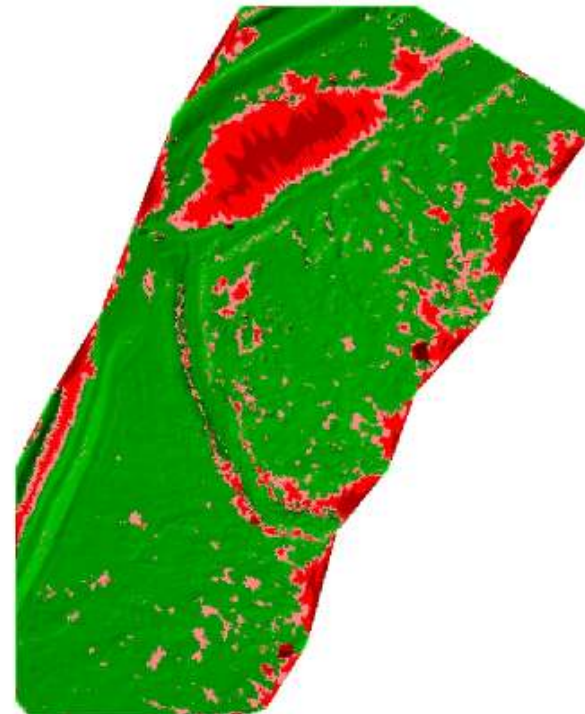


Automated Assessment of Digital Terrain Models Derived From Airborne Laser Scanning

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Castelldefels, Spain

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Agenda

- Current situation

- Proposed approach
 - Predicted point quality
 - Predicted surface quality
 - Example

- 'Real-time' demo

Current situation (ALS providers)

In-flight

- Trajectory "quality " (e.g. #of SV, time in flight-line)
- Laser:
 - % of returns or (predicted) point density (recently)
 - Swath/coverage – predicted or real (only recently)

After flight

Internal

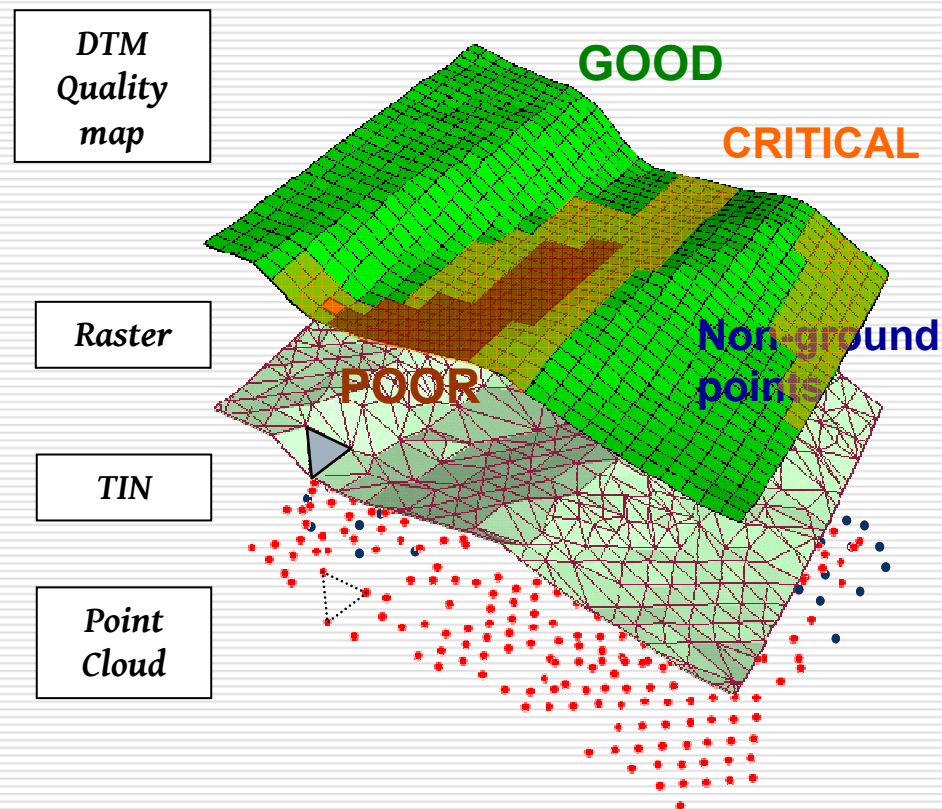
- Points: overlaps -> strip adjustment (cloud or rigorous)
- Surface: **ad-hoc**

External

- Points (usually non-signalized)
- Surface patches (TLS, photogrammetry)
- Problem: **restriction in area & accuracy**

