Assessing High-Resolution CubeSat Imagery to Infer Detailed Snow-Covered Areas for Studying Changes in Mountain Ecosystems

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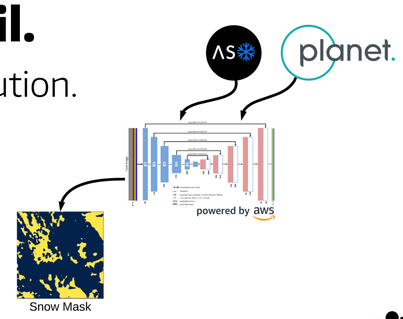
DEPARTMENT OF BIOLOGY

Neural Networks can leverage CubeSat imagery to detect snow in mountains in fine detail.

- Many landscape-scale **hydrology and ecology** studies require snow observations at daily-to-weekly timescales with sub-10m resolution.
- MODIS and Landsat products cannot directly fulfill this data need. We use **Planet**, a 3m, 4-band, ~daily CubeSat imagery product.
- This project bridges the gap between **accurate but expensive/sparse** observations and **imagery** for snow.
- Advances in **computer vision techniques**, aided by convolutional neural networks (CNNs), enable this technique.
- Public cloud compute infrastructure greatly simplifies the workflow required to complete this analysis.



Data: we merge two high-res remote platforms to jointly leverage their advantages.

- Challenge:
  - Snotel and Airborne lidar is accurate, but expensive and sparse.
  - Planet Labs imagery is global, high-resolution, but narrow bandwidth means **traditional snow detection approaches** (e.g. spectral indices) **do not work.**
- Availability:
  - The NASA Airborne Snow Observatory (ASO) produces high-resolution (3m) snow depth products at a weekly-to-monthly revisit time across several U.S. watersheds.
  - **Planet Labs**, a commercial satellite imagery company, provides a 4-band (R, G, B, NIR), 3m, 1-5 day revisit imagery product to researchers.

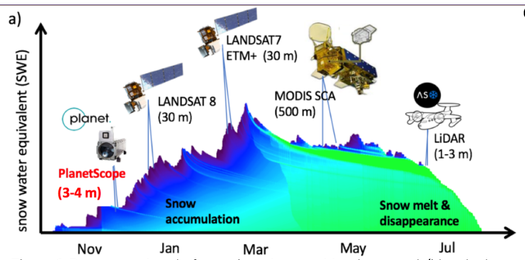


Figure 1: Remote sensing platforms observing transitional snowpack (blue shades are lower, and green shades are higher snowpack density)

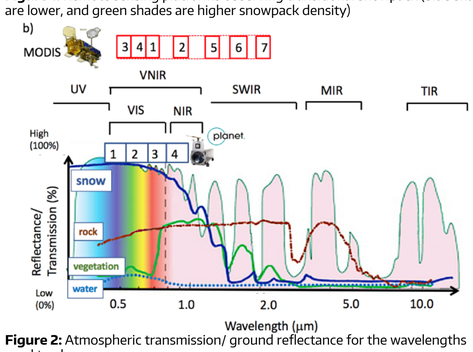


Figure 2: Atmospheric transmission/ ground reflectance for the wavelengths used to observe snow cover

Analysis: a cloud-based workflow allows for quick experimentation and reproducibility.

- We use ASO-derived snow masks to create "training data" for a neural network-based machine learning model. The CNN uses spatial context to make pixel-level predictions.
- We reserve a segment of these data to assess model performance (e.g.: "How well does the model identify snow in an image it has never seen before?")

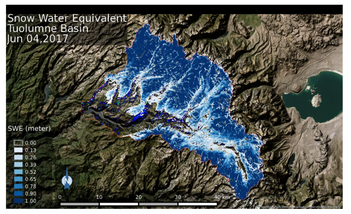


Figure 3: ASO collect over Tuolumne Watershed, California USA.

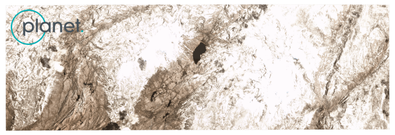


Figure 4: Planet 4-band image over Tuolumne Watershed, California, USA. © 2019 Planet Labs Inc., All Rights Reserved.

