Towards an object-oriented validation system for high-resolution NWP models

Janice L. Bytheway and Christian Kummerow
Department of Atmospheric Science
Colorado State University
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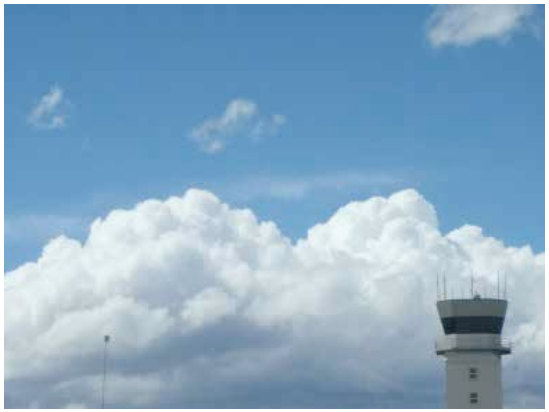
Introduction

- Many improvements to models in recent years
  - Increased resolution
  - Improved assimilation
  - Assimilation of cloudy and precipitation-affected observations
- St
  - What makes a good forecast?
  - How does HRRR perform with assimilated radar?
  - How does HRRR performance evolve with time?
  - What can observations tell us about what the model is doing well/poorly?
- High Resolution Rapid Refresh (HRRR)
  - Designed for convection
  - Radar reflectivity assimilation (diabatic initialization)
  - 15-hour forecasts produced hourly at 3km
  - Recently transitioned to operational status.

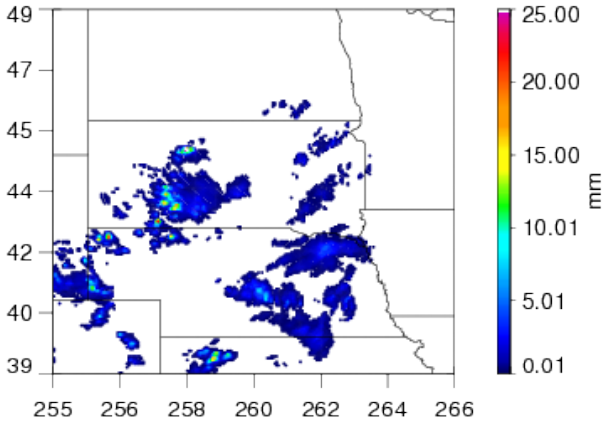
What makes a good forecast?

- Timing, location, intensity
- Different users, different needs
- Common Metrics

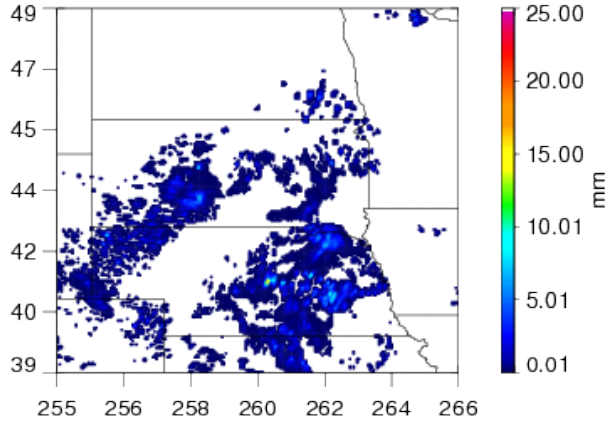


Sometimes HRRR Performs Well:

Stage IV Observed Hourly Rainfall

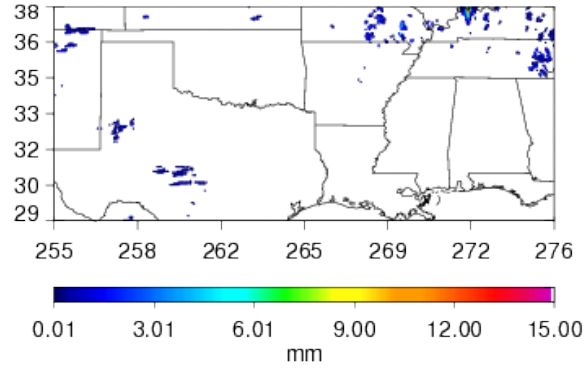


HRRR Forecast Hourly Rainfall

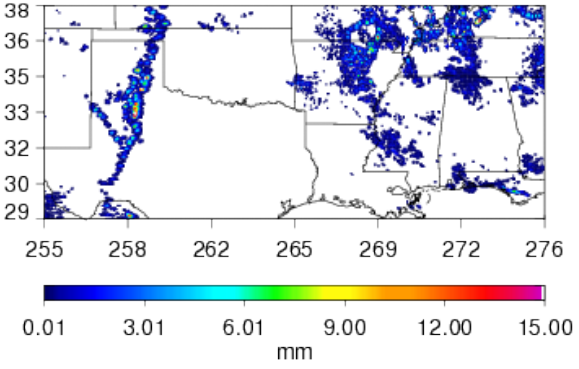


Sometimes HRRR Performs Poorly:

