An Introduction to Weather Modification in West Texas

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What to expect:

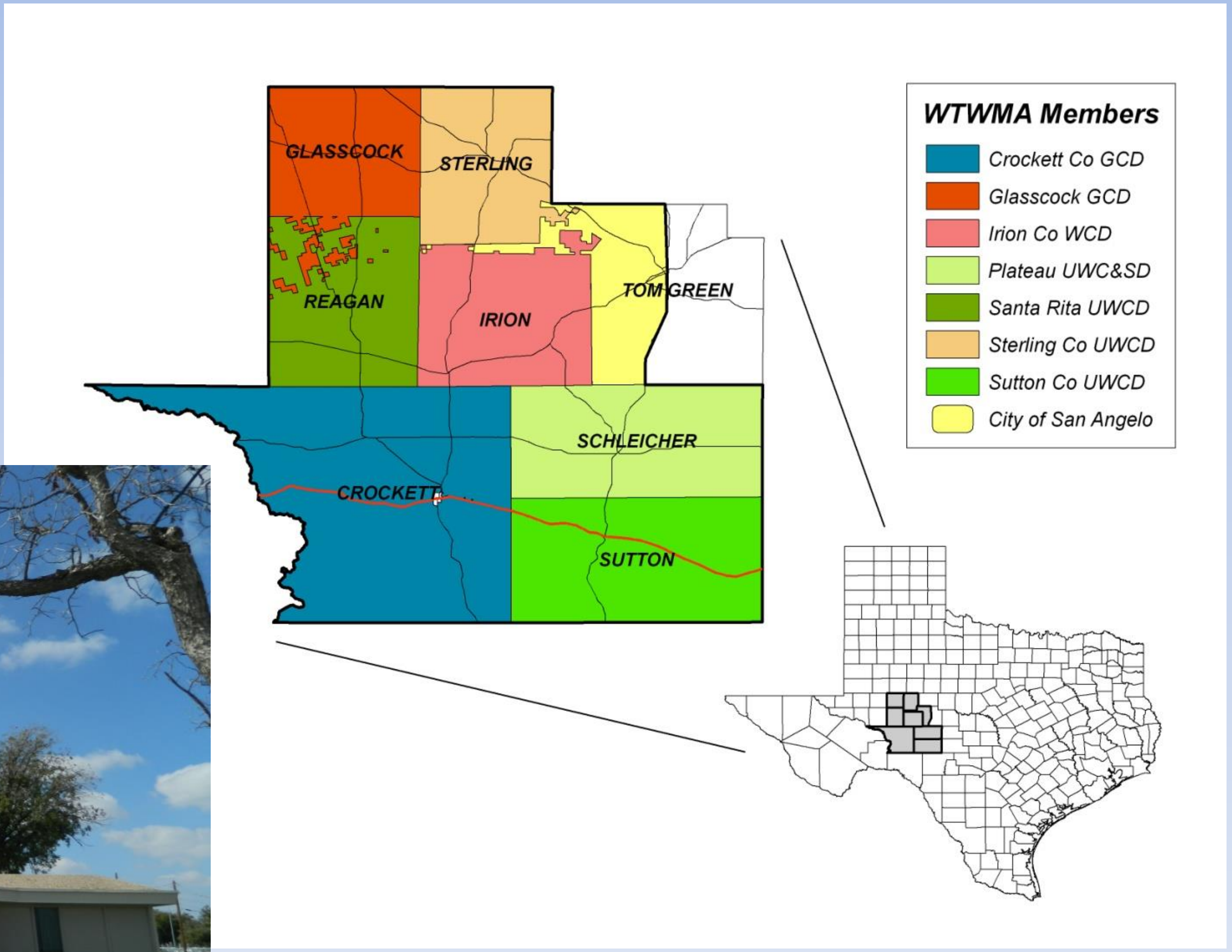
- WTWMA and TWMA target areas
- Texas Climatology
- Purpose
- Methodology
- Examples
- Analysis
- Benefits
- Ongoing/future work

WTWMA Target Area

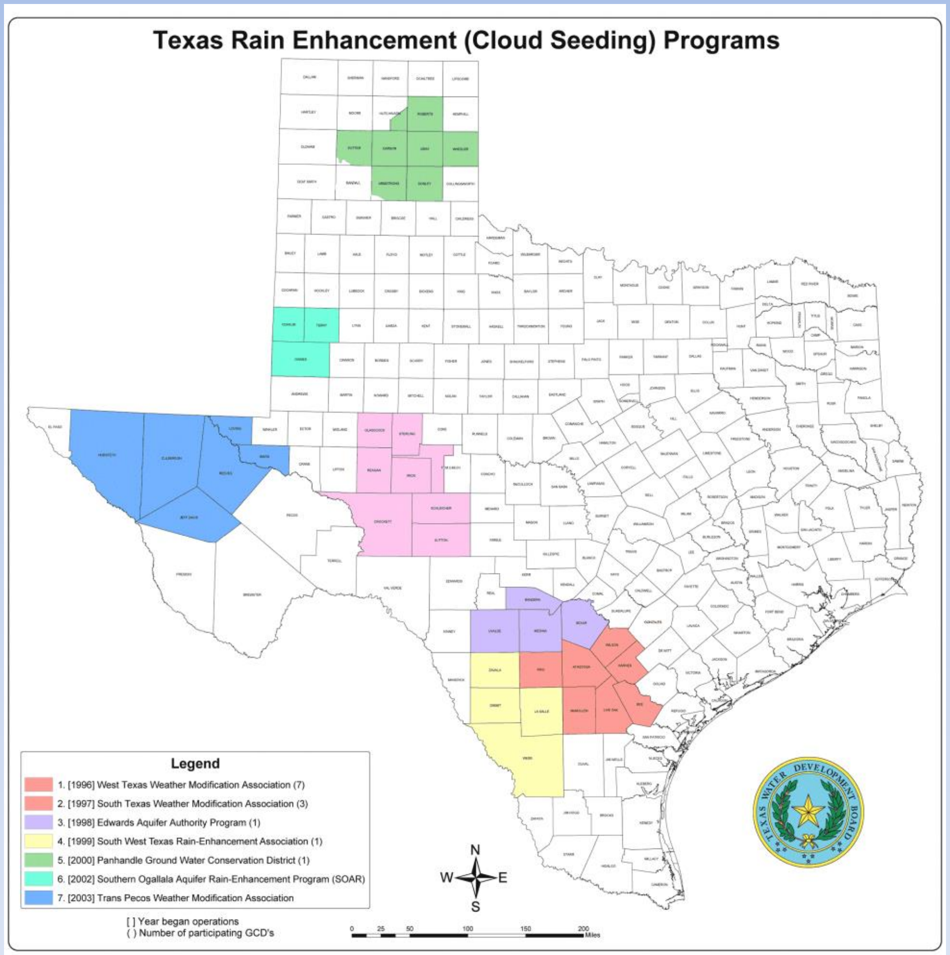
- Covers 7 ½ Counties in West Texas

- Total area covers 6.4 million acres

- Based out of San Angelo, TX at San Angelo Regional Airport

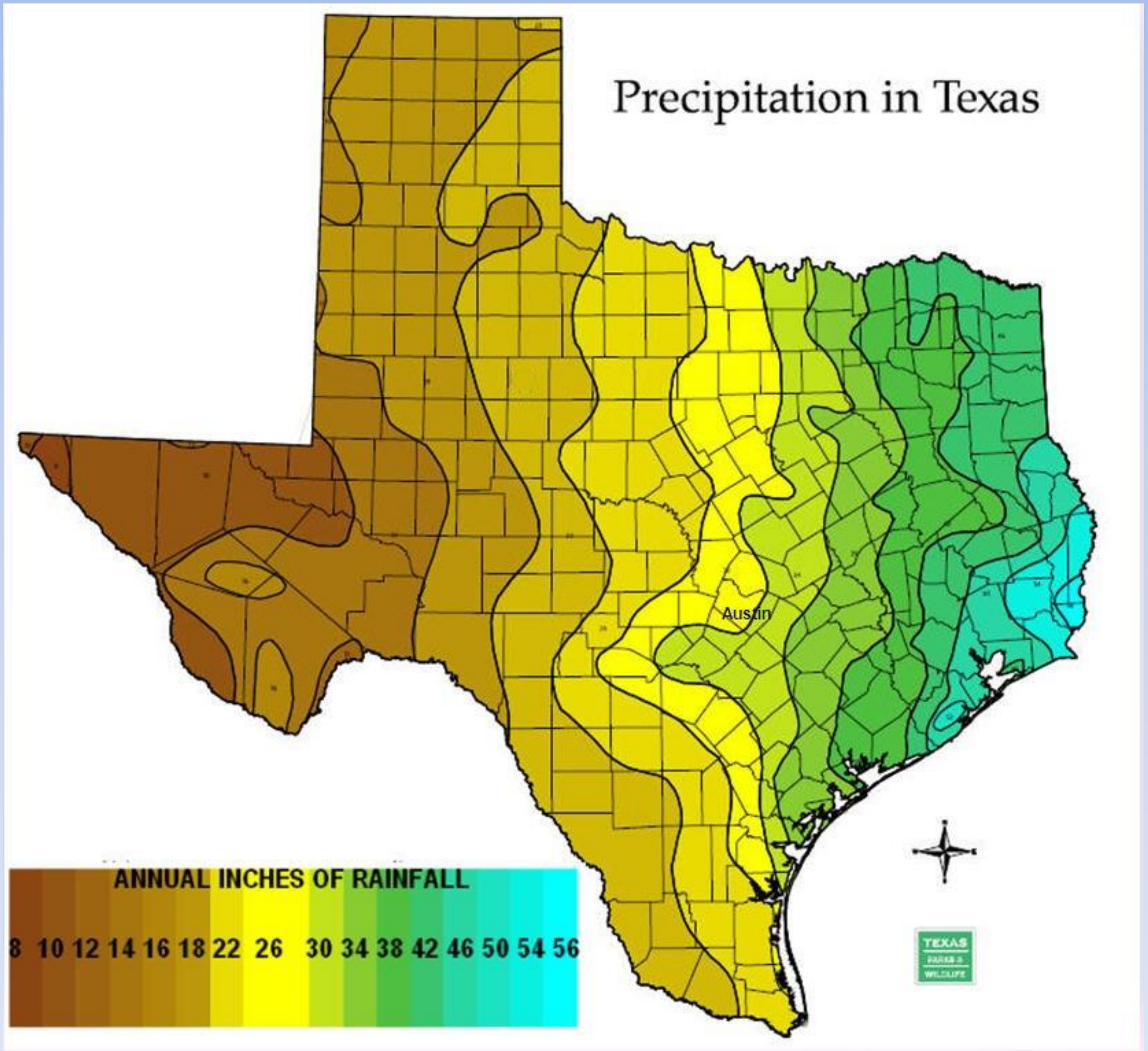


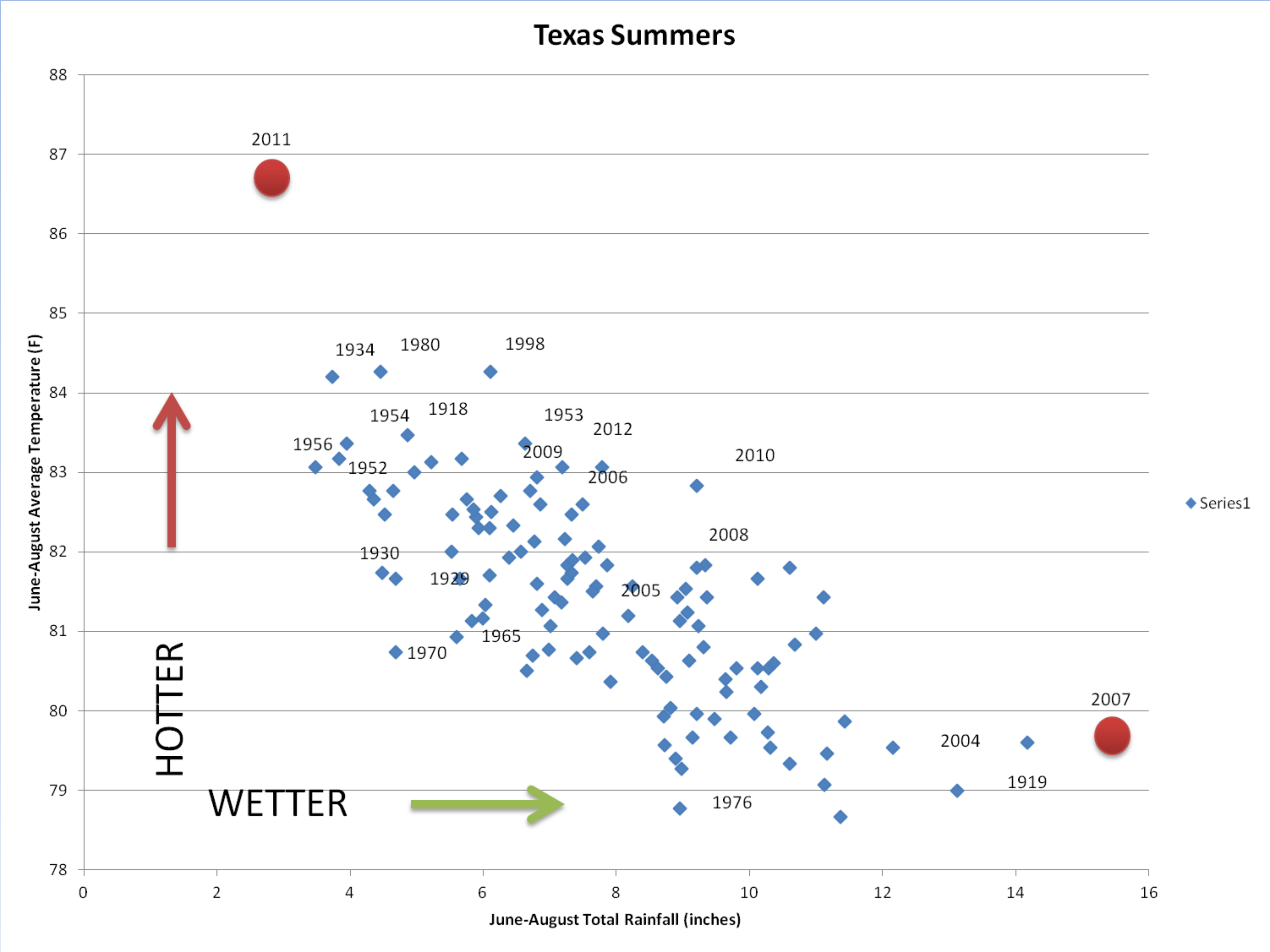
TWMA Target Areas



- 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.
- Covers 36 Counties in Texas
- Area covered in 22.7 million acres

Quick look at Texas Climatology




Texas Summers
June-August Average Temperature (F)
June-August Total Rainfall (inches)
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2005
1965
1970
2007
2004
1919
1976
HOTTER
WETTER
Series1

Why modify the weather?

