Eigenschaften und Verarbeitung topo-bathymetrischer Punktwolken – Von der Wellenform zum DGM

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Mit Beiträgen des AAHM-R2P Projektteams:

UIBK: Michaela Wörndl, Stefan Jocham
AHM: Ramona Bara, Wolfgang Dobler, Frank Steinbacher

Alpine Airborne Hydromapping – from research to practice
Area 2: Data processing

Nr.	Project Title
2.1	Data Management and Visualization
2.2	Full Waveform Analysis
2.3	Calibration
2.4	Classification
2.5	Data Fusion
2.6	Software Development

Tutorial: *(Sem 127)*

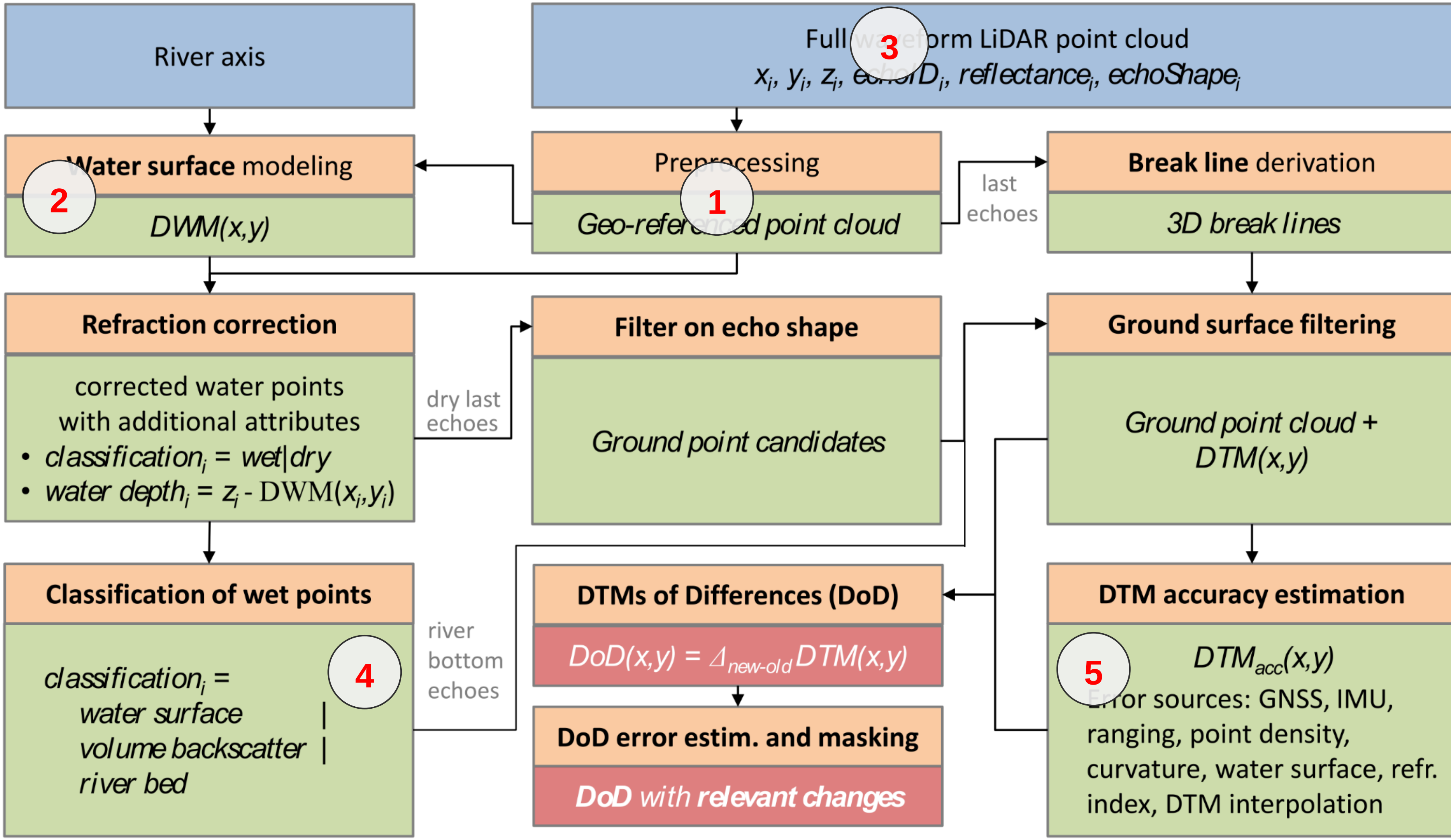
Tutorial: *(Geodäten-HS)*

Tutorial: HN-modelling *(Sem 124)*

Tutorial: *(Sem 122)*

Data processing -Workflow diagram

http://www.geo.tuwien.ac.at/opals



Reference:

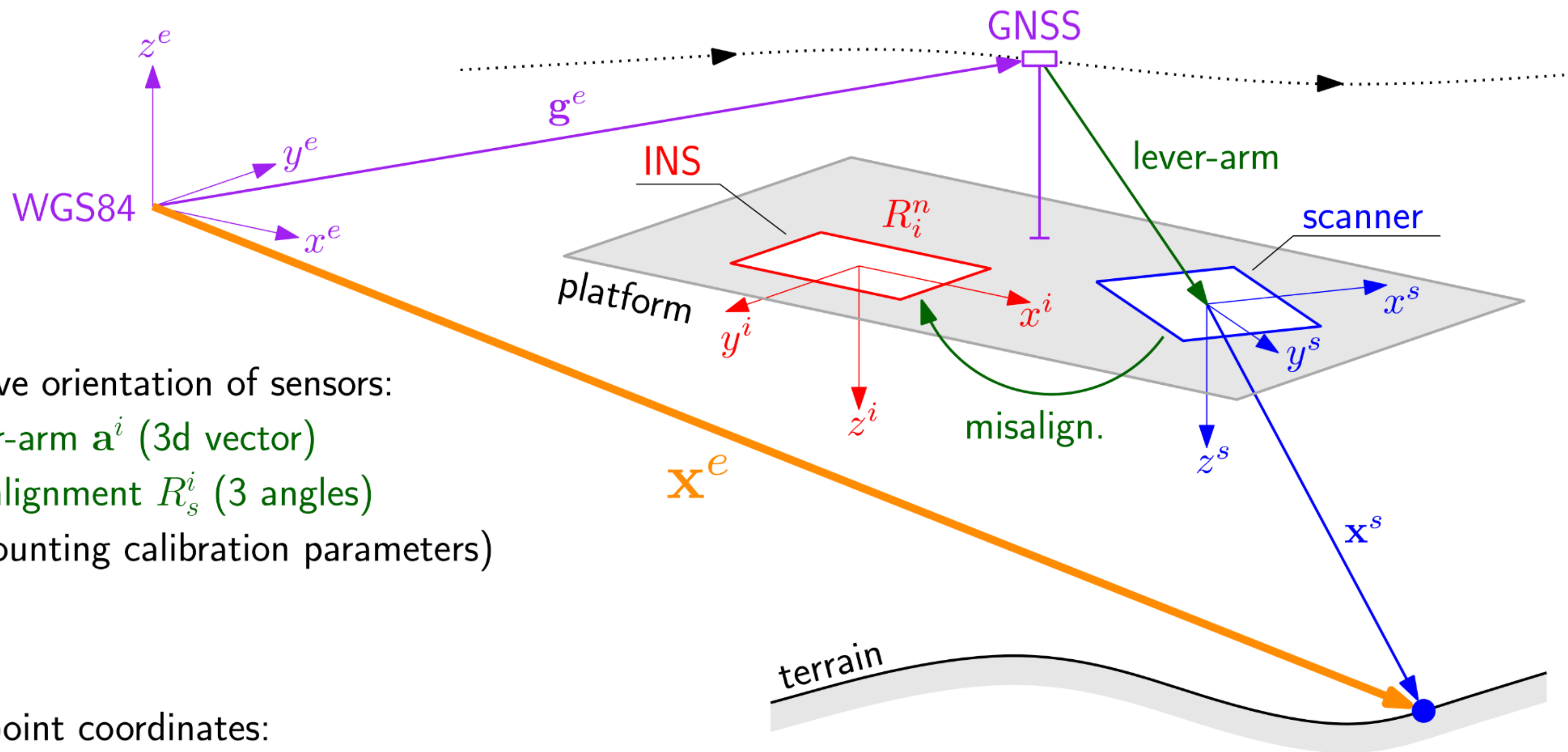
- Mandlburger, G., Hauer, Ch., Wieser, M. and Pfeifer, N. 2015. Topo-bathymetric LiDAR for monitoring river morphodynamics and instream habitats – A case study at the Pielach River. Remote Sensing, accepted: 2015-05-05

ALS sensor model

ALS is a multisensor system:

- Scanner: range, deflection angle
- GNSS: position of platform
- INS: orientation of platform

} Kalman filter → trajectory (3 coordinates $\mathbf{g}^e$, 3 angles R_i^n)



Relative orientation of sensors:

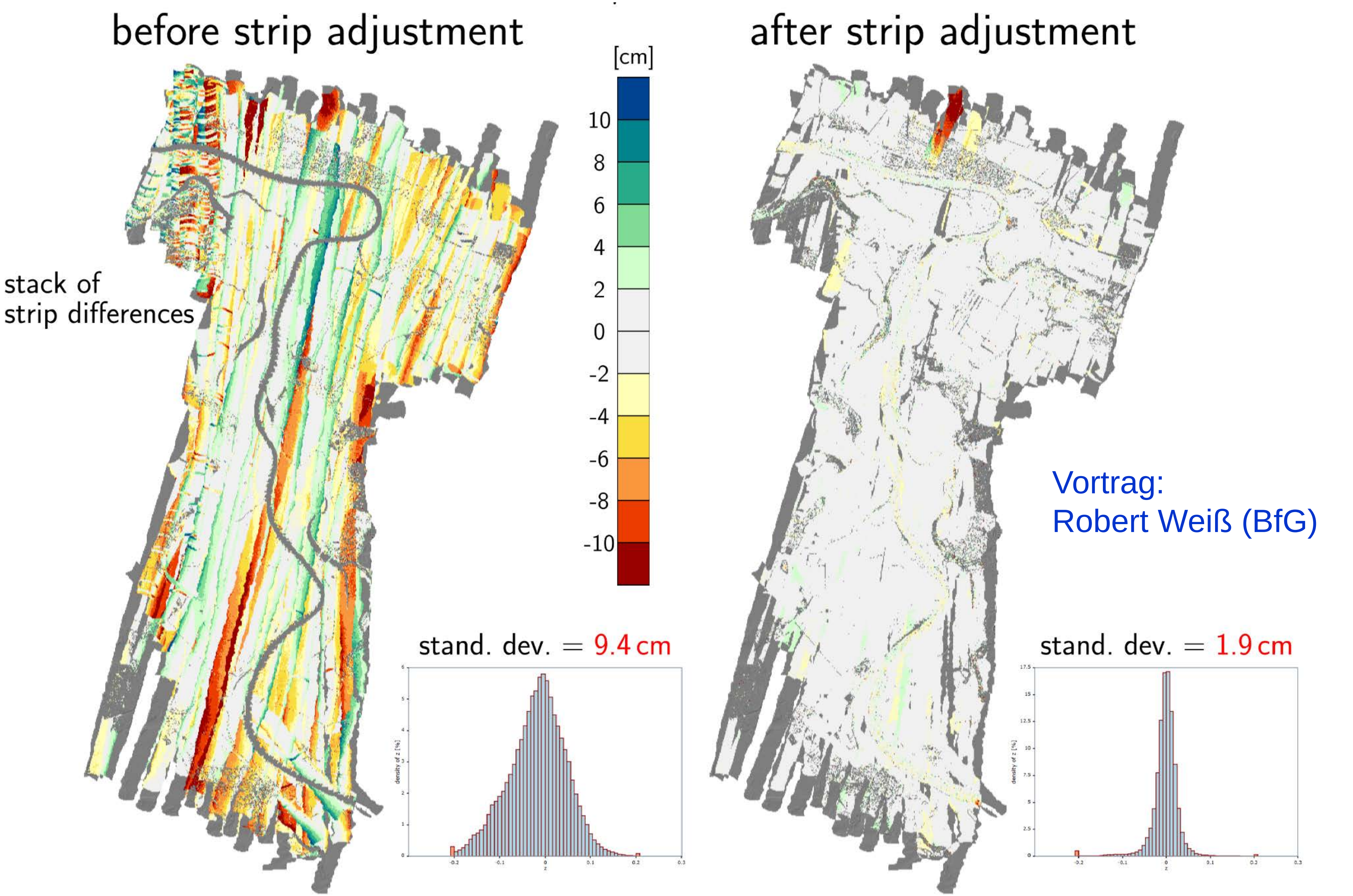
- lever-arm $\mathbf{a}^i$ (3d vector)
- misalignment R_s^i (3 angles)

(= mounting calibration parameters)

ALS point coordinates:

$$\mathbf{x}^e(t) = \mathbf{g}^e(t) + R_n^e(t)\, R_i^n(t)(\mathbf{a}^i + R_s^i\, \mathbf{x}^s(t))$$

Sensor calibration – Flight block Elbe (BfG)



Vortrag:
Robert Weiß (BfG)

Sensor calibration – Trajectory correction parameters

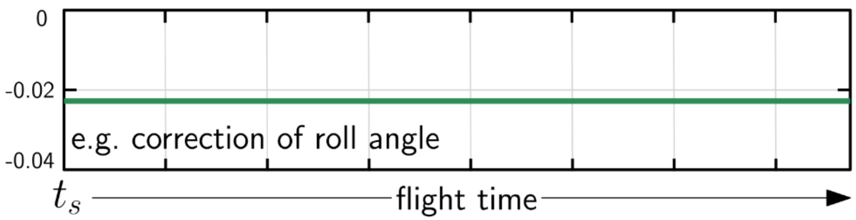
Accuracy of trajectory is strongly affected by external influences:

- satellite constellation
- distance from GNSS reference stations
- roll, pitch, yaw drift
- airplane movements, e.g. vibrations

$\rightarrow$ Trajectory errors are corrected individually for each strip!

