

Cardinal direction and landscape scale color change:

Is there a correlation?

Human Ecology Senior Project 2017-2018

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1. Introduction

For my senior project at College of the Atlantic I knew I wanted to explore plants in a scientific study that was my own from beginning to end. I wanted a field work component where I gathered my data in the wild, not just from organisms controlled experimentally. Preferably it would be local to Mount Desert Island, giving me a chance to further explore the place I had lived for the past four years. A study of autumn leaf color change in Acadia National Park fit all my criteria.

After many students go through traditional beginning biology courses, they are left with a feeling that scientists know everything there is to know about life. A comprehensive introductory biology course includes the history of how we know what we know. Through this history, students are introduced to the ingenuity of simple experiments and questioning the status quo, but it can be difficult for them to find this same ingenuity and questioning in their own work when it seems the answers are already known. Although I have been fortunate to participate in multiple studies during my time as an undergraduate, each of these studies seemed obscure in its origins and application. Some, such as one focused on ecotypic differentiation, were solely botanical in focus. Other studies tackled the greatest issues of the world but addressed these issues through an organism or location so specific that it was difficult to see how the researchers connected a tiny plant and global climate change.

The first time that I confronted an issue both narrow in scope but global in application and still full of pure speculation was at the University of St Andrews. In a lecture on Animal-Plant Interactions, Professor Graeme Ruxton presented leaf coloration as a field of research still mysterious. When I discussed anthocyanins with him, I discovered that the *why* behind autumn

leaf coloration was still a great big unknown. Several leading leaf color change biologists drew attention to the lack of research in a paper summarizing hypotheses on color change: “It is curious how autumn colours, given that they are such an astonishing and well-known phenomenon, have continuously escaped the attention of evolutionary biologists.... [W]e have...an expectation of unexplored and fascinating mysteries to unravel” (Archetti et al. 2009). I could not resist the lure of these mysteries. What triggered leaf color change? Why did some species turn red while others turned purple or yellow? Why was it evolved at least twenty-eight times (Archetti 2009)? Why were so few people studying such a visible phenomenon?

My initial question was a specific hypothesis about leaf color change: If the timing of leaf coloration correlated with cardinal direction, I could suggest possible anthocyanin functions based on which aspect turned first. If south faces changed first, light stress might have the greatest impact. If east faces changed first, temperature stress might have the greatest impact. Of course, since I was only taking observations I could not determine the cause, only make suggestions.

From the start, this project has been mine. I have decided the directions to take, the procedures and methods to use, and arbitrated the excellent but sometimes conflicting advice received. My senior project was as much about uncovering the experience of science as performing the methods. Because of this, my report is divided between a narrative explanation of my project—the human ecology of color change research—and the more technical record of my efforts. The methods are rough and the data lower quality than any ideal because this my very first scientific project to see all the way through the first nebulous stages to the hard fieldwork to grappling with the analyses and presentation. However, as a learning experience it has been highly successful. I have thought on my feet and met the unexpected challenges of fieldwork. My

field season immersed me in a local plant phenomenon that is globally renowned. I grappled with unexpected results and emerged with more questions, few answers, and a thirst to continue working with my data in hopes of understanding it better.

Although I am a student of botany, this project is the culmination of my degree in human ecology. As such, my report is more interdisciplinary than a standard science thesis. The first section is a human-based view of my project that is accessible to a readership wider than simply scientists. Through this narrative essay, I lay out my experience working on the landscape scale portion of my project on color change. The second section is a science-based view of my project that is written for a more technical audience. This section revisits the process outlined in the first section and gives greater detail of my methods and results. The sections complement each other but each can stand alone depending on the reader's intentions.

As part of this final interdisciplinary project, I will exhibit my landscape scale photographs in the Thorndike Library along with a copy of the following essay on the human ecology of color change.

2. The Human Ecology of Color Change

The trail was crisp and golden as I flew down the mountain, feet barely touching granite steps that I took two at a time. Beech trees stretched above me, a canopy of leaves that colored the air as I continued running into the darker, coniferous depths of the mountain. A couple hours and a rapid bike ride later, I wedged my hands between steep chunks of granite, finding slippery footholds between fallen leaves until I pulled myself on top of Connors Nubble where the mountains of Acadia stretched around me in a riot color. Black huckleberry created puddles of bright red that marked depressions in the rock. Eagle Lake reflected the colors back in rippling waves as I carefully positioned myself and raised my camera towards Cadillac Mountain. A pause, a sip of water, and I was away again, scrambling down the rocks to my bike and onward to the next mountain. My heart was pounding, my lungs ached, but never had I felt more alive than chasing peak to peak to photograph neighboring mountains to better understand the colors around me.

Every year, the trees in New England exchange their leaves of decorous deep green for vibrant reds, oranges, yellows, and purples before they shrivel to brown and fall off for the winter. Different chemicals are responsible for different colors. Yellows and oranges are carotenoids, present throughout the year and revealed as the trees disassemble their chlorophyll for winter storage. Reds and purples are created by anthocyanins, a molecule more familiar to us in fruits such as blueberries and wine grapes that stain our fingers red. Anthocyanins give red maple leaves their colors in the fall as the trees create the molecules from scratch. These anthocyanins were why I ran relentlessly onward, trying to capture the transition from green to red to brown. Scientists know that anthocyanins are antioxidants, molecules that protect living tissue against

damage from reactive oxygen molecules. They are also pigments that block light from the photosynthetic organs of a leaf—one way that they can prevent damage from oxygen molecules excited by light.

We know that leaves of some tree species turn red from anthocyanins in the fall. We know that anthocyanins protect living tissue from destructive oxygen. What we don't know is just about everything in between. What triggers plants to produce anthocyanins? Why do only some plants produce them in the fall? How did this color change evolve? Do anthocyanins protect against light damage? Temperature damage? I thought I might be able to find out at least a little bit more about this visible but little researched phenomenon.

Mount Desert Island has a unique geography. Its mountains were carved by glaciers retreating to the north, leaving each mountain with a similar shape. The north slope is long, the south slope short, and the east and west slopes steep. Each mountain can be climbed in no more than an hour if you run a bit. And each mountain in Acadia National Park has fairly similar vegetation that mixes conifers such as white pines and spruces with deciduous trees of yellows and oranges (beeches and aspen), reds (red maple), and browns (red oak). Because it is a national park, there are good trails to the peaks of each mountain. I just had to climb them each and take a photograph of a neighboring mountain from the exact same point as often as possible.

When I set out to learn more about leaf color change, I never thought athletics would play such a big role in my project. By the time the season ended, I was climbing eight mountains and visiting an additional four lakes and roads on foot and by bike every twelve days. I reached three more lakes by car. Every Wednesday, I joined the freshman class on *Osprey*, the college's forty-foot Wesmac boat, for a tour of Frenchman Bay to photograph the Porcupine Islands from every angle and Mount Desert Island's mountains from the north and the east. Along the way, I

learned just how many mountains I could—or could not—climb in a day, the easiest carriage roads for biking, the slipperiness of granite and lichen after rain, how to enjoy every available moment of fall out of doors but also immense thankfulness when it was over. What I did not learn was why leaves change color or even what might trigger them to change color.

If trees turn color to protect against sunlight damage or low temperatures in the morning, they should be affected by what direction of the mountain they are on. Sunlight is particularly strong on southern slopes. Eastern slopes will receive the most light during low dawn temperatures. By organizing my photographs by cardinal direction and analyzing how early in the season each direction turned red, I thought I might have a hint as to *why* they turned red. Instead, I found that the least expected direction—west—was significantly different from the other three. On the western faces, it appeared that leaves started out red and maintained that redness throughout the season. Everywhere else the leaves started out green and became red over time, as anyone watching fall color change would predict. An important distinction here is that the leaves *looked* more red at the end of the season than the beginning on all four slopes. The computer analysis was the only indication that something else might be going on.

After my strenuous fall chasing color changing mountain sides, I sat at my computer during the cold snows of winter trying to understand the resulting figures. The beginning of a natural history story was in my hands, if only I could untangle the plot. After many months of thought, I'm pretty sure I hold a few key chapters and a number of extraneous paragraphs in the story of leaf color change. I have a few leads I would follow given more time.

The first question to ask when presented with any scientific data is “is this a real biological phenomenon?” Are the numbers an artifact of the act of observing or do they reflect what is observed in a natural setting? My instinct is that these data reflect a “real” phenomenon,

although it may be a very localized one. If I were to verify this, I would repeat my observations several years in a row. To better understand what may be causing this phenomenon, I would need to perform experiments on maple trees. If I brought young trees into a greenhouse environment, I could vary the available light, water, and nutrients to see which brought on leaf reddening. If none of my hypothesized environmental factors made a difference, I would look to see what effects the surrounding plant and fungal communities might have.

For now, however, I must be content with holding the first few pages of this natural history story. My models suggest that hydrology and plant distribution play the biggest role in this early reddening of western faces. Weather may play a big role as well—the fall that I observed had the earliest but slowest color change I have seen during my four years in Maine. It was also the warmest.

Although I do not have answers, I do have experiences. Fall leaf color change is a phenomenon best experienced outside immersed in trails that vary scenic vistas with forested paths. Other fall color change researchers use automated cameras, and, going forward, I would too. But by having my feet on the trails and by watching the color change happen around me, I have gained valuable visceral knowledge that cannot be obtained any way other than experience. My answers are unclear but I hope I have shared some of my excitement with this unknown. The trees change to the most unlikely fiery shades every year, drawing crowds from around the world to watch organisms often lumped together as “landscape,” and no one knows how or why. Someday we shall know more but for now, how amazing is that?

3. The Science of Color Change

Acadia National Park is known for its spectacular autumn colors—every year, the forests that burned in 1947 and regrew full of maple, oak, beech, and birch change from glossy green to a riot of red, orange, and yellow spattered with late green and early brown. The nights are brisk and the days are warm from summer air laced with crisp hints of winter to come. Fall term at College of the Atlantic has been my favorite term for all four years because I cannot resist such impressive displays of botanical beauty.

It is surprising how little we know about a phenomenon as visible and admired as New England's autumn leaf color change. We know the how, but not the why—yellows and oranges are revealed by chlorophyll breakdown and reds and purples are created when plants produce anthocyanins. Anthocyanins are not an intermediate molecule in chlorophyll breakdown, so plants produce them *de novo*. Why are some plants adapted to produce these metabolically expensive molecules? This was the ambitious question I decided to tackle in my senior project.

3.1 Observation of mountains in Acadia National Park

Landscape scale approach

3.1.a Introduction

Because of the declination of the sun, plants on the south face of a mountain receive more direct light than the north face. Similarly, plants on the east face receive direct light earlier in the day than plants on the west face. I hypothesized that this direct light difference would affect when trees changed color. If anthocyanins protect against the damage caused by direct light when a plant is vulnerable from degrading chlorophyll, the amount of direct light or the temperature at the time of this light could affect the color change.

Red-osier dogwood (*Cornus stolonifera*) has leaves that turn either red or yellow depending on lighting conditions, making it an excellent study species for these effects. Feild et al. (2001) experimented with the effects of lighting conditions on yellow-senescing and red-senescing leaves and found that the latter were better adapted to full light during senescence. Anthocyanin production was facultative, and most often in fully lit conditions.

Michelson et al. (2017) found that Eurasian aspen (*Populus tremula*) color change was not triggered by photoperiod. They suggested that the speed of color change was primarily determined by ambient temperature, although the exact trigger is unknown. Anthocyanins have been shown to protect against oxidative damage, such as the damage caused at low temperatures or under extreme light stress. Trees on mountains are subjected to differential stress depending on which slope they are on. For example, trees on the eastern face of a mountain are subjected to higher light conditions during cold morning temperatures than trees on the western face.

3.1.b Materials and Methods

Mount Desert Island's topography was shaped by receding glaciers, leaving mountains with a distinct north-south orientation and a characteristic profile called *roche montonnée*. The

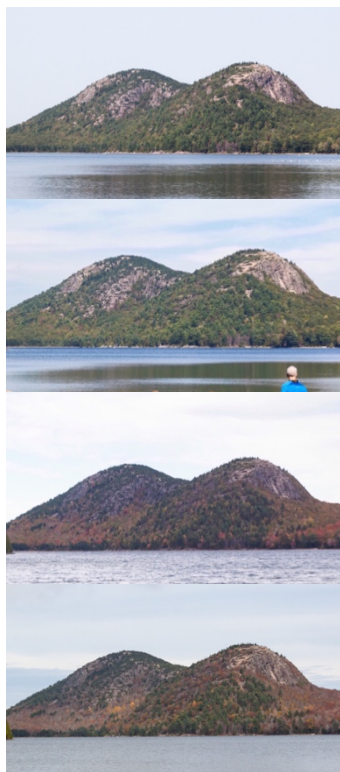


Figure 1 Example of repeat photography.

Subjects are the south faces of the Bubbles from Jordan Pond taken on 16 Sep, 27 Sep, 16 Oct, and 29 Oct 2017. Images have been edited for clarity.

mountains on the east half of MDI are within Acadia National Park (ANP) and are undeveloped. The Porcupine Islands in Frenchman Bay are also *roche montonnée* and managed by ANP.

I took 155 photographs of 16 mountains and 4 islands between 16 September and 13 November 2017 for a total of 31 mountain faces and 4 island faces (figure 1, appendices A and B). I used an EOS Rebel T1i (Canon, Tokyo) with an 18-55mm kit lens. To decide mountain face direction, I electronically measured the direction of each photograph with the Set Compass online interface (Barcelona Field Studies Centre) using a topographical map with trail marks. The readings were transformed to reflect face instead of direction (e.g. a photograph taken pointing 0° (north) was transformed to represent the face of the mountain at 180° (south)) and assigned a cardinal direction based on their value (north: 315°-45°, east: 45°-135°, south: 135°-225°, west: 225°-315°). There were 9 north aspects, 7 east aspects, 10 south aspects, and 11 west aspects.

I used Adobe Lightroom Classic CC to remove distortion and Adobe Photoshop CC to align and calibrate images using the Color Match tool with selection. I processed the resulting JPEGs in ImageJ using the Color Histogram plugin (Schindelin et al. 2015) and transcribed the

results in Microsoft Excel. Conversion between RAW and JPEG has been shown to not lose any phenologically relevant data (Sonnentag et al. 2012). All analyses were performed in R code (R core team 2017; Appendix C). Data and analyses are available at github.com/hrdawson/leafcolor and in Appendix D.

3.1.c Results

Change in redness varied significantly between the four faces when controlling for day of year (mixed effect ANOVA, $P = 0.027$). Focal mountain was treated as a random effect. Figure 2 shows that the west face is nearly horizontal while the north, south, and east faces steadily gain in redness. The cause of this horizontal slope is demonstrated in figure 3: redness in the west is consistently higher throughout the season while the other faces have an intersection where redness surpasses greenness. This intersection is earliest in the east (day 273.85) and south (day 281.03) with north much later (day 292.89). Intersections are not significantly different (chi-square goodness-of-fit test, $\chi^2 = 0.42$, $df = 1$, $n = 3$, $P > 0.05$).

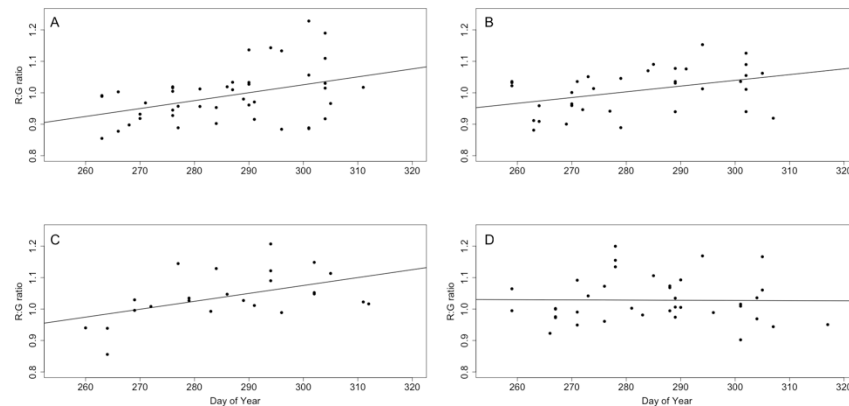


Figure 2 Redness compared to greenness for each direction during fall 2017

A: north, B: south, C: east, D: west. Day of year spans 259 (16 September) to 317 (13 November). Each point represents the red:green ratio of a single photograph.

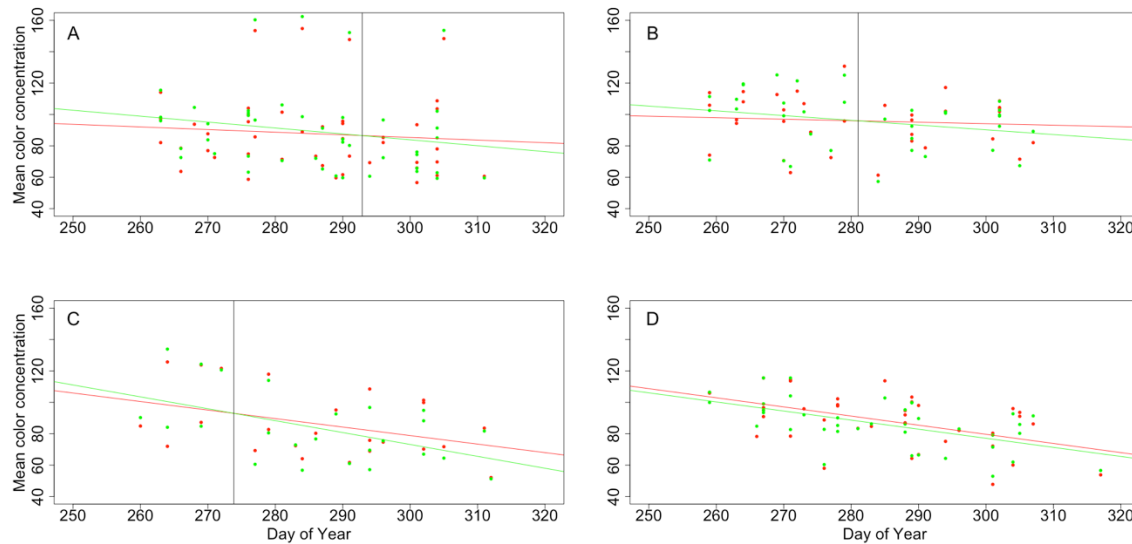


Figure 3 Concentration of redness and greenness for each direction during fall 2017

A: north, B: south, C: east, D: west. Data points represent red or green measurement of mean intensity from one photograph. Slopes intersect at day 292.89 (north), day 281.03 (south), and day 273.85 (east). West slopes do not intersect (red slope: -0.583, green slope: -0.580).

I hypothesized three ways that western faces may be different from other faces: hydrology, water exposure, and vegetation. Hydrology was measured using a pixel-flow model. There was a significant difference between the pixel-flow count of each direction (chi-squared goodness-of-fit test, $\chi^2 = 33.46$, $df = 3$, $n = 4$, $P < 0.0001$). West (125 pixels) and north (164 pixels) faces received less hypothetical water than expected under a random distribution (181 pixels). East (211 pixels) and south (223 pixels) faces received greater hypothetical water than expected. To measure water exposure, I classified each face according to the quantity of water it was exposed to (“full,” “partial,” and “none”). There was no significant effect of water exposure on red:green ratio when controlling for the fixed effect of day of year and random effect of focal mountain (ANCOVA, $P = 0.427$). I used the layer created by Lubinski *et al.* (2003) in ArcPro (ESRI, Redlands, CA) to measure area of evergreen, deciduous, and mixed vegetation coverage

of each face in acres (figure 4, Appendix E). There was a significant difference between the vegetation distribution on each mountain face (chi-squared contingency test, $\chi^2 = 778.16$, $df = 6$, $n = 35$, $P < 0.0001$).

