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Weather Impacts on UAV Flight Availability for Agricultural Purposes in Oklahoma

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Abstract. *This research project analyzed 21 years of historical weather data from the Oklahoma Mesonet system. The data examined the practicality of flying unmanned aircraft for various agricultural purposes in Oklahoma. Fixed-wing and rotary wing (quad copter, octocopter) flight parameters were determined and their performance envelope was verified as a function of weather conditions. The project explored Oklahoma's Mesonet data in order to find days that are acceptable for flying unmanned aircraft and determining specific time periods which meet criteria for varying degrees of accuracy. Since Oklahoma has great regional variability in weather and crops, the flight recommendations were assigned to specific Mesonet sites. The results of this work will help define optimum dates of flight for specific crop issues and determine which Mesonet sites to utilize for those crops. Weather data studied included wind speed and direction, cloud cover, relative humidity, precipitation, and solar radiation. Varying levels of UAV/sensor performance based on data requirements (i.e., pretty pictures, relative NDVI, geo-rectified radiometric imagery, research-grade data) were considered when establishing flyable weather criteria.*

Keywords. *Unmanned aircraft systems, weather conditions, autonomous flight, agricultural aviation.*

Introduction

Unmanned aerial systems (UAS) have recently provided new capabilites to remote sensing in precision agriculture. Flights above the Kauai Coffee Company plantation color images were analyzed to map weed outbreaks and to spot irrigation and fertilization anomalies (Herwitz, 2004). Since then UAS have been used for rangeland management, weed management, livestock monitoring, frost mitigation, fertilizer application and assessment of grain crop atributes (Hardin and Jackson, 2005; Bryson & Sukkarieh, 2011; Jensen, Baumann, & Chen, 2008; Mancini et al., 2013; Sato, 2003; Jorge Torres-Sánchez et al., 2013; Turner, Lucieer, & Watson, 2011; Jensen et al. 2003; Hunt et al., 2005).

Remote sensing has shown promise as a tool to enhance crop scouting efforts (Simpson, Stombaugh, Wells & Jacob, 2003). Unmanned aerial systems can carry significant payloads for remote sensing. They have the benefit of being able to fly at lower altitudes than other systems which allow for increased image quality and resolution. UASs are more accessible due to their low cost and UAVs do not require scheduling (Simpson, Stombaugh, Wells & Jacob 2003).

According to recent market research, the global UAV market is estimated to be $6.76 billion in 2014 and is expected to register a compound annual growth rate of 7.73% to reach $10.57 billion in 2020 (MarketsandMarkets, 2013). The increasing drone market will allow for more widespread adoption. Agriculture related UAV applications are expected to be more than $75 billion for the U.S. economy (Vasigh, 2013).

Objectives

The goal of this project was to evaluate weather data for the state of Oklahoma from 1994-2015 to determine the feasibility of drone flight during various times of the year. The project included multiple sub-objectives:

- Determine the number of flyable periods per day for various tolerance levels corresponding to different drone activities.
- Determine the frequency of weather conditions that made flight unfeasible.

Procedure

Weather data was obtained from the Oklahoma Mesonet (www.mesonet.org). The Oklahoma Mesonet has 120 active stations as of December 31st, 2015. These stations record weather conditions every five minutes. Data collected includes humidity, air temperature, wind speed and direction, precipitation, atmospheric pressure, solar radiation, as well as various soil temperature and moisture readings.

