Impacts of beetle-kill and wildland fire on regional water and energy cycles, and climate in western North America

Fei Chen, Michael Barlage, Christine Wiedinmyer, Ying Zhang, NCAR

Jeffrey Hicke and Arjan Meddens, University of Idaho

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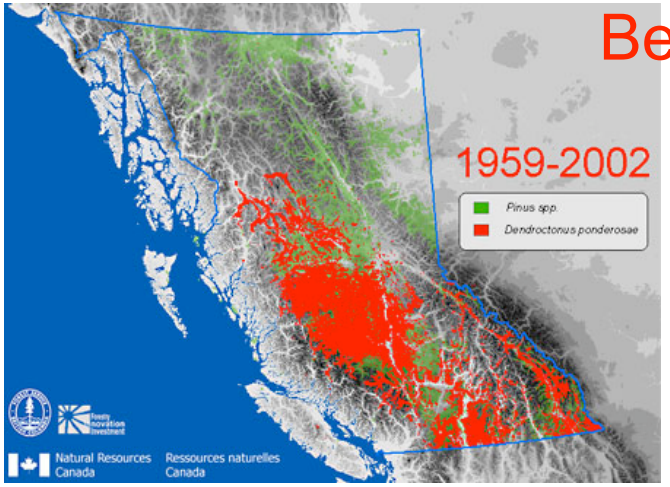
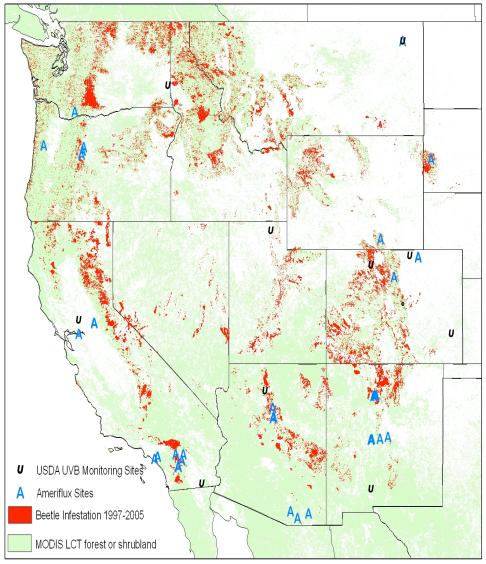
Continental-scale Forest Natural Disturbances

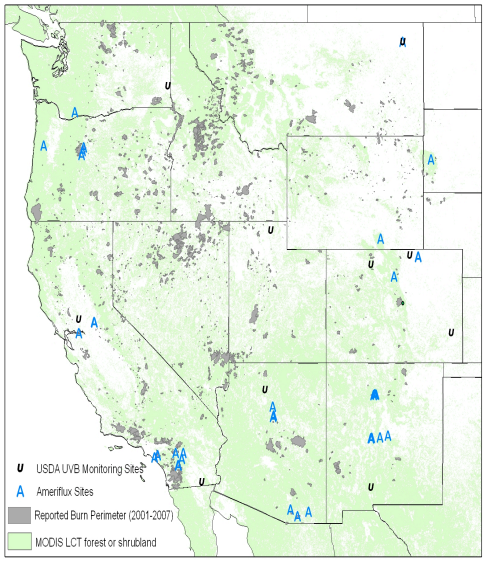
Warmer winter and drought



Beetle infestation

Forest burned area





Regions of identified beetle infestation from aerial surveys from 1997-2005 (in red in the left panel) and burned area perimeters reported to the USGS from 2001-2007 (in gray in the right panel) for the western U.S

Effects of beetle-kill

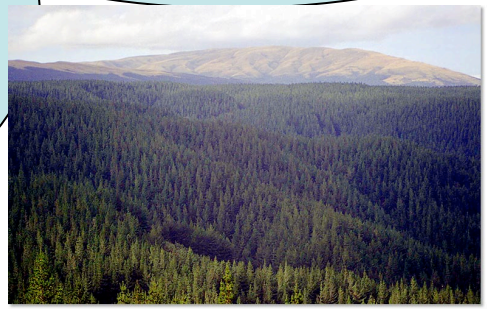
- Increase surface heterogeneity/diversity
- Reduction of LAI, interception, carbon fluxes, transpiration by 50% 3 weeks after infestation
- Increase soil moisture and temperature
- Increase snow depth
- Carbon and Nitrogen cycles decoupling two years after infestation
- Higher nitrate in stream water (Fraser watersheds)

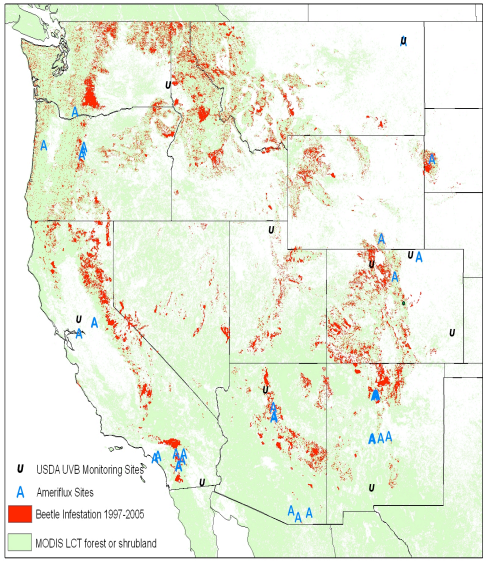
Multi-scale interactions among biosphere, hydrosphere, and atmosphere

Regional effects:
Clouds and precipitation
Climate variability
Flood and drought

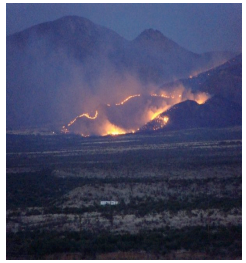
Watershed effects:
Streamflow
Water quality
Atmospheric boundary layer

Local effects:
Biological particles and VOC emissions
Latent and sensible heat
Soil moisture and snow
Carbon and nitrogen emission and deposition





