Forest Canopy Mapping from TanDEM-X Interferometry and High-Resolution Lidar DEM

PROCESSING DESCRIPTION, GEOCODING ACCURACY, AND GEOMETRIC FIDELITY ASSESSMENT

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OUTLINE

- Study goal
- Lidar & DEM data
- SAR data
- Interferometric processing
- First evaluation of the results
- Conclusions

ABBREVIATIONS ETC.

In the following:

DEM = **ground** height map

DCM = forest **canopy** height map

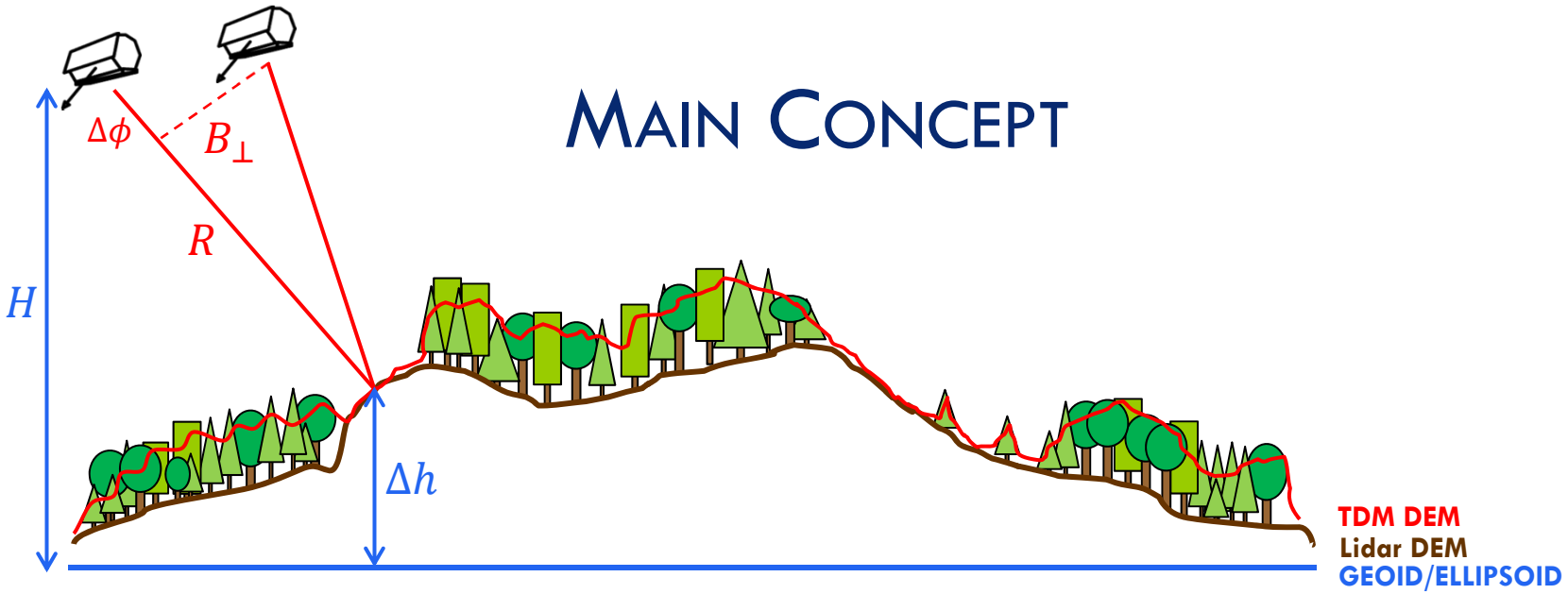
DSM = **any** height map

TSX = TerraSAR-X satellite

TDX = TanDEM-X satellite

TDM = TanDEM-X interferometer system

MAIN CONCEPT



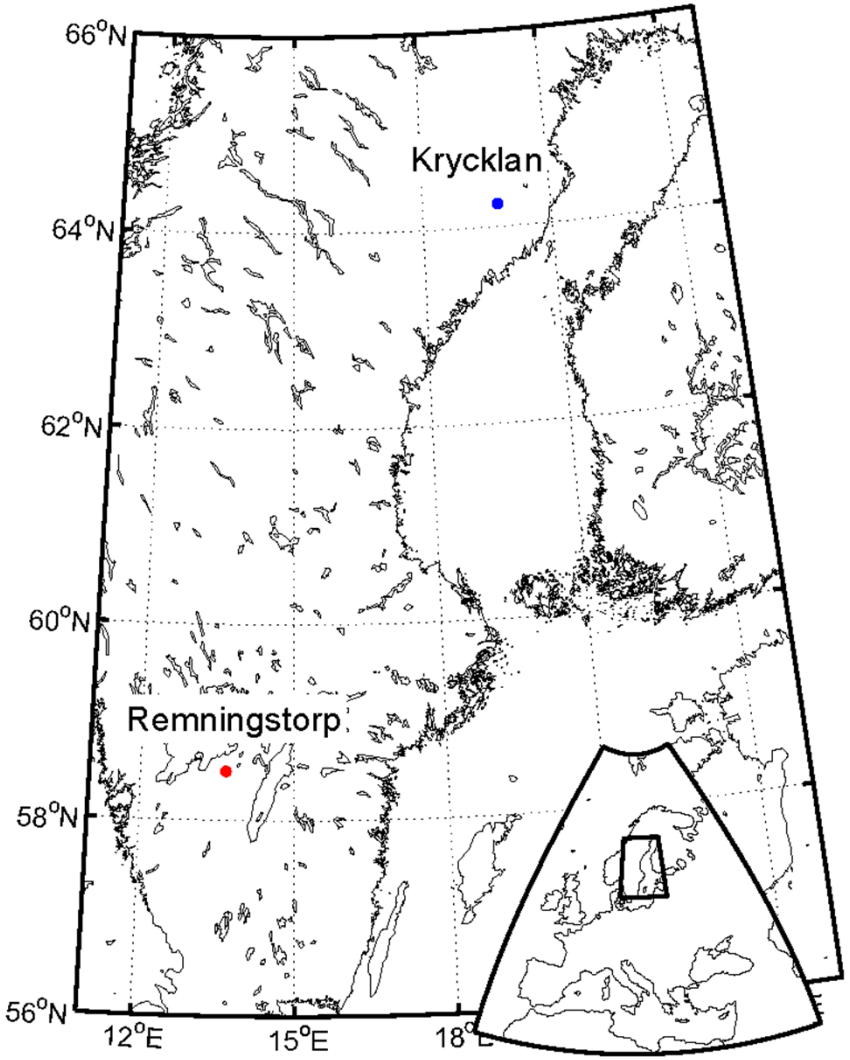
TDM DCM = TDM phase height – Lidar DEM

Compare to:

