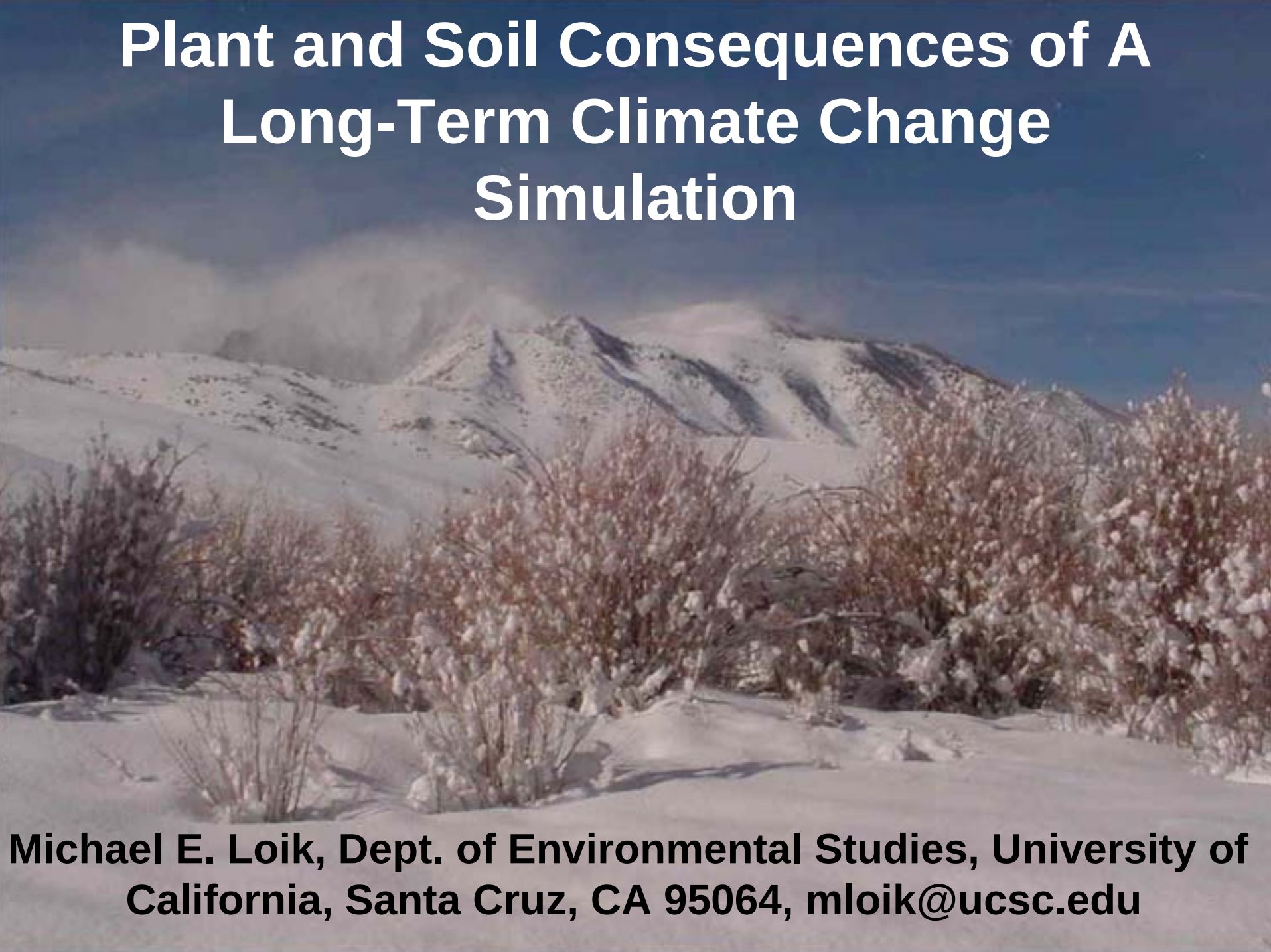
Plant and Soil Consequences of A Long-Term Climate Change Simulation



Michael E. Loik, Dept. of Environmental Studies, University of California, Santa Cruz, CA 95064, mloik@ucsc.edu

precipitation magnitude, timing, variation

tree encroachment

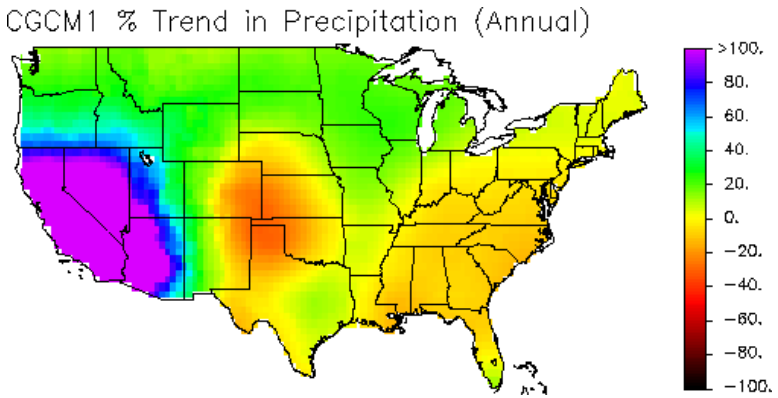
carbon storage

fire risk

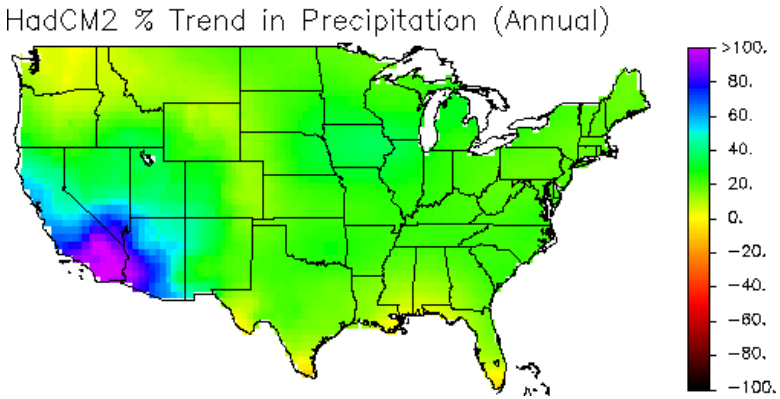
conservation

hydrology

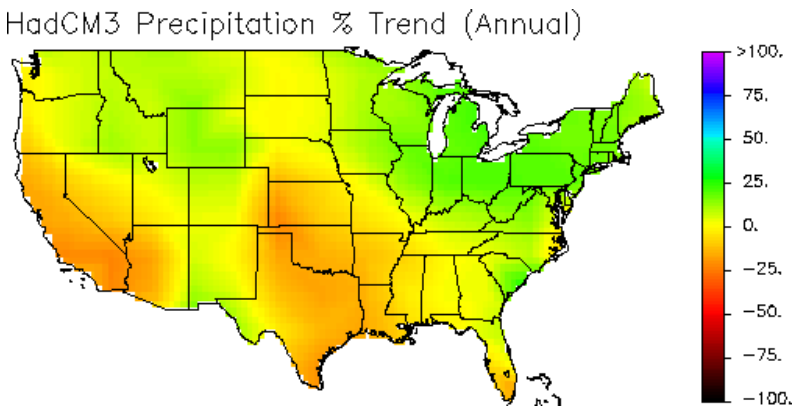
Precipitation Scenarios & Model Uncertainty



Canadian Global Climate Model 1
CGCM1



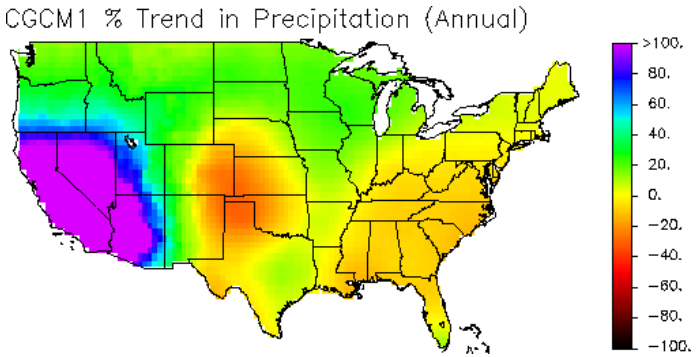
Hadley Centre for Climate Prediction
HadCM2

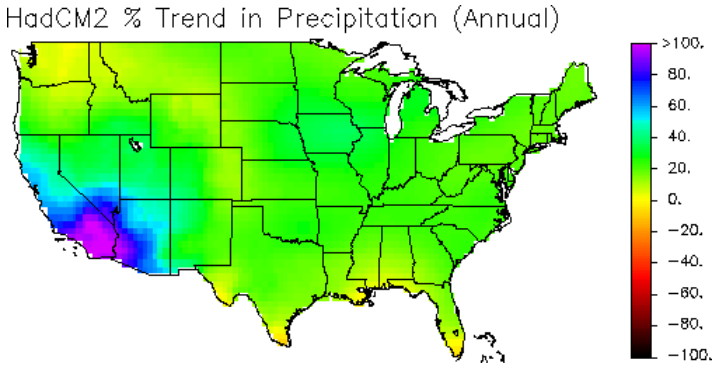


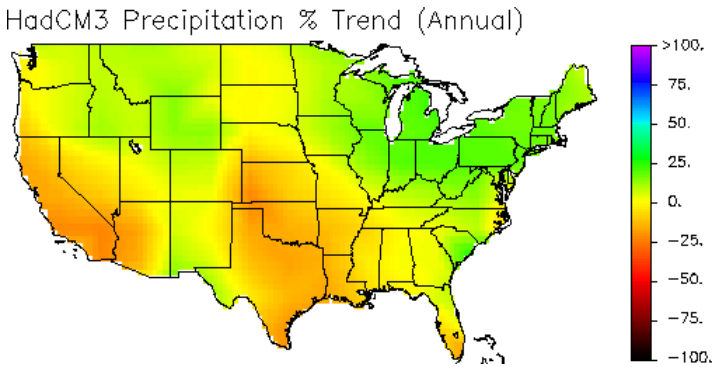
Hadley Centre for Climate Prediction
HadCM3

(annual changes compared
to 1961 – 1990)

Valentine Eastern Sierra UC Reserve, Mammoth Lakes, CA







For Mammoth Lakes, CA…

CGCM1 predicts
+ >100%

HadCM2 predicts
+80%

HadCM3 predicts
–10%

(annual changes compared to 1961 – 1990)

Approach

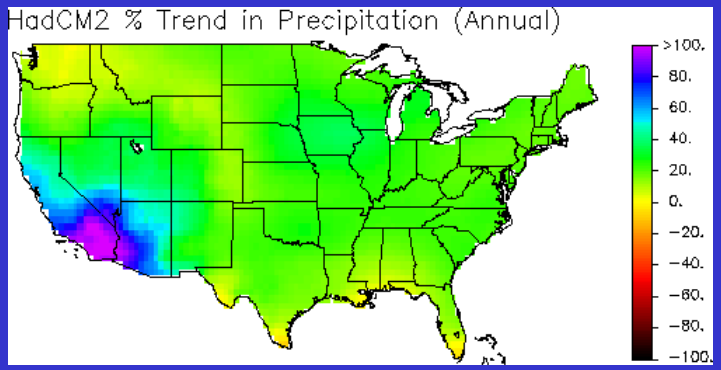
- use of 50 year old snow fences along a 50 km transect to cause snow depth forcing

Snow Fences

- used by highway departments, ski areas, and railroads for snow control
- also by water districts for water management

