Verifying HWRF Forecasts using Synthetic Satellite Imagery

09-05-12 HFIP Teleconference

David Zelinsky (NHC)

In collaboration with:

Vijay Tallapragada (EMC), Sam Trahan (EMC)

Background: Why verify synthetic satellite forecasts?

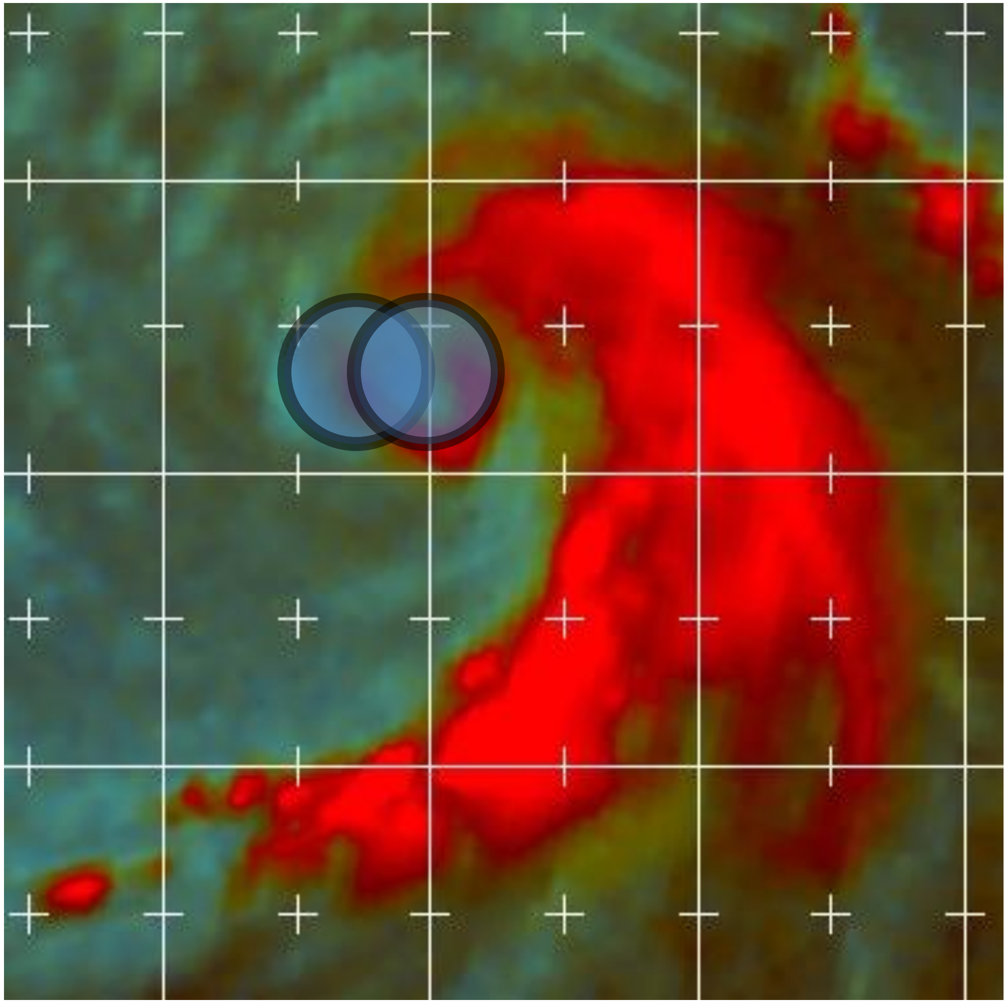
- Traditional track/intensity verification
  - Limited by lack of in-situ ground truth in TCs.
  - Does not account for storm structure.
  - Wind radii / RMW verification is also limited by a lack of data.
- Goal:
  - Address these shortcomings by systematically evaluate TC structure forecasts through the comparison of real and synthetic satellite data.

Background:
Synthetic Satellite Imagery

- EMC uses the Community Radiative Transfer Model (CRTM) to generate synthetic brightness temperatures based on variables such as water vapor, temperature, and surface properties within the HWRF model.
  - 4 synthetic channels (SSMIS), and 4 IR channels (GOES).
- Focus on microwave data
  - Microwave imagery provides more information than IR about inner-core structure.

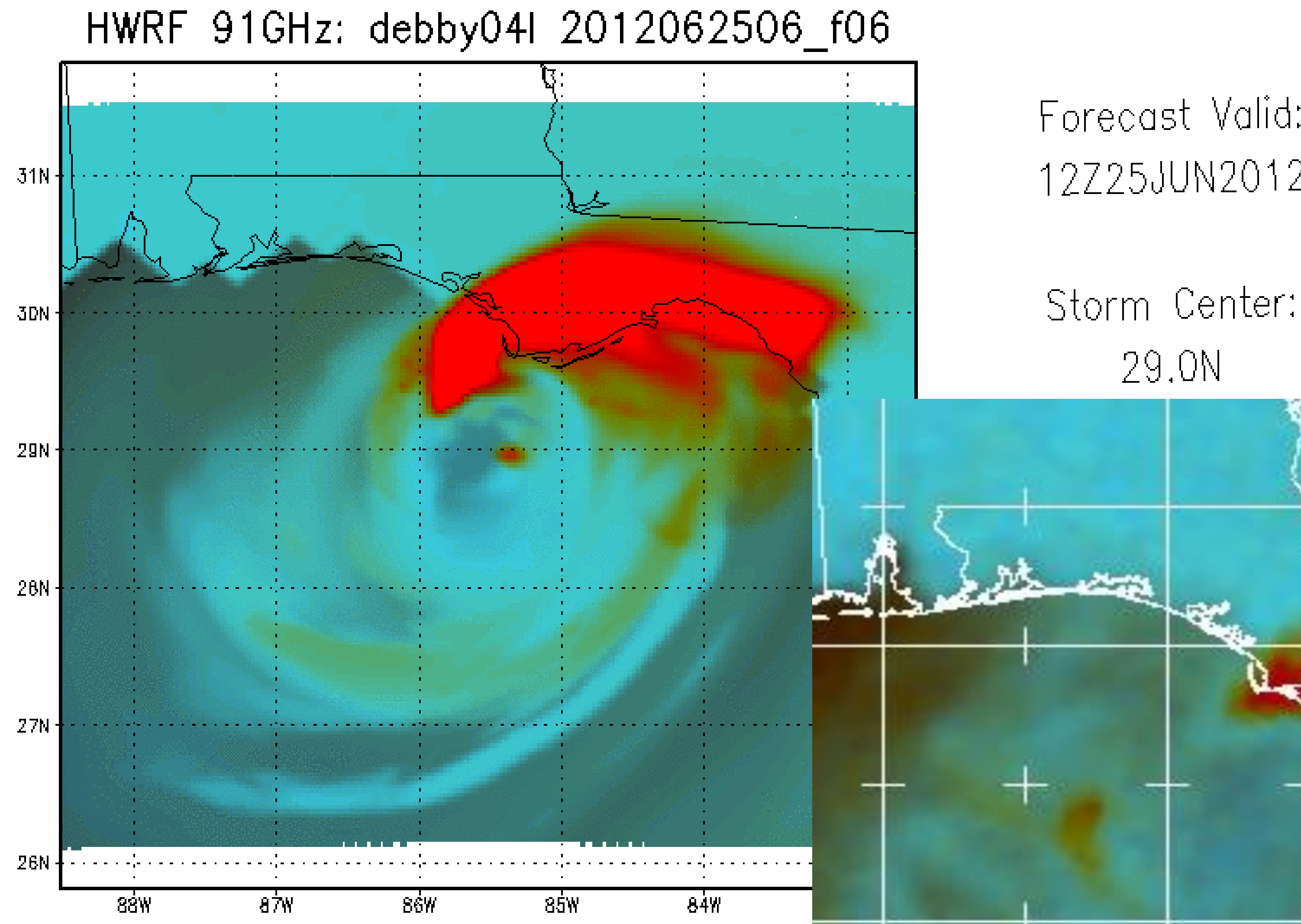
Methodology

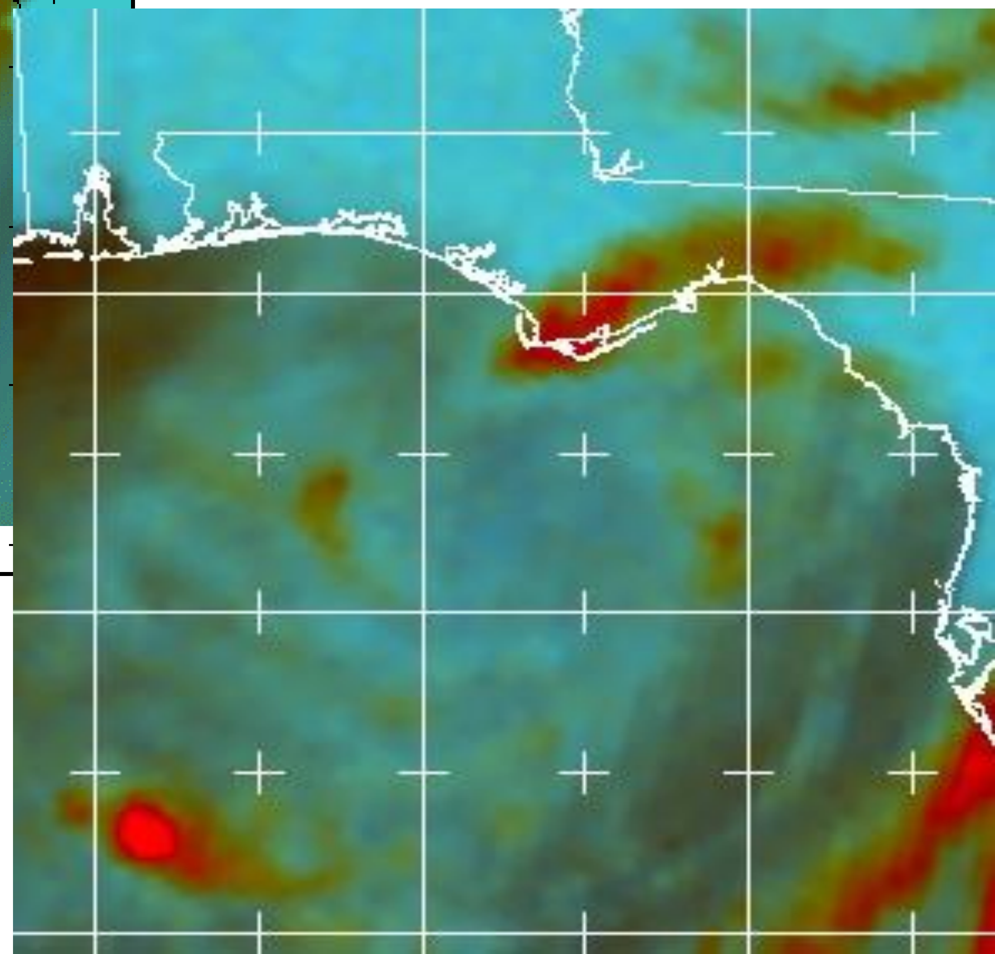
- Horizontal and Vertical polarized brightness temperatures are converted to color composites using the NRL method
  - Minimizes the impact of resolution, instrument differences, and CRTM assumptions
- 91GHz selected because real instruments operating at or near that frequency have relatively high resolutions.



