Presenter: Blake C. Kronksoky, P.E. (TTU PhD Candidate)

Rainfall Statistics: (Where we were, Where we are, Where are we going?)

The ability to predict floods or extreme rainfall is one of mankind's most exasperating challenges. Unfortunately most Engineers/Scientists/Statisticians have no crystal ball to help predict the "Big One". The tools we are given are based on sound science and mathematics evident in literature pre-dating the 1900's.

The statistics used to describe such events are predominately implemented with two methods: Annual Maxima Series (AMS) and Partial Duration Series (PDS). AMS is used to evaluate maximum values from yearly data with cumulative density functions (CDF) to predict Annual Exceedance Probabilities (AEP). The latter method, PDS, predicts Average Recurrence Intervals (ARI) for exceedance values with probability count distributions (Poisson) or log-based regression models.

This presentation will cover a historical review of eight rainfall studies from 1913 to the current NOAA 14 Atlas (2015) ~100 years of analysis; focusing on the statistical methods (PDS/AMS) and provide a comparison of the (100-year) 24-hour/1-day results. The objective of this presentation is to show (where we were, where we are, and where are we going?) with hydrological statistics. The presentation will be thought provoking and postulate the question ("Do the numbers really change?"). The closing of this presentation will introduce a new PDS methodology developed by the presenter as part of his PhD Research at Texas Tech University (Where he is going).

2016 Fall TFMA Conference

RAINFALL STATISTICS:

(WHERE WE WERE, WHERE WE ARE, WHERE ARE WE GOING?)

Presented by :

Blake C. Kronkosky (P.E.) , StateTech Engineering LLC

Ph.D. "Aspirant" Texas Tech University

TEXAS TECH UNIVERSITY

STATETECH ENGINEERING, LLC

About the Presenter

- **B.S.C.E (2008) Oklahoma State University**
- **Licensed TBPE (2013)**
- **StateTech Engineering (2013)**
- **M.S.C.E. (2015) Texas Tech University (TTU)**
- **Doctorial Student (TTU); anticipated graduation May 2017**
- **Dissertation Topic : Rainfall Statistics/Risk Modeling**

Outline

- **Review 7 Rainfall Studies between (1917-2013) in Oklahoma and Texas:**

  "brief synopsis of statistical methods and results"

- **1-Day, 100-yr DDF ; Isopluvial Maps (Precipitation Contours Maps)**
- **Compare 1-Day, 100-yr DDF at County Centroids**
- **Intro to Presenters Ph.D. Research at TTU**

Outline

Where We Were

- Miami Conservancy District (1917), T.R. Part V “Storm Rainfall of Eastern United States”, (MCD 1917)
- Floods, “Continuation of (MCD 1917)” (Switzer 1929)
- Rainfall Intensity-frequency Data (USDA 1935)
- TP-40 (USWB 1963)

Where We Are

- DDF Precipitation for Oklahoma, (USGS 1999)
- Atlas of DDF of Precipitation Annual Maxima for Texas, (USGS 2004)
- NOAA Atlas 14 Vol 8 Ver 2.0 , (NOAA 2013)

Where Are We Going?

- NOAA Atlas 14 “Texas”
- Intro to Presenters Ph.D. Research

Where We Were

Where We Were (MCD 1917) 6

Miami Conservancy District, "Storm Rainfall of Eastern United States", Technical Report V (MCD 1917) :

- **First Extreme Rainfall study performed in the U.S.**
- **USWB Daily Rainfall Data (1850-1914) ; ~4,500 locations**
- **Excess Rainfall >=1 in/ Day (PDS)**
- **Aggregated records within 2 –(deg) grids to one record**
- **Calculated probabilities base on % Ranking (eg. 100-yr Freq = 5th largest value in 500 samples)**

Where We Were (MCD 1917) 6

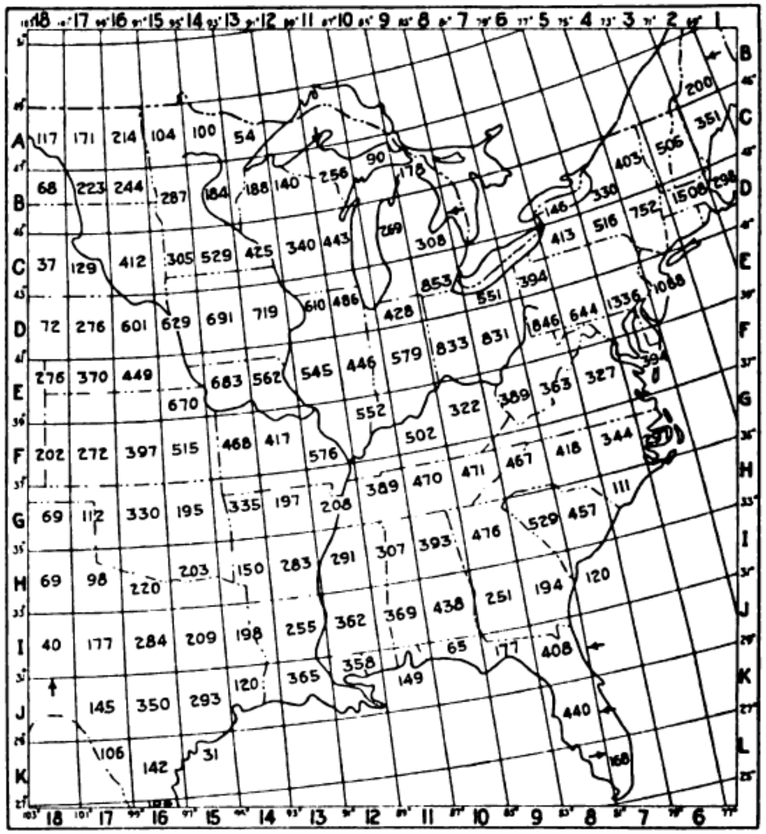


FIG. 37.—AGGREGATE YEARS OF RECORD IN EACH QUADRANGLE.

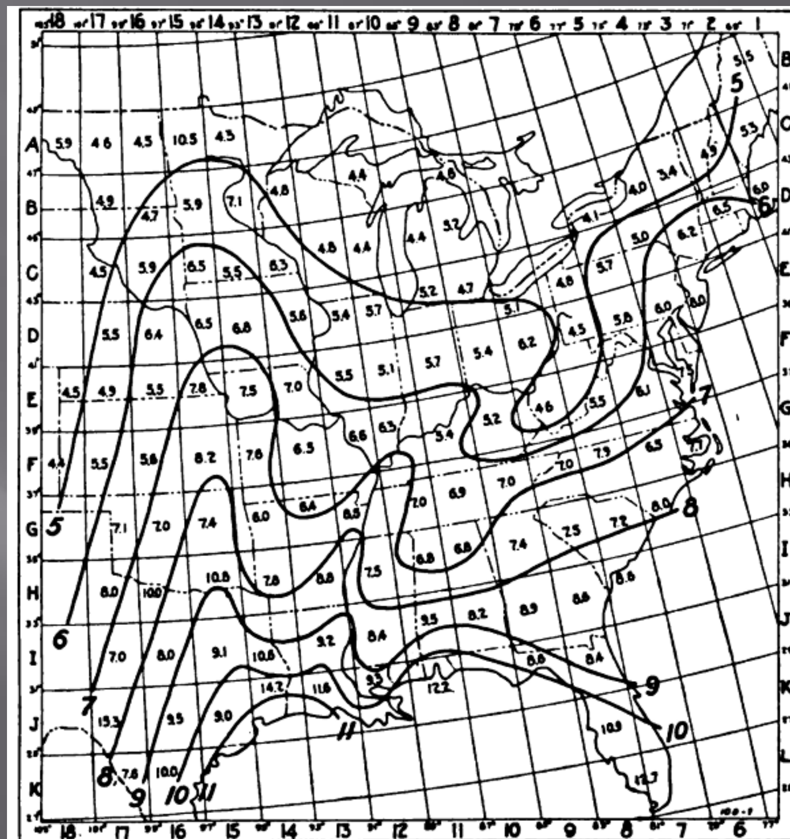


FIG. 31.—ISOPLUVIAL CHART FOR 100-YEAR PERIOD AND 1-DAY RAINFALL.

Where We Were (Switzer 1929) [8]

