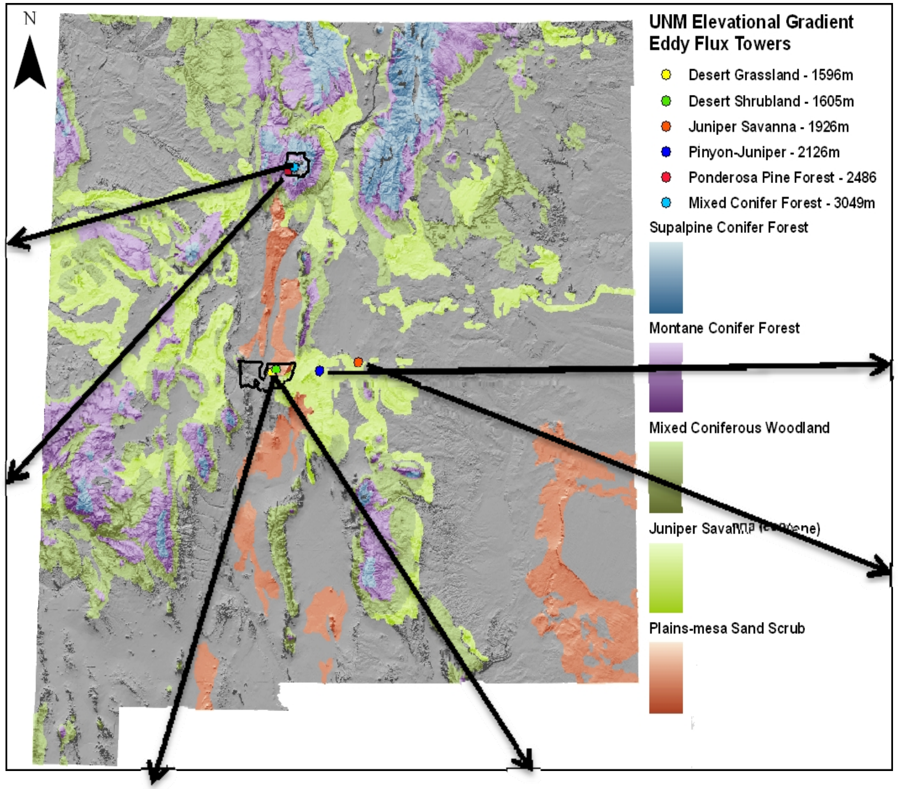
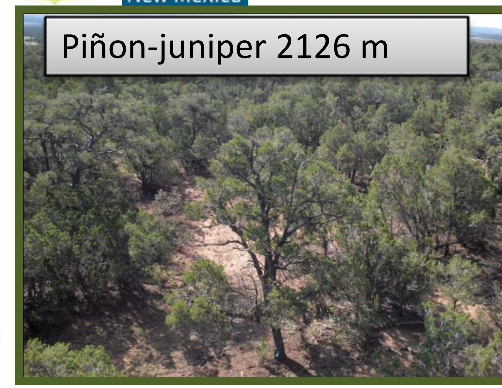
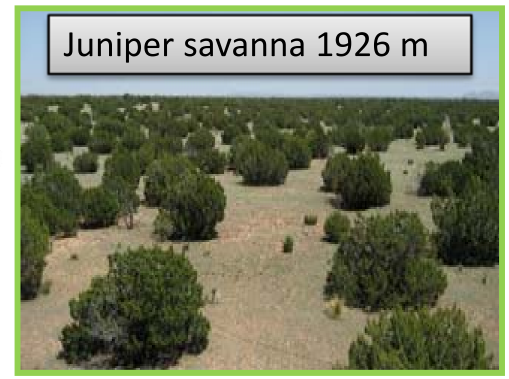
Use of a tower network to reduce uncertainties about how carbon balance in the southwest will respond to climate change

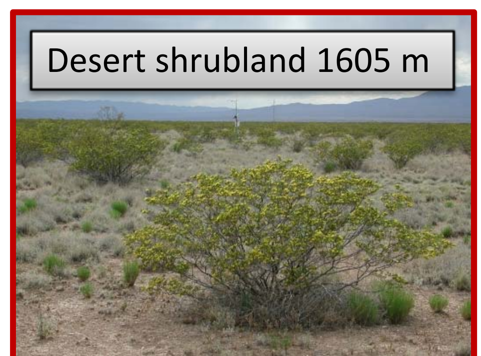
Marcy Litvak
University of New Mexico, Albuquerque, NM
Sevilleta LTER

New Mexico Elevation Gradient



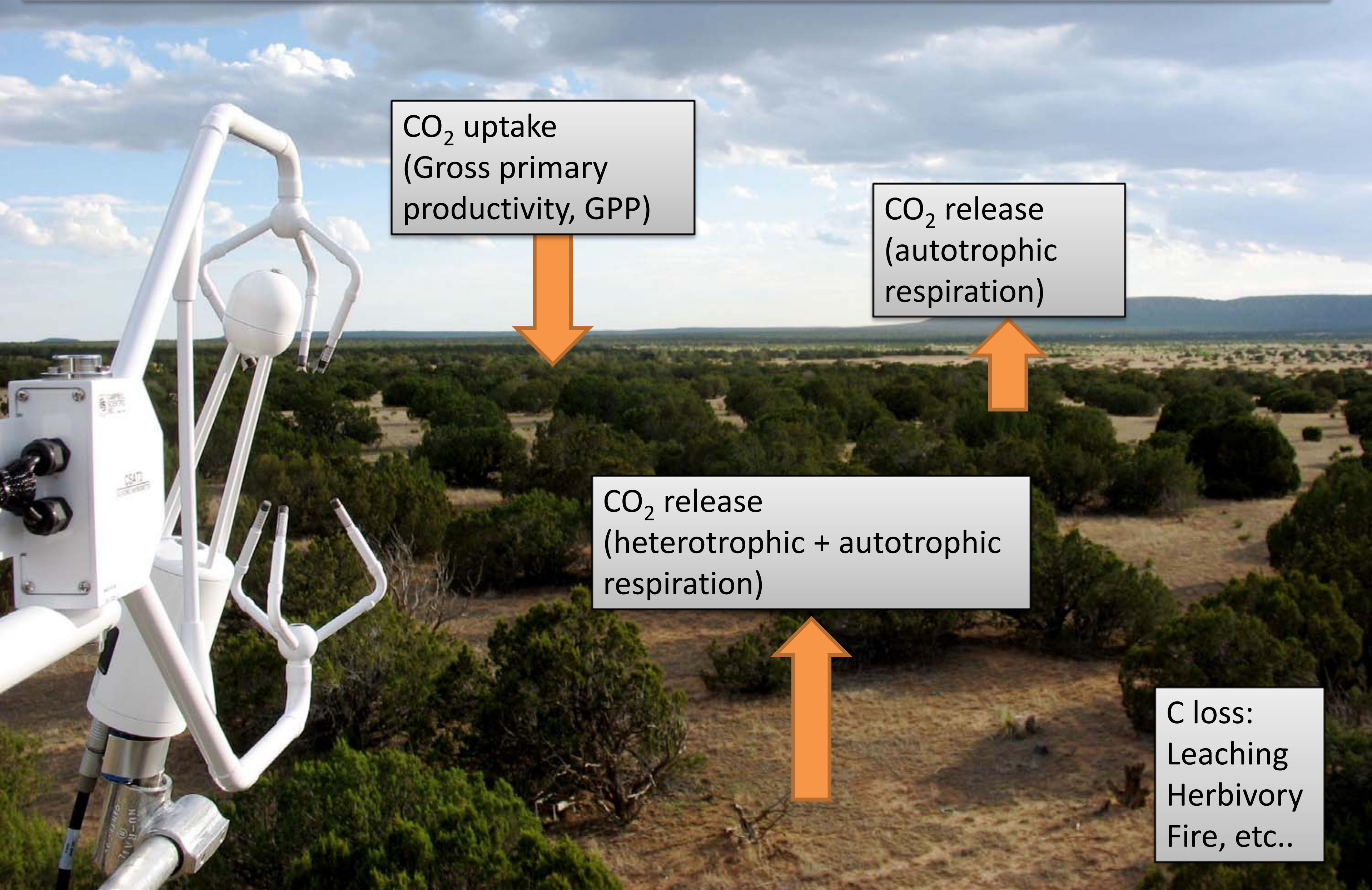






Sevilleta LTER
Long Term Ecological Research

Eddy covariance – ecosystem carbon fluxes



Eddy covariance – ecosystem carbon fluxes

Net ecosystem exchange (NEE) = Net CO_2 uptake

g C m^{-2} $time^{-1}$ (day, month, yr)

