Module 3108: Urban Areas

Urban DSM

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SAREDU Remote Sensing Education Initiative

Content of Module Urban Areas

- Introduction (Module #3104)
- Urban footprints (Module #3105)
- Urban land cover / land cover change classification (Module #3106)
- Extraction of urban objects (Module #3107)
- Urban DSM (Module #3108)
- Synergy of optical remote sensing and SAR (Module #3109)
- Tutorial – Urban footprint mapping utilizing Sentinel – 1 data (Module #3110)

Educational Objectives

- Understand the importance of urban DSM mapping
- Understand SAR features relevant for urban DSMs
- Understand the different approaches established in urban DSM mapping from SAR data

Requirements

- You know and understand the mathematical and physical basics
  (Module ID 1100: Mathematics & physics)
- You know and understand SAR technology
  (Module ID 1300: SAR basics)
- You know and understand main SAR processing steps
  (Module ID 1200: Data processing)
- You know and understand main image interpretation techniques
  (Module ID 2100: Image processing)
- You know and understand urban areas and their varieties
  (Module ID 3104: Urban Introduction)

Structure

- Introduction
- Urban DSM mapping with SAR

Structure

- Introduction
- Urban DSM mapping with SAR

Introduction

- Urban DSM = Digital Surface Model of settlements
- DSM describes the elevation above sea level of the ground and all features on it
- DTM (Digital Terrain Model) describes the ground elevation above sea level
- Normalized DSM can be derived by subtraction of DTM from DSM → contains only heights of objects on the surface

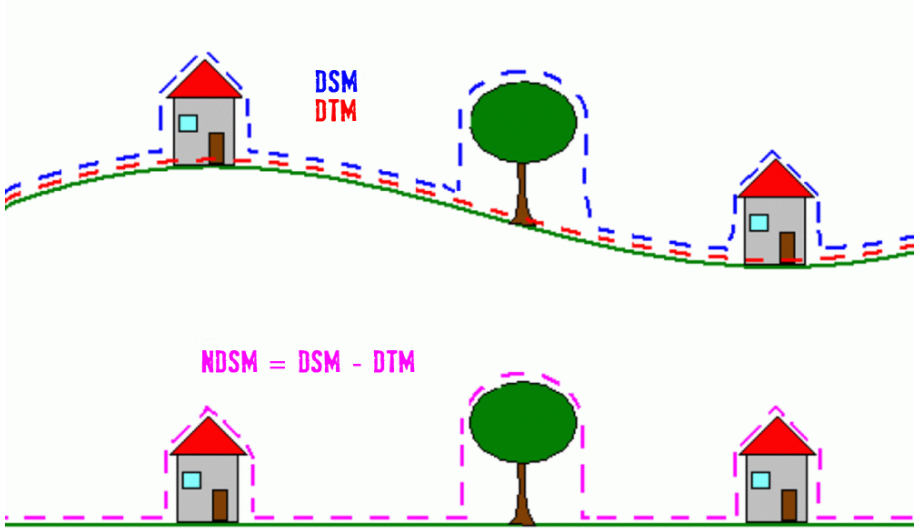

Fig.: DSM, DTM, and the calculation of an NDSM (http://www.stadtentwicklung.berlin.de/umwelt/umweltatlas/ed610_03.htm)

Importance of urban DSMs

- DSMs of urban areas are important for city planning, companies, and research
  - Quantification of solar insolation for photovoltaics
  - Telecommunication
  - Estate agencies
  - Transport
  - Tourism
  - Air stream analyses
  - Flood models, noise models
  - Damage detection
  - 3D visualization
  - Improved urban area mapping

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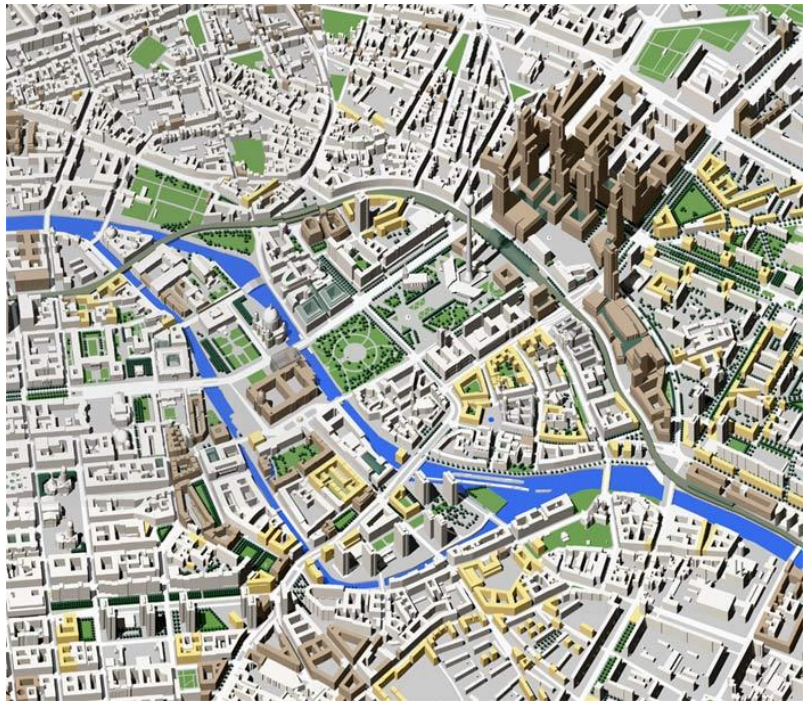


Fig.: City model
(http://www.veps3d.org/site/249.asp)

Derivation of urban DSMs

Optical data

- Derivation based on matching stereo image pairs or analysis of shadows of objects on the surface for height estimation

LiDAR (Light detection and ranging)

- Precise DSM generation based on pulsed lasers measuring the distance to objects by time-of-flight

