

Haleakalā Viewing Conditions for Space Observations

Richy Peterson

Background

- Haleakalā one of best locations in the world for space observations
 - Location: Maui, HI
 - Elevation: 10,023 ft



- The AF's 3.6 m optical telescope is the largest in the DoD



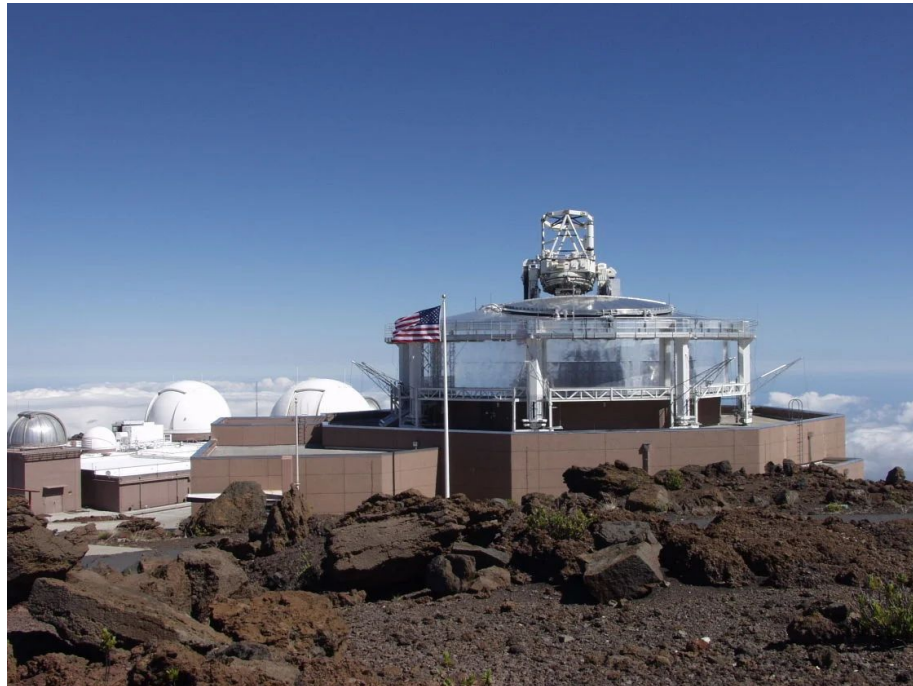
Motivation

- Researchers travel to Maui for collection campaigns
- Telescope operations are dependant on weather conditions
 - Green - all weather conditions meet thresholds
 - Yellow - operations permitted, degraded performance
 - Red - no operations



Motivation

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Does one month have more 'Green Weather' hours than the others?

Pre-Processing the Data

The Institute for Astronomy (IfA) archived weather data from 1994-2019

- Not all measurements available each year
- Recorded data switched from 10 min averages to raw measurements in 2006

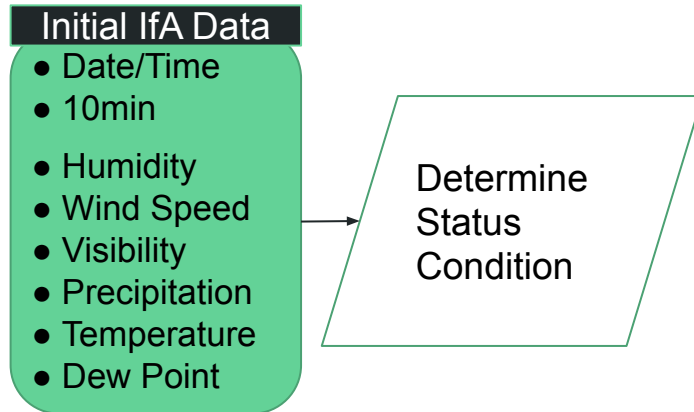
Initial IfA Data

- Date/Time
- 10min
- Humidity
- Wind Speed
- Visibility
- Precipitation
- Temperature
- Dew Point

