TerraSAR-X High Resolution Spotlight Persistent Scatterer Interferometry

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Persistent Scatterers (PSs) in 3D

Berlin Central Train Station

Color-coding:
Amplitudes of seasonal deformation
(Period: 1 year)
Densities of Persistent Scatterer Candidates

High Resolution Spotlight Data

6 (small) Stacks in HH and VV
Densities of PS Candidates

- Density of HH slightly higher than of VV (locally up to ~20%)
- Main influence: geometrical configuration (scene & satellite)
  - shadow effects, PS from facades,…
Available data for Berlin:

- 6 Stacks VV
  - 3 ascending tracks
    - \(\sim30^\circ\): 22 acquisitions, 16:45 h
    - \(\sim42^\circ\): 16 acquisitions, 16:52 h
    - \(\sim51^\circ\): 21 acquisitions, 17:00 h
  - 3 descending tracks
    - \(\sim36^\circ\): 20 acquisitions, 5:25 h
    - \(\sim47^\circ\): 21 acquisitions, 5:16 h
    - \(\sim55^\circ\): 22 acquisitions, 5:08 h

Temporal window:

- 1st acquisitions: February 2008
- Last acquisitions: February 2009
Relative Localization Accuracy

PS from Lines of Windows on Facades
Relative Accuracy

- Investigation of PS originating from windows in each floor
- Geocoded PS show regular pattern on facades
Relative Accuracy

- Investigation of PS originating from windows in each floor
- Geocoded PS show regular pattern on facades
- Relative accuracy from LSA of single rows (equal weights)
  - Mean difference to adjusted line in 3D
  - Calculated in r,x,s (range, azimuth, elevation)

Example 1: ($\Delta l = 2.7$ m)

- $\Delta r : 0.20$ m
- $\Delta x : 0.14$ m
- $\Delta r : 0.94$ m

Example 2: ($\Delta l = 2.7$ m)

- $\Delta r : 0.06$ m
- $\Delta x : 0.21$ m
- $\Delta r : 0.40$ m

- Largest mean deviation in elevation direction
Deformation Estimates from PSI

Central Train Station Berlin
Decision for using periodic functions in deformation model:
  - Phase history (deformation) between 2 points

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| deformation [cm]: 854749 - 800526 |
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- periodic model
- insufficient model...
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June - Sept.
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Phase Histories (Deformation)

- Decision for using periodic functions in deformation model:
  - Phase history (deformation) between 2 points

- Estimation of amplitudes for periodic functions
Estimated amplitudes of periodic movement

- Larger values at central part as well as on halls to the right and left
- Change of sign at eastern part of rail tracks
Comparison of Estimation Results from 6 Different Stacks

Berlin Central Train Station
Seasonal Amplitudes

- Amplitudes of periodic deformation
  - 30°, 42°, 51° ASC
  - 36°, 47°, 55° DESC
Seasonal Amplitudes

- 51° ASC vs. 55° DESC

- Large vertical components for central building

Decomposition
W-E & vertical

Tower
dx: -1.5 mm
dz: +8.7 mm

Central building
dx: +5.6 mm
dz: +8.7 mm
Seasonal Amplitudes

- 51° ASC vs. 55° DESC

Decomposition
W-E & vertical

Left part
dx: +8.8 mm
dz: +0.2 mm

Right part
dx: -6.4 mm
dz: +1.2 mm

- Large vertical components for central building
- Large horizontal components for western hall and eastern rail tracks
Seasonal Amplitudes

- 51° ASC vs. 55° DESC

- Large vertical components for central building
- Large horizontal components for western hall and eastern rail tracks
- Exact position of construction gaps on bridges visible
Dependence of Amplitudes on Heights

Amplitudes of Periodic Deformation vs. PS-Heights
Inspection of vertical components…

Necessary difference in temperature to expand steel by 16 mm on 45 m

\[ \Delta T = \frac{\Delta L}{kL} = \frac{0.016m}{12.2e^{-6} \, K^{-1} \cdot 45m} = 29.1^\circ K \]
Deformation vs. Heights

- Temperature histories of Berlin
  - Differences in temperatures between summer and winter sufficient for expansion

Lowest Temperatures 01.02.2008 - 01.03.2009

![Temperature graph showing the lowest temperatures](image1)

Highest Temperatures 01.02.2008 - 01.03.2009

![Temperature graph showing the highest temperatures](image2)

~ 29°

~ 33°

Data basis: http://www.wetter-berlin-online.de/
Remote Sensing Technology

Summary

- **PS Densities**
  - Vast increase due to high resolution
  - Highly correlated to geometry (acquisition parameters & orientation of objects)

- **PS Localization**
  - Lower accuracy in elevation direction
  - Mainly due to low standard deviation of baselines

- **Periodic deformation model (Central Train Station)**
  - Appropriate due to seasonal deformation
  - Correlation of amplitudes on building height
  - Movement caused by thermal expansion of steel construction

- **Given Stacks enable separation of horizontal & vertical components**
  - Large vertical components at tower and central building
  - Good agreement in W-E with respect to constructional conditions (gap)