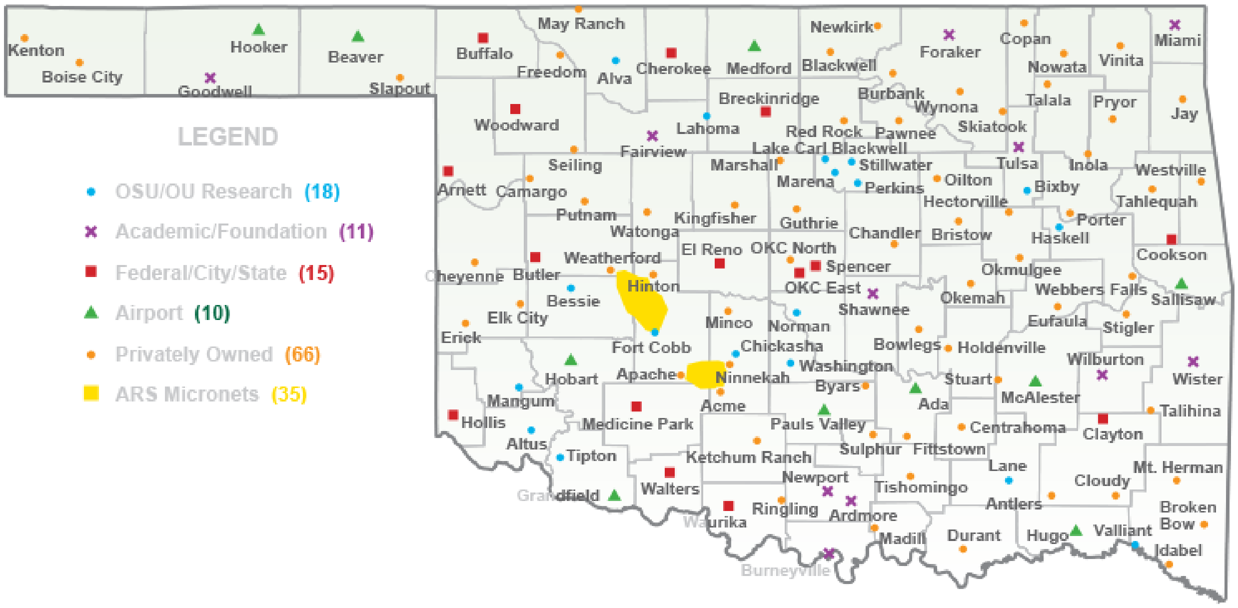

Fig 1. Shows the 120 active sites in the Oklahoma Mesonet. Not shown are 20 retired sites that have been moved or special projects ended. "Station Name Map" *Oklahoma Mesonet.* 2016.

Data was provided in a plain-text, MTS file with variables collected in columns and observations every five minutes in each row. Each day at each site was a separate file. A program was written in R in order to determine the number of flyable periods per day. A flyable period was defined as 30 consecutive minutes with acceptable conditions. The conditions required for each tolerance level are given in Table 1.

Table 1. Outlines the requirements at the four tolerance levels for each 5 minute observation to be considered flyable.

Usage	Maximum Precipitation	Time from Solar Noon	Maximum Wind Speed	Maximum Wind Gust	Minimum Solar Radiation
Livestock Monitoring	0	N/A	15 mph	18 mph	150 W/M^2
Color Photography	0	N/A	10 mph	15 mph	300 W/M^2
Crop Assessment	0	+/- 3 Hours	10 mph	10 mph	600 W/M^2
Research	0	+/- 2 Hours	5 mph	10 mph	600 W/M^2

The R program iterated through each of the 938,617 files. The fully commented source code can be found on GitHub (www.github.com/coopermor/Mesonet-Flyable). The file was read in as a data frame, data flagged as inaccurate by the Mesonet was removed, the sanitized data was checked against the conditions, and if it met all of them the observations were stored in a true/false logical vector. The vector was then checked to find the number of six consecutive flyable observations. The count was stored in a table which was written to a file for further statistical analysis.

The computations were performed at the OSU High Performance Supercomputing Center. The files were split by year and the 21 years were analyzed in 21 separate processes. Each process was running on a 12 core machine. The application was multi-threaded to run on 11 threads.