Four models depending on the trajectory quality:

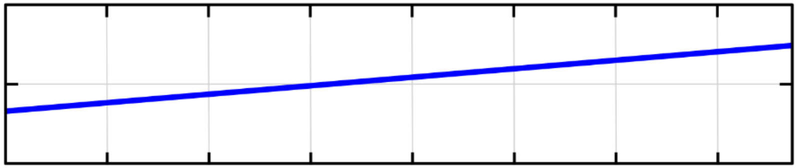
1) Constant correction model



$$\phi(t) = \underline{\phi_0(t)} + \underline{a_0}$$

$\rightarrow$ 6 parameters per strip

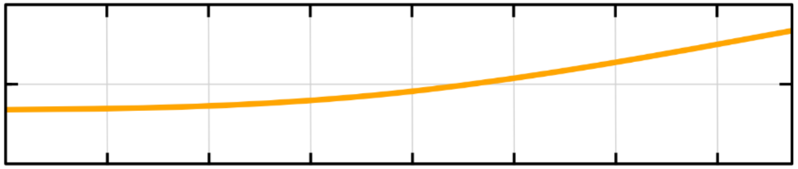
2) Linear correction model



$$\phi(t) = \underline{\phi_0(t)} + \underline{a_0} + \underline{a_1}(t - t_s)$$

$\rightarrow$ 12 (=6*2) parameters per strip

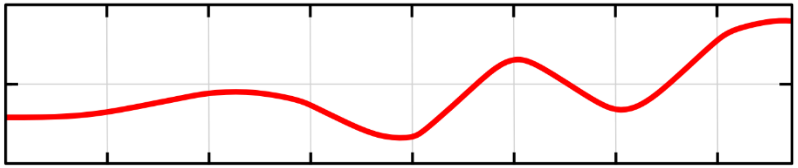
3) Quadratic correction model



$$\phi(t) = \underline{\phi_0(t)} + \underline{a_0} + \underline{a_1}(t - t_s) + \underline{a_2}(t - t_s)^2$$

$\rightarrow$ 18 (=3*6) parameters per strip

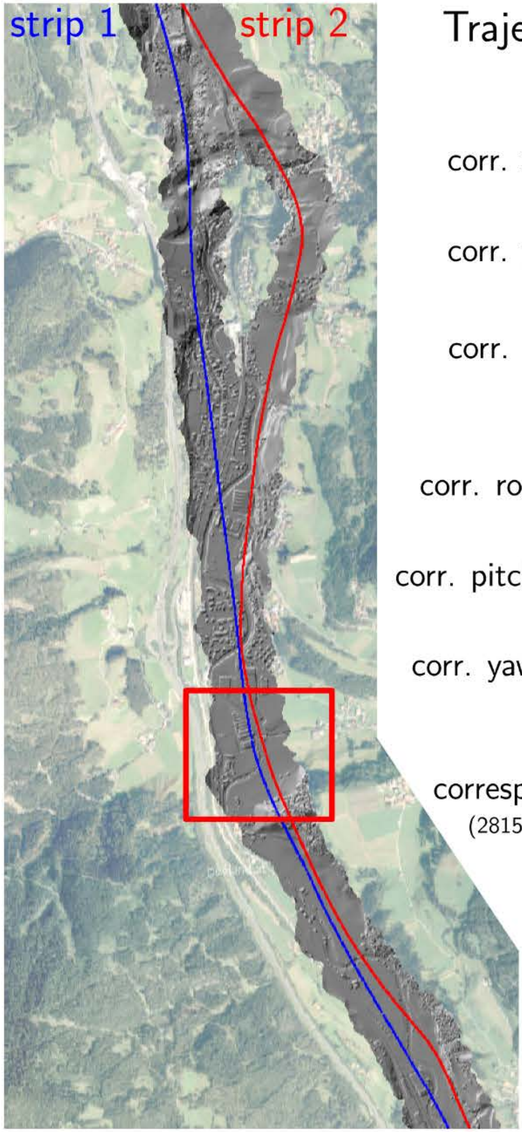
4) Spline correction model



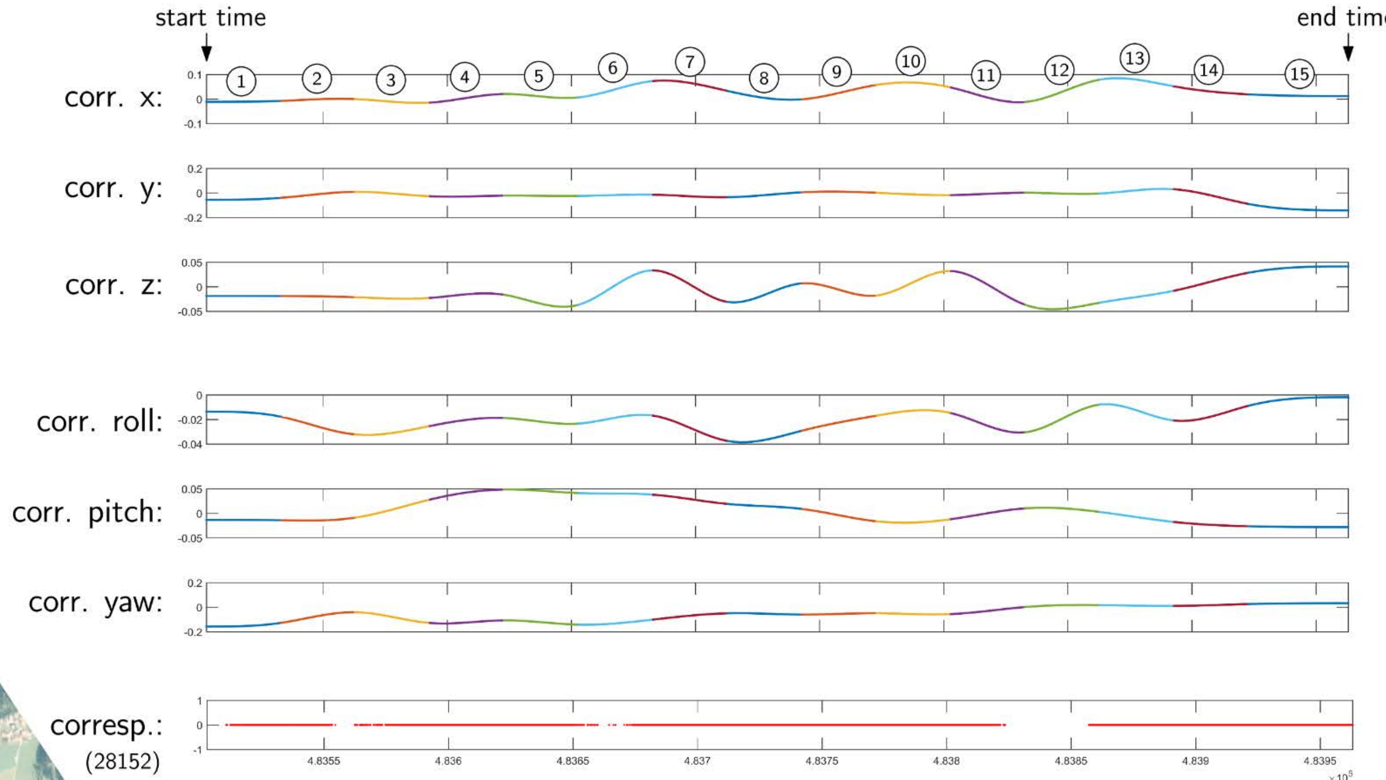
$\rightarrow$ for highest accuracy requirements
or very bad trajectory quality

Sensor calibration – Flight block Sill

Example: 2 strips with very bad trajectory quality



Trajectory correction for strip 1 (flight time = 460 sec):

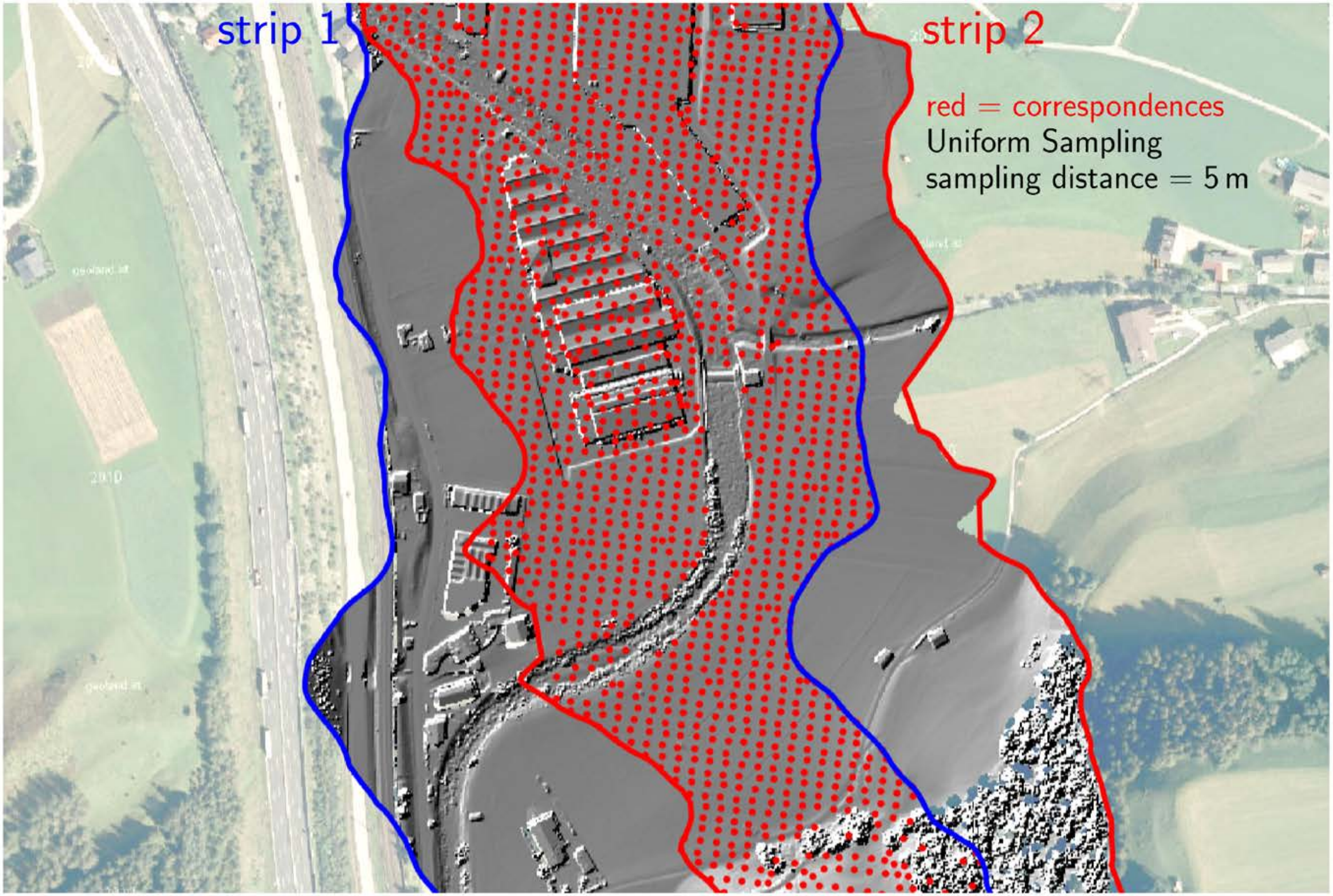


- Each cubic polynomial has a length of 30 sec ($=\Delta t$)

$$\phi(t) = \underline{\phi_0(t)} + \underline{a_0} + \underline{a_1}(t - t_s) + \underline{a_2}(t - t_s)^2 + \underline{a_3}(t - t_s)^3$$ → 360 prm per strip

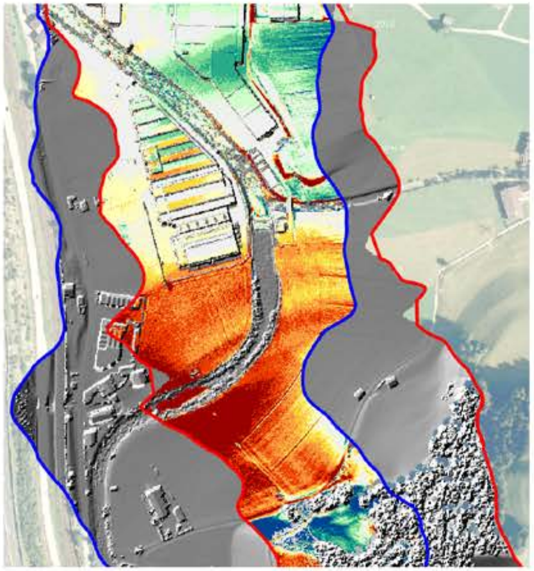
- C2-continuity (1. and 2. deriv. are continuous) as constraints in adj.
- 1. and 2. derivative = 0 at start and end time