Partition NEE into component fluxes

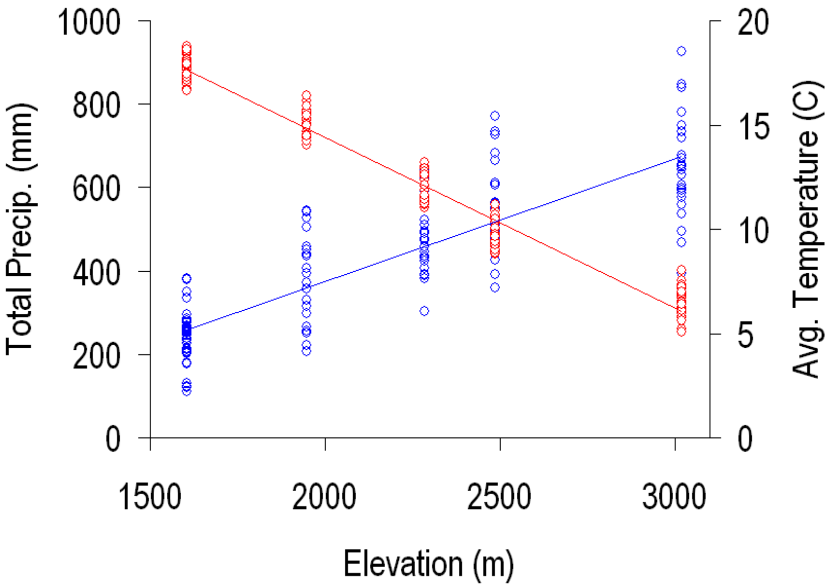
GPP: total carbon in

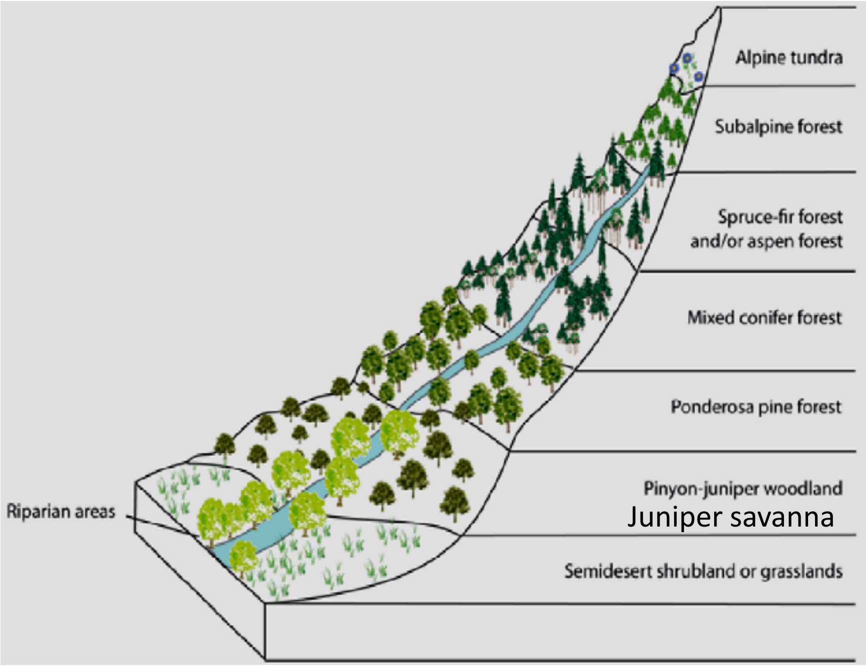
R_e : total carbon out

GPP = gross primary productivity

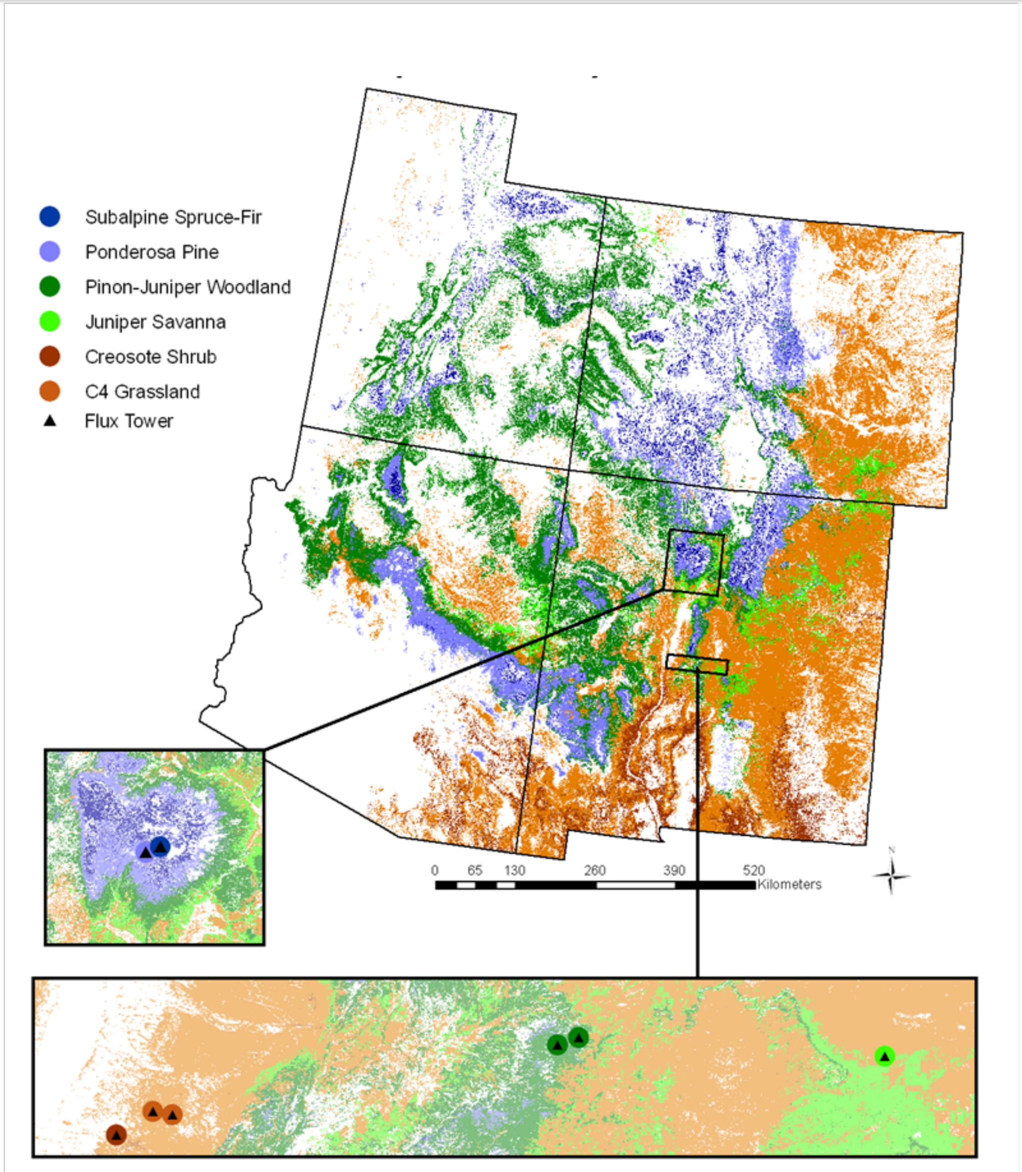
R_e = Ecosystem respiration

Spatial heterogeneity in SW



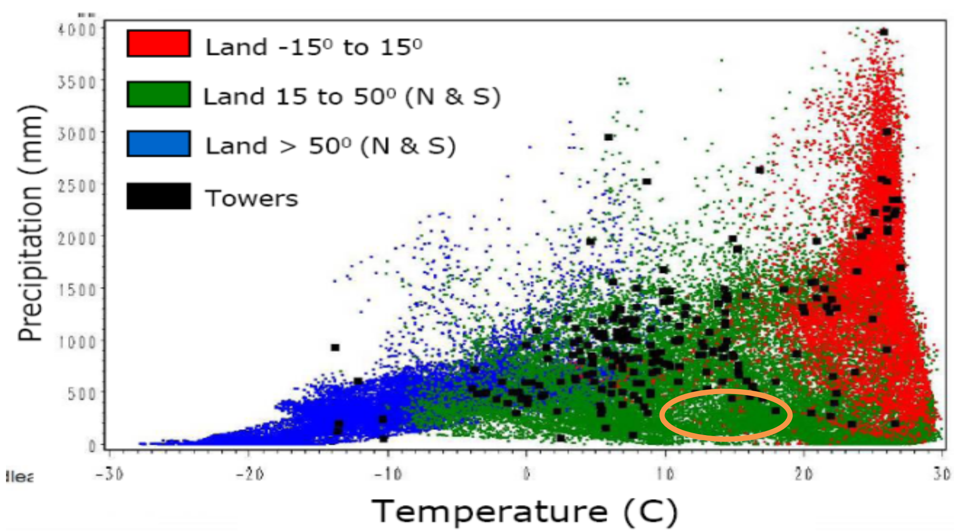


Biomes represented by the NMEG



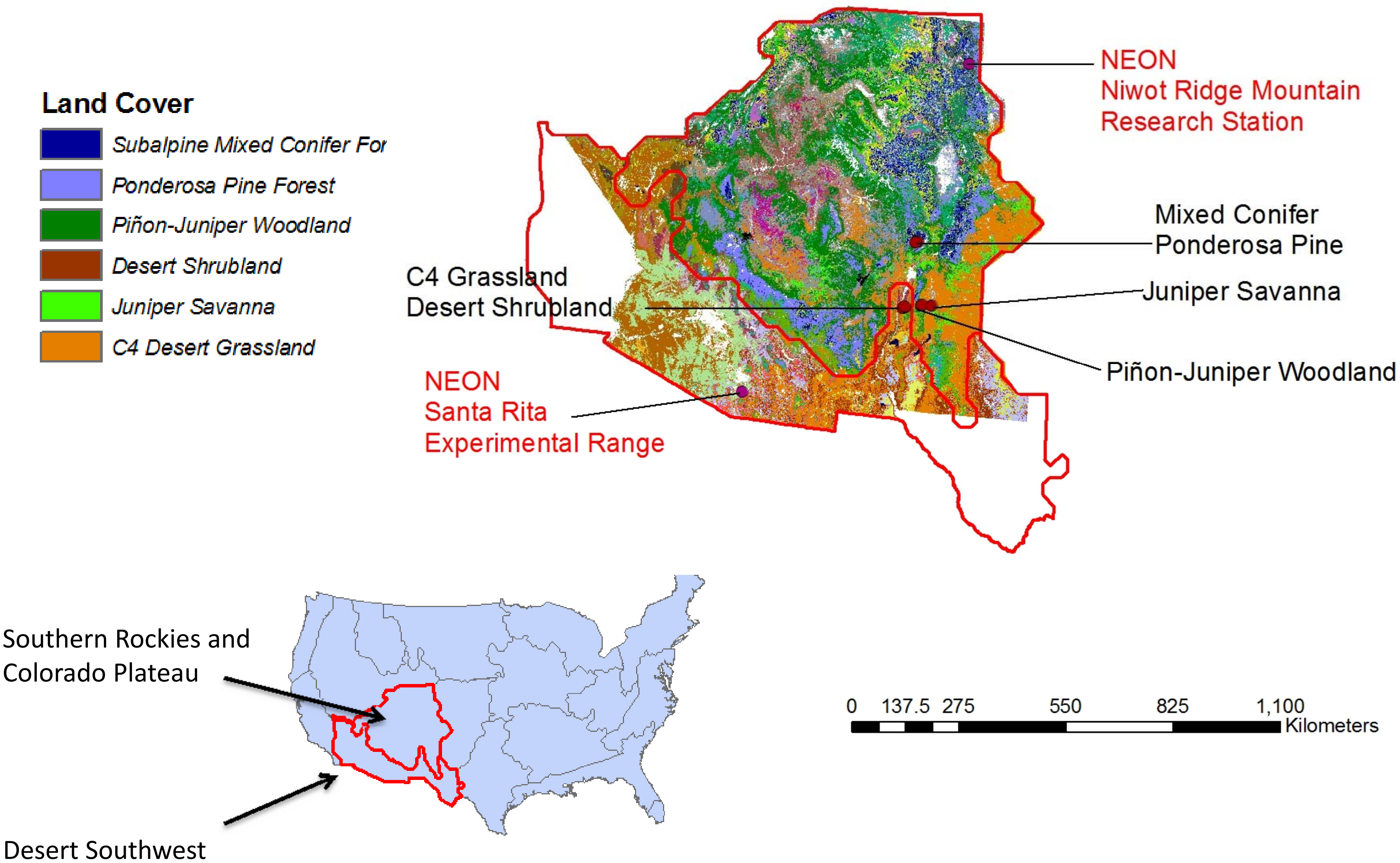
landcover data from the Southwest Regional Gap Analysis Project (SWReGAP)(http://earth.gis.usu.edu/swgap).

Contributions to Ameriflux, FLUXNET



FLUXNET synthesis 2007

Contributions to NEON



NM Elevation Gradient data sets

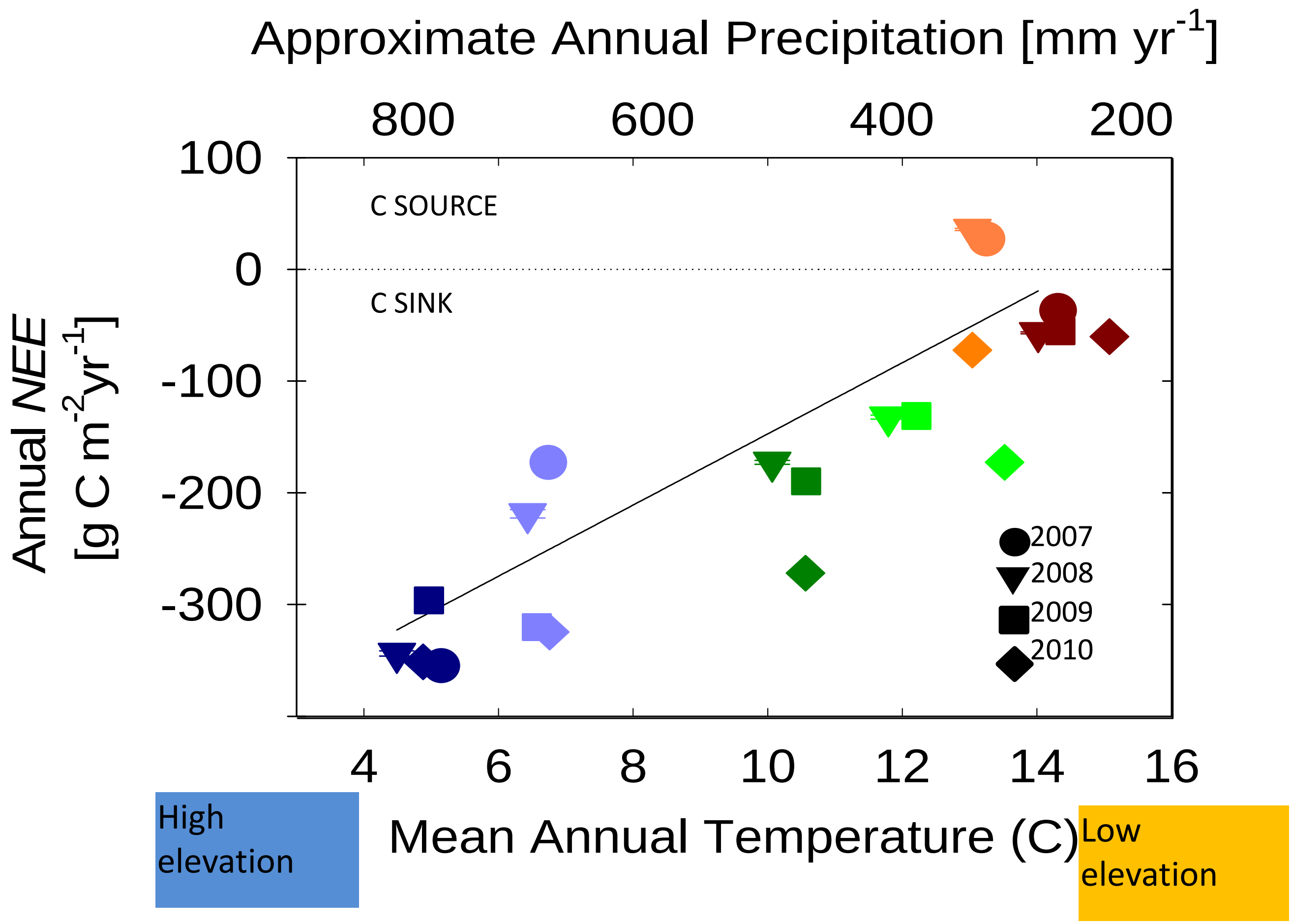
- **Tower-based open-path eddy covariance (since 2007)**
  - Net Ecosystem Exchange of carbon , Latent Heat flux, Sensible Heat flux
- **Carbon pools (2007, 2010)**
  - aboveground biomass, leaf area index, course/fine woody debris, litter, soil
- **Micrometeorological variables**
  - Air T, RH, Net radiation and components, PAR, Soil T and H_2O content profiles
- **Physiology**
  - Leaf-level gas exchange, soil, foliar and bole respiration, sap flow, soil CO_2, chlorophyll fluorescence
- **Detailed ecosystem structure and function**
  - Airborne LiDAR (summer 2011), QuickBird (4 acquisitions, 2011-2012)
  - NDVI and PRI sensors