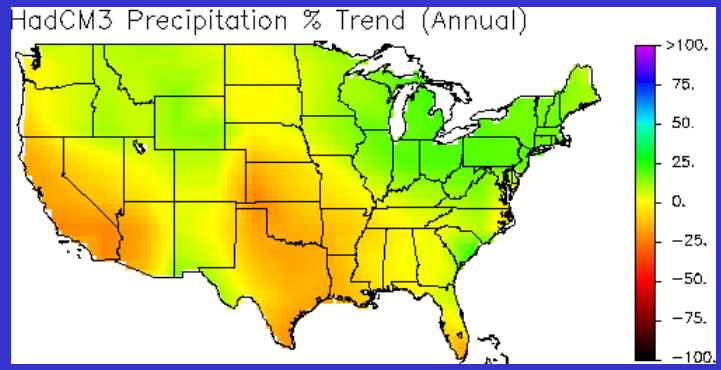

Prevailing
wind
accumulation
ablation
US Hwy 395
ca. 100 m »

Incorporating Climate Model Uncertainty



HadCM2 predicts +80%

(simulated by the snow accumulation zone)



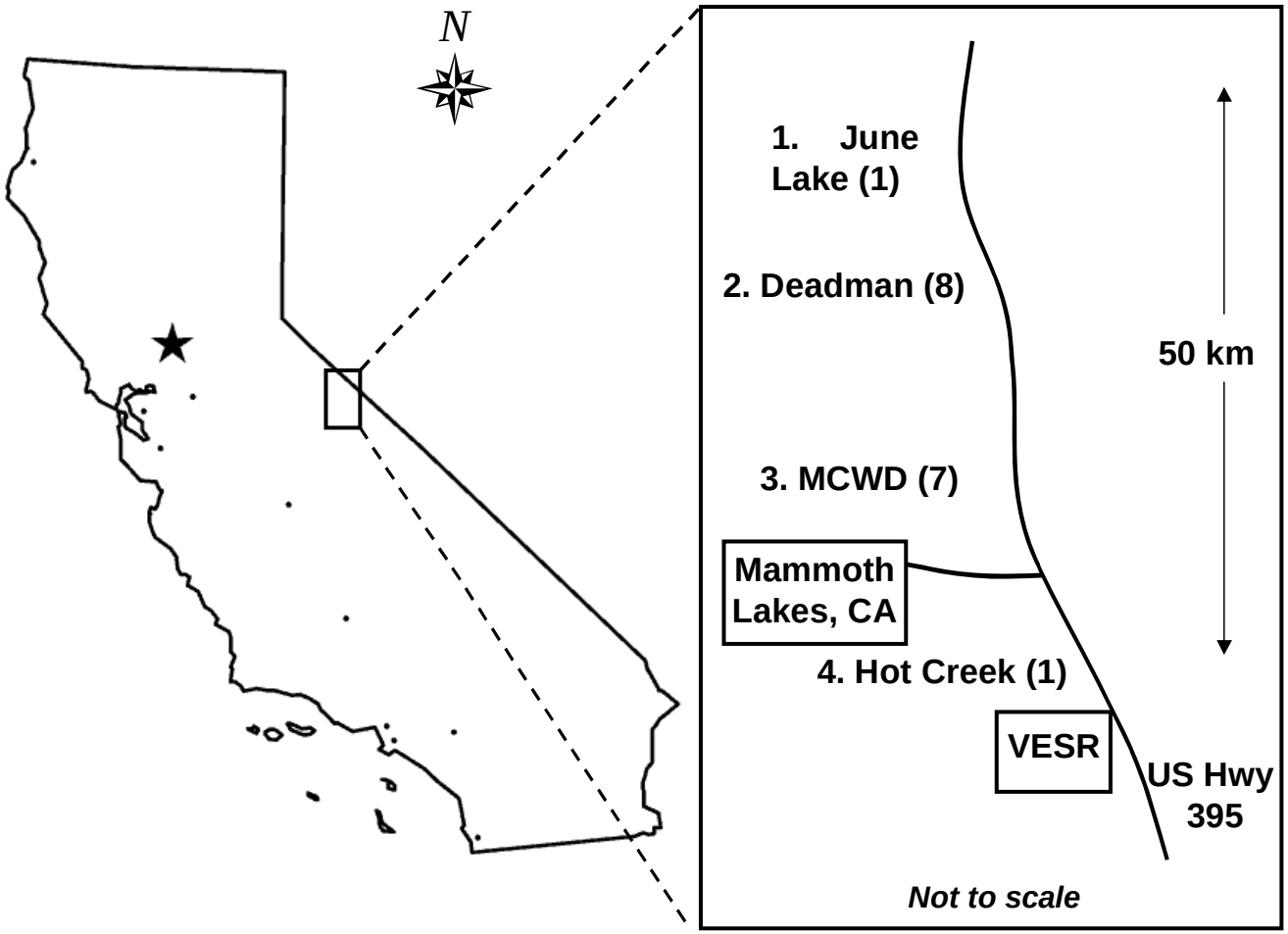
HadCM3 predicts –10%

(simulated by the snow ablation zone)

Prevailing wind

accumulation

ablation


N
1. June Lake (1)
2. Deadman (8)
3. MCWD (7)
Mammoth Lakes, CA
4. Hot Creek (1)
VESR
US Hwy 395
50 km
Not to scale

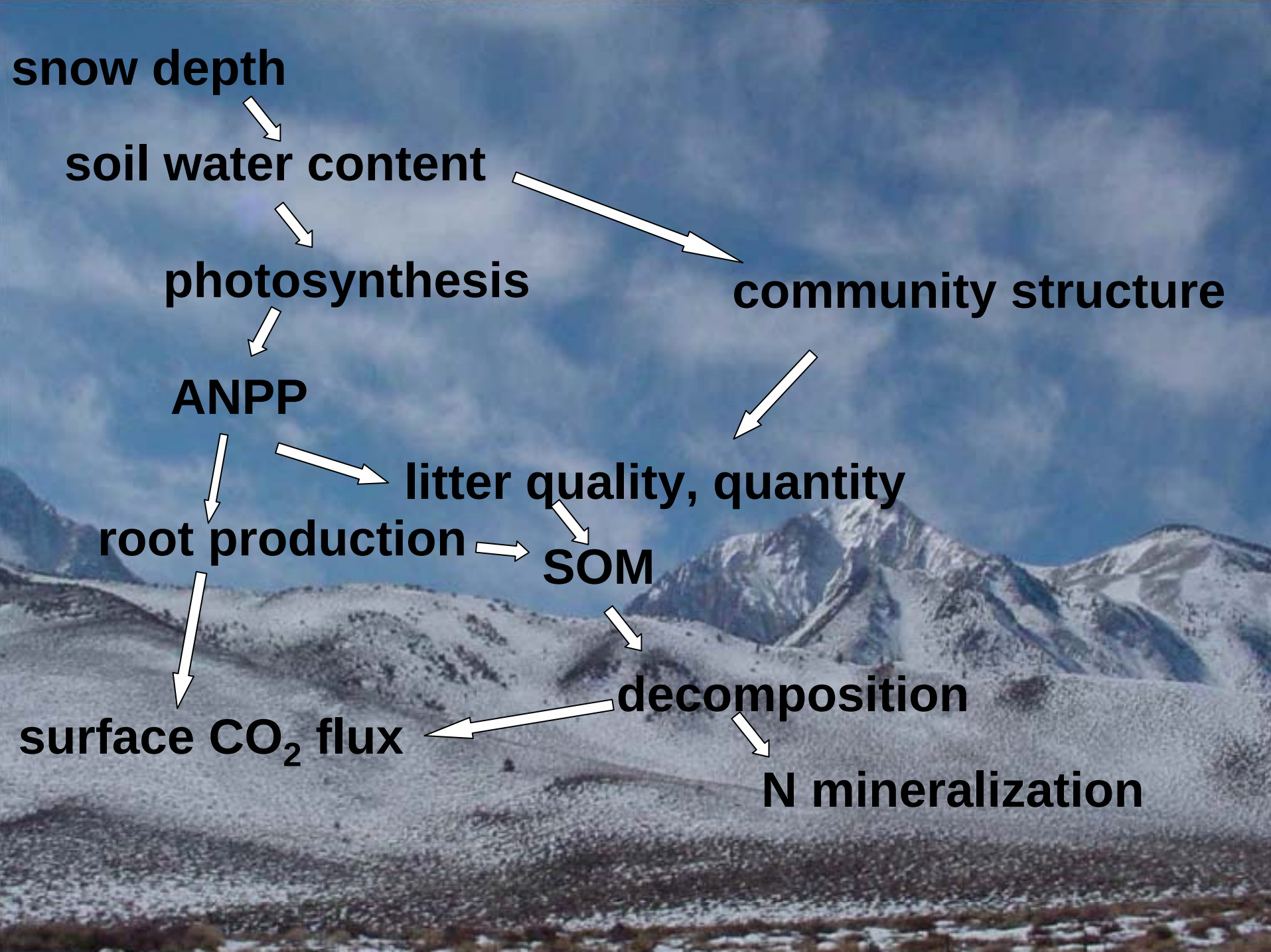
- Inyo NF, BLM, LADWP
- headwaters for Owens River (Los Angeles)
- land use: recreation, grazing, timber
- invasive species; fire risk
- recreation: 12 million visitor days per year
- increasing development and population in Mammoth Lakes

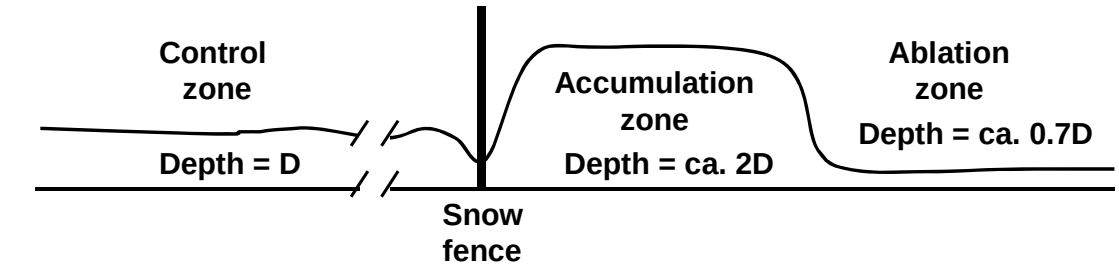
Hypotheses

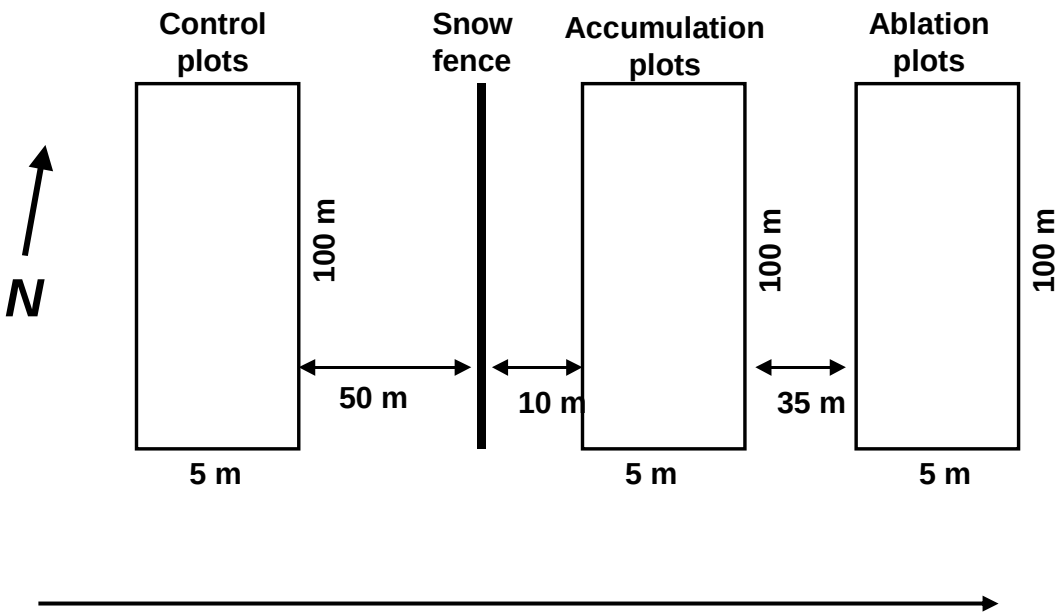
1. Snow depth in the non-growing season affects photosynthesis during the subsequent growing season.

