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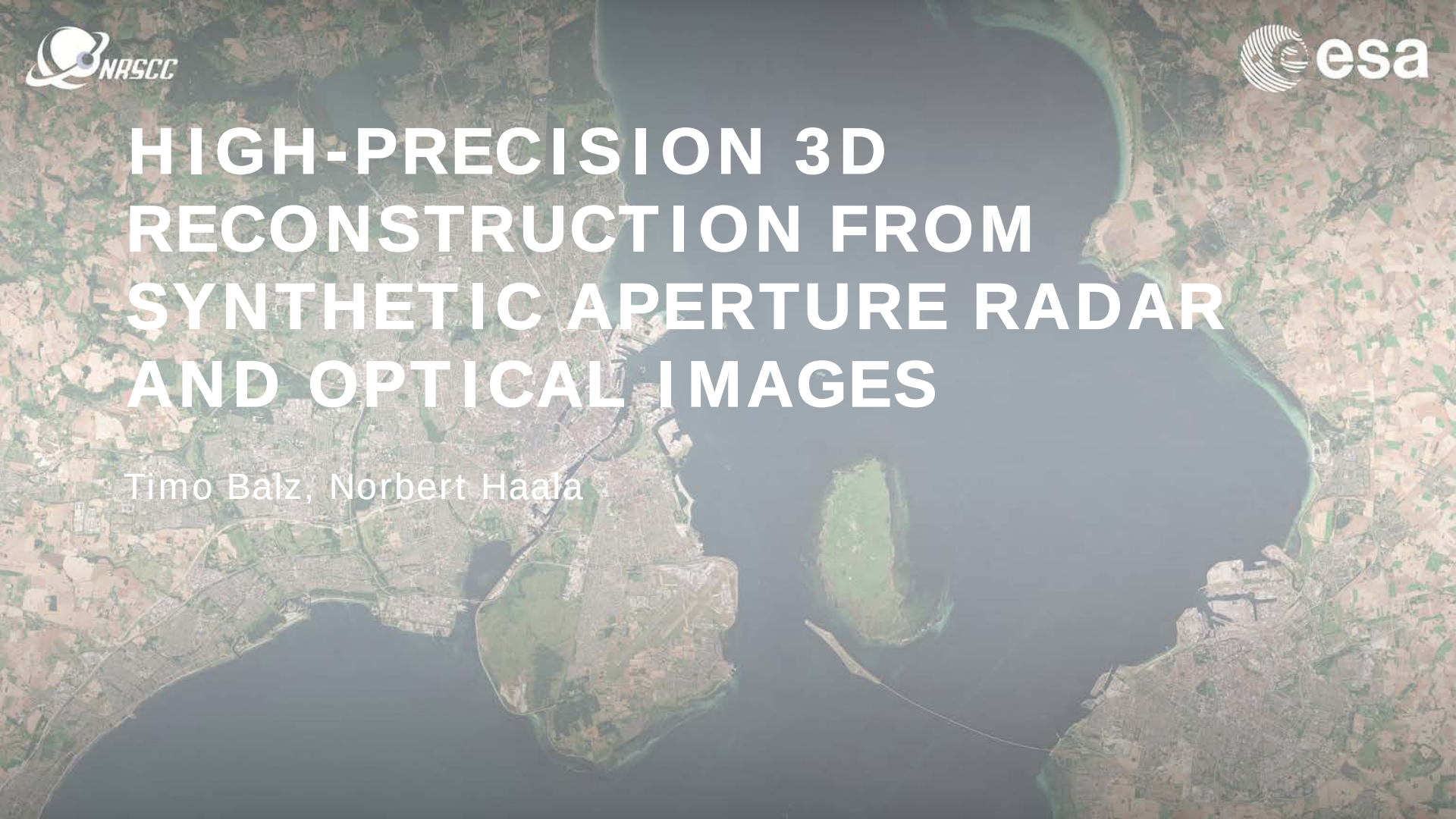

HIGH-PRECISION 3D RECONSTRUCTION FROM SYNTHETIC APERTURE RADAR AND OPTICAL IMAGES

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Introduction

- Brief overview over the activities of our team
- High-precision absolute geo-positioning with SAR
- Concept of SAR geodesy
- Our results
- Test fields
- Future work

Main objectives

- Absolute geo-coordinate estimation of artificial targets in optical and SAR imagery and the validation of their accuracy
- Digital elevation model (DEM) generation with optical and SAR data using different techniques
- Validation of the DEM accuracies
- Surface motion estimation from interferometric SAR and pixel tracking