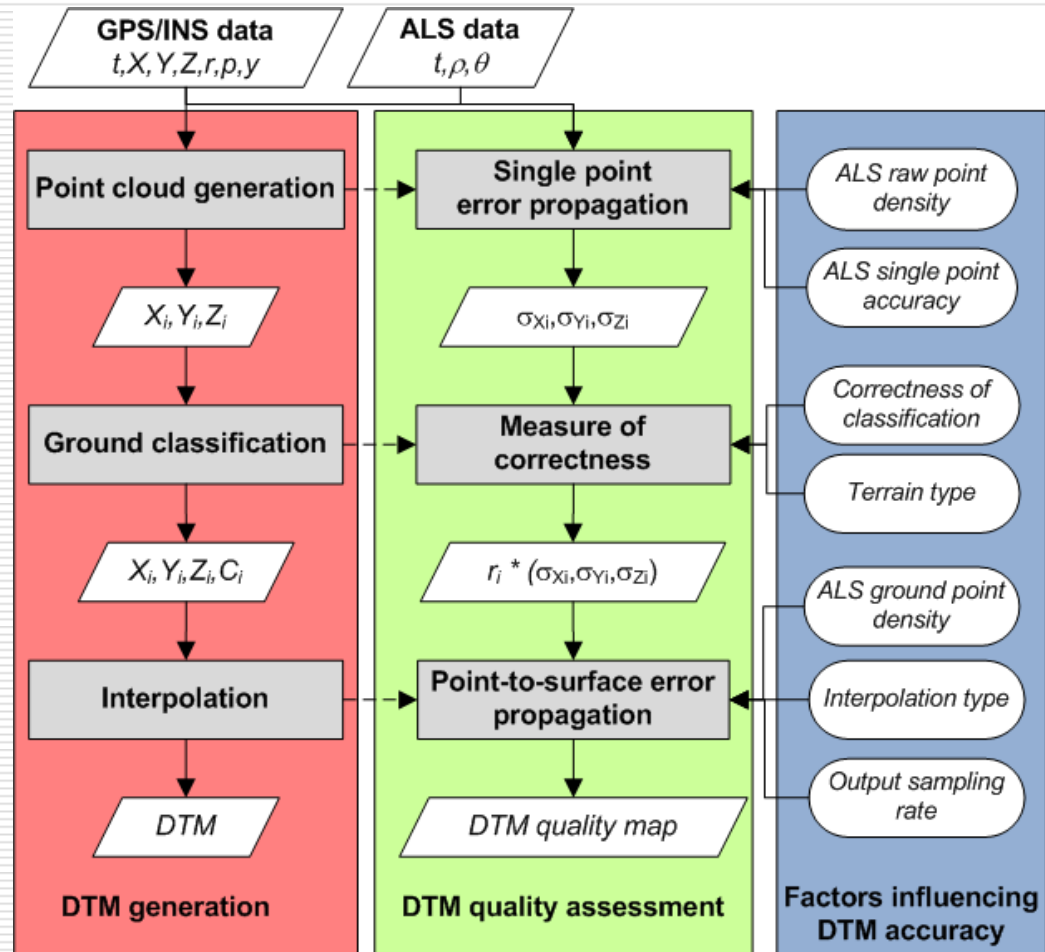
Proposed surface quality metric in ALS

- Considers sampling density + surface model type



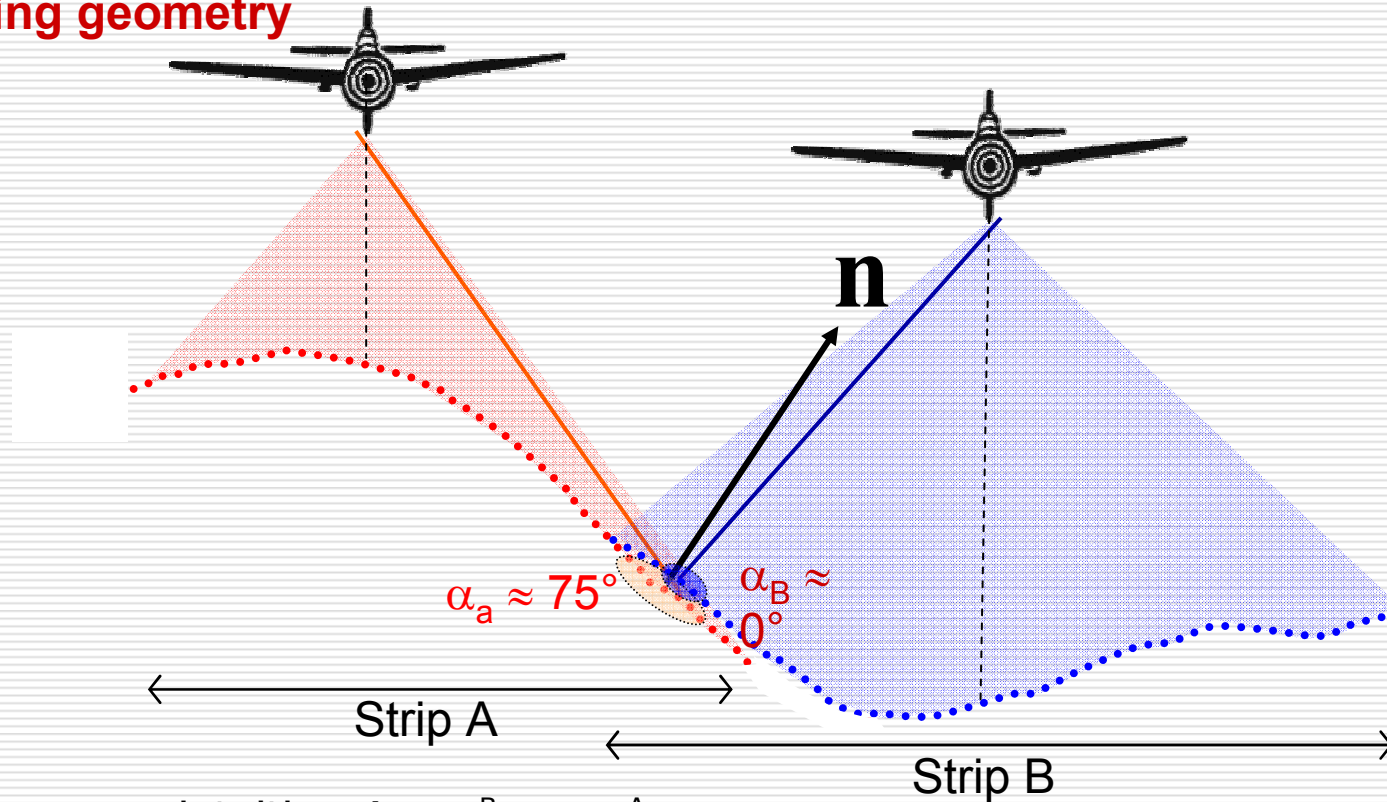
DTM accuracy

- Influence
 - Georeferencing
 - Classification
 - Interpolation



Influence of scanning parameters

Goal: Estimate point cloud accuracy within unclassified data including scanning geometry



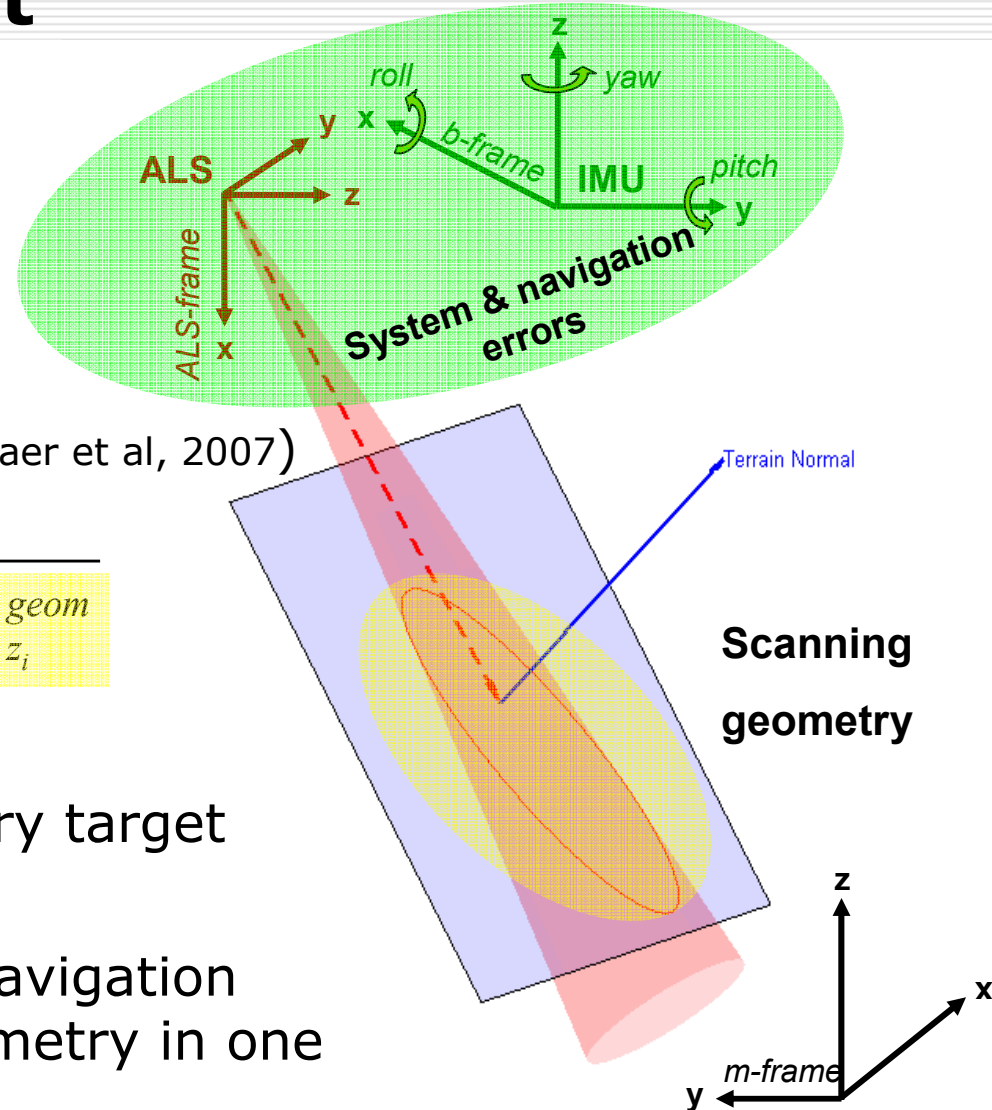
- Surveyors intuition $\rightarrow \sigma_{xyz}^B < \sigma_{xyz}^A$
- What is the influence of the incidence angle on precision of single point ?
- How to estimate incidence angle for each measurement if terrain is not known apriori ?

Target error budget

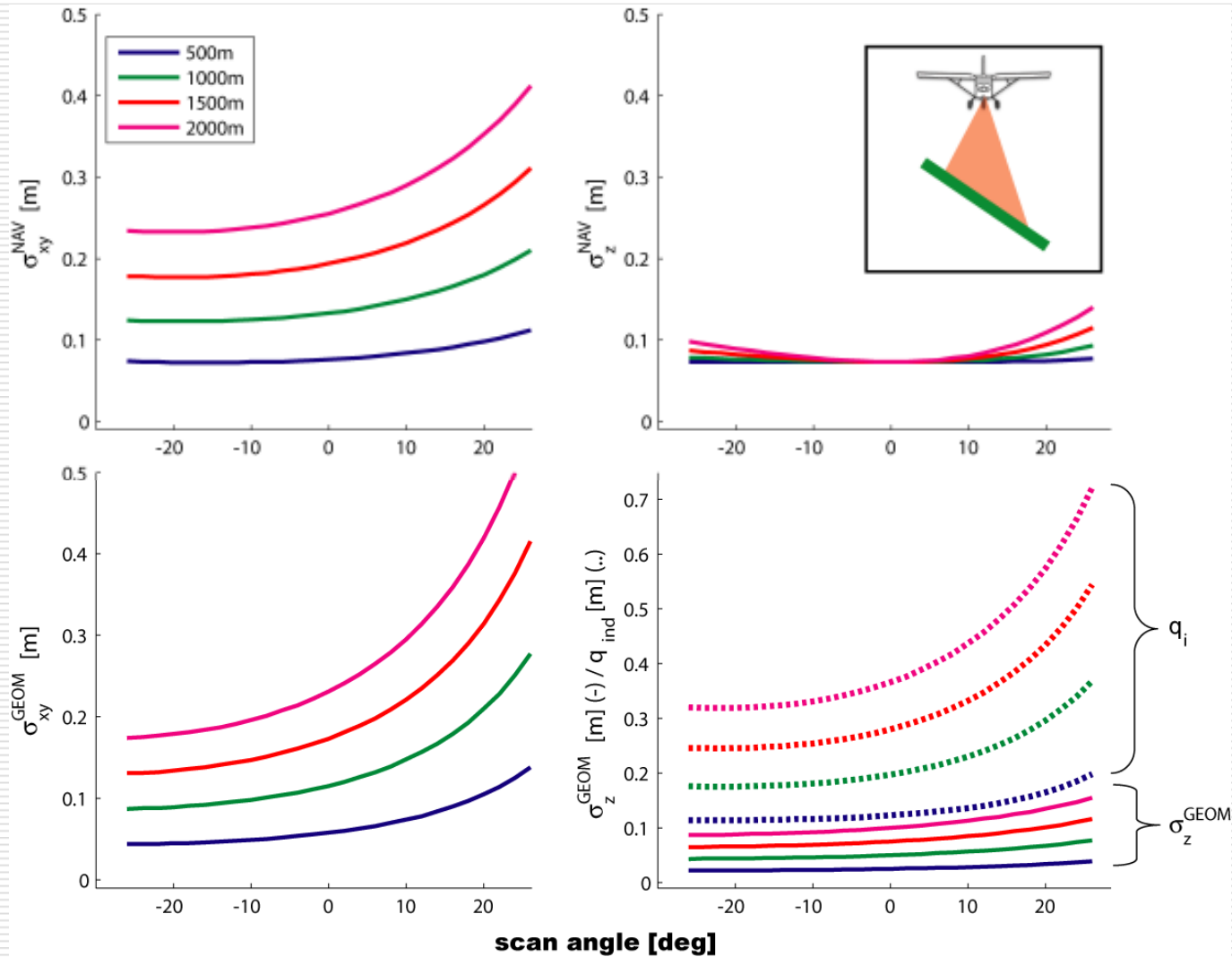
- (Most) ALS production
 - evaluates trajectory
 - assumes uniformity
- Rigorous
 - quality indicator (after Schaer et al, 2007)

$$q_i = \sqrt{\text{trace}(\mathbf{C}_{xyz_i}) + \sigma_{xy_i}^2 \text{ geom} + \sigma_{z_i}^2 \text{ geom}}$$

