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BRDF Effects Based on Optical Multi-Angular Laboratory and Hyperspectral UAV Measurements

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Introduction

Bidirectional Reflectance Distribution Function (BRDF) effects are a commonly known source of error in remote sensing data. The aim of this study was to investigate and compare BRDF effects observed under laboratory conditions using a goniometer, and under natural conditions, using an unmanned aerial vehicle (UAV).

Laboratory goniometer measurements

The laboratory goniometer facility [1] of Wageningen University was used to measure the BRDF of sugar beet plants, collected from the field that was measured by the UAV. The measurements were taken from a distance of 1 meter using an 8° foreoptic.

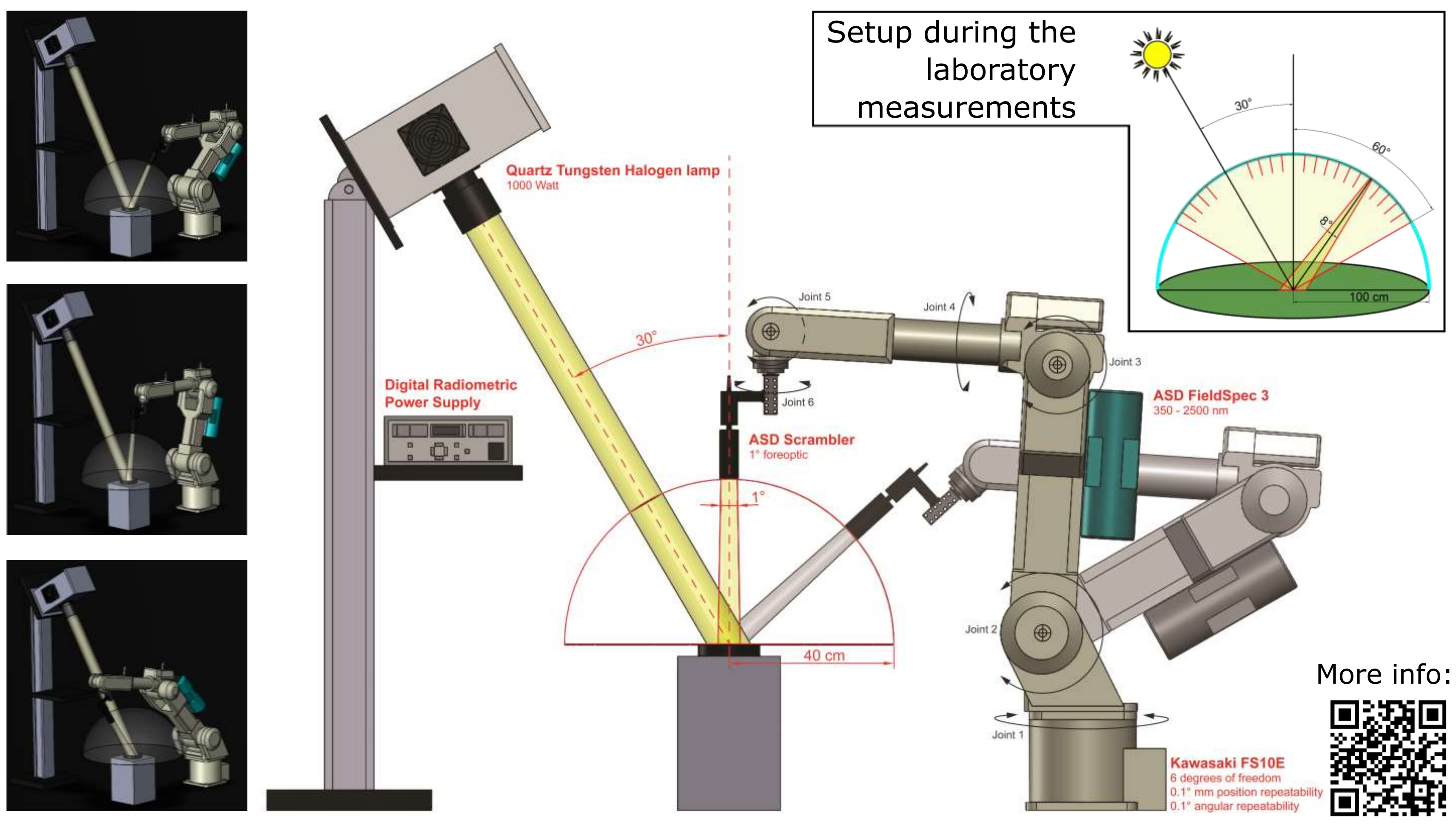


Figure 1. The laboratory goniometer facility. The setup consists of an industrial robot arm on which a spectrometer is mounted. The custom software that drives the setup allows for fully automated reflectance measurements over the complete hemisphere.