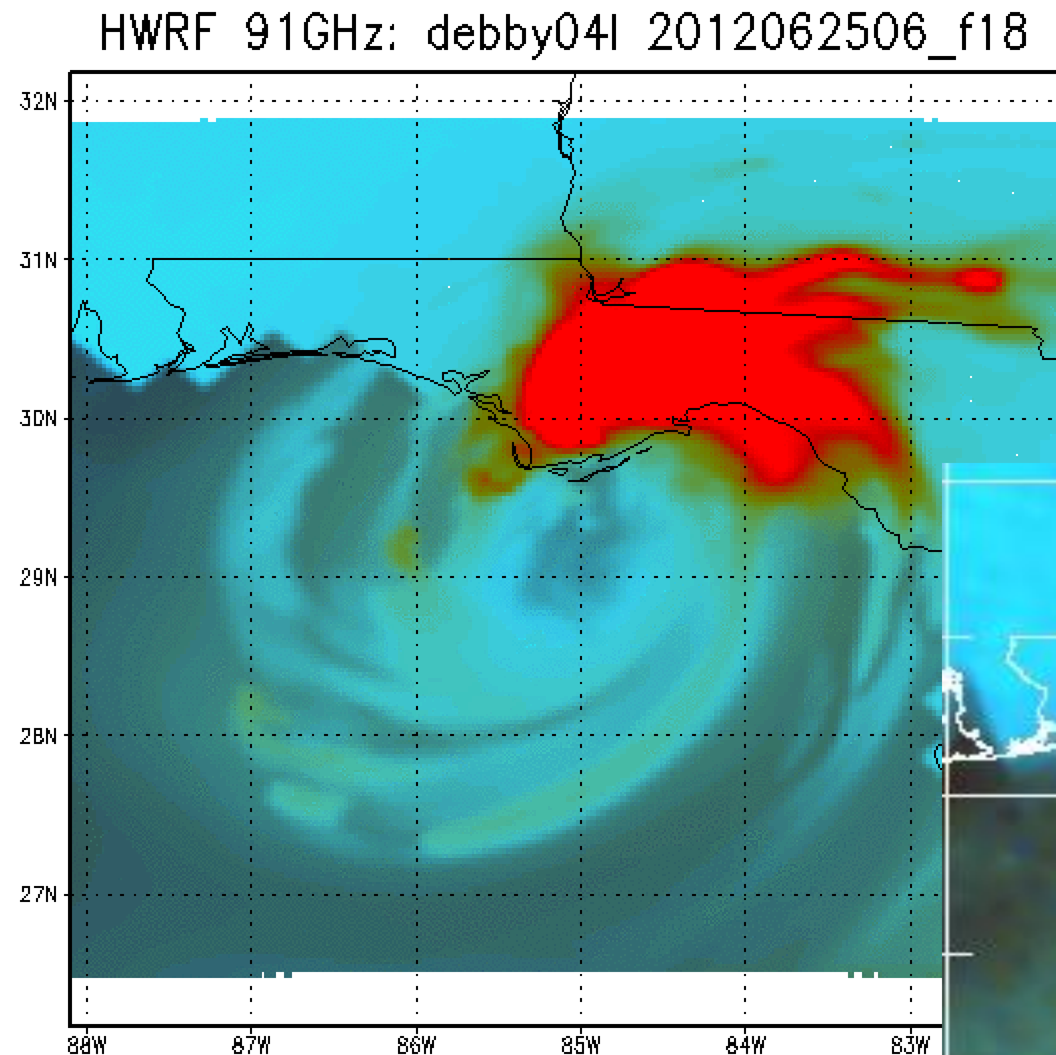
Leslie 09/04/12: SSMIS 0952

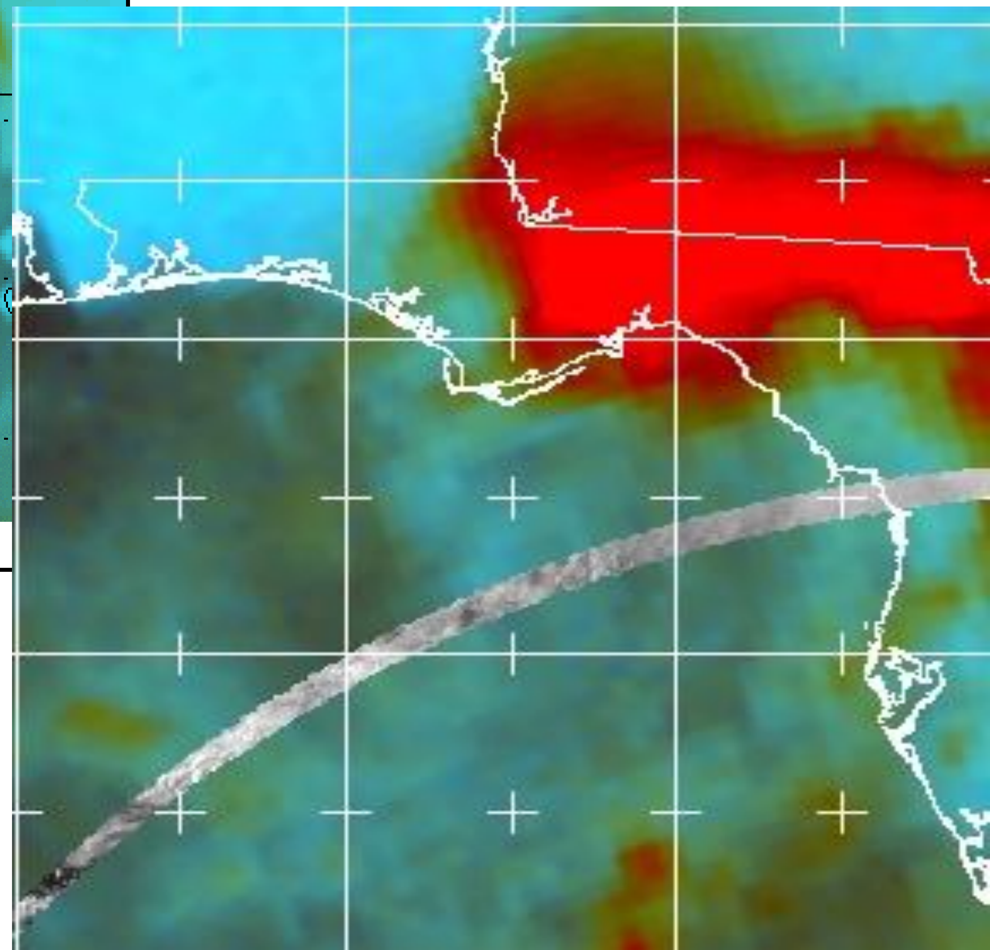
Sample:
Debby 20120625 06Z Forecast





Sample Forecast: Debby HWRF forecast (above) and observed microwave images (right)





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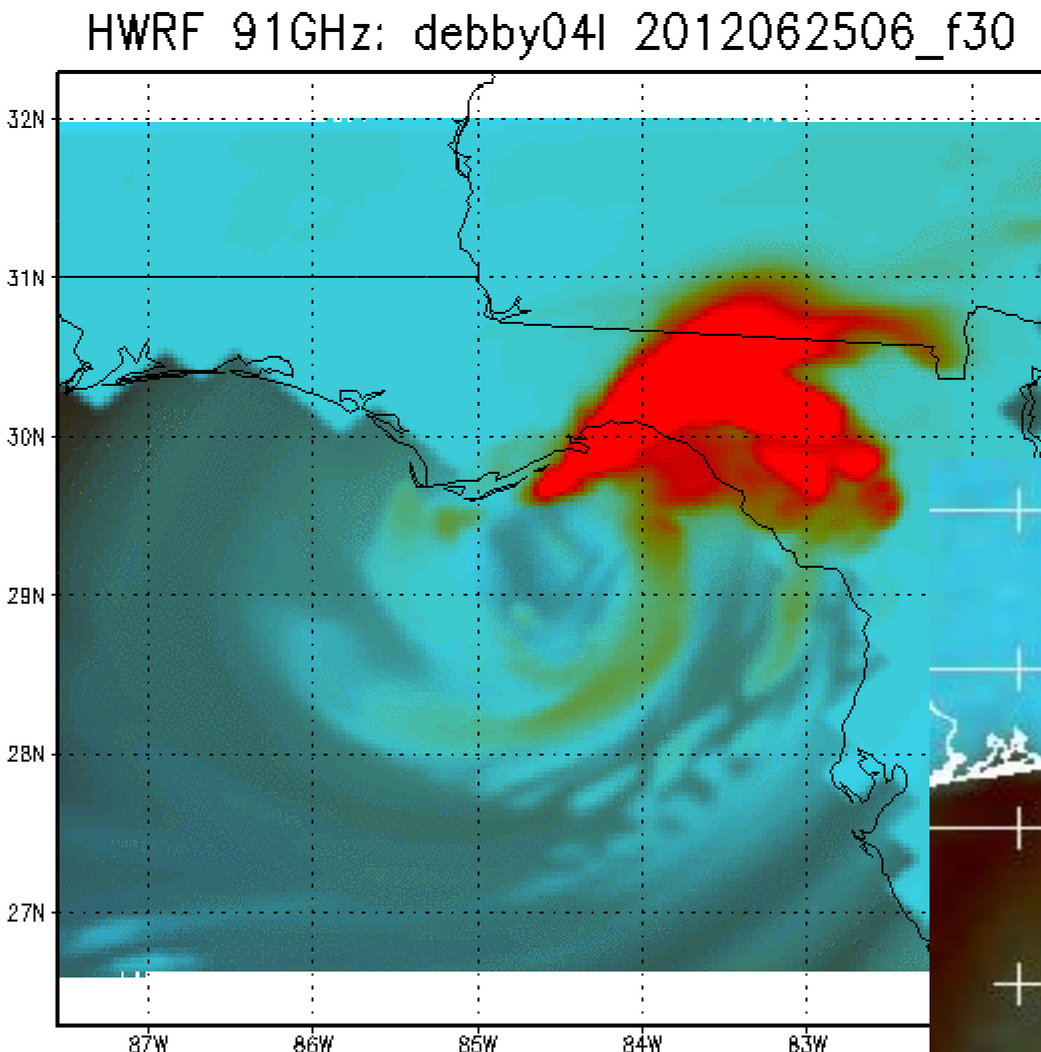
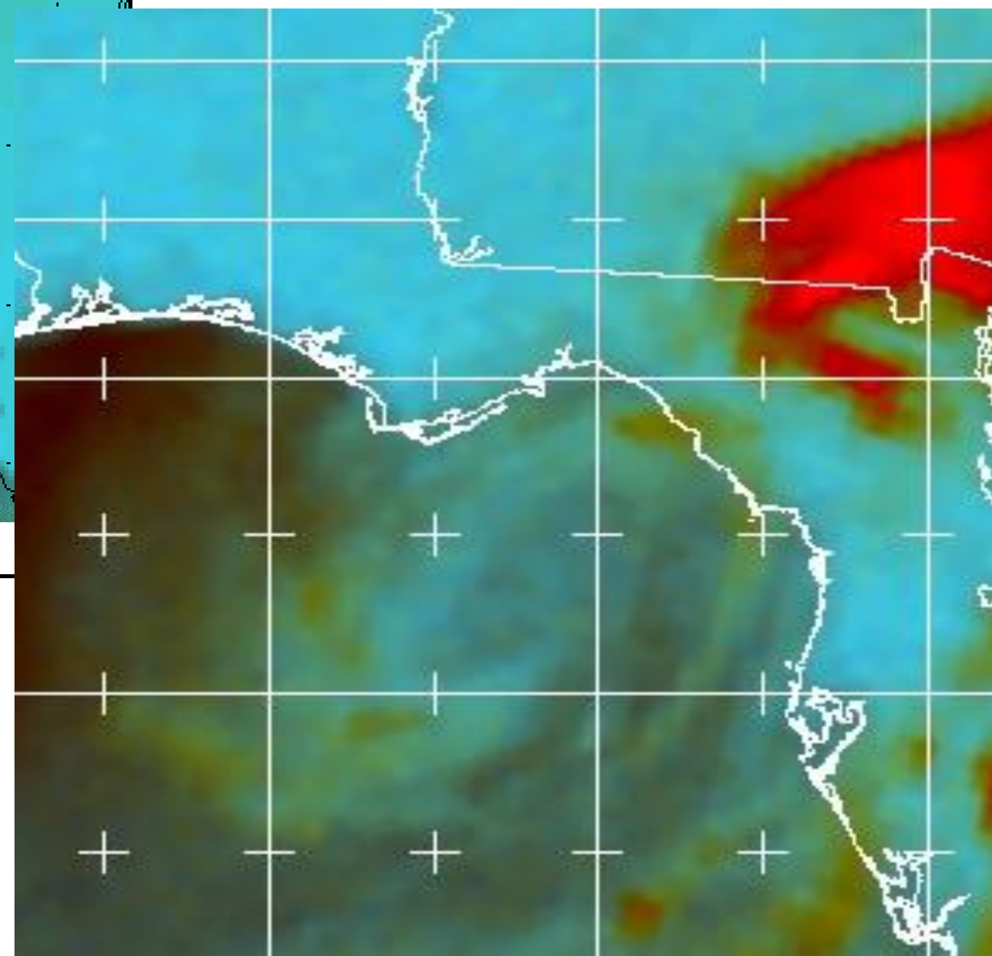


