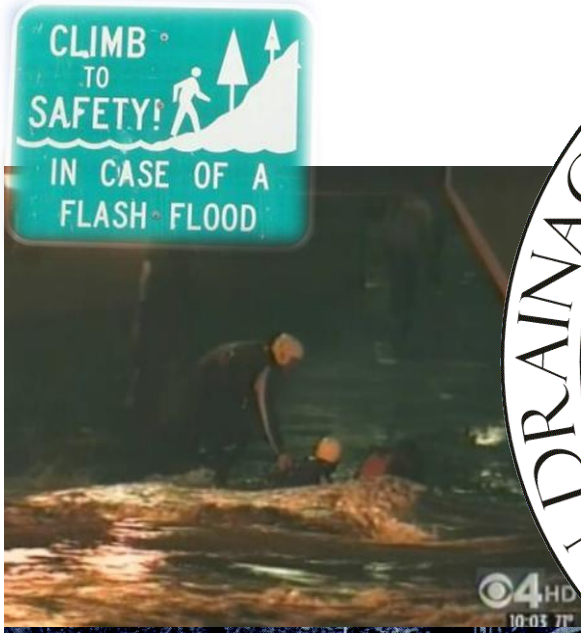
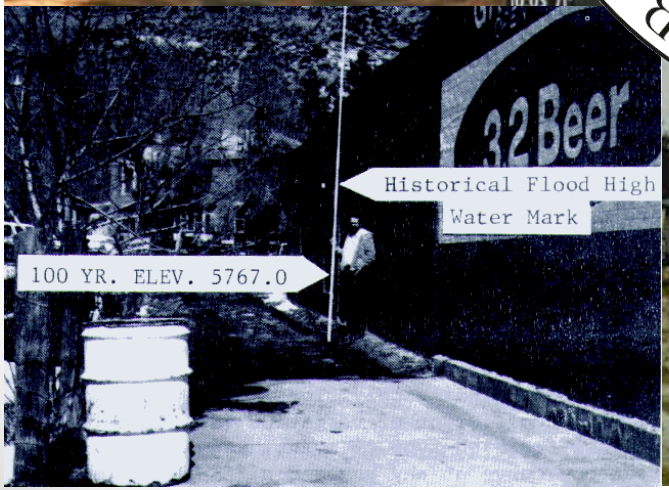
State of the Science (SOS)—*Recognizing flood threats hours before the rains come*

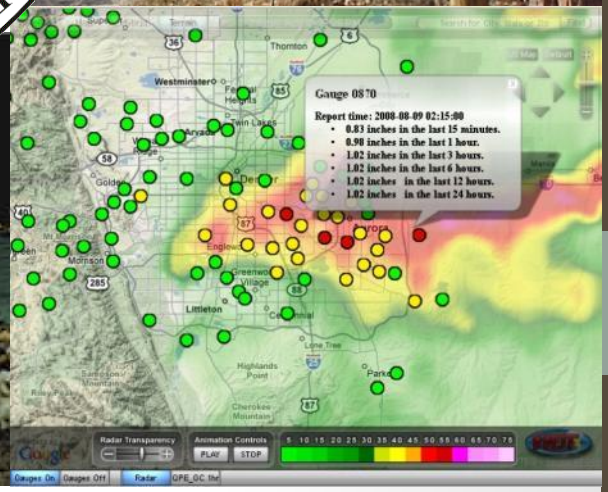
Kevin Stewart, PE, Program Manager
Dmitry "Dima" Smirnov, Ph.D., Meteorologist, Dewberry

2016 UDFCD Annual Seminar April 5, 2016

Flood Warning Program







Focusing on PREDICTION

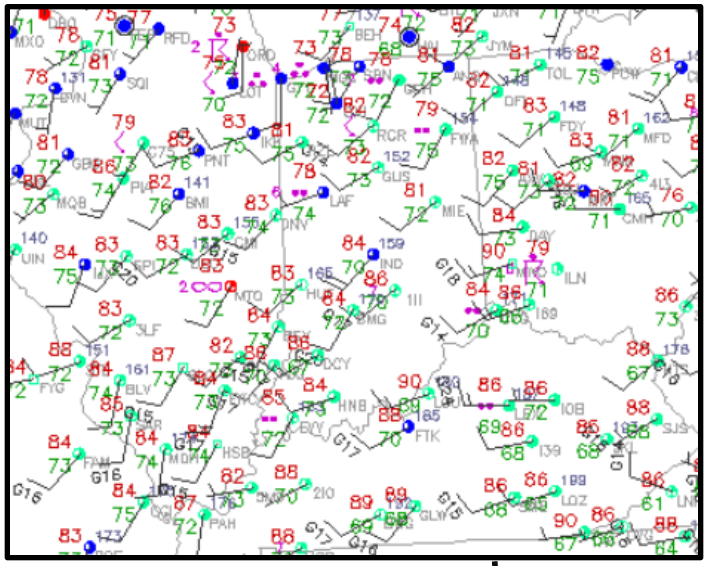
Using High-Resolution Quantitative Precipitation Forecasts for Heavy Rainfall Prediction in Colorado

Dmitry Smirnov, Ph.D.
Kevin Stewart, P.E.
Stu Geiger, C.F.M.

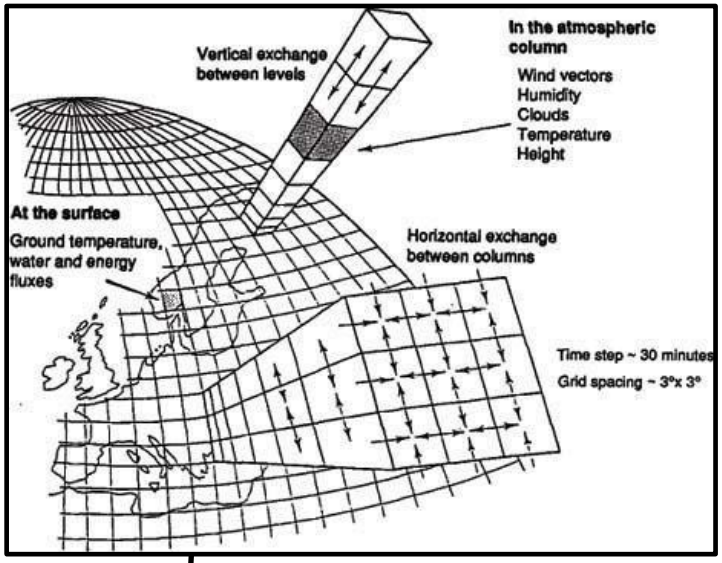
UDFCD Annual Seminar 2016

What makes a good forecast?

OBSERVATIONS



WEATHER MODELS



HYDRO-METEOROLOGISTS

Outline

- Brief primer on weather models
  - Importance of resolution
  - Defining an "Ensemble"
- Applying models. Two real-world examples:

1. Colorado Flood Threat Bulletin
2. Urban Drainage and Flood Control District Heavy Rainfall Guidance

- **WHERE?**
- **WHEN?**
- **HOW MUCH?**
- **HOW SURE ARE YOU?**

Lots of data!

