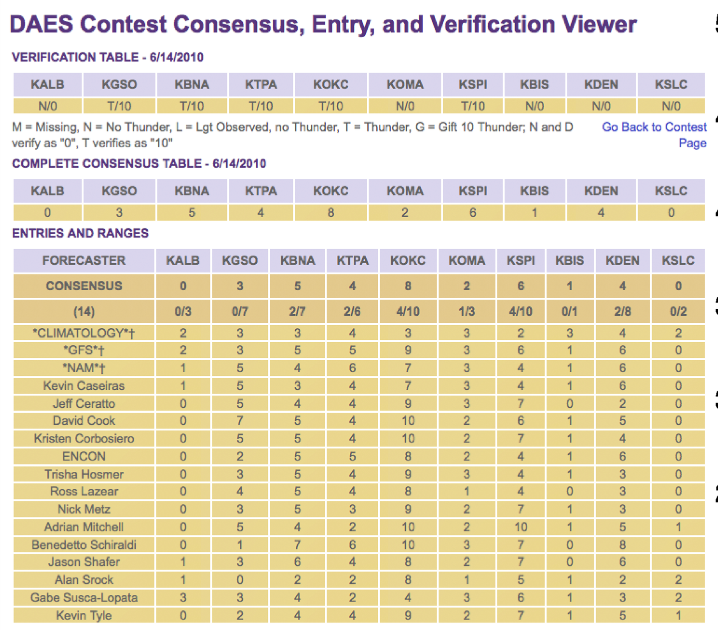
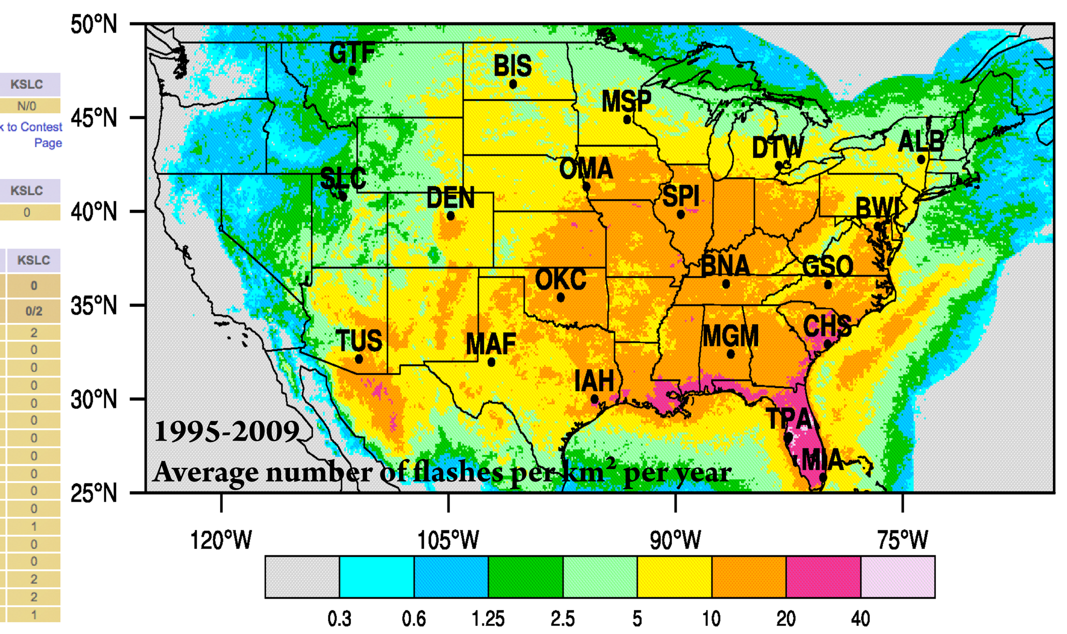
Verification of Thunderstorm Occurrence Using the National Lightning Detection Network