Stage IV Observed Hourly Rainfall

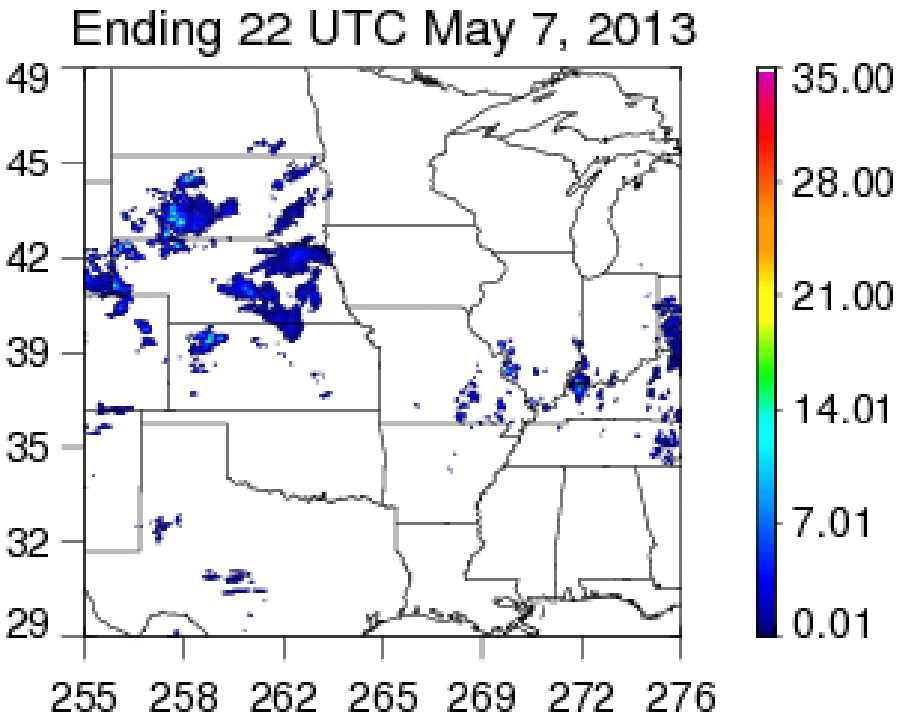


HRRR Forecast Hourly Rainfall

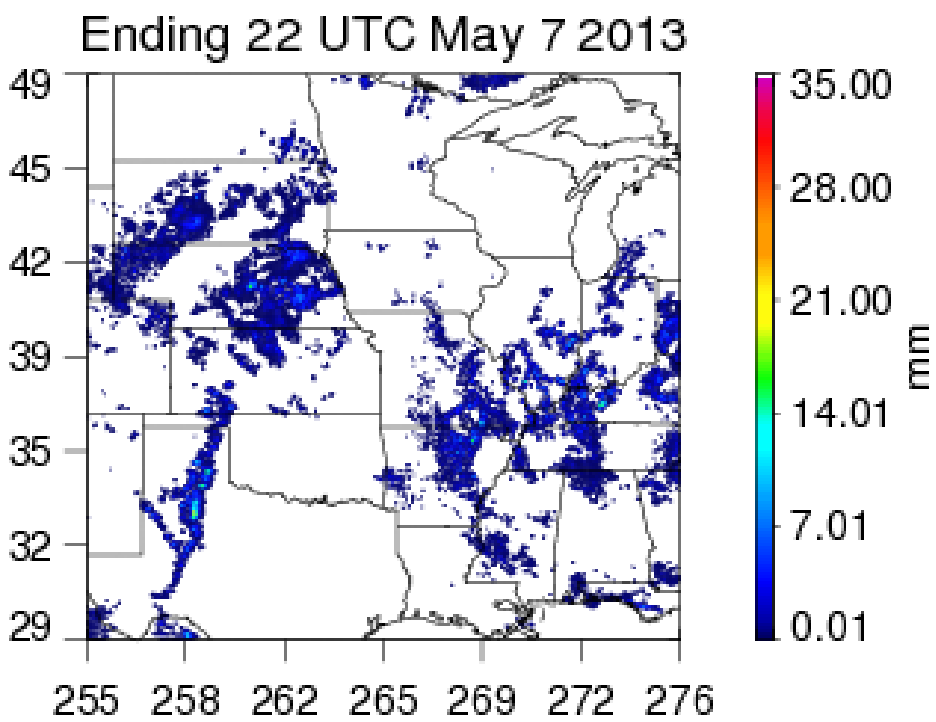


Sometimes all at the same time

Stage IV Radar Hourly Rainfall



HRRR Forecast Hourly Rainfall



Object Oriented Verification

- Identify precipitating features of interest and validate each one separately.
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  - def
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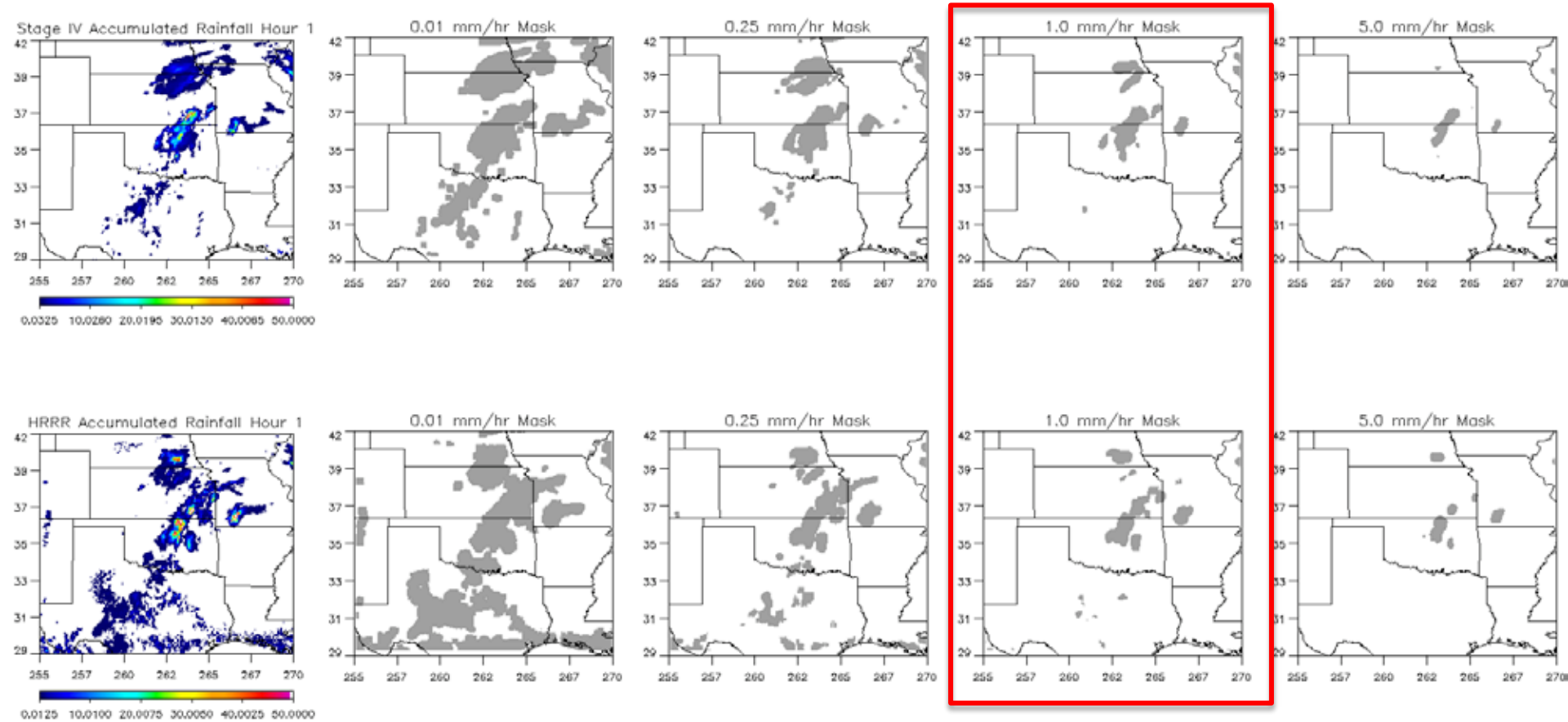
    feat
  - the diagnostics considered
- Ebert and McBride [2000], Ebert et and Gallus [2010], Wernli et al. [2008, 2009], Lack et al. [2010], Davis et al. [2006; 2009]

Goal:

A database of well defined observed convective precipitation features assumed to have been assimilated at t=0 that can be used not just for model validation of a single event, but to evaluate model performance through the duration of the forecast and under different conditions with the intent to improve the model.

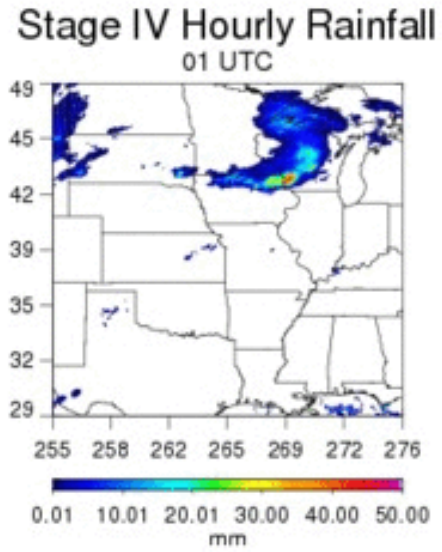
ID features with different rainfall thresholds:



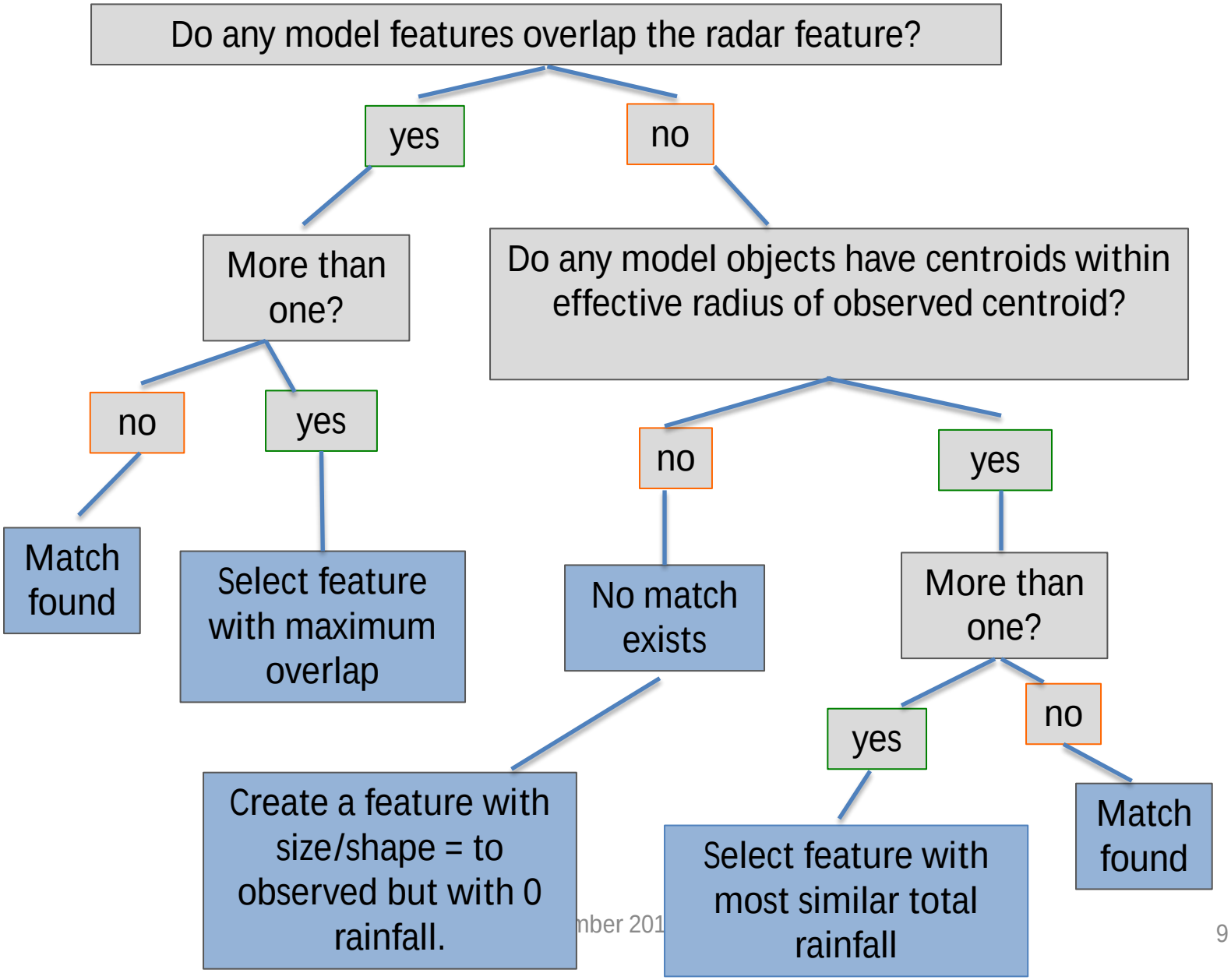
Define and Track observed features

Observed Precipitation Feature Criteria:

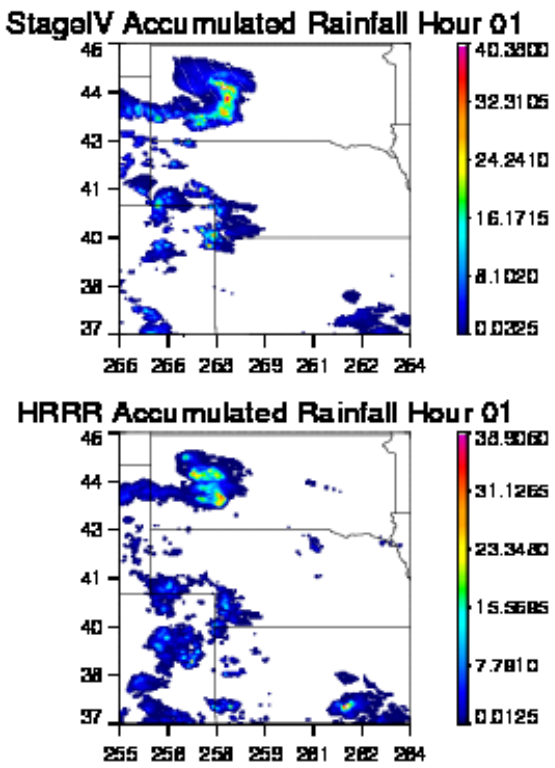
- Observed at forecast hour 1
- Maximum observed rain rate ≥ 10 mm/hr
- Observed area ≥ 5000 km^2
- Trackable for ≥ 10 hours

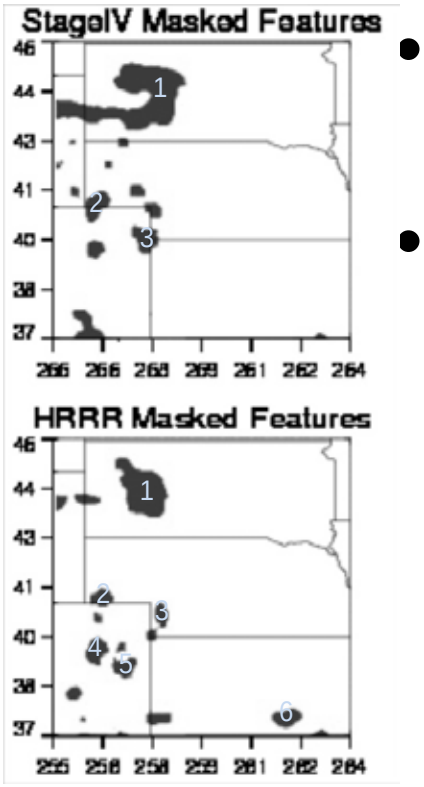


Match model feature to observed



Feature Database





- For the 2013 Warm Season (May-Aug)
- For each model run:
  - Radar and Model rainfall and binary masks
  - Statistics file
    - Radar feature number, matched model feature number, descriptive properties

Summary of findings from hourly forecasts

- Placement of raining features tends to fall within ~50km of the observed, with better placement in the N-S direction than E-W.
- Validation statistics tend to be better at FH3 than at FH1, indicating a model spin-up of 1-2 hours before optimum forecast quality is obtained.
- Total rainfall bias is mostly positive throughout the first several forecast hours, however biases in raining area and maximum intensity are generally low, while mean rainfall is generally well matched.
- Even with assimilated radar, POD is relatively low. This, along with low biases in areal coverage and maximum intensity indicates that the model is not creating enough rainfall.