Lidar DCM = Lidar DSM – Lidar DEM

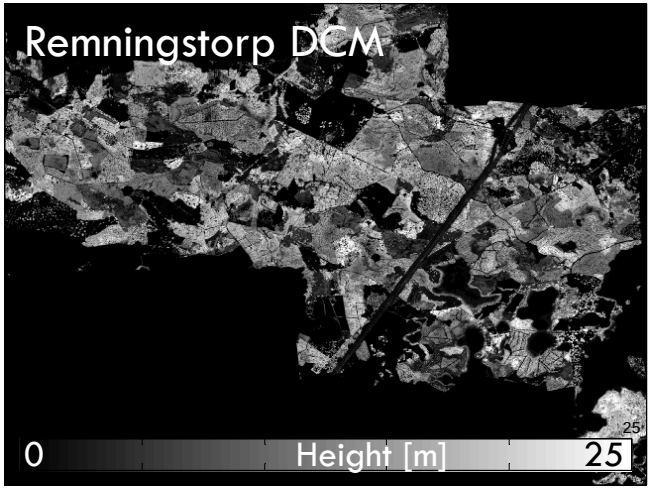
TEST SITES

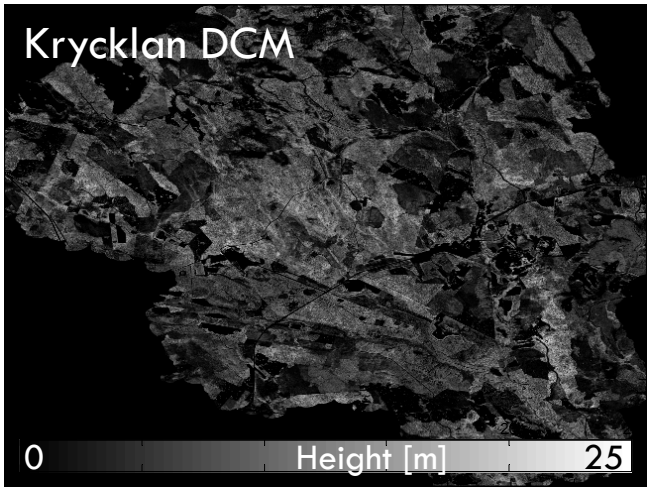
- Remningstorp:
  - Southern Sweden
  - Hemi-boreal forest (spruce, pine, birch)
  - Flat terrain
- Krycklan:
  - Northern Sweden
  - Boreal forest (spruce, pine)
  - Hilly terrain



LIDAR DATA

- Airborne Topeye system
  - Remningstorp: August 2010 (BioSAR 2010)
  - Krycklan: August 2008 (BioSAR 2008)
- Hi-res lidar DCM
  - pixel size: 0.5 m x 0.5 m
- Maps with vegetation ratios, height percentiles, etc., derived biomass maps
  - pixel size: 10 m x 10 m
- Stand delineations with forest, open fields, marshes, pastures, etc.





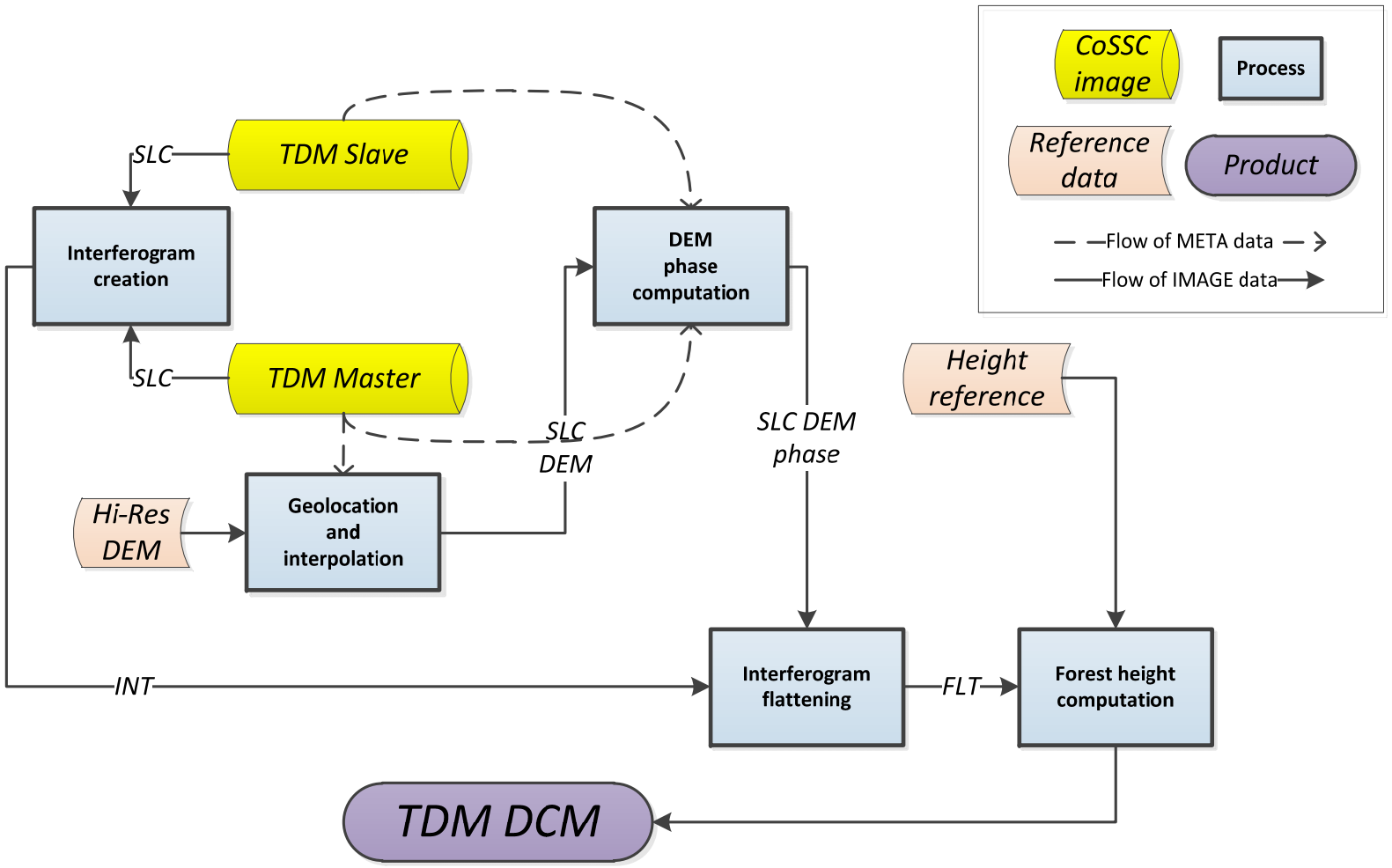
DEM DATA

- Acquired by Swedish Land Survey with airborne lidar
- Ongoing nationwide campaign (to be finished by 2015)
- Grid: 2 m x 2 m
- Mean error: <0.5 m

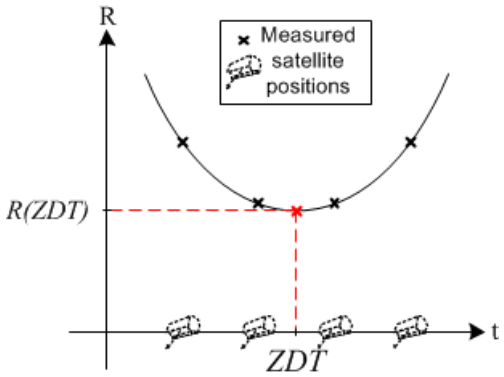
SAR DATA

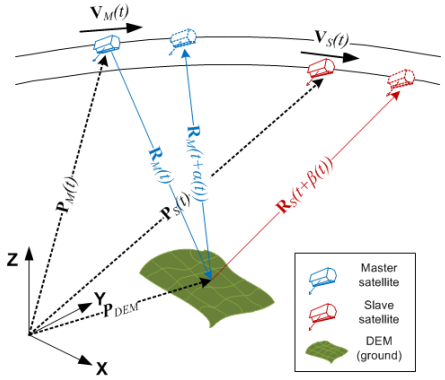
- Remningstorp & Krycklan are supersites
  → large amounts of data available
  - 50+ acquisitions in Re
  - 100+ acquisitions in Kr
- Primary focus:
  - Bistatic mode data
  - Co-polarized (mostly VV)
  - Stripmap mode