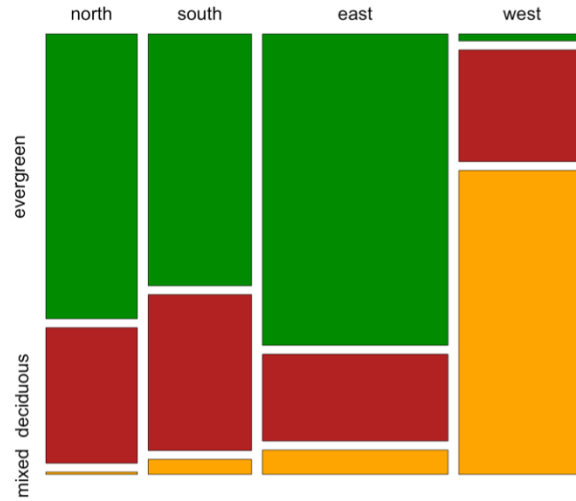


Figure 4 Habitat area by mountain face.

Band width represents proportion of the total. Colors represent vegetation type: evergreen (green), deciduous (red), and mixed (yellow). Calculations were made in ArcPro using the MDI vegetation layer created by Lubinski *et al.* (2003).

Dawn temperature was a significant predictor of change in redness (Kendall-Theil Sen nonparametric linear regression, $n = 30$, $P < 0.0001$) (figure 5). Change in redness was measured as $dR:G = \frac{(Red_2 - Red_1) / (Green_2 - Green_1)}{DoY_2 - DoY_1}$. To ensure independence of all observations, I selected a single value for $dR:G$ per slope where $DoY_2 - DoY_1$ was not greater than 12 (the median number of days between observations). When more than one observation qualified, I used a random number generator to select between them.

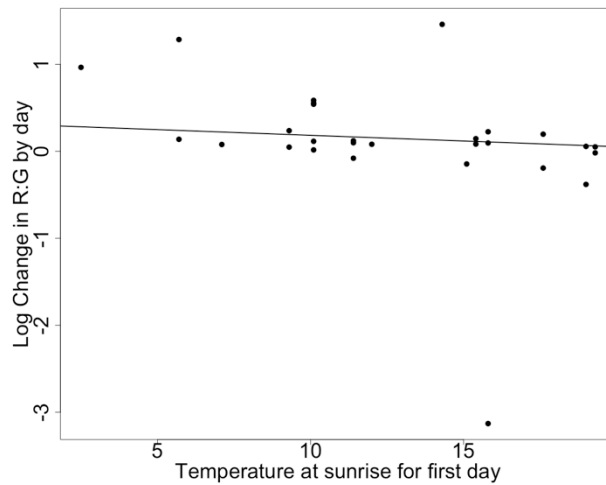


Figure 5 Correlation of change in red:green ratio compared to sunrise temperature.

Data points were calculated from change in ratio over a period of days no greater than twelve days. Sunrise temperature was measured on the first day of the interval.

3.1.d Discussion

Effect of temperature

The early reddening of eastern faces and the correlation between change in redness and temperature suggest that early morning temperature may contribute to the timing of autumn leaf coloration. Although senescence is not triggered by temperature, the overall warmth of autumn affects how long leaves stay green (Michelson et al. 2017). Plants on eastern faces must cope with both low temperatures and early light, a combination which leaves them vulnerable to damage (Lukatkin et al. 2012), especially as they break down and re-assimilate nutrients. Plants on north mountain faces are the most protected from light damage, although they also do not receive as much solar radiation and the associated temperature increase. Northern redness is greater than

greenness two to three weeks after southern and eastern faces reach the same point, suggesting that plants on the north face are less stressed by light than on the other faces.

At lower temperatures, the enzymes in the Calvin cycle (a light-independent reaction in photosynthesis) are sluggish, a fact which leads to low carbon fixation rates and the accumulation of NADPH₂ (Holaday et al. 1992). The lack of available NADP combined with the onset of light reactions when the plant receives solar light at sunrise may in turn create reactive oxygen species (ROS; Alam and Jacob 2002). The ROS will damage the cell structures if not removed. Anthocyanins have known antioxidant properties (Murakami et al. 2008, Hoch et al 2003) that help with ROS, in addition to the fact that they are pigments and physically shield tissues from light. It is worth noting, however, that anthocyanins are not stored in chloroplasts, limiting their ability to control oxidative stress (Hoch et al 2001). We should not immediately reject the possibility that anthocyanins protect against oxidative stress while leaves are reabsorbing nutrients but this location suggests that their role in fall leaf physiology is much more complex than a simple antioxidant.

Effect of direction

Despite the potential differences in light and temperature exposure, north, south, and east faces changed at a consistent rate overall (Figure 2). This may indicate that the effects of direction on *rouche montounée* are not significant enough to study how exposure affects anthocyanin production. However, there is a difference when photographed faces changed from computer-detected green to red (Figure 3). The data are too coarse to draw significant conclusions but suggest that further studies on the different exposures may be worth pursuing.

How does light and temperature vary between mountains and between mountain faces? More precise data answering this question could help future studies using a similar design.

The consistent redness of western faces remains puzzling. To the eye, the photographs appear to become significantly redder as the season progresses (i.e. there is a clear difference between “summer,” “fall,” and “winter” photographs of the western faces; see Appendix B). Color intensity overall recedes (approaches black) as the season progresses for both red and green bands. In north, south, and east faces, the slope of greenness recedes more rapidly than the slope of redness because green leaves are turning to red before falling, or turning to grey from the perspective of the camera. However, the west face has a nearly parallel slope between redness and greenness and reached greater redness than greenness sometime earlier in the season.

Water availability of the western faces included in this study was significantly less than the east and south faces in a theoretical hydrology model; however, further research is needed to support this hypothesis. What groundwater is available? How accurate is a hydrology model using Flow Accumulation models? What field data could be used to back up the theoretical data?

When I isolated data from the island faces, all of which were on the west, the results are more similar to MDI non-west faces than to MDI west faces. One common factor is water exposure— island faces are exposed to ocean, as are many of the north, south, and east faces. However, water exposure was not significant in statistical tests. Even if not deemed significant in statistics, this could have a biological—if slight—effect. Future research could include expanding study faces to mountains on the west side of MDI. This would control for any possible effects from water exposure by including an even number of mountain faces exposed to water.

West faces have significantly different vegetation—there is much less evergreen canopy and much more “mixed” canopy (figure 4, Appendix E). Although this does not present as clear

and easy an answer as an emphasis on evergreen or deciduous trees would, it does present a possible solution to the difference of western faces. First, why is there so little evergreen canopy on west faces? Could this be the source of the low green intensities seen on these faces? Second, how does the ecology of a mixed canopy affect leaf color change? This second question returns to the ultimate question of how and when leaves change color. Michelson et al. (2017) determined that quaking aspen (*Populus tremuloides*) must have a light-based primary signal to initiate leaf senescence. This could be either a second critical photoperiod (the first being when bud set begins) but there are a number of other potential light-based signals. Perhaps the light available in the mixed canopy is less consistent or triggers anthocyanin production earlier than the light available in a predominantly deciduous canopy.

A final possibility is that the west faces changed to a greater red intensity before my data collection began. Maples began changing color as early as 12 August 2017 (S. Morse pers. comm.) but I did not gather any data until 16 September 2017. The temperatures were considered unusually warm for Bar Harbor during that fall and the leaves appeared to change color at a slower rate than previous years. If there is a point of peak color change with a steady decline after this point, the west faces would appear to change hardly at all during my observation period. As mentioned above, the enzymes in the Calvin cycle are temperature sensitive. High temperatures can also limit their activity and it is not uncommon for plants to experience high heat and high light simultaneously. This can have both a positive and negative effect on damage to photosynthetic systems (Allakhverdiev et al. 2008); however, it is likely that further protection from anthocyanins would be beneficial. Excess light can result in a greater concentration of ROS and anthocyanins could perform the same dual role of sunshade and ROS controllers in heat as in low temperatures.

4. Conclusions and Future Directions

Fall leaf color change as caused by anthocyanin production is likely linked to light exposure and temperature change. More data is needed to draw significant conclusions but both my experimental and my observational studies supported this hypothesis. My study supports the hypothesis that anthocyanin production may be linked to an interaction between light and temperature as temperature at dawn was significantly correlated with the change in redness in leaves. The eastern faces also changed to a greater redness than greenness earlier than the other faces, with the exception of the western faces. Western faces changed at a significantly different rate which may be correlated with other factors including hydrology or vegetation.

Some simple questions persist that could be answered with little additional research. Further examination of western mountain faces is by no means exhausted and could be pursued without even setting foot on the mountains. The next step would be to revisit Lubinski et al. (2003) and create as fine-grained a map as possible to answer what “mixed vegetation” truly is. Another map to create using the same layer would be one of areas with *Acer rubrum* or *Gaylussacia baccata* to see if these are differently distributed across the mountain faces. The data of mean red, green, and blue intensities for each direction and each mountain should be further scrutinized for patterns. How do these colors change over time in comparison to each other? Are there any questions that could be answered with mean blueness?

Although my results present no definitive answers, they provide the backbone of a story: something unexpected is occurring in autumn leaf color change. My allotted time for this project has closed but by no means do I feel it is finished. The simplest way of continuing this research is to repeat the mountain observations for another season (or three). The weather during fall 2017

was unusual because the season began early and went late with unseasonably warm temperatures throughout. My observations may be an artifact of this weather and another year's data will add needed detail. Another avenue to explore would be expanding the study sites. Do the mountains on the western half of MDI exhibit a similar pattern? What about *rouche montonnée* in other locations? These observations could draw on PhenoCam networks that are increasingly available.

Both of these options combined with experimentation would enable me to further unravel the mystery of fall leaf color change. I would enjoy the opportunity to pair a greenhouse experiment with similar observational data so that I could manipulate the light, water, and nutrient availability of *Acer rubrum* young trees while gathering field data as well. I would also design an experiment girdling *A. rubrum* to further explore the results of Murakami et al. (2008). They focused primarily on southern branches without exploring the effect of cardinal direction on individual trees. A related study would include exploring the effect of temperature fluctuations on anthocyanin production and sugar content in leaves on girdled branches.

6. Acknowledgements

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8. About the researcher



Photo by Gemma Venuti '18

Hilary Rose Dawson came to College of the Atlantic in 2014 intent on pursuing teacher certification. She quickly fell in love with the field sciences, particularly botany and ecology. During her time at COA, she has participated in research on ecotypic differentiation under Dr. Nishanta Rajakaruna (COA) and plant phenology under Dr. Caitlin McDonough MacKenzie (Boston University). In summer 2016, she interned under Drs. Jill Anderson and Susana Wadgyamar (University of Georgia, Athens) at Rocky Mountain Biological Laboratory working on the effects of climate change on genetic adaptation in plants. As part of this internship, she conducted an independent project in plant communities across elevations. In winter 2017, she studied at the University of St. Andrews, Scotland, where she first formulated the hypotheses for this thesis.

Appendix A: Field Guide to Mountain Faces photographed



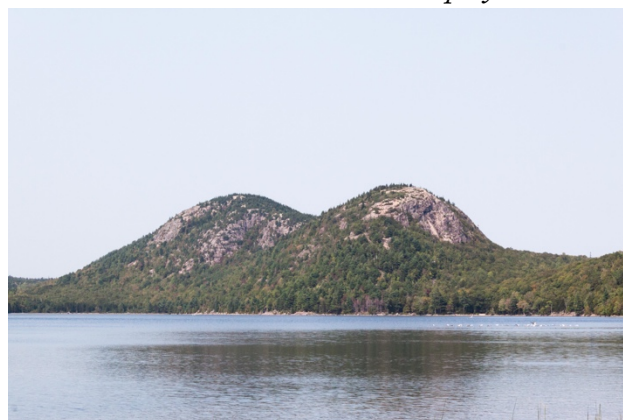
Bald Island west from Bar Harbor



The Beehive south from *Osprey*



Bald Peak south from Lower Hadlock Pond



North and South Bubble from Jordan Pond



Bar Island west from COA



Cadillac east from Dorr



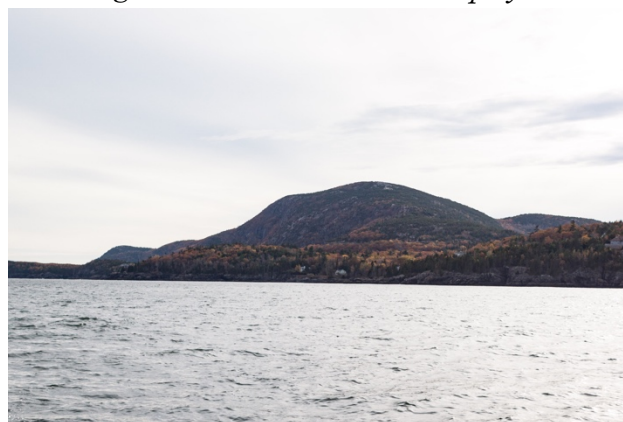
Cadillac west from Connors Nubble



Huguenot Head north from *Osprey*



Cedar Swamp Mountain west from Lower
Hadlock Pond



Champlain north from *Osprey*



Champlain east from Schooner Head Road



Champlain west from Dorr



Connors Nubble south from Pemetie



Dorr south from Park Loop Road at Otter Cliffs



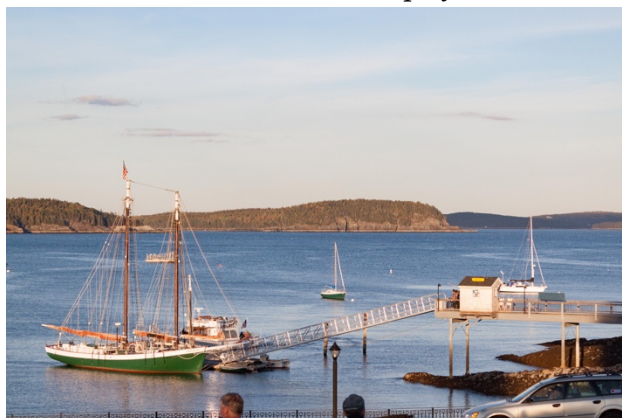
Dorr east from Huguenot Head



Gorham east from *Osprey*



Dorr north from Park Loop Road intersection with Great Meadow Drive



Long Island west from Bar Harbor



McFarland north from the carriage road at
Breakneck Pond



North Bubble south from Pemetic



McFarland south from Pemetic



North Bubble north from Connors Nubble



Connors Nubble north from Eagle Lake



North Bubble west from Penobscot



Pemetic north from Eagle Lake



Penobscot north from Sargent



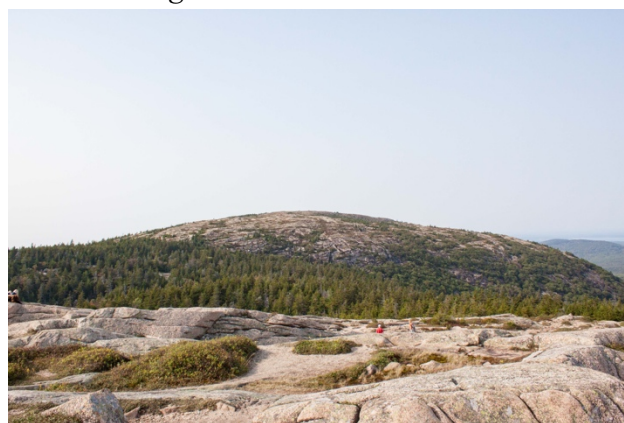
Pemetic west from Penobscot



Sargent east from Pemetic



Penobscot east from Pemetic



Sargent south from Penobscot



South Bubble south from Pemetic



Sheep Island west from Bar Harbor



South Bubble north from North Bubble



White Cap west from Connors Nubble



South Bubble west from Penobscot

Appendix B: Leaf color change over time

In this appendix, two examples of mountain photographs are given for each cardinal direction. The numbers on each photograph indicate the day of year the photograph was taken. All photographs have been edited for printing.

West

Sheep Island
from Bar Harbor



North Bubble
from Penobscot



East

Champlain
from Schoonerhead Road



Sargent
from Pemetic



South

Connors Nubble
from Pemetic



Sargent
from Penobscot



North

Dorr
from Park Loop Road



Penobscot
from Sargent



Appendix C: R Code

Introduction

All of my analyses were performed in RStudio using R code. To replicate my results, you will need everything listed in section 1. As of Spring 2018, all files and code were available through GitHub at [github.com/hrdawson/leafcolor]. An additional copy of my leaf color data will be available in PDF format through the NPS IRMA database. Note that code is organized by function: set up and data input (section 1), tests and analyses (section 2), and visualizations (section 3). To fully understand an analysis, you may have to reference more than one section.

Section 1: Set up

1.1 Necessary Packages

The following packages should be loaded for this code to run.

- *car*
- *lme4*
- *lmerTest*
- *mblm*

1.2 Data files

Place the following files in one folder for easy access. A brief description of each file follows its name. All files have headers.

- *islands.csv* This file contains data for the island faces only.
- *islandsonwest.csv* This file contains data for the western faces only.
- *leafcolor.csv* This file contains the bulk of the data.
- *ozone.csv* This file contains data on ozone pollution.

1.3 Objects: data loading

Create the following objects by loading the files in 1.2.

- *islands*
- *islandsonwest*
- *leafcolor*
- *ozone*

1.4 Objects: data modification

Modify the data using this script to update the files in 1.3.