Sensor calibration – Flight block Sill

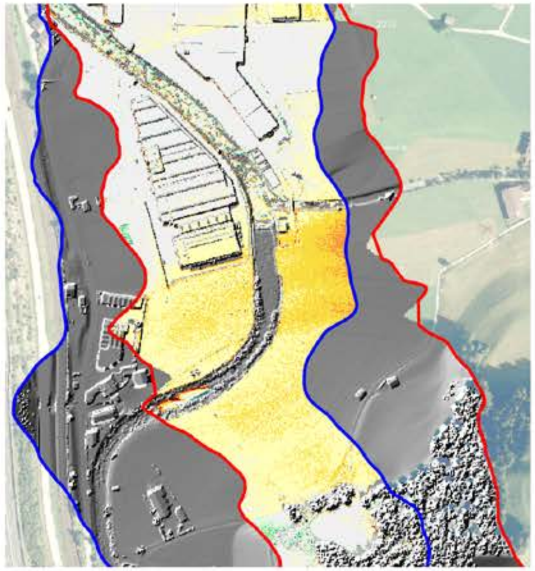


Sensor calibration – Flight block Sill

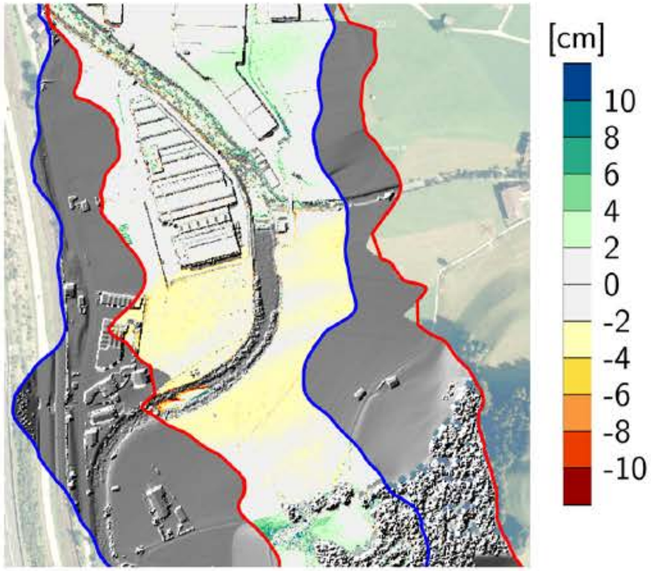
Constant correction model

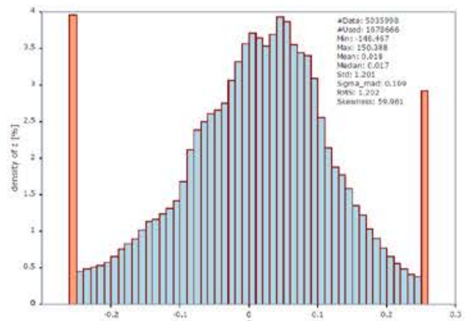


Spline correction model
$\Delta t = 60\,s$

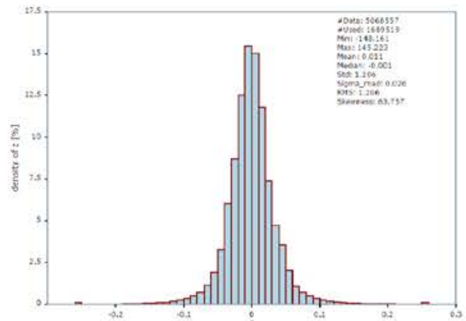


Spline correction model
$\Delta t = 30\,s$

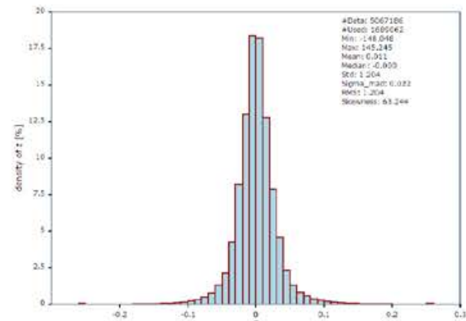




median = 1.7 cm
std.dev. = 10.9 cm

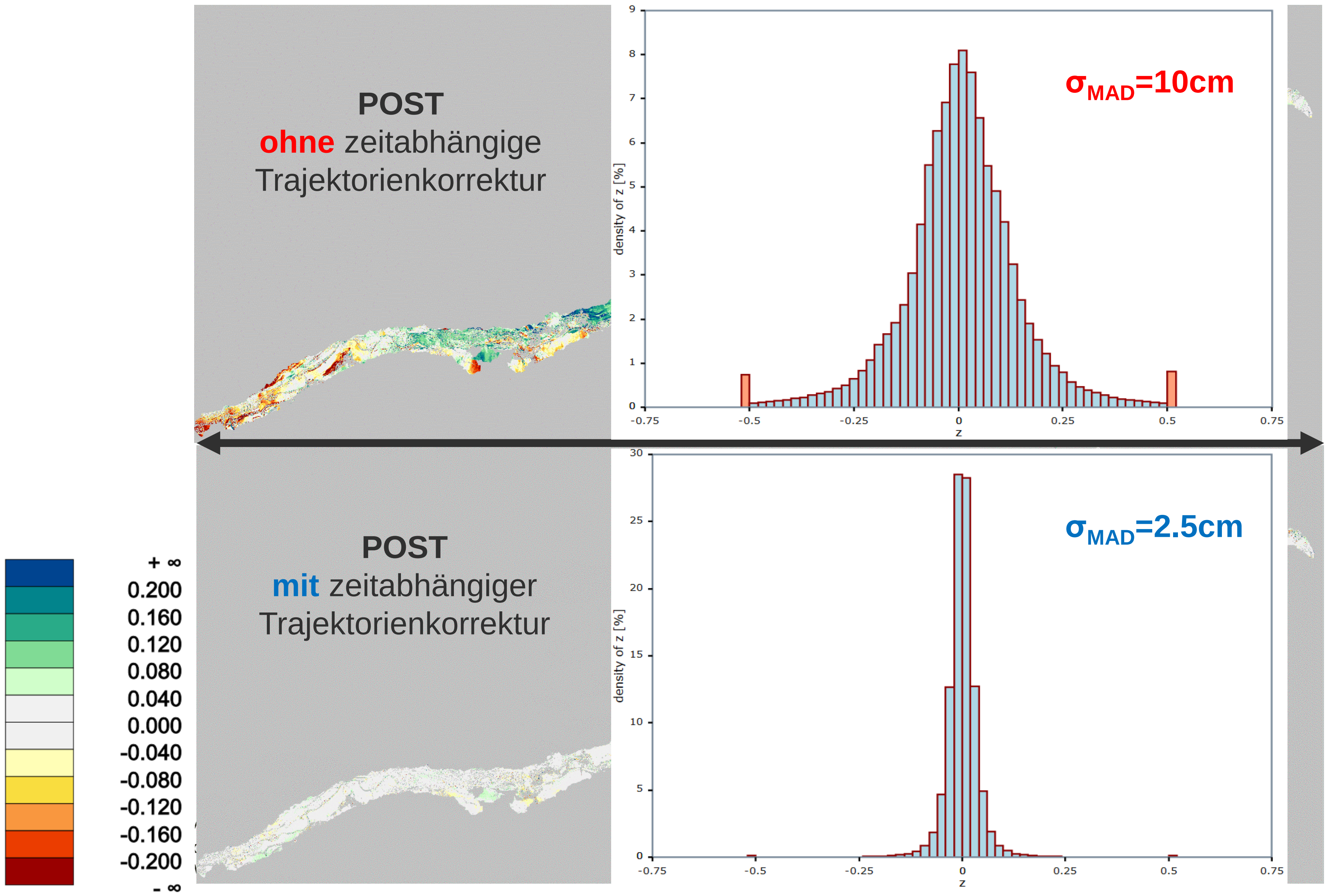


