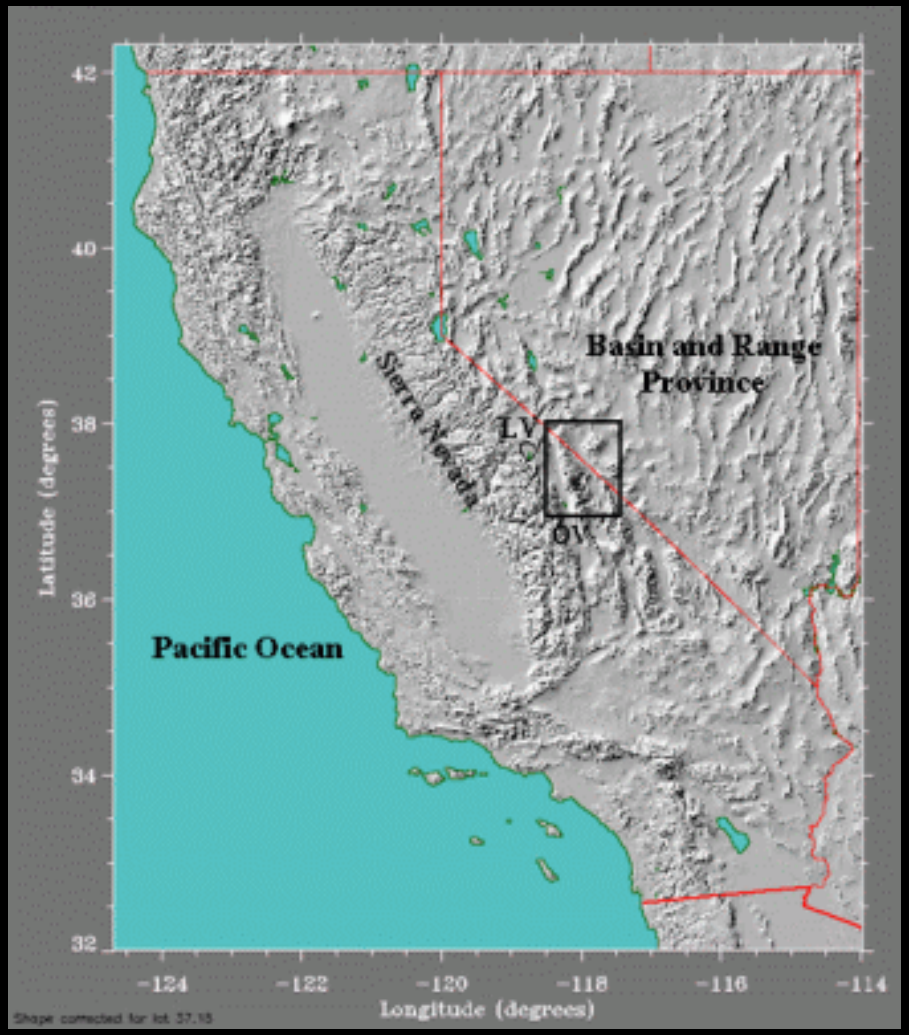
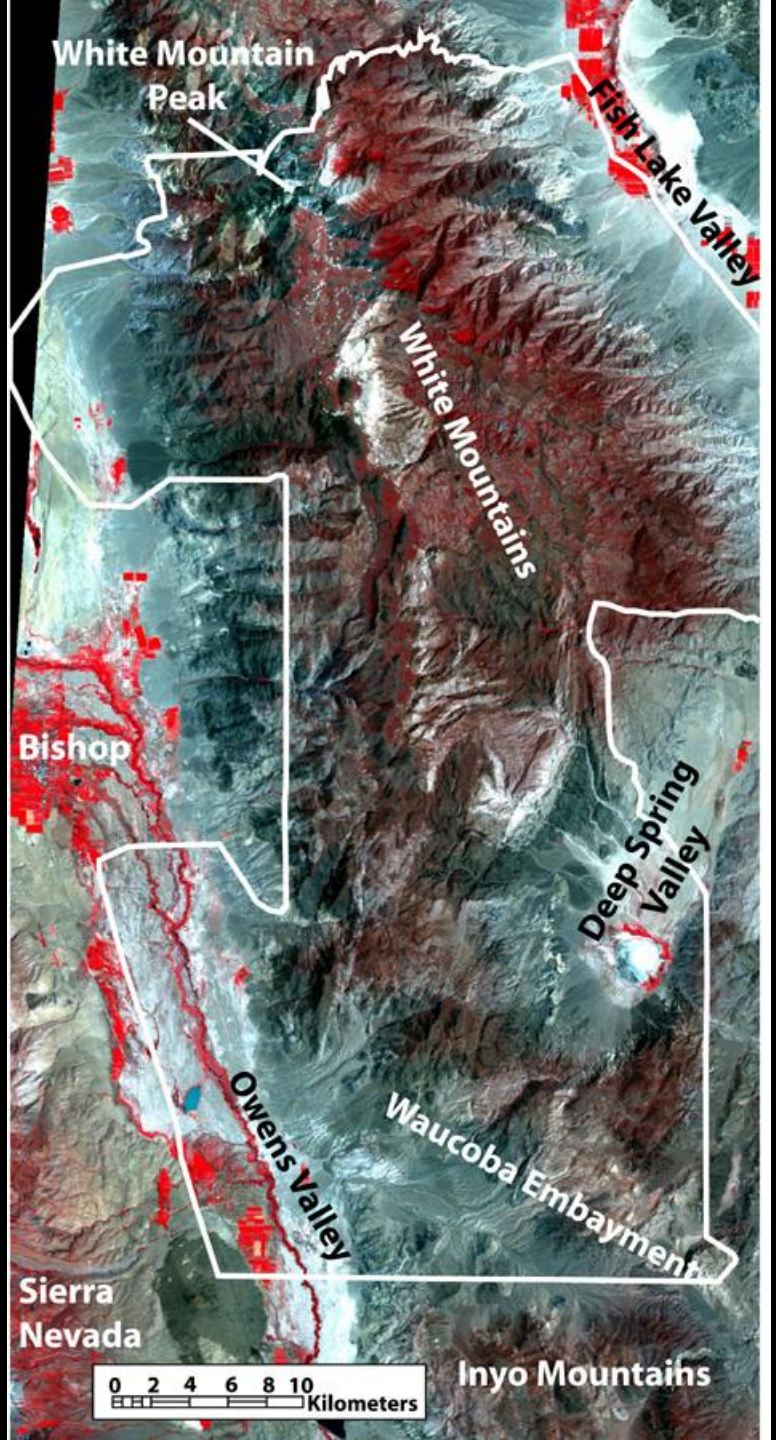
Up, down, and sideways: species shifts in the White Mountains under climate change

Stuart B. Weiss

Creekside Center for Earth Observation

Setting


Basin and Range Province
Sierra Nevada
LV
OV
Pacific Ocean
Latitude (degrees)
Longitude (degrees)
42
40
38
36
34
32
-124
-122
-120
-118
-116
-114


White Mountain Peak
Fish Lake Valley
White Mountains
Bishop
Deep Spring Valley
Owens Valley
Waucoba Embayment
Sierra Nevada
Inyo Mountains
0 2 4 6 8 10 Kilometers

EARTH Interactions

Copyright © 2007, Paper 11-009; 10,744 words, 12 Figures, 3 Animations, 1 Table.
http://EarthInteractions.org

Plant Species Distributions under Present Conditions and Forecasted for Warmer Climates in an Arid Mountain Range

Christopher M. Van de Ven*

Department of Geological Sciences, Albion College, Albion, Michigan

S. B. Weiss

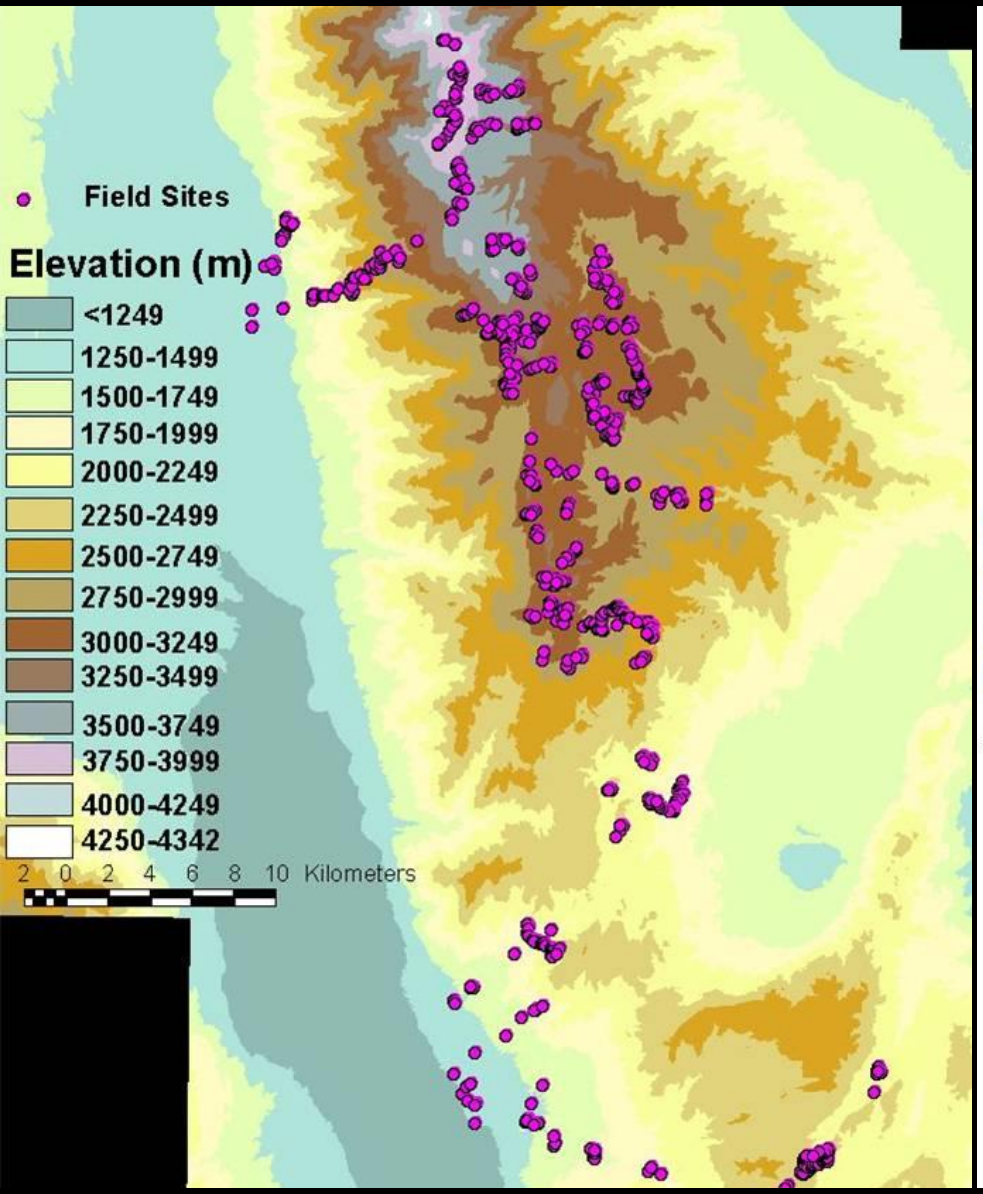
Creekside Center for Earth Observations, Menlo Park, California

