Application of UAVs in the Environmental Sciences
Workshop, October 4th 2022, Dresden

Towards a standardized protocol for Structure-from-Motion photogrammetric studies

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Motivation

Structure-from-Motion (SfM) – Multi-View-Stereo (MVS) photogrammetric applications have emerged to become one of the main methods of acquiring high-resolution topographic data for geoscientific studies. Whilst plenty of SfM-MVS-based studies exploit the technique's ease of use and high-quality results, reporting of methodological details are not uniform, particularly of the acquisition and processing workflow(s) used. Since those details directly affect the quality of the results, the assessment of the quality is consequentially subjective to a certain degree, which may be in conflict with scientific standards. Recently, the call for standardized protocols is gaining increased value in geoscientific studies, but corresponding suggestions of how such protocols could be designed are rather underrepresented.

Methods

Based on literature review we formulate a survey protocol, which we subsequently apply and test using case studies. By showing the effects the suggested protocol details have on the interpretation of the survey results, the importance of the protocol is emphasized.

Results

Table 1: SfM-based photogrammetric survey protocol.

Research contribution		
Equipment	Platform company name [except self-built]	
	Platform name	
	Platform type [tripod, fixed wing, rotary wing, ...]	
	Sensor name	
	Sensor type [SLR, CSC,...]	
	Sensor pixel size [mm]	
	Lens type [fixed, zoom]	
	Image resolution [pix]	
	Spectral resolution [RGB, RGBN, ...]	
	Radiometric resolution [bit]	
	Focal length [mm]	
	ISO [fixed, variable]	
	Shutter speed [sec]	
	Shutter type [rolling, global]	
Survey design	GSD [mm]	
	Image overlap (forward, sideward)[%]	
	Sensor to surface distance [m]	
	Study area extent [m²]	
	Network conf.[grid, conv., ...]	
	Image number [planned]	
	Image base [m]	
	Georeferencing [RTK, PPK, GCPs]	
	Onboard GNSS RTK/PPK accuracy [mm]	
	GCP number	
	ICP number	
	GCP density [km^{-2}]	
	GCP distribution [NN analysis]	
	Theoretical precision est. [mm]	
	GNSS accuracy (H, V) [mm]	
Survey implementation	UAS Control software*	
	Illumination condition	
	Wind power [m/s]	
	Survey time [min]	
	Image format[raw, jpeg, ...]	
	Image number [captured]	
Photogrammetric processing	Software (version number)	
	Camera calibration [pre-calib., self-calib.]	
	Camera lens [e.g., frame, fish-eye]	
	Rolling shutter compensation	
	Calibrated parameters [f, cx, cy, k1, ...]	
	Reflectance panel number**	
	Alignment quality**	
	Reference preselection**	
	Key point limit**	
	Tie point limit**	
	Guided image matching**	
	Adaptive camera model fit**	
	Coordinate system**	
	Camera quality [m]***	
	Camera quality [deg]***	
	Marker quality [m]**	
	Scale bar quality [m]**	
	Rotation angles [yaw,...]**	
	Marker quality [pix]**	
	Tie point quality [pix]**	
	Dense cloud quality**	
	Depth filtering**	
	DEM resolution [m]	
Error assessment	Inner constraints mean tie point precision [mm]	
	RMS reprojection error [pix]	
	Max reprojection error [pix]	
	Mean image residuals [pix]	
	Mean error of GCPs [mm]	
	Standard deviation of GCPs [mm]	
	Mean error of CPs [mm]	
	Standard deviation of CPs [mm]	
	GCP/ICP mean error [mm]	
	Spatial distribution of error; Precision map [mm]	
	Relative precision ratio (measurement precision: observation distance)	
* Only for UAS surveys		
** Only if processed with Agisoft Metashape, otherwise equivalent parameters		
*** Only for direct georeferencing		

