



# Updates on PEGASAS Project 36: Weather Information Risk and Uncertainty Resolution

Presented by  
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**2024 PEGASAS Annual Meeting**

*Although the FAA has sponsored this project, it neither endorses nor rejects the findings of this research. The presentation of this information is in the interest of invoking technical community comment on the results and the conclusions of the research.*

## Executive Summary Slide (1 slide)

- Decision Making Studies at WJHTC with Experienced Pilots
- Surprising Findings in Predictions of Risk and Uncertainty based on Information “Availability”
  - How many locations with known conditions are shown
  - Precursor to adding non-authorized ASOS/AWOS sites
- Need Further Unpacking of Pilot Decision Processes
- Role of New Metrics to Address Risk for Low Altitude Operations and Conditions between Reporting Stations
- Expand / Elaborate Past Results with New WJHTC Experiment
- Increasing Roles of Machine Learning for Future Development

## The Team (1 slide)

- Thanks to FAA Project Management Team: Gary Pokodner and Ian Johnson, PhD
- Project 36 PI: Barrett Caldwell, Purdue
  - A. N. “Evv” Boerwinkle here this week
  - C. Barazandeh, L. Davis, C. McCormack
- Florida Tech co-I: Mike Splitt
  - Robbie Breininger, Marcus Cote
  - Other MS and REU undergrad students
- *Growing interest from Google and Collins Aerospace*

# Research Objective 1

- What is the reasoning behind the study design?
  - Increases in pixel resolution of display images have not reduced GA fatalities or accidents
  - Though interface visibility changed, general aviation pilot confidence and understanding of tools not tracking these changes (e.g., Project 4 / 33 studies of NEXRAD delay)
  - Derive solution to address these gaps and trends



# Research Objective 1

Category	Ceiling		Visibility
Visual Flight Rules VFR (green sky symbol)	Greater than 3,000 feet AGL	and	Greater than 5 miles
Marginal Visual Flight Rules MVFR (blue sky symbol)	1,000 to 3,000 feet AGL	And/or	3-5 miles
Instrument Flight Rules IFR (red sky symbol)	500 to below 1,000 feet AGL	And/or	1 mile to less than 3 miles
Low Instrument Flight Rules LIFR (magenta sky symbol)	Below 500 feet AGL	And/or	Less than 1 mile



# Survey REGIONS (Great Lakes, Cumberland, LA Basin) and INCIDENTS



Forkston, PA: 20210423\_0100

Flatrock, NC: 20090910\_1815

Crescent Mills, CA:  
20180518\_1509

<b>Location:</b>	Forkston, Pennsylvania	<b>Accident Number:</b>	<a href="#">ERA21LA191</a>
<b>Date &amp; Time:</b>	April 22, 2021, 21:04 Local	<b>Registration:</b>	N4055N
<b>Aircraft:</b>	ROBINSON HELICOPTER R44	<b>Aircraft Damage:</b>	Destroyed
<b>Defining Event:</b>	VFR encounter with IMC	<b>Injuries:</b>	1 Fatal
<b>Flight Conducted Under:</b>	Part 91: General aviation - Personal		

<b>Location:</b>	Crescent Mills, California	<b>Accident Number:</b>	WPR18TA157
<b>Date &amp; Time:</b>	May 18, 2018, 08:09 Local	<b>Registration:</b>	N9163X
<b>Aircraft:</b>	Cessna 182D	<b>Aircraft Damage:</b>	Substantial
<b>Defining Event:</b>	Fuel related	<b>Injuries:</b>	2 None
<b>Flight Conducted Under:</b>	Part 91: General aviation - Personal		

<b>Location:</b>	Flat Rock, North Carolina	<b>Accident Number:</b>	ERA09FA514
<b>Date &amp; Time:</b>	September 10, 2009, 14:15 Local	<b>Registration:</b>	N888WD
<b>Aircraft:</b>	Beech A36	<b>Aircraft Damage:</b>	Substantial
<b>Defining Event:</b>	Controlled flight into terr/obj (CFIT)	<b>Injuries:</b>	1 Fatal
<b>Flight Conducted Under:</b>	Part 91: General aviation - Personal		



WJHTC  
Survey  
Questions

**Appendix D - Experiment I Questionnaire**

You just viewed and evaluated a weather scenario. Your task is to predict the weather conditions at the open circled locations (locations where weather conditions are unknown) based upon the closed circled locations (locations where weather conditions are known). Please indicate your flight condition estimate for the open circled locations by marking one of the four boxes below.

LIFR	IFR	MVFR	VFR

Mark your willingness / risk tolerance to operate in Marginal VFR conditions?

1-2	3-4	5	6-7	8-9
Not at all	Willing to accept slight risk	Willing to accept moderate risk	Willing to accept high risk	Willing to accept all risk

For your flight condition estimate above, state your confidence in that estimate by marking one of the qualitative descriptors below.

1-2	3-4	5	6-7	8-9
Not at all confident	Slight confident	Somewhat confident	Fairly confident	Completely confident

If you had intended to fly this scenario as a VFR pilot, and your destination was an **open-circled** airport, based on all the information available to you - would you have made a 'Go' or 'No-Go' decision?

+	
Go	No-Go

If you had intended to fly this scenario as a VFR pilot, and your destination was a **closed-circled** airport, based on all the information available to you - would you have made a 'Go' or 'No-Go' decision?

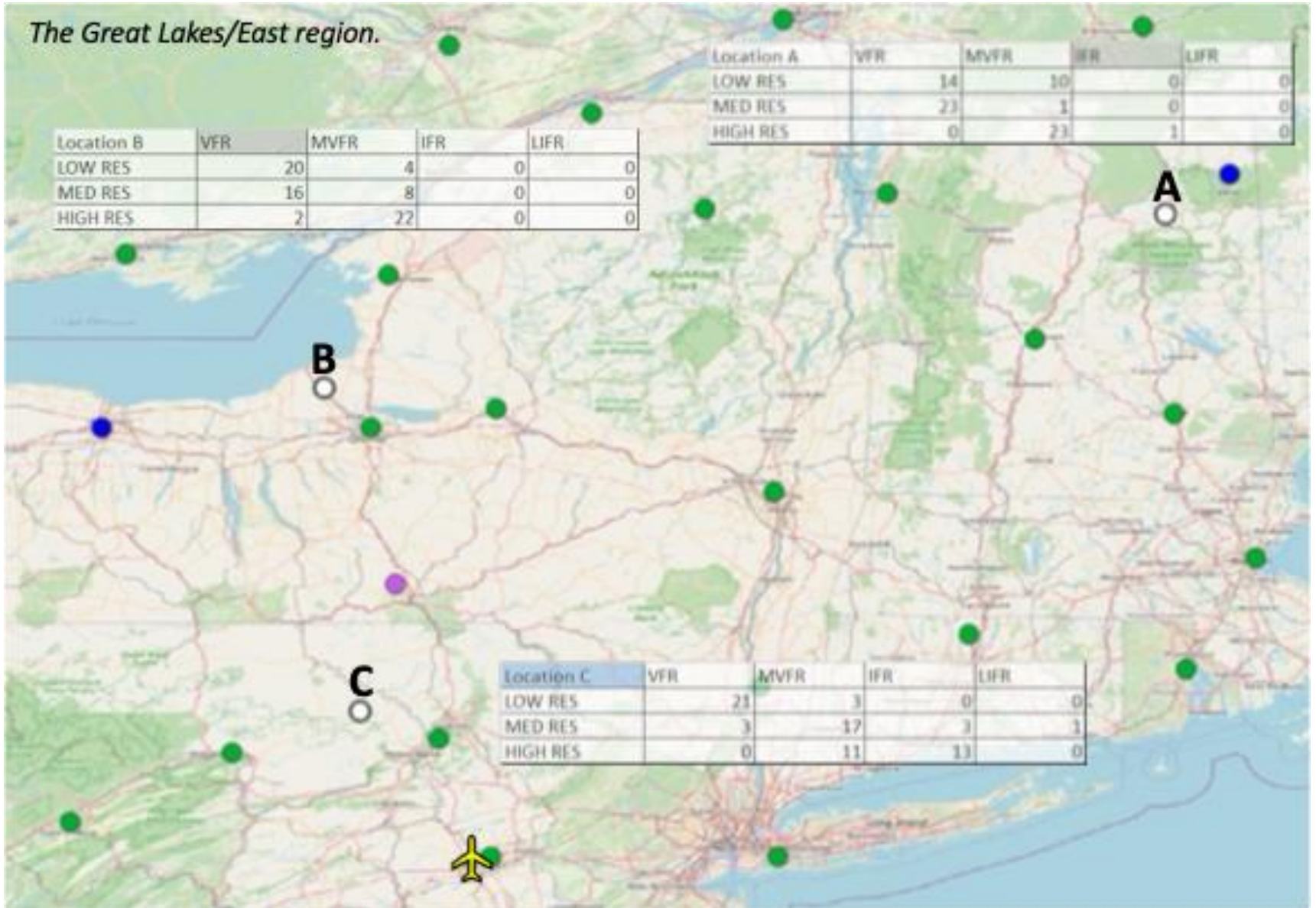
Go	No-Go
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*The Great Lakes/East region.*

