Evaluation of a Radar-Based Multi-Scale Storm Tracking Technique For Very Short-Term QPF

Andrew Osborne
Cooperative Institute for Mesoscale Meteorological Studies, Norman, OK

Jian Zhang
NOAA National Severe Storms Laboratory, Norman, OK

Ken Howard
NOAA National Severe Storms Laboratory, Norman, OK

Motivation

-Short term (0-3 hour) quantitative precipitation forecasts (QPF) important for the anticipation of flash flood occurrence

-Radar extrapolation/nowcasting to obtain QPF estimates may be more accurate than NWP models in this time frame

-NWP models suffer from “spin up” problems due to errors in initial conditions (Lin et al. 2005) as well as longer latency periods for high resolution forecast output to become available (Sokol et al. 2012)

-**Focus on QPF here whereas most previous radar extrapolation work has focused on forecast of storms**

Multi-Radar Multi-Sensor (MRMS)

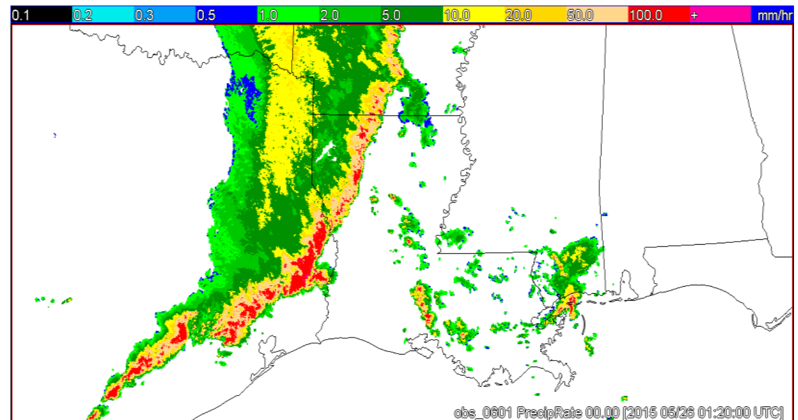
-Suite of QPE data based on input from radar, satellite, and gauges

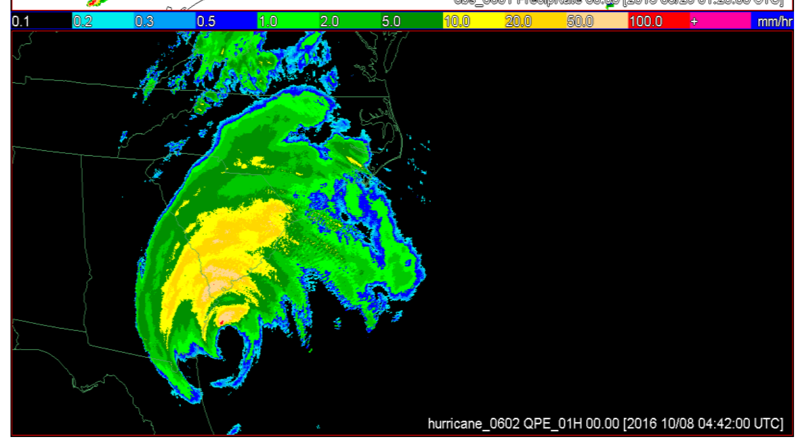
-This work utilizes two of the MRMS products to create forecasts:

- Radar-based rain rate
- Radar-based hourly accumulated precipitation

-2 minute temporal resolution for the real-time MRMS

- 0.01°x0.01° lat/lon spatial resolution





w2segmotion

w2segmotionII, a nowcasting tool from WDSS-II, is evaluated here

How it works (Lakshamanan et al. 2003):

-Identifies K-means clusters of precipitation areas at different scales (hierarchical technique including texture segmentation)

-Generates a motion field via error minimization where a mask of each cluster is moved around the previous image to find the best match

-Variable field (QPE here) is advected using the scale 1 motion vectors obtained for that time

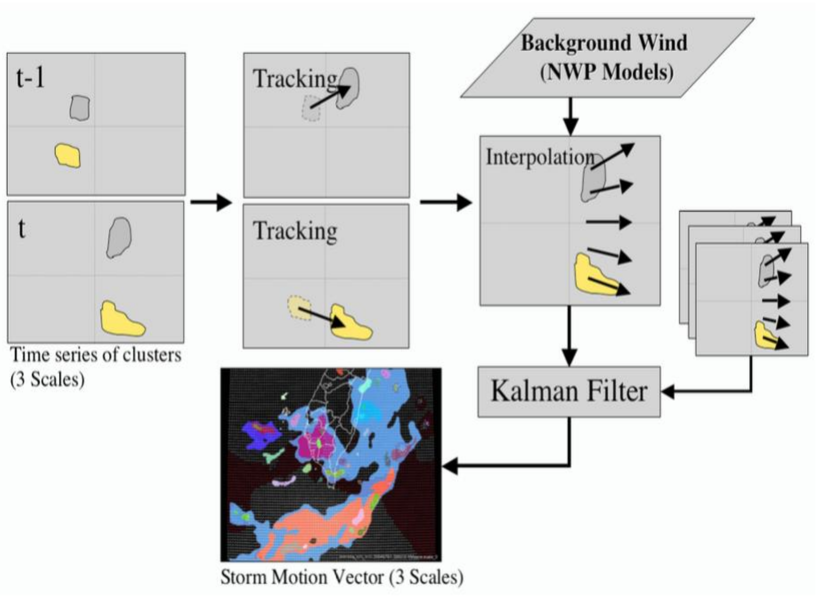


Fig. 1. A flowchart shows the process of storm motion estimation.

Experiments

-Vary active data range with -d parameter

-Vary cluster size with -p parameter

-Use instantaneous rain rate and hourly accumulated rainfall as the field being tracked

-Test inclusion of RAP model wind data into the motion estimate

Verification

-Qualitative verification by visual inspection

-Quantitative comparison of QPF with radar-based QPE via Equitable Threat Score (ETS) calculation

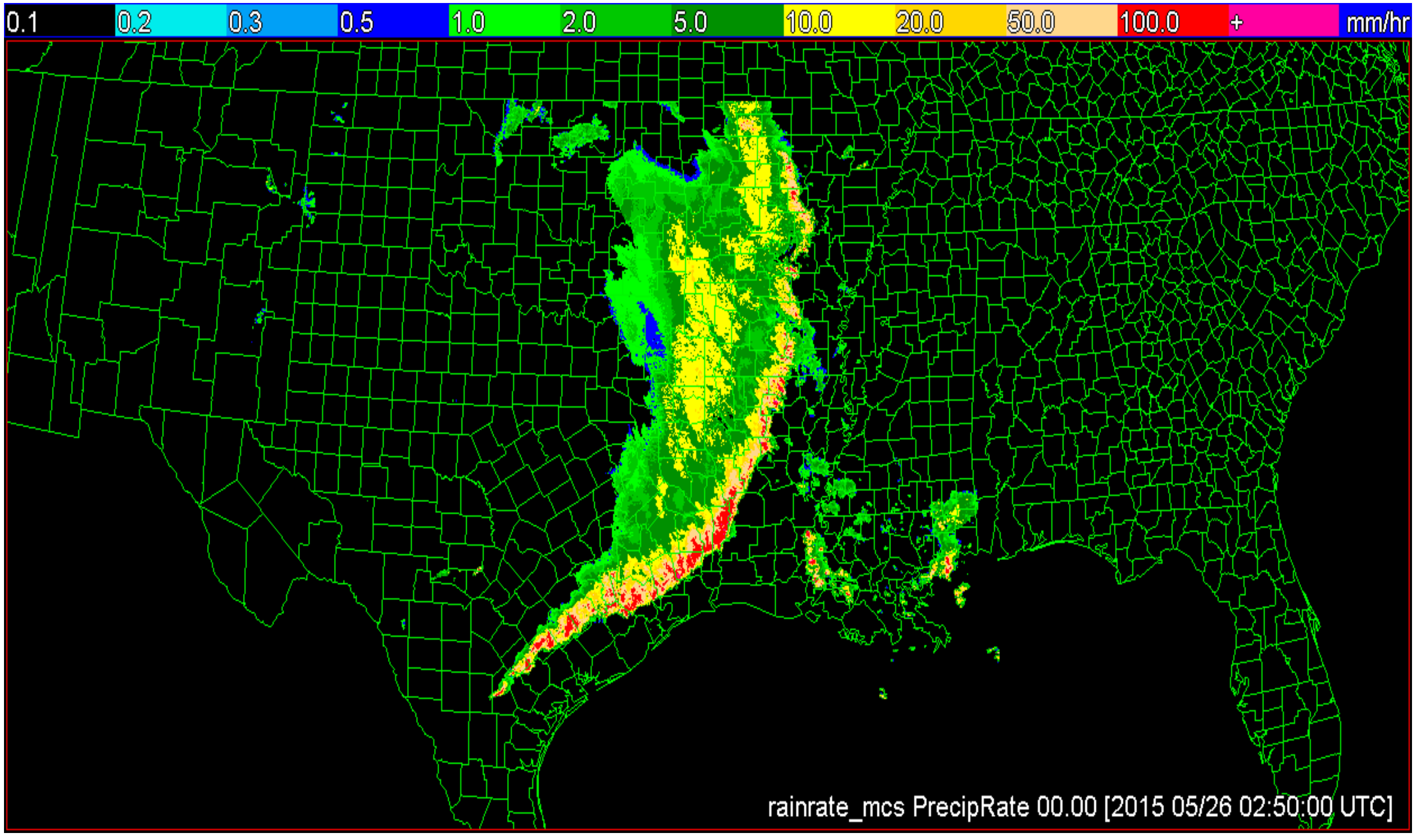
-RMS evaluation using gauge data

Case 1 (26 May 2015 MCS)

-Experiments start at 0220 UTC

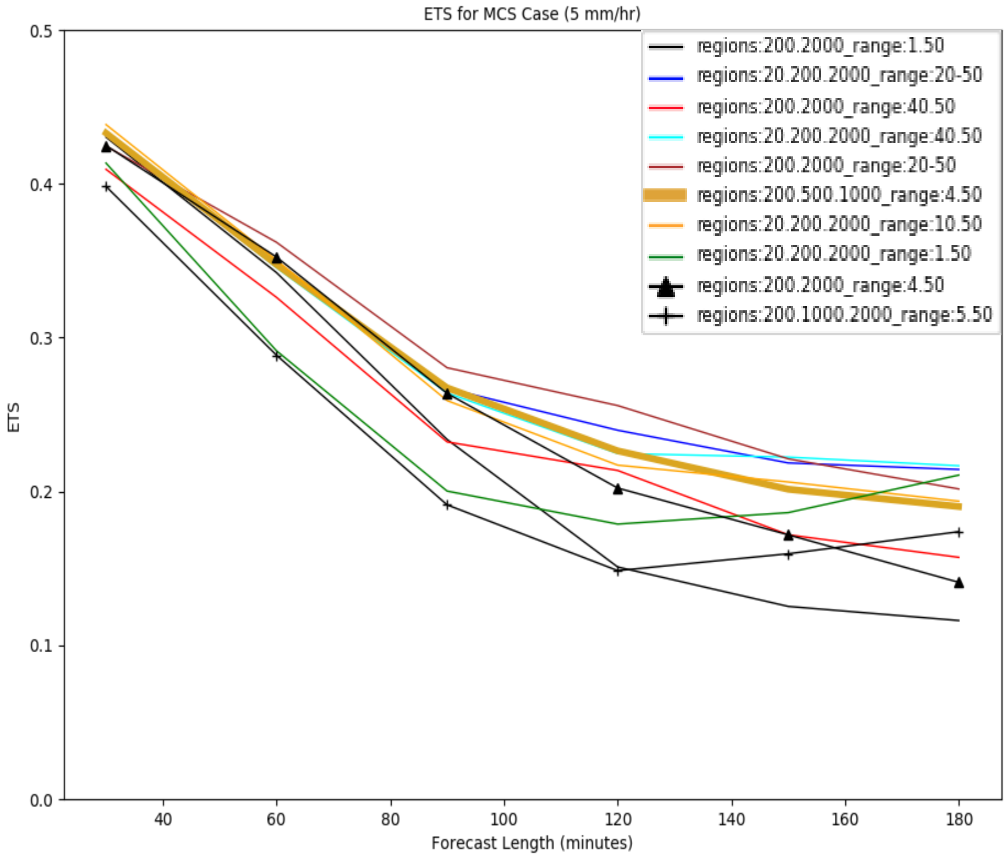
-Forecasts every 30 minutes out to 3 hours

