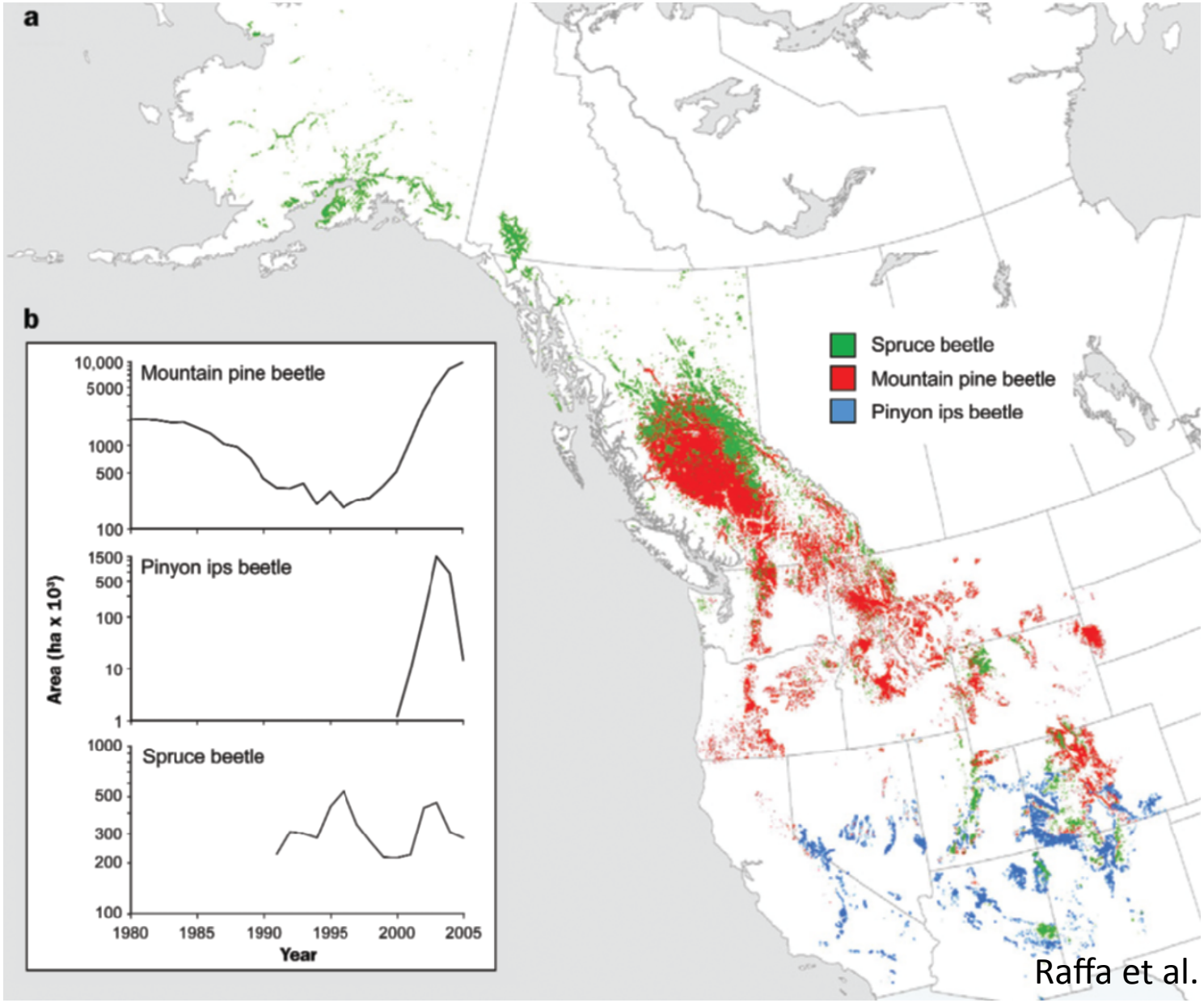
Quantifying the Effects of Large-Scale Vegetation Change on Coupled Water, Carbon and Nutrient Cycles: Beetle Kill in Western Montane Forest

PD Brooks, HR Barnard, S Edburg, BE Ewers, D. Gochis, A Guenther, E Gutmann, P Harley, A Harpold, J Hicke, A Meddens, U Norton, E Pendall, A Somor, P Troch

Hydrological and Biogeochemical Responses to MPB Infestation

Western North American forests are undergoing widespread mortality



Raffa et al. 2008

Hydrological and Biogeochemical Responses to MPB Infestation

Potential Impacts: MPB Infestation and tree death has potential, but unclear, impacts on:

- River Discharge
- Groundwater Recharge
- Plant Available Water
- Water Quality
- Forest Products
- Regional Carbon Sinks
- Recreation
- Fuel Loads
- Erosion/ Sedimentation
- Regional Climate Feedbacks
- Management Decisions

Hydrological and Biogeochemical Responses to MPB Infestation

Approach:

- **Assemble an interdisciplinary team (hydrology, biogeochemistry, ecosystem and physiological ecology, spatial analysis, hydrometeorology, atmospheric science)**
- **Work at a range of sites that vary in spatial scale and level of impact**
- **Include both catchment and land-surface measurement and modeling**
- **Partner with other projects and researchers**
- **Organize around broad, unifying questions**

How do changes in vegetation structure associated with MPB, including density, leaf area, and species composition, alter the partitioning of energy and water, including sublimation, evaporation, transpiration, recharge, and stream flow?

How do these changes in energy and water availability affect local to regional scale biogeochemical cycles including a) carbon uptake, respiration, and export in stream flow, b) N deposition, availability, emission, and N export in stream flow, and c) emissions of biogenic trace gases?