- Lack of Rain!
- Demand for water increases while the supply is decreasing
- Clouds in Texas are very vulnerable to aerosols
  - Dust, smoke, sulfate, etc.
- Texas is very susceptible to drought
- ENSO conditions impact Texas more so than any other state in terms of changing weather patterns

Why continued:

- Least expensive way to increase water supplies for:
  - Drinking water
  - Irrigation

- While also…
  - Reducing the amount of irrigation needed
  - Fill area lakes, rivers and reservoirs
  - Aquifer Recharge

Methodology

- Current program operations are built 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
  - TEXARC (90's)
    - Another randomized cloud seeding experiment in San Angelo
  - SPECTRA (00's)
    - Cloud Sampling in the Texas Panhandle
- Target convective thunderstorms with good vertical depth during "VFR" flight conditions

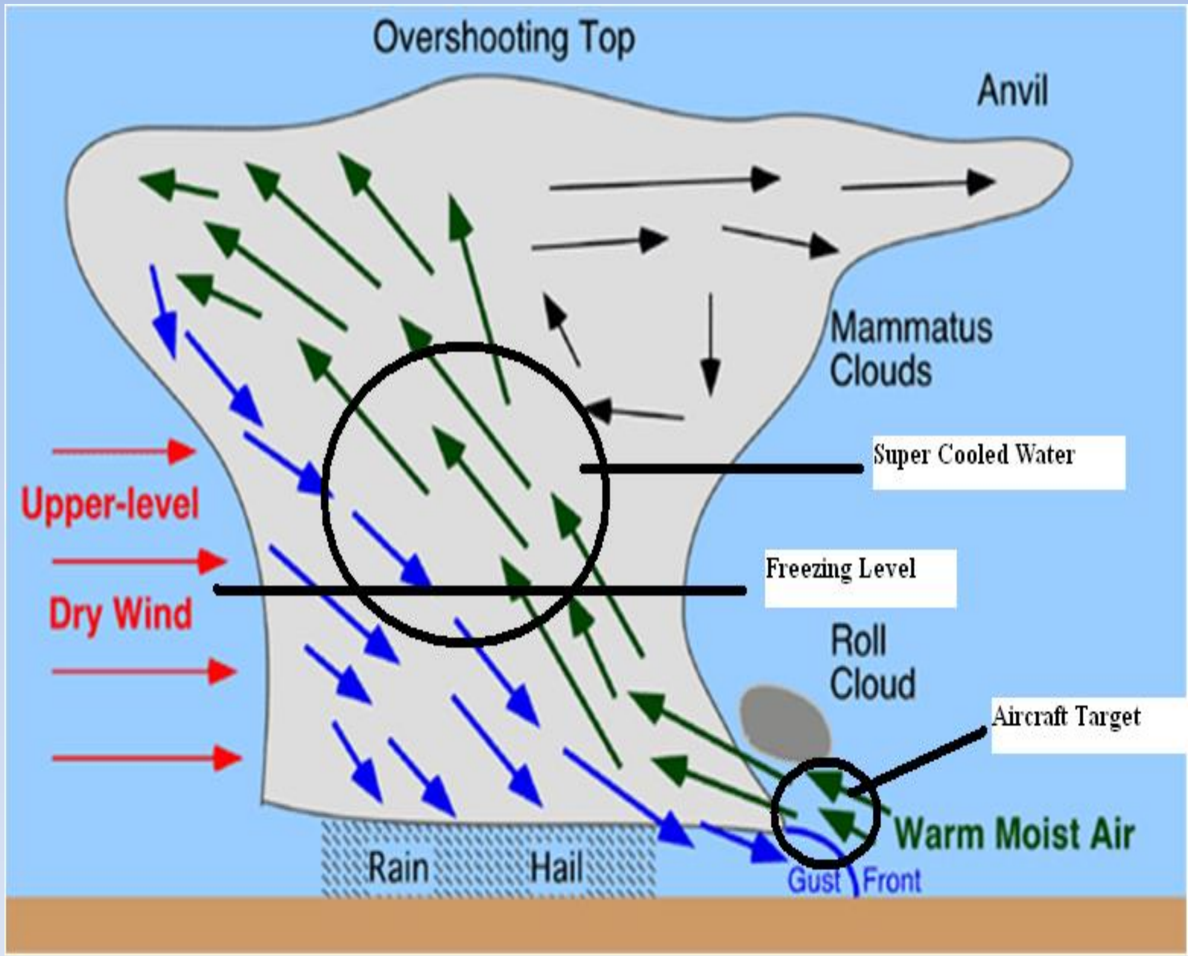
Methodology

- Base seeding via aircraft using two different type of flares
  - Glaciogenic Flares (Silver Iodide)
  - Hygroscopic Flares (Calcium Chloride)

- Rely on inflow at the cloud base to transport material into the cloud

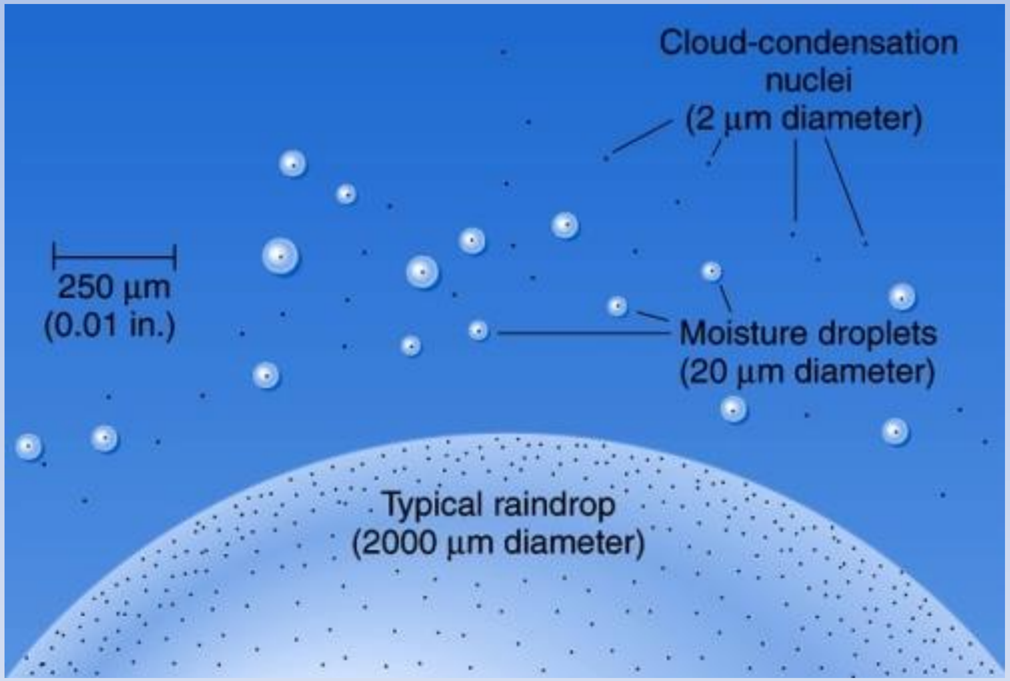
Why Silver Iodide?

- Glaciogenic seeding is used in clouds that have great vertical depth
- Super cooled water within the cloud struggles to freeze
- Silver Iodide closely resembles the structure of an ice crystal.
- Upon contact, super cooled water freezes
  - Also serves as hail suppression.



Why Calcium Chloride?

- Increases the number clouds we can target.
- Hygroscopic Seeding introduces larger cloud condensation nuclei into a cloud
- Deliquescence Relative Humidity of 65%
- Larger Droplets able to freeze
- Fracturing of frozen, larger ice crystals also severs as hail suppression

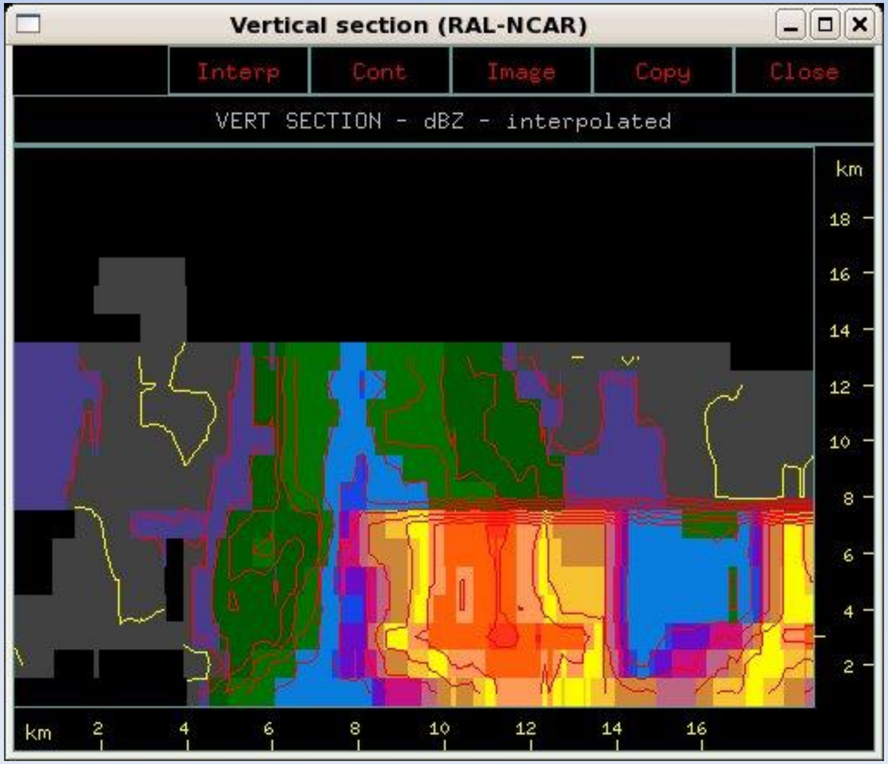


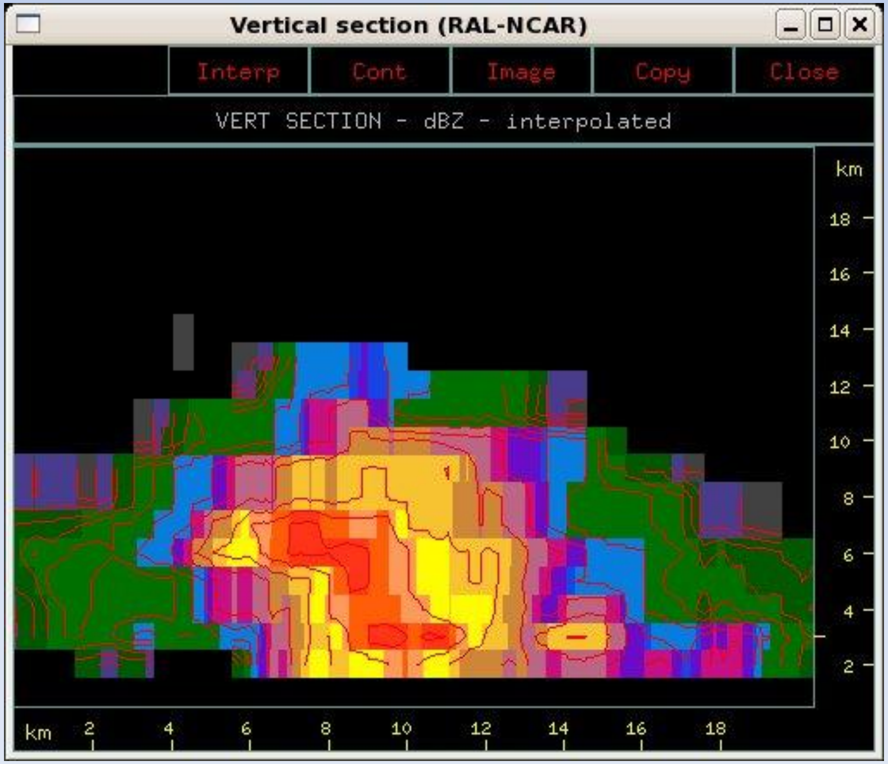
How do we know if clouds need to be seeded?

- For Glaciogenic Seeding
  - Cores of higher dBZ stuck in the middle portion of the cloud (above the freezing level)
- For Hygroscopic Seeding
  - Index of Coalescence Activity
  - Warm Cloud Depths
  - Cloud Base Heights
  - Radar Signatures
- For “dual-seeding”
  - If the criteria is met for Hygroscopic Seeding but also has a higher dBZ core above the freezing level

How do we know if clouds need to be seeded?

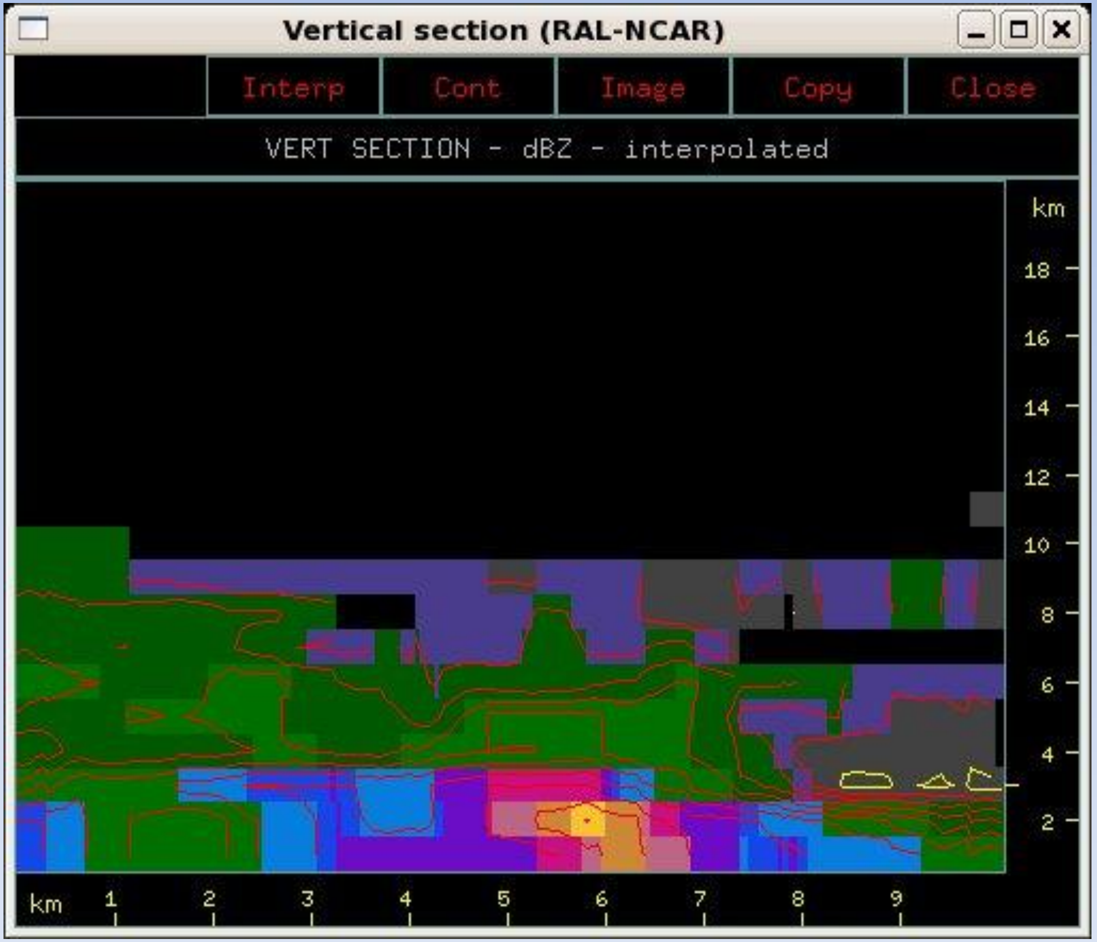
- Glaciogenic Seeding
  - Radar Cross Section showing a core of higher dBZ values higher then the freezing level