-Different speed and direction along line but overall movement to southeast



Observed radar-based instantaneous precipitation rate

ETS values for better experiments

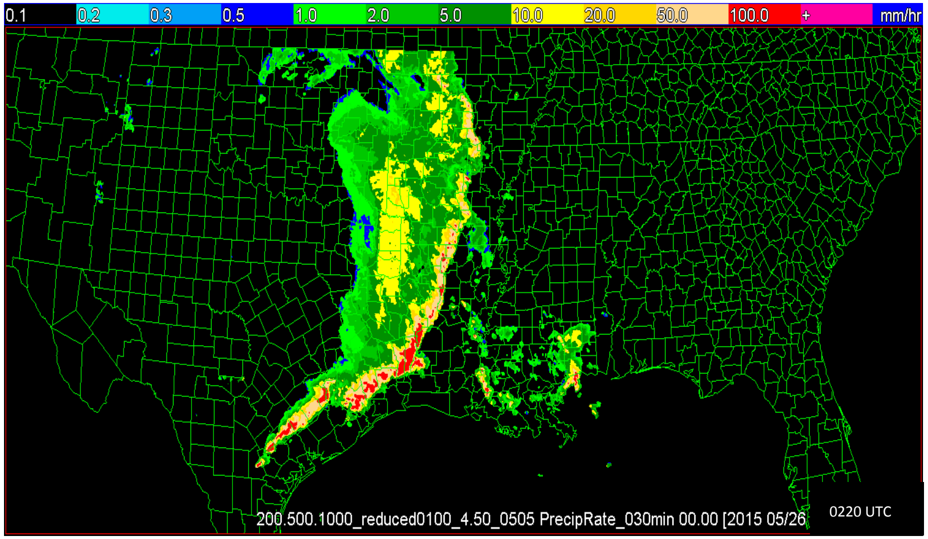


-Threshold: 5 mm/hr

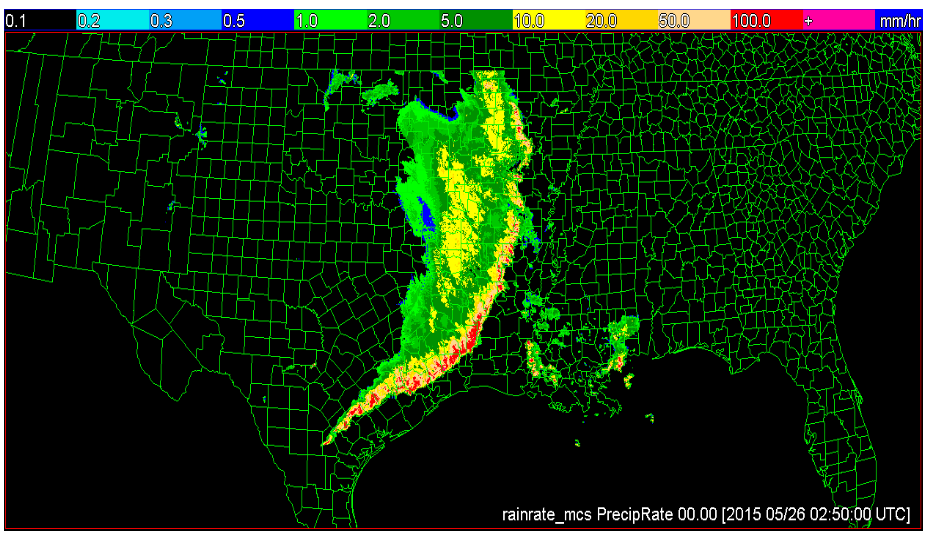
-Experiments with scale 1 clusters that are similar to the scale of the individual convective cells along the line generally perform well

-Each of these experiments track the rain rate field rather than the accumulation field

Exp corresponding to bold gold line (optimal)

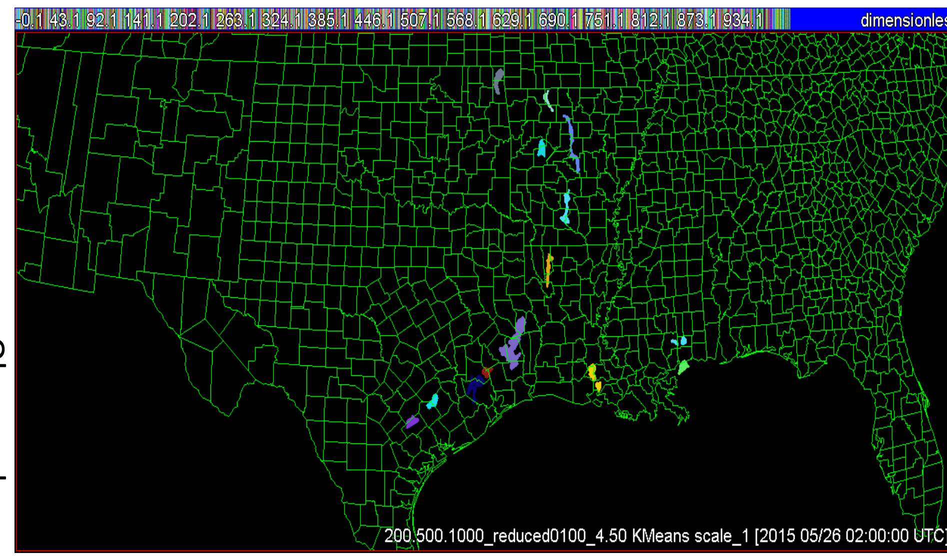


Fcst

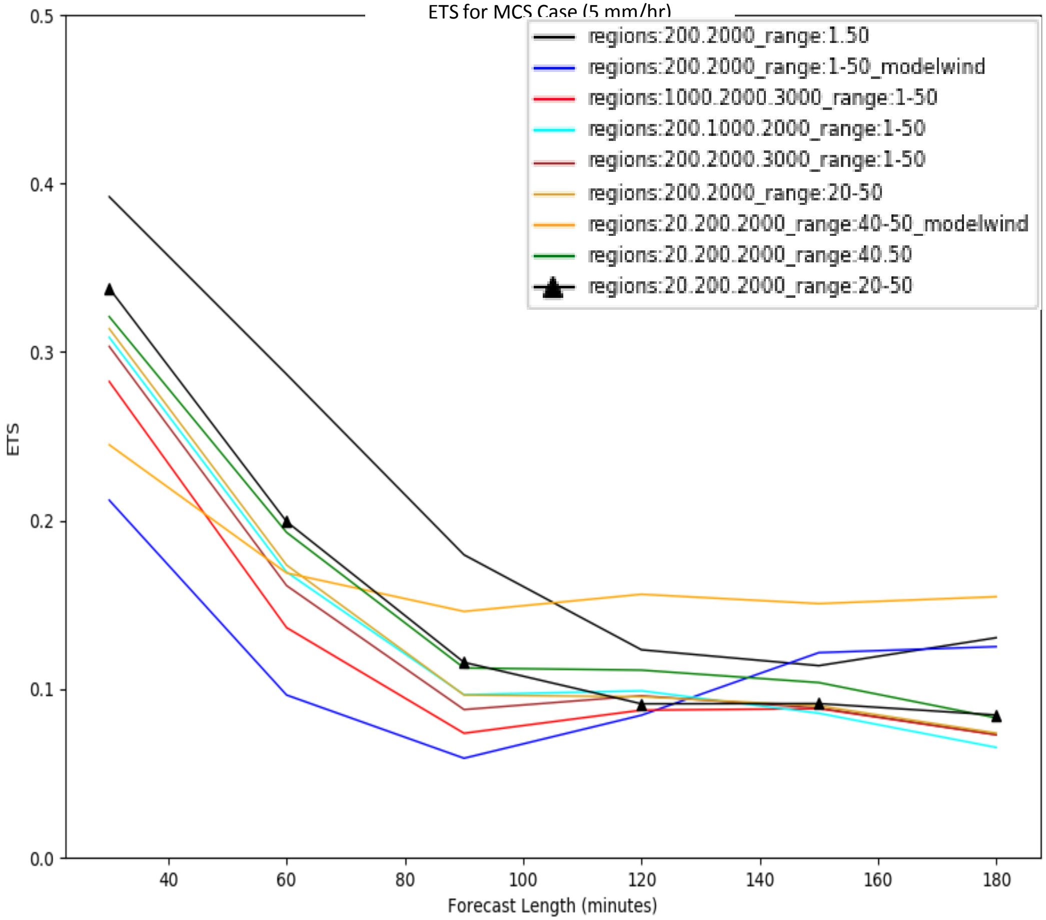


Observed

-d “200,500,1000:0:0.8,0.4,0.2”
-p “4 50 7.5 -1 0.4”
-T PrecipRate
-A PrecipRate
-E 20
-O 20
-F 20 (tracked and forecasted every 20 minutes)



ETS for worse performing experiments



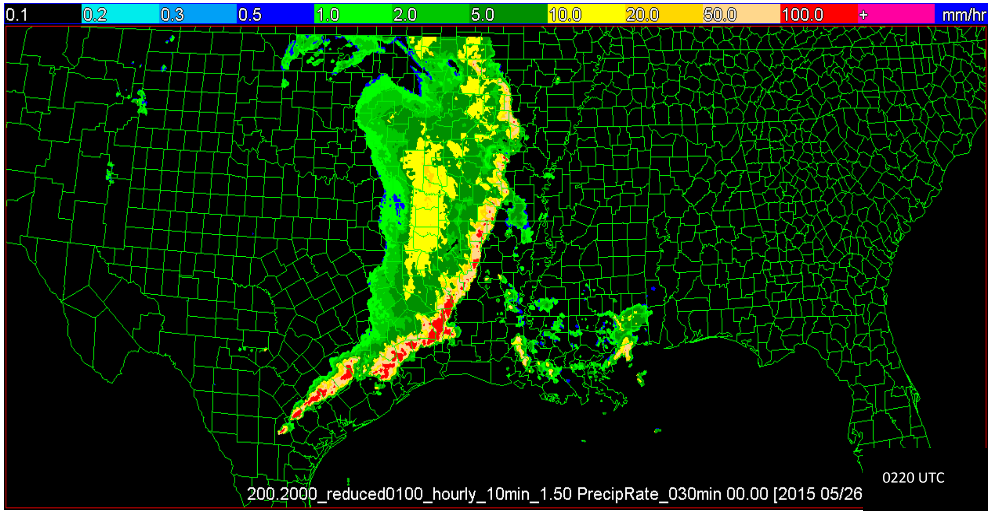
-One large cluster for the whole line in many of these experiments