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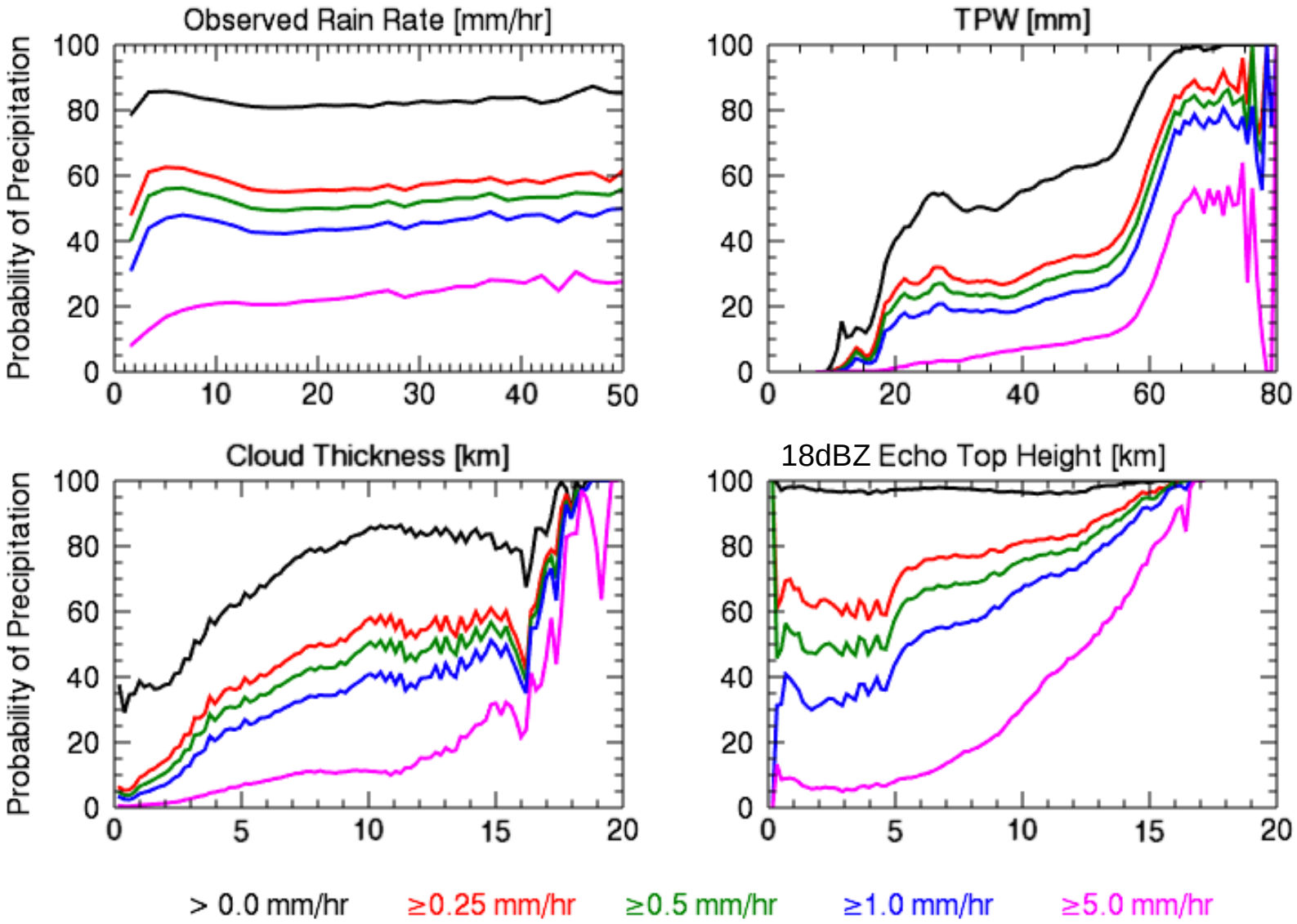
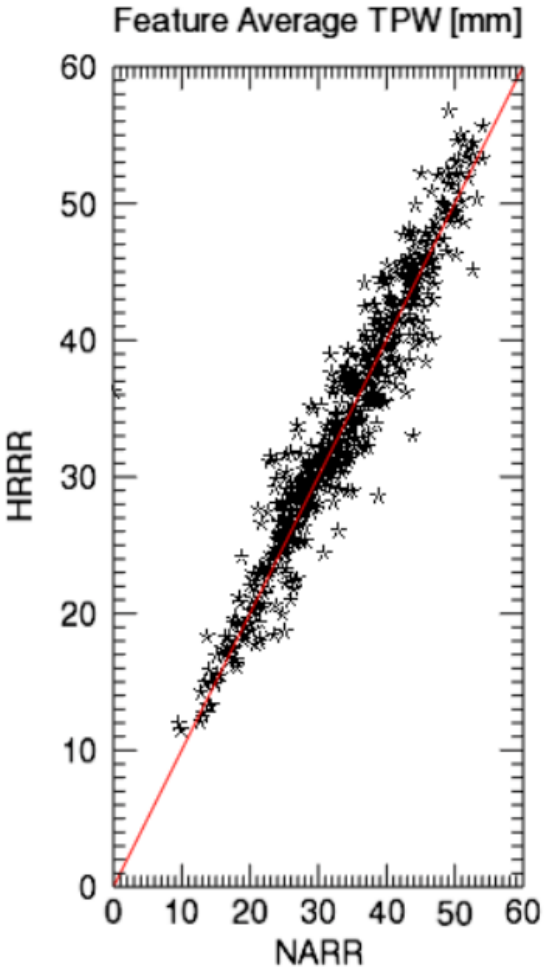
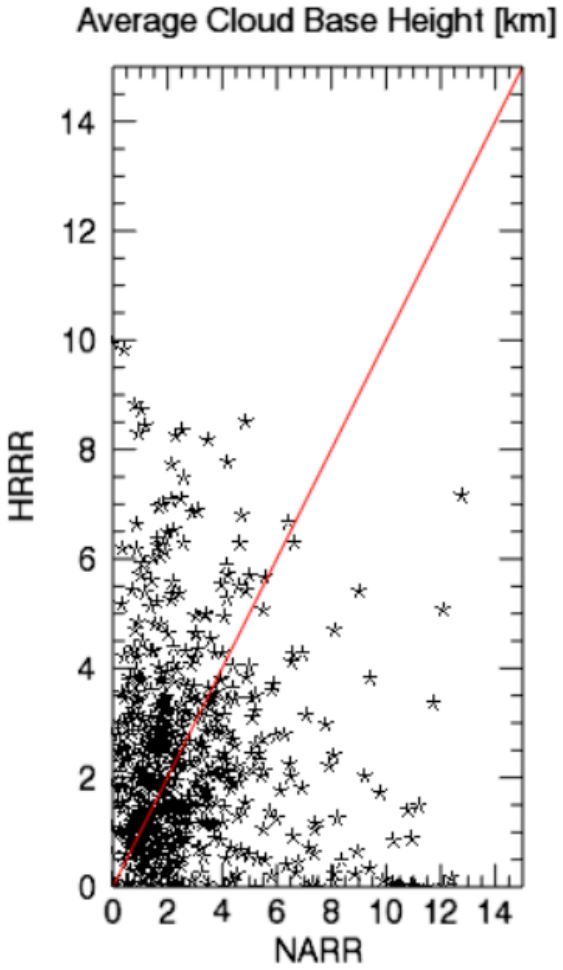
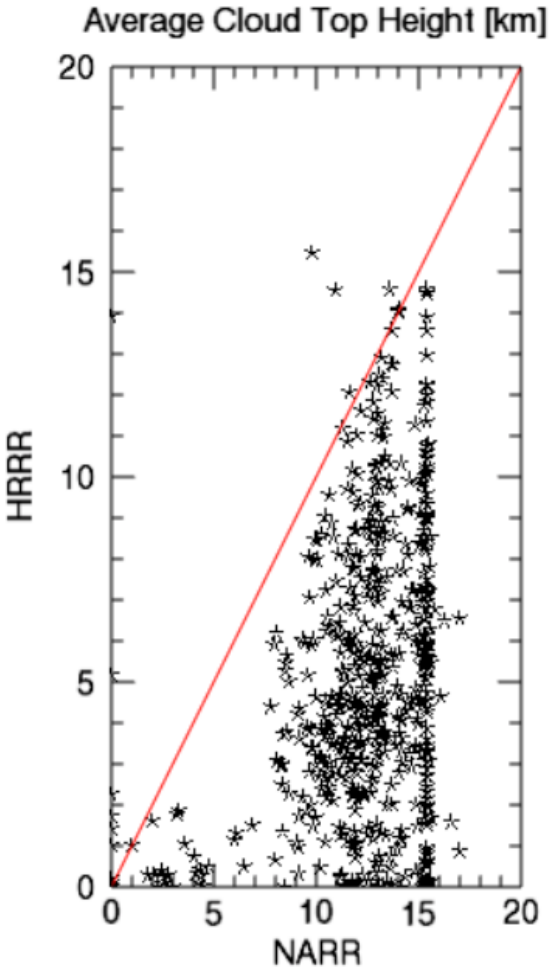
Probability of Model Precipitation Exceeding a Given Rain Rate as a Function of Model Variables, given observed 1mm/hr rainfall