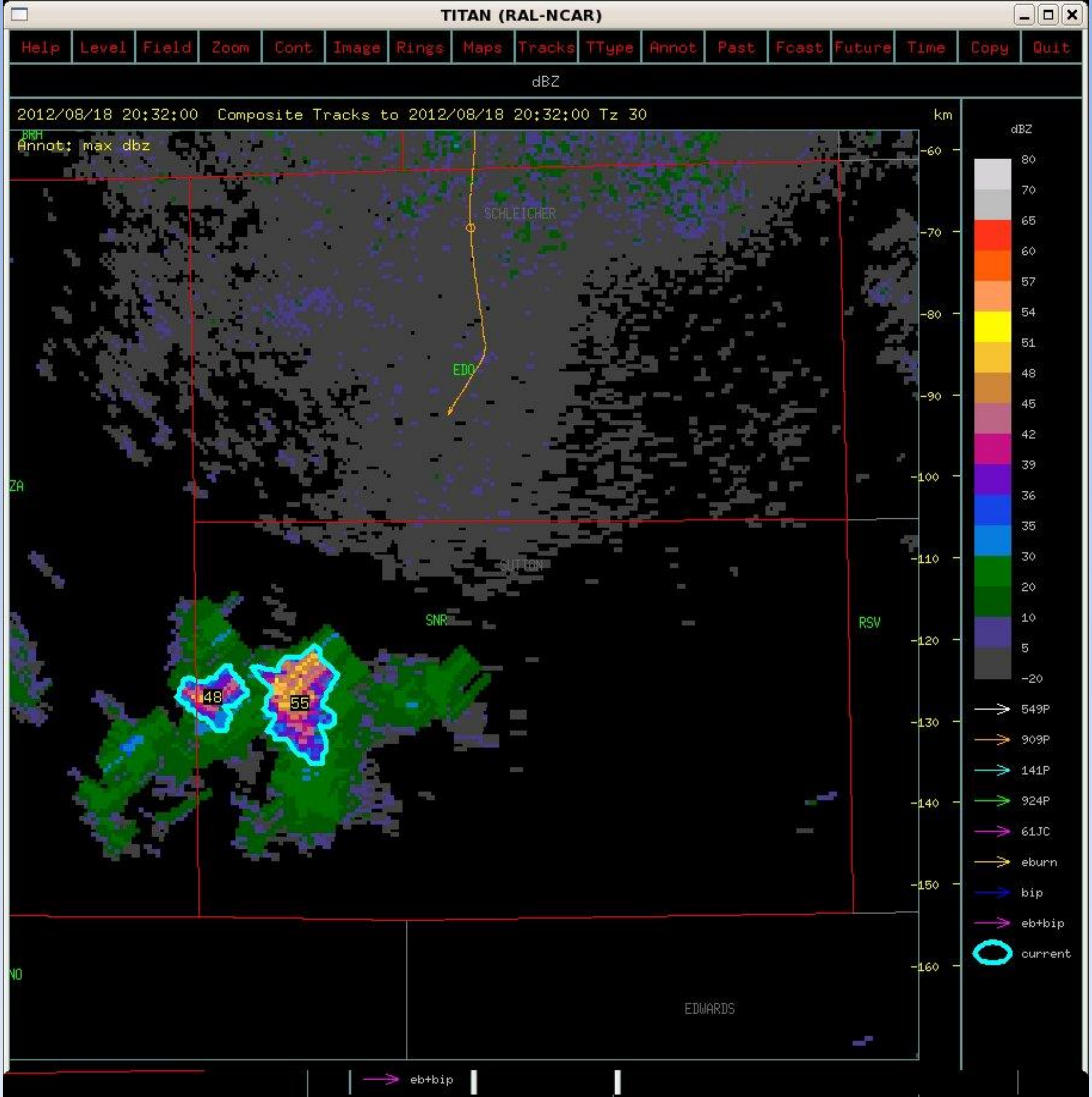


How do we know if clouds need to be seeded?

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



Example



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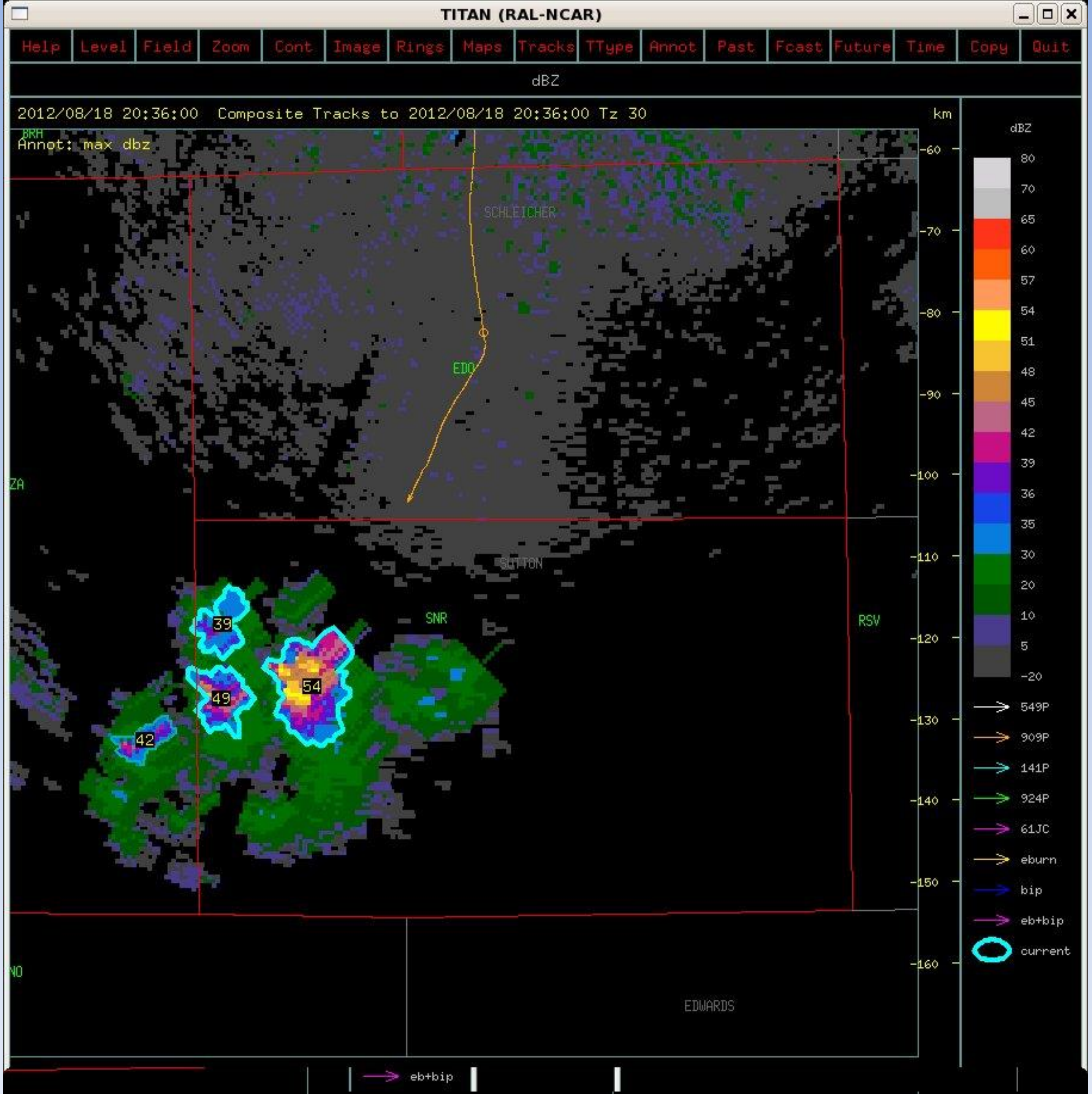
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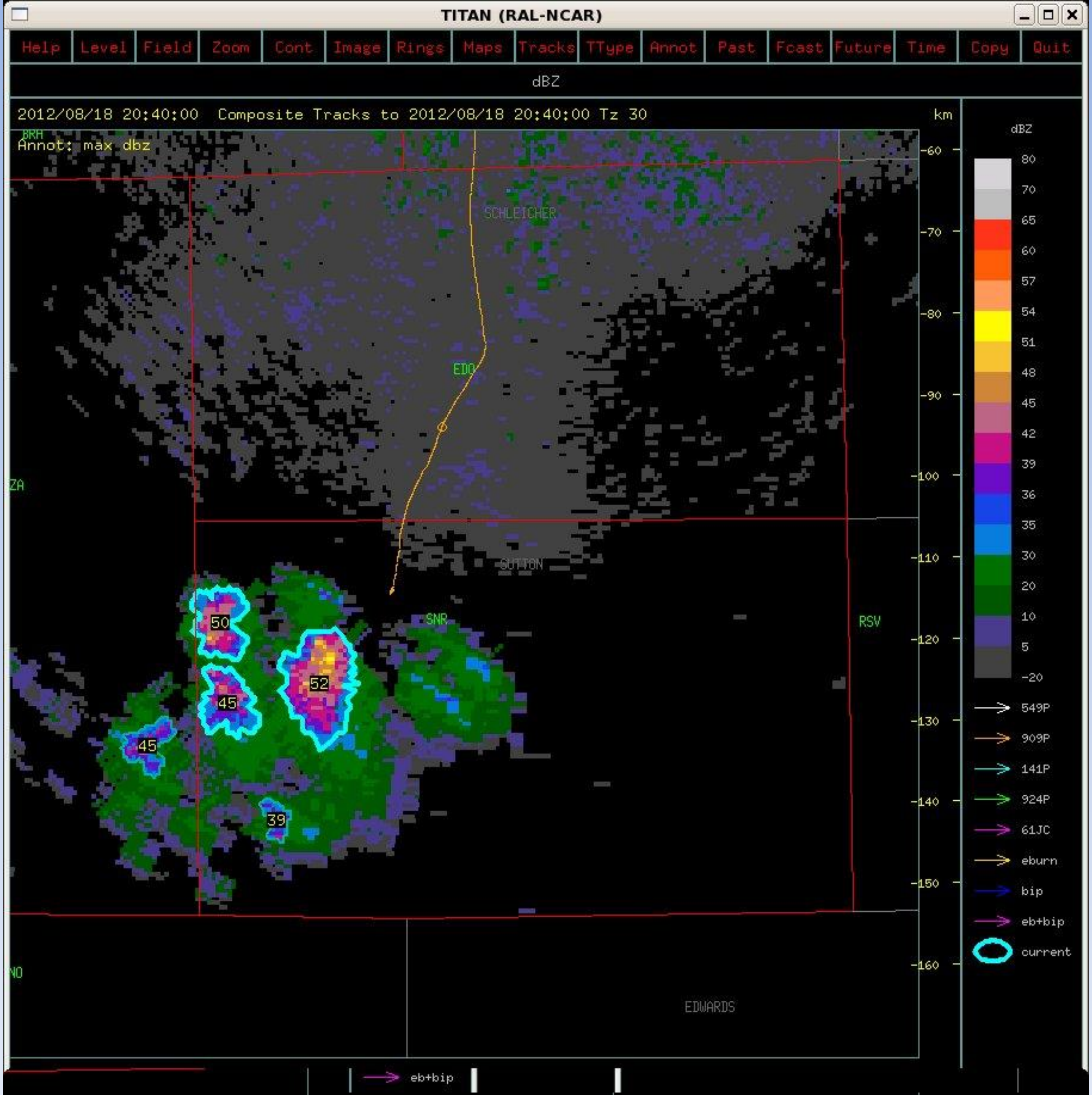

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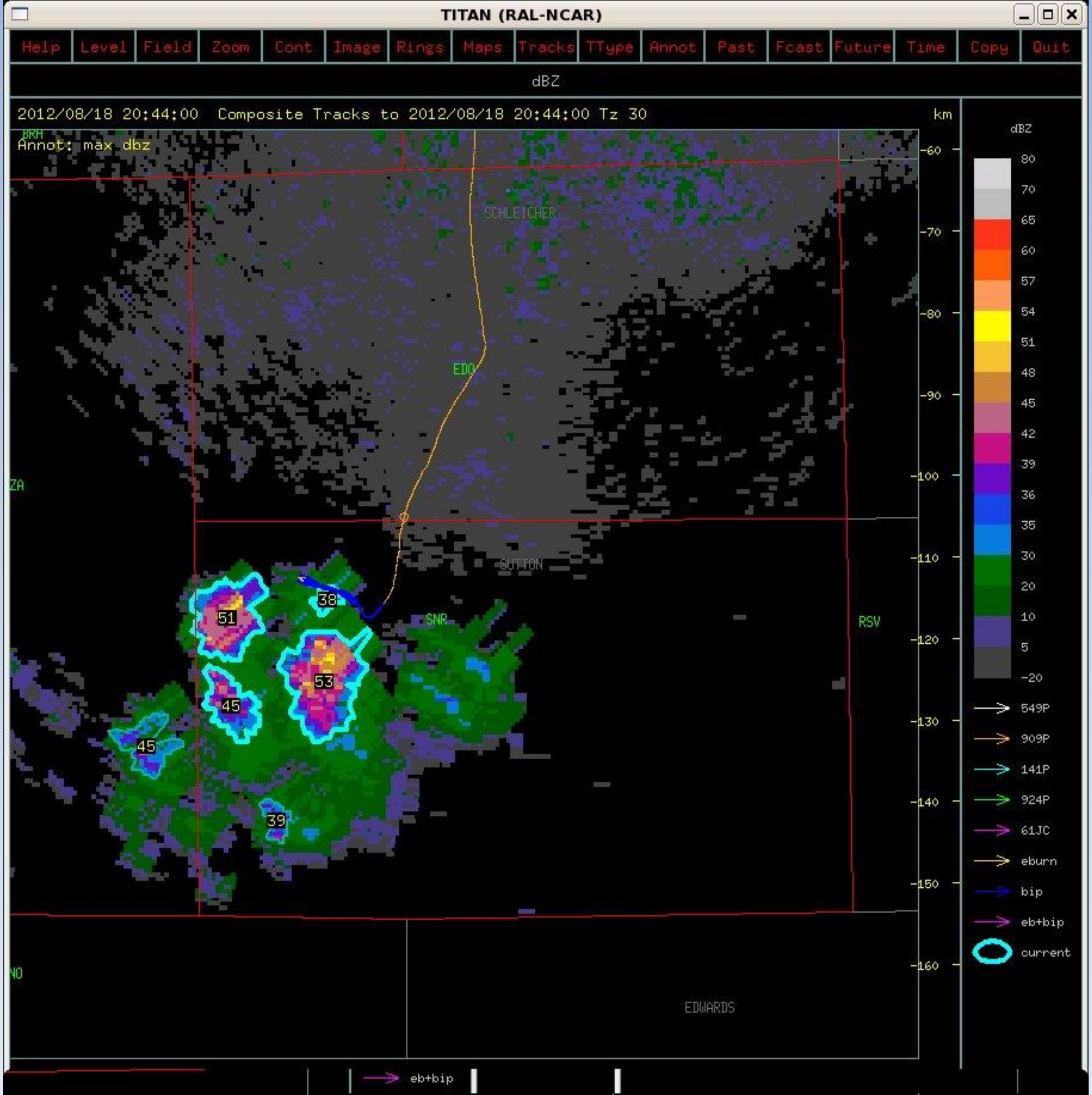
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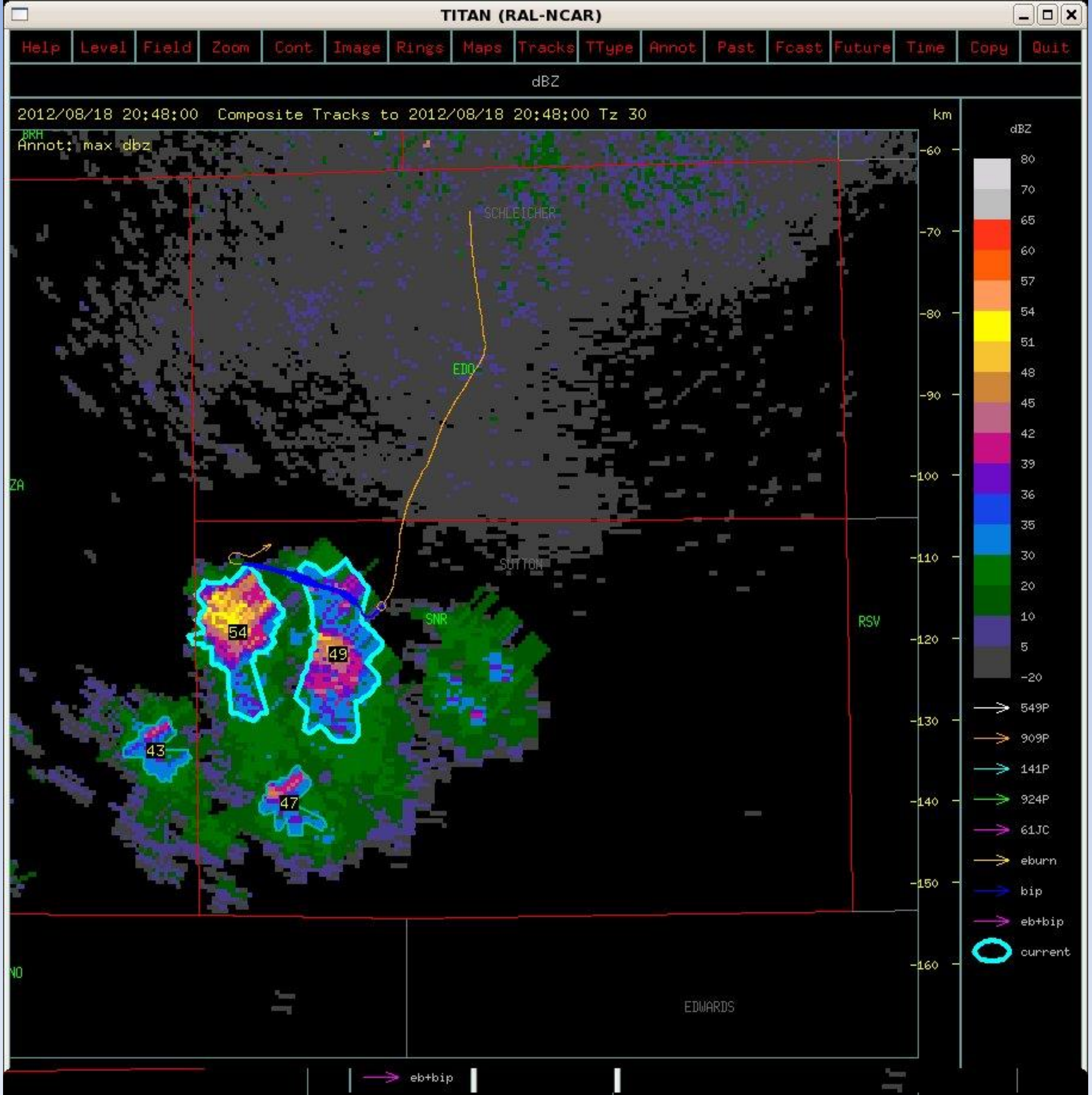
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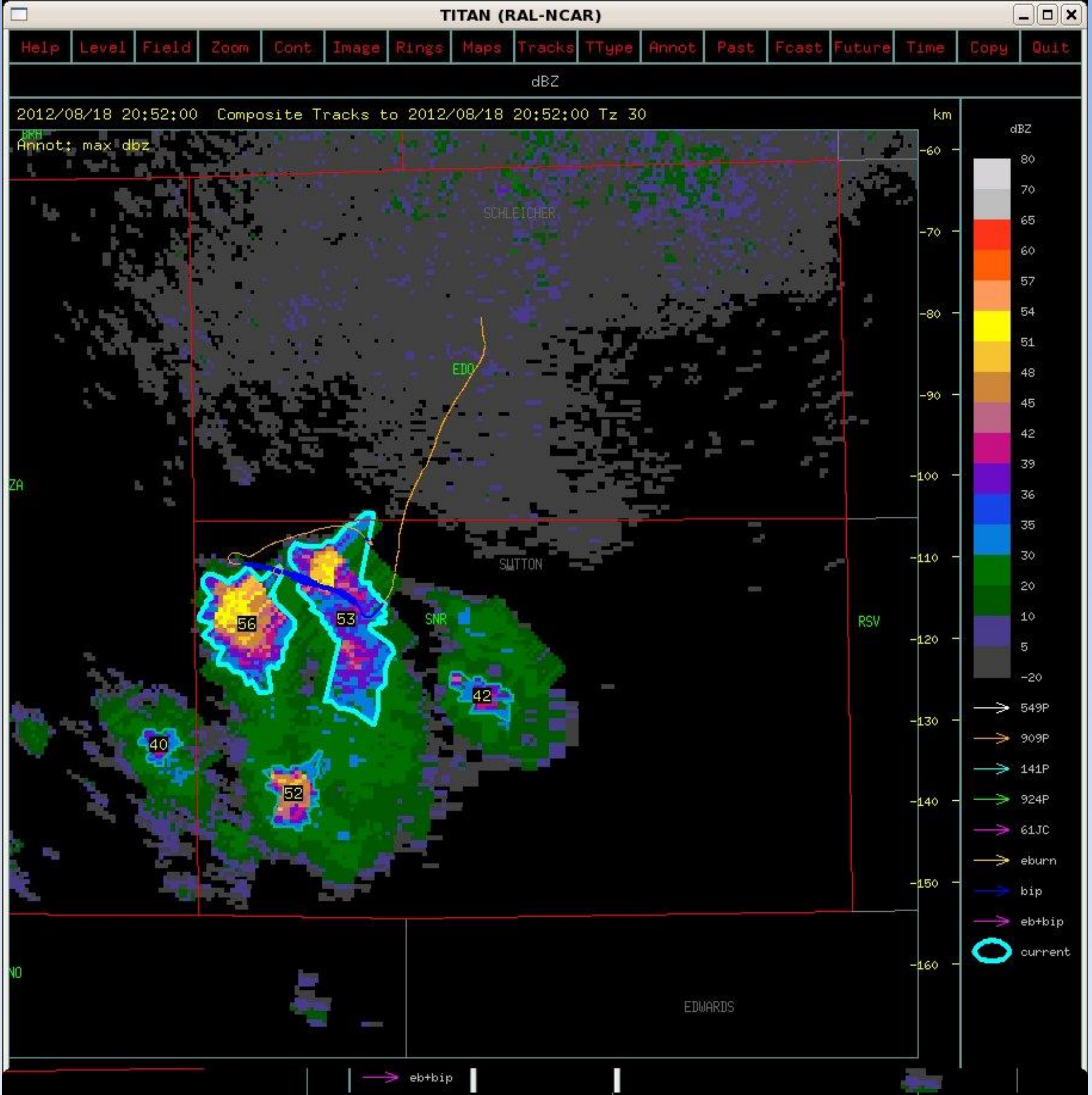