Location B	VFR	MVFR	IFR	LIFR
LOW RES	20	4	0	0
MED RES	16	8	0	0
HIGH RES	2	22	0	0

Location A	VFR	MVFR	IFR	LIFR
LOW RES	14	10	0	0
MED RES	23	1	0	0
HIGH RES	0	23	1	0

Location C	VFR	MVFR	IFR	LIFR
LOW RES	21	3	0	0
MED RES	3	17	1	1
HIGH RES	0	11	13	0



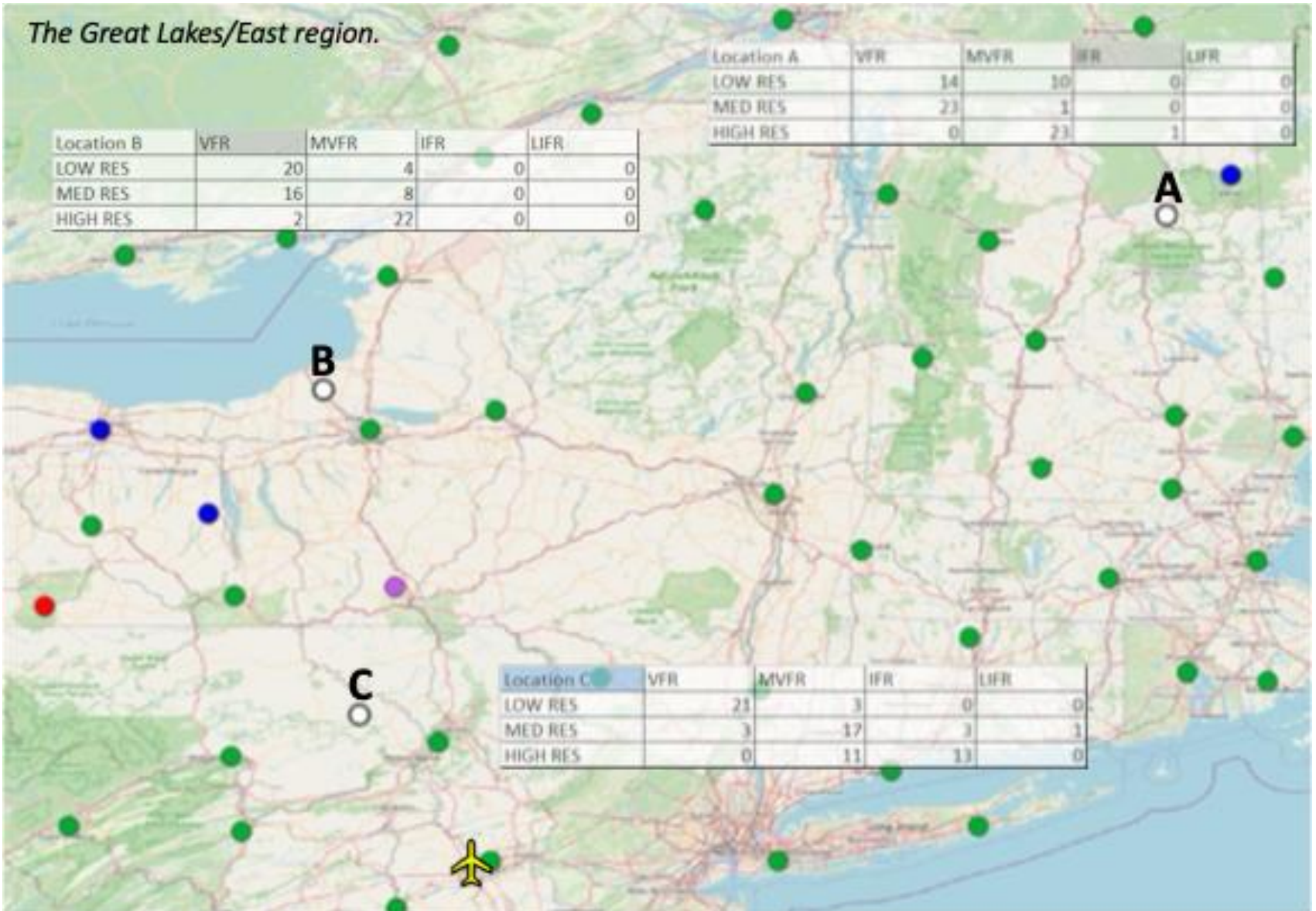


*The Great Lakes/East region.*

Location B	VFR	MVFR	IFR	LIFR
LOW RES	20	4	0	0
MED RES	16	8	0	0
HIGH RES	2	22	0	0

Location A	VFR	MVFR	IFR	LIFR
LOW RES	14	10	0	0
MED RES	23	1	0	0
HIGH RES	0	23	1	0

Location C	VFR	MVFR	IFR	LIFR
LOW RES	23	3	0	0
MED RES	3	17	3	1
HIGH RES	0	11	13	0

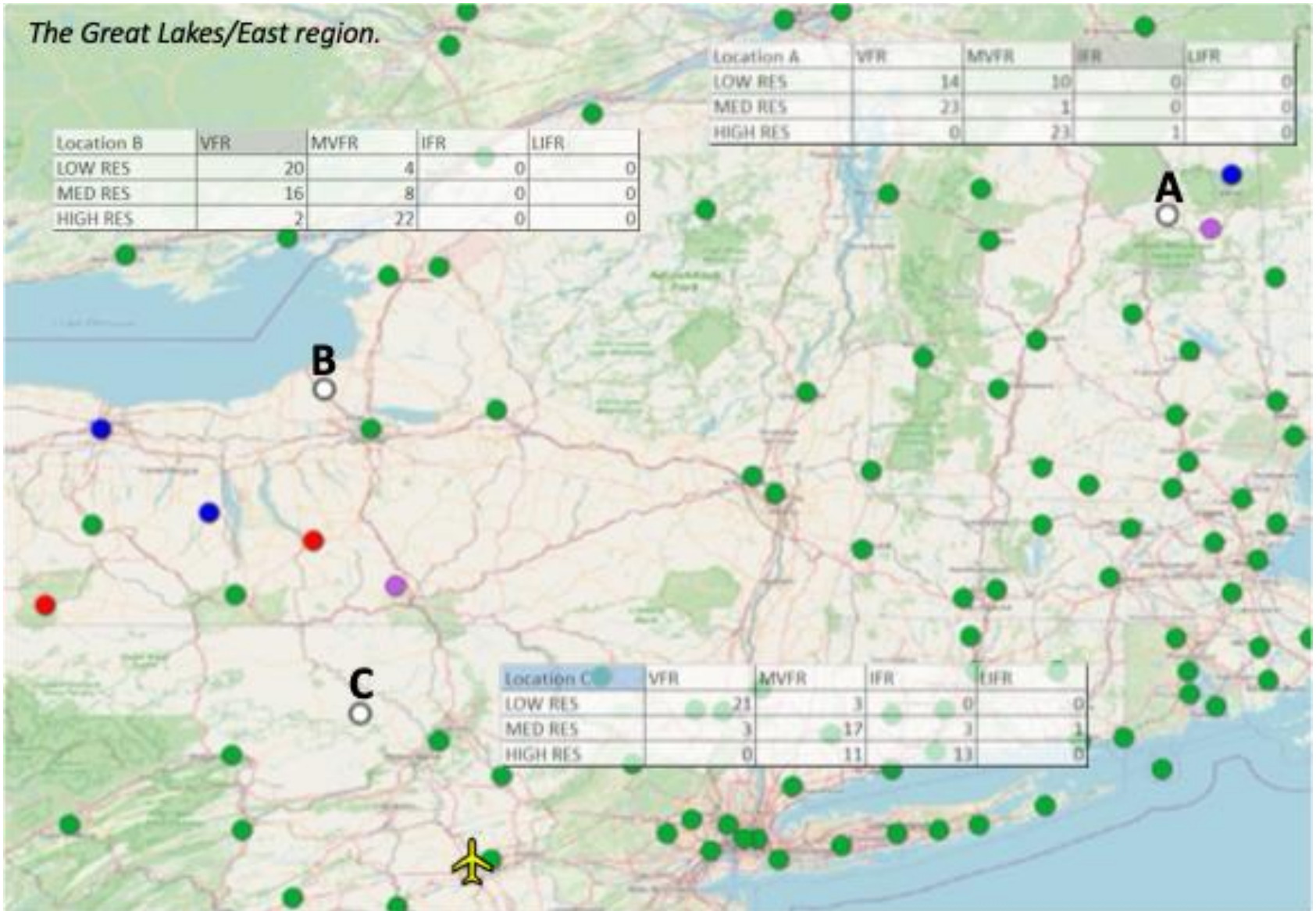