Hydrological and Biogeochemical Responses to MPB Infestation

Approach: Develop hypotheses coupling hydrology and biogeochemistry

Infestation Stage	Hydrology	Biogeochemistry
	•Controlled by climate and ecosystem interactions	•Controlled by climate and ecosystem interactions
	•Transpiration decreases •Runoff increases •Baseflow increases	•NPP decreases •Rh increases •N export increases
	•Interception decreases •Melt rate increases •Runoff increases (?) •Evaporation increases	•DOM export increases •Particulate export increases

Hydrological and Biogeochemical Responses to MPB Infestation

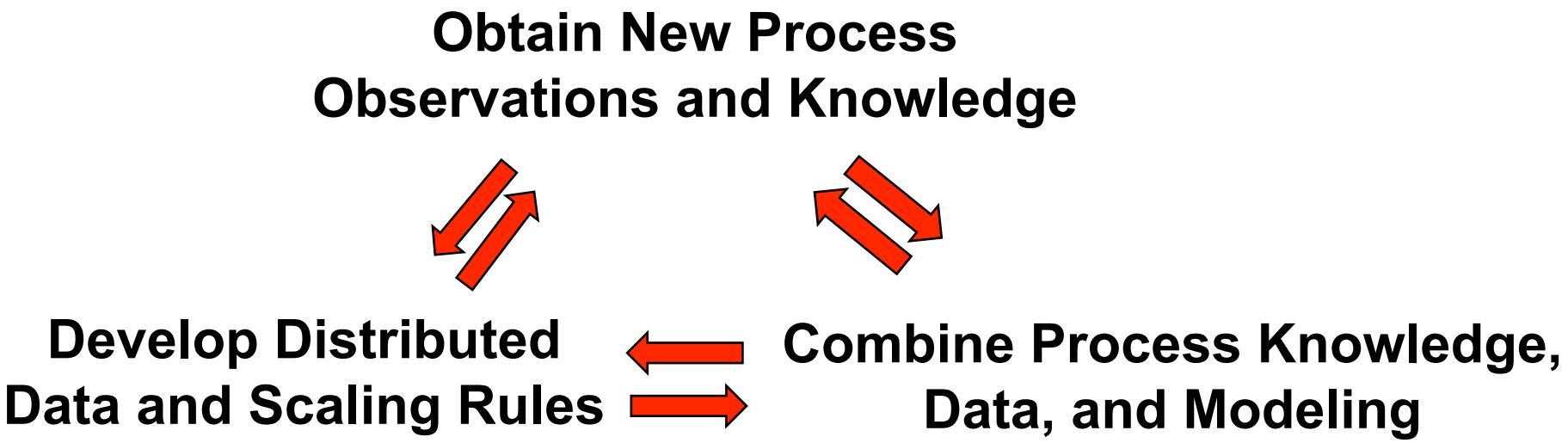
Study Design: Iterative process of measurement and modeling

1)Plot-scale measurements of hydrological, biogeochemical, and ecological processes

2)Simultaneous flux tower and catchment measurements; integrating water and biogeochemical cycles in catchment ecosystems,

3)Development of ***distributed data*** sets describing the spatial extent and biophysical response to MPB infestation, and

4)Develop and refine ***quantitative models*** of water and biogeochemical cycles