MODEL	RESOLUTION	RUNS / DAY	LEAD TIME	ENS
Nested NMM-B	1			---
Univ. of Arizona WRF	1.8			2 or 3
NCAR DART Ensemble				10
High Resolution Rapid Refresh (HRRR)				---
NSSL-WRF				8
NCEP HIRES WRF (ARW & NMM)				2
Dewberry Colorado WRF				---
Canadian GEM	10km	4	87H	---
North American Mesoscale	12km	4	84H	---
Rapid Refresh				---
Short-Range Ensemble Forecasts				21
CMC NAEFS				20
Global Forecast System	1			21
ECMWF	1			51
NCEP Climate Forecast System				4
ECMWF	70km	1/month	7M	51

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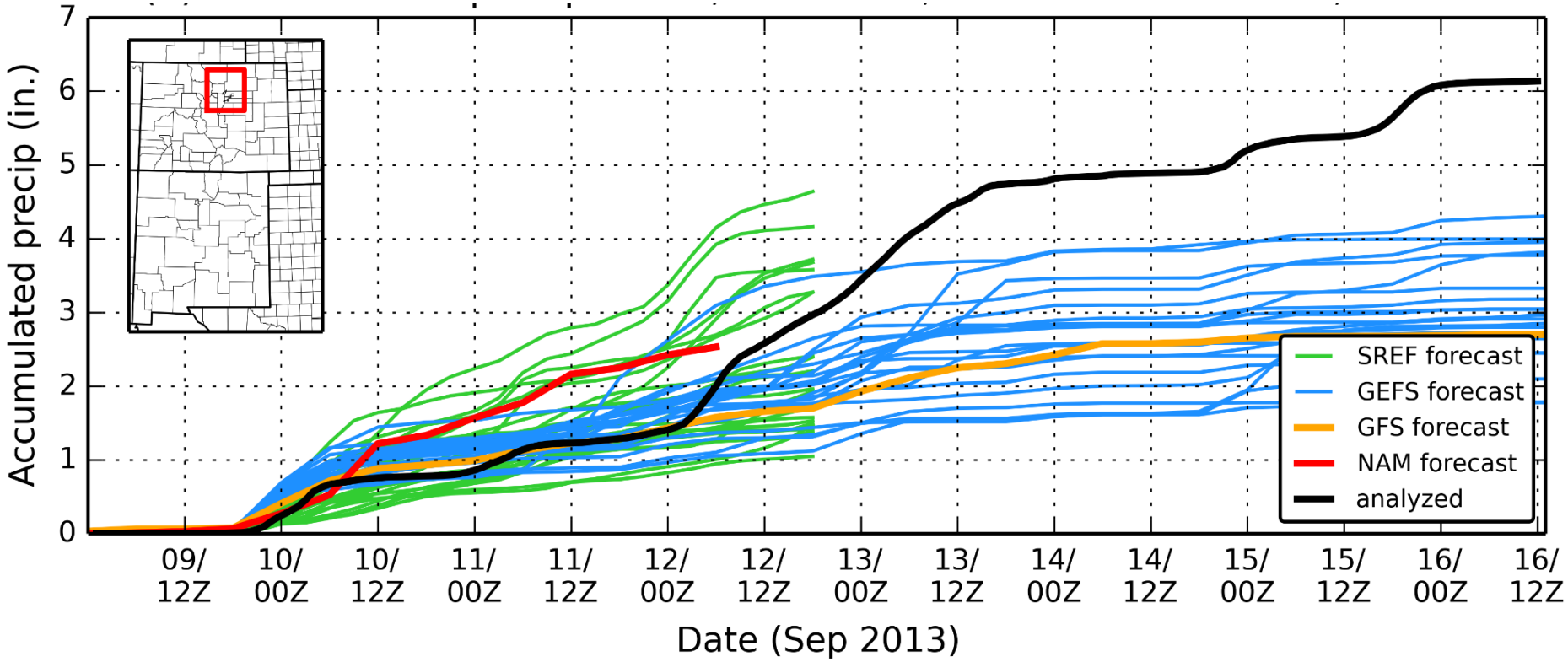
Dewberry

What is an ensemble?



