Interpreting changes to Upper Colorado River Basin hydrologic response via alternate climatic and land-cover scenarios

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CIRES
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INSTAAR
University of Colorado Boulder

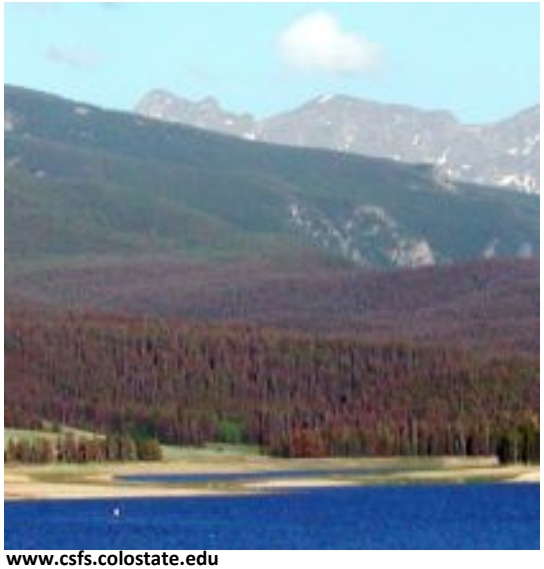
Western Water Assessment

University of Colorado Boulder

Overview

- Quantify impacts of changes to catchments in the Colorado River headwaters (*WWA project*)

Bark Beetle



www.csfs.colostate.edu

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Desert Dust on Snow

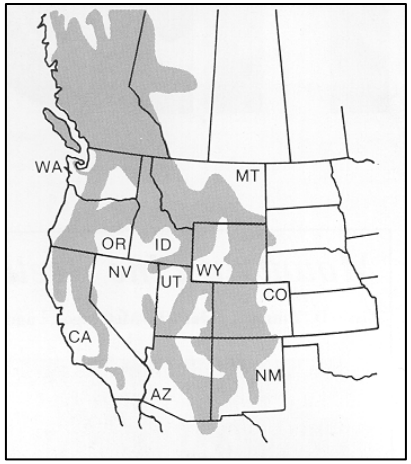
Photo: Chris Landry

= ?

- <u>Impacts on hydrology</u> [modeling + observations]
- *Expected outcomes…*

Bark Beetle (BB) impacts

- Prevalent in western North America
- Recent outbreak since 1996
- Colorado headwaters vital resource
- Few large-scale studies to date



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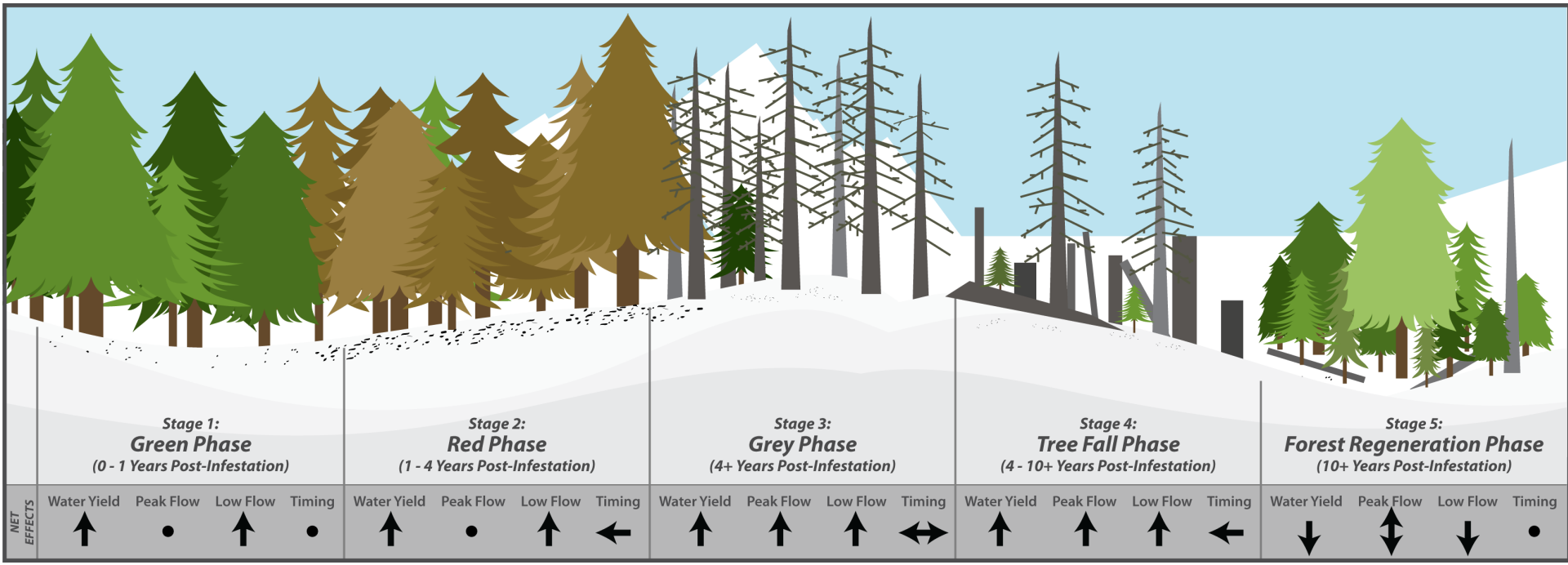

Courtesy: Eric Gordon

Dust on snow

- Impacts reflectivity of snowpack, rate of melt

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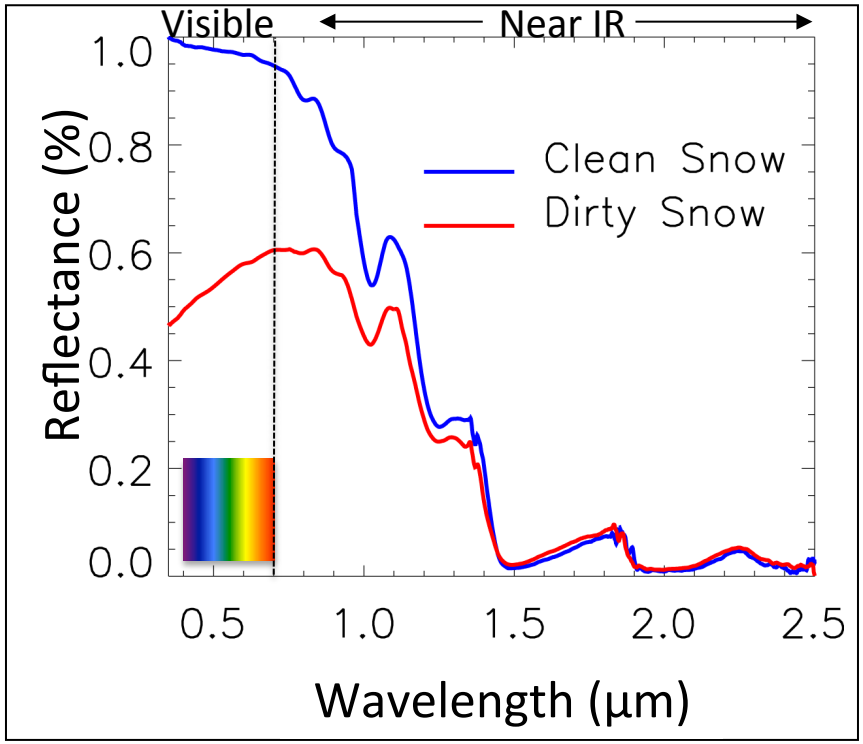
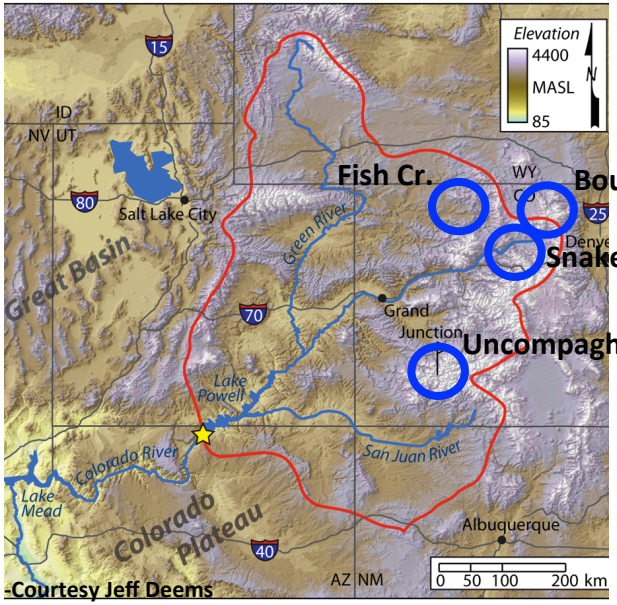


