Snowmelt-timing

JiHyun Kim, Eric Gagliano, Catherine Breen, Megan Mason, Lila Rickenbaugh, Mahboubeh Boueshagh, Santiago Munevar, Anika Krishnan, Akintunde Kuye, Shaun Joseph

SNOWEX NASA

UNIVERSITY of WASHINGTON
eScience Institute

Photo credit: J. Ramage

Image from https://www.pngaaa.com/detail/996438

Importance of snowmelt-timing and in-situ snow data

Snowmelt-timing vital for:

- Managing water resource (one-sixth of the world's population relies on rivers fed by the melting of seasonal snow and glaciers, ESA, 2015)
- Controlling environmental hazards such as flooding, wildfire, drought, etc.
- Predictioning and modelling albedo for climate change impacts

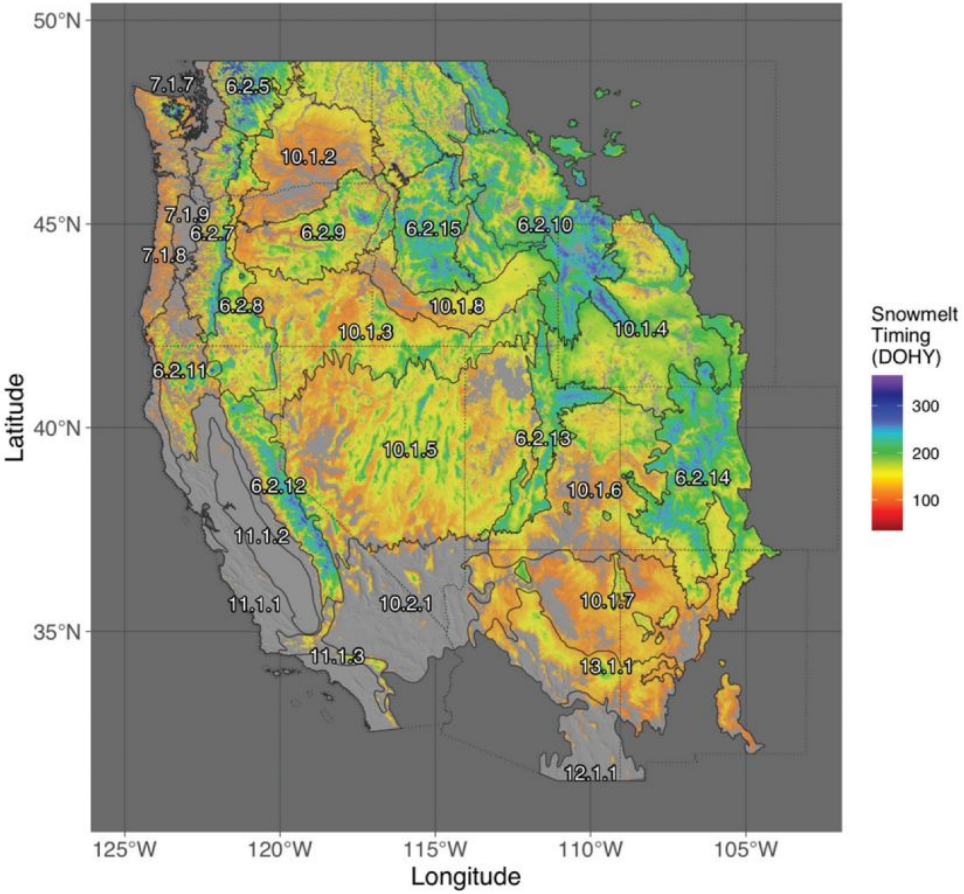
In-situ measurements of snow critical for:

- Documenting snow hydrology, including seasonal snow-evolution
- Quantifying uncertainty in the remote sensing-based estimates

Previous study

O'Leary III et al. (2022) Physical Geograph

- Study area : the western US with 10+ years snow throughout the study period (hydrologi years 2001–2018)
- Data: MODIS cloud-gap filled normalized-difference snow index (NDSI) daily snow-cover product (MOD10A1F)
- Results : 7.04% of study area experiences statistically significant (α = 0.05) trends of earlier snowmelt, and 2.62% with significant trends of later snowmelt
- Limitation: little consideration about the uncertainty in the MODIS-based estimates



[Regional trends in snowmelt timing for the western United States throughout the MODIS era]

Objectives

Overarching goal, *initially*:

- To estimate the uncertainty in the snowmelt timing estimates from different remote sensing data (e.g. MODIS & Sentinel-1) with various spatio-temporal resolutions using SnowEx data
- To analyze the meteorological and topographical effects on the long-term trends in snowmelt timings and also to identify potential future campaign sites

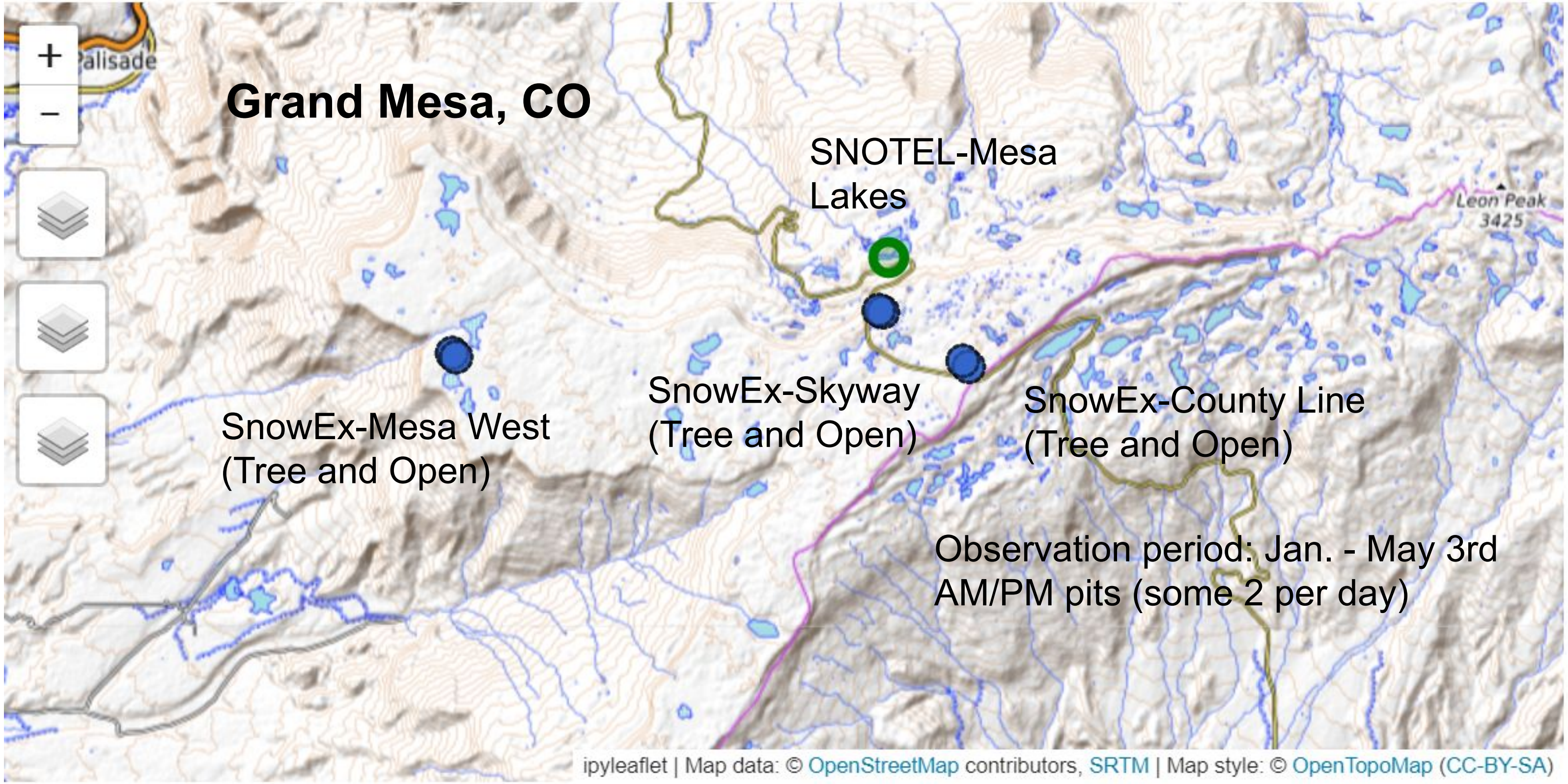
New overarching goal:

- To present the overall seasonal profile of snowpack-ripe-runoff-melt processes using different types of data (both remote-sensing estimates and ground measurements)

Hackweek goals, *always*:

- To get to know SnowEx data (e.g., 2020 Grand Mesa campaign)
- To learn the tools (Jupyter notebook, git/gitHub) to work with SnowEx data and remote sensing datasets
- To develop programming and visualization skills
- To meet snow community!

