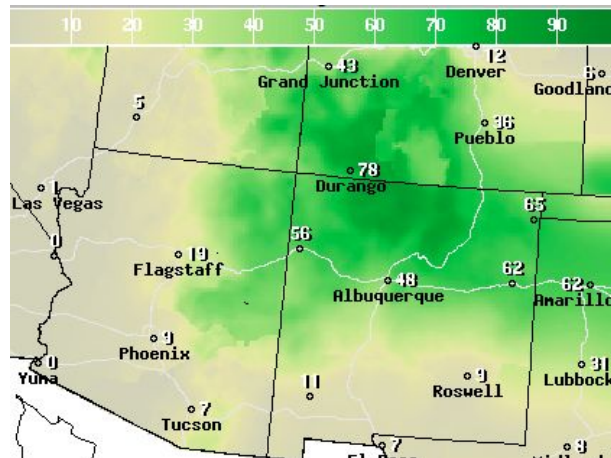
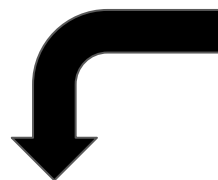
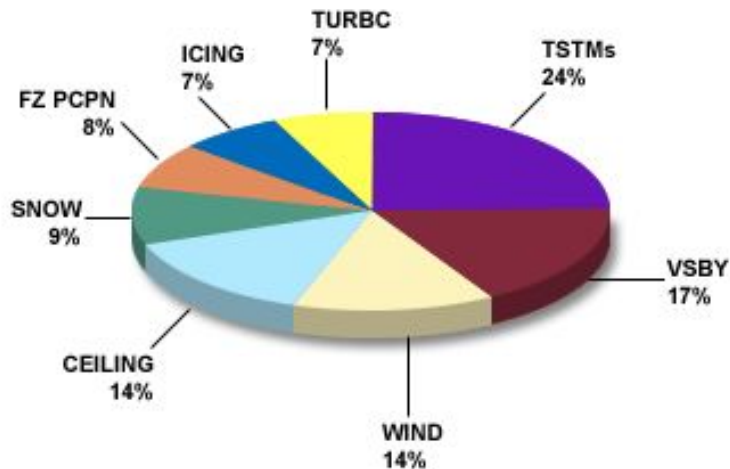




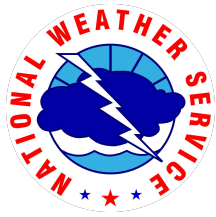
Motivation: Improving Convective TAFs

- Thunderstorms most significant weather-related aviation impact
- Better understanding thunderstorm climatologies - important as we move towards Digital Aviation Services grids driving TAFs

Rankings of Impact to the NAS by Significant Weather Elements



```
KABQ 280137Z 2802/2824 12012G18KT P6SM VCTS SCT070CB  
TEMPO 2802/2803 VRB20G30KT BKN060CB  
FM280300 09015G25KT P6SM VCSH BKN070  
FM281100 04007KT P6SM VCSH BKN040  
FM281500 VRB06KT P6SM BKN060  
FM281900 29010KT P6SM VCTS SCT080CB
```

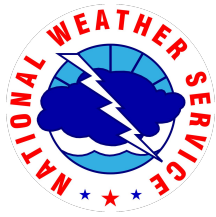


Warm Season CONUS Climatology of Vicinity Versus Prevailing Thunderstorms

Larry Hopper | NOAA/NSSL (formerly NWS Phoenix)

Caroline Jones (NASA SRPO-Wallops Island/Virginia Tech) | Paul Iñiguez (NWS Phoenix)

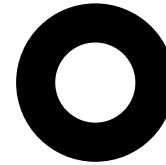
SAWS IX Workshop | Albuquerque, NM | November 5-6, 2021



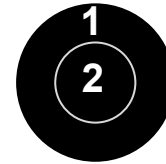
Objectives



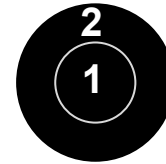
- Better understand climatological frequency and duration of “vicinity” (VCTS) versus “prevailing” (TS) thunderstorms to improve **Terminal Aerodrome Forecasts (TAFs)** and **Airport Weather Warnings (AWWs)**
- Investigate regional differences and what implications they may have on convective aviation **impact-based decision support services (IDSS)?**



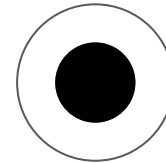
VCTS Only



VCTS First



TS First




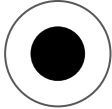


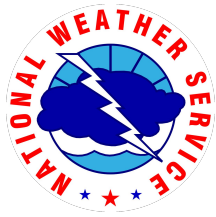
TS Only



Definition of Storm Categories



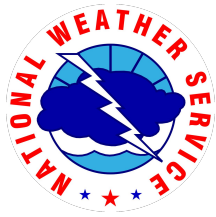
VCTS Only		No strikes within 0-5 SM for entire storm duration.
VCTS First		First strike is within 5-10 SM, but there are also strikes within 0-5 SM during storm.
TS First		First strike is within 0-5 SM, but there are also strikes within 5-10 SM during storm.
TS Only		No strikes within 5-10 SM for entire storm duration.