Goniometer results

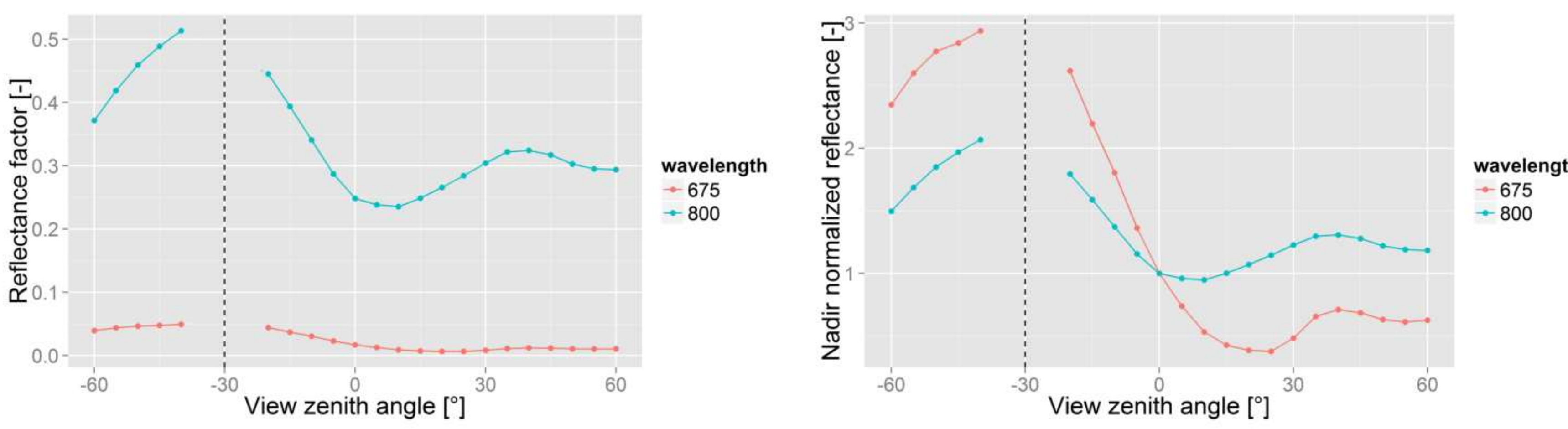
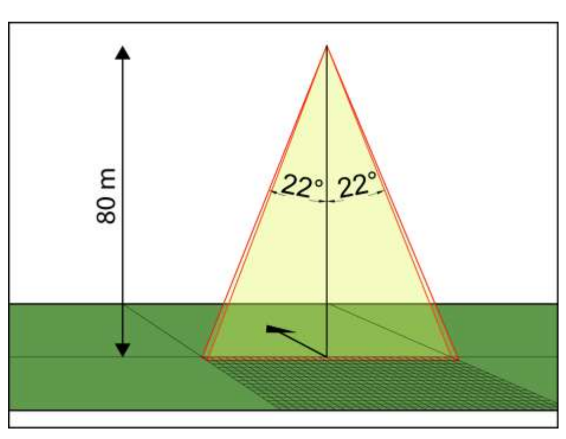


Figure 2. Red and NIR reflectance factors of a sugar beet plant measured in the principal plane. The illumination source was placed at a -30° zenith angle.

UAV measurements

The hyperspectral mapping system (HYMSY, [2]) was used to capture BRDF effects under field conditions. The hyperspectral pushbroom sensor was tilted 12° to create a field of view (FOV) up to 34°. BRDF effects in the solar principal plane were captured by flying the UAV with the FOV pointed towards and away from the sun.



Hyperspectral Pushbroom Spectrometer

- 400–950 nm
- 9 nm FWHM
- 25 lines/s
- 328 px/line

Figure 3. The HYMSY, a lightweight hyperspectral mapping system, carrying a pushbroom spectrometer, a photogrammetric camera and a GPS-Inertial Navigation System. Typical products are a RGB orthomosaic (1–5 cm resolution), a digital surface model (5–10 cm resolution) and a hyperspectral datacube (10–50 cm resolution).