INTERFEROMETRIC PROCESSING SUMMARY



INTERFEROMETRIC PROCESSING SUMMARY





1) Find R & ZDT for master satellite and each DEM pixel → geocoding LUT
   Account for dry tropospheric delay
2) Find true monostatic and bistatic R for each DEM pixel → DEM interferogram
   Account for signal propagation
3) Flatten interferogram by conjugate multiplication with DEM interferogram
   Apply complex multilooking after flattening prior to phase retrieval
4) Compute HOA map from satellite positions and DEM
5) Create DCM from phase as:

$$h_{DCM} = h_0 + \phi_{FLT} \cdot \frac{HOA}{2\pi}$$

Ground reference points used to determine offset

GEOCODING ACCURACY (RE)

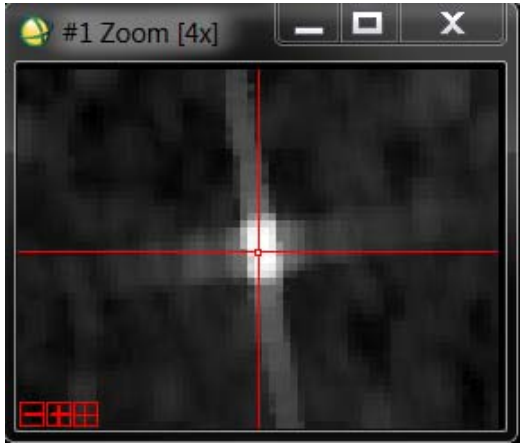
- Remningstorp trihedral
  - Top image:

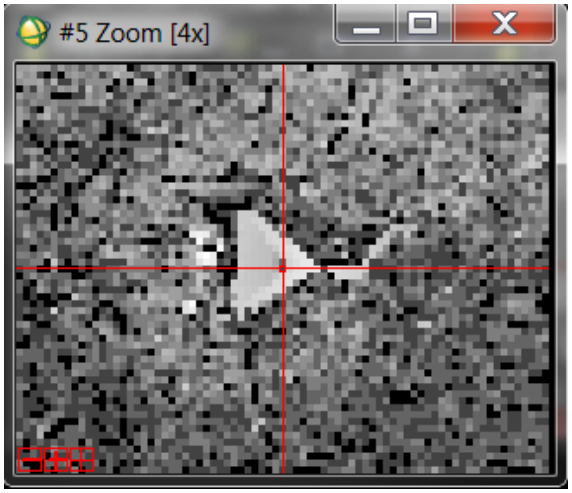
TDX intensity, VV, 20110604,
pixel size: 2 m x 2 m

  - Bottom image:

Lidar height, 20100829,
pixel size: 0.5 m x 0.5 m

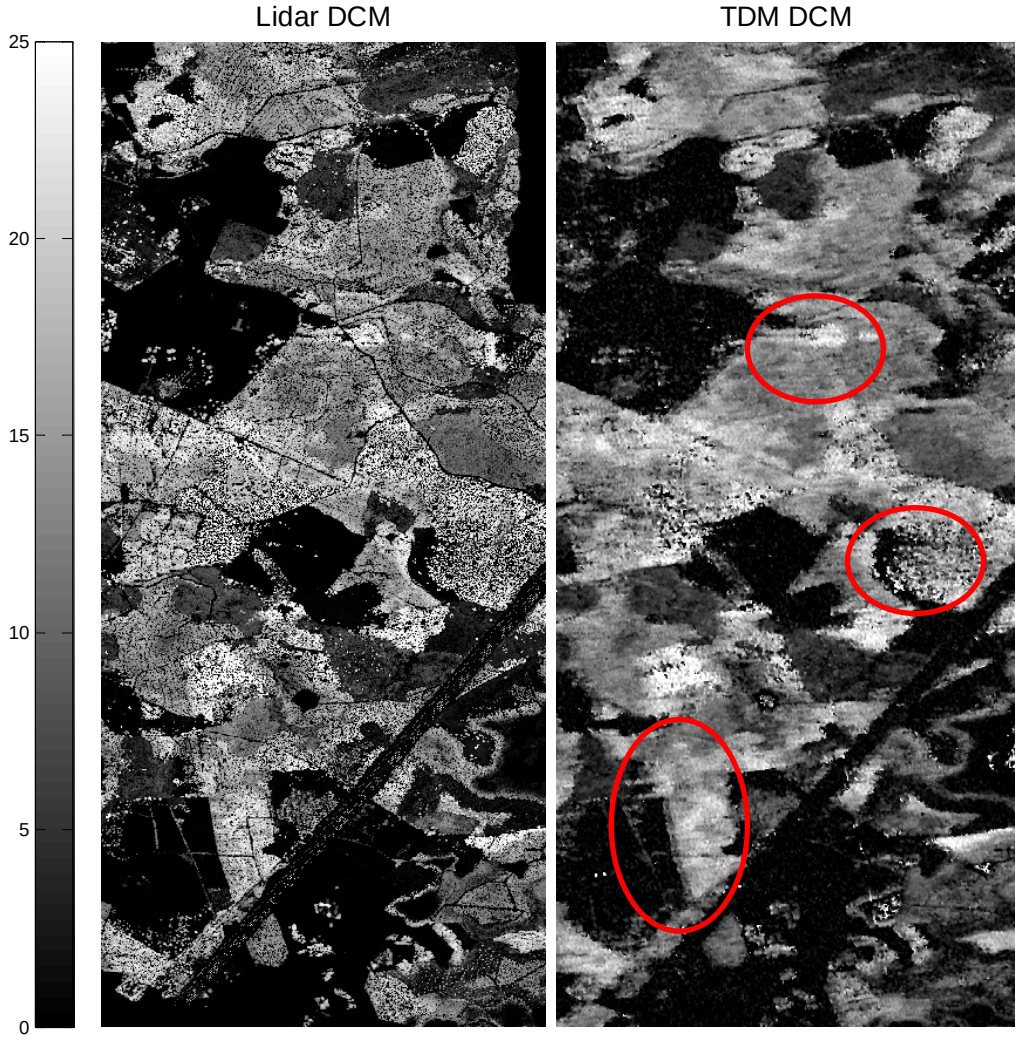
- Relative accuracy: better than 2 m
- No trihedrals in Kr, other verification methods required



