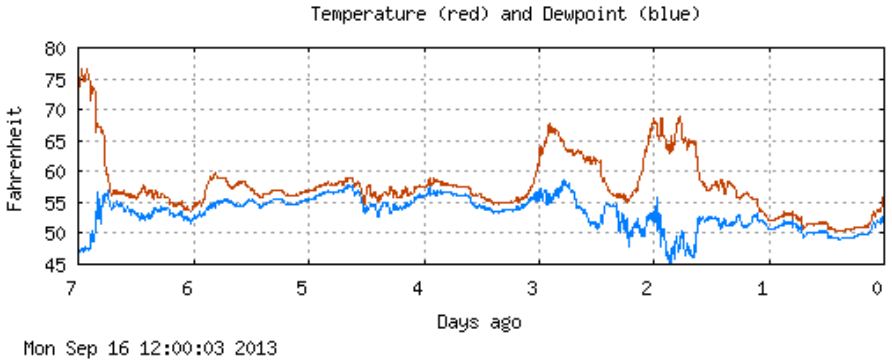
# The Great Colorado flood of 9-16 Sep 2013

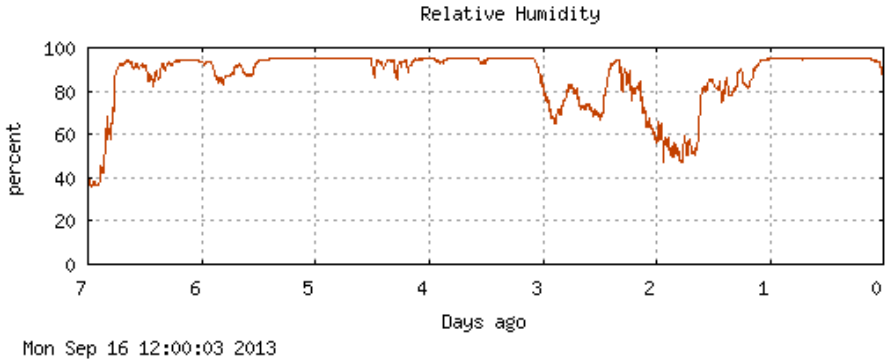
- What is in this presentation
  - Overview of the event
    - Some Precip plots, plus items from many emails
    - Look at mon-thu 9-12 Sep 500 mb and Sfc and radar/satellite overview
  - Model forecasts – borrowed from NCEP and CSU and other ppts
    - Longer range – trend was apparent for a wet week
    - Mid to shorter range – but what was with the 12z/11 Sep runs?
    - Hi-res models, etc. – a mixed bag of results
  - Focus on the first big period late on 11 Sep into 12 Sep
    - What seemed to occur to lock in precip into the foothlls/Front Range the night of 11 Sep
    - And how the models handled this

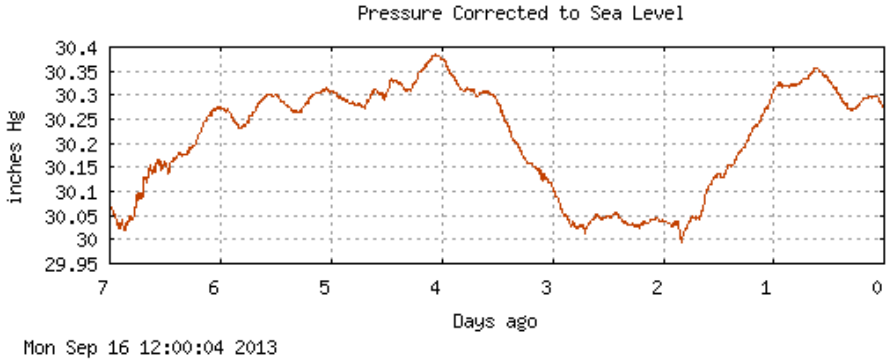
# The Great Colorado flood of 9-16 Sep 2013

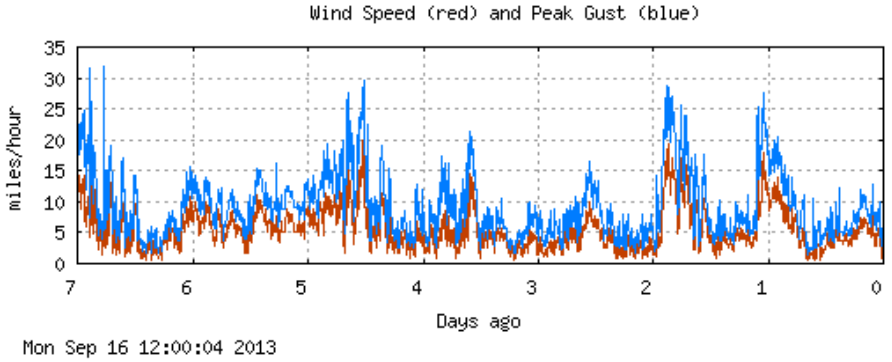
- Websites of interest
  - http://www.esrl.noaa.gov/psd/boulder/flood2013/precipplots/ - has AHPS daily analyses CO to NM and also summary of precipitation totals for entire period
  - http://www.esrl.noaa.gov/psd/boulder/flood2013/ - ESRL site with variety of information
  - Other sites....

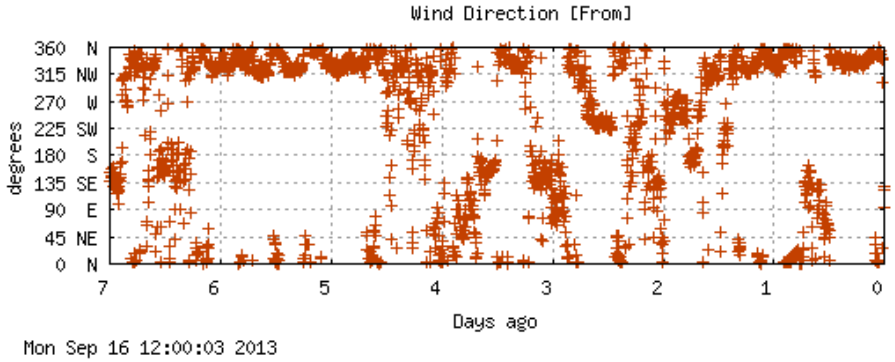
# The Great Colorado flood of 9-16 Sep 2013

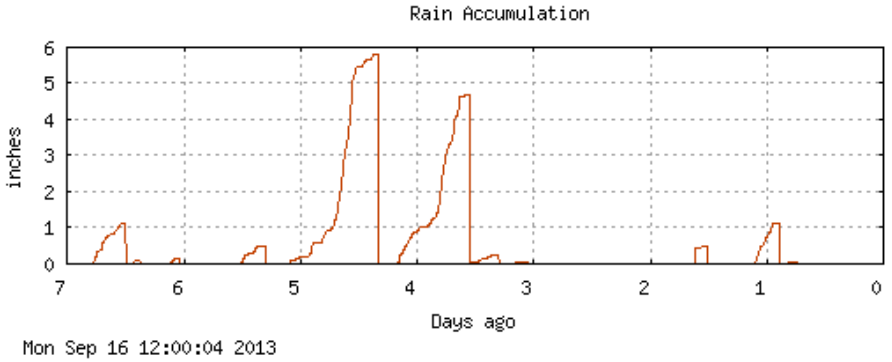


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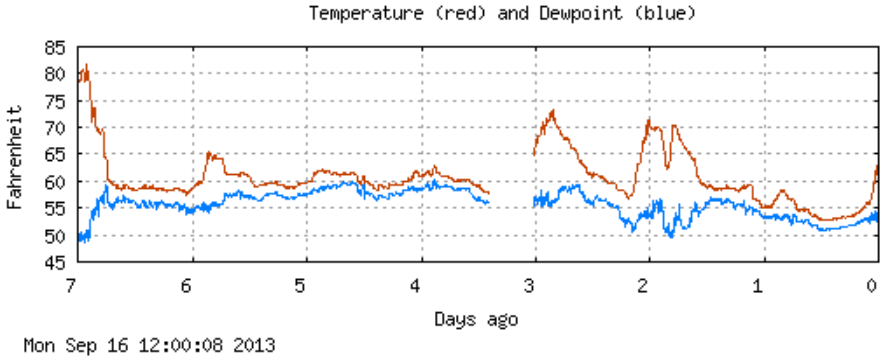
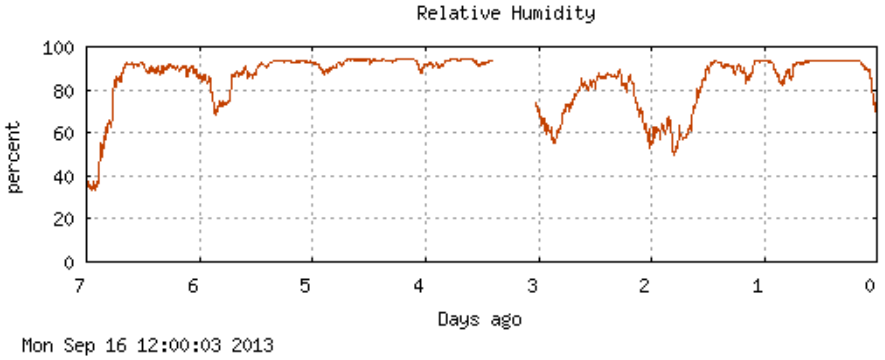



Mon Sep 16 12:00:08 2013

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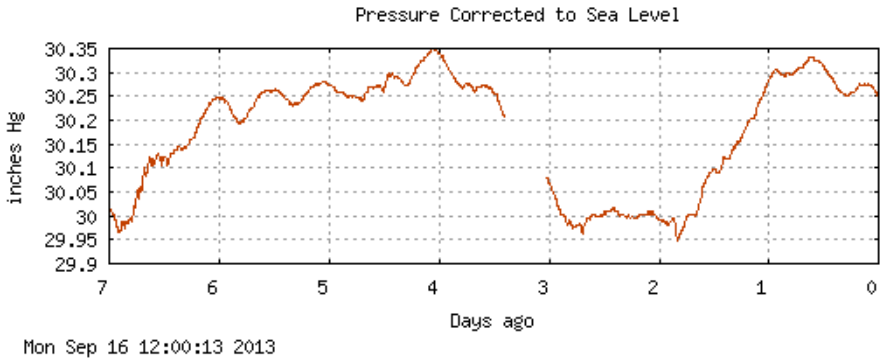


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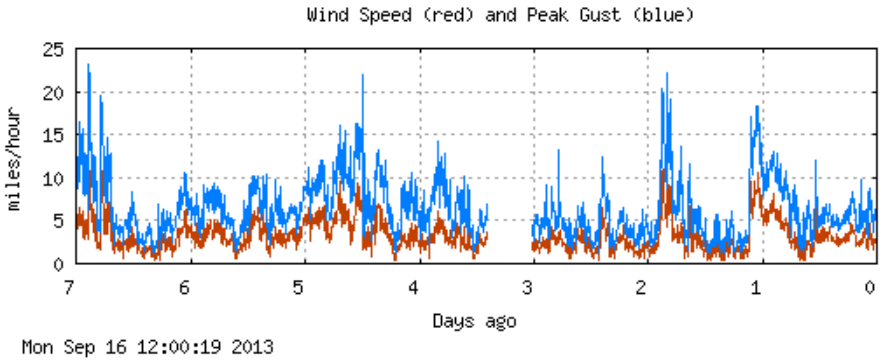


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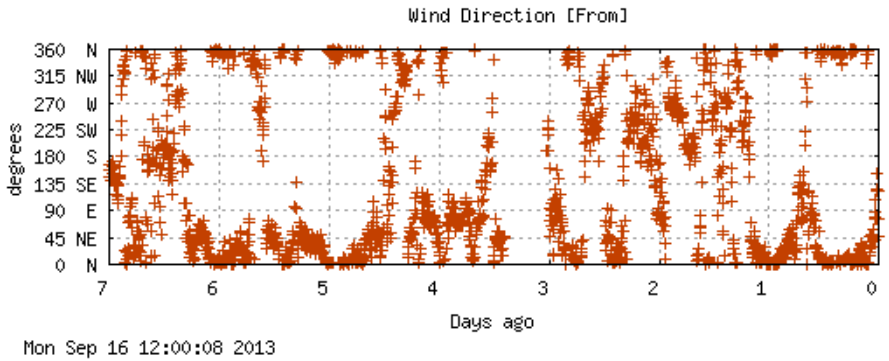


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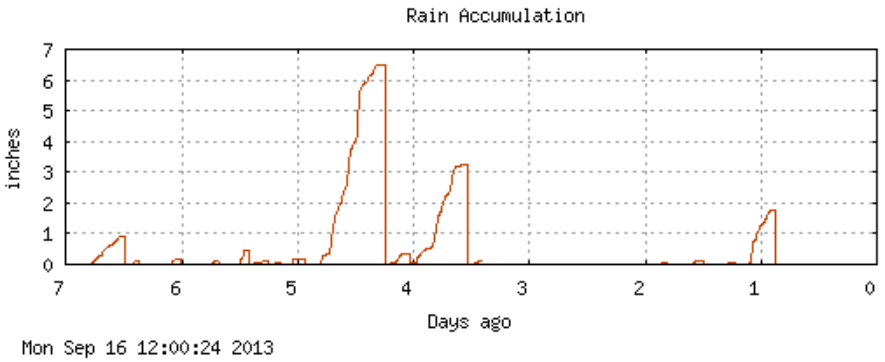


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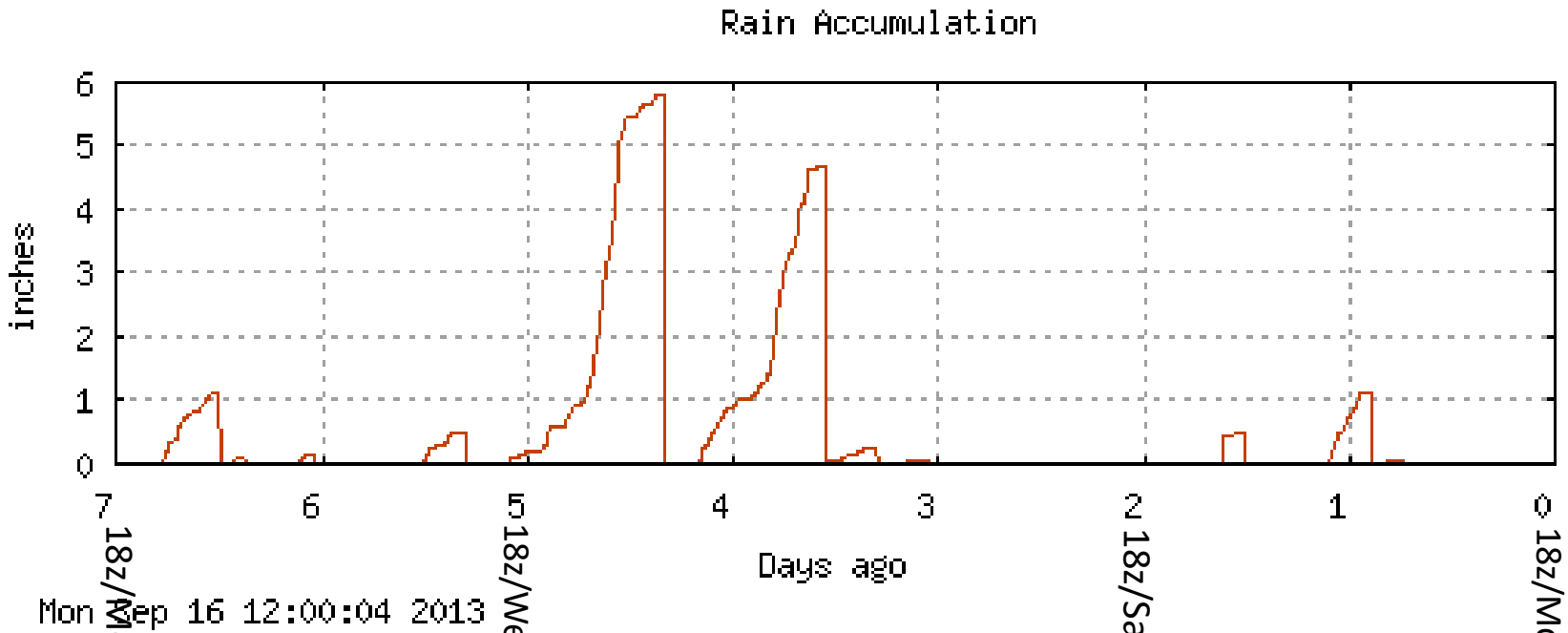
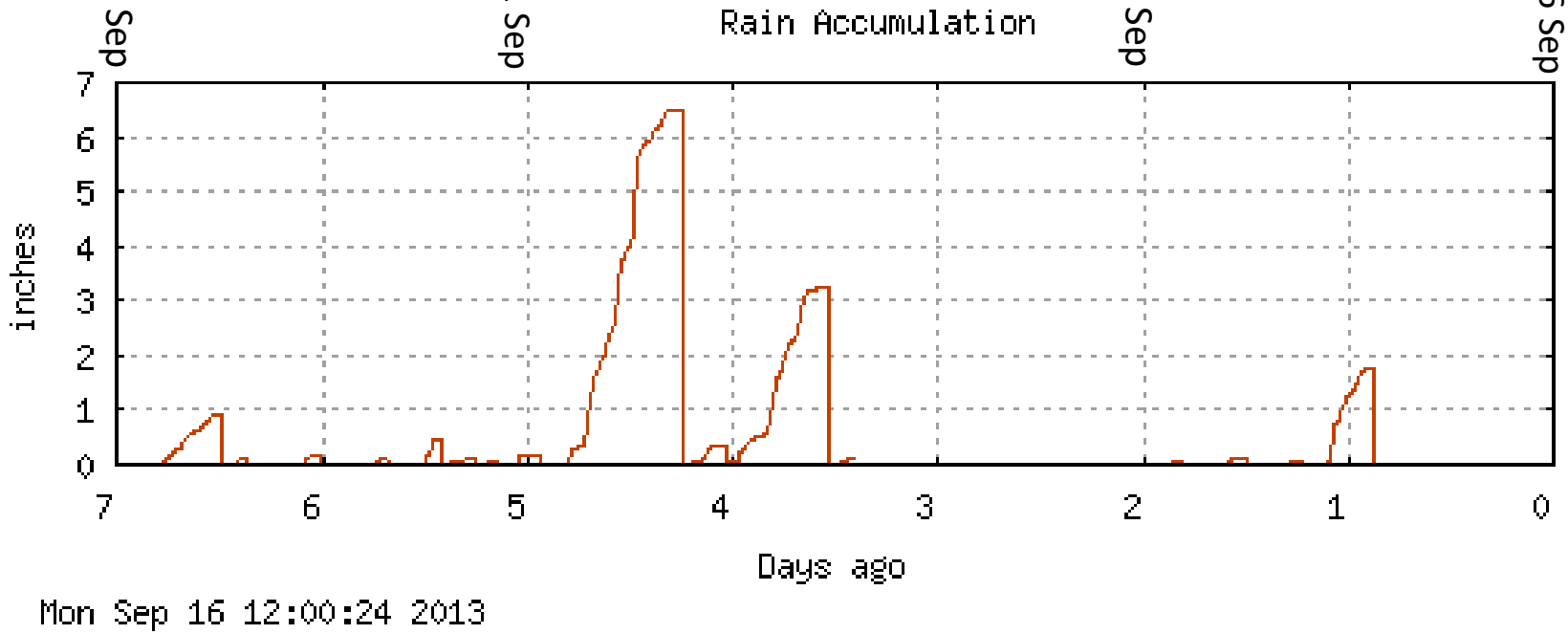
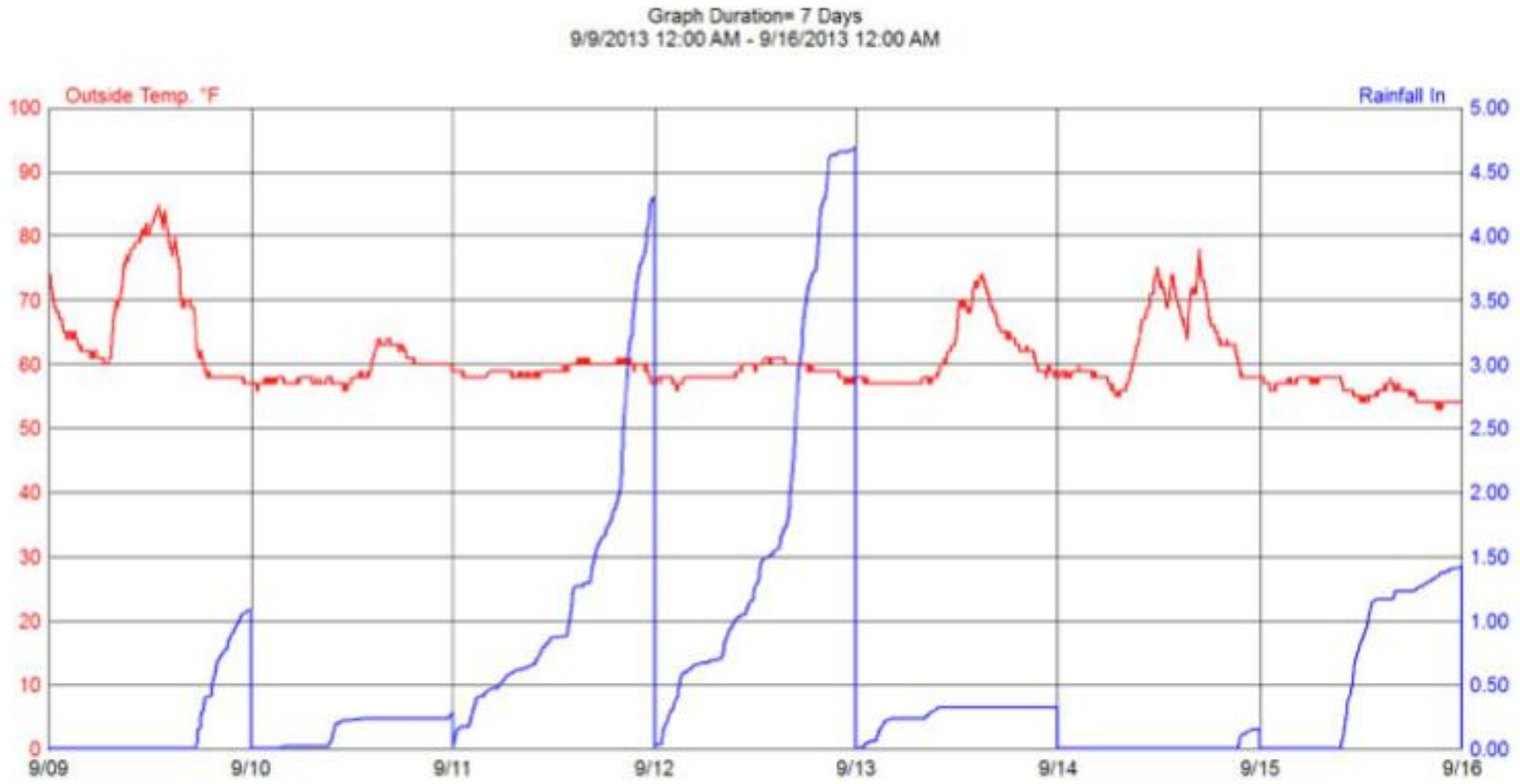



Foothills Lab




Mesa Lab

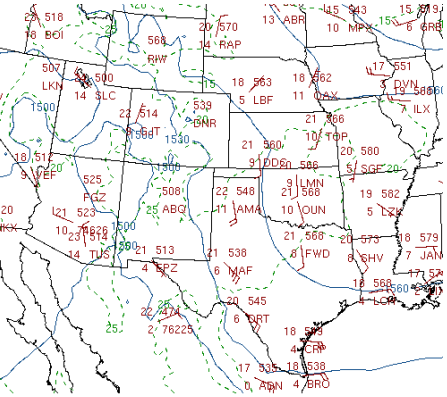
# The Great Colorado flood of 9-16 Sep 2013



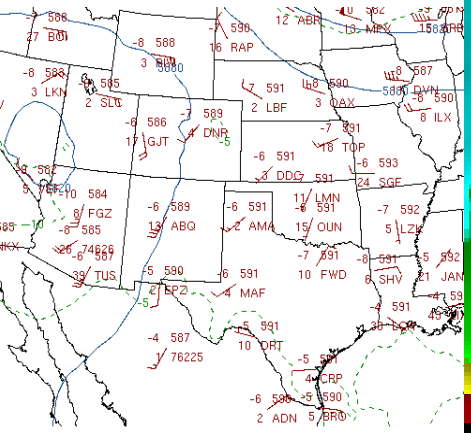

Colorado 100 Year Flood Cumulative Daily Rain Totals South Boulder Shanahan Ridge

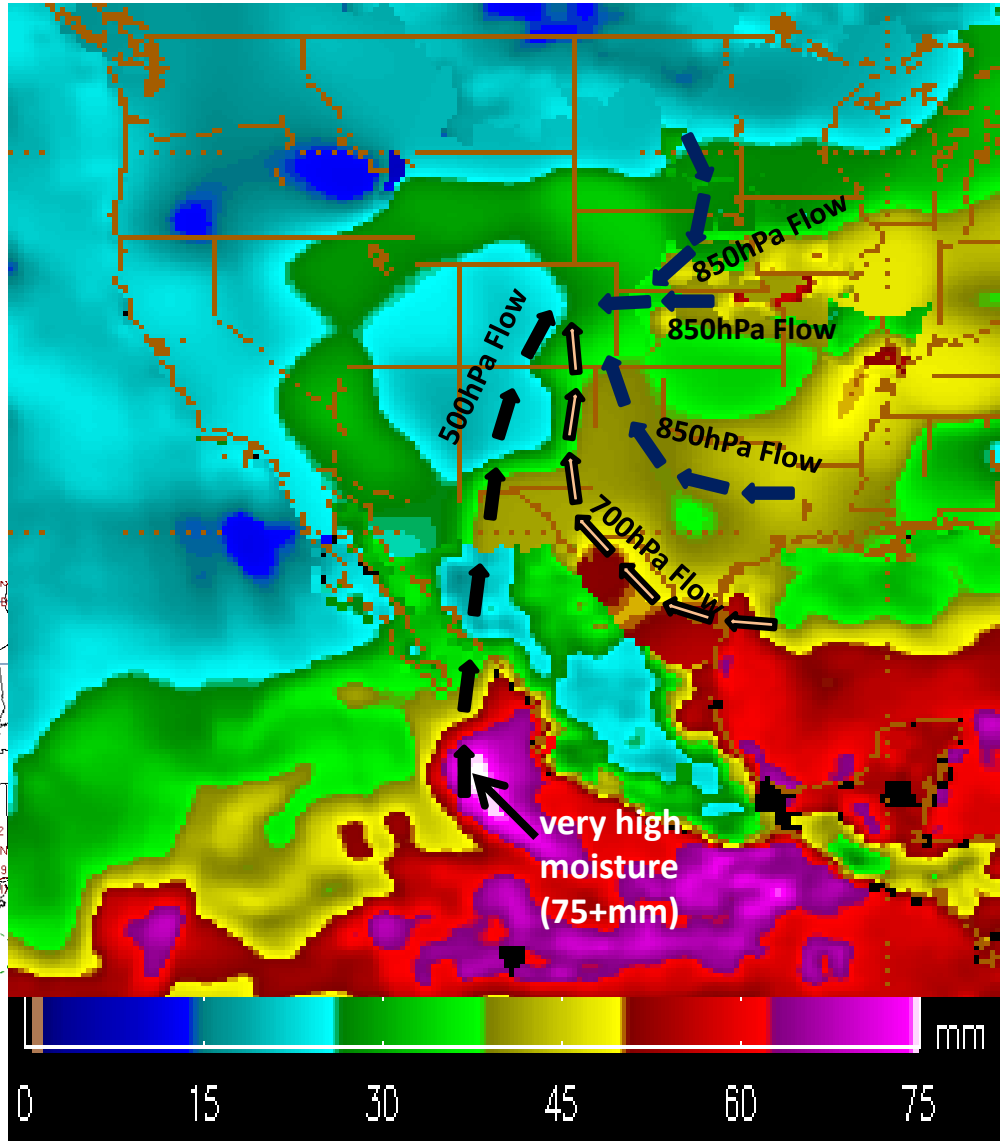
# Blended Total Precipitable Water (TPW)
# 00 UTC 12 September 2013

850hPa 00 UTC 12 Sep 2013

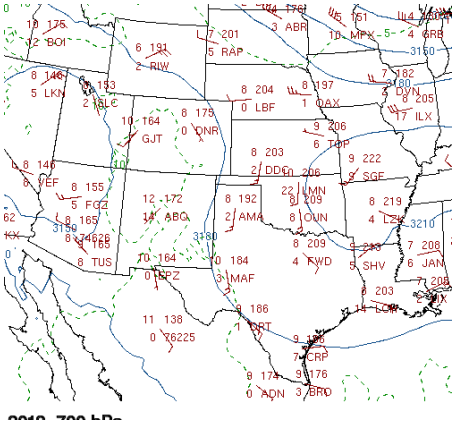


500Pa 00 UTC 12 Sep 2013






700hPa 00 UTC 12 Sep 2013

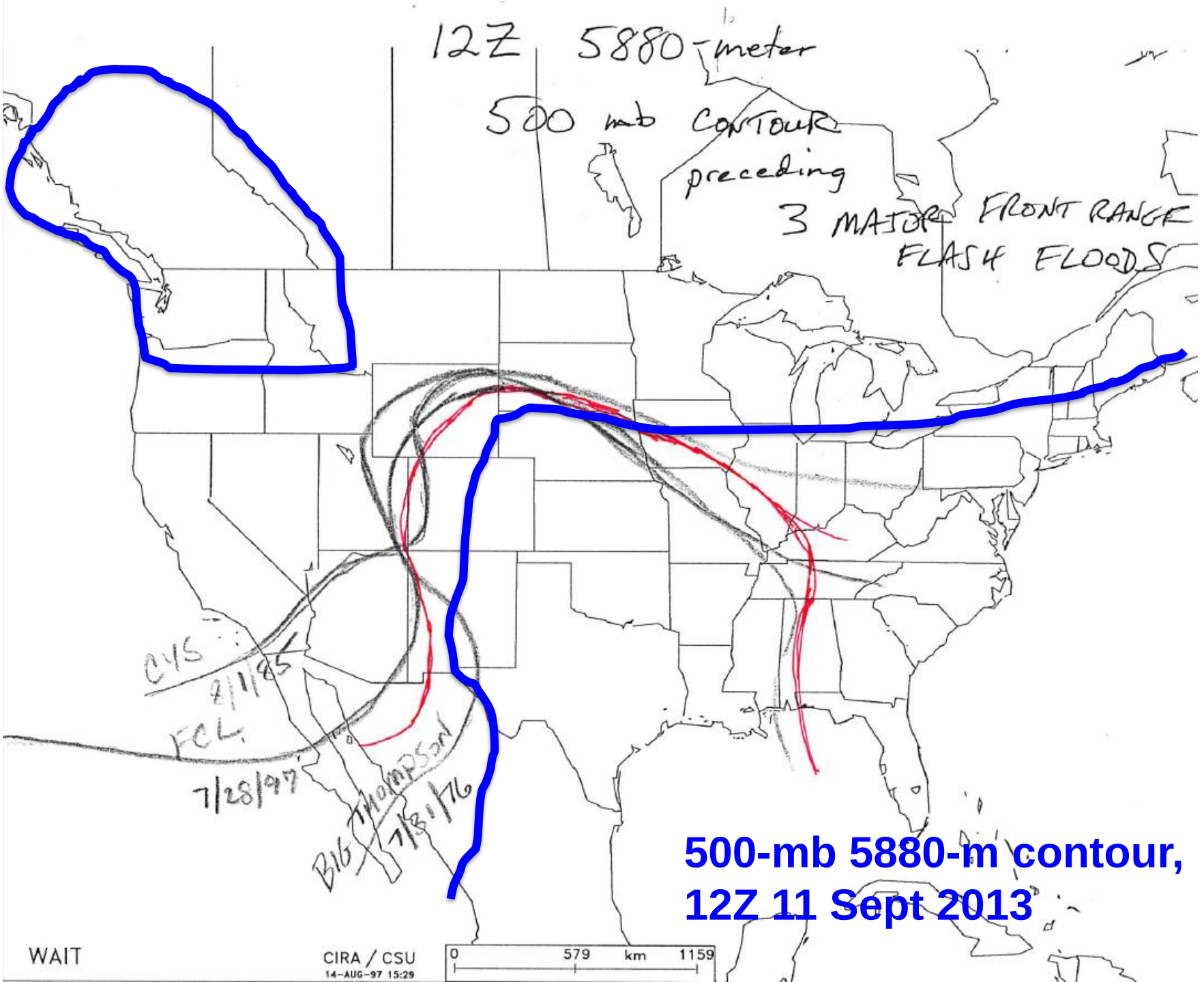


Moisture Advection

850hPa

700hPa

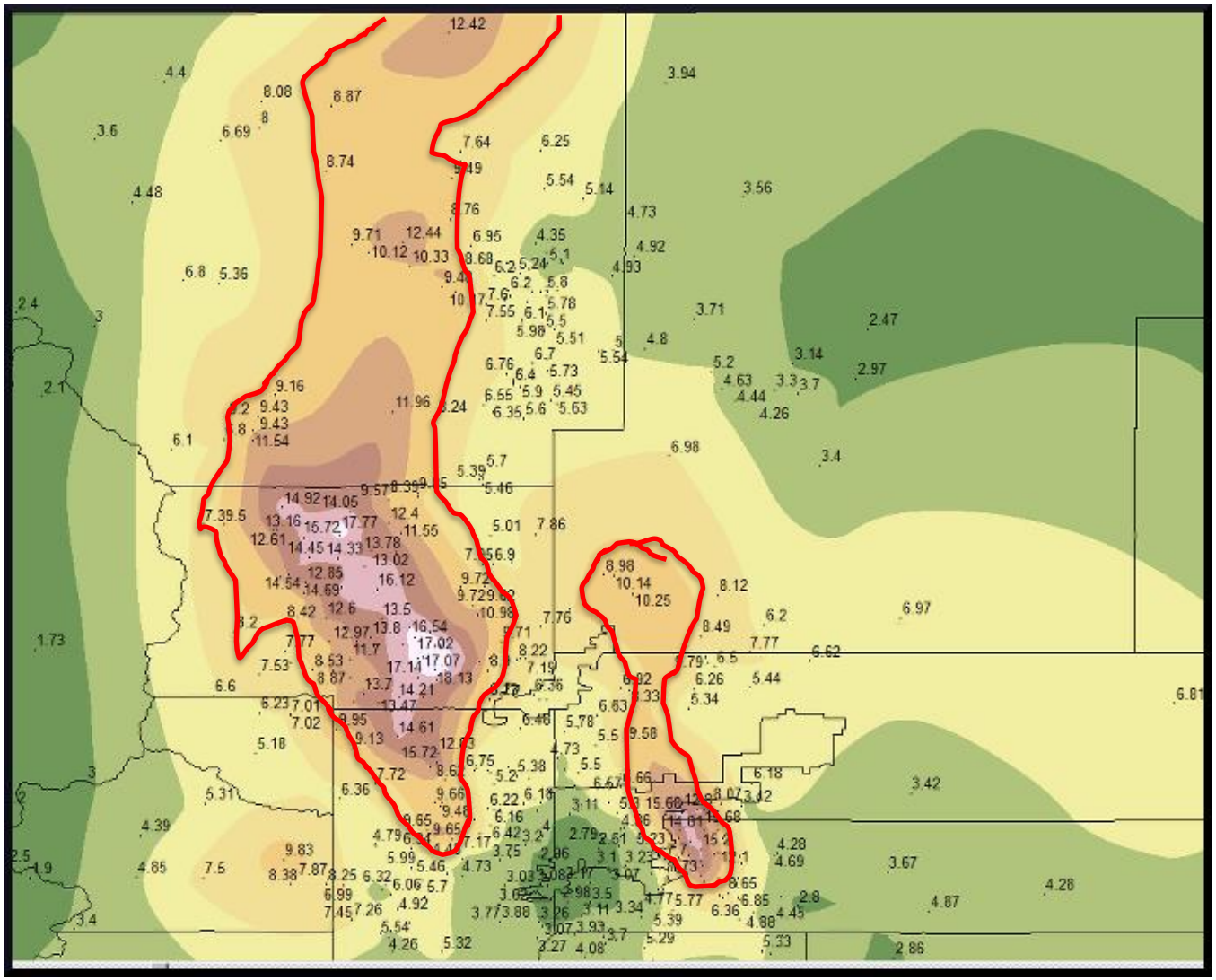
500hPa




**500-mb 5880-m contour,**
**12Z 11 Sept 2013**

# Rainfall amounts: 9-16 September 2013

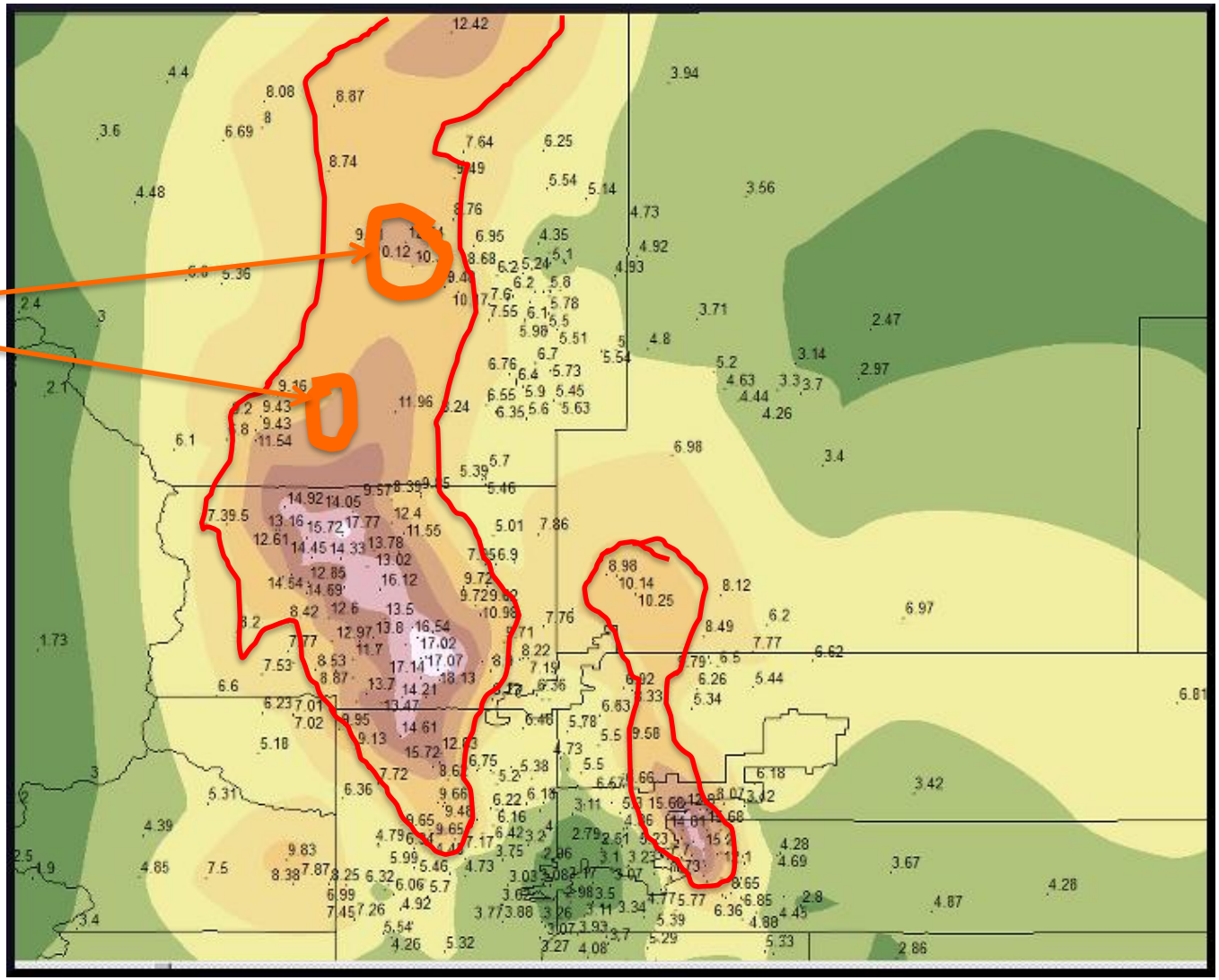
Red outline shows 8” (~200 mm) rainfall contour for 7-day precipitation, September 2013



Source: http://www.crh.noaa.gov/images/bou/precip/prelim_raintotal.png

# Rainfall amounts: 9-16 September 2013

**Estimate of 8” contour for 1976 Big Thompson flash flood, based on Maddox et al. (1978)**

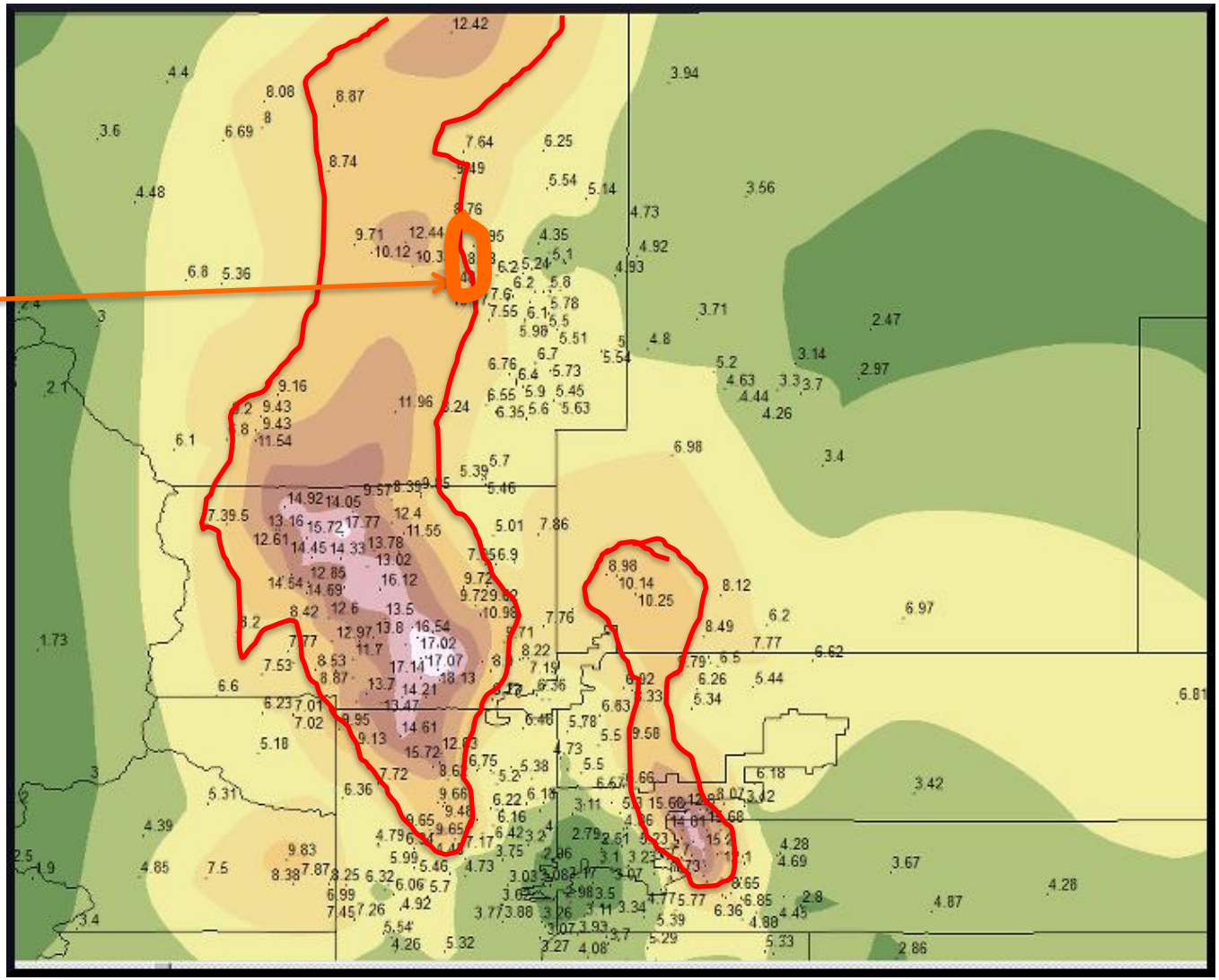


Source: http://www.crh.noaa.gov/images/bou/precip/prelim_raintotal.png

# Rainfall amounts: 9-16 September 2013

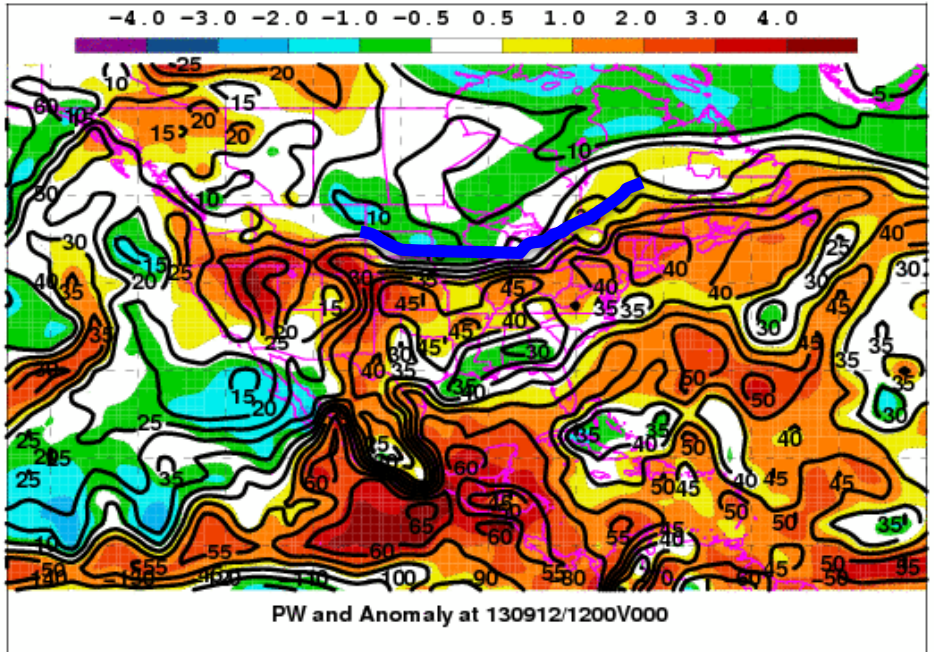
**Estimate of 8” contour for 1997 Fort Collins flash flood, based on Doesken and McKee (1998)**

**Note: short-duration rainfall rates were higher in those events**

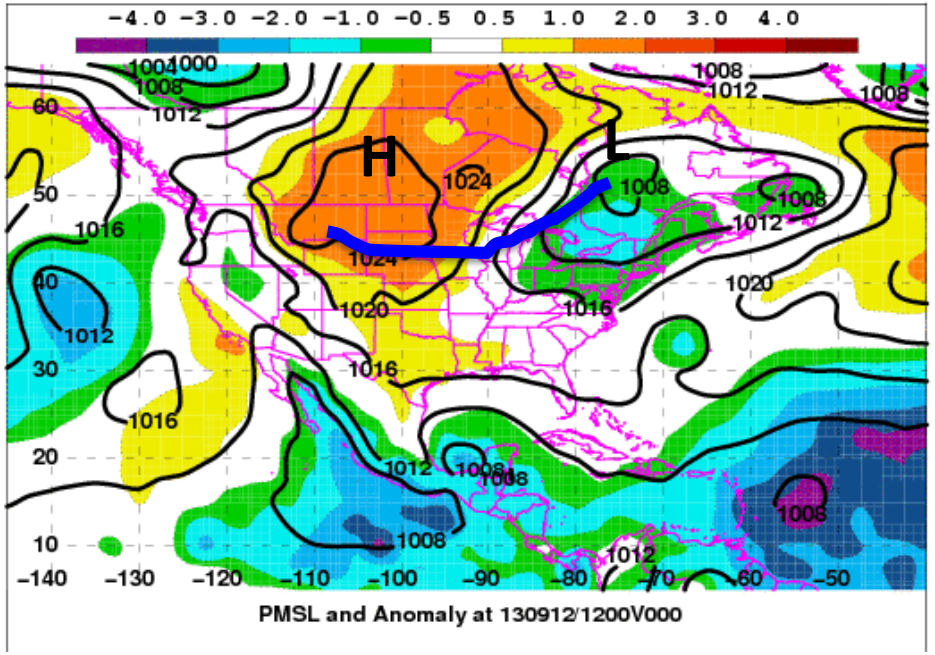


Source: http://www.crh.noaa.gov/images/bou/precip/prelim_raintotal.png

Precipitable water and standardized anomaly




MSLP and standardized anomaly




**Eight consecutive soundings with PW at or above the previous daily record!**
**(And the next seven were above the 99th percentile for Sept.)**

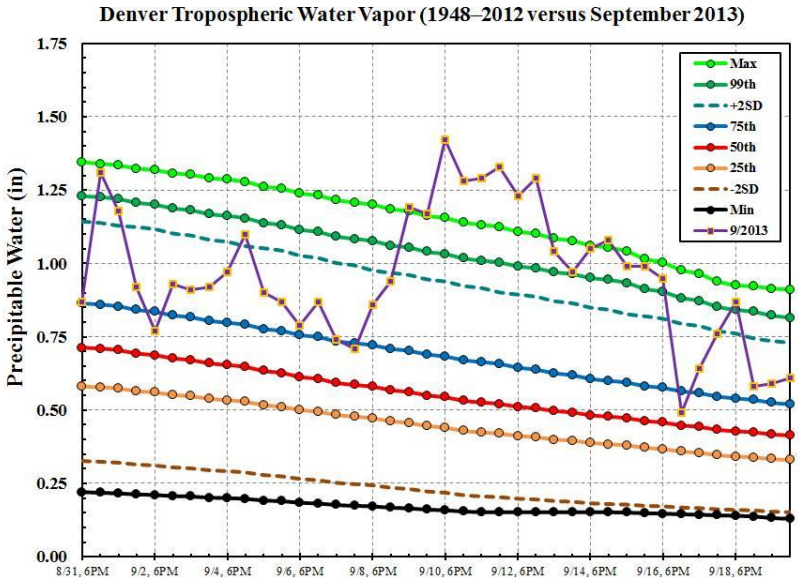
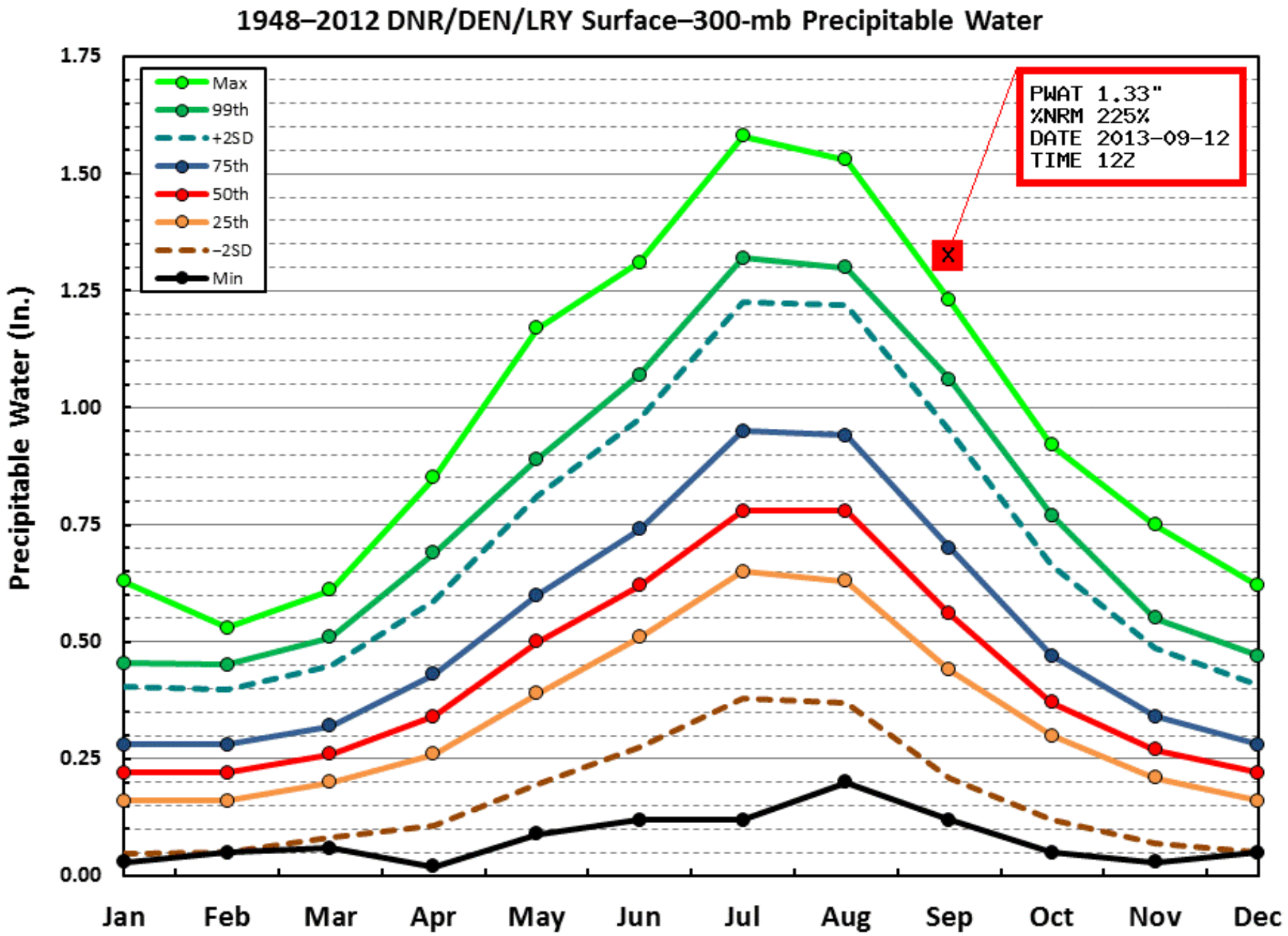



Image courtesy of Matt Bunkers, NWS Rapid City


1948–2012 DNR/DEN/LRY Surface–300-mb Precipitable Water
Precipitable Water (In.)
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
Max
99th
+2SD
75th
50th
25th
-2SD
Min
PWAT 1.33"
%NRM 225%
DATE 2013-09-12
TIME 12Z
X
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

The Narrows in Big Thompson Canyon. Photo by Larimer Sheriff Justin Smith:

https://www.facebook.com/photo.php?fbid=503206203101227&set=a.415768821844966.100567.407464109342104

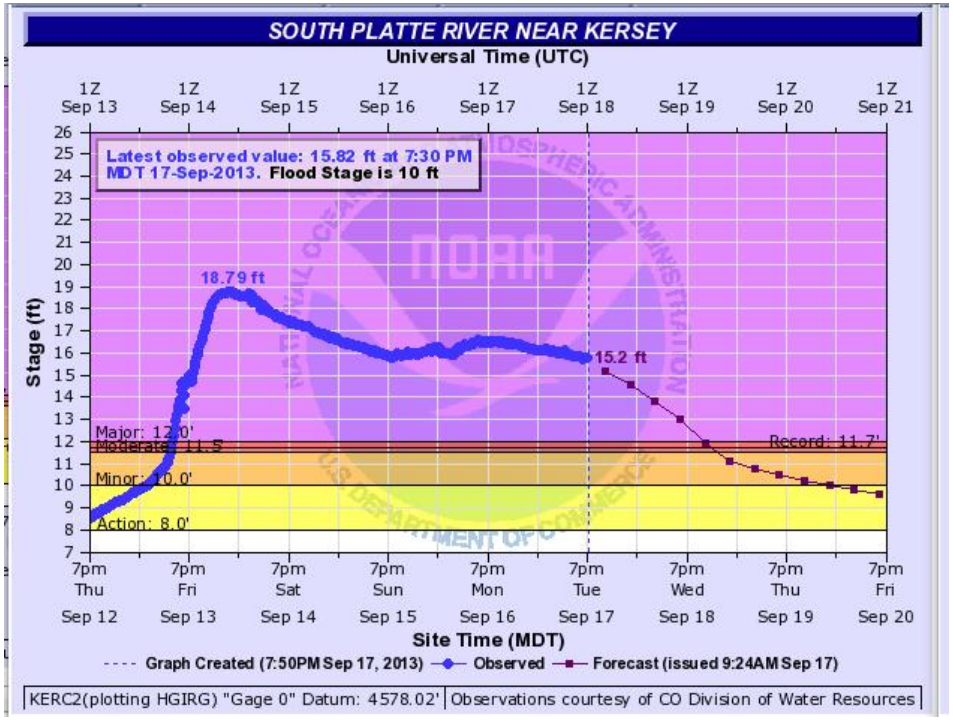
Photo by Noel Bryan, administrative staff in our department, from very near her home in Big Thompson canyon, 2 miles down from Estes Park

After the flash flooding in the foothills and mountains, the floodwaters moved downstream into the South Platte

The South Platte near Kersey (east of Greeley) was flowing higher than its previous record (from May 1973) for 5+ days!

Flooding in Evans (just south of Greeley) was particularly bad, with mobile home parks completely inundated and wastewater treatment unavailable

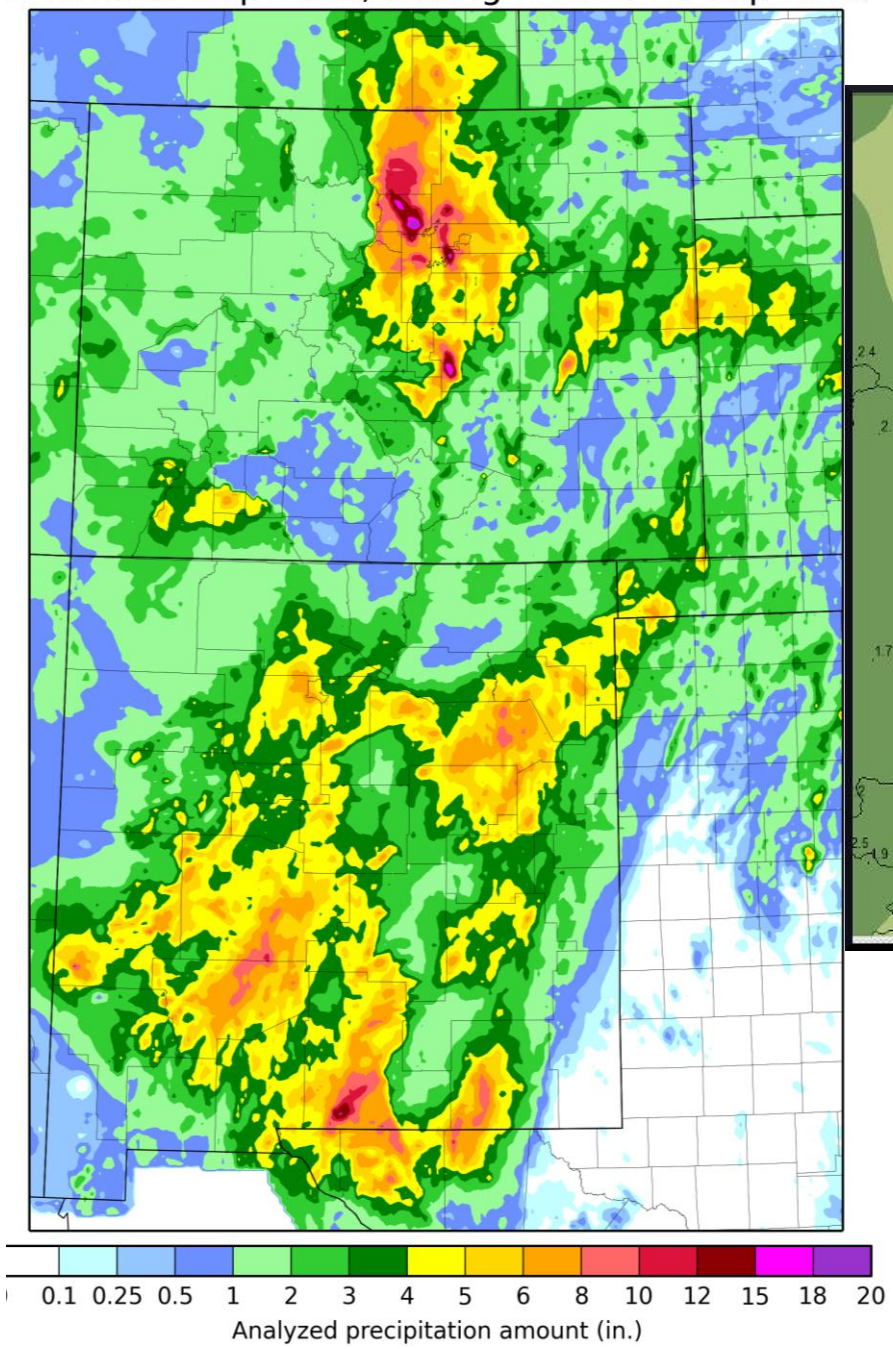
Landsat image of South Platte River in Greeley, CO: http://en.es-static.us/upl/2013/09/greeley-CO-9-17-2013.jpg

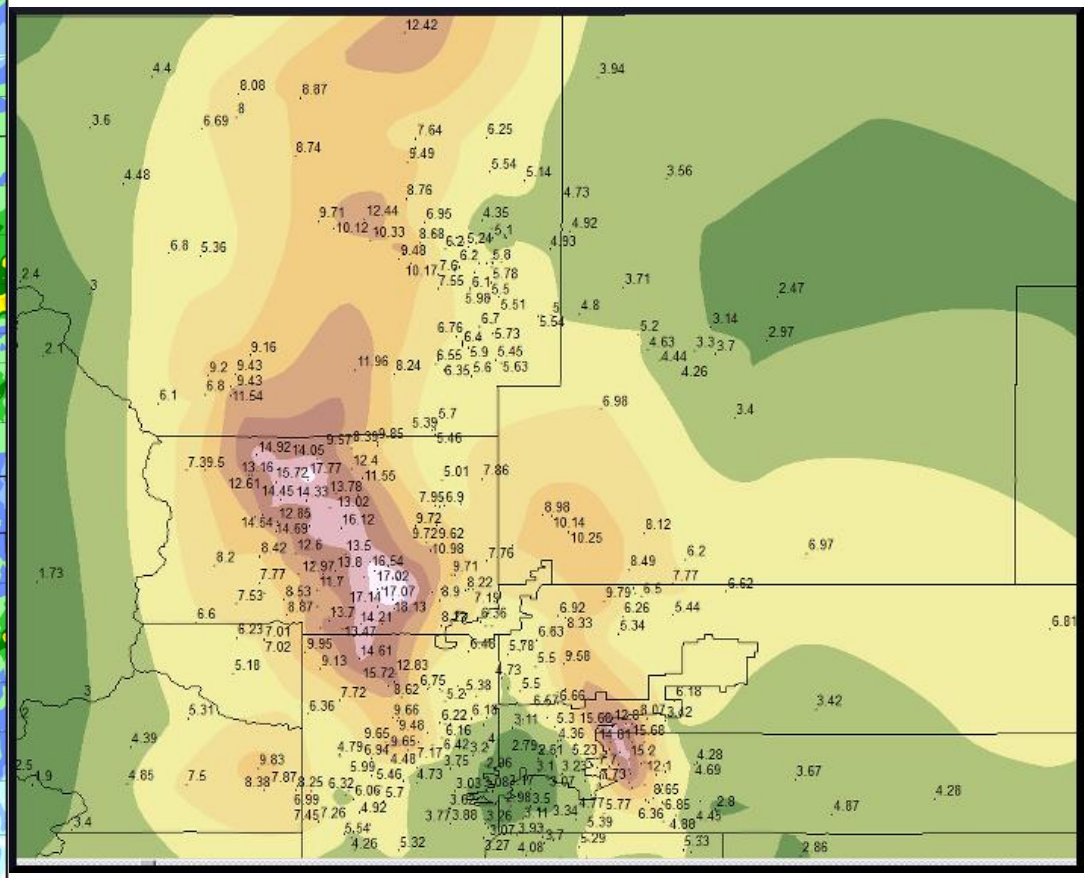



# The Great Colorado flood of 9-16 Sep 2013

- Next: overview plots
  - A look at each day for the period monday/9 Sep through Thu/12 Sep
  - What was different between the start of the week and mid week?
    - By Monday – ridge shifted eastward, eastern half of CO in PW plume, cold front passes with enhanced low level moist easterly flow
      - But precip generally stays out of the foothills
    - Tuesday – similar set up with upper level weak low strengthening slightly to our west near sw UT
      - Shortwaves moving north in the deep southerly flow
    - Wednesday 11 Sep – more of the same

# 9-16 Sep 2013 Total Precip

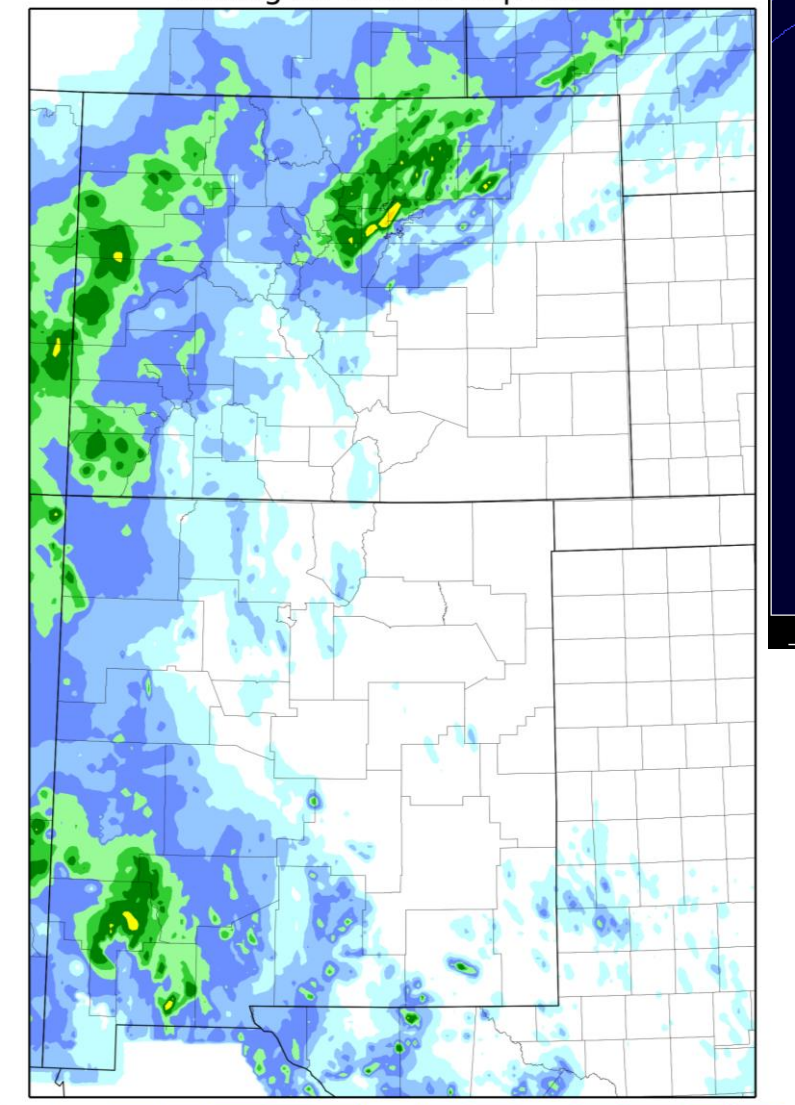


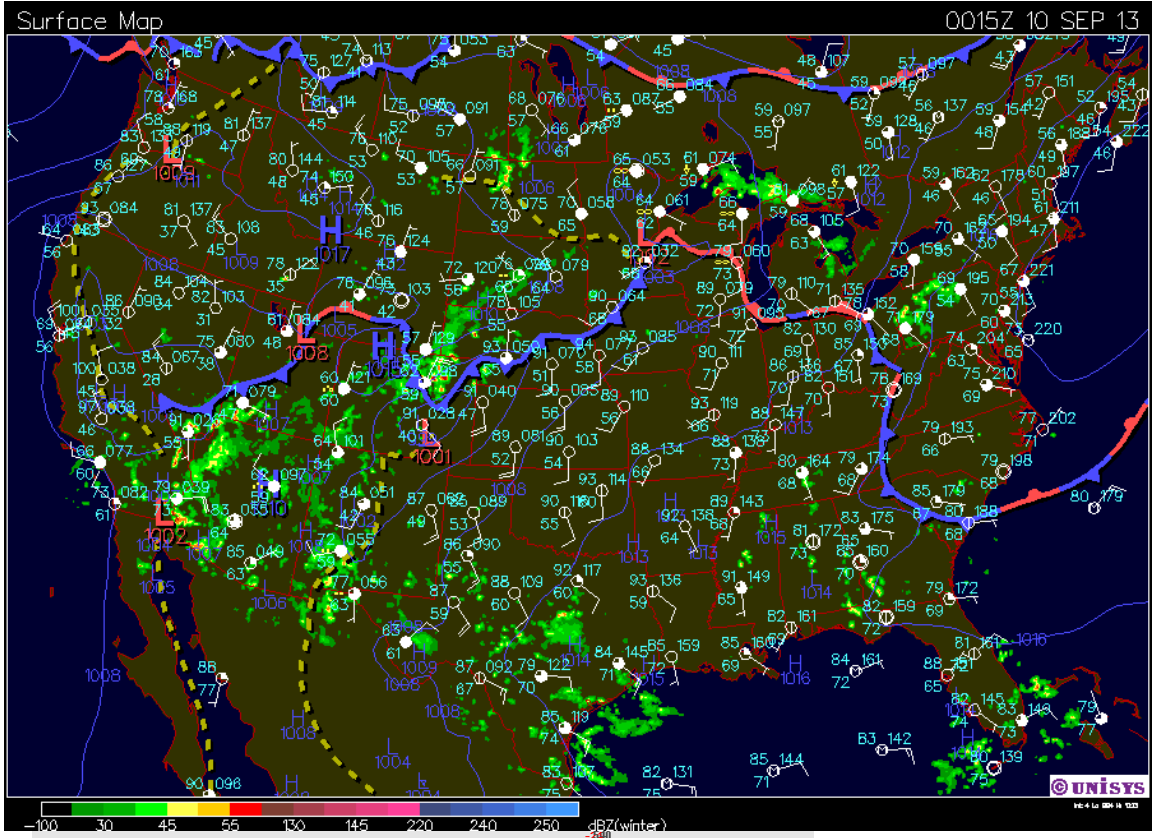



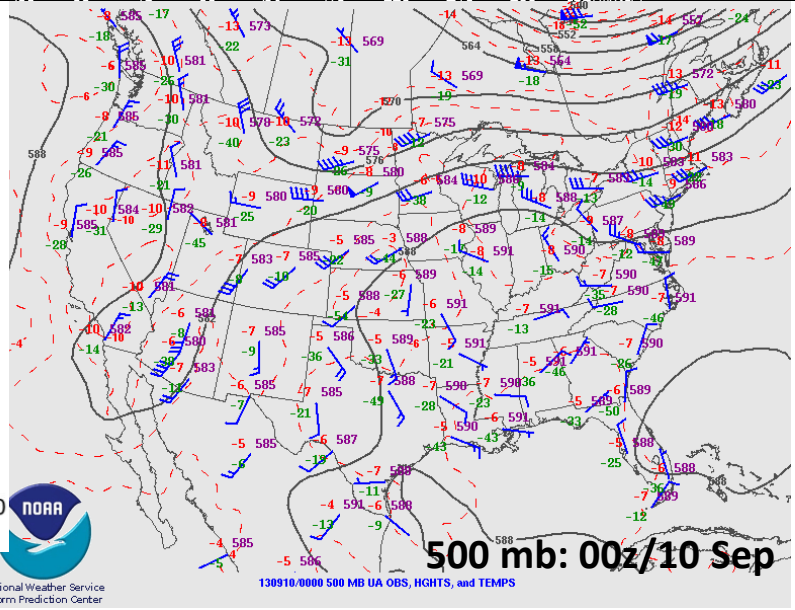
Precipitation analysis from the Advanced Hydrological Precipitation Service (AHPS) (left) and from Boulder WFO (using CoCoRaHS and other data sources). *Note that this was a very wet week in NM as well, with flooding also reported.*