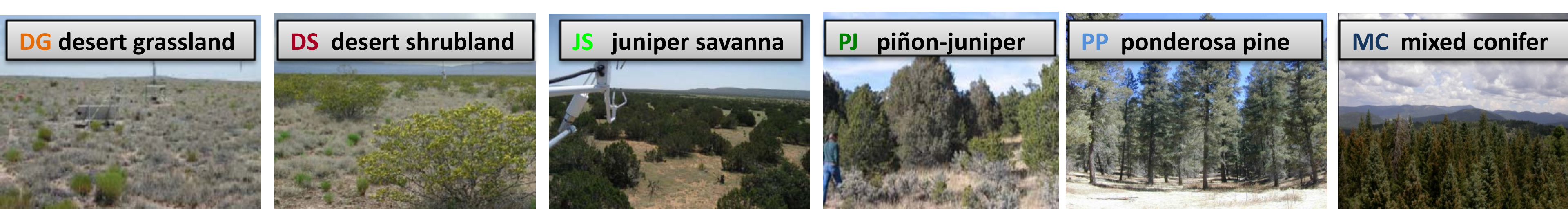





Climate dependence of carbon fluxes and storage

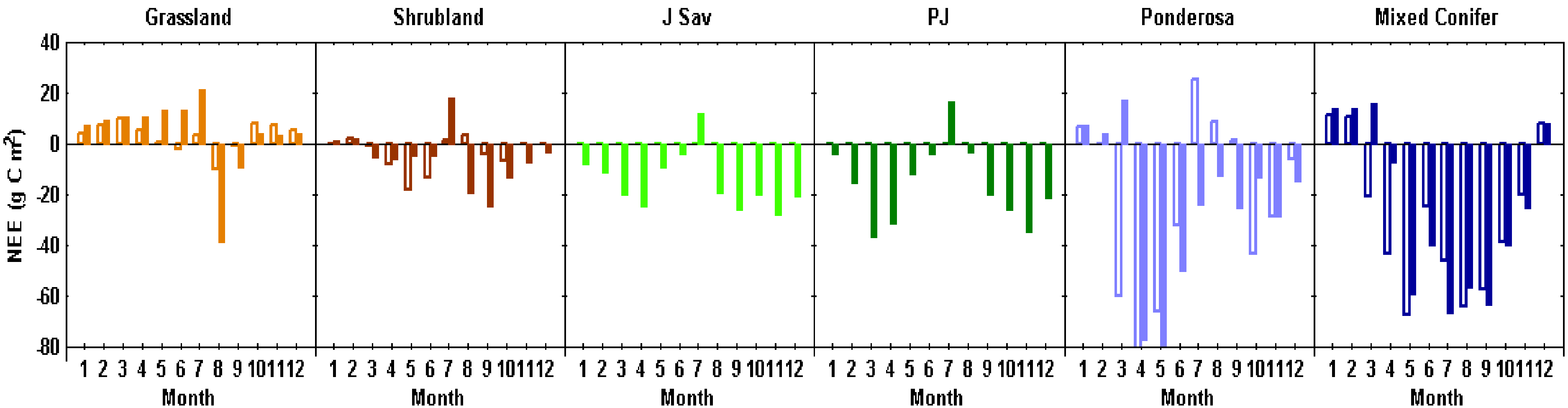
Anderson-Teixera et al. GCB, 2011



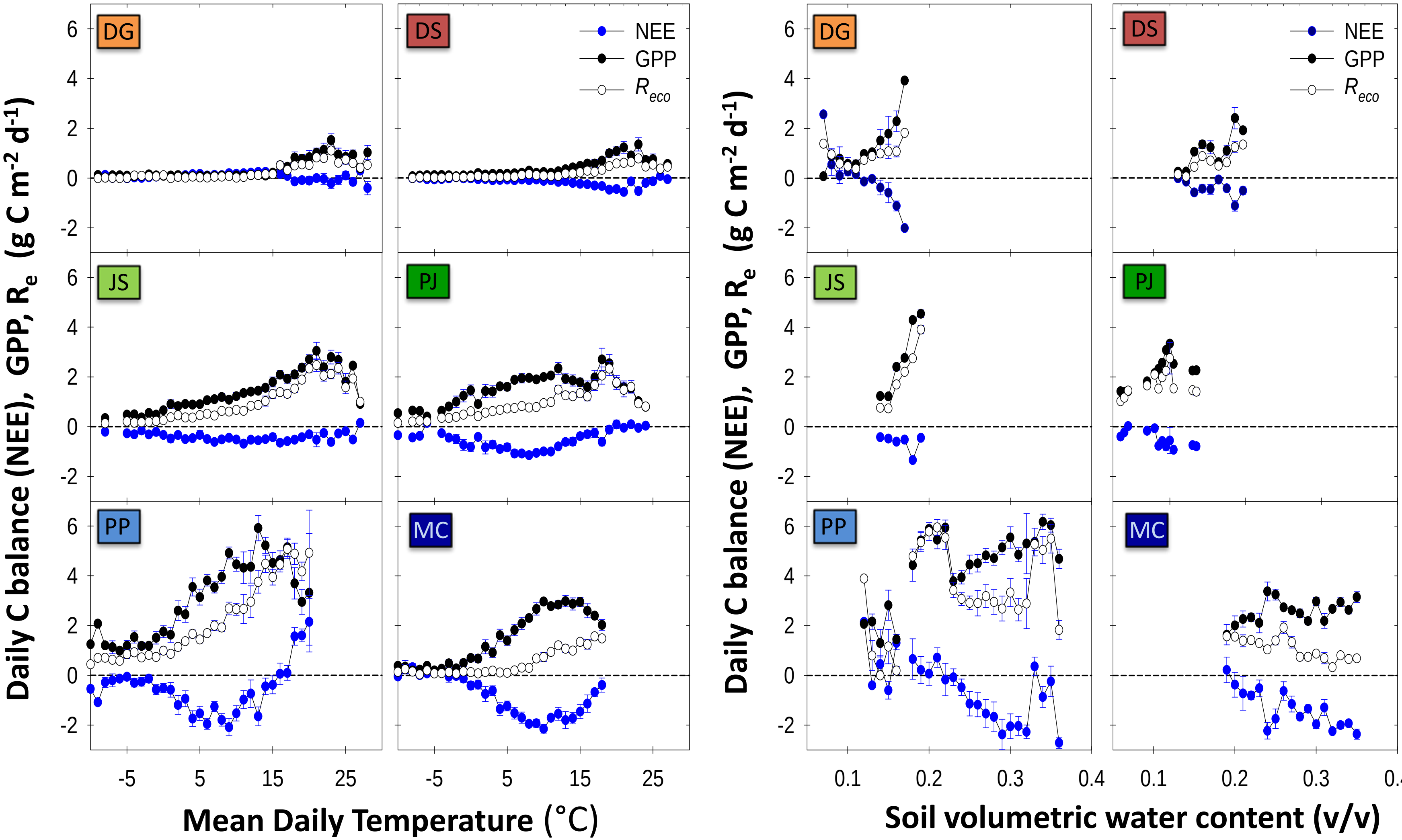


Seasonal Patterns – Carbon uptake

Open bars = 2007 Closed = 2008

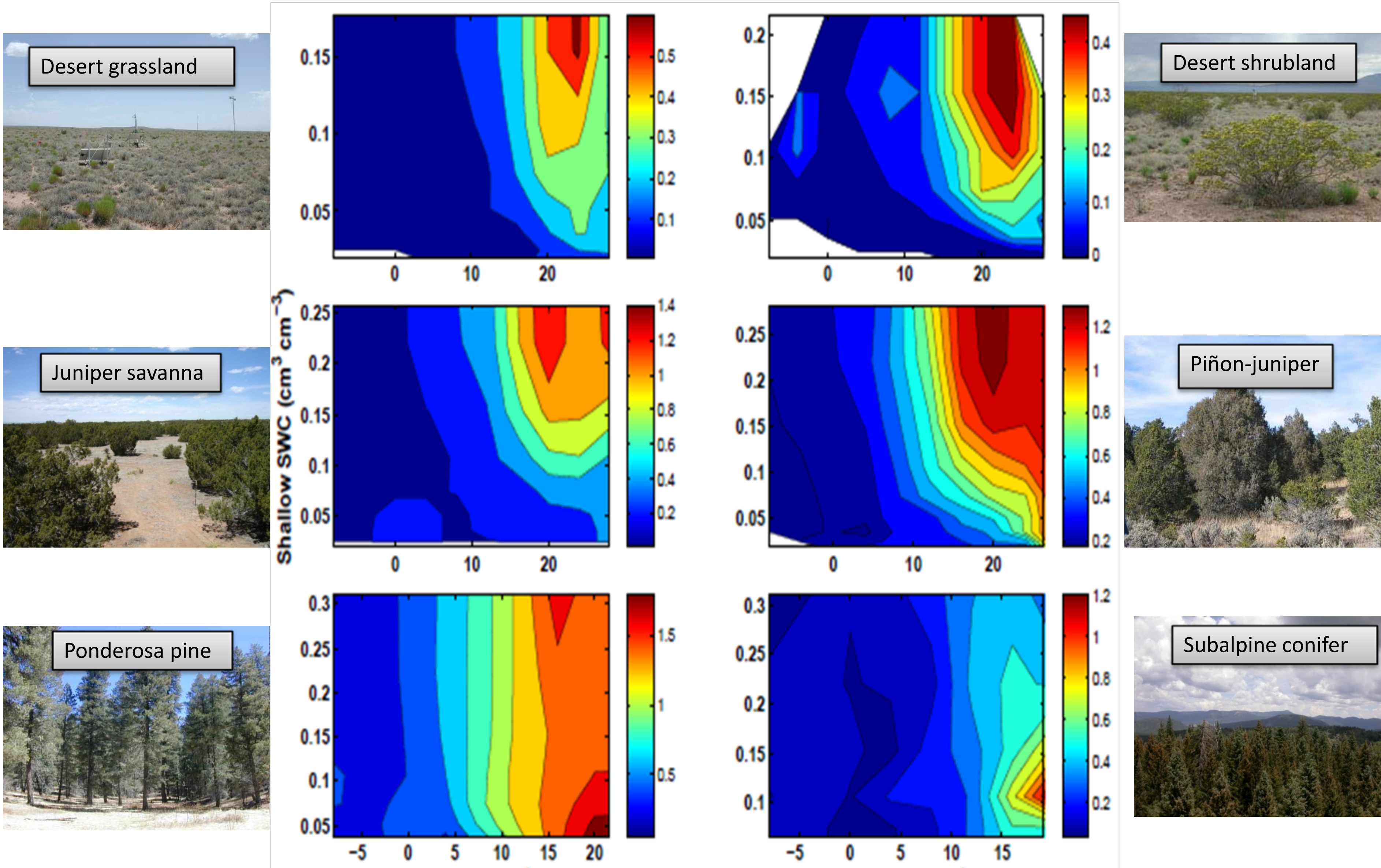


Response curves to temperature, soil water content



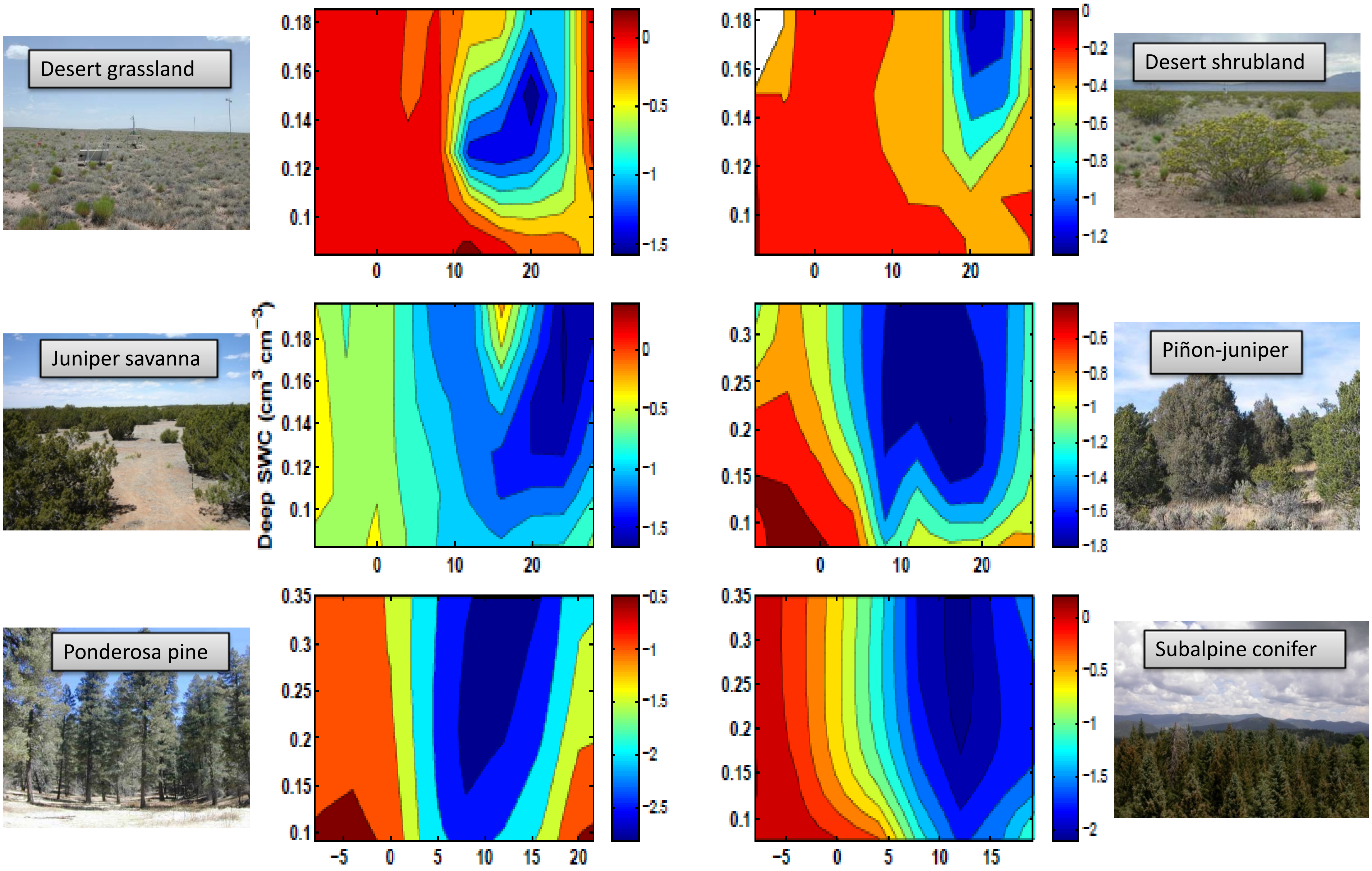
Anderson-Teixeira et al. (*GCB; 2011*)

Total nighttime ecosystem respiration rates (g C m^{-2} $night^{-1}$)



Mean night air temp (°C) Mean night air temp (°C)

Total daily C uptake (g C m^{-2} day^{-1})

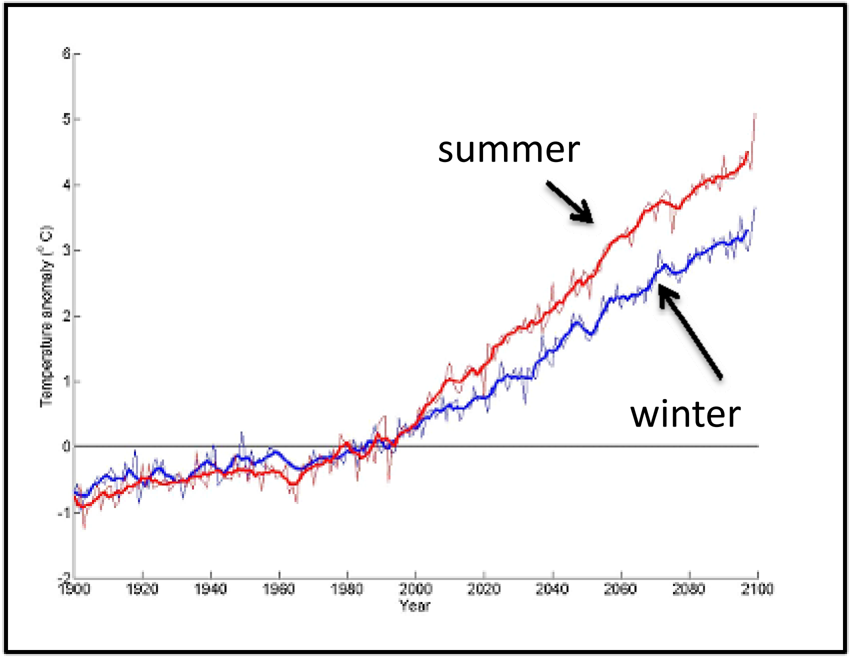


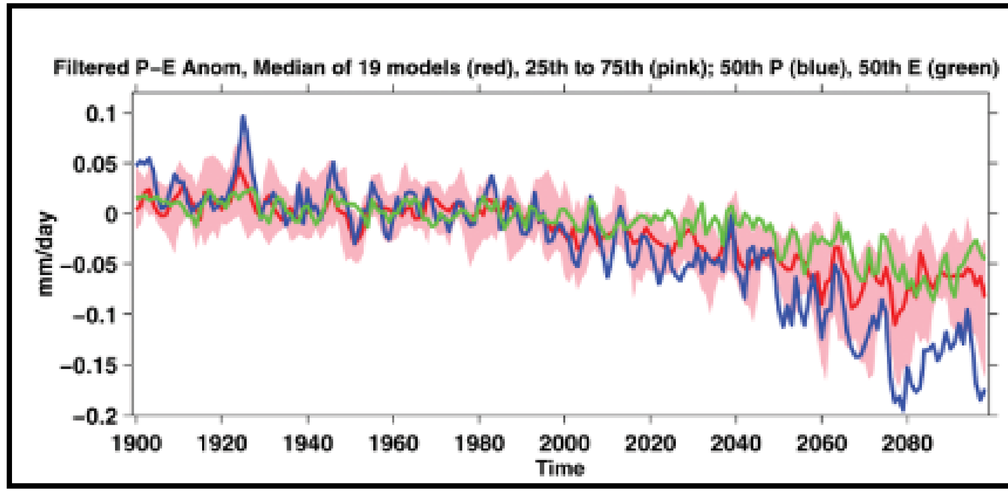
Mean day air temp (°C) Mean day air temp (°C)