Conclusion or Summary

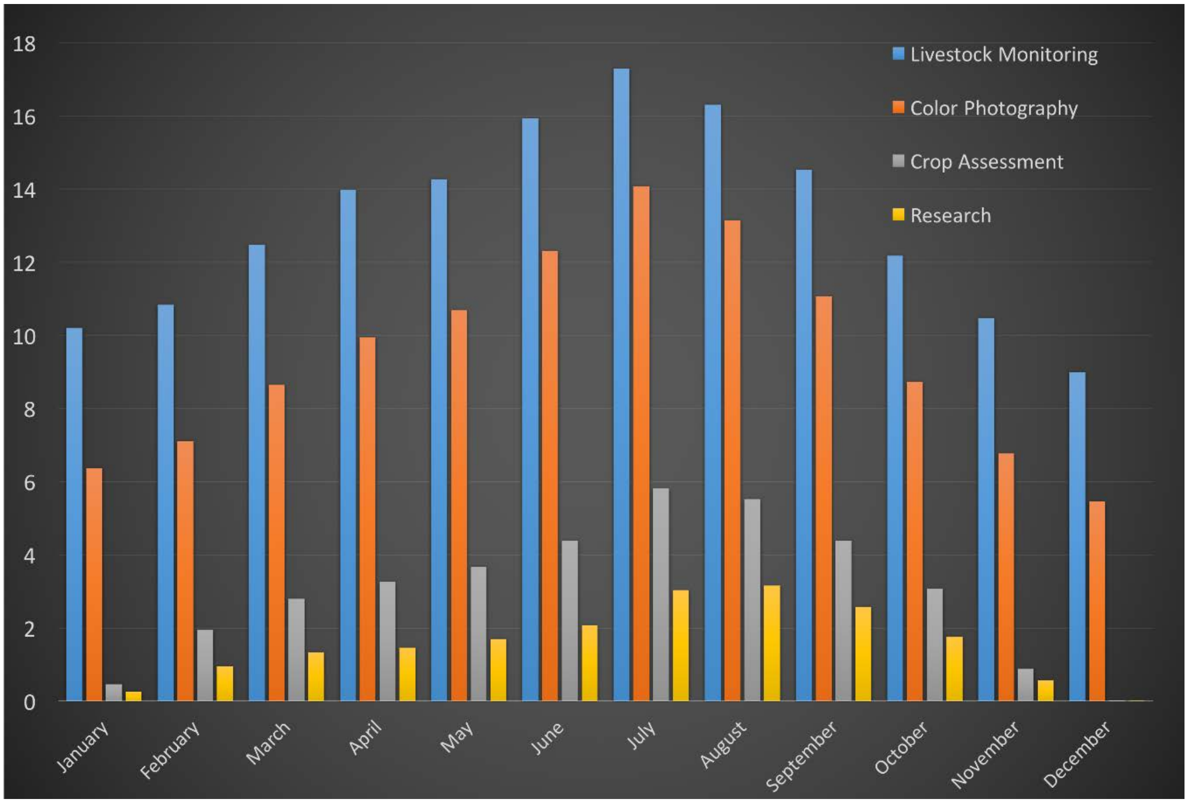

Fig 2. Shows the average number of 30 minute flyable periods per month since 1994 based on the thresholds given in Table 1.

Figure 2 shows that the number of flyable periods follow a relatively normal distribution curve that decreases in magnitude with each increase in tolerance level. For livestock monitoring there is a year round average of 6.56 hours per day, making flight feasable year round. If flight data collection at higher tolerances is desired, (*such as crop assessment or research*), more careful planning is required based on the weather predictions.

Table 2. Statistics per month for the livestock monitoring tolerance levels.

Month	Min	Max	Median	Mean	Standard Deviation
January	0	18	13	10.20	6.43
February	0	20	14	10.84	7.28
March	0	22	17	12.48	8.18
April	0	24	19	13.97	8.95
May	0	25	20	14.27	9.79
June	0	25	22	15.93	9.86
July	0	26	22	17.29	8.94
August	0	24	21	16.29	8.42
September	0	22	19	14.53	8.12
October	0	20	16	12.17	7.70
November	0	18	14	10.47	6.80
December	0	17	12	8.99	6.41

Table 3. Statistics per month for the color photography tolerance levels.

Month	Min	Max	Median	Mean	Standard Deviation
January	0	15	7	6.37	5.29
February	0	17	8	7.11	6.15
March	0	20	10	8.65	7.13
April	0	21	12	9.94	7.88
May	0	22	13	10.70	8.44
June	0	22	16	12.31	8.58
July	0	22	18	14.08	7.86
August	0	21	17	13.15	7.32
September	0	19	14	11.07	6.97
October	0	17	11	8.72	6.58
November	0	15	8	6.78	5.63
December	0	14	5	5.46	5.01

Table 4. Statistics per month for the crop assessment tolerance levels.

Month	Min	Max	Median	Mean	Standard Deviation
January	0	8	0	0.47	1.19
February	0	10	0	1.95	2.76
March	0	11	0	2.80	3.63
April	0	12	0	3.27	4.20
May	0	12	1	3.68	4.38
June	0	12	3	4.39	4.43
July	0	12	7	5.81	4.25
August	0	12	7	5.52	4.07
September	0	11	4	4.39	4.01
October	0	10	1	3.09	3.51
November	0	9	0	0.89	1.69
December	0	7	0	0.03	0.22

Table 5. Statistics per month for the research tolerance levels.