-Most of these experiments use the accumulation field to do the tracking

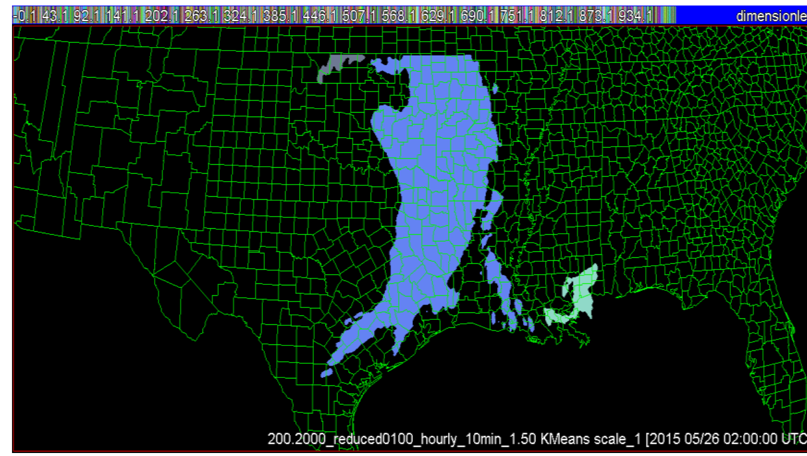
-Some of these poorer performing experiments incorporate the RAP model wind field as a weighted component of the motion estimate

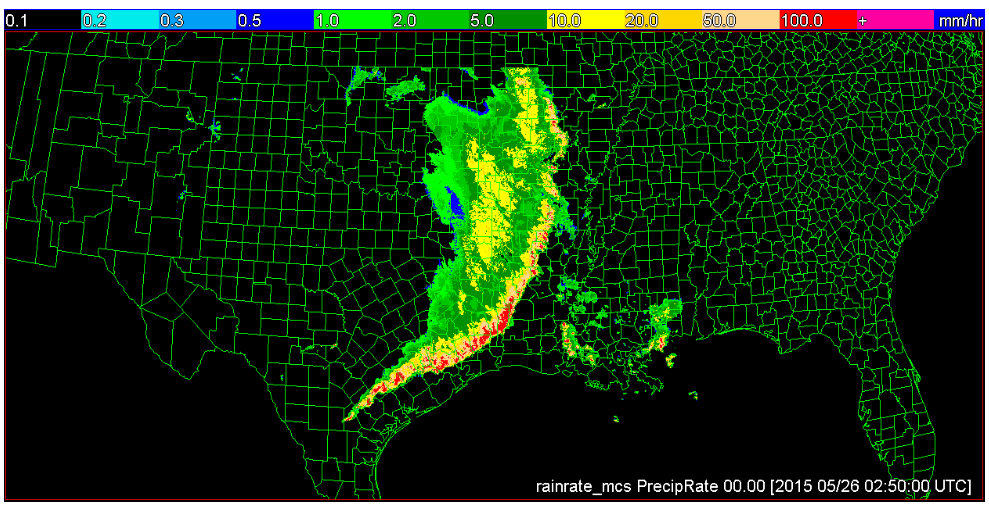
Exp corresponding to solid black line

-d “200,2000:0:0.8,0.4”
-p “1 50 7.5 -1 0.4”
-T QPE_01H
-A PrecipRate
-E 10
-O 10
-F 10 (tracked and forecasted every 10 minutes)



Fcst





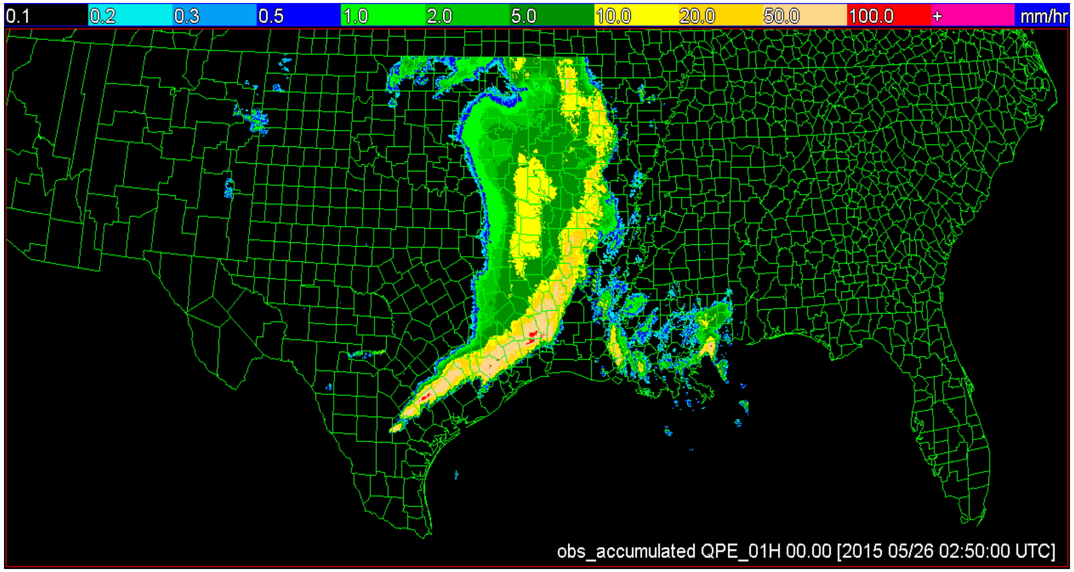
Observed

- The forecast for this experiment is too slow/uniform and does not capture the differential movement of the precip field

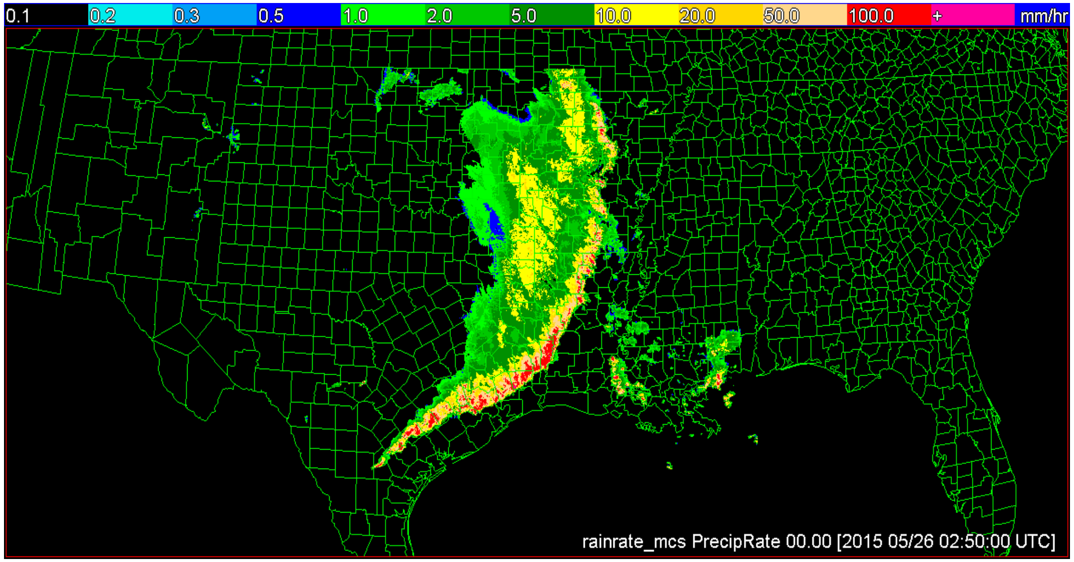
-The accumulation field is broader and smoother with less cell-like structure

-Rate field has many distinct, easily tracked entities along the line allowing for easier differential motion estimates

Hourly Accumulated QPE



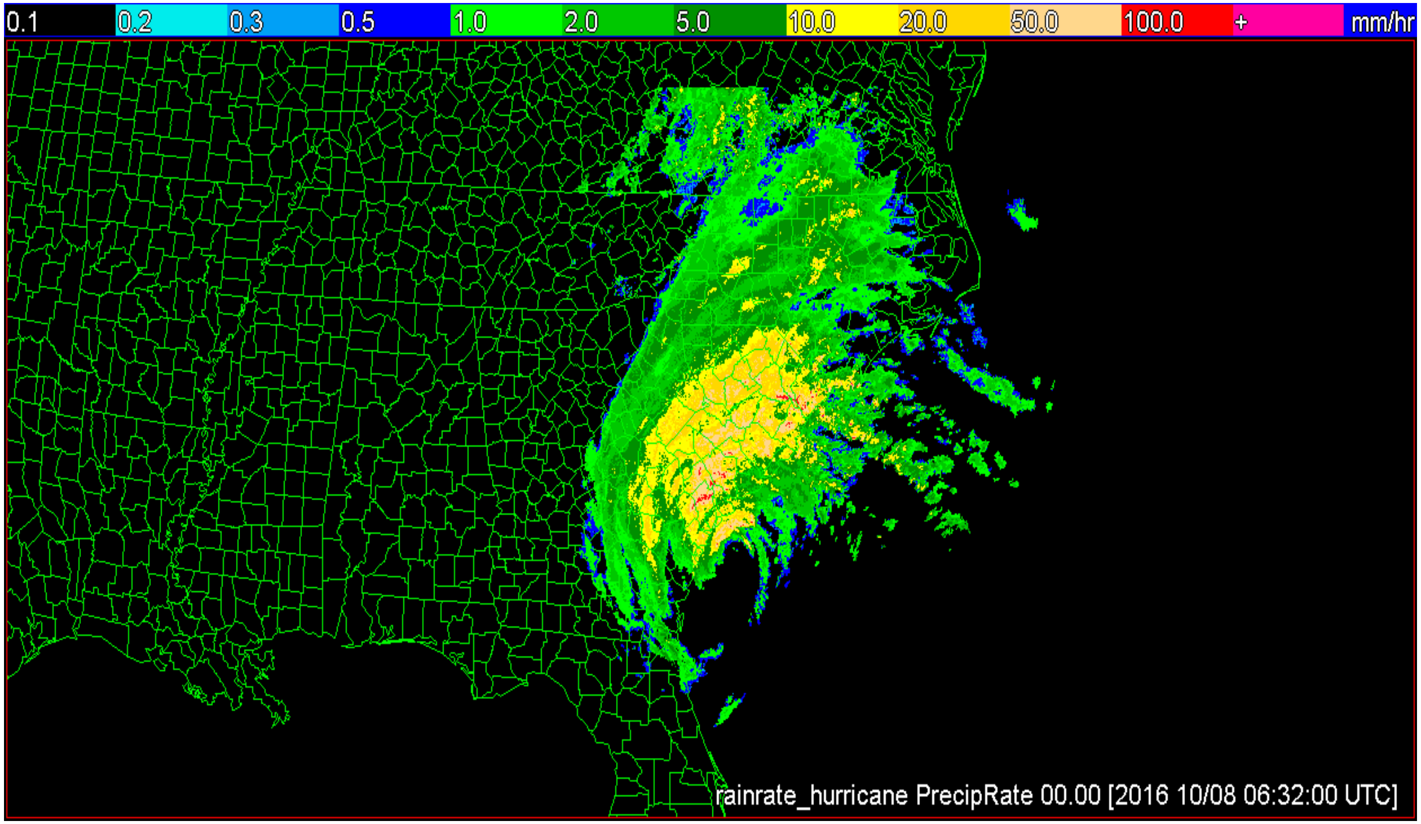
Instantaneous Rain Rate



Case 2 (Hurricane Matthew)

