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

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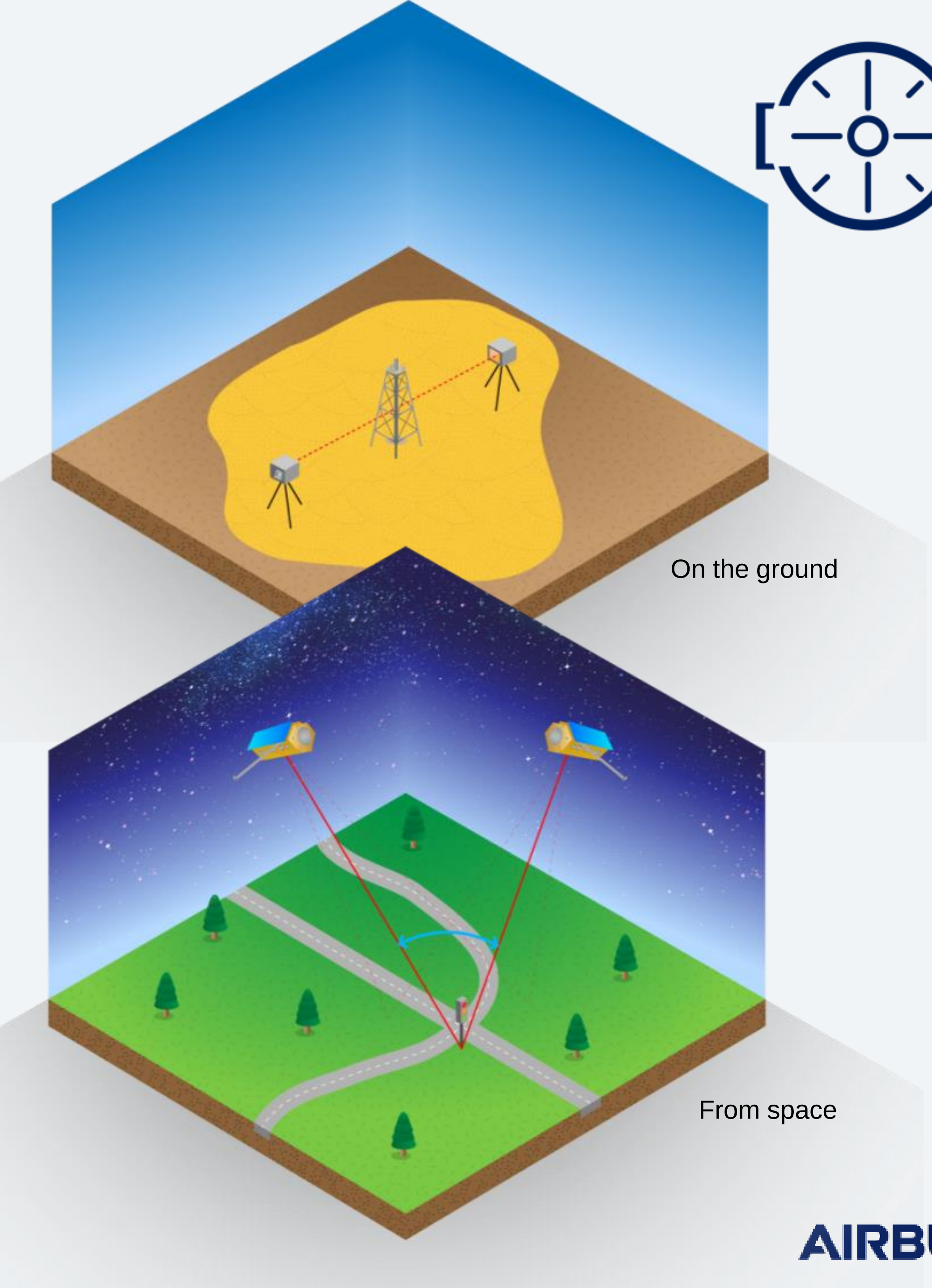
Background