Bind in new and revised data

```
leafcolor$mtn.n.aspect = paste(leafcolor$focalmountain, leafcolor$corr.aspect, sep = "-")
leafcolor$ccratio = leafcolor$rcc/leafcolor$gcc
leafcolor$water.exp.test = "none"
leafcolor$water.exp.test[leafcolor$water.exposure=="partial ocean"|leafcolor$water.exposure=="partial lake"]="partial"
leafcolor$water.exp.test[leafcolor$water.exposure=="full ocean"|leafcolor$water.exposure=="full lake"]="full"
```

Create vegetation type data.

```
vegtype = as.data.frame(matrix(c(157.09, 74.67, 1.33, 157.09, 97.18, 9.39, 348.91, 97.30, 27.42, 5.45, 85.54, 232.88), byrow = TRUE, nrow = 4)); dimnames(vegtype) = list(c("north", "south", "east", "west"), c("evergreen", "deciduous", "mixed"))
mosaicplot(vegtype, main = "")
roundveg = as.data.frame(matrix(c(157, 75, 1, 157, 97, 9, 349, 97, 27, 5, 85, 233), byrow = TRUE, nrow = 4)); dimnames(roundveg) = list(c("north", "south", "east", "west"), c("evergreen", "deciduous", "mixed"))
vegetable = vegtype
vegetable$total = vegetable$evergreen+vegetable$deciduous+vegetable$mixed
vegetable$evergreen.per = vegetable$evergreen/vegetable$total
vegetable$deciduous.per = vegetable$deciduous/vegetable$total
vegetable$mixed.per = vegetable$mixed/vegetable$total
```

Create hydrology data.

```
hydrotable = as.data.frame(matrix(c(0, 1202841, 211.17, 11031.86, 0, 2638496, 164.46, 13306.55, 0, 1324894, 223.09, 12112.36, 0, 2631889, 125.31, 14068.30), byrow = TRUE, nrow = 4, dimnames = list(c("east", "north", "south", "west"))
```

```
, c("min", "max", "mean", "sd"))))
hydrotable$direction = c("east", "north", "south", "west")'
```

1.5 Objects: subsetting

Create the following objects by subsetting the data files in 1.2 and 1.3.

```
east = as.data.frame(subset(leafcolor, corr.aspect=="East"))
west = subset(leafcolor, corr.aspect=="West")
north = subset(leafcolor, corr.aspect=="North")
south = subset(leafcolor, corr.aspect=="South")
doy.interval = subset(leafcolor, least.interval == "x")
ran.interval = subset(leafcolor, ran.interval == "x")
west.noislands = subset(west, focalmountain!="Island, Bar"&focalmountain!="Island, Bald"&focalmountain!="Island, Long"&focalmountain!="Island, Sheep")
west.islands = subset(islands, corr.aspect=="West")
noislands = subset(leafcolor, focalmountain!="Island, Bar"&focalmountain!="Island, Bald"&focalmountain!="Island, Long"&focalmountain!="Island, Sheep")
full.lake = subset(leafcolor, water.exposure=="full lake")
part.lake = subset(leafcolor, water.exposure=="partial lake")
no.water = subset(leafcolor, water.exposure=="none")
full.ocean = subset(leafcolor, water.exposure=="full ocean")
part.ocean = subset(leafcolor, water.exposure=="partial ocean")
aspectcount = as.data.frame(table(leafcolor$mtn.n.aspect))
print = subset(aspectcount, aspectcount$Freq>=4)
```

Section 2: Tests and Analyses

2.1 Is the timing of R:G ratio change correlated with mountain face direction?

Response variable: R:G ratio (fixed) Explanatory variables: day of year (doy) (fixed), mountain face direction (random) Test: Mixed-Effect ANOVA

Create model that reflects fixed and random effects

```
leveneTest(leafcolor$rgratio, leafcolor$corr.aspect)
aspectmodel=lmer(rgratio~doy*corr.aspect+(1|focalmountain), data=leafcolor, R
EML = FALSE)
summary(aspectmodel)
```

Run ANCOVA

```
aspect.test = Anova(aspectmodel, type="II")
aspect.test
```

Post hoc

```
lsmeans(aspectmodel, list(pairwise~corr.aspect), adjust = "Tukey")
lsmeansLT(aspectmodel, test.offs="corr.aspect", adjust = "Tukey")
```

Plot for the ANOVA of R:G given aspect and doy

```
par(mfrow=c(1,1), ps = 20,mar=c(5,6,4,1)+.1)
plot(rgratio~doy, data=north, main = "Plot of R:G and DoY", pch=16, xlab = "D
ay of Year", ylab = "R:G ratio", cex = 1.2, cex.axis = 1.2, cex.lab = 1.2)
points(rgratio~doy, data = east, col = "green4", pch=19, cex = 1.2); points(r
gratio~doy, data=west, col="orange",pch=17, cex = 1.2);points(rgratio~doy, da
ta = south, col="purple",pch=18, cex = 1.2);
elml = lm(rgratio~doy, data=east); wlml = lm(rgratio~doy, data = west); slml
= lm(rgratio~doy, data = south); nlml = lm(rgratio~doy, data=north)
abline(elml, col = "darkgreen", lwd = 1.5); abline(wlml, col = "orange", lwd
= 1.5); abline(slml, col = "purple", lwd = 1.5); abline(nlml, lwd = 1.5)
legend("topleft",legend=c("North face","South face","East face","West face"),
col = c("black","purple","green","red"), pch = c(16,19,17,18))
```

Plot R:G given aspect and doy

```
par(mfrow=c(2,2), ps = 20,mar=c(5,6,4,1)+.1)
plot(rgratio~doy, data=north, main = "", pch=16, xlab = "", ylab = "R:G ratio
", cex = 1.2, xlim=c(255,320), ylim=c(0.80,1.25)); nlml = lm(rgratio~doy, dat
a=north);abline(nlml, lwd = 1.5)
plot(rgratio~doy, data = south, pch=16, xlab = "", ylab = "", cex = 1.2,xlim=
c(255,320), ylim=c(0.80,1.25)); slml = lm(rgratio~doy, data = south);abline(s
lml, lwd = 1.5)
plot(rgratio~doy, data = east, pch=16, xlab = "Day of Year", ylab = "R:G rati
o", cex = 1.2,xlim=c(255,320), ylim=c(0.80,1.25)); elml = lm(rgratio~doy, dat
a=east);abline(elml, lwd = 1.5)
plot(rgratio~doy, data=west, pch=16, xlab = "Day of Year", ylab = "R:G ratio"
, cex = 1.2,xlim=c(255,320), ylim=c(0.80,1.25));wlml = lm(rgratio~doy, data =
west);abline(wlml, lwd = 1.5)

legend("topleft",legend=c("North face","South face","East face","West face"),
col = c("black","purple","green","red"), pch = c(16,19,17,18))
```

Graph comparing red:green concentrations across all aspects

```
par(mfrow=c(2,2))
plot(north$doy, north$rmean, col = "red", ylab = "Mean color concentration",y
lim = c(40,160), xlim=c(250,320), xlab = "Day of Year", main = "North: Compar
ing mean red and mean green slopes by aspect"); points(north$doy, north$gmean
, col = "green");
nrml = lm(rmean~doy, data = north); nglm = lm(gmean~doy, data = north)
abline(nrml, col = "red", lty = 3); abline(nglm, col = "green", lty = 3)
plot(south$doy, south$rmean, col = "red", ylab = "Mean color concentration",y
lim = c(40,160), xlim=c(250,320), xlab = "Day of Year", main = "South: Compar
ing mean red and mean green slopes by aspect"); points(south$doy, south$gmean
, col = "green");
```

```

srlm = lm(rmean~doy, data = south); sglm = lm(gmean~doy, data = south)
abline(srlm, col = "red", lty = 3); abline(sglm, col = "green", lty = 3)
plot(east$doy, east$rmean, col = "red", ylab = "Mean color concentration", ylim = c(40,160), xlim=c(250,320), xlab = "Day of Year", main = "East: Comparing mean red and mean green slopes by aspect"); points(east$doy, east$gmean, col = "green");
erlm = lm(rmean~doy, data = east); eglm = lm(gmean~doy, data = east)
abline(erlm, col = "red", lty = 3); abline(eglm, col = "green", lty = 3)
plot(west$doy, west$rmean, col = "red", ylab = "Mean color concentration", ylim = c(40,160), xlim=c(250,320), xlab = "Day of Year", main = "West: Comparing mean red and mean green slopes by aspect"); points(west$doy, west$gmean, col = "green");
wrlm = lm(rmean~doy, data = west); wglm = lm(gmean~doy, data = west)
abline(wrlm, col = "red", lty = 3); abline(wglm, col = "green", lty = 3)

```

Comparing elevation differences visible in photographs by direction

```

par(mfrow=c(1,1))
plot(d.elev1~corr.aspect, data = leafcolor, ylab = "Change in elevation", xlab = "Aspect", main = "Change in elevation between photograph site and focal mountain", rm.na=TRUE)
par(mfrow = c(2,2))
boxplot(d.elev1~corr.aspect, data = leafcolor, ylab = "Change in elevation", xlab = "Aspect", main = "Change in elevation")
boxplot(d.elev1~corr.aspect, data = noislands, ylab = "Change in elevation", xlab = "Aspect", main = "No Islands: Change in elevation", rm.na=TRUE)
boxplot(d.elev1~corr.aspect, data = islandsonwest, ylab = "Change in elevation", xlab = "Aspect", main = "Islands only for west: Change in elevation")

```

Testing the different intersections/slopes

Calculate slopes and intersections

```

wrslope = coef(wrlm); wgslope = coef(wglm)
erslope = coef(erlm); egslope = coef(eglm)
nrslope = coef(nrml); ngslope = coef(nglm)
srslope = coef(srlm); sgslope = coef(sglm)
wrslope; wgslope
erslope; egslope
nrslope; ngslope
srslope; sgslope

```

I then used an online calculator for intersection of two lines. Code should also be available.

```

slopes=matrix(c(-0.583, -0.580, -0.543, -0.759, -0.169, -0.377, -0.096, -0.303), byrow= TRUE, nrow = 4); colnames(slopes) = c("red", "green"); rownames(slopes) = c("west", "east", "north", "south")
slopes
slope.intersect=matrix(c(292.89,86.51,281.03,95.92, 273.85, 92.97, 1176.25, -

```

```
413.14), byrow=T, nrow=4); colnames(slope.intersect) = c("doy", "meancol"); r
ownames(slope.intersect) = c("north", "south", "east", "west")
slope.intersect
slopechitable = as.data.frame(slope.intersect[1:3,])
slopechi = chisq.test(slopechitable$doy)
1-pchisq(slopechi$statistic,df=1)
slopechi
slopechi$expected
slopechi$observed
outlierTest(eglm)
```

2.2 Testing low temperature at dawn against d.R:G

Regression plot for low random doy interval delta t dawn

```
par(mfrow=c(1,1))
plot(corr.d.rgratio~prev.t.sunrise, data = ran.interval, pch = 16, ylab = "Lo
g Change in R:G by day", xlab = "Temperature at sunrise for first day", cex.a
xis = 1.5, cex.lab = 1.5, cex.axis=1.5, cex = 1.5)
abline(templm, lwd = 2)
```

Theil-Sen nonparametric linear regression

```
templm = mbglm(corr.d.rgratio~prev.t.sunrise, data = ran.interval)
summary(templm)
plot(corr.d.rgratio~prev.t.sunrise, data=ran.interval, pch=16, xlab = "Temper
ature sunrise", ylab = "Delta R:G", main = "Change in red:green ratio compare
d to sunrise temperature"); abline(templm)
```

2.3 Testing correlation of ozone and dR:G

Regression plot for low random doy interval ozone

```
par(mfrow=c(1,1))
plot(corr.d.rgratio~prev.ozone, data = ran.interval, pch = 16, ylab = "Log Ch
ange in R:G by day", xlab = "Average ozone for first day", cex.axis = 1.5, ce
x.lab = 1.5, cex.axis=1.5, cex = 1.5)
ozonelm = mbglm(corr.d.rgratio~prev.ozone, data = ran.interval)
abline(ozonelm, lwd = 2)
summary(ozonelm)
```

2.4 Red/Green correlation by aspect

```
par(mfrow=c(2,2))
nrglm = lm(rmean~gmean, data = north); srglm = lm(rmean~gmean, data = south);
```

```

erglm = lm(rmean~gmean, data = east); wrglm = lm(rmean~gmean, data = west);
summary(nrglm); summary(srglm); summary(erglm); summary(wrglm)
plot(rmean~gmean, data = north, main = "North: Red green correlation", xlim =
c(45,160), ylim = c(45,170)); abline(lm(rmean~gmean, data = north))
legend("topleft", expression(r^2==0.93), bty = "n")
plot(rmean~gmean, data = south, main = "South: Red green correlation", xlim =
c(45,160), ylim = c(45,170)); abline(lm(rmean~gmean, data = south))
legend("topleft", expression(r^2==0.83), bty = "n")
plot(rmean~gmean, data = east, main = "East: Red green correlation", xlim = c(
45,160), ylim = c(45,170)); abline(lm(rmean~gmean, data = east))
legend("topleft", expression(r^2==0.93), bty = "n")
plot(rmean~gmean, data = west, main = "West: Red green correlation", xlim = c(
45,160), ylim = c(45,170)); abline(lm(rmean~gmean, data = west))
legend("topleft", expression(r^2==0.89), bty = "n")

```

2.5 Non-linear models of red and green over time

Plot non-linear models independent of each other

```
par(mfrow=c(2,2))
```

East

Red

```

plot(rmean~doy, data = east, main = "East: Non-linear red")
loess_fit = loess(rmean~doy, data = east)
lines(east$doy, predict(loess_fit), col = "blue")

```

Green

```

plot(gmean~doy, data = east, main = "East: Non-linear green")
loess_fit = loess(gmean~doy, data = east)
lines(east$doy, predict(loess_fit), col = "blue")

```

North

Red

```

plot(rmean~doy, data = north, main = "North: Non-linear red")
loess_fit = loess(rmean~doy, data = north)
lines(north$doy, predict(loess_fit), col = "blue")

```

Green

```

plot(gmean~doy, data = north, main = "North: Non-linear gree")
loess_fit = loess(gmean~doy, data = north)
lines(north$doy, predict(loess_fit), col = "blue")

```

South

Red

```
plot(rmean~doy, data = south, main = "South: Non-linear red")
loess_fit = loess(rmean~doy, data = south)
lines(south$doy, predict(loess_fit), col = "blue")
```

Green

```
plot(gmean~doy, data = south, main = "South: Non-linear gree")
loess_fit = loess(gmean~doy, data = south)
lines(south$doy, predict(loess_fit), col = "blue")
```

West

Red

```
plot(rmean~doy, data = west, main = "West: Non-linear red")
loess_fit = loess(rmean~doy, data = west)
lines(west$doy, predict(loess_fit), col = "blue")
```

Green

```
plot(gmean~doy, data = west, main = "West: Non-linear gree")
loess_fit = loess(gmean~doy, data = west)
lines(west$doy, predict(loess_fit), col = "blue")
```

Fit it all together on one graph for each aspect. #####North

```
plot(rmean~doy, data = north, main = "North: Non-linear", col="red");points(g
mean~doy, data = north, col="green")
nrloess = loess(rmean~doy, data = north); ngloess = loess(gmean~doy, data = n
orth)
lines(north$doy, predict(nrloess), col = "red"); lines(north$doy, predict(ngl
oess), col = "green")
```

South

```
plot(rmean~doy, data = south, main = "South: Non-linear", col="red");points(g
mean~doy, data = south, col="green")
srloess = loess(rmean~doy, data = south); sgloess = loess(gmean~doy, data = s
outh)
lines(south$doy, predict(srloess), col = "red"); lines(south$doy, predict(sgl
oess), col = "green")
```

East

```
plot(rmean~doy, data = east, main = "East: Non-linear", col="red");points(gmean~doy, data = east, col="green")
erloess = loess(rmean~doy, data = east); egloess = loess(gmean~doy, data = east)
lines(east$doy, predict(erloess), col = "red"); lines(east$doy, predict(egloess), col = "green")
```

West

```
plot(rmean~doy, data = west, main = "West: Non-linear", col="red");points(gmean~doy, data = west, col="green")
wrloess = loess(rmean~doy, data = west); wgloess = loess(gmean~doy, data = west)
lines(west$doy, predict(wrloess), col = "red"); lines(west$doy, predict(wgloess), col = "green")
```

Testing different vegetation types

```
mosaicplot(vegtype, main = "Habitat type by mountain face (no islands)", col = c("green4", "firebrick", "orange"), cex.axis = 1.2)
```

Test: Chi-squared test of independence

```
vegtest = chisq.test(roundveg, correct = F)
vegtest$expected
vegtest$observed
vegtest
```

2.6 Testing water exposure

Test: Mixed-Effect ANOVA

```
par(mfrow=c(1,1))
```

Set contrasts required for Type III ANOVA

```
options(contrast=c("contr.sum", "contr.poly"))
```

Check the slopes aren't wildly different

```
water.aov=aov(rgratio~doy+water.exp.test+doy*water.exp.test,data=leafcolor)
summary(water.aov)
```

The P value is 0.84 for the interaction term so we fail to reject the null that the slopes are the same.

Create model that reflects fixed and random effects

```
watermodel1=lmer(rgratio~doy+water.exp.test+(1|focalmountain)+doy*water.exp.test, data=leafcolor, REML = FALSE)
summary(watermodel1)
watermodel2 = lmer(rgratio~doy+water.exp.test+(1|focalmountain), data = leafcolor, REML = FALSE)
watermodel3 = lmer(rgratio~doy+(1|focalmountain), data = leafcolor, REML = FALSE)
summary(watermodel2)
```

Run ANCOVA

```
water.test = anova(watermodel2, watermodel3)
water.test
```

Plot for the ANOVA of R:G given water exposure and doy

```
plot(rgratio~doy, data=full.lake, main = "Plot of R:G and DoY", pch=16, xlab = "Day of Year", ylab = "R:G ratio")
points(rgratio~doy, data = part.lake, col = "green", pch=19); points(rgratio~doy, data = part.ocean, col="red", pch=17); points(rgratio~doy, data = no.water, col="orange", pch=18)
plml = lm(rgratio~doy, data=part.lake); flml = lm(rgratio~doy, data = full.lake); nwml = lm(rgratio~doy, data = no.water); foml = lm(rgratio~doy, data=full.ocean); poml = lm(rgratio~doy, data=part.ocean)
abline(plml, col = "green"); abline(foml, col = "red"); abline(poml, col = "purple"); abline(flml); abline(nwml, col= "orange")
legend("topleft", legend=c("North face", "South face", "East face", "West face"), col = c("black", "purple", "green", "red"), pch = c(16, 19, 17, 18))
```

2.7 Testing underlying hydrology

```
hlm = lm(mean~direction, data = hydrotable)
hanova = Anova(hlm)
```

Section 3: Data manipulations

Sometimes I needed to manipulate the data before testing it. Many of these manipulations are derived from Sonnentag et al., 2012.

3.1 Examine ExG

Excess green (ExG) is sometimes used to isolate the difference between leaves and bare soil.

```
par(mfrow=c(2,2))
plot(north$exg~north$doy); abline(lm(north$exg~north$doy))
```

```
plot(south$exg~south$doy, col = "purple"); abline(lm(south$exg~south$doy), col = "purple")
plot(east$exg~east$doy, col = "green4"); abline(lm(east$exg~east$doy), col = "green4")
plot(west$exg~west$doy, col = "red"); abline(lm(west$exg~west$doy), col = "red")
)
```

3.2 Examine rcc and gcc

rcc and gcc (red- and green chromatic coordinates) suppress the influence of brightness levels in a photograph.

```
par(mfrow = c(1,1))
plot(north$rcc~north$doy); points(south$rcc~south$doy, col = "purple"); points(east$rcc~east$doy, col = "green4"); points(west$rcc~west$doy, col = "red")
abline(lm(north$rcc~north$doy)); abline(lm(south$rcc~south$doy), col = "purple"); abline(lm(east$rcc~east$doy), col = "green4"); abline(lm(west$rcc~west$doy), col = "red")
plot(north$gcc~north$doy); points(south$gcc~south$doy, col = "purple"); points(east$gcc~east$doy, col = "green4"); points(west$gcc~west$doy, col = "red")
abline(lm(north$gcc~north$doy)); abline(lm(south$gcc~south$doy), col = "purple"); abline(lm(east$gcc~east$doy), col = "green4"); abline(lm(west$gcc~west$doy), col = "red")
```

Graph comparing red:green concentrations across all aspects

```
par(mfrow=c(1,2))
plot(west$doy, west$rcc, col = "red", ylab = "Mean color concentration", xlab = "Day of Year", main = "West: Comparing mean red and mean green slopes by aspect"); points(west$doy, west$gcc, col = "green");
wrlm = lm(rcc~doy, data = west); wglm = lm(gcc~doy, data = west)
abline(wrlm, col = "red", lty = 3); abline(wglm, col = "green", lty = 3)
```

Repeat this graph with other aspects for comparison.

```
plot(east$doy, east$rcc, col = "red", ylab = "Mean color concentration", xlab = "Day of Year", main = "East: Comparing mean red and mean green slopes by aspect"); points(east$doy, east$gcc, col = "green");
```

Compare with the original

```
plot(east$doy, east$rmean, col = "red1", ylab = "Mean color concentration", xlab = "Day of Year", main = "East: Comparing mean red and mean green slopes by aspect"); points(east$doy, east$gmean, col = "green1"); erlm = lm(rmean~doy, data = east); eglm = lm(gmean~doy, data = east)
abline(erlm, col = "red", lty = 3); abline(eglm, col = "green", lty = 3)
```

3.3 Comparing fits of cc vs means

First, create lms for each term ###East

```
rceastlm = lm(doy~rcc, data = east); gceastlm = lm(doy~gcc, data = east); rmeastlm=lm(doy~rmean, data = east); gmeastlm = lm(doy~gmean, data = east)
```

West

```
rcwestlm = lm(doy~rcc, data = west); gcwestlm = lm(doy~gcc, data = west); rmwestlm=lm(doy~rmean, data = west); gmwestlm = lm(doy~gmean, data = west)
```

North

```
rcnorthlm = lm(doy~rcc, data = north); gcnorthlm = lm(doy~gcc, data = north); rmnorthlm=lm(doy~rmean, data = north); gmnorthlm = lm(doy~gmean, data = north)
```

South

```
rcsouthlm = lm(doy~rcc, data = south); gcsouthlm = lm(doy~gcc, data = south); rmsouthlm=lm(doy~rmean, data = south); gmsouthlm = lm(doy~gmean, data = south)
```

Next, create a matrix from all of these

```
ccmeans = matrix(c(summary(rceastlm)$r.squared,summary(rcwestlm)$r.squared,summary(rcnorthlm)$r.squared,summary(rcsouthlm)$r.squared,summary(gceastlm)$r.squared,summary(rmwestlm)$r.squared,summary(rmnorthlm)$r.squared,summary(rmsouthlm)$r.squared,summary(gcwestlm)$r.squared,summary(gcnorthlm)$r.squared,summary(gcsouthlm)$r.squared,summary(rmeastlm)$r.squared,summary(gmeastlm)$r.squared,summary(gmwestlm)$r.squared,summary(gmnorthlm)$r.squared,summary(gmsouthlm)$r.squared), dimnames = list(c("east", "west", "north", "south"), c("rcc", "rmean", "gcc", "gmean")), ncol = 4)
```

cc does not reduce the variance (and in fact may introduce further variance, particularly in red).

