Beetles, dust, snow, & climate change:

Unraveling drivers of snowmelt in the Intermountain West

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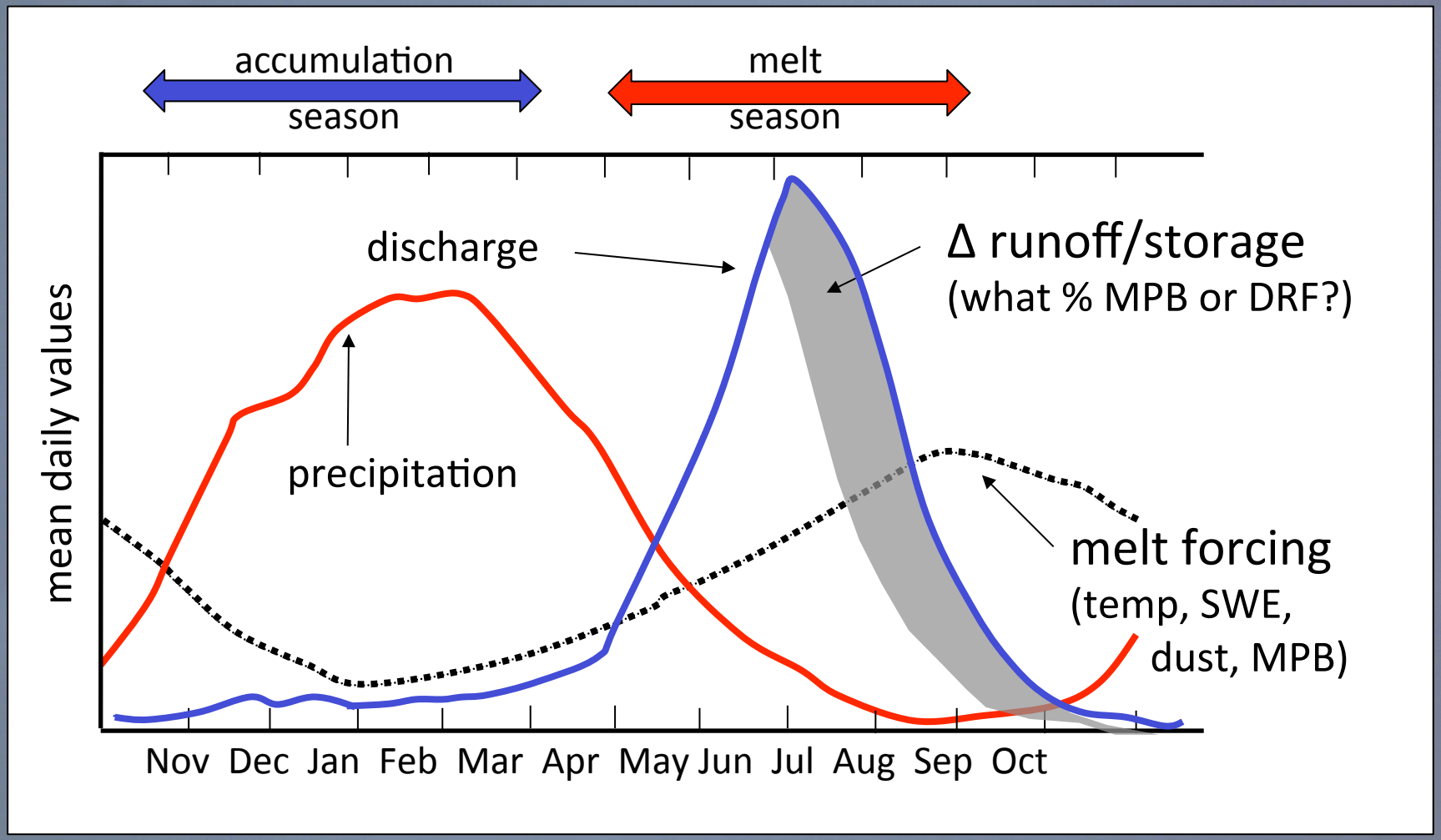
Western Water Assessment

Project Objectives

- Assess influence of snowmelt perturbations on streamflow timing & magnitude
  - Dust
  - MPB
  - Wx/SWE anomalies
- Quantify the relative impacts of these perturbations on snowmelt timing