median = -0.1 cm
std.dev. = 2.6 cm

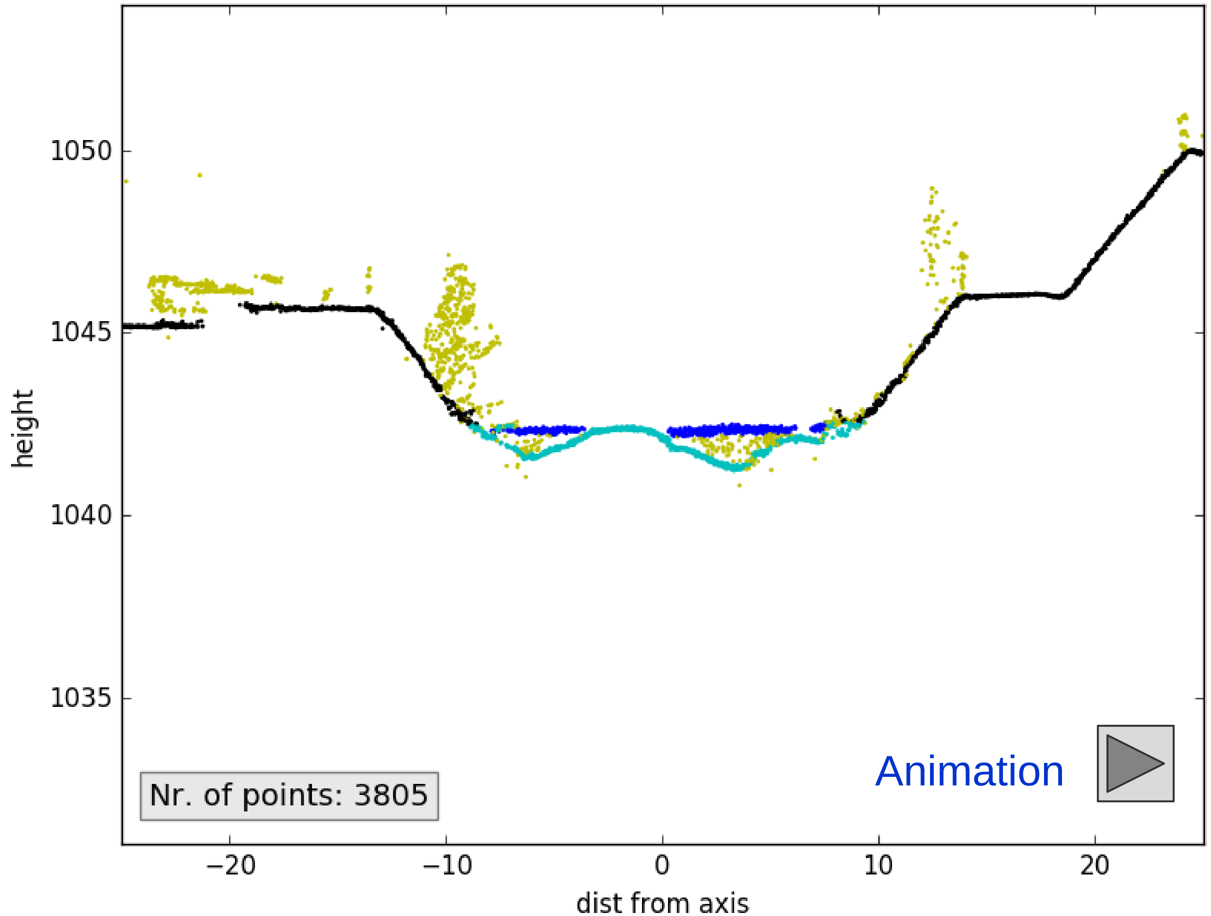


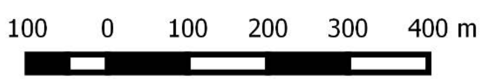
median = 0.0 cm
std.dev. = 2.2 cm

Flight block Sill

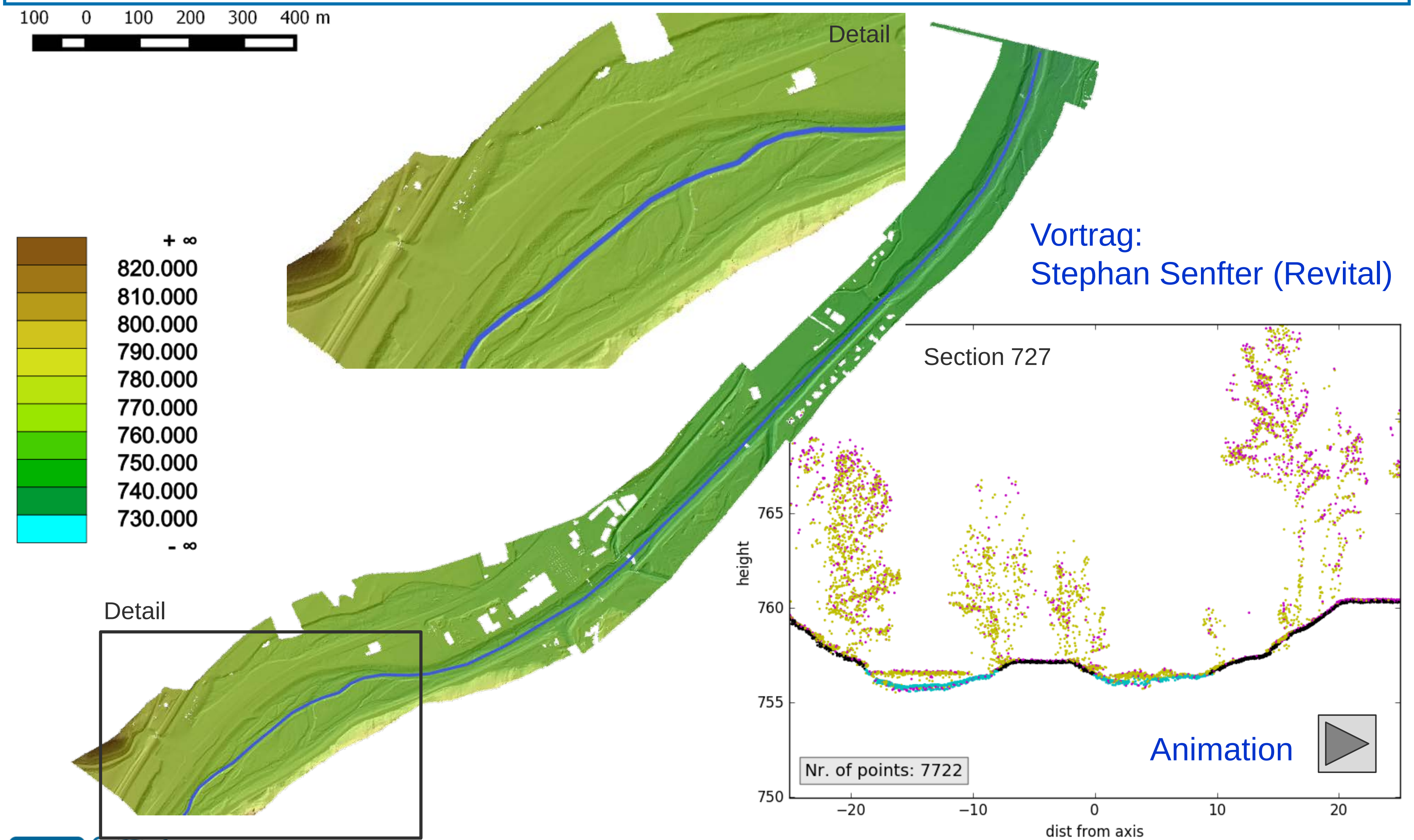


AAHM project area: Sill



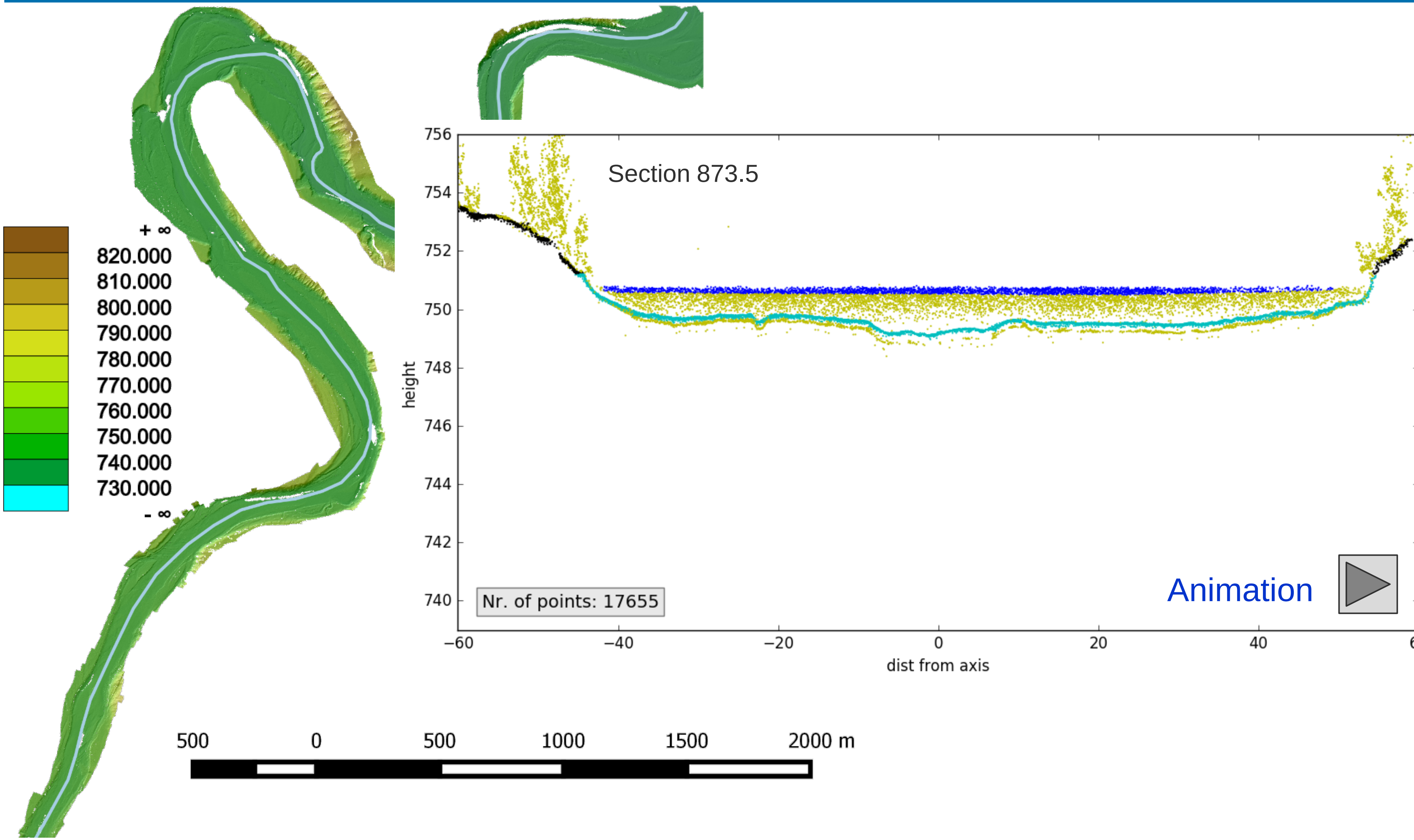


AAHM project area: Drau (Osttirol)

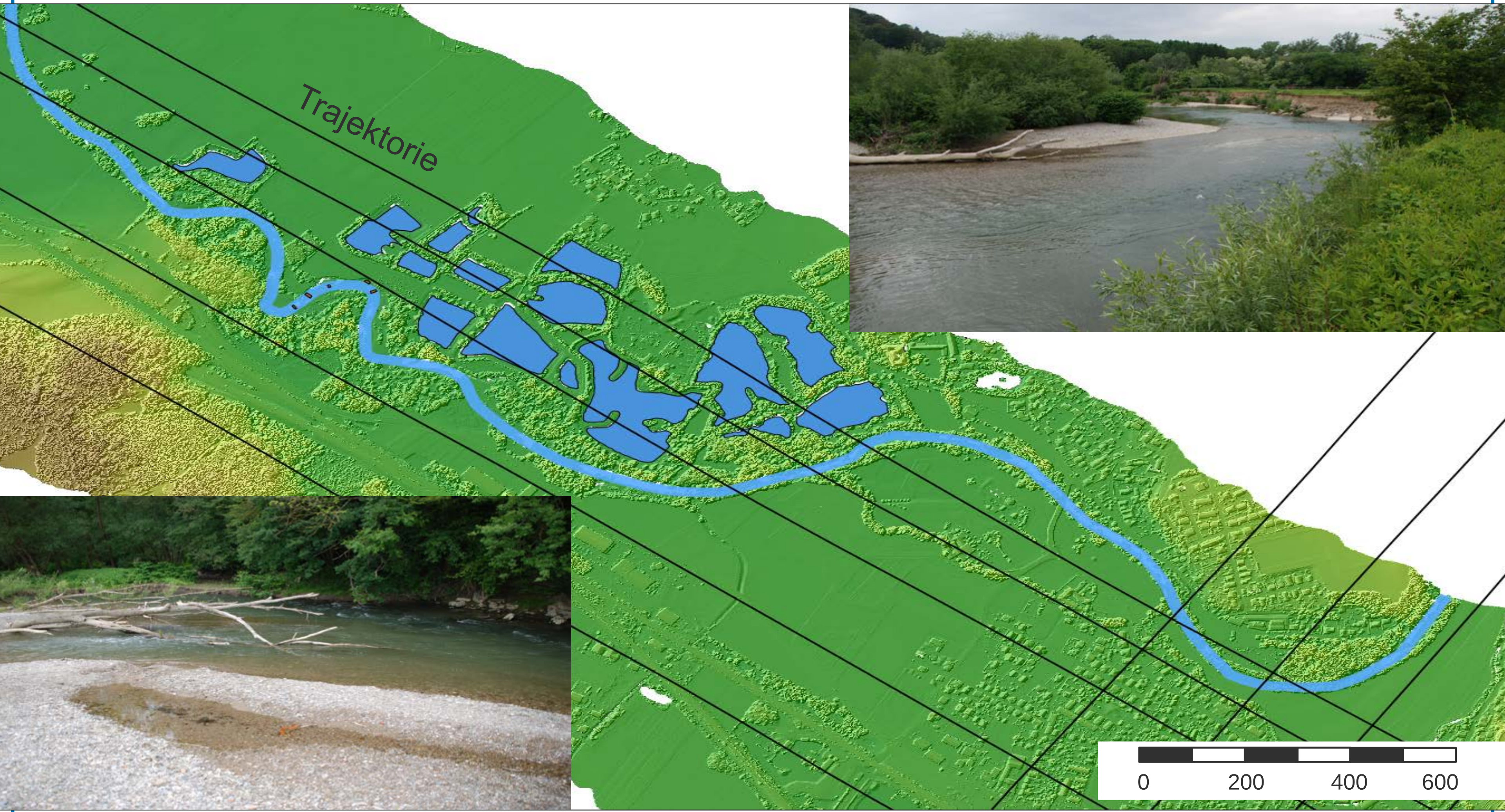


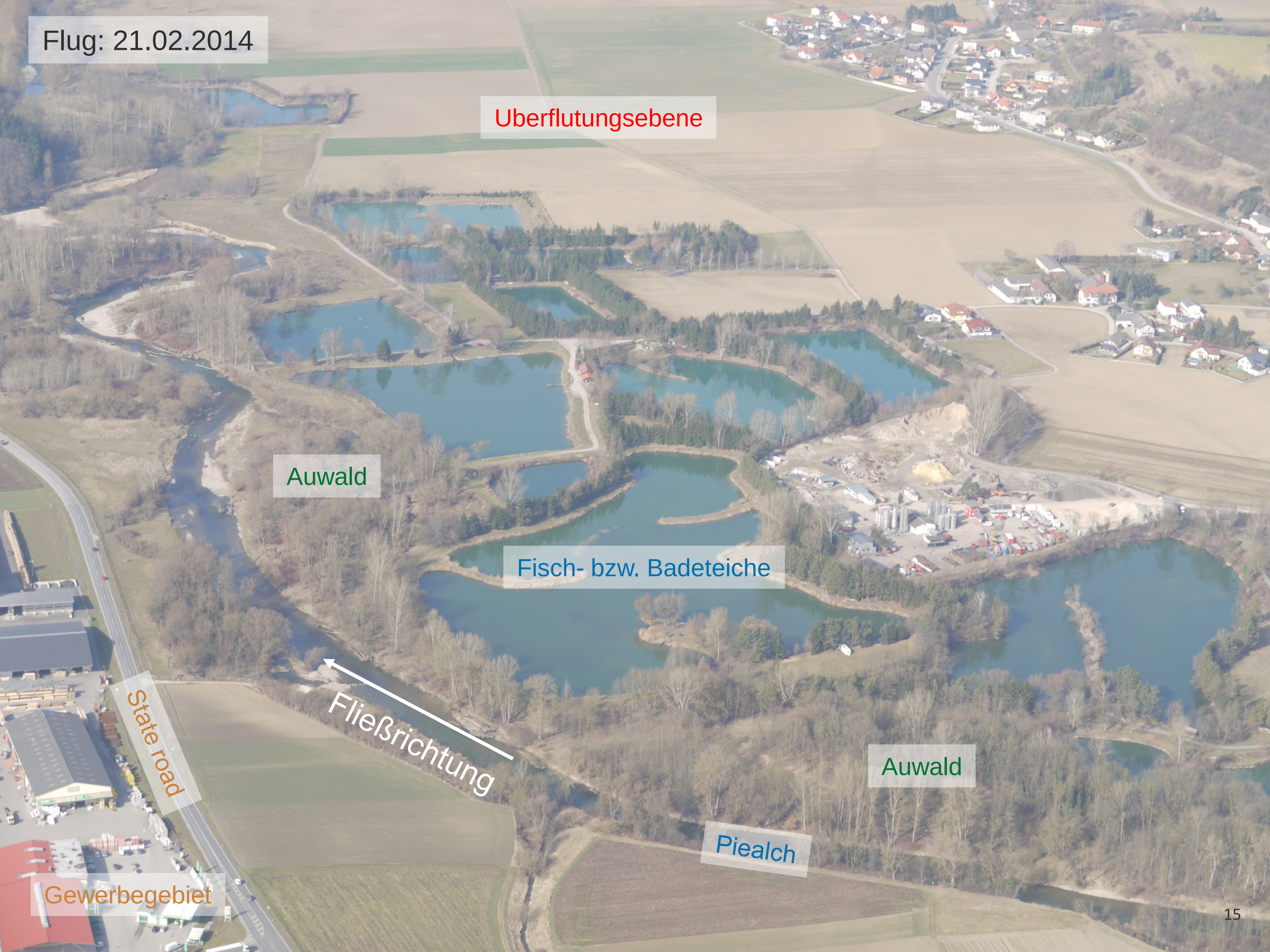
Vortrag:
Stephan Senfter (Revital)

AAHM project area: Litschauer Schleife (Lech)

