



Introduction to NASA Snow and Ice Data Products and Applications

Part 1: Overview of NASA Snow and Ice Data Products

ARSET Host: Amita Mehta (612, GESTAR II)

Instructors: Andy Barrett (NSIDC), Walter Meier (NSIDC), Ryan Theurer (ASO)

July 24, 2025





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About ARSET

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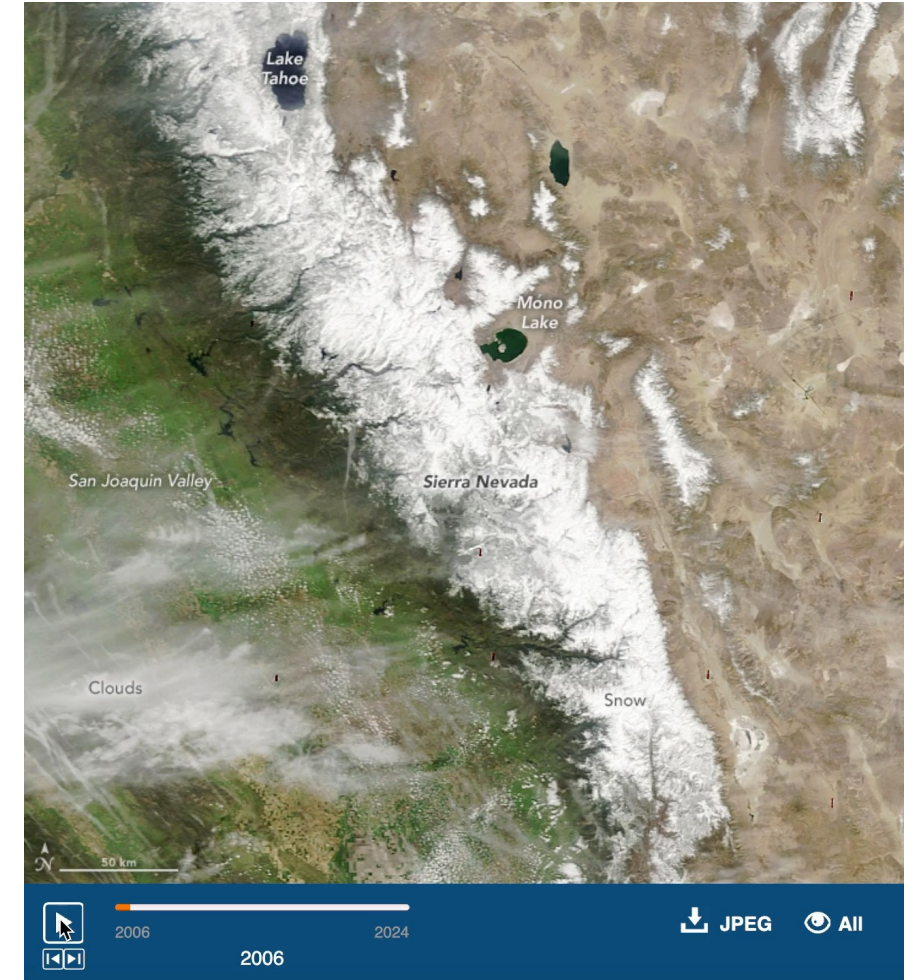


Introduction to NASA Snow and Ice Data Products and Applications

Overview

Importance of Frozen Water in the Earth System

- Frozen water on and below the Earth's surface includes snow, glaciers, ice sheets, sea ice, and permafrost.
- Approximately 75% of the Earth's total freshwater is stored in glaciers, ice sheets, and permafrost.
- Snow and ice play a crucial role in Earth's water cycles:
 - Snowmelt serves an important source of water in many regions.
 - Interannual variations in snowpack have a substantial impact on regional water availability and can lead to floods or droughts.
- Snow and ice affect albedo (a fraction solar radiation reflected back to space affecting energy balance and temperature of the Earth system).



[Snowpack in the Sierra Nevada from Terra MODIS](#)



Training Learning Objectives

By the end of this training, participants will be able to:

- Recognize the importance and applications of snow data and Snow Water Equivalent (SWE) in monitoring water availability in snow-fed rivers.
- Identify NASA snow and ice data products and their applications for water resource management and disaster monitoring.
- Access and visualize snow and ice data products using NASA webtools for water supply prediction.
- Compare how snow data across platforms are utilized in water resources management and monitoring snow-fed river flow.



Prerequisites

- [Fundamentals of Remote Sensing](#)



Training Outline

Part 1

**Overview of NASA
Snow and Ice Data
Products**

July 24, 2025

11:00 AM – 12:30 PM ET

Part 2

Access, Analysis,
and Visualization of
NASA Snow and Ice
Data Products

July 31, 2025

11:00 AM – 12:30 PM ET

Part 3

Monitoring Mountain
Snowpack and
Prediction of Water
Availability in the
Western US for Water
Resources and
Disaster Applications

August 7, 2025

11:00 AM – 12:30 PM ET

Homework

Opens August 07 – Due August 21 – Posted on Training Webpage

A certificate of completion will be awarded to those who attend all live sessions and complete the homework assignment(s) before the given due date.





Part 1: Overview of NASA Snow and Ice Data Products

Part 1 Objectives

By the end of Part 1, participants will be able to:

- Recognize the impacts of snow and ice parameters to water resources applications.
- Identify NASA snow and ice data products and their applications for water resource management and disaster monitoring.
- Identify snow and ice data parameters and their characteristics.
- Explore examples of applications of snow and ice data for water resource management.



Part 1 Outline

- Snow and Ice Geophysical Parameters For Water Resources Applications
- NASA's Remote Sensing-Based Snow Data Products
- Example of Snow Data Application: Evaluating Snow Variability through a Climatological Analysis to Support Ecological Monitoring in Northeast Alaska



How to Ask Questions

- Please put your questions in the Questions box and we will address them at the end of the webinar.
- Feel free to enter your questions as we go. We will try to get to all of the questions during the Q&A session after the webinar.
- The remainder of the questions will be answered in the Q&A document, which will be posted to the training website about a week after the training.



Part 1 – Instructors

Andrew Barrett

Senior Associate Scientist
NASA National Snow and Ice
Data Center (NSIDC)



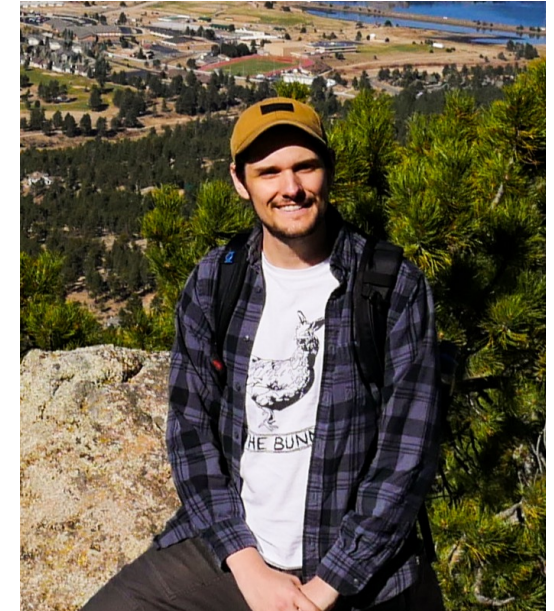
Walter Meier

Senior Research Scientist
NASA National Snow and Ice
Data Center (NSIDC-DAAC)



Ryan Theurer

Senior Software Engineer
Airborne Snow Observatory
(ASO)

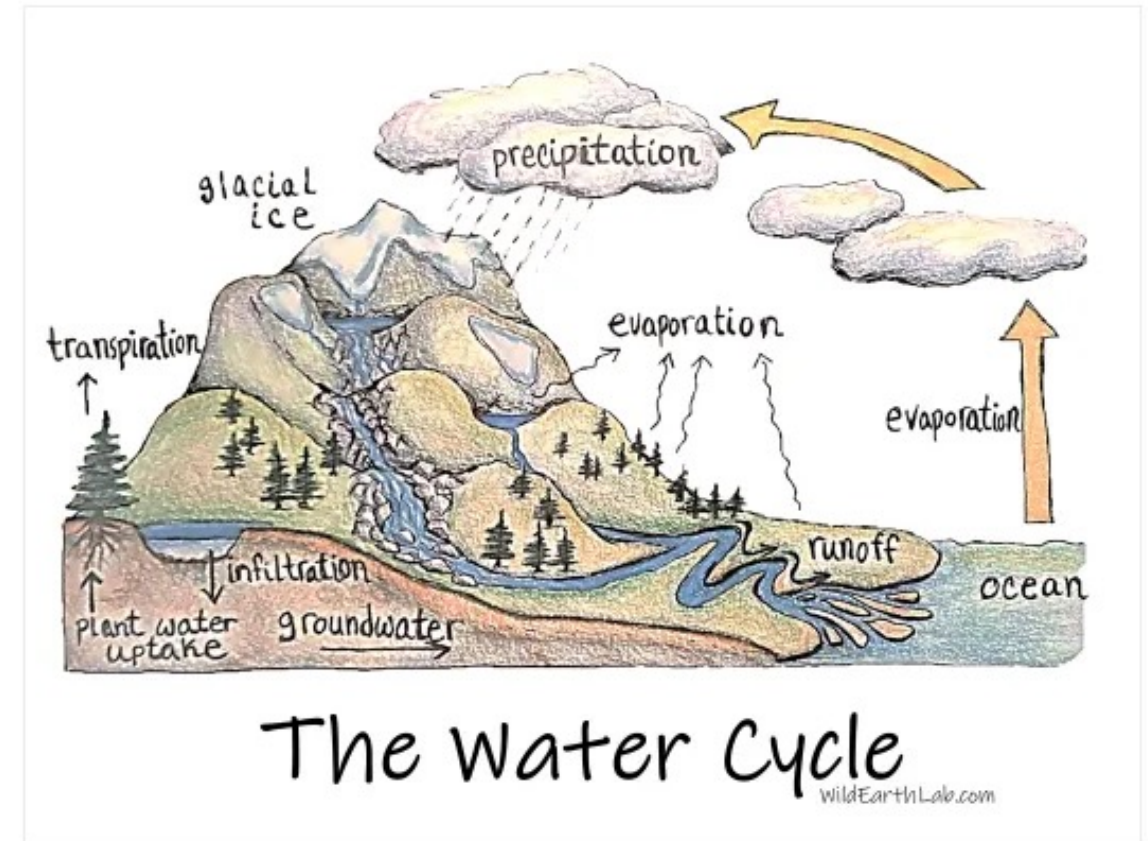
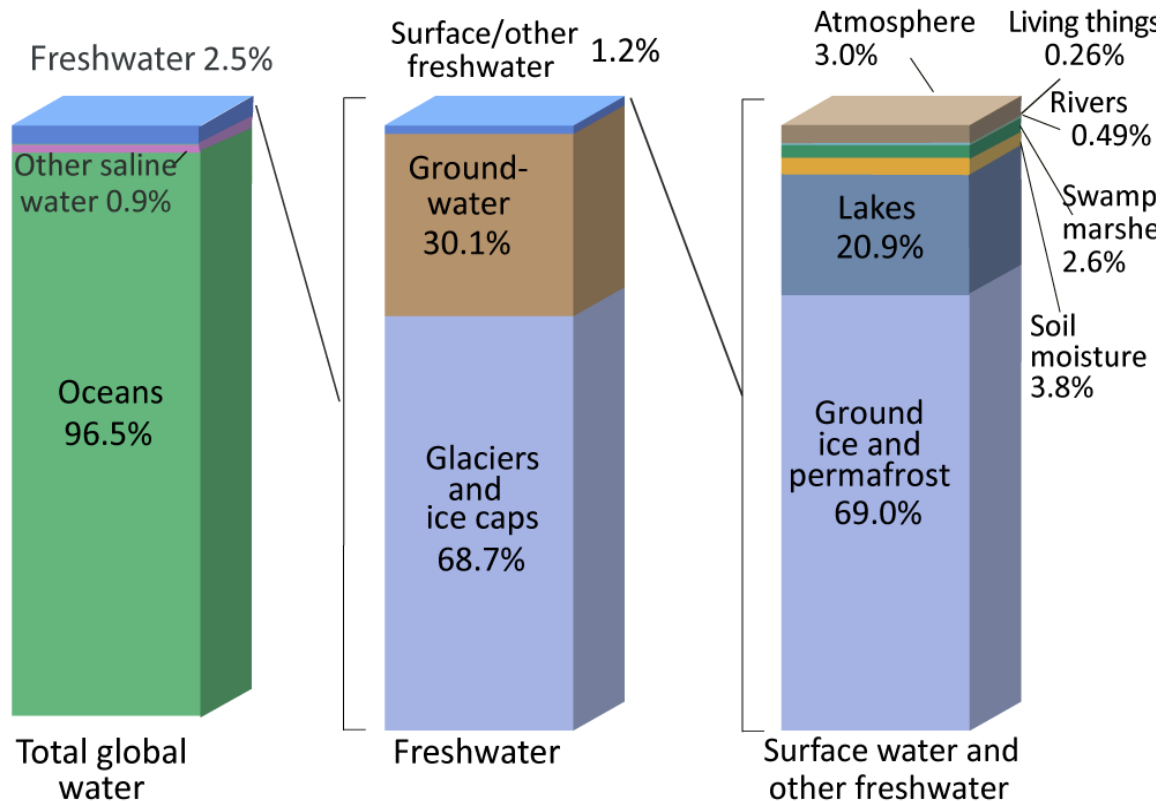




Snow and Ice Geophysical Parameters For Water Resources Applications

Role of Snow and Ice in the Hydrological Cycle

Where is Earth's Water?



Source: Igor Shiklomanov's chapter "World fresh water resources" in Peter H. Gleick (editor), 1993, *Water in Crisis: A Guide to the World's Fresh Water Resources*. (Numbers are rounded).



Snow and Ice as Storage Reservoirs

- When snow accumulates at high latitudes or high elevations, water is stored for days to months.
- Glaciers (the result of snow accumulating over years) store water for hundreds to tens of thousands of years.
- Meltwater from snow and ice is an important contribution to runoff, especially in basins that have less precipitation in spring and summer.

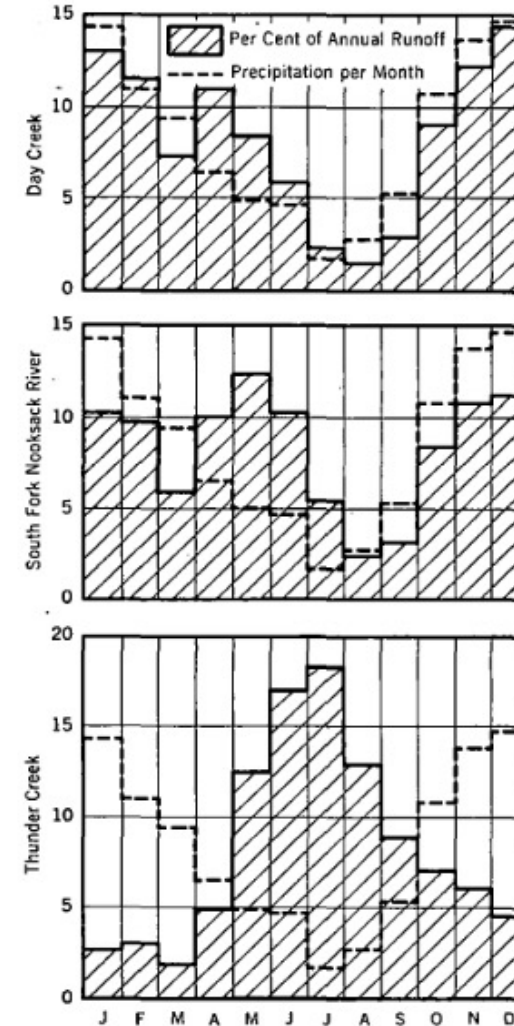


Fig. 3. Runoff From Three Drainage Basins

Values are means for the period 1951–60. Precipitation curve is the average for a larger area, which includes the three drainage basins.

Low Elevation Basin

Mountainous, Snow-Covered Basin

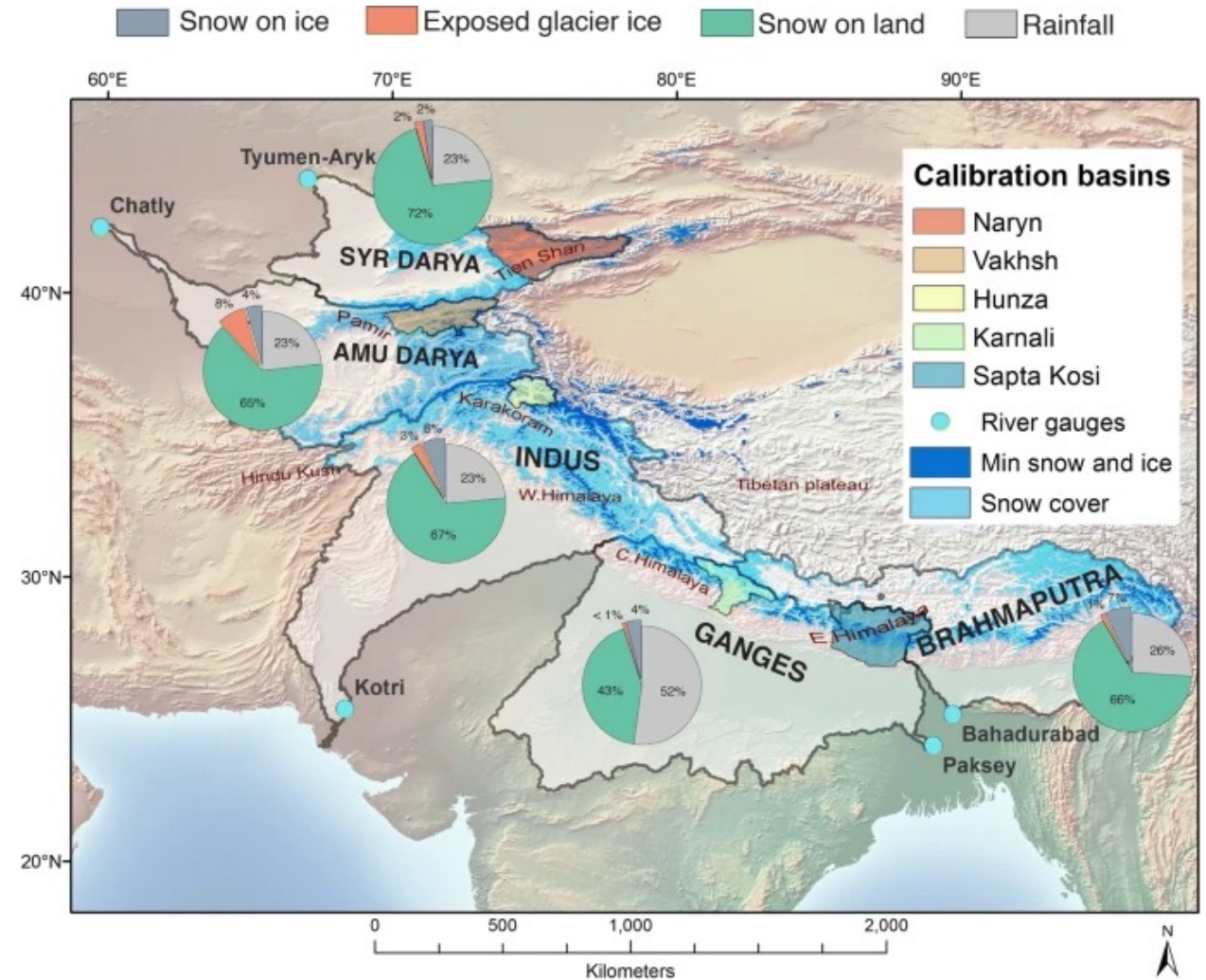
Glacierized Basin

[Meier, M.F. \(1969\), GLACIERS AND WATER SUPPLY. Journal - American Water Works Association, 61: 8-12.](#)



Snow and Ice as a Water Resource

- The contribution of snowmelt to runoff in mountain-fed basins can be large.
 - High Mountain Asia (HMA): 43% to 72%
 - Colorado River: ~70%
- Glacier contributions are small.



How much snow?

- The key question is: how much snow do we have?
 - Often, we are interested in the mass or volume of snow expressed as an equivalent volume of water (Snow Water Equivalent – SWE).
 - We might also be interested in snow thickness.
- We can estimate the mass of snow at a point.
 - By digging a snow pit and measuring thickness and density.
 - By taking a snow core and weighing it to get the mass or melting it to get a volume.
- Finding out how much snow we have at the basin-scale or even at the continental-scale is more difficult.



NSIDC, Flickr



Courtesy of UNR
Special Collections



Estimating the Amount of Snow with Remote Sensing

Direct Measurements:

- Gravimetry (GRACE) can be used to estimate mass of snow, but resolution is coarse.
- Using Snow Covered Area (SCA)
 - Can be used in conjunction with modelling to estimate snow melt runoff
 - Provides input to models
 - Can be used with depletion curves
- Snow Thickness
 - Requires knowledge of snow density – this can be estimated by models or measured in the field.
- Snow Water Equivalent (SWE)
 - Can be retrieved from passive microwave brightness temperatures but signal influenced by many factors: snow crystal size and shape, snowpack temperature, density, etc.

Snow Properties:

- Snow Albedo
- Snow Grain Size
- Snow Impurities





NASA's Remote Sensing-Based Snow Data Products

Observing Snow with Remote Sensing Instruments

- **Passive Microwave Emission:** Emission from the ground is scattered by snow cover, so change in emission received by sensor.
- **Visible Wavelengths:** Snow is white, so reflectance/albedo can be used to identify snow-covered vs. bare ground.
- **Lidar:** Altimeter measures distance from sensor to surface; difference in height of bare surface and snow-covered surface yields snow depth
- **Radar (SAR):** Active microwave sensor also potentially useful: backscatter from surface affected by snow and snow properties.



Photo from [NASA SnowEx](#)



Passive Microwave (PM) Emission

- Sensors detect energy in microwave frequencies emitted by an object.
- Emitted energy is dependent on frequency of the microwaves, the temperature of the object, and the properties of the object.
- **Brightness Temperature (TB)** describes PM emission from satellites, units of Kelvin
 - TB: Temperature if object were a perfect blackbody emitter.
- Simple Equation: **$TB = \epsilon * T$**
 - T is the physical temperature.
 - ϵ is the emissivity, a property of the emitting object.
- For surface remote sensing, **useful microwave frequencies range from ~1 GHz to ~90 GHz.**
 - Not much atmospheric emission, so surface can be seen through clouds.
 - Spatial resolution on the ground varies with frequency (higher frequency = higher resolution).
 - ~19 GHz and ~37 GHz are most useful for snow, though other frequencies can augment.



