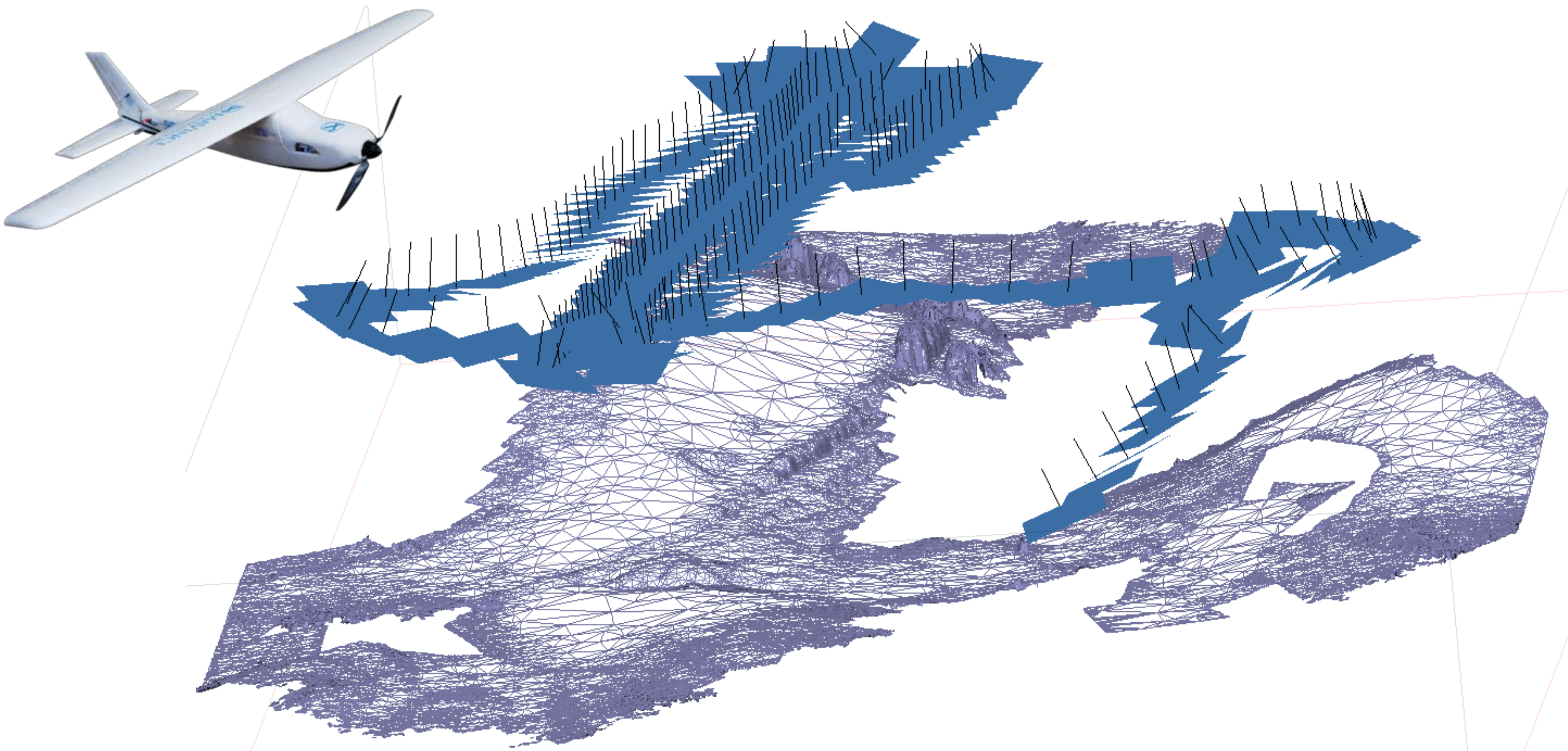
High-Res Digital Surface Modeling using Fixed-Wing **UAV**-based Photogrammetry

