Airbus Ground Control Points (GCPs)

DEFENCE AND SPACE

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Airbus Ground Control Points

GCP Background

Extraction Workflow

- Range Delay Correction Layers
- SAR Candidate Detection
- Epipolar Image Rectification and Point Matching

Validation

Summary

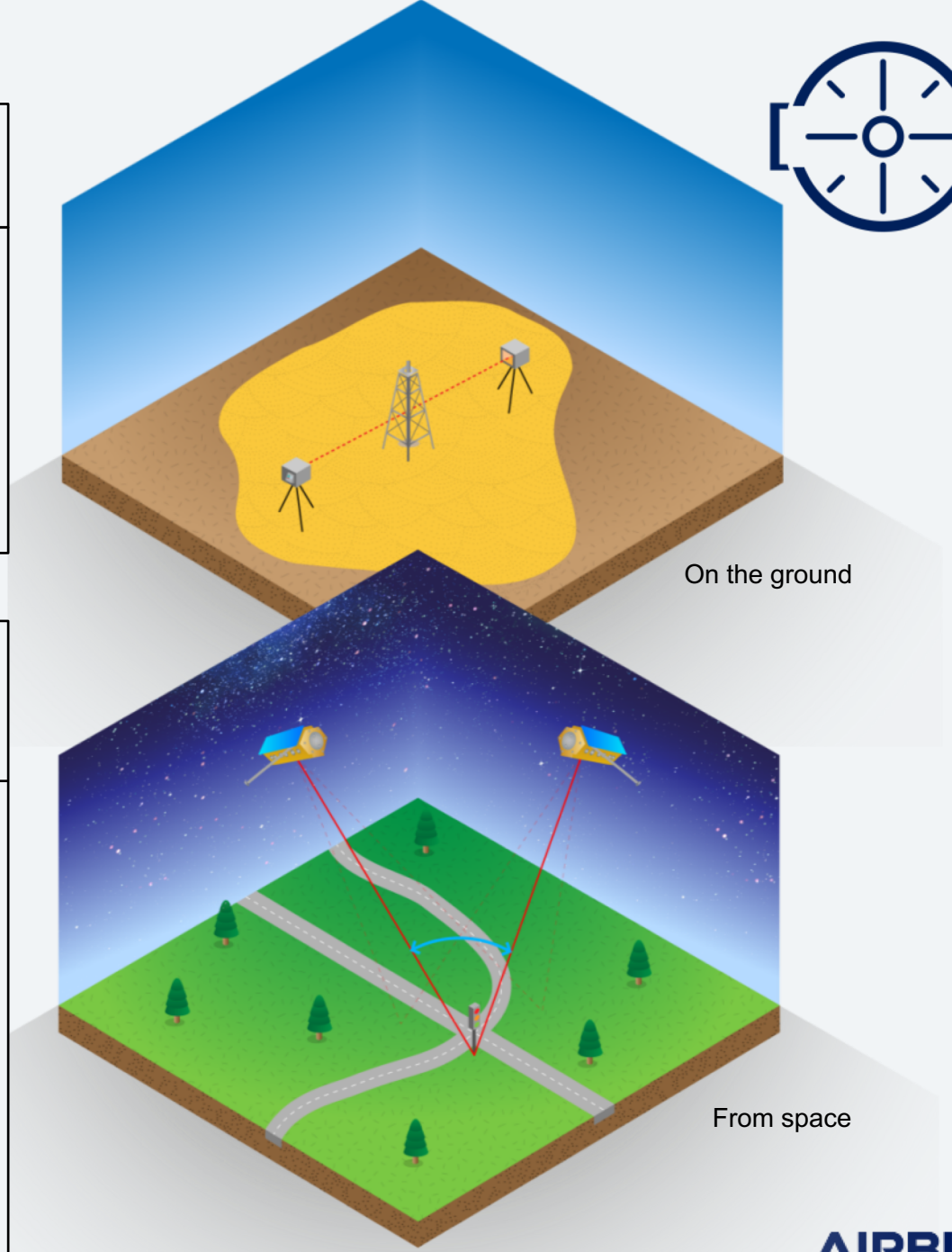
Background

Ground Control Point (GCP)

- A measured land mark on earth with a known geo-location given in coordinates (X,Y,Z) in an related geo reference system
- The coordinates are measured *in-situ* with a DGPS

TerraSAR-X measured Ground Control Points

- **Highest level of precision:** measured from space with geo-location accuracies up to 10 cm
- **World-wide available:** Independent of cloud cover & illuminating
- **Maximum efficiency:** save costs & avoid in-situ risks
- **Fresh & Quick:** comprising data collection and processing