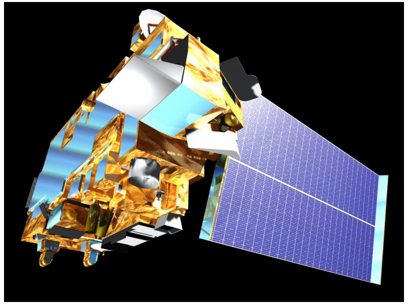
Study site


Palisade
Grand Mesa, CO
SNOTEL-Mesa Lakes
Leon Peak 3425
SnowEx-Mesa West (Tree and Open)
SnowEx-Skyway (Tree and Open)
SnowEx-County Line (Tree and Open)
Observation period: Jan. - May 3rd
AM/PM pits (some 2 per day)
ipyleaflet | Map data: © OpenStreetMap contributors, SRTM | Map style: © OpenTopoMap (CC-BY-SA)

Data - Remote sensing

MODIS (Moderate Resolution Imaging Spectroradiometer)

- On Terra (since 1999) and Aqua (since 2002)
- Temporal resolution : 1 - 2 days
- Spatial resolution: 250 m - 1000 m (varies by bands)
- Descending pass at 11 (Terra), Ascending pass at 14 (Aqua)
- High radiometric sensitivity (12 bit) with swath covering 2,300 km
- Pros: effective to monitor large area
- available for long-time (since 2000),
- => suitable for long-term change analysis
- Cons: unable to discriminate dry (ice+air) and wet (ice+air+water) snow



https://eos.com/find-satellite/modis-mcd43a4/

Sentinel-1

- On two identical radar satellites (launched in 2014. Ascend node at 6pm)
- Temporal resolution : 6 days
- Spatial resolution : 5 - 40 m
- Descending pass at 6:30, Ascending pass at 18:30
- Synthetic aperture radar operating day and night on C-band with swath covering 80 km
- Dual polarisation for all modes-VV + VH OR HH + HV
- Pros: able to identify wet snow as the changes in the backscatter ratio (-2 ~ -3dB)

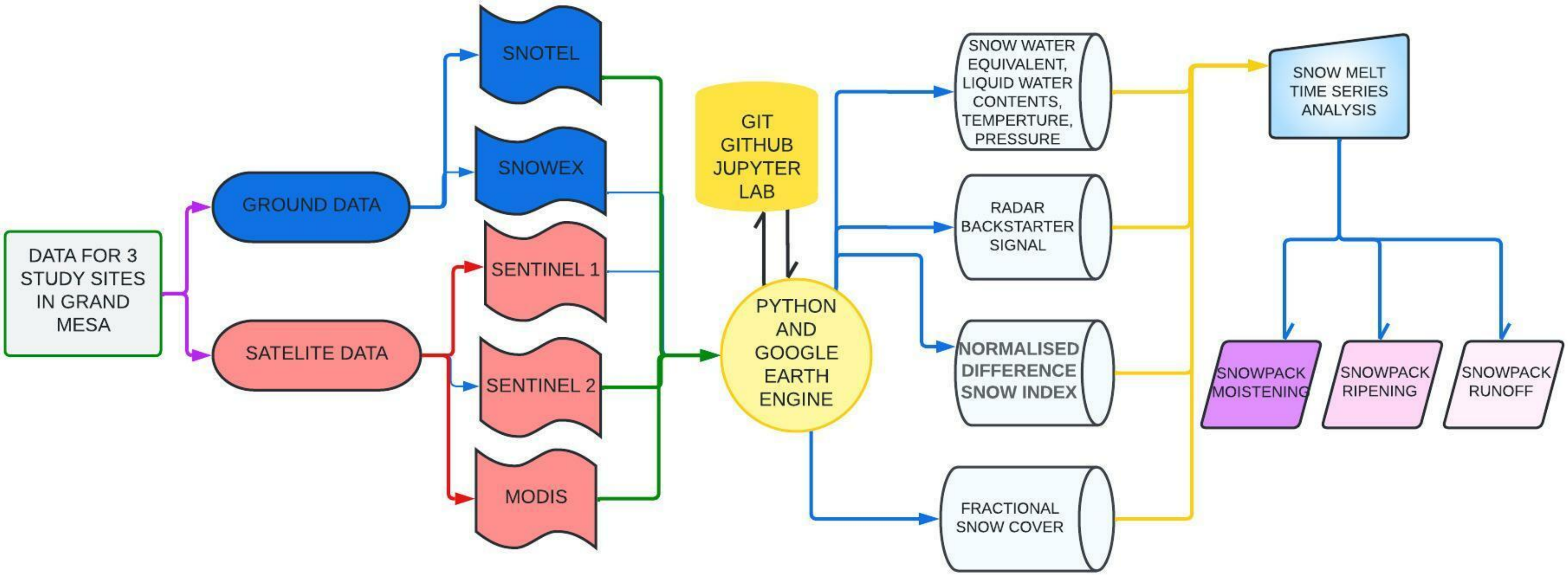
https://sentinel.esa.int/web/sentinel/missions/sentinel-1

Data - SnowEx snow pits

- Many NASA scientists and volunteers gathered for three days of work in order to collect measurements. Some snow pit measurements are incomplete due to shallow or discontinuous snow cover.
- The main parameters were temperature, snow density, stratigraphy, and grain size.
- Some occasions allowed for the measurement of liquid water content (LWC).

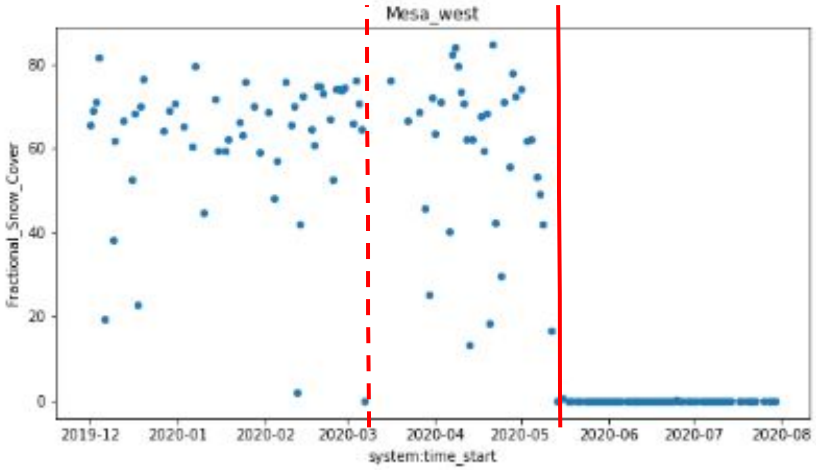
Nasa scientists dig snow pits to measure the depth. Photo courtesy of NASA. http://api.durangoherald.com/articles/137951#slide=10