UAV flight pattern

12° tilt of the sensor

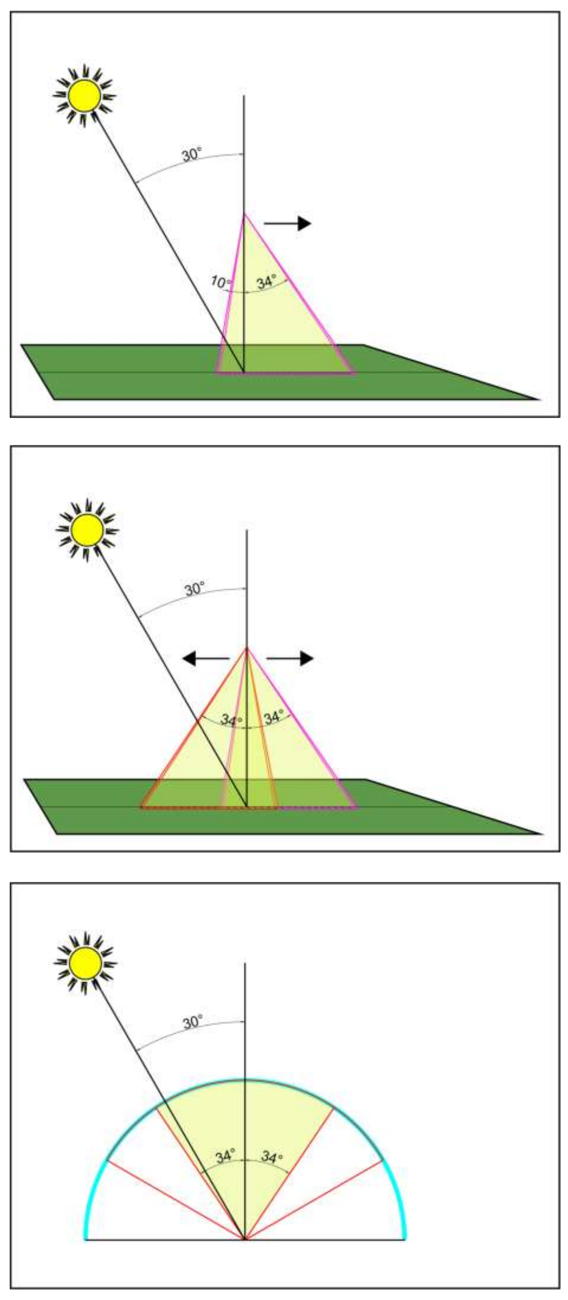


Figure 4. The hyperspectral sensor was tilted 12°. By flying towards and away from the sun with the sensor pointed towards or away from the sun, pixels were captured in the principal plane with view zenith angles up to 34°.

