# Remote Monitoring of Snow Water Resources

**Marianne Cowherd** and Manuela Girotto
cowherd@berkeley.edu
University of California, Berkeley

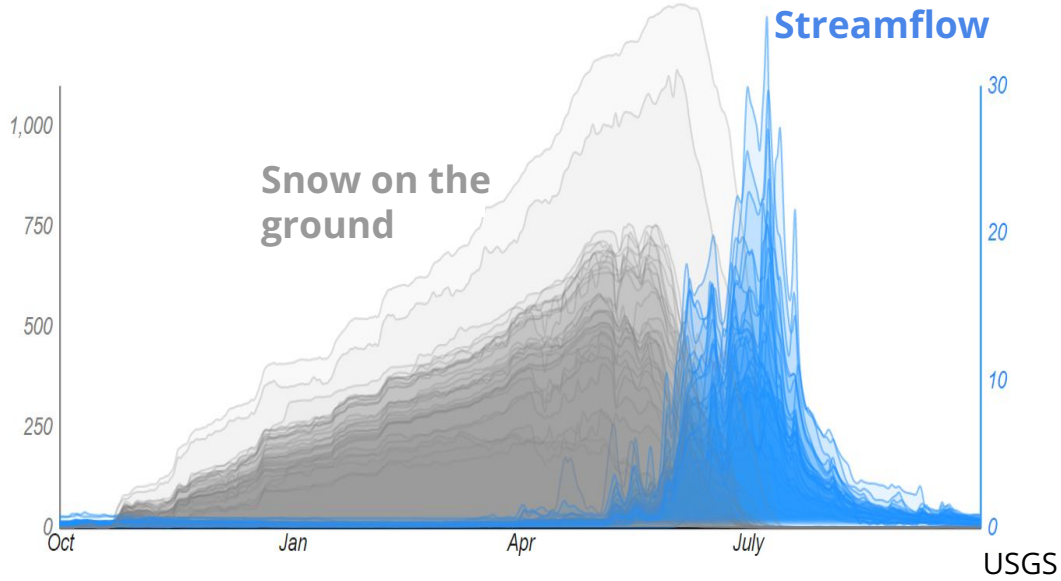

DEPARTMENT *of* ENVIRONMENTAL SCIENCE, POLICY, AND MANAGEMENT

Webinar on Satellite Data for Hydrological Applications
20 September 2022

# Outline

1. The global importance of snow
2. Overview of satellite remote sensing of snow
3. Case study: post-fire snow hydrology

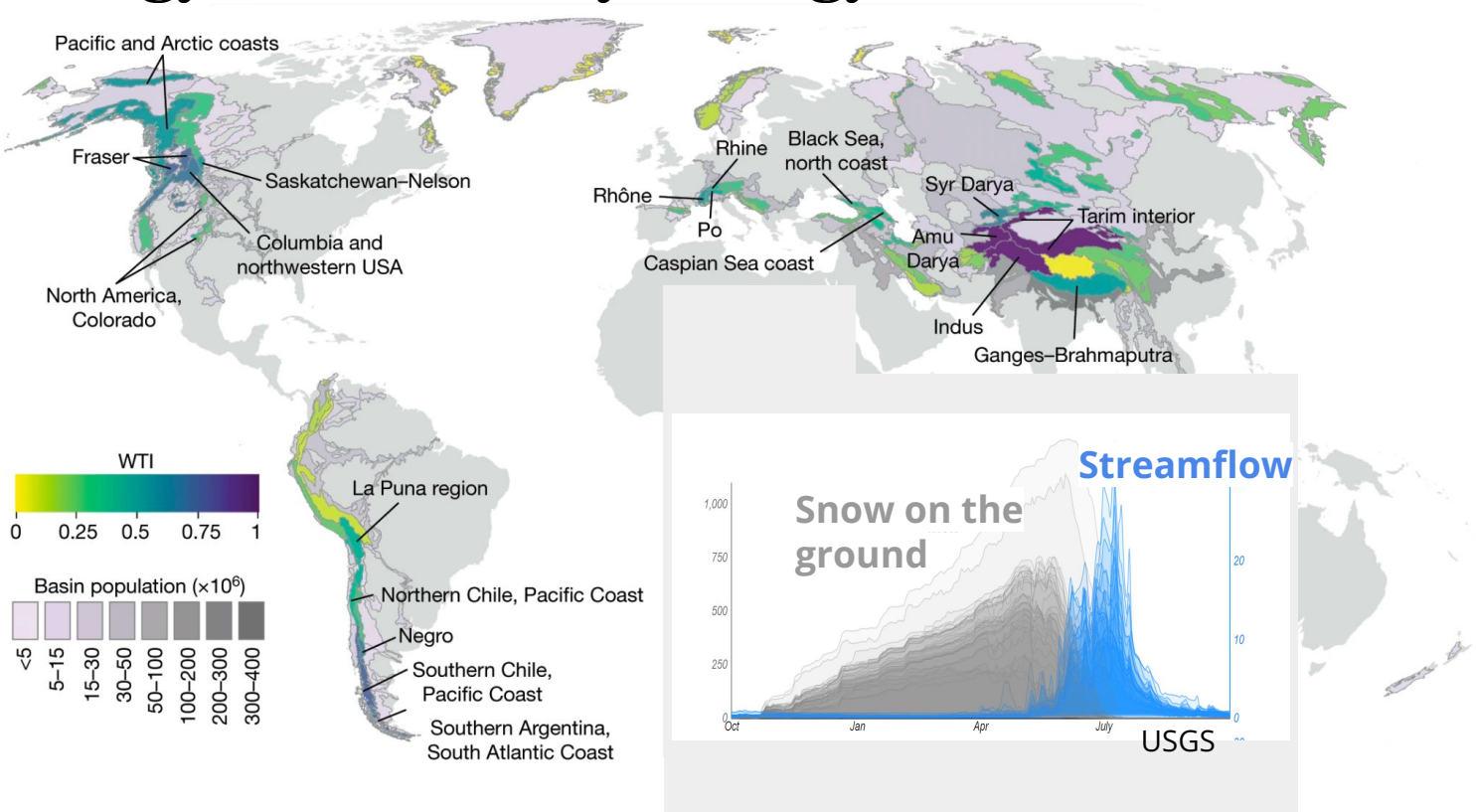
# Q: What makes snow different from rain?
# A: Timing