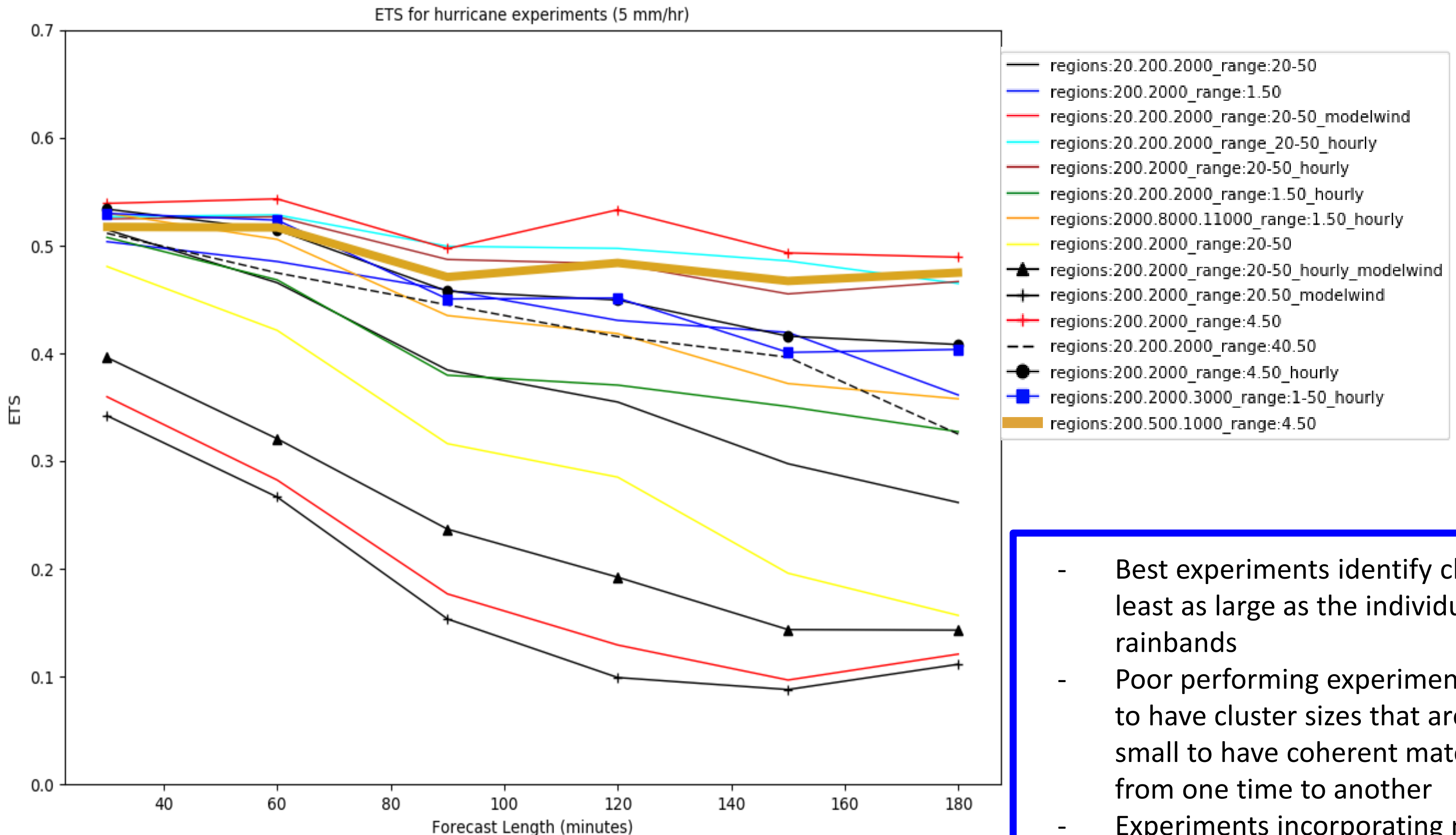
-Experiments start at 0600 UTC

-Center of storm moves NNE along South Carolina coastline while bands rotate to the NW around the center



Observed radar-based instantaneous precipitation rate

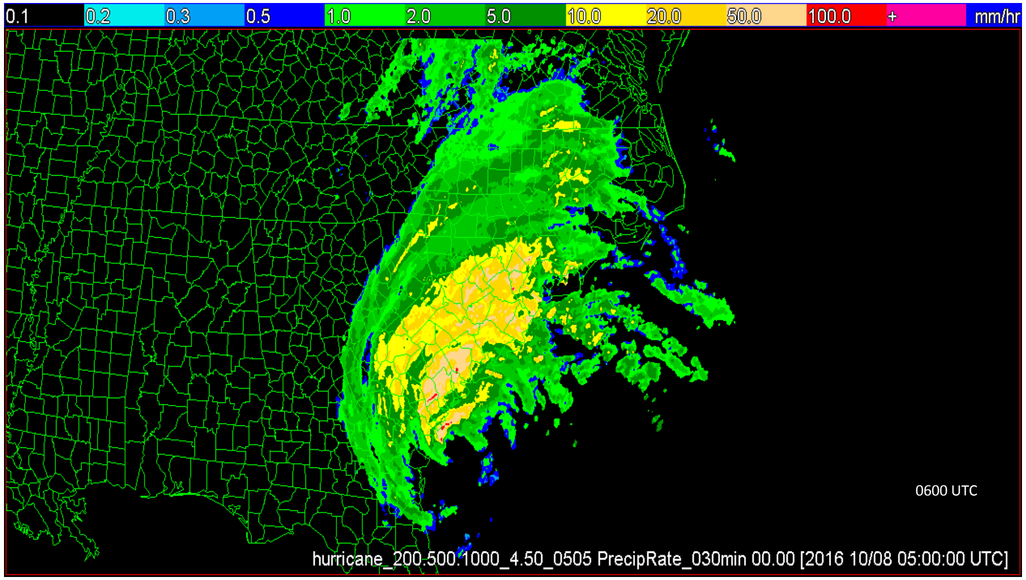
ETS Scores



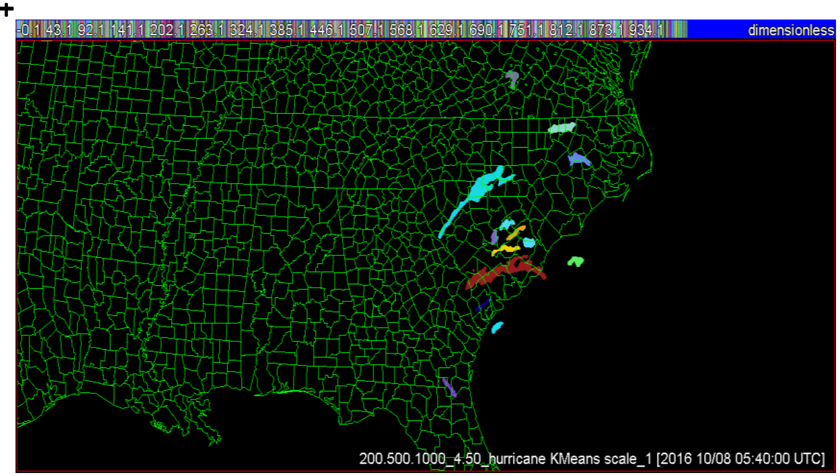
- Best experiments identify clusters at least as large as the individual rainbands
- Poor performing experiments tend to have cluster sizes that are too small to have coherent matches from one time to another
- Experiments incorporating model wind data perform poorly

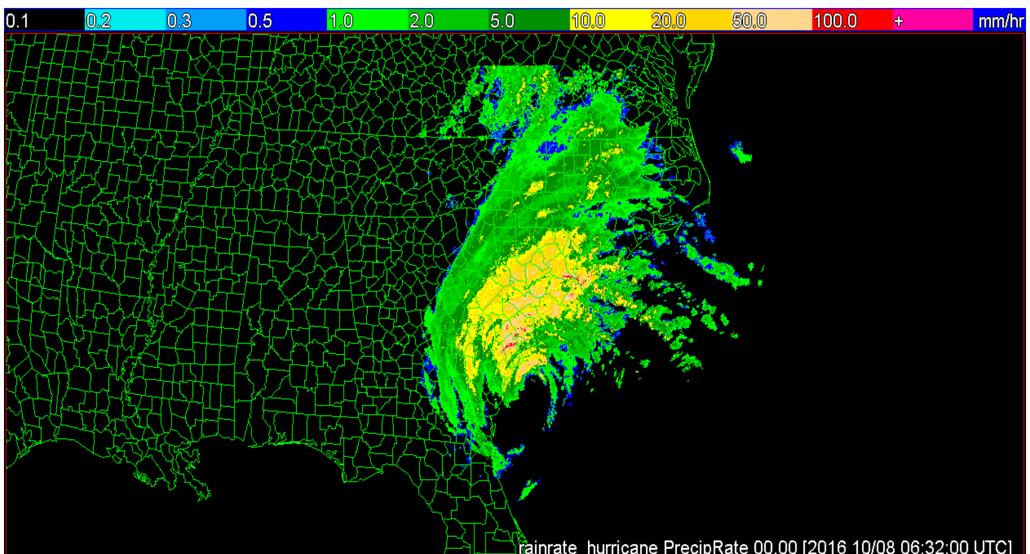
Exp corresponding to bold gold line

-d “200,500,1000:0:0.8,0.4,0.2”
-p “4 50 7.5 -1 0.4”
-T PrecipRate
-A PrecipRate
-E 20
-O 20
-F 20 (tracked and forecasted every 20 minutes)



Fcst



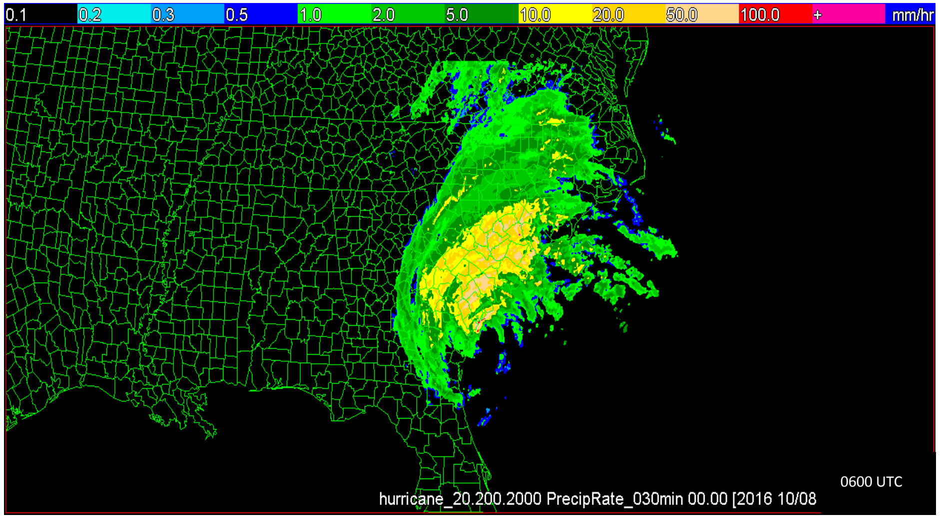


Observed

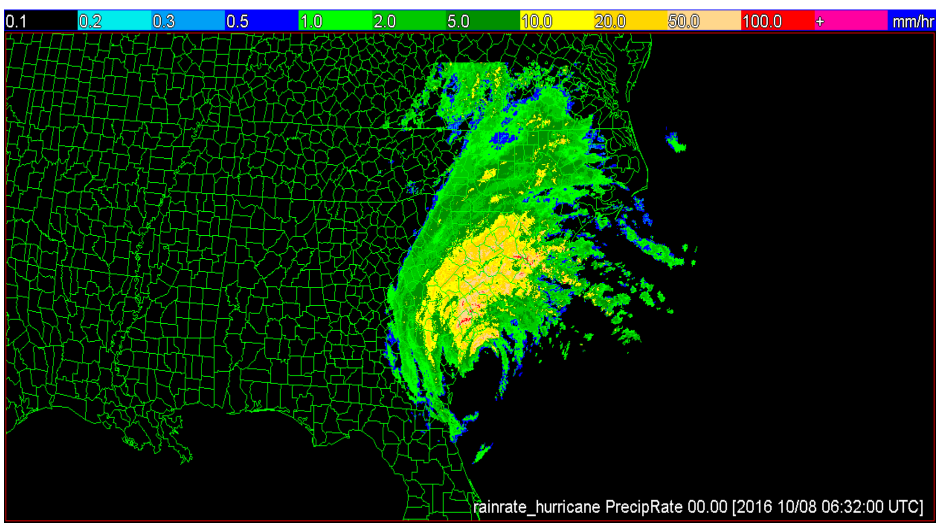
- Clusters have similar shape to bands and are large enough (~500 km^2) to accurately track the overall NNE motion