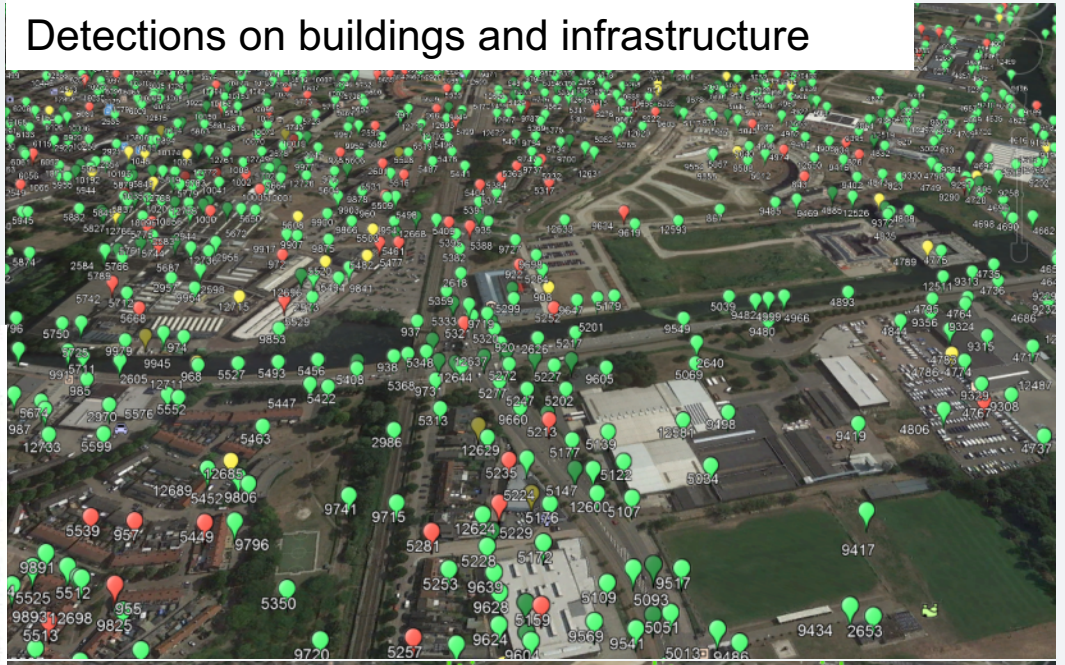


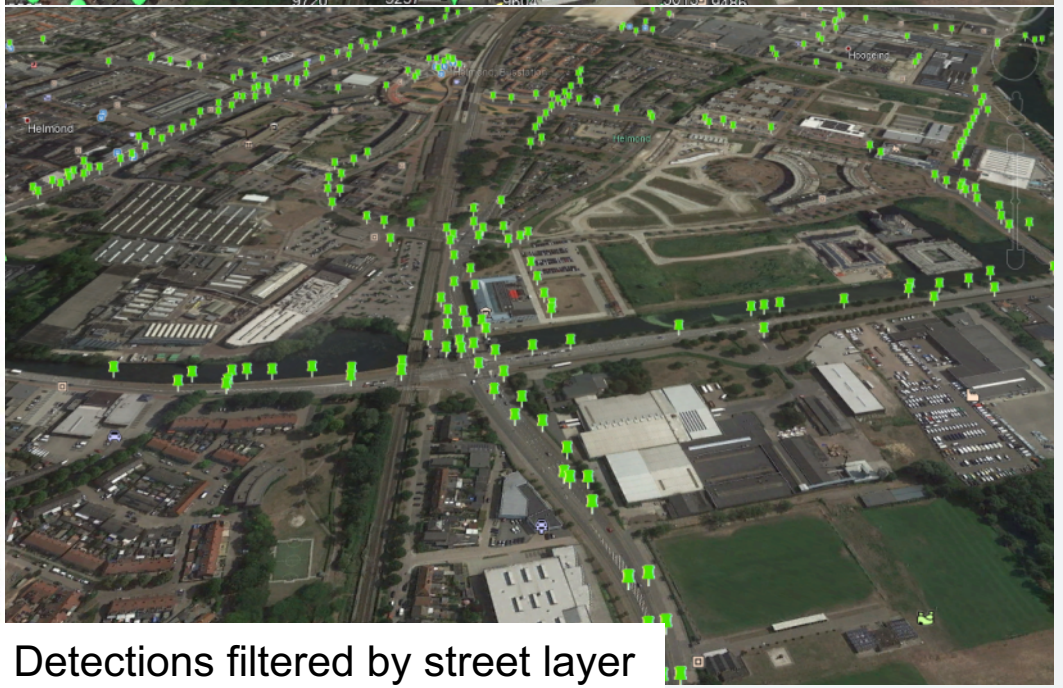
Background

Example Eindhoven, Netherlands

Detected objects

Detections on buildings and infrastructure

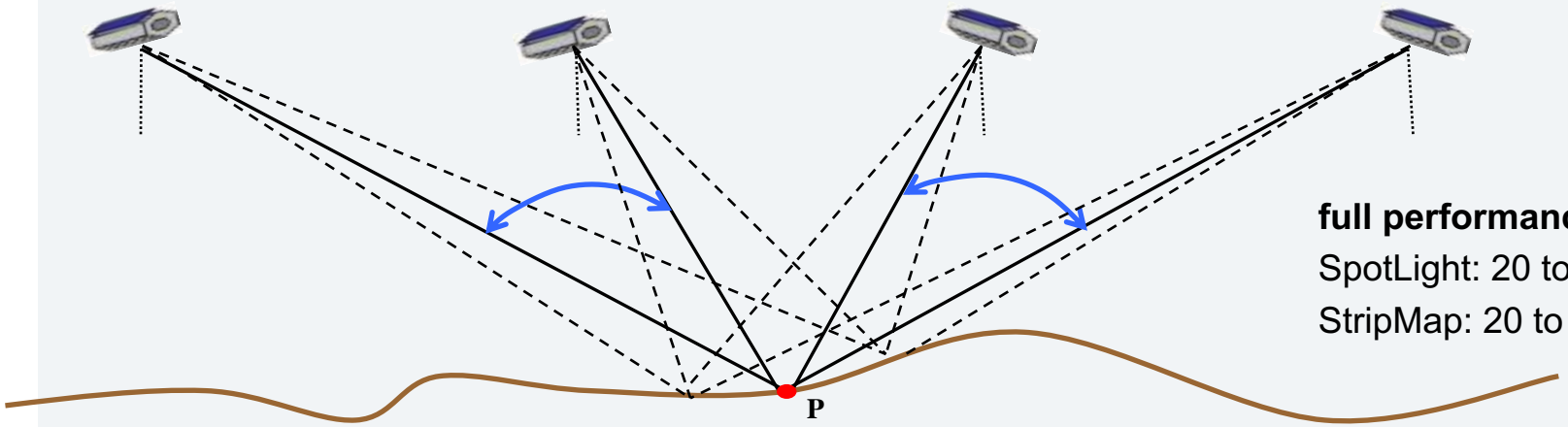




Detections filtered by street layer

Background

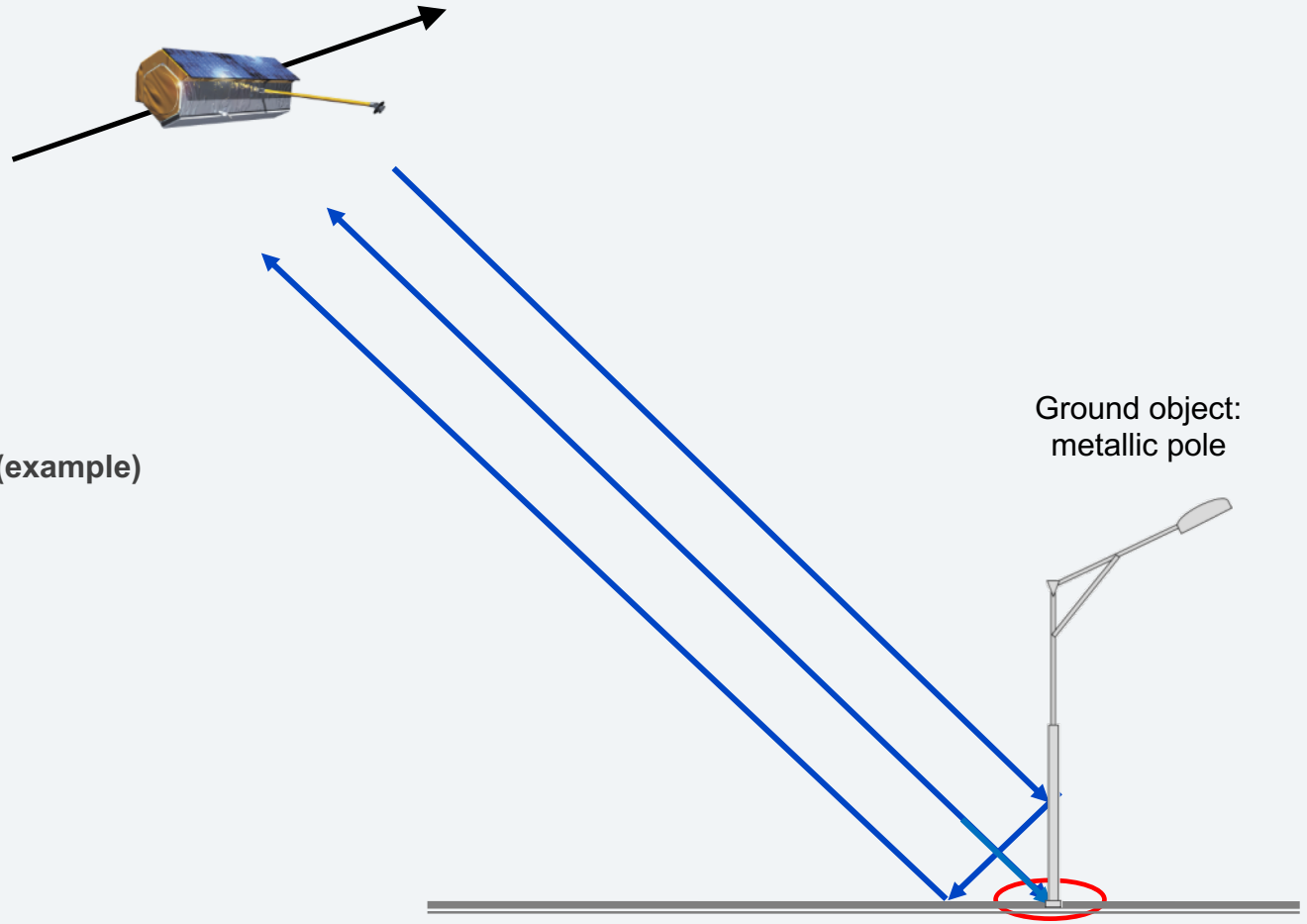
- TerraSAR-X capabilities: High resolution, multi-beam image acquisition
- Along with the image data, detailed and very precise metadata are provided
- → high accurate 3D information extraction using stereo or multiple image data sets



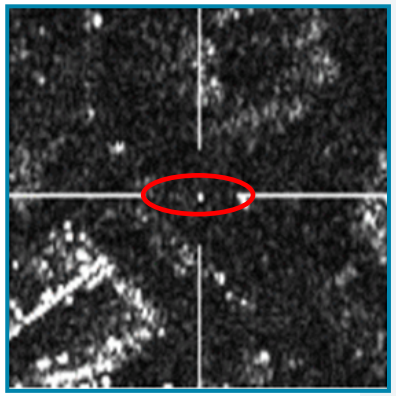
Multi-beam imaging scheme of TerraSAR-X / PAZ (Ascending and Descending)

Background

- Radar satellite microwave are reflected from pole & ground
- All signals have the same traveling time and get focused within one point



Signature of detected point (example)