Survey design controls results

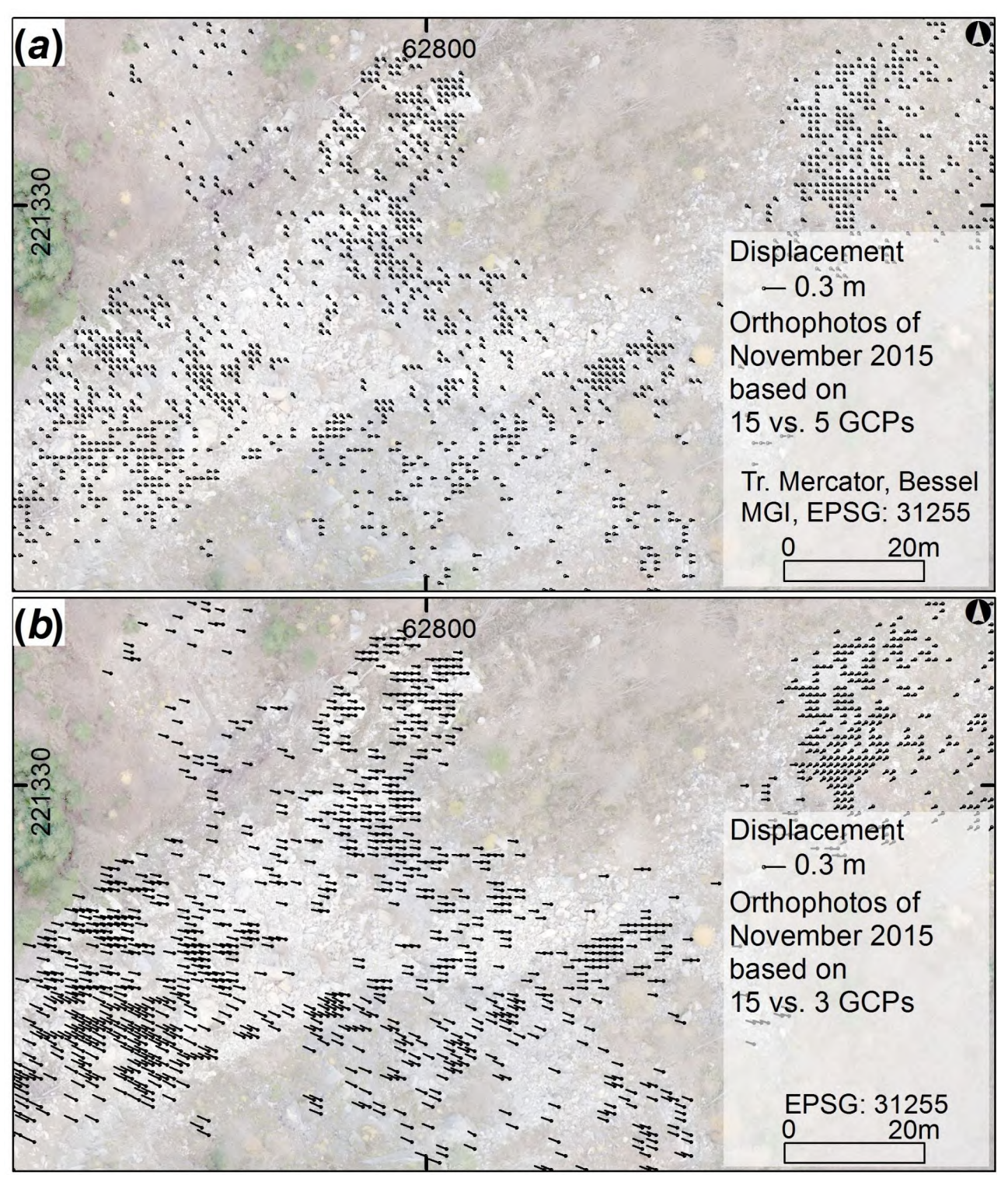

Figure 1: Planimetric discrepancies of orthophotos resulting from different processing conditions, namely the number and distribution of GCPs. Source: Seier et al. (2018).

Sensors used and survey implementation determine results

Table 2: Example of characteristics of air- and UAV-borne data acquisition along with theoretical precision estimates. Source: G. Seier et al. (unpublished).