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

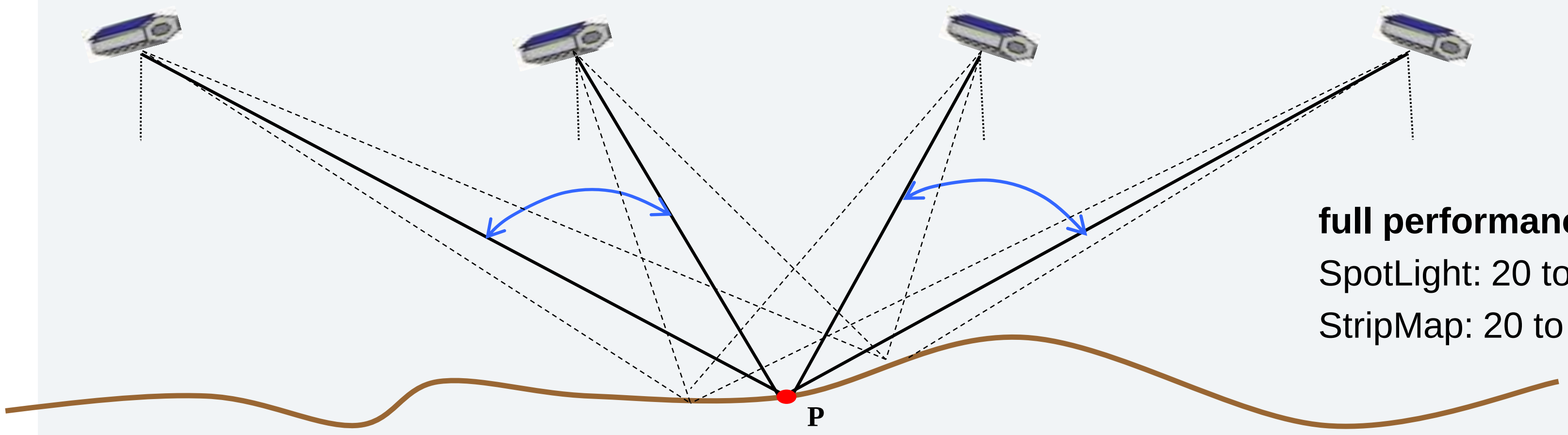
Detected objects

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

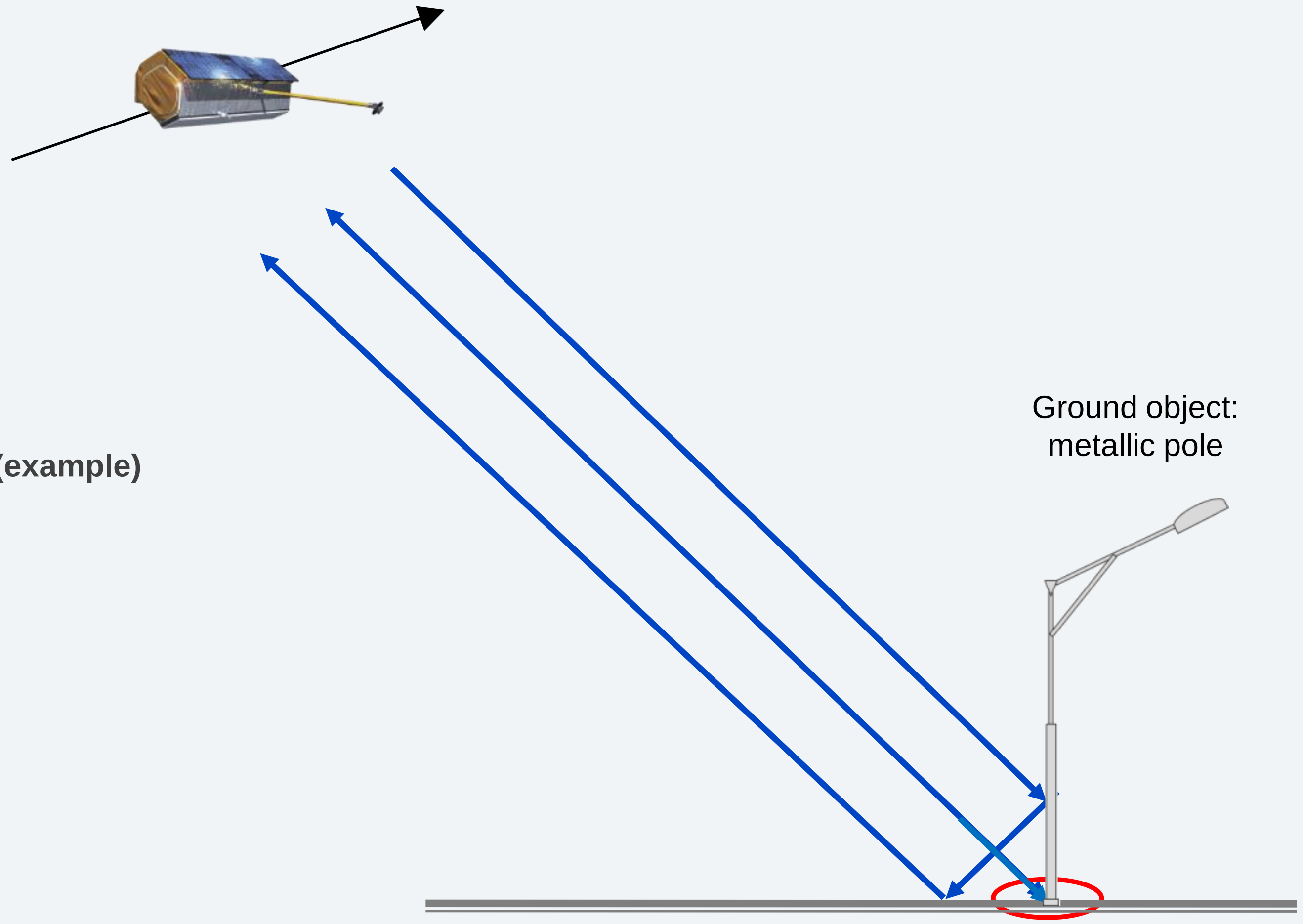


full performance range:
SpotLight: 20 to 55 degree
StripMap: 20 to 45 degree

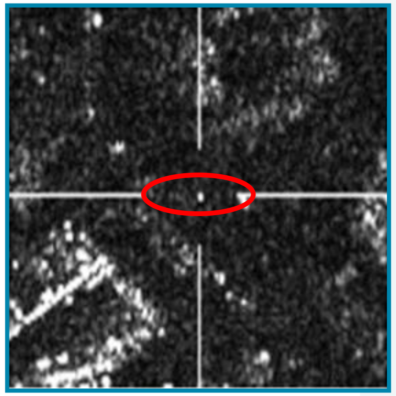
Multi-beam imaging scheme of TerraSAR-X / PAZ (Ascending and Descending)

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)



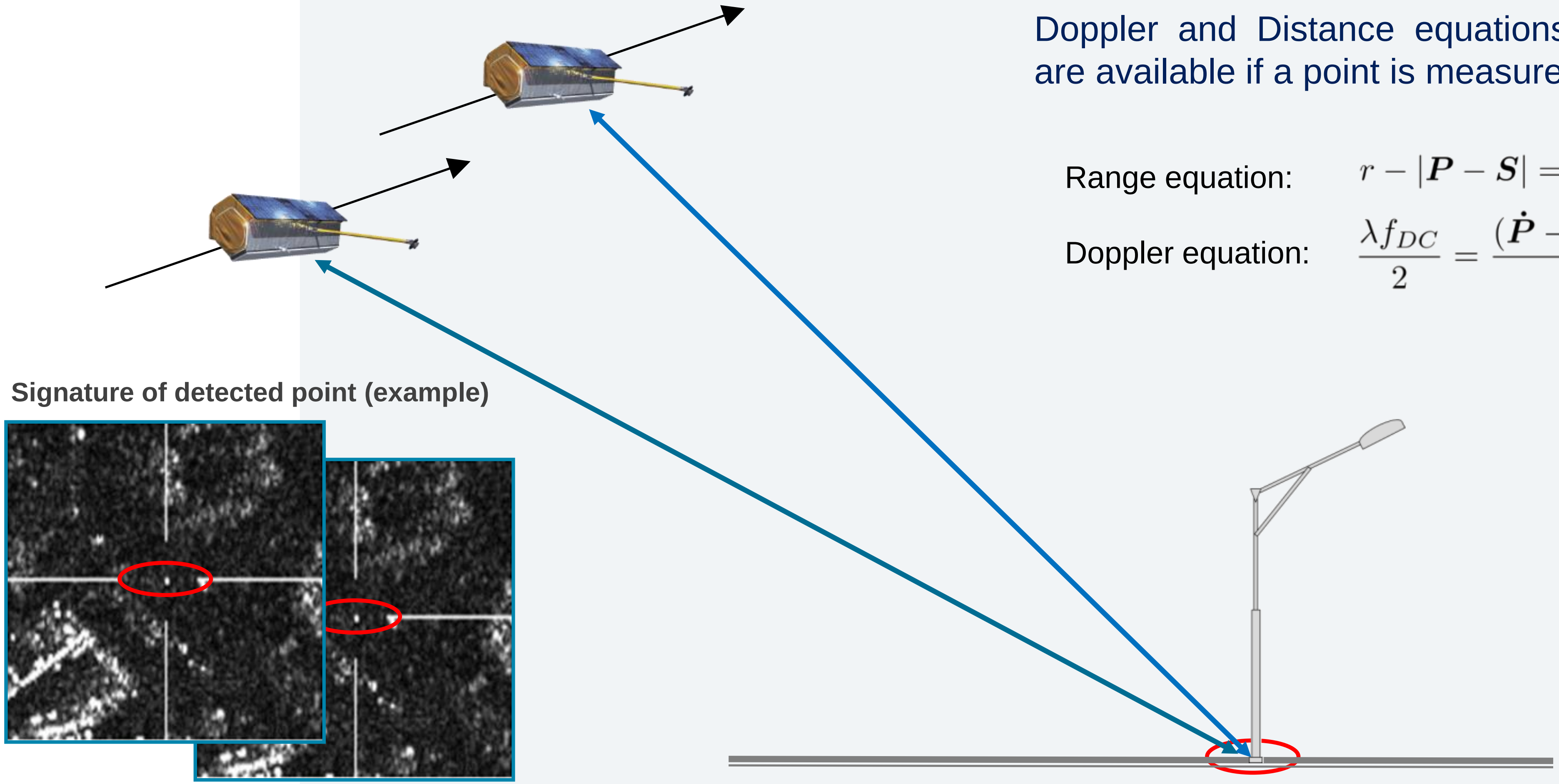
Radar images 1…n

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

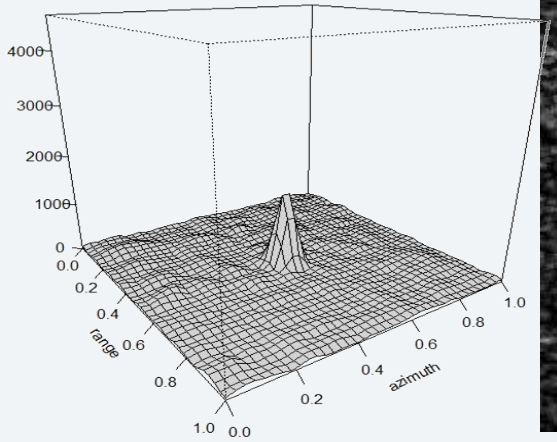
Doppler equation: $\frac{\lambda f_{DC}}{2} = \frac{(\dot{\boldsymbol{P}} - \dot{\boldsymbol{S}})(\boldsymbol{P} - \boldsymbol{S})}{|\boldsymbol{P} - \boldsymbol{S}|}$