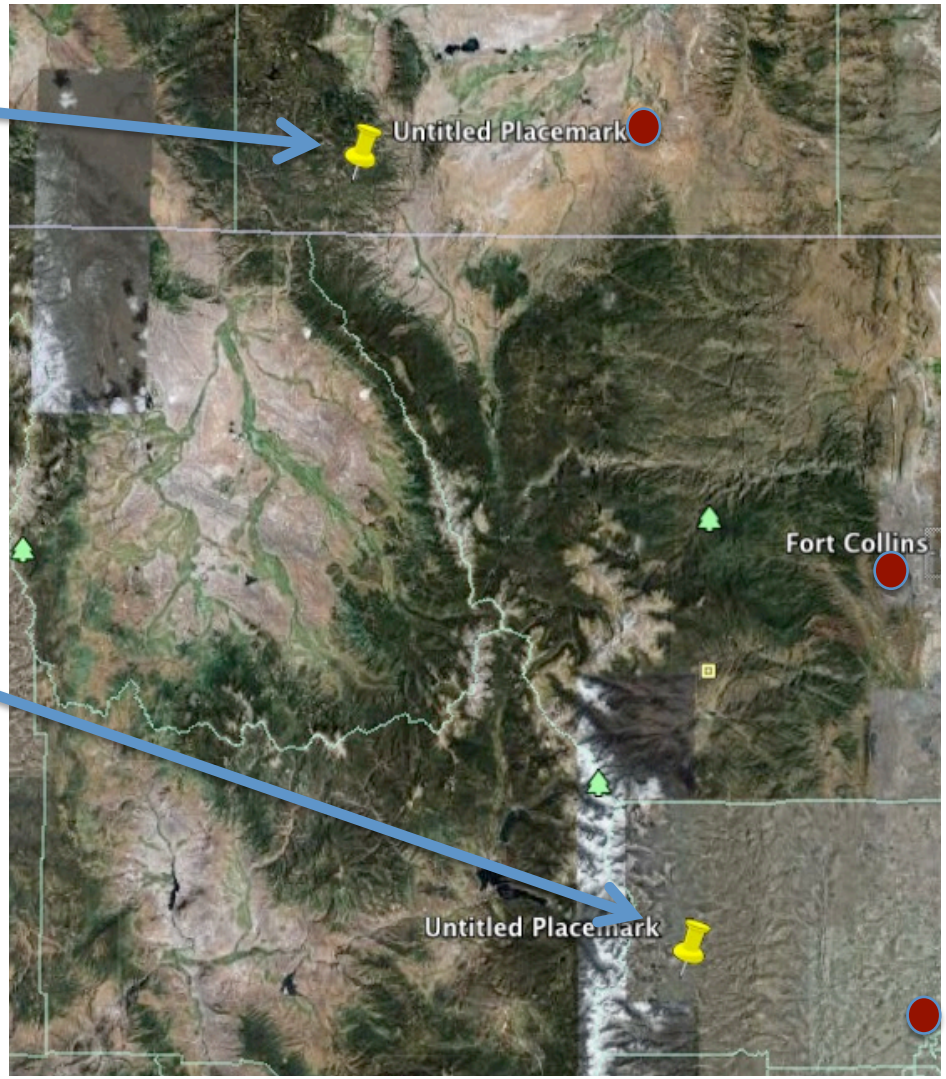
Intensive, Process Study Sites

Chimney Park, WY

- Five stands and three hillslopes
- Sites hit in 2007, 2008, 2009

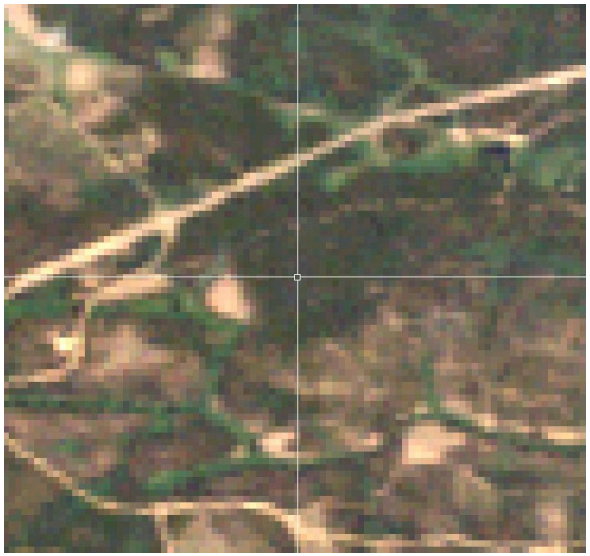
Niwot Ridge, CO

- Two stands and hillslopes
- Minimal/ background level of infestation

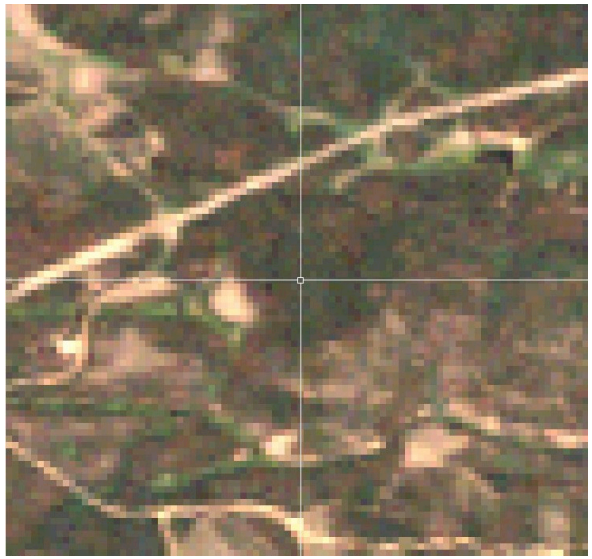


Hydrological and Biogeochemical Responses to MPB Infestation

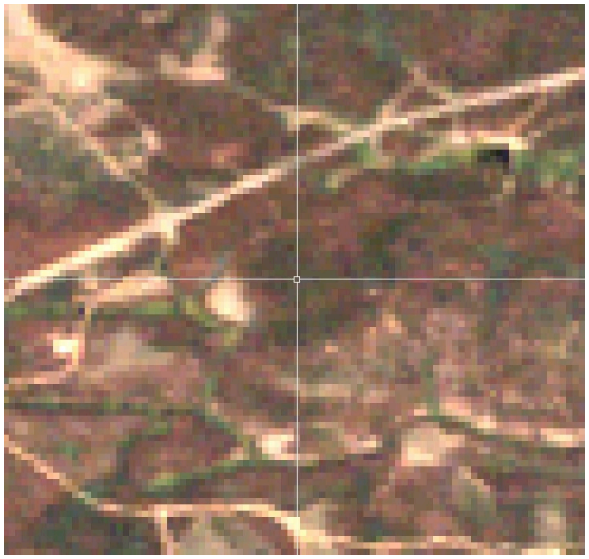
Chimney Park, WY



2007

