Standardized Anomalies Associated with the 2009 Christmas Snowstorm

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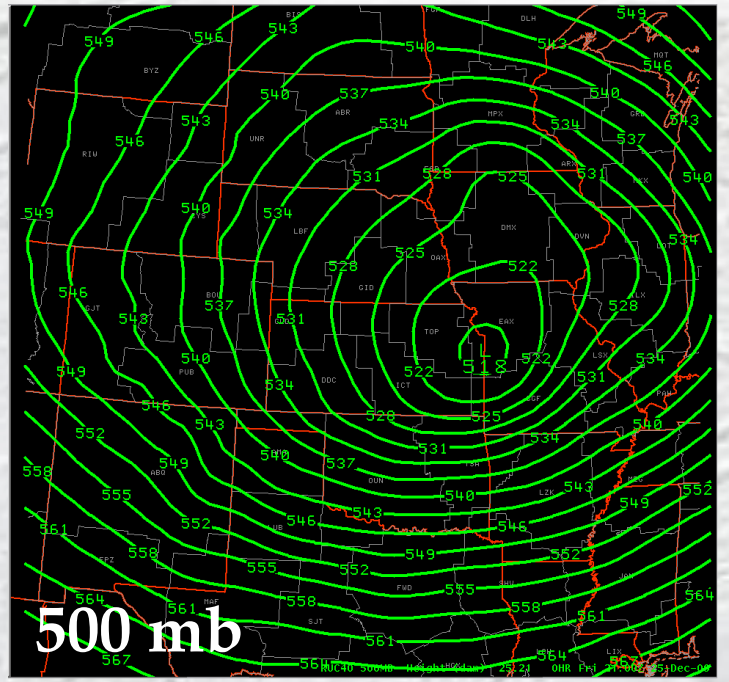
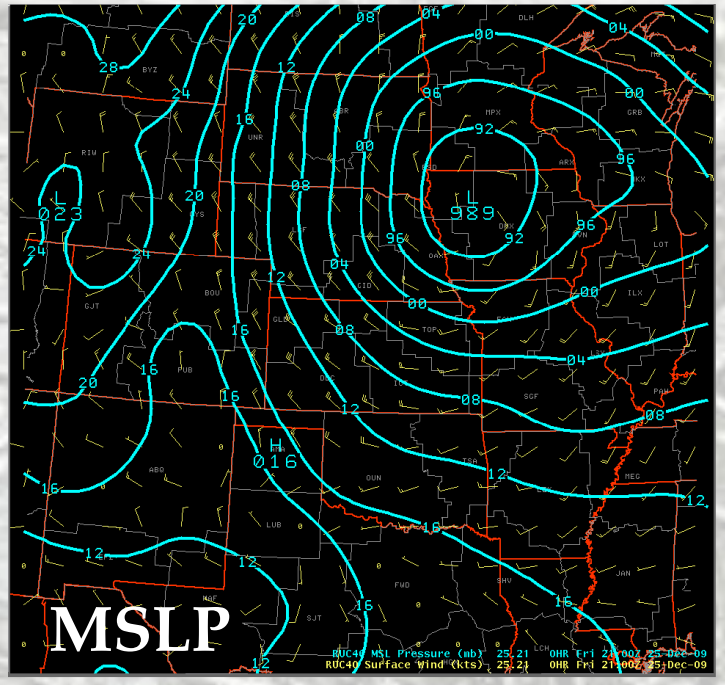
Event Recap