Radar images 1…n

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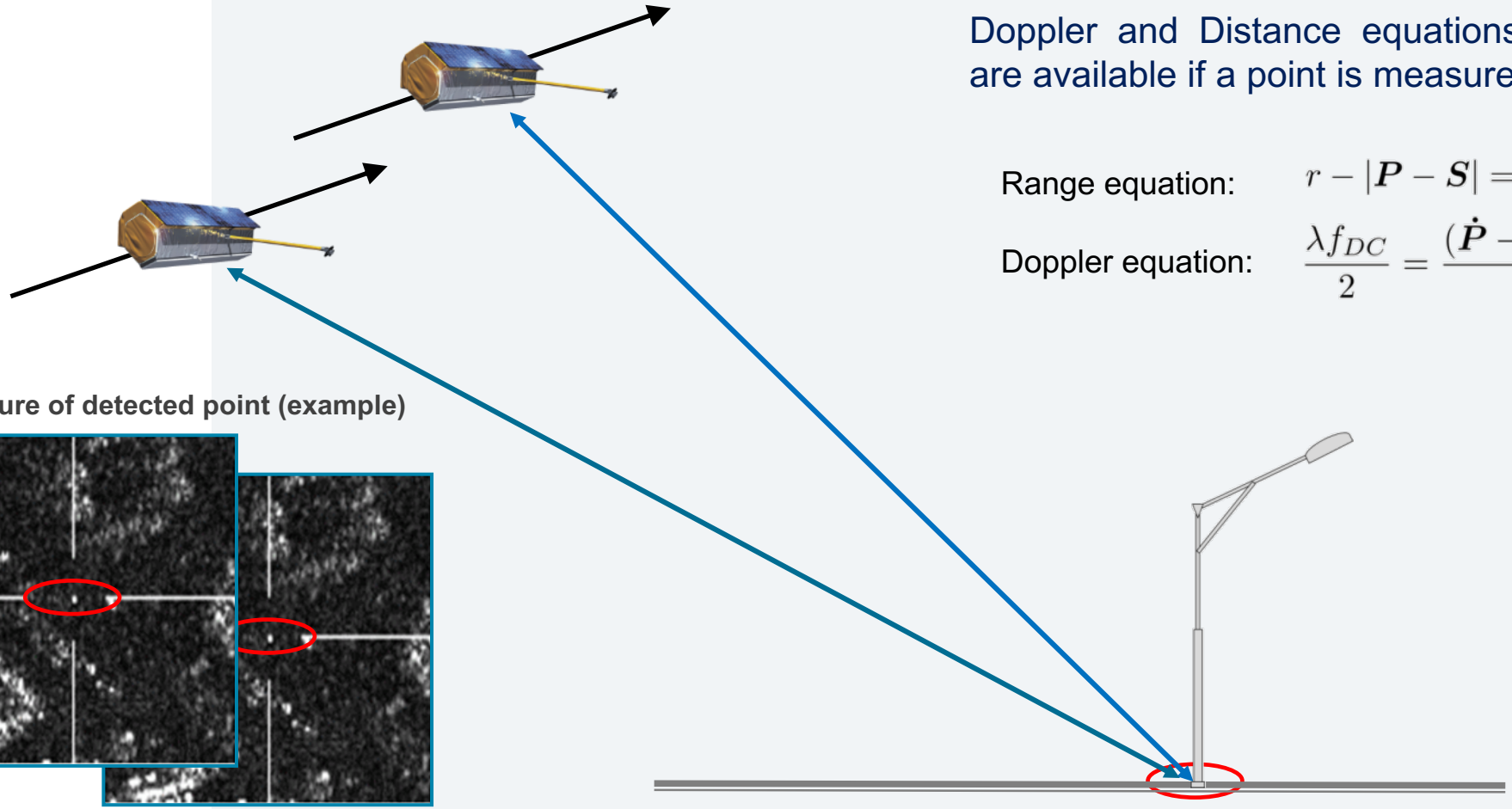
Background

- Point measurements made in two or more images are used to determine the corresponding ground coordinates
- Intersection of two or more Radar Images→ SAR Doppler and Distance equations → four equations are available if a point is measured in a stereo pair

Range equation: $r - |\boldsymbol{P} - \boldsymbol{S}| = 0$

Doppler equation: $\frac{\lambda f_{DC}}{2} = \frac{(\dot{\boldsymbol{P}} - \dot{\boldsymbol{S}})(\boldsymbol{P} - \boldsymbol{S})}{|\boldsymbol{P} - \boldsymbol{S}|}$

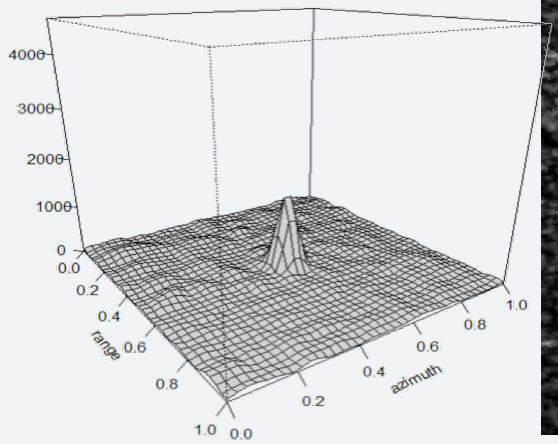


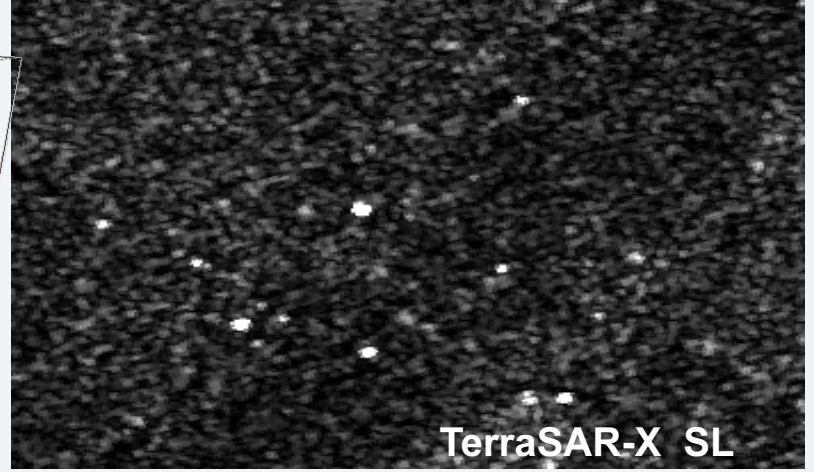
Signature of detected point (example)

