A Retrospective Look at the CIMSS NearCast Model Performance during the May 2013 Tornado Events in Central Oklahoma

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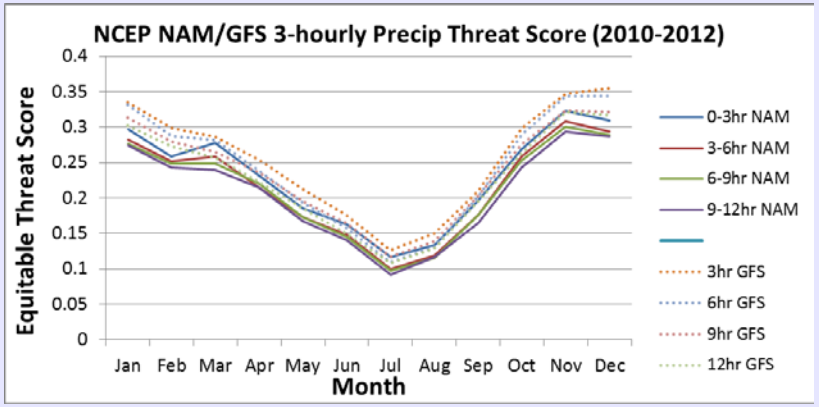
Thank you: Steve Weiss, Phillip Bothwell

OUTLINE

- NearCast System - Background
- NearCast performance for May 20 and 31 and event background
- NearCast in the GOES-R era

Motivation

- NWP performance in predicting short term convective weather/QPF needs to be improved, especially in warm season
  - Partially due to inability to observe/predict mesoscale moisture features



- Satellite observations reveal such details well
  - GOES retrievals = **data fusion**: melds NWP, surface obs, and satellite radiance information
    - Correct errors in model first guess
    - Available at high temporal and horizontal resolution
    - Pre-convective environment
    - **Under-utilized**
- How can we use this information?
  - NearCast Model takes advantage of the detailed, under-utilized satellite moisture retrievals in a data-driven trajectory model

NearCast Model Background

- Lagrangian model dynamically projects satellite temperature and moisture data forward in space and time to 9 hours at multiple atmospheric levels
  - Expands the utility of sounding products from observations to forecast tools as well
  - Large timestep (10-15 minutes) leads to quick run-times (1-2 minutes) and small data latency
  - Model updates when new observations are available (hourly for current GOES)
  - No smoothing of data, so details detected in the observations (moisture minima, maxima, boundaries) are preserved at full 10 km resolution
  - Model retains up to 10 hours of previous observations, filling in data-gaps, further utilizing every observation.

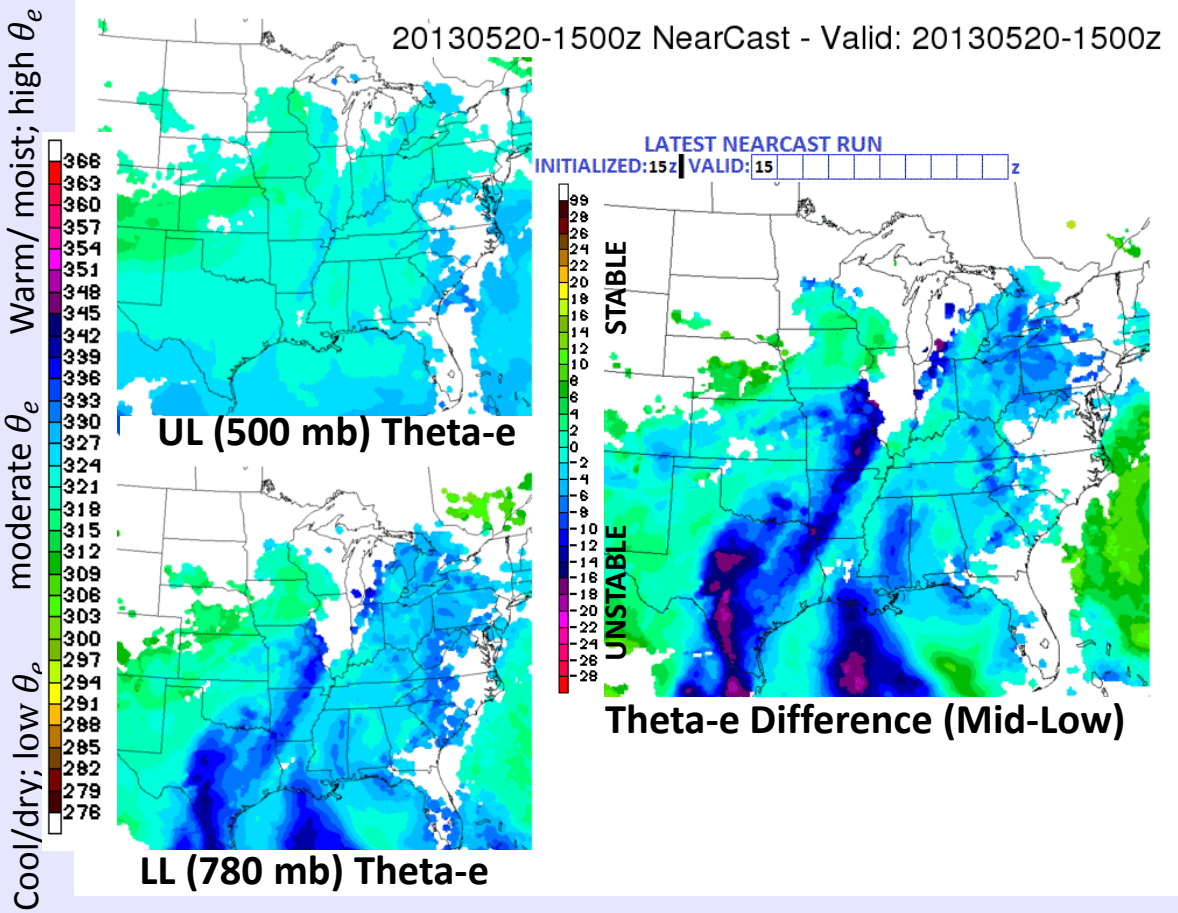
NearCast Model Background

- NearCast model provides forecasters with observation-based analyses and 1-9 hour forecasts of the thermodynamic environment
  - Vertical moisture and stability information helps forecasters to:
    - Predict where/when convection is more (and less) likely to occur in the near future
    - Assess whether the downstream environment will support persistence or further growth of existing convection
    - Monitor NWP model performance
- Information displayed as layer theta-e, PW, layer difference fields, and other derived parameters

❖Products are meant to compliment other meteorological tools; not to be used alone

Sample NearCast

- Theta-e computed within each layer
  - Each field represents a 200-300 hPa thick layer average, the resolving power of GOES
- Theta-e difference, or lapse rate, computed for deep layer (convective instability of layer)
  - Objective way to show where dry/cool air at upper levels is moving over relatively warm/moist air at lower levels.
  - This method mimics water vapor imagery
- Similar technique done for layer PW
- Other derived parameters



