Colorado Airborne Snow Measurement Program Airborne Snow Observatory overview & 2022 data

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COLORADO Colorado Water Conserva Home Department of Natural Resources

ASO 3m Snow Depth Quandry Peak, CO 18 April 2021

outline

CASM Working Group Airborne Snow Observatory: why / what / how / where 2022 Colorado program results to-date Upcoming activities & CASM program build-out

Colorado Airborne Snow Measurement Program

Formed in 2020

- Leadership: Denver Water; Northern Water; Dolores WCD; Lynker; ASO, Inc.
- WSRF funded to engage stakeholders & produce report
 - Letters of support from all Roundtables
 - >100 engaged stakeholders regularly participating
 - Report out soon: details program need & sustained pathway

2022 Water Plan Grant program expansion

- Leveraging local & federal program match funds
- Added snow-on flights in CO Headwaters, upper Gunnison, Dolores, Conejos
- Snow-free data development in summer 2022 to expand "shovel-ready" basins
- Outreach & data workshops

Foundation & pathway for a sustained program

- State/federal partnership
- Collaborations with forecast agencies



Decision-making with uncertainty

Rio Grande @ Del Norte

June Forecast & measured Apr-Sept Volumes

- Over-forecast: risk of compact shortage
- Under-forecast: unnecessary curtailment



Rio Grande @ Del Norte Apr-Sept forecast vs observed (kAF)

			June Forecast	Observed	Forecast	- Obs
		2005	795	683	+112	16%
ies		2006	350	412	-62	-15%
		2007	450	593	-143	-24%
		2008	655	623	+32	5%
		2009	490	513	-23	-5%
		2010	485	455	+30	6%
		2011	435	415	+20	5%
	Forecast >	2012	352	328	+24	7%
	TU% LOW	2013	230	344	-114	-50%
	10% High	2014	420	519	-99	-24%
Data courtesy Craig Cotton		2015	385	556	-171	-31%
		2016	475	566	-91	-16%
	3 Engineer	2017	535	574	-39	-7%

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Snow Water Equivalent

Percent NRCS 1991-2020

≥ 2009

175%

150%

125%

100%

75% 50% 25% ____≤0% No basin value

⊖ Observation Missing O Average is zero ⊗ Average missing Watershed Boundaries - Region (2-Digit HUC) Subregion (4-Digit HUC)

Basin (6-Digit HUC)

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Subbasin (8-Digit HUC) **ONRCS** Natural Resources Conservation Service

Average May 17, 2022, end of day



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53

Snow Water Equivalent

≥ 2009

175%

150%

125%

100%

75% 50% 25% ____≤0%

⊖ Observation Missing O Average is zero ⊗ Average missing Watershed Boundaries

d 5-18-2022 07:35 AM MDT

Average



Operational forecast models are vulnerable to changing conditions... Statistical streamflow forecast ...and conditions are changing Change factors include: a) April 1 Observed SWE Trends 1955-2016 - Warming temperatures 60% - Snow season duration 40% 20% Rain/snow fraction - Mid-winter melt Temperature index forecast - Rain-on-snow - Wildfire - Beetle-kill Dust on snow * Forecast methods based on historic Mote et al. 2018 data assume that calibrations apply to current conditions

Snowmelt timing & volume is controlled by SWE patterns & snow albedo

Accurate, full-basin SWE & albedo can reduce forecast uncertainty

- Decrease reliance on historic record
- Avoid assumptions about how stations represent basin water volume
- Put existing networks to work in new ways





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mapping the two most critical snow properties to forecast runoff volume & timing

Snow Water Equivalent

Snow depth from elevation mapping with Riegl VQ1560II-S SWE from insertion of obs & modeled density

Snow Albedo

HySpex VSWIR Spectrometers Snow properties retrieval

Physical Modeling

Coupled lidar & spectrometer measurements Snowpack process modeling

Operations

Unique high-altitude operations Unique rapid product turnaround

Ground Track



California & Colorado parallel applications development



California

- 350+ snow-on flights since 2013 in 10 basins
- Operationally mapping southern Sierra SWE volume
- Continuing program in southern & central Sierra, building to full-state coverage over next 2 years

