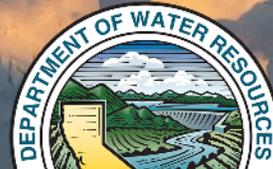


# Airborne Snow Observatory 2019 Recap

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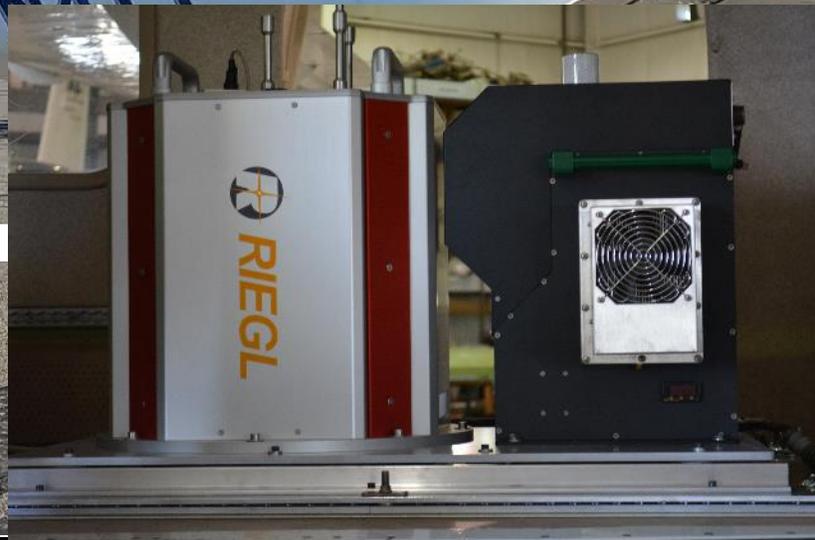
# NASA's Airborne Snow Observatory

- Basin-wide mapping of depth, SWE, and albedo
- 24-72 hour turnaround of data products in established basins

