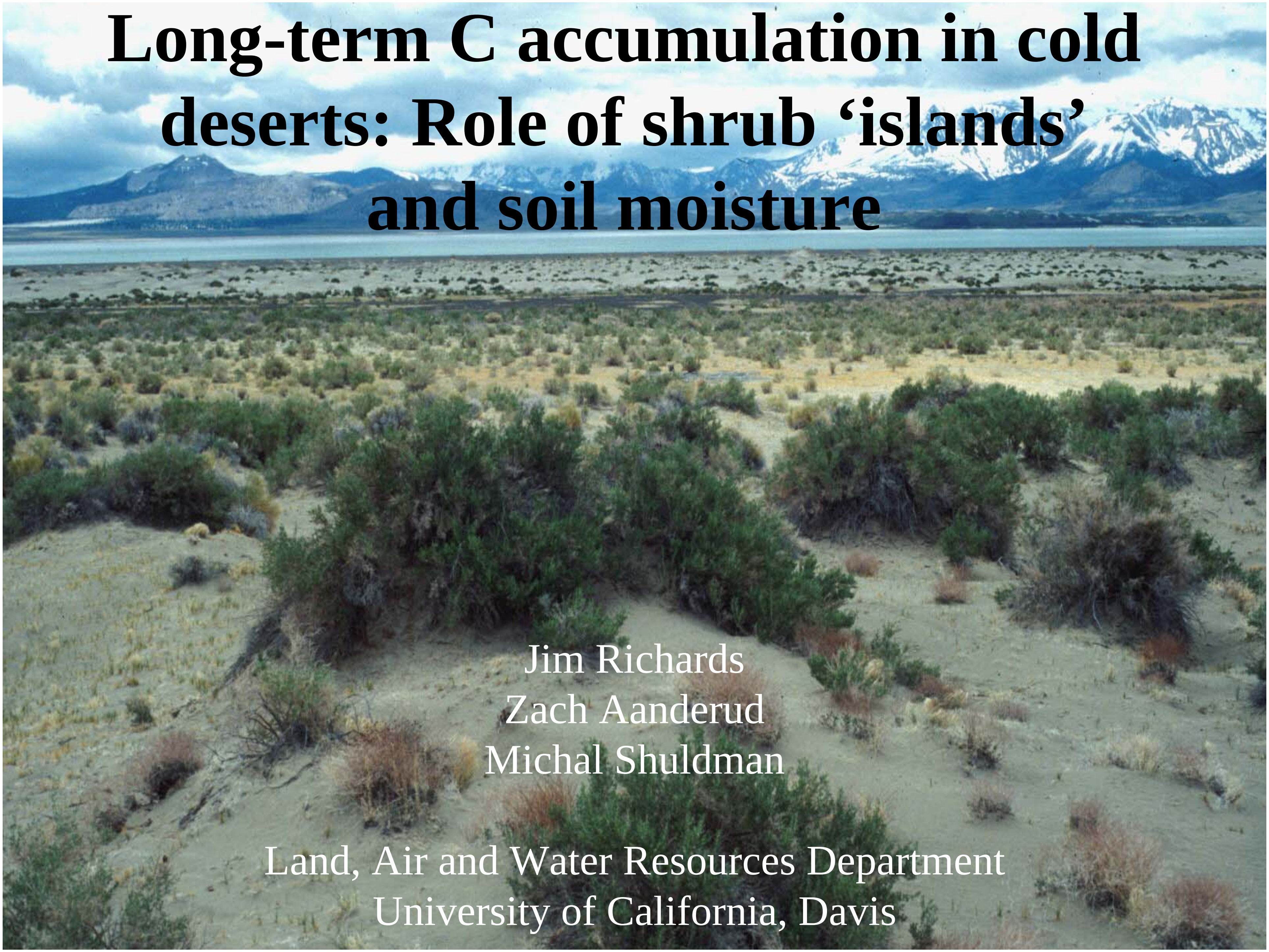
Long-term C accumulation in cold deserts: Role of shrub ‘islands’ and soil moisture



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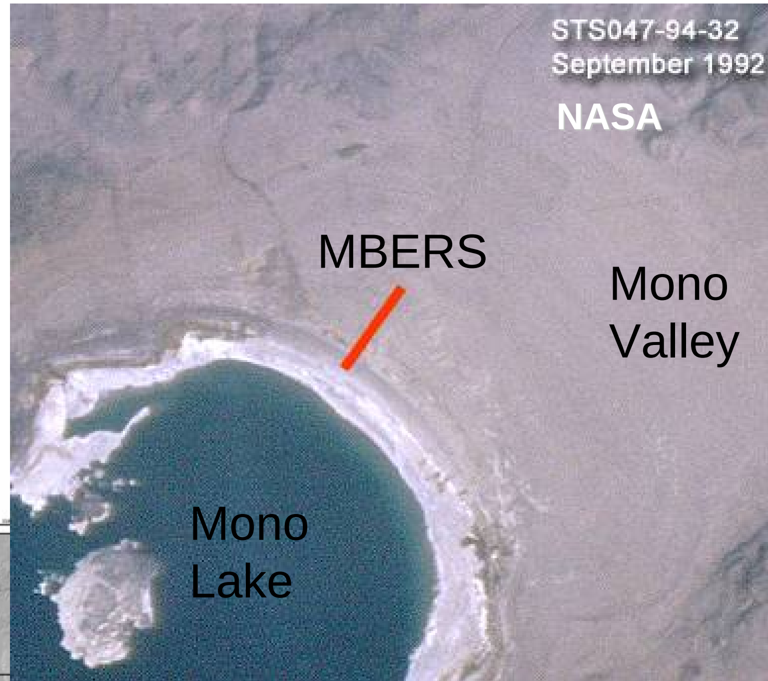
Overview