USGS

# Snow hydrology is human hydrology

**Where is snow an important water source?**

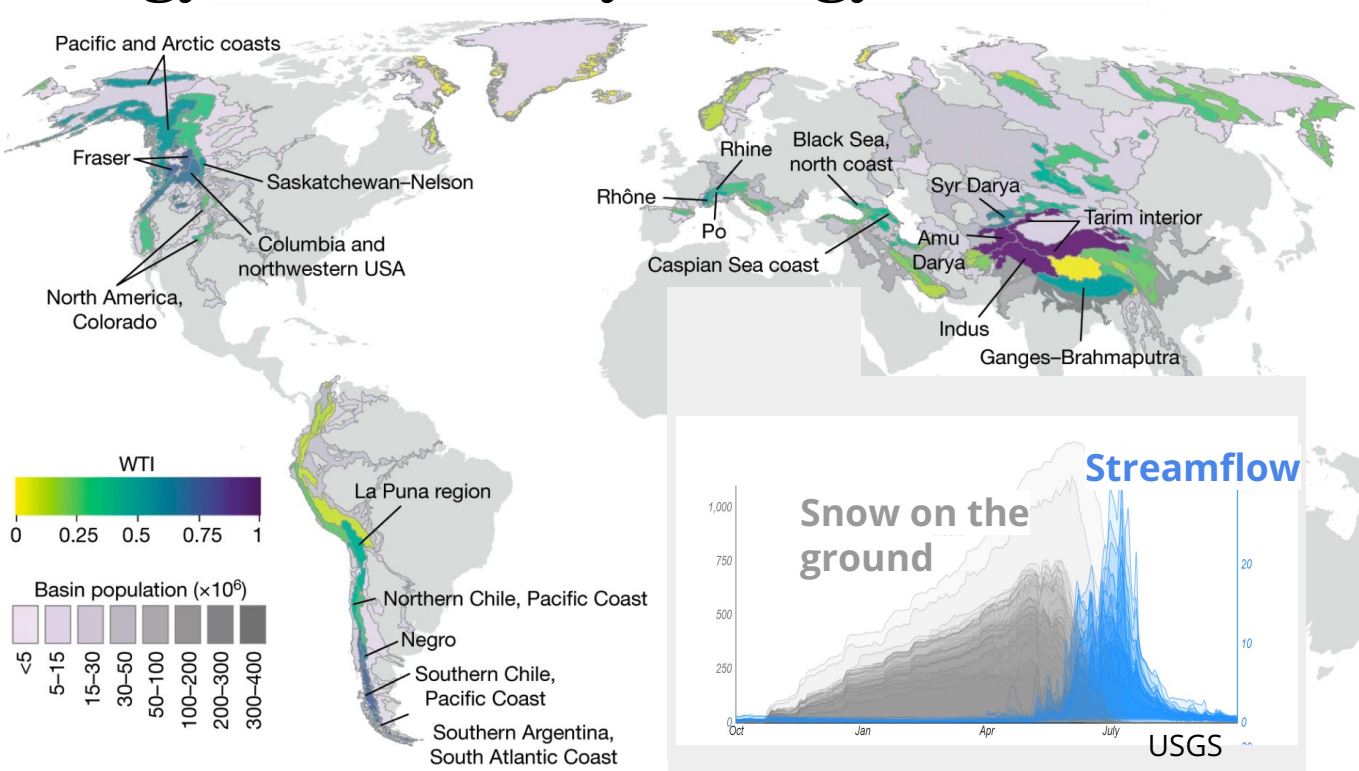



Immerzeel et al., 2019

# Snow hydrology is human hydrology

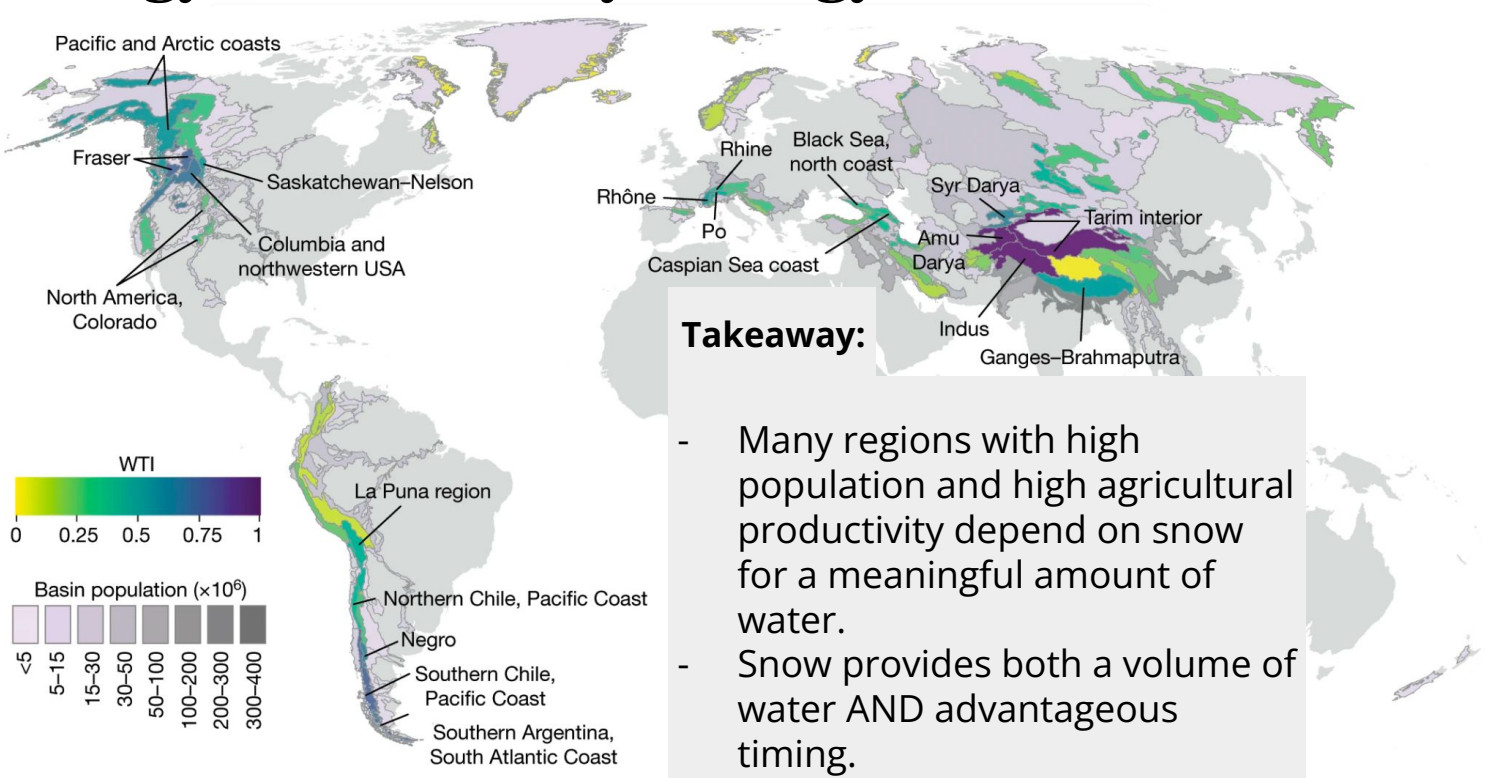
**Where is snow an important water source?**

**How many people depend on that water source?**




Immerzeel et al., 2019

# Snow hydrology is human hydrology




**Where is snow an important water source?**

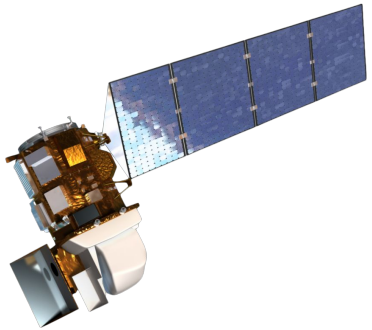
**How many people depend on that water source?**