Research Questions



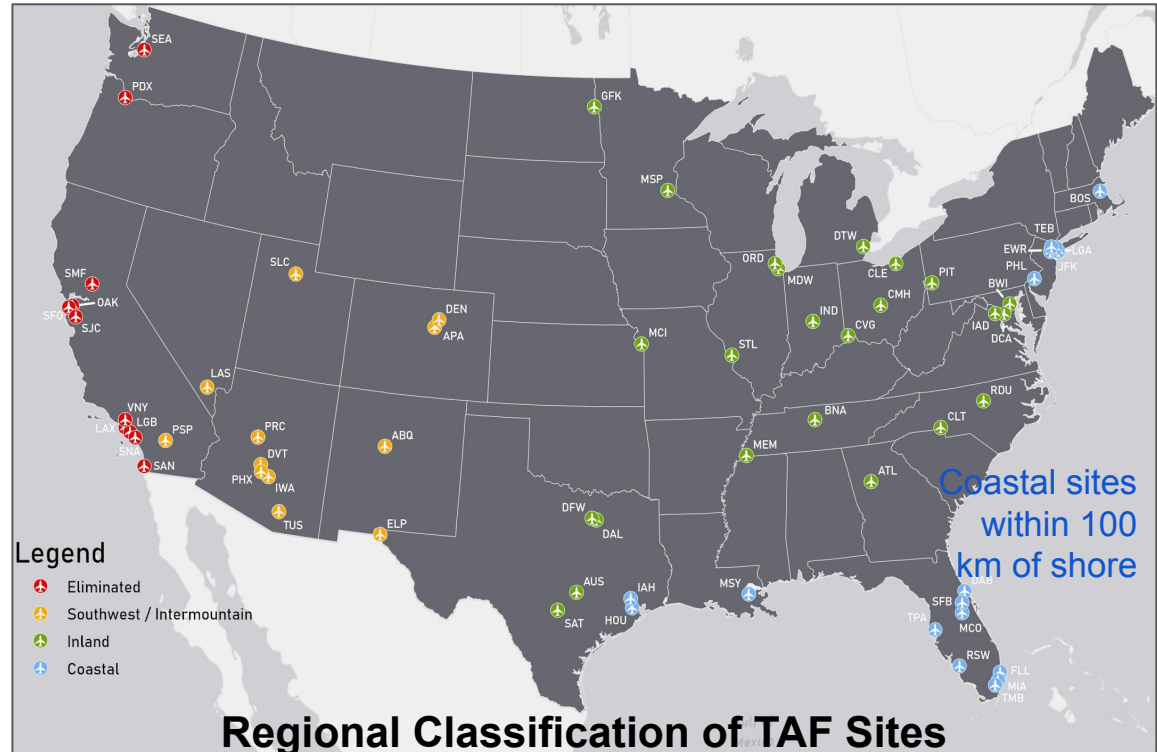
- What are the characteristics (i.e., lightning count and duration) of thunderstorms that produce lightning only in the vicinity (i.e., “VCTS Only”) of an airport versus thunderstorms that also produce lightning within 0-5 miles of an airport?
 - What percent of storms’ first strike is within 5 SM vs. 5-10 SM?
 - What percent of storms ONLY have lightning within 0-5 SM?
 - What percent of storms ONLY have lightning within 5-10 SM?
- Is there a greater chance of “VCTS Only” storms in the Desert Southwest and Intermountain region relative to other regions of the CONUS?