Kristen L. Corbosiero
University of California, Los Angeles

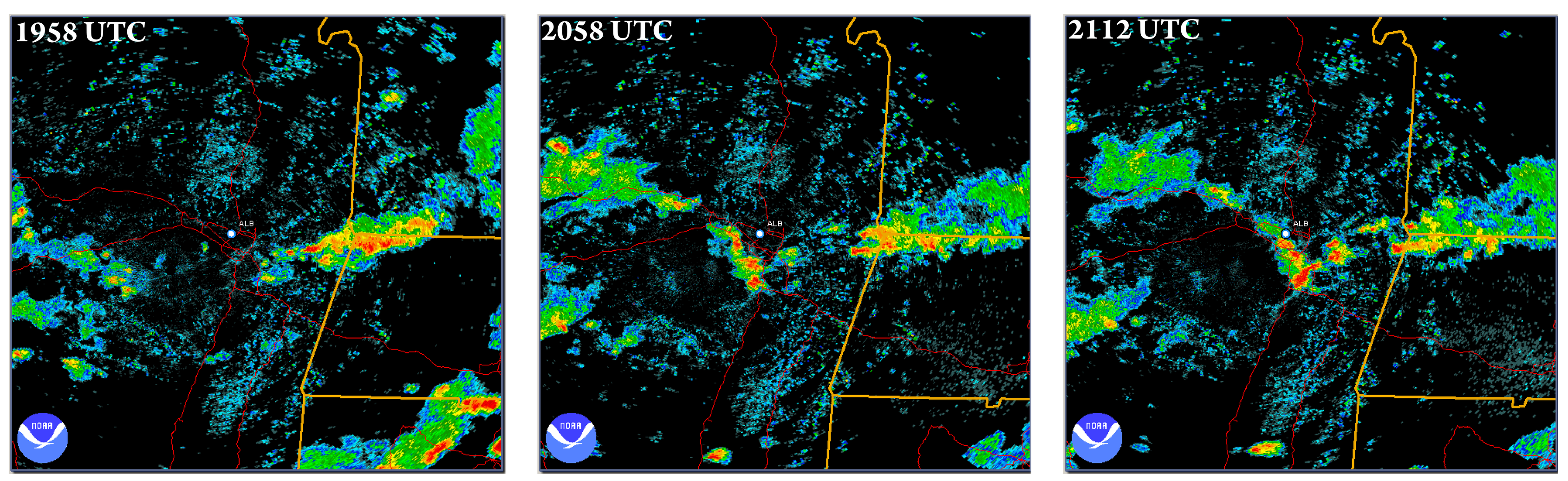
Introduction and Motivation

Since 1983, a daily thunderstorm probability forecast contest has been organized by the Department of Atmospheric and Environmental Sciences (DAES) at the University at Albany during the summer months of June, July, and August.

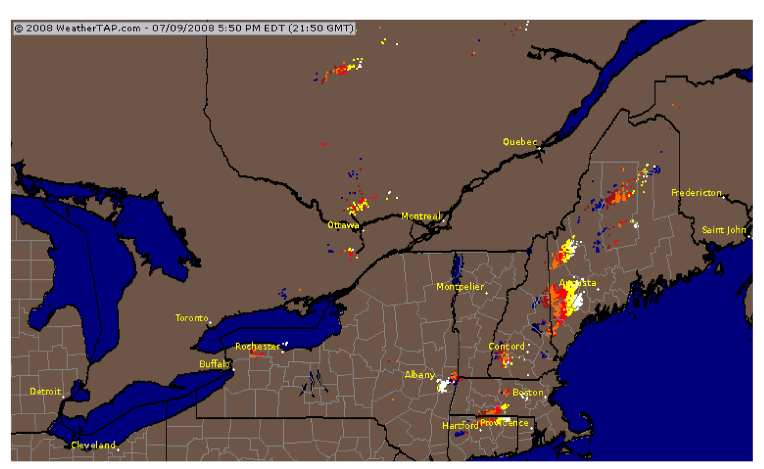




The contest involves predicting the probability to the nearest 10% that a thunderstorm (TS) will be reported during a 24 hour period at 10 locations across the continental U.S. listed in the table above.