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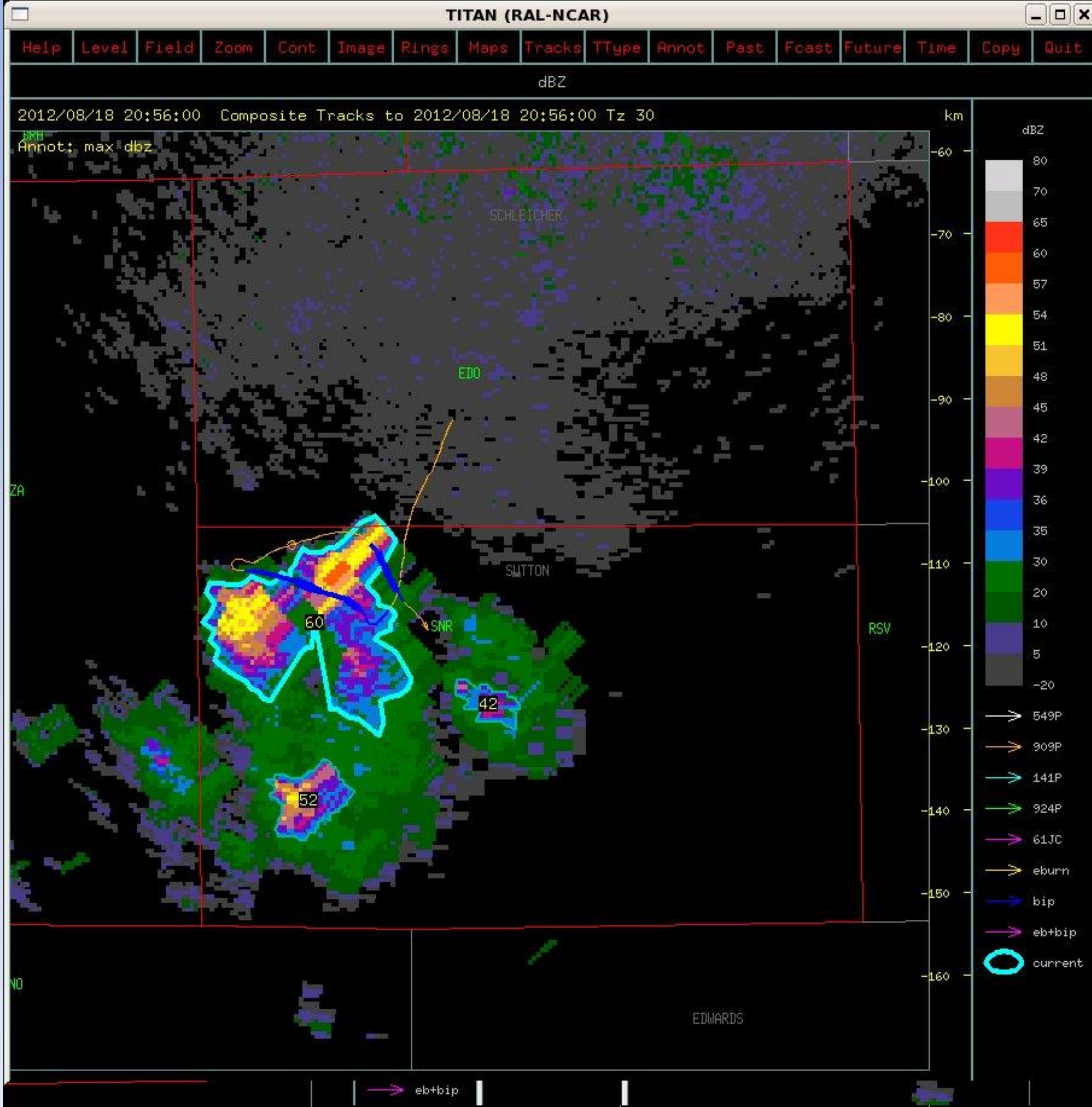

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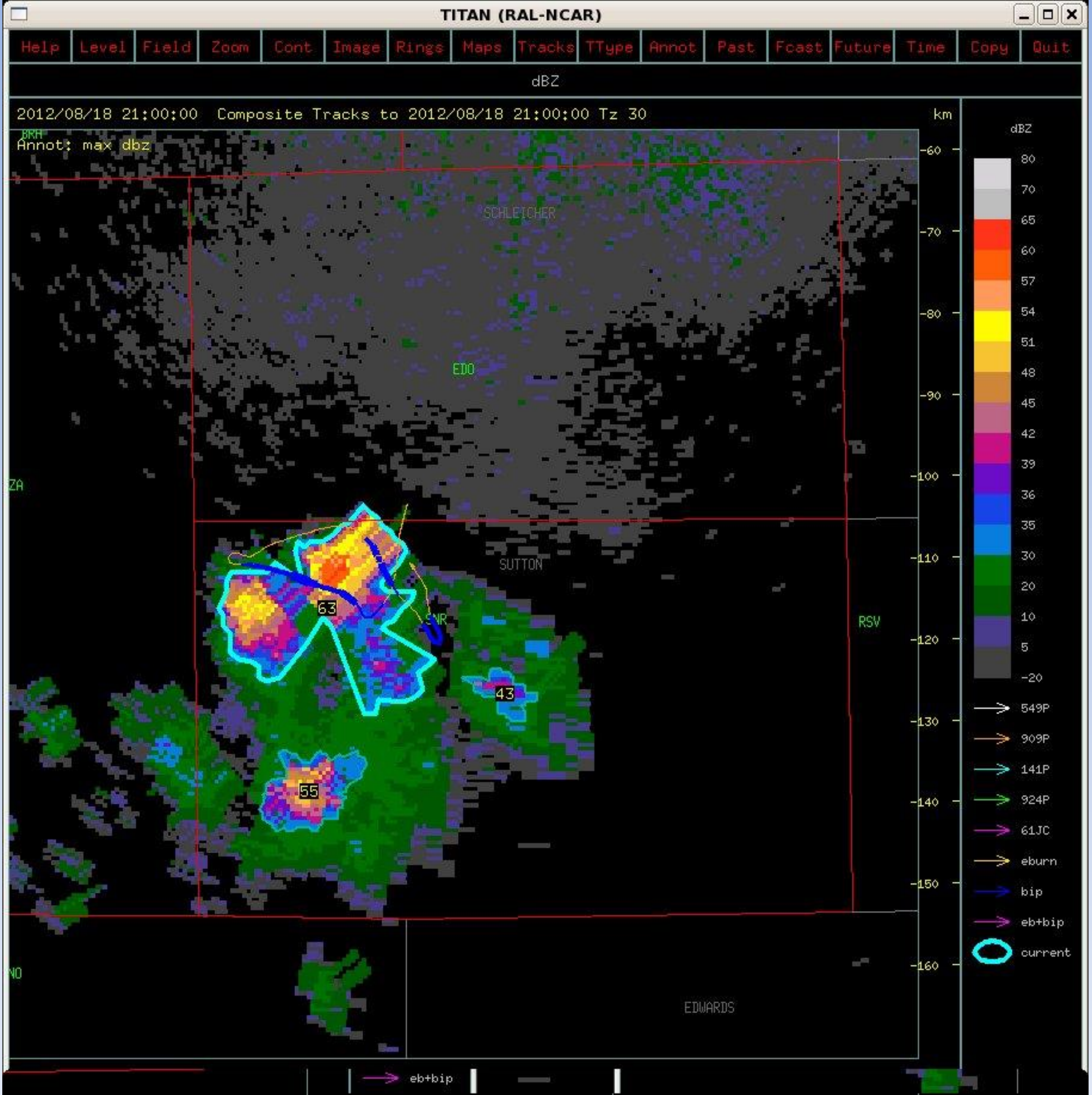

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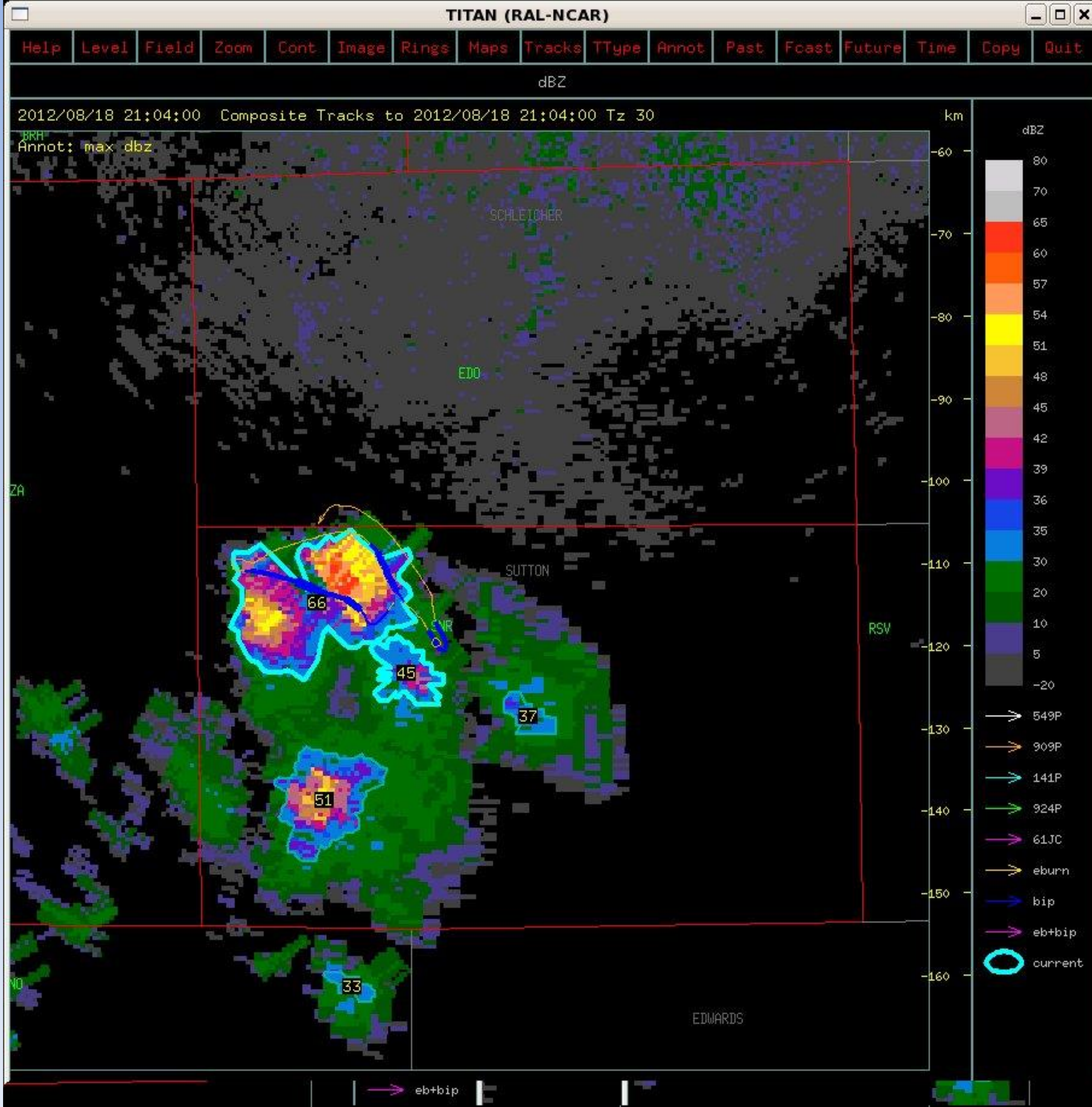