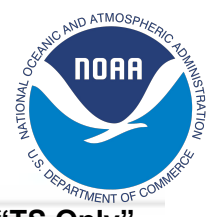


Data and Methods



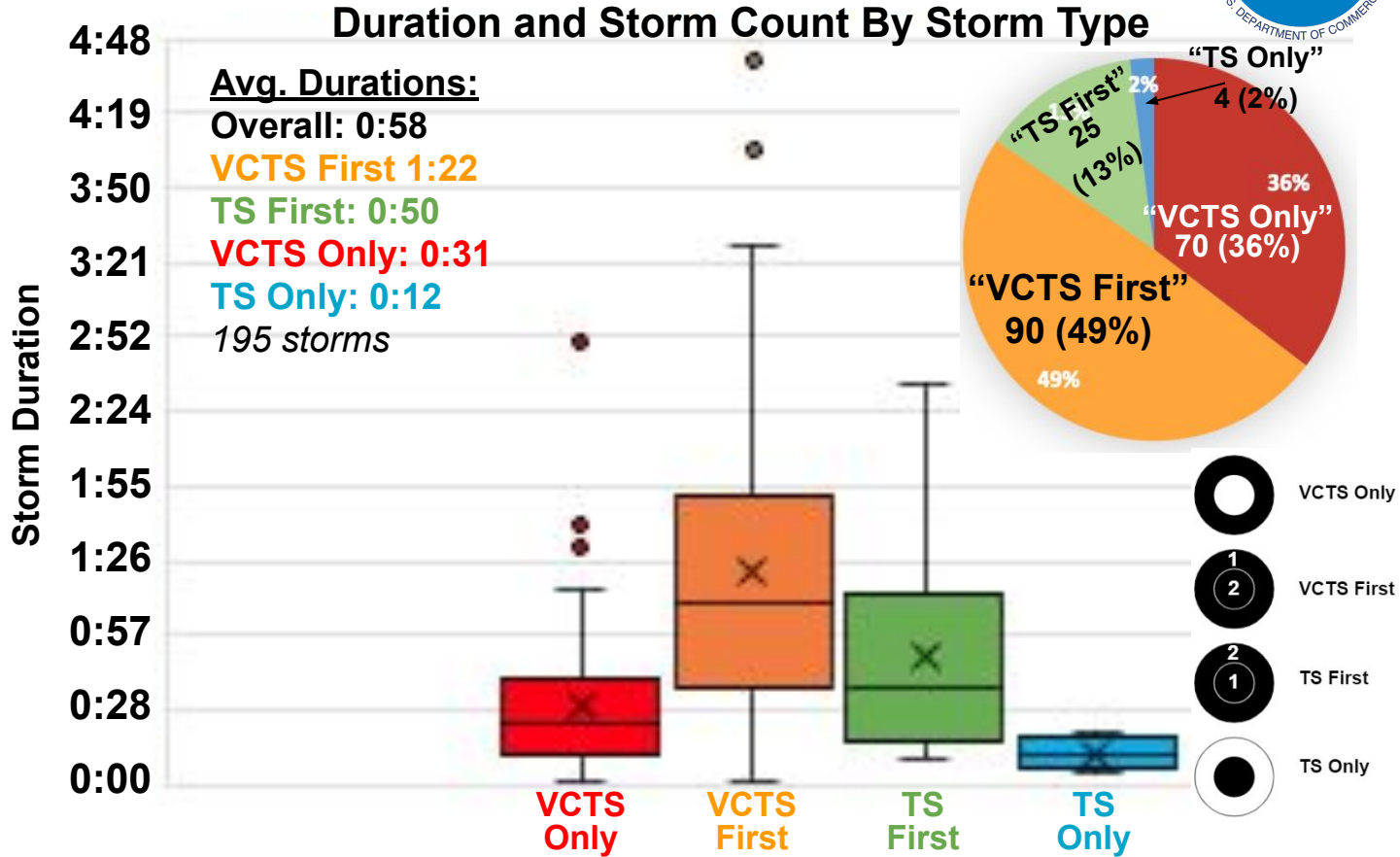
- Warm season (April-October)
NLDN data from 2010-2019
- **34,524 “storms” from 53 TAF sites in Top 50 of total ops or passengers***
 - Excluded 6,106 (18%) single CG storms (rest have 2+ CGs)
 - 1 hr break in CGs = new storm
 - ***Removed sites with less than 50 storms and added four SW/ Intermountain sites in Top 100 passengers**





SW/Intermountain Example (PHX)

- 15% of “TS First” storms at KPHX have first CG within 5 SM
 - 17% DVT
 - 11% KIWA
- “VCTS First” storms longest, but nearly all finish in 2-3 hrs





Other Examples: ABQ vs. MIA (coastal)

ABQ Avg Duration:

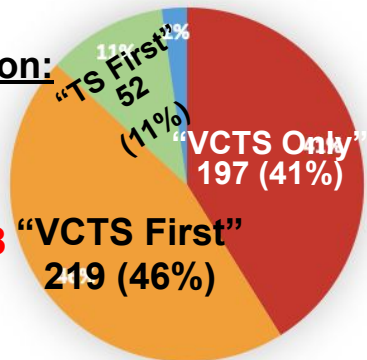
Overall: 0:53

VCTS First 1:17

TS First: 1:02

VCTS Only: 0:28

TS Only: 0:07



8:24

MIA Avg Duration:

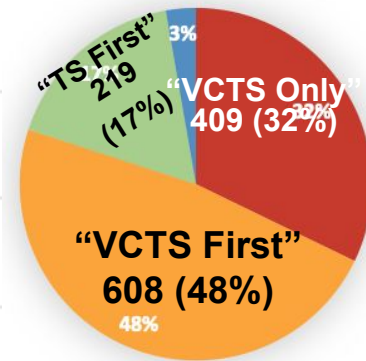
Overall: 1:10

VCTS First 1:36

TS First: 1:17

VCTS Only: 0:33

TS Only: 0:14



7:12

6:00

4:48

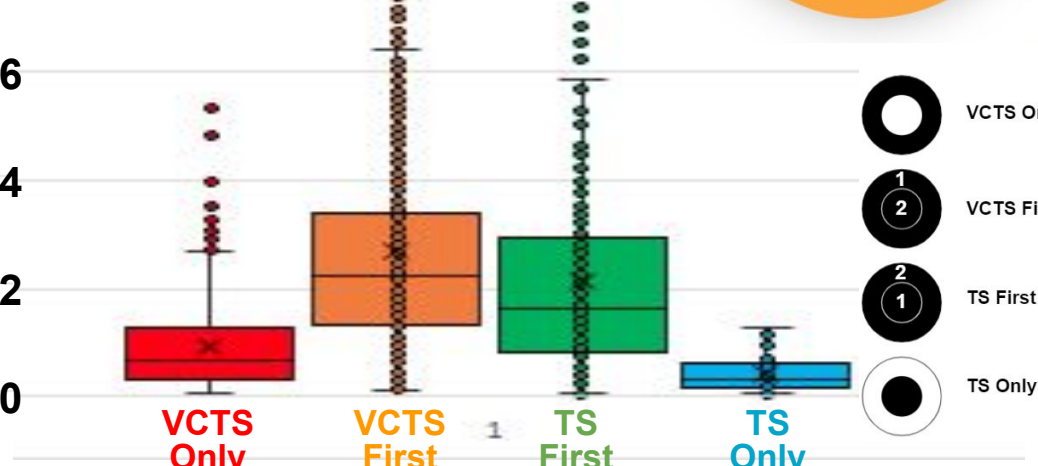
1271 storms

3:36

2:24

1:12

0:00



6:00

4:48

479 storms

3:36

2:24

1:12

0:00





Other Examples: ABQ vs. MCI (inland)