# 9-10 Sep 2013

24-h accumulated precipitation for the period ending 12 UTC 10 Sep 2013

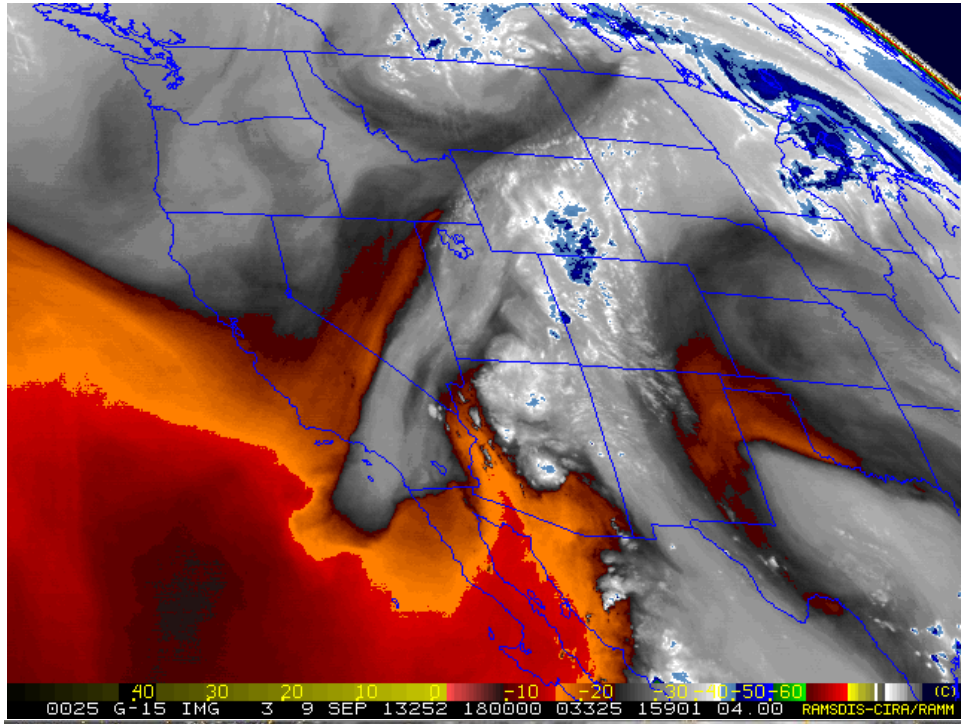


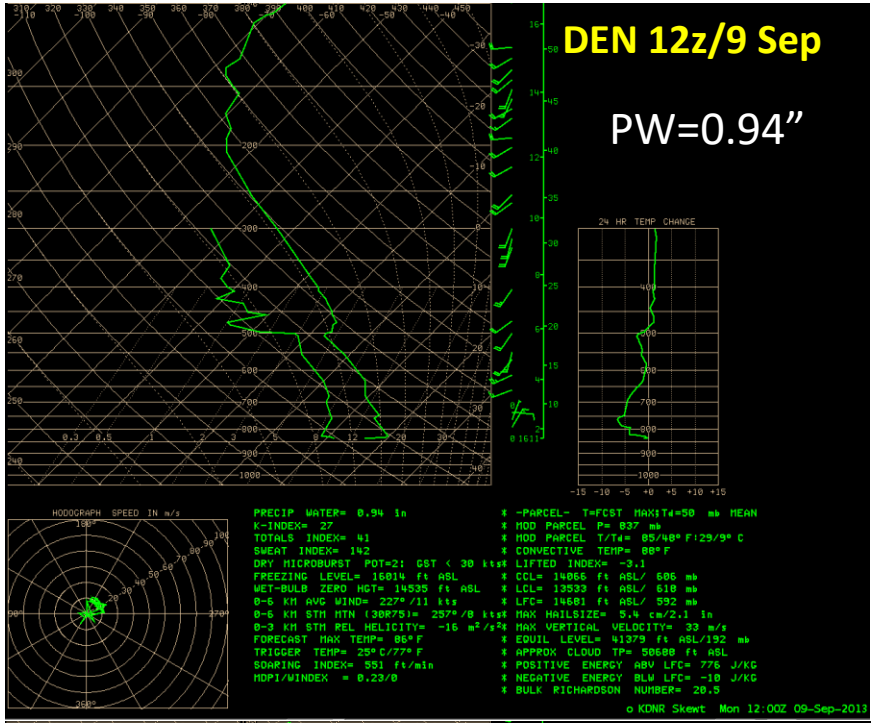




*A couple of very heavy tstms occured mid to late aftn with lots of small hail nw Denver area. Then band of more heavy rain into the evening, but not much in the foothills by 12z/10 Sep. A cold front had pushed south across the eastern Plains early in the morning setting up low-level upslope.*

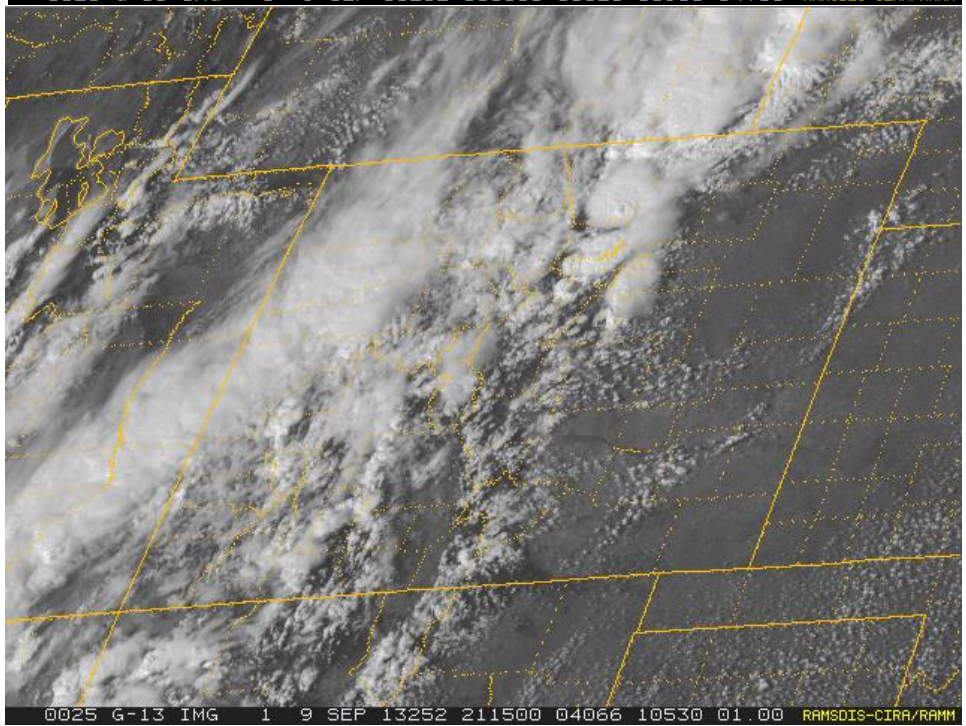
Water Vapor 18z/9 Sep

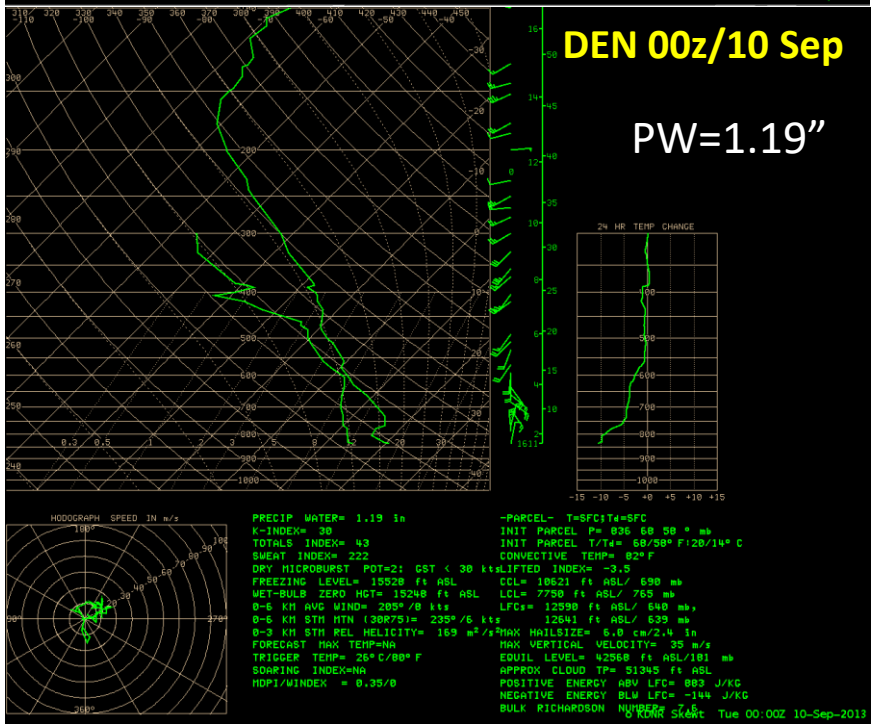



Monday 9 Sep

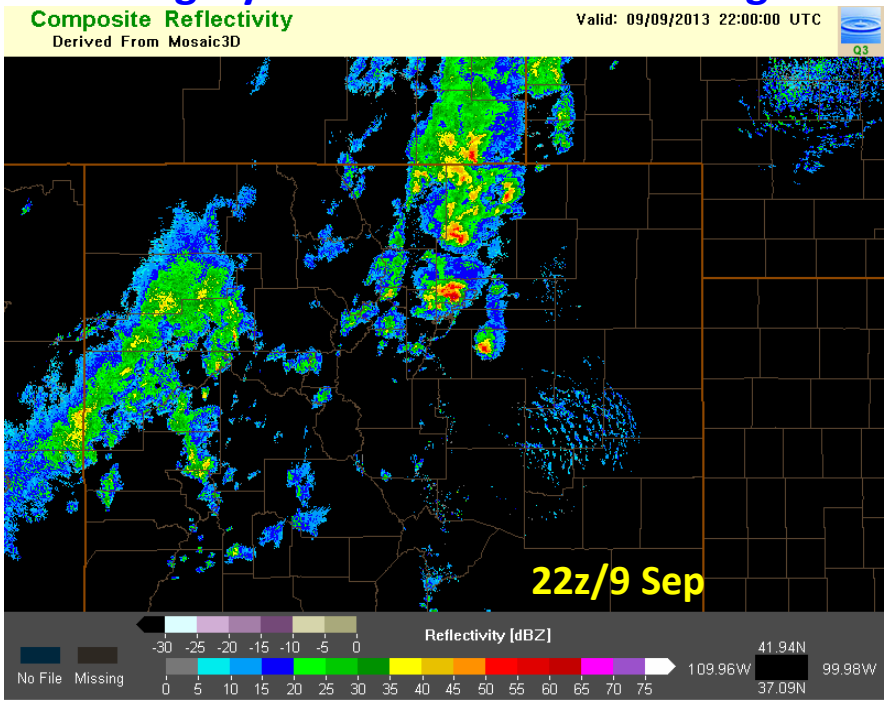


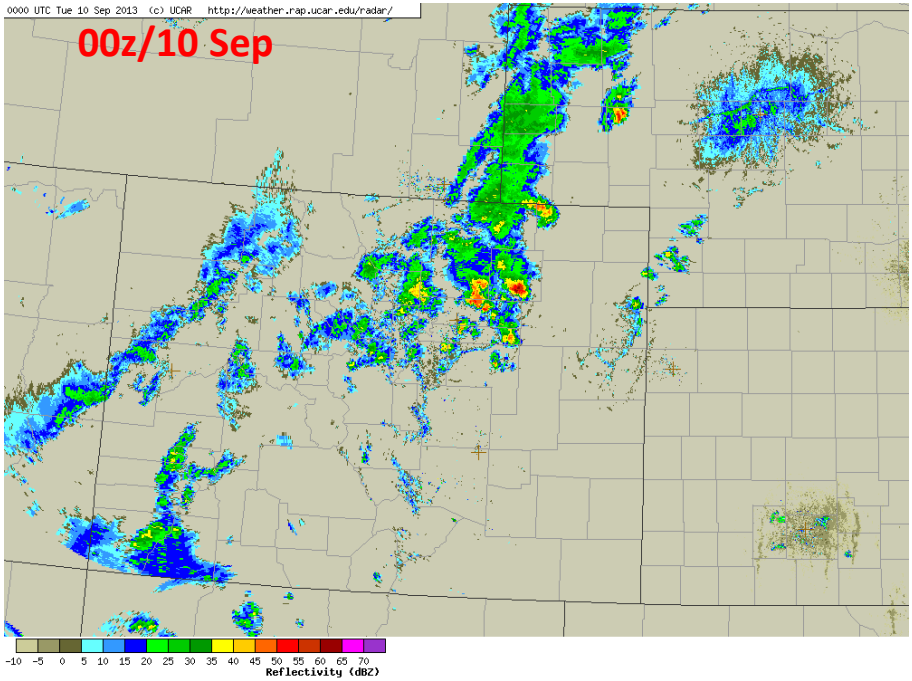

Visible 2115z/9 Sep

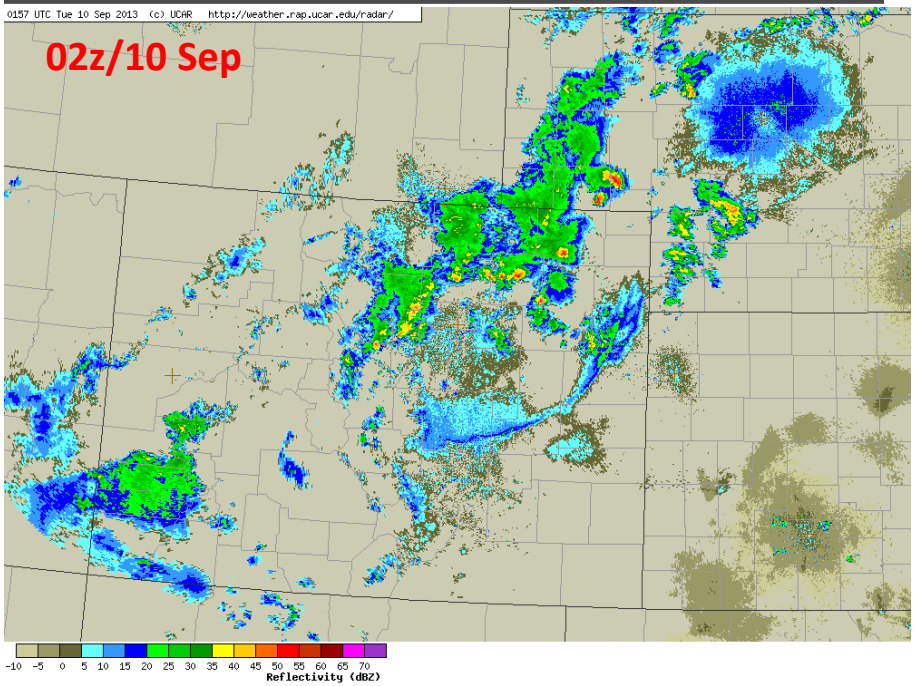


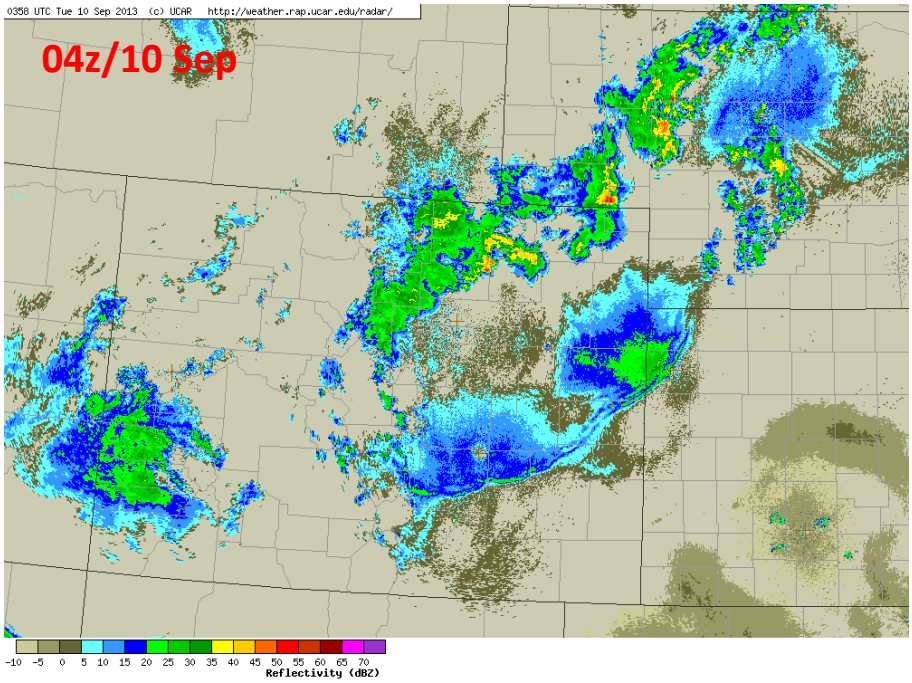



# Radar imagery for late afternoon through the evening on Monday 9 Sep



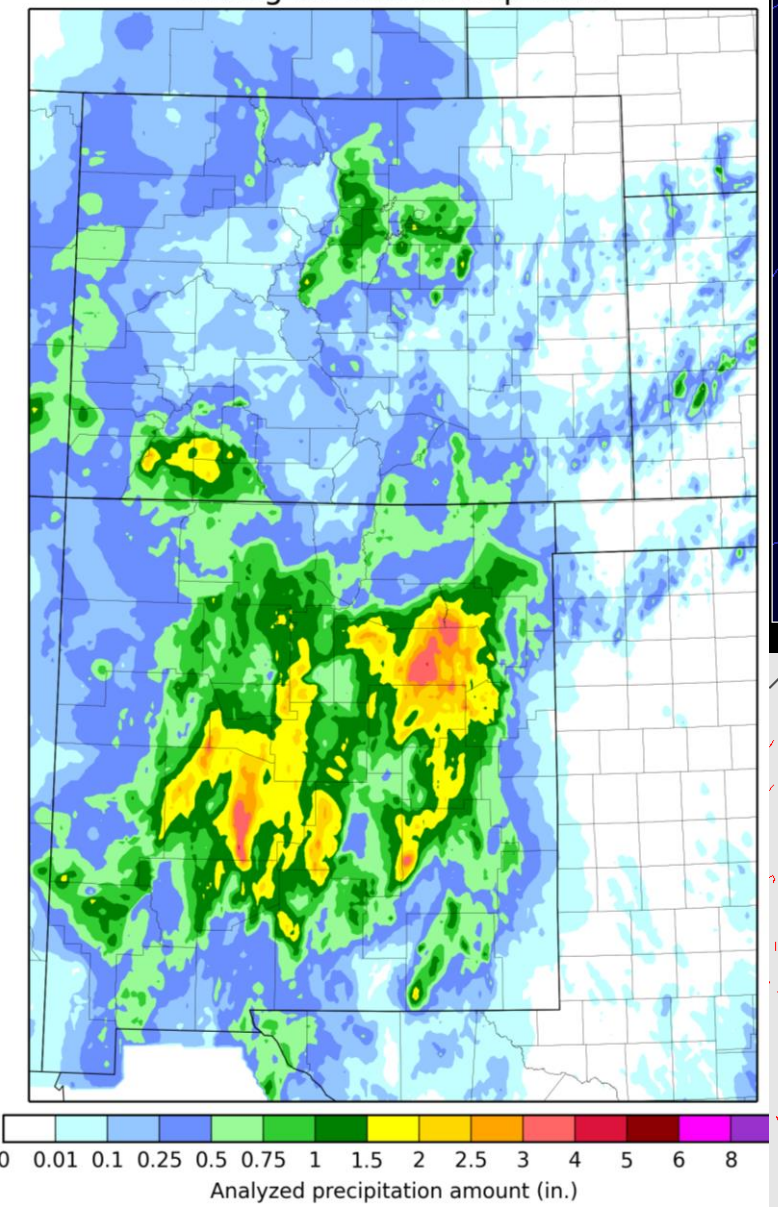



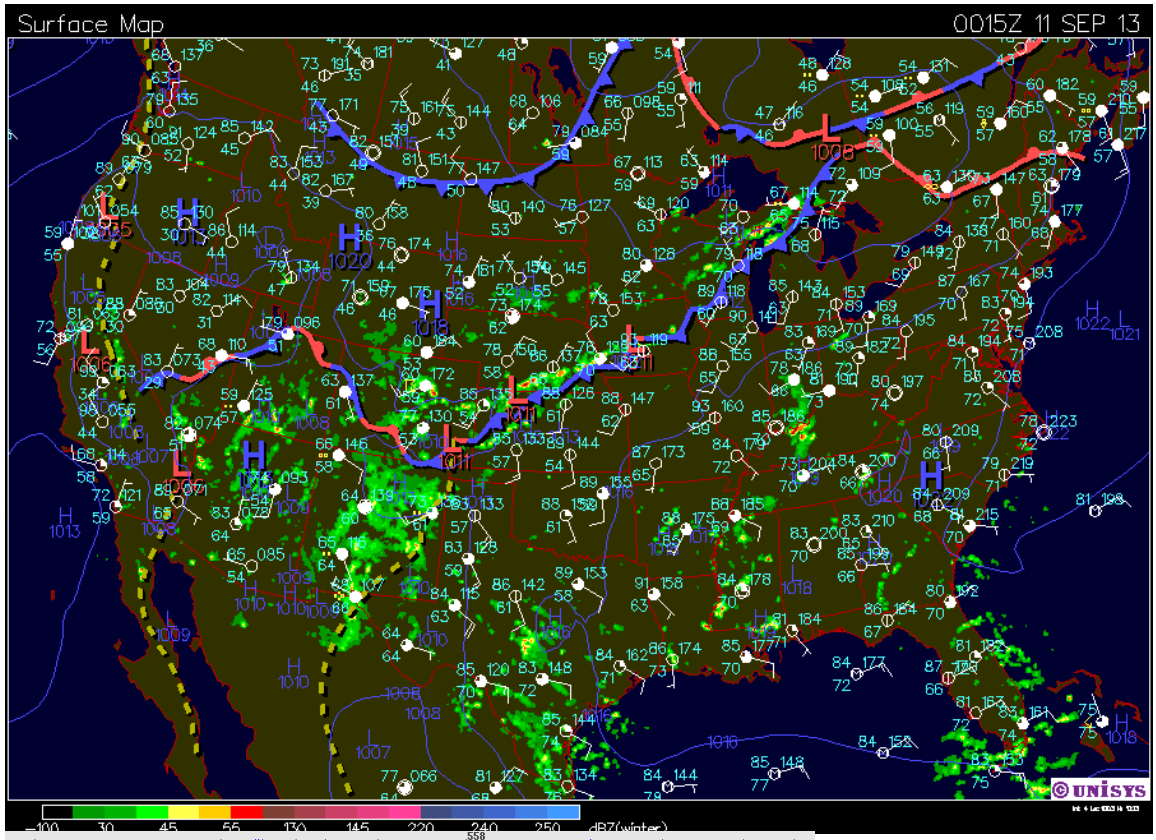



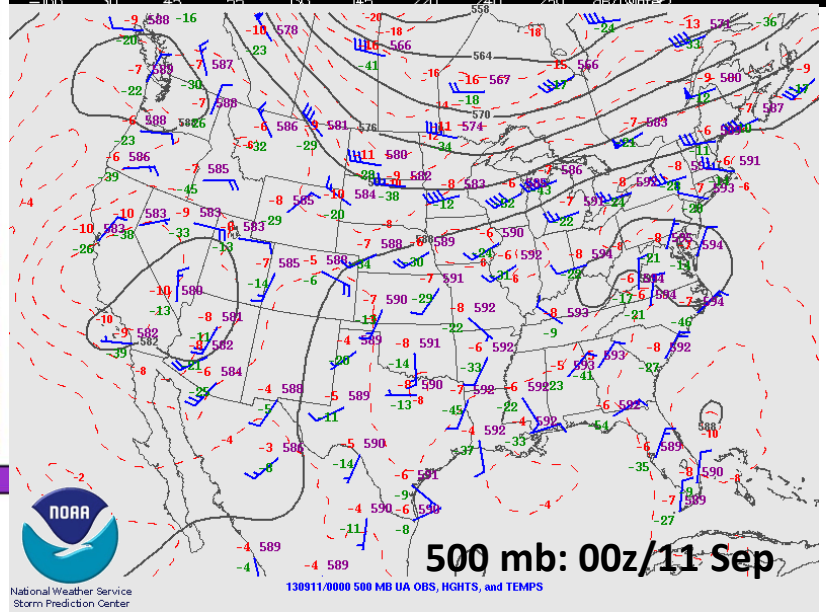



# 10-11 Sep 2013

24-h accumulated precipitation for the period ending 12 UTC 11 Sep 2013



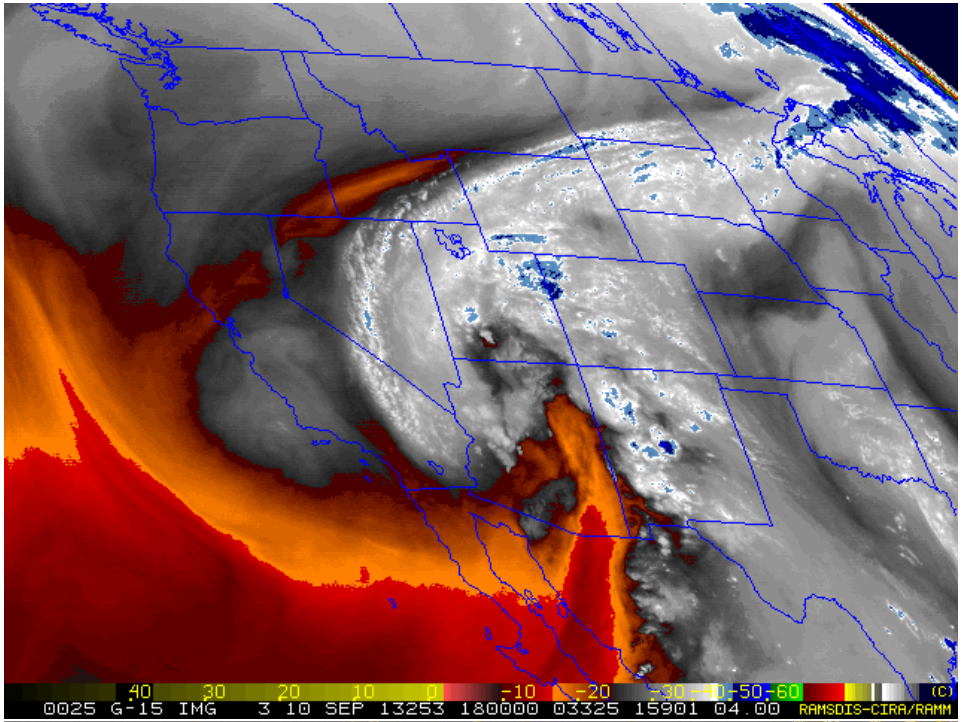

500 mb: 00z/11 Sep

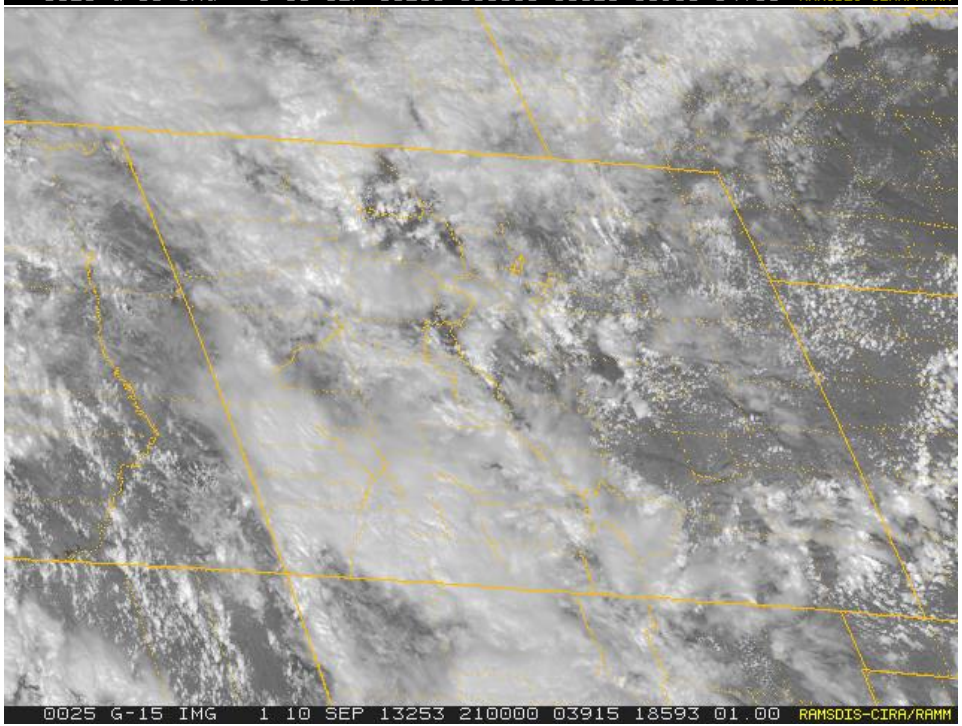
*Not a lot of activity during the day but a shortwave moved north from NM overnight, with rains still occurring in Weld and Larimer County on the morning of 11 Sep.*

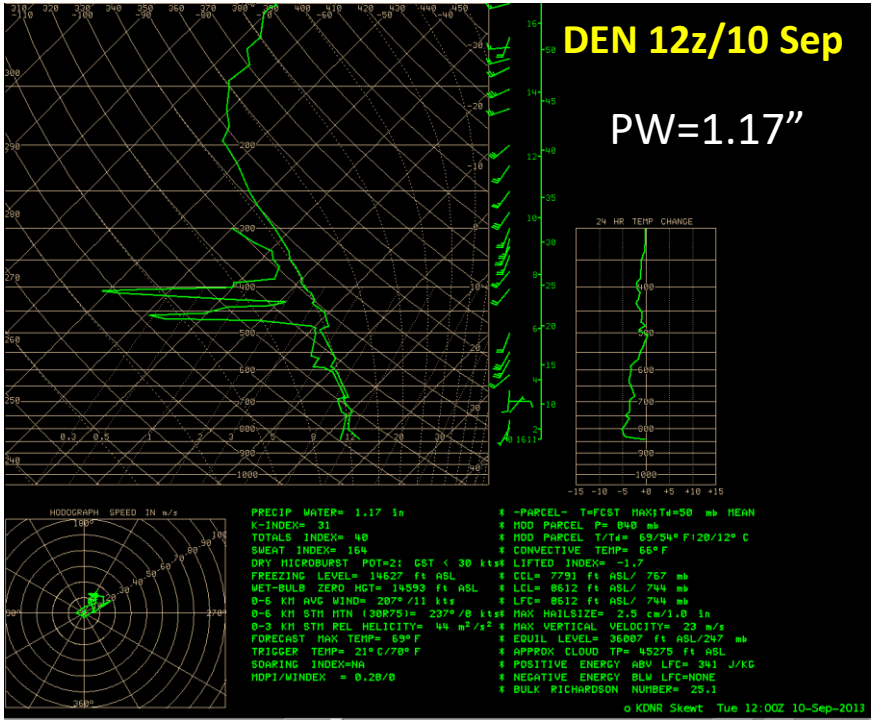
Water Vapor 18z/10 Sep

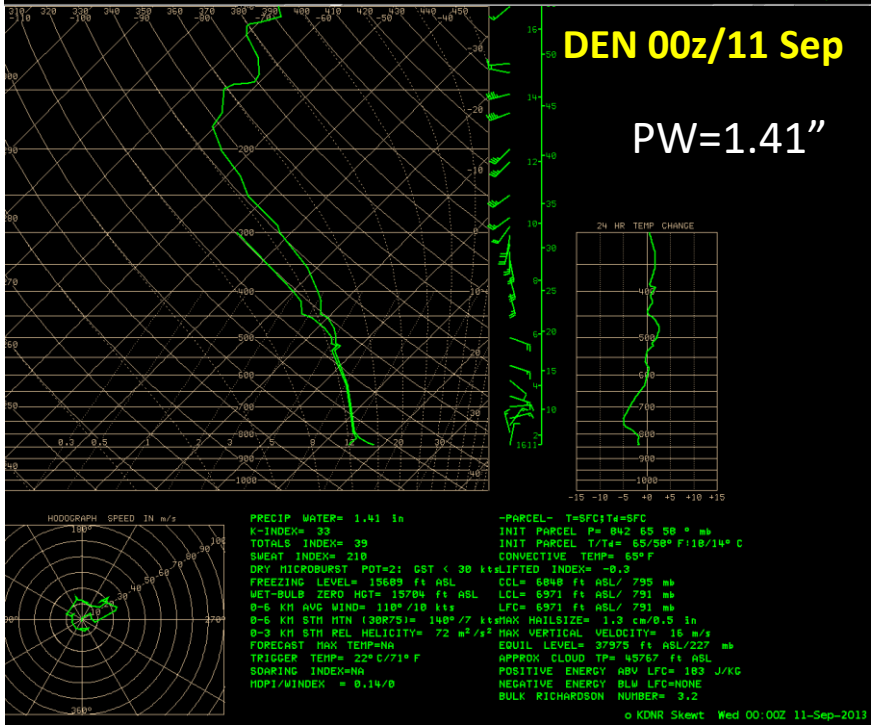
Tuesday 10 Sep

Visible 21z/10 Sep

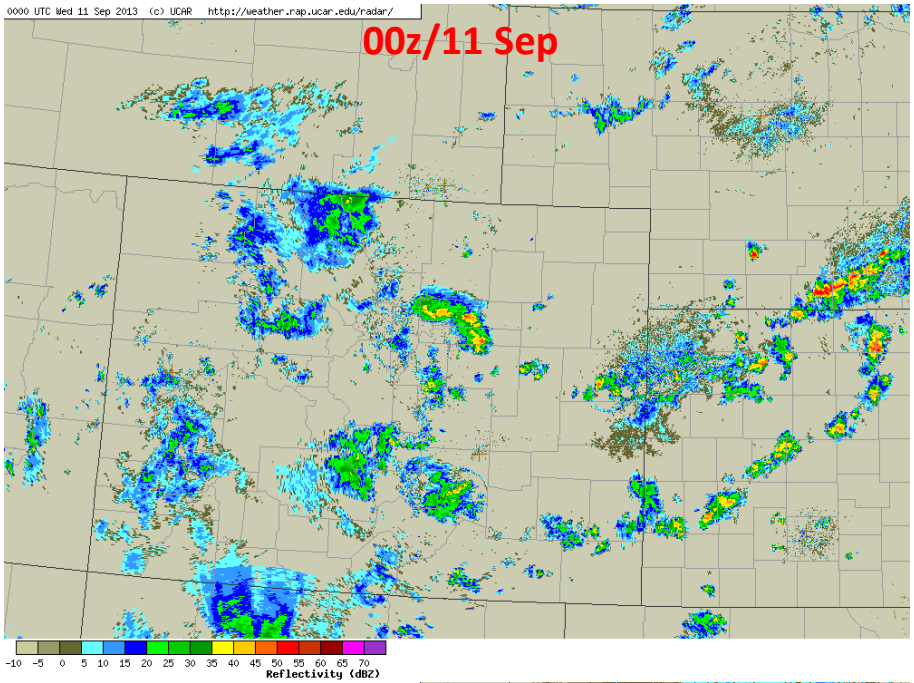


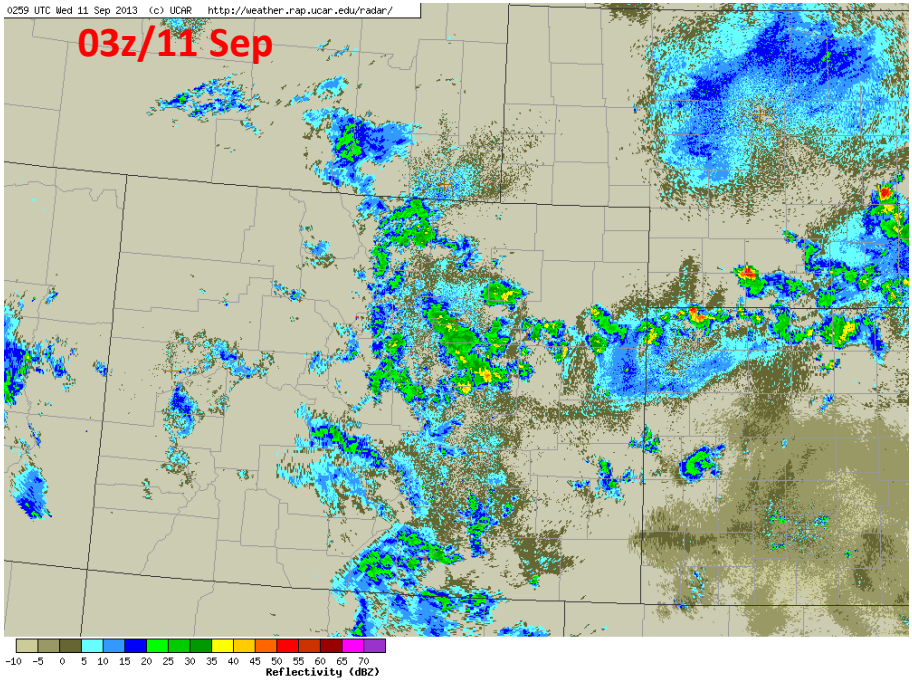



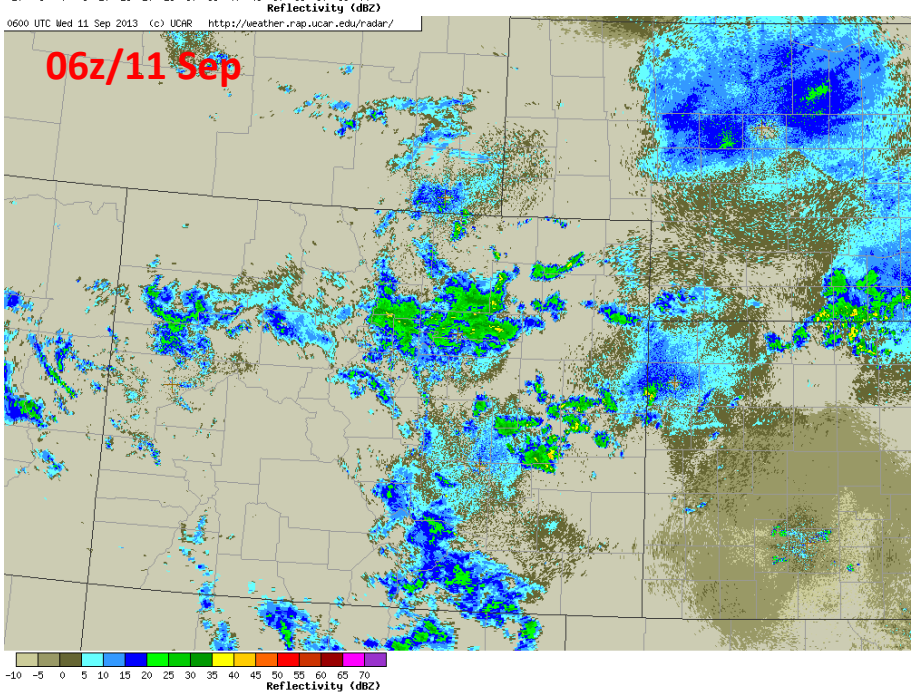



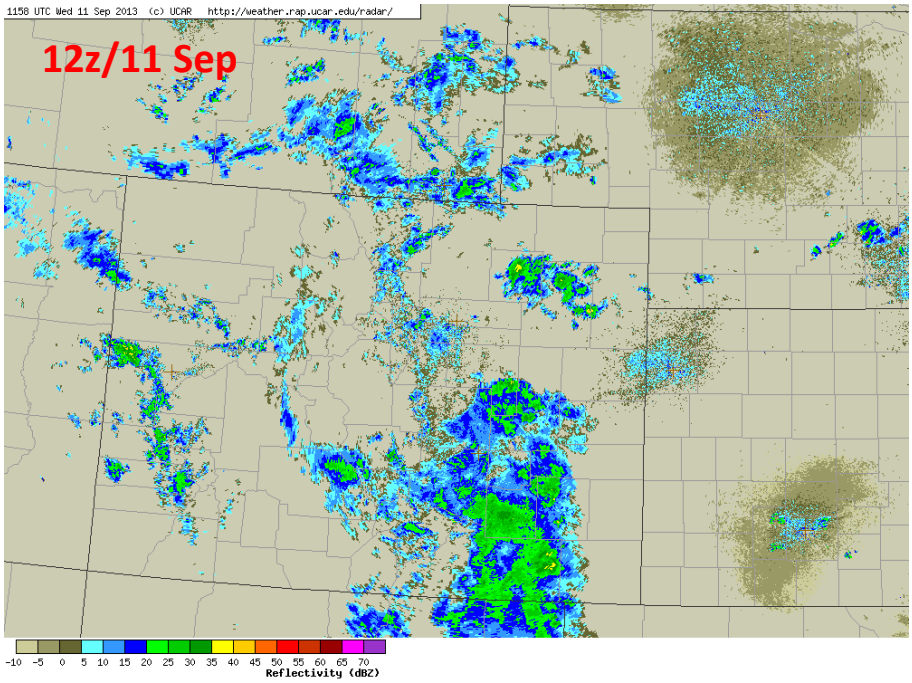



# Radar imagery for the evening and overnight on Tuesday 10 Sep

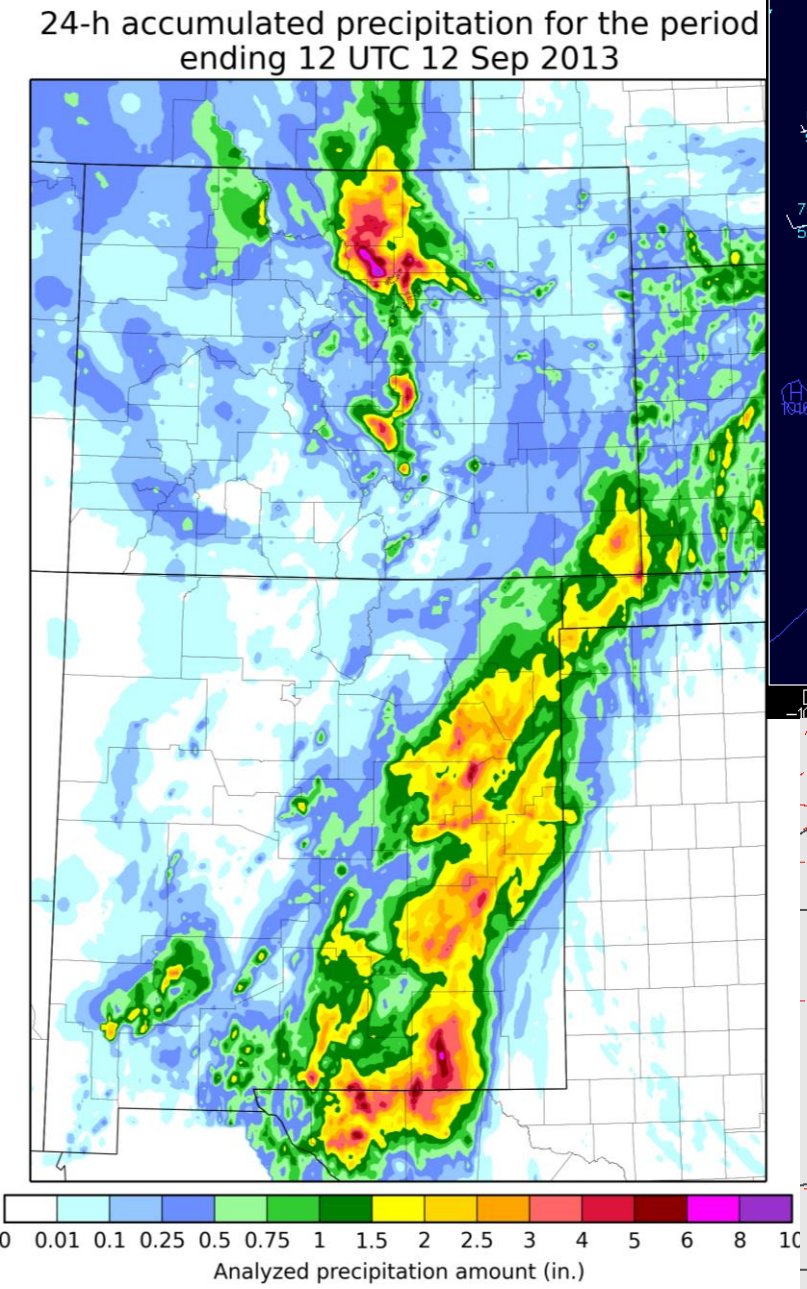


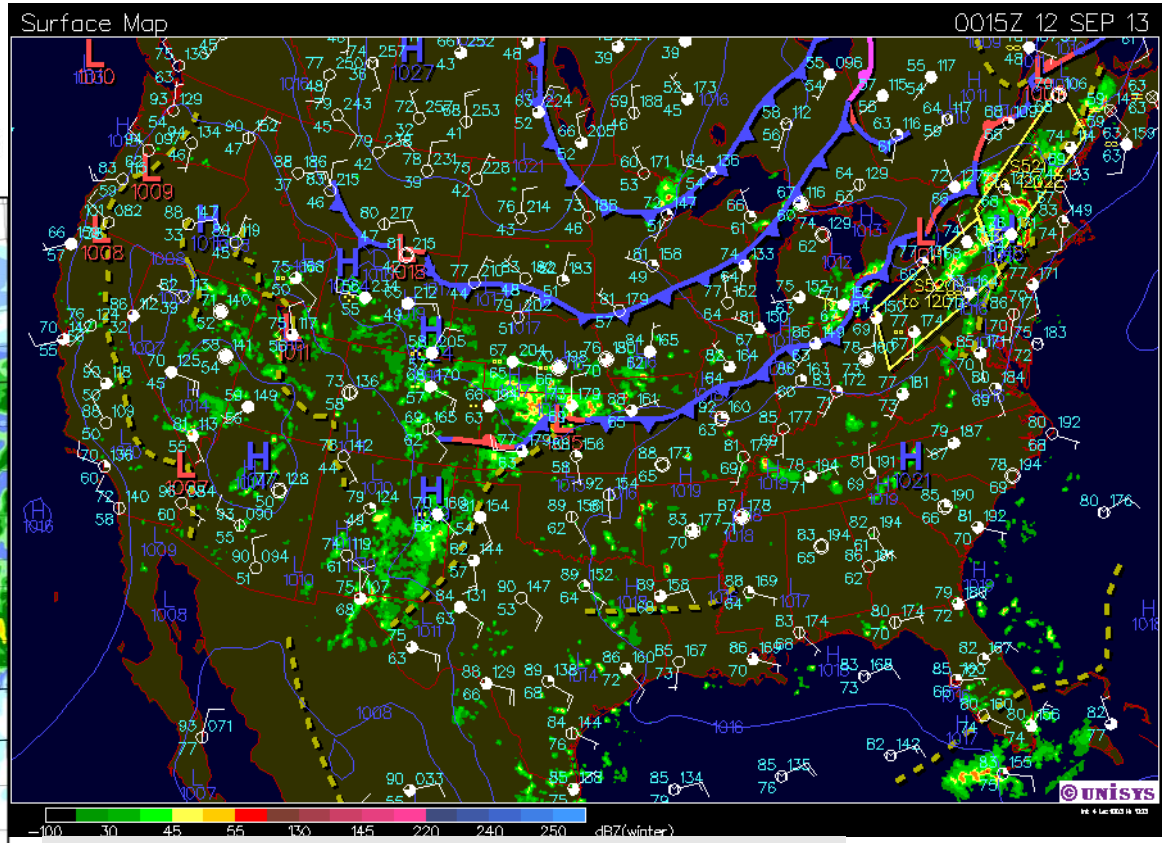



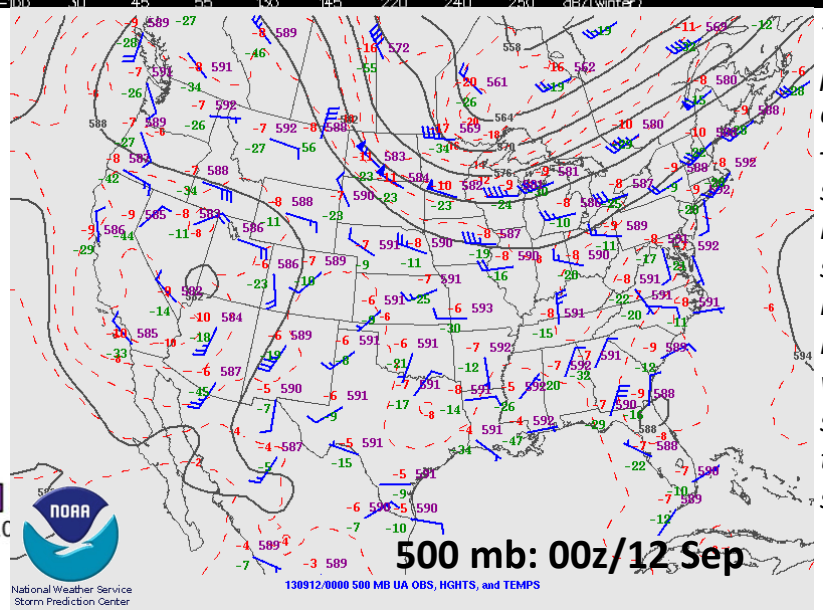



# 11-12 Sep 2013

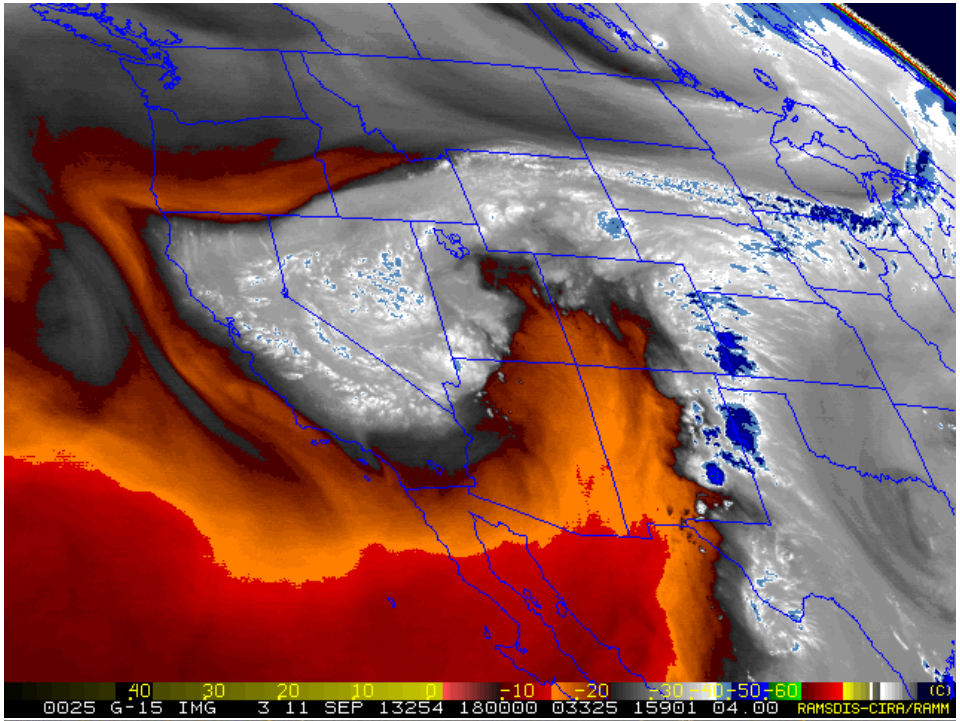


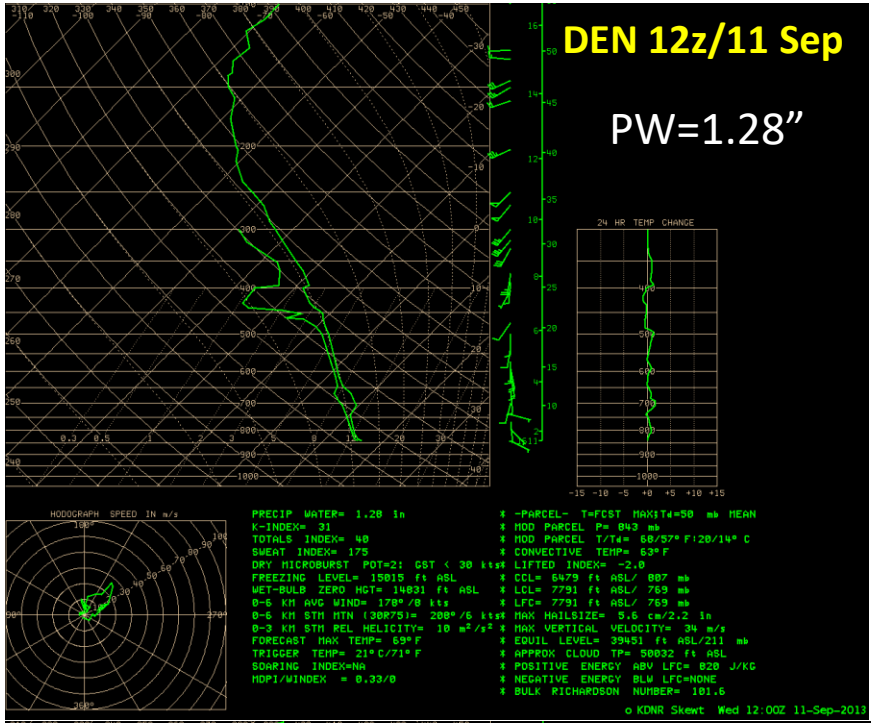




*This is the big night of precip. Synoptically compared to Monday – a stronger shortwave dropping into the Midwest supports new surge of ne upslope at lower levels, while to the west we find a stronger circulation that has stalled over sw UT.*

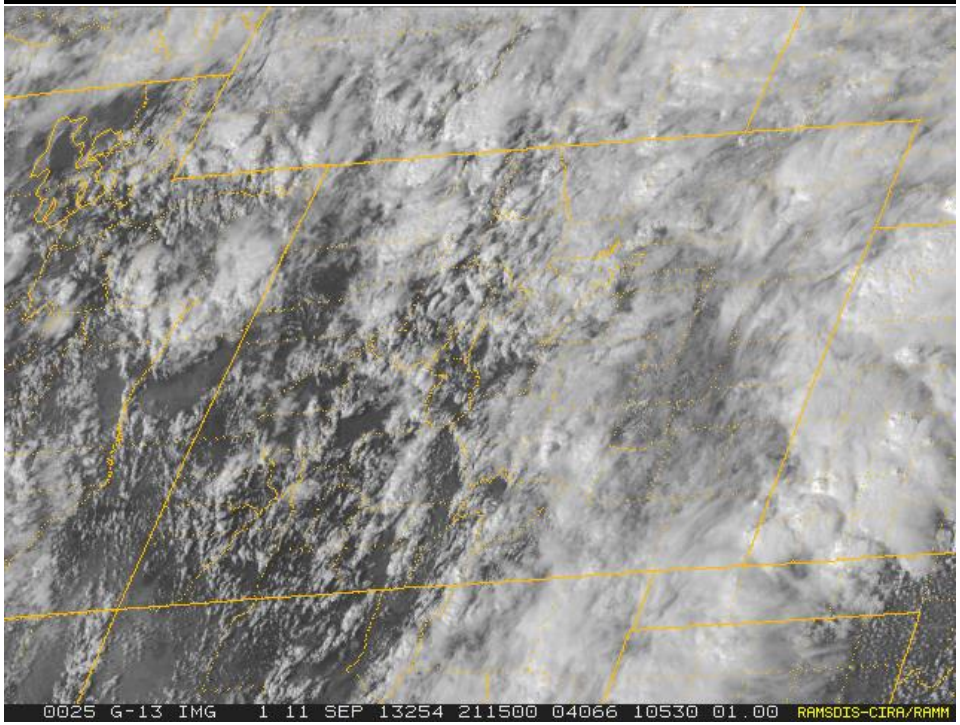
Water Vapor 18z/11 Sep

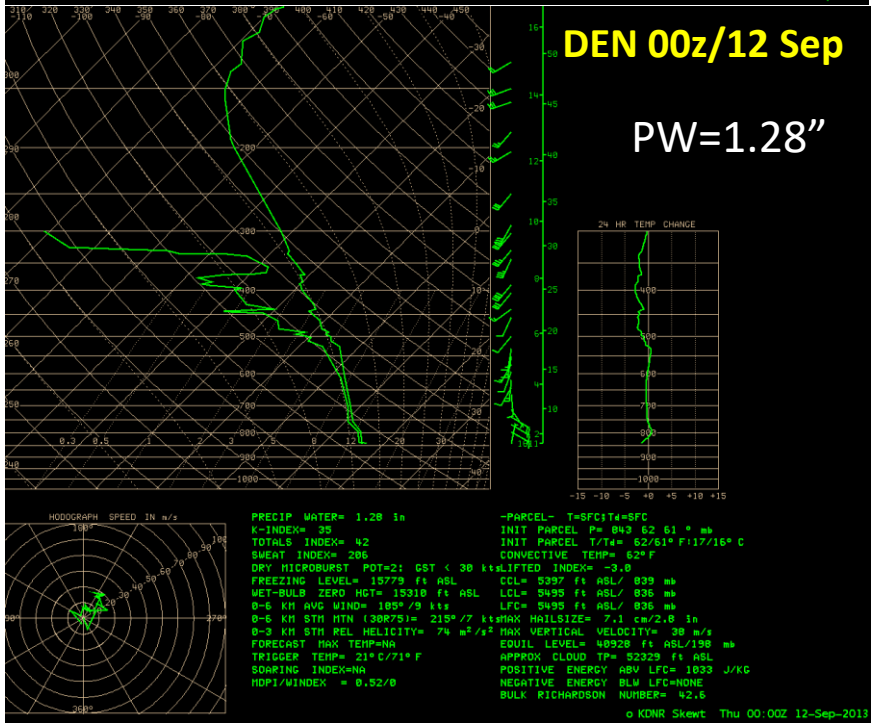


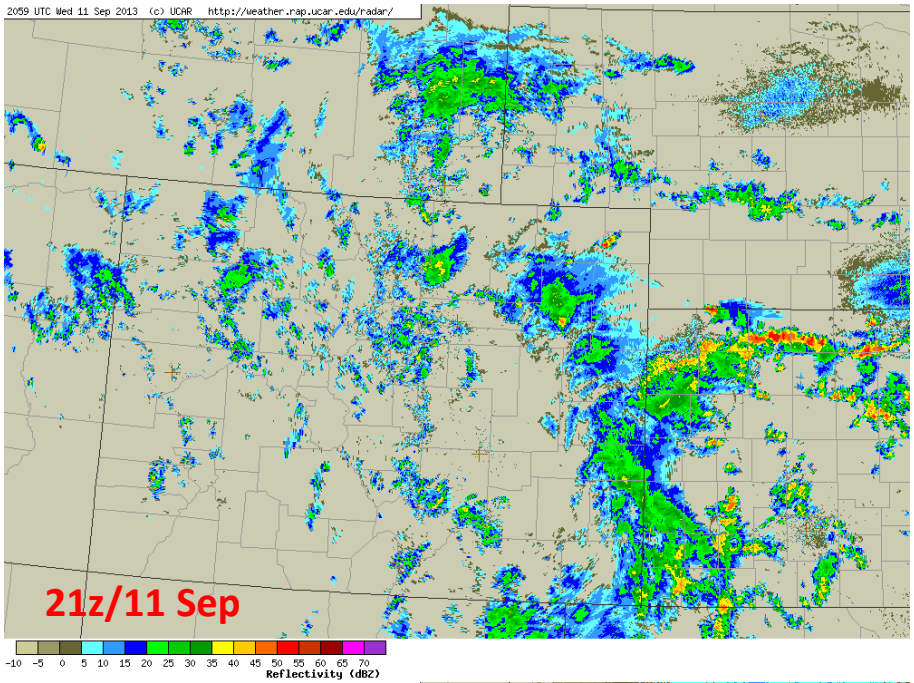

Wednesday 11 Sep

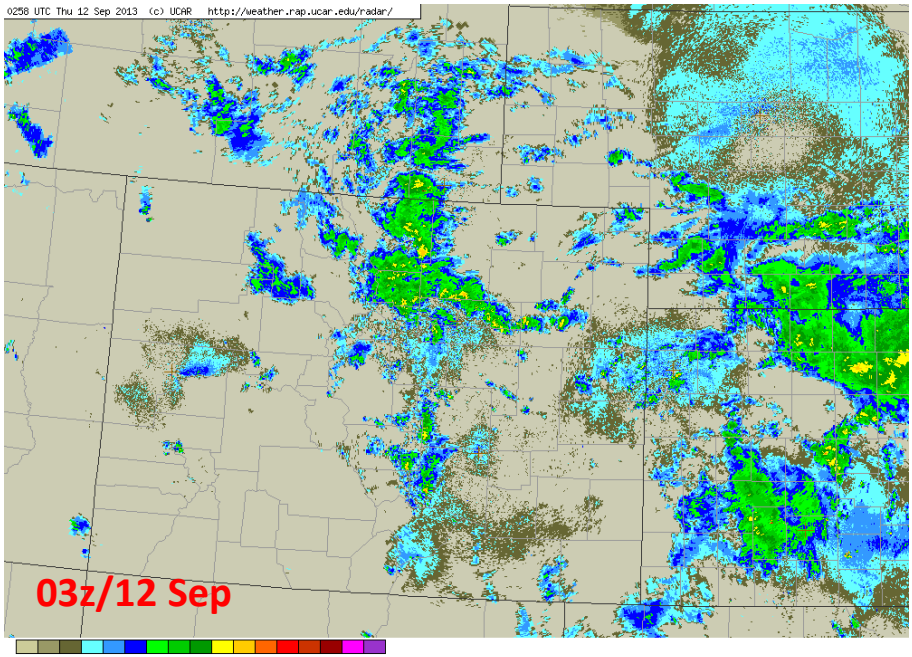
Visible 21z/11 Sep

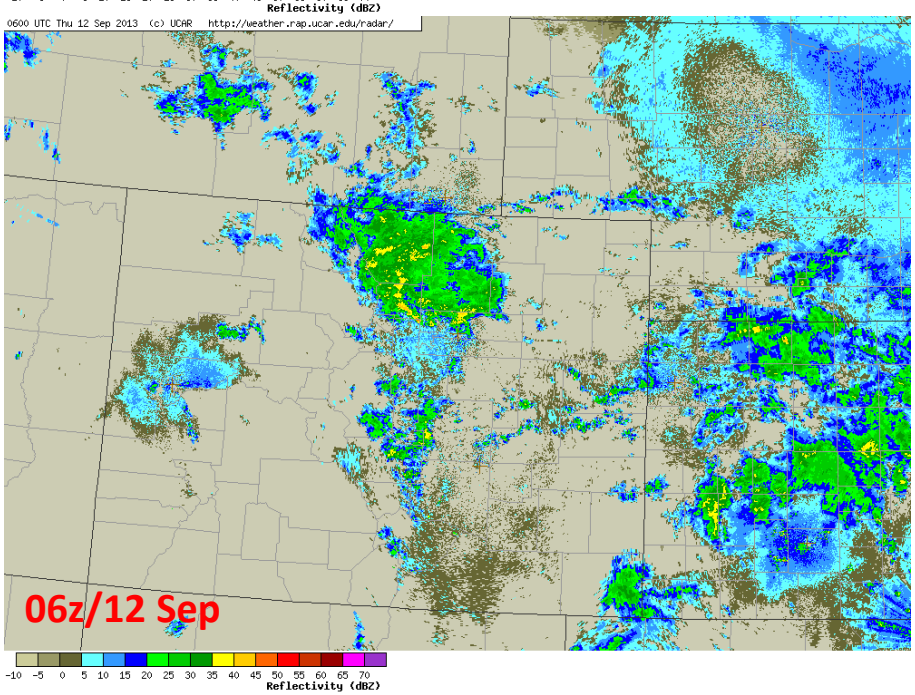


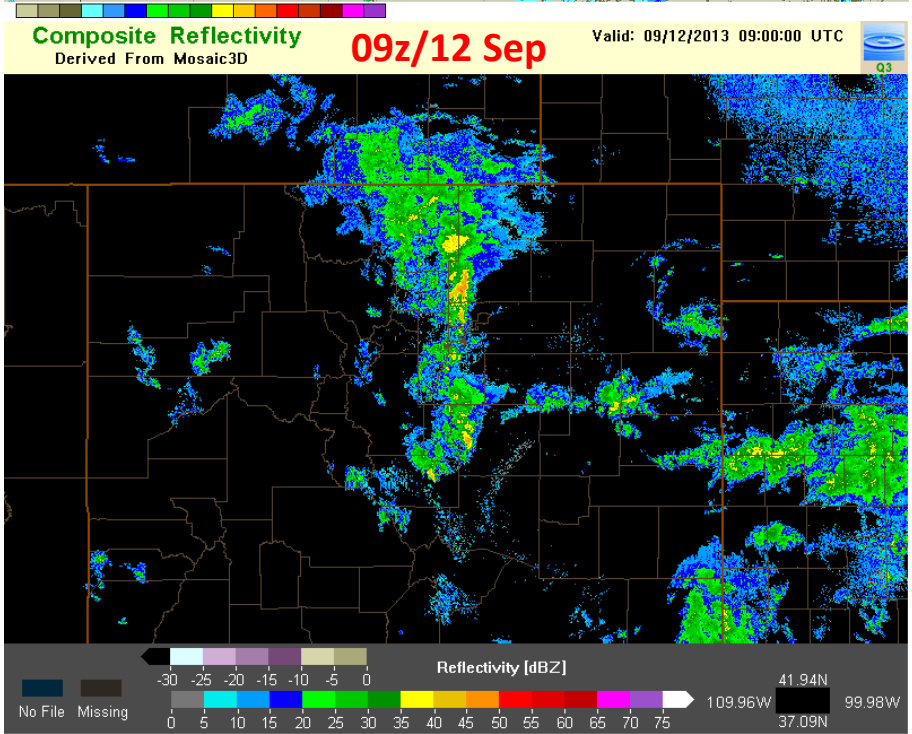



# Radar imagery for the evening and overnight on Wednesday 11 Sep



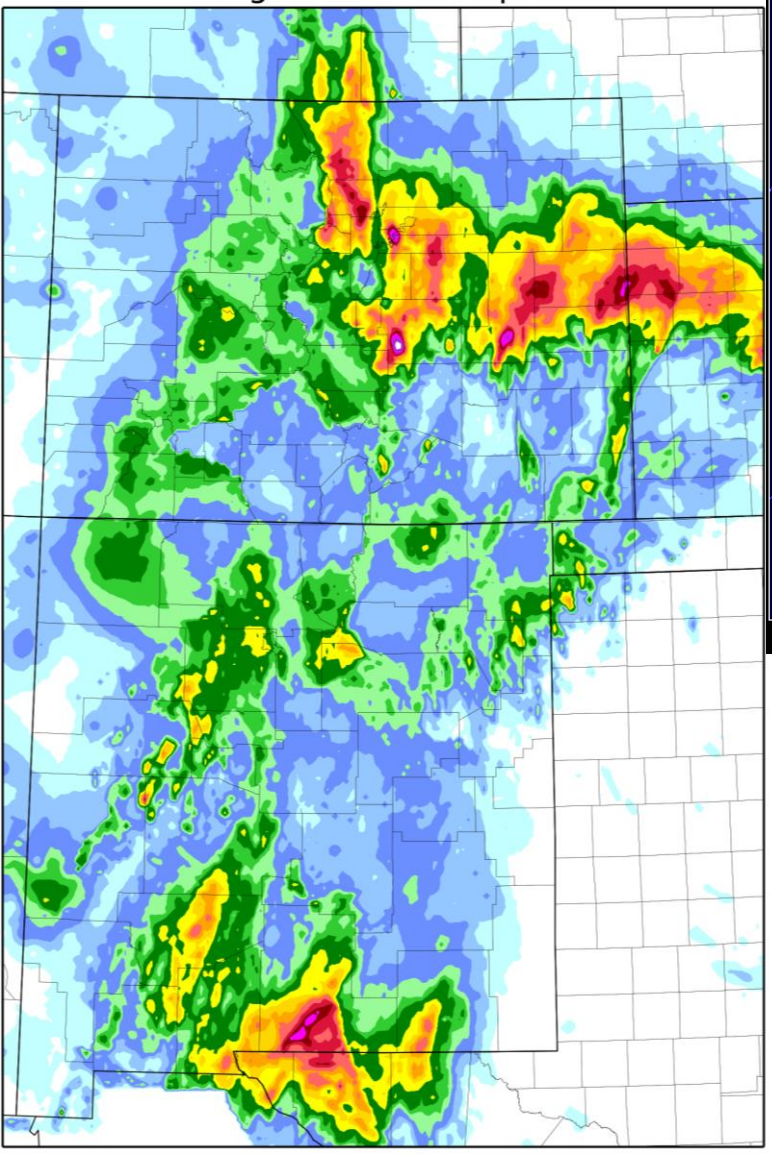



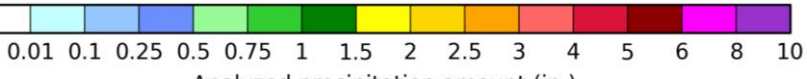



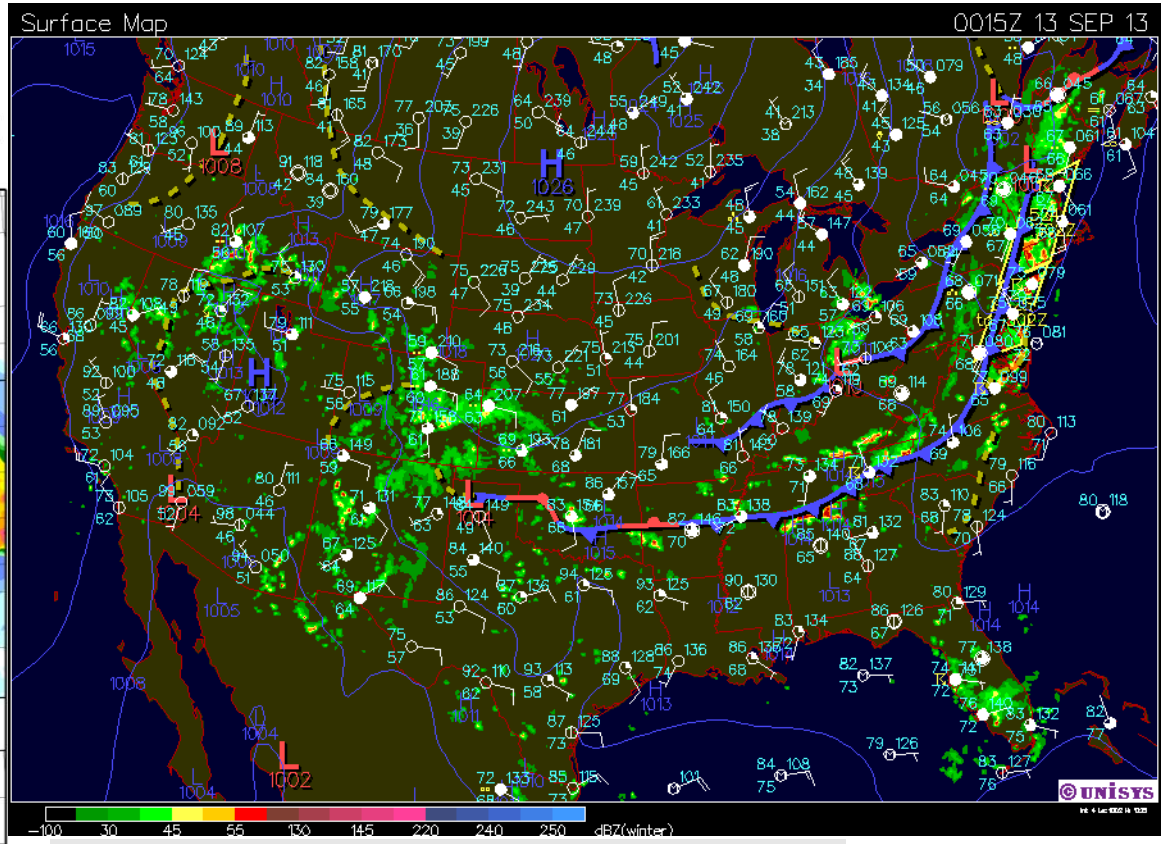



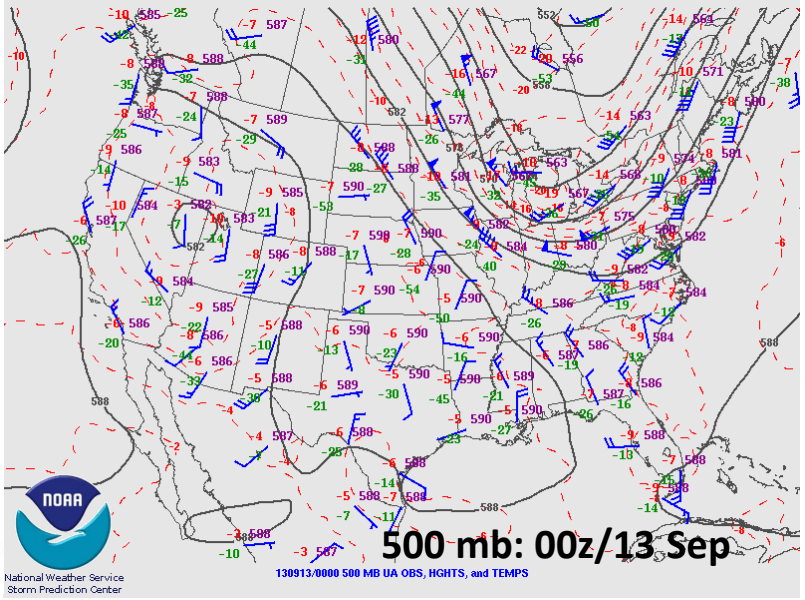
# 12-13 Sep 2013

24-h accumulated precipitation for the period ending 12 UTC 13 Sep 2013





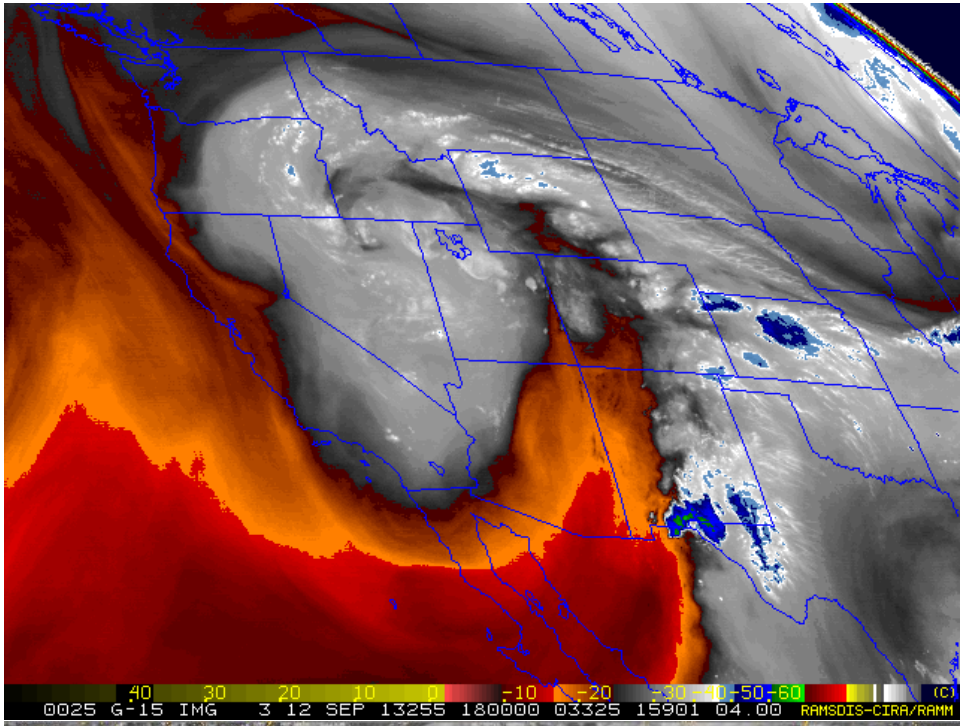



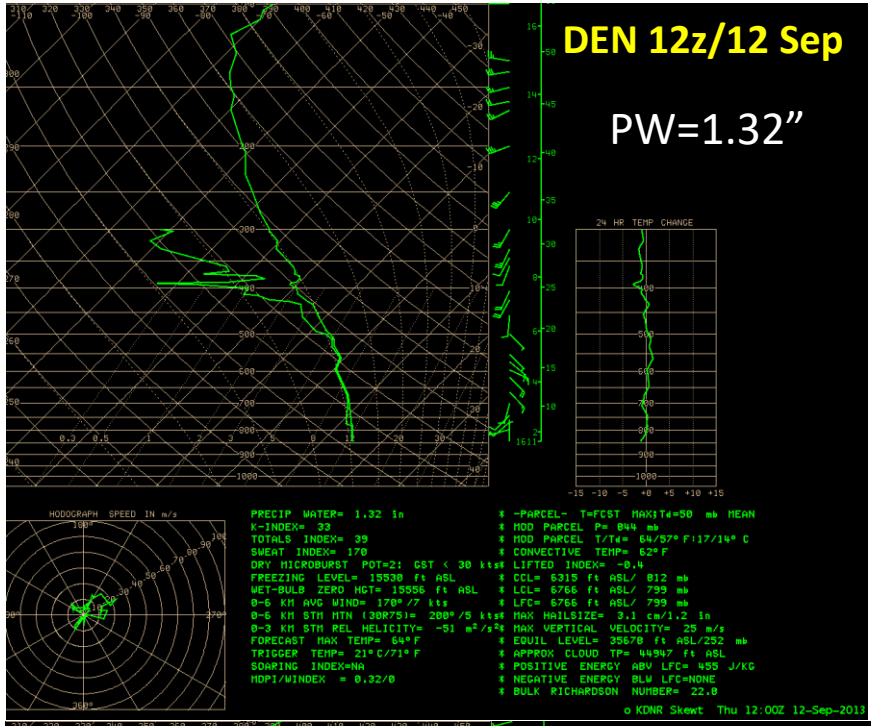




**500 mb: 00z/13 Sep**

*Lots of precipitation again and after the previous night of course lots of trouble. Note that there is far more precip on the plains in this 24-h period. Also the intense max over Aurora. The upper level low to our west is slowly lifting northward.*