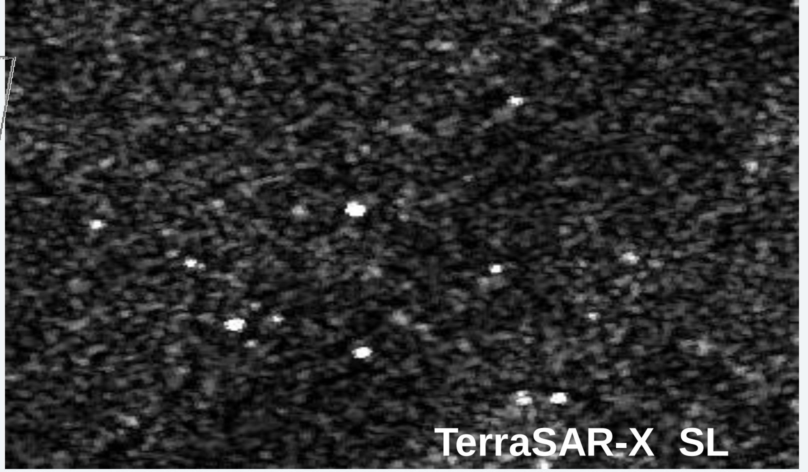


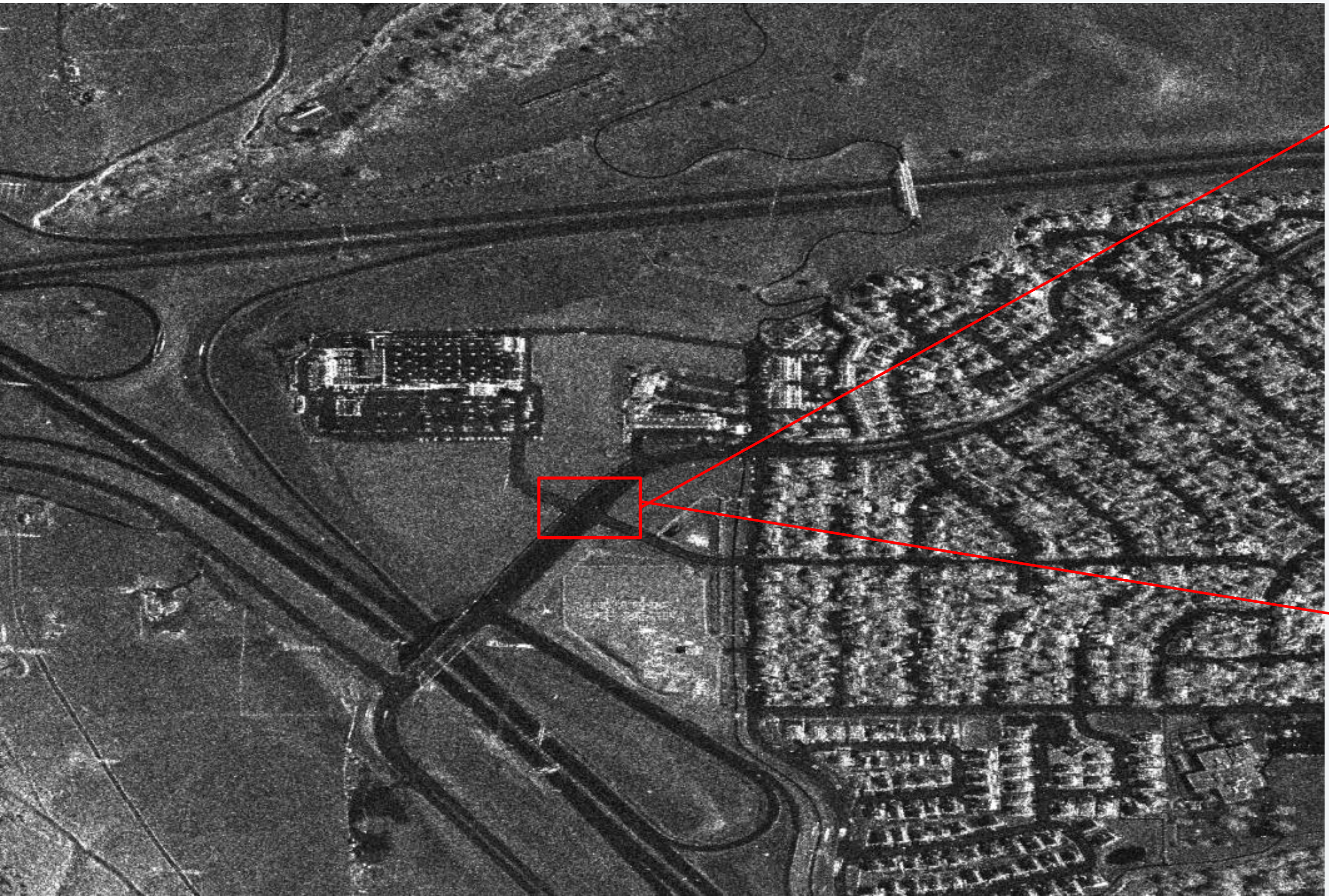
Radar images 1…n

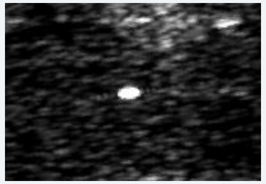
Background

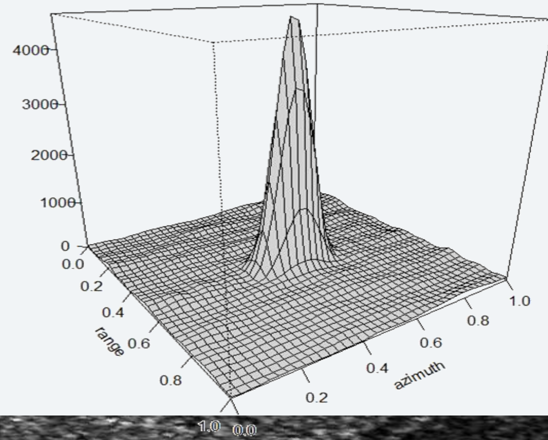
- Resolution and Signal to noise Ratio important for automatic extraction

