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Long Term Soil Water Trends Along a 1000 Meter Elevation Gradient

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INTRODUCTION

Many of the issues associated with ongoing global climate change hinge on the impacts of the documented physical changes (e.g., rising temperature) on the biological systems that sustain life. A primary interface between these two is the soil. Most GCM forecasts indicate that increasing temperatures will result in increasing evaporation rates and an increase in drought. However:

- very few measurements have been made to either confirm or contradict the simulated impacts and
- impacts can be expected to vary with precipitation amount and evaporative demand

Global Change at RCEW

Analysis of the hydroclimatic record at the Reynolds Creek Experimental Watershed (RCEW) for the past 45 years indicates the following significant trends:

- temperature increase throughout the watershed (0.35C/decade),
- the seasonal snowpack disappears earlier in the spring,
- streamflow, due primarily to snowmelt, occurs earlier in the year.

It is also notable that no significant trend in annual precipitation or total discharge was detected.

Soil water data have been collected, by neutron probe, on a regular basis, since 1976 at four sites with widely varying climates resulting from a 1000 m elevation gradient.

Objectives

Examine long-term soil water data set to determine:

How is inter-annual variability of soil water affected by climate and soil differences in the elevation gradient?

Are there measureable temporal trends of soil water associated with the documented climate change?

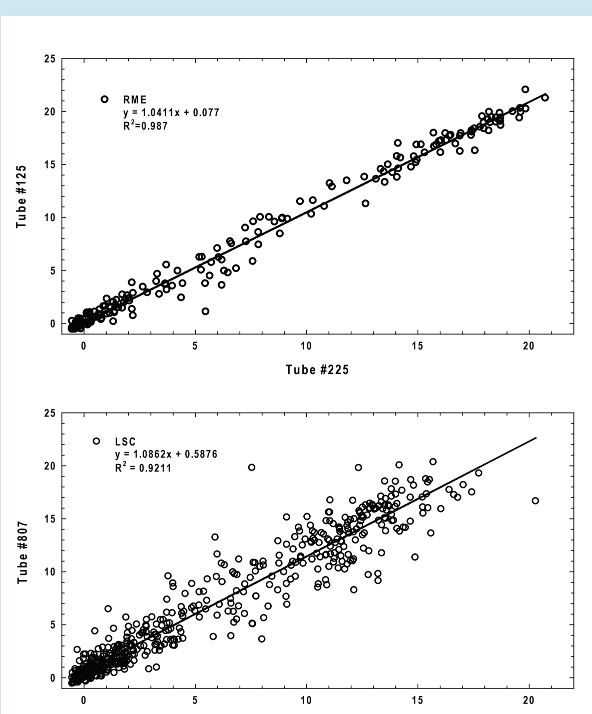
DATA COLLECTION

Neutron Probe Data Collection

Measurements were made at depths of 15, 30, 61 and 91 cm, about 20 times per year. Some critical features of the neutron probe:

- old, "mature" technology,
- uses a down hole approach, repeatedly measuring the same soil volume,
- very large measurement volume, a cylinder roughly 1 m deep and 30 cm in diameter, ideal for measuring soil profile water content but not for examining water content at a specific depth,
- requires physical site visit, so not appropriate for small time scale events, especially in remote sites.

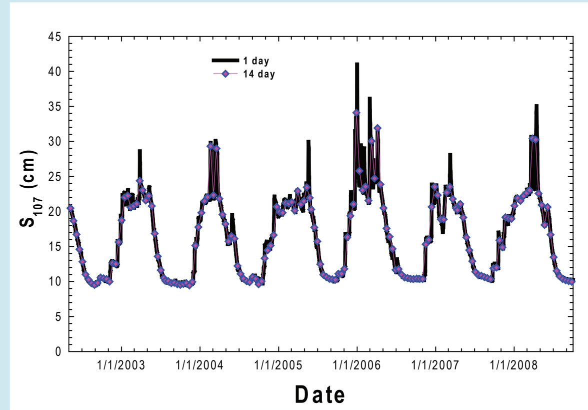
DATA ACCURACY AND VARIABILITY



Comparison of nuetron probe and lysimeter measurements of soil water storage indicate average differences of about 1 cm (depending on site). The data above illustrate the correlation between two neutron access tubes located about 1 m apart. We don't know why the two sites are so different.