ABQ Avg Duration:

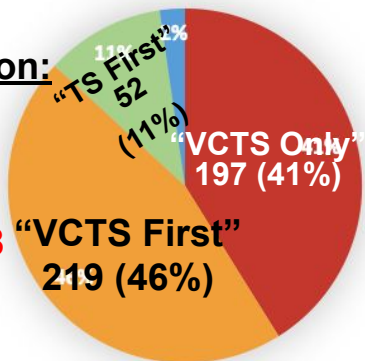
Overall: 0:53

VCTS First 1:17

TS First: 1:02

VCTS Only: 0:28

TS Only: 0:07



8:24

MCI Avg Duration:

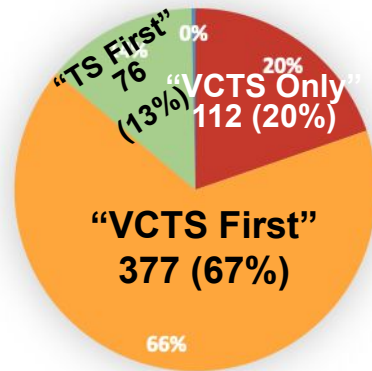
Overall: 1:27

VCTS First 1:48

TS First: 1:10

VCTS Only: 0:26

TS Only: 0:25



7:12

6:00

4:48

3:36

2:24

1:12

0:00

Overall: 1:27

VCTS First 1:48

TS First: 1:10

VCTS Only: 0:26

TS Only: 0:25

568 storms

3:36

2:24

1:12

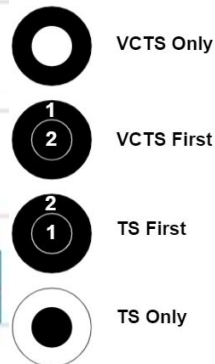
0:00

VCTS Only

VCTS First

TS First

TS Only



6:00

4:48

3:36

2:24

1:12

0:00

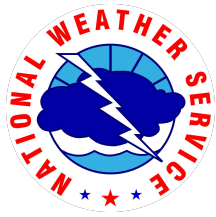
479 storms

VCTS Only

VCTS First

TS First

TS Only



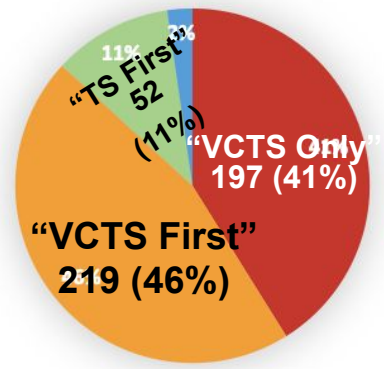
What Might This Mean for PROB30 TS usage in TAFs during the warm season?

ABQ (SW Site)

~60% TS within 5 SM

~40% VCTS (btwn 5-10 SM)

3:2 ratio TS:VCTS

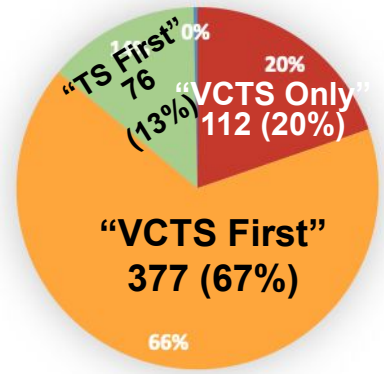


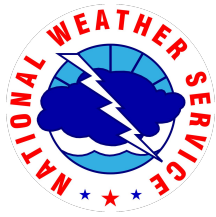
MCI (Inland Site)

~80% TS within 5 SM

~20% VCTS (btwn 5-10 SM)

4:1 ratio TS:VCTS





What Might This Mean for PROB30 TS usage in TAFs during the warm season?



ABQ (SW Site)

~60% TS within 5 SM

~40% VCTS (btwn 5-10 SM)

3:2 ratio TS:VCTS

1 + 2/3 = 5/3 multiplier to get chance of TS or VCTS

30% chance of TS * 5/3 =
50% chance of TS or VCTS

MCI (Inland Site)

~80% TS within 5 SM

~20% VCTS (btwn 5-10 SM)

4:1 ratio TS:VCTS

1 + 1/4 = 5/4 multiplier to get chance of TS or VCTS

30% chance of TS * 5/4 =
37.5% chance of TS or VCTS



“VCTS Only” Storms Most Likely in SW/IM

- 85% of storms’ first strike within 5-10 SM; 15% within 5 SM
 - No significant regional difference (81-89% range for 5-10 SM)*
- Southwest/Intermountain sites **significantly*** most likely to produce “VCTS Only” storms; inland least likely
 - *p<0.00001 for all 3 regions using Z-test for two proportions*

Ranks of “VCTS Only” Sites (Top Half)