*The Great Lakes/East region.*

Location B	VFR	MVFR	IFR	LIFR
LOW RES	20	4	0	0
MED RES	16	8	0	0
HIGH RES	2	22	0	0

Location A	VFR	MVFR	IFR	LIFR
LOW RES	14	10	0	0
MED RES	23	1	0	0
HIGH RES	0	23	1	0

Location C	VFR	MVFR	IFR	LIFR
LOW RES	21	3	0	0
MED RES	3	17	3	1
HIGH RES	0	11	13	0

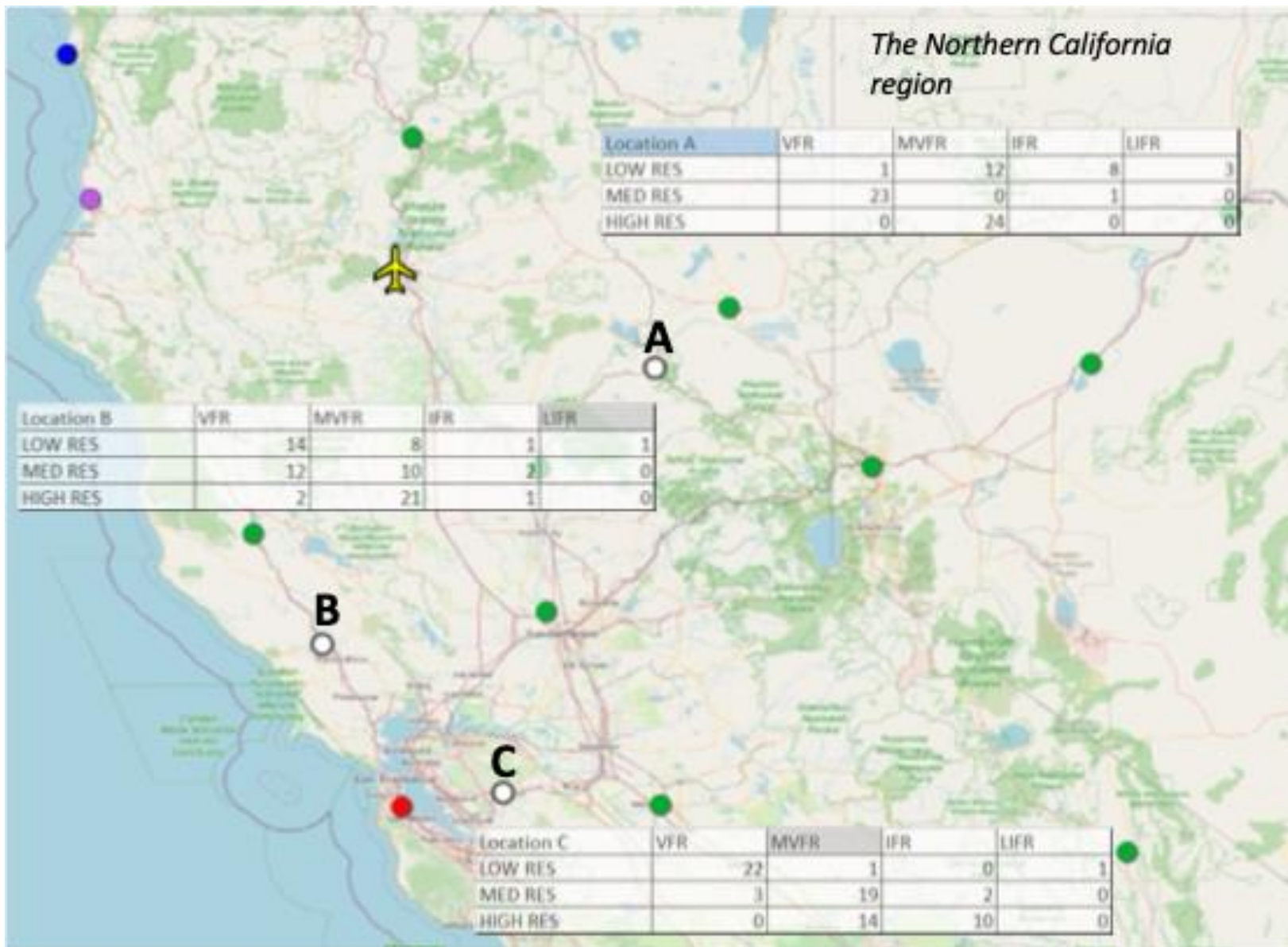


The Northern California region

Location A	VFR	MVFR	IFR	LIFR	
LOW RES		1	12	8	3
MED RES		23	0	1	0
HIGH RES		0	24	0	0

Location B	VFR	MVFR	IFR	LIFR	
LOW RES		14	8	1	1
MED RES		12	10	2	0
HIGH RES		2	21	1	0

Location C	VFR	MVFR	IFR	LIFR	
LOW RES		22	1	0	1
MED RES		3	19	2	0
HIGH RES		0	14	10	0