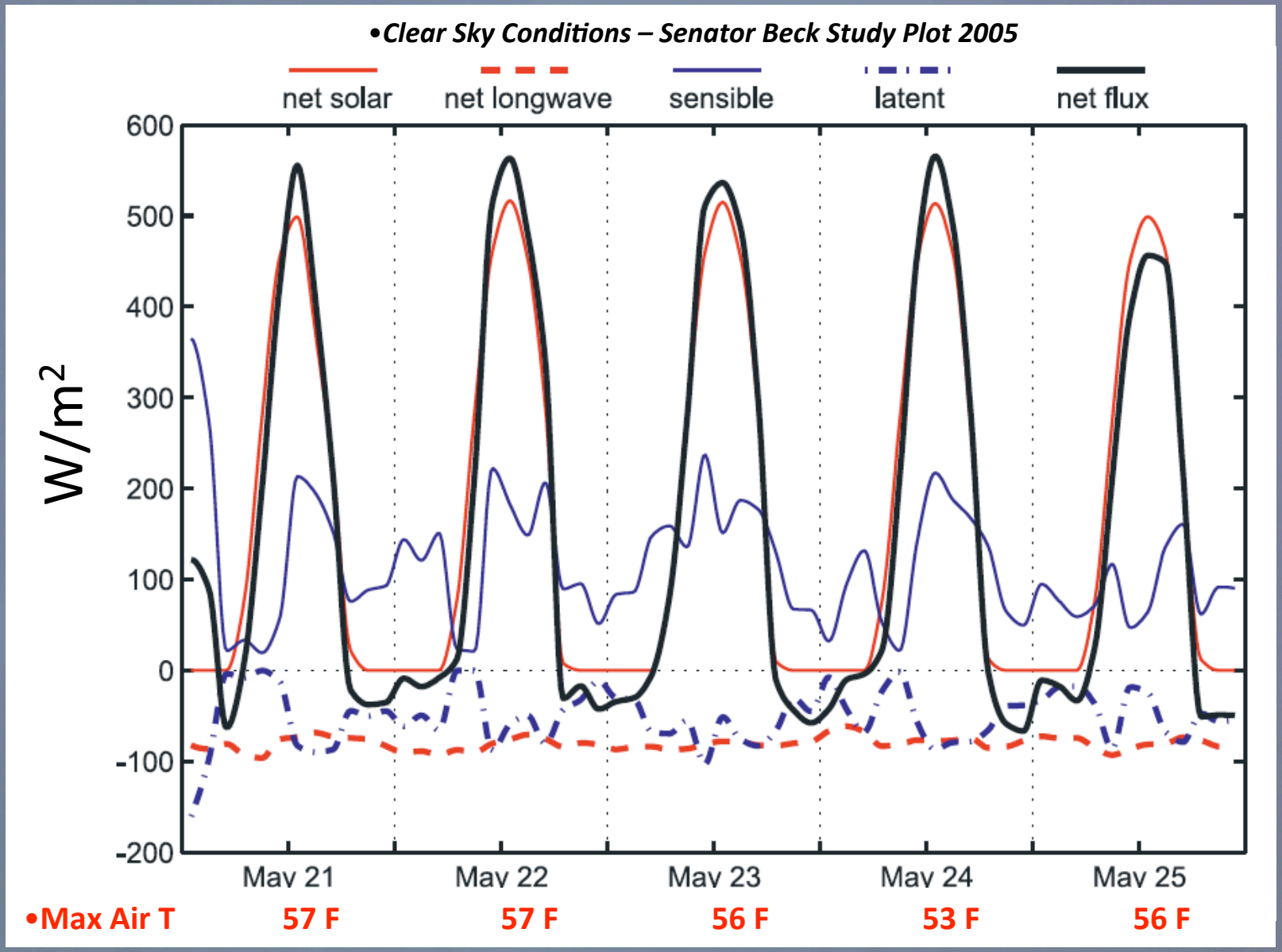
Photo: Bruce Thomson

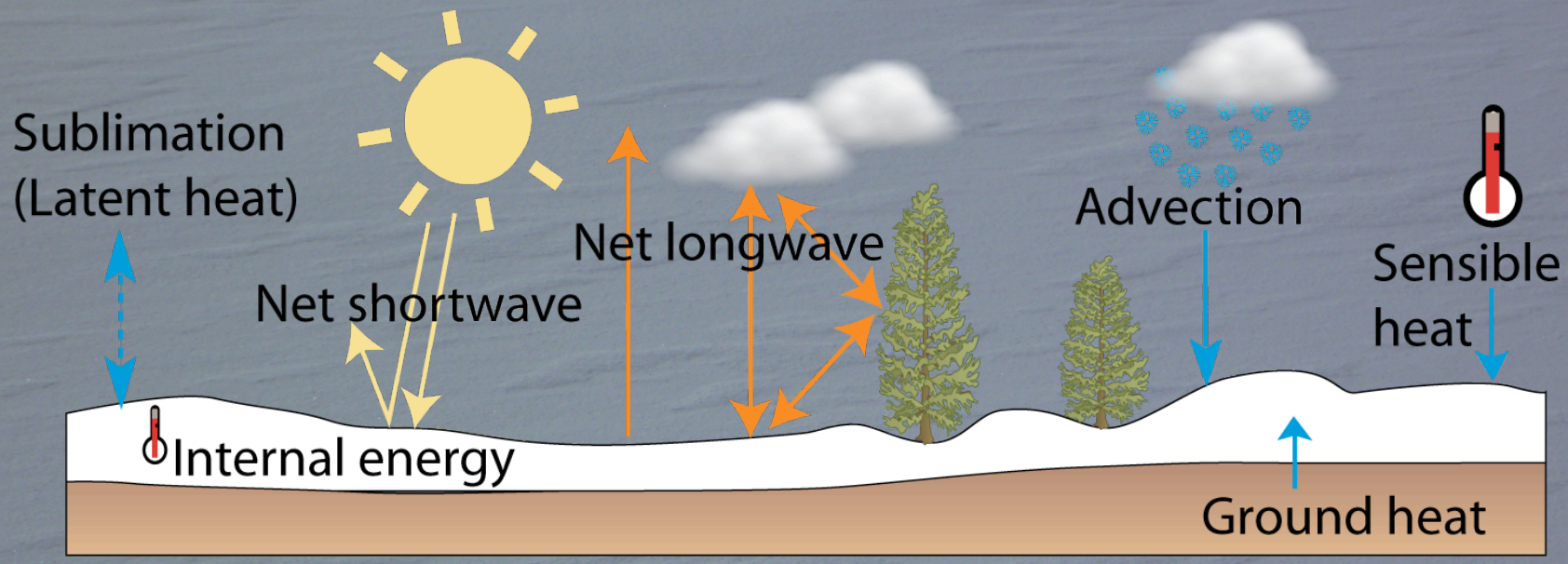
The snowmelt hydrograph



adapted from *Peterson et al., 1997*

Solar energy melts snow in open settings





$$Q_m + \frac{dU}{dT} = (1-\alpha)S + L^* + Q_s + Q_v + Q_a + Q_g$$

Change in internal energy

Melt energy

Albedo

Shortwave radiation

Net Longwave radiation

Sensible heat

Latent heat

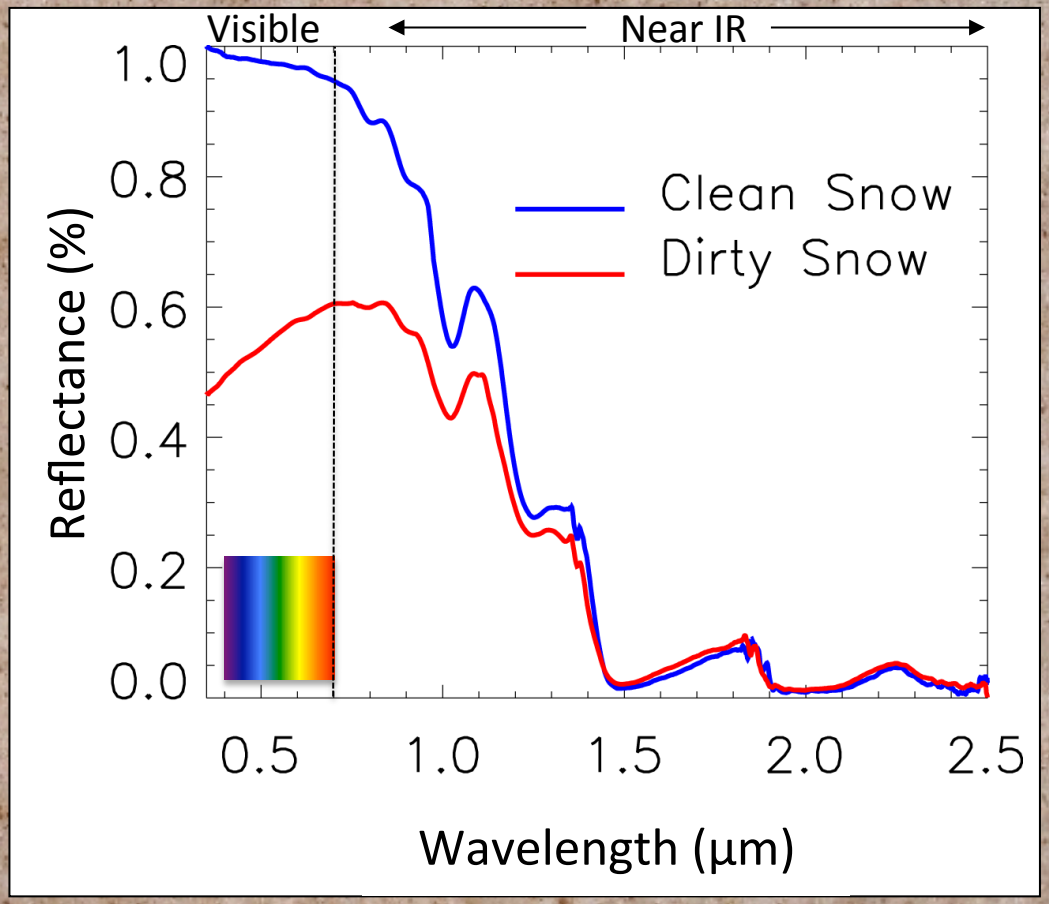
Advection

Ground heat

Goodwin-Greene Hut
near Aspen
April 3, 2009

near Goodwin-Greene Hut
April 4, 2009
April 3
March 29
March 22
b) Alta 30 Apr 2000
Steenburgh *et al.* (*in prep*)