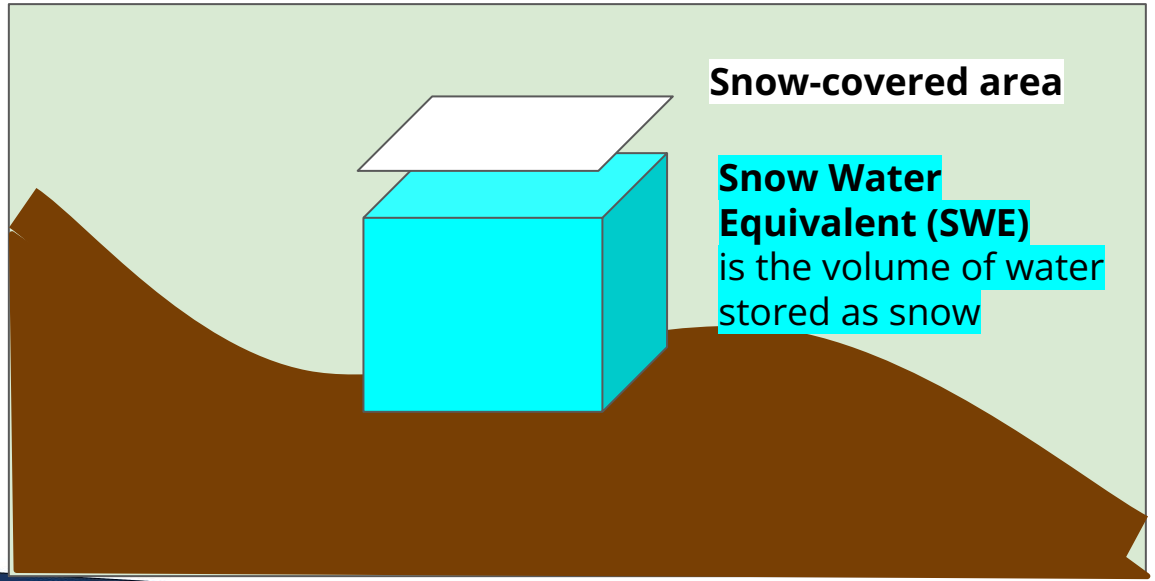
**Takeaway:**

- Many regions with high population and high agricultural productivity depend on snow for a meaningful amount of water.
- Snow provides both a volume of water AND advantageous timing.

Immerzeel et al., 2019

# Satellite missions

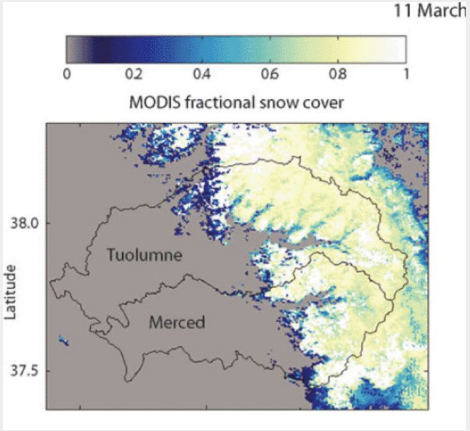




# Satellite missions

**Passive Visible/Near Infrared**

*Examples: Landsat, MODIS, many commercial satellites*



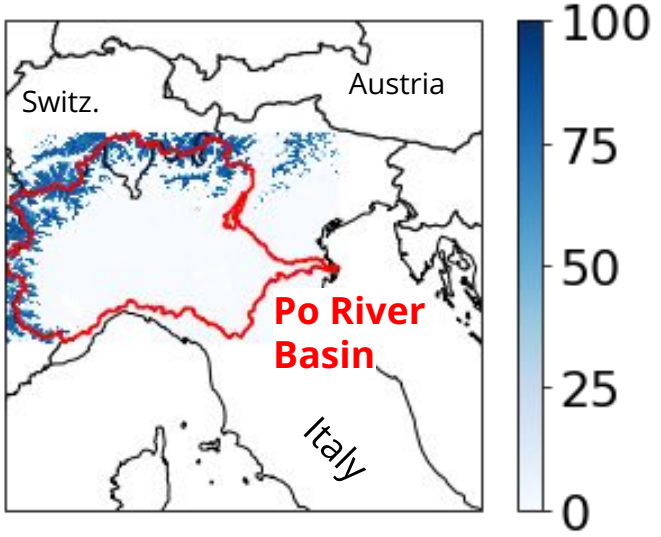

Nolin, 2017

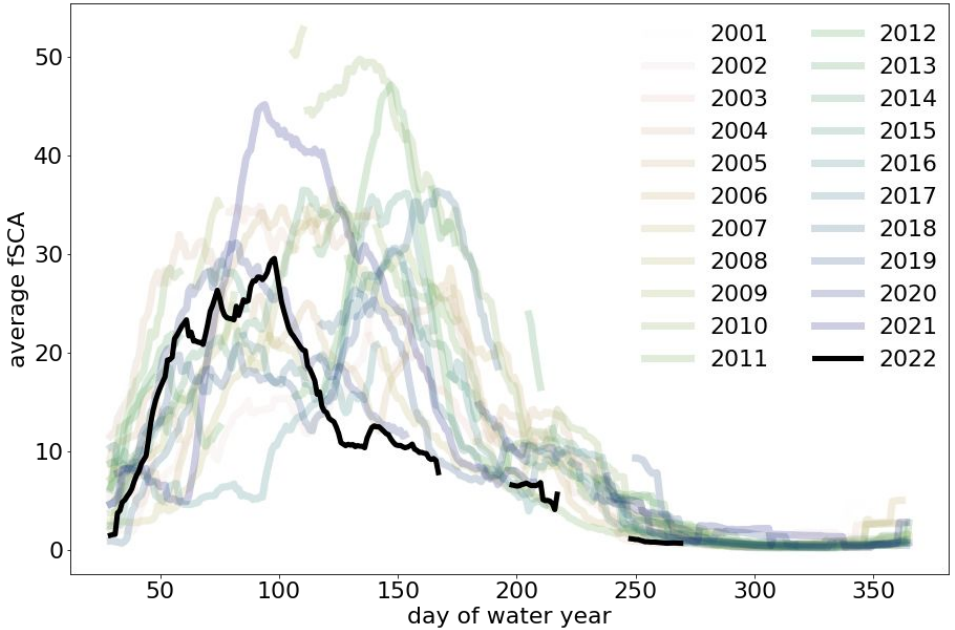
\+ Daily to weekly repeat times for measurements
\+ Available in near-real time
\+ Used as inputs to models to update estimate for specific mountain areas

