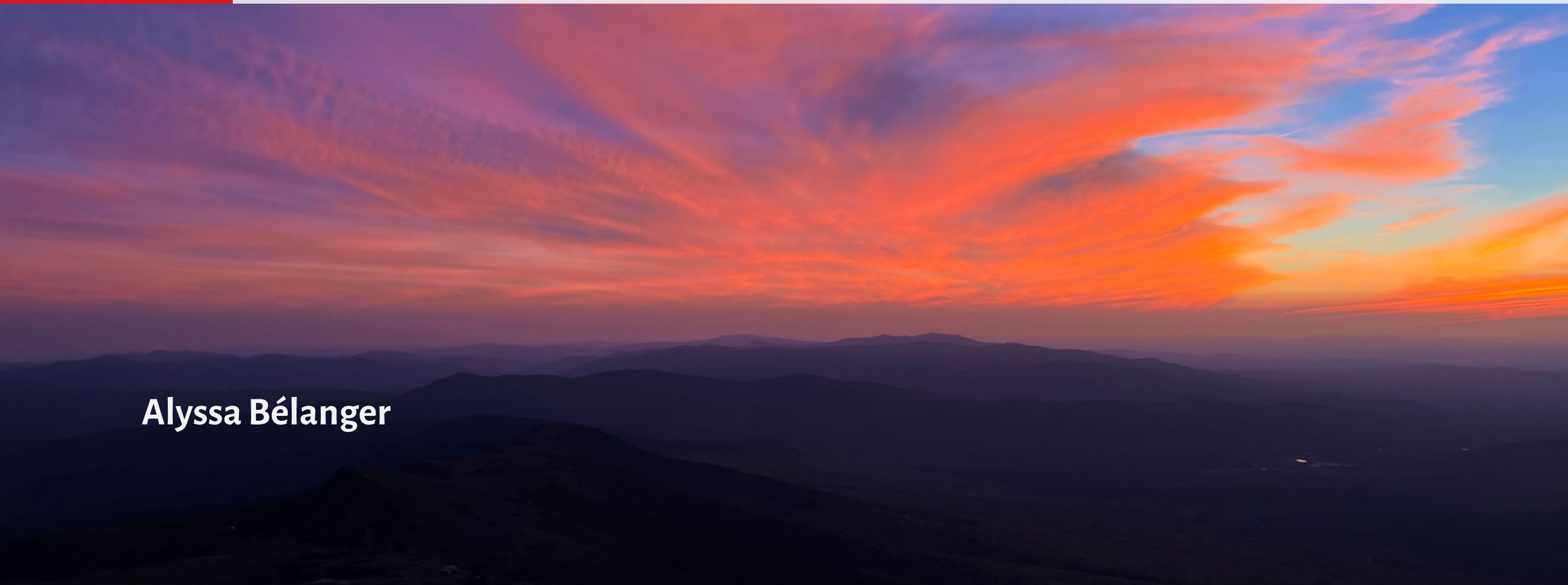
Anthocyanins and the PhenoCam Network: This Red Pigment as the Key to Predicting Fall Foliage



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Introduction

Why are anthocyanins important and how can the PhenoCam Network help identify when peak foliage occurs?

TASKS:

- Provide a literature review on anthocyanins
  - What roles do they play
  - Motivation for future examination of them
- Lay the groundwork for analyzing data from the PhenoCam Network
- Determine how well PhenoCam's data predicts peak foliage

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Introduction

Refresher on senescence and what are anthocyanins?