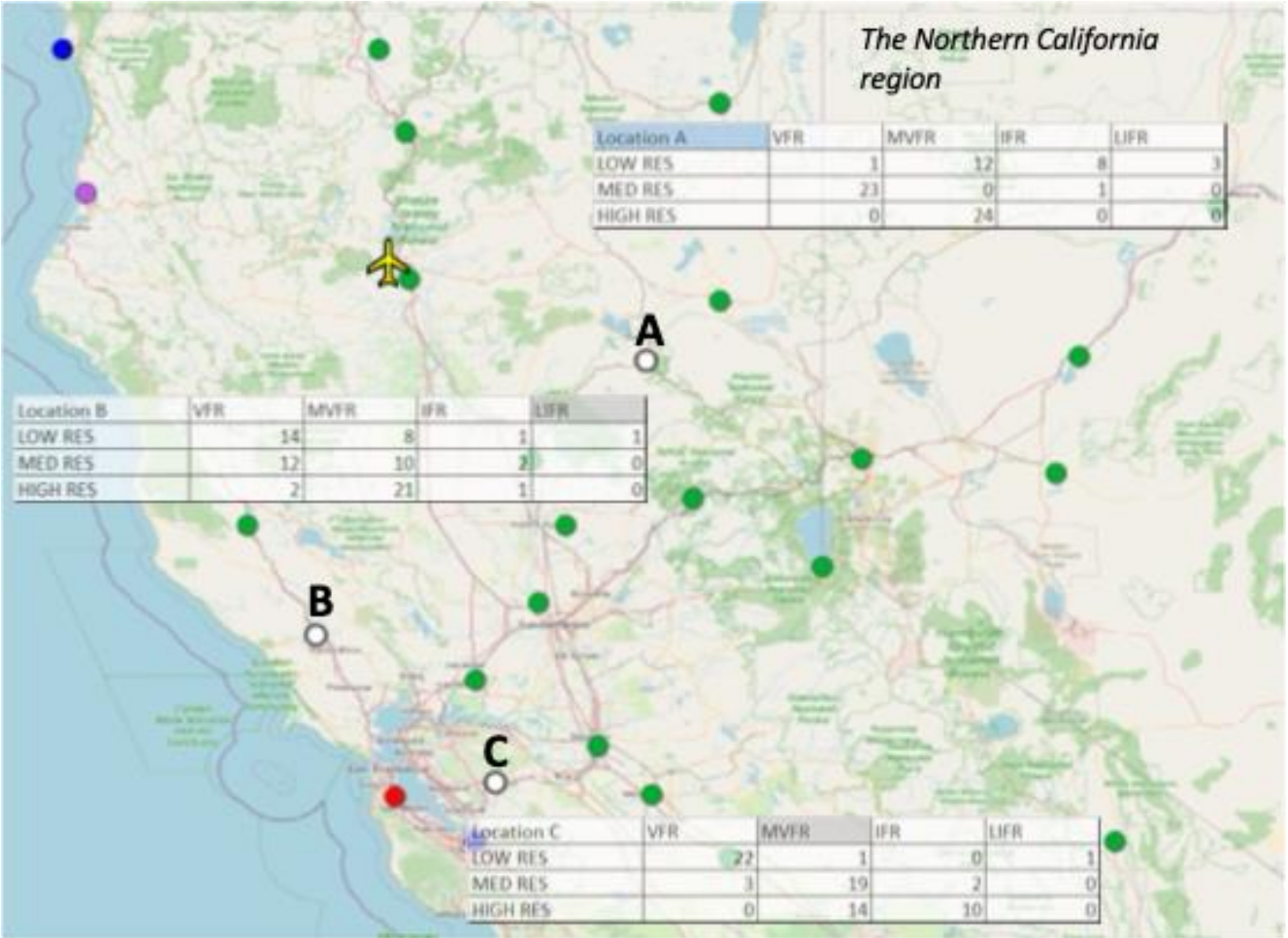


The Northern California region

Location A	VFR	MVFR	IFR	LIFR	
LOW RES		1	12	8	3
MED RES		23	0	1	0
HIGH RES		0	24	0	0

Location B	VFR	MVFR	IFR	LIFR	
LOW RES		14	8	1	1
MED RES		12	10	2	0
HIGH RES		2	21	1	0

Location C	VFR	MVFR	IFR	LIFR	
LOW RES		22	1	0	1
MED RES		3	19	2	0
HIGH RES		0	14	10	0

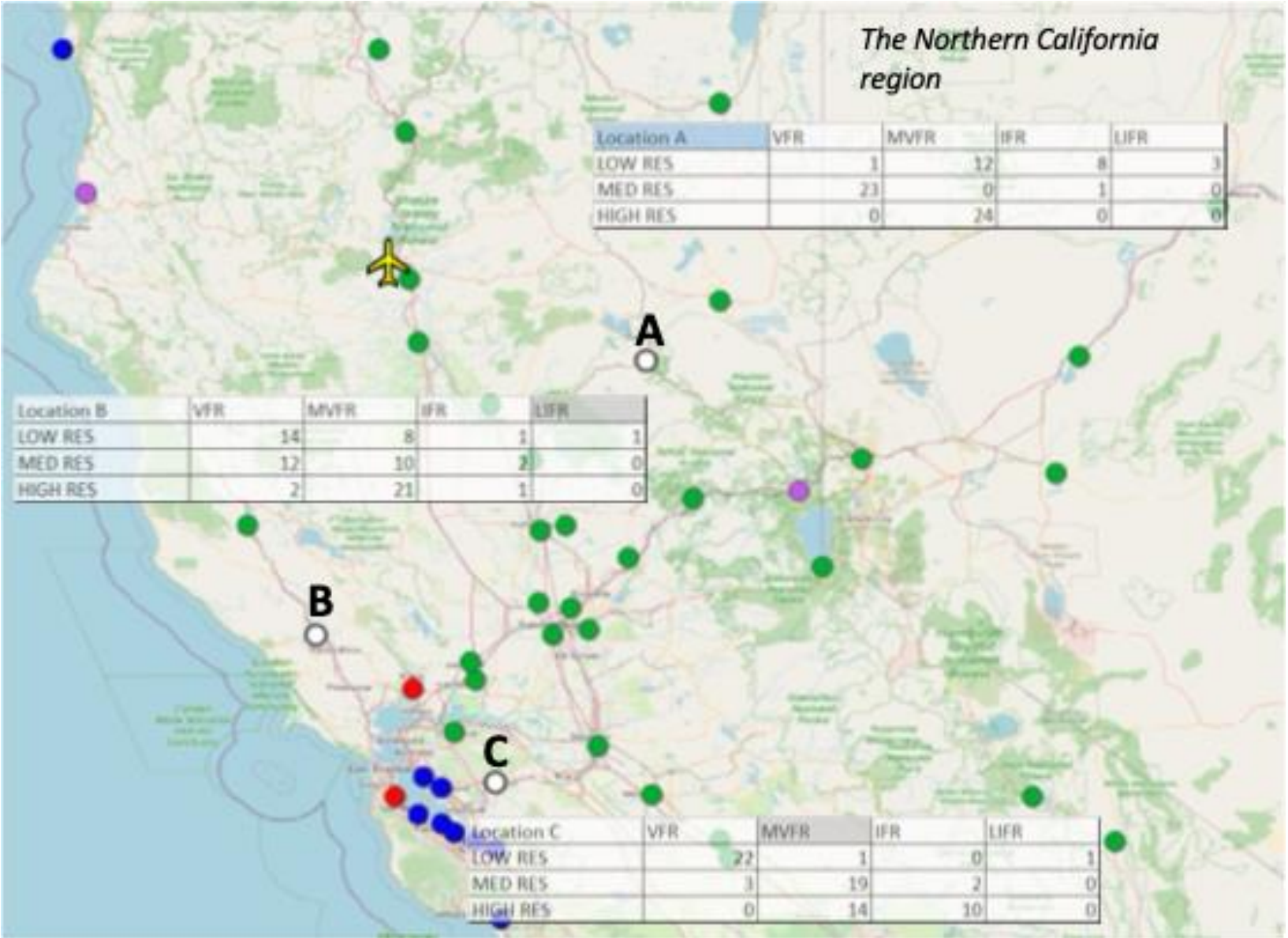


*The Northern California region*

Location A	VFR	MVFR	IFR	LIFR	
LOW RES		1	12	8	3
MED RES	23		0	1	0
HIGH RES	0		24	0	0

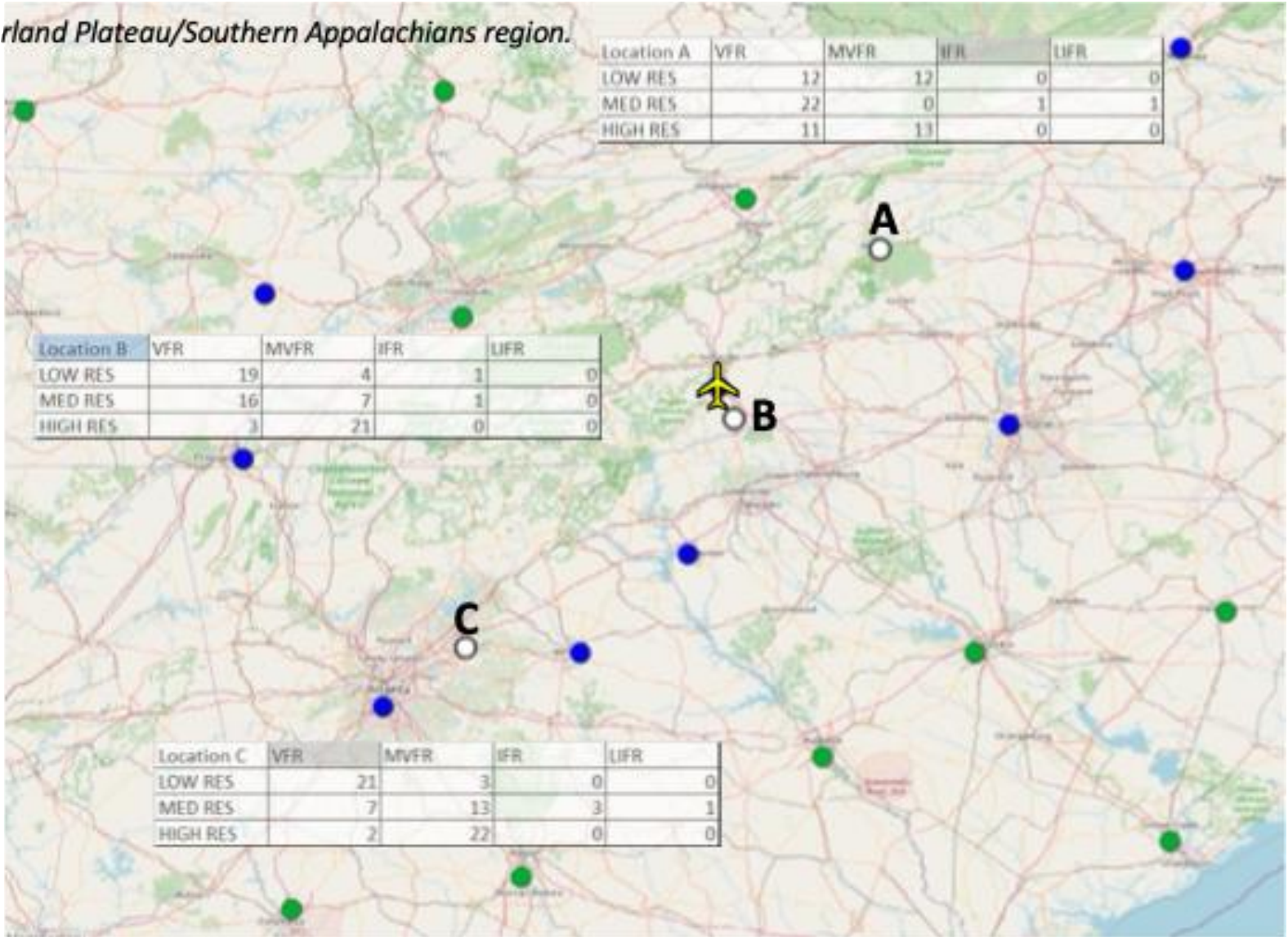
Location B	VFR	MVFR	IFR	LIFR	
LOW RES		14	8	1	1
MED RES	12		10	2	0
HIGH RES	2		21	1	0

