Hydrometeorological Prediction Center

Hydrometeorological Testbed concept,

Objective is to improve the quality and use of precipitation forecasts

Possible ways to achieve this objective

- Provide a conduit between research and operations
  - Increase interaction between HPC forecasters, NWP modelers, users and the research community.
  - Start visiting scientist program
- Gather information from users
  - How are qpf products used and what are the best ways to use them.
- Make sure forecasters are aware of research that may be applicable to the QPF problem.
- Provide new tools to forecasters
  - And training to forecasters

Recent and current HMT research/efforts

- Normalized anomaly research
- Reforecast Project analog PQPF
- Training manual of topics pertaining to forecasting heavy precipitation
- MCVs and decaying tropical storms
  - Which ones will be the big rainfall makers

The use of normalized anomalies to identify heavy rainfall events.

- **we started in northern California**
- **tried to answer three questions.**
  - **Were there differences in the anomaly patterns for 3 different rainfall groupings**
  - **Identify which anomaly fields would be most useful**
  - **Can normalized anomalies patterns be used to identify potential extreme rainfall events.**
  - **How common are these high anomaly field days.**

Sierra Nevada precipitation study.

- **Binned 163 precipitation days into 3 grouping (heavy, moderate and light) based on the maximum rainfall analyzed in the Sierra Nevada mountains on the HPC analyses between 37.5°N and 41°N.**

- **used 30-year NCEP reanalysis data to develop composite mean and anomaly fields for various parameters**

A few definitions

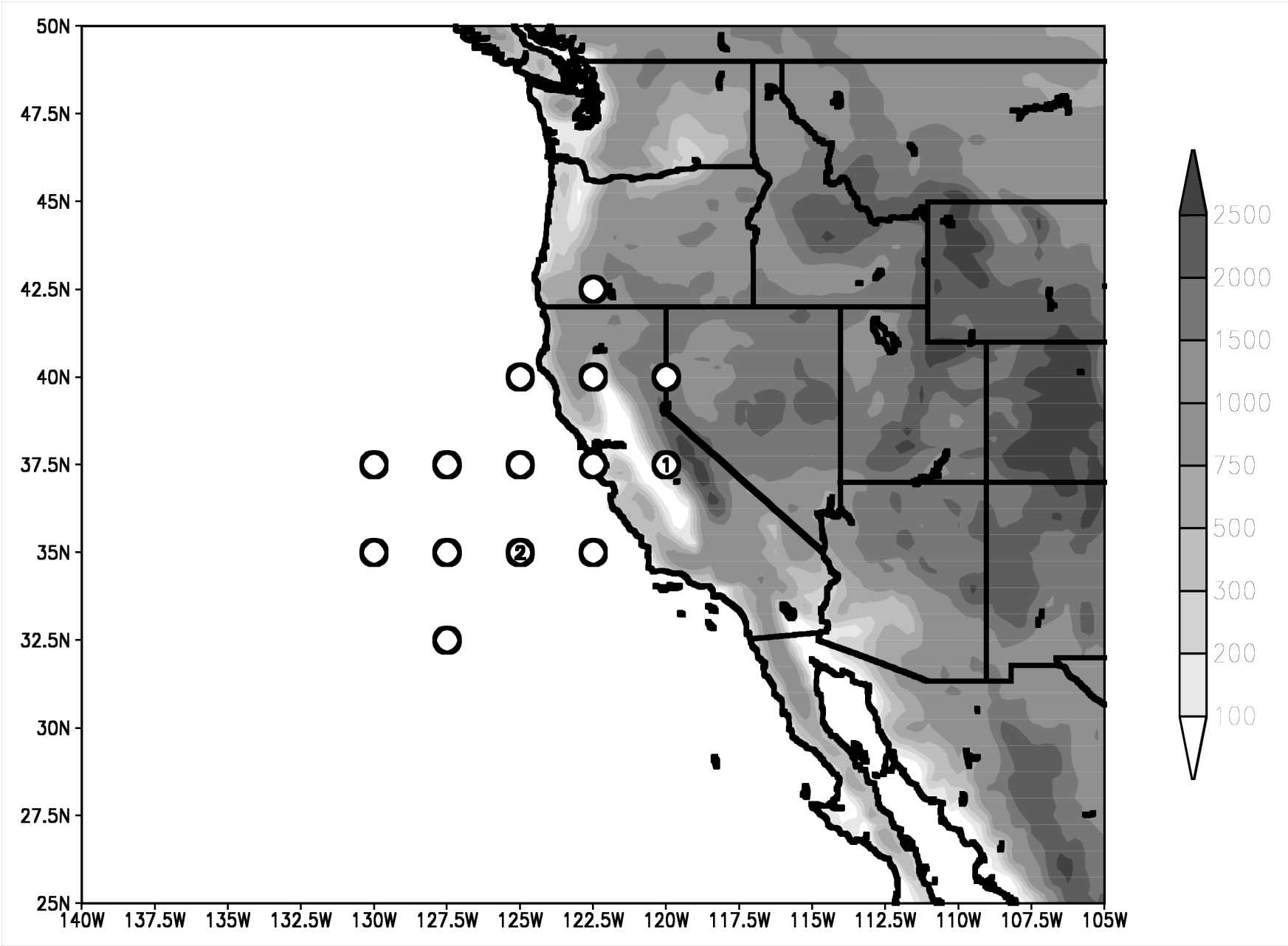
- normalized departure of any meteorological variable can be defined by

$$N=(X-\mu)/\sigma$$

X is the value of the variable (ie. geopotential height, PW, moisture flux)

μ *is the mean of that variable (based on a 21-day runnning mean)*

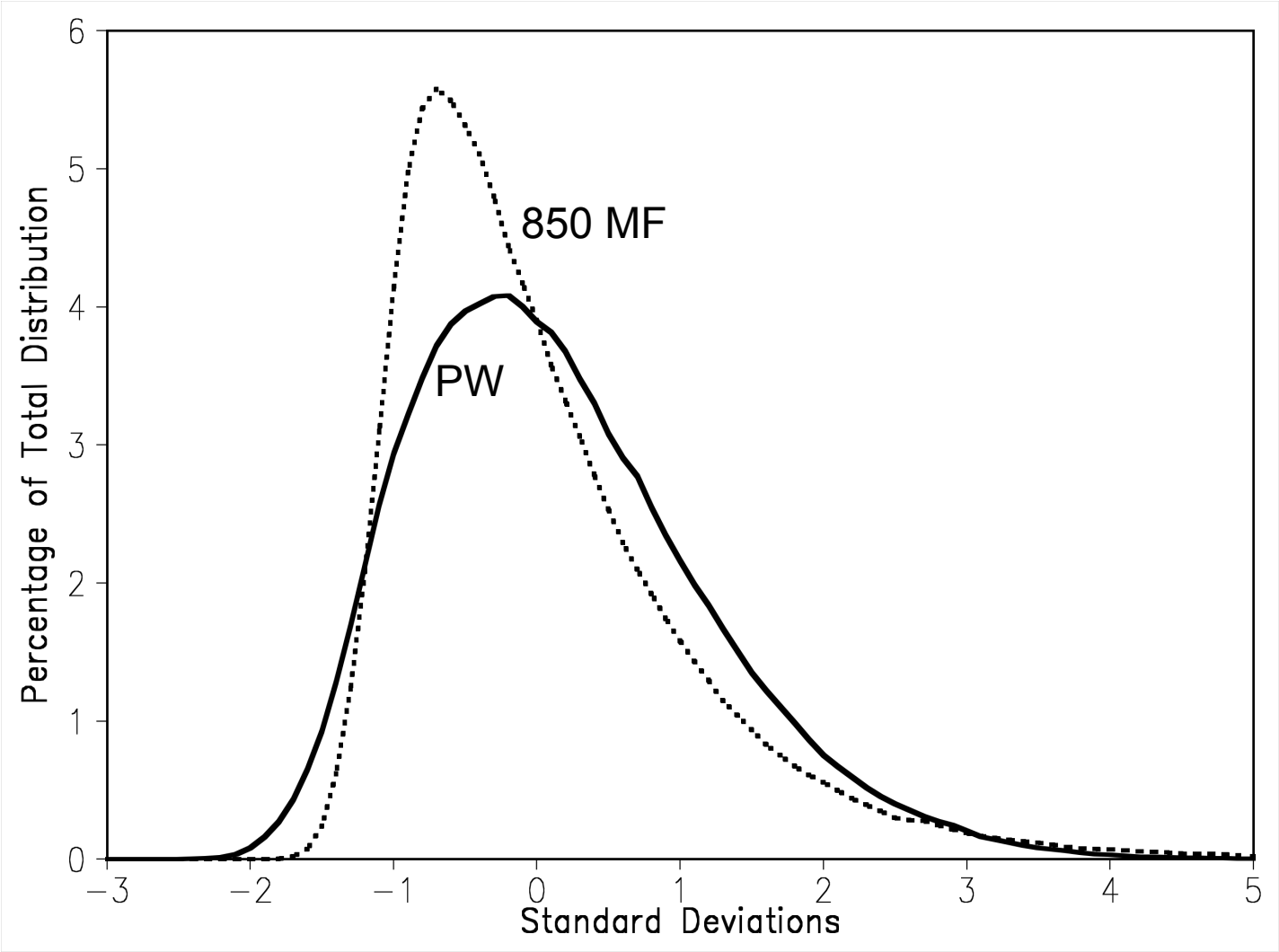
σ ***Is the standard deviation at the point (based on a 21-day running mean)***


50N
47.5N
45N
42.5N
40N
37.5N
35N
32.5N
30N
27.5N
25N
140W
137.5W
135W
132.5W
130W
127.5W
125W
122.5W
120W
117.5W
115W
112.5W
110W
107.5W
105W
1
2
2500
2000
1500
1000
750
500
300
200
100

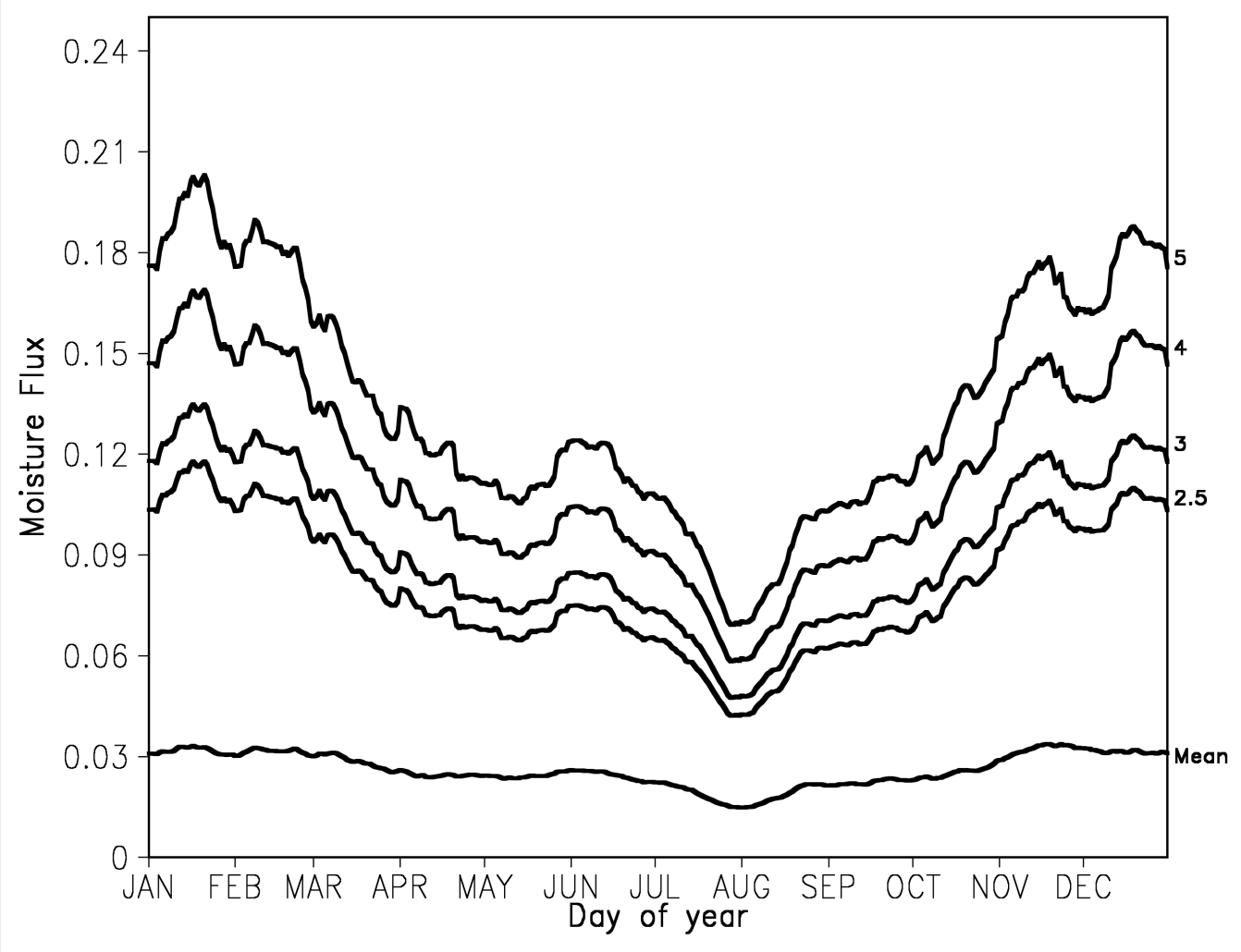
Normalized anomalies

- **Chebyshev's Theorem**
  - **At least 88.7% of cases lie between 3 sigma.**
  - **At least 93.7% lie between 4 sigma**
  - **At least 96% lie between 5 sigma**
- **Empirical rule (for normal distribution)**
  - **95% will fall within 2 sigma**
  - **99.7 will fall within 3 sigma**
  - **99.994 will fall within 4 sigma**
  - **99.99994 will fall within 5 sigma**
  - **99.9999998 will fall within 6 sigma**

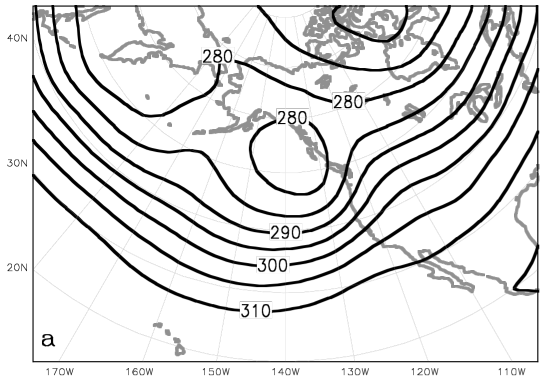
Histogram showing the percentage of the total distribution for normalized anomalies of PW (solid line) and magnitude of the 850-hPa MF (dotted line).

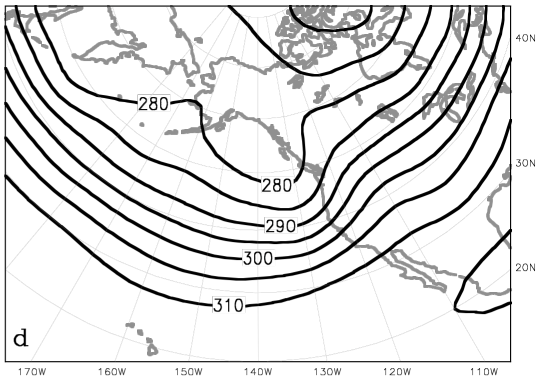


Annual cycle of the mean magnitude of the MF (interval=0.03ms-1) and the mean magnitude of the MF associated with normalized anomalies of 2.5, 3, 4, 5 standard deviations at 37.5°N 125°W.



T+00



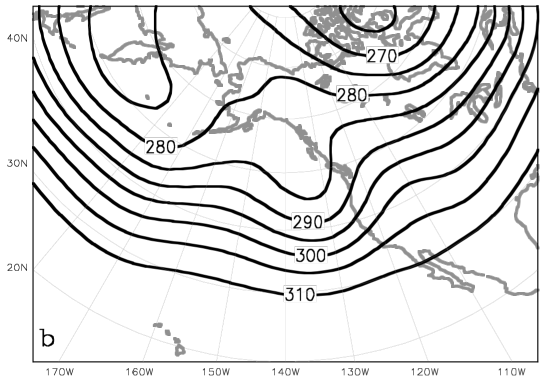


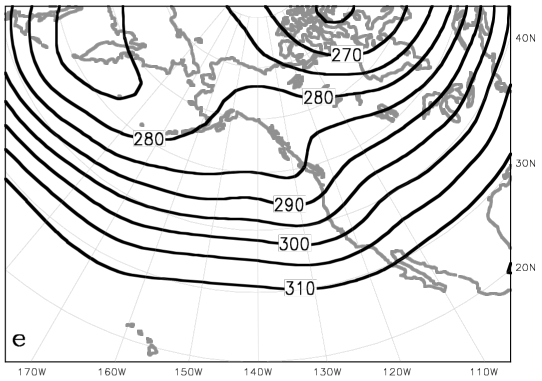
T+24

Greater than 4.00”

Composite mean 700-hPa pattern for three different groupings

T+00

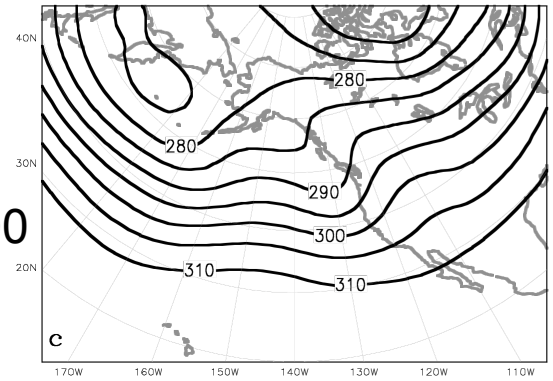


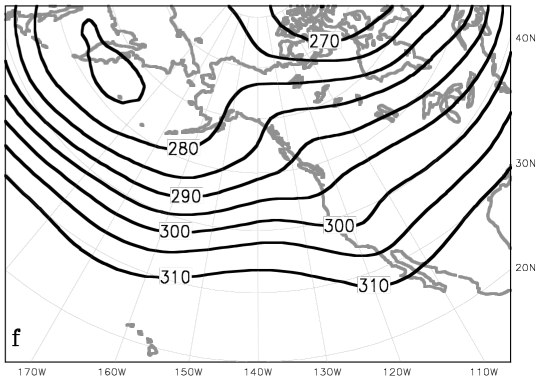


T+24

Greater than 2.00” but less than 4.00”

T+00



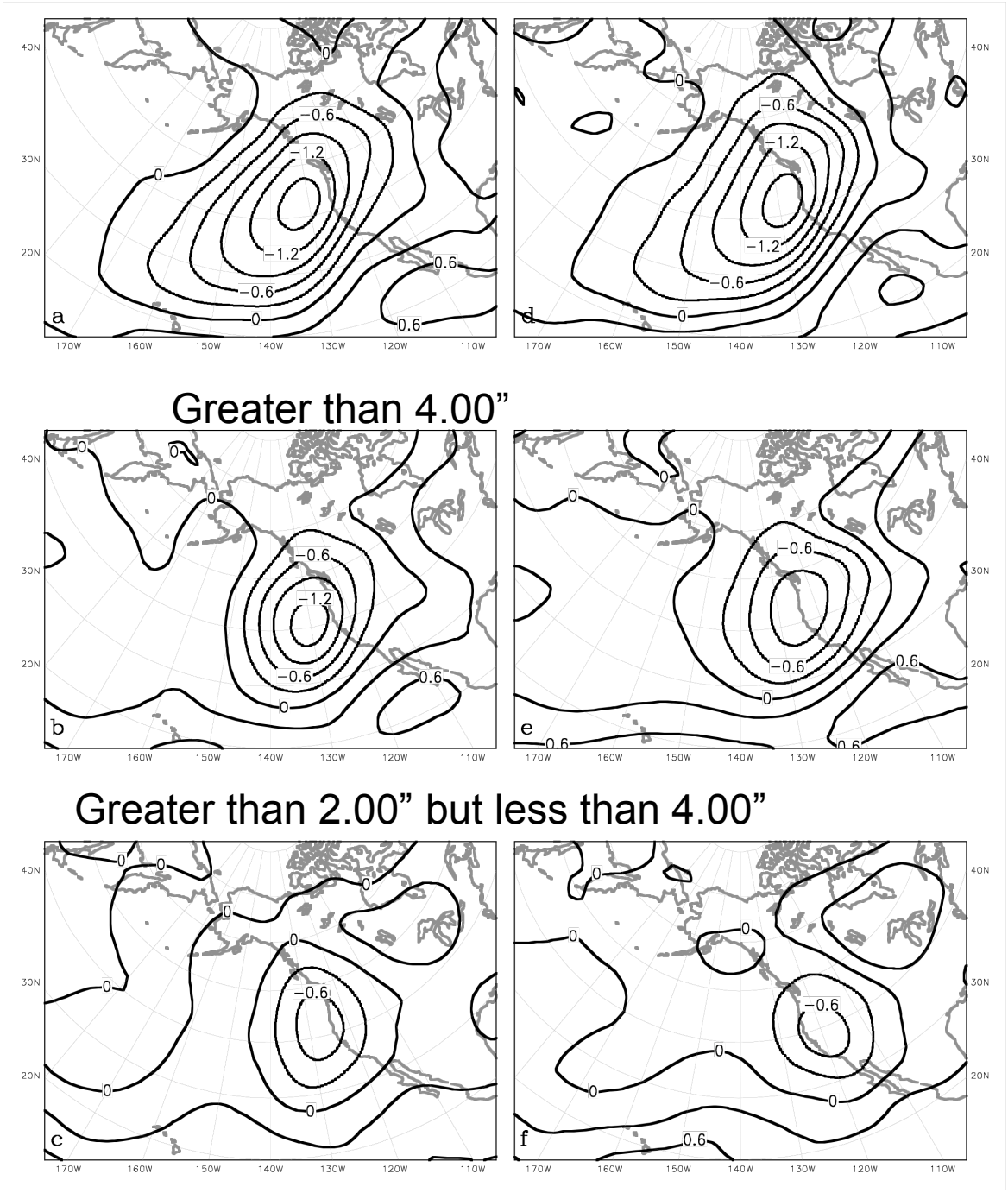


T+24

Greater than 0.50” but less than 2.00”

T+00

T+24

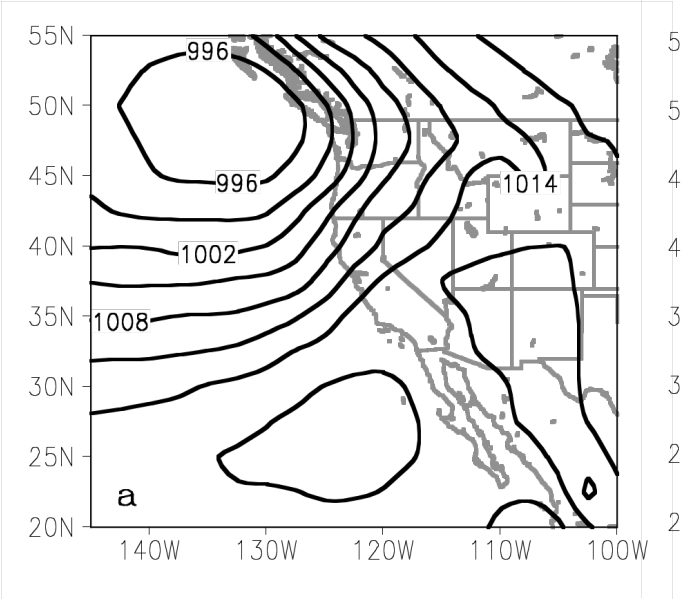


Greater than 4.00”

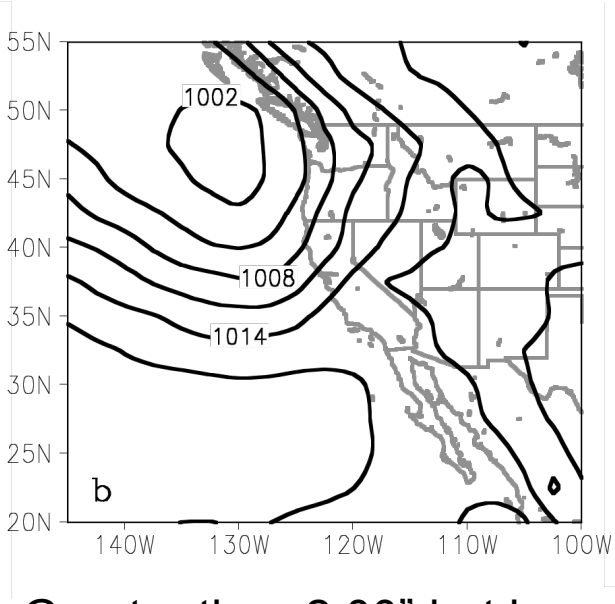
Greater than 2.00” but less than 4.00”

Greater than 0.50” but less than 2.00”

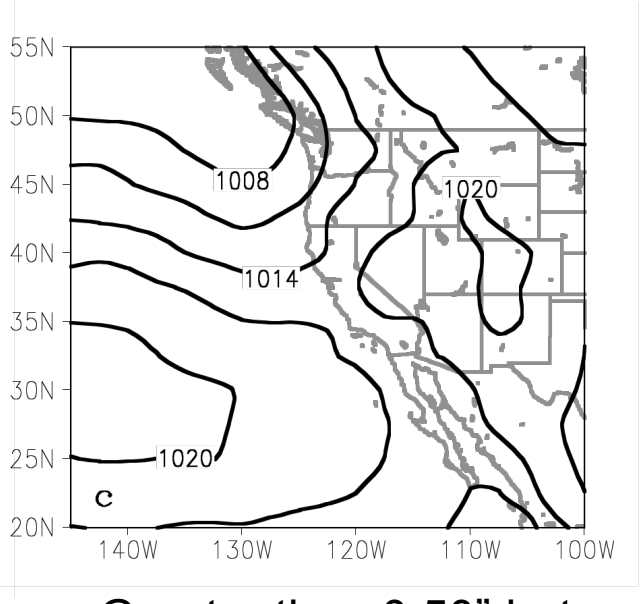
Composite mean 700-hPa height normalized anomaly pattern for three different groupings



Greater than 4.00”

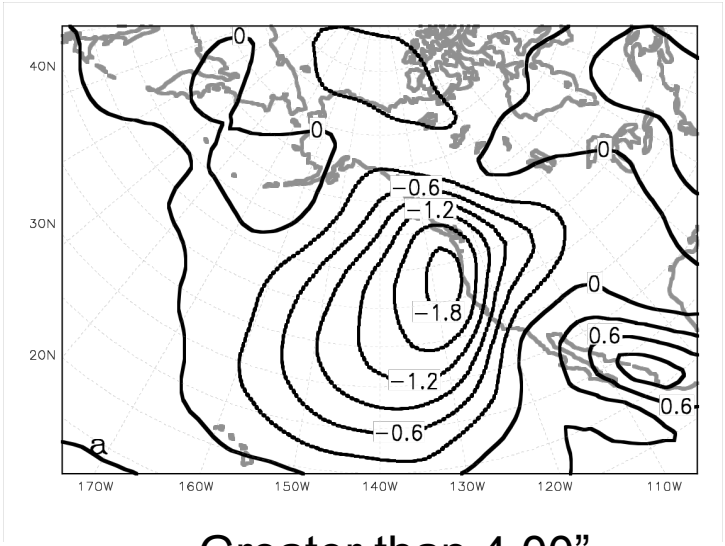


Greater than 2.00” but less than 4.00”

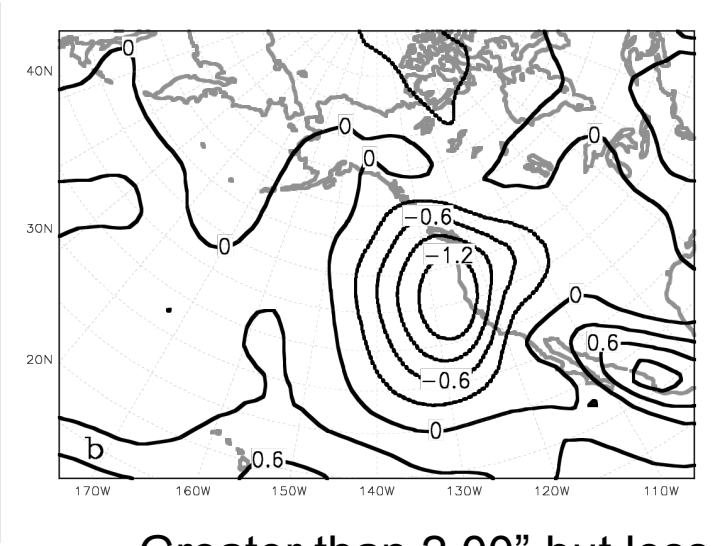


Greater than 0.50” but less than 2.00”