2. Long-term changes in snow depth (increases and decreases) alter plant community patterns.

3. Results in 1 & 2 lead to altered litter production, decomposition, and soil C and N content.

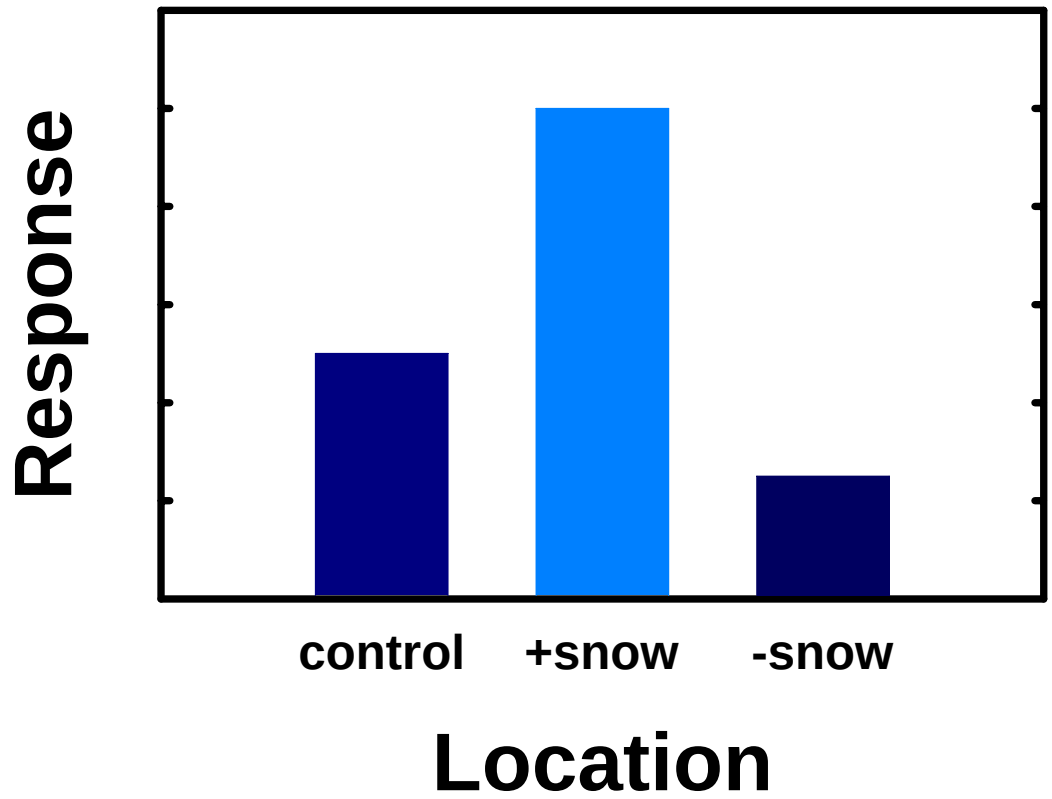

snow depth
soil water content
photosynthesis
community structure
ANPP
litter quality, quantity
root production
SOM
decomposition
surface CO_2 flux
N mineralization





Prevailing wind direction

Hypothesized Response



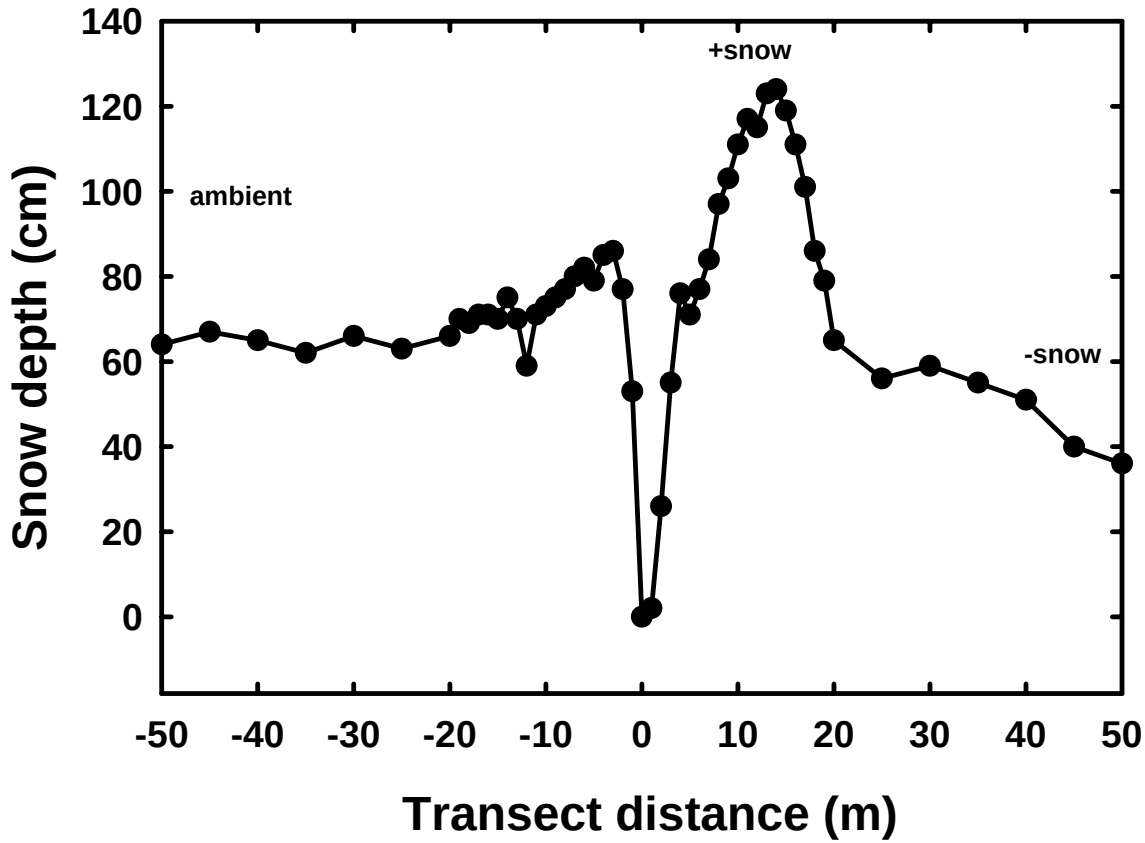
(assuming that snow depth impacts soil water content, community patterns, and ecosystem processes.)

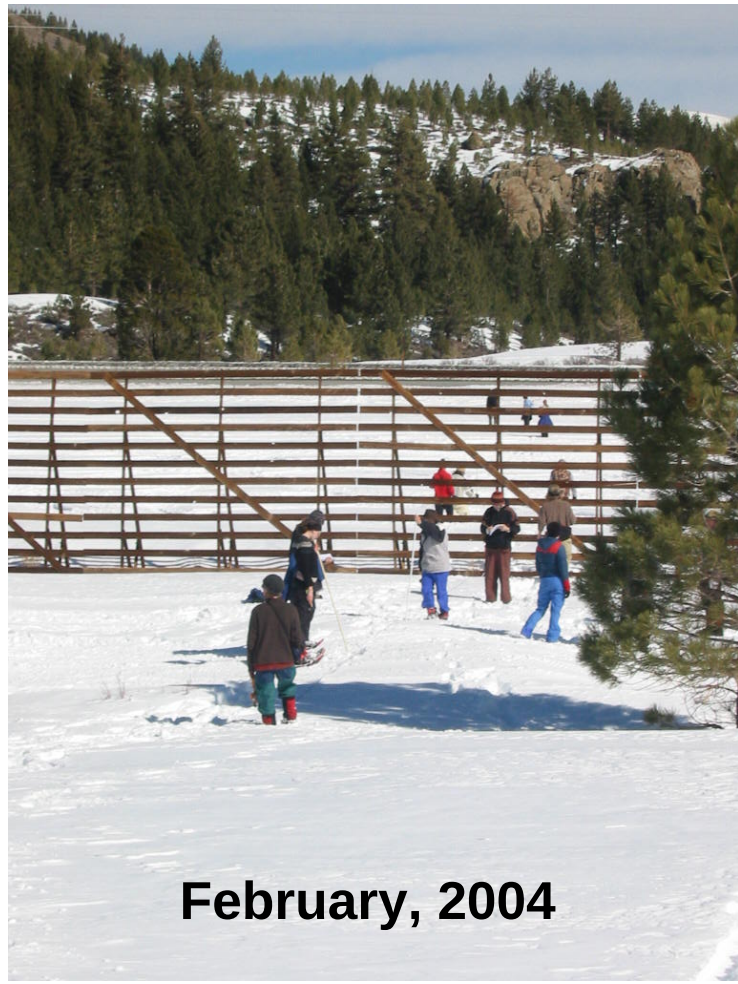
Hypotheses

1. Snow depth in the non-growing season affects photosynthesis during the subsequent growing season.

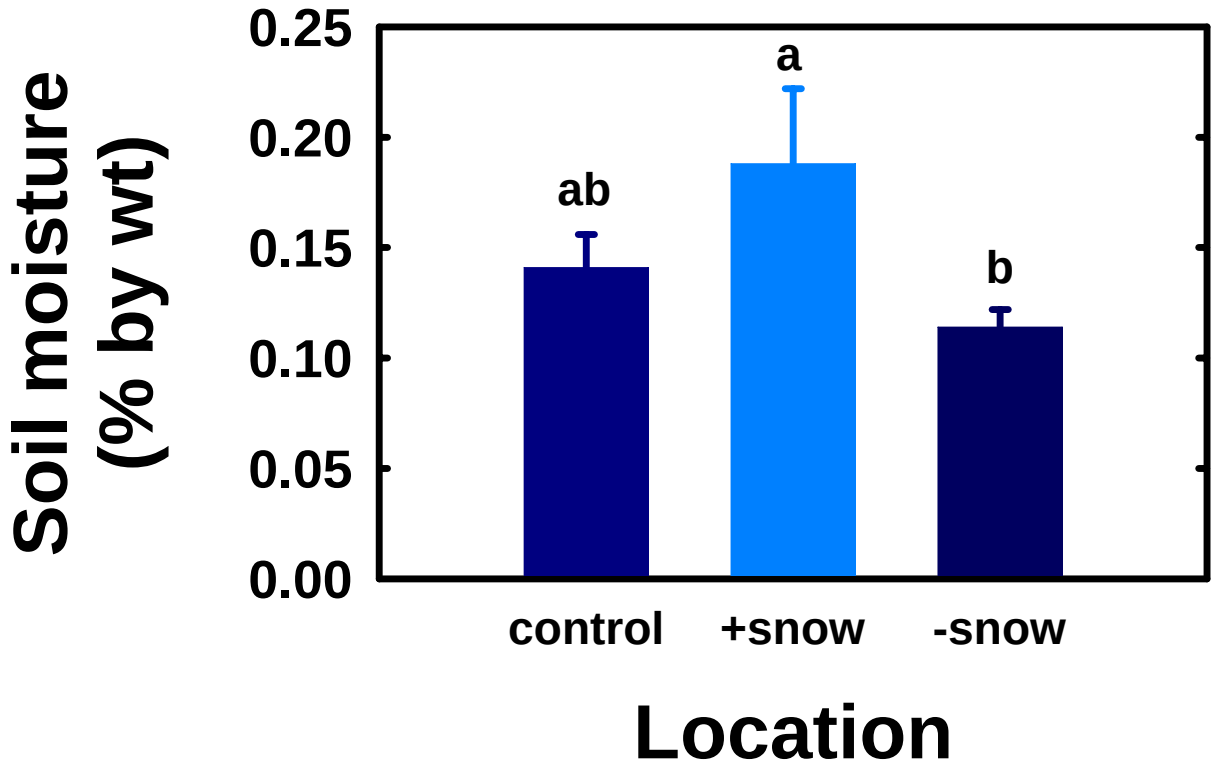
2. Long-term changes in snow depth (increases and decreases) alter plant community patterns.