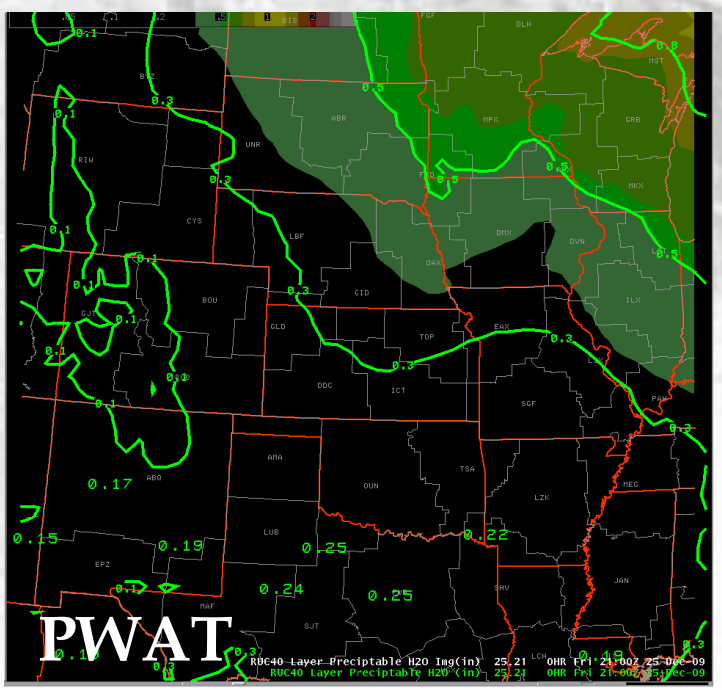
- **Event spanned roughly 00z 24 Dec through 18z 27 Dec 2009**
  - Stretched from North Texas northward to the Canadian border.
  - Affected: Oklahoma City, Tulsa, Topeka, Kansas City, Omaha, Sioux Falls, Minneapolis, and Duluth.
    - 9.8 million people (metro)
- **Heavy snow and strong wind for several hours**
  - 7 to 10 inches of snow across the Southern and Central Plains with 40 to 50 mph winds (peak gusts up to 68 mph in C. Oklahoma)
  - 15 to 25 inches of snow across Northern Plains. Winds still strong, but weaker than Southern Plains (gusts 25-40 mph – Rapid City 76 mph).
- **Christmas Holiday**
  - 78 million road travellers nationwide (AAA), untold number of cancelled flights
    - 21 fatalities (Oklahoma/Nebraska), Hundreds of injury accidents
  - Several million dollars in damages, cleanup costs, and lost commerce.