Chronosequence at MBERS and *Sarcobatus*

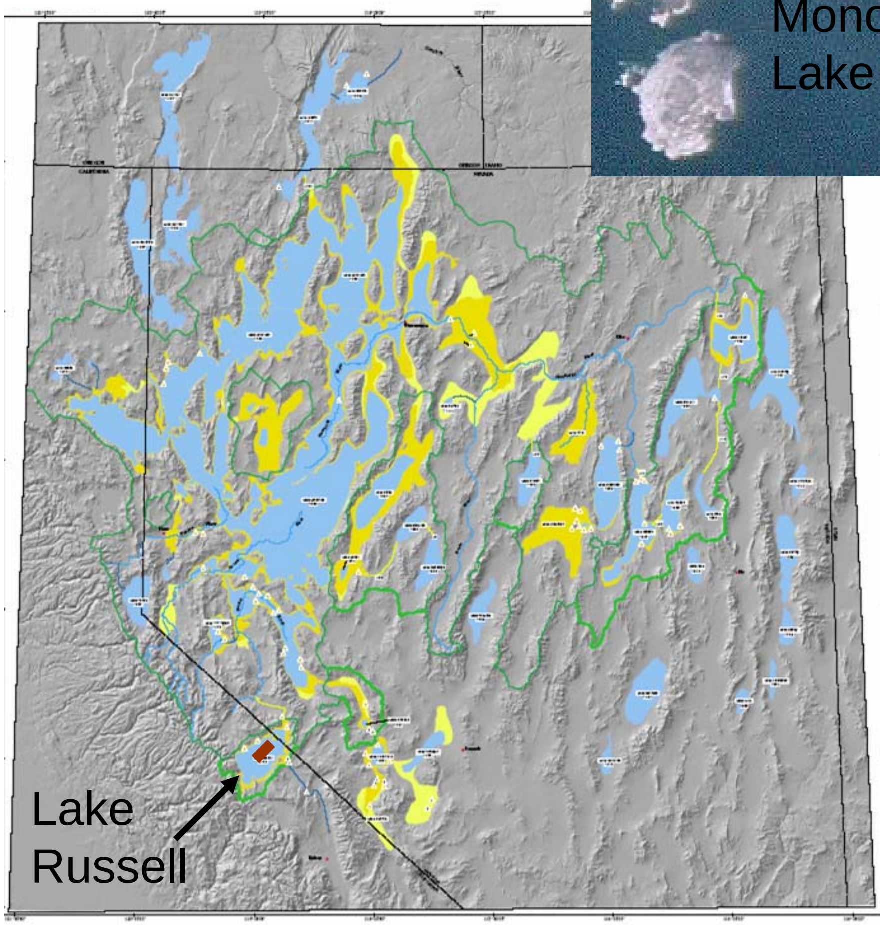
Three major research activities

1. Inventory of C accumulation and fractions at landscape and shrub-island/interspace spatial scales; Landscape is the space-for-time ~3000 year chronosequence
2. Decomposition rates of four litter types relative to abiotic and biotic environment across landscape and shrub/island spatial scales
3. Experimentally assess effects of hydraulic redistribution on decomposition, litter and SOC fractionation, and soil decomposition processes

Chronosequence background



M. Reheis 1999 USGS



Large areas in the Great Basin were lake bottoms during early and late Pleistocene.

Natural recession exposed extensive areas and this has been augmented recently by very rapid exposure of additional lake bottom by water diversion for urban uses.

Shorelines were colonized by *Sarcobatus vermiculatus* which trapped windblown materials building large biogenic dunes and dune complexes.

Sarcobatus vermiculatus (black greasewood)

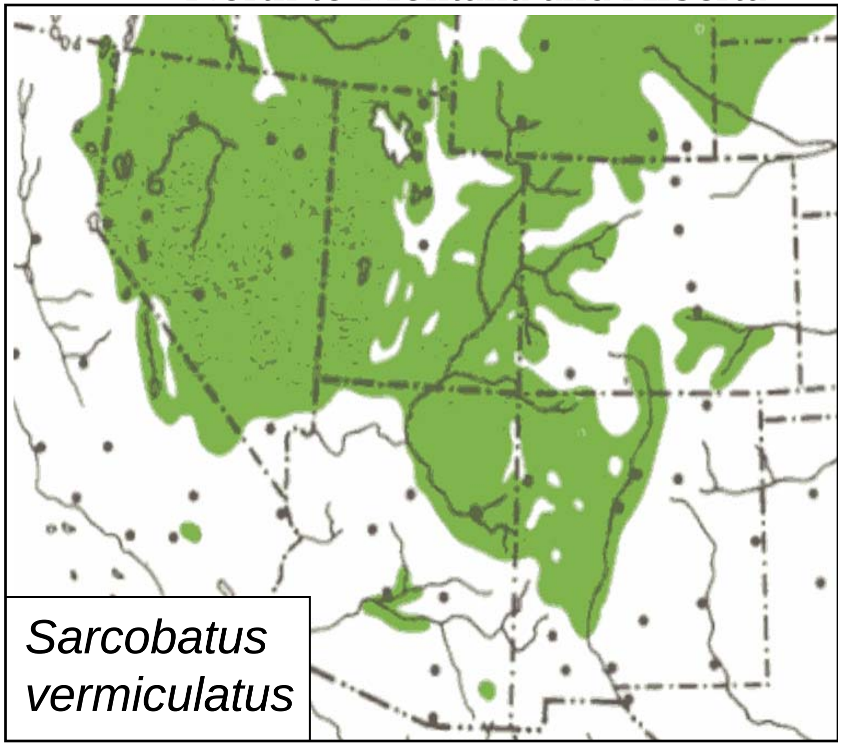
Most widespread phreatophyte in W. North America; root depth up to 17 m
Dominates on over 4.8 x 10^6 ha and major component of other desert communities
Primary colonizer of exposed lake sediments and forms persistent biogenic dunes

Sarcobatus colonizing 1982-84 shoreline at Mono Lake (1996 photo)