Acquisition date	Aircraft, camera	Flying height (m), number of images	Sensor, focal length (mm)	Image size (pixel), pixel size (µm)	GSD, σ_x, σ_z (m)
03.11.2016	Quest UAV, Sony alpha ILCE-6000	138, 343	APS-C CMOS, 16.00	6000 × 4000, 4.1 × 4.1	0.03, 0.05, 0.12
31.07.2017	Quest UAV, Sony alpha ILCE-6000	188, 341	APS-C CMOS, 16.00	6000 × 4000, 4.1 × 4.1	0.05, 0.07, 0.18
12.10.2017	Quest UAV, Sony alpha ILCE-6000	184, 542	APS-C CMOS, 16.00	6000 × 4000, 4.1 × 4.1	0.05, 0.07, 0.17
15.11.2018*	Flight Design CTSW, Phase One IQ180	1350, 112	CCD, 70 mm f/16-4	10328 x 7760 5.17 x 5.15	0.10, 0.15, 0.22
17.06.2019	DJI Phantom, integrated camera (FC330)	132, 304	1/2.3" CMOS, 3.61	4000 × 3000, 1.56 × 1.56	0.05, 0.09, 0.13
14.09.2020*	Flight Design CTSW, Phase One iXM-RS150F	1396, 75	CCD, 50 mm f/16-4	14204 × 10652, 3.76 × 3.76	0.10, 0.16, 0,23
24.09.2021	Twinfold hexacopter, Sony alpha ILCE-6000	140, 644	APS-C CMOS, 16.00	6000 × 4000, 4.1 × 4.1	0.03, 0.05, 0.12