Colorado

- Numerous NASA, State, & Local projects since 2013
- CASM Stakeholder group defining a sustainable statewide program

Westwide & Global

- WRF-Hydro assimilation & runoff forecasting
- USBR projects in NV, WY, AZ
- Norway hydropower









Operational guidance: California

San Joaquin River: Restoration flows for salmon

- ASO data used in forecast for USBR Fish Recovery Program
- Improved accuracy enables restoration flows & re-watering lower San Joaquin

Environmental

1) Restoration

Flow Scheduling

2) Temperature

Management

Flow Factor

• Early forecast accuracy key to achieving flow factors & summer supply reliability





Kings River 2019: Managing supply & flood risk

- Flood declaration: Army Corps takes over Pine Flat Dam ops & operates solely to protect infrastructure
- 2019: ASO forecast allowed KRWA to operate on 10% exceedance

	Apr-Jul Runoff Forecast Exceedance			
Forecasts	10%	50%	90%	
CA DWR	2.1 MAF	1.8 MAF	1.6 MAF	
NOAA RFC	2.3 MAF	2.1 MAF	1.9 MAF	
ASO		2.5 MAF		

• Saved 100 TAF or ~\$100M of water

"ASO provides invaluable information that is not otherwise available, most importantly information about the rate of melt that provides a real opportunity to optimize reservoir operations for water supply, flood control, and instream requirements."

> Steve Haugen, Watermaster, Kings River Water Association

Water Year 2019 Blue River Basin Denver Water

- 2019 Flights: April 19 & June 24
- May + June storms maintained high elevation snowpack
- SNOTELs snow-free on June 28
- June 24 flight SWE volume: *115 TAF*
 - half of total inflow left to melt
 - enabled response to double flow peak









WY 2022 Colorado Program

Surveys Completed To-date:

- Dolores River: April 15 & May 10
- Conejos River: April 15 & May 10
- CO River @ Windy Gap: April 18
- Blue River @ Dillon: April 19
- East R. @ Almont: April 21 & May 18*
- Taylor R. @ TPR: April 21

Data freely accessible at: data.airbornesnowobservatories.com



















Basin	Estimated SWE volume (TAF) April 15	Estimated SWE volume (TAF) May 10
Full Basin	188	61
Uncertainty range	182 - 194	56 - 66









CASM Stakeholder engagement

Outreach & program planning survey

(detailed in report)

- Highly engaged stakeholders
- Agreement that ASO will add value
- Strong interest in creating/funding program
- ASO would add confidence to annual operations and planning
- Incorporating ASO into forecasting is important
- Strong interest in stakeholder-led flight planning group



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Expanding ASO applications: *operational models*

NOAA River Forecast Center testing/evaluation

• ASO SWE data nudges RFC forecast close to observed AJRO 2 months earlier than manual tuning

	Source / Run Type	Volume	Percent of USGS
	USGS AJRO Volume (target)	29.1 KAF	100%
	CBRFC - unmodified	35.2 KAF	121%
flow	CBRFC ASO 3/31	30.2 KAF	104%
oir In	CBRFC ASO 5/24	30.0 KAF	103%
serva	CBRFC ASO both	29.2 KAF	100%
or Re	CBRFC FM 3/27 (added swe)	35.3 KAF	121%
Taylo	CBRFC FM through 4/28 (lz)	35.1 KAF	121%
	CBRFC FM through 5/15	33.3 KAF	114%
	CBRFC FM through 5/25	30.8 KAF	106%

courtesy Pat Kormos, CBRFC

WRF-Hydro applications data assimilation

• High elevation snow data from 24 May ASO assimilation reduces low forecast bias in ESP AJRO forecast

East River @ Almont

Taylor River @ Taylor Park



courtesy Dave Gochis, NCAR

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East River @ Almont

Taylor River @ Taylor Park



Next Generation Water Management in CO

An integrated monitoring & forecasting system



Supporting evolving challenges & programs

- decision support information
- providing best snowpack data to experienced forecast teams
- realizing full potential of advanced model systems
- accurate SWE inventory for equitable decision-making

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Colorado Airborne Snow Measurement Program *Program Build-Out*

- Colorado's Water Plan
- Stakeholder engagement
- New funding partnerships
- Federal collaboration
- Snow & runoff model refinement





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