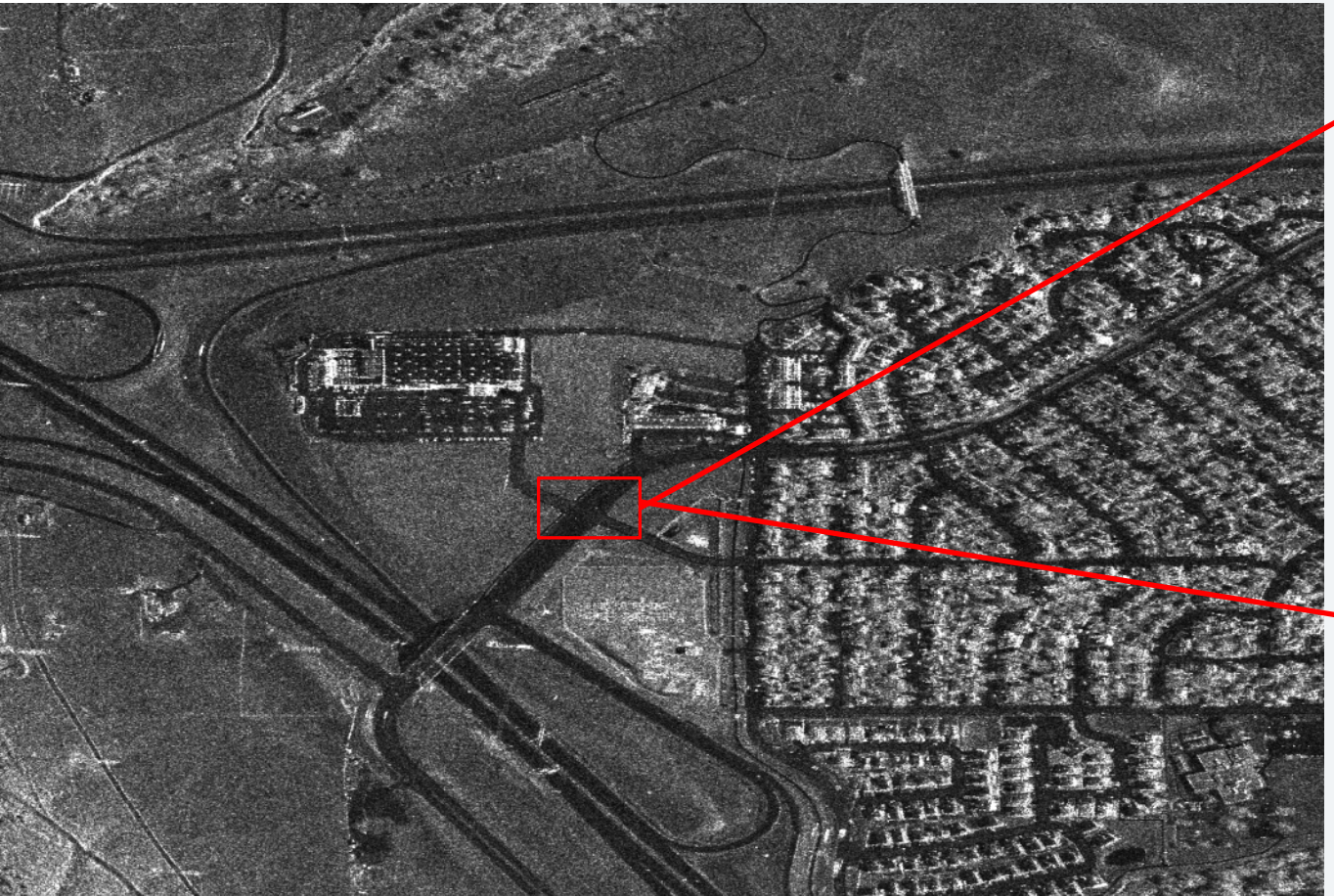
Radar images 1…n

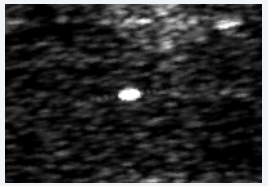
Background

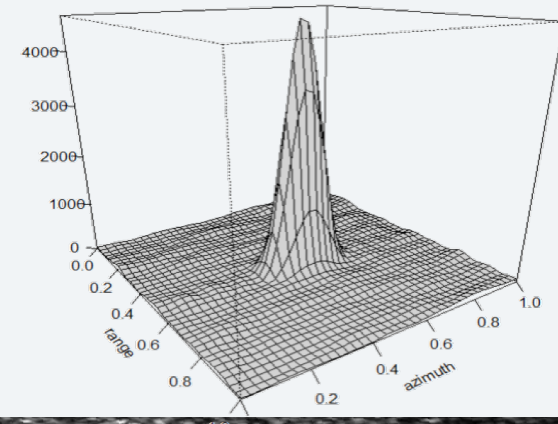
- Resolution and Signal to noise Ratio important for automatic extraction

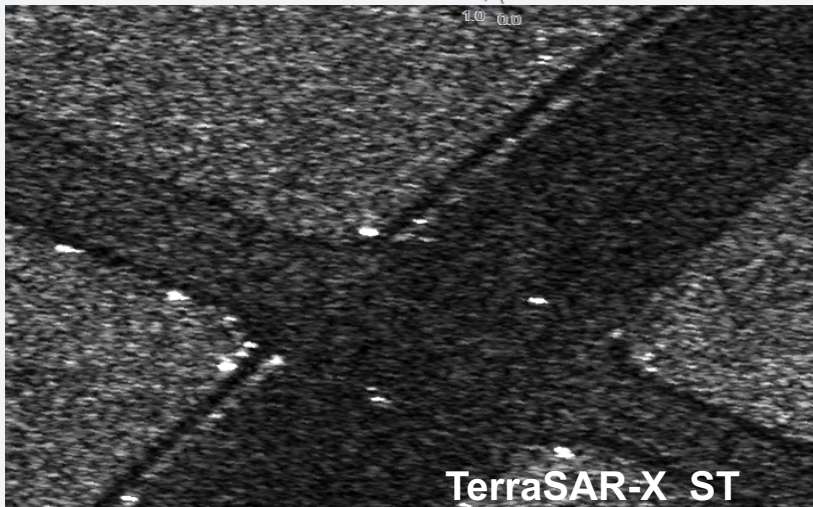








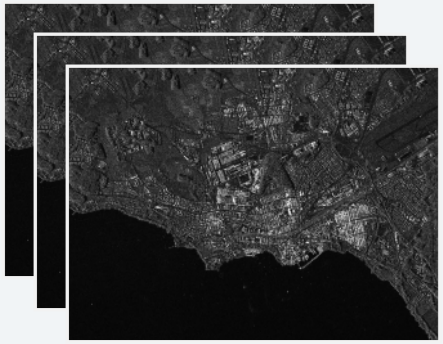




GCP Extraction

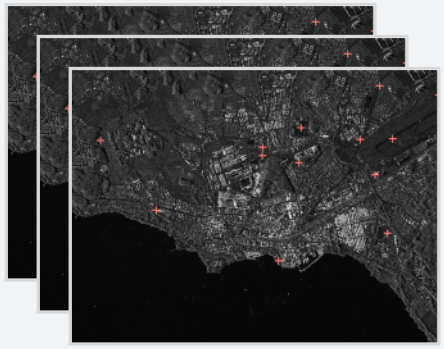
Fully Automatic Processing Chain

Range Delay Correction



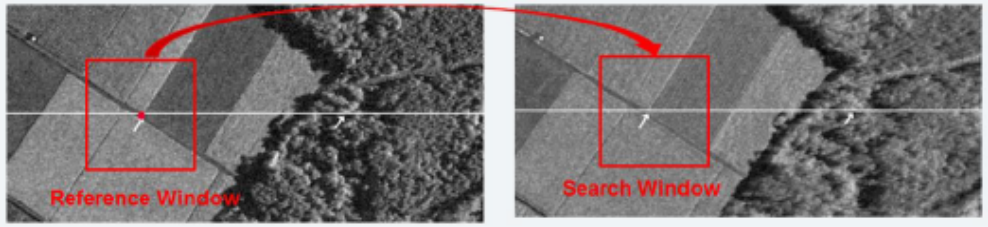
Geodetic Correction

Blob Detection



For n>1 SAR images of different imaging geometries

Epipolar Image Rectification and Point Matching

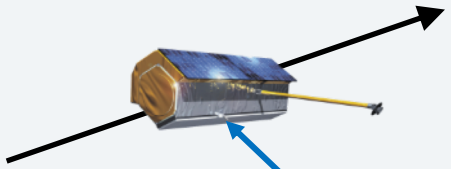


Epipolar rectification of images using a coarse DEM
Find corresponding points via weighted KNN matching

GCP Extraction

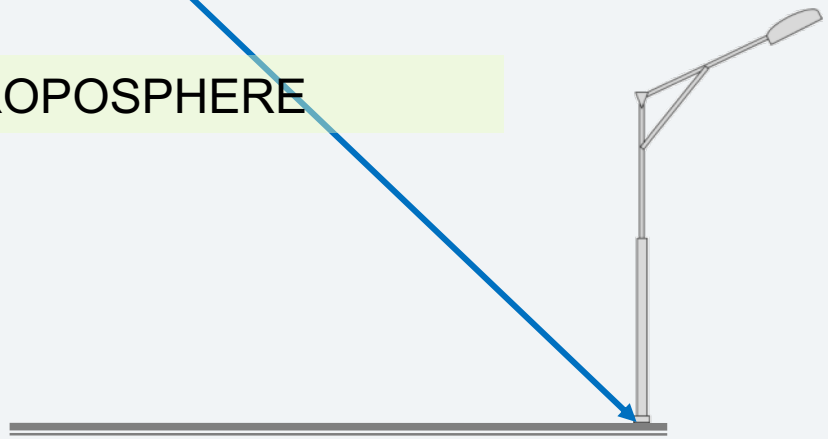
Accuracy: Influencing Components 1

Range Delay Correction

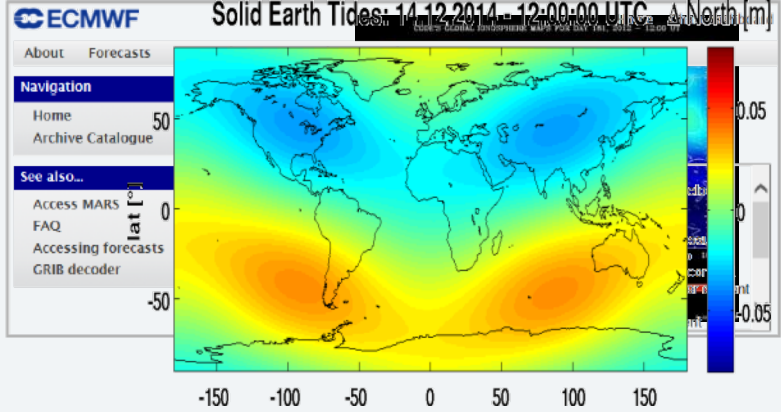


IONOSPHERE

TROPOSPHERE



SOLID EARTH TIDES



- High precise TerraSAR-X **orbit**
- **Ionospheric signal propagation delay** (caused by electrons)
- **Tropospheric signal propagation delay** (caused by air conditions, e.g. water vapor)
- **Solid earth tides** (caused by gravity of moon and sun)
- **Plate tectonics** (“continental drift”)