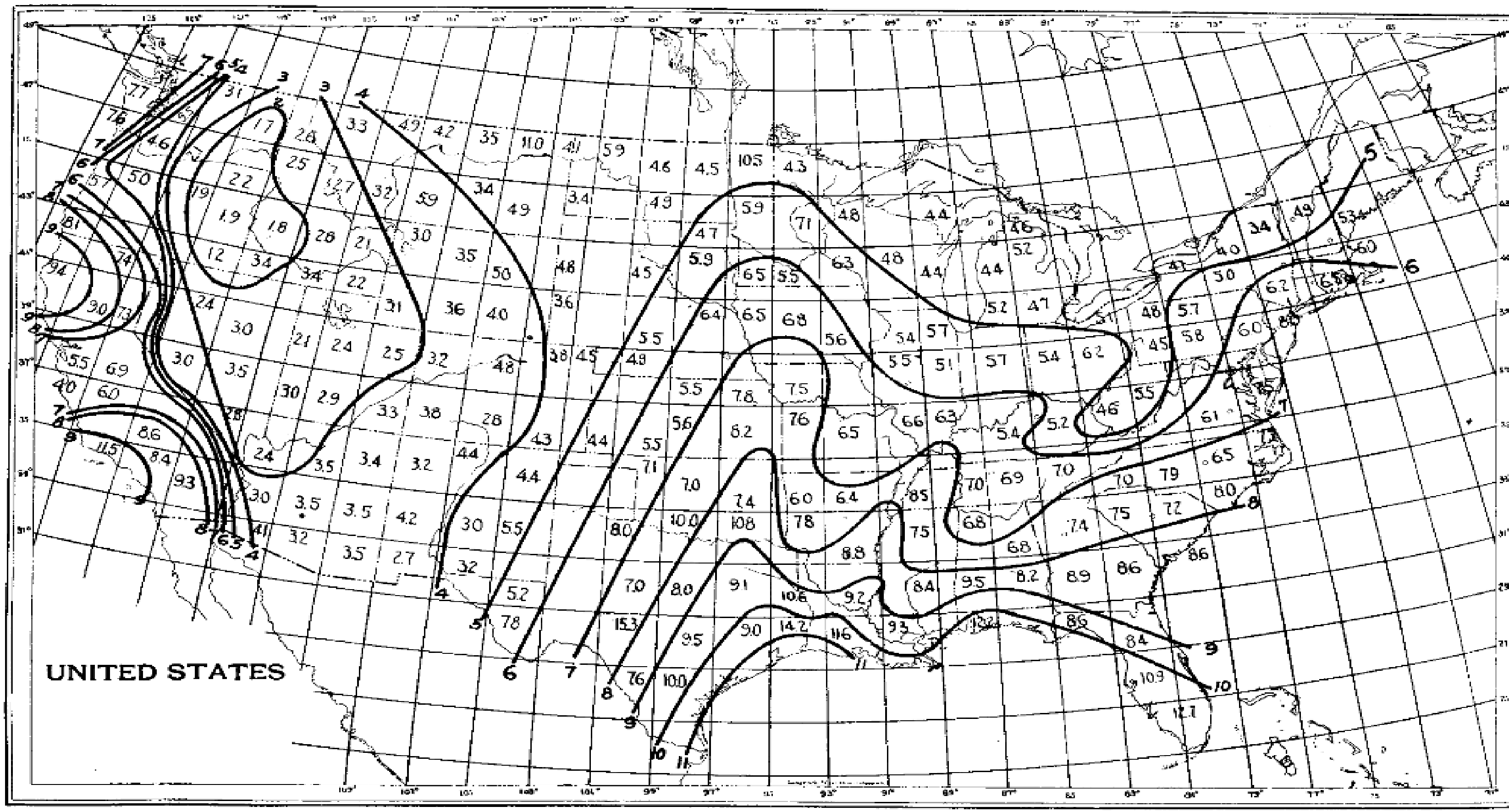


FIG 7 - ISOPLUVIAL CHART - 100 YEAR PERIOD ONE DAY RAINFALL
EAST OF 103° MERIDIAN DATA FROM MIAMI CONSERVANCY DISTRICT

Where We Were (USDA 1935) 11

Unites States Department of Agriculture-Misc Publication 24

“Rainfall-Intensity-Frequency Data (USDA 1935) :

- **USWB 5-Min records (1893-1933) , 211 locations**
- **Evaluated Storm Depths ~(28,000 storms)**
- **DDF for (5min-24 hours) , (5-100 year Frequencies)**
- **Extreme Rainfall (PDS) NOT DESCRIBED IN REPORT**
- **Used semi-log (Curve fitting) for frequency predictions**

Where We Were (USDA 1935) 11

FIGURE 1.—Weather Bureau stations furnishing data for determining high short-time rates of rainfall.

Where We Were (USDA 1935) [11]

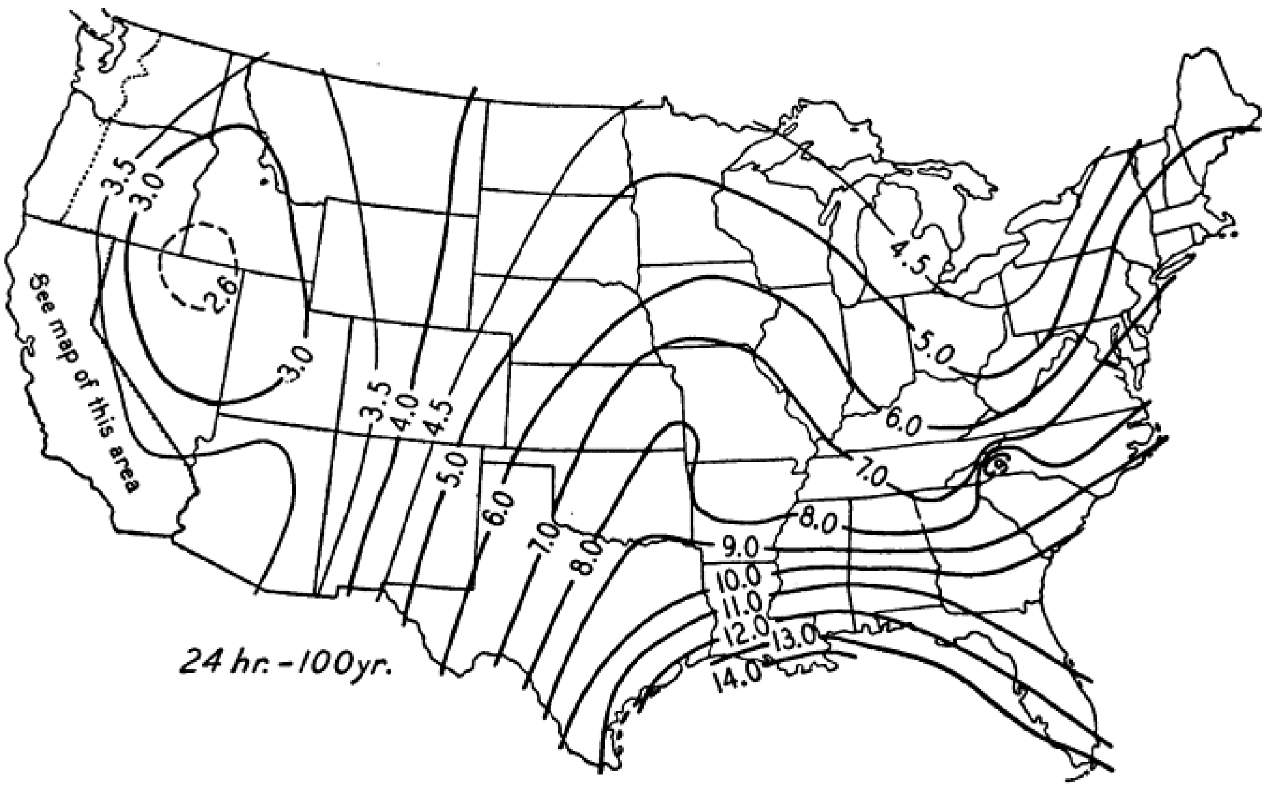


FIGURE 59.—Twenty-four-hour rainfall, in inches, to be expected once in 100 years. (Data for Pacific Coast area are given in fig. 62.)

Where We Were (NOAA TP40 1963) 3

NOAA –Technical Paper 40-“Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years”, (TP40 1963):

- **5,000 stations across the U.S. (min 5 years of record)**
- **Converted (AMS) to (PDS) with ratios**
- **Adjusted Daily Records by 1.13 factor (sample bias)**
- **Gumbel Extreme Value Distribution**