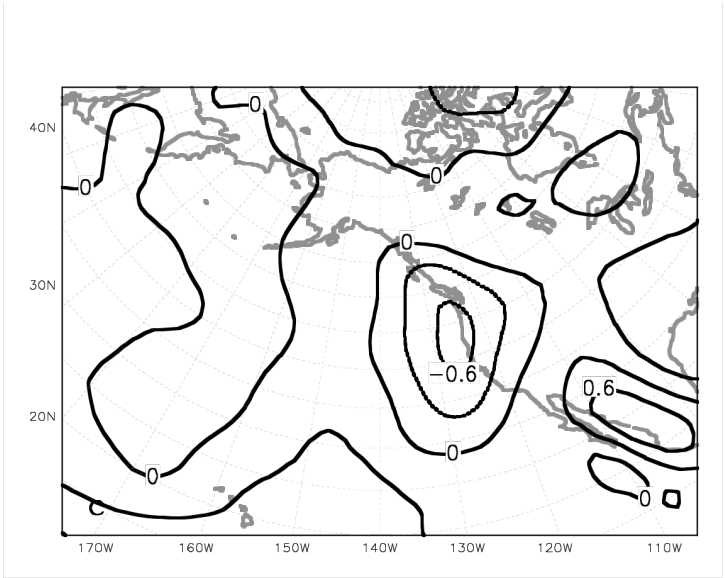
Composite mean MSLP pattern at T+00 for the three groups



Greater than 4.00”



Greater than 2.00” but less than 4.00”

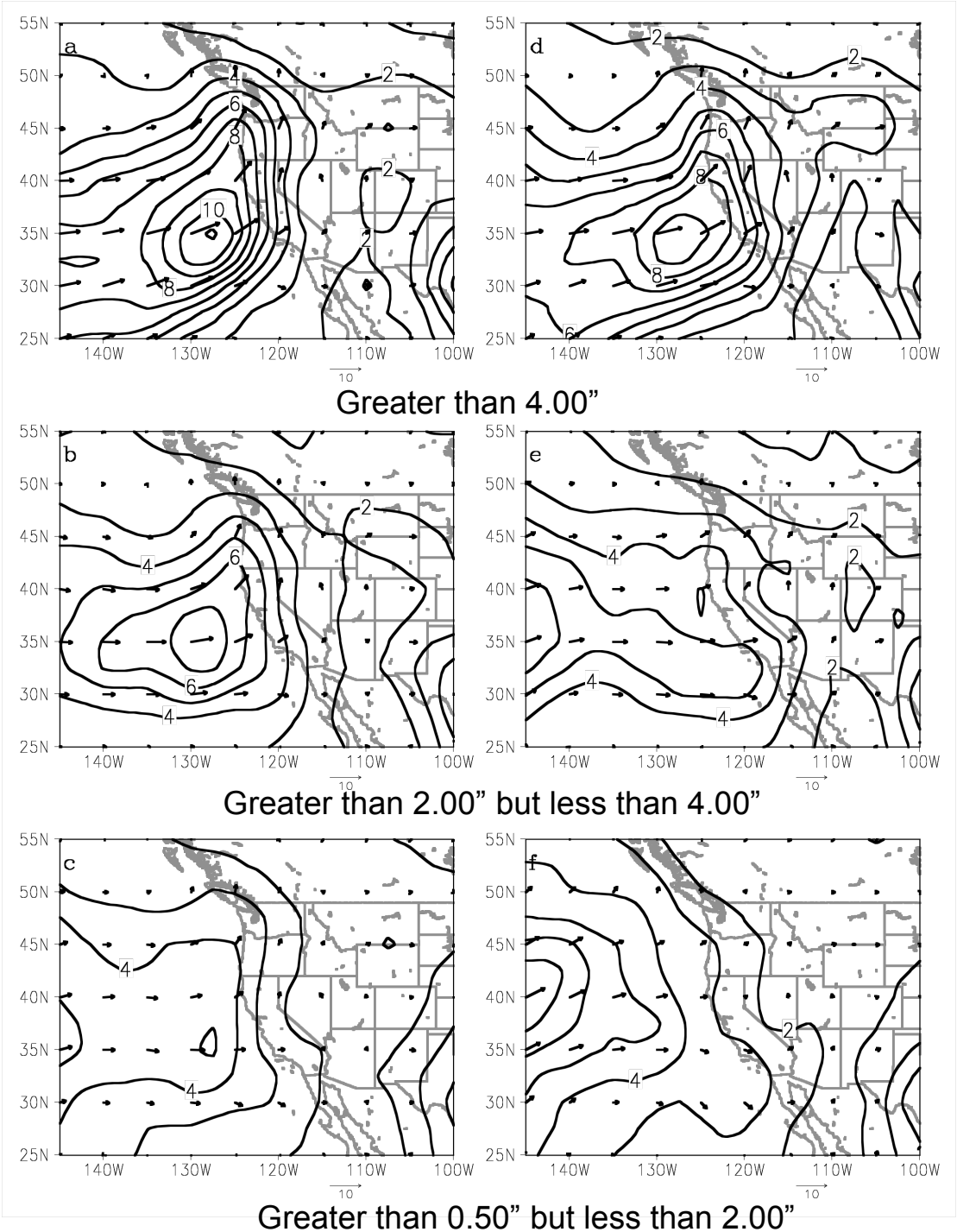


Greater than 0.50” but less than 2.00”

Composite mean 500-hPa anomaly pattern at T+00 for the three groupings.

T+00

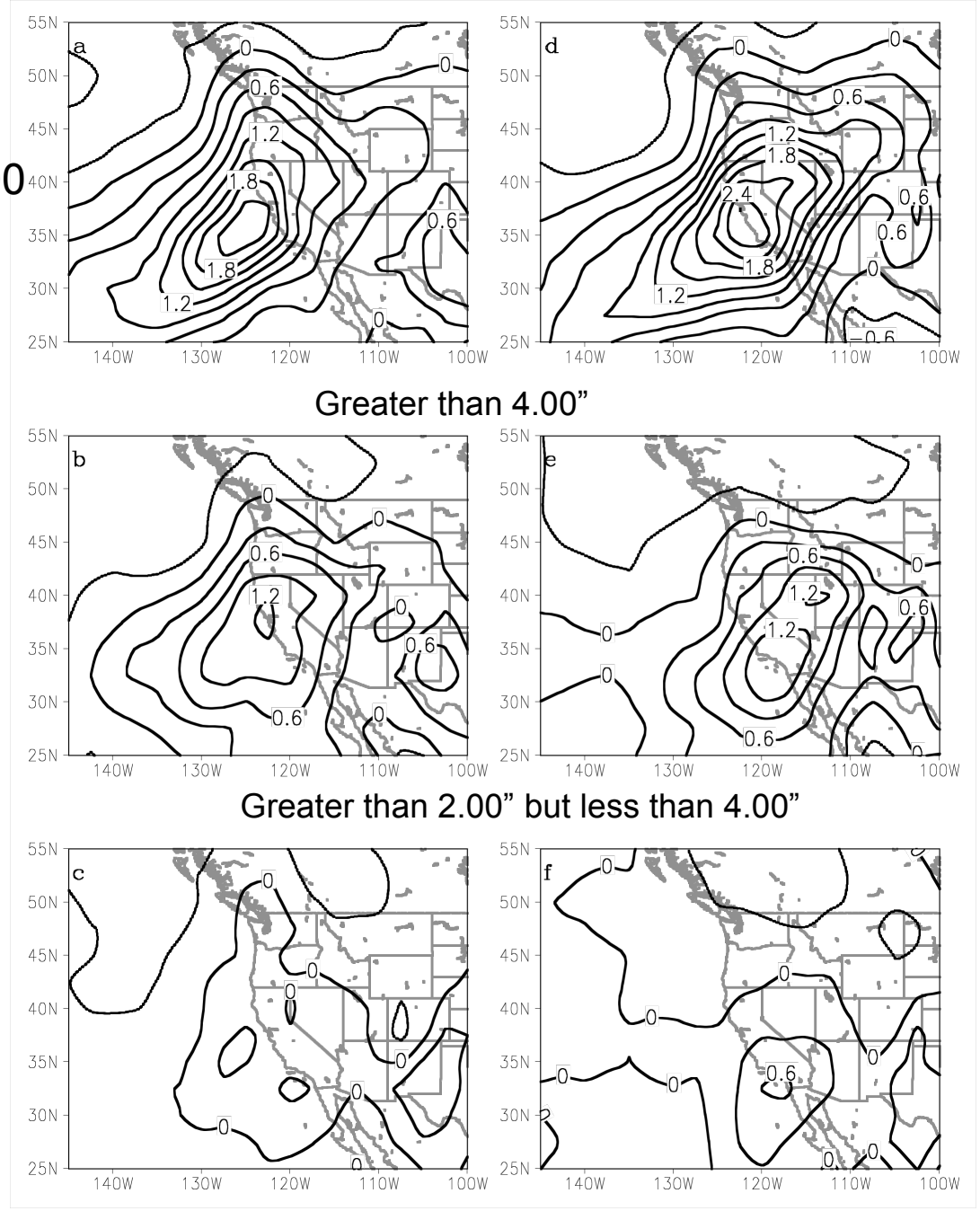
T+24



Composite mean 850-hPa MF and magnitude of MF for three groupings

Significant differences show up in the MF pattern. Note that the MF plume appears to get sheared on the moderate rainfall grouping.

T+00

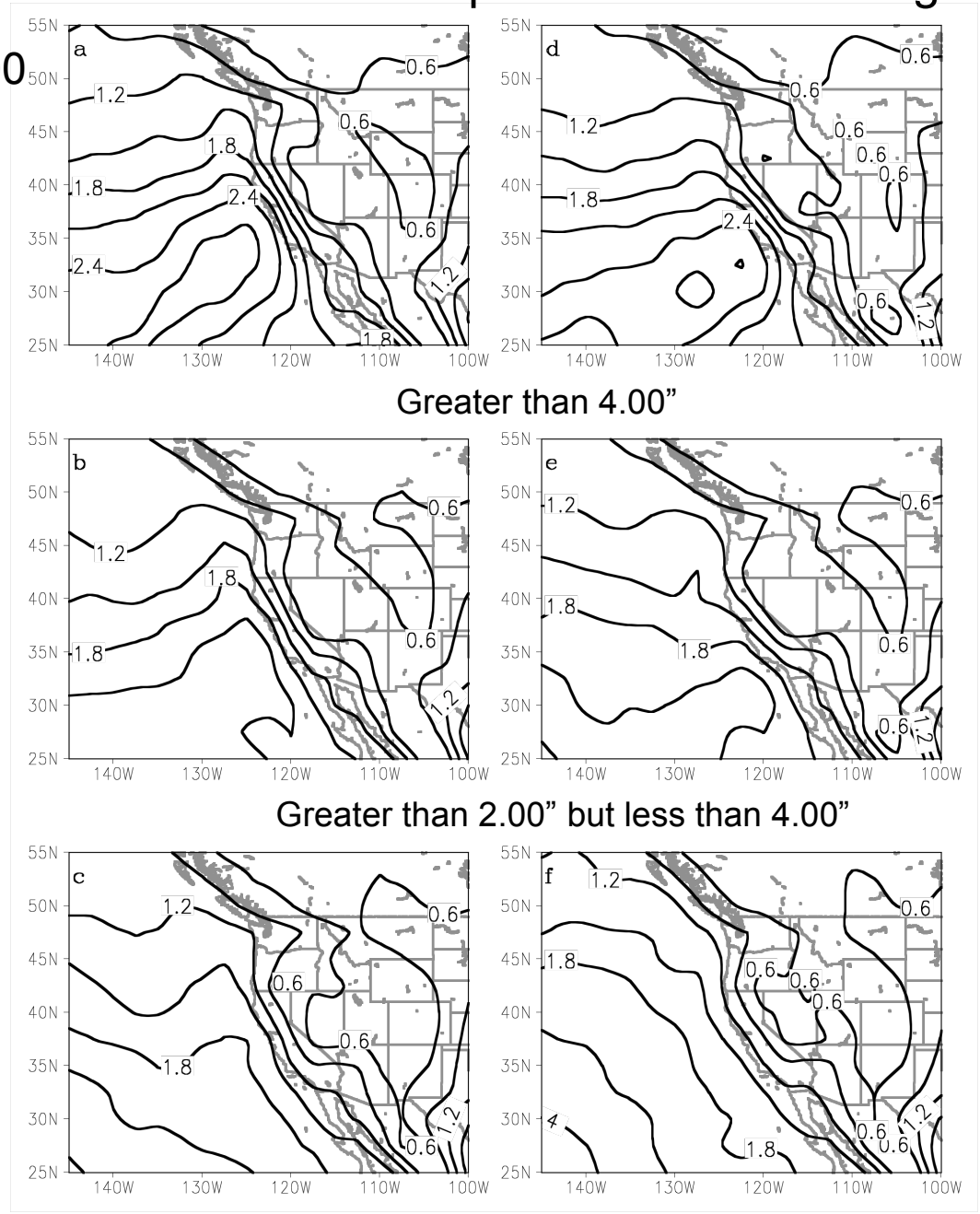


T+24

Composite mean normalized anomaly of 850-hPa MF for three groupings

Composite mean PW for groupings

T+00



T+24

Greater than 4.00”

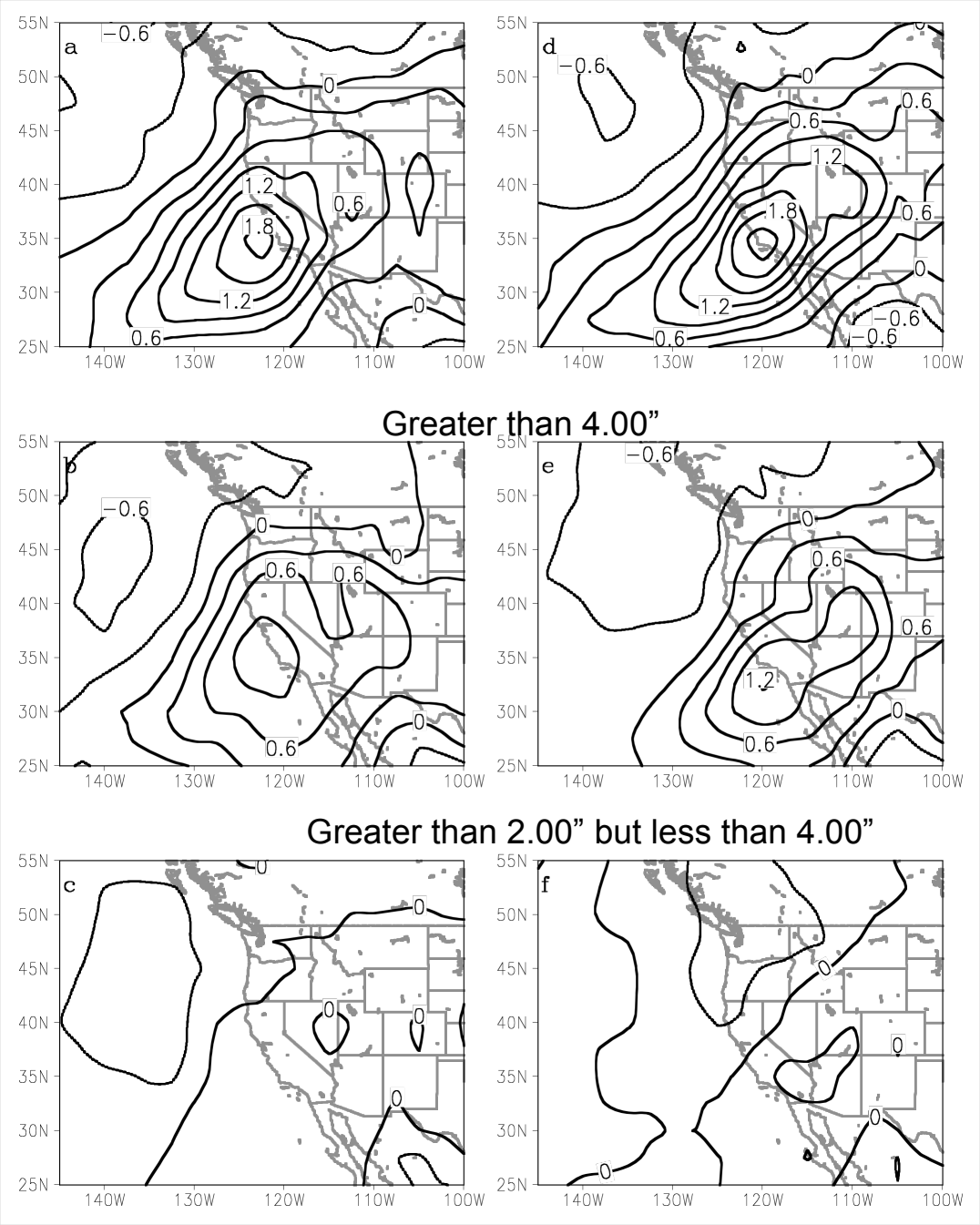
Greater than 2.00” but less than 4.00”

Greater than 0.50” but less than 2.00”

Associated with atmospheric rivers (usually strong ones) that are slow moving

Are usually associated with atmospheric rivers (meet the minimum requirement for Neiman et al classification)

Are not associated with atmospheric rivers.



Greater than 4.00”

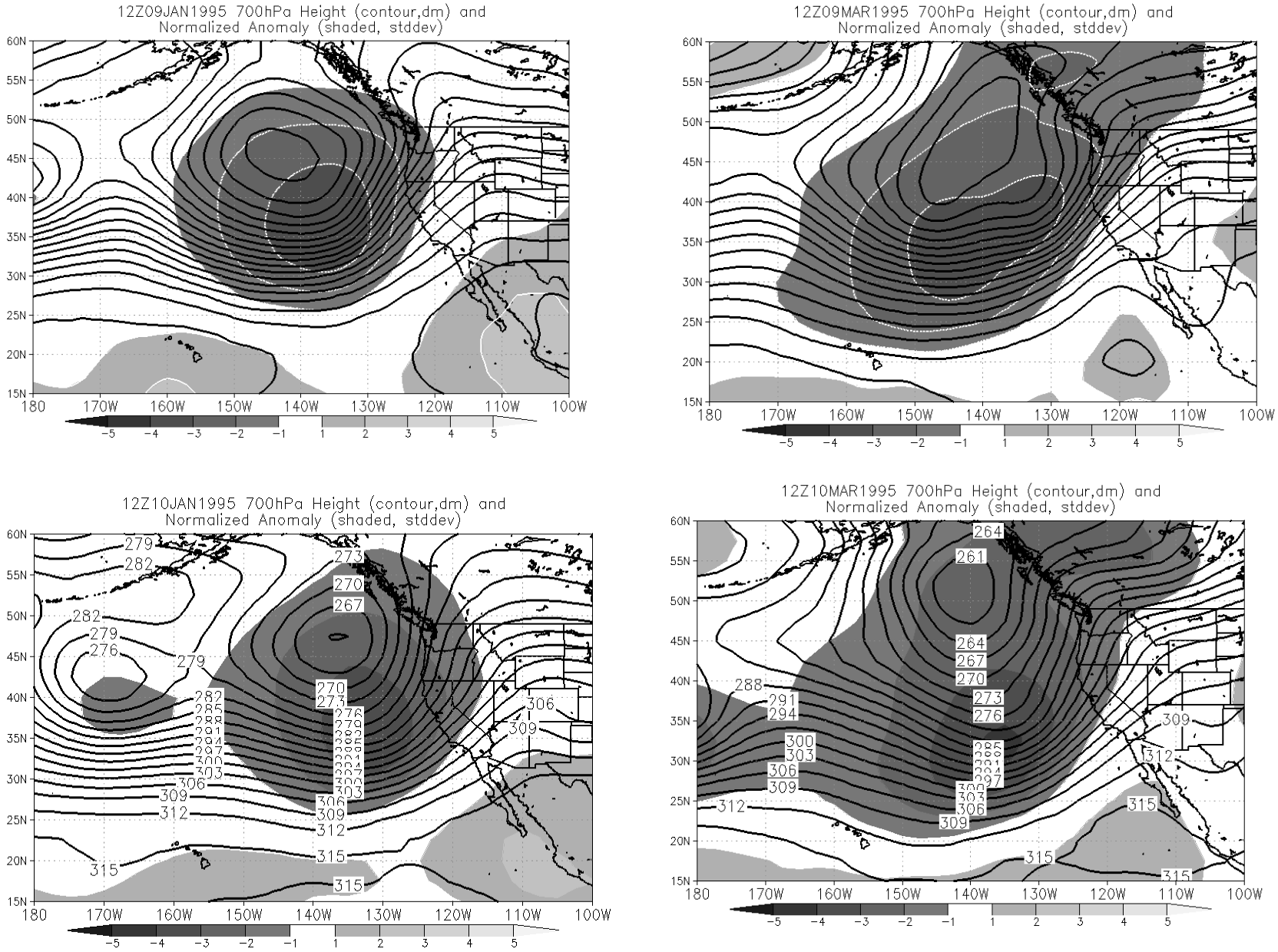
Greater than 2.00” but less than 4.00”

Greater than 0.50” but less than 2.00”

Composite mean normalized anomaly field for PW

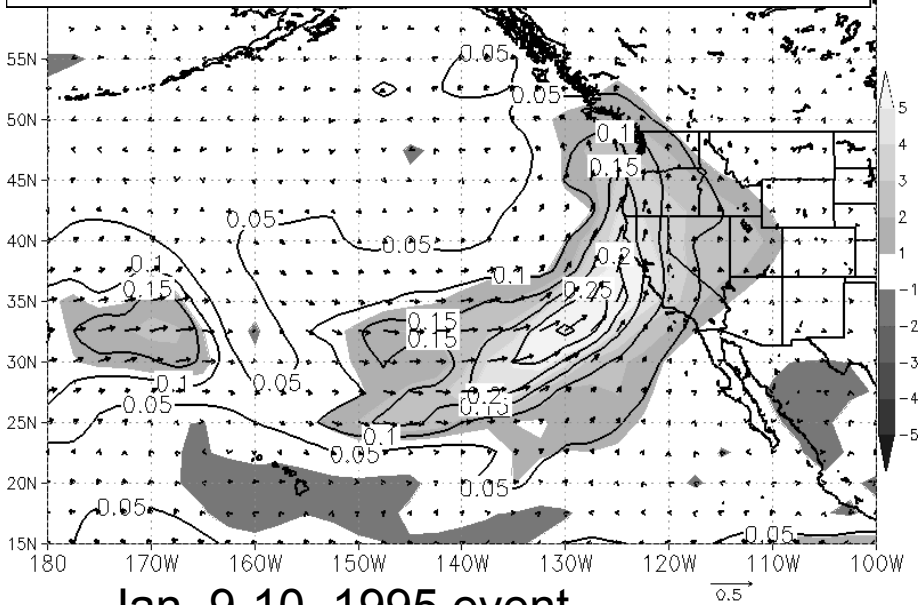
A look at three muli-day extreme rainfall events.

- Look at similarities at in the magnitude scale and position of the 700-hPA anomalies.
- The strong atmospheric rivers and associated normalized anomalies of 850-hPA moisture flux
- And how the position of the precipitation maxima seem to be related to the position of the atmospheric rivers.



700-hPa normalized anomaly pattern for Jan. 9-10 (left) and Mar. 9-10, 1985 (right) multi-day heavy rain event

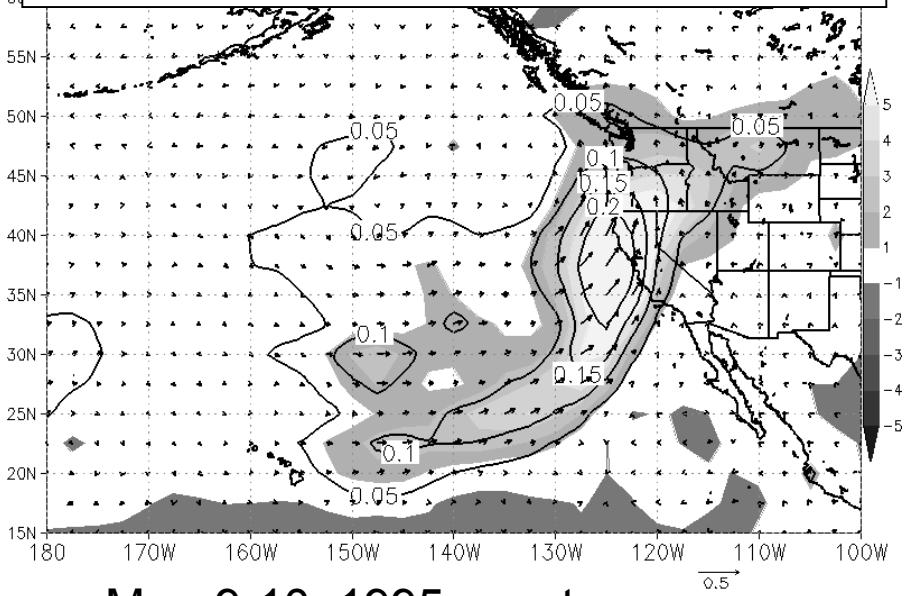
1200 UTC 9 Jan 1995



Jan. 9-10, 1995 event

12Z10JAN1995 850hPa Moisture Flux Magnitude (contour, [kg/kg][m/s]),
Normalized Anomaly (shaded, stddev),

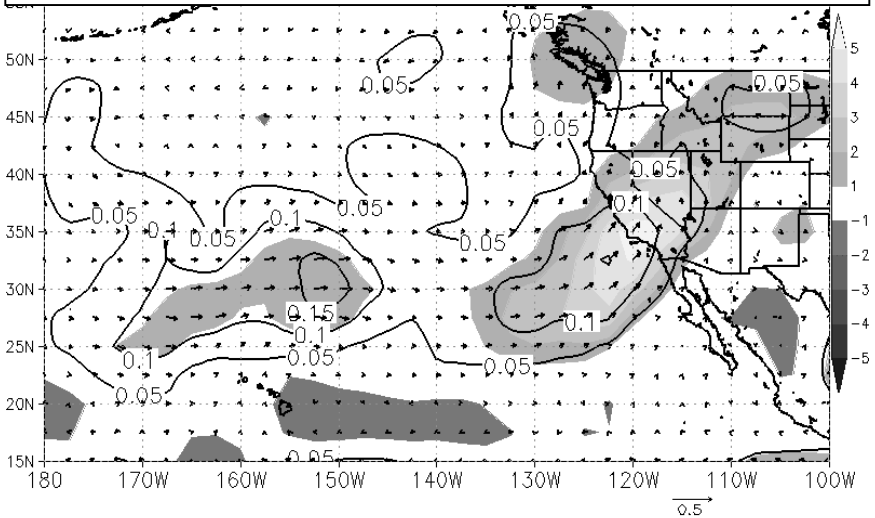
1200 UTC 9 Mar 1995



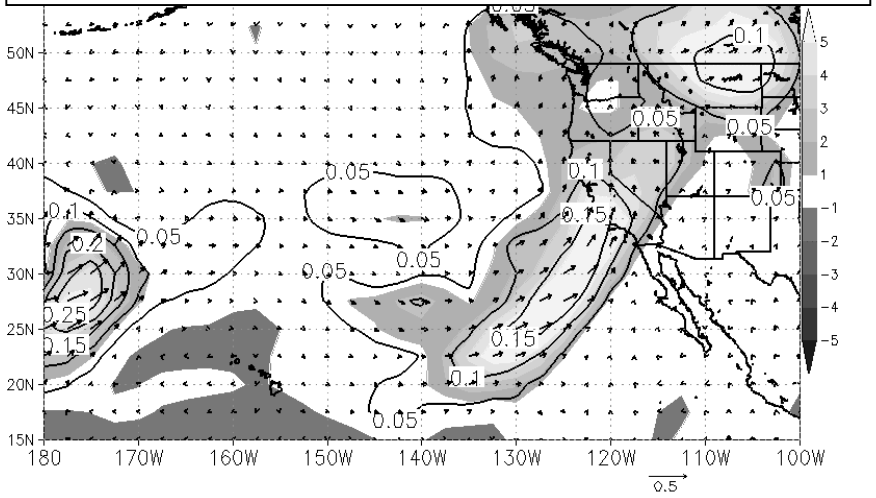
Mar. 9-10, 1995 event

12Z10MAR1995 850hPa Moisture Flux Magnitude (contour, [kg/kg][m/s]),
Normalized Anomaly (shaded, stddev),