SENESCENCE AND NUTRIENT RESORPTION:

- Leaves go through an annual death where chlorophyll degrades, revealing yellow pigments
- Red pigments, like anthocyanins, are produced in the leaf rather than present year-round (Lee et al., 2003)
- A goal of the tree is to resorb as many nutrients from the leaves as it can before the leaves fall off (Lee et al., 2003)

Anthocyanins:

- One of the red pigments in leaves
- Their function is not entirely understood
- Possible properties that aid in this nutrient resorption

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Introduction

Anthocyanins

Anthocyanins (a red pigment) likely have properties that aid in nutrient resorption through a photoprotection role

Possible Photoprotection Properties:

- Antioxidants (Tsuda et al., 1994)
  - Scavenge damaging free radicals from photooxidation (Lee et al., 2003)
- Extended: free radicals can disrupt nutrient flow (Lee et al., 2003)
- Protect photosynthetic apparatus from photoinhibition (Hoch et al., 2001)
  - Need apparatus functioning for nutrient resorption

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Introduction

The PhenoCam Network

Phenocams are used to observe vegetation at over 700 sites

- Running since 2008
- Focused on understanding the effects of meteorological factors and climate change on vegetation and ecosystems
- Images at each site are taken every 15 minutes to an hour in the same direction
- Green chromatic coordinate (GCC) and RCC (red chromatic coordinate)
  - How they measure “greenness” or “redness”
- Available to the public!
  - Images as well as provisional data

(Northern Arizona University, Perkins, and Richardson)

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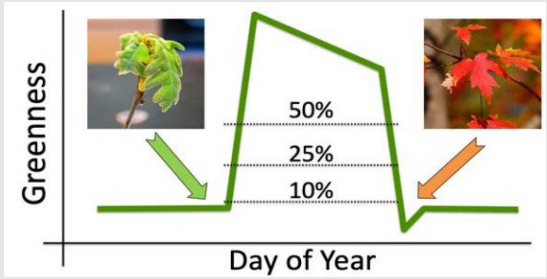
Methods