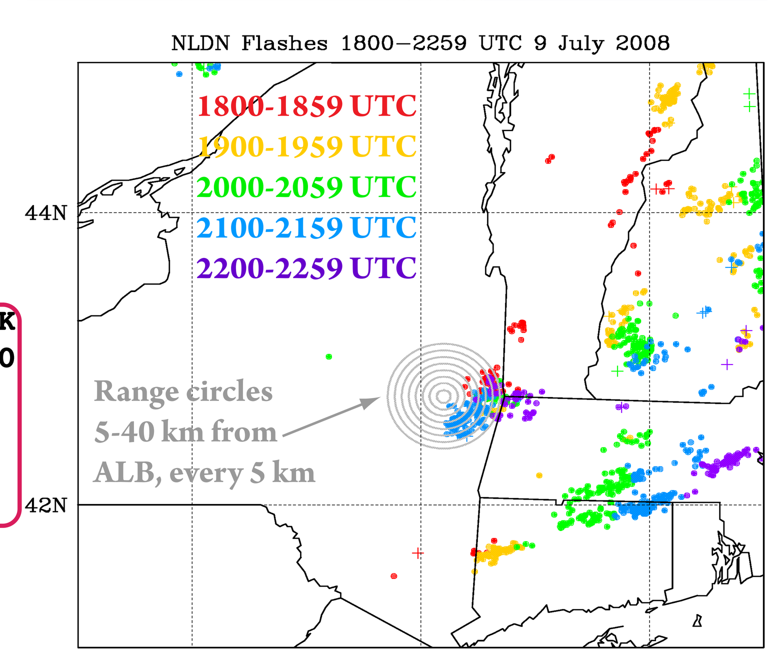
In recent years however, there have been several instances in which a TS failed to be reported despite its occurrence. During such instances, the forecast contest was verified by contacting the attendant NWS office directly and/or examining WSR-88D and National Lightning Detection Network (NLDN) data.



```
KALB 091714Z 25008KT 2SM HZ FEW003 BKN026 BKN039
26/23 A2971 RMK AO2 SFC VIS 4 RAE14 P0013

KALB 091732Z 23008G18KT 1 3/4SM R01/3500VP6000FT
HZ BKN024 BKN029 26/23 A2971 RMK AO2 TWR VIS 3
RAE31 P0018

KALB 091751Z 28007KT 6SM HZ FEW024 28/23 A2971 RMK
AO2 RAE31 SLP056 P0018 60025 T02830228 10289 20250
56012
```

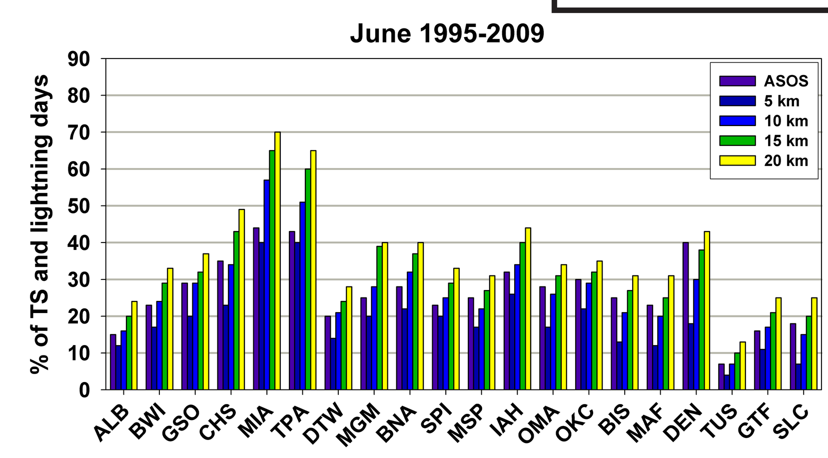
Four hour gap without observations!