GNSS/IMU – Applanix AP60  
RTX GNSS correction

## Snow depth

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

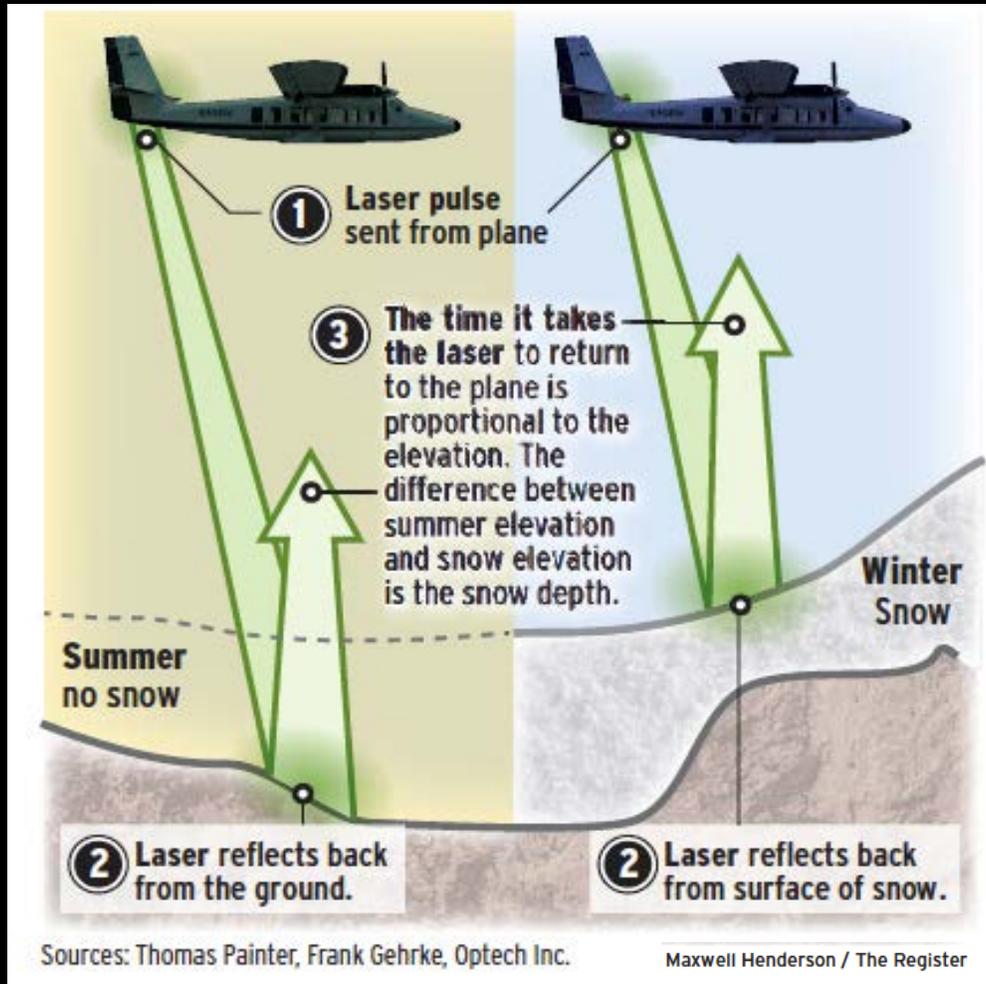


## Snow albedo

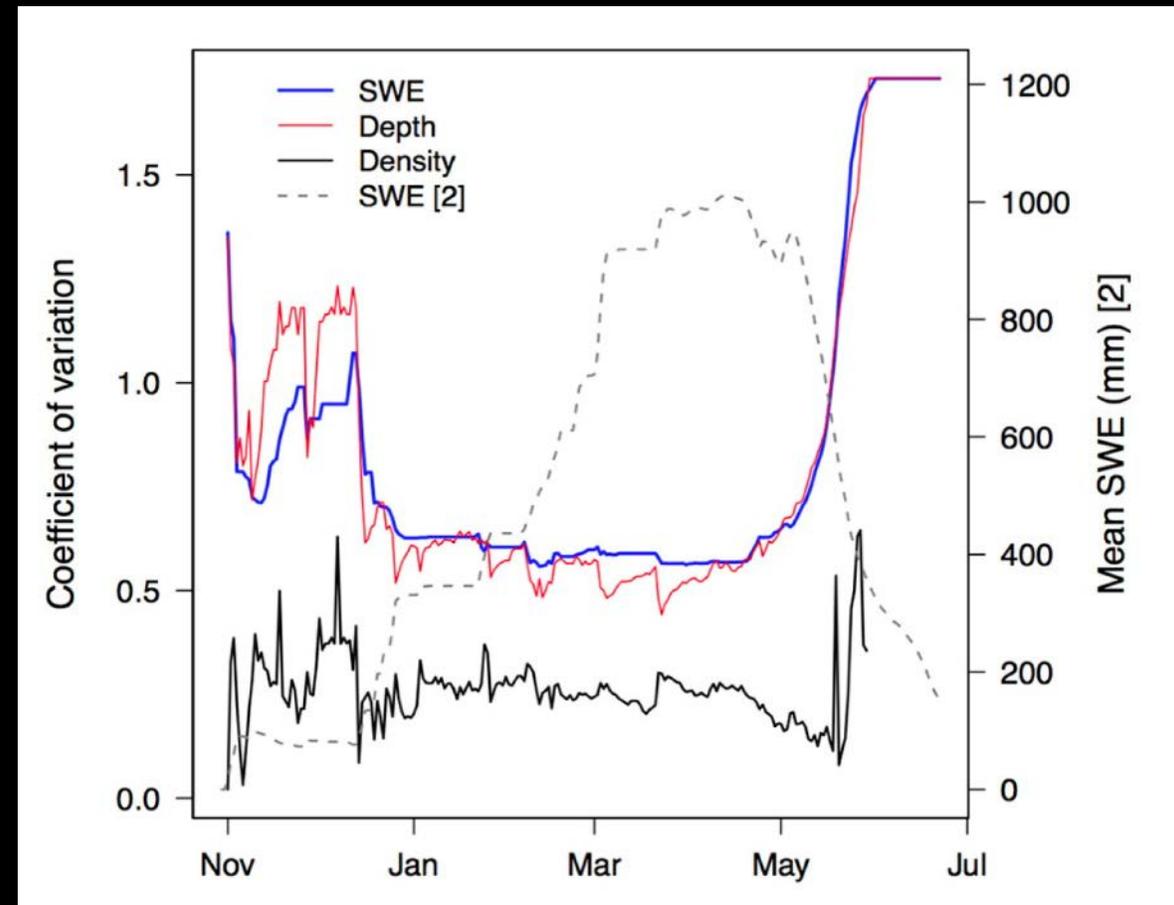
- *CASI-1500 Imaging Spectrometer*