1200 UTC 10 Jan 1995

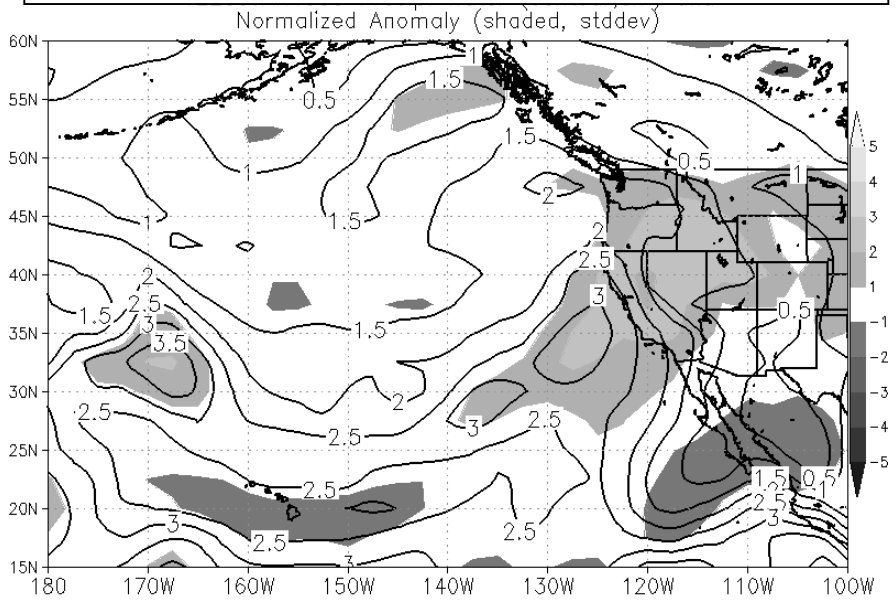


1200 UTC 10 Mar 1995

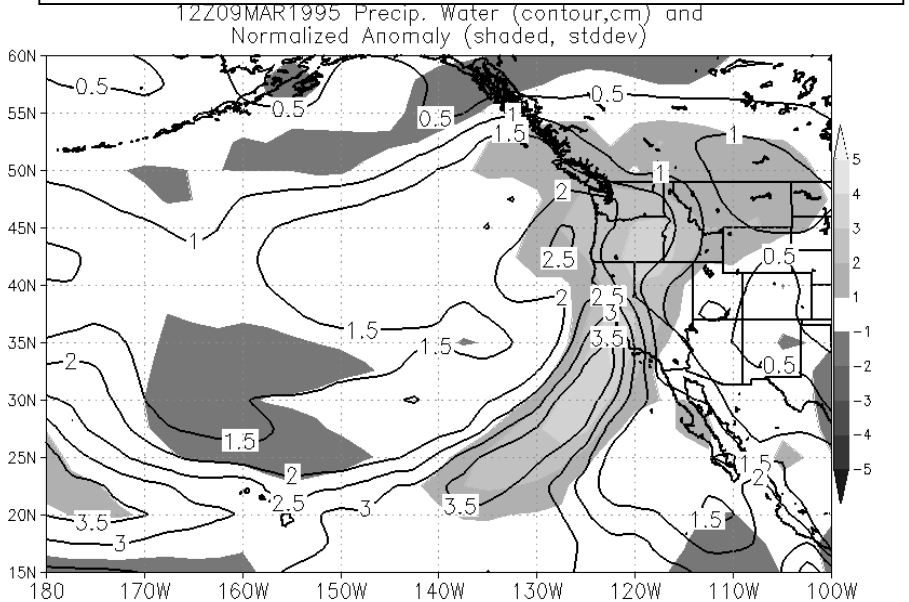


850-hPa Moisture flux (arrows) and normalized moisture flux anomalies (shaded)

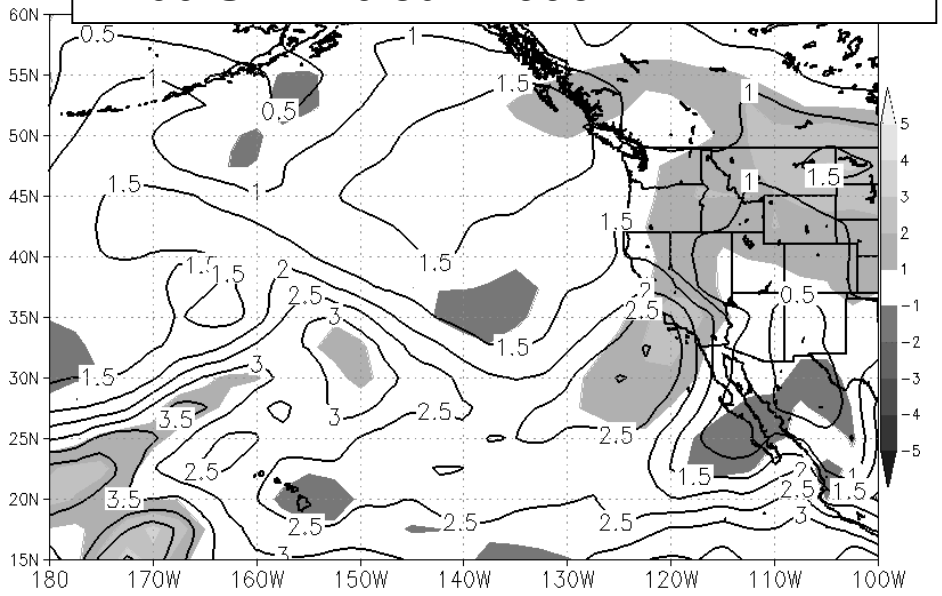
1200 UTC 9 Jan 1995



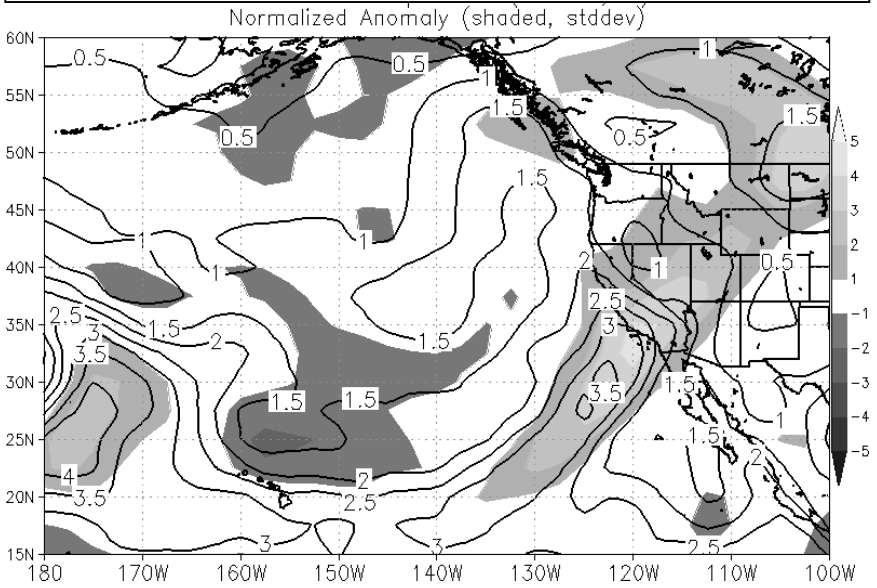
1200 UTC 9 Mar 1995



1200 UTC 10 Jan 1995

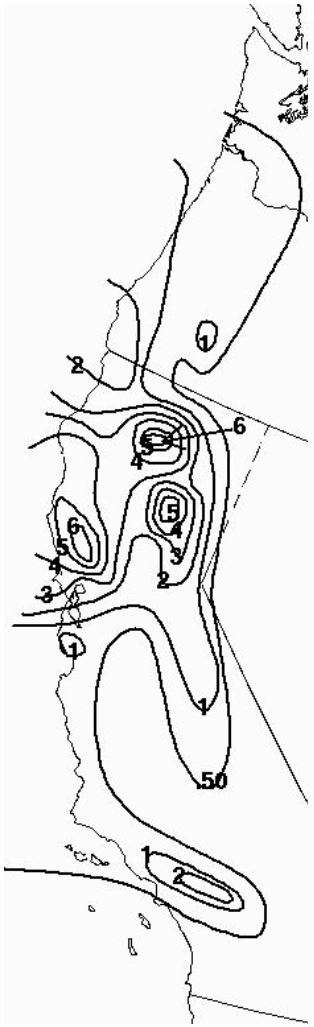


1200 UTC 10 Mar 1995

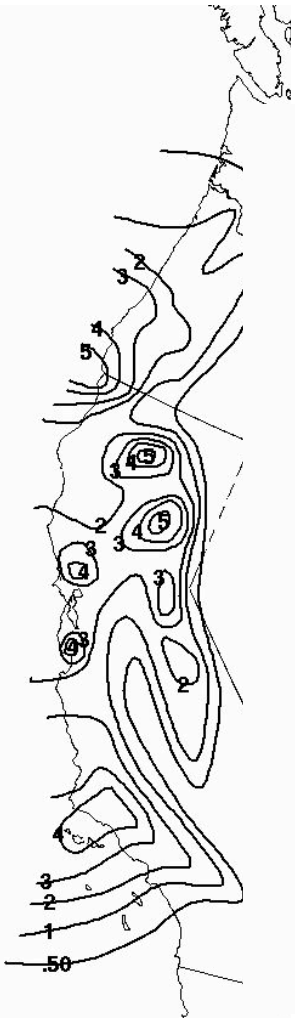


PW (cm) and normalized anomalies of PW.

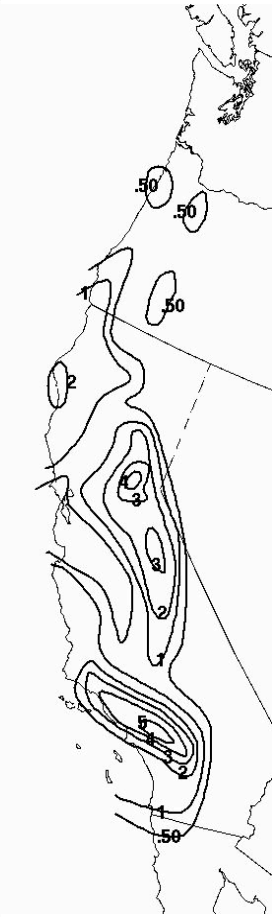
Precipitation during 3 days of the two multi-day events during 1995



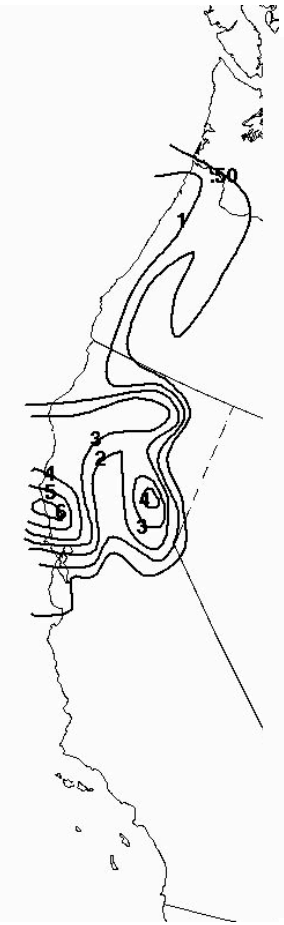
12Z 9 Jan 1995



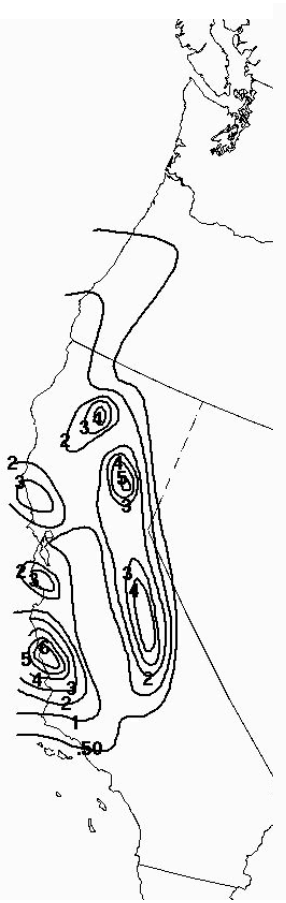
12Z 10 Jan 1995



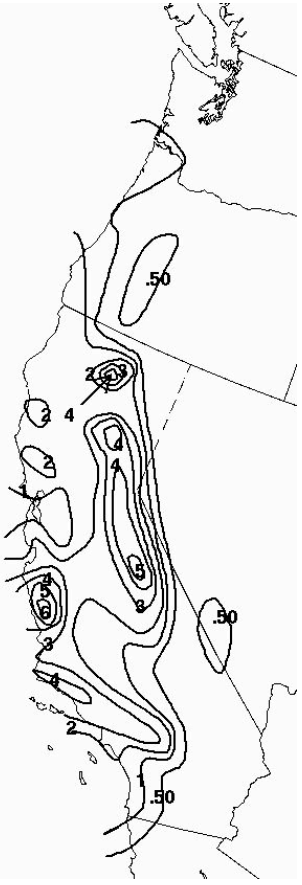
12Z 11 Jan 1995



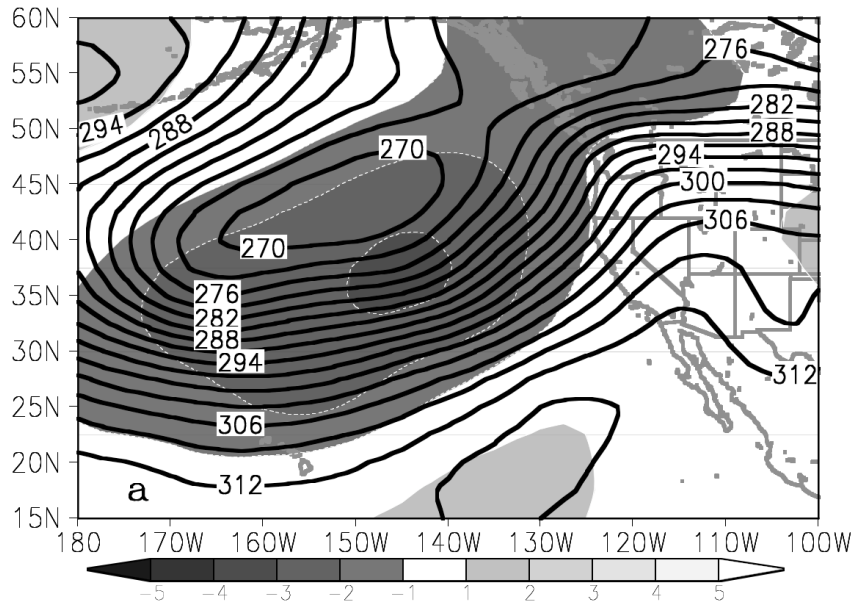
12Z 9 Mar 1995

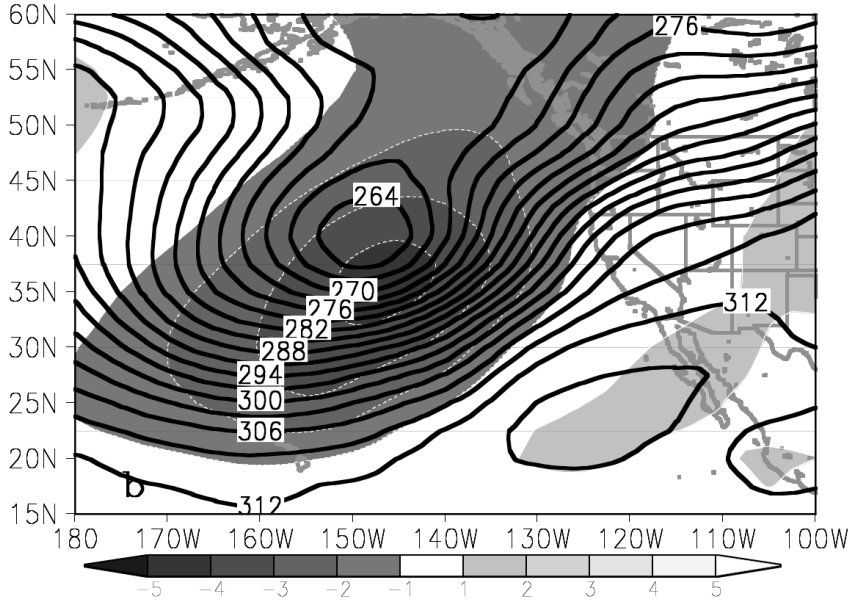


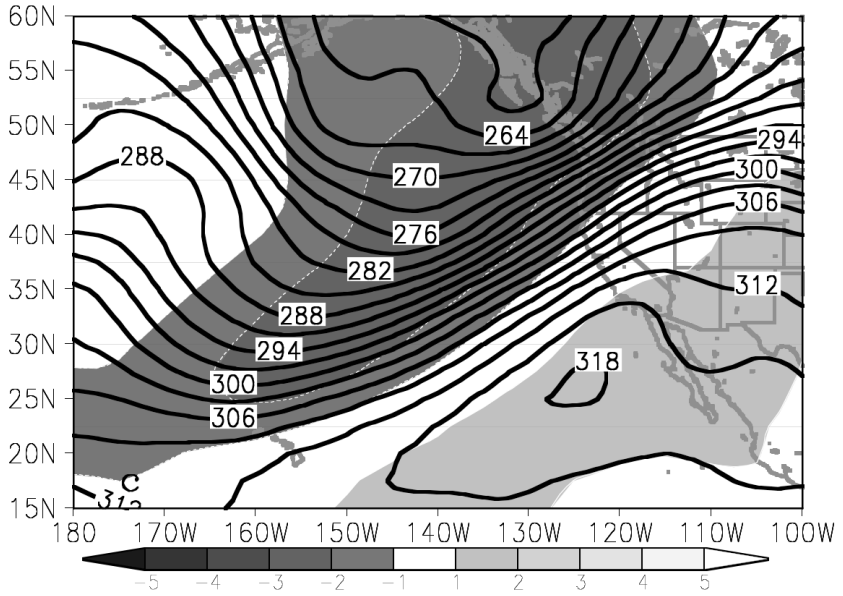
1200 UTC 10 Mar 1995



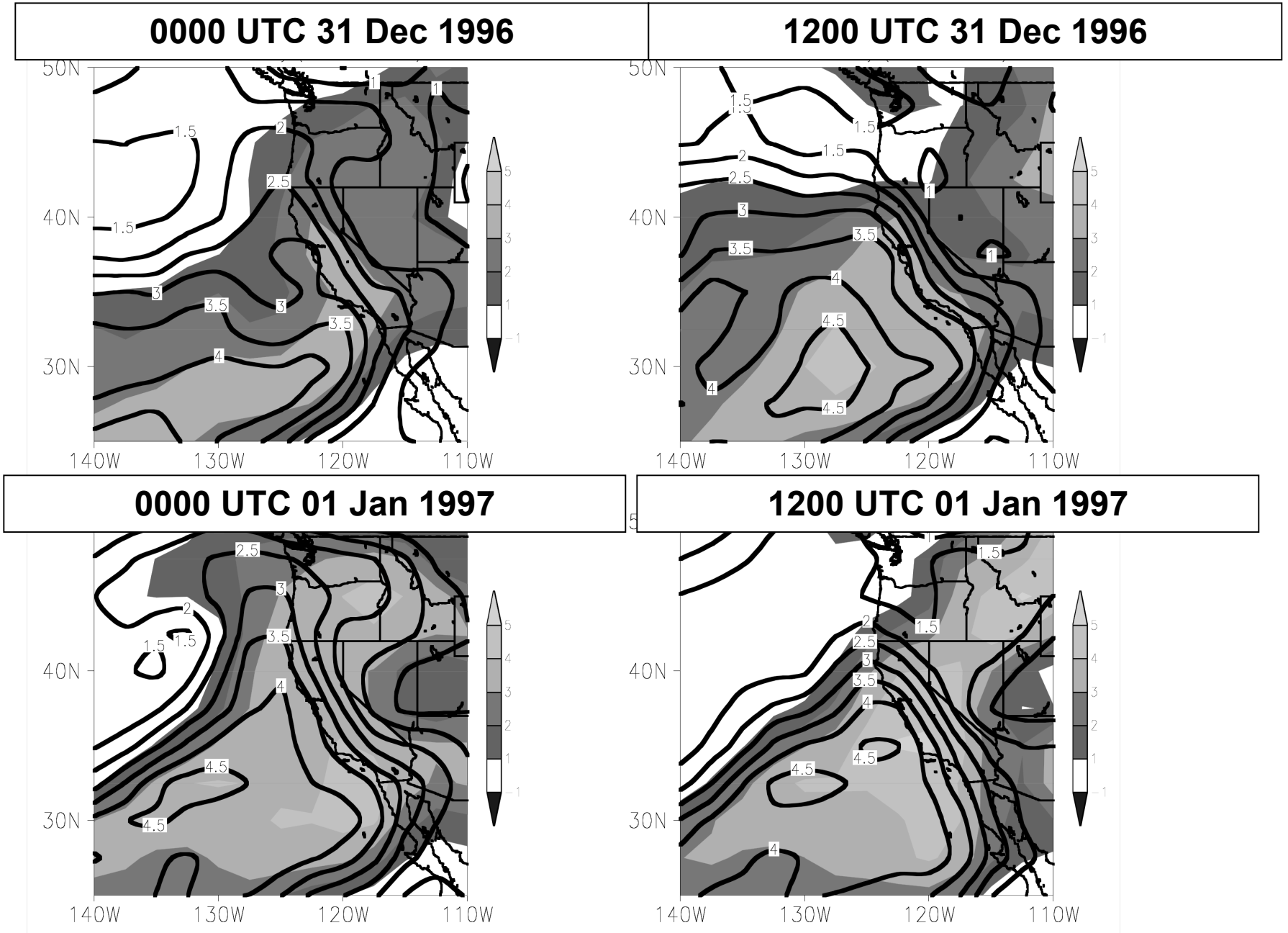
1200 UTC 11 Mar 1995



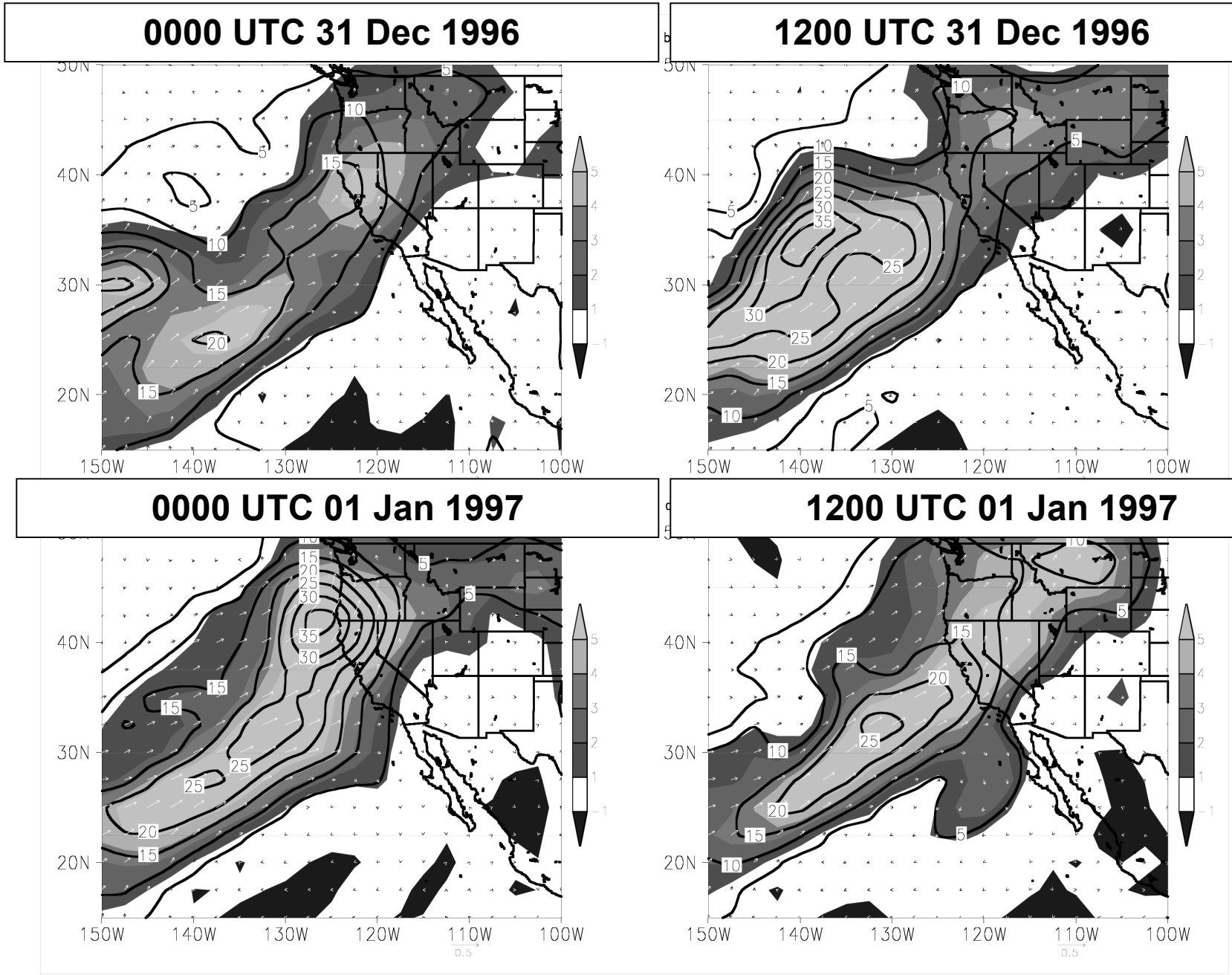




700-hPa geopotential heights (dm) and normalized anomalies (shaded, contour interval=1σ) for a) 1200 UTC 30 Dec. 1996, b) 1200 UTC 31 Dec. 1996, and c) 1200 UTC 01 Jan. 1997.