DATA ISSUES WITH LONG TERM DATA

Collecting data over a 35 year time span introduces issues that aren't encountered in most research. For this neutron probe data set, three issues became apparent: **1.** Different instruments were used. Even though there were all co-calibrated, measurement volumes and sources are different and will yield slightly different results. **2.** Measurement depths change slightly over time due mostly to slippage along the cable and confusion among operators as to the location of the source center. **3.** Measurement frequency was not even across sites, especially at the higher elevation site, which was not measured duriong the winter months for the first several years.

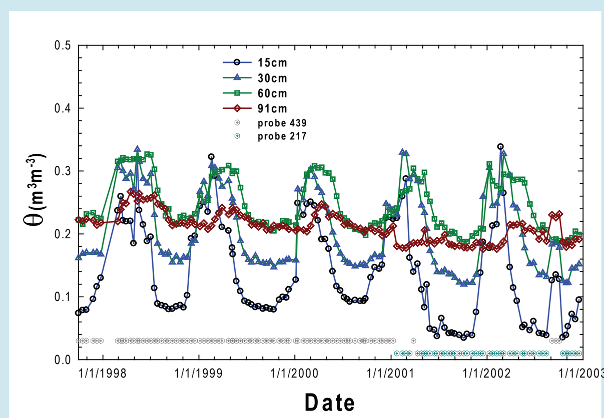


Comparison of information obtained with biweekly versus hourly SR,107 data taken from hourly TDR data collected from a site at the RCEW. The biweekly points, which represent the neutron probe data we discuss, miss some of rapid input events but capture the overall seasonal dynamics quite closely. Agreement is especially good during the late spring-summer decline.

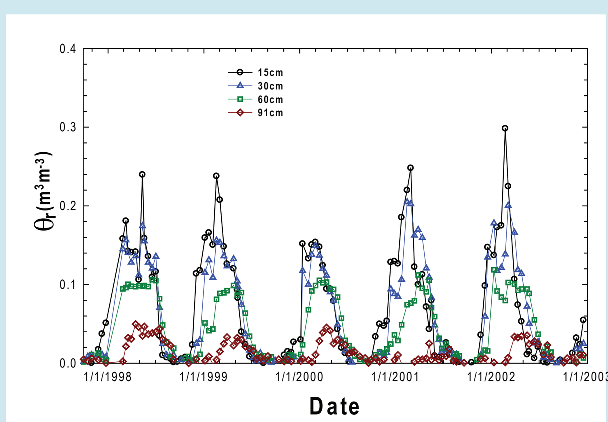
DATA PROCESSING

Basis for the Approach Used

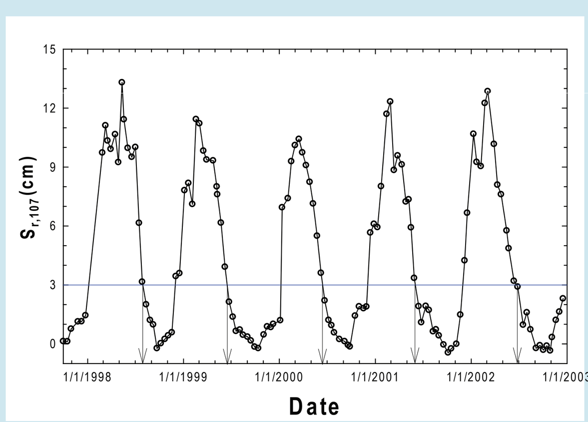
1. The vegetative cover is dominated by perennial vegetation. It will take up water when climate and soil conditions permit and, it is not highly sensitive to surface dynamics.
2. The seasonal pattern of precipitation and evaporative demand result in extremely dry conditions every summer.
3. The empirical observation that all soil horizons return to the same, low water content each year during the period of high evaporative demand.



Raw neutron probe data from four depths collected at Lower Sheep Creek. Minima are reproducible but change with the switch from from probe 1 to probe 2.