Appendix D: Data from photographs

This appendix contains the data I analyzed in R. It also contains a metadata sheet associated with the data explaining the function of each column of data as well as how it was derived.

Column name Explanation

focalmountain	Mountain being measured
aspect	INVALID, use corr.aspect (original designation during fieldwork)
location	Location I was standing when I took the photograph
direction	INVALID, use corr.direction
corr.direction	Compass direction of the mountain face (NOT the camera pointing) Final designation of direction of each mountain face (NOT the
corr.aspect	camera pointing)
water exposure	Amount of water focal mountain is exposed to
loc.elev	Elevation of photograph location
foc.elev	Elevation of photograph focus Difference in elevation between location and focus. Positive number indicates look UP at mountain, negative number indicates
d.elev	looking DOWN
doy	Day of year
day	Date (2017)
rgratio	Ratio between rmean and gmean
count	Pixel count of each ImageJ analysis
rmean	Mean intensity of red
gmean	Mean intensity of green
rsd	Standard deviation of red intensity
gsd	Standard deviation of green intensity
bsd	Standard deviation of blue intensity
bmean	Mean intensity of blue
rmode	Mode of red intensity
gmode	Mode of green intensity
bmode	Mode of blue intensity
d.rmean	Change in rmean between two observations
d.gmean	Change in gmean between two observations
d.rgratio	Change in R:G ratio between two observations Change in R:G ratio between two observations divided by the
corr.d.rgratio	number of days that passed between observations
rcc	Red chromatic concentration (See Sonnerberg 2012)
gcc	Green chromatic concentration (see Sonnerberg 2012)
sunrise	Time of sunrise on a given date (EST)
t.sunrise	Temperature of sunrise on a given date (MacFarland Hill)
rad.sunrise	Solar radiation at sunrise
noon	Time of solar noon (EST)
t.noon	Temperature at solar noon (EST)
rad.noon	Radation at solar noon (EST)

Column name Explanation

exg	ExG (see Sonnerberg 2012)
prev.ozone	Ozone at sunrise on the first day of observation
prev.t.sunrise	Temperature at sunrise on the first day of observation
prev.rad.noon	Solar radiation at solar noon on the first day of sunrise
doy.interval	Number of days between observations
ran.interval	A random selection of a single point per aspect selected among all days that doy.interval was equal to or less than 12 (the median number)

	A	B	C	D	E	F	G	H	I	J
1	focalmounta	corr.aspect	location	aspect	direction	corr.direction	water exposu	loc.elev	foc.elev	d.elev
2	Bald Peak	South	Hadlock	South	382	202	partial lake	180	960	780
3	Bald Peak	South	Hadlock	South	NA	NA	partial lake	180	960	780
4	Bald Peak	South	Hadlock	South	NA	NA	partial lake	180	960	780
5	Bald Peak	South	Hadlock	South	NA	NA	partial lake	180	960	780
6	Beehive	South	Osprey	East	346	166	partial ocean	0	520	520
7	Beehive	South	Osprey	East	NA	NA	partial ocean	0	520	520
8	Beehive	South	Osprey	East	NA	NA	partial ocean	0	520	520
9	Beehive	South	Osprey	East	NA	NA	partial ocean	0	520	520
10	Beehive	South	Osprey	East	NA	NA	partial ocean	0	520	520
11	Cadillac	East	Dorr	East	285	105	none	1240	1520	280
12	Cadillac	East	Dorr	East	NA	NA	none	1240	1520	280
13	Cadillac	East	Dorr	East	NA	NA	none	1240	1520	280
14	Cadillac	West	Connors	West	115	295	partial lake	580	1520	940
15	Cadillac	West	Connors	West	NA	NA	partial lake	580	1520	940
16	Cadillac	West	Connors	West	NA	NA	partial lake	580	1520	940
17	Cedar Swam	West	Hadlock	West	49	229	full lake	180	920	740
18	Cedar Swam	West	Hadlock	West	NA	NA	full lake	180	920	740
19	Cedar Swam	West	Hadlock	West	NA	NA	full lake	180	920	740
20	Champlain	East	Schooner	East	285	105	full ocean	80	1040	960
21	Champlain	East	Schooner	East	NA	NA	full ocean	80	1040	960
22	Champlain	East	Schooner	East	NA	NA	full ocean	80	1040	960
23	Champlain	East	Schooner	East	NA	NA	full ocean	80	1040	960
24	Champlain	North	Osprey	North	178	358	full ocean	0	1040	1040
25	Champlain	North	Osprey	North	NA	NA	full ocean	0	1040	1040
26	Champlain	North	Osprey	North	NA	NA	full ocean	0	1040	1040
27	Champlain	North	Osprey	North	NA	NA	full ocean	0	1040	1040
28	Champlain	North	Osprey	North	NA	NA	full ocean	0	1040	1040

	A	B	C	K	L	M	N	O	P	Q	R
1	focalmounta	corr.aspect	location	doy	date	rgratio	count	rmean	gmean	bmean	rsd
2	Bald Peak	South	Hadlock	273	30-Sep	1.05	394674	106.89	101.69	97.72	34.5
3	Bald Peak	South	Hadlock	274	1-Oct	1.01	394674	88.73	87.56	91.57	36.21
4	Bald Peak	South	Hadlock	285	12-Oct	1.09	391011	105.79	97.02	96.15	30.77
5	Bald Peak	South	Hadlock	307	3-Nov	0.92	392575	82.05	89.27	92.72	21.8
6	Beehive	South	Osprey	270	27-Sep	1.00	1183438	70.61	70.55	69.57	41.49
7	Beehive	South	Osprey	277	4-Oct	0.94	1169114	72.55	77.06	84.37	47.66
8	Beehive	South	Osprey	284	11-Oct	1.07	1181153	61.33	57.32	56.31	18.41
9	Beehive	South	Osprey	291	18-Oct	1.08	1173605	78.75	73.2	72.22	53.31
10	Beehive	South	Osprey	305	1-Nov	1.06	1175213	71.56	67.38	69.32	17.96
11	Cadillac	East	Dorr	260	17-Sep	0.94	5467273	84.89	90.3	92.75	32.09
12	Cadillac	East	Dorr	283	10-Oct	0.99	5468361	72.36	72.89	69.52	34.31
13	Cadillac	East	Dorr	296	23-Oct	0.99	5466138	74.67	75.52	76.92	34.04
14	Cadillac	West	Connors	276	3-Oct	0.96	2907343	57.99	60.35	65	19.06
15	Cadillac	West	Connors	290	17-Oct	1.01	2907135	66.76	66.41	67.38	22.94
16	Cadillac	West	Connors	304	31-Oct	0.97	2904428	60.03	61.96	67.58	23.95
17	Cedar Swam	West	Hadlock	273	30-Sep	1.04	265318	95.89	92.05	92.73	33.67
18	Cedar Swam	West	Hadlock	285	12-Oct	1.11	266094	113.69	102.79	96.25	22.53
19	Cedar Swam	West	Hadlock	307	3-Nov	0.94	265443	86.25	91.38	99.16	13.81
20	Champlain	East	Schooner	269	26-Sep	1.00	2201875	123.8	124.32	109.41	33.41
21	Champlain	East	Schooner	272	29-Sep	1.01	2198949	121.62	120.63	111.72	36.22
22	Champlain	East	Schooner	289	16-Oct	1.03	2200076	95.13	92.61	90	19.13
23	Champlain	East	Schooner	302	29-Oct	1.15	2198796	101.36	88.26	84.78	18.67
24	Champlain	North	Osprey	270	27-Sep	0.93	637105	87.7	94.1	107.16	13.09
25	Champlain	North	Osprey	277	4-Oct	0.96	636491	153.44	160.31	172.24	7.31
26	Champlain	North	Osprey	284	11-Oct	0.95	635704	154.75	162.37	173.44	7.59
27	Champlain	North	Osprey	291	18-Oct	0.97	635693	147.72	152.19	163.24	5.59
28	Champlain	North	Osprey	305	1-Nov	0.97	636549	148.35	153.59	162.39	6.77

	A	B	C	S	T	U	V	W	X	Y	Z
1	focalmounta	corr.aspect	location	gsd	bsd	rmode	gmode	bmode	d.rmean	d.gmean	d.rgratio
2	Bald Peak	South	Hadlock	27.85	25.62	90	94	86	NA	NA	NA
3	Bald Peak	South	Hadlock	26.32	18.84	94	58	81	-18.16	-14.13	1.29
4	Bald Peak	South	Hadlock	25.23	22.21	102	90	88	17.06	9.46	1.80
5	Bald Peak	South	Hadlock	15.57	16.09	69	83	85	-23.74	-7.75	3.06
6	Beehive	South	Osprey	31	19.57	43	52	63	NA	NA	NA
7	Beehive	South	Osprey	37.22	24.01	43	53	70	1.94	6.51	0.30
8	Beehive	South	Osprey	14.62	13.57	52	53	50	-11.22	-19.74	0.57
9	Beehive	South	Osprey	34.24	20.51	45	52	64	17.42	15.88	1.10
10	Beehive	South	Osprey	15.55	14.81	67	65	65	-7.19	-5.82	1.24
11	Cadillac	East	Dorr	30.83	32.05	73	82	81	NA	NA	NA
12	Cadillac	East	Dorr	30.14	29.47	60	69	56	-12.53	-17.41	0.72
13	Cadillac	East	Dorr	28.65	27.55	100	93	90	2.31	2.63	0.88
14	Cadillac	West	Connors	14.88	16.24	56	60	63	NA	NA	NA
15	Cadillac	West	Connors	16.6	14.53	58	62	64	8.77	6.06	1.45
16	Cadillac	West	Connors	19.24	24	57	55	57	-6.73	-4.45	1.51
17	Cedar Swam	West	Hadlock	25.36	18.11	109	103	90	NA	NA	NA
18	Cedar Swam	West	Hadlock	16.56	15.83	102	99	94	17.8	10.74	1.66
19	Cedar Swam	West	Hadlock	13.73	14.41	82	87	96	-27.44	-11.41	2.40
20	Champlain	East	Schooner	27.31	35.47	109	114	90	NA	NA	NA
21	Champlain	East	Schooner	30.34	37.93	103	108	91	-2.18	-3.69	0.59
22	Champlain	East	Schooner	16.92	18.09	89	110	83	-26.49	-28.02	0.95
23	Champlain	East	Schooner	16.71	19.64	117	83	78	6.23	-4.35	-1.43
24	Champlain	North	Osprey	11.66	10.34	90	95	106	NA	NA	NA
25	Champlain	North	Osprey	6.44	5.96	152	160	171	65.74	66.21	0.99
26	Champlain	North	Osprey	5.97	5.23	153	162	173	1.31	2.06	0.64
27	Champlain	North	Osprey	4.37	3.89	148	152	163	-7.03	-10.18	0.69
28	Champlain	North	Osprey	5.52	5.31	146	152	162	0.63	1.4	0.45

	A	B	C	AA	AB	AC	AD	AE	AF	AG	AH	AI
1	focalmounta	corr.aspect	location	corr.d.rgratio	rcc	gcc	sunrise	t.sunrise	rad.sunrise	noon	t.noon	rad.noon
2	Bald Peak	South	Hadlock	NA	0.35	0.33	05:29	5.7	6	11:23	11.5	607
3	Bald Peak	South	Hadlock	1.29	0.33	0.33	05:30	7	131	11:23	15.6	632
4	Bald Peak	South	Hadlock	0.16	0.35	0.32	05:44	4.8	90	11:19	12.2	582
5	Bald Peak	South	Hadlock	0.14	0.31	0.34	06:12	14.7	17	11:16	18.8	377
6	Beehive	South	Osprey	NA	0.34	0.33	05:26	17.6	13	11:24	24.5	602
7	Beehive	South	Osprey	0.04	0.31	0.33	05:34	12	101	11:22	20.9	611
8	Beehive	South	Osprey	0.08	0.35	0.33	05:43	11.4	33	11:20	14.9	612
9	Beehive	South	Osprey	0.16	0.35	0.33	05:51	8.7	24	11:18	17.9	546
10	Beehive	South	Osprey	0.09	0.34	0.32	06:10	4.7	28	11:16	9.2	241
11	Cadillac	East	Dorr	NA	0.32	0.34	05:14	17.1	22	11:27	22.5	609
12	Cadillac	East	Dorr	0.03	0.34	0.34	05:41	17.2	48	11:20	20.8	559
13	Cadillac	East	Dorr	0.07	0.33	0.33	05:58	10.9	22	11:17	14.3	506
14	Cadillac	West	Connors	NA	0.32	0.33	05:30	9.3	120	11:22	15.4	604
15	Cadillac	West	Connors	0.10	0.33	0.33	05:50	2.5	72	11:18	10	517
16	Cadillac	West	Connors	0.11	0.32	0.33	06:08	8.6	30	11:16	13.1	477
17	Cedar Swam	West	Hadlock	NA	0.34	0.33		5.7	6		11.5	607
18	Cedar Swam	West	Hadlock	0.14	0.36	0.33		4.8	90		12.2	582
19	Cedar Swam	West	Hadlock	0.11	0.31	0.33		14.7	17		18.8	377
20	Champlain	East	Schooner	NA	0.35	0.35	05:24	17.6	15	11:24	26.3	538
21	Champlain	East	Schooner	0.20	0.34	0.34	05:28	7	6	11:23	13.9	648
22	Champlain	East	Schooner	0.06	0.34	0.33	05:49	15.4	27	11:18	9.9	216
23	Champlain	East	Schooner	-0.11	0.37	0.32	06:06	12.1	21	11:17	15.5	370
24	Champlain	North	Osprey	NA	0.30	0.33		17.6	13		24.5	602
25	Champlain	North	Osprey	0.14	0.32	0.33		12	101		20.9	611
26	Champlain	North	Osprey	0.09	0.32	0.33		11.4	33		14.9	612
27	Champlain	North	Osprey	0.10	0.32	0.33		8.7	24		17.9	546
28	Champlain	North	Osprey	0.03	0.32	0.33		4.7	28		9.2	241

	A	B	C	AJ	AK	AL	AM	AN	AO
1	focalmounta	corr.aspect	location	exg	prev.ozone	prev.t.sunris	prev.rad.noc	doy.interval	ran.interval
2	Bald Peak	South	Hadlock	-1.23		NA	NA	NA	
3	Bald Peak	South	Hadlock	-5.18	27.42	5.7	607	1	x
4	Bald Peak	South	Hadlock	-7.9	28.35	7	632	11	
5	Bald Peak	South	Hadlock	3.77	26.21	4.8	582	22	
6	Beehive	South	Osprey	0.92		NA	NA	NA	
7	Beehive	South	Osprey	-2.8	24.5	17.6	602	7	
8	Beehive	South	Osprey	-3	39.79	12	611	7	x
9	Beehive	South	Osprey	-4.57	21.43	11.4	612	7	
10	Beehive	South	Osprey	-6.12	22.29	8.7	546	14	
11	Cadillac	East	Dorr	2.96		NA	NA	NA	
12	Cadillac	East	Dorr	3.9	28.39	17.1	609	23	
13	Cadillac	East	Dorr	-0.55	22.77	17.2	559	13	
14	Cadillac	West	Connors	-2.29		NA	NA	NA	
15	Cadillac	West	Connors	-1.32	30.27	9.3	604	14	
16	Cadillac	West	Connors	-3.69	26.17	2.5	517	14	
17	Cedar Swam	West	Hadlock	-4.52		NA	NA	NA	
18	Cedar Swam	West	Hadlock	-4.36	27.41	5.7	607	12	x
19	Cedar Swam	West	Hadlock	-2.65	26.21	4.8	582	22	
20	Champlain	East	Schooner	15.43		NA	NA	NA	
21	Champlain	East	Schooner	7.92	24.91	17.6	538	3	x
22	Champlain	East	Schooner	0.09	29.29	7	648	17	
23	Champlain	East	Schooner	-9.62	24.08	15.4	216	13	
24	Champlain	North	Osprey	-6.66		NA	NA	NA	
25	Champlain	North	Osprey	-5.06	24.5	17.6	602	7	
26	Champlain	North	Osprey	-3.45	39.79	12	611	7	
27	Champlain	North	Osprey	-6.58	21.43	11.4	612	7	x
28	Champlain	North	Osprey	-3.56	33.38	8.7	546	14	

	A	B	C	D	E	F	G	H	I	J
1	focalmounta	corr.aspect	location	aspect	direction	corr.direction	water exposu	loc.elev	foc.elev	d.elev
29	Champlain	West	Dorr	West	132	312	none	1240	1040	-200
30	Champlain	West	Dorr	West	NA	NA	none	1240	1040	-200
31	Champlain	West	Dorr	West	NA	NA	none	1240	1040	-200
32	Connors	North	Eagle	North	215	35	full lake	280	580	300
33	Connors	North	Eagle	North	NA	NA	full lake	280	580	300
34	Connors	North	Eagle	North	NA	NA	full lake	280	580	300
35	Connors	North	Eagle	North	NA	NA	full lake	280	580	300
36	Connors	North	Eagle	North	NA	NA	full lake	280	580	300
37	Connors	North	Eagle	North	NA	NA	full lake	280	580	300
38	Connors	South	Pemetic	South	355	175	partial lake	1220	580	-640
39	Connors	South	Pemetic	South	NA	NA	partial lake	1220	580	-640
40	Connors	South	Pemetic	South	NA	NA	partial lake	1220	580	-640
41	Connors	South	Pemetic	South	NA	NA	partial lake	1220	580	-640
42	Dorr	East	Huguenot	East	291	111	partial lake	680	1240	560
43	Dorr	East	Huguenot	East	NA	NA	partial lake	680	1240	560
44	Dorr	East	Huguenot	East	NA	NA	partial lake	680	1240	560
45	Dorr	East	Huguenot	East	NA	NA	partial lake	680	1240	560
46	Dorr	North	Park Loop	North	221	41	none	20	1240	1220
47	Dorr	North	Park Loop	North	NA	NA	none	20	1240	1220
48	Dorr	North	Park Loop	North	NA	NA	none	20	1240	1220
49	Dorr	North	Park Loop	North	NA	NA	none	20	1240	1220
50	Dorr	South	Park Loop	South	358	178	full ocean	20	1240	1220
51	Dorr	South	Park Loop	South	NA	NA	full ocean	20	1240	1220
52	Dorr	South	Park Loop	South	NA	NA	full ocean	20	1240	1220
53	Dorr	South	Park Loop	South	NA	NA	full ocean	20	1240	1220
54	Gorham	East	Osprey	East	298	118	full ocean	0	500	500
55	Gorham	East	Osprey	East	NA	NA	full ocean	0	500	500