Event Evolution

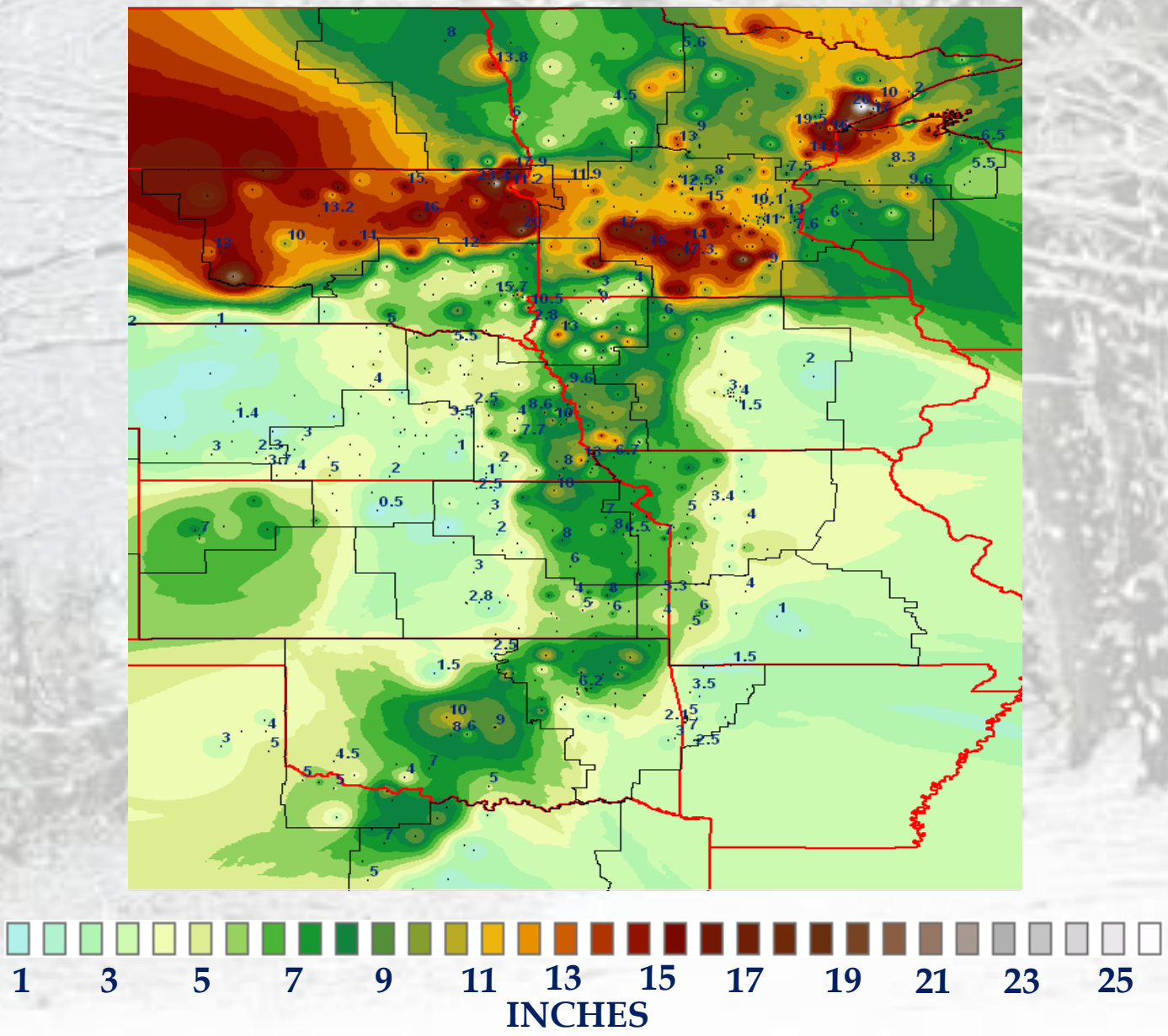
00z 24 Dec – 00z 26 Dec 2009


500 mb

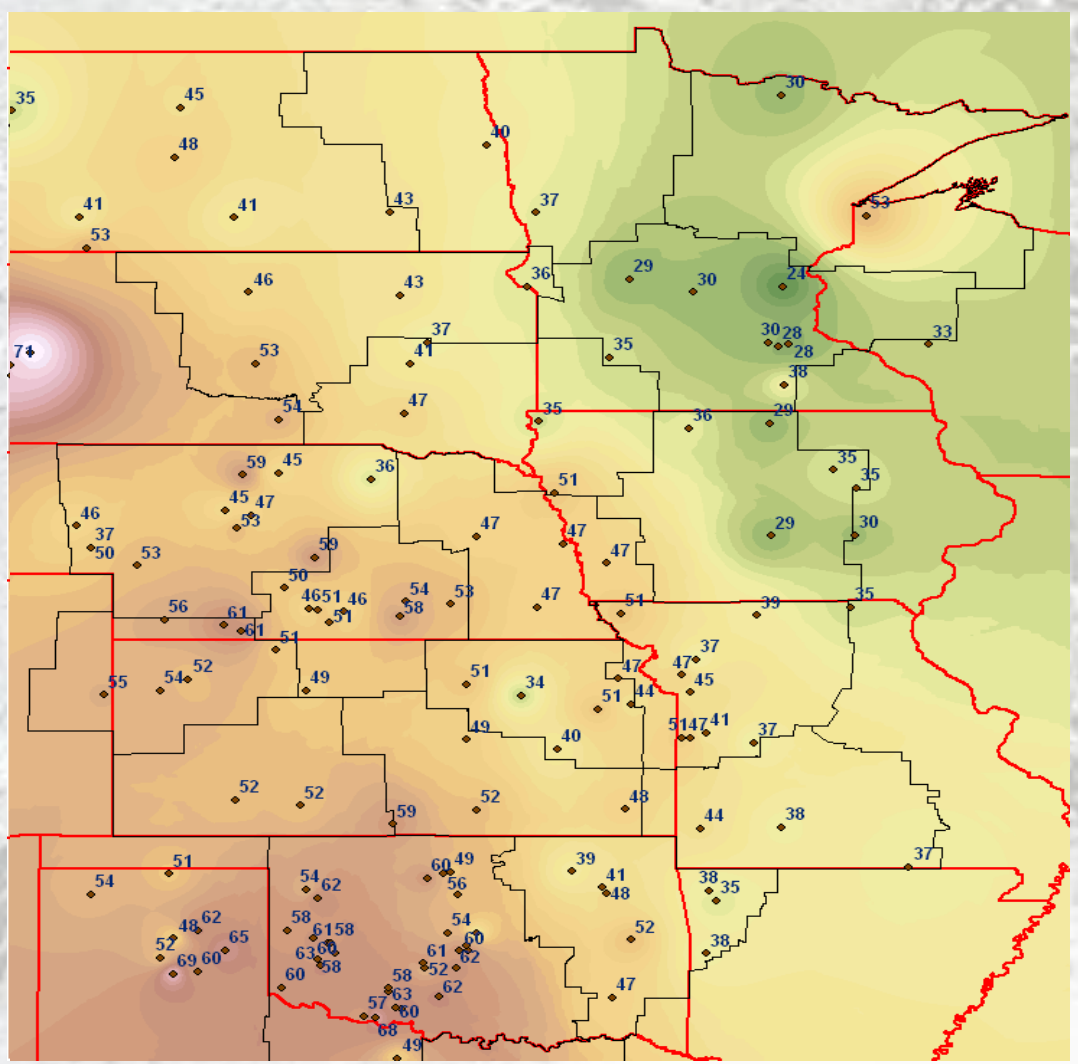

MSLP


PWAT

Snowfall Dec 24 00z – Dec 27 18z