Rank	Site	VCTS Only	VCTS First	TS First	TS Only	Storms
1	PSP	51.85%	35.80%	9.88%	2.47%	81
2	LAS	42.08%	44.55%	12.38%	0.99%	202
3	ELP	41.41%	44.44%	12.12%	2.02%	396
4	SLC	41.40%	44.59%	12.10%	1.91%	314
5	ABQ	41.13%	45.72%	10.86%	2.30%	479
6	FLL	37.63%	45.05%	15.70%	1.62%	1172
7	PRC	36.35%	47.40%	14.57%	1.68%	597
8	IWA	36.23%	52.66%	9.66%	1.45%	207
9	PHX	35.90%	49.23%	12.82%	2.05%	195
10	DEN	34.36%	51.44%	12.09%	2.11%	521
11	DCA	33.58%	51.58%	12.65%	2.19%	411
12	APA	33.11%	51.78%	13.24%	1.87%	589
13	TUS	33.10%	55.01%	10.96%	0.93%	429
14	TMB	32.87%	49.18%	16.07%	1.89%	1220
15	TPA	32.69%	52.56%	13.41%	1.34%	1193
16	MIA	32.18%	47.84%	17.23%	2.75%	1271
17	HOU	31.55%	53.69%	13.60%	1.16%	691
18	TEB	31.44%	53.85%	13.71%	1.00%	299
19	LGA	31.43%	57.14%	10.36%	1.07%	280
20	MSY	30.63%	53.44%	14.12%	1.81%	1048
21	ATL	30.58%	53.26%	14.60%	1.55%	582
22	IAD	30.41%	56.70%	12.37%	0.52%	388
23	IAH	30.00%	58.79%	9.85%	1.36%	660
24	BOS	29.79%	54.26%	15.96%	0.00%	188
25	DVT	29.63%	53.44%	16.40%	0.53%	189
26	EWR	28.82%	54.86%	14.58%	1.74%	288
27	RSW	28.61%	56.32%	14.59%	0.49%	1234



	SW / IM (n=4200)	Coastal (n=13,399)	Inland (n=10,819)	CONUS (n=28,418)
VCTS Only	36.96%	30.46%	25.70%	29.61%
VCTS First	48.87%	54.08%	59.47%	55.36%
TS First	12.46%	14.00%	13.62%	13.63%
TS Only	1.74%	1.46%	1.21%	1.41%



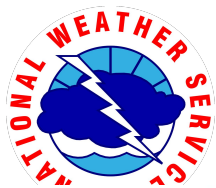
“VCTS Only” Storms Most Likely in SW/IM

- Results also **significant*** when looking at the ranks of individual airport sites
 - *p<0.00001 for all 3 regions using Kruskal-Wallis H Test*

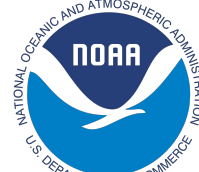
- Southwest/Intermountain regional considerations:
 - Positive: VCTS TAF groups may verify more often
 - Negative: Using lightning within 5-10 SM to predict lightning within 5 SM may result in more false alarms