Satellite Passive Microwave Remote Sensing Instruments

- US Department of Defense Meteorological Satellite Program (DMSP)
 - Special Sensor Microwave Imager (SSM/I), 1987–2008
 - Special Sensor Microwave Imager and Sounder (SSMIS), 2003–2025
- NASA/JAXA Advanced Microwave Scanning Radiometer for the Earth Observing System (AMSR-E), 2002–2011
- JAXA AMSR2, 2012–Present
- JAXA AMSR3, launched 28 June 2025

Archived at the
NSIDC DAAC as
AMSR Unified
(AMSRU) Products



Theory of Passive Microwave Snow Retrieval

- Emission from ground scattered by overlying snow cover
- Amount of emitted energy detected by sensor is dependent on the amount of the snow and characteristics of the snow.
 - Higher scattering → less emission to sensor → more snow
 - The scattering is different for different frequencies → use difference in energy received by the sensor to estimate the amount of snow.
 - Dependent on density: snow grain size and “wetness”
 - Dry snow scatters less than wet snow.
- Two Parameters Retrieved by PM Sensors:
 - Snow Depth (SD): Thickness of the snow layer
 - Snow Water Equivalent (SWE): Amount of liquid water when snow is melted
 - $SWE = SD * (Snow\ Density)$

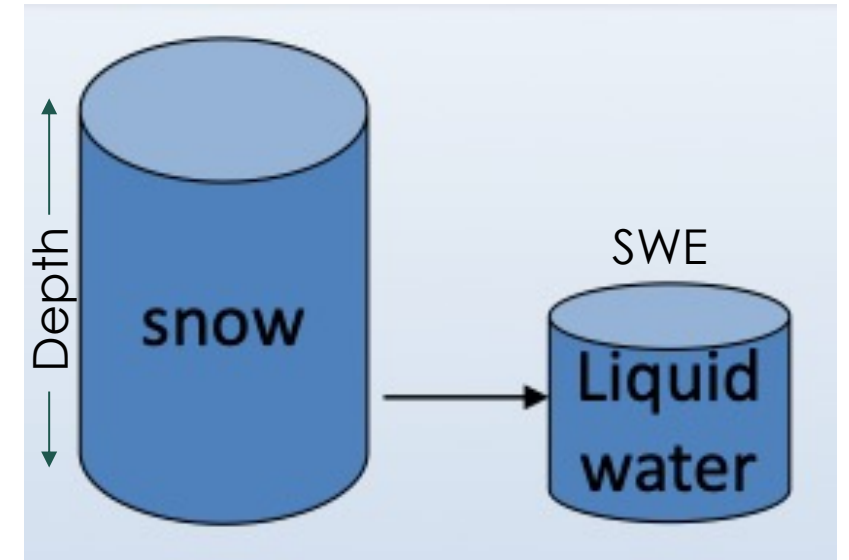


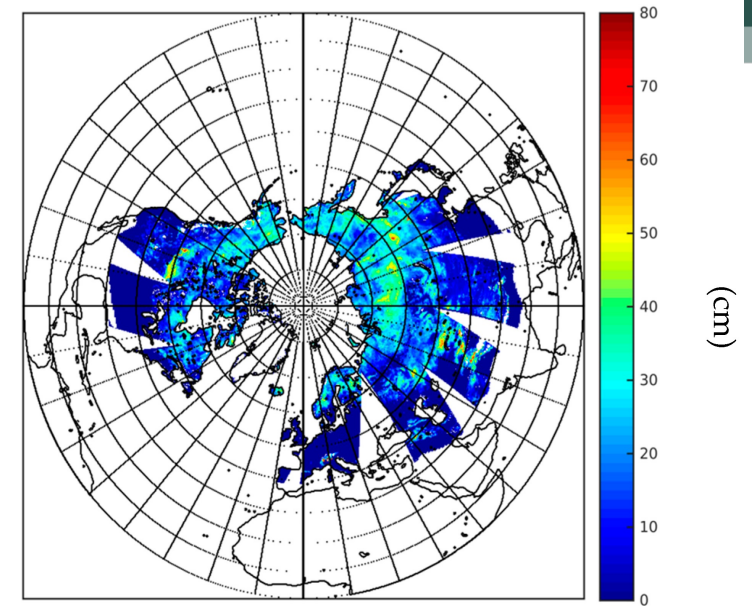
Image from E. Kim, NASA Goddard



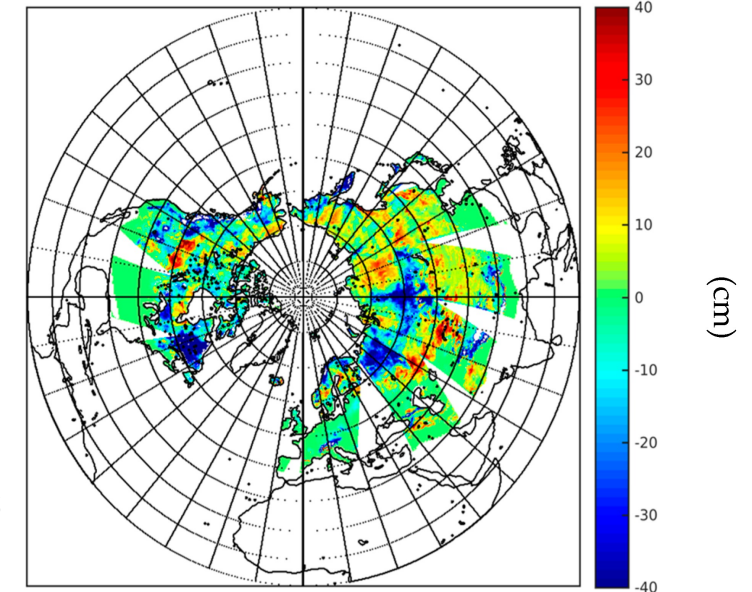
Limitations of Passive Microwave Snow Products

- Low spatial resolution (25 km)
- Lower performance in heavily forested and mountainous regions
- Even with advancements, uncertainties due to forestation, lake coverage, grain size, and density
- Shallow snow tends to get missed or underestimated

CMC = Canadian Meteorological Center
Data from Ground Stations and Other Sources



AMSR2 SWE



AMSR2 Minus CMC

Tedesco and Jeyaratnam, 2016, <https://doi.org/10.3390/rs8121037>



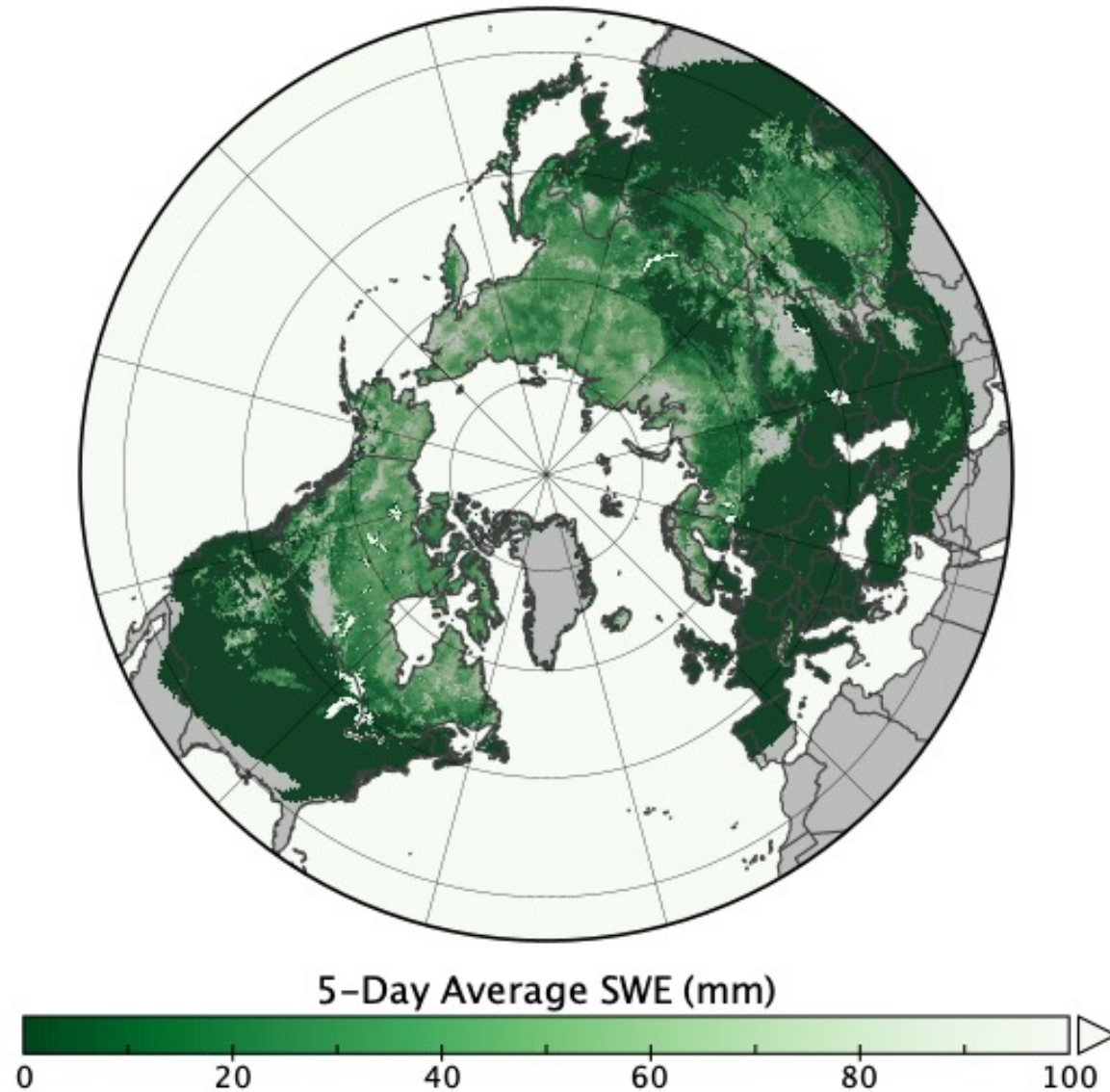
AMSRU Snow Products at the NSIDC DAAC

Product Name	Short Name	DOI
AMSR-E/AMSR2 Unified L3 Global Daily 25 km EASE-Grid Snow Water Equivalent, Version 1	AU_DYSNO	https://doi.org/10.5067/8AE2ILXB5SM6
AMSR-E/AMSR2 Unified L3 Global 5-Day 25 km EASE-Grid Snow Water Equivalent, Version 1	AU_5DSNO	https://doi.org/10.5067/0PX911G6417E
AMSR-E/AMSR2 Unified L3 Global Monthly 25 km EASE-Grid Snow Water Equivalent, Version 1	AU_MOSNO	https://doi.org/10.5067/43NH9LHM9YRK

All products are in HDF-EOS5 format.

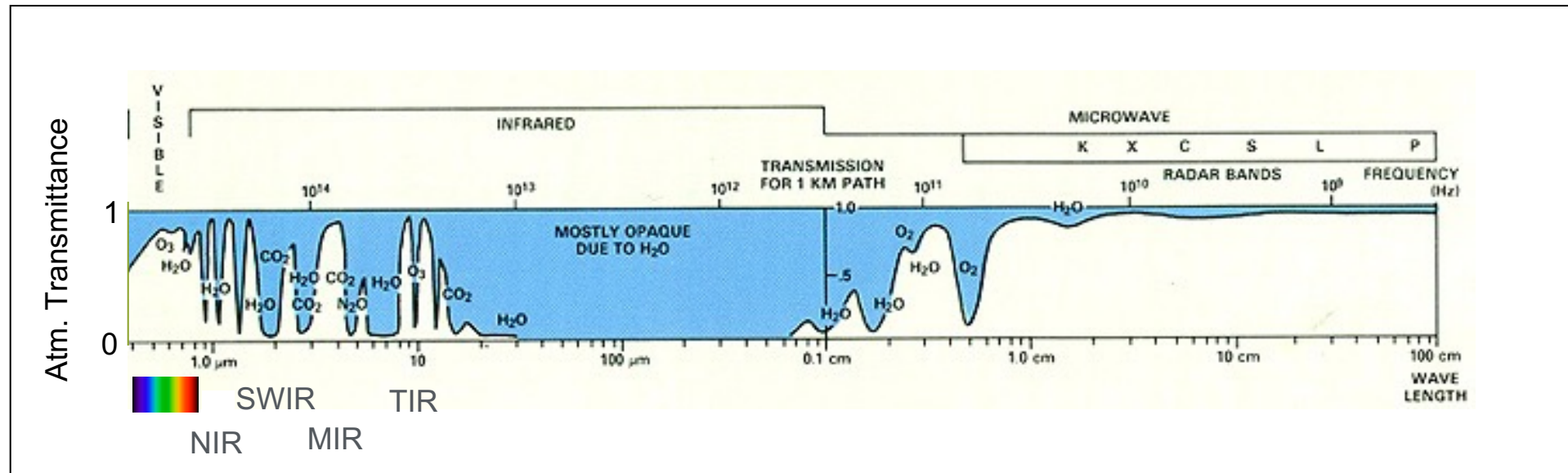


AMSR2 5-Day Average SWE Example, 13–17 March 2025



Visible and Near-Infrared Wavelengths

- Visible and some parts of the infrared are atmospheric windows – i.e., surface reflectance is transmitted through the atmosphere to a satellite sensor.



Transmitted Through Atmosphere

Absorbed By Atmosphere

NIR = Near Infrared
SWIR = Short-Wave Infrared
MIR = Mid-Infrared
TIR = Thermal Infrared

From [Forbes](#)



Snow in Visible and IR

- Snow has high and consistent reflectance in visible wavelengths → snow is white!
- Snow has low reflectance in SWIR and TIR.

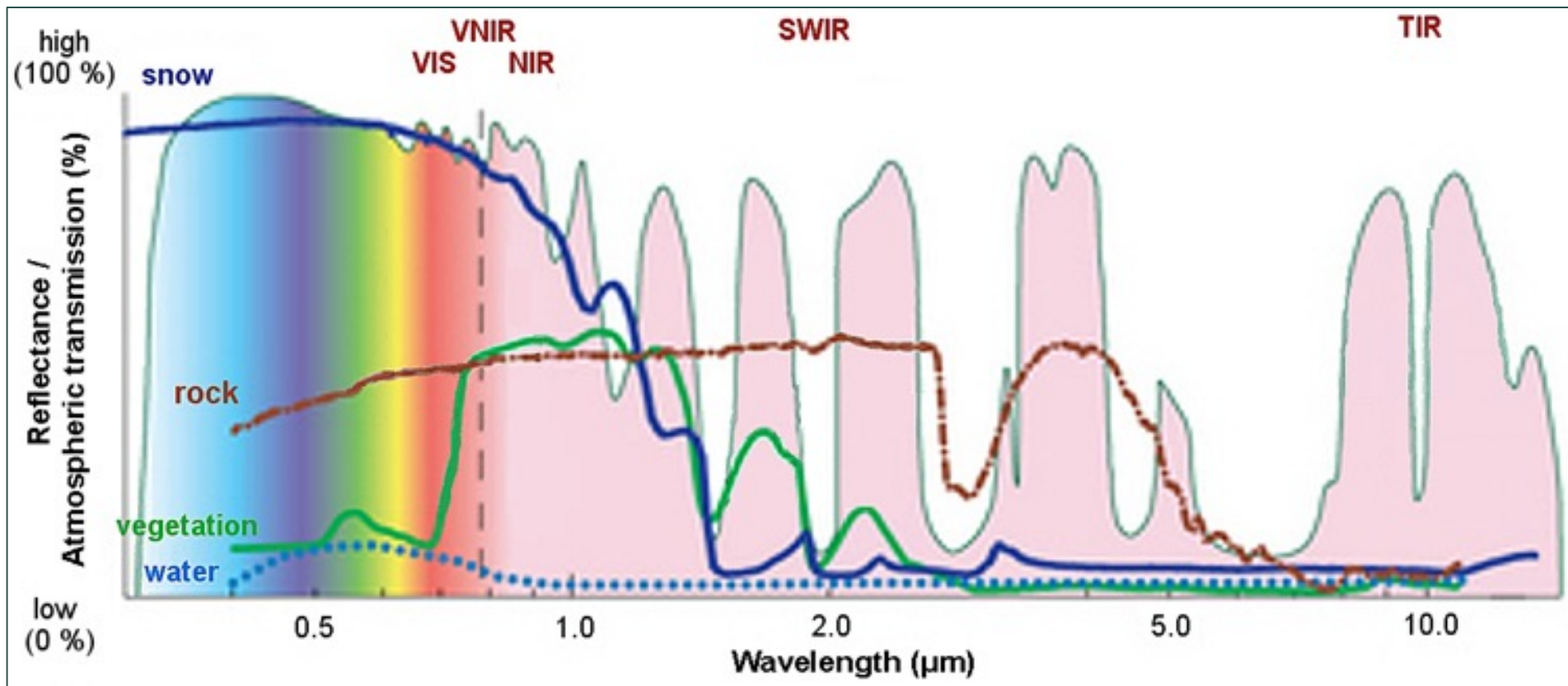
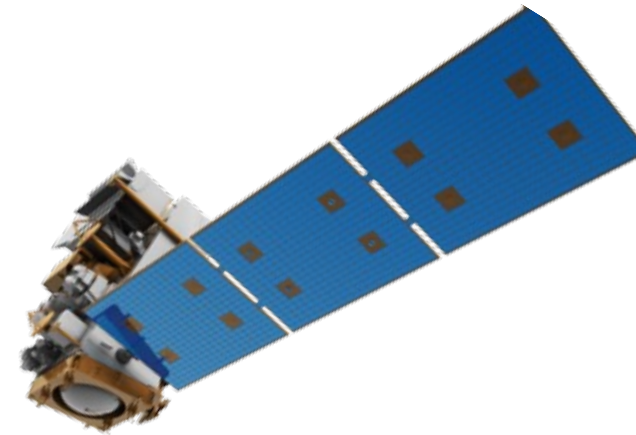
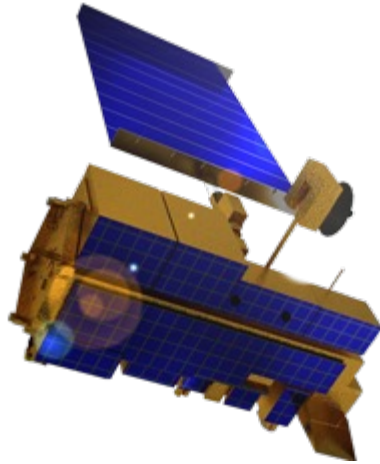


Image by Andreas Kaab, Univ. Oslo, from [EUMeTrain](https://eumetrain.org/)

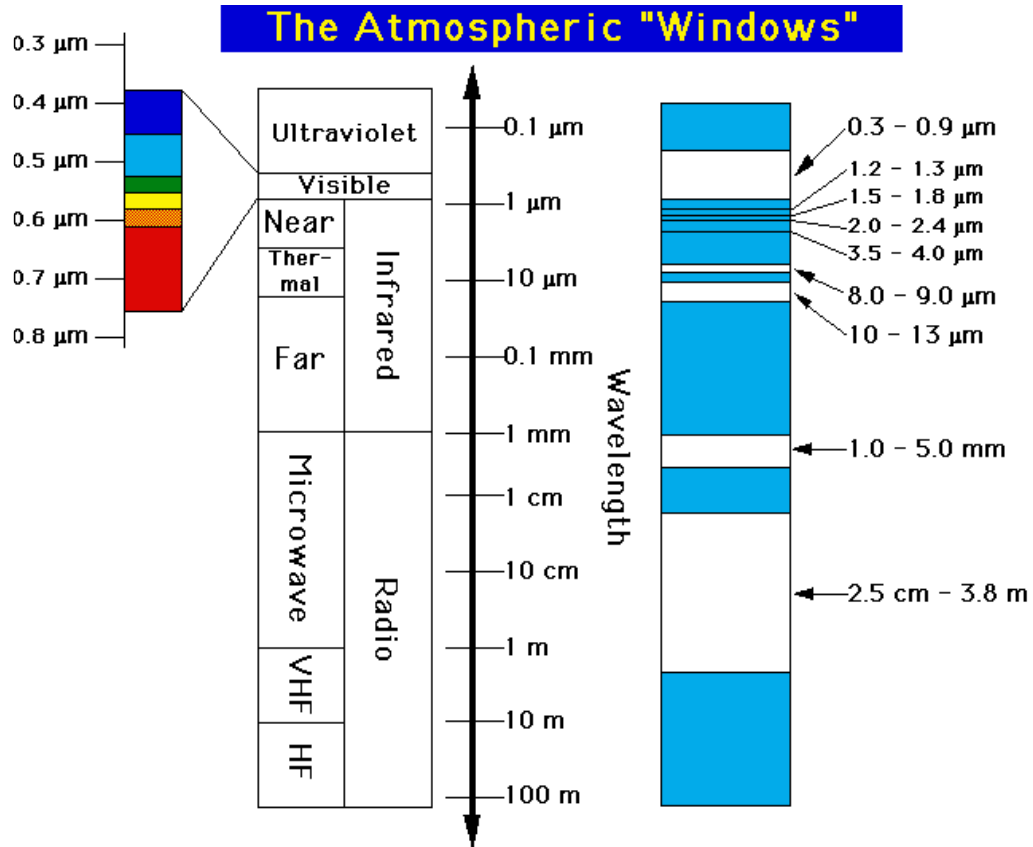


Multispectral Sensors used for Satellite Snow Retrievals

- **AVHRR:** Advanced Very High-Resolution Radiometer on NOAA polar orbiting satellites (NOAA-8 through NOAA-19, 1979–2025) and on European Meteorological Satellites (EUMETSAT Metop, 2007–Present)
- **MODIS:** MODerate-resolution Imaging Spectroradiometer (1999–Present) on NASA EOS Terra (1999–Present) and Aqua (2002–Present) Satellites
- **VIIRS:** Visible Infrared Imaging Radiometer Suite on Suomi NPP (2011–Present), NOAA-20 (2017–Present), and NOAA-21 (2022–Present)



AVHRR, MODIS, and VIIRS Wavelengths



Channel	AVHRR	MODIS	VIIRS
Red	0.615	0.645	0.672
Green		0.555	0.555
Blue		0.469,...	0.488,...
Near/SW IR	0.912	0.905,...	0.865
SWIR		1.64	1.61
Thermal/Mid	3.74	3.75,...	3.70,...
Thermal IR	11.0	11.0,...	10.763,...
Thermal IR	12.0	12.0,...	12.013,...
Total Chan.	5	36	22

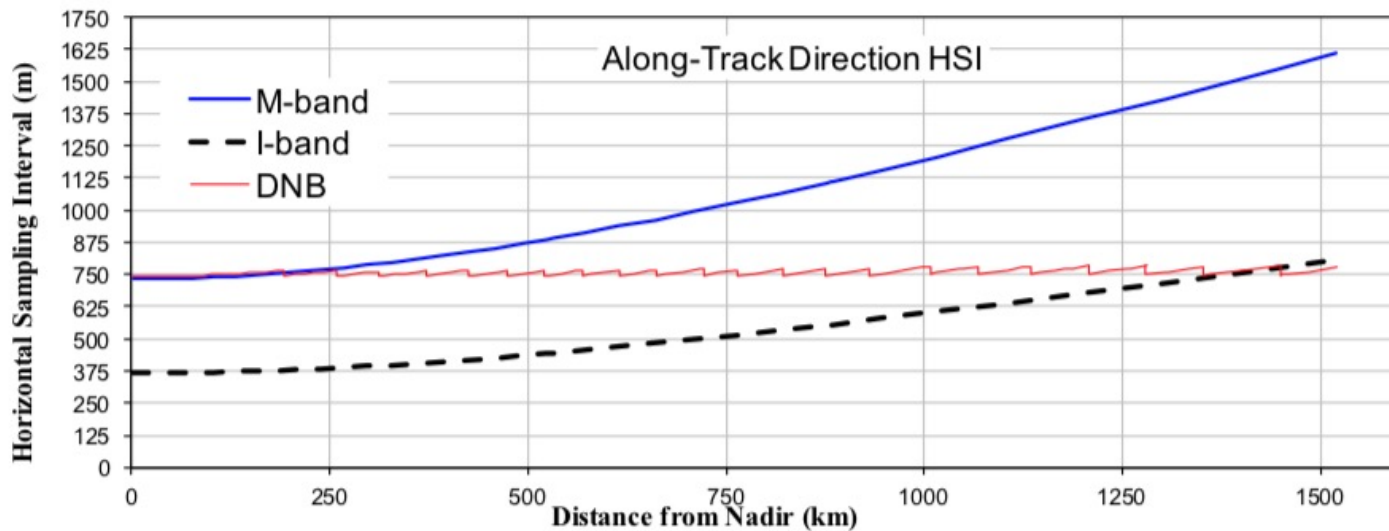
Wavelengths in μm

Wavelengths given are central values – in reality, energy collected over a range, the bandwidth

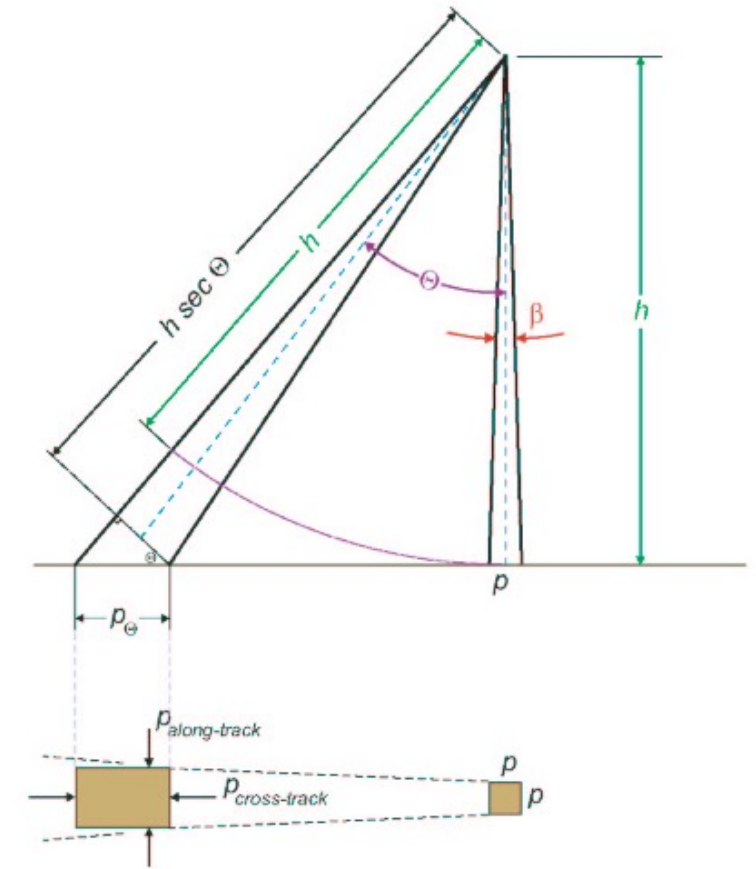


Sensor Spatial Resolution

- MODIS and VIIRS are cross-track scanners.
- Spatial resolution is defined as Instantaneous Field of View (IFOV) or “footprint”).
- Sensor footprints are smallest at nadir (directly below sensor).
- Footprint size increases further away from nadir.