- *72 bands between 0.35 and 1.05  $\mu\text{m}$*
- *40° field of view*

# How it works

## Snow depth from lidar

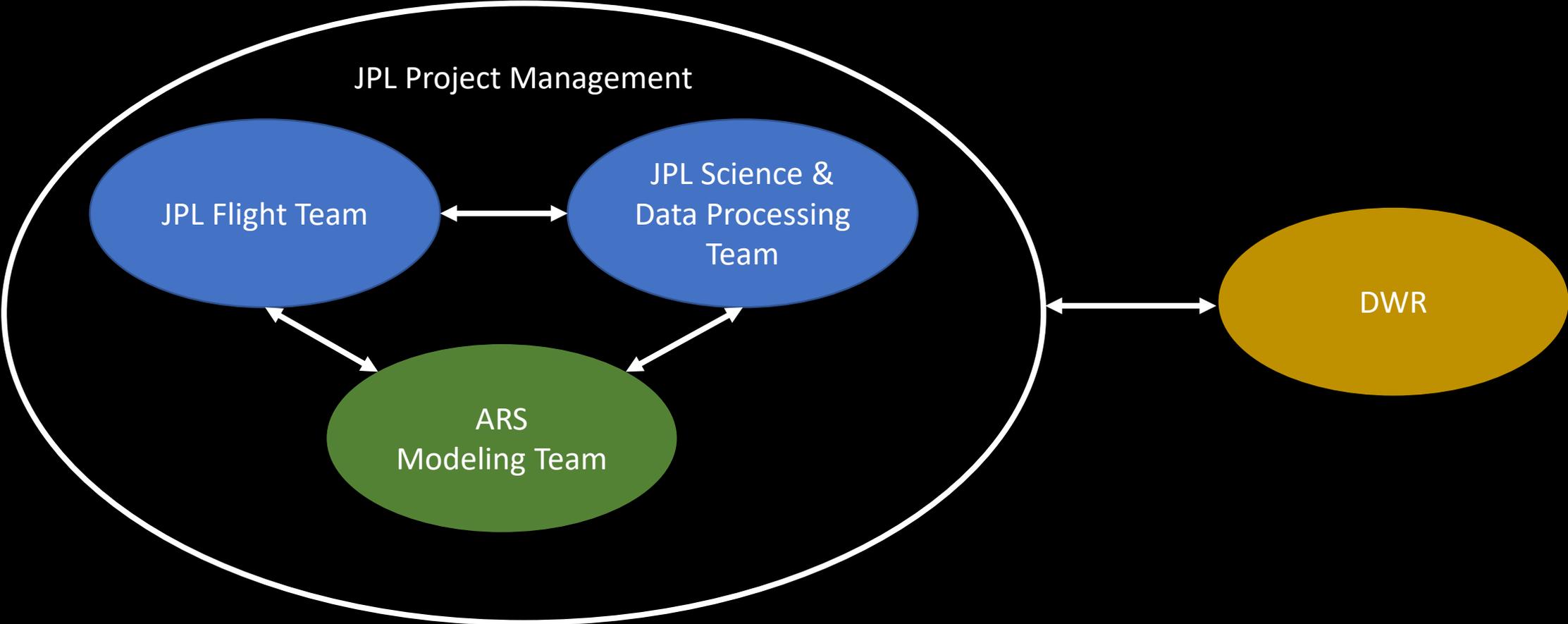


Snow depth observations are converted to SWE using snow density maps from the physically-based ARS iSnobal model