- Individual metric for every target
- Regroups influences of navigation errors and scanning geometry in one value

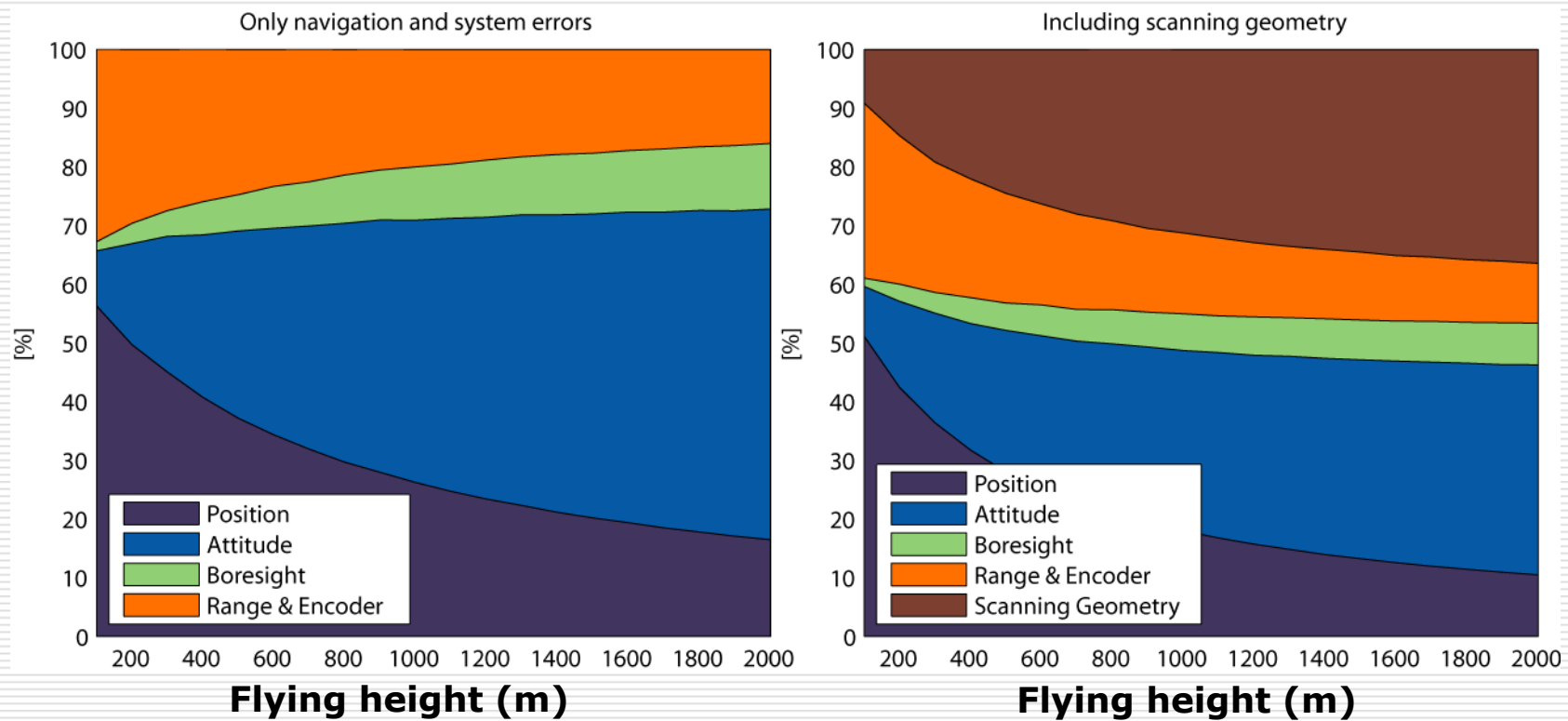


Error budget: **inclined terrain**

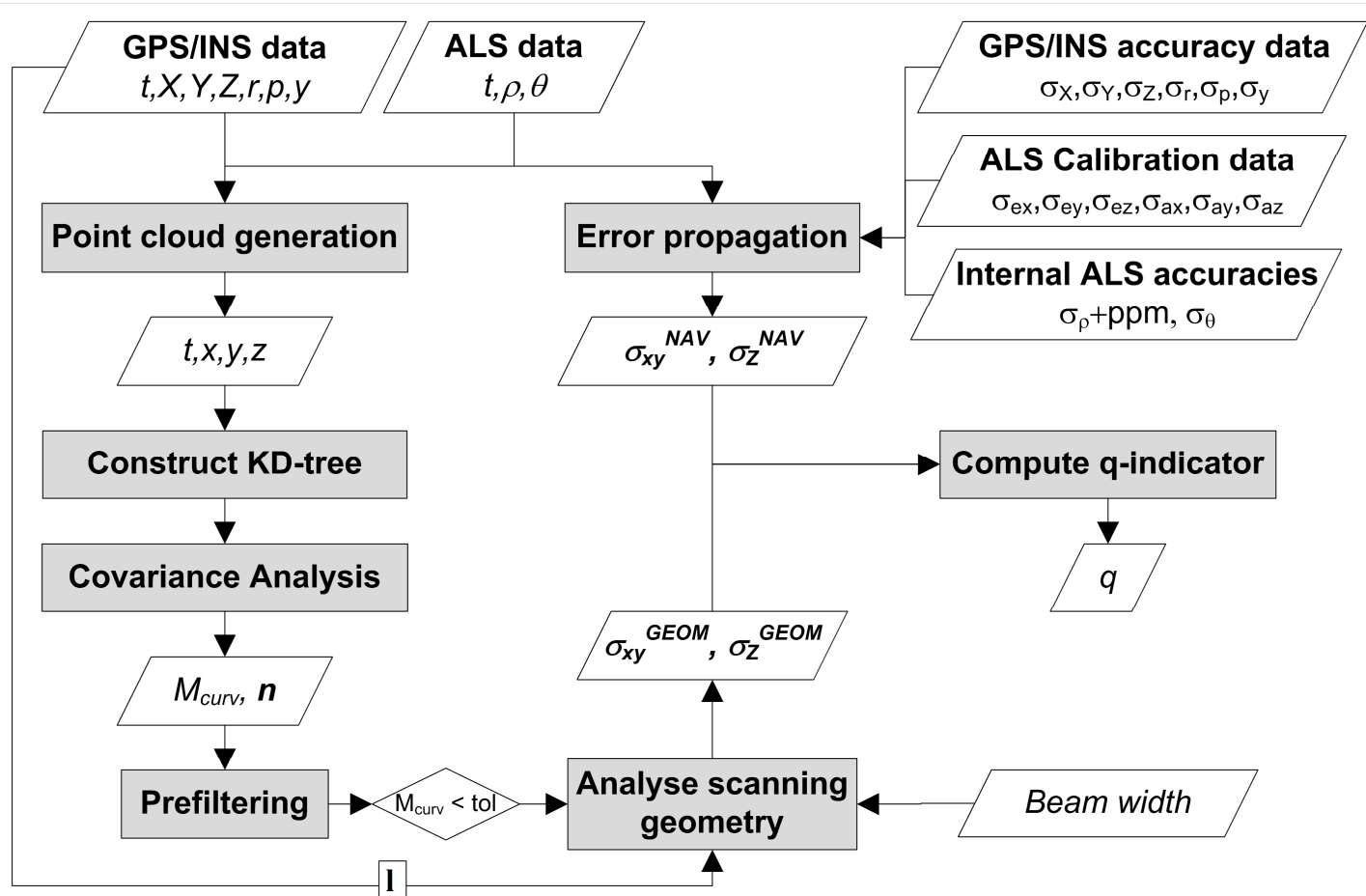


Error budget: distribution

□ Nadir-scan on tilted terrain (30 deg)