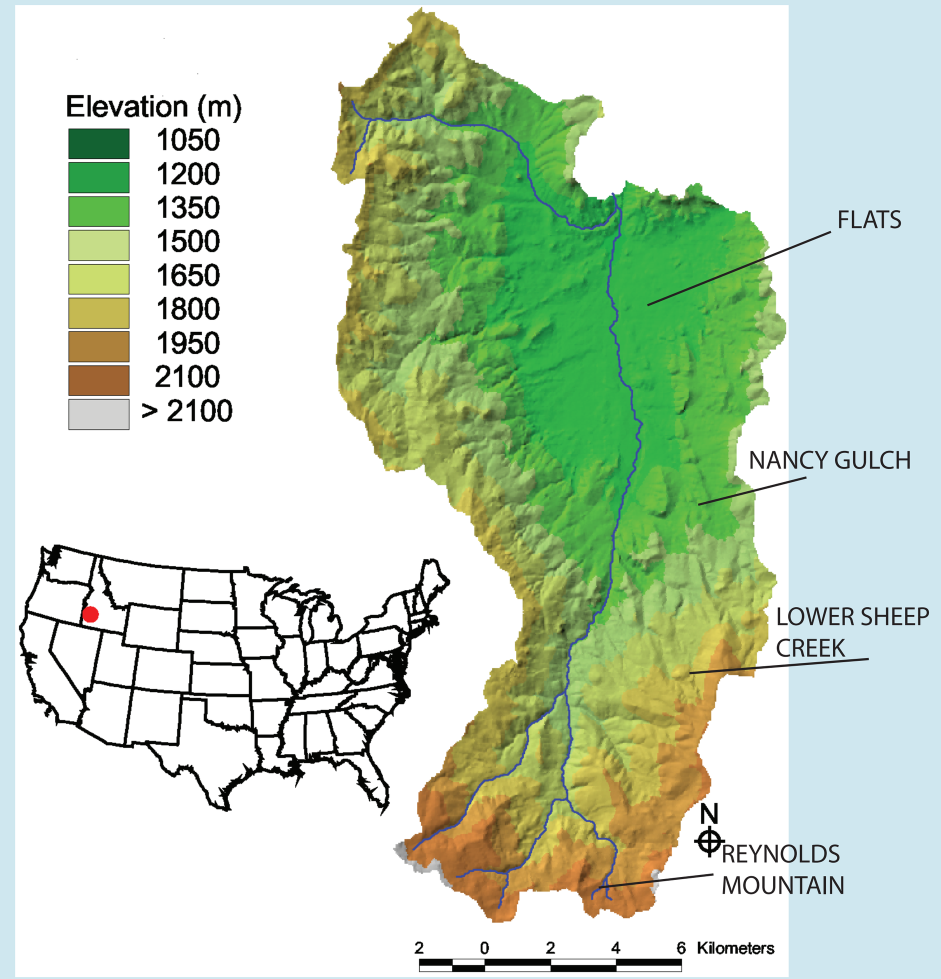


Water contents calculated relative to annual minima to correct for instrument effects.



Profile storage to 107 cm (S) calculated from the relative water contents in the figure above. Arrows indicate the day of stress (DOS) for five years as the date that S drops below 3 cm. An indication that climate change is impacting plant water stress would be if DOS trended earlier in the year over time.

SITE DESCRIPTION

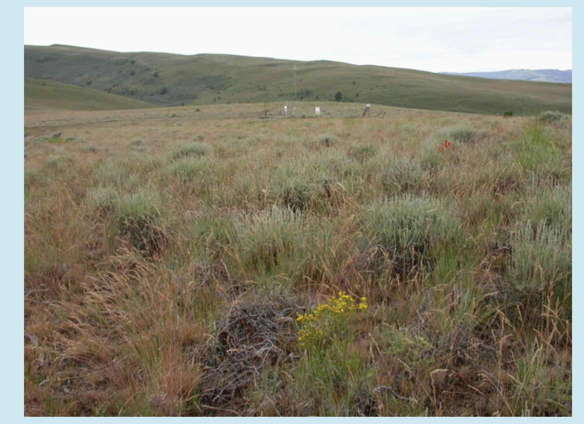


Reynolds Creek Experimental Watershed (RCEW)