\- Cannot estimate snow under clouds
\- Estimate quality is worse in vegetated areas
\- Cannot directly estimate snow depth or SWE

# Example: MODIS snow cover of the current drought in the Po River in Italy

MODIS fractional snow-covered area

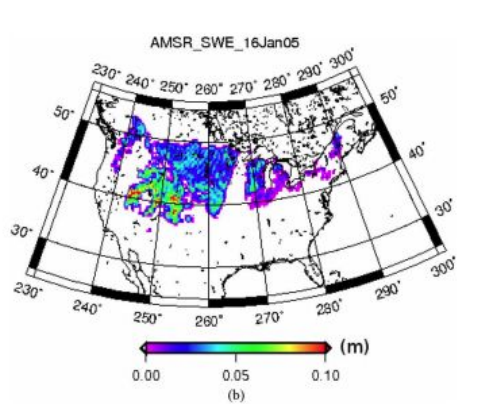


# Satellite missions

**Passive Microwave**

*Examples: AMSR-E*




Tedesco and Narvekar, 2010

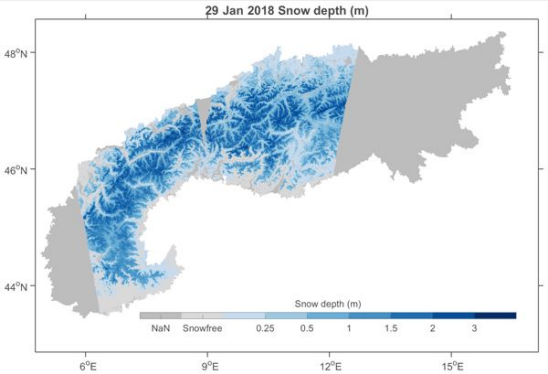
\+ Estimates of brightness temperature linked to water content

\- Underestimates SWE when vegetation is present
\- Wet snow and dry snow scatter microwaves differently

# Satellite missions

**Active Microwave**

*Examples: Sentinel-1, other SAR*




Lievens et al., 2022

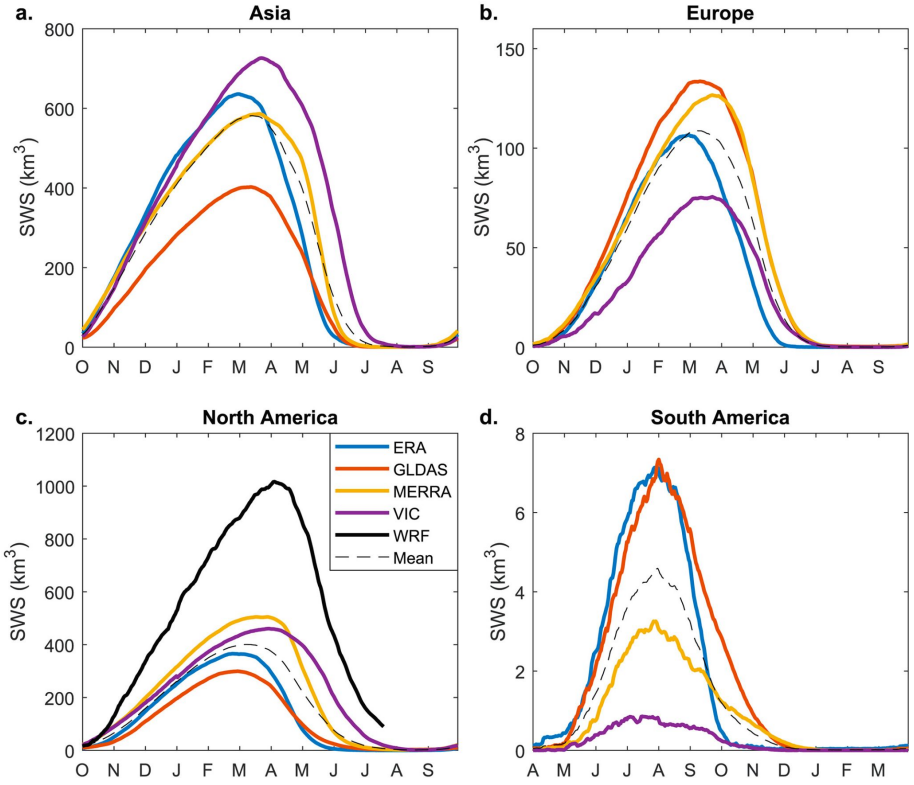
\+ Estimates of brightness temperature linked to water content
\+ Can observe under clouds
\+ Signal is sensitive to density and depth