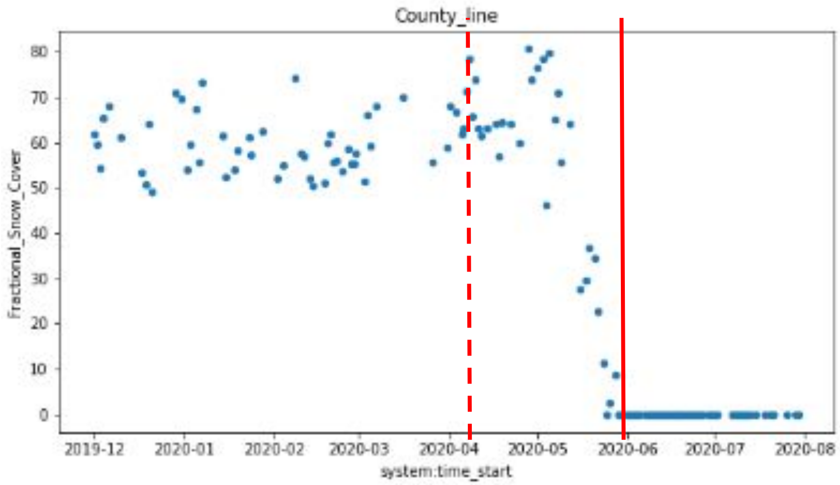
Project Workflow

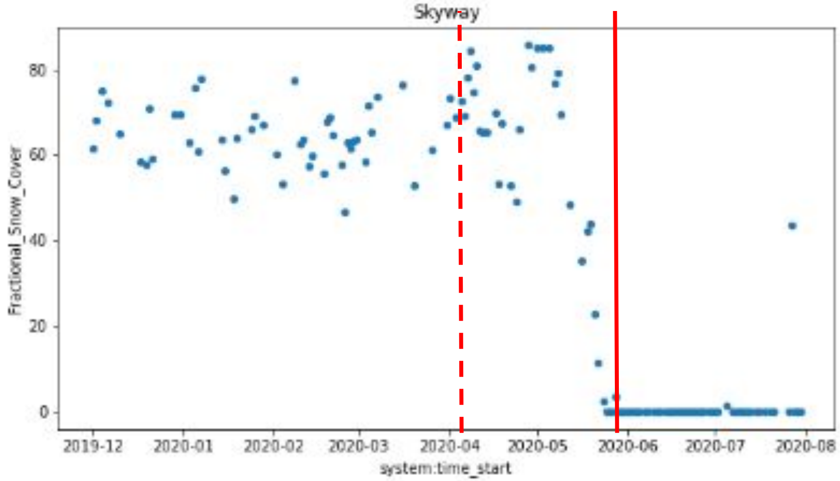


Results: MODIS

Fractional Snow Cover (from GEE)

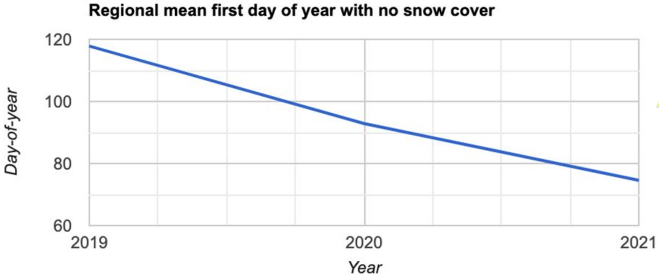




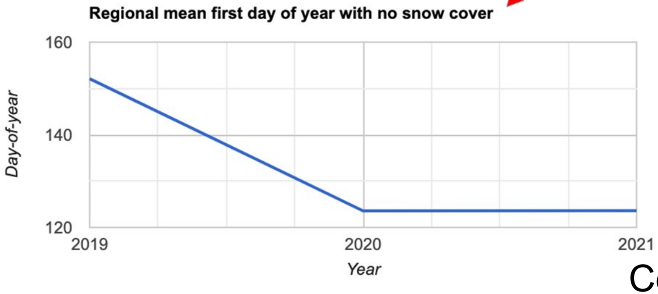


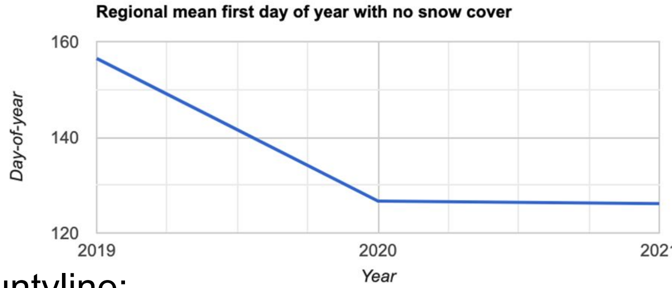
Results: MODIS-*cont'd*

Mean first day (Julian day) of year with no-snow (from GEE)