Where We Were (NOAA TP40 1963) 3

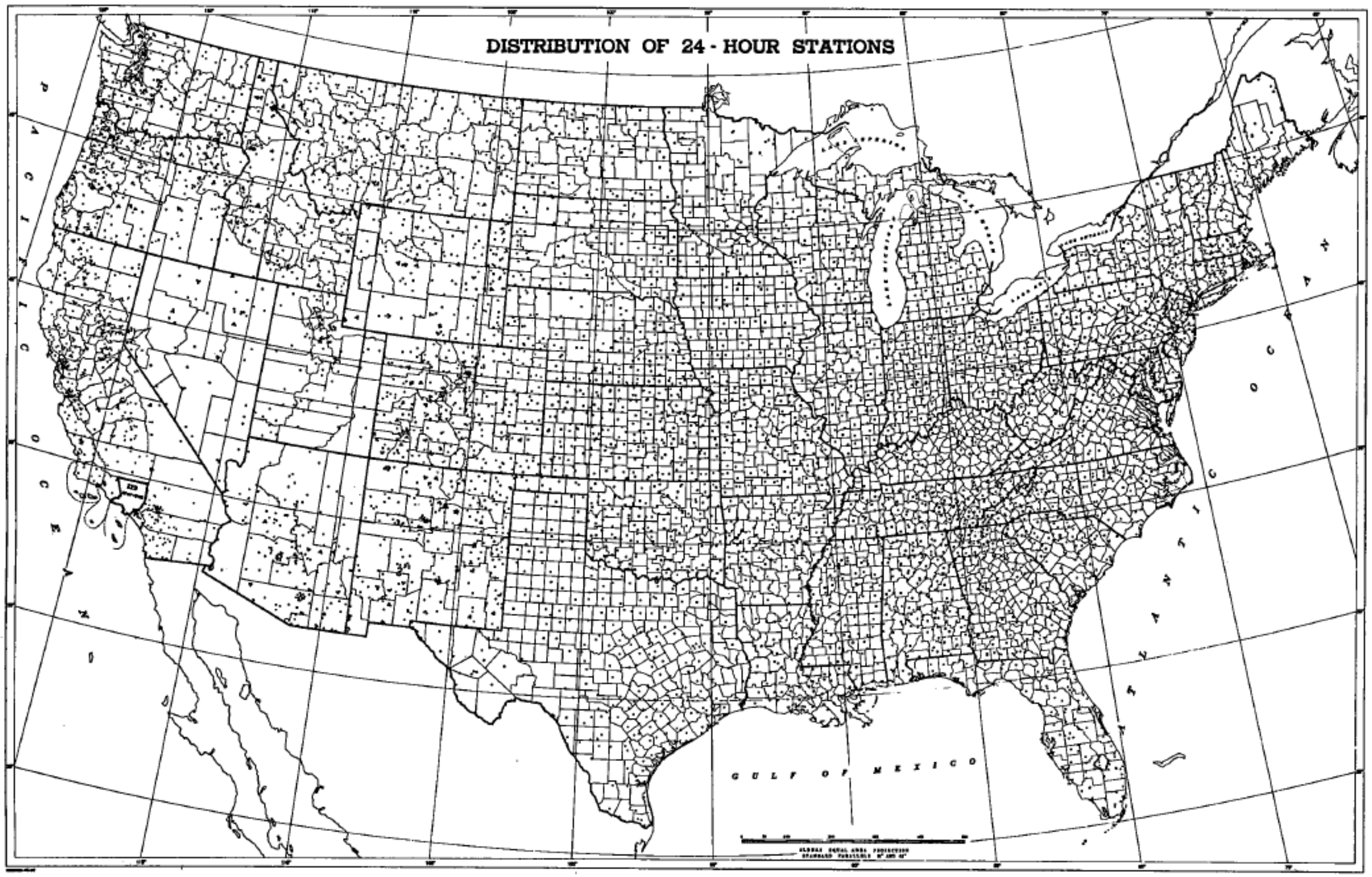
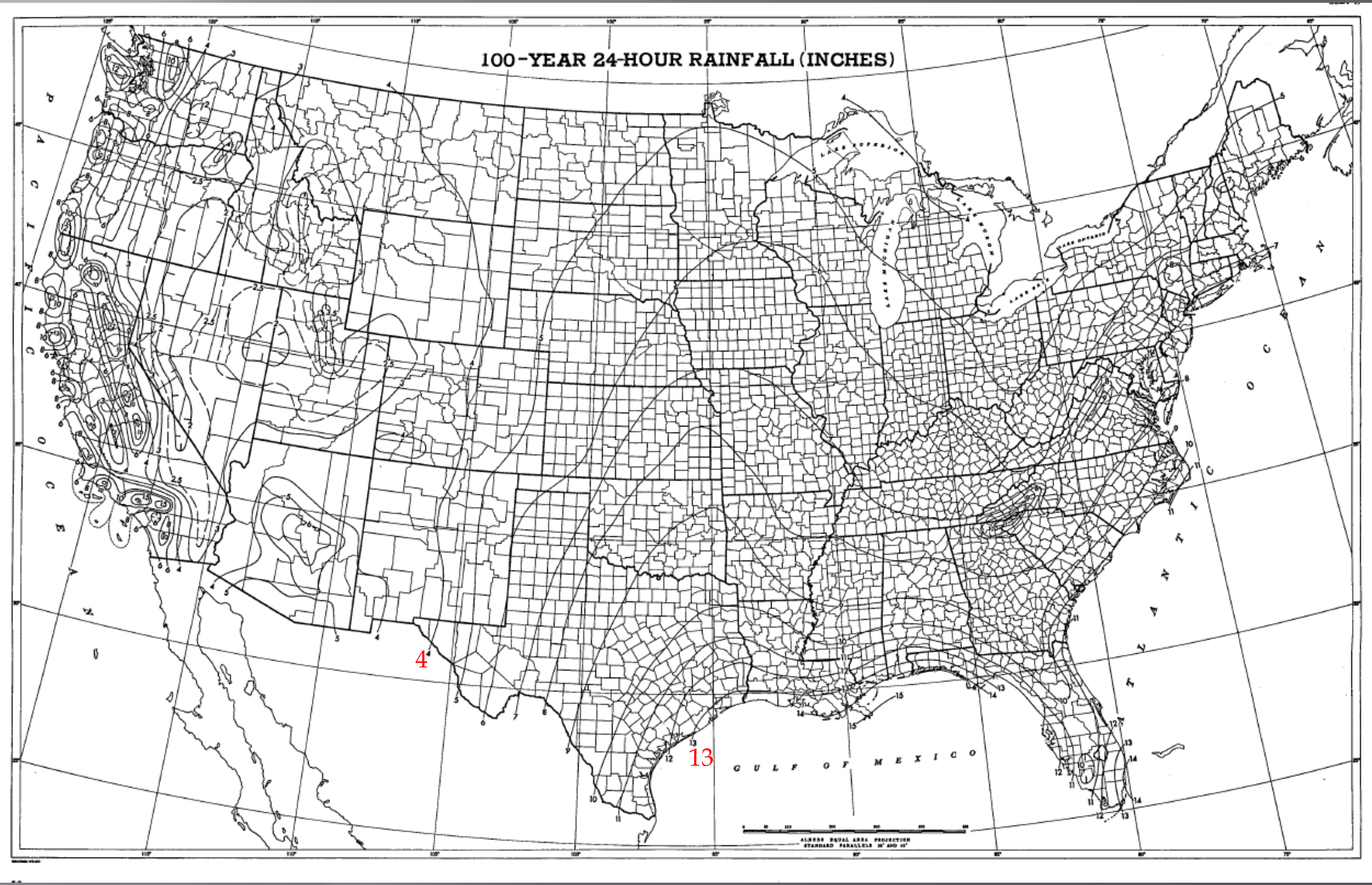


FIGURE 9.—Distribution of 24-hour stations.

Where We Were (NOAA TP40 1963) 3



Where We Are

Where We Are (USGS OK 1999) 9

USGS –DEPTH-DURATION FREQUENCY OF PRECIPITATION FOR OKLAHOMA (USGS OK 1999)

- **413 Daily stations (minimum 10 years of record); ~19,200 years of record**
- **Adjusted Daily Records by 1.13 factor (sample bias)**
- **DDF (15min-7Days) and (2-500 year) frequencies (AMS)**
- **L-moment statistics , Generalized Extreme Value (GEV) function**
- **Geospatial statistics (Kriging) 2 km grid size ;~45,000 cells**

Where We Are (USGS OK 1999) [9]

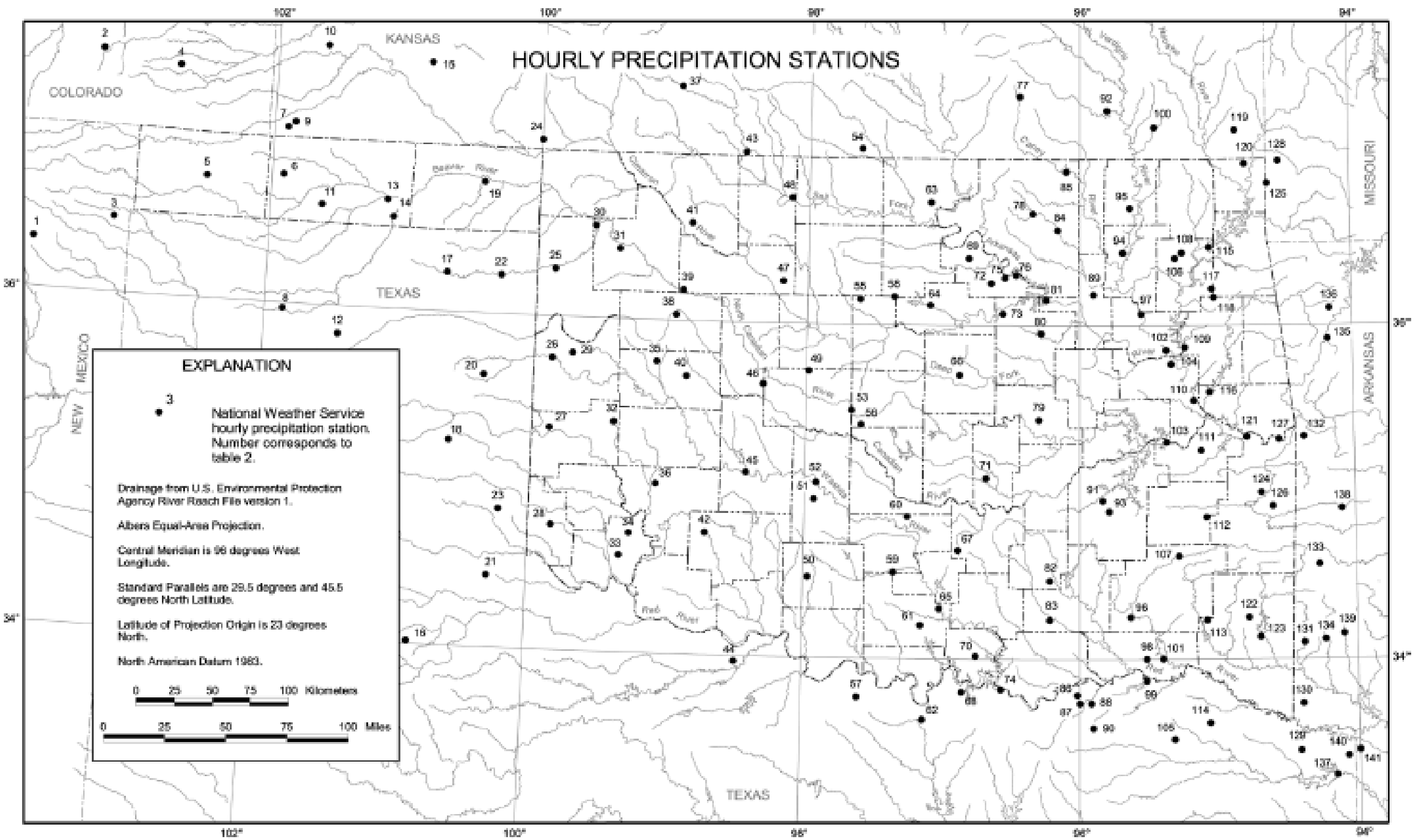


Figure 2. Location of National Weather Service hourly precipitation stations used in study.

