The Use of Hyperspectral Imagery to Assess the Sensitivity of Ecosystem Photosynthetic Parameters Along Two California Climate Gradients

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1 Introduction

- Sensitivity of ecosystem parameters essential to estimating the impact of climate change
- We combined imaging spectroscopy (IS) with thermal infrared (TIR) imagery to create spatially explicit estimates of two key photosynthetic traits
- Maximum rates of RuBP carboxylation (V_{cmax}) and regeneration (J_{max}) are typically determined through gas exchange (Fig. 1a,) but we estimate traits using IS & TIR data
- Hyperspectral remote sensing data used in conjunction with leaf level spectroscopy, gas exchange, and flux tower data are used to characterize ecosystem photosynthetic parameters, CO_2 uptake, and climate forcing across land use and cover gradients
- Development of universally applicable remote sensing methods to estimate ecosystem metabolism will enable retrievals from future satellite-based imaging spectrometers

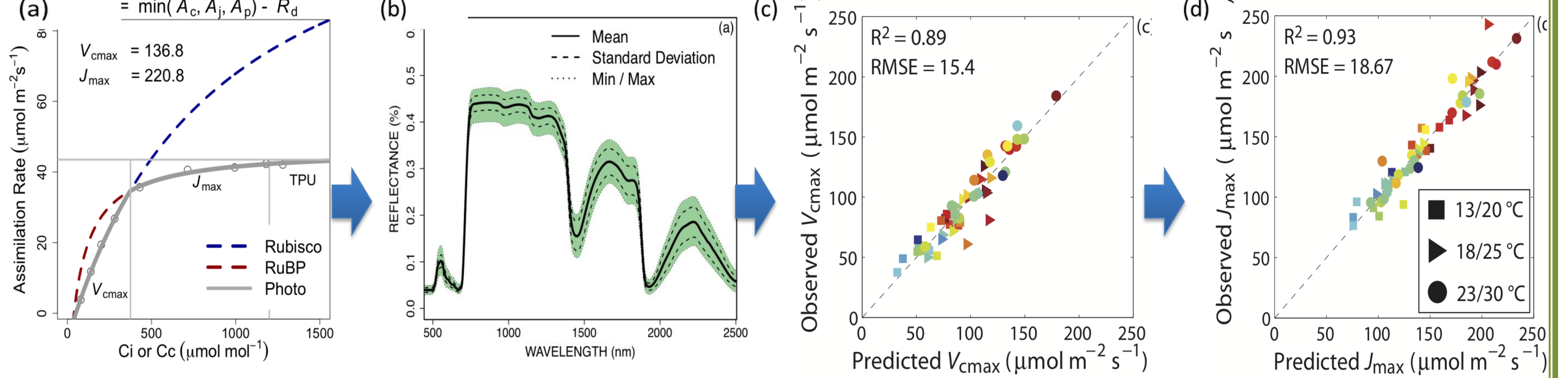

Figure 1. Leaf-level measurements of photosynthesis (a) and optical properties (b) are linked through a partial least-squares regression modeling approach (Serbin et al., 2012) to yield spectra-based algorithms for estimating V_{cmax} (c) & J_{max} (d).

2 Study Area

- Two climate-elevation gradients comprised of 10 ecosystems, including four forests (Fig. 2a)
- Broad vegetation and land use found at field sites allow for robust testing of our methods

