An Overview of Weather Modification in Texas

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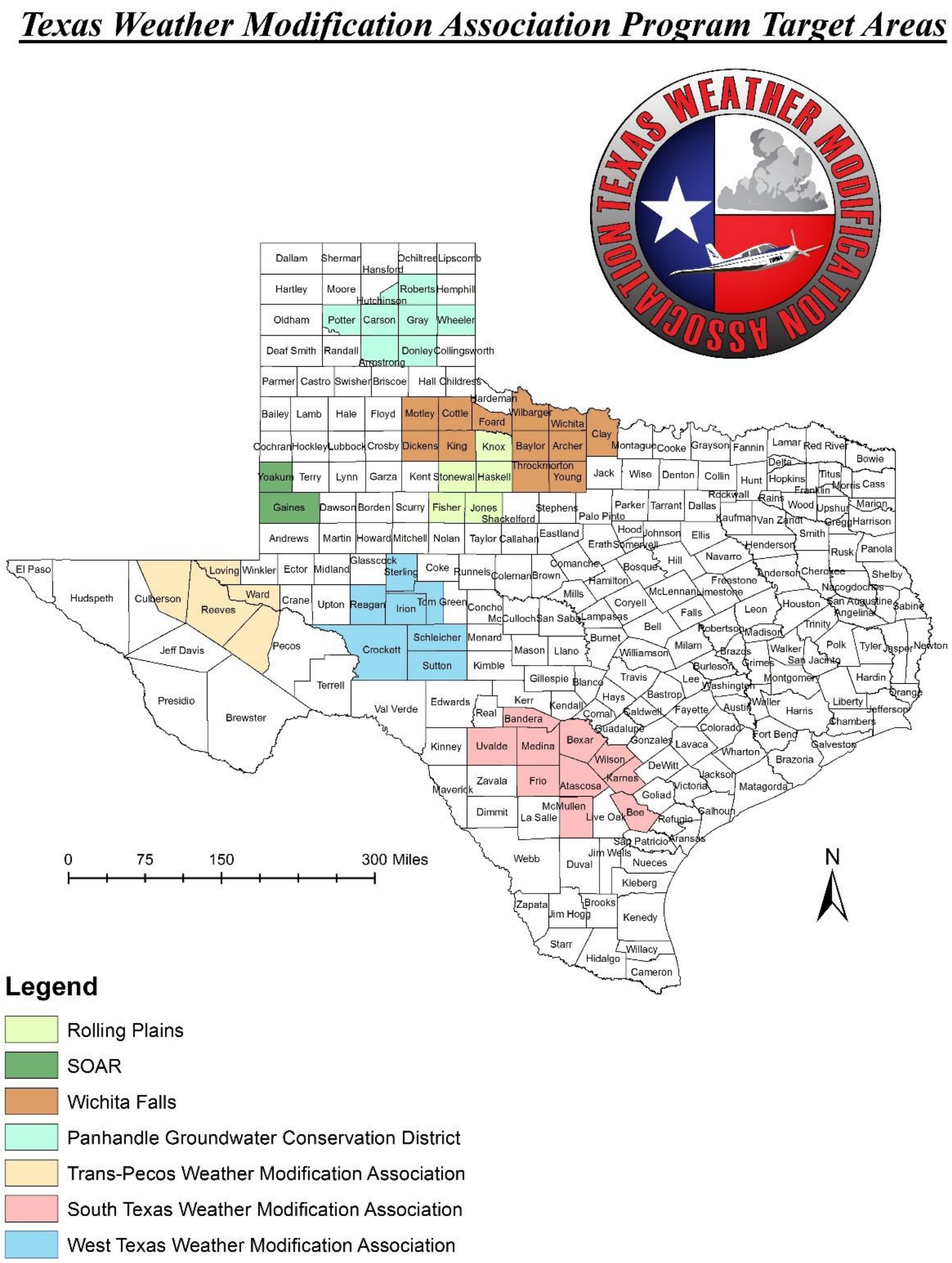
2015 PowerPoint

What to Expect

- TWMA Target Areas
- Purpose
- Methodology
- Examples
- Analysis
- Benefits
- Ongoing/Future Research

TWMA Target Areas

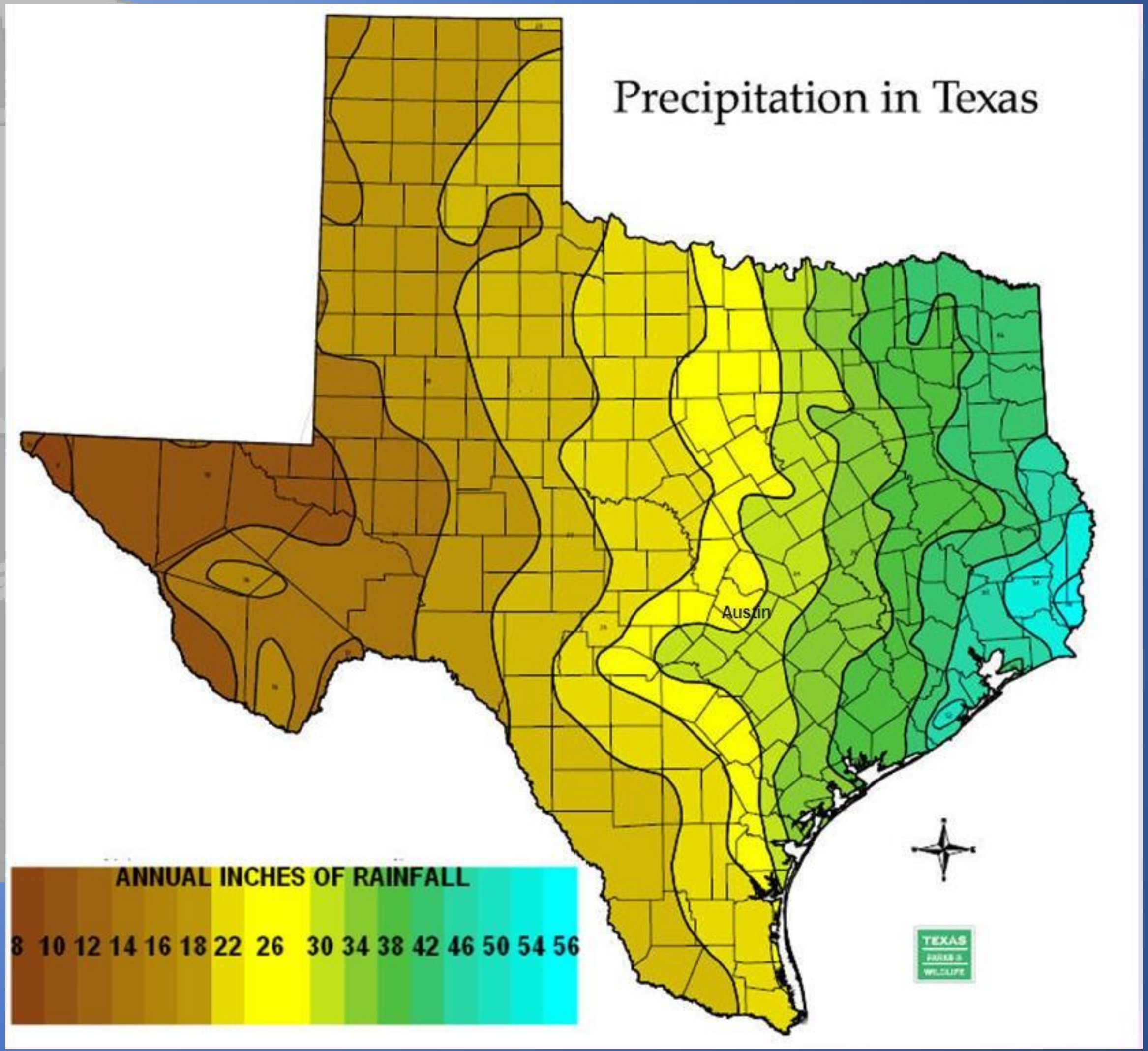
- First of the modern programs started in 1996 (WTWMA)
- Programs in South Texas, Far West Texas and into the Texas Panhandle
- Focus is on areas where rainfall is limited compared to parts of East Texas.