Climate change in the SW

Temperature

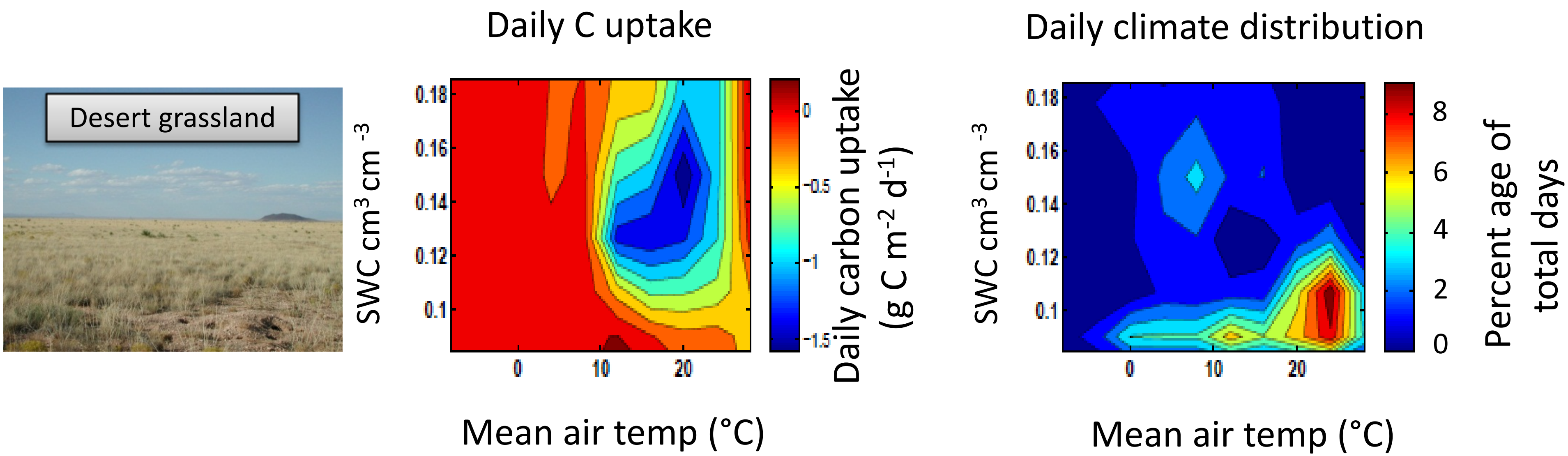
Precipitation

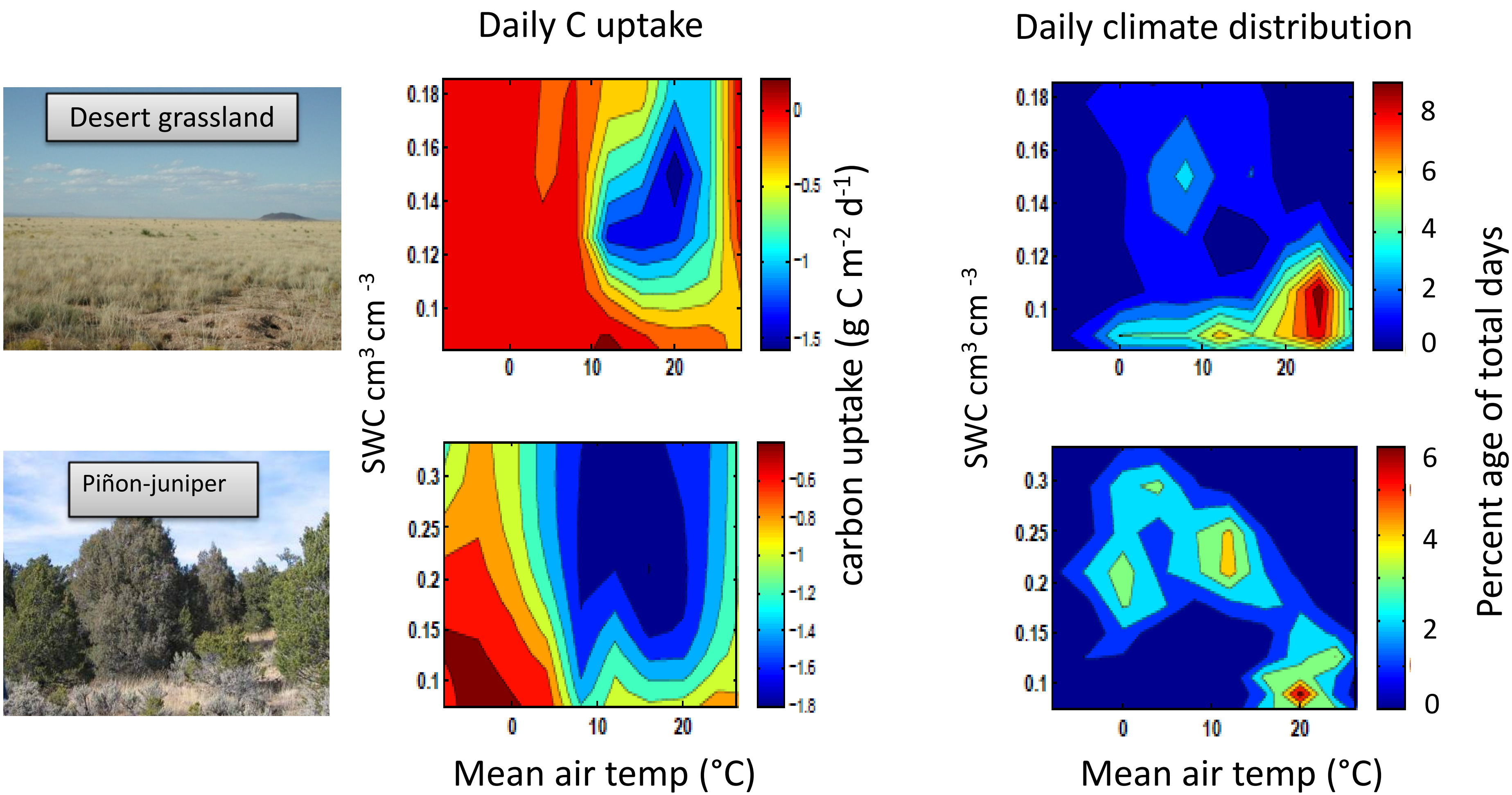




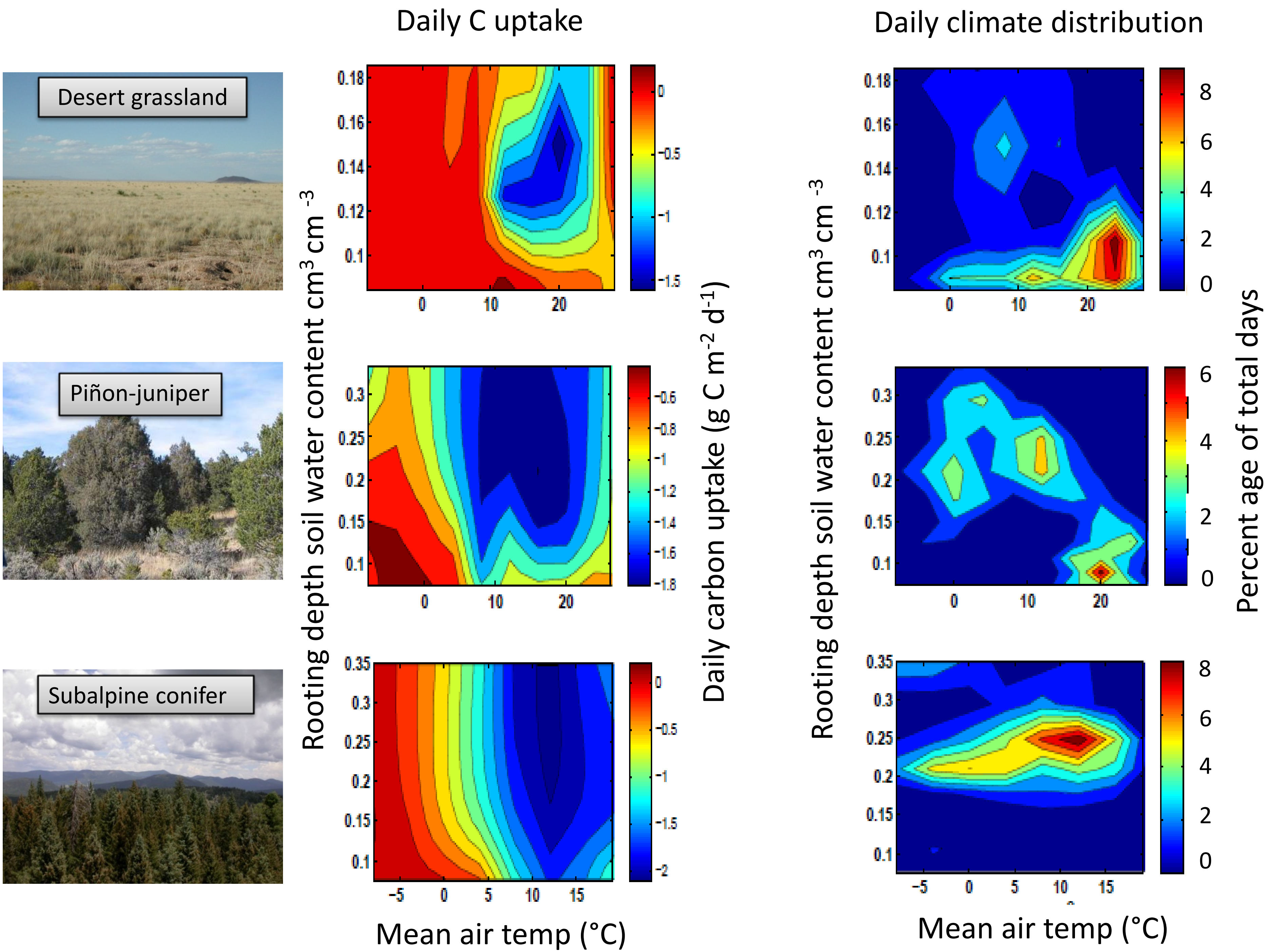
19 models used A1B emissions storyline
Seager et al., 2007

Predicted temperature increase of 3 - 4 C
18 models used A1B emissions storyline
Gutzler 2007

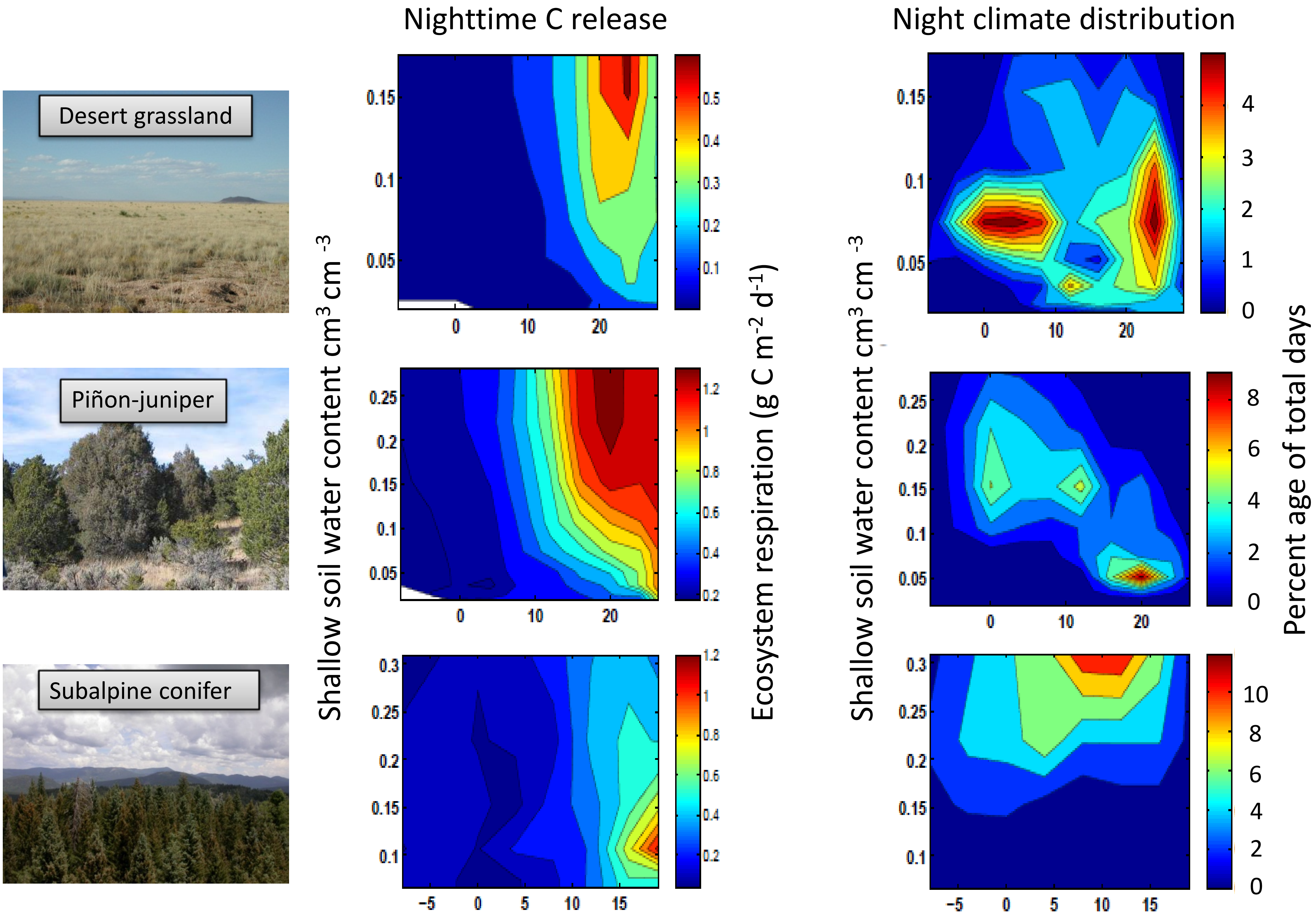

Desert grassland
Daily C uptake
SWC cm3 cm -3
0.18
0.16
0.14
0.12
0.1
0
10
20
Mean air temp (°C)
0
-0.5
-1
-1.5
Daily carbon uptake
(g C m-2 d-1)
Daily climate distribution
SWC cm3 cm -3