photo courtesy Tom Painter

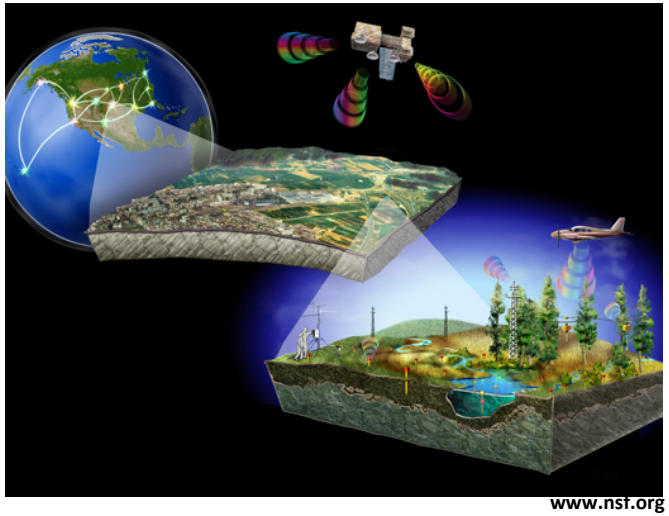
Modeling framework

Domain: catchments with range of BB, dust ; varying hydro-climatology,



-Courtesy Jeff Deems

Ground observations and satellite imagery



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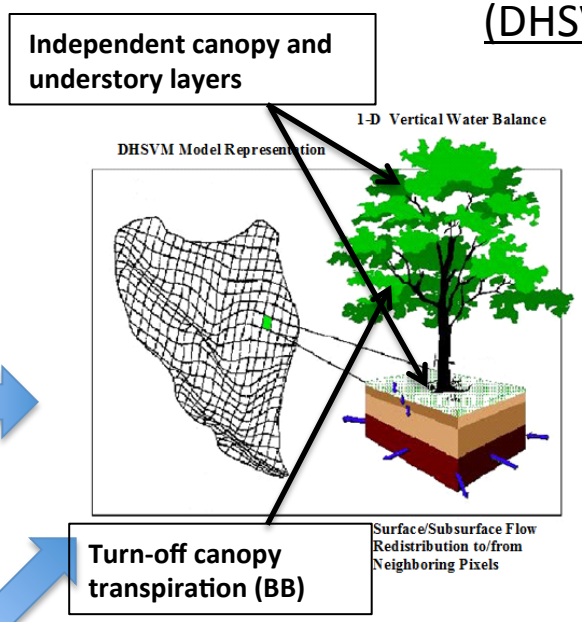
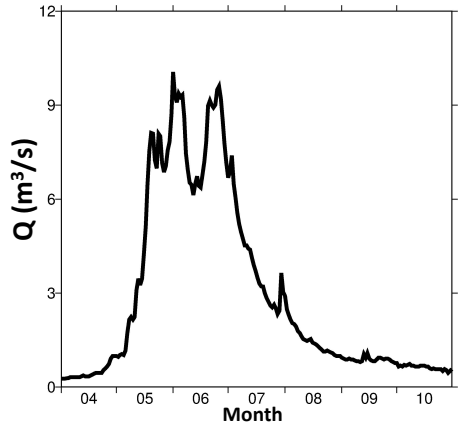
Distributed hydrology soil vegetation model (DHSVM)



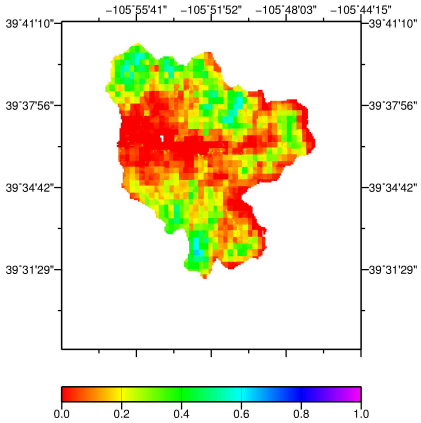
- Physically based hydrologic model that represents the effects of
  - Topography
  - Soil
  - Vegetation
- Solves the energy and water balance at each grid cell at each timestep

100 m spatial resolution

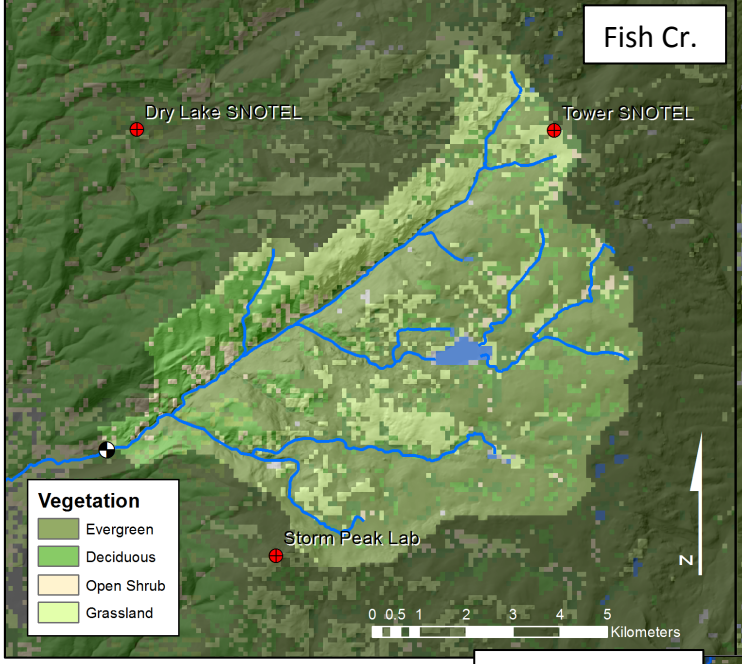
Explore hydrologic sensitivities to BB, dust

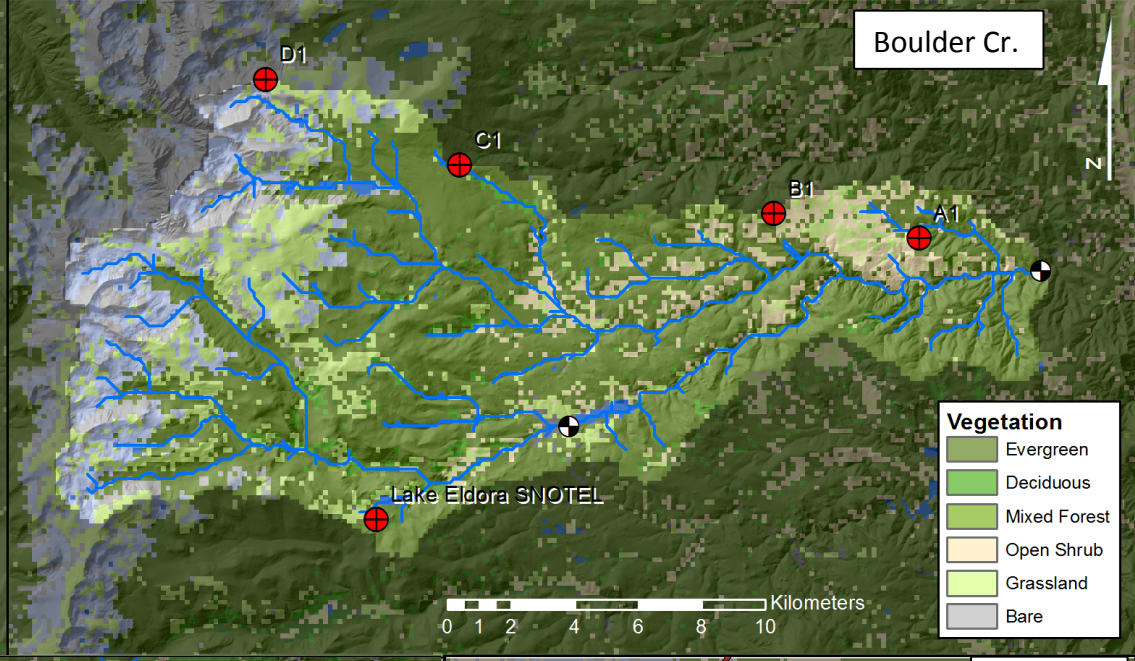


Discharge (Q) magnitude and timing



Snow Water Equivalent (SWE)