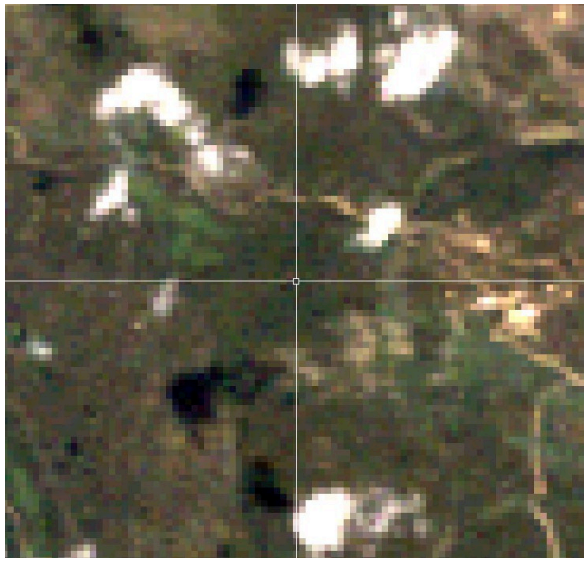


2008

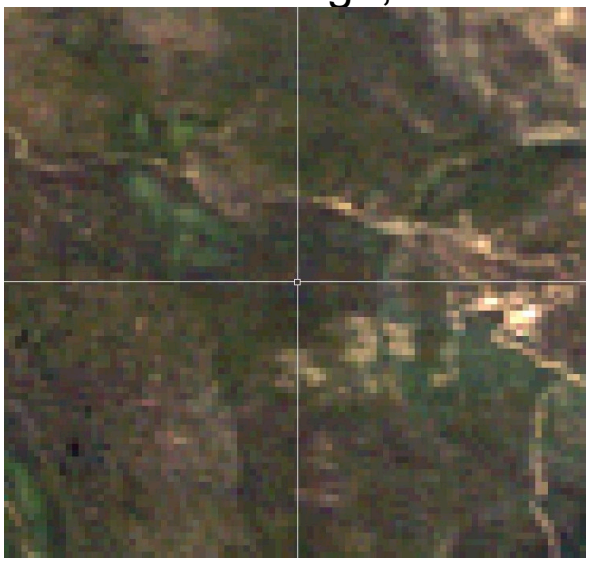


2009

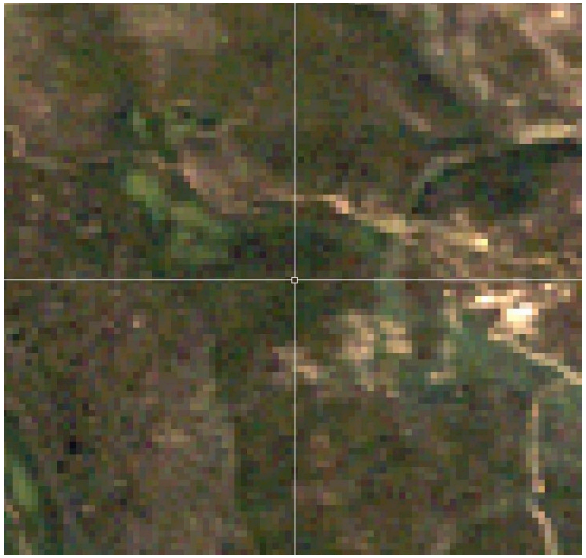
Niwot Ridge, CO



2007



2008

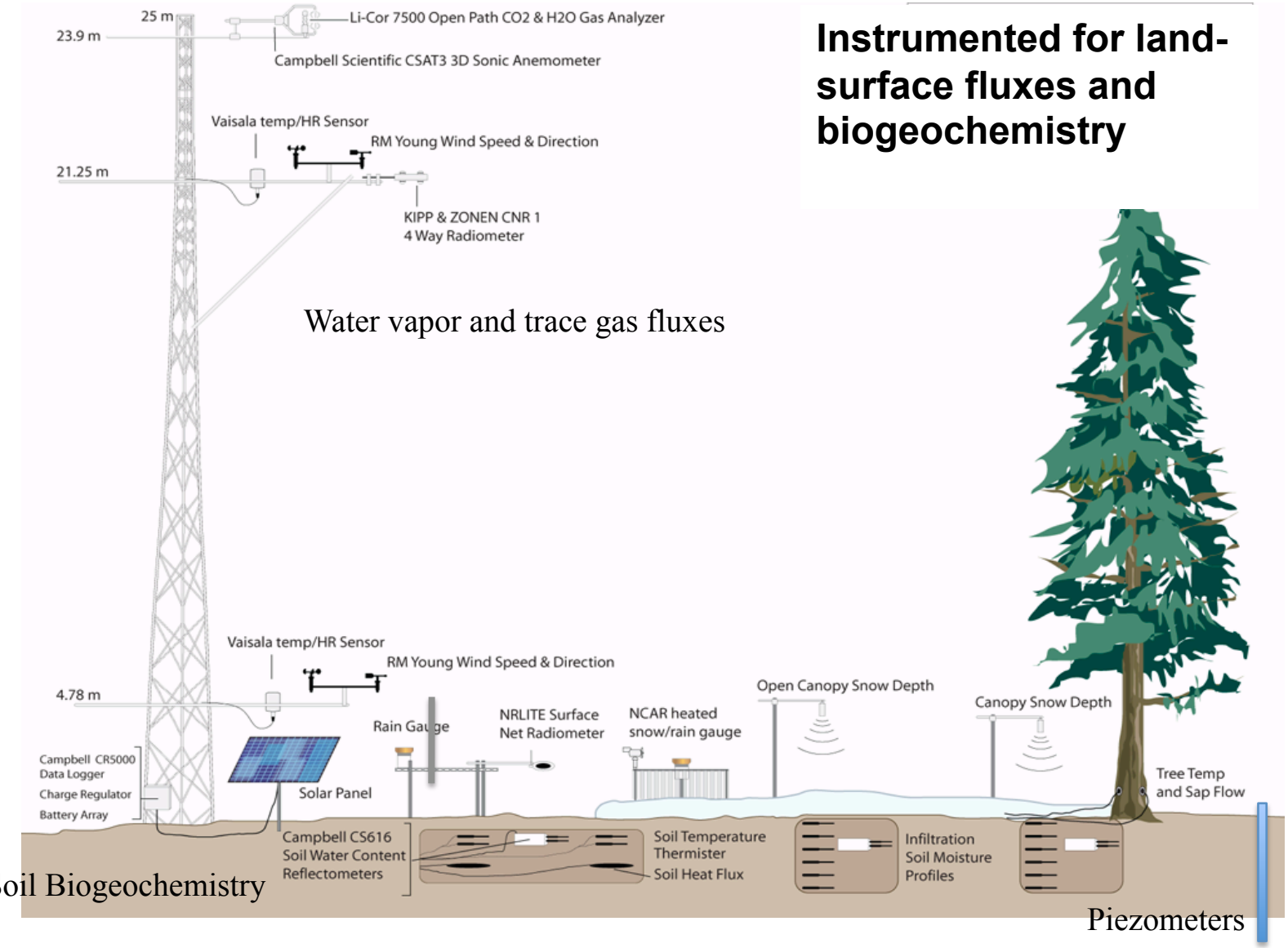


2009

Hydrological and Biogeochemical Responses to MPB Infestation

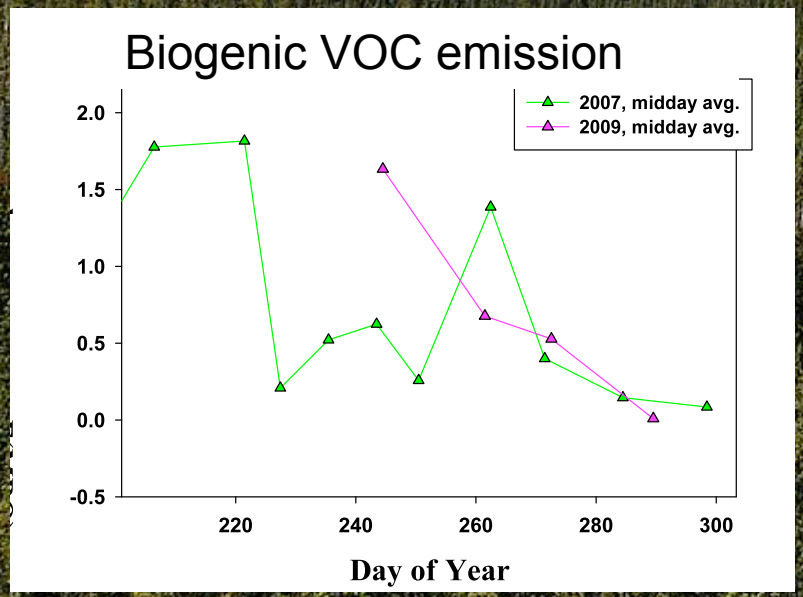
Intensive study sites: Chimney Park, WY: Niwot Ridge, CO

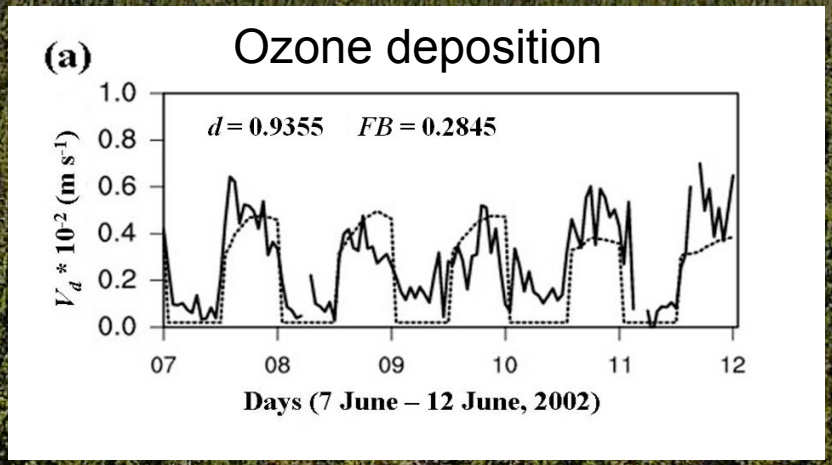
Instrumented for land-surface fluxes and biogeochemistry