Forecast Valid:
12Z26JUN2012

Storm Center:
29.3N



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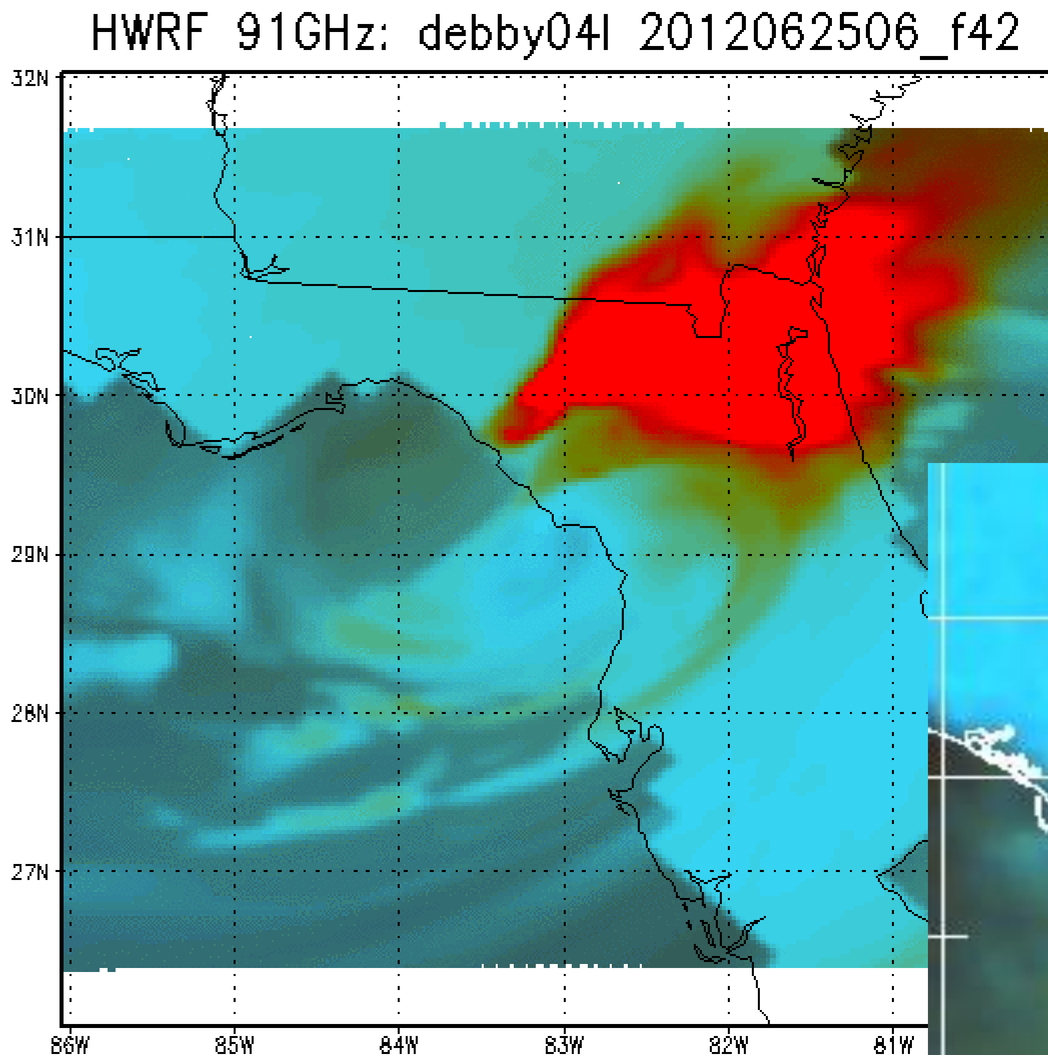