Location C	VFR	MVFR	IFR	LIFR	
LOW RES		22	1	0	1
MED RES	3		19	2	0
HIGH RES	0		14	10	0



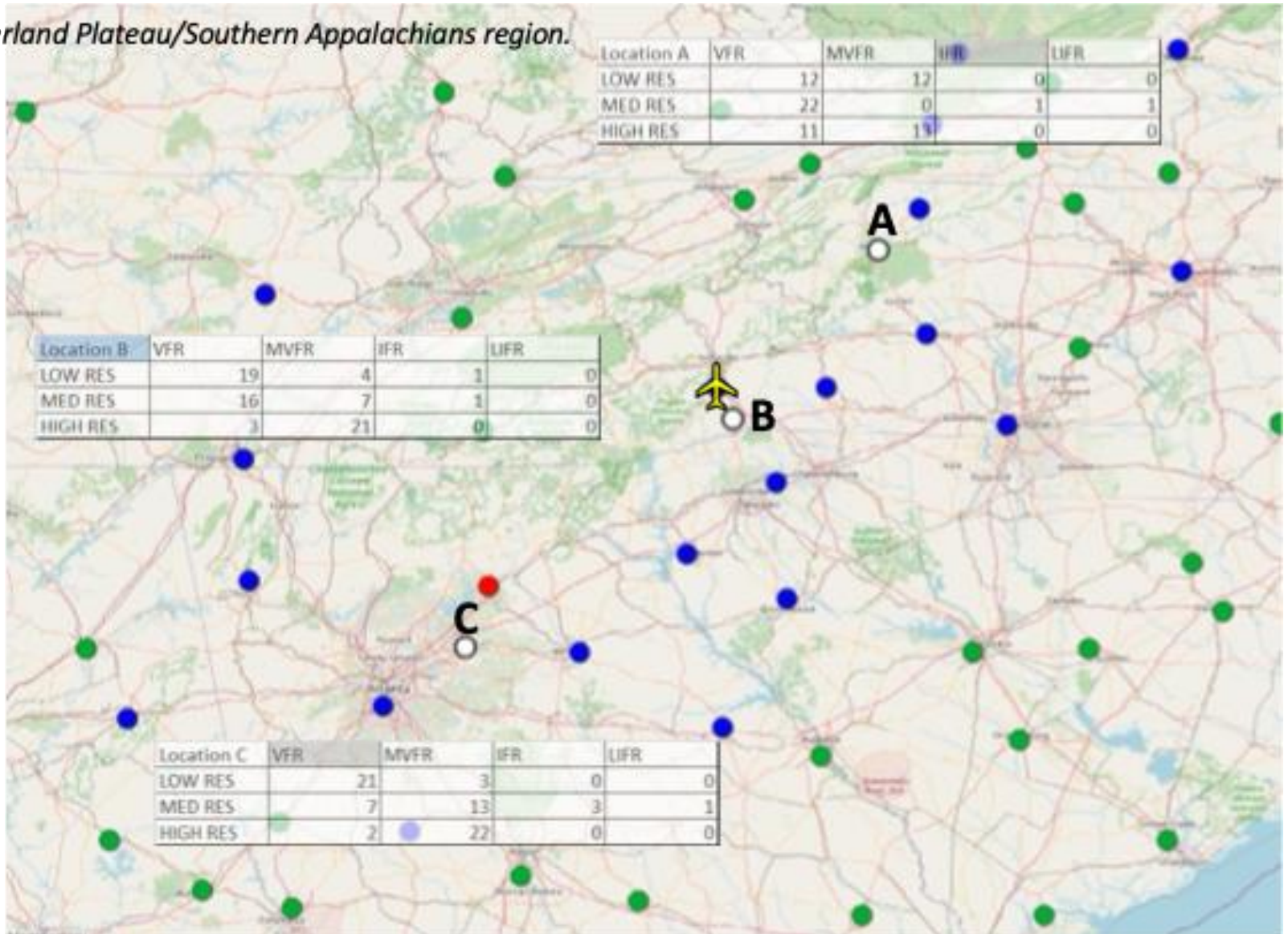


*The Cumberland Plateau/Southern Appalachians region.*



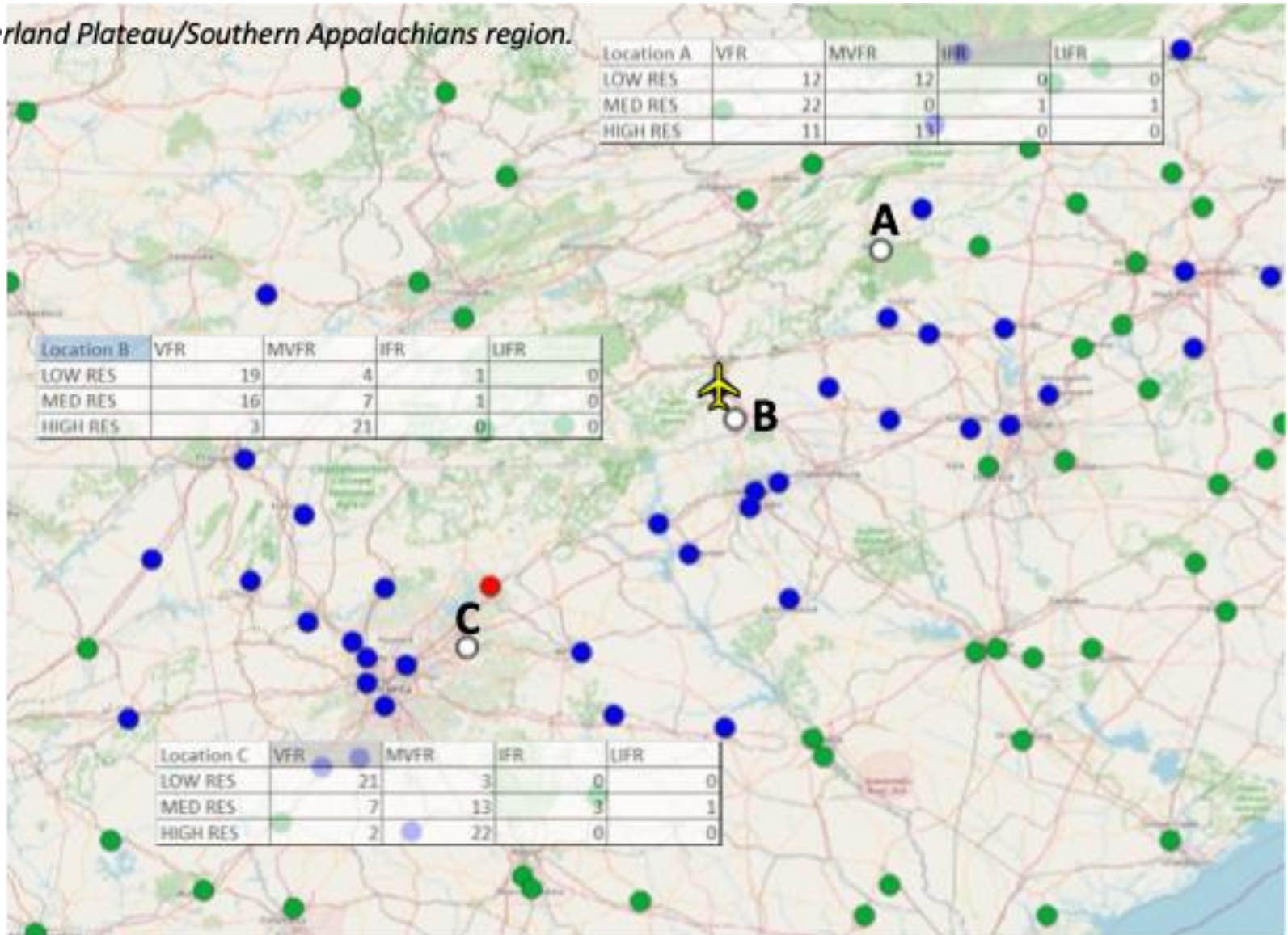


*The Cumberland Plateau/Southern Appalachians region.*





*The Cumberland Plateau/Southern Appalachians region.*







## Counts of Pilot Select Flight Rule Category by Point/Scenario/Resolution

- The thick border represents the observed for the “distractors”
- The “Green” point location is the location of the incident and might be debatable whether those are IFR or LIFR.

GREAT LAKES					NCAL					C. PLAT				
258					369					147				
A	VFR	MVFR	IFR	LIFR	A	VFR	MVFR	IFR	LIFR	A	VFR	MVFR	IFR	LIFR
LOW RES	14	10	0	0	LOW RES	1	12	8	3	LOW RES	12	12	0	0
MED RES	23	1	0	0	MED RES	23	0	1	0	MED RES	22	0	1	1
HIGH RES	0	23	1	0	HIGH RES	0	24	0	0	HIGH RES	11	13	0	0
B	VFR	MVFR	IFR	LIFR	B	VFR	MVFR	IFR	LIFR	B	VFR	MVFR	IFR	LIFR
LOW RES	20	4	0	0	LOW RES	14	8	1	1	LOW RES	19	4	1	0
MED RES	16	8	0	0	MED RES	12	10	2	0	MED RES	3	21	0	0
HIGH RES	2	22	0	0	HIGH RES	2	21	1	0	HIGH RES	19	4	1	0
C	VFR	MVFR	IFR	LIFR	C	VFR	MVFR	IFR	LIFR	C	VFR	MVFR	IFR	LIFR
LOW RES	21	3	0	0	LOW RES	22	1	0	1	LOW RES	21	3	0	0
MED RES	3	17	3	1	MED RES	3	19	2	0	MED RES	7	13	3	1
HIGH RES	0	11	13	0	HIGH RES	0	14	10	0	HIGH RES	2	22	0	0

	OVERALL			
	VFR	MVFR	IFR	LIFR
LOW RES	144	57	10	5
MED RES	112	89	12	3
HIGH RES	36	154	26	0



# Survey Takeaways

The survey results indicated a relatively low skill in survey participants being able to estimate the correct weather flight rules category conditions. Surprisingly, increasing levels of reporting station observability did not systematically improve accuracy, or influence confidence, in pilot estimations of flight conditions or confidence in their estimates. There were very few correct estimations of flight rule conditions at targeted locations. Few estimations of conditions at known airport reporting stations were correct; accuracy did not increase with increasing observability of other nearby airport reporting stations.

Despite these errors, pilot estimates of their confidence were rated “fairly confident” or “completely confident” (the highest rating) in the overwhelming majority of evaluations. There is more spread in confidence estimates in the medium- and high-observability conditions than the low-resolution condition, with notably higher numbers of “slightly confident” estimates in the medium- and high-observability conditions. The medium observability level had the highest number of completely confident selections. It is also important to note that confidence does not uniformly shift in either direction with presentation of more weather observations (“greater resolution”), even when the additional observations indicate increased variability in reported weather conditions .

## Climate Zones Models: More Variation – More Uncertainty?

- *Koppen-Geiger climate zones*
- *Major Land Resource Area*
- *Level IV Ecoregions*
- *Jepson Ecoregions*
- *Evapotranspiration (ET<sub>0</sub>) zones*
- *Plant Hardiness Zones*
- *Fenneman/Johnson physiographic divisions*
- *National Interagency Fire Center Dispatch Center zones*
- *National Predictive Service Area (PSA)*





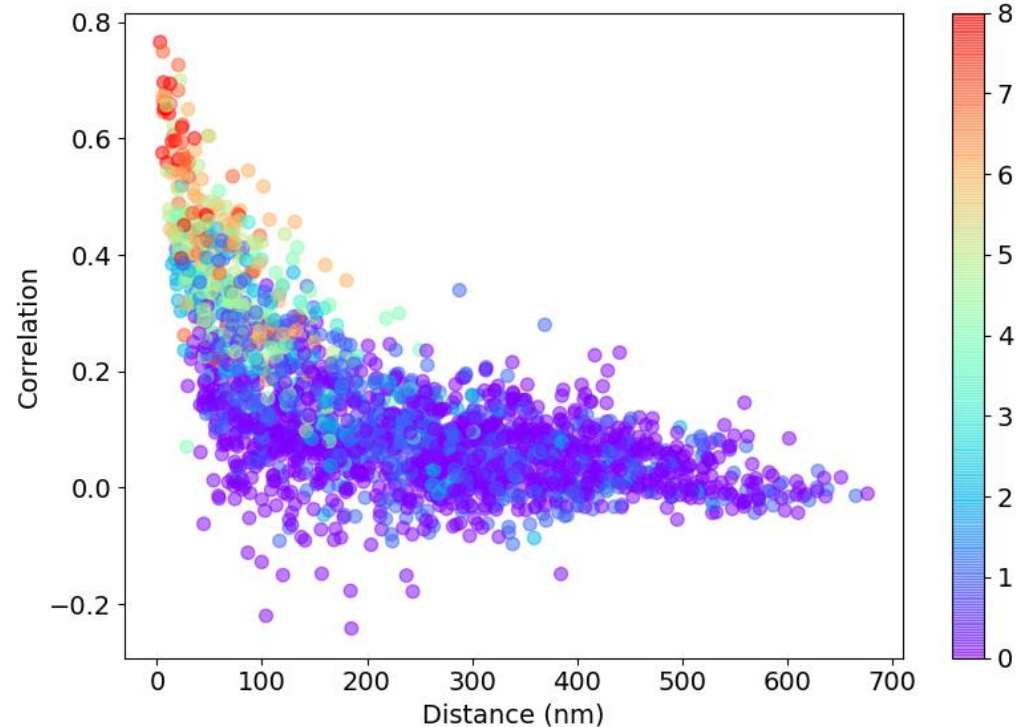
# Central Valley & South Coast Regions

## Developing a “Climate Zones Matching Index” (CZMI)





- Spatial correlation
  - Classic decrease vs. station separation distance
- Climate Zone Matching Index
  - Number of matching climate zones for each station pair (ranges from 0 to 8)





## Immediate Next Steps (1 slide)

- Making Sense of Previous Results
  - Questions regarding order of presentation
  - Why are risk perceptions not shifting in expected ways?
  - Are impacts of terrain and zone uncertainty recognized?
- Apply CZMI to Additional Regions
  - Cumberland, Appalachia, Great Lakes, Upper Plains
- Next Set of Studies for Pilot Decision Making and Impact of Information Availability
  - Extensions of Project 36
  - More research generating more questions than answers?