SAR

- Commonly phase information of complex SAR data under slightly different incidence angles are used (SAR interferometry)

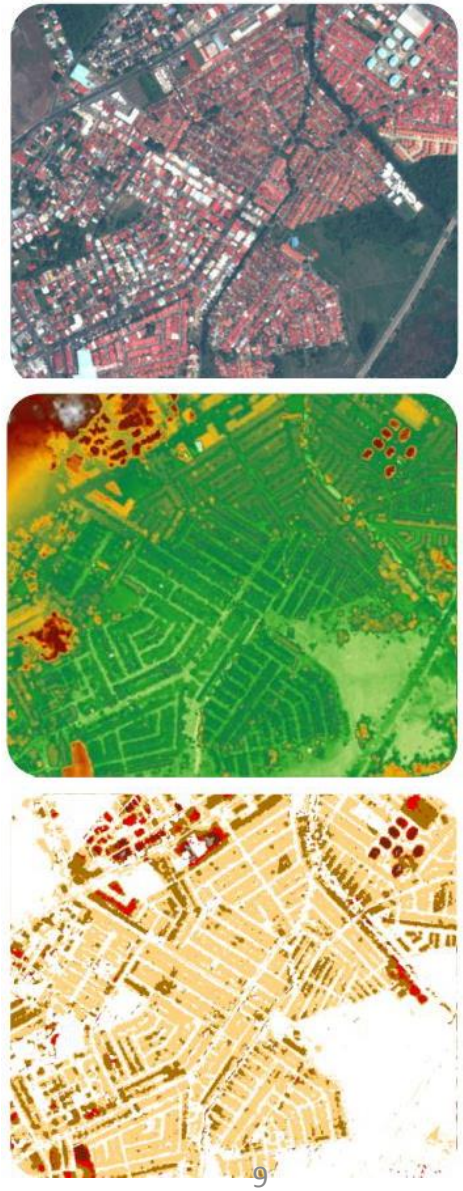


Fig.: Satellite image, DSM, and nDSM (Poli & Caravaggi 2012)

Structure

- Introduction
- Urban DSM mapping with SAR

DSM derivation with interferometric SAR data

Basics

- Challenge: accurate height and shape for each object of urban area
- Interferometry is capable to capture 3D features of urban objects
- Interferogram: phase difference of two SAR scenes with slightly different incidence angles (see Module ID 2201: SAR interferometry basics)

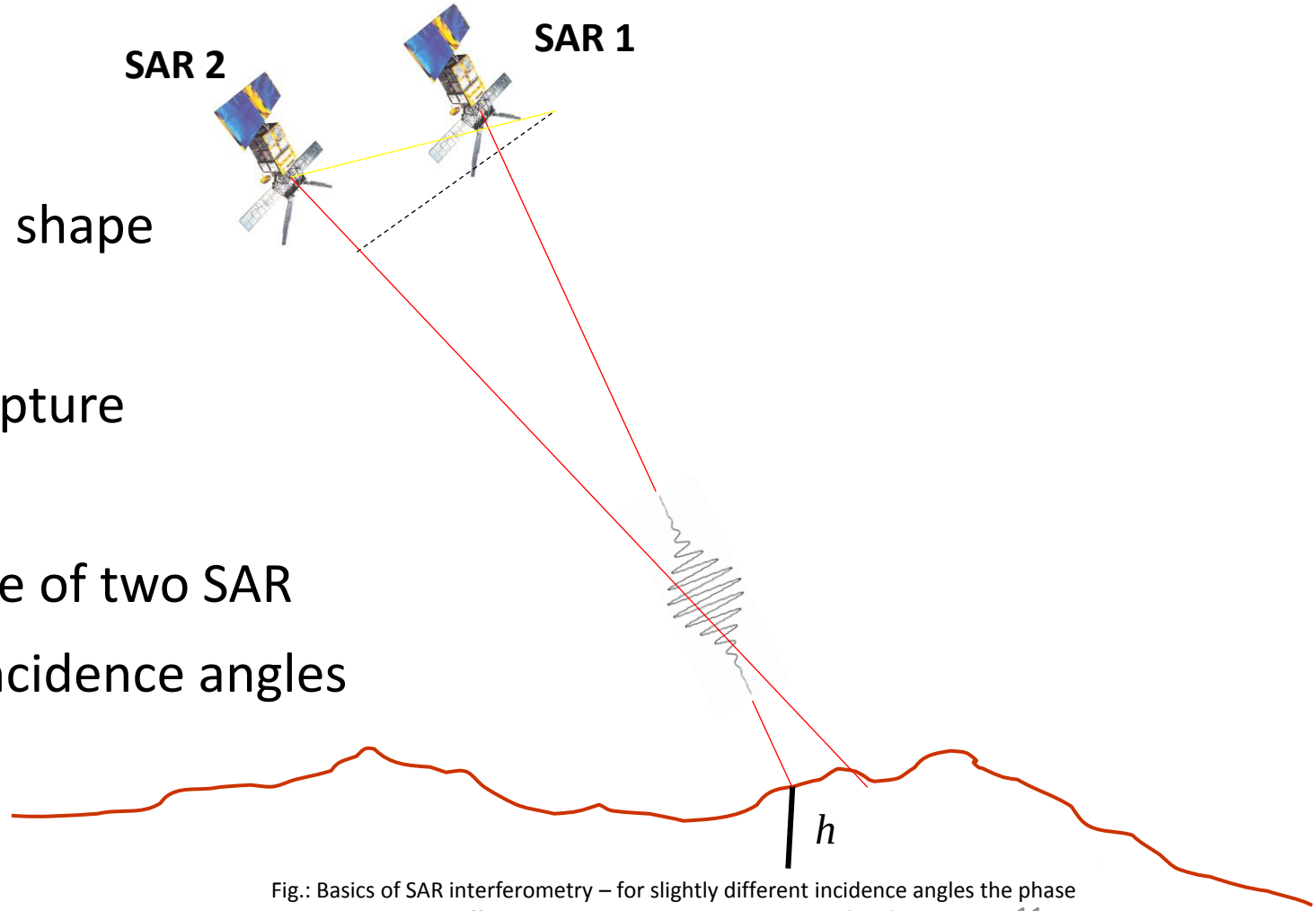


Fig.: Basics of SAR interferometry – for slightly different incidence angles the phase difference is linked to scene topography (DLR)

