Demonstration of TerraSAR-X ScanSAR Persistent Scatterer Interferometry

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Terrafirma – ESA Project

- Preparation for Sentinel-1 TopSAR acquisition mode
- Wide Area PSI demonstration with TerraSAR-X ScanSAR Mode
Terrafirma – ESA Project

• Azimuth variant spectrum -> Coregistration requirement

\[
\frac{\Delta f_{DC}}{BW_{az}} \approx 14
\]

\[
\frac{\Delta f_{DC}}{BW_{az}} \approx 4
\]

Sentinel-1 TopSAR Mode

TerraSAR-X ScanSAR Mode
Test Site: Lake Mead - Hoover Dam
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- Lake Mead water elevation

Dataset: TerraSAR-X ScanSAR Stack
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Time vs. Effective Baseline

Effective baseline [m]

Temporal baseline [days] (Reference: 2009-12-10T01:25:32.083323Z)
Dataset: TerraSAR-X ScanSAR Stack

INT_13633

- Slave Acquisition: 2009-11-29
- Effective Baseline: 51.6 m
- Height of Ambiguity: -73.5 m

INT_8957

- Slave Acquisition: 2009-01-25
- Effective Baseline: 40.4 m
- Height of Ambiguity: -93.8 m
Dataset: TerraSAR-X ScanSAR Stack

Slave Acquisition: 2009-07-09
Effective Baseline: 107.7 m
Height of Ambiguity: -35.2 m
PSI Detection

- Partition of scene for SCR-based detection
PSI Detection

- Effect of burst synchronization on stack
PSI Arc Estimation

• Point target response squint

\[
s(t, \tau) = s_r(\tau - \tau_0) \cdot s_r(t - t_0 - k \cdot (\tau - \tau_0)) \cdot \\
\exp \left(-j \frac{4\pi}{\lambda} r_0 \right) \cdot \exp(-j2\pi f_0 (\cos \beta - 1)(\tau - \tau_0)) \cdot \exp(j2\pi f_{DC} (t - t_0))
\]
PSI Arc Estimation

- Interferogram

\[
\phi_1^I = \phi_1^M - \phi_1^S = -\frac{4\pi}{\lambda} (r_{01}^M - r_{01}^S) - 2\pi (f_{DC,1}^M - f_{DC,1}^S) \Delta t_{PTA,1} + 2\pi f_{DC,1}^S \Delta t_{CO}
\]

\[
= -\frac{4\pi}{\lambda} \Delta r_{0,1}^{M\rightarrow S} - 2\pi \Delta f_{DC,1}^{M\rightarrow S} \Delta t_{PTA,1} + 2\pi f_{DC,1}^S \Delta t_{CO}
\]
Stratification Mitigation

- Simplified estimation: linear fit of phase-versus-height for a target area
  - Limitations, valid for processor initial testing

Raw extracted PS phase

PS phase after stratification mitigation
Stratification Mitigation

- Effect in arcs estimates and network construction
  - Higher coherence
  - Arcs between different heights, higher redundancy / control

Arc quality and network construction

without stratification mitigation

Arc quality and network construction with
stratification mitigation
PSI Processing

- Further steps remain algorithmically unchanged
  - Reference network inversion
  - APS estimation
  - Final estimations
Linear Deformation Rate

Linear deformation (ramp compensated)

Without stratification mitigation
Linear Deformation Rate

Linear Deformation Rate
Linear Deformation Rate
Residual Topography

- Residual topography between
  - STRM
    - Acquired in February 2000
    - Lake Mead water level: 370 m (1213.79 feet, monthly average)*
  - Master scene
    - Acquired in December 2009
    - Lake Mead water level: 334 m (1096.30 feet, monthly average)*

Residual Topography
Residual Topography
Spatial average PS coherence
PS coherence statistics

- PS Coherence evaluated in 200 Hz Doppler Centroid bins
Spatial average PS Density
PSI Detection

- Partition of scene for SCR-based detection
Secondary PS

- Extraction at sub-pixel position detected in another burst
  → Every secondary PS has a corresponding primary PS
  → But with a different Doppler Centroid
Secondary PS

- Primary – Secondary PS -pairs

- ~2000 Hz Intra Beam
- ~ 1500 Hz Inter Beam
- ~ 500 Hz Inter Beam
Secondary PS Estimates

- Pairs - Delta fdc = 2000 Hz
- Pairs - Delta fdc = 1500 Hz
- Pairs - Delta fdc = 500 Hz

~2000 Hz Intra Beam  ~1500 Hz Inter Beam  ~500 Hz Inter Beam
Secondary PS

- Coherence loss versus power loss

~ 1500 Hz Inter Beam

~ 500 Hz Inter Beam
Behaviour of Scatterers

- Std. deviation of phase residuals

0.9 < Coherence < 1.0
Secondary PS

- Primary – Secondary PS -pairs

![Graphs showing frequency differences and range samples for intra and inter beam scenarios with different frequency differences.](chart33)
Secondary PS

- Potential uses of Primary – Secondary pairs
  - Potential use of PS Enhanced Spectral Diversity

![Chart 34](image-url)

- ESD
- PS ESD
- ~2000Hz Intra Beam
Conclusions and Outlook

• Demonstration of TerraSAR-X ScanSAR PSI
  • Revisit available ScanSAR stacks

• Strategy to exploit PS ESD to control coregistration after PS detection

• Further work
  • Exploitation of PSI APS for DSI processing
  • Study the overlap area in urban areas
  • Exploitation of Sentinel-1