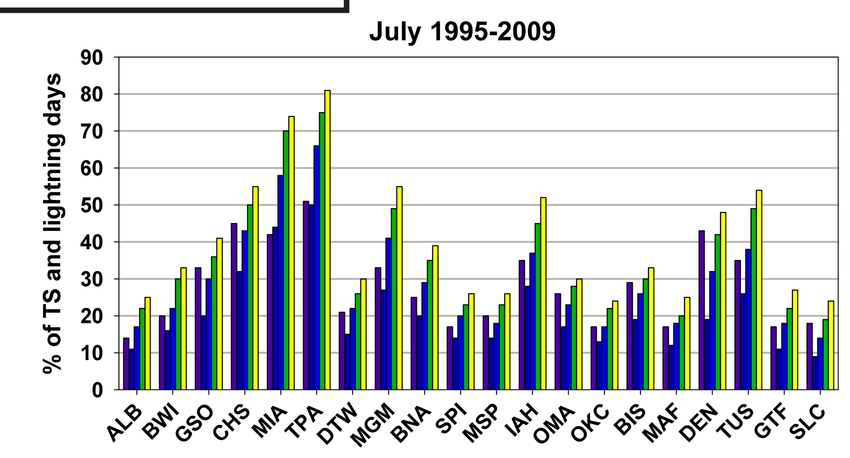
```
KALB 092151Z 26010KT 9SM CLR 26/21 A2969 RMK AO2
PK WND 26027/2109 RAB10E28 SLP051 P0001 T02610211

KALB 092251Z 28006KT 9SM FEW060 26/22 A2971 RMK
AO2 SLP058 T02610217
```

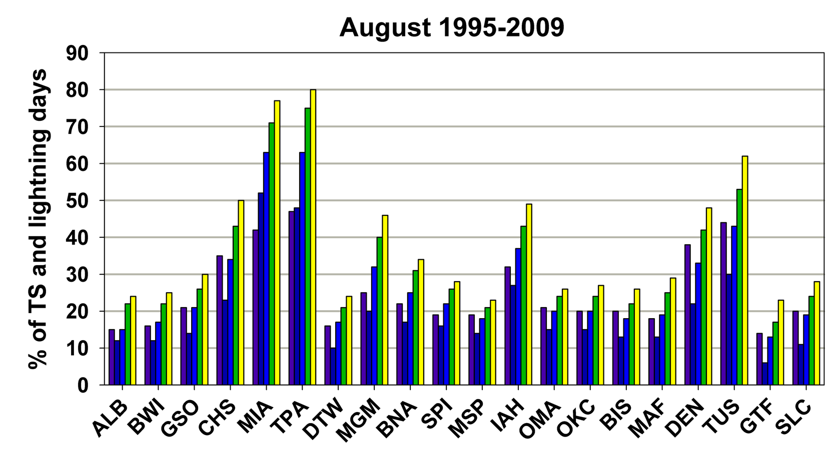


Given its continuous space and time coverage, average detection efficiency of ~95% and mean location errors of <500 m, using the NLDN to verify TS occurrence is explored between 1995 and 2009 at the original 10 stations of the Albany forecast contest, plus 10 additional cities to cover the full spectrum of summertime, synoptic environments and rates of thunderstorm occurrence across the continental U.S.

