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Tracking forest canopy stress from an automated proximal hyperspectral monitoring system

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Increasing climate variability and associated extreme weather events such as drought are likely to profoundly affect ecosystems, as many ecological processes are more sensitive to climate extremes than to changes in the mean states. However, the response of vegetation to these changes is one of the largest uncertainties in projecting future climate, carbon sequestration, and water resources. This remains a major limitation for long term climate prediction models integrating vegetation dynamics that are crucial for modelling the interplay of water, carbon and radiation fluxes. Satellite remote sensing data, such as that from the MODIS, Landsat and Sentinel missions, are the only viable means to study national and global vegetation trends. Highly accurate in-situ data is critical to better understand and validate our satellite products.

Here, we developed a fully automated hyperspectral monitoring system installed on a flux monitoring tower at a mature Eucalypt forest site. The monitoring system is designed to provide a long-term (May 2014 - ongoing) and high temporal characterisation (3 acquisitions per day) of the proximal forest canopy to an unprecedented level of detail. The system comprises four main instruments: a thermal imaging camera and hyperspectral line camera (spectral ranges 7.5-14 μm and 0.4-1 μm, respectively), an upward pointing spectrometer (350-1000 nm), and hemispherical camera. The time series of hyperspectral and thermal imagery and flux tower data provides a unique dataset to study the impacts of logging, nutrient, and heat stress on trees and forest. Specifically, the monitoring system can be used to derive a range of physiological and structural indices that are also derived by satellites, such as PRI, TCARI/OSAVI, and NDVI.

The monitoring system, to our knowledge, is the first fully automated data acquisition system that allows for spatially resolved spectral measurements at the sub-crown scale. Preliminary results indicate that canopy stress is non-uniform with tree height and among different trees. A further objective is to establish a link between these spectral measurements, photosynthetic rate and light use efficiency of the canopy, made possible through integration with tower measured flux data. Accounting for different structural and illumination conditions is integral for future work interpreting and scaling these findings from imagery data. The ultimate aim of this work is to significantly advance our understanding of the impacts of lagged climate effects on vegetation by assimilating relevant remotely sensed data streams into a dynamic-vegetation-enabled land surface model (CABLE) at the regional, continental and global scale.