Contribution of the partners

LIESMARS, Wuhan University

- Test site at Mount Song
- InSAR and StereoSAR processing for DEM generation
- Surface motion estimation from PS-InSAR

Institute of Photogrammetry, Stuttgart University

- Test site at Vaihingen/Enz
- Photogrammetric processing for DEM generation
- DEM validation

Progress

- Data collection started
- Exchange is in preparation
- Topic definition and third-party financing on-going
- Field-work for 2018 is in preparation
    - Difficulties due to the lack of viable Young Scientists

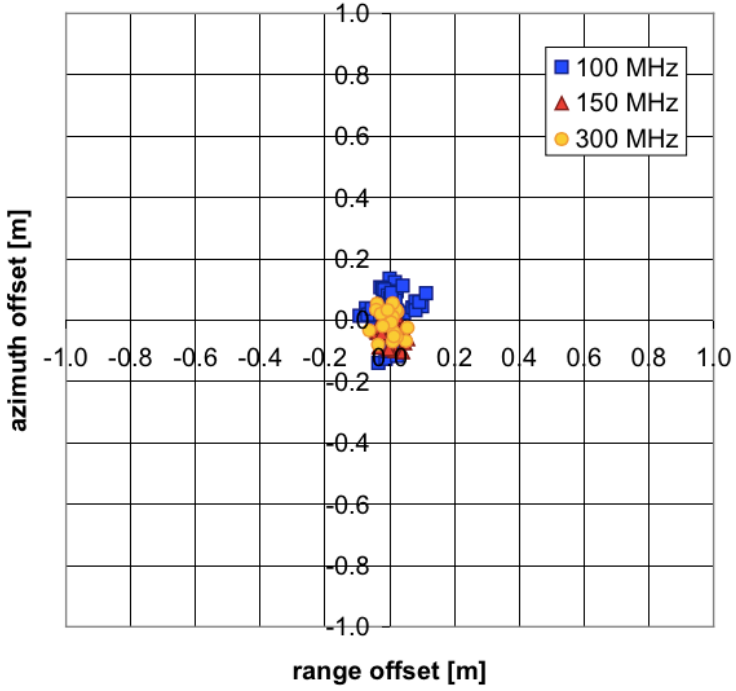
SAR (InSAR) is relative

- SAR is very precise in relative measurements
  - Height differences from one pixel to another in an InSAR pair
  - Motion differences between one persistent scatter to another persistent scatterer
- However, in applications we are interested in absolute positions, heights, motions, etc.
- Therefore, the next step in SAR remote sensing is moving from relative measurements to absolute measurements
- Two main methods:
  - Including artificial targets for referencing
  - Including additional stereo-measurements referencing

Precise absolute 3d point position estimation from TSX

- TerraSAR-X is the most precise RS system in space
- Very high orbit accuracy
- Can be used for estimating absolute 3D point positions using stereo configuration
- Need for correction of azimuth timing, range path delay, and geo-dynamic processes
- Typically referred to as SAR geodesy

