Interferometric Investigations with the Sentinel-1 Constellation and Results

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Sentinel-1 Constellation InSAR Performance
Orbit Analysis

- Baselines. 12 days S1B-S1B pairs and 6 days S1A-S1B pairs. Amplitude of one revolution for each pair is shown.

- Burst mis-synchronization for 1 revolution (1 pair) better than 5 ms → Az. spectral correlation better than 97%.

- Small crossing angles along the orbit -> az. spectral shift due to crossing angle negligible.
Temporal Analysis of Burst Mis-Synchronization Analysis

- Effect also identified by the Mission Performance Center (MPC) team (Aresys).
- Being currently investigated by ESA → Potential improvement of the burst mis-synchronization performance (already very good! → Relevant for future SAR missions)
Doppler Centroid Analysis

- Use of IW annotation products from S1B CP (mid-June – beginning of sept.):
  - 16444 S1A products
  - 11048 S1B products
  - 799 S1B-S1B pairs
  - 419 S1A-S1B pairs

Total = 1218 pairs
S1B-S1B Baseline Analysis

- **Physical baseline (B)**: 94.4 m
- **Perp. baseline (Bperp)**: 81.22 m
- **Parallel baseline (Bpar)**: 63.67 m

**Standard deviation**
- **Radial Component (Br)**: 12.5 m
- **Across-track component (Bcross)**: 93.56 m

**Standard deviation**
- **(single platform)**: 8.83 m

**S1A**
- radial = 12 m;
- cross-track = 66 m
S1A-S1B Baseline Analysis

<table>
<thead>
<tr>
<th></th>
<th>S1B-S1B</th>
<th>Physical baseline (B)</th>
<th>Perp. baseline (Bperp)</th>
<th>Parallel baseline (Bpar)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard deviation</td>
<td>105.82 m</td>
<td>89.43 m</td>
<td>73.35 m</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>S1B-S1B</th>
<th>Radial Component (Br)</th>
<th>Across-track component (Bcross)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard deviation (baseline)</td>
<td>11 m</td>
<td>105.24 m</td>
<td></td>
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</tbody>
</table>
Common Doppler Bandwidth Analysis S1B-S1B

- Burst mis-synchronization requirement fulfilled
- Common Doppler bandwidth larger than 95% (1-sigma)
- Burst mis-synchronization requirement fulfilled
- Mis-pointing for Sentinel-1B not yet corrected for the analyzed period. After mis-pointing correction common Doppler bandwidth between both units is larger than 95% (1-sigma)
Sentinel-1 Constellation InSAR Results
S1A-S1B Cross-Interferogram over Europe

Master: S1A acquired on June 13, 2016
Slave: S1B acquired on June 19, 2016
Length: 1400 km / 3 min 20 sec / 72 bursts

Large jitter due to atmosphere
(ascending data take at dusk)
S1A-S1B Cross-Interferogram over Mexico City

Master: S1A acquired on December 9, 2015
Slave: S1B acquired on June 24, 2016
Burst mis-synchronisation: 2.8 ms
Perpendicular baseline: 120 m
Central Italy Earthquake, August 24th

Ascending
S1B: August 21st
S1A: August 27th

Descending
S1A: August 21st
S1B: August 27th
Central Italy Earthquake, August 24th (cont.)

East/West component

Vertical component
Central Italy Earthquake, October

- S1A: October 21st
- S1B: October 27th
- S1B: October 27th
- S1A: November 2nd

Seismic events on October 26th

Seismic event on October 30th
Central Italy Earthquake, October (cont.)

S1B: October 27th  
S1A: November 2nd

Seismic event on October 30th
Sentinel-1 Constellation PSI Results
Campi Flegrei Time Series Analysis

14.10.2014 – 02.03.2017

\[ N_{\text{img}} = 63 \]
Campi Flegrei Time Series Analysis

East/West component

Vertical component
Validation with cGPS (Ascending)
Validation with cGPS (Descending)
PSI Results Over Mexico City
M. Costantini et al. “Complementarity of high-resolution COSMO-SkyMed and medium-resolution Sentinel-1 SAR interferometry capabilities: analysis, experiments and use cases”

Methodology and Techniques – PSI (Wednesday) @11:50
Beijing area: PS mean velocity with Sentinel-1 A/B (2015 – 2017)