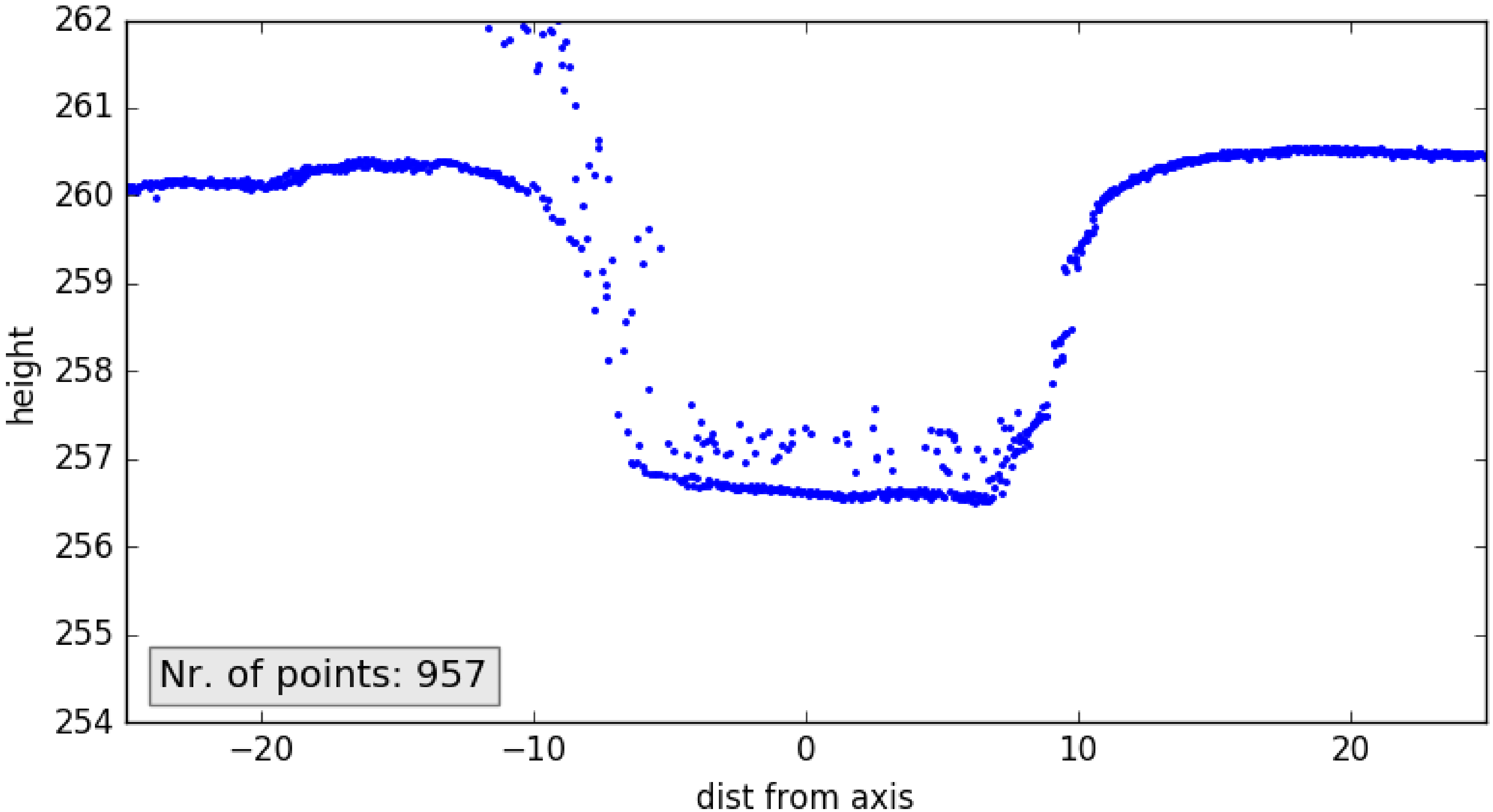


AAHM project area: Pielach – Neubacher Au II

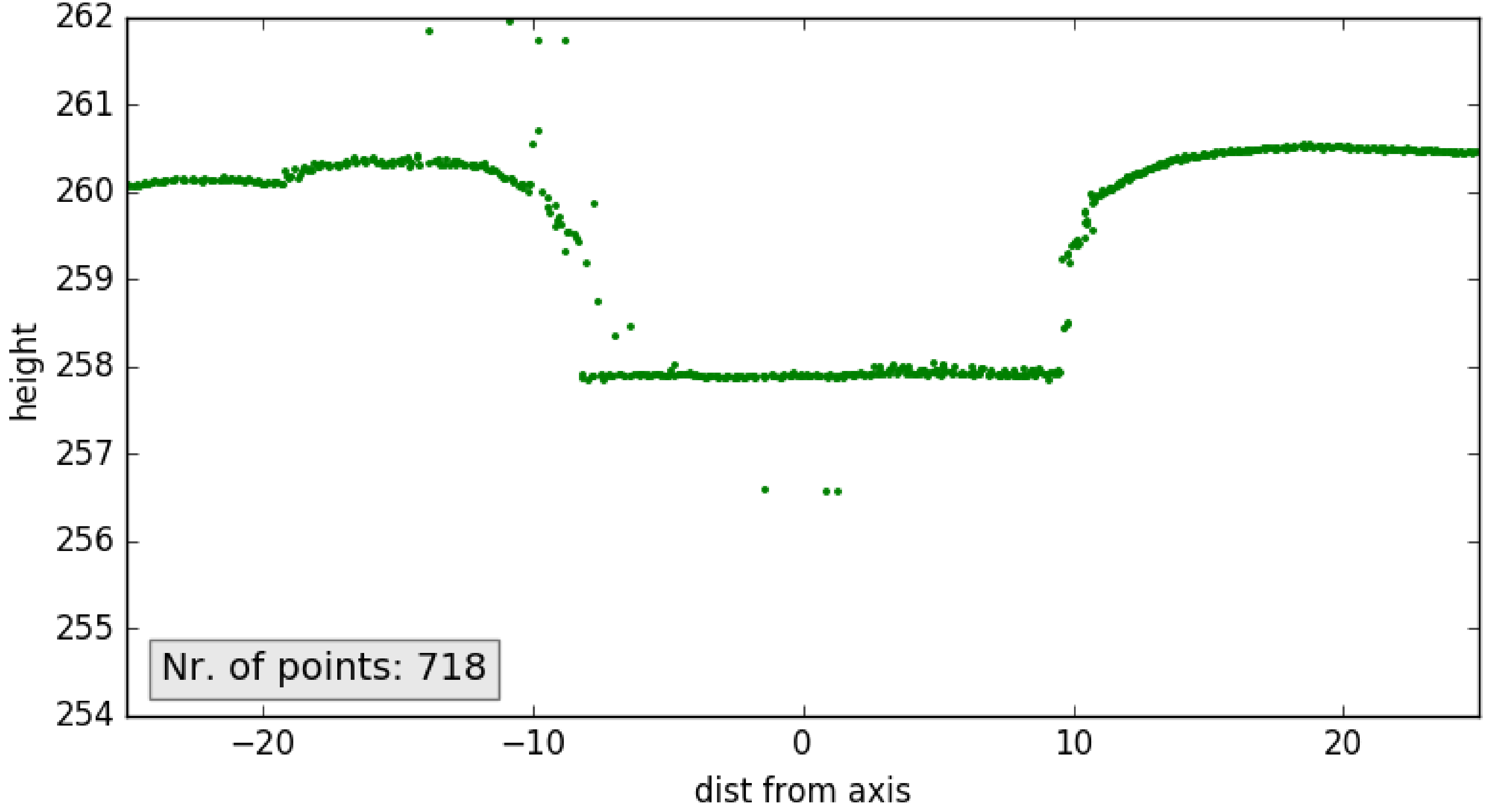



Flug: 21.02.2014
Uberflutungsebene
Auwald
Fisch- bzw. Badeteiche
Fließrichtung
State road
Auwald
Piealch
Gewerbegebiet

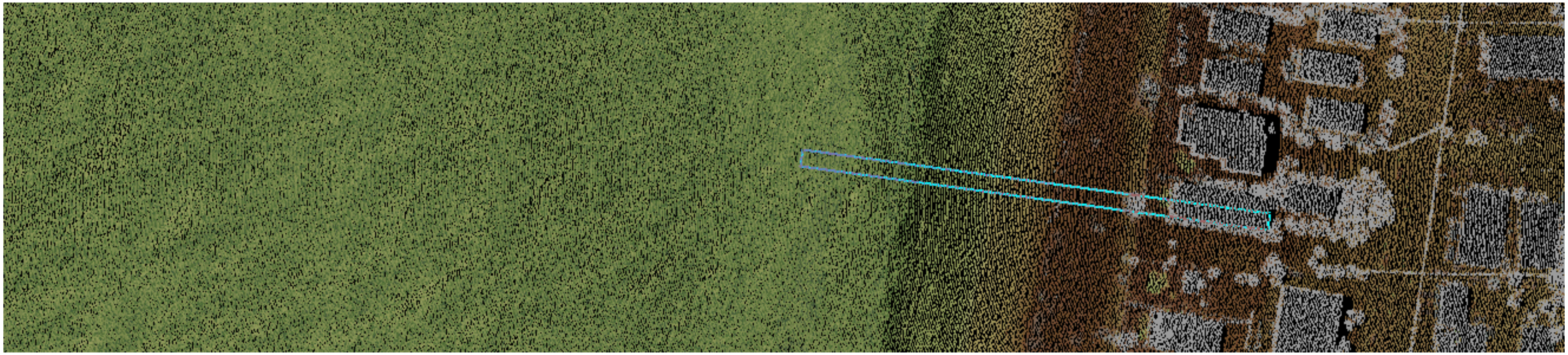
AAHM project area: Pielach – Section example