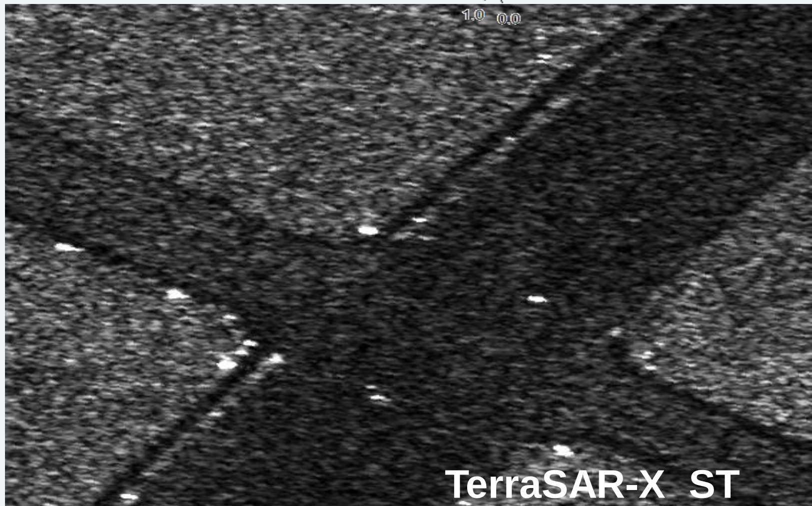








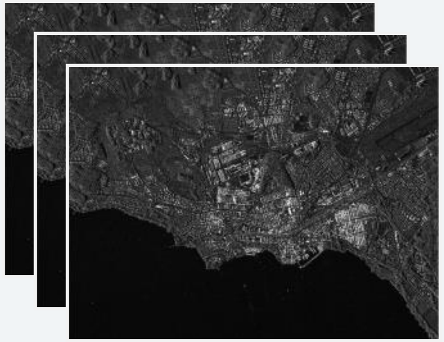




GCP Extraction

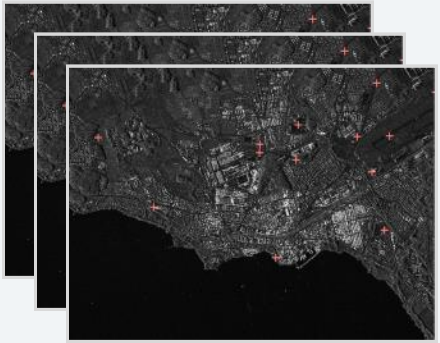
Fully Automatic Processing Chain

Range Delay Correction



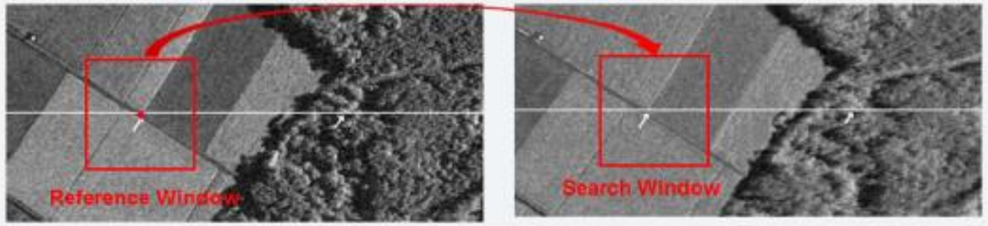
Geodetic Correction

Blob Detection



For n>1 SAR images of different imaging geometries

Epipolar Image Rectification and Point Matching

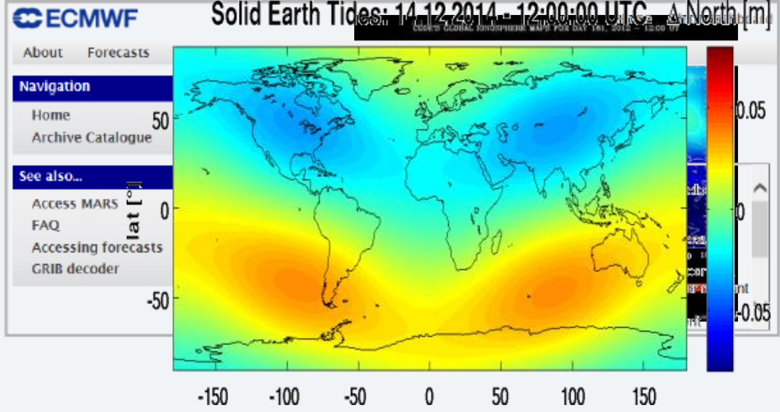


Epipolar rectification of images using a coarse DEM
Find corresponding points via weighted KNN matching