Ranks of “VCTS Only” by Site

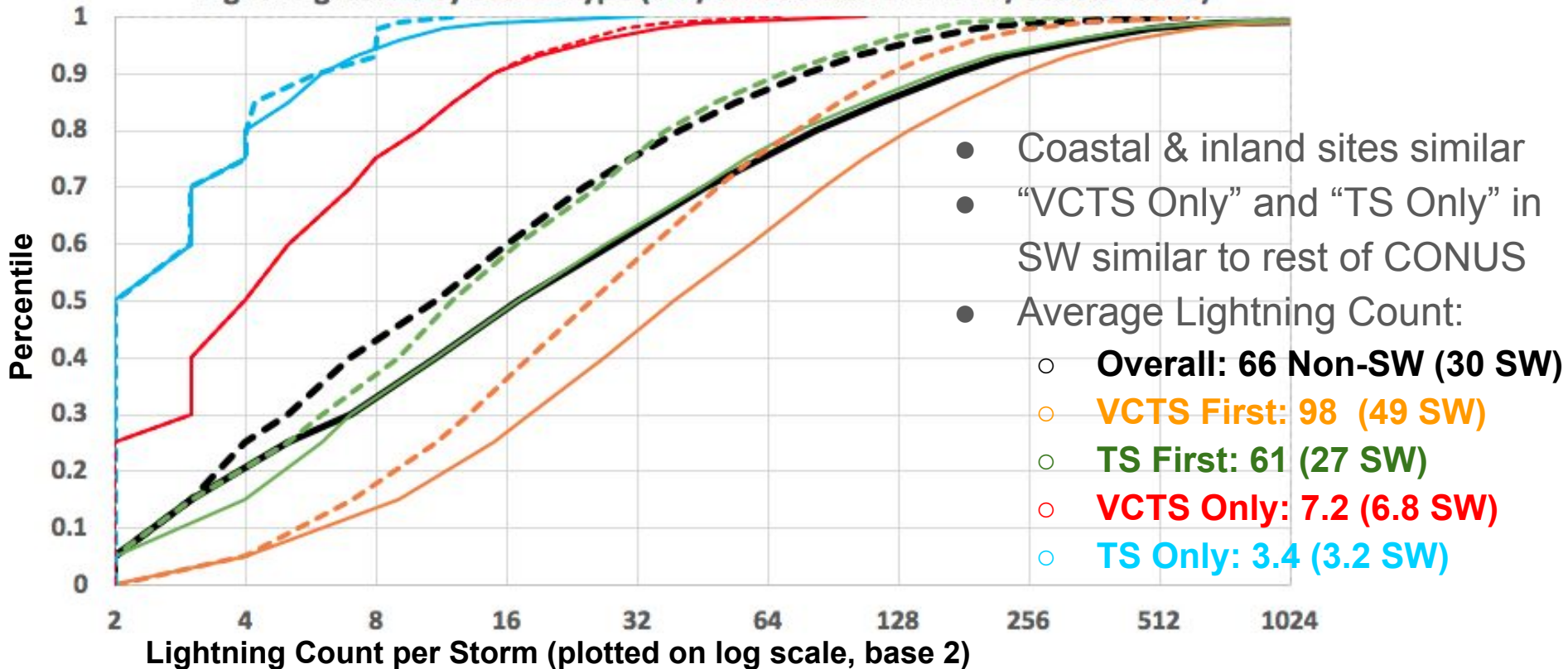
Rank	Site	VCTS Only	VCTS First	TS First	TS Only	Storms	Rank	Site	VCTS Only	VCTS First	TS First	TS Only	Storms
1	PSP	51.85%	35.80%	9.88%	2.47%	81	28	DAB	28.33%	78.36%	14.04%	1.47%	819
2	LAS	42.08%	44.55%	12.38%	0.99%	202	29	CLE	27.79%	56.49%	13.90%	1.82%	439
3	ELP	41.41%	44.44%	12.12%	2.02%	396	30	PIT	27.73%	57.76%	13.87%	0.84%	476
4	SLC	41.40%	44.59%	12.10%	1.91%	314	31	JFK	27.49%	58.57%	11.55%	2.39%	251
5	ABQ	41.13%	45.72%	10.86%	2.30%	479	32	SAT	27.49%	59.94%	11.70%	0.88%	342
6	FLL	37.63%	45.05%	15.70%	1.62%	1172	33	CLT	27.36%	57.55%	14.49%	0.60%	497
7	PRC	36.35%	47.40%	14.57%	1.68%	597	34	SFB	27.00%	58.70%	12.49%	1.81%	937
8	IWA	36.23%	52.66%	9.66%	1.45%	207	35	RDU	26.80%	56.60%	15.60%	1.00%	500
9	PHX	35.90%	49.23%	12.82%	2.05%	195	36	CMH	26.65%	57.35%	13.79%	2.21%	544
10	DEN	34.36%	51.44%	12.09%	2.11%	521	37	AUS	26.58%	56.99%	13.70%	2.74%	365
11	DCA	33.58%	51.58%	12.65%	2.19%	411	38	MEM	26.23%	57.92%	15.32%	0.53%	568
12	APA	33.11%	51.78%	13.24%	1.87%	589	39	BNA	25.99%	57.83%	14.97%	1.20%	581
13	TUS	33.10%	55.01%	10.96%	0.93%	429	40	PHL	25.72%	62.70%	10.29%	1.29%	311
14	TMB	32.87%	49.18%	16.07%	1.89%	1220	41	IND	25.59%	60.83%	12.80%	0.79%	508
15	TPA	32.69%	52.56%	13.41%	1.34%	1193	42	MDW	25.44%	61.45%	12.33%	0.78%	511
16	MIA	32.18%	47.84%	17.23%	2.75%	1271	43	BWI	25.38%	60.66%	12.44%	1.52%	394
17	HOU	31.55%	53.69%	13.60%	1.16%	691	44	MCO	24.90%	62.50%	11.83%	0.77%	1040
18	TEB	31.44%	53.85%	13.71%	1.00%	299	45	DTW	24.82%	59.61%	14.60%	0.97%	411
19	LGA	31.43%	57.14%	10.36%	1.07%	280	46	DFW	24.47%	60.21%	14.26%	1.06%	470
20	MSY	30.63%	53.44%	14.12%	1.81%	1048	47	MSP	24.29%	64.62%	9.91%	1.18%	424
21	ATL	30.58%	53.26%	14.60%	1.55%	582	48	DAL	23.11%	62.63%	12.53%	1.73%	463
22	IAD	30.41%	56.70%	12.37%	0.52%	388	49	ORD	23.06%	63.22%	12.52%	1.19%	503
23	IAH	30.00%	58.79%	9.85%	1.36%	660	50	STL	22.98%	60.03%	15.78%	1.20%	583
24	BOS	29.79%	54.26%	15.96%	0.00%	188	51	CVG	22.03%	65.52%	11.69%	0.77%	522
25	DVT	29.63%	53.44%	16.40%	0.53%	189	52	GFK	21.80%	58.65%	18.05%	1.50%	266
26	EWR	28.82%	54.86%	14.58%	1.74%	288	53	MCI	19.72%	66.37%	13.56%	0.35%	568
27	RSW	28.61%	56.32%	14.59%	0.49%	1234							