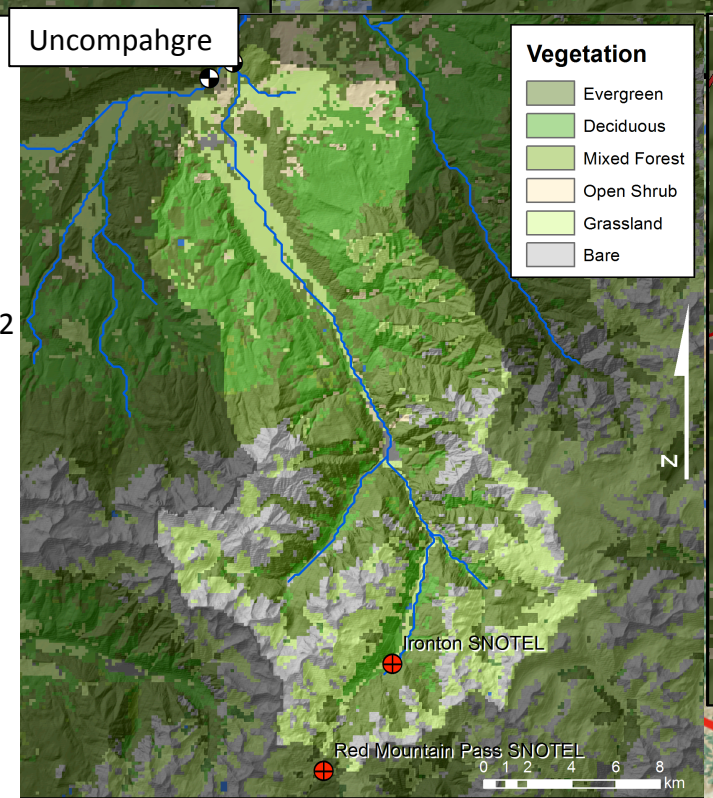


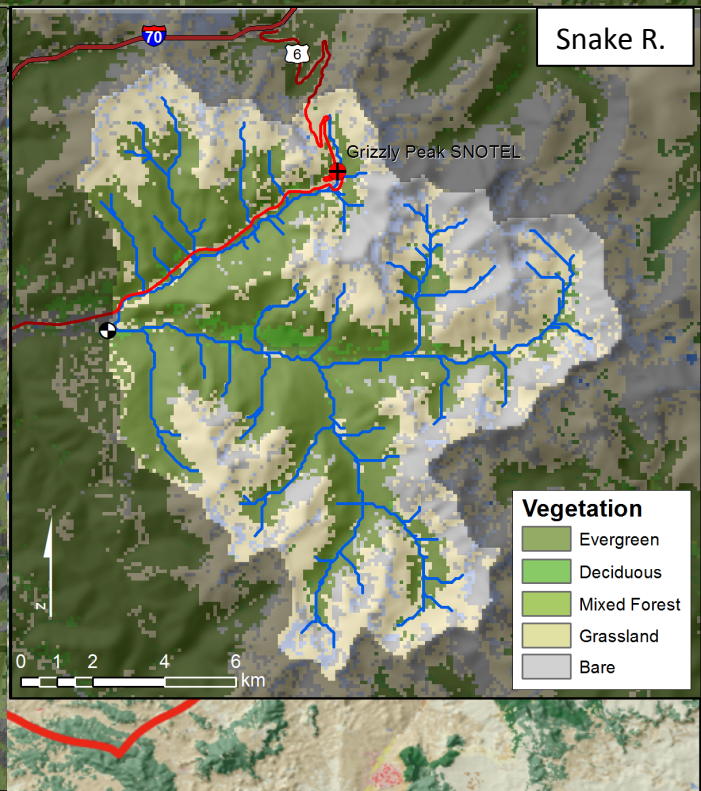
Fish Creek, 67 km^2
(Yampa River Basin)

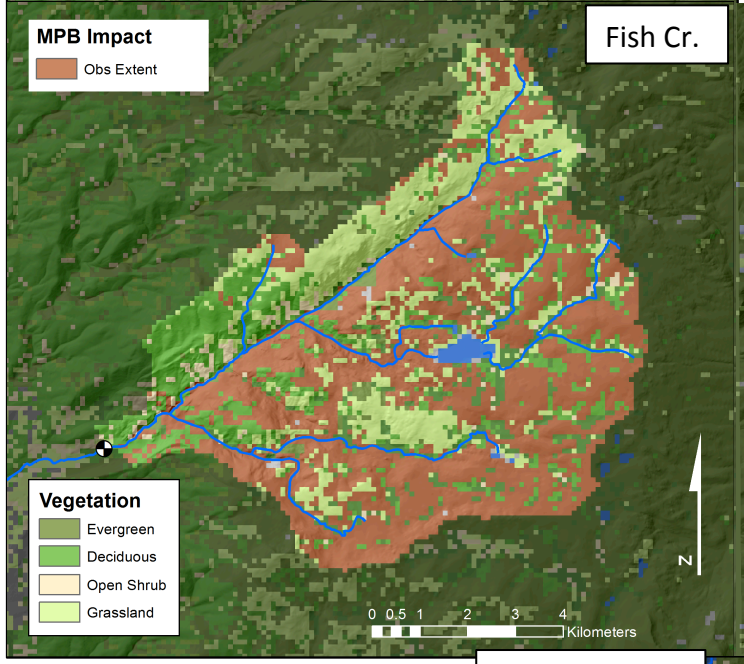
Boulder Creek, 264 km^2
(Upper South Platte)

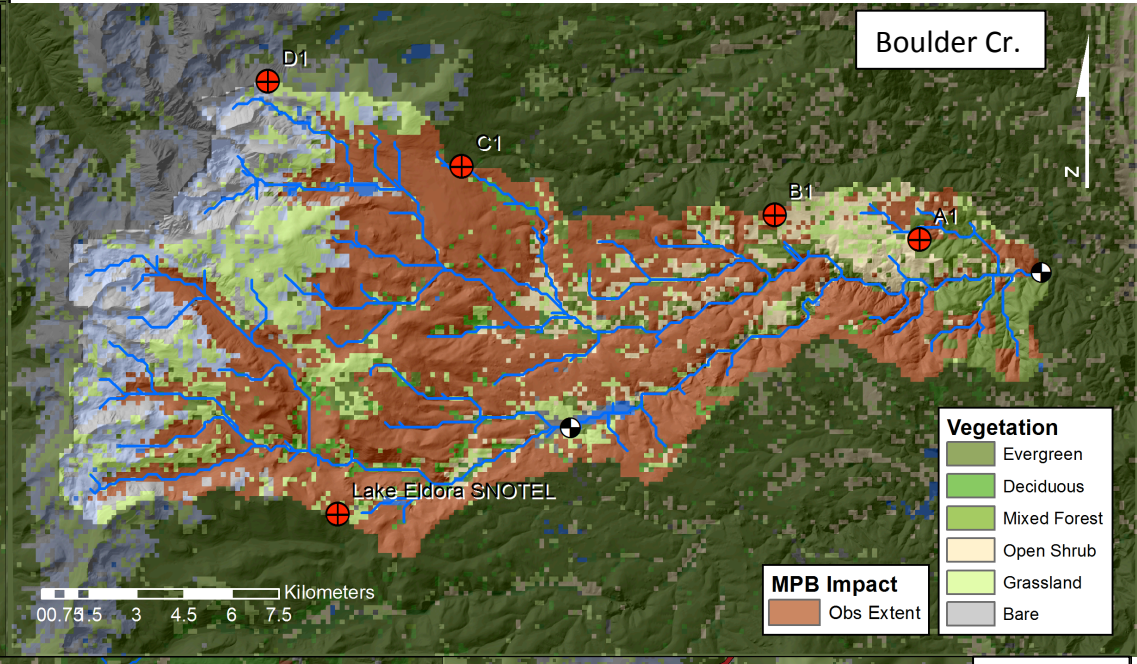
Uncompaghre R., 386 km^2
(Gunnison)

Snake River, 150 km^2
(Upper Colorado)