# ASO Team

ASO is a partnership between NASA-Jet Propulsion Lab (JPL) and  
USDA Agricultural Research Service (ARS)



# ASO Operational Data Products

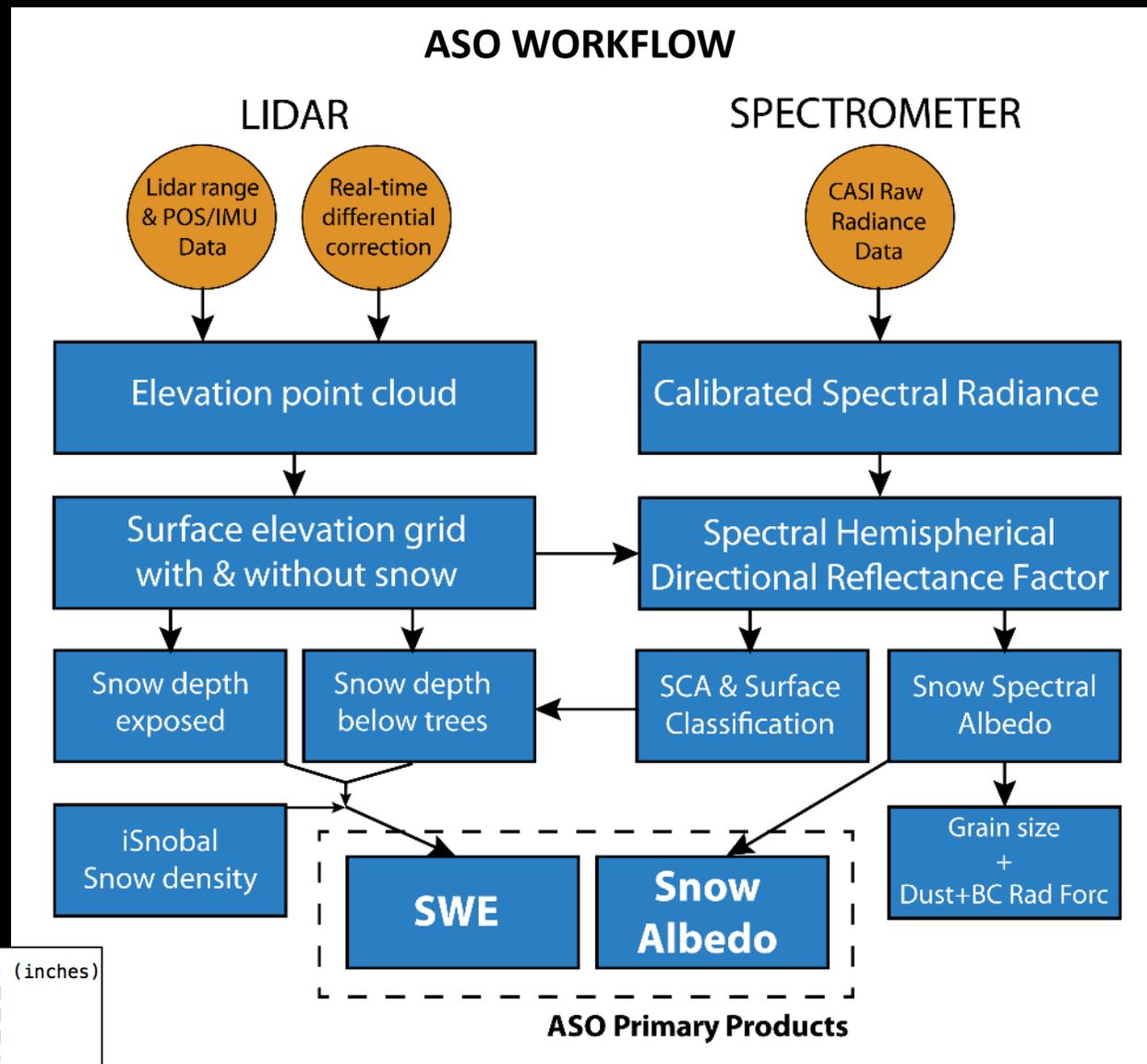
GeoTIFF maps of:

- Snow depth (3m)
- SWE (50m) using observed + modeled densities
- broadband albedo (3m)

Text products:

- Total basin SWE
- Elevation-banded SWE

24-hour turnaround for established basins



Band,	total area (sq.mi),	snow area (sq.mi),	band coverage (%)	SWE volume (AF)	Mean SWE depth (inches)
Band1	0.0125	0.0000	0.0	0.	NaN
Band2	0.0039	0.0000	0.0	0.	NaN
Band3	0.0116	0.0000	0.0	0.	NaN
Band4	0.0193	0.0010	5.0	0.	0.0609
Band5	0.0251	0.0019	7.7	0.	0.1648
Band6	0.0125	0.0000	0.0	0.	NaN
Band7	0.0193	0.0010	5.0	0.	0.4256
Band8	3.5444	3.4344	96.9	638.	3.4846
Band9	23.5369	23.0388	97.9	8280.	6.7389
Band10	20.8255	20.6874	99.3	14721.	13.3423
Band11	13.6883	13.5928	99.3	13593.	18.7503
Band12	6.7163	6.5512	97.5	7311.	20.9246
Band13	0.3523	0.3195	90.7	309.	18.1381