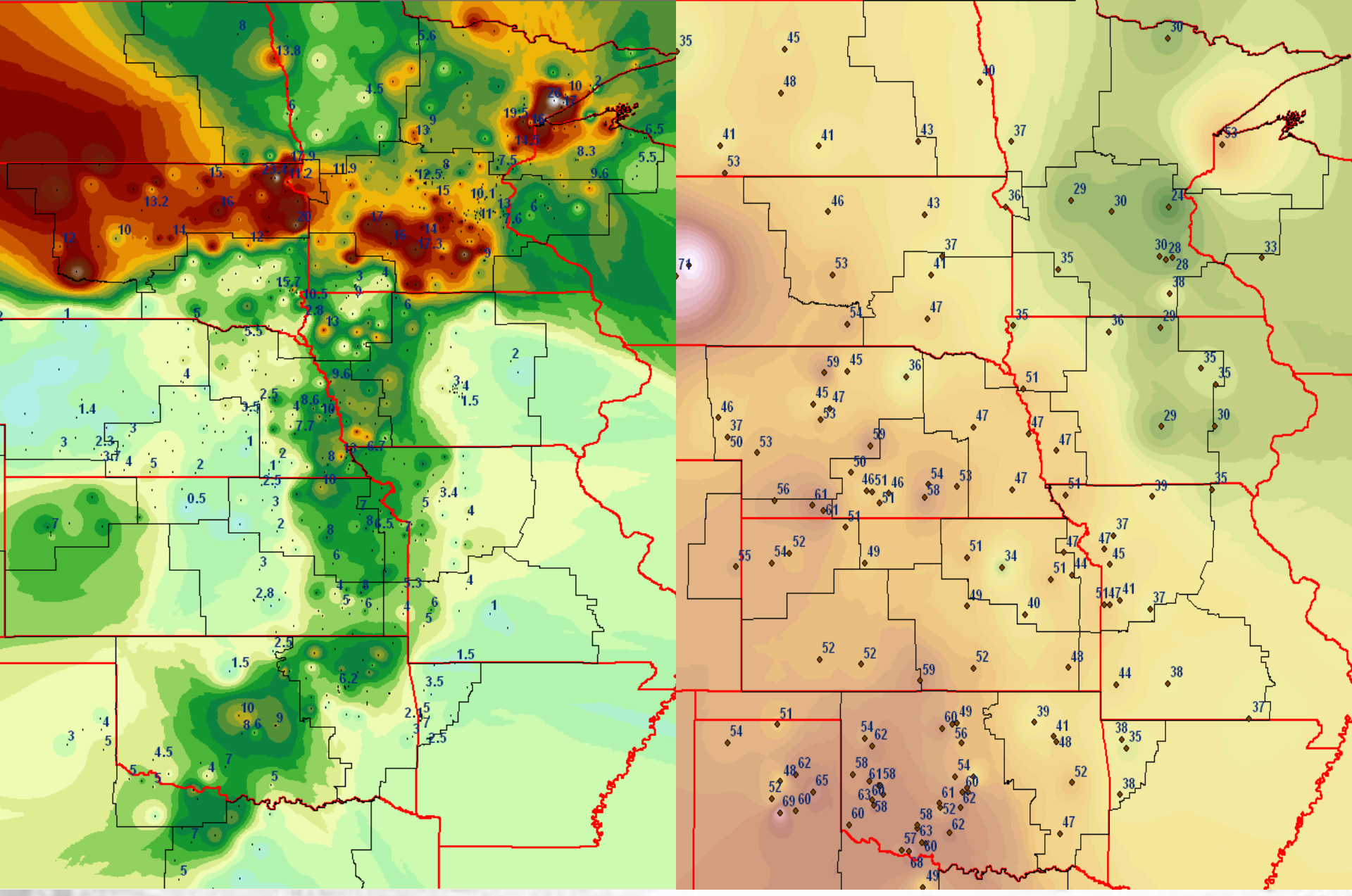


Peak Wind Dec 24 00z – Dec 27 18z



25 30 35 40 45 50 55 60 65 70

MPH


1 3 5 7 9 11 13 15 17 19 21 23 25
INCHES
25 30 35 40 45 50 55 60 65 70
MPH

What is an Anomaly?

