Patterns and controls of land-atmosphere carbon, water, and energy exchange

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Long-term context: Drylands appear to play an important role in regulating the seasonal amplitude of CO₂ in the Earth’s atmosphere (Ahlstrom et al. 2015, Poulter et al. 2014). Understanding how such mechanisms manifest from seasonal to decadal time scale variability and change at multiple spatial scales is important for understanding trajectories and biophysical mechanisms of change and how global change impacts and management of drylands could alter future Earth System states. The JER is a critical platform for advancing dryland-focused global change science because sustained observations and integrated experiments relevant to understanding the biophysical controls of land-atmosphere carbon, water, and energy exchange have been maintained and documented for more than a Century. This study was performed on the JER as a collaboration between an NSF-CREST funded research lab at UTEP and the Jornada LTER.

Our approach to understanding the Biophysical controls of land-atmosphere carbon, water, and energy exchange in drylands has been to (1) establish and sustain a heavily instrumented site in a piedmont slope shrubland with both proven and novel infrastructure suited to scaling observations from the plant to regional-scales [Fig. 1]; (2) use discovery analytics to determine likely biophysical controls of fluxes over seasonal and inter-annual time-scales and in response to episodic events; and (3) define an experimental approach that includes a minimalist suite of autonomous sensors suitable for empirical derivation of land-atmosphere fluxes that can be deployed in multiple dryland land cover types to better parameterize models capable of regional-scale analysis.

Specific objectives in the past 3 years include: (1) Sustaining measurements from an eddy covariance tower, micrometeorological sensor network, robotic tramline that measures hyperspectral reflectance, phenocam (Ramirez et al. 2015) and SpecNet phenostation network, and periodic plant based measurements of phenophase development and chlorophyll fluorescence; (2) initialize discovery analytics of likely seasonally dependent biophysical controls of ecosystem fluxes; and (3) explore the phenological variability of key plant species and multiple landscapes across the JER (not reported here).

Relationship with the LTER VI proposal: This study is primarily addressing objective 3 Shrubland->shrubland transitions and is specifically examining species and landscape-specific responses to climatic variability on the JER.

Our results show both substantial seasonal and inter-annual variability in Net Ecosystem Exchange (NEE) and differential responses of NEE to rainfall [Fig. 2]. In all years except 2013, the study site was a net sink for carbon with source activity in summer periods and sink activity in late spring and early fall. In 2013, following two years of below average rainfall, the site was an annual source of atmospheric carbon. This occurred as a result of high ecosystem respiration during the summer growing season and is likely a response of the soil microbial community to persistent but not intense precipitation events that resulted in relatively high soil water content in the upper soil layer that sustained microbial activity. Sink strength was greatest in 2014 under a precipitation regime similar to that experienced in 2013, suggesting buildup of organic carbon during
the relatively dry 2010-2012 period was re-mobilized through microbial activity responding to increased moisture availability in 2013 when GEE was relatively low following several drought years and the impact this had on foliage cover (data not shown). Random forest analysis showed that interactions between air and soil temperature, Photosynthetically Active Radiation, landscape greenness measured with phenocams, and soil moisture explained 85-95% of the variability in fluxes between 2010-2012 (Jaimes 2014). Interestingly, the relative importance of each factor varied by flux (NEE, GEE, R), season, and year. At present, such results appear difficult to model, suggesting a need for re-parameterization of drylands in ecosystem models (Xu pers. Comm. 2015). This study has helped showcase a new paradigm in dryland sensing (Browning et al. 2015), and ecological data management (Laney et al. 2015, Peters et al. 2014).

**Future analyses:** Current funding will permit measurements to be sustained through 2017. Several significant papers are in preparation and the analysis to determine a minimal sensor suite is underway. Landscape and intra and inter-species phenological trends across multiple land cover types on the JER is a focal topic of a Masters student. It is intended that these studies will culminate in the preparation of a future study that will explore patterns and controls of ecosystem fluxes in multiple managed landscapes to ascertain land cover, land use, global change, and their interactions convolve to impact regional scale fluxes. It is foreseen that NEON data will be integral to this project.

**Literature Cited** (*indicates a paper associated with this study and ^ indicates student authorship):