Total SWE Volume (AF) = 44852.6 AF



# History of ASO program

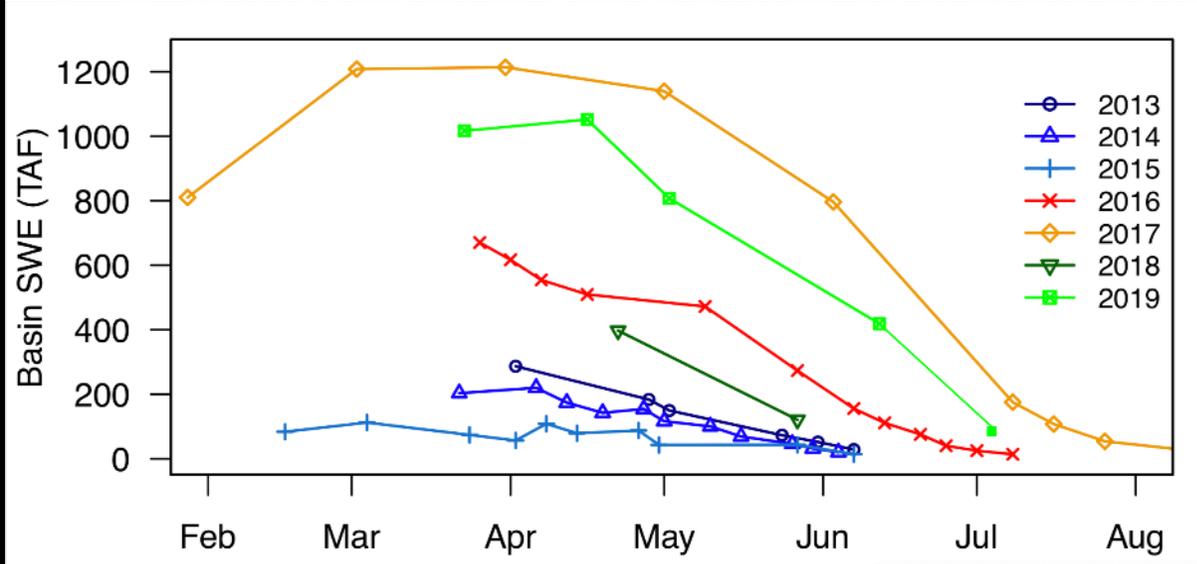


- Considered in 2009
- Startup commitment by JPL in 2010
- Partnership with DWR initiated in 2011
- Funding committed by NASA in 2012
- First snow-free flights Aug 2012 (Tuolumne)
- First snow-on acquisition Apr 3 2013 (Tuolumne)
- First 24 hour turnaround late April 2013
- Expansion of California to include Lakes, Merced, Kings, Rush in 2014
- Expansion to include Cherry/Eleanor (2016) and San Joaquin (2017)
- 50<sup>th</sup> full Tuolumne acquisition (2018)
- 300+ snow-on acquisitions by ASO (2013-2019)



# Building a legacy in the southern Sierra Nevada: 7 years of ASO in the Tuolumne

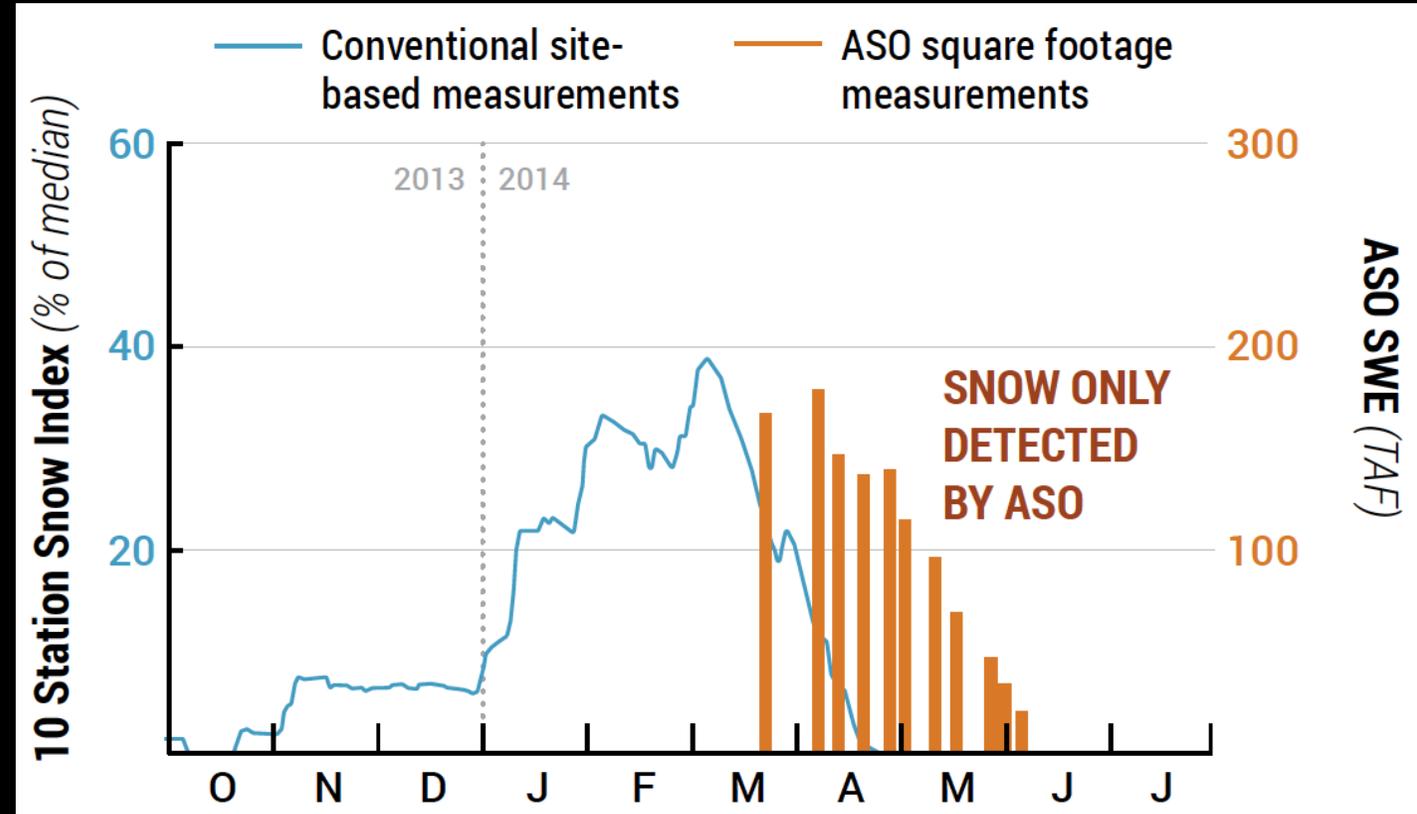
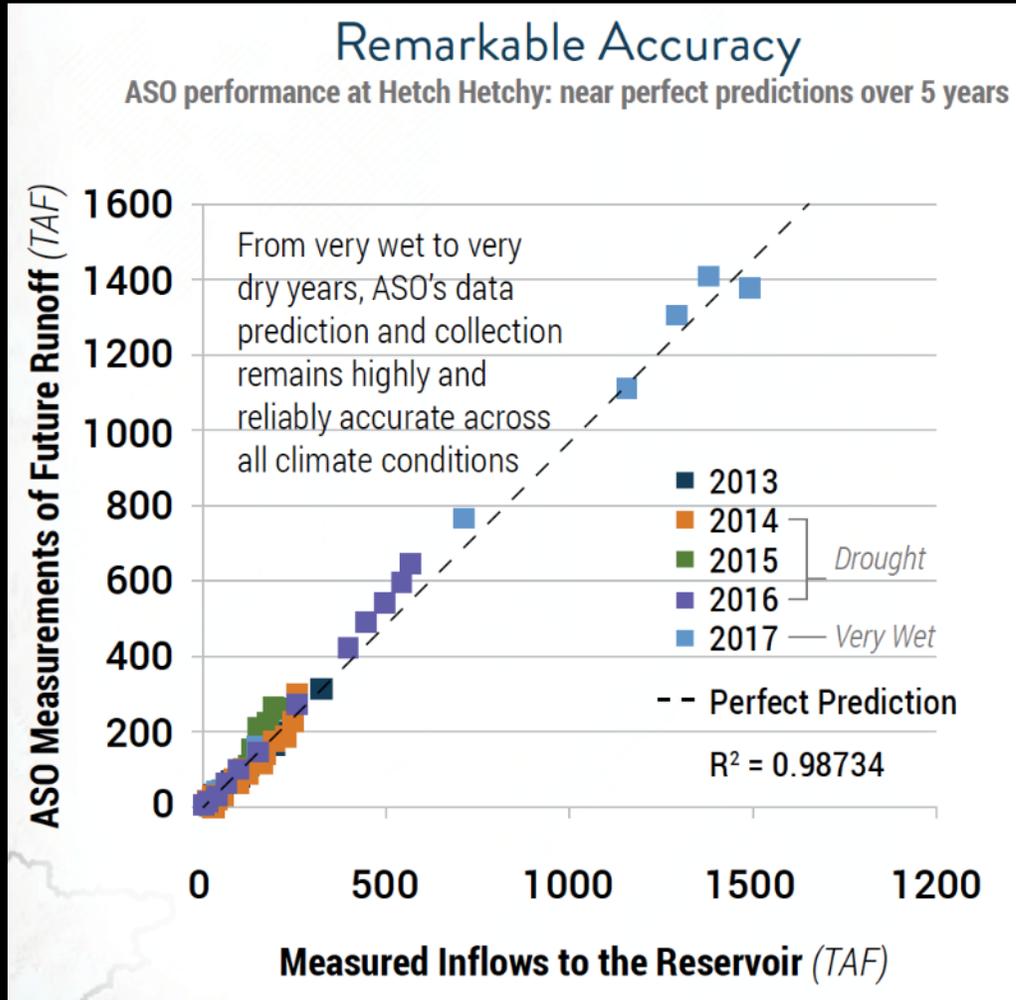
Snow Water Equivalent  
Tuolumne Basin  
Apr 26, 2016