PW (cm) and normalized PW anomaly. **Strongest atmospheric river during the 10-year study**



850 MF and normalized anomalies of MF

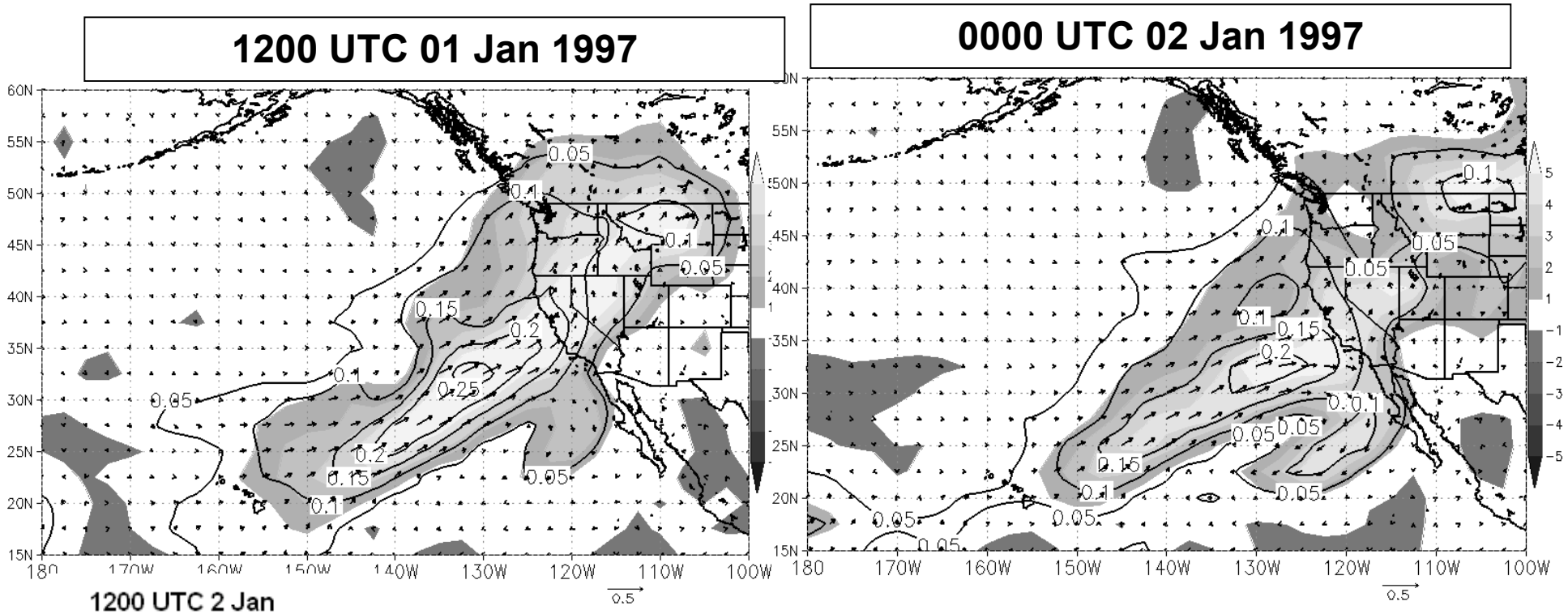
HPC 24-hour precipitation analysis valid at,

1200 UTC 31 Dec 1996

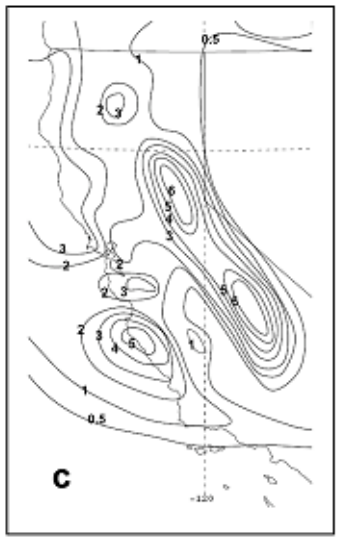
1200 UTC 1 Jan 1997

1200 UTC 2 Jan 1997

Note through 1200 UTC 1 Jan 1997, most of the precipitation was north of SFO. The axis of strongest MF reaches SFO at 1200 UTC 1 Jan.



1200 UTC 2 Jan 1997



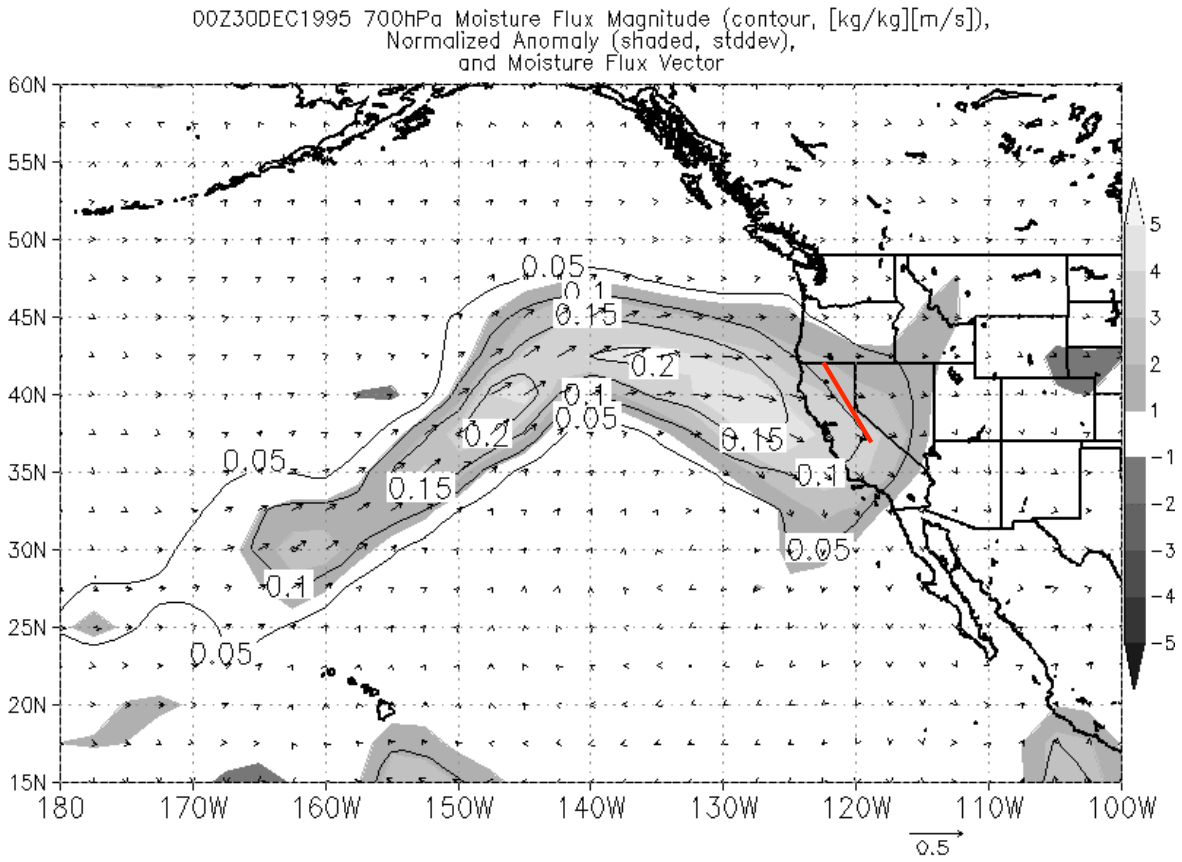
850-hPa MF and normalized MF anomaly pattern

Note as the axis of strongest moisture flux shifts south of SFO, the rainfall maximum also shifts south.

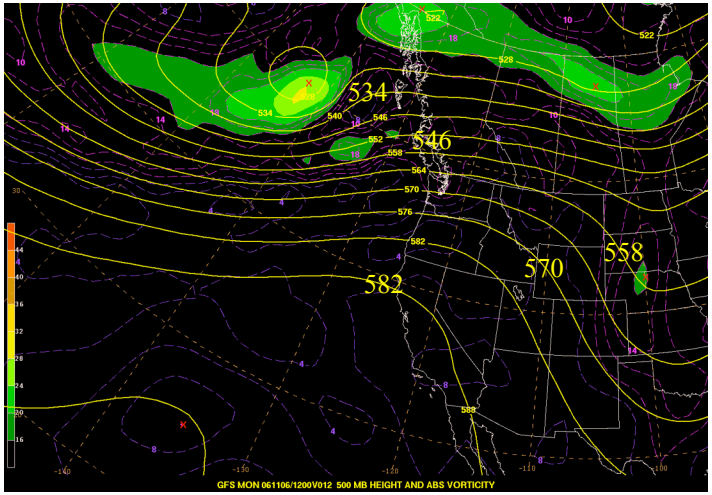
Correlations between the normalized anomalies of various parameters and the maximum analyzed precipitation contour

Parameter	R-square (P1)	R-square (P2)
850-hPa MF	.52	.50
700-hPa MF	.59	.47
700-hPa component of MF perpendicular to the Sierra Range	.51	.40
850-hPa component of MF perpendicular to the Sierra Range	.54	.43
PW	.48	.40
700-hPa u-component	.25	.22
700-hPa v-component	.15	.24
850-hPa u-component	.07	.28
850-hPa v-component	.32	.28

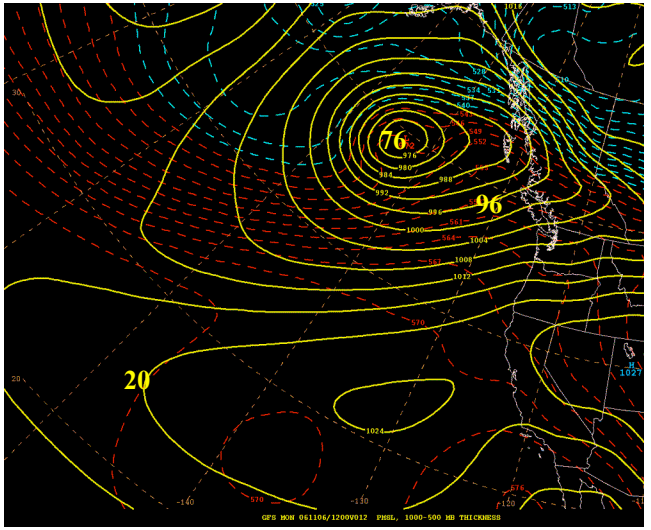
Why perpendicular r square is not higher.



6 inches of rain occurred during the 24 hr period. The flow was almost parallel to the orientation of the Sierra range. Therefore component perpendicular to the mountains was low. There were 3 similar heavy rainfall cases.



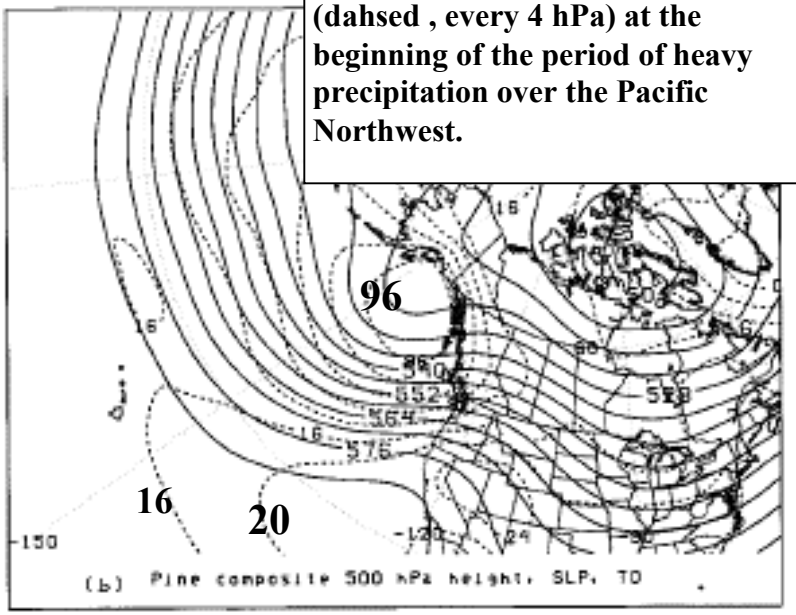
12-hr GFS forecast of 500-hPa geopotential height and vorticity valid 1200 UTC 6 Nov. 2006



12-hr GFS forecast mslp and 100-500-hPa thickness (dashed) valid 1200 UTC 6 Nov. 2006

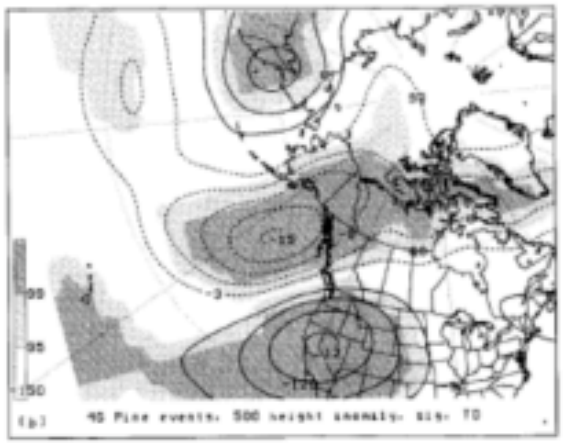
Note similarities between the forecast 500-hPa and MSL patterns and the composite. Using anomalies one tool to use to help diagnose the possibility of a significant precipitation event.

Composite mean 500-hPa height (solid) and sea level pressure (dahsed , every 4 hPa) at the beginning of the period of heavy precipitation over the Pacific Northwest.



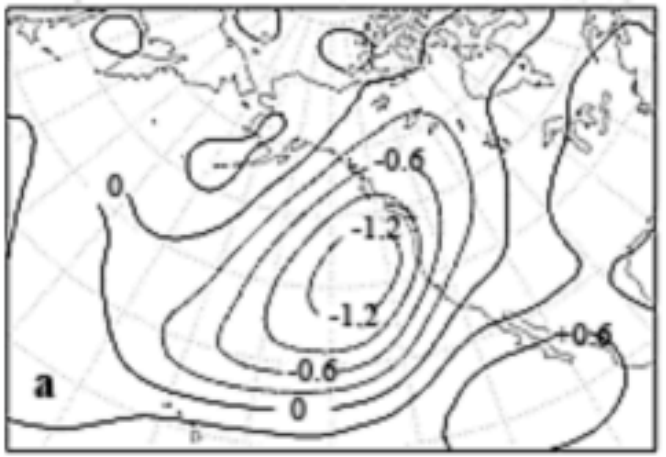
Note the similarities between the Pac Northwest heavy rainfall composite mean 500-hPa pattern to the pattern found by Junker et al. Both show a negative/positive couplet.

From Lackmann and Gyakum 1999
Pacific Northwest composite



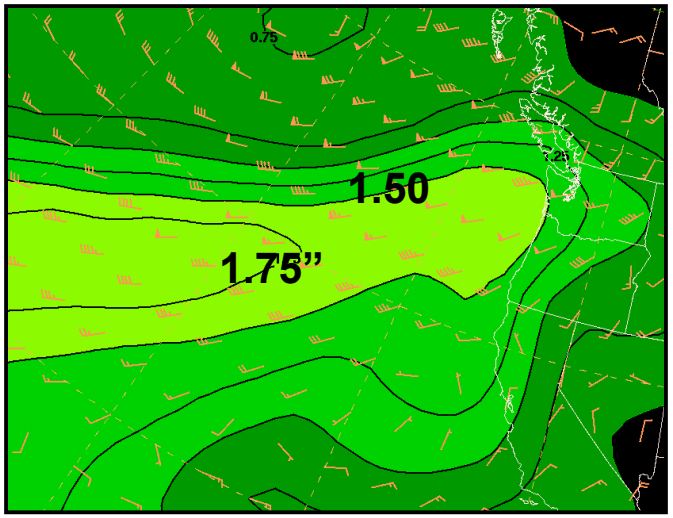
Composite mean 500-hPa departure from normal (positive departures are solid, negative departures are dashed, contour interval=3 dam). Shaded areas are the 95% and 99% probably that the composite belongs to a distinct population from climatology.

Northern California composite

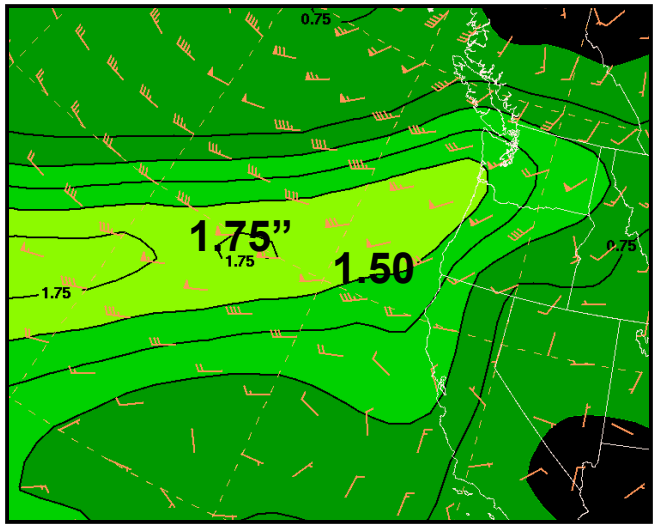


Composite mean 500-hPa normalized departures from normal. Unit is 0.3 standard deviations. Negative values are below normal heights, positive are above normal heights. From Junker et al. 2007.

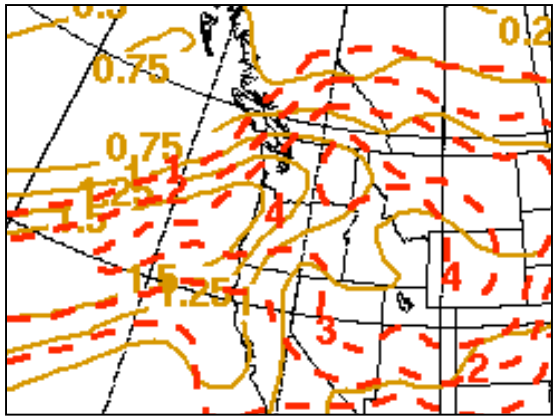
12-hr GFS forecast of PW and 850-hPA winds valid 1200 UTC 6 Nov. 2006



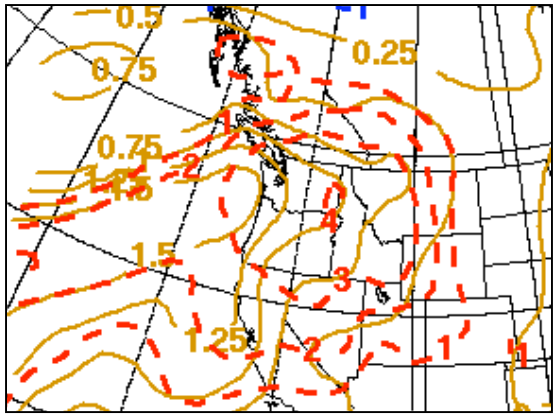
24-hr GFS forecast of PW and 850-hPA winds valid 0000 UTC 7 Nov. 2006



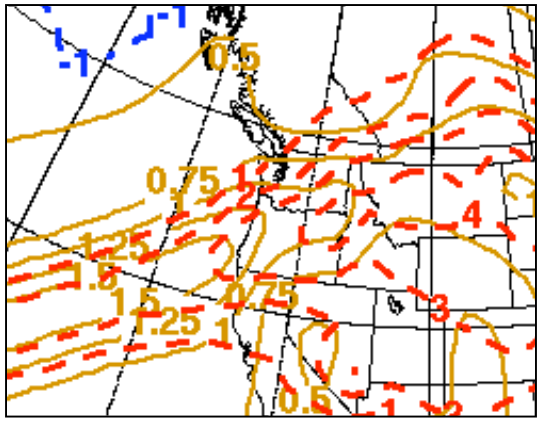
The PWs are high but how high compared to normal? What about the winds? Moisture flux?



15 hr v.t. 1200 UTC 6 Nov

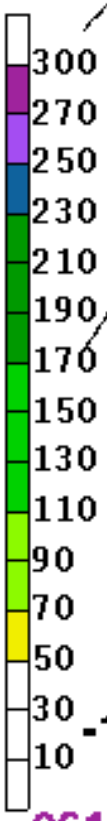


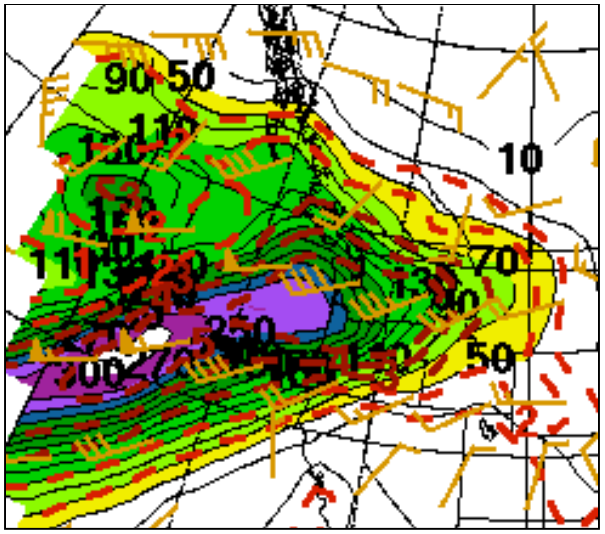
27 hr v.t. 0000 UTC 7 Nov



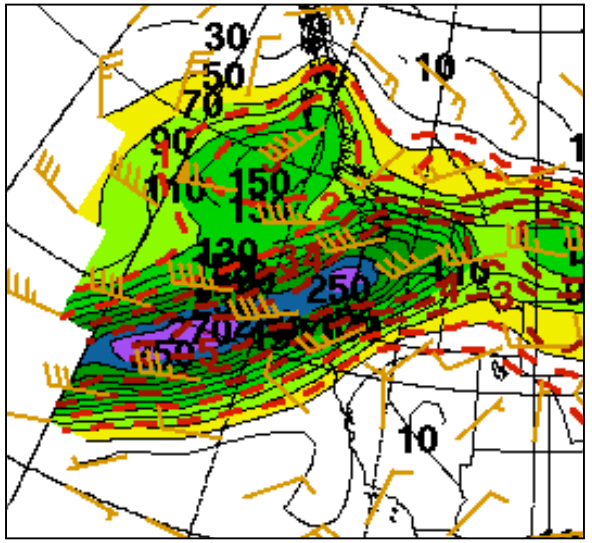
39 hr v.t. 1200 UTC 7 Nov

SREF ensemble mean forecasts of PW and normalized PW anomalies during the event. Normalized anomalies in red

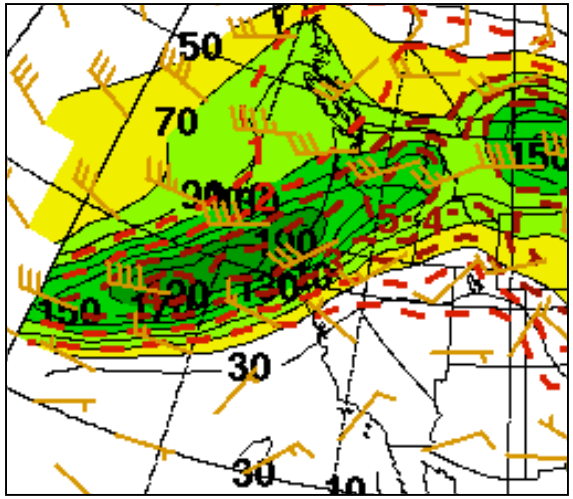




15 hr SREF 850-hPa MF (g/kg) ms^{-1} and normalized anomaly of MF valid 1200 UTC 6 Nov. 2006.



27 hr SREF 850-hPa MF (g/kg) ms^{-1} and normalized anomaly of MF valid 0000 UTC 7 Nov. 2006.

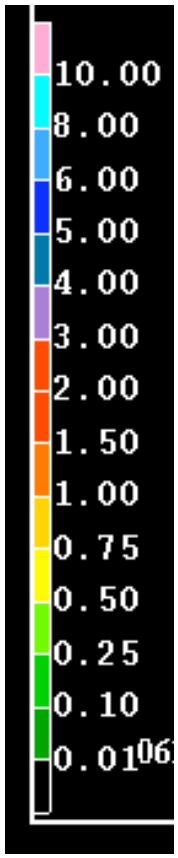


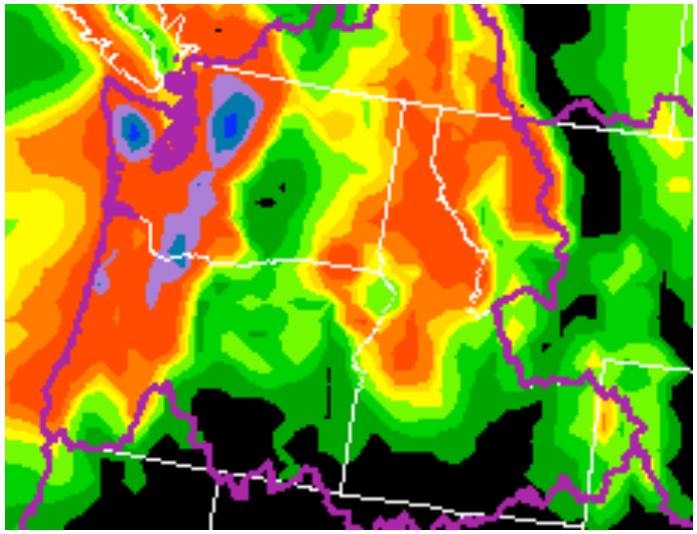
39 hr SREF 850-hPa MF (g/kg) ms^{-1} and normalized anomaly of MF valid 1200 UTC 7 Nov. 2006.

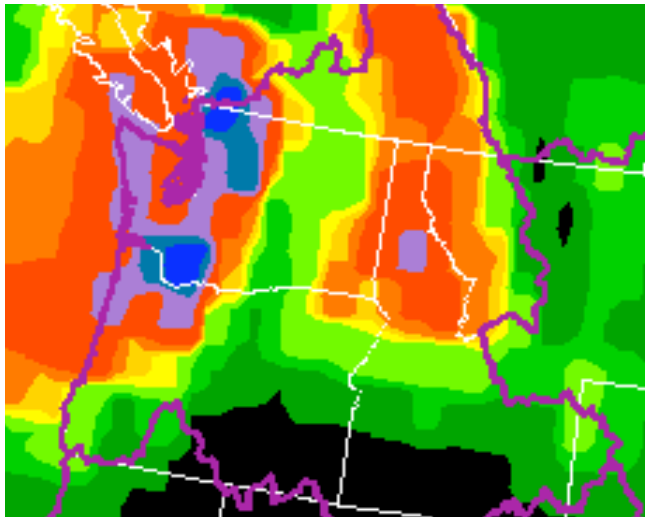
The SREF ensemble mean was predicting an extended period with the normalized MF anomalies greater than 5 sigma!!

An ensemble mean was signaling a rare event

12- 36 hr Model QPFs are shown below (on a 32-km grid) .







The GFS and NAM are predicting heavy rainfall but not a extremely rare event,

10-km PRISM climatology for November. Blue areas are mountainous areas with enhanced precipitation.

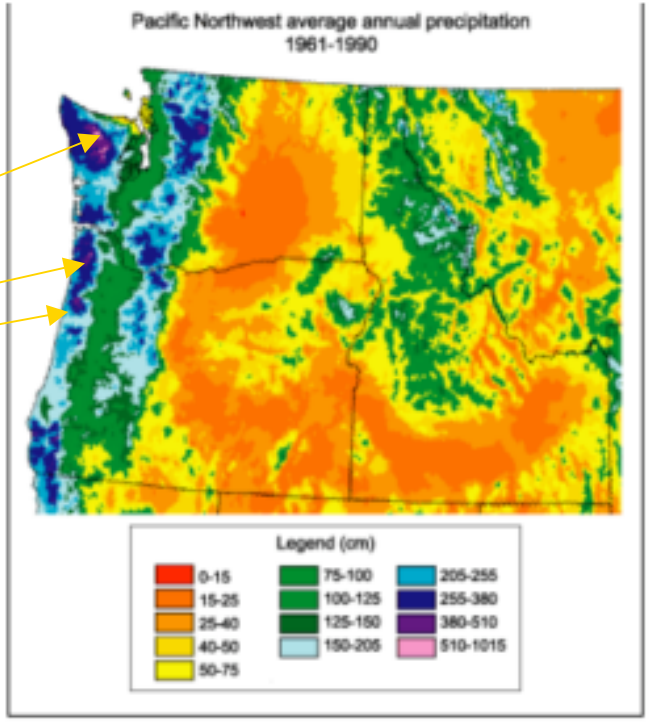
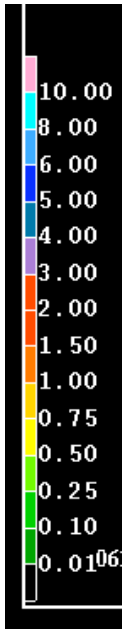
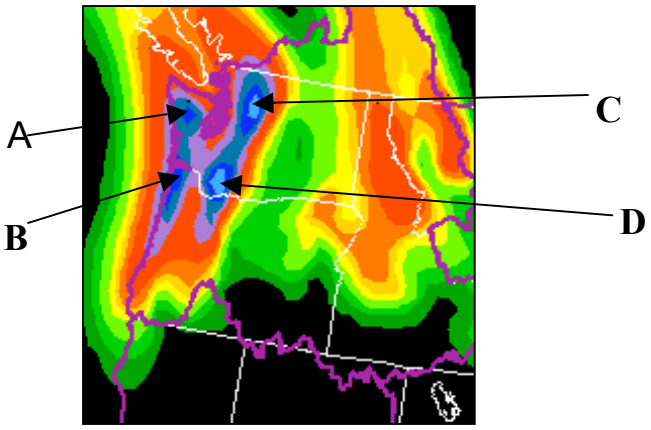


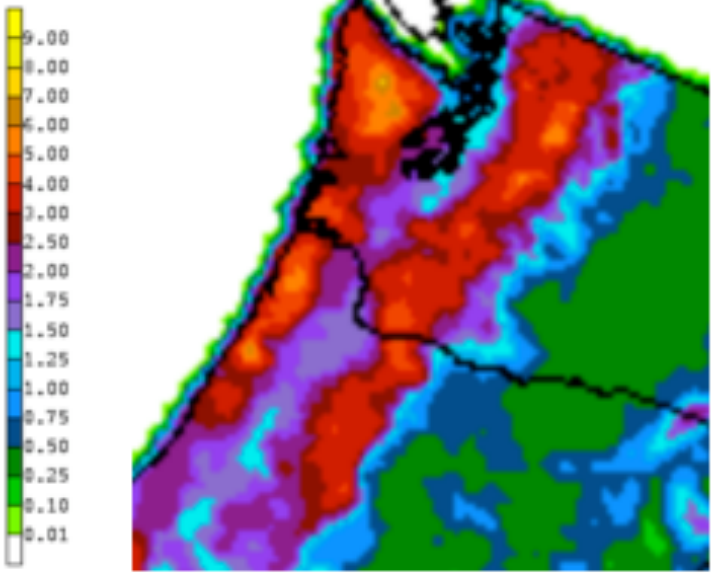
Figure 2 Annual mean precipitation for the Pacific Northwest. Figure courtesy of Oregon Climate Service (Oregon State University).