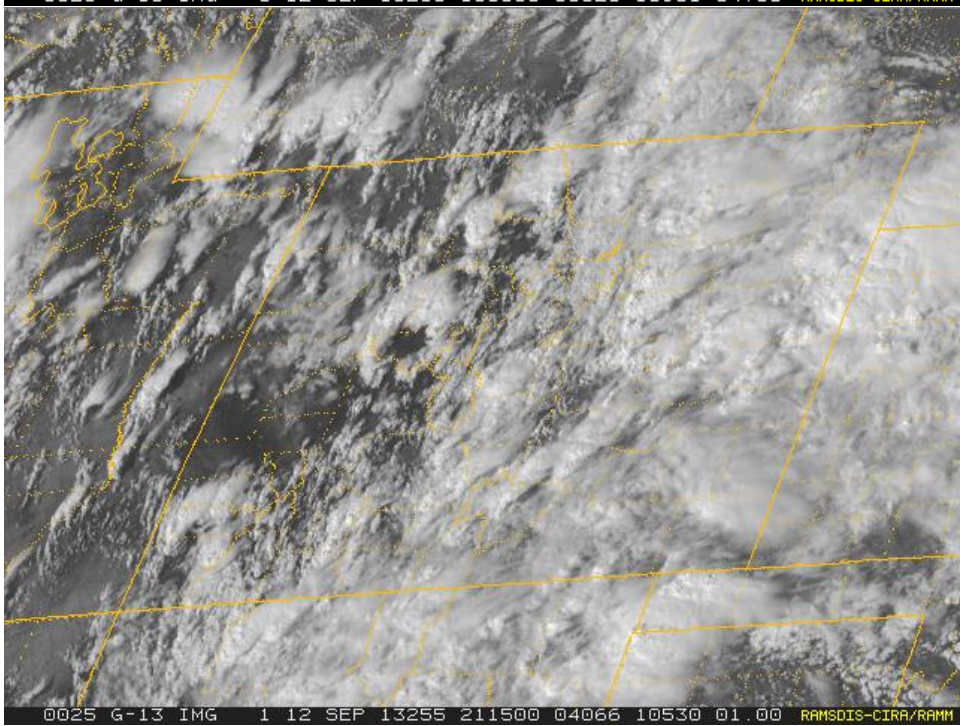
Water Vapor 18z/12 Sep

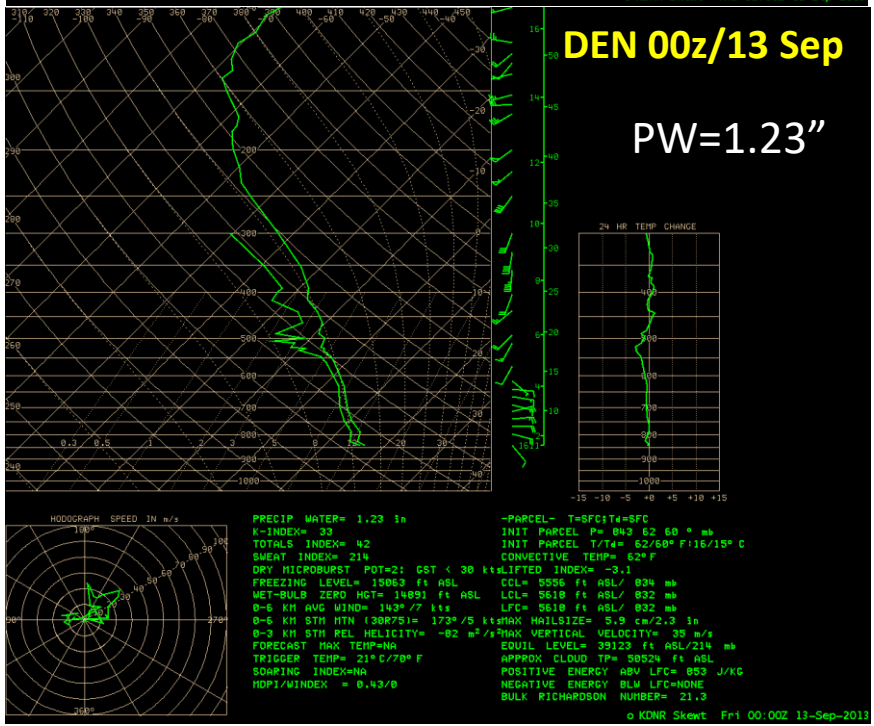


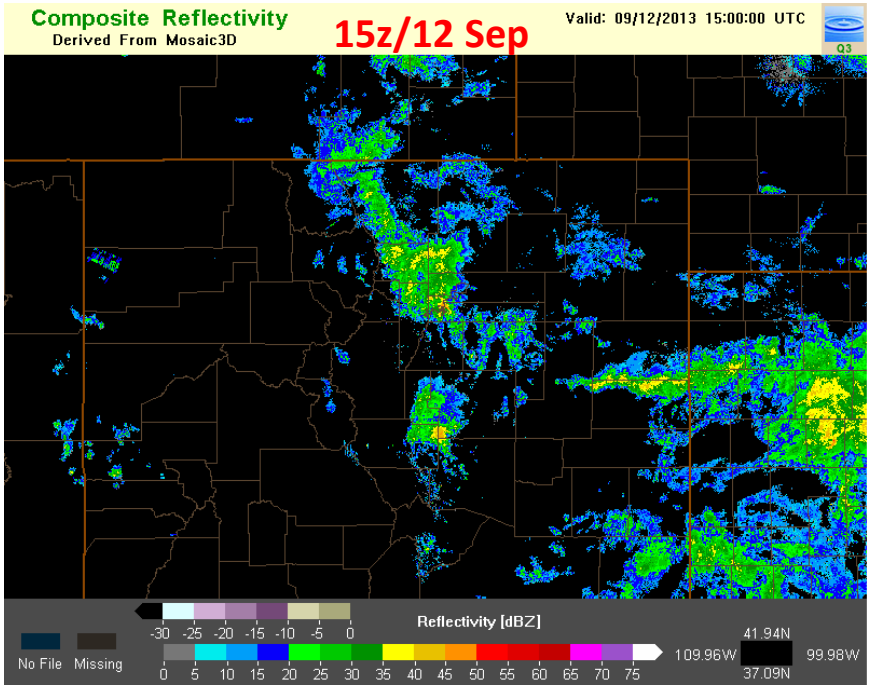

Thursday 12 Sep

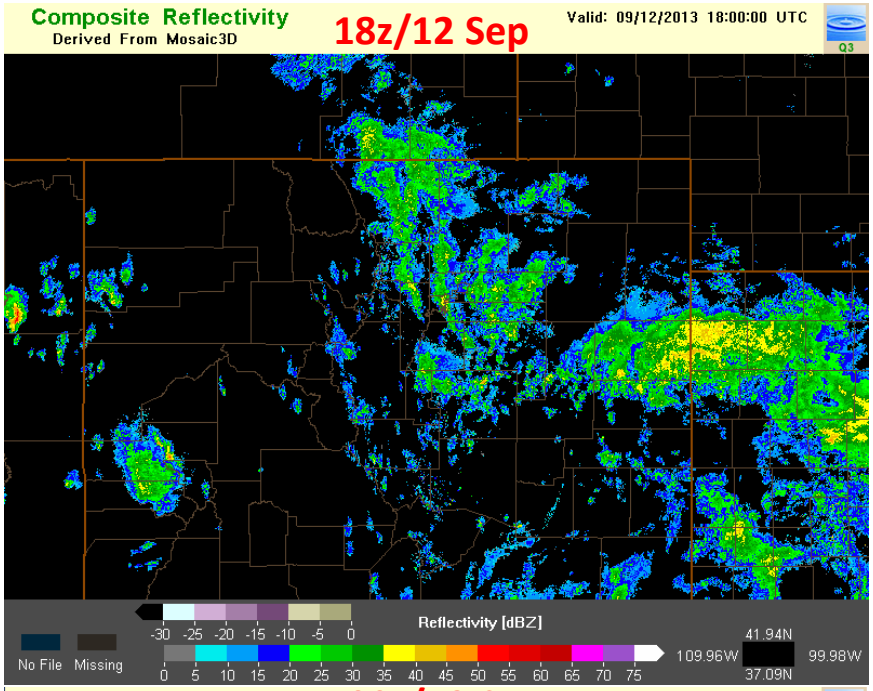
Visible 21z/12 Sep

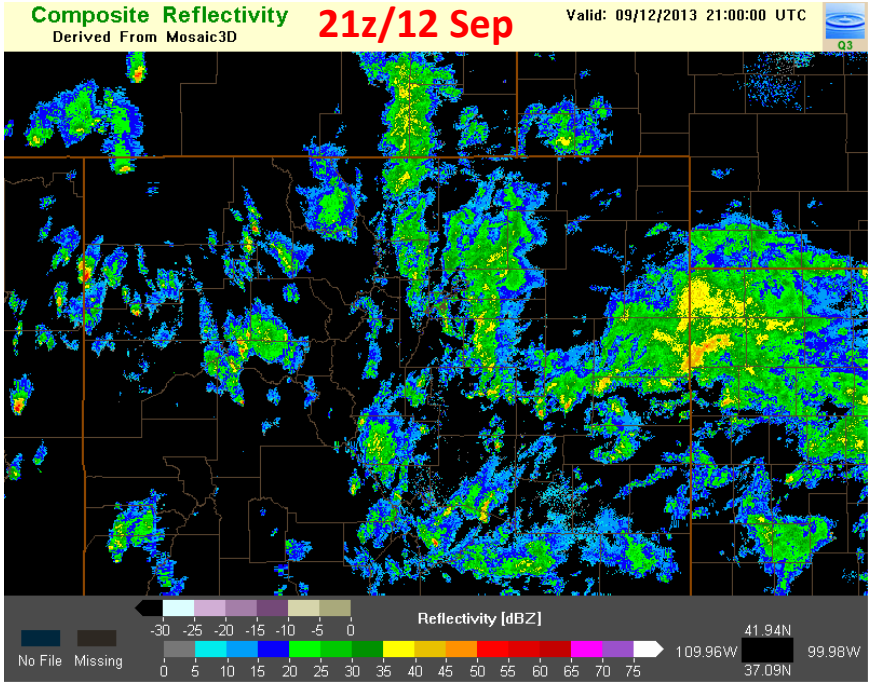


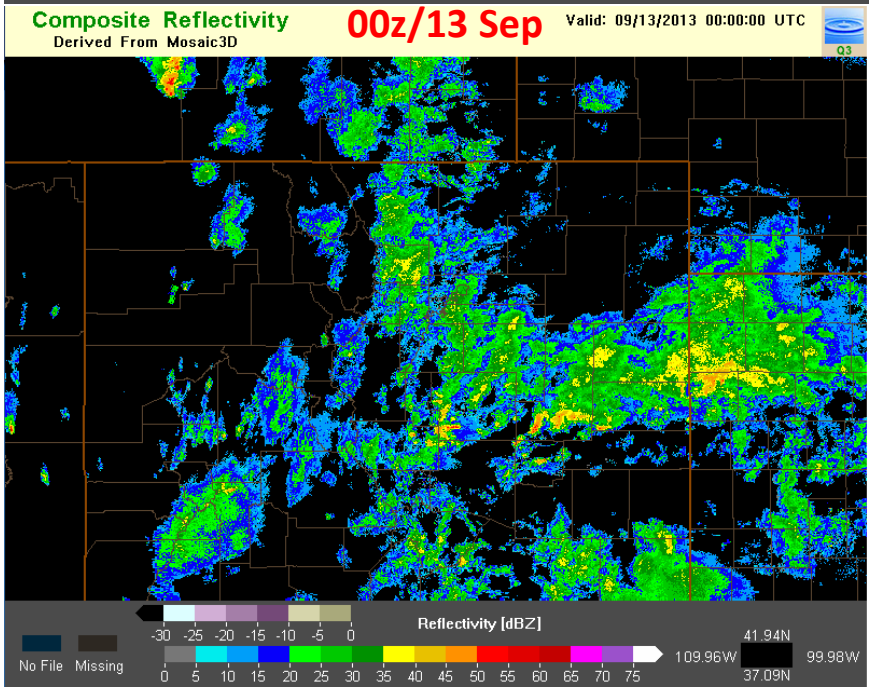



# Radar imagery for daytime on Thursday 12 Sep – *rains continue into the foothills, heavy band Aurora, bigger band east*

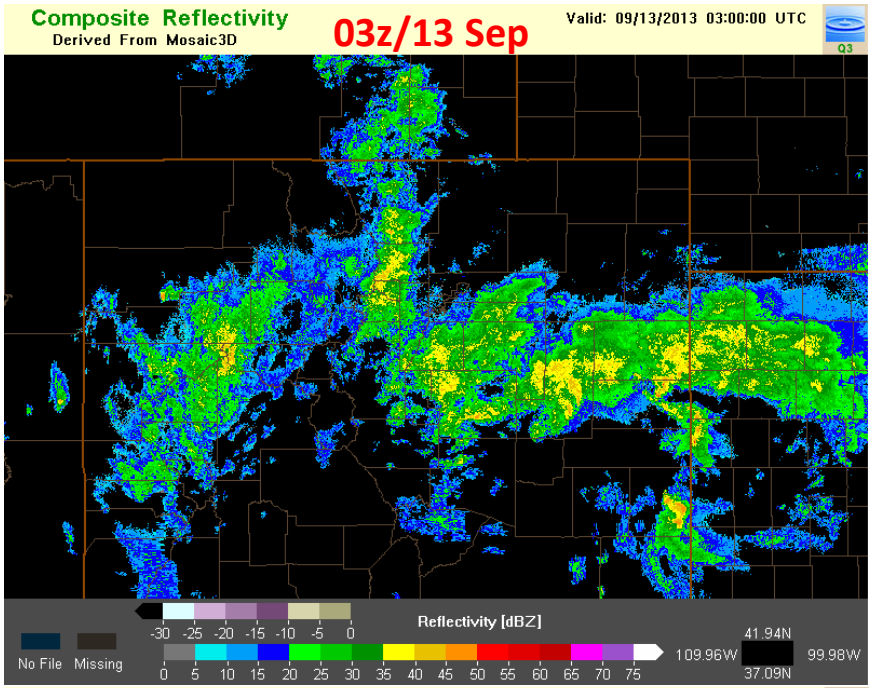


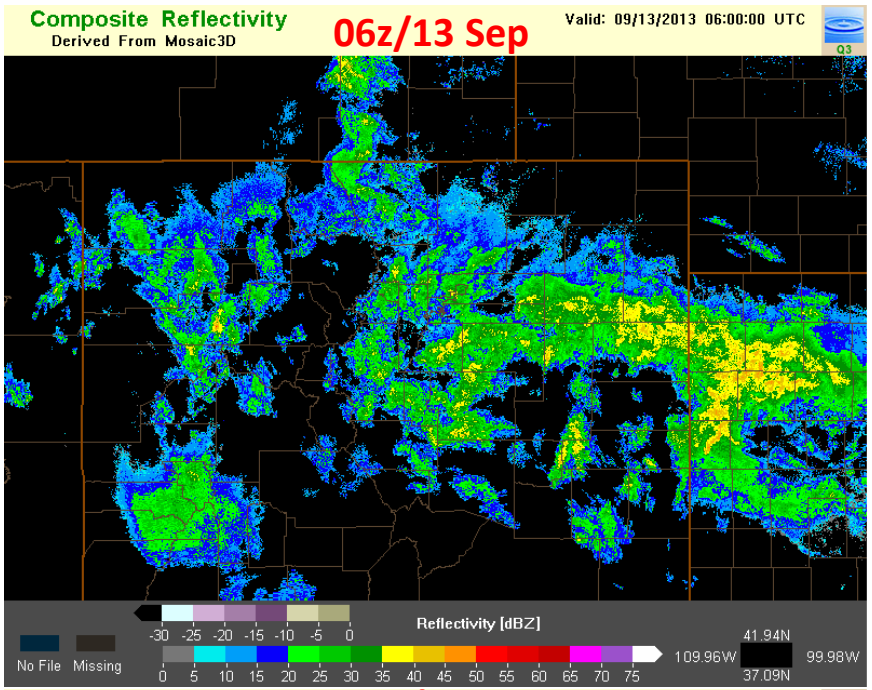



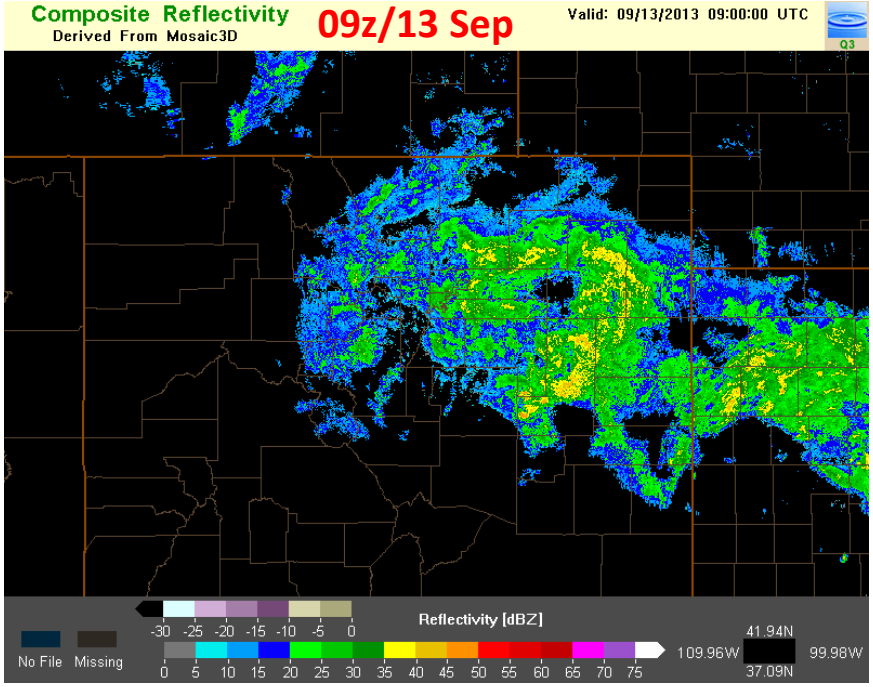



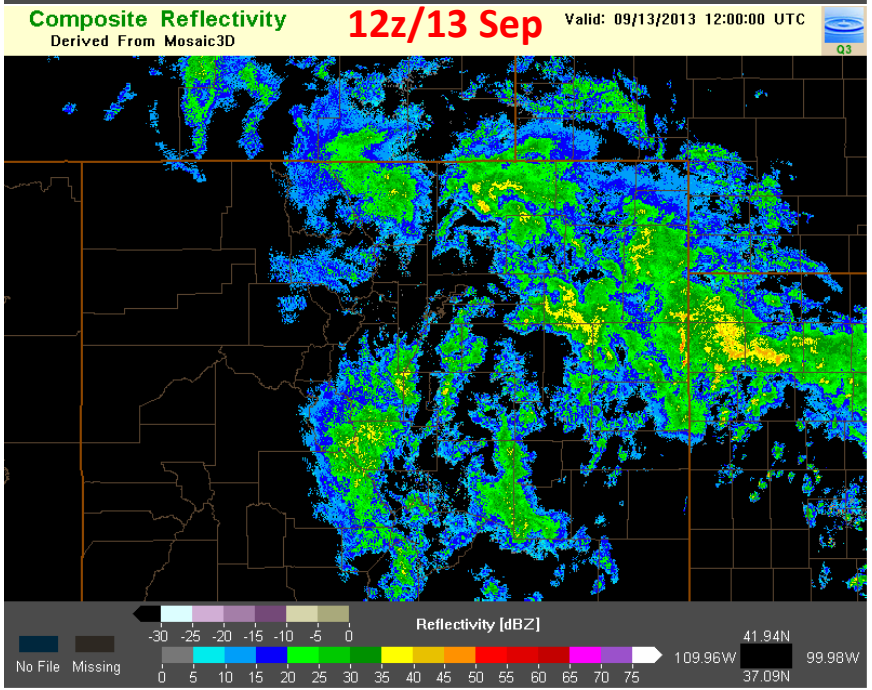



# Radar imagery for overnight on Thu 12 Sep – *The larger scale band continues north and finally clearing develops behind it*



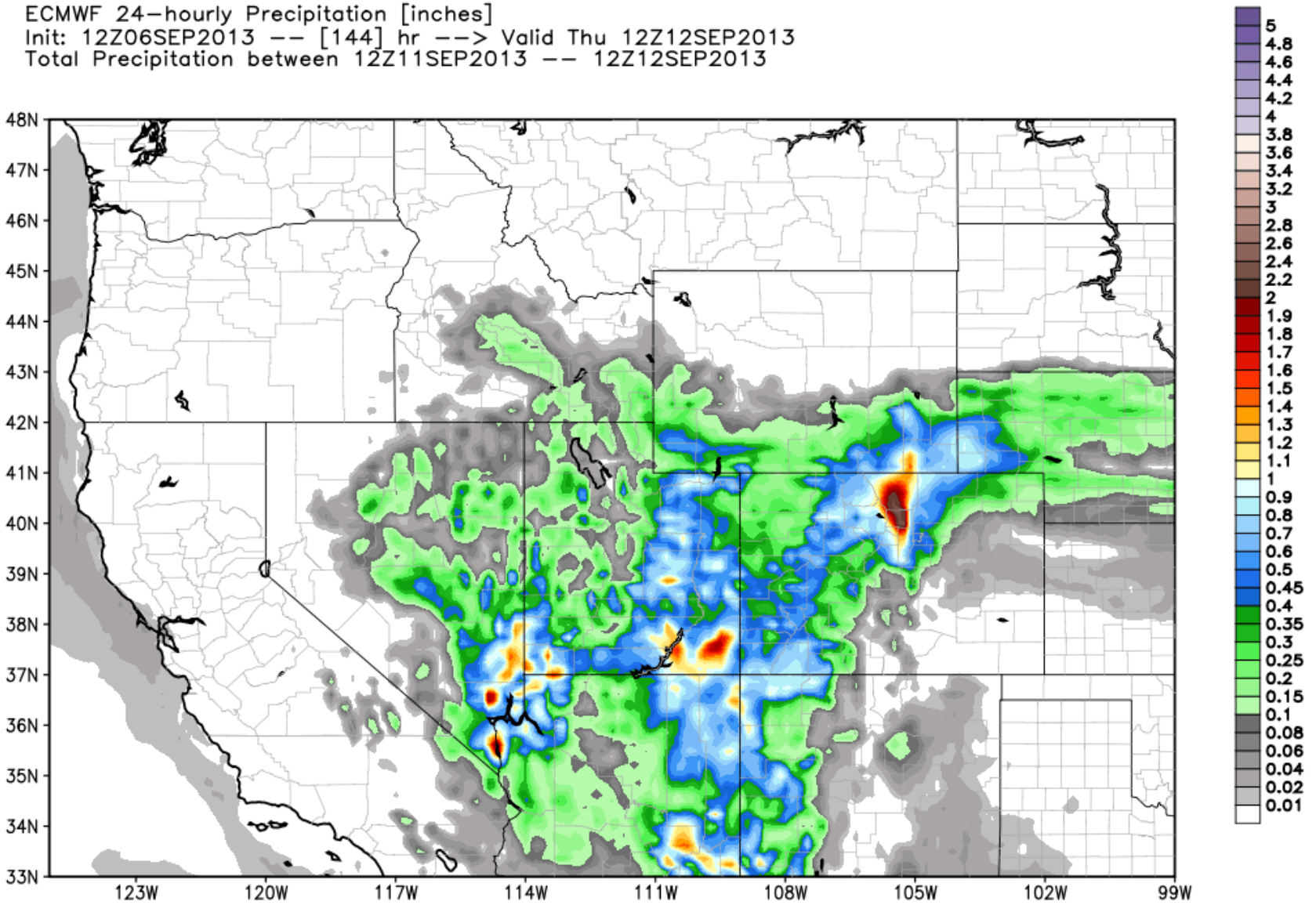



# Longer range forecasts

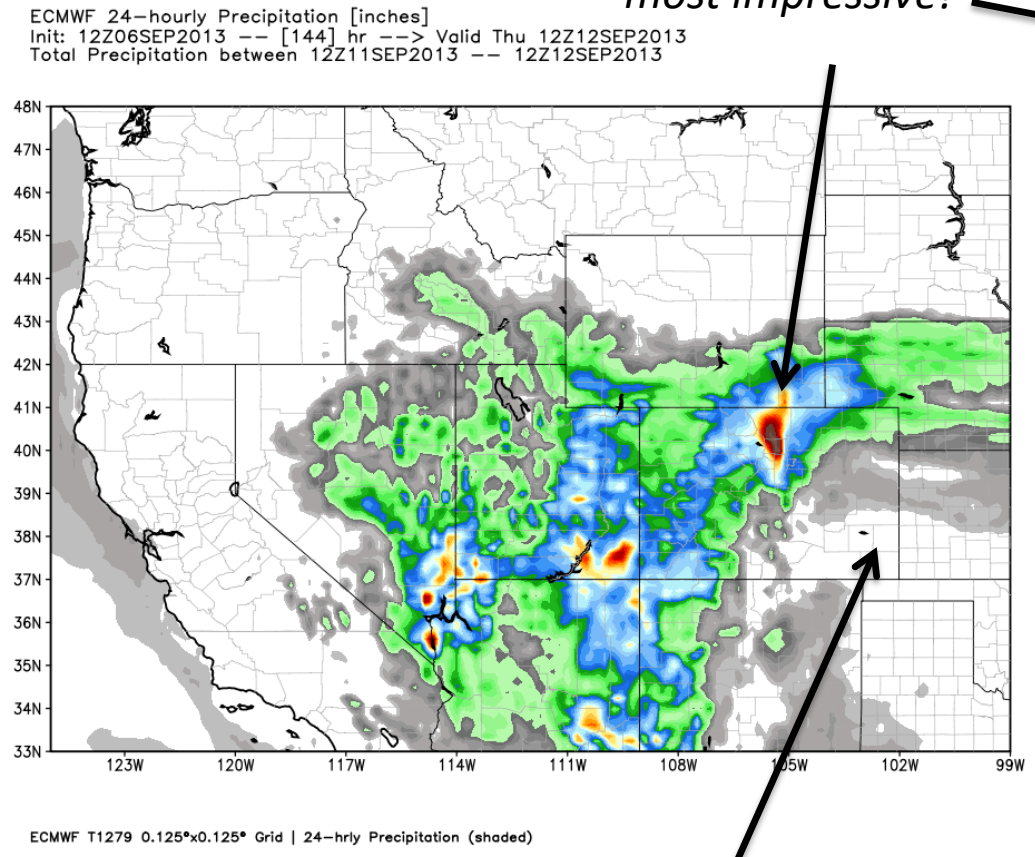
# **Longer range forecasts –** "cherry picking" a specific forecast?



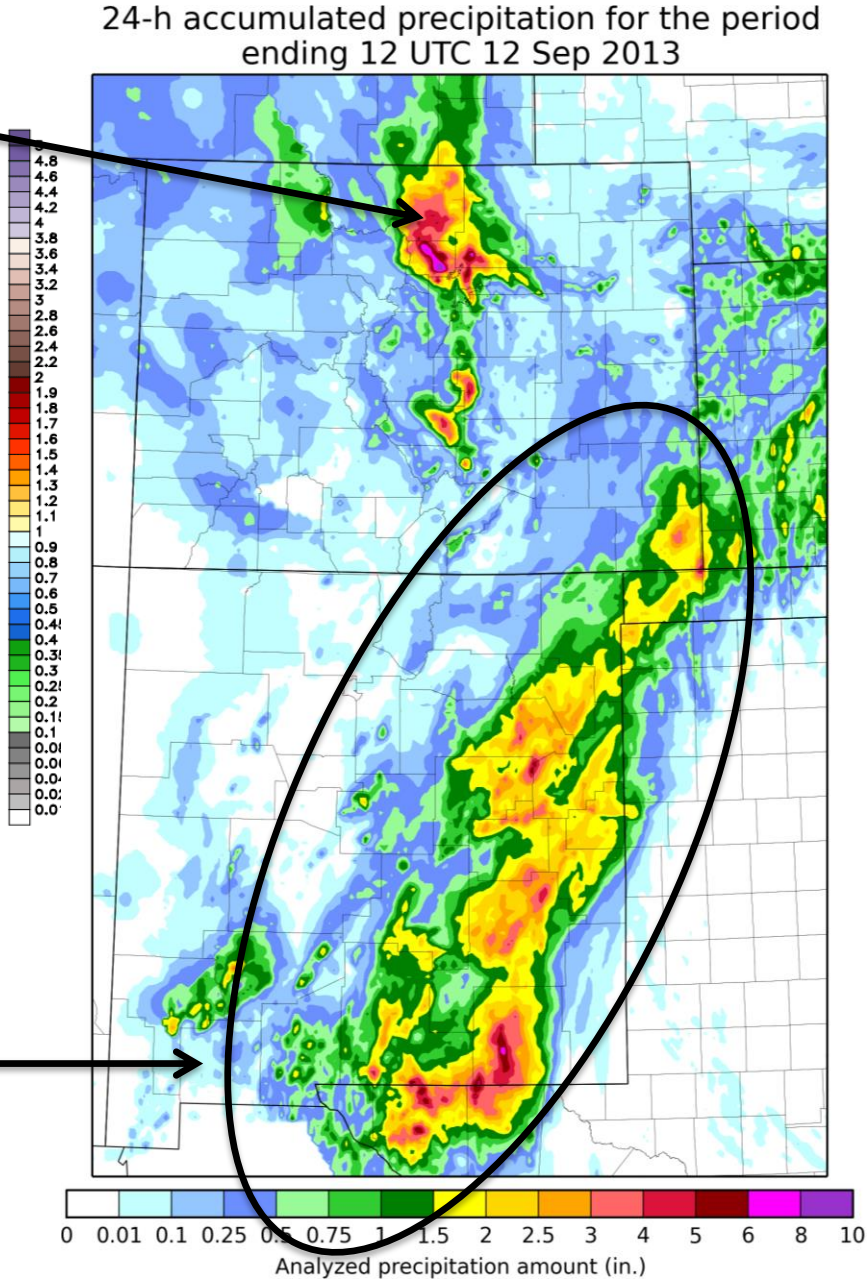

*Impressive 144-h forecast of 24-h precip ending 12z/12 Sep from 12z/6 Sep ECMWF*

# But upon further review...

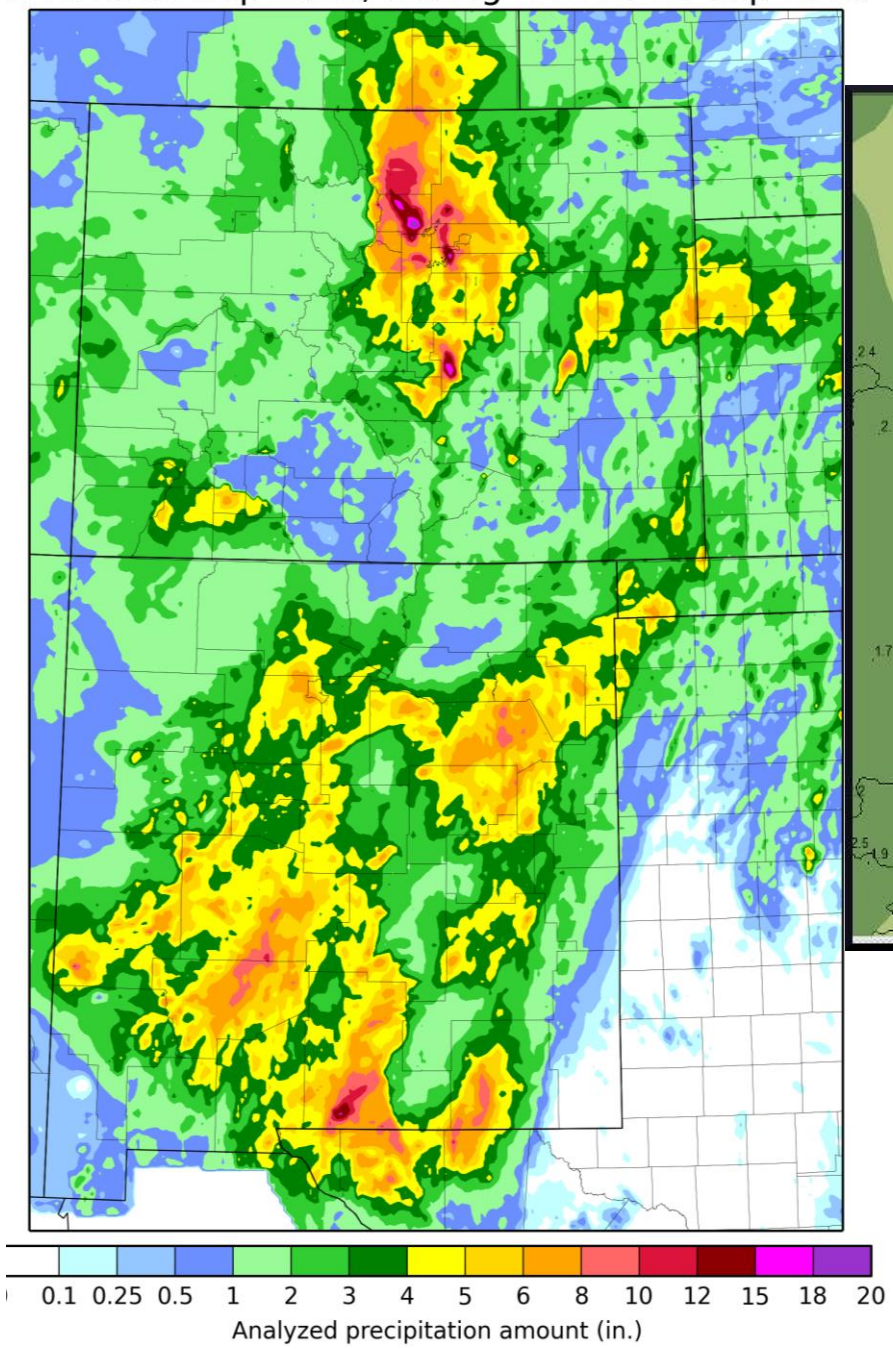
*most impressive!*

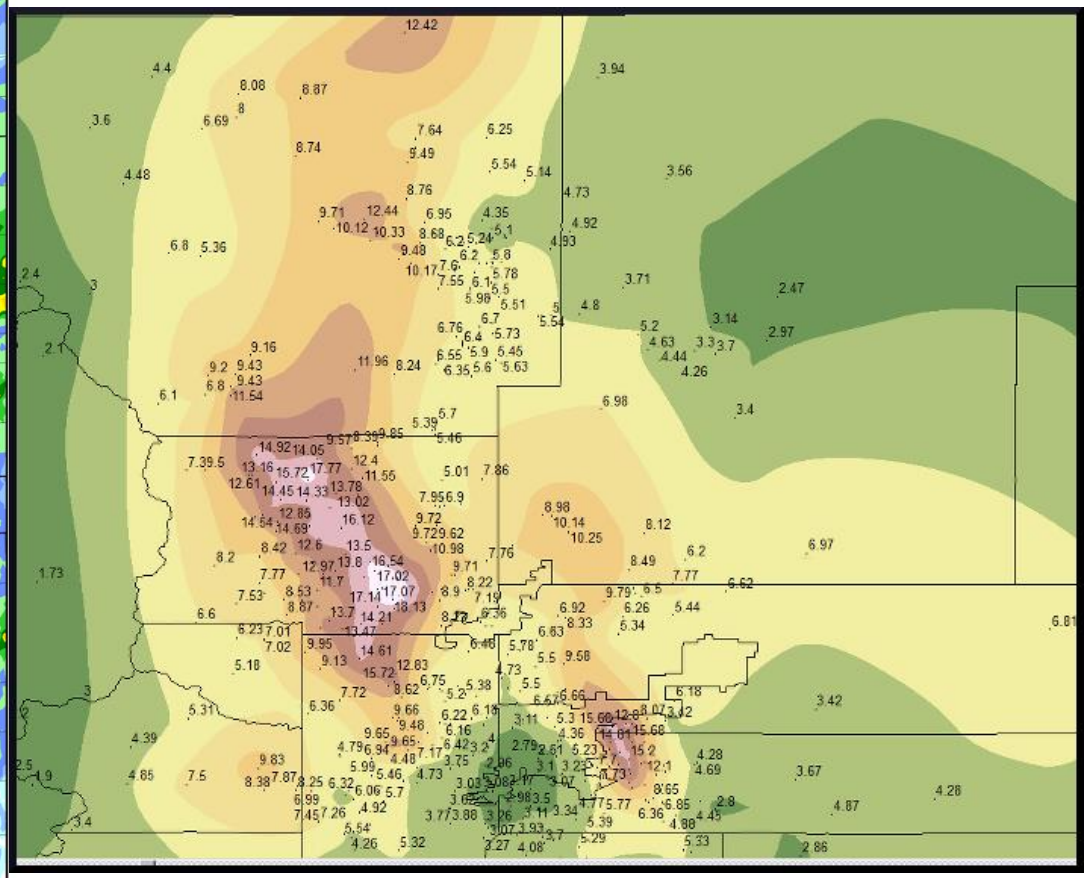



*But not so good here*

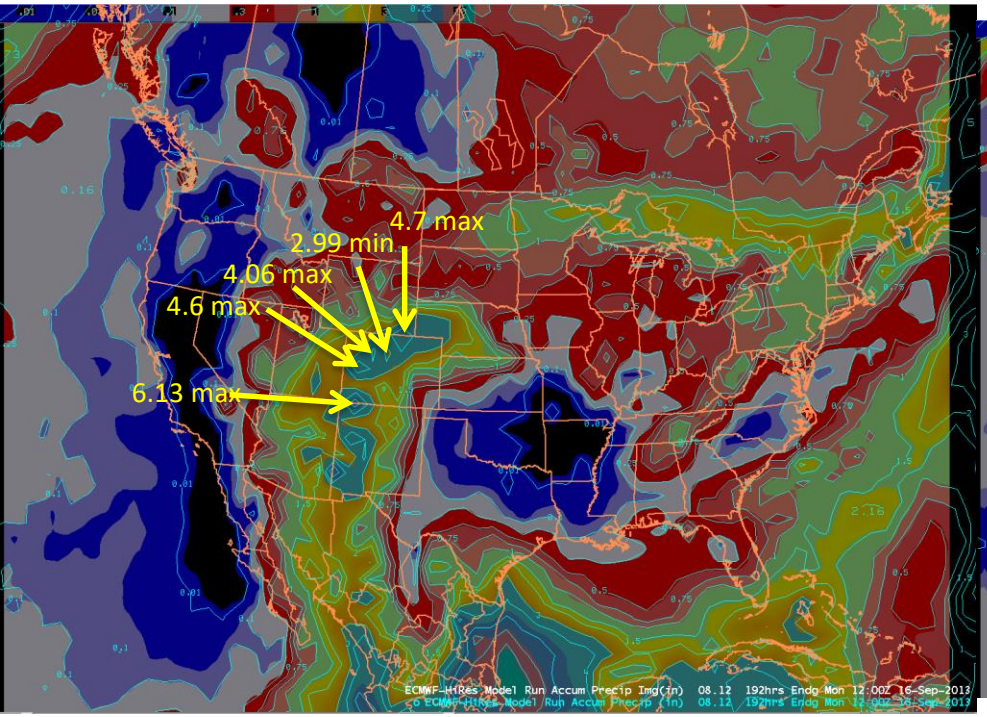


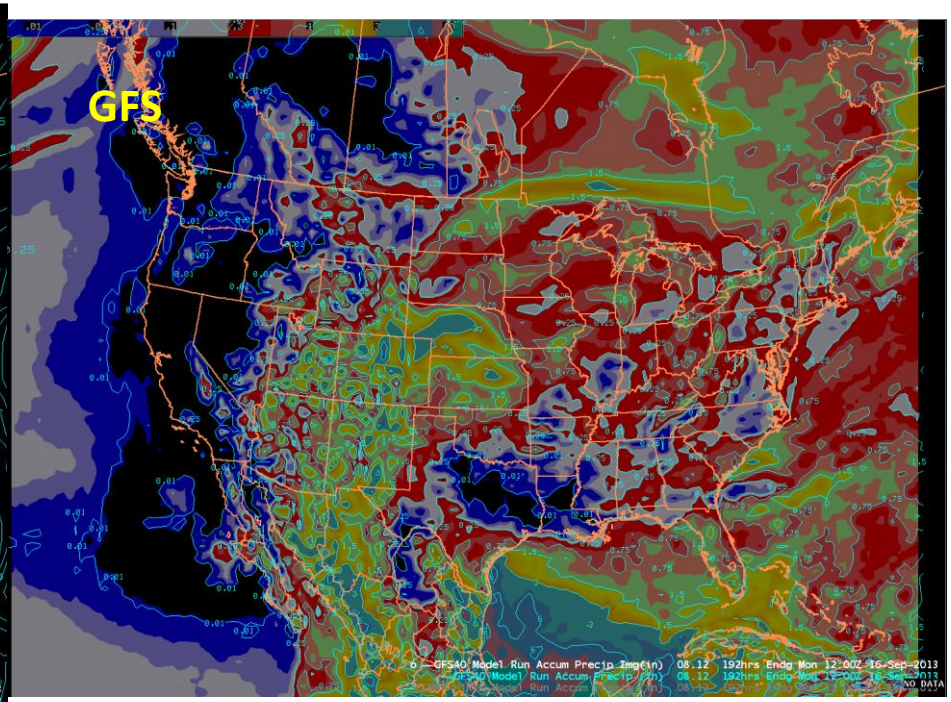
# 9-16 Sep 2013 Total Precip

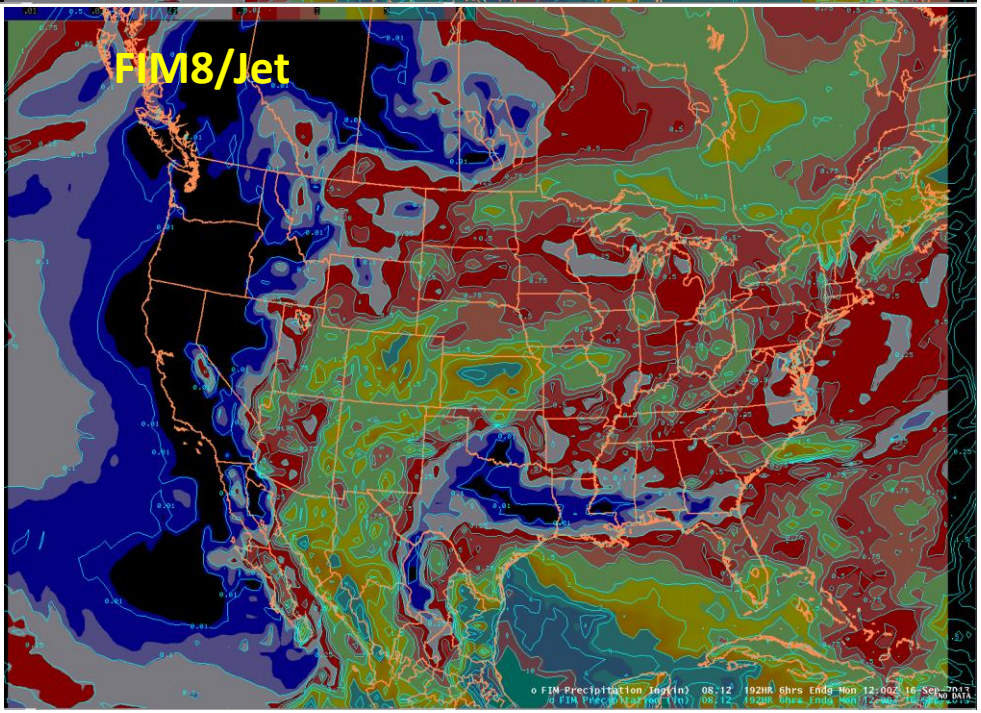


Precipitation analysis from the Advanced Hydrological Precipitation Service (AHPS) (left) and from Boulder WFO (using CoCoRaHS and other data sources). *Note that this was a very wet week in NM as well, with flooding also reported.*



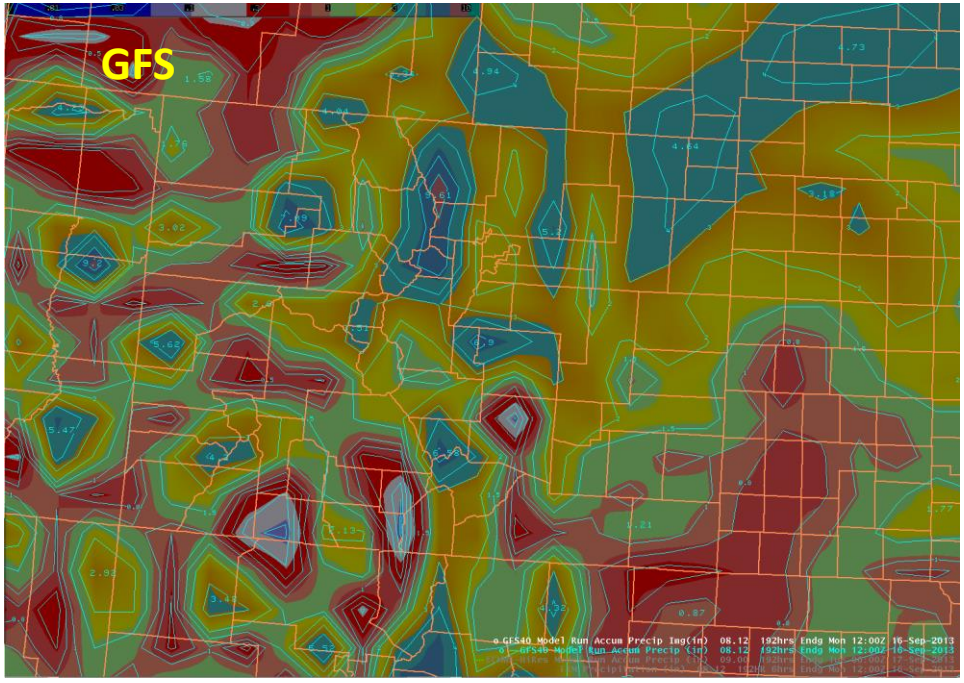



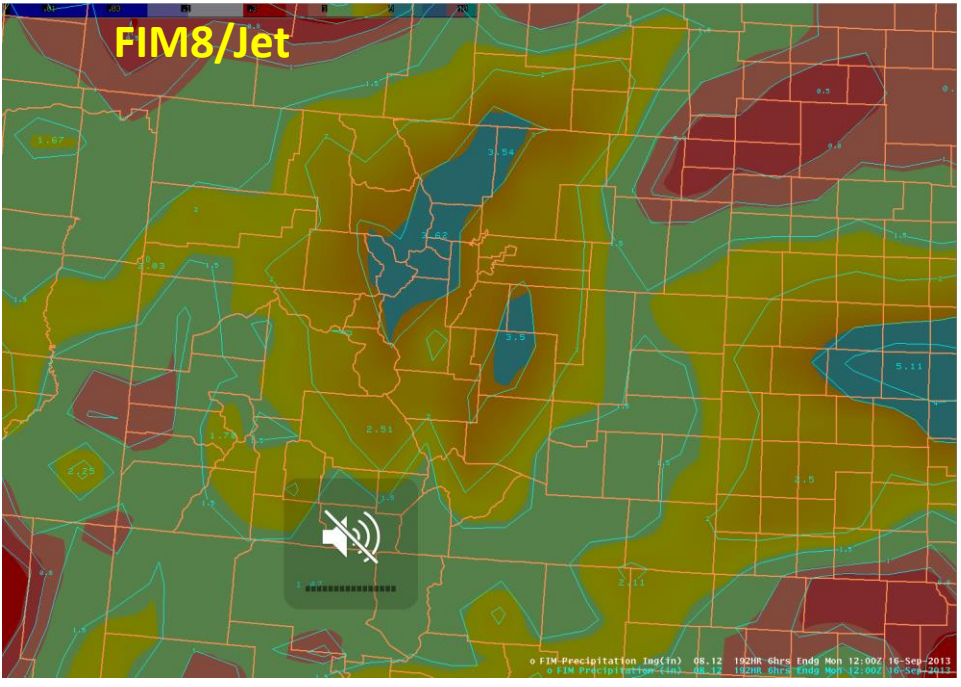

# 192-h total precipitation forecasts from 12z/8 Sep runs valid at 12z/16 Sep

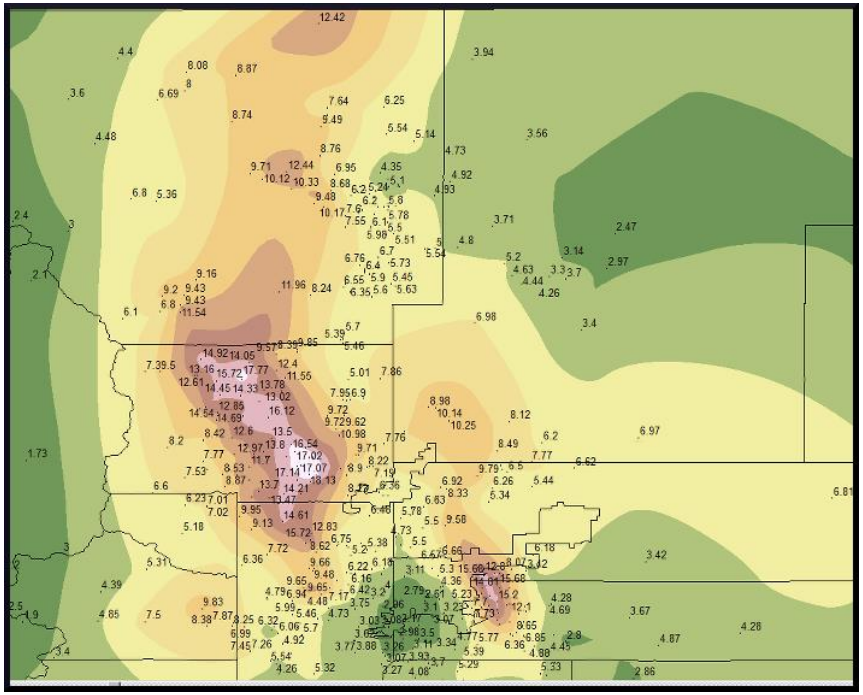
*The color table has gradients of 1-3", then 3-5, the >5". Earlier forecasts from several days before also had a fairly consistent picture of a wet week.*

# 192-h total precipitation forecasts from 12z/8 Sep runs valid at 12z/16 Sep – CO closeup

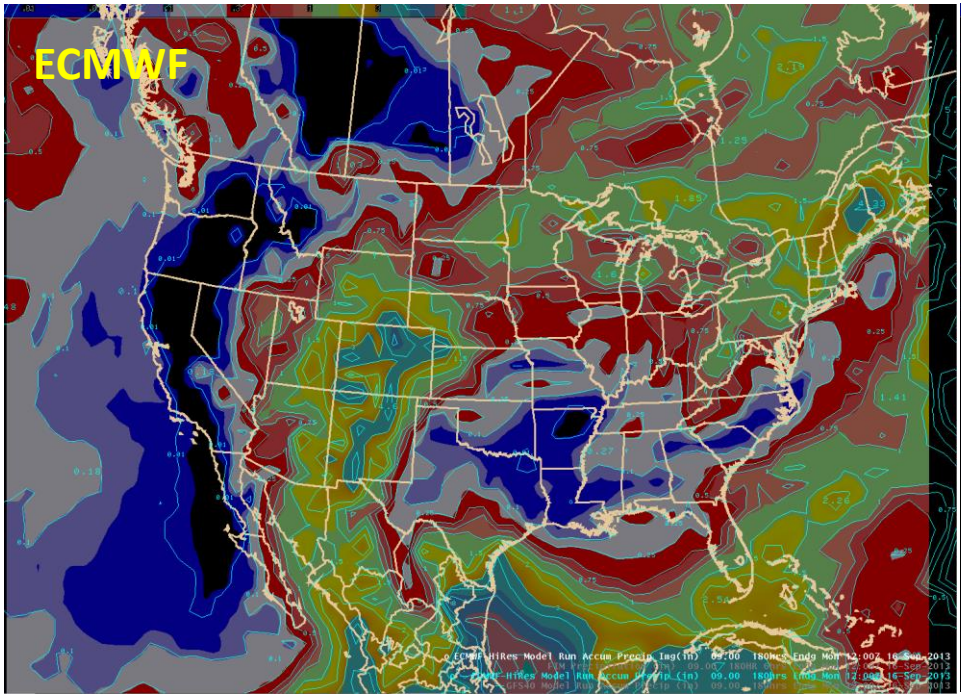
ECMWF

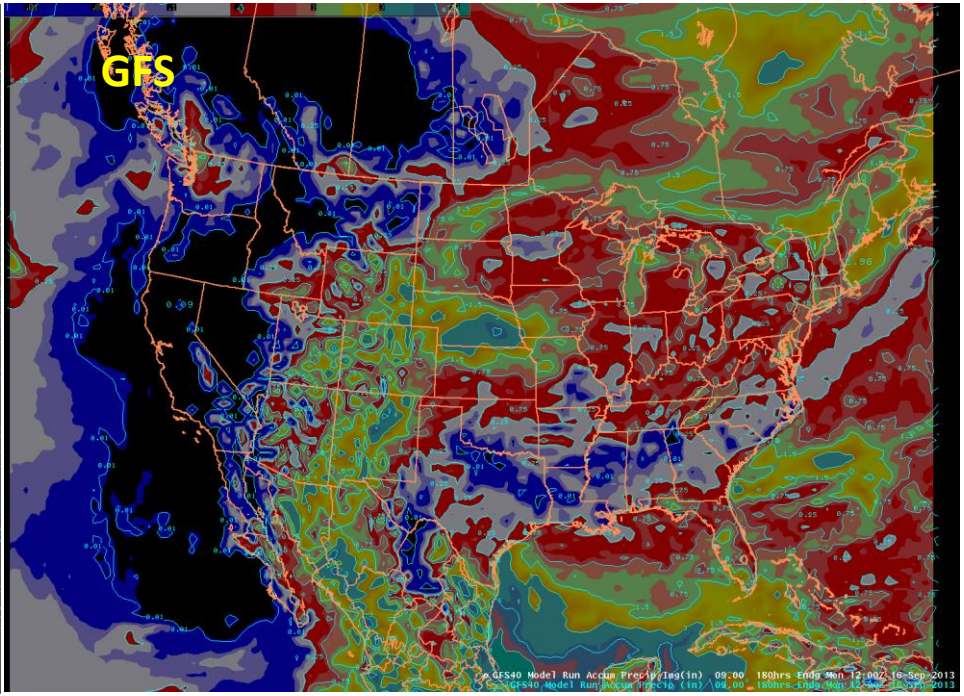


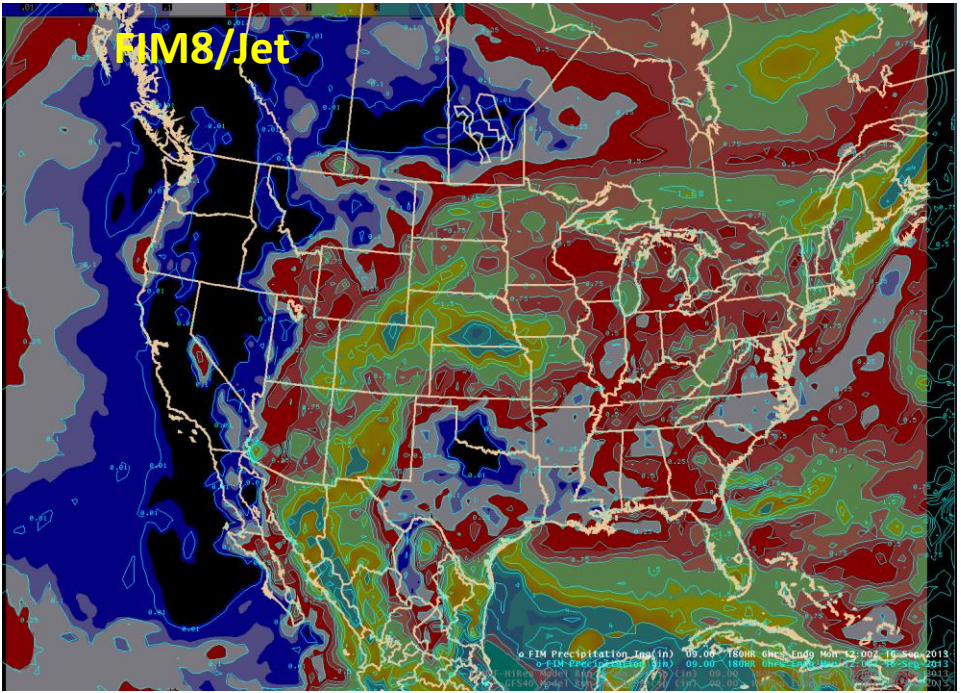



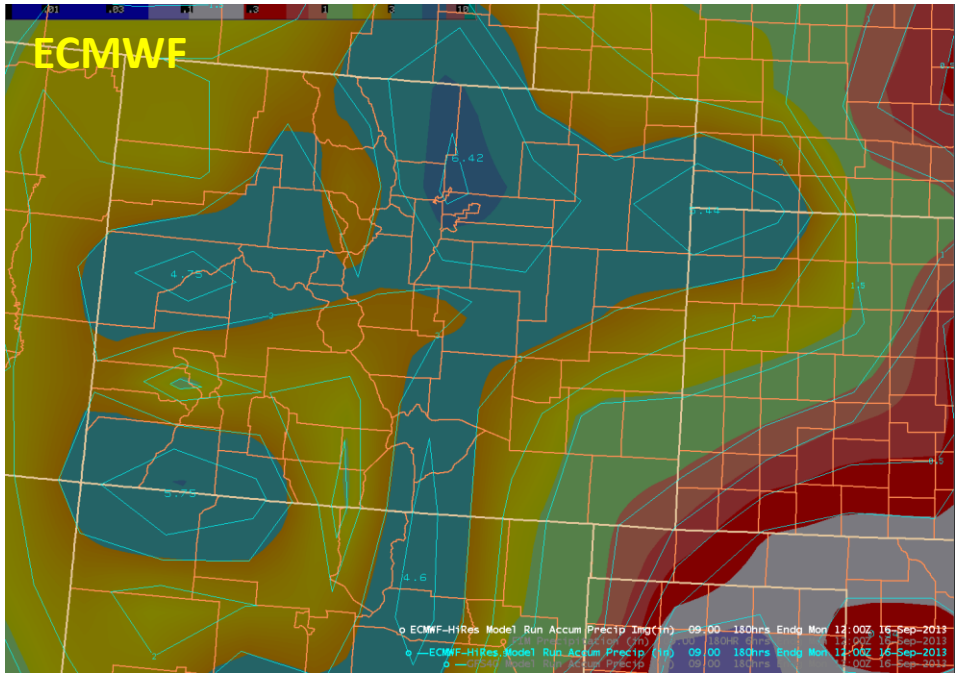
# 180-h total precipitation forecasts from 00z/9 Sep runs valid at 12z/16 Sep

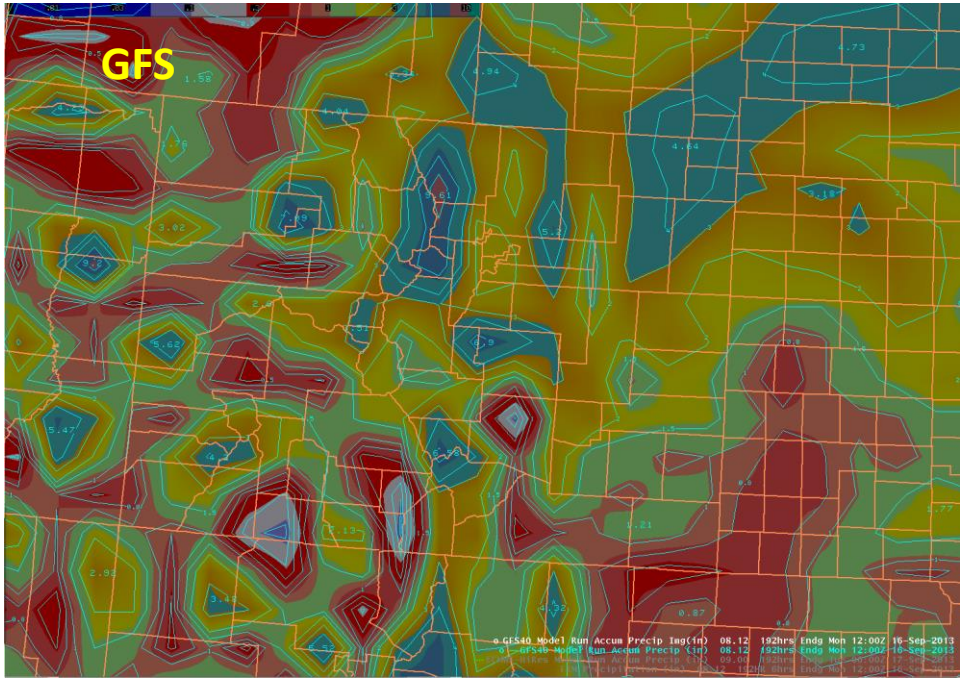


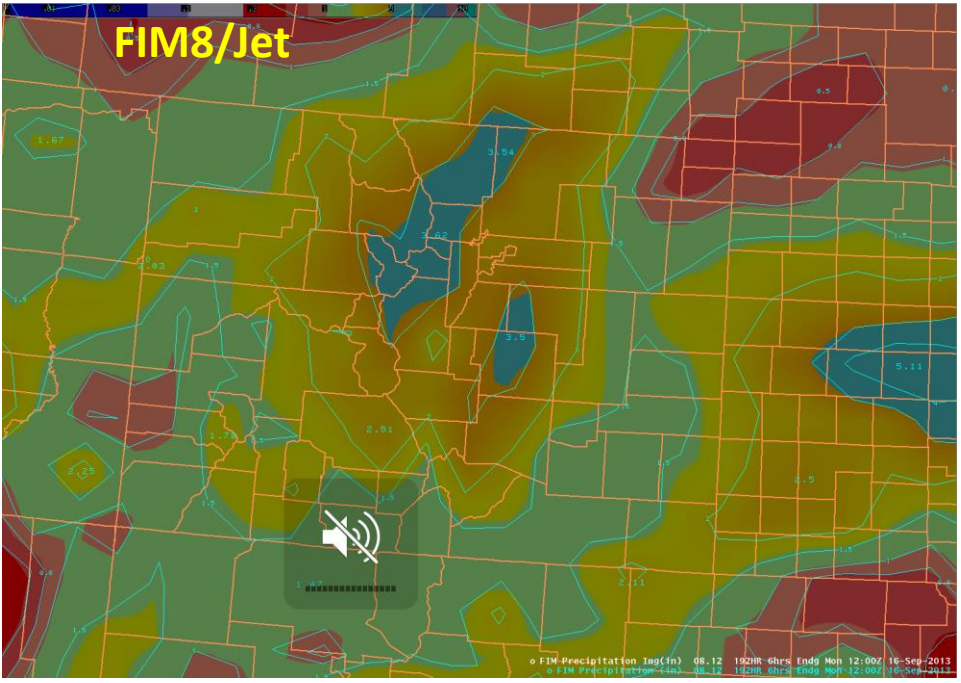



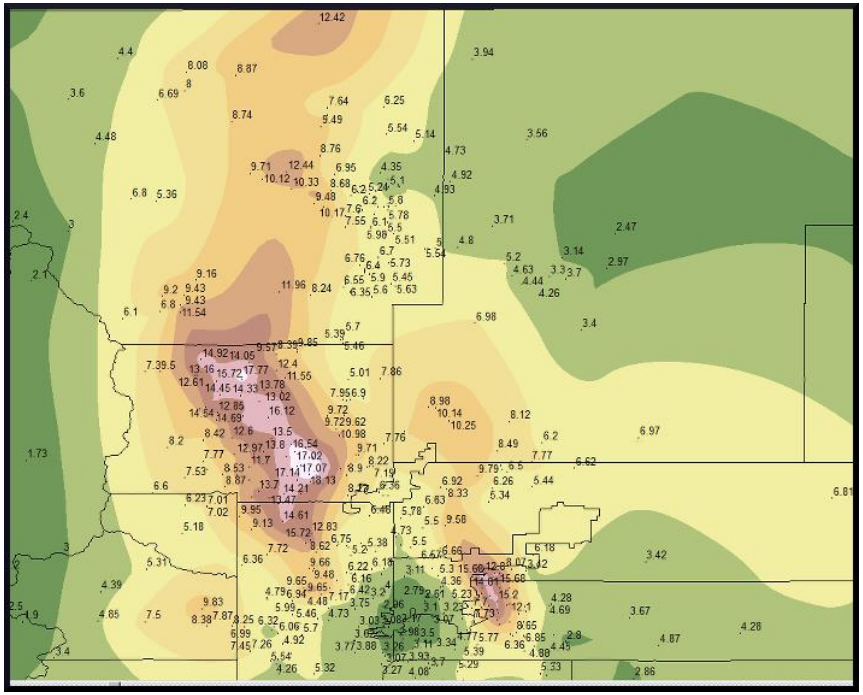



# 180-h total precipitation forecasts from 00z/9 Sep runs valid at 12z/16 Sep – CO closeup

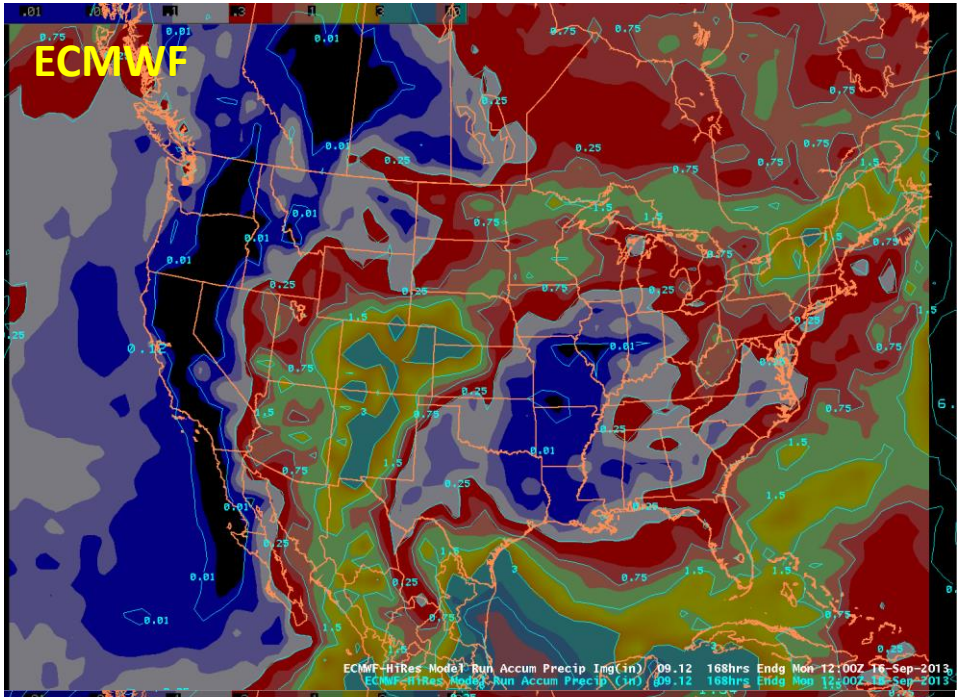


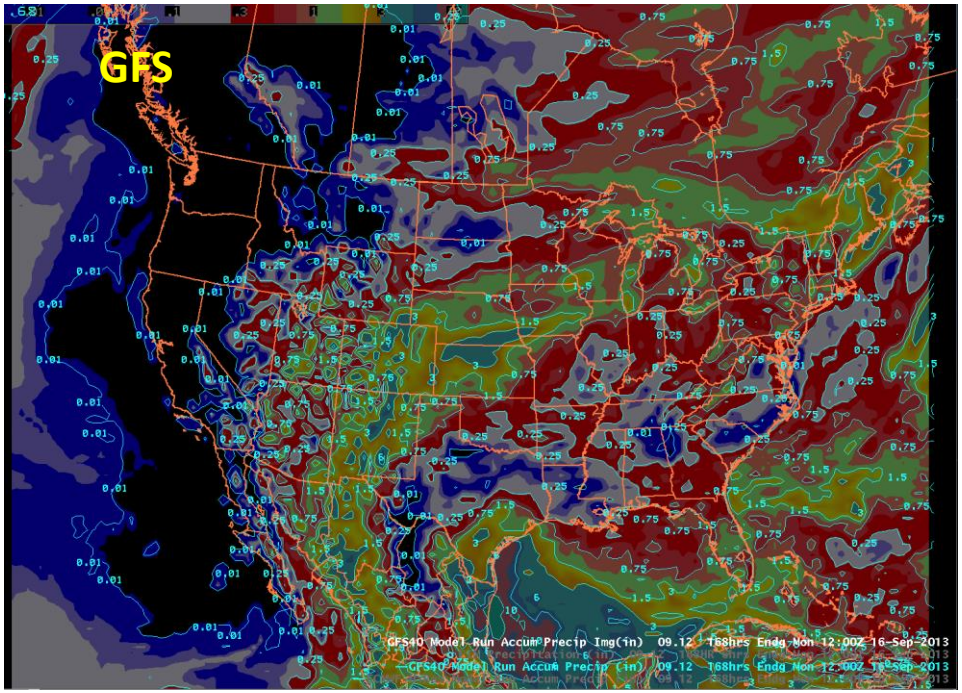



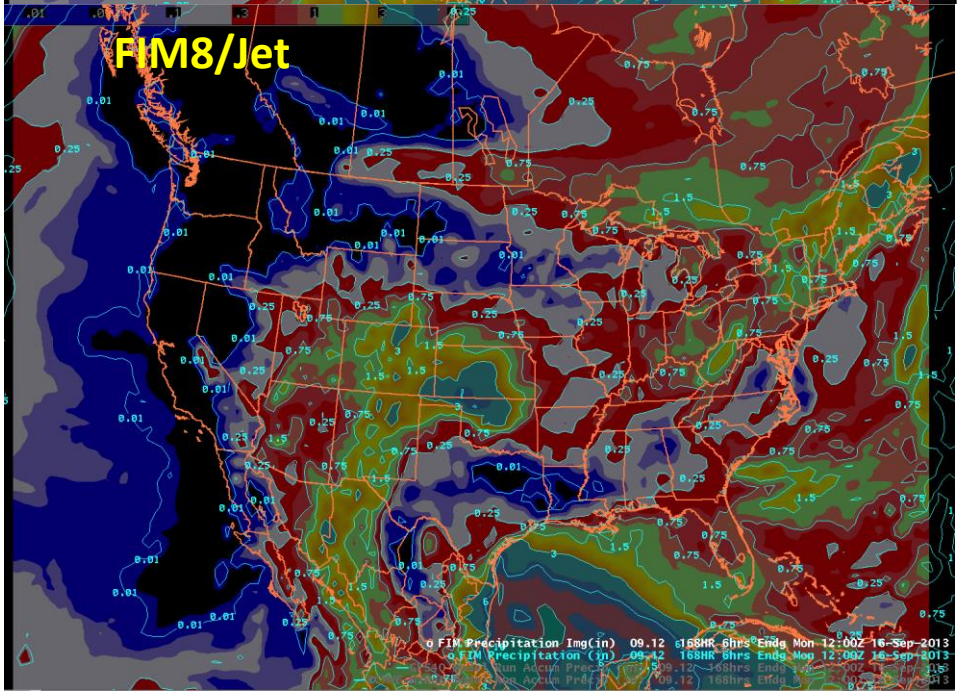



# 168-h total precipitation forecasts from 12z/9 Sep runs valid at 12z/16 Sep



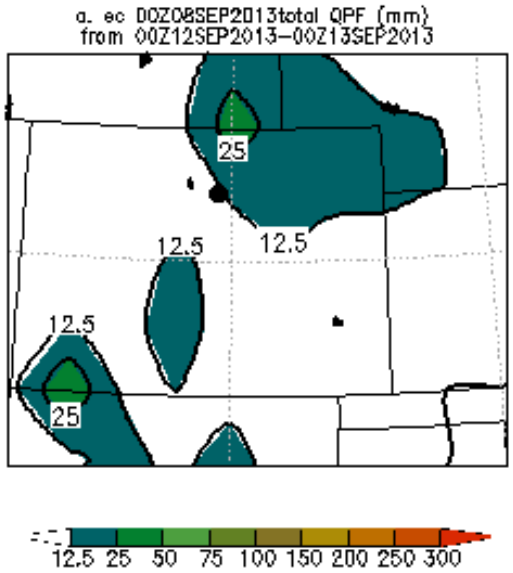

*The forecasts from the Monday morning runs still showed a wet week but see some hints of backing off from the amounts seen in earlier runs.*