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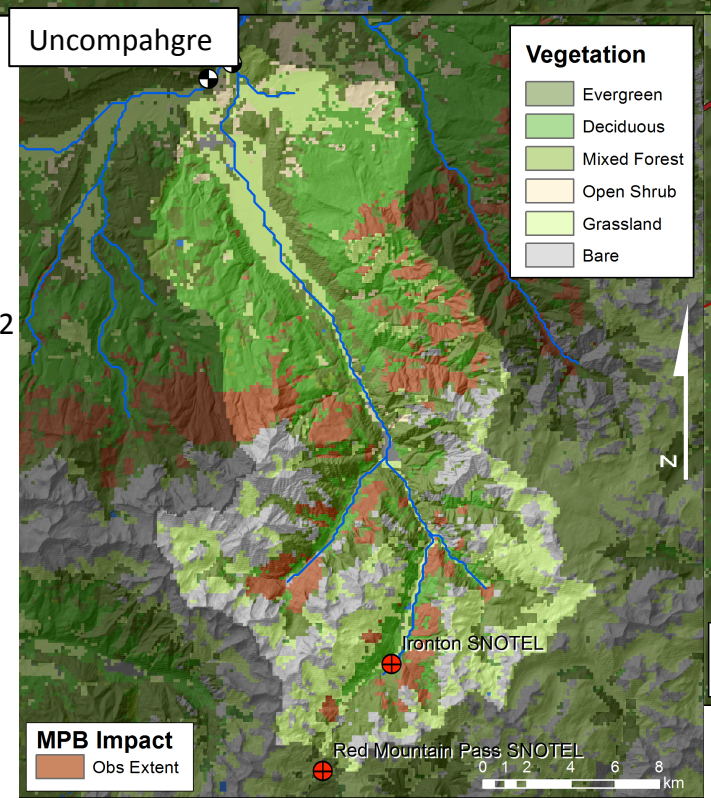
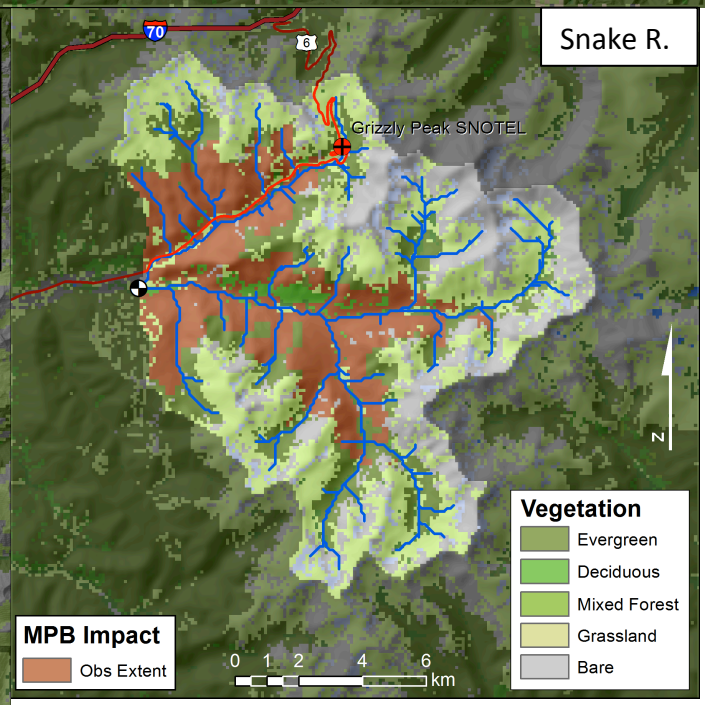
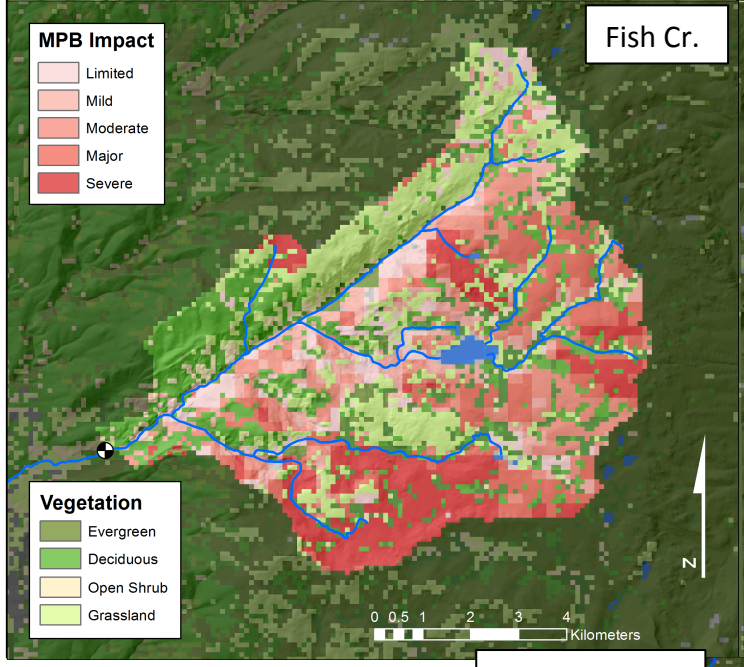
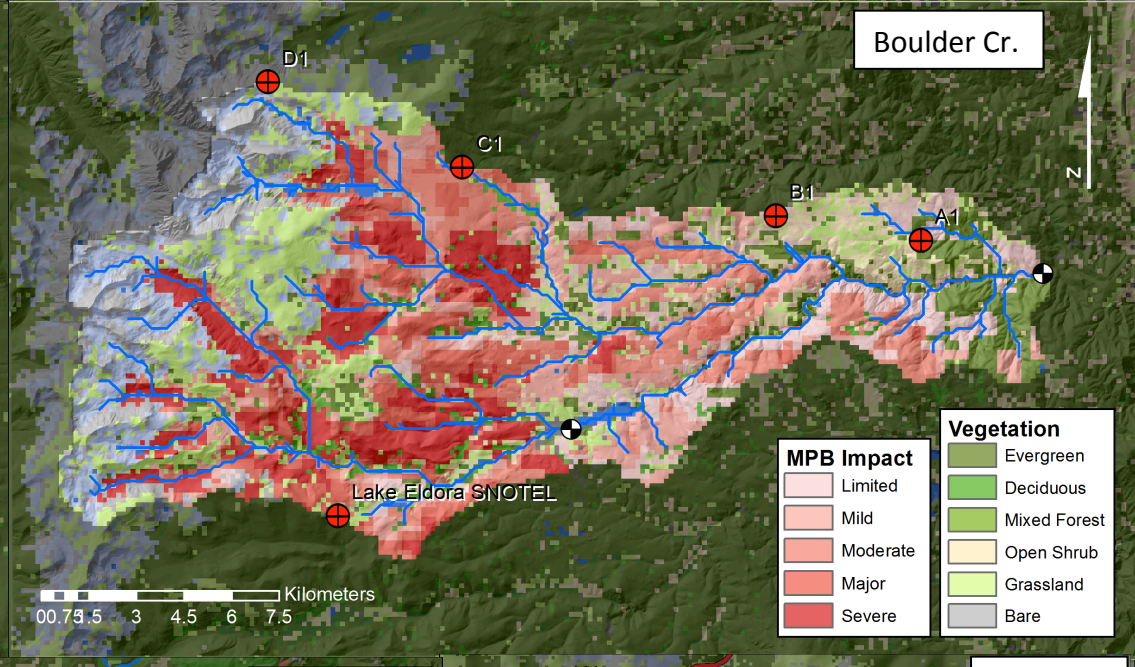




Aerial Survey Data





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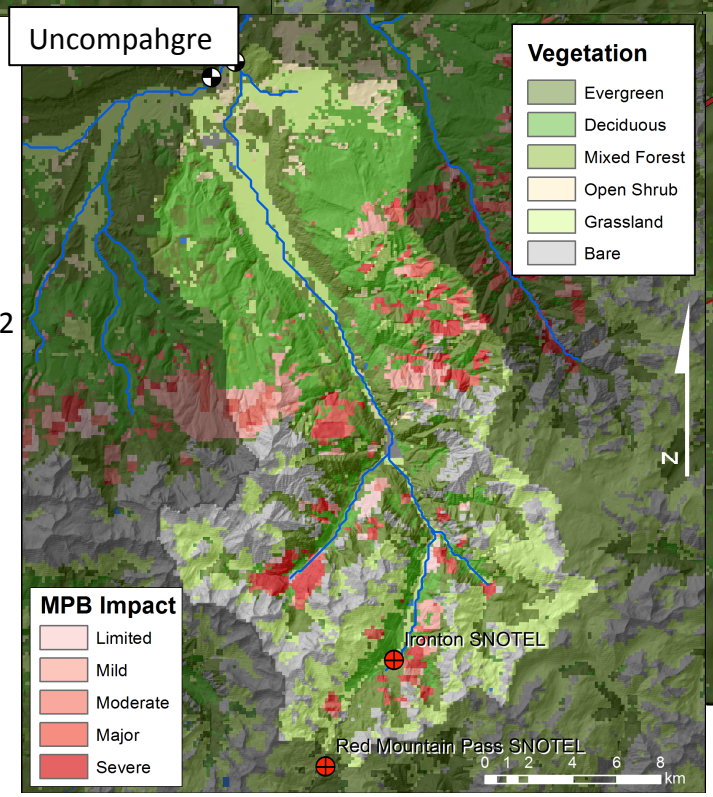
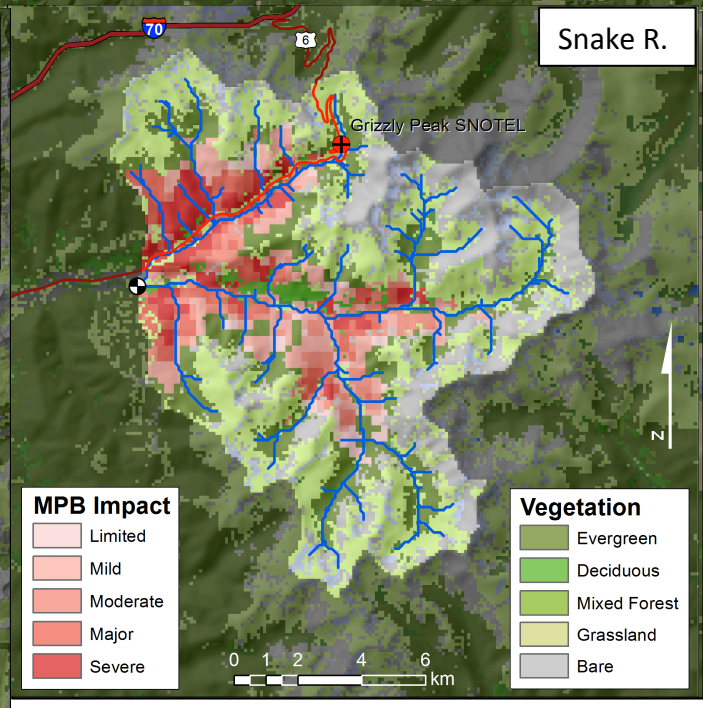
**Severity based on trees killed per acre*





