



How does Snowpack Evolution Affect Climate?



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Research Objectives

- Measure fluctuations in surface albedo over time and across New Hampshire using a network of citizen-scientists.
- Evaluate the physical properties that drive changes to albedo and develop predictive albedo relationships with the interest of modelling regional climate effects.

What is Albedo?

- Albedo is the ratio of reflected energy to total incoming solar energy expressed as a unitless number between 0 and 1.
- Light colored surfaces such as new snow have a high albedo (0.8-0.9) while darker surfaces such as forest canopies and pavement have low albedo (0.05-0.15).

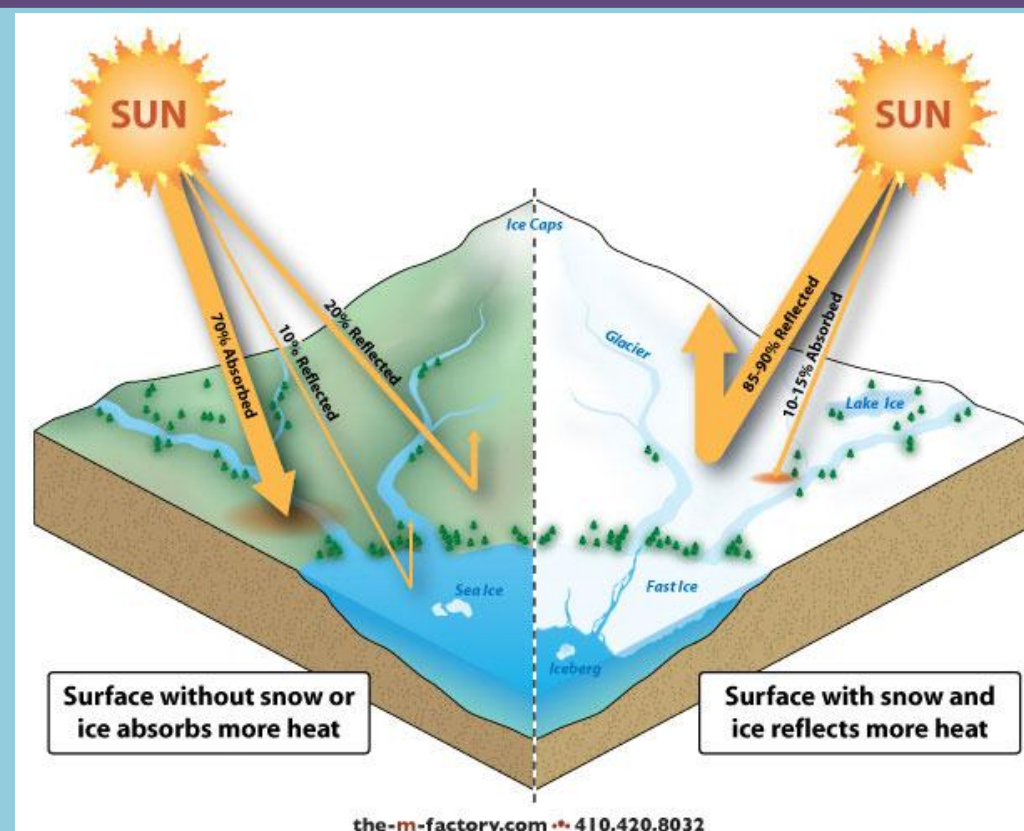


Figure 1: Albedo values differ depending on land surface type.