VIIRS Footprint Size Across Scan, from [NOAA VIIRS SDR User's Guide](#)

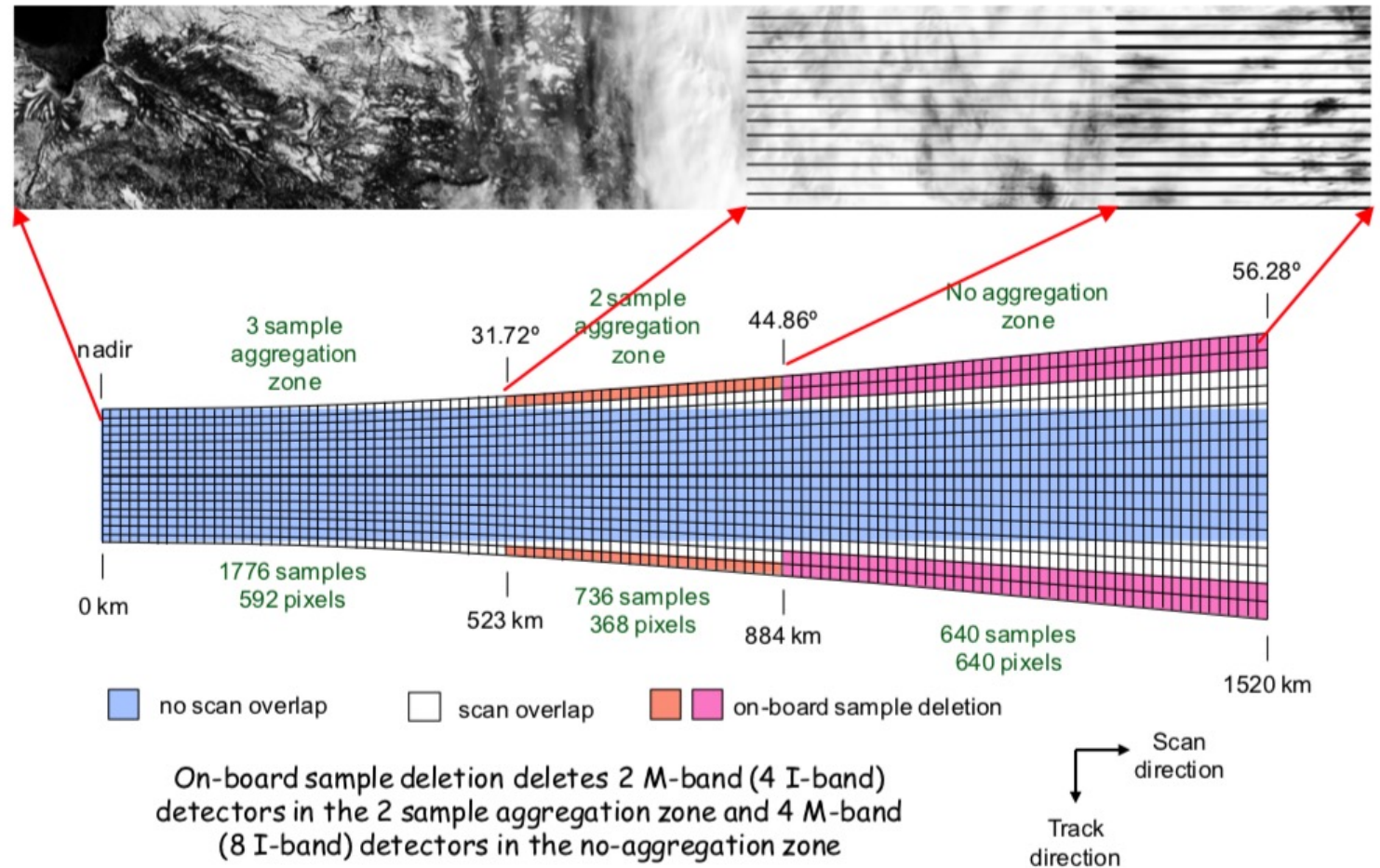


[Oregon State Geography Department](#)



Sensor Resolution and Bow-Tie Effect

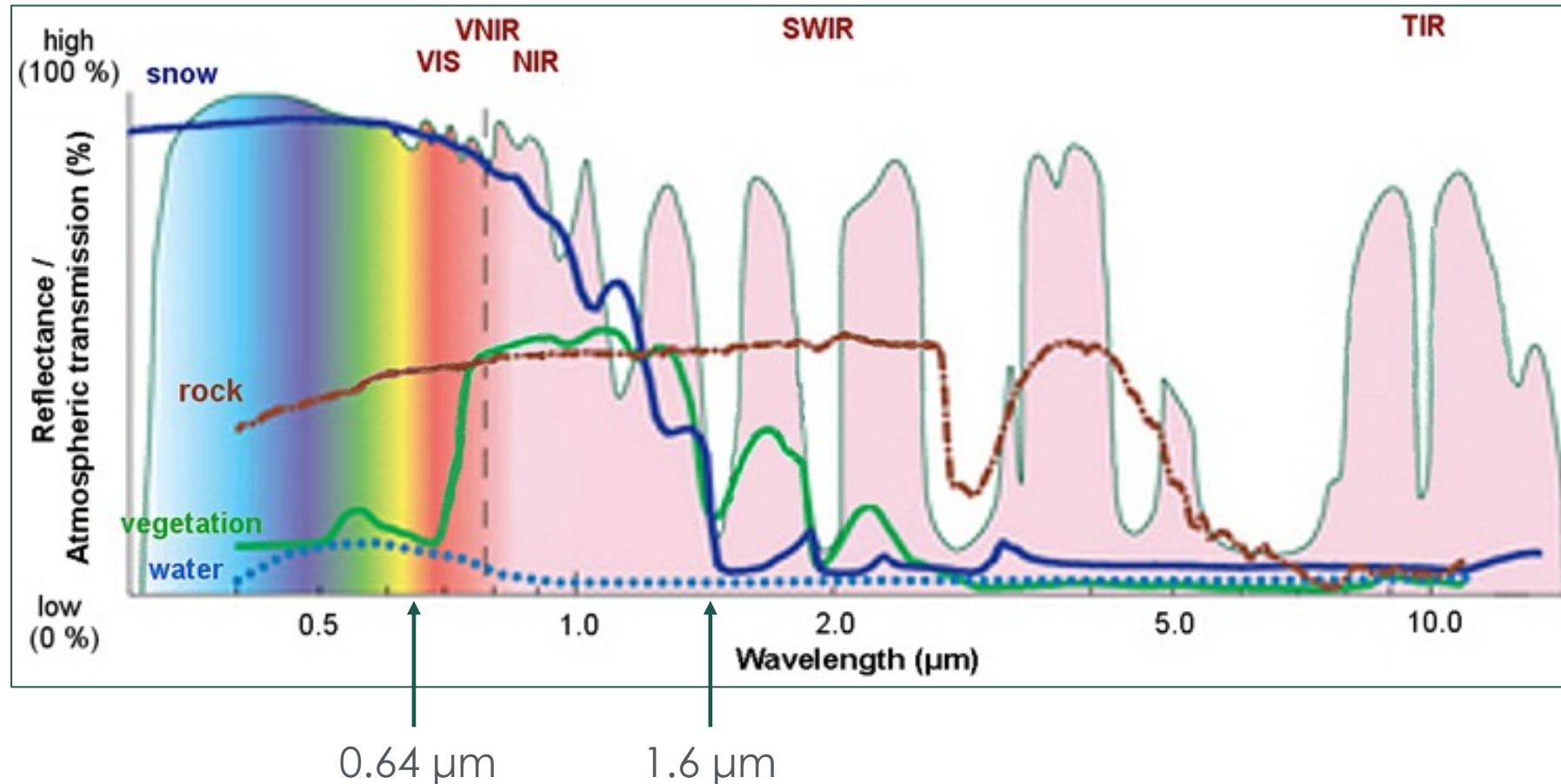
- Sensor footprints get wider with scan angle and start to overlap each other.
- Overlaps are removed onboard the satellite to save download bandwidth.



[NOAA VIIRS SDR User's Guide](#)



Deriving Snow Cover from MODIS and VIIRS



Snow reflectance is high at $\sim 0.64 \mu\text{m}$ and low at $1.6 \mu\text{m}$.



Normalized Difference Snow Index (NDSI) for VIIRS

$$\text{NDSI} = \frac{(\text{Vis} - \text{SWIR})}{(\text{Vis} + \text{SWIR})} = \frac{(R_{0.64} - R_{1.6})}{(R_{0.64} + R_{1.6})}$$

NDSI < 0, Definitely Not Snow

NDSI > 0, Possibly Snow

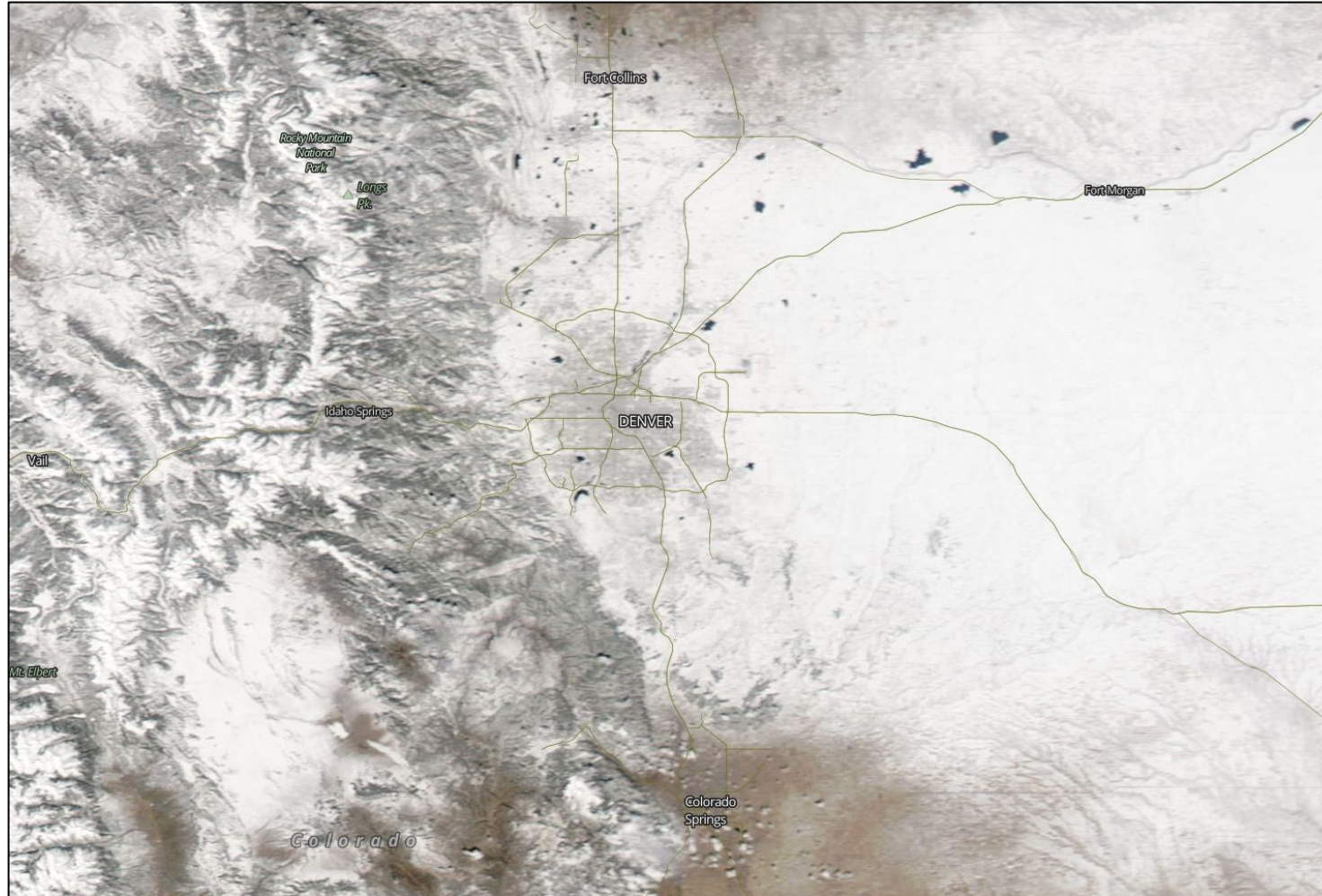
NDSI > 0.4, Likely Snow

Snow always has an NDSI > 0, but not all surfaces with an NDSI > 0 are snow!

*MODIS uses slightly different wavelengths.



MODIS Snow Example: Denver, March 25, 2013

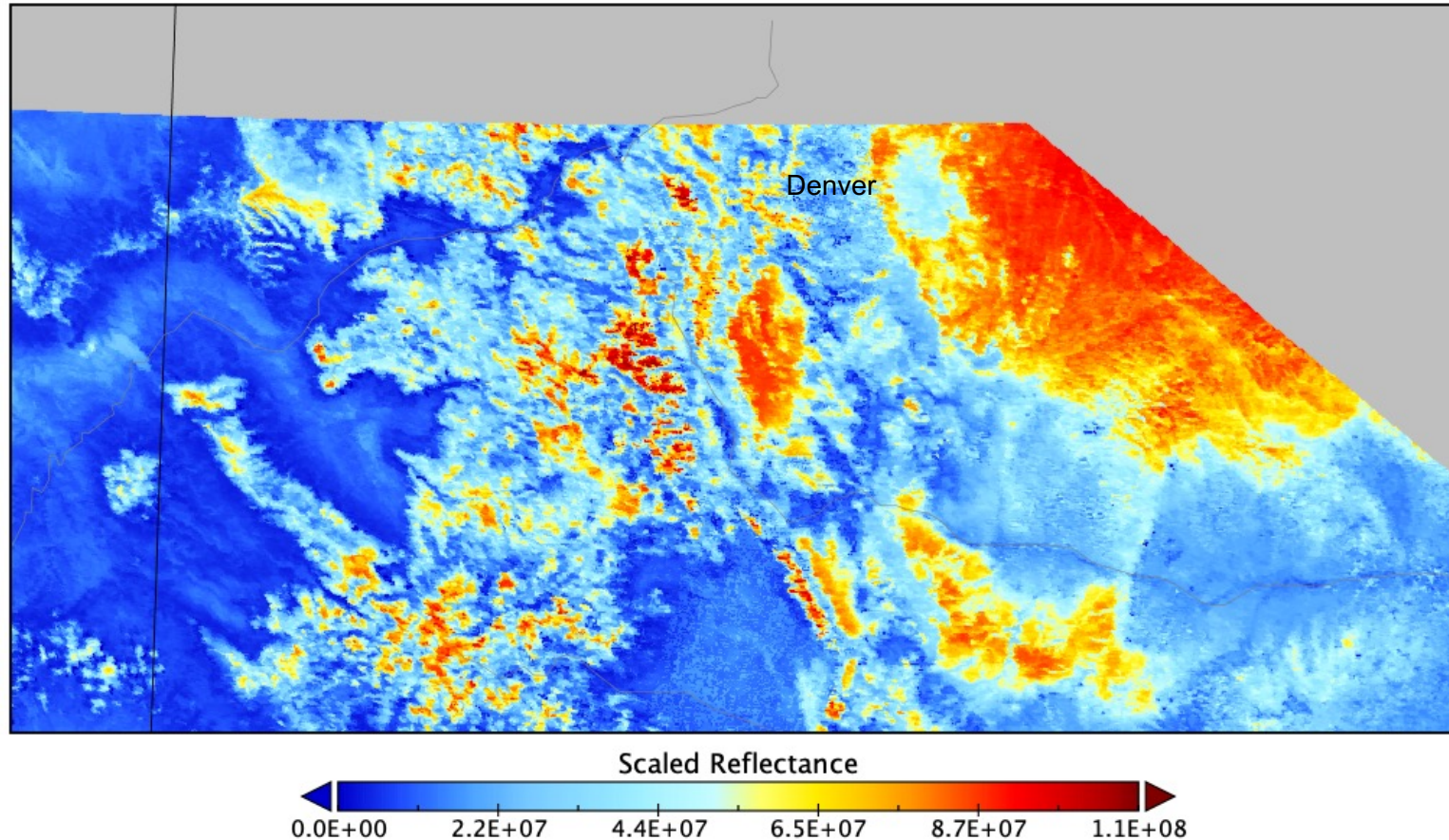


MODIS True Color from NASA WorldView



MODIS Snow Example: Denver, March 25, 2013

500m Surface Reflectance Band 4, 0.55 microns
March 25, 2013

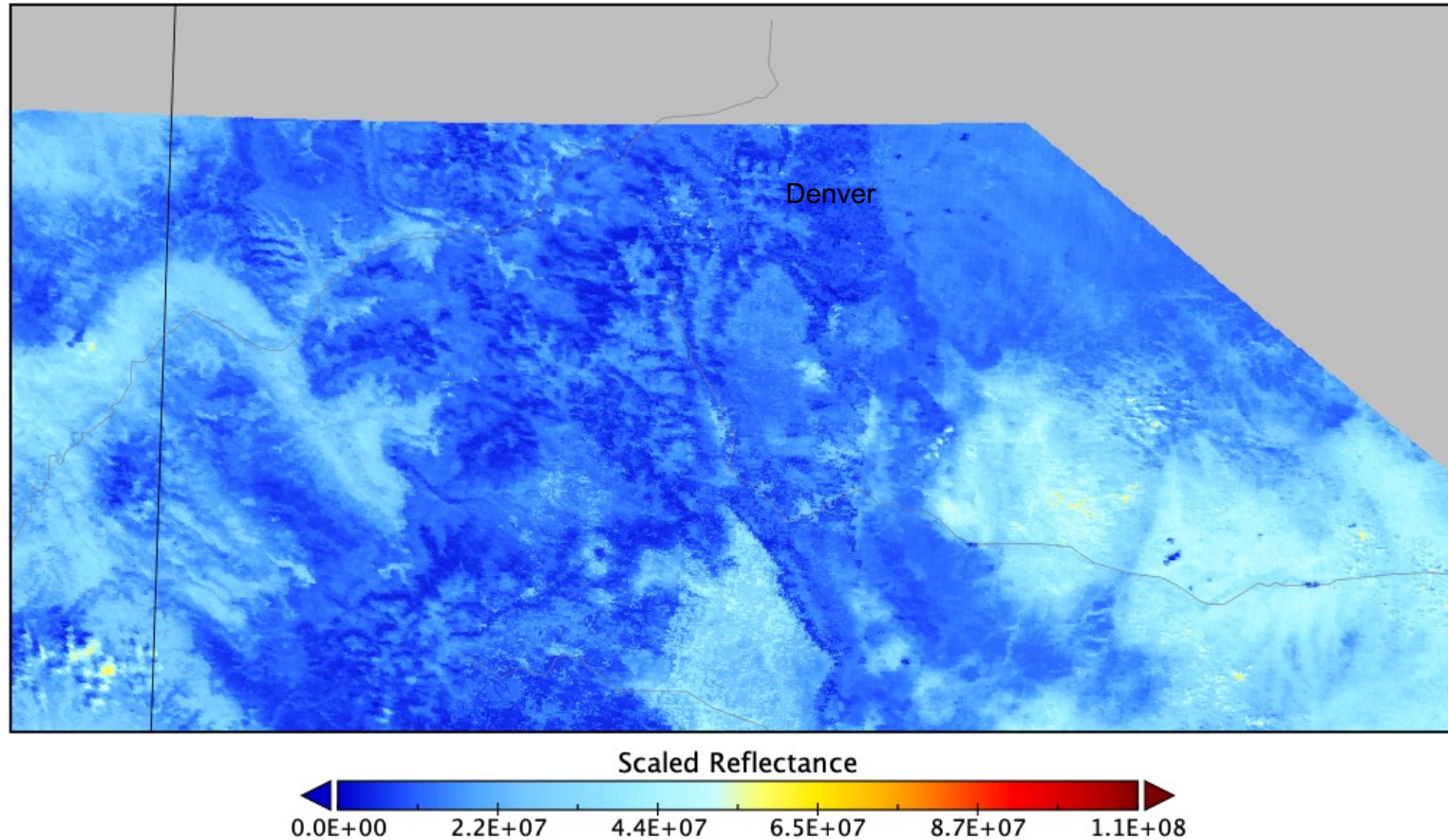


MODIS MOD09GA Product, from [NASA LPDAAC](https://lpdaac.nasa.gov/)