Where We Are (USGS OK 1999) [9]

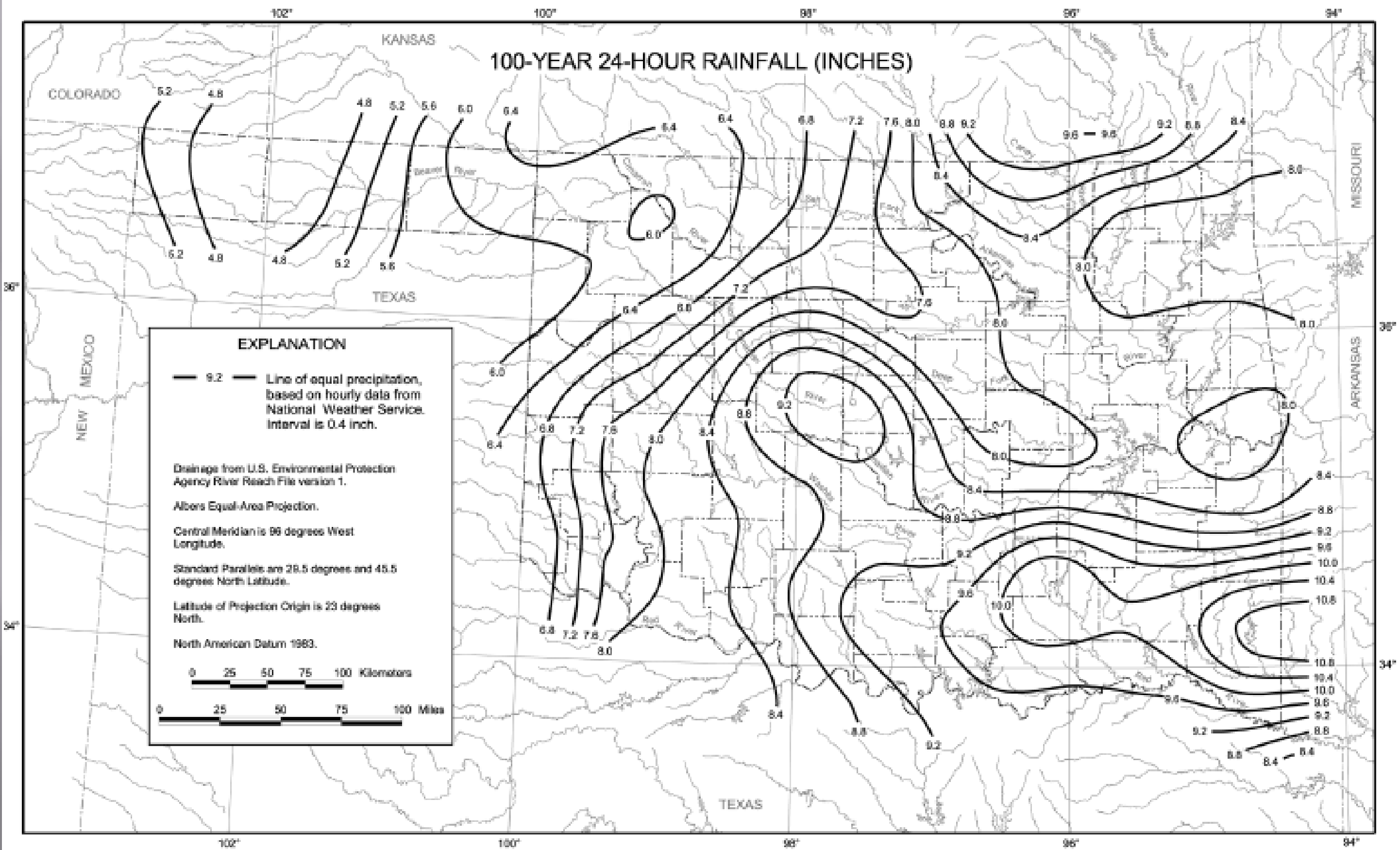


Figure 70. Depth of 100-year storm for 24-hour duration in Oklahoma.

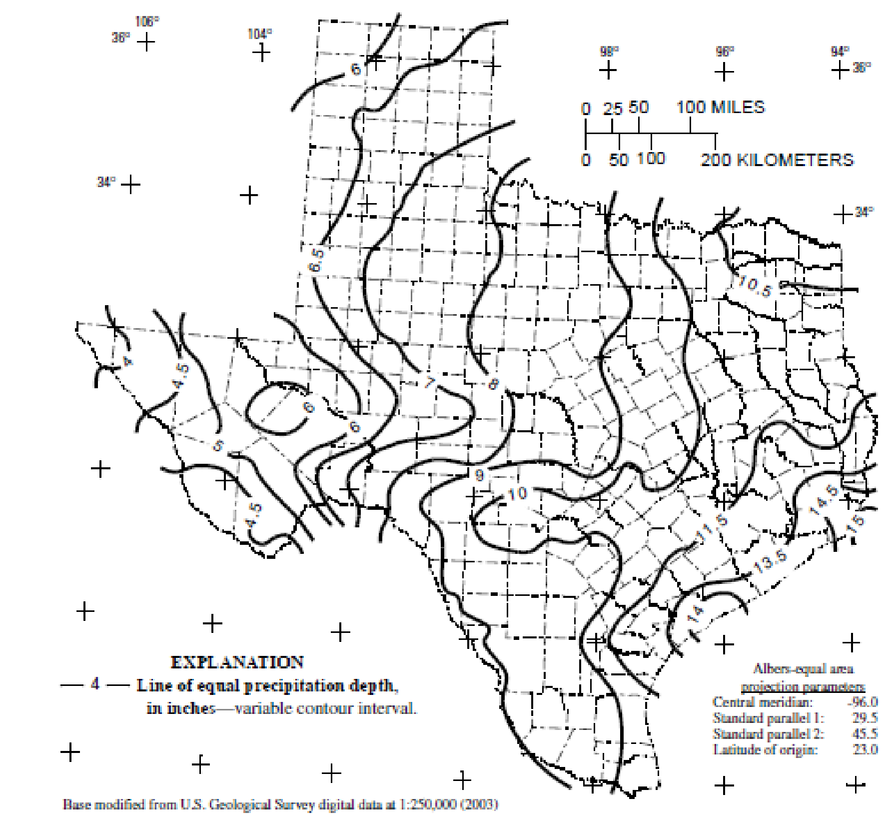
Where We Are (USGS TX 2004) 2

USGS –Atlas of Depth-Duration Frequency of Precipitation Annual Maxima for Texas(USGS Texas 2004)

- **865 Daily stations (minimum 10 years of record) up to year 1995 (~38,100 daily records)**
- **Adjusted Daily Records by 1.13 factor (sample bias)**
- **DDF (15min-7Days) and (2-500 year) frequencies (AMS)**
- **L-moment statistics , Generalized Extreme Value (GEV) function**
- **Geospatial statistics (Kriging) ~3 mile grid size (5km) ; 67,000 cells**

Where We Are (USGS TX 2004) $_2$

Atlas of Depth-Duration Frequency of Precipitation Annual Maxima for Texas



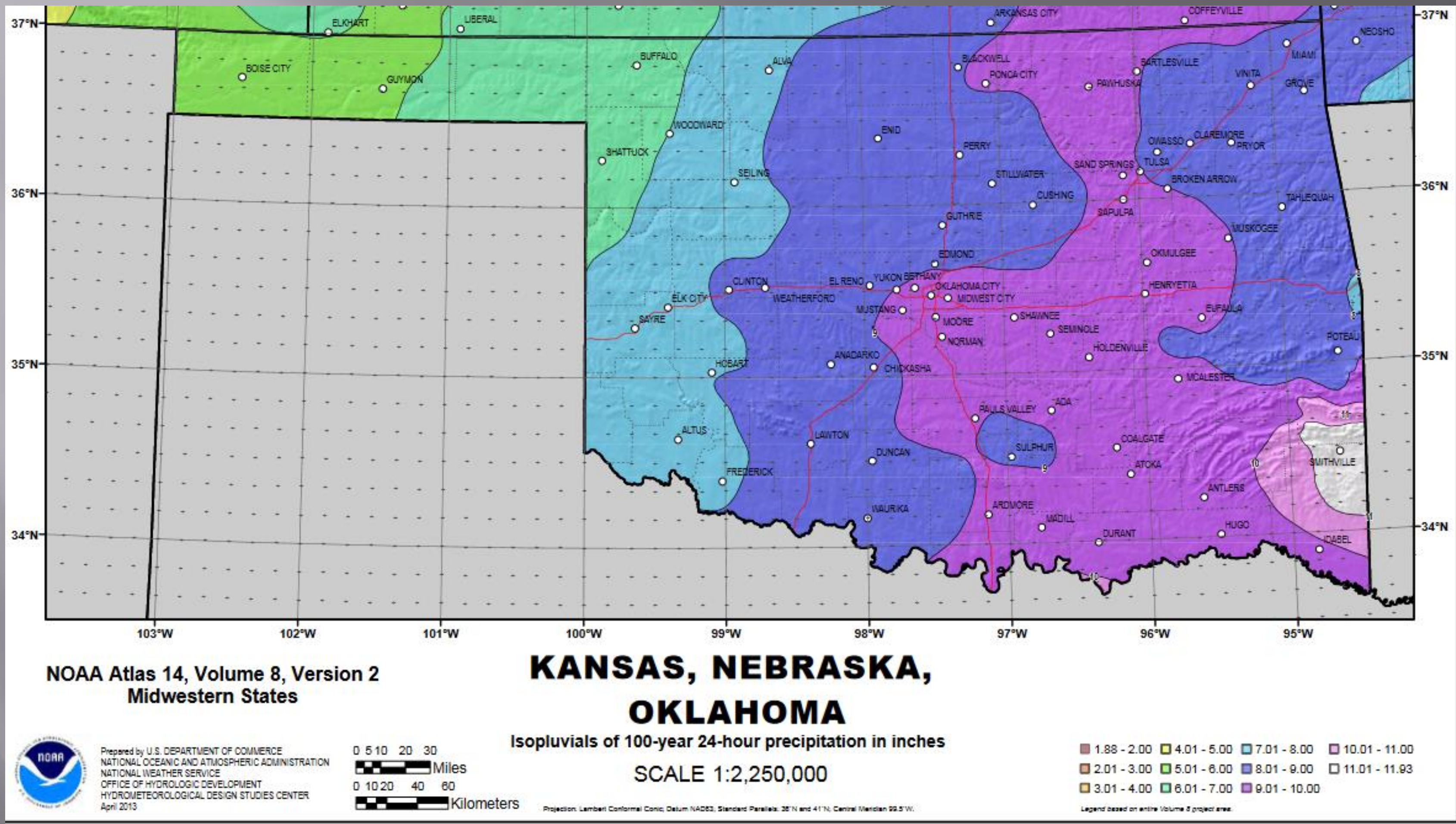
71. Depth of precipitation for 100-year storm for 1-day duration in Texas.