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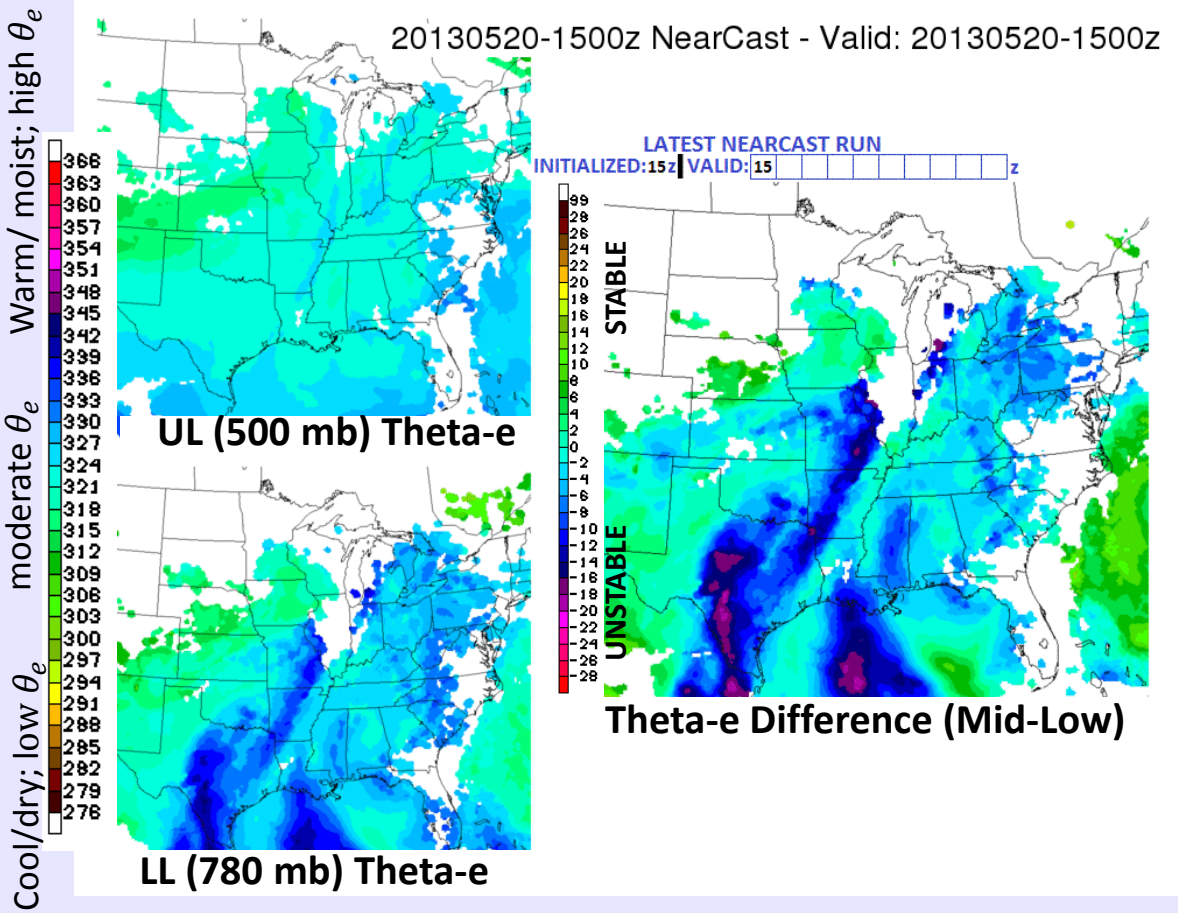
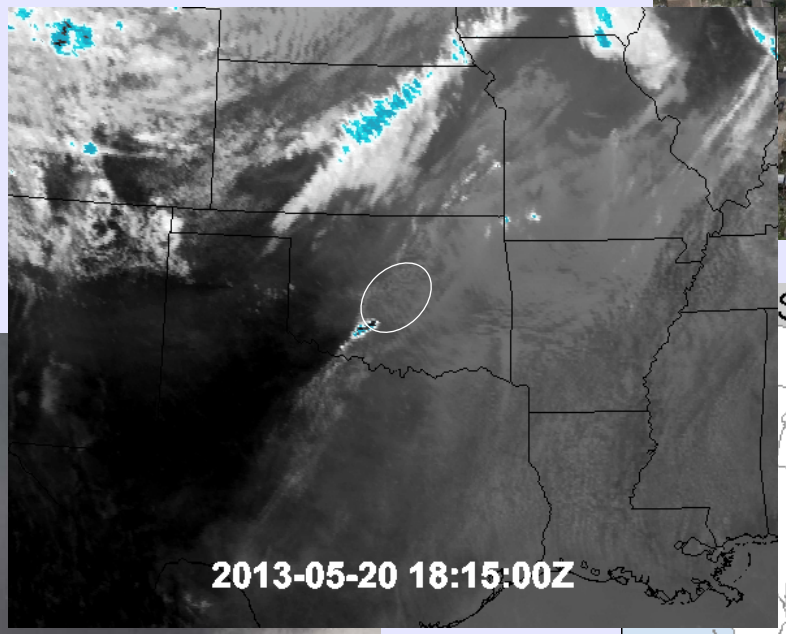
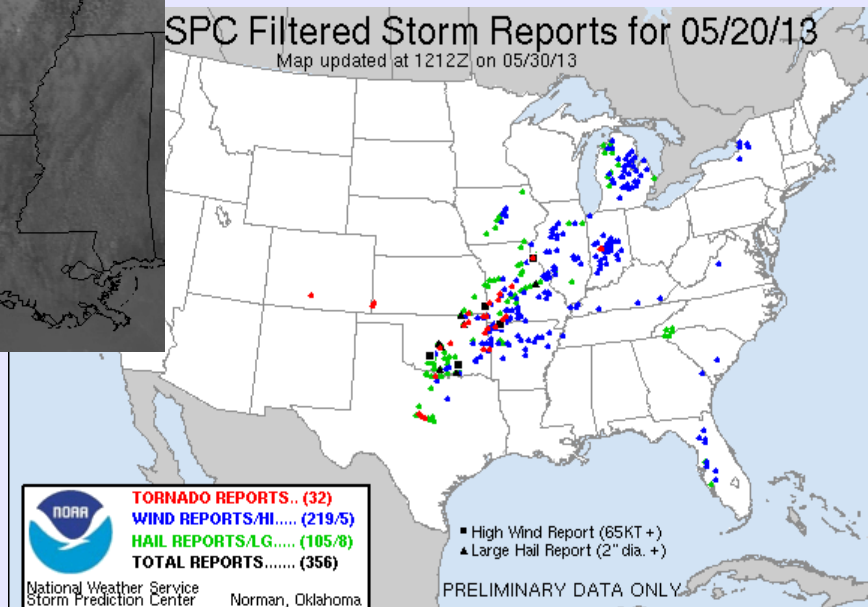


Lagrangian Model Projects observations forward in space and time 9 hours

May 20, 2013

- Moore, Oklahoma tornado
  - 24 fatalities, 377 injuries
  - >$2 billion damages (estimated)
- Large hail and damaging winds