dust decreases snow albedo

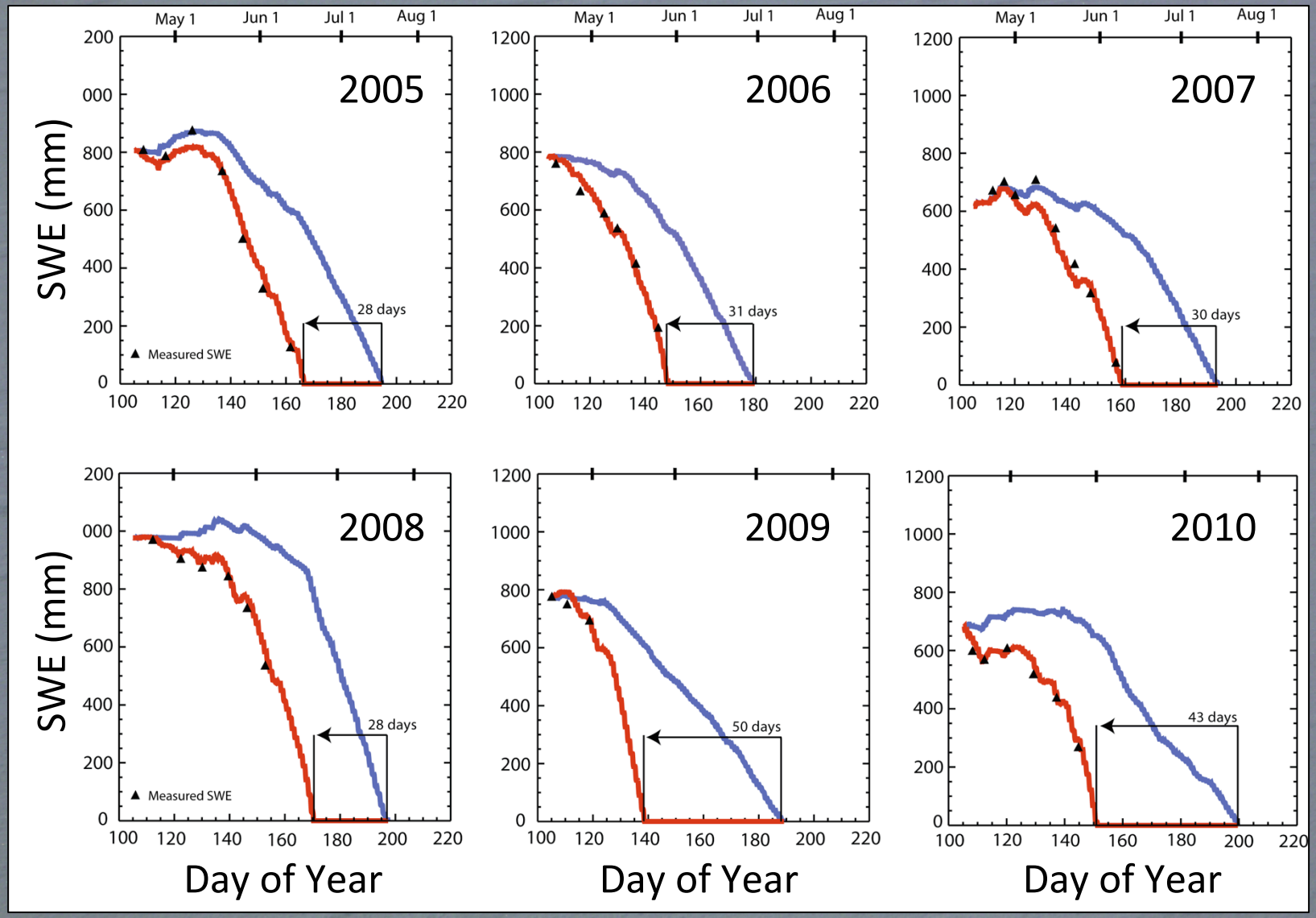


dusty snow surface, May 2009

photo courtesy Tom Painter

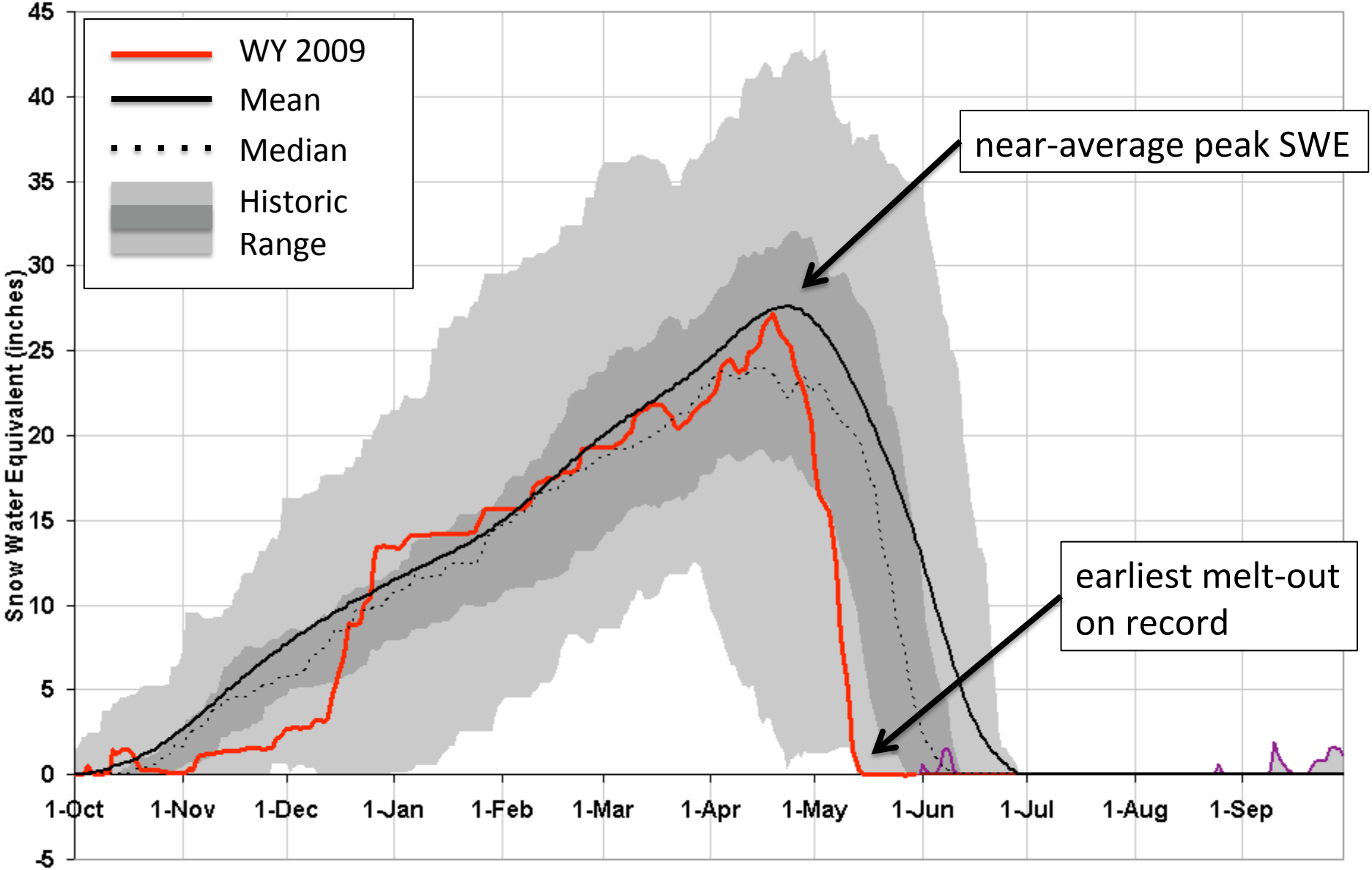
dust enhances snowmelt

Swamp Angel Study Site: observed & modeled SWE



Skiles *et al.* (*in prep*)

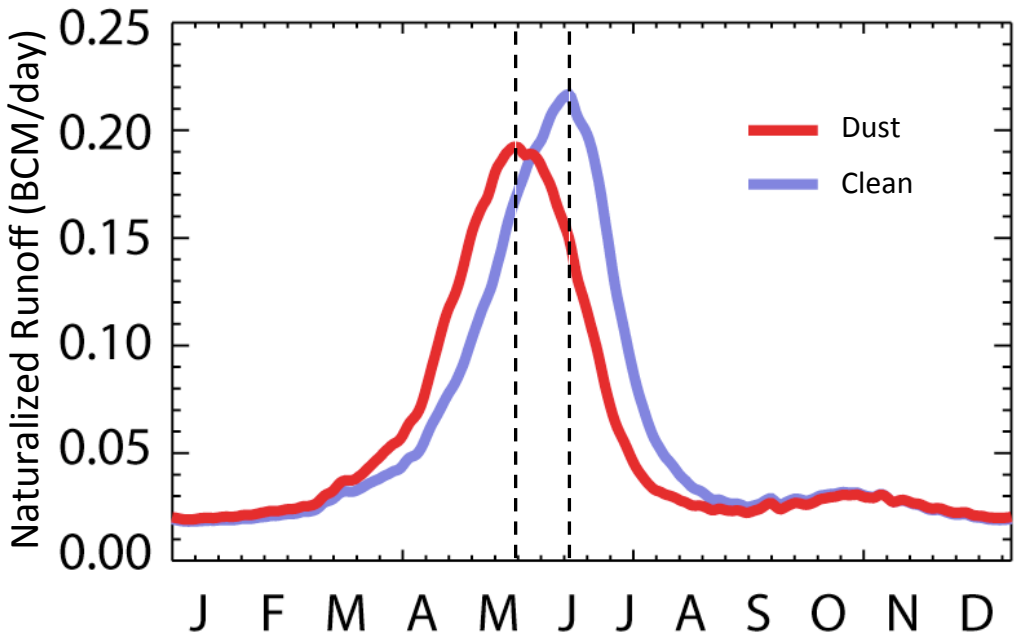
Beartown SNOTEL, Rio Grande Headwaters, 2009