Mesa west:
2019: 118.2
2020: 93.3
2021: 74.7



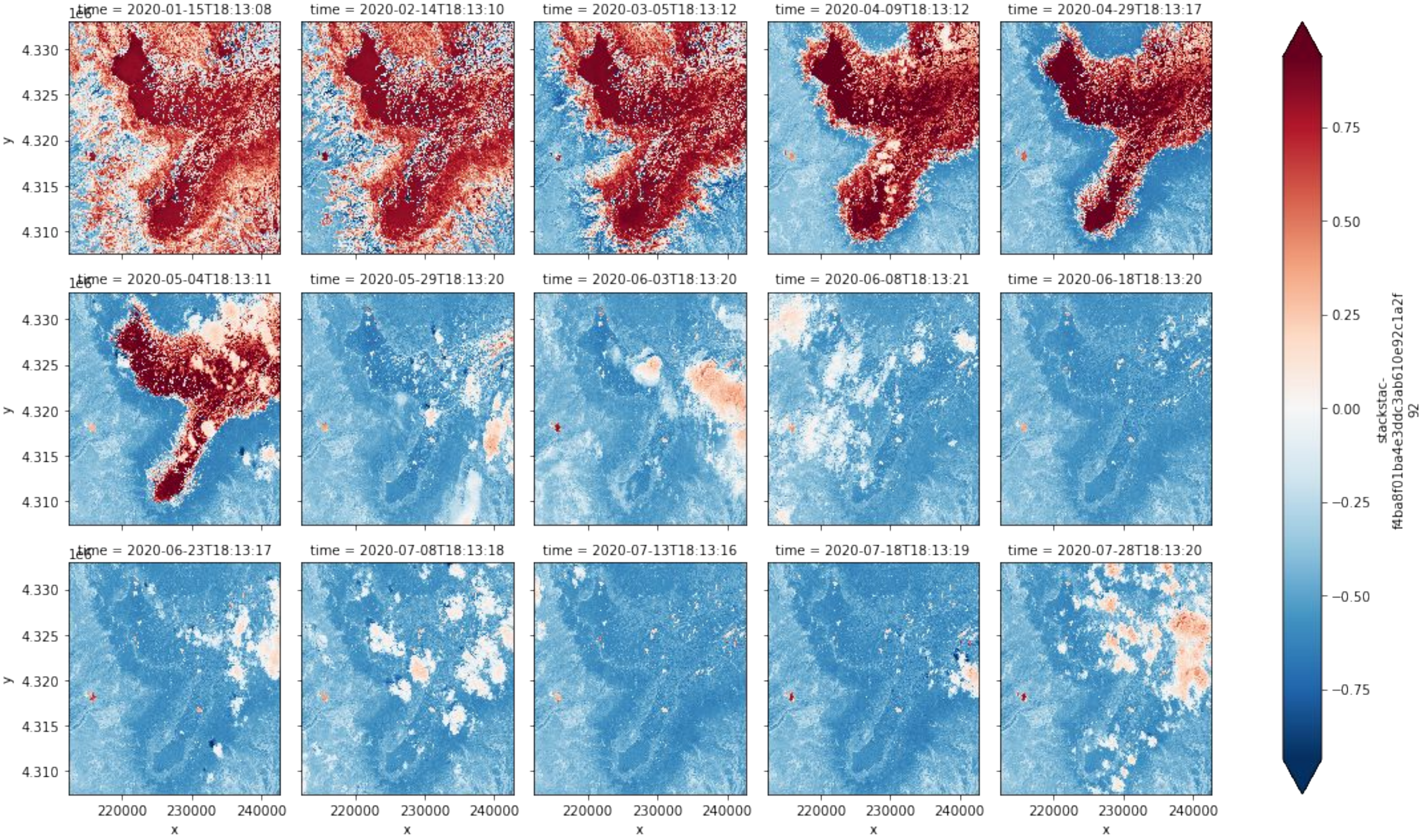


Skyway:
2019: 152.1 2020: 123.6 2021: 123.6

Countyline:
2019: 156.5 2020: 126.7 2021: 126.1

Results: Sentinel-2

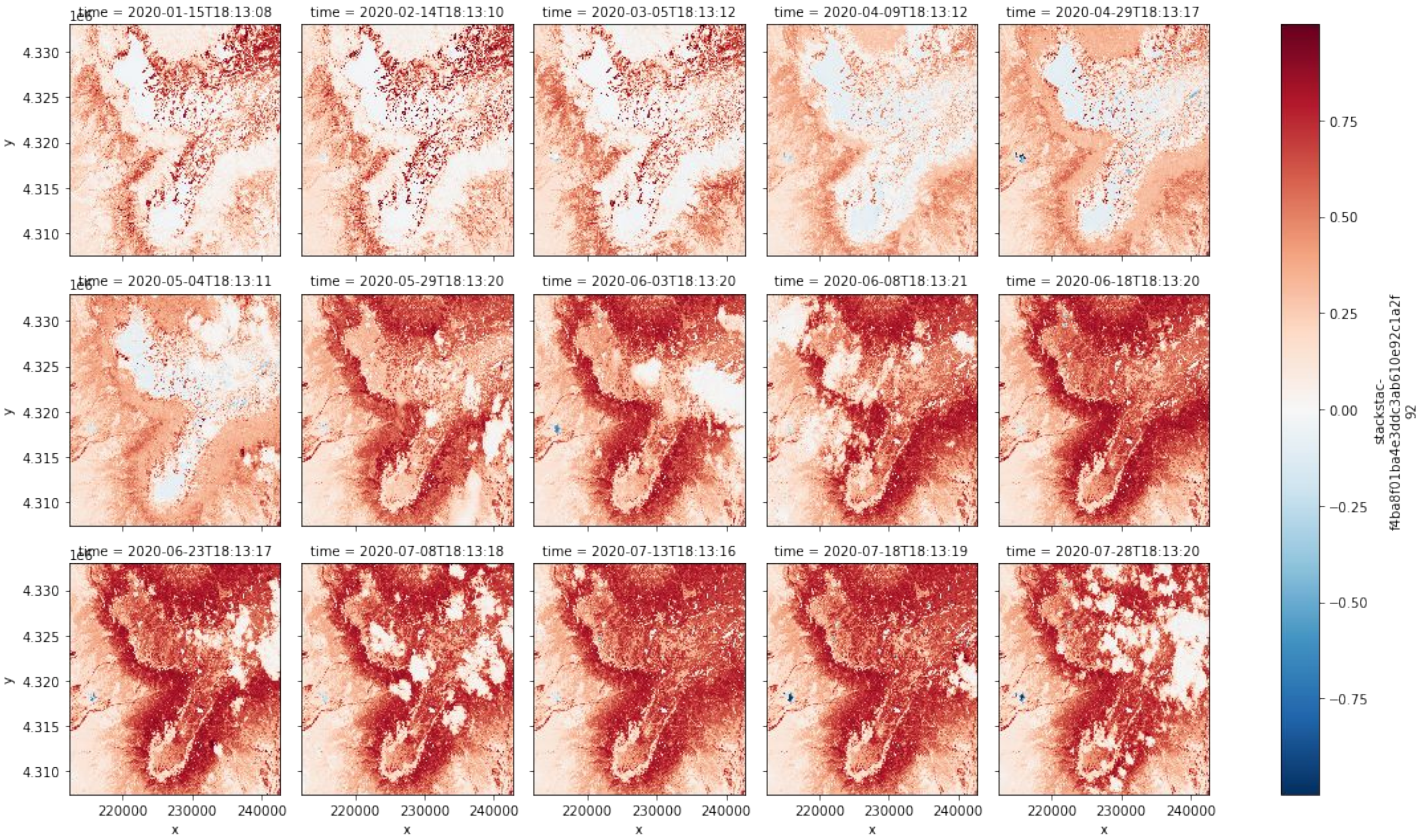
NDSI
(2019-12-01 to
2020-08-01)



Results: Sentinel-2

-cont'd

NDVI/RGB (2019-12-01 to 2020-08-01)



Results: Sentinel-2 *-cont'd*

-RGB/NDVI gifs of Grand Mesa from (2019-2020) from Landsat-8

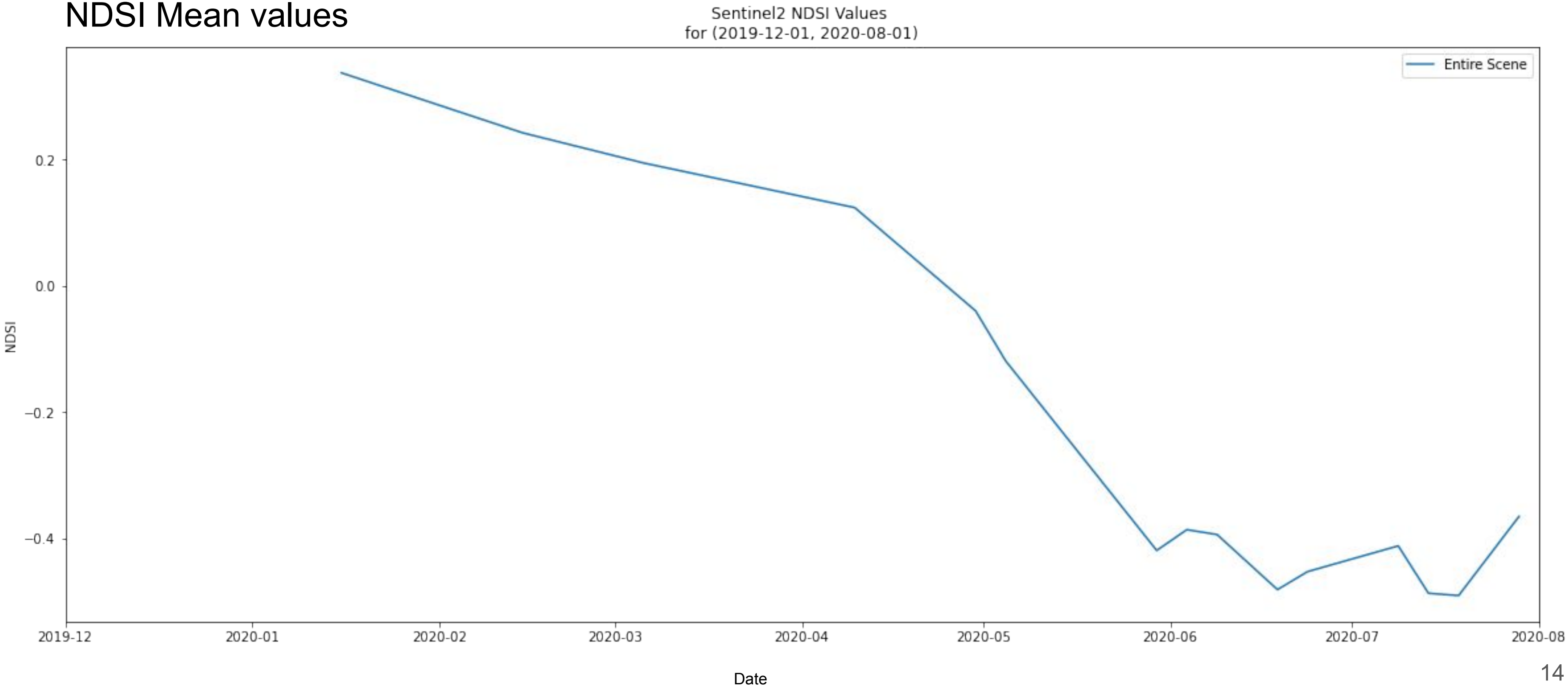
-Limitations: Grand Mesa is in two different UTM zones (EPSG 32612/32613) and cloud cover.

-Conflicts between using different bands/imagery databases

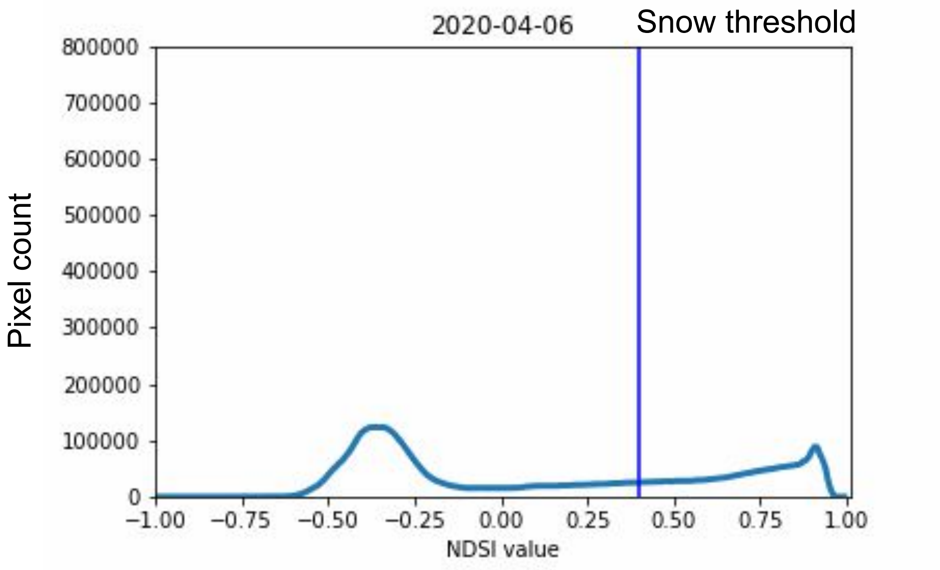
-Each .geojson had different data when used for the previous tables.