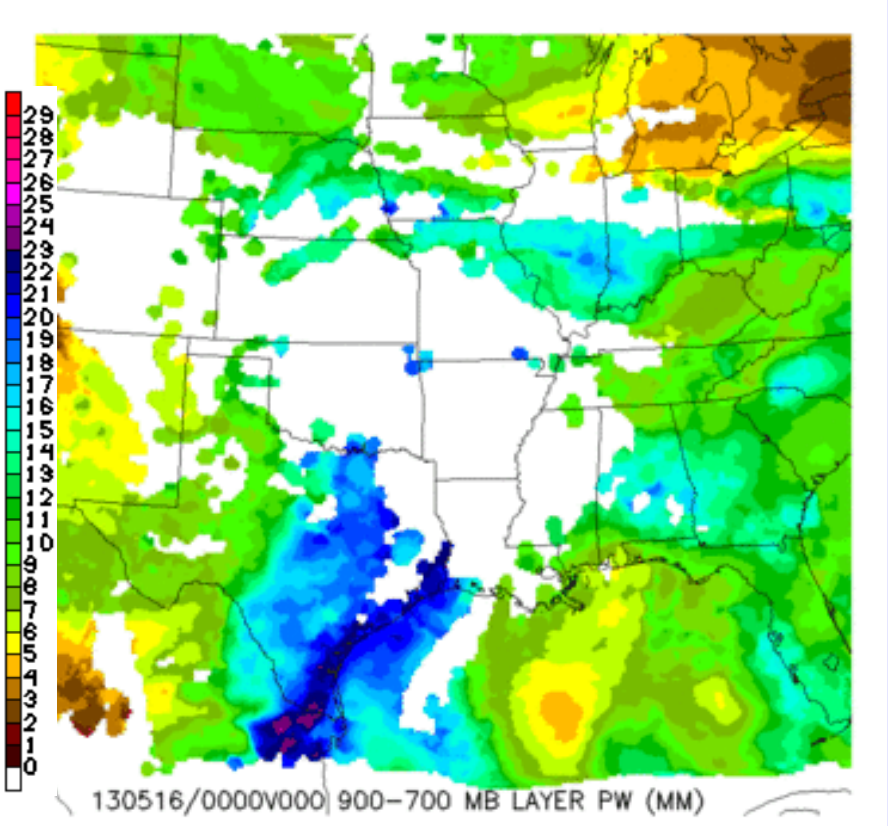




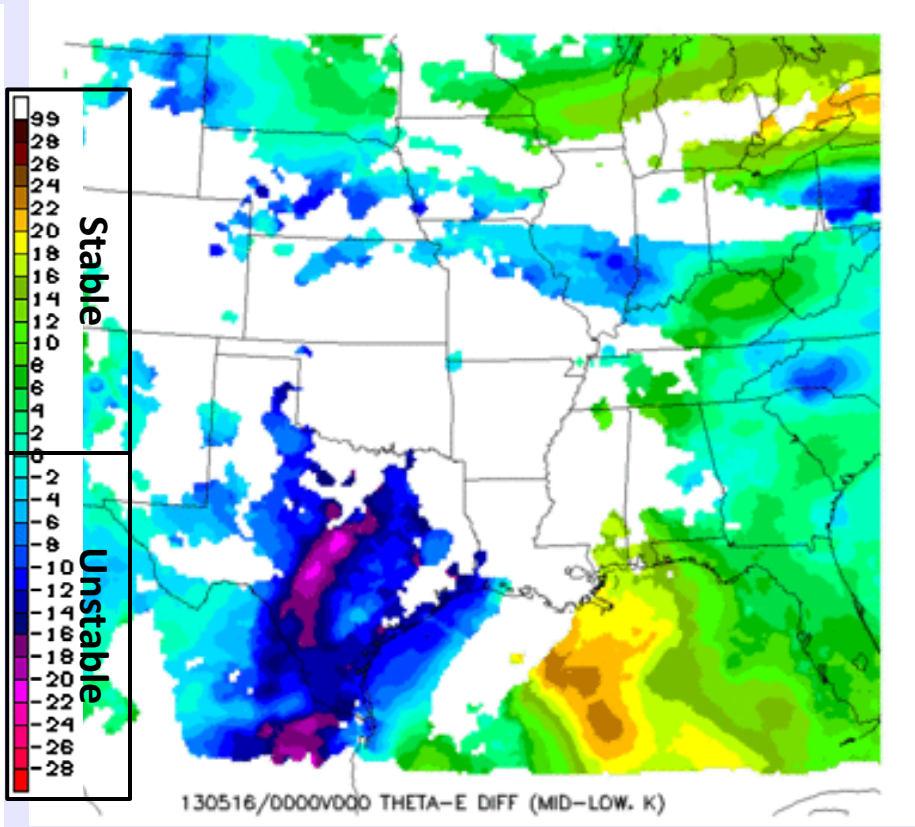
NearCast Analyses

May 16, 00Z - May 21, 06Z

Low-level moisture return evident in loops of analyses leading up to events



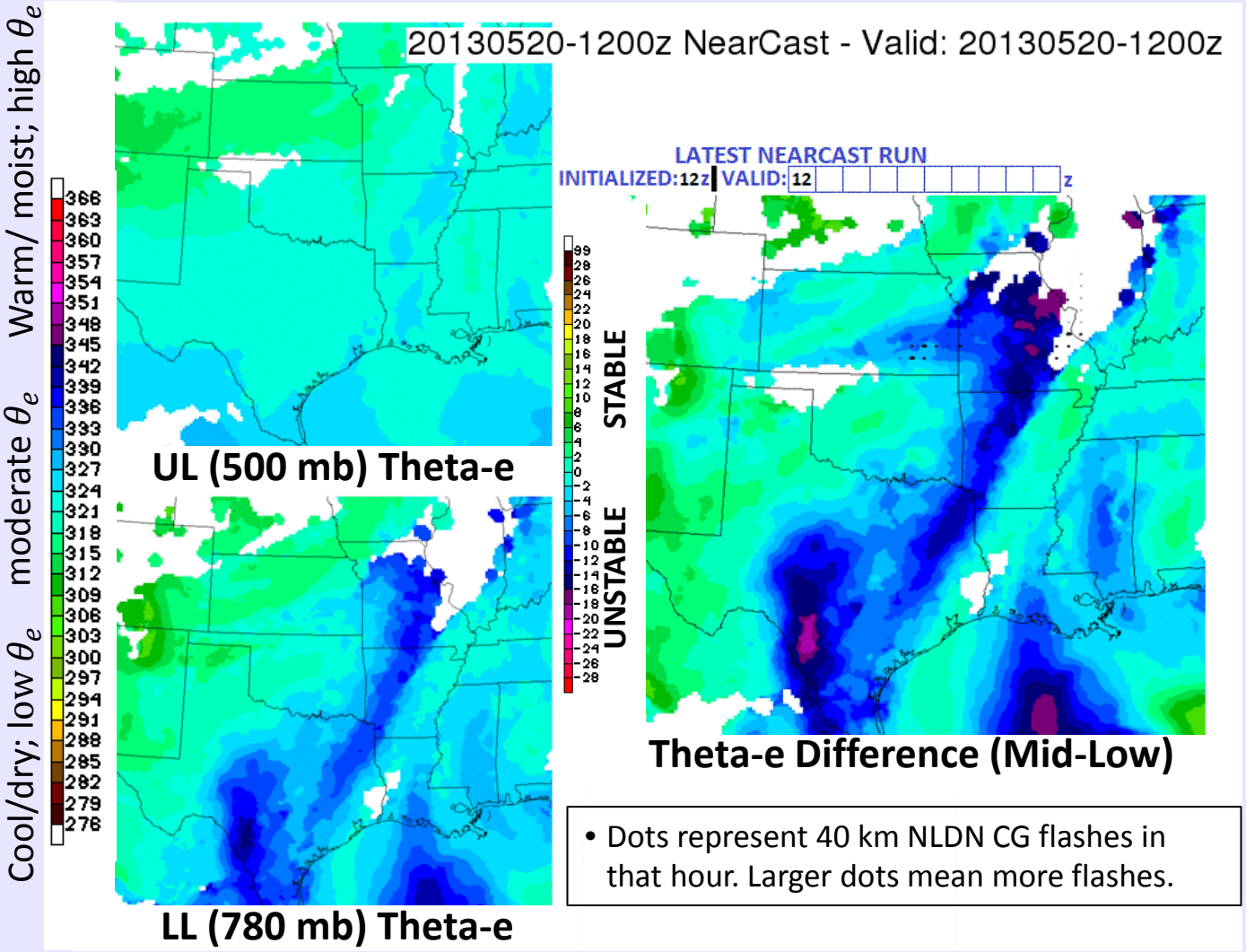
Low-Mid Layer PW



Theta-e Layer Difference (Mid-Low)

May 20, 2013 Moore Tornado

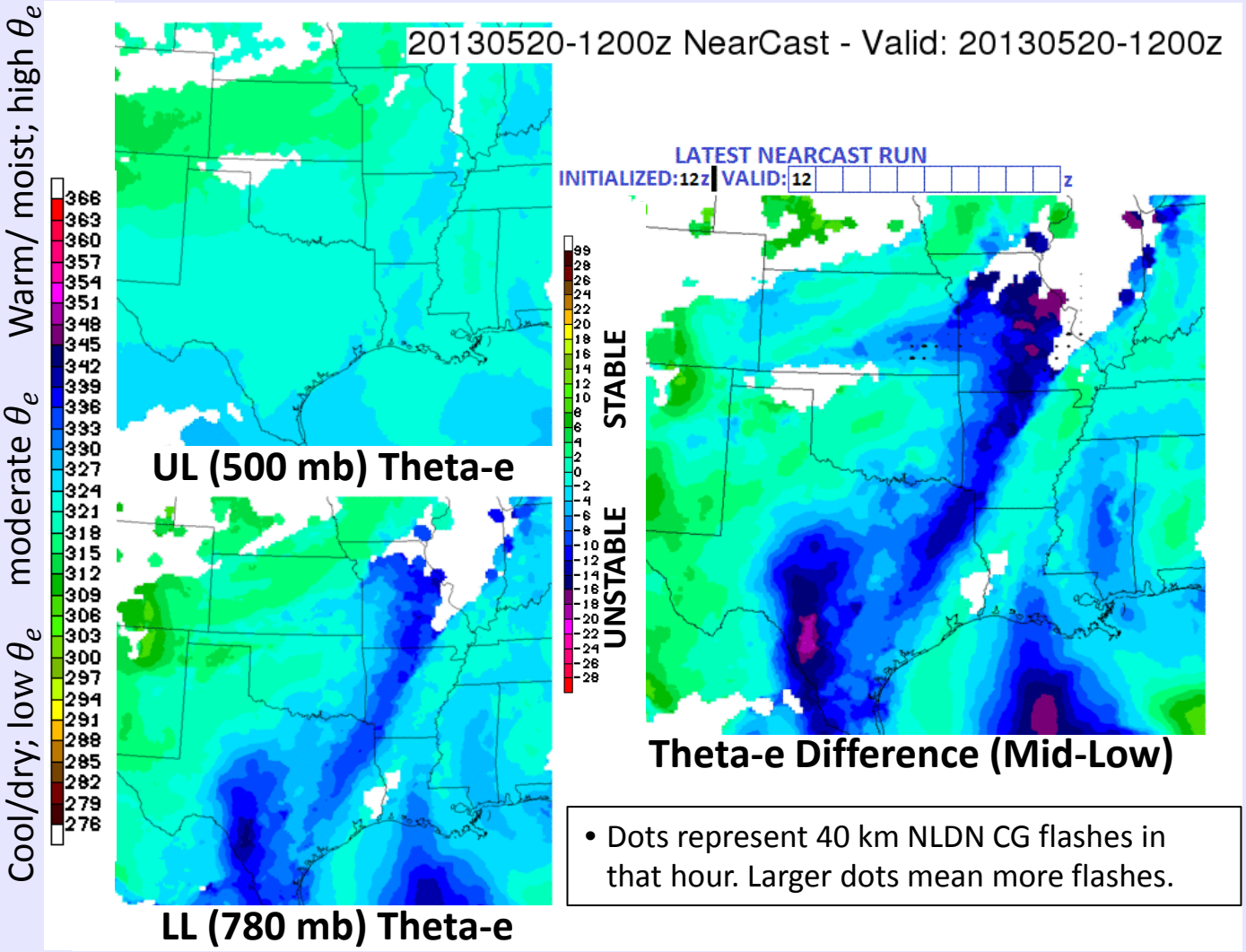
12Z Forecast



- Dots represent 40 km NLDN CG flashes in that hour. Larger dots mean more flashes.

May 20, 2013 Moore Tornado

12Z Forecast



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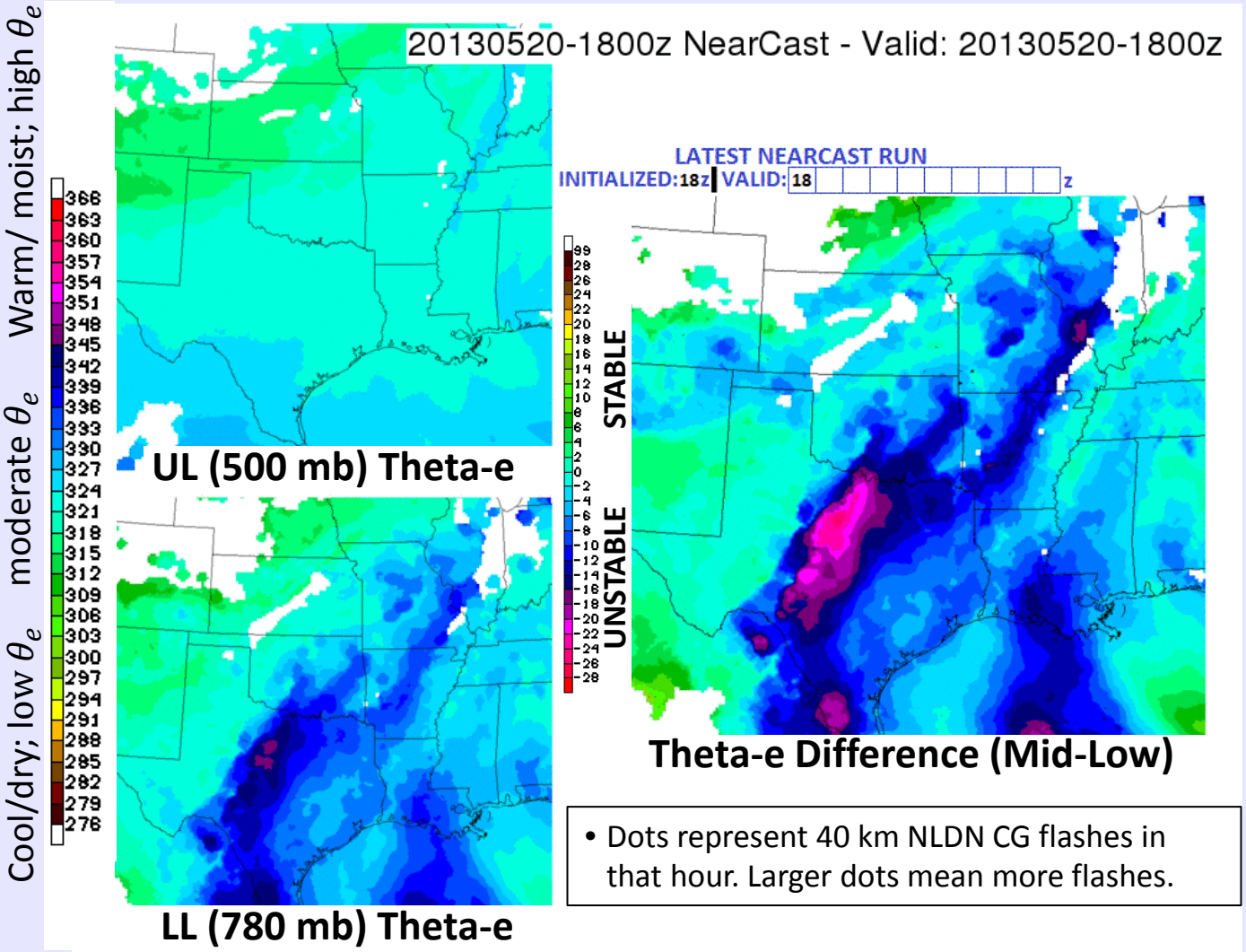
May 20, 2013 Moore Tornado