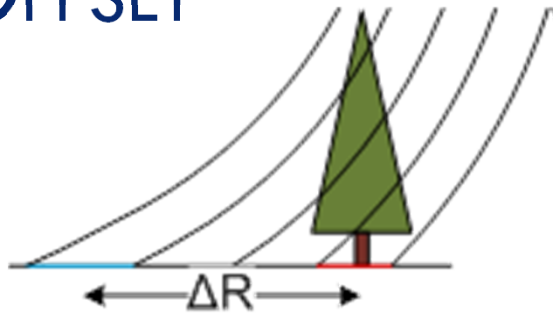


GEOMETRIC FIDELITY

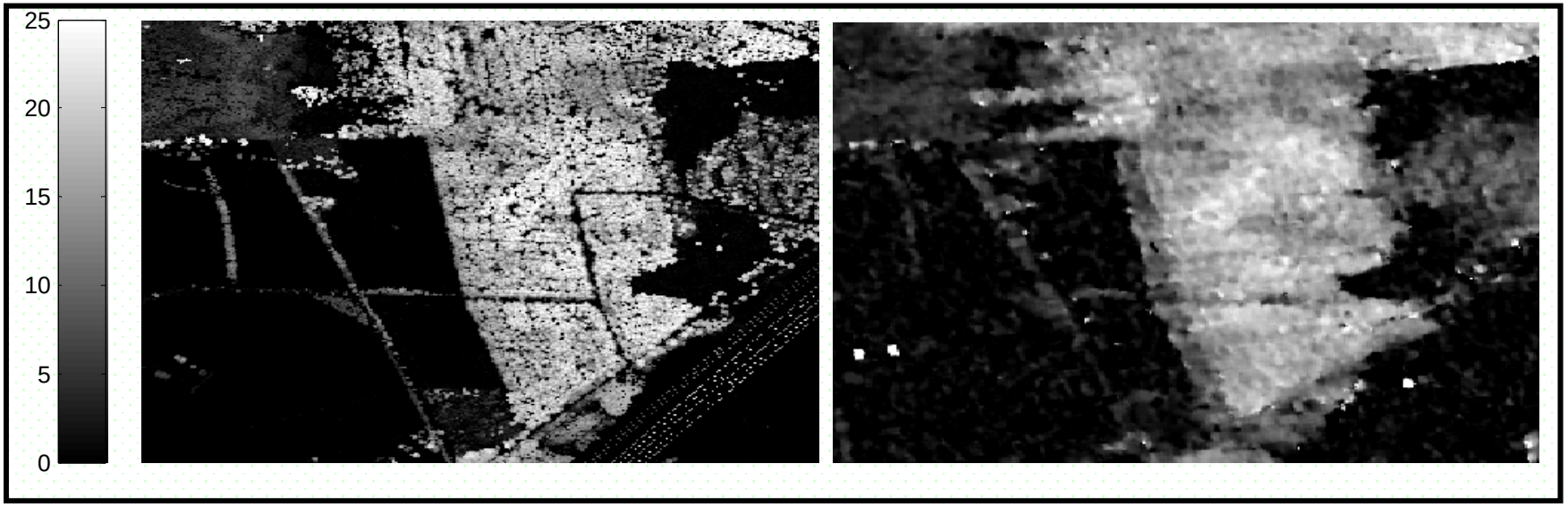
- Good general agreement with favourable baselines
- However:
  - Edge effects & range offset
  - Noise (phase noise & speckle effect)
  - Lower resolution
  - Incidence angle dependence



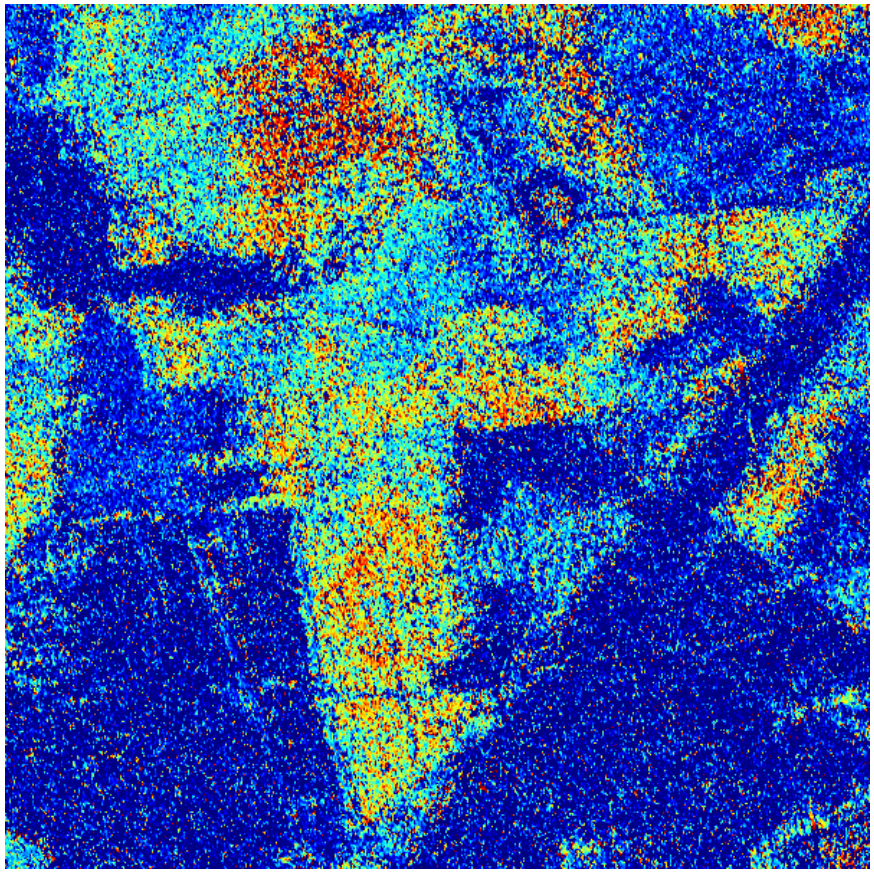
EDGE EFFECTS & RANGE OFFSET



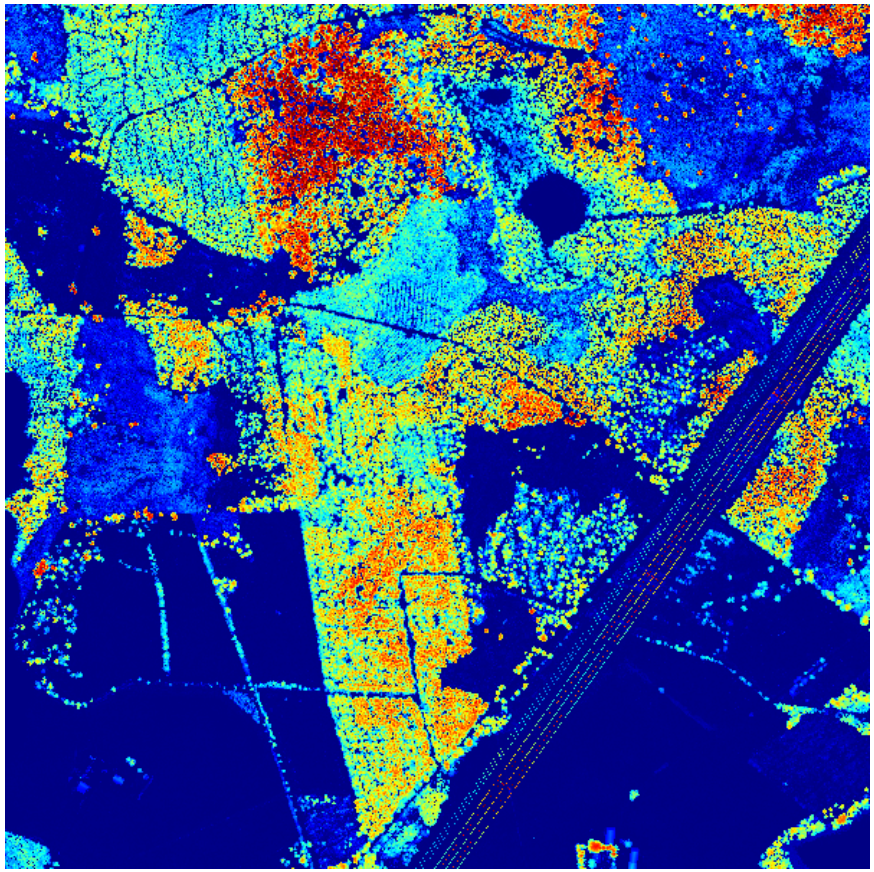
- Height offset from DEM
  → range offset
- Angle of incidence and local TDM height
  → first order correction through interpolation
- Corrects geometric agreement but destroys some patterns