Where We Are (NOAA Atlas 14 Vol 8) 7

NOAA Atlas 14 Vol 8 Ver 2.0 for Oklahoma

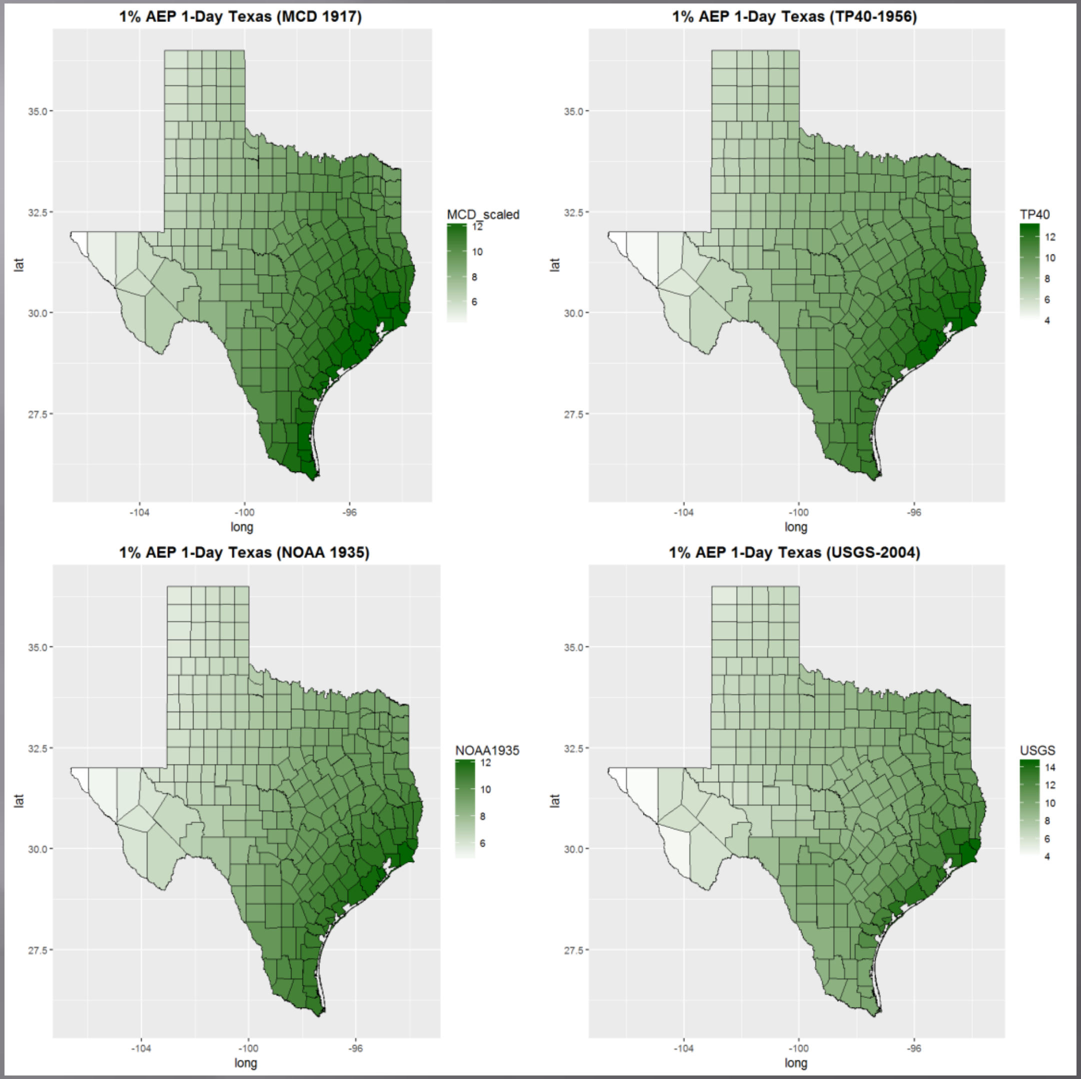
- **http://hdsc.nws.noaa.gov/hdsc/pfds/**
- **Data up to 2012**
- **DDF(5-min to 60 Day) , (1-1,000) Year) , 90% Confidence intervals**
- **Adjusted Daily Records by 1.13 factor (sample bias)**
- **L-moment statistics, GEV distribution**
- **Geospatial statistics using PRISM (MAR) correlation to 30-(arcsec) grids (~0.25 sqm) or (0.5 X 0.5) miles ; ~250,000 cells**

Where We Are (NOAA Atlas 14 Vol 8) [7]

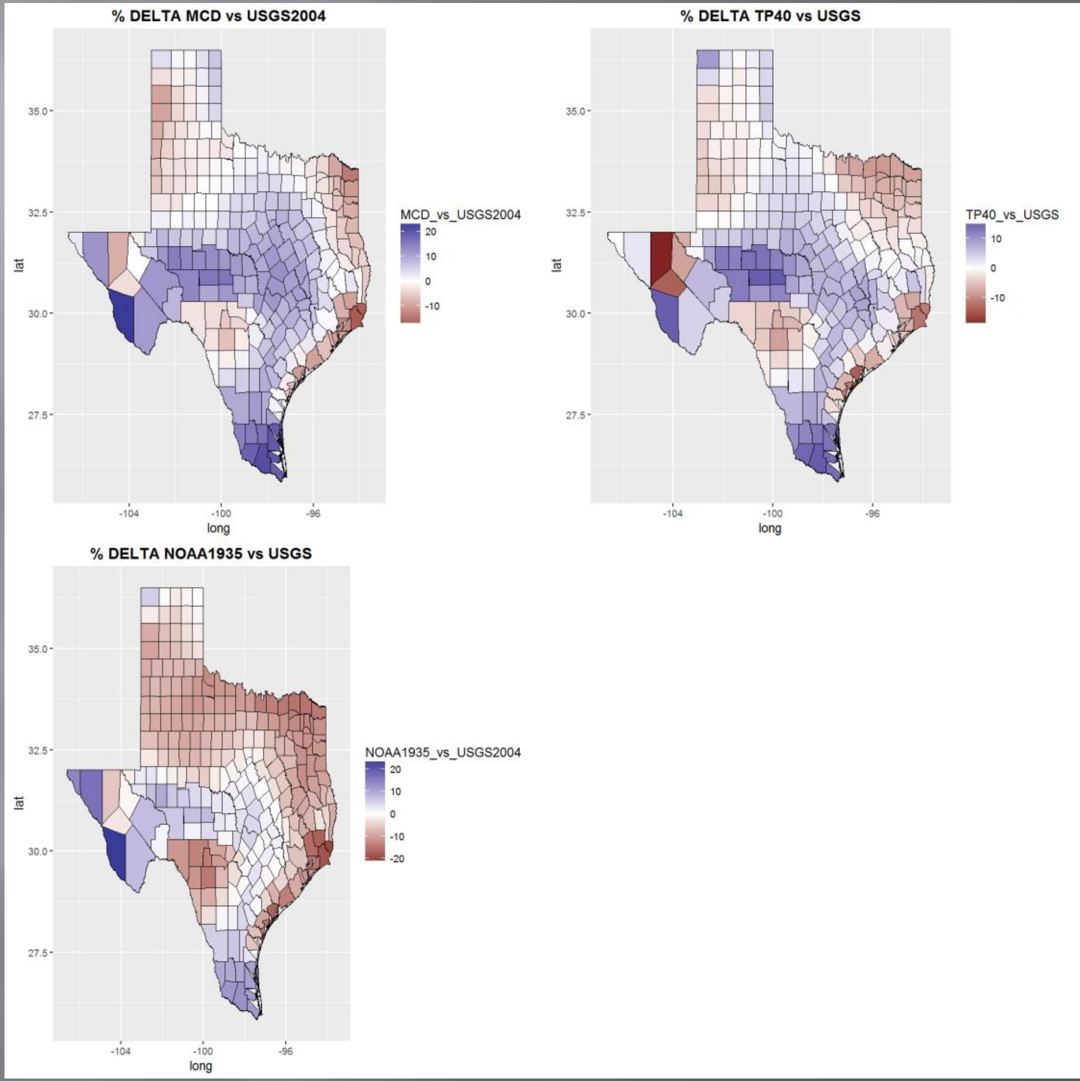


Comparison

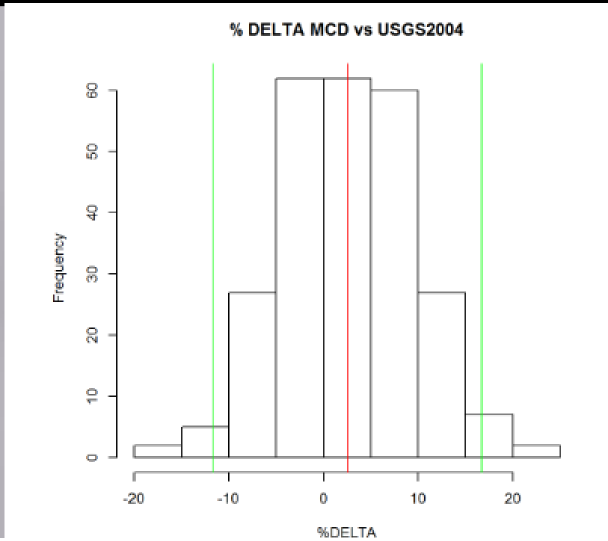
Texas 1-Day, 1% AEP Depths (in)



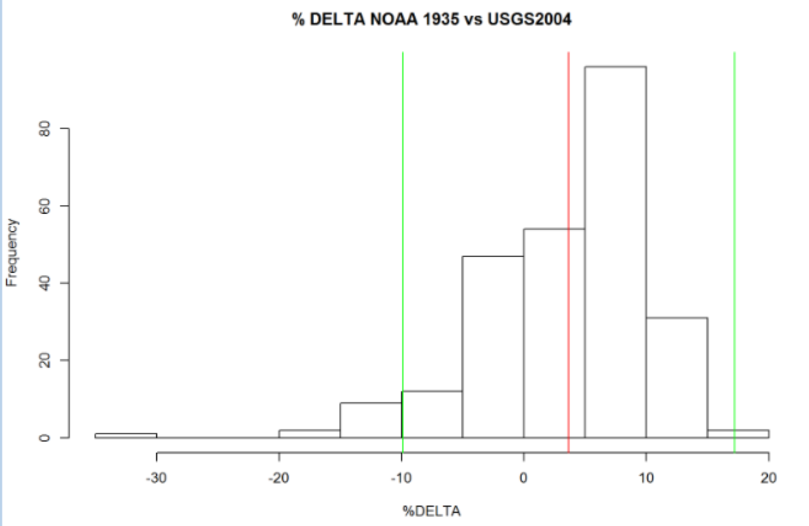
Texas 1-Day, 1% AEP (USGS 2004 Comparison)