0.18
0.16
0.14
0.12
0.1
0
10
20
Mean air temp (°C)
8
6
4
2
0
Percent age of
total days



Daily C uptake
Daily climate distribution
Desert grassland
Piñon-juniper
SWC cm3 cm -3
carbon uptake (g C m-2 d-1)
Percent age of total days
Mean air temp (°C)
Mean air temp (°C)

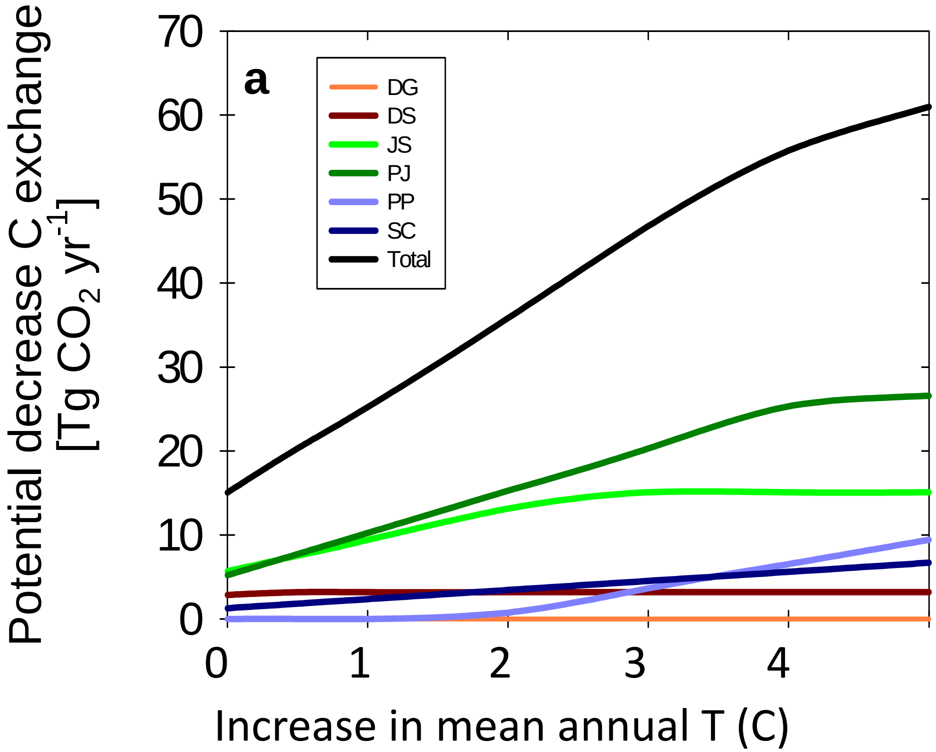


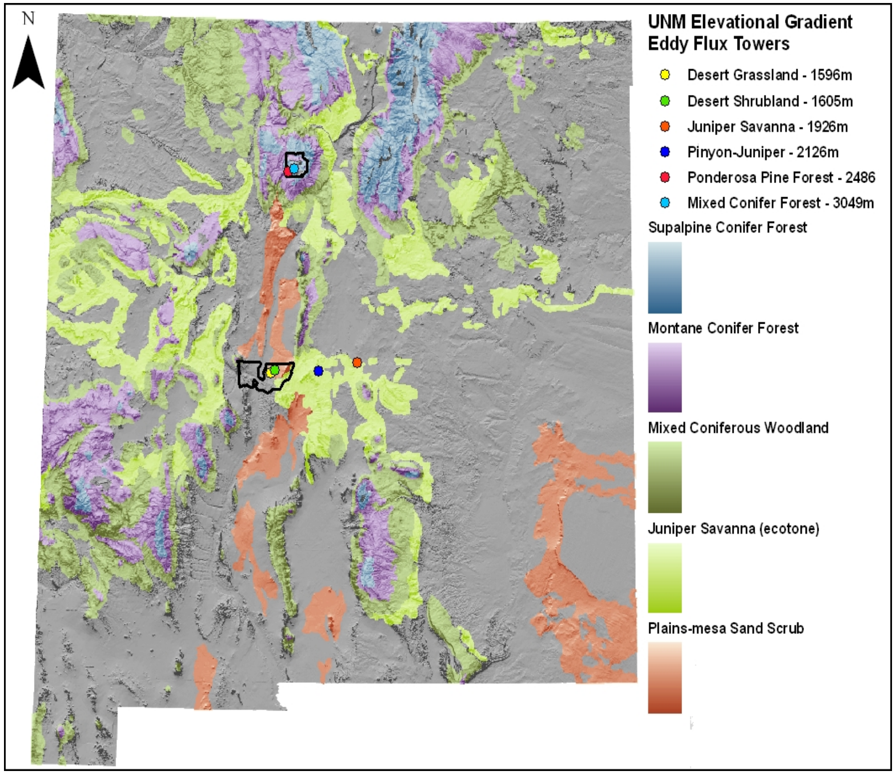
Daily C uptake
Daily climate distribution
Desert grassland
Piñon-juniper
Subalpine conifer
Rooting depth soil water content cm3 cm -3
Daily carbon uptake (g C m-2 d-1)
Percent age of total days
Mean air temp (°C)