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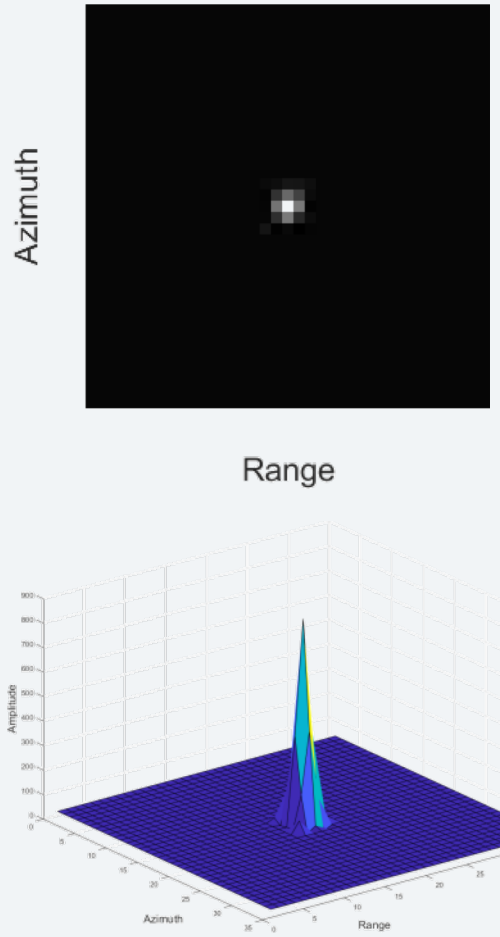
GCP Extraction

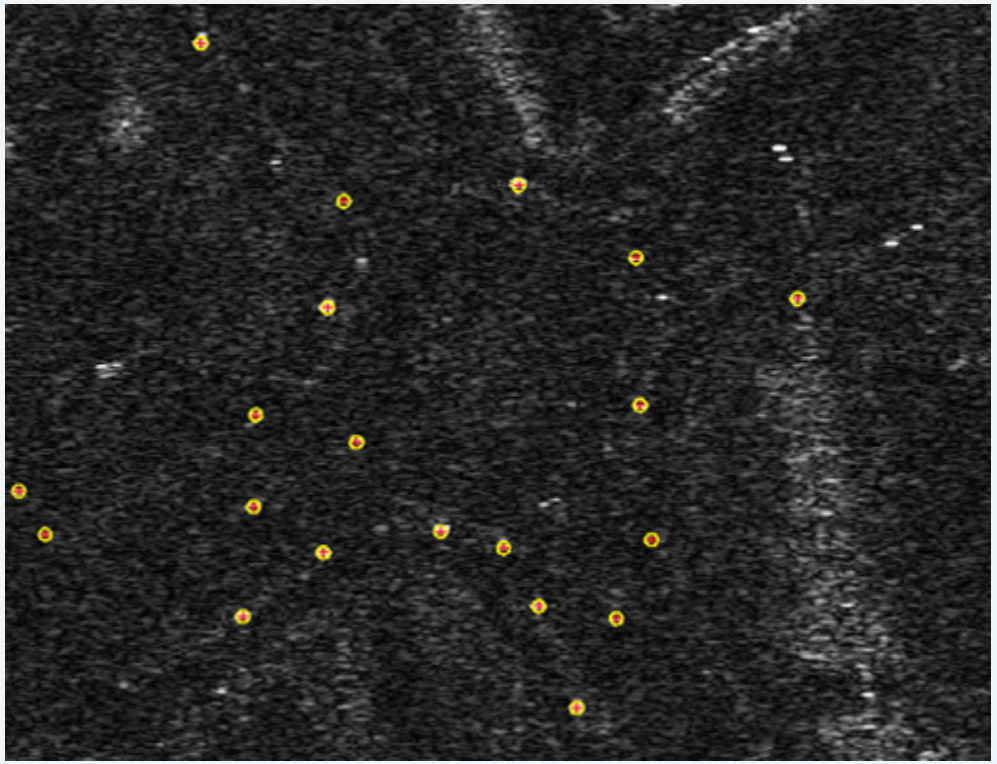
Blob Detection

GCP Extraction

Blob Detection

Blob Detection via Matched Filter



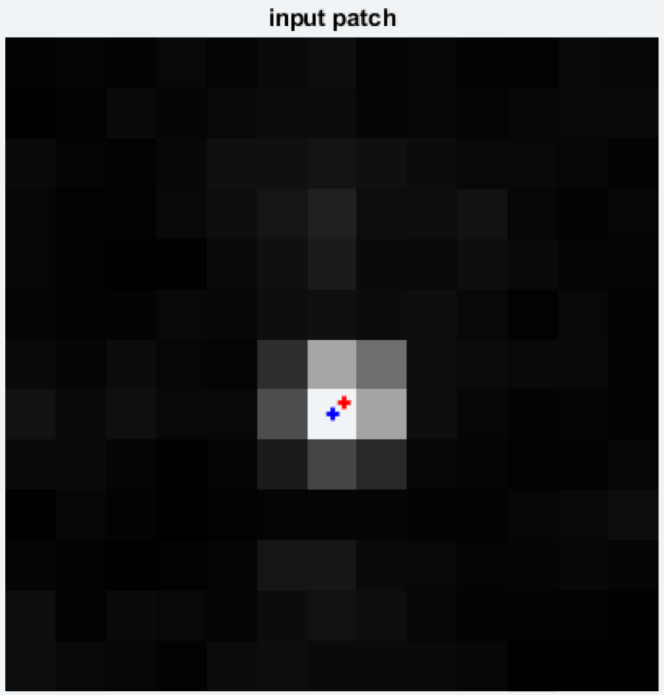


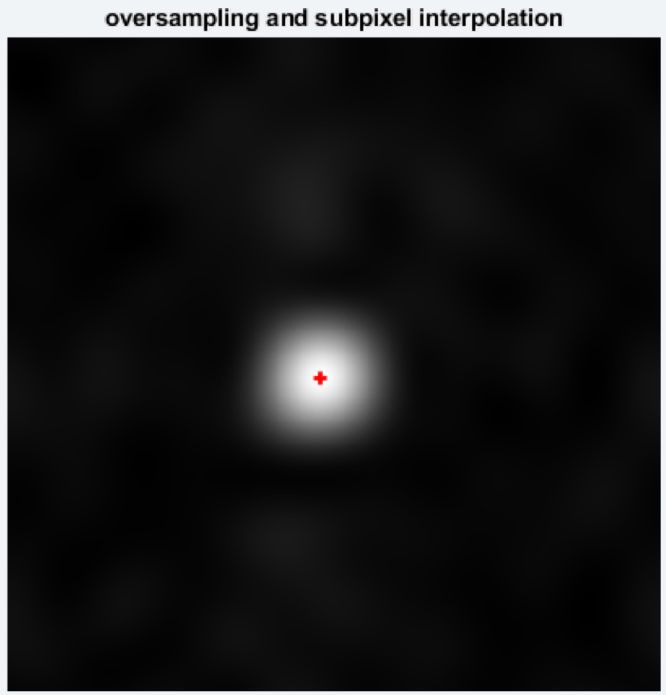
Detections

GCP Extraction

Blob Detection

Blob Detection Subpixel Refinement, Optimizing an energy functional for segmentation