Climatology



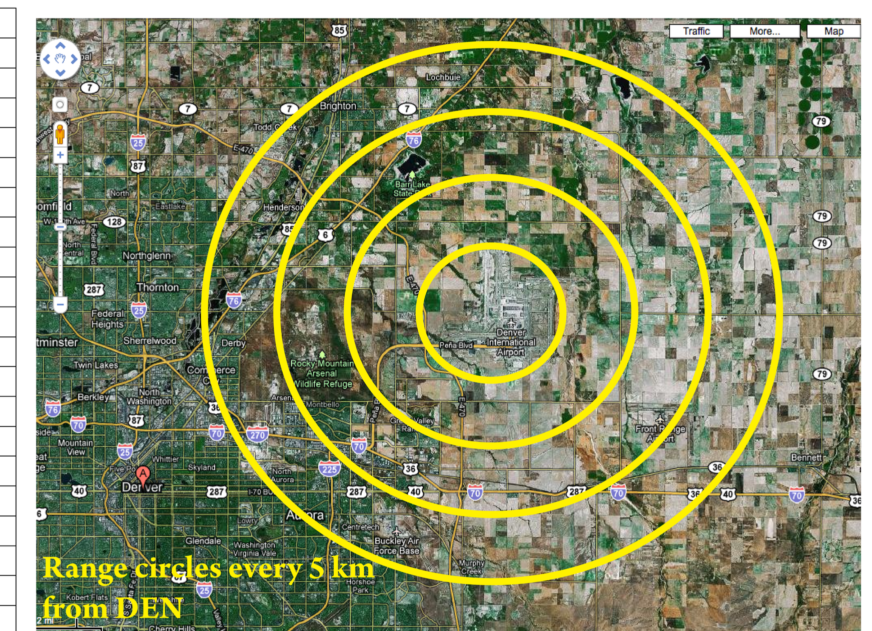




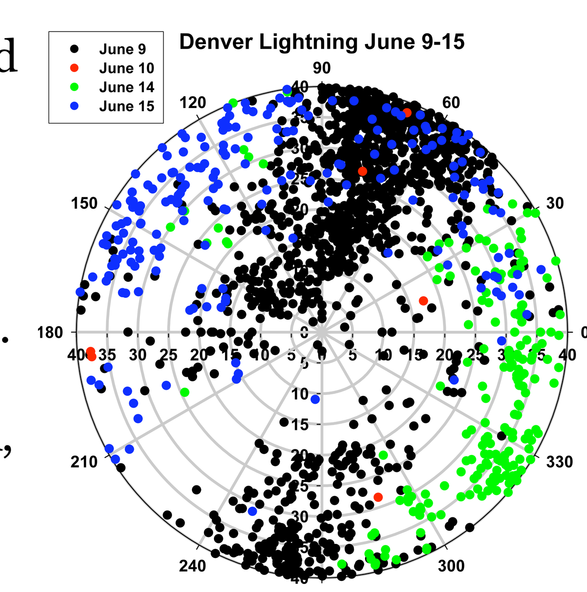
The tables & bar charts show the June, July & August METAR TS climatologies (ASOS) and the climatology of lightning within 5, 10, 15 & 20 km of each station as the fraction of days with a TS report or flash. Red numbers show the radial bin with the NLDN value closest to the ASOS. Blue numbers show cases where the 5 km NLDN value exceeds the ASOS.

July 1995-2009					
ASOS		5	10	15	20
.14	ALB	.11	.17	.22	.25
.20	BWI	.16	.22	.30	.33
.33	GSO	.20	.30	.36	.41
.45	CHS	.32	.43	.50	.55
.42	MIA	.44	.58	.70	.74
.51	TPA	.50	.66	.75	.81
.21	DTW	.15	.22	.26	.30
.33	MGM	.27	.41	.49	.55
.25	BNA	.20	.29	.35	.39
.17	SPI	.14	.20	.23	.26
.20	MSP	.14	.18	.23	.26
.35	IAH	.28	.37	.45	.52
.26	OMA	.17	.23	.28	.30
.17	OKC	.13	.17	.22	.24
.29	BIS	.19	.26	.30	.33
.17	MAF	.12	.18	.20	.25
.43	DEN	.19	.32	.42	.48
.35	TUS	.26	.38	.49	.54
.17	GTF	.11	.18	.22	.27
.18	SLC	.09	.14	.19	.24

August 1995-2009					
ASOS		5	10	15	20
.15	ALB	.12	.15	.22	.24
.16	BWI	.12	.17	.22	.25
.21	GSO	.14	.21	.26	.30
.35	CHS	.23	.34	.43	.50
.42	MIA	.52	.63	.71	.77
.47	TPA	.48	.63	.75	.80
.16	DTW	.10	.17	.21	.24
.25	MGM	.20	.32	.40	.46
.22	BNA	.17	.25	.31	.34
.19	SPI	.16	.22	.26	.28
.19	MSP	.14	.18	.21	.23
.32	IAH	.27	.37	.43	.49
.21	OMA	.15	.20	.24	.26
.20	OKC	.15	.20	.24	.27
.20	BIS	.13	.18	.22	.26
.18	MAF	.13	.19	.25	.29
.38	DEN	.22	.33	.42	.48
.44	TUS	.30	.43	.53	.62
.14	GTF	.06	.13	.17	.23
.20	SLC	.11	.19	.24	.28