Nighttime C release
Night climate distribution
Desert grassland
Piñon-juniper
Subalpine conifer
Shallow soil water content cm3 cm -3
Ecosystem respiration (g C m-2 d-1)
Percent age of total days

Predicted change to NM terrestrial ecosystem carbon balance as mean annual temperature (MAT) increases



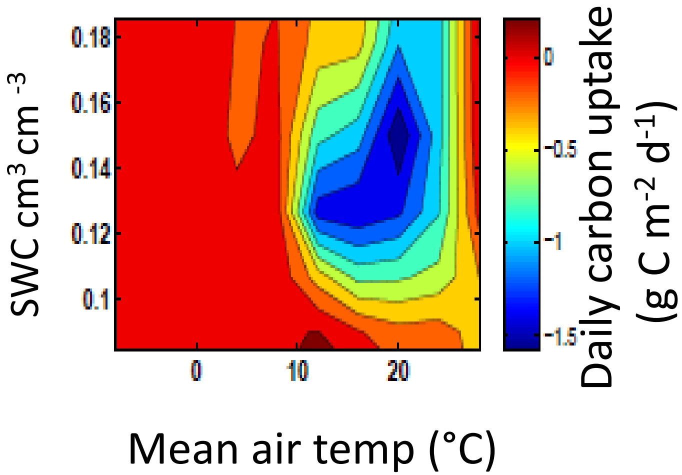


A 4°C increase in MAT could reduce annual C sequestration by ~56 Tg CO_2 y^{-1}

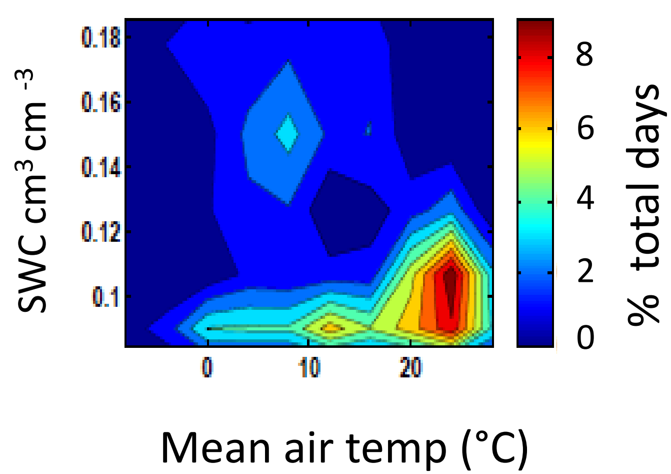
- 16% annual US residential emissions
- 8% annual US industrial emissions
- 3% of US transportation emissions

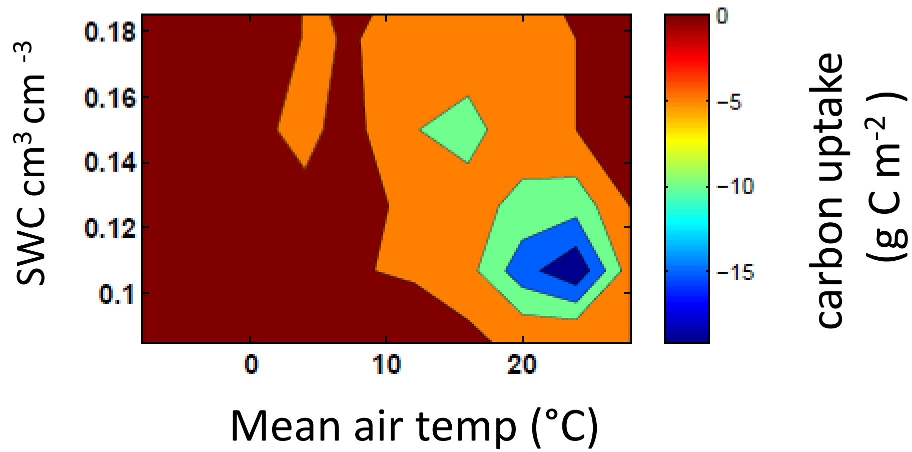
Anderson-Teixeira et al. (*GCB; 2011*)

Daily C uptake



Daily climate distribution

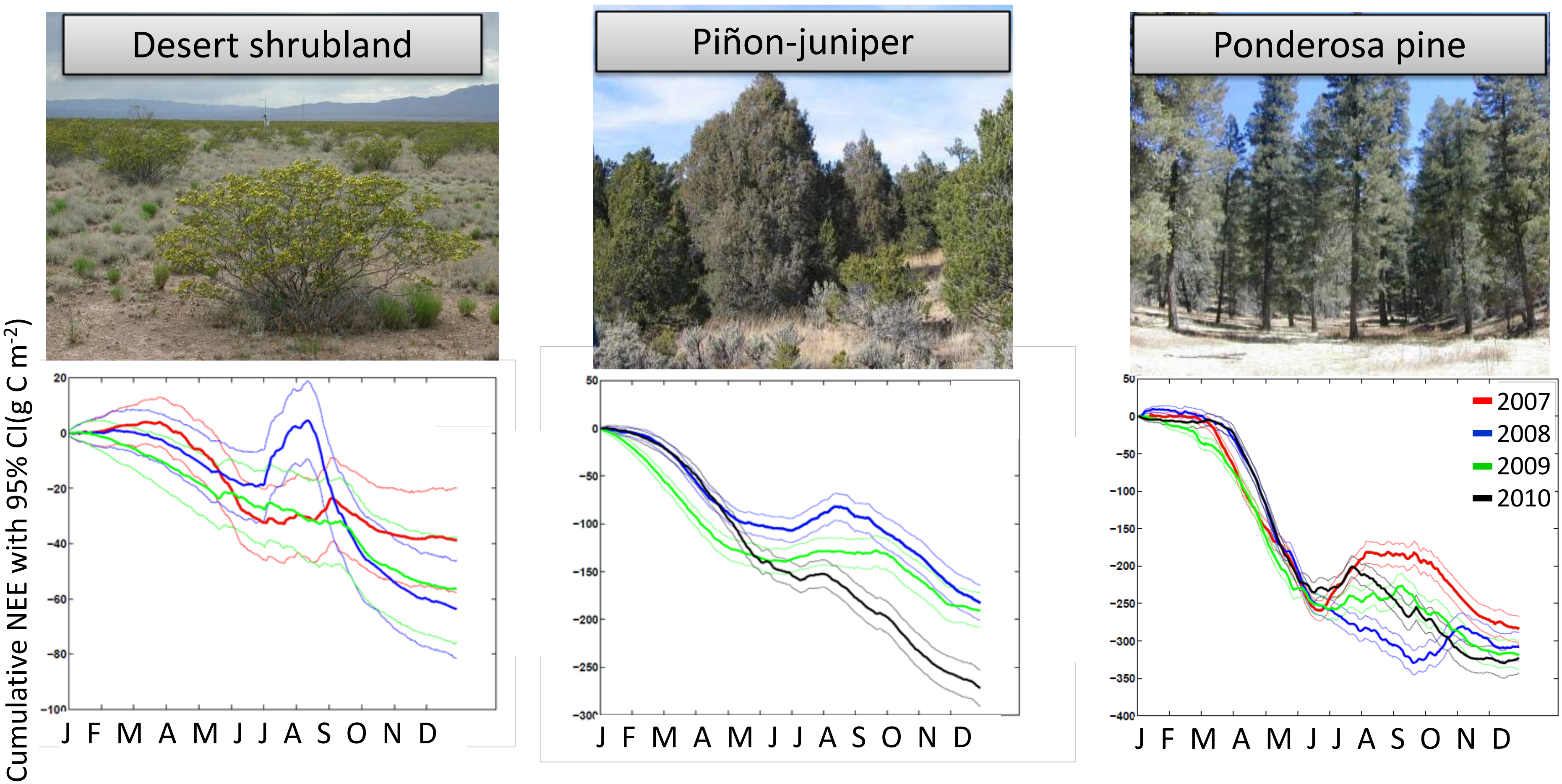




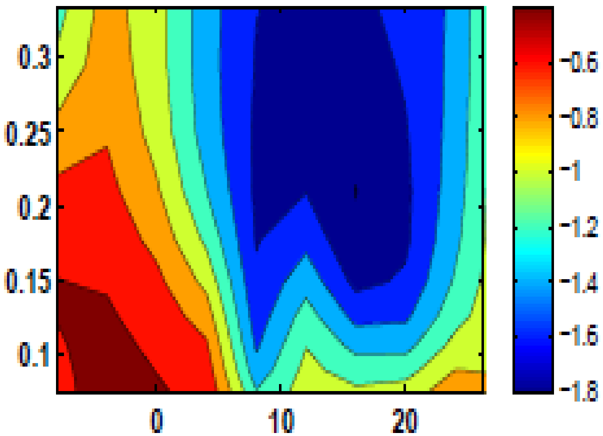
Importance of long term research

Long term continuous measurements of NEE will:

- ❑ Represent the full range of climate variability
- ❑ Measure the effects of disturbance on ecosystem function



Response surfaces should change with climate and disturbance



?

?

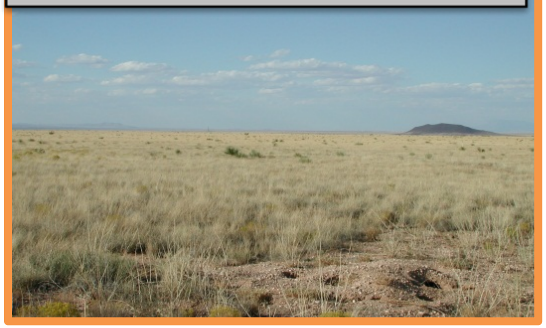
Change in:
- Temperature
- precipitation regime
- cloud cover
- etc.........

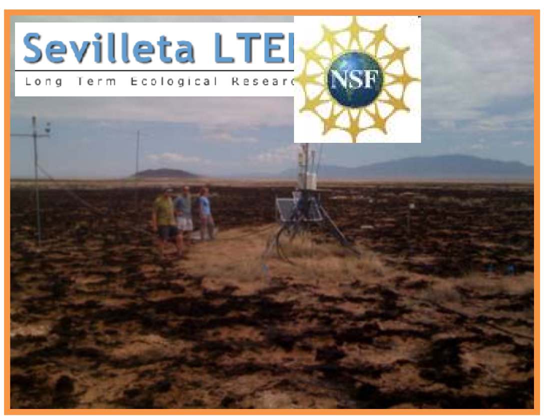
Extensive piñon mortality in N. NM in 2002
Photo credit: Dr. Craig Allen, USFS

