Quenching the Valley’s thirst: The connection between Sierra Nevada snowpack & regional water supply

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- Snow conditions
- Snow & climate change
- Research directions
Sierra Nevada snow depth, April 13, 2005

April 1 snowpack was 3rd largest in last 10 years

Source: NWS-NOHRSC
Snow contributions to annual precipitation

Serreze et al., 1999
Expected seasonal runoff, % of average

Yuba 105%
American 118%
Cosumnes 116%
Mokelumne 130%
Stanislaus 137%
Tuolumne 144%
Merced 155%
San Joaquin 146%
Kings 139%
Kaweah 135%
Tule 123%
Kern 136%
Feather 91%
Truckee 103%
Tahoe 104%
Carson 126%
Walker 133%
Mono * 137%
Owens * 133%

Source: CA DWR
Snow cover in the Western U.S.

- exhibits considerable interannual variability
- occurs on only a small fraction of the landscape
- yet it sustains the streamflow & groundwater recharge of much of the west
Having 6 years of drought focused attention on western water. It made scientists & decision-makers alike push for new measurements & understanding of mountain hydrology to close critical knowledge gaps. This understanding is needed for longer-term sustainable water management.
Conditions have improved in California & the Southwest, but the West still has a drought.
Jul-Aug-Sep temperature outlook
April 2005

Lack of anomaly
Snow cover & climate change

- Western snowpacks hold less water than 50 years ago
- They are also melting earlier
- Result is earlier runoff & drier summer soil
- These trends should continue as climate warms further
Climate change

There are 3 important points on which the science community agrees:

– global warming is occurring
– fossil fuel consumption contributes to the warming
– if we fail to act now to reduce greenhouse gases it will get worse

Many government & private sector planners consider climate change in:

– planning infrastructure
– evaluating investments
– protecting public health, welfare & natural resources
Global average temperature

Temperature, °C

1880 1900 1920 1940 1960 1980 2000
20th century temperature trends

Positive trends of 2-3°C (3-5°F) per century over much of the West

Kart et al., 1996
Snowpack decline in Cascades

April 1 snow water equivalent (SWE) in Pacific NW has declined up to 60% since 1950

Mote et al., GRL 2
Estimating influence of possible +6°C on SNOW vs RAIN

"Great things are done when men & mountains meet." -- William Blake

Derived from UW’s VIC model daily inputs, 1950-1999

Dettinger, unpublished
Estimating influence of possible +6°C on SNOW-SEASON LENGTH

Derived from UW’s VIC model daily inputs, 1950-1999

Dettinger, unpublished
Estimating influence of possible +6°C on RAIN-FLOOD STORMS

*Derived from UW’s VIC model daily inputs, 1950-1999*

Dettinger, unpublished
The combined effects of climate change, population growth, land-use change & landcover changes are placing increasing stresses on mountain environments & on the imbalance between water demand & supply.
Research directions: snow hydrology

- SWE estimation
- Fractional SCA
- Canopy corrections
- Tokapah
- MODIS fractional SCA
- Ground measurements
- Energy balance
- Satellite remote sensing
- Hydrologic modeling
Sierra Nevada snowcover & Kings River runoff

1998 snow-covered area

Red: clouds
Black: no snow
Greyscale: SCA

R. Davis, CRREL
Research directions: snow hydrology

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- 9 Mar 2004
Point measurements of snowpack — not quantitative measures of basin-scale snow water equivalent
- Established as index sites to estimate seasonal runoff using statistical models — located at sites with persistent snowcover
Gin Flat snow studies

Gin Flat Pilot Study Plot

Yosemite National Park

Gin Flat

SNOTEL

Snowcourse

Gin Flat snow studies
Research directions: snow hydrology

MODIS fractional SCA 9 Mar 2004

Fractional SCA

SWE estimation

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Ground measurements

Satellite remote sensing

Hydrologic modeling
Spatial snowmelt modeling: albedo parameterization

empirical  observed  AVRIS

day of year: 112

snow:  
no snow:
Spatial snowmelt modeling: albedo parameterization

day of year: 125

empirical  observed  AVRIS

snow:  no snow:
Spatial snowmelt modeling: albedo parameterization

empirical  observed  AVRIS

day of year: 128

snow:  no snow:
Spatial snowmelt modeling: albedo parameterization

*empirical*  
*observed*  
*AVRIS*

**Day of year: 141**

Snow:  
No snow:
Spatial snowmelt modeling: albedo parameterization

day of year: 160

empirical | observed | AVRIS

snow: | no snow:
Spatial snowmelt modeling: albedo parameterization

day of year: 176

empirical observed AVRIS

snow: white no snow: green
Spatial snowmelt modeling: albedo parameterization

day of year: 192

empirical  observed  AVRIS
Spatial snowmelt modeling: albedo parameterization

day of year: 208

empirical  observed  AVRIS

snow:  no snow:
Research directions: integrating water & biogeochemical cycles

- snow distribution
  - melt timing
    - infiltration
      - ET
      - recharge
    - partitioning
      - infiltration
      - runoff
  - runoff
- evapotranspiration
- precipitation
- snowmelt
- infiltration
- sublimation
- ground & surface water exchange

wireless pod for snow depth
Mountain water & carbon balance

Very active forest synthesis & respiration even in winter – controlled by snow & soil moisture
Snow: the way forward

Demonstrate usefulness of satellite remote sensing products to research & applications communities
- hydrologic forecasts
- water resources decisions
- biogeochemistry

Create new demands for satellite snow products

Integrate ground & space measurements for snow estimation

Enhance dialog between research & applications communities on topics of snow measurement & modeling
Concluding thoughts

Current ability to quantitatively estimate water fluxes & reservoirs in mountains is woefully inadequate (also ecological & biogeochemical linkages)

Economic value of & societal demand for new knowledge & tools for mountain hydrology is very large

Advances will require sustained investments in new measurements & infrastructure, including data & information systems (plus research)

Measurement strategies will rely heavily on remote sensing — need complimentary ground-based systems
Sierra Nevada Hydrologic Observatory

- Building new research infrastructure for Sierra Nevada hydrology & related fields
- How the mountain range responds to perturbations
- Need to understand the pulse of the system
- Scaling relationships, feedbacks, sensitivities, time lags, response time