18Z Forecast



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May 20, 2013 Moore Tornado

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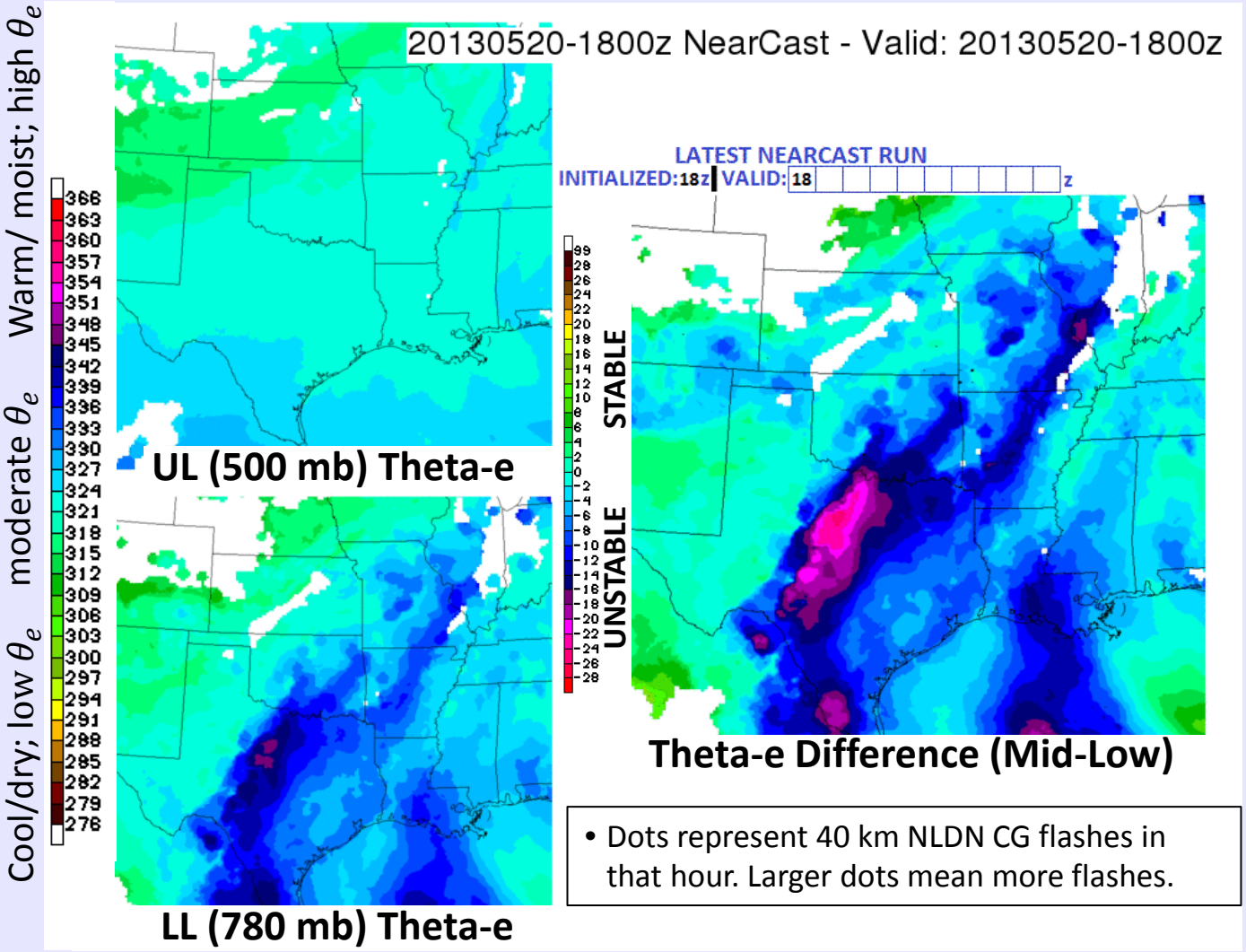

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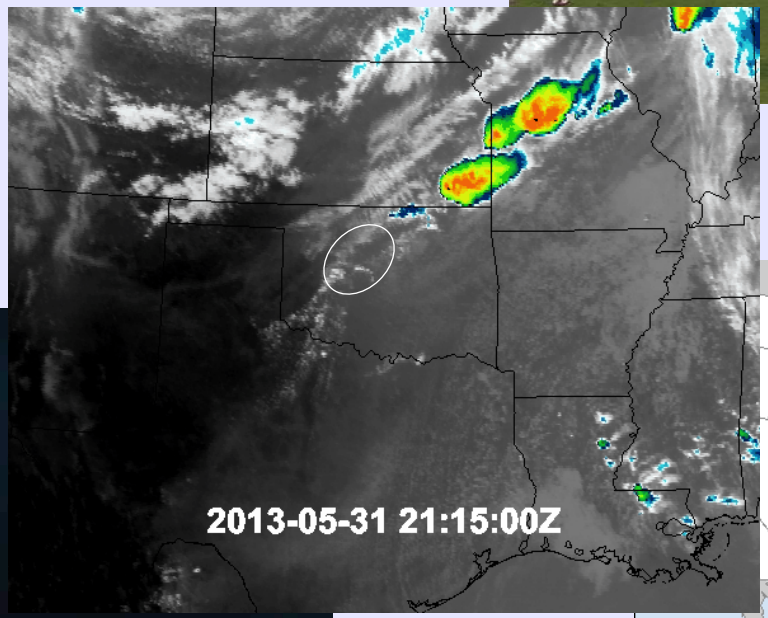
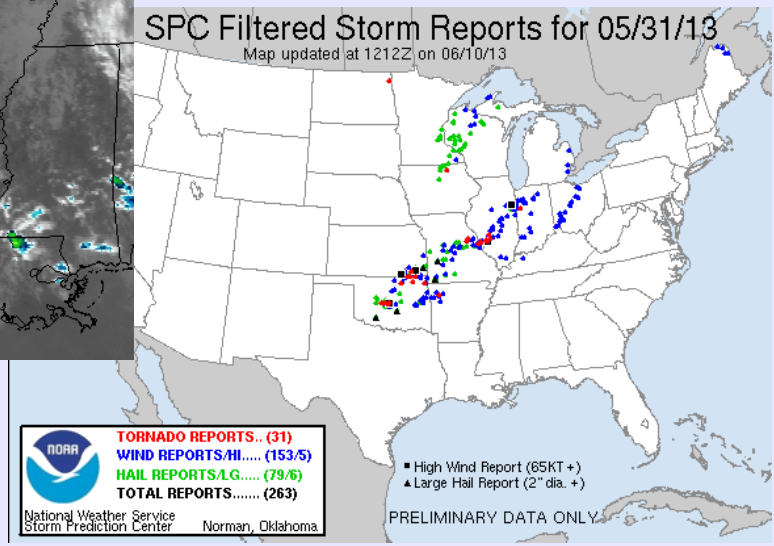
May 31, 2013

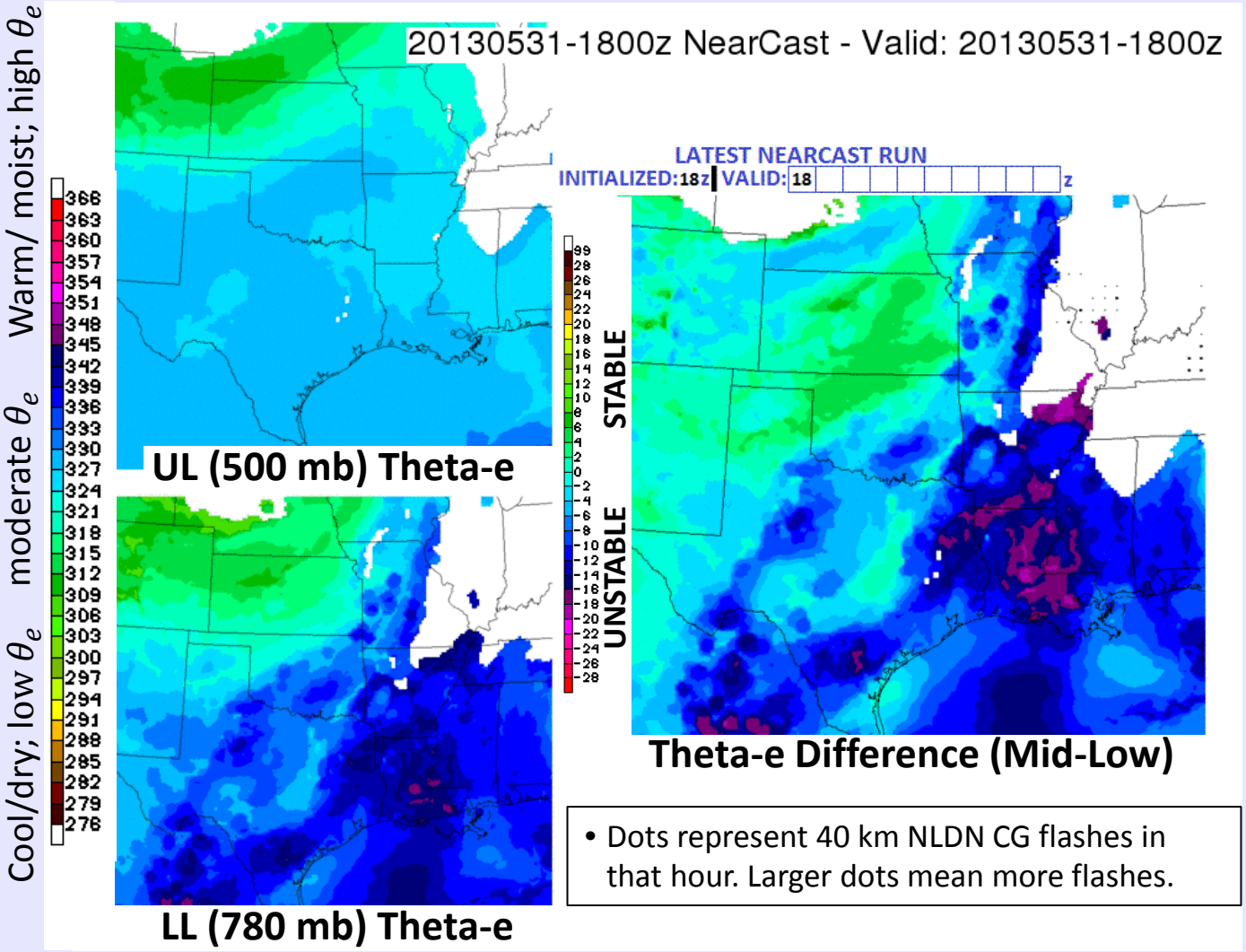
- El Reno, Oklahoma tornado
  - 8 deaths, 151 injuries
  - >$30 million (estimated)
  - Widest tornado on record
- Large hail and damaging winds and fatal flooding