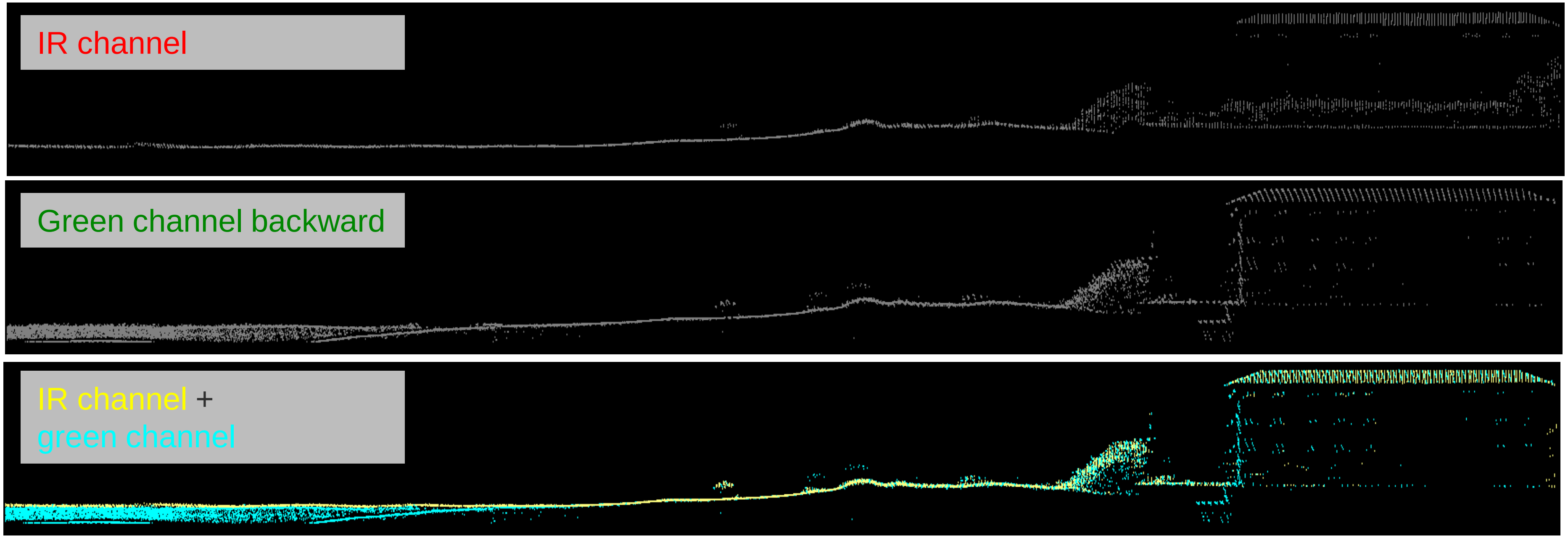


AAHM project area: Pielach – Section example

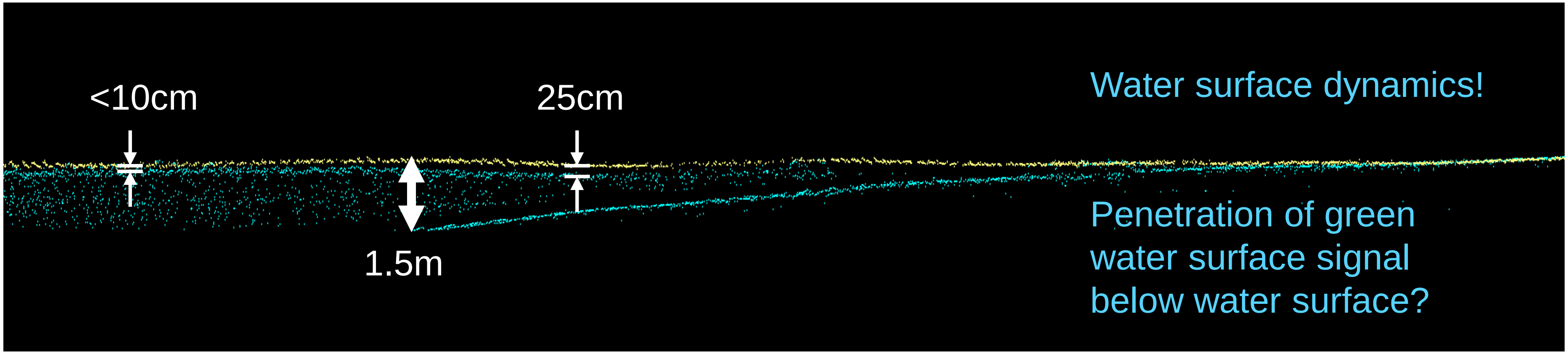


TampaBay: Point cloud section

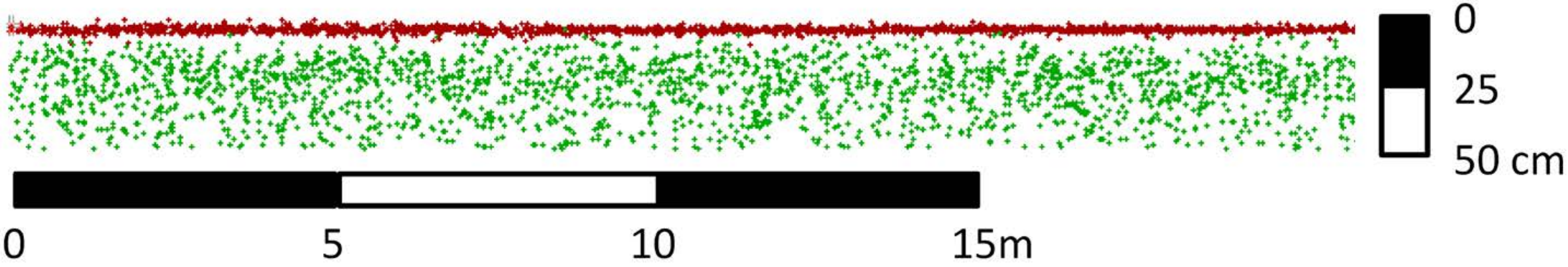




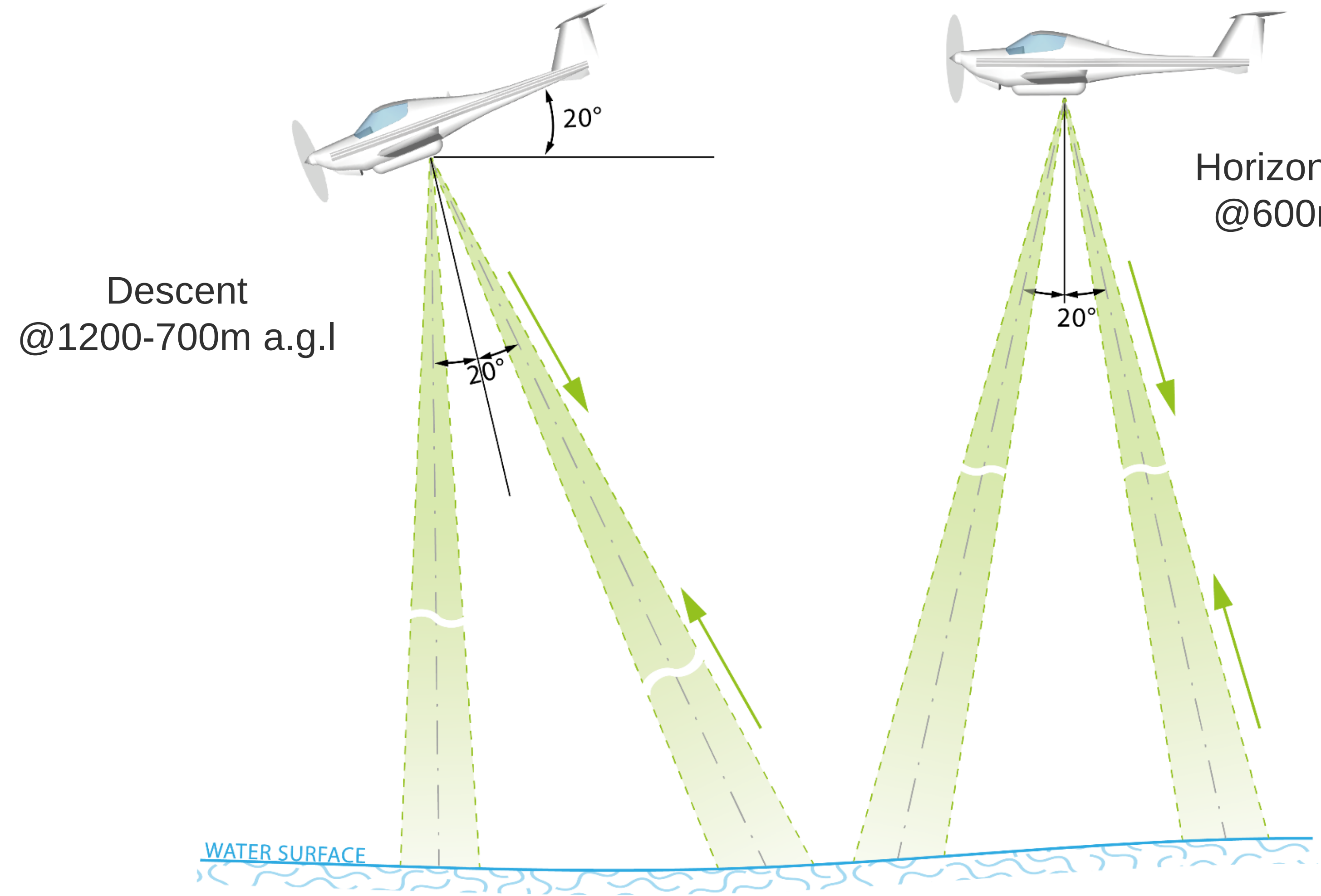
Point cloud section (detail)

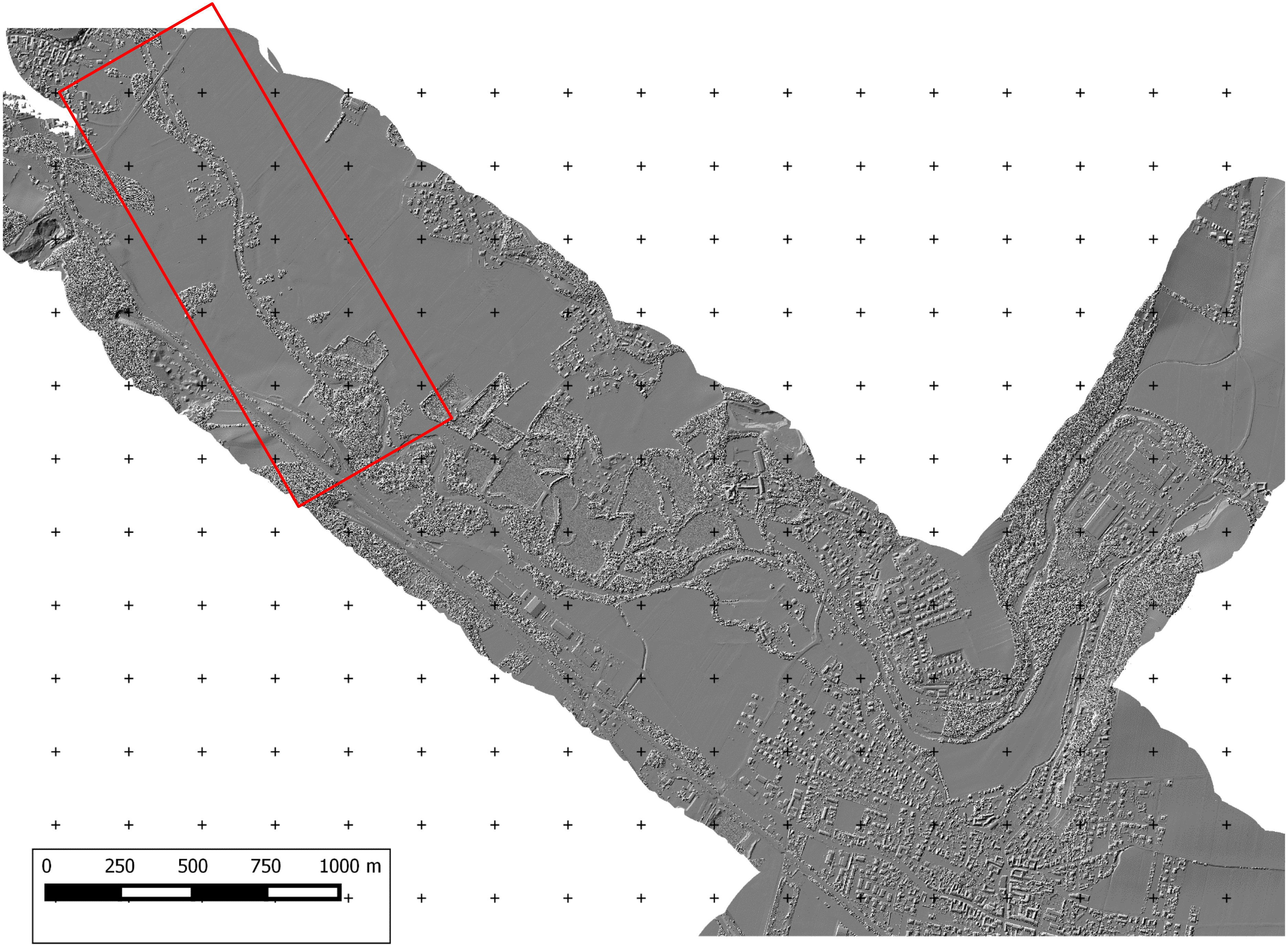


- Prior Study: G. Mandlburger, M. Pfennigbauer, N. Pfeifer: "*Analyzing near water surface penetration in laser bathymetry - A case study at the River Pielach*"; in: "*ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*", II-5/W2 (2013), 175 - 180.