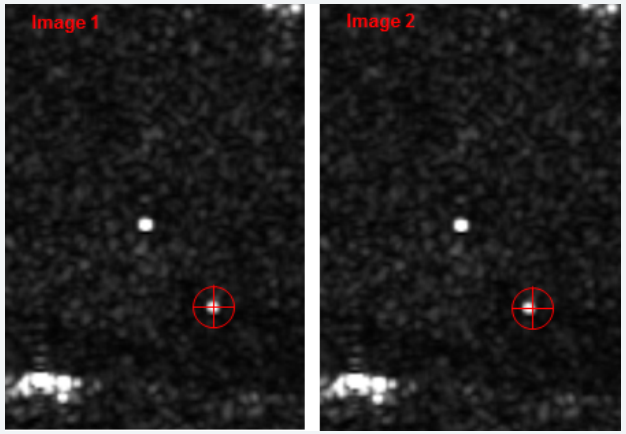
Coordinates: blue – input; red - refined

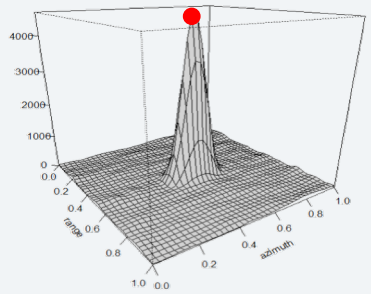
GCP Extraction

Accuracy: Influencing Components 2

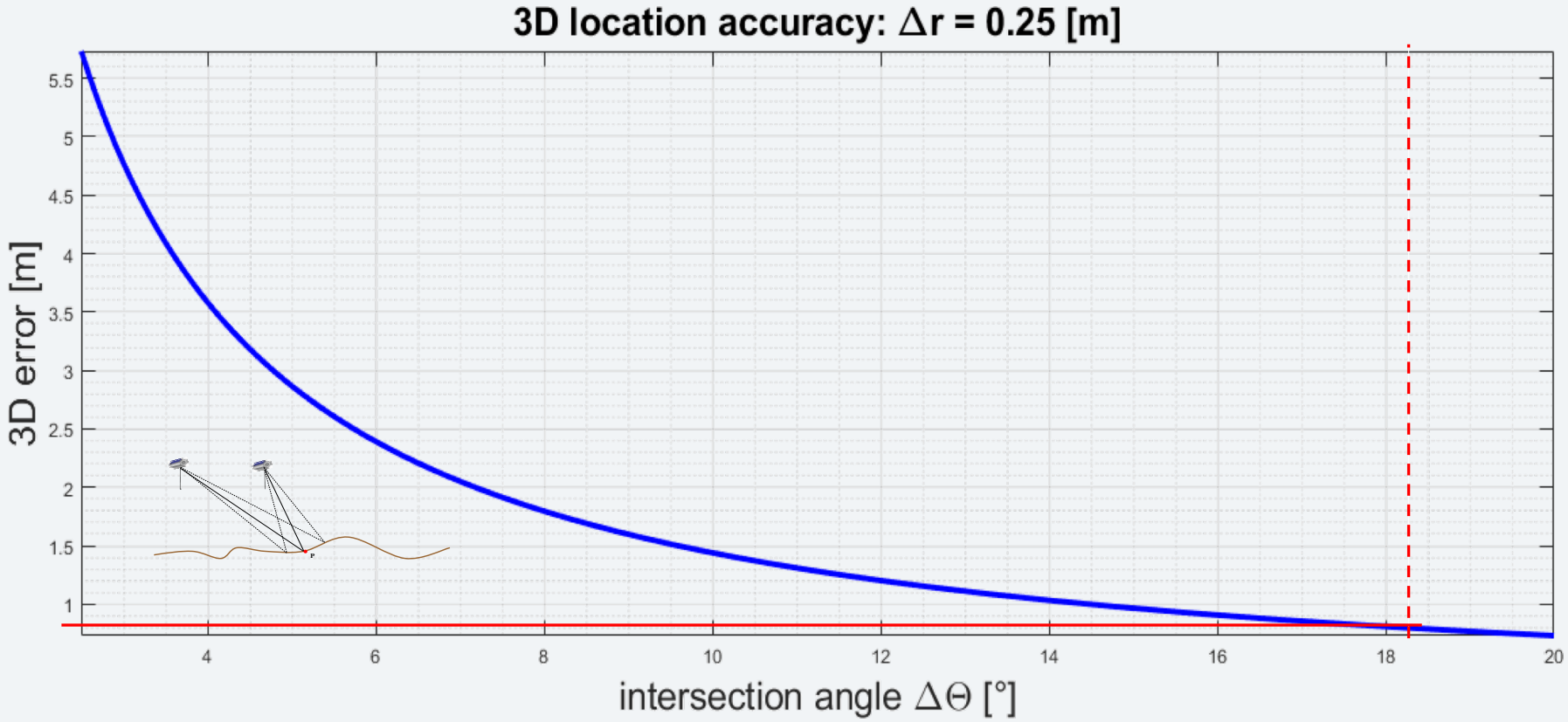
Error Budget: Geometric Constellation

Blob Detection





error of 0.5 Pixel (~0.25m)



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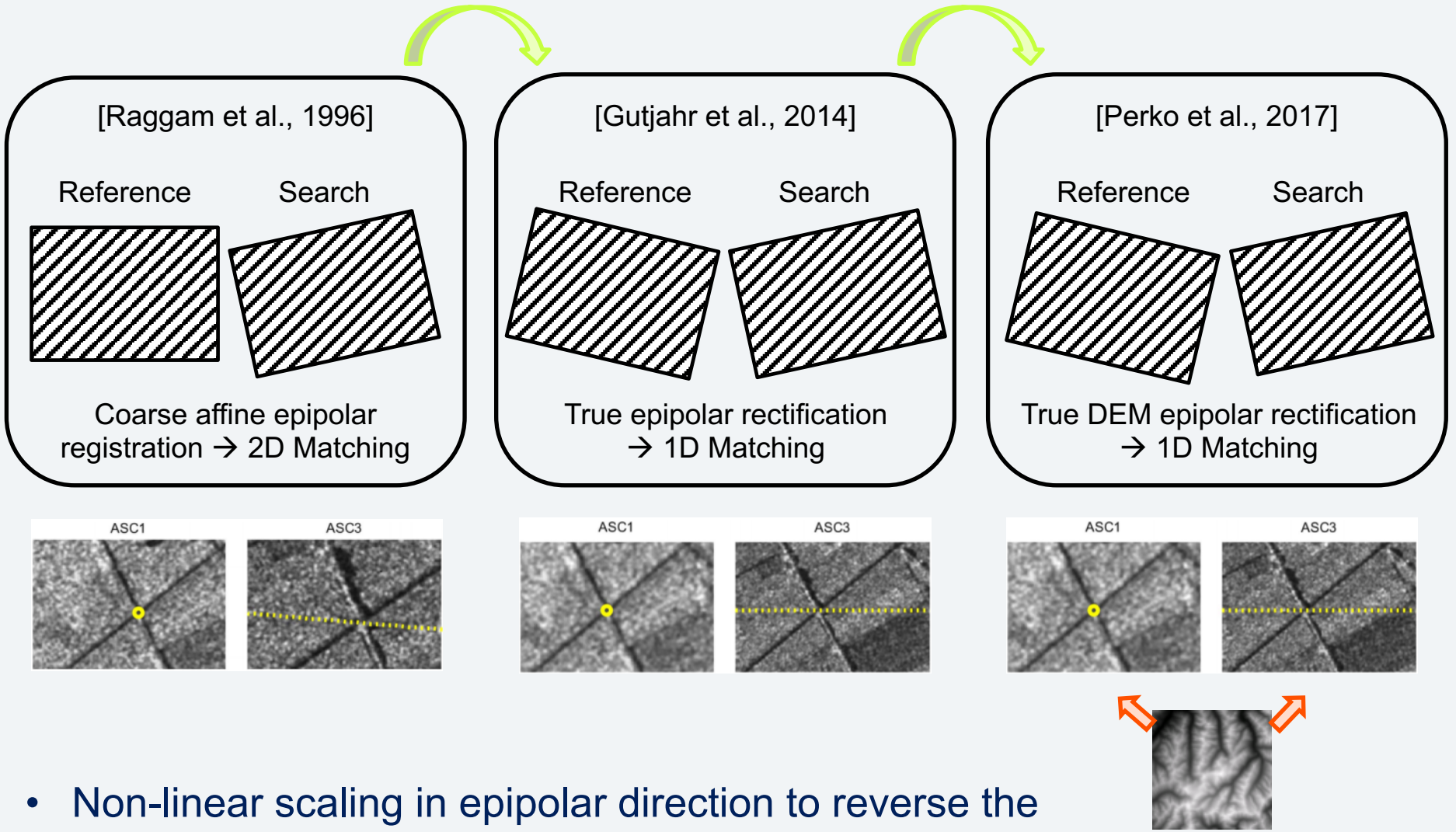
GCP Extraction