	A	B	C	K	L	M	N	O	P	Q	R
1	focalmounta	corr.aspect	location	doy	date	rgratio	count	rmean	gmean	bmean	rsd
29	Champlain	West	Dorr	283	10-Oct	0.98	1232320	84.69	86.32	84.01	28.2
30	Champlain	West	Dorr	296	23-Oct	0.99	1230652	82.13	83.06	83.2	30.61
31	Champlain	West	Dorr	317	13-Nov	0.95	1231927	53.81	56.61	59.1	20.01
32	Connors	North	Eagle	266	23-Sep	0.88	538953	63.7	72.58	86.65	22.46
33	Connors	North	Eagle	276	3-Oct	1.02	538616	74.85	73.46	75.54	18.6
34	Connors	North	Eagle	281	8-Oct	1.01	536180	71.47	70.61	75.5	24.66
35	Connors	North	Eagle	287	14-Oct	1.03	539345	67.45	65.27	68.41	15.23
36	Connors	North	Eagle	301	28-Oct	1.06	539078	69.48	65.78	76.35	23.38
37	Connors	North	Eagle	304	31-Oct	1.11	539130	69.78	62.9	70.51	22.42
38	Connors	South	Pemetic	264	21-Sep	0.96	576317	114.57	119.5	119.79	28.85
39	Connors	South	Pemetic	279	6-Oct	1.05	576126	130.75	125.04	113.05	22.32
40	Connors	South	Pemetic	294	21-Oct	1.15	576160	117.18	101.63	82.22	23.71
41	Connors	South	Pemetic	302	29-Oct	1.09	575840	108.66	99.71	90.85	19.53
42	Dorr	East	Huguenot	269	26-Sep	1.03	11257147	87.25	84.77	65.63	38.22
43	Dorr	East	Huguenot	286	13-Oct	1.05	11257030	80.29	76.68	65.92	33.37
44	Dorr	East	Huguenot	294	21-Oct	1.09	11262205	75.81	69.55	60.47	33.47
45	Dorr	East	Huguenot	311	7-Nov	1.02	11248243	83.55	81.71	78.83	26.35
46	Dorr	North	Park Loop	286	13-Oct	1.02	1901810	73.44	72.07	69.02	25.58
47	Dorr	North	Park Loop	294	21-Oct	1.14	1901157	69.33	60.65	56.69	27.18
48	Dorr	North	Park Loop	296	23-Oct	1.13	1901989	82.14	72.48	70.95	30.79
49	Dorr	North	Park Loop	311	7-Nov	1.02	1901387	60.62	59.59	62.65	19.67
50	Dorr	South	Park Loop	269	26-Sep	0.90	503670	112.71	125.18	131.29	22.99
51	Dorr	South	Park Loop	272	29-Sep	0.95	503623	114.89	121.41	127.53	22.82
52	Dorr	South	Park Loop	289	16-Oct	0.94	504303	96.47	102.66	104.25	19.37
53	Dorr	South	Park Loop	302	29-Oct	0.94	503529	101.88	108.39	118.12	14.03
54	Gorham	East	Osprey	277	4-Oct	1.14	1814945	69.29	60.54	60.62	35.5
55	Gorham	East	Osprey	284	11-Oct	1.13	1815445	64.07	56.76	52.01	19.44

	A	B	C	S	T	U	V	W	X	Y	Z
1	focalmounta	corr.aspect	location	gsd	bsd	rmode	gmode	bmode	d.rmean	d.gmean	d.rgratio
29	Champlain	West	Dorr	23.07	21.82	80	87	76	NA	NA	NA
30	Champlain	West	Dorr	24.9	23.35	73	78	76	-2.56	-3.26	0.79
31	Champlain	West	Dorr	16.71	17.21	47	50	51	-28.32	-26.45	1.07
32	Connors	North	Eagle	15.68	8.22	40	58	83	NA	NA	NA
33	Connors	North	Eagle	13.5	8.93	72	73	73	11.15	0.88	12.67
34	Connors	North	Eagle	23	25.17	61	64	70	-3.38	-2.85	1.19
35	Connors	North	Eagle	10.37	9.6	61	64	67	-4.02	-5.34	0.75
36	Connors	North	Eagle	14.24	10.65	56	61	73	2.03	0.51	3.98
37	Connors	North	Eagle	14.51	12.34	64	59	65	0.3	-2.88	-0.10
38	Connors	South	Pemetic	20.99	11.57	82	97	113	NA	NA	NA
39	Connors	South	Pemetic	15.54	13.05	134	127	110	16.18	5.54	2.92
40	Connors	South	Pemetic	17.47	14.91	125	100	78	-13.57	-23.41	0.58
41	Connors	South	Pemetic	14.37	12.54	115	103	89	-8.52	-1.92	4.44
42	Dorr	East	Huguenot	NA	33.02	100	103	68	NA	NA	NA
43	Dorr	East	Huguenot	29.27	29.05	79	81	62	-6.96	-8.09	0.86
44	Dorr	East	Huguenot	28.48	27.17	70	70	54	-4.48	-7.13	0.63
45	Dorr	East	Huguenot	23.06	26.47	76	79	72	7.74	12.16	0.64
46	Dorr	North	Park Loop	18.75	16.11	61	71	67	NA	NA	NA
47	Dorr	North	Park Loop	16.65	13.58	52	61	57	-4.11	-11.42	0.36
48	Dorr	North	Park Loop	21.15	23.74	81	92	52	12.81	11.83	1.08
49	Dorr	North	Park Loop	11.04	13.91	47	59	66	-21.52	-12.89	1.67
50	Dorr	South	Park Loop	15.82	14.37	108	126	127	NA	NA	NA
51	Dorr	South	Park Loop	17.05	16.04	108	120	124	2.18	-3.77	-0.58
52	Dorr	South	Park Loop	15.28	14.4	91	101	98	-18.42	-18.75	0.98
53	Dorr	South	Park Loop	12.93	14.4	97	104	110	5.41	5.73	0.94
54	Gorham	East	Osprey	28.25	26.68	39	39	44	NA	NA	NA
55	Gorham	East	Osprey	12.43	11.07	50	55	51	-5.22	-3.78	1.38

	A	B	C	AA	AB	AC	AD	AE	AF	AG	AH	AI
1	focalmounta	corr.aspect	location	corr.d.rgratio	rcc	gcc	sunrise	t.sunrise	rad.sunrise	noon	t.noon	rad.noon
29	Champlain	West	Dorr	NA	0.33	0.34		17.2	48		20.8	559
30	Champlain	West	Dorr	0.06	0.33	0.33		10.9	22		14.3	506
31	Champlain	West	Dorr	0.05	0.32	0.33	06:26	-0.8	0	11:17	4.2	246
32	Connors	North	Eagle	NA	0.29	0.33	05:21	14.3	9	11:25	24.2	644
33	Connors	North	Eagle	1.27	0.33	0.33		9.3	120		15.4	604
34	Connors	North	Eagle	0.24	0.33	0.32	05:39	17.3	19	11:20	17.3	30
35	Connors	North	Eagle	0.13	0.34	0.32	05:46	13	25	11:19	16.5	316
36	Connors	North	Eagle	0.28	0.33	0.31	06:04	7.6	36	11:17	13.5	484
37	Connors	North	Eagle	-0.03	0.34	0.31		8.6	30		13.1	477
38	Connors	South	Pemetic	NA	0.32	0.34	05:19	15.4	21	11:26	20.3	679
39	Connors	South	Pemetic	0.19	0.35	0.34	05:36	12.6	53	11:21	14.2	262
40	Connors	South	Pemetic	0.04	0.39	0.34	05:55	10.1	53	11:17	16.9	496
41	Connors	South	Pemetic	0.55	0.36	0.33		12.1	21		15.5	370
42	Dorr	East	Huguenot	NA	0.37	0.36		17.6	15		26.3	538
43	Dorr	East	Huguenot	0.05	0.36	0.34	05:45	7.1	83	11:19	13.9	578
44	Dorr	East	Huguenot	0.08	0.37	0.34		10.1	53		16.9	496
45	Dorr	East	Huguenot	0.04	0.34	0.33	06:18	0.3	11	11:16	4.3	447
46	Dorr	North	Park Loop	NA	0.34	0.34		7.1	83		13.9	578
47	Dorr	North	Park Loop	0.04	0.37	0.32		10.1	53		16.9	496
48	Dorr	North	Park Loop	0.54	0.36	0.32		10.9	22		14.3	506
49	Dorr	North	Park Loop	0.11	0.33	0.33		0.3	11		4.3	447
50	Dorr	South	Park Loop	NA	0.31	0.34		17.6	15		26.3	538
51	Dorr	South	Park Loop	-0.19	0.32	0.33		7	6		13.9	648
52	Dorr	South	Park Loop	0.06	0.32	0.34		15.4	27		9.9	216
53	Dorr	South	Park Loop	0.07	0.31	0.33		12.1	21		15.5	370
54	Gorham	East	Osprey	NA	0.36	0.32		12	101		20.9	611
55	Gorham	East	Osprey	0.20	0.37	0.33		11.4	33		14.9	612

	A	B	C	AJ	AK	AL	AM	AN	AO
1	focalmounta	corr.aspect	location	exg	prev.ozone	prev.t.sunris	prev.rad.noc	doy.interval	ran.interval
29	Champlain	West	Dorr	3.94		NA	NA	NA	
30	Champlain	West	Dorr	0.79	22.77	17.2	559	13	
31	Champlain	West	Dorr	0.31	36.67	10.9	506	21	
32	Connors	North	Eagle	-5.19		NA	NA	NA	
33	Connors	North	Eagle	-3.47	25.71	14.3	644	10	
34	Connors	North	Eagle	-5.75	30.27	9.3	604	5	x
35	Connors	North	Eagle	-5.32	25.96	17.3	30	6	
36	Connors	North	Eagle	-14.27	35.92	13	316	14	
37	Connors	North	Eagle	-14.49	28.33	7.6	484	3	
38	Connors	South	Pemetic	4.64		NA	NA	NA	
39	Connors	South	Pemetic	6.28	23.5	15.4	679	15	
40	Connors	South	Pemetic	3.86	27.71	12.6	262	15	
41	Connors	South	Pemetic	-0.09	32.79	10.1	496	8	x
42	Dorr	East	Huguenot	16.66		NA	NA	NA	
43	Dorr	East	Huguenot	7.15	24.91	17.6	538	17	
44	Dorr	East	Huguenot	2.82	29.29	7.1	578	8	x
45	Dorr	East	Huguenot	1.04	32.79	10.1	496	17	
46	Dorr	North	Park Loop	1.68		NA	NA	NA	
47	Dorr	North	Park Loop	-4.72	29.29	7.1	578	8	
48	Dorr	North	Park Loop	-8.13	32.79	10.1	496	2	x
49	Dorr	North	Park Loop	-4.09	36.67	10.9	506	15	
50	Dorr	South	Park Loop	6.36		NA	NA	NA	
51	Dorr	South	Park Loop	0.4	24.91	17.6	538	3	x
52	Dorr	South	Park Loop	4.6	29.29	7	648	17	
53	Dorr	South	Park Loop	-3.22	24.08	15.4	216	13	
54	Gorham	East	Osprey	-8.83		NA	NA	NA	
55	Gorham	East	Osprey	-2.56	39.79	12	611	7	

	A	B	C	D	E	F	G	H	I	J
1	focalmounta	corr.aspect	location	aspect	direction	corr.direction	water exposu	loc.elev	foc.elev	d.elev
56	Gorham	East	Osprey	East	NA	NA	full ocean	0	500	500
57	Gorham	East	Osprey	East	NA	NA	full ocean	0	500	500
58	Gorham	East	Osprey	East	NA	NA	full ocean	0	500	500
59	Huguenot	North	Osprey	North	183	3	full ocean	0	680	680
60	Huguenot	North	Osprey	North	NA	NA	full ocean	0	680	680
61	Huguenot	North	Osprey	North	NA	NA	full ocean	0	680	680
62	Huguenot	North	Osprey	North	NA	NA	full ocean	0	680	680
63	Island, Bald	West	Bar Harbo	North	123	303	full ocean	20	180	160
64	Island, Bald	West	Bar Harbo	North	NA	NA	full ocean	20	180	160
65	Island, Bald	West	Bar Harbo	North	NA	NA	full ocean	20	180	160
66	Island, Bald	West	Bar Harbo	North	NA	NA	full ocean	20	180	160
67	Island, Bar	West	COA	West	59	239	full ocean	20	160	140
68	Island, Bar	West	COA	West	NA	NA	full ocean	20	160	140
69	Island, Bar	West	COA	West	NA	NA	full ocean	20	160	140
70	Island, Bar	West	COA	West	NA	NA	full ocean	20	160	140
71	Island, Long	West	Bar Harbo	West	83	263	full ocean	20	160	140
72	Island, Long	West	Bar Harbo	West	NA	NA	full ocean	20	160	140
73	Island, Long	West	Bar Harbo	West	NA	NA	full ocean	20	160	140
74	Island, Sheep	West	Bar Harbo	South	57	237	full ocean	20	120	100
75	Island, Sheep	West	Bar Harbo	South	NA	NA	full ocean	20	120	100
76	Island, Sheep	West	Bar Harbo	South	NA	NA	full ocean	20	120	100
77	Island, Sheep	West	Bar Harbo	South	NA	NA	full ocean	20	120	100
78	McFarland	North	Carriage M	East	145	325	partial lake	260	720	460
79	McFarland	North	Carriage M	East	NA	NA	partial lake	260	720	460
80	McFarland	North	Carriage M	East	NA	NA	partial lake	260	720	460
81	McFarland	North	Carriage M	East	NA	NA	partial lake	260	720	460
82	McFarland	North	Carriage M	East	NA	NA	partial lake	260	720	460

	A	B	C	K	L	M	N	O	P	Q	R
1	focalmounta	corr.aspect	location	doy	date	rgratio	count	rmean	gmean	bmean	rsd
56	Gorham	East	Osprey	291	18-Oct	1.01	1814384	61.7	61.01	70.08	34.61
57	Gorham	East	Osprey	305	1-Nov	1.11	1812676	71.74	64.44	62.38	22.14
58	Gorham	East	Osprey	312	8-Nov	1.02	1810592	52.1	51.26	56.56	14.86
59	Huguenot	North	Osprey	270	27-Sep	0.92	245072	76.98	83.83	100.57	8.6
60	Huguenot	North	Osprey	277	4-Oct	0.89	245090	85.72	96.46	116.17	12.66
61	Huguenot	North	Osprey	284	11-Oct	0.90	245036	88.96	98.6	114.45	14.86
62	Huguenot	North	Osprey	291	18-Oct	0.92	245131	73.49	80.28	98.91	10.25
63	Island, Bald	West	Bar Harbo	267	24-Sep	1.00	715537	115.53	115.55	116.07	26.03
64	Island, Bald	West	Bar Harbo	278	5-Oct	1.16	712995	98.49	85.27	76.65	28.24
65	Island, Bald	West	Bar Harbo	288	15-Oct	1.07	713984	92.01	86.15	80.21	28.17
66	Island, Bald	West	Bar Harbo	305	1-Nov	1.06	713984	91.09	85.9	88.42	27.2
67	Island, Bar	West	COA	266	23-Sep	0.92	627963	78.25	84.79	74.3	24.51
68	Island, Bar	West	COA	267	24-Sep	0.97	628662	90.89	93.45	85.49	28.68
69	Island, Bar	West	COA	281	8-Oct	1.00	628064	83.45	83.23	80.21	20.43
70	Island, Bar	West	COA	294	21-Oct	1.17	629405	75.14	64.28	55	27.18
71	Island, Long	West	Bar Harbo	267	24-Sep	0.98	302712	96.61	99.03	100.9	18.73
72	Island, Long	West	Bar Harbo	278	5-Oct	1.13	303364	102.22	90.12	81.59	19.32
73	Island, Long	West	Bar Harbo	288	15-Oct	0.99	302637	94.73	95.26	94.76	19.98
74	Island, Sheep	West	Bar Harbo	267	24-Sep	1.00	867794	95.08	94.92	88.23	24.44
75	Island, Sheep	West	Bar Harbo	278	5-Oct	1.20	867216	97.71	81.45	67.53	28.04
76	Island, Sheep	West	Bar Harbo	288	15-Oct	1.07	866456	86.96	81.02	65.81	27.94
77	Island, Sheep	West	Bar Harbo	305	1-Nov	1.17	867971	93.6	80.25	70.16	28.17
78	McFarland	North	Carriage I	266	23-Sep	1.00	399969	78.56	78.33	67.75	22.78
79	McFarland	North	Carriage I	268	25-Sep	0.90	400755	93.79	104.48	109.51	16.81
80	McFarland	North	Carriage I	276	3-Oct	1.00	400755	99.85	99.39	84.23	23.43
81	McFarland	North	Carriage I	281	8-Oct	0.96	400288	101.46	106.08	97.47	12.69
82	McFarland	North	Carriage I	287	14-Oct	1.01	399483	92.17	91.29	79.3	15.2

	A	B	C	S	T	U	V	W	X	Y	Z
1	focalmounta	corr.aspect	location	gsd	bsd	rmode	gmode	bmode	d.rmean	d.gmean	d.rgratio
56	Gorham	East	Osprey	20.91	16.23	44	50	61	-2.37	4.25	-0.56
57	Gorham	East	Osprey	17.46	17.87	62	60	58	10.04	3.43	2.93
58	Gorham	East	Osprey	13	13.52	48	47	53	-19.64	-13.18	1.49
59	Huguenot	North	Osprey	8.09	7.38	75	83	100	NA	NA	NA
60	Huguenot	North	Osprey	10.84	8.77	81	95	114	8.74	12.63	0.69
61	Huguenot	North	Osprey	10.82	9.45	84	97	115	3.24	2.14	1.51
62	Huguenot	North	Osprey	8.04	6.56	73	80	99	-15.47	-18.32	0.84
63	Island, Bald	West	Bar Harbo	17.95	14.01	114	115	110	NA	NA	NA
64	Island, Bald	West	Bar Harbo	19.74	14.19	104	88	73	-17.04	-30.28	0.56
65	Island, Bald	West	Bar Harbo	20.69	15.51	90	83	72	-6.48	0.88	-7.36
66	Island, Bald	West	Bar Harbo	17.23	13.1	71	76	81	-0.92	-0.25	3.68
67	Island, Bar	West	COA	23.18	15.72	80	83	70	NA	NA	NA
68	Island, Bar	West	COA	25.67	21.43	93	100	85	12.64	8.66	1.46
69	Island, Bar	West	COA	18.56	15.85	98	100	74	-7.44	-10.22	0.73
70	Island, Bar	West	COA	20.11	17.01	66	69	52	-8.31	-18.95	0.44
71	Island, Long	West	Bar Harbo	16.37	15.14	88	92	93	NA	NA	NA
72	Island, Long	West	Bar Harbo	16.56	14.77	93	86	77	5.61	-8.91	-0.63
73	Island, Long	West	Bar Harbo	16.69	15.53	91	93	87	-7.49	5.14	-1.46
74	Island, Sheep	West	Bar Harbo	19.52	15.57	95	95	83	NA	NA	NA
75	Island, Sheep	West	Bar Harbo	20.06	12.98	109	89	66	2.63	-13.47	-0.20
76	Island, Sheep	West	Bar Harbo	20	17.88	73	71	57	-10.75	-0.43	25.00
77	Island, Sheep	West	Bar Harbo	7.89	18.09	72	75	61	6.64	-0.77	-8.62
78	McFarland	North	Carriage I	18.95	12.03	83	83	64	NA	NA	NA
79	McFarland	North	Carriage I	13.87	13	91	101	103	15.23	26.15	0.58
80	McFarland	North	Carriage I	19.57	15.47	109	107	85	6.06	-5.09	-1.19
81	McFarland	North	Carriage I	8.33	9.83	95	105	98	1.61	6.69	0.24
82	McFarland	North	Carriage I	10.08	11.22	87	91	80	-9.29	-14.79	0.63