Analog PQPF products can help

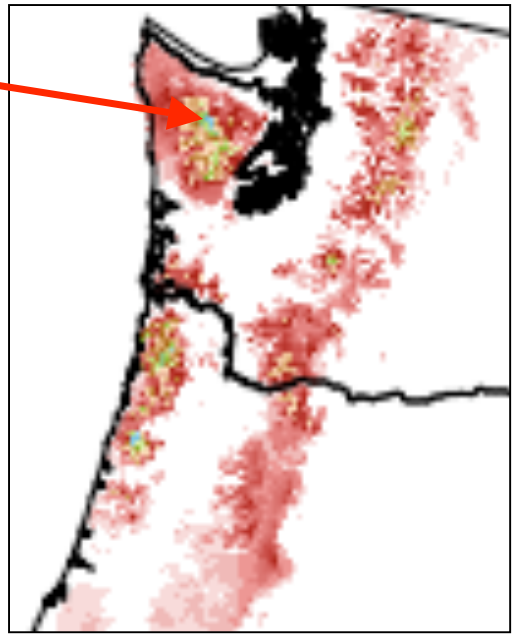




12-36 hr QPF from the HPC forecaster. Depicted on a 32-km grid.



24-h analog ensemble QPF-90th percentile (upper decile) (in) product valid 1200 UTC 7 Nov. 2006.

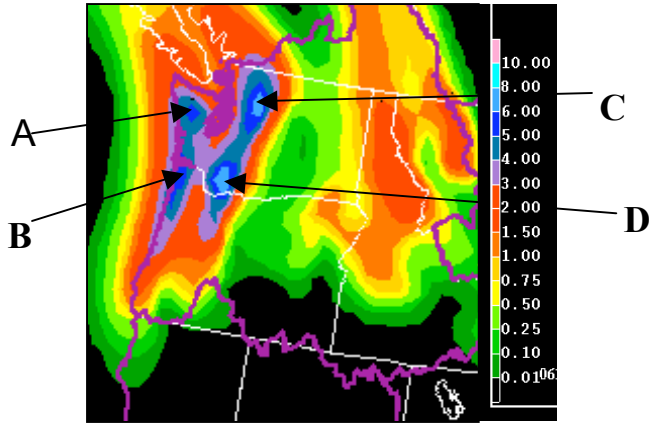


Probability of 4 inches

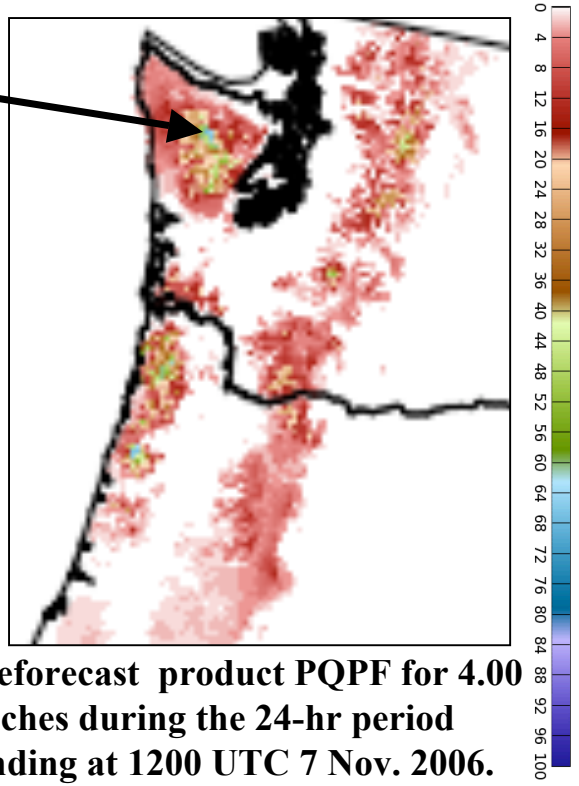
Reforecast product PQPF for 4.00 inches during the 24-hr period ending at 1200 UTC 7 Nov. 2006.

The Hamill et al. guidance products suggested that the mountains near the WA and OR coasts would get more than forecast by the models or by HPC. Their guidance suggests amounts at “A” and “B” should be at least as heavy as at “C” and D”

One forecast tool

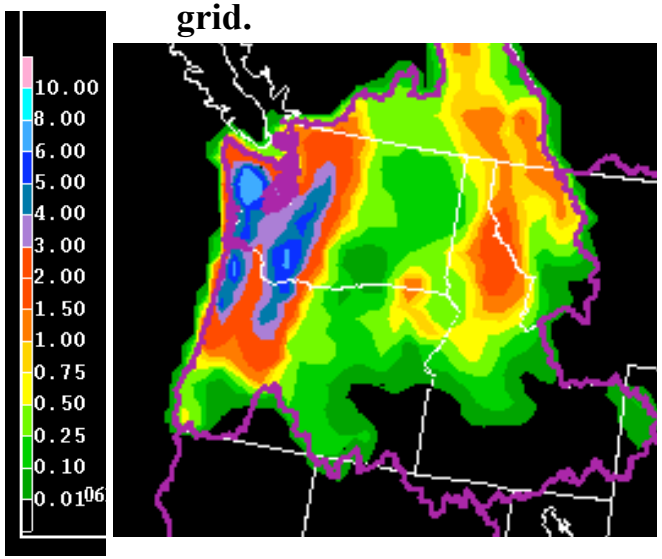


12-36 hr QPF from the HPC forecaster. Depicted on a 32-km grid.

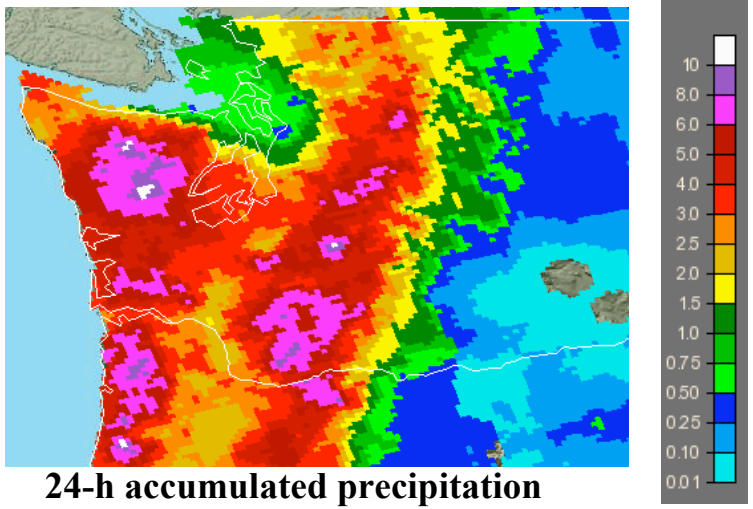


Probability of 4 inches

Reforecast product PQPF for 4.00 inches during the 24-hr period ending at 1200 UTC 7 Nov. 2006.

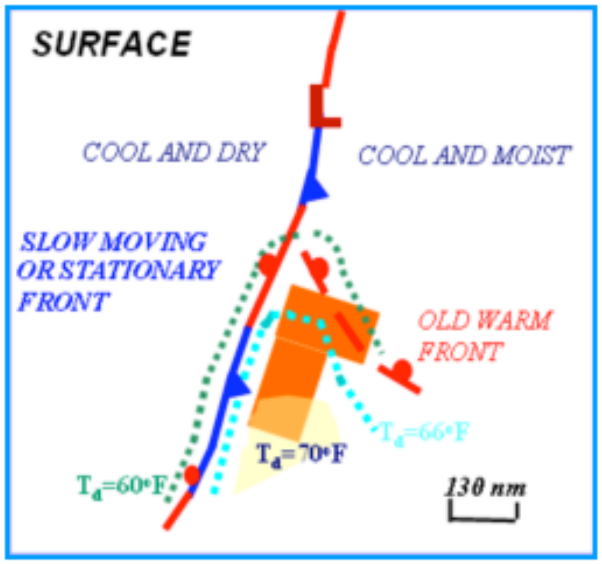


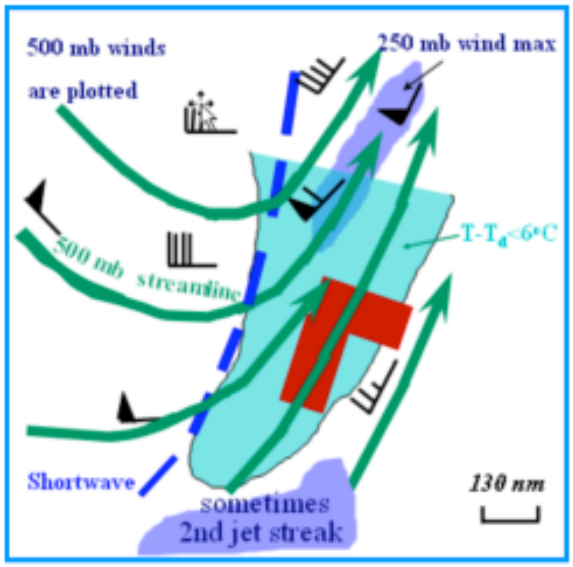
24-h accumulated precipitation (32 km grid) valid 1200 UTC 7 Nov. 2006.

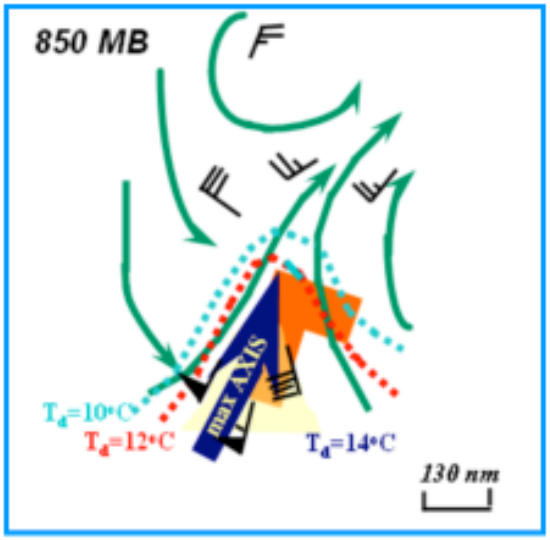


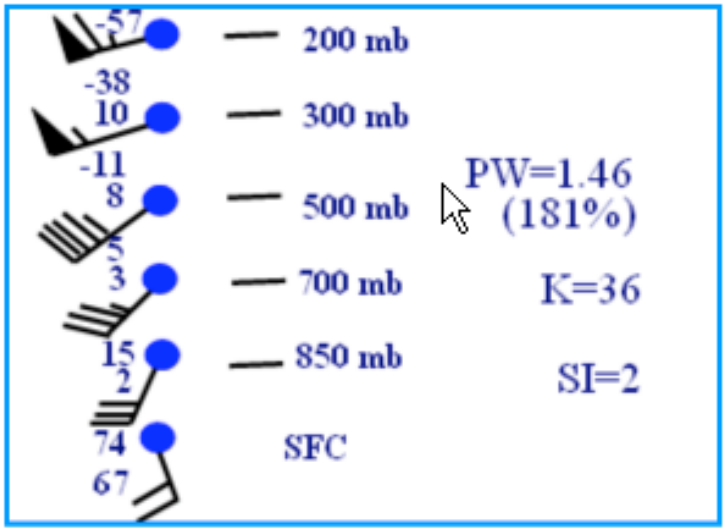
24-h accumulated precipitation (4 km grid) valid 1200 UTC 7 Nov. 2006.

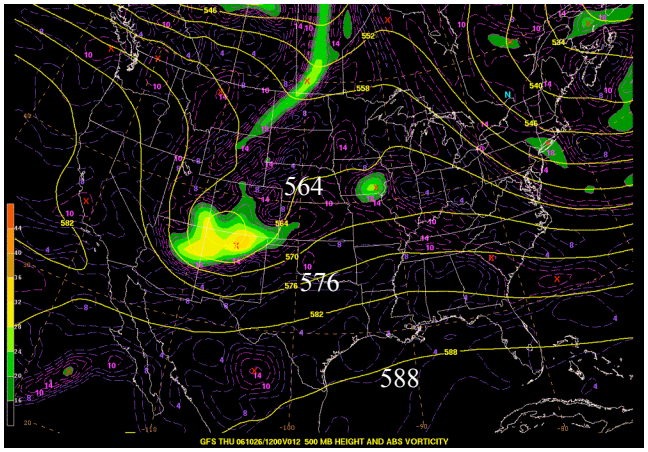
Will it work other places? Maddox Synoptic type flood, most likely in Spring and fall.



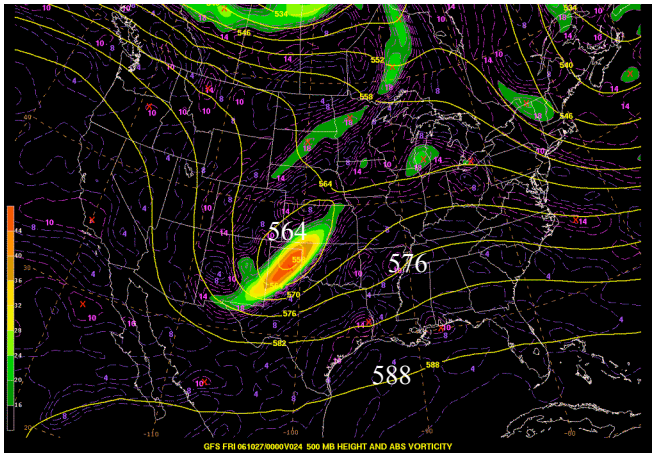




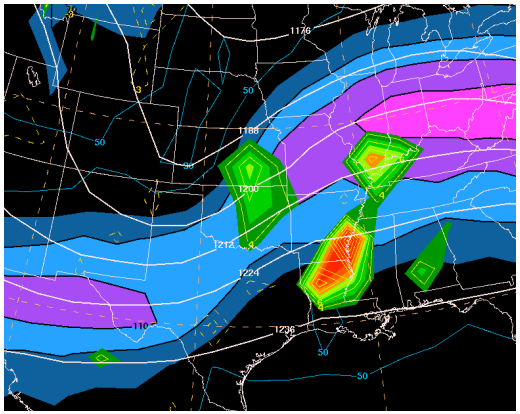




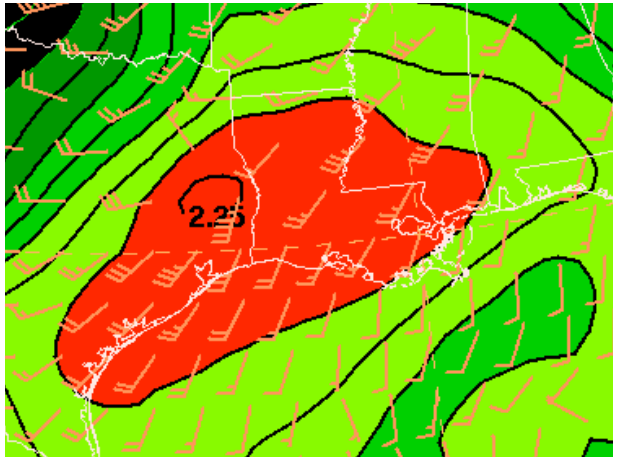
12hr GFS 500-hPa heights and vorticity valid 1200 UTC 26 Oct 2006.



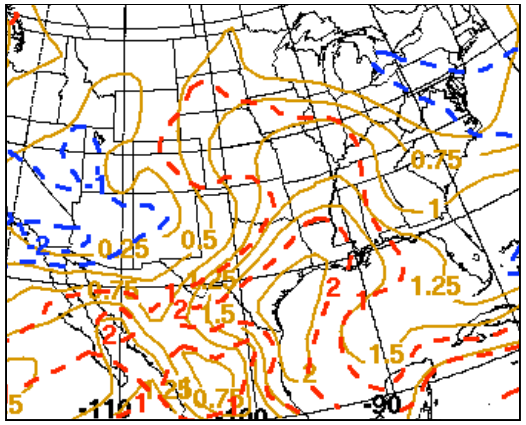
27hr GFS 500-hPa heights and vorticity valid 0300 UTC 27 Oct 2006.



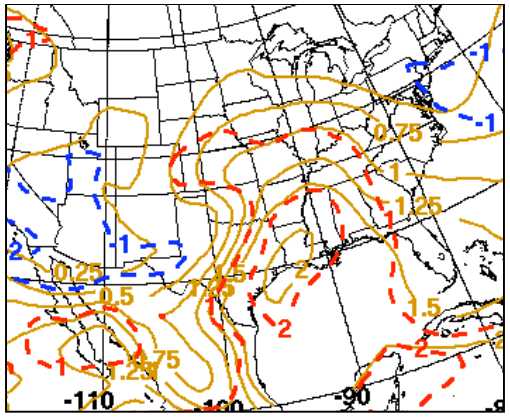
27hr GFS 250 heights and isotachs valid 0300 UTC 27 Oct 2006.



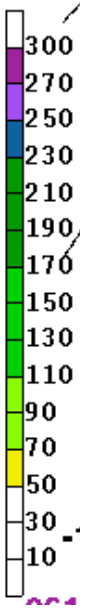
24 hr GFS 850-hPa wind and PW forecast valid at 0000 UCT 27 Oct. 2006.

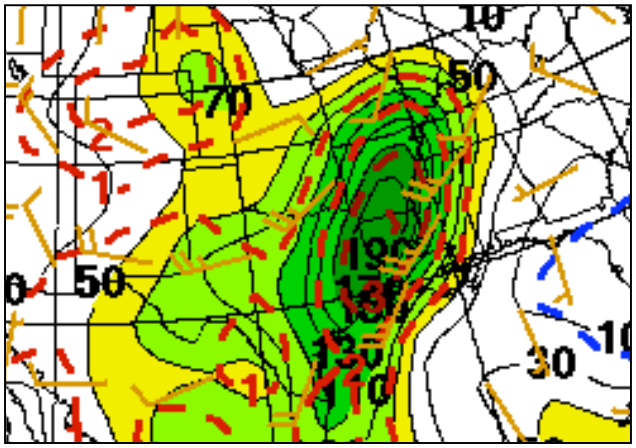


15-hr SREF ensemble mean forecast of PW (brown, inches) and standardized anomaly of PW (dashed red) valid 1200 UTC 26 Oct. 2006.

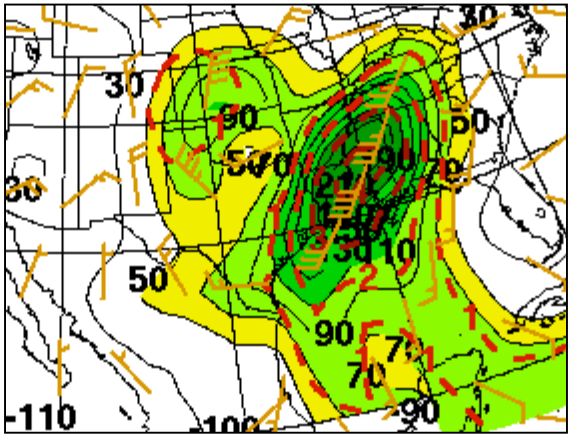


27-hr SREF ensemble mean forecast of PW (brown line, in inches) and standardized anomaly of PW (dashed red) valid 0000 UTC 27 Oct. 2006.





15-hr SREF ensemble mean forecast of 850-hPa magnitude of moisture flux (scale at left, (g/kg)(ms^{-1}), standardized anomaly of magnitude of moisture flux (dashed red) and 850-hPa wind (barbs).

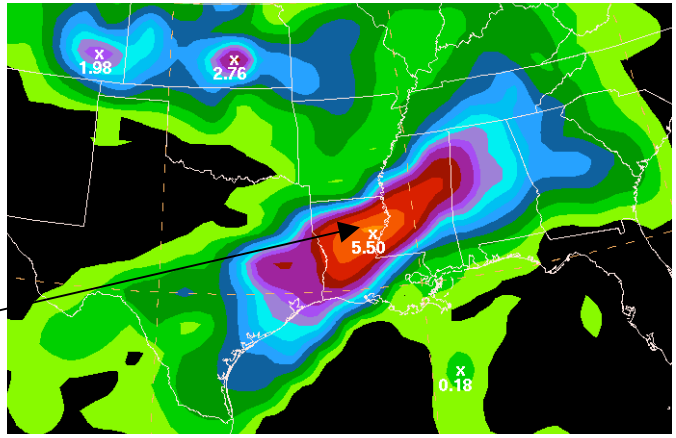


27-hr SREF ensemble mean forecast of 850-hPa magnitude of moisture flux (scale at left, (g/kg)(ms^{-1}), standardized anomaly of magnitude of moisture flux (dashed red) and 850-hPa wind (barbs).

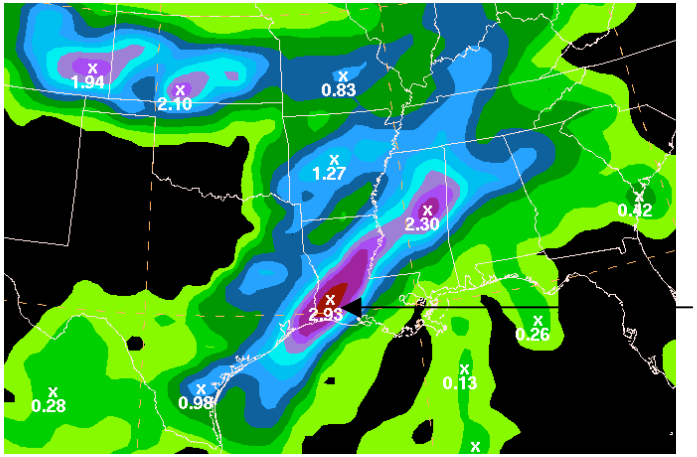
Moisture transport is forecast to be greater than 4 standard deviations from the norm……..a relatively rare event.

No ensemble member predicted 4”

5.55” max



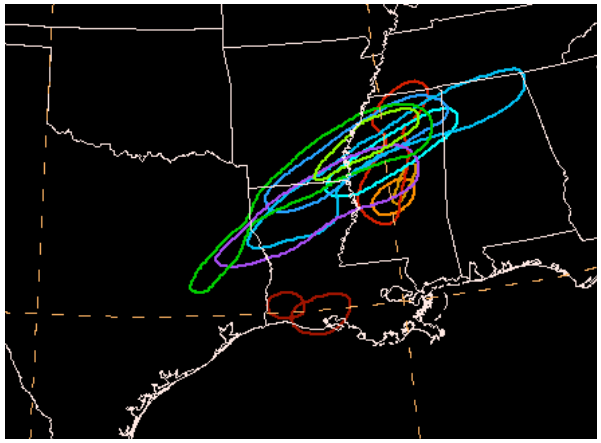
12-36 hr GFS QPF valid 1200 UTC 27 Oct. 2006.



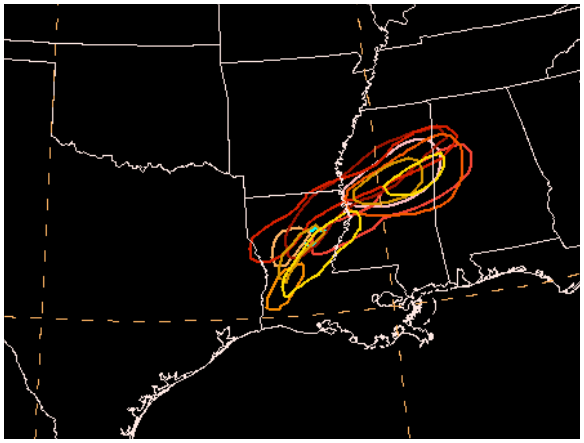
12-36 hr NAM QPF valid 1200 UTC 27 Oct. 2006.

2.93” max

24 hr 3 inch spaghetti diagrams valid 1200 UTC 17 Oct. 2006

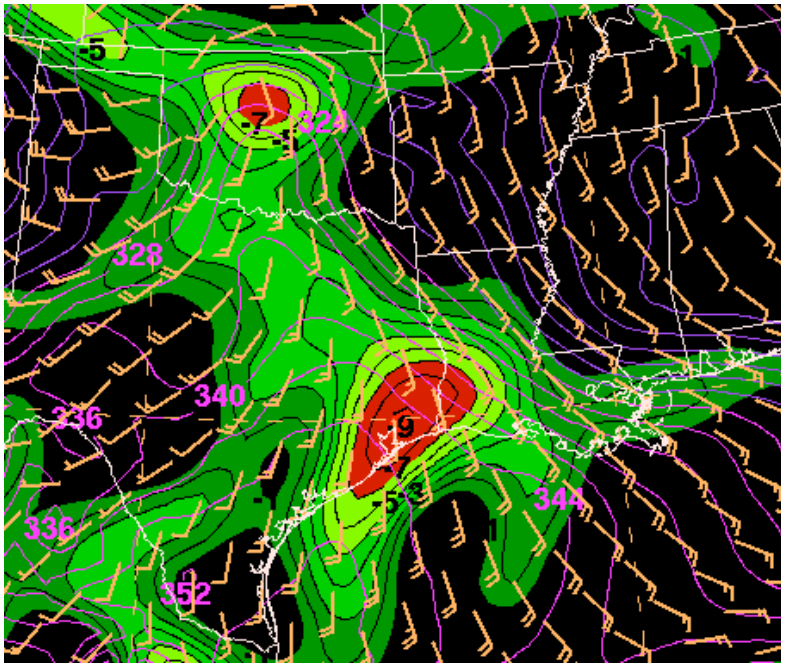


SREF members, eta members are red/yellow, rsm members are blue/purple and wrf members are green.

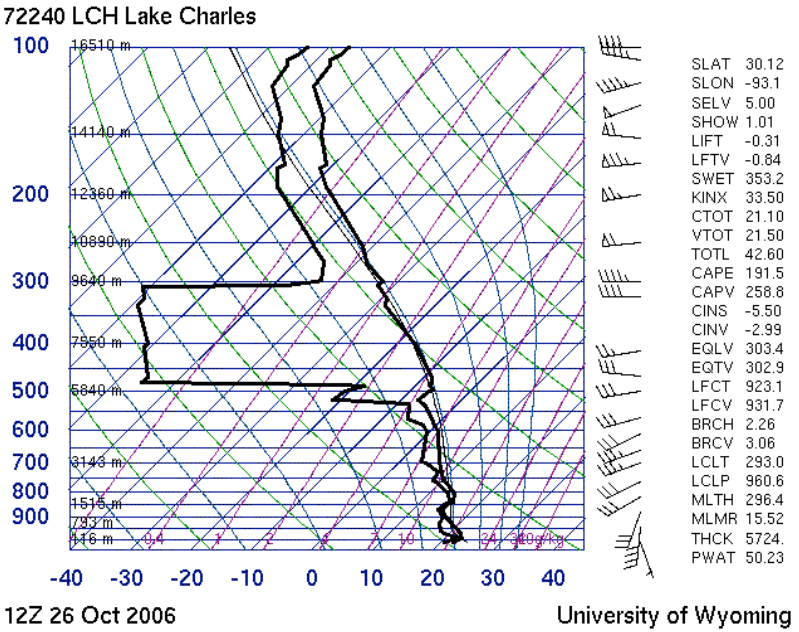


GEFS members, only initial conditions are perturbed.

Which model is more correct? Where is the biggest heavy rainfall threat?



12-hr NAM forecast of , boundary layer theta-e, winds and moisture convergence v.t. 1200 UTC 26 Oct. 2006. .