- What is the design of the next study (studies)?
  - Determine the nature of shifts in pilot decisions
  - Distinction of showing pilots different levels of visibility sequentially vs random
  - Display changes in decisions bias
  - How decision-making shifts with more visual availability
  - Presentation of climate zone matching index and if and how it can be utilized by pilots





## Next Steps Objectives

- Where are the three scenarios of interest?
  - Locations:
    - Cumberland Plateau
    - Northern Great Lakes
    - Western Great Plains
  - Interface Visibility:
    - Low Observability
    - Medium Observability
    - High Observability



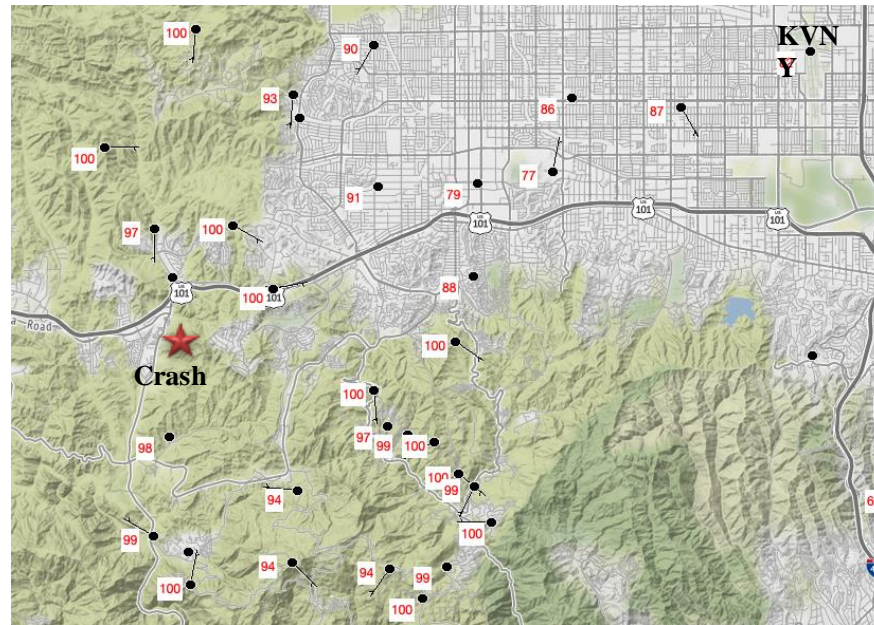
## Conclusions (1 slide)

## Case 4: DCA20MA059 Calabasas, CA

- Relative humidity representativeness (KVN Y vs. crash region)
- Ceilings at KVN Y and terrain in the incident region.

**Incident METAR indicating a ceiling of 1300 feet at KVN Y (crash at 1745 UTC):**

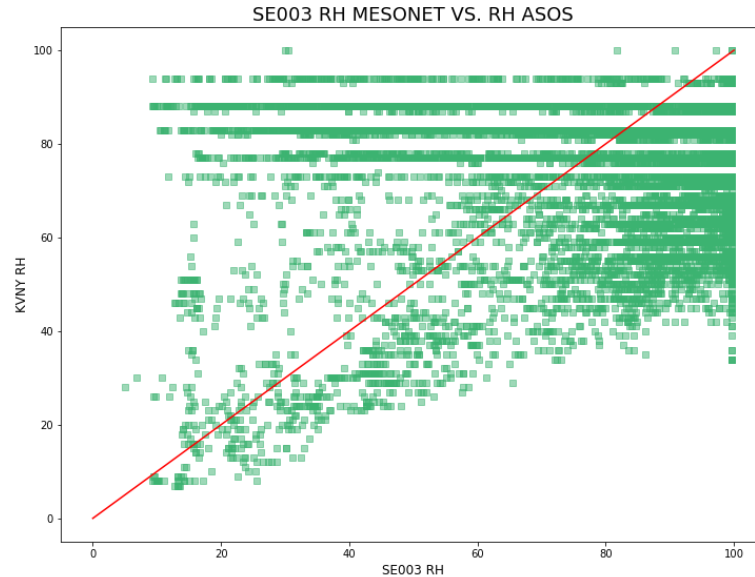
**METAR KVN Y 261751Z  
00000KT 2 1/2SM HZ **OVC013**  
**12/09** A3016 RMK AO2 SLP212  
T01220089 10122 20111 51010= I**



Relative humidity near the incident time from MesoWest

## Case 4: DCA20MA059 Calabasas, CA

- How does relative humidity compare between ASOS stations and mesonet stations in the incident region.
  - Mesonet stations typically will only report relative humidity in terms of a variable of interest related to ceilings and visibility
  - ASOS reports a temperature and dew point that can be converted to a relative humidity
  
- Relative humidity compares poorly between KVNY and SE003.
  - SE003, Saddle Peak, is a Southern California Edison weather station in the Santa Monica Mountains



Scatterplot comparison of relative humidity at SE003 and KVNY for a period of over 2 years