Pre-Processing the Data

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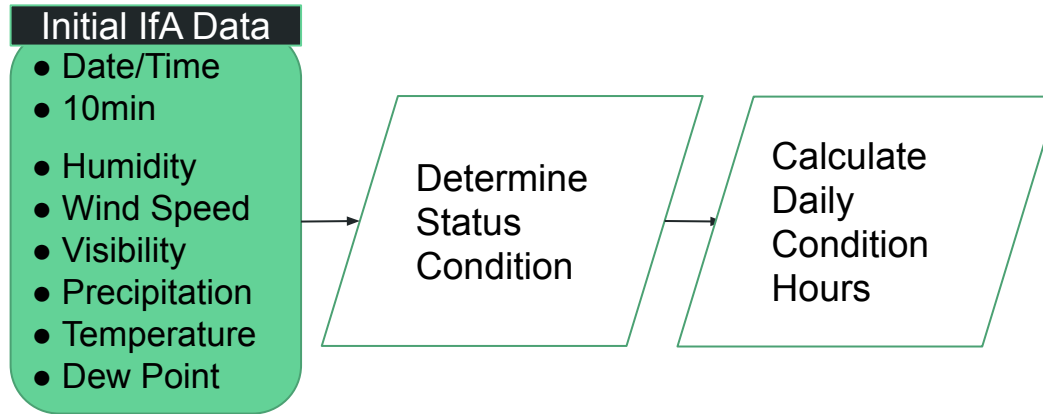
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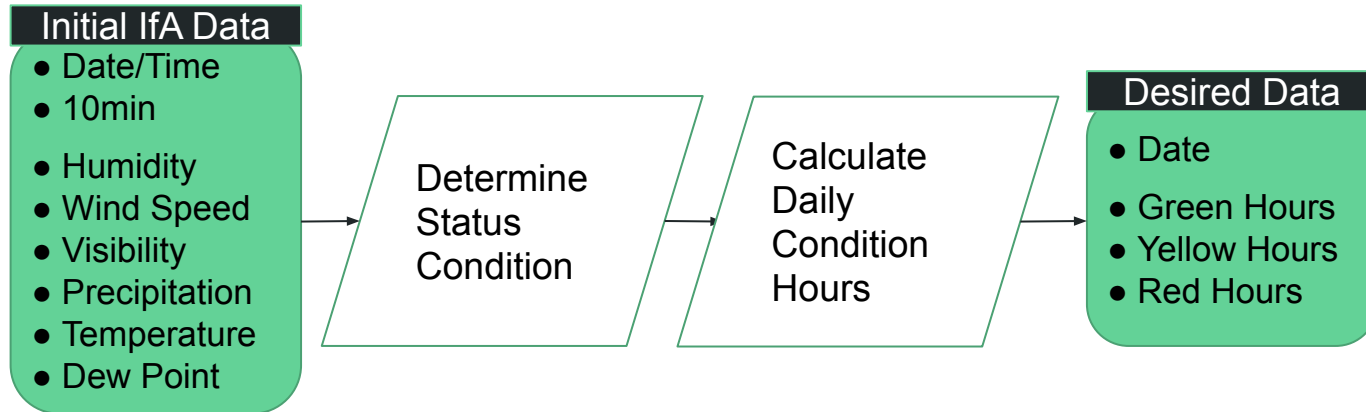
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Pre-Processing the Data

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EDA

Weather Status Condition Requirements:

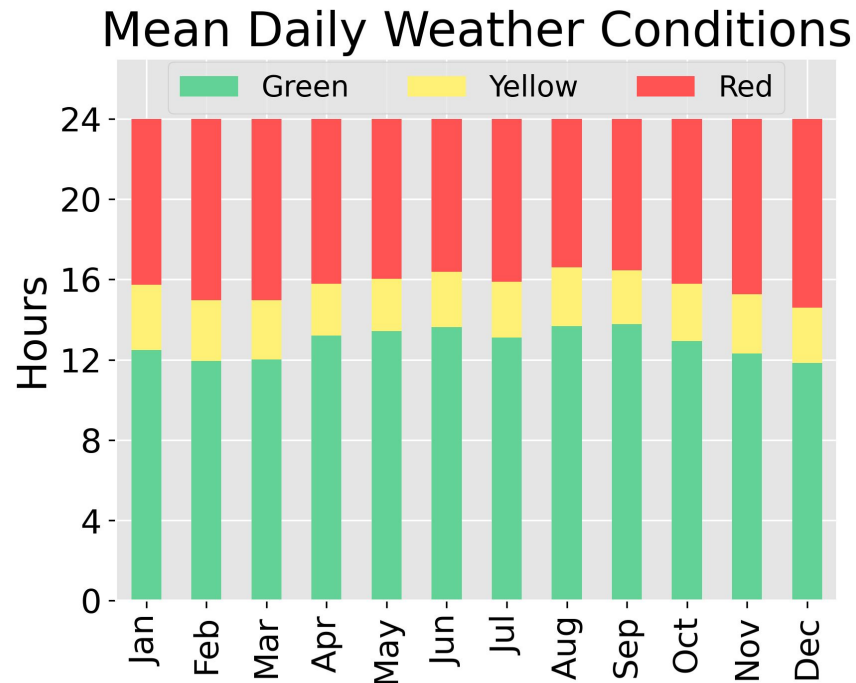
Green: All weather aspect measurements meet green threshold values

Yellow: Any weather aspect measurement not green, but none are red

Red: Any weather aspect measurement exceeds red threshold value

Highest Mean Green Weather:
Sep: 13.8 hours/day

Lowest Mean Green Weather:
Dec: 11.9 hours/day



Hypothesis Test

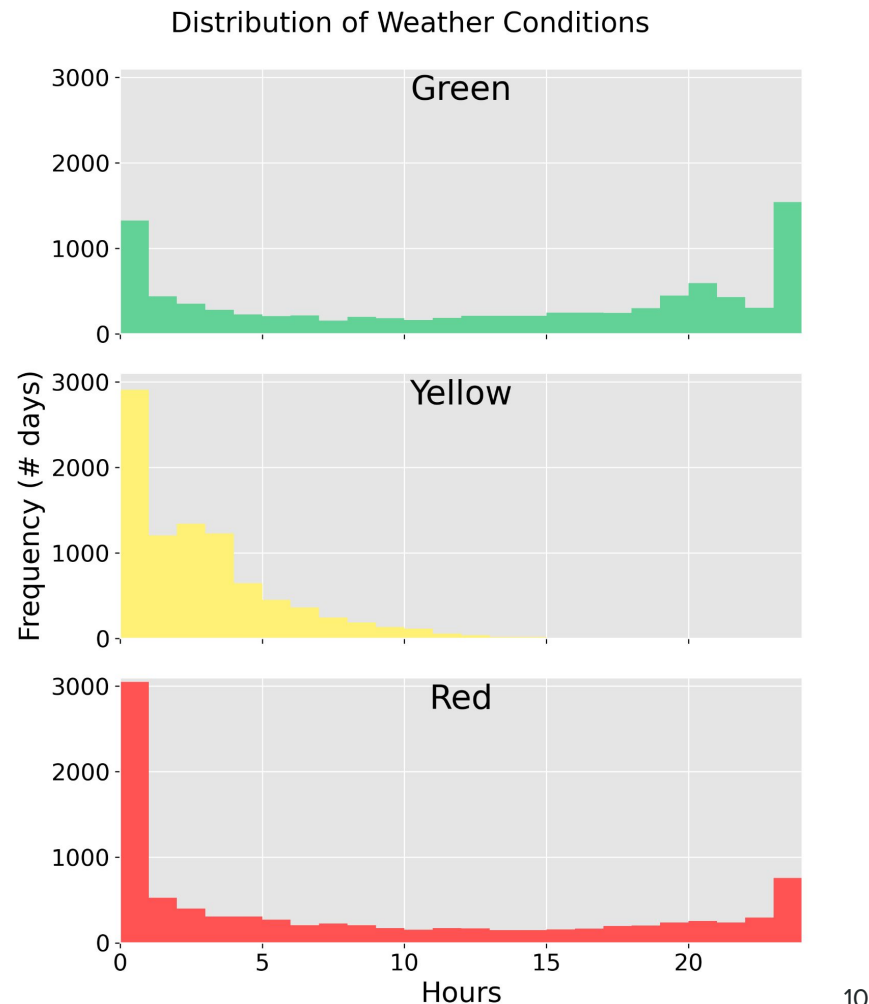
Null - There is no significant difference between the daily hours of green weather each month.