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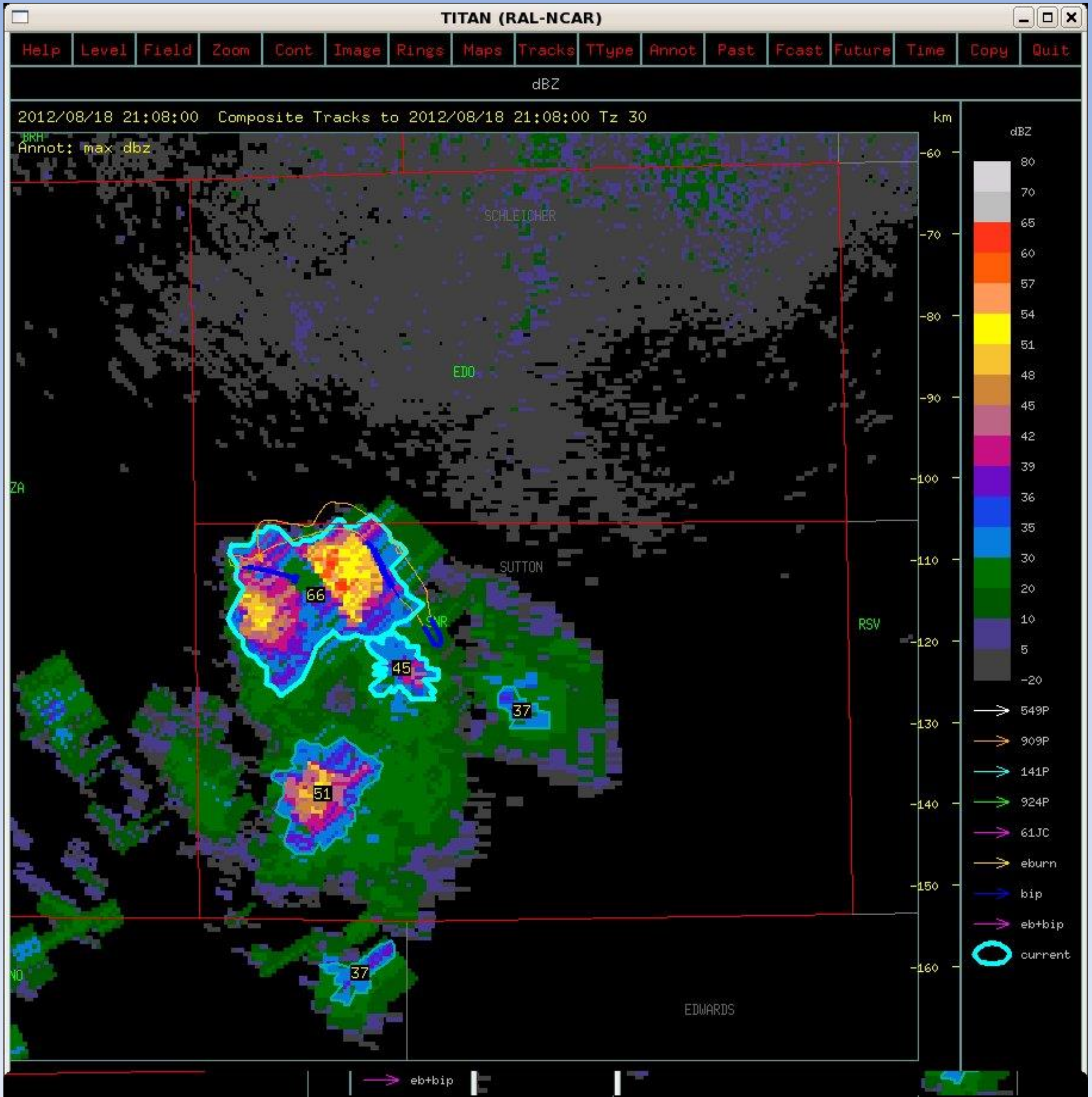

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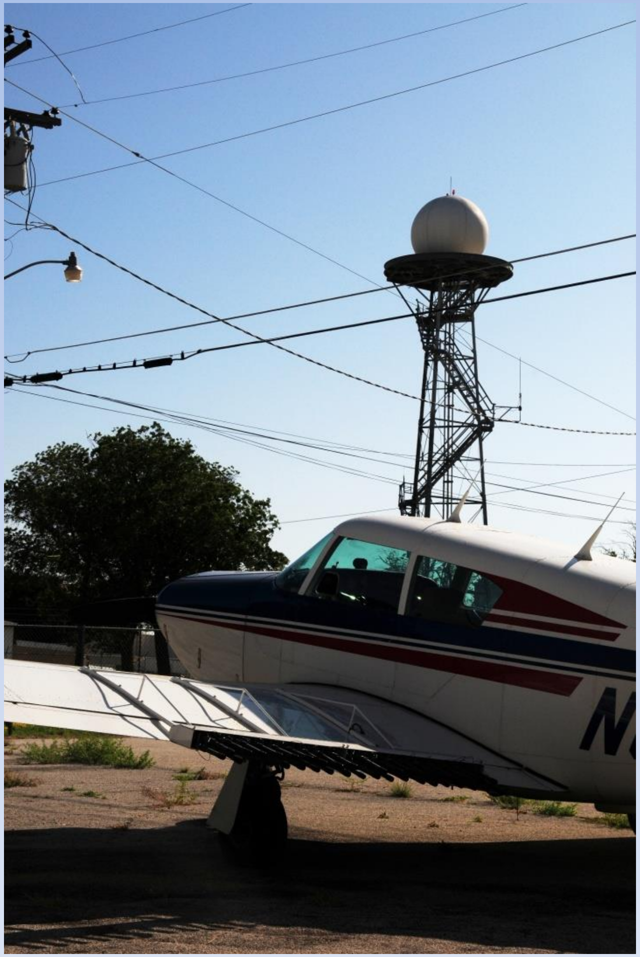

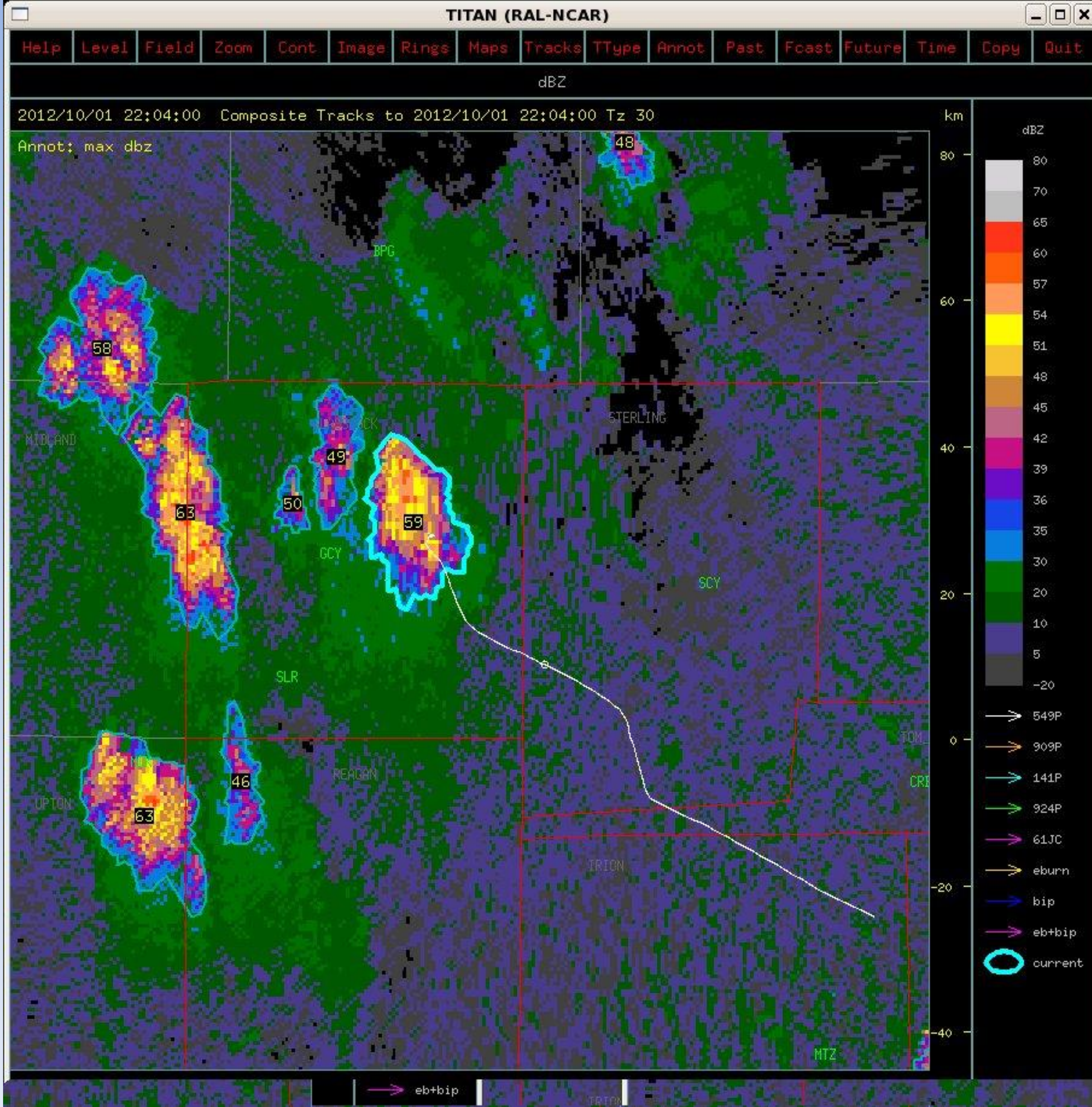
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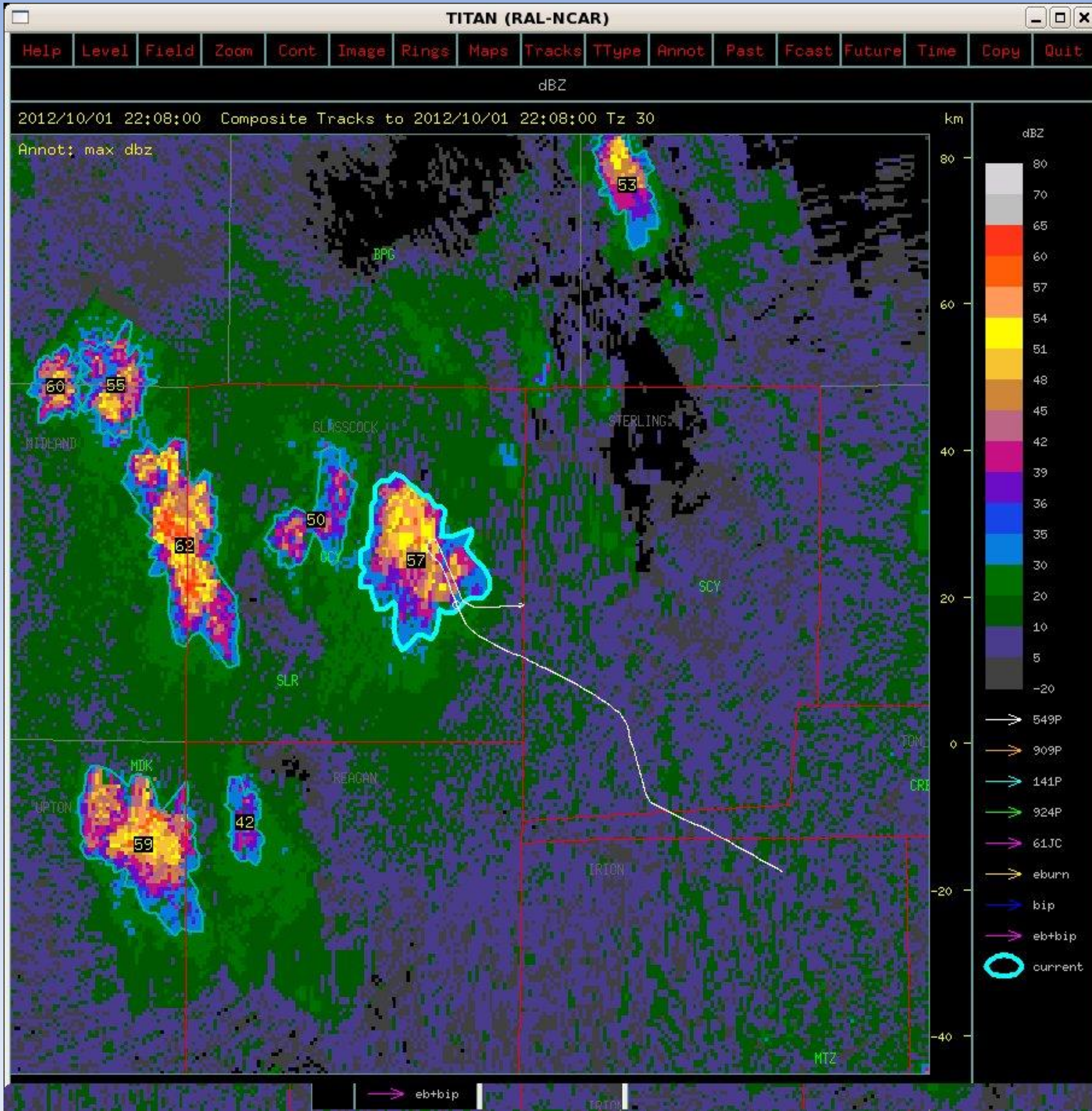
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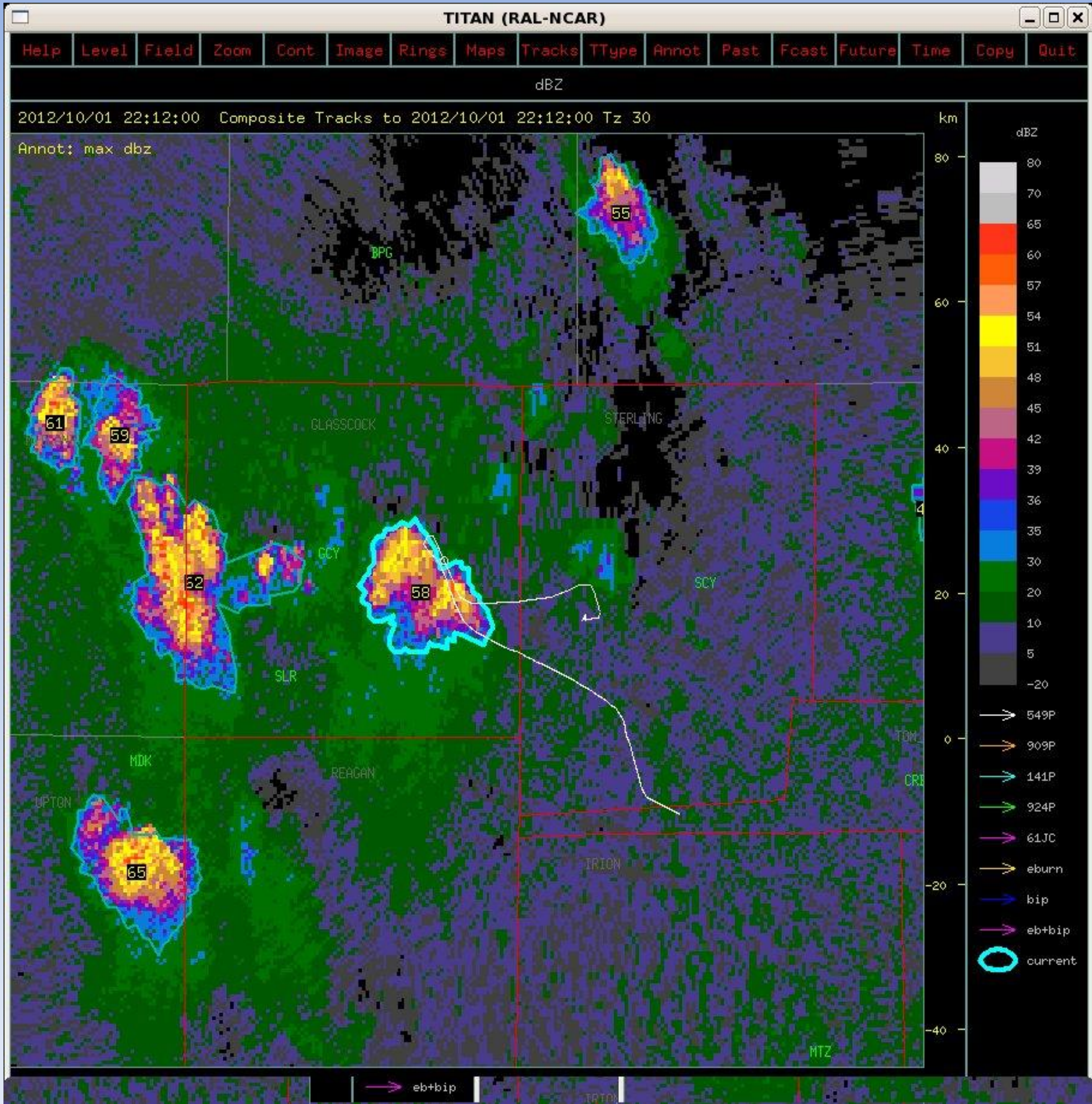
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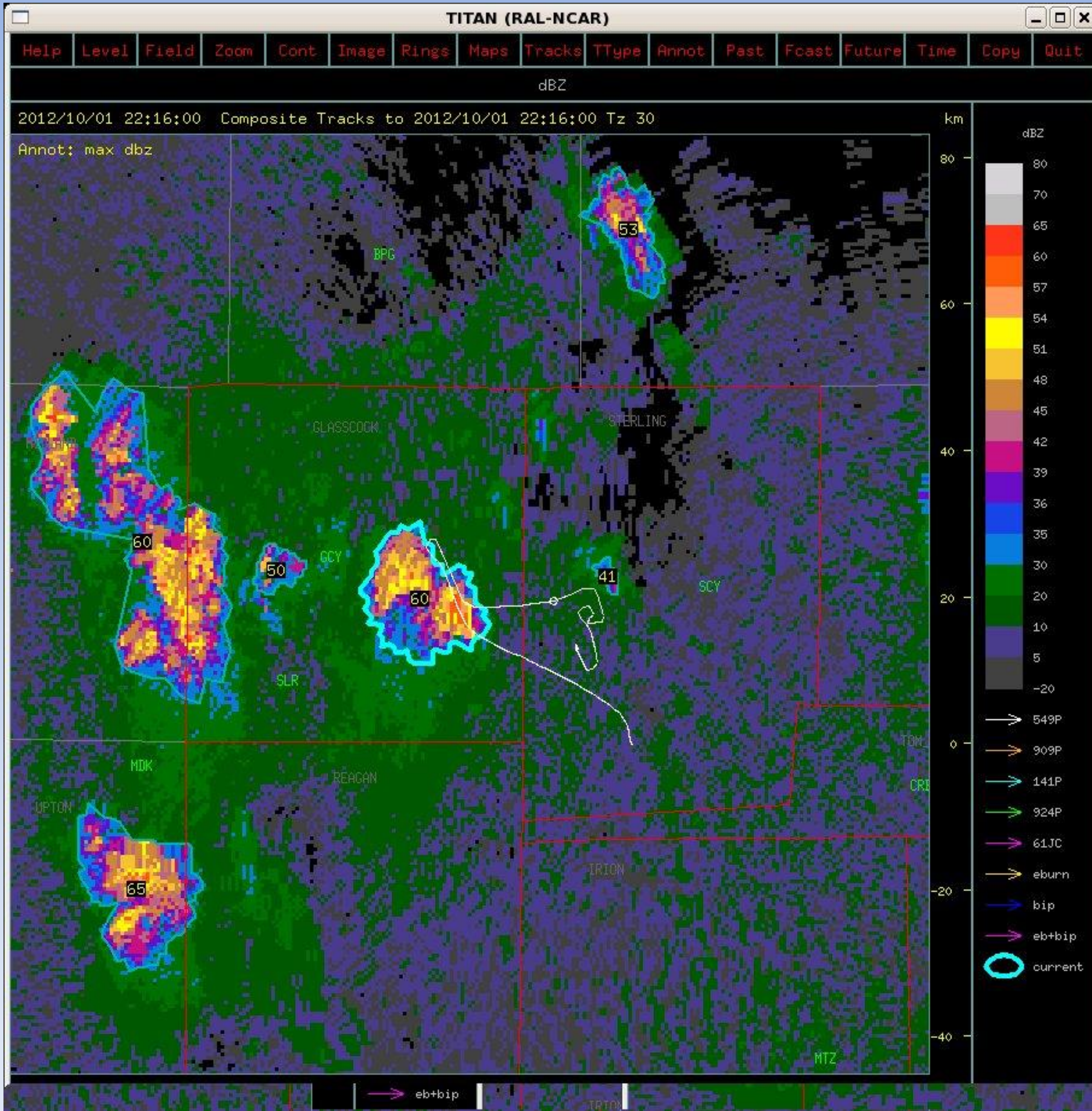