- Hart and Grumm 2001, Graham and Grumm 2010, Mayes et al. 2009
- Climatic Mean taken over a 30 year period (POR)
  - Mean is calculated from a running 21 day average
  - NARR data taken over a 32 km grid (1978-present)
    - ❖ Better temporal/spatial resolution
  - GR data taken over a 2.5° x 2.5° grid (1948-present)
- Departure from the mean divided by σ.
  - $N = (X-\mu)/\sigma$
    - ❖ X= variable, μ=mean value, σ=1 standard deviation
      - This eliminates seasonal and latitudinal variations.
- Determine: $M_{wind} + M_{height} + M_{temp} + M_{Moisture}$

$$M_{var} = \frac{N_{1000} + N_{925} + N_{850} + N_{700} + N_{600} + N_{500} + N_{400} + N_{300} + N_{250} + N_{200}}{n}$$

$$M_{total} = \frac{|M_{wind}| + |M_{height}| + |M_{temp}| + |M_{Moisture}|}{n}$$

Anomaly Caveats

- **Not all anomalies are created equal**
  - Some anomalous systems moderate an otherwise extreme situation
    - Ex: Anomalously high temperatures in January vs. Anomalously low temperatures in January
  - Overall anomaly (M_{total}) could be dominated by one variable
    - Strong ridge with less anomalous flow and moisture fields
  - Conversely, the overall anomaly of a significant system could be diminished by a single less consequential variable
    - Ex: Christmas Blizzard
  - Duration is not taken into account.

- **Future work could include classifying anomalies for better historical context**
  - Ranking by types of systems (snow storms, severe weather, heat waves, etc…)
    - Many systems contain more than one "type" of weather.

Strongest Departures since 1948

Central U.S.

Rank	Date	M_{total}	Event Description
1.	January 11, 1975	4.65	Great Storm of 1975 (Blizzards midwest, tornadoes SE)
2.	October 13-14, 1997	4.60	South Texas/Coastal Bend Flood
3.	December 27-28, 1980	4.40	Deep coastal Florida low
4.	January 8, 1958	4.31	Record high temps in SD, MN; FL low
5.	May 27-28, 1973	4.24	Tornado outbreak from MI to AL. S. Appalachian floods
6.	January 9-10, 1953	4.23	Heavy Rain/T-Storms SE, FL tornadoes
7.	November 21, 2006	4.23	Deep SE low. Snow into central FL
8.	October 20, 1989	4.20	Lower Mississippi record cold/snow
9.	December 22, 1972	4.17	Deep Gulf system
10.	November 2, 1966	4.13	Appalachian snowstorm, lower Mississippi cold intrusion
⋮			
20.	October 16, 2006	4.04	Severe weather/flooding TX/MS

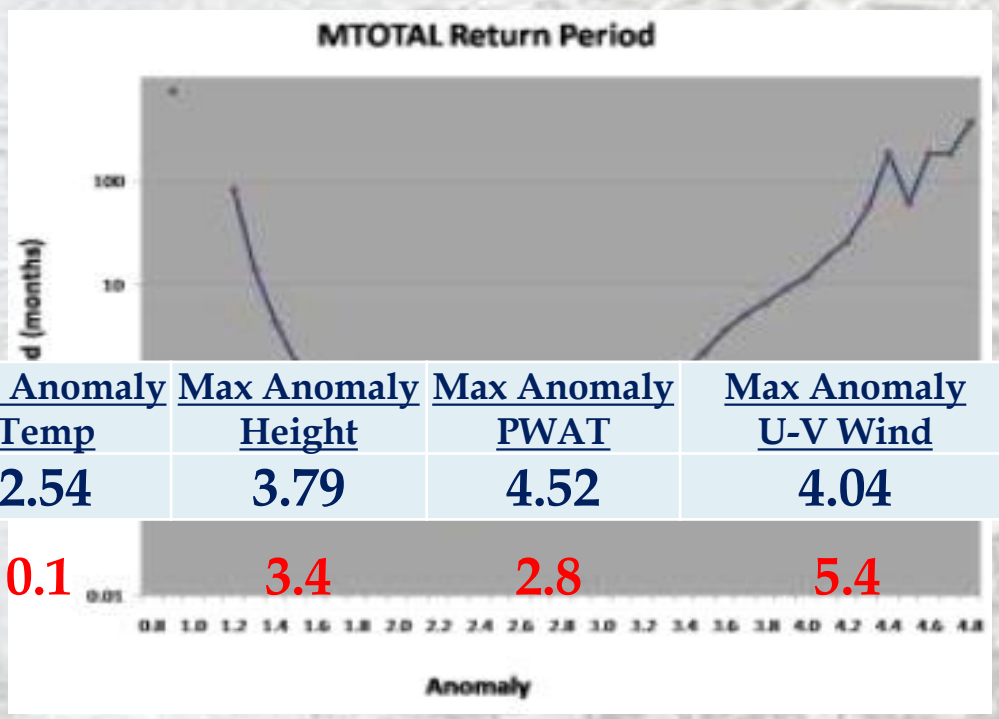
Tropical Storms excluded due to overwhelming the rankings.