DSM derivation with interferometric SAR data

Shape-from-shadow

Building footprints and heights estimated from shadows in amplitude images

- Shadow size linked to object height and incidence angle
- 2 or more SAR images (from different directions) are utilized to detect shadows
  → shape of buildings is described
- Building height either estimated from shadow length or from interferogram (where shadows help to detect building footprints)
- Method fails for dense urban areas (layover and shadows occlude building parts)

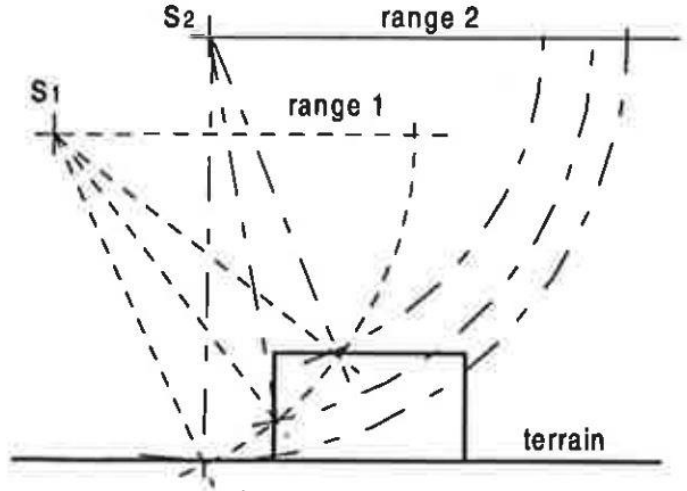


Fig.: Layover and interferometry – range distance to sensor 1 is equal for the three selected points, but varys for sensor 2 for the same points (Bolter & Leberl 2000)

DSM derivation with interferometric SAR data

Approximation by planar surfaces

Filtering of interferograms to detect planar surfaces

- Segmentation of interferograms
- Line segments are clustered to planes by iterative region growing
- Resulting planes are approximated with horizontal planes
  → simulation of building roofs
- Accurate results only for large / isolated buildings

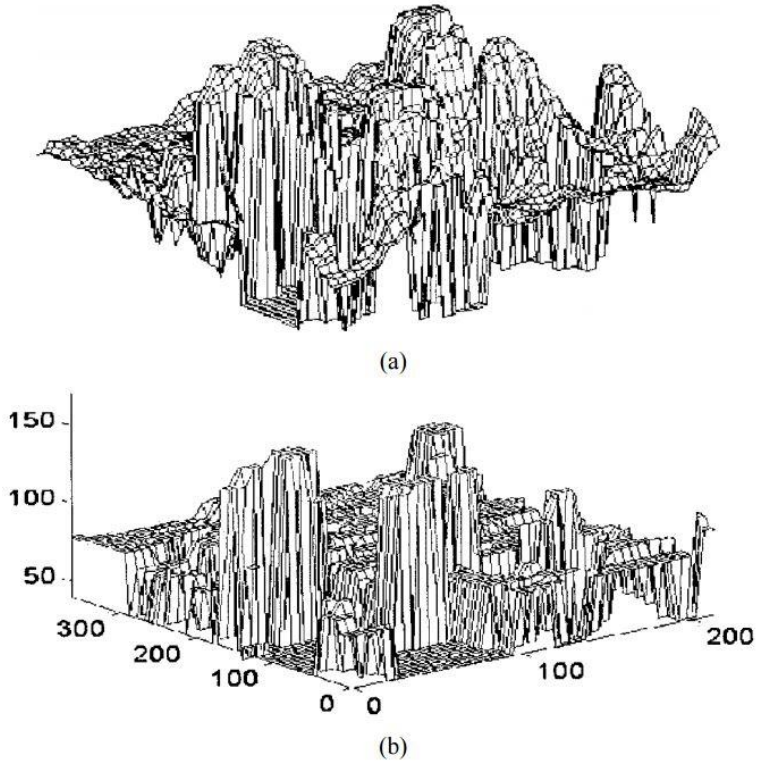


Fig.: Raw 3-D surface extracted from interferogram (top) and approximation by planar surfaces (bottom) with noise reduction, structure recognition and segmentation (Gamba et al. 2000)

DSM derivation with interferometric SAR data

Stochastic geometry

Shapes and position of buildings are modeled with unique building model

- Optimization of model parameters by amplitude, coherence, and interferometric phase
- Thorough object-oriented modelling helps to cope with noise
- Buildings modeled as parallelepipeds with gabled roof
- Method is limited to certain building shapes in order to reduce computation time

DSM derivation with interferometric SAR data

Interferogram filtering and 3D estimation

DSM estimation based on segmentation and classification

- Segmentation of the image to derive building footprints
- Interferometric heights used to determine ground altitude and matched with previously detected features
- Contextual information (such as road orientation and orthogonality of walls) utilized for corrections
- Modelling of different roof types
- Very flexible approach