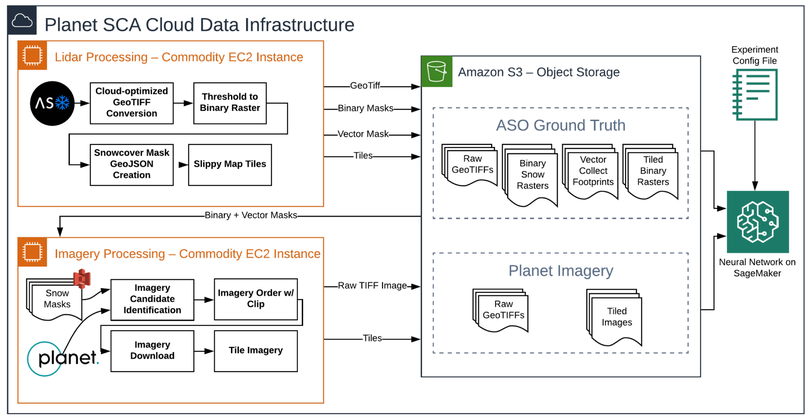


Figure 5: Conceptual schematic of Amazon Web Services (AWS) based cloud workflow architecture, from imagery acquisition and preprocessing to machine learning.

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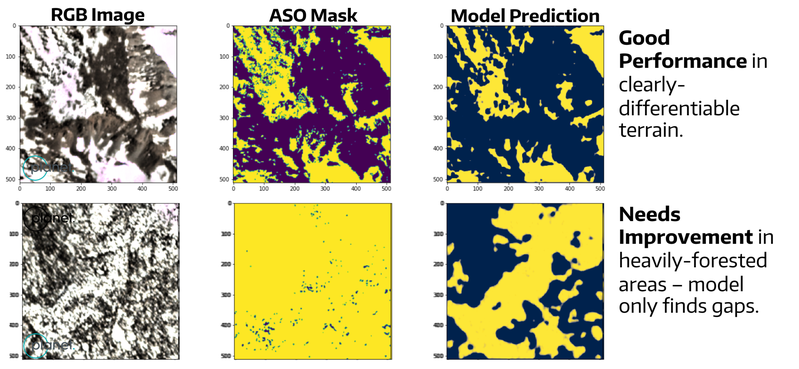
Results: this neural network approach is a powerful technique across several snow classes, and there's room for improvement in heavily forested areas .

code + docs available: https://github.com/acannistra/planet-snowcover

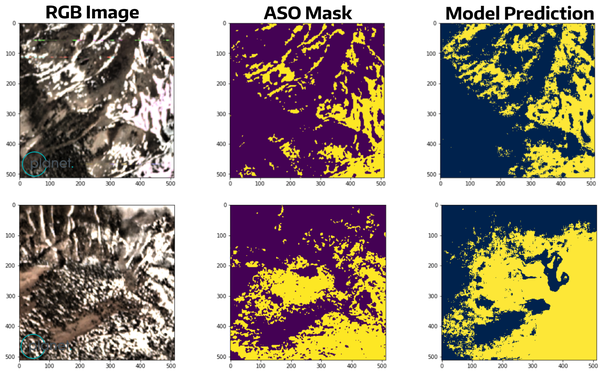
Tuolumne, CA, USA Snow class: Maritime / Alpine



Good Performance in clearly-differentiable terrain.

Needs Improvement in heavily-forested areas – model only finds gaps.

Grand Mesa, CO, USA Snow class: Continental



Good Performance in clearly-differentiable terrain.

Surprisingly decent performance in forested areas.

These results are from a model trained using a network pre-trained with Tuolumne data.

Conclusions & Next Steps

- We can **use these trained CNN models** to build snow masks from Planet imagery.
- This result paves the way for 3m, ~daily snow masks during the ablation period, which is **invaluable data for mountain ecology and hydrology research.**
- Several research questions follow:
  - How does model performance vary across regions and land-cover types?
  - Can models be used in regions other than the one on which they were trained?

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This work is supported by NSF IGERT grant DGE-1258485, the eScience Institute at UW, Planet Labs Research, the ESIP Incubator program, the NASA Terrestrial Hydrology program, and the NSF Graduate Research Fellowship Program.

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