Niels Anders, Rens Masselink, Saskia Keesstra, Juha Suomalainen



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Outline

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  - Research objective
- **Methods**
  - Study area
  - Airplane specifications
  - Flight campaign
  - Data processing
- **Results**
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  - Visualization of Land Surface Parameters
- **Discussion**
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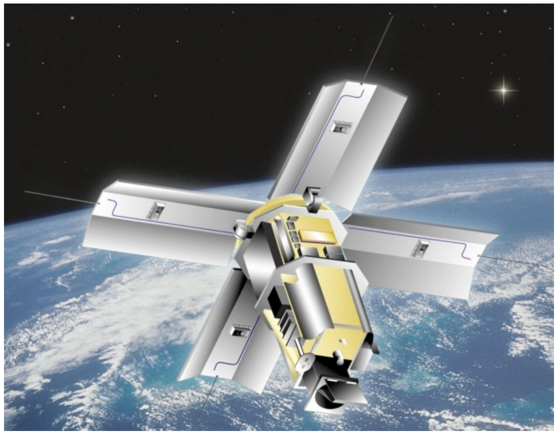
  - Potential for geomorphometrical and geomorphological research
- **Conclusions**

What?

- Unmanned Aerial Systems
  1. Remotely Piloted Aircrafts
     - Rotary-wings, multicopters
     - Fixed-wing aircrafts
  2. Flight planning software and GPS-based automated navigation
- Typical carrying capacity: 0.5 – 3kg
  - RGB cameras for photogrammetry
  - Multi-/hyperspectral sensing
  - Radar? LiDAR?

Why Unmanned Aerial Systems?



	Satellite	Manned Aircraft	Unmanned Aerial Systems	
			rotary wing	*fixed-wing*
Area coverage	++	+	-	+/-
Spatial resolution	-	+/-	+	+
Temporal resolution	-	+/-	+	+
Sensors	+	+	+/-	-
Costs	+/-	-	+	+

Research objective

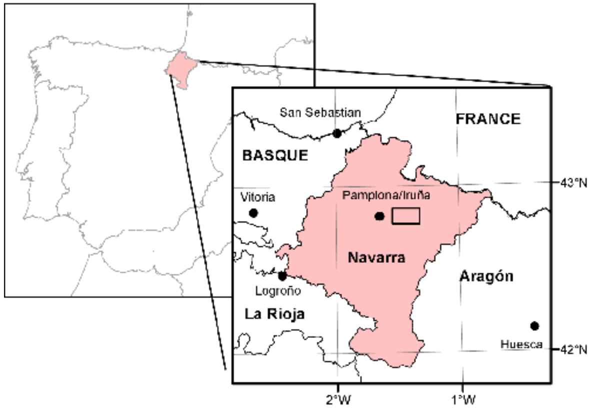
- Test UAS photogrammetry as a tool for acquisition of high-res multi-temporal digital surface models
  - Spatial resolution
  - Vertical accuracy
  - Effect of flight altitude

- Investigate the potential for geomorphological applications

Methods

Study area

- 2 km^2 agricultural catchment in Navarra, N-Spain
- 500-700 m; 700 mm mean annual precipitation
- Marls and clayey soils
- Erosion processes
  - Sheet erosion
  - Rill erosion
  - Shallow landsliding



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Methods

Airplane specifications

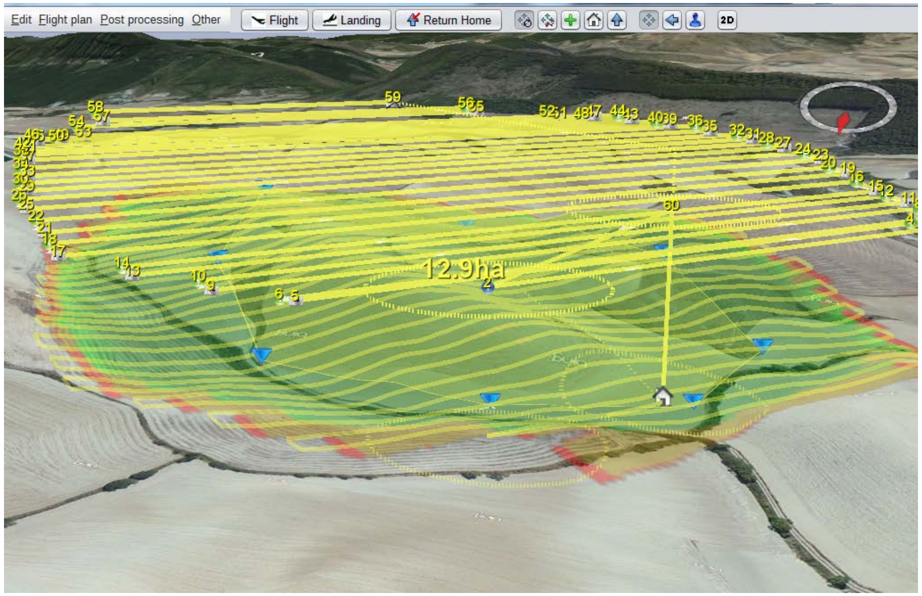
- MAVinci fixed-wing aircraft
  - 1.6 m wingspan
  - 2.6 kg (incl. camera)
  - Electrically powered (LiPo)
- Panasonic Lumix GX1
  - 16 MP, 2.5 fps
  - 20 mm f1.7 lens