E.G. Holly Barnard's, Evan Hugh's, Noah Molotch's, Rob Hubbard's presentation's

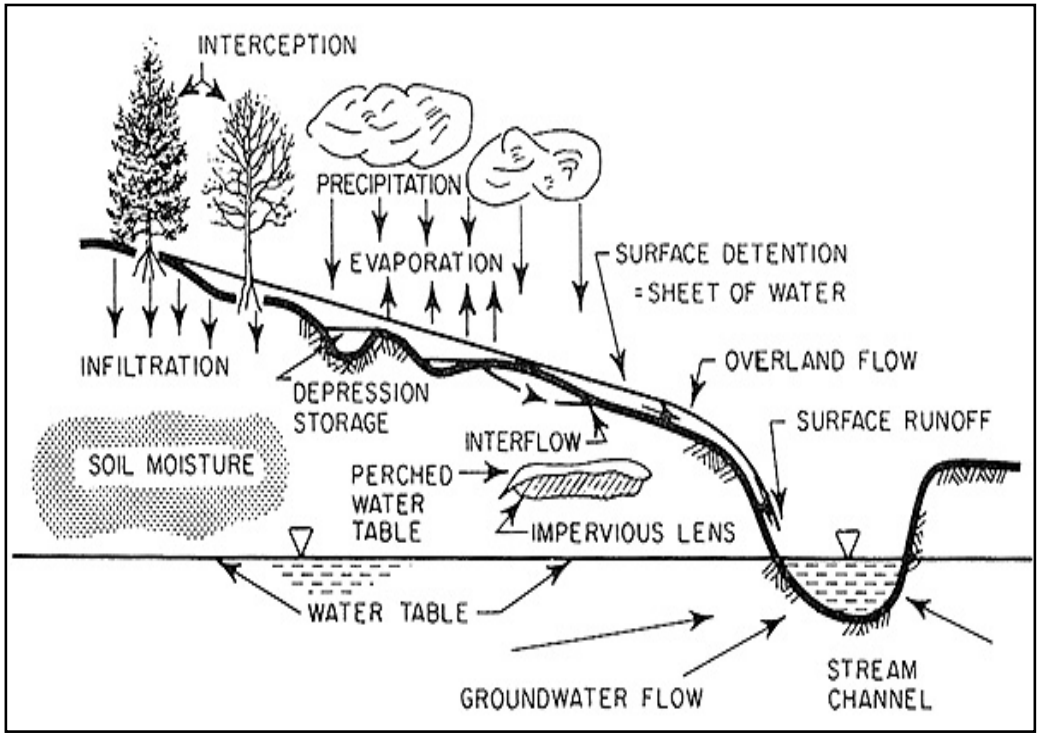
Above canopy flux measurements of trace gas (ozone, VOC) fluxes before, during and after beetle infestation at Niwot Ridge

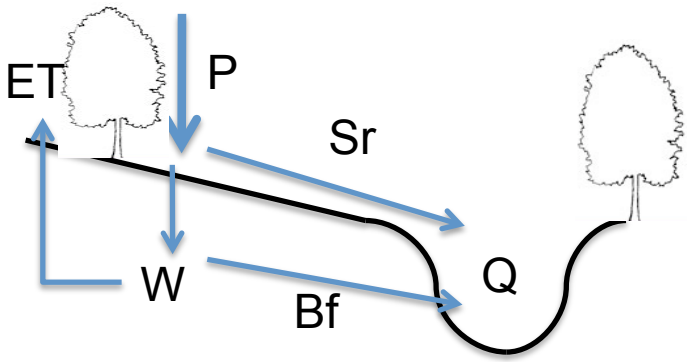




Intensive study sites: Chimney Park, WY: Niwot Ridge, CO

Instrumented for hill-slope to nested catchment to groundwater hydrological and biogeochemical fluxes