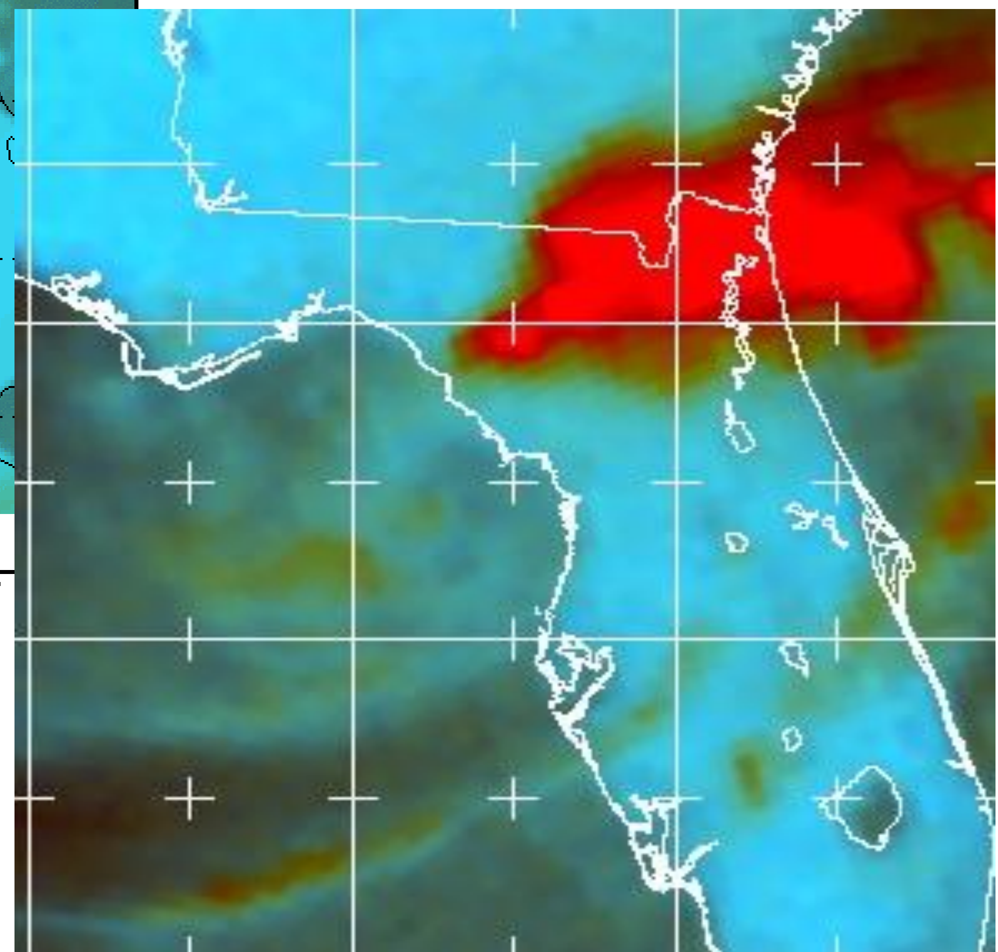

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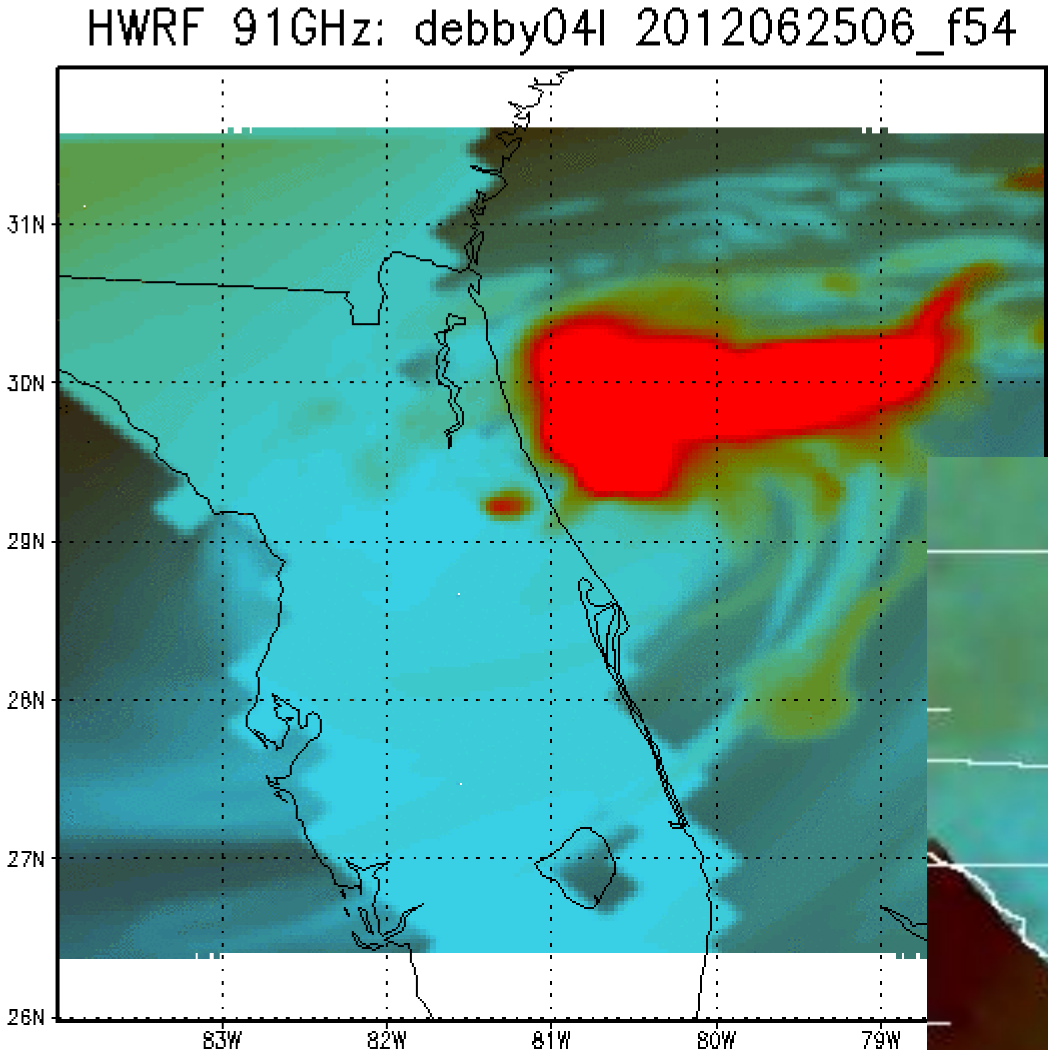
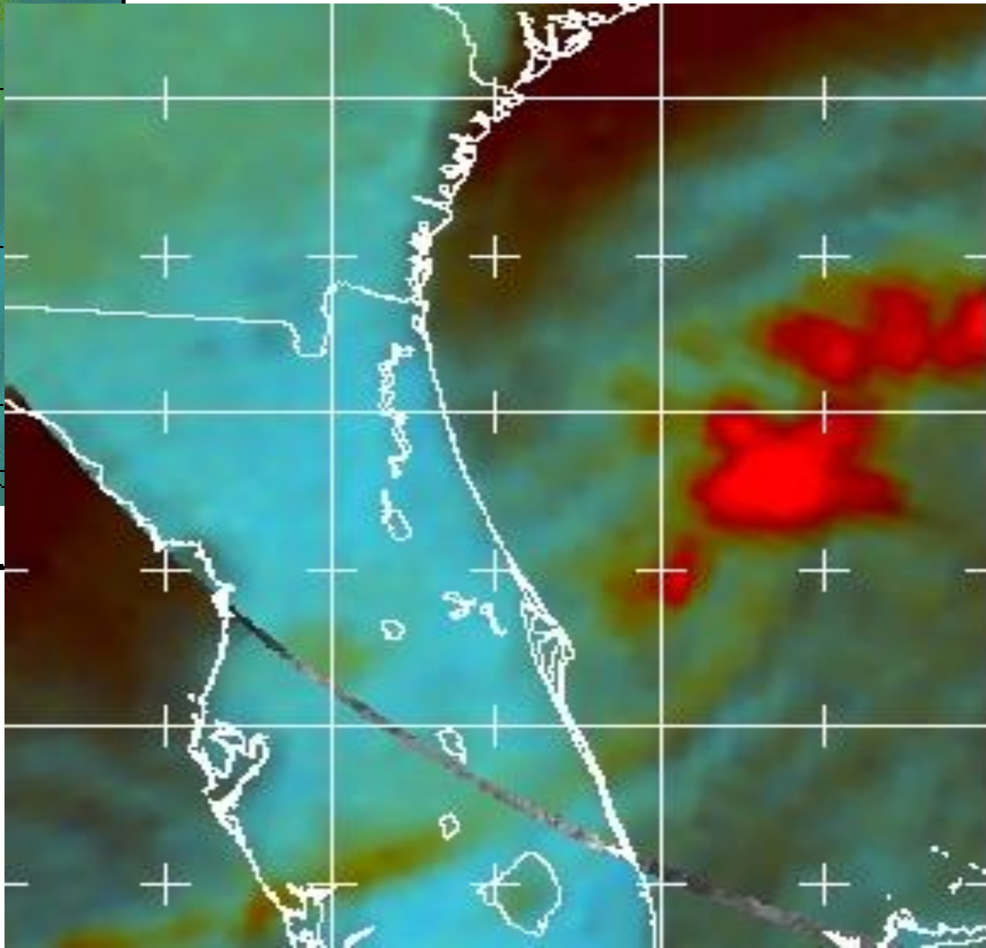


Forecast Valid:
12Z27JUN2012

Storm Center:
29.3N



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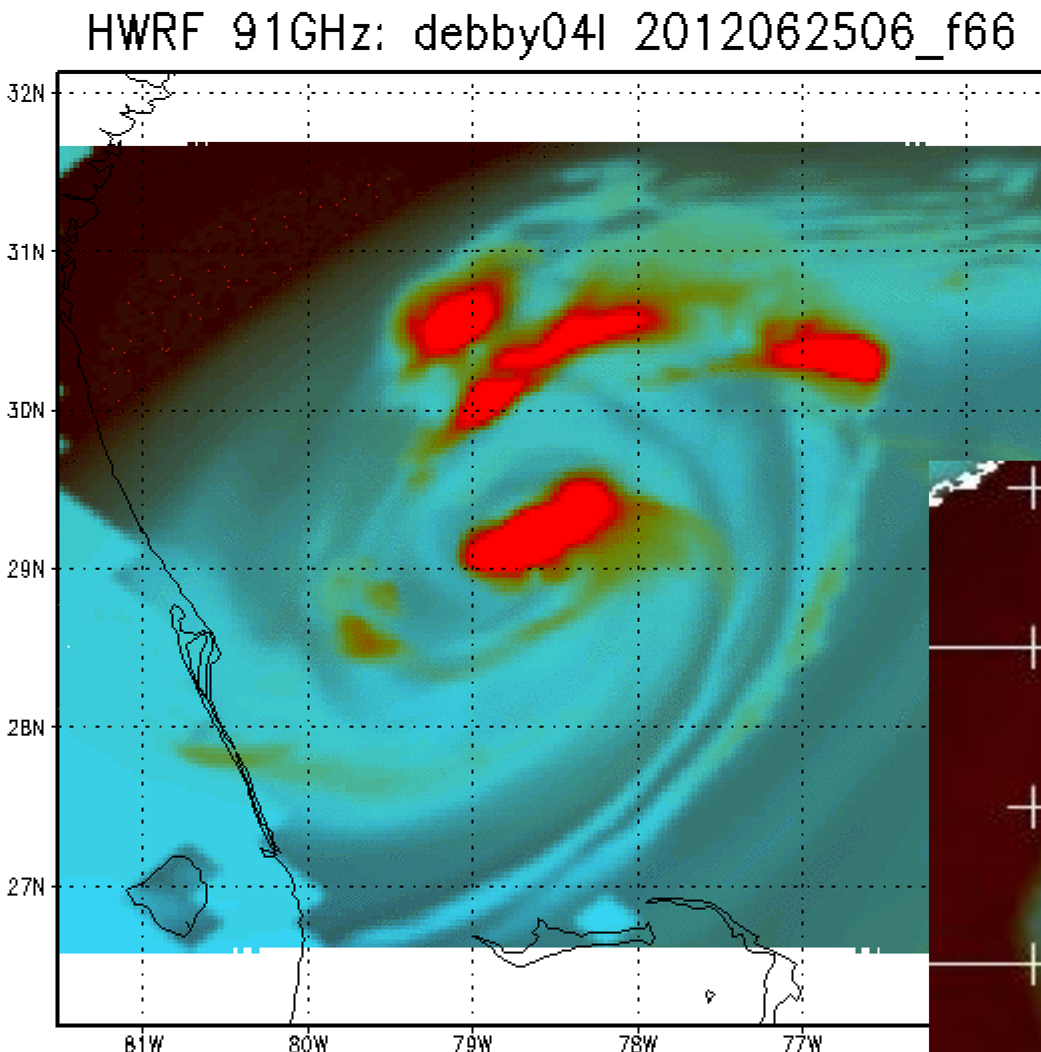
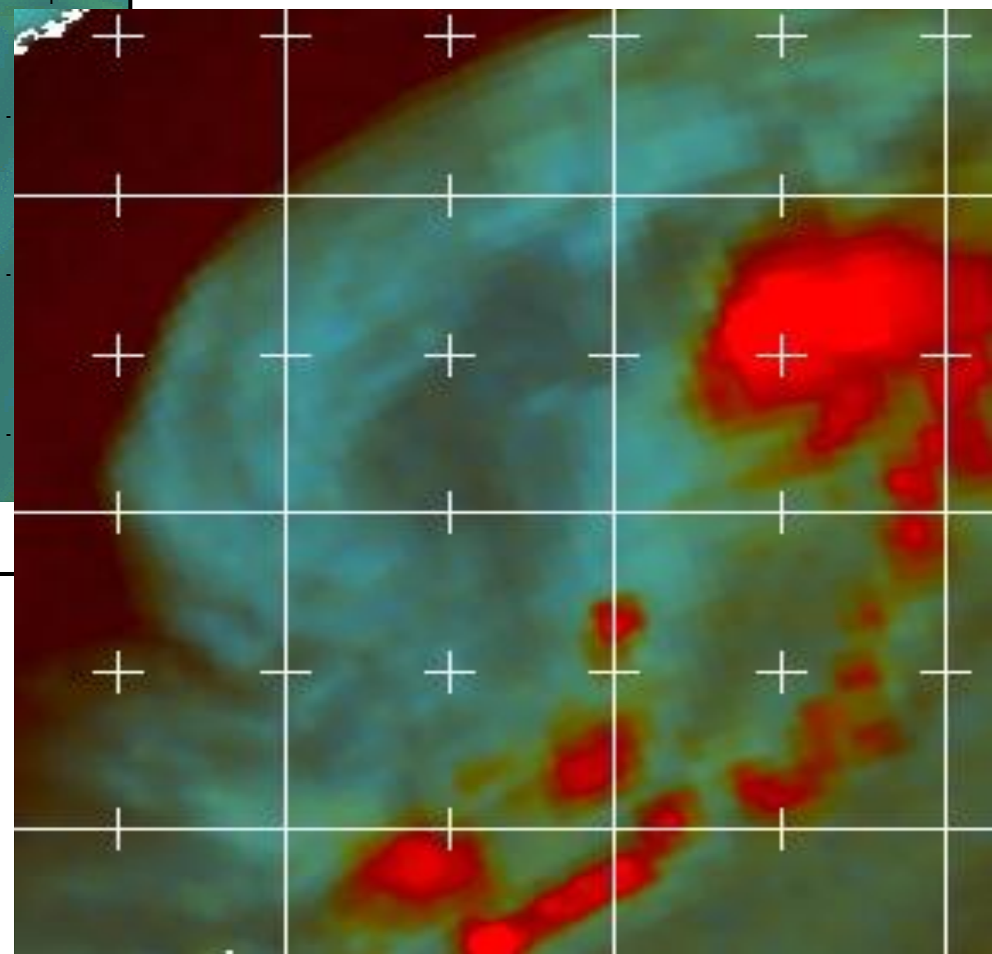