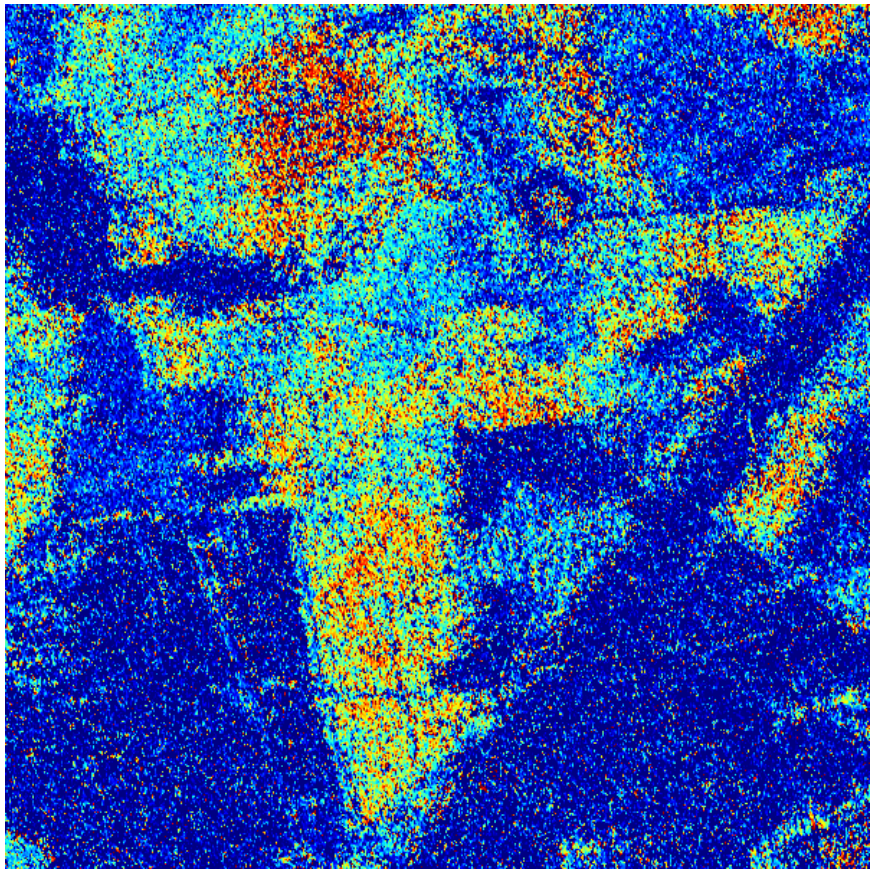
Geometric Correction



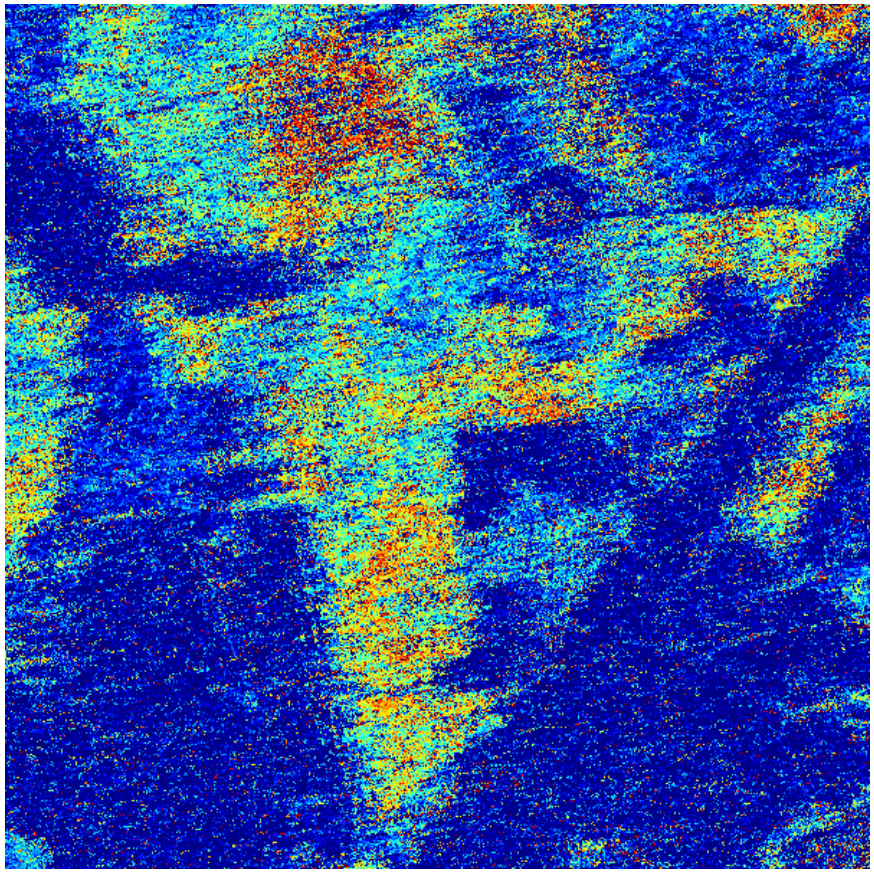
Geometric Correction



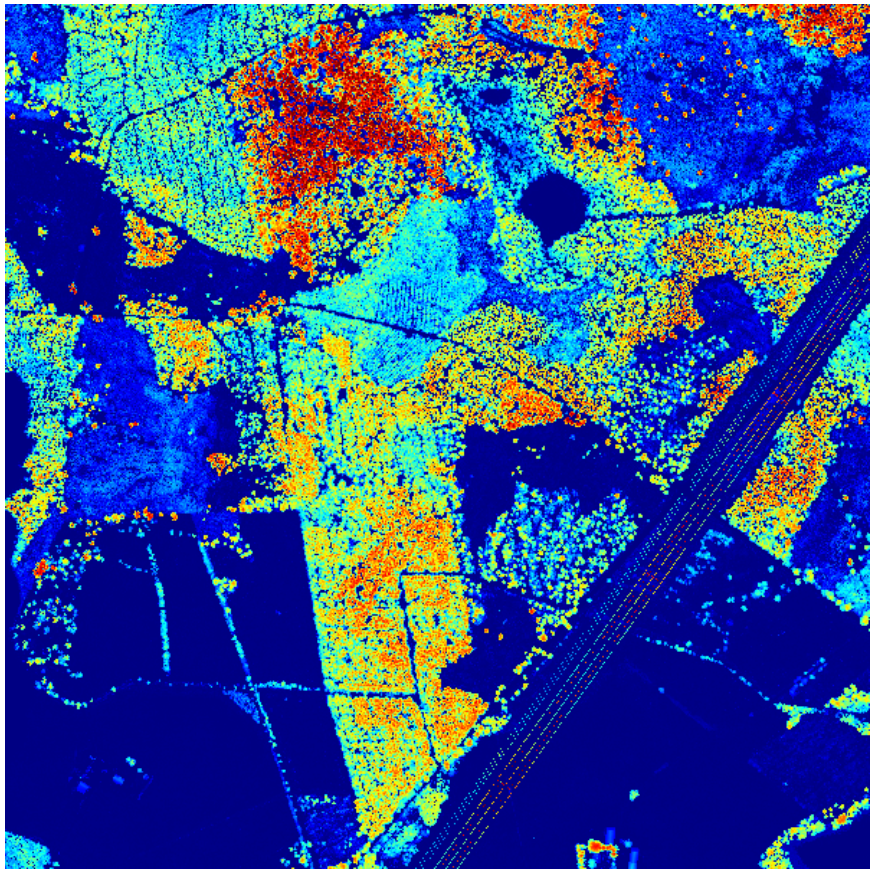
Geometric Correction



Geometric Correction