Month	Min	Max	Median	Mean	Standard Deviation
January	0	6	0	0.26	0.82
February	0	8	0	0.96	1.80
March	0	8	0	1.34	2.43
April	0	8	0	1.47	2.67
May	0	8	0	1.70	2.76
June	0	8	0	2.07	2.91
July	0	8	2	3.04	3.13
August	0	8	2	3.17	3.16
September	0	8	1	2.58	3.07
October	0	8	0	1.76	2.59
November	0	7	0	0.57	1.35
December	0	6	0	0.02	0.18

Tables 2 thru 5 show the distribution of flyable periods per day across each month at all four tolerances.

The data were also analyzed to show the reason certain periods were not flyable.

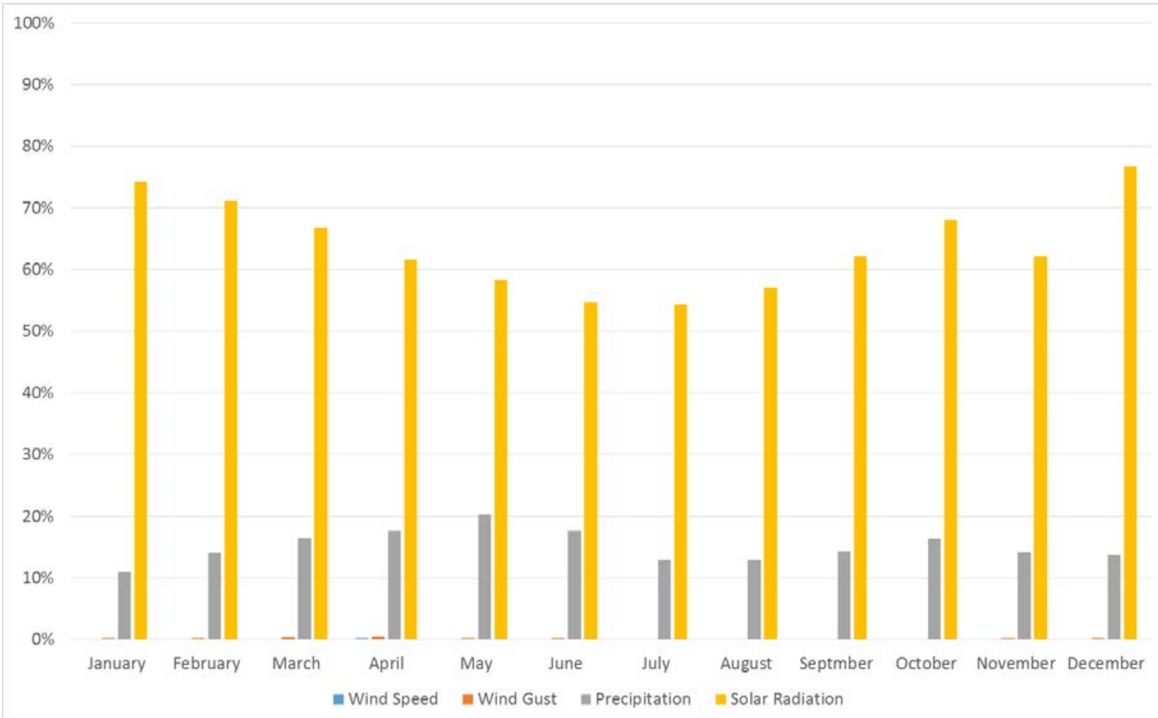

Fig. 3 The weather reason periods aren't flyable for all twelve months at the livestock monitoring tolerance level.

Solar radiation appears to be much larger in magnitude in Figure 3 than at other tolerance levels. At the lowest two tolerance levels, time was not a factor so the flyable time was only limited by solar radiation. For this reason, all of the flyable periods during the night hours were not flyable due to the lack of sun. It should also be noted that these percentages can add up to greater than 100% due to the fact that a period for flight is not mutually exclusive (ex. it can be both raining and windy). Figure 3 shows that flight at the livestock monitoring tolerance level is feasible during most of the daylight hours except for 15.11% of the time when there is precipitation.