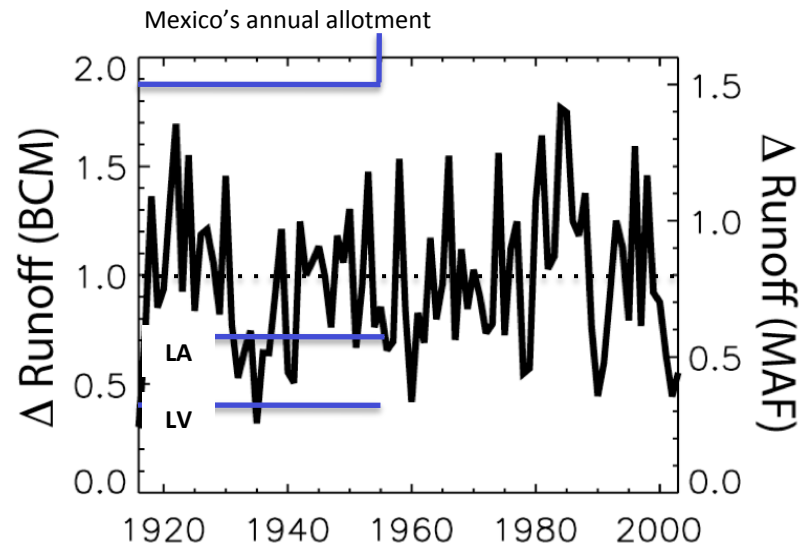


NRCS

Response of Colorado River runoff to dust radiative forcing in snow

Thomas H. Painter[a,b,1], Jeffrey S. Deems[c,d], Jayne Belnap[e], Alan F. Hamlet[f], Christopher C. Landry[g], and Bradley Udall[d]





Present dusty conditions:

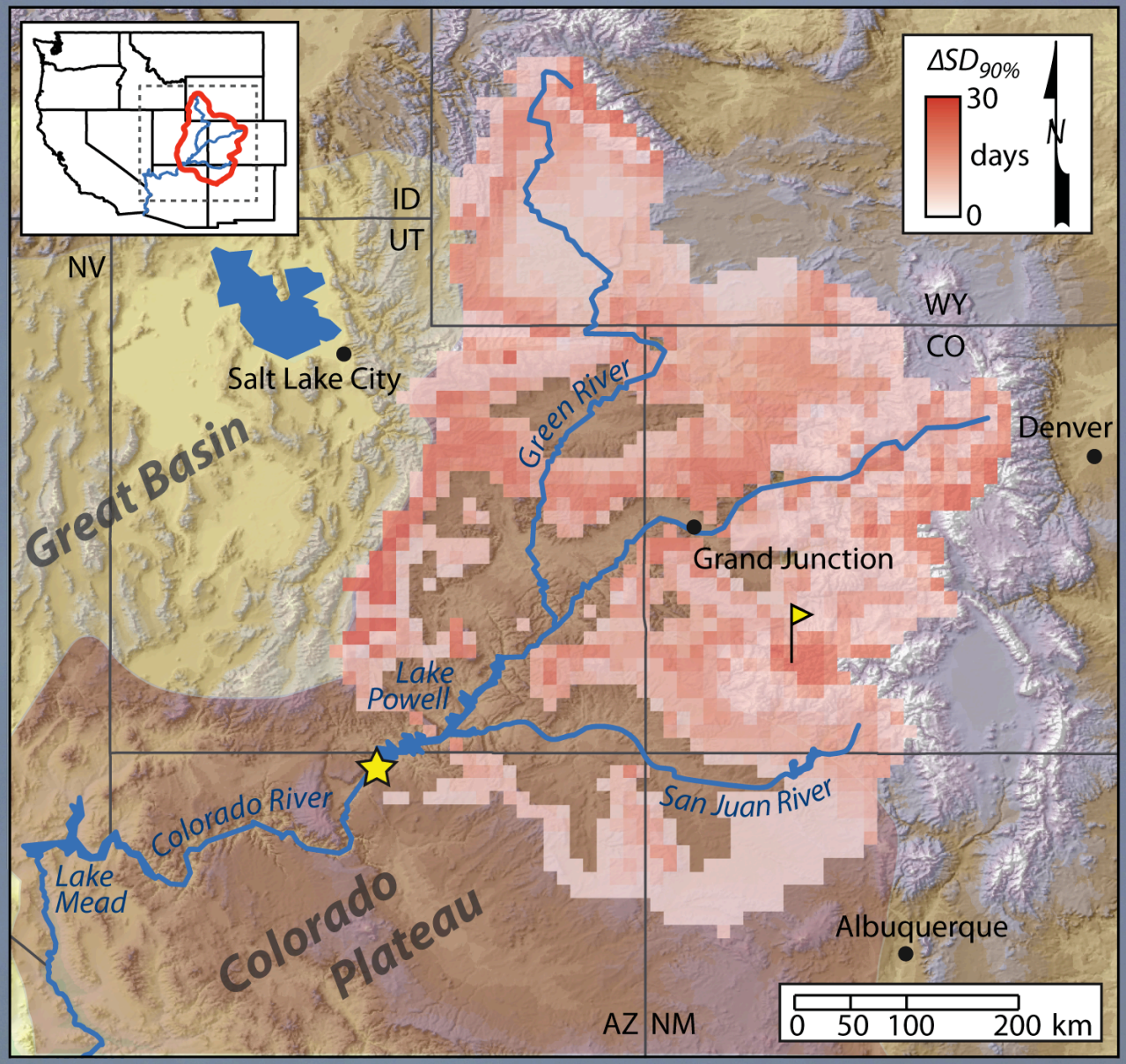
- 3 week earlier peak
- Steeper rising limb
- 5% less annual runoff

5% is:

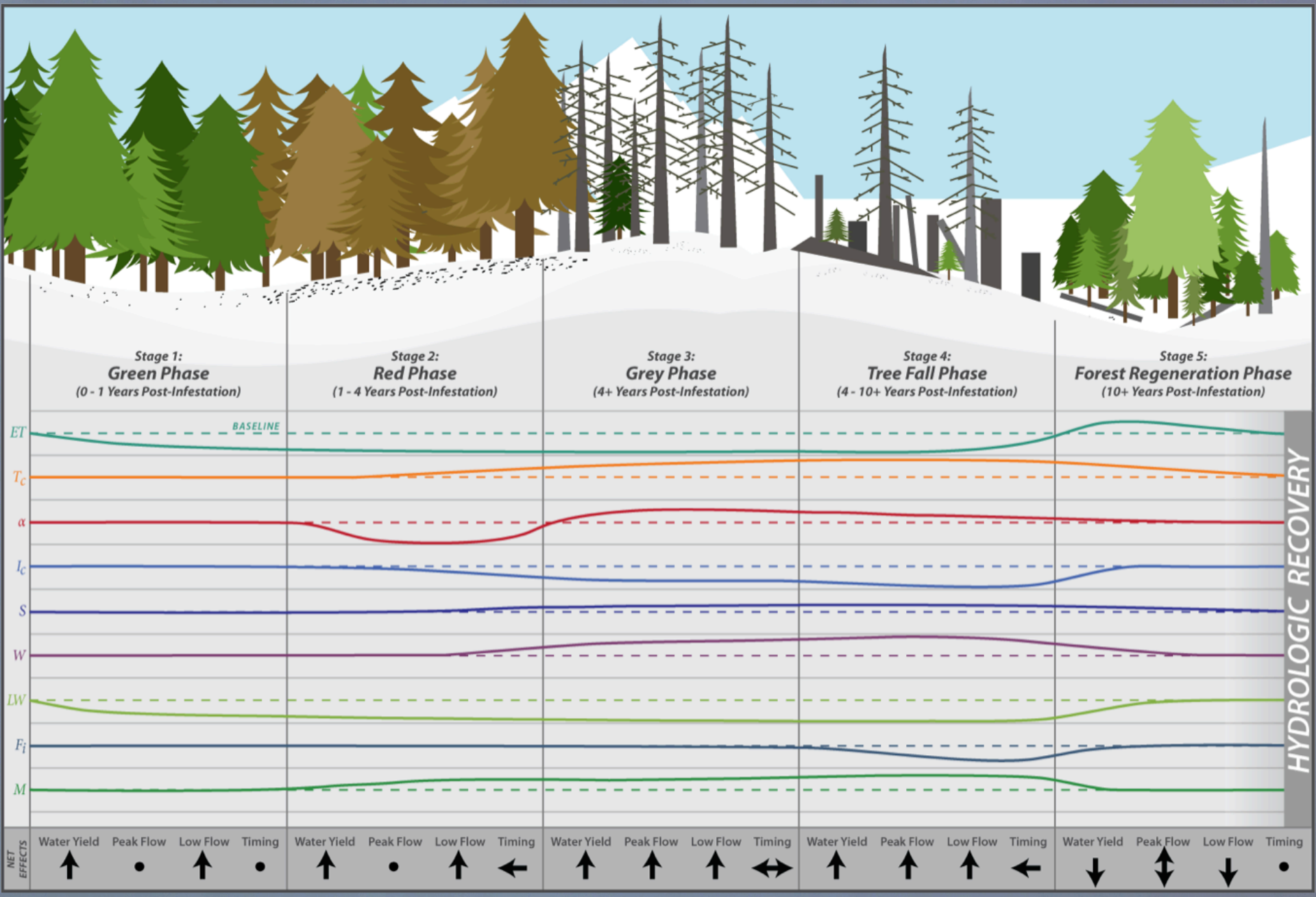
- 2x Las Vegas' allocation
- 18 months of L.A.'s use
- ½ Mexico's allocation

Dust changes melt-out dates basin-wide

** Based on pre-2009 dust loading.*



Painter, Deems, *et al.*, *PNAS* (2010)



Gordon & Pugh (*submitted to Hydrological Processes*)

Scenario Analysis

- In UCRB / Platte Domain: 4 basins with varying MPB impacts
  - Fish Creek (Yampa basin)
  - Snake River (Blue basin)
  - Boulder Creek (Platte basin)
  - Uncompaghre (Gunnison basin)
- Over 10-year MODIS record, explore relative impacts of different perturbations on discharge
  - varying dust impacts
  - varying interannual precip/SWE
  - sensitivity to forest cover change

Data Sets & Models

- ***Distributed Hydrologic Model (DHSVM)***
  We plan to use the *Distributed Hydrologic, Soil, Vegetation Model* to simulate the water and energy balance across the domain at high spatial and temporal resolution (150 m; 3 hour)

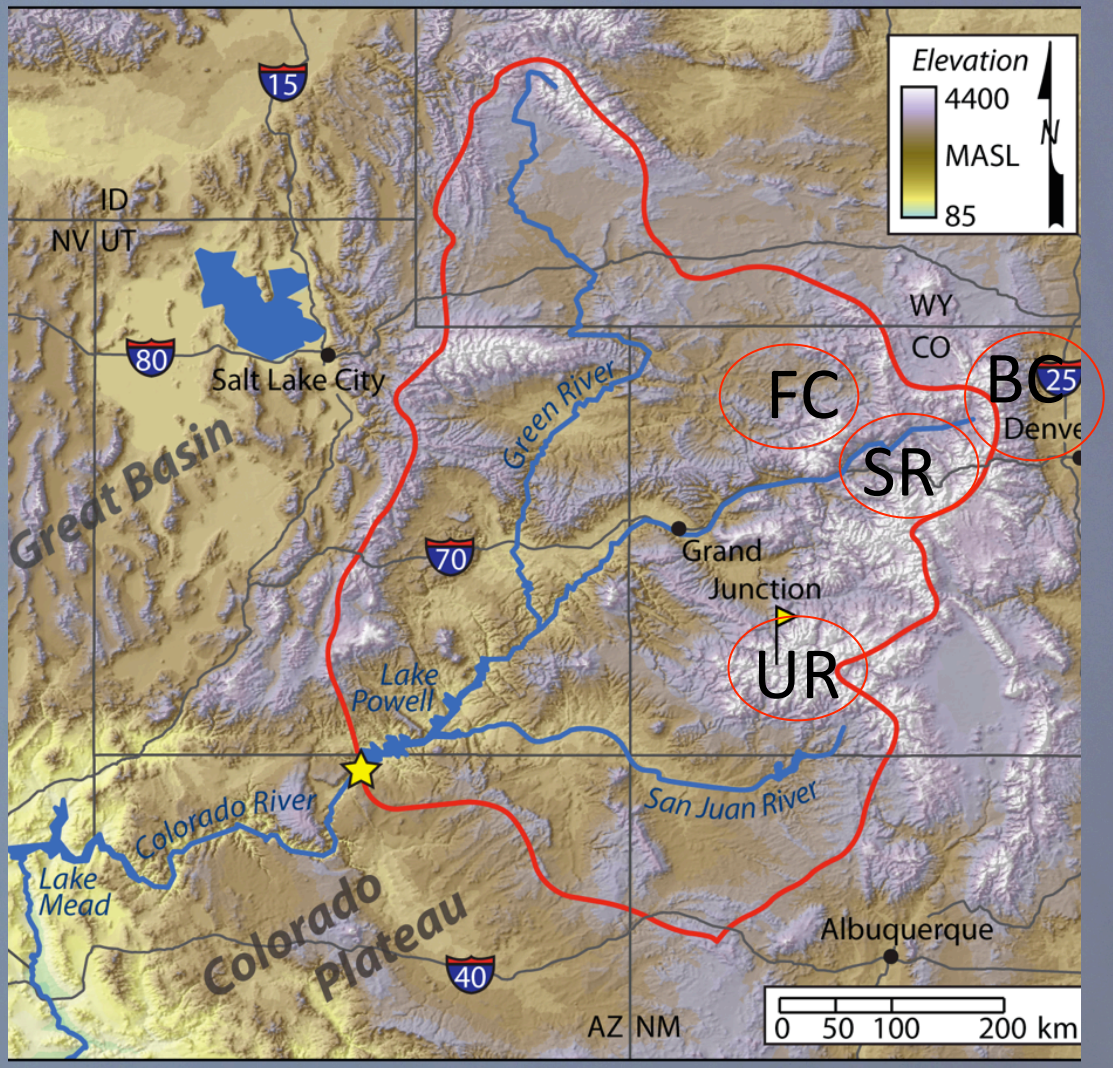
- ***Mountain Pine Beetle***
  MODIS NDVI (250 m resolution, 2000 to present) and USFS aerial surveys of forest health (1996 to present) used to produce forest phenology and estimates of forest cover model parameters (LAI, albedo, cover fraction)

- ***Dust Radiative Forcing***
  Maps of dust radiative forcing (from Co-I Painter's MOD-DRFS product) will be produced for the model time period (the MODIS period of record: 2000-current)

- ***SWE Distribution Anomalies***
  Daily SWE distribution and SWE anomalies (2000 – present) across the UCRB and neighboring headwater catchments will be produced using Molotch reconstruction method

