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Vegetation stress from soil moisture and chlorophyll fluorescence: synergy between SMAP and FLEX approaches

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Vegetation stress detection continues being a focal objective for remote sensing techniques. It has implications not only for practical applications such as irrigation optimization or precision agriculture, but also for global climate models, providing data to better link water and carbon exchanges between the surface and the atmospheric and improved parameterization of the role of terrestrial vegetation in the coupling of water and carbon cycles. Traditional approaches to map vegetation stress using remote sensing techniques have been based on measurements of soil moisture status, canopy (radiometric) temperature and, to a lesser extent, canopy water content, but new techniques such as the dynamics of vegetation fluorescence emission, are also now available.

Within the context of the preparatory activities for the SMAP and FLEX missions, a number of initiatives have been put in place to combine modelling activities and field experiments in order to look for alternative and more efficient ways of detecting vegetation stress, with emphasis on synergistic remote sensing approaches.

The potential of solar-induced vegetation fluorescence as an early indicator of stress has been widely demonstrated, for different type of stress conditions: light amount (excess illumination) and conditions (direct/diffuse), temperature extremes (low and high), soil water availability (soil moisture), soil nutrients (nitrogen), atmospheric water vapour and atmospheric CO_2 concentration. The effects caused by different stress conditions are sometimes difficult to be decoupled, also because different causes are often combined, but in general they then to change the overall fluorescence emission (modulating amplitude) or changing the relative contributions of photosystems PSI and PSII or the relative fluorescence re-absorption effects caused by modifications in the structure of pigment bed responsible for light absorption, in particular for acclimation for persistent stress conditions. While soil moisture deficit is often the reason for the stress, the capability for an early detection of short-time stress conditions is one of the main advantages of vegetation fluorescence.

The combined usage of active and passive techniques is also discussed. In the case of soil moisture, combination of active (radar) and passive (L-band radiometry) approaches are used, while in the case of fluorescence active (laser induced) and passive (solar induced) techniques are used as well. Experience from active techniques in laboratory and field conditions helps the operational usage of passive techniques which are readily applicable to satellite observations.

Vegetation fluorescence dynamics, particularly over boreal forest, is characterized by an abrupt change in fluorescence levels in coincidence with the activation and deactivation of the photosynthetic machinery at start/end of growing season, which is also related to freeze/thaw state of soil conditions. The interest of looking at such transitions both on the side of photosynthetic activity (combined fluorescence and temperature measurements) and freeze/thaw conditions (L-band radiometry) can provide an unprecedented description of the soil and vegetation interactions and dynamical feedbacks in the energy and chemical exchanges with the atmosphere.

A review of methods and results will be discussed in this paper, including suggestions for synergistic approaches to be exploited in future research priorities in vegetation stress detection.