Epipolar Image Rectification and Point Matching

True DEM Epipolar Rectification Evolution



- Non-linear scaling in epipolar direction to reverse the local scaling in range direction
- Image matching must not deal with SAR specific geometric constraints

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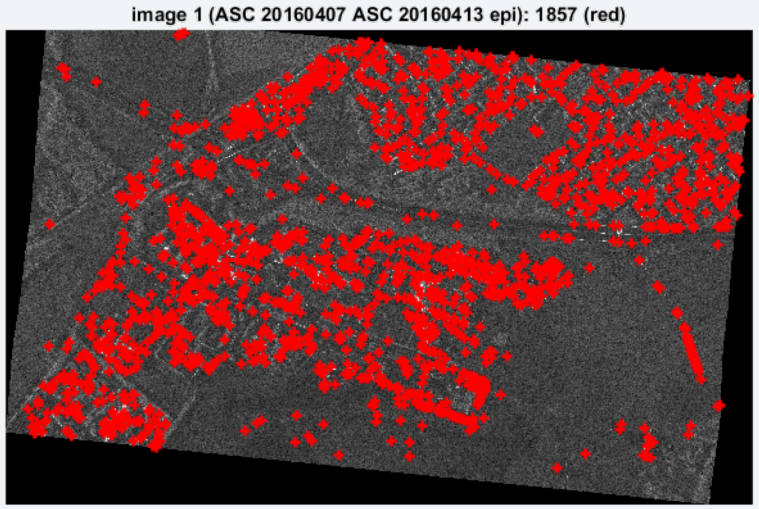
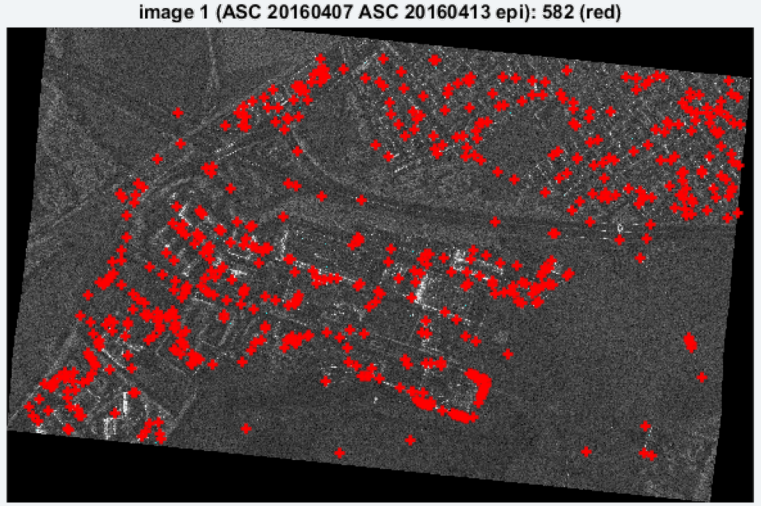
GCP Extraction

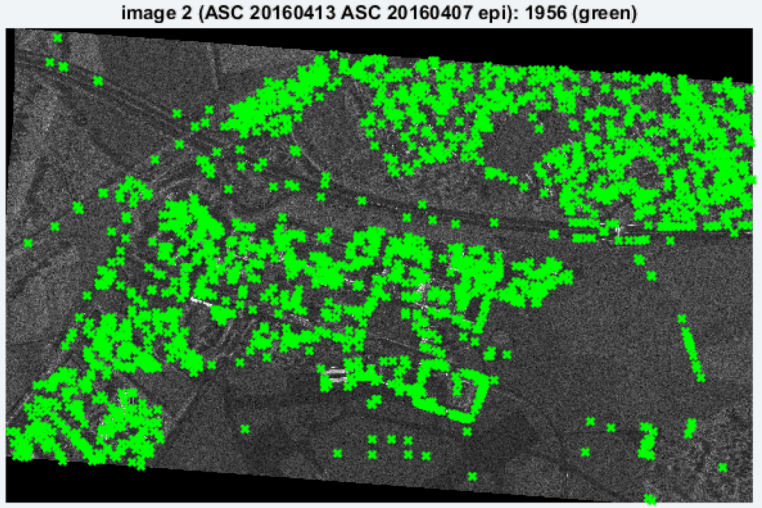
Epipolar Image Rectification and Point Matching