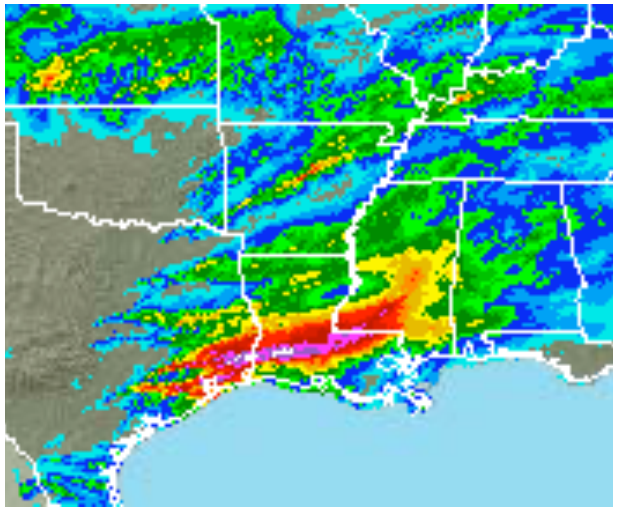


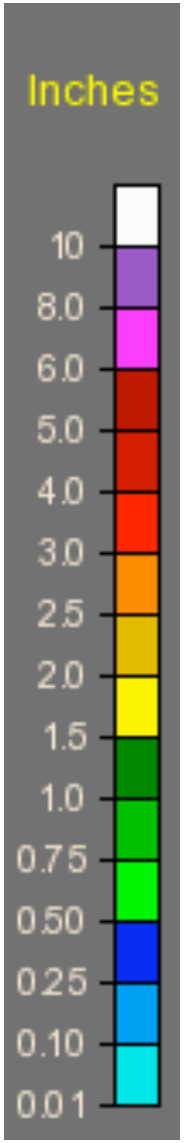
Observed sounding at 1200 UTC 26 Oct.

What do these two fields suggest about where the first convection will start and do they say suggest anything about propagation and precipitation efficiency.

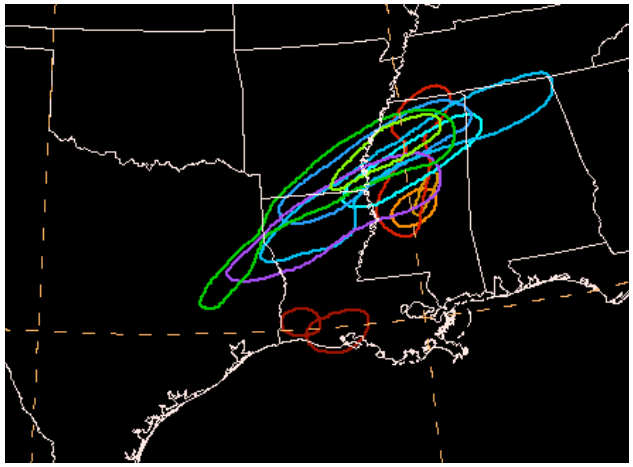
The bulk of the ensembles were too far north with their heavy rainfall axis. This is a common error, especially of the GEFS and it's babies. Also for K/F scheme members.

24 hr observed accumulated precipitation

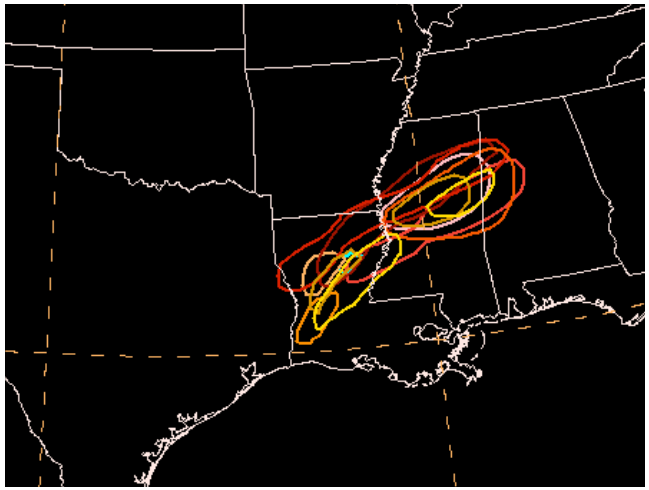




24 hr 3 inch spaghetti diagrams valid 1200 UTC 17 Oct. 2006

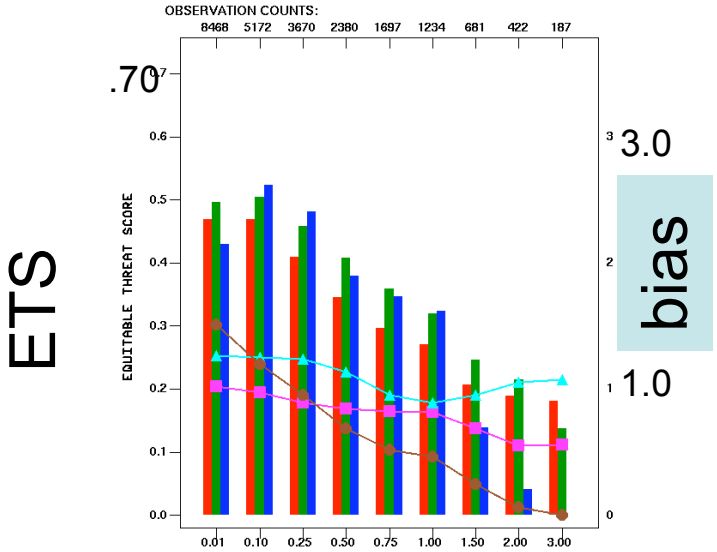


SREF members, eta members are red/yellow, rsm members are blue/purple and wrf members are green.

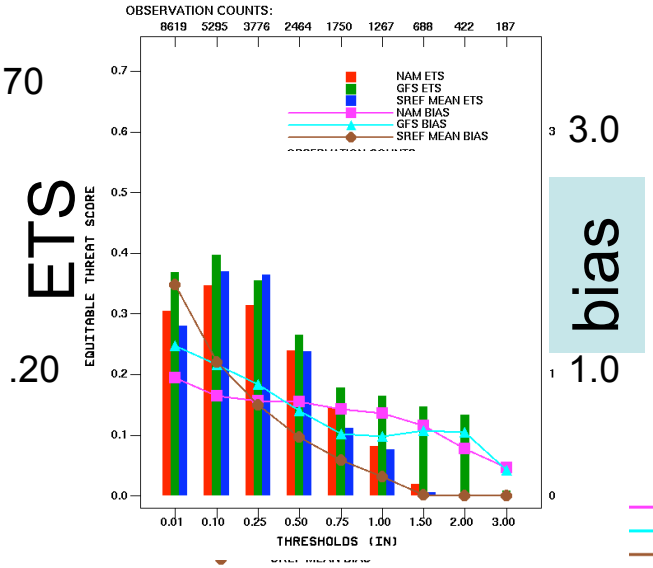


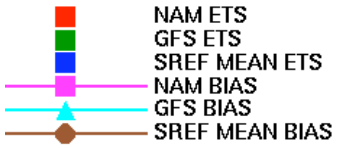
GEFS members, only initial conditions are perturbed.

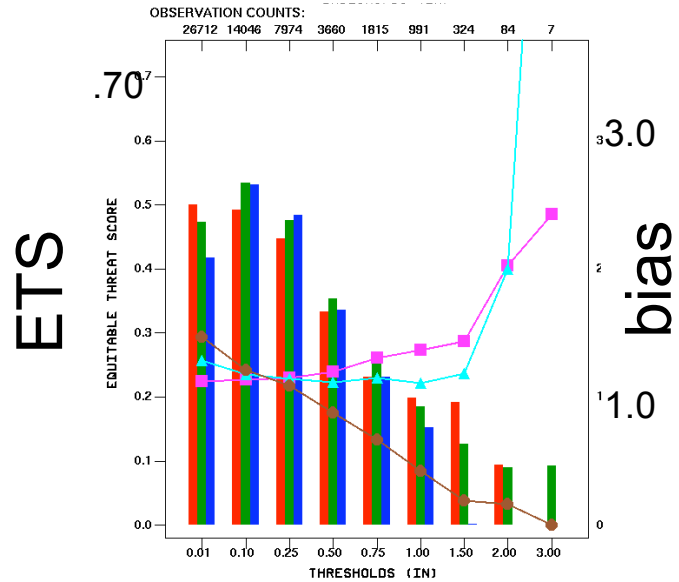
12-36 hr scores over Gulf Coast Region 3 month verification Sept-Nov



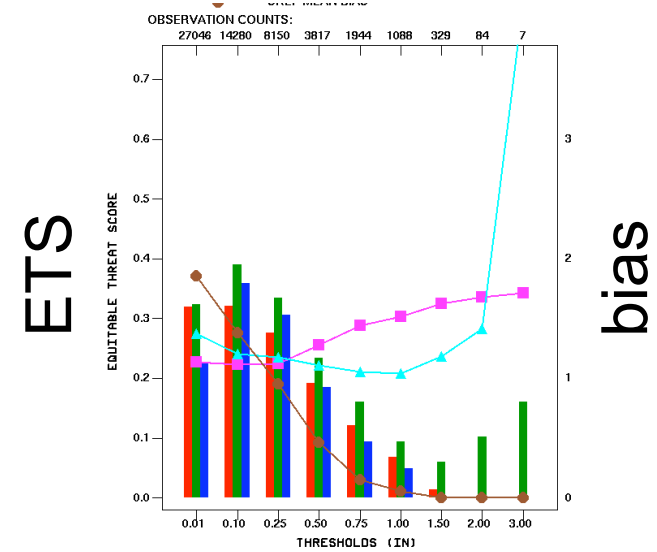
60-84 hr scores over Gulf Coast for Region for 3 month period Sept-Nov







12-36 hr scores over Midwest Region for Region for 3 month period Sept-Nov



60-84 hr scores over Midwest Region for Region for 3 month period Sept-Nov

Reforecast PQPF

Started working with Hamill and Whitaker in 2005

- Feb 2007-teleconference held with Hamill, Whitaker and Grumm to investigating whether using moisture flux would improve the analog PQPF.
  - Discussion included attempts to improve the forecasts and underprediction of the heavier thresholds.
  - H & W found that including moisture flux did not help forecasts,
  - Logistic regression did slightly improve PQPF for highest thresholds.

http://www.hpc.ncep.noaa.gov/research/mcs_web_test_test.htm

Table of contents

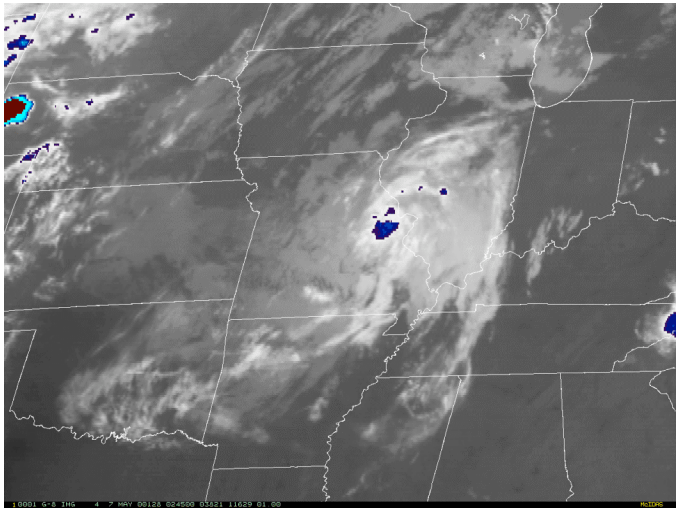
Multiple pages and links

T.S. Elena (1985), Erin and the Union MO flash flood.

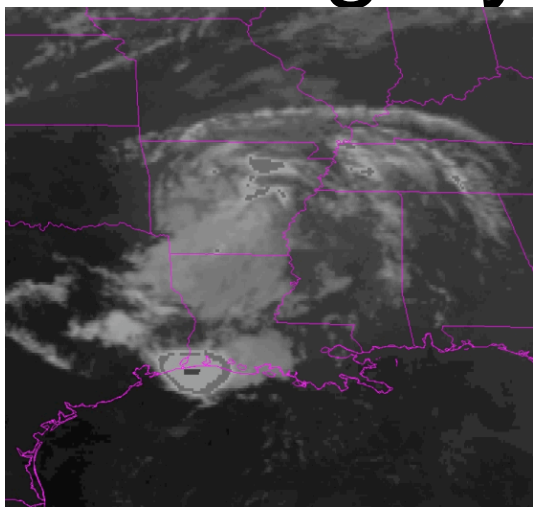
- Similarities
  - A strong low-level jet
  - Weak mid to upper-level shear
  - A mid level PV maximum
  - High relative humidity
    - A conditionally unstable air mass
    - A Moist absolutely unstable layer?
  - Max convection during night near the circulation center.

Are dynamics similar to those described by Raymond and Jiang (1990) and Trier et al. (2000)?

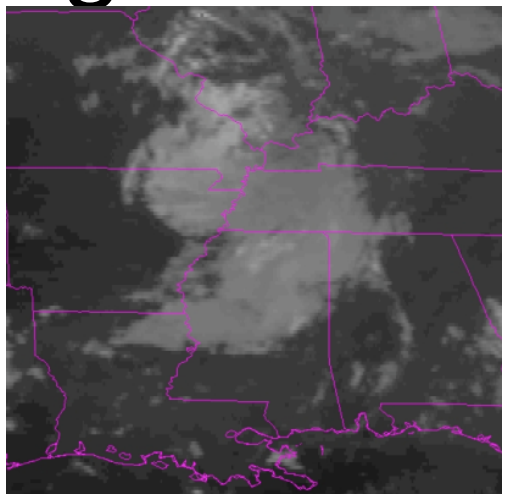
Similar satellite imagery signatures



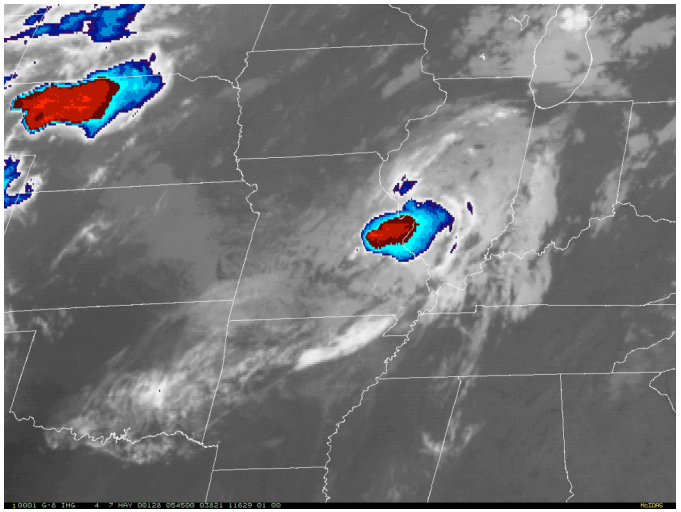
0215 UTC 7 May 2000



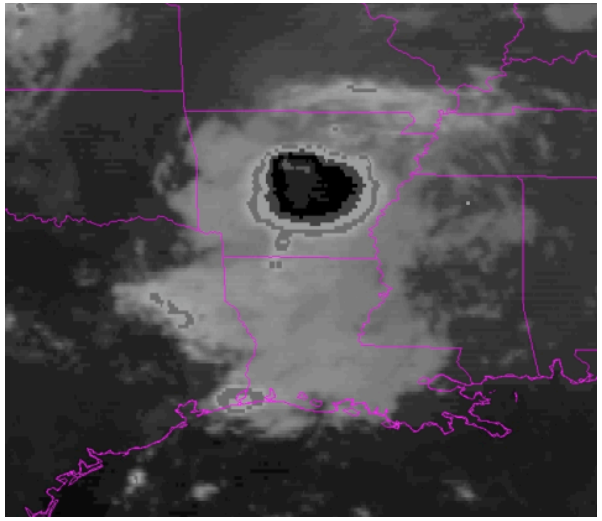
0415 UTC 4 Sept. 1985



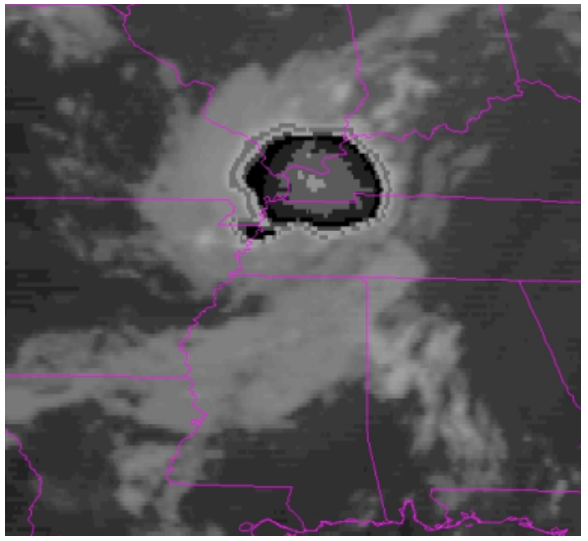
0415 UTC 5 Sept. 1985



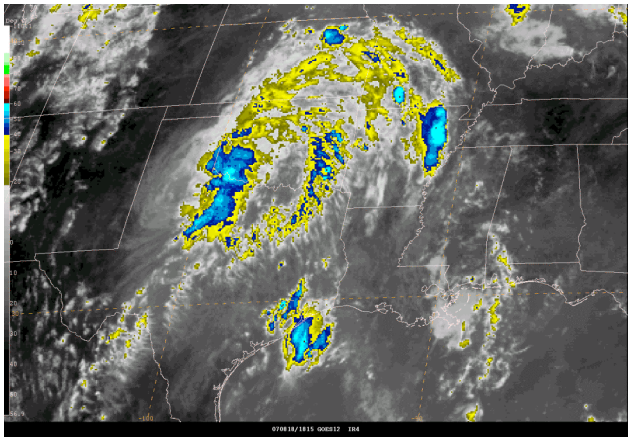
0545 UTC 7 may 2000



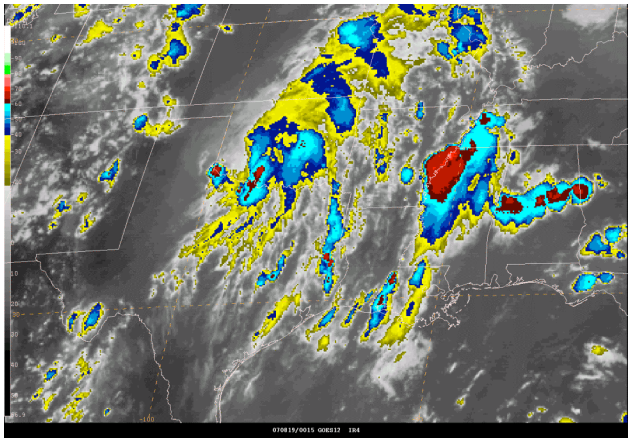
1015 UTC 4 Sept. 1985



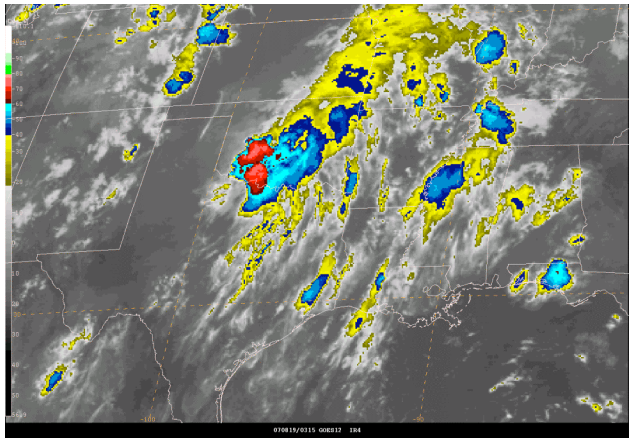
1015 UTC 5 Sept. 1985



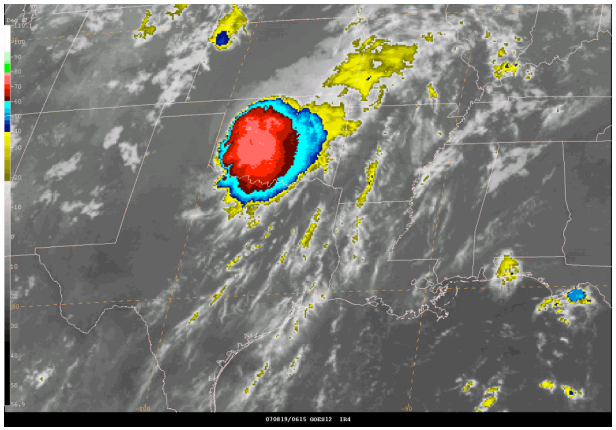
GOES IR imagery v.t. 18 UTC 18 August 2007



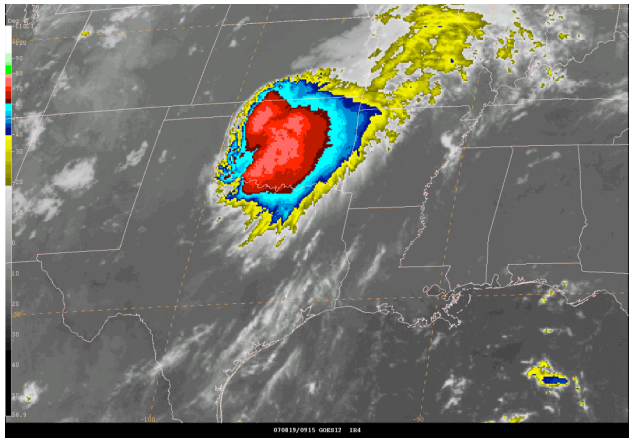
GOES IR imagery v.t. 00 UTC 19 August 2007



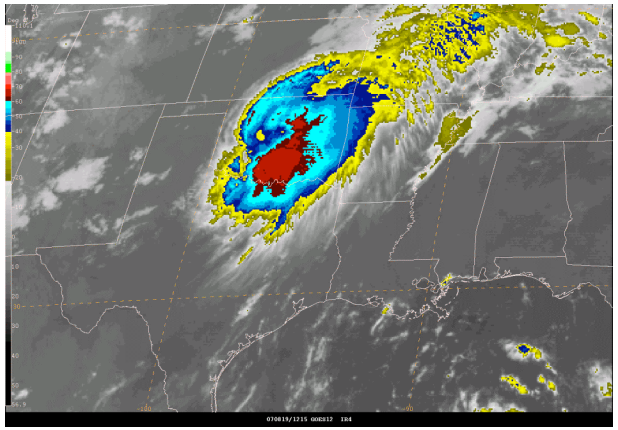
GOES IR imagery v.t. 03 UTC 19 August 2007



GOES IR imagery v.t. 06 UTC 19 August 2007



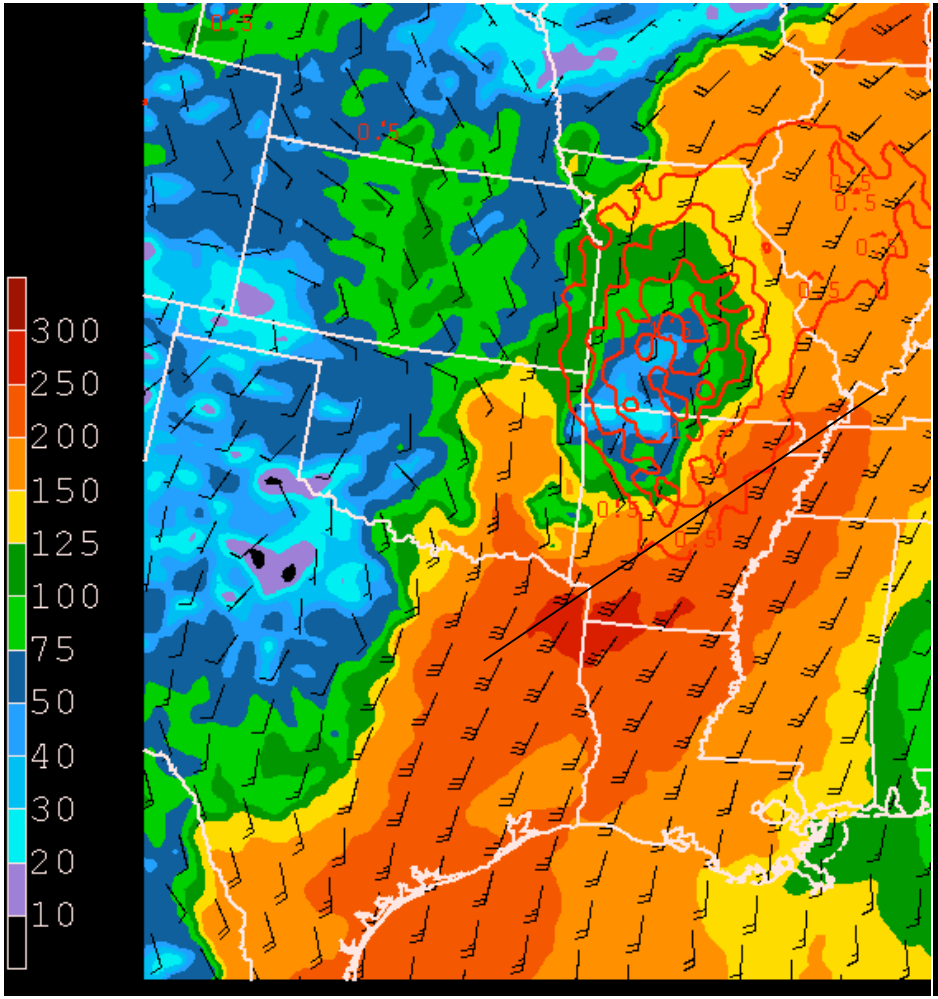
GOES IR imagery v.t. 09 UTC 19 August 2007



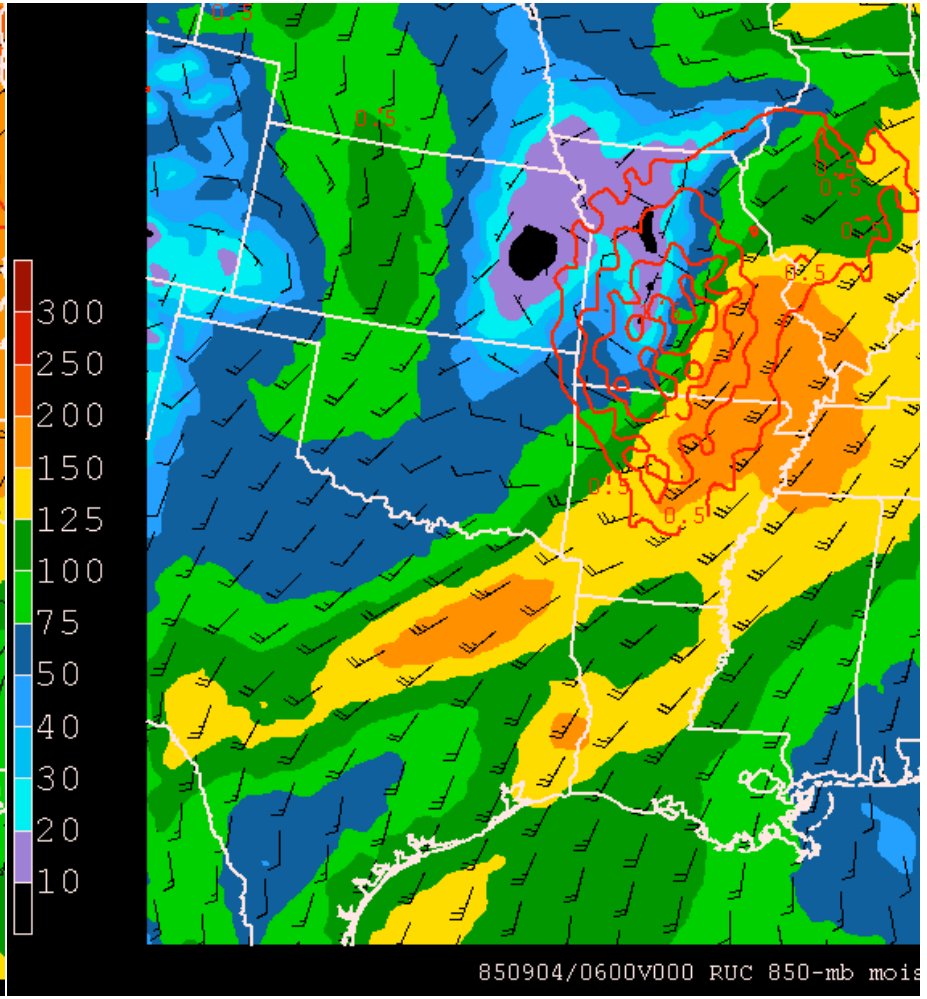
GOES IR imagery v.t. 12 UTC 19 August 2007

Maximum occurs coincident with low level jet.