3. Results in 1 & 2 lead to altered litter production, decomposition, and soil C and N content.


Snow depth (cm)
140
120
100
80
60
40
20
0
+snow
ambient
-snow
-50
-40
-30
-20
-10
0
10
20
30
40
50
Transect distance (m)

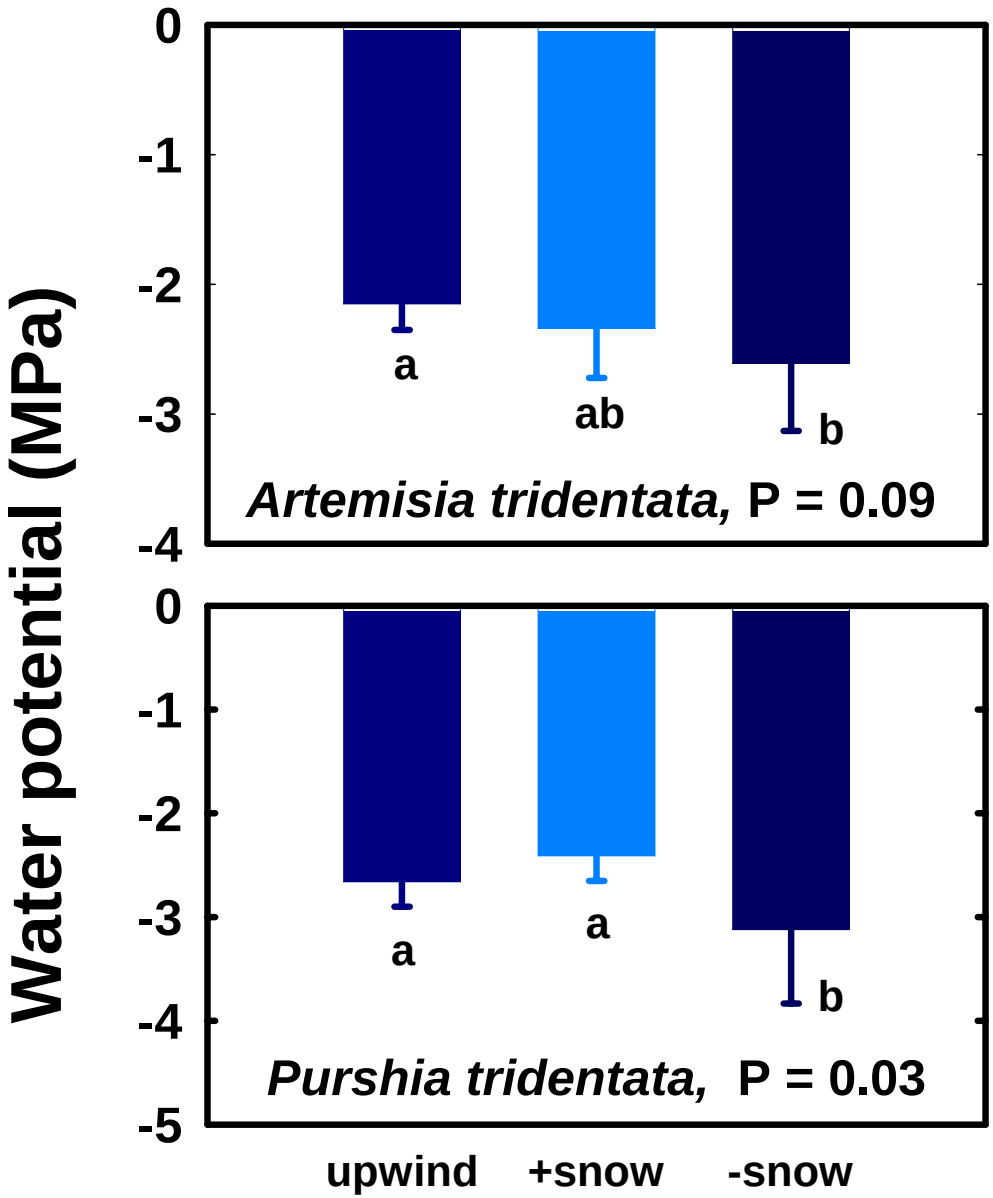

February, 2004

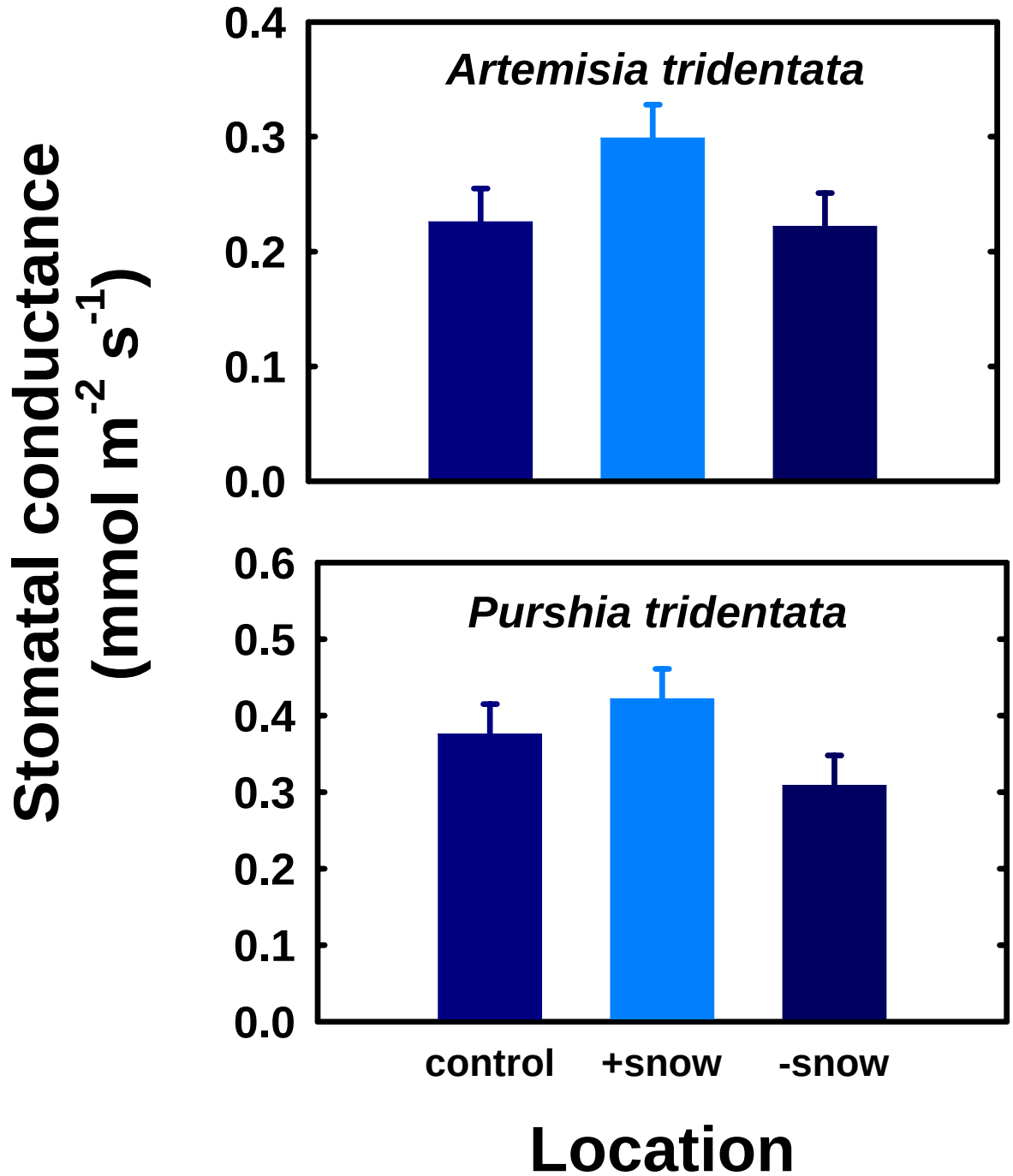
April, 2004 following snowmelt

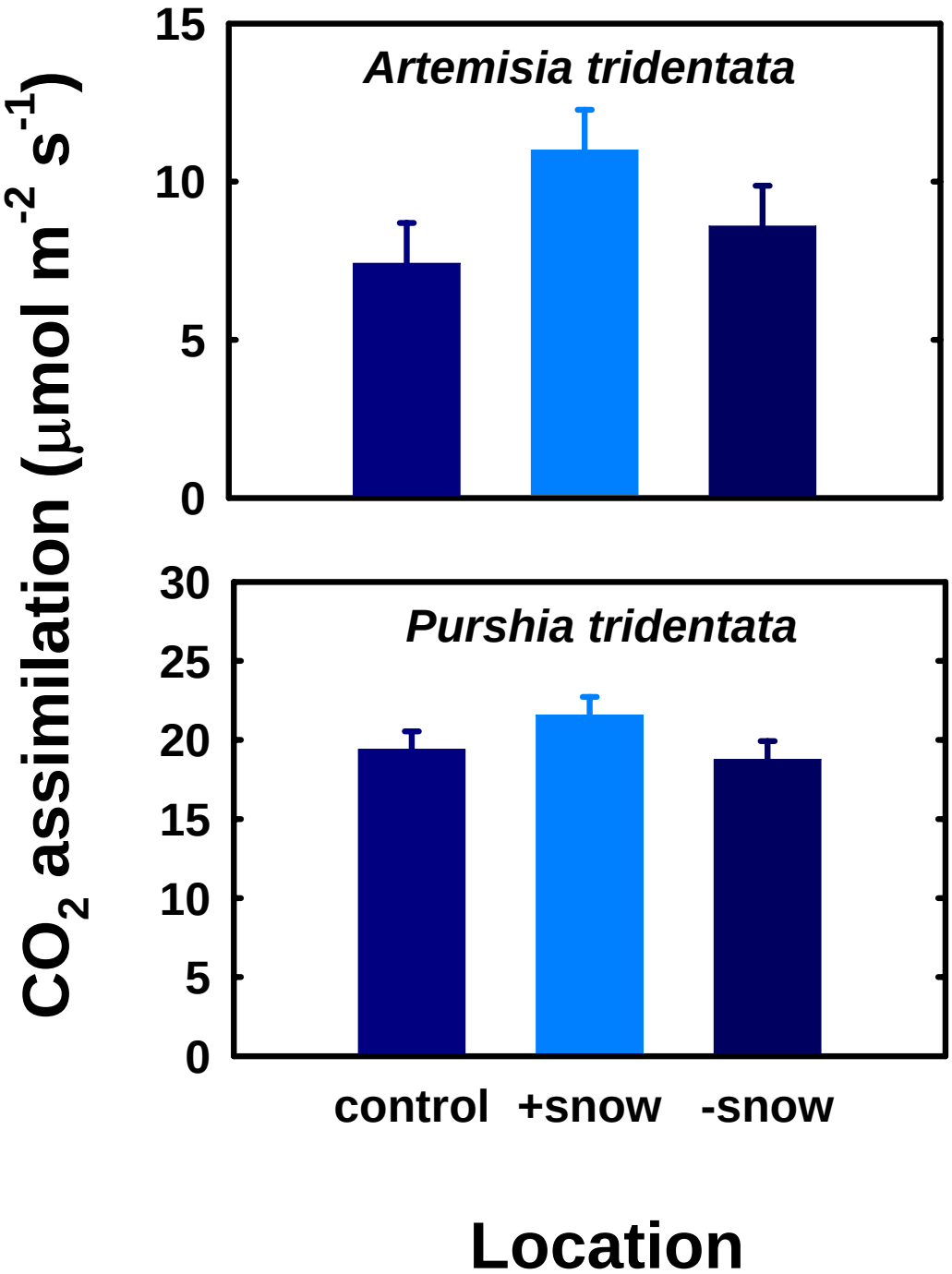


Artemisia tridentata
(Asteraceae)
Great Basin Sagebrush

Purshia tridentata
(Rosaceae)
Antelope Bitterbrush


Water potential (MPa)
0
-1
-2
-3
-4
a
ab
b
Artemisia tridentata, P = 0.09
0
-1
-2
-3
-4
-5
a
a
b
Purshia tridentata, P = 0.03
upwind
+snow
-snow
Location