# Mid to Longer range forecasts

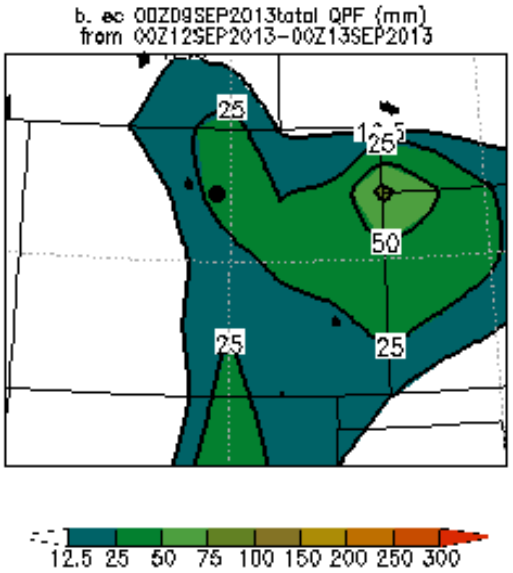
- Next couple of slides show a series of forecasts from the ECMWF and GFS for the first and very sig 24-h period of heavy rains (00z/12-00z/13 Sep)
- Note that we certainly see variability from run to run
  - And certainly not all the runs predicted big precip amounts for the foothills

# Overview- EC Forecasts QPF for 24-h period of 00z/12-00z/13 Sep (note: units are mm)

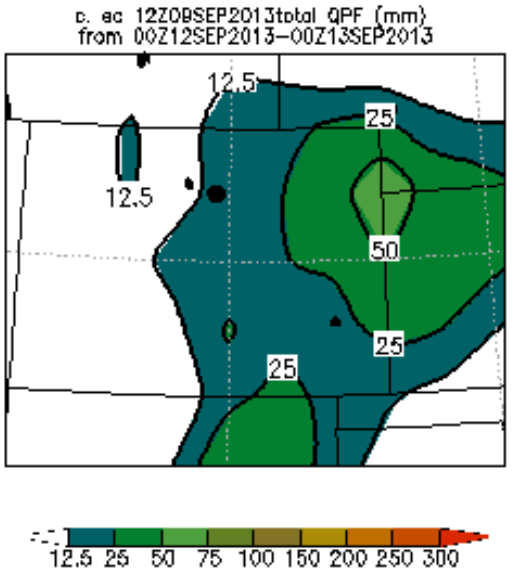
From: 00z/8 Sep



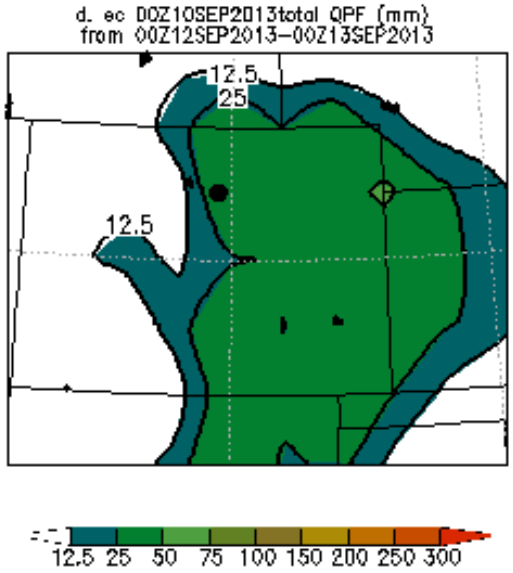

00z/9 Sep



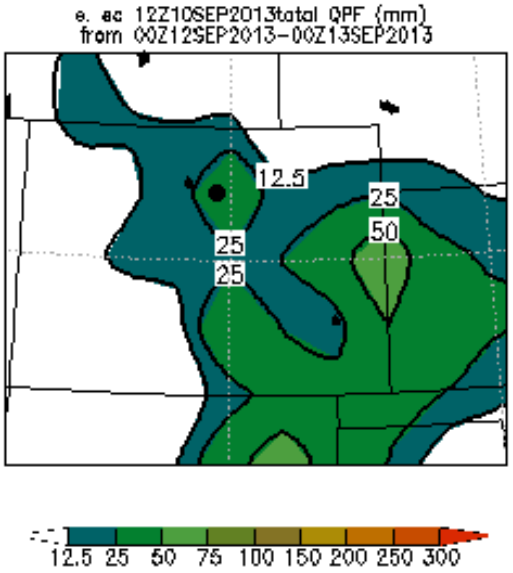

12z/9 Sep



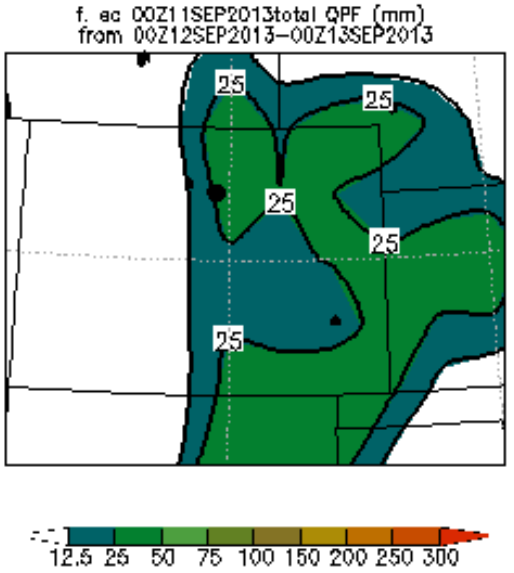

From: 00z/10 Sep




12z/10 Sep

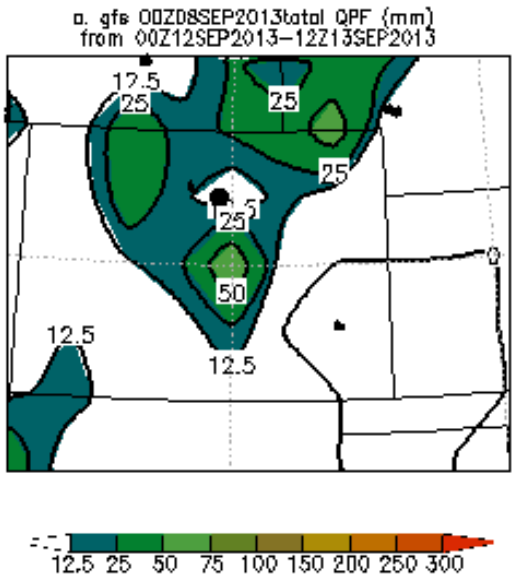



00z/11 Sep

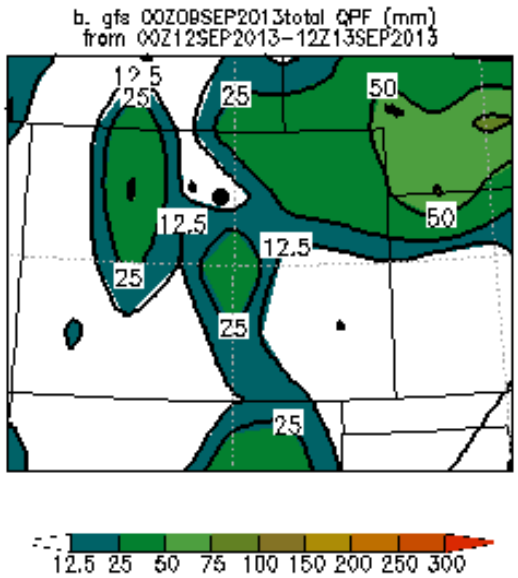


# Overview- GFS Forecasts QPF for 24-h period of 00z/12-00z/13 Sep (note: units are mm)

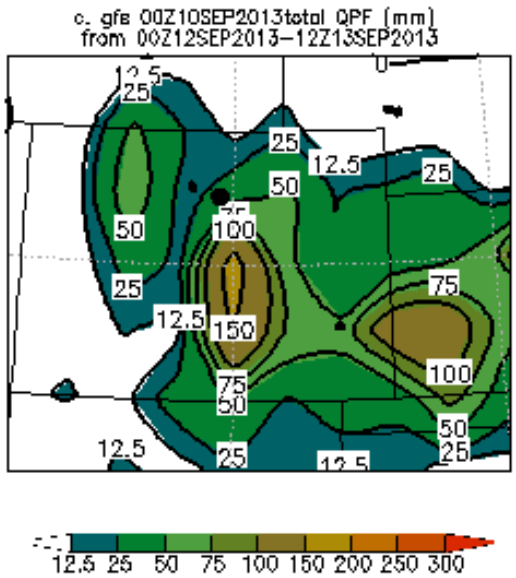
From: 00z/8 Sep



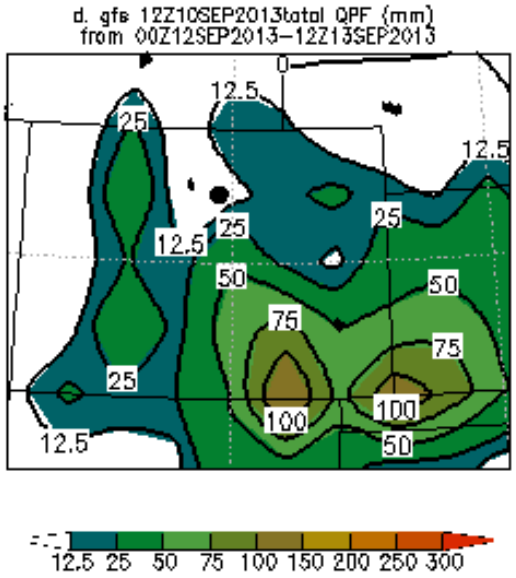

00z/9 Sep



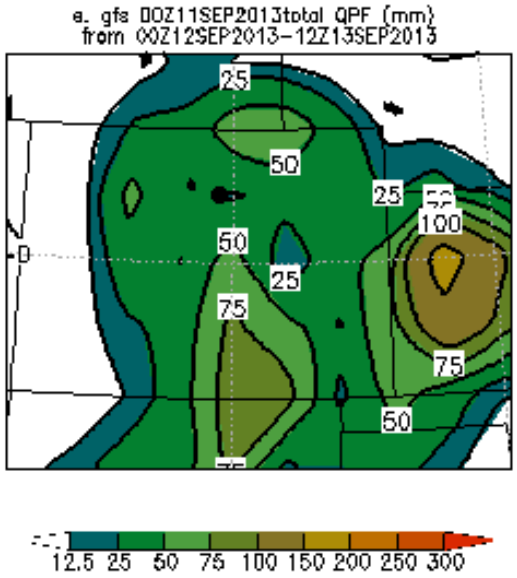

00z/10 Sep



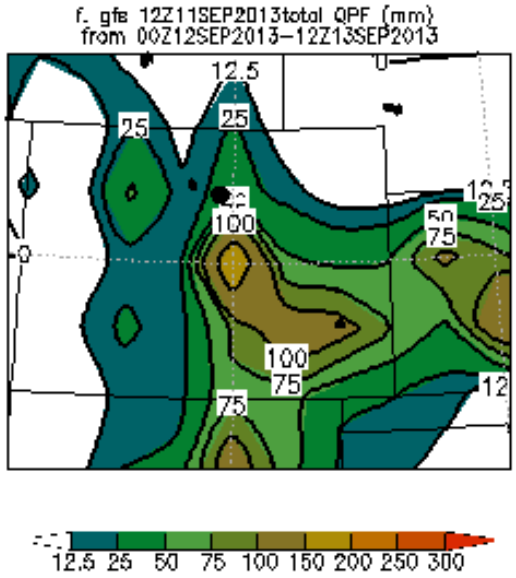

From: 12z/10 Sep




00z/11 Sep

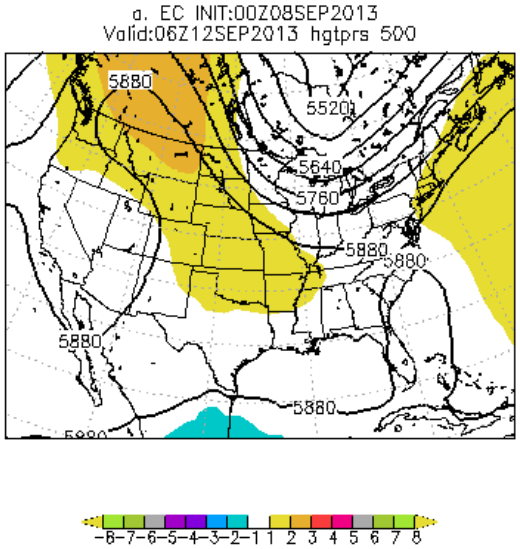



12z/11 Sep

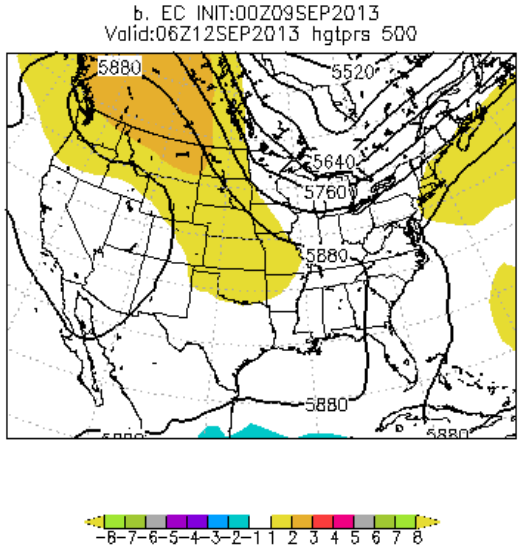


# Generally all the models predicted the pattern fairly well – EC shown here 500mb valid 06z/12 Sep

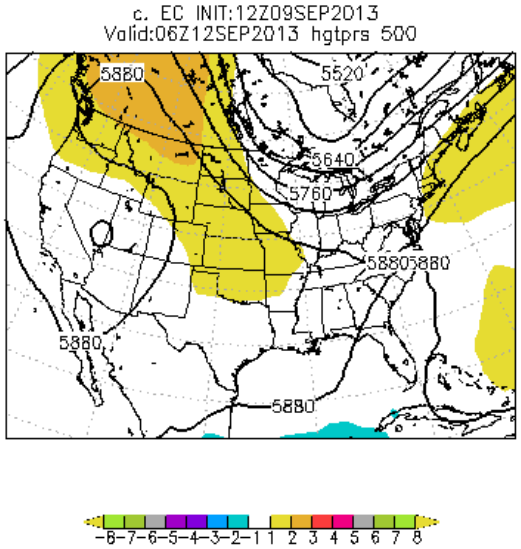
From: 00z/8 Sep




00z/9 Sep




12z/9 Sep

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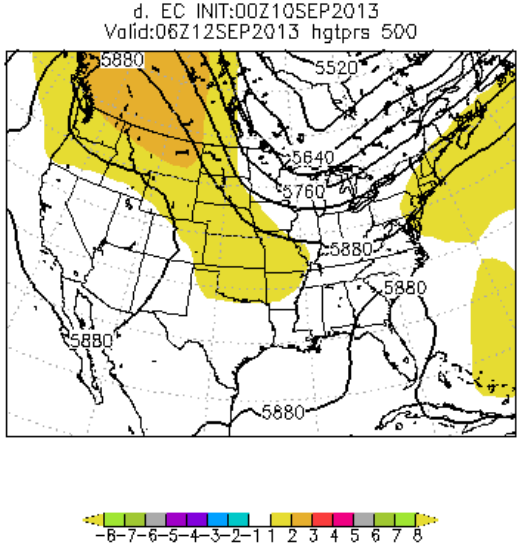
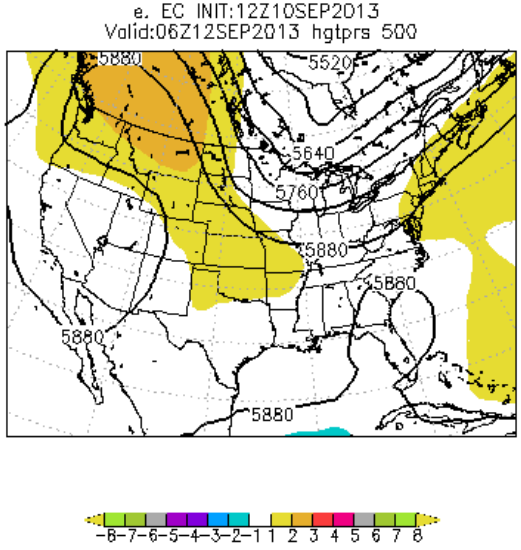
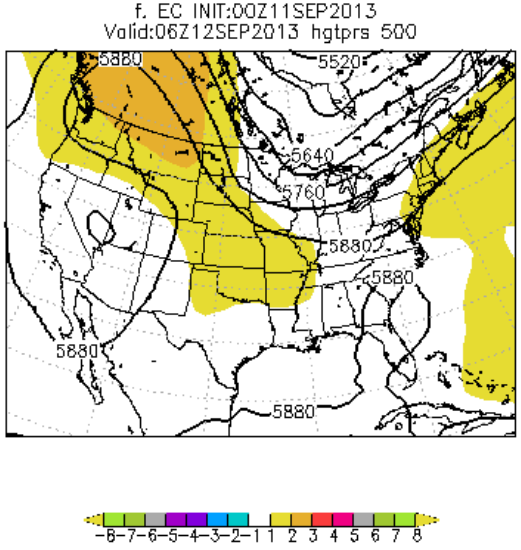



12z/10 Sep

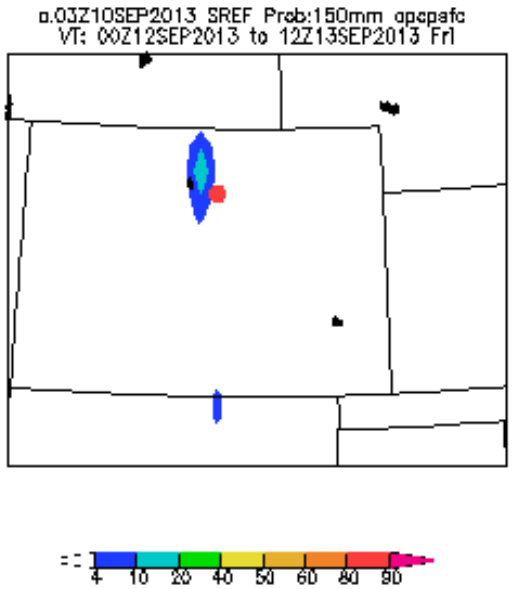



00z/11 Sep

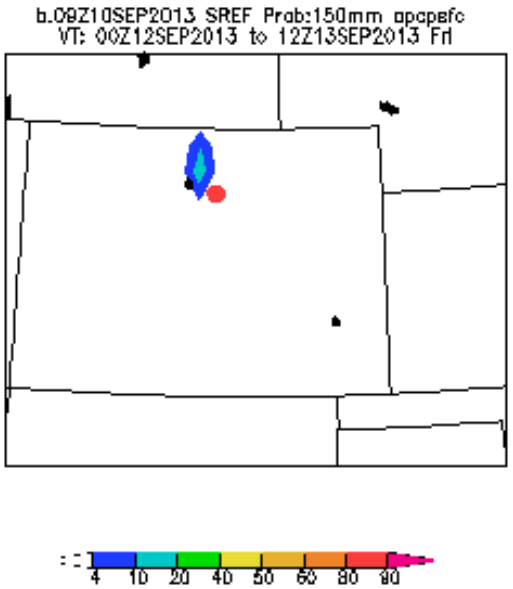


# SREF Probability of 150 mm for period 00z/12 – 12z/13 Sep *Boulder is a red dot…..*

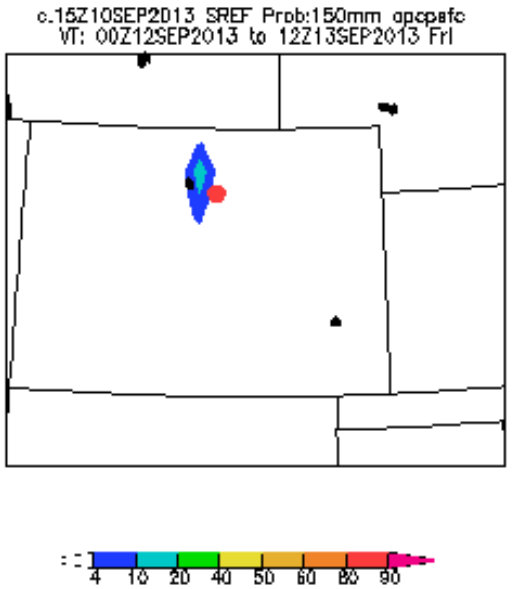
From: 03z/10 Sep




09z/10 Sep




15z/10 Sep

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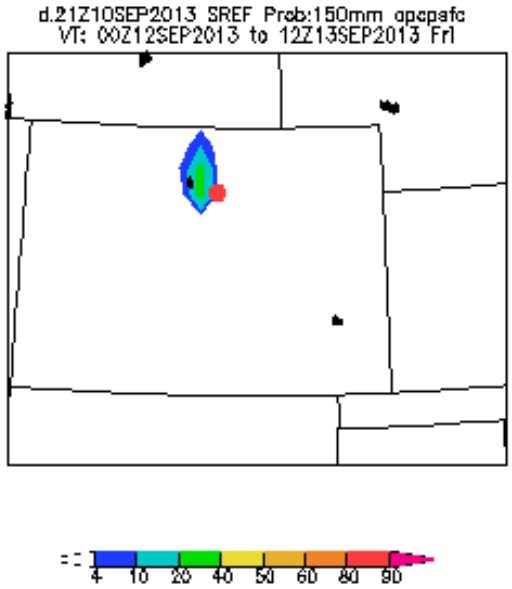
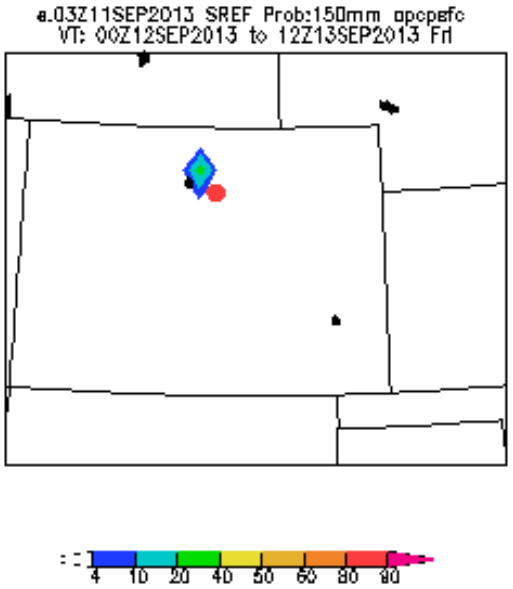
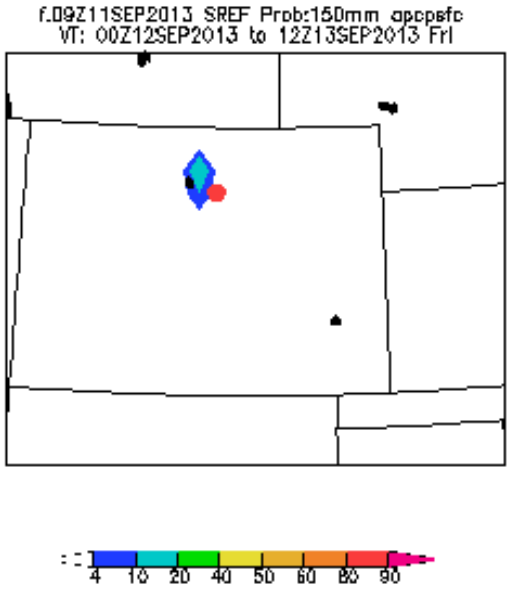



03z/11 Sep

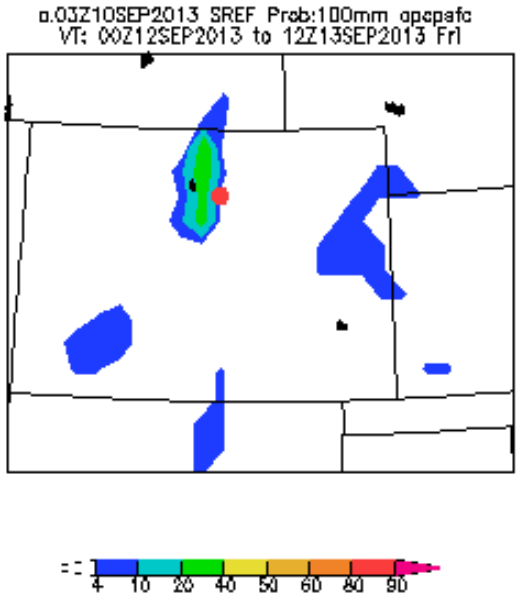



09z/11 Sep

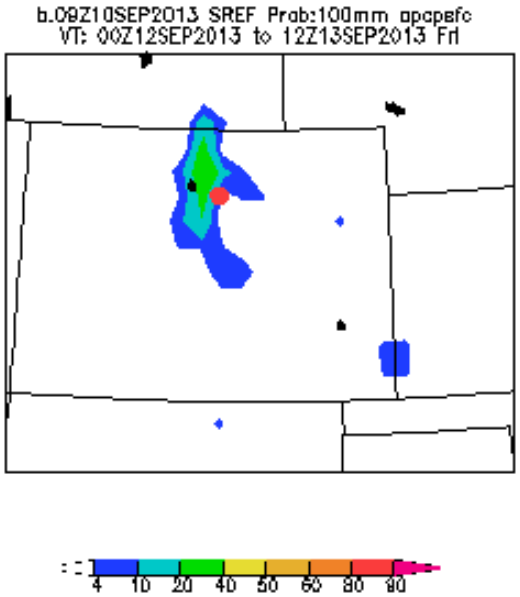


# SREF Probability of 100 mm for period 00z/12 – 12z/13 Sep *Boulder is a red dot…..*

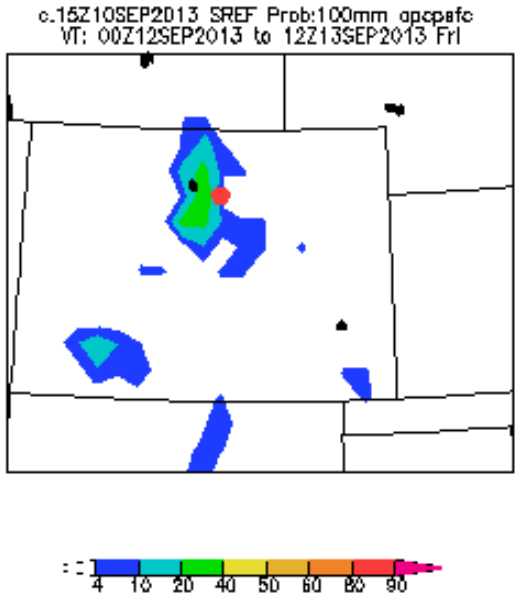
From: 03z/10 Sep




09z/10 Sep




15z/10 Sep

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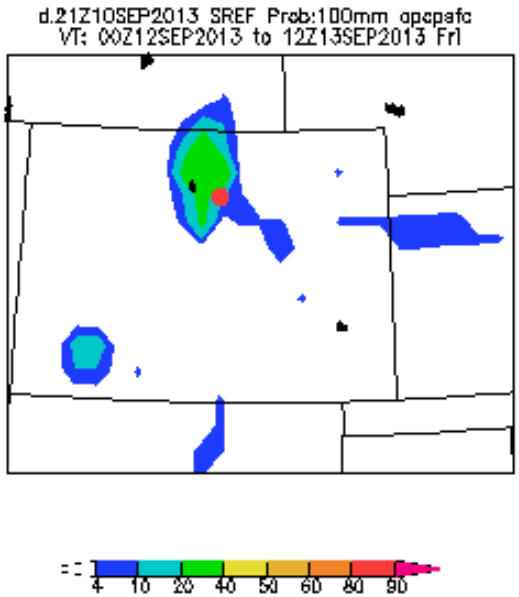
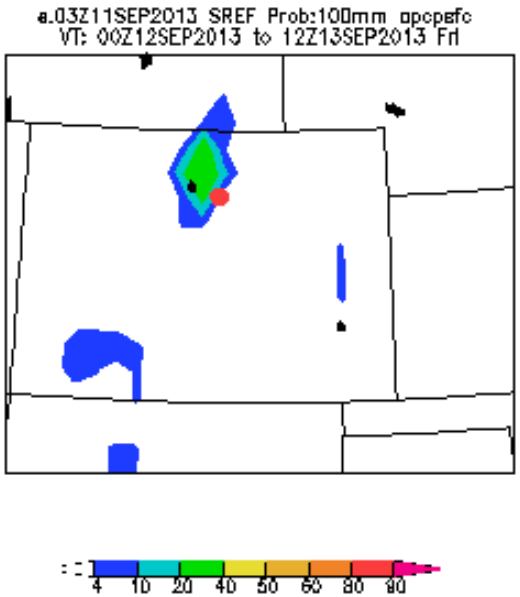
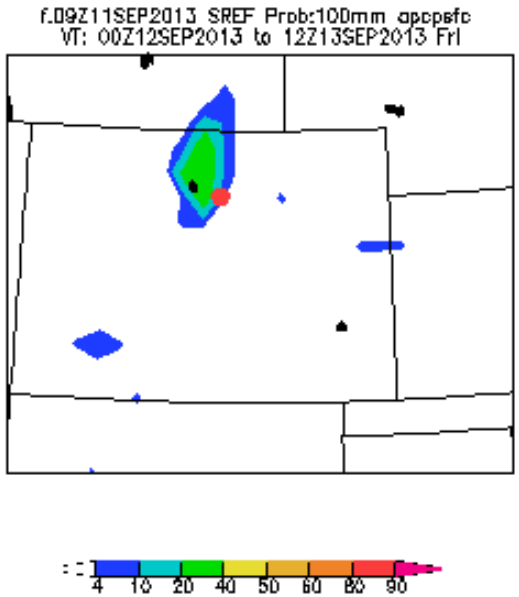



03z/11 Sep



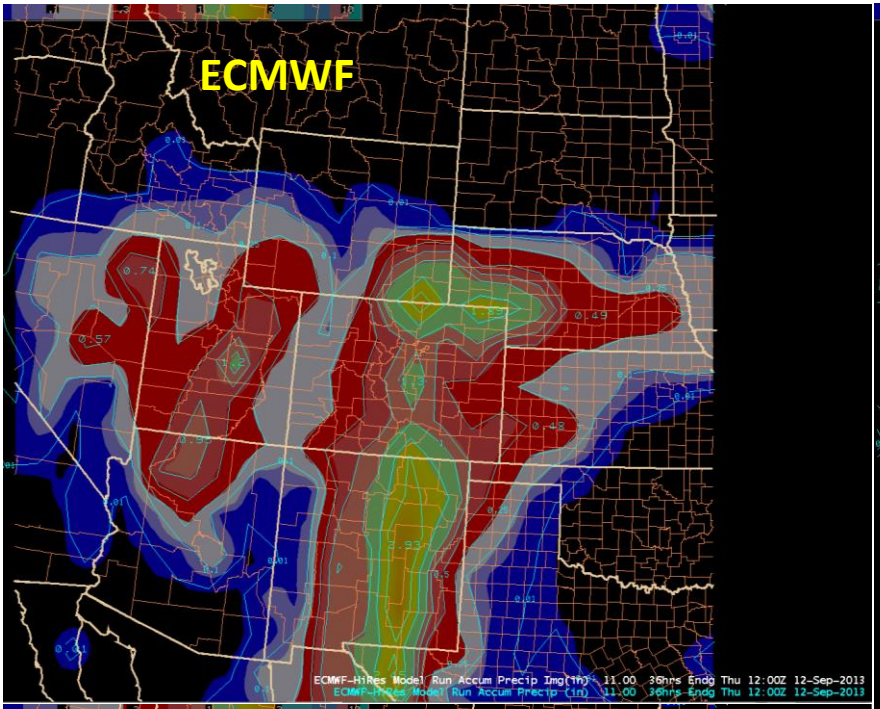

09z/11 Sep

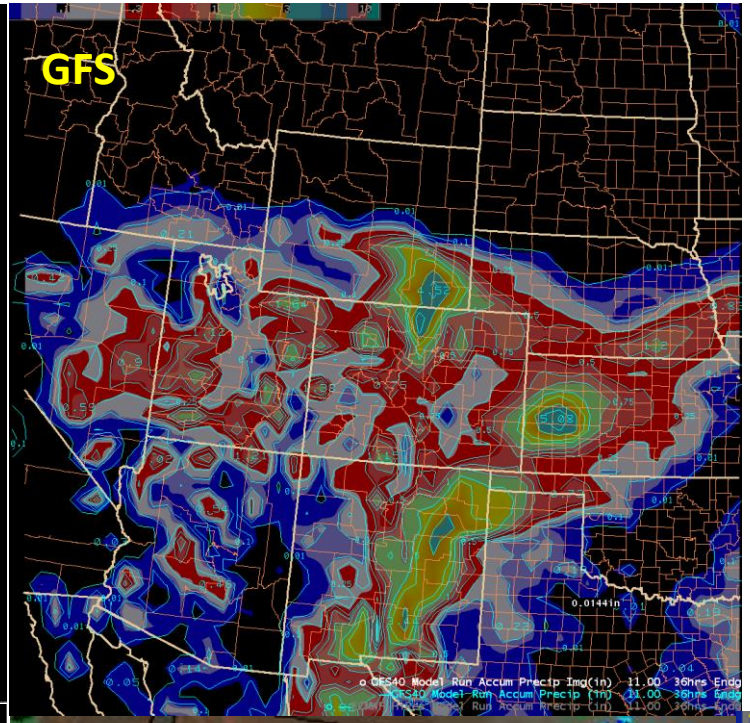


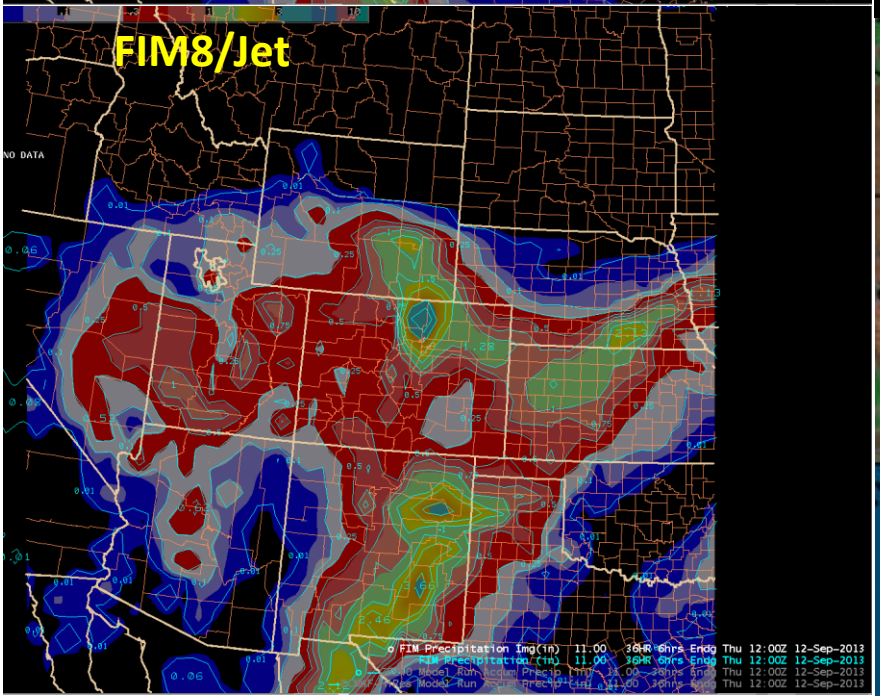
# A look at forecasts closer to the big period on 11-12 Sep

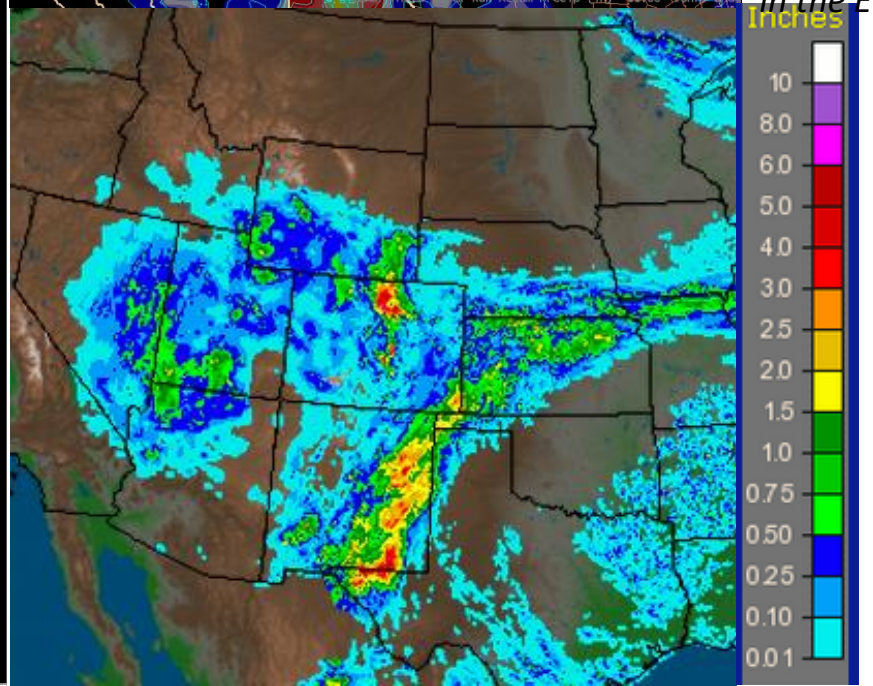
- First the forecasts from the operational models (and FIM8) from 00z/11 Sep ending 12z/12 Sep
  - Still consistent with earlier runs – some big amounts into the foothills
- But – 12z/11 Sep forecasts
  - These go the other way, considerably less precip predicted

# 36-h total precipitation forecasts from 00z/11 Sep valid at 12z/12 Sep



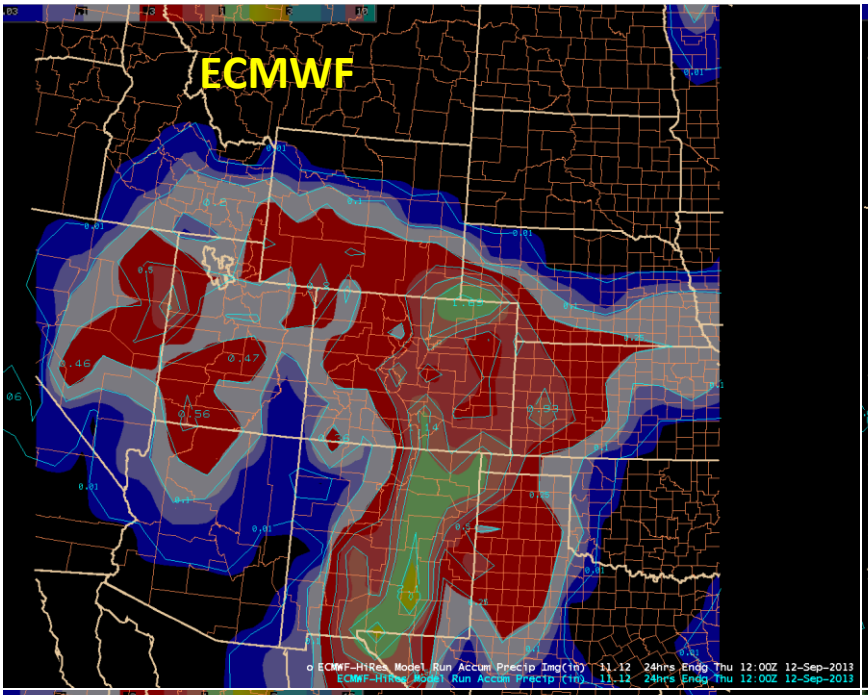



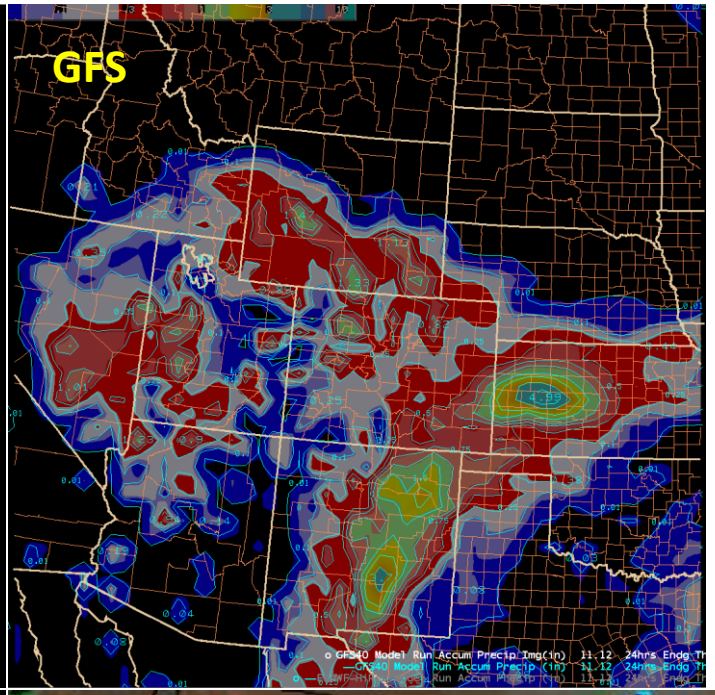



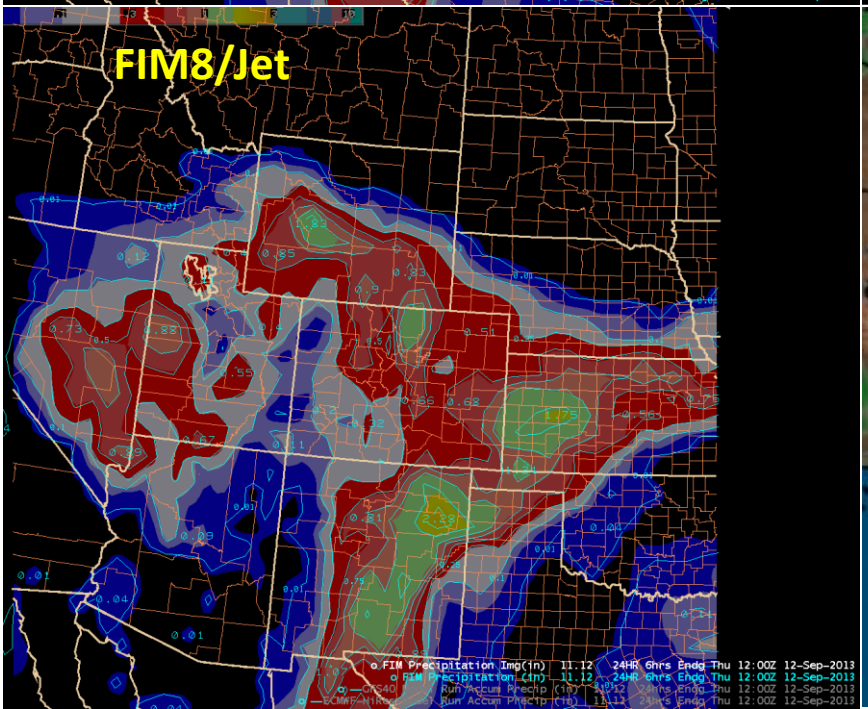



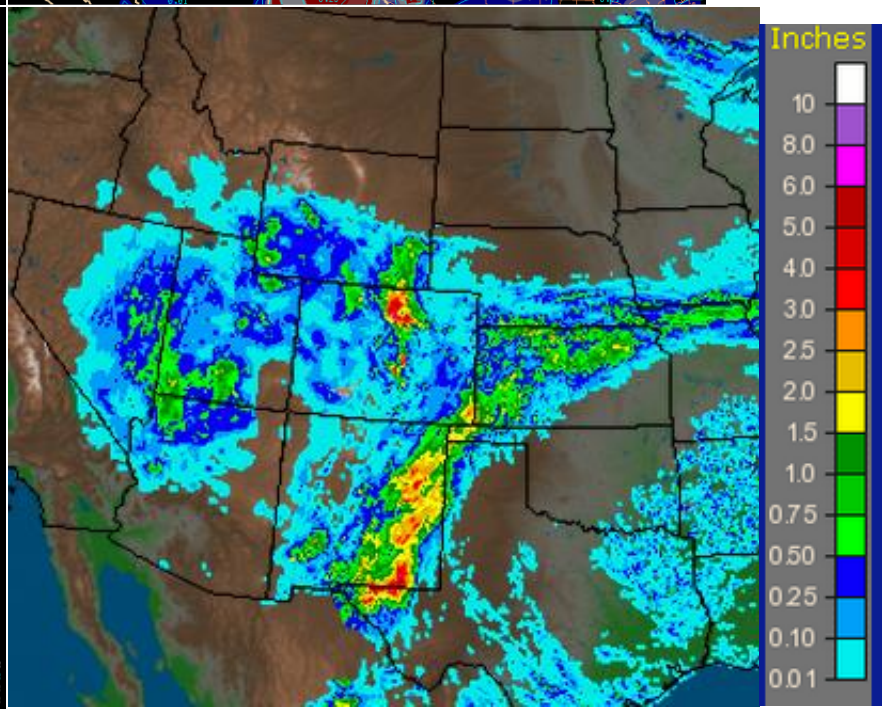

*The color table has 1-3" for the green shades then next major color change starts at 3". The most consistent part of these forecasts is the heavy rains in eastern NM. As for CO, the FIM and GFS both had high maxima in/near the foothills with ~5" max. Not as much in the EC.*

# 24-h total precipitation forecasts from 12z/11 Sep valid at 12z/12 Sep

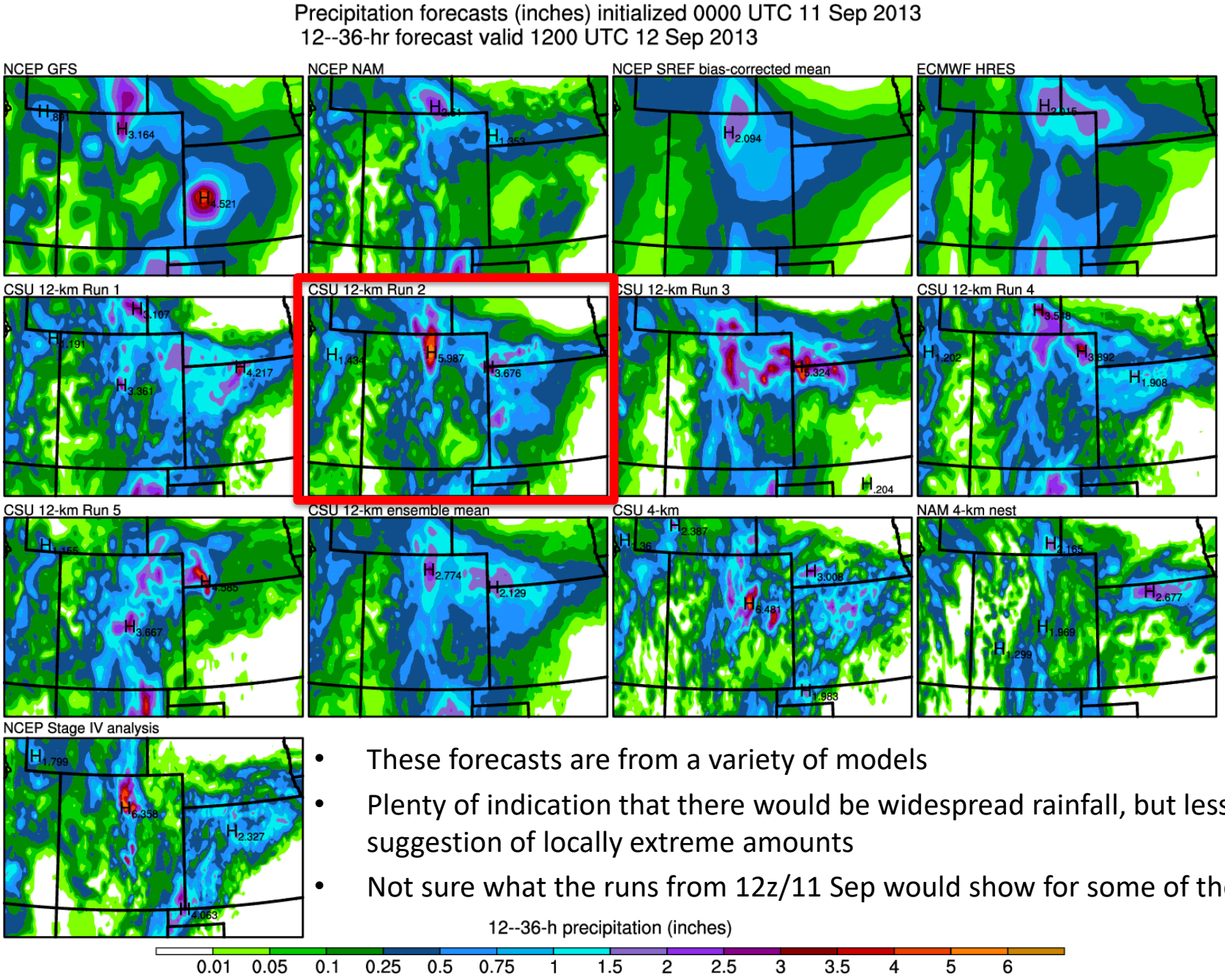



*Here we are 12-h later and the trend is the wrong way, maybe to a lesser extent for FIM8, and with the exception of eastern NM, where all models remained quite wet.*

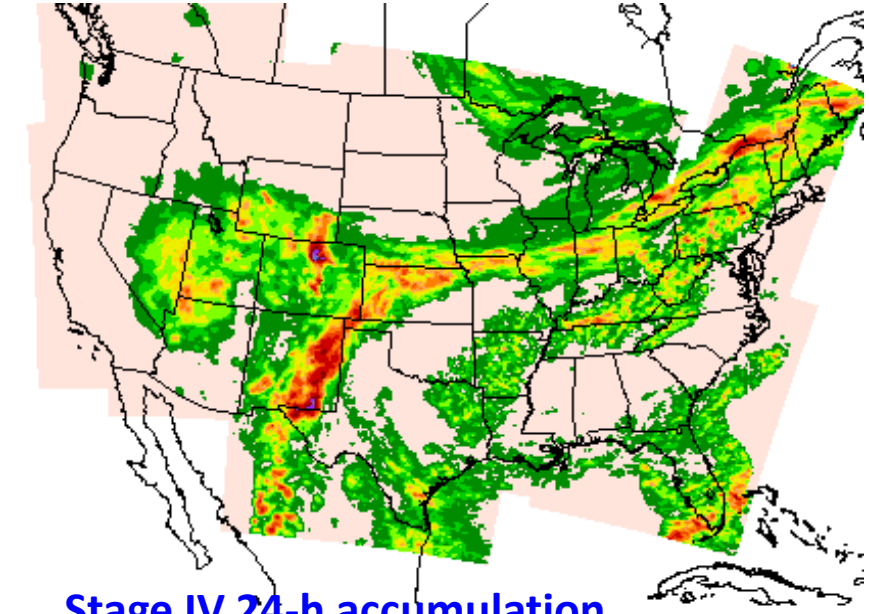



**OBS**

- These forecasts are from a variety of models
- Plenty of indication that there would be widespread rainfall, but less suggestion of locally extreme amounts
- Not sure what the runs from 12z/11 Sep would show for some of these

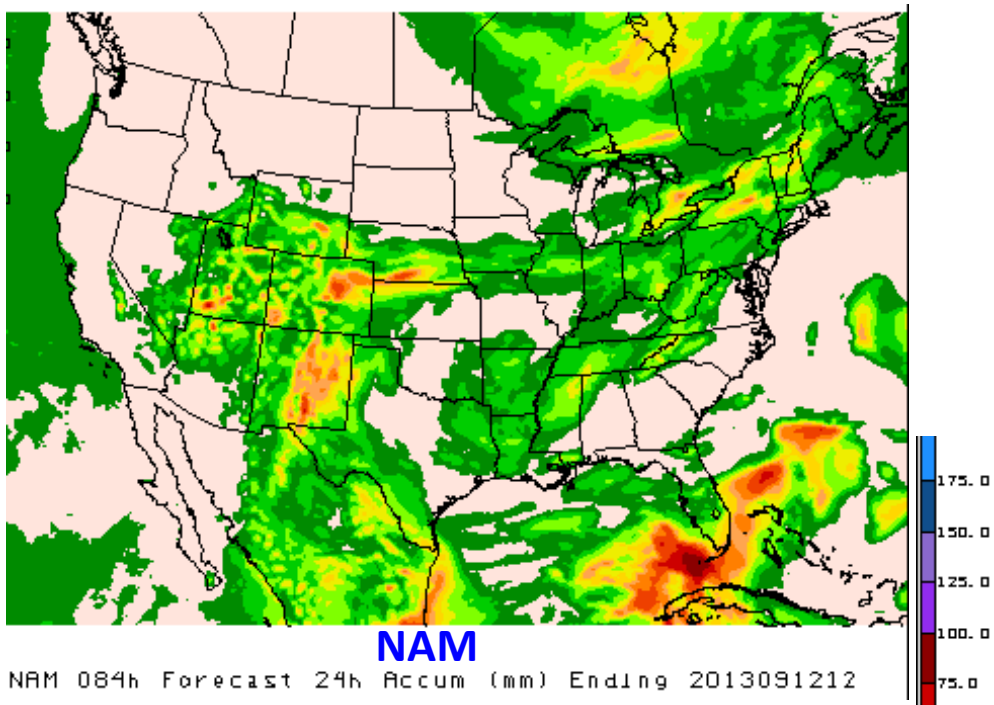
The next set of slides from the NCEP Model Evaluation Group (MEG) Short-Range Discussion presented by Geoff Manikin on 19 Sep

# 84-h precipitation forecasts (mm) from 00z/9 Sep runs for the 24-h period ending at 12z/12 Sep



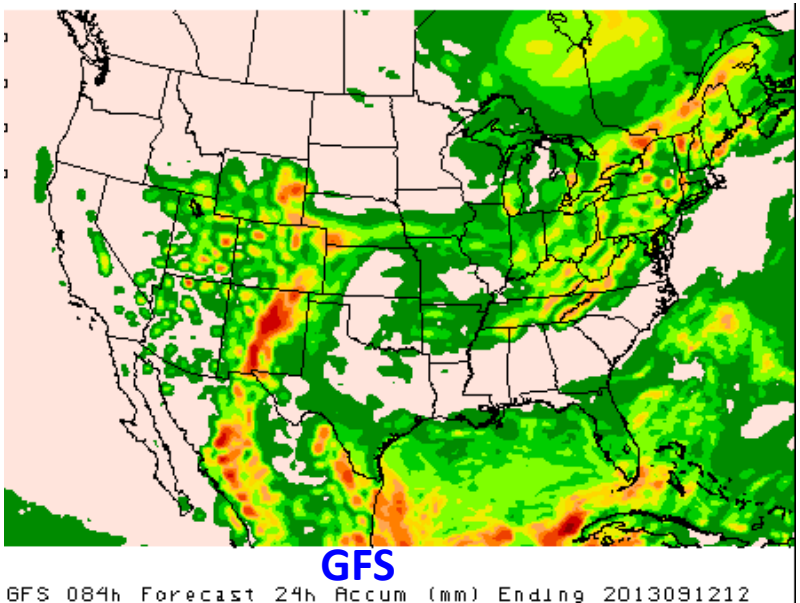
**Stage IV 24-h accumulation**

Stage IV (3 mos) 24h Accum (mm) Ending 2013091212



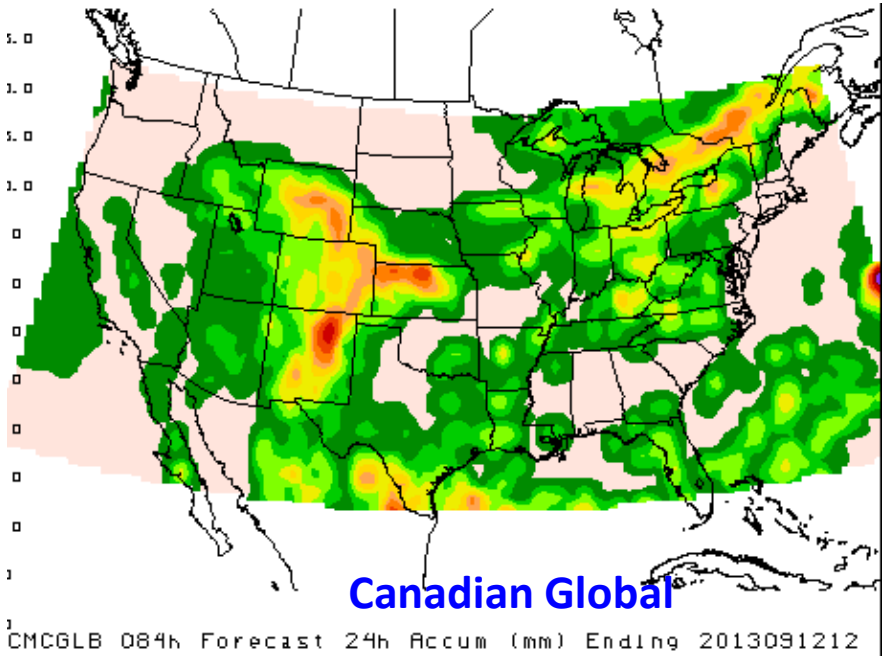

**NAM**

NAM 084h Forecast 24h Accum (mm) Ending 2013091212



**GFS**

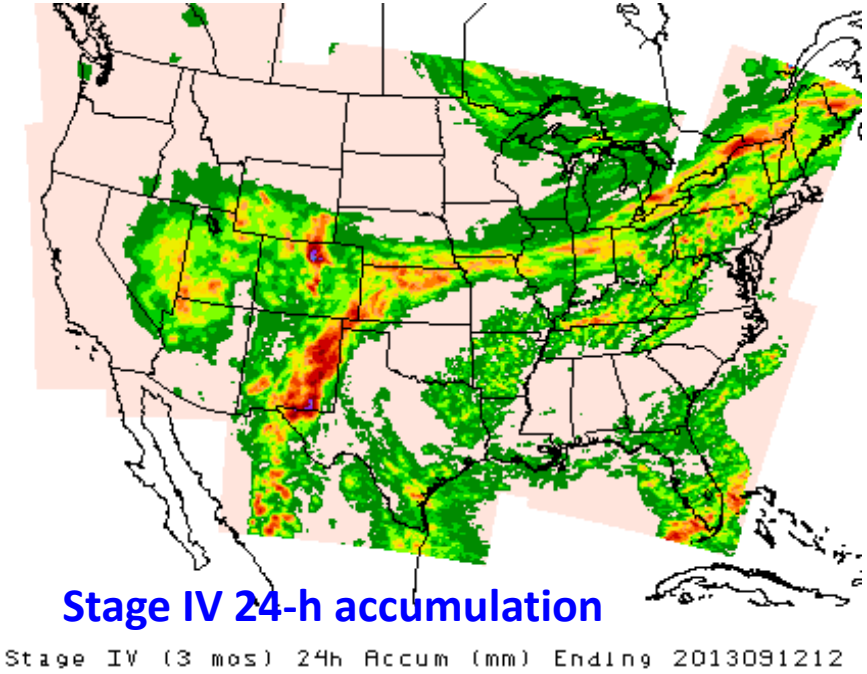
GFS 084h Forecast 24h Accum (mm) Ending 2013091212



**Canadian Global**

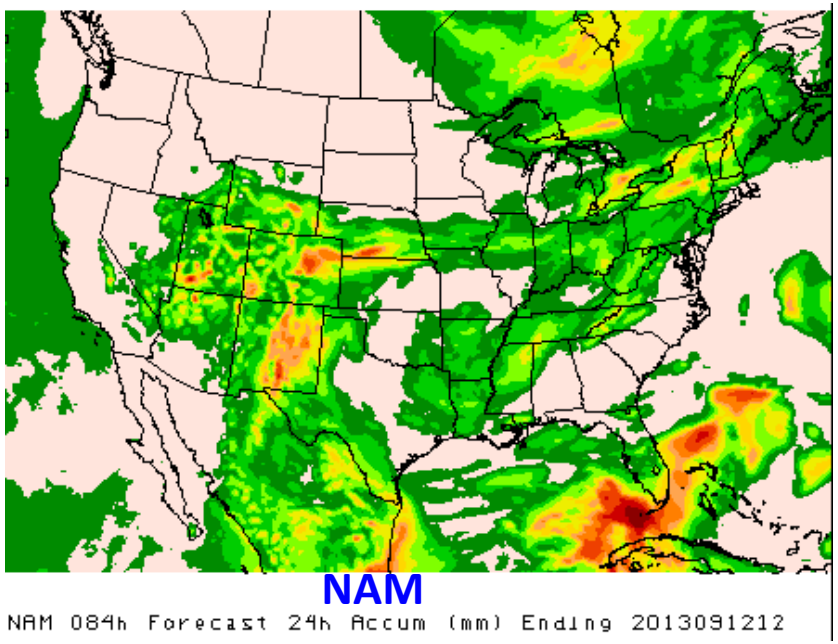
CMCGLB 084h Forecast 24h Accum (mm) Ending 2013091212

# 84-h precipitation forecasts (mm) from 00z/9 Sep runs for the 24-h period ending at 12z/12 Sep



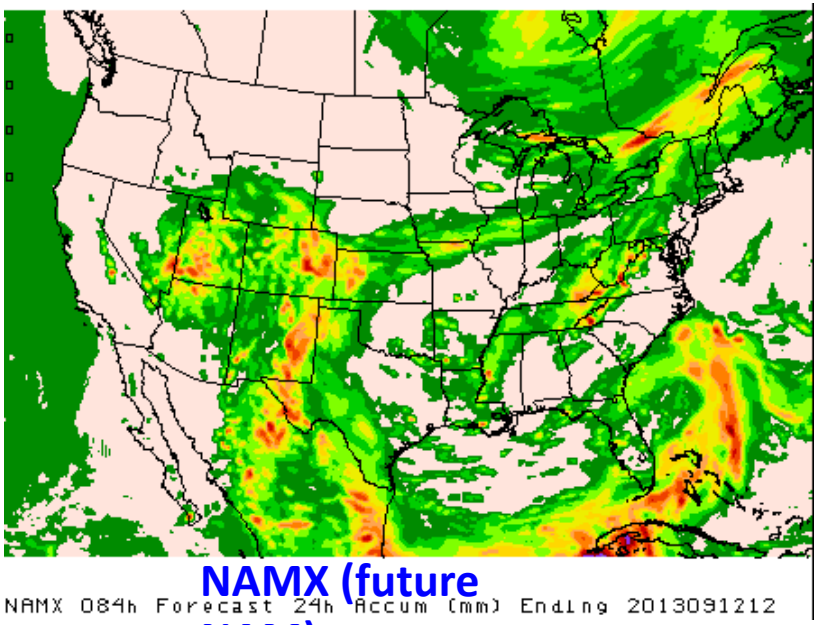
**Stage IV 24-h accumulation**

Stage IV (3 mos) 24h Accum (mm) Ending 2013091212



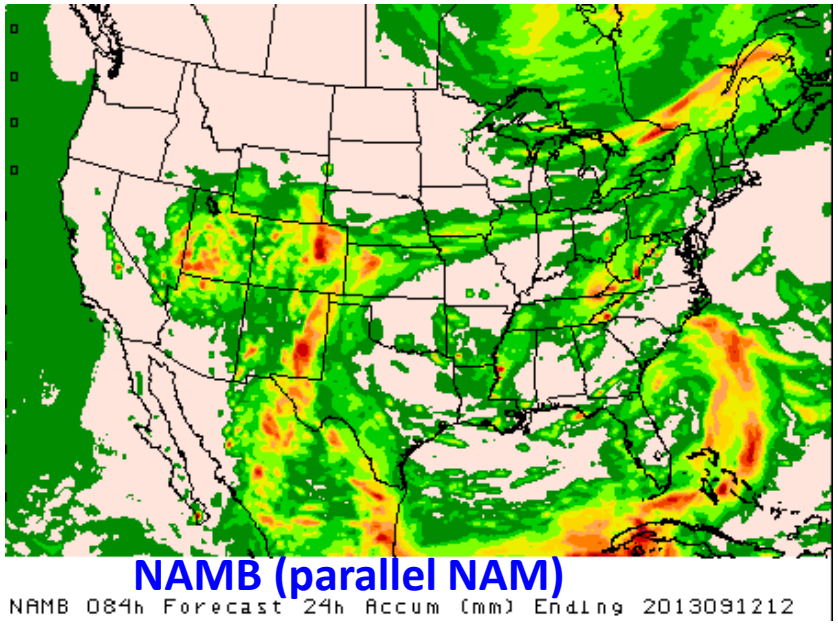

**NAM**

NAM 084h Forecast 24h Accum (mm) Ending 2013091212



**NAMX (future NAM)**

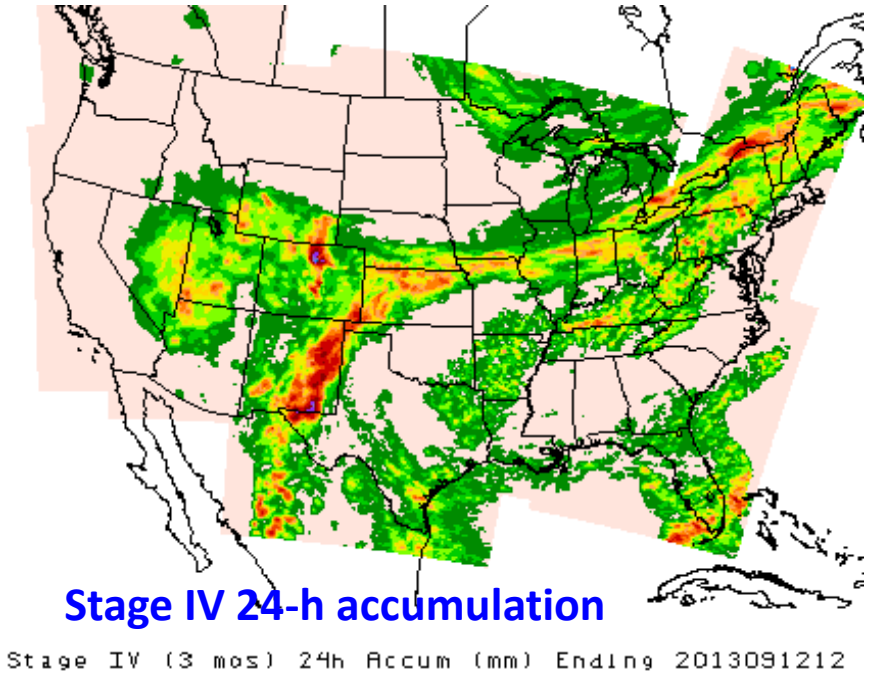
NAMX 084h Forecast 24h Accum (mm) Ending 2013091212



**NAMB (parallel NAM)**

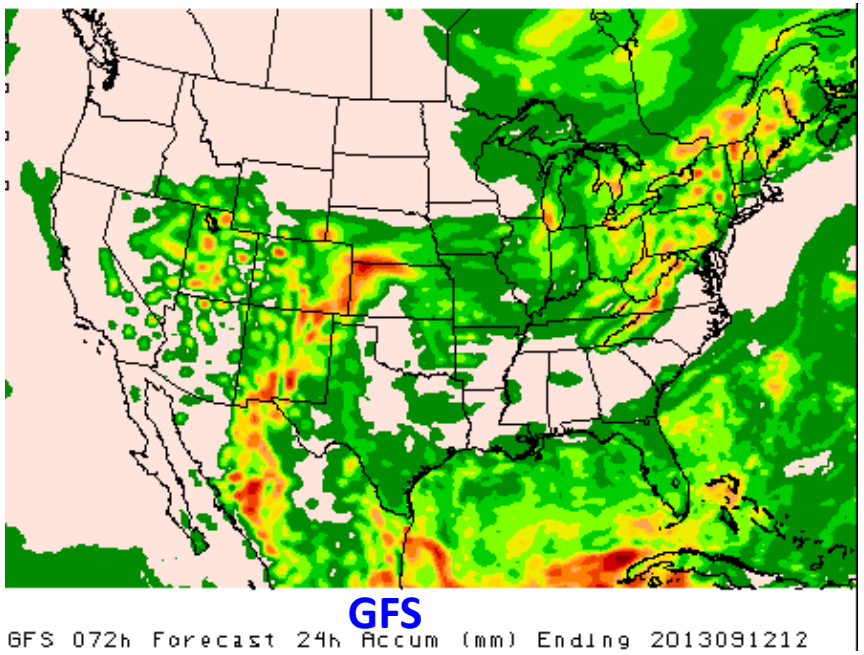
NAMB 084h Forecast 24h Accum (mm) Ending 2013091212