Thanks to: Tom Hamill, NOAA-ESRL

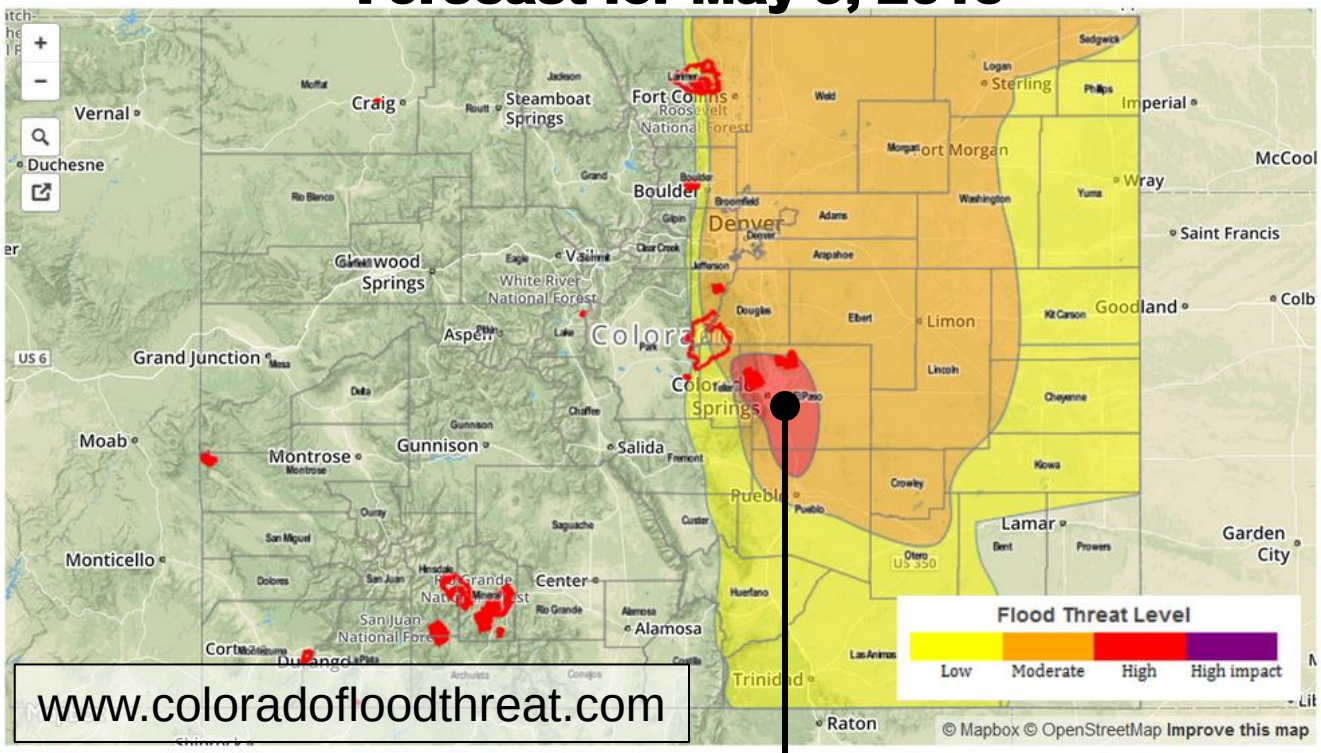
1. Colorado Flood Threat Bulletin

Colorado Flood Threat Bulletin

@COFloodUpdates

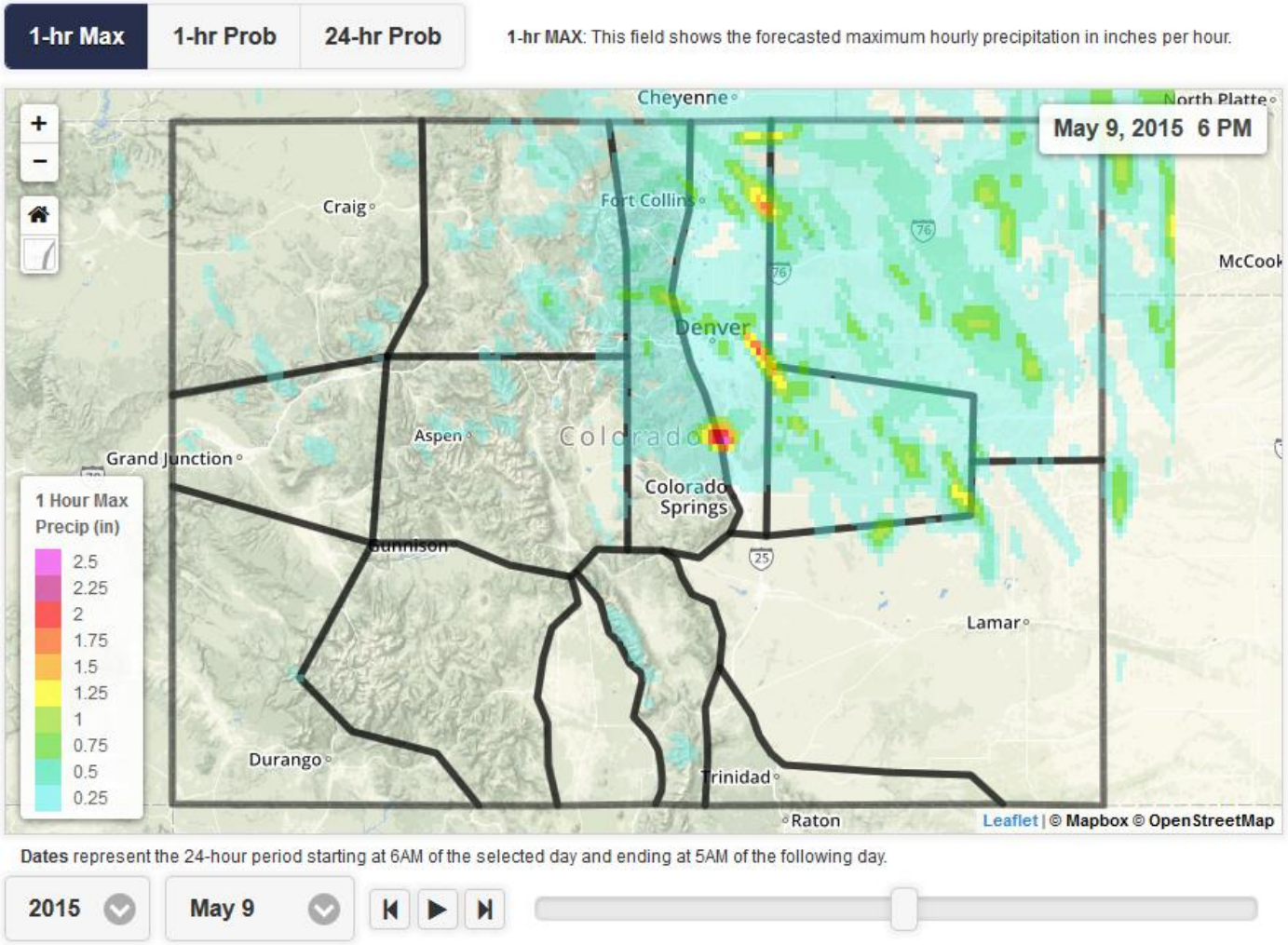
- Specifies:
  - Location
  - Timing
  - Intensity
  - Confidence
- Includes:
  - Riverine flooding
  - Flash flooding (esp. urban)
  - Snow-melt
  - Drought
- Tools:
  - Processed high-res model guidance

Forecast for May 9, 2015



Chance of Precip	Prime Time	Discussion
>90%	11AM – 1AM	**HIGH flash flood threat:** High antecedent rainfall along with 2-3 inches of additional rainfall will cause widespread street and stream flooding.

Flood Threat Bulletin QPF Viewer



www.coloradofloodthreat.com

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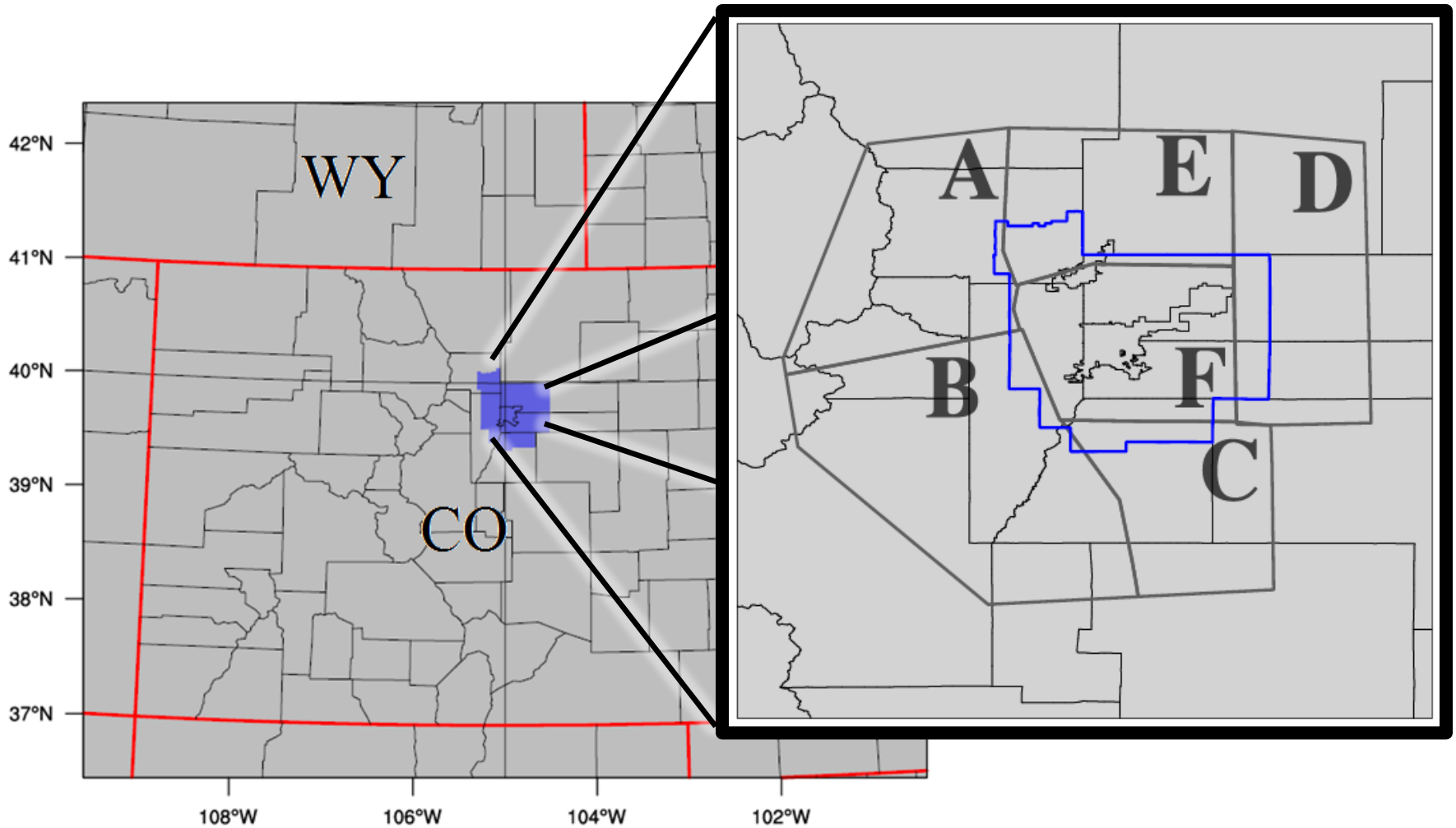
2. Heavy Rainfall Guidance Tool