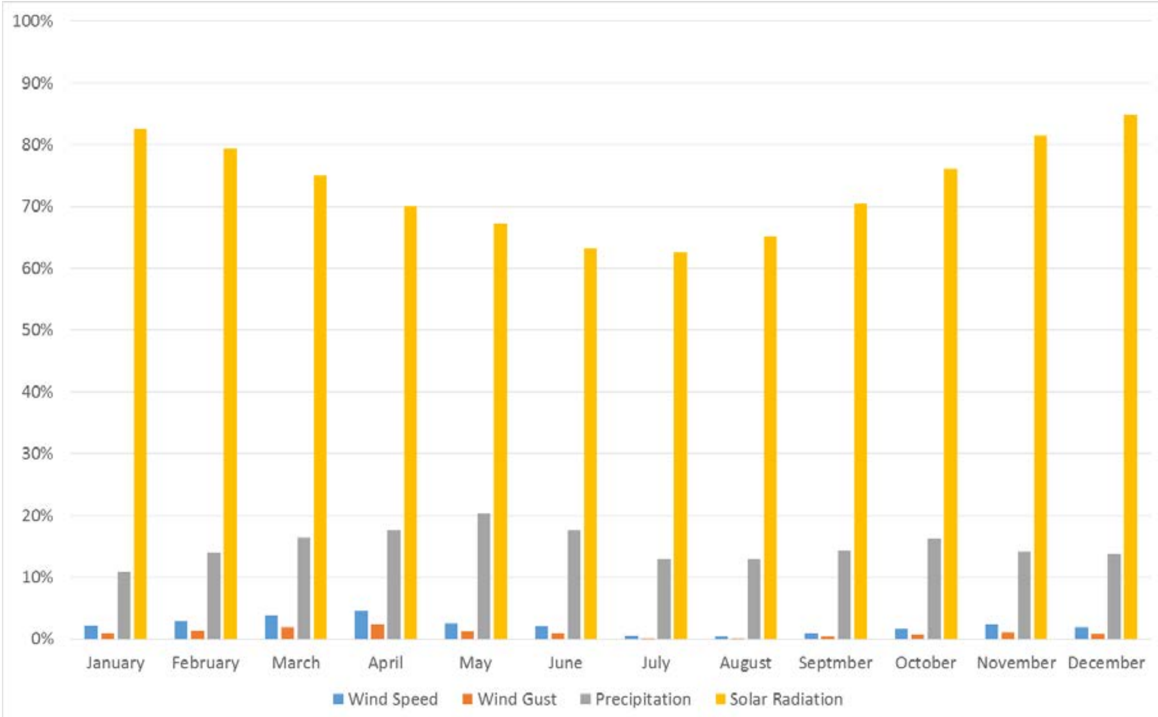

Fig. 4 The weather reason periods aren't flyable for all twelve months at the color photography tolerance level

Figure 4 shows that the distribution of unflyable conditions are very similar to that of the livestock monitoring level. There is a greater influence on wind at 2.17% unflyable due to wind speed.