Experiment corresponding to solid black line

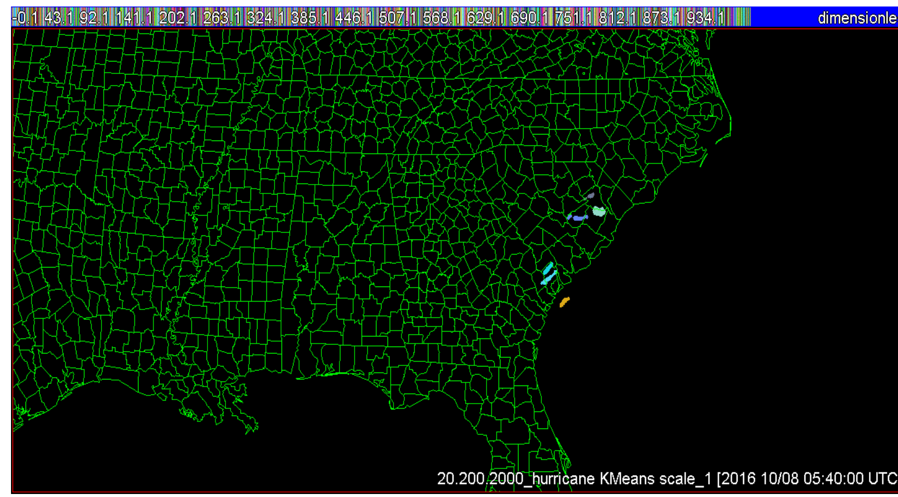
-d “20,200,2000:0:0.8,0.4,0.2”
-p “20 50 7.5 -1 0.4”
-T PrecipRate
-A PrecipRate
-E 20
-O 20
-F 20 (tracked and forecasted every 20 minutes)



Fcst

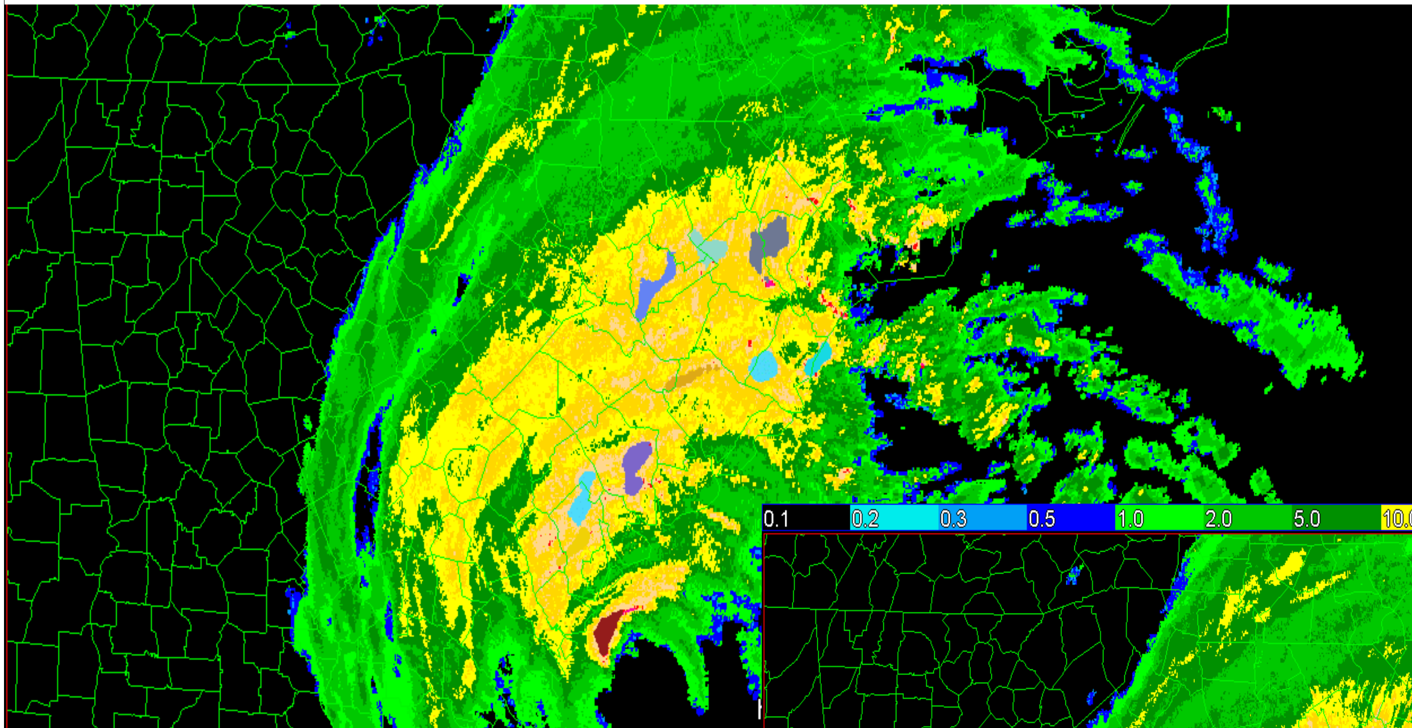


Observed

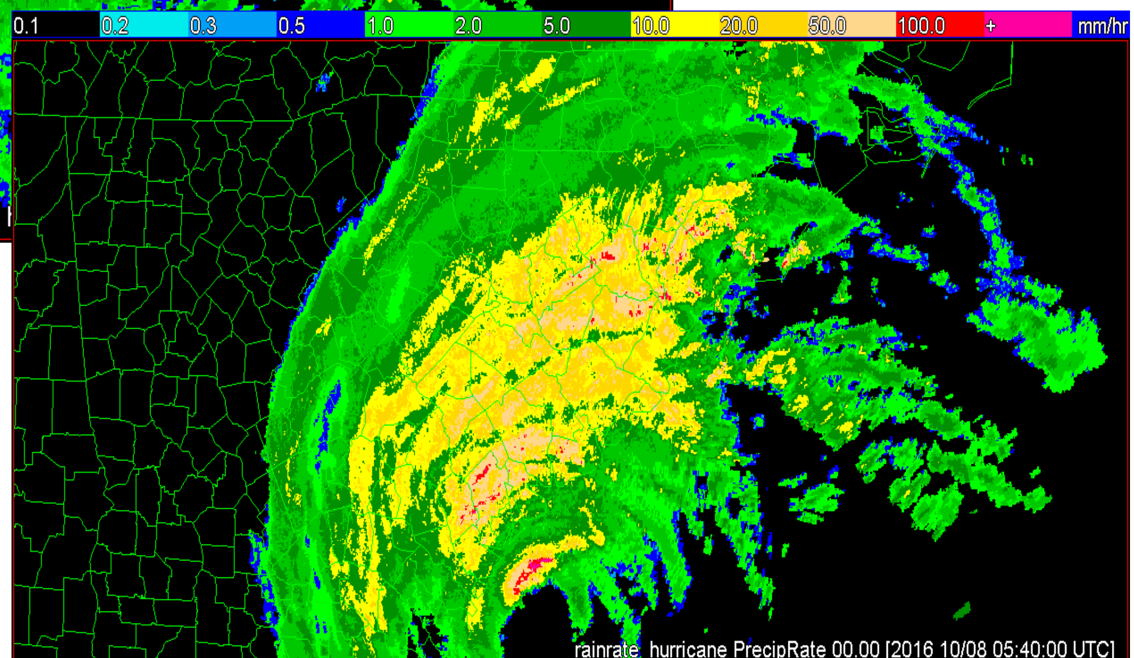


- Clusters identified are smaller than the scale of trackable features for this event
- Result is random associations which can lead to inaccurate motion for the whole system

0600 UTC

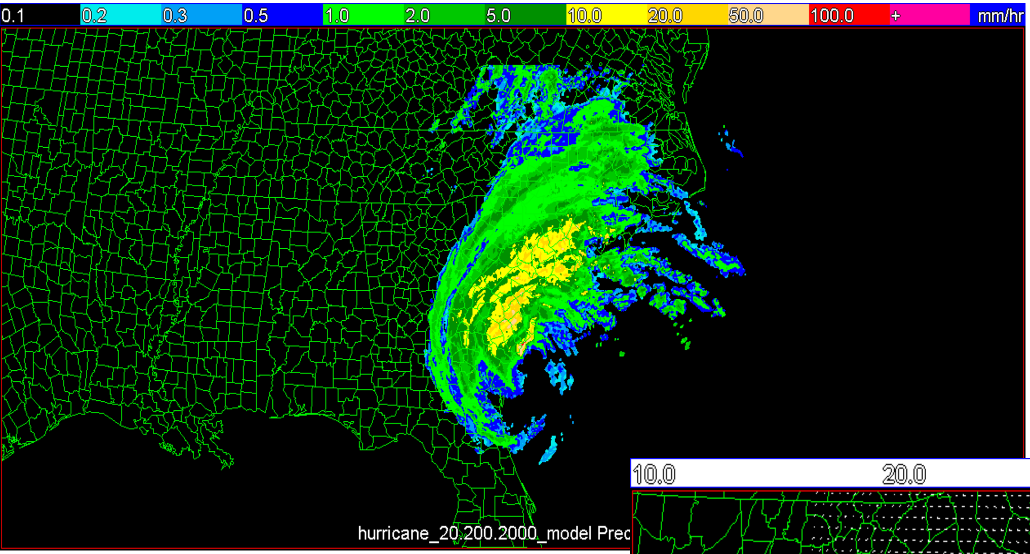


0540 UTC



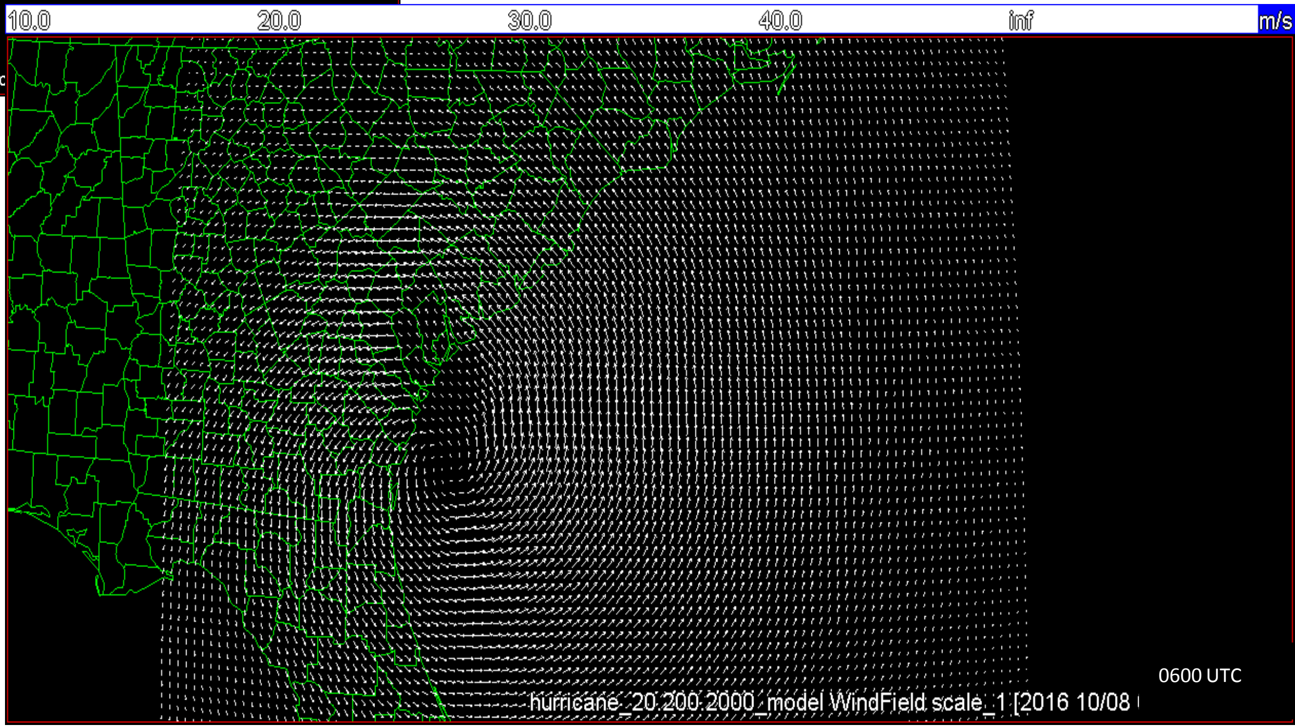
The cells identified for experiment shown on previous slide are too transient to track from the image 20 minutes prior

