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Monitoring Vegetation Dynamics and Stress with Optical Sensors: A study of Alpine Grasslands among Multiple Spatial Scales

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Grasslands are a dominant land cover in many alpine regions. They vary from intensively managed meadows to semi-natural pastures for livestock. Grasslands in the Alps are of elevated ecological (e.g. biodiversity, slope stability, carbon and water storage) and economic importance (e.g. livestock habitat, fodder production) and highly sensitive towards climatic and land-use changes. Although grasslands ecology is widely studied, the possibility to monitor stress periods like droughts, weather extremes and land use activities (e.g. harvest) over time gained less attention. As a response during the past years many sensors and sensor networks for environmental monitoring with optical and/or biophysical sensors became operational in alpine ecosystems such as remote sensing platforms, Unmanned Aerial Vehicles (UAV), spectral reflectance sensors (SRS), and field campaigns with spectroradiometers. However, their potential of synergetic use across scale is by far not yet fully exploited. This study focusses on the retrieval of vegetation dynamics and stress periods detectable with optical sensors on multiple spatial scales ranging from extensive satellite-based data to plot-level ground measurements.

This research concentrates on both mountainous meadows and pastures on different altitudes and expositions in order to extensively monitor the most common alpine grasslands. The study sites are located in two climatically different regions in the Autonomous Province of Bolzano (Italy). The optical sensors contain satellite-based Sentinel-2 Multi Spectral Instrument (MSI), Phenocams, station-based SRS, and in-situ spectrometer measurements. Furthermore, other biophysical variables (e.g. precipitation, temperature, soil water content and –temperature) and phytomass are integrated in this research.

The optical response in form of vegetation indices (VIs) such as the Normalized Difference Vegetation Index (NDVI) of the sensors across spatial scales are compared to each other and together with phytomass samples over time. Differences, similarities, and the use in vegetation phytomass prediction are assessed for the given sensors. Phases of vegetation stress are assessed using machine-learning algorithms in order to identify the type of stress the vegetation is suffering by combining the optical response measurements with biophysical variables.

Results show that the NDVI from different optical sensors has a high correlation among each other ($0.48 < R2 < 0.89$; $0.02 < RMSE < 0.08$) but has to pass an intensive filtering process to clean for outlier, time gaps, snow, or other unfavourable weather conditions. The correlation with phytomass is smaller throughout scales ($0.26 < R2 < 0.29$; $0.05 < RMSE < 0.07$), hence a better indicator needs to be identified. Stress periods or management activities caused visible responses at each scale, but these range from abrupt and noisy optical signal for Phenocams and SRS sensors to a less incisive and less noisy signal in Sentinel and Spectrometer NDVI signals. This is related to the temporal scale of the acquisition, the dynamic of a stress event over time, as well as the spatial extent of the event. It shows that stress events can be characterized differently with each sensor on different spatial scales and that the combination of these sensors could lead to a more accurate monitoring of stress events in vegetation communities.