Texas Climatology

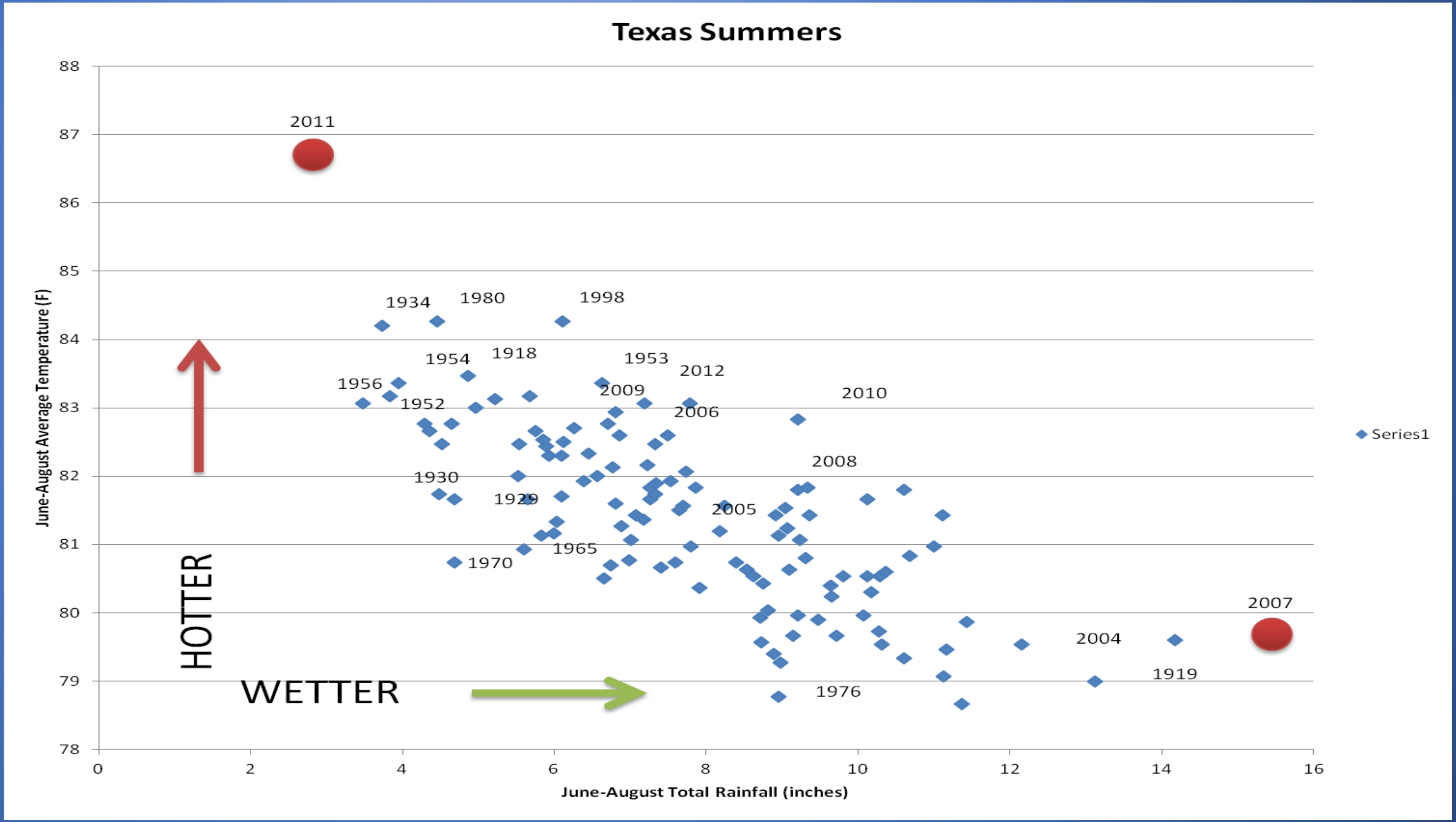
- Annual Precipitation on average is 15-20” from the Panhandle southwest into West Central Texas to Far West Texas

- Precipitation across South Texas, on average, exceeds 20” with some areas nearing 30” annually.



Texas Climatology

- Texas Climatology is heavily dependent upon temperatures, especially in the summer, when weather modification operations are ongoing.
- Extreme years can be very close to one another (2007 vs. 2011).
- Photo, right (John Nielson-Gammon)



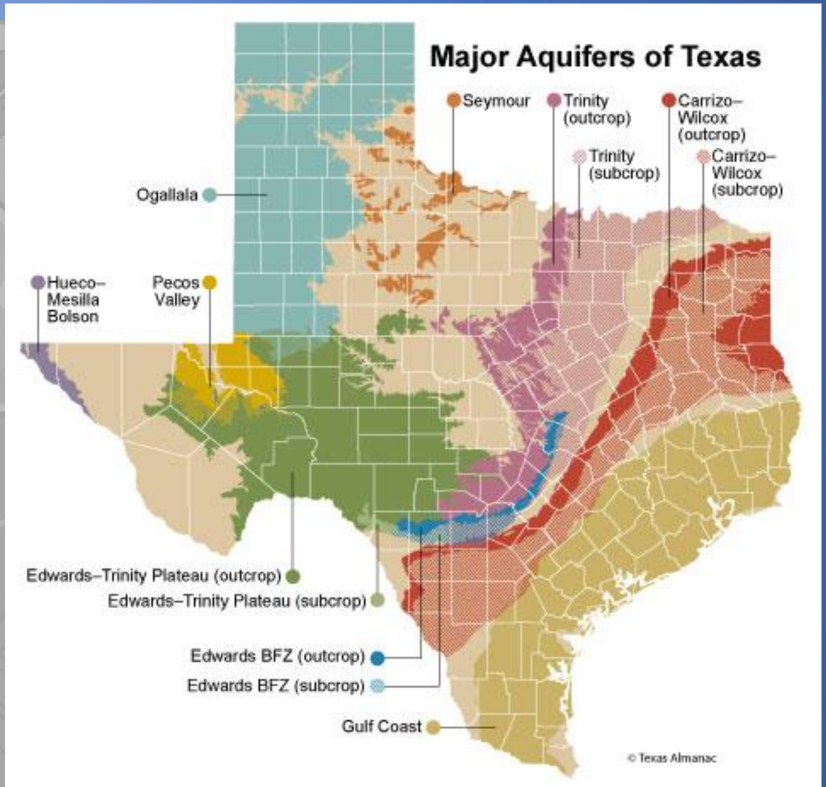
Why Modify the Weather?

- Demand for water increases while the supply decreases
- Clouds in Texas are very vulnerable, especially those in West Texas
  - Impacts from dust, smoke, sulfates and other small aerosols
- Texas is very susceptible to drought
- ENSO conditions impact Texas more so than any other state in terms of changing weather patterns
  - La Nina
  - El Nino

Program Goals

- Help increase water supply for:
  - Drinking water
  - Irrigation
  - Area Lakes, Rivers and Reservoirs
  - Aquifer Recharge

- While reducing:
  - Need to irrigate
  - Groundwater Consumption



Methodology

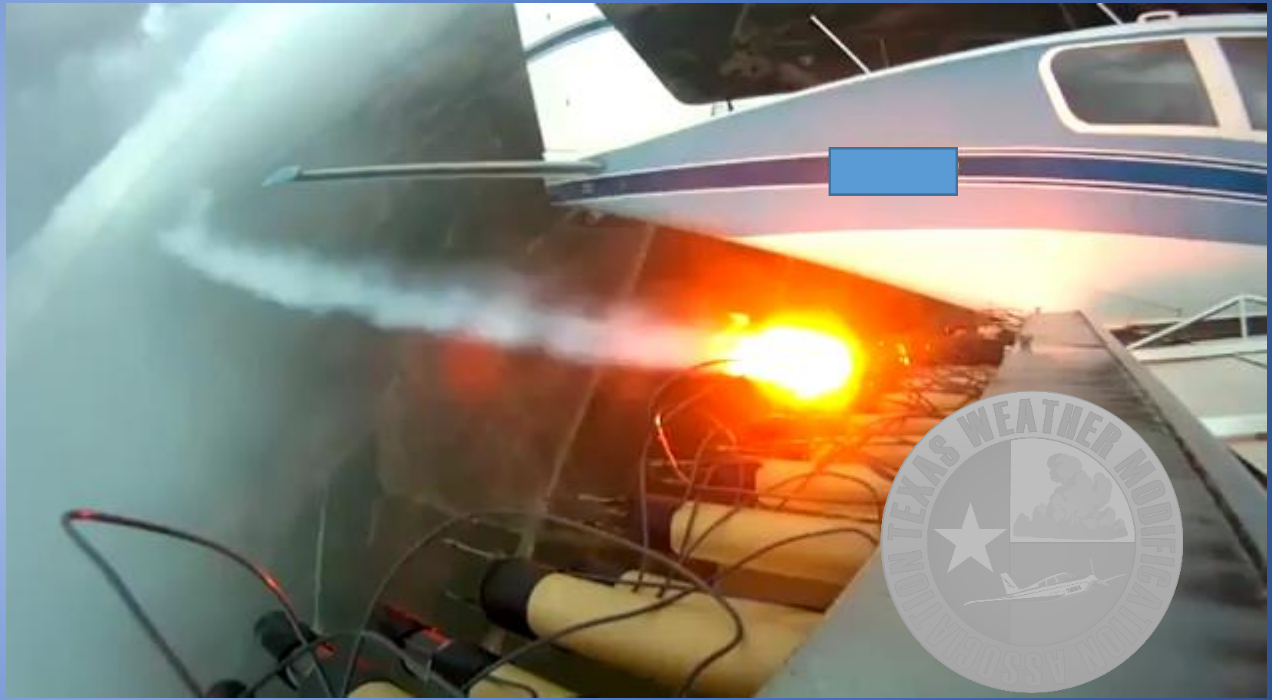
- Current program operations are build on a series of research conducted in the state of Texas
  - HIPLEX (70’s)
    - Data Collection
  - SWCP (80’s)
    - Randomized cloud seeding experiment from Big Spring to San Angelo
      - Seeded cells 36% increase in lifetime and 130% increase in volume
  - TEXARC (90’s)
    - Randomized cloud seeding experiment in San Angelo
      - Similar results to SWCP
  - SPECTRA (00’s)
    - Cloud Sampling in Texas Panhandle