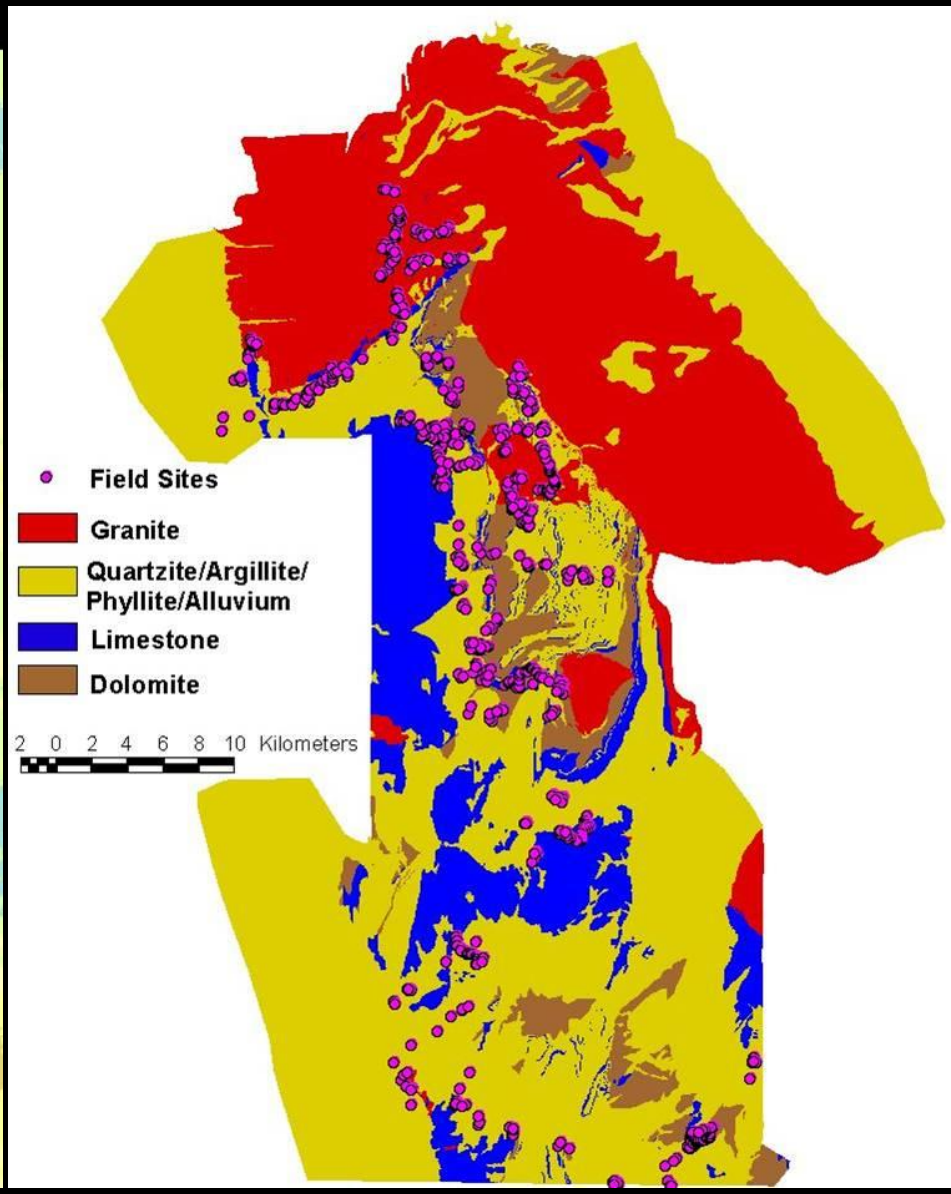
W. G. Ernst

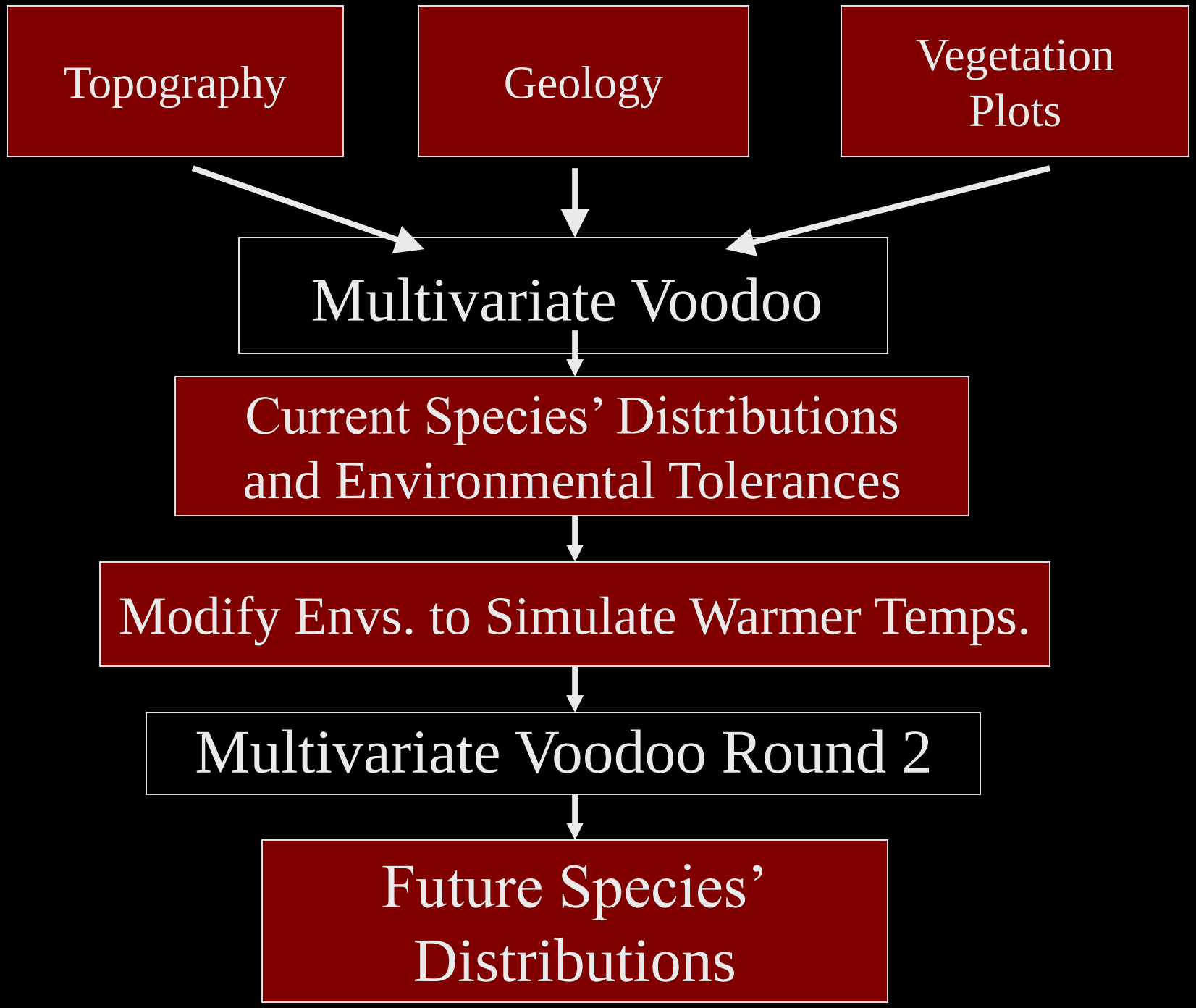
Department of Geological and Environmental Sciences, Stanford University, Stanford, California