\- Wet snow and dry snow scatter microwaves differently
\- Many sensors are new


cowherd@berkeley.edu

# Satellite missions

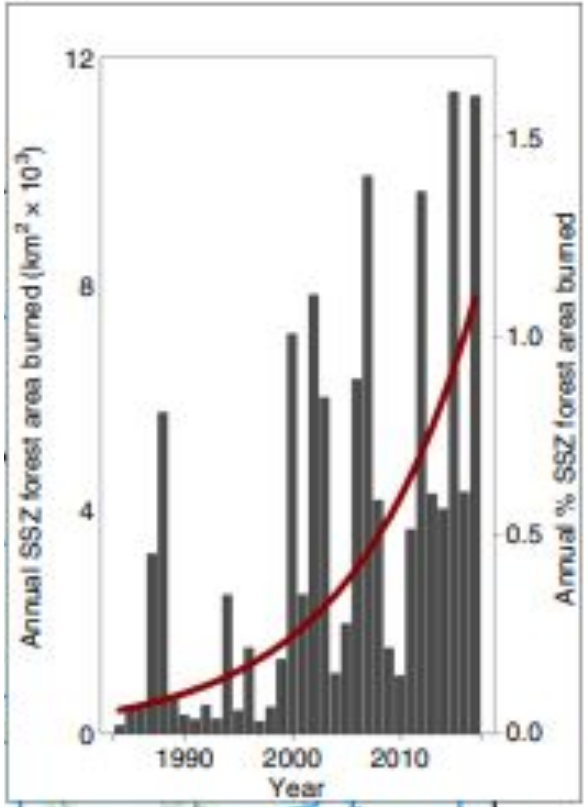
- Current snow estimates **do not agree** with each other
- There is currently **no dedicated satellite mission** for snow observation