Methodology

- Base Seeding via aircraft using two different types of flares
  - Glaciogenic Flares (Silver Iodide)
  - Hygroscopic Flares (Calcium Chloride)
- Flares are similar to roadside flares.
  - Burn in place (BIP)
  - Particles volatilize reforming to the sizes/distributions favorable for seeding

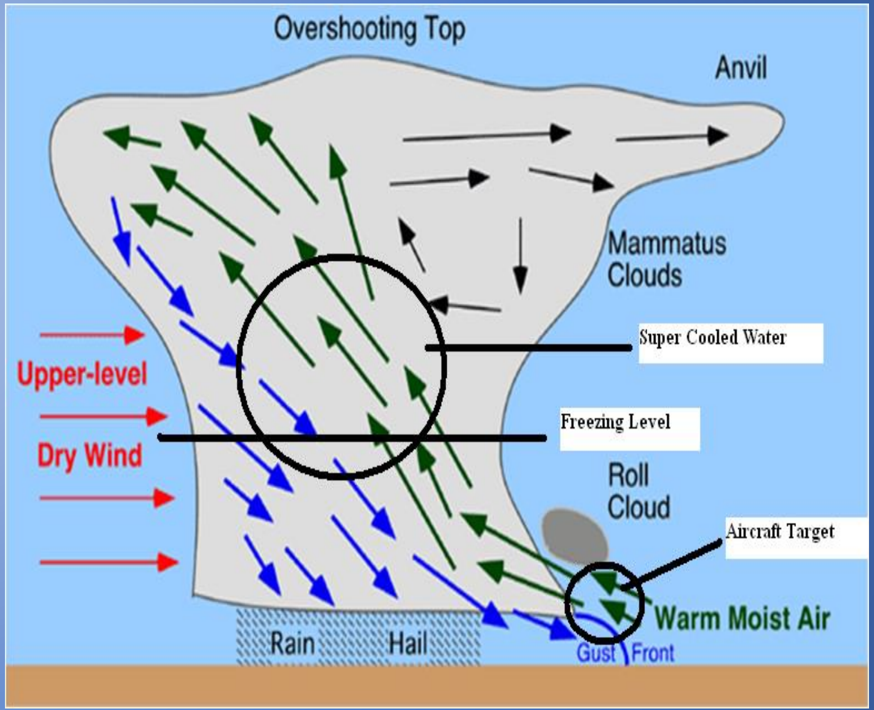
Methodology

- Storms must be convective in nature
  - 1. to ensure the possibility of super cooled water
  - 2. to ensure the chances of strong enough inflow reliable enough to transport material
- Rely on inflow at the cloud base to transport material into the cloud
- Must have “VFR” flight conditions
  - Allows us to target clouds on an as-need basis



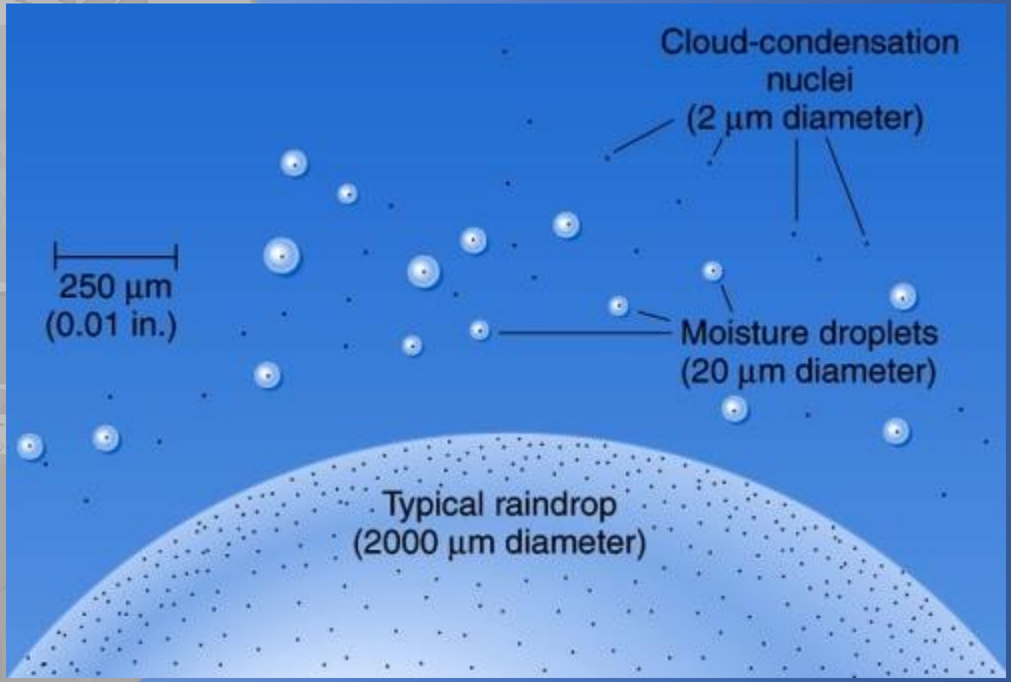
Why Silver Iodide?

- Target clouds with vertical depth extending beyond the freezing level
- Looking to help super cooled water nucleate into an ice crystal
- Silver Iodide is very similar in structure to an ice crystal



Why Calcium Chloride

- Increase the number of clouds we can target
- Introduces larger CCN into a cloud
- Deliquescence Relative Humidity of only 65%



Hail Suppression

- Both forms of seeding also serves as hail suppression
- Glaciogenic seeding creates a larger concentration of ice crystals throughout the cloud
  - Allows for a larger number of ice crystals to be spread out throughout the cloud
- Hygroscopic seeding focuses on the warm layer of the cloud and usually does not extend into the freezing level
  - However, some droplets could extend into the freezing level freezing earlier allowing for a larger concentration of ice to develop within the cloud

How do we know if clouds need to be seeded?