Alternates - There is a significant difference between any combination of months.
(66 combinations)

Alpha = 0.05

Bonferroni Correction $\Rightarrow 0.0008$

Used Mann-Whitney U test because data did not follow any type of distribution.



Results

Summary of significant results (p value < 0.0008) listed below. Complete results in appendix.

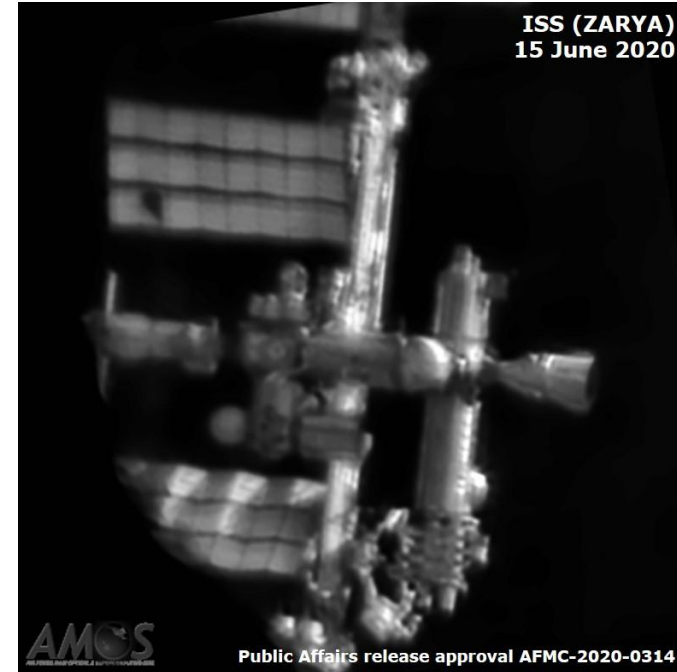
1. May thru Sept (excluding July) were all significantly greater than Nov thru Mar.
2. Apr and Jul were significantly greater than Feb, Mar, and Dec.
3. Oct was significantly greater than Feb and Dec.

Conclusions and Next Steps

May thru September provides the most hours of daily green weather on average.

Future Work

- Divide the analysis into daylight/twilight/nighttime
- Consider all operational conditions (green + yellow)
- Investigate oddities
 - Drop in mean green weather in 2012-2019
 - July not matching other summer months
- Build model to predict missing values



Questions?



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<https://github.com/richy-p/haleakala-viewing-conditions>

Video From [Airman Magazine](#)

Appendix

Key Assumptions/Processes to Note

Want to state assumptions clearly - limiting range values, handling NaNs, calculating hours, adjusting total time

1. If measurement values were not in specified acceptable range, they were changed to null values.
2. Null values were assumed to be 'green' weather conditions.
3. Condition hours were calculated using the time interval between subsequent measurements (either 10 minutes or 10 seconds).
 - a. For example, if there were 100 timestamps with green weather status and the time interval was 10 min, the green hours for that day would be $100 \times 10/60 = 16.67$.
4. The total daily hours of green, yellow, and red weather were normalized to sum to 24.
5. Nothing was done to account for missing days.