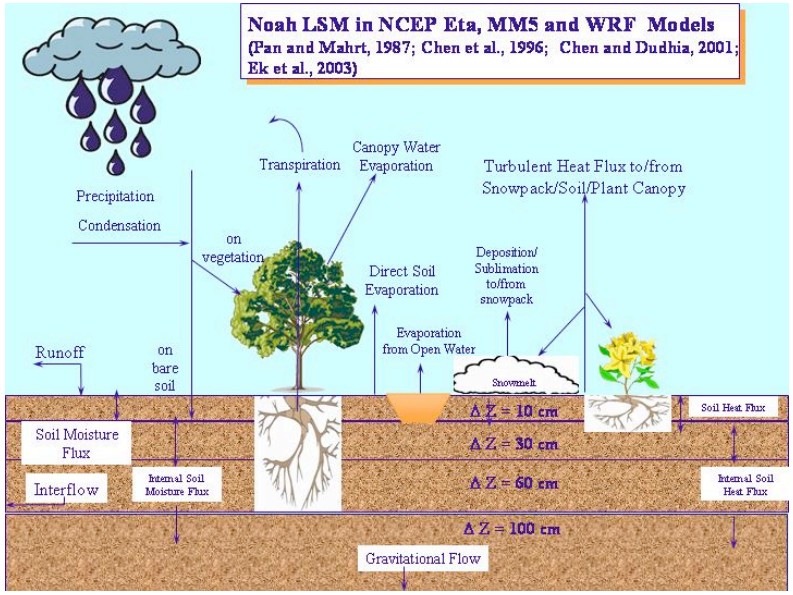
Insect outbreaks



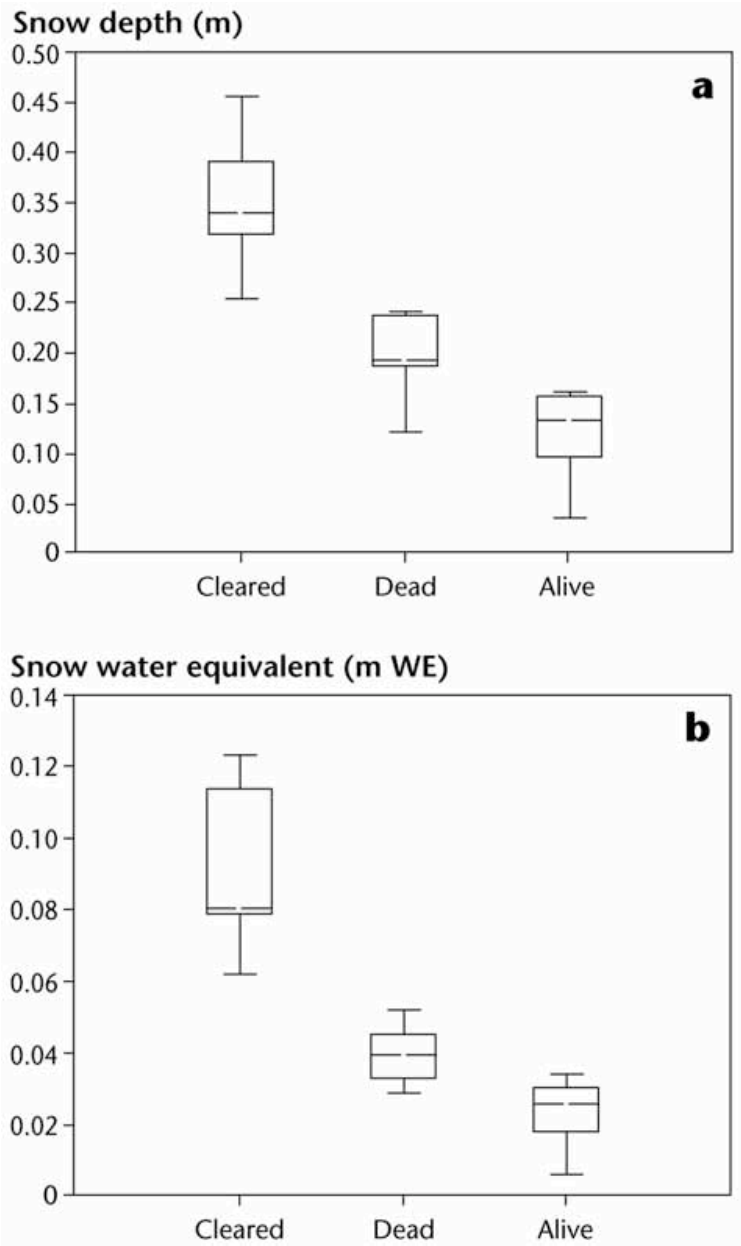
Fire

Our approach
Focus on biogeophysical effects

- Local and watershed scale: produce 10-year (2000-2010) reanalysis
  - using 1-km uncoupled High Resolution Land Data Assimilation system (HRLDAS) based on the Noah land surface model (LSM).
  - Examine surface fluxes, soil moisture, snow, runoff with reanalysis with and without disturbed forests



- Regional-continental scale: conduct high-resolution WRF/Noah LSM regional climate simulations for selected summer and winter months
  - Analyze precipitation and interannual climate variability



MPB reduce snow ablation and increase ground snow accumulation

Example for Northern British Columbia 2005-2006 data

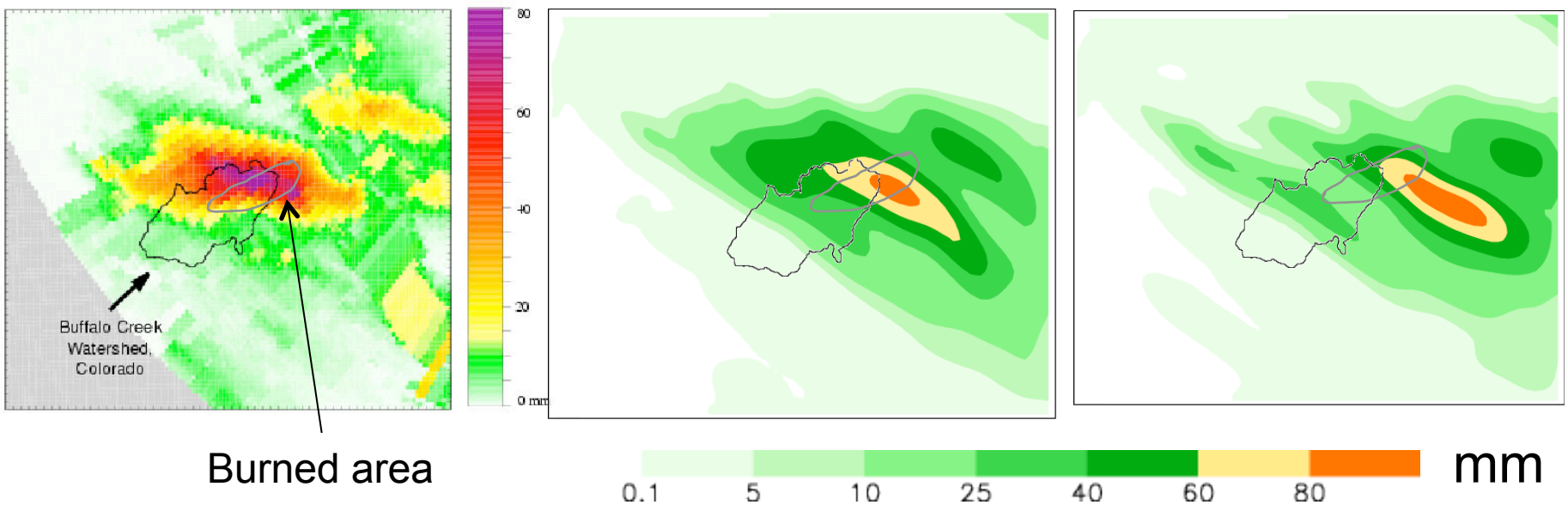
Boon, 2007, *BC Journal of Ecosystems and Management.*

Burned area enhance precipitin and result in 1996 flash flood in Buffalo Creek watershed, CO

S-Pol Radar Analysis

MM5 4-h (1700-2100 MST) rainfall with burned area

MM5 4-h (1700-2100 MST) rainfall without burned area



Burned area simulation produced 2-3 times more rain in the Buffalo Creek Watershed