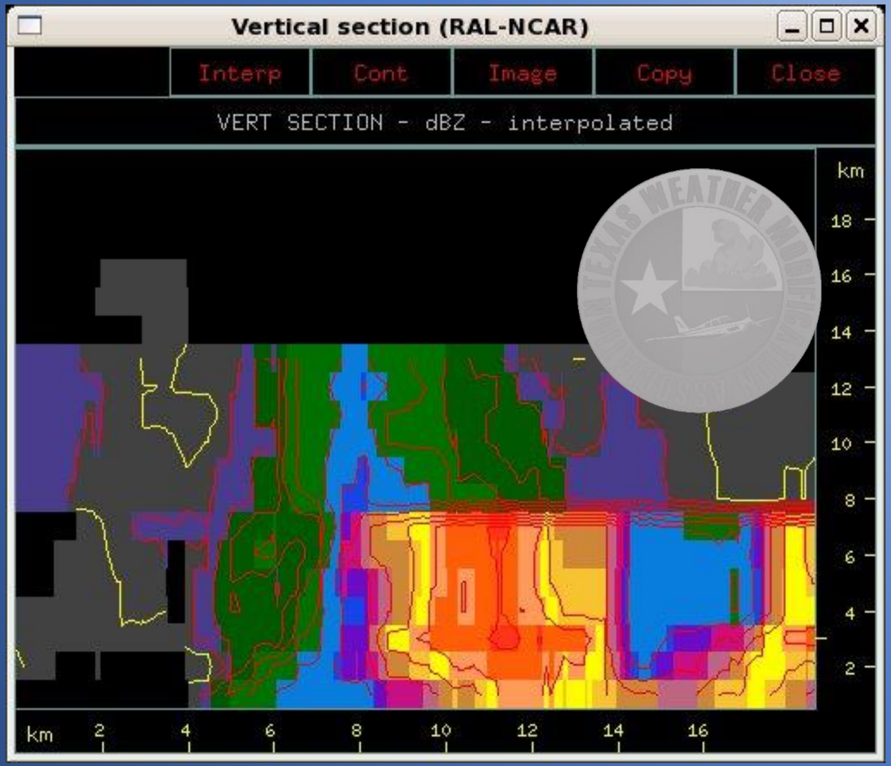
- For Glaciogenic Seeding
  - Cores of higher reflectivity suspended in the middle portion of the cloud (at or above the freezing level)

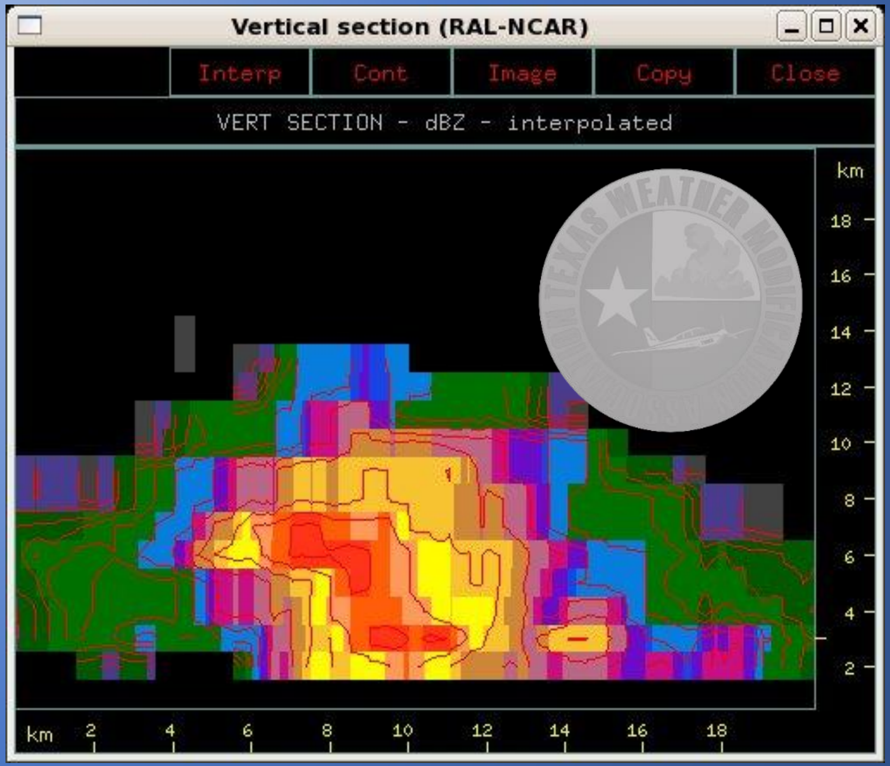
- For Hygroscopic Seeding
  - Index of Coalescence Activity (ICA)
  - Warm Cloud Depths
  - Cloud Base Heights
  - Radar Signatures

- For “dual-seeding”
  - If the criteria is met for Hygroscopic seeding but also has a higher reflectivity core above the freezing level

How do we know if clouds need to be seeded?

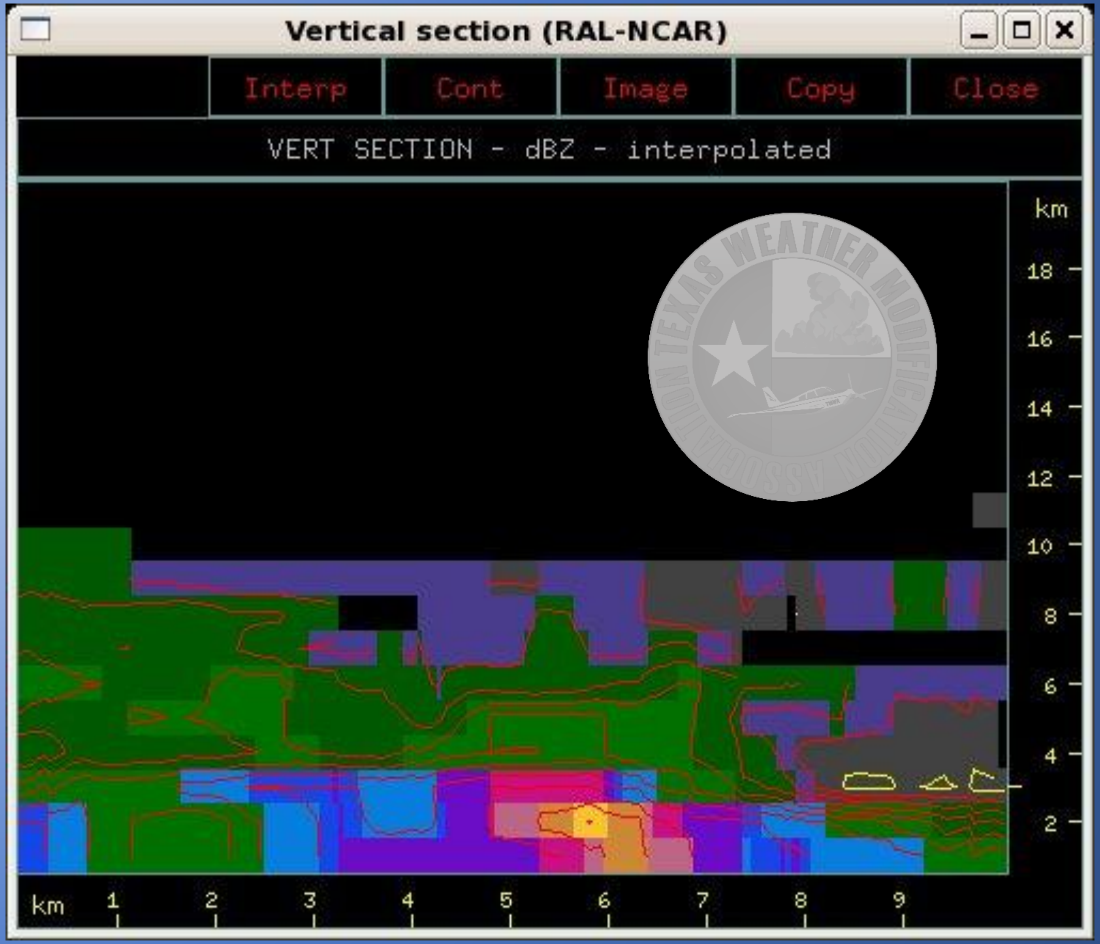
- Glaciogenic Seeding
  - Radar Cross Section showing a core of higher dBZ values at or above the freezing level





How do we know if clouds need to be seeded?