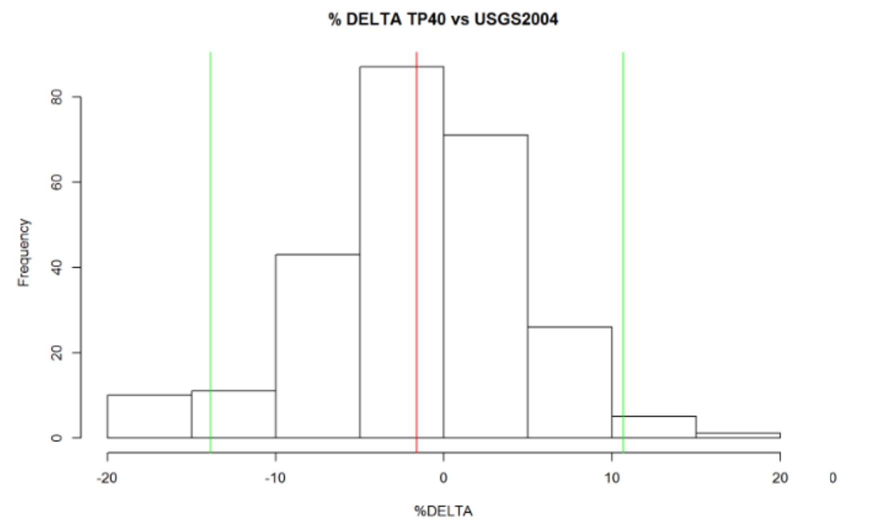


Texas 1-Day, 1% AEP (USGS 2004 Comparison)

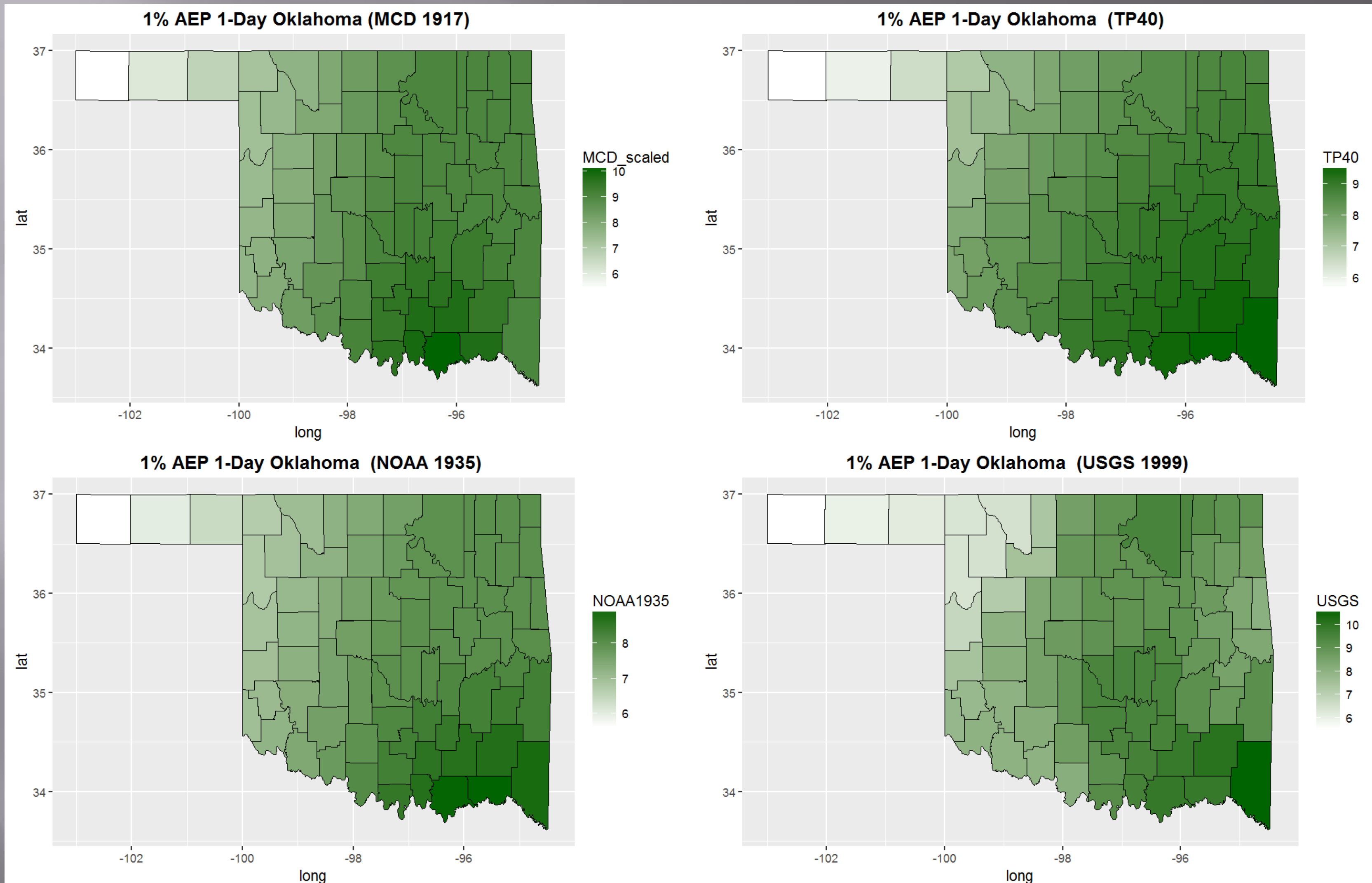


Study Comparison	Student T Test (mean)		Variance Test	
	P value	>0.05	P value	>0.05
MCD_VS_USGS	0.163	accept	0.843	accept
NOAA1935_VS_USGS	0.028	reject	0.085	accept
TP40_VS_USGS	0.514	accept	0.580	accept