NARR reanalysis Elena

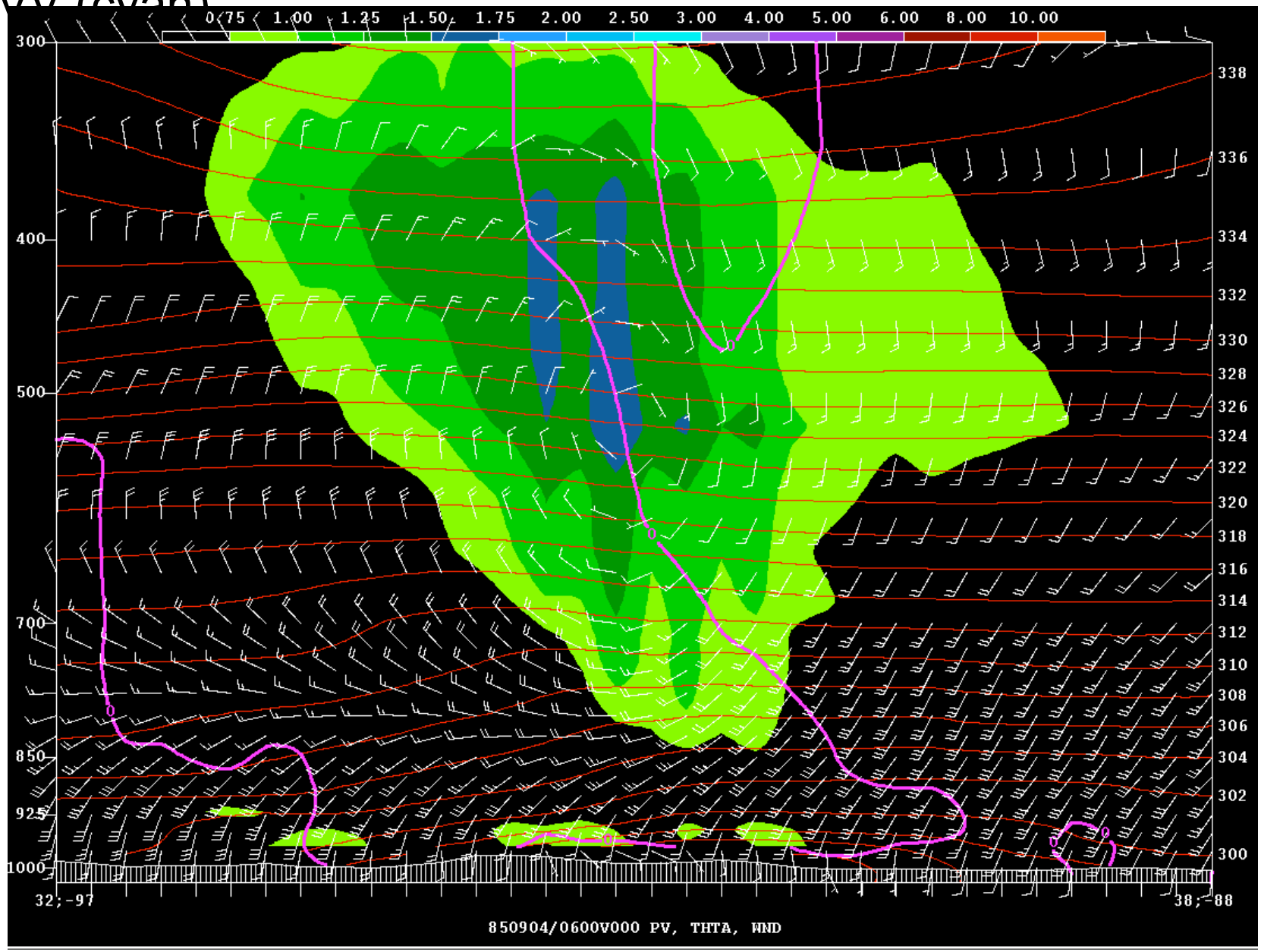


950-hPA MF, wind and 900-700 PV valid
0600 UTC Sept. 4, 1985



850-hPA MF, wind and 900-700 PV valid
0600 UTC Sept. 4, 1985

0600 UTC cross section, PV (color filled), winds, theta (red), UVV (cyan)



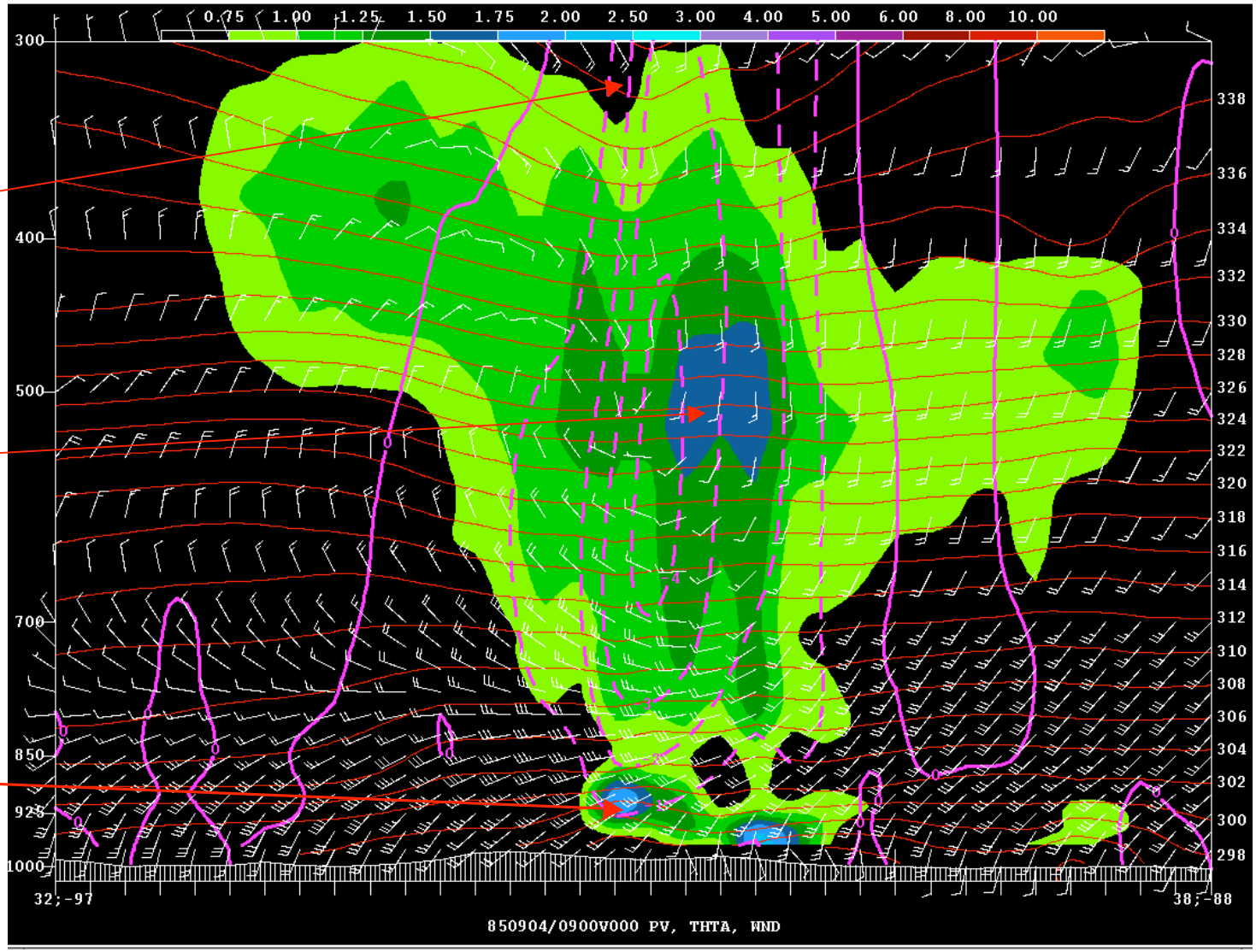
Alongstream

0900 UTC cross section, PV (color filled), winds, theta

PV min

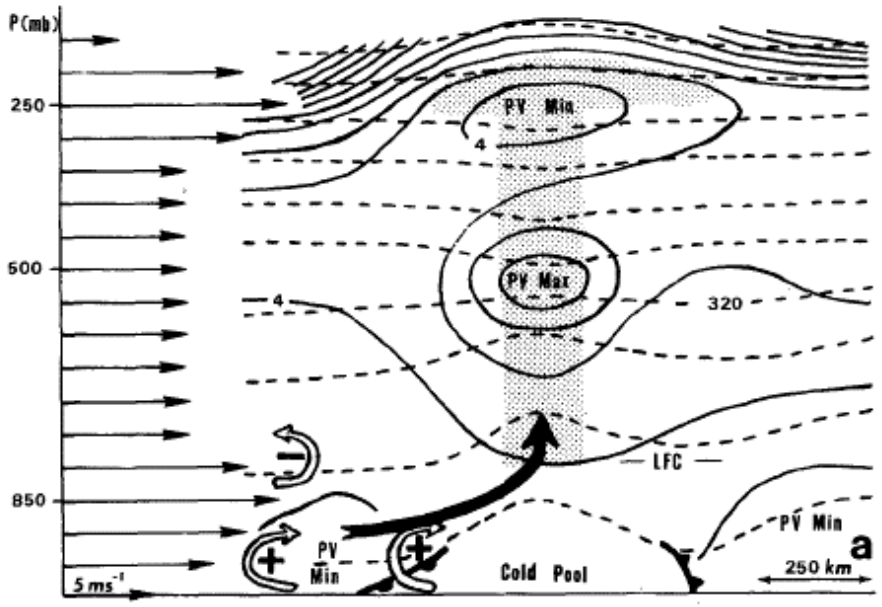
PV max

Cold pool



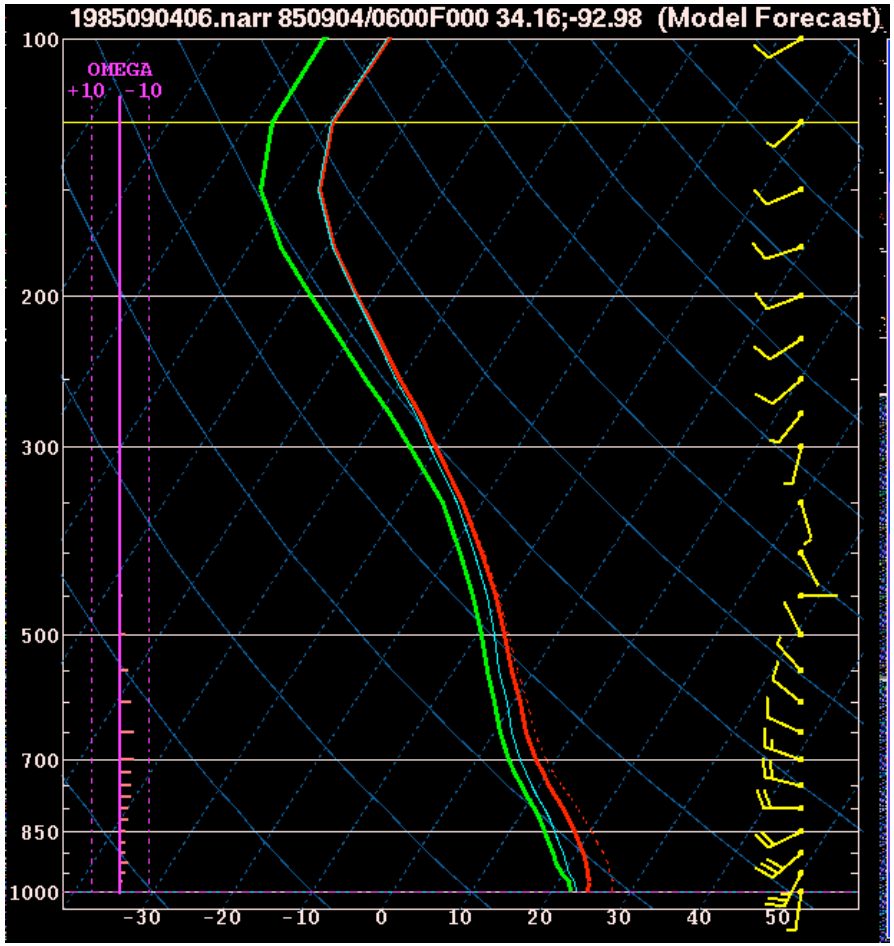
Note similarities with Fritsch et al (1994) figure

From Fritsch et al. 1994



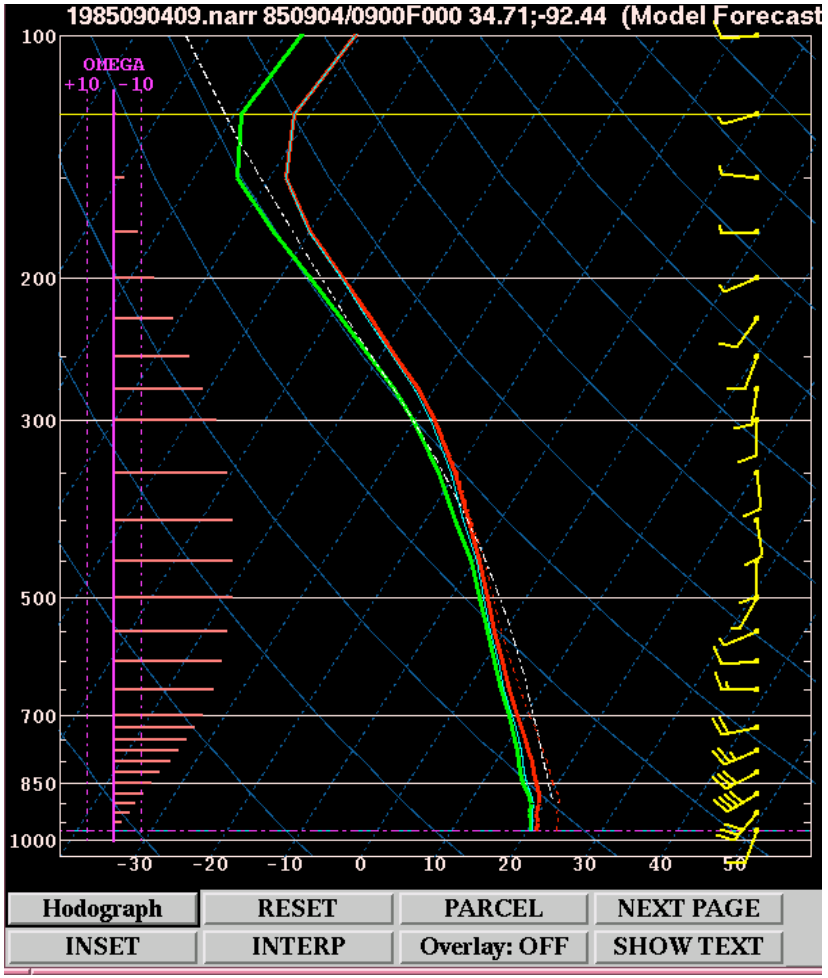
Conceptual model of MCV that is moving slow enough that air is overtaking the system due to a low-level jet to the west or southwest. The dashed lines are potential temperature, solid lines are potential vorticity. Note that where there is rain cooled air the isentropes bulge upward and where there is warming due to latent heat the potential temperature lines bulge downward. The positive PV anomaly is located where the potential temperature gradient is greatest between the two.

0600 UTC, conditionally unstable



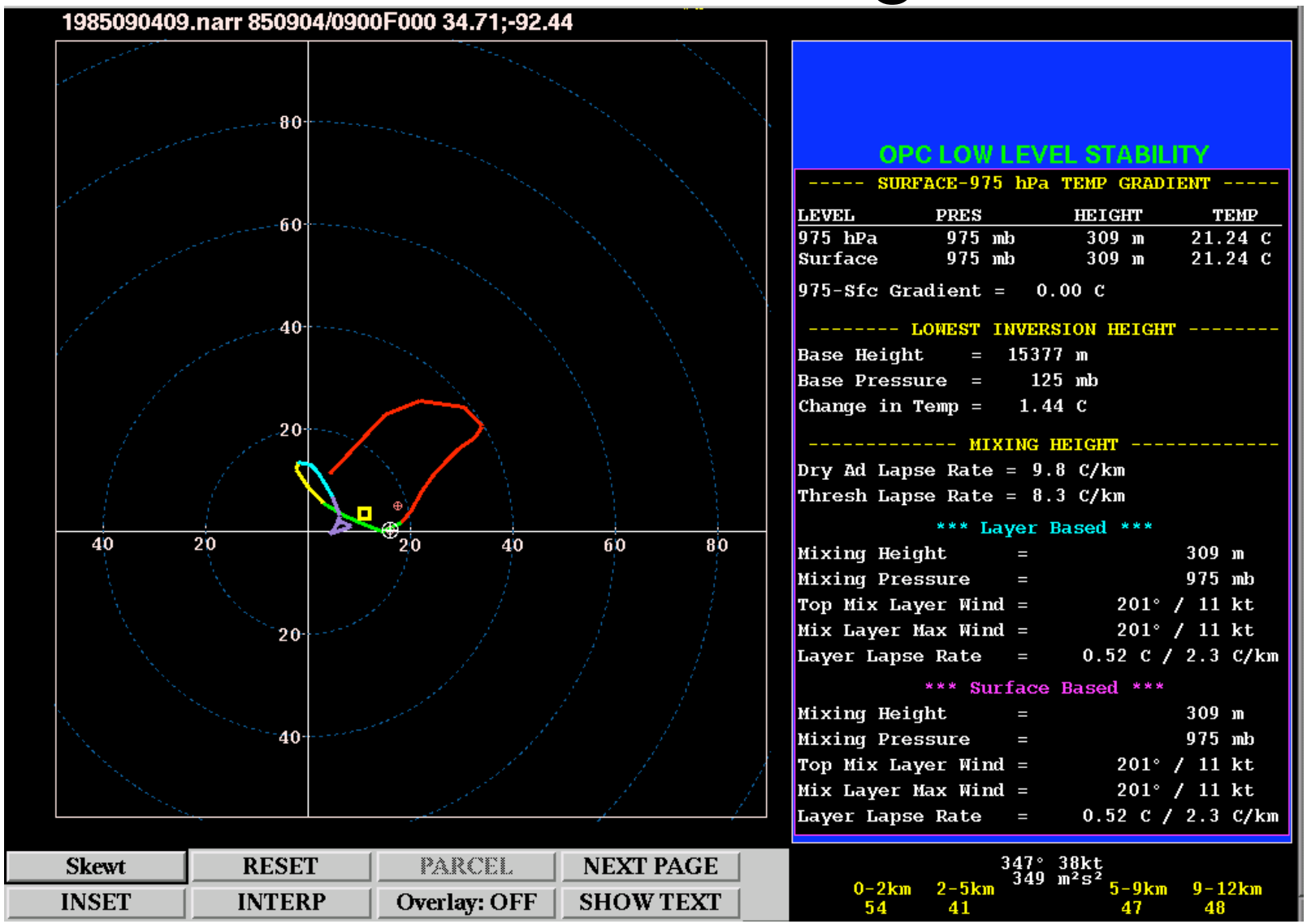
Mean RH 70%, Mean LRH 81%, PW=2.04”, Cape=914

0900 UTC saturated and neutral or unstable

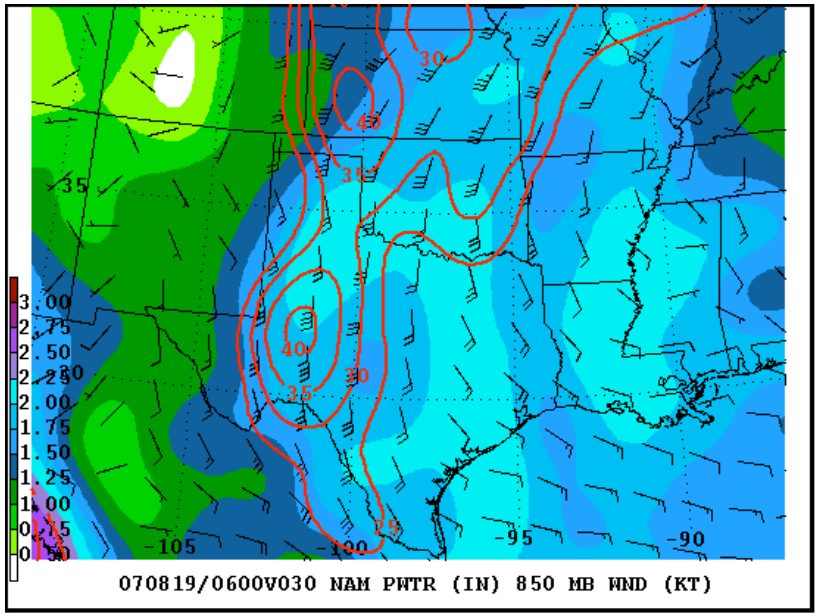


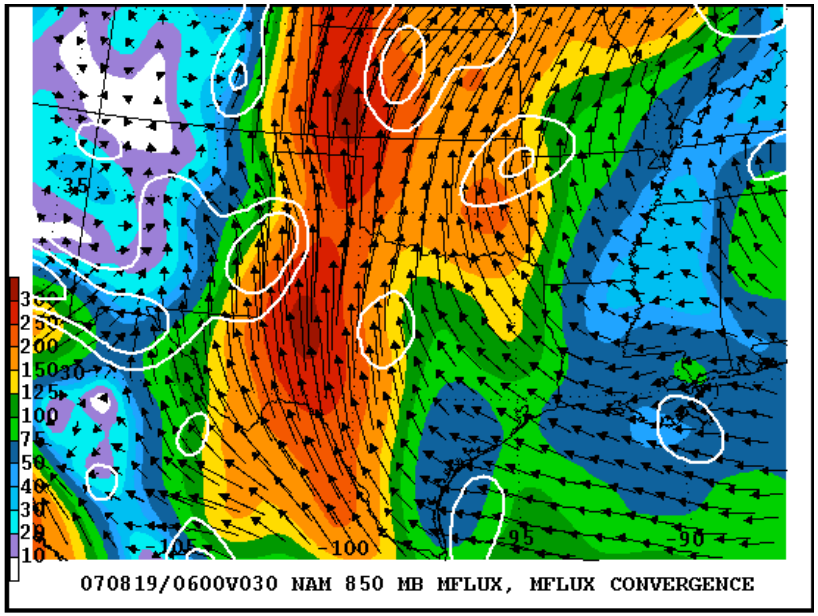
Mean RH 80%, LRH 92%, PW 2.16”, Cape 120 J/kg

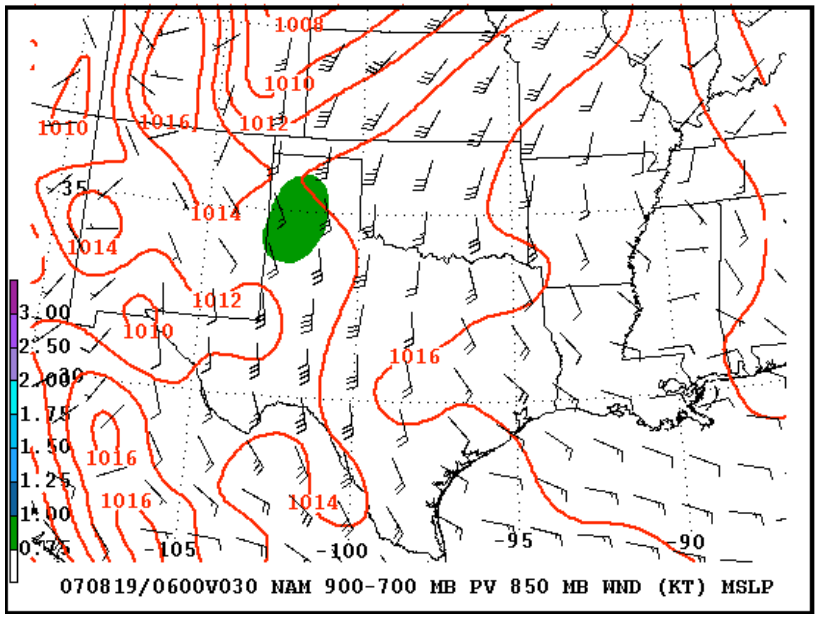
Hodograph shows a look of the top of a coat-hanger