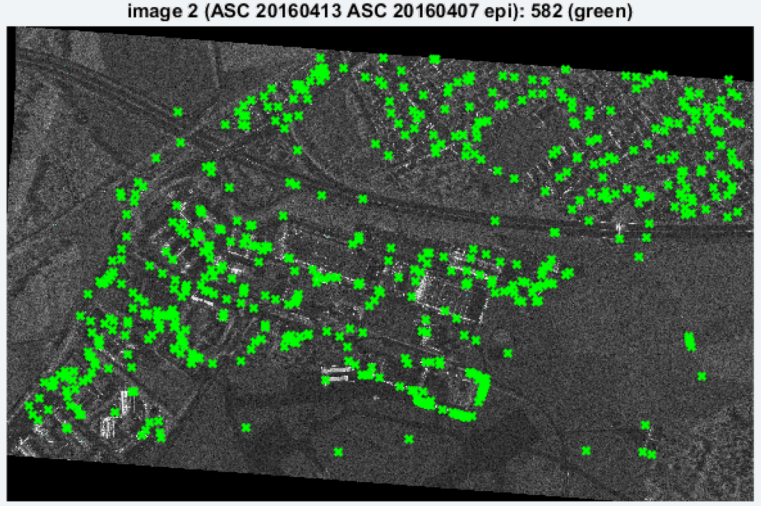




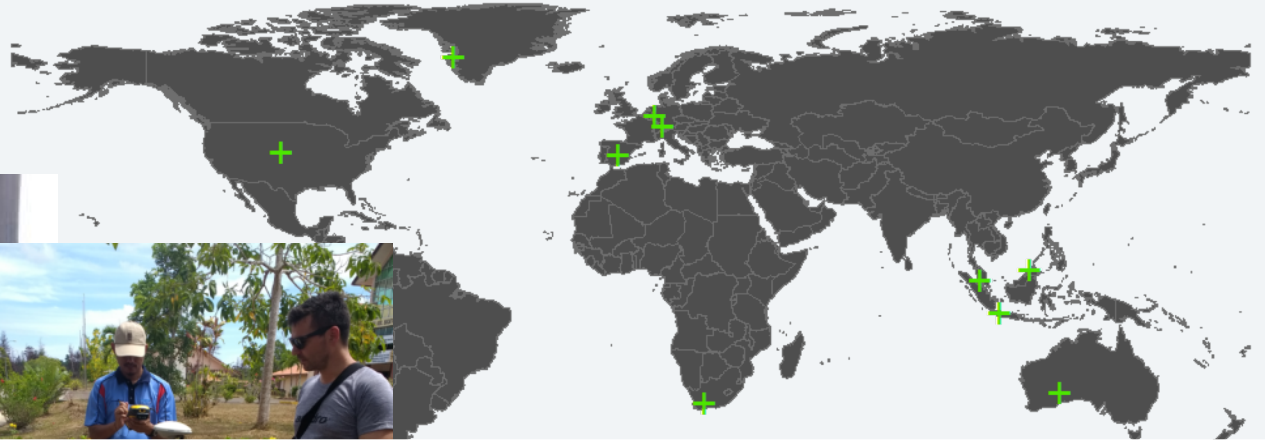
Epipolar transformed Images

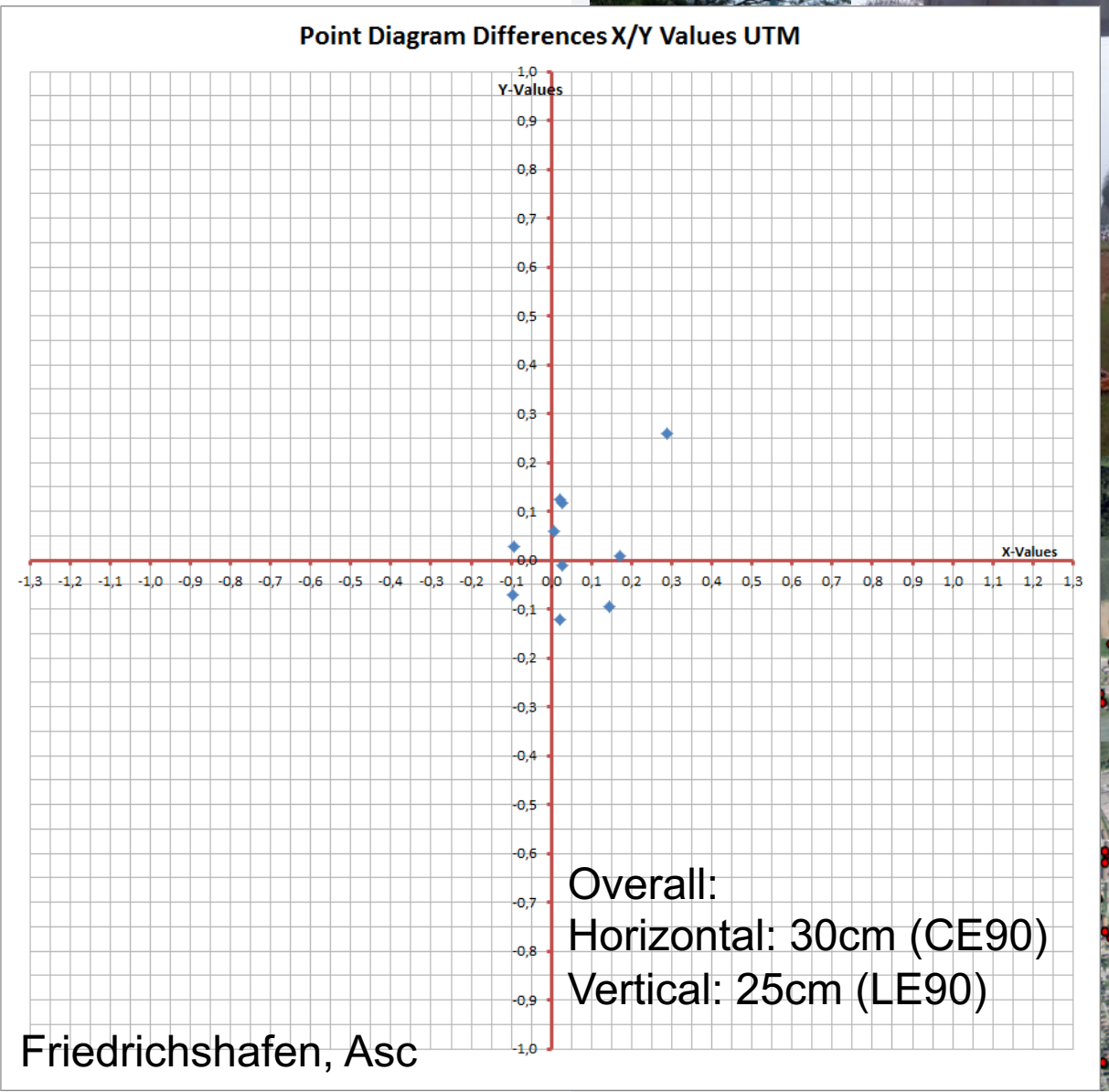
Finding Corresponding Points via Weighted KNN-Matching





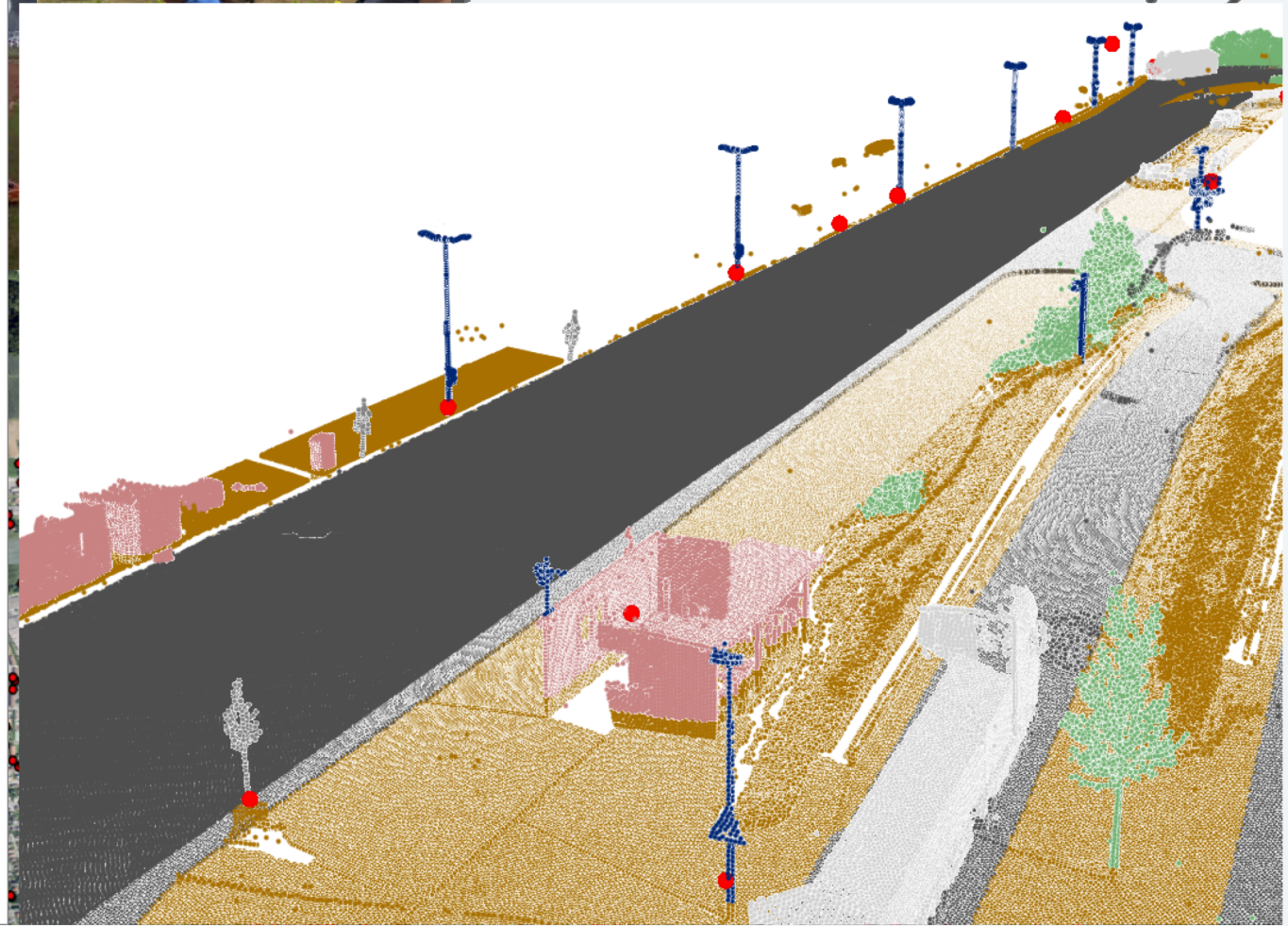
Validation





Overall:
Horizontal: 30cm (CE90)
Vertical: 25cm (LE90)

Friedrichshafen, Asc



Summary

- Identify man made scatters in SAR images and extract their 3D position using radargrammetry at decimeter accuracy (worldwide)
- Point matching is performed in 1D based on novel true DEM epipolar rectification
- Atmospheric path delay causes range offsets and is corrected with local and timely information
- Constraints: point identification in different images
- Horizontal Accuracy for well detected pole structures up to 10cm
- Challenge: to filter highly accurate points out of the point cloud

1. Hannes Raggam et al. “Assessment of the stereo-radargrammetric mapping potential of TerraSAR-X multibeam spotlight data”, IEEE TGRS, 48(2):971-977, 2010.
2. Perko et al.,”Forest assessment using high resolution SAR data in X-band”, Remote Sensing, 3(4):792-815, 2011.
3. Gutjahr et al. “The epipolarity constraint in stereo-radargrammetric DEM generation”, IEEE TGRS, 52(8):5014-5022, 2014.
4. Gutjahr et al., “3D-mapping from TerraSAR-X staring spotlight data”, IEEE IGARSS, 1817-1820, 2015.
5. Perko et al., “DEM-based epipolar rectification for optimized radargrammetry”, IEEE IGARSS, 969-972, 2017.

Thank you!

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