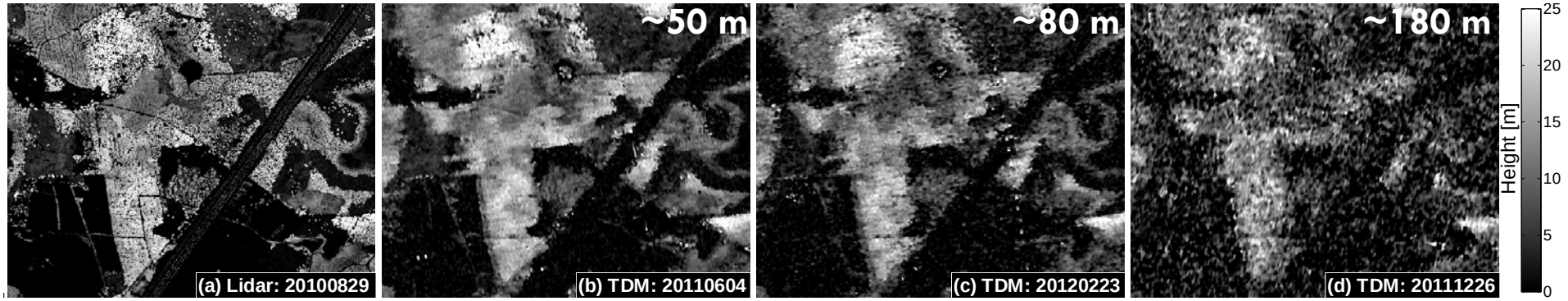


Geometric Correction

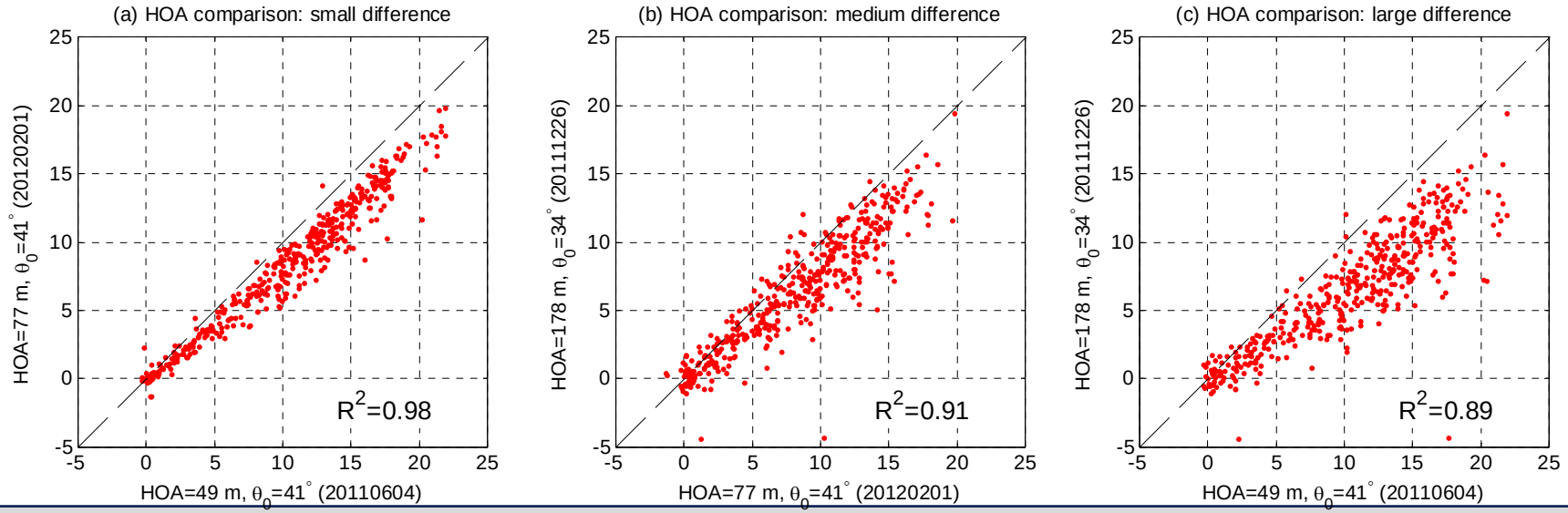


HEIGHT OF AMBIGUITY INFLUENCE

HOA influence (Remningstorp)



Stability across different HOA levels (Remningstorp forest stands)