MODIS Snow Example: Denver, March 25, 2013

500m Surface Reflectance Band 6, 1.6 μm
March 25, 2013

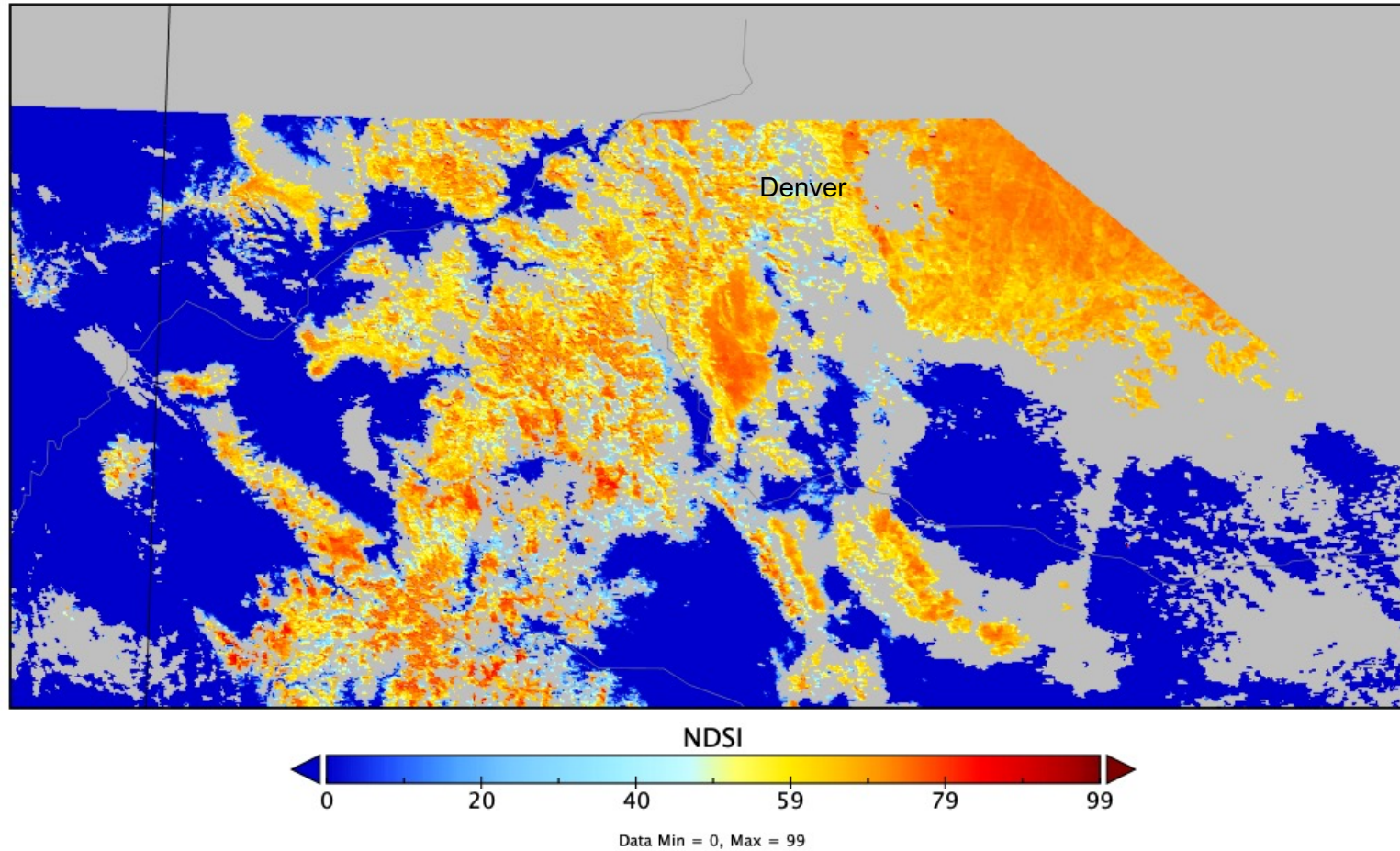


MODIS MOD09GA Product, from [NASA LPDAAC](https://lpdaac.nasa.gov/)



MODIS Snow Example: Denver, March 25, 2013

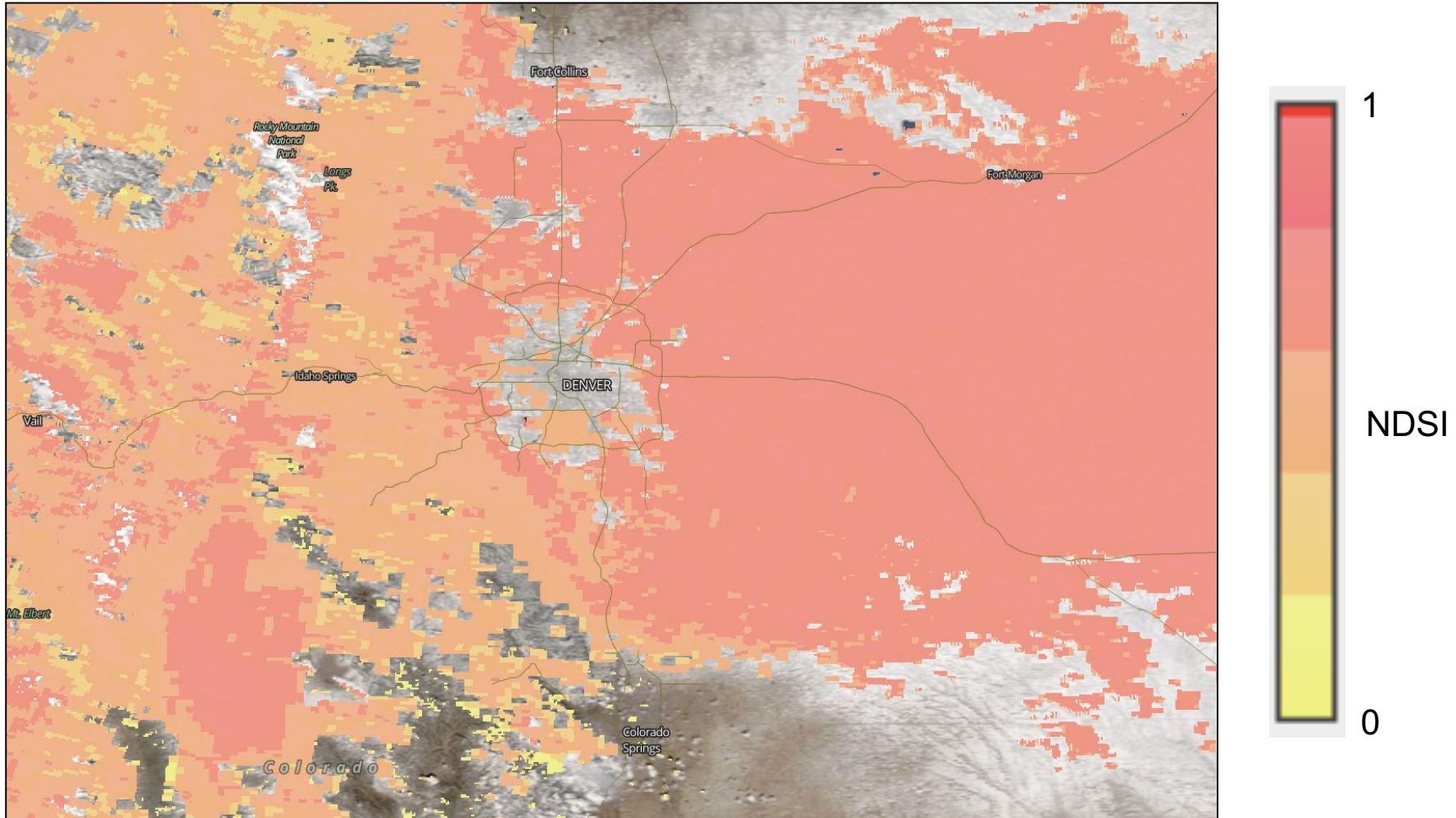
NDSI Snow Cover from Terra
March 25, 2013



MODIS MOD10A Product, from [NSIDC DAAC](https://nsidc.org/data/modis/daac)



MODIS Snow Example: Denver, March 25, 2013



MODIS Aqua and Terra NDSI from [NASA WorldView](https://worldview.nasa.gov/)

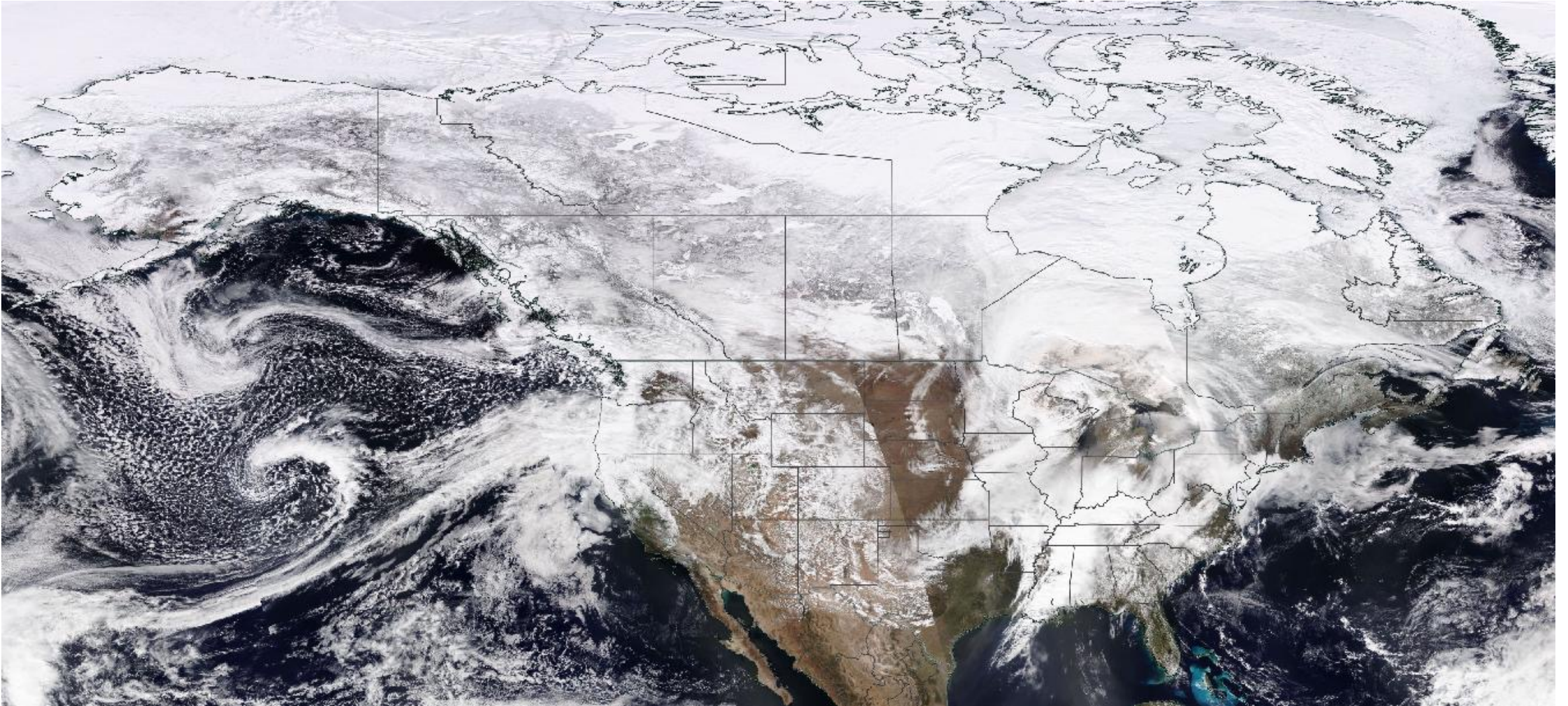


Limitations of Snow Retrievals from Visible/Infrared Radiometers

- Clouds!
 - No data under clouds
 - Clouds can be mistaken as snow
 - Complex series of tests with different channels to mask clouds
 - Cloud gap-filled products, multi-day composites
- Night for visible wavelengths
- Vegetation can alter reflectance
- Cities, densely populated areas can lower reflectance
- Shadows and oblique incidence angles in mountains



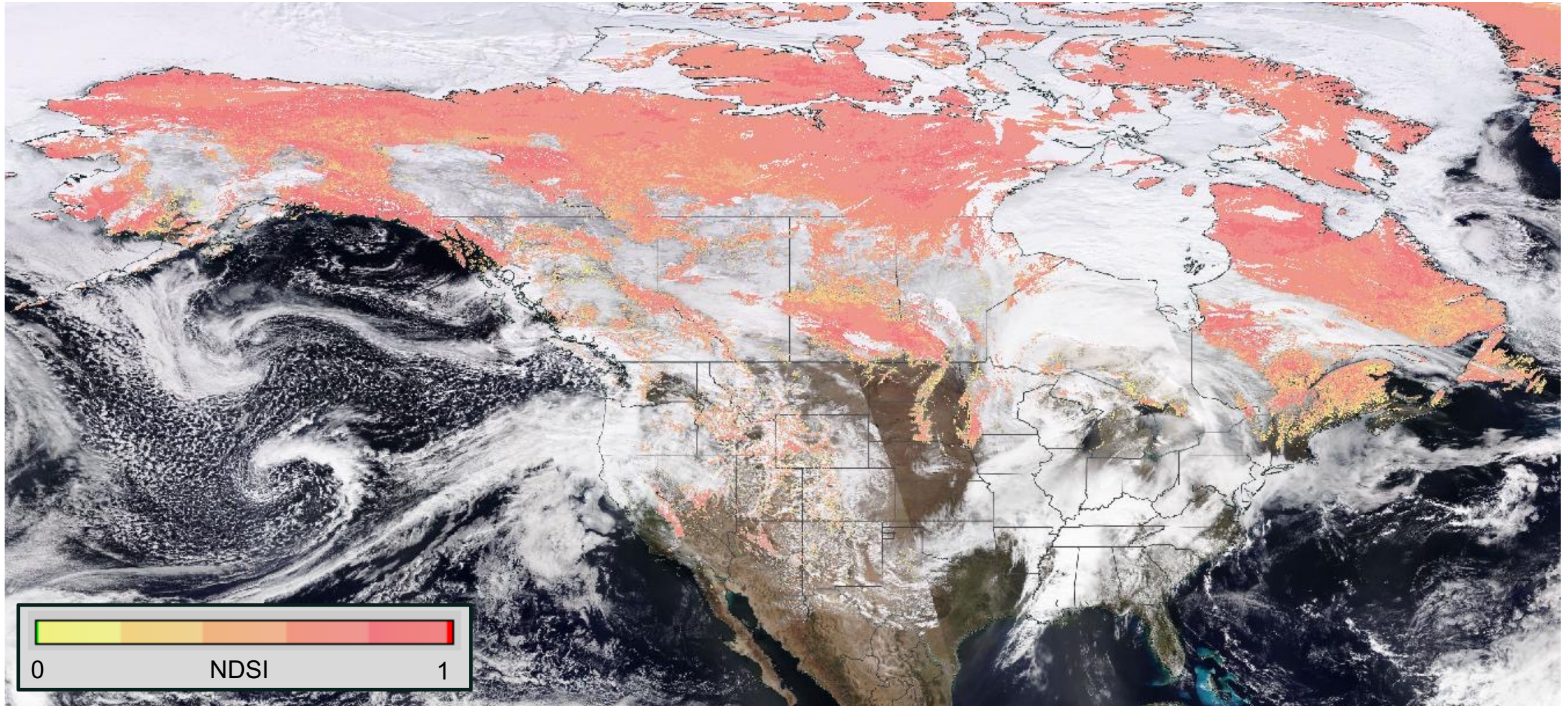
North American Snow Example, 15 March 2025



NOAA-20 VIIRS True Color Composite from [NASA WorldView](#)



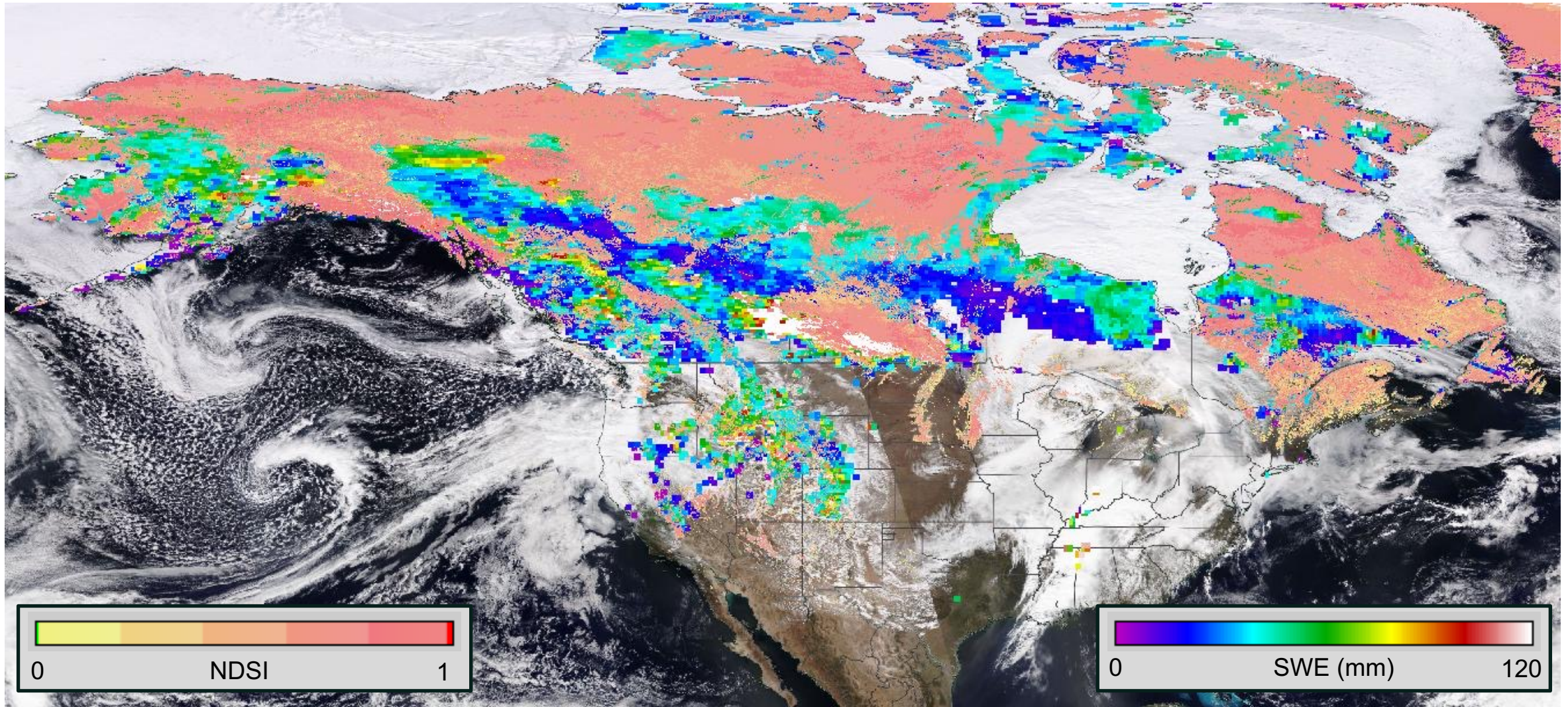
North American Snow Example, 15 March 2025



NOAA-20 VIIRS NDSI from [NASA WorldView](#)



North American Snow Example, 15 March 2025



NOAA-20 VIIRS NDSI and AMSR2 SWE from [NASA WorldView](#)



MODIS Snow Products

Product	Parameter	Spatial Res.	Level/Grid	Sampling
MOD10_L2	NDSI	500 m	Swath (L2)	5-minute
MOD10A1	Snow Cover, Albedo	500 m	Sinusoidal Gridded Tiles (L3)	Daily
MOD10C1	% Snow Cover	0.05 deg	Climate Model Grid (L3)	Daily
MOD10A2	Snow Extent	500 m	Sinusoidal Gridded Tiles (L3)	8-day
MOD10C1	% Snow Cover	0.05 deg	Climate Model Grid (L3)	Daily
MOD10C2	% Snow Cover	0.05 deg	Climate Model Grid (L3)	8-day
MOD10CM	Monthly Mean Snow Cover	0.05 deg	Climate Model Grid (L4)	1-month

The product ID above refers to MODIS on Terra product. The same products are also produced from Aqua MODIS.

"MOD" refers to MODIS on Terra.

"MYD" refers to MODIS on Aqua.

Currently, Version 61/Collection 6.1 is available at the NSIDC DAAC, HDF-EOS2 format.



VIIRS Snow Products

Product	Parameter	Spatial Res.	Level/Grid	Sampling
VNP10	NDSI	375 m	Swath (L2)	6-minute
VNP10A1	NDSI	375 m	Sinusoidal Gridded Tiles (L3)	Daily
VNP10C1	% Snow Cover	0.05 deg	Climate Model Grid (L3)	Daily
VNP10A1F	Cloud gap-filled snow	375 m	Sinusoidal Gridded Tiles (L3)	Daily

The product ID above refers to VIIRS on Suomi NPP. The same products are also available from JPSS-1/NOAA-20.

"VNP" refers to VIIRS on Suomi NPP.

"VJ1" refers to VIIRS on JPSS-1/NOAA-20.

Currently, Version 2 is available at the NSIDC DAAC, HDF-EOS5 format.