May 31, 2013 El Reno Tornado

18Z Forecast



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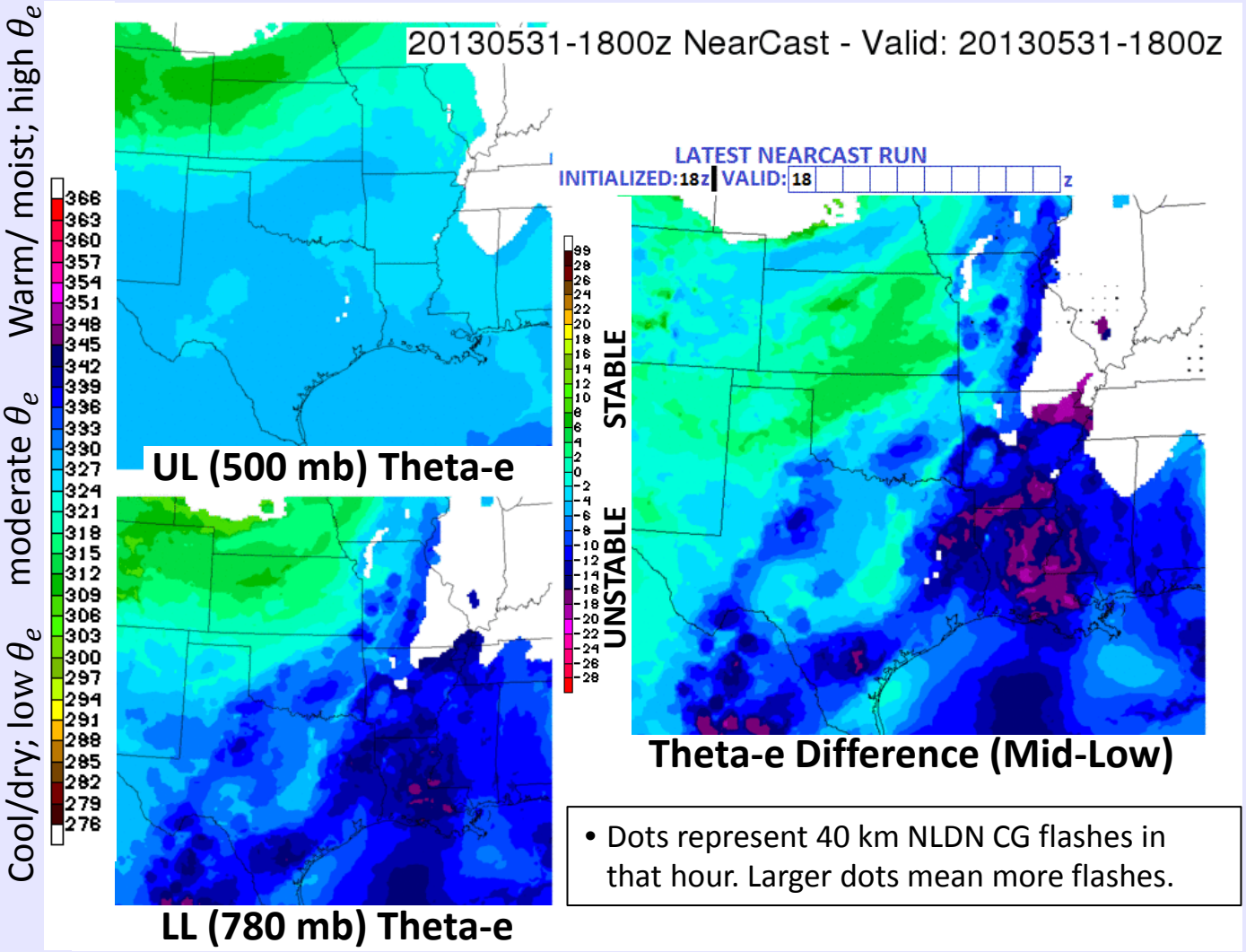
May 31, 2013 El Reno Tornado

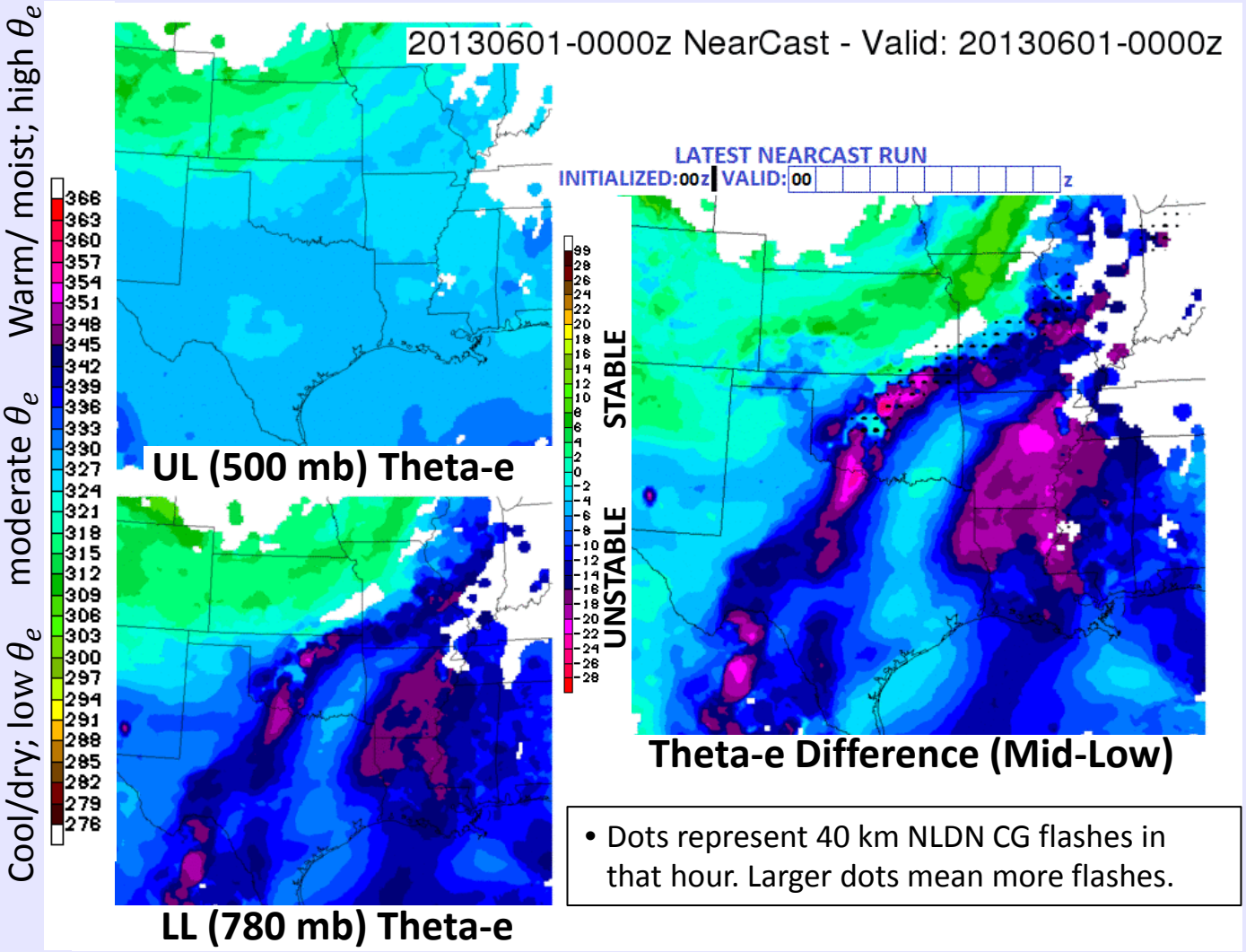
18Z Forecast



- Dots represent 40 km NLDN CG flashes in that hour. Larger dots mean more flashes.