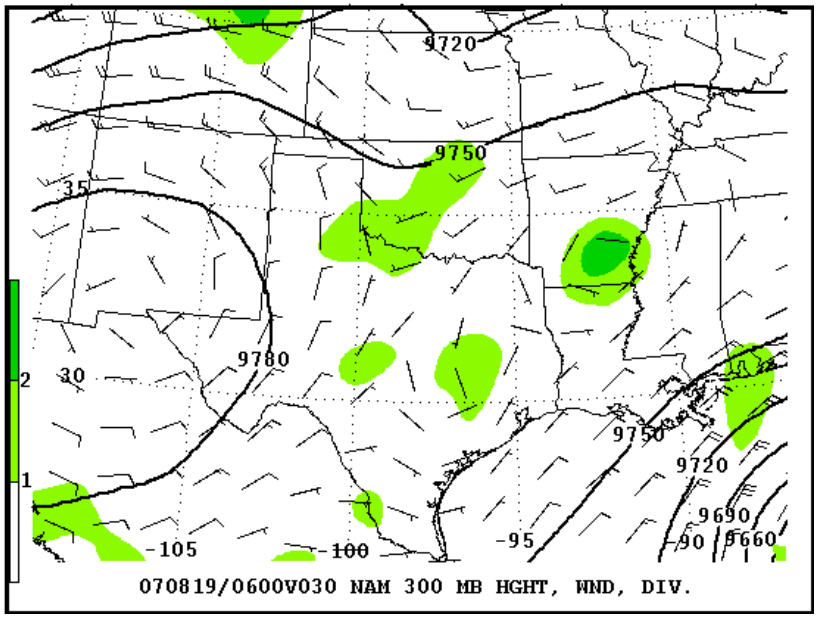


Now lets look at Erin

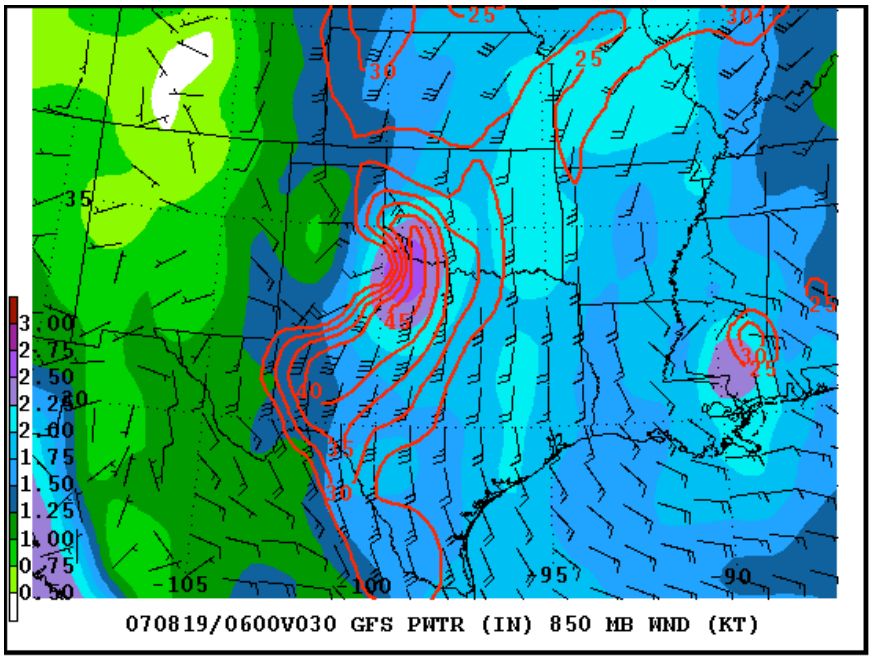


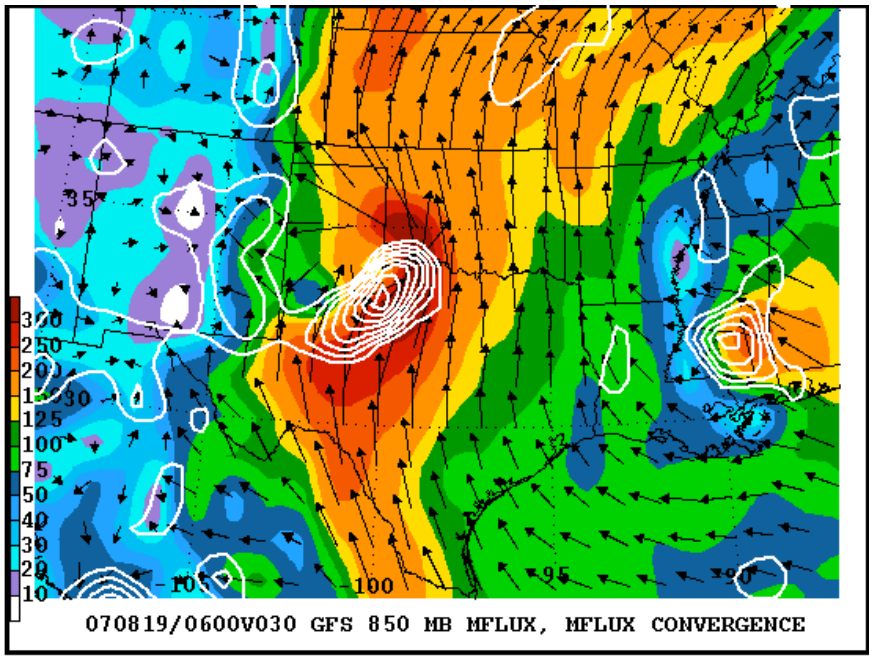


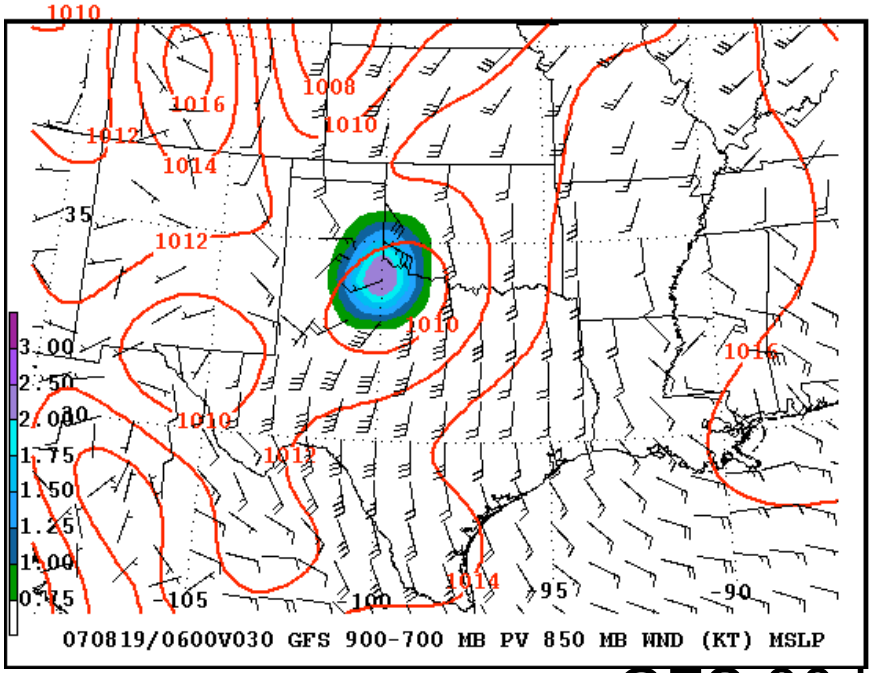


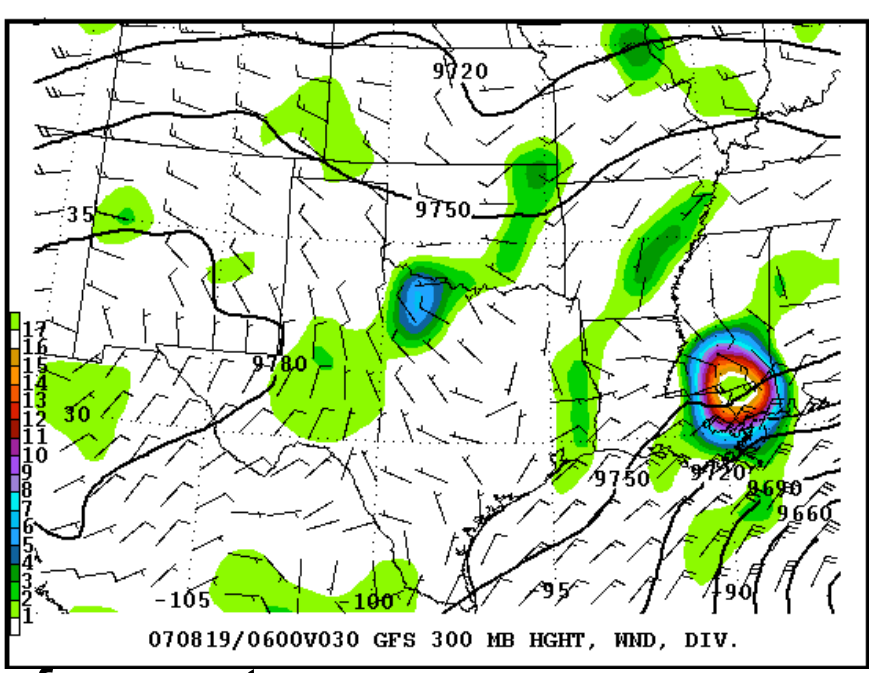


NAM 30 hr forecast

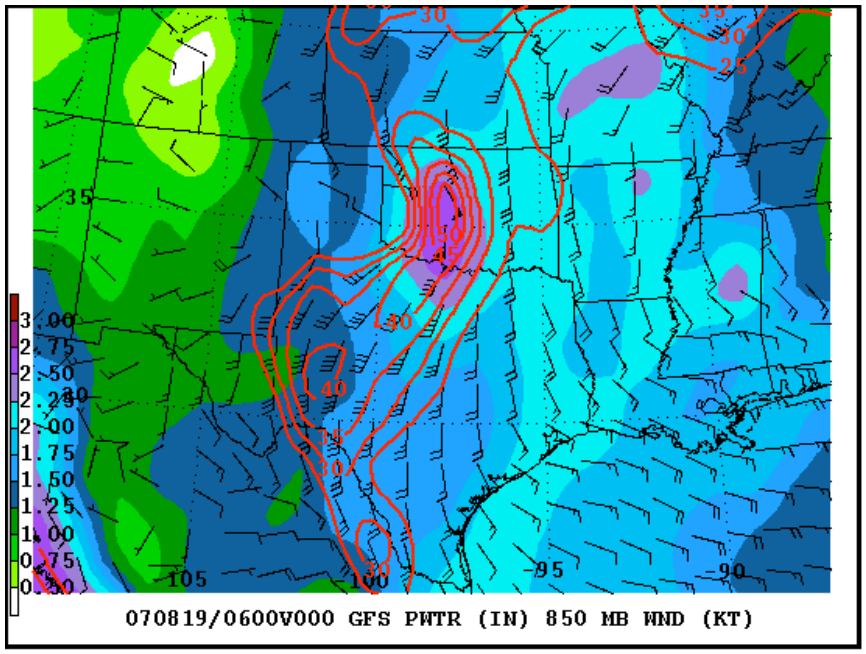


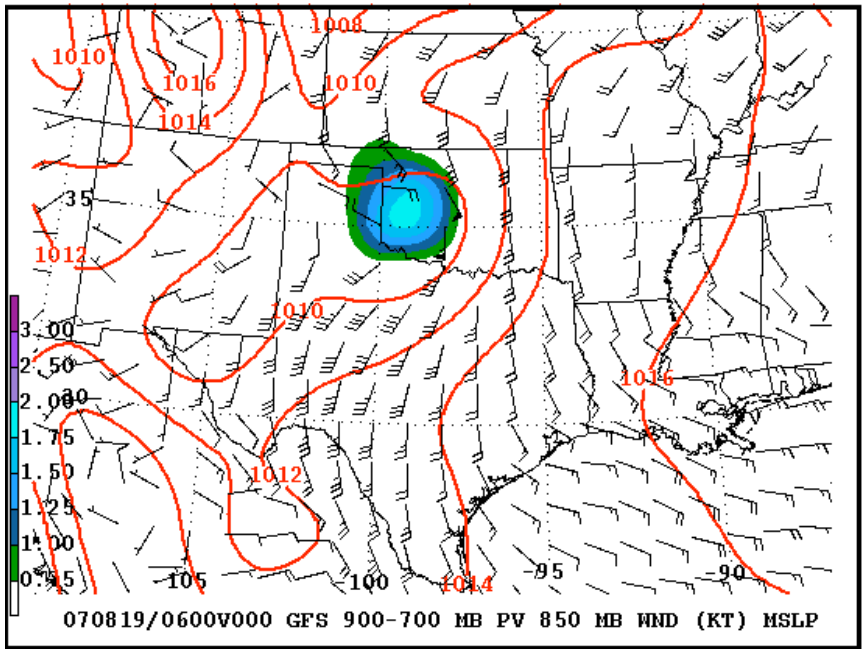




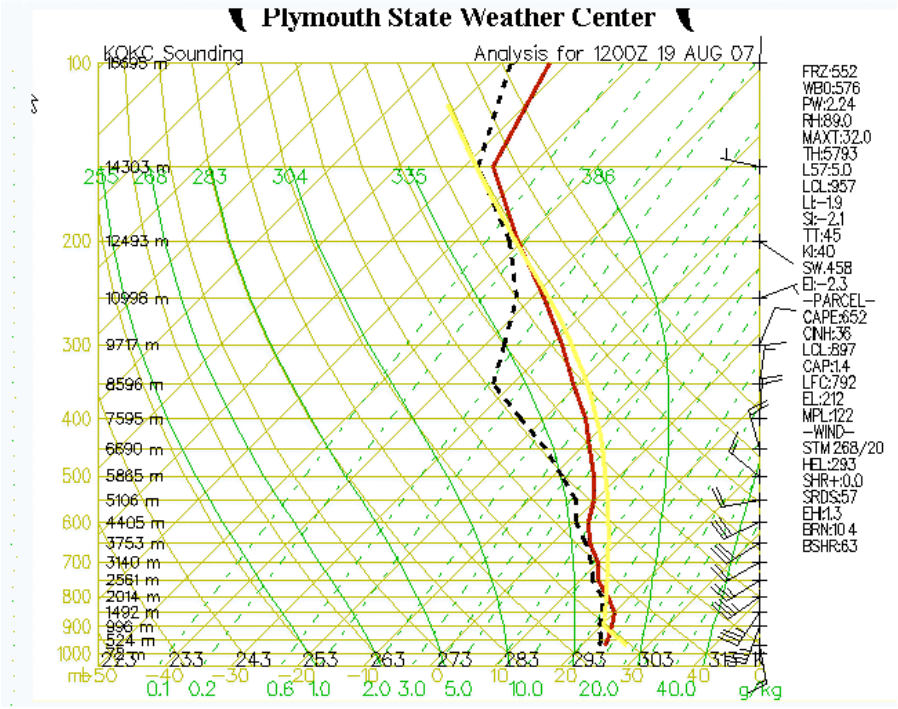


GFS 30 hr forecast



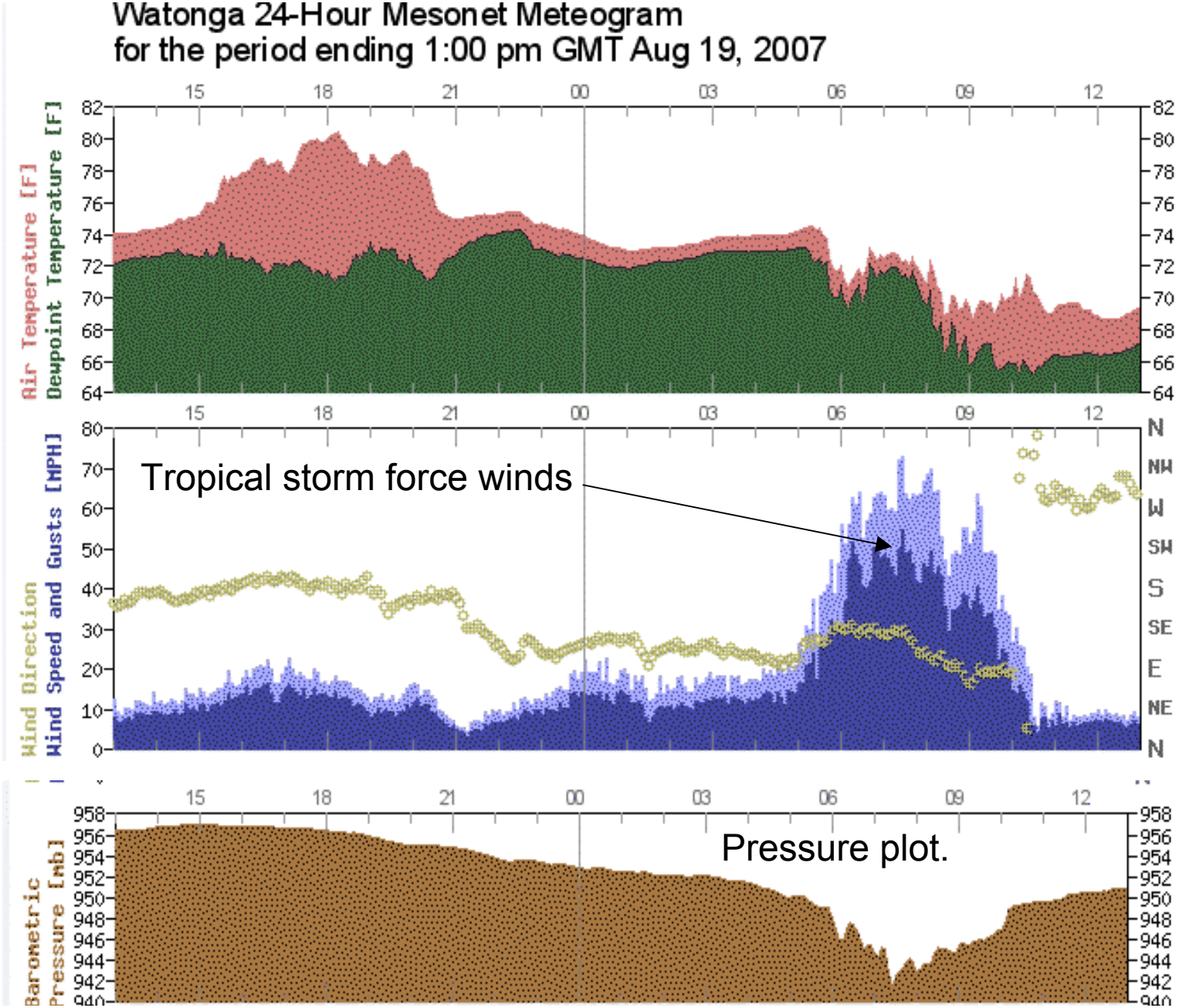


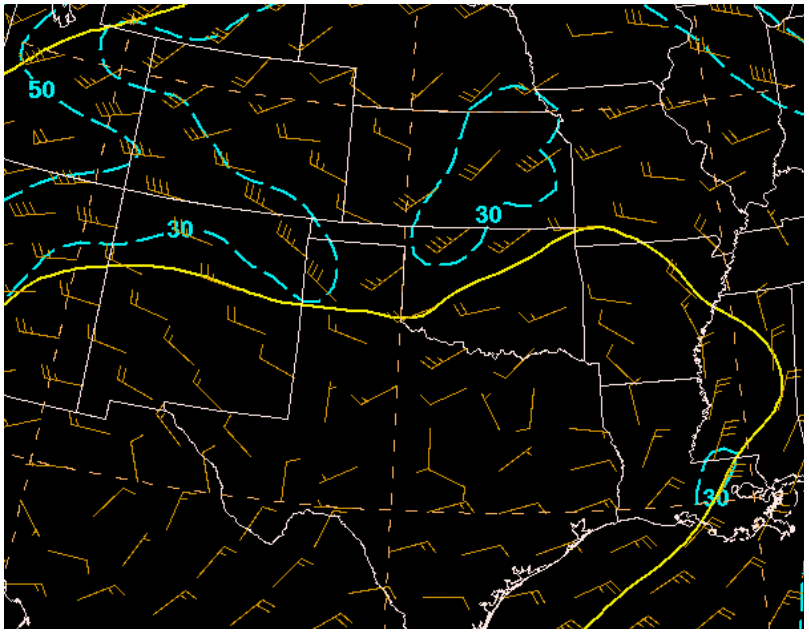
0600 UTC f00 GFS



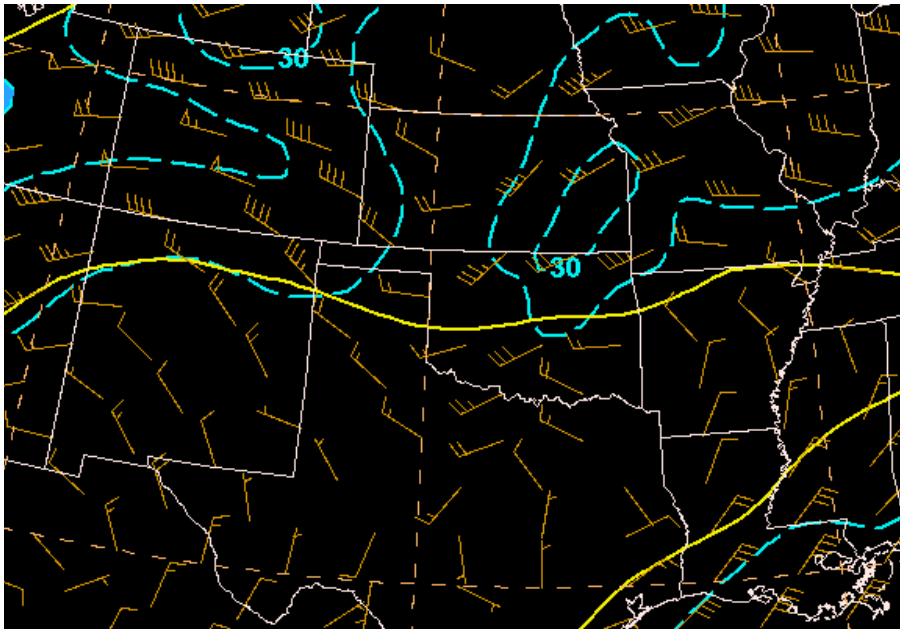
1200 UTC OKC sounding, note the MAUL

What are keys to redevelopment of convection during MCVs and decaying tropical storms?

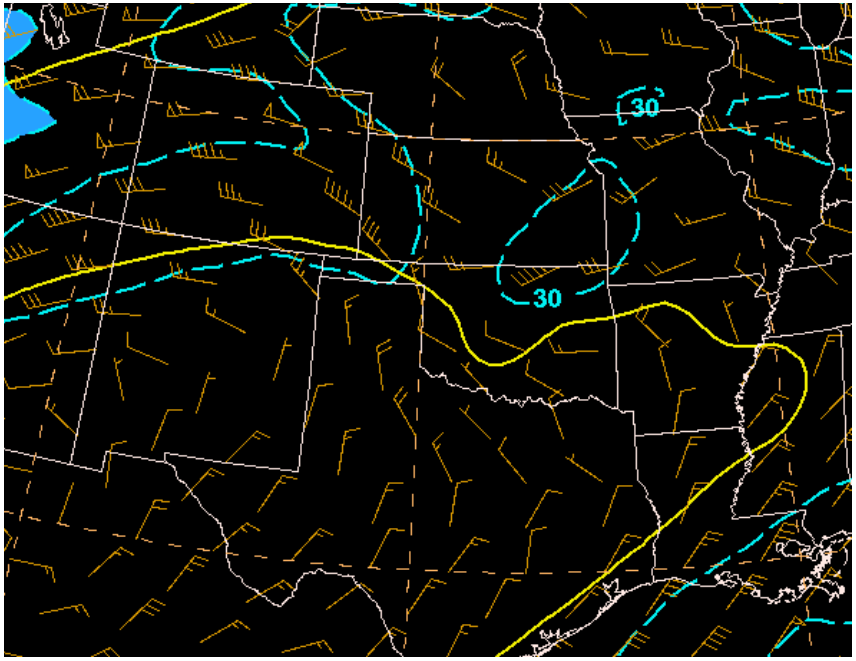

Watonga 24-Hour Mesonet Meteogram
for the period ending 1:00 pm GMT Aug 19, 2007
15
18
21
00
03
06
09
12
Air Temperature [F]
Dewpoint Temperature [F]
82
80
78
76
74
72
70
68
66
64
Wind Direction
Wind Speed and Gusts [MPH]
Tropical storm force winds
80
70
60
50
40
30
20
10
0
N
NW
W
SW
S
SE
E
NE
N
Barometric Pressure [mb]
Pressure plot.
958
956
954
952
950
948
946
944
942
940



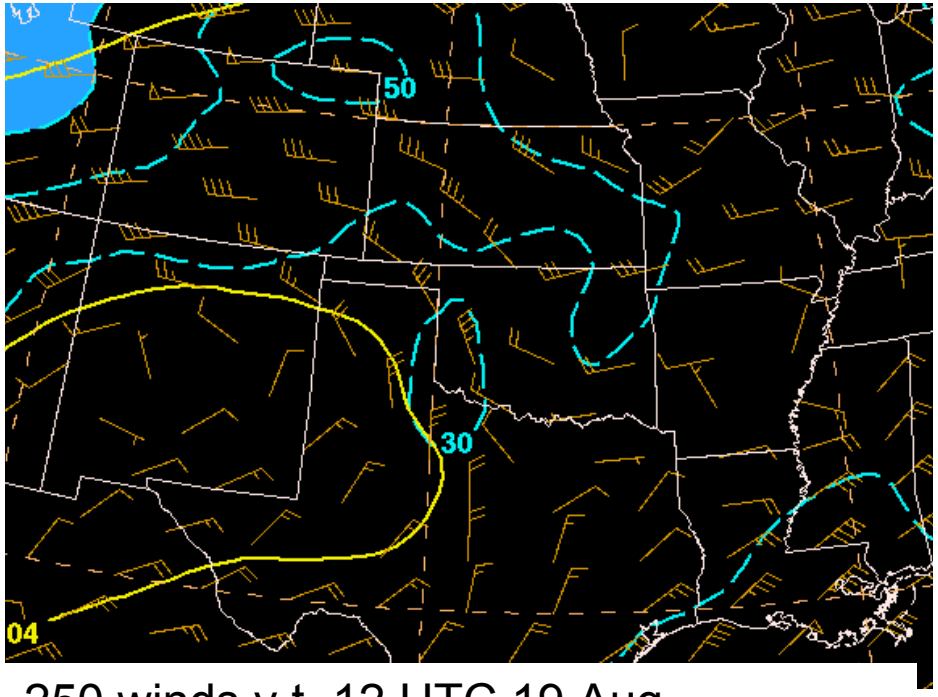
250 winds v.t. 18 UTC 18 Aug



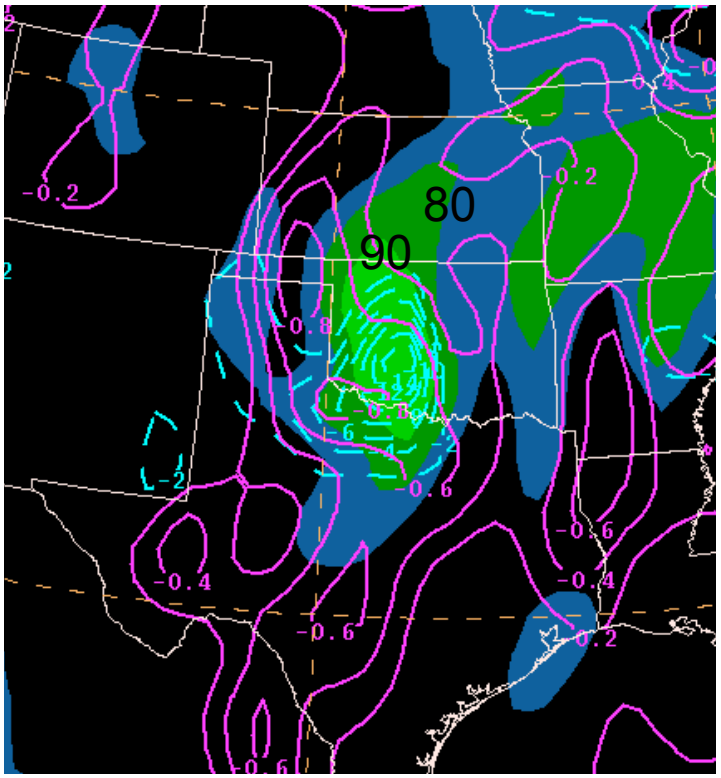
250 winds v.t. 00 UTC 19 Aug



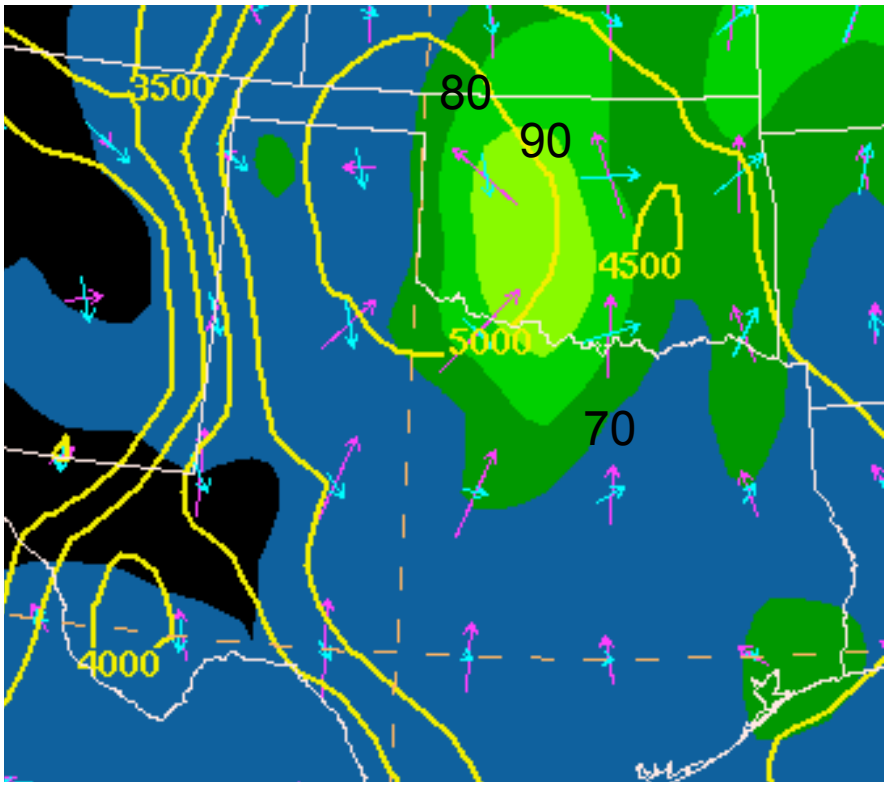
250 winds v.t. 06 UTC 19 Aug



250 winds v.t. 12 UTC 19 Aug



GFS f00 relative humidity, vertical motion (cyan, dashed), and saturated EPV valid 0600 UTC 19 Aug 2007



GFS f00 relative humidity, warm layer depth (m),850 wind (magenta), 400 wind (cyan) valid 0600 UTC 19 Aug 2007

Would these graphics be useful during an event or prior to an event? They show instability, high RH, and give idea of the shear profile.

Continuing efforts

- Look into how MCS/MCV QPF might be improved.
- Continue to work on Tropical cyclone QPF problem.
  - Cyclone phase diagrams
- Need better ensemble guidance training on how best to use it.
- Will continue to work on training manual

For HMT

- Continue working with Rich Grumm on "fingerprinting" extreme events
  - Need to get forecasters involved in the research
- Look for opportunities to extend HMT efforts into eastern U.S. and summer season.