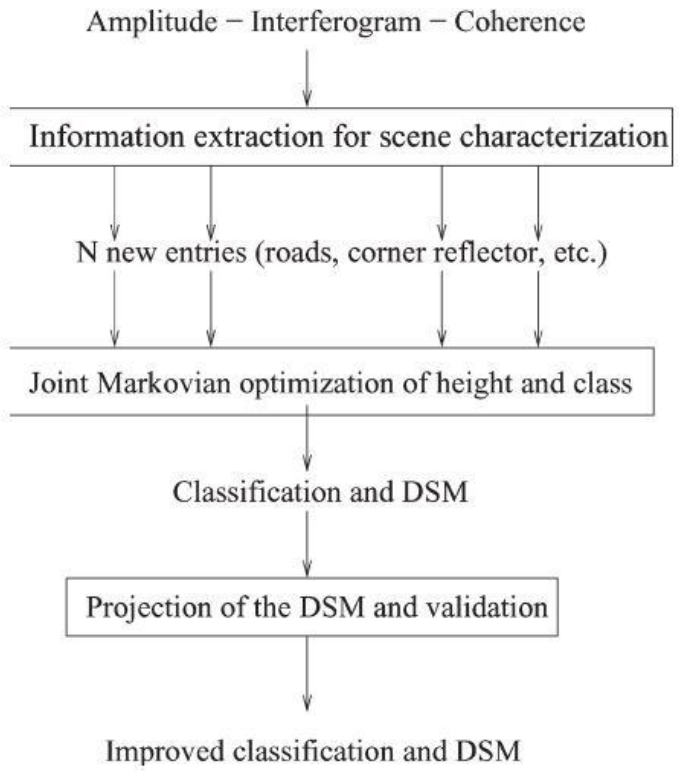


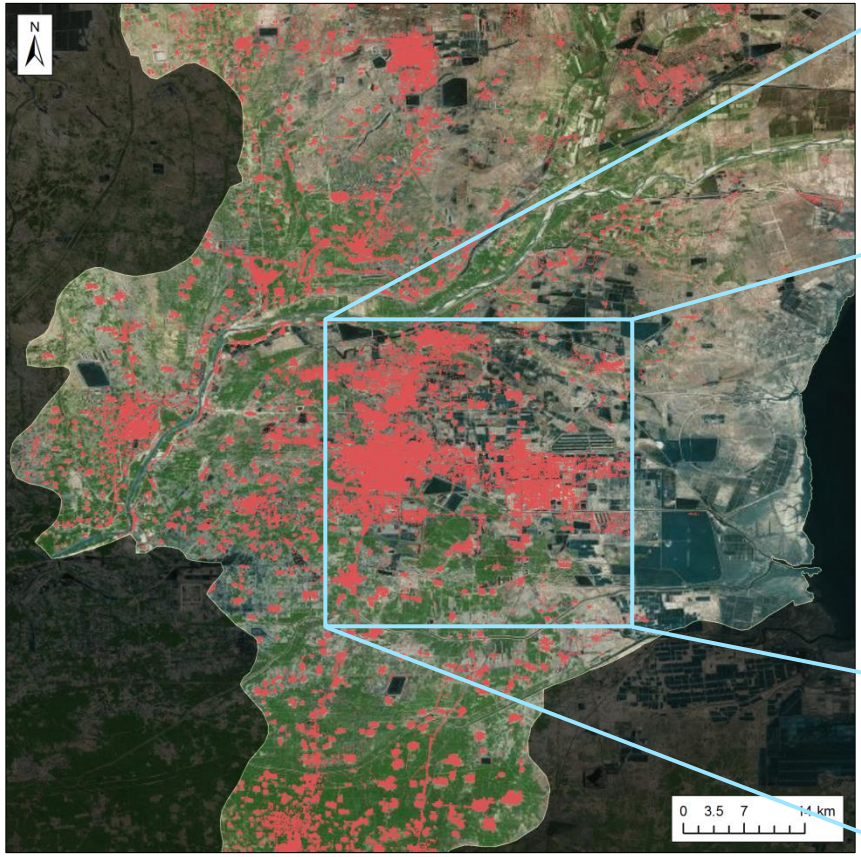
Fig.: Processing scheme for DSM derivation, height estimation and classification are jointly linked (Tison et al. 2007)

DSM derivation with interferometric SAR data

Unsupervised height derivation of built-up areas

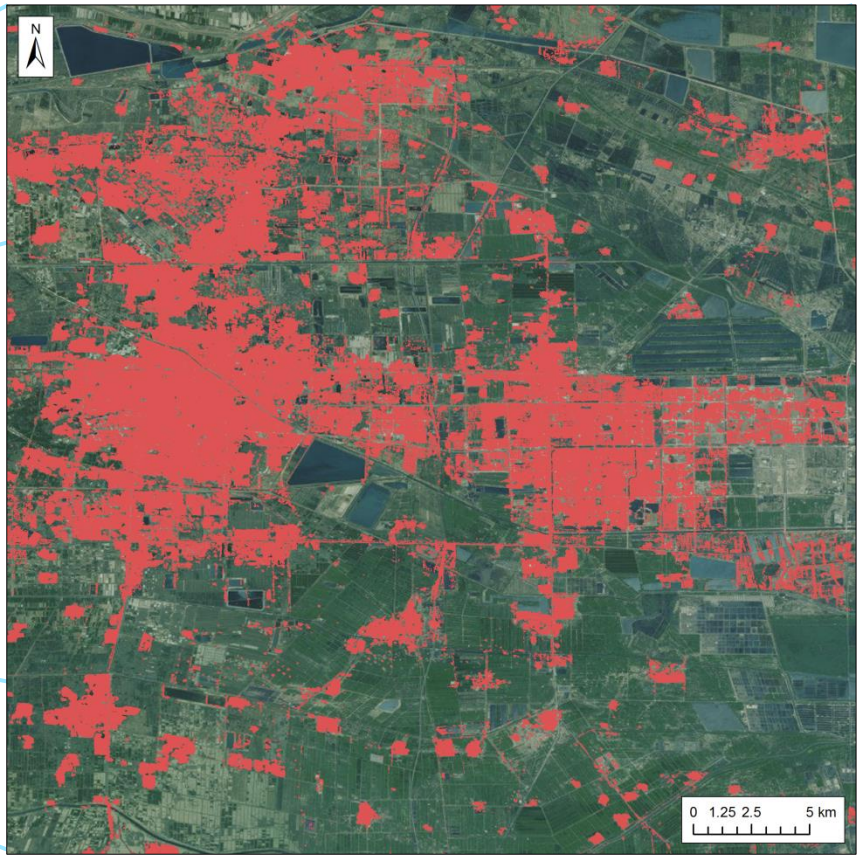
TanDEM-X DEM and Global Urban Footprint (see Module 3702) used for DEM mapping