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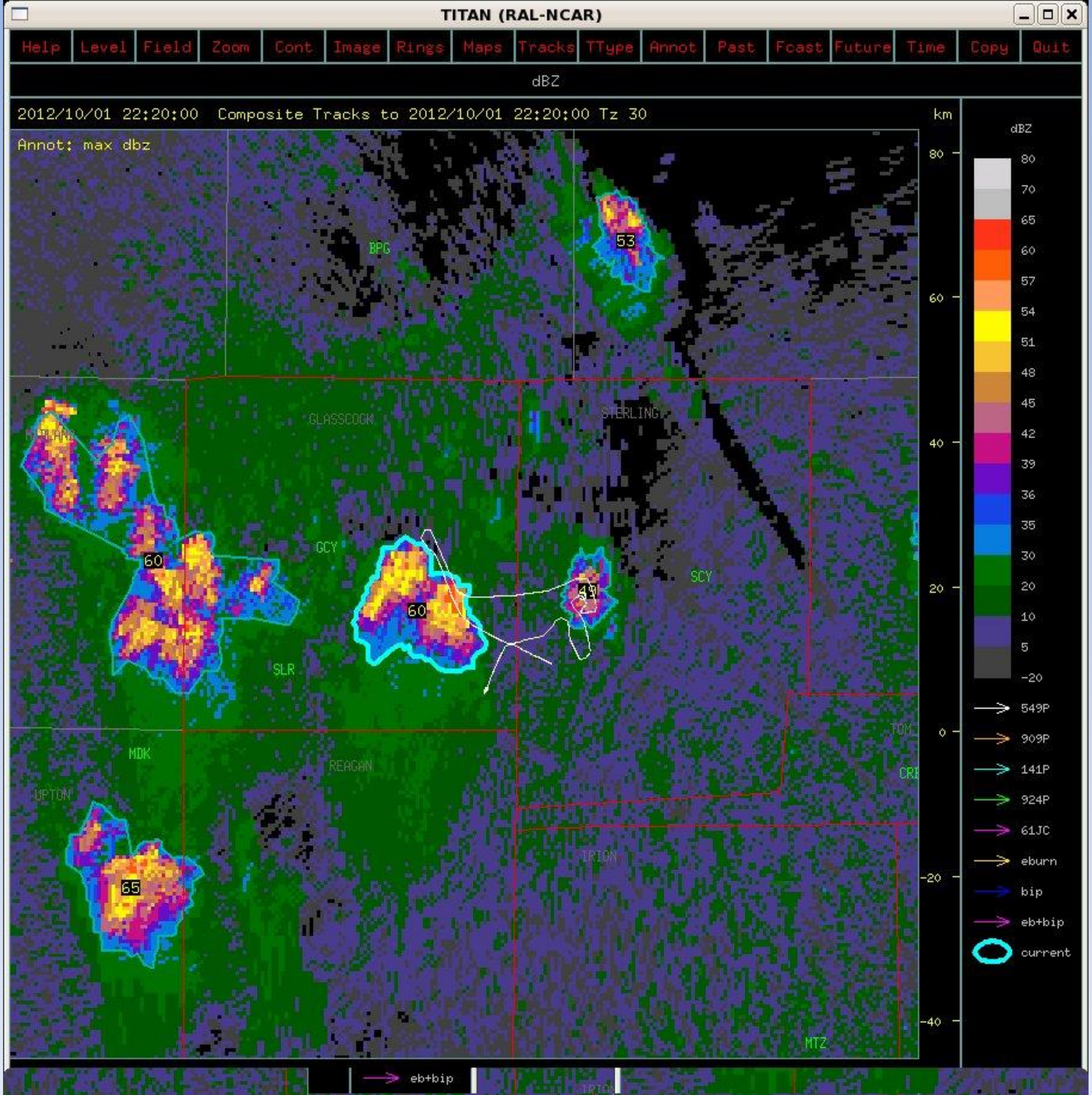

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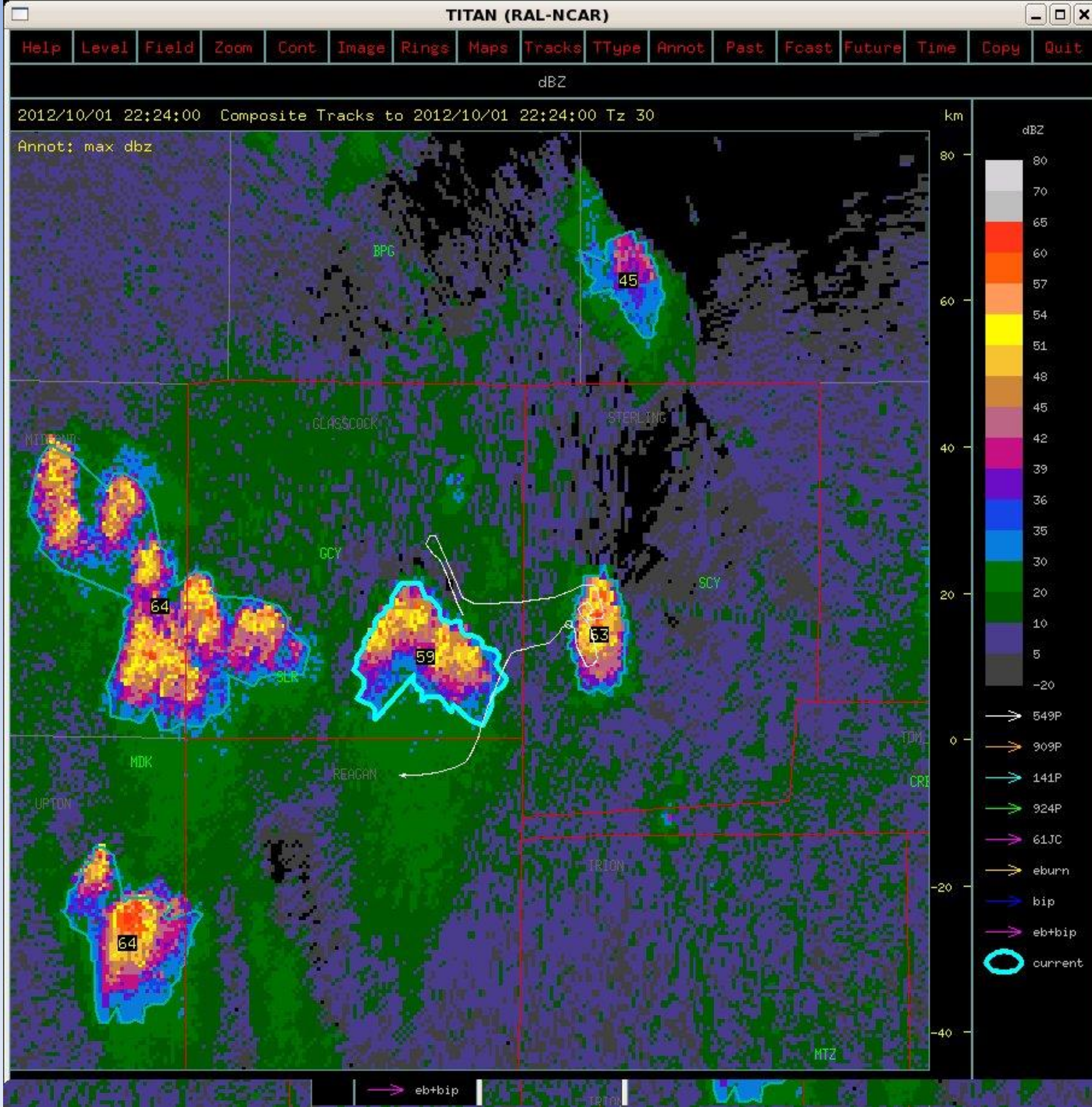

