The Airborne Snow Observatory

current state-of-the-art for instantaneous SWE mapping in the mountains
Overview

- State of observations of the snow pack in the Western US
- Use of observations in operational forecasts
- The Airborne Snow Observatory for SWE mapping
- Improvement in operational forecasts
Voids in our observations

- Snowmelt dominates runoff signal across much of the Western US
- Sparse in-situ networks (few per watershed)
- Poor representation of high and low elevation conditions
- Point measurements of SWE, spatial measurement of snow cover
- Clouds obscure satellite view
- Need models/relationships to use these obs. for runoff forecasting
These observations drive our Operational forecasts

Statistical streamflow forecast
• Regression relates spring SWE to spring/summer flows

Temperature index runoff forecast
• Calibrated air temperature/snowmelt relationship

Snow water resources & forecasts
affected by:
  Warming temperatures
  Snow season duration
  Rain/snow fraction
  Mid-winter melt
  Rain-on-snow
  Forest change
  Dust on snow

Operational forecasts are therefore vulnerable to unusual conditions...
...and conditions are changing
Operational forecasts

- Subject to non-negligible error when conditions that impact the snow pack deviate from "average"
- To improve forecasts at the watershed scale, we need to improve our SWE monitoring at the watershed scale
- Along with our use of observations in runoff models

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<th>Year</th>
<th>April Forecast</th>
<th>Obs Inflow</th>
<th>% Difference</th>
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1 April Apr-Jul runoff forecast errors
American River, CA 1990–2011

Data courtesy Nathan Elder, Denver Water
Pathfinder: The Airborne Snow Observatory

Riegl Q1560 dual laser scanning lidar
- 1064 nm
- Full-waveform
- 60° field of view

CASI-1500 Imaging Spectrometer
- 72 bands between 0.35 and 1.05 μm
- 40° field of view

GNSS/IMU – Applanix AP60
- RTX GNSS correction
- PPRTX Processing
• Spatially-distributed snow depth observations
• Snow depth maps at 3 m spatial resolution
• Snow depth observations are converted to SWE using snow density maps from a physically-based model
• SWE maps at 50 m spatial resolution
MODSCAG Fractional snow cover area (background)
Not just watershed SWE
Derived metrics:
• Distribution with elevation
• Distribution with time
• Distribution per sub basin
Building a legacy in the southern Sierra Nevada

Example: Tuolumne River Basin
utility to operations in a wide range of conditions
refined data processing for fast data turnaround
bridge to partnerships in neighboring basins
Improvement brings impact …
Spatial extent of activities
Outlook to the future

• ASO started at the NASA Jet Propulsion Laboratory in 2012, first as a demonstration mission and then starting in 2016, mostly funded by operational entities

• These operations will be transitioning out of JPL at the end of the year

• A private company will be taking over the ASO tech transfer, with lidar, spectrometer and modeling surveys for water management entities in both California and Colorado, starting in 2020

• Contact at California Cooperative Snow Survey Program
  Sean De Guzman  Sean.DeGuzman@water.ca.gov
The Airborne Snow Observatory

kathryn.j.bormann@jpl.nasa.gov
What is the accuracy?

Snow depths in exposed areas are within 1-2 cm at the 50 m scale

Currier et al., 2019