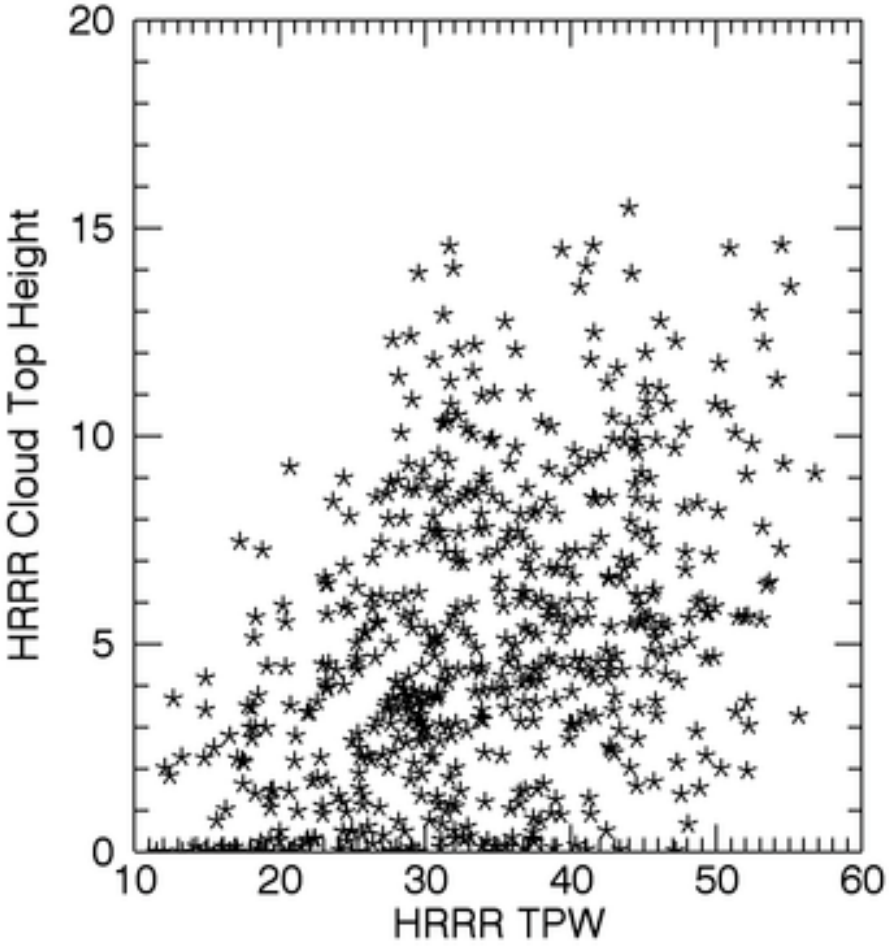
Forecast vs. Observed Environment (Forecast Hour 1)