Yellow River Delta



GUF (DLR)

Dongying



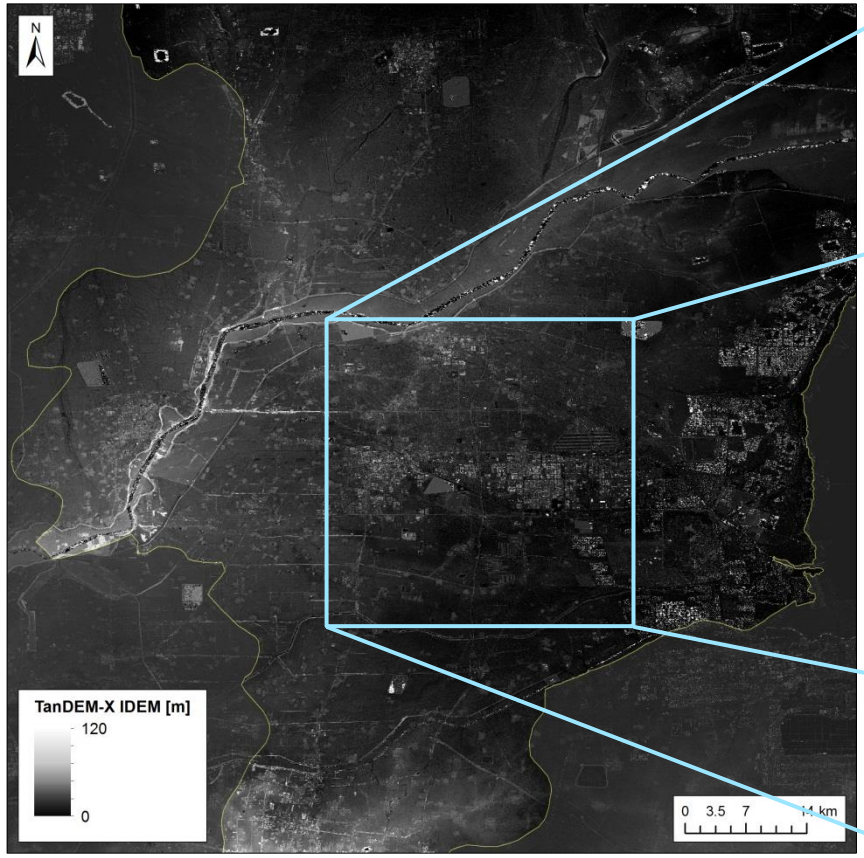
GUF (DLR)

DSM derivation with interferometric SAR data

Unsupervised height derivation of built-up areas

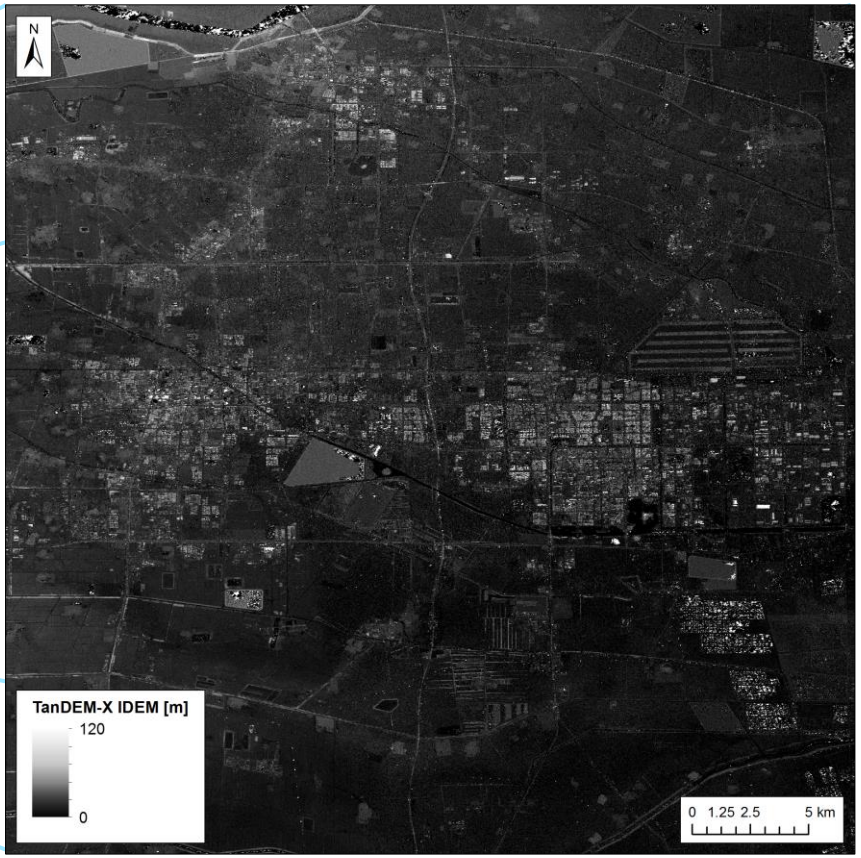
- Relative change in elevation of pixels in contrast to neighbor pixels used for detection of objects on the ground

Yellow River Delta



TanDEM-X IDEM (DLR)