Data Collection

Community Collaborative of Rain, Hail & Snow (CoCoRaHS) Network

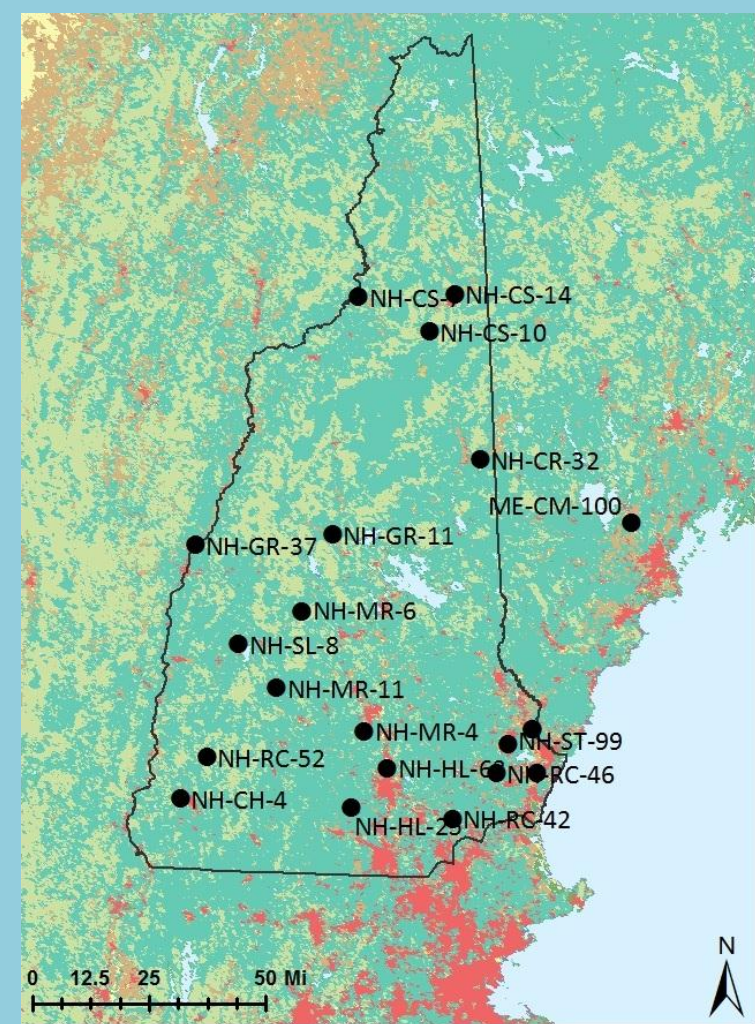


Figure 2 (left): Map showing CoCoRaHS-Albedo sites for past two winters.

Figure 3 (right): "Albedo kit" includes temperature gun, pyranometer, snow tubes, hanging scale, log book and spatula.



- Figures 4 & 5: Measurements are taken of:
1. Albedo
 2. Snow depth
 3. Snow weight
 4. Surface Temperature
 5. Cloud cover/weather observations