Improvements from Standard MODIS Snow Products: MODSCAG/DRFS

- Signal received by MODIS/VIIRS is a mixture of signals from everything within the sensor footprint
 - Mixture of snow with different properties, soil, and vegetation
 - Ideally, want contribution from each individual surface type
- Spectral unmixing method assumes reflectance measured by sensor is a linear combination from individual surfaces
- MODIS Snow Cover and Grain Size (SCAG)
- MODIS Dust Radiative Forcing in Snow (DRFS)
- MOD09GA (Surface Reflectance) used as input

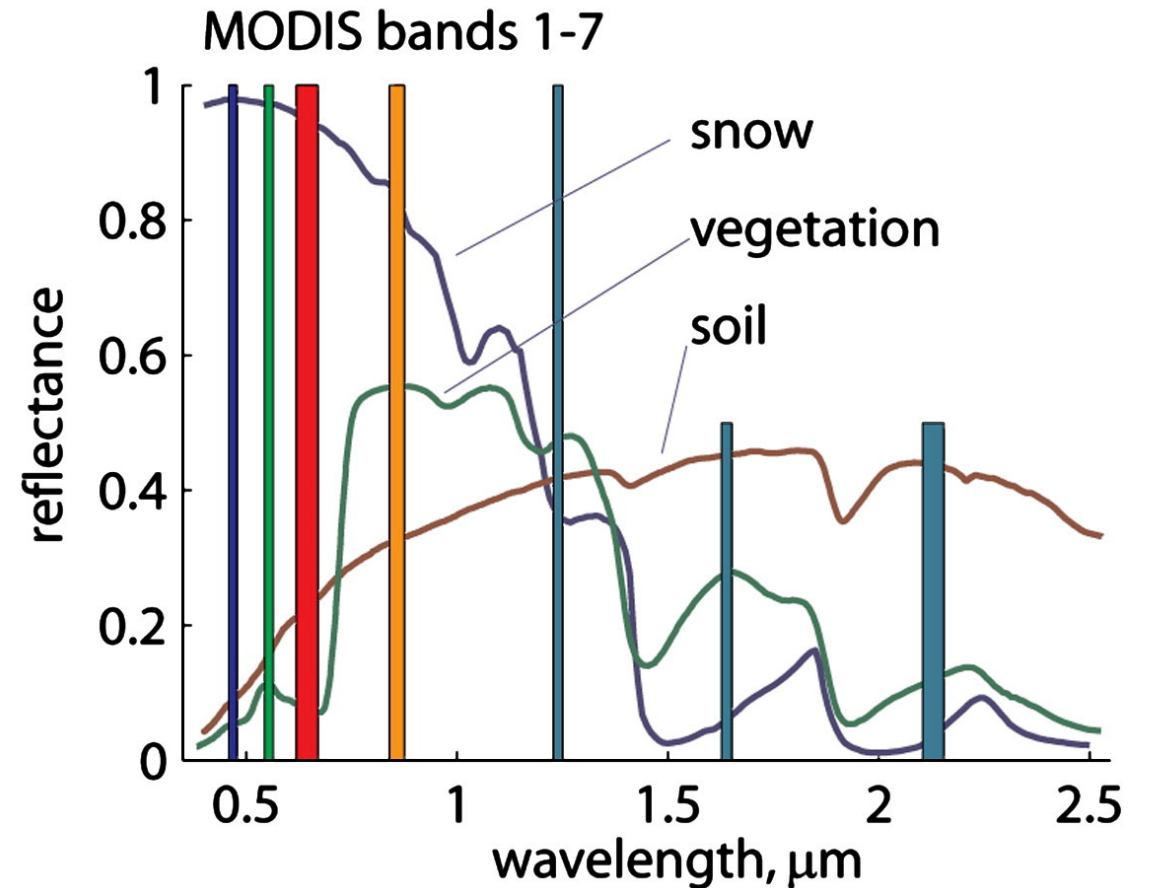


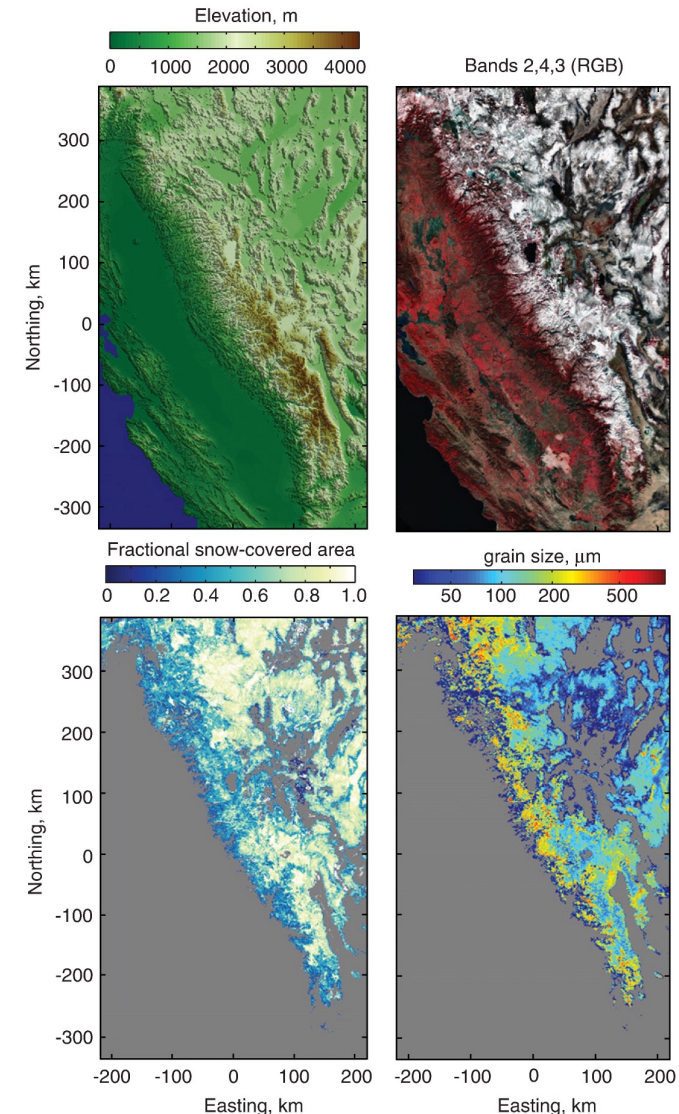
Image from Painter et al., 2009, <https://doi.org/10.1016/j.rse.2016.06.018>



Improvements from Standard MODIS Snow Products: MODSCAG/DRFS

- MODIS Snow Cover and Grain Size (SCAG)
- MODIS Dust Radiative Forcing in Snow (DRFS)
- MOD09GA (Surface Reflectance) used as input
- Spectral unmixing method assumes radiance measured by sensor is a linear combination from individual surfaces
- Spectral unmixing, models, and ancillary data are used to simultaneously solve for snow fraction, grain size, and radiative forcing
- Newer Spatially and Temporally Complete (STC) version ([Rittger et al., 2020](#) & [Rittger et al., 2024](#)) combines grain size from SCAG and snow darkening to produce snow albedo

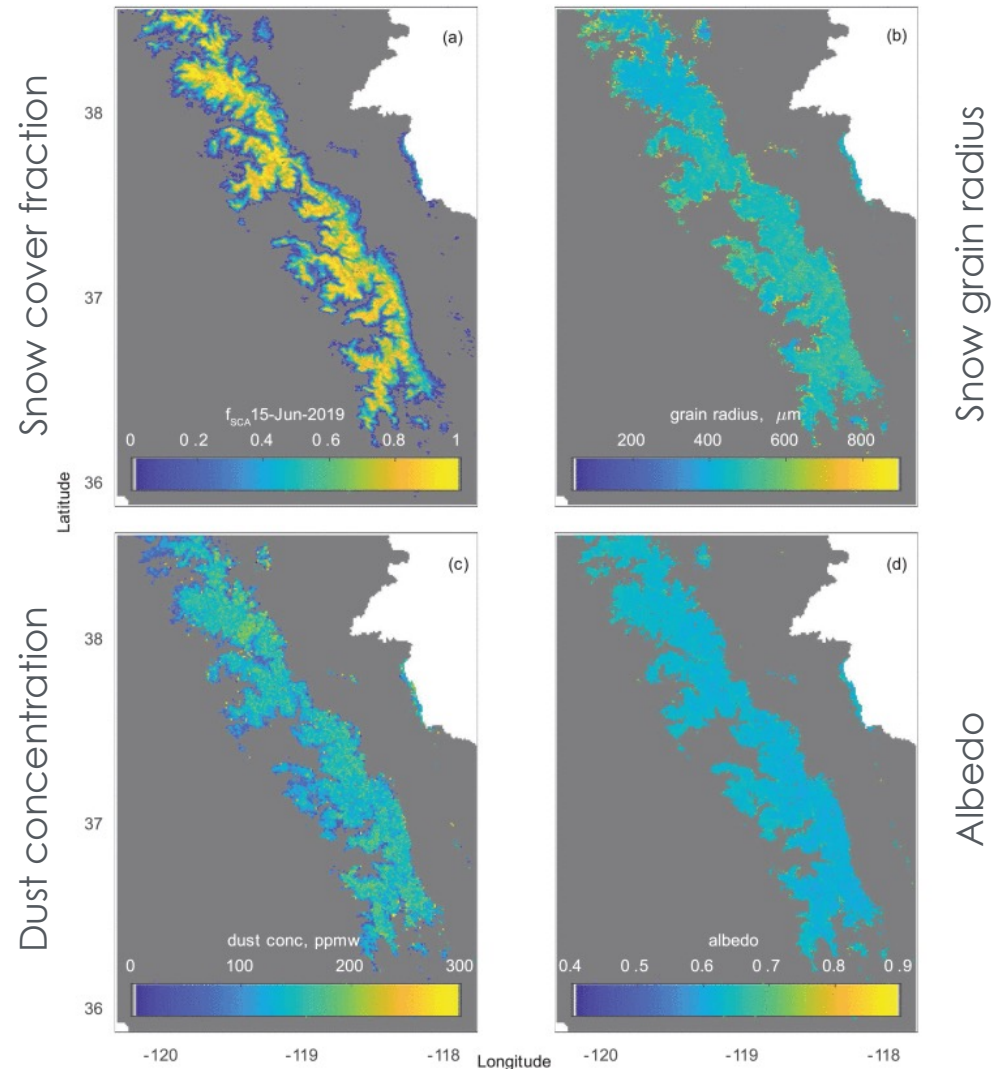
Image from Painter et al., 2009, <https://doi.org/10.1016/j.jrse.2016.06.018>



Improvements from Standard MODIS Snow Products: SPIReS

- Snow Property Inversion from Remote Sensing (SPIReS)
- Optimized processing for large number of pixels
- Solves for light absorbing particles (LAP) and grain size simultaneously
- Adaptable to any sensor with visible through SWIR channels
- Uses MOD09GA and Landsat 9 Operational Land Imager (OLI)
- [Near-real-time](#) and [historical](#) SPIReS data from MODIS at the NSIDC DAAC
- Being adapted to VIIRS as well

Image from Bair et al., 2021, <https://doi.org/10.1109/TGRS.2020.3040328>



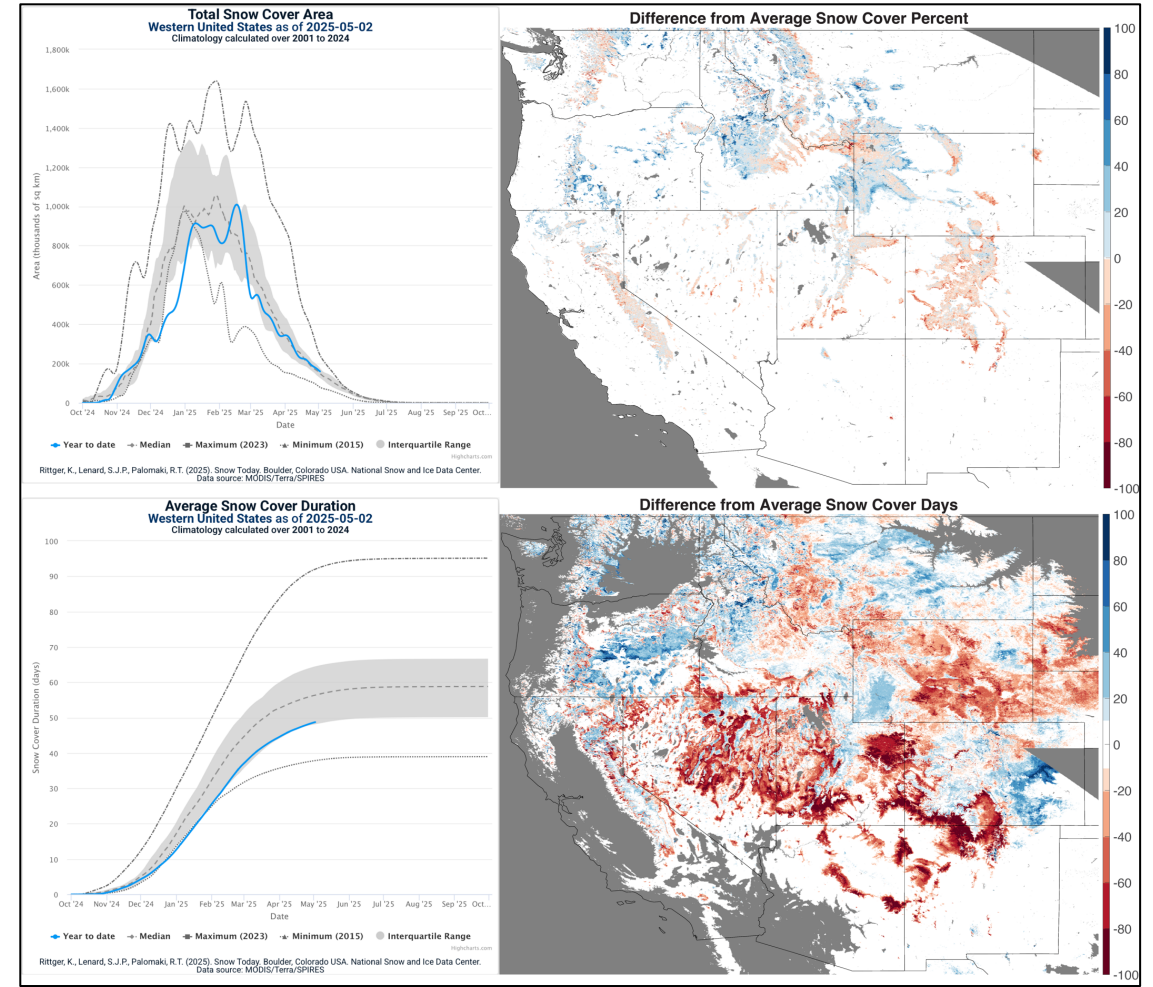
Comparison Between SCAG/DRFS and SPIReS

	Approach 1: STC-SCAG/DRFS	Approach 2: SPIReS
Spectral Mixture	Endmembers for snow, ice, rock, vegetation	Endmembers for snow, background for others
Outputs	Snow fraction, albedo, grain size, vegetation fraction, rock fraction, ice fraction , snow darkening, and radiative forcing	Snow fraction, albedo*, grain size, LAP concentration, snow darkening, and radiative forcing** *, ** - Snow Today version of SPIReS (v1)
LAP Method	LAP estimated separately (hybrid method)	Simultaneous solution for LAP (full mixed pixel method)
Development Stage	Frozen	Early
Operational Use	NRT 2020-2023 by INSTAAR for NSIDC's Snow Today. Transition to DAAC.	NRT starting 2024 by INSTAAR for NSIDC's Snow Today. USBR continued funding.



Application of MODSCAG/DRFS and SPIReS: Snow Today

- [Snow Today](#) is an NSIDC website providing daily updated snow conditions in the Western US and monthly analyses during the snow season.
- Data based on STC-SCAG/DRFS and SPIReS
- Funded by NASA Terrestrial Hydrology Program
- PI: Karl Rittger, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado



[Snow Today](#), 7 May 2025



Airborne Snow Observatory (ASO), 2013-Present

- Current satellite sensors have limitations in detecting snow cover
 - Individual sensors cannot resolve all relevant properties
 - Spatial resolution of sensors too coarse for important local and basin scale details
- NASA/JPL Airborne Snow Observatory (ASO) mission was developed for:
 - Quantifying snow water equivalent and snow albedo for entire mountain watersheds at high spatial resolution
 - Improving knowledge of snow properties and their spatial and temporal variability
 - Providing input data for future water-management models and systems
- Collaboration with California Department of Water Resources
- After end of NASA mission in 2019, ASO became a commercial entity ([ASO Inc.](#))
 - Focused primarily on Sierra Nevada mountains and California water resources
- NSIDC DAAC archives ASO data from the NASA mission (not the commercial data)



ASO Primary Instruments

- Scanning LIDAR
 - Laser altimeter to calculate snow depth
- Imaging Spectrometer
 - Estimate spectral albedo
 - Discriminate changes in albedo due to:
 - Changes in snow grain size
 - Dust
 - Black carbon
 - Organic material
- Snow Density Model

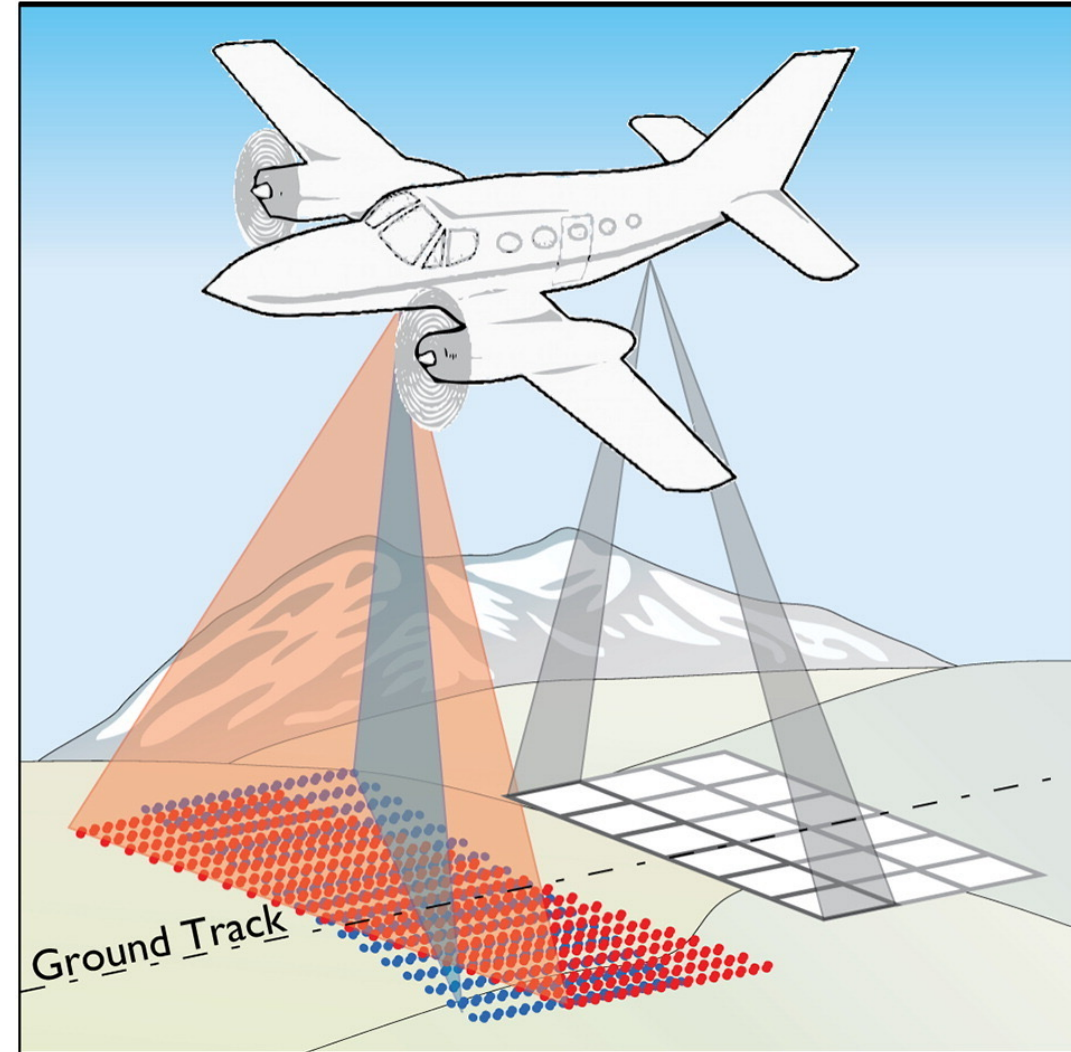
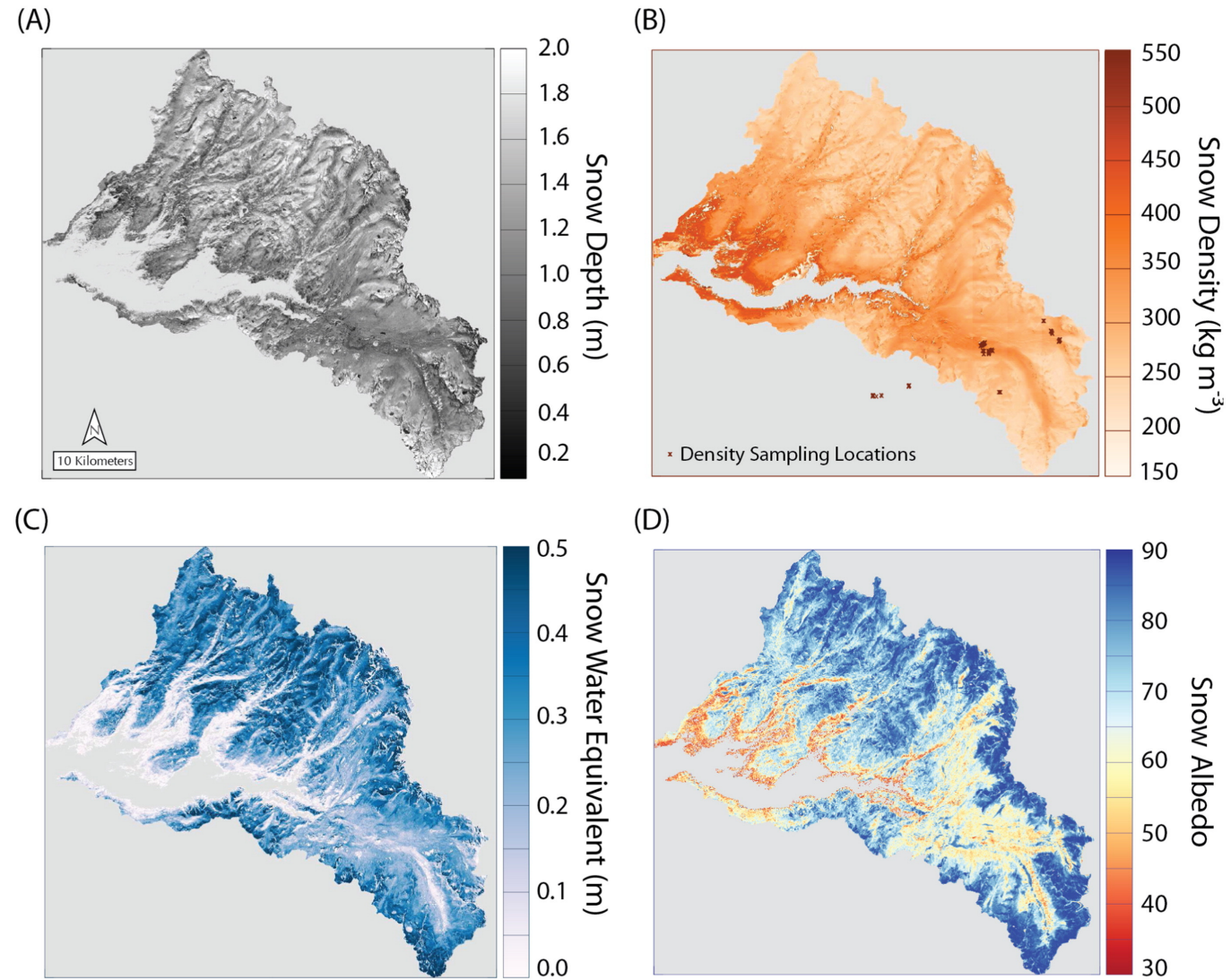


Image from Painter et al., 2016, <https://doi.org/10.1016/j.rse.2016.06.018>



Example ASO Data

Tuolumne River Basin
7 April 2014



From Painter et al., 2016, <https://doi.org/10.1016/j.rse.2016.06.018>



ASO Snow Products at NSIDC DAAC

Product	Product ID	Parameter
ASO L4 Lidar Point Cloud Digital Terrain Model 3m UTM Grid	ASO_3M_PCDTM	Terrain Elevation
ASO L4 Lidar Snow Depth 3m UTM Grid	ASO_3M_SD	Snow Depth
ASO L4 Lidar Snow Depth 50m UTM Grid	ASO_50M_SD	Snow Depth
ASO L4 Lidar Snow Water Equivalent 50m UTM Grid	ASO_50M_SWE	Snow Water Equivalent

NSIDC DAAC products are in GeoTIFF format, spanning April 2013 to October 2019.



SnowEx

- Series of NASA airborne and field campaigns between 2017 and 2023, in Western US (mostly Colorado) and Alaska, funded by NASA Terrestrial Hydrology Program
- Goals of SnowEx were to:
 - More accurately measure snow characteristics in a variety of terrain and vegetation canopy
 - Validate airborne measurements against ground-truth fieldwork
 - Compare different remote sensing technologies
 - Inform future potential snow satellite mission design



Photo by Alan Bourgeois, NSIDC



SnowEx

- 100 datasets spanning:
 - Airborne Lidar
 - UAV L-band SAR
 - SWE
 - Snow Depth
 - Ground Penetrating Radar
 - Surface Spectral Reflectance
 - Snow Pit Measurements
 - Meteorological Data

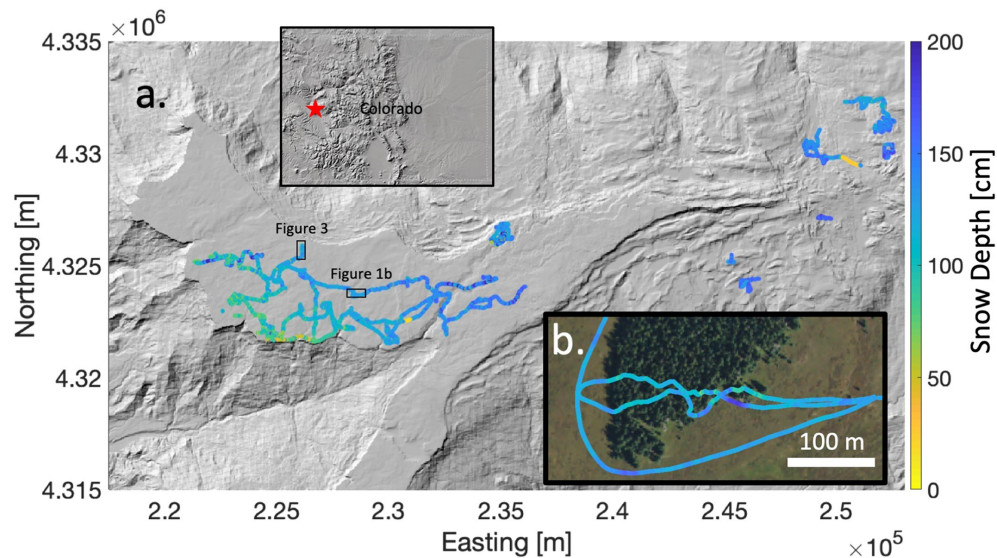


Photo by H.P. Marshall, Boise State Univ.