- Total costs: € 30 k, incl. software
  - *Ready-to-fly* for non-pilots
- Other *Do-It-Yourself* aircrafts for experienced pilots available from € 2 k

Methods

Flight planning software

- AOI selection on Google/Bing maps
- Defining ground sample distance
  - Flight altitude is estimated based on camera specifications
- Automated generation of flight plan (3D GPS waypoints)
- Possible optimizations for minimum flight length or topography



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Methods

Ground targets

- 50 ground control targets
  - Self-placed targets and easy-to-identify fixed targets
- Measured with Leica dGPS system

Methods

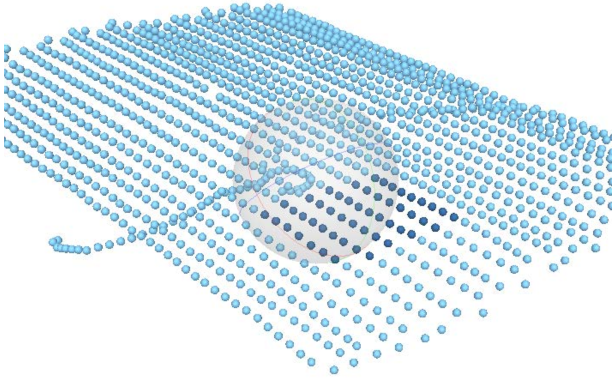
Flight campaign

- Flight
  - Take off from hand
  - Wait for airplane to finish flight plan
  - Monitoring status on laptop
- Assist airplane to land
  - Manual mode
  - Assisted mode
  - Fully automatic
- Output: 8-bit JPEG
  - 65-85% side-/overlap
  - 1-2 k images per 0.2 - 0.5 km^2

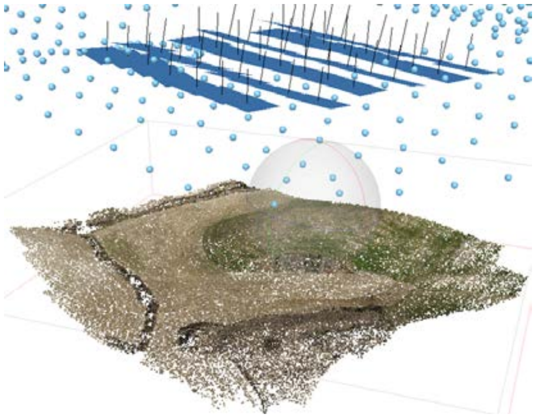
Methods

Data processing

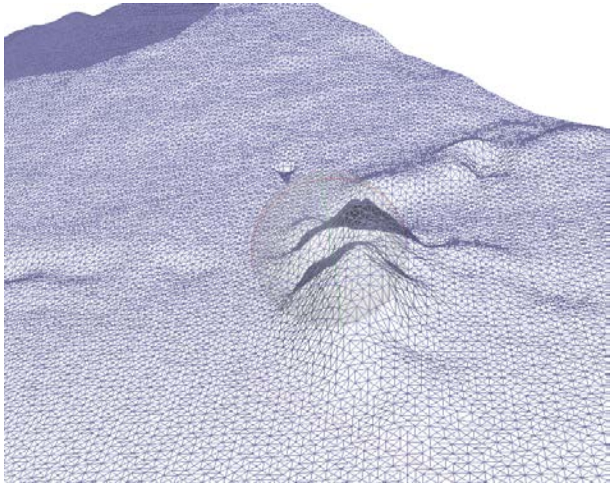
- Structure from Motion/MultiView Stereopsis
  - Agisoft PhotoScan Pro (commercial, € 500)
  - VisualSfM (open-source)