The tables above explore the number of METAR TS and NLDN lightning days without taking into account whether these days actually match. The tables below take date matching into account and address two fundamental questions. Red (blue) numbers denote values one standard deviation above (below) the mean.



MSP, OMA and DEN are excellent verifiers, while MIA, TPA, and GTF are poor verifiers. A strong east/west dichotomy is noted with stations in the western U.S. verifying TSs with lightning at much farther distances.

If the NLDN detects lightning within X km of a station, what percentage of the time does the station report a TS?

Station	5	10	15	20
ALB	86	75	65	57
BWI	93	84	72	64
GSO	95	86	80	74
CHS	95	89	81	75
MIA	81	69	63	59
TPA	85	74	68	62
DTW	88	80	73	66
MGM	86	76	66	58
BNA	86	78	70	64
SPI	85	78	73	67
MSP	95	89	83	77
IAH	91	84	76	71
OMA	95	90	86	80
OKC	95	89	80	76
BIS	91	87	83	78
MAF	91	83	75	65
DEN	96	94	89	83
TUS	84	78	71	66
GTF	83	73	65	56
SLC	94	85	81	69
Average	**90**	**82**	**75**	**68**

If a TS is reported by a station, what percentage of the time does the NLDN detect lightning within X km?

Station	5	10	15	20
ALB	67	84	93	95
BWI	70	86	96	98
GSO	62	82	90	96
CHS	65	86	96	98
MIA	83	95	99	99
TPA	83	95	99	100
DTW	59	86	91	95
MGM	71	91	97	98
BNA	69	90	97	98
SPI	75	90	97	99
MSP	66	82	92	96
IAH	72	90	95	97
OMA	63	81	93	95
OKC	70	86	93	96
BIS	56	76	88	95
MAF	55	78	90	94
DEN	46	73	88	95
TUS	61	80	93	99
GTF	52	79	85	92
SLC	43	70	88	95
Average	**64**	**84**	**93**	**96**

Interannual Variability

City	Correlation		# of years NLDN10 > METAR	Average # of days difference
	r	ρ		
ALB	.70	.63	9	3.0
BWI	.88	.89	7	3.0
GSO	.85	.68	6	3.1
CHS	.72	.72	6	3.0
MIA	.39	.29	15	15.5
TPA	.69	.74	15	12.3
DTW	.82	.86	5	1.9
MGM	.58	.48	12	5.9
BNA	.50	.49	13	5.1
SPI	.78	.74	12	3.0
MSP	.80	.75	4	2.5
IAH	.87	.89	12	3.9
OMA	.67	.66	3	3.0
OKC	.93	.93	3	1.7
BIS	.68	.68	3	3.6
MAF	.71	.74	6	3.1
DEN	.90	.84	0	8.2
TUS	.38	.45	7	8.5
GTF	.62	.53	5	3.9
SLC	.87	.82	2	3.5