Dongying



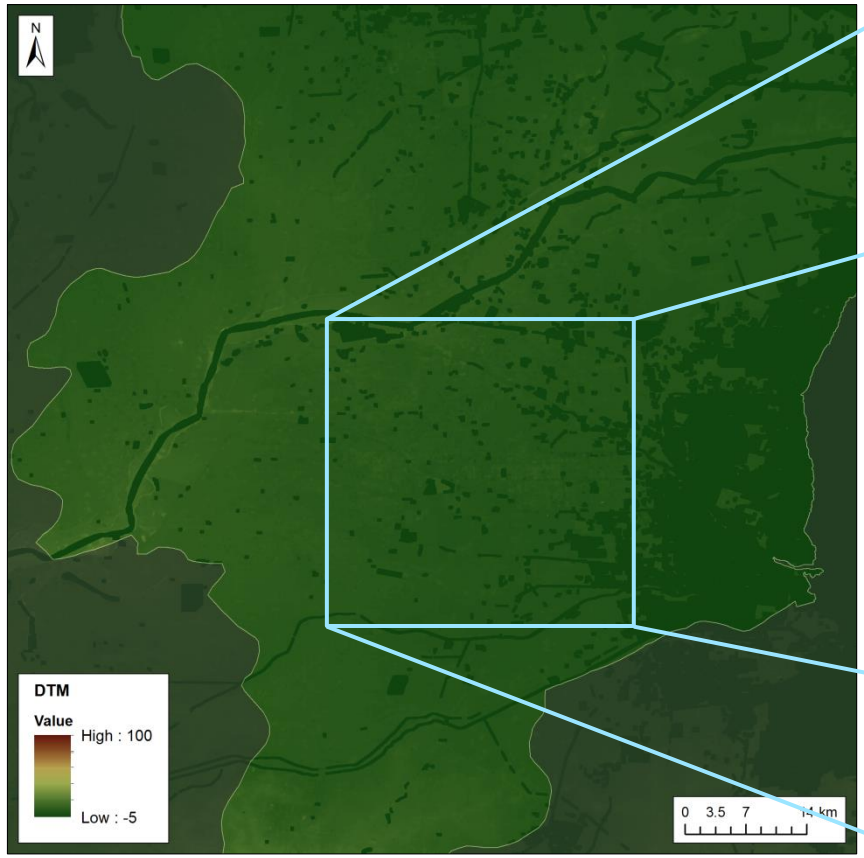
TanDEM-X IDEM (DLR)

DSM derivation with interferometric SAR data

Unsupervised height derivation of built-up areas

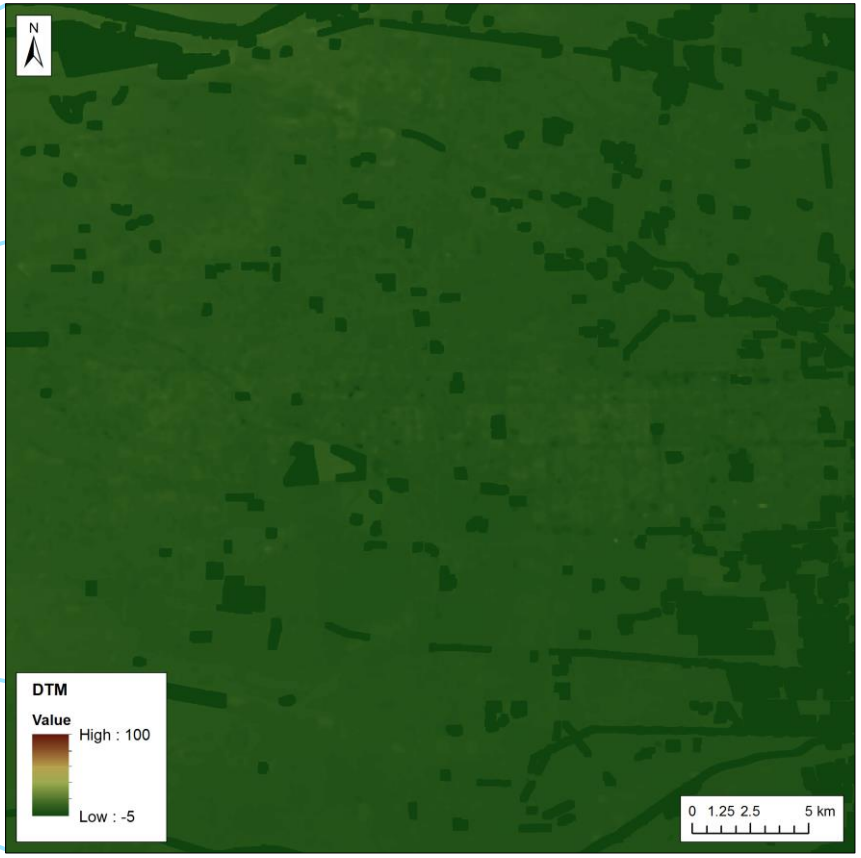
- Delineation of ground points by excluding the prior extracted objects
- Ground pixels used to generate DTM with natural neighbors interpolation

Yellow River Delta



estimated DTM (DLR)