Received 19 May 2006; accepted 11 January 2007

Elevation and Geology



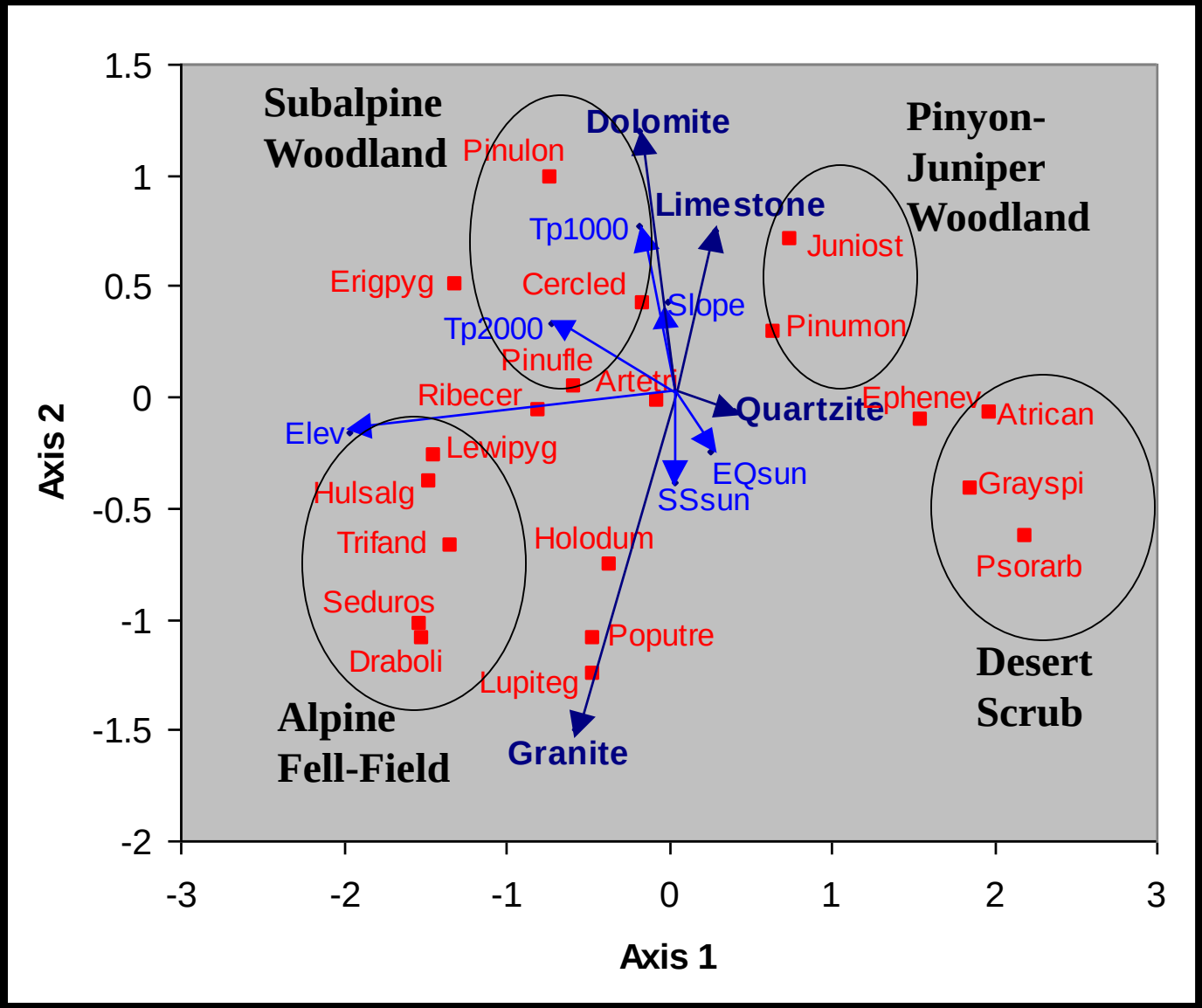



Topography
Geology
Vegetation Plots
Multivariate Voodoo
Current Species' Distributions and Environmental Tolerances
Modify Envs. to Simulate Warmer Temps.
Multivariate Voodoo Round 2
Future Species' Distributions

Dolomite/
Ridge Crest

Geology/
Topographic
Position

Granite/
Canyon Bottom



High/Cool/Wet

Low/Hot/Dry

Elevation/Temp./Precip. Gradient

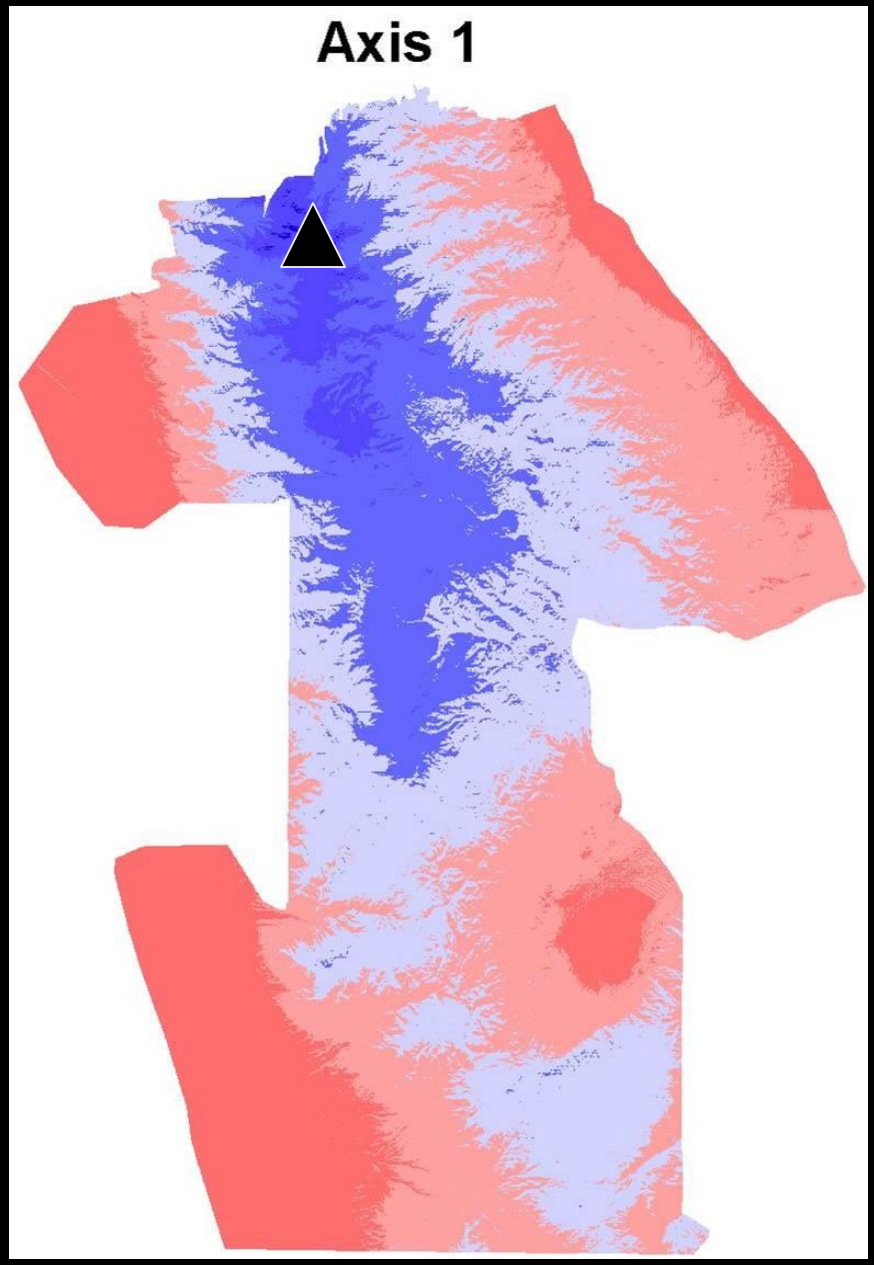
Desert Scrub (4000-6500ft)

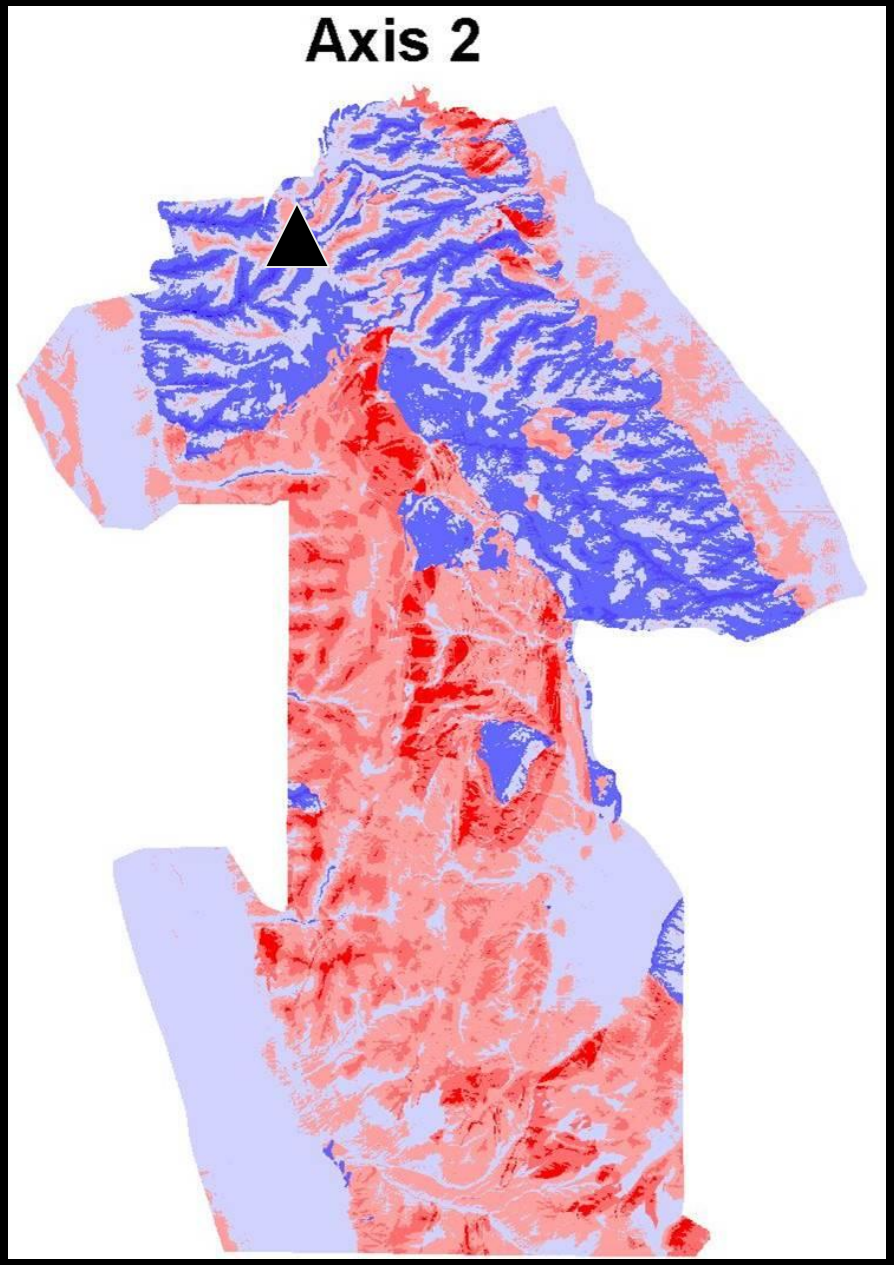
Pinyon-Juniper Woodland (6500-9500ft)