Transverse Dunes (TD); 86 yr old. Groundwater > 8 m deep

Diverse Dunes (DD); ~300 yr old

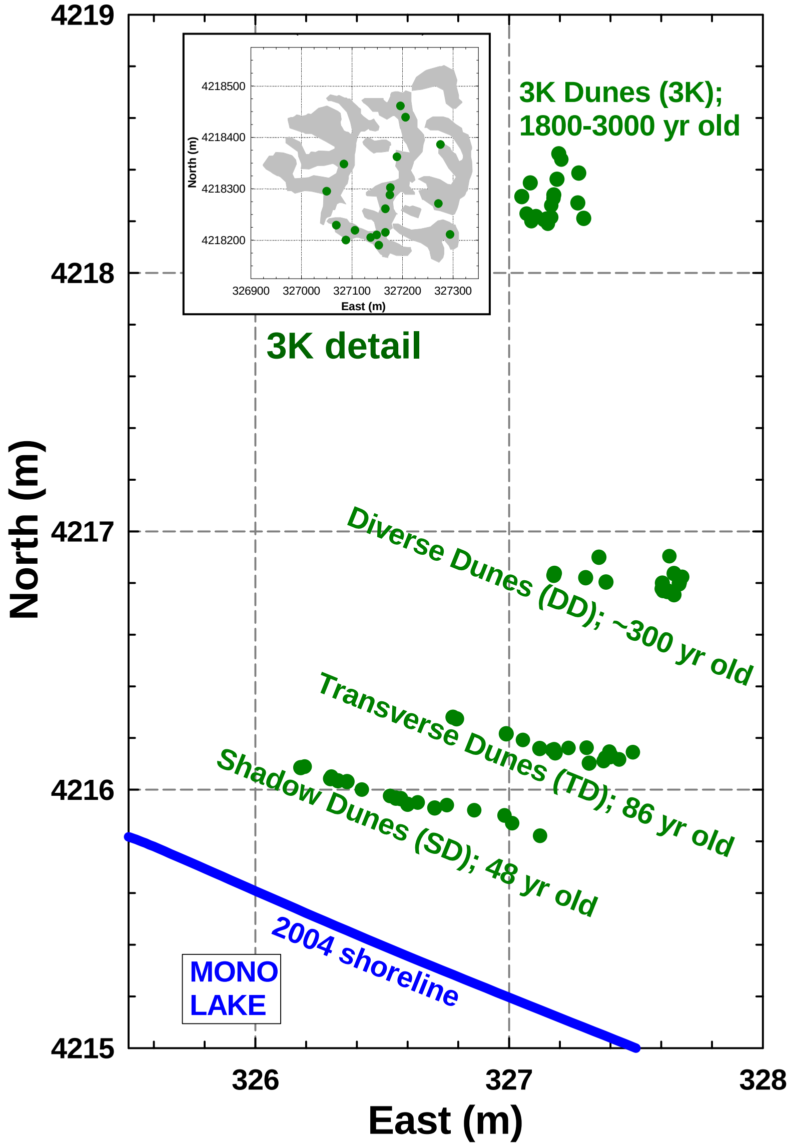
North to Montana and Alberta

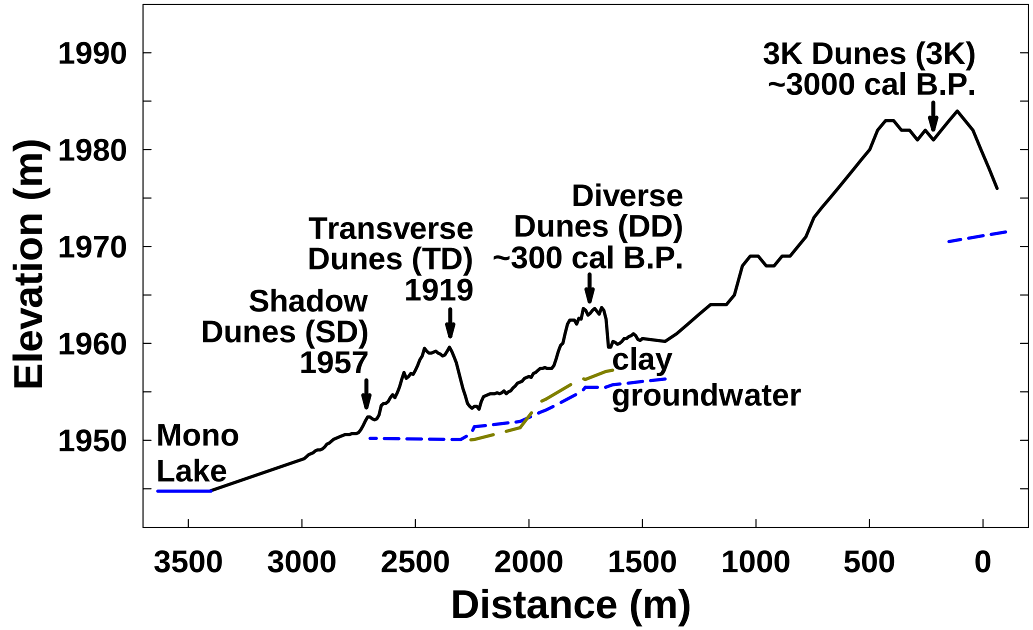


Benson and Darrow (1981)

Chronosequence of sites dominated by *Sarcobatus*

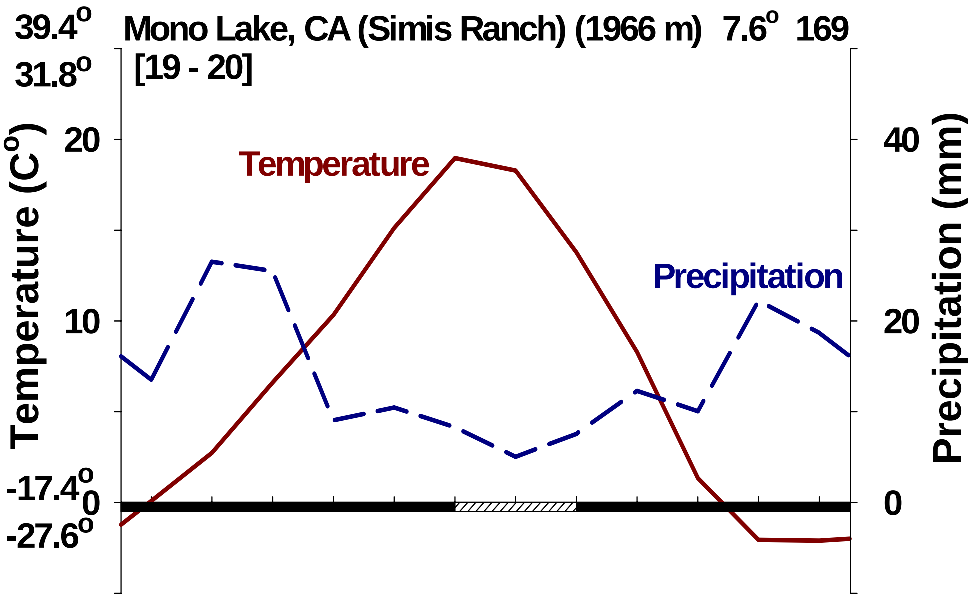
MONO BASIN ECOSYSTEM RESEARCH SITE (MBERS)





	SD	TD	DD	3K
pH	9.8	9.8	8.4	8.3
EC_e (dS/m)	13.4	8.8	1.7	2.2
EC_{gw} (dS/m)	16.1	5.4	1.5	--
D_{gw} (m)	2.2	7.4	9.4	~10

MBERS cold desert chronosequence



Spatial variability in snow deposition, infiltration, and soil moisture are hypothesized to be major abiotic drivers, along with differences in salinity, pH, and temperature. Biotic factors such as shrub density, NPP, litter inputs, microbial communities, and hydraulic redistribution differ at both landscape and microsite scales.

22 FEB 2005 photos

1. Inventory of C accumulation and fractions at landscape and shrub-island/interspace spatial scales;

2004 sampling:

4 sites (SD, TD, DD, 3K)

8 shrub islands & 8 interspaces at each site; stratified random

4 depths (0-20, 20-60, 60-120, 120-200 cm)

C pools: (incl. C, N, $\delta^{13}C$)

Shrubs (1/4 shrub): leaves, stems, dead; coarse roots (2005)

Soils: SIC of all fractions, OC: fine roots, coarse litter, fine litter,

SOC (light, heavy, microbial biomass, DOC)

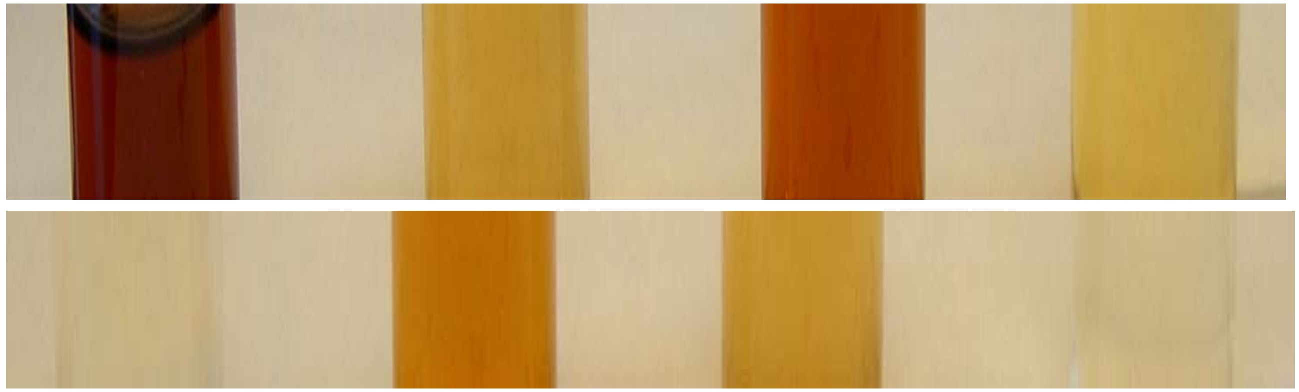
Plant community:

Cover of all species, interspaces, standing dead; canopy areas & volumes

Substantial SOC is present in very deep sandy soils at the older sites. This example shows extracts from one 3K site