Wrzesein et al., 2019

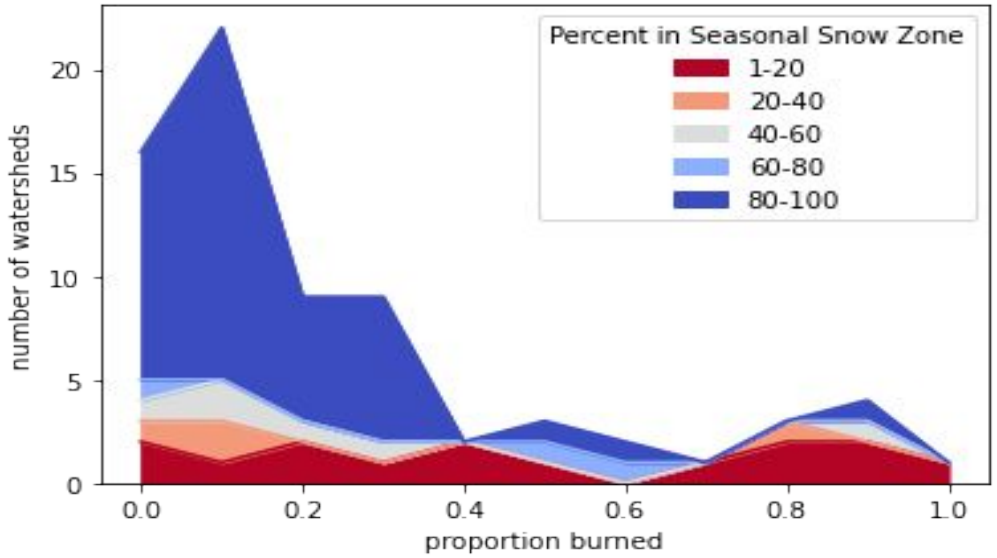
# Post-fire snow hydrology

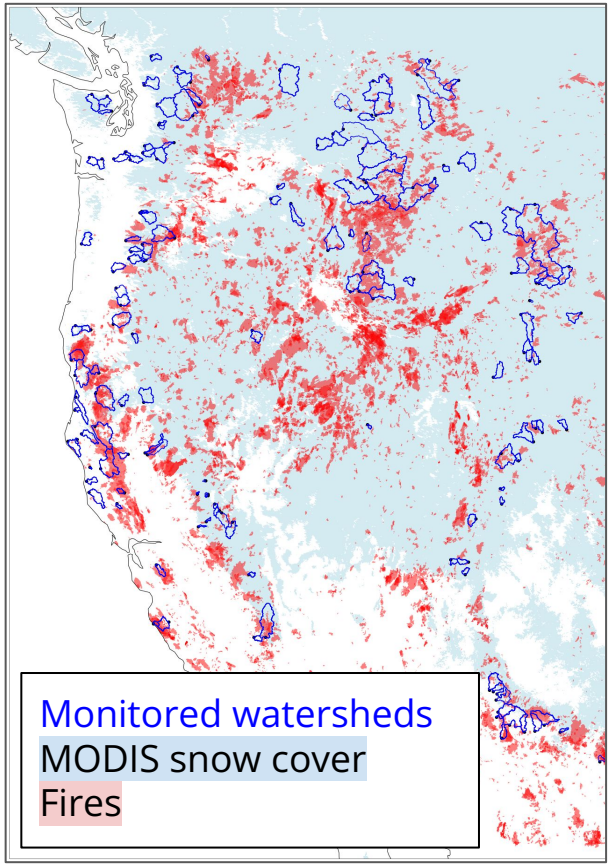
- The number, size, and intensity of wildfires in snowy basins are increasing around the world
- **Fires change the snow energy and mass balance through snow-vegetation interactions and increasing radiative forcing from black carbon deposition**
- Season-long snow presence make snow vulnerable to dramatic energy input change



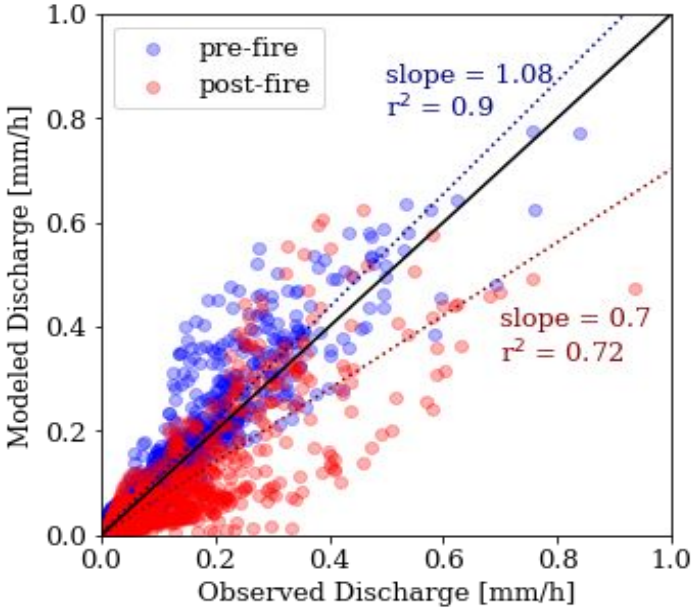

Gleason et al., 2019

# Fires in the Western US



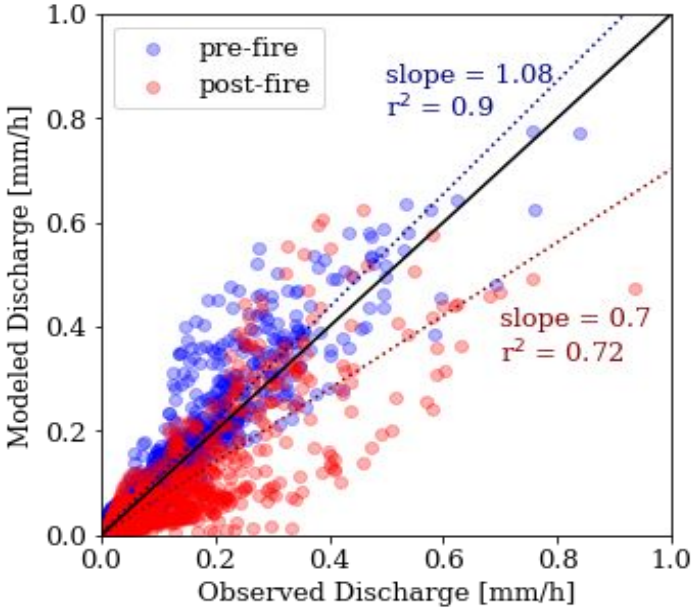



# Does streamflow change after a fire?




1. Model climate-streamflow relationships from pre-fire data
2. Apply models to post-fire climate data
3. Compare post-fire observations to model predictions