Flats

Nancy Gulch

Lower Sheep Creek



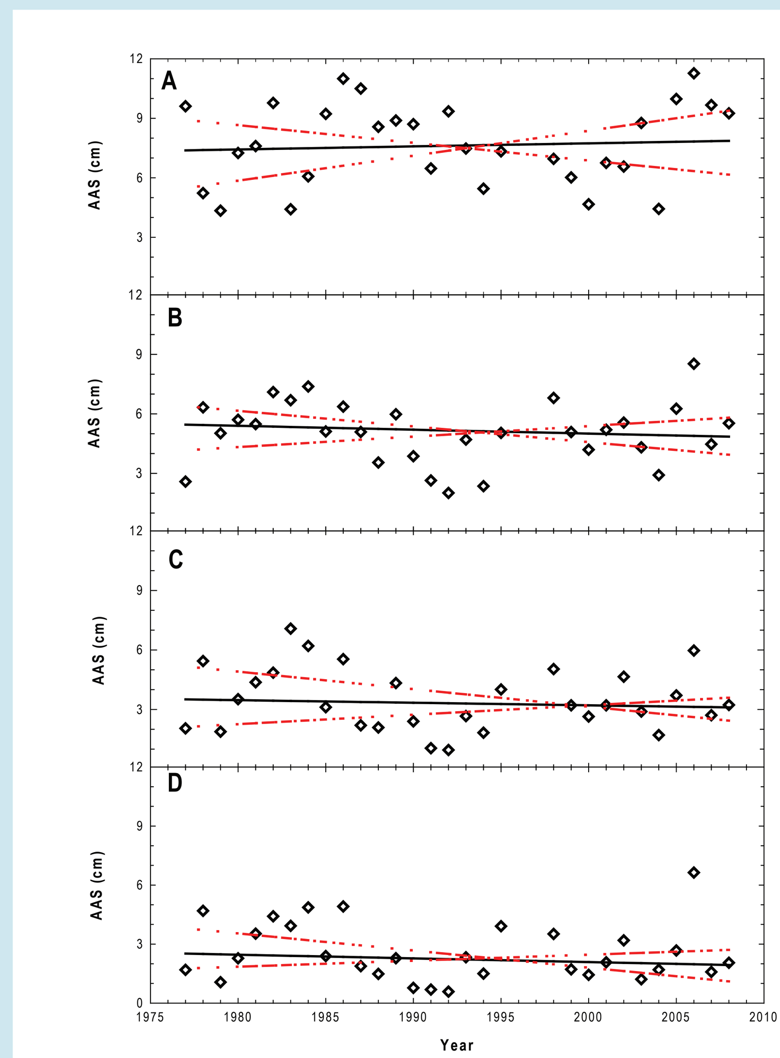
Reynolds Mountain

Site	Elevation m	MAP mm	MAT C	% snow %	Veg
Flats	1186	227	9.3	10%	WS, AC
Nancy Gulch	1413	289	9.1	20	WS
Lower Sheep	1653	330	7.9	45	LS
Reynolds Mt	2067	772	4.7	85	MS

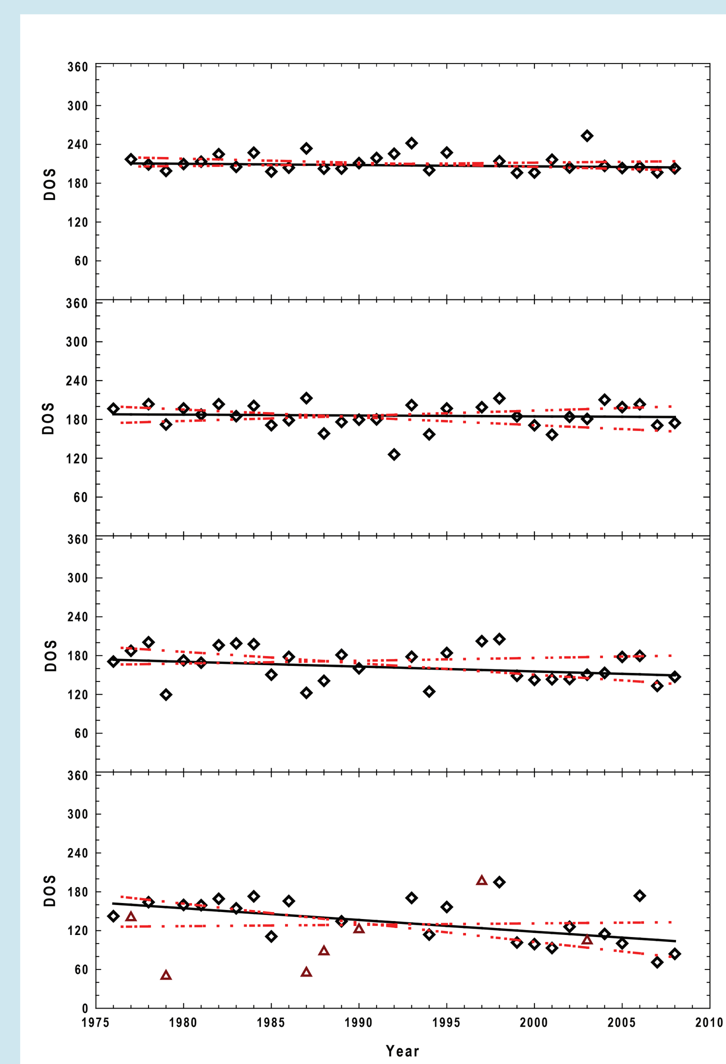
There is a large temperature and precipitation gradient with elevation across the four sites. All four sites are dominated by different types of sagebrush, Mountain (MS), Low (LS), and Wyoming (WY). Although the precipitaiton amounts and form vary considerably among the sites, they share a very dry summer, which is common to the entire region.