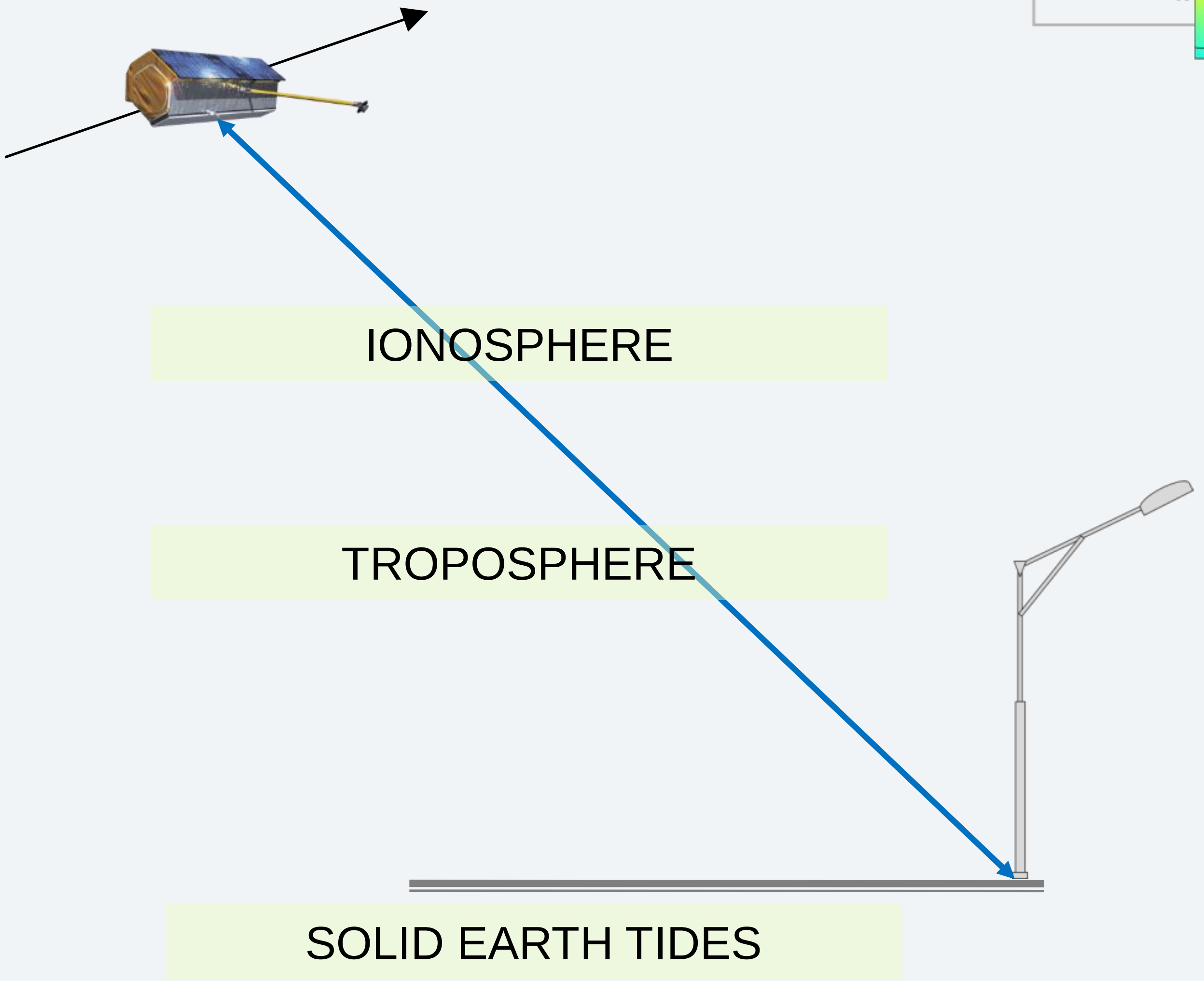
GCP Extraction

Accuracy: Influencing Components 1

Range Delay Correction



- 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

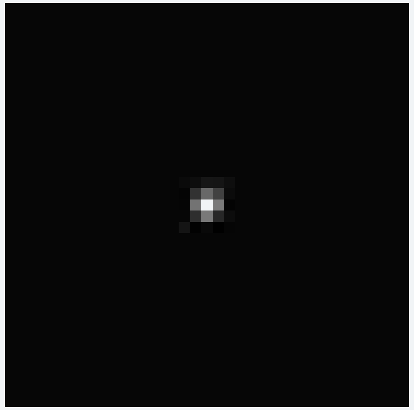
Blob Detection

GCP Extraction

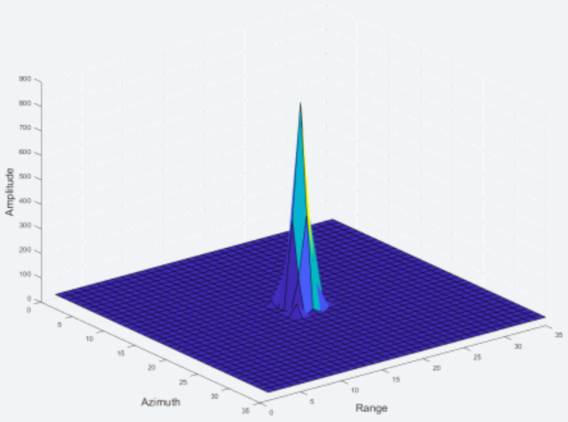
Blob Detection

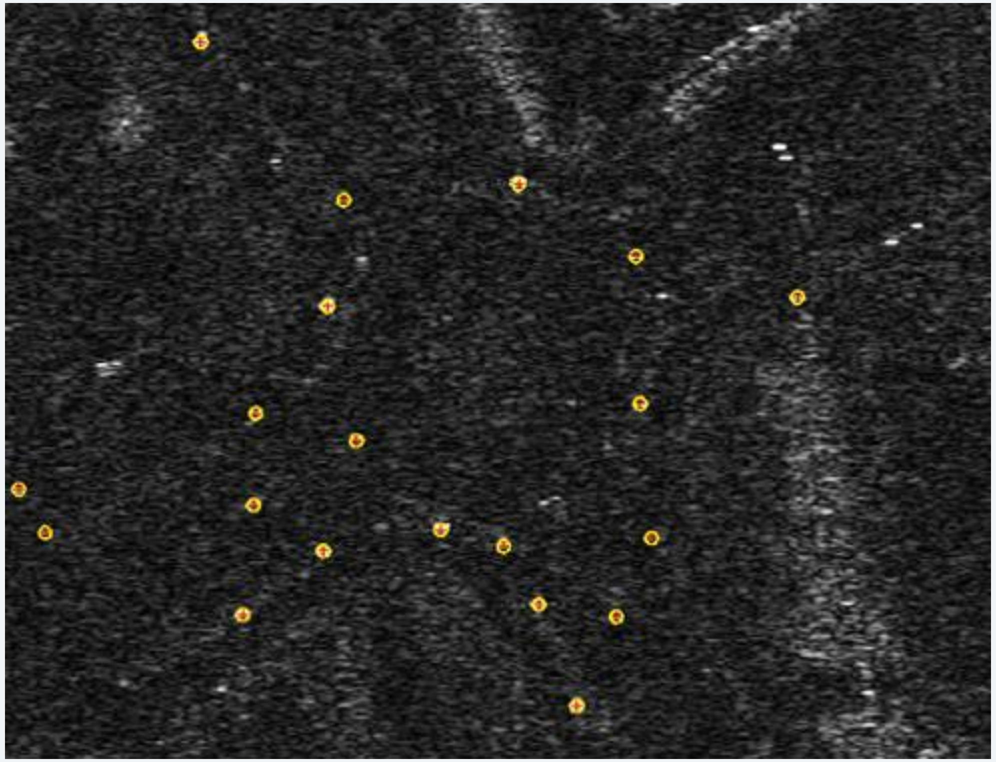
Blob Detection via Matched Filter

Azimuth



Range



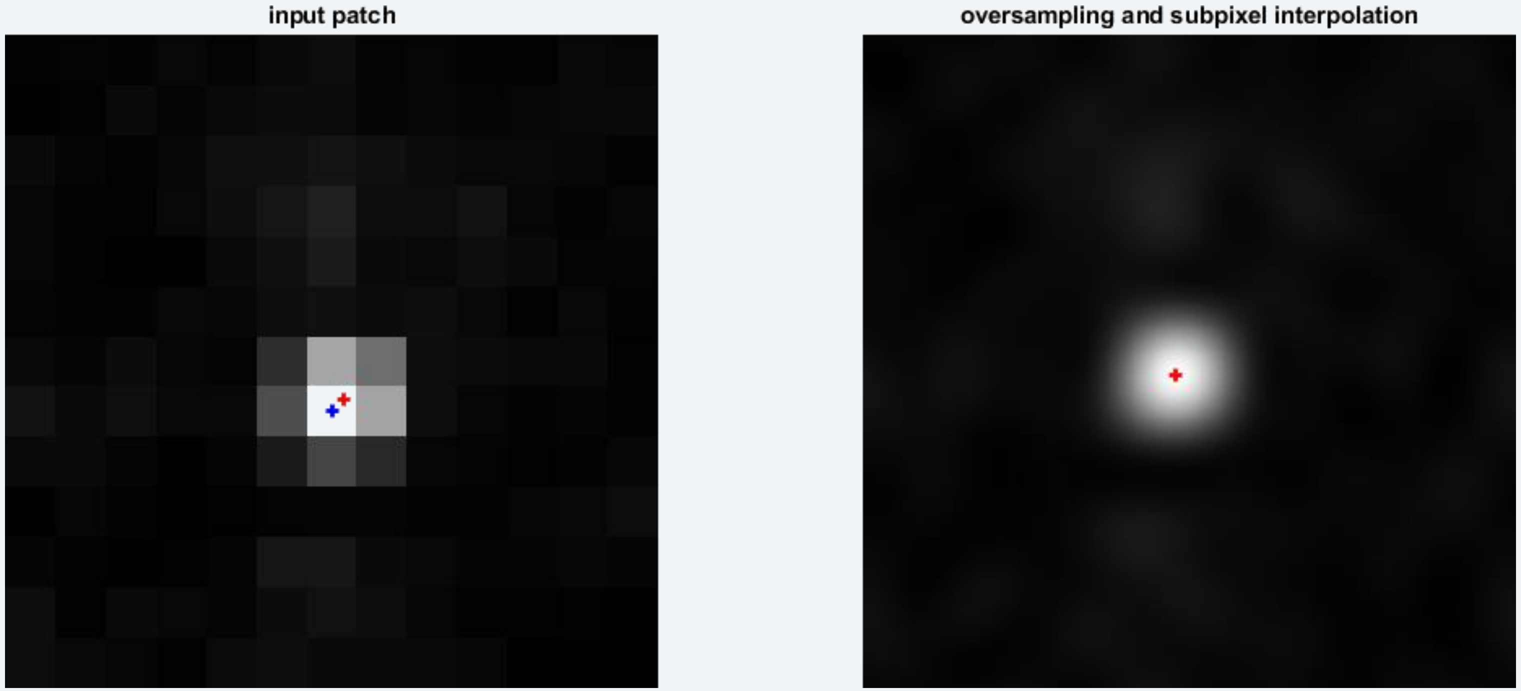


Detections

GCP Extraction

Blob Detection

Blob Detection Subpixel Refinement, Optimizing an energy functional for segmentation



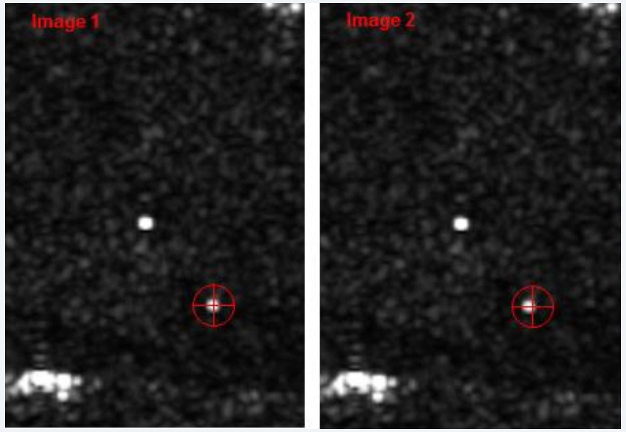
Coordinates: blue – input; red - refined