Forecast Valid:
00Z28JUN2012

Storm Center:
29.2N



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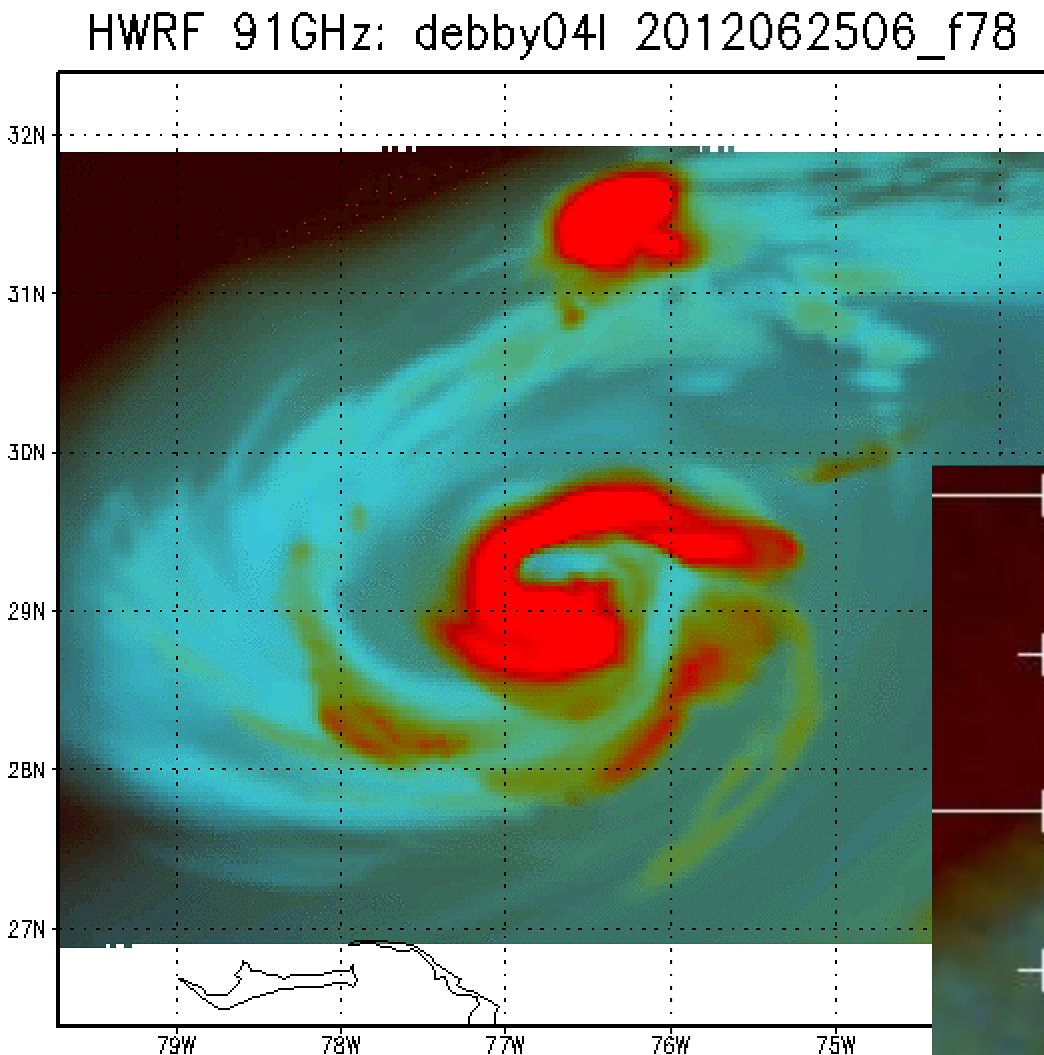
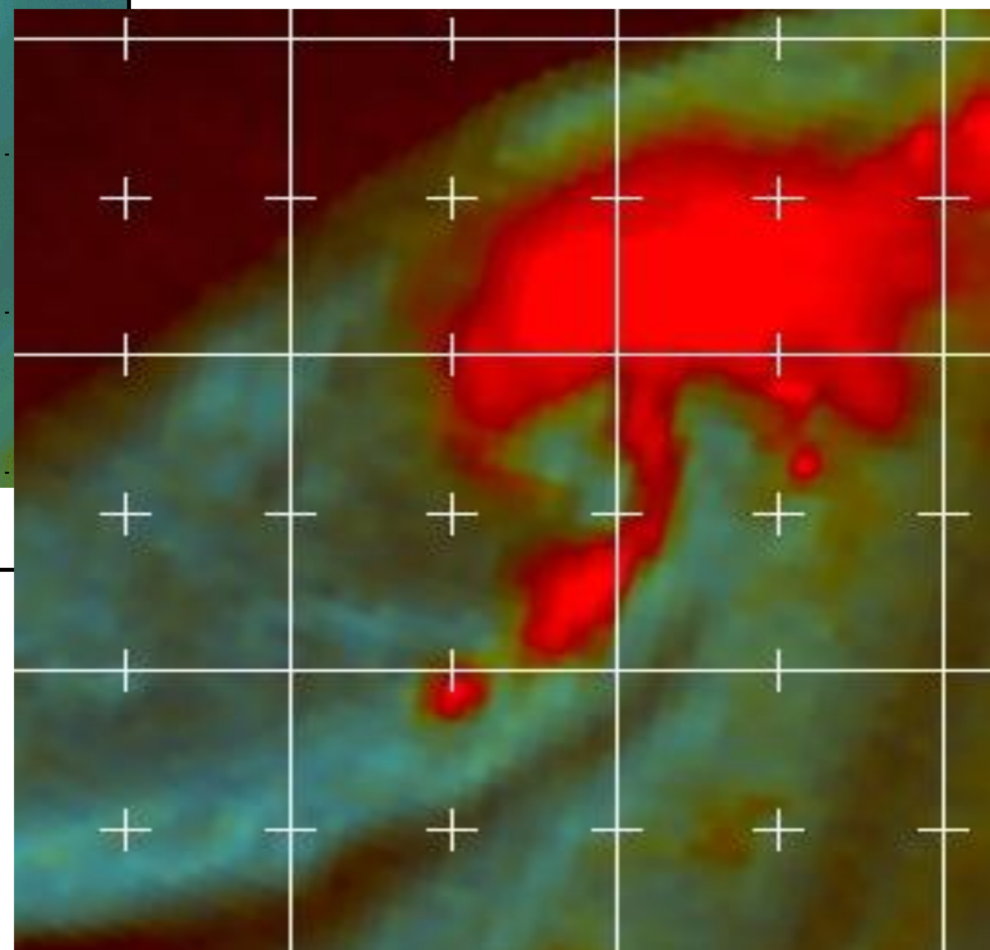