Chen et al., 2001, *J. Atmos. Sci.*

Our approach (conti.)
Focus on biogeophysical effects

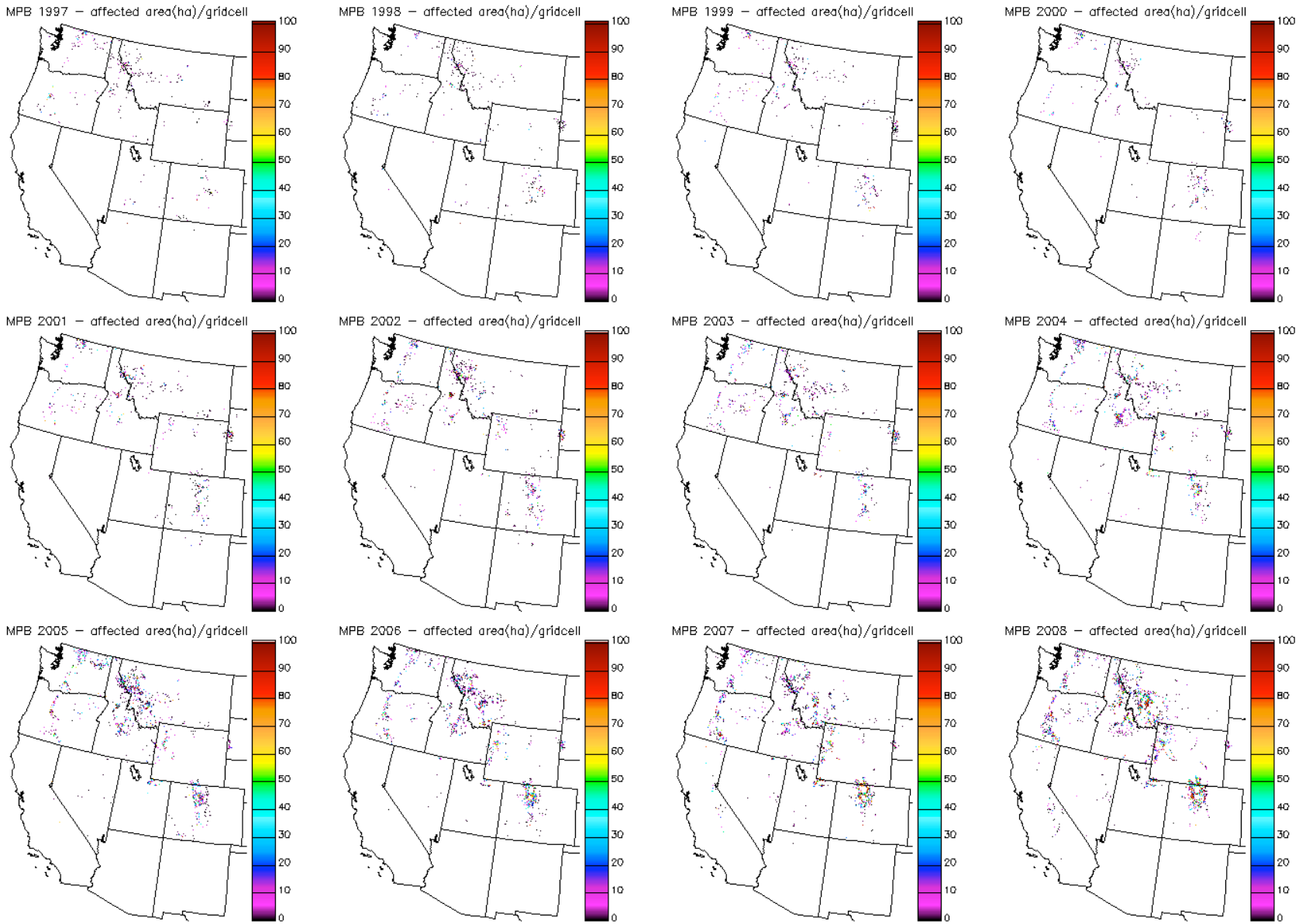
- Consolidate in-situ, air survey, and remote-sensing data to construct trajectories of MPB and fire outbreak

- Improve Noah LSM to represent the MPB and fire disturbances

Beetle-kill products

- Aerial survey: ADS (aerial detection survey)
  - Degree of beetle-kill (US+Canda)
- MODIS 500-m products:
  - MPB outbreak
  - Vegetation parameters
    - LAI
    - Green vegetation fraction
    - Albedo, emissivity

Constructing beetle-kill trajectory (1997-2008)



1 gridcell = 100ha (or 1km^2)

Impacts of beetle-kill on LAI and GPP

Sites in North Central Colorado

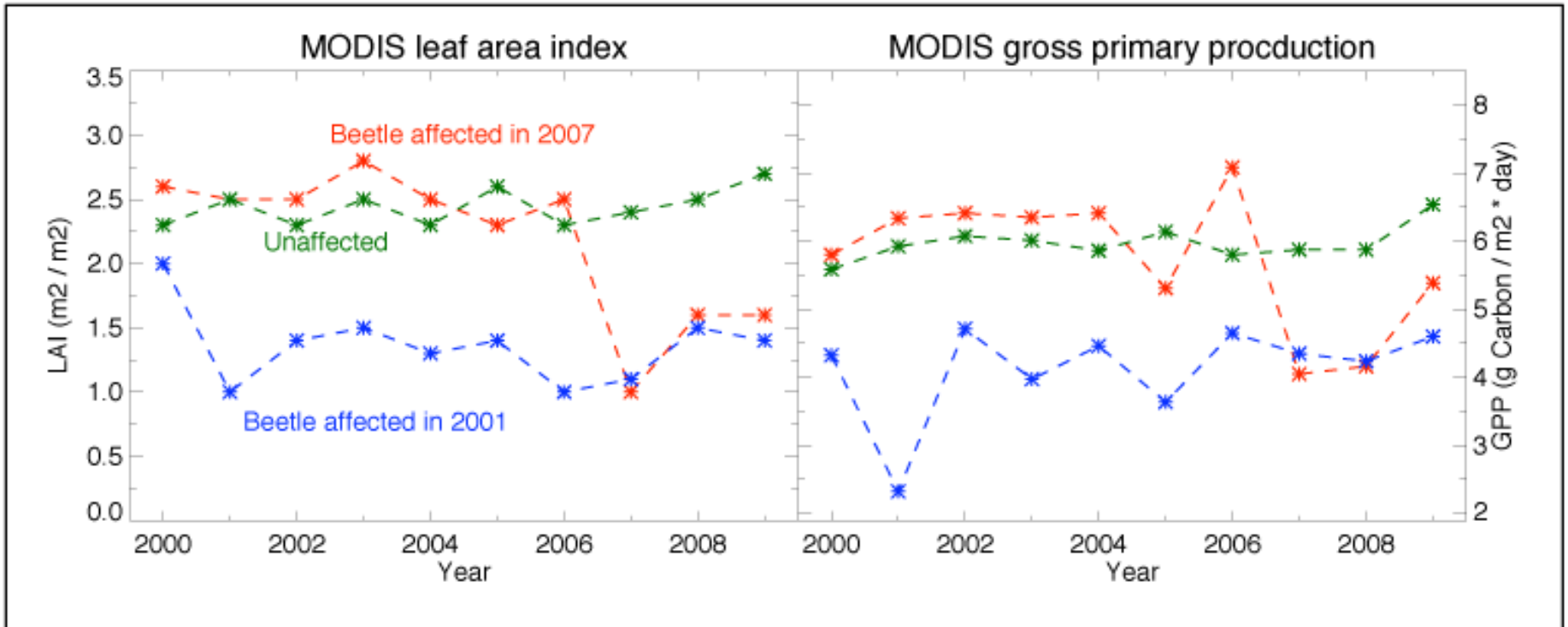


Figure 5: MODIS time series of (a) leaf area index and (b) gross primary production. The green line corresponds to an unaffected pixel location; the red line to a 2007 beetle-affected location and the blue line the a 2001 beetle-affected location.