Experiment with model wind field



-d “200,2000:0:0.8,0.4”
-p “20 50 7.5 -1 0.4”
-T PrecipRate
-A PrecipRate
-E 20
-O 20
-F 20 (tracked and forecasted every 20 minutes)
-w StormMotion_Windfield
(model wind used)

- ❑ Addition of model wind field as a constraint in the motion estimate results in a very rotational motion field
- ❑ Unrealistic circular bands moving radially outward are a result of using these vectors for the 0-3 hr fcst

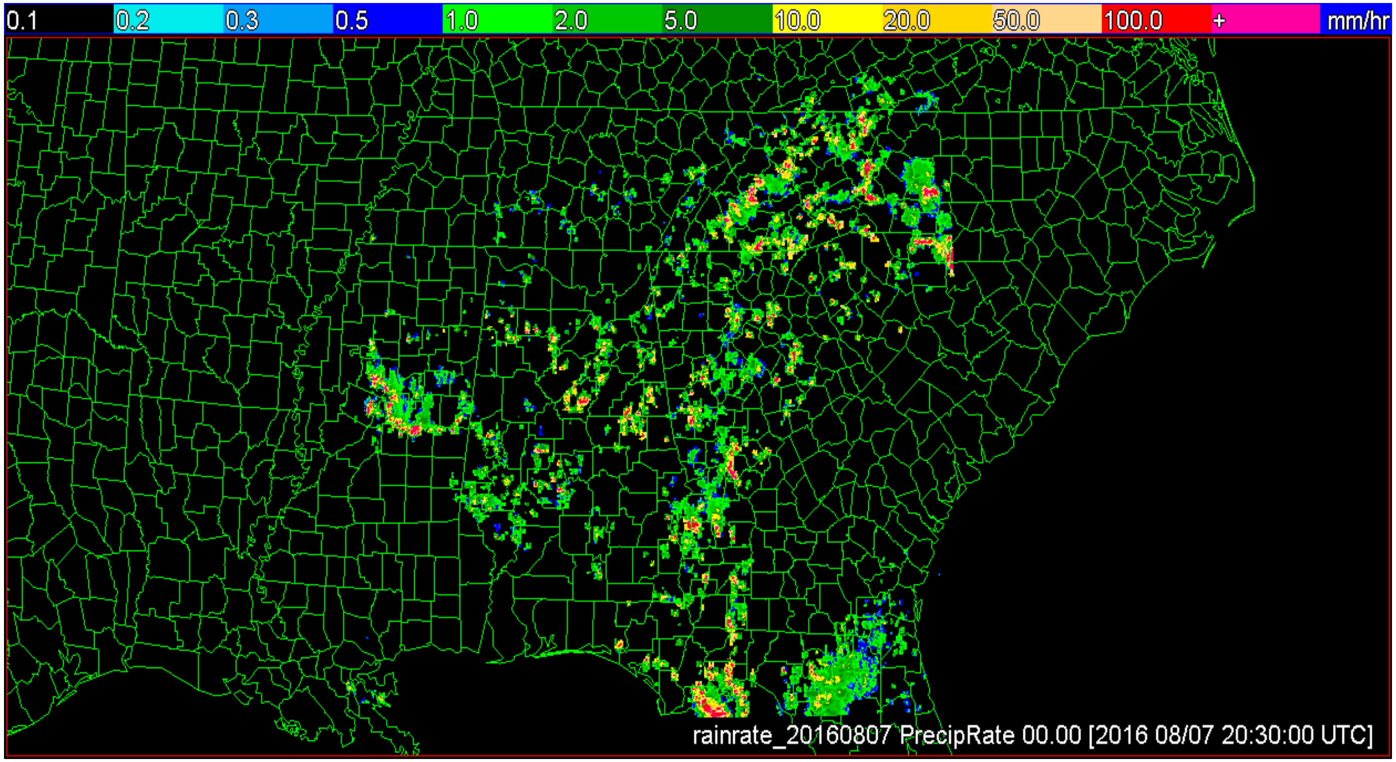


Case 3 (Pop-up thunderstorms)

-August 7, 2016

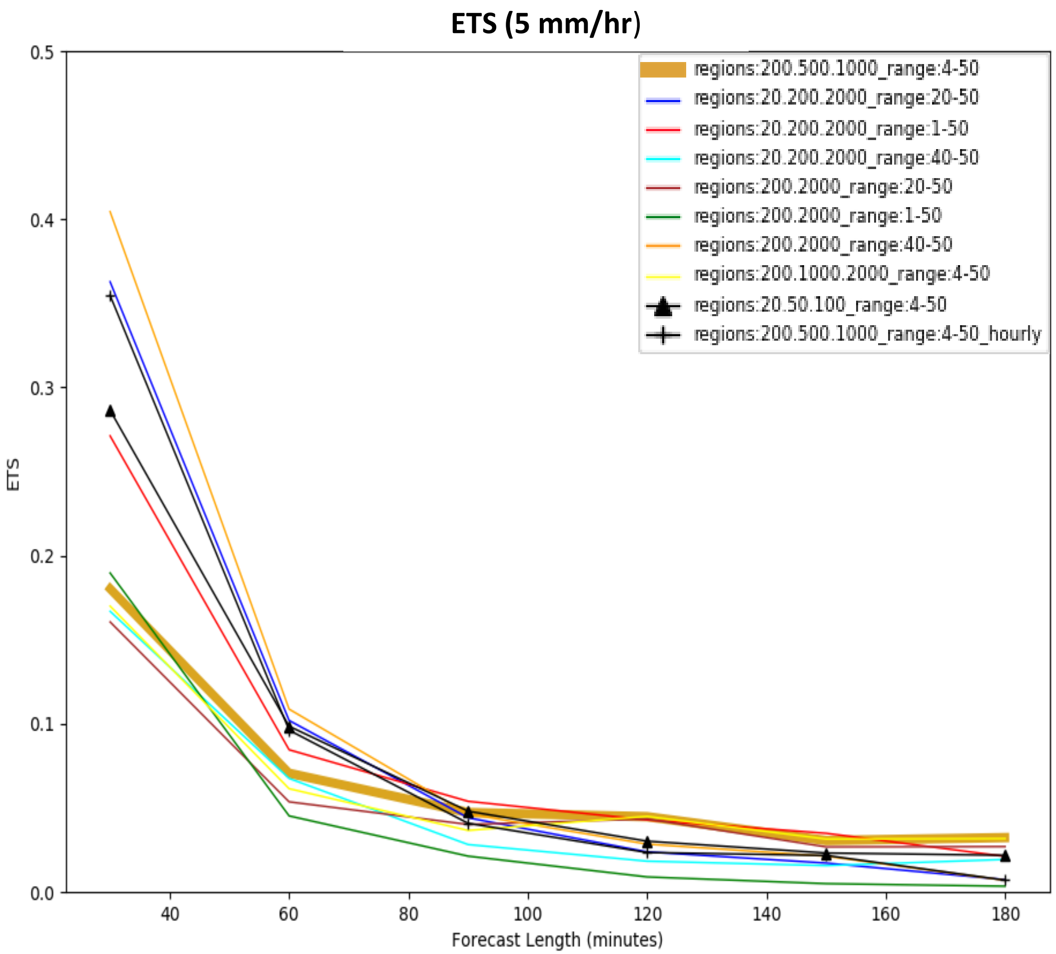
-Experiments start at 2000 UTC

-Thunderstorms pulse up and down without much movement



Observed radar-based instantaneous precipitation rate

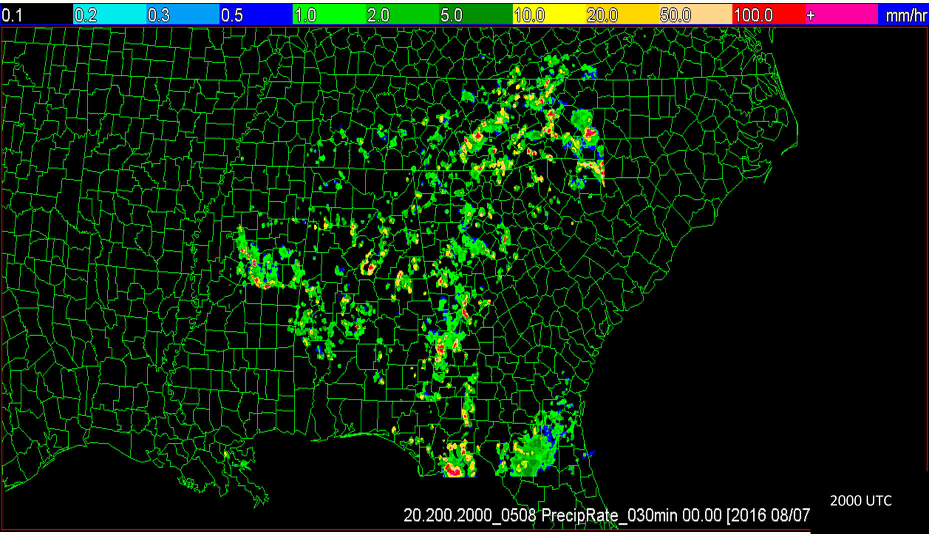
Case 3



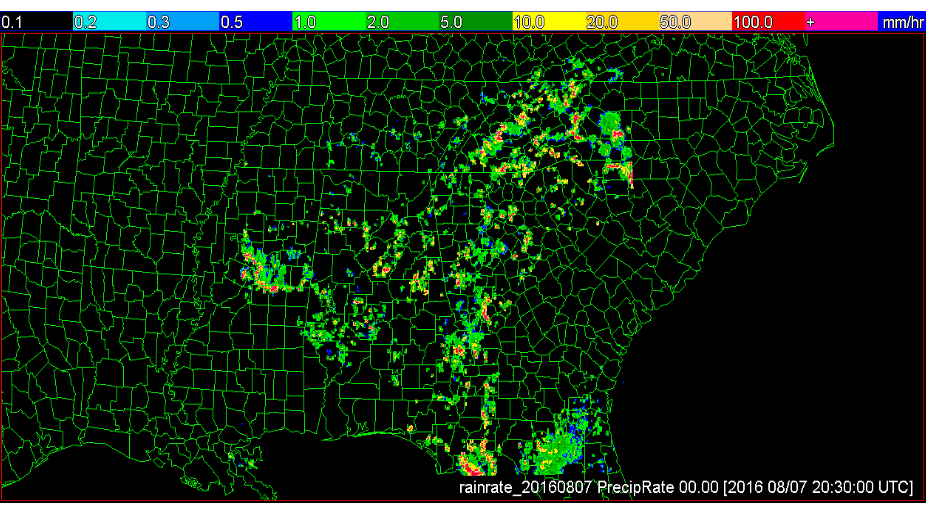
-Complex setup with many storms initiating, decaying, and interacting on very short time scales results in poor performance from the radar extrapolation method, especially beyond a 1 hour forecast