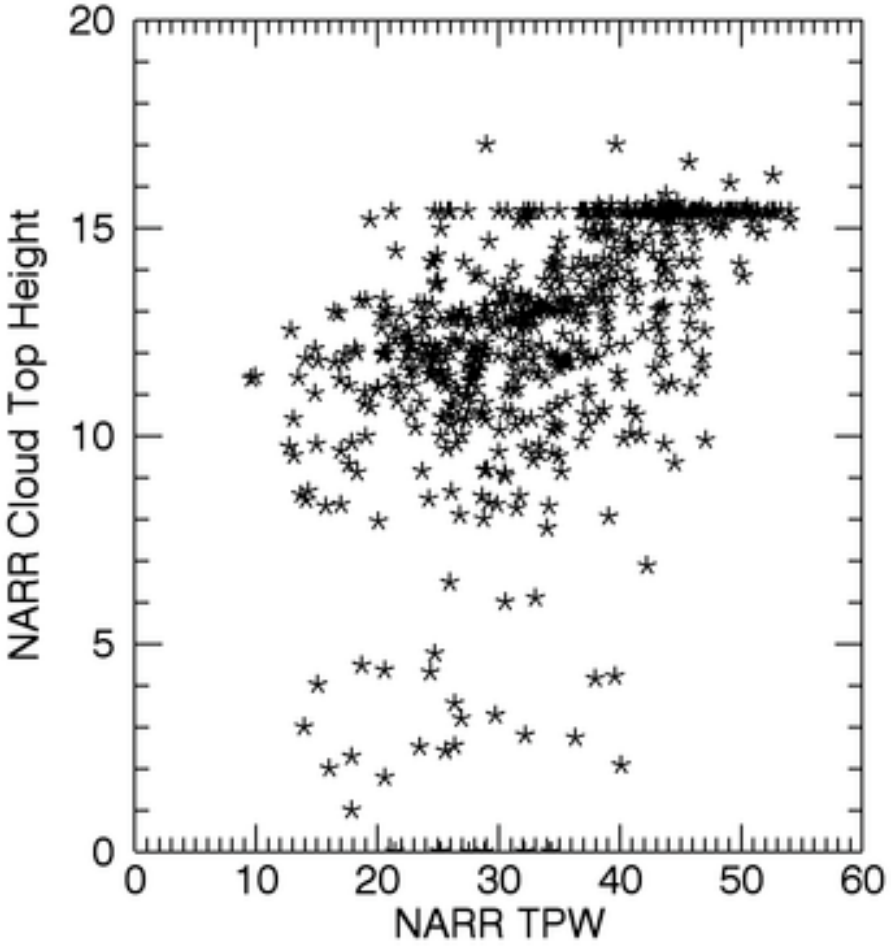


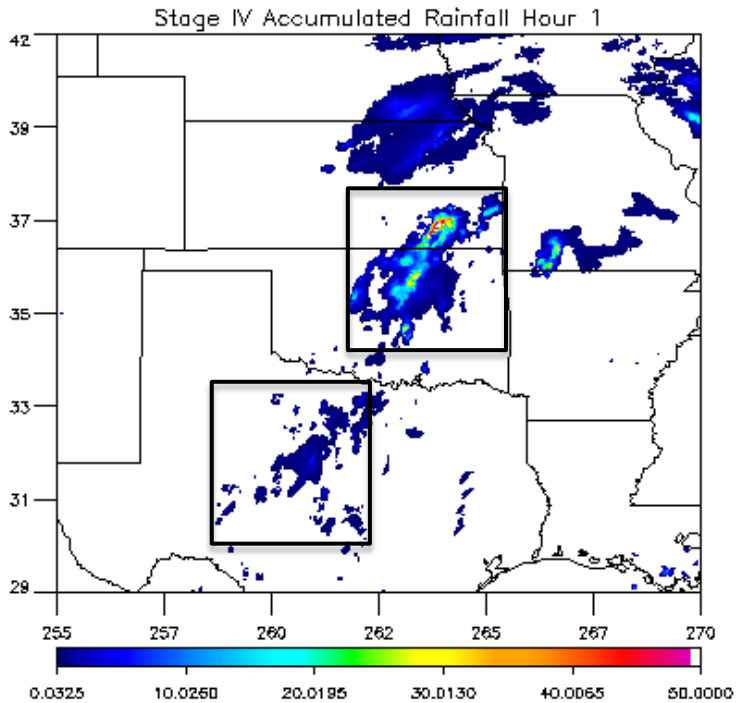


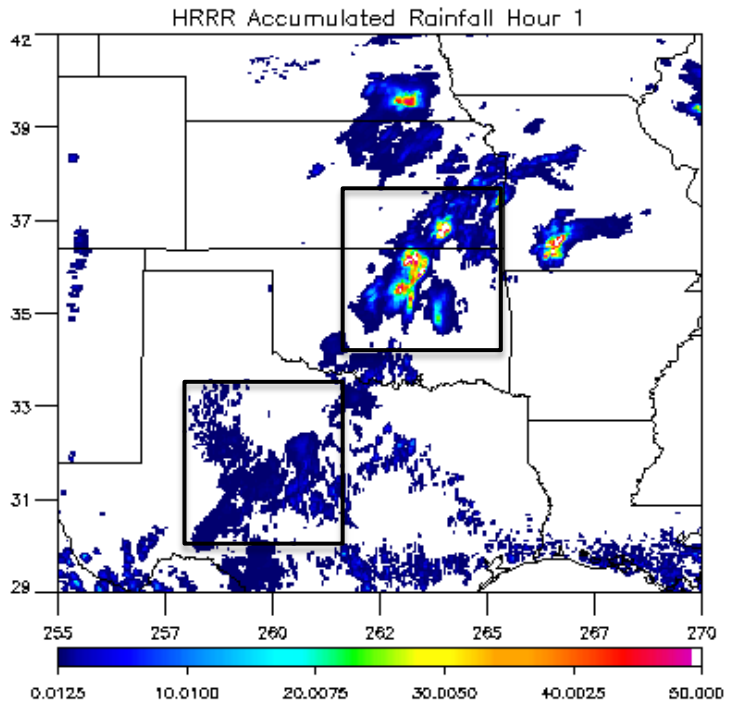


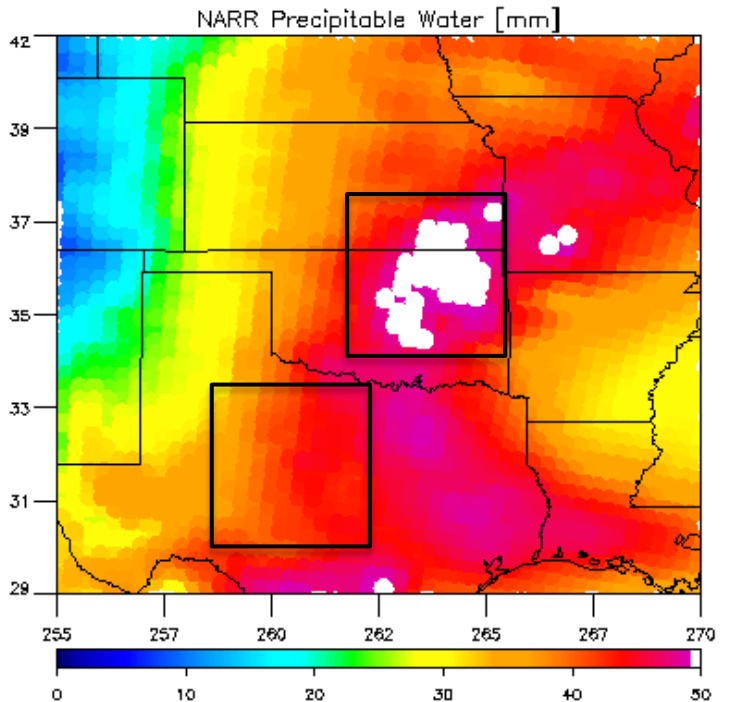
TPW vs. Cloud Top Height Forecast vs. Observed (FH1)

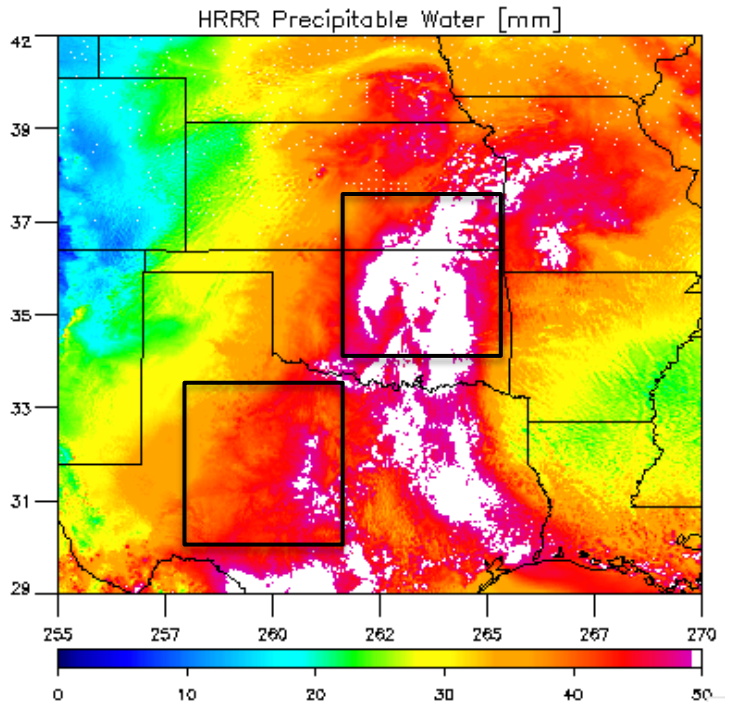












While HRRR and NARR exhibit similar TPW values in the environment of the observed precipitation, HRRR exhibits higher TPW in environments where precipitation is forecast but not observed.

Summary

- Long-lived convective features were identified and tracked in the observations, and matched to model features.
- Features database allows quality to be assessed for different user needs.
- HRRR forecasts generally predict accurate storm position and mean rainfall, too much total rainfall, and too little areal coverage, suggesting that the model is not creating enough precipitation outside of the convective cores.
- An examination of the forecast and observed near-storm environment implies that the model is inefficient at producing deep clouds and precipitation in moderate TPW environments commonly found in the US Great Plains during the warm season.
- HRRR underwent an upgrade in May 2014.
- Continued research relating performance to region, season, diurnal cycle, system characteristics.
- Results can be further explored using satellite retrieved cloud and environment characteristics, as well as space-borne radar reflectivity profiles.