Disturbance and long term research

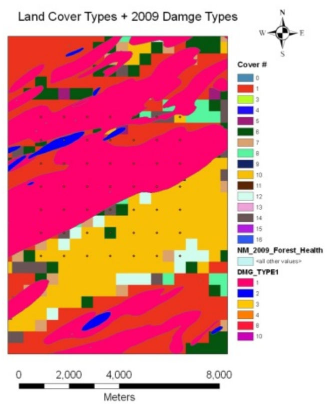
Fire

Desert grassland 1596 m

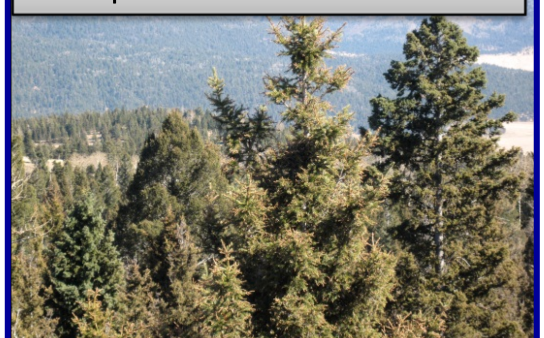




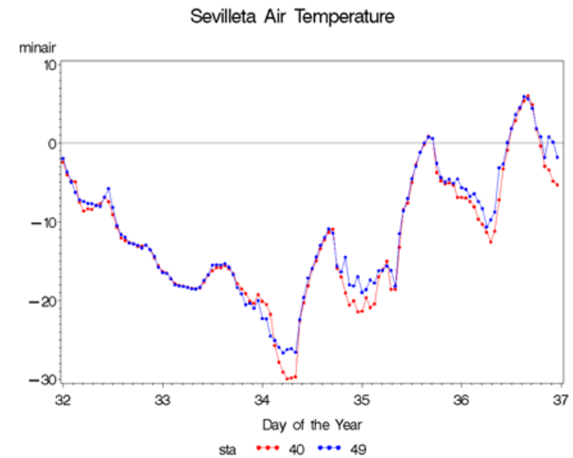
Spruce budworm



Subalpine conifer 3049 m



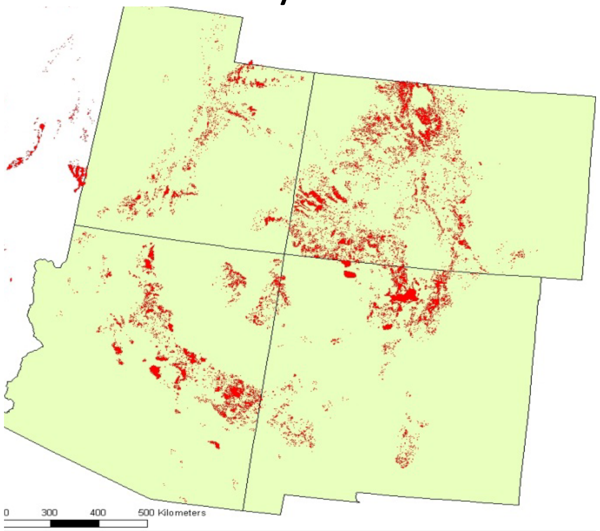
Extreme cold

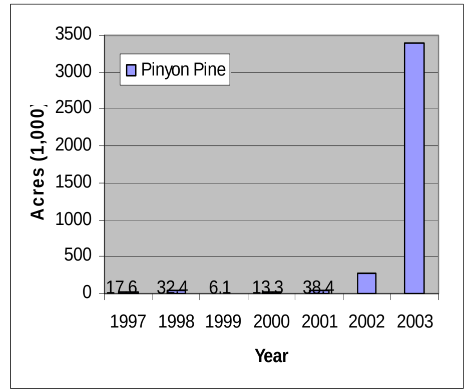


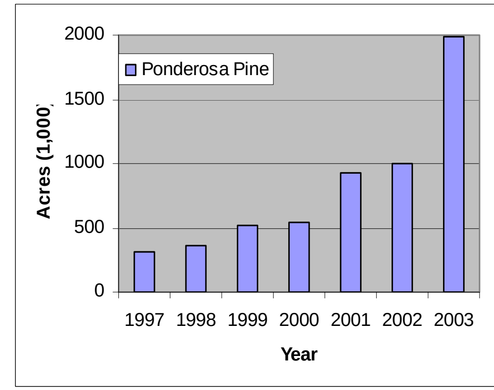
Desert shrubland 1605 m

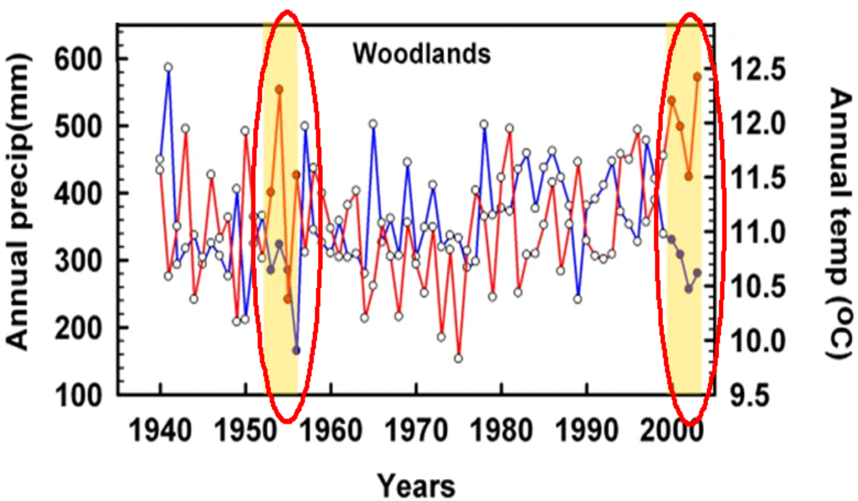
Piñon mortality in the SW US

Tree mortality in SW

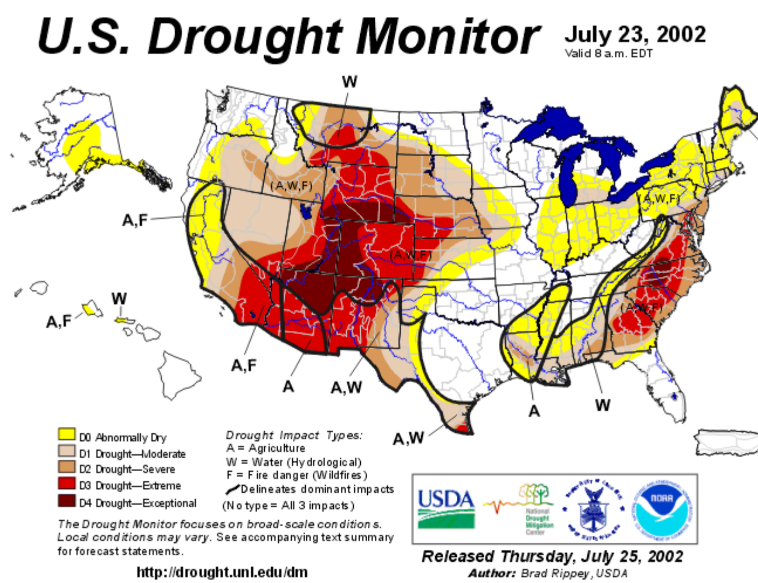




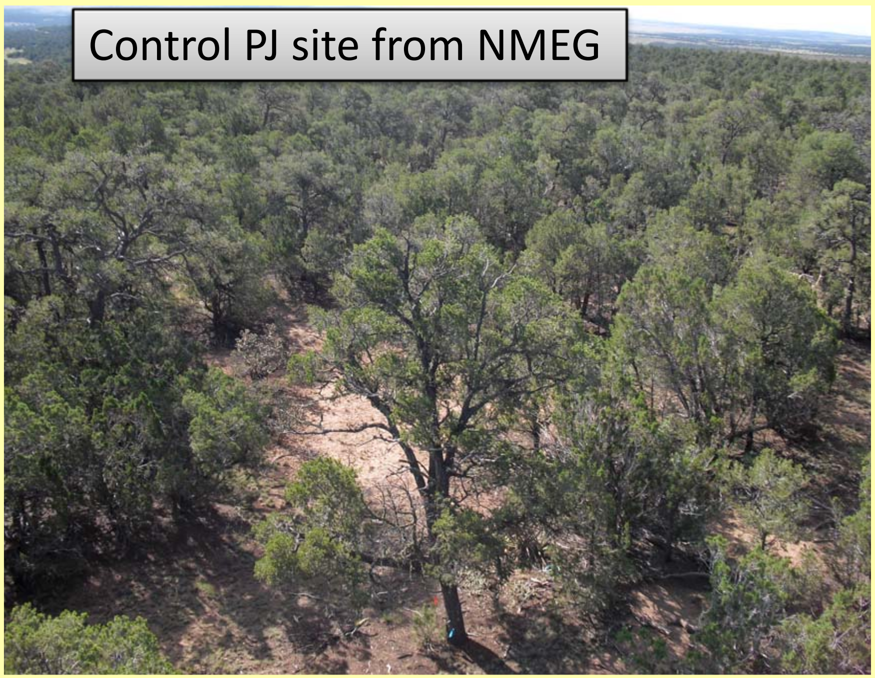




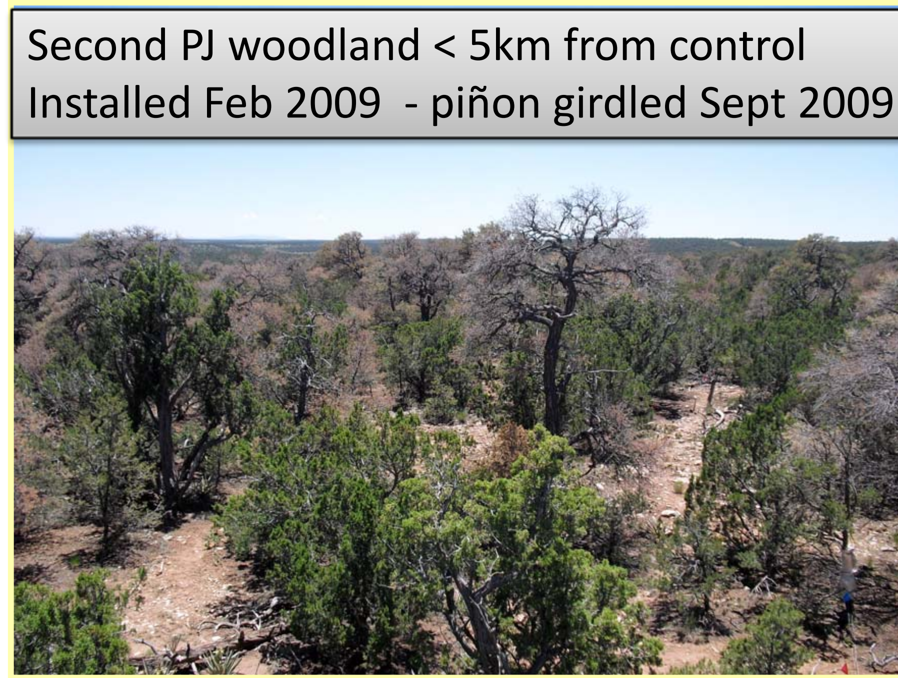
Breshears et al. 2005 PNAS



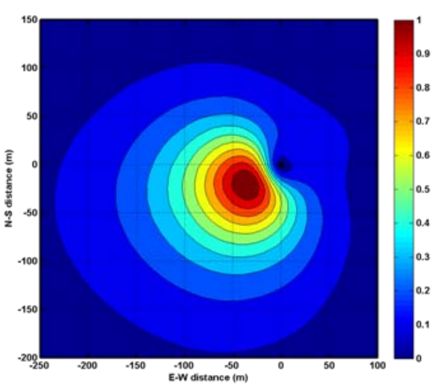
Large scale manipulation experiment

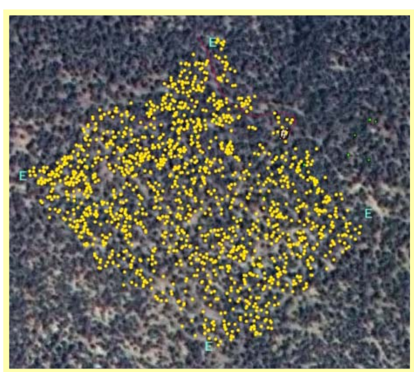


Control PJ site from NMEG

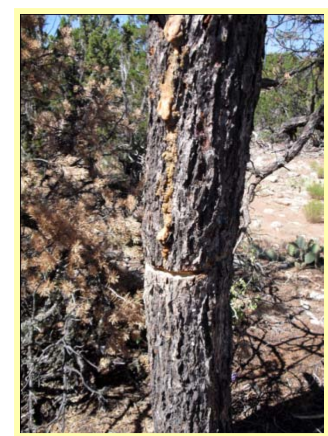


Second PJ woodland < 5km from control
Installed Feb 2009 - piñon girdled Sept 2009





300 m x 300 m



Overall Conclusions

1. NMEG valuable network for examining C dynamics in semi-arid ecosystems in the SW US

2. Spatial heterogeneity in SW should not be ignored. Semi-arid biomes vary distinctly in C sink strength and sensitivity to temperature and precipitation

3. We are likely to see a decrease in C sequestration throughout the region if temperature increases and precipitation decreases.