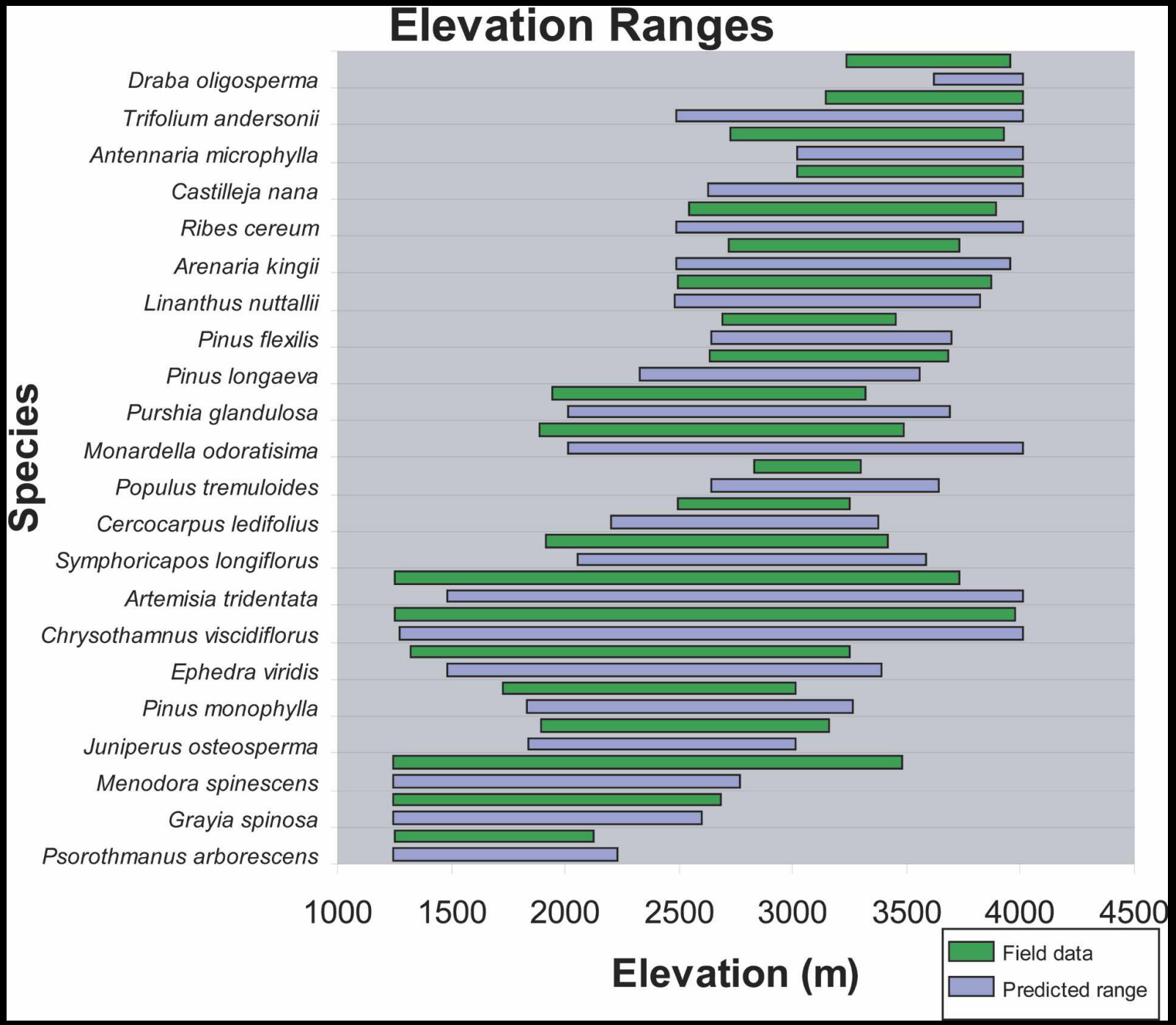
Subalpine Woodland (9500-11,500ft)

Alpine sagebrush (11,500-12,500 ft.)

Alpine Fell-Fields (12,500-14,246ft)

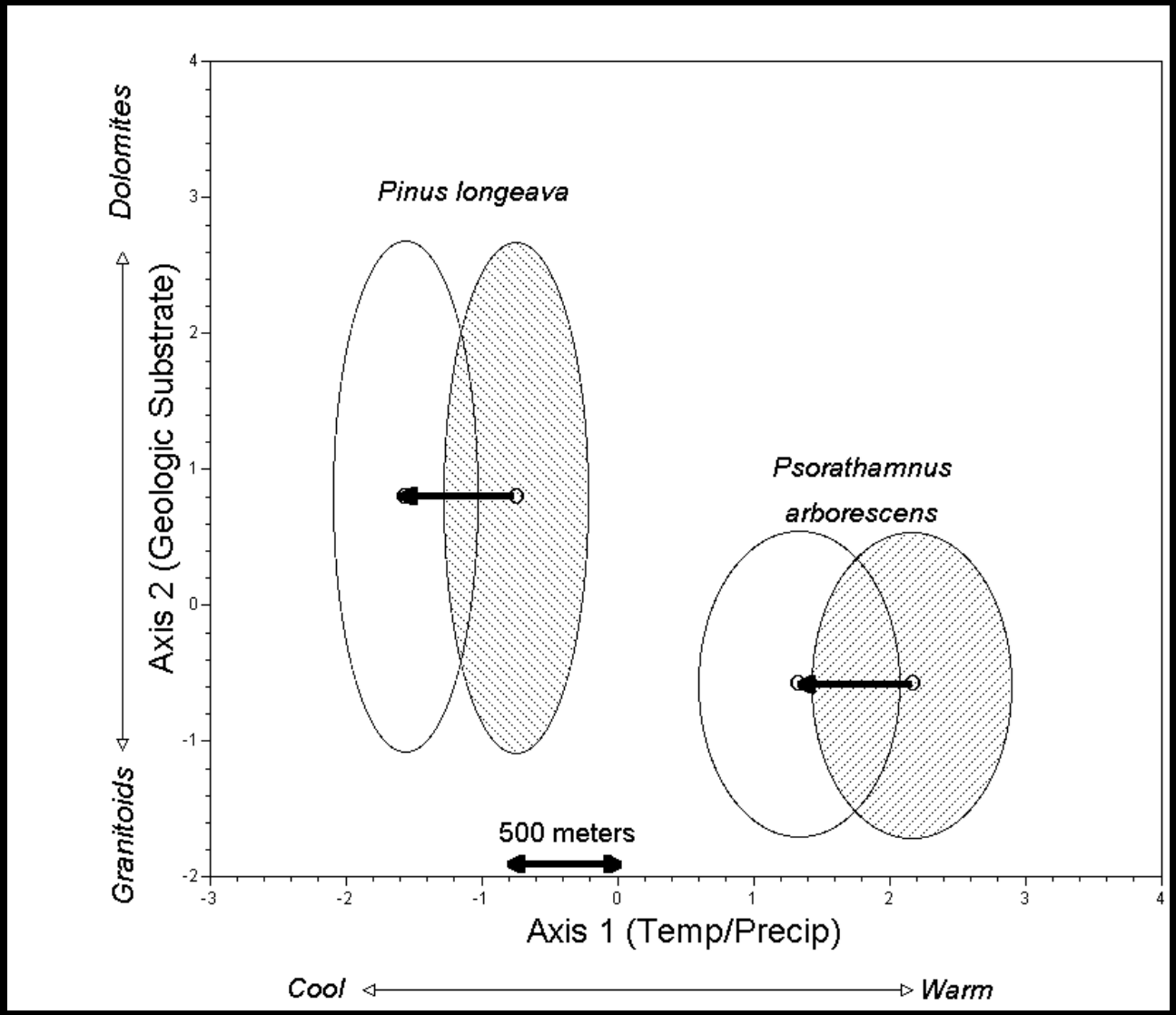

Axis 1


Axis 2


Elevation Ranges
Species
Draba oligosperma
Trifolium andersonii
Antennaria microphylla
Castilleja nana
Ribes cereum
Arenaria kingii
Linanthus nuttallii
Pinus flexilis
Pinus longaeva
Purshia glandulosa
Monardella odoratisima
Populus tremuloides
Cercocarpus ledifolius
Symphoricapos longiflorus
Artemisia tridentata
Chrysothamnus viscidiflorus
Ephedra viridis
Pinus monophylla
Juniperus osteosperma
Menodora spinescens
Grayia spinosa
Psorothmanus arborescens
1000
1500
2000
2500
3000
3500
4000
4500
Elevation (m)
Field data
Predicted range

Axis 2

Modeling Climate Change

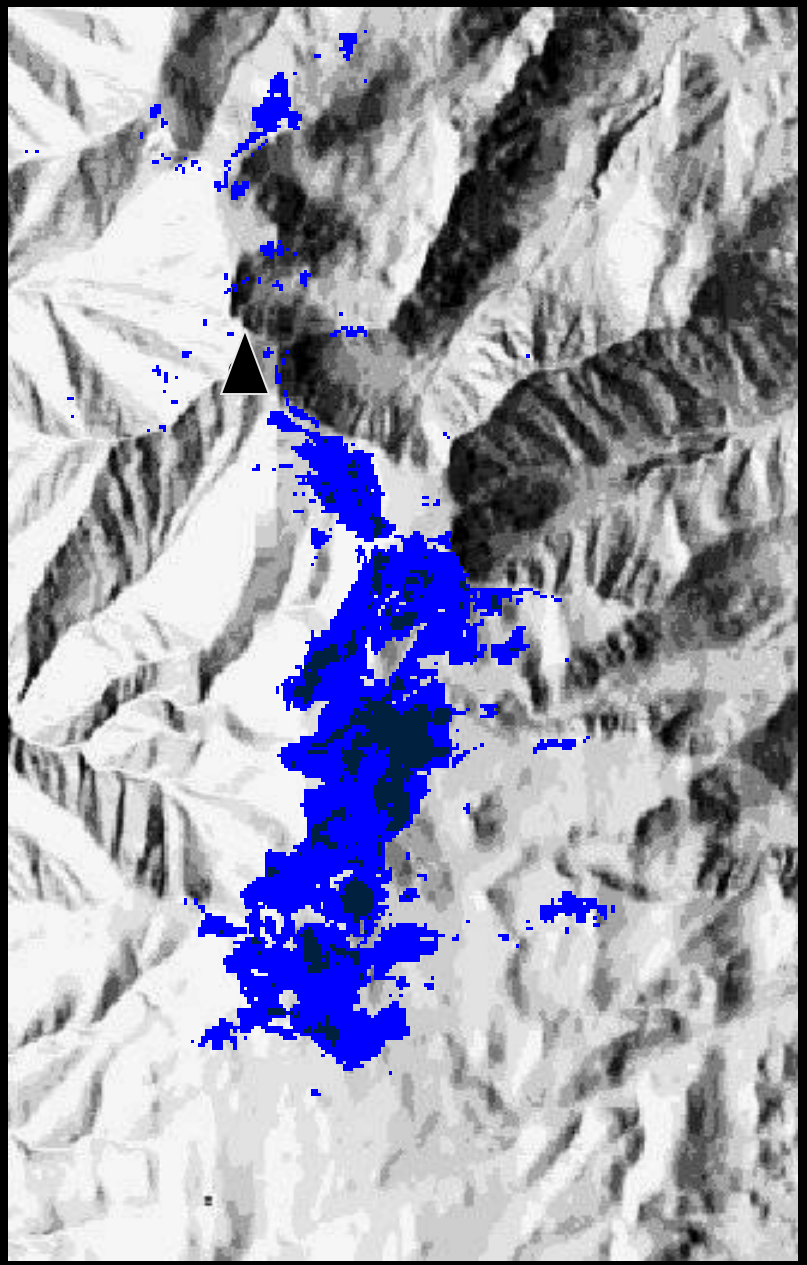


- Lapse rate: 3ºC/500m
- 1ºC = 167m = -0.29 Axis 1 std. devs.

