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Optimizing sensitivity of Unmanned Aerial System optical sensors for low zenith angles and cloudy conditions

Sheng Wang[1], , Carsten Dam-Hansen[2], Pablo J. Zarco Tejada[3], Anders Thorseth[2], Radu Malureanu[2], Filippo Bandini[1], Jakob Jakobsen[4], Andreas Ibrom[1], Peter Bauer-Gottwein[1], Monica Garcia[1*]

1. Department of Environmental Engineering, Technical University of Denmark, 2800 Kgs. Lyngby, Denmark
2. Department of Photonics Engineering, Technical University of Denmark, Denmark
3. European Commission, Joint Research Centre, Directorate D - Sustainable Resources, Via E. Fermi 2749, 21027 Ispra (VA), Italy
4. National Space Institute, Technical University of Denmark, 2800 Kgs. Lyngby, Denmark

*corresponding author: mgarc@env.dtu.dk

Satellite-based imagery in optical domains cannot provide information on the land surface during periods of cloud cover. This issue is especially relevant for high latitudes where overcast days and low solar zenith angles are common. Current remote sensing-based models of evapotranspiration or carbon assimilation are biased towards clear sky conditions, lacking important information on biophysical processes under cloudy conditions. Unmanned Aerial Vehicle (UAV) imagery has great potential to monitor and understand surface fluxes under cloudy conditions. For instance, in Denmark 73.54% of all days are non-clear (fraction of direct radiation less than 50%). UAV multispectral imagery acquired in these conditions tends to present low brightness and dynamic ranges, and high noise levels. Another problem is the influence of land cover types on the signal. For instance, over vegetated areas, even with low irradiance, saturation is reached in the near Infrared, while visible channels have low brightness. An individual camera setting for each channel and light conditions can improve sensor sensitivity while preventing saturation. This study aims to optimize the settings and radiometric corrections of a multispectral camera to produce high quality UAV imagery under low but homogeneous irradiance conditions. Laboratory experiments were conducted to link irradiance levels to different camera settings and calibration procedures. Results were tested outdoors over homogeneous and vegetated surfaces.

The multispectral camera (Tetra Mini-MCA6) has 6 channels in the visible and near Infrared. For the laboratory calibration experiment, different camera settings and typical irradiance levels from cloudy to clear sky were designed. The light-source is based on super-continuum generation to produce a continuous solar spectrum. It allows more flexible settings in illumination levels than tungsten halogen lamps. A Li-Cor 1800 integrating sphere and an ASD spectroradiometer (FieldSpec HandHeld 2) were also used. Images were acquired under varying integration time and illumination levels from 0.005 to 0.2 $W \cdot m^{-2} \cdot nm^{-1} \cdot sr^{-1}$. Two radiometric calibration methods were applied to find gains to convert digital numbers (DN) into radiance and also to correct vignetting effects, apparent as the fall-off pixel intensity from the image center towards edges. The first is to apply a pixel-wise calibration from DN to radiance. The second performs a vignetting correction based on distance from each pixel to the highest DN pixel and then a global image calibration of averaged DN to radiance. To test calibration performance, images were acquired outdoors over (i) homogeneous targets (Teflon panels, grass and soil plots)

and (ii) with UAV flight campaigns over a willow eddy covariance flux site under different cloudiness levels and solar zenith angles using varying camera settings. Radiance, reflectance, and vegetation indices were validated with ASD measurements and signal to noise metrics and dynamic ranges were assessed. Our results indicate that the spectral gains and camera settings can be tuned to allow higher signal to noise ratio and optimize the sensor sensitivity. This maximizes the image radiometric resolution and prevents sensor saturation for each channel. This paper is a step forward for UAV campaigns using optical cameras for low zenith angles and/or cloudy conditions.

Key words: Sensor calibration, Unmanned Aerial Vehicle, Low illumination conditions