Shrub island

Interspace



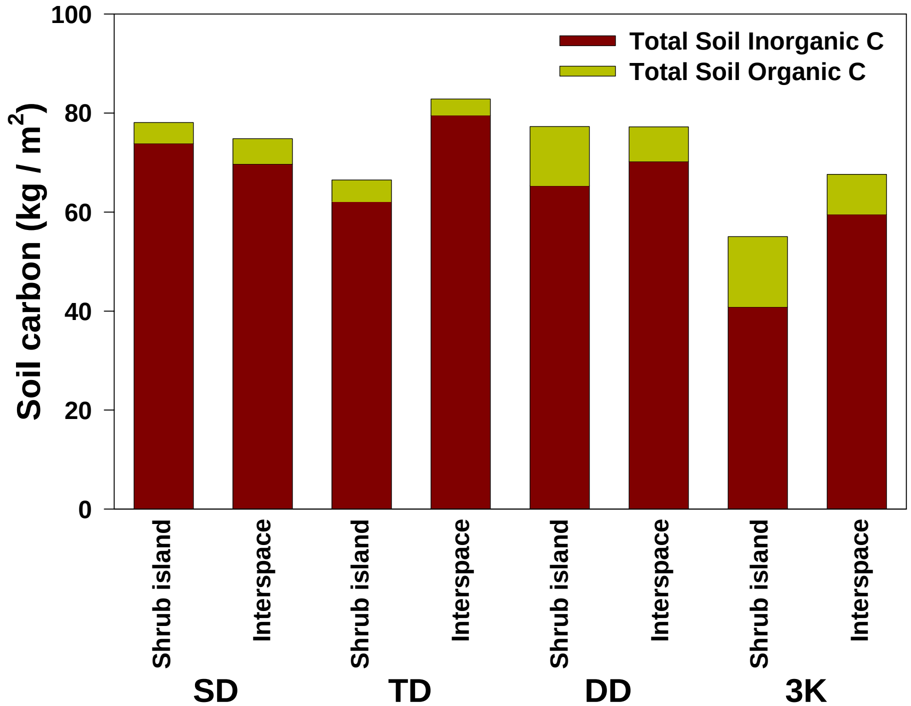
Depth (cm) 0-20 20-60 60-120 120-200

Based on samples so far, a very high percentage of soil C is in 3 deep layers:

86% of coarse litter

81% of fine litter

95% of roots



93% of soil carbon is SIC at SD (pH 9.8)
84% of soil carbon is SIC at 3K (pH 8.3)

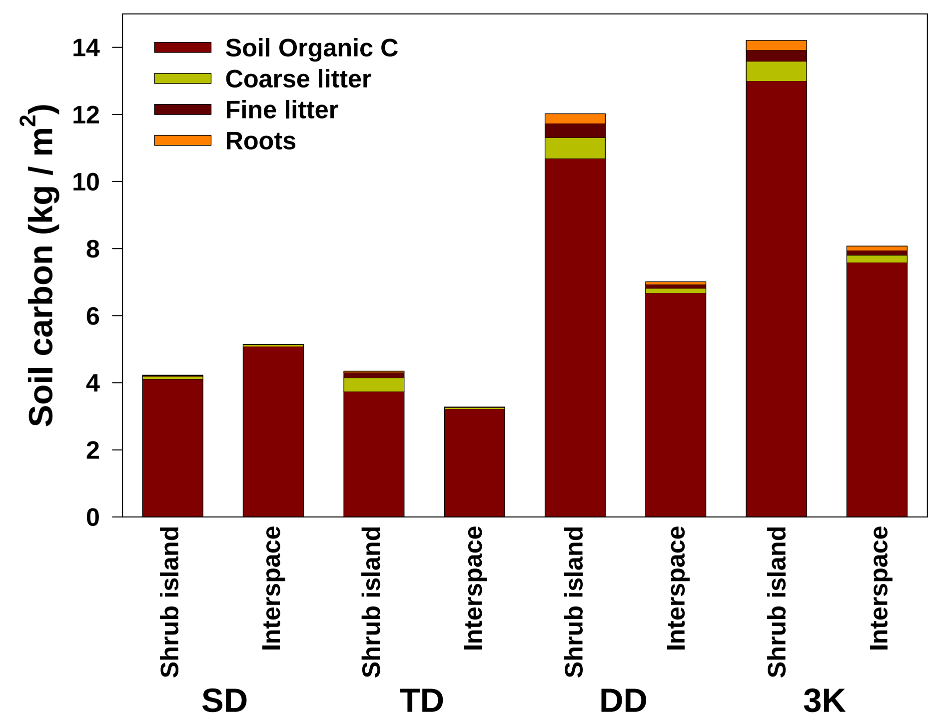
Differences in aqueous chemistry at time when shorelines formed may be important

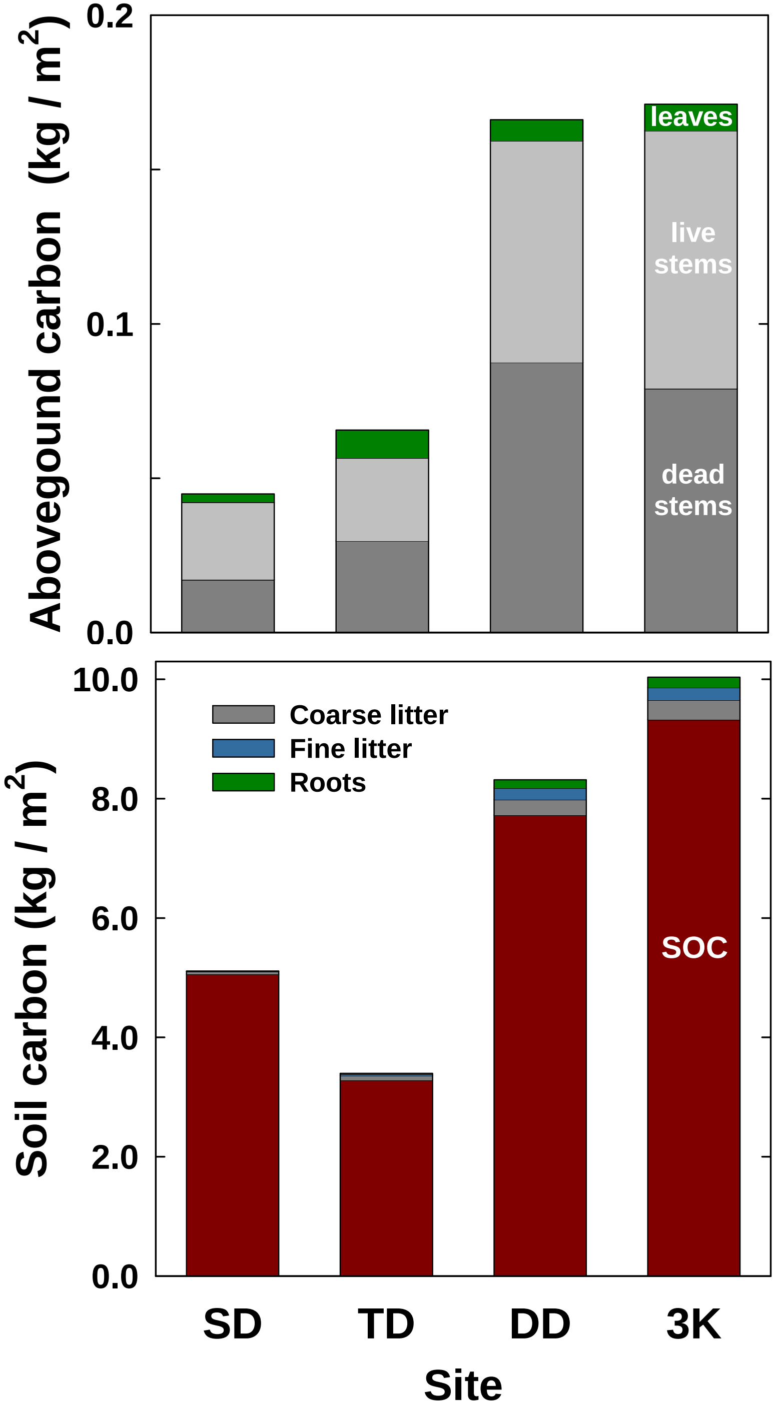
SIC proportion in shrub islands lower than interspaces in three older sites

Majority of organic carbon is SOC

Two oldest sites have ~ two-fold more SOC in shrub islands than in interspaces

Large accumulation by 300 yr. (i.e. "old growth" deserts)





Large accumulation of soil carbon in "old growth" cold desert ecosystems.