May 31, 2013 El Reno Tornado

00Z Forecast



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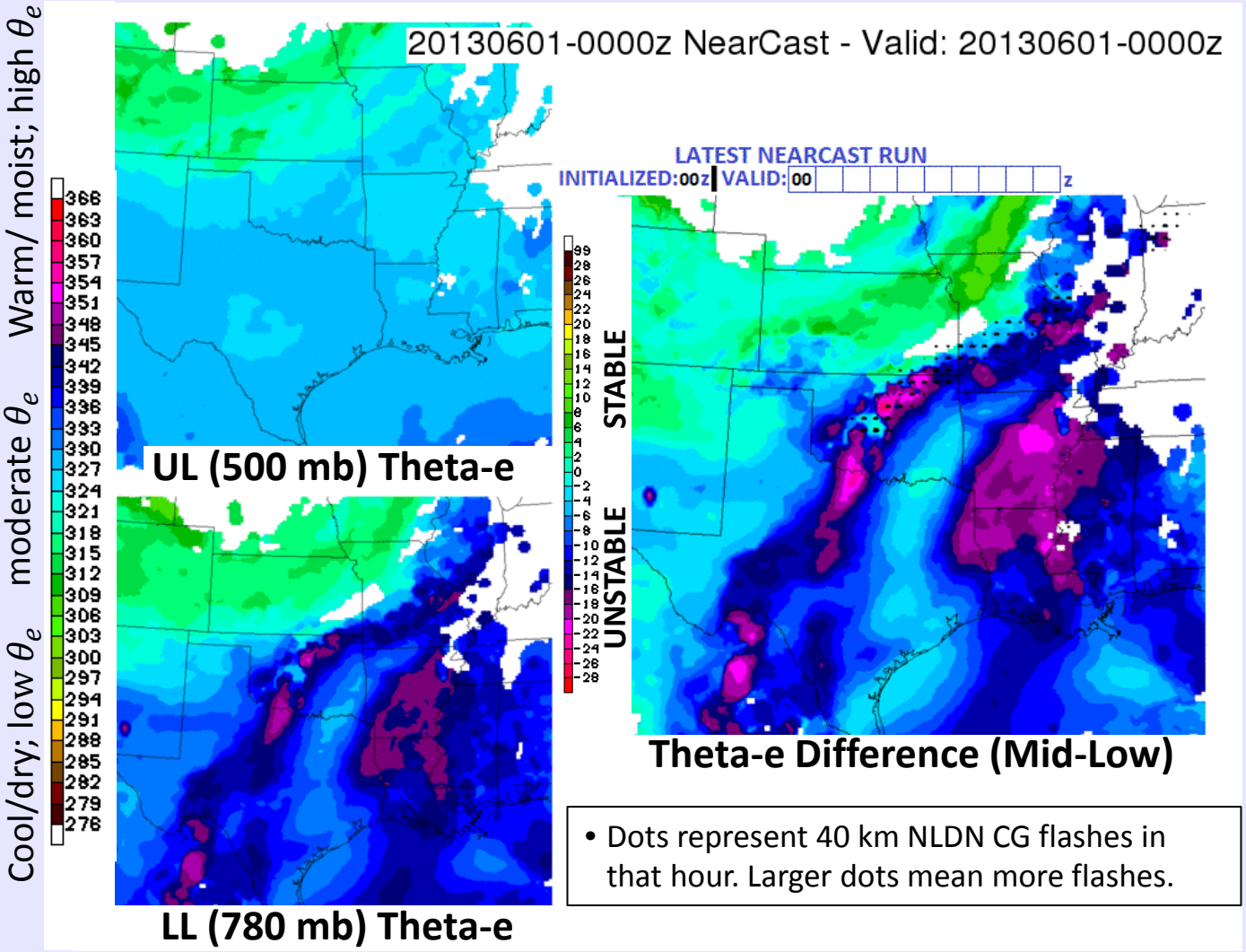
May 31, 2013 El Reno Tornado

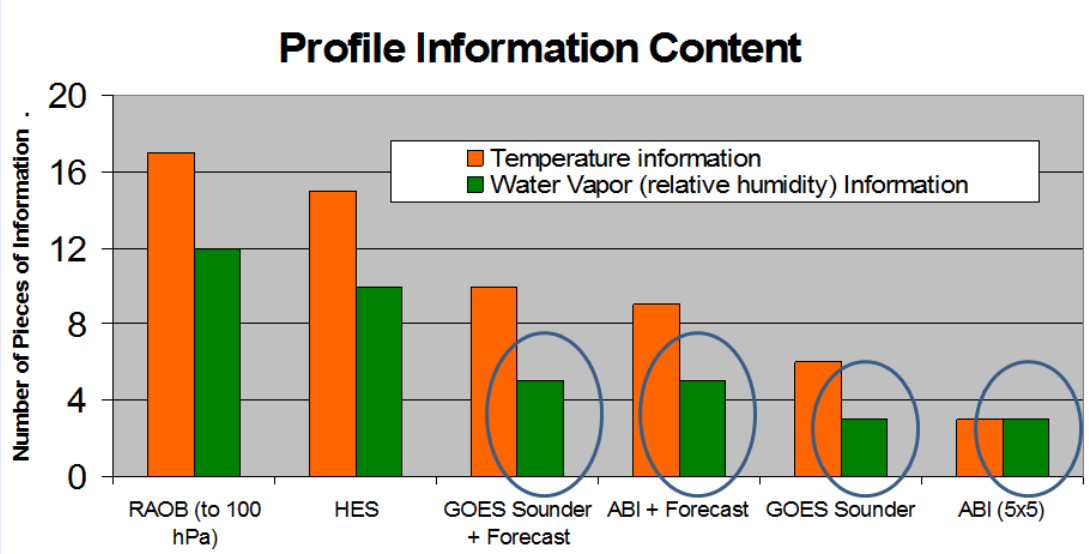
00Z Forecast



- Dots represent 40 km NLDN CG flashes in that hour. Larger dots mean more flashes.

NearCast in the GOES-R era

- NearCast model will utilize GOES-R **baseline products:** 'legacy vertical temperature and moisture profiles', which will provide information that is a continuation of the current GOES sounder products:
  - Similar spectral information (3 tropospheric moisture channels)
  - Same spatial information (10 km, may be improved)
  - Sub-hourly availability (every 30 minutes, possibly more)



Summary

- NearCast system provides **observation-based** analyses and forecasts of the thermodynamic environment up to 9 hours in advance
  - By preserving full-resolution, under utilized moisture retrieval data in a quick-updating Lagrangian model
- Trends in NearCast analyses are useful in showing the recent evolution of moisture and stability fields leading up to the present time
- Forecasts are helpful in predicting the development and evolution of convection in the near future, especially when used in conjunction with other forecast tools
- NearCast system in the GOES-R era will use the baseline legacy sounding products which will provide similar moisture information to what is currently available

EXTRA SLIDES

The GOES-R Advanced Baseline Imager and the continuation of current GOES sounder products

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The GOES-R Advanced Baseline Imager and the Continuation of Current Sounder Products

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ABSTRACT

The first of the next-generation series of Geostationary Operational Environmental Satellites (GOES-R) is scheduled for launch in the 2015 time frame. One of the primary instruments on GOES-R, the Advanced Baseline Imager (ABI), will offer more spectral bands, higher spatial resolution, and faster imaging than does the current GOES Imager. Measurements from the ABI will be used for a wide range of qualitative and quantitative weather, land, ocean, cryosphere, environmental, and climate applications. However, the first and, likely, the second of the new series of GOES will not carry an infrared sounder dedicated to acquiring high-vertical-resolution atmospheric temperature and humidity profiles that are key to mesoscale and regional severe-weather forecasting. The ABI will provide some continuity of the current sounder products to bridge the gap until the advent of the GOES advanced infrared sounder. Both theoretical analysis and retrieval simulations show that data from the ABI can be combined with temperature and moisture information from forecast models to produce derived products that will be adequate substitutes for the legacy products from the current GOES sounders. Products generated from the Spinning Enhanced Visible and Infrared Imager (SEVIRI) measurements also demonstrate the utility of those legacy products for nowcasting applications. However, because of very coarse vertical resolution and limited accuracy in the legacy sounding products, placing a hyperspectral-resolution infrared sounder with high temporal resolution on future GOES is an essential step toward realizing substantial improvements in mesoscale and severe-weather forecasting required by the user communities.

1. Introduction

As we prepare for the next generation of geostationary satellites, it is important to ensure the continuity and quality of products that users depend on from the current satellite series. The Geostationary Operational Environmental Satellite (GOES) sounders (Menzel and Purdom 1994) have provided quality hourly radiances and derived products over the continental United States and adjacent oceans for over a decade (Menzel et al. 1998; Daniels et al. 2001; Hillger et al. 2003). The derived products include clear-sky radiances, temperature and moisture profiles, total precipitable water vapor (TPW) and layer precipitable water, atmospheric stability indices such as convective available potential energy and lifted index (LI), cloud-top properties (Schreiner et al. 2001), clear-sky water vapor winds through radiance tracking (Velden et al. 1998), and total column ozone (Li et al. 2007; Li et al. 2001). These products are used for a number of numerical weather prediction (NWP) and forecasting applications (Menzel and Purdom 1994; Bayler et al. 2000; Dostalek and Schmit 2001; Schmit et al. 2002). The *GOES-13*/O/P sounders will continue this mission of nowcasting (short-term forecasts) and NWP support. *GOES-13* is the current on-orbit spare, and GOES-O and GOES-P have not yet been launched.

The next-generation geostationary satellite series will enable many improvements and new capabilities for imager-based products. Given that GOES-R will not