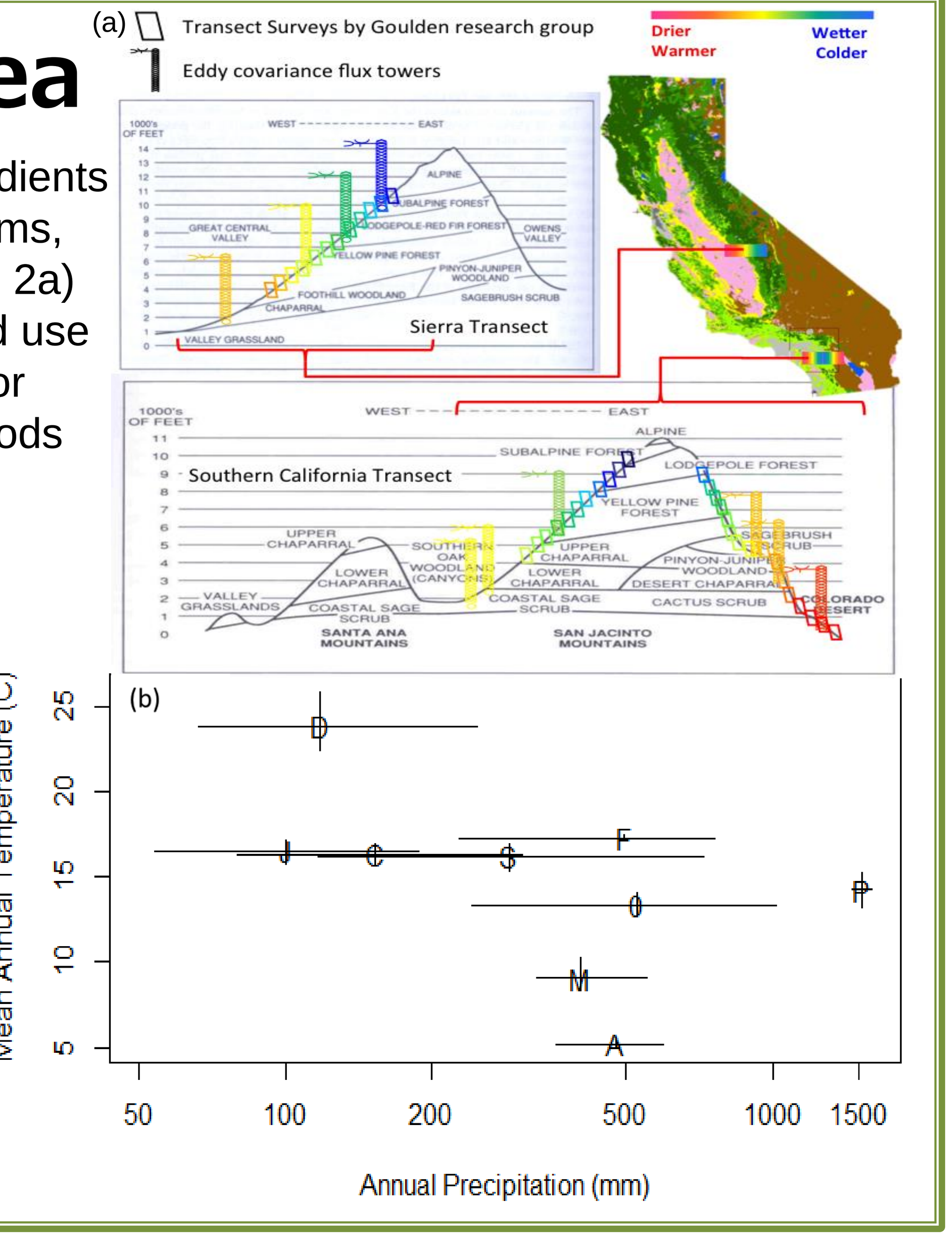

***Figure 2. (a)** The location of the ten eddy covariance tower sites comprising the southern California and Sierra transects that are being leveraged in this project. **(b)** The range of annual mean temperatures and annual mean precipitation values recorded over the last several years at each site, including desert(D), pinyon/juniper (J), montane chaparral (C), coastal sagebrush (S), oak-pine forest (F), Ponderosa Pine (P), oak-pine woodland (O), mixed conifer forest (M), and subalpine forest (A). The variability of annual precipitation is orders of magnitude larger than that of temperature.*

3 Results

- V_{cmax} estimates from flux tower data show significantly lower values than from gas exchange and spectral measurements made on vegetation found within the flux tower footprint
- Drought conditions associated with decline in Gross Primary Productivity (GPP)
- V_{cmax} estimates correlated with GPP, indicating decreased photosynthetic capacity during drought conditions
- Variability in precipitation is the main driver for inter-annual variation in productivity for each site