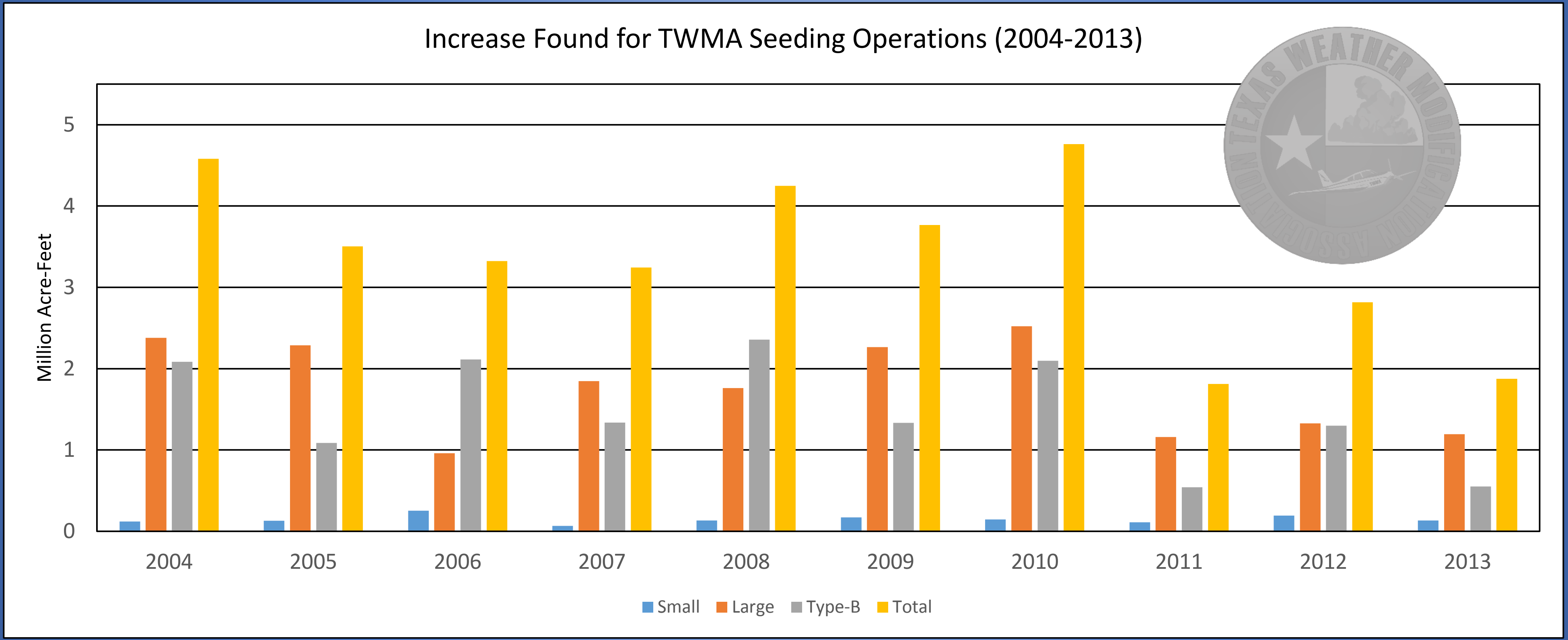
- Hygroscopic Seeding
  - Higher Cloud Bases then normal
  - Thin warm cloud depths (Cloud base – freezing level)
  - Lack of precipitation falling out of congested cloud



Analysis

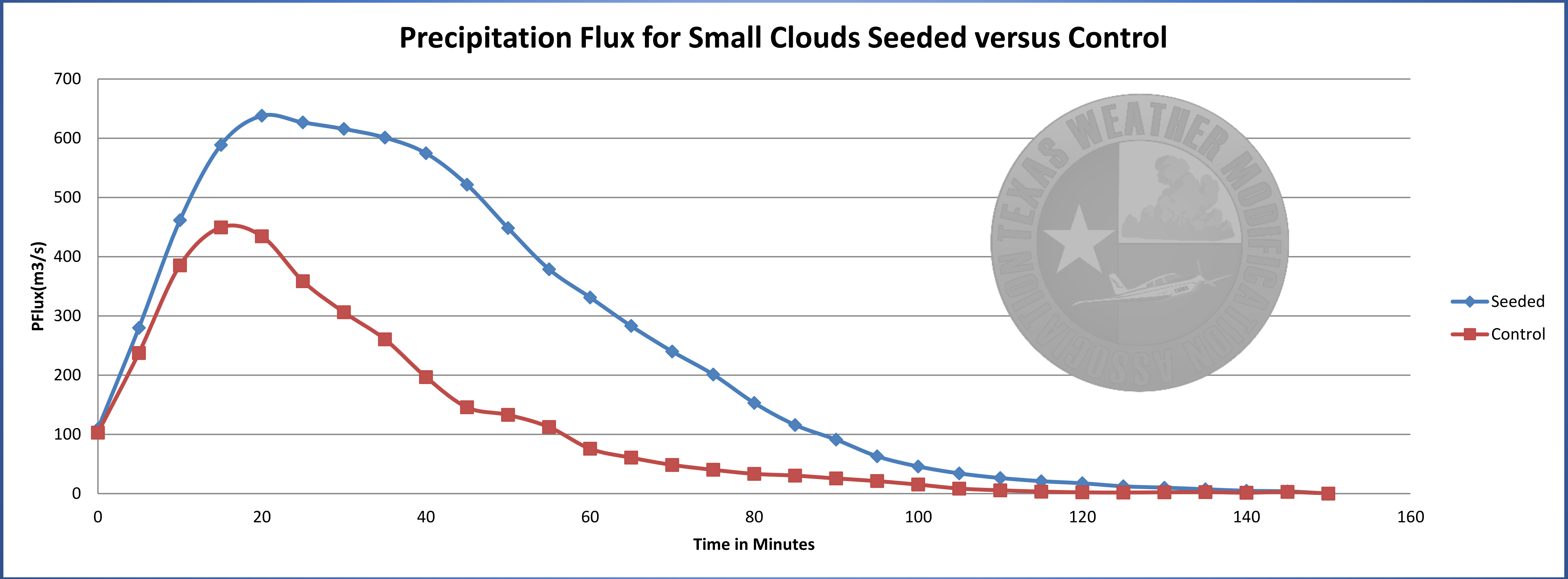
- Conducted by Dr. Arquimedes Ruiz-Columbè
- Began analysis in 2001 using TITAN analysis package
- Starting in 2004 the TWMA began using radar feed from the NWS WSR-88D provided by Weather Decision Technologies
  - Data before 2001 will not be included in totals or averages presented today

Analysis for the TWMA



- Average of 3.4 million acre-feet of increases.
- This translates to 1.45” annually (12% increase across all target areas in Texas)