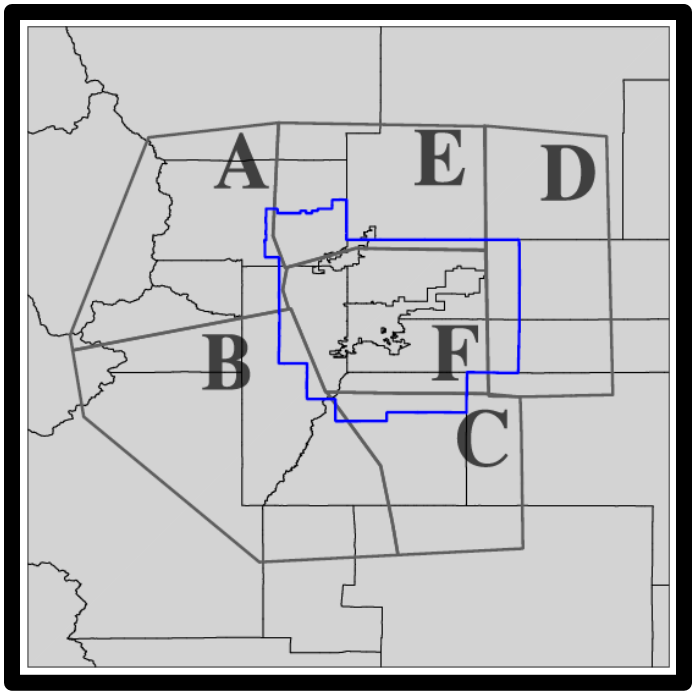
- Overview & Features
- Overall performance in 2015
- Examples of several events
- Improvements for 2016

Domain

District domain ~1,600 sq. miles
Tool domain ~7,650 sq. miles



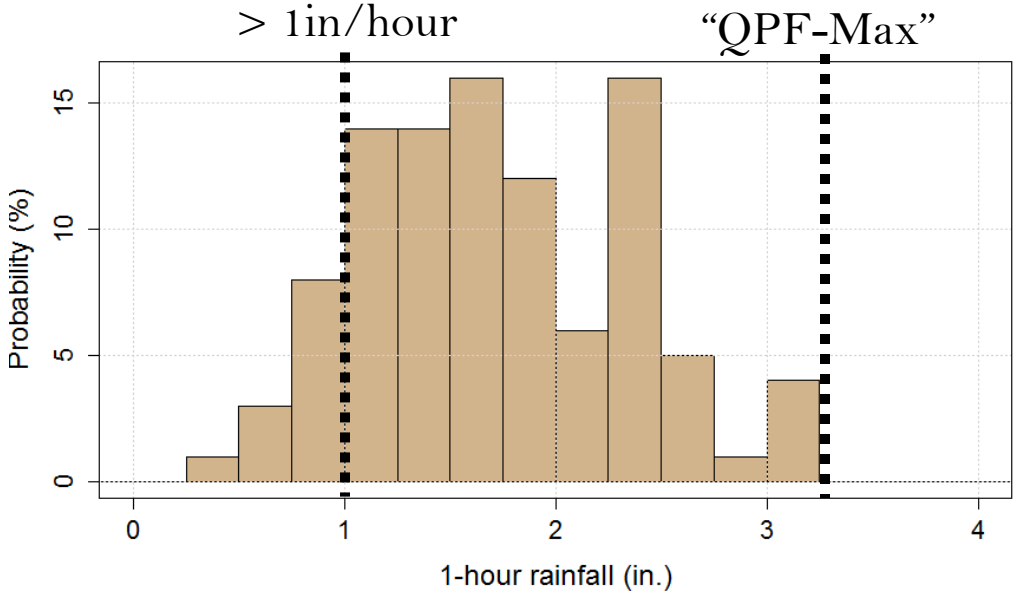
Forecast Zones



Forecast Zone	Area (sq. mi.)	# of ALERT gauges
(A) Northern Foothills	1,316	49
(B) Southern Foothills	2,029	38
(C) Palmer Divide	933	22
(D) Plains	1,283	0
(E) Northern Metro	1,053	14
(F) Central Metro	1,043	97
All Zones	**7,657**	**220**

Data & Methods Used

- 13 operational and research weather models
- Spatial resolution: 4km (2.5 miles)
- Time resolution: 1 hour
- Lead time: 24 hours
- Ensemble processing techniques



QPF = Quantitative Precipitation Forecast

Translating rainfall to threat

Duration	Intensity Threshold
1-hour	1 inch
3-hour	2.5
6-hour	3.5
24-hour	4.5

Threat	Intensity	Probability of Exceedance
LOW	At least 1 threshold is broken	---
MODERATE	i) At least 1 threshold is broken AND	>50%
	ii) More than 1 threshold is broken AND	>40%
HIGH	More than 1 threshold is broken AND	>60%
VERY HIGH	More than 1 threshold is broken AND	>80%

Tool Overview: Daily Summary

Dewberry

UDFCD Heavy Rainfall Guidance

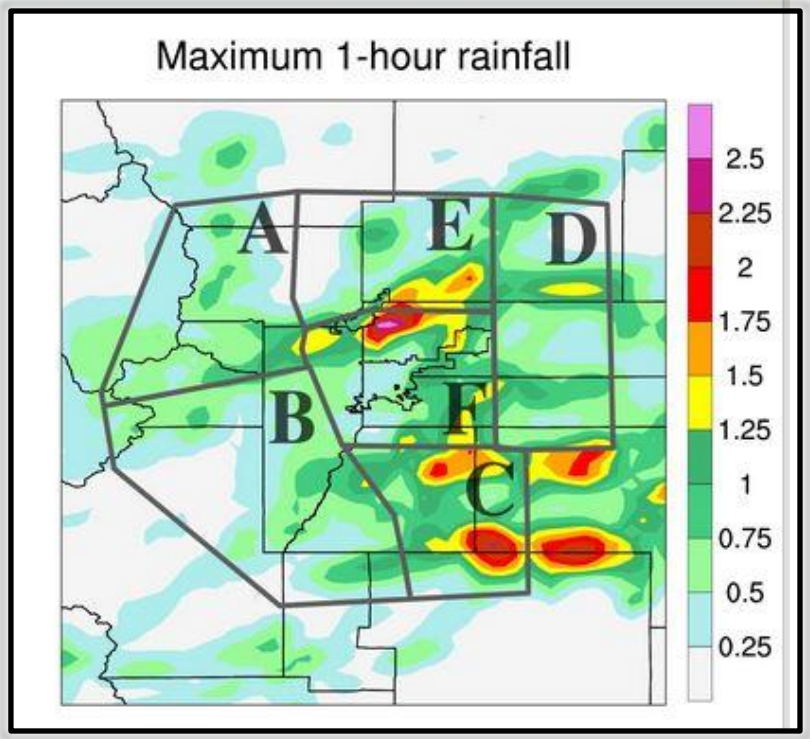
Help

Daily Summary: June 10, 2015
Updated: 12:05 PM

Quality Control: See Below for Meteorologist's Note

Meteorologist's Note: Highest threat appears to be between 3-6pm local time. Storms, already ongoing, will move into a favorable region southeast of Denver Metro where very heavy rainfall is possible. 1hr rates up to 2.4 inches are possible. After 7 pm, current indications are westerly low-level flow will drastically lower heavy rain threat.