Study basins

- Fish Creek (Yampa River Basin)
  - Storm Peak Lab
  - Zirkel studies / CLPX
- Snake River (Upper Colorado)
  - Denver Water
- Boulder Creek (Upper South Platte)
  - NWT / CZO
- Uncompaghre River above Ridgeway Dam (Gunnison)
  - CSAS/SBB



DHSVM land surface hydrology model

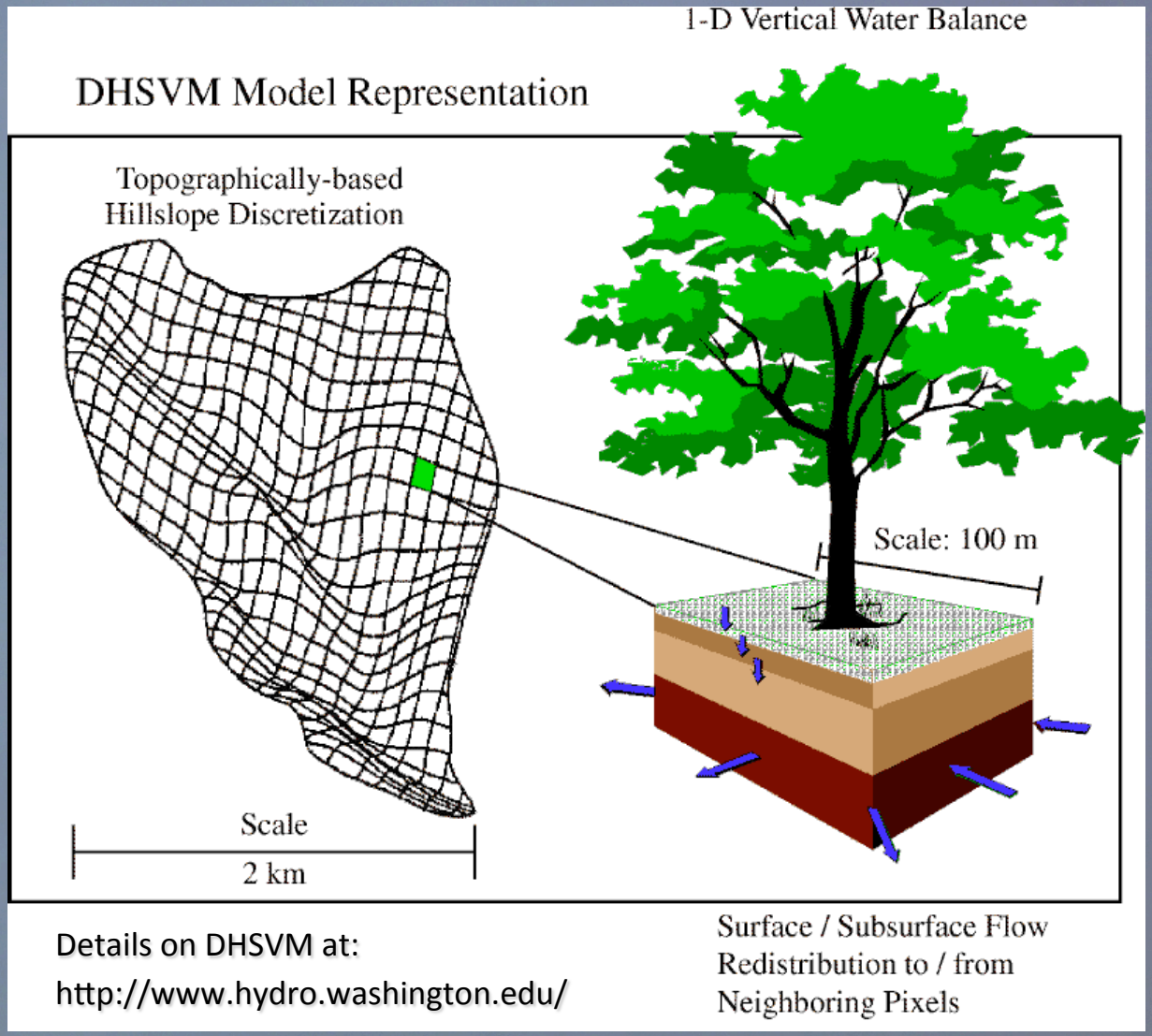
Physically-based, distributed model

Solves water & energy balance at each grid cell at each time step

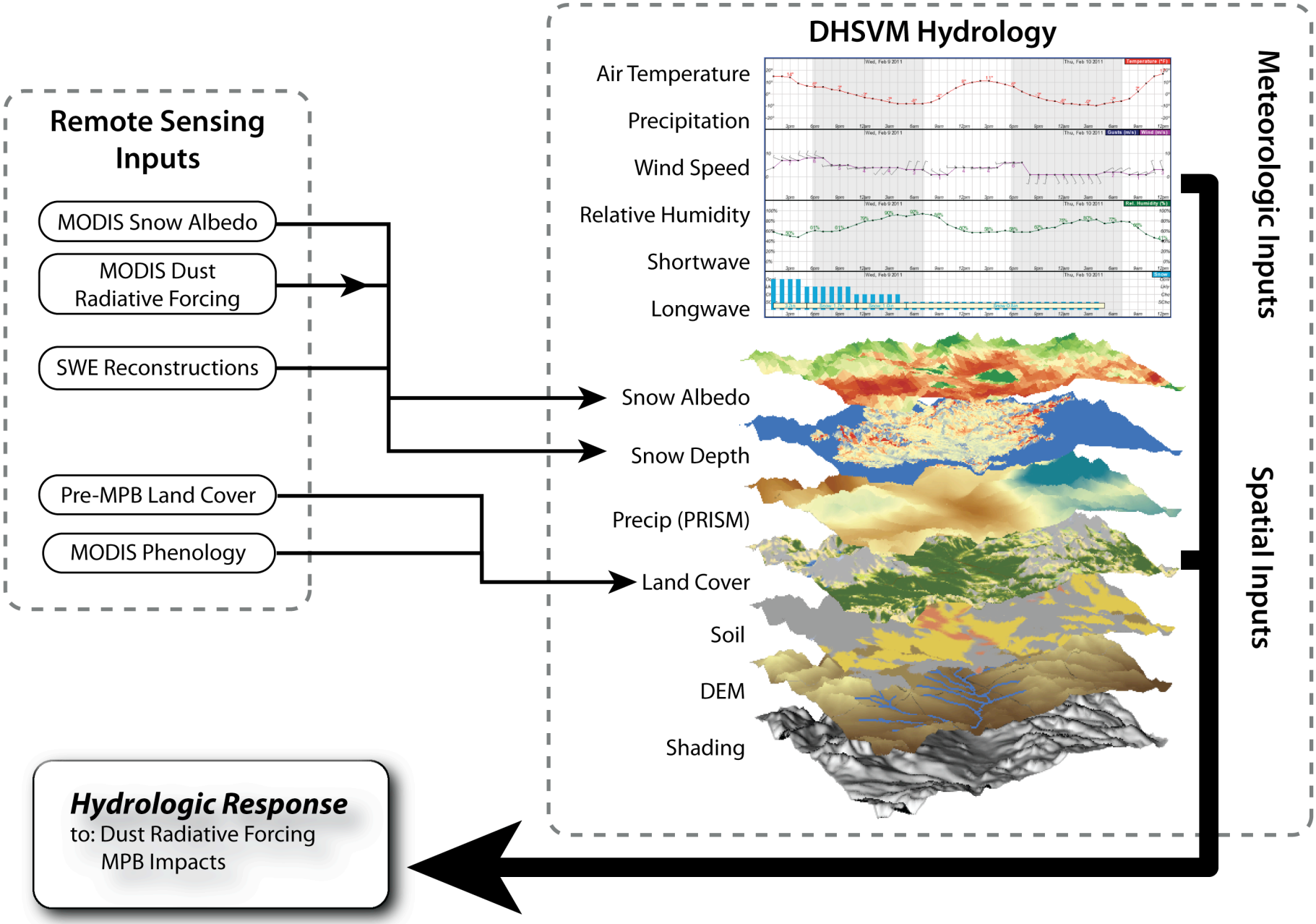
Integrated routing

Horizontal scales typically 30 - 150m

Designed for and extensively tested in complex terrain



Details on DHSVM at:
http://www.hydro.washington.edu/


Remote Sensing Inputs
MODIS Snow Albedo
MODIS Dust Radiative Forcing
SWE Reconstructions
Pre-MPB Land Cover
MODIS Phenology
DHSVM Hydrology
Air Temperature
Precipitation
Wind Speed
Relative Humidity
Shortwave
Longwave
Snow Albedo
Snow Depth
Precip (PRISM)
Land Cover
Soil
DEM
Shading
Meteorologic Inputs
Spatial Inputs
Hydrologic Response
to: Dust Radiative Forcing
MPB Impacts

Expected Deliverables

Provide stakeholders with more information to diagnose forecast errors

Work with CBRFC to evaluate snowmelt rate parameters

Evaluate retrospective examples based on stakeholder needs.