Optional: GPS-tagged images



Camera alignment and matching image points (Structure-from-Motion)



Revisit images and calculating geometry/dense point cloud (MultiView stereopsis)

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Results

Dense point cloud

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Results

Data products

- Main data products
  - 3D point cloud
    - 750,000,000 Pts / 25ha
    - 3000 Pts / m^2
  - Digital Surface Model
    - Weighted average
    - Natural Neighbor
  - Orthomosaic

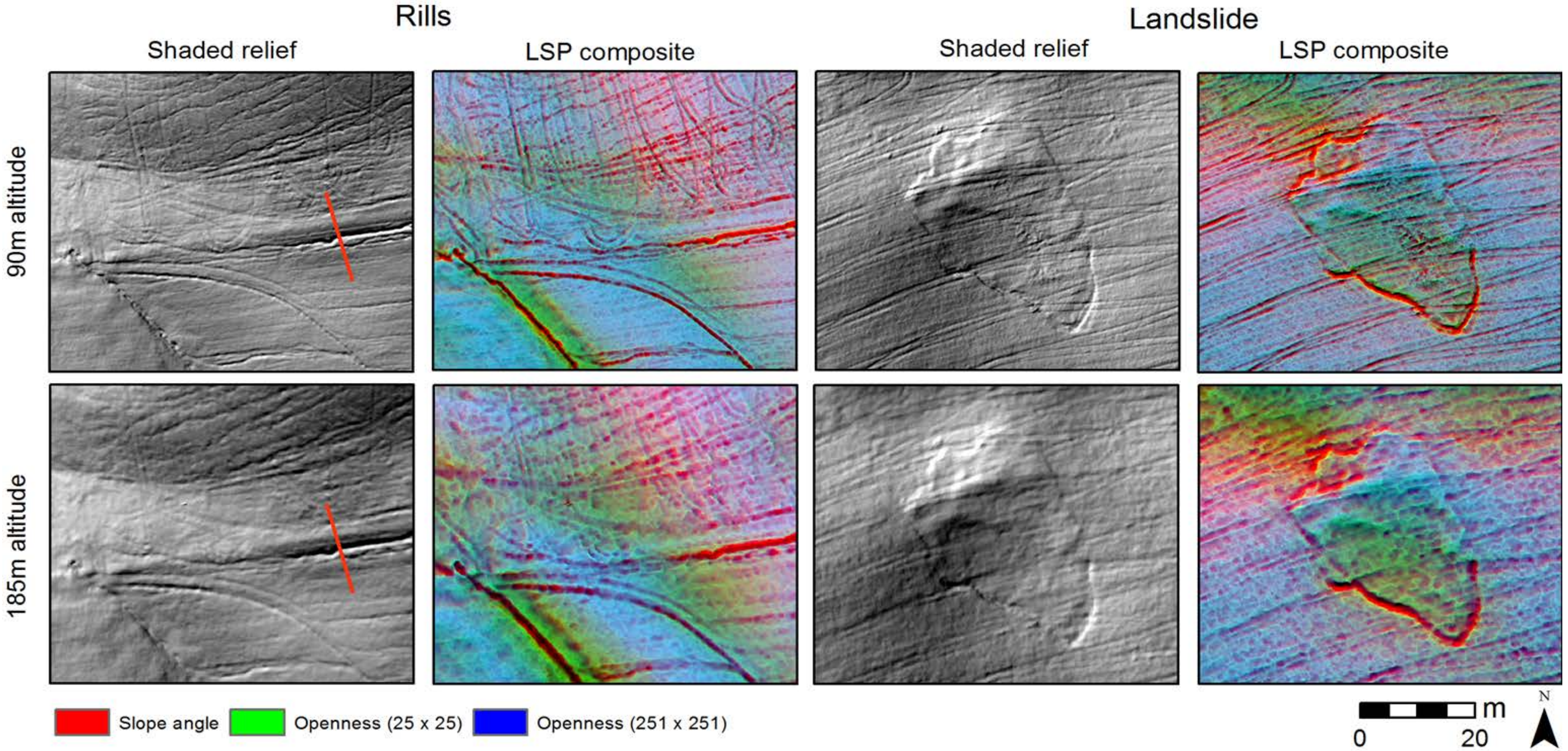
Point cloud

Orthomosaic

DSM

Results

Altitude versus data quality



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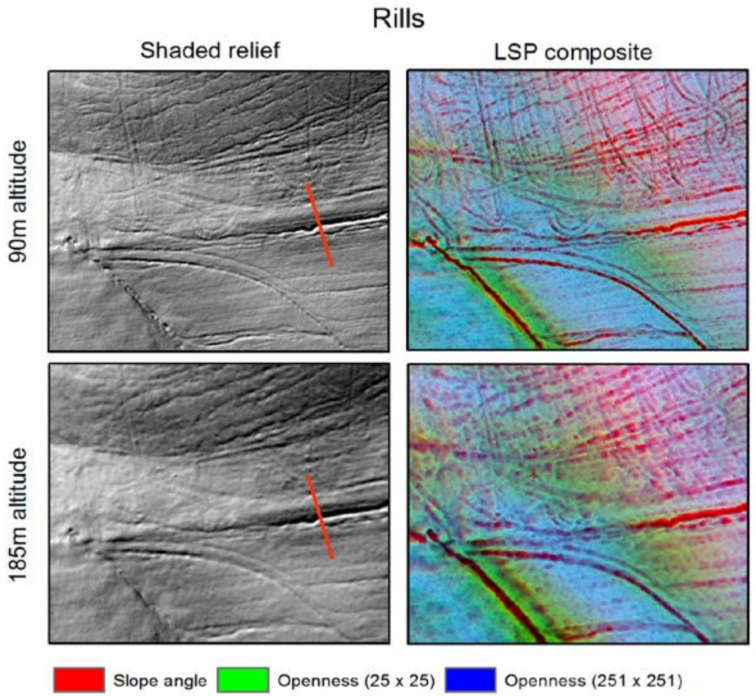
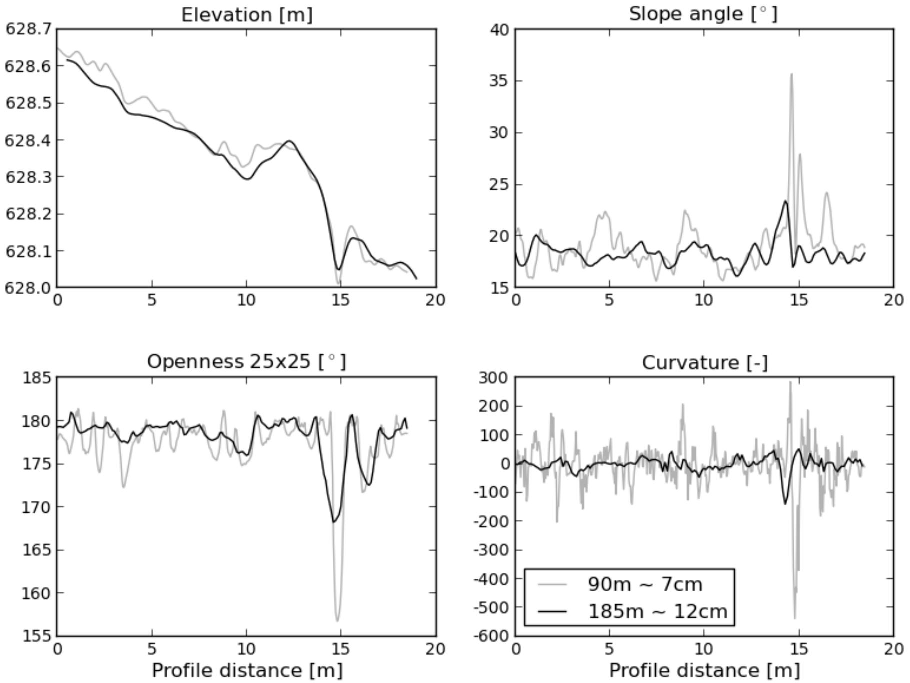
Results