Figure 4



Figure 5

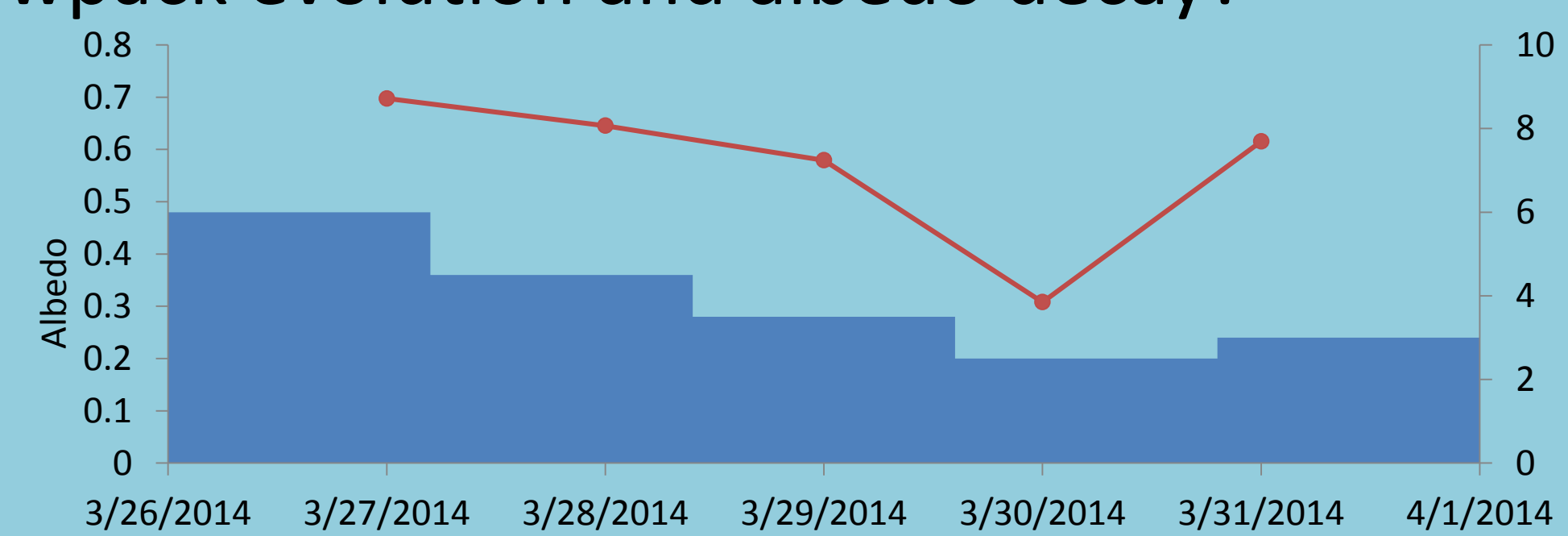
Project Rationale

1. Surface albedo plays an important role in local radiative forcing: *Small changes in albedo are significant for local climates.*
2. During winter, the albedo of snow can range from around 0.3 to above 0.9. This variation has important implications for the timing and pace of snowmelt events.
3. Although physical relationships between snow albedo and snowpack properties are well established, abundant field observations supporting these conclusions are lacking.

Results

What is meant by snowpack evolution and albedo decay?

Figure 6 (right): Following a snowfall event, there is decreasing snow depth (blue) and albedo (red) until subsequent snowfall event.