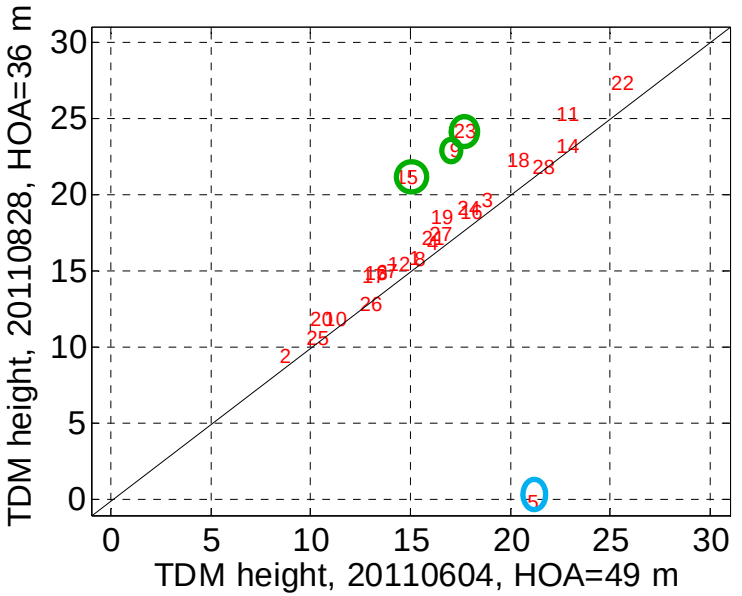
HEIGHT OF AMBIGUITY INFLUENCE

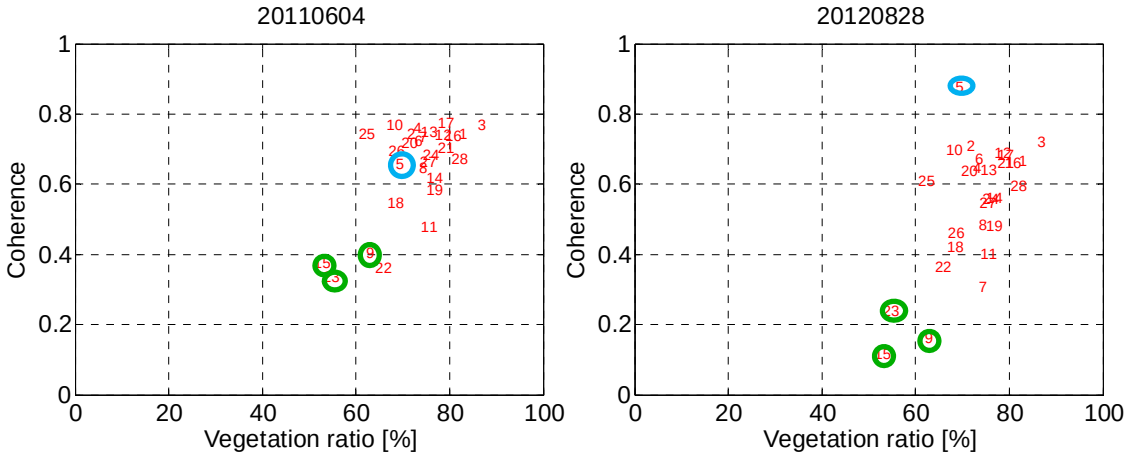
- Plot-level averages:
  20110604 (HOA=49 m) &
  20120828 (HOA=36 m)

1 clear-cut

3 suspicious ”growths” of 5 m

Low vegetation ratio
+ high baseline
= strong decorrelation





SUMMARY

- High potential of TDM for DCM mapping
- Range offset correction for better comparison with e.g. lidar data
- Favourable HOA values between 50 and 80 metres
  (low enough for high SNR & high enough for good coherence)
- Clear-cuts and forest changes can easily be detected

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- Swedish National Space Board (SNSB) for funding
- German Aerospace Center (DLR) for SAR data (within project XTI_VEGE0376)
- Swedish Land Survey (Lantmäteriet) for DEM data
- Swedish University of Agricultural Sciences (SLU) for ground reference data
- Swedish Metereological and Hydrological Insitute (SMHI) for weather data
- European Space Agency (ESA) for lidar data (within BioSAR campaigns)

INCIDENCE ANGLE AND SENSITIVITY

20120403
HOA: 68 m
INC: 19 deg
-5.8 deg

STUDY GOAL

- General:

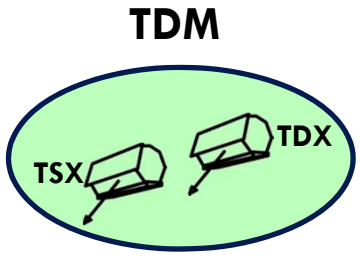
  3D forest parameter retrieval from interferometric TanDEM-X data (XTI_VEGE0376)

- This presentation:

  Processing chain and firs evaluation of the results.

TSX, TDX, TDM

TanDEM-X (**TDM**): SAR interferometer system



Two satellites:

- TerraSAR-X (**TSX**, launched in June 2007)
- TanDEM-X (**TDX**, launched in June 2010)

Helical orbit and bistatic mode:

✓ Flexible baseline

✓ Low temporal decorrelation

SPECKLE, NOISE & BASELINE INFLUENCE

Speckle (in radians) function of coherence and number of looks

Additive phase noise

Baseline decorrelation
(high baseline → low coherence)

Phase-to-height scaling factor: $HOA = \frac{\lambda R \sin\theta}{2B_\perp}$

(high baseline → low HOA
but: increased risk of phase wrapping

Boreal forest height within approx. 0-30 m

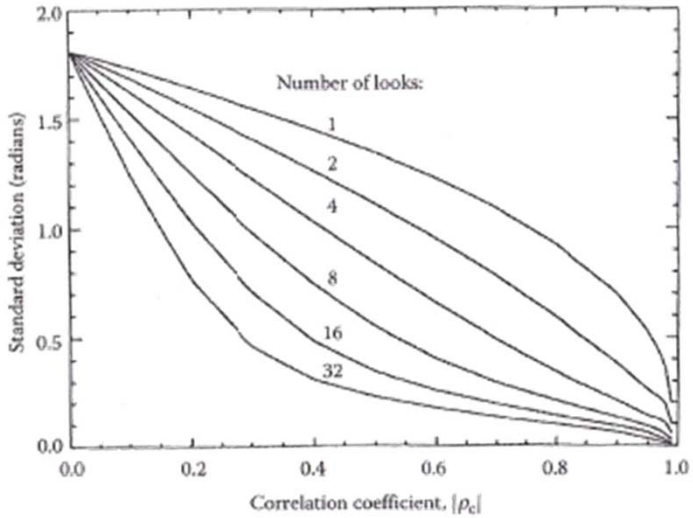


FIGURE 4.6 Phase difference standard deviation versus $|\rho_c|$.

Source: Lee & Pottier, *Polarimetric Radar Imaging*, CRC Press, 2009

Best quality: HOA around **50-80 m,**
but also dependent on incidence angle, season, etc.