Meddens and Hicke, 2009, AGU

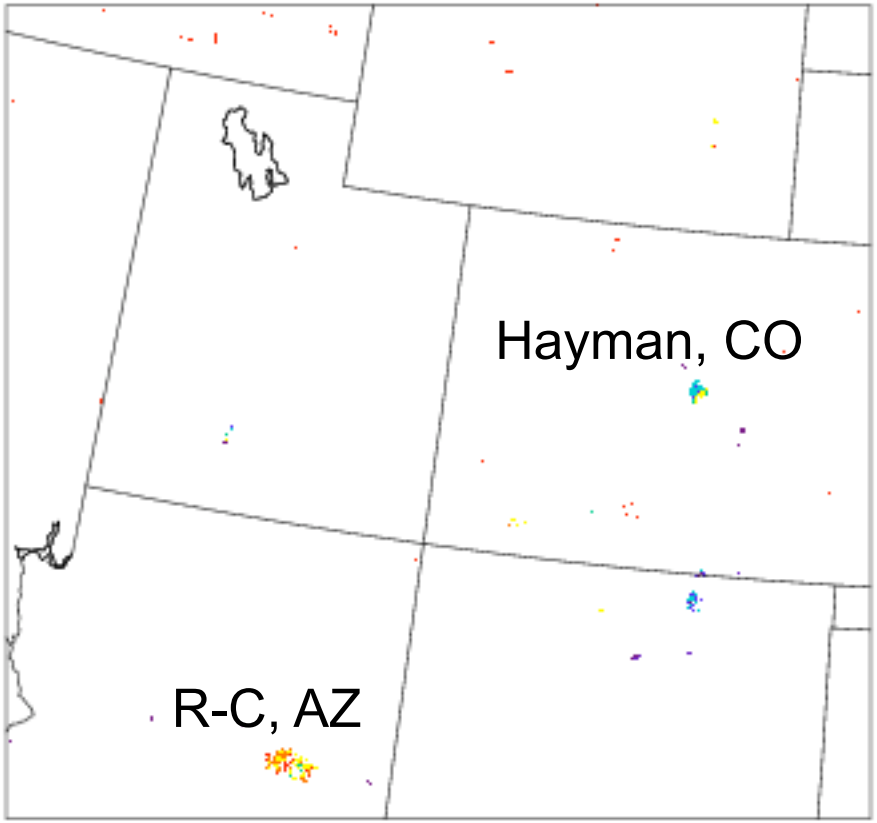
Burned area products

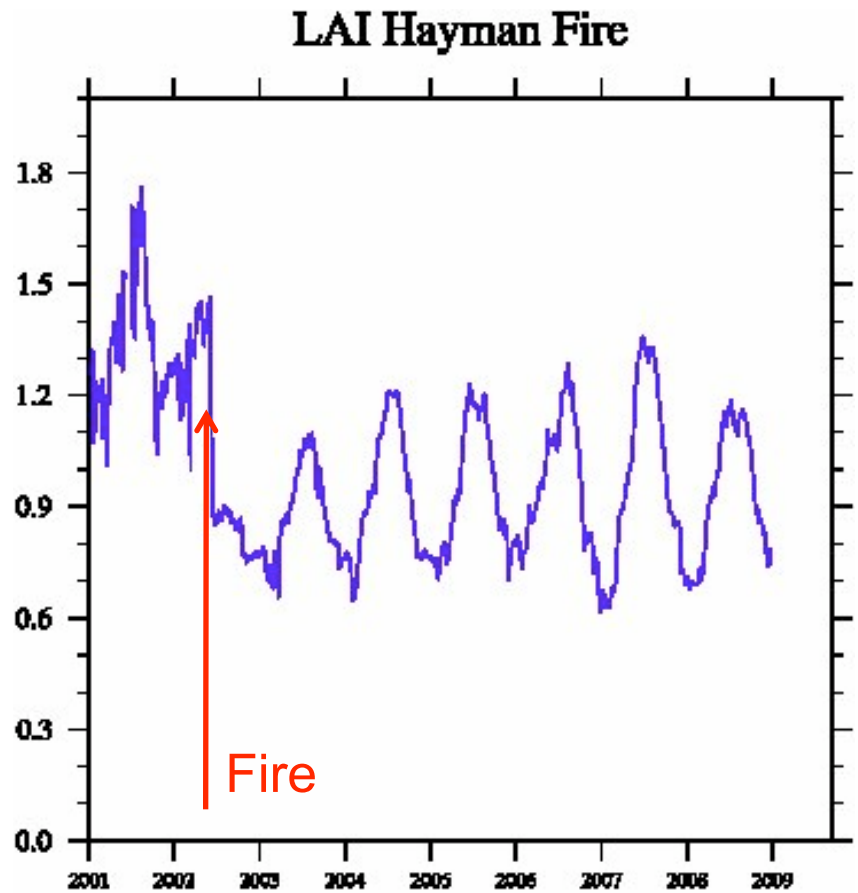
- MTBS (Monitoring Trends in Burn Severity) product
  - Federal agency aggregated into the Incident Command System database (ICS 209). Maintained by the National Interagency Fire Center (NIFC) in Boise, ID.
  - Fire Severity and Perimeter Mapping: > 8 acres.

- MODIS (MCD45A1):
  - Raw data - 500m Julian day of burn
  - Convert raw tile data to WRF/WPS intermediate file format - binary geographic projection 0.005°

MODIS in WRF: Colorado Hayman - started 8 Jun, controlled 18 Jul
Arizona Rodeo-Chediski - started 18 Jun, controlled 7 Jul.