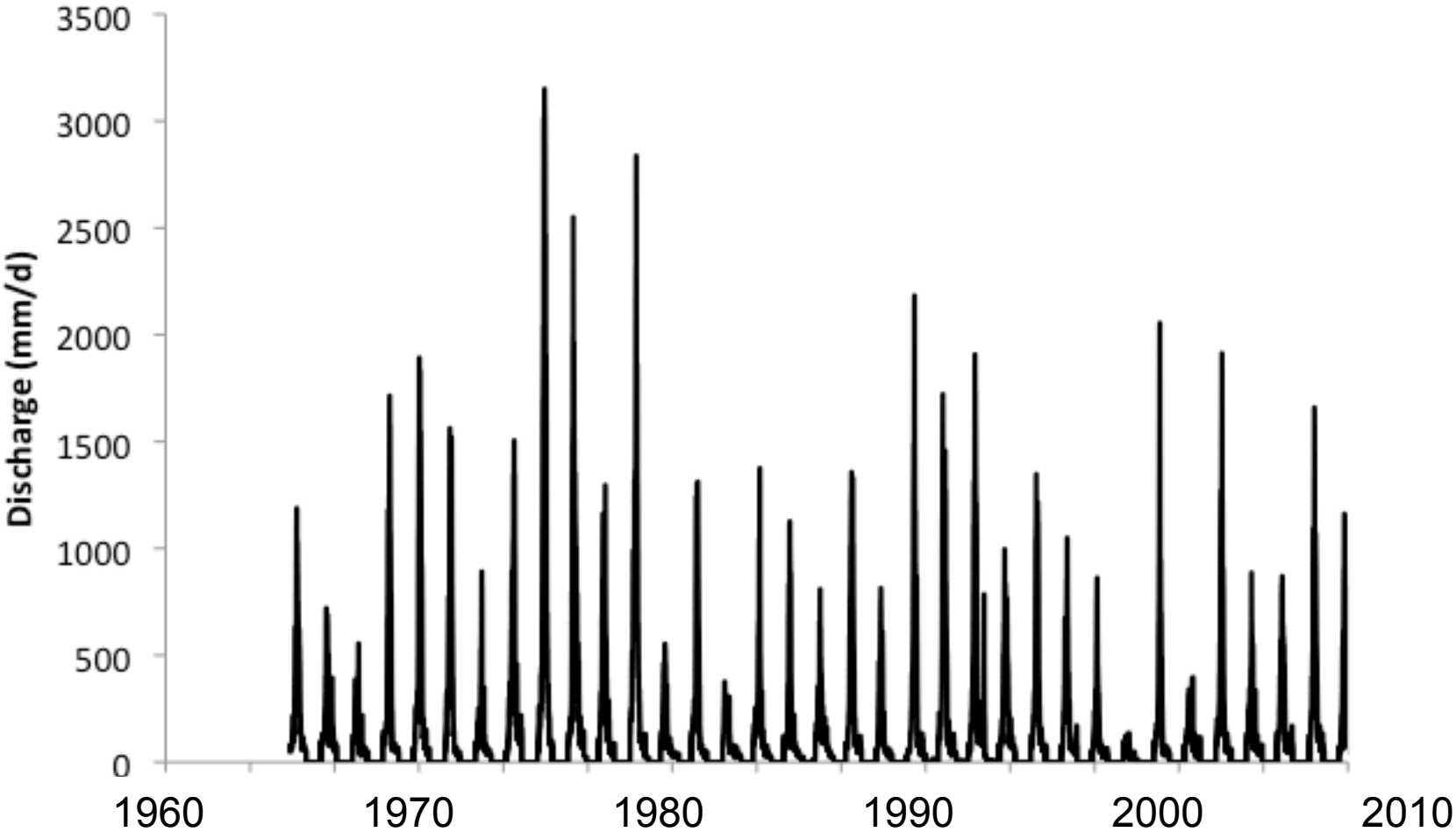


P = W + Sr
W = ET + Bf
Q = Sr + Bf

E.G. *Ty Atkins* presentation on Como Creek earlier today

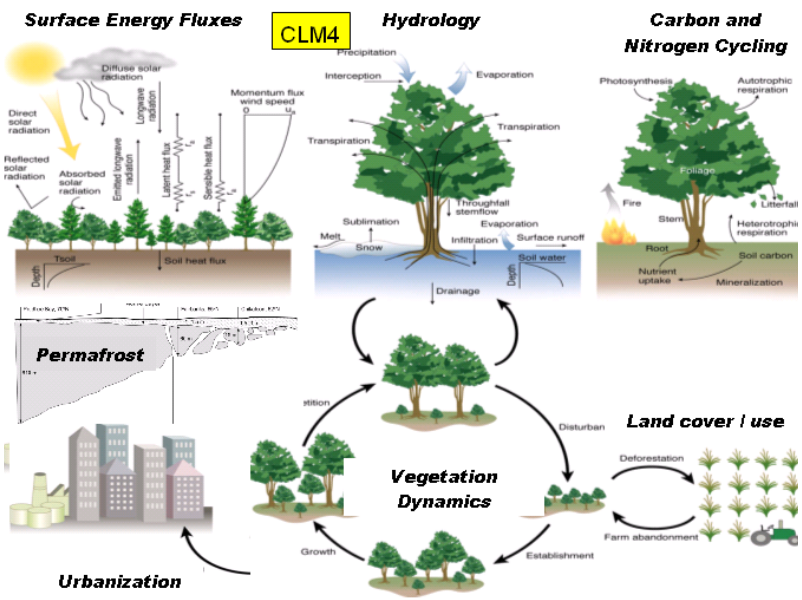
Regional-scale ecosystem response to changes in precipitation