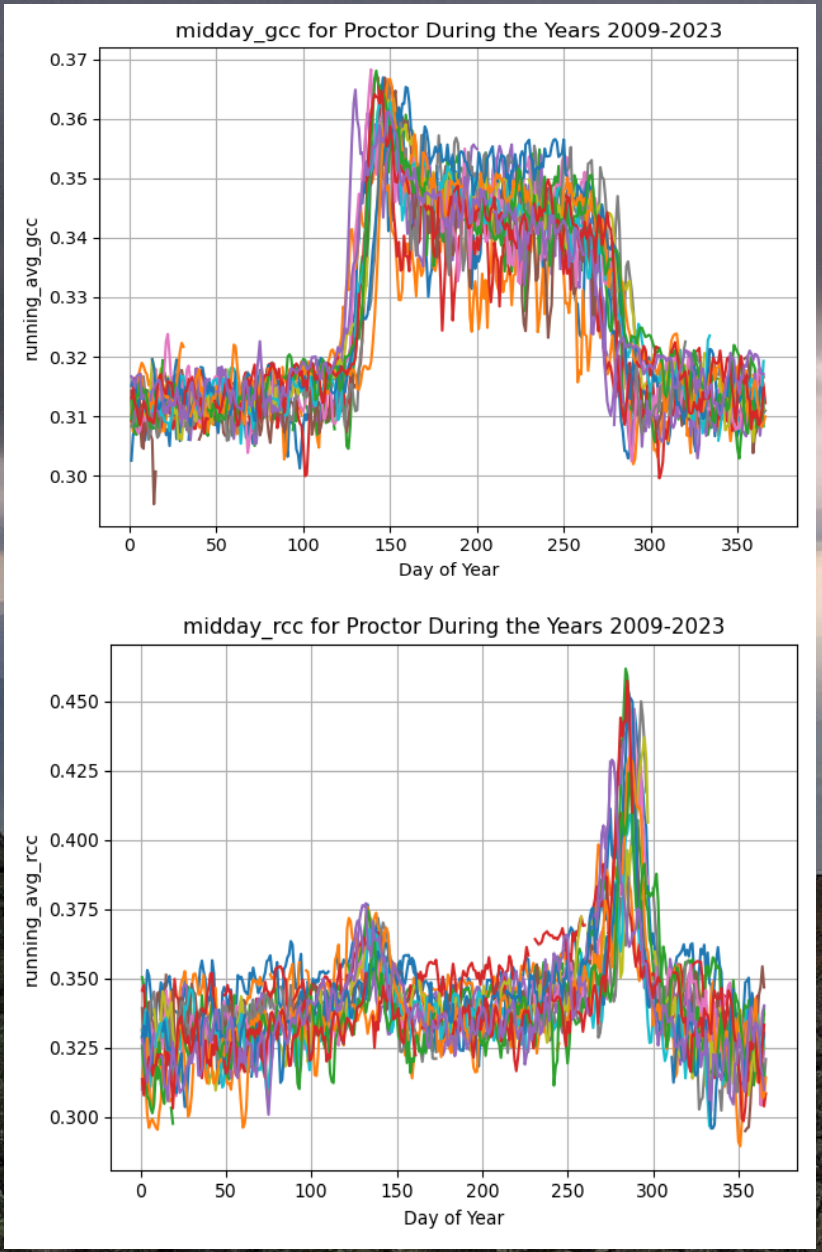
Data from PhenoCam Network

(Northern Arizona University, Perkins, and Richardson)

- Site: proctor at Proctor Maple Research Center in Vermont
  - 15 years of data (2009-2023)
  - Site has masks (bottom left figure) – area of data processing
- Downloaded provisional data from the site including midday_gcc and midday_rcc and uploaded to Python for analysis
- Calculated a three-day running average on both midday gcc and rcc to smooth out some wiggles
- Performed two visual assessments on images from each year to determine subjective dates of peak color
  - These served as the standard to which to compare peak coloration dates from PhenoCam's data
- Analyzed gcc and rcc data including…
  - Similar trends in both from year to year?
  - Testing different thresholds for each*
    - Calculated proportion of gcc and rcc
  - Visualizing how the different methods of determining peak foliage compare



Results



Verifying that GCC and RCC have similar trends for each year

There's variability, but similar

- Plotting the three-day running averages for gcc and rcc values all together exemplifies that the years are comparable
- GCC starts to increase during leaf-out in the spring, peaks near the end of May, stays steady, then declines around September
- RCC is low most of the year except for a jump around leaf-out and the peak between mid-September and end of October

Three-day average for midday GCC and RCC. Each colored line represents a year. Day 150 is May 30th, day 200 is July 19th, day 250 is September 7th, day 300 is October 27th, day 350 is December 16th. The range for GCC and RCC is the y-axis.

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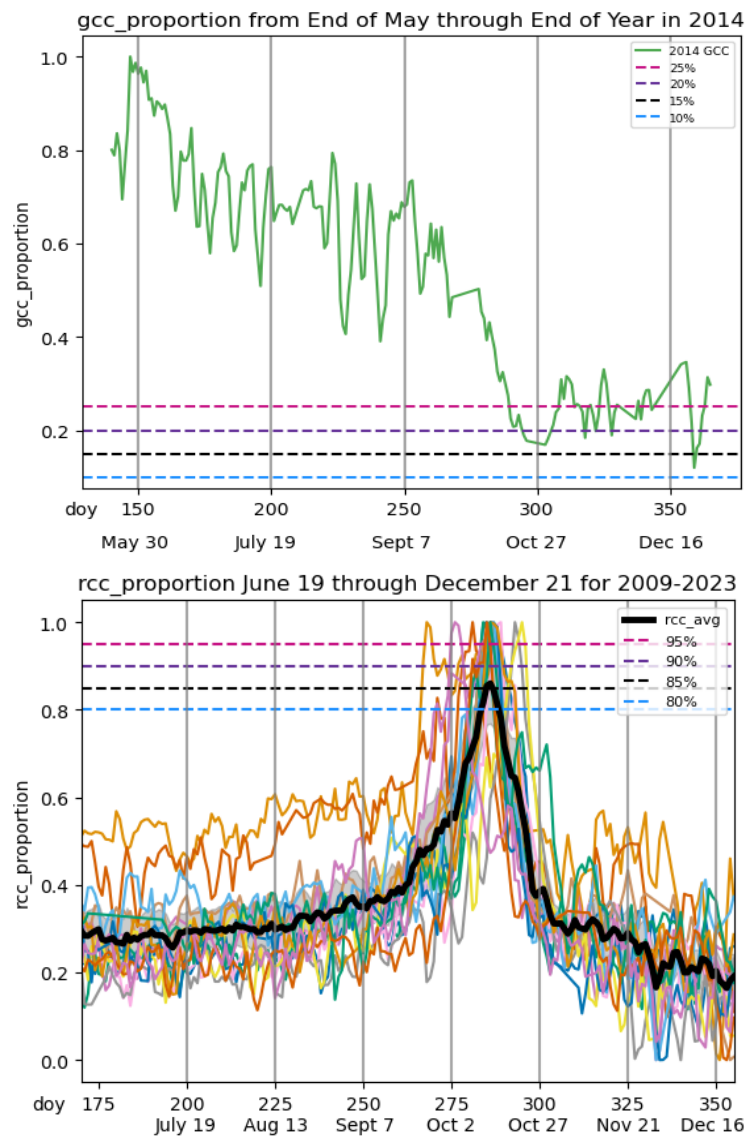
Results