Altitude versus data quality



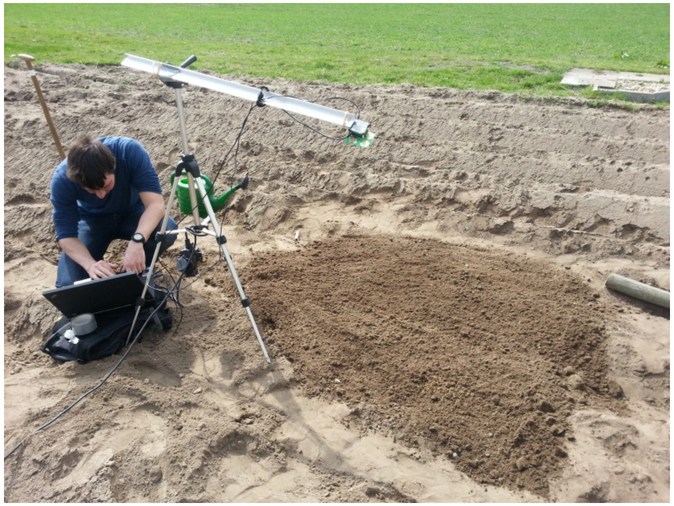


Flight altitude [m]	GSD [cm]	DSM cell size [cm]	Standard deviation [cm]
90	1.5	7	35
185	3	12	45

Discussion

Pros

- UAVs can be utilized at almost any moment in time (not too strong wind/rain) -> highly flexible for acquisition of multi-temporal data
- Very high detail, even small rills and tractor paths are captured
- Continuous developments of light-weight sensors -> possible equipment in the near future
- Fully automated (with the exception of placing and identifying ground control points)



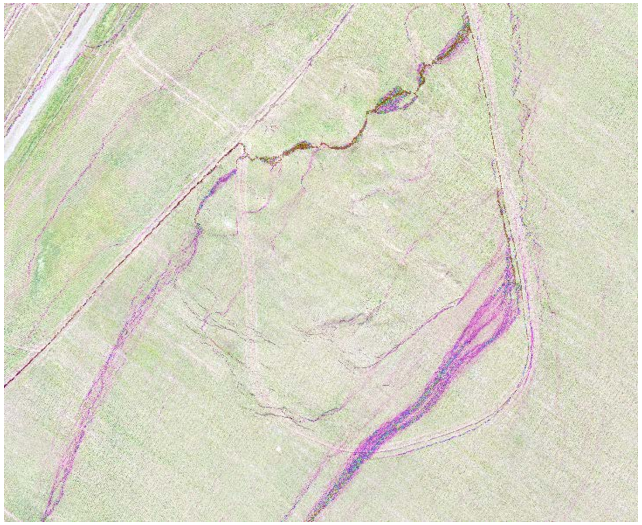
Discussion

Cons

- GSD is not uniform in areas with high relief. Effective resolution may be larger in lower situated areas.
- DEM quality is highly dependent on the number and distribution of ground control points. Inaccessible areas are prone to lower accuracy
- In highly vegetated areas there are few ground points
- Large areas -> many images -> long processing time
  - 1 k ~ few hours processing on a single modern PC

Outlook

- UAVs provide a flexible platform in both space and time for generation very high-resolution imagery and surface models
- More research is required to analyse the effect of amount and distribution of ground control points and increase DEM accuracy
- Potential applications in short-term geomorphological/ecological research and monitoring:
  - Detailed geomorphological change detection with multi-temporal DEMs after heavy rainfall events, earthquakes, etc.
  - Connectivity of rills or landscape objects
  - Quantifying vegetation dynamics or land use vs soil erosion
  - Analysing detailed glacial activity along seasons



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