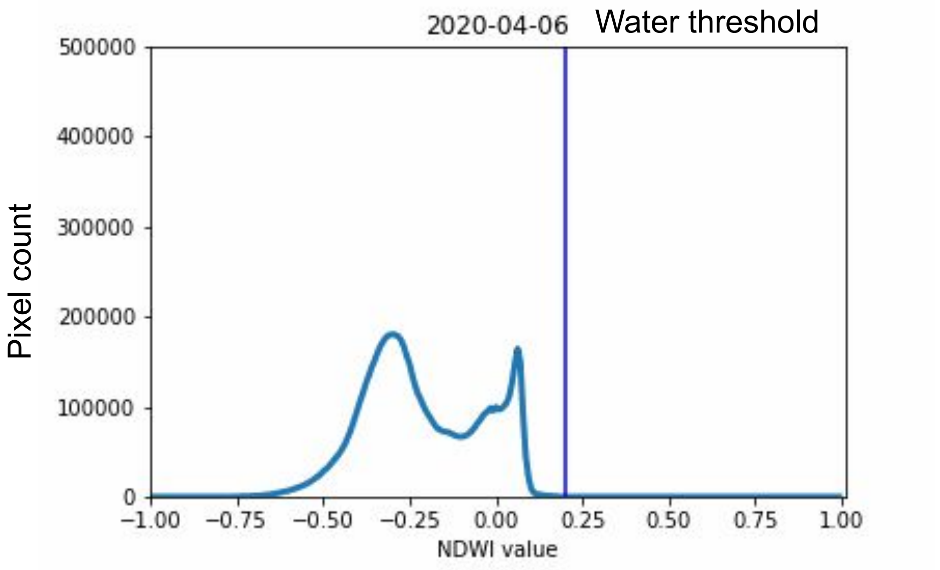
Results: Sentinel-2 *-cont'd*

NDSI Mean values



Results: Sentinel-2



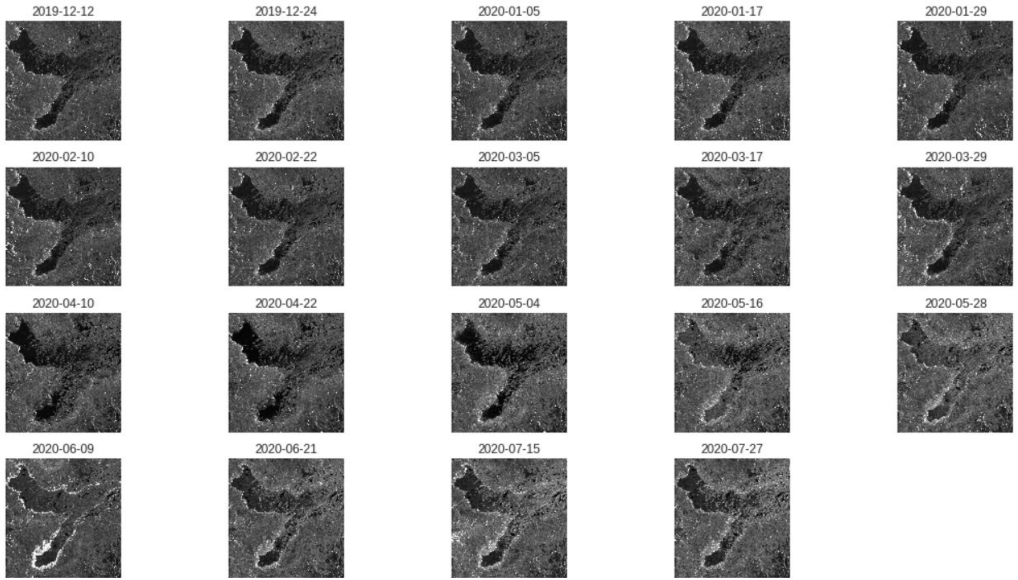


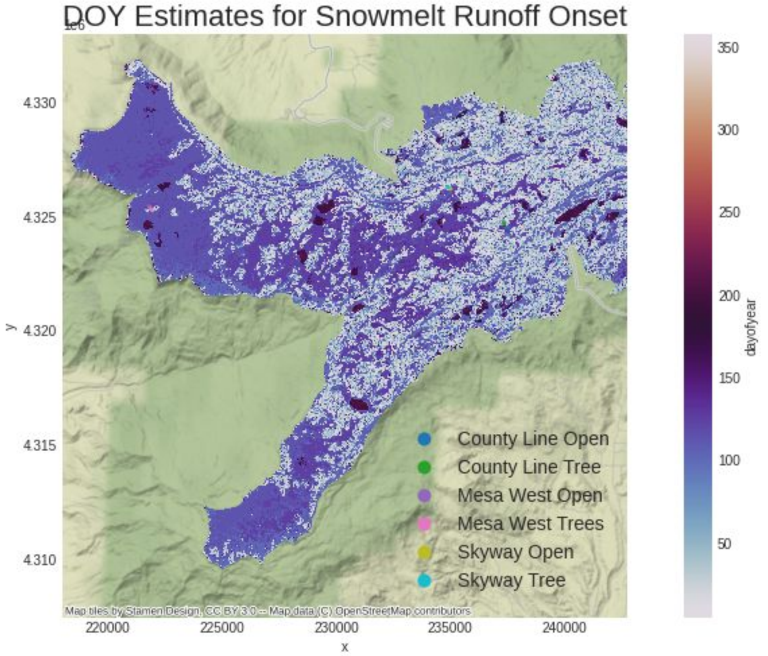
High count of snow pixels in April 2020
Moderate count in early May
Minimal count in late May

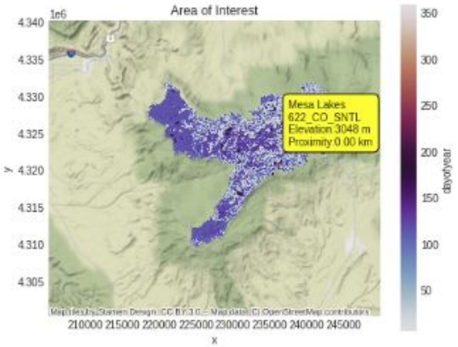
Little change in NDWI values throughout season

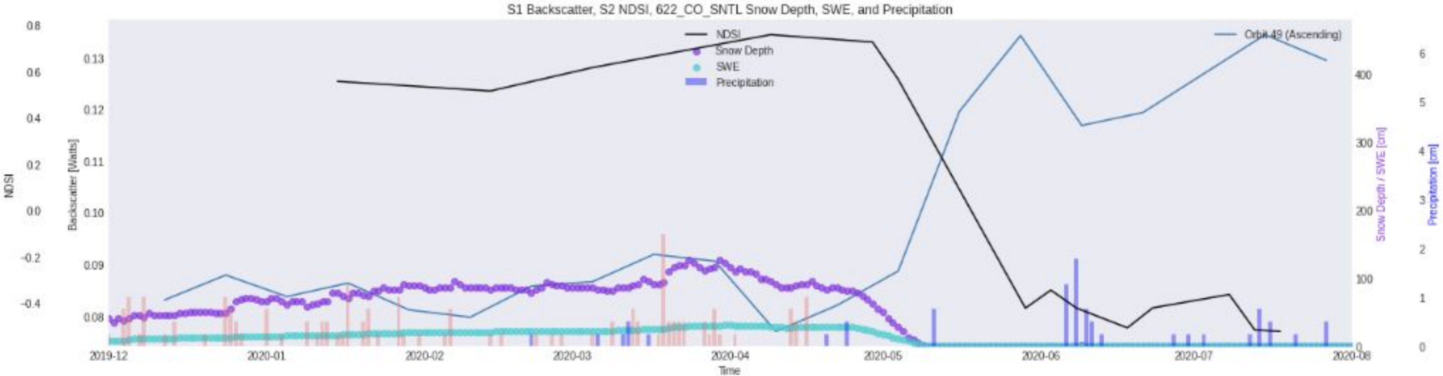
Limitations: Low temporal resolution, optical sensor of Sentinel-2 for water content, my Python skills