Inter-annual variability in Little Laramie River discharge



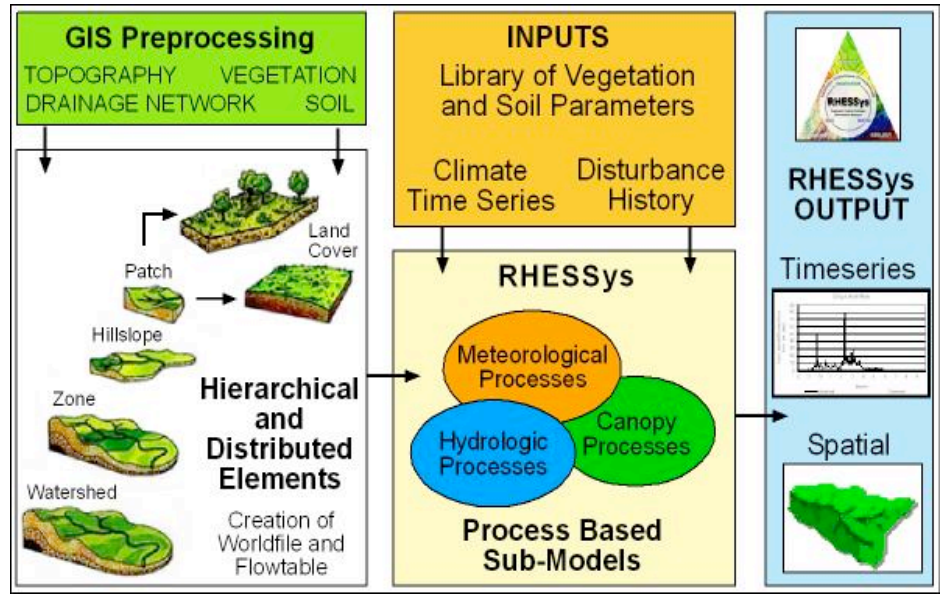
Comparative modeling: RHESSys and CLM

Land Surface Focus



CLM-C/N

Catchment Focus



RHESSys

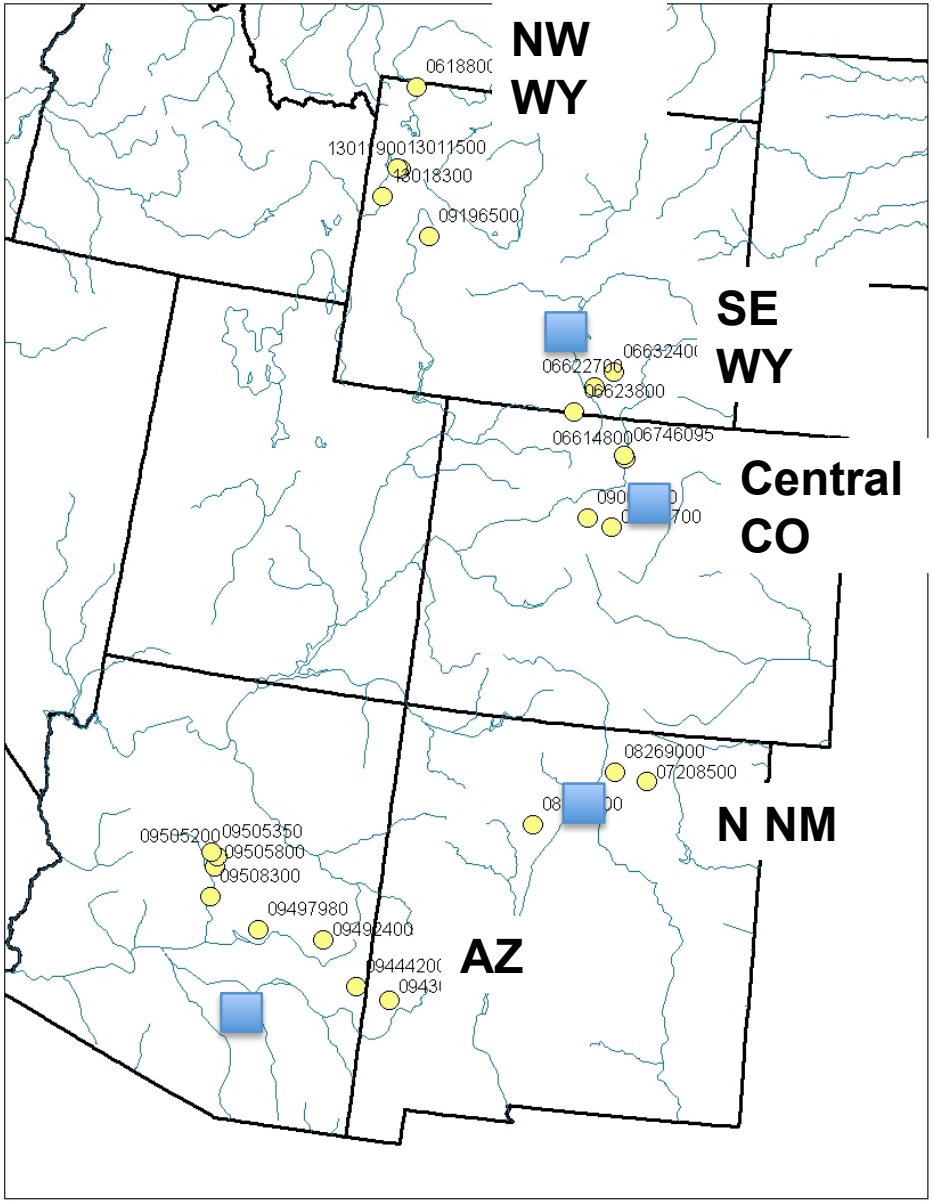
- Model Evaluation Metrics/Emphases:
  - Land-atmosphere exchange of energy, moisture, carbon and nitrogen
  - Catchment fluxes and residence times of water, carbon and nitrogen
  - Canopy structure and exchange parameters in response to infestation and mortality (e.g. color, needle fall, woody fall, succession)
  - Stand, hillslope, footprint, catchment and regional scales

Distributed Data Collection: Rocky Mountain Transect

Leveraging with other projects we examine a latitudinal transect of sites including:

Intensively instrumented sites in AZ, NM, CO, and WY

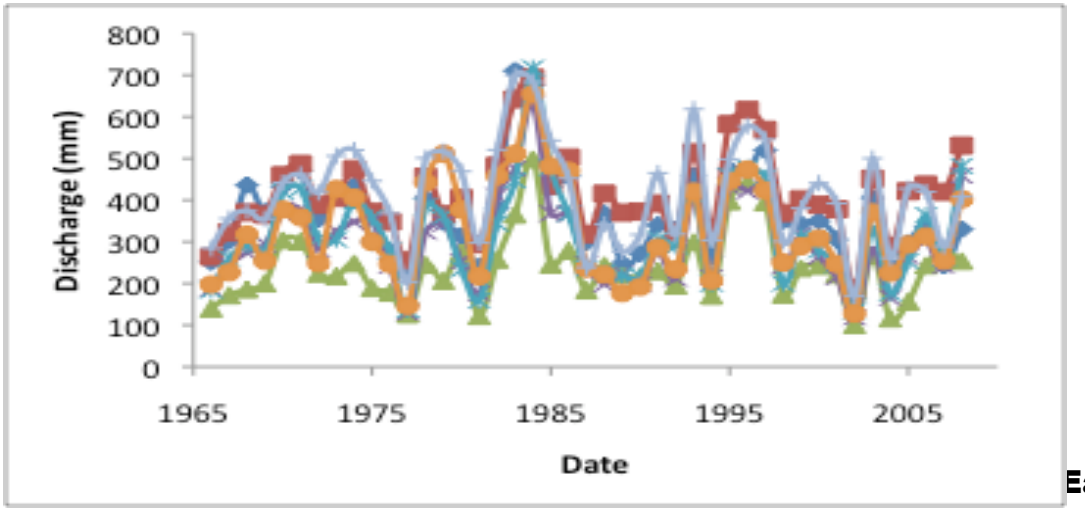
Sparsely instrumented gaged and remotely-sensed sites