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

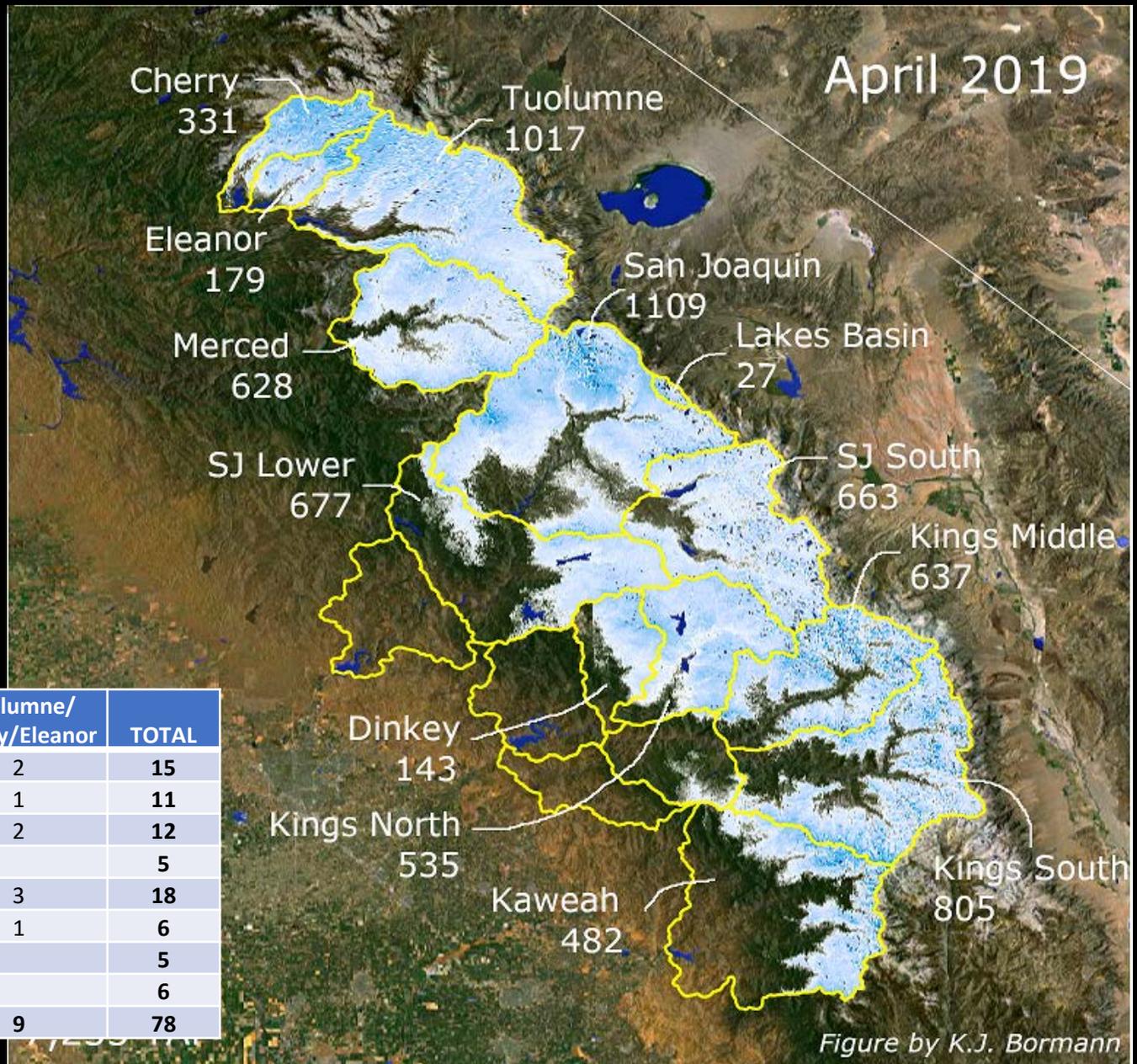


# Improvement brings impact ...



# ASO California 2019

- 2019 Snow Survey Areas:
  - Tuolumne/Cherry/Eleanor
  - Merced
  - San Joaquin
  - Lakes
  - Kings
  - Kaweah

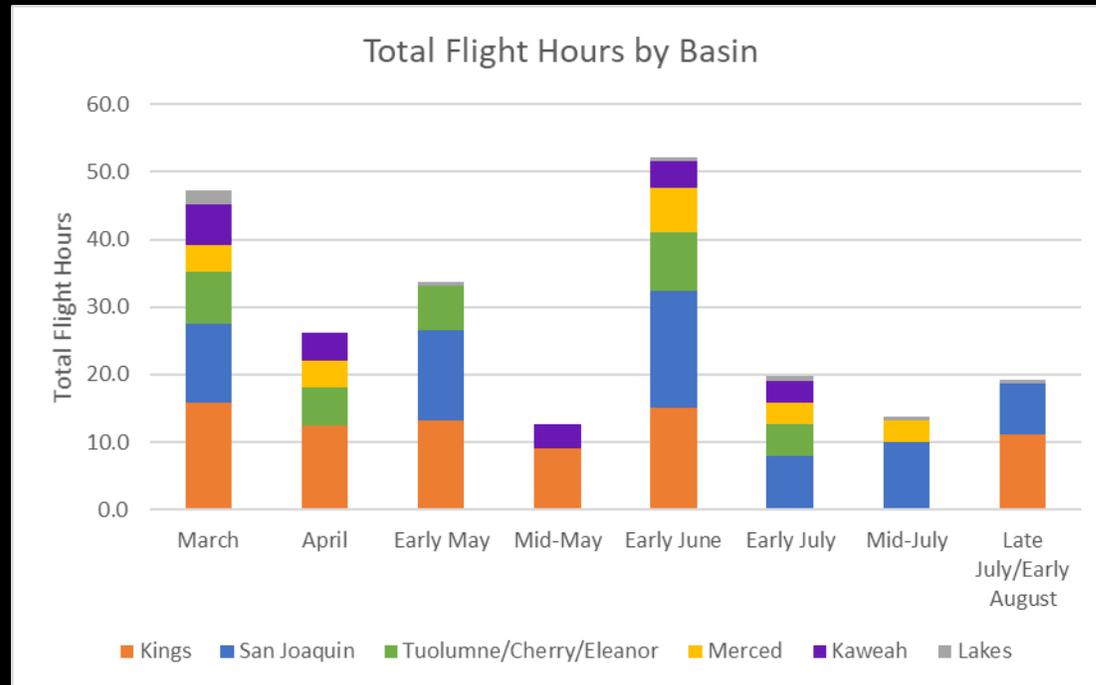


Number of Flights (Sorties)	Kaweah	Kings	Lakes	Merced	San Joaquin	Tuolumne/ Cherry/Eleanor	TOTAL
March (3/9-3/29)	3	4	2	1	3	2	15
April (4/17-4/21)	2	6		2		1	11
Early May (4/27-5/5)		3	1		6	2	12
Mid-May (5/12-5/14)	2	3					5
Early June (6/4-6/15)	1	3	1	3	7	3	18
Early July (7/3-7/7)	1		1	1	2	1	6
Mid-July (7/13-7/16)			1	1	3		5
Late July/Early August (7/26-8/2)		3	1		2		6
<b>Grand Total</b>	<b>9</b>	<b>22</b>	<b>7</b>	<b>8</b>	<b>23</b>	<b>9</b>	<b>78</b>