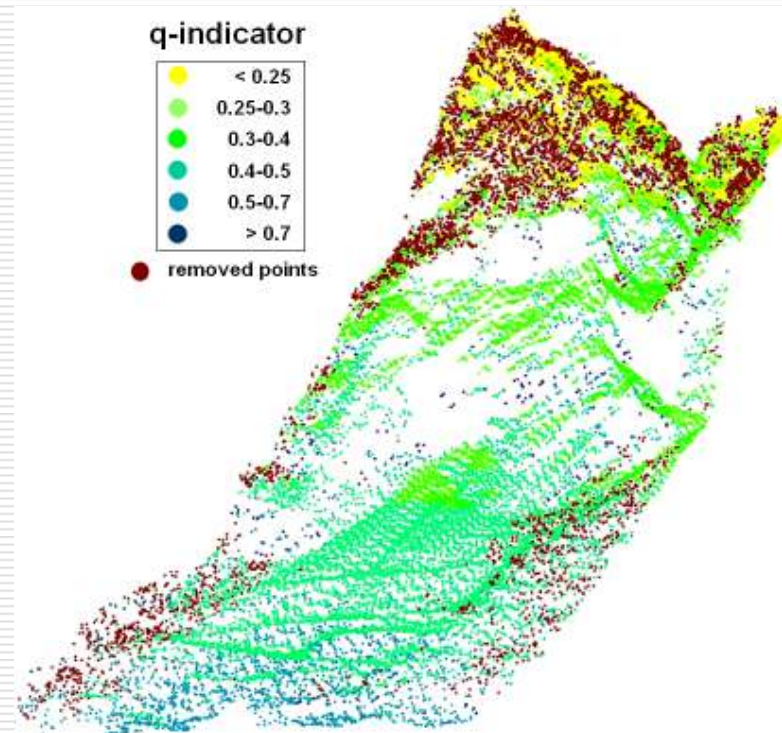


Point quality indicator workflow



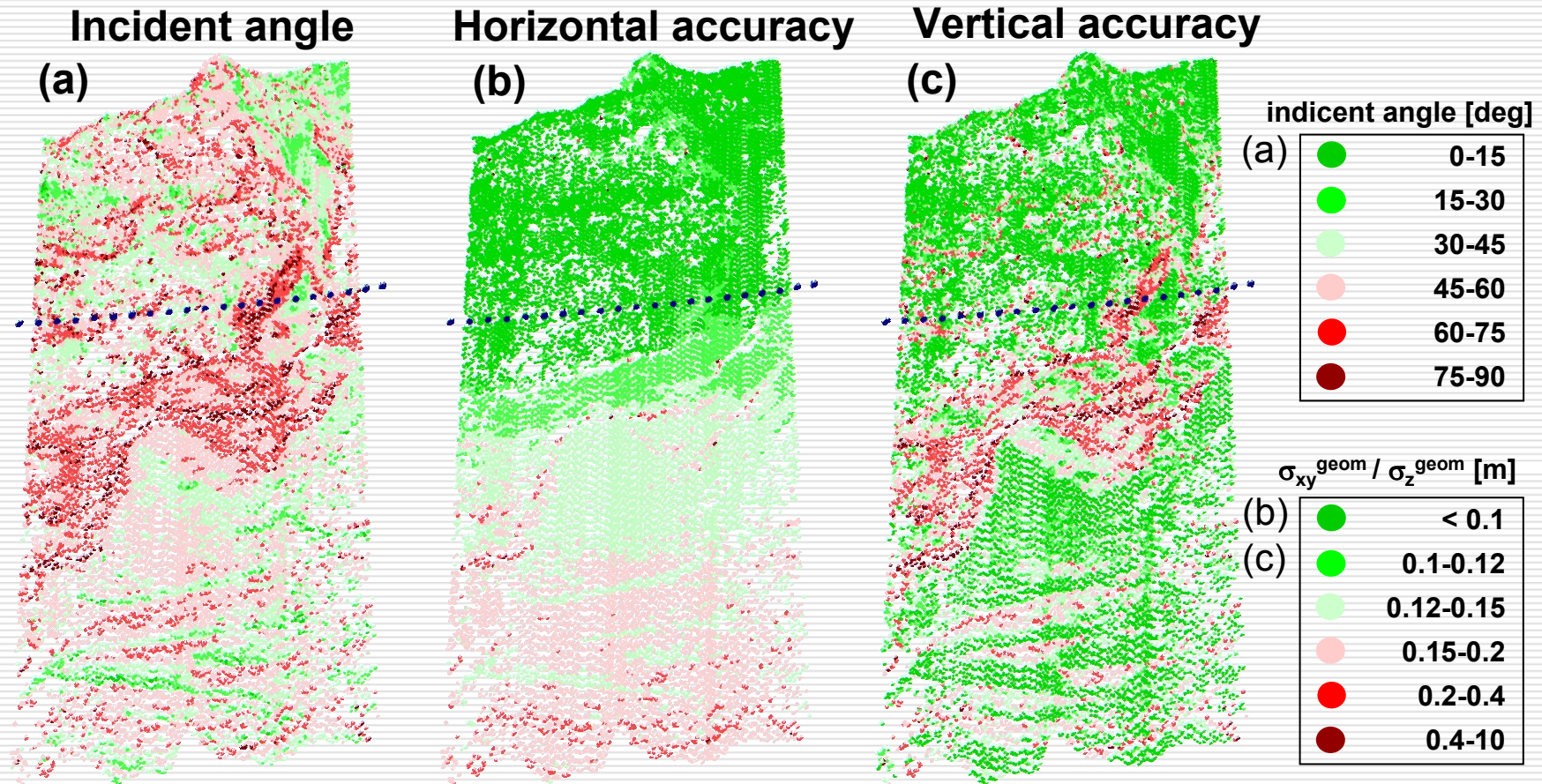
Example: long-range ALS

- Final quality (q) indicator



Point cloud accuracy

- Including scanning geometry



Motivation for surface indicator

- Practical example:



Limits of point quality indicator

- Good geometric quality (*q*-indicator) is not everything!
 - Point – is a discrete value!
 - Good *q* is only a **prerequisite** but ***not a guarantee*** for mapping surface with sufficient quality (sampling!)

- Possible approaches to surface quality:
 - **Ad hoc** quality measures
 - **Intuitive** - selection of points ($q > \text{threshold}$) + combination of density maps
 - **Rigorous** - use all points in a weighted manner (i.e. by *q*) while considering sampling density at the same time

Ad hoc (practical) quality measures

Example: after Vosselman 2010

□ Netherlands, country-wide ALS

□ Planimetric accuracy

■ Measuring ridge lines in strip overlaps

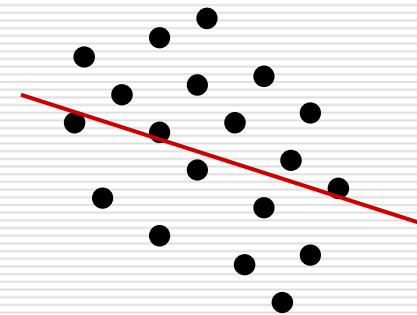
■ An object of 2x2 m can be outlined with the point cloud with a max. error of 0.5 m