Mayes et al. (2009)

Anomalies

Time	Date	Max Anomaly Temperature	Max Anomaly Height	Max Anomaly PWAT	Max Anomaly U-V Wind	Mtotal
00Z	24 DEC 2009	2.38	2.97	2.51	2.98	2.71
06Z	24 DEC 2009	2.54	3.38	2.56	2.98	2.86
12Z	24 DEC 2009	2.32	3.28	2.56	3.32	2.87
18Z	24 DEC 2009	2.09	3.79	3.02	3.55	3.11
00Z	25 DEC 2009	1.98	3.51	3.14	3.45	3.02
06Z	25 DEC 2009	2.23	3.51	3.82	3.50	3.26
12Z	25 DEC 2009	2.21	3.24	4.51	3.86	3.46
18Z	25 DEC 2009	2.43	3.47	4.38	4.04	3.58
00Z	26 DEC 2009	2.41	3.31	4.44	3.85	3.50
06Z	26 DEC 2009	2.29	2.97	4.27	3.82	3.34
12Z	26 DEC 2009	2.24	2.64	3.68	3.46	3.00
18Z	26 DEC 2009	2.21	2.44	3.80	3.22	2.92
00Z	27 DEC 2009	2.17	2.25	4.52	3.11	3.01
06Z	27 DEC 2009	2.25	2.25	4.11	3.06	2.92
12Z	27 DEC 2009	2.31	2.21	3.49	2.81	2.70
18Z	27 DEC 2009	2.07	2.22	3.83	2.76	2.72

Return Interval



	Max Anomaly Temp	Max Anomaly Height	Max Anomaly PWAT	Max Anomaly U-V Wind	Mtotal
	2.54	3.79	4.52	4.04	3.58
Return Interval (months)*	0.1	3.4	2.8	5.4	3.6