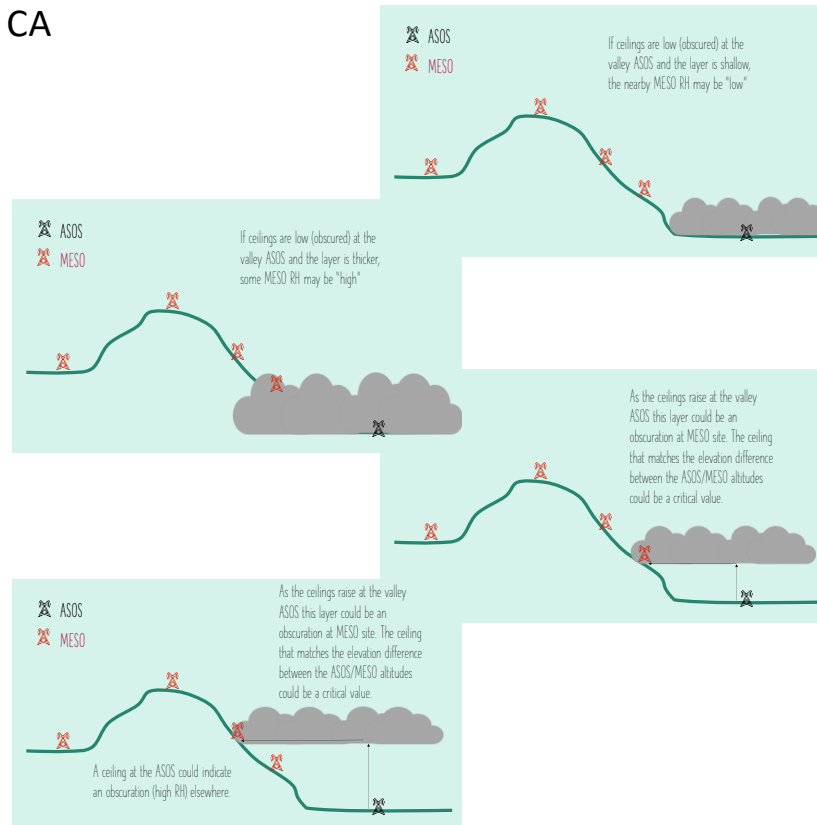
## Case 4: DCA20MA059 Calabasas, CA

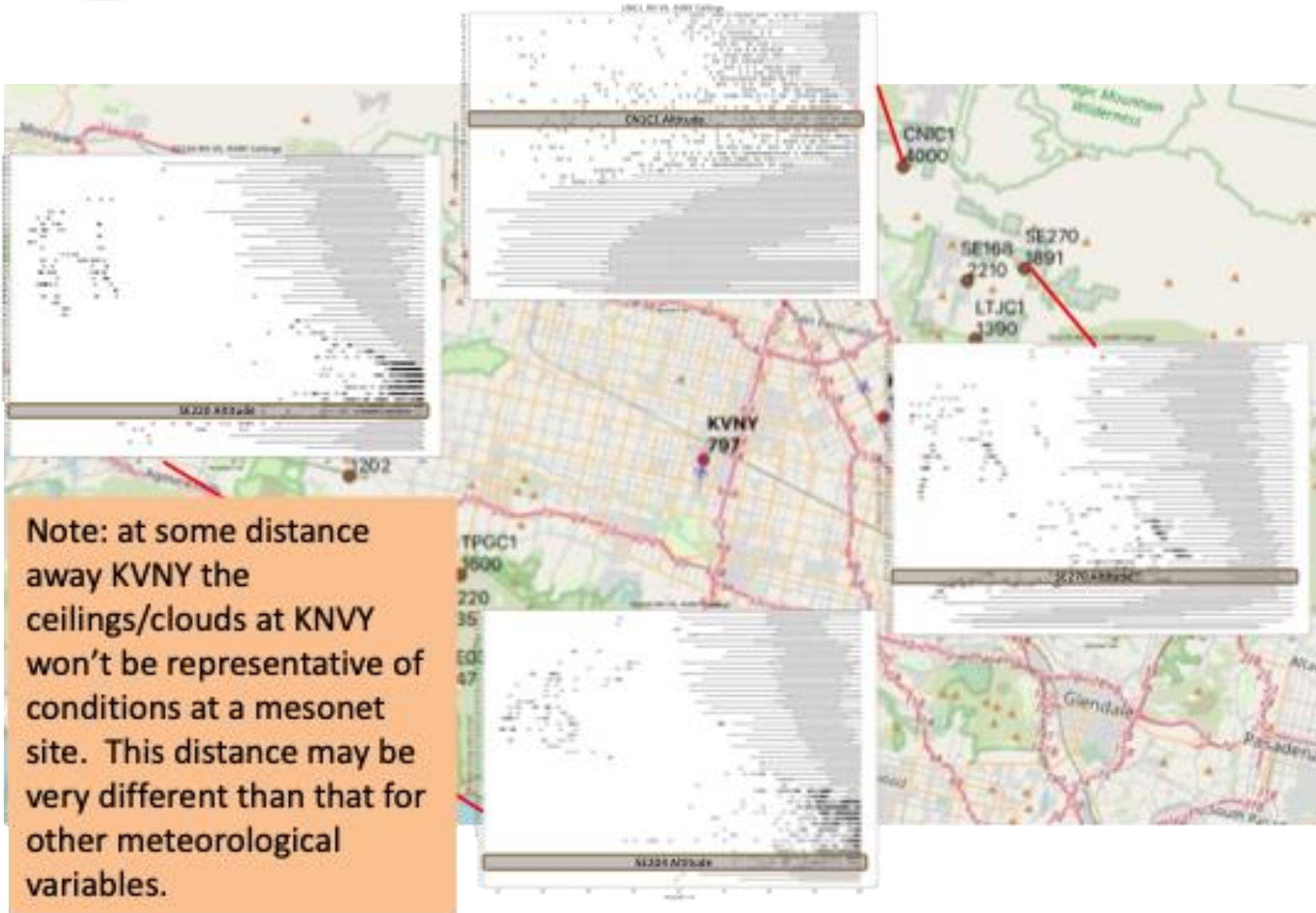
- Conceptual Model

ASOS/AWOS are typically in the low-lying areas or valleys

When there are low clouds or obscurations at low altitude mesonet stations at higher altitude be at lower relative humidity.

As cloud layers rise with respect to the valley, mesonet stations at higher altitude may get into “weather” and the relative humidity increases while decreasing at the valley floor.





Note: at some distance away KVNY the ceilings/clouds at KVNY won't be representative of conditions at a mesonet site. This distance may be very different than that for other meteorological variables.

## Case 4: DCA20MA059 Calabasas, CA

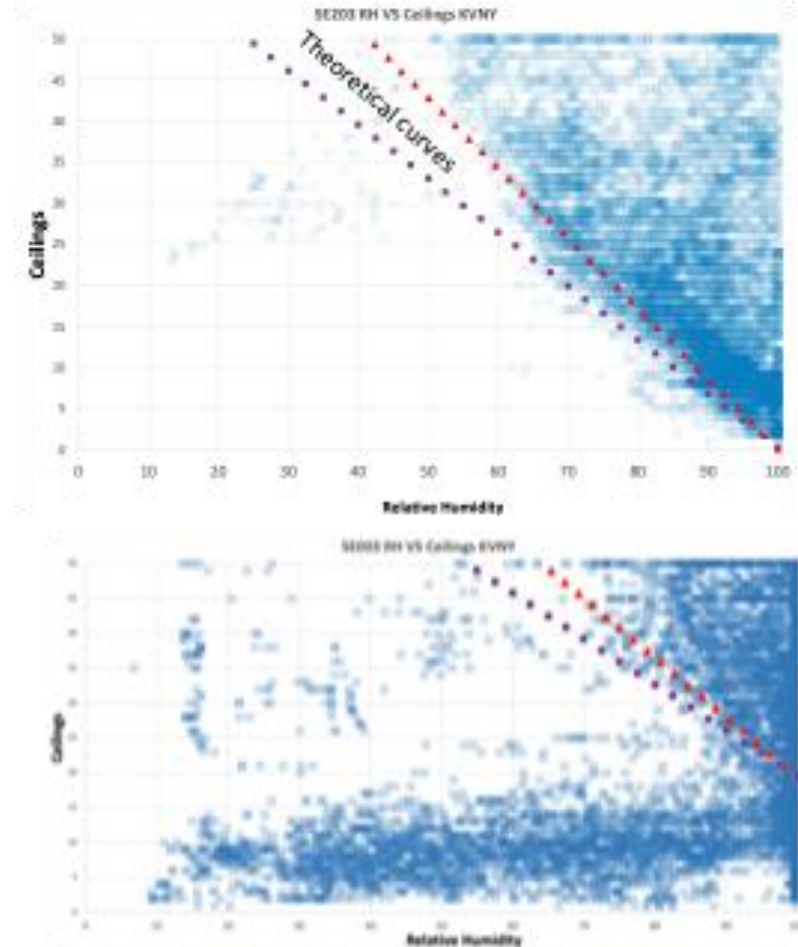
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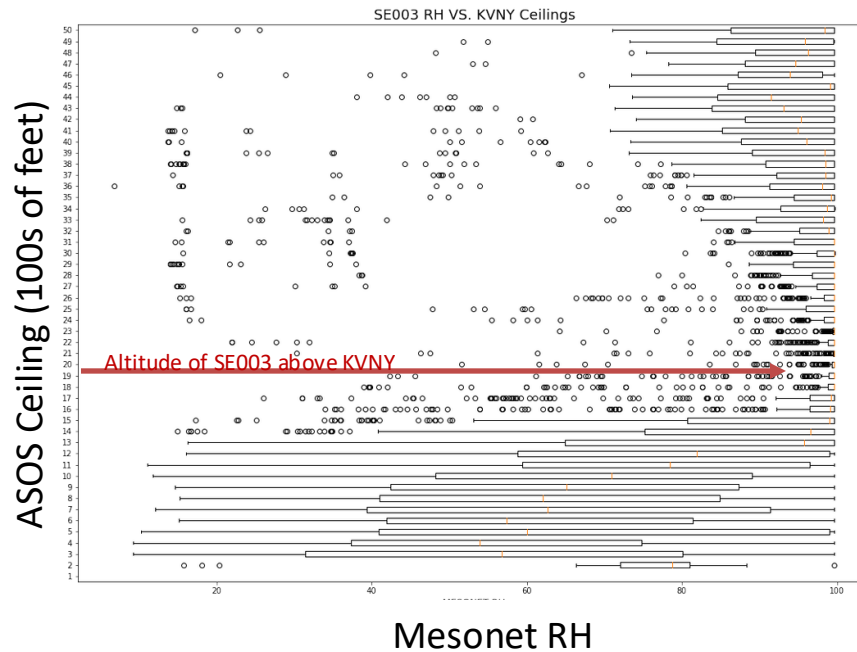
As cloud layers rise with respect to the valley, mesonet stations at higher altitude may get into “weather” and the relative humidity increases while decreasing at the valley floor.

As ceilings raise to the mesonet station altitude the relative humidity range is constrained and very high.



## Case 4: DCA20MA059 Calabasas, CA

- As ceilings rise to near the mesonet station altitude the RH in very small and values are near saturation indicative of the mesonet station being in or near the cloud obscuration.
- The combination of RH information from the mesonet site and the ceiling from the nearby ASOS provide a more confident indication of obscuration at the mesonet site than just using relative humidity alone.

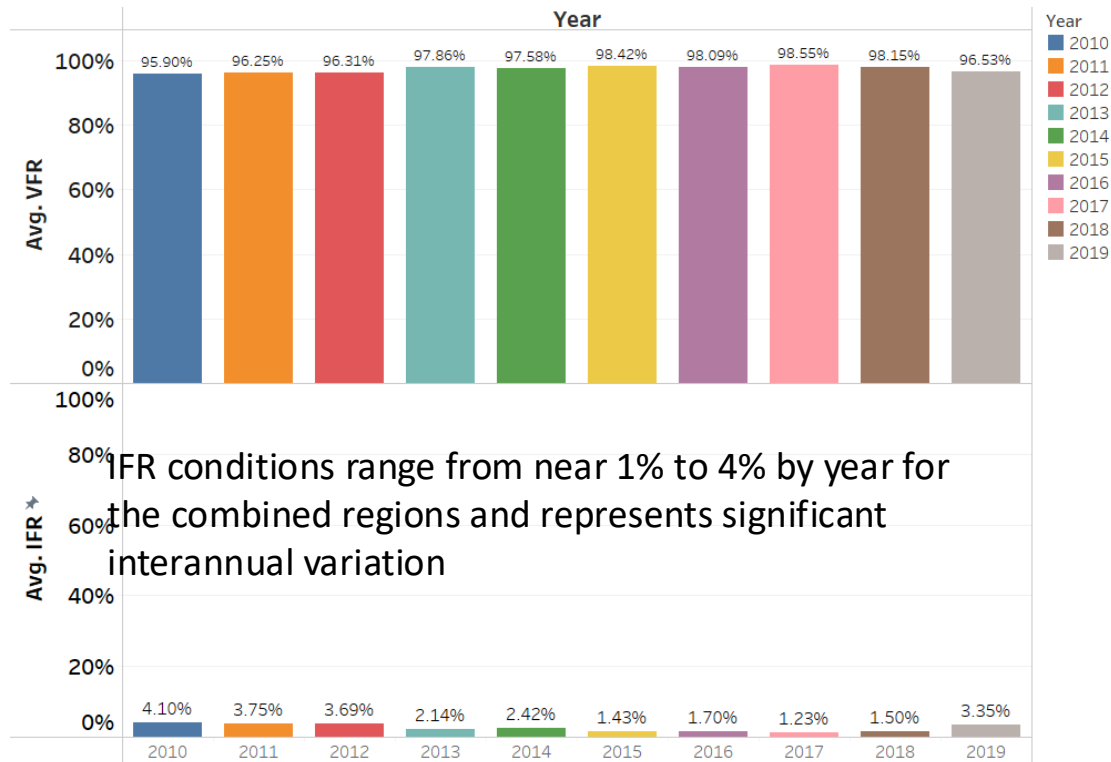






# Ripe for Machine Learning Application: Central Valley/South Coast Interannual Variation

Annual Average Flight Rule Percentages For Central Valley and South Coast  
Region