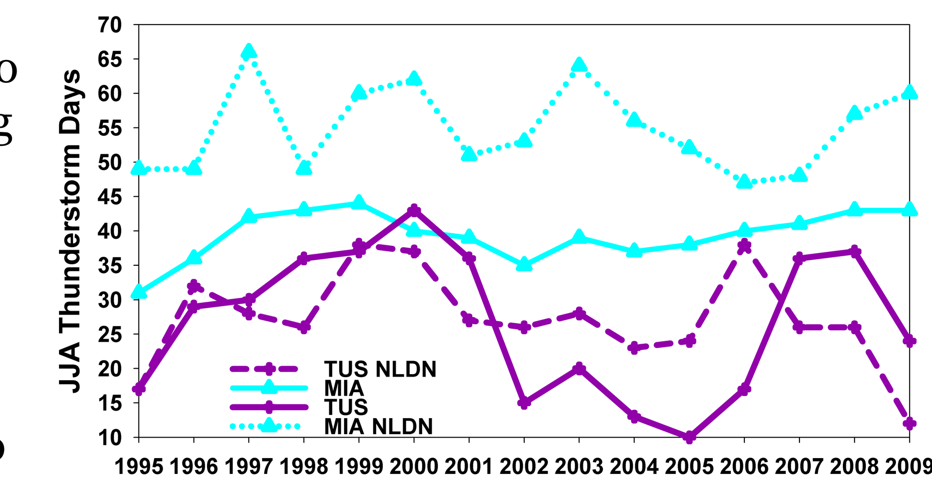
The table to the left shows the Pearson (r) and Spearman rank (ρ) correlation coefficients between METAR and NLDN10, the number of years NLDN10 > METAR, and the absolute value of NLDN10-METAR (the number of days difference between the two measures).

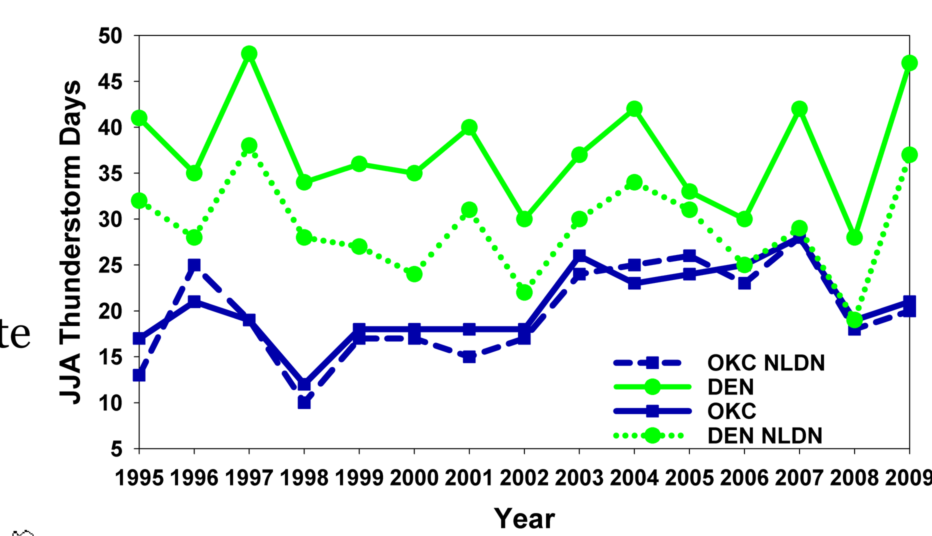
MIA, TUS, BNA, MGM, GTF and ALB all fail to have significant positive correlations between the number of METAR reported TS days and the number of days with lightning within 10 km. On the other end of the spectrum, OKC, DEN, BWI, and IAH have very high correlations.