Forecast Valid:
12Z28JUN2012

Storm Center:
29.4N



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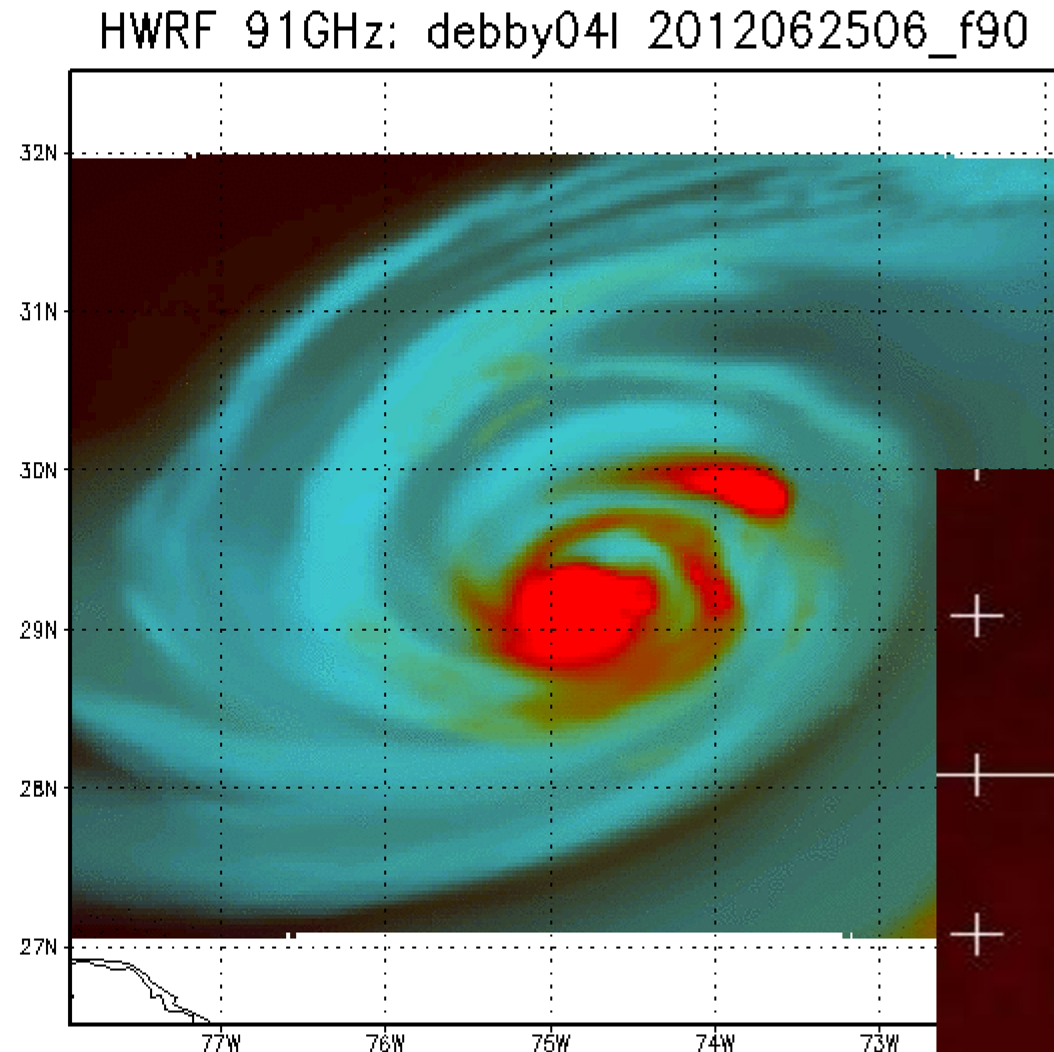
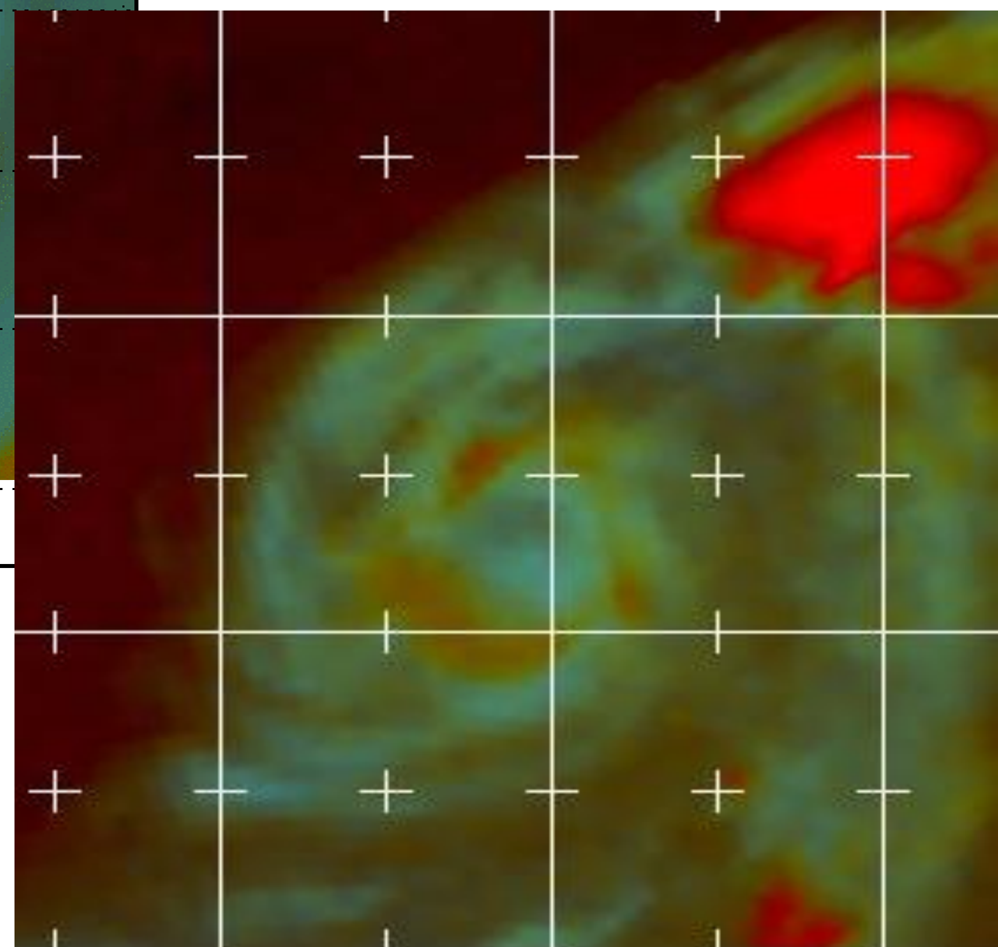


Forecast Valid:
00Z29JUN2012

Storm Center:
29.5N



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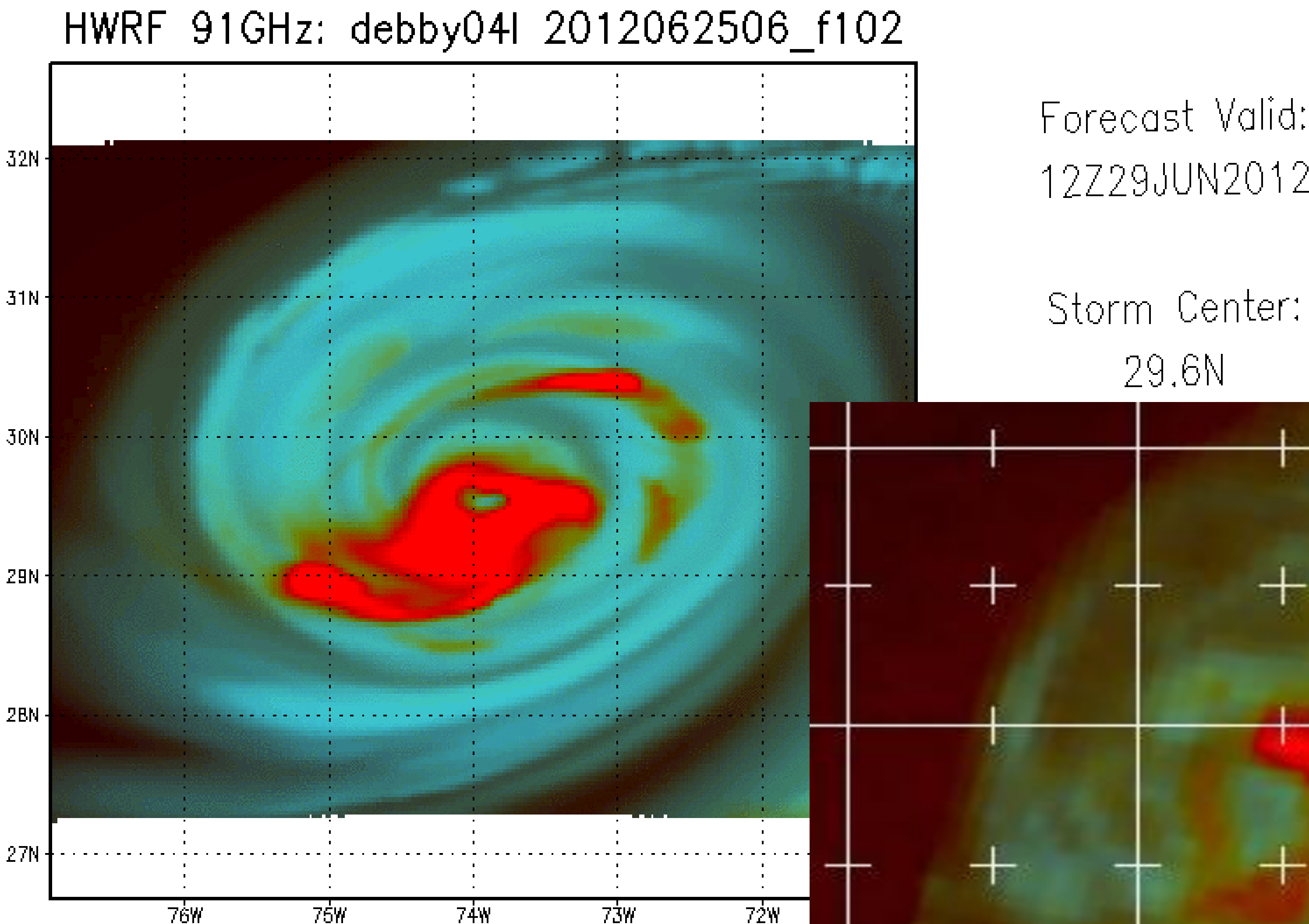

