Geophysical Research Abstracts,
Vol. 11, EGU2009-11324-1, 2009
EGU General Assembly 2009

Relationships between canopy greenness and CO2 dynamics of a Mediterranean deciduous forest assessed with webcam imagery and MODIS vegetation indices

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Phenological observations of foliar development and senescence are needed to understand the relationship between canopy properties and seasonal productivity dynamics (e.g., carbon uptake) of terrestrial ecosystems. Traditional phenological ground observations based on a visual observation of different vegetation growth phases (from first leaf opening, to first leaf flowering, full bloom until senescence) are laborious and typically limited to observations on just a few individual subjects. On the contrary, remote sensing techniques appear to offer the potential for assessing long-term variability in primary productivity at a global scale (Field et al., 1993). Recent studies have shown that biochemical and biophysical canopy properties can be measured with a quantifiable uncertainty that can be incorporated in the land-biosphere models (Ustin et al., 2004a; Ollinger et al 2008). Canopy greenness can be quantified by the use of vegetation indices (VIs) as, for example, Normalized Difference Vegetation Index (NDVI, Rouse et al., 1974; Deering, 1978), but a disadvantage of this approach is that there are uncertainties associated with these indices (due to the spatial and temporal resolution of the data), and the interpretation of a specific VI value, in the context of on-the-ground phenology, is not clear. Improved ground-based datasets are needed to validate and improve remotely-sensed phenological indices. Continuous monitoring of vegetation canopies with digital webcams (Richardson et al. 2007) may offer a direct link between phenological changes in canopy state and what is “seen” by satellite sensors.
The general objective of this study is to analyze the relationship between biosphere-atmosphere CO2 exchange (measured by eddy covariance) and phenological canopy status, or greenness, of a Mediterranean deciduous broadleaf forest in central Italy (Roccarespampani, 42°24’ N, 11°55’ E). Canopy greenness is quantify using two different approaches: from digital webcam images, using indices derived from red, green and blue (RGB) color channel brightness (RGBi, after Richardson et al. 2007) and with VIs (e.g. NDVI, SR, MSR, GRDI, NCI, CI and SLAVI) derived from MODIS surface reflectance data (MOD09A1). Since MOD09A1 reflectance data represent the maximum surface reflectance of each band for a consecutive 8-day period, webcam imagery, as fluxes data, acquired whit half-hourly temporal resolution have been time averaged on 8 day period. Evaluation of performance of RGBi-VIs, RGBi-CO2flux and MODIS-CO2flux relationships were performed by linear regression analyses using the classical least squares (LS) statistical technique. Among all calculated vegetation indexes, GRDI (Green Red Difference Index: Gitelson et al., 2002) and SLAVI (Specific Leaf Area Vegetation Index: Lymburner et al., 2000) showed best linear fit with webcam RGBi greenness. SLAVI was also one of the vegetation indices best correlated with mean daily CO2 flux (R2=0.79). Finally, the relationship between RGBi and CO2 flux had a R2 of 0.67. Concluding, both webcam and MODIS greenness indices offer potential for assessing seasonal variation in the productivity of terrestrial ecosystems. Future work will focus on reducing the uncertainties inherent in these approaches, and integrating field observations of phenology into this study.