Thresholds

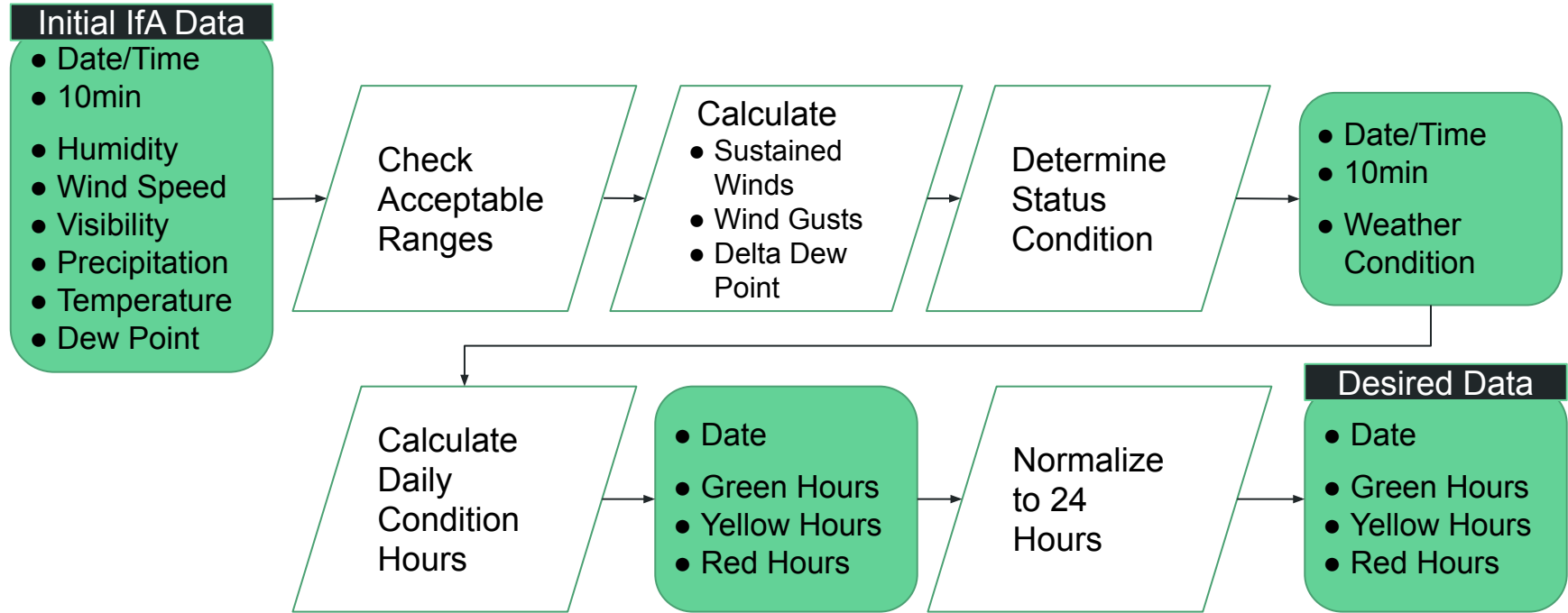
	Green	Red
Humidity	< 75 %	> 85 %
Sustained Wind Speed	< 10 m/s	> 12 m/s
Wind Gust Speed	< 15 m/s	> 15 m/s
Visibility	>= 50,000 m	< 40,000 m
Precipitation	0	> 0
Delta Dew Point (T-DP)	> 6 deg C	< 3 deg C

Reasonable Ranges Used

Values outside these ranges were converted to NaN

	Min	Max
Temperature	-273 deg C	40 deg C
Humidity	0 %	100 %
Wind Speed	0 m/s	100 m/s
Visibility	0 meters	100,000 meters
Precipitation	0 inches	100 inches
Dew Point	-273 deg C	40 deg C

Pre-Processing Pipeline



Significant Results

Summary of significant results (p value < 0.0008) listed below. Mean green weather hours for each month are in parenthesis.

1. May thru Sept (excluding July) were all significantly greater than Nov thru Mar.

May (13.42)
Jun (13.64)
Aug (13.68)
Sep (13.77)



Nov (12.31)
Dec (11.85)
Jan (12.48)
Feb (11.95)
Mar (12.00)

2. Apr and Jul were significantly greater than Feb, Mar, and Dec.

Apr (13.20)
Jul (13.11)



Dec (11.85)
Feb (11.95)
Mar (12.00)

3. Oct was significantly greater than Feb and Dec.

Oct (12.94)



Dec (11.85)
Feb (11.95)

Complete Results (1/5)