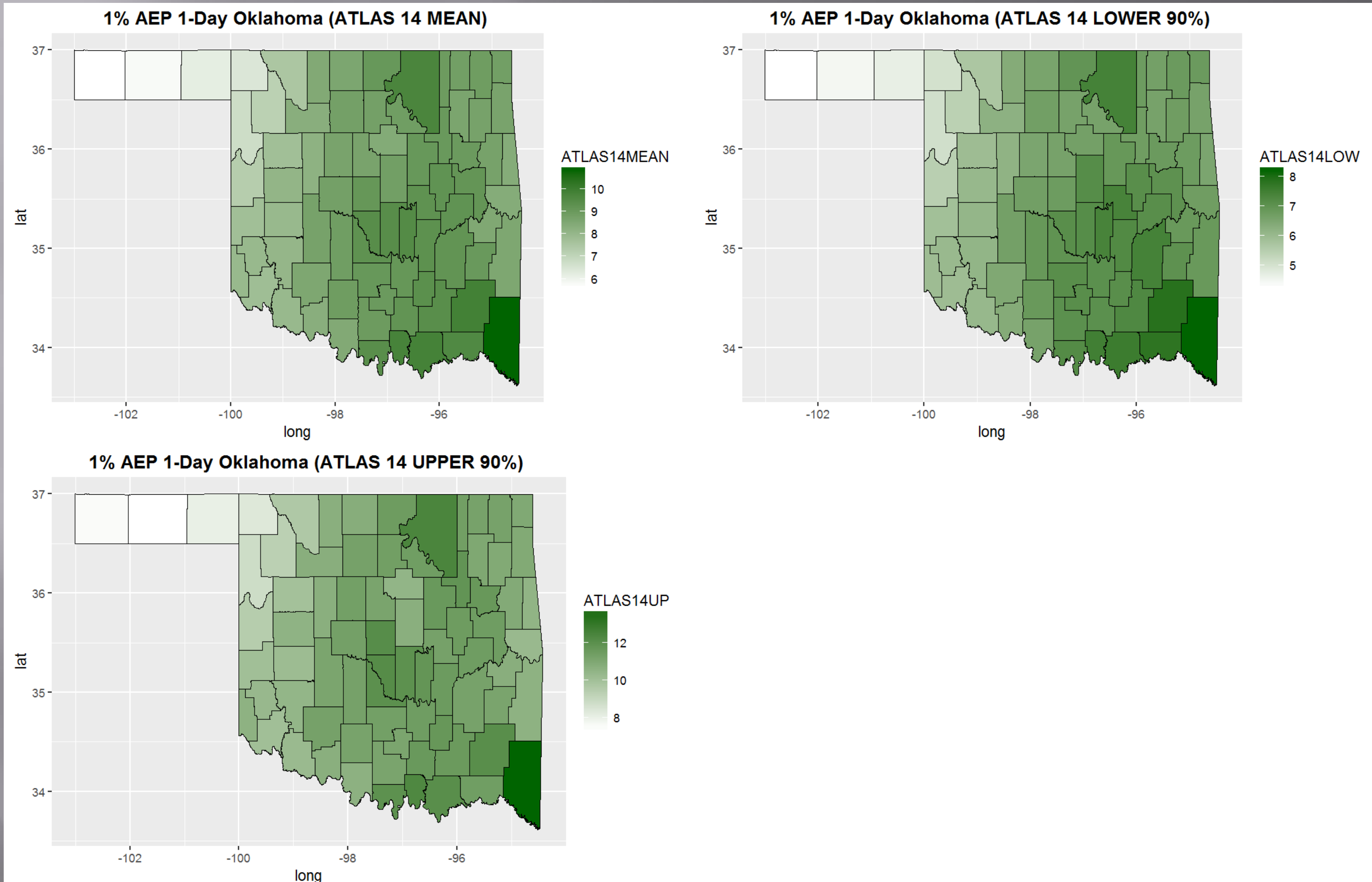




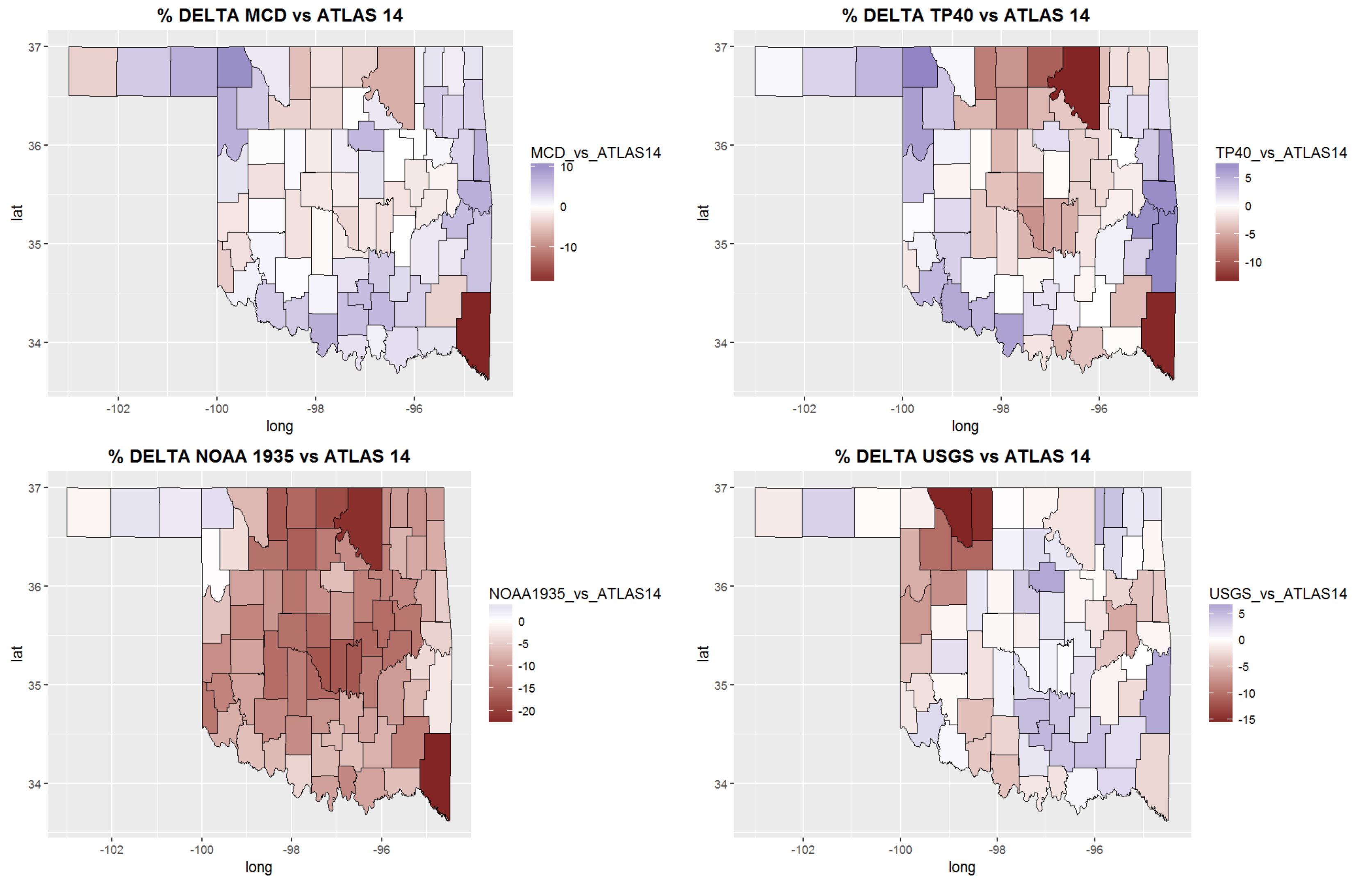
Oklahoma 1-Day, 1% Depths (in)



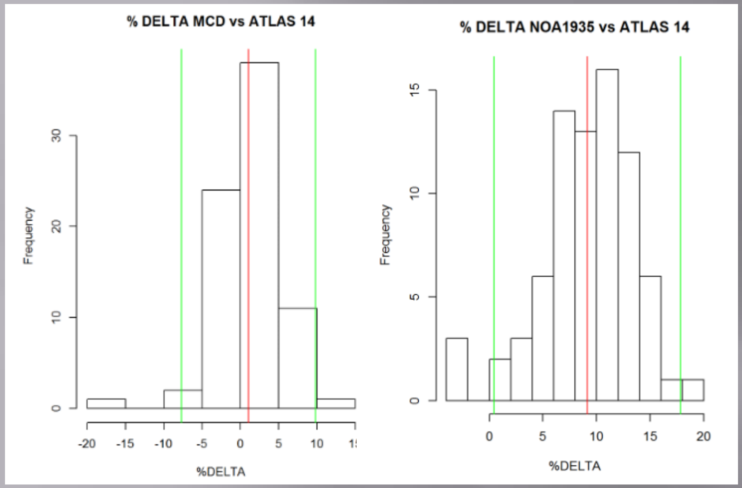
Oklahoma 1-Day, 1% Depths (in)



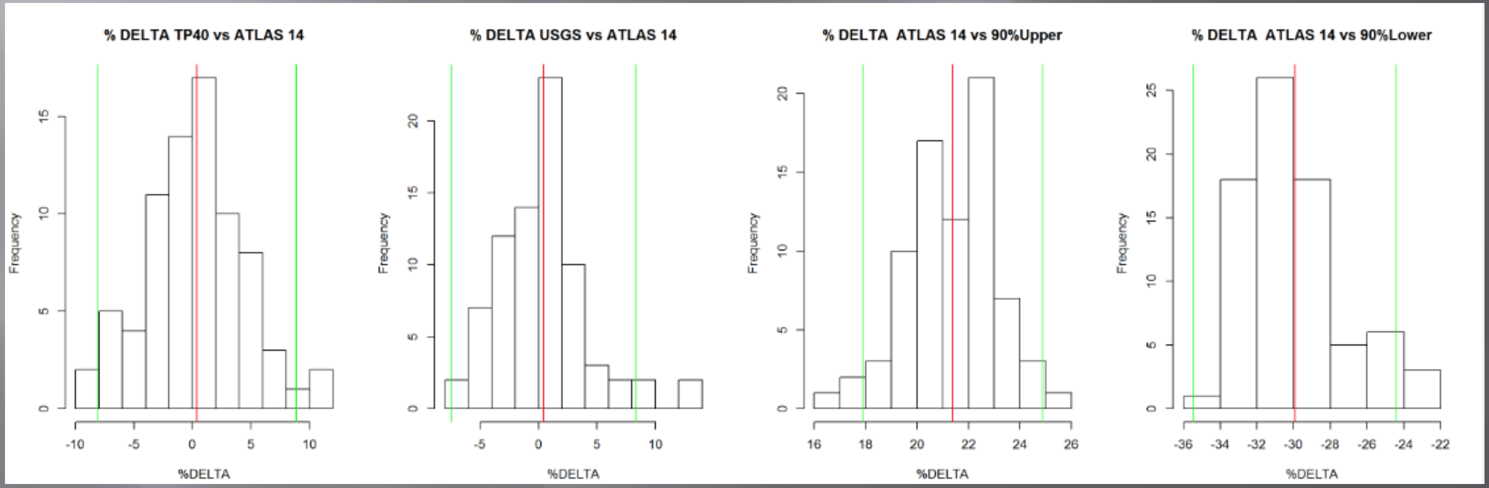
Oklahoma 1-Day, 1% (Atlas 14 Comparison)



Oklahoma 1-Day, 1% (NOAA Atlas 14 Comparison)



Study Comparison	Student T Test (mean)		Variance Test	
	P value	>0.05	P value	>0.05
MCD_VS_ATLAS14	0.50	accept	0.63	accept
NOAA1935_VS_ATLAS14	1.2E-09	reject	0.004	reject
TP40_VS_ATLAS14	0.70	accept	0.16	accept
USGS_VS_ATLAS14	0.84	accept	0.25	accept



Comparison

What is the Difference?

- **Spatial Statistics**
  - **MCD 2-(deg) grids ~15,000 (sqm) (Hand Contours)**
  - **TP40 ~800 (sqm) per station (Hand Contours)**
  - **USGS OK 1999 ; Kriging 2 km grid**
  - **- 413 Station across 70,000 (sqm) ~ 1 station / 170 (sqm)**

    - spatial predictions~ 110 X greater in precision to station coverage

    - ~10,000 X more descriptive MCD

Comparison

- **USGS TX 2004; Kriging 5 km grid**

  - ~1,600 X more descriptive MCD

  -865 Station across 270,000 (sqm) ~1 station/300 (sqm)

  -spatial predictions ~ 30 X greater in precision to station coverage

- **Atlas 14 Vol 8 Ver 2 Oklahoma; PRISM (MAR) Correlations 30-(arcsec) grid ~800 (m) or 0.5 (miles)**

  - 254 Stations across 70,000 (sqm) ~1 station/280 (sqm) ;