4. Long-term monitoring of these sites crucial to accurately predict how C dynamics will respond to changes in climate and/or disturbance

5. More complex ecosystem models required (currently using SIPNET, CLM)






Acknowledgements

- **People**

  <u>Litvak Lab</u>

  Andy Fox, Krista Anderson-Teixera, Leo Stoscheck, Dan Krofcheck, John DeLong, Daniel Brese, Andy Hawk, Sarah Hicks, Alek Chakroff, Shaila Cockar, Alexandra Reinwald (REU), Dena Smith, Emma Elliot Smith, Cecilia Payan, Scott Rossol, Tallie Segel

  <u>UNM</u>

  Renee Brown, Don Natvig, Cliff Dahm, Will Pockman, Scott Collins, James Cleverly, James Thibault, Stephen Teet, Barbara Kimball, Jim Gosz

  <u>SAHRA, CZO, U of Arizona, Valles Caldera sites</u>

  Paul Brooks, Scott Gilmore, John Petti, Jon Chorover, Peter Troch

  <u>Sevilleta Bigfoot sites</u>

  Shirley Kurc and Eric Small

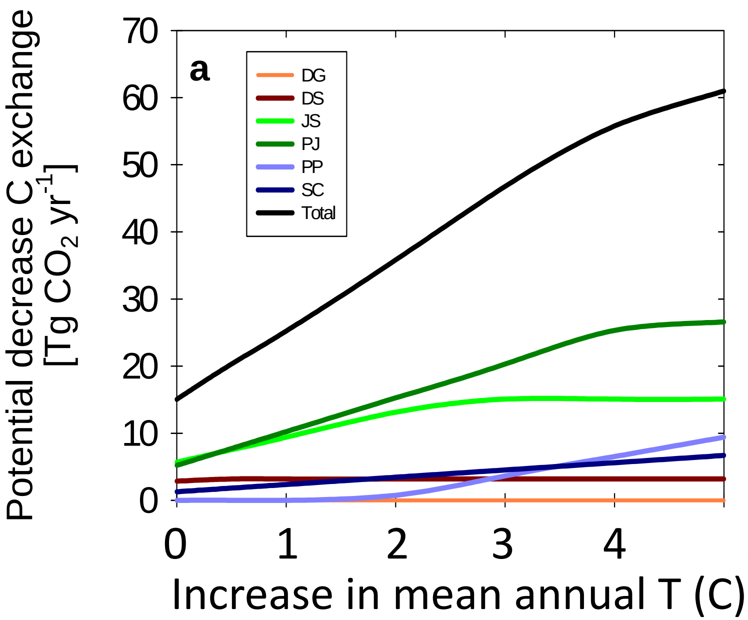
  <u>Land owners/managers</u>

  Seven Up Seven Down Ranch, Heritage Land Institute, Sevilleta LTER, Valles Caldera (Bob Parmenter)

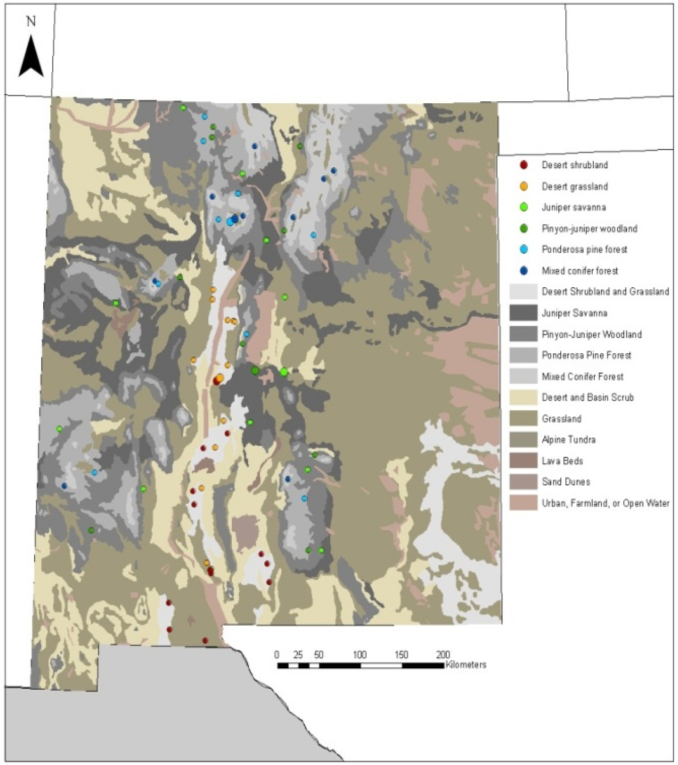
- **Funding sources**

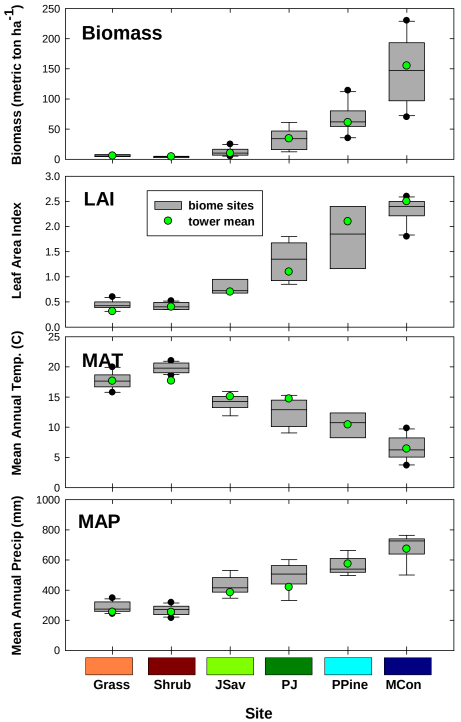
UNM BIOLOGY
THE UNIVERSITY of NEW MEXICO
Sevilleta LTER
Long Term Ecological Research
SAHRA
CZO
NSF
EPSCoR New Mexico
EPSCoR DEPARTMENT of ENERGY

Predicted change to NM terrestrial ecosystem carbon balance as mean annual temperature (MAT) increases



Biomes account for 57% of area in NM





A 4°C increase in MAT would reduce C sequestration by ~56 Tg CO_2 y^{-1}

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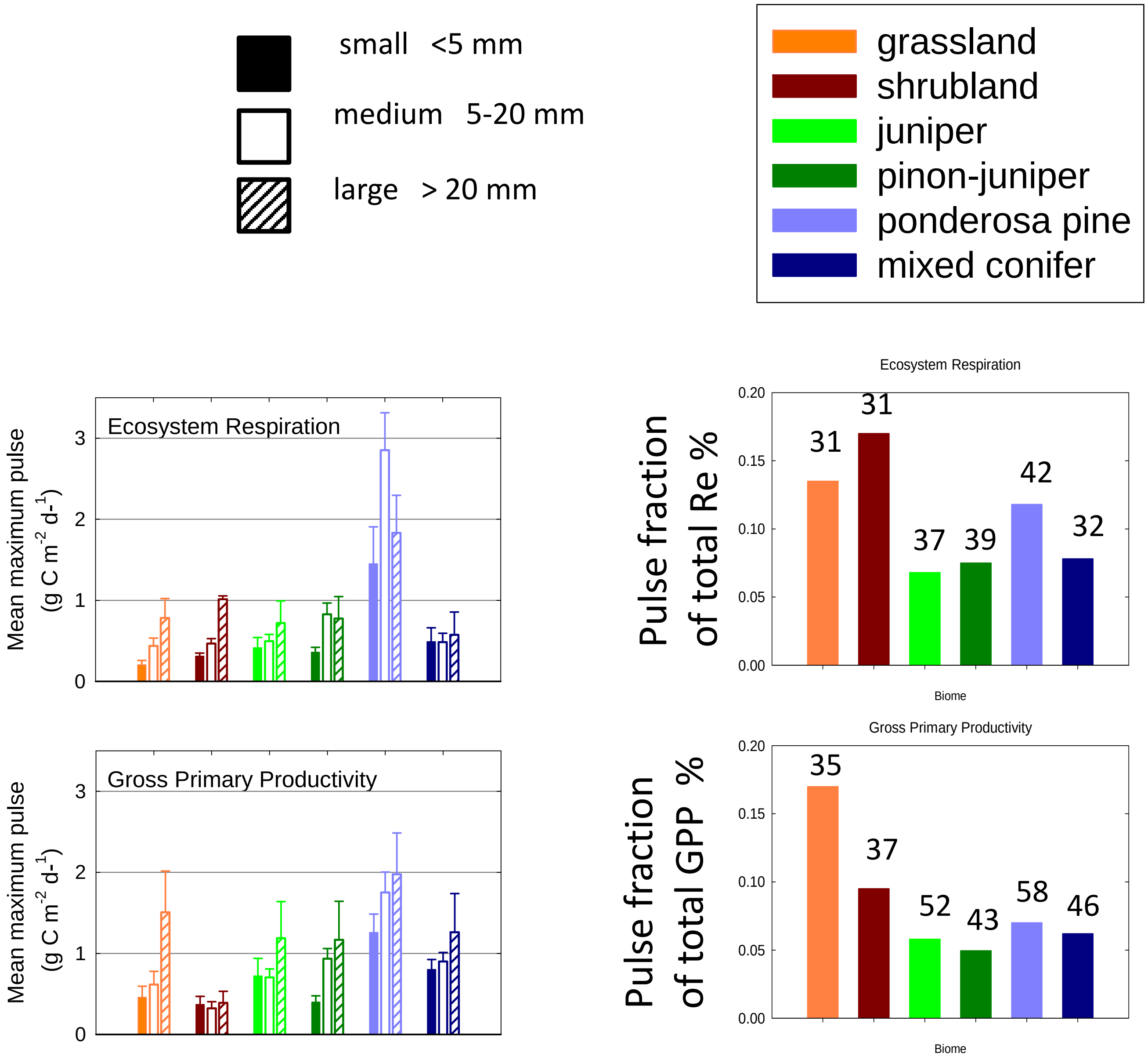
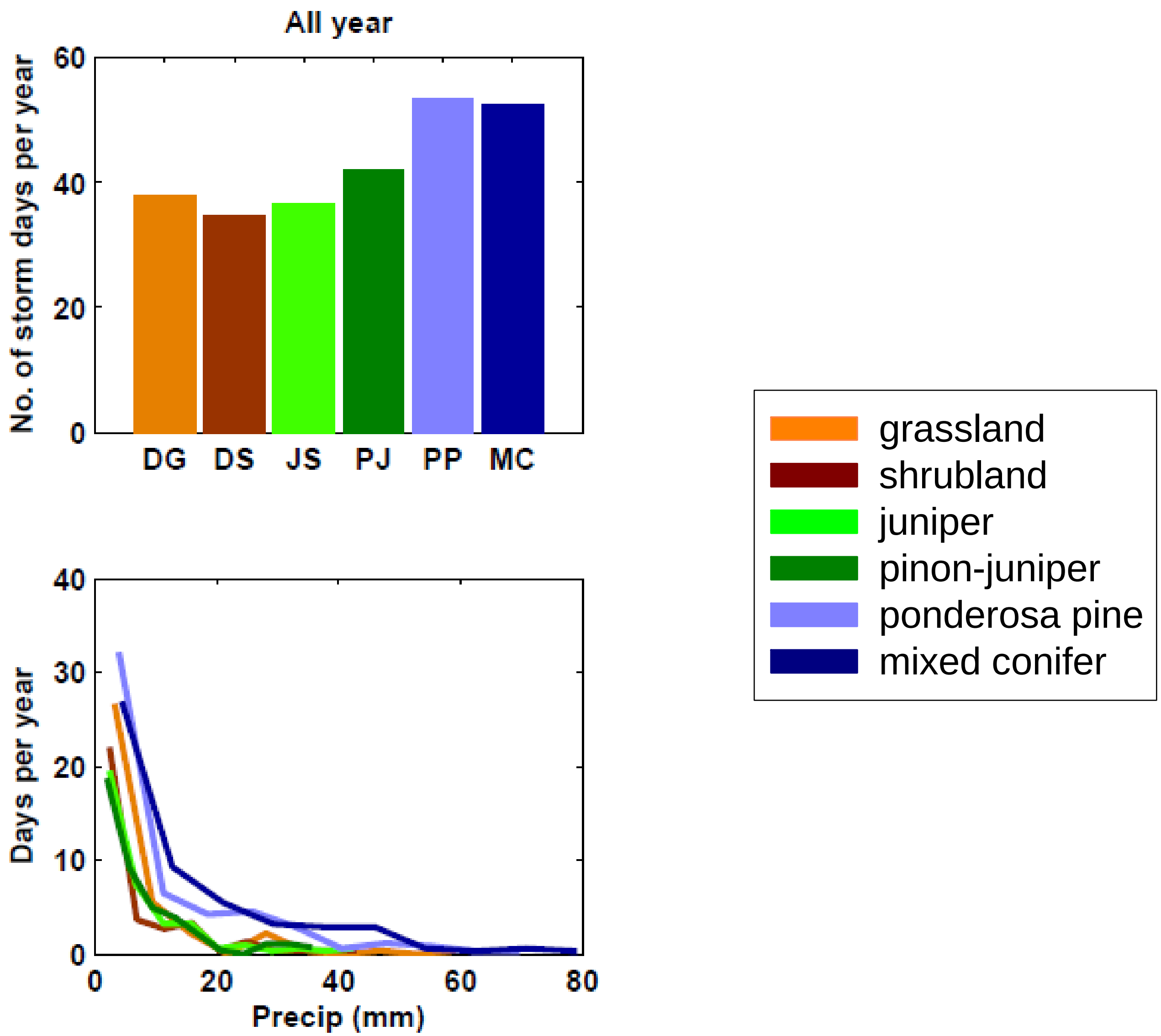
- 3% of transportation emissions

Anderson-Teixeira et al. (*GCB; 2011*)


small <5 mm
medium 5-20 mm
large > 20 mm
grassland
shrubland
juniper
pinon-juniper
ponderosa pine
mixed conifer
Ecosystem Respiration
Mean maximum pulse
(g C m-2 d-1)
0
1
2
3
Gross Primary Productivity
Mean maximum pulse
(g C m-2 d-1)
0
1
2
3
Ecosystem Respiration
Pulse fraction
of total Re %
0.00
0.05
0.10
0.15
0.20
31
31
37
39
42
32
Biome
Gross Primary Productivity
Pulse fraction
of total GPP %
0.00
0.05
0.10
0.15
0.20
35
37
52
43
58
46
Biome


All year
No. of storm days per year
60
40
20
0
DG
DS
JS
PJ
PP
MC
Days per year
40
30
20
10
0
0
20
40
60
80
Precip (mm)
grassland
shrubland
juniper
pinon-juniper
ponderosa pine
mixed conifer