Accumulation rates are very slow after first couple of centuries.

Nitrogen limitations (more than water) limit *Sarcobatus* growth at DD and 3K
(Donovan & Richards 2000, Snyder et al. 2004, Drenovsky & Richards 2005)

2. Decomposition rates of four litter types relative to abiotic and biotic environment across landscape and shrub/island spatial scales

<u>Litter bags installed November 2003:</u>

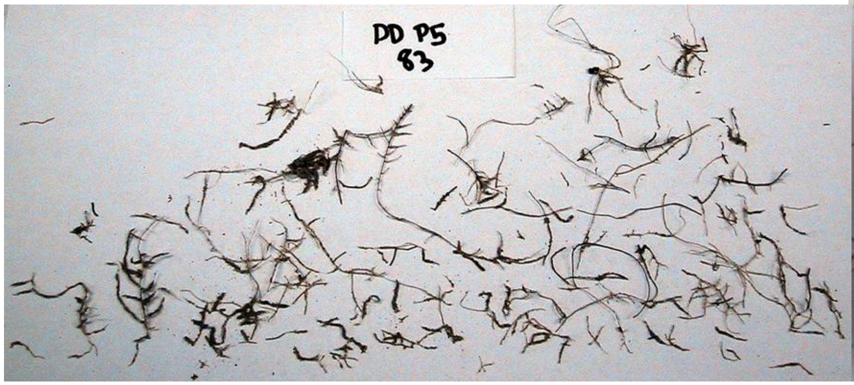
- 4 sites (SD, TD, DD, 3K)
- 8 shrub islands & 5 interspaces at each site; stratified random
- 4 litter types (leaves, stems, coarse roots, fine roots)

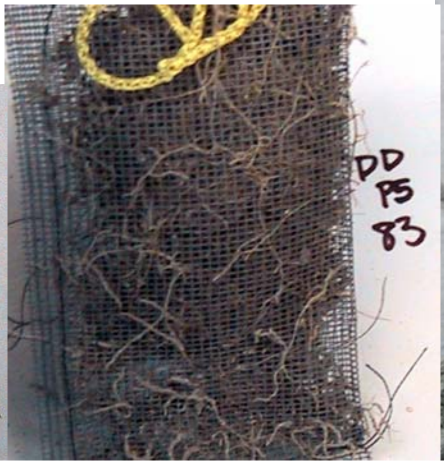
<u>Litter bag harvests: Nov 2004, Nov 2005, Nov 200?:</u>

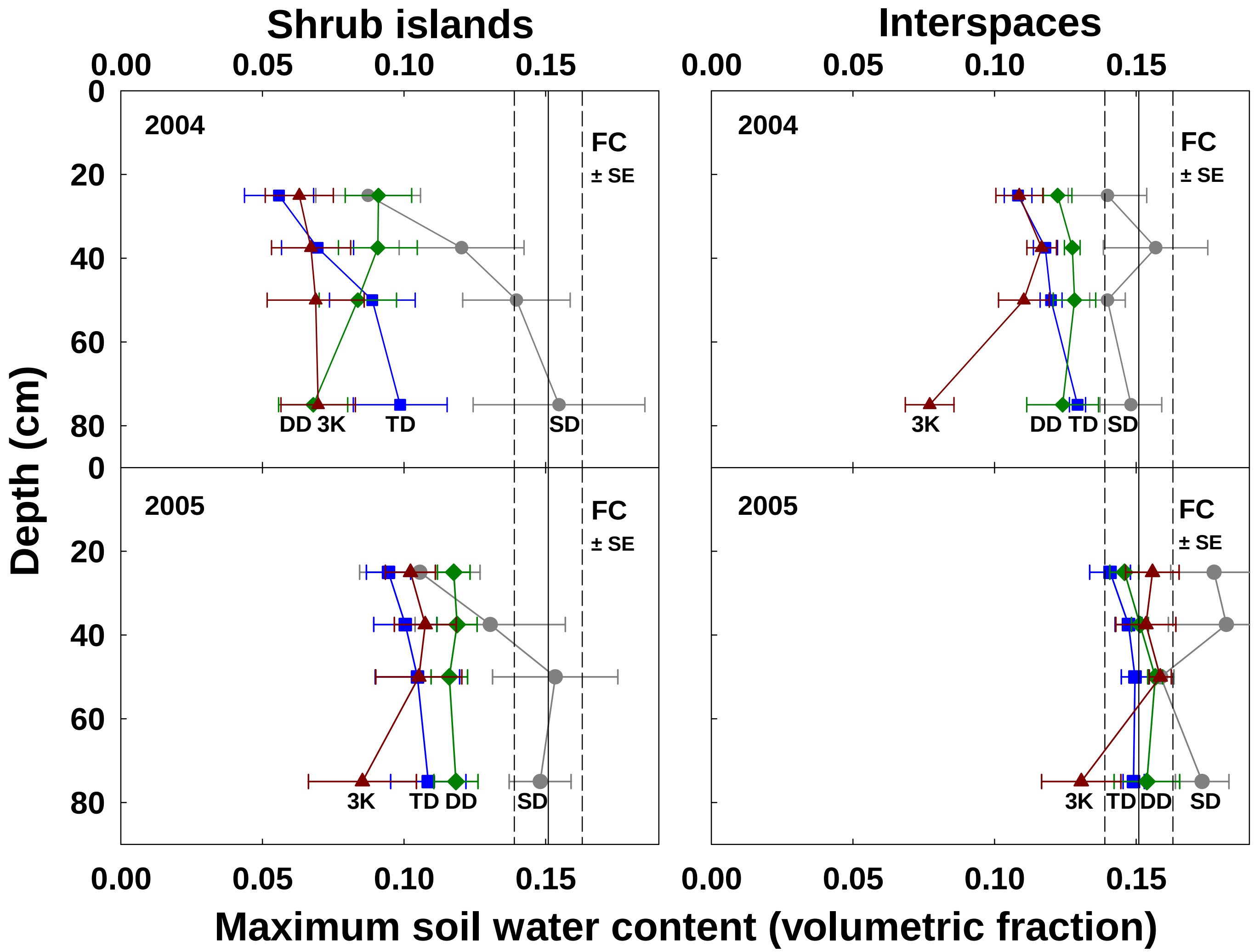
- biomass, C, N change; lignin, cellulose, hemicellulose change

<u>Abiotic variables:</u> soil moisture, soil temperature, EC, pH

<u>Biotic variables:</u> PLFA of microbial community (0-20, 20-60 cm depths, respiration incubations, microbial biomass, potential mineralizable N