LONG TERM SOIL WATER TRENDS

We used two metrics to determine long term temporal trends, the average anual soil water storage to a depth of 107 cm (AAS) and the date of soil water stress (DOS). The AAS is simply the average of sotrage measurements made during the water year. The DOS is somewhat arbitrarily defined as the date that storage drops below 3 cm of water. The idea is that, in this climate there is a summer drought every year. If the soil drys out earlier in the year, then the vegetation must experience more water-relalted stress.



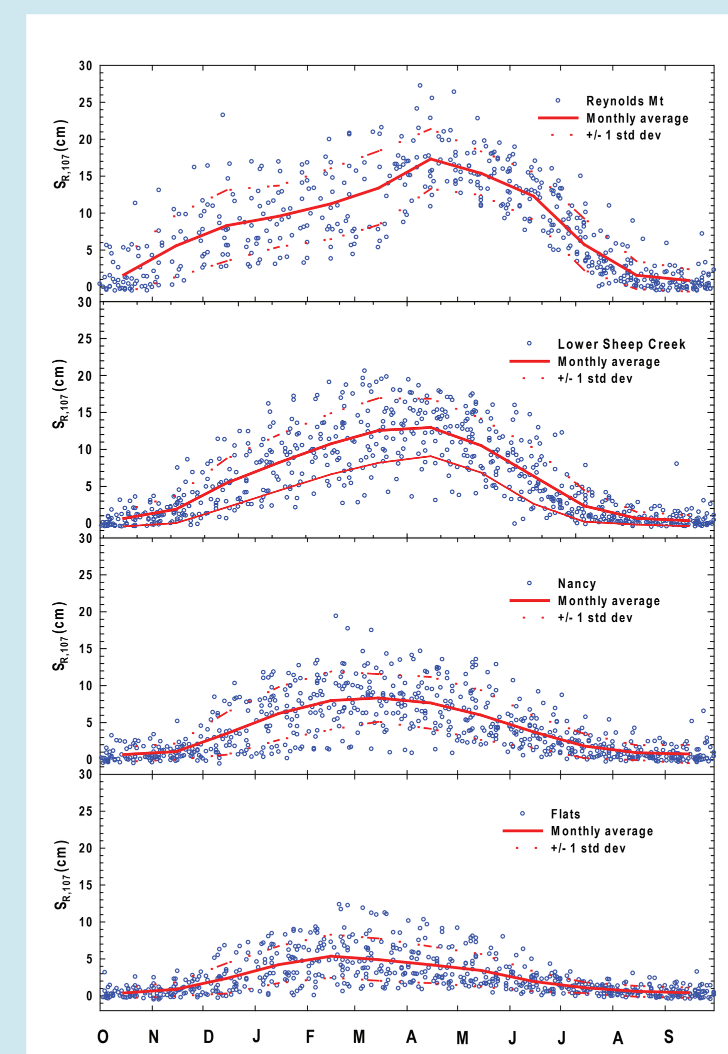
Average annual storage with 95% confidence interval at: A. Reynolds Mt, B. Lower Sheek Creek, C, Nancy Gulch and D., Flats. Slopes are calculated with Sen's slope estimator and significance is determined by Mann-Kendall test. None of the slopes are significant ($\alpha = 0.10$), indicating no change in soil water storage at any of the sites.