Month 1	Month 2	Month 1 Mean	Month 2 Mean	Mean Diff	p value	Is Significant
Sep	Aug	13.77	13.68	0.10	0.80941	No
Sep	Jun	13.77	13.64	0.14	0.94694	No
Sep	May	13.77	13.42	0.35	0.79176	No
Sep	Apr	13.77	13.20	0.57	0.19681	No
Sep	Jul	13.77	13.11	0.66	0.16699	No
Sep	Oct	13.77	12.94	0.83	0.08917	No
Sep	Jan	13.77	12.48	1.30	0.00032	Yes
Sep	Nov	13.77	12.31	1.46	0.00042	Yes
Sep	Mar	13.77	12.00	1.77	0.00003	Yes
Sep	Feb	13.77	11.95	1.82	0.00001	Yes
Sep	Dec	13.77	11.85	1.92	0.00001	Yes

Complete Results (2/5)

Month 1	Month 2	Month 1 Mean	Month 2 Mean	Mean Diff	p value	Is Significant
Aug	Jun	13.68	13.64	0.04	0.86547	No
Aug	May	13.68	13.42	0.26	0.98959	No
Aug	Apr	13.68	13.20	0.47	0.34080	No
Aug	Jul	13.68	13.11	0.56	0.26183	No
Aug	Oct	13.68	12.94	0.74	0.14089	No
Aug	Jan	13.68	12.48	1.20	0.00108	Yes
Aug	Nov	13.68	12.31	1.37	0.00124	Yes
Aug	Mar	13.68	12.00	1.68	0.00011	Yes
Aug	Feb	13.68	11.95	1.73	0.00007	Yes
Aug	Dec	13.68	11.85	1.83	0.00004	Yes
Jun	May	13.64	13.42	0.22	0.87832	No
Jun	Apr	13.64	13.20	0.43	0.24450	No
Jun	Jul	13.64	13.11	0.52	0.20944	No
Jun	Oct	13.64	12.94	0.70	0.11733	No
Jun	Jan	13.64	12.48	1.16	0.00073	Yes
Jun	Nov	13.64	12.31	1.32	0.00121	Yes
Jun	Mar	13.64	12.00	1.63	0.00008	Yes
Jun	Feb	13.64	11.95	1.68	0.00006	Yes
Jun	Dec	13.64	11.85	1.78	0.00003	Yes

Complete Results (3/5)

Month 1	Month 2	Month 1 Mean	Month 2 Mean	Mean Diff	p value	Is Significant
May	Apr	13.42	13.20	0.22	0.27863	No
May	Jul	13.42	13.11	0.30	0.29176	No
May	Oct	13.42	12.94	0.48	0.20480	No
May	Jan	13.42	12.48	0.94	0.00153	Yes
May	Nov	13.42	12.31	1.11	0.00393	Yes
May	Mar	13.42	12.00	1.42	0.00021	Yes
May	Feb	13.42	11.95	1.47	0.00012	Yes
May	Dec	13.42	11.85	1.57	0.00008	Yes
Apr	Jul	13.20	13.11	0.09	0.95856	No
Apr	Oct	13.20	12.94	0.27	0.83606	No
Apr	Jan	13.20	12.48	0.73	0.02201	No
Apr	Nov	13.20	12.31	0.89	0.05385	No
Apr	Mar	13.20	12.00	1.20	0.00623	Yes
Apr	Feb	13.20	11.95	1.25	0.00356	Yes
Apr	Dec	13.20	11.85	1.35	0.00298	Yes

Complete Results (4/5)

Month 1	Month 2	Month 1 Mean	Month 2 Mean	Mean Diff	p value	Is Significant
Jul	Oct	13.11	12.94	0.18	0.75674	No
Jul	Jan	13.11	12.48	0.64	0.03640	No
Jul	Nov	13.11	12.31	0.80	0.04941	No
Jul	Mar	13.11	12.00	1.11	0.00600	Yes
Jul	Feb	13.11	11.95	1.16	0.00415	Yes
Jul	Dec	13.11	11.85	1.26	0.00258	Yes
Oct	Jan	12.94	12.48	0.46	0.05790	No
Oct	Nov	12.94	12.31	0.63	0.09577	No
Oct	Mar	12.94	12.00	0.94	0.01204	No
Oct	Feb	12.94	11.95	0.99	0.00582	Yes
Oct	Dec	12.94	11.85	1.09	0.00483	Yes