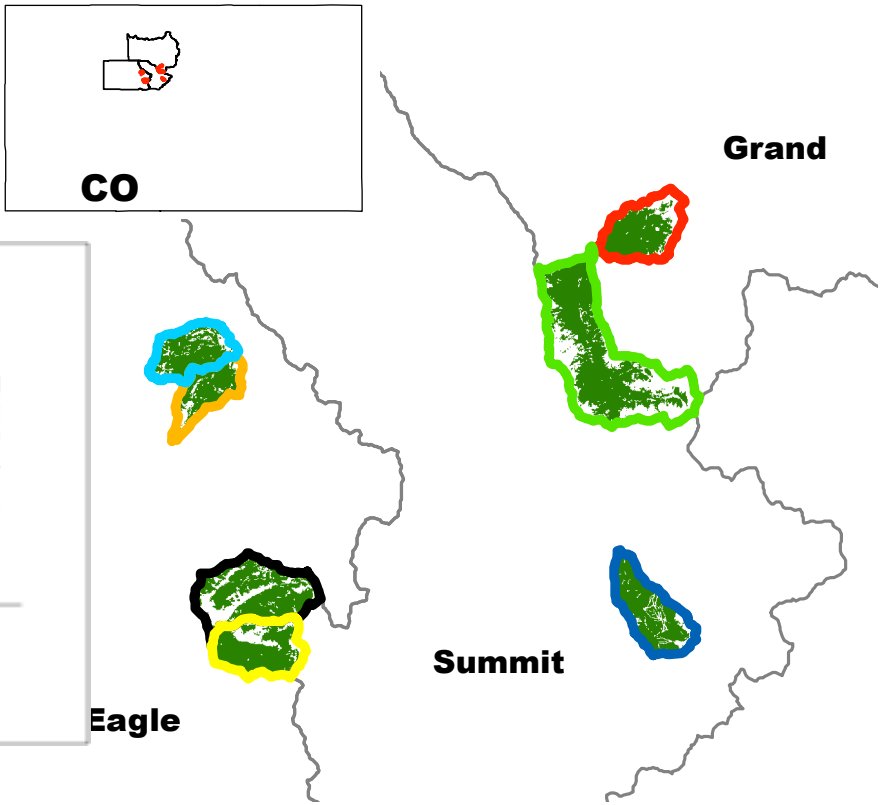


Preliminary Results: Catchment-scale Responses to MPB

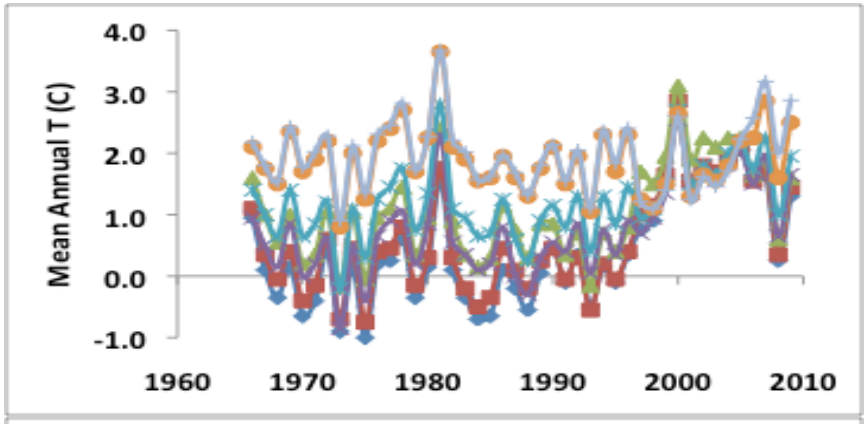
Seven watersheds in central Colorado

- No reported diversions or regulation of flow
- Discharge (USGS) and climate (PRISM) since 1966
- MPB Infestation began in late 1990's
- Similar long-term discharge patterns

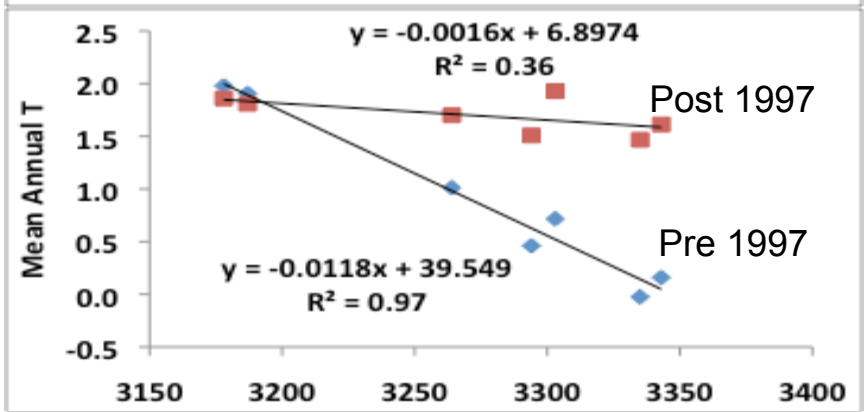




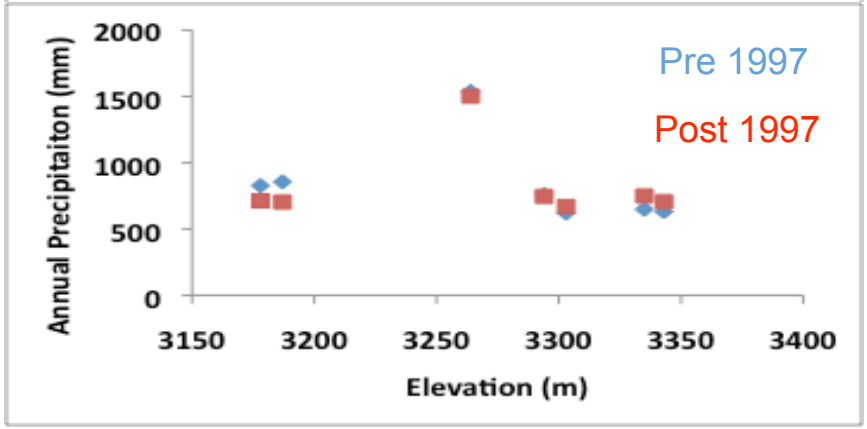
Preliminary Results: Catchment-scale Responses to MPB



Pronounced warming since 1997



Warming restricted to higher elevations



Decreased precipitation at lower elevations; increased precipitation at higher elevations

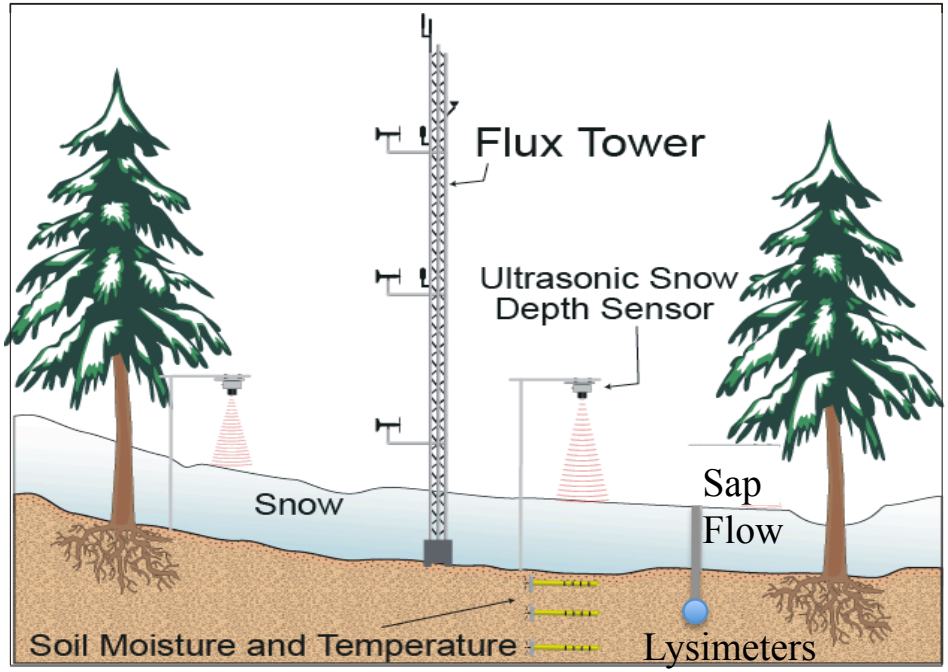
Preliminary Results: Catchment-scale Responses to MPB

NOTE: Preliminary results on hydrologic response were not included in this version of the presentation. Contact Paul Brooks (pdbrooks@email.arizona.edu)

Message to Stakeholders (see Fei Chen's message)

There is no simple relationship between MPB infestation and water resources (stationarity is dead)

- Surface water yield may increase or decrease
- Groundwater recharge is largely unexplored
- Water yields may be more sensitive to climate than vegetation change (or to their interaction)
- Catchment similarity indices may aid in prediction of both the direction and magnitude of hydrologic response

Summary:

Increases