Zone	Threat	Primetime
A	LOW	14-16Wed
B	LOW	16-19Wed
C	MOD	12-19Wed
D	MOD	14-19Wed
E	HIGH	14-18Wed
F	HIGH	13-18Wed

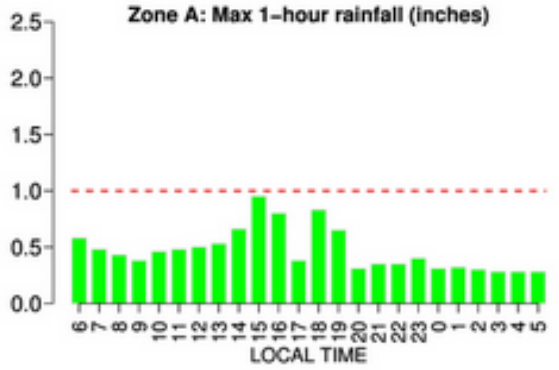


Tool Overview: Zone forecasts

Zone-specific Forecasts

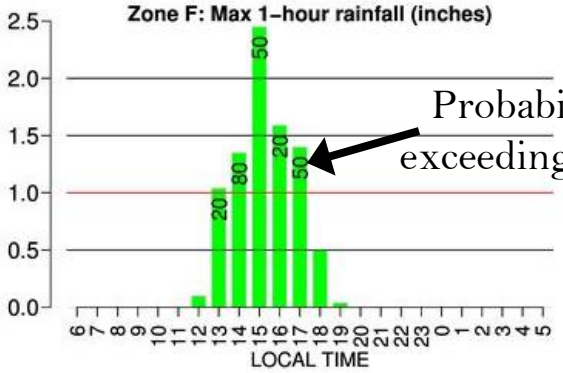
Zone A: Northern Foothills

ZONE A: Overall Threat	NONE
% precipitation	>90%
% exceeding 1in. per 1hr	<10%
% exceeding 2.5in. per 3hr	<10%
% exceeding 3.5in. per 6hr	<10%
% exceeding 4.5in. per 24hr	<10%
Primetime	---



Zone F: Central Metro

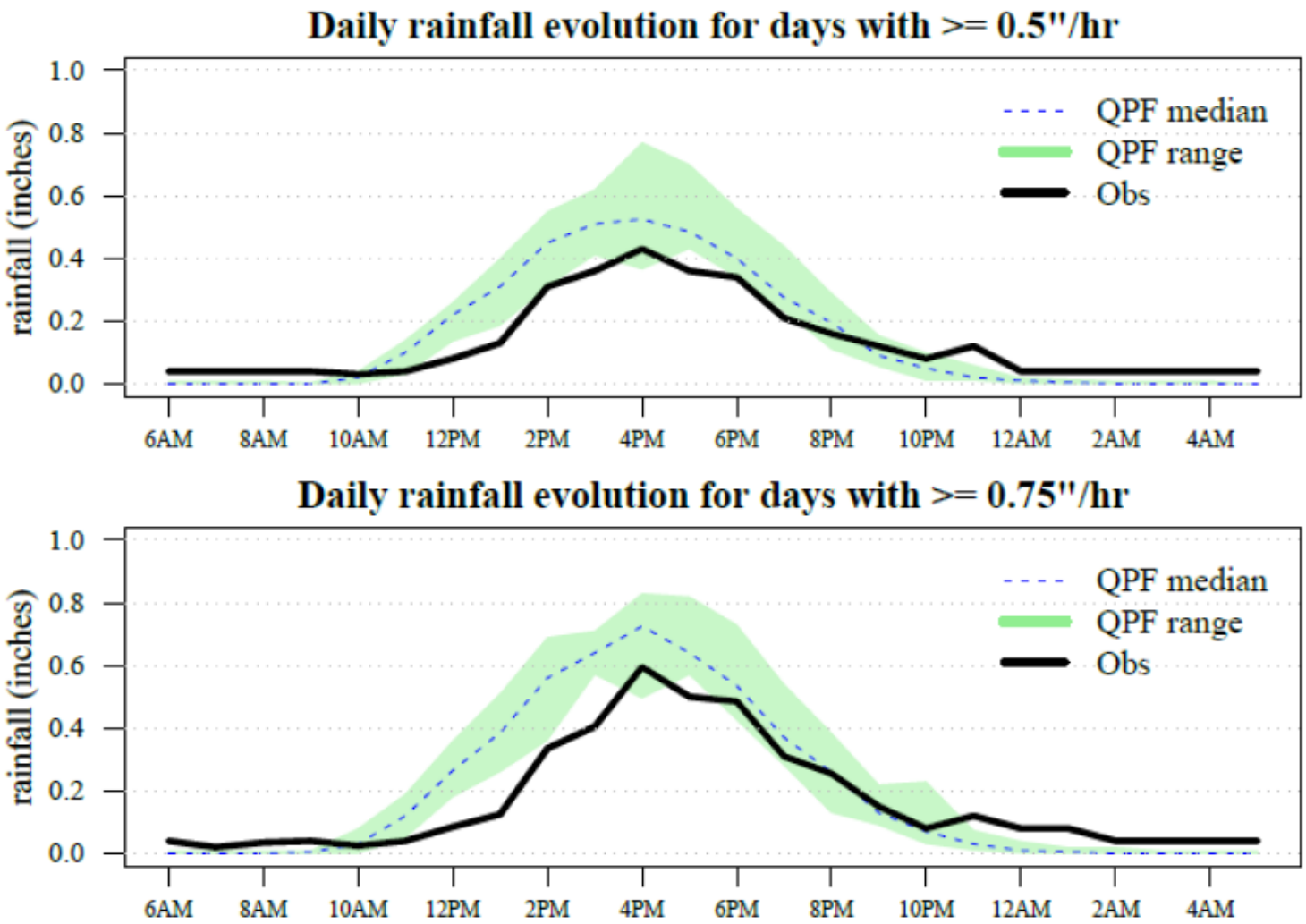
ZONE F: Overall Threat	HIGH
% precipitation	>90%
% exceeding 1in. per 1hr	>90%
% exceeding 2.5in. per 3hr	25%
% exceeding 3.5in. per 6hr	25%
% exceeding 4.5in. per 24hr	<10%
Primetime	13-18Wed



Probability of exceeding 1 in/hr

Performance in 2015

Timing


Daily rainfall evolution for days with >= 0.5"/hr
rainfall (inches)
1.0
0.8
0.6
0.4
0.2
0.0
QPF median
QPF range
Obs
6AM
8AM
10AM
12PM
2PM
4PM
6PM
8PM
10PM
12AM
2AM
4AM
Daily rainfall evolution for days with >= 0.75"/hr
rainfall (inches)
1.0
0.8
0.6
0.4
0.2
0.0
QPF median
QPF range
Obs
6AM
8AM
10AM
12PM
2PM
4PM
6PM
8PM
10PM
12AM
2AM
4AM

Location

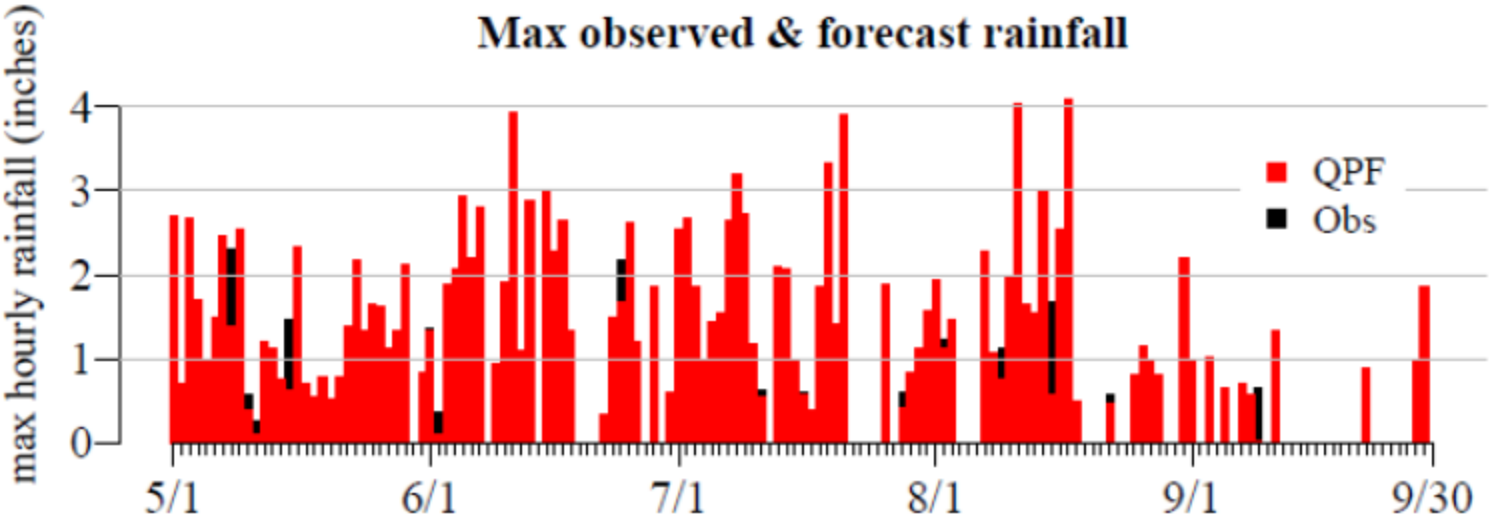
Heavy Rainfall Observed	Heavy Rainfall Forecasted: NO	Heavy Rainfall Forecasted: YES
NO	HIT	FALSE ALARM
YES	MISS	HIT

