UAV in combination with a thermal infrared sensor for the use in groundwater research

Mallast, U.[1], **Siebert, C.** [1]

[1] *Helmholtz Centre for Environmental Research (UFZ)*

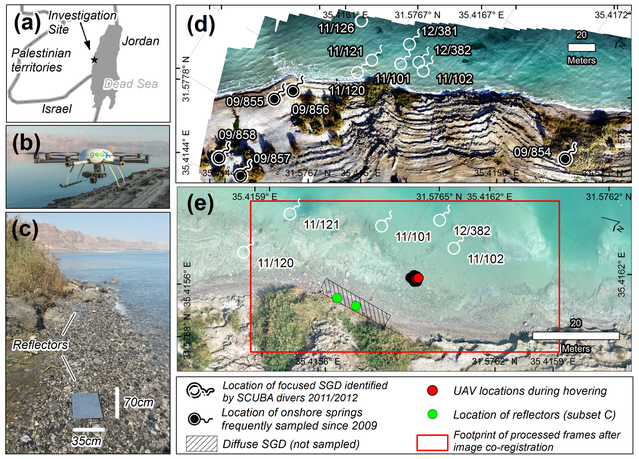
1. Problem definition

Submarine groundwater discharge (SGD) is highly variable in spatial and temporal terms due to interplay of several terrestrial and marine processes. In contrast to discrete in-situ measurements, remotely sensed thermal infrared radiation has proven to reveal horizontal SGD variability in a spatially continuous context. Yet, it lacks temporal information that is crucial to understand highly dynamic systems as represented by many coastal environments. Thus, Instead of flying over the study area we exploit the UAV ability to observe predefined locations by hovering above a predefined SGD spot to study spatio-temporal characteristics of SGD.

2. Objectives

i. Investigate the spatiotemporal variability of focused and diffuse SGD based on contrasting sea surface temperatures
ii. Elaborate on additional values of a hovering UAV over classical flyovers
iii. Point out limitations during the conduction (flight stability, flight duration, thermal sensor drift) and processing (image registration) but also
iv. Future improvements that may influence UAV-based groundwater investigations

3. UAV and Study Site



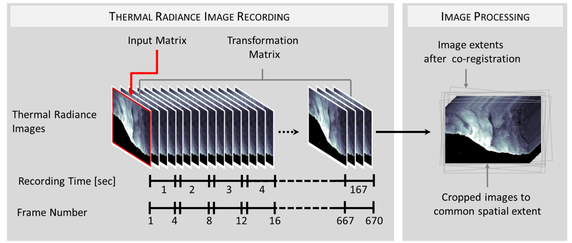
UAV/Sensor

- Multicopter – model: geo-X8000
- FLIR Tau2/ 19mm lens / 640x512 FPA / ThermalCapture/ frame rate 4-5Hz
- Flight time: 12:45-12:48 LT (10 Feb. 2016)
- Flight altitude: 65m
- Hovering pos.: 31.57° / 35.41°

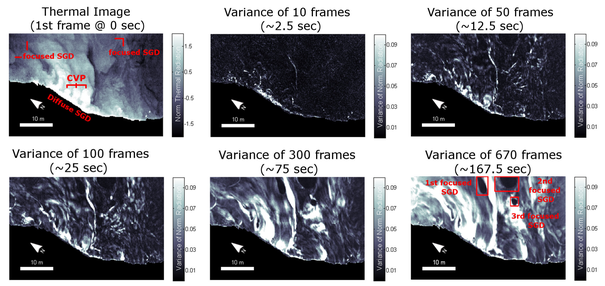
Study Site

- pre-investigated SGD site at the western coast of the Dead Sea
- Salt-karst environment
- SGD emergence at depths <30m
- SGD Temp. = 21-31.5° C (DS: 21° C)
- SGD Density = 1-1.19 g*cm^{-3} (DS: 1.23 g*cm^{-3})