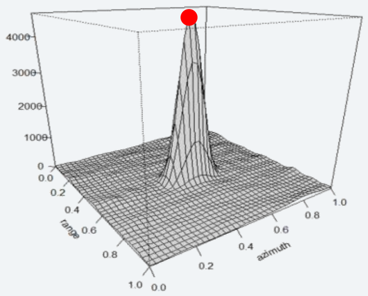
GCP Extraction

Accuracy: Influencing Components 2

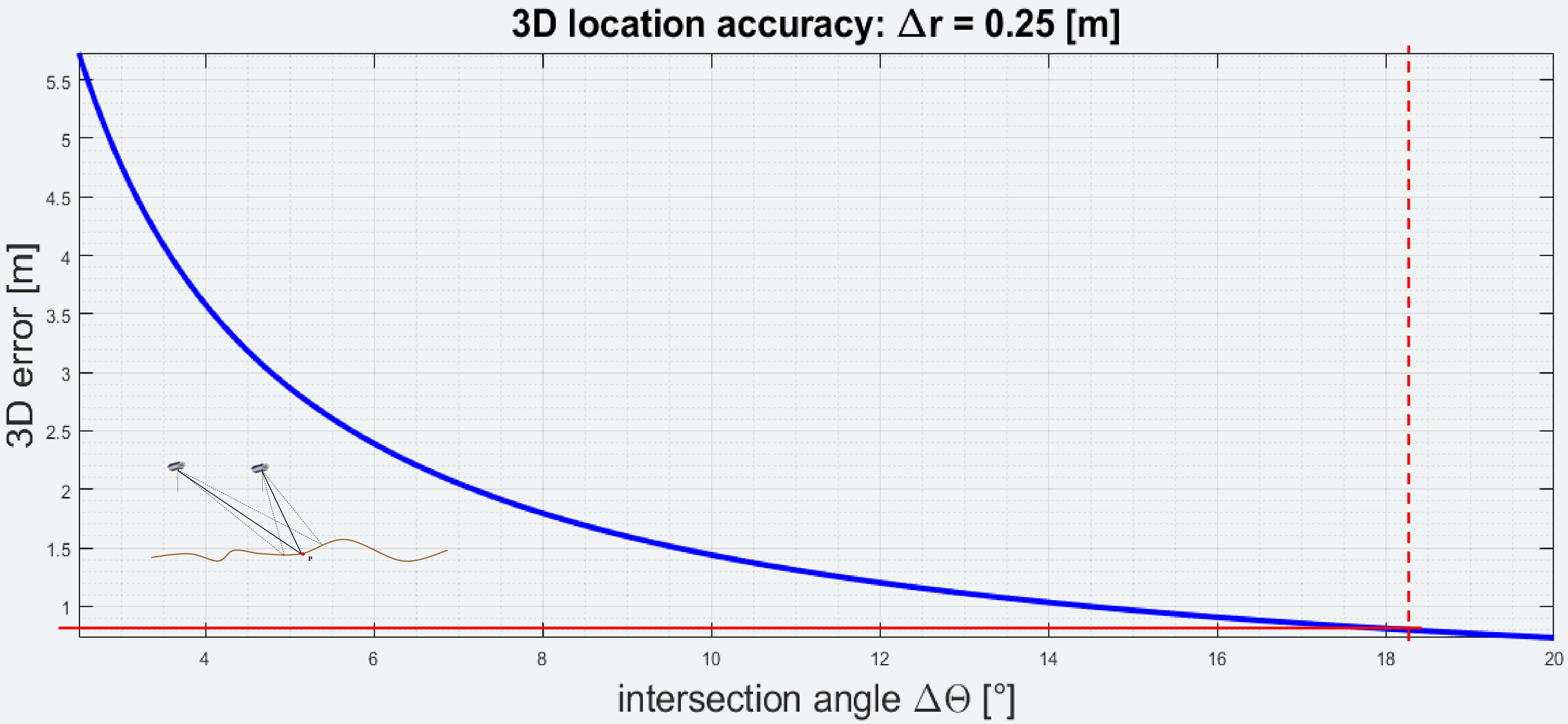
Error Budget: Geometric Constellation

Blob Detection





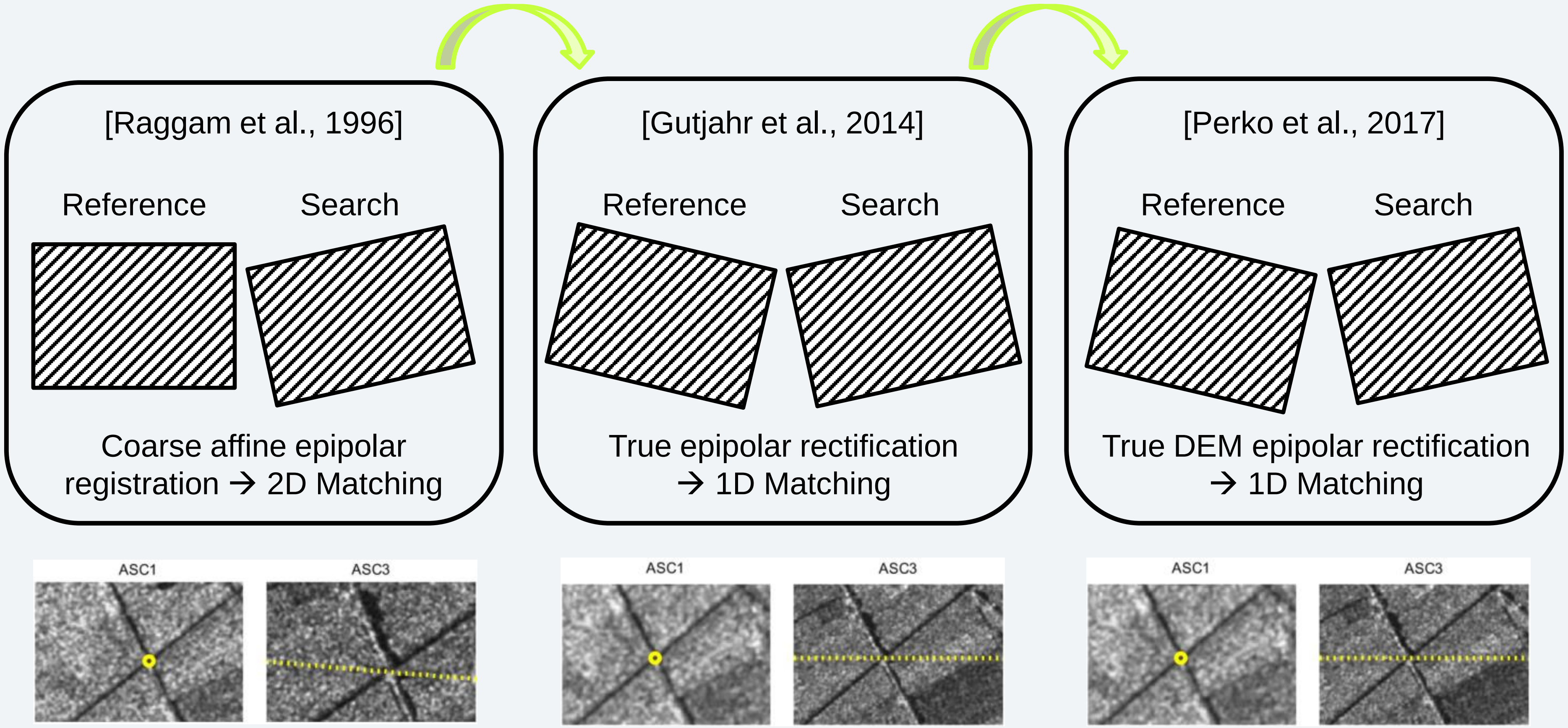
error of 0.5 Pixel (~0.25m)