9 Year Analysis on Small Clouds

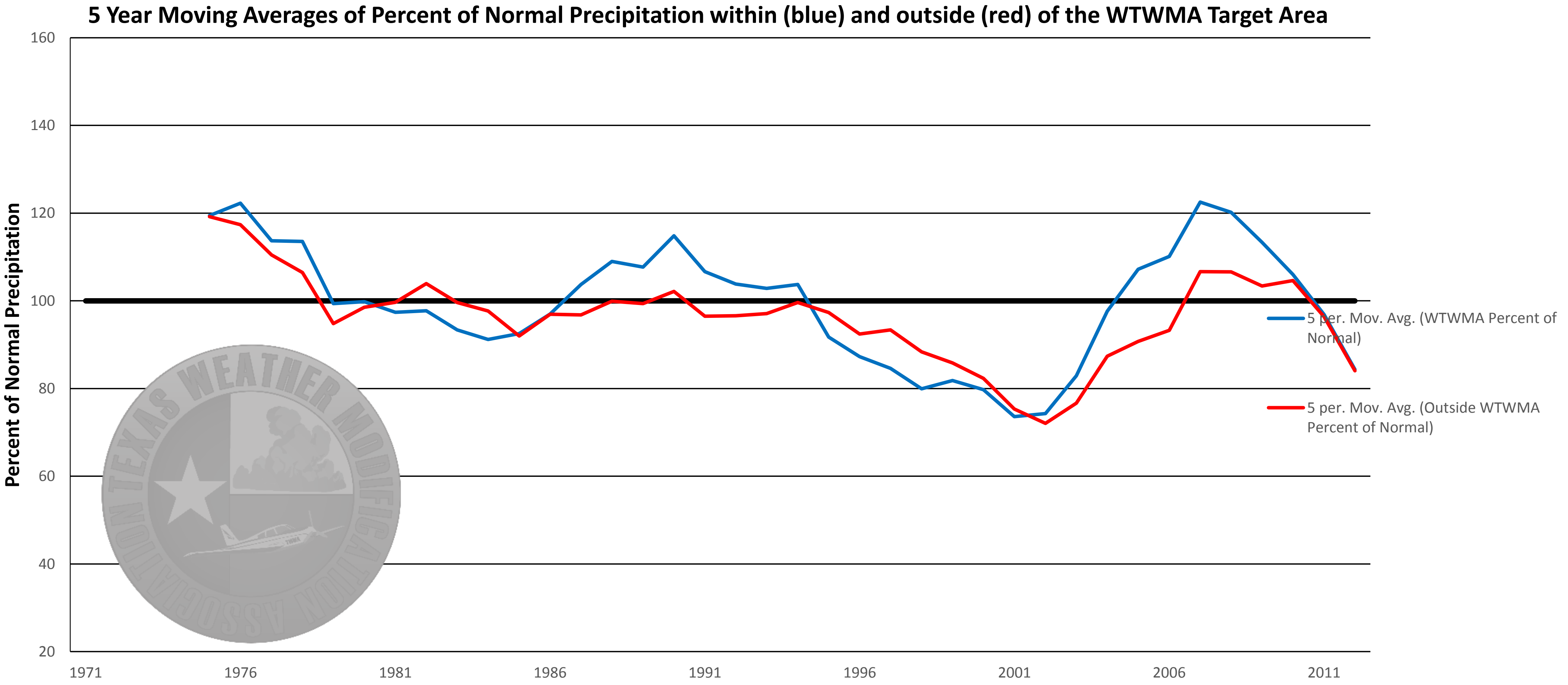


Credit: Dr. Arquimedes Ruiz-Columbiè, TTU

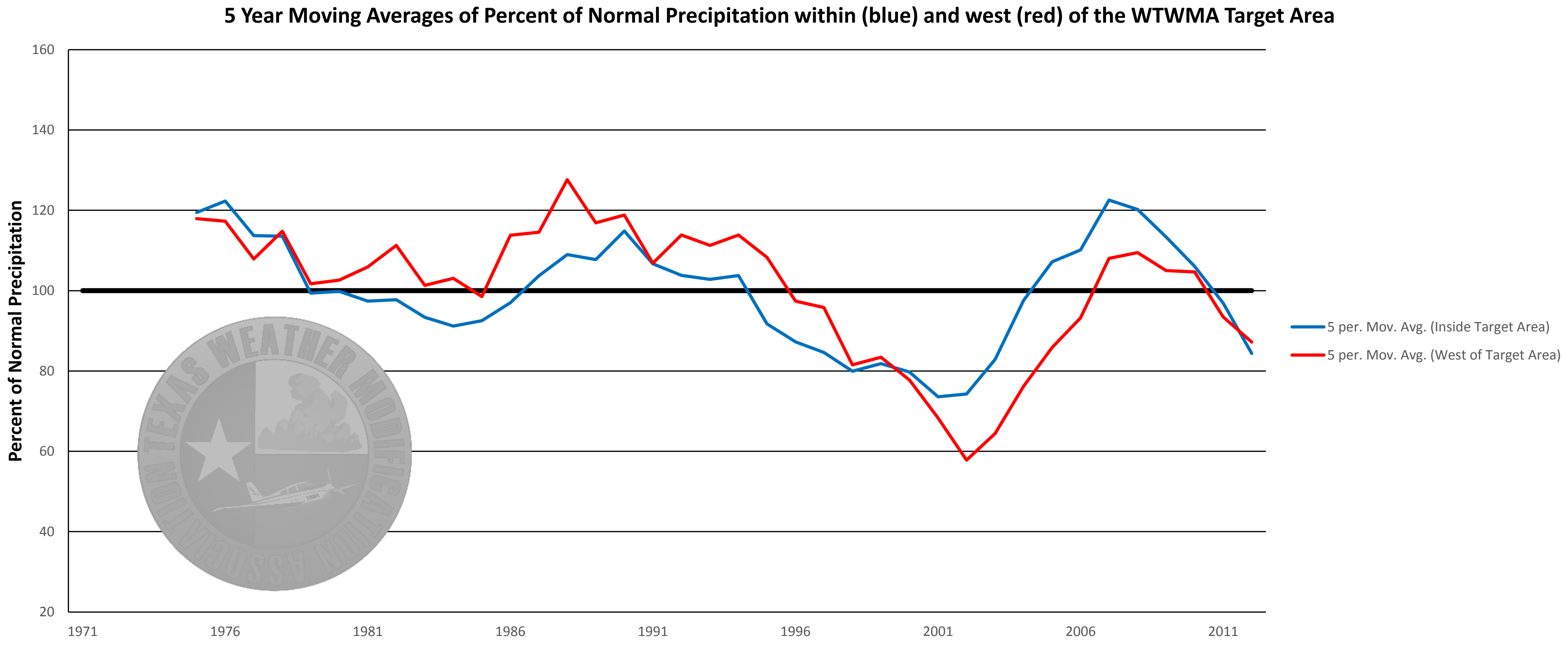
Precipitation Analysis

- Percent of Normal rainfall was compared within the target area to areas outside of the target area.
- Weather Modification began in West Texas in 1996 (first operational year)
- In 2004, meteorologist began using high resolution radar data. Therefore I have called the 2004-2012 the "modern era" of weather modification