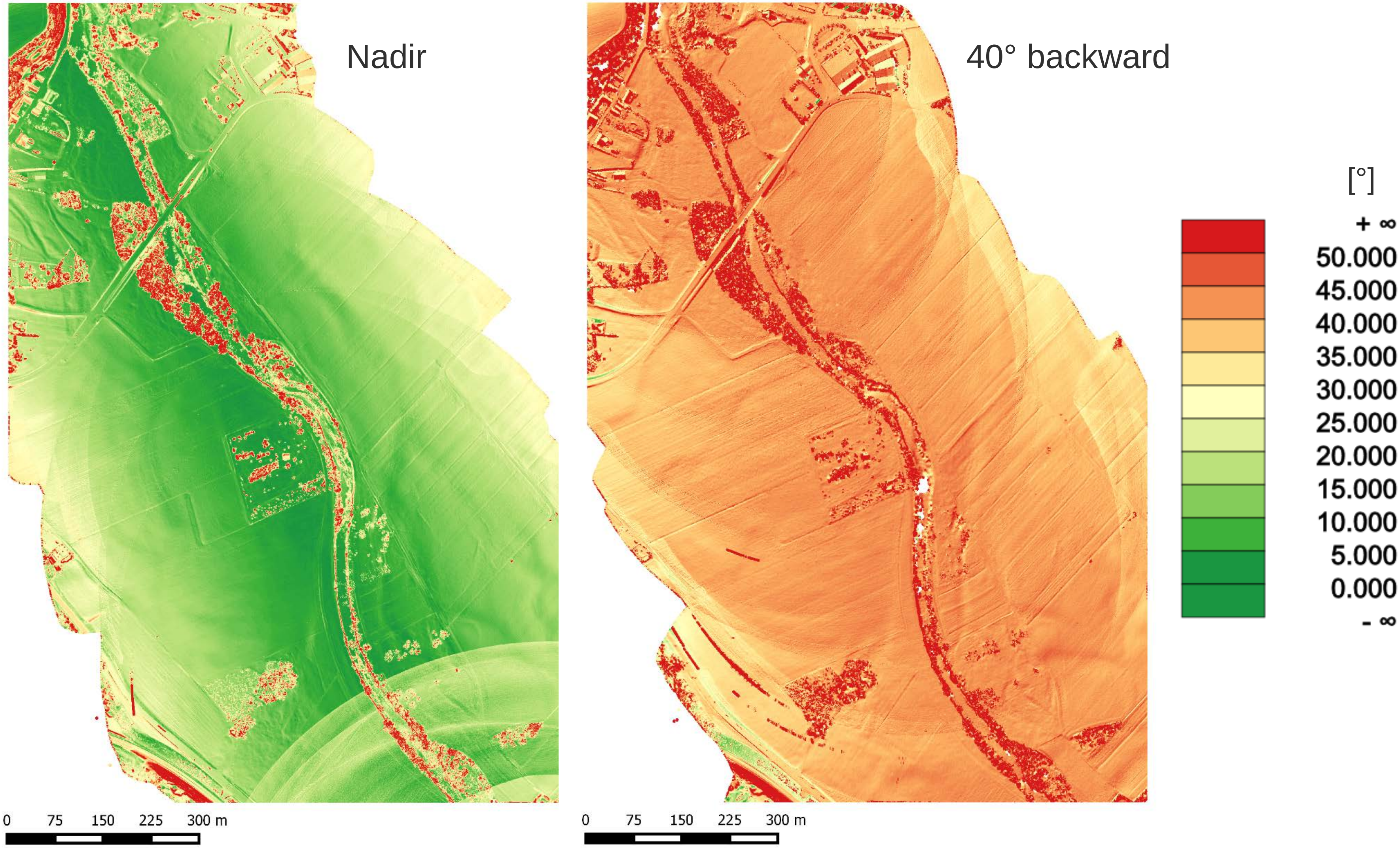


VQ-890-G: Descent experiment

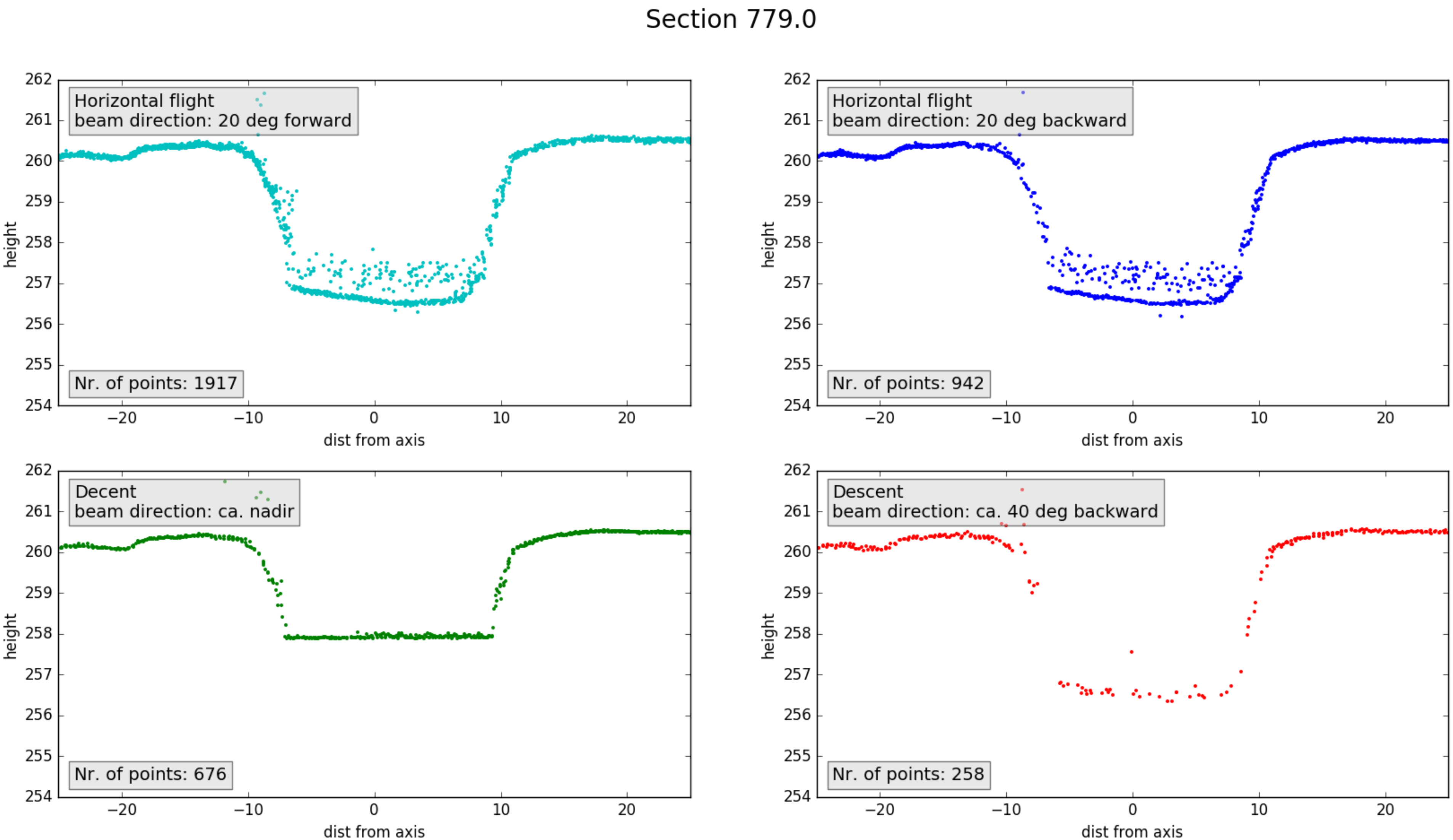



0
250
500
750
1000 m

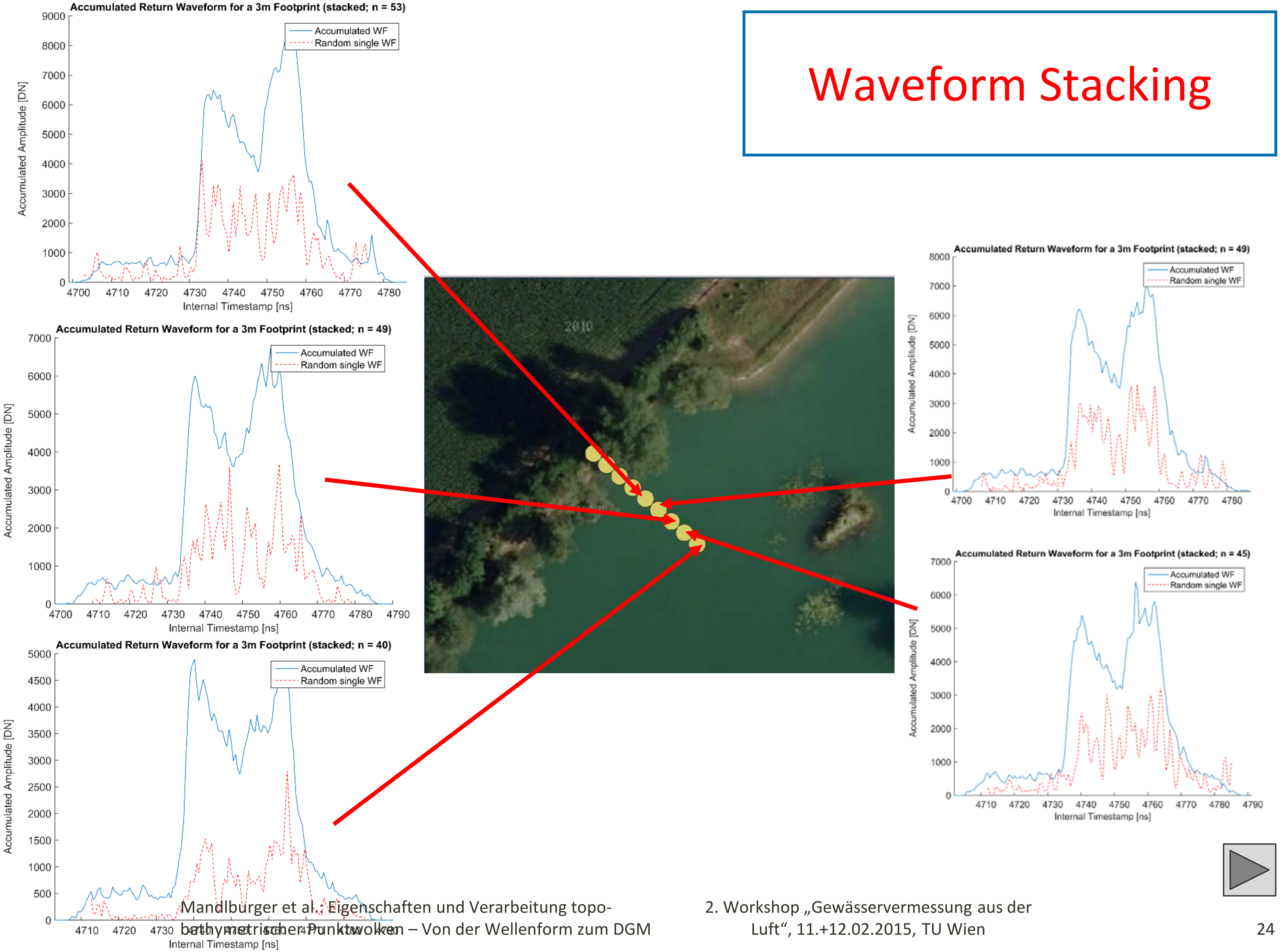
Incidence angle: Descent



Cross section comparison



Waveform Stacking



Lidar equation (bathymetry)

Pfeifer et. al.: Handbuch der Geodäsie, Springer (in preparation)
nach: Abdallah et al, 2014

Signal strength

$$P_E = P_O + P_W + P_B + P_{HG} + P_{DR}$$

Water surface | Water column | Water bottom | Background + detector noise

$$P_O = \frac{P_S T_{ATM}^2 A_E \eta_S \eta_E L_O \cos\alpha_L}{\pi H^2}$$

$$P_W(z) = \frac{P_S T_{ATM}^2 A_E \eta_S \eta_E F (1 - L_O)^2 \beta(\varphi) e^{\frac{-2kz}{\cos\alpha_W}}}{\left(\frac{n_W H + z}{\cos\alpha_L}\right)^2}$$

$$P_B = \frac{P_S T_{ATM}^2 A_E \eta_S \eta_E F (1 - L_O)^2 R_B e^{\frac{-2kZ}{\cos\alpha_W}}}{\pi \left(\frac{n_W H + Z}{\cos\alpha_L}\right)^2}$$

H.... Flying height

L_0... Loss due to surface albedo

k..... Diffuse attenuation coeff.

z..... Height/length water column

Z..... Water depth

R_b... Bottom reflectivity

Exponential decrease of signal intensity

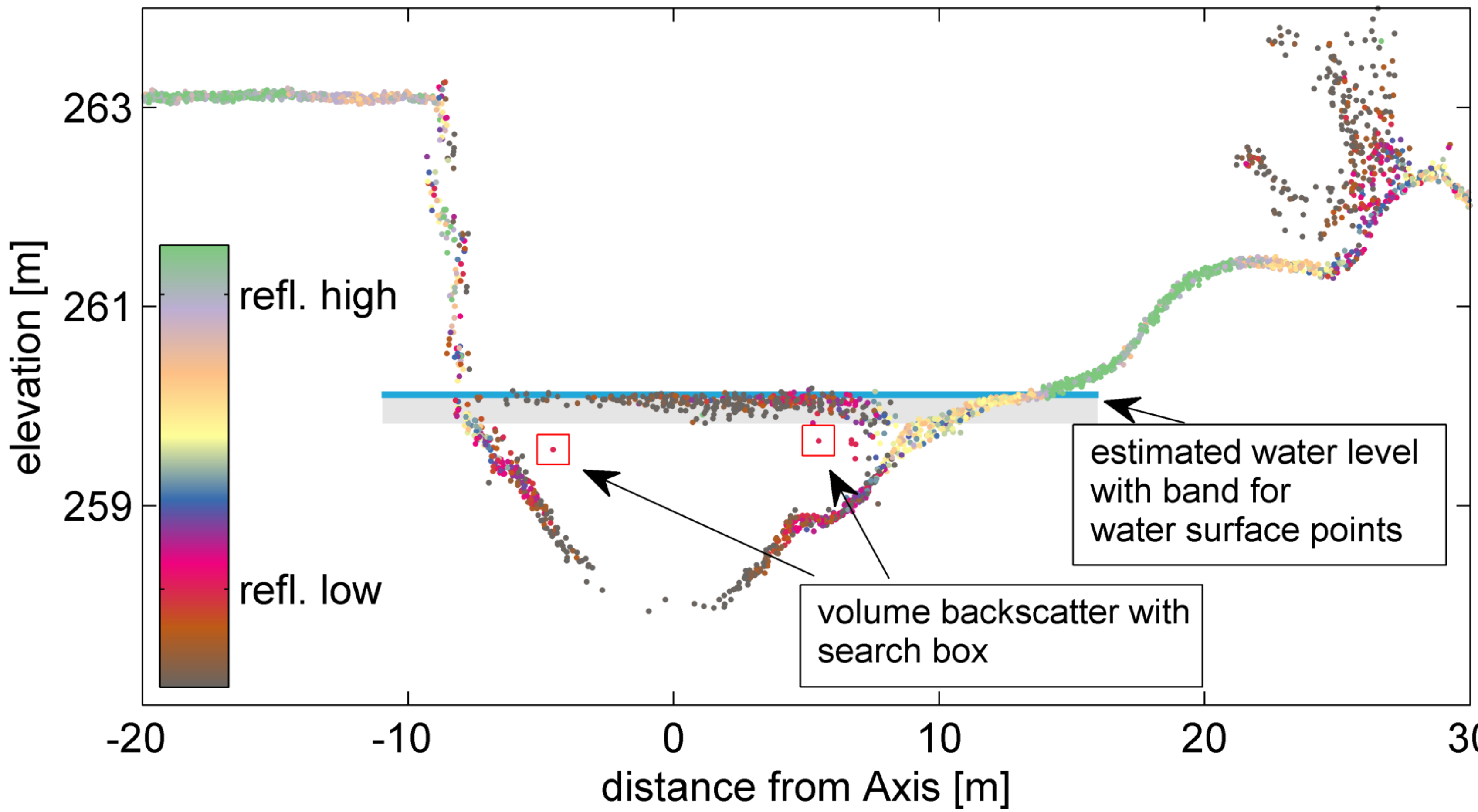
Presentation: Roland Schwarz

Classification of water points I

point cloud

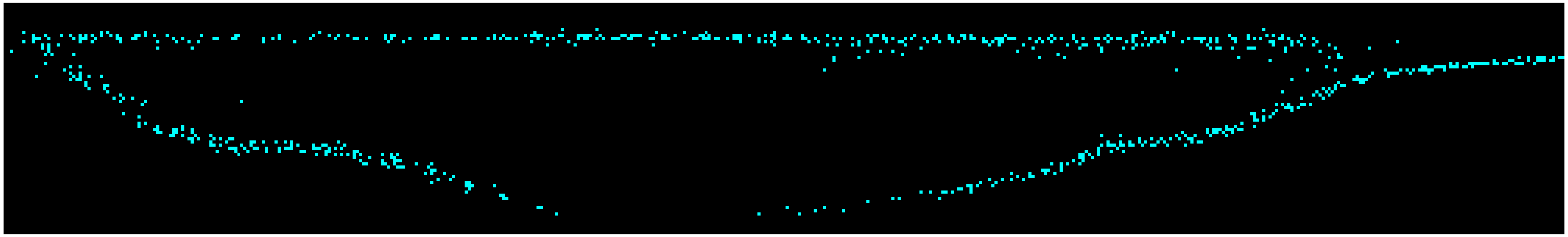
DTM

Tutorials: TU Wien, Riegl, AHM



Classification of water points II

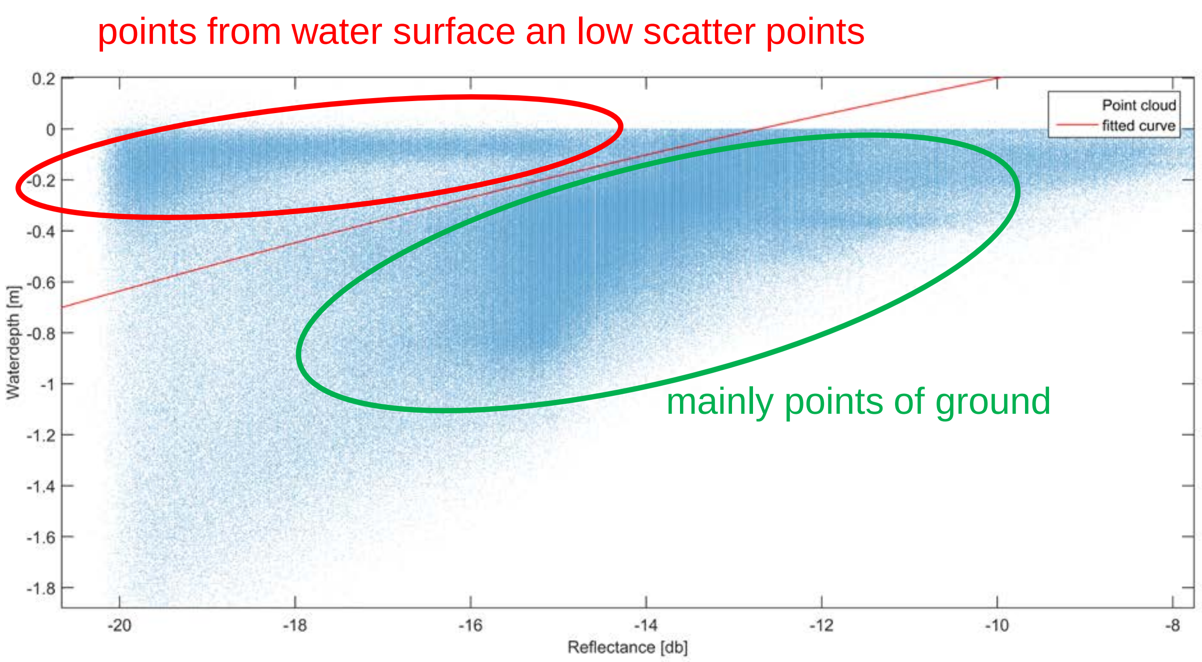
- Classification of points below water table into river bottom / water column / water surface required
- Problem area: Water surface and volume backscatter points available but no returns from river bottom
  → DTM calculation can be wrong
- Returns from ground but no return from water surface
  →DWM estimation can be a problem