Draba oligosperma

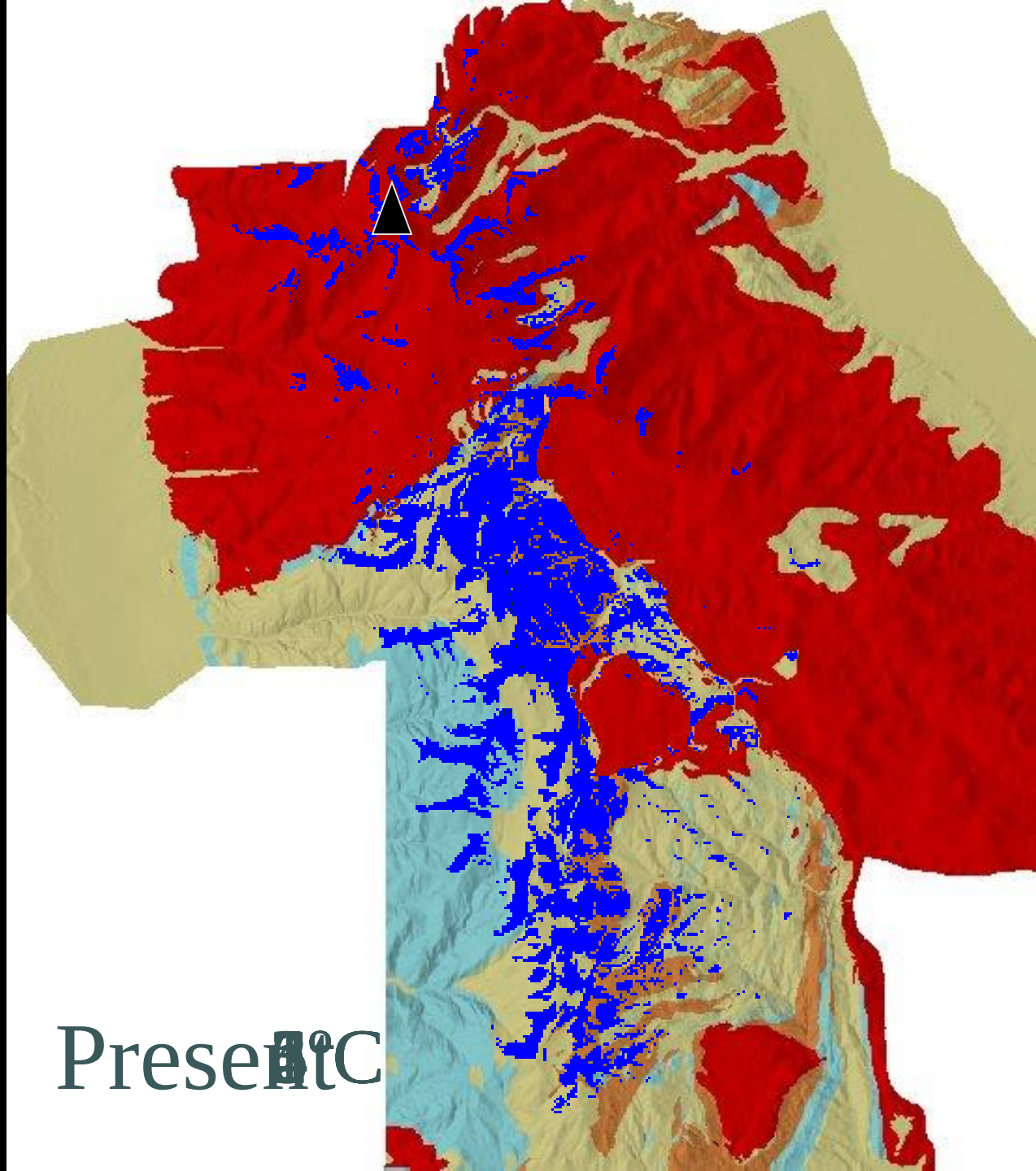
- White Mountain Peak

Photo © Dean Wm. Taylor, 1972



Pinus longaeva

Granite
Clastic
Limestone
Dolomite
White Mtn. Pk.



Species Temperature Limits

- Extinct after warming 3°C
- Extinct after warming 4°C
- Extinct after warming 5°C
- Extinct after warming 6°C

- *Antennaria microphylla*
- *Astragalus calycosus*
- *Cryptantha flavoculata*
- *Draba breweri*
- *Draba oligosperma*
- *Ericameria cuneata*
- *Ericameria discoidea*
- *Erigeron pygmaeus*
- *Hulsea algida*
- *Hymenoxis cooperi*
- *Ivesia lycopodioides*
- *Lewisia glandulosa*
- *Lewisia pygmaea*
- *Pinus longaeva*
- *Sedum roseum*
- *Trifolium andersonii*

Other Species at Risk

- Species not modeled, at higher elevations than our field sites
  - *Ranunculus eschscholtzii* (11,400-14,000ft; 3350-4267m)
  - *Erigeron vagus* (>13,000ft; 4000m)
  - *Polemonium chartaceum* (>13,000ft; 4000m)
  - *Anelsonia eurycarpa* (>13,000ft; 4000m)

E. vagus

P. chartaceum

Photos
© Dean Wm. Taylor
1977, 1975

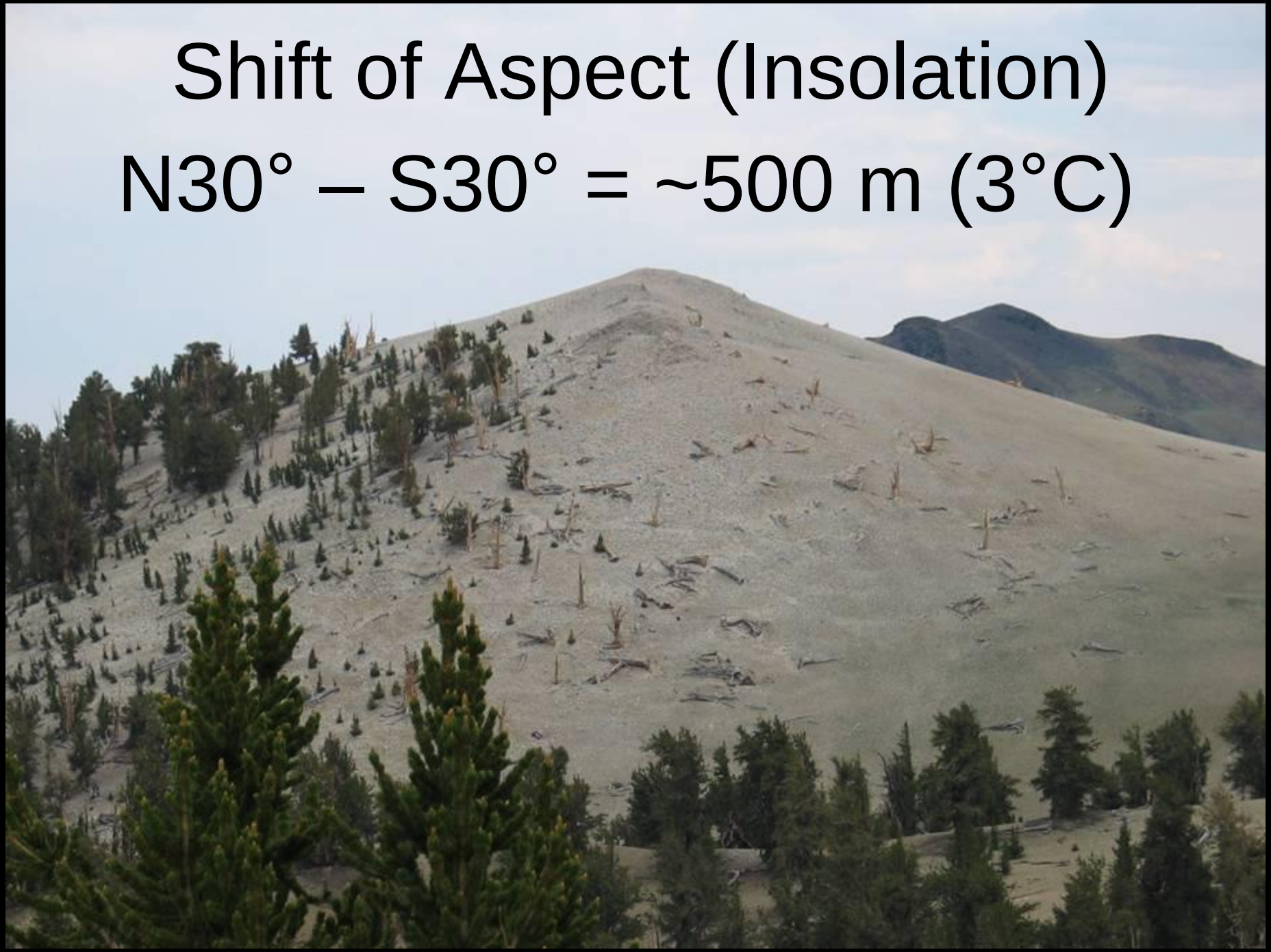
Additional Considerations

- Establishment rates and processes not considered
  - Dispersal and establishment are not limiting
  - Interspecies interactions ignored
  - Some species will migrate faster than others, potentially inhibiting other species from their upslope migration
- Ecological inertia is not considered
  - Long-lived species may retain lower elevation limits long after climates change