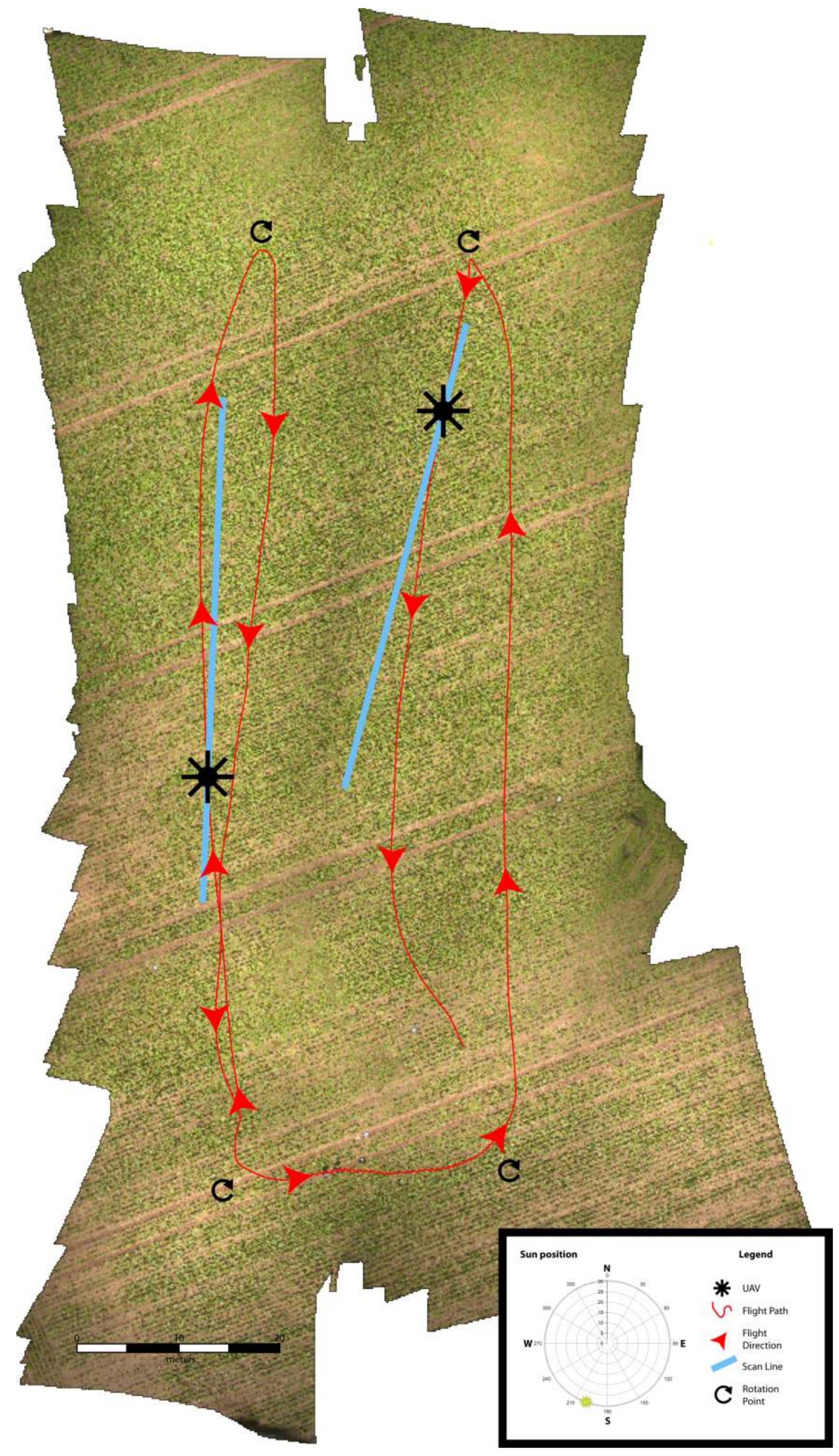


Figure 5. The UAV flight over the sugar beet field projected on a RGB orthomosaic. The UAV was flying at an altitude of 80 m, resulting in a scan line of just over 60 m with approximately 20 cm pixels. For each pixel, the observation azimuth and zenith angles were calculated.

UAV results

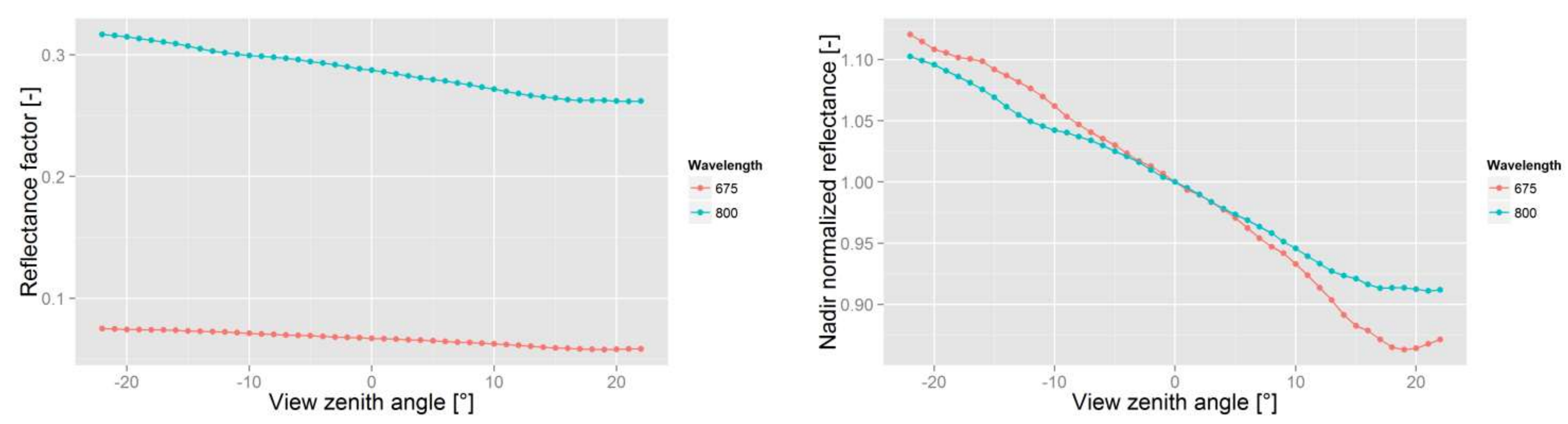


Figure 6. Red and NIR reflectance factors of the sugar beet field of pixels within a 5° azimuth distance of the principal plane. The sun zenith angle was at -30°. Both the goniometer and UAV data sources show a similar trend in forward and backward scattering intensity. Further analysis of the data is still in progress.