Snow Albedo vs Age

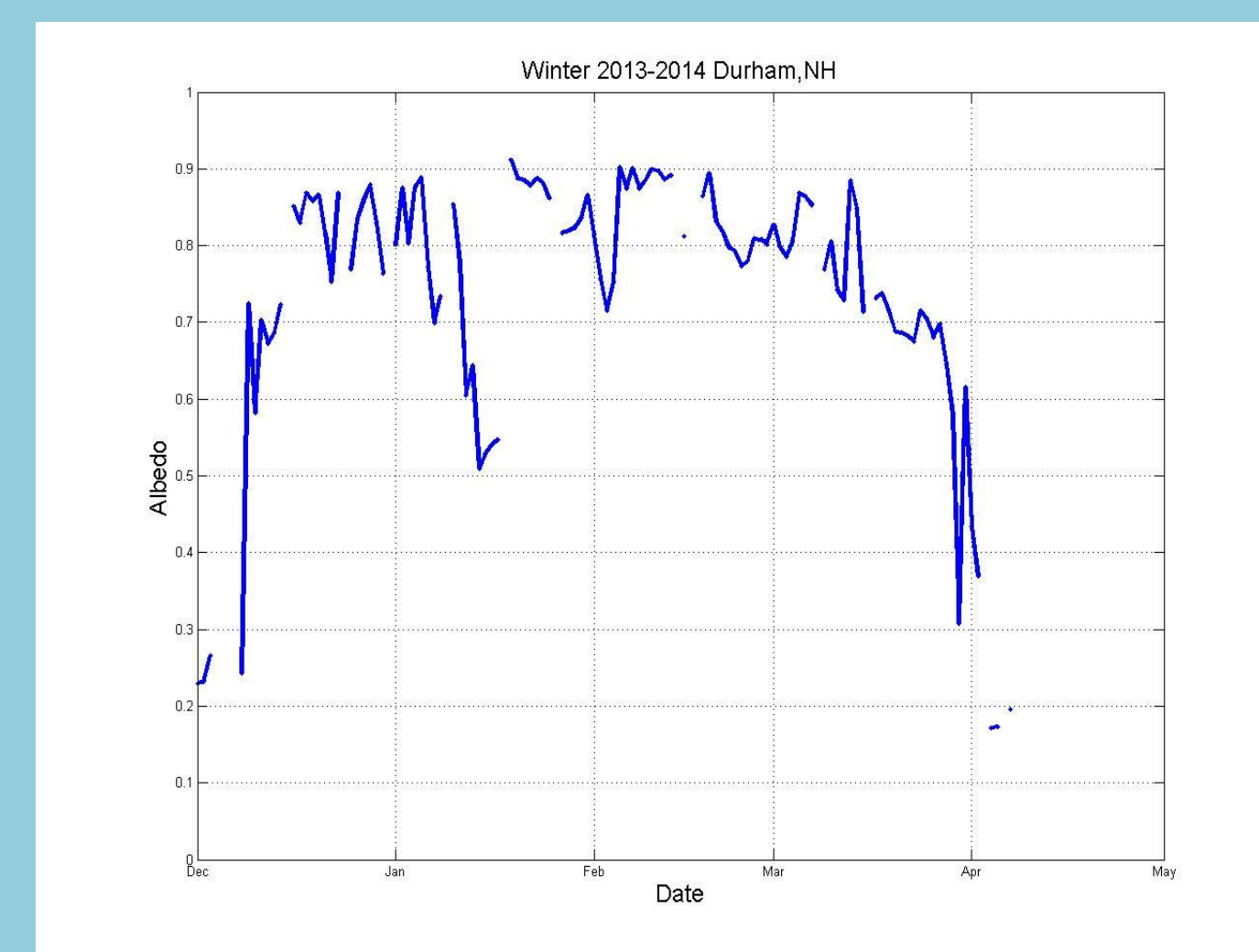


Figure 7: Daily snow albedo observations taken by author during winter 2013-2014 in Durham, NH

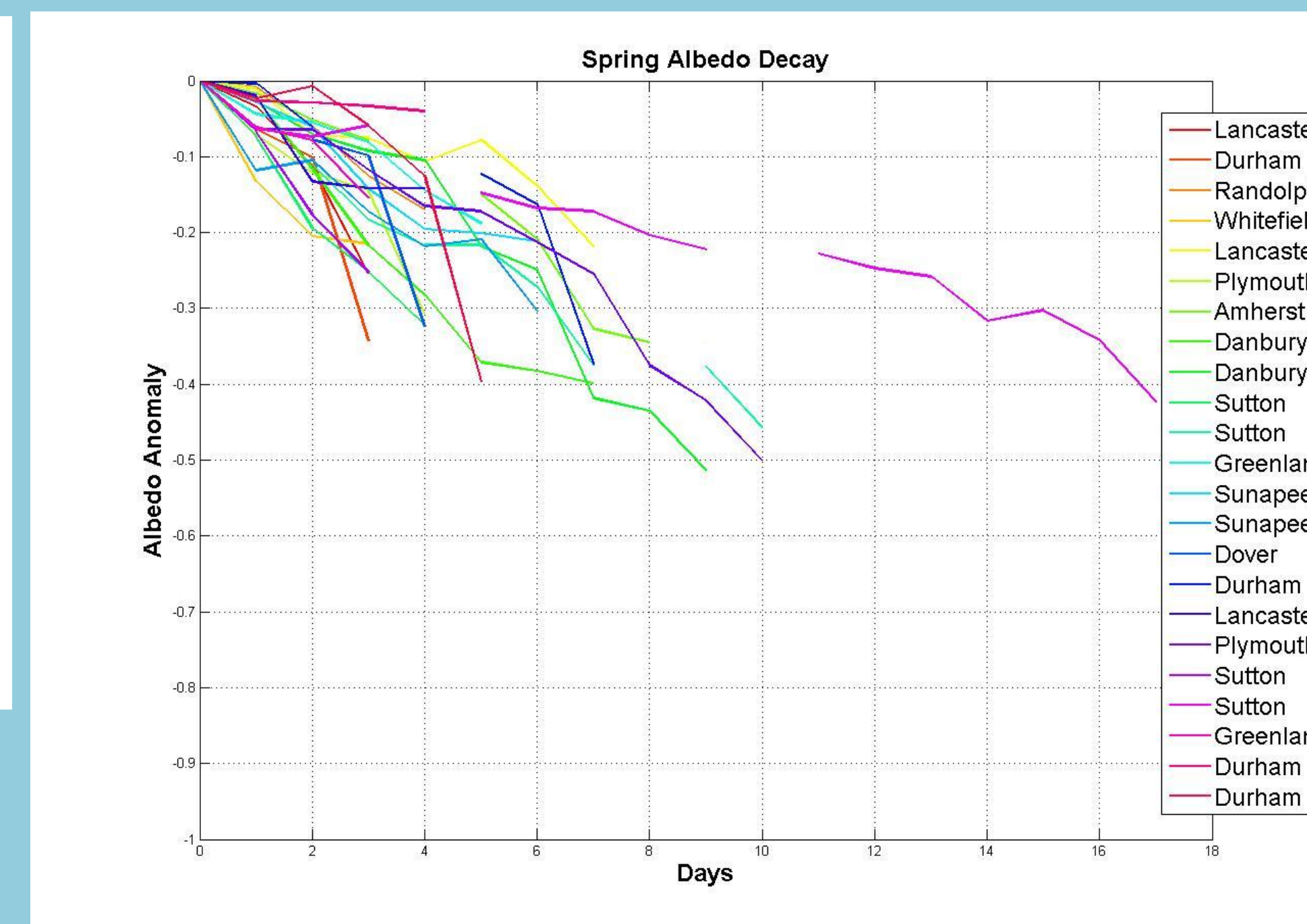


Figure 8 (right): Observations of spring melt conditions from twelve observer stations from winters 2011-2012, 2012-2013 and 2013-2014 display a general decrease in albedo as snow ages. Note the extreme variability between different stations as well as albedo decay rate variability between data from the same stations just at different times (Ex. Durham).