Stomatal conductance
(mmol m-2 s-1)
Artemisia tridentata
0.4
0.3
0.2
0.1
0.0
Purshia tridentata
0.6
0.5
0.4
0.3
0.2
0.1
0.0
control
+snow
-snow
Location


Artemisia tridentata
Purshia tridentata
15
10
5
0
30
25
20
15
10
5
0
CO2 assimilation (μmol m-2 s-1)
control
+snow
-snow
Location

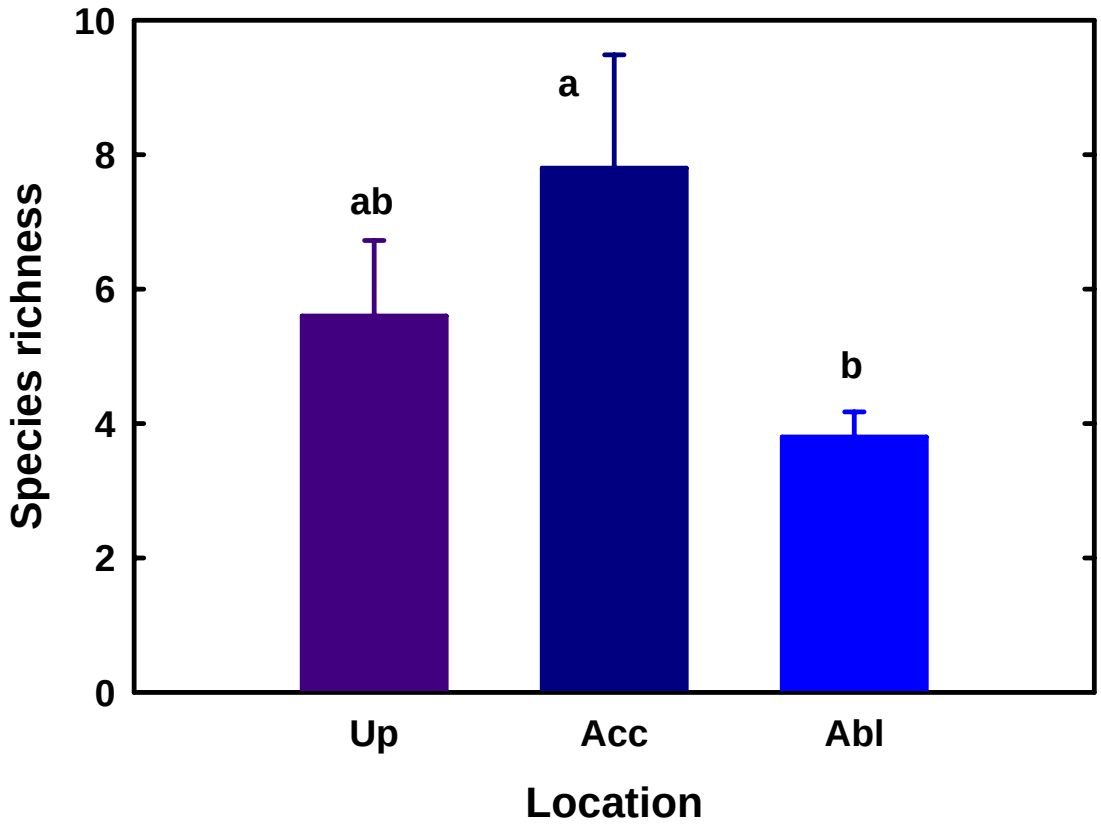
Hypotheses

1. Snow depth in the non-growing season affects photosynthesis during the subsequent growing season.

2. Long-term changes in snow depth (increases and decreases) alter plant community patterns.

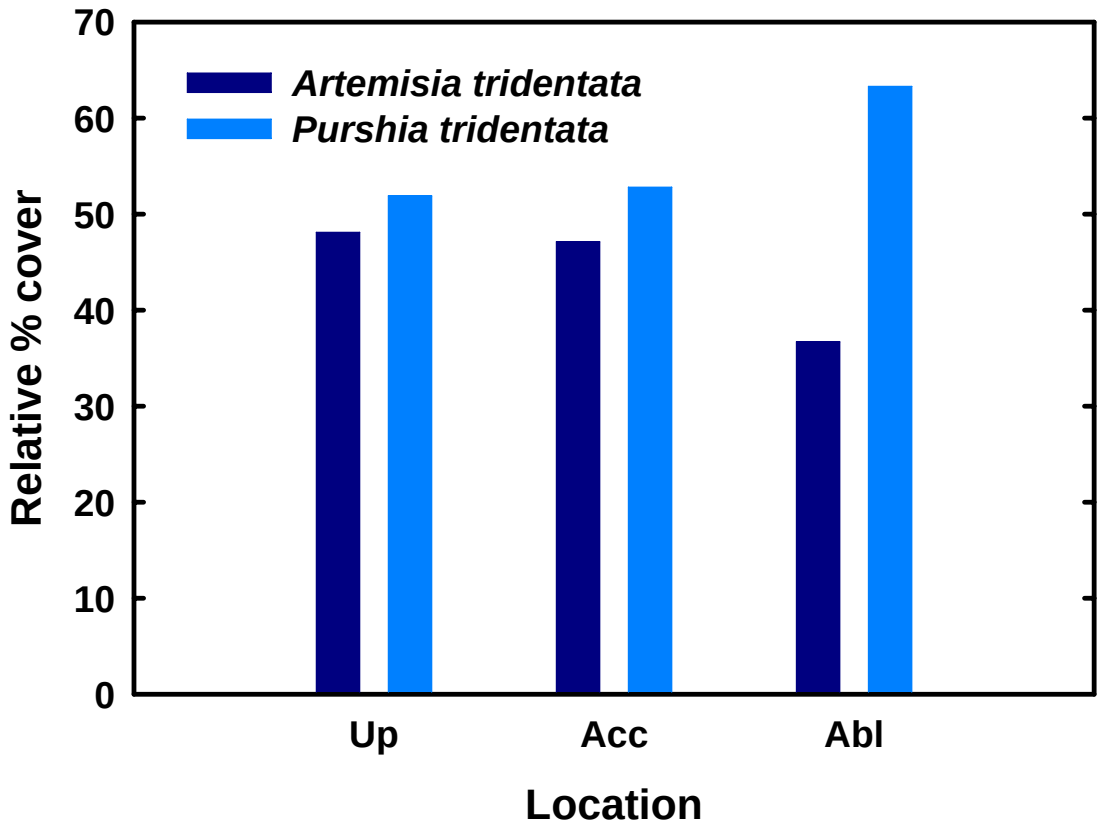
3. Results in 1 & 2 lead to altered litter production, decomposition, and soil C and N content.