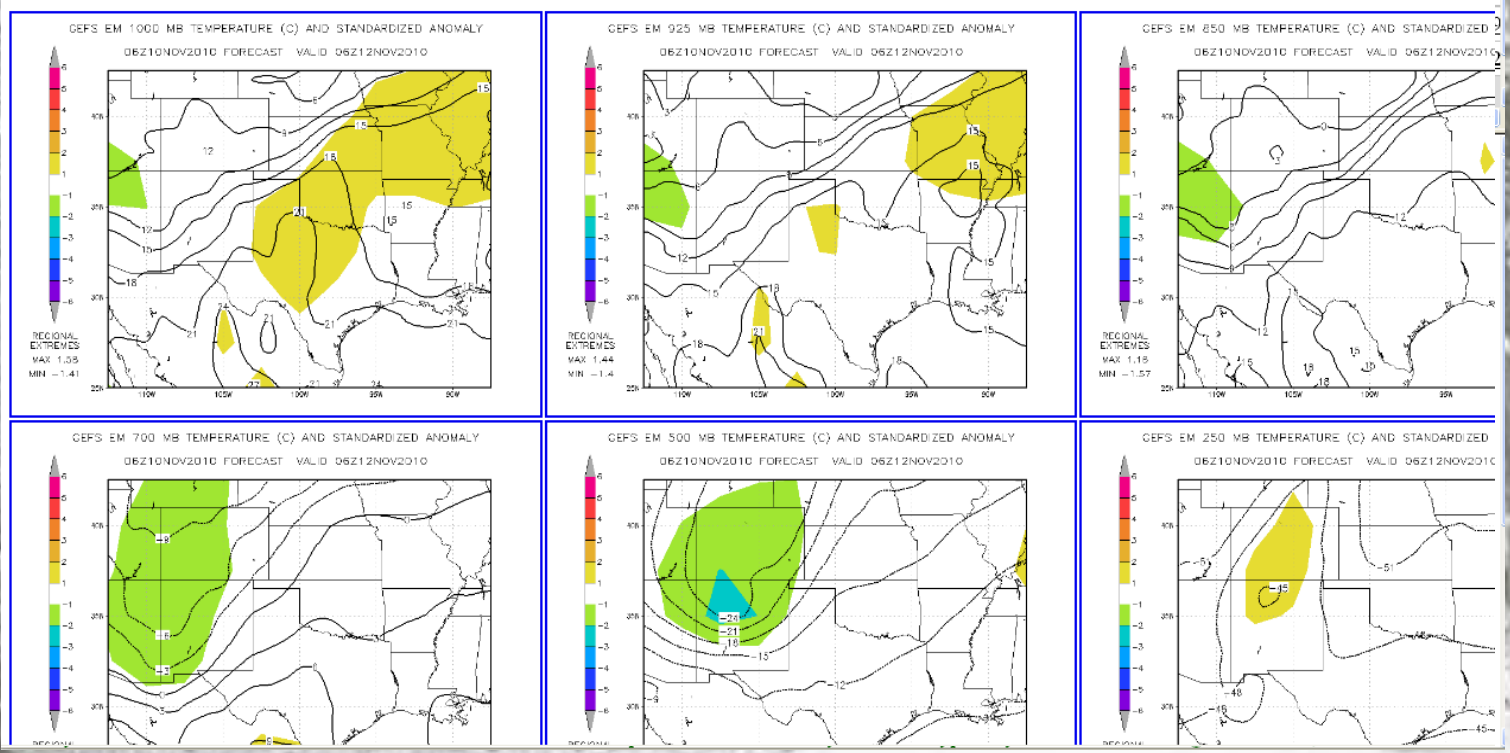
*Return Interval does not exclude tropical systems (excluded from anomaly rankings)

Mayes et al. (2009)

Accessing Anomalies

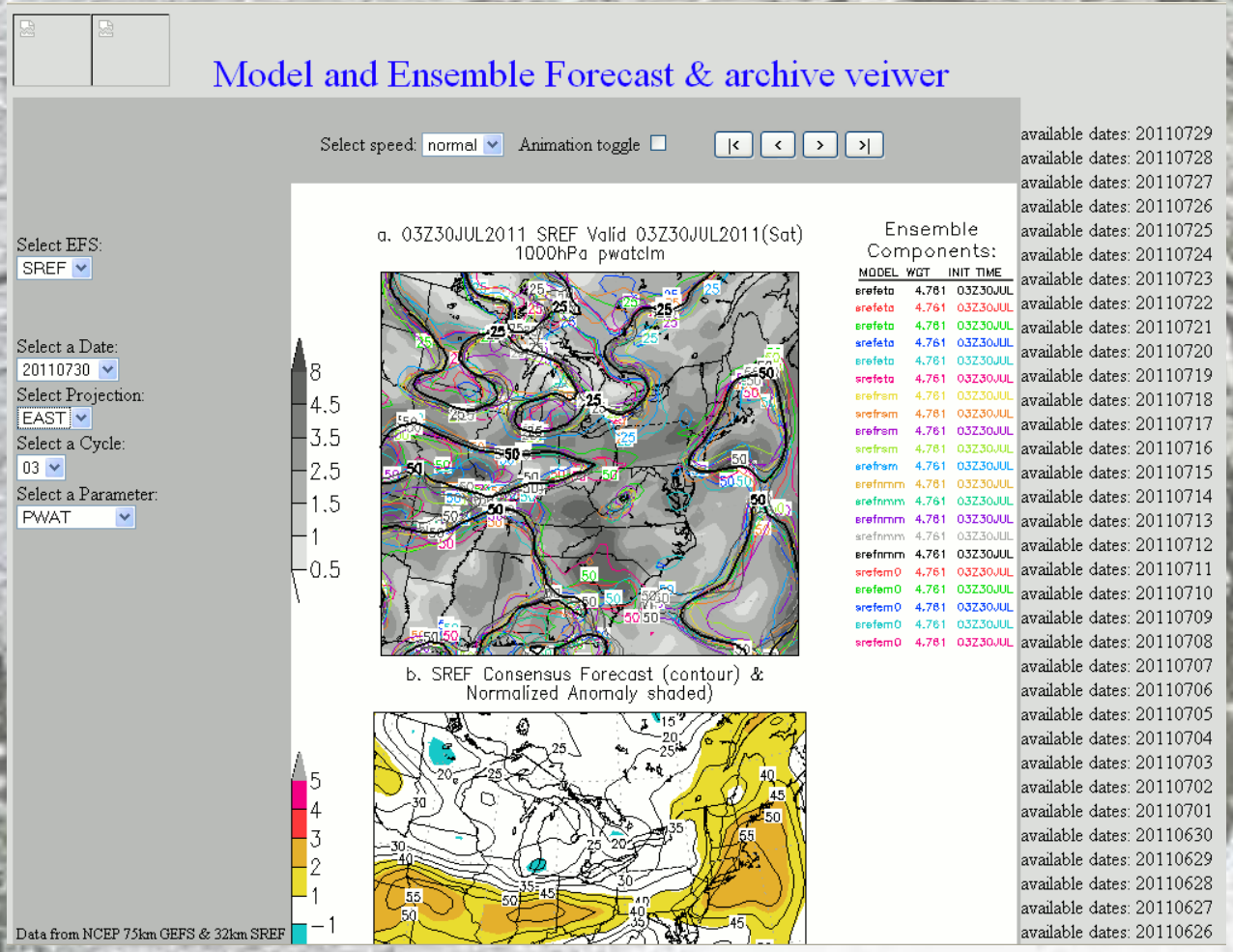
South Central US Table | November 10th 2010 | **06z run**