SW/IM Storms Produce Less Lightning

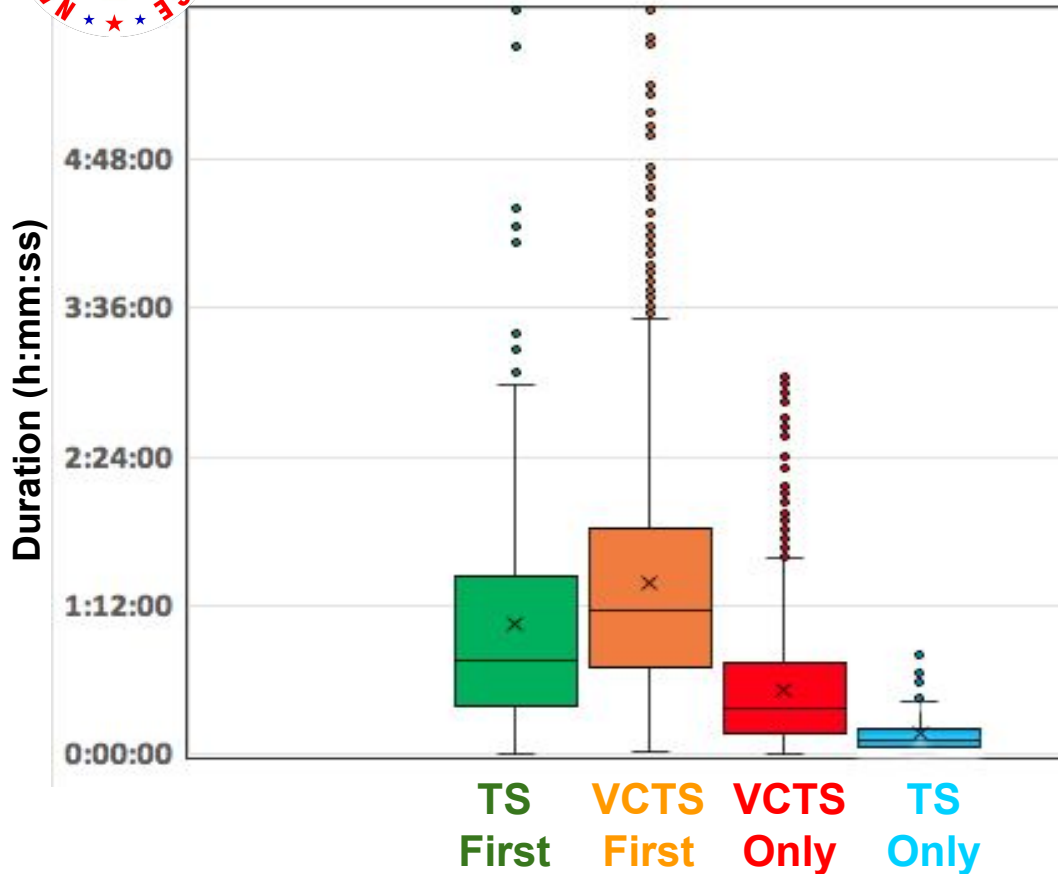


Lightning Count by Storm Type (SW/IM-dashed vs. Inland/Coastal-solid)





SW/IM and “VCTS Only” Storms Shorter



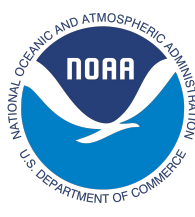
- “VCTS Only” storms are about 2-3x shorter than those that produce lightning within 5 SM
- Southwest/Intermountain storms shown have slightly shorter duration than other regions
- Average Storm Duration:
 - Overall: 1:00 SW (1:13 non-SW)
 - 1. VCTS First: 1:23 (1:35 non-SW)
 - 2. TS First: 0:57 (1:14 non-SW)
 - 3. VCTS Only: 0:32 (0:31 non-SW)
 - 4. TS Only: 0:11 (0:11 non-SW)



Conclusions (with Research Questions)



- What are the characteristics (i.e., lightning count and duration) of thunderstorms that produce lightning only in the vicinity (i.e., “VCTS Only”) of an airport versus thunderstorms that also produce lightning within 0-5 miles of an airport?
 - **“VCTS Only” storms generally produce an order magnitude (~10x) fewer strikes within 10 SM and last 2-3x shorter than storms that produce lightning within 5 SM**
 - What percent of storms’ first strike is within 5 SM vs. 5-10 SM? **~15% (11-19% range)**
 - What percent of storms ONLY have lightning within 0-5 SM? **Minimal (<3% all sites)**
 - What percent of storms ONLY have lightning within 5-10 SM? **Varies (20-42%; PSP 52%)**
- Is there a greater chance of “VCTS Only” storms in the Desert Southwest and Intermountain region relative to other regions of the CONUS? **YES, a significant one!**



Implications: Informing Convective TAFs

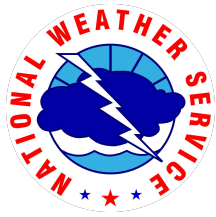
ZAB Collab: ZAB disc in "azchat" by 1630/2230Z; respond by 1645/2245Z

VCTS: High confidence ($\geq 50\%$) iso-sct TS within 10-15 mi, but low confidence where (upgrade for high confidence; use sparingly 0-3 hrs for low confidence)

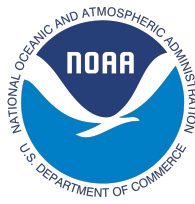
VCSH: Low impact convection (limited instability/very low lightning potential)

TCF Coverage: TEMPO TS, VCTS, or VCSH for sparse; Prevailing TS or TEMPO TS for medium; Prevailing TS for solid/lines (ZAB collaborates on TCF).