Provide data sets to stakeholders based on various forcings and model outputs

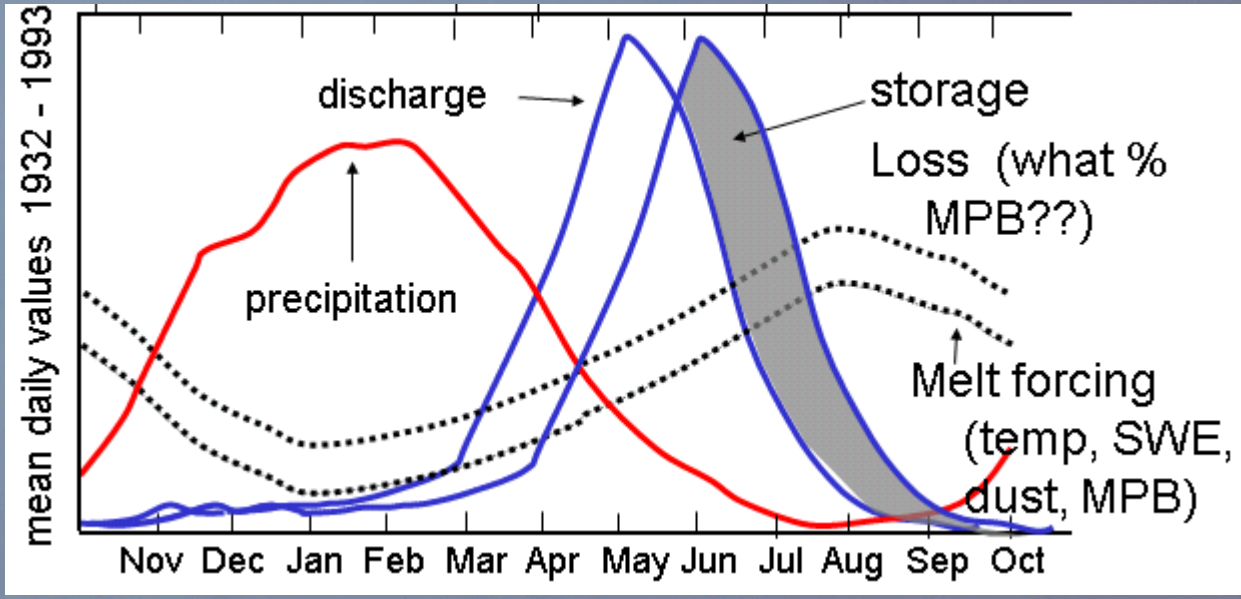
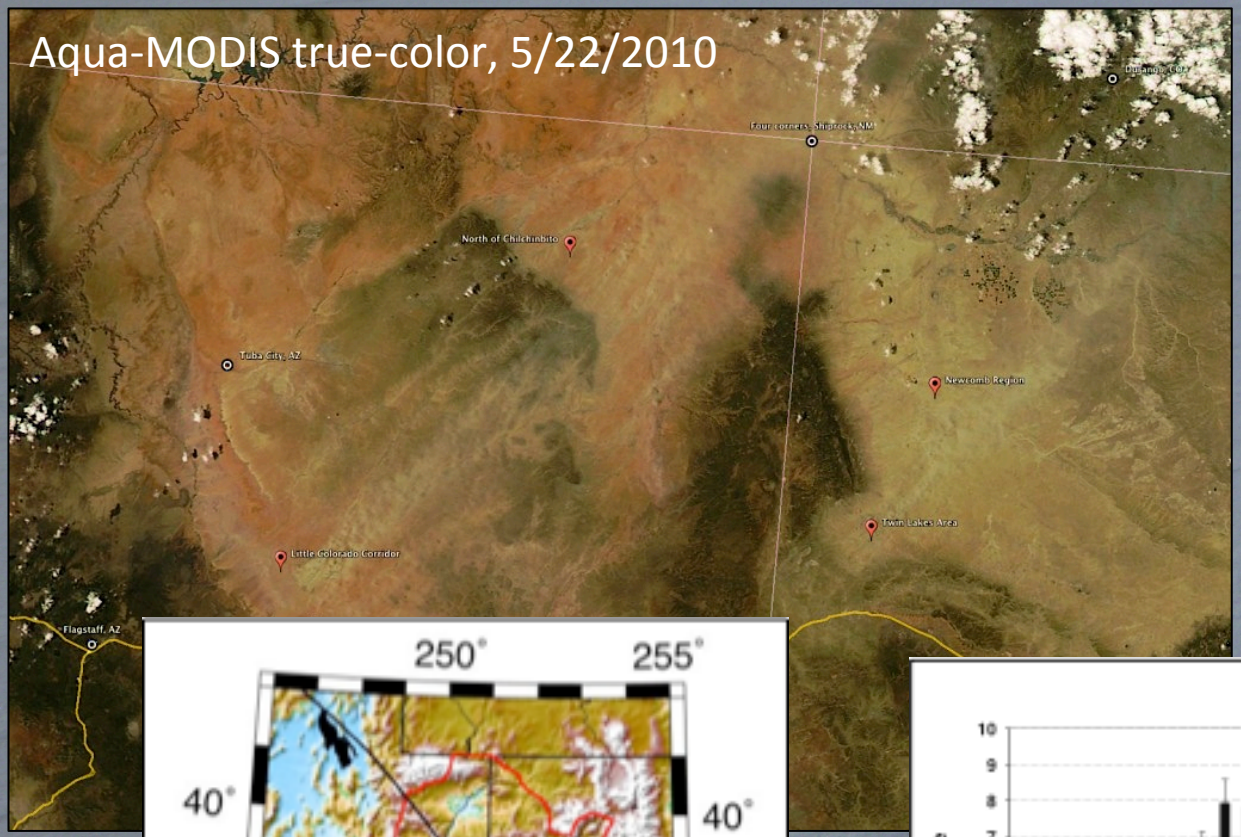
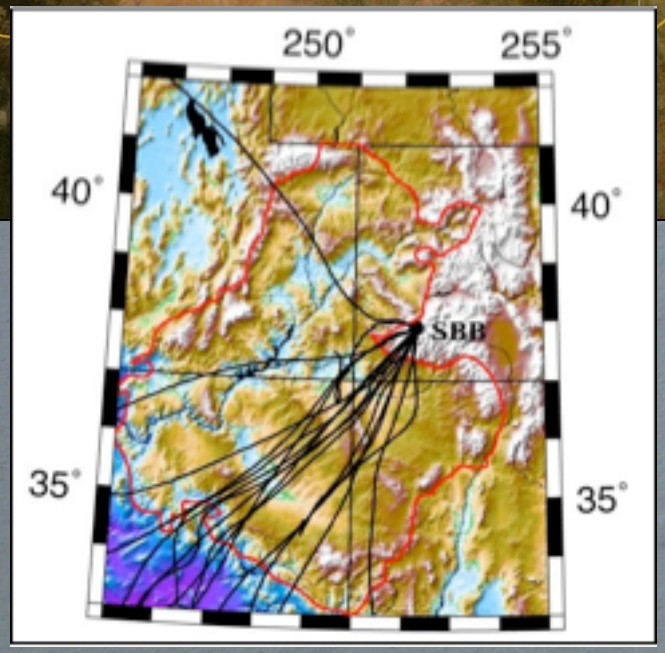