	A	B	C	AA	AB	AC	AD	AE	AF	AG	AH	AI
1	focalmounta	corr.aspect	location	corr.d.rgratio	rcc	gcc	sunrise	t.sunrise	rad.sunrise	noon	t.noon	rad.noon
56	Gorham	East	Osprey	-0.08	0.32	0.32		8.7	24		17.9	546
57	Gorham	East	Osprey	0.21	0.36	0.32		4.7	28		9.2	241
58	Gorham	East	Osprey	0.21	0.33	0.32	06:19	-0.4	13	11:17	4	454
59	Huguenot	North	Osprey	NA	0.29	0.32		17.6	13		24.5	602
60	Huguenot	North	Osprey	0.10	0.29	0.32		12	101		20.9	611
61	Huguenot	North	Osprey	0.22	0.29	0.33		11.4	33		14.9	612
62	Huguenot	North	Osprey	0.12	0.29	0.32		8.7	24		17.9	546
63	Island, Bald	West	Bar Harbo	NA	0.33	0.33	05:22	19.3	15	11:25	27.1	622
64	Island, Bald	West	Bar Harbo	0.05	0.38	0.33	05:35	15.1	103	11:21	21.4	587
65	Island, Bald	West	Bar Harbo	-0.74	0.36	0.33	05:48	15.2	19	11:19	14.9	250
66	Island, Bald	West	Bar Harbo	0.22	0.34	0.32		4.7	28		9.2	241
67	Island, Bar	West	COA	NA	0.33	0.36		14.3	9		24.2	644
68	Island, Bar	West	COA	1.46	0.34	0.35		19.3	15		27.1	622
69	Island, Bar	West	COA	0.05	0.34	0.34		17.3	19		17.3	30
70	Island, Bar	West	COA	0.03	0.39	0.33		10.1	53		16.9	496
71	Island, Long	West	Bar Harbo	NA	0.33	0.33		19.3	15		27.1	622
72	Island, Long	West	Bar Harbo	-0.06	0.37	0.33		15.1	103		21.4	587
73	Island, Long	West	Bar Harbo	-0.15	0.33	0.33		15.2	19		14.9	250
74	Island, Sheep	West	Bar Harbo	NA	0.34	0.34		19.3	15		27.1	622
75	Island, Sheep	West	Bar Harbo	-0.02	0.40	0.33		15.1	103		21.4	587
76	Island, Sheep	West	Bar Harbo	2.50	0.37	0.35		15.2	19		14.9	250
77	Island, Sheep	West	Bar Harbo	-0.51	0.38	0.33		4.7	28		9.2	241
78	McFarland	North	Carriage I	NA	0.35	0.35		14.3	9		24.2	644
79	McFarland	North	Carriage I	0.29	0.30	0.34	05:23	20	13	11:25	26	625
80	McFarland	North	Carriage I	-0.15	0.35	0.35		9.3	120		15.4	604
81	McFarland	North	Carriage I	0.05	0.33	0.35		17.3	19		17.3	30
82	McFarland	North	Carriage I	0.10	0.35	0.35		13	25		16.5	316

	A	B	C	AJ	AK	AL	AM	AN	AO
1	focalmounta	corr.aspect	location	exg	prev.ozone	prev.t.sunris	prev.rad.noc	doy.interval	ran.interval
56	Gorham	East	Osprey	-9.76	21.43	11.4	612	7	x
57	Gorham	East	Osprey	-5.24	33.38	8.7	546	14	
58	Gorham	East	Osprey	-6.14	22.29	4.7	241	7	
59	Huguenot	North	Osprey	-9.89		NA	NA	NA	
60	Huguenot	North	Osprey	-8.97	24.5	17.6	602	7	
61	Huguenot	North	Osprey	-6.21	39.79	12	611	7	
62	Huguenot	North	Osprey	-11.84	21.43	11.4	612	7	x
63	Island, Bald	West	Bar Harbo	-0.5		NA	NA	NA	
64	Island, Bald	West	Bar Harbo	-4.6	38.3	19.3	622	11	x
65	Island, Bald	West	Bar Harbo	0.08	37.46	15.1	587	10	
66	Island, Bald	West	Bar Harbo	-7.71	32.65	15.2	250	17	
67	Island, Bar	West	COA	17.03		NA	NA	NA	
68	Island, Bar	West	COA	10.52	38.3	14.3	644	1	x
69	Island, Bar	West	COA	2.8	25.96	19.3	622	14	
70	Island, Bar	West	COA	-1.58	25.96	17.3	30	13	
71	Island, Long	West	Bar Harbo	0.55		NA	NA	NA	
72	Island, Long	West	Bar Harbo	-3.57	38.3	19.3	622	11	
73	Island, Long	West	Bar Harbo	1.03	37.46	15.1	587	10	x
74	Island, Sheep	West	Bar Harbo	6.53		NA	NA	NA	
75	Island, Sheep	West	Bar Harbo	-2.34	38.3	19.3	622	11	x
76	Island, Sheep	West	Bar Harbo	9.27	37.46	15.1	587	10	
77	Island, Sheep	West	Bar Harbo	-3.26	32.65	15.2	250	17	
78	McFarland	North	Carriage I	10.35		NA	NA	NA	
79	McFarland	North	Carriage I	5.66	25.71	14.3	644	2	
80	McFarland	North	Carriage I	14.7	35.26	20	625	8	
81	McFarland	North	Carriage I	13.23	30.27	9.3	604	5	x
82	McFarland	North	Carriage I	11.11	25.96	17.3	30	6	

	A	B	C	D	E	F	G	H	I	J
1	focalmounta	corr.aspect	location	aspect	direction	corr.direction	water exposu	loc.elev	foc.elev	d.elev
83	McFarland	North	Carriage	East	NA	NA	partial lake	260	720	460
84	McFarland	North	Carriage	East	NA	NA	partial lake	260	720	460
85	McFarland	North	Carriage	East	NA	NA	partial lake	260	720	460
86	McFarland	South	Pemetic	South	358	178	none	1220	720	-500
87	McFarland	South	Pemetic	South	NA	NA	none	1220	720	-500
88	McFarland	South	Pemetic	South	NA	NA	none	1220	720	-500
89	McFarland	South	Pemetic	South	NA	NA	none	1220	720	-500
90	Nbubble	North	Connors	North	196	16	partial lake	580	860	280
91	Nbubble	North	Connors	North	NA	NA	partial lake	580	860	280
92	Nbubble	North	Connors	North	NA	NA	partial lake	580	860	280
93	Nbubble	North	Connors	North	NA	NA	partial lake	580	860	280
94	Nbubble	South	Jordan	South	374	194	partial lake	280	860	580
95	Nbubble	South	Jordan	South	NA	NA	partial lake	280	860	580
96	Nbubble	South	Jordan	South	NA	NA	partial lake	280	860	580
97	Nbubble	South	Jordan	South	NA	NA	partial lake	280	860	580
98	Nbubble	South	Jordan	South	NA	NA	partial lake	280	860	580
99	Nbubble	West	Penobsco	West	NA	NA	none	1180	860	-320
100	Nbubble	West	Penobsco	West	46	226	none	1180	860	-320
101	Nbubble	West	Penobsco	West	NA	NA	none	1180	860	-320
102	Nbubble	West	Penobsco	West	NA	NA	none	1180	860	-320
103	Pemetic	North	Eagle	North	193	13	full lake	280	1220	940
104	Pemetic	North	Eagle	North	NA	NA	full lake	280	1220	940
105	Pemetic	North	Eagle	North	NA	NA	full lake	280	1220	940
106	Pemetic	North	Eagle	North	NA	NA	full lake	280	1220	940
107	Pemetic	North	Eagle	North	NA	NA	full lake	280	1220	940
108	Pemetic	West	Penobsco	West	108	288	full lake	1180	1220	40
109	Pemetic	West	Penobsco	West	NA	NA	full lake	1180	1220	40

	A	B	C	K	L	M	N	O	P	Q	R
1	focalmounta	corr.aspect	location	doy	date	rgratio	count	rmean	gmean	bmean	rsd
83	McFarland	North	Carriage	290	17-Oct	1.14	399869	95.7	84.22	64.84	26.18
84	McFarland	North	Carriage	301	28-Oct	1.23	400225	93.48	76.12	66.18	22.57
85	McFarland	North	Carriage	304	31-Oct	1.19	399943	108.71	91.38	86.18	23.68
86	McFarland	South	Pemetic	264	21-Sep	0.91	2035781	108.09	118.93	130.15	17.34
87	McFarland	South	Pemetic	279	6-Oct	0.89	2036619	95.82	107.77	114.59	15.97
88	McFarland	South	Pemetic	294	21-Oct	1.01	2034438	102.08	100.82	97.4	20.92
89	McFarland	South	Pemetic	302	29-Oct	1.01	2035002	103.84	102.73	103.42	18.98
90	Nbubble	North	Connors	263	20-Sep	0.99	5387035	114.14	115.46	84.76	31.69
91	Nbubble	North	Connors	276	3-Oct	1.02	5382474	103.99	102.38	88.93	30.53
92	Nbubble	North	Connors	290	17-Oct	1.03	5383515	84.62	82.39	73.93	35.66
93	Nbubble	North	Connors	304	31-Oct	1.01	5384603	103.59	102.08	94.01	27.45
94	Nbubble	South	Jordan	259	16-Sep	1.02	621354	113.9	111.43	106.35	22.98
95	Nbubble	South	Jordan	263	20-Sep	0.88	621656	96.63	109.67	113.77	18.31
96	Nbubble	South	Jordan	270	27-Sep	0.96	621636	102.94	107.3	104.58	22.73
97	Nbubble	South	Jordan	289	16-Oct	1.03	621880	87.3	84.71	87.49	20.54
98	Nbubble	South	Jordan	302	29-Oct	1.05	621102	104.43	98.99	99.11	25.64
99	Nbubble	West	Penobsco	259	16-Sep	1.06	1768571	106.33	99.9	87.94	32.95
100	Nbubble	West	Penobsco	271	28-Sep	1.09	1766551	113.63	104.09	89.69	37.52
101	Nbubble	West	Penobsco	289	16-Oct	1.03	1768125	103.33	99.88	94.51	26.1
102	Nbubble	West	Penobsco	301	28-Oct	1.02	1767180	80.32	79.1	76.44	27.23
103	Pemetic	North	Eagle	276	3-Oct	0.94	1425903	95.41	100.97	116.16	18.48
104	Pemetic	North	Eagle	290	17-Oct	0.96	1425683	94.24	98.06	115.83	24.4
105	Pemetic	North	Eagle	296	23-Oct	0.88	1426372	85.32	96.52	115.6	18.81
106	Pemetic	North	Eagle	301	28-Oct	0.89	1423905	65.96	74.45	94.05	11.9
107	Pemetic	North	Eagle	304	31-Oct	0.92	1425865	78.06	85.1	102.5	13.88
108	Pemetic	West	Penobsco	259	16-Sep	0.99	2281675	105.91	106.47	103.4	25.93
109	Pemetic	West	Penobsco	271	28-Sep	0.95	2282025	78.46	82.66	77.74	26.46

	A	B	C	S	T	U	V	W	X	Y	Z
1	focalmounta	corr.aspect	location	gsd	bsd	rmode	gmode	bmode	d.rmean	d.gmean	d.rgratio
83	McFarland	North	Carriage l	18.05	11.7	93	76	61	3.53	-7.07	-0.50
84	McFarland	North	Carriage l	17.05	14.71	92	69	62	-2.22	-8.1	0.27
85	McFarland	North	Carriage l	19.55	19	113	92	83	15.23	15.26	1.00
86	McFarland	South	Pemetic	13.9	12.53	110	122	136	NA	NA	NA
87	McFarland	South	Pemetic	12.28	12.85	98	115	124	-12.27	-11.16	1.10
88	McFarland	South	Pemetic	14.48	12.46	103	109	103	6.26	-6.95	-0.90
89	McFarland	South	Pemetic	11.53	13.44	116	109	109	1.76	1.91	0.92
90	Nbubble	North	Connors	27.82	20.99	106	110	77	NA	NA	NA
91	Nbubble	North	Connors	25.81	15.82	89	92	85	-10.15	-13.08	0.78
92	Nbubble	North	Connors	26.79	17.35	83	93	73	-19.37	-19.99	0.97
93	Nbubble	North	Connors	21.58	17.21	107	103	95	18.97	19.69	0.96
94	Nbubble	South	Jordan	16.58	15.87	111	108	101	NA	NA	NA
95	Nbubble	South	Jordan	13.29	12.76	90	107	110	-17.27	-1.76	9.81
96	Nbubble	South	Jordan	17.17	17.15	98	104	98	6.31	-2.37	-2.66
97	Nbubble	South	Jordan	13.37	12.55	72	80	84	-15.64	-22.59	0.69
98	Nbubble	South	Jordan	16.6	14.56	81	89	92	17.13	14.28	1.20
99	Nbubble	West	Penobsco	24.34	24.62	90	92	76	NA	NA	NA
100	Nbubble	West	Penobsco	30.34	31.7	95	94	73	7.3	4.19	1.74
101	Nbubble	West	Penobsco	19.78	9.81	88	92	84	-10.3	-4.21	2.45
102	Nbubble	West	Penobsco	22.98	20.8	72	74	65	-23.01	-20.78	1.11
103	Pemetic	North	Eagle	13.25	11.27	89	101	120	NA	NA	NA
104	Pemetic	North	Eagle	13.85	11.34	83	94	118	-1.17	-2.91	0.40
105	Pemetic	North	Eagle	14.49	12.57	80	92	113	-8.92	-1.54	5.79
106	Pemetic	North	Eagle	7.64	7.99	61	74	97	-19.36	-22.07	0.88
107	Pemetic	North	Eagle	10.54	10.46	74	85	105	12.1	10.65	1.14
108	Pemetic	West	Penobsco	19.05	19.29	97	105	99	NA	NA	NA
109	Pemetic	West	Penobsco	22.9	21.47	71	78	74	-27.45	-23.81	1.15

	A	B	C	AA	AB	AC	AD	AE	AF	AG	AH	AI
1	focalmounta	corr.aspect	location	corr.d.rgratio	rcc	gcc	sunrise	t.sunrise	rad.sunrise	noon	t.noon	rad.noon
83	McFarland	North	Carriage l	-0.17	0.39	0.34		2.5	72		10	517
84	McFarland	North	Carriage l	0.02	0.40	0.32		7.6	36		13.5	484
85	McFarland	North	Carriage l	0.33	0.38	0.32		8.6	30		13.1	477
86	McFarland	South	Pemetic	NA	0.30	0.33		15.4	21		20.3	679
87	McFarland	South	Pemetic	0.07	0.30	0.34		12.6	53		14.2	262
88	McFarland	South	Pemetic	-0.06	0.34	0.34		10.1	53		16.9	496
89	McFarland	South	Pemetic	0.12	0.33	0.33		12.1	21		15.5	370
90	Nbubble	North	Connors	NA	0.36	0.37	05:17	19	6	11:26	19.7	170
91	Nbubble	North	Connors	0.06	0.35	0.35		9.3	120		15.4	604
92	Nbubble	North	Connors	0.07	0.35	0.34		2.5	72		10	517
93	Nbubble	North	Connors	0.07	0.35	0.34		8.6	30		13.1	477
94	Nbubble	South	Jordan	NA	0.34	0.34	05:13	15.8	13	11:28	20.5	635
95	Nbubble	South	Jordan	2.45	0.30	0.34		19	6		19.7	170
96	Nbubble	South	Jordan	-0.38	0.33	0.34		17.6	13		24.5	602
97	Nbubble	South	Jordan	0.04	0.34	0.33		15.4	27		9.9	216
98	Nbubble	South	Jordan	0.09	0.35	0.33		12.1	21		15.5	370
99	Nbubble	West	Penobsco	NA	0.36	0.34		15.4	27		9.9	216
100	Nbubble	West	Penobsco	0.15	0.37	0.34	05:27	19.3	72	11:24	15.1	537
101	Nbubble	West	Penobsco	0.14	0.35	0.34		15.4	27		9.9	216
102	Nbubble	West	Penobsco	0.09	0.34	0.34		7.6	36		13.5	484
103	Pemetic	North	Eagle	NA	0.31	0.32		9.3	120		15.4	604
104	Pemetic	North	Eagle	0.03	0.31	0.32		2.5	72		10	517
105	Pemetic	North	Eagle	0.97	0.29	0.32		10.9	22		14.3	506
106	Pemetic	North	Eagle	0.18	0.28	0.32		7.6	36		13.5	484
107	Pemetic	North	Eagle	0.38	0.29	0.32		8.6	30		13.1	477
108	Pemetic	West	Penobsco	NA	0.34	0.34		15.8	13		20.5	635
109	Pemetic	West	Penobsco	0.10	0.33	0.35		19.3	72		15.1	537

	A	B	C	AJ	AK	AL	AM	AN	AO
1	focalmounta	corr.aspect	location	exg	prev.ozone	prev.t.sunris	prev.rad.noc	doy.interval	ran.interval
83	McFarland	North	Carriage l	-7.9	35.92	13	316	3	
84	McFarland	North	Carriage l	-7.42	26.17	2.5	517	11	
85	McFarland	North	Carriage l	-12.13	28.33	7.6	484	3	
86	McFarland	South	Pemetic	-0.38		NA	NA	NA	
87	McFarland	South	Pemetic	5.13	23.5	15.4	679	15	
88	McFarland	South	Pemetic	2.16	27.71	12.6	262	15	
89	McFarland	South	Pemetic	-1.8	32.79	10.1	496	8	x
90	Nbubble	North	Connors	32.02		NA	NA	NA	
91	Nbubble	North	Connors	11.84	14.63	19	170	13	
92	Nbubble	North	Connors	6.23	30.27	9.3	604	14	
93	Nbubble	North	Connors	6.56	26.17	2.5	517	14	
94	Nbubble	South	Jordan	2.61		NA	NA	NA	
95	Nbubble	South	Jordan	8.94	26.17	15.8	635	4	
96	Nbubble	South	Jordan	7.08	14.63	19	170	7	x
97	Nbubble	South	Jordan	-5.37	24.5	17.6	602	19	
98	Nbubble	South	Jordan	-5.56	24.08	15.4	216	13	
99	Nbubble	West	Penobsco	5.53		NA	NA	NA	
100	Nbubble	West	Penobsco	4.86	26.16	15.4	216	12	x
101	Nbubble	West	Penobsco	1.92	22.89	19.3	537	18	
102	Nbubble	West	Penobsco	1.44	24.08	15.4	216	12	
103	Pemetic	North	Eagle	-9.63		NA	NA	NA	
104	Pemetic	North	Eagle	-13.95	30.27	9.3	604	14	
105	Pemetic	North	Eagle	-7.88	26.17	2.5	517	6	x
106	Pemetic	North	Eagle	-11.11	36.67	10.9	506	5	
107	Pemetic	North	Eagle	-10.36	28.33	7.6	484	3	
108	Pemetic	West	Penobsco	3.63		NA	NA	NA	
109	Pemetic	West	Penobsco	9.12	26.17	15.8	635	12	x