Exp corresponding to solid blue line

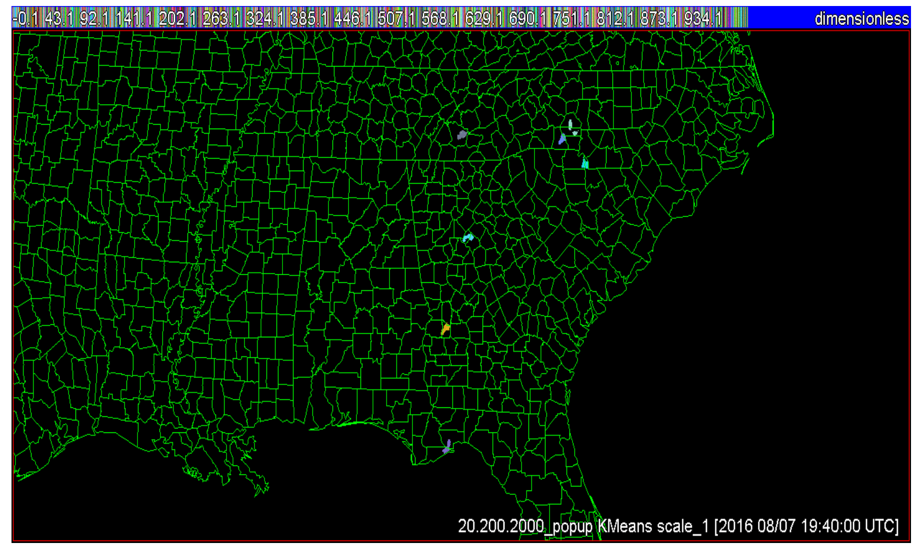
-d "20,200,2000:0:0.8,0.4,0.2"
-p "20 50 7.5 -1 0.4"
-T PrecipRate
-A PrecipRate
-E 20
-O 20
-F 20 (tracked and forecasted every 20 minutes)



Fcst

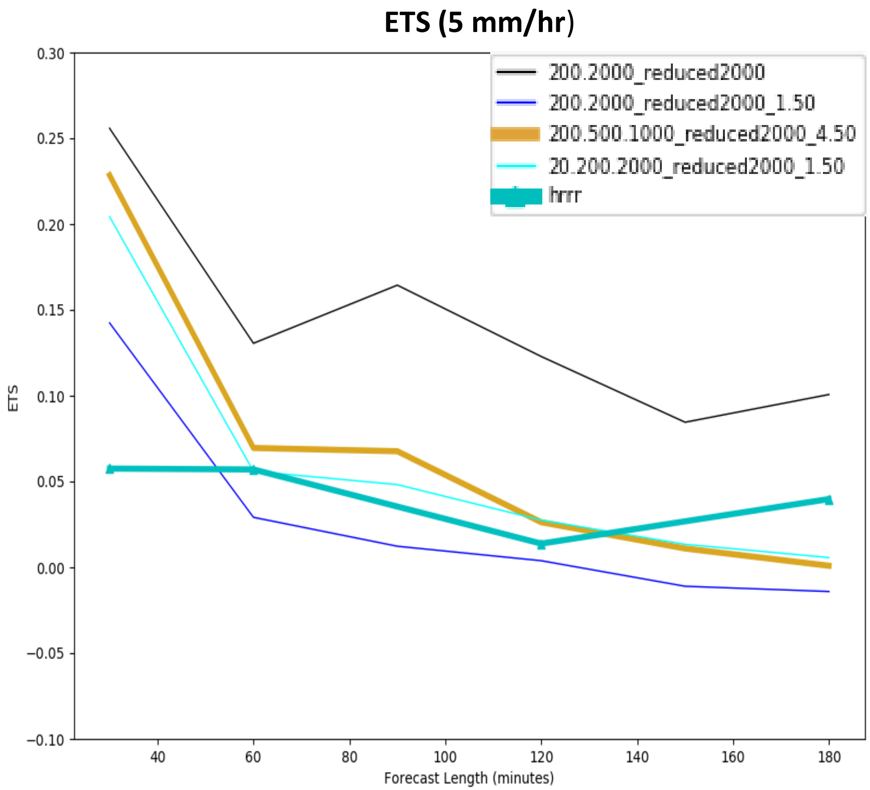


Observed

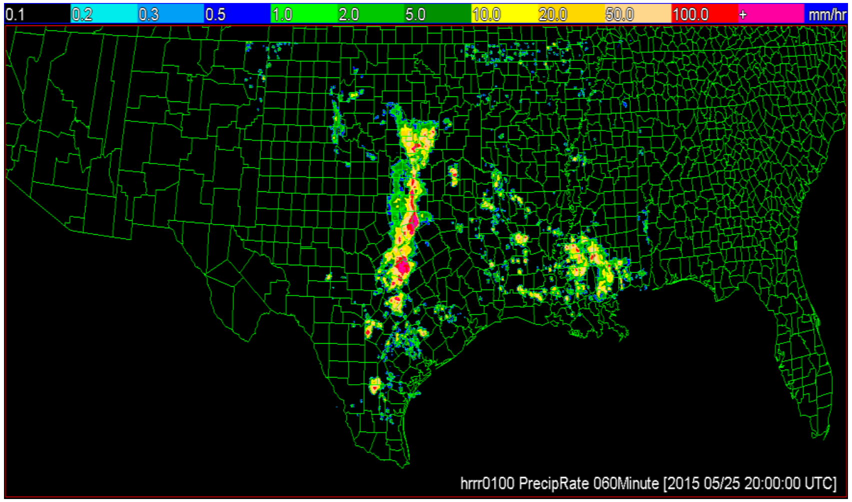


- Identifies a few small KMeans clusters at scale 1
- Forecast is nearly stationary with only a couple areas where cluster-based motion estimates were available