Most precise results presented by the DLR



$\sigma_{azimuth} = 6.3$ cm
$\sigma_{range} = 3.8$ cm

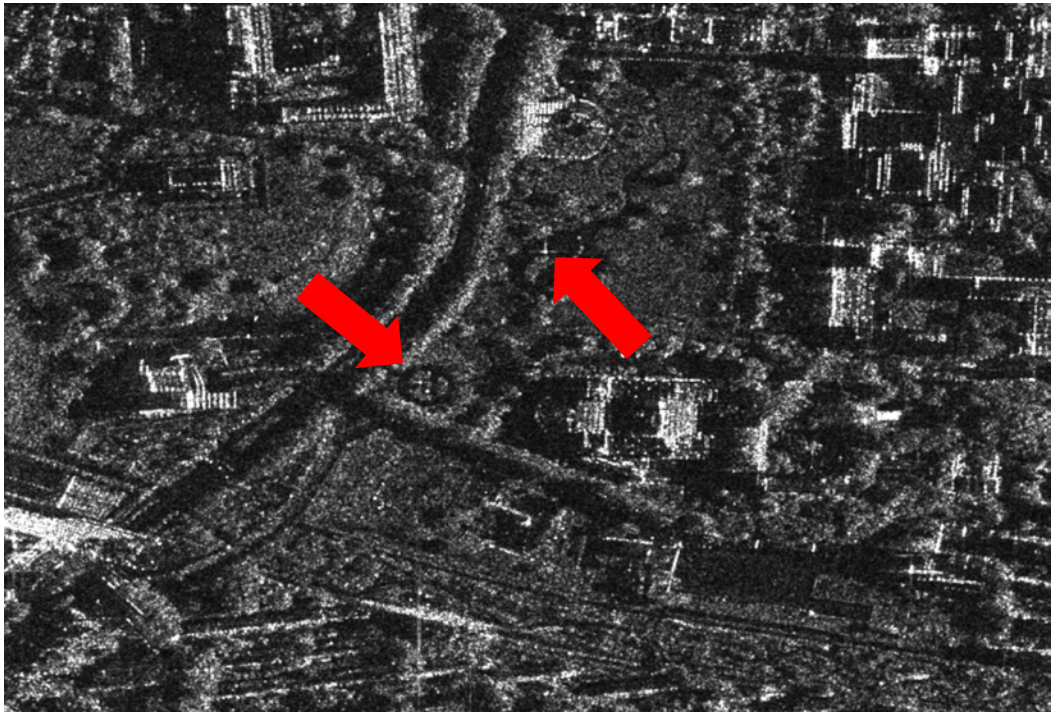
Deutsches Zentrum für Luft- und Raumfahrt e.V. in der Helmholtz-Gemeinschaft

The following offsets are subtracted:
azimuth offset: +8 cm
range offset : -29 cm

Reprocessing done with
- actual TMSP version
- improved atmospheric delay
- improved instrument delay values

Balss et al, 2014

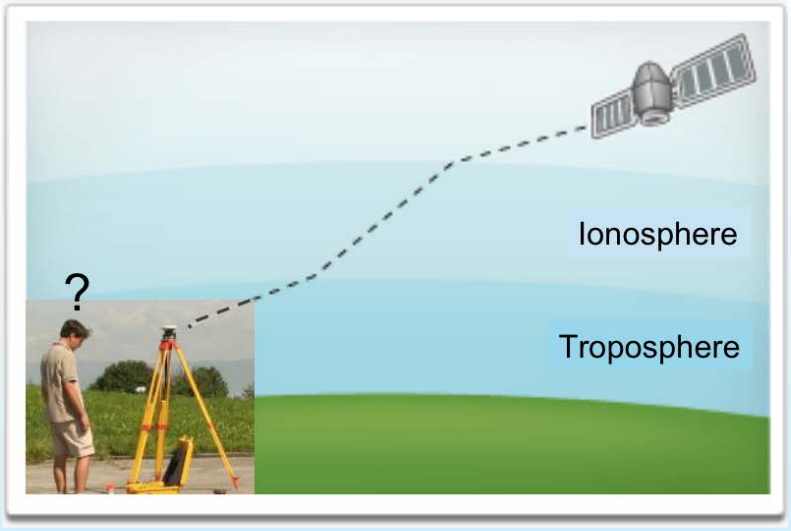
Experiments in Wuhan



First TSX experiment

- GPS measurement as ground-truth
    - Approximately better than centimeter accuracy
- No correction for TSX – naïve out-of-the-box geocoding
- Very high precision in azimuth
    - 1/10th of a pixel
    - Around 2 cm precision
        - GPS accuracy probably not optimal
        - In the estimated orbit accuracy of TSX (~ 2cm)
        - Other corrections have not been applied – we do not fully trust this result
- Less precise in range
    - Around 2 pixel = around 1.6m
    - Mostly due to atmospheric effects – signal is NOT travelling at the speed-of-light in vacuum