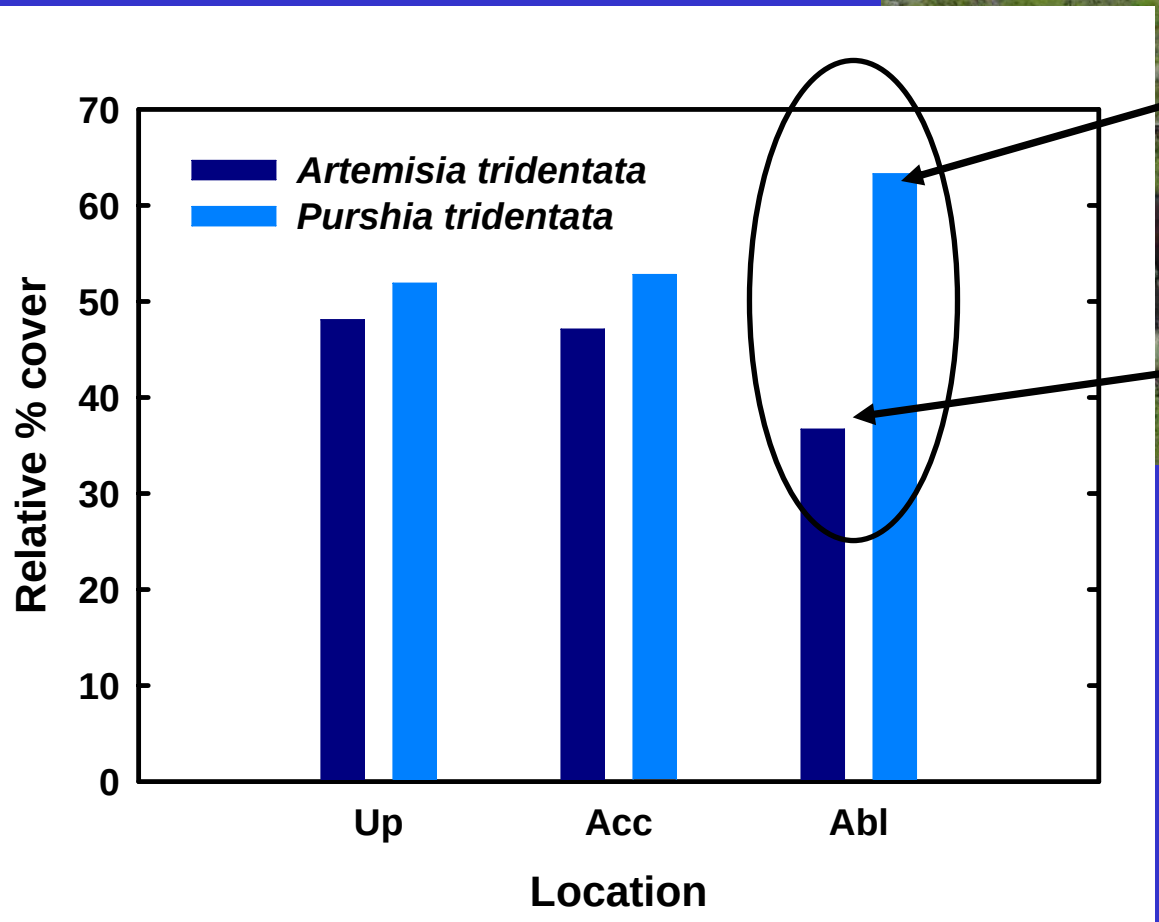
Species Richness

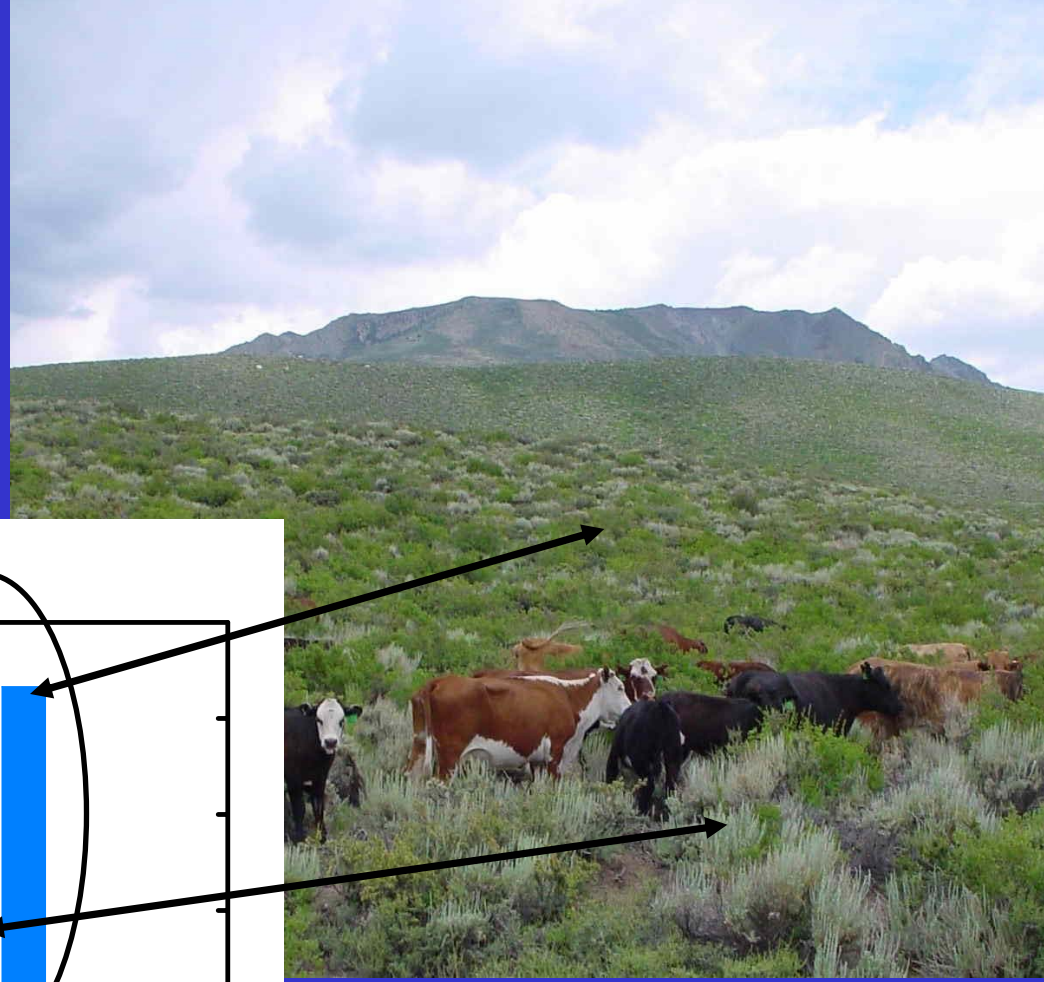


One-way ANOVA: F = 2.84, P = 0.09

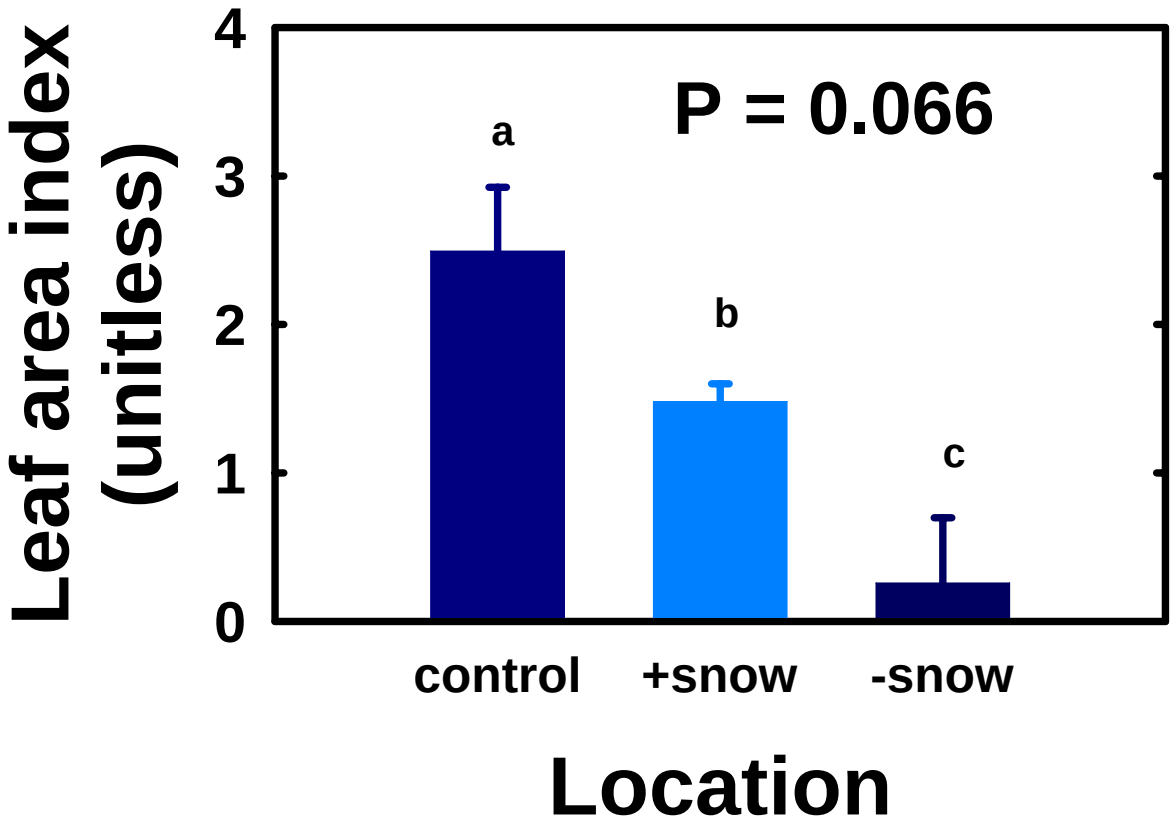
Relative Cover

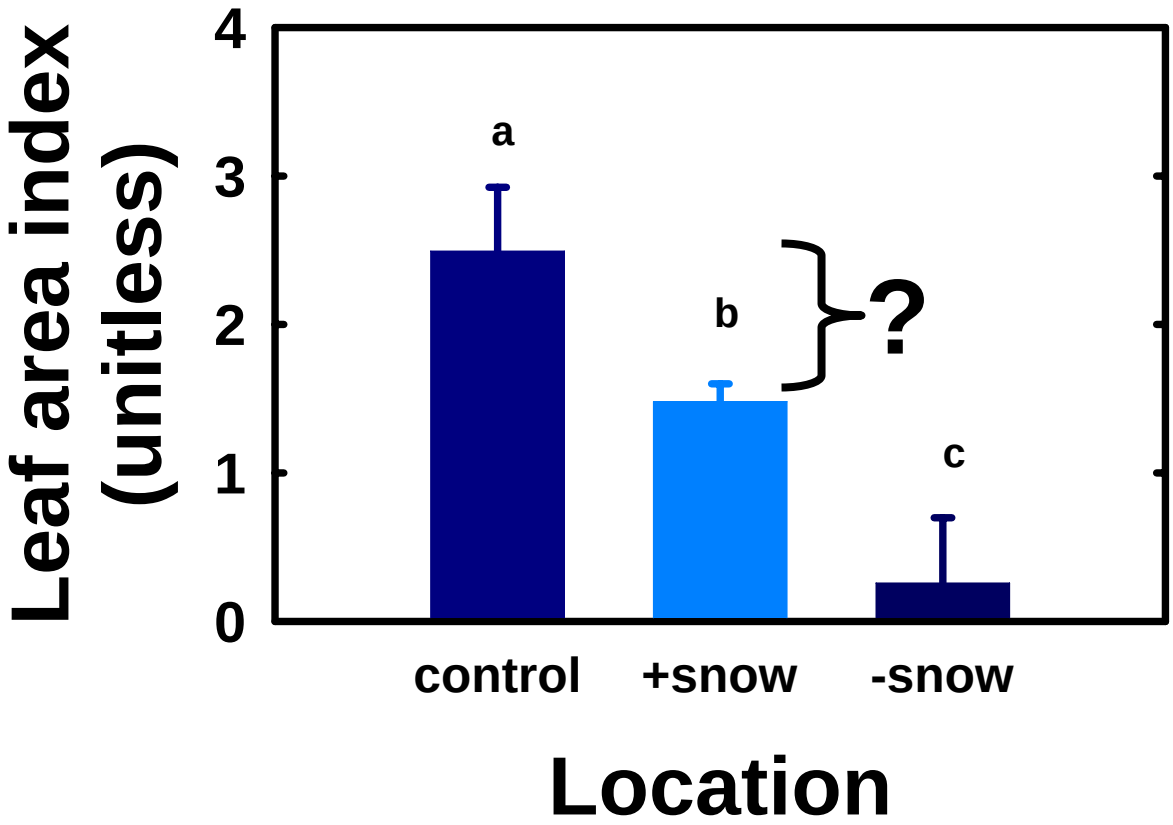


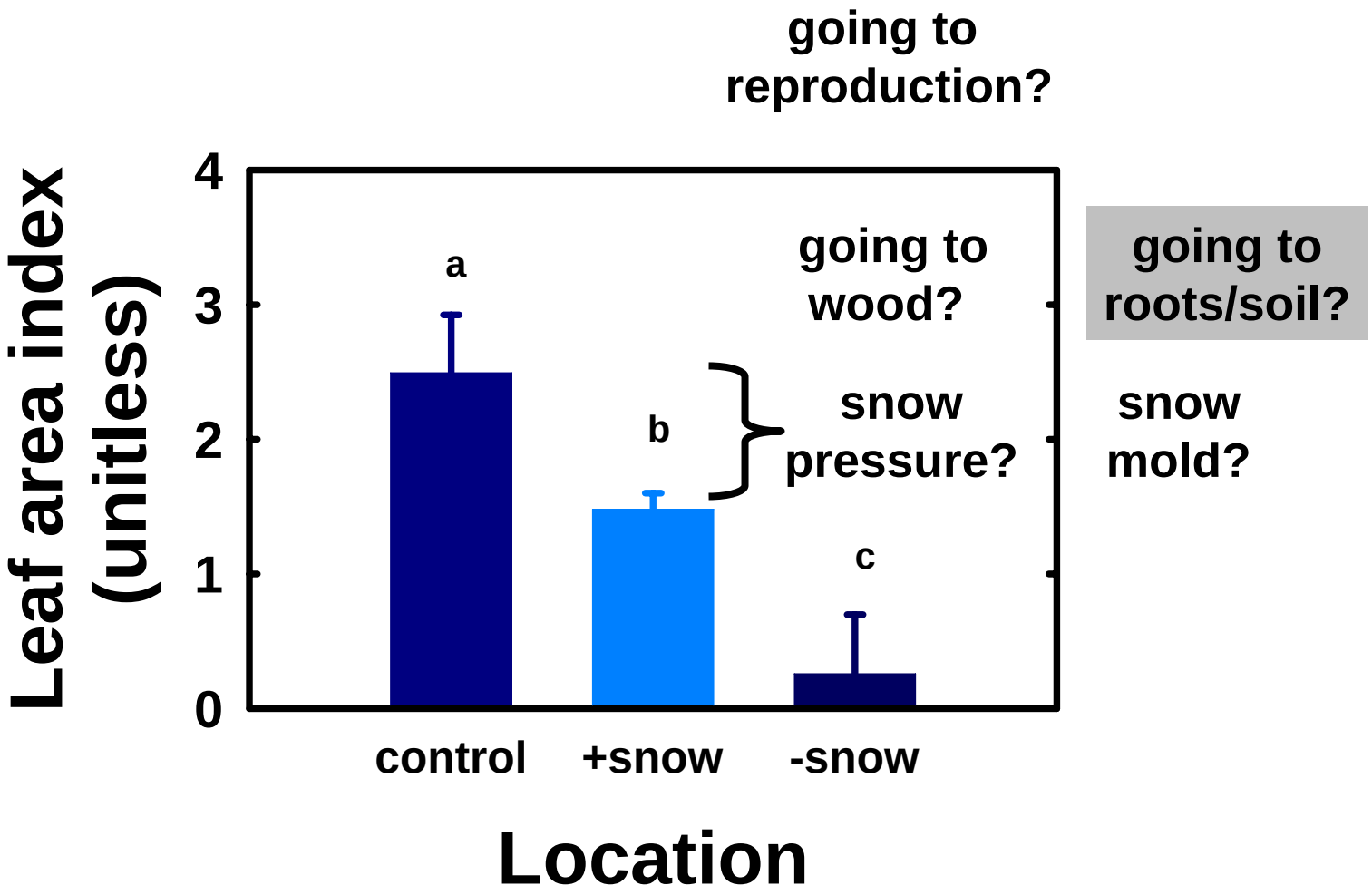


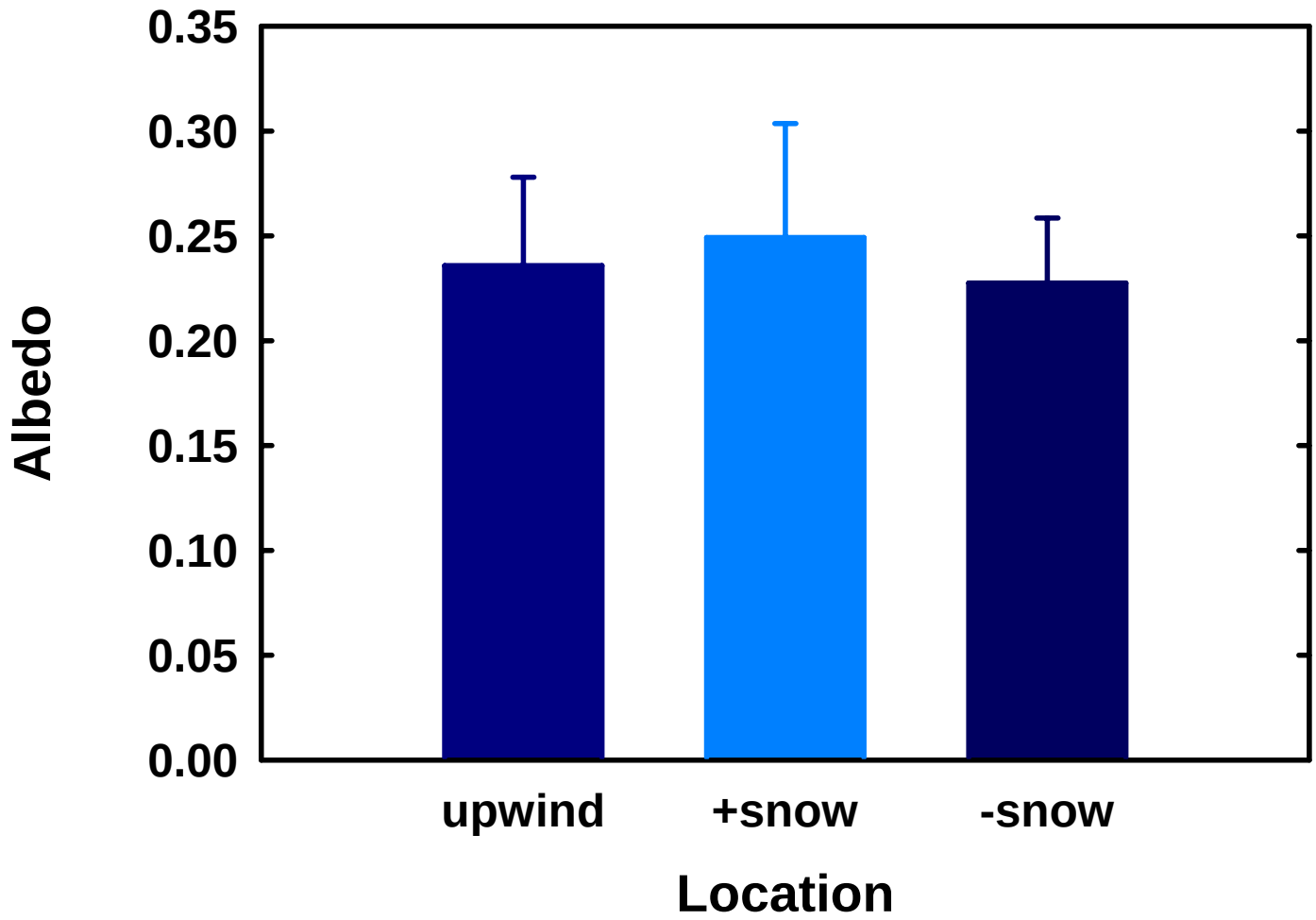


Decreased albedo on – snow plots?


Leaf area index (unitless)
4
3
2
1
0
P = 0.066
a
b
c
control
+snow
-snow
Location


Leaf area index
(unitless)
4
3
2
1
0
a
b
c
?
control
+snow
-snow
Location


going to reproduction?
Leaf area index (unitless)
4
3
2
1
0
a
b
c
going to wood?
snow pressure?
going to roots/soil?
snow mold?
control
+snow
-snow
Location


