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Derivating forest structure from Sentinel-1 time series to assist forest fire risk assessments

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The assessment of forest fire risk has recently gained interest in countries of Central Europe and the alpine region since the occurrence of forest fires is expected to increase with a changing climate. Information on forest fuel structure, which is related to forest structure, is a key component in such assessments. Forest structure information can be derived from airborne laser scanning (ALS) data, whose value for the derivation of respective metrics at a high accuracy level has been demonstrated in numerous studies over the last years.

Yet, the temporal resolution of ALS data is low as flight missions are typically carried out in time intervals of five to ten years in Central Europe. ALS-derived forest structure descriptors for fire risk assessments, therefore, are often outdated. Open access earth observation data offer the potential to fill these information gaps. Data provided by synthetic aperture radar (SAR) sensors, in particular, are of interest in this context since this technology has a known sensitivity to the vegetation structure and acquires data independent of weather or daylight conditions.

In our study, we investigate the potential to derive forest structure descriptors from time series of Sentinel-1 (S-1) SAR data for a deciduous forest site in the Eastern part of Austria. We focus on forest stand height and fractional cover, which is a measure for forest density, as both of these components impact forest fire propagation and ignition. The two structure metrics are estimated using a random forest (RF) model, which takes a total of 36 predictors as input, which we compute from the S-1 time series. The model is trained using ALS-derived structure metrics acquired during the same year as the S-1 data.

We estimated stand height with a root mean square error (RMSE) of 4.76 m and a bias of 0.09 m at 100 m resolution, while the RMSE for the fractional cover estimation is 0.08 with a bias of zero at the same resolution. The spatial comparison of the structure predictions with the ALS reference further shows that the general structure is well reproduced. Yet, fine scale variations cannot be

completely reproduced by the S1-derived structure products, and the height of tall stands and very dense canopy parts are underestimated. Due to the high correlation of the predicted values to the reference (Pearson's R of 0.88 and 0.94 for the stand height and the fractional cover, respectively), we consider S-1 time series in combination with ALS data with low temporal resolution and machine learning techniques to be a reliable data source and workflow for regularly (e.g. < yearly) updating ALS structure information in an operational way.