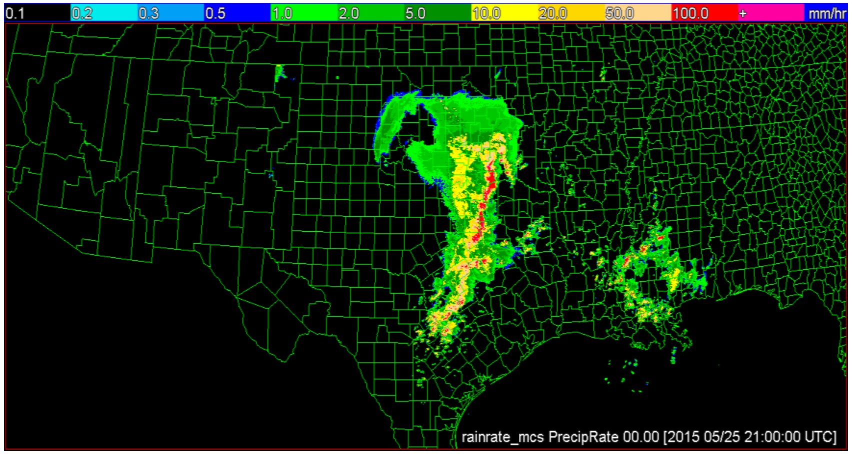
MCS Case Stats with HRRR



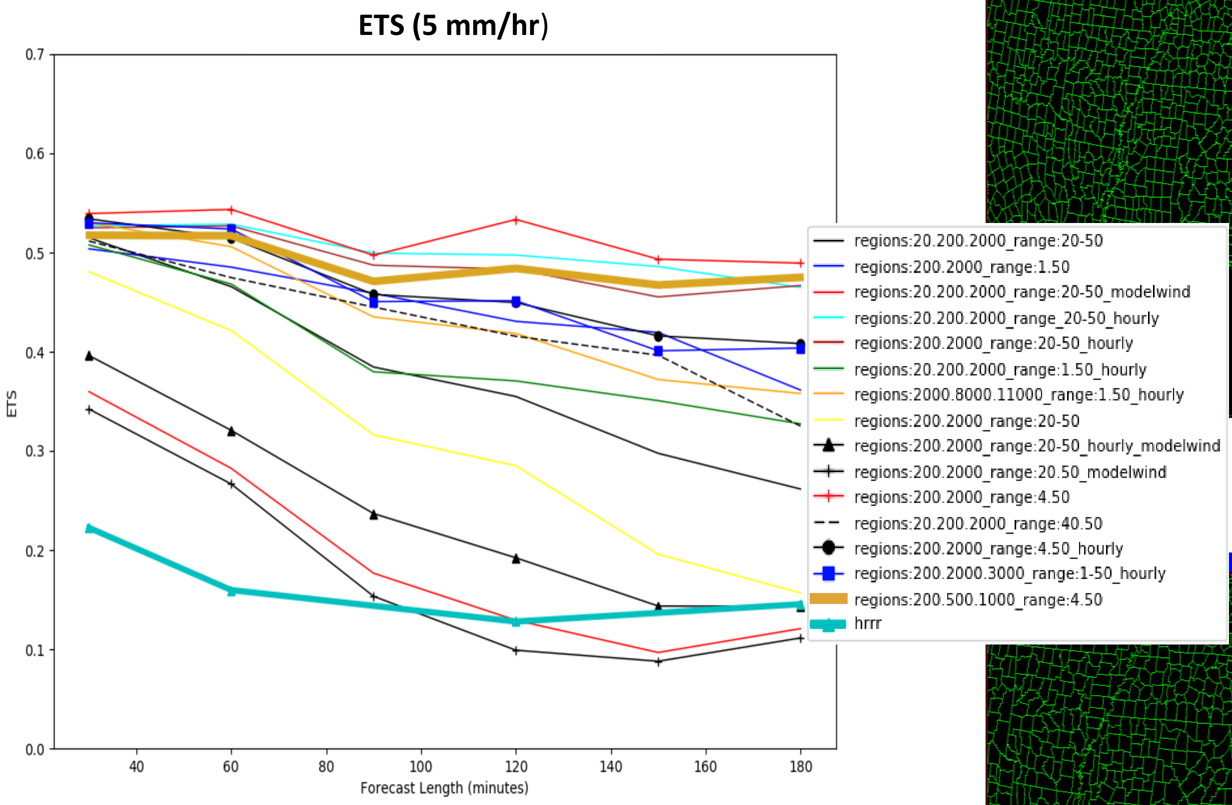
HRRR Forecast



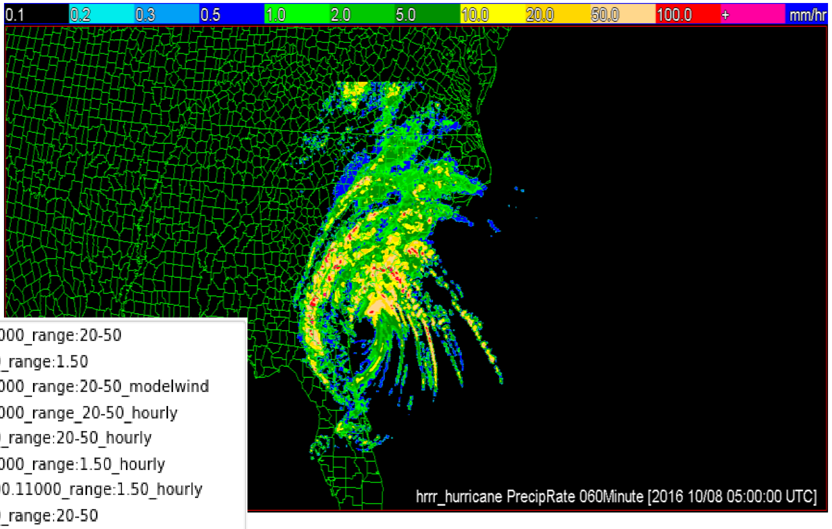
Observed



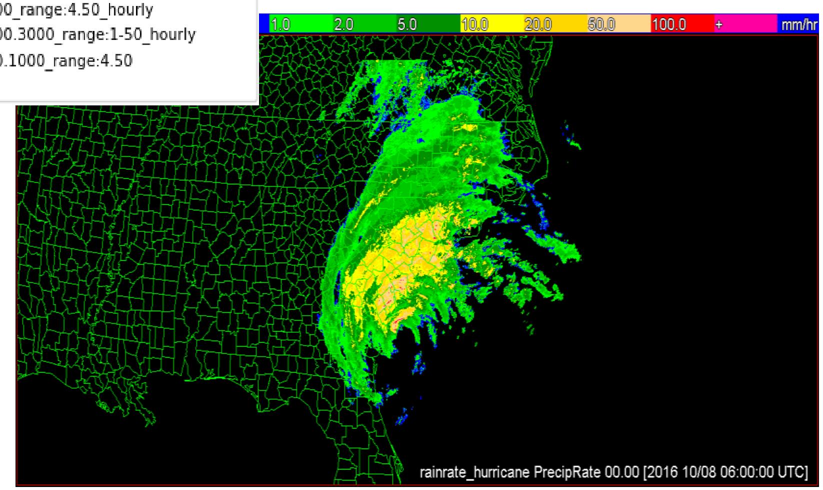
Hurricane Case ETS with HRRR



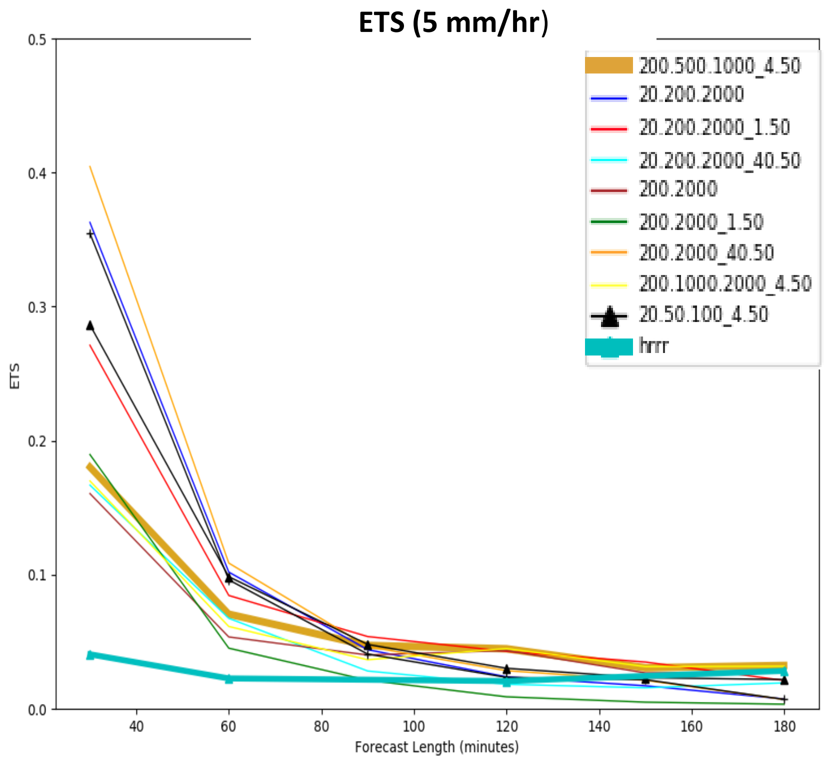
HRRR forecast



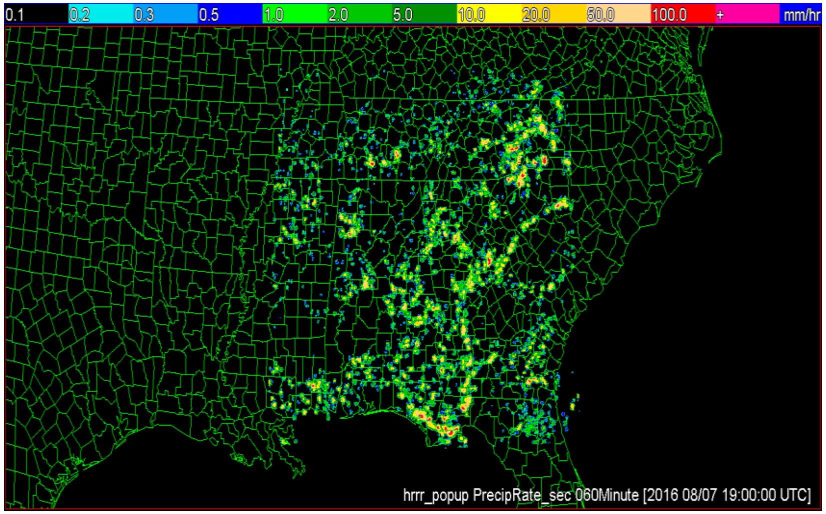
Observed



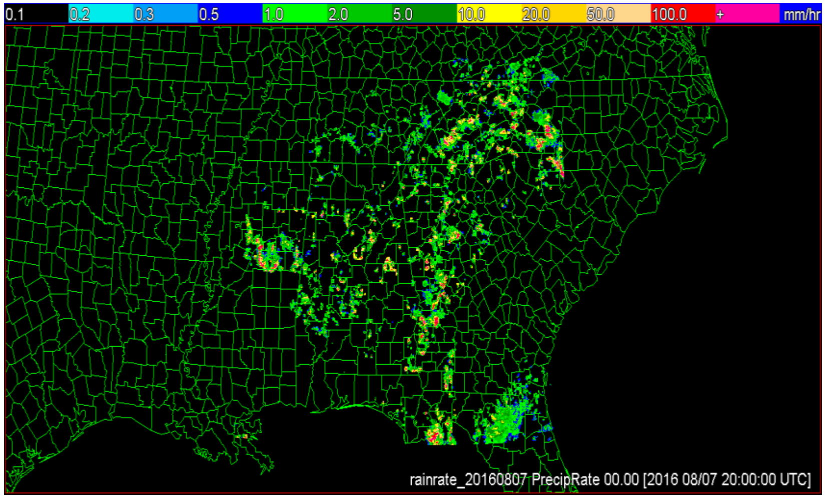
Pop-up Thunderstorm Case Stats with HRRR



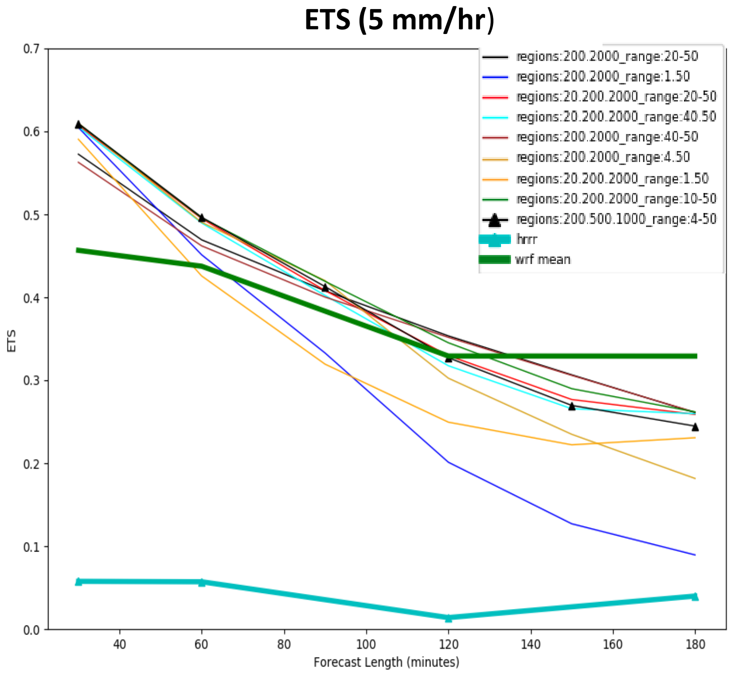
HRRR Forecast



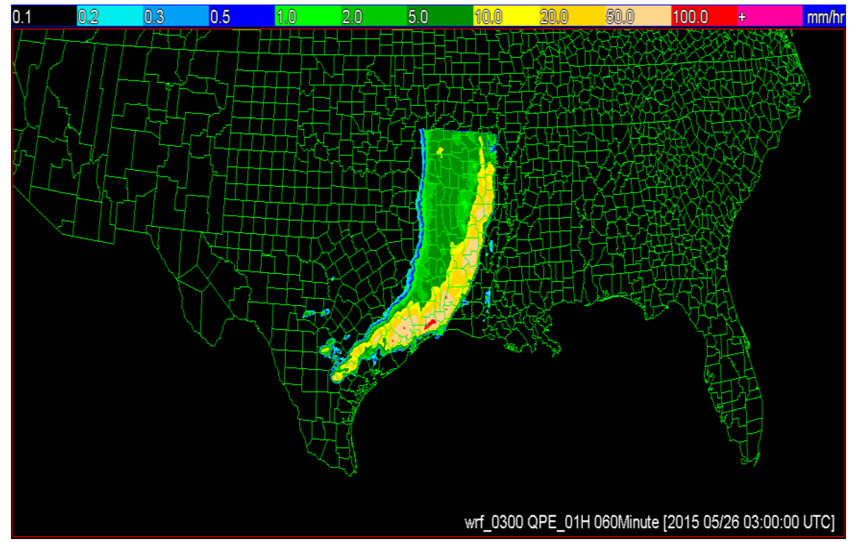
Observed



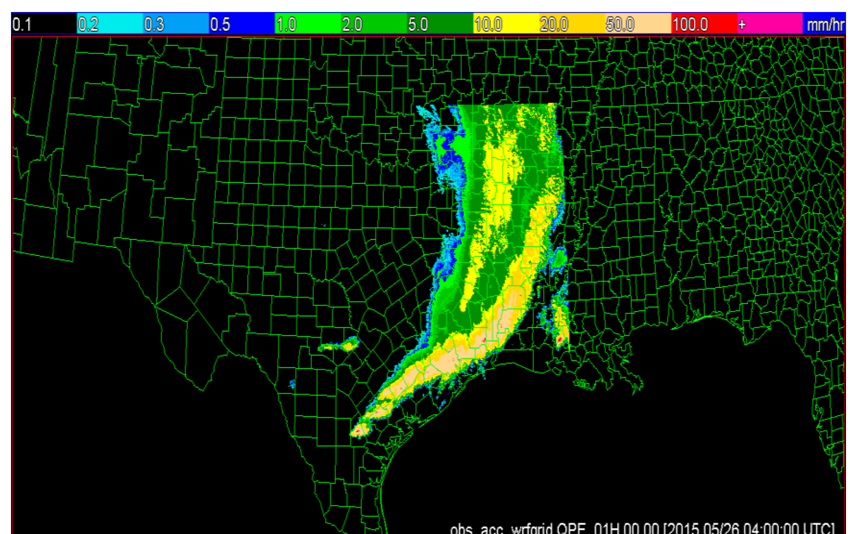
WRF Verification



WoF WRF



Observed



-Radar extrapolation looks to have value over WRF for the 0-60 minute forecast

Conclusions

Identified optimal parameter settings for each case

-optimal experiments result in QPF skill that is substantially better than the HRRR and near the level of the WRF WoF ensemble

Forecasts are highly dependent on the identified clusters

-most accurate forecasts identify precipitation areas similar to the scale of trackable entities for the particular event

Incorporation of RAP model wind data:

-mostly not helpful in the MCS case other than to correct for highly erroneous motion vectors resulting from misassociations

-degrades forecast performance in the hurricane case

Tracking accumulation field rather than rate field results in less accurate forecasts for MCS case

-difference for other two cases less conclusive

Radar extrapolation approach with suggested modifications seems to be capable of generating high accuracy QPF in the 0-2 hour time frame

Recommendations/Future Work

Should preferentially search in the direction of the background wind field for object association

-Segmotion searches over a box surrounding the center point of each cluster resulting in many mis-associated cells

Track areal changes to allow for forecast of growth and decay in size of cells

-Segmotion currently includes only an adjustment for tracked intensity changes

Radar extrapolation parameter settings should be optimized for the scale of precipitation areas present. The determination of which parameters settings to use could be made in real time via a storm scale analysis or ensemble of radar extrapolations