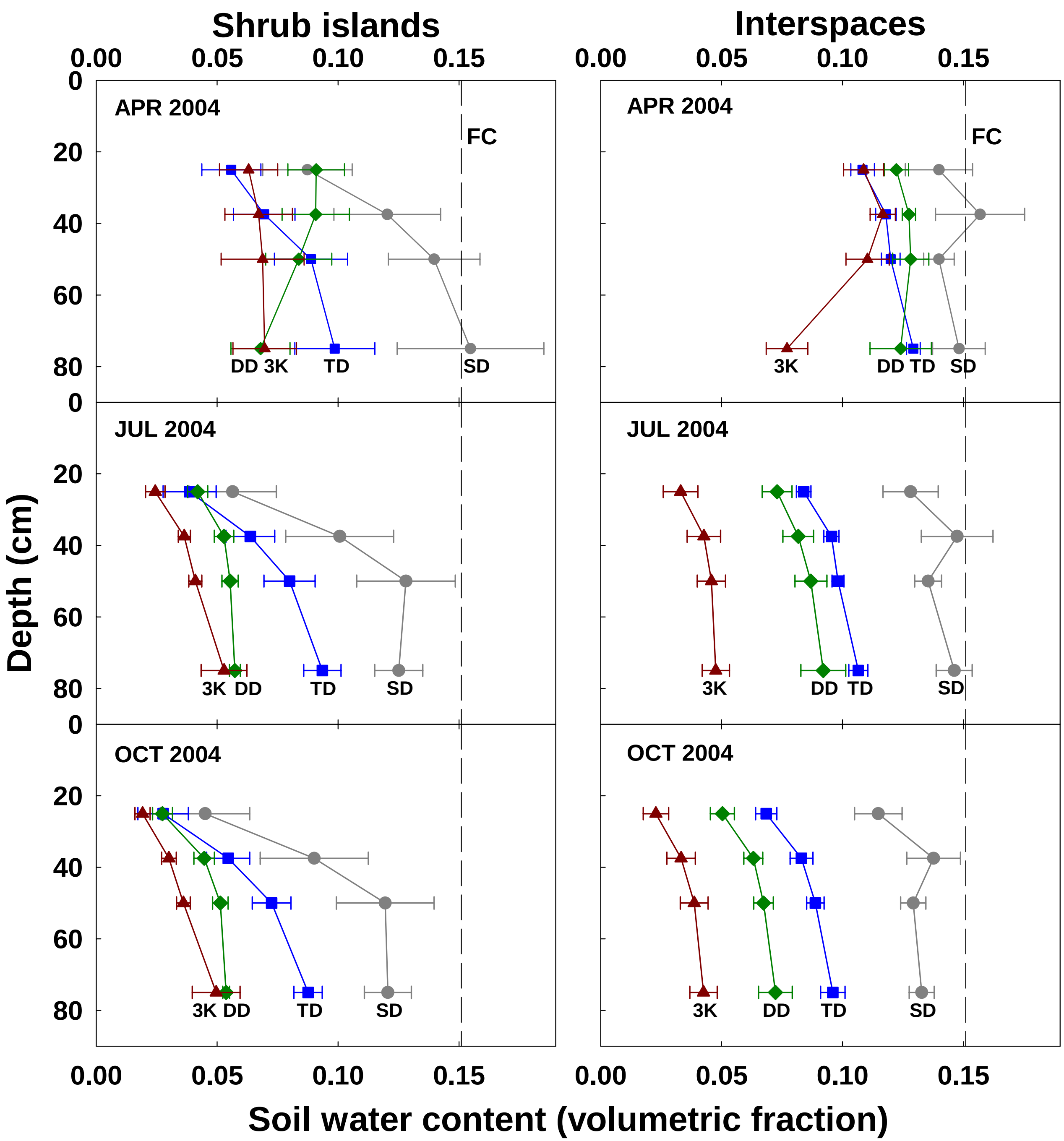






At the time of maximum soil moisture content in early spring, shrub islands are much drier than interspaces

This pattern is still present in 2005 with extremely high precipitation, similar to pattern seen in 2004 when precipitation was normal

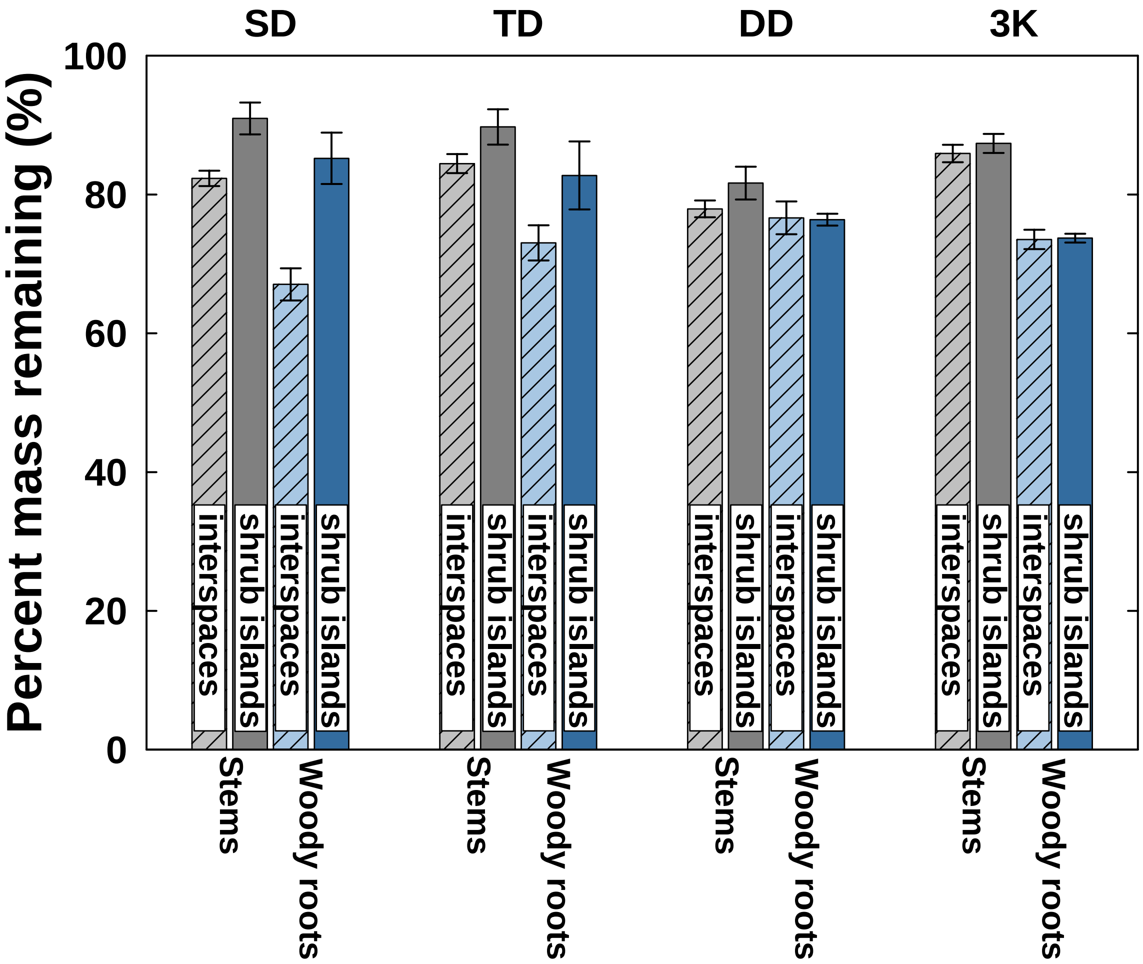


Shrub islands, where the majority of litter is deposited, are much drier (3-7% vol water content) than interspaces at all times during warm season

Water extraction is greater from interspaces on older versus younger sites

All age sites have extensive depletion by roots in surface (30 cm) horizon in shrub islands