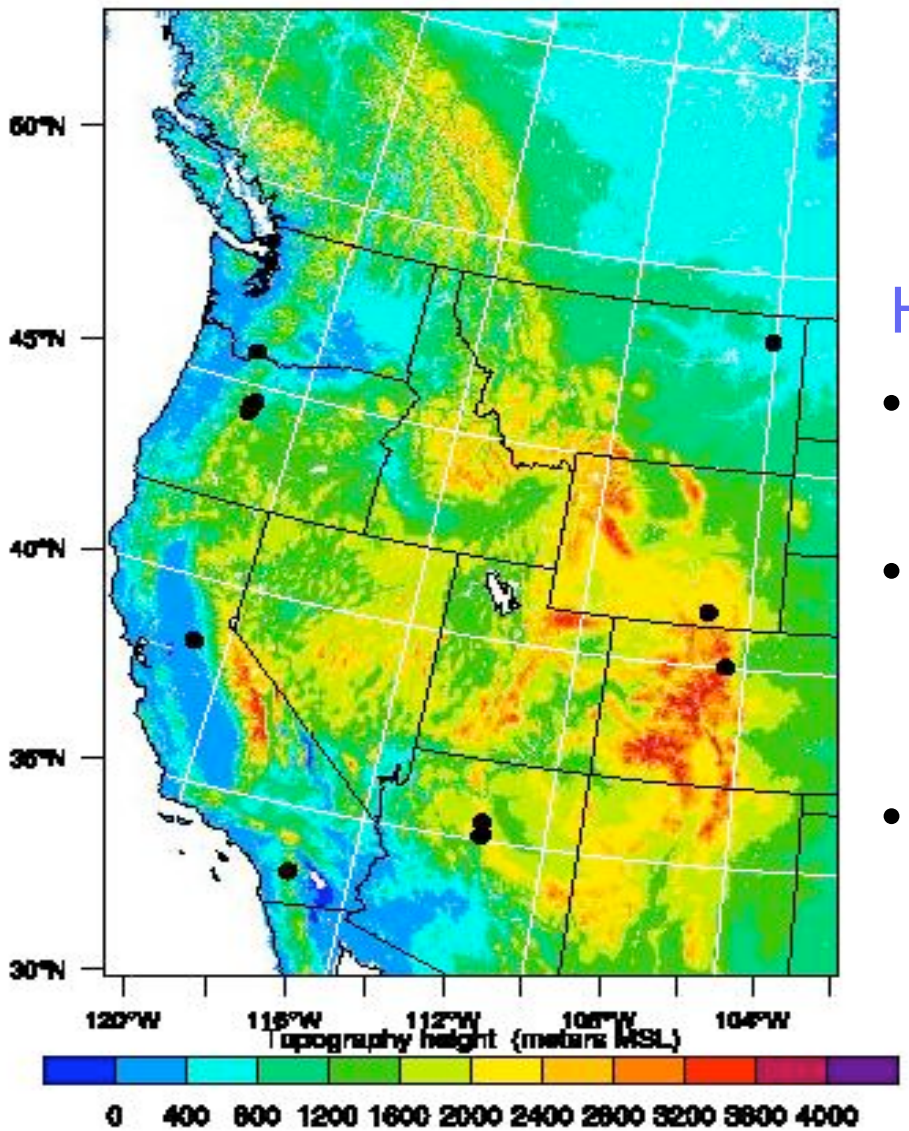
All 2002 burn areas





1-km MODIS averaged for 353 km^2

High-resolution land data assimilation (HRLDAS)
10-year 1-km modeling domain

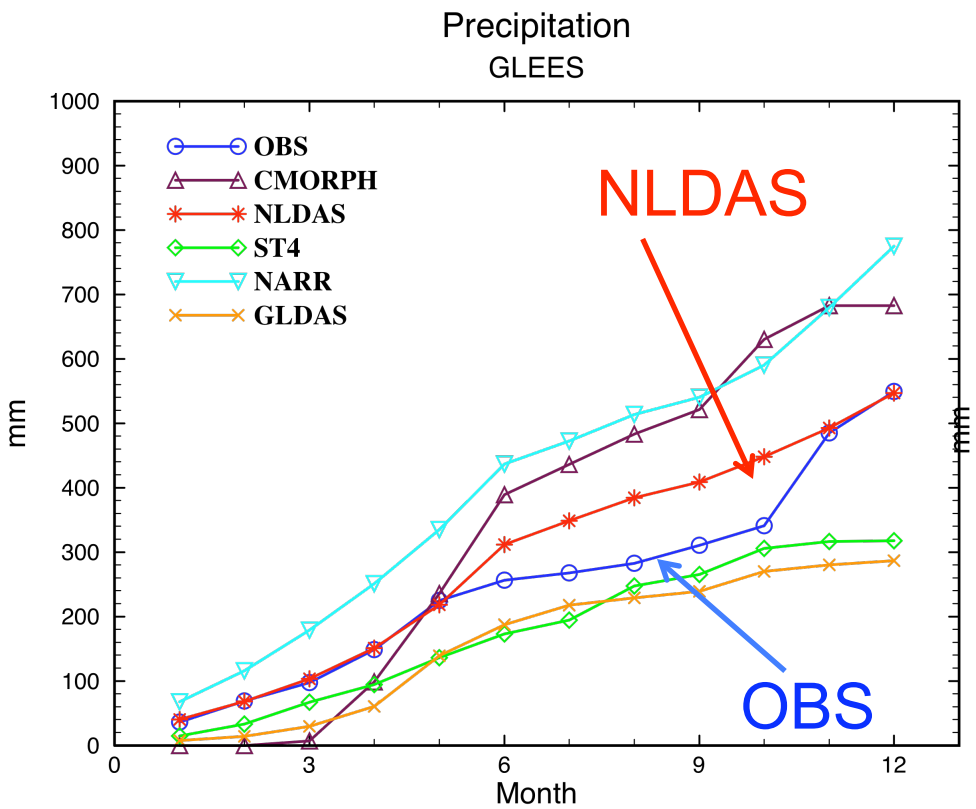


Terrain height (m)
Dots are AmeriFlux sites

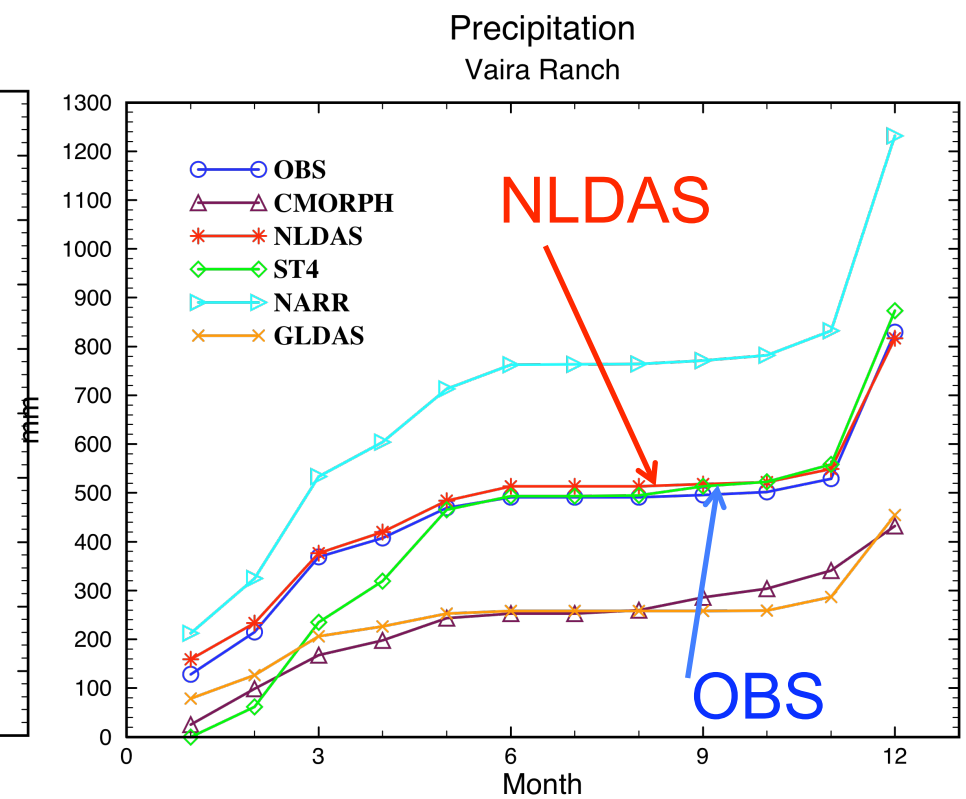
HRLDAS forcing conditions

- NARR 32-km: t, q, u/v, p, longwave radiation.
- National LDAS (NLDAS): precipitation, 1/8 degree, hourly.
- U. Maryland/NOAA GOES 0.5-deg hourly solar downward radiation.