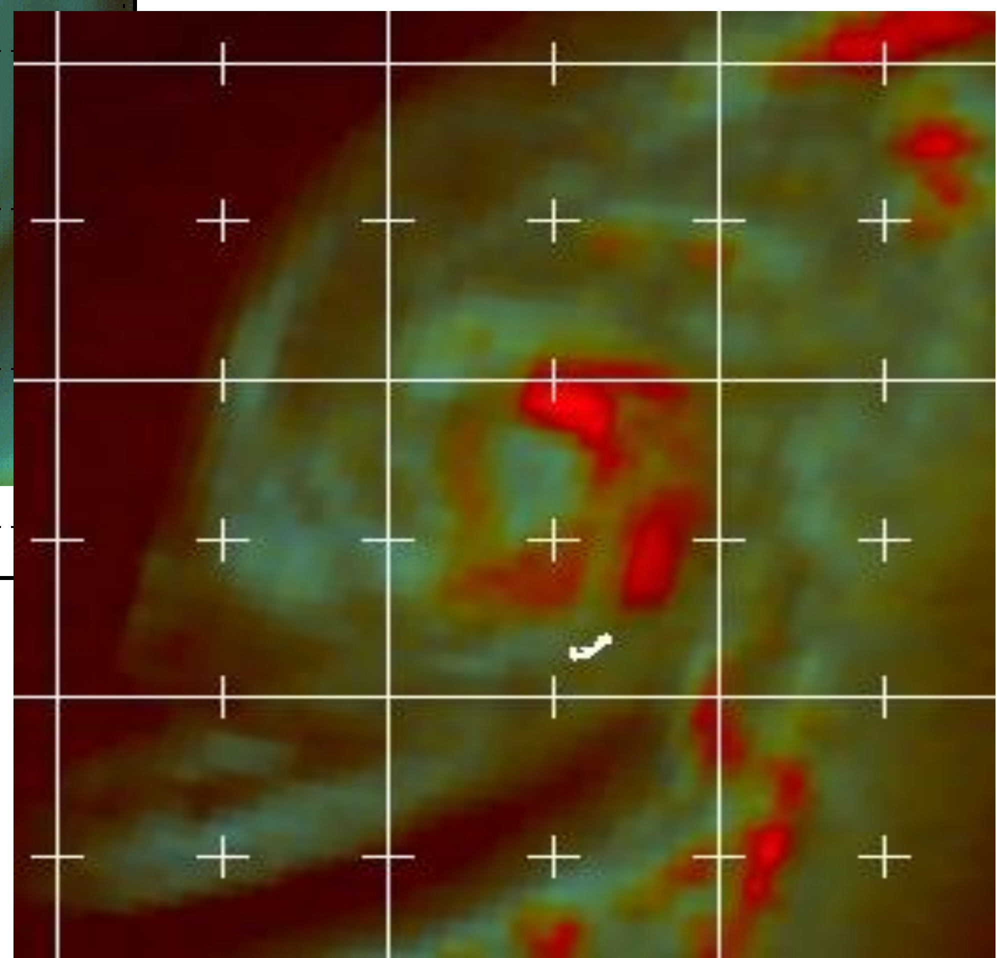

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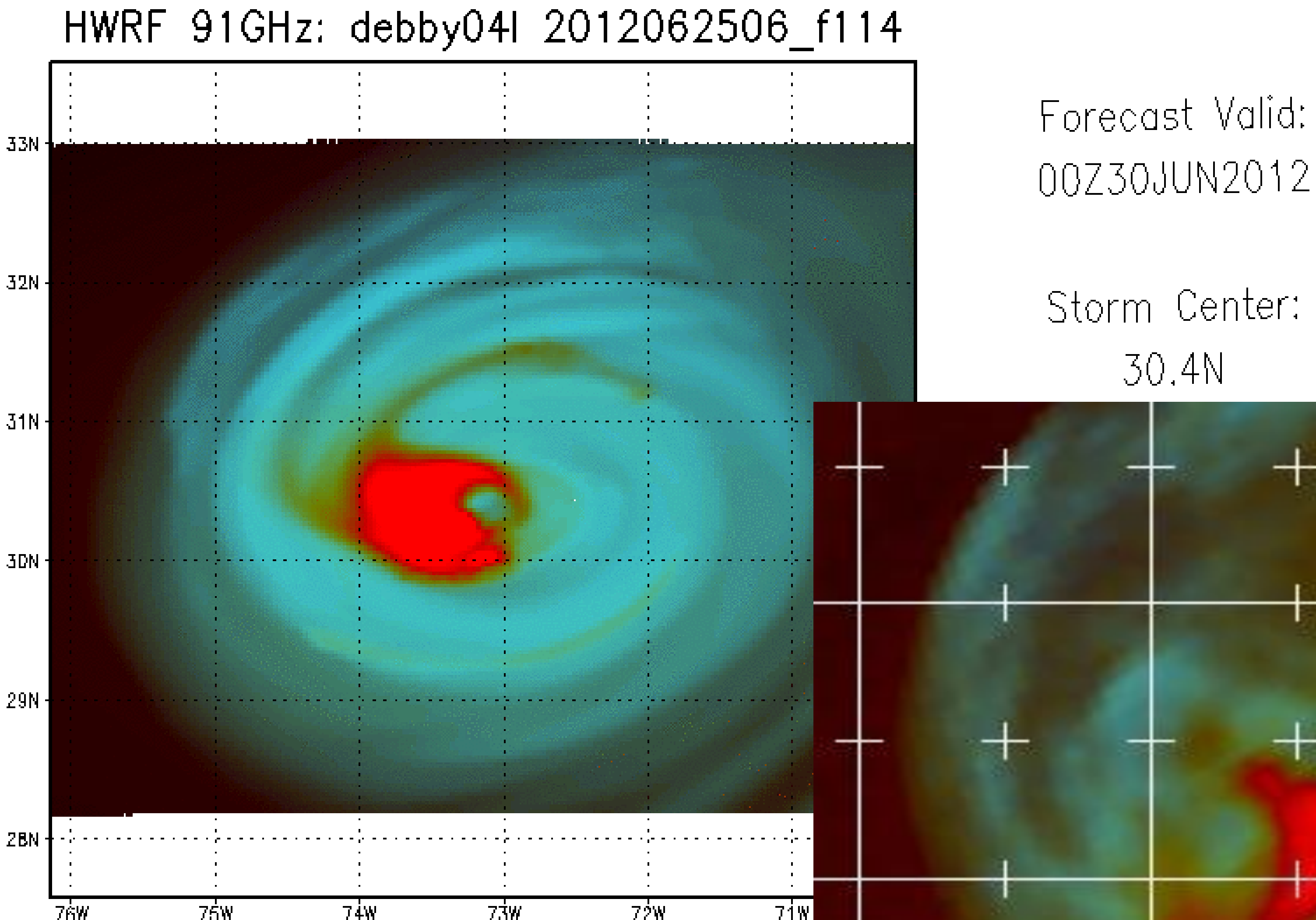
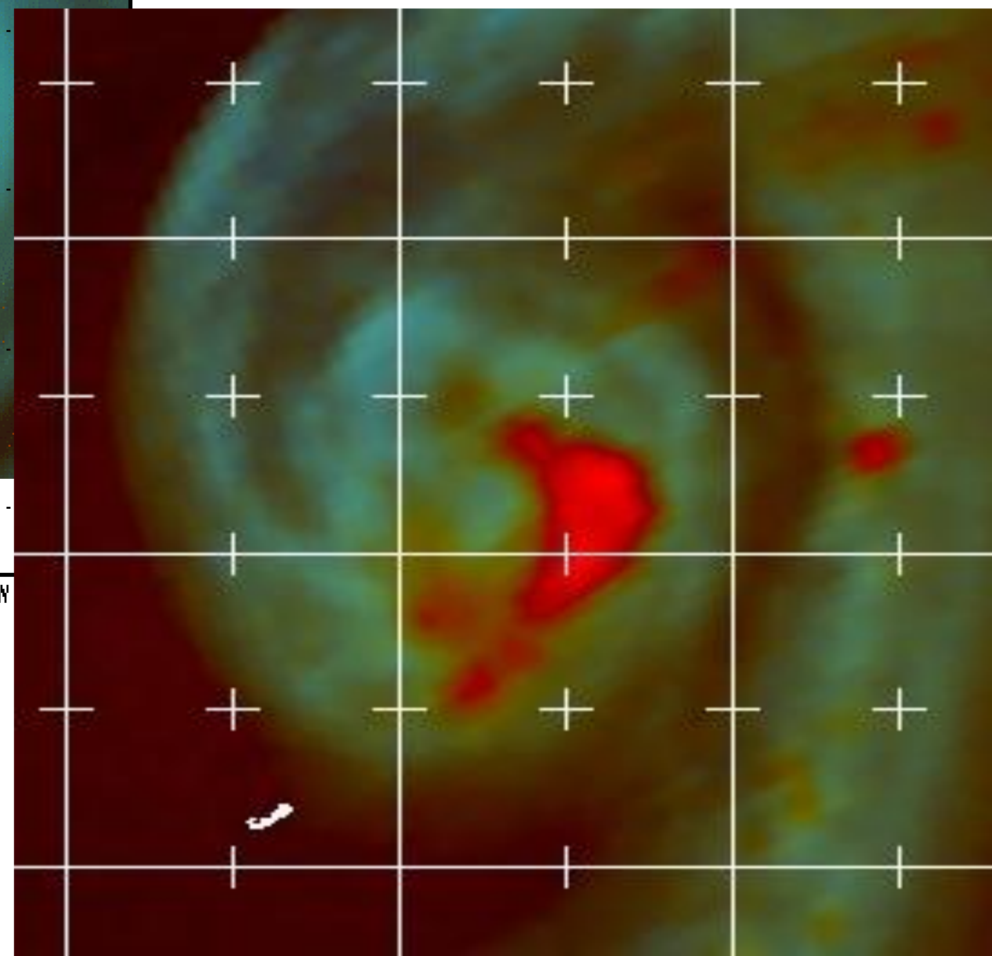




Sample Forecast: Debby HWRF forecast (above) and observed microwave images (right)

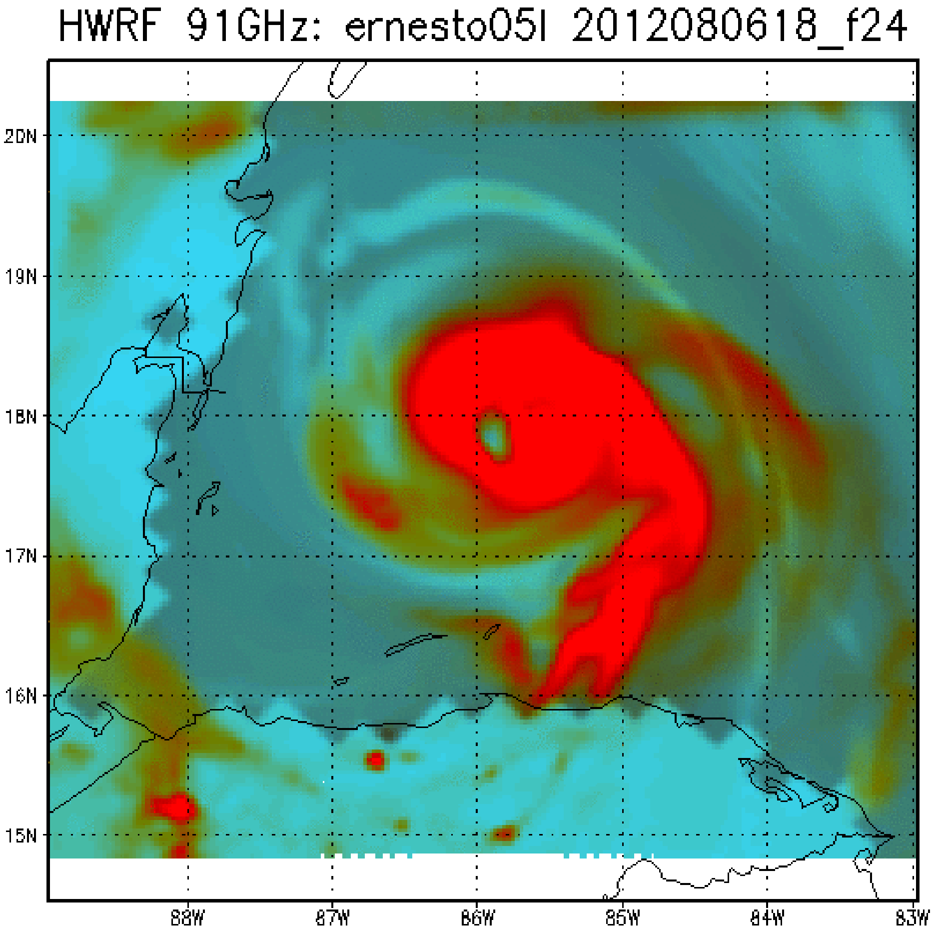
Methodology

- Satellite imagery was analyzed by determining the extent to which an eyewall and a primary band were present.
- Eyewall quantified by determining how many tenths of an eyewall exist .
  - (10 = closed eyewall)
- Primary band quantified in terms of tenths.
  - Similar to banding in the Dvorak technique
    - 10 = band wraps all the way around the center
    - May exceed 10

Methodology: Evaluating Satellite imagery

1) Determine if the center is clearly defined.