- Mass loss of woody litter has been faster than expected
- Woody roots appear to lose mass faster than woody stems
- At younger sites, mass loss is greater in interspaces than in shrub islands, consistent with soil moisture differences
- At older sites, mass loss is similar in interspaces and shrub islands, in contrast to the large differences in soil moisture between the microsites



3. Experimentally assess effects of hydraulic lift on decomposition, litter and SOC fractionation, and soil decomposition processes

Core treatments installed March 2004 at DD site:

Natural with roots included; Roots excluded; Watered and roots excluded

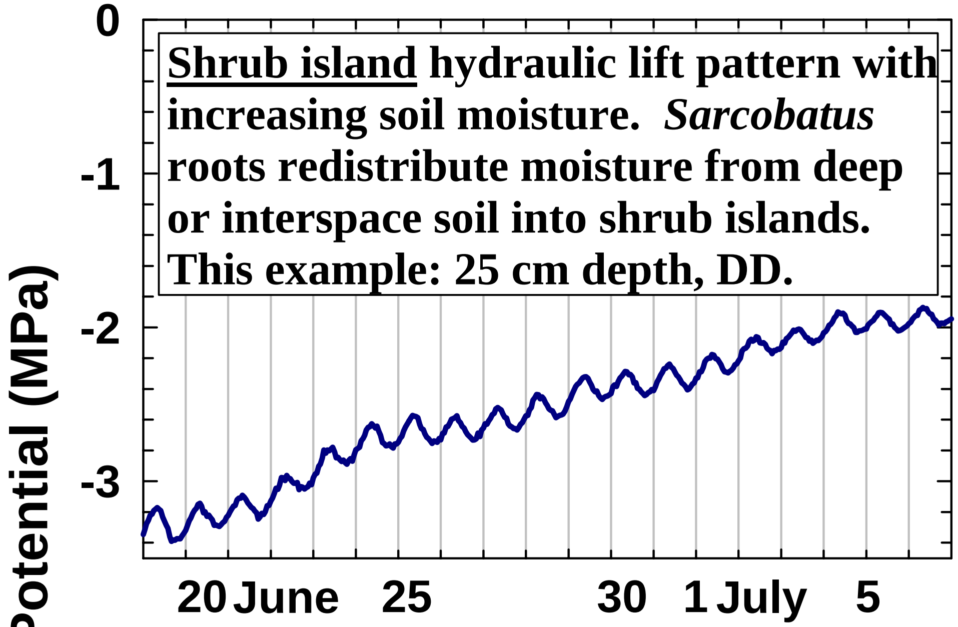
Each core included 2 litter bags (fine roots, leaves)

3 harvests; 14-16 reps/harvest

1 year, Mar 04-05; Spring, Mar-Jun 05; Summer, Jun-Oct 05

Measurements:

Soil CO_2 flux, hydraulic lift, root ingrowth, litter mass & quality changes, SOC fractions, microbial biomass, inorganic N, DON, mineralization, pH, EC