Convective TAF Guidance (TS Probability within 5 SM)				
Time to TS	Max TS Length	Slight Chc (15-24%)	Chance (25-54%)	Likely ($\geq 55\%$)
0-3 hours	2 hours (3-VCTS)	VCTS (or VCSH)	VCTS (TEMPO impacts)	TS (TEMPO impacts)
3-9 hours	3 hours (4-VCTS)	VCSH or AFD	VCTS (TEMPO impacts)	TS or VCTS w/ TEMPO TS
9-30 hours	4 hours (5-VCTS)	AFD	VCTS (TEMPO Impacts) PROB30	VCTS w/ TEMPO TS



Implications: Differing VCTS Probabilities for the same TS Probability



ABQ (SW Site)

~60% TS within 5 SM

~40% VCTS (btwn 5-10 SM)

3:2 ratio TS:VCTS

*1 + 2/3 = 5/3 multiplier to get
chance of TS or VCTS*

30% chance of TS * 5/3 =
50% chance of TS or VCTS

MCI (Inland Site)

~80% TS within 5 SM

~20% VCTS (btwn 5-10 SM)

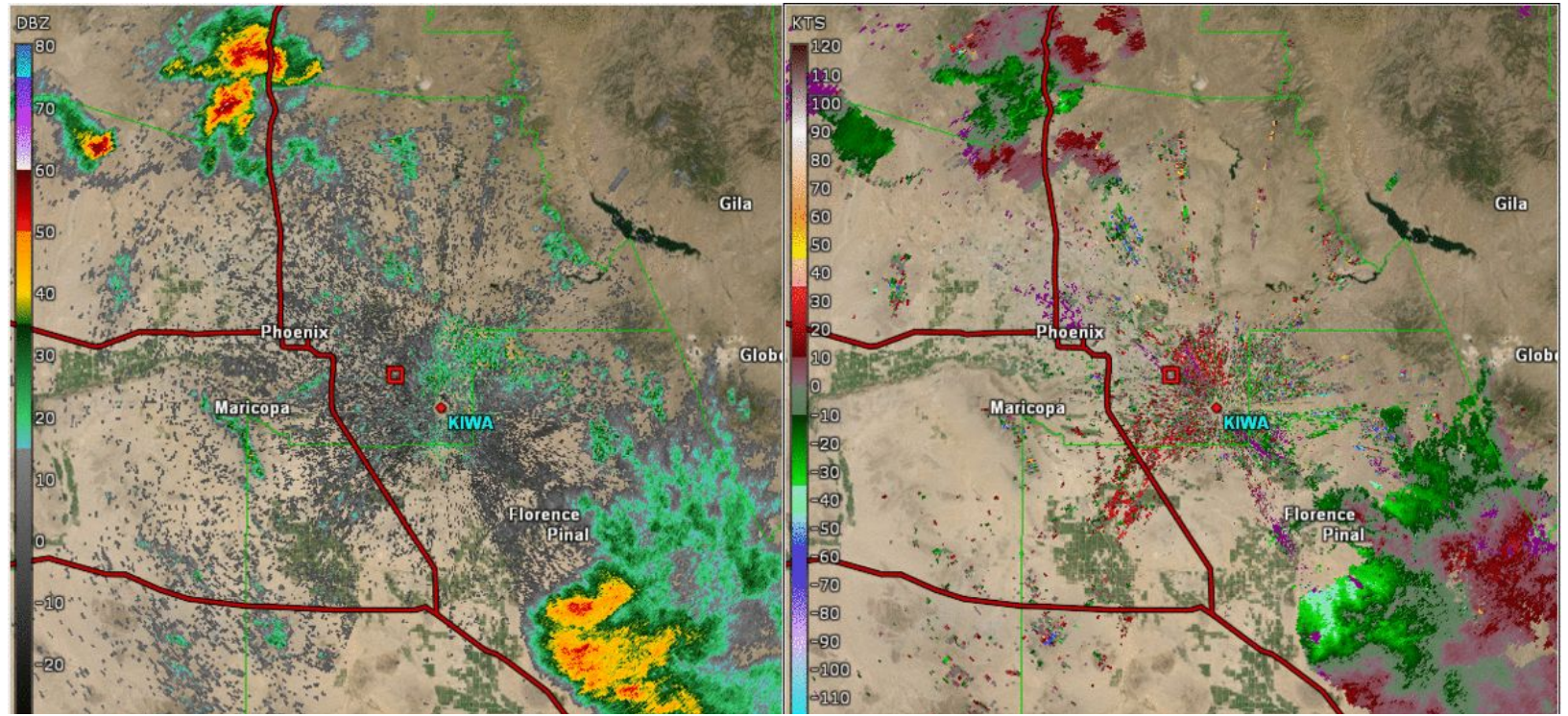
4:1 ratio TS:VCTS

*1 + 1/4 = 5/4 multiplier to get
chance of TS or VCTS*

30% chance of TS * 5/4 =
37.5% chance of TS or VCTS



Pitfalls: Convective Impacts without VCTS





Pitfalls: Convective Impacts without VCTS



Dust Storm Warning

Valid Until
7:30 PM MST Sunday
August 16, 2020

Threat Information

Hazard
Near zero visibility
in blowing dust

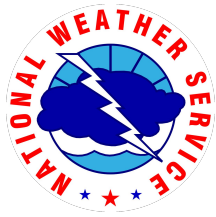
Impact
Dangerous life-
threatening travel

Potential Exposure

Population: 2,888,181
Highways: I-10
I-17
I-8

- Dust storm (<1/4 SM) 0139-0155Z
 - Blowing dust (<6 SM) 0125-0215Z
 - SSE 27 kt max gust, **NO LIGHTNING**





Next Steps and Questions?



- Add sites to fill gaps/better represent the entire CONUS
- “Impact-based” climatology:
 - Duration and intensity of wind gusts and reductions in visibility due to dust (important in the SW)
 - Range at which storms may cause impacts (even if lightning > 10 SM?)
 - Seasonal and diurnal variations to assist in FAA staffing schedules (as requested by PHX TRACON/Tower)