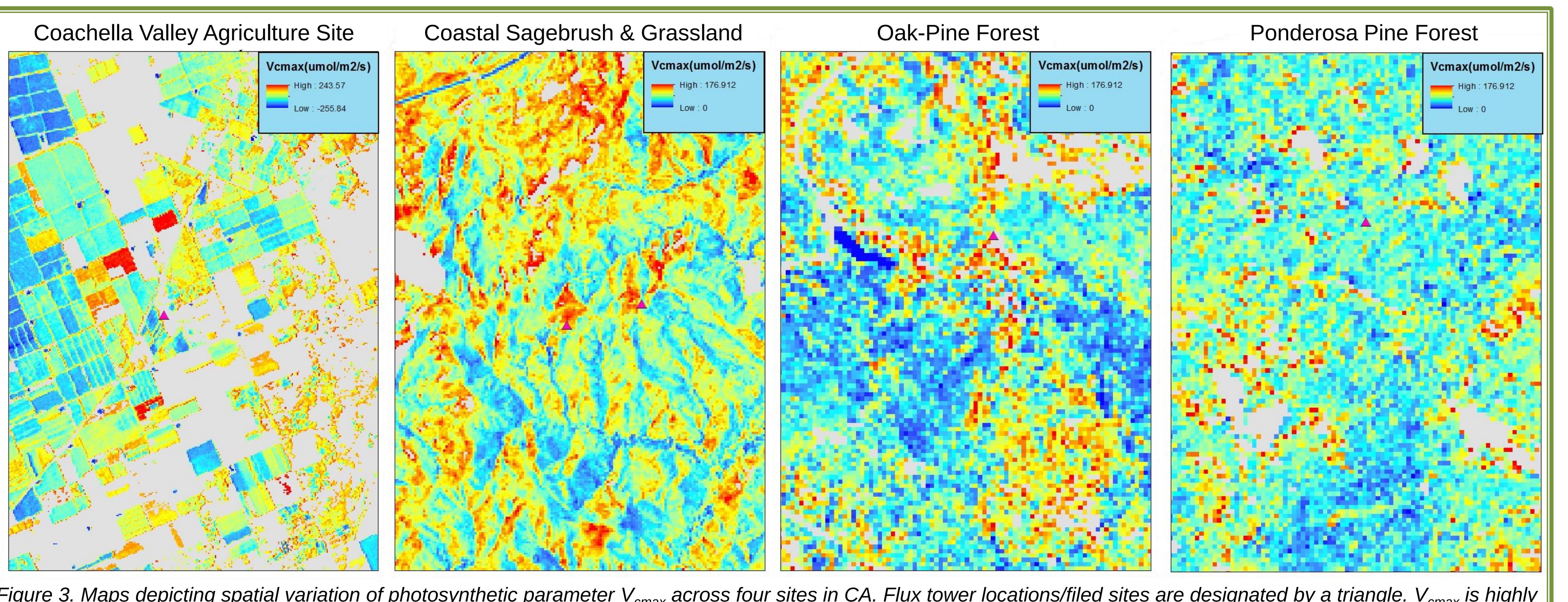

Figure 3. Maps depicting spatial variation of photosynthetic parameter V_{cmax} across four sites in CA. Flux tower locations/filed sites are designated by a triangle. V_{cmax} is highly variable across the landscape for the exception of the agricultural sites. These estimates are created from AVIRIS imagery collected on April 19, 2013 (109th day of the year).

Methods
AVIRIS and MASTER imagery were used to estimate photosynthetic metabolism through the implementation of PLSR algorithms (Singh et al., in prep). This allowed for the creation of maps depicting the spatial variation of V_{cmax} around the flux tower sites (Fig. 3). Flux tower data were used to estimate V_{cmax} by inversion of Farquarian photosynthesis model, and to model GPP via flux partitioning.