4. Method



5. Result (Integration)



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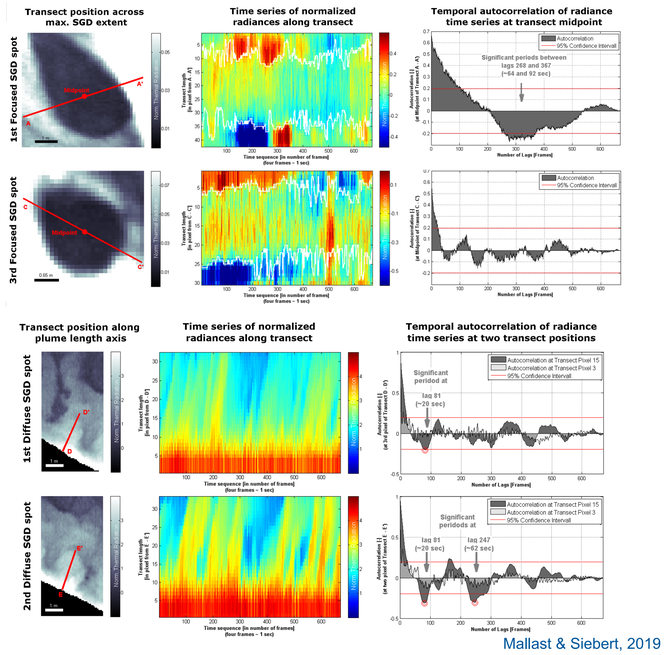
6. Result (Spatiotemporal)



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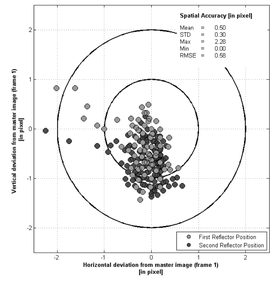
7. UAV Limitation



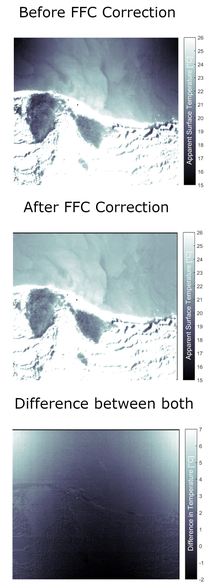
i. **Limited flight time** due to battery capacity – usually in the range of 12-45min

Solution: Using tethered UAVs with unlimited flight time due to generator based batteries

ii. **GPS inaccuracies** during flight

Solution: Either RTK/PPK for sub-centimeter accuracy or image co-registration

8. Sensor Limitation



i. **Non-linear FFC effect / temperature drift** due to external influences (wind, sun etc.) with up to 0.7K per minute or 7K between frames

Solution 1: External heated shutter
Solution 2: SIFT/ SURF between consecutive frames along with a linear re-calibration (Mesas-Carrascosa et al. 2018)
Solution 3: General rules of thumb for using uncooled microbolometer (Kelly et al. 2019)

ii. **Sensor distortion** (geometric) especially for wide-angle lens

Solution: Determine distortion using a black body or calibration chart (Yahyanejad et al. 2011)

9. Conclusion

Hovering with an UAV over a predefined location recording thermal radiances at a temporal resolution of 4–5 Hz is a novel application technique combining continuous spatial and temporal scales for SGD research and shedding light on their spatiotemporal behaviour.

Technical limitations in terms of UAV and sensor exist and potentially limit the application. However, solutions and corrections do also exist to improve and adopt the presented approach, making it even possible to conduct long-term (>d) experiments.

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CONTACT:

Ulf Mallast
Helmholtz Centre for Environmental Research (UFZ)
Department Catchment Hydrology
ulf.mallast@ufz.de

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Kelly, J. et al.: Challenges and Best Practices for Deriving Temperature Data from an Uncalibrated UAV Thermal Infrared Camera, Remote Sensing, 11, 567, 2019.

Mesas-Carrascosa, et al.: Drift Correction of Lightweight Microbolometer Thermal Sensors On-Board Unmanned Aerial Vehicles, Remote Sensing, 10, 615, 2018.

Mallast, U., and Siebert, C.: Combining continuous spatial and temporal scales for SGD investigations using UAV-based thermal infrared measurements, Hydrol. Earth Syst. Sci., 23, 1375-1392, 10.5194/hess-23-1375-2019, 2019.

Yahyanejad, S. et al.: Lens distortion correction for thermal cameras to improve aerial imaging with small-scale UAVs, 2011 IEEE International Symposium on Robotic and Sensors Environments (ROSE), 2011, 231-236.