Figure by K.J. Bormann

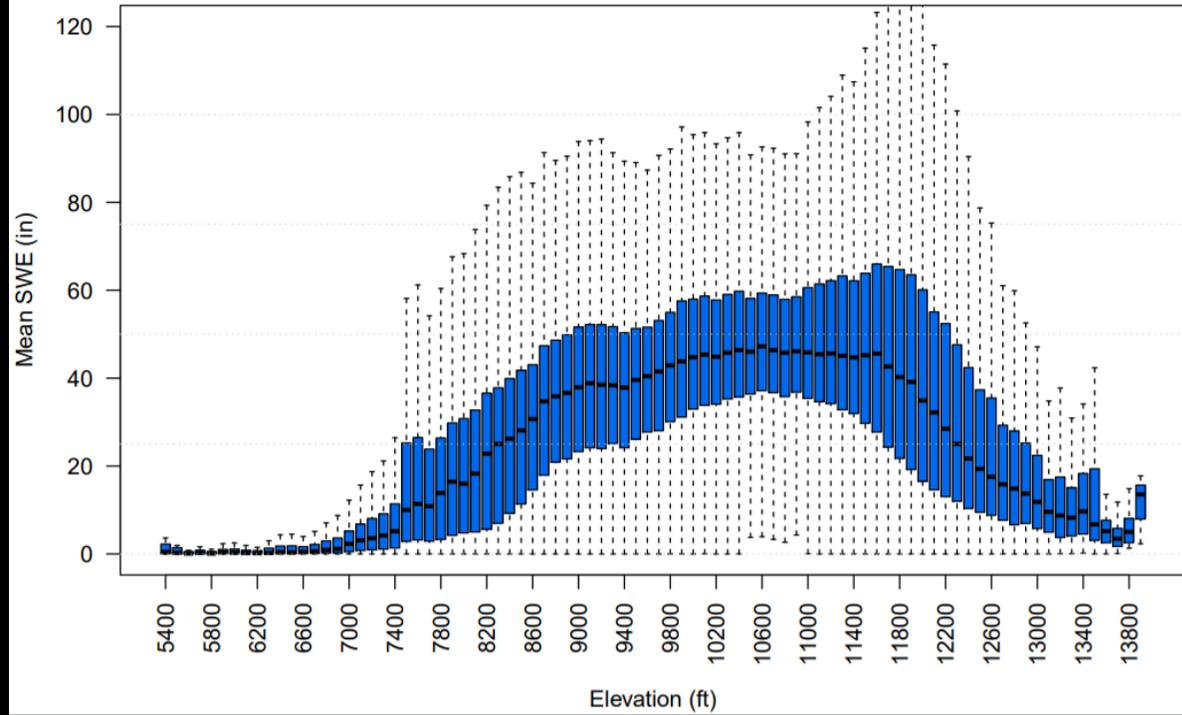
# 2019 Total Flight Hours by Basin

Total Flight Hours	Kaweah	Kings	Lakes	Merced	San Joaquin	Tuolumne/ Cherry/Eleanor	TOTAL
March (3/9-3/29)	6.0	15.8	2.2	3.9	11.7	7.7	47.3
April (4/17-4/21)	4.1	12.4		3.9		5.8	26.1
Early May (4/27-5/5)		13.2	0.7		13.5	6.5	33.8
Mid-May (5/12-5/14)	3.5	9.2					12.7
Early June (6/4-6/15)	3.9	15.0	0.7	6.6	17.4	8.7	52.2
Early July (7/3-7/7)	3.2		0.7	3.3	7.9	4.7	19.8
Mid-July (7/13-7/16)			0.6	3.1	10.1		13.7
Late July/Early August (7/26-8/2)		11.1	0.5		7.7		19.2
<b>Grand Total</b>	<b>20.6</b>	<b>76.6</b>	<b>5.4</b>	<b>20.7</b>	<b>68.1</b>	<b>33.3</b>	<b>224.8</b>