IFR conditions range from near 1% to 4% by year for the combined regions and represents significant interannual variation

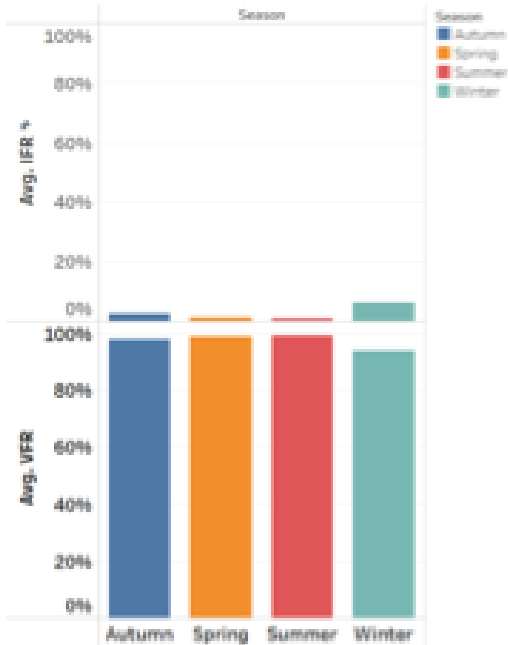
Average of VFR and average of IFR for each Year. Color shows details about Year. For pane Average of IFR: The marks are labeled by average of IFR. For pane Average of VFR: The marks are labeled by average of VFR.

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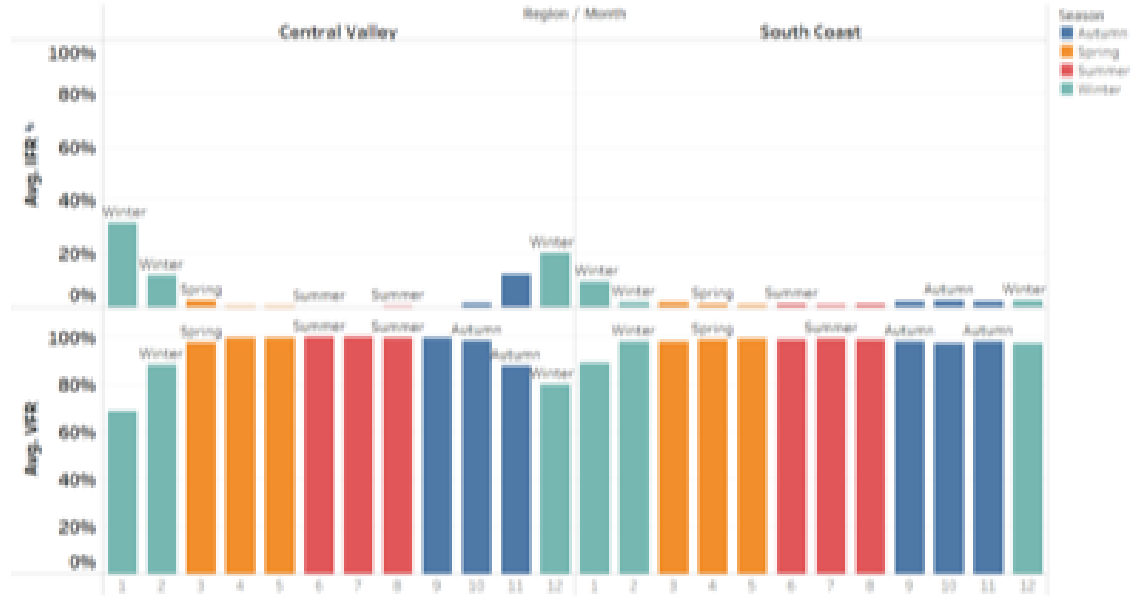
# Seasonal/Monthly Variation

Flight Rule Agreements Comparisons by Season



Average of IFR and average of VFR for each Season. Color shows details about Season.

Average Flight Rule Agreement Comparisons for Central Valley and South Coast Regions: Jan-Dec (2010-2019)

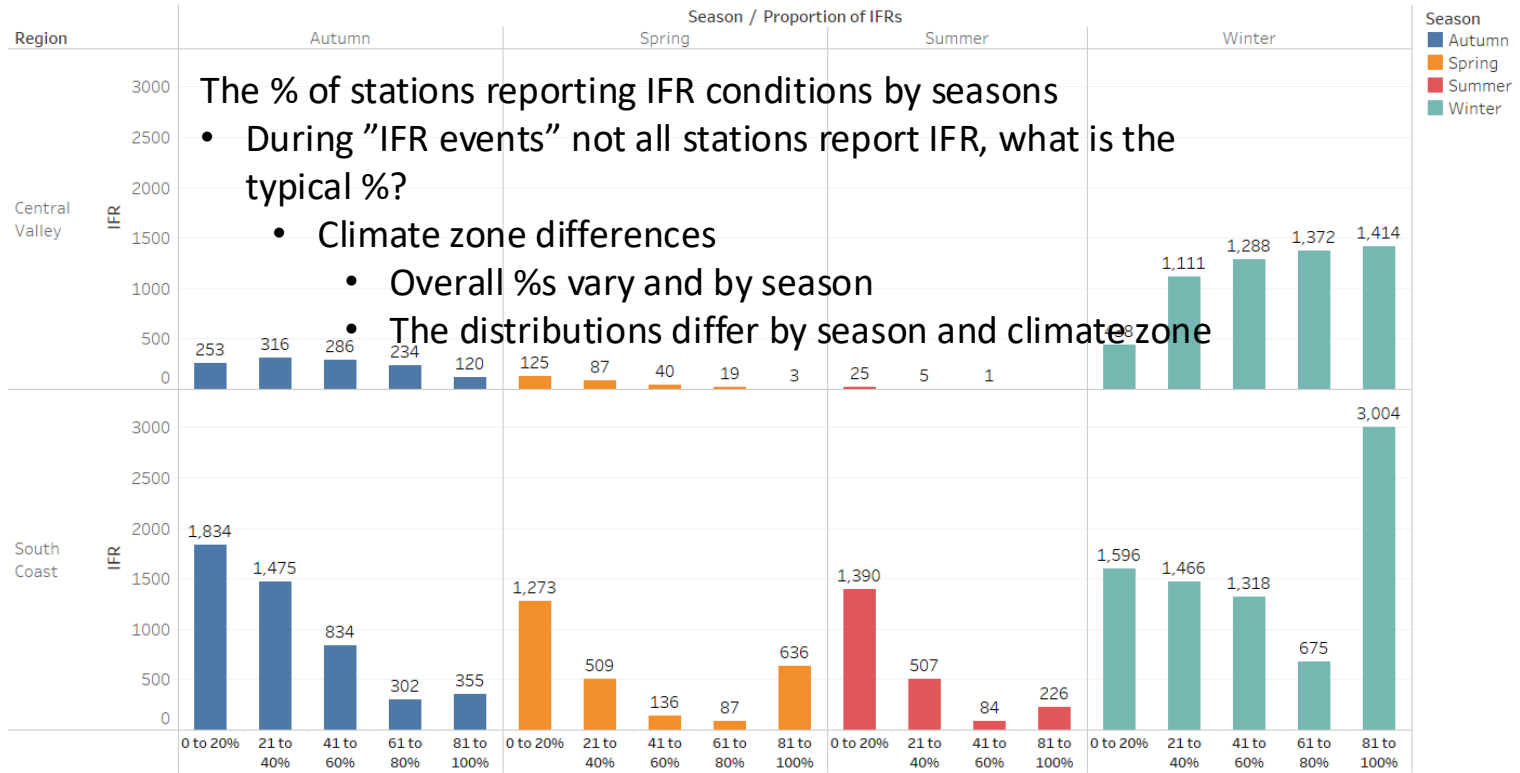


Average of IFR and average of VFR for each Month broken down by Region. Color shows details about Season. The marks are labeled by Season.

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### IFR Percentage Comparisons in Each Percentage Category for Central Valley and South Coast Regions



- The % of stations reporting IFR conditions by seasons
- During "IFR events" not all stations report IFR, what is the typical %?
    - Climate zone differences
      - Overall %s vary and by season
      - The distributions differ by season and climate zone

Sum of IFR for each Proportion of IFRs broken down by Season vs. Region. Color shows details about Season. The marks are labeled by sum of IFR. The data is filtered on Time Series Month and Year. The Time Series Month filter keeps 12 of 12 members. The Year filter keeps 10 of 10 members.