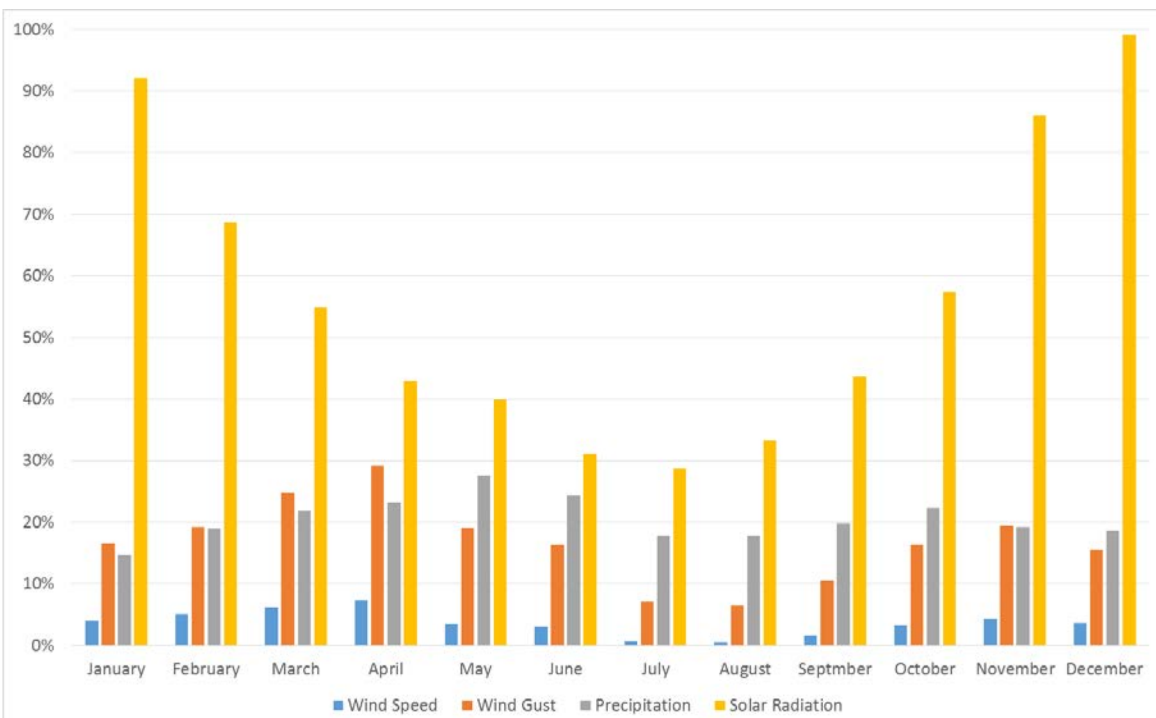

Fig. 5 The weather reason periods aren't flyable for all twelve months at the crop assessment tolerance level

Figure 5 shows that the wind becomes a much bigger factor when the tolerances are tightened to the third level. The percentage of periods that are ruled out due to solar radiation sees a significant drop during April to September.

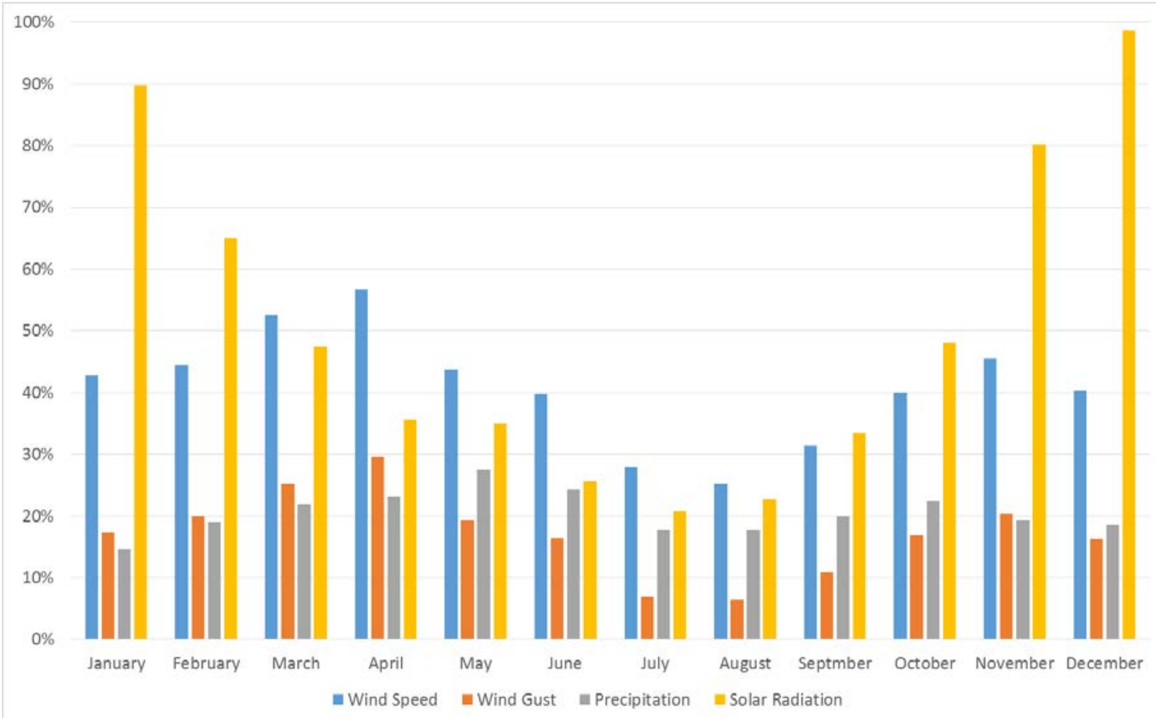

Fig. 6 The weather reason periods aren't flyable for all twelve months at the research tolerance level

At the strictest tolerance level (research), wind speed becomes the most significant factor during the late spring to early fall months.

The feasibility of UAS flight in Oklahoma varies greatly depending on the desired application and time of year that flight is required. No particular type of UAS is a "one size fits all" solution. For summer flights at a research level tolerance, it would be more advisable to seek out a UAS type that would be more tolerant of higher wind speeds.

The application of UAS technology for agricultural purposes in Oklahoma appears to be feasible despite Oklahoma's highly variable weather based on this study. Agricultural UAS applications could see use up to 8.6 hours per day. Even at the strictest of flight tolerances, they could operate nearly a half hour of flight every day of the month for nine months out of the year, and with five months of the year averaging over an hour of flight each.

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