# 72-h precipitation forecasts (mm) from 12z/9 Sep runs for the 24-h period ending at 12z/12 Sep



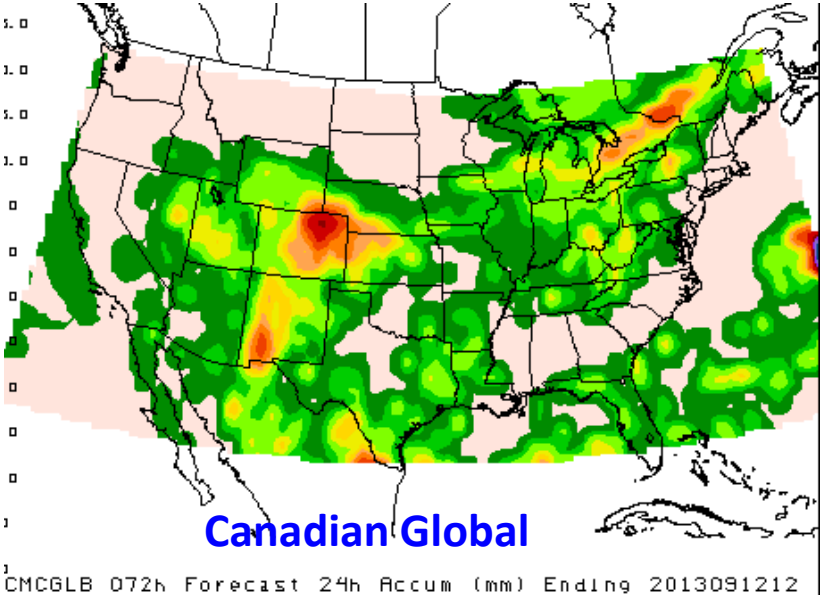
**Stage IV 24-h accumulation**

Stage IV (3 mos) 24h Accum (mm) Ending 2013091212



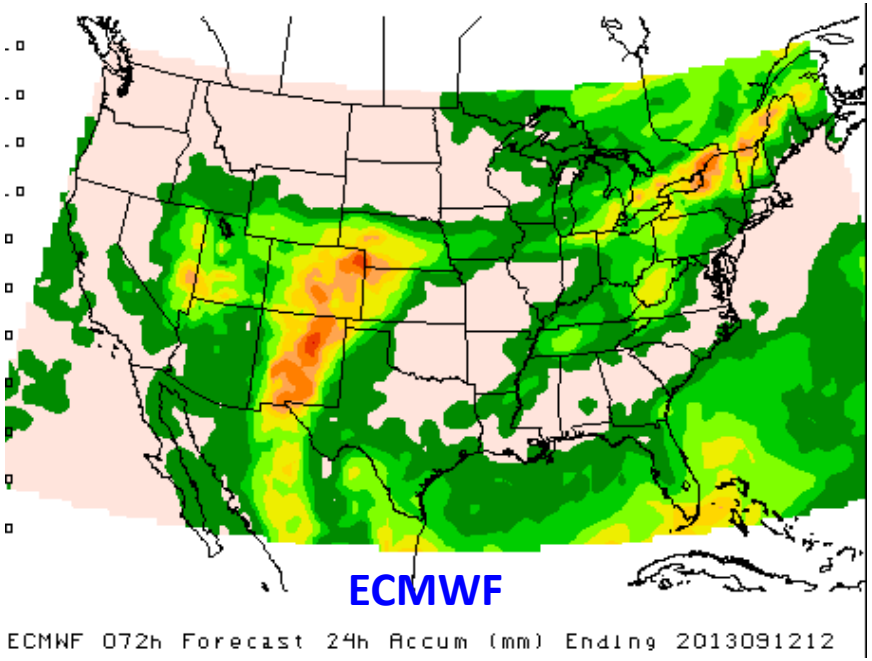
**GFS**

GFS 072h Forecast 24h Accum (mm) Ending 2013091212



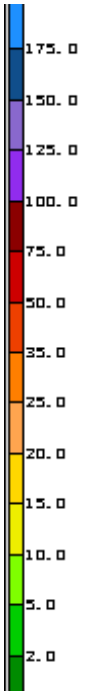
**Canadian Global**

CMCGLB 072h Forecast 24h Accum (mm) Ending 2013091212

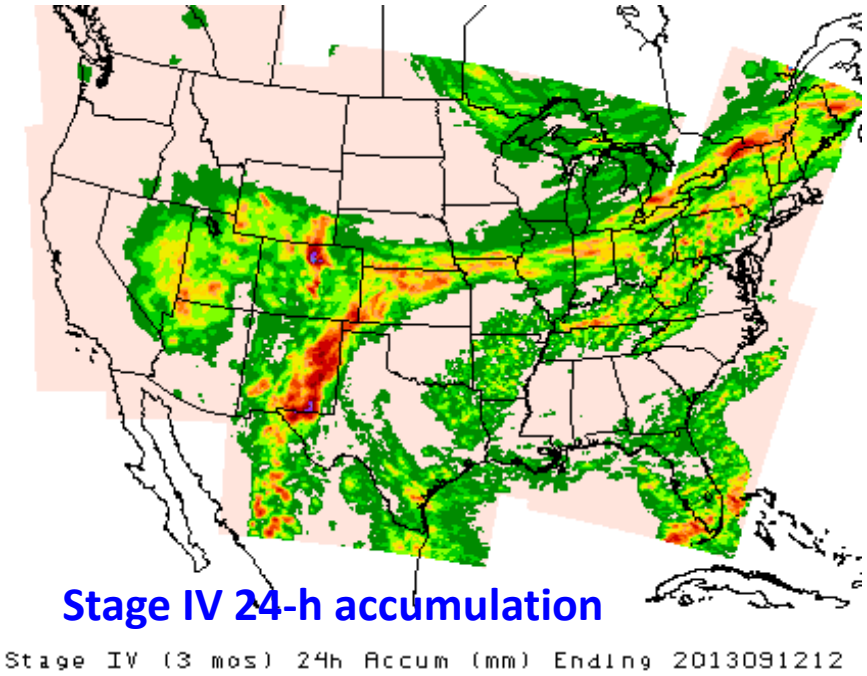


**ECMWF**

ECMWF 072h Forecast 24h Accum (mm) Ending 2013091212

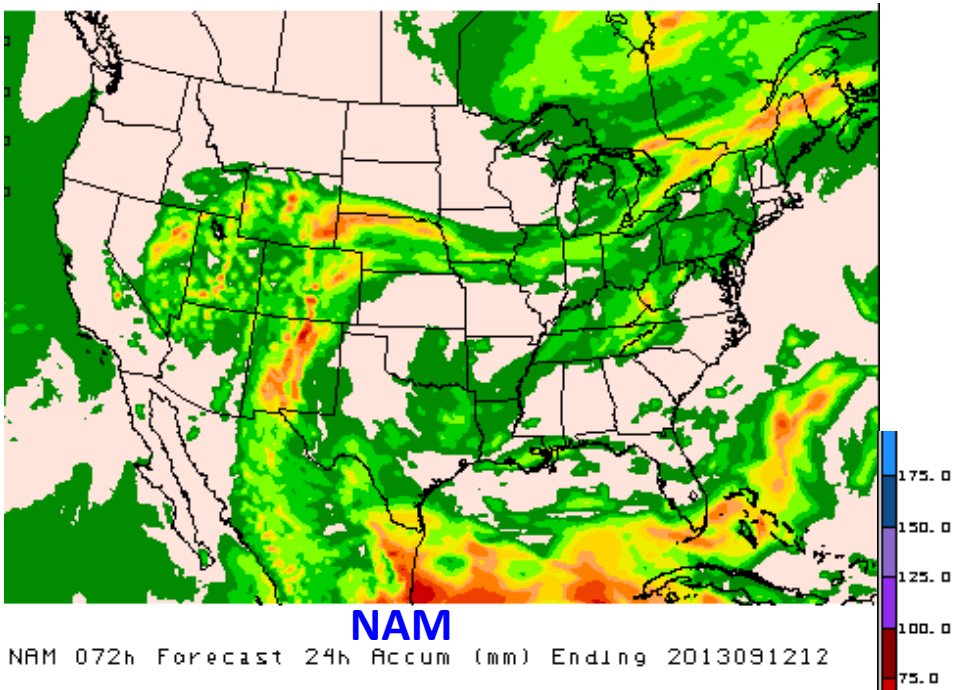


# 72-h precipitation forecasts (mm) from 12z/9 Sep runs for the 24-h period ending at 12z/12 Sep



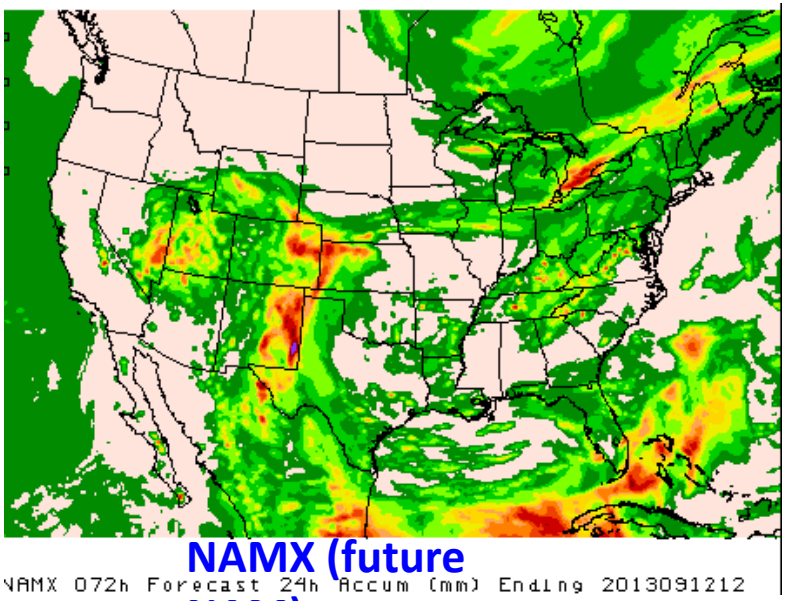
**Stage IV 24-h accumulation**

Stage IV (3 mos) 24h Accum (mm) Ending 2013091212



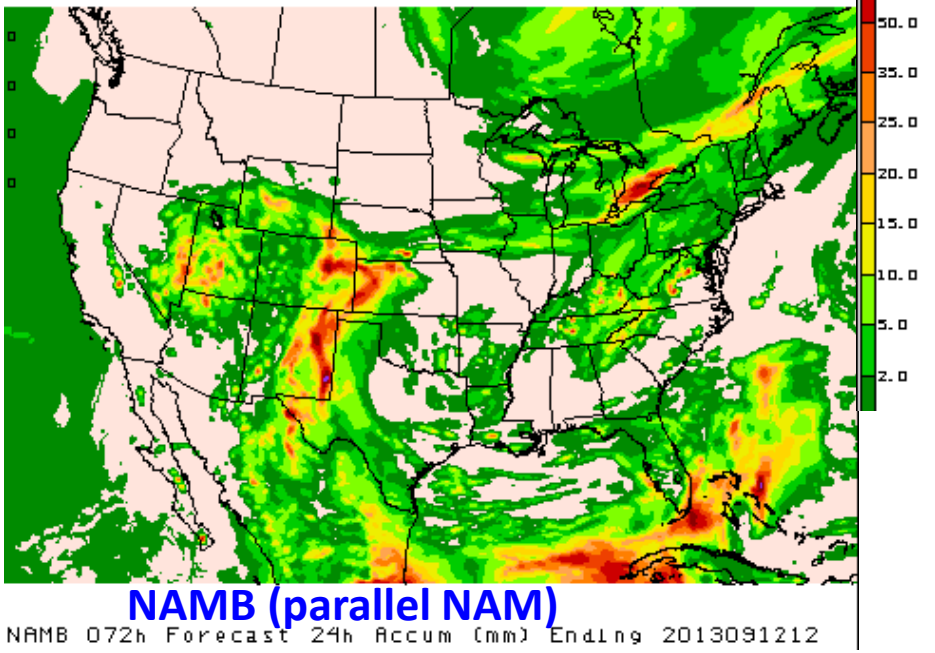

**NAM**

NAM 072h Forecast 24h Accum (mm) Ending 2013091212



**NAMX (future NAM)**

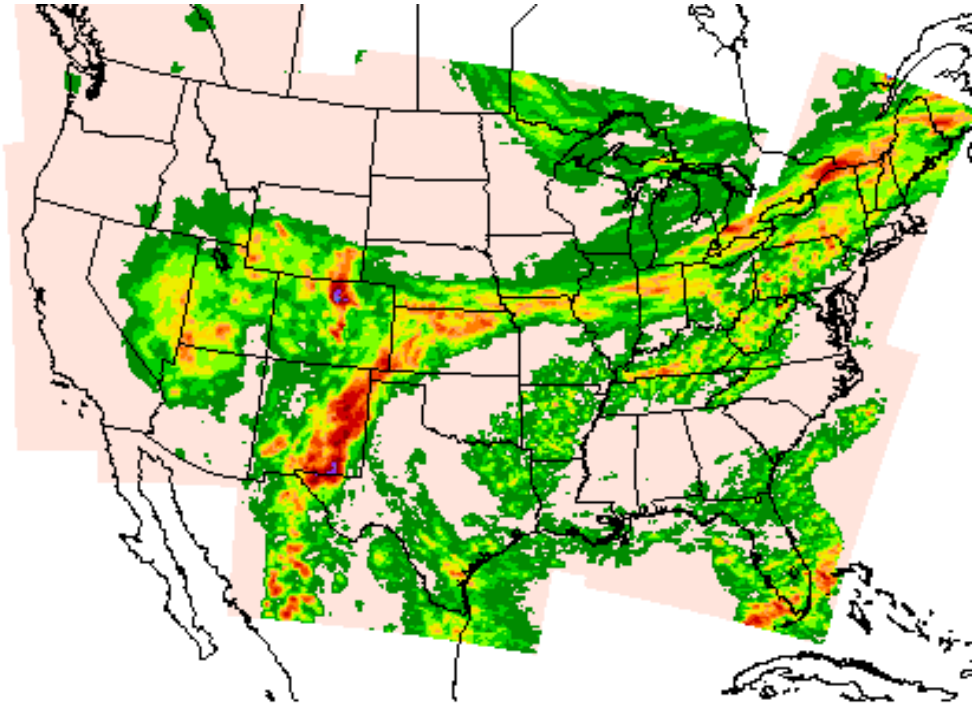
NAMX 072h Forecast 24h Accum (mm) Ending 2013091212

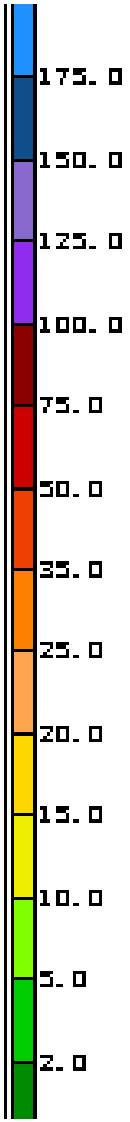


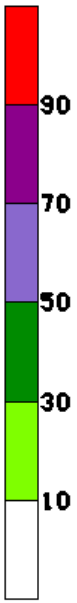
**NAMB (parallel NAM)**

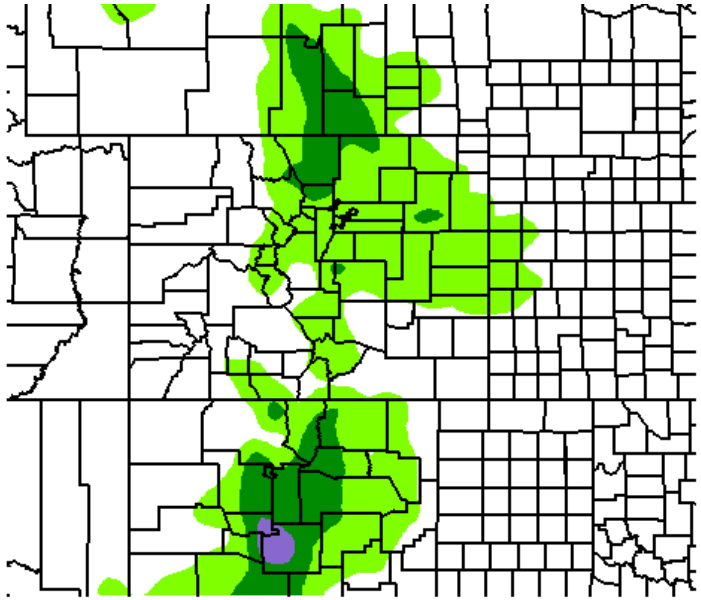
NAMB 072h Forecast 24h Accum (mm) Ending 2013091212

# SREF – some of these shown before but different collection

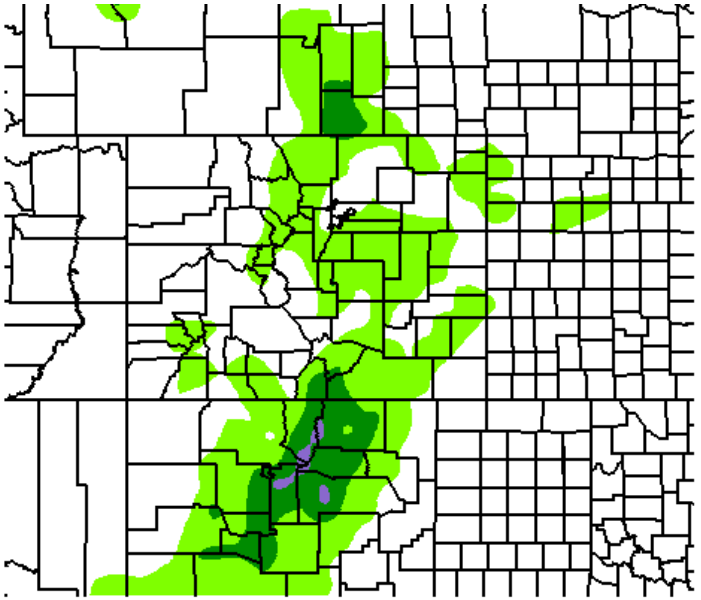




130912/1200V081 SREF PROB of 1"



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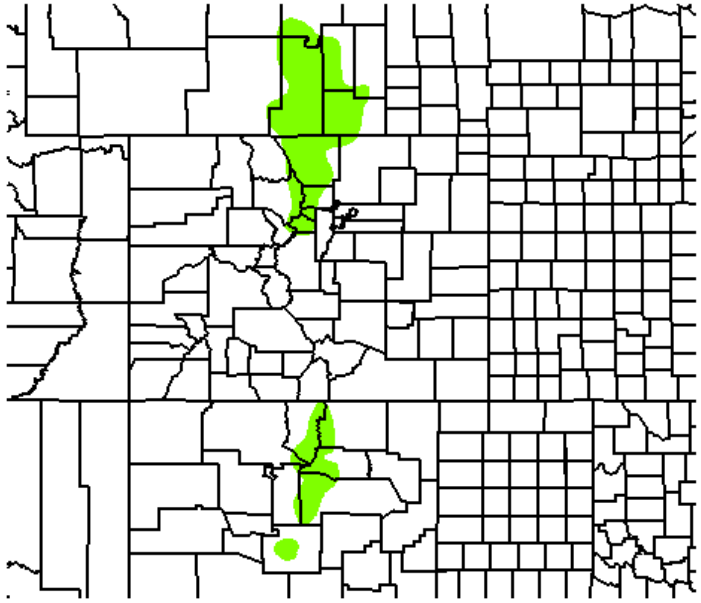

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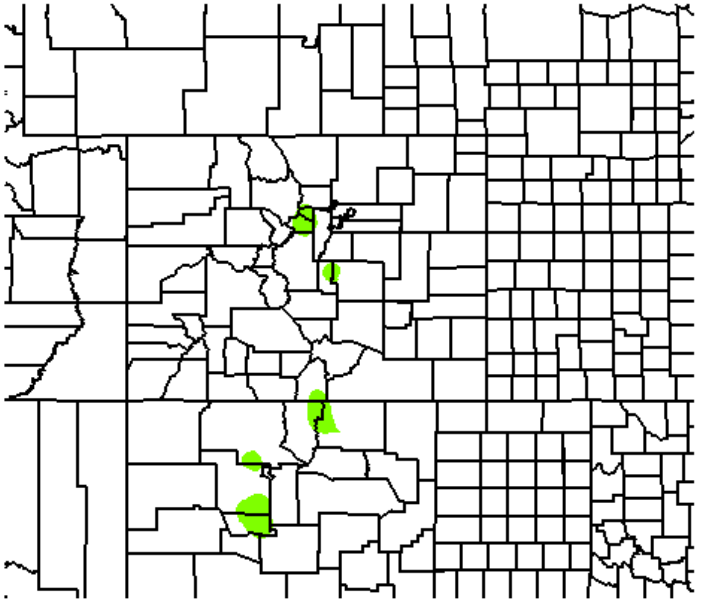

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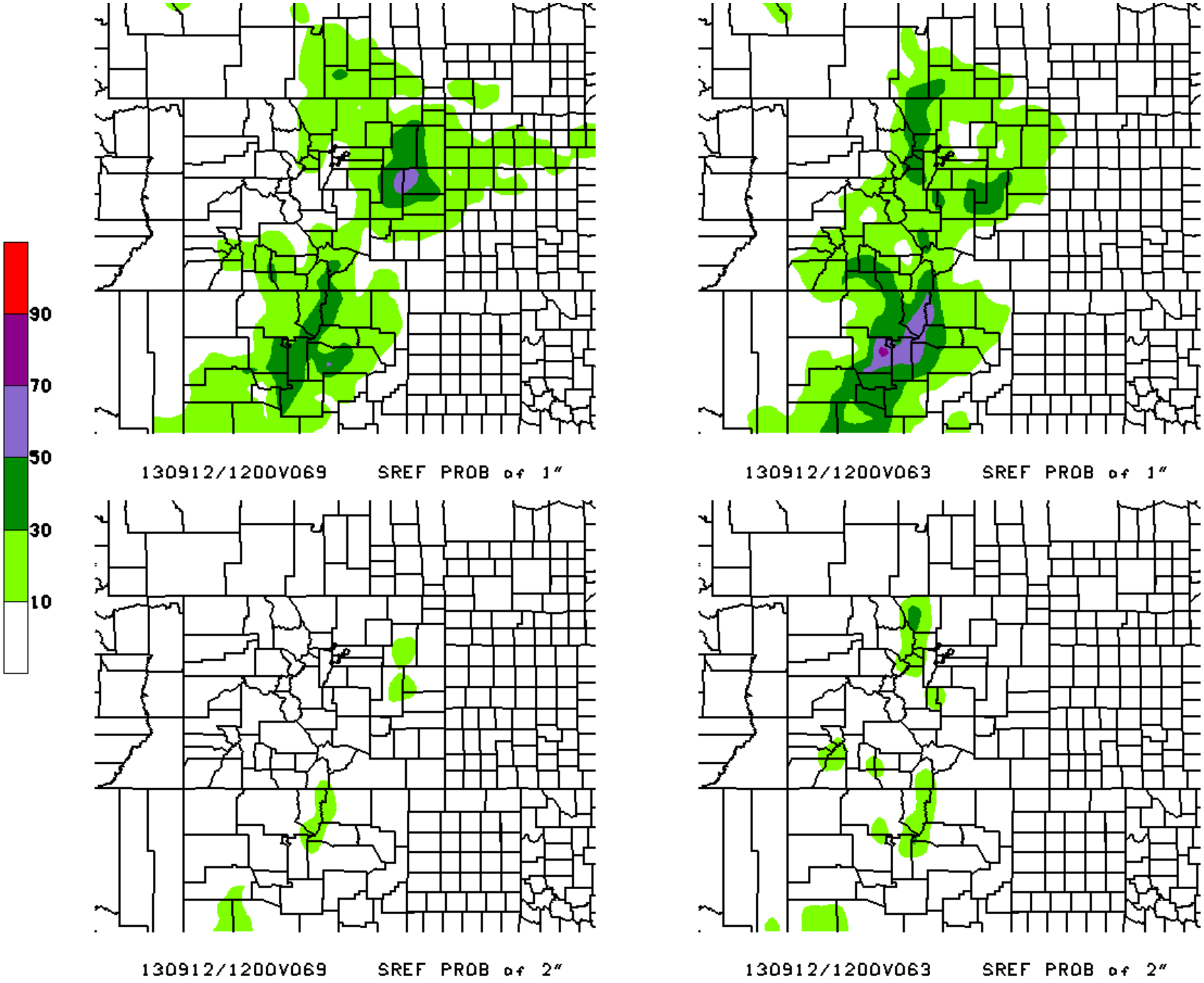
90
70
50
30
10
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130912/1200V063 SREF PROB of 1"
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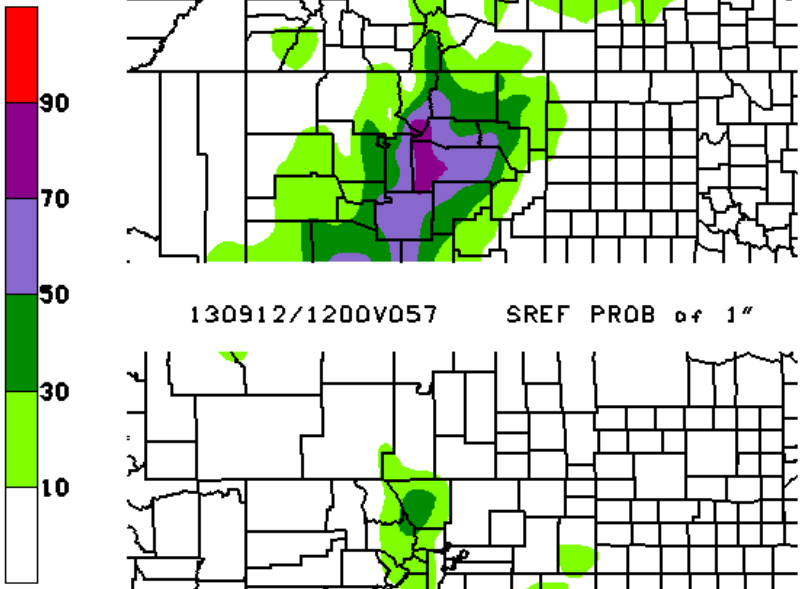


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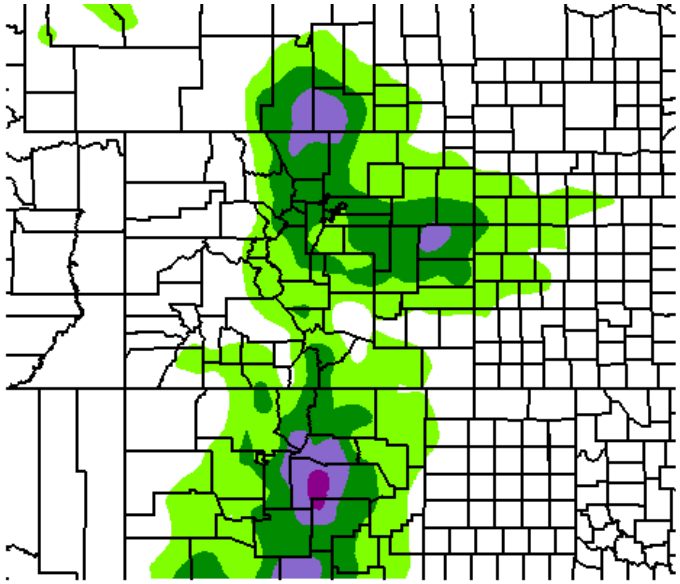

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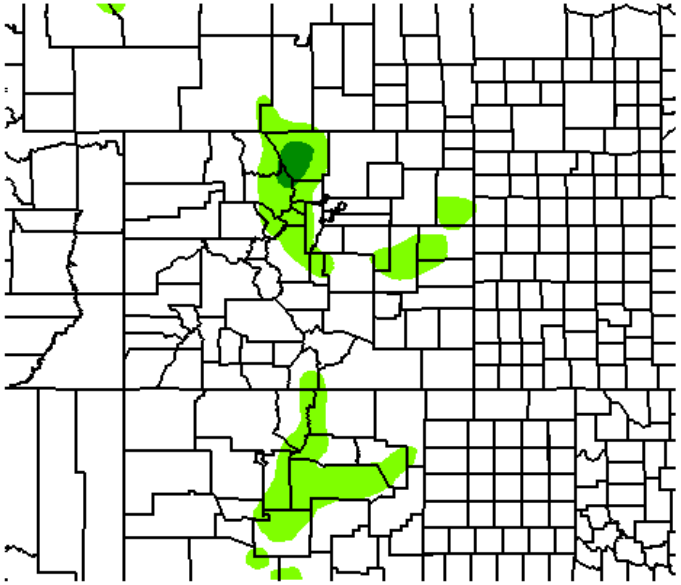

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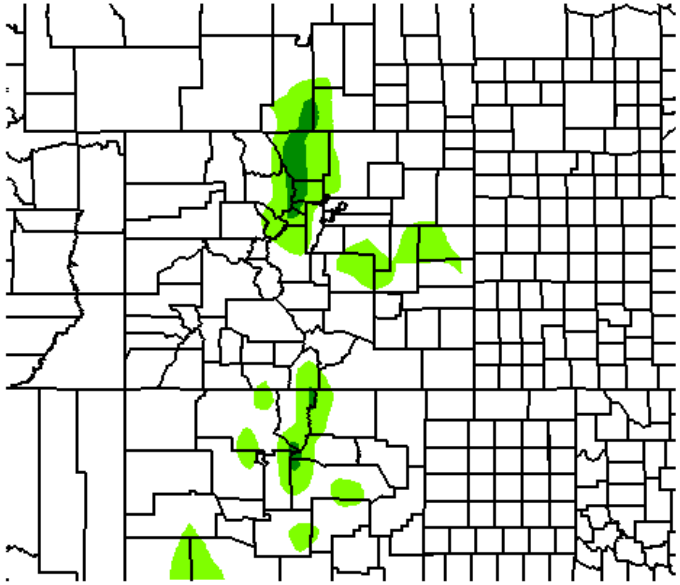

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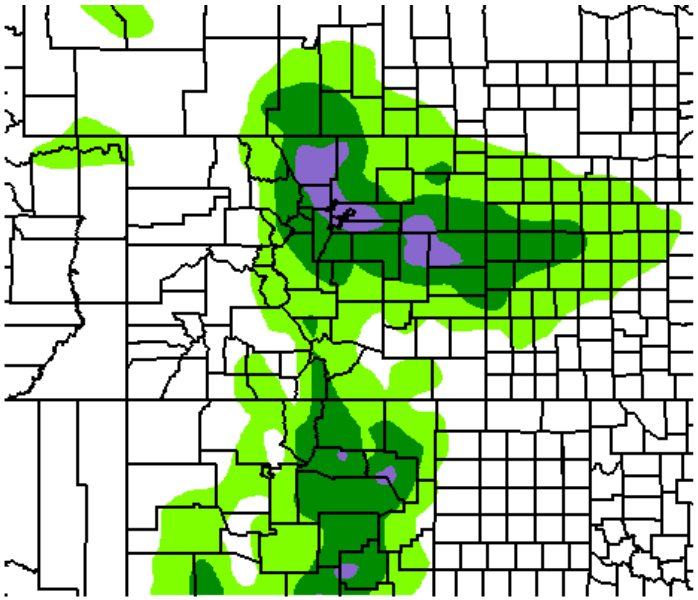

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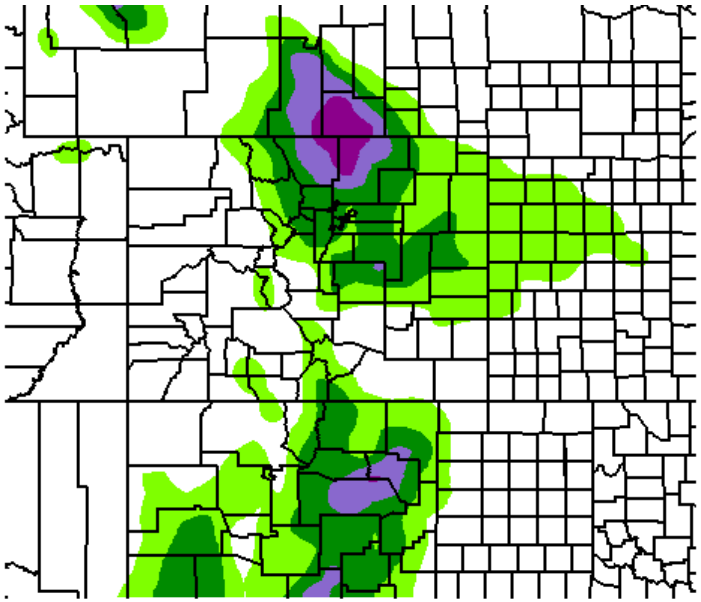

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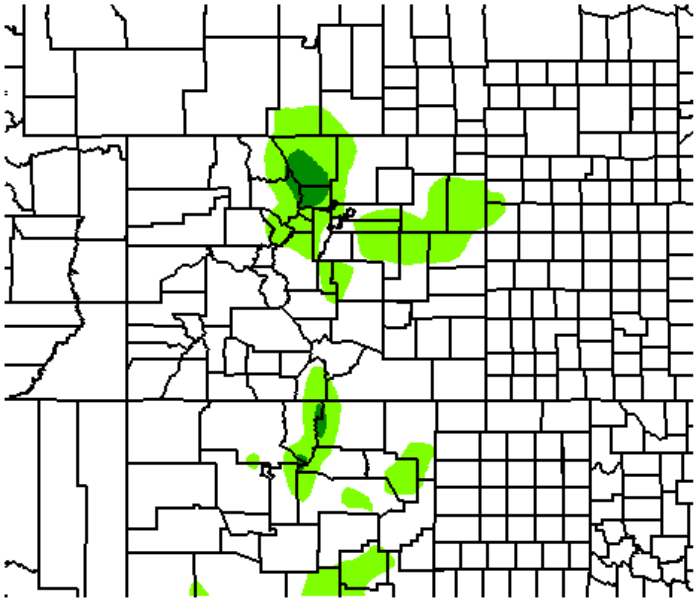

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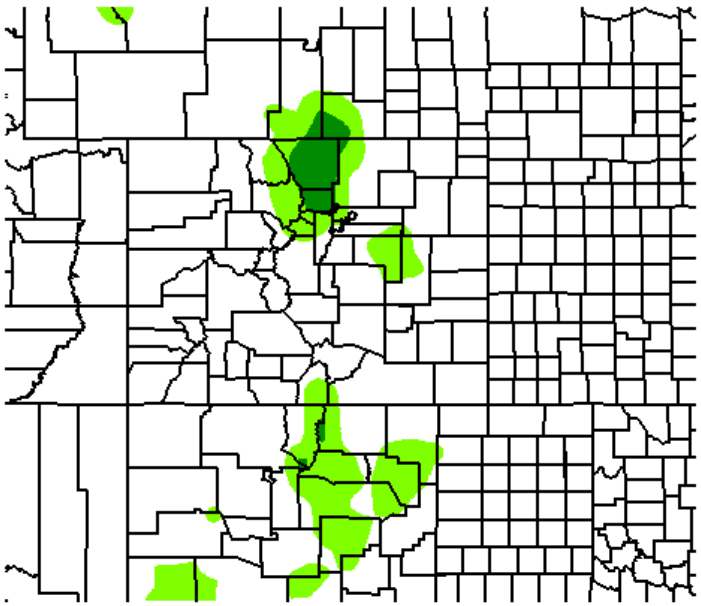

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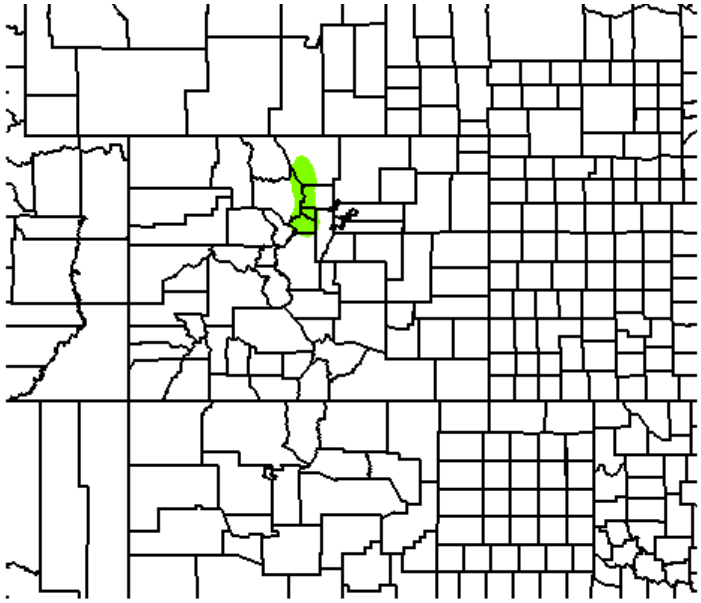

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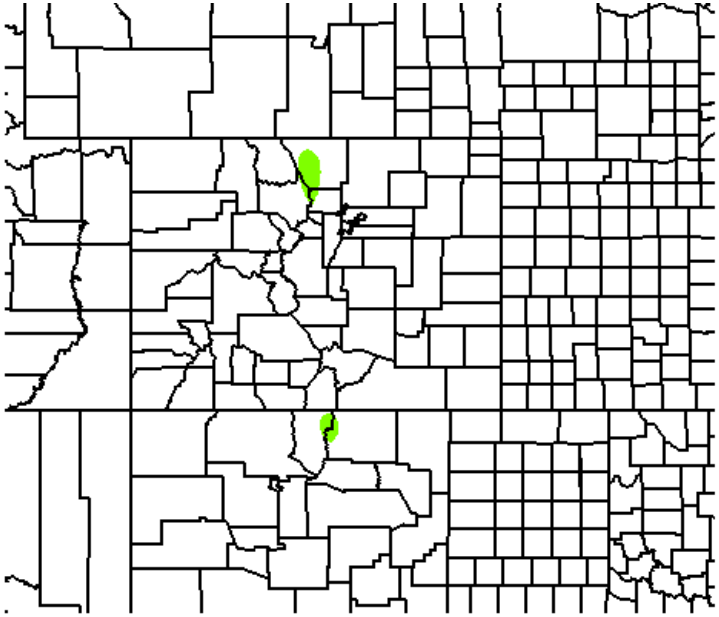

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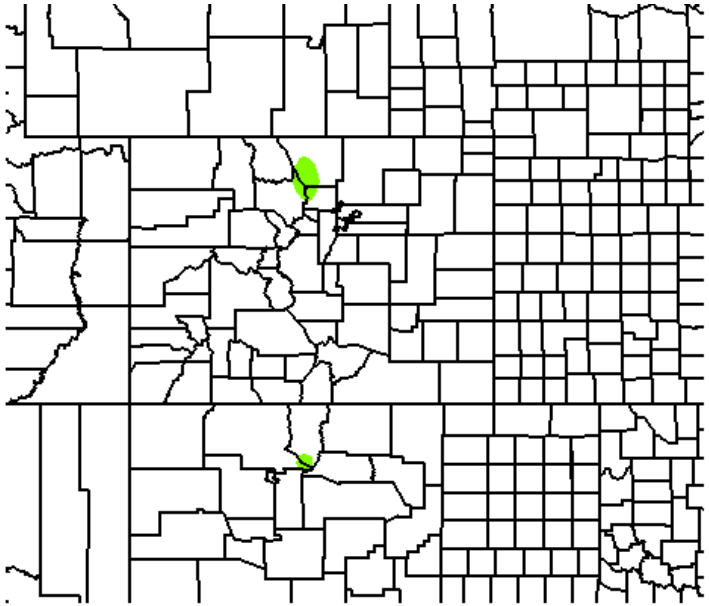

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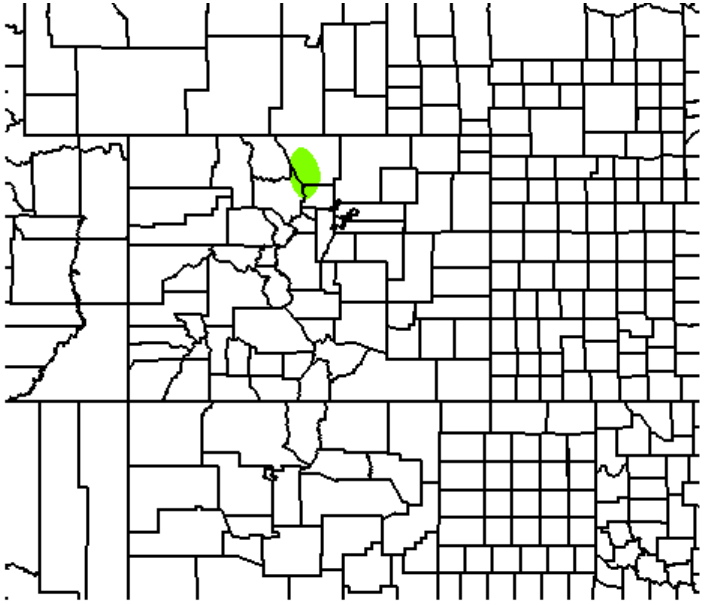

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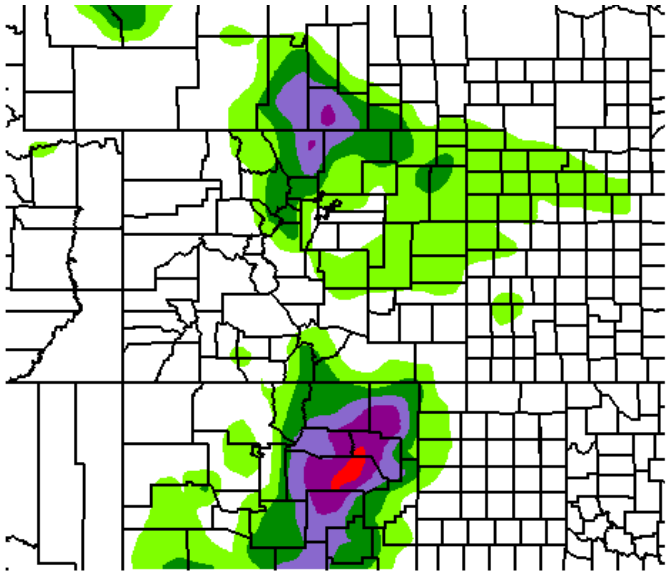

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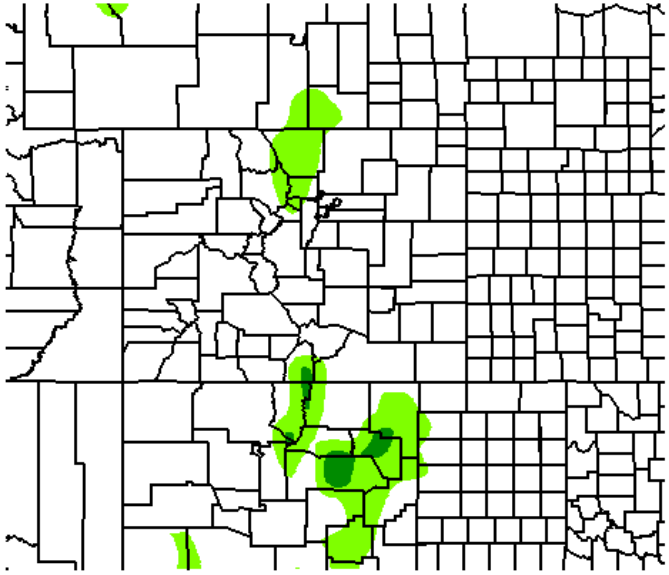

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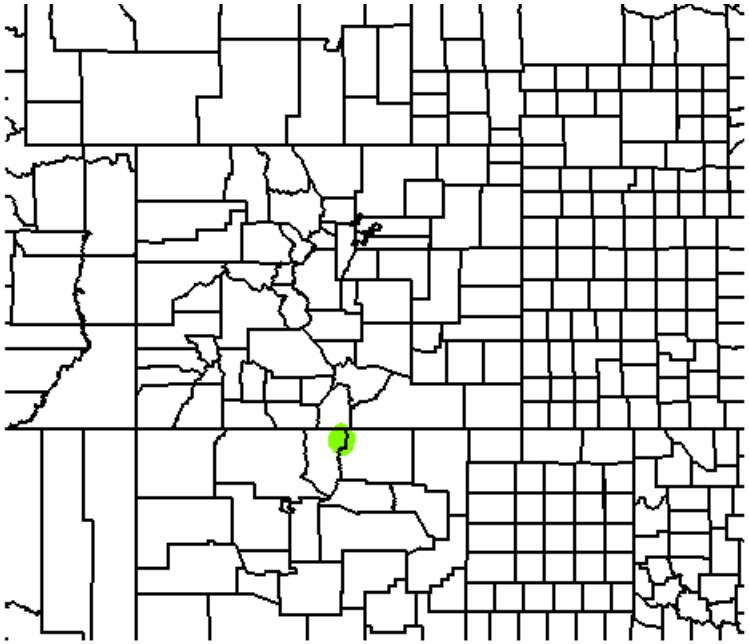
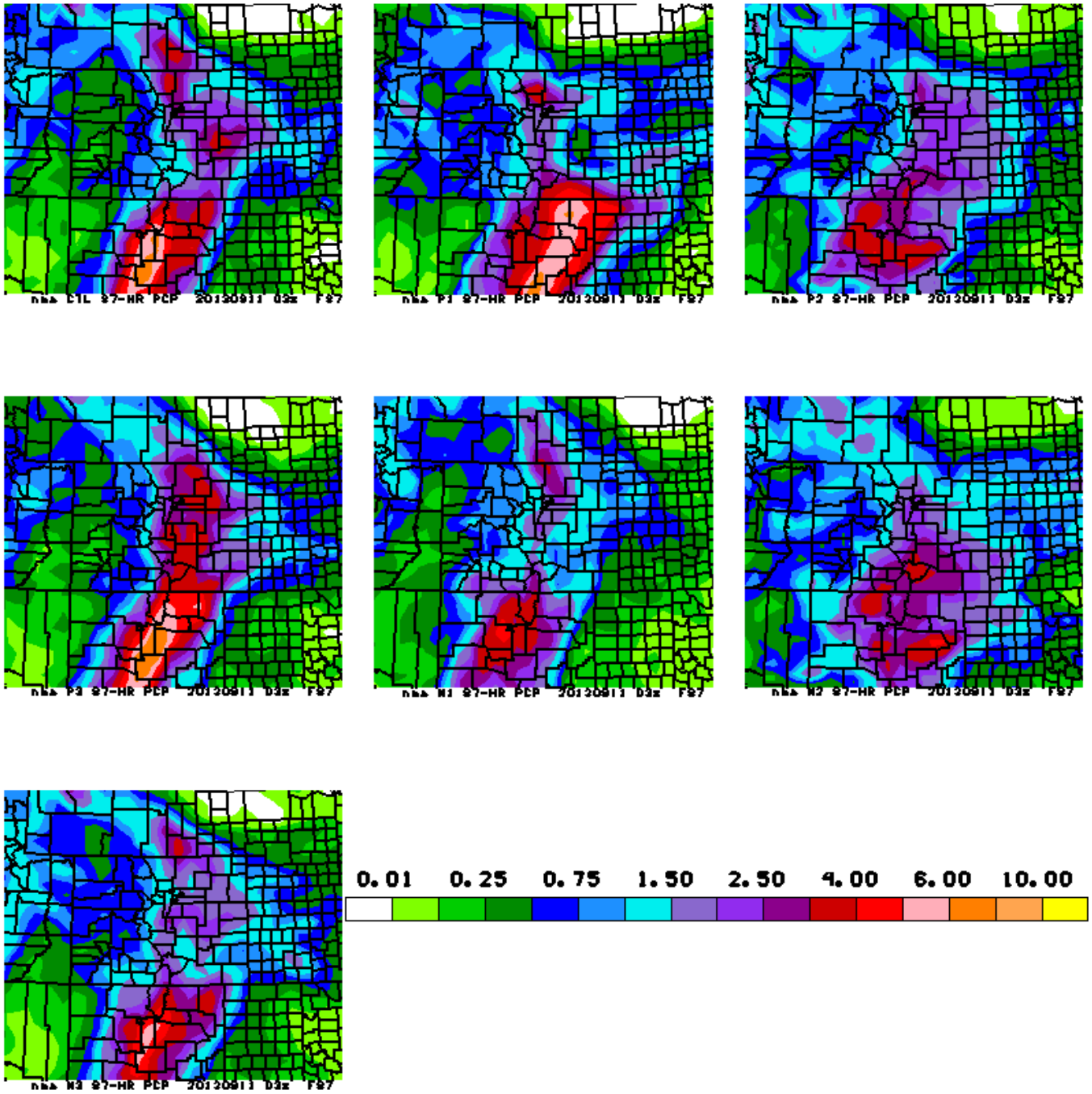
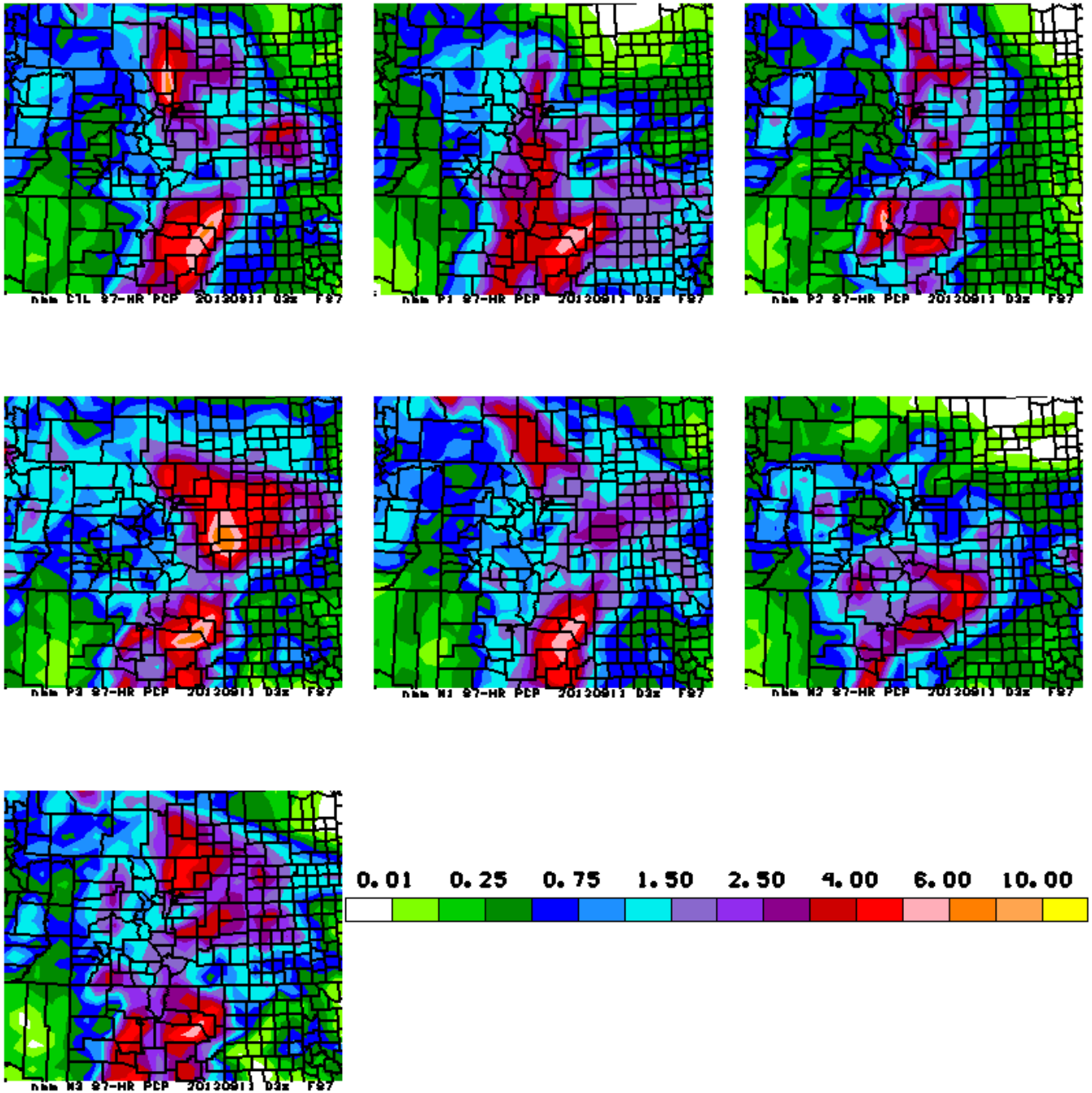


130912/1200V033 SREF PROB of 4"

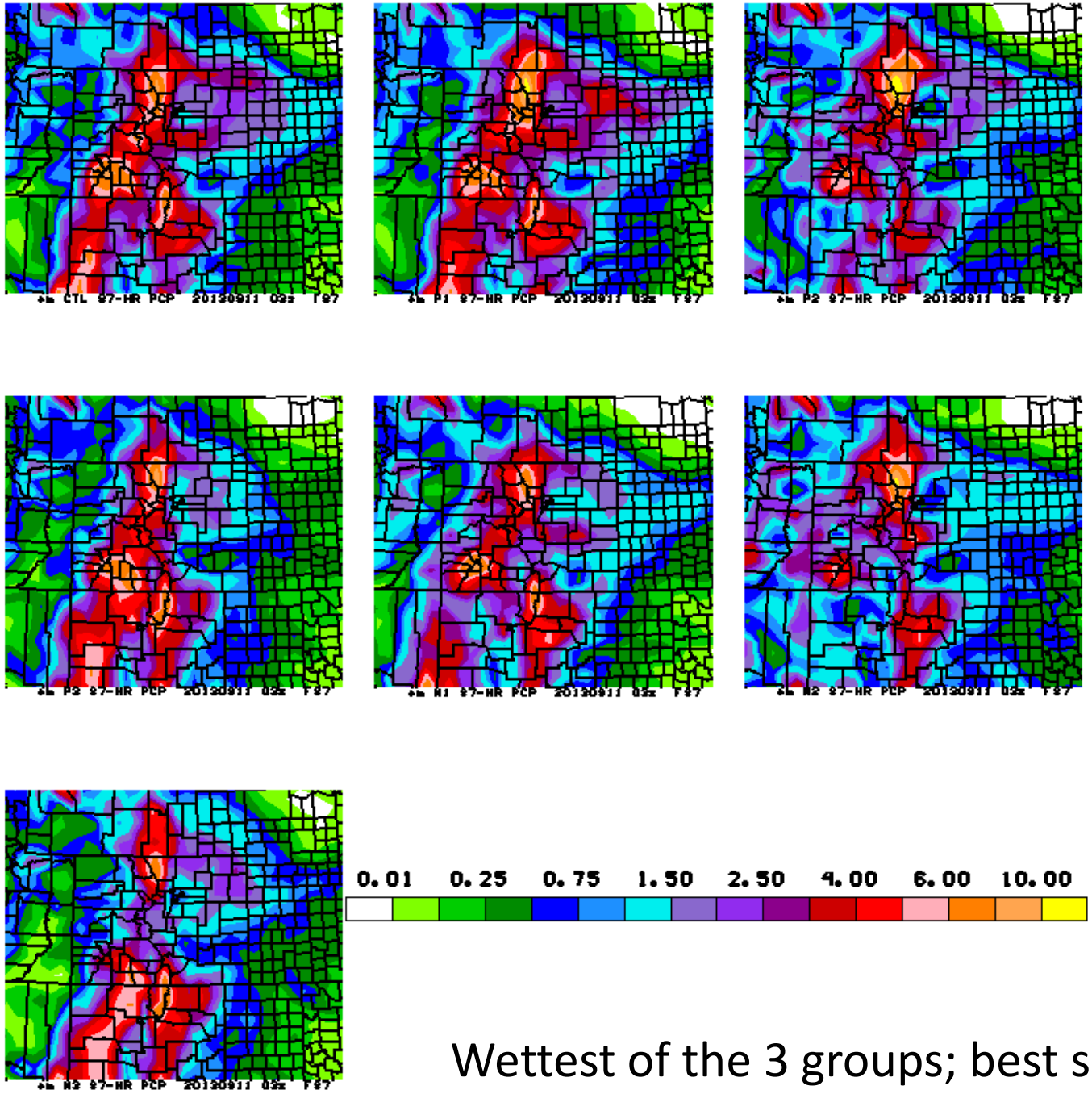
Interesting – even for the SREF run from 11 Sep at 06z the probabilities were rather "modest"




**03z 9/11**
**NMB**
**MEMBERS**




**03z 9/11**
**NMM**
**MEMBERS**

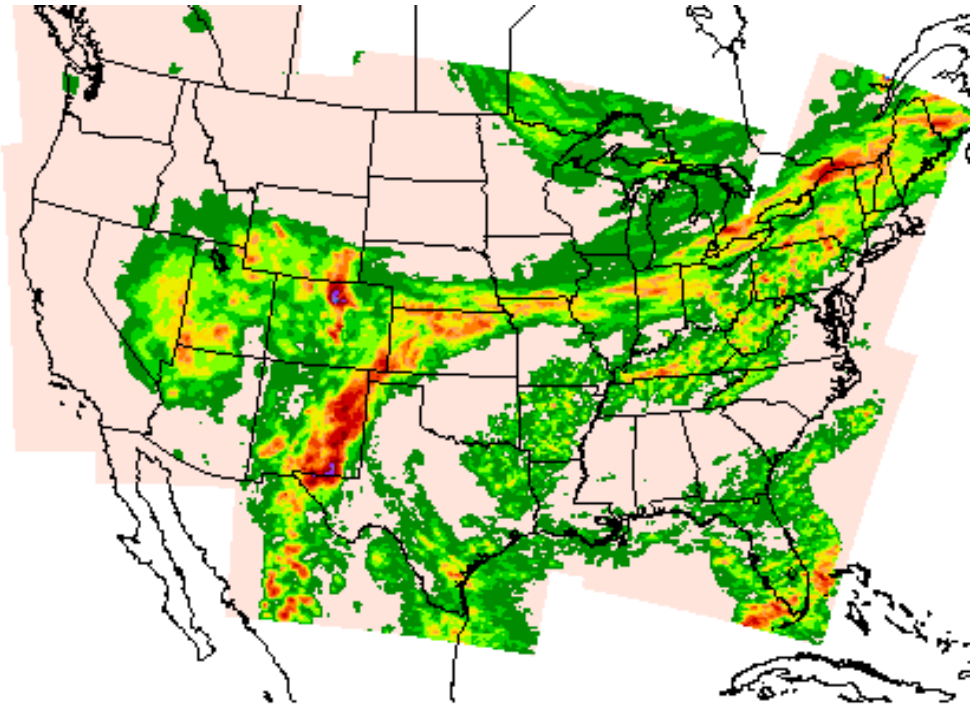


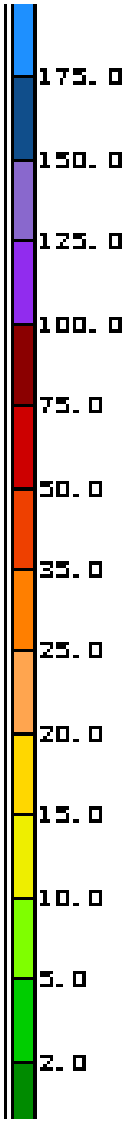

**03z 9/11**
**EM**
**MEMBERS**

Wettest of the 3 groups; best singal for BOU

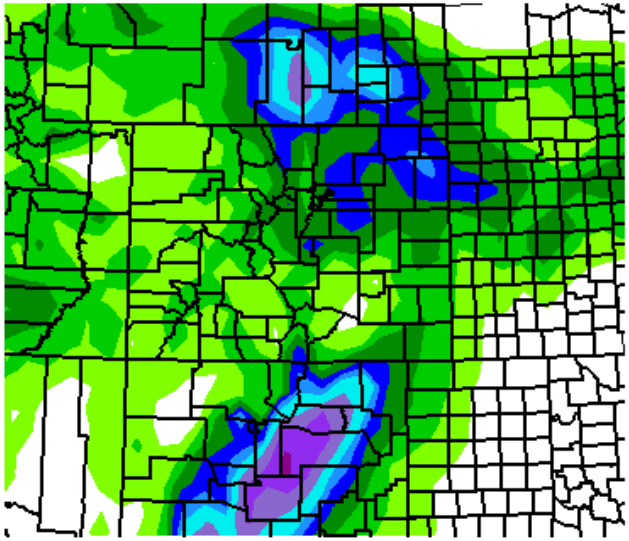
# More NON-HIRES GUIDANCE

## verifying for 24-h period ending 12z/12 Sep

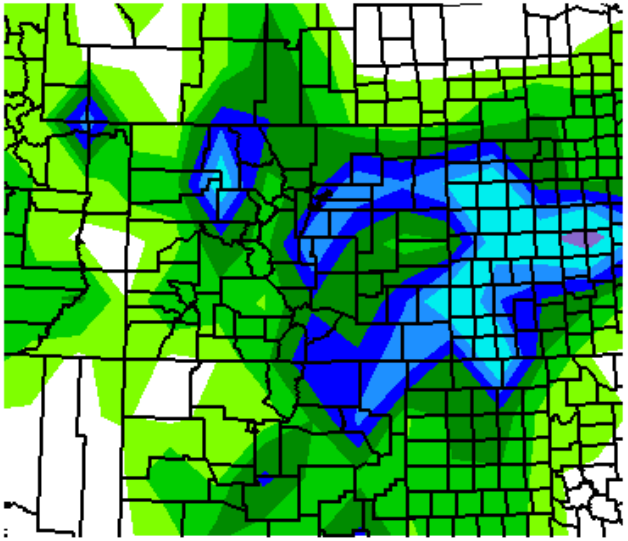


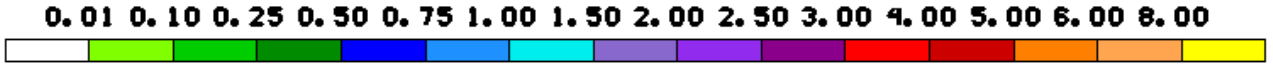
**60-h precipitation forecasts (inches) from 00z/10 Sep runs for the 24-h period ending at 12z/12 Sep**

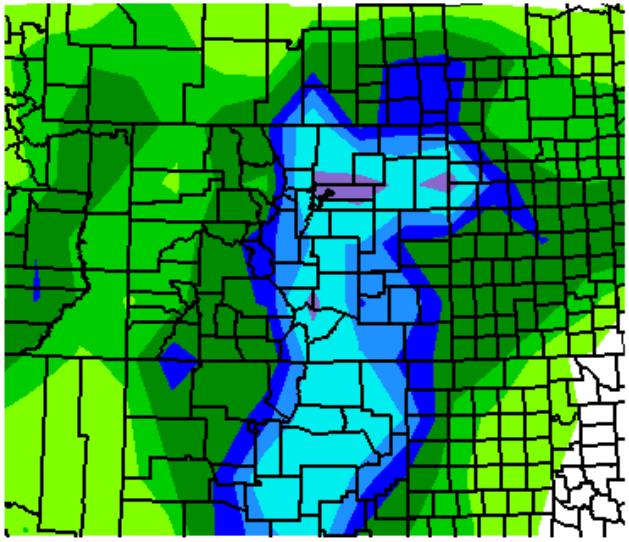



NAM

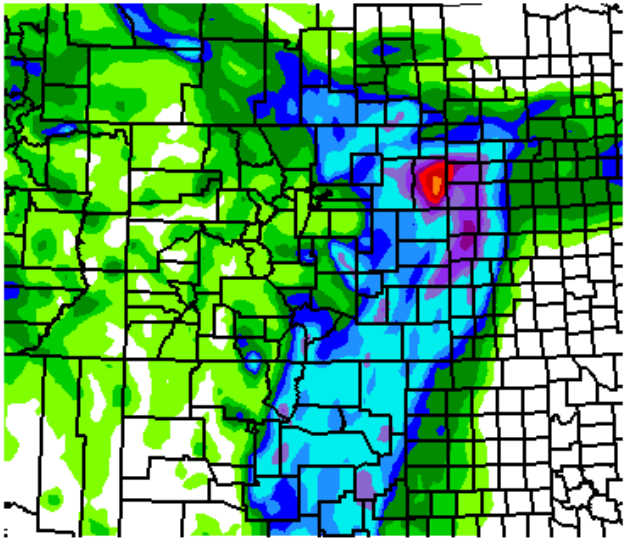



GFS



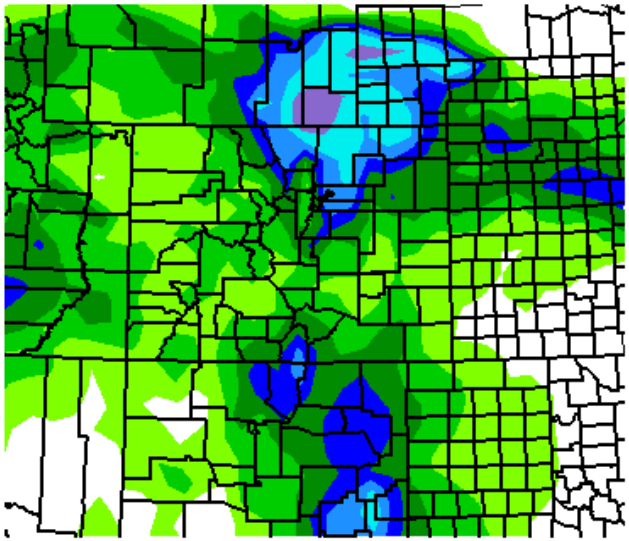




ECMWF




NAMX

**48-h precipitation forecasts (inches) from 12z/10 Sep runs for the 24-h period ending at 12z/12 Sep**

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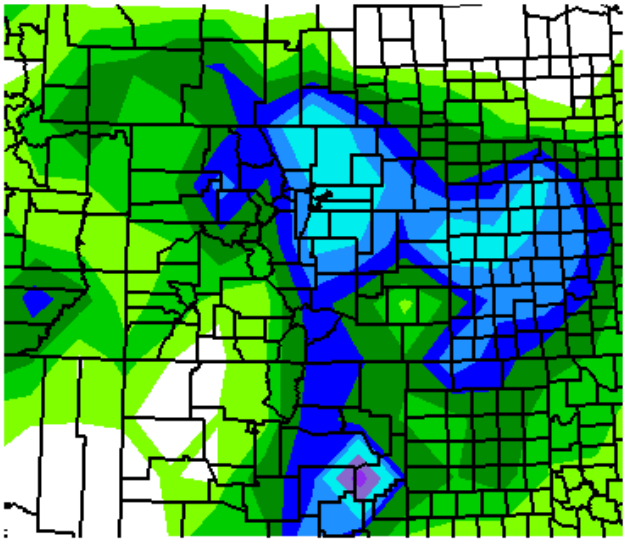


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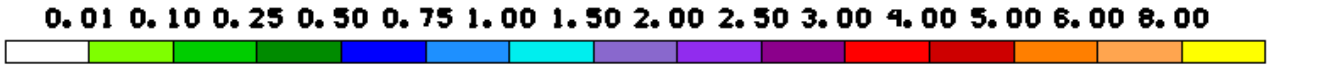


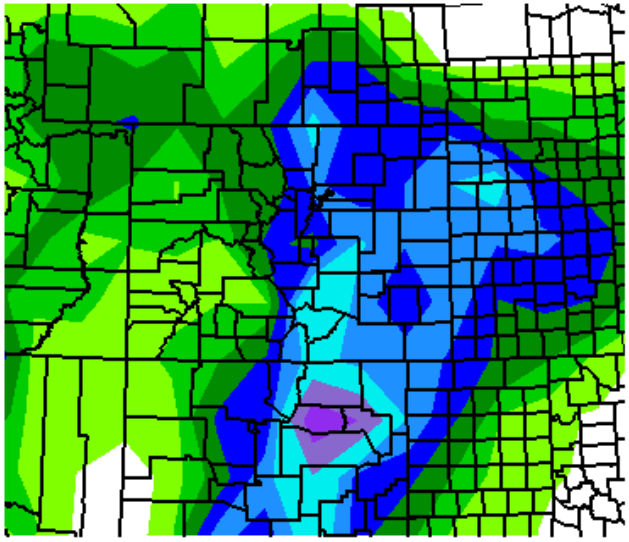


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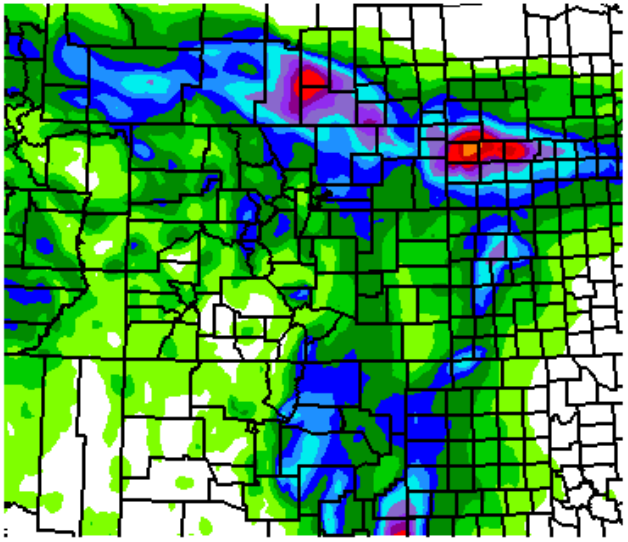
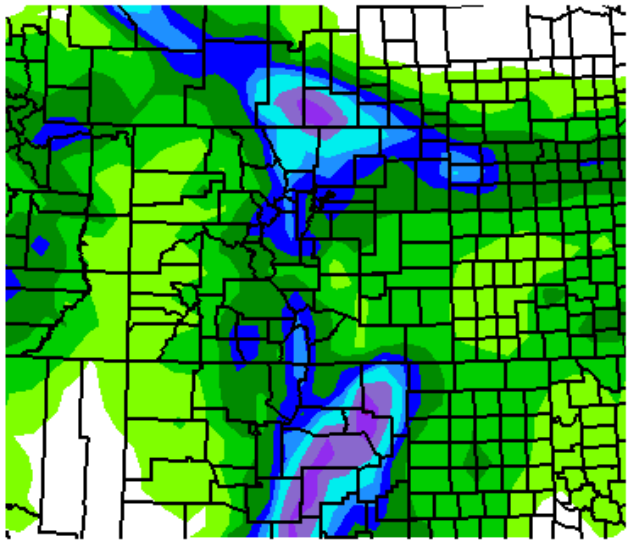



NAMX

**36-h precipitation forecasts (inches) from 00z/11 Sep runs for the 24-h period ending at 12z/12 Sep**

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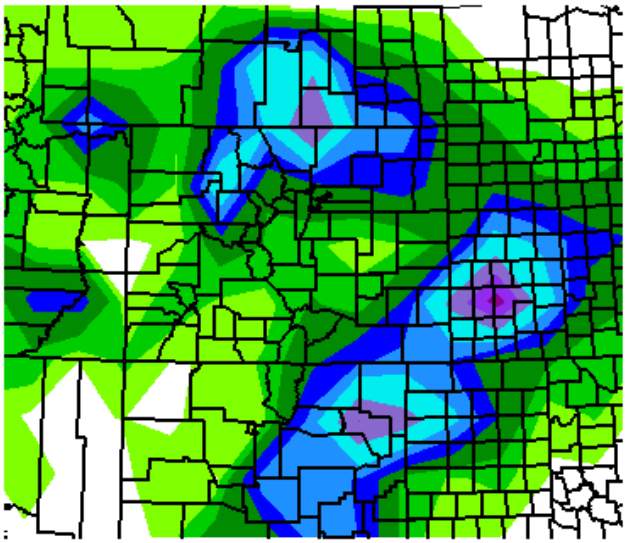


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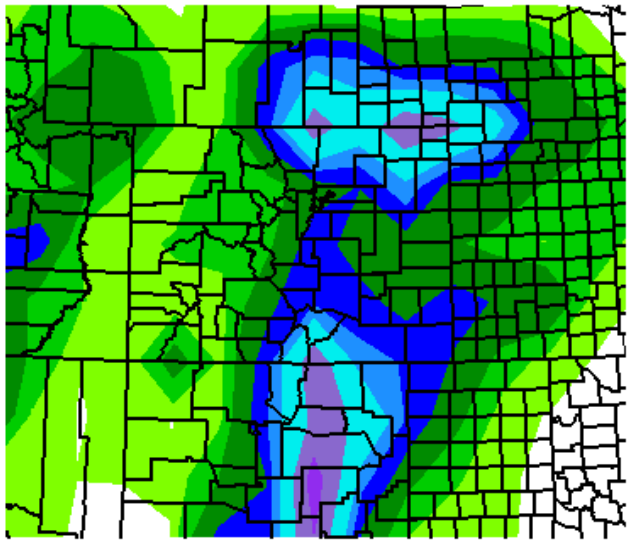
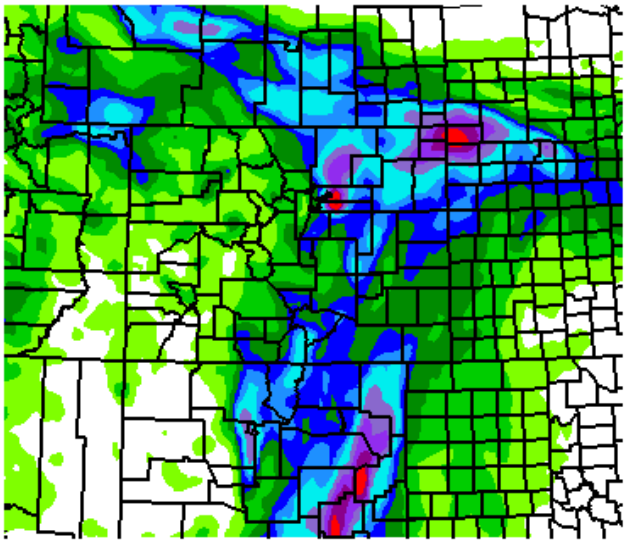
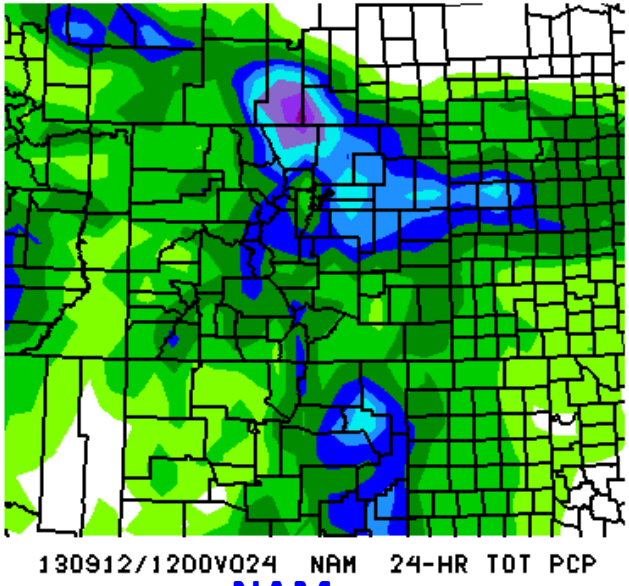



ECMWF




NAMX

**24-h precipitation forecasts (inches) from 12z/11 Sep runs for the 24-h period ending at 12z/12 Sep**

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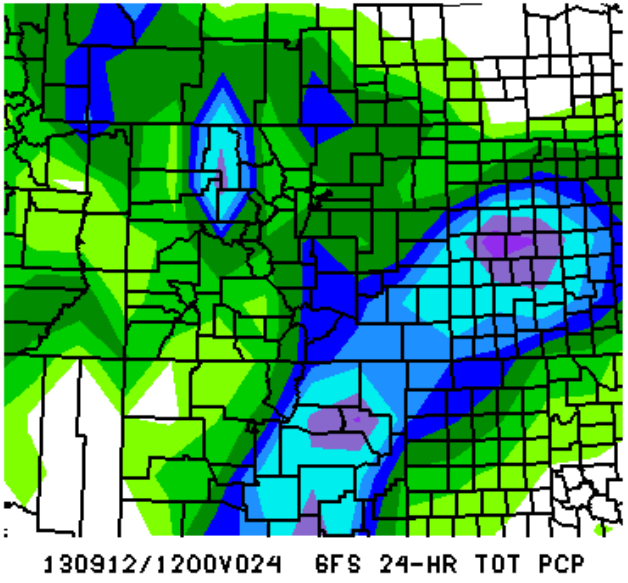


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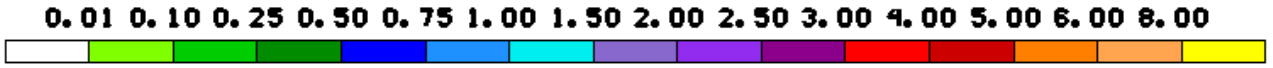
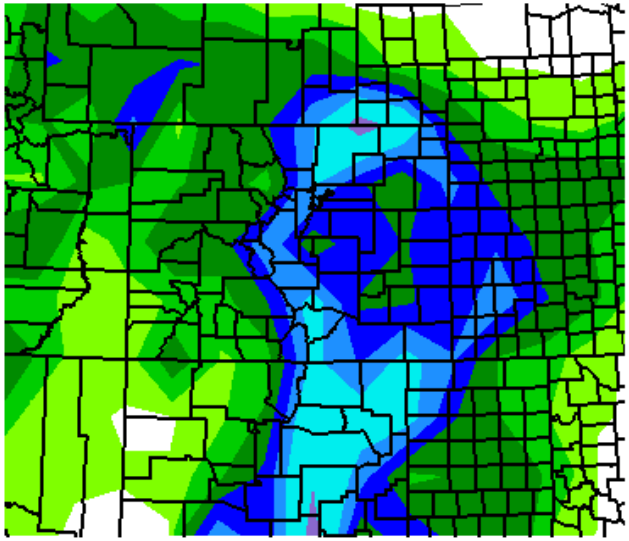
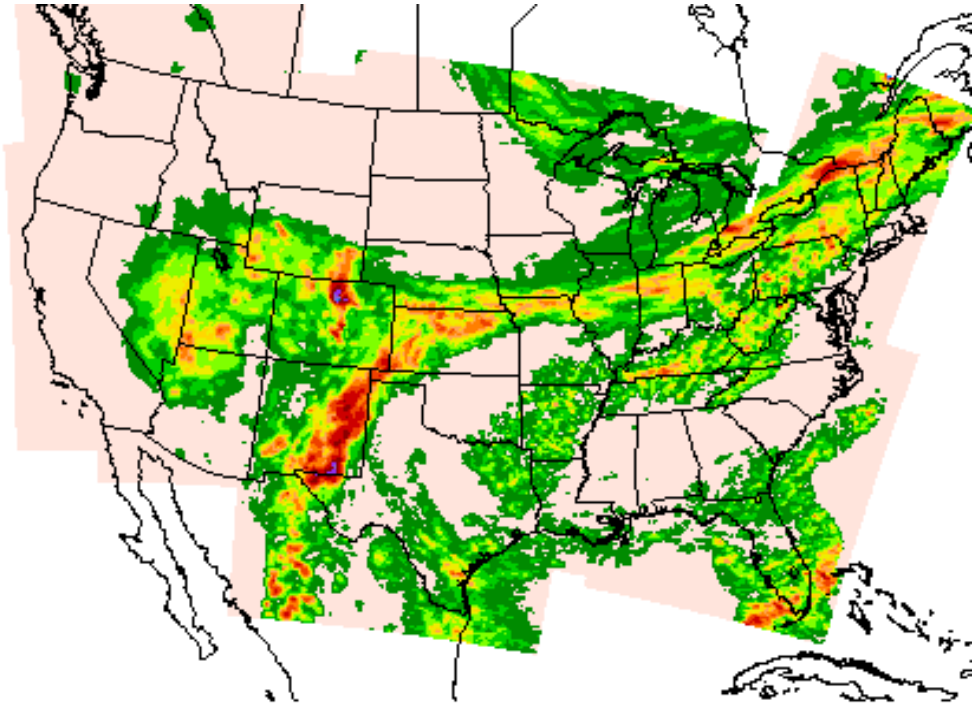



ECMWF

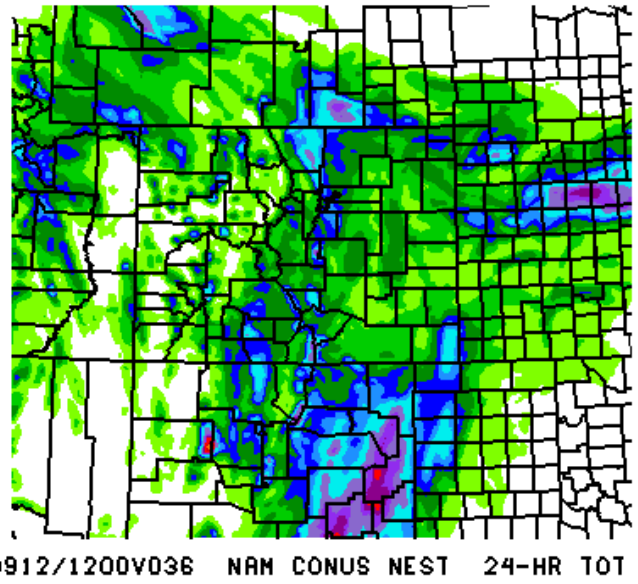
Notice how these runs, now closer to the event, back off on precip amounts.