*Manned aircraft

Processing settings result in different interpretation

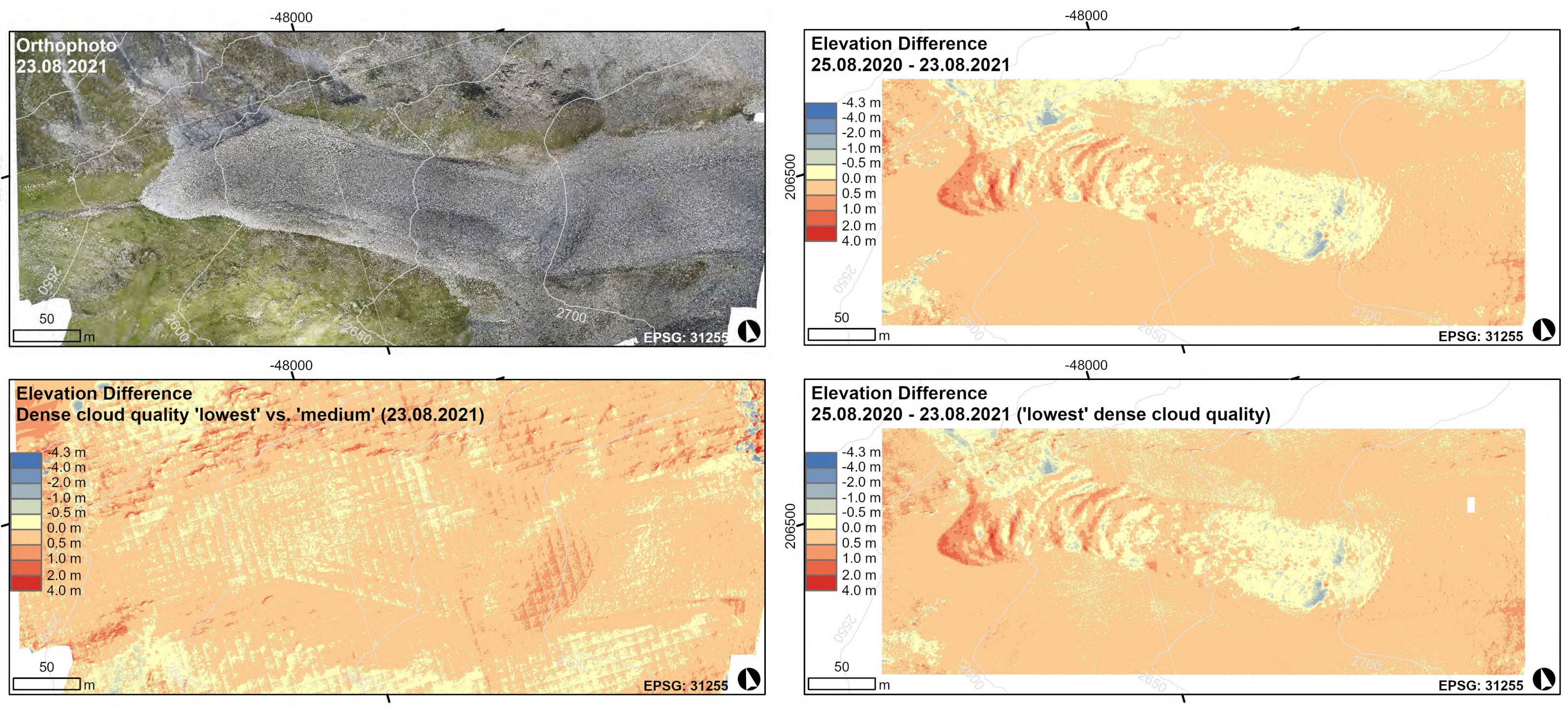

Figure 2: UAV-based orthophotos and DEMs of the Tschadinhorn rock glacier (Schobergruppe, Central Eastern European Alps) processed using different settings (see image title). Source: G. Seier et al. (unpublished).

Insufficient quality measures result in incomparable outcomes

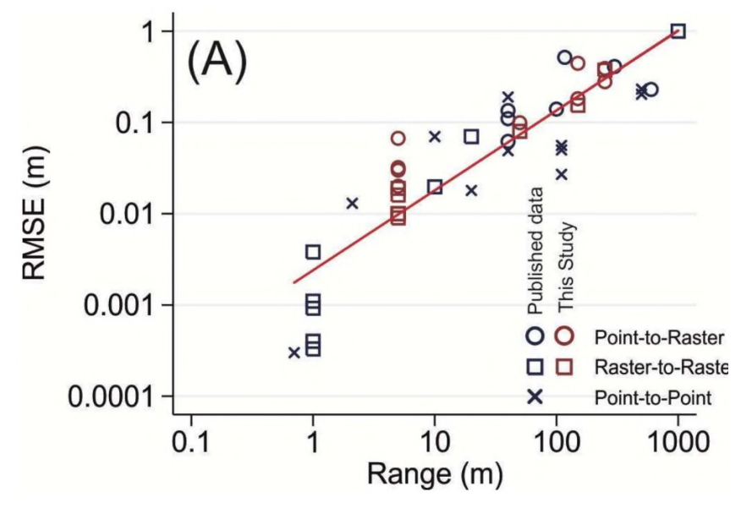

Figure 3: The effect of survey range against RMSE. Source: Smith and Vericat (2015).

Discussion

We showed the importance of reporting metadata of SfM-MVS studies in a standardized manner by using a survey protocol. However, it needs to be clarified, which parameters definitely need to be included and which ones are optional.

Conclusion

In order to assist researchers implementing SfM-MVS-photogrammetric studies to present their results in a more comprehensible way, we suggest a standardized survey protocol for SfM-MVS studies.

We propose that the detailed workflow should be reported: from data acquisition (equipment used, survey design, and survey implementation), through photogrammetric processing to error assessment. Even though such a protocol entails a certain effort, we argue that by providing detailed information in SfM-MVS studies, added value results for both, professionals/technophile researchers and the rather subject-specific non-specialist.

References

Seier, G., Sulzer, W., Lindbichler, P., Gspurning, J., Hermann, S., Konrad, H.M., Irlinger, G., Adelwöhrer, R., 2018. Contribution of UAS to the monitoring at the Lärchberg-Galgenwald landslide (Austria). Int. J. Remote Sens., 39, pp. 5522-5549. DOI: 10.1080/01431161.2018.1454627

Smith, M.W., Vericat, D., 2015. From experimental plots to experimental landscapes: Topography, erosion and deposition in sub-humid badlands from Structure-from-Motion photogrammetry. Earth Surface Processes and Landforms, 40 (12), pp. 1656-1671. DOI: 10.1002/esp.3747