Max error in linear segment:
= half of the point spacing

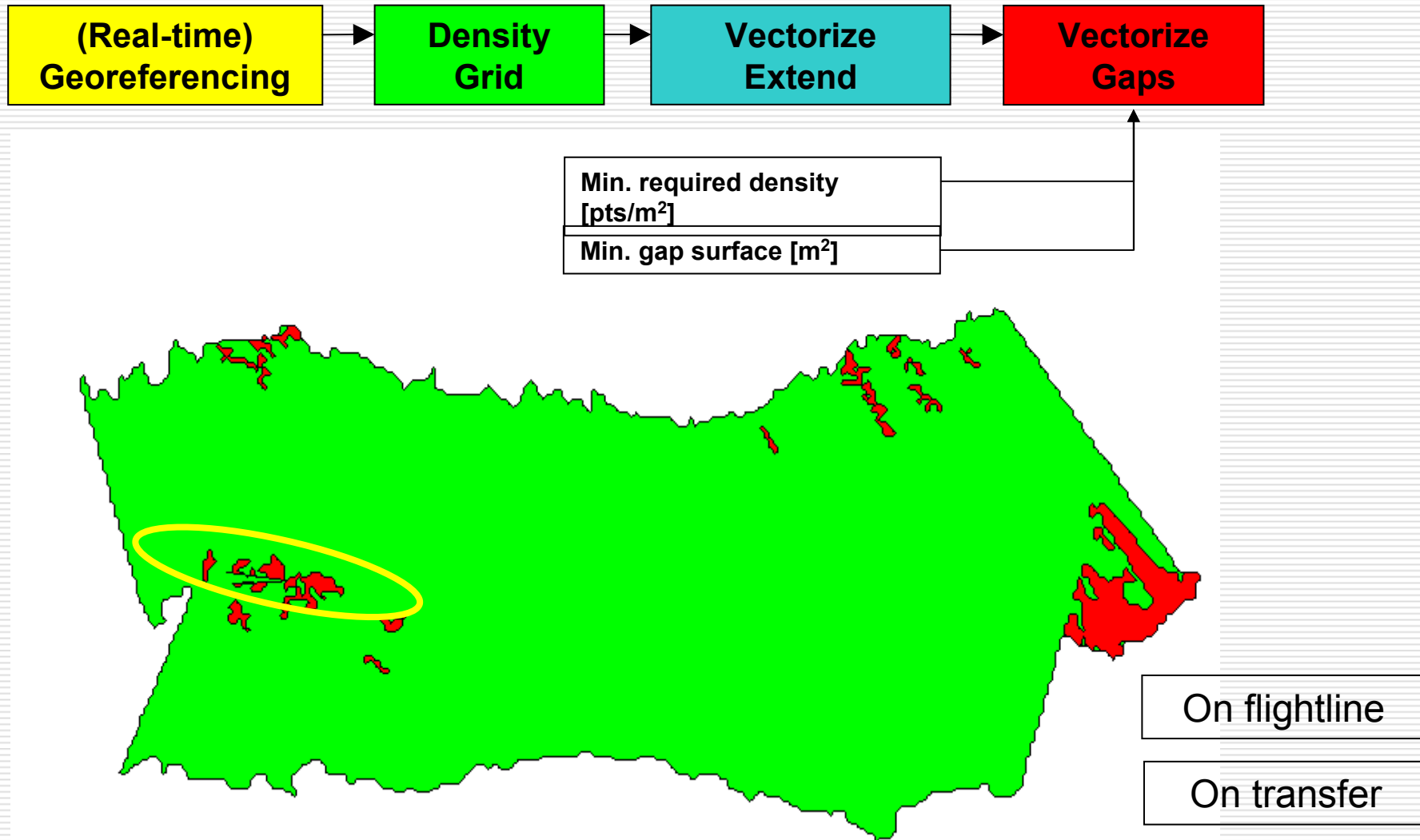
■ Point spacing/density

$$\Delta_{pd} = \frac{1}{2\sqrt{n}} m$$

■ Max. error:

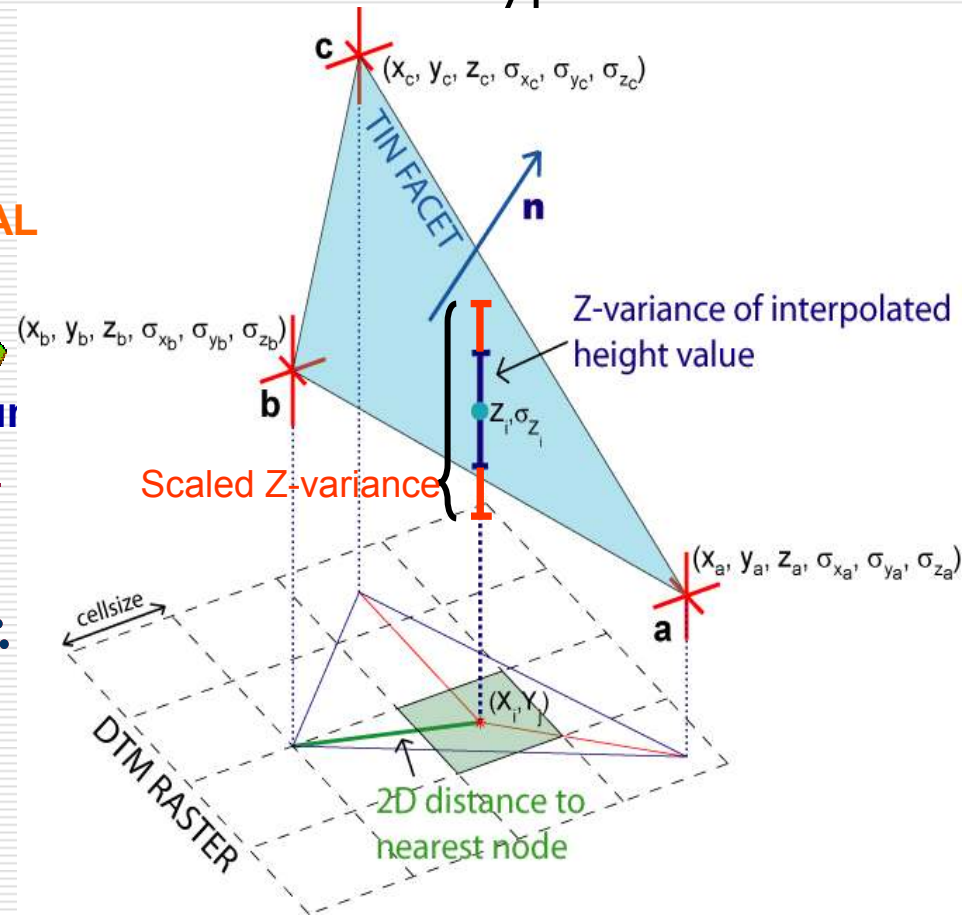
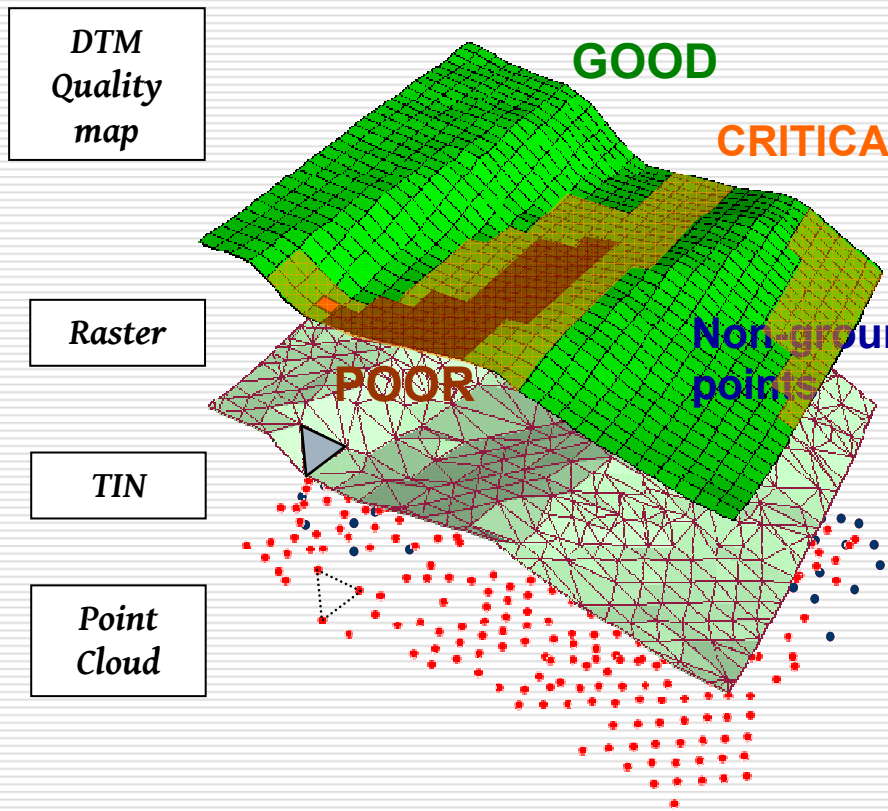


