac{\bar{e}_i}{\sum \bar{e}_i} \quad \Rightarrow \quad \sum e_i = \begin{bmatrix} \cos(\bar{\alpha}_i) \exp(i\bar{\alpha}_i) \\ \sin(\bar{\alpha}_i) \cos(\bar{\alpha}_i) \exp(i\bar{\alpha}_i) \\ \sin(\bar{\alpha}_i) \sin(\bar{\alpha}_i) \exp(i\bar{\alpha}_i) \end{bmatrix} \]

\[ [T_2] := \langle \mathbf{k}_2 \cdot \mathbf{k}_2^+ \rangle \quad \Rightarrow \quad [T_2] = [U_2][\mathbf{\bar{E}}_2][U_2]^{-1} \]

\[ [\mathbf{\bar{E}}_2] = \begin{bmatrix} \bar{e}_1 & 0 \\ 0 & \bar{e}_2 \end{bmatrix} \quad \Rightarrow \quad [U_2] = \begin{bmatrix} \bar{e}_1 & \bar{e}_2 \end{bmatrix} \]

\[ P_i := \frac{\bar{e}_i}{\sum \bar{e}_i} \quad \Rightarrow \quad \bar{e}_i = \begin{bmatrix} \cos(\bar{\alpha}_i) \exp(i\bar{\alpha}_i) \\ \sin(\bar{\alpha}_i) \cos(\bar{\alpha}_i) \exp(i\bar{\alpha}_i) \\ \sin(\bar{\alpha}_i) \sin(\bar{\alpha}_i) \exp(i\bar{\alpha}_i) \end{bmatrix} \]

\[ \bar{\alpha}_1 \quad \Rightarrow \quad \bar{\alpha}_2 = \frac{\vartheta}{2} - \bar{\alpha}_1 \]

\[ H := \sum_{i=1}^{3} P_i \log_3 P_i \quad \text{Entropy} \]

\[ A := \frac{P_2 - P_3}{P_2 + P_3} \quad \text{Anisotropy} \]

\[ \bar{\alpha} := \sum_{i=1}^{3} P_i \bar{\alpha}_i \quad \text{Alpha Angle} \]

\[ H := \sum_{i=1}^{2} P_i \log_2 P_i \quad \text{Entropy} \]

\[ A := \frac{P_1 - P_2}{P_1 + P_2} \quad \text{Anisotropy} \]

\[ \bar{\alpha} := \sum_{i=1}^{2} P_i \bar{\alpha}_i \quad \text{Alpha Angle} \]

randomness scat.mechan.
2-dim Polarimetry – 2\textsuperscript{nd} Order

Example over Urban Area (PISAR – Japanese airborne SAR)
TS-X SPOT over Rural Area: Neustrelitz
HH-VV Coherence Image

HH-VV Phase Image

Track ID = TSX-Neustrelitz-Spot-049
Mean H Value = -12.1078
Std. Deviation = 26.0387
Max. H Value = -11.6050

Track ID = TSX-Neustrelitz-Spot-049
Mean H Value = 0.429813
Std. Deviation = 0.150142
Max. H Value = 0.423000
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2-dim Pol Classification
TS-X SPOT over Alpine Glacier: Argentiere
TS-X SPOT over Land Ice: Svalbard - Austfonna

HH-VV Coherence Image
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2-Dim Pol. Entropy

2-Dim Pol. α Angle
TS-X SPOT over Urban Area: Gifu

HH-VV Coherence Image
Coherent Scatterer (CS‘s) @ SPOT - TSX

HH CSs @ 34000 CSs
VV CSs @ 28000 CSs
TerraSAR-X Science Service System

The TerraSAR-X Science Service System allows for the submission and evaluation of proposals, as well as for the submission of reports. It is further used to monitor and track proposals and therewith help to organize the science user community of TerraSAR-X.

Depending on who you are and what you like to do you have the following possibilities to proceed via the sidemenu on the left of this page:

- Anybody may receive information about which proposals are accepted and read their executive summaries.
- Principal Investigators of TerraSAR-X data may enter and maintain their proposals and are able to submit reports. Proposals and reports should be in English.
- Evaluators may receive detailed information about the proposals they have been appointed to and submit their comments and rating.

The pdf document: How to submit a TSX proposal gives a short description of the procedure for submitting proposals.

Investigator will get the data for the costs of fulfilling the user request. Discounts will be applied for larger order volumes, and for dedicated research programs and institutions contributing to the TerraSAR-X mission, especially by financial or operational support. Special conditions might be applied for the ACIs.

- The current COFUR pricelist is applicable to proposals presented to the permanent submission interface.

- The Science Service System is now open for the submission of general proposals.

ATTENTION: The download of TerraSAR-X data requires special security regulations which are described in the FAQ document.