Downscaling Geostationary Surface Albedo Using Neural Networks for Snow-Melt Processes

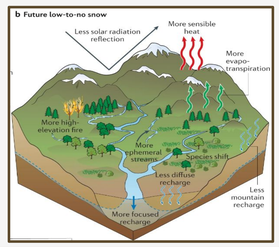
Felix Yu[1], William Rudisill[2], Utkarsh Mital[2], Anna Spiers[2], Daniel Feldman[2]
[1]University of Michigan, [2]Lawrence Berkeley National Laboratory

Abstract

Snow albedo is crucial for understanding mountain snowpack changes and estimating water resources. In the Upper Colorado River Basin, climate change has significantly impacted snowpack, but the role of processes in this change, particularly snowmelt and water discharge, remains unclear. This project combines satellite and field observations from the SAIL field site to estimate surface albedo at high temporal and spatial resolution. We use a U-Net neural network to create a surface albedo product from 2-km geostationary satellite data by downscaling to 500m with MODIS, and then further downscaling to 20m with Sentinel-2. Current studies seldom address the downscaling of albedo from GOES satellites. Predicting albedo at 20m resolution remains challenging, requiring more research to improve accuracy at 20m.

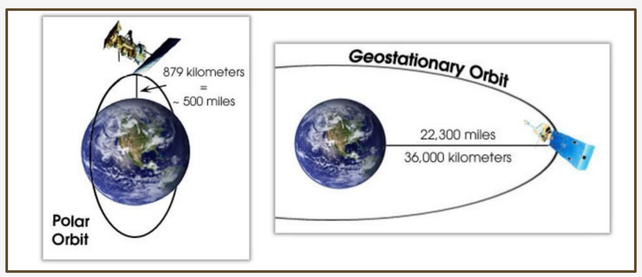
Motivation: Snowmelt affects water resources

The Upper Colorado River basin supplies water for 40 million people and supports $1.3 trillion in annual economic activity



Snowpack and surface albedo changes impact river discharge timing/amount as well as reservoir levels of the Colorado River Basin

Key Remote Sensing Terms



MODIS/Sentinel-2 -
Polar Orbit
Low temporal resolution
(~ 1 per day)
High spatial resolution
(20 - 500 meters)

+

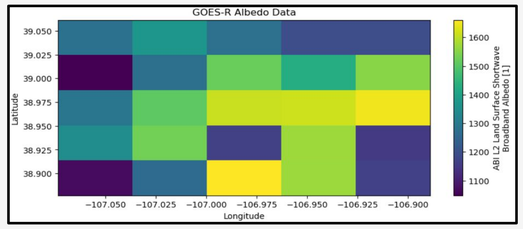
GOES -
Geostationary
High temporal resolution
(~ 10 minutes)
Low spatial resolution
(~ 2 km)

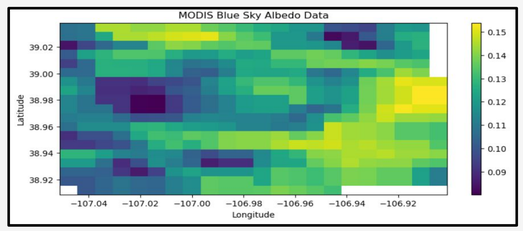
Combined Goal:
High temporal resolution
High spatial resolution
(20m, 1 per day)

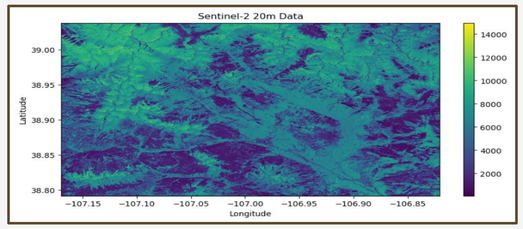
Surface Albedo: Range from 0 - 1 (low to high) of how much shortwave solar radiation is reflected by the surface
Fresh Snow Albedo: 0.80 Average Ground Albedo: 0.30
White Sky Albedo: Albedo measurement under cloudy conditions
Black Sky Albedo: Albedo measurement with clear skies
Blue Sky Albedo: Albedo measurement in real-time conditions as a combination of white sky and black sky albedo

Goal: Downscale 2km satellite data to 20m

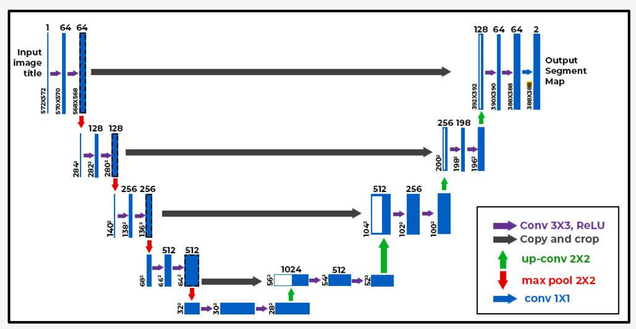
Goal: Downscale 2-km resolution GOES surface albedo data to 20m
Approach: Use GOES and MODIS/Sentinel-2 to train a U-Net to learn patterns of coarse/fine relationships when collocated and then predict fine-scale features from coarse-scale predictors.

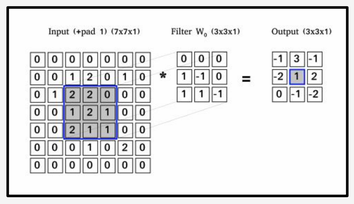






Methodology - U-Net Explained





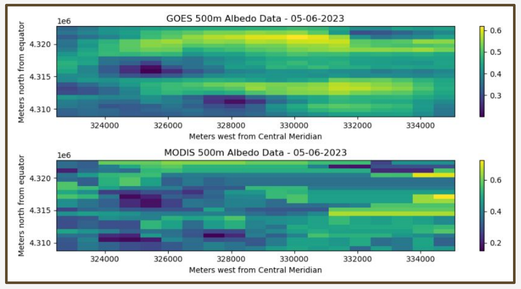
How Does a U-Net Downscale?

Key Steps:

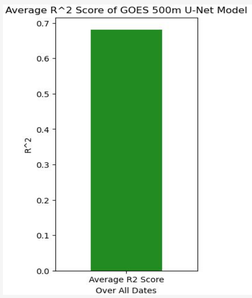
1. Pre-process all GOES, MODIS, and Sentinel-2 data to the same grid, size, and projection system (24x24).
2. Downscale 2km GOES to 500m MODIS using a U-Net.
3. Evaluate/validate U-Net against albedo statisistics.
4. Re-do U-Net downscaling to 20m using Sentinel-2 data as predictors.

Results

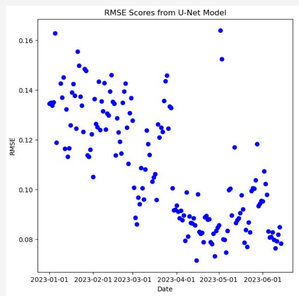
GOES 500m Data Alongside MODIS 500m Data



U-Net R^2 Score



All RMSE Scores



Discussion

Next Steps:

Downscale GOES 500m to 20m Sentinel resolution
Validate data with SAIL pyranometer instruments

Impact:

Integrate albedo findings into a climate model to improve snowmelt timing prediction, with typical melt-out errors of 3 weeks.

Understand where and when snowmelt occurs and if patterns are stationary over MODIS mission duration (2000-present).

Acknowledgements

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