Results: Sentinel-1

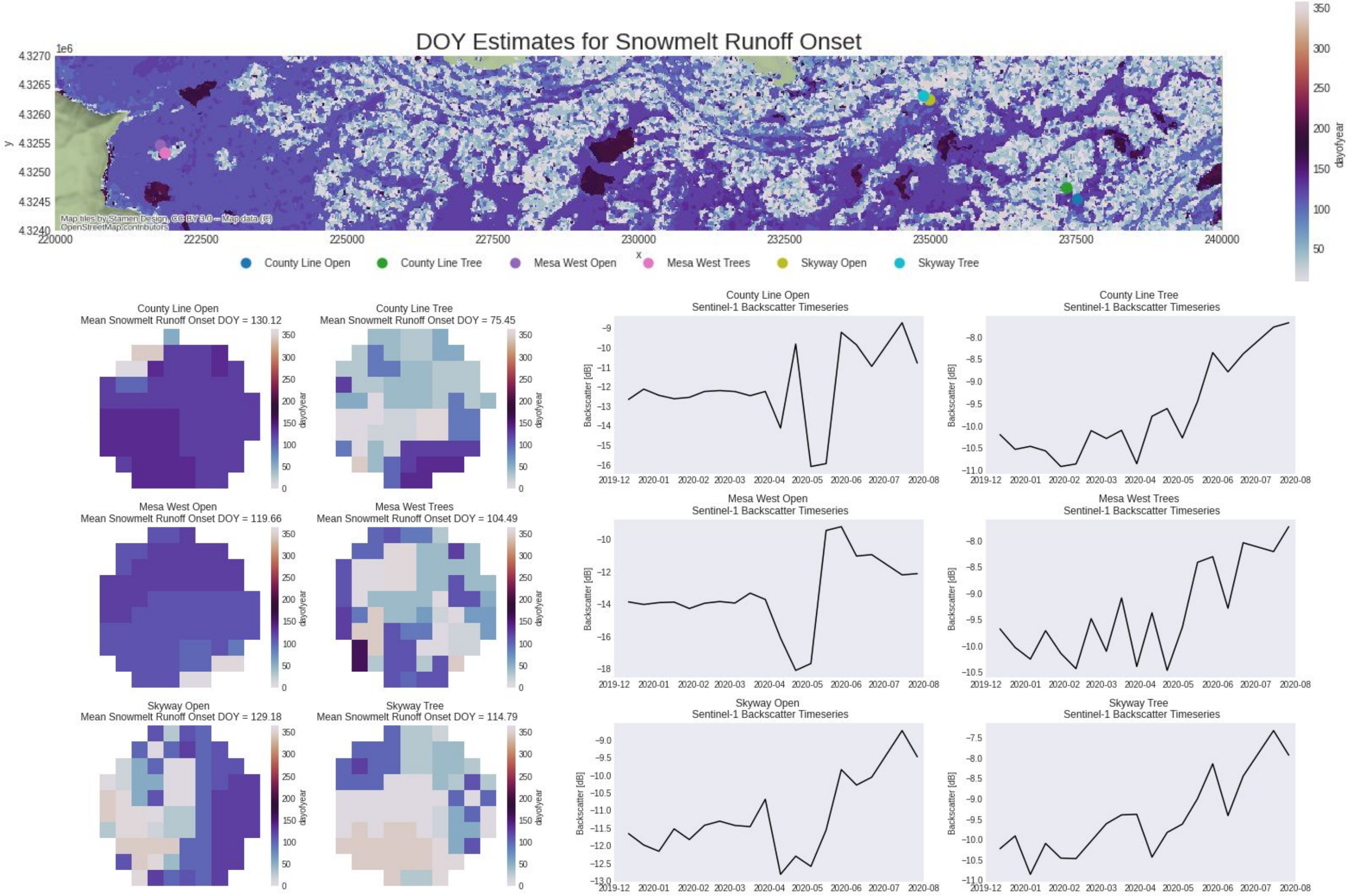




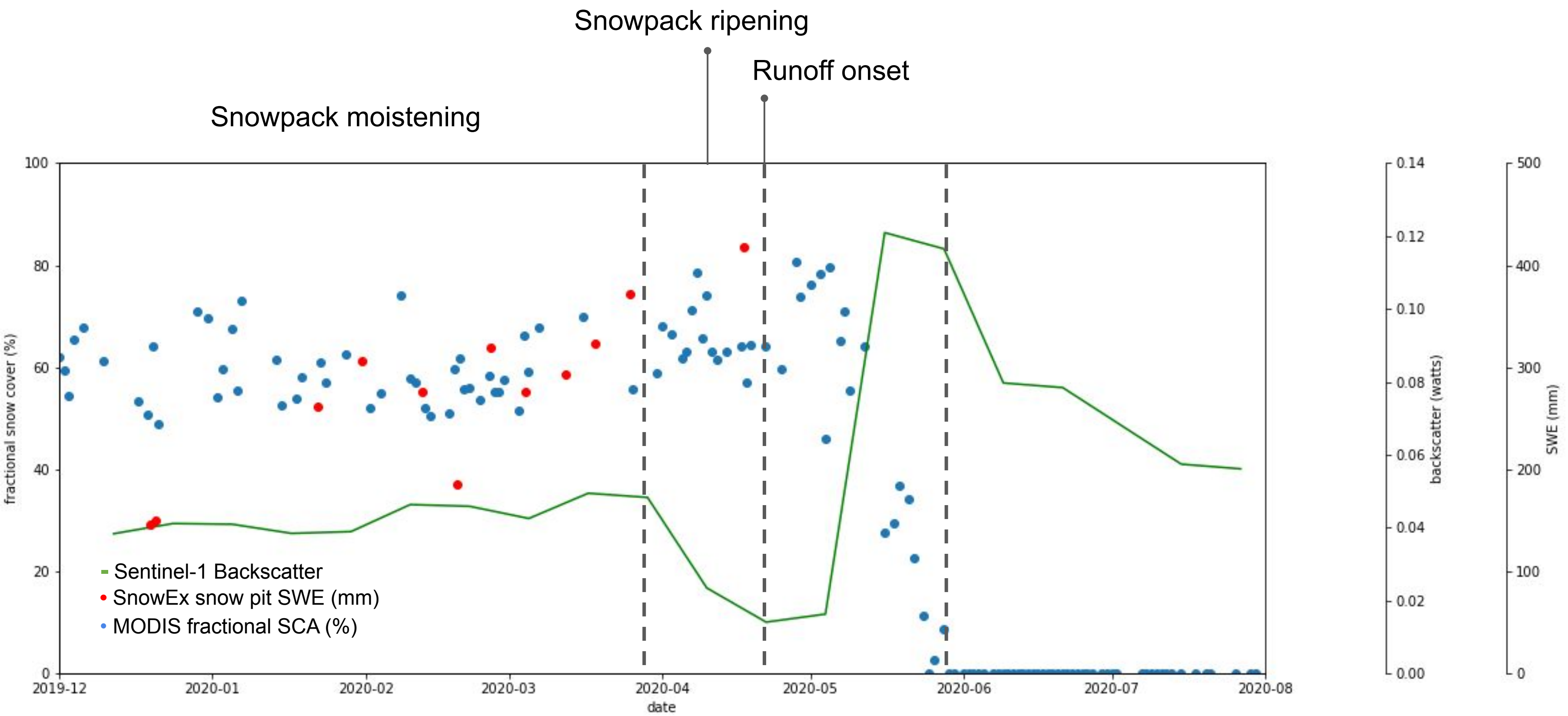




Results Sentinel-1

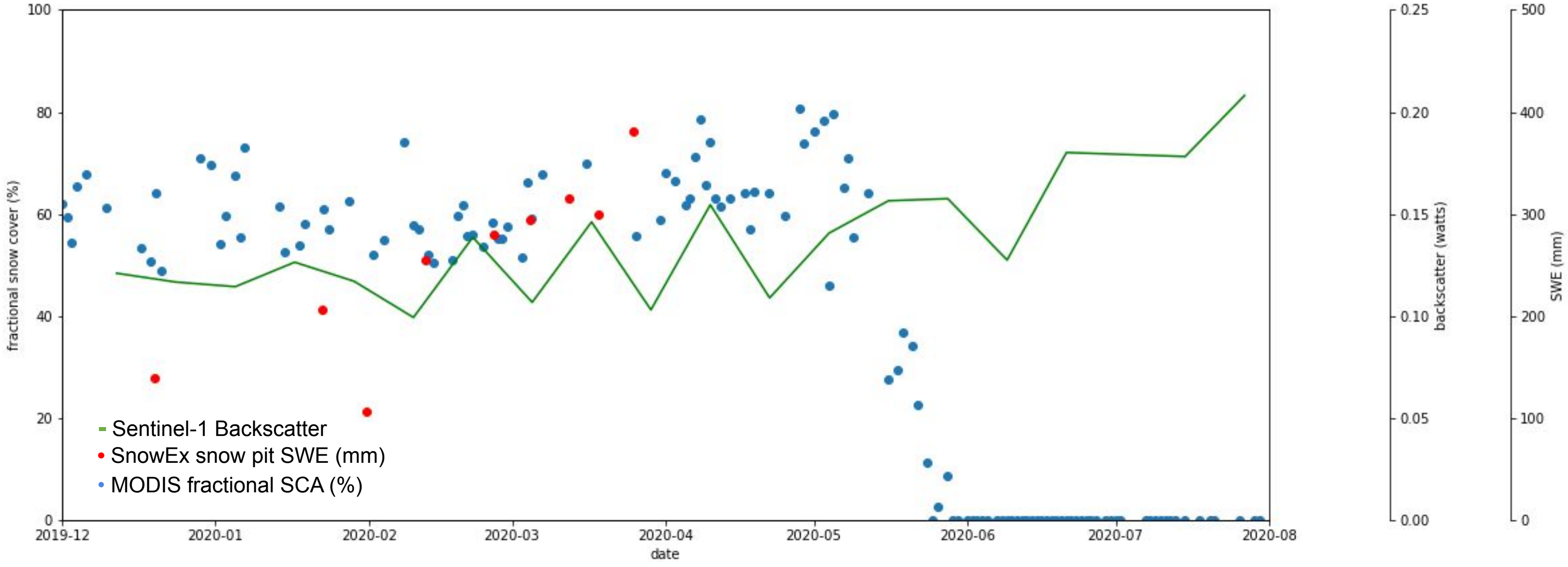


Results: Comprehensive seasonal profile

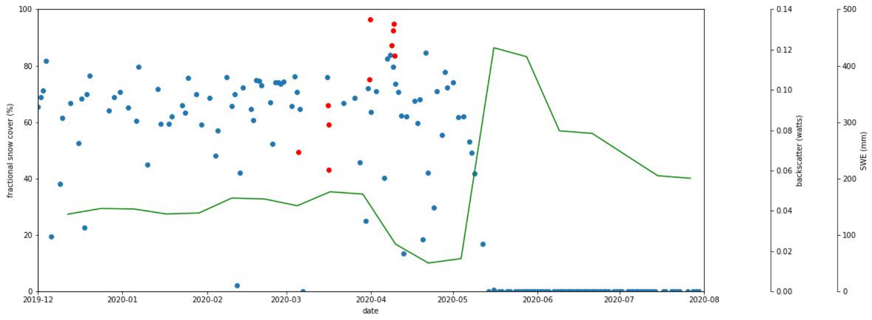


County line, open

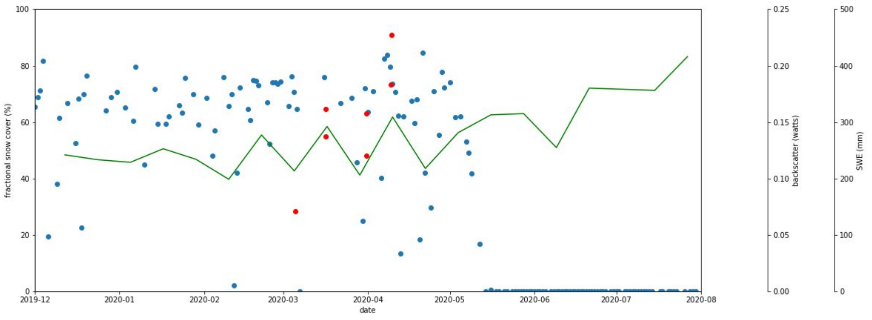
Results: Comprehensive seasonal profile



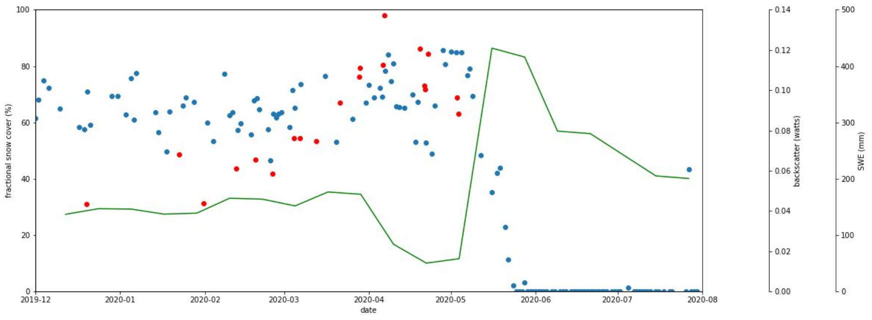
County line, trees