Dongying



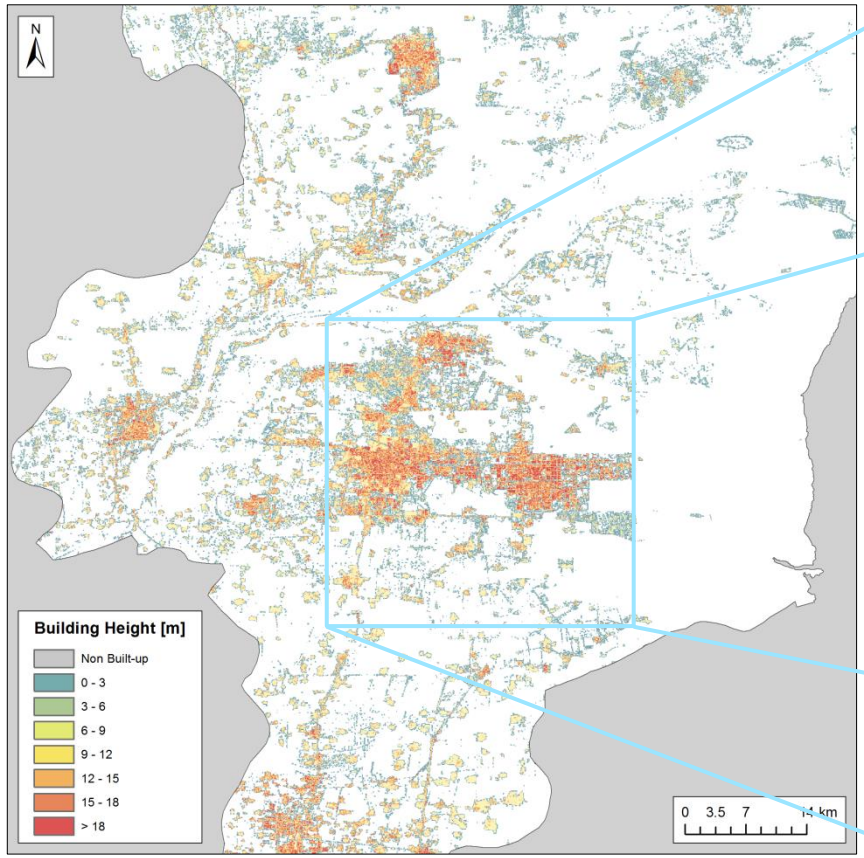
estimated DTM (DLR)

DSM derivation with interferometric SAR data

Unsupervised height derivation of built-up areas

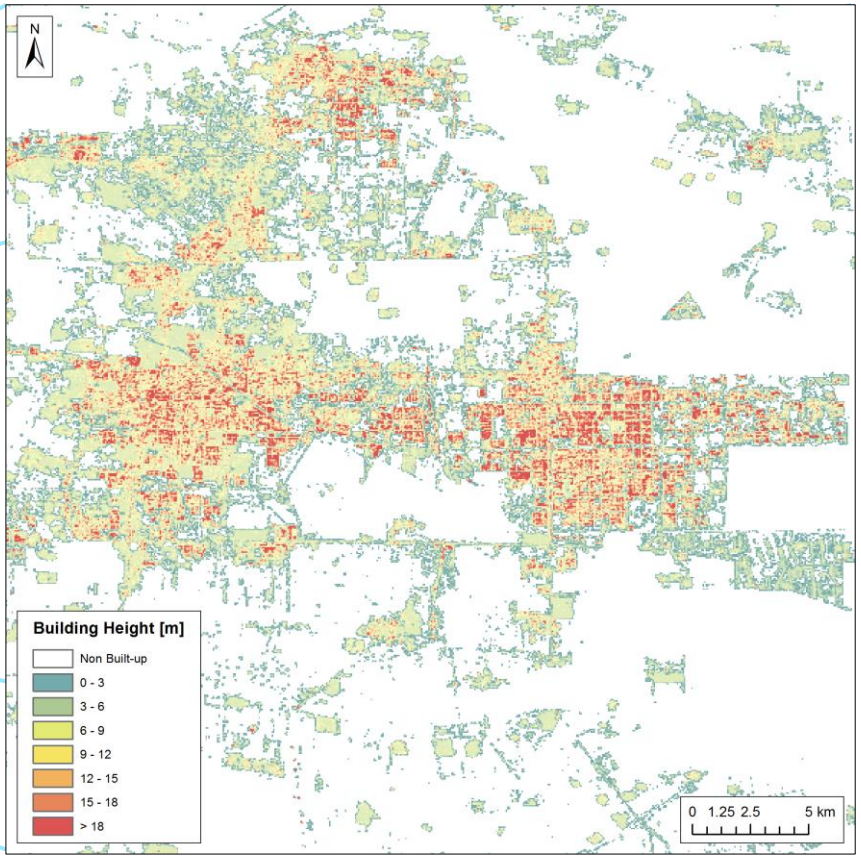
- Building heights derived by subtraction of DTM from original DEM for pixels marked as urban in Global Urban Footprint

Yellow River Delta



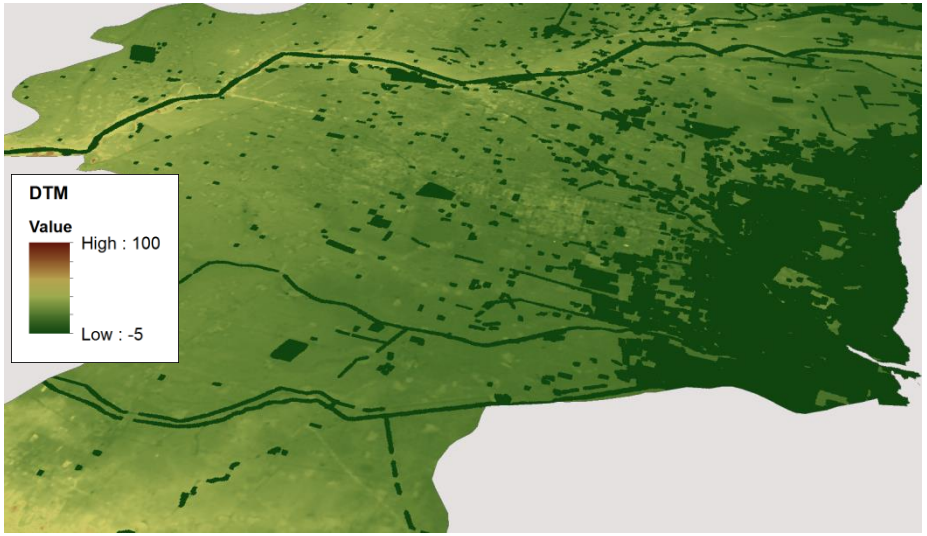
estimated building height (DLR)