GCP Extraction

Epipolar Image Rectification and Point Matching

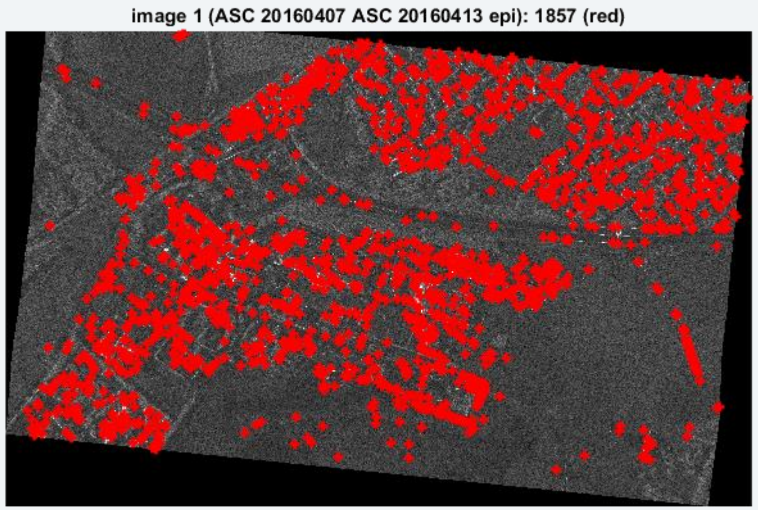
True DEM Epipolar Rectification Evolution

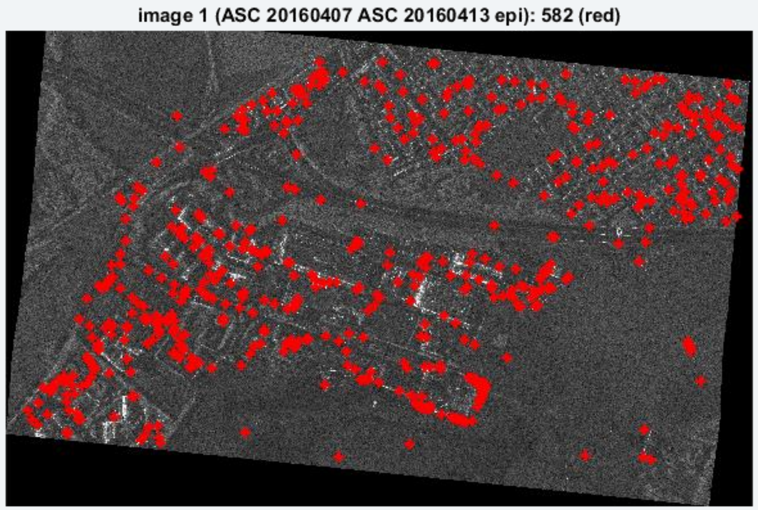


- Non-linear scaling in epipolar direction to reverse the local scaling in range direction
- Image matching must not deal with SAR specific geometric constraints

GCP Extraction

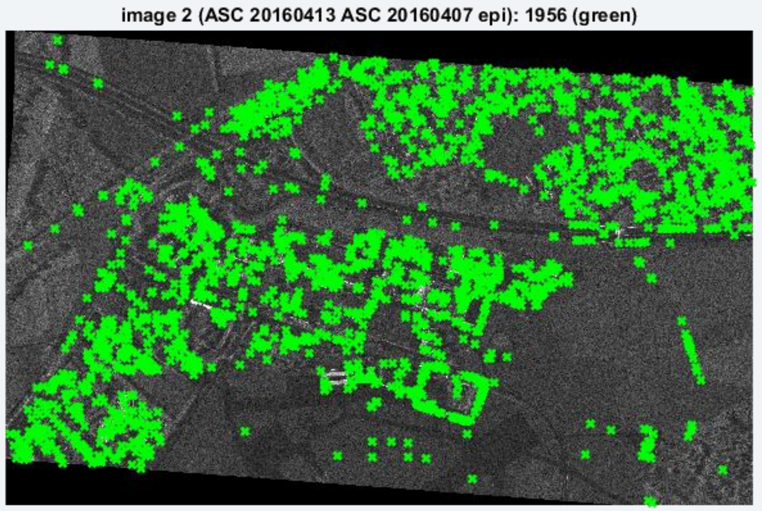
Epipolar Image Rectification and Point Matching