	a)Zone A	Heavy Rainfall Forecasted: NO	Heavy Rainfall Forecasted: YES	
Heavy Rainfall Observed	NO	114 (74.5%)	35 (22.9%)	Accuracy: 76%
	YES	1 (0.7%)	3 (2%)	False Alarm: 23%
				Misses: 1%

	b)Zone B	NO	YES	
Heavy Rainfall Observed	NO	100 (65.4%)	42 (27.5%)	Accuracy: 71%
	YES	2 (1.3%)	9 (5.9%)	False Alarm: 28%
				Misses: 1%

	c)Zone C			
Heavy Rainfall Observed	NO	99 (64.7%)	34 (22.2%)	Accuracy: 75%
	YES	5 (3.3%)	15 (9.8%)	False Alarm: 22%
				Misses: 3%

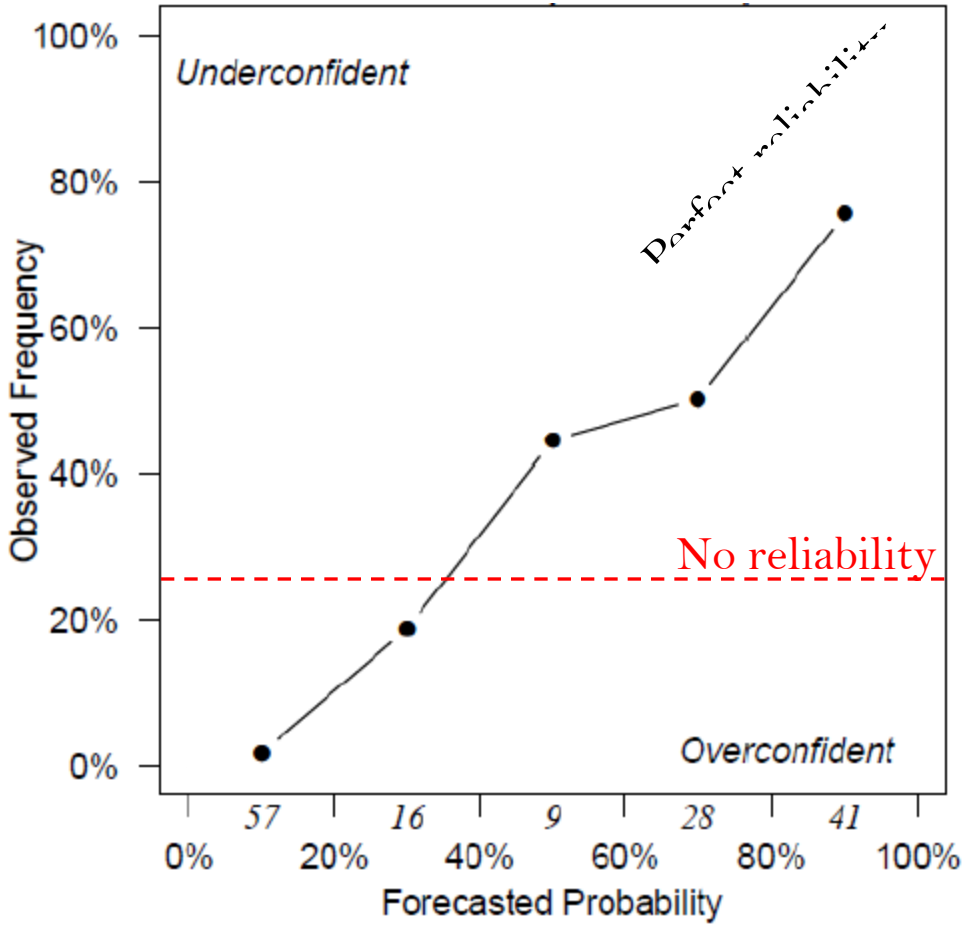
Intensity



Zone	Absolute timing	+/- 2 hours
A	69%	96%
B	78%	98%
C	64%	93%
D	61%	94%
E	55%	93%
F	52%	84%
All Zones	76%	97%

Confidence: Reliability Diagram

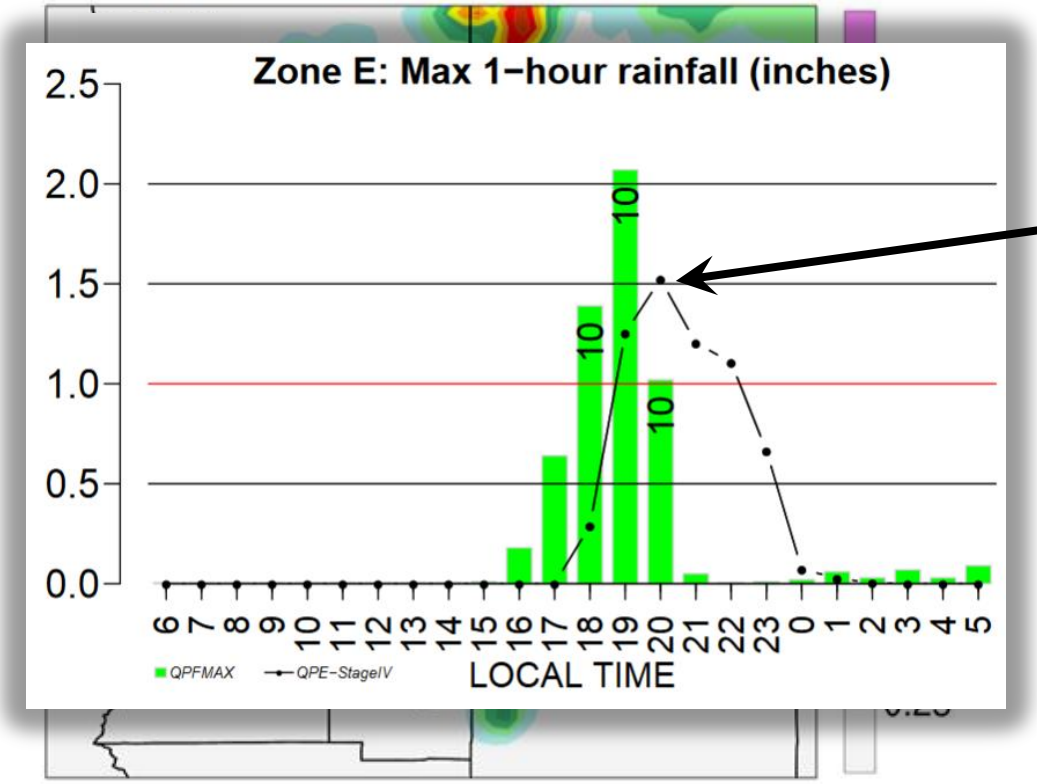
If the forecast for exceeding 0.5 inches per hour today is X%, how often is that forecast actually observed?