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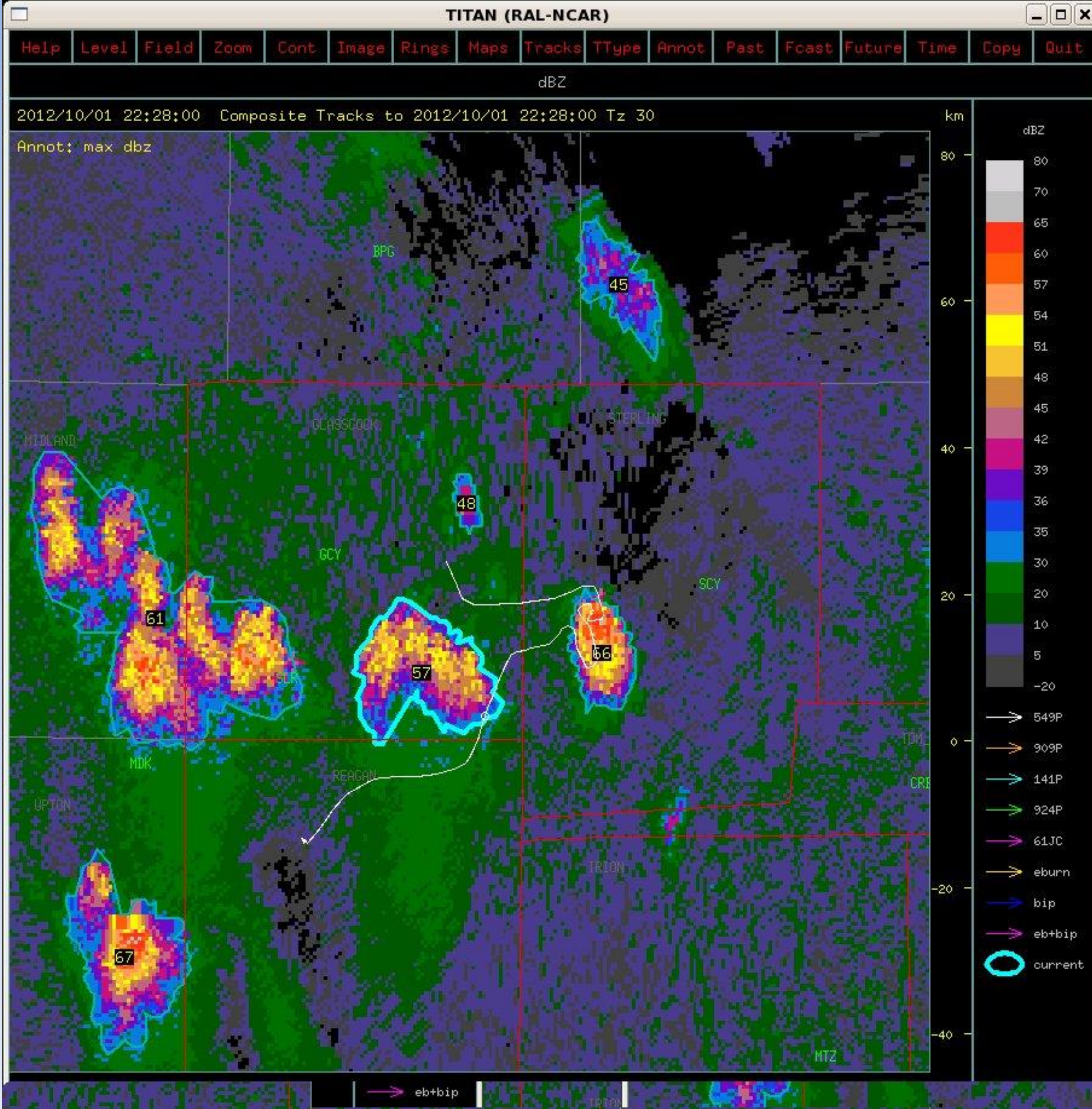
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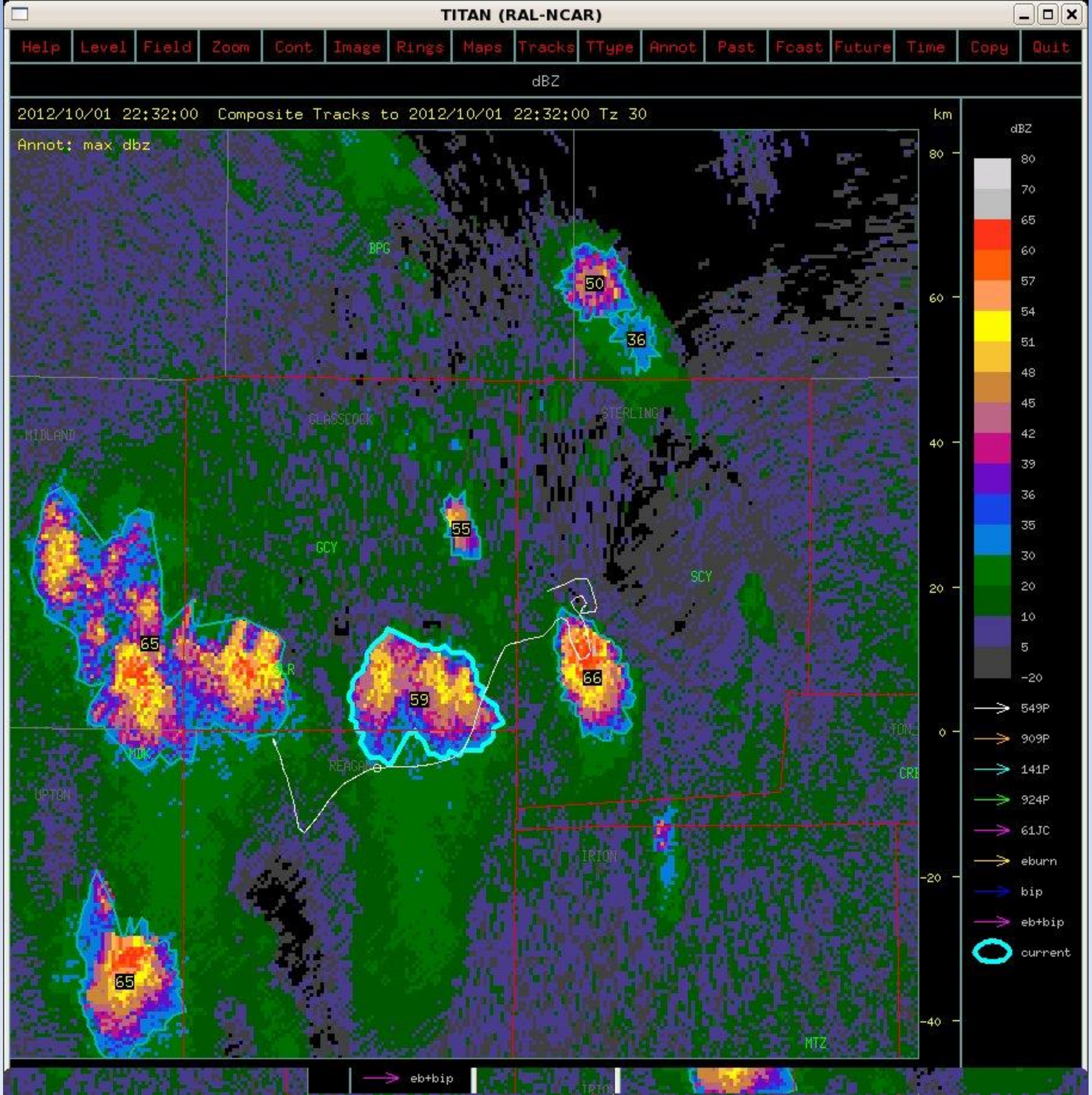
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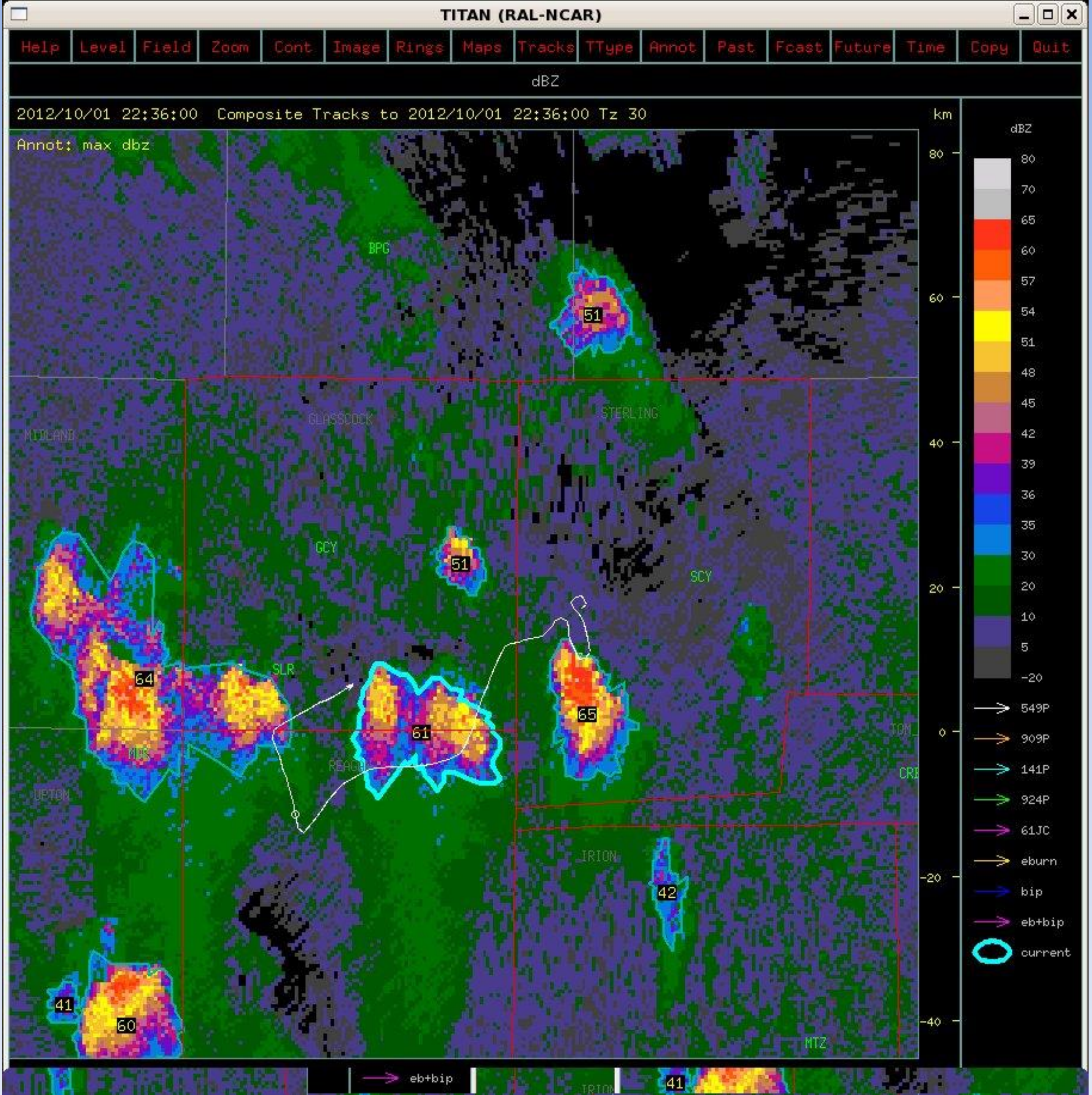

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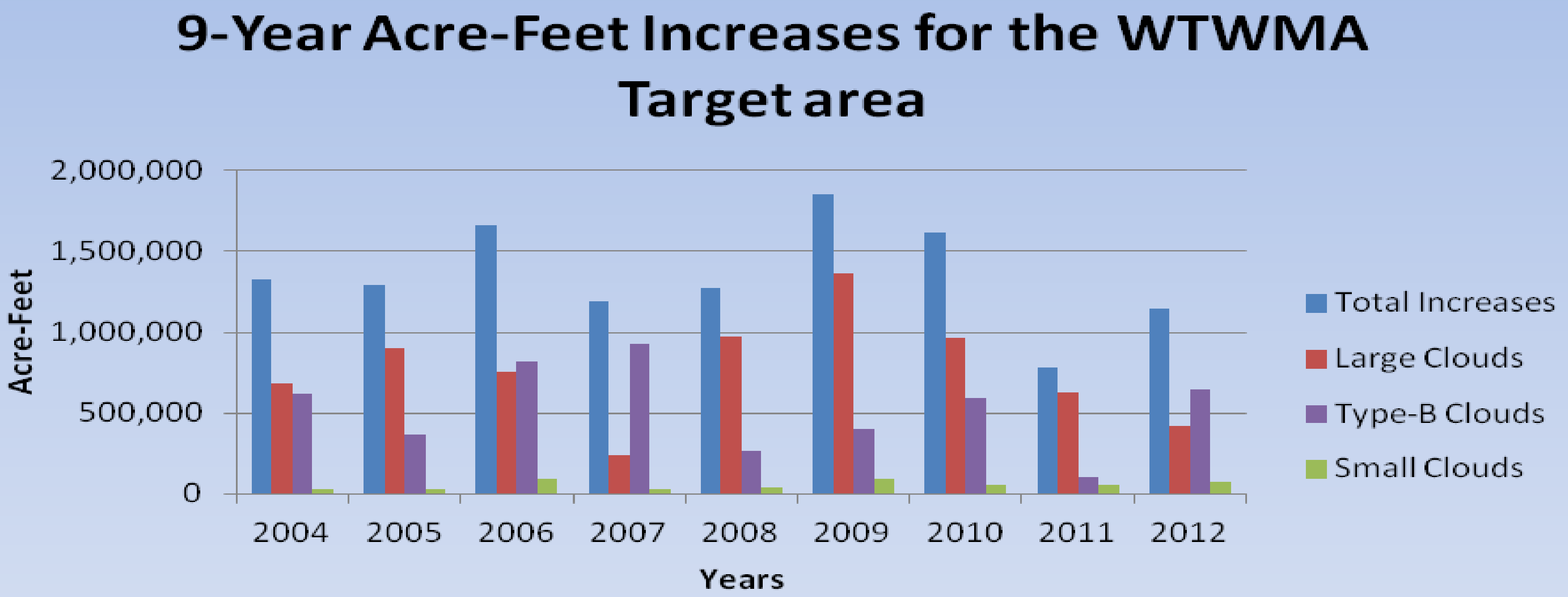
Analysis

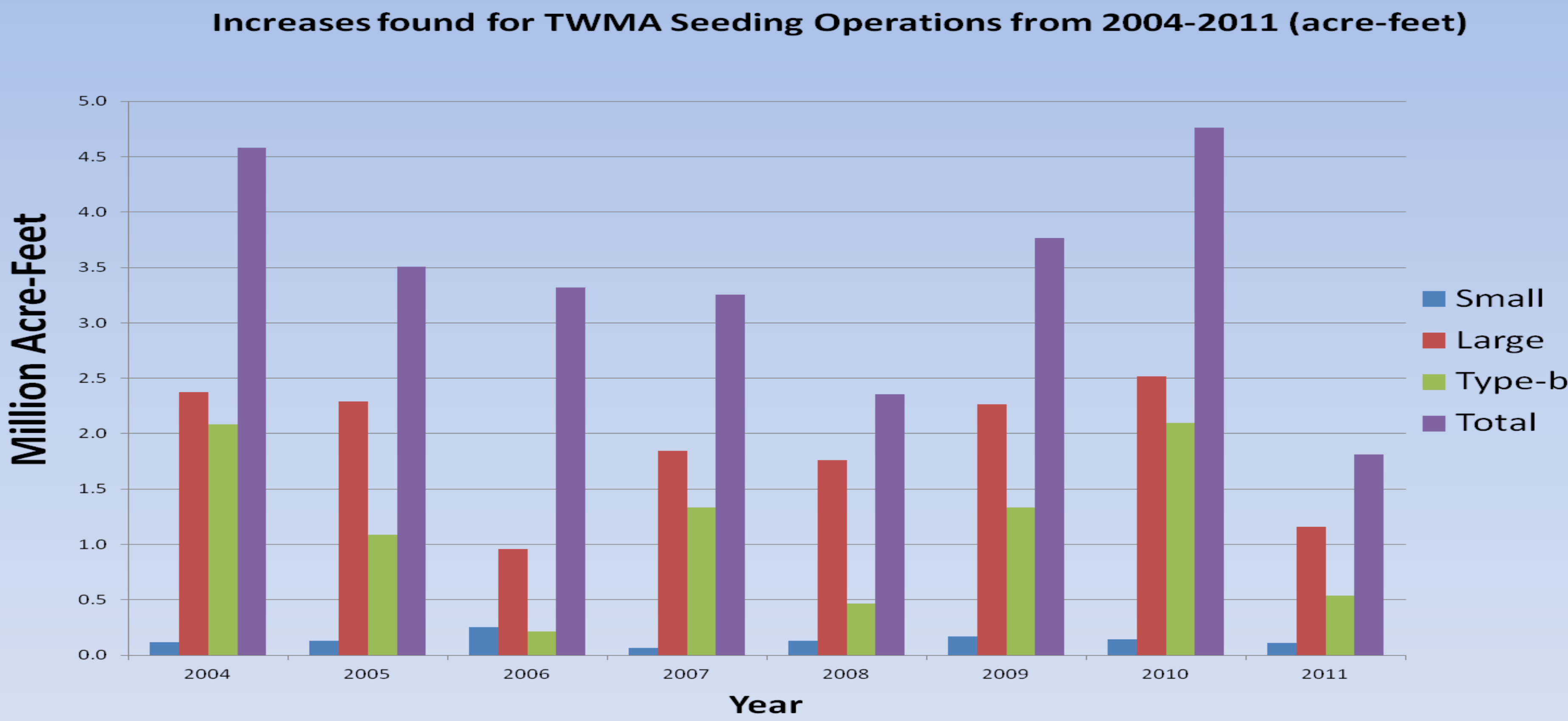
- Conducted by Dr. Arquimedes Ruiz-Columbè
- Began analysis in 2001 using TITAN analysis package
- Starting in 2004 the TWMA began using radar feed from NWS WSR-88D provided by Weather Decision Technologies.
  - Data before 2004 will not be included in totals or averages presented today