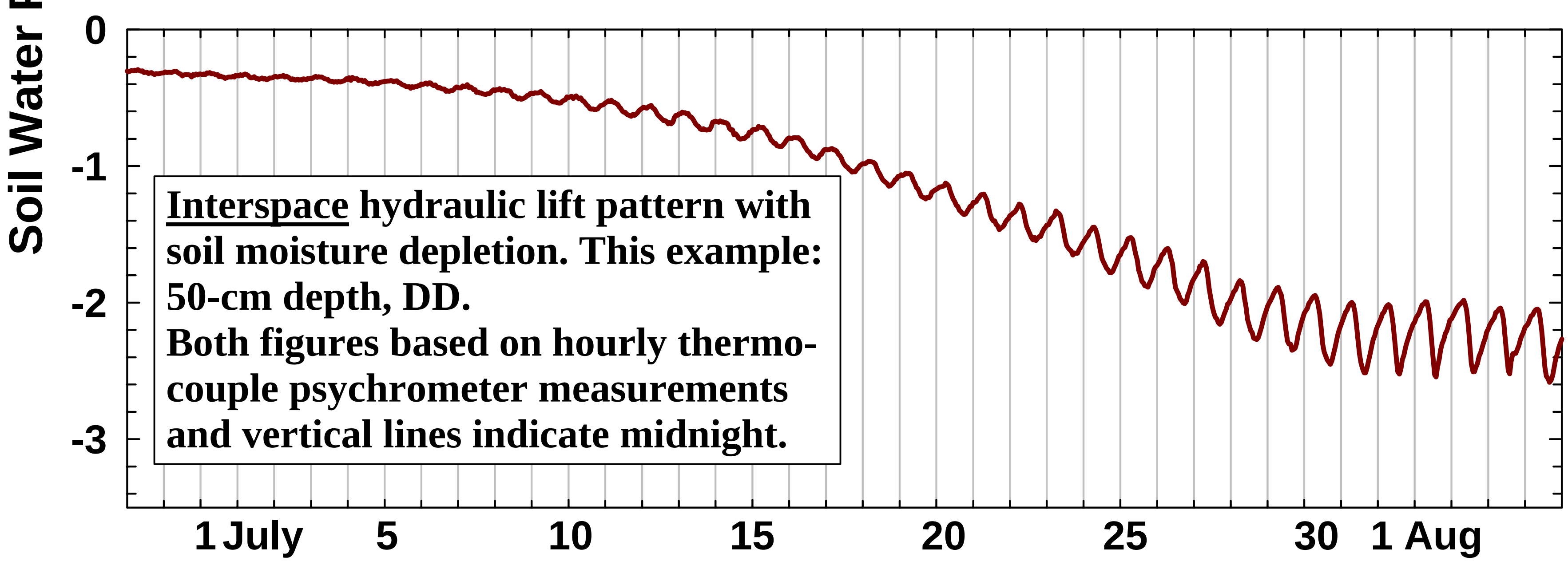


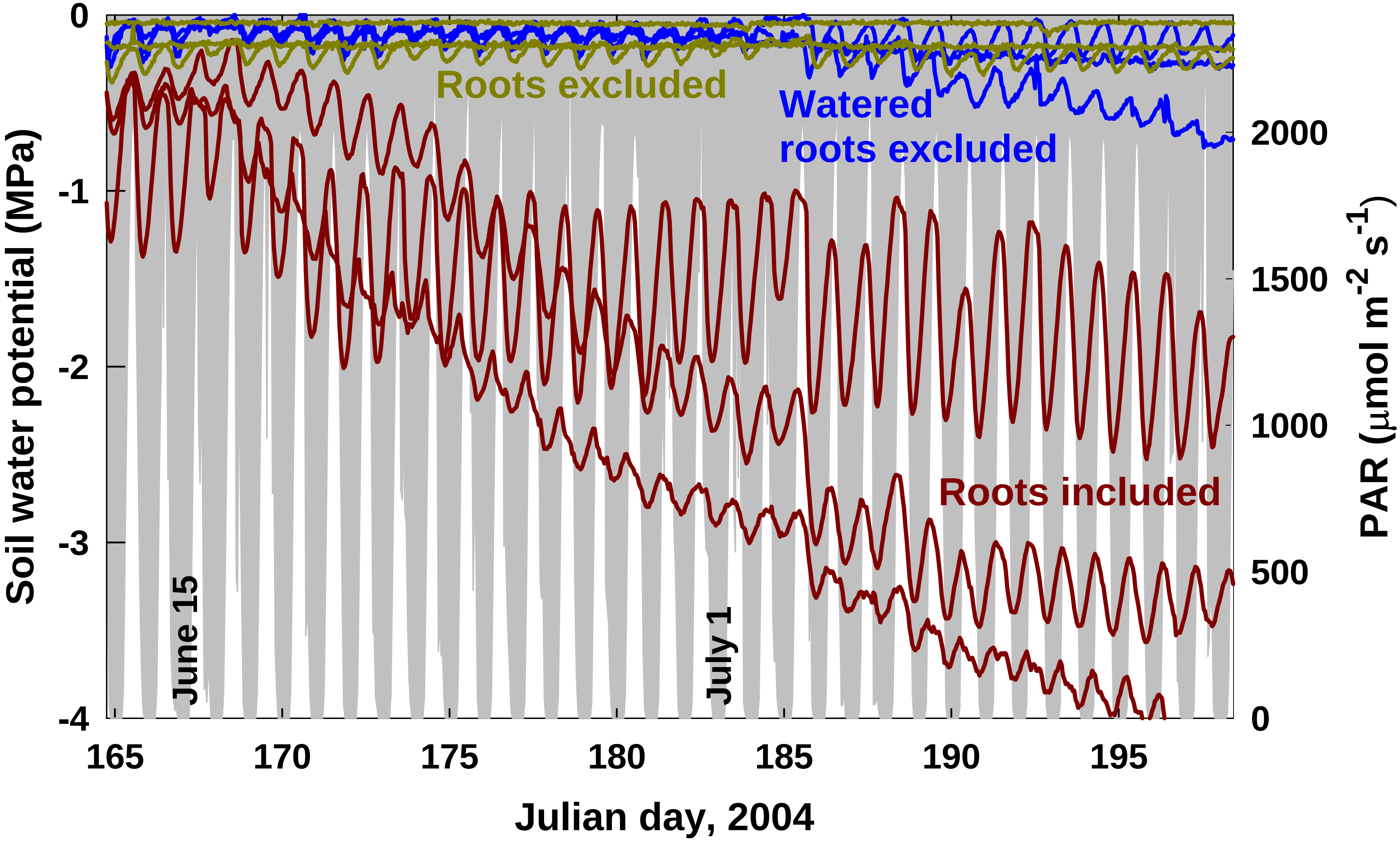
Hydraulic lift increased soil moisture early in the warm season (left).

85% of shrub islands had increases over 3-yr continuous monitoring.

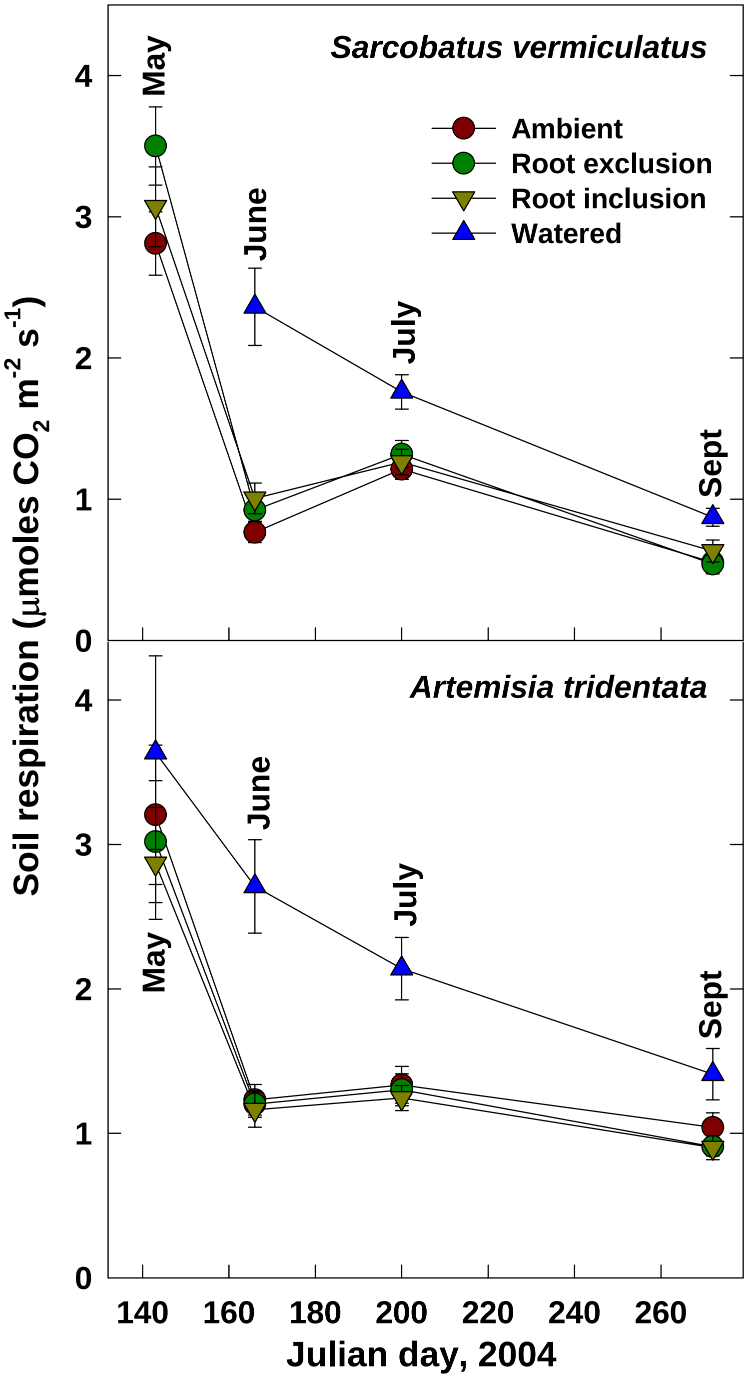
Late in season moisture was extracted by *Sarcobatus* to < -5 MPa.

	Initial (Apr-May)	Max (mid-late Jul)
range:	-0.6 to -4.5	-0.3 to -3.2
mean:	-2.7 (0.4) n=35	-1.4 (0.3) n=35





0
-1
-2
-3
-4
Soil water potential (MPa)
2000
1500
1000
500
0
PAR (μmol m-2 s-1)
165
170
175
180
185
190
195
Julian day, 2004
June 15
July 1
Roots excluded
Watered roots excluded
Roots included



Soil CO^2 flux from cores was approximately doubled by water addition, but no differences were seen between root exclusion cores and natural cores (with roots included).

Water extraction patterns are not consistent with these flux rates.

Long-term measurements may help solve this puzzle.

Summary of current progress

1.) Storage of C in cold desert soils is a function of spatio-temporal variation at the landscape scale and also at the smaller spatial scale of shrub-islands and interspaces. Quantification of C pools and fractions is nearly complete.

2.) Shrub-island soils are typically drier than the adjacent barren interspace soils. The majority of coarse woody debris, leaf litter, and soil organic C are found in these dry sites. Yet decomposition is more rapid than expected. Relationships to biotic (microbial and root) environment are being investigated.

3.) Hydraulic lift was re-confirmed in soils beneath two desert shrub species (*Sarcobatus* and *Artemisia*). Effects on decomposition, CO_2 evolution, and microbial communities are being assessed in experimental cores.

Kearney Foundation of Soil Science
Jastro-Shields Grad Research Grants
Soils & Biogeochemistry Grad Group

Special thanks:

Tad Doane	**Maggie Caird**
Stephanie Blazej	**Vera Chio**
Steven Chang	**Maunil Bhatt**
Carey Batha	**Rebecca Hundt**
Dan Shuldman	**Hsien Easlon**
Joshua Christman	**Ben Richards**