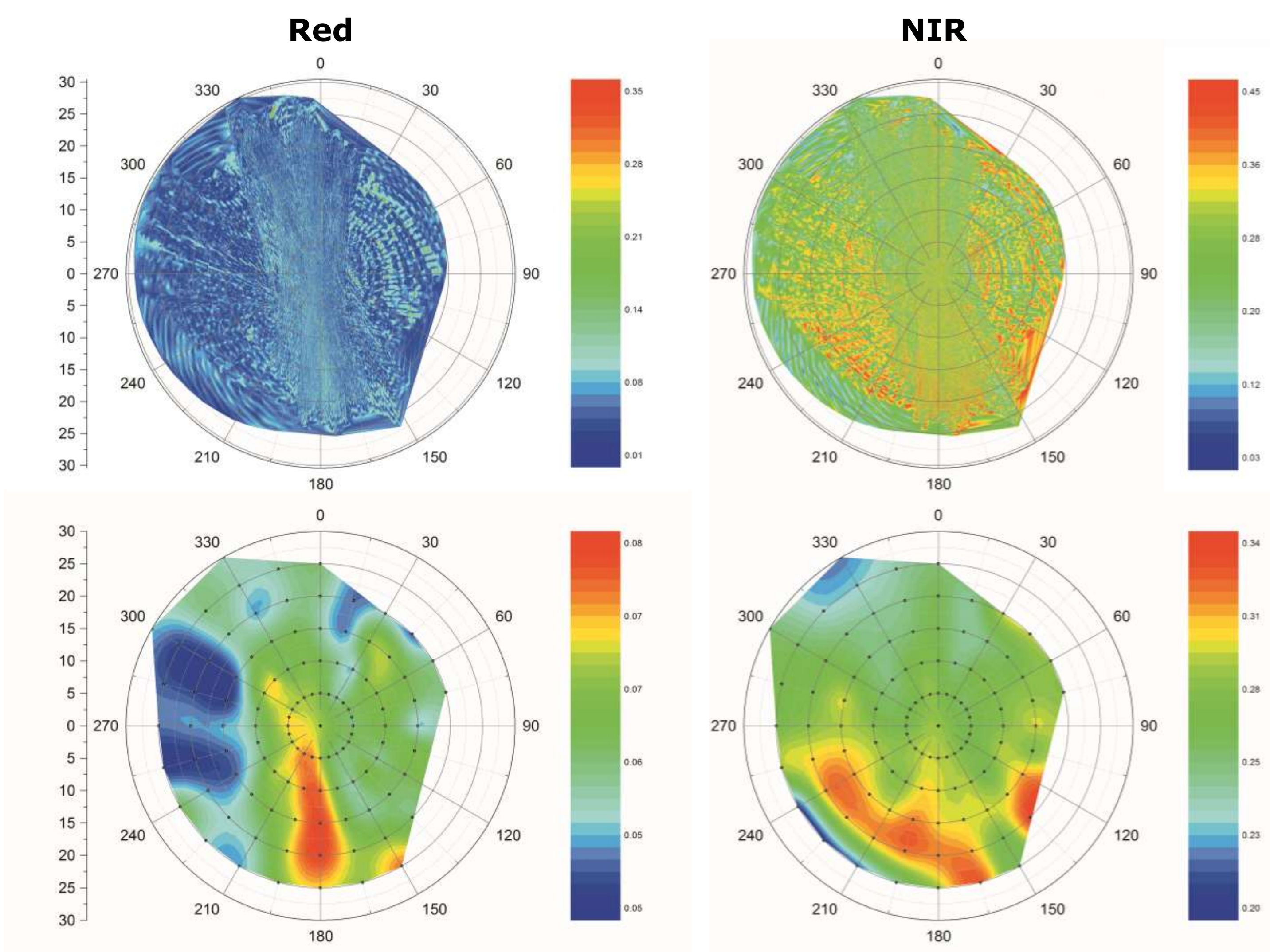


Figure 7. Red and NIR reflectance factors over the full hemisphere, collected by the UAV. The top figures show all individual pixels and the bottom figures show the average of all pixels within a 15° azimuth and 5° zenith interval. The bottom figures show a clear increase of reflectance factor in the back scattering direction. Sun positon is 30° zenith and 198°-201° azimuth.

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References

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[2] Suomalainen, J., Anders, N., Iqbal, S., Roerink, G., Franke, J., Wenting, P., Hünniger, D., Bartholomeus, H., Becker, R. & Kooistra, L., "A Lightweight Hyperspectral Mapping System and Photogrammetric Processing Chain for Unmanned Aerial Vehicles", Remote Sensing, 2014, 6, 11013-11030. doi:10.3390/rs61111013