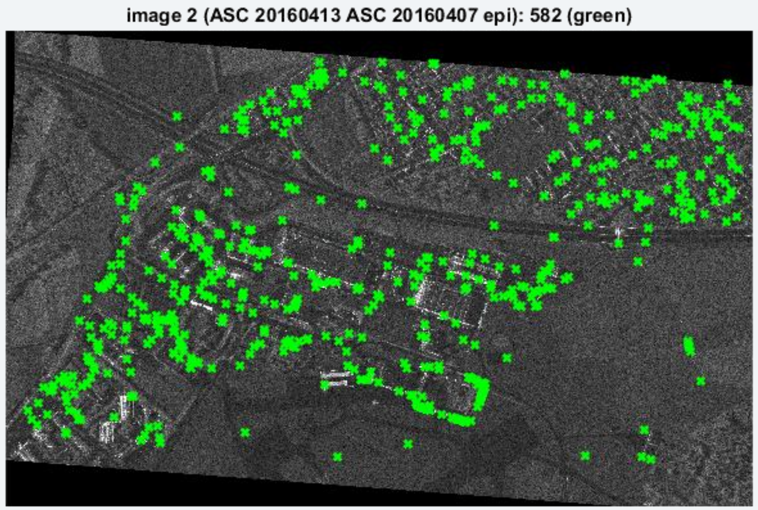




Epipolar transformed Images

Finding Corresponding Points via Weighted KNN-Matching





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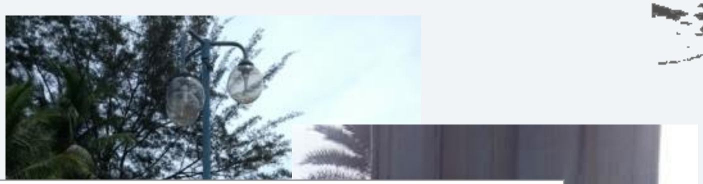
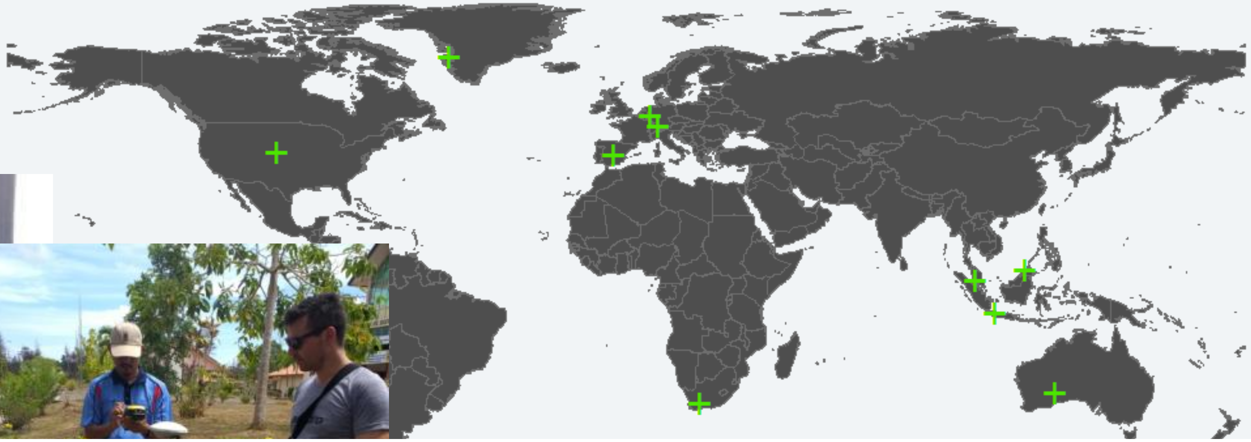
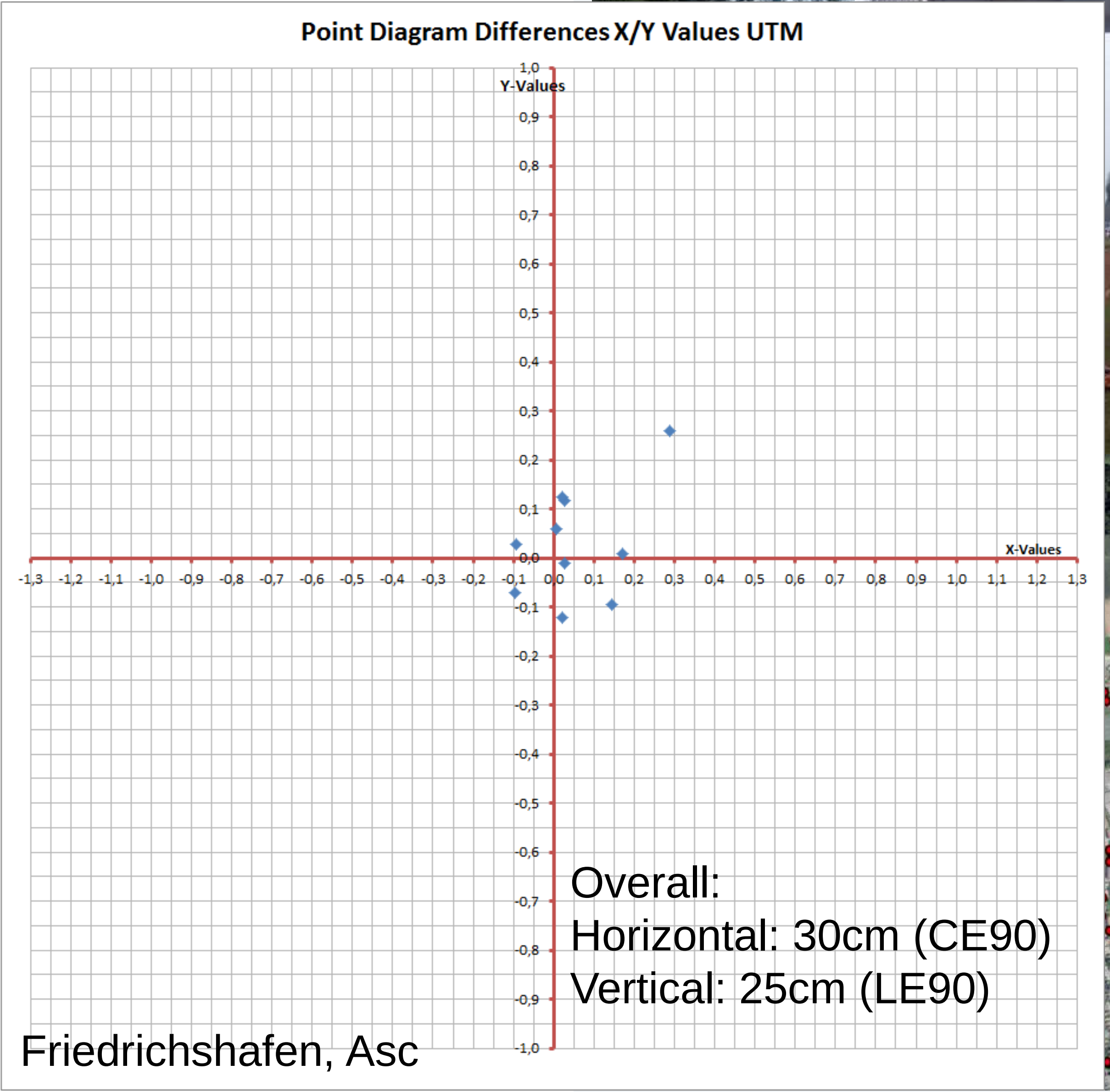
Validation

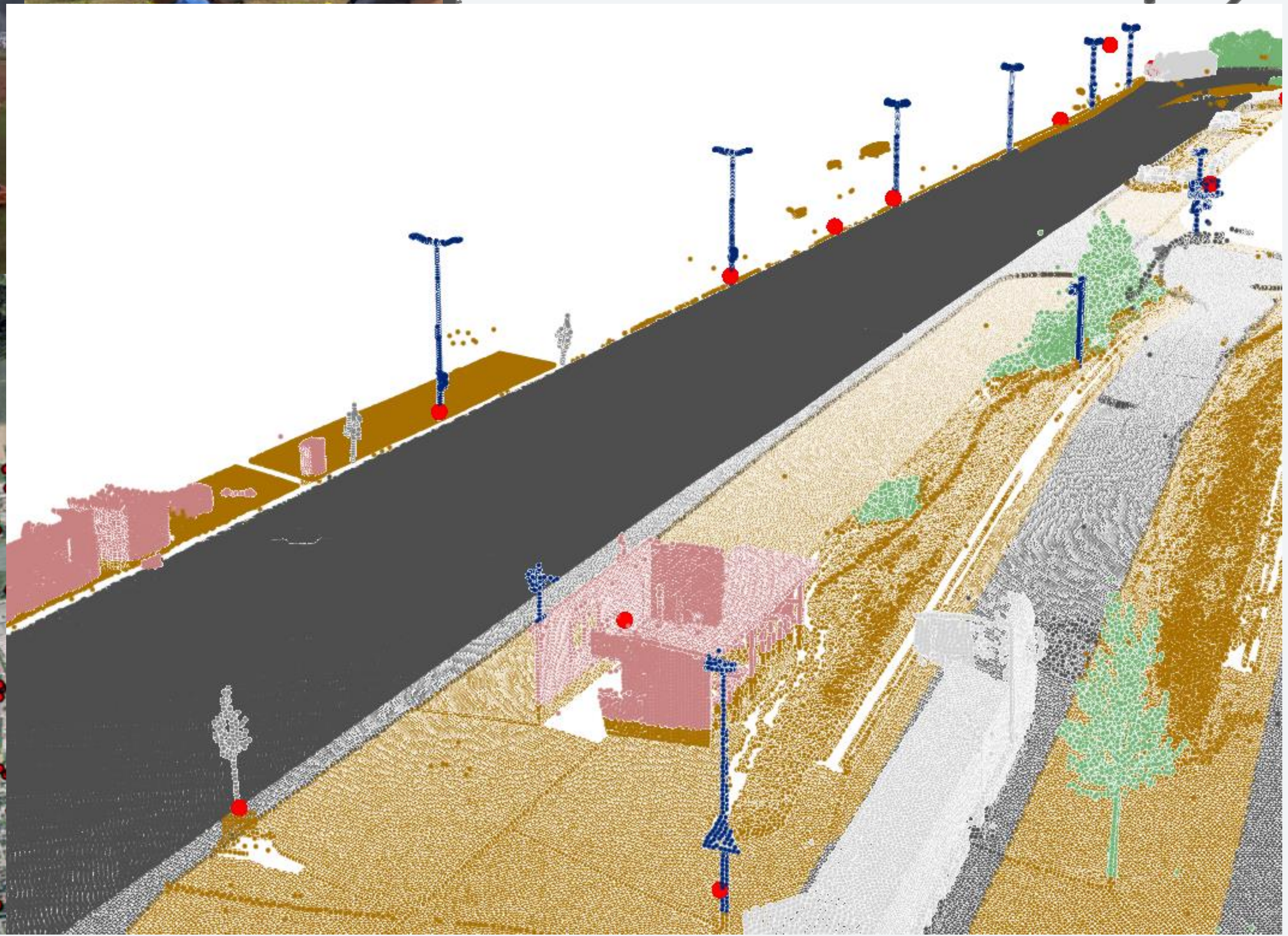






Overall:
Horizontal: 30cm (CE90)
Vertical: 25cm (LE90)

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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