2D density grid – use of gaps + extend



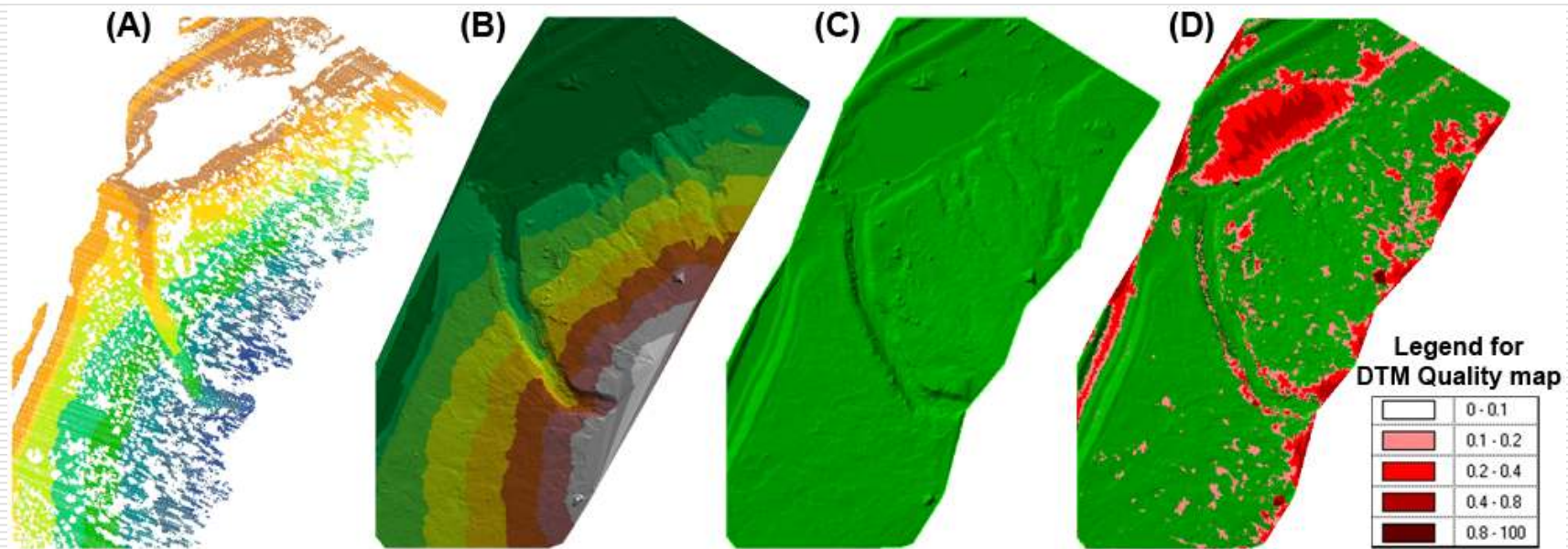
Proposed surface quality metric

- Considers sampling density + surface model type



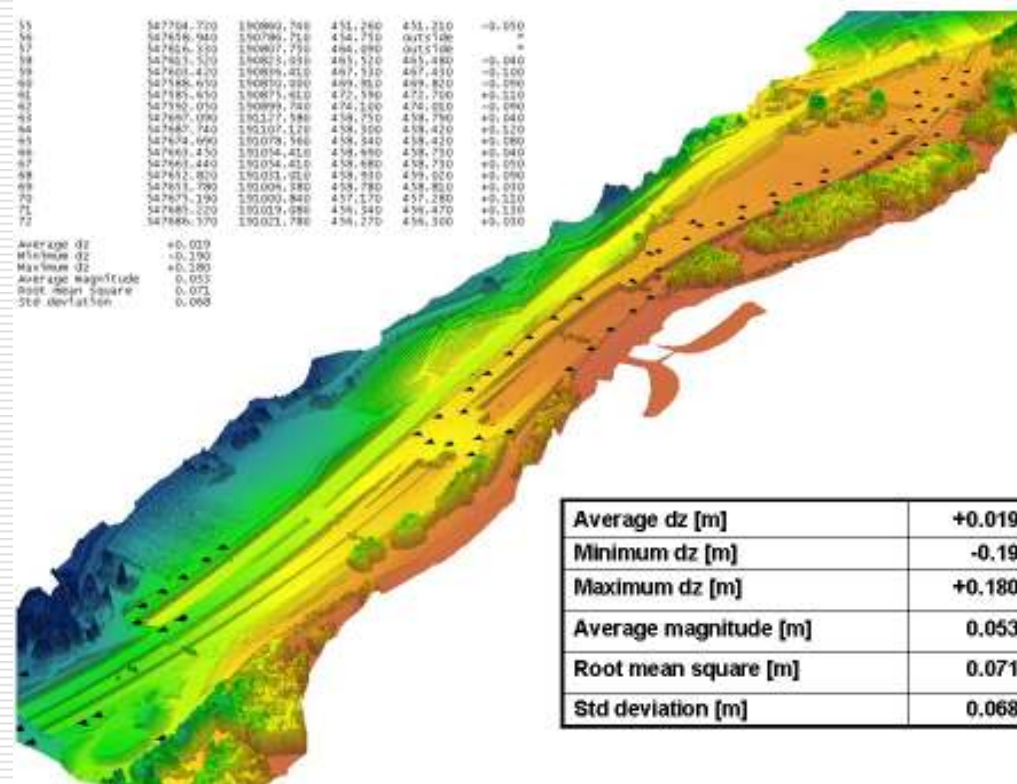
Application example

- (A) – auto classified ground points colored by elevation
- (B) – DTM-TIN
- (C) – DTM raster interpolated from TIN
- (D) – DTM quality map superimposed on DTM & color-coded