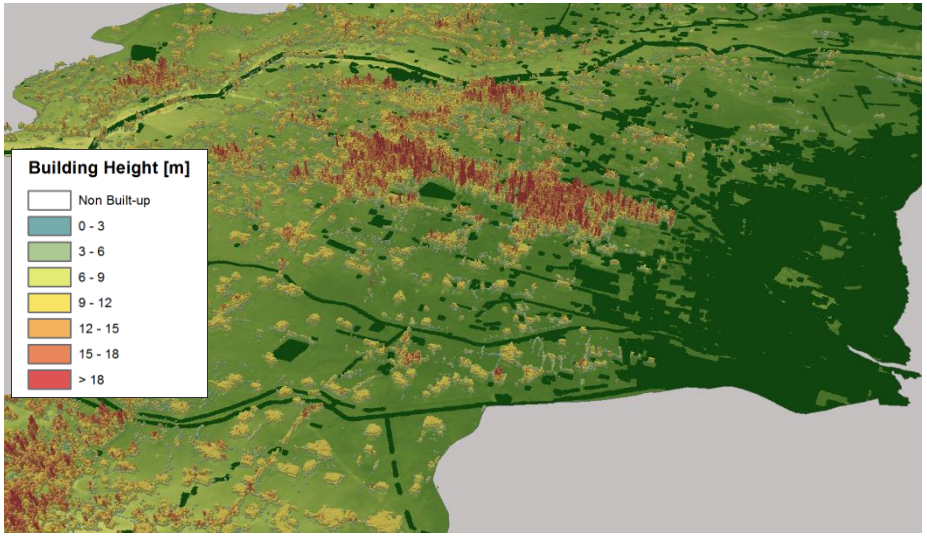
Dongying



estimated building height (DLR)

DSM derivation with interferometric SAR data





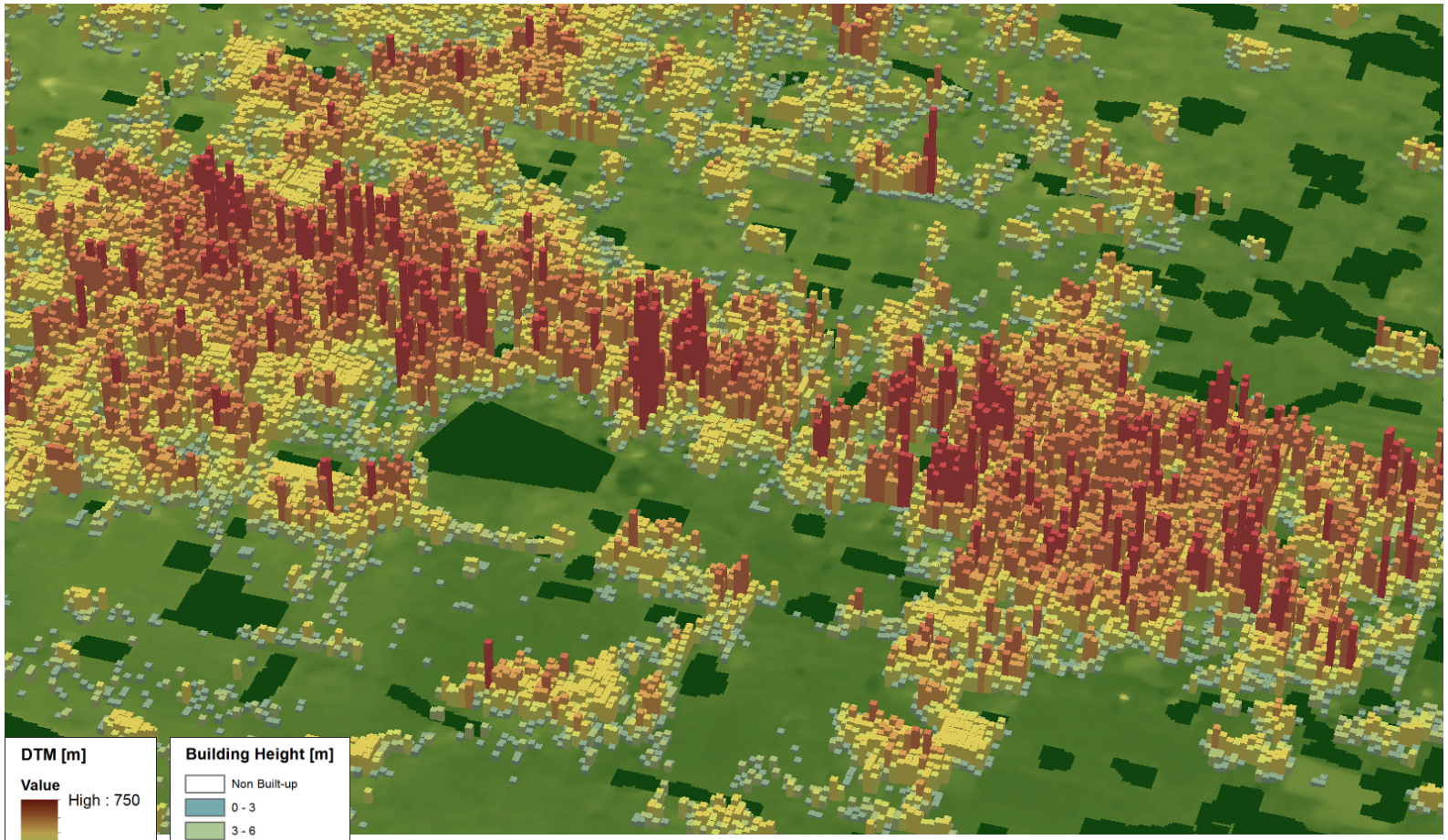


Fig.: DTM (left top), building heights (left bottom), and detailed view of derived buiding heights (right) for Dongying, China (DLR)

References and ***further reading***

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