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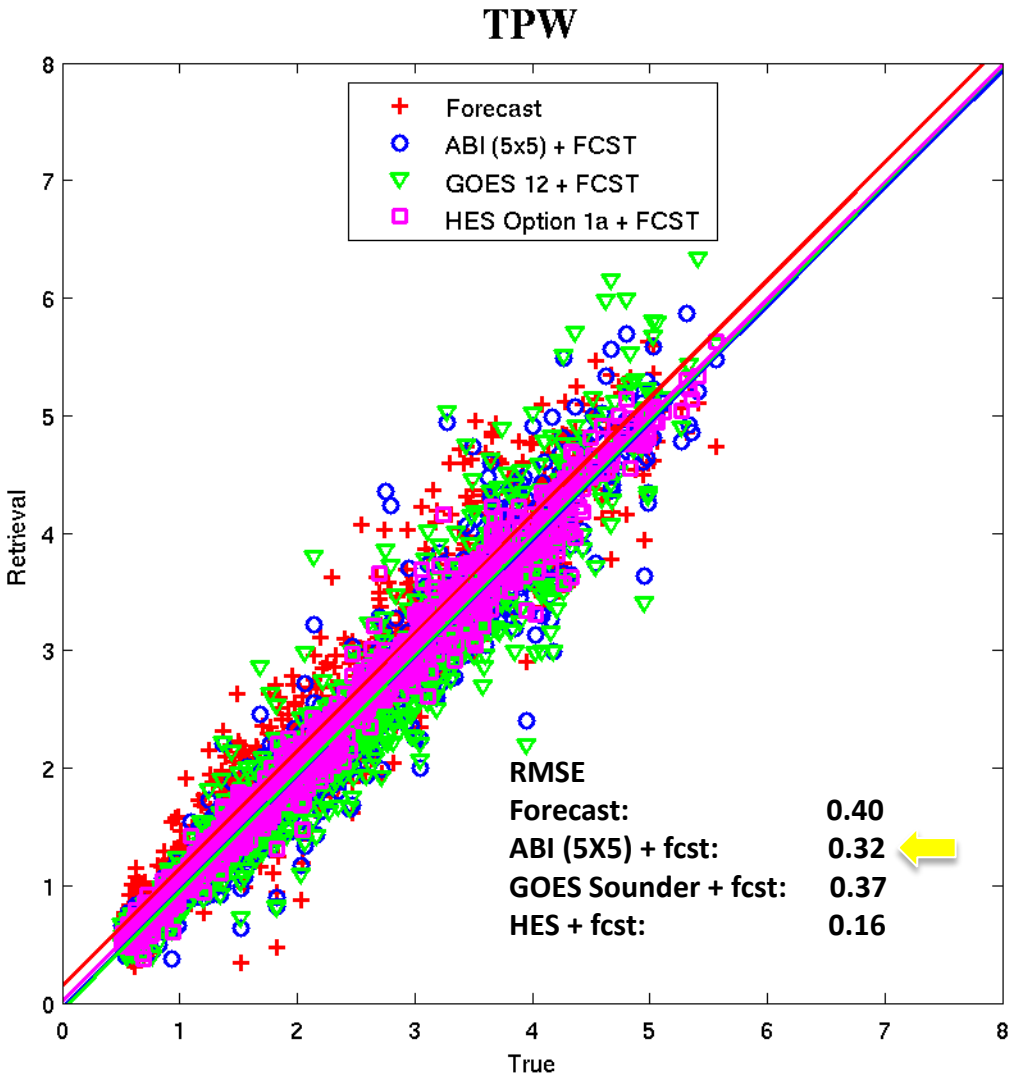
- Schmit, T. J., J. Li, J. J. Gurka, M. D. Goldberg, K. Schrab, Jinlong Li, and W. Feltz, 2008: The GOES-R Advanced Baseline Imager and the continuation of current GOES sounder products, J. of Appl. *Meteorol. and Climatology*, 47, 2696 – 2711.

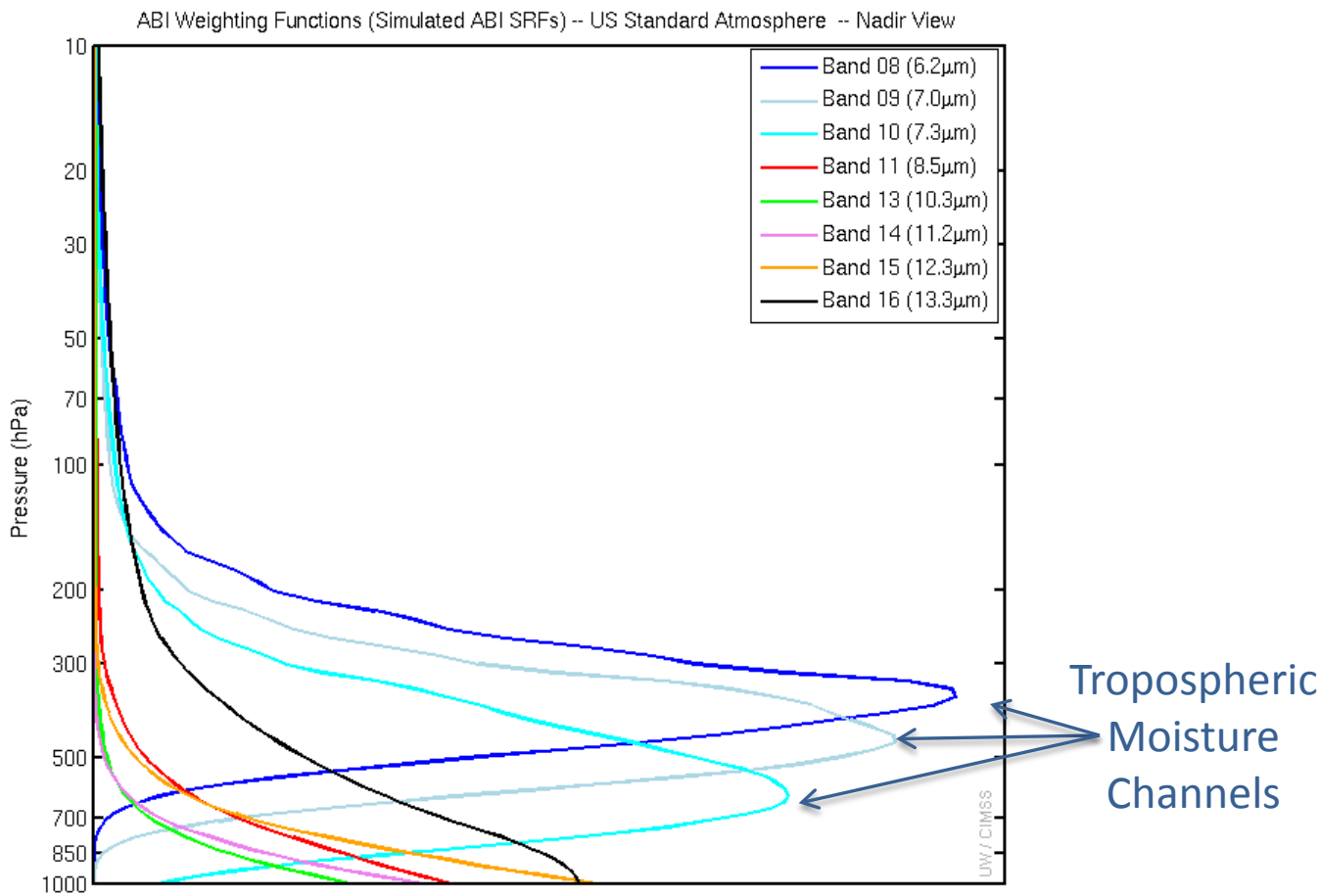
(Download)

ABI Retrieval Performance

Regional simulation (06Dec2006)

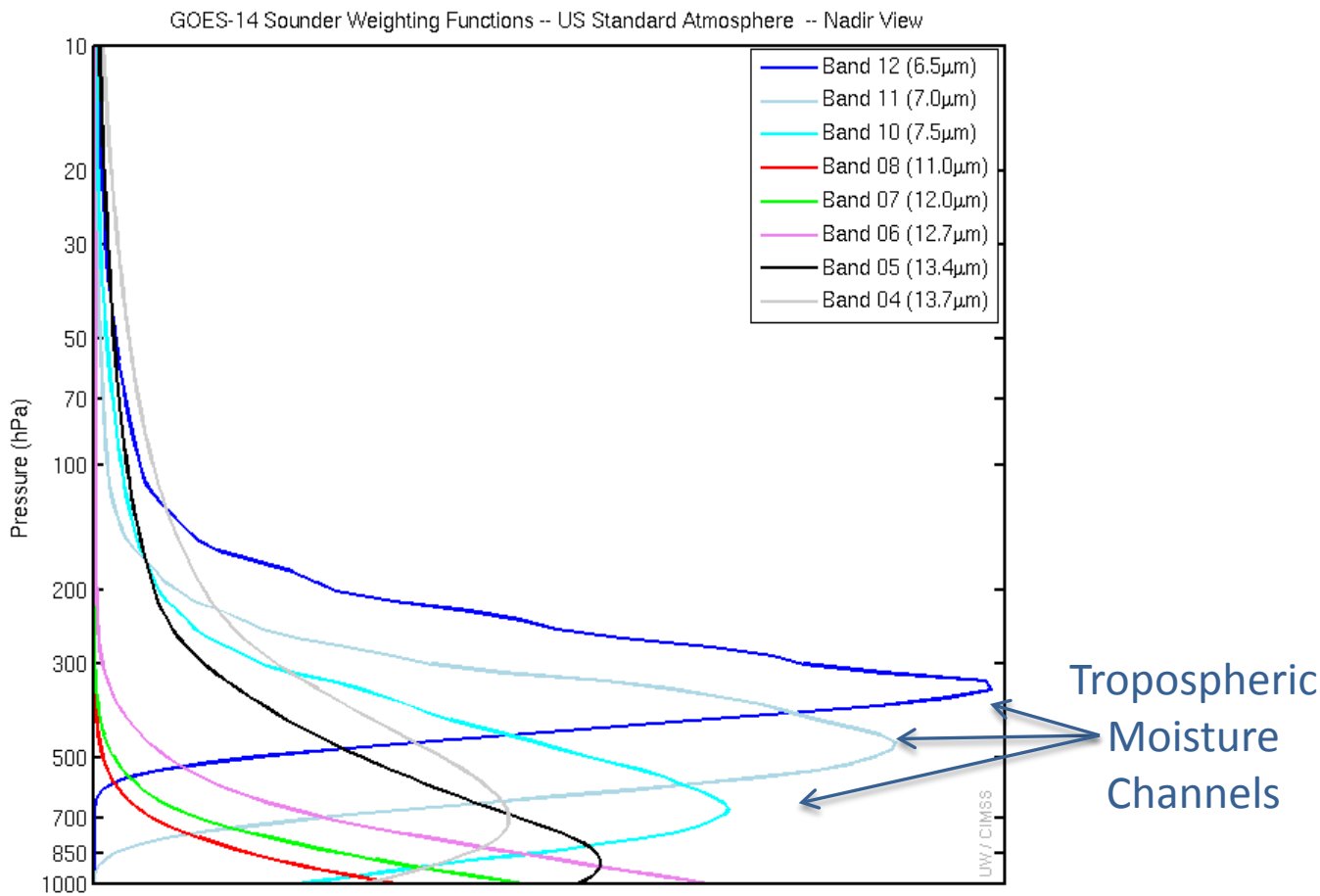


GOES-R ABI Weighting Functions (moisture sensitive bands)



Note that both the ABI and GOES Sounders have 3 mid-tropospheric water vapor bands. The ABI does have a 'cleaner' 10.35 micrometer band.