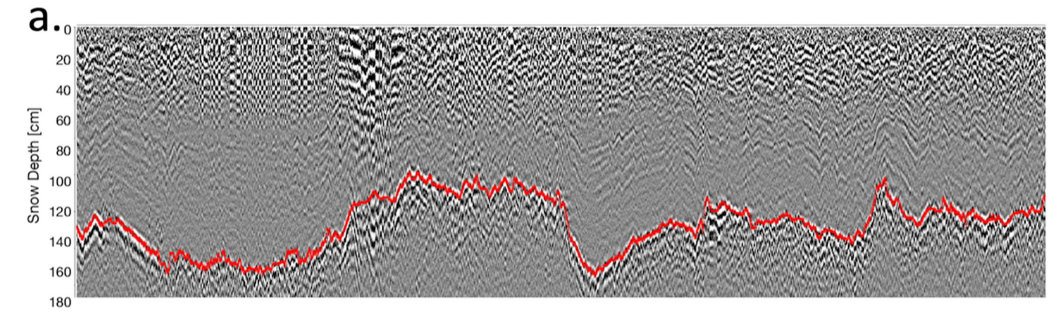


SnowEx Example Results

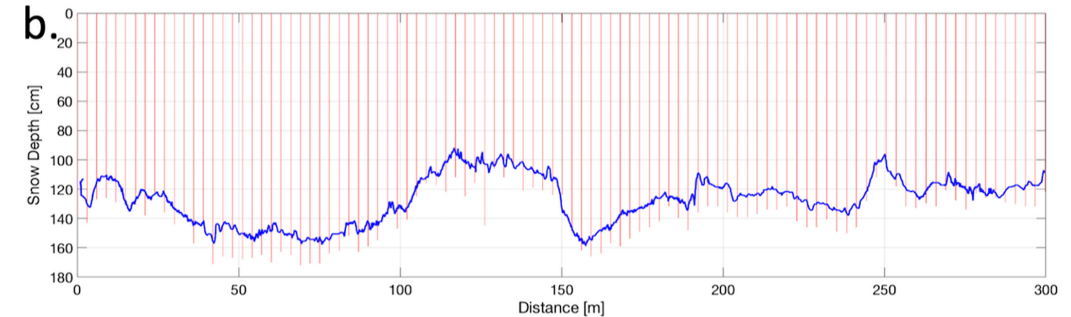
- Comparison of ground penetrating radar (GPR) with in situ snow depth probes from 2017 campaign in Grand Mesa, Colorado
- High correlation between GPR and probes, but GPR bias of -10 cm



GPR Returns



GPR Overlayed on Snow Probes



GPR Track and Instrument



McGrath et al., 2019, <https://doi.org/10.1029/2019WR024907>



Resources

- AMSR Unified: <https://nsidc.org/data/amsru>
- MODIS: <https://nsidc.org/data/modis>
- VIIRS: <https://nsidc.org/data/viirs>
- Airborne Snow Observatory: <https://nsidc.org/data/aso>
- SnowEx: <https://nsidc.org/data/snowex>
- NASA “Got Snow?": https://snow.nasa.gov/sites/default/files/Got_SnowSM.pdf
- Snow Today: <https://nsidc.org/snow-today>

References:

- Meier, M.F. (1969), GLACIERS AND WATER SUPPLY. Journal - American Water Works Association, 61: 8-12. <https://doi.org/10.1002/j.1551-8833.1969.tb03696.x>

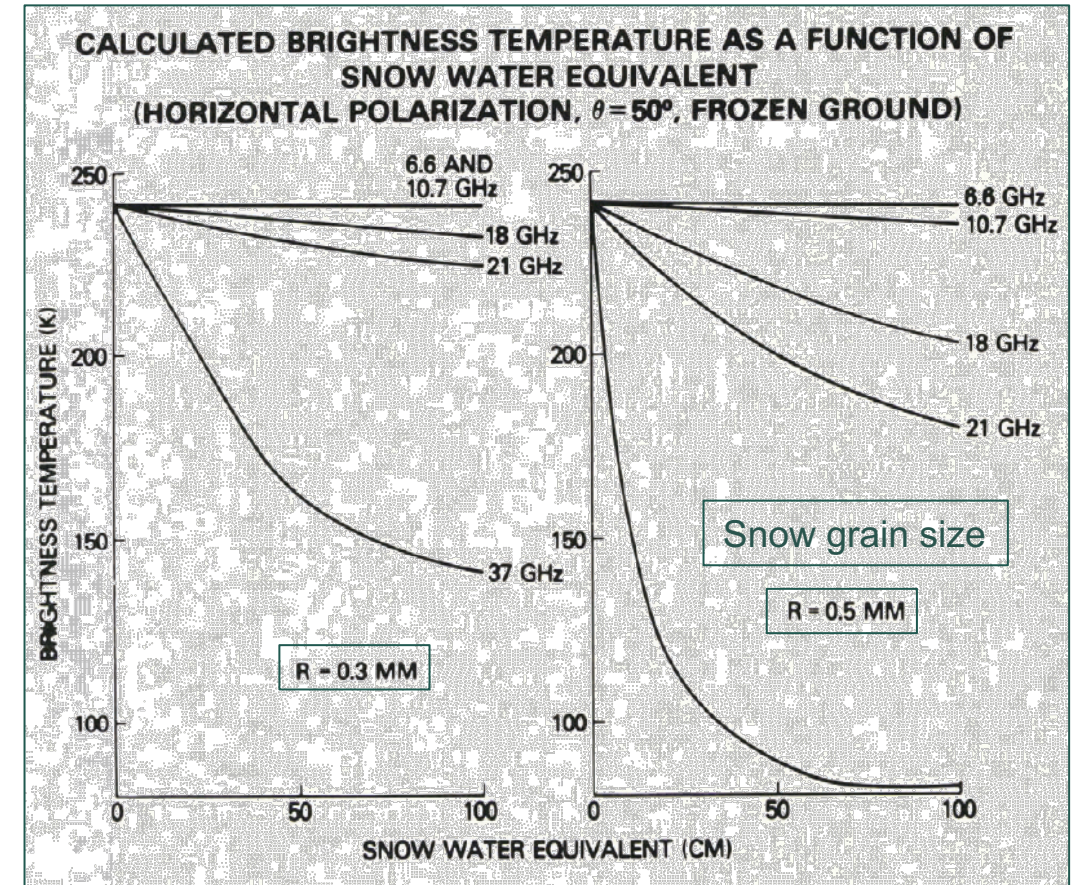




Appendix

Passive Microwave Snow Algorithm

- Simple passive microwave snow algorithms (Chang et al., 1982, 1987):
 - $SD = R_c * (TB_{19GHz} - TB_{37GHz})$
 - $SWE = R_{c'} * (TB_{19GHz} - TB_{37GHz})$
 - R_c and $R_{c'}$ are empirically derived coefficients (units of cm/K)
 - Chang et al., 1987: $R_c = 1.59$ with horizontal (H) polarization channels



From Chang et al., 1987

Chang et al., 1982, [https://doi.org/10.1016/0165-232X\(82\)90019-2](https://doi.org/10.1016/0165-232X(82)90019-2)

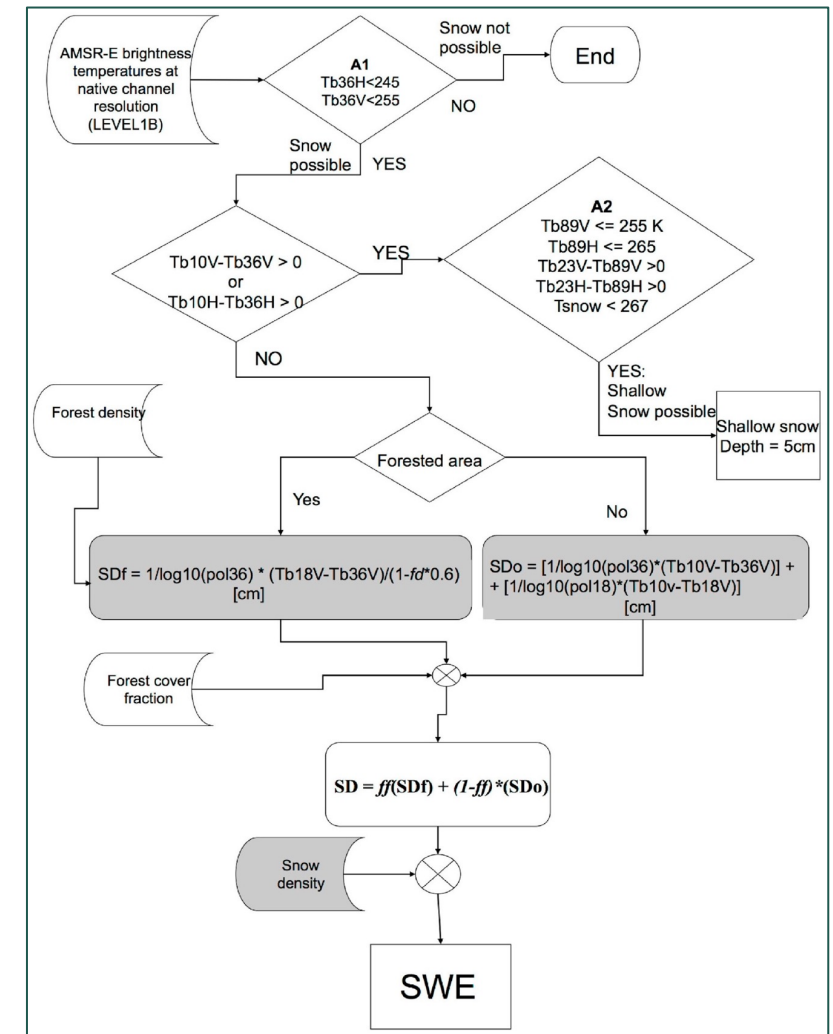
Chang et al., 1987, <https://doi.org/10.3189/S0260305500200736>

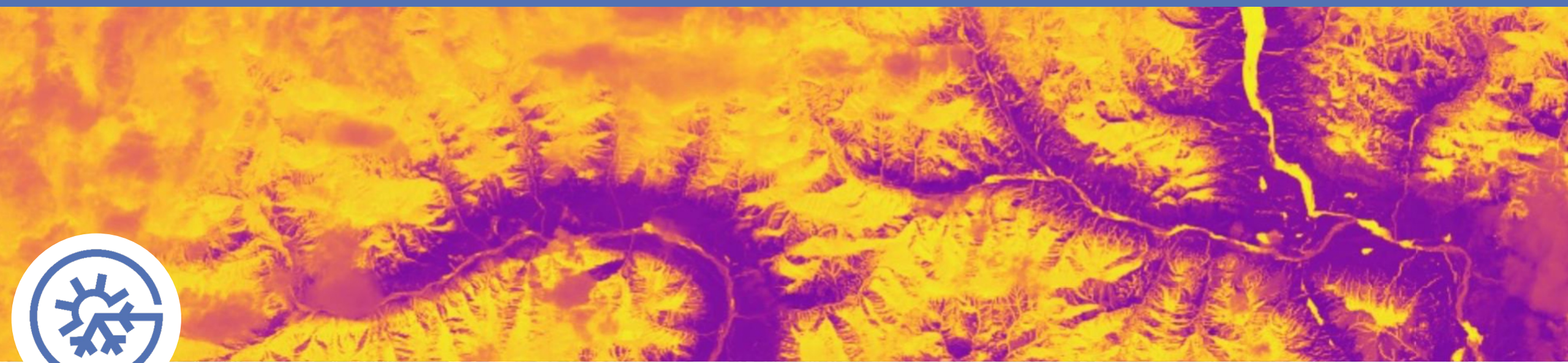


Improvements Over the Years to PM Snow Retrievals

- Vegetation also scatters PM emission from snow, particularly forests, so a forest fraction (ff) was added:
 - $SD = R_c * (TB_{18H} - TB_{37H}) / (1 - ff)$, $R_c = 0.79$ (Foster et al., 1997)
 - Correction improves estimates, but is not perfect
- More recent advancements have incorporated climatological ancillary data, a snow emission model, and Artificial Neural Networks (ANNs), to improve performance in varied conditions (forest, snow grain size, snow density, temperature; [Tedesco and Jeyaratnam, 2016](#))
- Used for the NASA AMSRU snow products at the NSIDC DAAC

Tedesco and Jeyaratnam, 2016, <https://doi.org/10.3390/rs8121037>





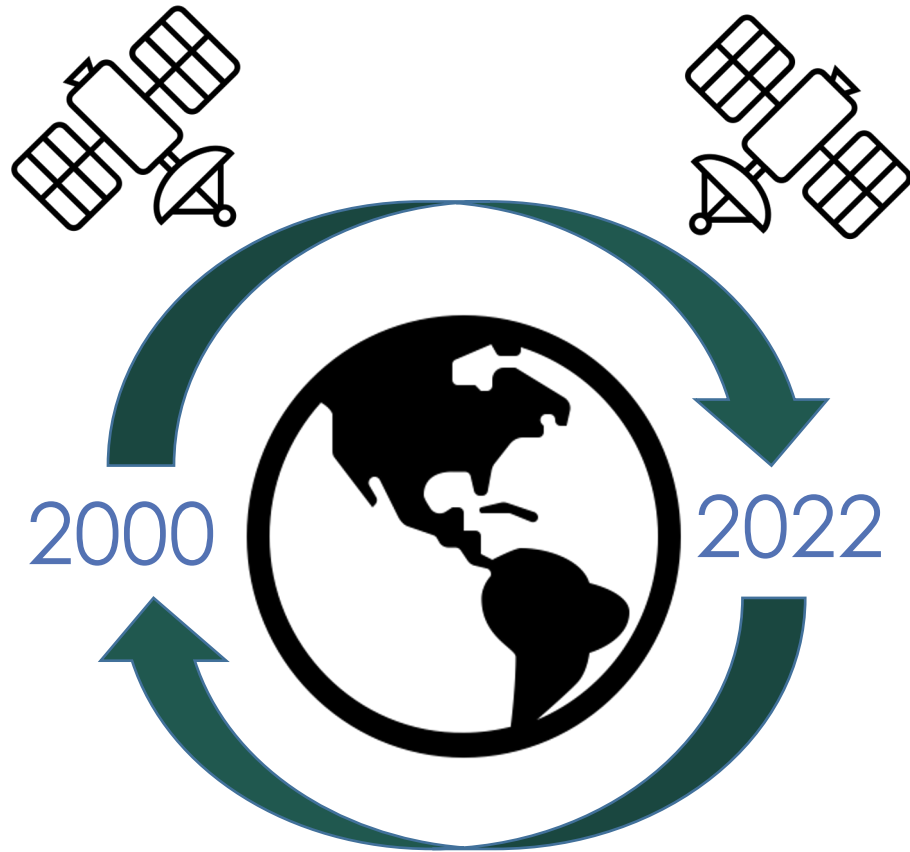
Northeast Alaska Climate

Evaluating Snow Variability through a Climatological Analysis to
Support Ecological Monitoring in Northeast Alaska

Kristin Anderson • Omeed Arooji • Isabella Chittumuri • Thomas Germann

25TH DEVELOP

Study Area and Period



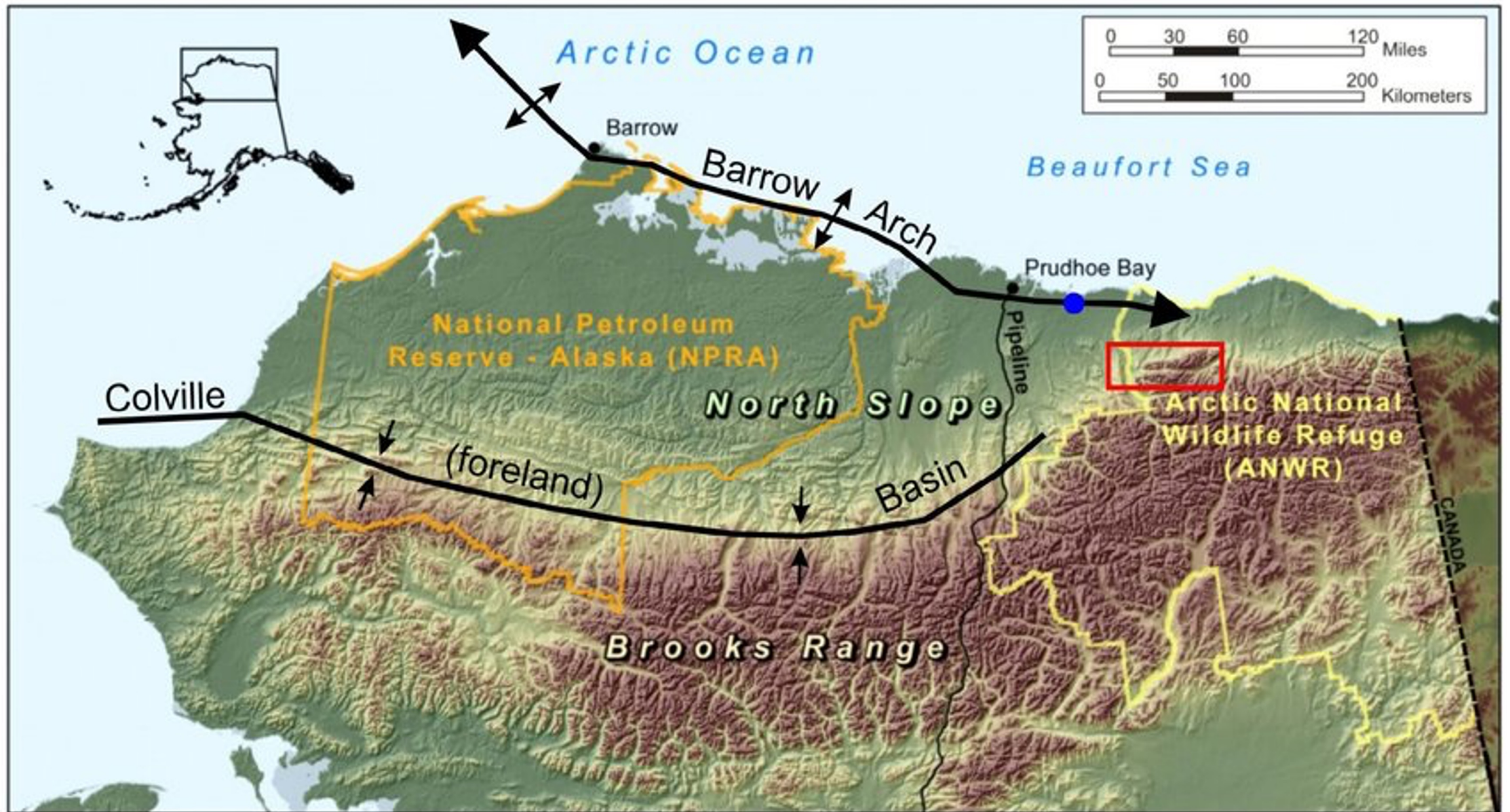
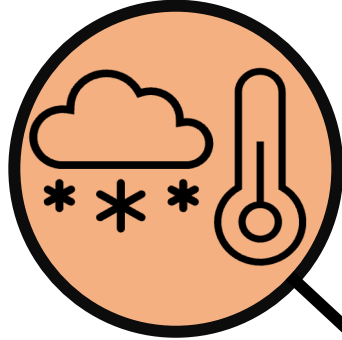


Image Credit: Michael T. Whalen



Community Concerns

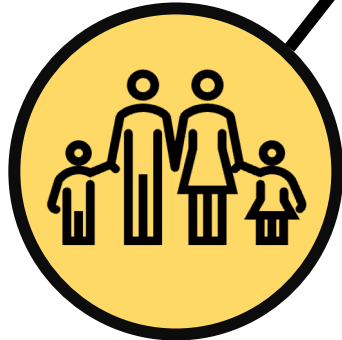
**Snow Cover
Loss**



**Oil
Exploration**



**Indigenous
Peoples**



**Biodiversity
Loss**



Limited Data



Partners

- US Fish and Wildlife Service, Arctic National Wildlife Refuge
- Alaska Climate Adaptation Science Center (CASC)



Objectives

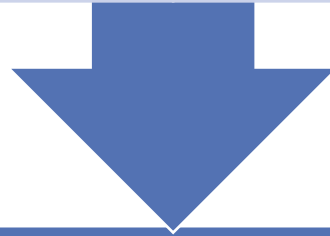


Evaluate historic snow variables



Snow cover fraction

Snow depth



Depict snow trends using end products



Time series
analysis

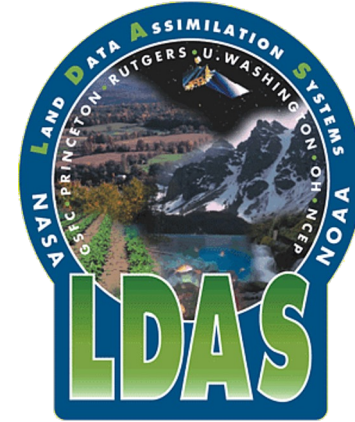
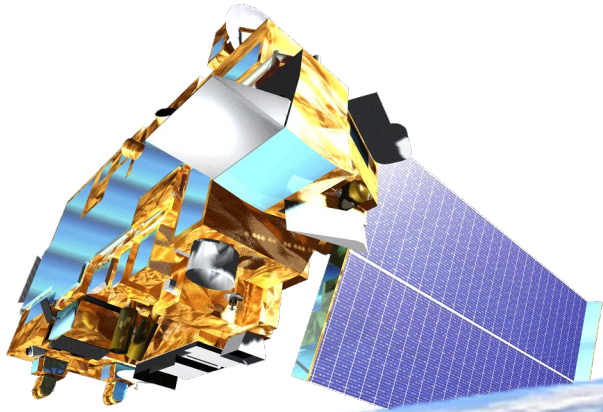
Snow variability
maps

