Challenges & opportunities: water resources measurement & information systems

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Problem: how to modernize California’s water information systems

Challenges:

Widely dispersed decision making & growing, heterogeneous demand for information

Decades old technology in use, with only modest, limited programs underway to upgrade systems

Diagram:

- Measure
- Store
- Search
- Retrieve
- Analyze
- Use

End-to-end process
Priority needs & opportunities involve both research & applications

Integrate the science

Bridge the gaps with current practice
Technological advances offer opportunities

Availability of satellite remote sensing information

Development of inexpensive, low-power sensors & powerful, ground-based sensor networks

Maturing of physically based, spatially distributed hydrologic models
Example: mountain hydrology

Identified as the priority area for new research infrastructure for hydrologic science & water resources in California

Researchers from over 50 institutions have contributed toward planning for a Sierra Nevada Hydrologic Observatory

https://ucmeng.net/snri/snho
Existing point measurements fail to sample spatial variability

Snow water equivalent measurements

- Snow Course (CCSS)
- Snow Pillow (CCSS)
- SNOTEL (USDA)

Other examples
- precipitation
- soil moisture
- snow albedo
- vegetation properties
- evapo-transpiration
Snowcover patterns follow topography

(Molotch et al., 2004)

relations differ at small catchment vs. regional watershed scale
Vegetation also controls snowcover patterns

![Vegetation Image]

**Graph:**
- **X-axis:** Date (3/1/2005 to 6/1/2005)
- **Y-axis:** Snow depth (cm)
- Lines represent:
  - Blue: Pods
  - Red: Snowpillow
  - Pink: Snow course

**Key Dates:**
- 3/1/2005
- 4/1/2005
- 5/1/2005
- 6/1/2005
Measuring mountain water cycles at the basin scale

- Satellite remote sensing
- Multiple instrument clusters in a basin
- Flux tower

**Instrument cluster**
- Flux tower or meteorological station
- Embedded sensor network
- Sap flow array
- Stream & groundwater sensors
- Data & communication hub
Embedded sensor network for mountain water cycle

One node

**Sensors**
- snow depth
- air temperature
- relative humidity
- solar radiation
- soil moisture
- soil temperature
...

**Pod**
- microcomputer
- data storage
- radio
- battery
- solar cell

signal/data to/from other nodes

**Mother pod**
- microcomputer
- radio
- battery
- solar cell

- data logger & IP connection via phone, radio or direct

network data & control

signal/data to/from UC Merced
Pod & snow pinger at Gin flat sensor network

Pods from Kevin Delin, JPL
Mother pod, data logger & snow pinger at Gin flat embedded sensor network
Sierra Nevada fractional snow cover from satellite: 3/7/04
Integration of satellite & ground-based measurement systems & modeling

Some opportunities:
- snowcover extent (SCA) & water equivalent (SWE)
- soil moisture
- precipitation
- streamflow/runoff forecasting

MODIS SCA + ground SWE = blended SWE
Energy balance modeling scheme

- Data cube
  - Time (t)
  - Y
  - X

- SWE
- Albedo
- SCA
- Incident solar
- Longwave
- Air temp
- Relative humidity
- Wind speed

- Vegetation
- Topography
- Soils

- Energy balance
- LSM

- Basin potential runoff

- Time

- SWE
  - Pixel by pixel SWE & SCA

- Pixel by pixel runoff potential
Scaling mountain water balance

Blending measurements from multiple scales

- **basin**
  - remote sensing
  - SCA
  - albedo
  - vegetation

- **ground/RS**
  - SWE
  - precip
  - radiation
  - EB
  - topography

- **ground**
  - soil moisture
  - micromet
  - bedrock
  - soils

- **plot/hillslope**
  - soil moisture
  - snow distribution
  - micromet
  - fluxes
  - infiltration & recharge
Applications: snowmelt modeling, Marble Fork of the Kaweah River (Molotch et al., *GRL*, 2004)

\[ Melt\ flux = (R_{net} m_q + T_d a_r) \times SCA \]

- net radiation > 0
- degree days > 0
- snow covered area

\[ m_q = \text{energy to water depth conversion, } 0.026 \text{ cm } W^{-1} \text{ m}^2 \text{ day}^{-1} \]

\[ a_r = \text{conversion parameter, based on wind, humidity, roughness} \]
Magnitude of snowmelt: modeled – observed snow water equivalent

AVIRIS albedo

SWE difference, cm
-250 - -140
-140 - -105
-105 - -70
-70 - -35
-35 - 35
35 - 70
70 - 105
105 - 140
140 - 286

Tokopah basin, Sierra Nevada
Bridging the gaps & integrating the science – next steps

Embedded sensor networks
- critical need for prototype deployments
- develop communications & systems for data integration

Data & information systems
- address need for user-oriented integration of heterogeneous data for decision support applications
- develop digital watershed tools & technologies
Who benefits

Benefit: enhance billions of dollars of decisions annually by reducing uncertainty & enabling efficient water management

Partners:
- State/federal water managers
- Water information providers
- Regional/local water managers (irrigation, urban, hydropower)
- Academic researchers
- Private sector