0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Albedo
upwind
+snow
-snow
Location

Hypotheses

1. Snow depth in the non-growing season affects photosynthesis during the subsequent growing season.

2. Long-term changes in snow depth (increases and decreases) alter plant community patterns.

3. Results in 1 & 2 lead to altered litter production, decomposition, and soil C and N content.

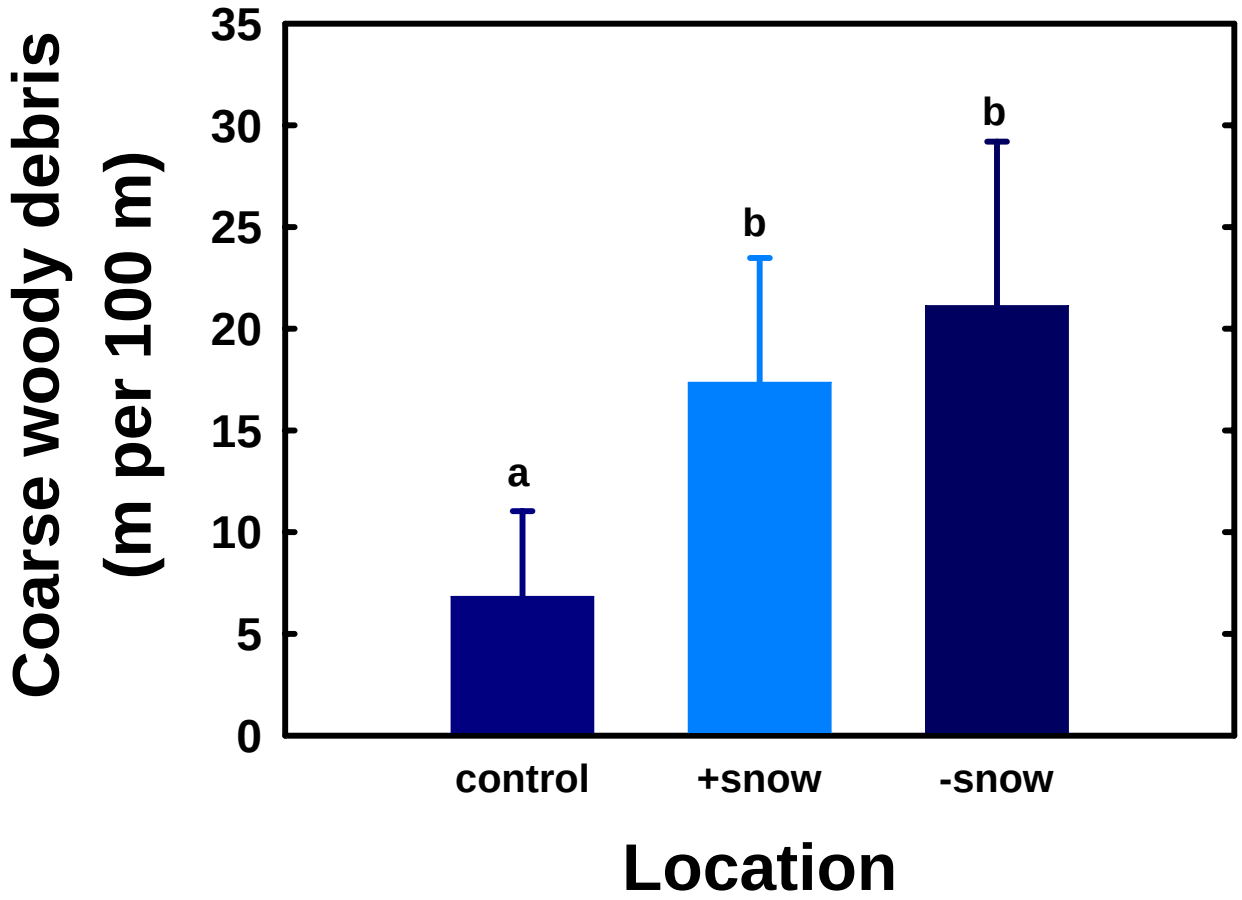
Mortality (shrub skeletons)

Artemisia tridentata

higher mortality on -snow plots

Purshia tridentata

no difference

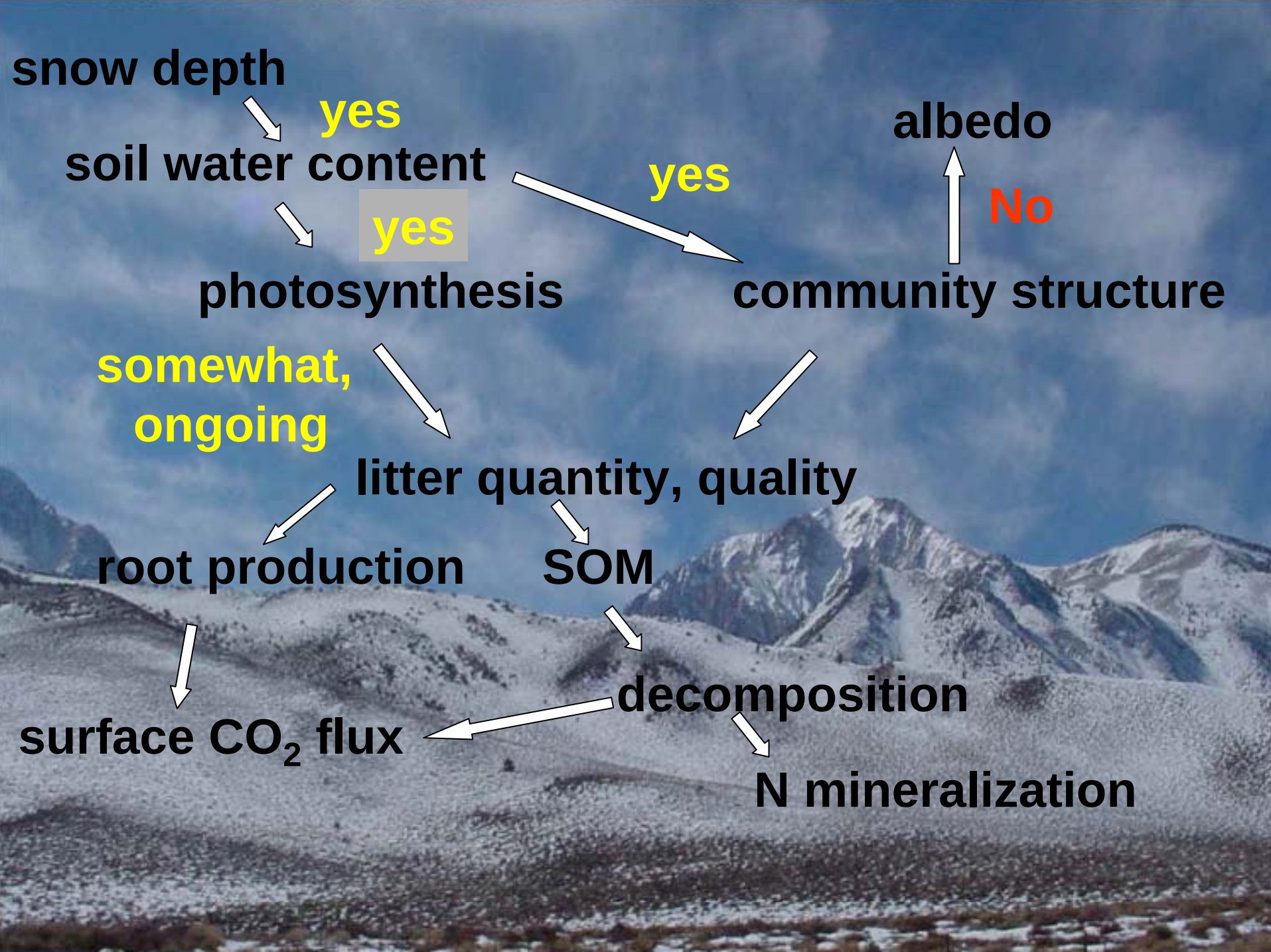

Coarse woody debris
(m per 100 m)
35
30
25
20
15
10
5
0
a
b
b
control
+snow
-snow
Location