NLDAS precipitation is better products among existing precipitation analysis



Elevation: 3190 m



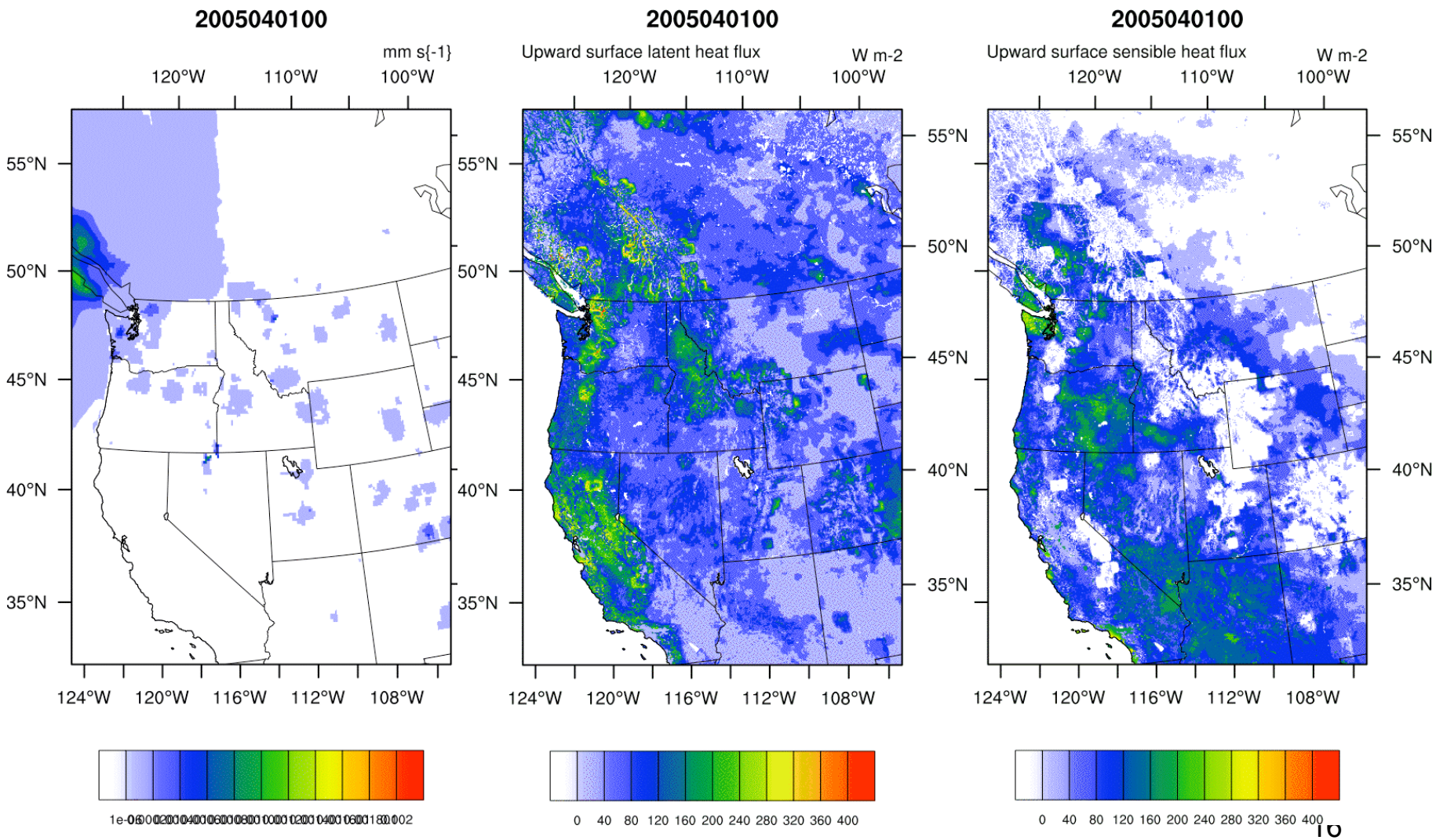
Elevation: 129 m

HRLDAS results, every 3 hour, from 1-30 April 2005

Precipitation (mm s-1)

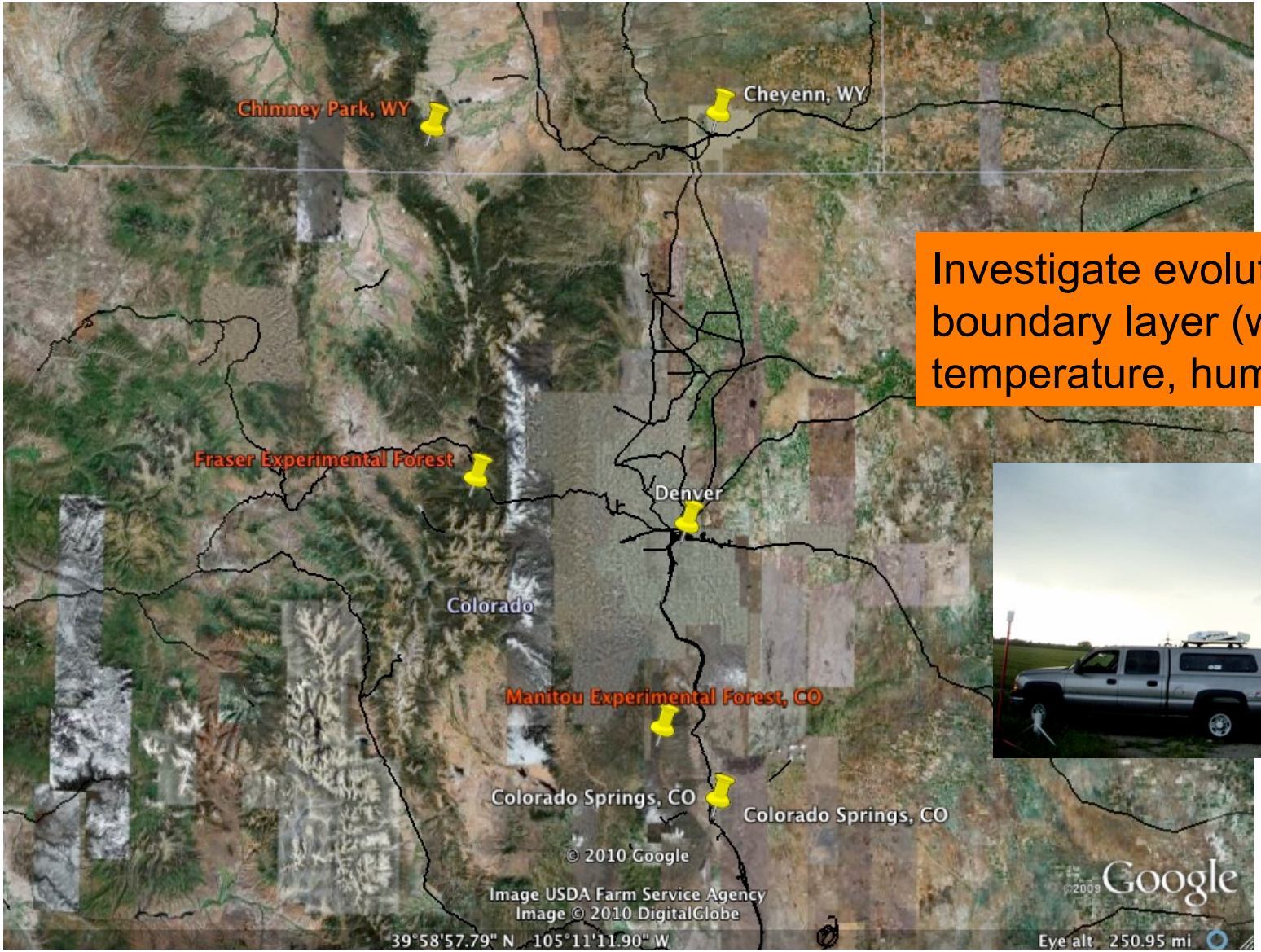
Latent heat flux (evapo.) (Wm-2)