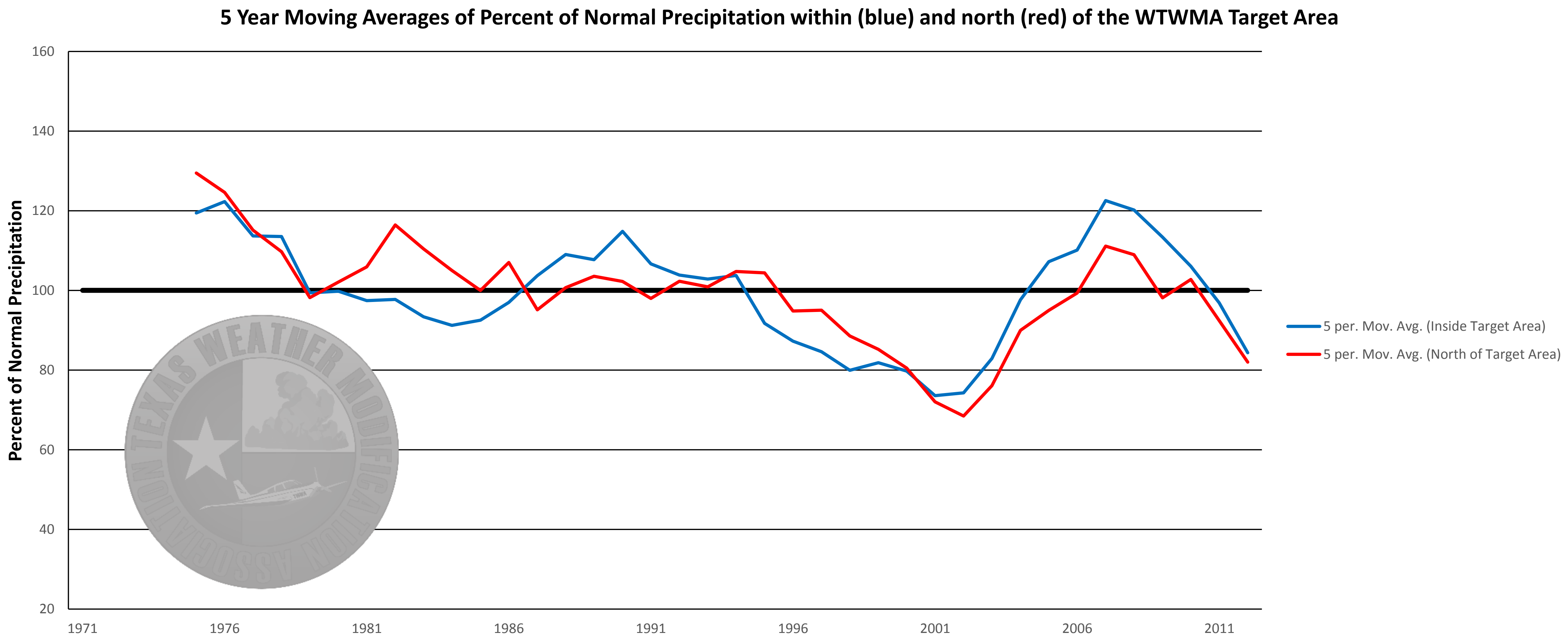
Outside vs. Inside of the Target Area



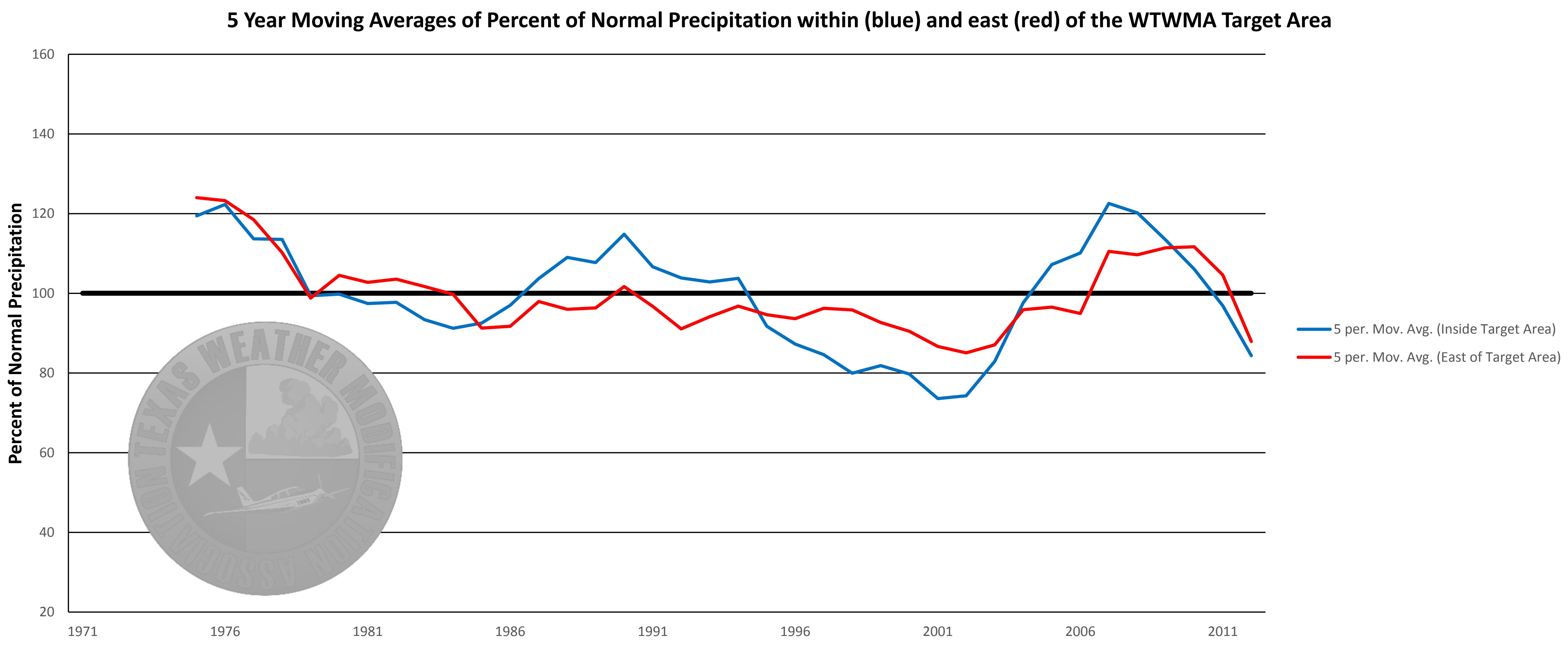
Target Area versus Outside (West)



Target Area versus Outside (North)



Target Area versus Outside (East)



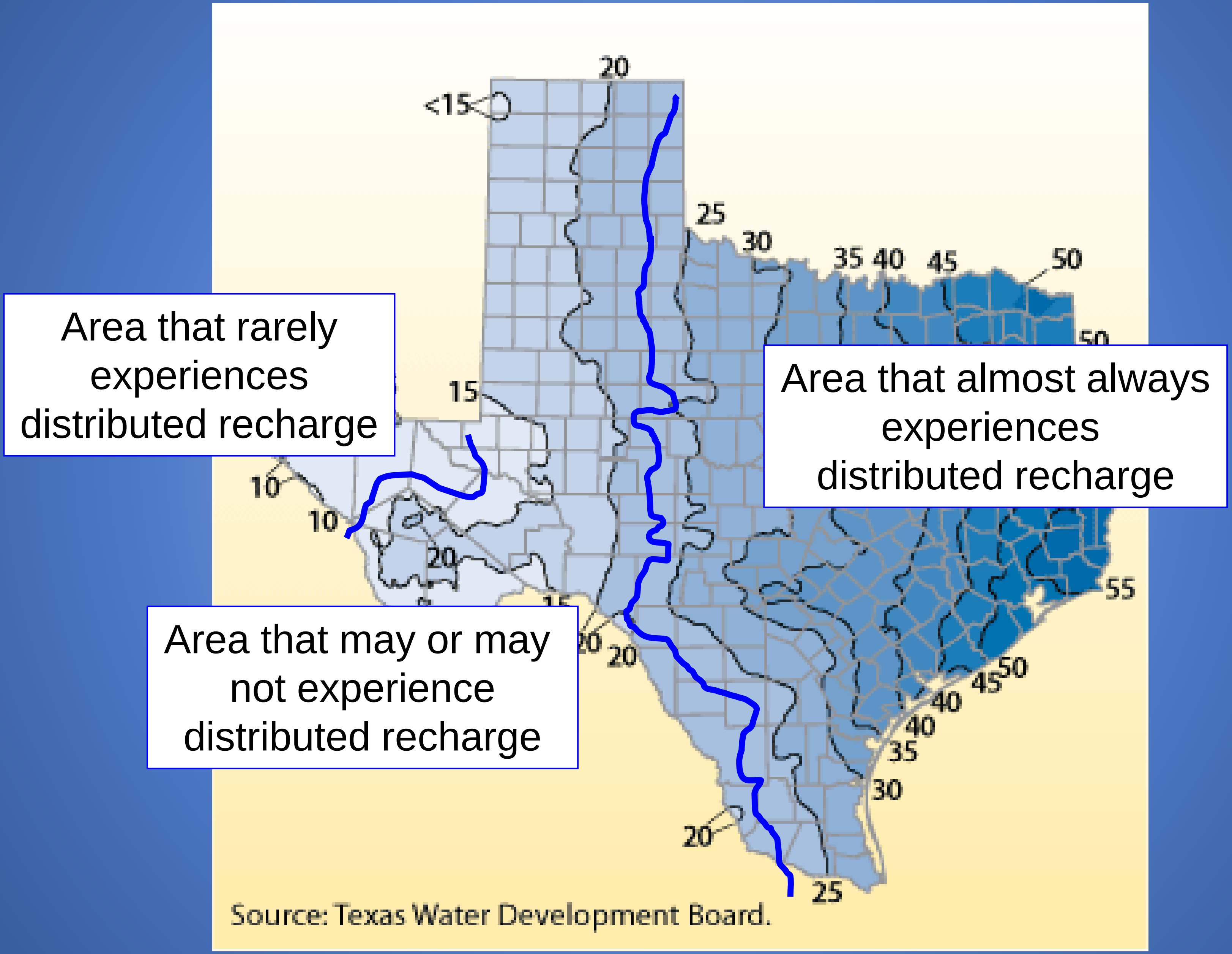
Aquifer Recharge

- Studies done by Green and Bertettie of the Southwest Research Institute indicate 16.5” of precipitation annually is needed for aquifer recharger across the Edwards-Trinity Aquifer

- Weather Modification could be the difference between seeing or not seeing recharge in a given time period

- An important benefit received from Weather Modification as additional rainfall is the only way to increase recharge

Texas Can be Sub-Divided by Area into Three Categories of Recharge



Source: Green, Bertettie, Southwest Research Institute (2010)

The impacts of Weather Modification on Recharge in West Texas

- The annual precipitation increase from weather modification was taken away from the annual rainfall.
- This allowed for a difference of recharge to be calculated. Then…
- Using:

R = 0.15(P-16.50)

- The amount of Recharge due to weather modification can be calculated
  - County by county, year by year.

The impacts of Weather Modification on Recharge in West Texas

- Once recharge was found the Thornthwaite equation for Potential Evapotranspiration

$$PET = 16\left(\frac{L}{12}\right)\left(\frac{N}{30}\right)\left(\frac{10T_{\alpha}}{5}\right)^{\alpha}$$