Upward population shift

Shift of Aspect (Insolation)

N30° – S30° = ~500 m (3°C)

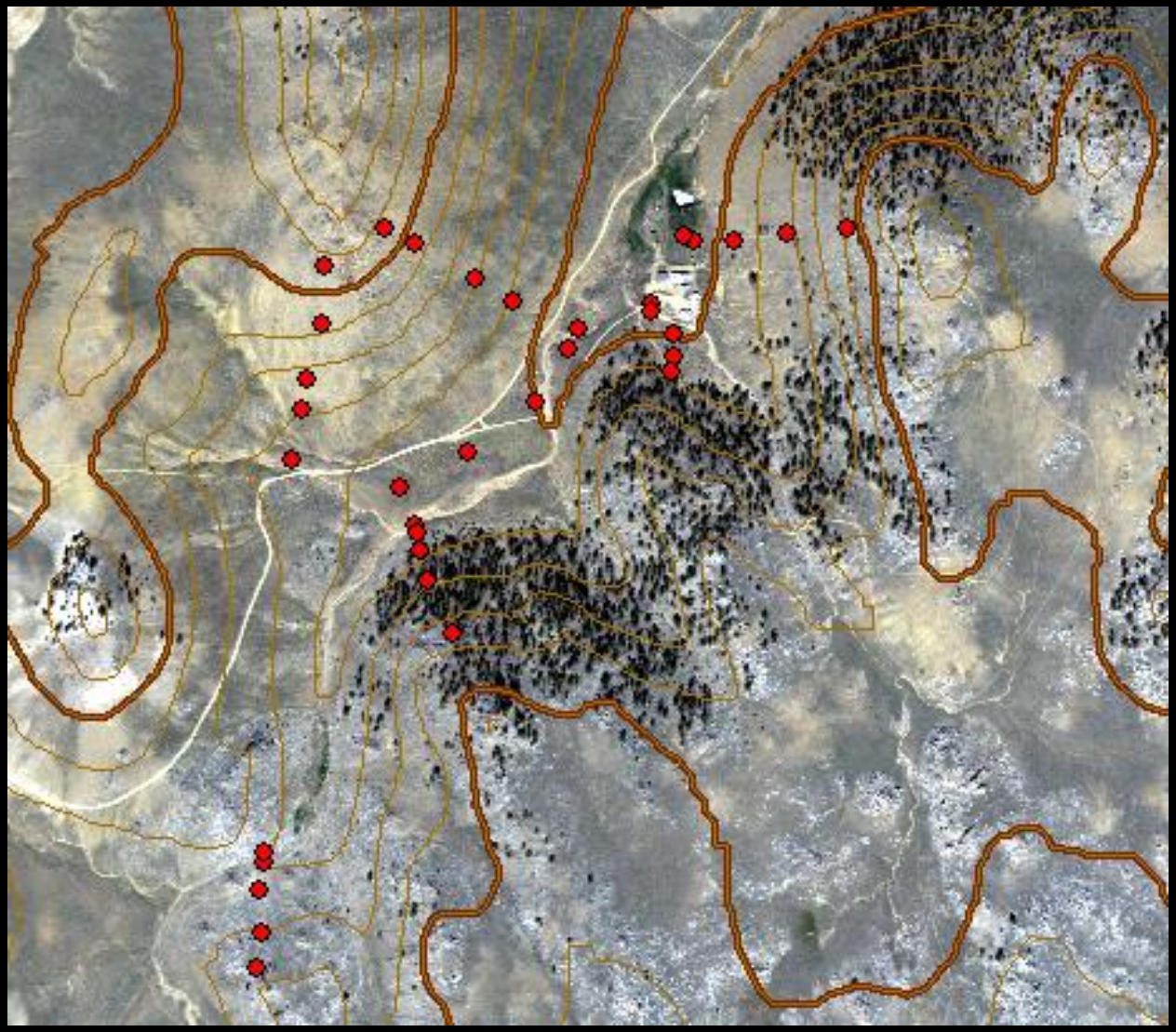


Downslope Shift

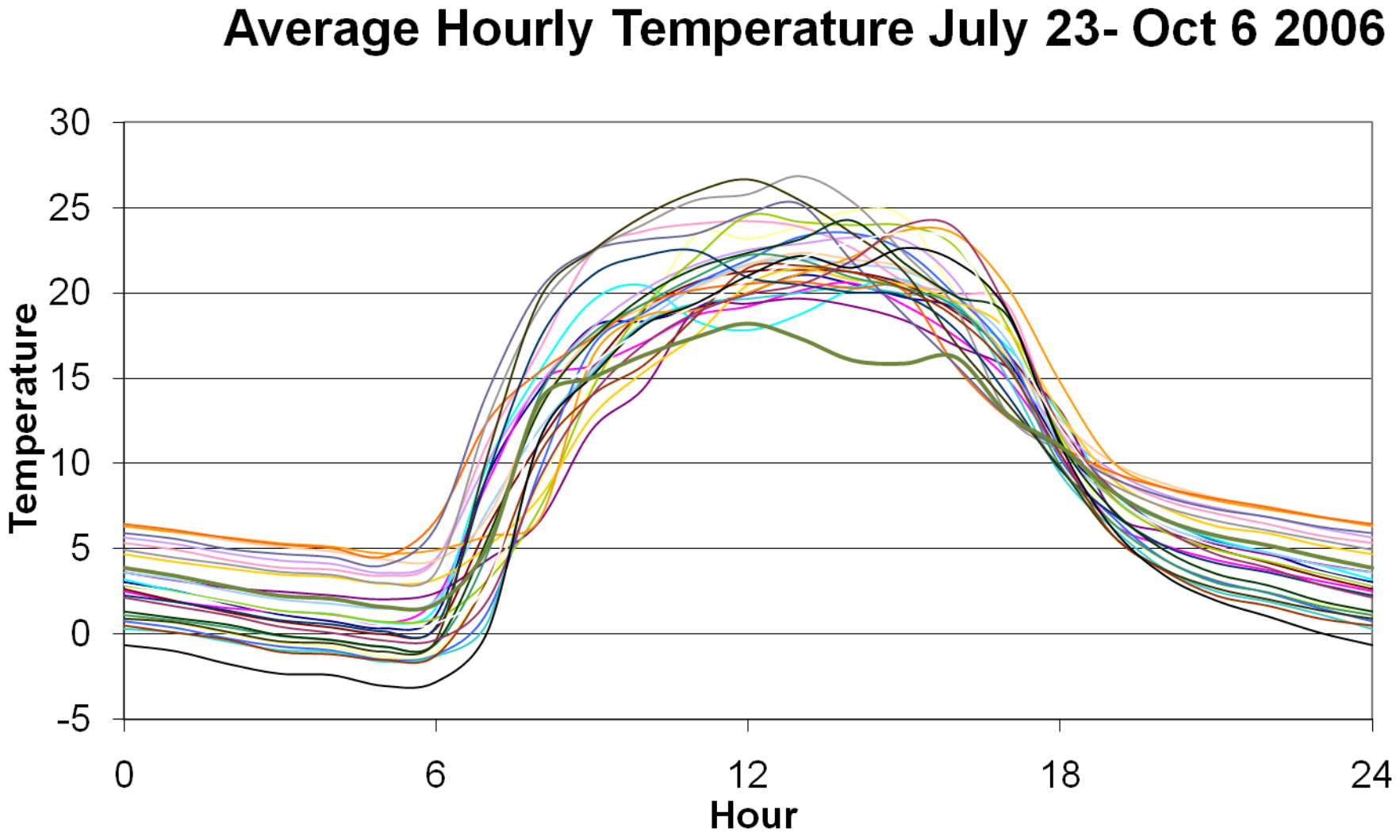
Millar, Westfall, Delany, 2007

- 35 iButton temperature data loggers
  - Affixed inside 6” lengths of white PVC tubes
  - Placed on ground beneath sagebrush
  - PVC openings facing north-south
  - Recorded hourly temp. Jul. 23-Oct. 6, 2006