Snow on/off
maps

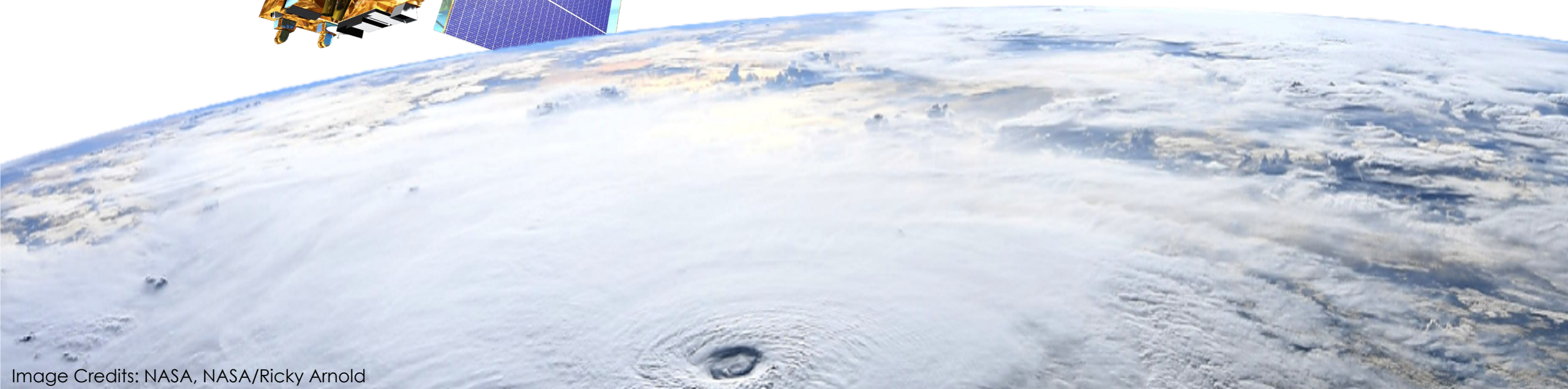


Earth Observations & Modeled Data

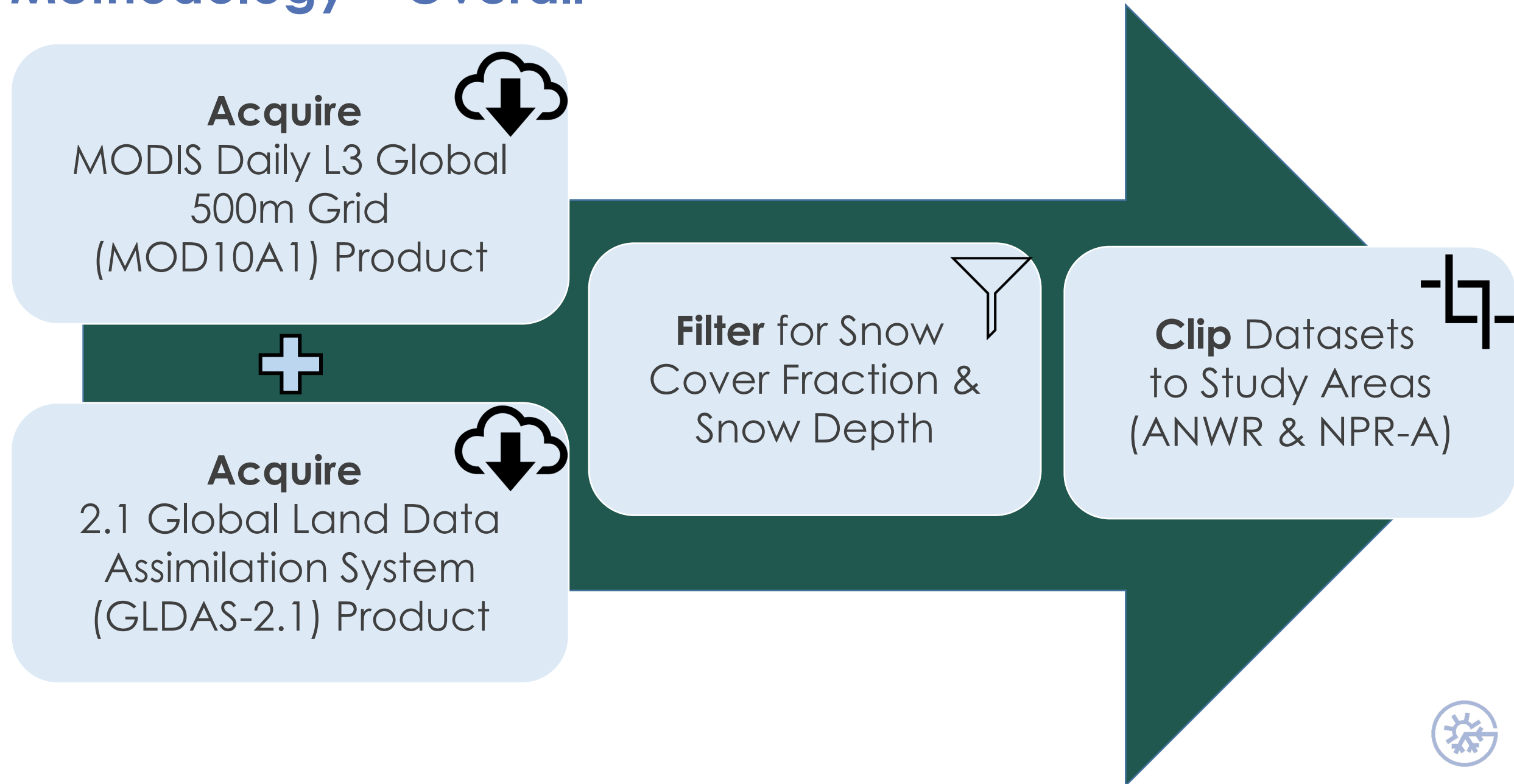
Terra MODIS Snow Cover
Daily L3 Global 500m Grid



2.1 Global
Land Data Assimilation
System (GLDAS-2.1)



Methodology – Overall



Methodology – NDSI Snow Cover and Snow Depth

Bit-Mask

- Reclassify Snow Cover Values

Change
Detection

- Pixel Change Between Snow Off and Snow On

Map

- First and Last Day of Snow
- Change Frequency
- Snow Season Duration

Classified

- Monthly Snow Depth Data

Averaged

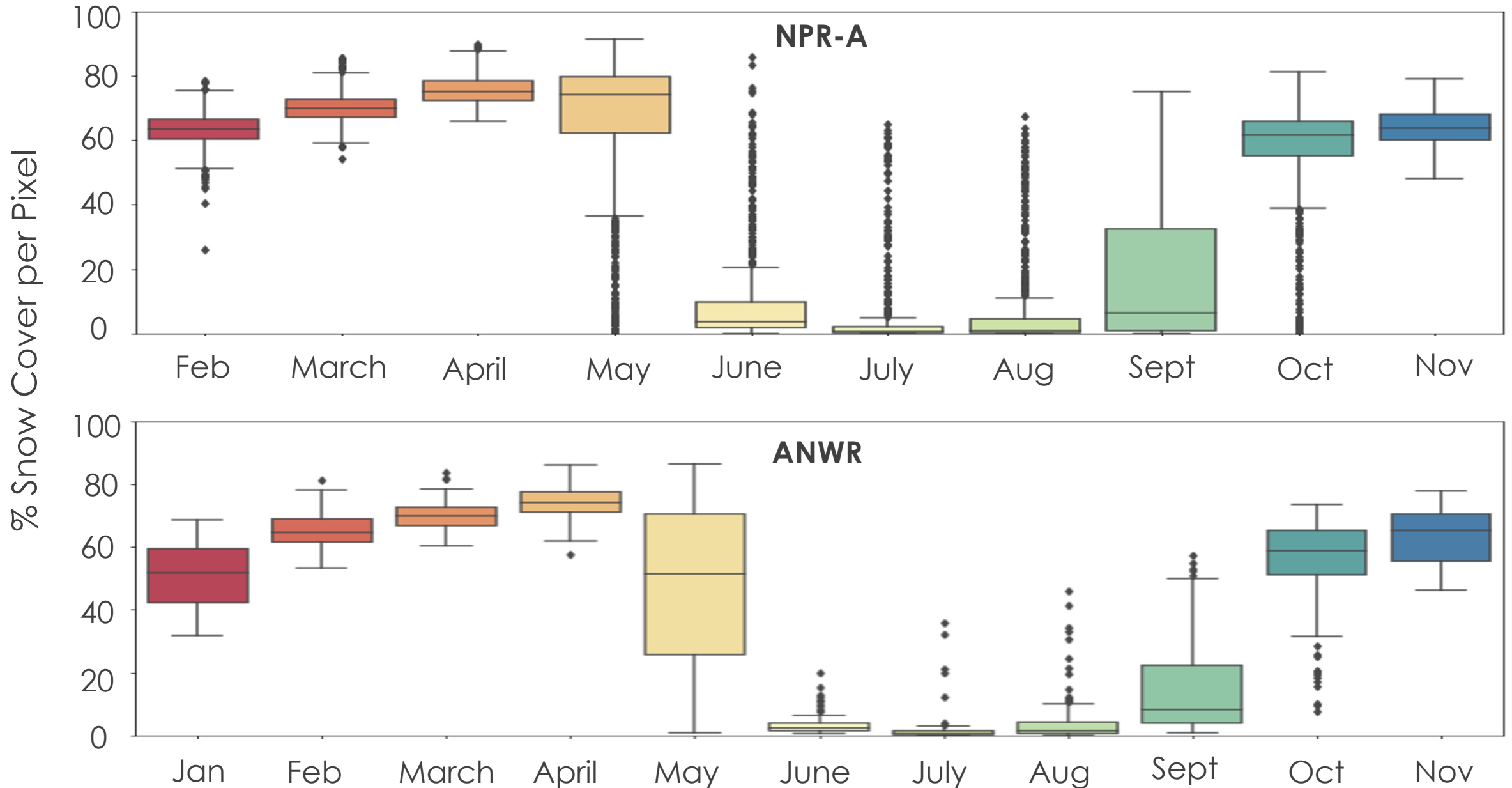
- Calculated Average Snow Depth Per Pixel

Map

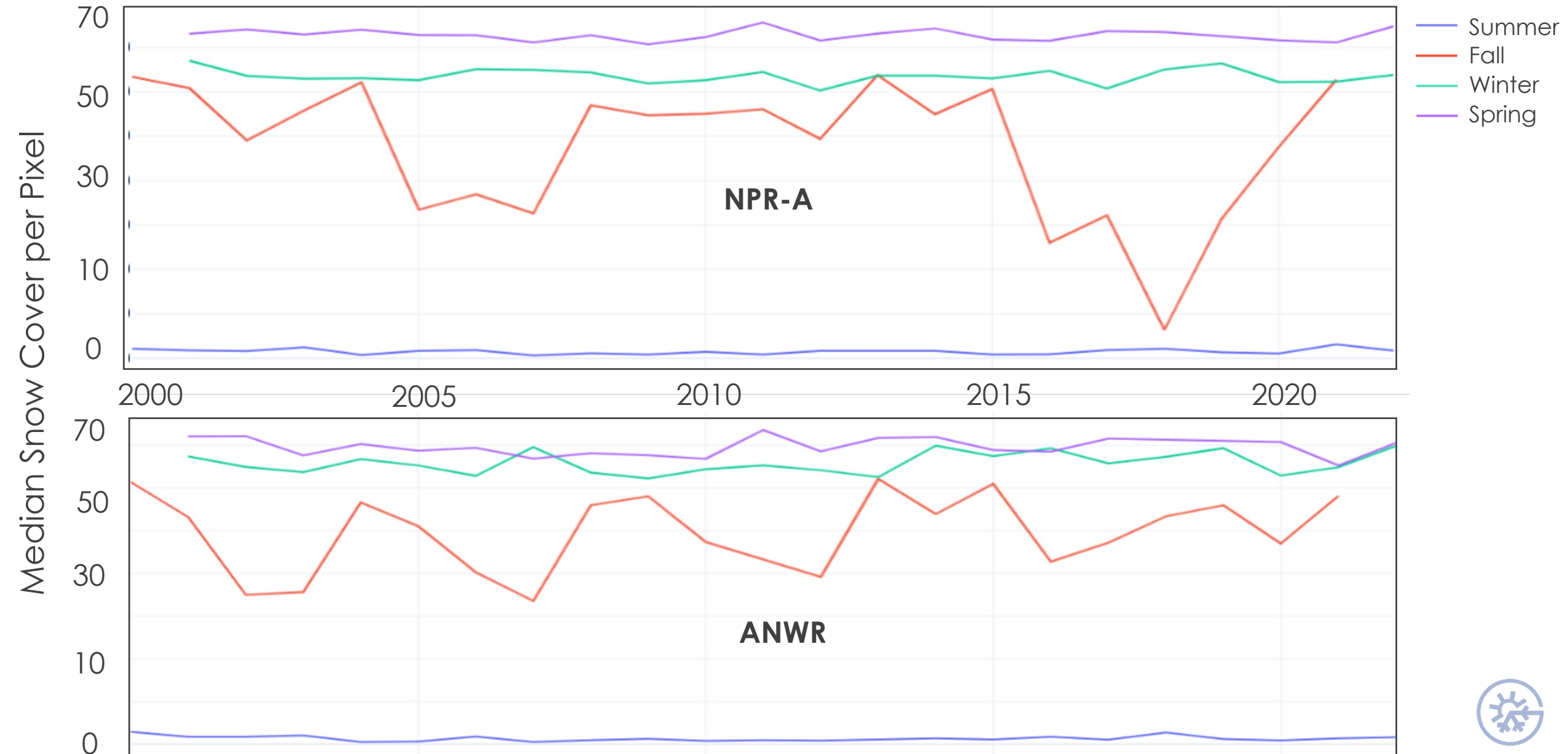
- Average Snow Cover per Pixel



Results – Monthly Snow Cover (2000–2022)



Results – Monthly Snow Cover Fraction



Results – Last Day of Snow Maps

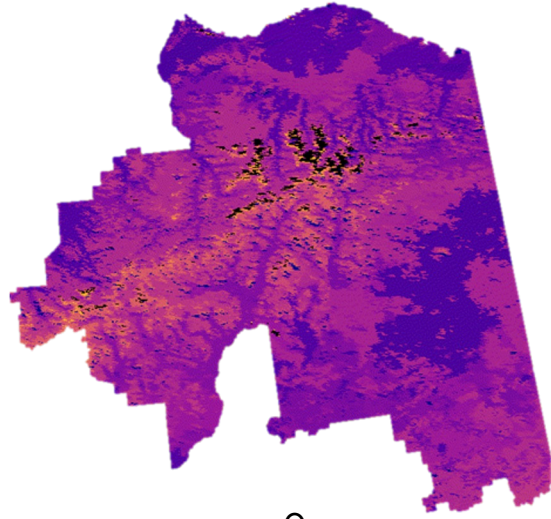
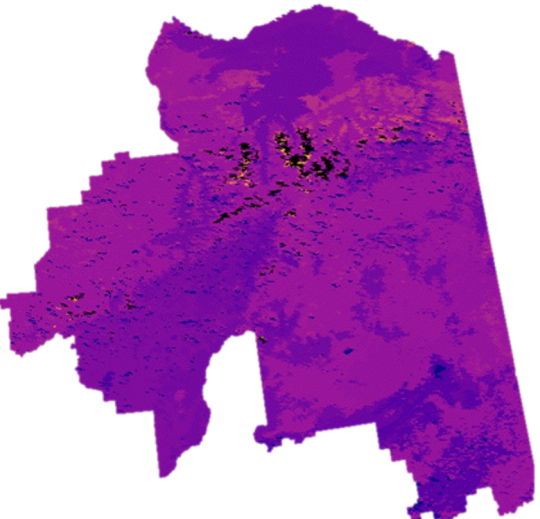
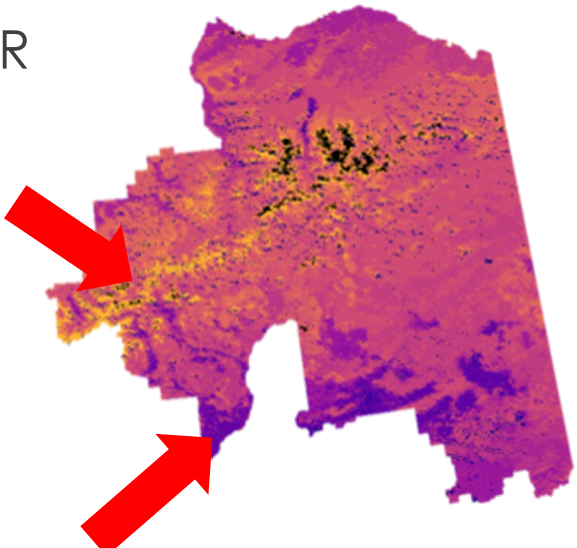


2000

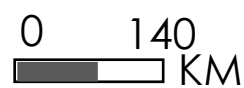
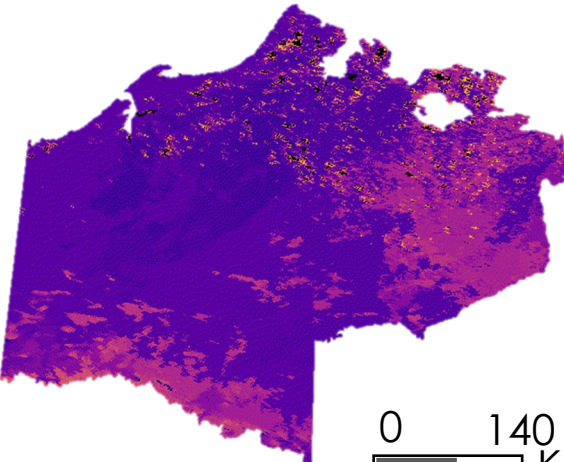
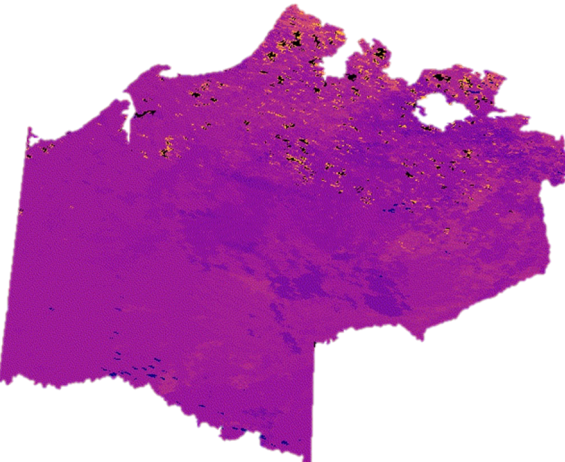
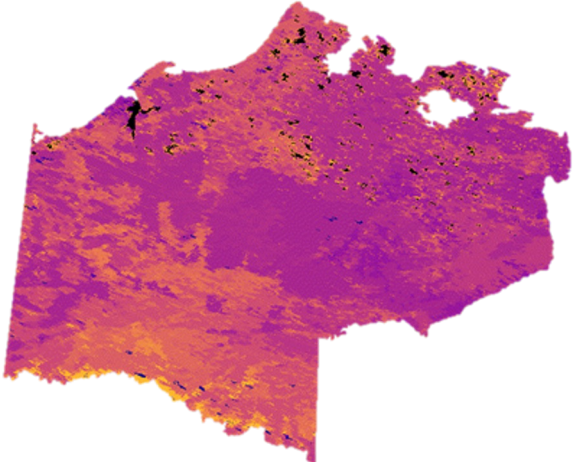
2010