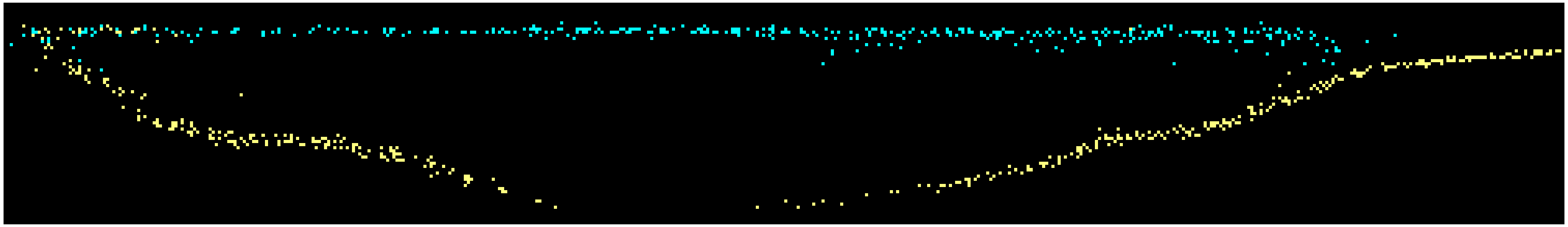


Classification of water points III

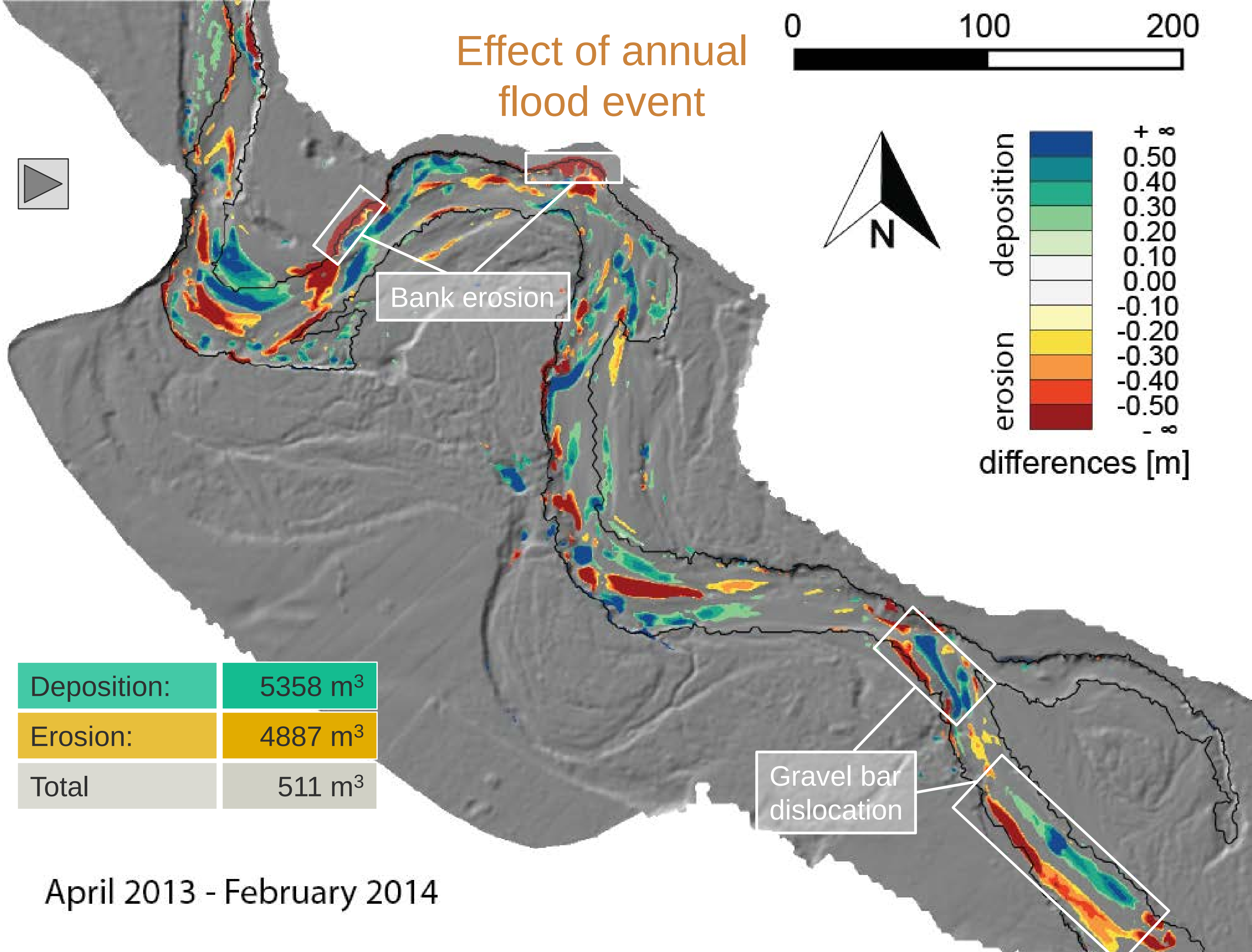
Analysis of decrease of the signal strength (reflectance) with increasing water depth

Ground point returns show higher reflectance than water surface and volume backscatter points at the same height.





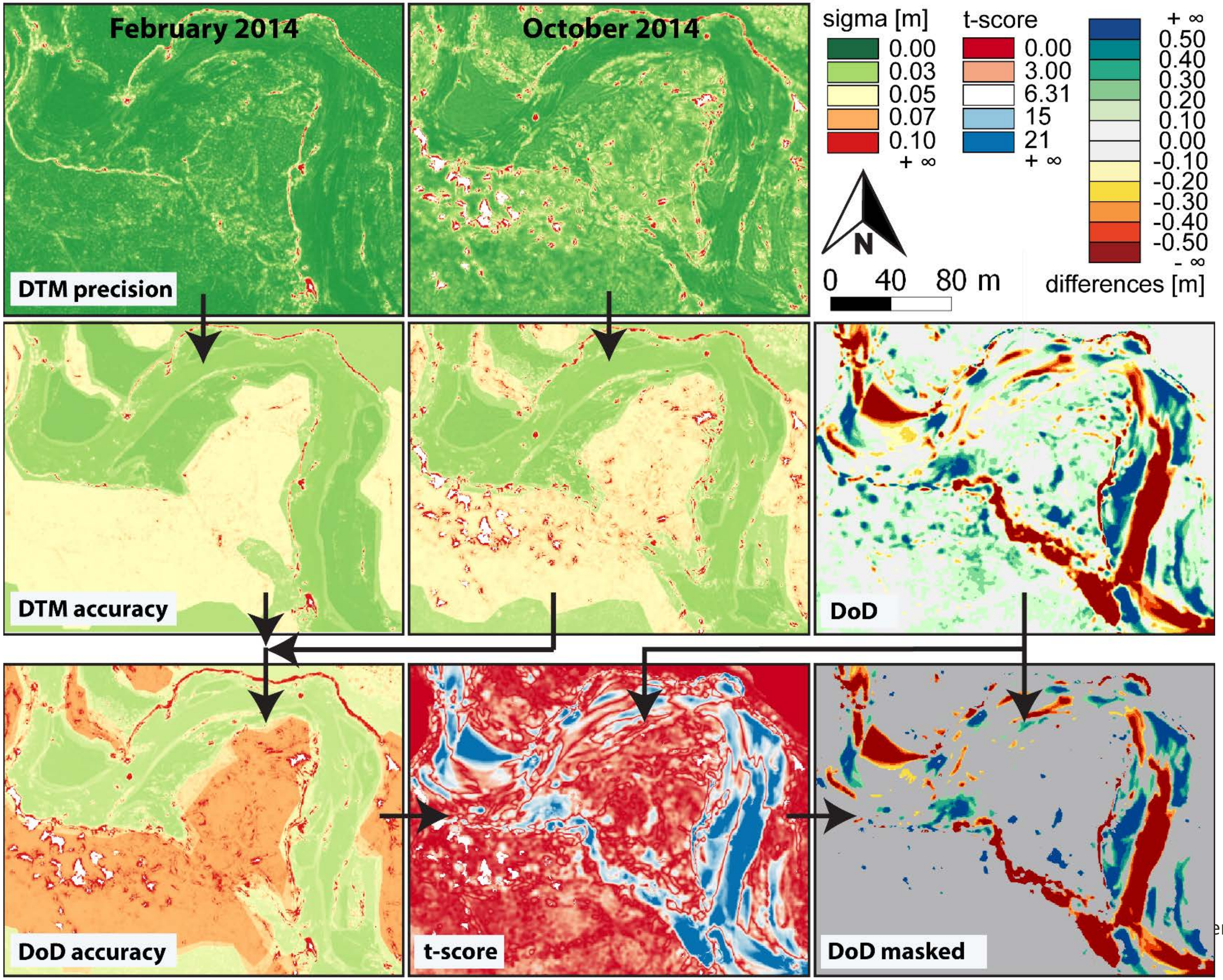
Effect of annual flood event



Deposition:	5358 m^3
Erosion:	4887 m^3
Total	511 m^3

April 2013 - February 2014

Documentation of morphodynamics based on DTM of Differences models



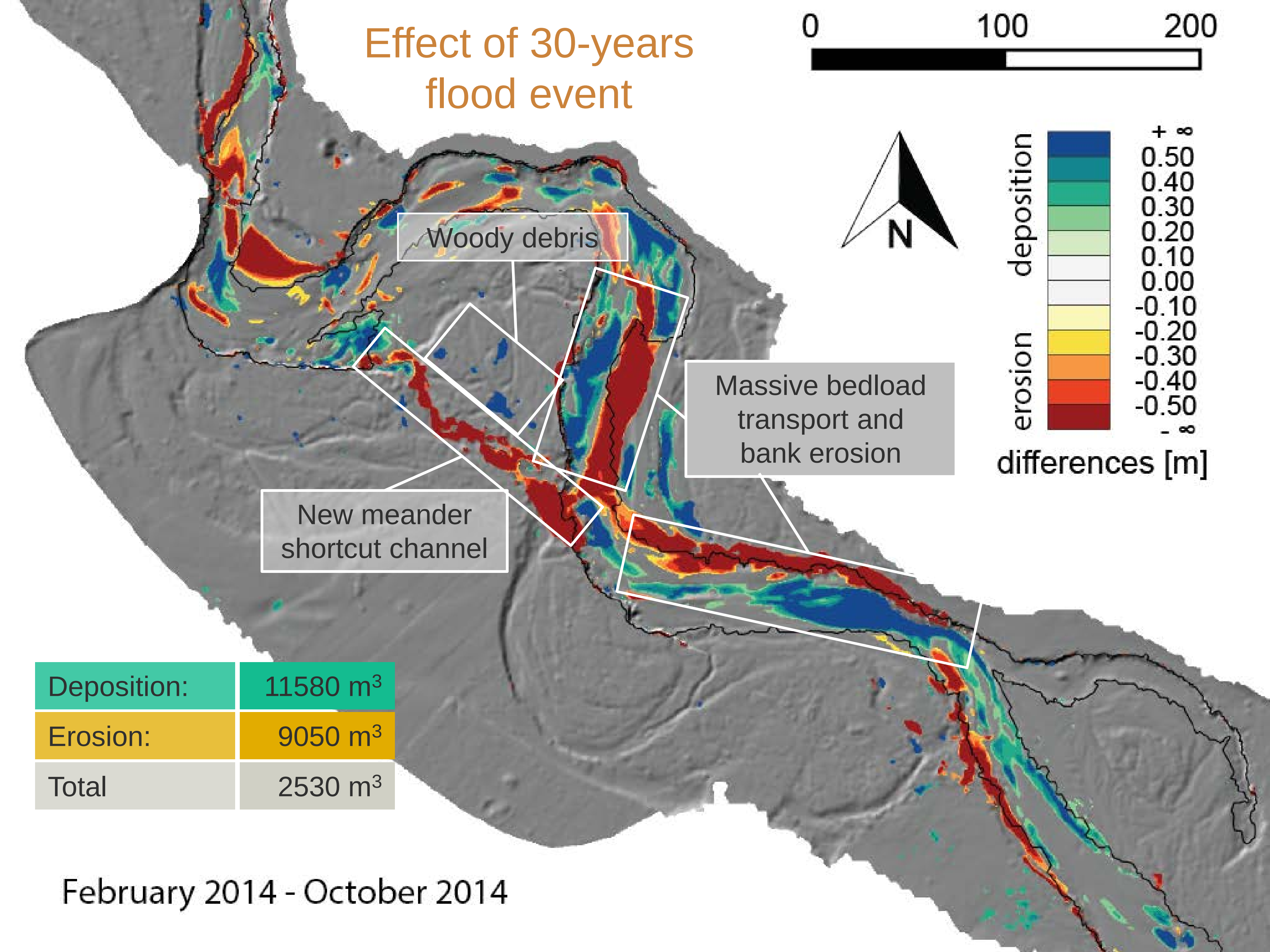
DTM precision

DTM accuracy + raw DoD

DoD accuracy + masked DoD

…r Luft",

Effect of 30-years flood event



Deposition:	11580 m^3
Erosion:	9050 m^3
Total	2530 m^3

February 2014 - October 2014

Ausblick auf Vorträge / Tutorials

- Waveform processing: Roland Schwarz
- Point cloud →DTM:
  - Presentation: Frank Steinbacher
  - Tutorials: Riegl/RiHydro, AHM/HydroVISH, TU Wien/OPALS
- Beyond DTM (Hydraulic modelling, habitat modelling):
  - Presentations: Wörndl/Jocham, Senfter, Hauer
  - Tutorial: UIBK
- User reports
  - Weiß (BfG), Rapp (Stadtwerke München)

Thank you for your attention

Neubacher Au, Pielach River, Data: Riegl LMS