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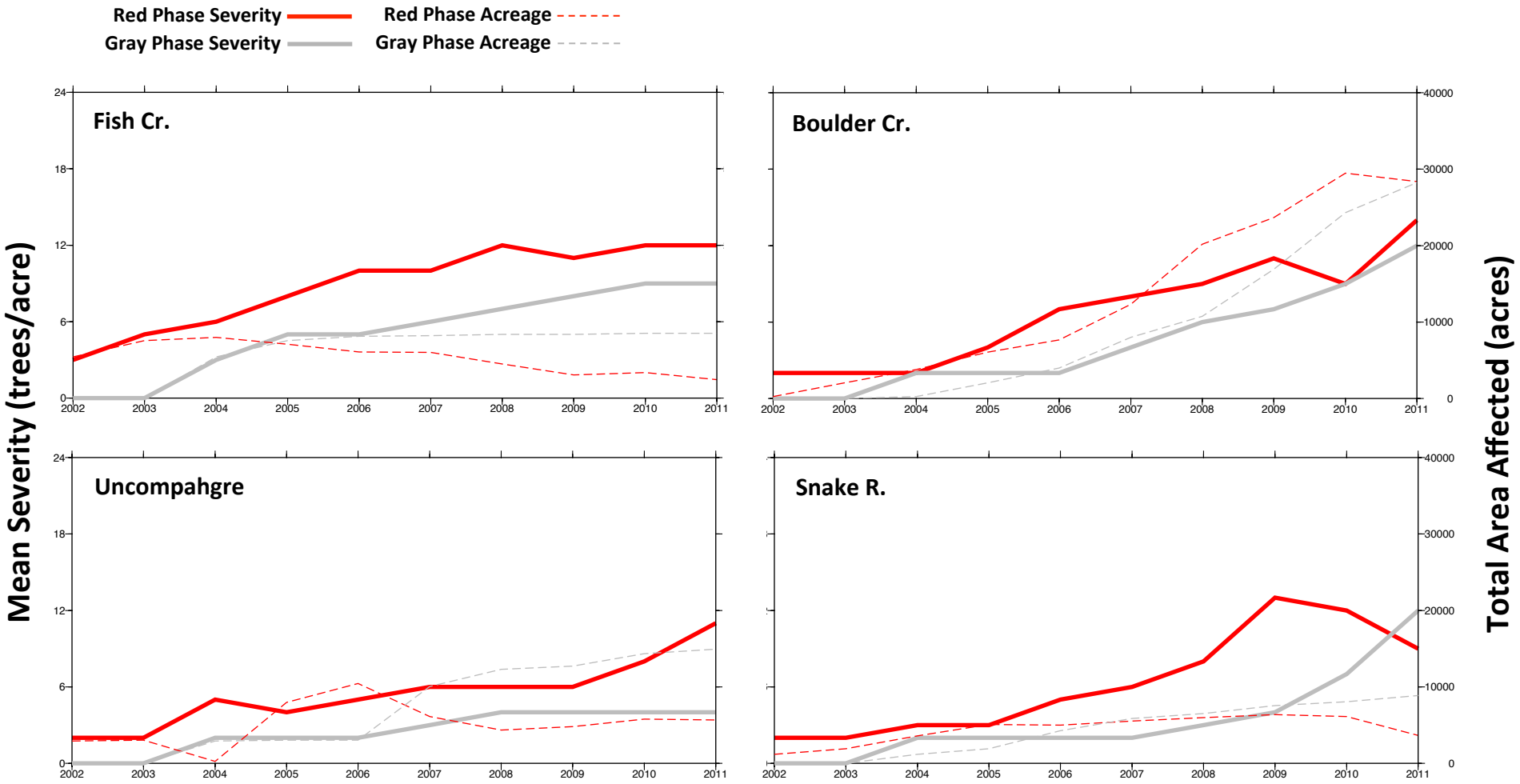
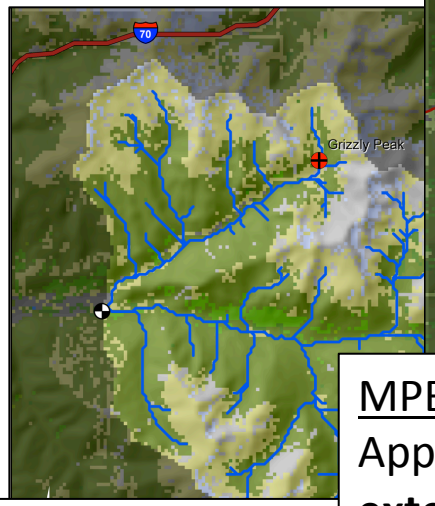
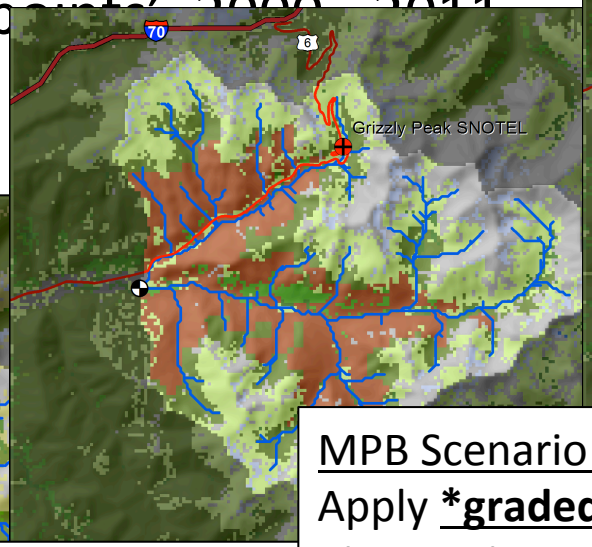
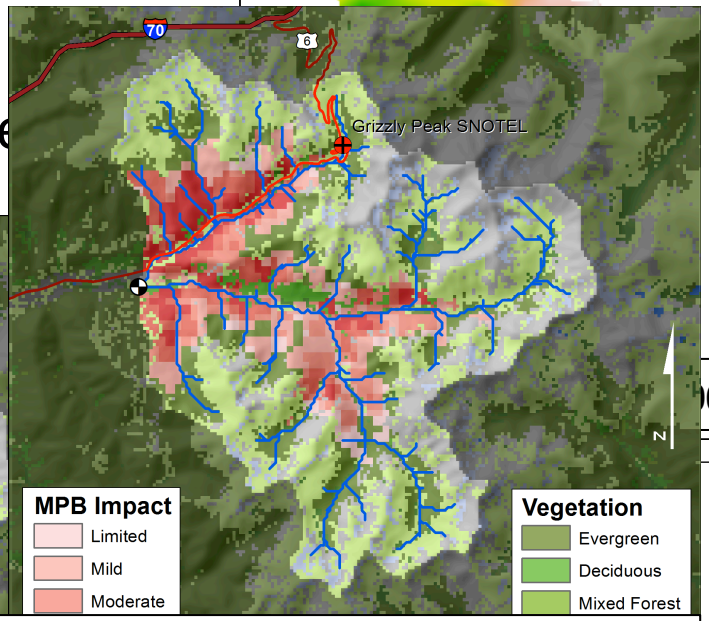

Red Phase Severity
Red Phase Acreage
Gray Phase Severity
Gray Phase Acreage
Fish Cr.
Boulder Cr.
Uncompahgre
Snake R.
Mean Severity (trees/acre)
Total Area Affected (acres)
0
6
12
18
24
0
10000
20000
30000
40000
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011

Example: Snake R.