What thresholds to use

- Different years were examined to see where the GCC and RCC proportion crossed certain thresholds
- GCC: experimented with 10% (PhenoCam's), 15%, 20%, and 25%
  - 10% is not accurate for all years, ex. 2014
- RCC: tested 80%, 85%, 90%, and 95%
  - Most proportion lines cross around 85 or 90
  - Consulted table of visual analysis dates to choose, even though both would have been fine

20% for GCC and 90% for RCC

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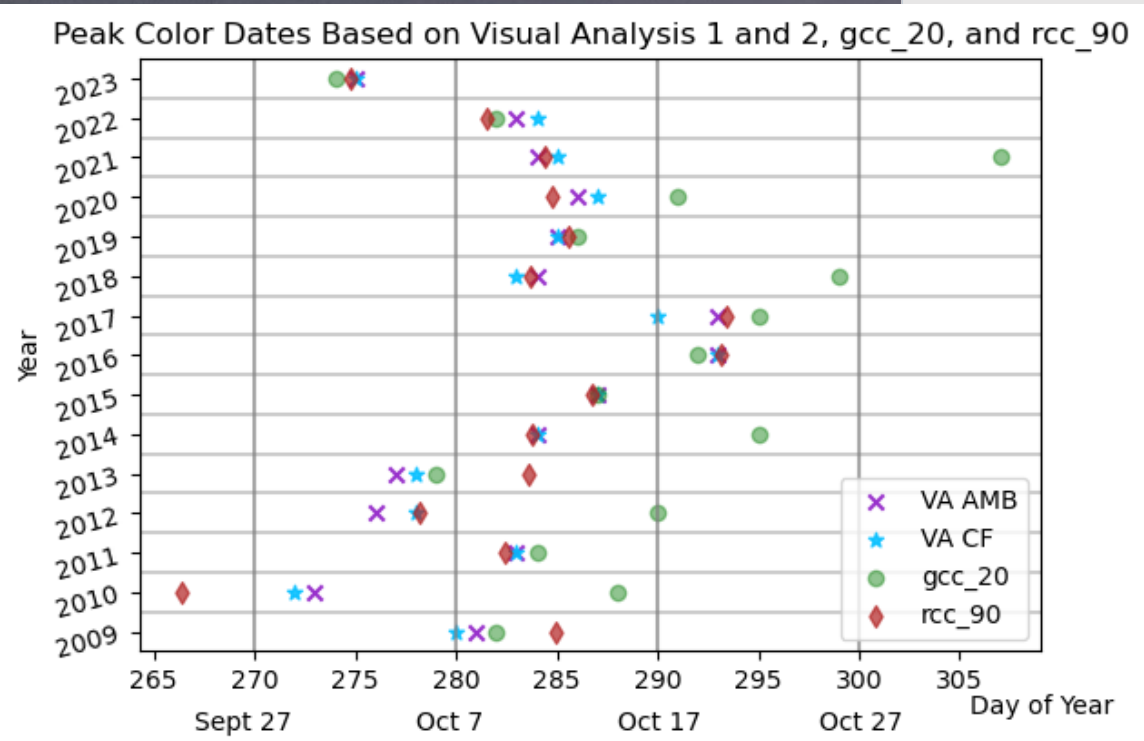
Results