# HI-RES GUIDANCE

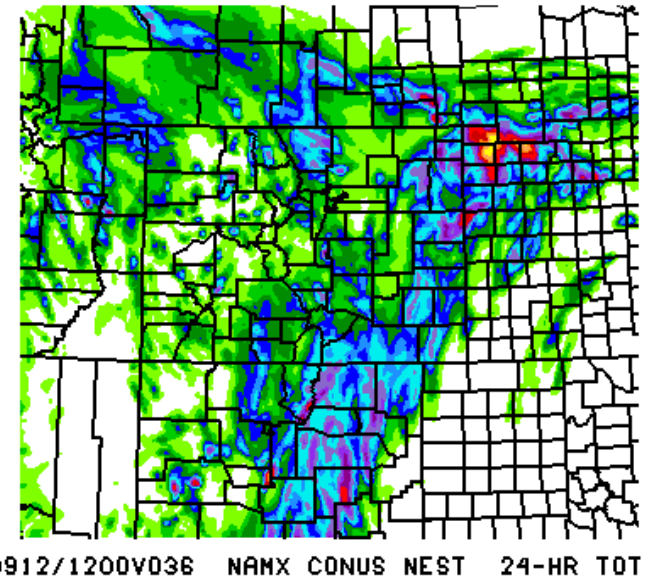



Stage IV (3 mos) 24h Accum (mm) Ending 2013091212

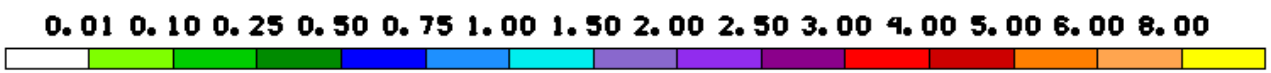
**36-h precipitation forecasts (inches) from 00z/11 Sep runs for the 24-h period ending at 12z/12 Sep**

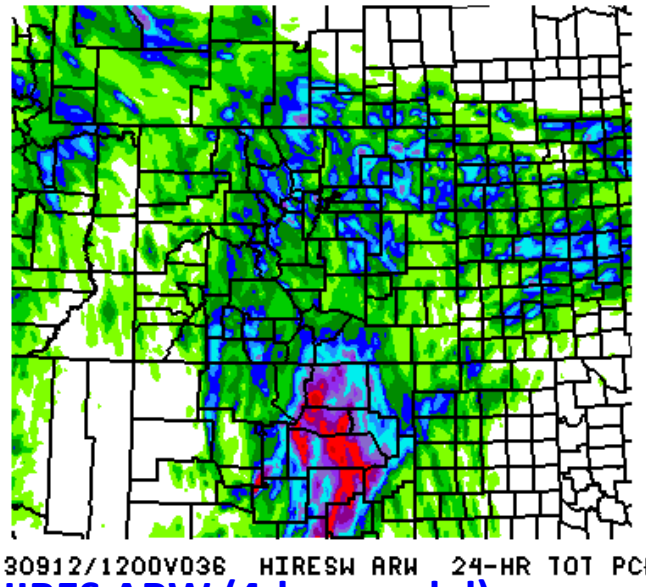



NAM CONUS NEST (4-km model)

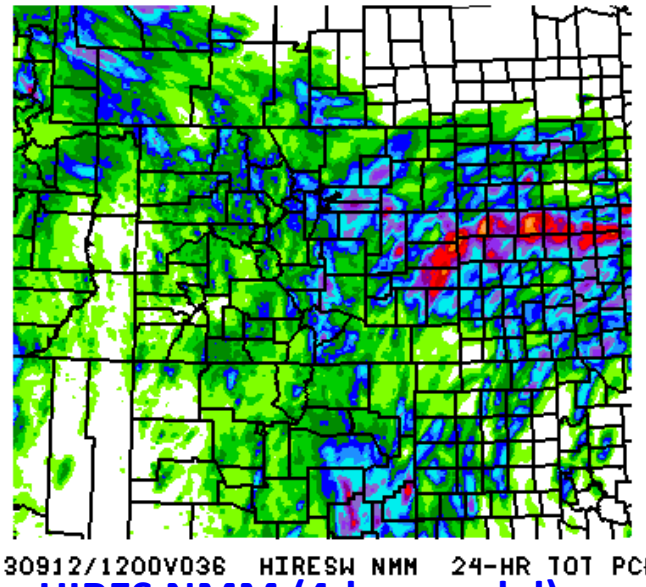



NAMX CONUS NEST (4-km model)



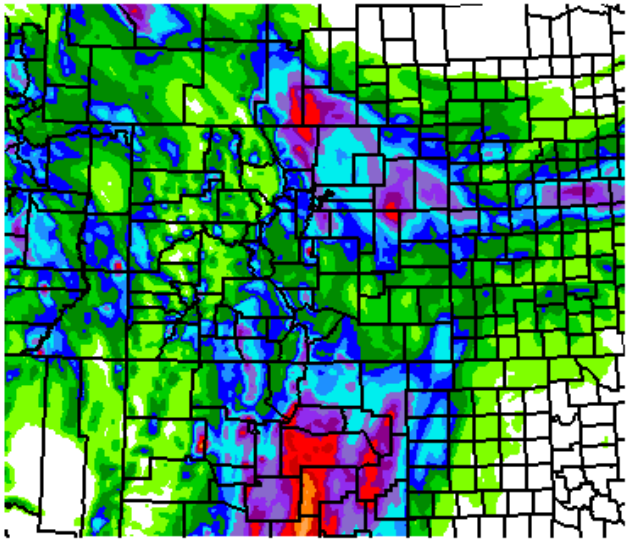




HIRES ARW (4-km model)

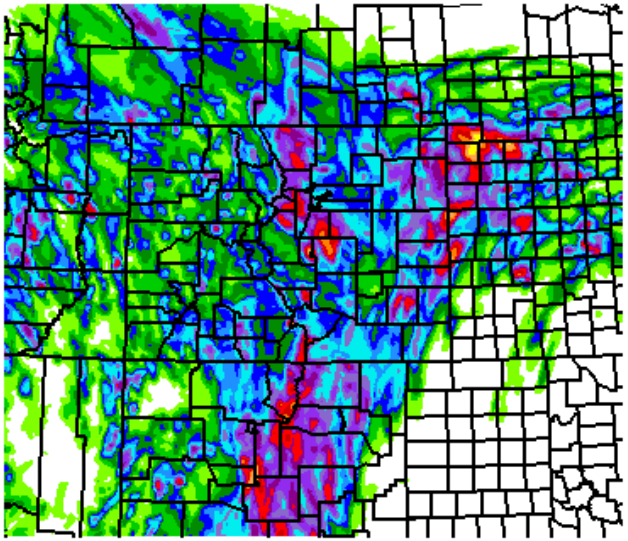



HIRES NMM (4-km model)

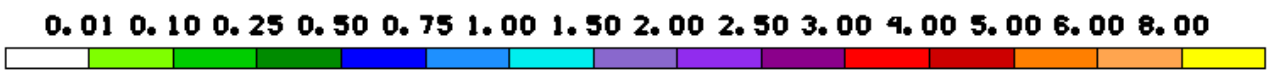
**48-h precipitation forecasts (inches) from 00z/11 Sep runs for the 48-h period ending at 00z/13 Sep**

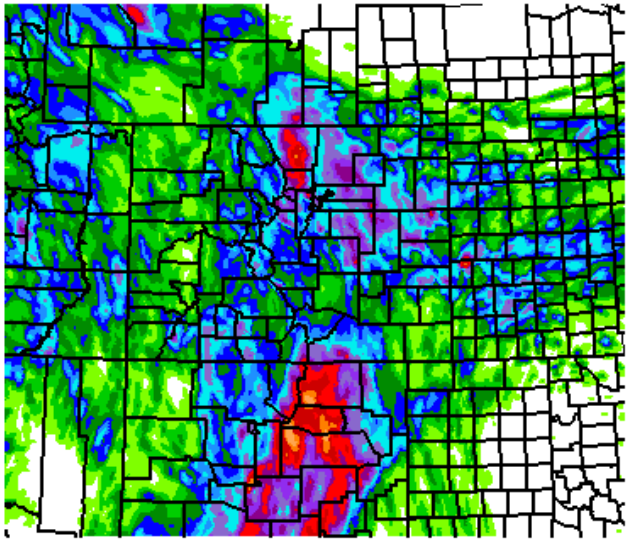



NAM CONUS NEST (4-km model)




NAMX CONUS NEST (4-km model)

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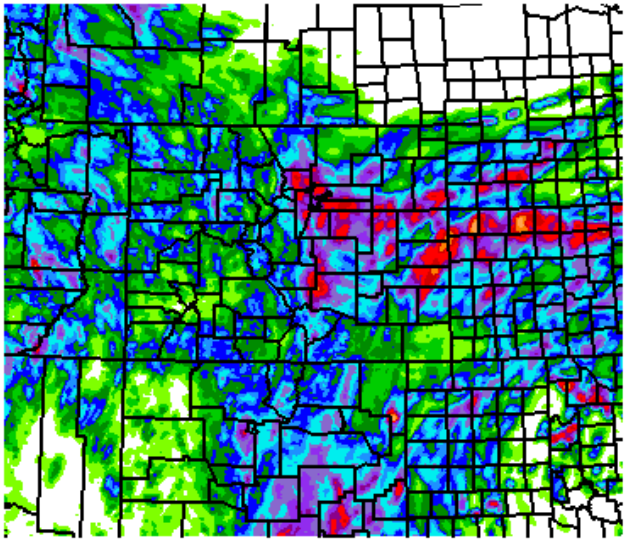
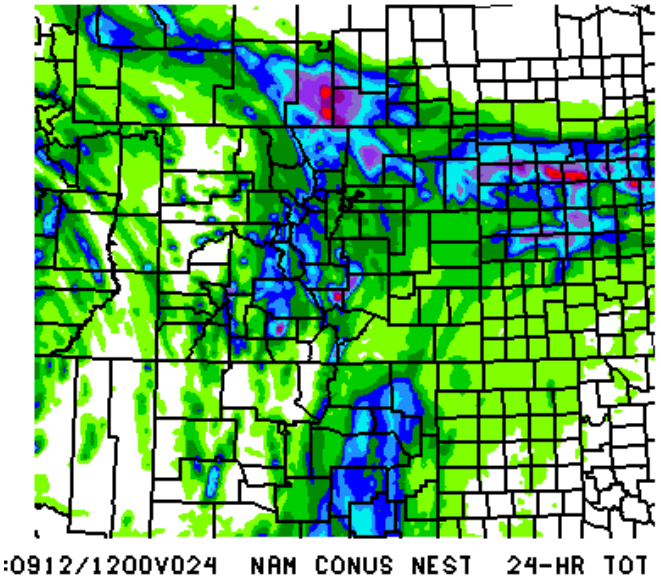


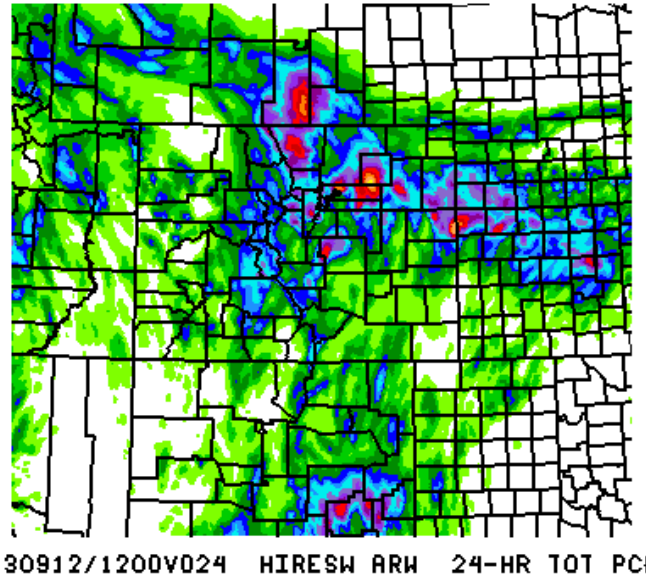

HIRES NMM (4-km model)

**24-h precipitation forecasts (inches) from 12z/11 Sep runs for the 24-h period ending at 12z/12 Sep**

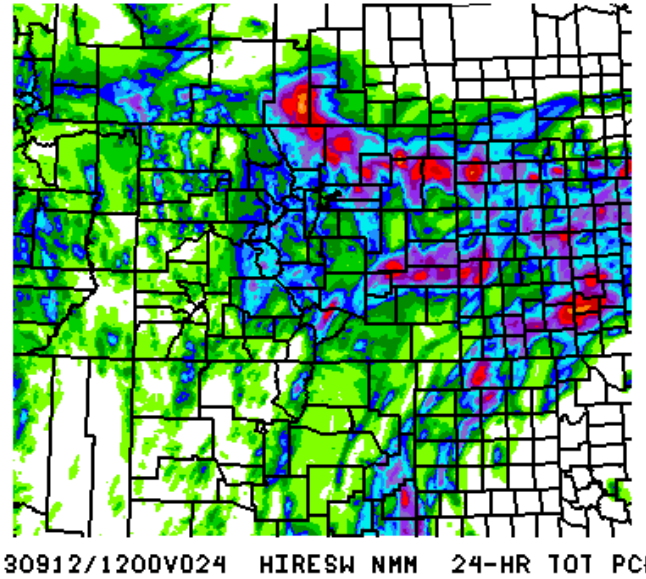



**NAM CONUS NEST (4-km model)**

0.01 0.10 0.25 0.50 0.75 1.00 1.50 2.00 2.50 3.00 4.00 5.00 6.00 8.00

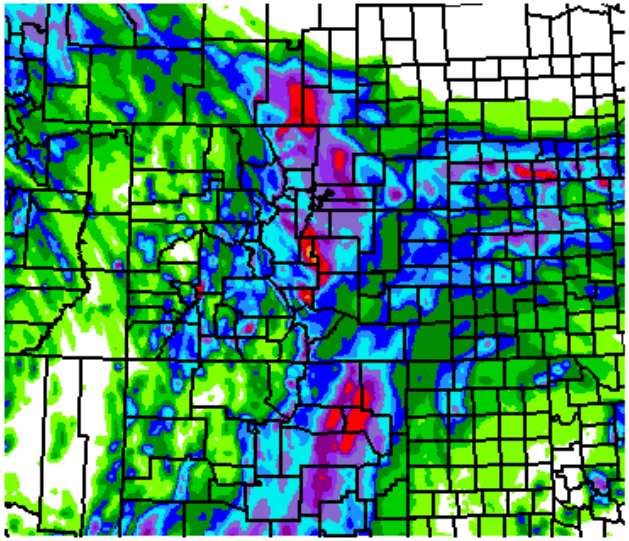



**HIRES ARW (4-km model)**



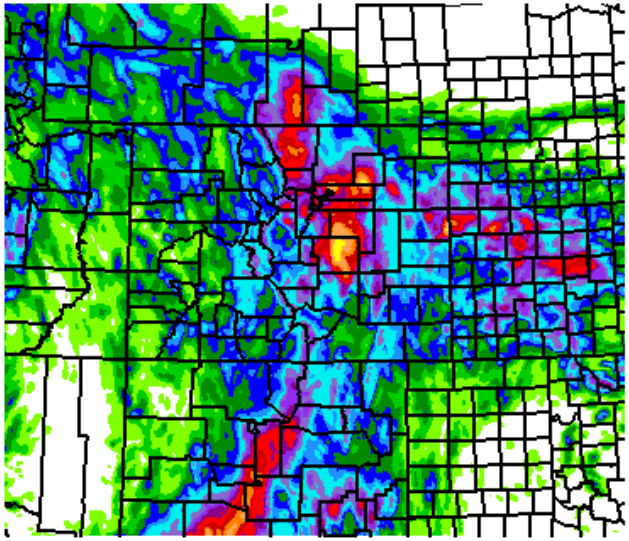

**HIRES NMM (4-km model)**

**48-h precipitation forecasts (inches) from 12z/11 Sep runs for the 48-h period ending at 12z/13 Sep**

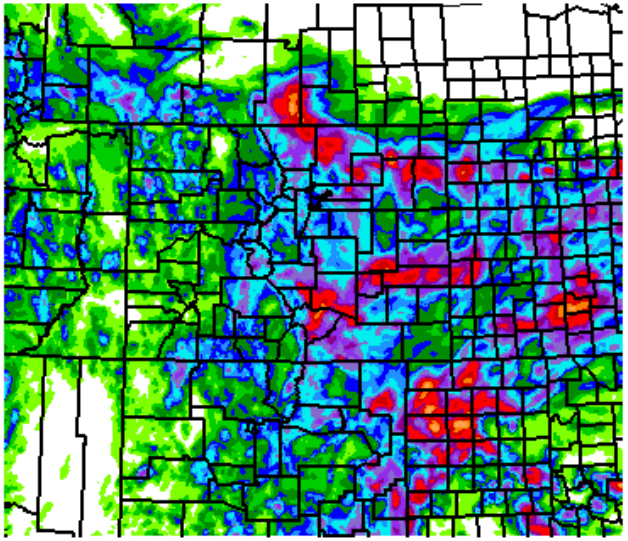



**NAM CONUS NEST (4-km model)**

0.01 0.10 0.25 0.50 0.75 1.00 1.50 2.00 2.50 3.00 4.00 5.00 6.00 8.00

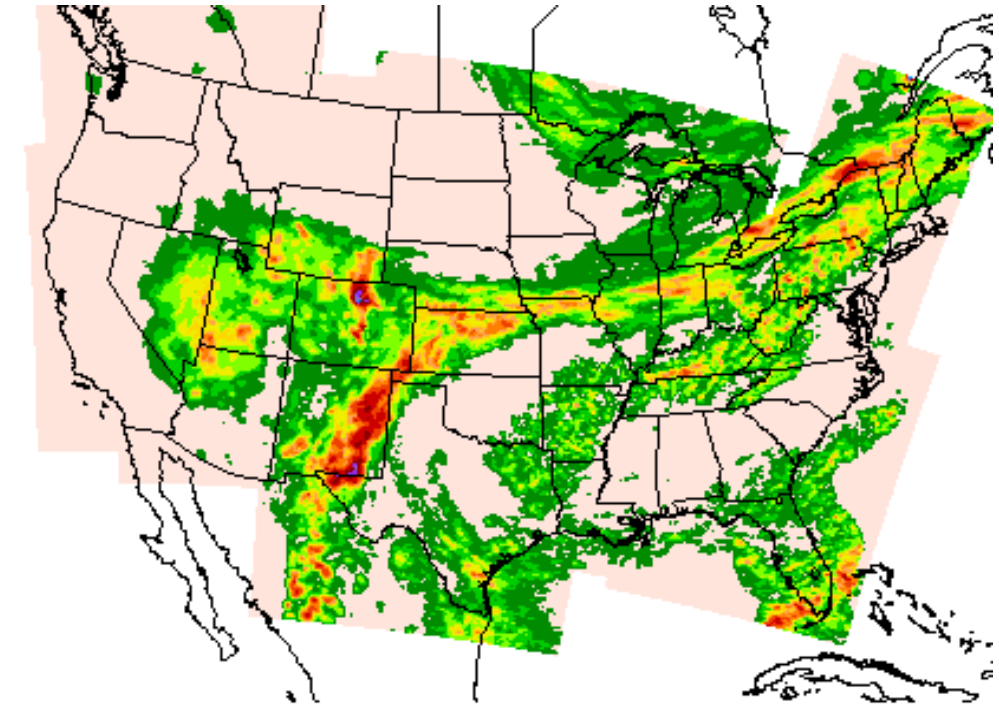



**HIRES ARW (4-km model)**

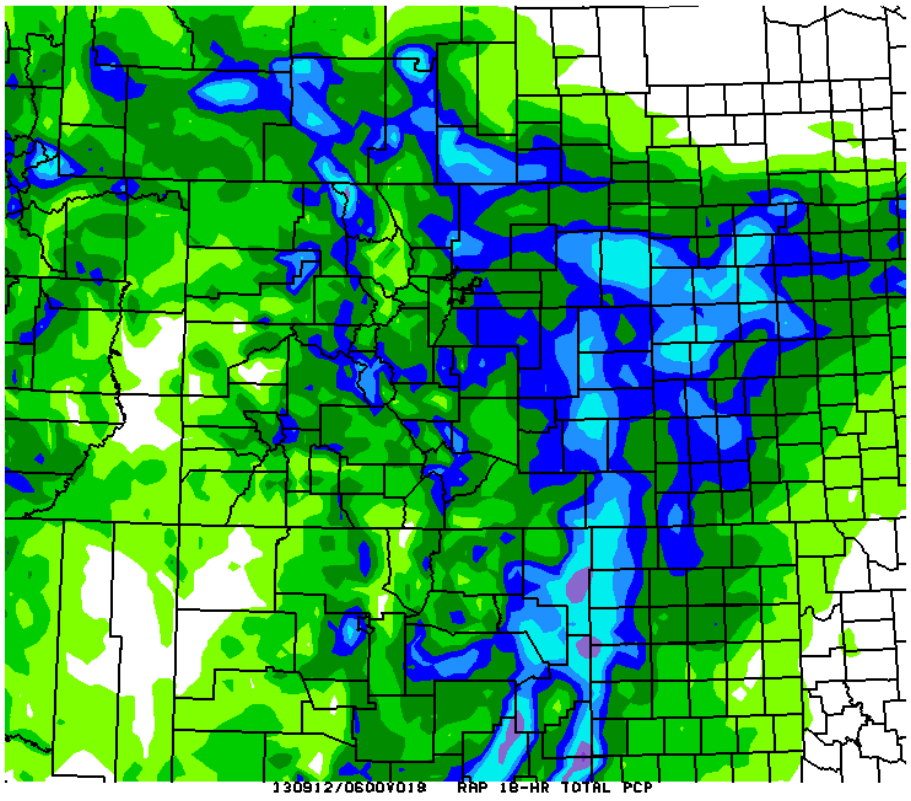



**HIRES NMM (4-km model)**

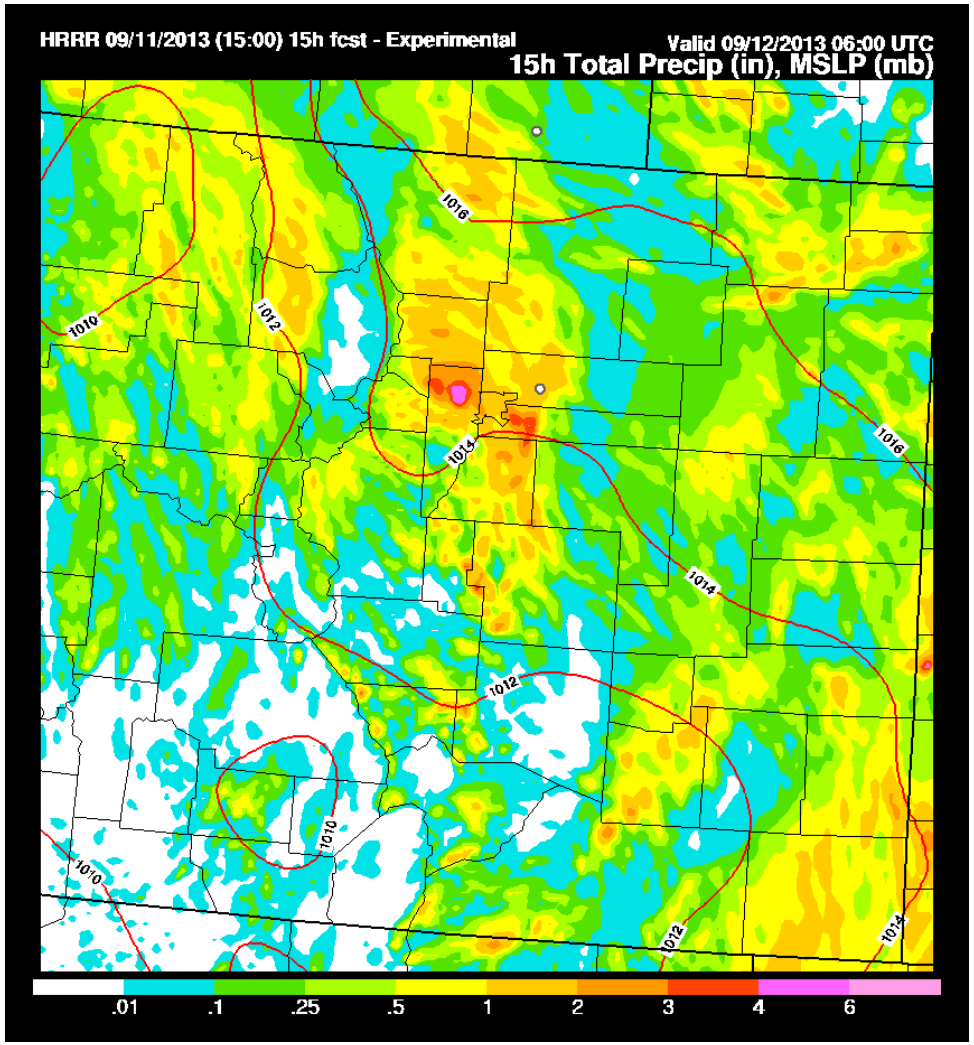
# RAP/HRRR runs



# Total precipitation forecasts

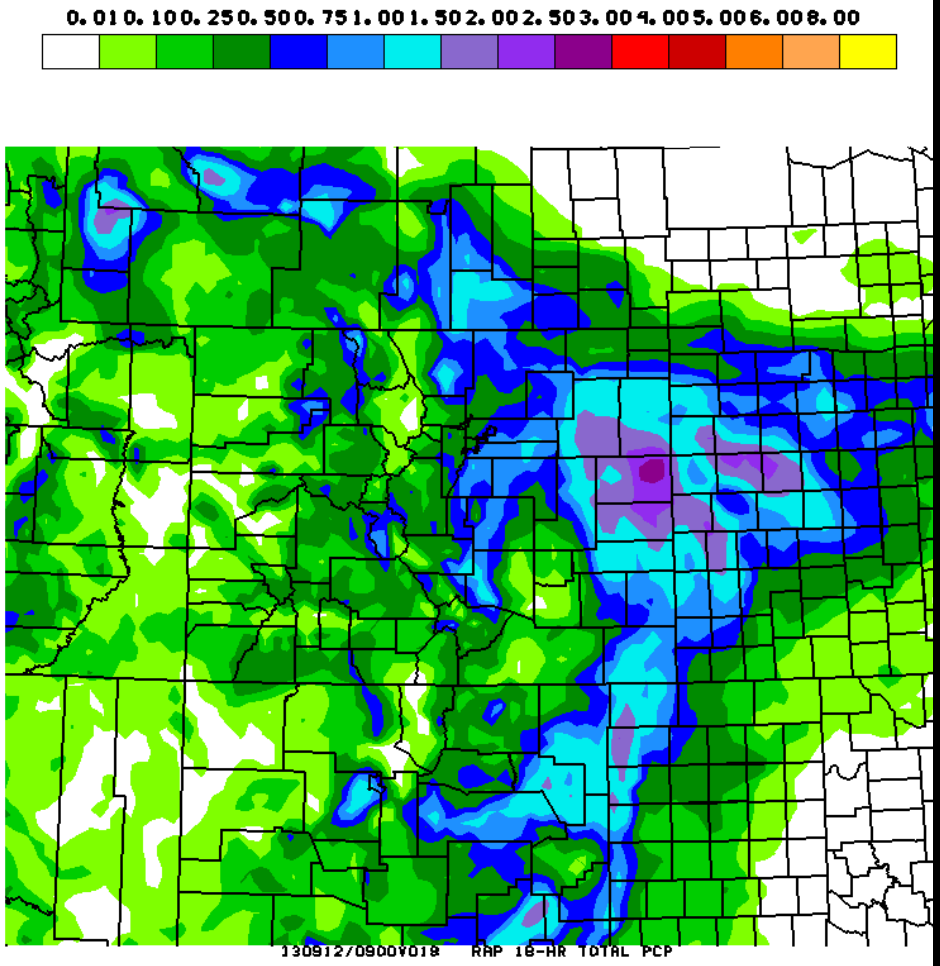



RAP 12z/11 Sep run: 18-h ending 06z/12 Sep

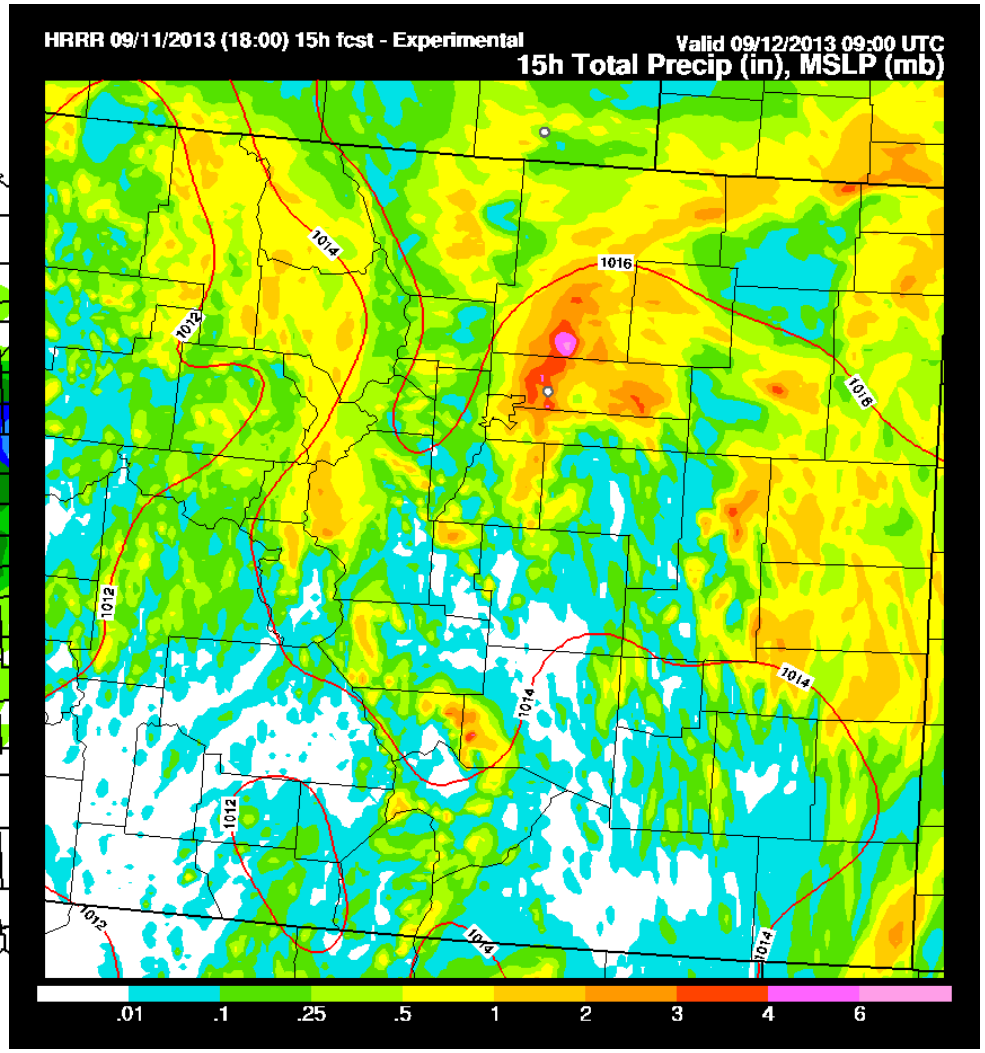



HRRR 15z/11 Sep run: 15-h ending 06z/12 Sep

# Total precipitation forecasts

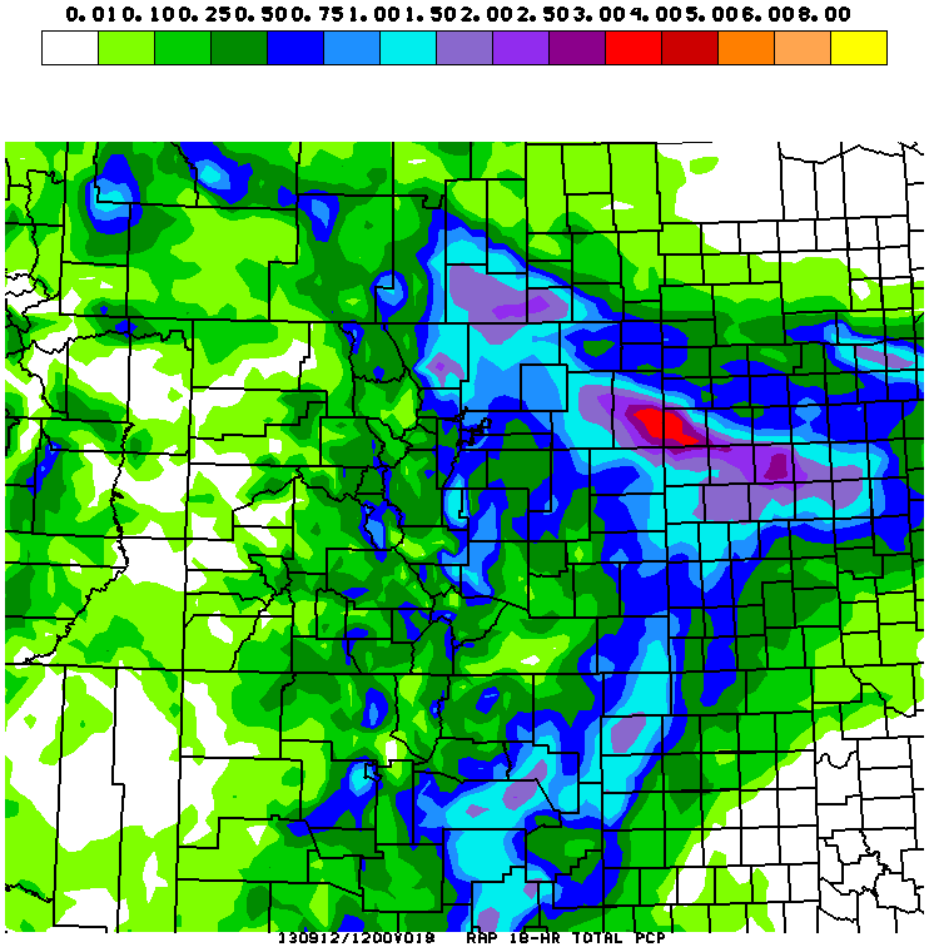



RAP 15z/11 Sep run: 18-h ending 09z/12 Sep

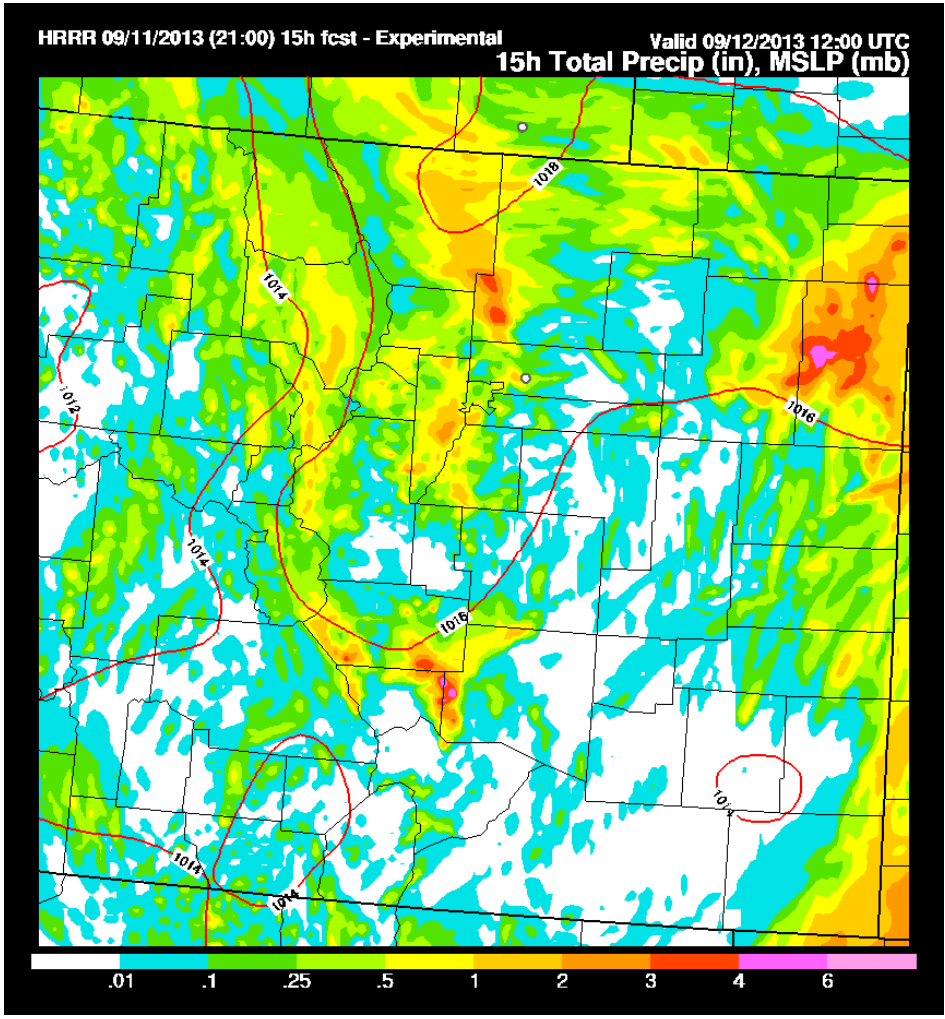



HRRR 18z/11 Sep run: 15-h ending 09z/12 Sep

# Total precipitation forecasts

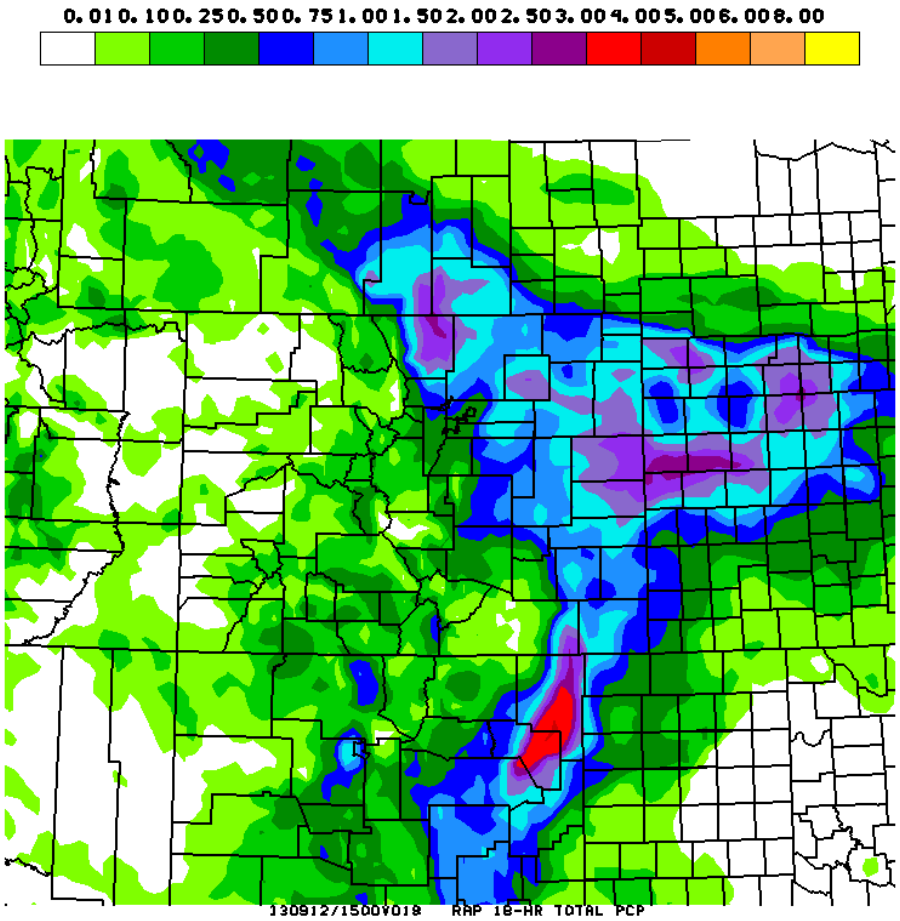



RAP 18z/11 Sep run: 18-h ending 12z/12 Sep

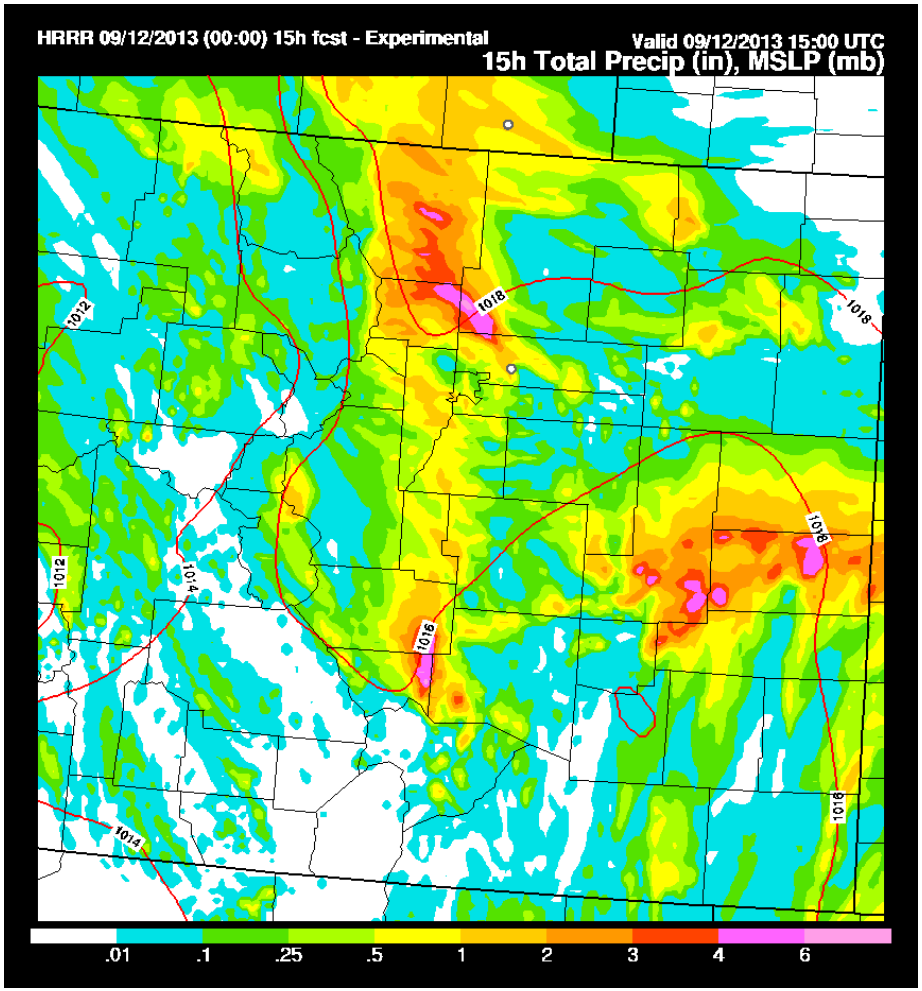



HRRR 21z/11 Sep run: 15-h ending 12z/12 Sep

# Total precipitation forecasts

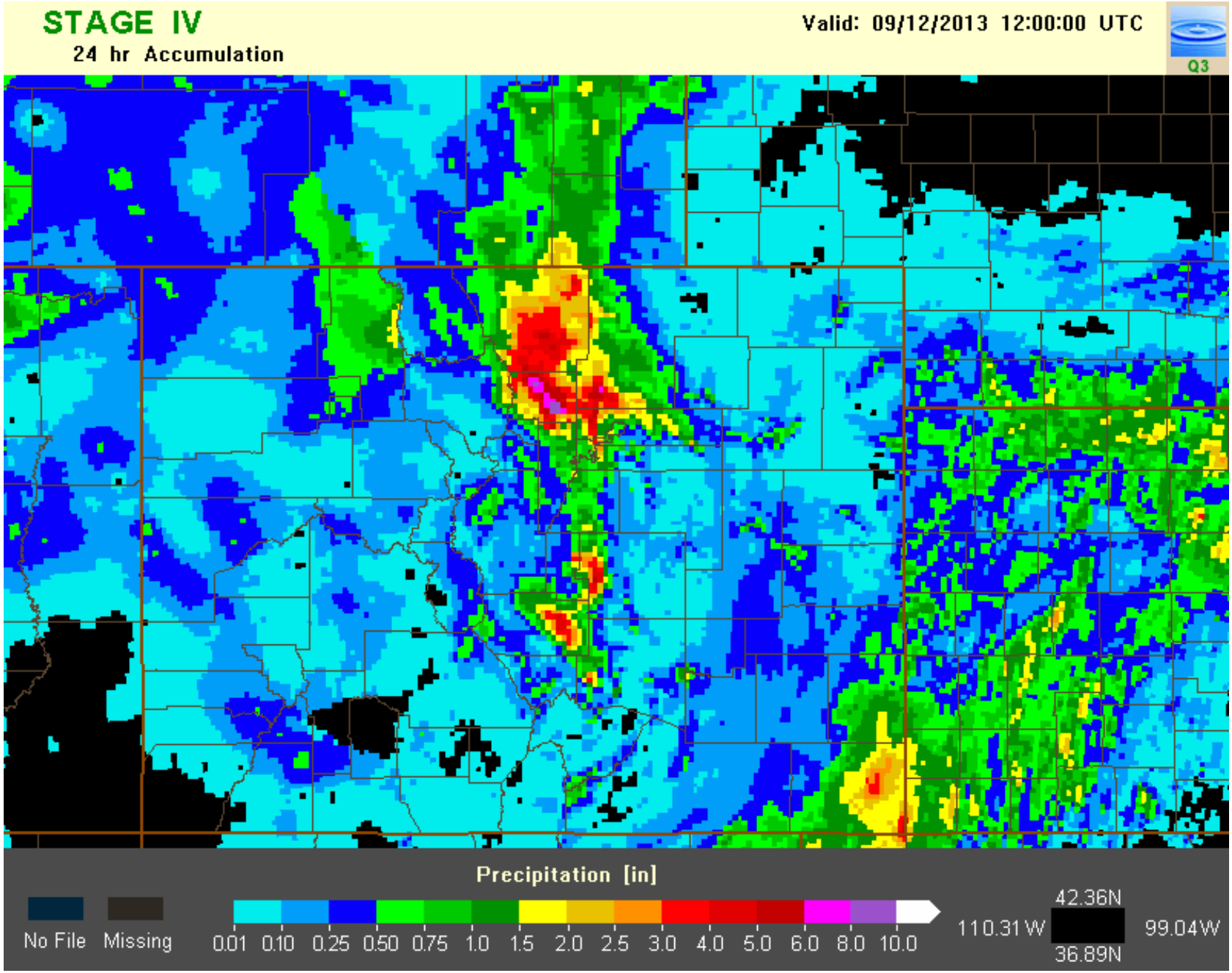


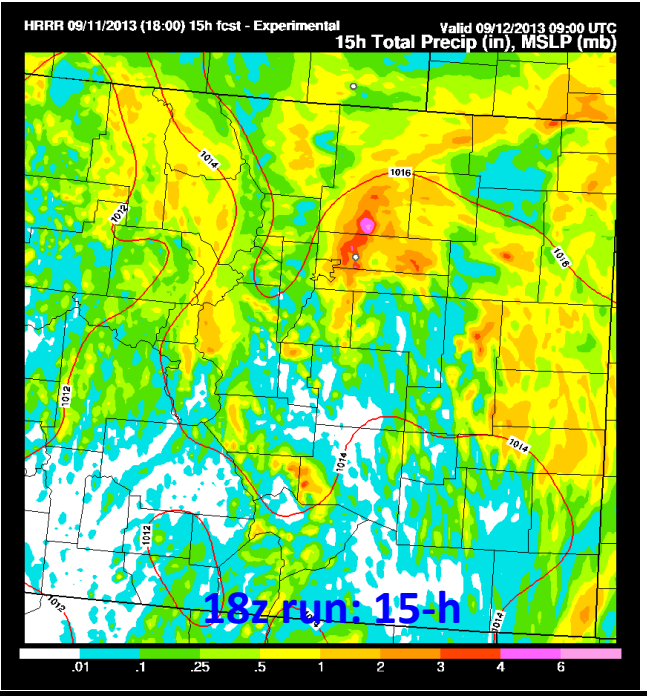

RAP 21z/11 Sep run: 18-h ending 15z/12 Sep



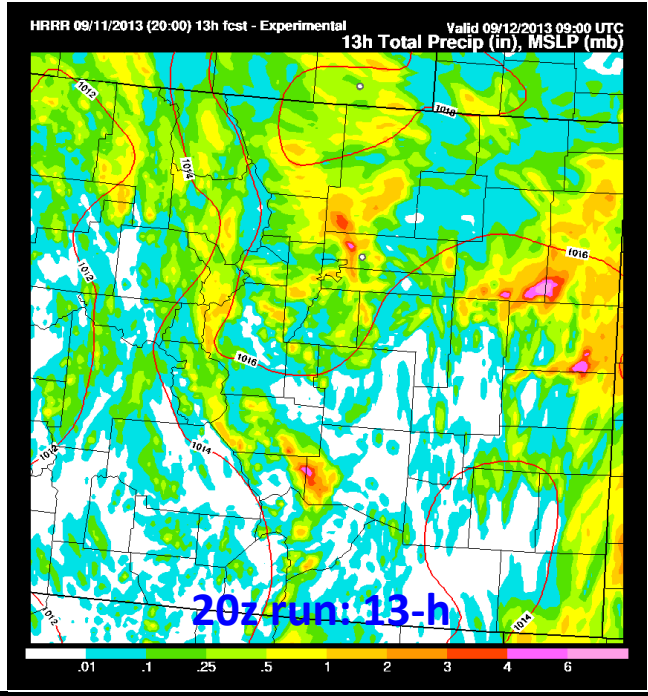

HRRR 00z/12 Sep run: 15-h ending 15z/12 Sep

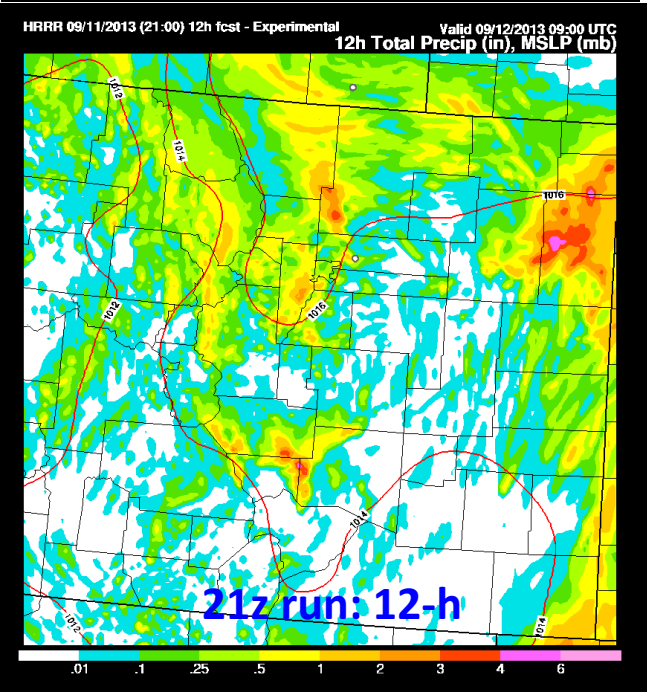
# QPE from Stage IV – 24h ending 12z/12 Sep 2013

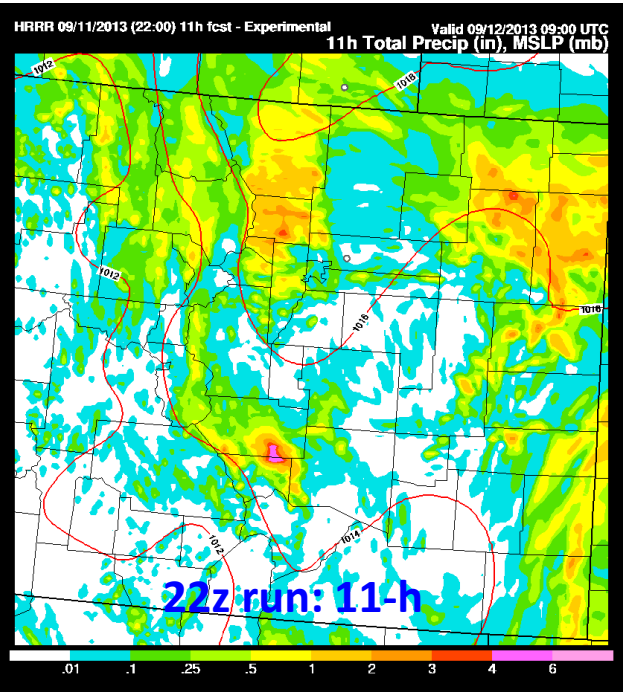


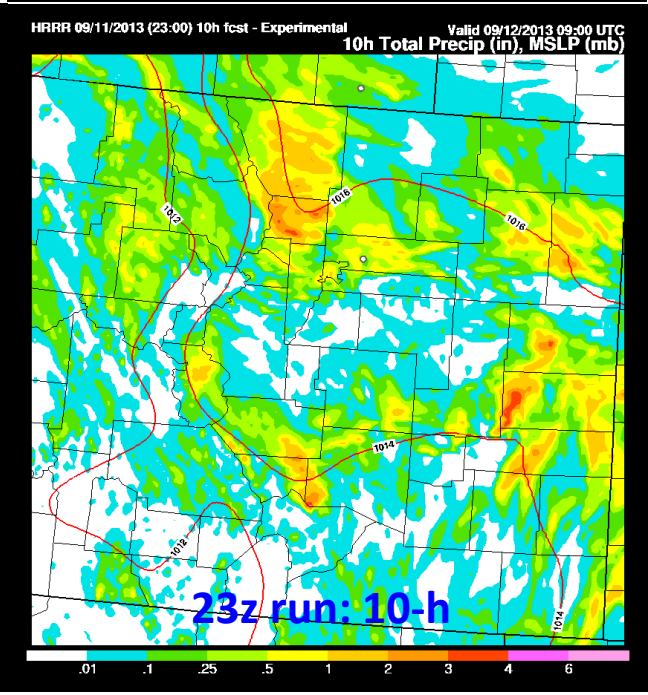



19z run: missing

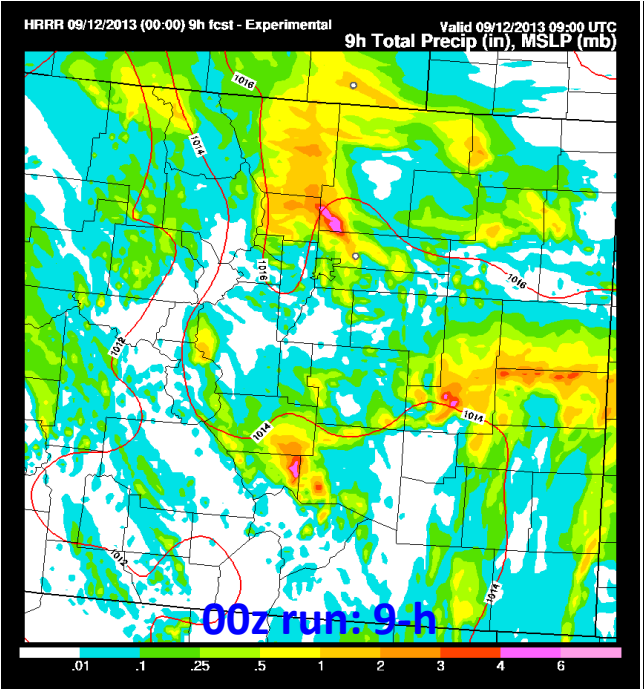


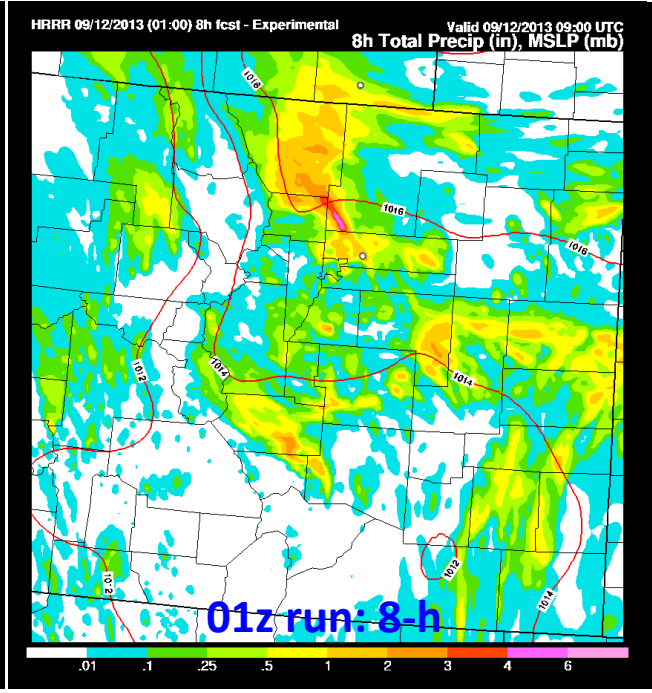



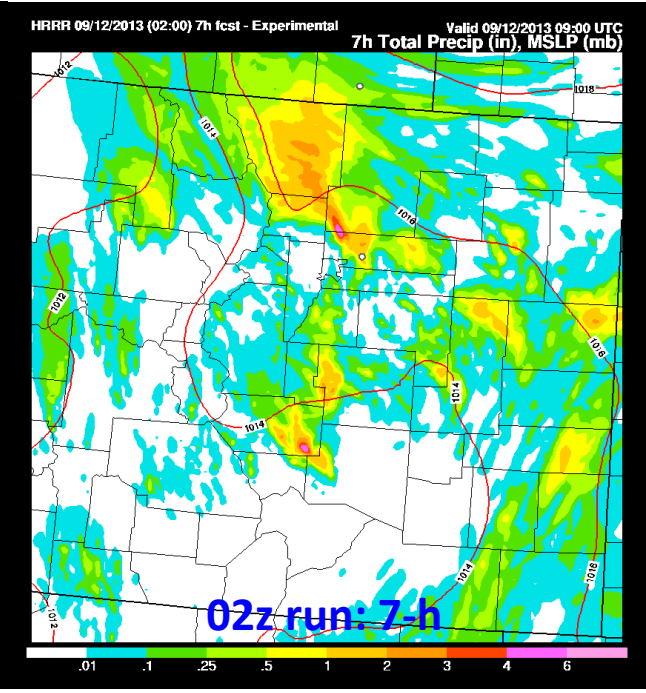




**HRRR Total Precipitation forecasts ending 09z/12 Sep:** *hours covered shrink with time but heaviest rains in area of interest began >00z.*

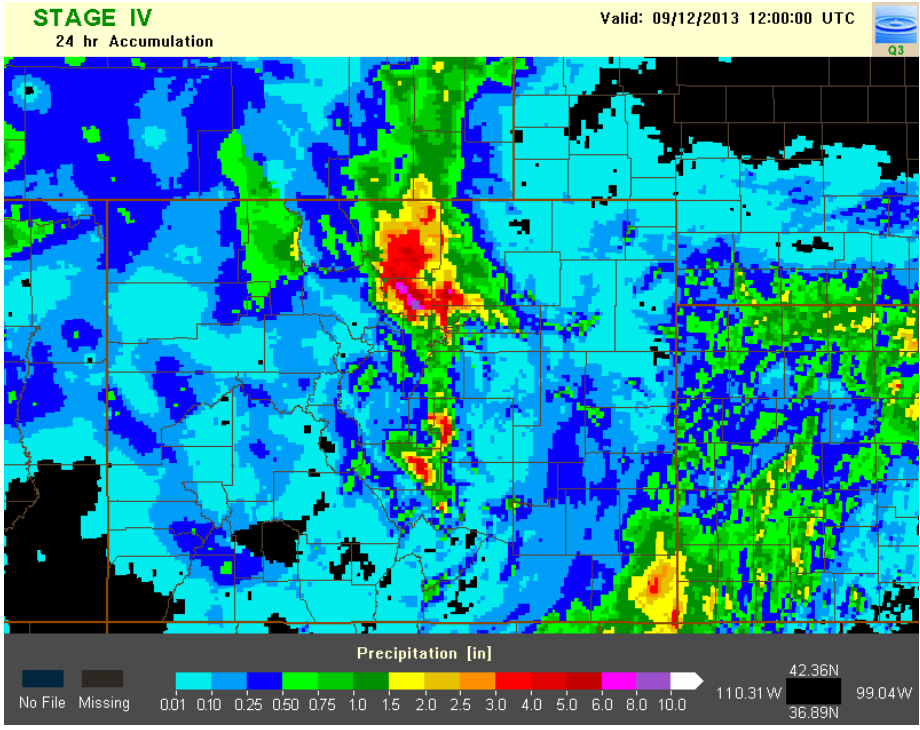


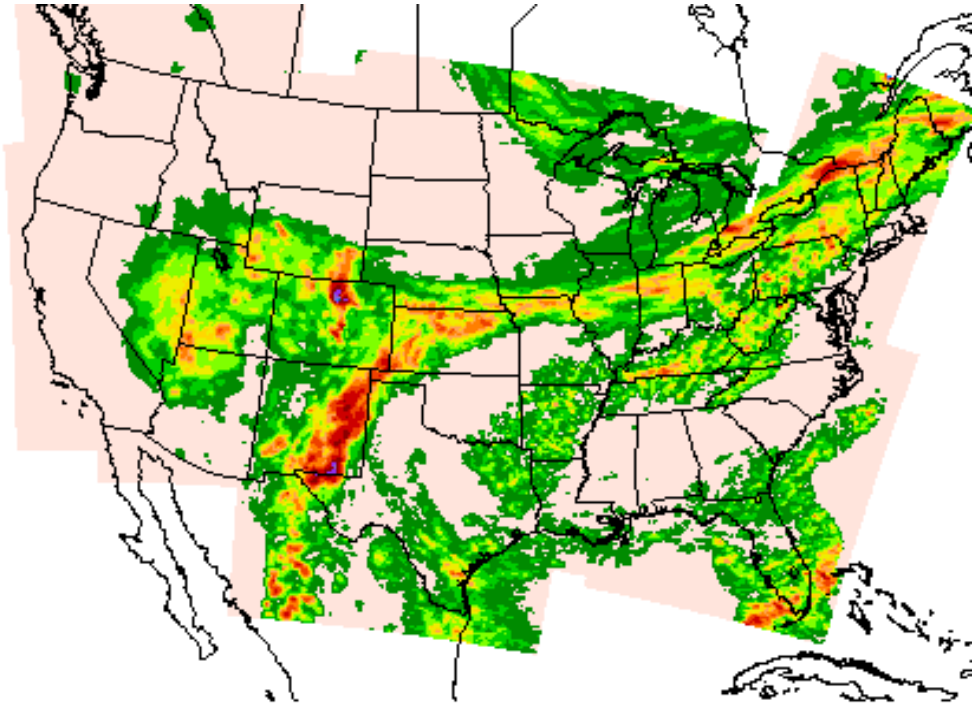



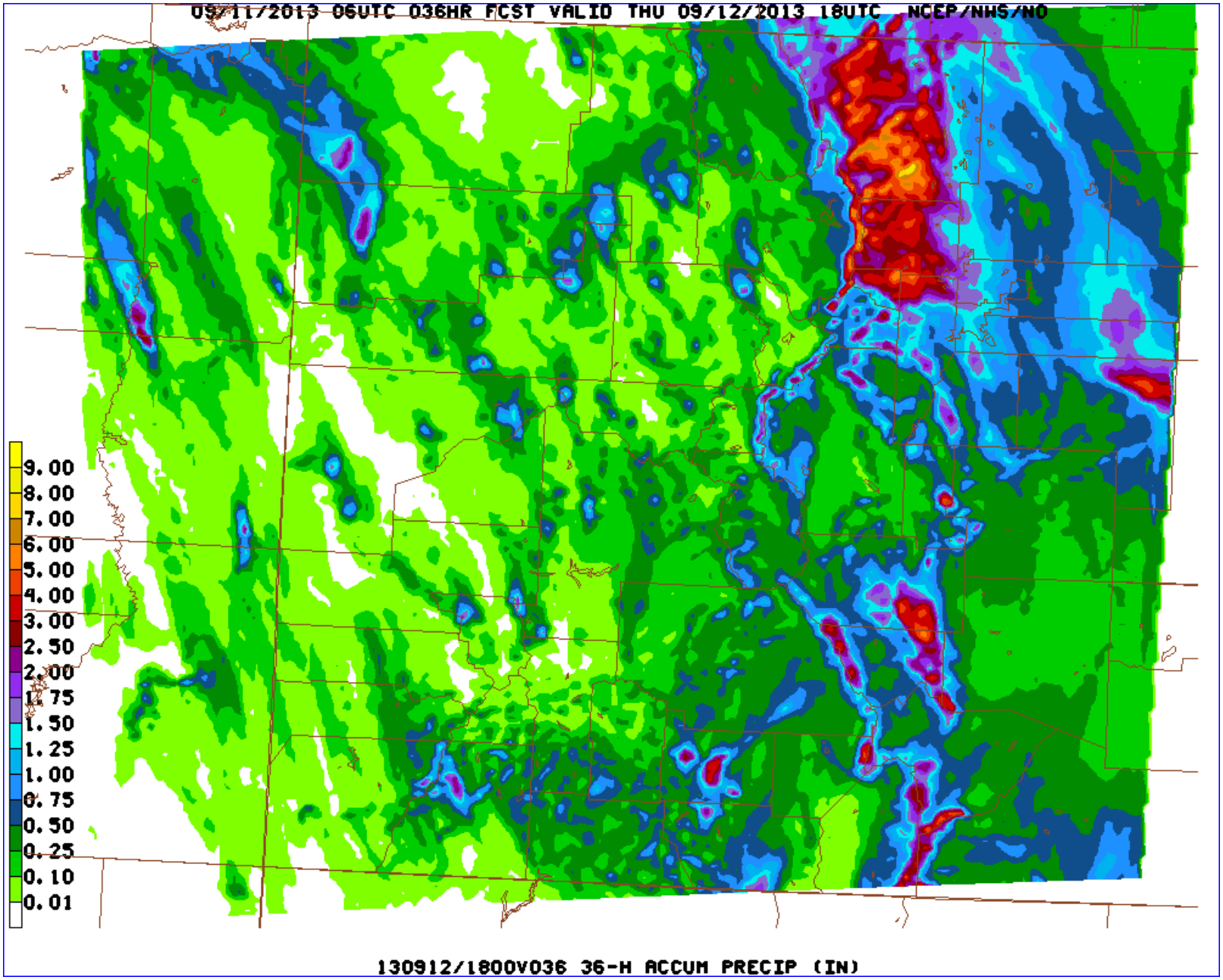

**HRRR forecasts valid 09z/12 Sep**

*The forecasts improved with the 22z run where we see the maximum of precip moving back into the foothills. But amounts do not increase until the 00z run, and then the heaviest is to the east of the foothills (where there was, though, a secondary max).*



# FIRE WX NEST

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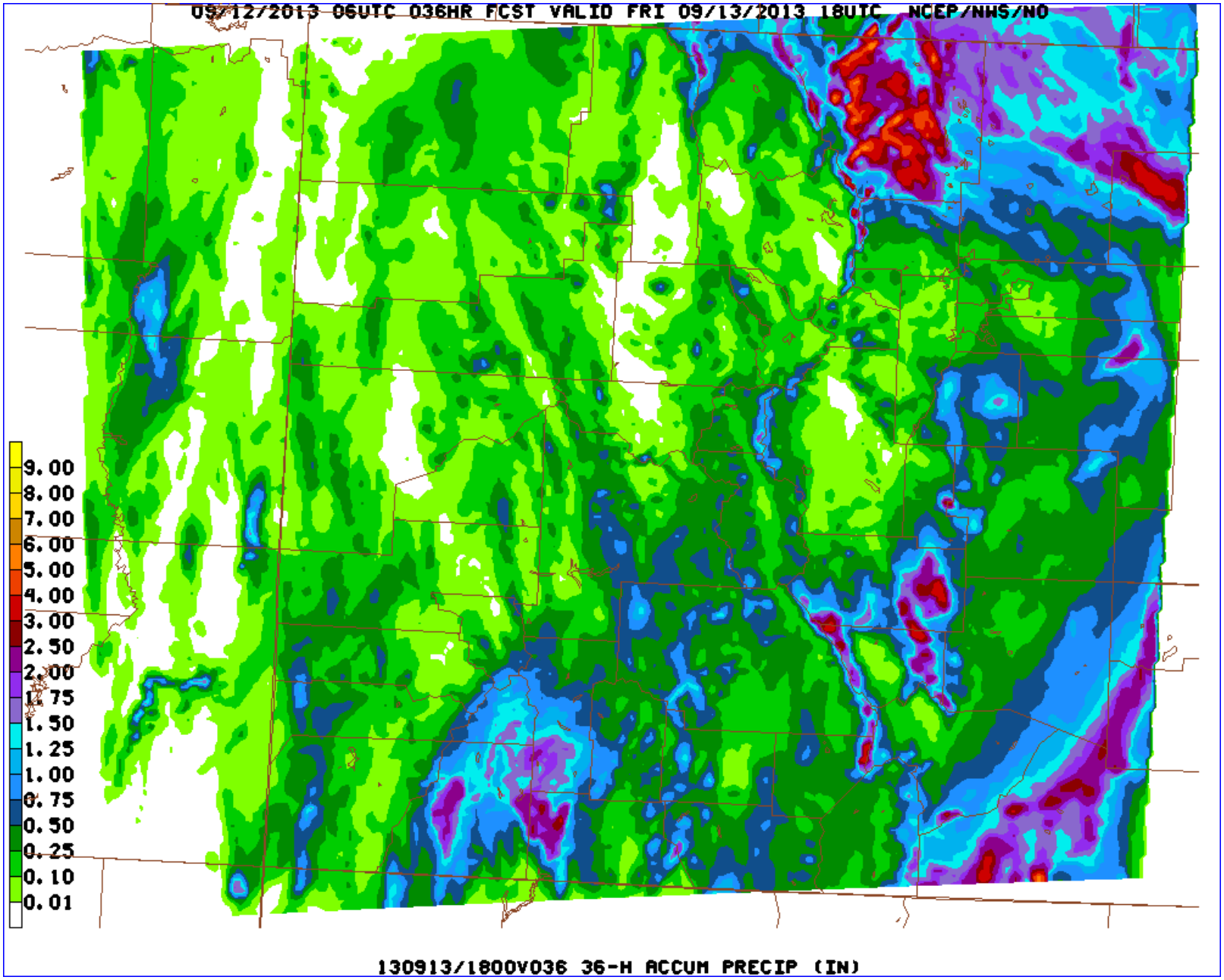
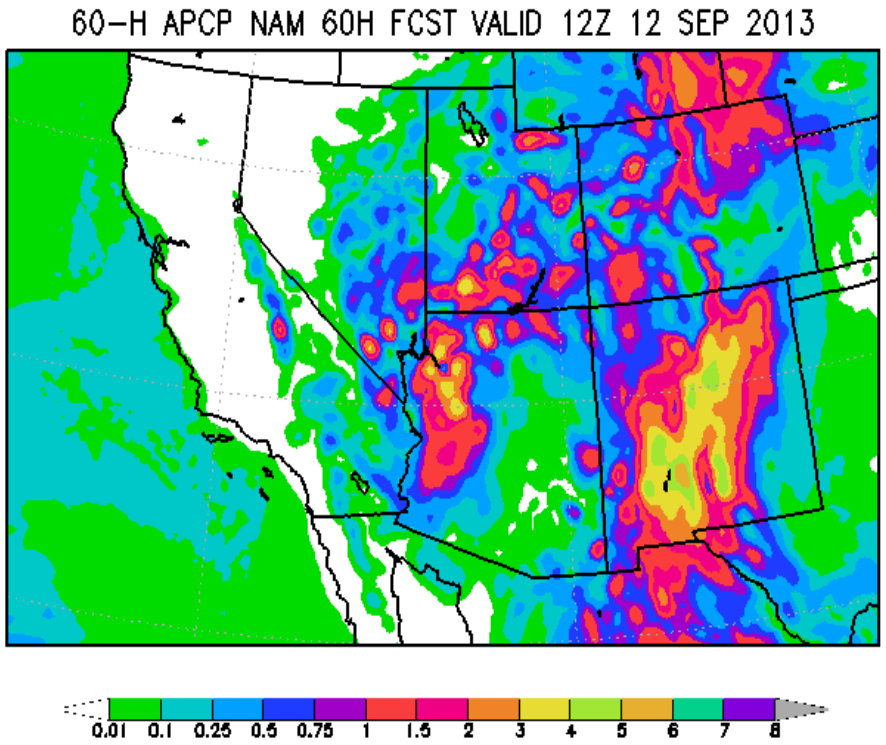
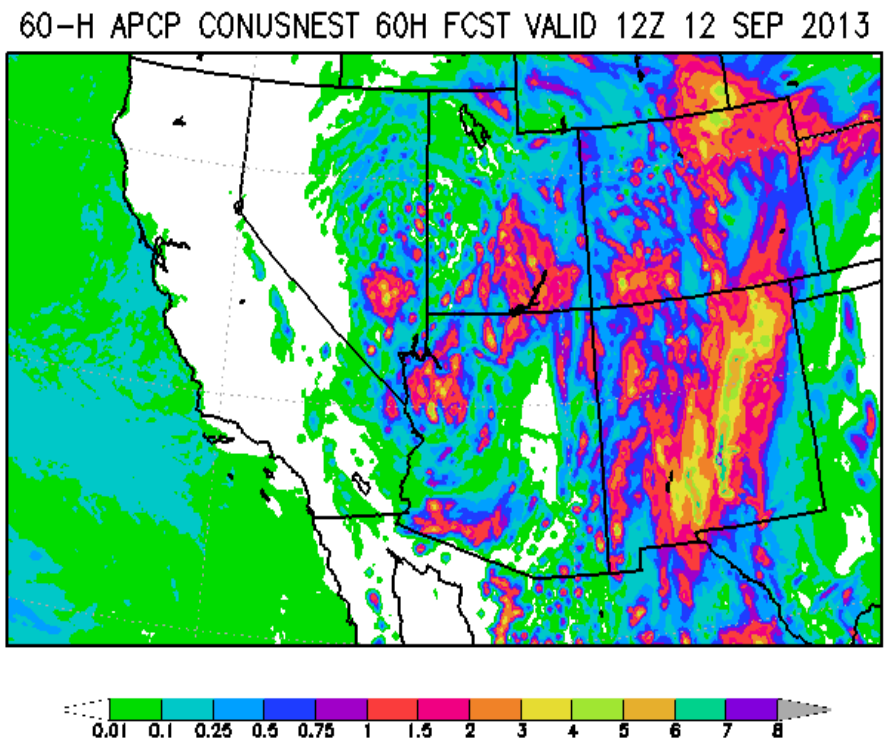
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.10
0.01
130912/1800V036 36-H ACCUM PRECIP (IN)