Soil C and N (to date)

- organic C is higher in ambient, compared to +snow and –snow plots

  - higher at 10 compared to 30 cm depth

- no differences for nitrogen content


snow depth
yes
soil water content
albedo
yes
No
yes
photosynthesis
community structure
somewhat,
ongoing
litter quantity, quality
root production
SOM
decomposition
surface CO_2 flux
N mineralization

Winter 2004 - 2005

- eight months of snow

57 cm SWE at fences

(25 feet on Tioga Pass)

Work in Progress

Litter production

Decomposition

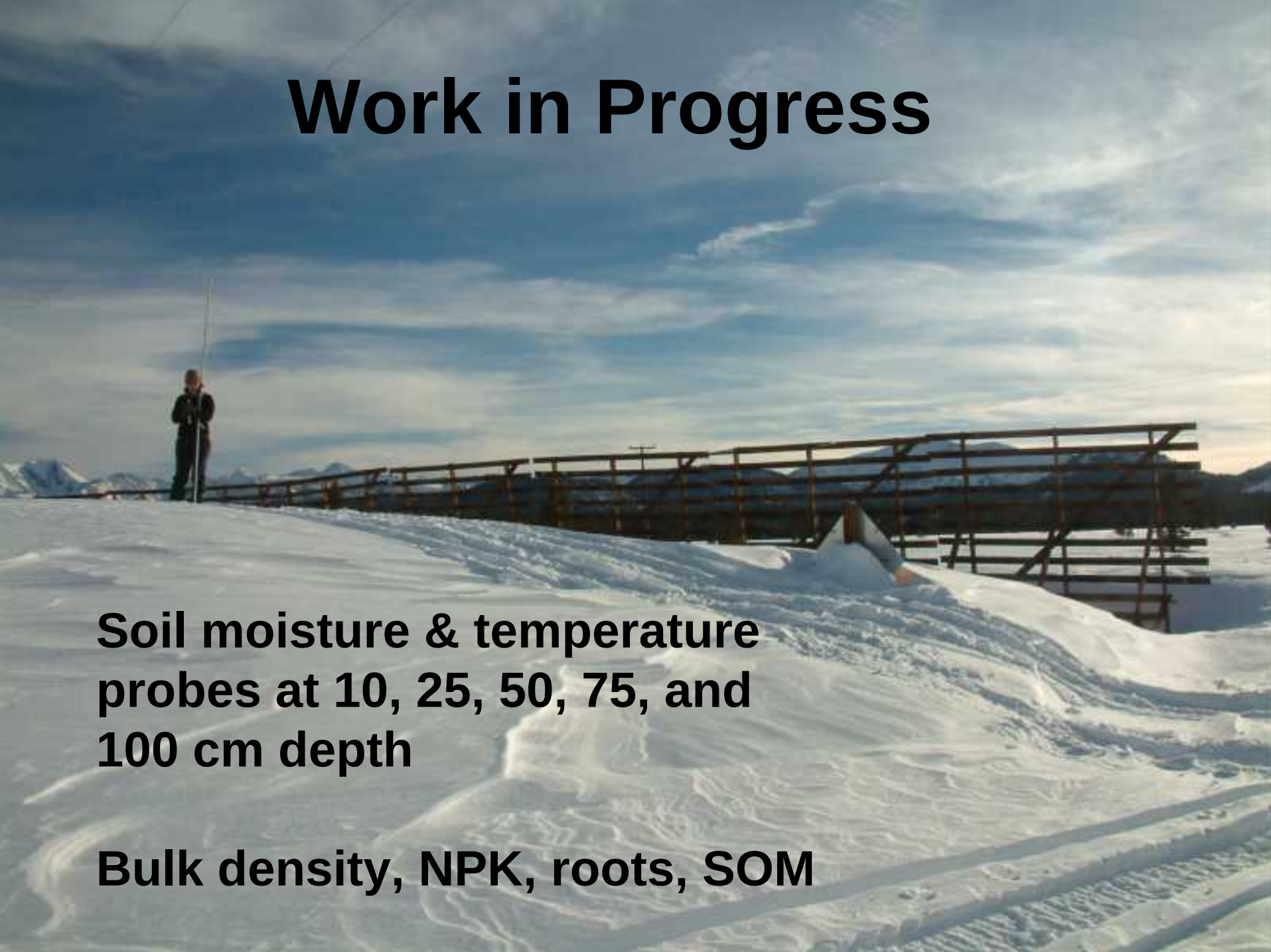
Soil Organic Matter

Work in Progress

- need to examine potential for “fertile island” effect

Do C, N, and other nutrients vary under the canopy of *A. tridentata* or *P. tridentata*, compared to open, inter-canopy sites?

Work in Progress



Soil moisture & temperature probes at 10, 25, 50, 75, and 100 cm depth

Bulk density, NPK, roots, SOM

Work in Progress

Seasonal water relations, gas exchange, LAI, NDVI, albedo

From snowmelt (May) to dormancy (Sept?) 2005

Annual growth rings

+ snow

- snow

^{13}C reconstruction of long-term WUE

Many thanks…

VALENTINE EASTERN SIERRA RESERVE

LOS ANGELES DEPARTMENT OF WATER & POWER

Caltrans

MAMMOTH COMMUNITY WATER DISTRICT

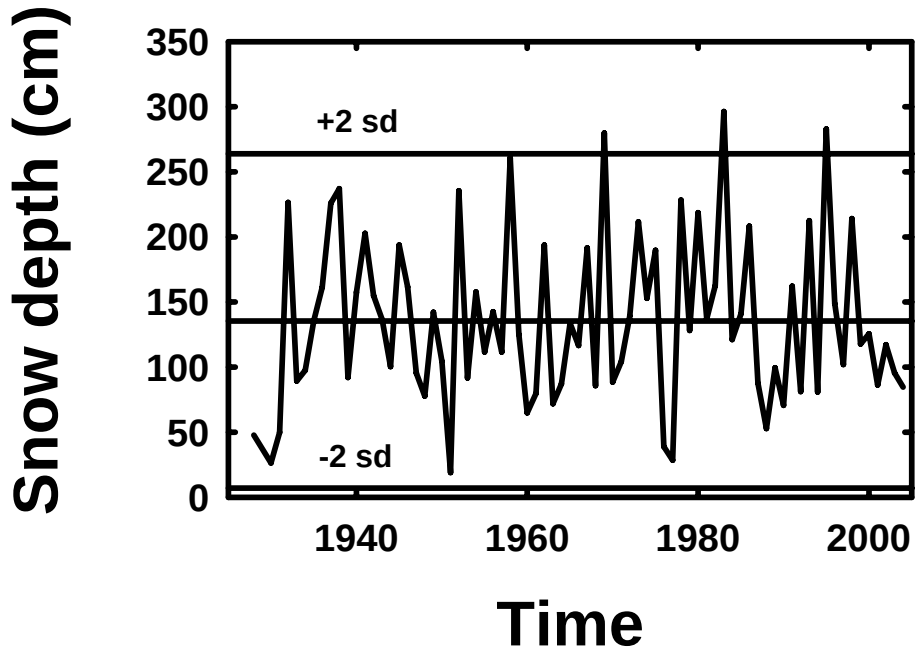
THE UNIVERSITY OF CALIFORNIA 1868

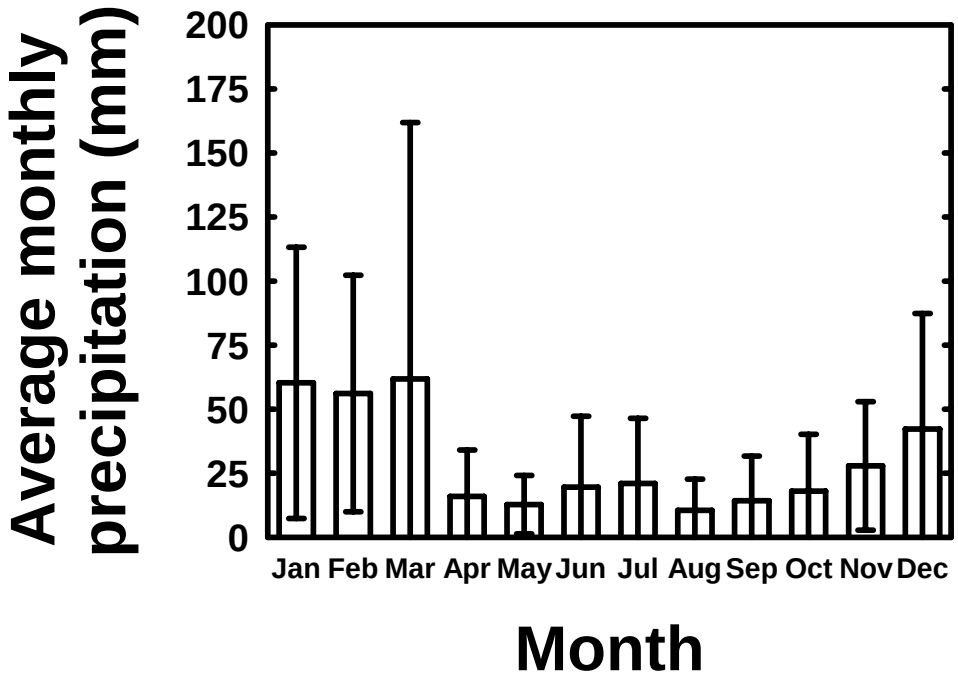
Alden Griffith, Holly Alpert , Dan Dawson and the Valentine Eastern Sierra Reserve staff, David and Jody Holl

M. Theo Kearney Foundation for Soil Science

EARTHWATCH INSTITUTE

Snow fence complex	Number snow fences	Elev (m)	Soil	Depth Vadose Zone (cm)	Infiltration rate (cm h^{-1})
June Lake	3	2320	Cozetica	>150	15 - 50
Deadman	8	2290	Vitrandic Xerorthent; Cryopsammet	100	15 - 50
Mammoth	10	2325	Haypress	>150	15 - 50
Hot Creek	1	2175	Torriothentic Haploxeroll	>150	5 - 15


Snow depth (cm)
350
300
250
200
150
100
50
0
+2 sd
-2 sd
1940
1960
1980
2000
Time


Average monthly precipitation (mm)
200
175
150
125
100
75
50
25
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month