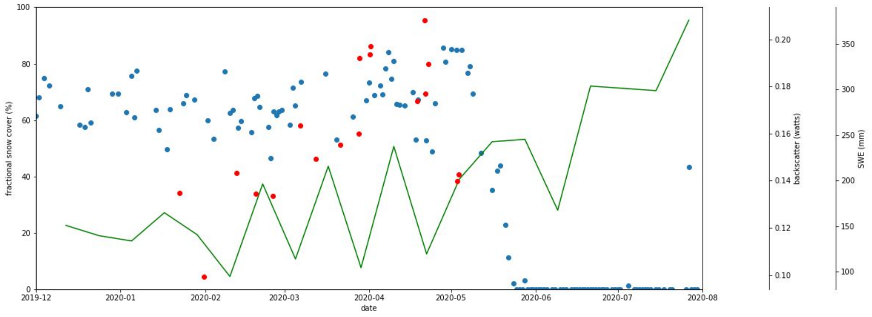
Mesa west, open



Mesa west, trees



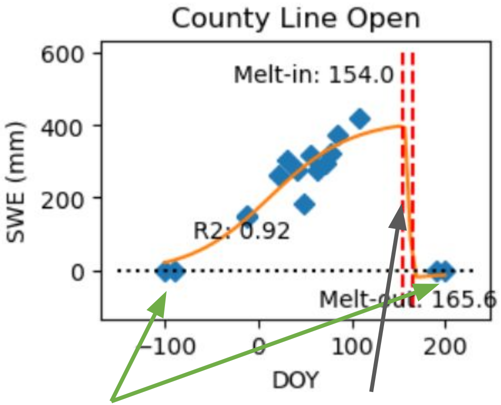
Skyway, open



Skyway, trees

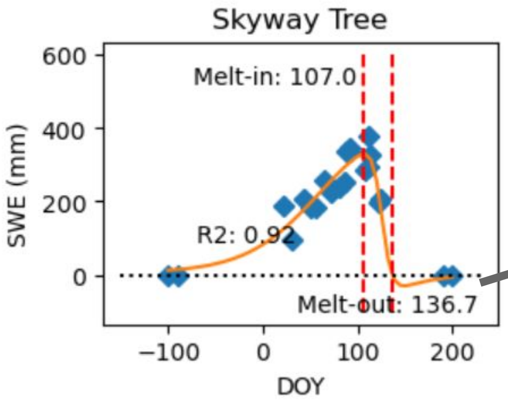
Results: Timing estimation

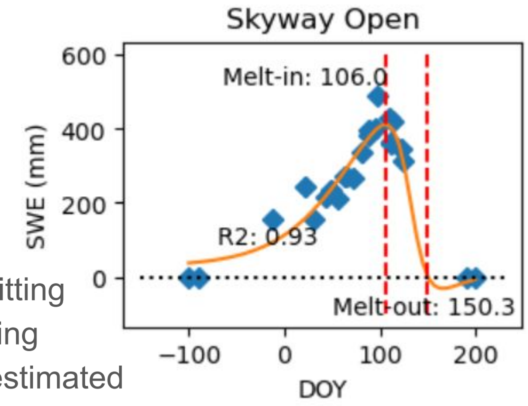
Melt-in and out timing estimation
- By fitting a double-logistic curve to the SnowEx SWE data in 2020
- Melt-in timing: when the curve == max
  Melt-out timing: when the curve == 0