09/12/2013 06UTC 036HR FCST VALID FRI 09/13/2013 18UTC NCEP/NWS/NCO
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.50
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.10
0.01
130913/1800V036 36-H ACCUM PRECIP (IN)

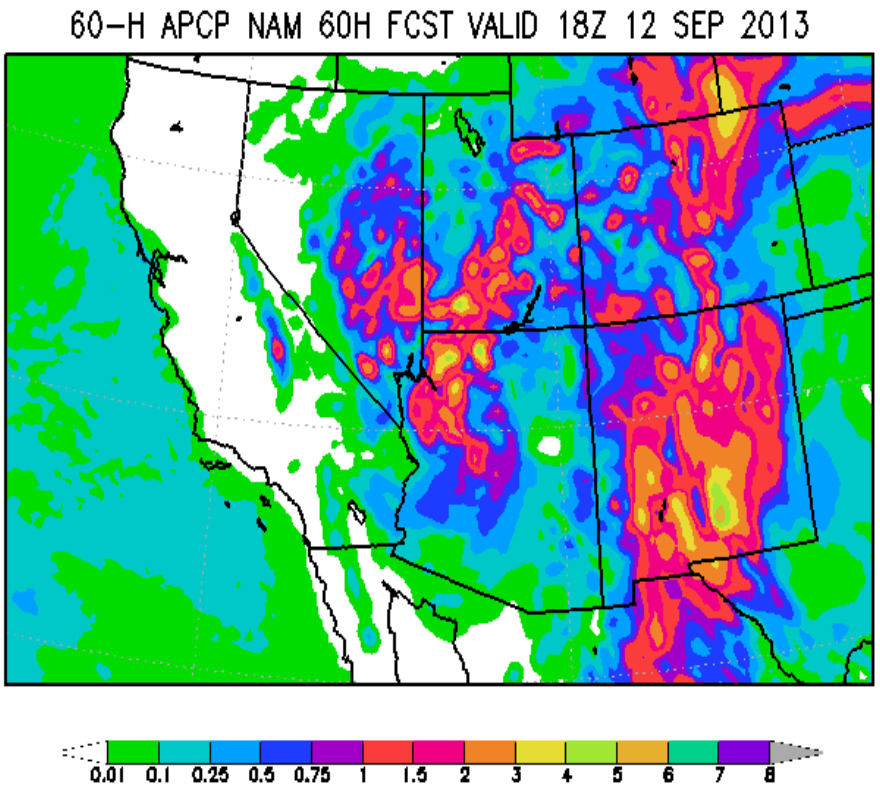
# 60-HR TOTALS FOR NAM and NAM NEST

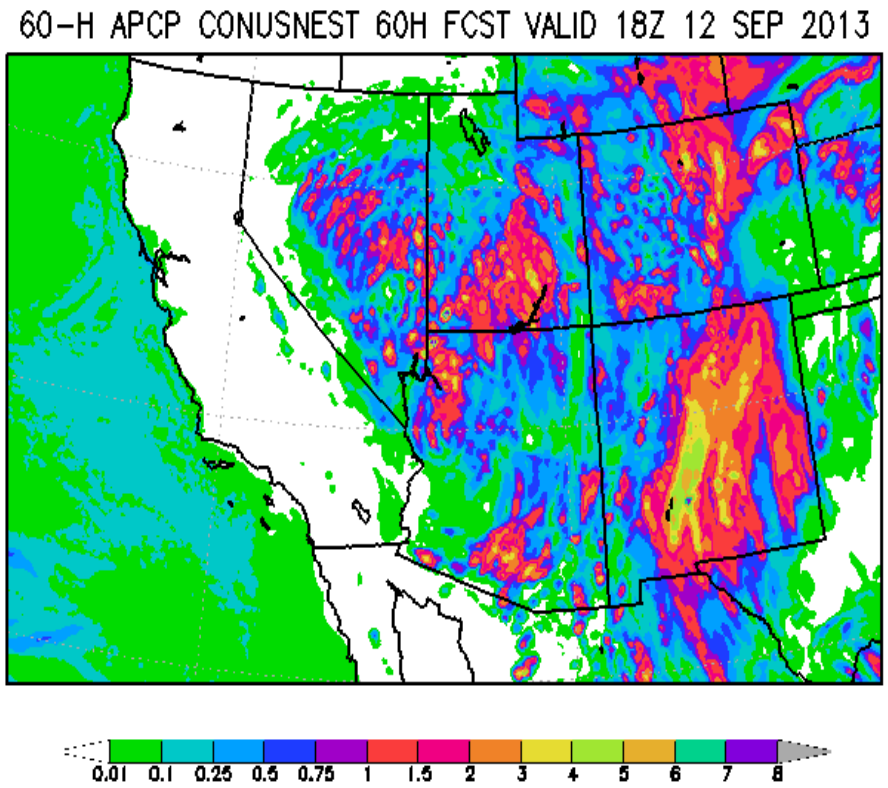
# Forecast from 00z 9/10



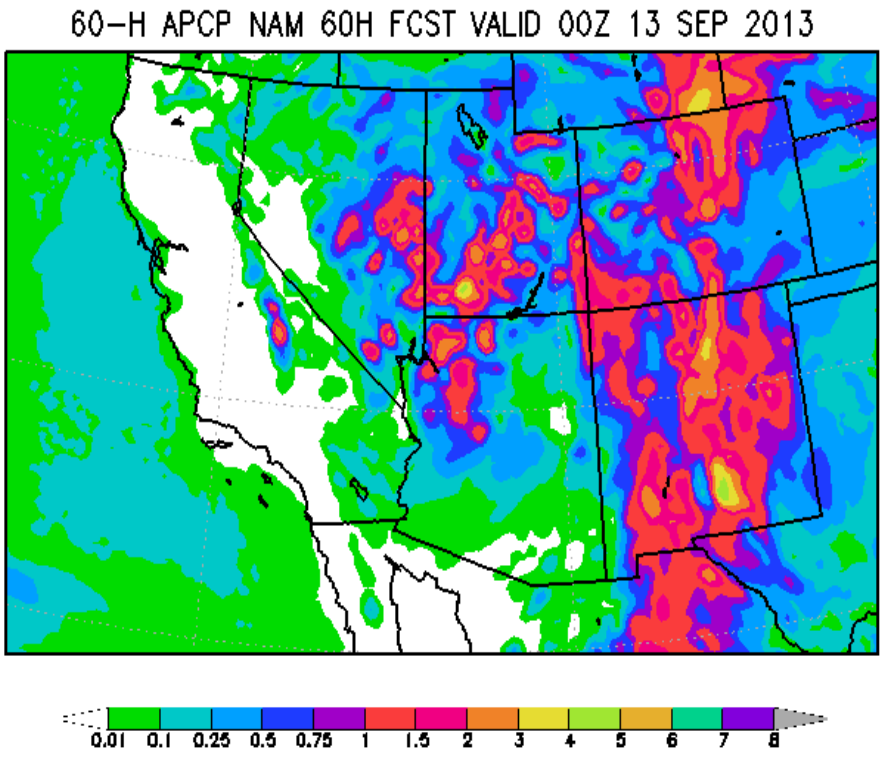



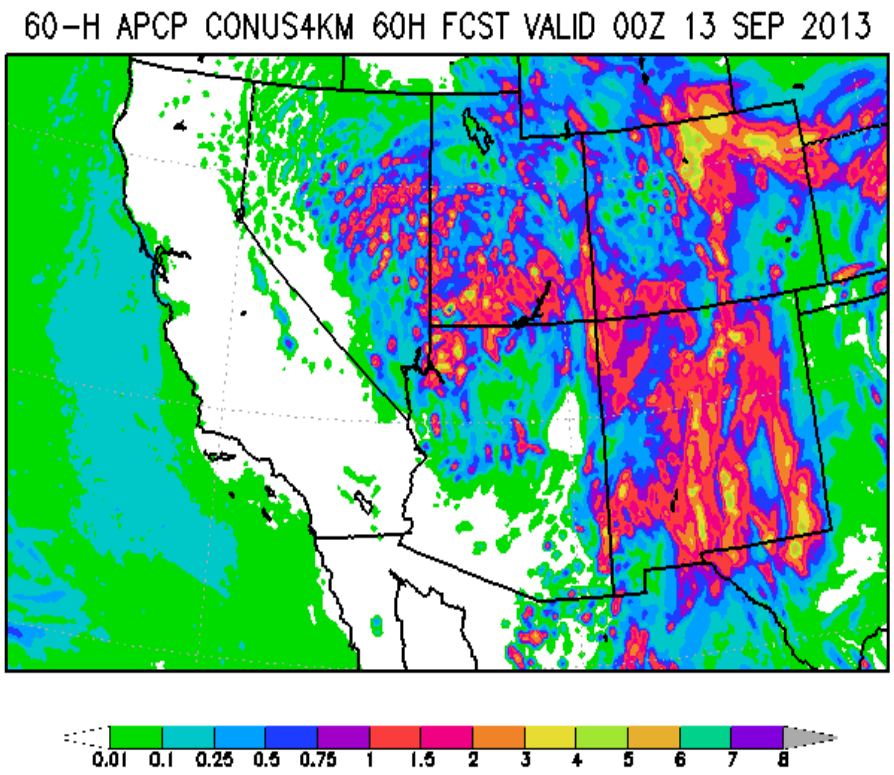
# Forecast from 06z 9/10



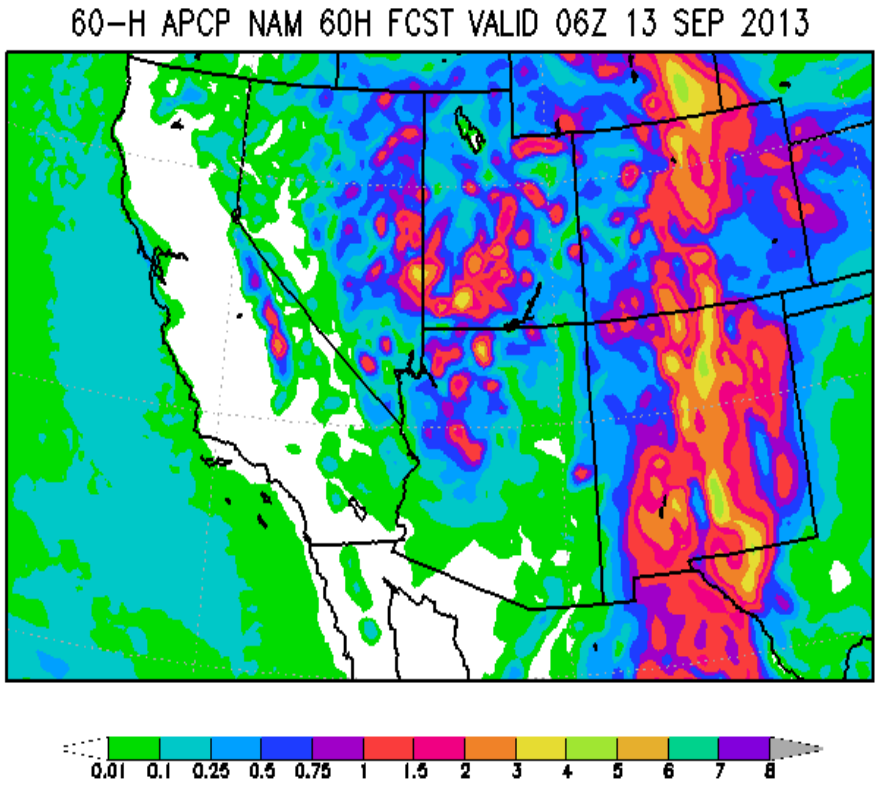



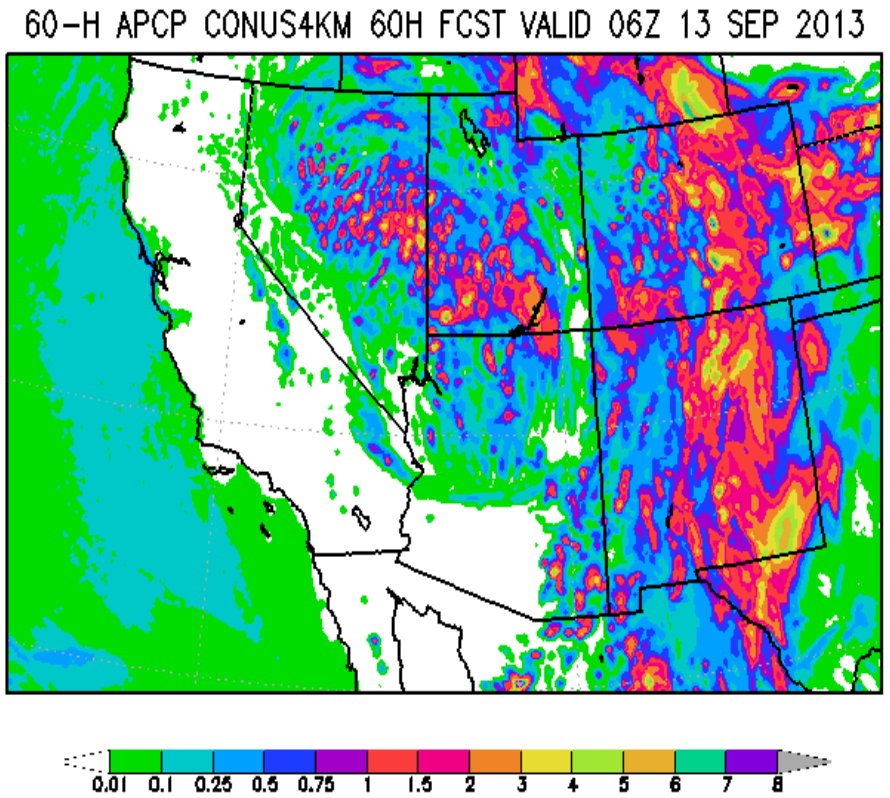
# Forecast from 12z 9/10



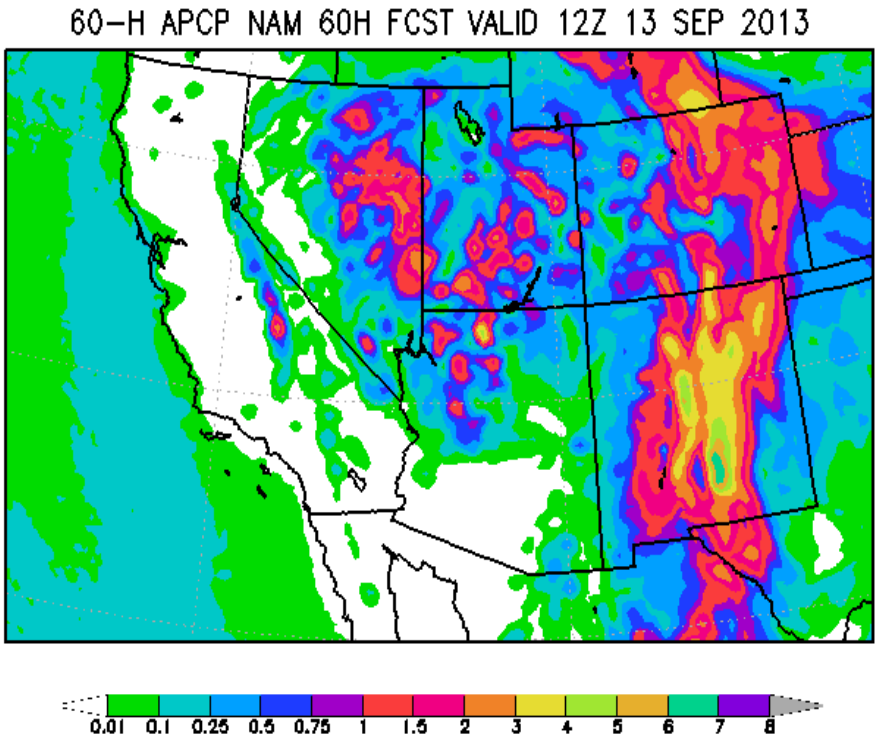



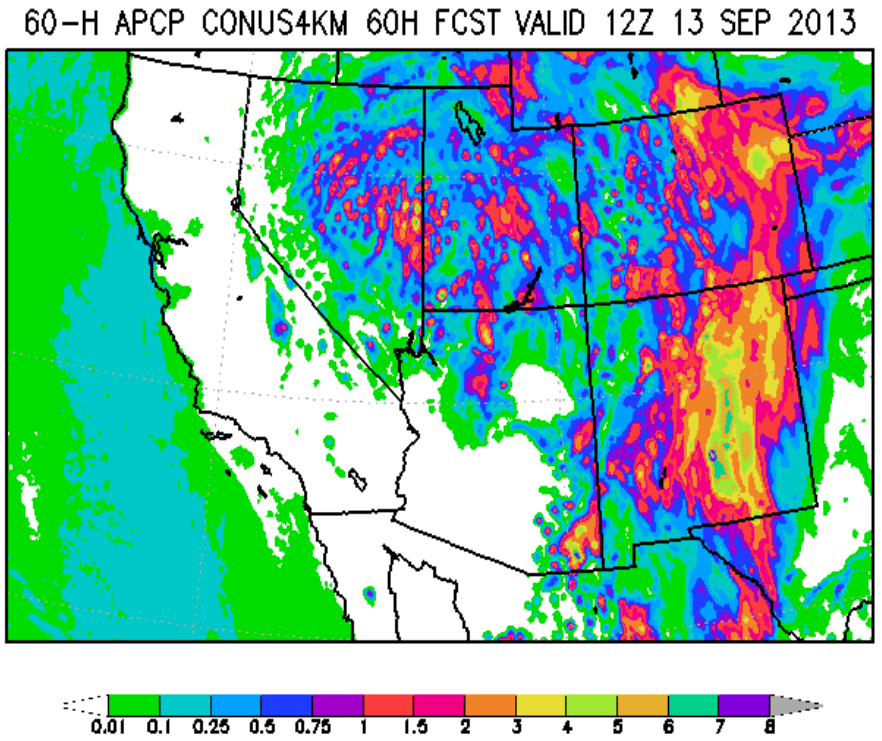
# Forecast from 18z 9/10



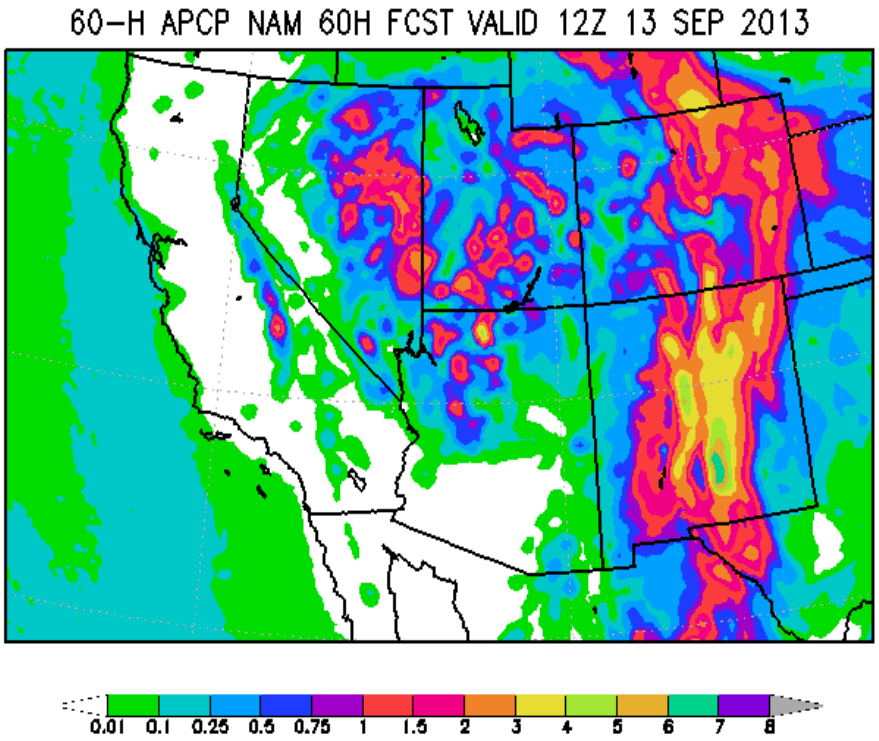



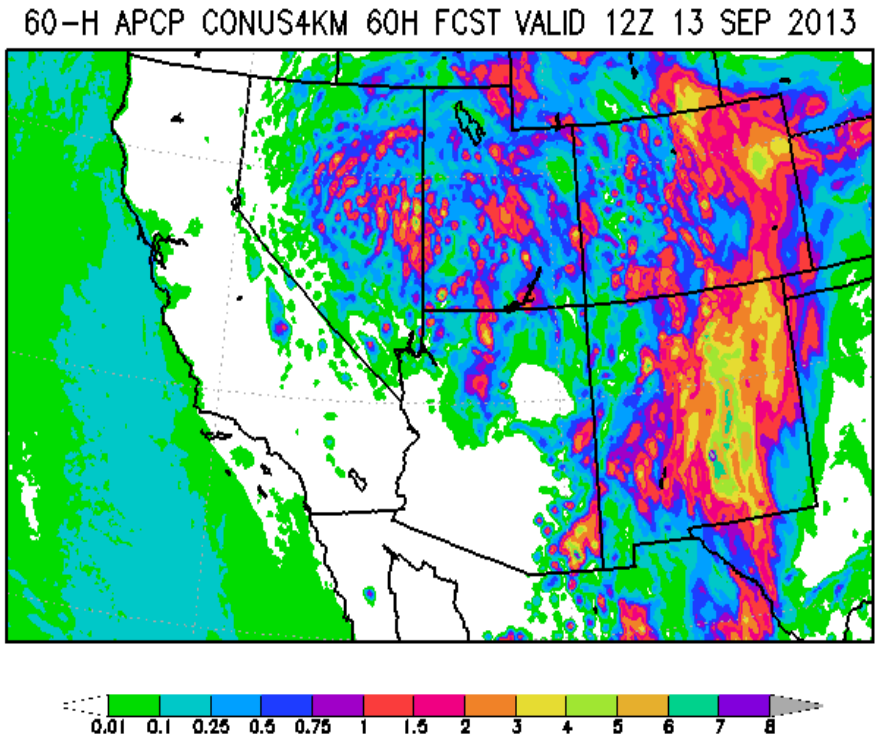
# Forecast from 00z 9/11



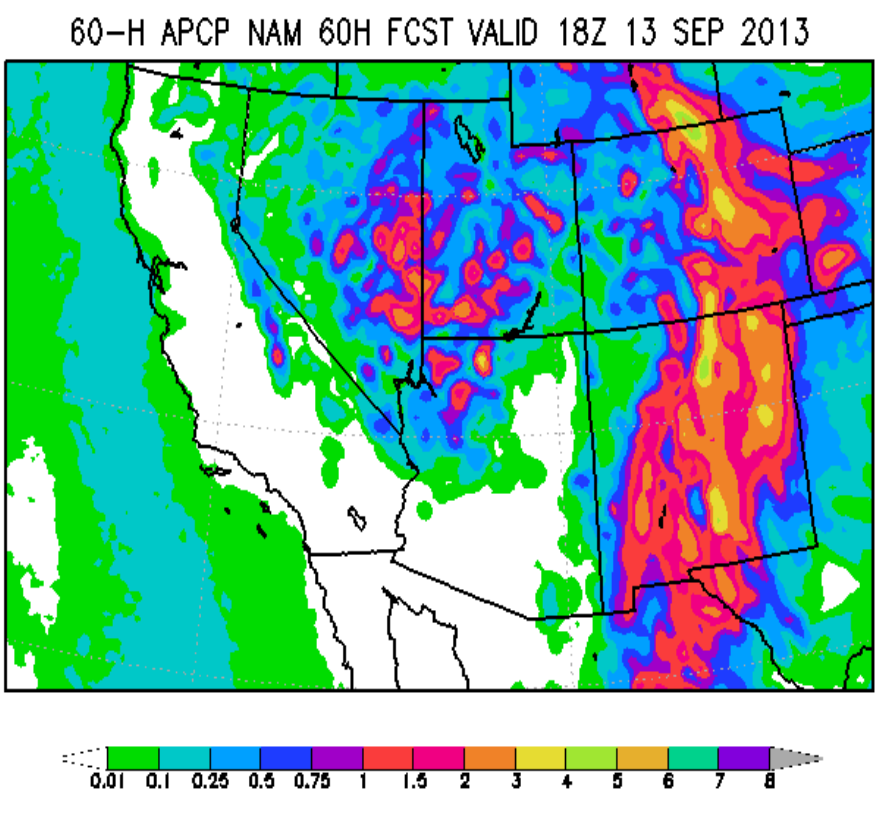



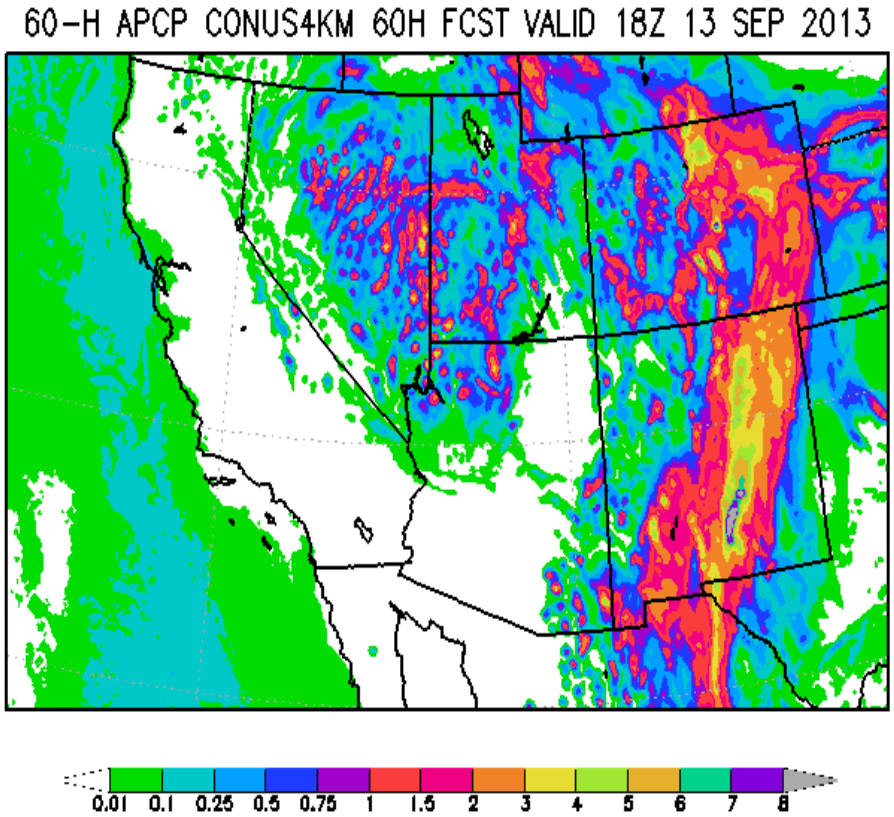
# Forecast from 00z 9/11



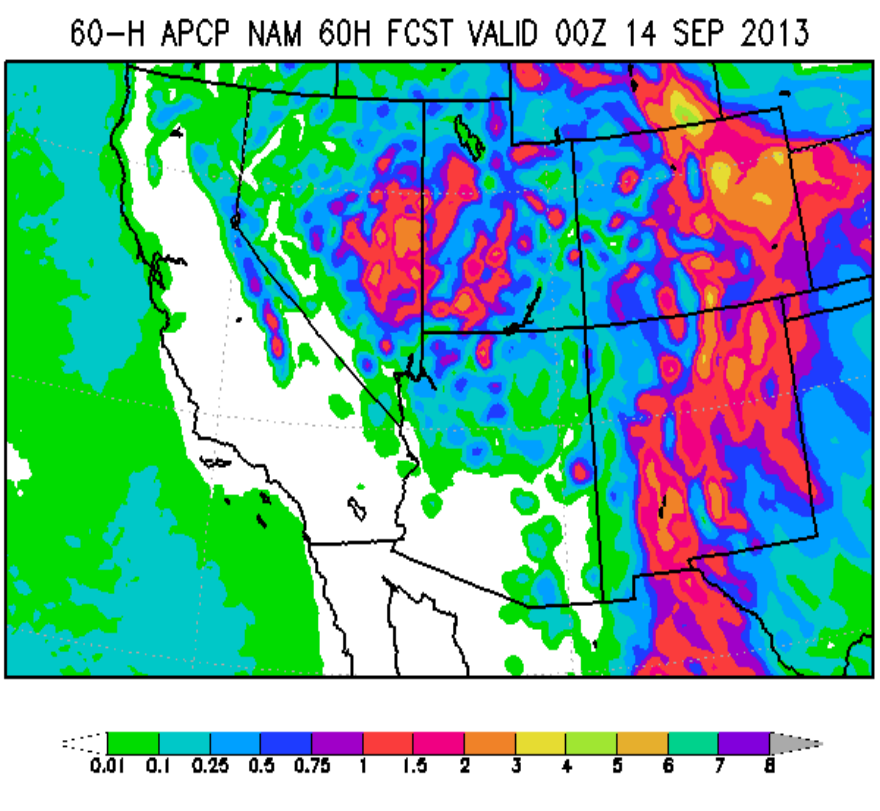



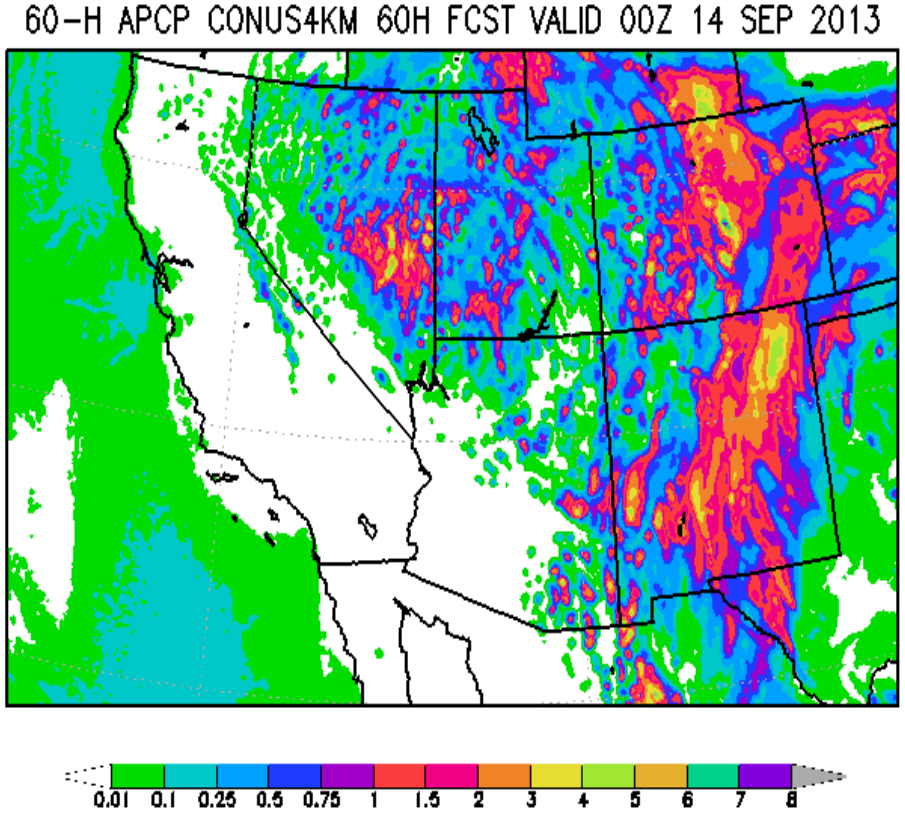
# Forecast from 06z 9/11



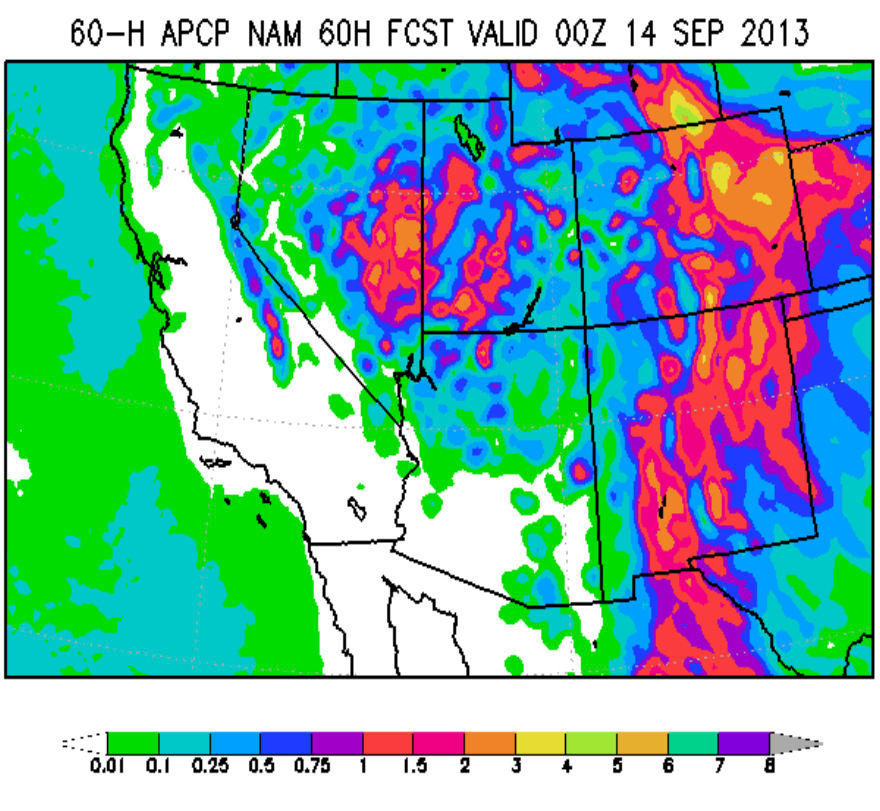



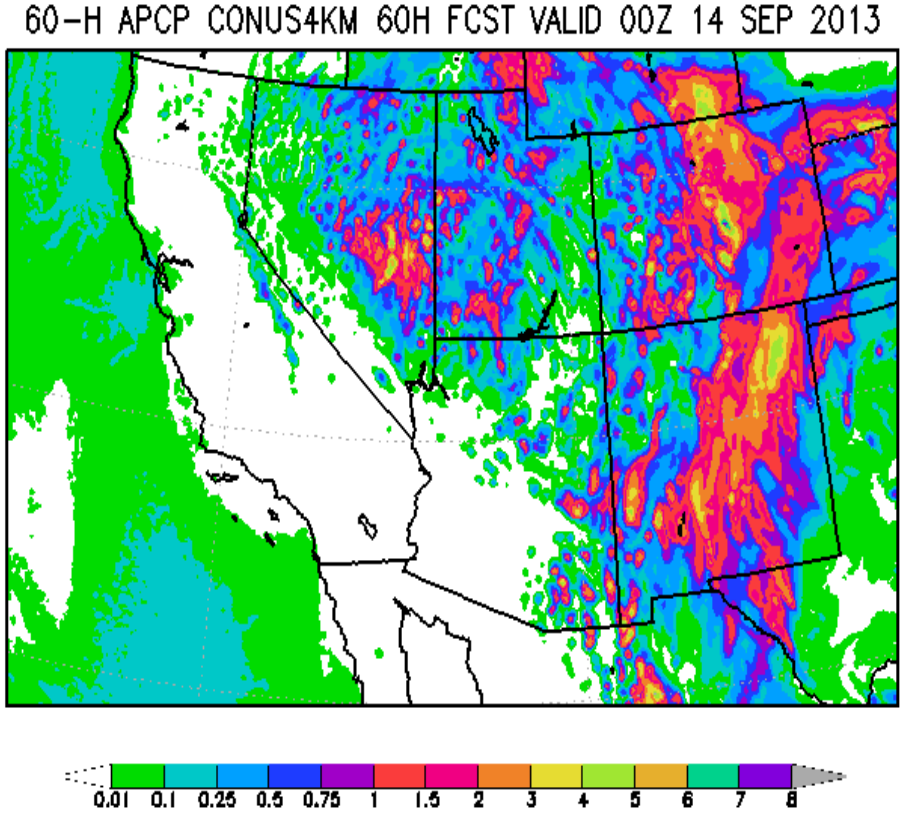
# Forecast from 12z 9/11



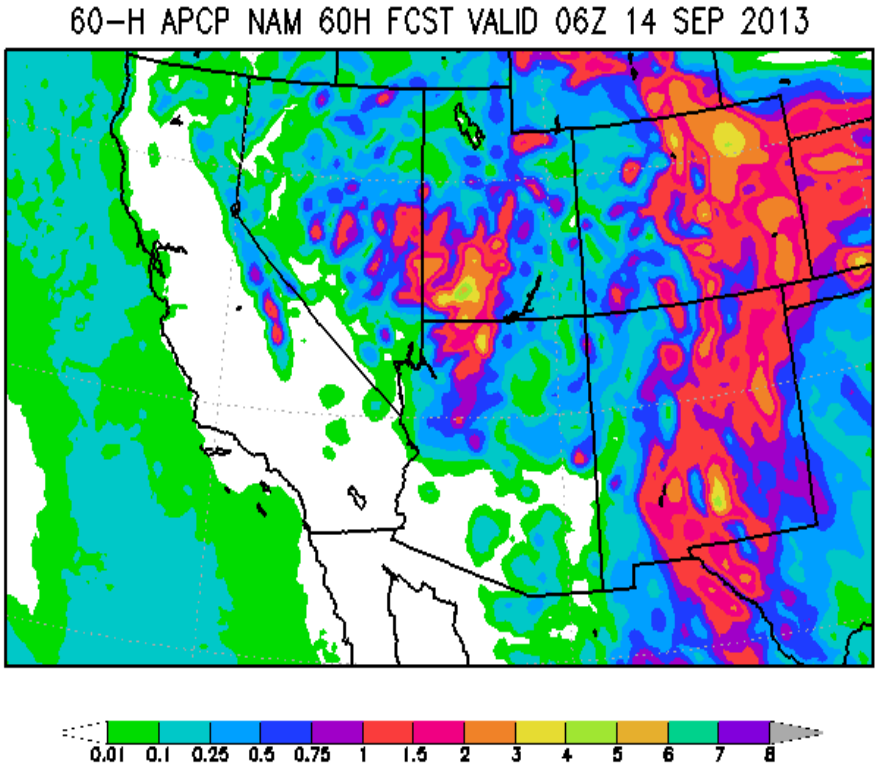



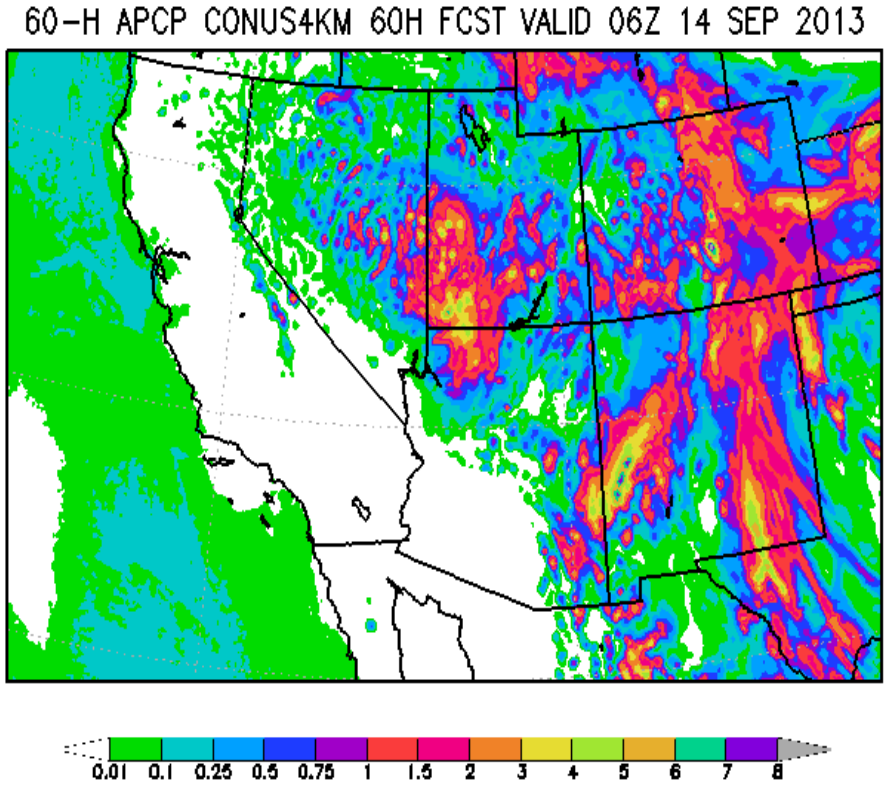
# Forecast from 12z 9/11



# Forecast from 18z 9/11



# The very heavy rains of 11-12 Sep 2013

- It is clear that there was a lot of variability in the forecasts from many different models on 11 Sep
- The “shortwave of the day” moving north in the southerly flow appears to have been captured
- But not the heavy rains that occurred the evening/night of 11-12 Sep
  - What was missed?

# A very early look at the historic September 2013 rainfall and flooding in Colorado

**Russ S. Schumacher** and Daniel T. Lindsey

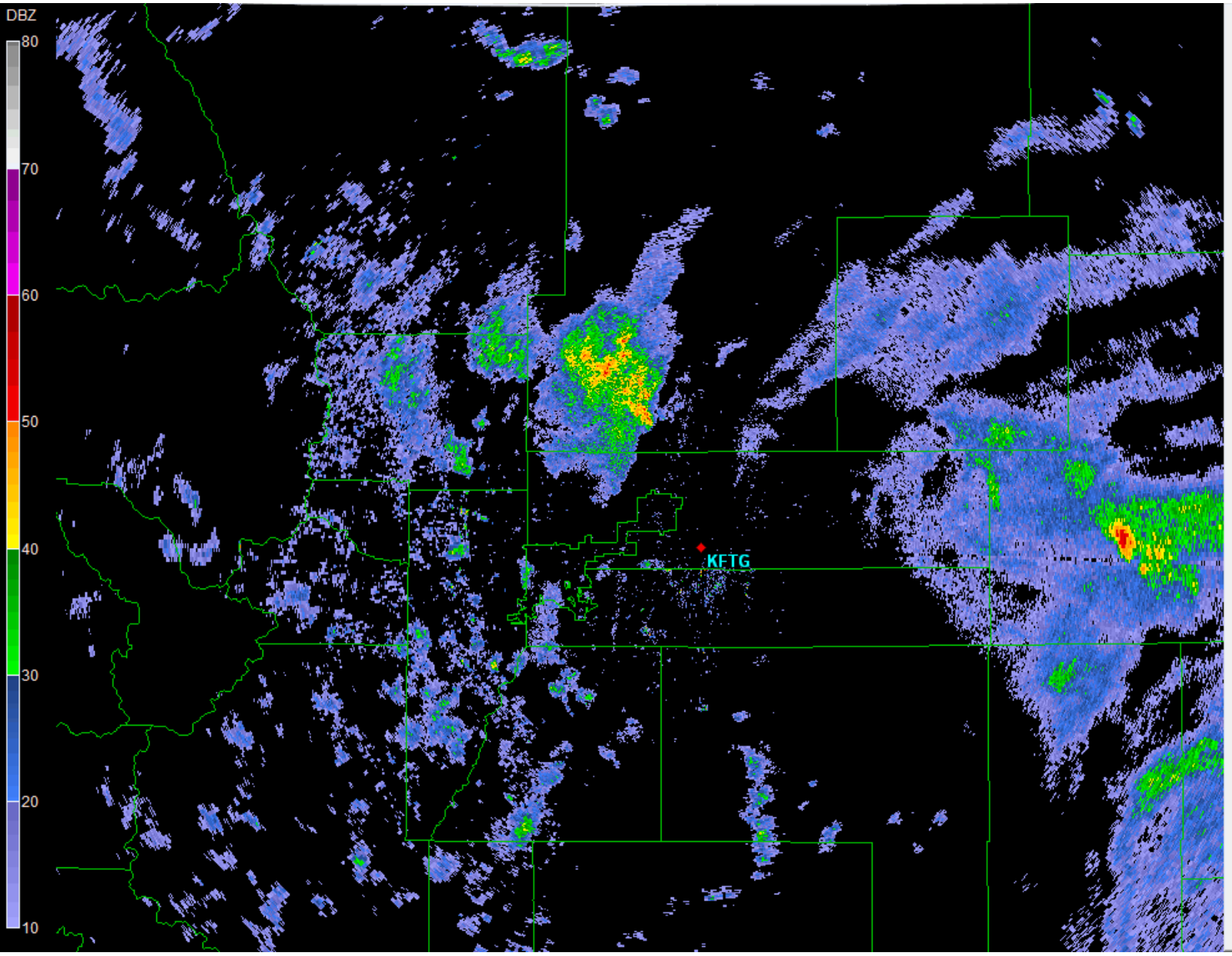
Department of Atmospheric Science,
Colorado State University

NOAA/RAMMB/CIRA


Acknowledgments: Lance Bosart and the Albany Map list; Kristen Corbosiero for allowing me to make a last-minute change to the program; NSF grant AGS-1157425

16th Cyclone Workshop
26 September 2013

So what led to the extremely heavy rain from 00-12 UTC 12 September? (And what might the models have missed?)

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VST: 09/11/2013 20:03:03 Z
Prod: 09/11/2013 20:03:00 Z
VCP: 212 SMV: ----
Tilt: 0.497°

Select Product:

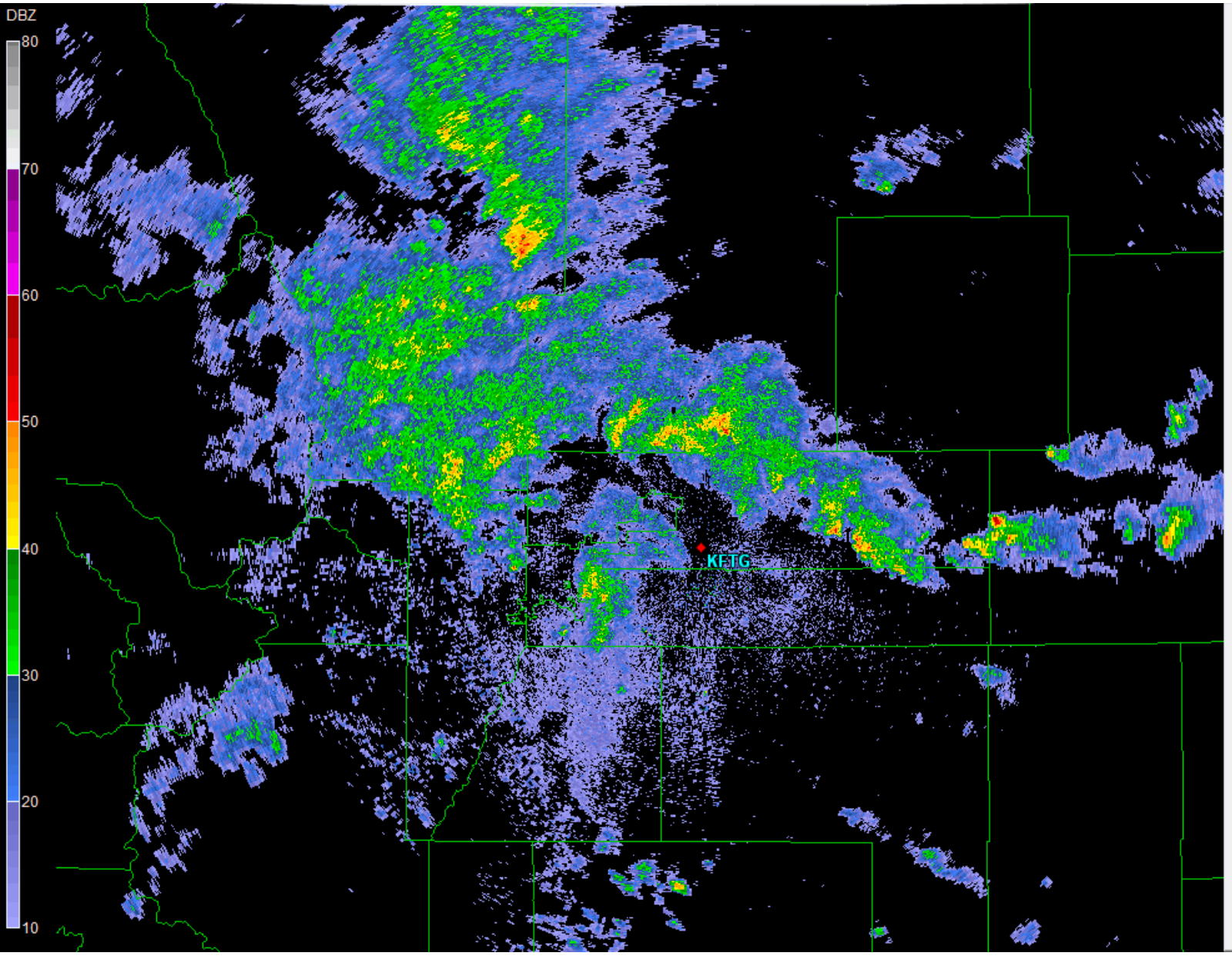
| | | |
|---|---|---|
| (•) BR | ( ) VIL | ( ) ZDR |
| ( ) BV | ( ) VILD | ( ) CC |
| ( ) SRV | ( ) POSH | ( ) PHI |
| ( ) SW | ( ) MEHS | ( ) KDP |
| ( ) ET | ( ) NROT | ( ) HCA |

Select Tilt:

| | | | |
|---|---|---|---|
| 0.5° | 0.9° | 1.3° | 1.8° |
| 2.4° | 3.2° | 4.0° | 5.1° |
| 6.4° | 8.0° | 10.0° | 12.5° |
| 15.6° | 19.5° | | |

Product Details:

Max: 61.0 dbz
Az: 113.8°
Ran: 6.4 nm




Site: KFTG
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Prod: 09/12/2013 02:56:20 Z
VCP: 212 SMV: ----
Tilt: 0.499°

Select Product:

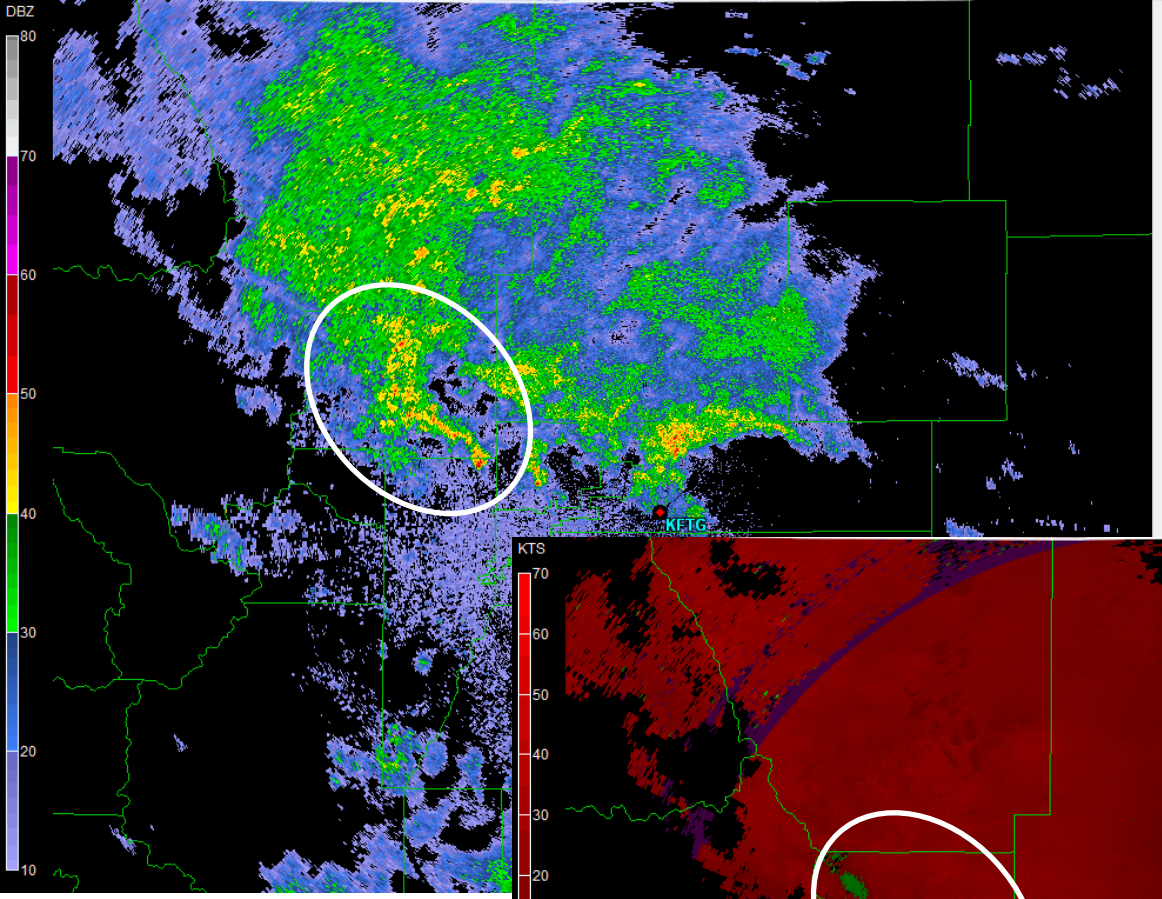
| | | |
|---|---|---|
| (•) BR | ( ) VIL | ( ) ZDR |
| ( ) BV | ( ) VILD | ( ) CC |
| ( ) SRV | ( ) POSH | ( ) PHI |
| ( ) SW | ( ) MEHS | ( ) KDP |
| ( ) ET | ( ) NROT | ( ) HCA |

Select Tilt:

| | | | |
|---|---|---|---|
| 0.5° | 0.9° | 1.3° | 1.8° |
| 2.4° | 3.2° | 4.0° | 5.1° |
| 6.4° | 8.0° | 10.0° | 12.5° |
| 15.6° | 19.5° | | |

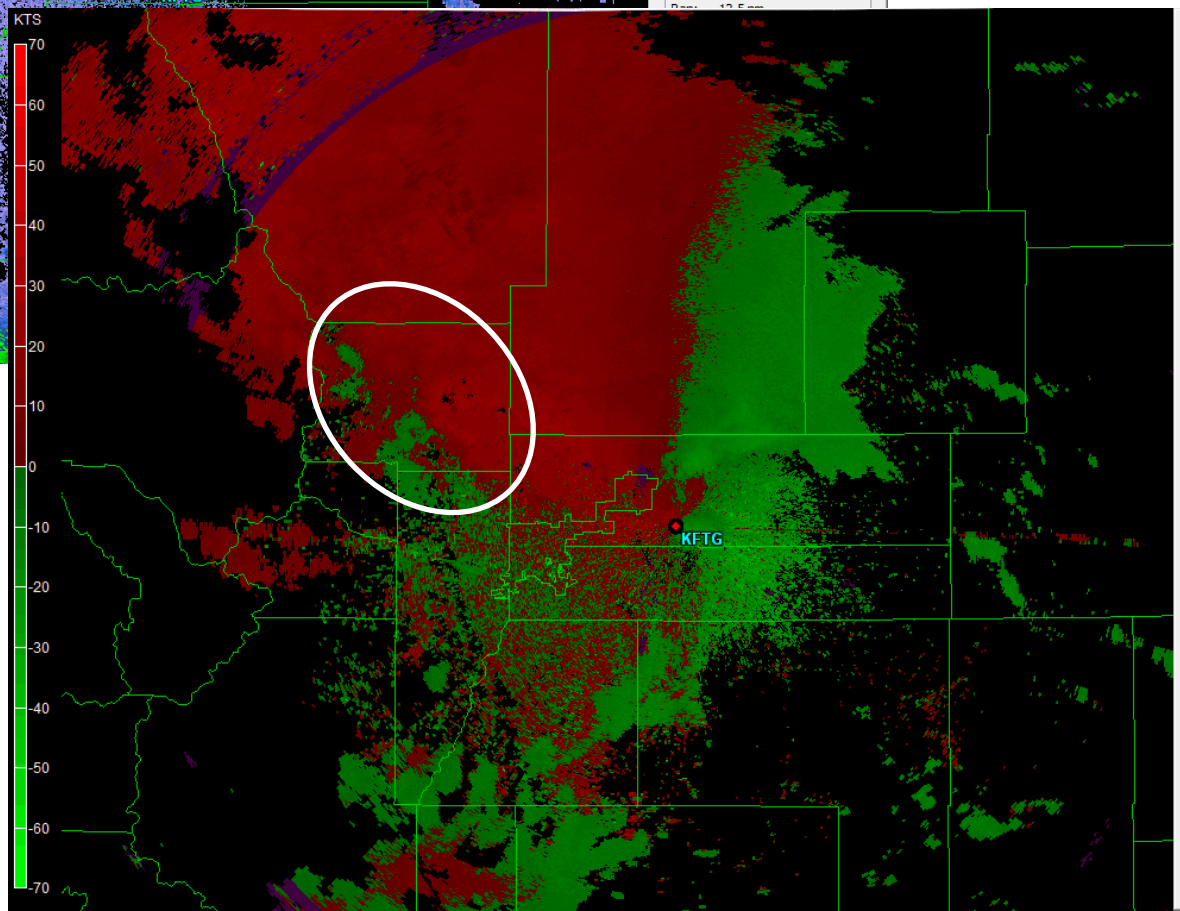
Product Details:

Max: 58.0 dbz
Az: 84.3°
Ran: 38.6 nm



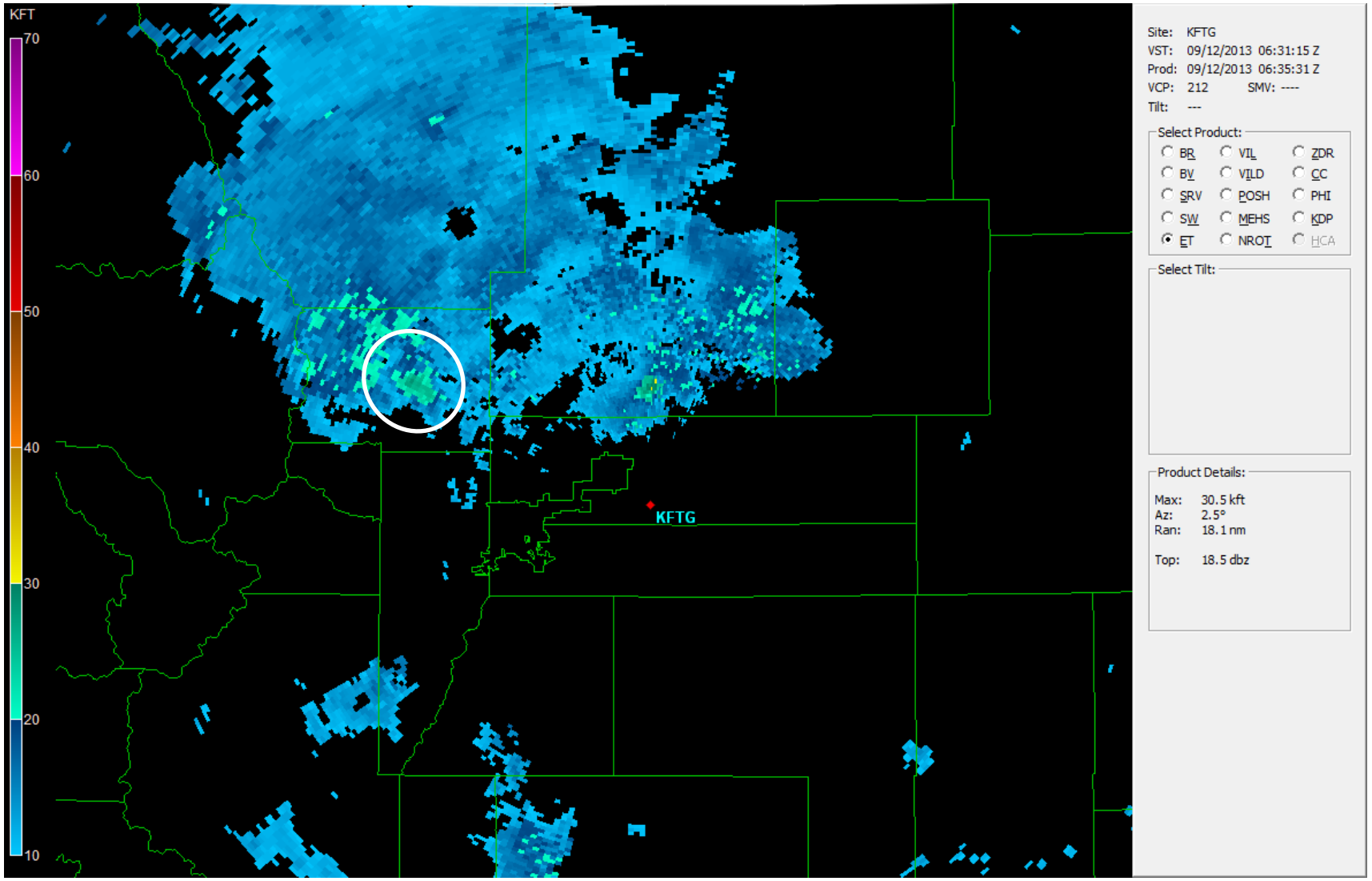

KFTG – 0.5 reflectivity and velocity

05:44 – 08:18 Z on 12 Sept. 2013



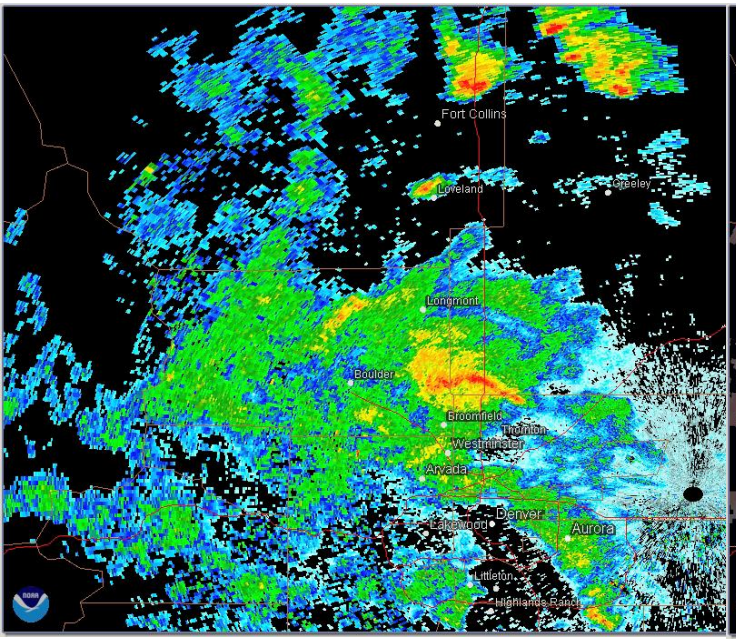

Note that the convective activity is associated with the center of the vortex, and was also associated with the largest rain rates

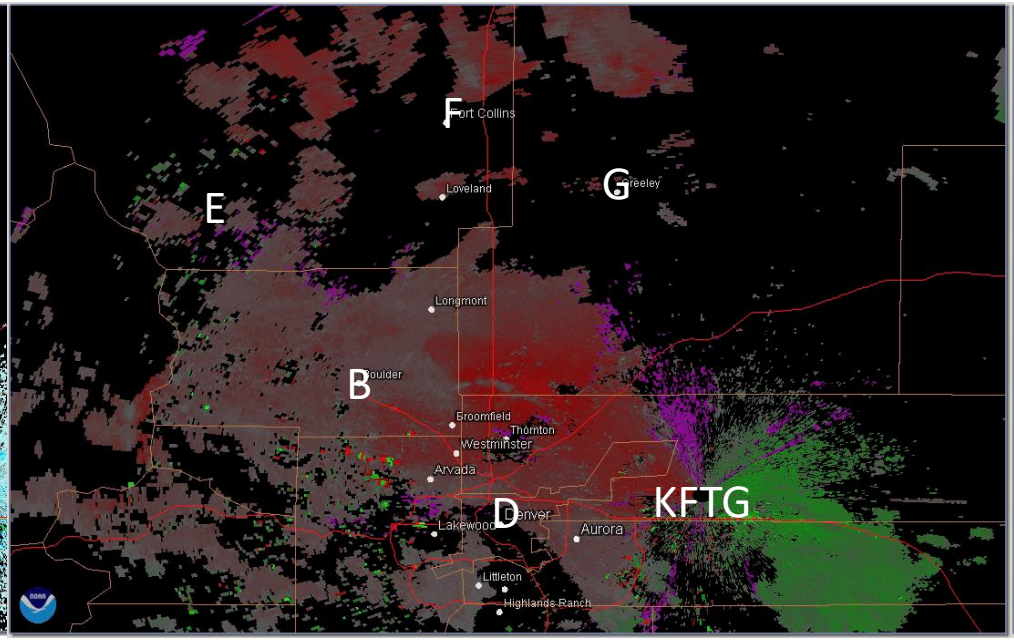
The KFTG echo top height varied from ~25 – 32 kft during the convective activity from 0330 – 0700 UTC on 12 Sep. In the example below it's around 28 kft at 06:31 Z

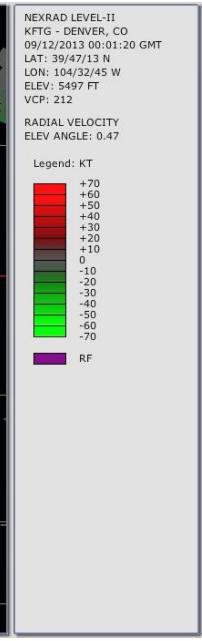


# Mesoscale features – early on 12 Sept.

Animations from Denver (KFTG) radar  0000-0730 UTC 12 September



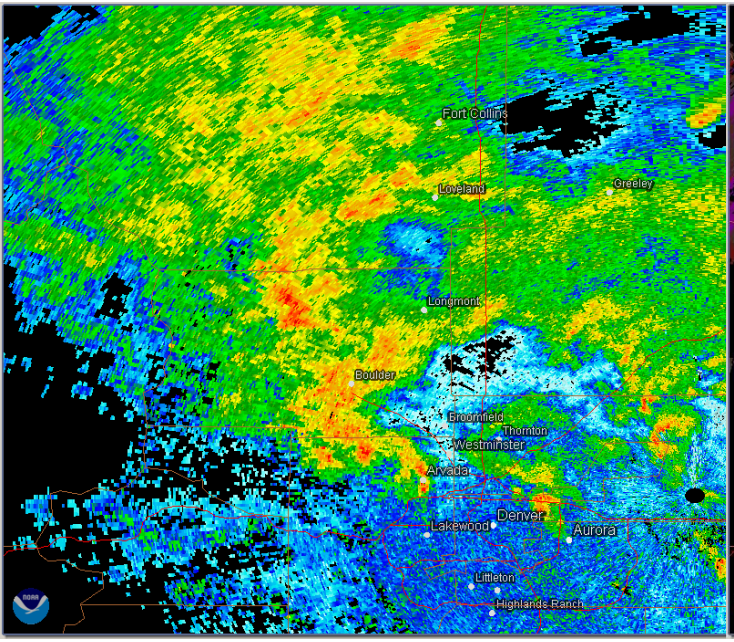



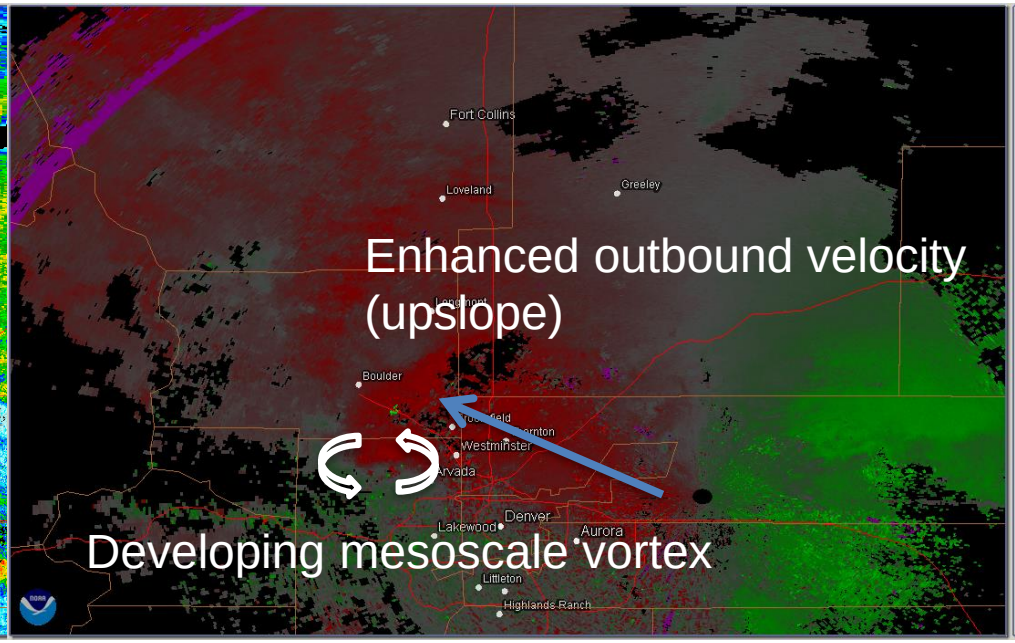

0.5° Reflectivity

0.5° Radial velocity

# Mesoscale features – early on 12 Sept.

Denver (KFTG) radar  0425 UTC



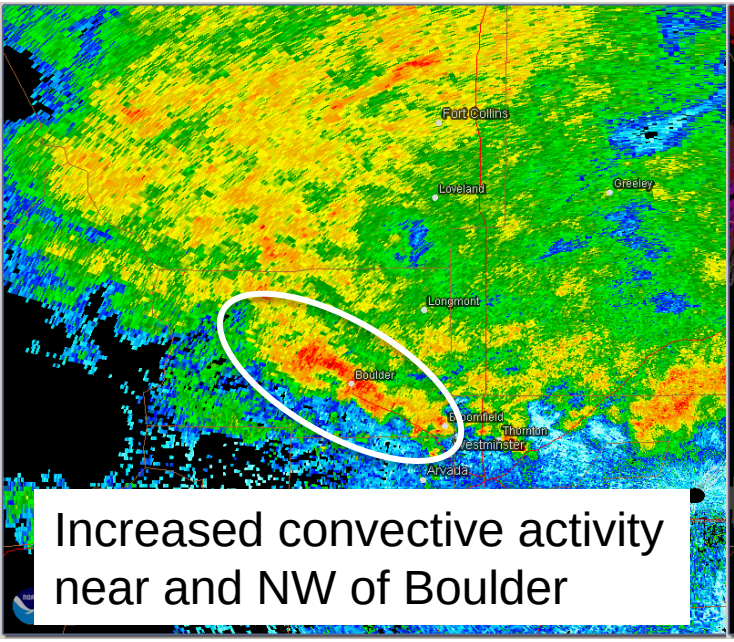



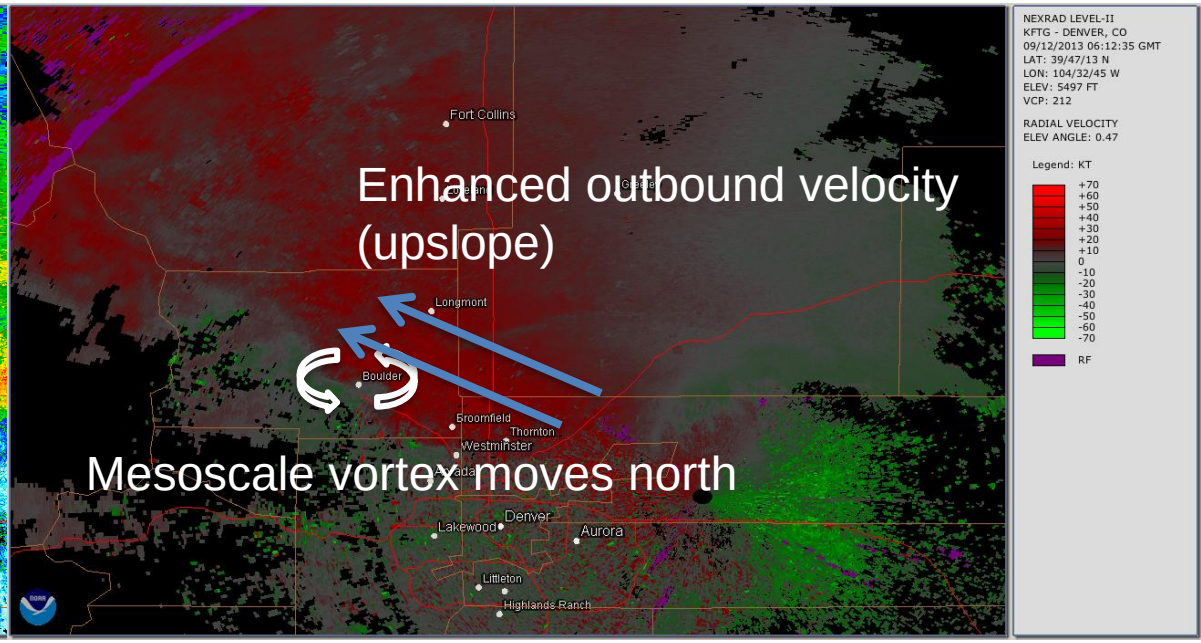

0.5° Reflectivity

0.5° Radial velocity

# Mesoscale features – early on 12 Sept.

Denver (KFTG) radar  0612 UTC



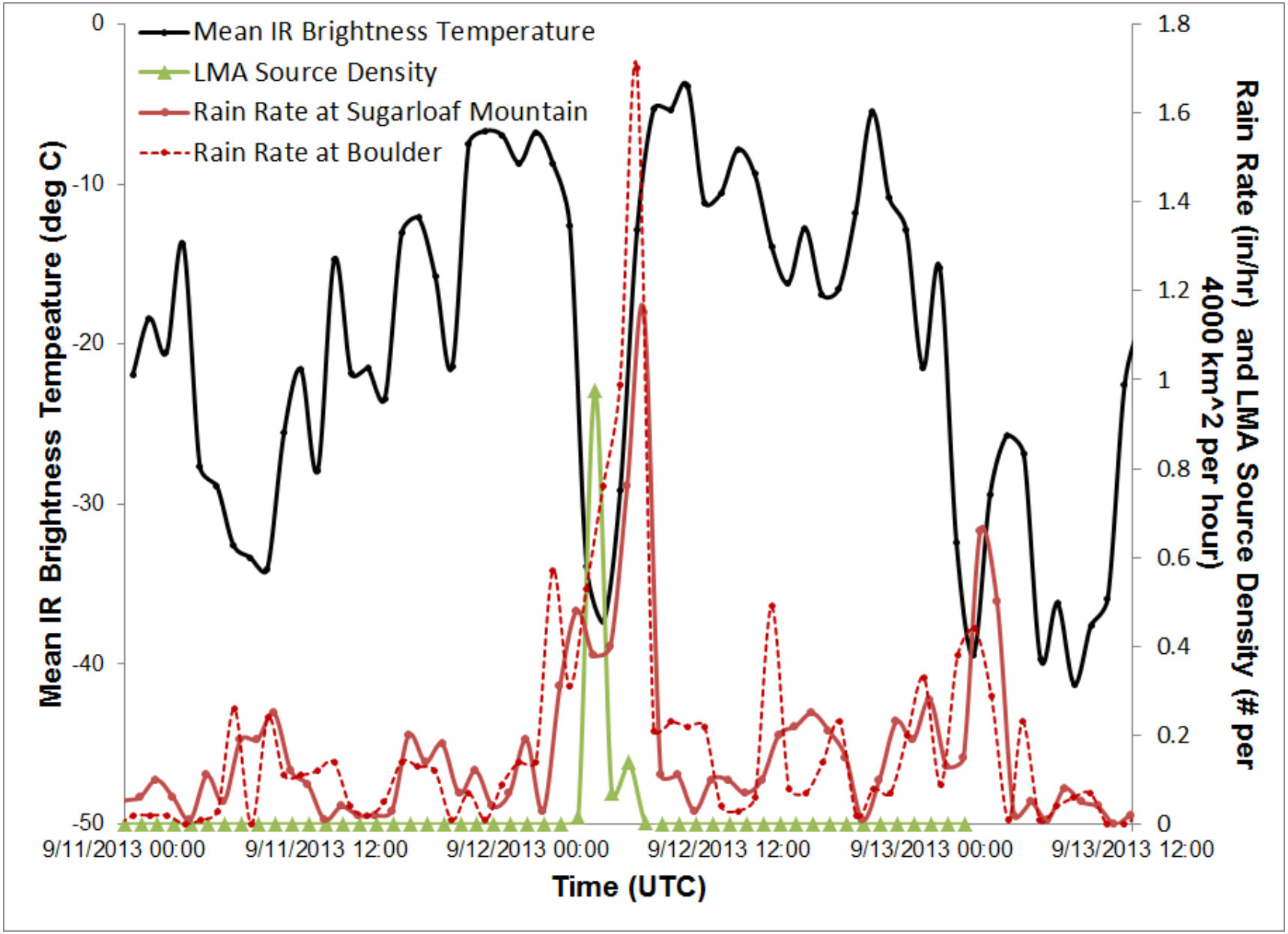

0.5° Reflectivity

0.5° Radial velocity

# The very heavy rains of 11-12 Sep 2013

The convective burst can be easily seen in this satellite loop beginning at 0330 Z on 9/12.