Temporal period
Jan. 2015
Mar. 2017

# images 45
# PS 4,963,841
Analyzed area (sqkm) 36,000

Mean velocity (mm/year)
- < -72.0
- -72.0 - -56.0
- -56.0 - -40.0
- -40.0 - -24.0
- -24.0 - -8.0
- -8.0 - 8.0
- 8.0 - 24.0
- 24.0 - 40.0
- 40.0 - 56.0
- 56.0 - 72.0
- > 72.0
InSAR Investigations with S1A&S1B
PSI Performance Improvement with S1A&S1B

- Evaluation of the HCRB*

- Exponential decorrelation model:
  - \( \gamma(t) = (\gamma_0 - \gamma_K)e^{-\frac{t}{\tau}} + \gamma_K \)
  - \( \gamma_0 = 1; \gamma_K = 0.2; \tau = 40 \text{ days} \)

- APS Standard deviation = 5 mm (same for all images)

- 1 satellite \( \rightarrow \delta t = 12 \text{ days} \)
- 2 satellites \( \rightarrow \delta t = 6 \text{ days} \)

- Number of samples within \( \Omega = 12 \times 4 \)


Improvement factor of \( \sqrt{2} = 1.4 \)
Evaluation of PSI Performance Improvement with S1A&S1B Ascending data set

Evaluation of PSI Performance Improvement with S1A&S1B Descending data set

Mean velocity map - S1B stack with 12 images

Mean velocity map - S1B + S1A stack with 23 images

Difference between mean velocity maps

\[ \frac{\sigma_{S1B}}{\sigma_{S1A+S1B}} = 1.32 \]
\[ \frac{\sigma_{HCRB,S1B}}{\sigma_{HCRB,S1A+S1B}} = 1.33 \]

2016.10.09 – 2017.03.02

\[ \sigma_{APS} \approx 4 \, \text{mm} \]
Analysis of the covariance matrices over selected points for Sentinel-1B and Sentinel-1A/Sentinel-1B configurations.
Analysis of the covariance matrices over selected points for Sentinel-1B and Sentinel-1A/Sentinel-1B configurations

Target 1 - City
Analysis of the covariance matrices over selected points for Sentinel-1B and Sentinel-1A/Sentinel-1B configurations.
Analysis of the covariance matrices over selected points for Sentinel-1B and Sentinel-1A/Sentinel-1B configurations
Analysis of the covariance matrices over selected points for Sentinel-1B and Sentinel-1A/Sentinel-1B configurations

Sentinel-1B stack with 12 images

Sentinel-1B + Sentinel-1A stack with 23 images

Target 4 - Field
Analysis of the covariance matrices over selected points for Sentinel-1B and Sentinel-1A/Sentinel-1B configurations
Analysis of the covariance matrices over selected points for Sentinel-1B and Sentinel-1A/Sentinel-1B configurations

Sentinel-1B + Sentinel-1A stack with 23 images

Extracted coherence profile

\[ \gamma_{S1B} = 0.72 \]
\[ \gamma_{S1B+S1A} = 0.83 \]

Gain in coherence useful, e.g., for the phase unwrapping
Further Investigations in the frame of the INSARAP Constellation Study

- N. Yague-Martinez et.al. “Coregistration of Interferometric Stacks of Sentinel-1 TOPS Data” TOPS InSAR @11:50
- M. Nannini et.al. “Geolocation accuracy investigations with Sentinel-1” TOPS InSAR @12:30
- N. Yague-Martinez et.al. “Time-Series Evaluation of Azimuth Displacements with the Experimental TerraSAR-X 2-looks TOPS Acquisition Mode” TOPS InSAR @2:00
- M. Costantini et. al. “Quantitative analysis of PS displacement and positioning accuracy exploiting co-polarized and cross-polarized Sentinel-1A/B interferometric wide-swath data” Poster Session Tuesday
Summary
Summary

• Several analyses performed to evaluate the InSAR compatibility ⇒ Very good interferometric compatibility between S1A and S1B. They are indeed twin satellites!

• No InSAR phase artifacts observed.

• Several InSAR and PSI results have been evaluated, which confirm the good InSAR performance.

• Quantitative evaluation of quality improvement (PSI, coherence) with both units has been presented.
Thank you for your attention!