- Changes in leaf-area index (LAI) used to characterize beetle kill
- Aerial surveys used to define BB exte
- Explore 'end-p







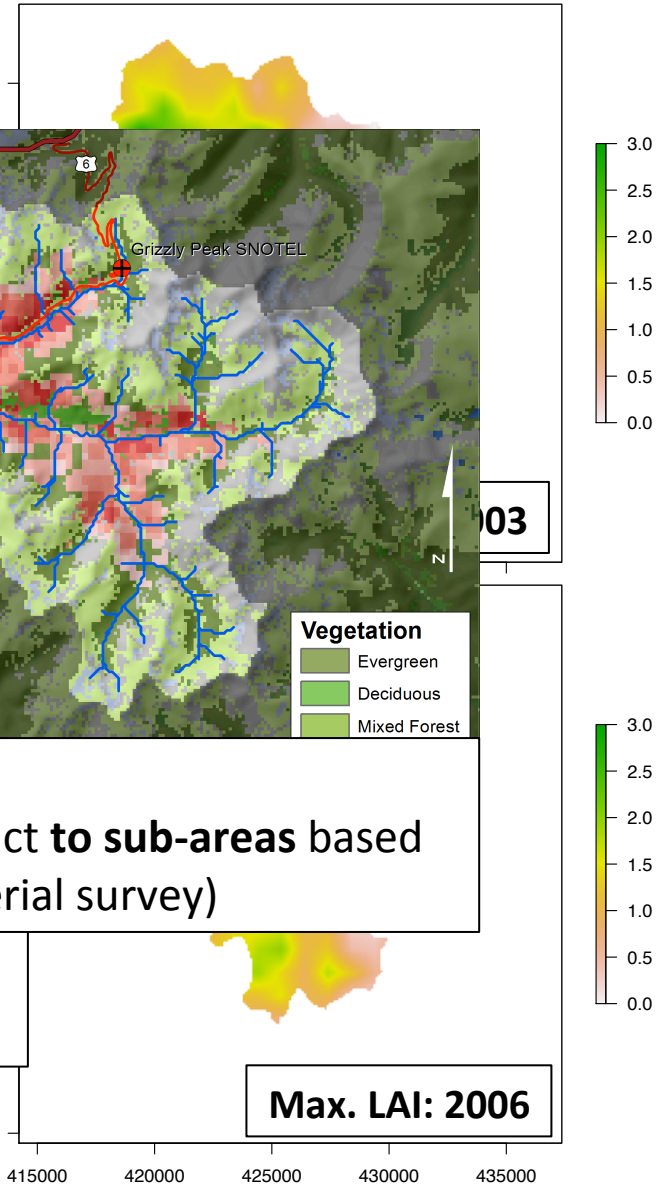
MPB Scenario 3:
Apply ***graded*** BB impact **to sub-areas** based observed BB severity (aerial survey)

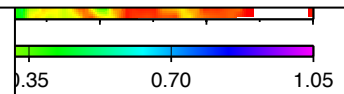
MPB Scenario 2:
Apply **maximum** BB impact to **observed extent** of BB disturbance (aerial survey)

MPB Scenario 1:
Apply **maximum** BB impact to **all Evergreen** areas, reducing canopy LAI

-Courtesy Jeff Deems

500m MODIS satellite imagery (2002-2011)





*Molotch et al., 2010

-Courtesy Brian Buma

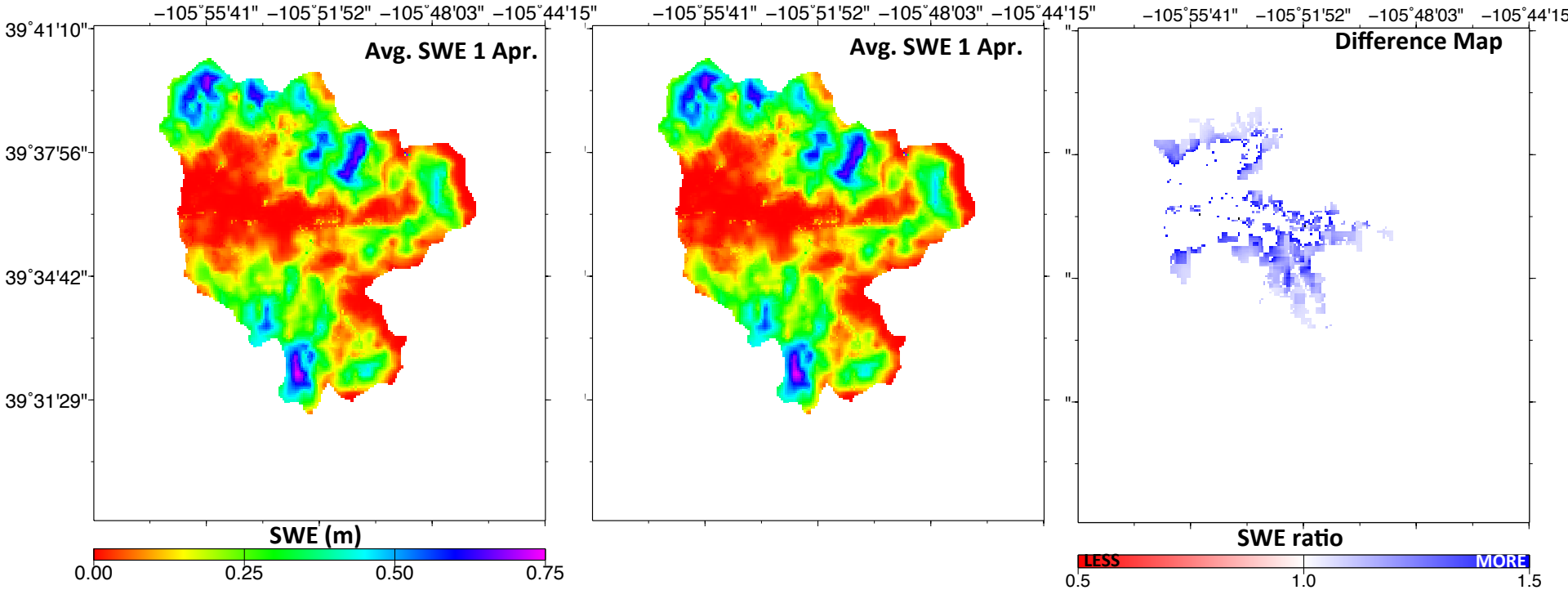
Model Results: Snake R.

- BB leads to higher accumulation of Snow Water Equivalent (SWE) → *reduced canopy interception, sublimation*
- Considerable variation between wet and dry years (<=300%) versus BB impact (<30%)

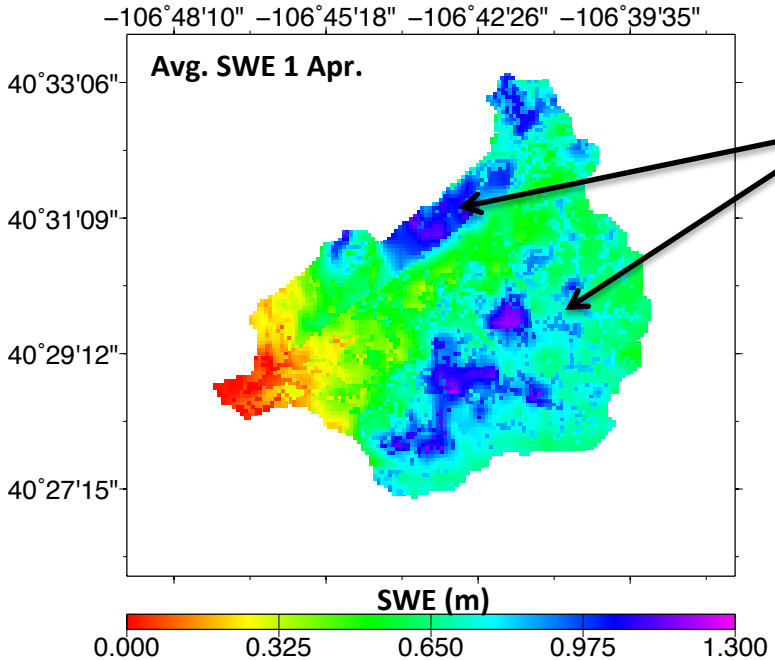
CONTROL: Moderate dust, no beetle impact

Scenario: Graded BB impact

Ratio of graded BB impact to BB-free case

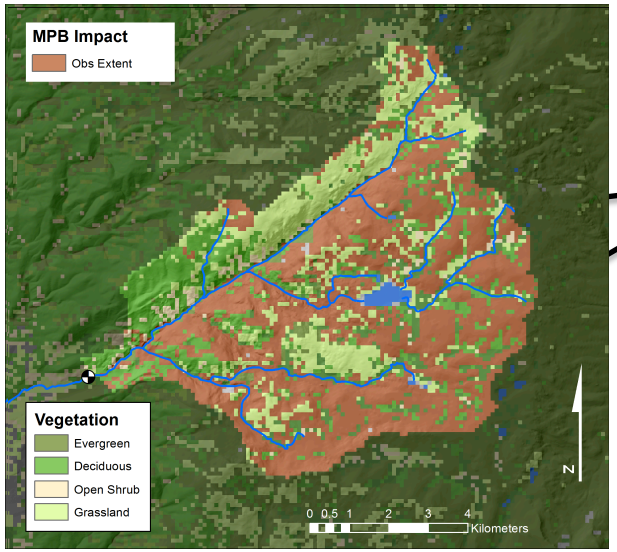


Results: Fish Cr.