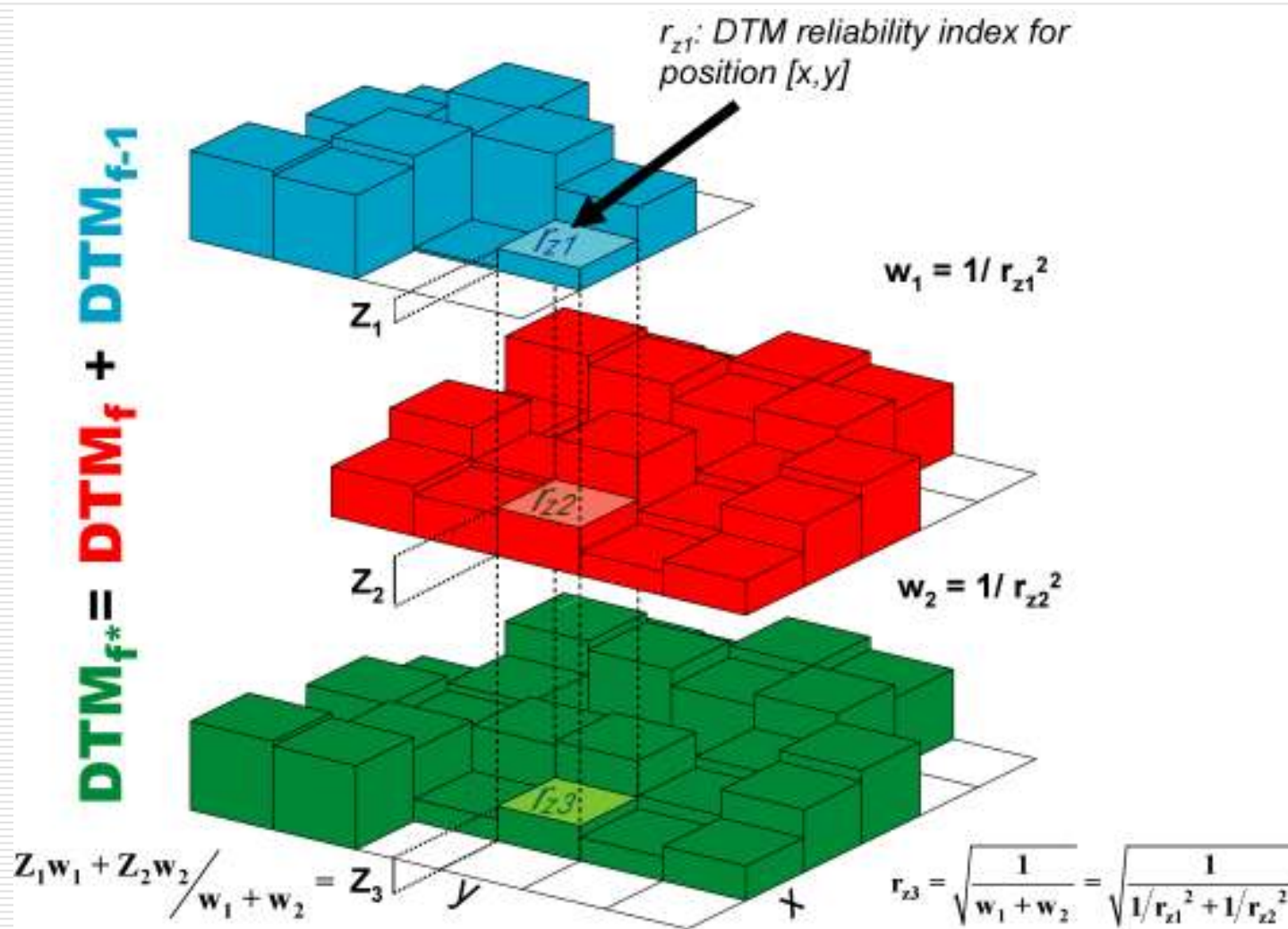


Applicability of DTM quality maps

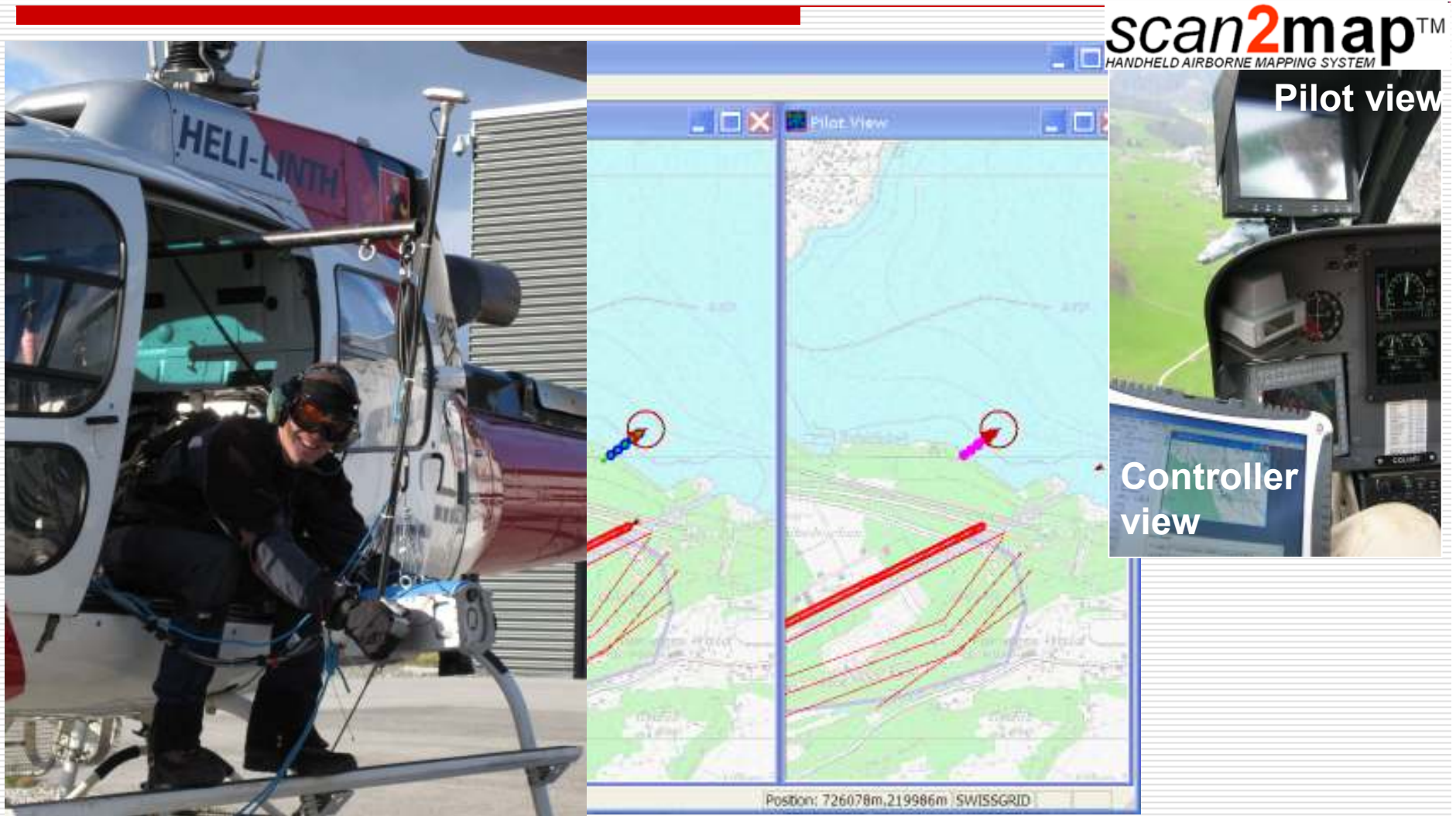
- ❑ Confidence of obtained DTM
- ❑ Reliability of derived quantities (aspects, slopes)
- ❑ DTM merge



Rigorous DTM merge: f (sampling & quality)



Demo in ALS mapping & quality control



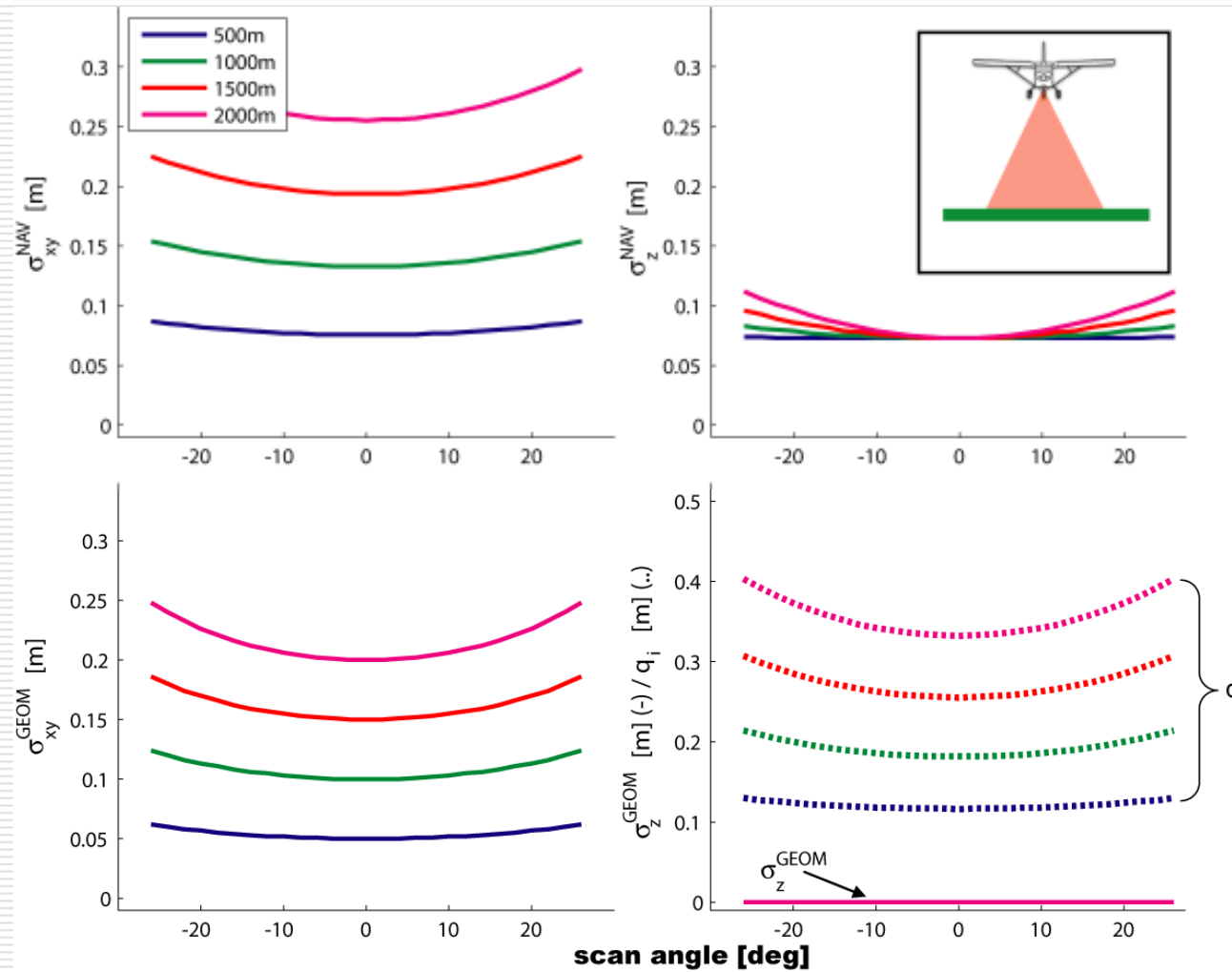
Summary

- Surface quality map
 - New rigorous approach to ALS surface quality
 - Based on combination of error propagation & sampling
 - Reflect dynamic nature of the process

- Internal measure (i.e. reconstructed from data itself)
 - Highlight area of low reliability or confidence
 - Global coverage
 - Compatible with strip adjustment

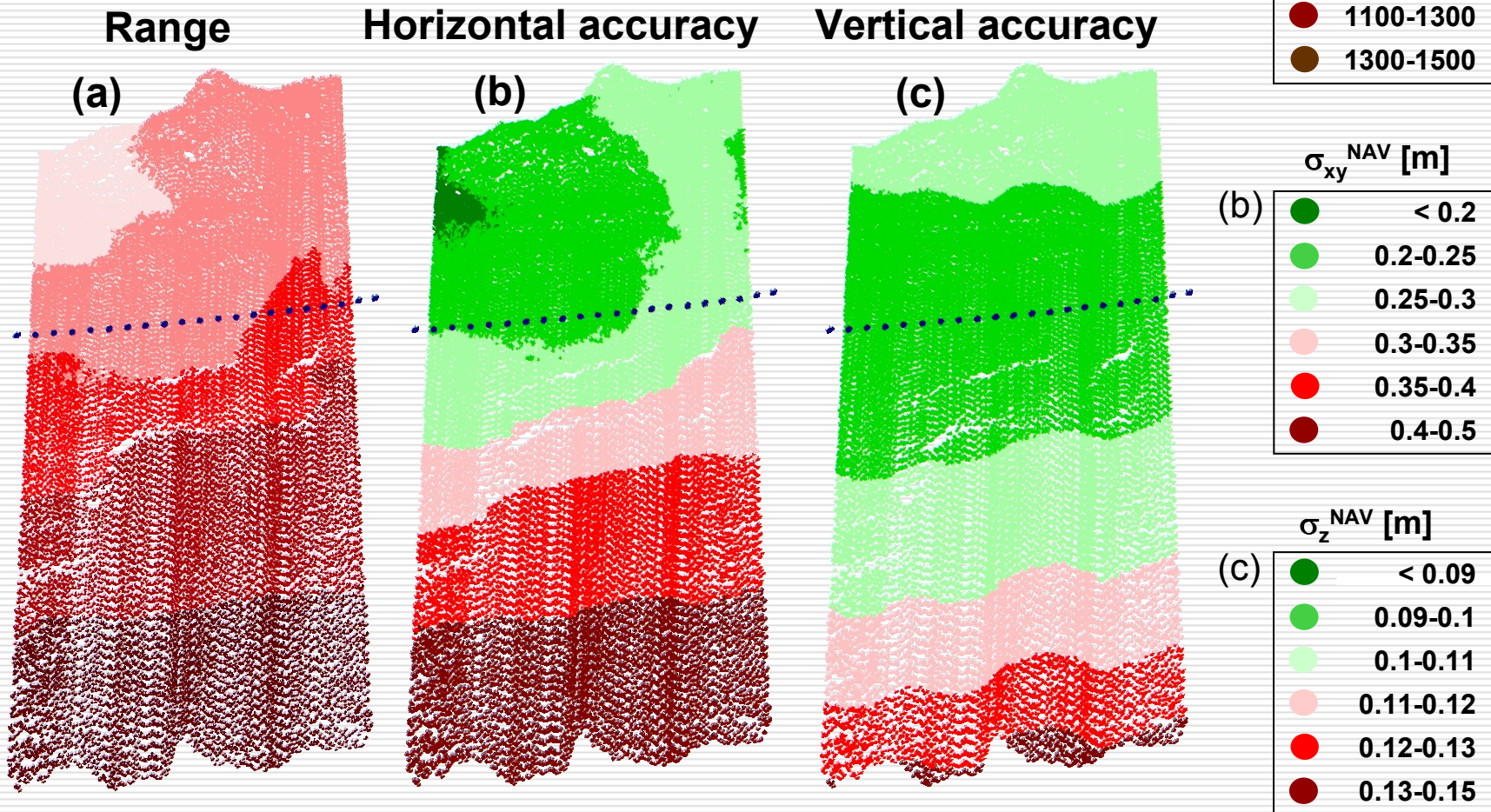
- Application
 - Post-processing or real-time (see Schaer et al. 2010)
 - Applicable for derived quantities (e.g. slope, aspects)
 - Merging data from different sources