	0	6	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120	126	132	138	144	150	156	162	168	1
Height	-2.1	-1.8	-1.7	-1.8	-1.7	1.8	1.9	2.3	2.3	2.1	1.9	2.5	1.6	1.7	1.5	1.6	-1.1	-1.2	-1.8	-2.1	-2.2	-2.4	-2.7	-2.8	-3.0	-3.0	-3.3	-3.2	-3.0	-2
Temp	-2.3	2.1	-2.0	-2.1	-2.3	-2.2	-2.6	-2.5	-2.4	-1.8	1.6	-1.7	1.8	1.7	-1.8	-1.7	-1.8	-2.0	-1.9	-2.0	-2.5	-2.6	-2.7	-2.8	-2.9	-2.7	-2.1	-2.2	-1.8	-2
U-Wind	2.5	-2.1	2.2	2.2	-2.5	-3.1	-3.2	-3.2	-2.2	-2.3	-1.6	2.0	-1.8	-2.1	-1.8	-2.2	-2.4	-2.8	-2.0	2.6	2.7	2.6	2.5	2.8	2.3	3.2	2.9	2.6	2.4	2.
V-Wind	-2.6	2.4	2.3	2.2	2.5	2.3	2.5	2.4	-2.6	2.3	-2.3	-2.3	-2.4	-2.0	-2.1	-1.8	-2.0	-2.2	-2.7	-2.9	-2.8	-2.7	-2.7	-2.4	-2.1	2.0	-1.9	-1.7	-1.9	1.



http://www.wrh.noaa.gov/slc/projects/anomaly/frames_sector.php?dom=nc&name=NC&heading=North%20Central

Accessing Anomalies



http://eyewall.met.psu.edu/rich/GFS

Conclusion

- Although the overall anomalies demonstrated a frequent return interval the impacts were high.
  - Duration
  - Area not accustomed to these conditions
  - Christmas Holiday

- Keep anomalies in context
  - Anomalies could show a high return frequency, but could still be rare for a given location
  - Anomalies enhancing a specific signal or seasonal normal could be an indicator of a high impact event
    - ❖ Anomalously high moisture or upper wind fields during a severe weather forecast
    - ❖ Anomalously high temperatures for a heat wave forecast
  - Keep social impacts in mind when using anomalies

Resources

Hart, R., and R.H. Grumm, 2001: Using normalized climatological anomalies to objectively rank extreme synoptic-scale events. *Mon. Wea. Rev.*, 129, 2426-2442.

Graham, R.A., and R.H. Grumm, 2010: Utilizing normalized anomalies to assess synoptic scale weather events in the western United States. *Wea Forecasting*, 25, 428–445.

Mayes, B.E., J.M. Boustead, M. O'Malley, S.M. Fortin, R.H. Grumm, 2009: Utilizing standardized anomalies to assess synoptic scale weather events in the central United States. Preprint.

Accessing Anomalies

http://www.wrh.noaa.gov/slc/projects/anomaly/frames_sector.php?dom=nc&name=NC&heading=North%20Central

http://eyewall.met.psu.edu/rich/GFS


Questions