Site	Year	LAI	V_{cmax} (umol/m2s)
Coastal Sagebrush	2011	2.3	123.8
	2012	2.4	34.6
	2013	2.7	16.8
Oak Pine Forest	2011	2.7	15.9
	2012	2.5	10.4
	2013	2.4	22.0
Ponderosa Pine Forest	2011	2.3	28.0

Table 1. Estimates of V_{cmax} from flux tower data, along with correlated LAI estimates. 2013 LAI estimates are similar to those made in the field. A drought induced decrease of V_{cmax} is apparent at the coastal sagebrush site over the last 3 yrs.

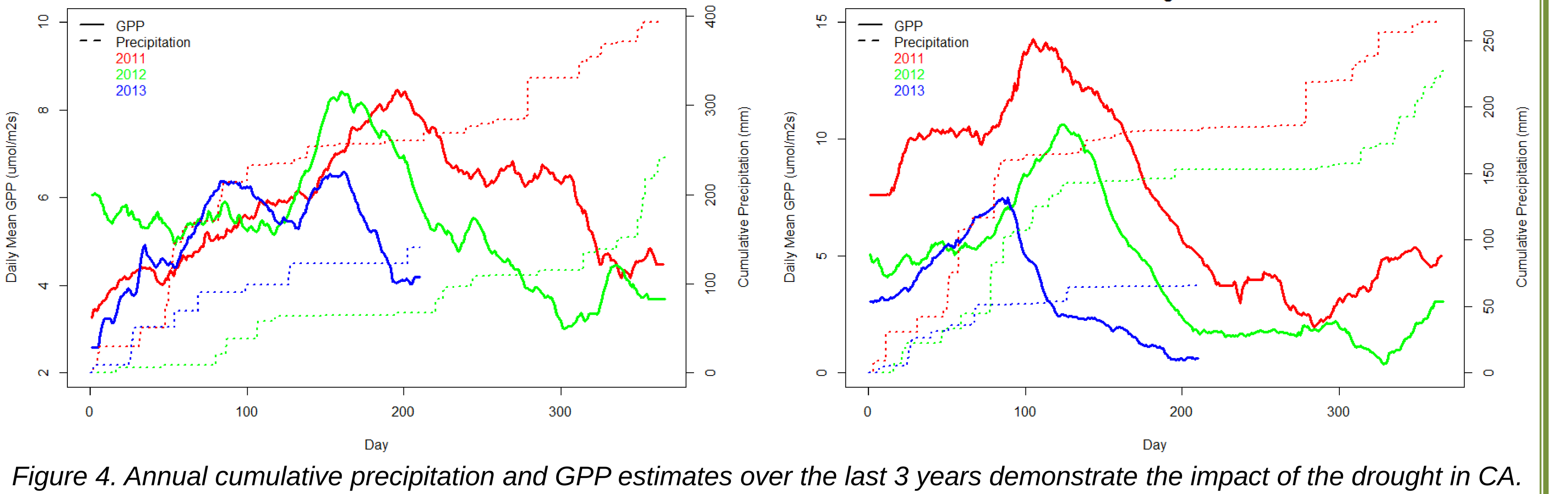

Figure 4. Annual cumulative precipitation and GPP estimates over the last 3 years demonstrate the impact of the drought in CA. Significant decreases in productivity are prevalent at the sagebrush site, and visible in 2013 estimates at the oak-pine forest.

4 Conclusion

- Scaling up leaf metabolism and chemistry to the canopy scale using novel algorithms is feasible with remote sensing data
- Correlated decrease in GPP and V_{cmax} demonstrates impact on vegetation of drought and has implications for the future
- Land use change, including transition to agriculture & urbanization, pollution & changing climate have dramatic effects on photosynthesis
- These and other stress events can be monitored on the regional scale by the methods used in this study
- Implementation of a space-borne imaging spectrometer offers the ability to monitor such global changes
- Further research is required to determine an efficient scaling method for V_{cmax} to eliminate discrepancy between flux tower estimates and those from gas exchange estimates & hyperspectral observations

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References

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