# Does streamflow change after a fire?



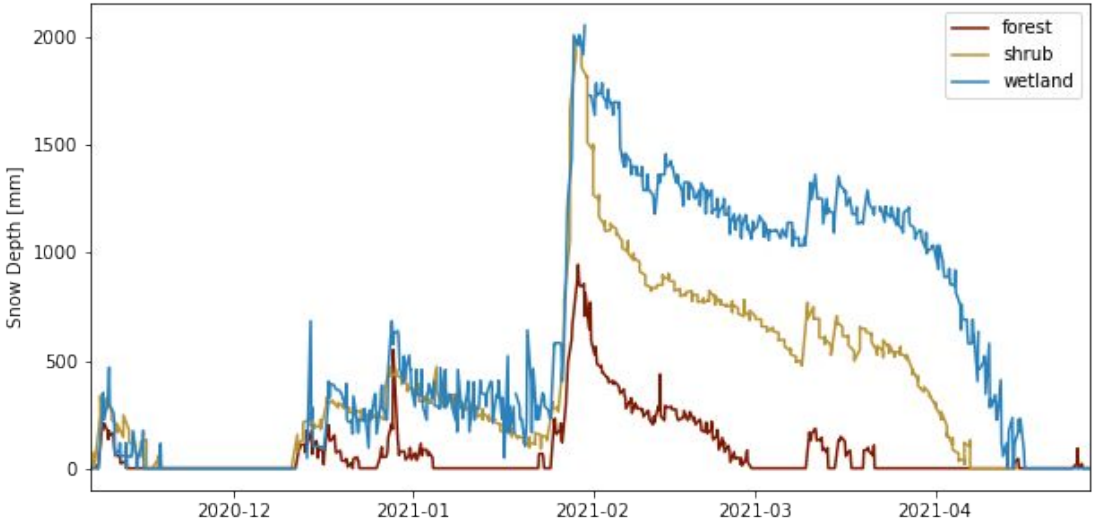

1. Model climate-streamflow relationships from pre-fire data
2. Apply models to post-fire climate data
3. Compare post-fire observations to model predictions

In general, streamflow increases after fires in the Western United States *(Williams et al., 2022)*

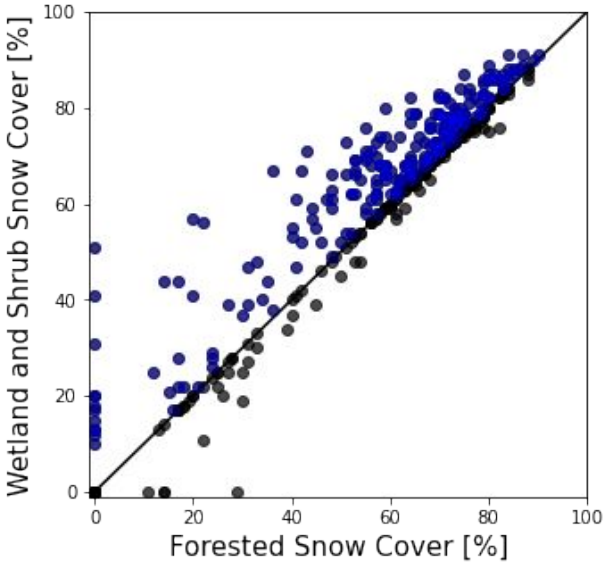
**Satellite monitoring helps us understand if that increase comes from snow-forest interactions**

# Vegetation cover drives local variance in response to snowfall events

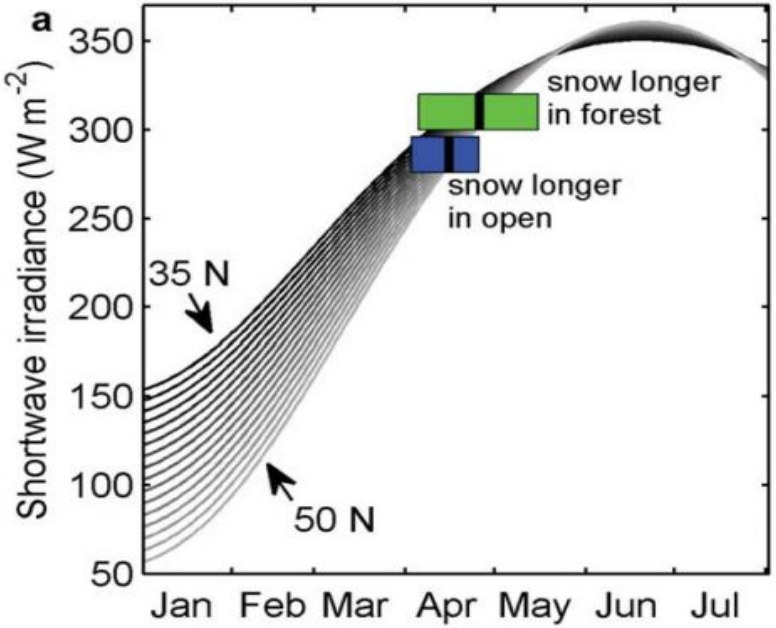
1. In-situ monitoring where land cover change is driven by wildland fire




2. MODIS fractional snow covered area



# Not all post-fire hydrology is the same




Lundquist et al. 2013

In cold areas, **forest cover is detrimental to snow duration**

In warm areas, **forest cover is protective snow duration**



cowherd@berkeley.edu

# Conclusions

1. Snow is an important global water resource
2. Some properties of snow are monitored by satellites, snow water equivalent cannot be directly estimated from space
3. Post-wildland fire snow hydrology is difficult to predict; satellite monitoring of water resources provides valuable management and scientific information

# Acknowledgements

Manuela Girotto, UC Berkeley

Scott Stephens, UC Berkeley

Gabrielle Boisrame, Desert Research Institute

Sabrina Chui, Blue Forest Conservation

U.S. Department of Energy, Computational Science Graduate Fellowship


# Thank you!

Marianne Cowherd

cowherd@berkeley.edu