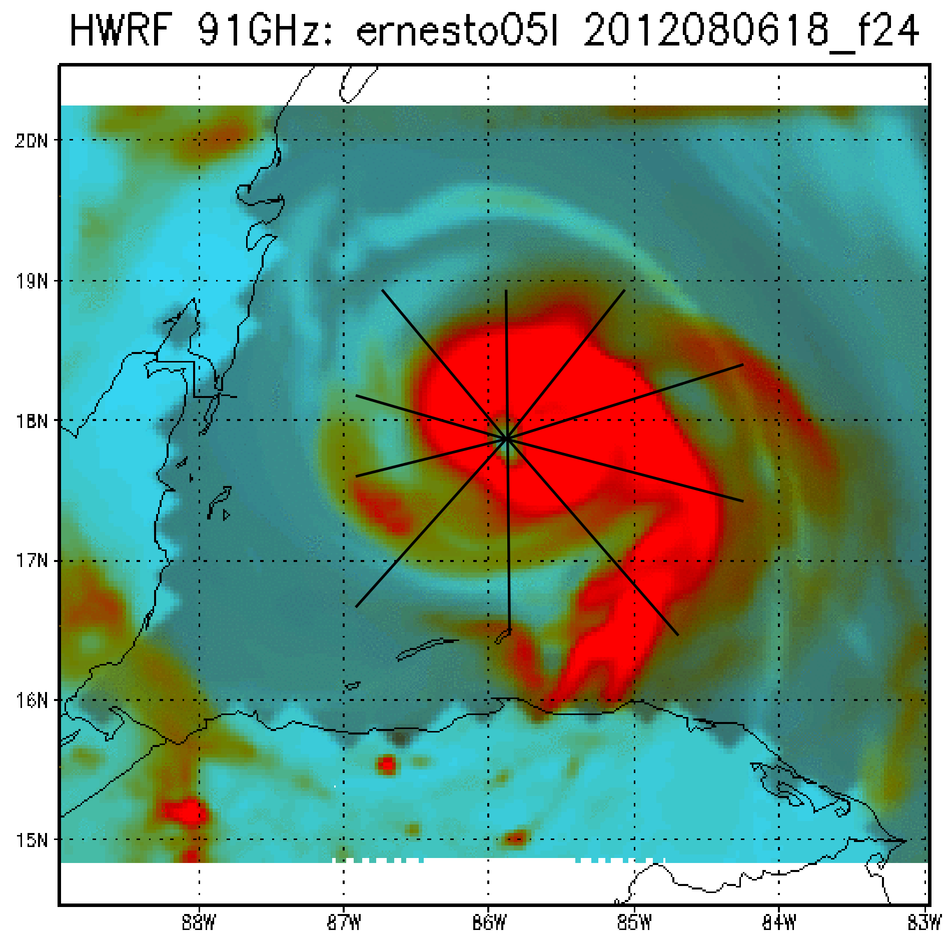
- If it is not, the eyewall fraction is automatically set to 0.



Methodology:
Evaluating Satellite imagery

2) Does deep convection (Red in the 91/89/85 GHz color composites) define the edge of the center?

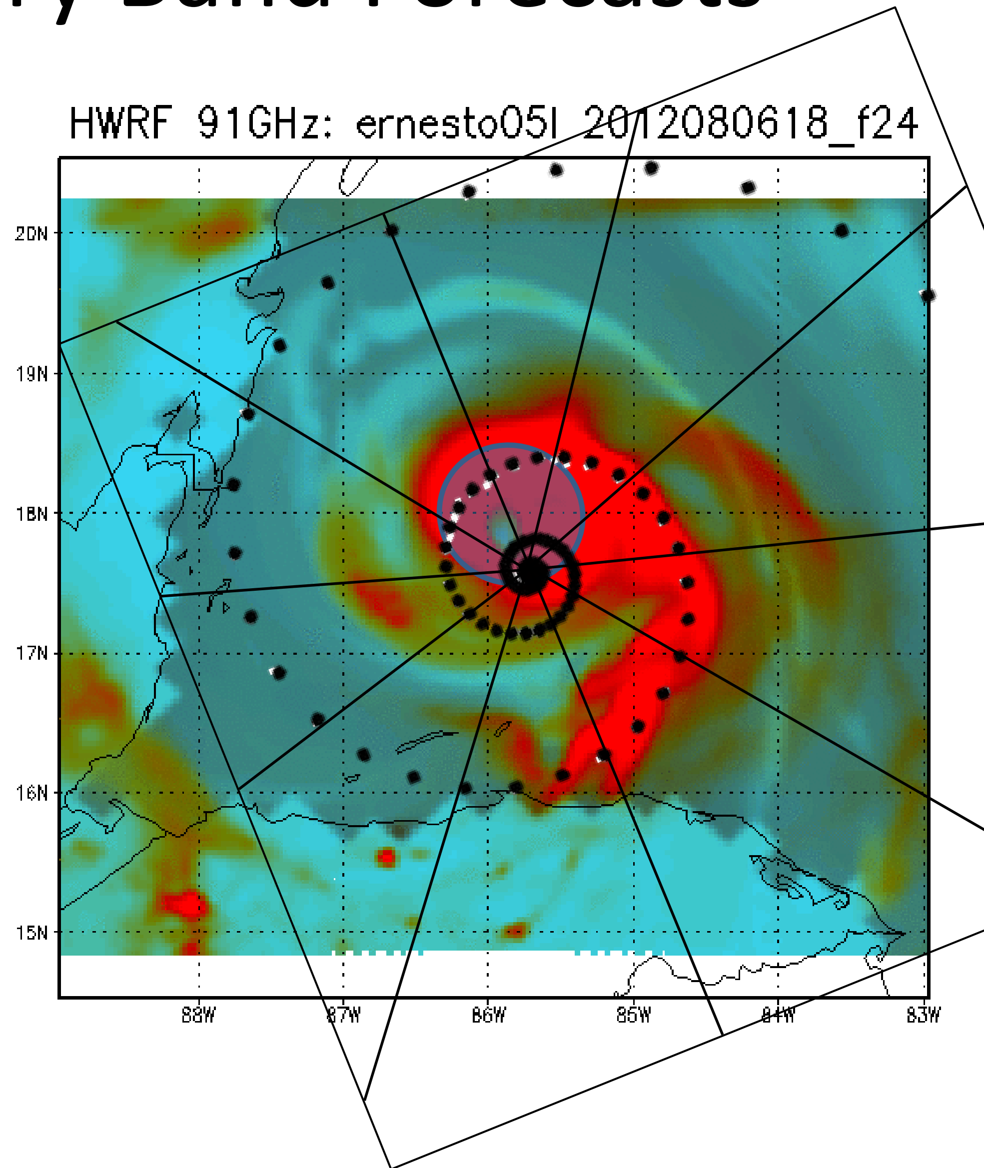
- If no, the eyewall fraction is 0.
- If yes, what percent? (to nearest 10^{th}, always rounding down)



Methodology: Evaluating Primary Band Forecasts

3) Is deep convection present within clearly defined (unbroken) bands that spiral around the center?

- If no, band = 0.
- If yes, fit the Dvorak log-10 spiral to the middle of the band and count the number of tenths.
- Note: If the band continues unbroken into an eyewall, the eyewall can count as part of the band, as long as at least 3/10 of that band exists completely independently of the eyewall itself.



Methodology: Evaluating real imagery

- Follows the same set of rules as HWRF
- Real images must be within 3 hours of the verifying HWRF forecast, and must show the entire inner-core of the tropical cyclone
- If multiple satellite passes are available, only the one closest to the verifying time is used.
  - Exception: If multiple passes are both within 1.5 hours of the verifying time, and one image is superior due to better resolution, or is somehow less subjective, then that image is used regardless of timing.
  - If no single pass covers the entire inner core, passes from 2 different satellites can be composited to get a depiction of the full storm
- If no images are available at all, that time is flagged as missing, and removed from the verification
  - No effort made to smooth the verification data

Caveats

- Differences between real and observed images
  - Resolution
  - Viewing angle
  - Instrument selection
  - Limitations of CRTM
- Timing considerations
  - Real images must be within 3 hours of verifying time
  - Tropical Cyclone convective structure may change rapidly over very short time-scales
- Manual analysis is inherently subjective
  - Eyewall and Primary band explicitly defined to try to limit this.
  - Excessively subjective cases flagged and removed from verification
- Landfall cases removed

Preliminary Results

- Eyewall results computed for TCs from HWRF implementation in May through early August.
  - "Eyewall" defined here as 6/10 of an eyewall or more.
- 24, 48, and 72 hour forecasts verified
- Atlantic cases
  - Beryl, Chris, Debby, Ernesto, Florence
- Pacific cases
  - Bud, Carlotta, Daniel, Emilia, Fabio, Gilma

Preliminary Results

- Contingency Accuracy
  - Overall, what fraction of the forecasts were correct (a “yes” forecast was observed as a “yes” or a “no” forecast was observed as a “no)?
- Probability of Detection
  - What fraction of the observed “yes” events were correctly forecast?
- False Alarm Rate
  - What fraction of the observed “no” events were incorrectly forecast as “yes”?
- Success Rate
  - What fraction of the forecast “yes” events were correctly observed?
- Equitable Threat Score (ETS)
  - How well did the forecast “yes” events correspond to the observed “yes” events (accounting for hits due to chance)?
  - -1/3 to 1, 0 indicates no skill, 1 = perfect score

Source: WCRP Forecast Verification Page

Preliminary Results: 24 hour Forecasts

Contingency Table

Forecast \ Observed	Yes	No
Yes	12	6
No	18	53

Observed

Stats

- Total Cases: **89**
- Contingency Accuracy: **73.03%**
- Probability of Detection: **40.00%**
- False Alarm Rate: **10.17%**
- Success Ratio: **66.67%**
- ETS: **0.20**

Preliminary Results: 48 hour Forecasts

Contingency Table

Forecast \ Observed	Yes	No
Yes	10	2
No	11	53

Stats

- Total Cases: **76**
- Contingency Accuracy: **82.89%**
- Probability of Detection: **47.62%**
- False Alarm Rate: **03.64%**
- Success Ratio: **83.33%**
- ETS: **0.34**

Preliminary Results: 72 hour Forecasts

Contingency Table

Forecast \ Observed	Yes	No
Yes	5	5
No	6	57

Stats

- Total Cases: **73**
- Contingency Accuracy: **84.93%**
- Probability of Detection: **45.45%**
- False Alarm Rate: **08.06%**
- Success Ratio: **50.00%**
- ETS: **0.24**

Future Work

- Continue analysis for the full 2012 season.
- Examine links between the structure and intensity forecasts, and look for red flags that may tip off forecasters that a forecast may have high errors. ("Guidance on guidance")
- ADT-based Dvorak structure analysis.
- Develop automated scripts to allow for similar studies to be done during pre-implementation testing.
- Analyze 37GHz imagery.
  - Must apply a resolution correction first.