GOES-13 Sounder WFs
(moisture sensitive bands)



Both the ABI and GOES Sounders have 3 mid-tropospheric water vapor bands. The ABI does have a 'cleaner' 10.35 micrometer band that the GOES Sounders do not.

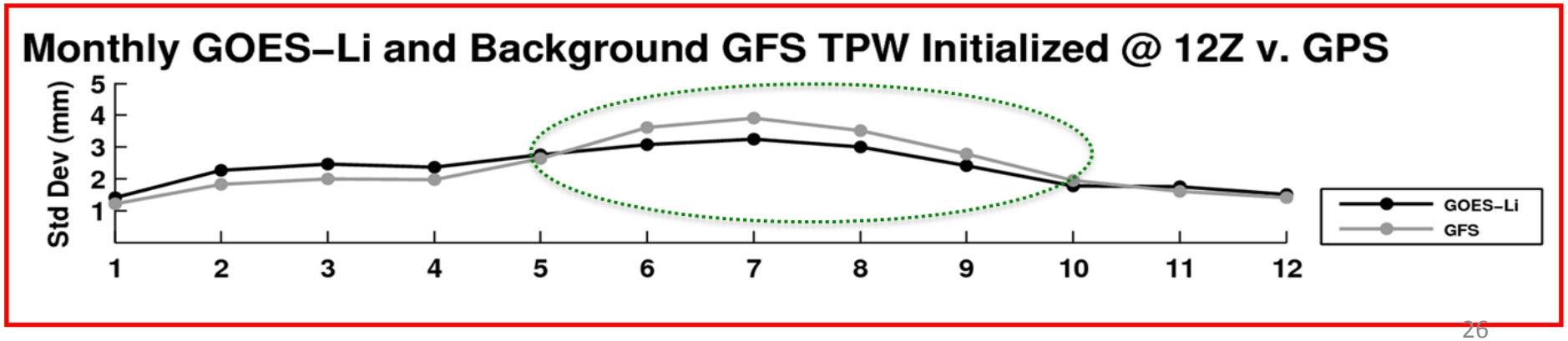
First, assure that the Satellite Soundings add information

Evaluation of GOES Precipitable Water Retrievals
(Using NCEP GFS for First Guess)

- Comparisons against GPS TPW observations around the US show:

- GOES TPW (Li retrievals) data have a wet bias
  - Worst at time of day when GFS has highest precipitation bias

- GOES TPW data show greatest improvement over GFS First Guess:
  1) In warm months (*when NWP precipitation skill is worst*) and
  2) Using 06Z, **12Z** and 18Z GFS guess fields



Explicit Trajectory Approach

- Method uses an initial wind (obtained from forecast gridded velocity field) to start trajectories.
- Trajectories are dynamically updated at every timestep using (forecasted) pressure gradient fields.

At each time increment, the acceleration of every parcel is updated using the inviscid equations of motion

$$a_x{}^t = -\frac{\Delta M^t}{\Delta x} + f^t v^t \qquad a_y{}^t = -\frac{\Delta M^t}{\Delta y} - f^t u^t$$

Then, parcel velocities and positions are updated, based on the discrete model formulation of Greenspan (1972, 1973):

$$u^{t+1} = u^t + \Delta t(\frac{3}{2} a_x{}^t - \frac{1}{2} a_x{}^{t-1}) \qquad x^{t+1} = x^t + \frac{1}{2}\Delta t(u^{t+1} + u^t)$$

$$v^{t+1} = v^t + \Delta t(\frac{3}{2} a_y{}^t - \frac{1}{2} a_y{}^{t-1}) \qquad y^{t+1} = y^t + \frac{1}{2}\Delta t(v^{t+1} + v^t)$$

The initial timestep requires a special “startup” formula to update parcel velocities

$$u^1 = u^0 + a_x{}^0 \Delta t \qquad v^1 = v^0 + a_y{}^0 \Delta t$$

(Petersen and Uccellini, 1979)

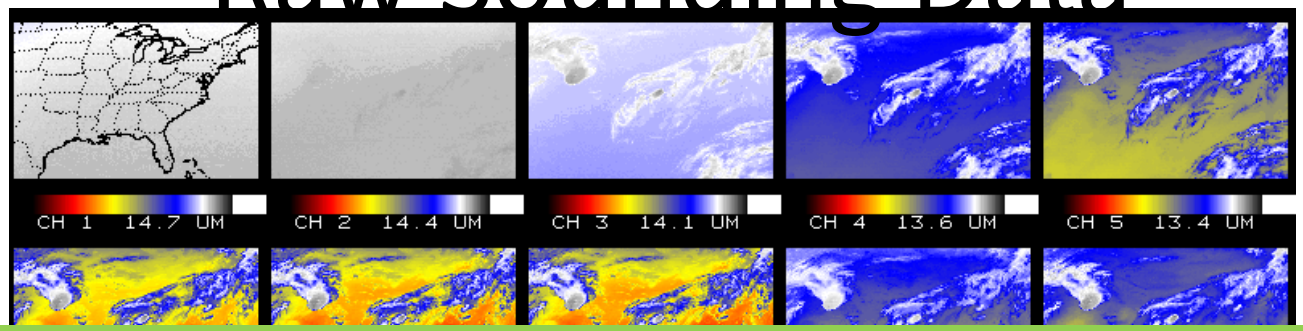
The importance of Preserving Previous Observations in NearCast Analyses and Forecasts

NearCasts analyses/forecast displays retain up to 10 hours of earlier observations in their hourly updates by including data projections (forecast trajectories) from previous model cycles, with recent observations weighted most heavily

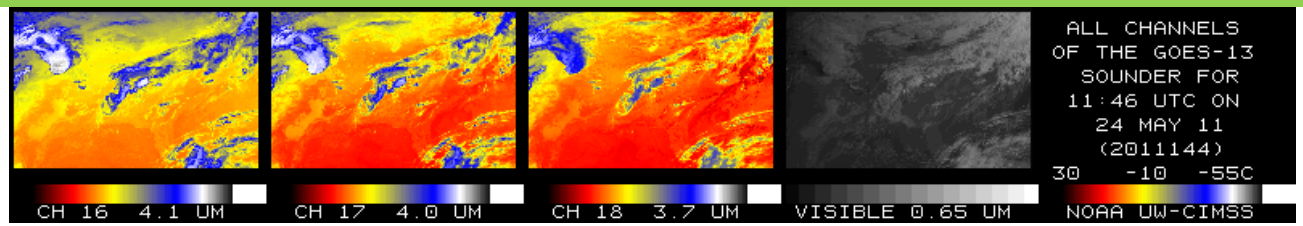
		Forecast Valid																				
		00z	01z	02z	03z	04z	05z	06z	07z	08z	09z	10z	11z	12z	13z	14z	15z	16z	17z	18z	19z	20z
Forecast Initialization	00z	A	1	2	3	4	5	6	7	8	9	10										
	01z		A	1	2	3	4	5	6	7	8	9	10									
	02z			A	1	2	3	4	5	6	7	8	9	10								
	03z				A	1	2	3	4	5	6	7	8	9	10							
	04z					A	1	2	3	4	5	6	7	8	9	10						
	05z						A	1	2	3	4	5	6	7	8	9	10					
	06z							A	1	2	3	4	5	6	7	8	9	10				
	07z								A	1	2	3	4	5	6	7	8	9	10			
	08z									A	1	2	3	4	5	6	7	8	9	10		
	09z										A	1	2	3	4	5	6	7	8	9	10	
	10z	←		CURRENT CYCLE								A	1	2	3	4	5	6	7	8	9	10

ANALYSIS 6HR FORECAST

Raw Sounding Data



Do these satellite data add info to the 1st guess profile about the moisture structure of the atmosphere?



- Retrieval:
  - Model provide a **first guess profile** (surface reports, SST, GFS forecast).
  - Perturb this profile, and resulting **calculated radiances**, until those radiances match the observed radiances.
  - When this is satisfied, the perturbed profile is the **retrieved profile**

NearCast Model in HWT Spring Experiment (2011, 2012, and 2013)

Select feedback:

- *I used it both as a **forecast tool and an analysis tool**.*
- *It really had a **clear picture** of the gradient of moisture and showed a strong push of cooler/dryer air where storms did not end up forming.*
- *The product **helped a lot** to focus on the anticipated area of **initiation**.*
- *... monitored what environment the storms were moving into... **helpful in identifying intensification.***
- *That was my **favorite product**...*
- *Would definitely like to see this in my home WFO.*

NearCast Model in AWT Summer Experiment (2012, 2013)

Select feedback:

- *The product was **VERY useful** in terms of assessing where the atmosphere would be most favorable for convection should there be a trigger and/or broad-scale lift support.*
- *It may aid in evaluating the evolution of mid-level instability in **data void areas** and between radiosonde launches in both space and time.*
- *This was of particular use over **off shore regions** where flight routes exist, but observations are much more sparse.*
- *… it was used to provide **situational awareness** for convective initiation and behavior later in the afternoon.*

20 June 2013 – Eastern Germany Convection

- Forecaster Comments:
- *"The NearCast gave a very good indication of where convection was started.*
- *It's really impressive to see that the convection was initiated at the northern edge of the ThetaE maximum over northeaster Bavaria and at another smaller ThetaE maximum located at the alpine foothills in the southwest of Bavaria.*
  - *There are some hills around 600 - 1000 m high which possibly could have helped to trigger convection.*
  - *Out of these cells, only the MCS over eastern Germany developed.*
- *Because the operational models missed this convective initiation there, they also missed the development of the MCS.*
- ***If we had had NearCast, we would have been able to make a first estimation of the position where the convection would be most probably initiated.***
- ***The NearCast would (have) improved the forecast of this day."***

Christian Herald, DWD Forecaster

06-23 UTC IR Loop