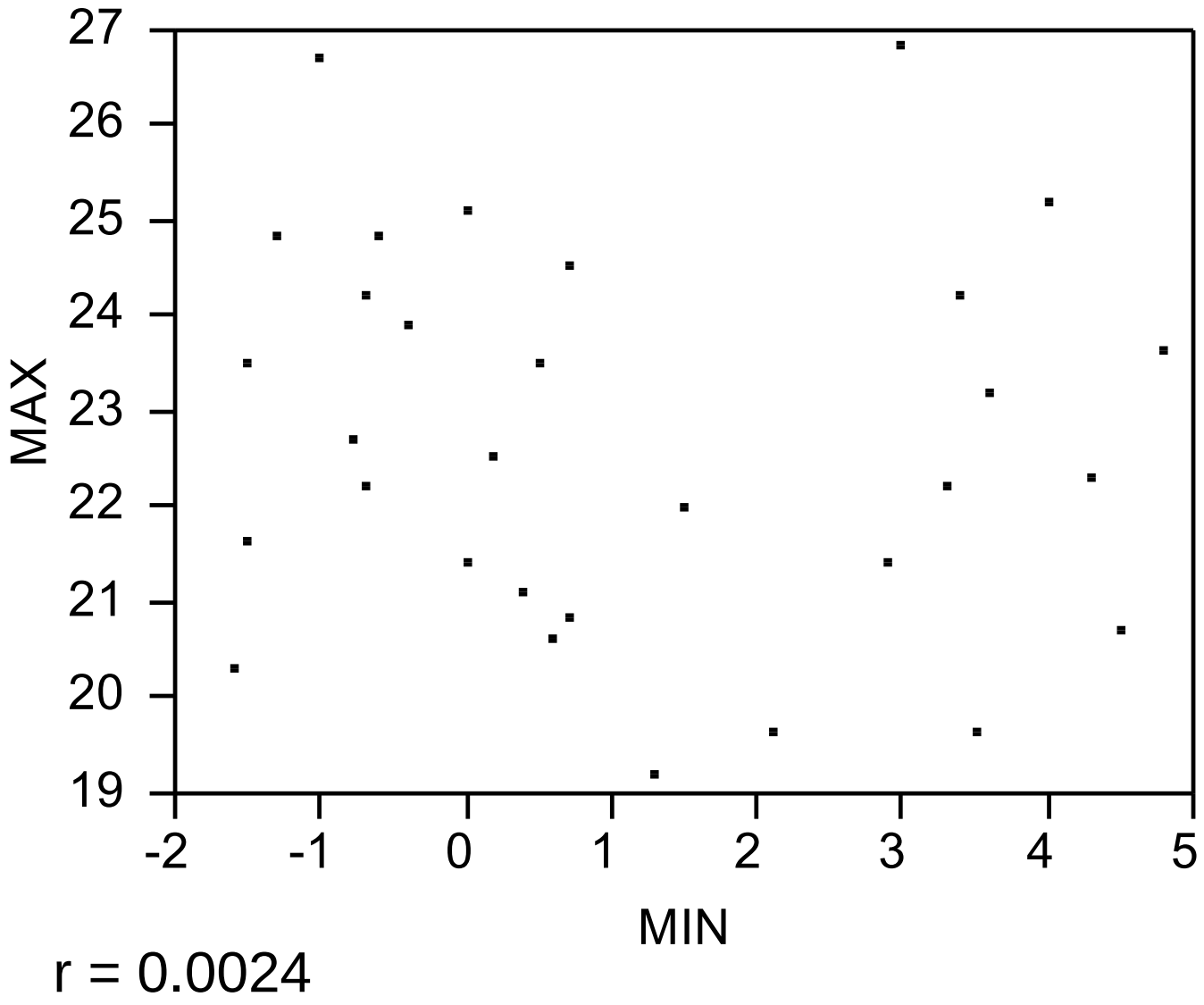
Distribution of Sensors



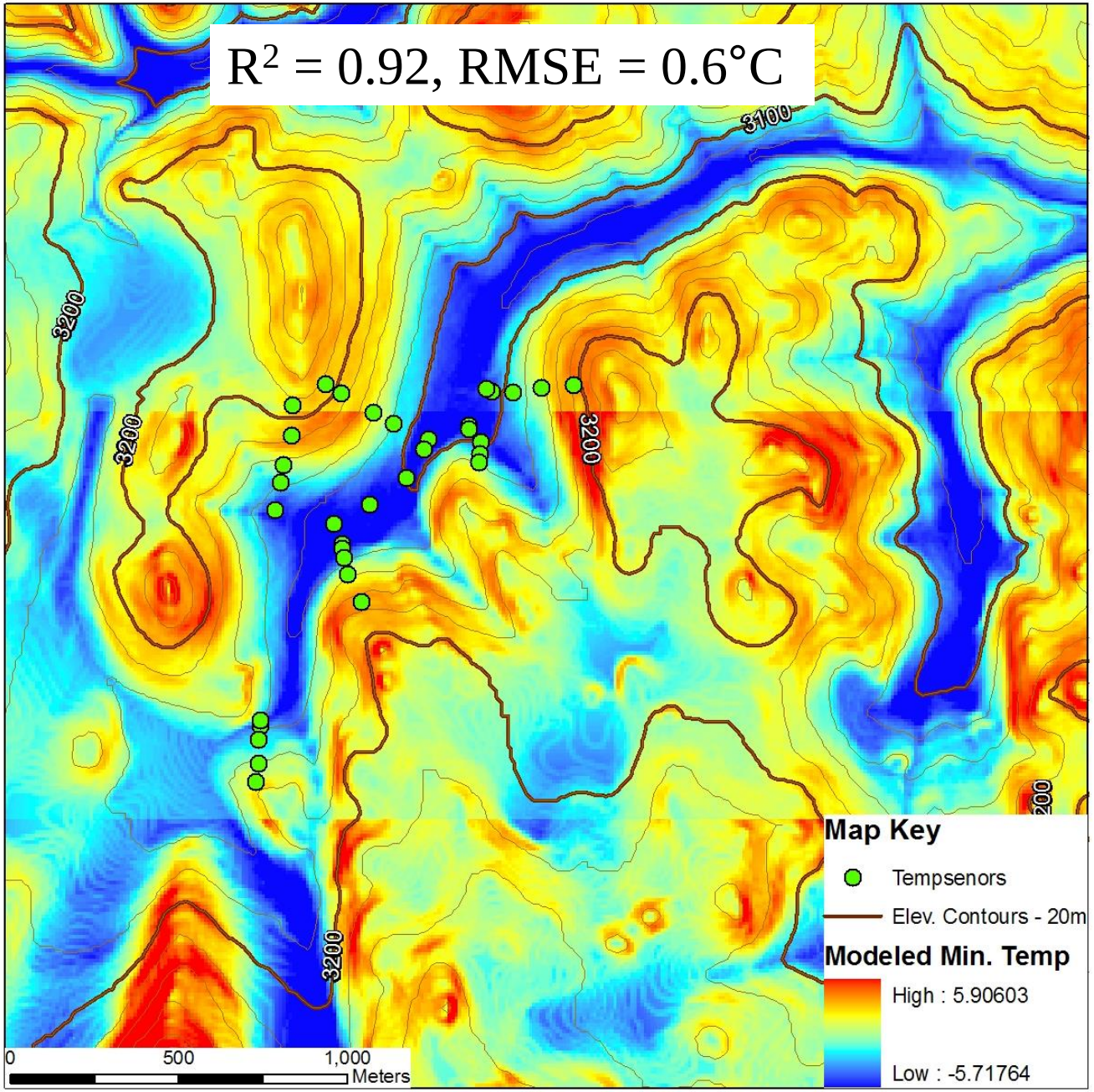
Topoclimate within 1 km^2

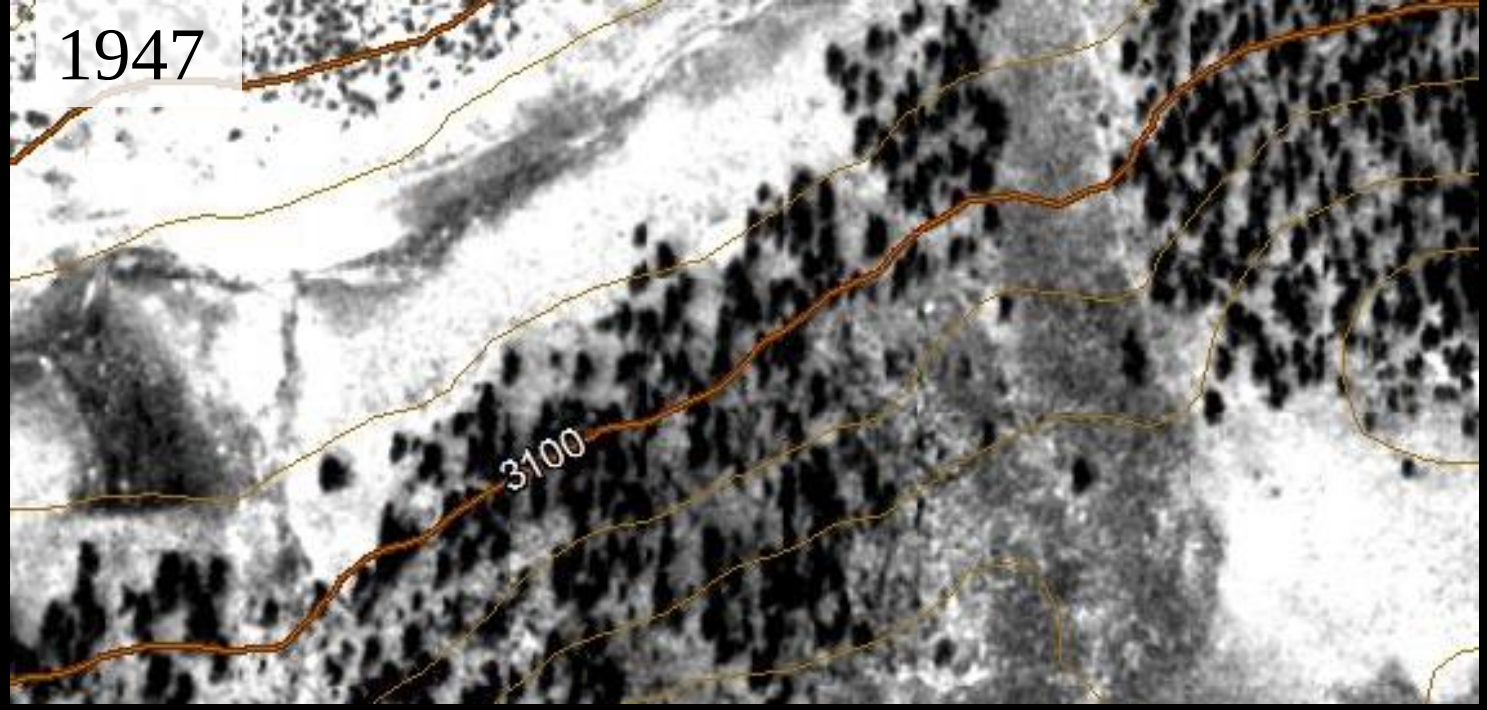


Uncorrelated T_{max} T_{min}

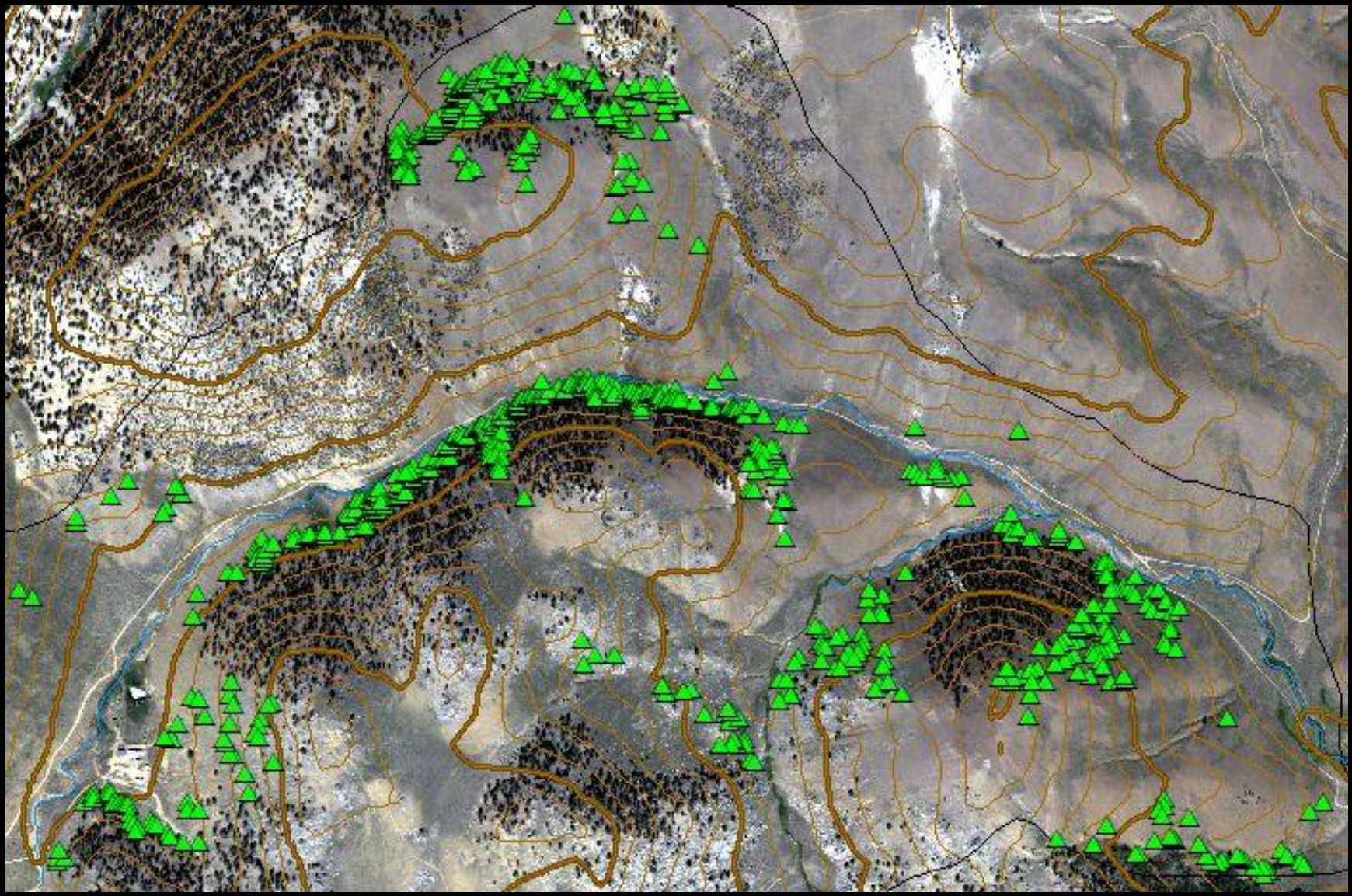


Modeled Minimum Temperature at Crooked Creek

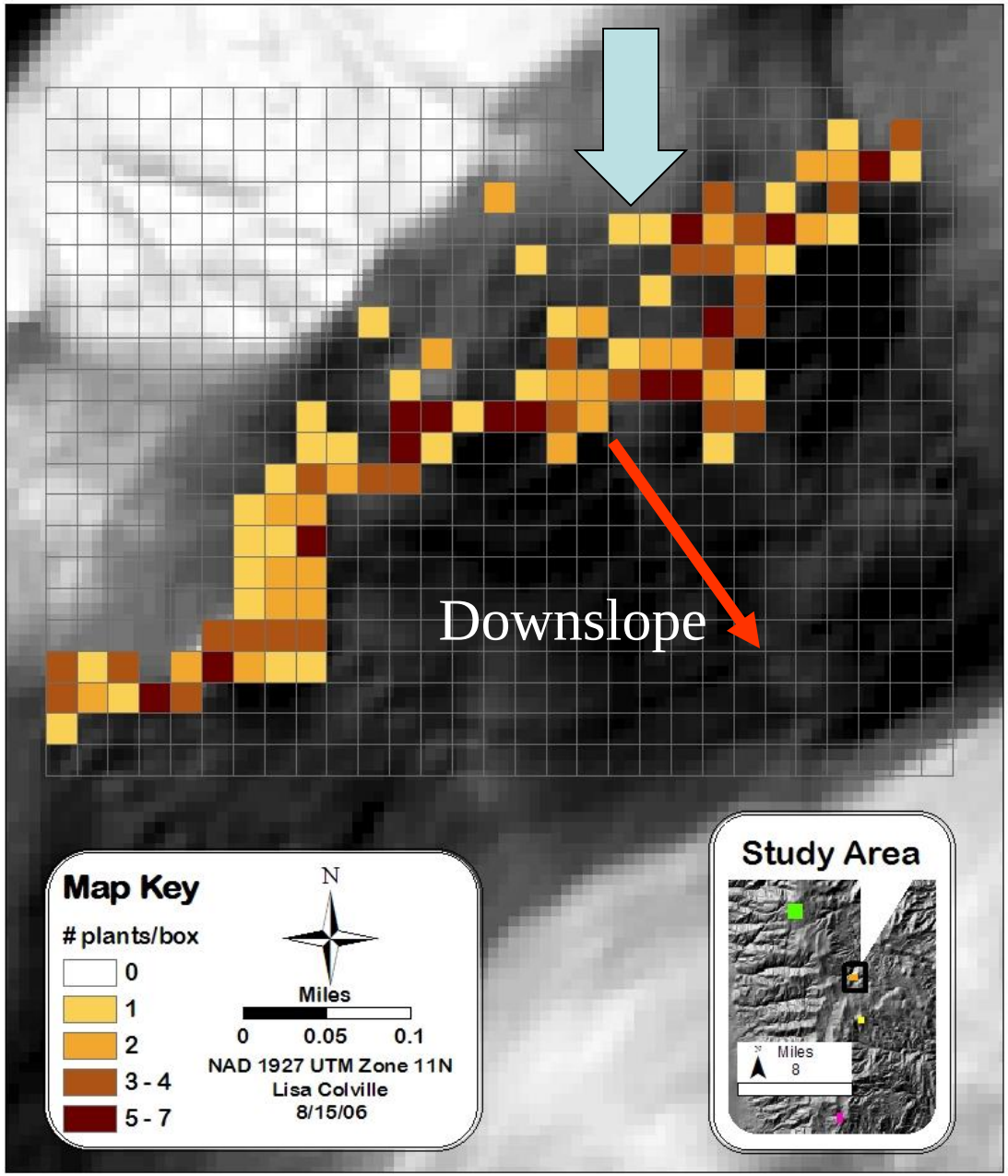



1947
3100

2005
3100



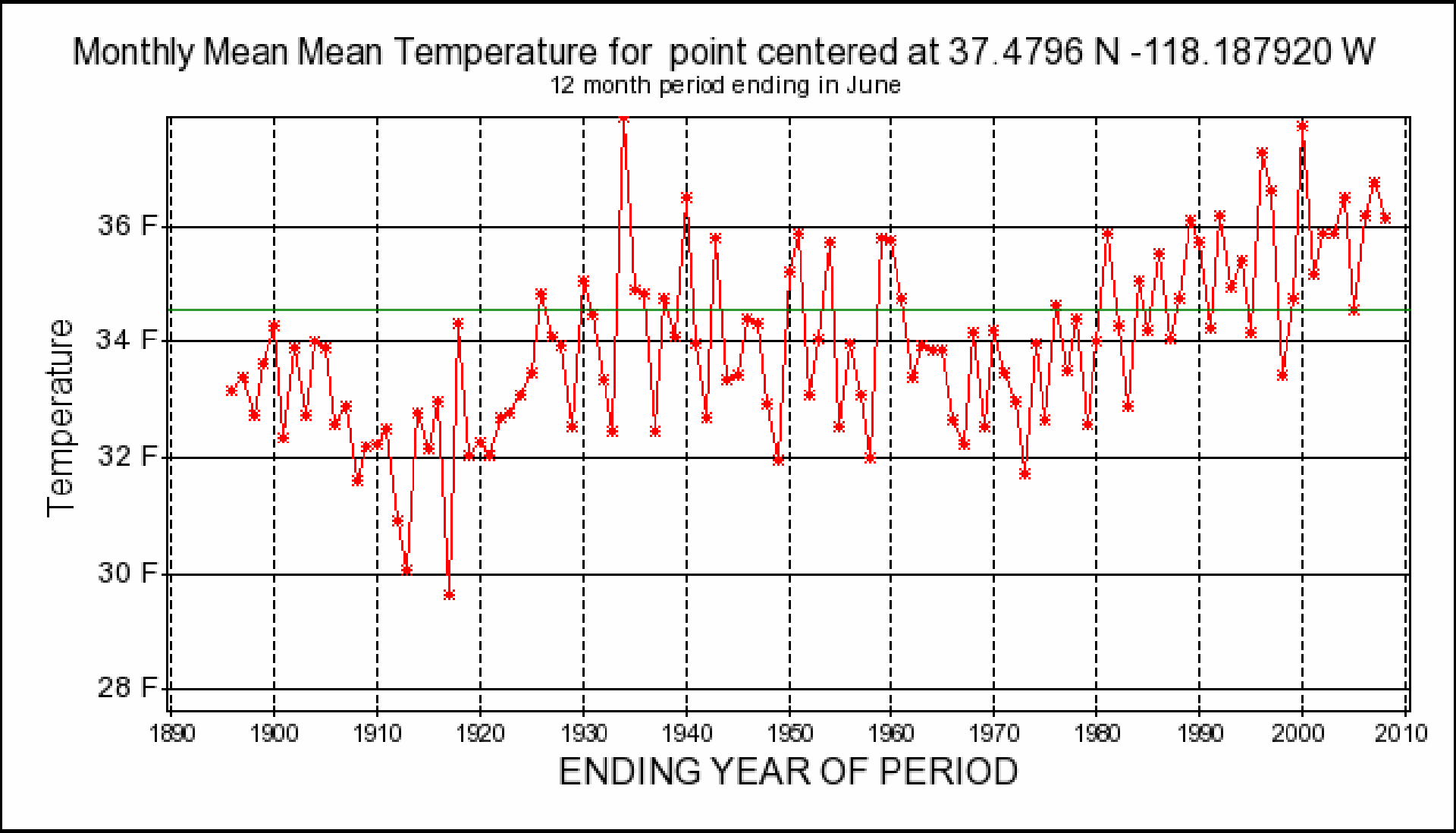
C. ledifolius Distribution 2006



Shrubbery Line 12,600 ft
(*Artemesia sp.*)

Shrubbery Line 12,600 ft

WESTMAP (PRISM)



Conclusions

- Complex environment – topography + geology makes for complex responses
- General upward movement
- Insolation and topographic position (sideways and down)
- T_{max} and T_{min} are decoupled on local scale
- Species will move at their own pace
- We can watch how it happened, and project where it will go.
- The “Nooks and Crannies” are the scale at which populations respond