Day of Stress with 95% confidence interval at: A. Reynolds Mt, B. Lower Sheep Creek, C, Nancy Gulch and D., Flats. Slopes are calculated with Sen's slope estimator and significance is determined by Mann-Kendall test. None of the slopes are significant ($\alpha = 0.10$), inidcating no change in the date of summer dry out at any of the sites.

INTER-ANNUAL VARIABLITY OF STORAGE

Data points represent all data collected at the site for each date. Average and standard deviation lines are monthly statistics.



The differences in average storge and drying noted in the Table are evident. The annual snowmelt at Reynolds Mt. assures that, in the spring, there is always stored soil water. Summers are virtually always dry at all sites and variability is minimal then. Variability is highest in the spring, with a standard deviation of about 3 cm at all the sites.

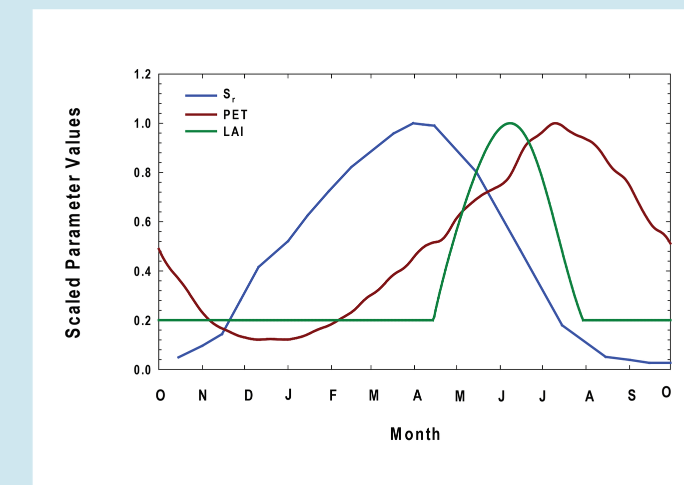
ELEVATIONAL TRENDS

	AAS			
	Flats	NG	LSC	RME
Avg (cm)	2.57	3.49	5.06	7.72
SD	1.49	1.58	1.58	2.06
N*	30	30	30	30
CV (%)	57.87	45.3	31.24	26.72
	DOS			
Avg	17-May	14-Jun	4-Jul	31-Jul
Std	33.56267	25.66557	19.52301	14.15175
N	26	30	31	30
CV(%)	24.57	15.5208	10.56162	6.669028

*lack 96 and 97

The AAS increases dramatically with elevation. It's 3 fold greater than at the Flats. This is a direct reflection of the increased precipitation and reduced PET with elevation. Interannual variability is about the same at all sites. Similarly, DOS is dramitically earlier at the Flats, about 10 weeks. The decreased interannual variability with elevation reflects the shortened growing season as elevation increases.

ECOHYDROLOGY AND SEASONAL DYNAMICS



Average timing of critical parameters associated with the annual pattern of soil water loss to transpiration. The system is somewhat sensitive to increased temperature for only a very short time period when S, PET and LAI are near maximum.

CONCLUSIONS

1. There are pronounced differences across sites both in terms of AAS and DOS. These differences quantify the soil water availability gradient that may induce future vegetative "migration".
2. There is a no apparent temporal trend for either of the metrics of soil water we used (AAS and DOS) at any of the sites studied. That is, there is no signicant effect of climate change on soil water.
3. Interannual variability of soil water storage is relatively high in late winter and spring.
4. High interannual varibility of precipitaiton only partly explains the lack of temporal trend.
5. There are two primary causes of the lack of temprol trend:
   A small "signal" due to the fact that increased demand can only be expressed when LAI and soil water contents are high,
   A large amount of noise due to a variety of causes, including precipitaiton variability.

Neutron probe currently in use at Nancy Gulch

ACKNOWLEDGEMENTS

This work was carried out by the ARS at the Northwest Watershed Research Center. This long term data set would not exist but for the work of Clayton Hanson, Deb Coon, Zane Cram and Mark Murdock.