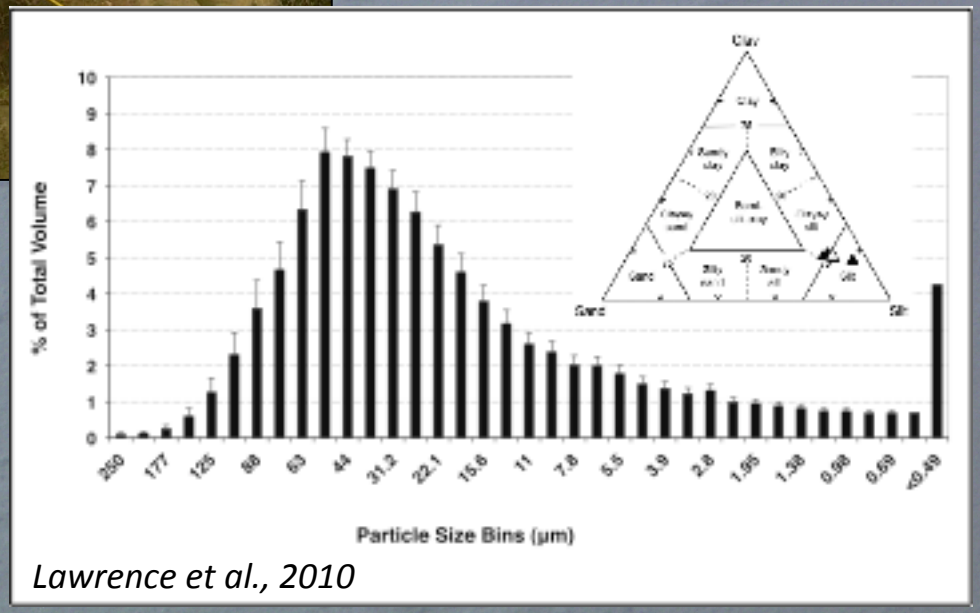
photo courtesy Chris Landry, CSAS

Extra slides…

regional dust sources

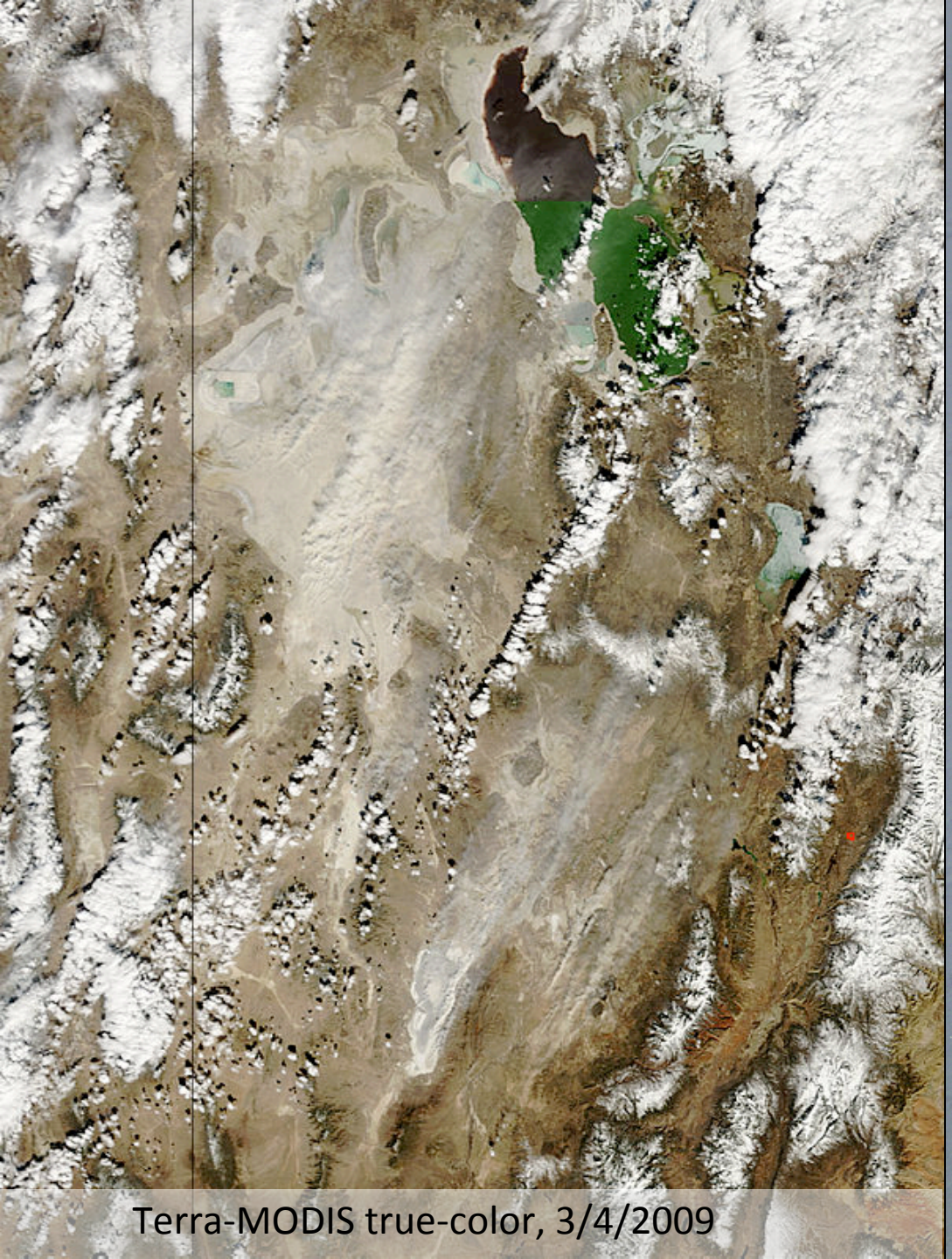






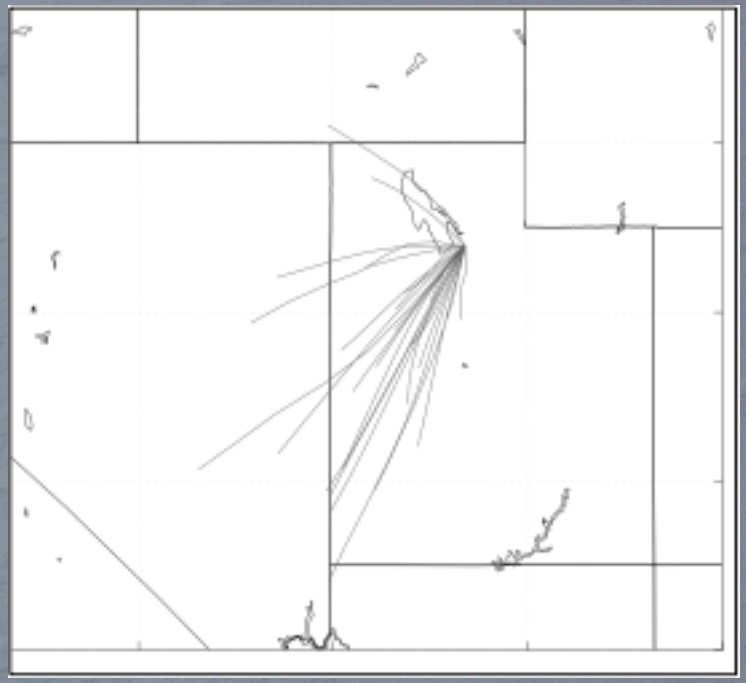
Lawrence et al., 2010

- satellite obs
- back-trajectory models
- particle size distribution
- mineralogy



Terra-MODIS true-color, 3/4/2009

regional dust sources



Steenburgh *et al., (in prep)*