Analysis

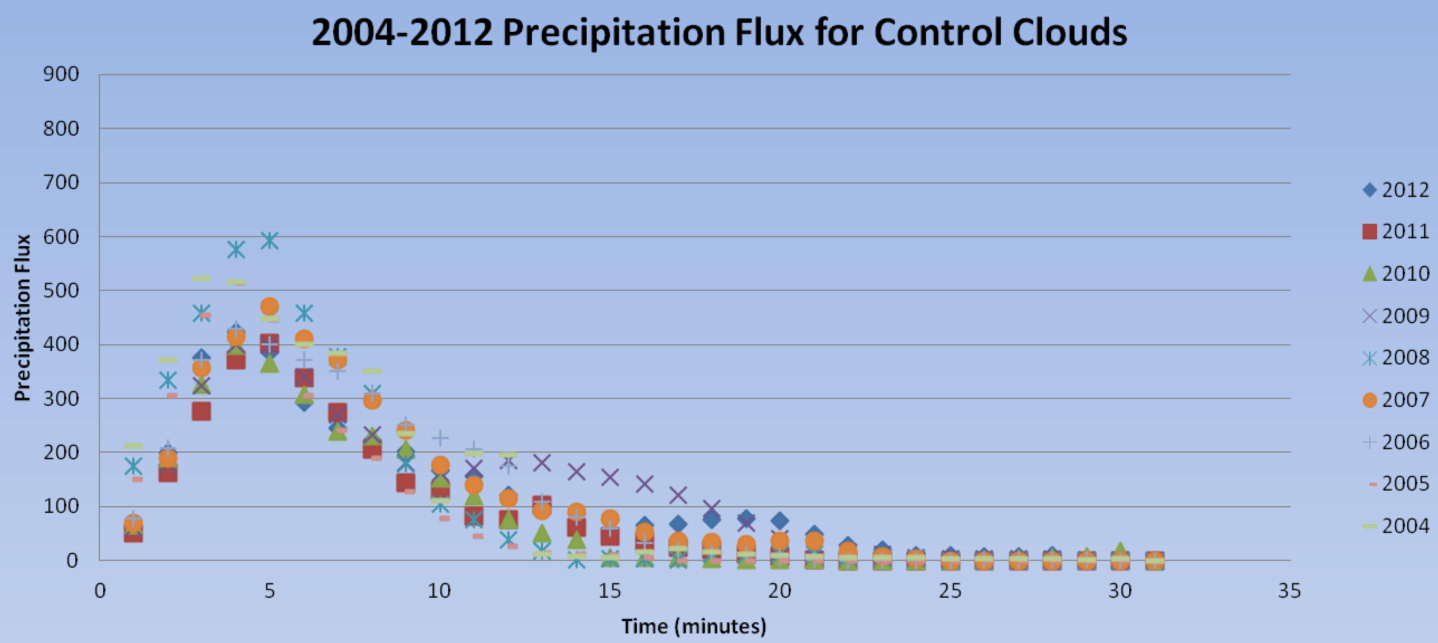


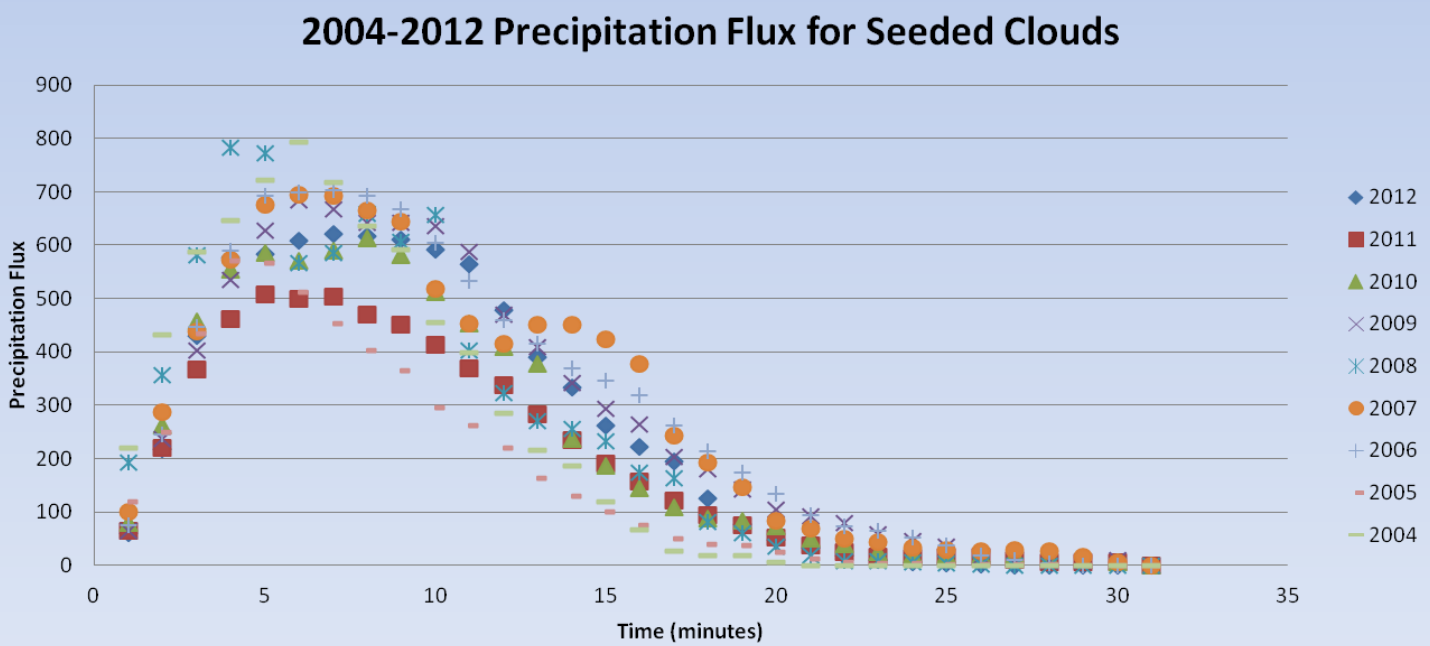
- Average increase of roughly 1.35 million acre-feet across the WTWMA target area
- This translates to roughly a 2.4" increase of precipitation across the WTWMA target area
- This leads to a 15% annual increase in precipitaton

Analysis for the entire TWMA

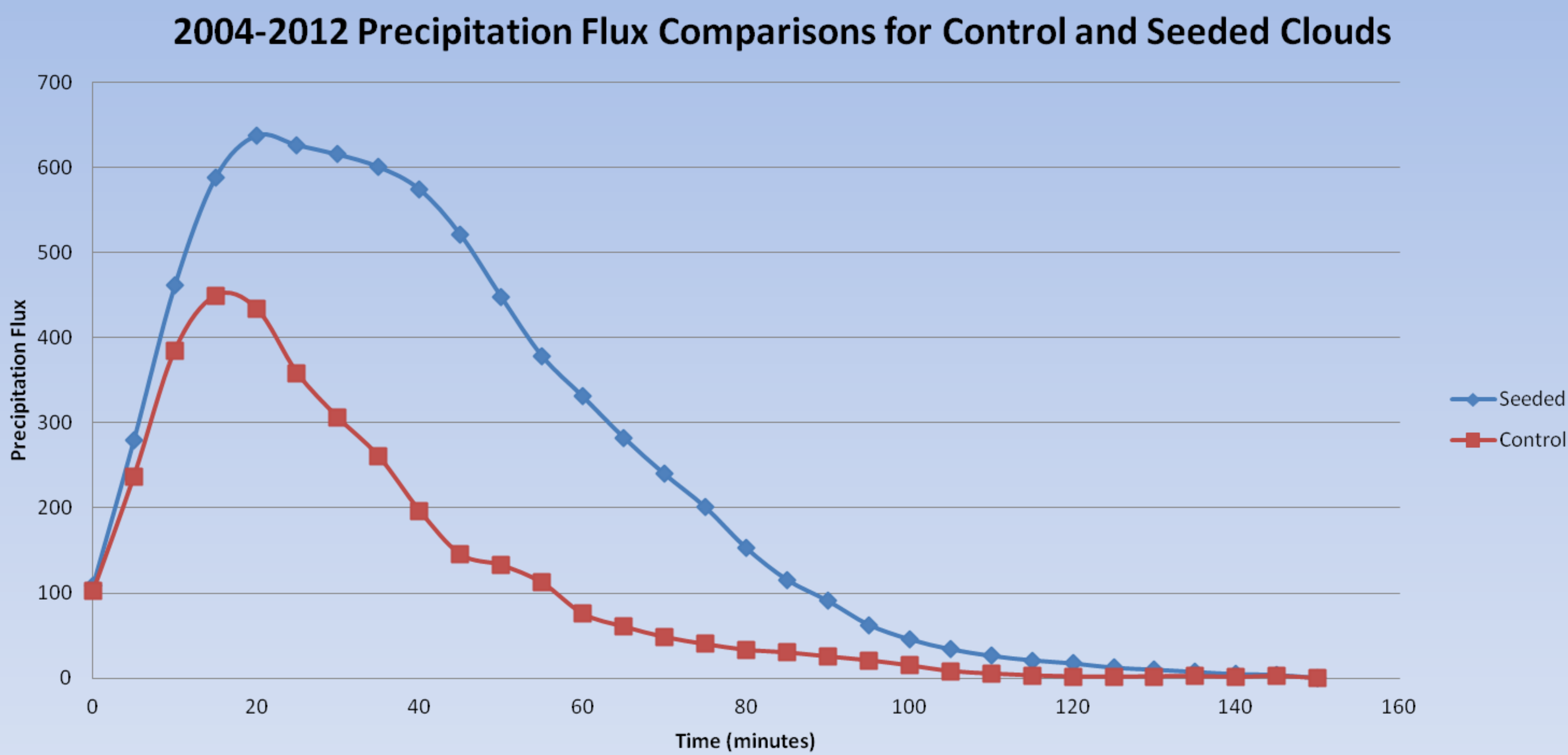


- Average of 3.4 million acre-feet of increases.
- This translates to 1.45” annually (12% increase across all target areas in Texas)





Credit: Dr. Arquimedes Ruiz, TTU



Credit: Dr. Arquimedes Ruiz, TTU

Percent of Normal (outside target area)

City (County)	Normal	9-Year Average	Percent of Normal
McCamey, TX (Upton)	15.14”	13.59”	89%
Sheffield, TX (Pecos)	15.54”	14.72”	95%
Midland, TX (Midland)	14.48”	11.89”	82%
Midland 4NE, TX (Midland)	14.80”	11.45”	77%
Big Spring, TX (Howard)	19.63”	12.26”	66%
Snyder, TX (Scurry)	22.70”	18.54”	81%
Abilene, TX (Taylor)	24.82”	22.75”	91%
Outside Area Average	**18.15”**	**15.02”**	**83%**

Percent of Normal (within target area)

City (County)	Normal	9-Year Average	Percent of Normal
Eldorado, TX (Schleicher)	22.40”	20.98”	93%
Sterling City, TX (Sterling)	19.50”	21.08”	108%
Big Lake, TX (Reagan)	16.61”	17.67”	104%
San Angelo, TX (Tom Green)	21.25”	21.83”	103%
Ozona, TX (Crockett)	19.00”	18.97”	99%
Sonora, TX (Sutton)	22.40”	21.15”	94%
Cope Ranch (NE Reagan)	18.27”	21.04”	115%
Lees (NE Glasscock)	19.49”	20.60”	106%
Area Average	**19.69”**	**20.01”**	**102%**

- Impressive considering the most intense 1 year drought on record (2011) where most areas were 50% of normal, if not worse.

Percent of Normal (cont.)

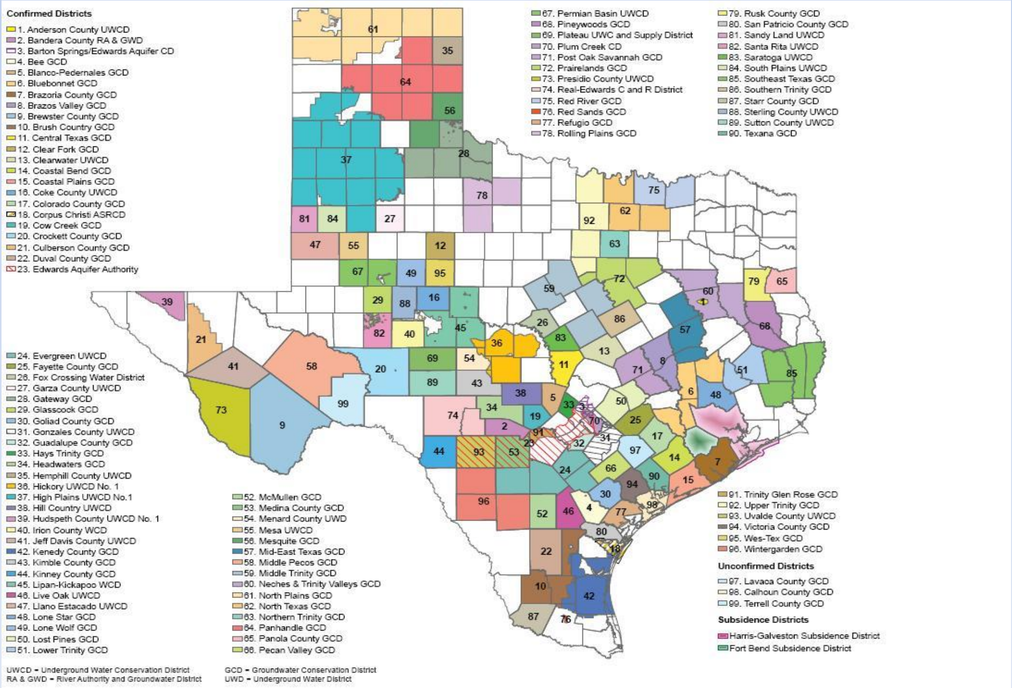
City (County)	9-Year Avg.	Minus Wx Mod Activity	New Total	New Percent of Normal
Eldorado, TX (Schleicher)	20.98”	-2.29”	18.69”	83%
Sterling City, TX (Sterling)	21.08”	-2.89”	18.19”	93%
Big Lake, TX (Reagan)	17.67”	-2.72”	15.60”	92%
San Angelo, TX (Tom Green)	21.83”	-3.01”	18.82”	88%
Ozona, TX (Crockett)	18.97”	-1.53”	17.44”	92%
Sonora, TX (Sutton)	21.15”	-1.51”	19.64”	88%
Cope Ranch (NE Reagan)	21.04”	-2.72”	18.32”	100%
Lees (NE Glasscock)	20.60”	-2.53”	18.07”	92%
Area Average	**20.01”**	**-2.4”**	**17.61”**	**89%**

Benefits (J.L. Johnson, 2001)

- Texas A&M Conducted a Benefit-Cost Analysis of the WCTWMA (Abilene) based on 1 addition inch of precipitation
- Benefits Included:
  - Reduction in Irrigation by 6.5%
  - Increased Agricultural Production by ~$7 million
  - Decreased surface and groundwater consumption
  - Increased reservoir levels
  - Increased lake and river levels
  - Replenishment of Aquifers
  - Increased and higher quality forage for wildlife

Benefits (Wyatt, Carver 1997)

- 1” of precipitation on a timely basis on the four major crops grown in the High Plains Underground Water Conservation District has a market value of $81 million, with a region economic impact of $283 million.
  - Cotton > $34/acre
  - Corn > $18/acre
  - Grain Sorghum > $10/acre
  - Wheat > $20/acre



Current and Future Projects

- Climate Impacts on the Physical Properties of Clouds in Texas
  - Ongoing for all programs
  - In cooperation with NCAR
- A 5-Year Synoptic Climatology of Weather Modification Operations in West Texas using the Miller's Guide [TR-200] Classification Scheme
  - Ongoing for the WTWMA
  - Attempting to link upper level patterns with seeding activity
- Cloud Seeding Effectiveness using the Hydrometeor Classification from the KSJT WSR-88DDP
  - Scheduled to start this summer
  - Attempting to see changes in the physical properties of clouds post seeding
- A Conceptual Model for Hygroscopic Seeding in Texas
  - Build a model similar to the current model we have for glaciogenic seeding

Questions?

- Thank You!
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  - meteorologist@wtwma.com
- http://www.wtwma.com