Sensible heat flux (Wm-2)



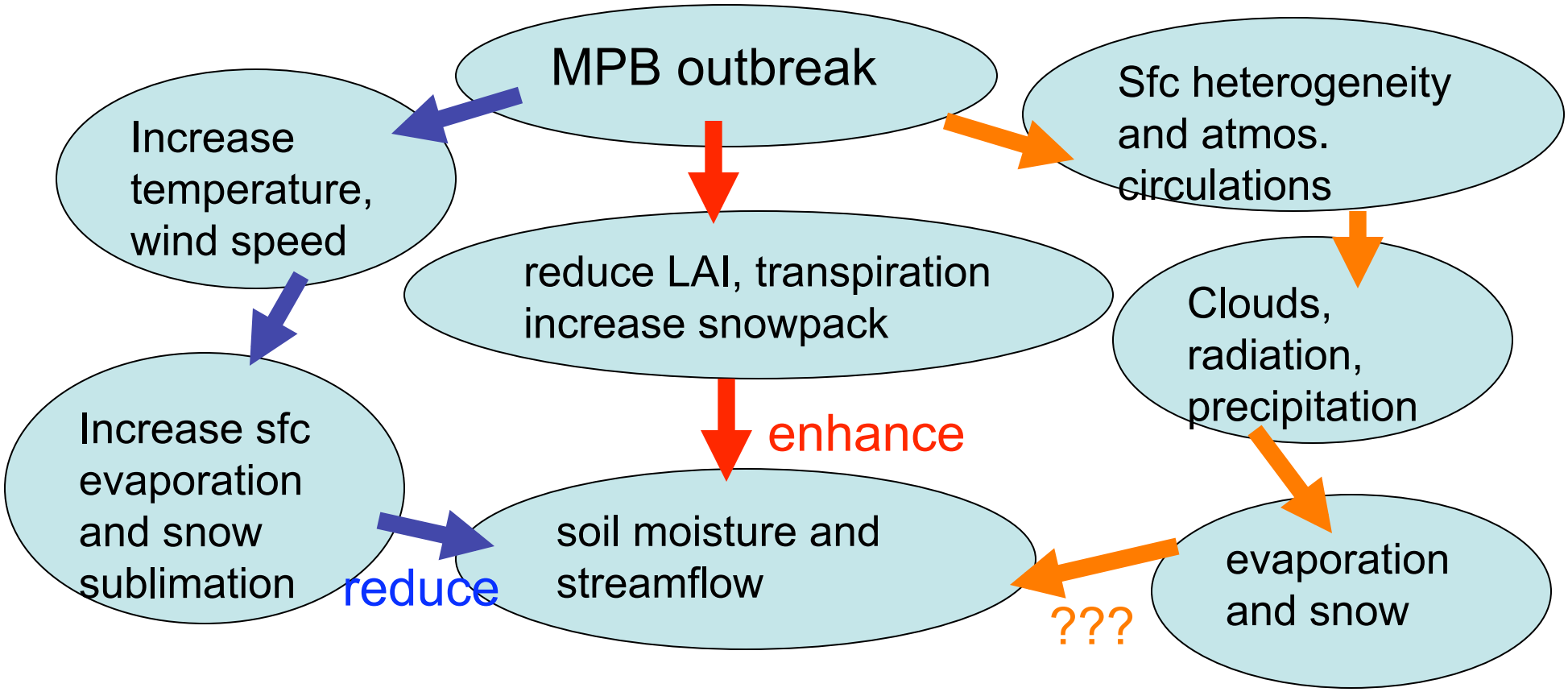
2010 August Intensive Field Campaign

Using NCAR GPS Advanced Upper-Air Sounding System (GAUS) over undisturbed and infested sites



Investigate evolution of boundary layer (wind, temperature, humidity)