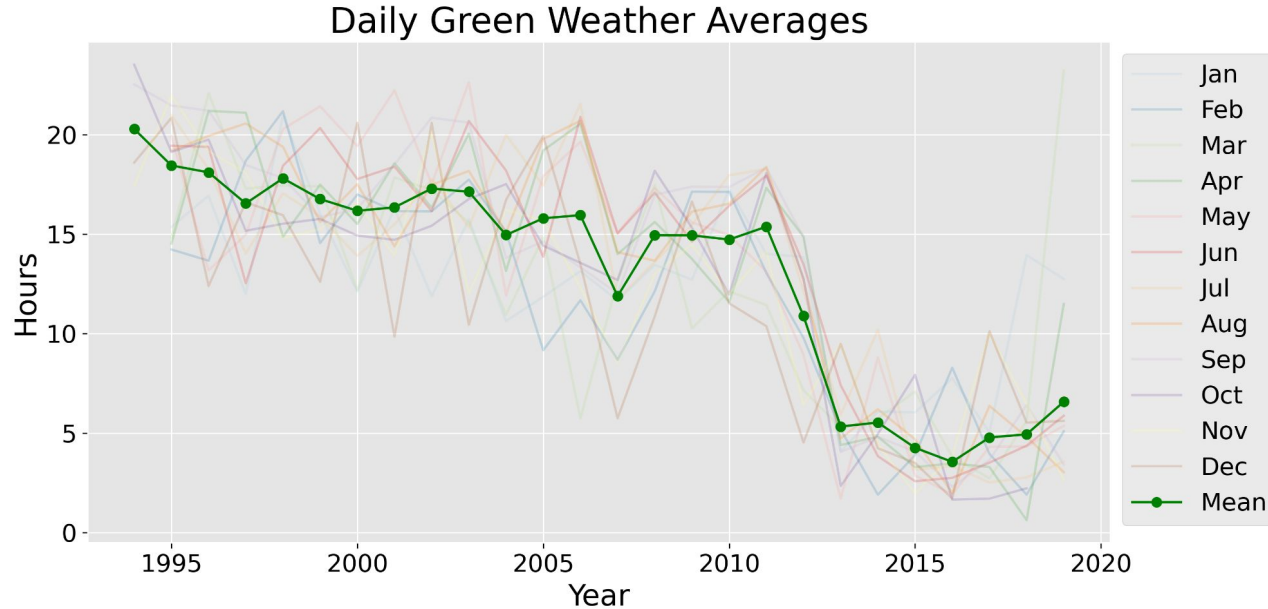
Complete Results (5/5)

Month 1	Month 2	Month 1 Mean	Month 2 Mean	Mean Diff	p value	Is Significant
Jan	Nov	12.48	12.31	0.17	0.91564	No
Jan	Mar	12.48	12.00	0.48	0.47942	No
Jan	Feb	12.48	11.95	0.53	0.33343	No
Jan	Dec	12.48	11.85	0.63	0.32702	No
Nov	Mar	12.31	12.00	0.31	0.35014	No
Nov	Feb	12.31	11.95	0.36	0.22849	No
Nov	Dec	12.31	11.85	0.46	0.18863	No
Mar	Feb	12.00	11.95	0.05	0.80398	No
Mar	Dec	12.00	11.85	0.15	0.74322	No
Feb	Dec	11.95	11.85	0.10	0.98973	No

Oddities in Data

- Values outside a reasonable (or even possible) range
 - Corrected for most - not sure how to handle dew point
- Humidity, visibility, and dew point not available until 1997, 2005, and 2012 respectively
- Precipitation not available after 2012
- Sudden drop in green hours in 2012
- Some complete days missing

Drop in Mean Green Weather



Sudden drop in the average green weather in 2012

Dew point recorded for the first time in 2012