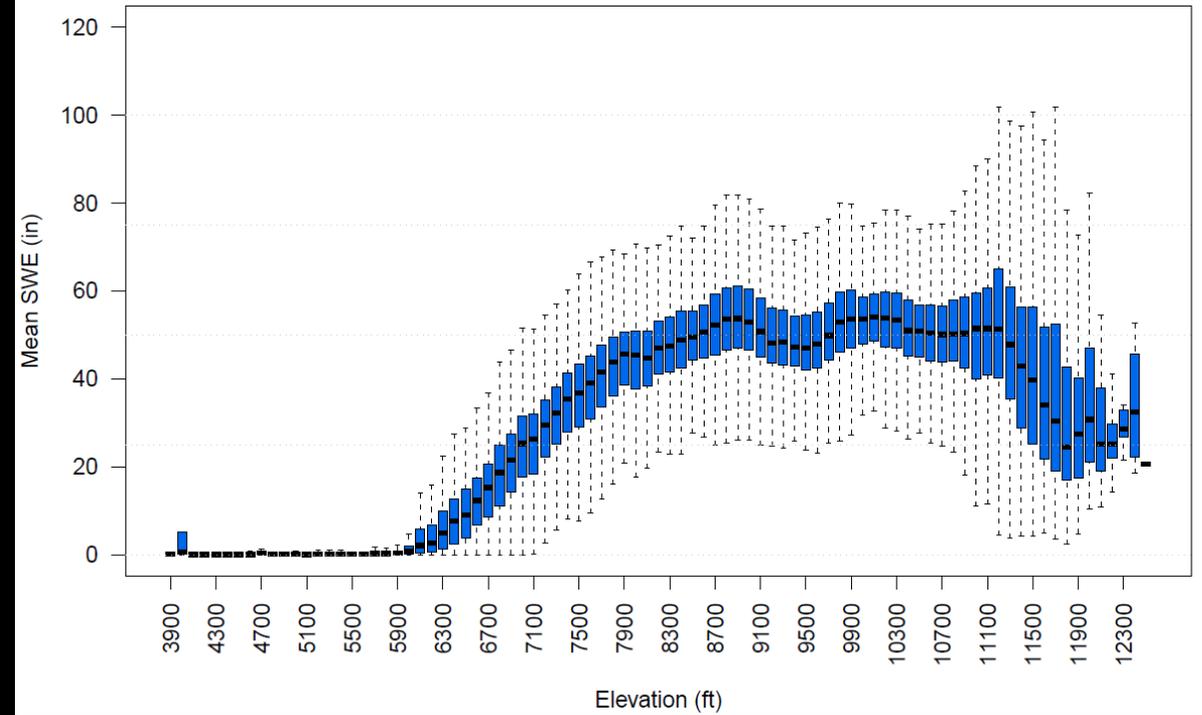


# April 2019 SWE by Elevation Band Examples

ASO: Kings River, South Fork, 27 April 2019

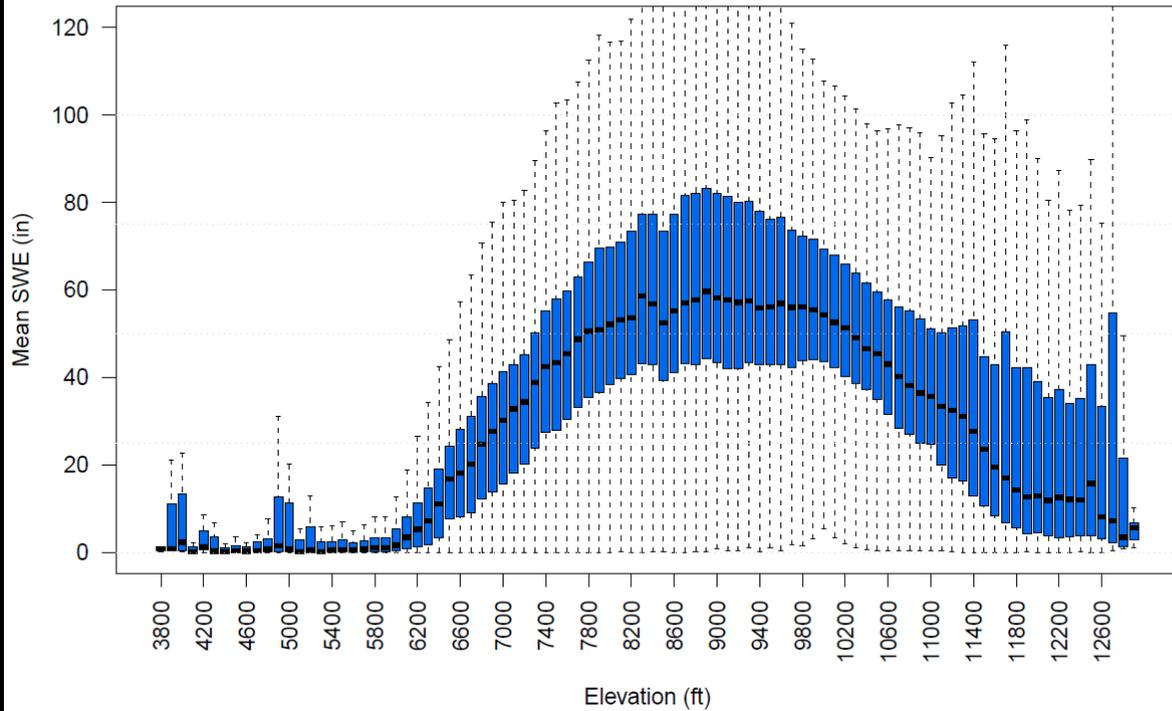


ASO: Kings North 04/17 - 04/18, 2019

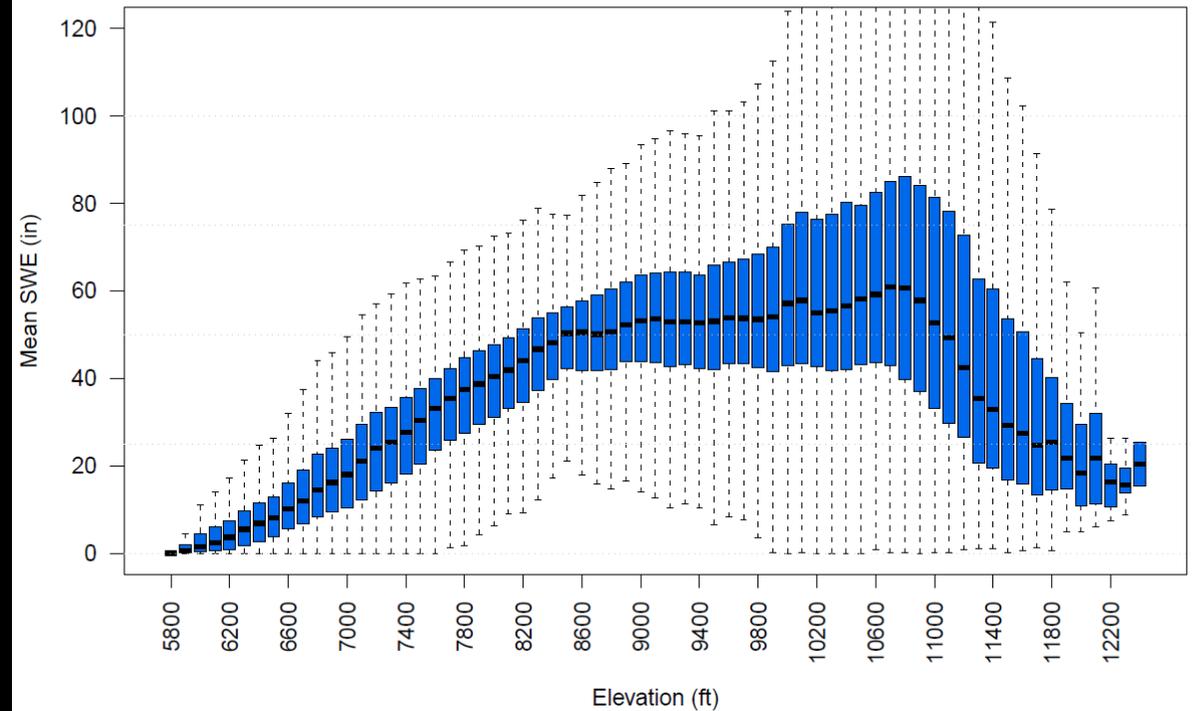


# April 2019 SWE by Elevation Band Examples

ASO: Tuolumne Basin 04/17/2019



ASO: Kaweah River Basin 04/18 - 04/21, 2019



# California Snow-Free ASO Coverage

Not shown:

- Kaweah (acquired September 2018)
- Tuolumne North Fork (acquired October 2019)



# Outlook to the Future

- ASO operations at JPL will cease at the end of 2019
- ASO data is being transferred to long-term archives:
  - National Snow & Ice Data Center (NASA Archive): <https://nsidc.org/>
  - CDEC: <https://cdec.water.ca.gov/>
- A private company will be taking over operational surveys for water management entities in both California & Colorado starting in 2020

**Thank you for 8 years of NASA/JPL ASO flights in California!**