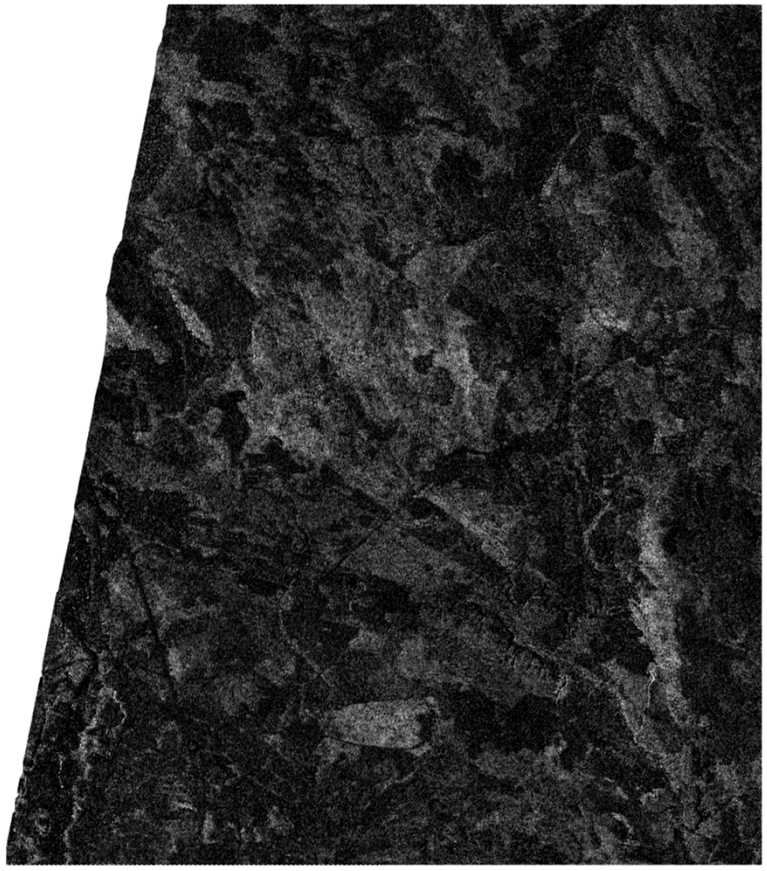
INCIDENCE ANGLE AND SENSITIVITY

20120414
HOA: 65 m
INC: 19 deg
1.2 deg

INCIDENCE ANGLE AND SENSITIVITY

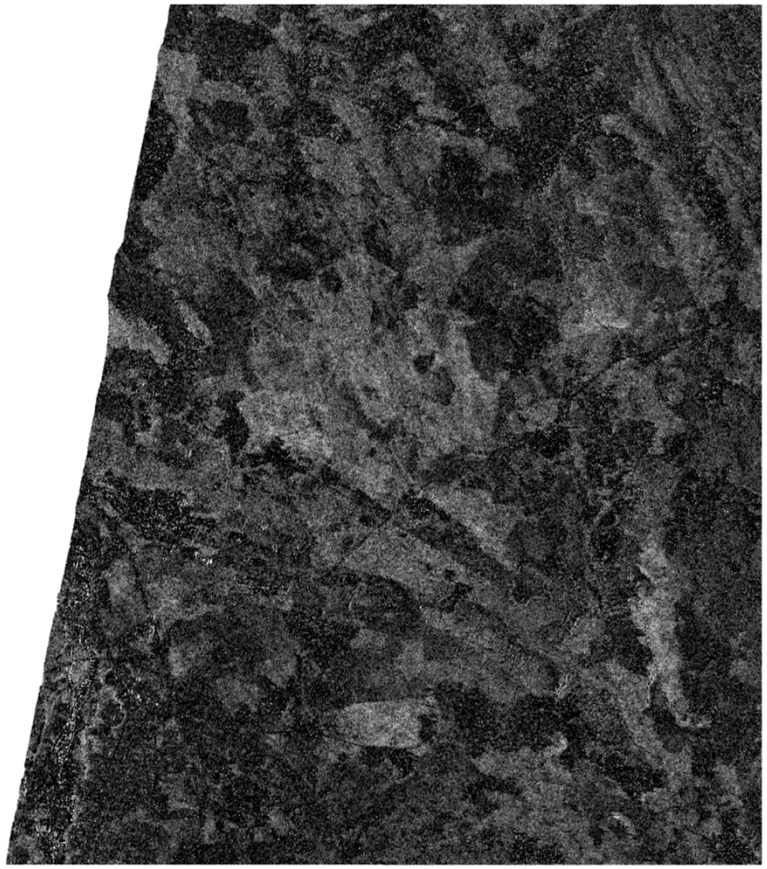
20120425
HOA: 68 m
INC: 19 deg
2.9 deg

INCIDENCE ANGLE AND SENSITIVITY



20120319
HOA: -133 m
INC: 44 deg
-3.2 deg

INCIDENCE ANGLE AND SENSITIVITY



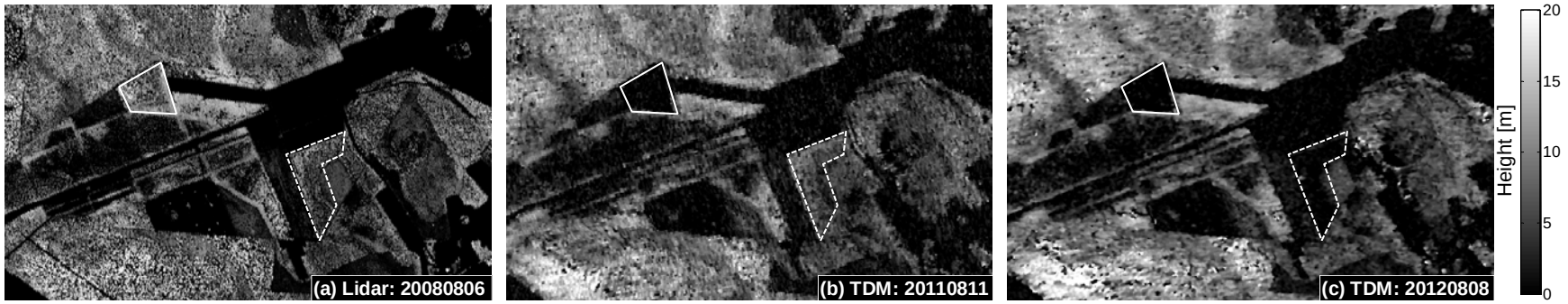
20120330
HOA: -130 m
INC: 44 deg
2.3 deg

TEMPORAL STABILITY

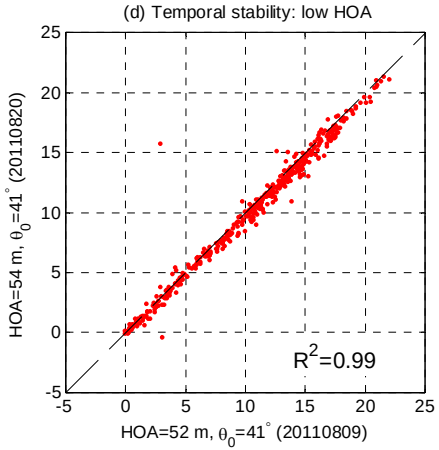
- TDM DCMs very stable over time
  (if similar geometry and weather)
- Seasonal changes observed
- Strong dependence on incidence angle
  - More sensitive to weather at steep angles

TEMPORAL STABILITY

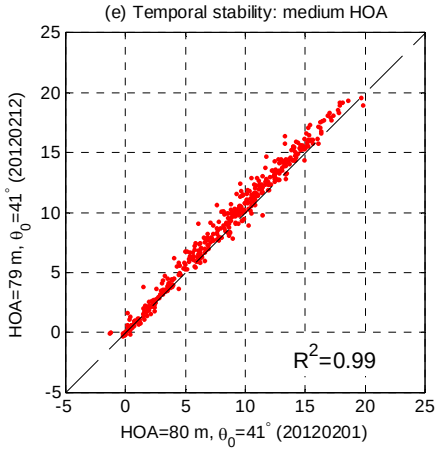
Detection of forest change (Krycklan)



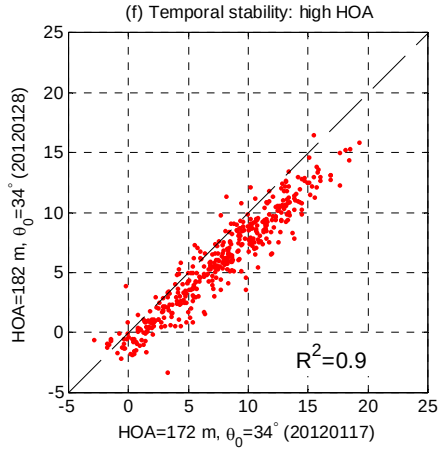
Temporal stability, 11-day separation, different HOA level (Remningstorp forest stands)



HOA≈50 m



HOA≈80 m



HOA≈180 m

SEASONAL CHANGE VS. SPECIES

- Height for birch stand decreases more
  → due to lack of leaves?

- Further investigated in the next presentation