	A	B	C	D	E	F	G	H	I	J
1	focalmounta	corr.aspect	location	aspect	direction	corr.direction	water exposu	loc.elev	foc.elev	d.elev
110	<i>Pemetic</i>	<i>West</i>	<i>Penobsco</i>	<i>West</i>	NA	NA	full lake	1180	1220	40
111	<i>Pemetic</i>	<i>West</i>	<i>Penobsco</i>	<i>West</i>	NA	NA	full lake	1180	1220	40
112	<i>Penobsco</i>	<i>East</i>	<i>Pemetic</i>	<i>East</i>	288	108	full lake	1220	1180	-40
113	<i>Penobsco</i>	<i>East</i>	<i>Pemetic</i>	<i>East</i>	NA	NA	full lake	1220	1180	-40
114	<i>Penobsco</i>	<i>East</i>	<i>Pemetic</i>	<i>East</i>	NA	NA	full lake	1220	1180	-40
115	<i>Penobsco</i>	<i>East</i>	<i>Pemetic</i>	<i>East</i>	NA	NA	full lake	1220	1180	-40
116	<i>Penobsco</i>	<i>North</i>	<i>Sargent</i>	<i>North</i>	169	349	none	1280	1180	-100
117	<i>Penobsco</i>	<i>North</i>	<i>Sargent</i>	<i>North</i>	NA	NA	none	1280	1180	-100
118	<i>Penobsco</i>	<i>North</i>	<i>Sargent</i>	<i>North</i>	NA	NA	none	1280	1180	-100
119	<i>Penobsco</i>	<i>North</i>	<i>Sargent</i>	<i>North</i>	NA	NA	none	1280	1180	-100
120	<i>Sargent</i>	<i>East</i>	<i>Pemetic</i>	<i>East</i>	306	126	none	1220	1280	60
121	<i>Sargent</i>	<i>East</i>	<i>Pemetic</i>	<i>East</i>	NA	NA	none	1220	1280	60
122	<i>Sargent</i>	<i>East</i>	<i>Pemetic</i>	<i>East</i>	NA	NA	none	1220	1280	60
123	<i>Sargent</i>	<i>East</i>	<i>Pemetic</i>	<i>East</i>	NA	NA	none	1220	1280	60
124	<i>Sargent</i>	<i>South</i>	<i>Penobsco</i>	<i>South</i>	NA	NA	none	1180	1280	100
125	<i>Sargent</i>	<i>South</i>	<i>Penobsco</i>	<i>South</i>	NA	NA	none	1180	1280	100
126	<i>Sargent</i>	<i>South</i>	<i>Penobsco</i>	<i>South</i>	348	168	none	1180	1280	100
127	<i>Sargent</i>	<i>South</i>	<i>Penobsco</i>	<i>South</i>	NA	NA	none	1180	1280	100
128	<i>Sbubble</i>	<i>North</i>	<i>Nbubble</i>	<i>North</i>	172	352	none	860	740	-120
129	<i>Sbubble</i>	<i>North</i>	<i>NBubble</i>	<i>North</i>	NA	NA	none	860	740	-120
130	<i>Sbubble</i>	<i>North</i>	<i>NBubble</i>	<i>North</i>	NA	NA	none	860	740	-120
131	<i>Sbubble</i>	<i>North</i>	<i>Nbubble</i>	<i>North</i>	NA	NA	none	860	740	-120
132	<i>Sbubble</i>	<i>South</i>	<i>Jordan</i>	<i>South</i>	374	194	full lake	280	740	460
133	<i>Sbubble</i>	<i>South</i>	<i>Jordan</i>	<i>South</i>	NA	NA	full lake	280	740	460
134	<i>Sbubble</i>	<i>South</i>	<i>Jordan</i>	<i>South</i>	NA	NA	full lake	280	740	460
135	<i>Sbubble</i>	<i>South</i>	<i>Jordan</i>	<i>South</i>	NA	NA	full lake	280	740	460
136	<i>Sbubble</i>	<i>South</i>	<i>Jordan</i>	<i>South</i>	NA	NA	full lake	280	740	460

	A	B	C	K	L	M	N	O	P	Q	R
1	focalmounta	corr.aspect	location	doy	date	rgratio	count	rmean	gmean	bmean	rsd
110	<i>Pemetic</i>	<i>West</i>	<i>Penobsco</i>	289	16-Oct	0.97	2281793	64.26	65.97	65.49	21.99
111	<i>Pemetic</i>	<i>West</i>	<i>Penobsco</i>	301	28-Oct	0.90	2281085	47.75	52.93	59.92	20.85
112	<i>Penobsco</i>	<i>East</i>	<i>Pemetic</i>	264	21-Sep	0.86	2933965	71.98	84.11	93.56	23.03
113	<i>Penobsco</i>	<i>East</i>	<i>Pemetic</i>	279	6-Oct	1.03	2932517	82.69	80.53	75.52	25.96
114	<i>Penobsco</i>	<i>East</i>	<i>Pemetic</i>	294	21-Oct	1.21	2933016	68.94	57.12	50.25	24.42
115	<i>Penobsco</i>	<i>East</i>	<i>Pemetic</i>	302	29-Oct	1.05	2933169	70.22	67	67.73	21.89
116	<i>Penobsco</i>	<i>North</i>	<i>Sargent</i>	263	20-Sep	0.85	1234343	82.08	96.01	96	43.51
117	<i>Penobsco</i>	<i>North</i>	<i>Sargent</i>	271	28-Sep	0.97	1233578	72.62	75.04	59.08	39.49
118	<i>Penobsco</i>	<i>North</i>	<i>Sargent</i>	289	16-Oct	0.98	1232730	59.63	60.85	52.2	24.98
119	<i>Penobsco</i>	<i>North</i>	<i>Sargent</i>	301	28-Oct	0.89	1234541	56.63	63.73	61.24	25.17
120	<i>Sargent</i>	<i>East</i>	<i>Pemetic</i>	264	21-Sep	0.94	1838879	125.71	133.91	142.2	34.93
121	<i>Sargent</i>	<i>East</i>	<i>Pemetic</i>	279	6-Oct	1.03	1835113	117.93	113.97	106.79	29.05
122	<i>Sargent</i>	<i>East</i>	<i>Pemetic</i>	294	21-Oct	1.12	1835153	108.5	96.73	86.34	24.12
123	<i>Sargent</i>	<i>East</i>	<i>Pemetic</i>	302	29-Oct	1.05	1828231	99.83	94.88	95.59	26.33
124	<i>Sargent</i>	<i>South</i>	<i>Penobsco</i>	259	16-Sep	1.04	2139363	74.11	71	60.16	29.67
125	<i>Sargent</i>	<i>South</i>	<i>Penobsco</i>	271	28-Sep	1.04	2138460	62.97	66.87	59.09	31.09
126	<i>Sargent</i>	<i>South</i>	<i>Penobsco</i>	289	16-Oct	1.04	2138615	99.65	92.52	77.52	32.35
127	<i>Sargent</i>	<i>South</i>	<i>Penobsco</i>	301	28-Oct	1.04	2136367	84.45	77.17	69.15	33.94
128	<i>Sbubble</i>	<i>North</i>	<i>Nbubble</i>	263	20-Sep	0.99	1030265	97.36	98.23	88.41	23.99
129	<i>Sbubble</i>	<i>North</i>	<i>NBubble</i>	276	3-Oct	0.93	1028661	58.69	63.26	52.76	24.18
130	<i>Sbubble</i>	<i>North</i>	<i>NBubble</i>	290	17-Oct	1.03	953588	61.64	59.68	50.62	24.61
131	<i>Sbubble</i>	<i>North</i>	<i>Nbubble</i>	304	31-Oct	1.03	1029843	61.09	59.31	57.27	14.37
132	<i>Sbubble</i>	<i>South</i>	<i>Jordan</i>	259	16-Sep	1.03	1183378	105.88	102.58	90.99	25.18
133	<i>Sbubble</i>	<i>South</i>	<i>Jordan</i>	263	20-Sep	0.91	1183197	94.36	103.5	100.37	22.7
134	<i>Sbubble</i>	<i>South</i>	<i>Jordan</i>	270	27-Sep	0.96	1184294	95.65	99.15	91.24	26.91
135	<i>Sbubble</i>	<i>South</i>	<i>Jordan</i>	289	16-Oct	1.08	1183724	83.09	77.12	74.01	23.76
136	<i>Sbubble</i>	<i>South</i>	<i>Jordan</i>	302	29-Oct	1.13	1184517	104.15	92.51	86.37	26.52

	A	B	C	S	T	U	V	W	X	Y	Z
1	focalmounta	corr.aspect	location	gsd	bsd	rmode	gmode	bmode	d.rmean	d.gmean	d.rgratio
110	Pemetic	West	Penobsco	14.82	14.28	53	59	59	-14.2	-16.69	0.85
111	Pemetic	West	Penobsco	14.71	12.24	32	46	54	-16.51	-13.04	1.27
112	Penobsco	East	Pemetic	20.97	20.88	66	85	99	NA	NA	NA
113	Penobsco	East	Pemetic	19.66	20.31	72	76	70	10.71	-3.58	-2.99
114	Penobsco	East	Pemetic	18.13	16.96	62	54	43	-13.75	-23.41	0.59
115	Penobsco	East	Pemetic	7.7	17.68	80	78	79	1.28	9.88	0.13
116	Penobsco	North	Sargent	36.05	36.3	58	78	73	NA	NA	NA
117	Penobsco	North	Sargent	35.35	36.43	65	68	45	-9.46	-20.97	0.45
118	Penobsco	North	Sargent	22.65	24.52	50	52	43	-12.99	-14.19	0.92
119	Penobsco	North	Sargent	23.93	26.75	52	59	47	-3	2.88	-1.04
120	Sargent	East	Pemetic	28.69	22.48	93	150	159	NA	NA	NA
121	Sargent	East	Pemetic	23.83	24.19	111	108	97	-7.78	-19.94	0.39
122	Sargent	East	Pemetic	20.44	20.68	99	88	76	-9.43	-17.24	0.55
123	Sargent	East	Pemetic	21.98	20.99	103	88	93	-8.67	-1.85	4.69
124	Sargent	South	Penobsco	25.47	25.87	67	66	49	NA	NA	NA
125	Sargent	South	Penobsco	28.1	25.32	62	69	45	-11.14	-4.13	2.70
126	Sargent	South	Penobsco	28.13	30.18	85	84	63	36.68	25.65	1.43
127	Sargent	South	Penobsco	30.62	31.19	87	68	62	-15.2	-15.35	0.99
128	Sbubble	North	Nbubble	22.31	20.23	96	93	83	NA	NA	NA
129	Sbubble	North	NBubble	21.96	14.86	55	59	46	-38.67	-34.97	1.11
130	Sbubble	North	NBubble	9.62	16.32	59	61	43	2.95	-3.58	-0.82
131	Sbubble	North	Nbubble	12.05	10.01	55	55	55	-0.55	-0.37	1.49
132	Sbubble	South	Jordan	18.97	17.39	105	103	87	NA	NA	NA
133	Sbubble	South	Jordan	17.66	14.89	89	104	97	-11.52	0.92	-12.52
134	Sbubble	South	Jordan	21.33	19.95	94	99	86	1.29	-4.35	-0.30
135	Sbubble	South	Jordan	15.85	14.36	66	74	69	-12.56	-22.03	0.57
136	Sbubble	South	Jordan	18.99	18.01	89	92	80	21.06	15.39	1.37

	A	B	C	AA	AB	AC	AD	AE	AF	AG	AH	AI
1	focalmounta	corr.aspect	location	corr.d.rgratio	rcc	gcc	sunrise	t.sunrise	rad.sunrise	noon	t.noon	rad.noon
110	Pemetic	West	Penobsco	0.05	0.33	0.34		15.4	27		9.9	216
111	Pemetic	West	Penobsco	0.11	0.30	0.33		7.6	36		13.5	484
112	Penobsco	East	Pemetic	NA	0.29	0.34		15.4	21		20.3	679
113	Penobsco	East	Pemetic	-0.20	0.35	0.34		12.6	53		14.2	262
114	Penobsco	East	Pemetic	0.04	0.39	0.32		10.1	53		16.9	496
115	Penobsco	East	Pemetic	0.02	0.34	0.33		12.1	21		15.5	370
116	Penobsco	North	Sargent	NA	0.30	0.35		19	6		19.7	170
117	Penobsco	North	Sargent	0.06	0.35	0.36		19.3	72		15.1	537
118	Penobsco	North	Sargent	0.05	0.35	0.35		15.4	27		9.9	216
119	Penobsco	North	Sargent	-0.09	0.31	0.35		7.6	36		13.5	484
120	Sargent	East	Pemetic	NA	0.31	0.33		15.4	21		20.3	679
121	Sargent	East	Pemetic	0.03	0.35	0.34		12.6	53		14.2	262
122	Sargent	East	Pemetic	0.04	0.37	0.33		10.1	53		16.9	496
123	Sargent	East	Pemetic	0.59	0.34	0.33		12.1	21		15.5	370
124	Sargent	South	Penobsco	NA	0.36	0.35		15.8	13		20.5	635
125	Sargent	South	Penobsco	0.22	0.33	0.35		19.3	72		15.1	537
126	Sargent	South	Penobsco	0.08	0.37	0.34		15.4	27		9.9	216
127	Sargent	South	Penobsco	0.08	0.37	0.33		7.6	36		13.5	484
128	Sbubble	North	Nbubble	NA	0.34	0.35		19	6		19.7	170
129	Sbubble	North	NBubble	0.09	0.34	0.36		9.3	120		15.4	604
130	Sbubble	North	NBubble	-0.06	0.36	0.35		2.5	72		10	517
131	Sbubble	North	Nbubble	0.11	0.34	0.33		8.6	30		13.1	477
132	Sbubble	South	Jordan	NA	0.35	0.34		15.8	13		20.5	635
133	Sbubble	South	Jordan	-3.13	0.32	0.35		19	6		19.7	170
134	Sbubble	South	Jordan	-0.04	0.33	0.35		17.6	13		24.5	602
135	Sbubble	South	Jordan	0.03	0.35	0.33		15.4	27		9.9	216
136	Sbubble	South	Jordan	0.11	0.37	0.33		12.1	21		15.5	370

	A	B	C	AJ	AK	AL	AM	AN	AO
1	focalmounta	corr.aspect	location	exg	prev.ozone	prev.t.sunris	prev.rad.noc	doy.interval	ran.interval
110	<i>Pemetic</i>	<i>West</i>	<i>Penobsco</i>	2.19	22.89	19.3	537	18	
111	<i>Pemetic</i>	<i>West</i>	<i>Penobsco</i>	-1.81	24.08	15.4	216	12	
112	<i>Penobsco</i>	<i>East</i>	<i>Pemetic</i>	2.68		NA	NA	NA	
113	<i>Penobsco</i>	<i>East</i>	<i>Pemetic</i>	2.85	23.5	15.4	679	15	
114	<i>Penobsco</i>	<i>East</i>	<i>Pemetic</i>	-4.95	27.71	12.6	262	15	
115	<i>Penobsco</i>	<i>East</i>	<i>Pemetic</i>	-3.95	32.79	10.1	496	8	x
116	<i>Penobsco</i>	<i>North</i>	<i>Sargent</i>	13.94		NA	NA	NA	
117	<i>Penobsco</i>	<i>North</i>	<i>Sargent</i>	18.38	14.63	19	170	8	x
118	<i>Penobsco</i>	<i>North</i>	<i>Sargent</i>	9.87	22.89	19.3	537	18	
119	<i>Penobsco</i>	<i>North</i>	<i>Sargent</i>	9.59	24.08	15.4	216	12	
120	<i>Sargent</i>	<i>East</i>	<i>Pemetic</i>	-0.09		NA	NA	NA	
121	<i>Sargent</i>	<i>East</i>	<i>Pemetic</i>	3.22	23.5	15.4	679	15	
122	<i>Sargent</i>	<i>East</i>	<i>Pemetic</i>	-1.38	27.71	12.6	262	15	
123	<i>Sargent</i>	<i>East</i>	<i>Pemetic</i>	-5.66	32.79	10.1	496	8	x
124	<i>Sargent</i>	<i>South</i>	<i>Penobsco</i>	7.73		NA	NA	NA	
125	<i>Sargent</i>	<i>South</i>	<i>Penobsco</i>	11.68	26.17	15.8	635	12	x
126	<i>Sargent</i>	<i>South</i>	<i>Penobsco</i>	7.87	22.89	19.3	537	18	
127	<i>Sargent</i>	<i>South</i>	<i>Penobsco</i>	0.74	24.08	15.4	216	12	
128	<i>Sbubble</i>	<i>North</i>	<i>Nbubble</i>	10.69		NA	NA	NA	
129	<i>Sbubble</i>	<i>North</i>	<i>NBubble</i>	15.07	14.63	19	170	13	
130	<i>Sbubble</i>	<i>North</i>	<i>NBubble</i>	7.1	30.27	9.3	604	14	
131	<i>Sbubble</i>	<i>North</i>	<i>Nbubble</i>	0.26	26.17	2.5	517	14	
132	<i>Sbubble</i>	<i>South</i>	<i>Jordan</i>	8.29		NA	NA	NA	
133	<i>Sbubble</i>	<i>South</i>	<i>Jordan</i>	12.27	26.17	15.8	635	4	x
134	<i>Sbubble</i>	<i>South</i>	<i>Jordan</i>	11.41	14.63	19	170	7	
135	<i>Sbubble</i>	<i>South</i>	<i>Jordan</i>	-2.86	24.5	17.6	602	19	
136	<i>Sbubble</i>	<i>South</i>	<i>Jordan</i>	-5.5	24.08	15.4	216	13	

	A	B	C	D	E	F	G	H	I	J
1	focalmounta	corr.aspect	location	aspect	direction	corr.direction	water exposu	loc.elev	foc.elev	d.elev
137	<i>Sbubble</i>	<i>West</i>	<i>Penobsco</i>	<i>West</i>	80	260		1180	740	-440
138	<i>Sbubble</i>	<i>West</i>	<i>Penobsco</i>	<i>West</i>	NA	NA		1180	740	-440
139	<i>Sbubble</i>	<i>West</i>	<i>Penobsco</i>	<i>West</i>	NA	NA		1180	740	-440
140	<i>White Cap</i>	<i>West</i>	<i>Connors</i>	<i>West</i>	75	255		580	900	320
141	<i>White Cap</i>	<i>West</i>	<i>Connors</i>	<i>West</i>	NA	NA		580	900	320
142	<i>White Cap</i>	<i>West</i>	<i>Connors</i>	<i>West</i>	NA	NA		580	900	320

	A	B	C	K	L	M	N	O	P	Q	R
1	focalmounta	corr.aspect	location	doy	date	rgratio	count	rmean	gmean	bmean	rsd
137	<i>Sbubble</i>	<i>West</i>	<i>Penobsco</i>	271	28-Sep	0.99	2430707	114.42	115.53	102.01	34.58
138	<i>Sbubble</i>	<i>West</i>	<i>Penobsco</i>	289	16-Oct	1.01	2426945	100.28	99.66	96.65	24.74
139	<i>Sbubble</i>	<i>West</i>	<i>Penobsco</i>	301	28-Oct	1.01	2426456	72.14	71.48	72.82	28.67
140	<i>White Cap</i>	<i>West</i>	<i>Connors</i>	276	3-Oct	1.07	3069116	88.78	82.78	74.94	27.41
141	<i>White Cap</i>	<i>West</i>	<i>Connors</i>	290	17-Oct	1.09	3061094	98.01	89.7	82.32	28.97
142	<i>White Cap</i>	<i>West</i>	<i>Connors</i>	304	31-Oct	1.04	3068163	96.03	92.72	89.02	33.5