Error budget: nadir-scan & flat terrain



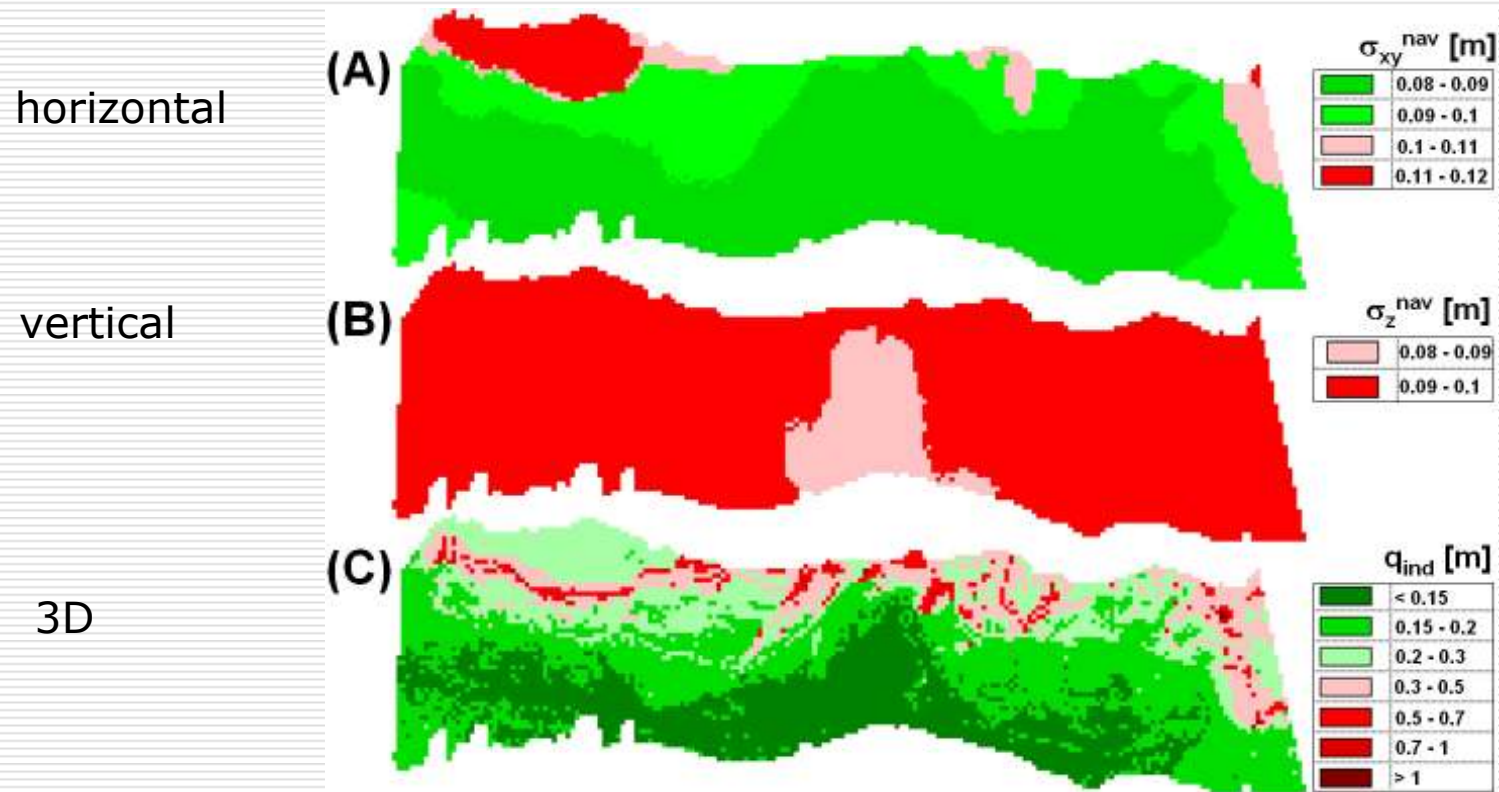
Point cloud accuracy

Navigation errors

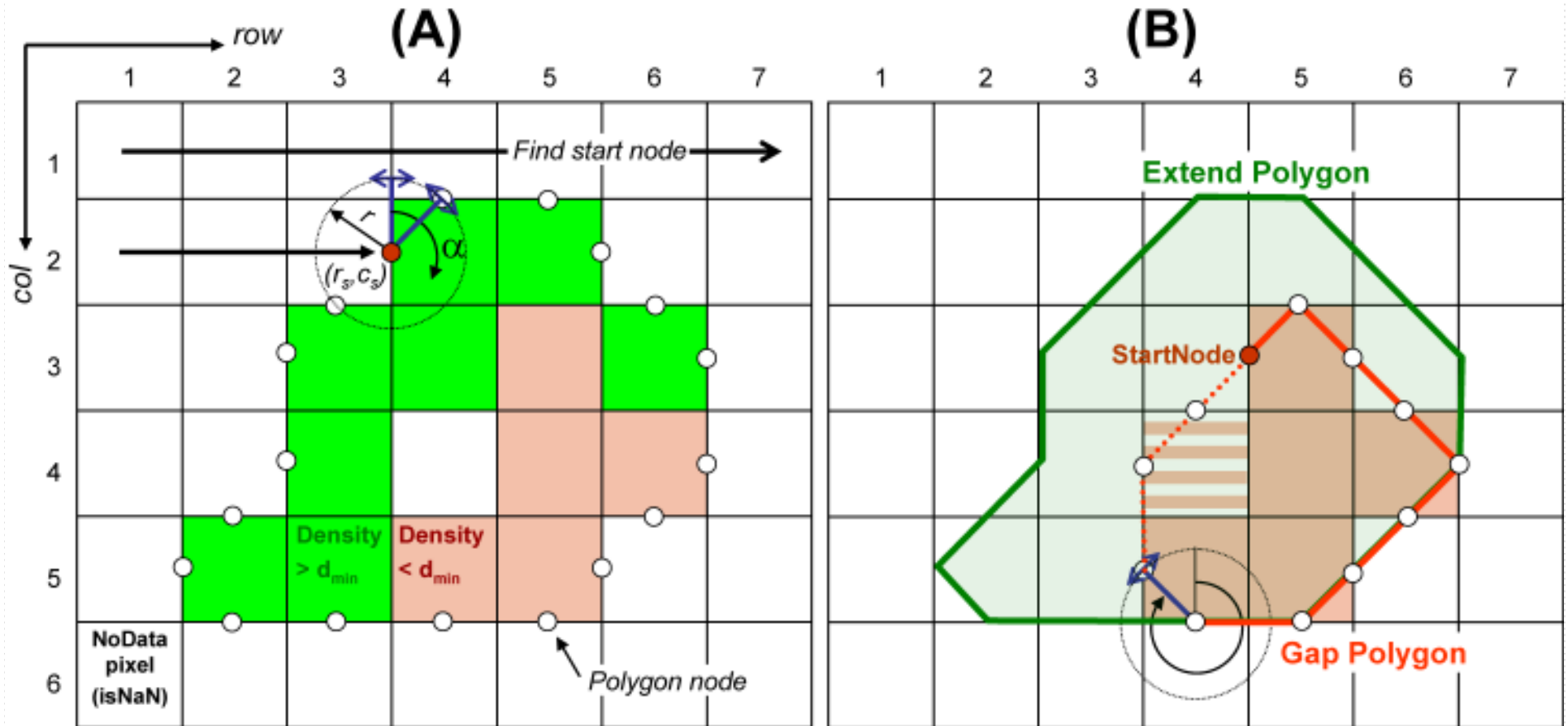


Point cloud accuracy

□ Accuracy map



Extend and gap evaluation



2D point density grid

- Create raster of certain size of a cell (c)
- Count the # of laser point per cell
- Normalize the count by the size of a cell (c^2)

$$\rho_{c \cdot c}^{2D} = n / c^2 \left[pts / m^2 \right]$$