How well peak foliage dates obtained from GCC_20 and RCC_90 compare to visual



year	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
visual analysis amb	10/08	09/30	10/10	10/02	10/04	10/11	10/14	10/19	10/20	10/11	10/12	10/12	10/11	10/10	10/02
visual analysis cf	10/07	09/29	10/10	10/04	10/05	10/11	10/14	10/19	10/17	10/10	10/12	10/13	10/12	10/11	10/02
gcc_20	10/09	10/15	10/11	10/16	10/06	10/22	10/14	10/18	10/22	10/26	10/13	10/17	11/03	10/09	10/01
rcc_90	10/11	09/24	10/10	10/05	10/10	10/11	10/14	10/19	10/19	10/11	10/12	10/11	10/13	10/08	10/02

Comparing all four methods of acquiring dates of peak

- Lot of information, let's step through
- First takeaway – dates using GCC_20 have a wider variability and is less close to dates using visual analyses
- Second – RCC_90 dates are better! But not perfect
- Overall: concluded that RCC is a better indicator of when maximum coloration occurs

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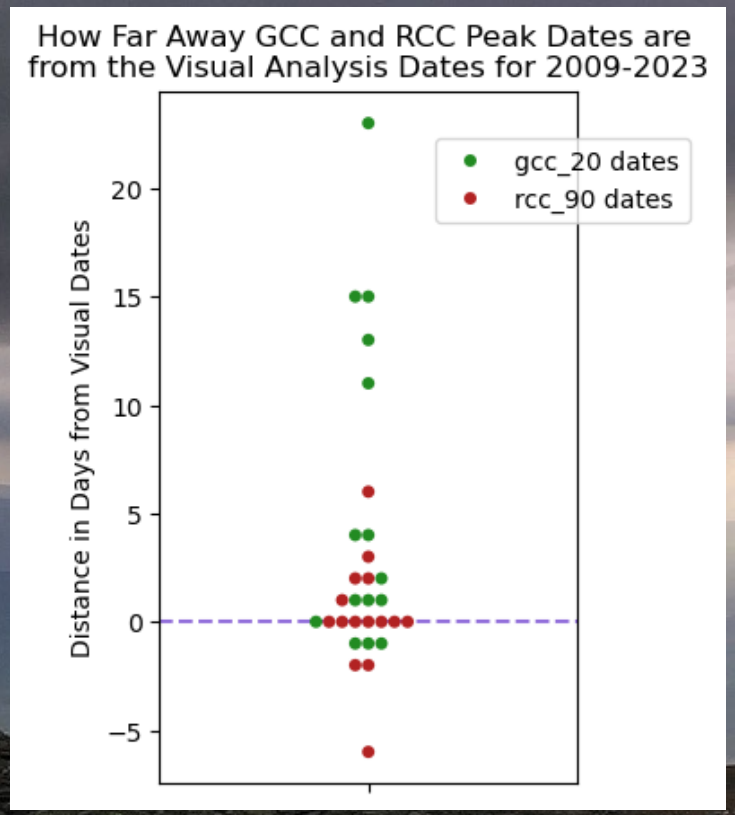
Results



How well peak foliage dates obtained from GCC_20 and RCC_90 compare to visual

Using RCC is more accurate than GCC

- Another way to visualize, showing similar data
- Y=0 line denotes the average visual analysis dates
- Green points are dates obtained from GCC_20, red points from RCC_90 dates
- Points are plotted as how far away they are from the visual analysis date of that year
- Standard deviation
  - GCC 7.59
  - RCC 2.63
- Overall: RCC more closely matches peak dates from visual assessments