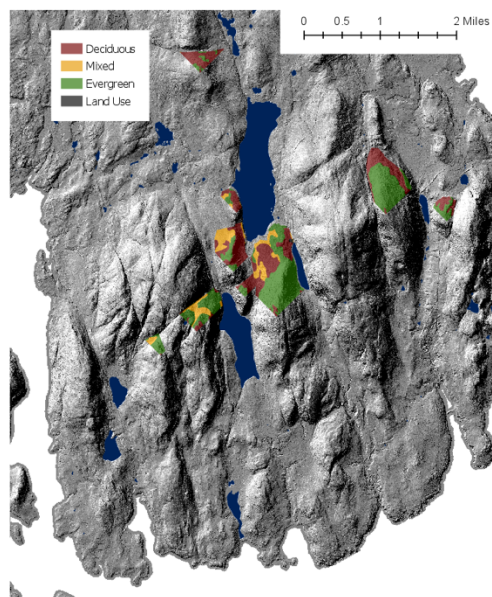
	A	B	C	S	T	U	V	W	X	Y	Z
1	focalmounta	corr.aspect	location	gsd	bsd	rmode	gmode	bmode	d.rmean	d.gmean	d.rgratio
137	<i>Sbubble</i>	<i>West</i>	<i>Penobsco</i>	28.84	31.84	104	112	88	NA	NA	NA
138	<i>Sbubble</i>	<i>West</i>	<i>Penobsco</i>	19.86	19.12	95	94	90	-14.14	-15.87	0.89
139	<i>Sbubble</i>	<i>West</i>	<i>Penobsco</i>	23.4	20.22	64	68	63	-28.14	-28.18	1.00
140	<i>White Cap</i>	<i>West</i>	<i>Connors</i>	21	16.32	91	84	75	NA	NA	NA
141	<i>White Cap</i>	<i>West</i>	<i>Connors</i>	20.17	17.72	90	89	80	9.23	6.92	1.33
142	<i>White Cap</i>	<i>West</i>	<i>Connors</i>	25.2	20.78	94	97	83	-1.98	3.02	-0.66

	A	B	C	AA	AB	AC	AD	AE	AF	AG	AH	AI
1	focalmounta	corr.aspect	location	corr.d.rgratio	rcc	gcc	sunrise	t.sunrise	rad.sunrise	noon	t.noon	rad.noon
137	<i>Sbubble</i>	<i>West</i>	<i>Penobsco</i>	NA	0.34	0.35		19.3	72		15.1	537
138	<i>Sbubble</i>	<i>West</i>	<i>Penobsco</i>	0.05	0.34	0.34		15.4	27		9.9	216
139	<i>Sbubble</i>	<i>West</i>	<i>Penobsco</i>	0.08	0.33	0.33		7.6	36		13.5	484
140	<i>White Cap</i>	<i>West</i>	<i>Connors</i>	NA	0.36	0.34		9.3	120		15.4	604
141	<i>White Cap</i>	<i>West</i>	<i>Connors</i>	0.10	0.36	0.33		2.5	72		10	517
142	<i>White Cap</i>	<i>West</i>	<i>Connors</i>	-0.05	0.35	0.33		8.6	30		13.1	477

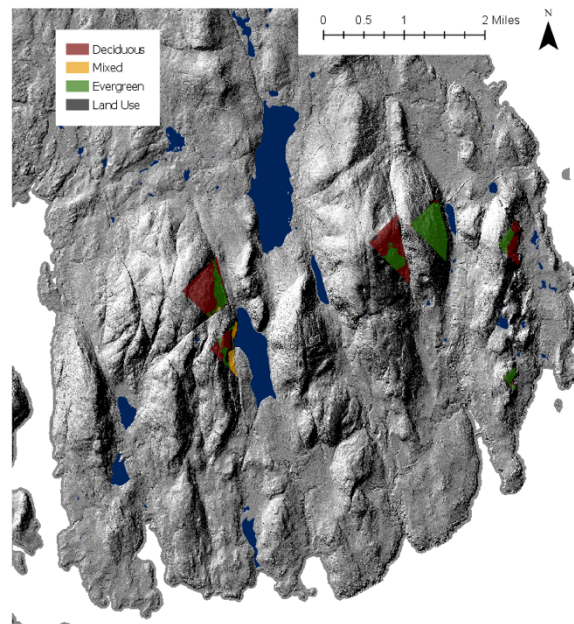
	A	B	C	AJ	AK	AL	AM	AN	AO
1	focalmounta	corr.aspect	location	exg	prev.ozone	prev.t.sunris	prev.rad.noc	doy.interval	ran.interval
137	<i>Sbubble</i>	<i>West</i>	<i>Penobsco</i>	14.63		NA	NA	NA	
138	<i>Sbubble</i>	<i>West</i>	<i>Penobsco</i>	2.39	22.89	19.3	537	18	
139	<i>Sbubble</i>	<i>West</i>	<i>Penobsco</i>	-2	24.08	15.4	216	12	x
140	<i>White Cap</i>	<i>West</i>	<i>Connors</i>	1.84		NA	NA	NA	
141	<i>White Cap</i>	<i>West</i>	<i>Connors</i>	-0.93	30.27	9.3	604	14	
142	<i>White Cap</i>	<i>West</i>	<i>Connors</i>	0.39	26.17	2.5	517	14	

Appendix E: Maps of vegetation on mountain faces

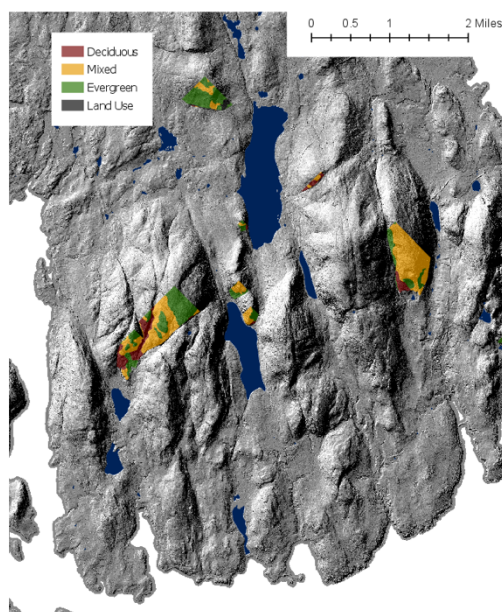
North faces



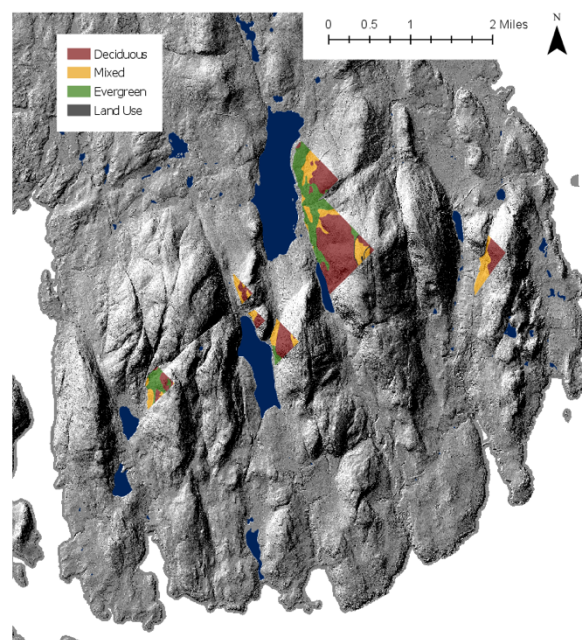
East faces



South faces



West faces



Appendix E: Vegetation maps

Appendix F: Posters associated with this project

I presented my project at two conferences during the time I was working on it. This appendix contains reformatted versions of each poster presented, followed by the citation of the conference where I presented.



Research in Progress

Investigating cardinal direction and landscape scale color change

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Introduction

Autumn leaf color change remains a botanical mystery—one proposal is that the synthesis of pigments protects the leaf as it degrades chlorophyll and exports sugars. In this study I am examining how color change is associated with differences in light intensity. Because of solar declination, cardinal direction affects light received by individual plants. If a correlation is shown, this may suggest that leaf color change adapted to combat UV and light stress.

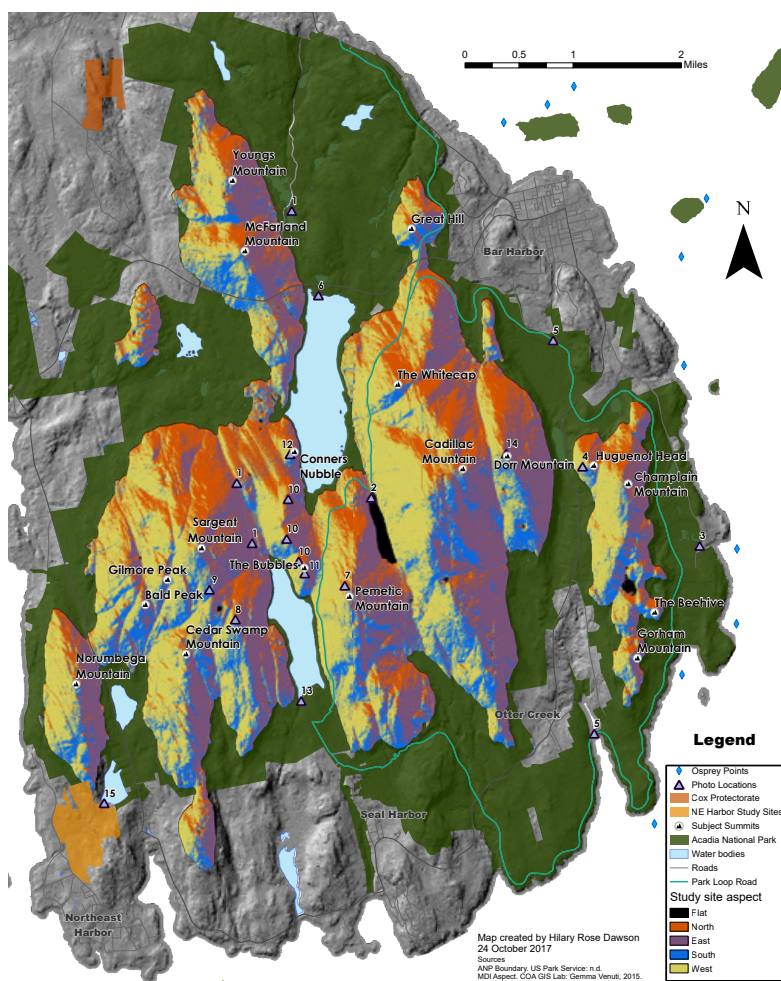


Figure 1. Study Site Locations on Mount Desert Island. Purple triangles indicate where mountain aspects are photographed from, blue triangles approximate the path taken by COA's research vessel M/V Osprey and possible aspects photographed. Photo location key: 1. Carriage Road, 2. Bubble Pond, 3. Schooner Head, 4. Huguenot Head, 5. Park Loop Road, 6. Eagle Lake, 7. Pemetic Mtn., 8. Penobscot Mtn., 9. Sargent Mtn., 10. North Bubble, 11. South Bubble, 12. Connors Nubble, 13. Jordan Pond, 14. Dorr Mtn., 15. Hadlock Pond

Study Sites Mountain Aspect Photography

Hypotheses

- Leaves change earlier on the south than the north if this phenomenon adapted to combat UV and light stress.
- Leaves change earlier on the east than the west if this phenomenon adapted to combat cold temperatures during autumn.

Method

- Regularly photograph 35 mountain aspects and 15 island aspects (**figures 1, 2**)
- Analyze photographs using Image J software (Schindelin et al. 2015)
- Test for a correlation between mountain aspect and timing of leaf color change on a population scale

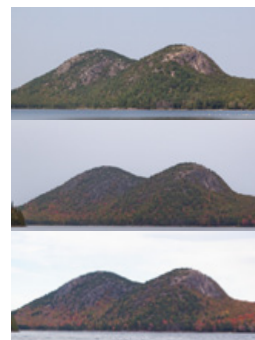


Figure 2. Example photographs of the Bubbles from Jordan Pond. Top to bottom, 16 Sep 2017, 6 Oct 2017, and 16 Oct 2017

UAS Photography

Method

- Regularly photograph tree crowns on Cox Protectorate using a Phantom 3 Standard (DJI, Shenzhen) (example in **figure 3**)
- Identify individual trees and compare photographs to monitor leaf color change

Outcome

The logistics of coordinating the UAS flights proved unmanageable and this method was discontinued as part of this project. This method has promise for future studies if weather and schedule conflicts can be managed.



Figure 3. UAS photograph taken on Cox Protectorate using a DJI Phantom 3 Standard from 50m height.



Figure 4. *Gaylussacia baccata* leaves (left) and a girdled branch (right).

Gaylussacia baccata Girdling

Hypothesis

Girdling involves stripping a branch of outer bark and inner cambium, interrupting nutrient flow. Murakami et al. (2008) found that branch girdling increases sugar concentration in *Acer saccharum*, a change which has been shown to affect anthocyanin expression. By girdling *G. baccata* branches, I can observe how abiotic stress affects leaf color change.

Methods

- Girdle 40 *G. baccata* individuals on Northeast Harbor conservation lands (methods modified from Murakami et al. (2008)) (**figure 4**)
- Collect and freeze two leaves from each individual (one control, one experimental) every week
- Record temperature using iButtons (Maxim Integrated, San Jose) and light levels using a light meter
- Test leaves for anthocyanin levels and sugar levels

Preliminary observations

Light may be the most correlated with an increase in anthocyanin production in girdled *G. baccata*.

Acknowledgements

The authors would like to thank Professor Graeme Ruxton, Jill Weber, Dr. Susan Letcher for their invaluable input; Captain Toby Stephenson for use of the Osprey; Douglas McMullin, Maine Coast Heritage Trust, and the Town of Mt Desert for use of conservation land; and Gordon Longworth, Gemma Venuti, and the COA GIS Lab for their assistance with UAS. This study operates under Acadia National Park permit #ACAD-2017-SCI-0082.

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- Murakami, P.F., et al., 2008. Stem girdling manipulates leaf sugar concentrations and anthocyanin expression in sugar maple trees during autumn. *Tree Physiol*, 28(10).
- Schindelin, J., et al., 2015. The ImageJ ecosystem: An open platform for biomedical image analysis. *Mol Reprod Dev*, 82(7-8).

Citation

Dawson, H.R. and S. Morse. 2017. Investigating cardinal direction and landscape scale color change. Poster presented at the Science Symposium at COA. College of the Atlantic, Bar Harbor, Maine, USA. October 27.

Correlations in Autumn Leaf Color Change and Cardinal Direction



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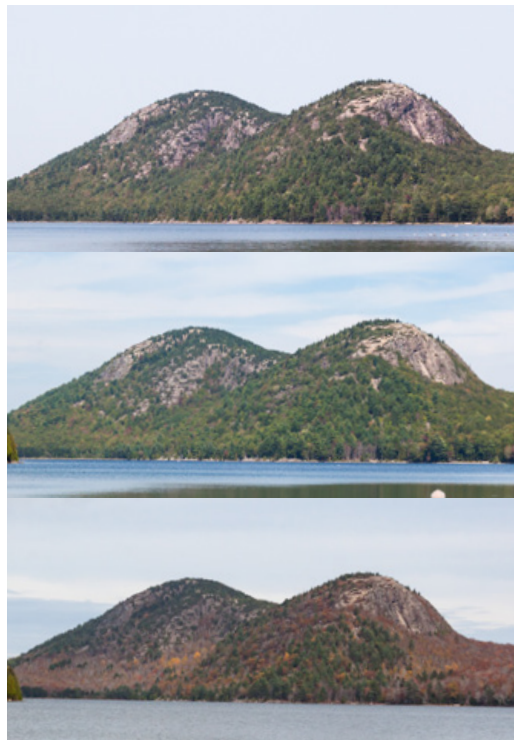


Figure 1. Example of repeat photography with south faces of the Bubbles from Jordan Pond taken on 16 Sep, 27 Sep, and 29 Oct 2017. Images have been edited for printing.

Introduction

Autumn leaf coloration was tracked through repeat photography of Maine mountains in September to November 2017. Preliminary results suggest that the cardinal direction of slopes correlates with timing of leaf color change. These correlations may relate to the abilities of anthocyanins to protect against temperature and UV light damage. Factors affecting the correlations include hydrology, water exposure, and vegetation. Preliminary analysis also suggest that dawn temperatures had a significant effect on the ratio of red to green with higher ratios associated with colder temperatures. Together, these results encourage future research in autumn leaf color change to explore the protective role of anthocyanins.

Methods

- Regularly photograph 31 mountain faces and 4 island faces (**figure 1**) on Mount Desert Island, Hancock County, Maine
- Compile photographs in Adobe Photoshop and use Color Match tool to adjust for weather and lighting differences
- Analyze photographs using ImageJ software (Schindelin et al. 2015)
- Process photograph data in R (R core team 2017)

Future research

- Use a PhenoCam network and localized weather stations to gather more regular data (Sonnentag et al. 2012).
- Surveys to better understand “mixed” vegetation on western faces.

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Results

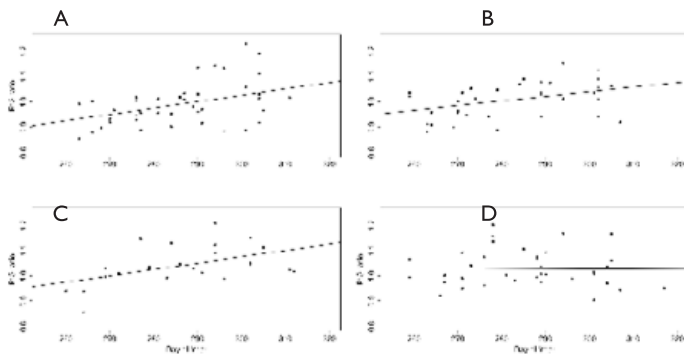


Figure 2. Redness compared to greenness for each direction during autumn 2017 (A: north, B: south, C: east, D: west). Day of year spans 259 (16 September) to 317 (13 November). Each point represents the red:green ratio of a single photograph (black circle = north, purple diamond = south, green circle = east, red triangle = west). Change in redness varied significantly between the four faces when controlling for day of year (mixed effect ANOVA, $P = 0.027$).

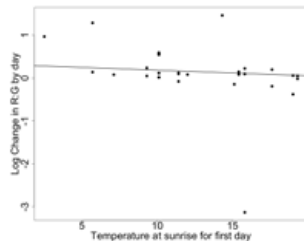


Figure 4. Correlation of change in red:green ratio compared to sunrise temperature. Data points were calculated from change in ratio over a period of days no greater than twelve days. Sunrise temperature was measured on the first day of the interval. Correlation was significant (Kendall-Theil Sen nonparametric linear regression, $n = 30$, $P < 0.0001$).

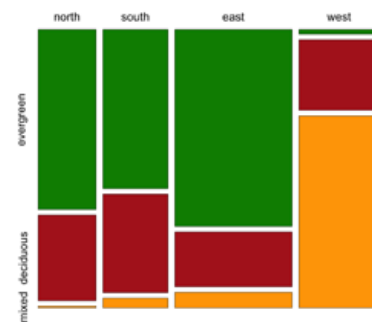


Figure 3. Habitat area by mountain face. Band width represents proportion of the total. Calculations were made in ArcPro (ESRI) using the MDI vegetation layer created by Lubinski *et al.* (2003). Vegetation type (evergreen, deciduous, mixed) was classified using the GIS layer created by Lubinski *et al.* (2003).

Red:green ratio over time

- Western faces change at a significantly different rate than other slopes which increase red to green ratio over time (**figure 2**).

Why western faces?

Hydrology

- Western faces have significantly less available water than east and south faces according to a flow accumulation model (X^2 goodness-of-fit test, $X^2 = 33.46$, $df = 3$, $n = 4$, $P < 0.0001$).

Water exposure

- No significant effect of water exposure on red:green ratio when controlling for the fixed effect of day of year and random effect of focal mountain (ANCOVA, $P = 0.427$).

Vegetation

- Western faces had significantly more mixed vegetation than other faces (**figure 3**, X^2 contingency test, $X^2 = 778.16$, $df = 6$, $n = 35$, $P < 0.0001$)
- Western faces change at a significantly different rate than other slopes which increase red to green ratio over time (**figure 2**).

Dawn temperature correlation

- Correlation significant but only slight variation (**figure 4**).

Citation

Dawson, H.R. 2018. Correlations in autumn leaf color change and cardinal direction. Poster presented at the 2018 Northeast Natural History Conference. Burlington, Vermont, USA. April 13-15.