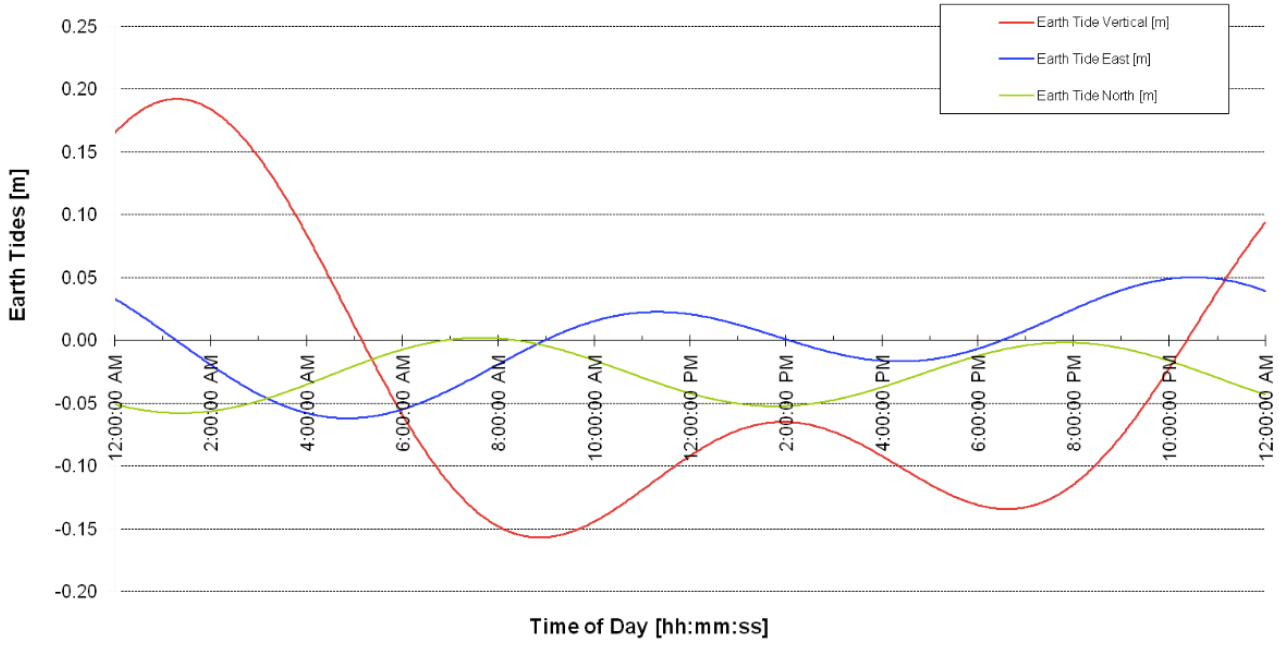
Reasons for inaccuracies



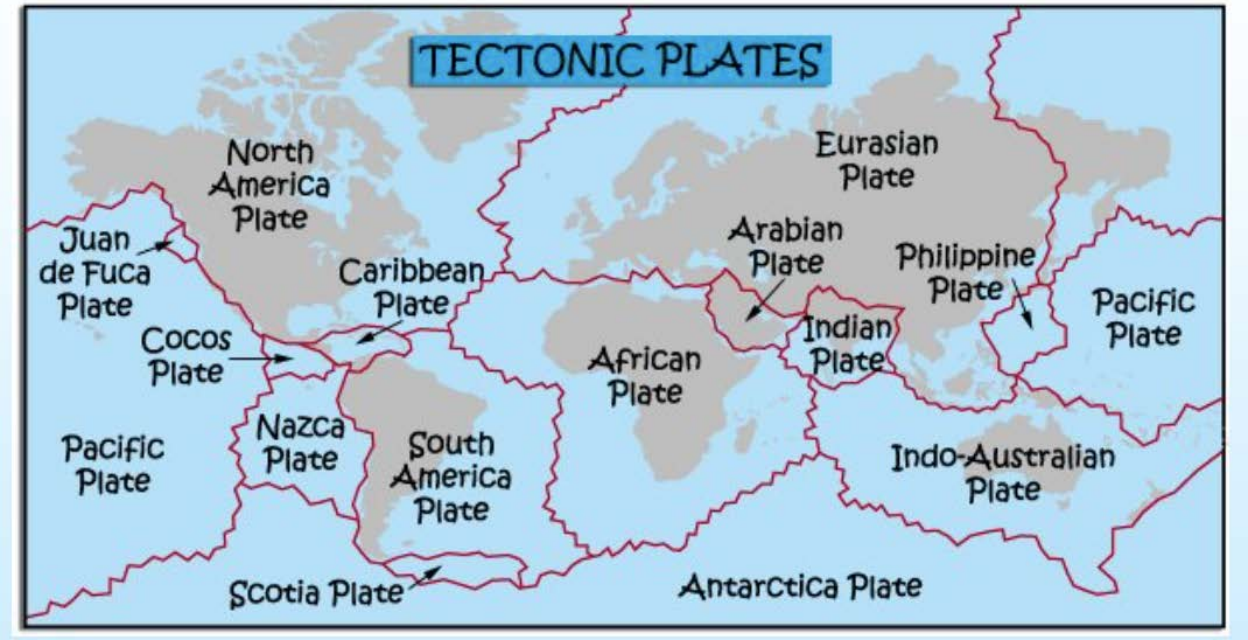
→ Range error ~ 20-40 cm *relative* to annotated constant PD
(one-way total error ~ 3 m)