Message to Stakeholders

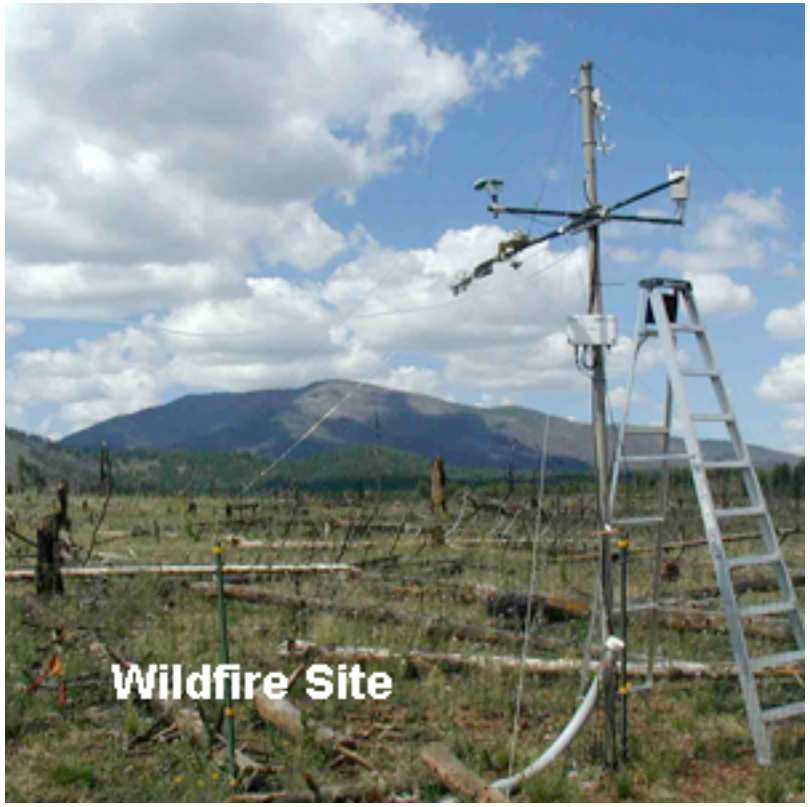


Need more research, particularly integrated study

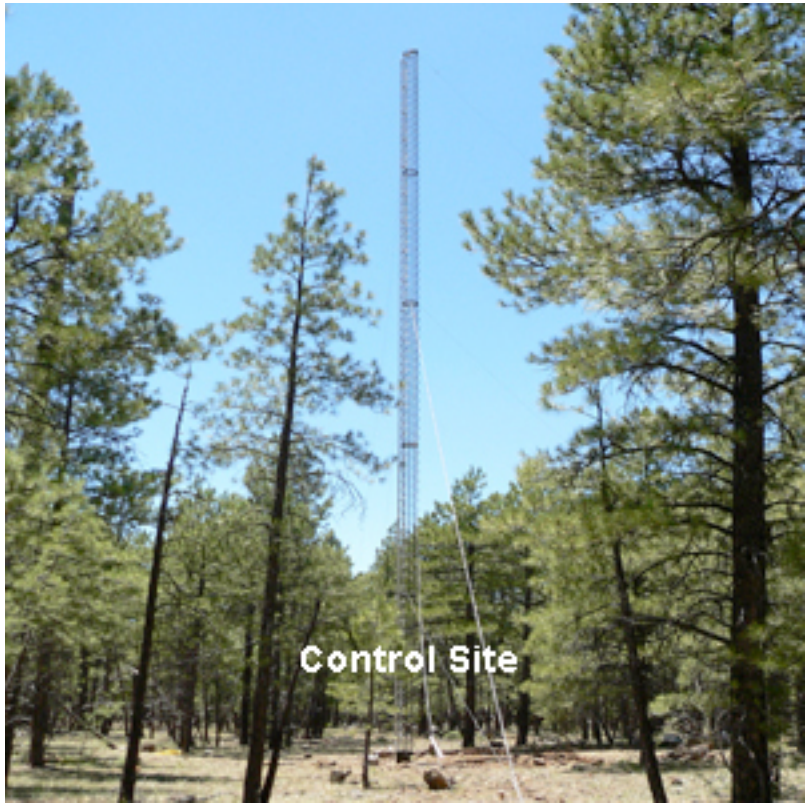
Thank you

AmeriFlux Sites affected by fire

Flagstaff widlfire (1996)
Herbaceous, shrubs

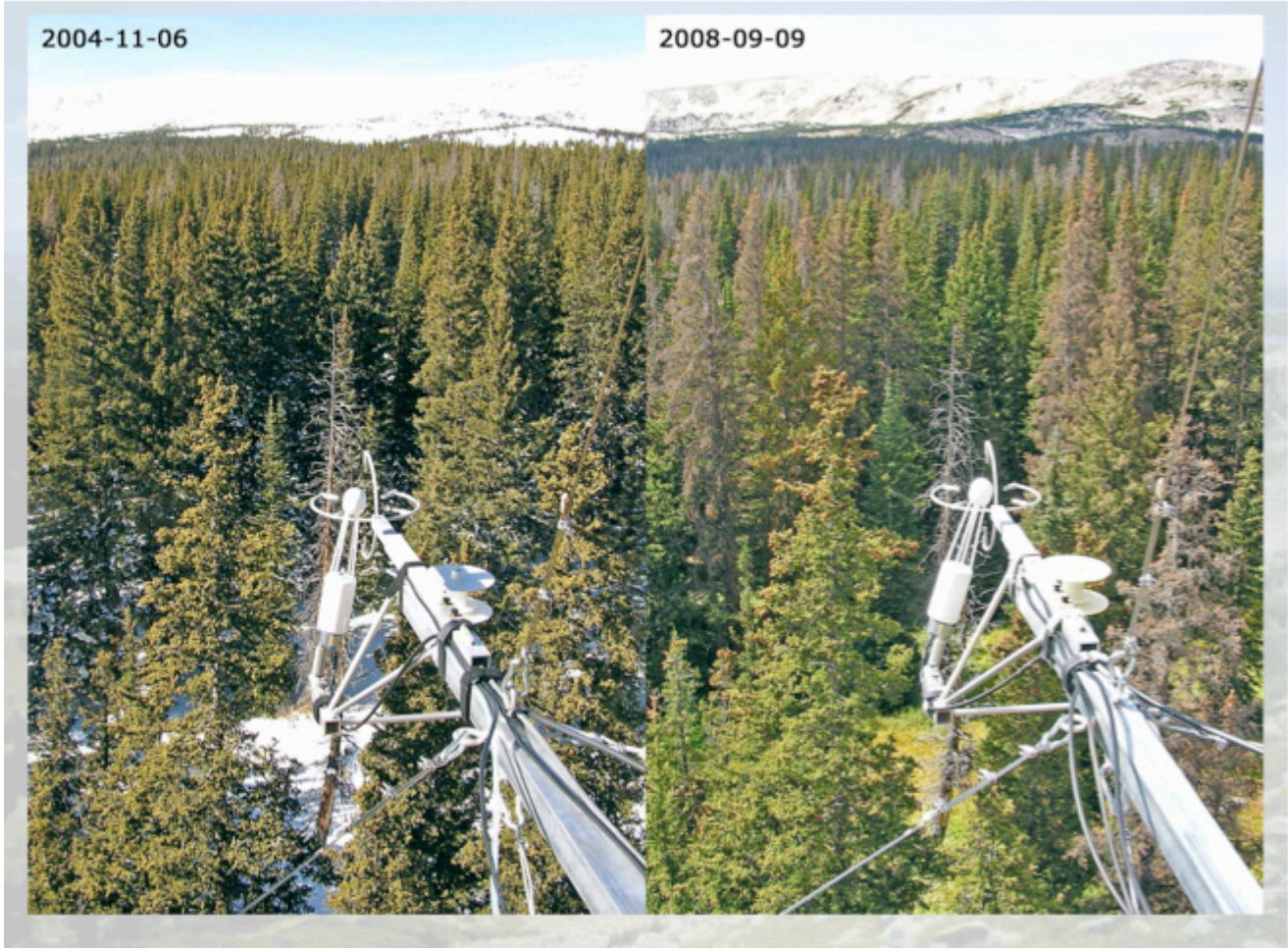


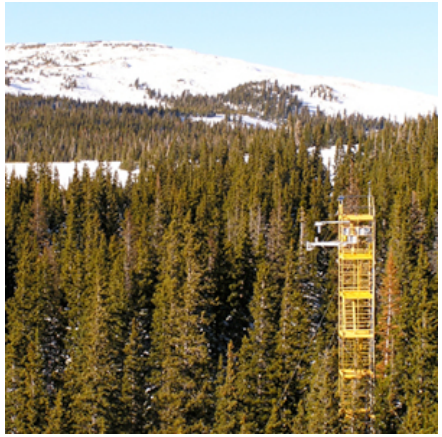
Flagstaff Unmanaged Forest
ponderosa pine



AmeriFlux Sites affected by beetle-kill

The Glacier Lakes Ecosystem Experiments Site (GLEES, Wyoming).
Spruce (85%), Subalpine fir (15%)





Courtesy of Robert Musselman, US Forest Service.