  - spatial predictions ~ 1,100 X greater in precision to station coverage

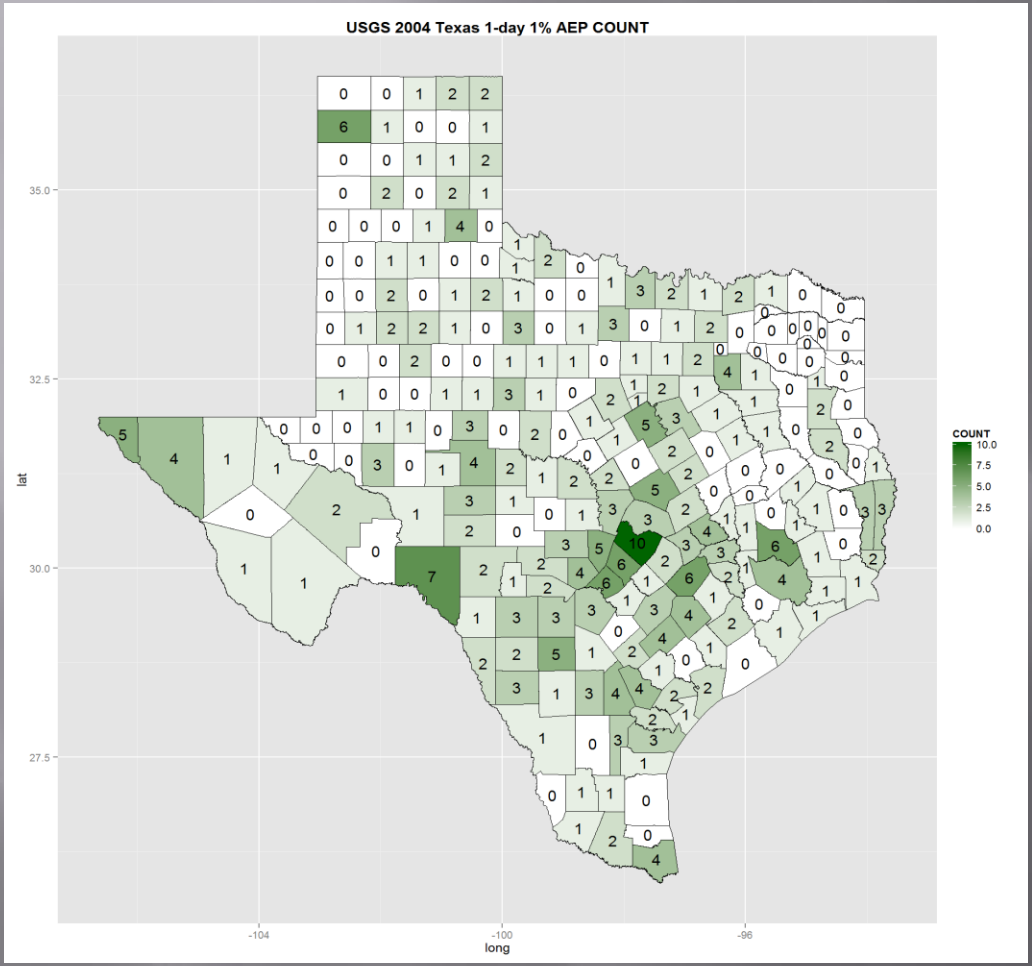
  - ~60,000 X more spatial descriptive than MCD

Where Are We Going?

Where Are We Going?

- My Research at TTU
- Evaluating the significance of AEP (AMS) statistics
  - Several studies have been conducted (presented in this presentation) and do not appear to change
  - Current practice applies binomial distribution to predict the likelihood of an event happing in number years (e.g. 1-1%AEP happening in 30-years ~26%)
  - AEP/ARI is not a statistic of time; only magnitude
- Developing a Period (cyclical) model to predict daily depth occurrence; regression with respect to depth and time

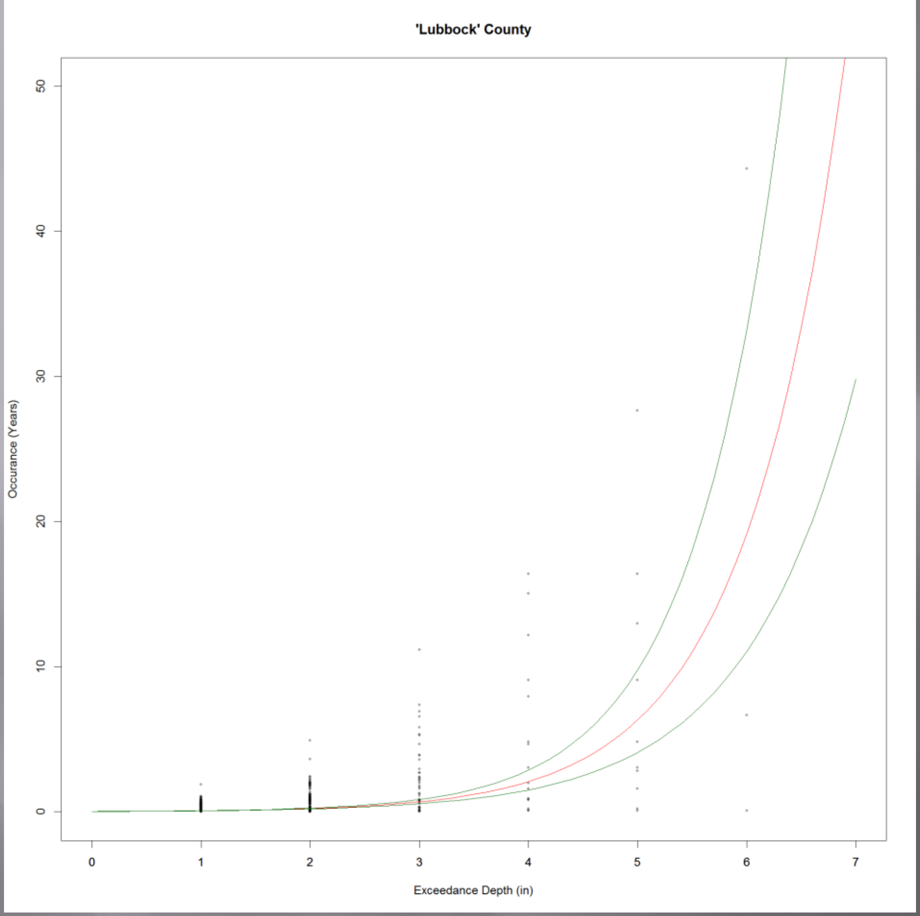
Where Are We Going?

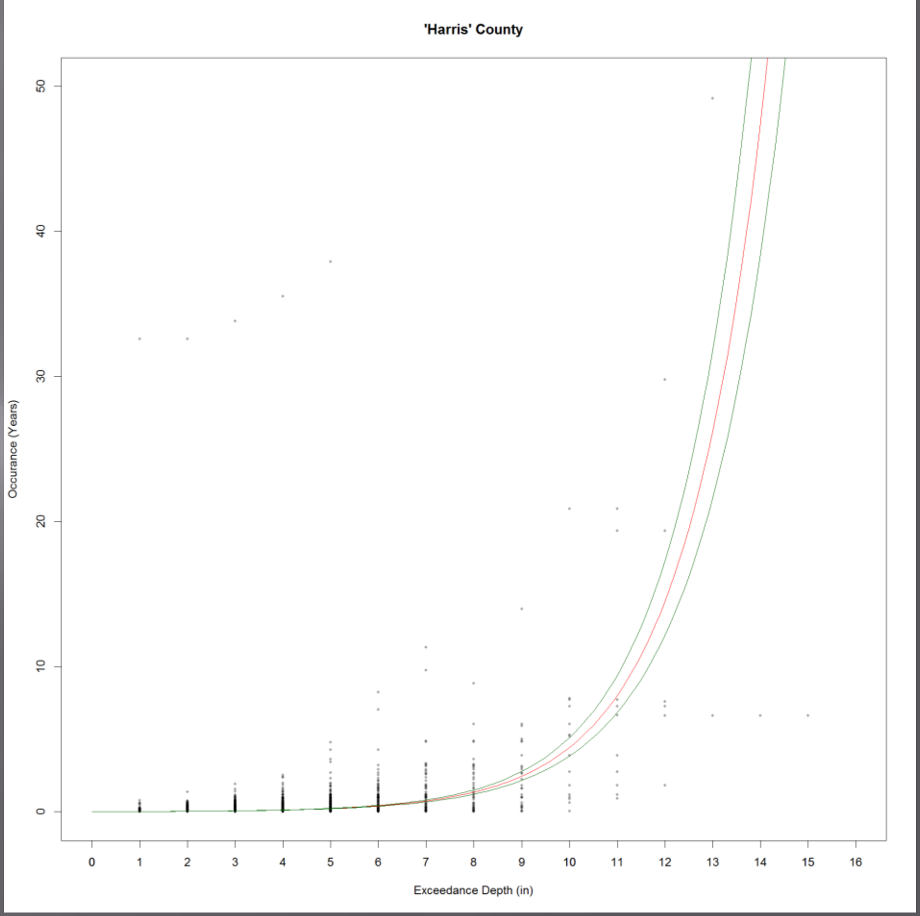


NCDC Daily data for Texas : 1850-2016
http://www.ncdc.noaa.gov/cdo-web/search?datasetid=GHCND

2004 USGS 1-Day , 1 AEP		
# of Independent Events	# Counties	Binomial # 1% AEP Events in 100 Years
1	167	63.0%
2	89	26.0%
3	47	8.0%
4	24	2.0%
5	12	0.3%
6	7	0.05%
7	2	~0.0%
10	1	~0.0%

Where Are We Going?





References

1) Asquith, W. (1998); “Depth-Duration Frequency of Texas”; U.S. GEOLOGICAL SURVEY.

2) Asquith, W., & Roussel, M. (2004); “Atlas of Depth-Duration Frequency of Texas Annual Maxima”; U.S. Geological Survey.

3) Hershfield, D. M. (1963);“Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and return Periods from 1 to 100 Years”; United States Weather Bureau.

4) Kite, G. (1977); “Frequency and Risk Analyses in Hydrology”; Water Resources Publications.

5) Lowry, R. (1934); “Excessive Rainfall in Texas Bulletin No. 25”; State Reclamation District.

6) Morgan, A. (1917); “Storm Rainfall of Eastern United States, Technical Report Part “;.The State of Ohio Miami Conservancy District.

7) Perica, S. ; et al. (2013); “Precipitation-Frequency Atlas , NOAA Atlas 14”; NOAA.

8) Switzer, F. (1929); “Floods”; Sibley Journal of Engineering, 362-366.

9) Tortorelli, R., Rea, A., & Asquith, W. (1999); “Depth-Duration Frequency of Precipitation for Oklahoma”; U.S. GEOLOGICAL SURVEY.

10) Williams, B. (1929); “A Study of Rainfall in Texas Bulletin No. 1”; State Reclamation District.

11) Yarnell, D. (1935); “Rainfall Intensity Frequency Data”. United States Department of Agriculture

Questions?

Supporting data