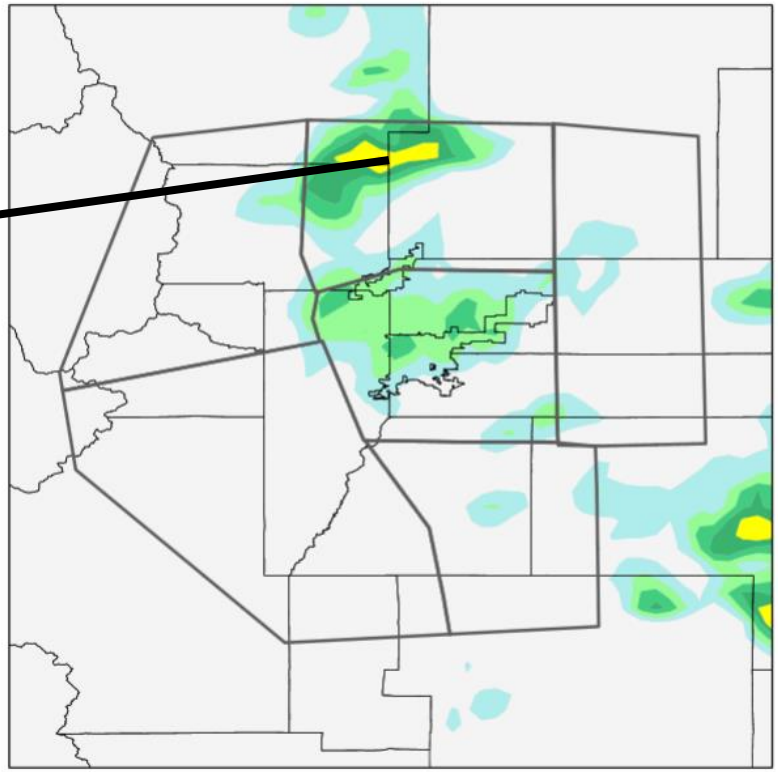
Examples of specific events

June 4, 2015

1-hr QPFMAX

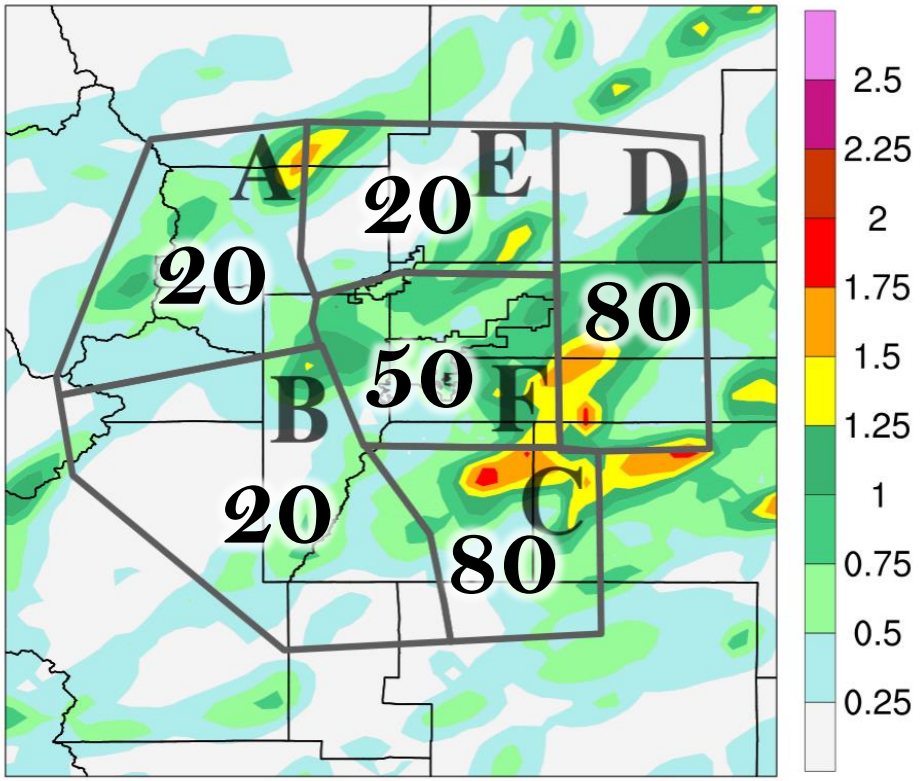


1-hr QPEMAX

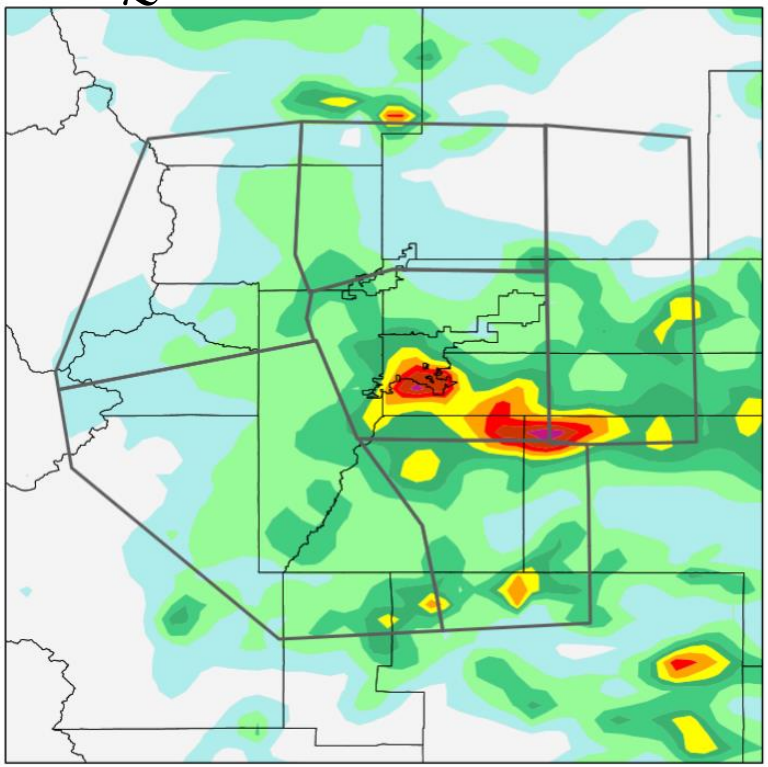


June 10, 2015

1-hr QPFMAX

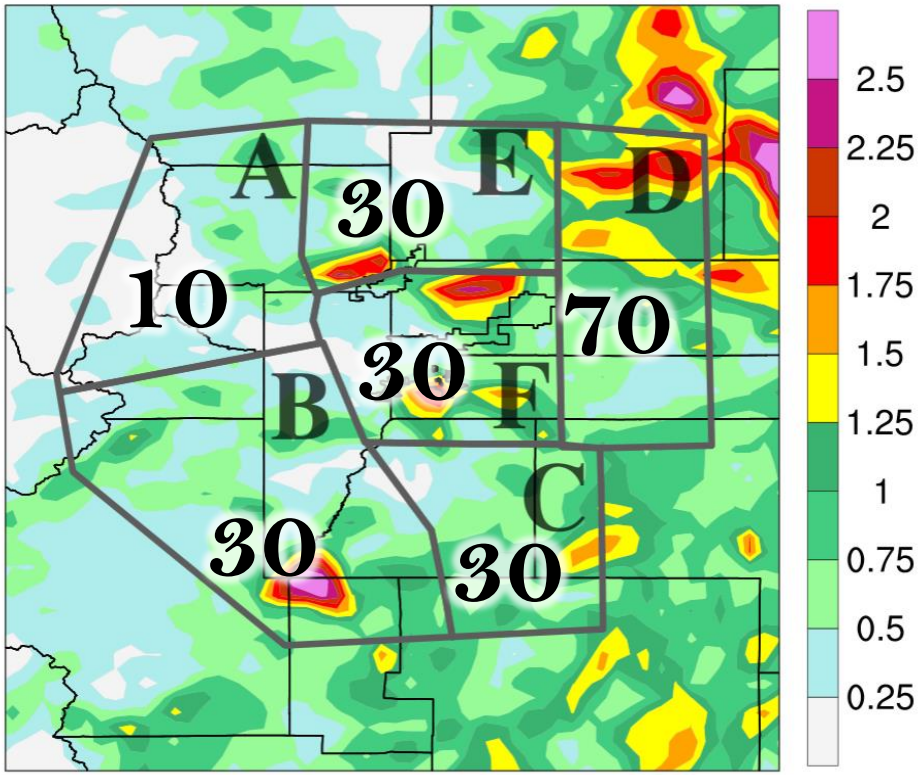


1-hr QPEMAX

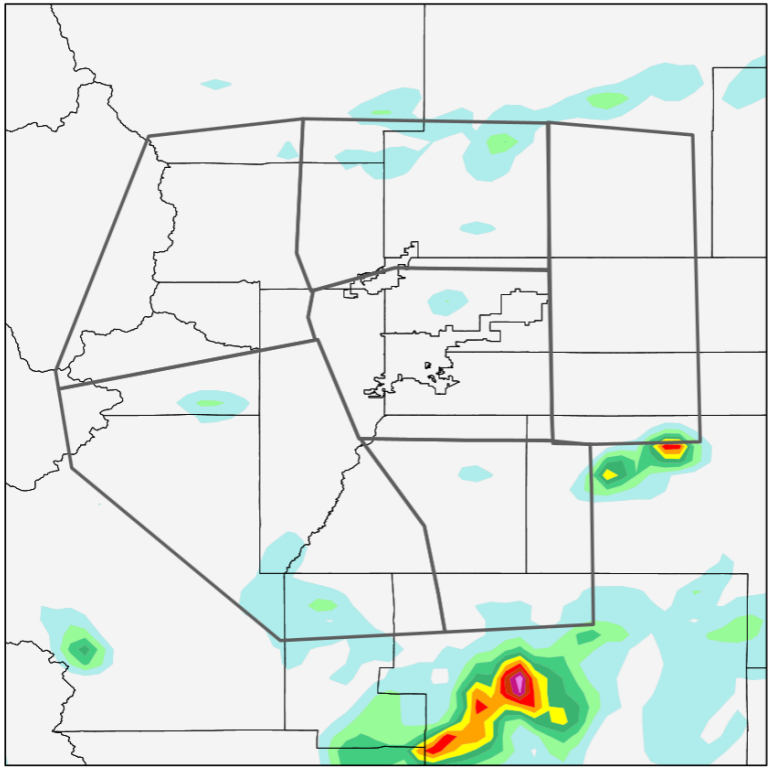


June 15, 2015

1-hr QPFMAX

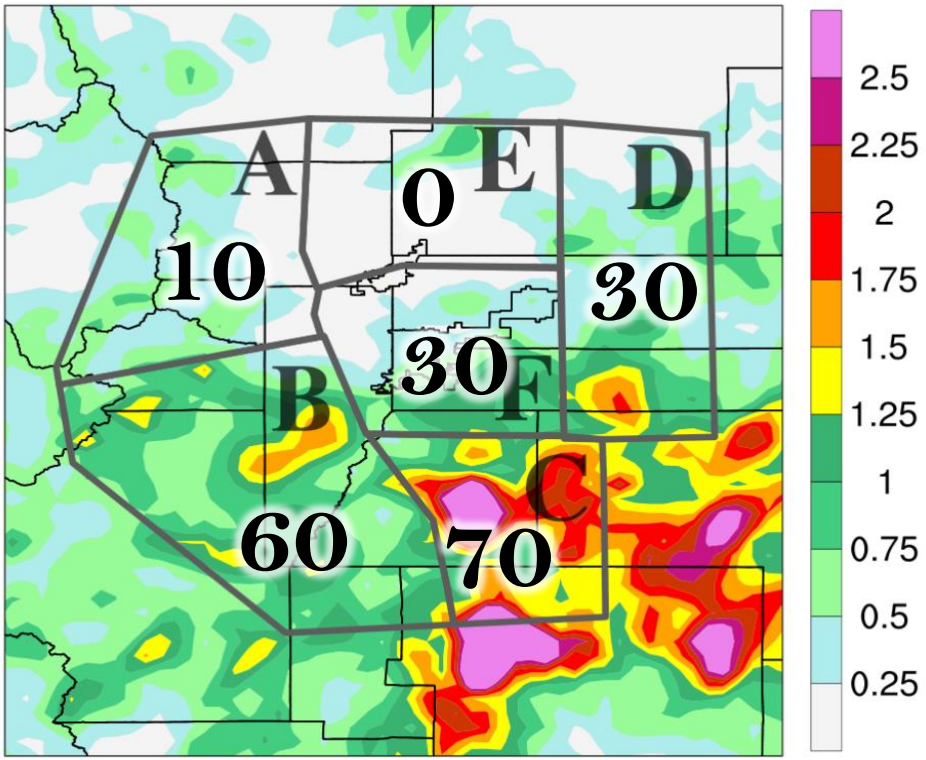


1-hr QPEMAX

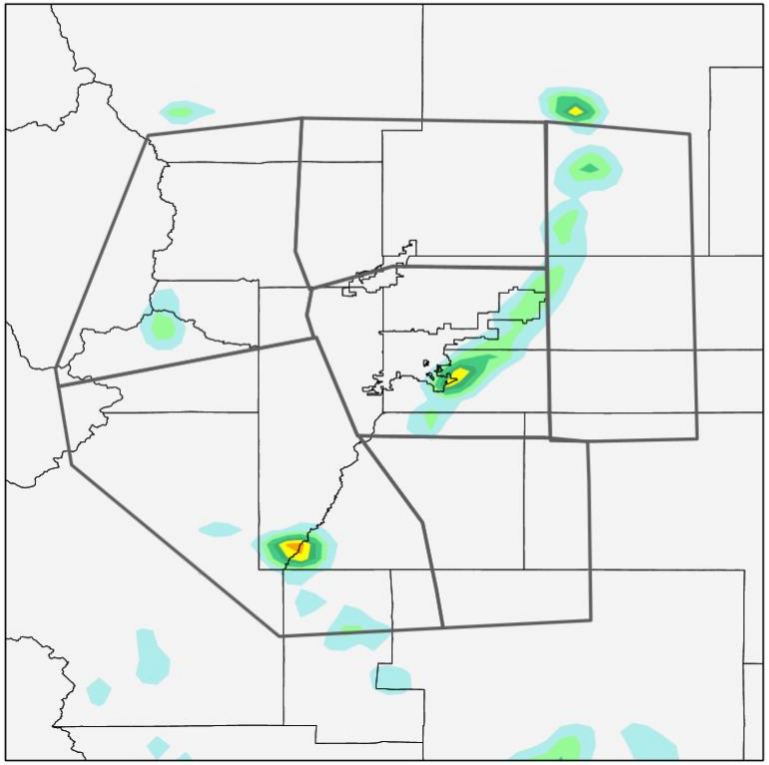


August 11, 2015

1-hr QPFMAX



1-hr QPEMAX



Take-aways

- Tool has so far achieved one of its main goals: provide an realistic estimate of the daily "worst-case scenario"
- Spatial accuracy is not perfect, but can be greatly supplemented with knowledge of probability
- Analysis of timing, location, intensity and confidence verification showed favorable results for first year in real-time setting

Improvements are underway

1. **Model Weighting**: Is there evidence to move away from "every model is equally realistic?"
2. **Historically-based Bias Correction:** Post-process model output using historical observations over the 1980-2015 period (e.g. precipitable water)
3. **(2017) Sub-hourly guidance:** Use archived ALERT data to develop 5-, 15- and 30-minute guidance

http://alert5.udfcd.org