What causes the albedo decay?

The three variables most correlated with albedo during episodes of decline are:

1. Time (days since maximum albedo)
2. Maximum Daily Air Temperature
3. Snow Density

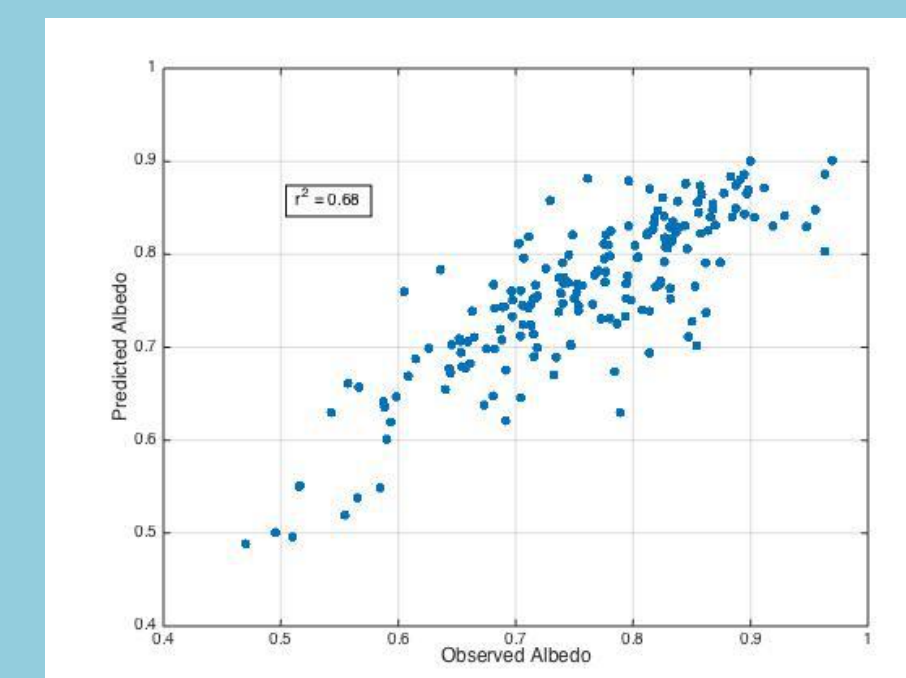


Figure 9: Comparison of albedo values predicted by below equation to observed values. $r^2 = 68$. Note: only for snow depths of 4.5 inches or more.

$$\text{Albedo} = 1 - 0.0017[\text{TMAX}] - 0.023[\text{DAYS}] - 4.06\text{E-}4[\text{Snow Density}] + 2.73\text{E-}7[\text{TMAX}][\text{DAYS}][\text{Snow Density}]$$

Equation 1: Snow albedo decay for optically thick (>4.5in.) snowpacks is best predicted in a multi-linear regression by the variables time, Tmax and snow density.

Summary

- During winters 2011-2012, 2012-2013 and 2013-2014, over a dozen citizen scientists in the CoCoRaHS-Albedo network have collected high-quality, daily snowpack measurements from locations around the state of New Hampshire, making it the largest array of albedo observations that we know of.
- These daily snowpack observations have successfully informed an empirical model that relies on snow age, snow density and maximum daily air temperatures to predict snow albedo decay with almost 70% accuracy.
- Measurements made by CoCoRaHS-Albedo volunteers have empirically demonstrated the importance of snowpack properties in driving changes to surface albedo over time and across New Hampshire.

Future Work

- Extend the predictive equation to include the albedo of shallow snowpacks and determine the degree to which the predictive model may inform the treatment of snow albedo decline in Northeast regional climate models.
- Continue the wintertime measurement efforts of the CoCoRaHS-Albedo network and expand public outreach and educational opportunities within secondary schools in New Hampshire.

References

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