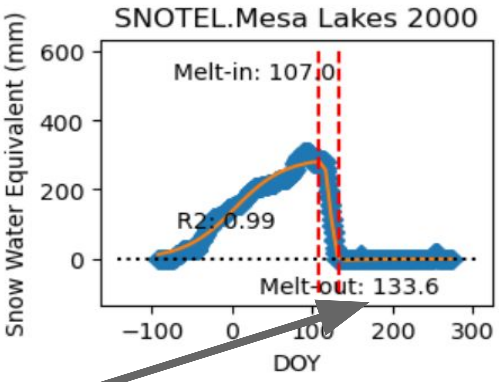


Synthetic points to define the beginning/end phase (i.e. no snow)

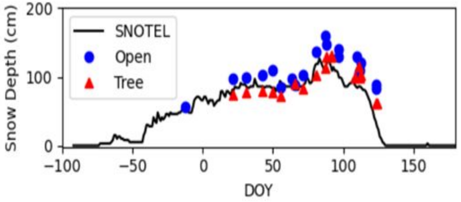
Not enough data for fitting the curve during melting (bad Covid!), so the estimated timings are less reliable







The melt-out timing from the fitted sigmoid-curve at the Tree site are close to the timings at the SNOTEL lake site (1.6 km away), where the snow depth profiles were similar



∴ Fitting a logistic curve could be a useful method to estimate snow-evaluation timings with a limited number of data (still! we need “some”)

Discussion

Challenges!!

- Finding the suitable SnowEx stations where had enough observations for our goals, two stations (County line and Skyway) were close to each other making it difficult for the satellite data with moderate-spatial resolution!
- Difference in the Sentinel-2 projection due to the Grand Mesa in two different UTM zones (EPSG 32612/32613)
- Gaps (i.e., missing data) due to the cloud coverage for optical sensors

Future works:

- More complete analysis of snowmelt timing!
- Working with more satellite data and snow modeling we learned from Hackweek!

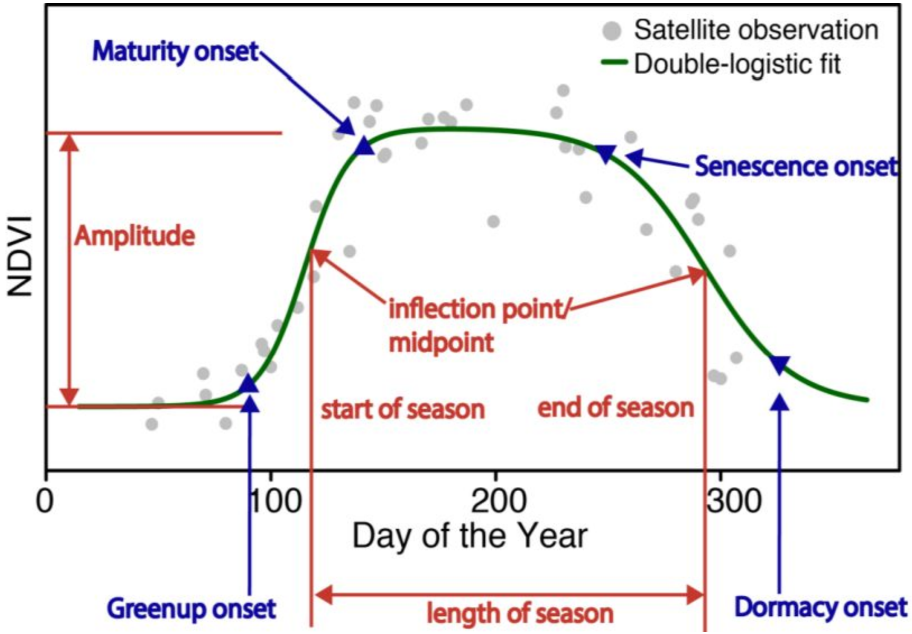
Thank you!

Question..?

Double logistic-curve

Estimating phenological timings (greenup, maturity, senescence, dormancy, and therefore growing season length) from the double-logistic curve fitted to the remote-sensing vegetation index (i.e., NDVI, EVI, EVI2, and LAI) is one of the widely-used methods by vegetation monitoring community (e.g., MODIS phenology products, MCD12.v1-5)

$$v(t) = v_{\min} + v_{amp}\left(\frac{1}{1+e^{m_1-n_1 t}} - \frac{1}{1+e^{m_2-n_2 t}}\right)$$

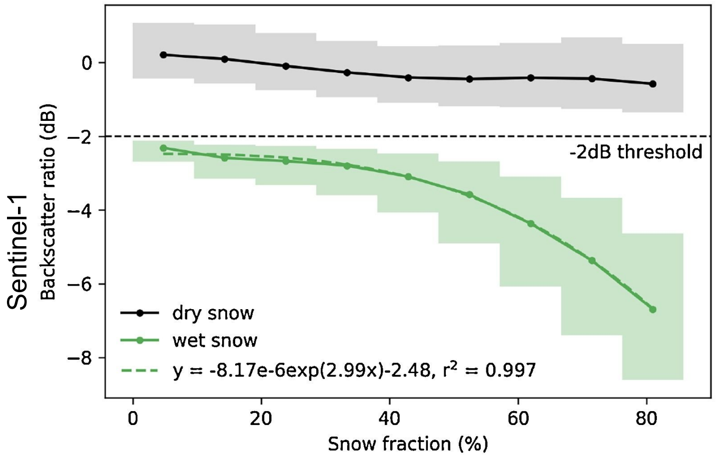


Equation from Yang et al., 2012, Journal of Geophysical Research Biogeosciences
Figure from https://eo4society.esa.int/wp-content/uploads/2021/01/GlobDiversity_ATBD_LSP_V3-4_FINAL.pdf

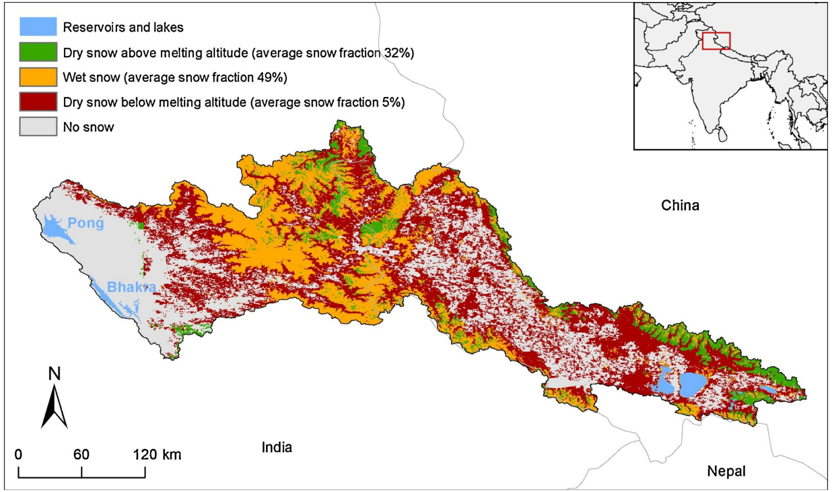
Previous study

Snapir et al. (2019), Int. J. Appl. Earth Obs. Geoinf.

- Study area : Catchments of two large reservoirs in the Indian state of Himachal Pradesh
- Data: MODIS fractional SCA products, calibrated and terrain-corrected Sentinel-1 wet snow mask
- Results : Monthly maps of dry and wet snow areas by fusing MODIS and Sentinel-1 data
- Limitation: little validation using ground measurements



MODIS



https://www.sciencedirect.com/science/article/pii/S0303243418305749

Acknowledgements

-