2022

ANWR

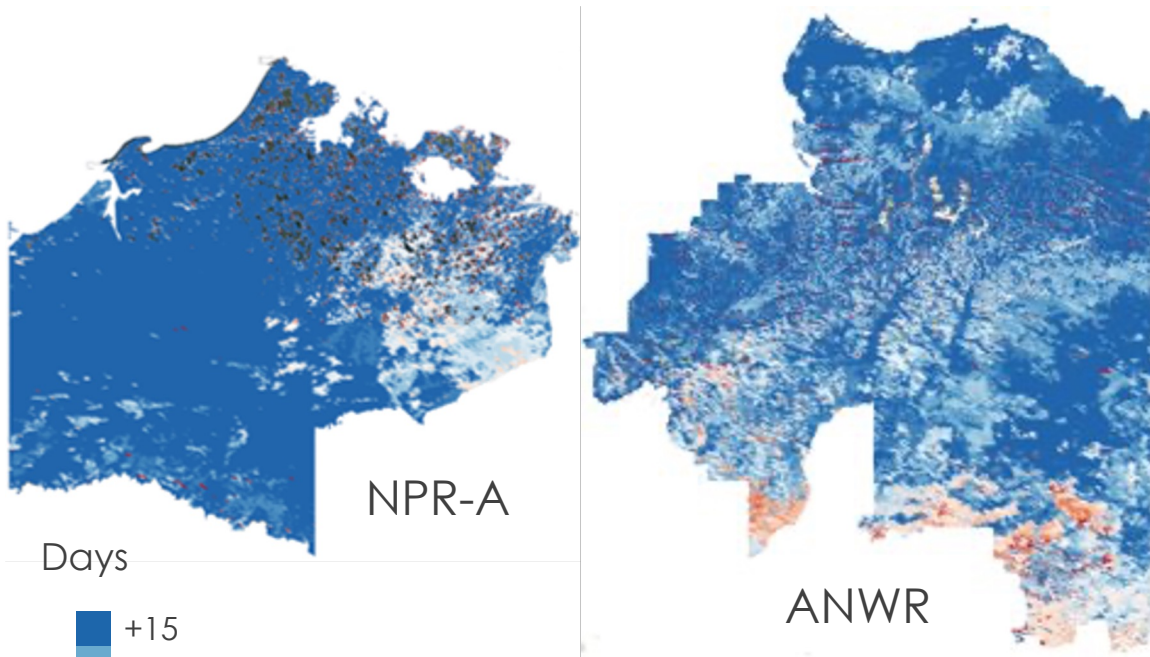


NPR-A

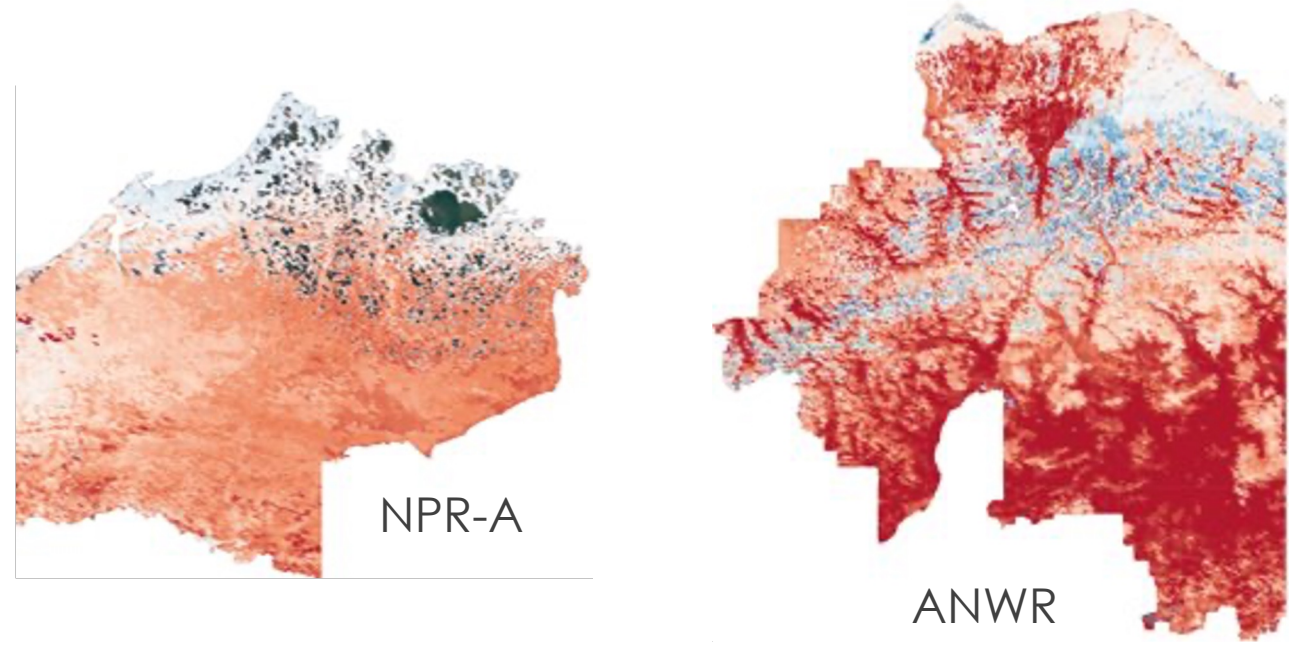


Results – Snow Season Start/End Date Change

First Day of the Snow Year
Difference Between 2000 and 2022



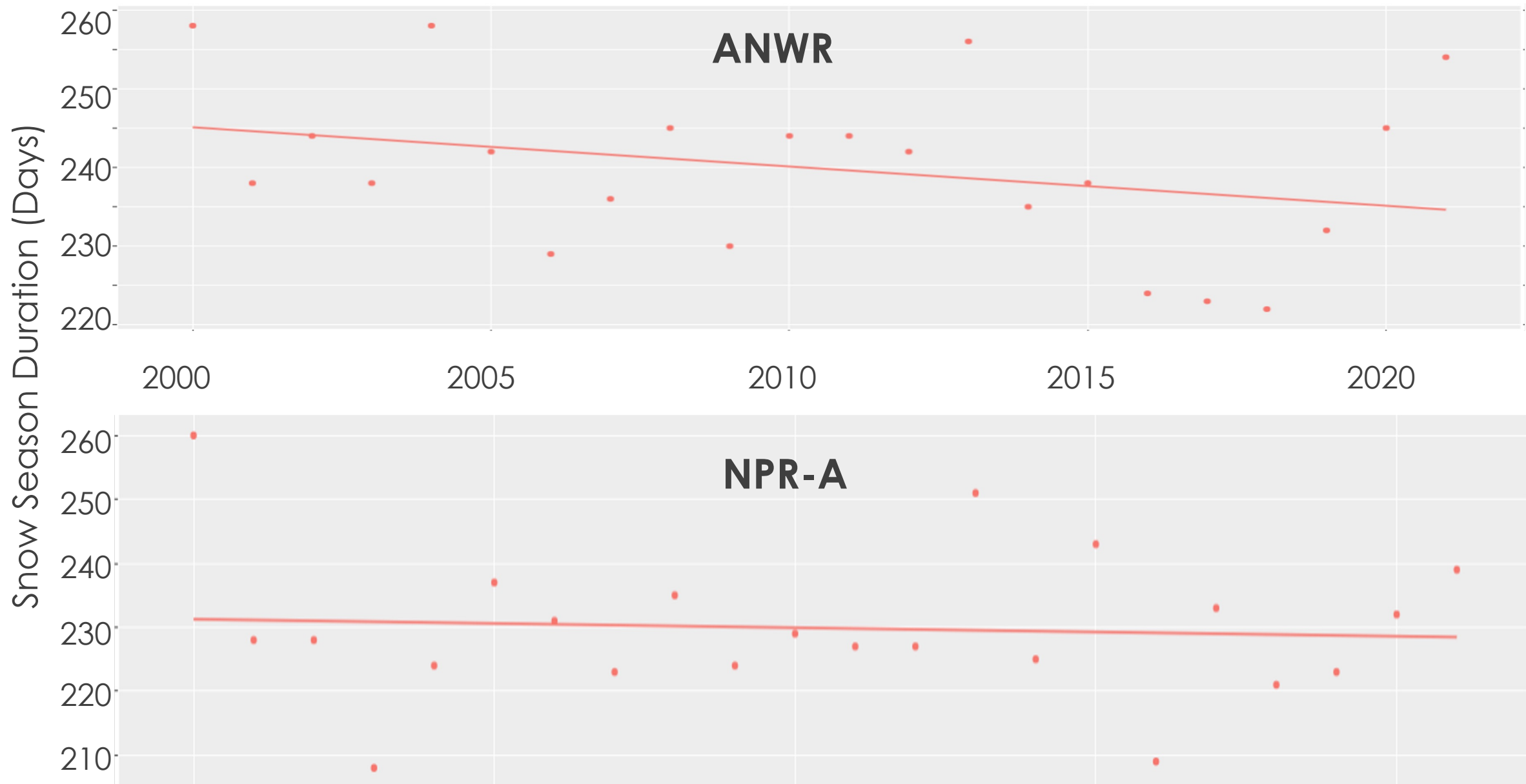
Last Day of the Snow Year
Difference Between 2000 and 2022



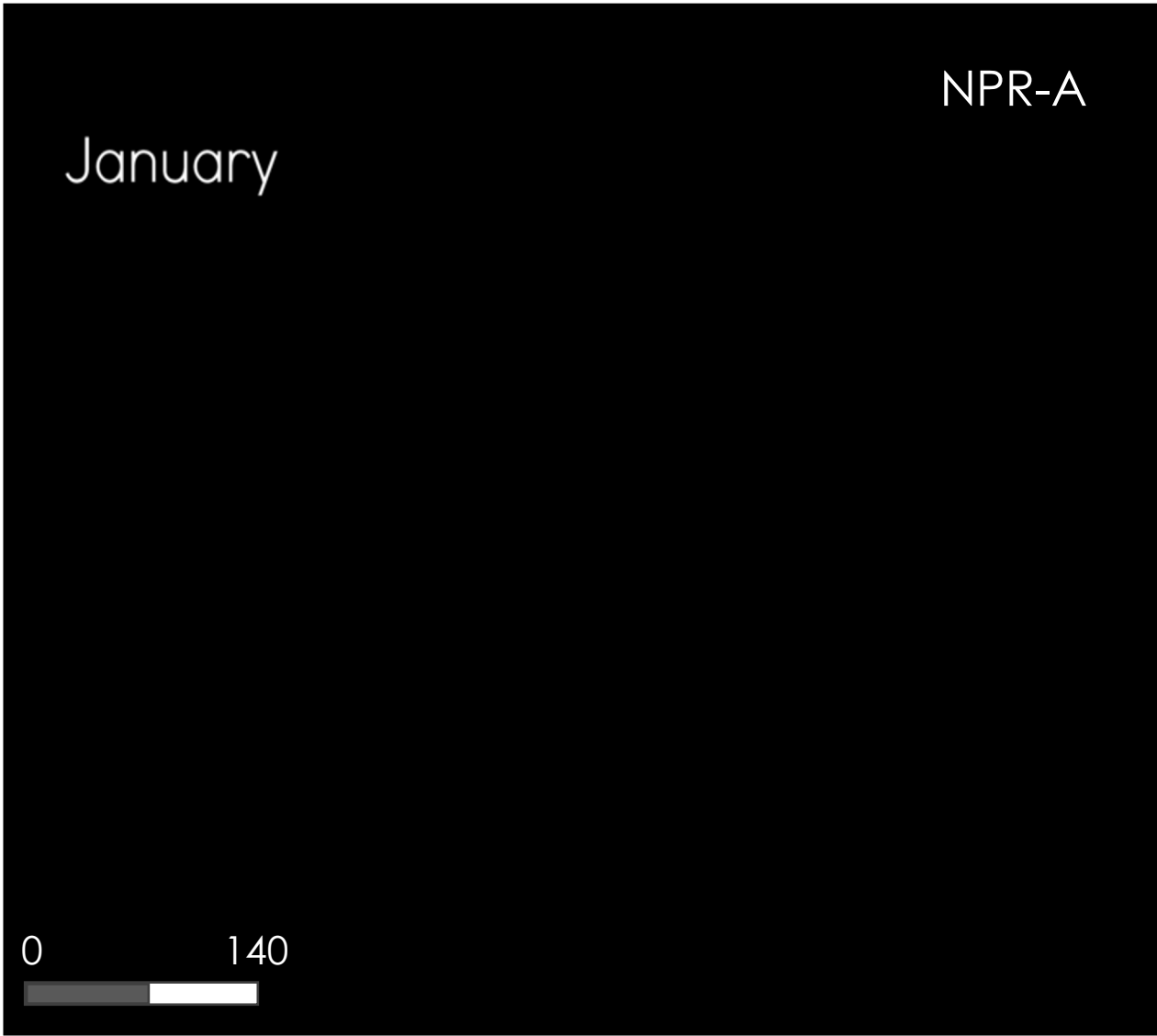
0 140 km



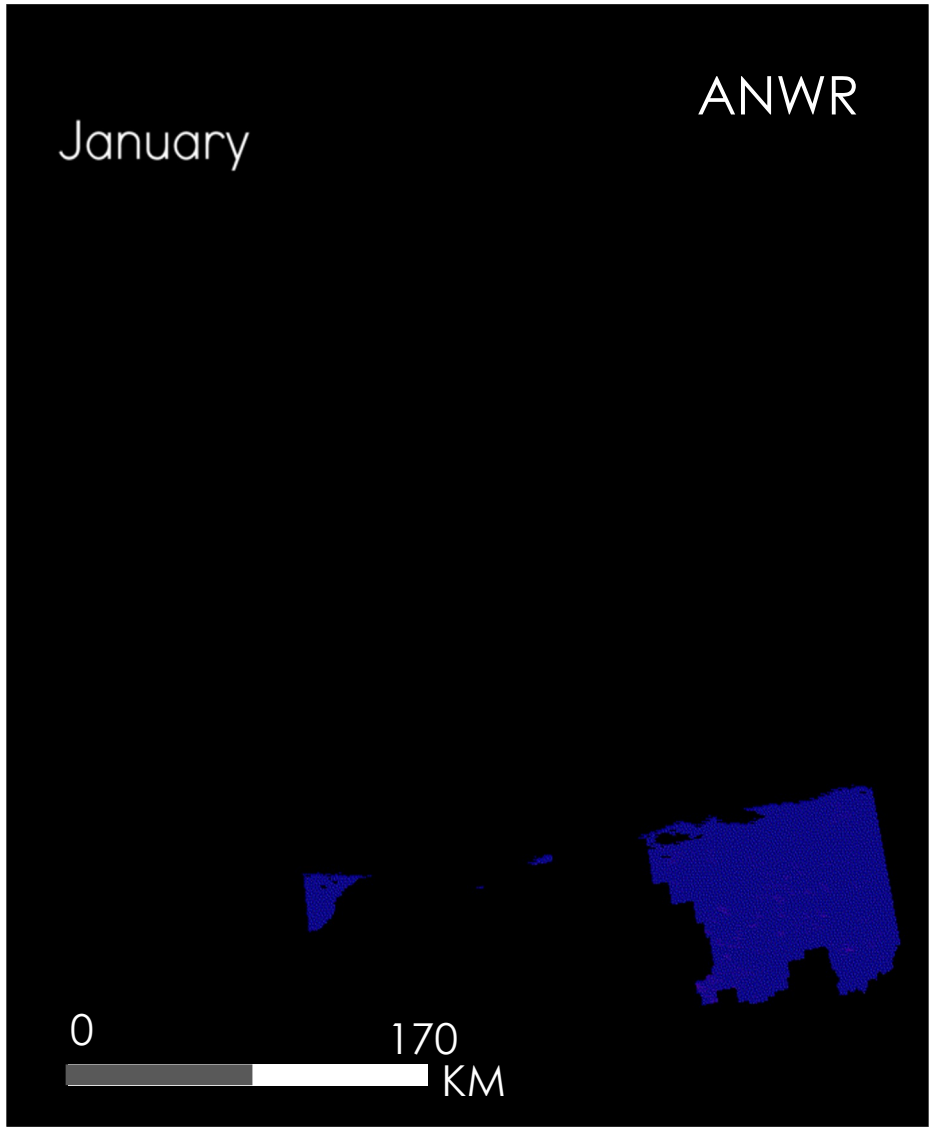
Results – Annual Snow Season Duration



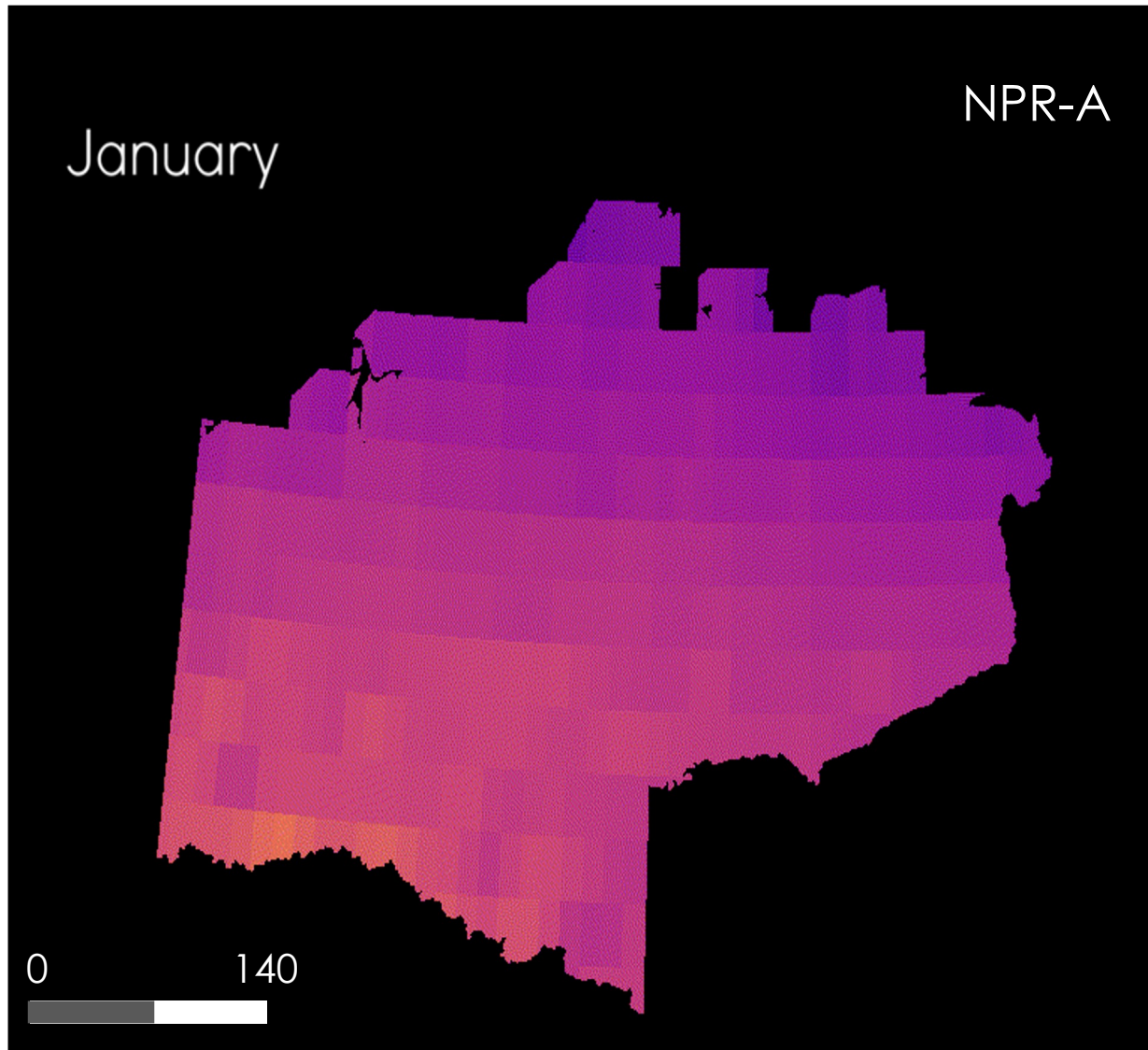
Results – Snow Cover Variability Map



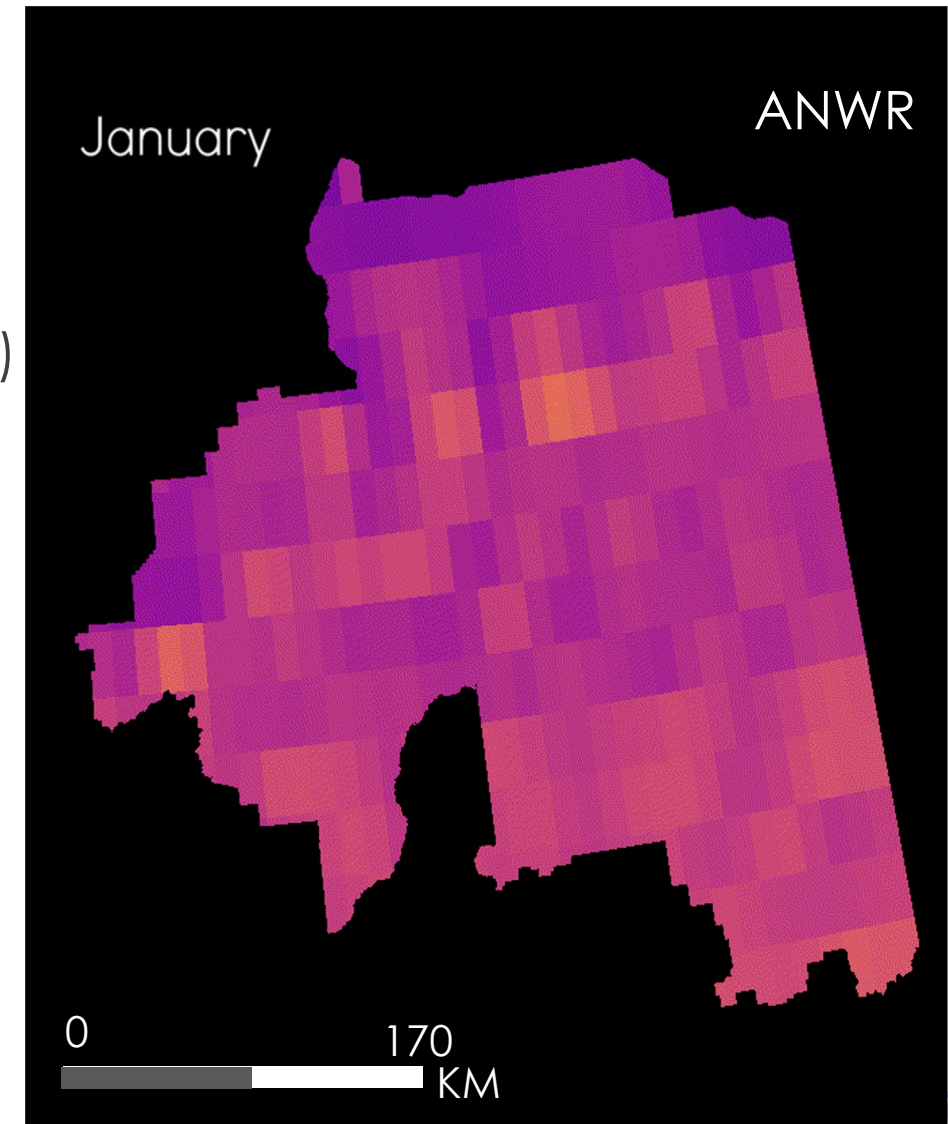
Snow
Cover
Pixel
Sum



Results – Snow Depth



Depth (m)



Conclusions



Image Credit: PowerPoint

- Snow cover variability differences between mountainous and coastal regions
- No significant trend was observed in snow season duration
- Snow depth appears to be steadily increasing closer to the Brooks range in both study areas





Errors & Uncertainties

- Limited by spatial and temporal resolution of MOD10A1 and GLDAS products
- Data gaps during polar nights and other environmental factors, such as cloud cover



Acknowledgements

- North Carolina - NCEI Fellow
 - Kathryn Caruso
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 - Dr. Kent Ross, NASA Langley Research Center
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 - Molly Woloszyn, National Integrated Drought Information System (NIDIS)
- Partners
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 - Dr. Paul Leonard, US Fish and Wildlife Service Arctic National Wildlife Refuge
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 - Brooke Adams, NCEI
 - Ellen Bartow-Gillies, NCEI
 - Steve Ansari, NCEI/NIDIS



Part 1: Summary

Snow and Ice are an Important Water Resource

- Snow and ice play a crucial role in Earth's water cycles.
 - Snowmelt serves as an important source of water in many regions.
 - Interannual variations in snowpack have a substantial impact on regional water availability and can lead to floods or droughts.
- When snow accumulates at high latitudes or in high elevations, water is stored for days to months.
- Glaciers (the result of snow accumulating over years) store water for hundreds to tens of thousands of years.
- **Measurements of Snow:**
 - Snow Covered Area (SCA)
 - Snow Thickness
 - Snow Water Equivalent (SWE)
- **Snow Properties:**
 - Snow Albedo
 - Snow Grain Size
 - Snow Impurities



Remote Sensing of Snow and Ice: Missions and Sensors

Spectral Measurement	Mission and Sensor	Temporal Coverage
Passive Microwave	DMSP NASA/JAXA SSMI SSMIS AMSR-E AMSR-2	1978 – 2008 2003 – 2025 2002 – 2011 2012 – Present
Visible and Near-Infrared	NOAA-8 to -19 NASA EOS. SNPP & NOAA-20 AVHRR MODIS VIIRS	1979 – Present 2002 – Present 2011 – Present 2017 – Present



Snow Products: Passive Microwave



Product Name	Short Name
AMSR-E/AMSR2 Unified L3 Global Daily 25 km EASE-Grid Snow Water Equivalent, Version 1	AU_DYSNO
AMSR-E/AMSR2 Unified L3 Global 5-Day 25 km EASE-Grid Snow Water Equivalent, Version 1	AU_5DSNO
AMSR-E/AMSR2 Unified L3 Global Monthly 25 km EASE-Grid Snow Water Equivalent, Version 1	AU_MOSNO



Snow Products: Visible & Near-Infrared

Product	Parameter	Spatial Res.	Level/Grid	Sampling
MOD10_L2	NDSI	500 m	Swath (L2)	5-minute
MOD10A1	Snow Cover, Albedo	500 m	Sinusoidal gridded tiles (L3)	Daily
MOD10C1	% Snow Cover	0.05 deg	Climate Model Grid (L3)	Daily
MOD10A2	Snow Extent	500 m	Sinusoidal gridded tiles (L3)	8-day
MOD10C1	% Snow Cover	0.05 deg	Climate Model Grid (L3)	Daily
MOD10C2	% Snow Cover	0.05 deg	Climate Model Grid (L3)	8-day
MOD10CM	Monthly Mean Snow Cover	0.05 deg	Climate Model Grid (L4)	1-month

Product	Parameter	Spatial Res.	Level/Grid	Sampling
VNP10	NDSI	375 m	Swath (L2)	6-minute
VNP10A1	NDSI	375 m	Sinusoidal gridded tiles (L3)	Daily
VNP10C1	% Snow Cover	0.05 deg	Climate Model Grid (L3)	Daily
VNP10A1F	Cloud gap-filled snow	375 m	Sinusoidal gridded tiles (L3)	Daily



Snow Products and Applications

- Improvement to standard MODIS snow products:
 - MODSCAG-DRFS (MODIS Snow Cover and Grain Size & Dust Radiative Forcing in Snow).
 - SPIReS (Snow Property Inversion from Remote Sensing).
- Application of MODSCAG & SPIReS:
 - [Snow Today](#) provides daily updated snow conditions in the Western US and monthly analyses during the snow season.
- Airborne Snow Observatory (ASO):
 - Primary focus on Sierra Nevada mountains and California water resources
- Snow-Ex:
 - Series of NASA airborne and field campaigns in western US, mostly Colorado and Alaska,
- Application of MODIS snow cover and GLDAS snow depth:
 - Monitoring variability of snow in Alaska for National Petroleum Reserve of Alaska (NPR-A) & Arctic National Wildlife Refuge (ANWR).



Homework and Certificates

- **Homework:**
 - One homework assignment
 - Opens on 7 August 2025
 - Access from the [training webpage](#)
 - Answers must be submitted via Google Forms
 - **Due by 21 August 2025**
- **Certificate of Completion:**
 - Attend all live webinars (attendance is recorded automatically)
 - Complete the homework assignment by the deadline
 - You will receive a certificate via email approximately two months after completion of the course.



Looking Ahead to Part 2

- Access, Analysis, and Visualization of NASA Snow and Ice Data Products.



Acknowledgements

Instructors:

Andrew Barrett	Senior Associate Scientist, NSIDC
Walter Meier	Senior Research Scientist, NSIDC – DAAC
Ryan Theurer	Senior Software Engineer, ASO

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Thank You!