Source: Schubert, Univ. Zurich

Solid-Earth Tides



Tectonics


TECTONIC PLATES
North America Plate
Eurasian Plate
Juan de Fuca Plate
Caribbean Plate
Arabian Plate
Philippine Plate
Pacific Plate
Cocos Plate
Indian Plate
African Plate
Nazca Plate
Pacific Plate
South America Plate
Indo-Australian Plate
Scotia Plate
Antarctica Plate

Based on TSX meta data alone

	Δ Easting	Δ Northing	Δ Height
B405	0.10	-0.005	0.231
P066	0.051	0.028	0.333

Decimeter accuracy in range direction!

Centimeter accuracy in azimuth direction!

Lessons learned

- Points can be measured with high absolute 3D precision using the SAR geodetic approach
- Solid-Earth tide correction
- Coordinates are in ITRF 2008
- Atmospheric path delay correction via weather models
  - ERA-Interim
  - Merra2

Including wet atmosphere – Descending using ERA-I

	Δ Easting	Δ Northing	Δ Height
B405	0.036	0.030	-0.046
P066	-0.021	0.017	0.052

Centimeter accuracy in all directions!

Including wet atmosphere – Descending using Merra2

	Δ Easting	Δ Northing	Δ Height
B405	-0.142	0.067	0.063
P066	-0.199	0.054	0.162

Reduced accuracy….

Ascending orbit

ERA-Interim

	Δ Easting	Δ Northing	Δ Height
B405	-0.682	0.121	-0.198
P066	-0.372	-0.093	0.080

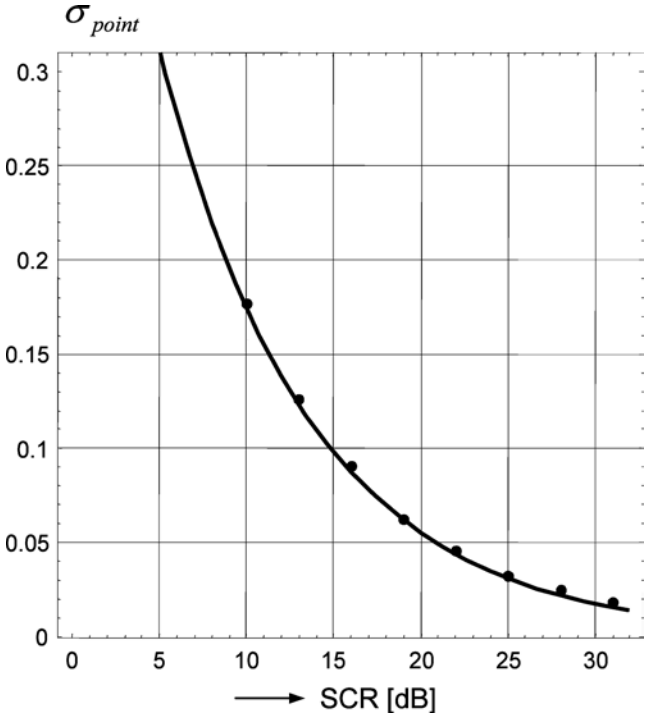
Merra2

	Δ Easting	Δ Northing	Δ Height
B405	-0.402	0.078	-0.002
P066	-0.437	-0.102	0.035

Lessons learned (so far)

- Weather models and therefore path-delay correction are not always accurate
- Errors in centimetres-decimetres possible
- High SCR targets are needed to get the sub-pixel accuracy necessary
- Need averaging over time to reduce path-delay correction errors

Theoretical SCR limits



Bamler & Eineder, 2005

High performance sensor validation European cal/val sites

Conclusions

- Very high precision absolute position estimation of high SCR points is possible with SAR geodesy
- Amazingly high decimetre precision “out-of-the-box” based on the TSX meta data
- Even higher precision when including weather models
- However, with weather models, a higher error volatility seem to appear

Future Work

- Move from static 3D point estimation with geodetic SAR to motion estimation
- Fast surface motions with decimetre / year or more
- More acquisitions to reduce errors and improve precision
- Estimation of motion models, e.g. linear motion
- Problem: High SCR targets necessary – difficult to find enough targets in rural areas