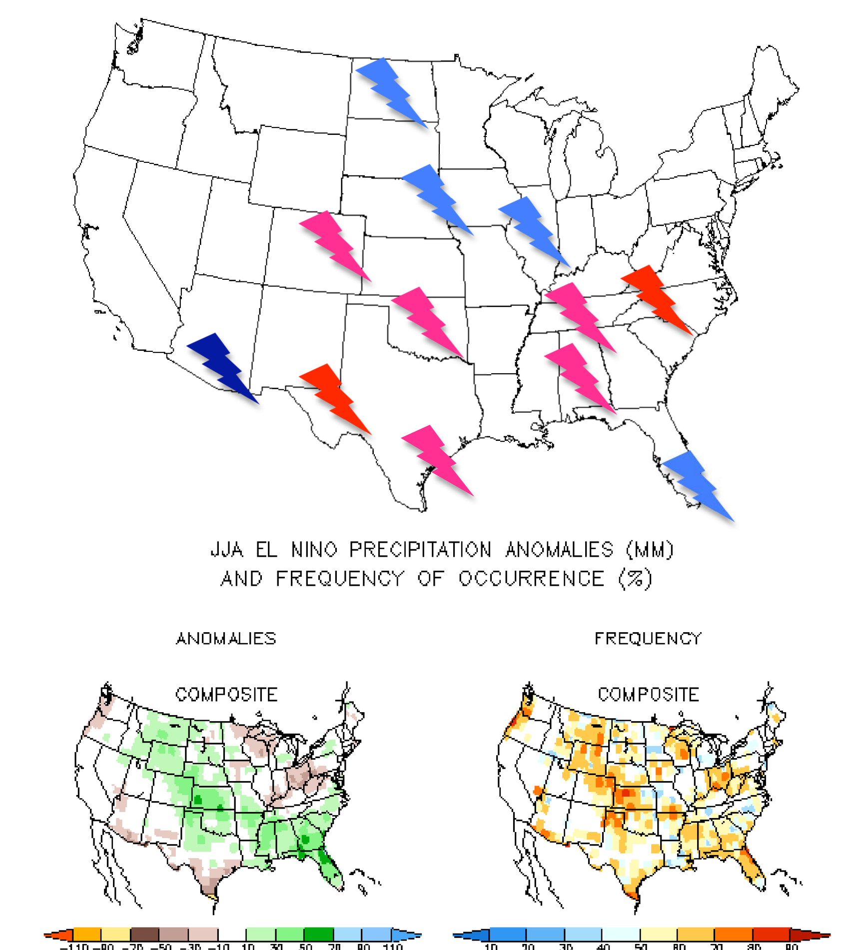
The poor correlation in TUS seems to be due to changes in METAR lagging those in NLDN10 by a year, and the strong interannual variability of rainfall associated with the North American Monsoon.

The low correlation in MIA is due to METAR remaining flat with time, while NLDN10 exhibits significant year-to-year variability.

DEN and OKC exhibit two of the largest correlation coefficients between METAR and NLDN10 despite METAR always being greater than NLDN10 at DEN.







	DJF NINO Correlation		MAM NINO Correlation		JJA NINO Correlation	
	METAR	NLDN10	METAR	NLDN10	METAR	NLDN10
ALB	.19	.19	.26	.10	.17	-.02
BWI	-.27	.04	-.44	-.13	-.07	.11
GSO	.40	.20	.44	.09	.68	.20
CHS	.21	.30	.10	.18	.19	.28
MIA	-.37	-.33	-.33	-.15	-.39	.27
TPA	-.35	.02	-.30	.05	.01	.20
DTW	.46	.39	.47	.34	-.09	-.19
MGM	.03	.34	-.07	.32	.31	.53
BNA	.10	.47	.25	.46	.33	.22
SPI	-.08	.09	.00	.11	-.43	-.26
MSP	.17	.53	.45	.63	.05	.16
IAH	.27	.38	.02	.19	.15	.40
OMA	.20	.16	.13	.10	-.35	-.32
OKC	.08	.05	-.10	-.08	.34	.33
BIS	-.06	-.23	-.06	-.11	-.41	-.15
MAF	-.24	.09	-.02	.16	.59	.69
DEN	.18	.38	.14	.44	.30	.51
TUS	-.49	-.44	-.63	-.50	-.71	-.33
GTF	.08	.02	.38	.01	.14	-.37
SLC	.00	.12	.27	.41	.08	.16

ORANGE, LIGHT BLUE = Significant @ 90%
RED, BLUE = Significant @ 95%
MAROON, NAVY = Significant @ 98%
PINK, PURPLE = Significant @ 99%

The city with the strongest and most consistent relationship with ENSO is TUS, exhibiting negative correlations (i.e., warm Pacific waters, less TS activity) across the seasons and measures of TS activity. DTW, BNA and MSP show positive correlations between DJF and MAM ENSO values and JJA TS activity, while GSO, MGM, MAF and DEN all exhibit statistically significant positive correlations between TS activity and ENSO in JJA, consistent with known precipitation signals.