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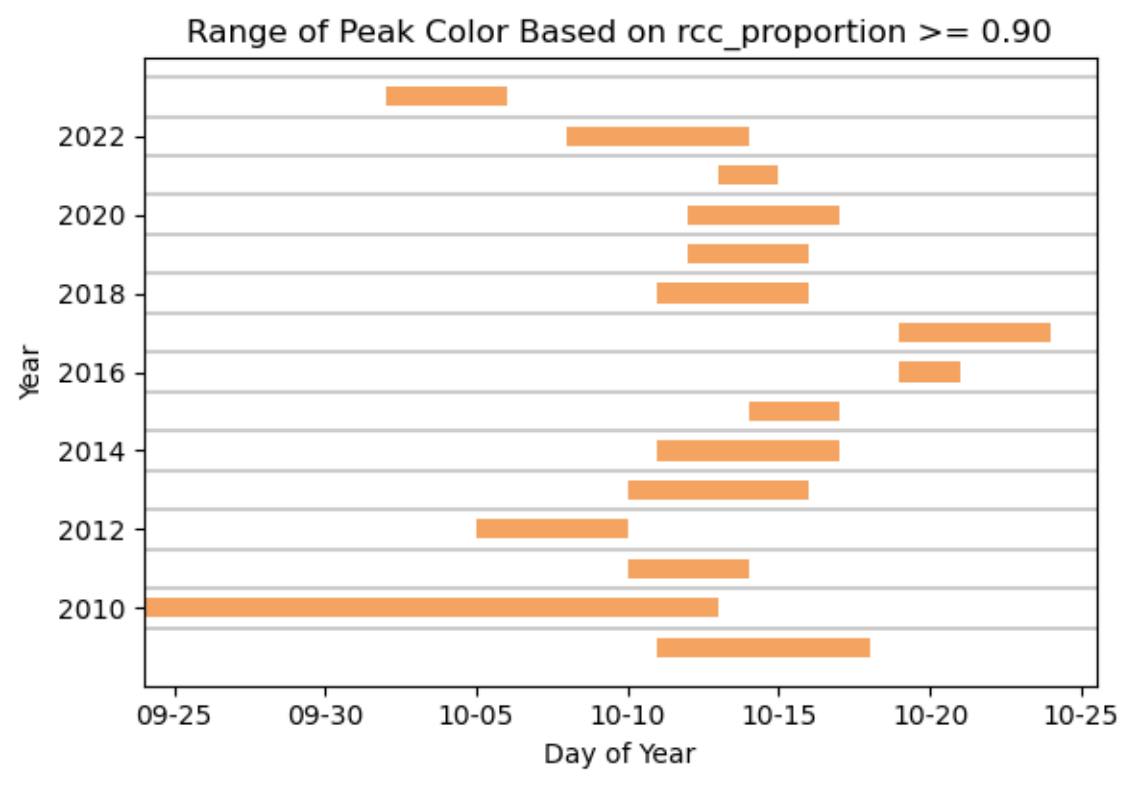
Results



What else can we learn using data from the PhenoCam Network?

Acquiring a range of peak foliage

- Here, when the proportion of RCC was greater than or equal to 0.90 was used to pull the "range"
  - Other thresholds could be used!
- This method gave a wide range year to year and of varying lengths
- Subjectivity: this is a quantitative measure of how long peak lasts, but this will vary from person to person
- Overall: interesting technique to play with in the future and to which to compare data from future years

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Conclusions

To Recap:

- Anthocyanins have properties that can aid in the nutrient resorption of a tree and protect against light damage
- Using a 10% threshold for GCC to determine the date of peak coloration is too low (especially when not doing a curve fit)
- RCC is a better indicator of fall foliage
- This led to many ideas…

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Future Work

ANTHOCYANINS:

- **Measuring anthocyanins directly rather than assumption that RCC is close enough**
- More exploration with drought and other meteorological factors
- **Which of their aforementioned roles is most dominant? A combination?**
- **Sugars as an indicator for anthocyanin production (Schaberg et al. 2003)**

PHENOCAM NETWORK DATA AND RCC:

- More phenocams near Mount Washington
  - Auto road, base, cog railway
- RCC data with a curve fit – more accuracy?
- Range of peak coloration – test different thresholds
- Compare near-surface observations to satellite remote sensing – verify and improve satellite data
- Look at more sites!

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Acknowledgements

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Thank you to my shift who saw me struggle and kept encouraging me

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Thank You!

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