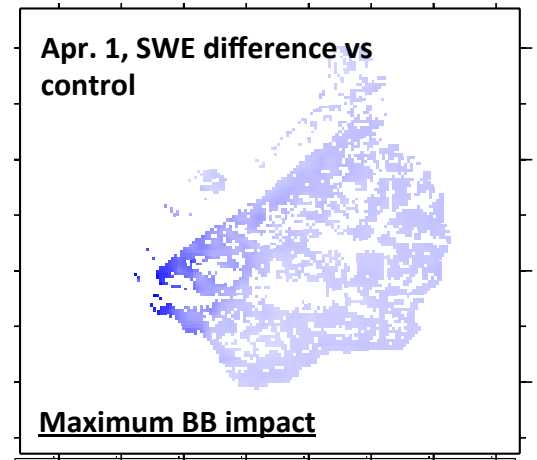


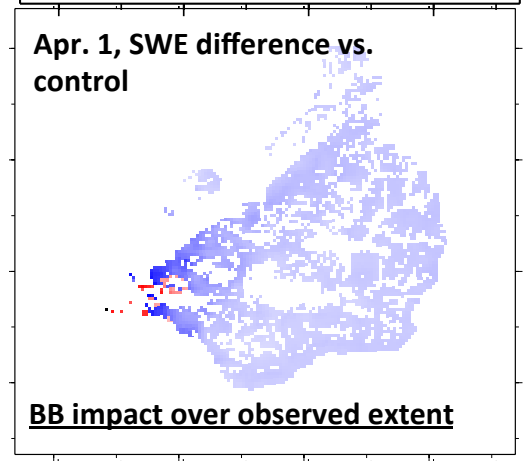
Areas of deep snowpack

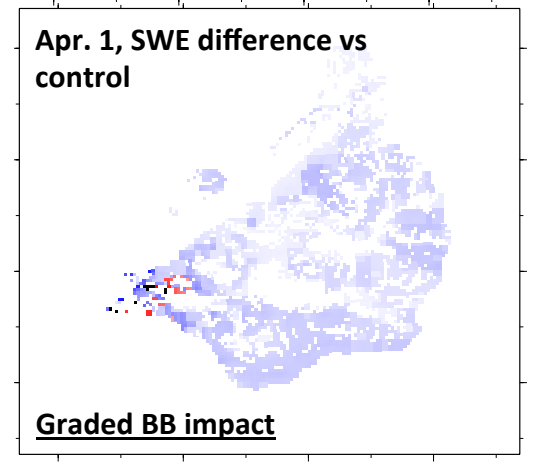
Coincedence is key



Susceptible areas for BB





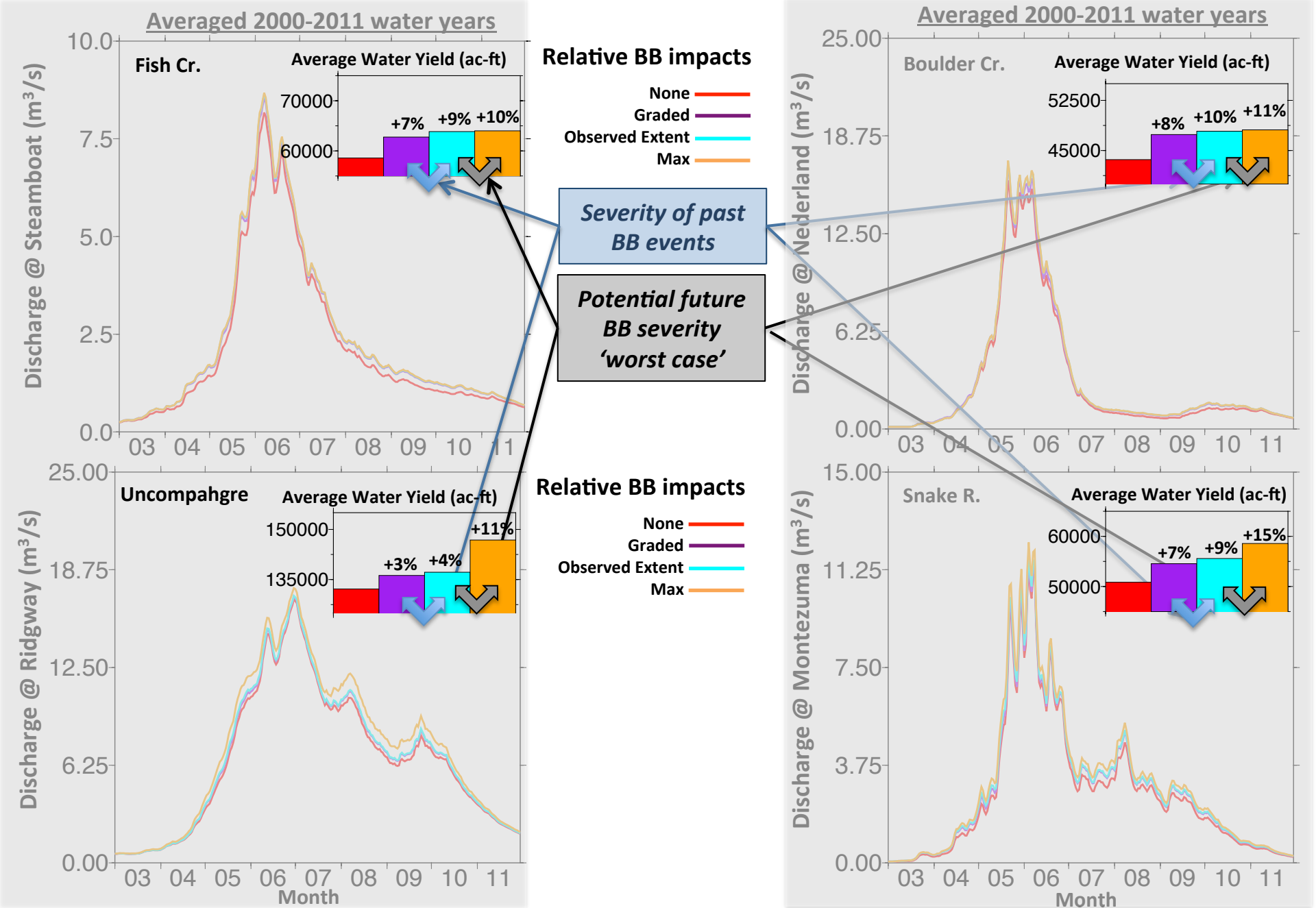


APRIL 1 SWE ratio

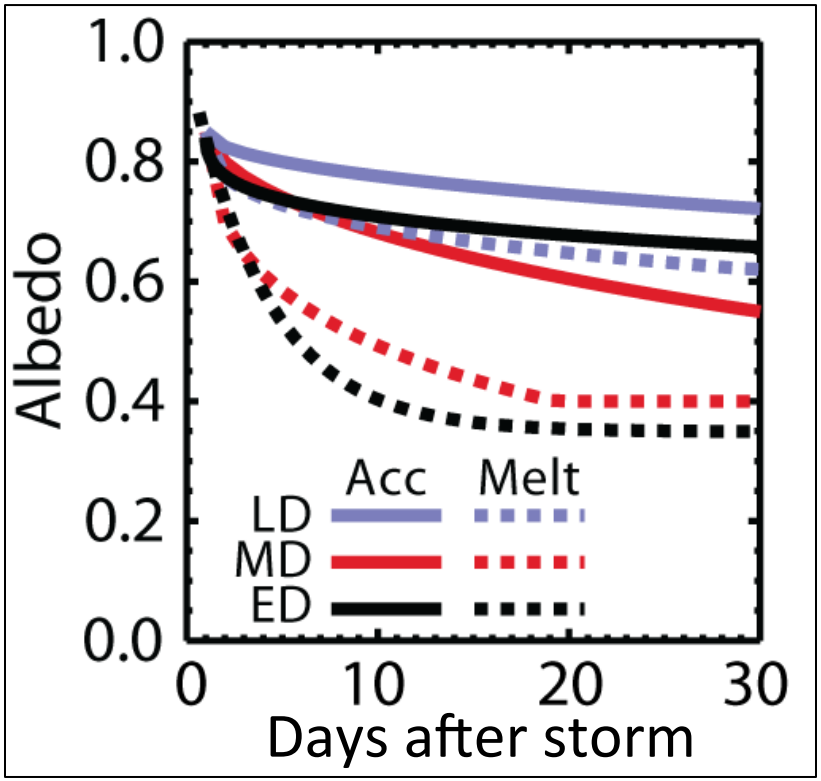
LESS — MORE

0.5 1.0 1.5

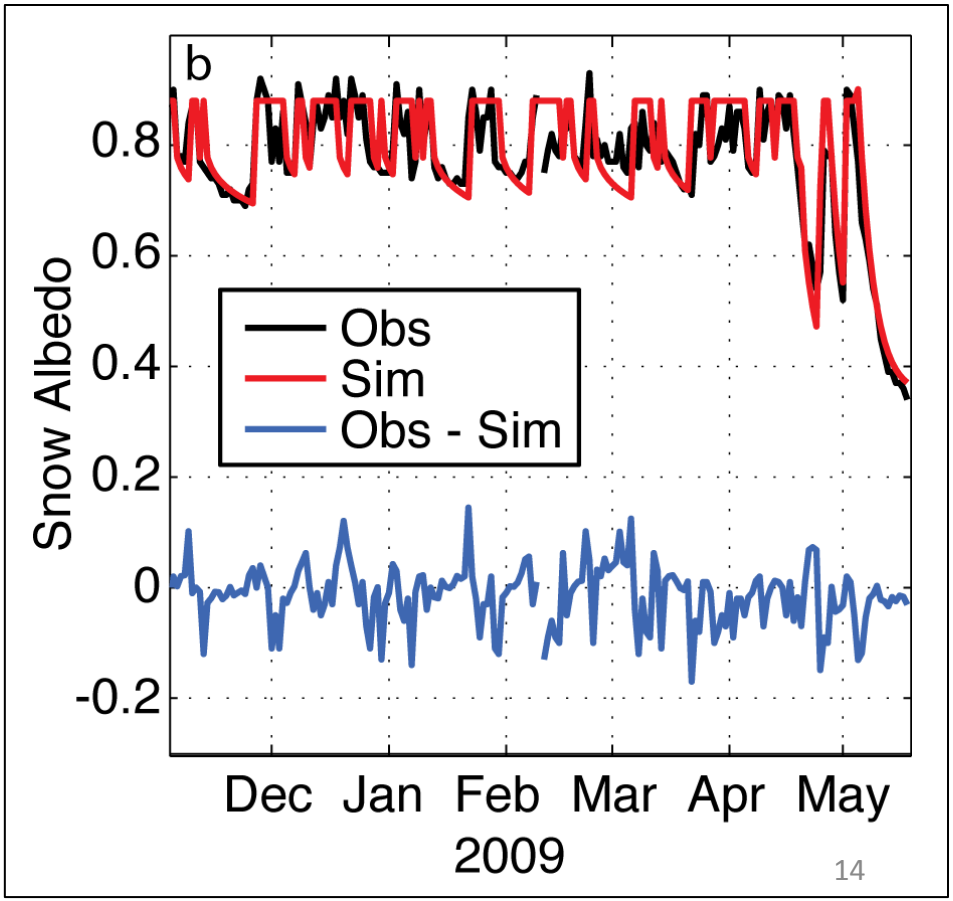
Streamflow Results: BB impacts increase snowmelt runoff (***larger snowpack***), increase warm-season flow (***reduced transpiration***)



Extreme Dust albedo decay curves



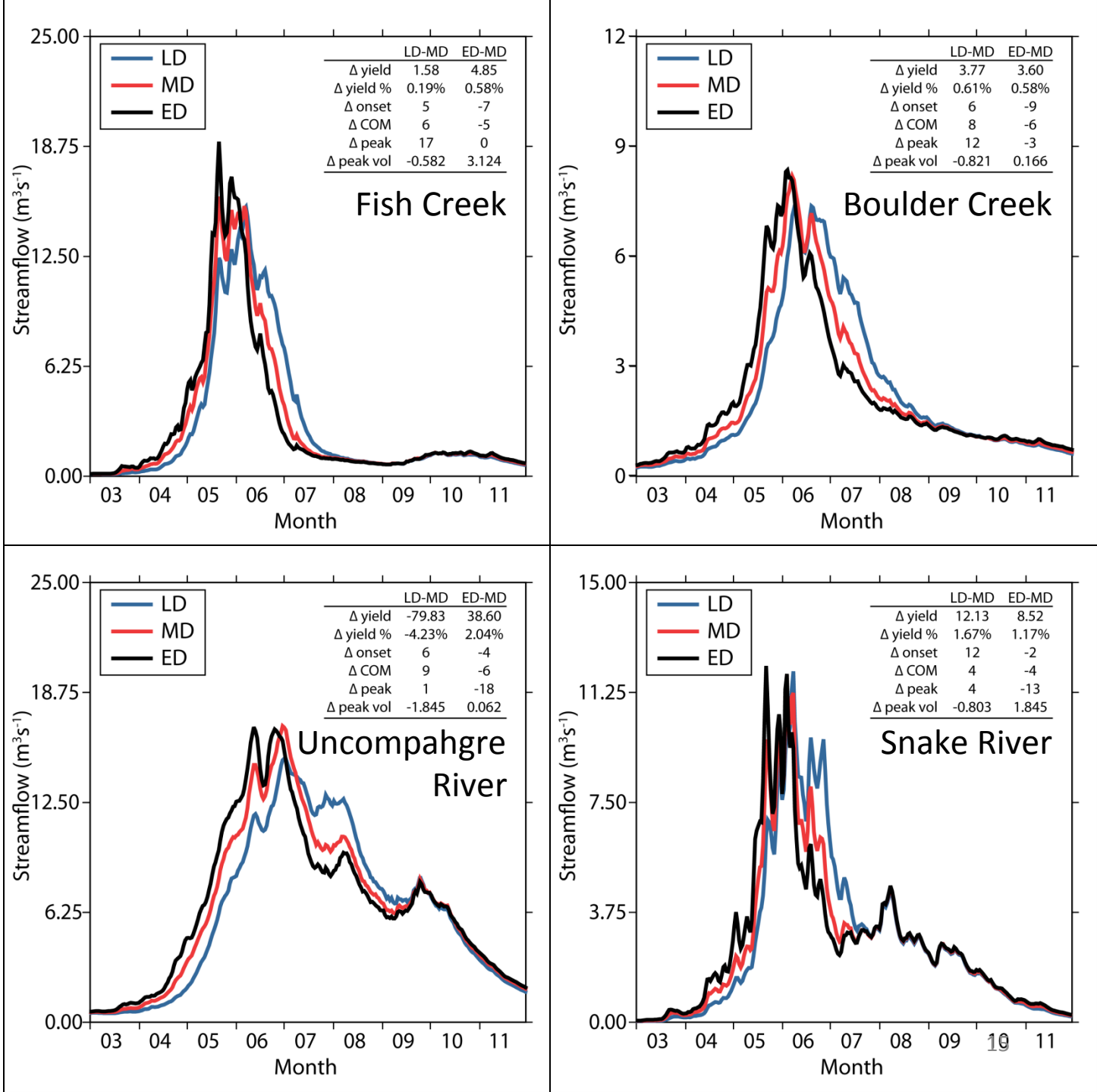
- based on 2009 & 2010 obs
- faster melt season decay
- lower minimum albedo



from Deems *et al.* (*in prep*)

Preliminary Streamflow Results

- Timing of peak flow
  - very sensitive to dust forcing
- Mixed yield response:
  - Increased yield with more dust
  - Δ yields are small relative to variability



courtesy Jeff Deems

Preliminary Conclusions

- BB leads to greater snowmelt runoff (SWE accumulation), and increased warm-season flows (reduced transpiration)
- Bulk sensitivities show reduction of canopy cover increases water yield 3% - 15 % depending on location, severity and timing of impacts << climatic variability
- Work in progress: Currently examining annual BB progression; individual dust years

Thank you!

- Contact: ben.livneh@colorado.edu