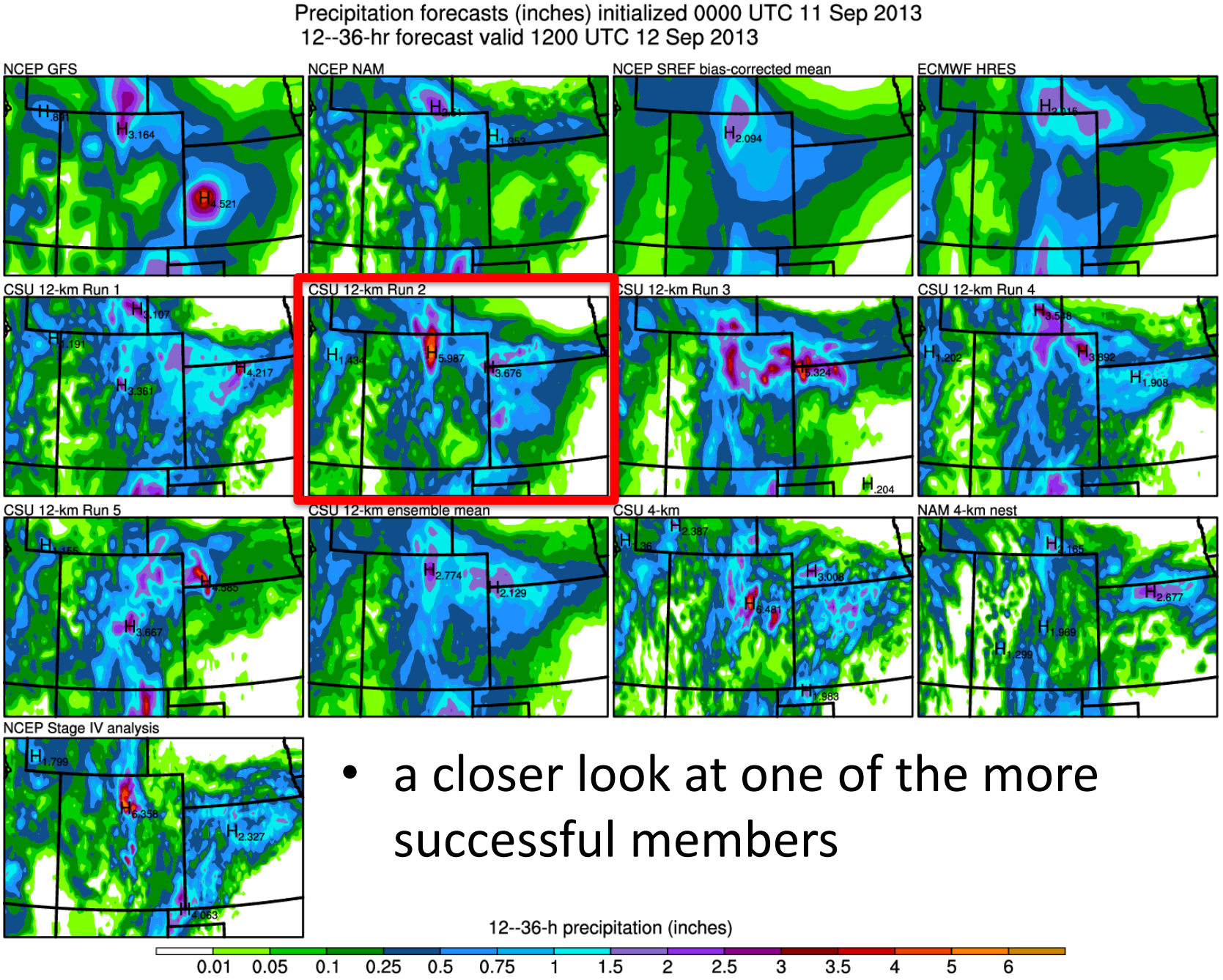
http://rammb.cira.colostate.edu/templates/loop_directory.asp?data_folder=dev/lindsey/loops/11sep13_ir&image_width=1020&image_height=720&no_toggle=1


Mean IR Brightness Temperature
LMA Source Density
Rain Rate at Sugarloaf Mountain
Rain Rate at Boulder
Mean IR Brightness Tempeature (deg C)
Rain Rate (in/hr) and LMA Source Density (# per 4000 km^2 per hour)
Time (UTC)
0
-10
-20
-30
-40
-50
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
9/11/2013 00:00
9/11/2013 12:00
9/12/2013 00:00
9/12/2013 12:00
9/13/2013 00:00
9/13/2013 12:00

# The Great Colorado flood of 9-16 Sep 2013

Station Number: CO-BO-67
Station Name: Boulder 4.7 E
Date: 9/11/2013 10:00 PM
Submitted 9/11/2013 10:10 PM
Notes: 6.29 is total since monday at 5pm. Since ~5pm today about 3" Heavy rain right now with lightning but don't hear much thunder. My kids reported sig flooding on S Boulder Road near Cherryvale, cars stalled in water there.

Station Number: CO-BO-67
Station Name: Boulder 4.7 E
Date: 9/11/2013 11:00 PM
Submitted 9/11/2013 11:22 PM
Notes: My amount seems quite in line with the Urban Drainage maps. Why the sw-ne band of heavier rains (seemingly for 2 days now) not sure. only R- now, see some ocnl lightning to the south. Drainage ditch down our road near bankfull (normally dry) and overflowing where it hits Baseline Road, but only minor amounts on the road. ed

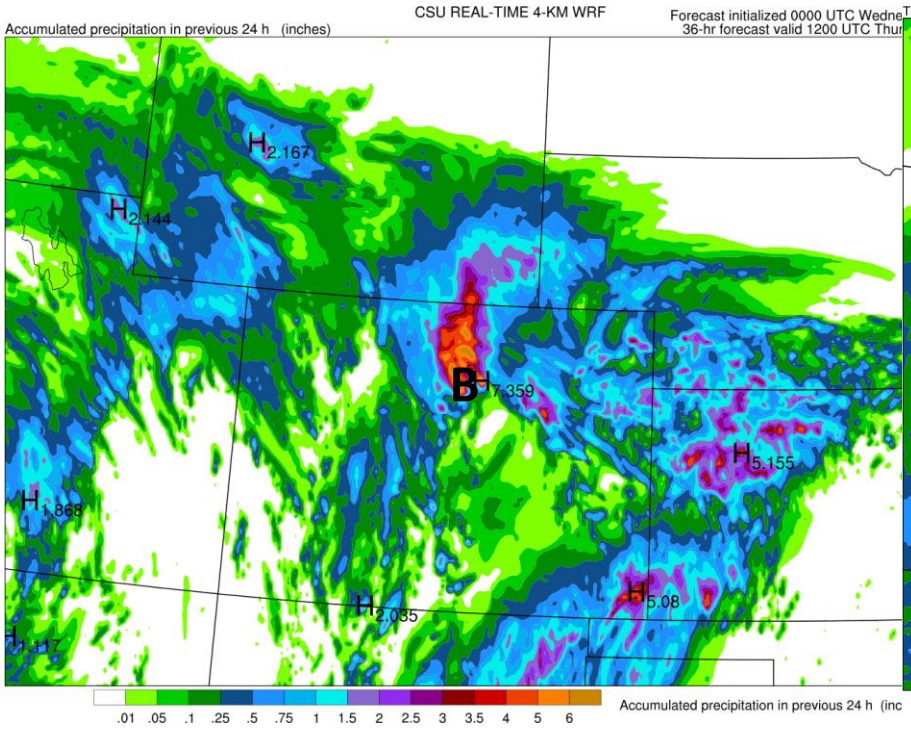



**OBS**

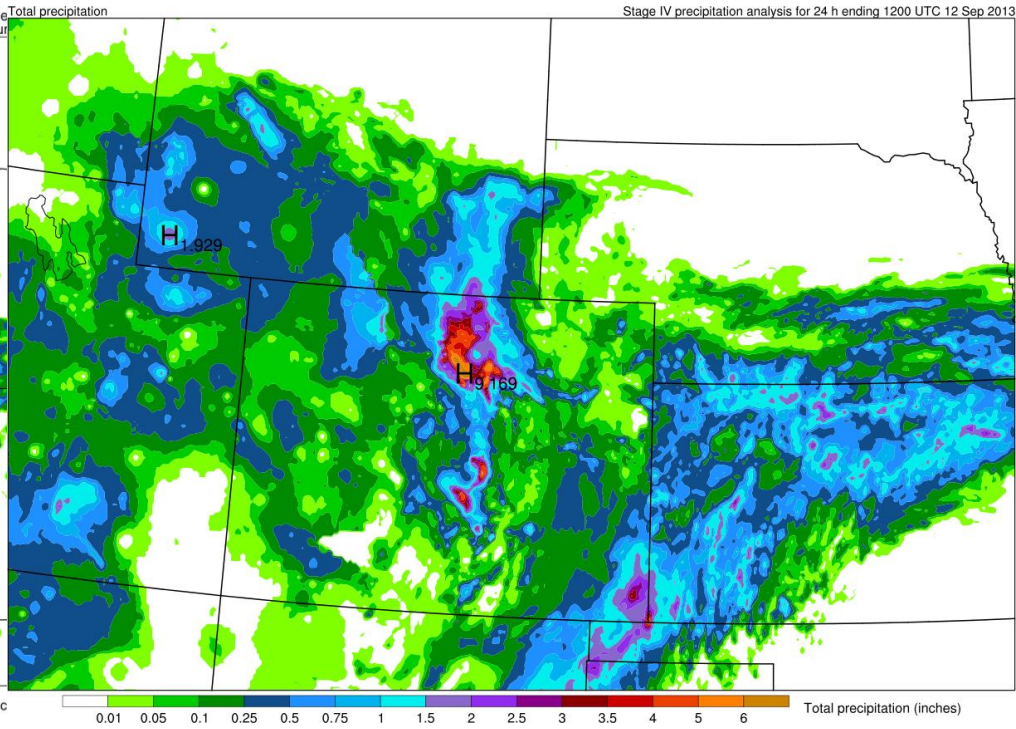
- a closer look at one of the more successful members

# Add 4-km nest to CSU member 2

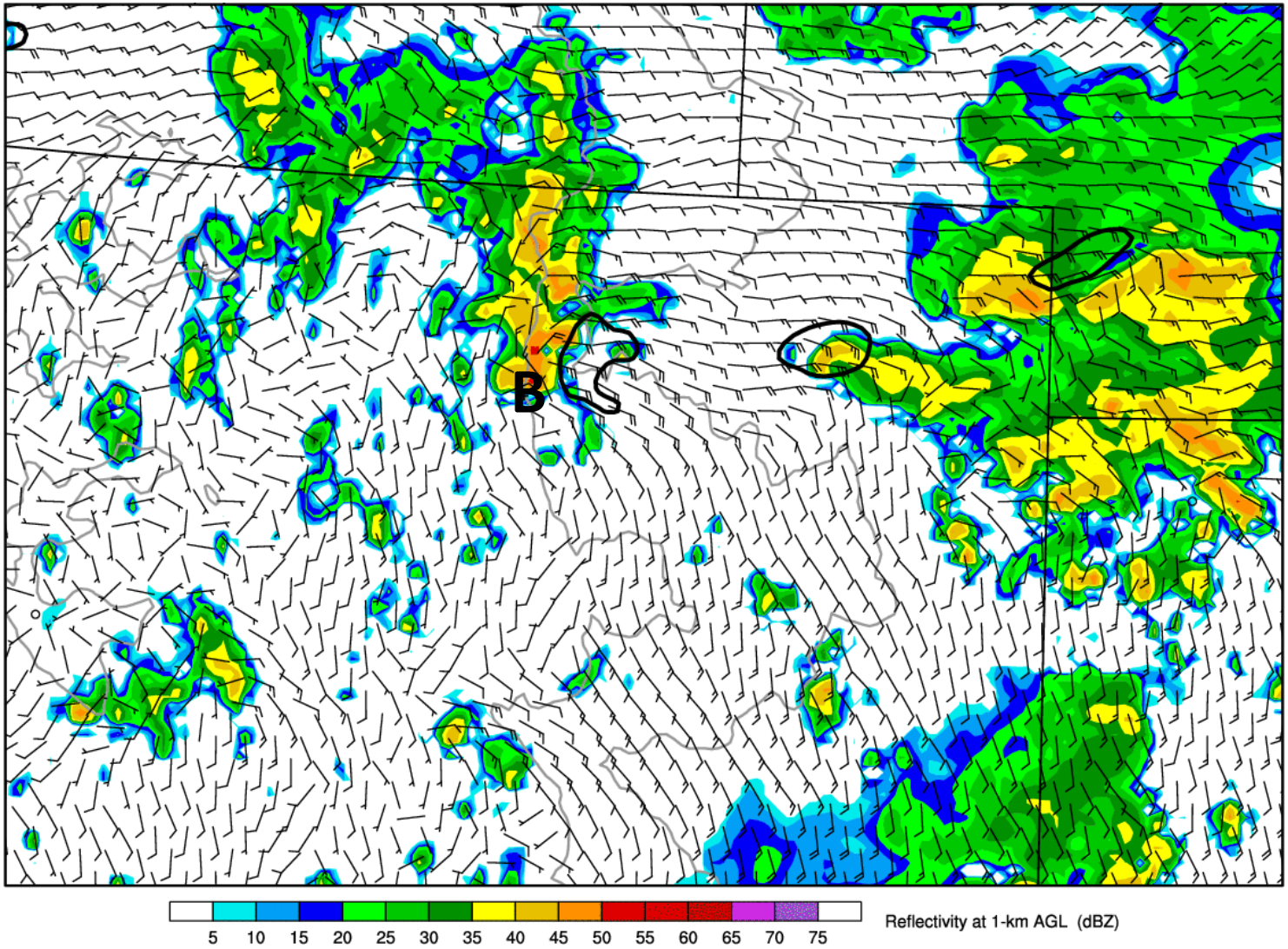
CSU 4-km WRF




Stage IV precipitation analysis




- This member uses GFS forecast initial/lateral boundary conditions, Thompson microphysics, YSU boundary layer scheme (12-km uses G3 cumulus; 4-km no cumulus)
- Provides fairly accurate depiction of large rain totals in Boulder and Larimer counties

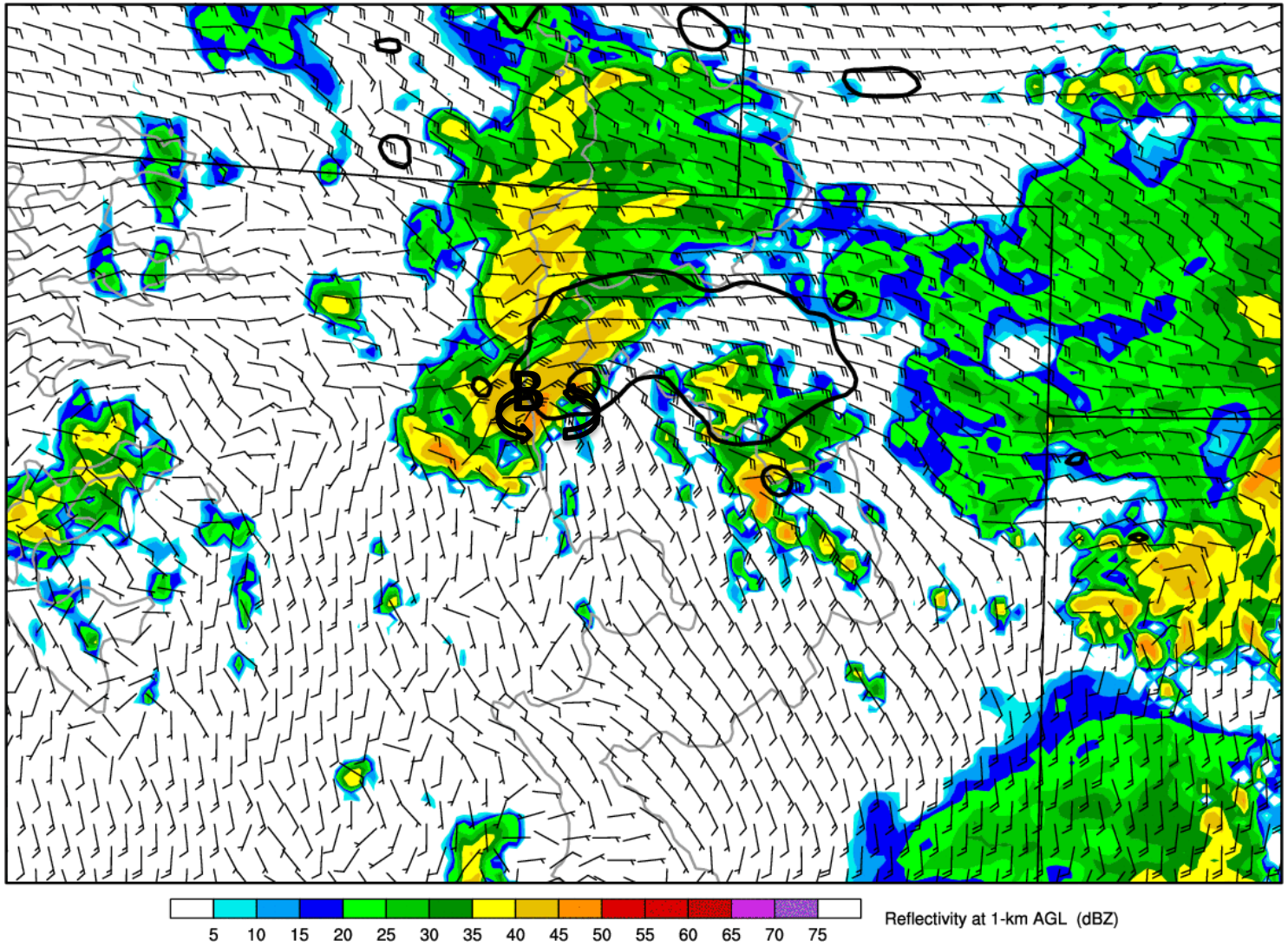



Simulated reflectivity at 1-km AGL

Wind barbs at 1-km AGL

-10 m/s u-wind contour (black)

24-h forecast (0000 UTC 12 Sept.)

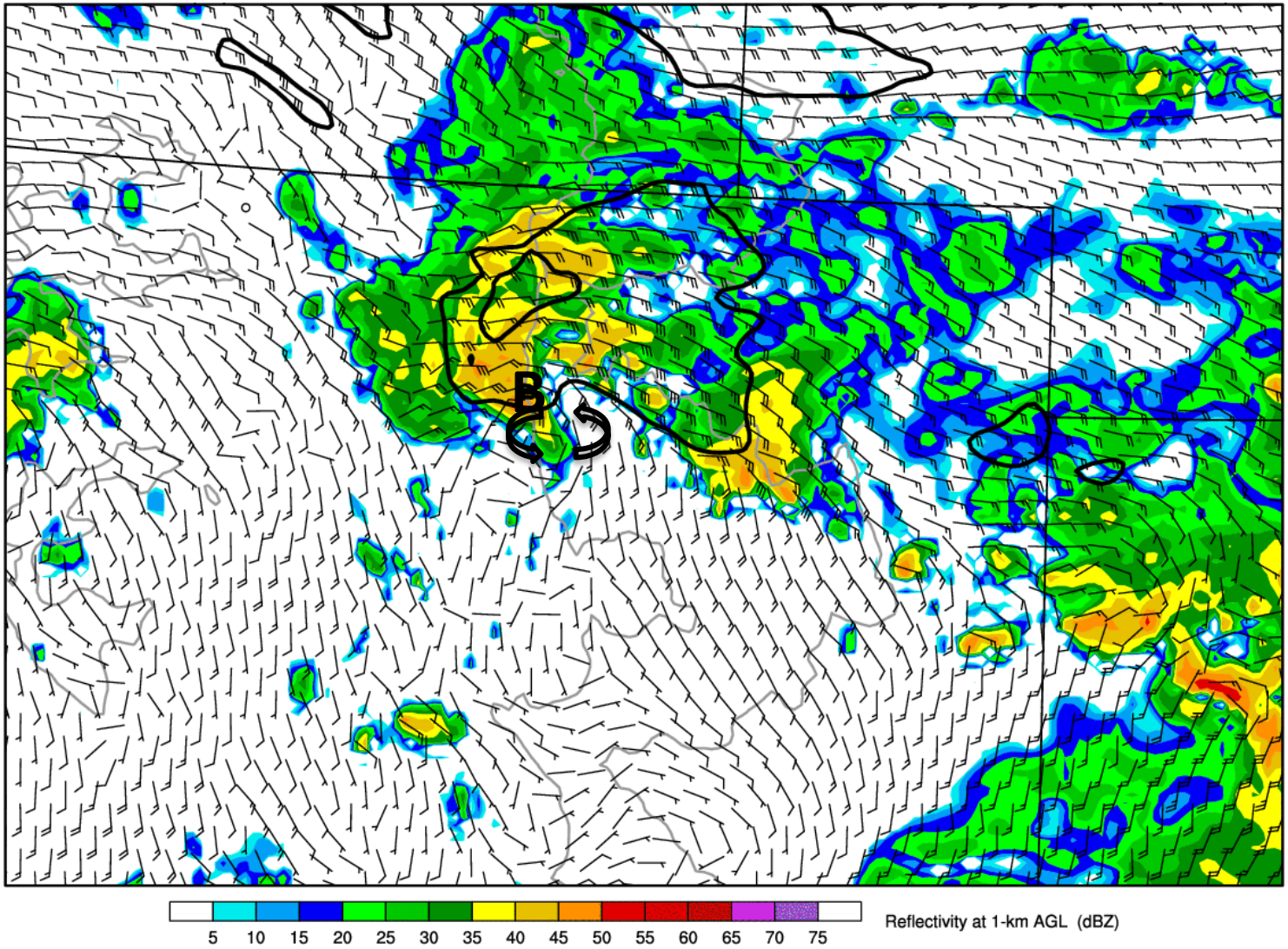



Simulated reflectivity at 1-km AGL

Wind barbs at 1-km AGL

-10 m/s u-wind contour (black)

28-h forecast (0400 UTC 12 Sept.)




Simulated reflectivity at 1-km AGL

Wind barbs at 1-km AGL

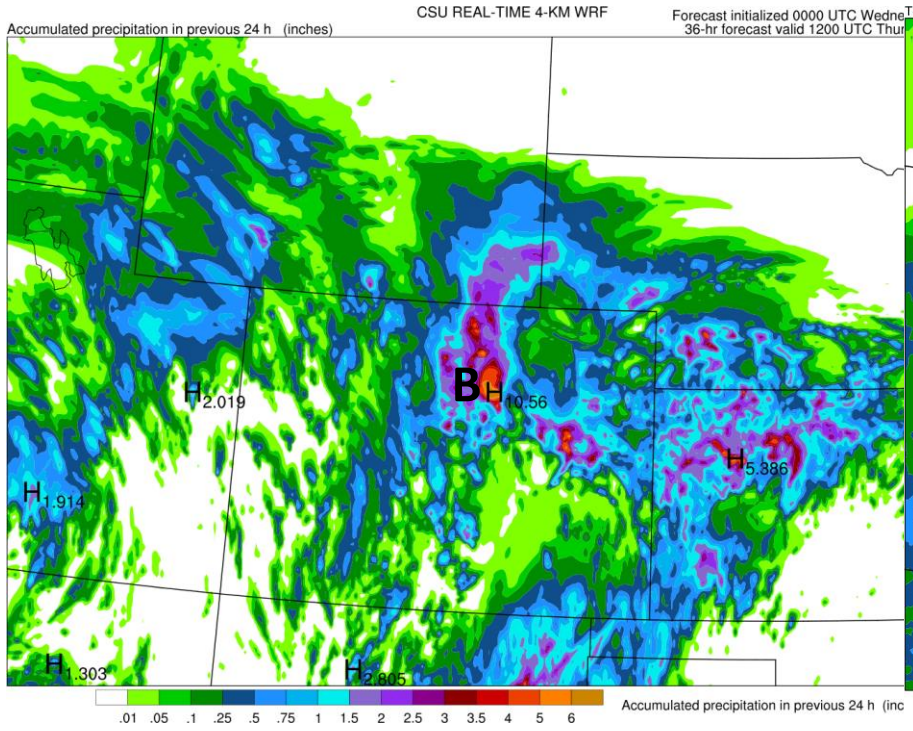
-10 m/s u-wind contour (black)

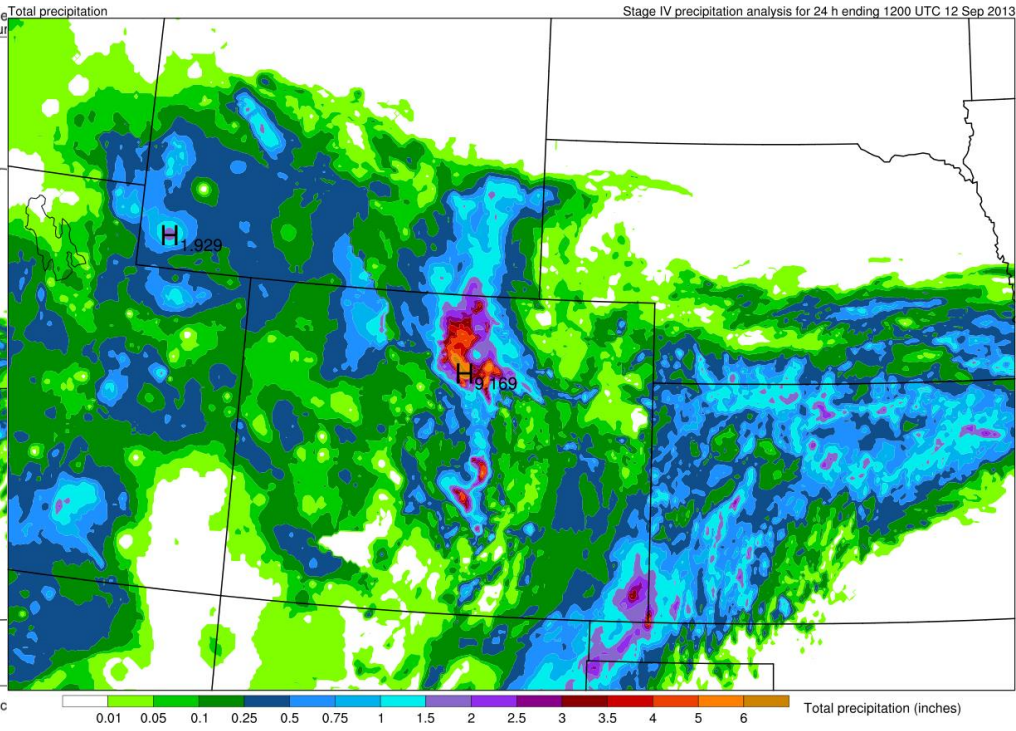
30-h forecast (0600 UTC 12 Sept.)

# A slightly different model configuration…

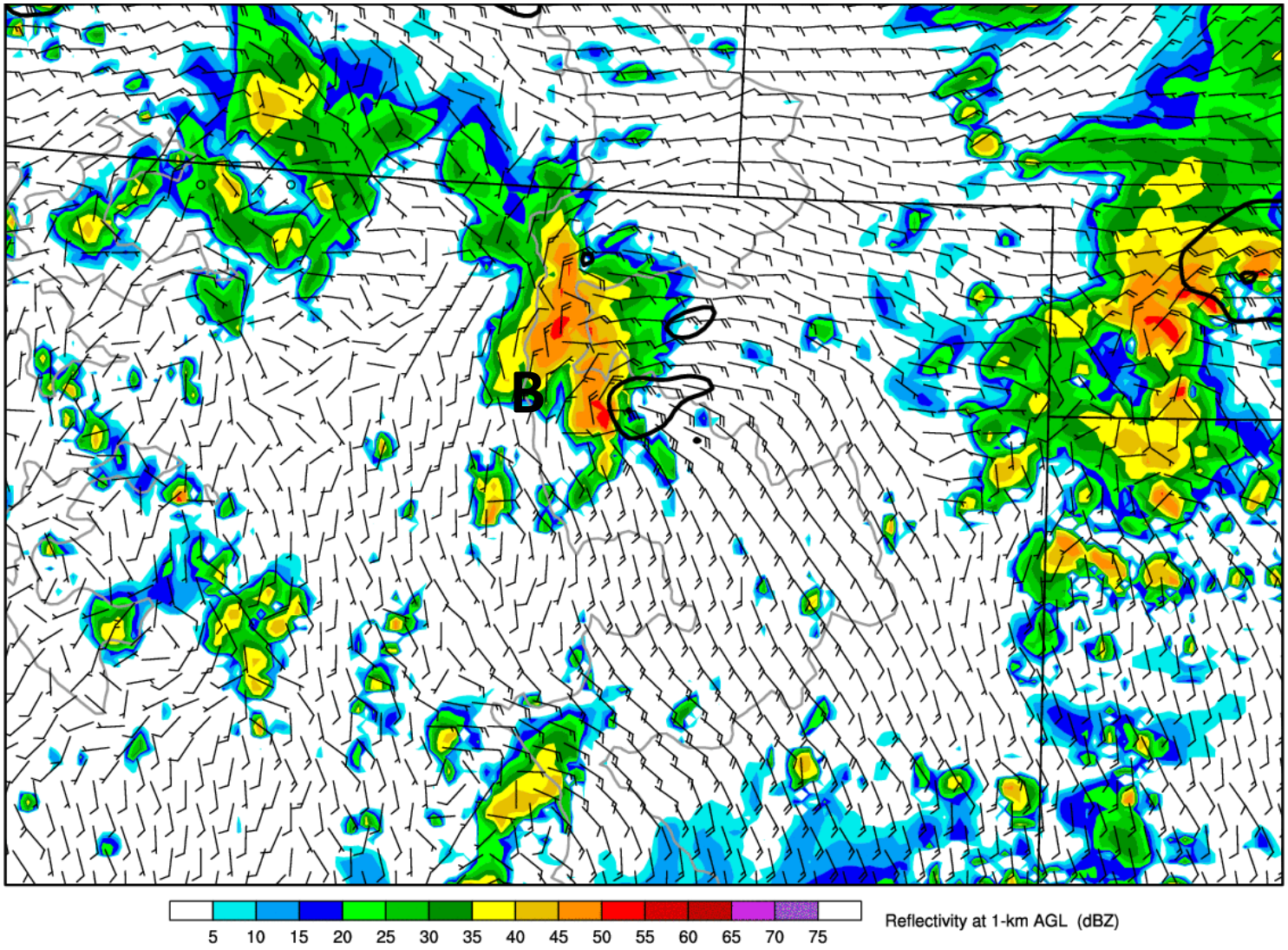
CSU 4-km WRF

Stage IV precipitation analysis




Still predicting extreme rainfall, but now deep convective storms over the Denver metro and the plains; more modest amounts in the mountains

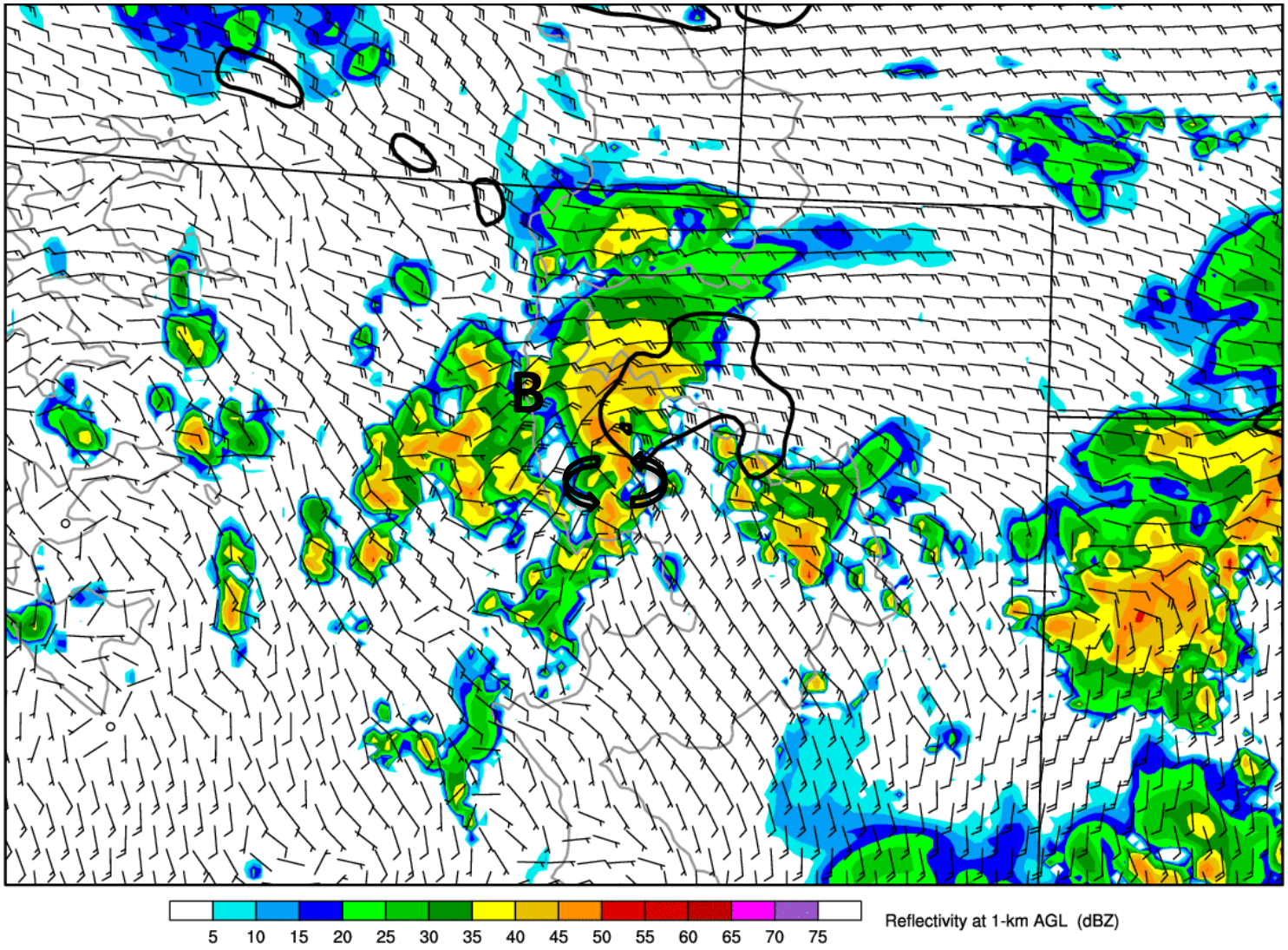



Simulated reflectivity at 1-km AGL

Wind barbs at 1-km AGL

-10 m/s u-wind contour (black)

24-h forecast (0000 UTC 12 Sept.)

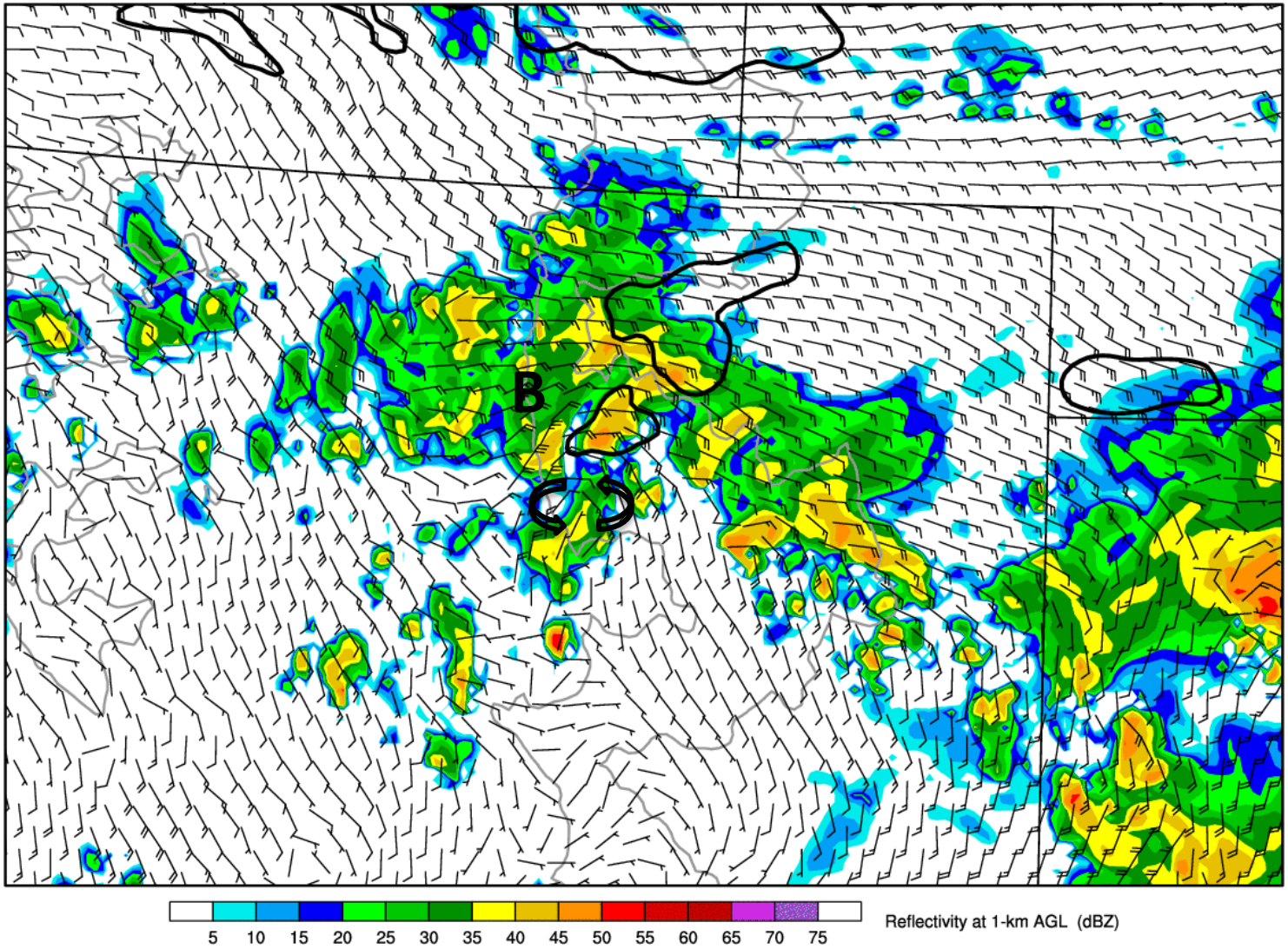



Simulated reflectivity at 1-km AGL

Wind barbs at 1-km AGL

-10 m/s u-wind contour (black)

28-h forecast (0400 UTC 12 Sept.)




Simulated reflectivity at 1-km AGL

Wind barbs at 1-km AGL

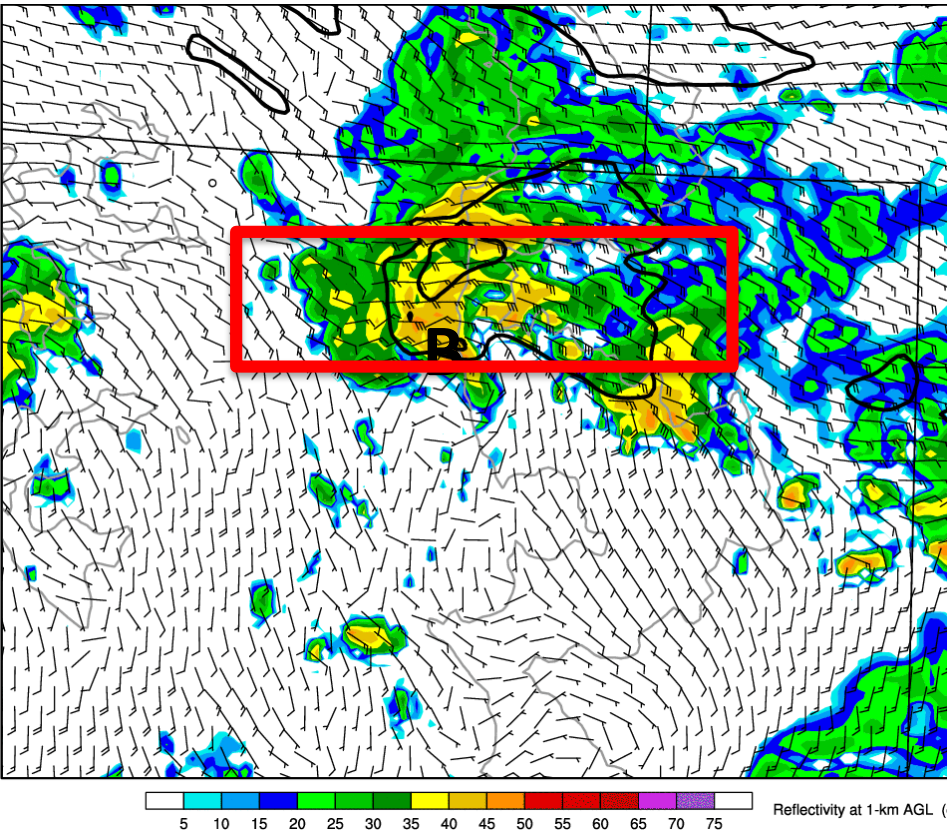
-10 m/s u-wind contour (black)

30-h forecast (0600 UTC 12 Sept.)

# What was the difference between the two configurations?

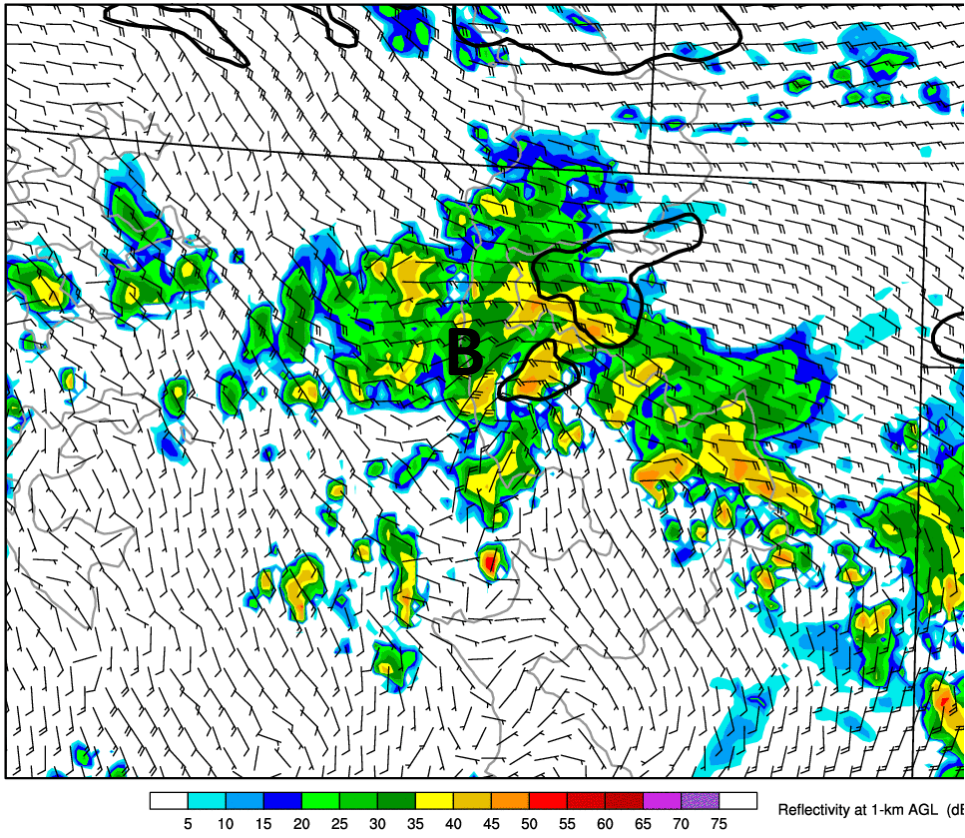
- The only change was to the microphysics parameterization! Thompson (2-moment rain) had correct distribution of rainfall; Morrison (2-moment rain) had heaviest rainfall on Plains

# Comparison at 0600 UTC




Strong, spatially coherent upslope low-level jet

Focused, intense rainfall

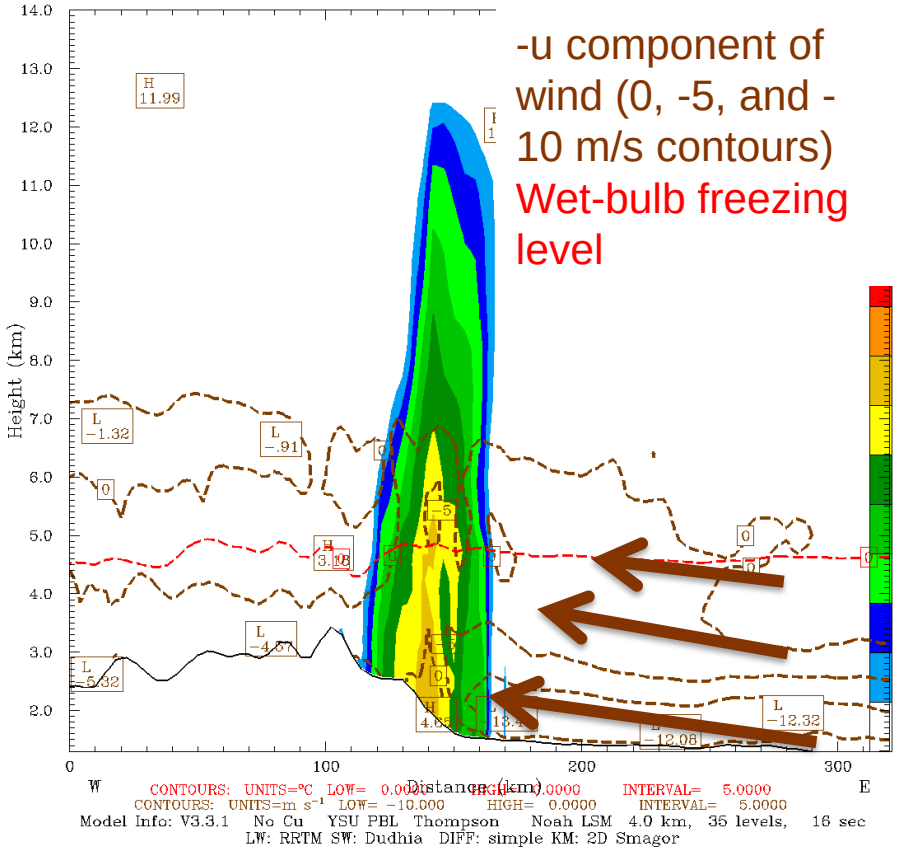



Low-level jet weaker and less expansive

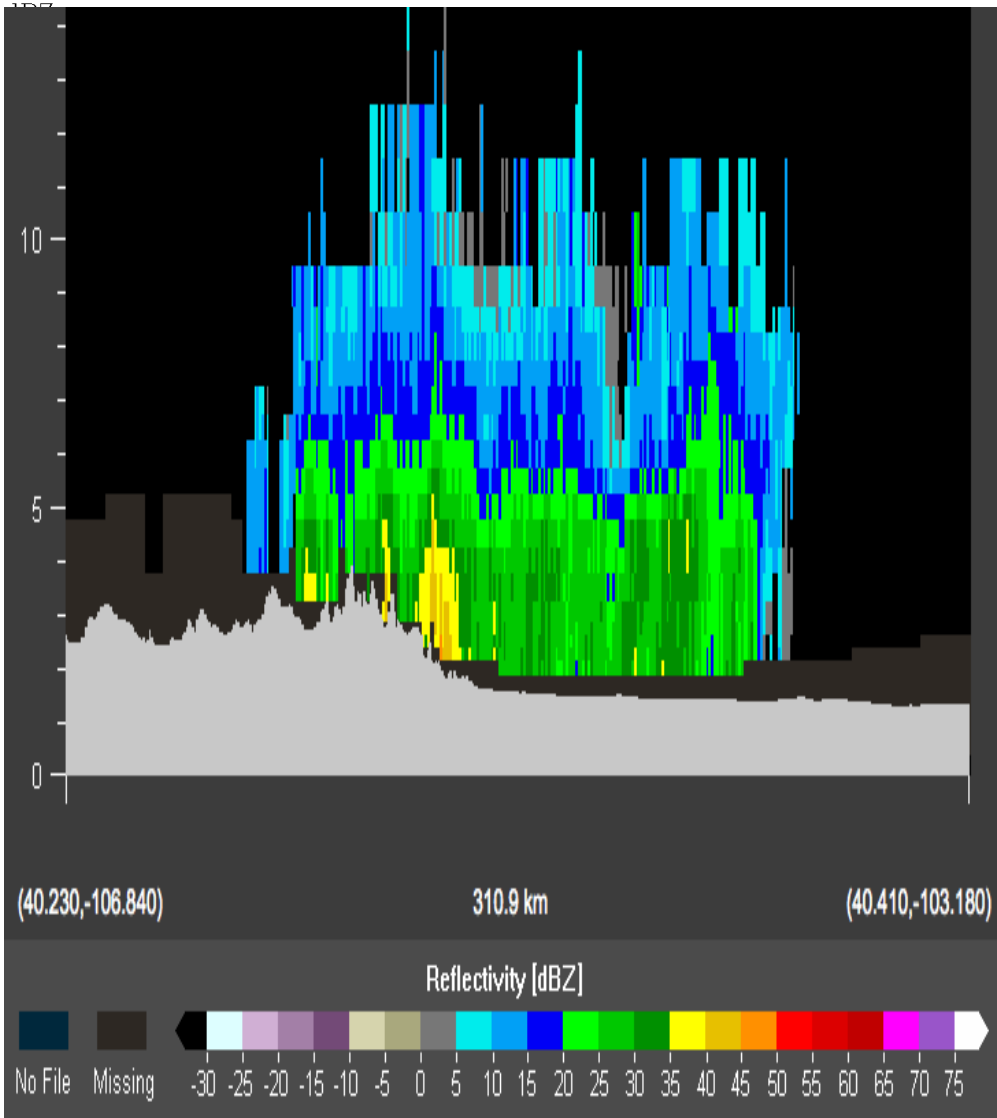
Heavy rain over plains, but not in mountains

# Simulated reflectivity, 0600 UTC

Model

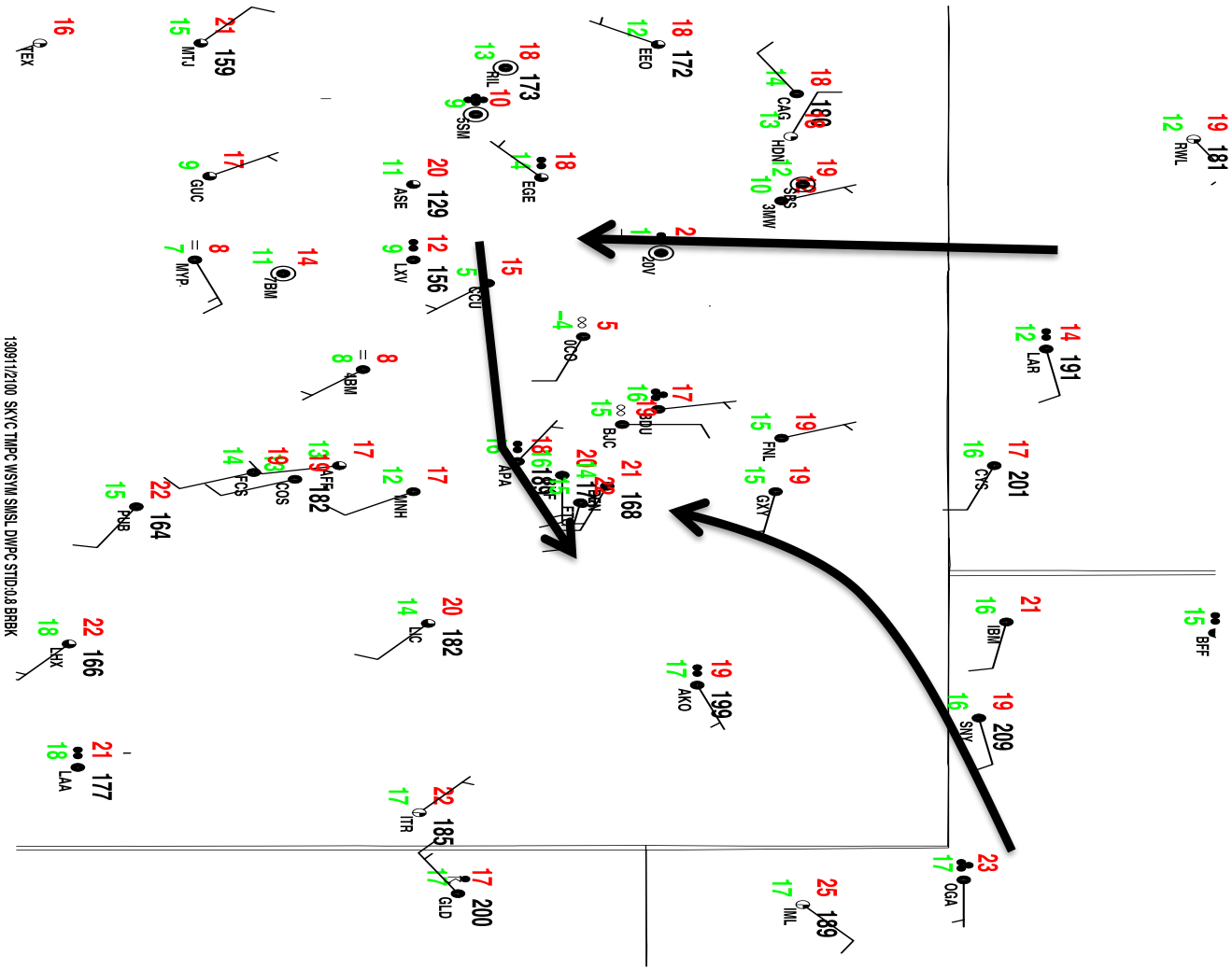



OU multi-radar/multi-sensor obs

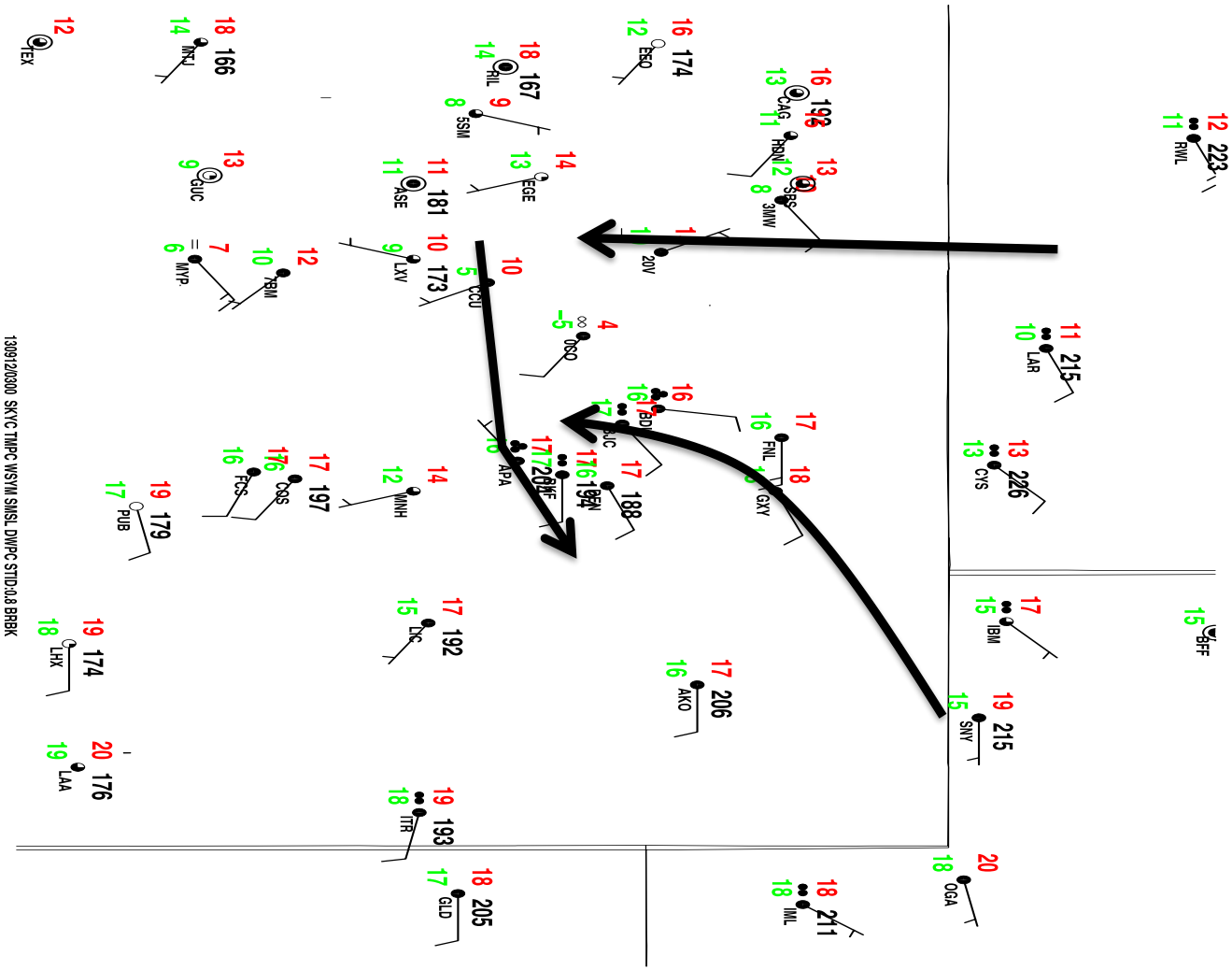



From OU/NMQ website

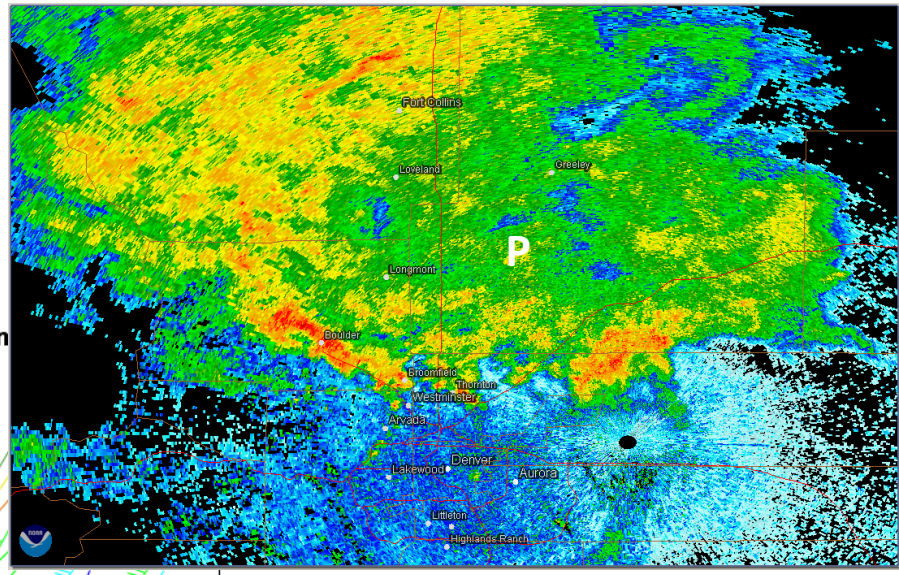
# Surface map: 2100 UTC 11 Sept.

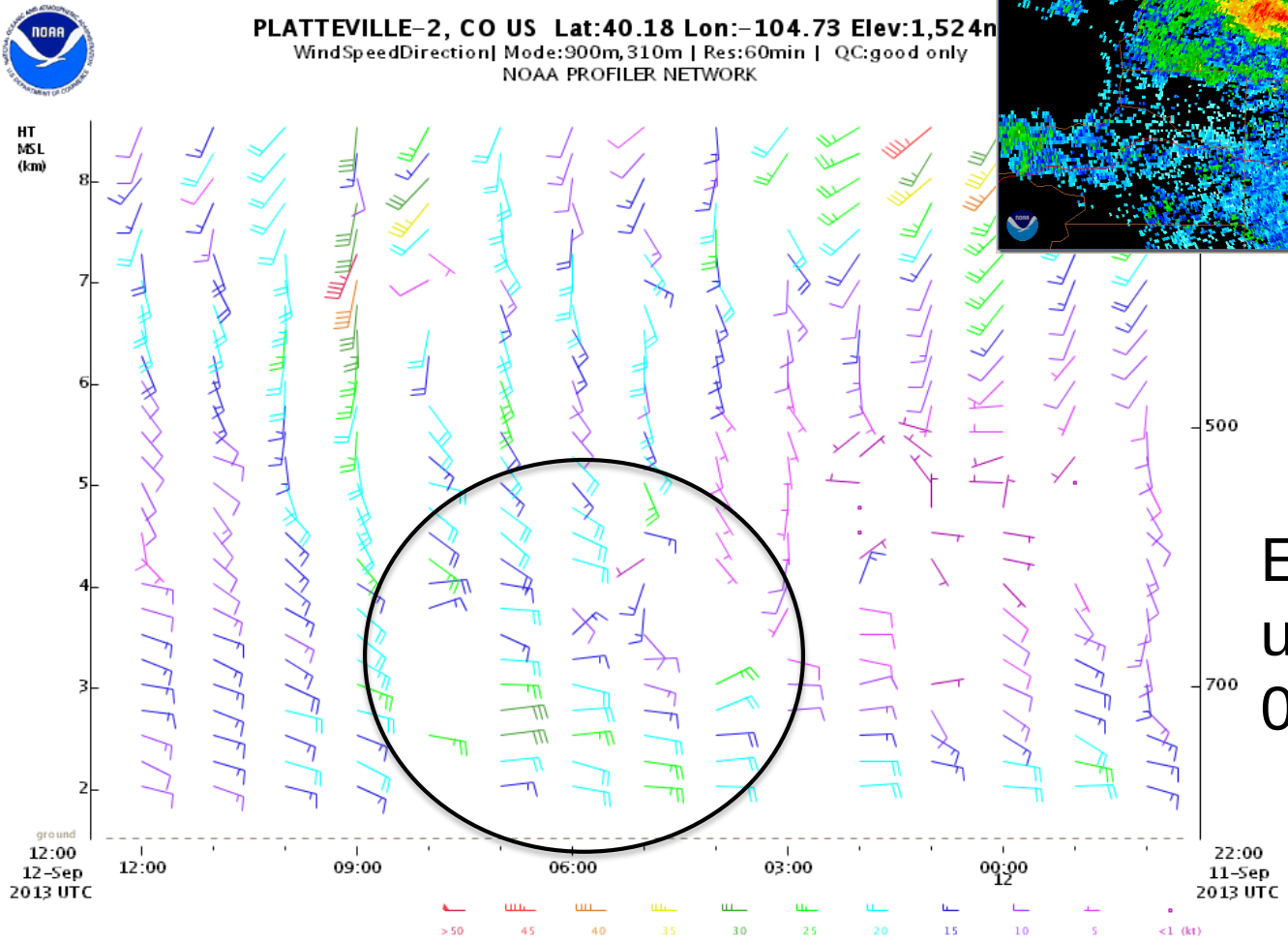


# Surface map: 0300 UTC 12 Sept.



# Platteville wind profiler

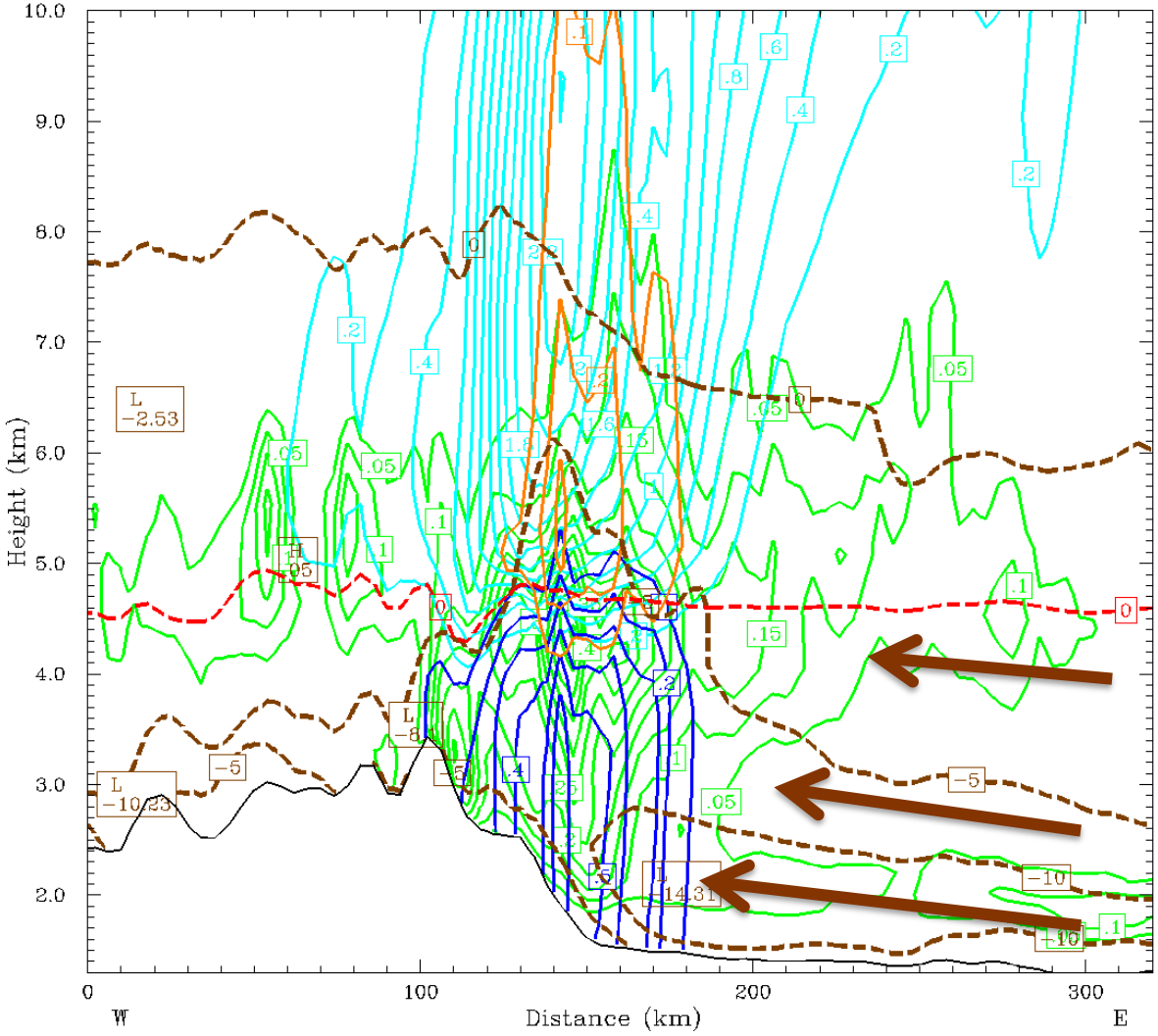



Enhancement of upslope flow from 0300-0900 UTC

12 UTC/12 Sept ← 22 UTC/11 Sept

# Time-averaged microphysical fields, 00-06 UTC 12 Sept




Rain water mixing ratio

Cloud water mixing ratio

Snow mixing ratio

Graupel mixing ratio

-u component of wind (0, -5, and -10 m/s contours)

Wet-bulb freezing level

# Summary, conclusions, and discussion

- Extreme rainfall occurred across much of northern Colorado during 11-16 September 2013 and produced deadly and destructive flooding
- Anomalously moist conditions persisted throughout the event, with forcing for ascent ahead of slow-moving trough in southwestern US and deep upslope flow
- Performance of NWP models was a mixed bag, with plenty of indication of widespread rains, but uncertainty regarding the amounts and location; event was not “unpredictable”, however.
- Even in favorable large-scale environment, mesoscale processes were crucial to the rainfall distribution
  - Locally enhanced upslope flow on the north side of a mesoscale vortex initiated deep convection and intense rain rates in Boulder County from 03-07 UTC 12 Sept.

# Summary, conclusions, and discussion

- What mechanisms govern the development of nocturnal, upslope low-level jets east of the Rockies?
- What mechanism caused the formation of the mesoscale vortex in the Denver area? (is this akin to the “Denver cyclone”, or something different?)
- What role do microphysical processes play in the development and maintenance of these features?
- What improvements need to be made in models, human forecasting techniques, and so on, to better anticipate an event like this that falls well outside the previous climatology?

what was this?

## EOC messages

## 09/12/2013 11:20 p.m. Four Mile Canyon flash flood

A large surge of water, mud, rocks and debris, including cars, about 30 feet deep is heading down Fourmile Creek, according to an 11:10 p.m. call to Boulder County by a resident of Emerson Gulch. The flow is expected to reach Boulder Creek at about midnight. Residents are warned to go to higher ground!

Emerson Gulch is in the midst of the Fourmile Canyon fire burn area which was denuded of grass, trees and brush.

# On a lighter note...I briefly had riverfront property

# On a lighter note...I briefly had riverfront property

# On a lighter note...I briefly had riverfront property

**wookiehangover** Follow

8 minutes ago

The #boulderflood has given way to a vicious onslaught from the CRAB PEOPLE

**ciceifh**, **okayjeffrey**, **rschleg** and **3** others like this.

**aspensnowmass**

Zombies, they are coming.

Leave a comment...

# The Great Colorado flood of 9-16 Sep 2013