Where L = average day length of month

Where N = number of days in each month

Where Ta = Average Daily Temperature of the month being calculated

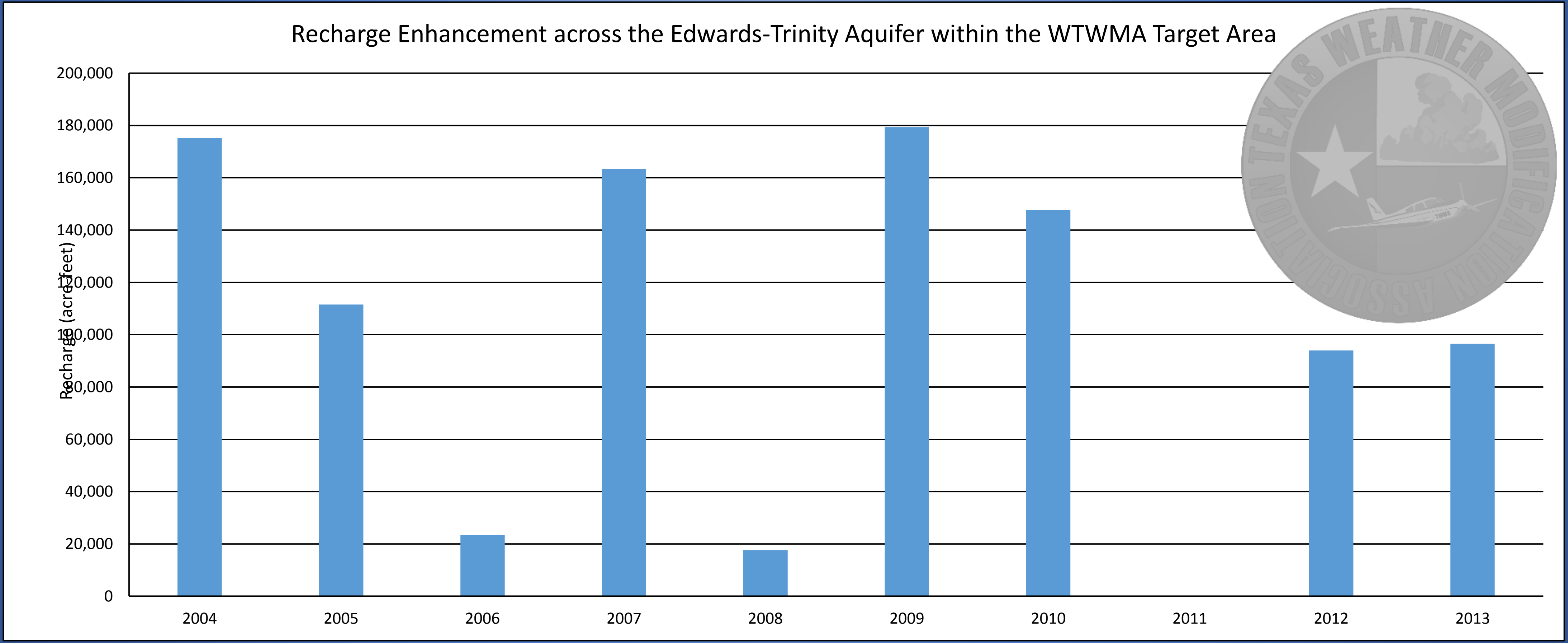
Where a = $(6.75 \times 10^{-7})I^3 - (7.71 \times 10^{-5})I^2 + (1.792 \times 10^{-2})I + 0.49239$

Where I = $\sum_{I=1}^{12}\left(\frac{Ta}{5}\right)^{1.514}$

The impacts of Weather Modification on Recharge in West Texas

- Estimated Recharge across the WTWMA target area over the last 9 years is:
  - 1 million acre-feet
    - Or ~100k acre-feet per year
- Nearly 10% of increases from weather modification in West Texas is expected to recharge into area aquifers

Annual Recharge across the WTWMA Target Area due to Rain Enhancement



Benefit Cost Analysis

- J.L. Johnson (Texas A&M)

- Benefit Cost Analysis done for WCTWMA (Abilene) in 2001
- Also a 2014 Study for PGCD/STWMA/SWTREA/WTWMA

- 2001 study found that one additional inch of rainfall across their target area would:
  - Reduce irrigation by 6.5%
  - Increase agricultural production by roughly $7 million
  - Increase reservoir, lake and river levels
  - Recharge Aquifers
  - Decrease surface and groundwater consumption

- Overall economic impact of $10 million/year

Johnson’s 2014 Study

- Study Focused on three areas of agriculture
  - Increasing Dryland Crop Revenues
  - Decreasing the amount of Irrigation Needed
  - Increasing Grazeland and Revenues
- Given in the chart below, Direct and Statewide Economic Impact as well as Direct and Statewide Benefit Cost Ratios.

PROGRAM	Direct EI	Statewide EI	Benefit Cost Ratio (D)	Benefit Cost Ratio (S)
WTWMA	$6,016,866	$12,757,566	1:16	1:34
STWMA**	$5,691,327	$10,850,560	1:21	1:39
PGCD	$4,877,938	$9,407,140	1:22	1:43
All Combined	**$16,586,131**	**$33,015,266**	**1:19**	**1:38**

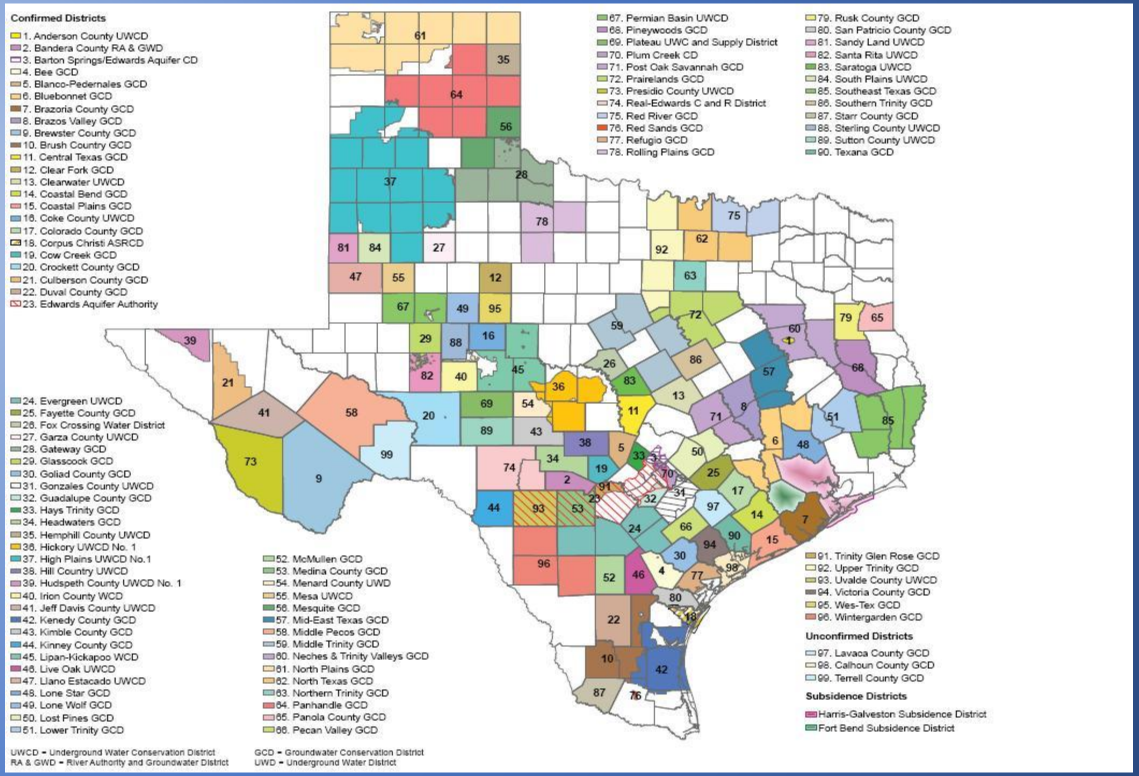
Data for SWTREA not added here due to inconsistent target area size and operating years, however, the ratios are as follows: 2009 through 2011 – 1:9, 1:18, 2012 – 1:7, 1:14

Of the 31 counties analyzed:

- Tom Green, Glasscock and Carson Counties are the top 3 in increased revenue from dryland crops from weather modification.
- Carson, Uvalde and Tom Green Counties are the top 3 in savings from irrigation due to weather modification.
- Webb, Crockett and Medina are the top 3 in increases from grazing land due to weather modification.
- Overall, the top three counties receiving benefits from weather modification are:
  - Tom Green
  - Glasscock
  - Carson

Similar Study in 1997

- Wyatt and Carver did a similar study for a program across the High Plains Underground Water Conservation District.
- Found that one additional inch brings:
  - $81 million/year across their target area
  - Economic Impact of $283 million/year across their region
- Found increases on their four major crops of:
  - $34/acre for Cotton
  - $18/acre for Corn
  - $10/acre for Grain Sorghum
  - $20/acre for Wheat



Conclusions

- Weather Modification of convective clouds will increase precipitation by 10-15% annually.
  - This translates to an addition 1.5" of precipitation (or 3.5 million acre-feet)
- Benefits from weather modification include:
  - Increases in dryland crop revenues and grazing land revenues
  - Decreasing the amount of irrigation and groundwater consumption
  - Aquifer Recharge
  - Increases in river flow leading to increases in lakes and reservoirs
  - Wildlife Management
  - Among others.
- The benefits far outweigh the cost of running a program:
  - Using only 3 of the benefits listed above, benefit cost ratios are 1/19 directly with a 1/38 ratio at the state level
  - The production of 1 acre-foot of water is roughly $1.50
- Weather Modification is NOT a short term fix, it is a long term water management strategy to be implemented with other innovative technologies to increase water supply.

Questions or Comments?

- Weather Modification in Texas is an always evolving service with several research programs ongoing.

- Please contact the Texas Weather Modification Association at:

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