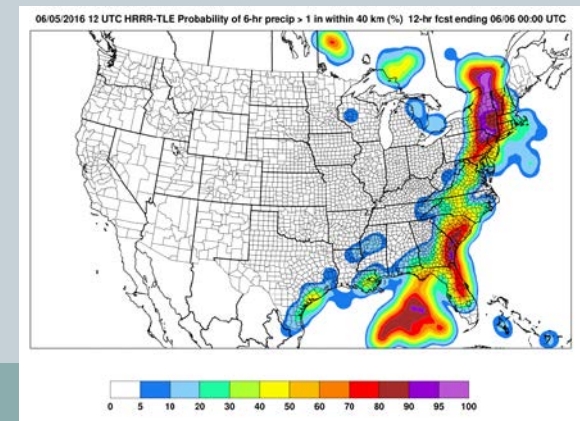
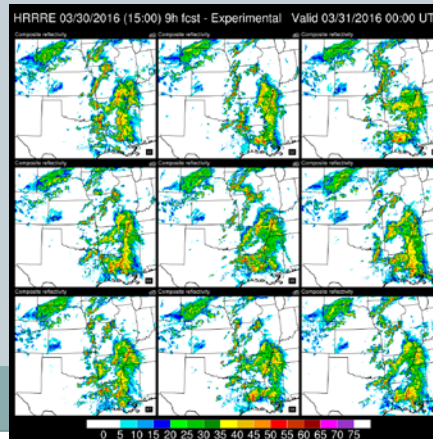
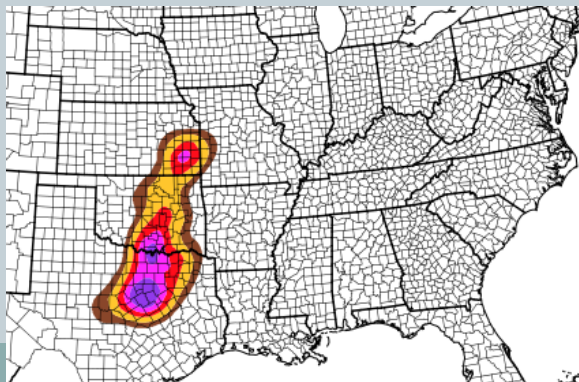


CORP Science Symposium, July 18-19, 2016, Fort Collins

Development of High-Resolution Rapid Refresh (HRRR) Ensemble Data Assimilation, Forecast and Post-Processing

Isidora Jankov, Curtis Alexander, David Dowel, Trevor Alcott, Stan Benjamin
and EMB



Outline



- RAP and HRRR models development including DA
- Shifting focus toward ensemble DA and forecasting
- Moving toward next generation of regional rapid-refresh storm-scale ensemble
- Starting points in DA
- Experiments in stochastic physics arena for the purposes of both DA and forecasting
- Statistical post-processing

RAP/HRRR: Hourly-Updating Weather Forecast Models

13-km Rapid Refresh (RAPv3) – to 21h (July 2016)

Initial & Lateral Boundary Conditions

3-km High-Resolution Rapid Refresh (HRRRv2) – to 18h (July 2016)

Initial & Lateral Boundary Conditions

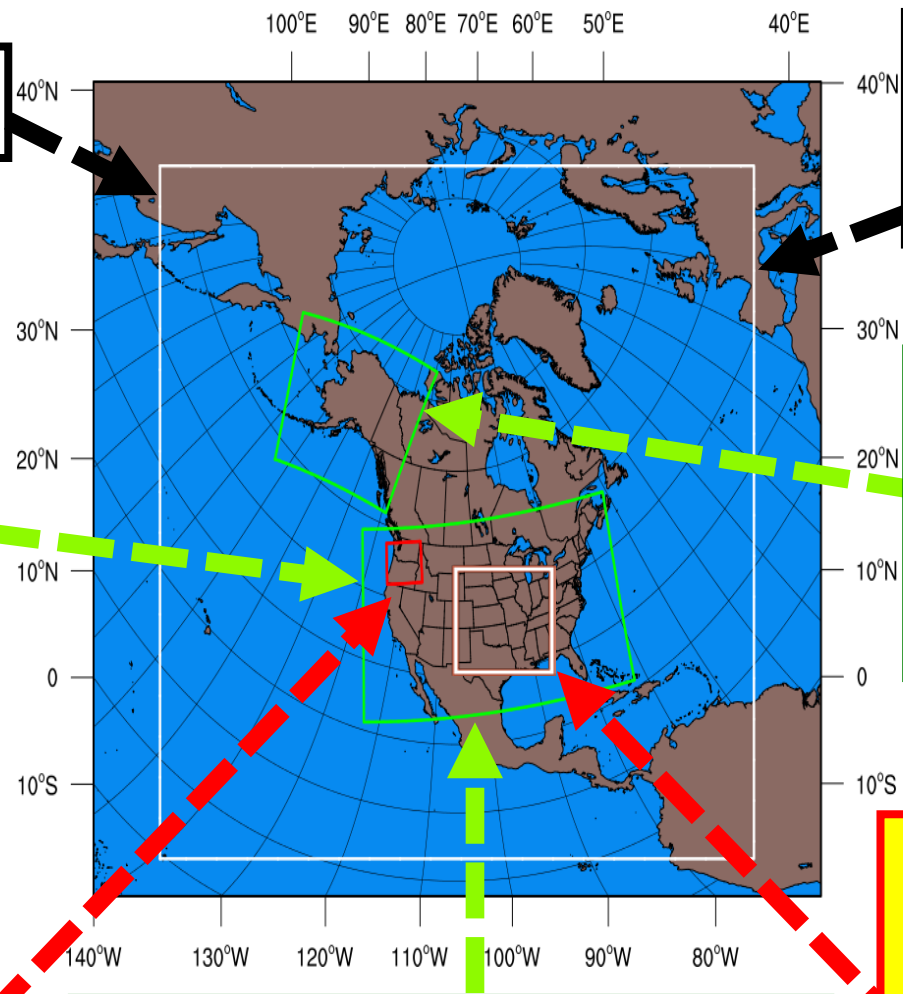
750-m HRRR nest Wind Forecast Improvement Project Experiment (ongoing)

3-km High-Resolution Time Lagged Ensemble (HRRR-TLE)

Expanded RAP to match NAM for SREF (July 2016)

3-km High-Resolution Rapid Refresh Alaska Testing (HRRR-AK) w/MRMS radar data (Spring 2016)

Prototype 3-km storm-scale HRRR ensemble (HRRRE) (Spring 2016)



Spring 2016 Experimental HRRRE



$\Delta x = 15$ km



BC from GFS



IC mean from
RAP, pert from
GFS ensemble



Real-Time Web Graphics
<http://rapidrefresh.noaa.gov/HRRRE>

HRRRE Design

- **Community tools**
 - WRF for numerical weather prediction
 - GSI for observation processing and ensemble-prior calculation
 - EnKF for data assimilation
- **Hourly data assimilation** from 2100 UTC day 0 to 1800 UTC day 1
 - conventional observations only (radar reflectivity soon)
 - pure ensemble Kalman filter (EnKF)
 - variety of scales, including explicit convection, represented in background error covariances from 3-km ensemble
 - updated state variables: u , v , T , q_v , geopotential, column dry air mass
 - covariance localization: 500 km horizontal, 0.4 scale height
- **Ensemble 12+ h forecasts** at selected times
 - 18-member forecast at 1500 UTC provides initial and boundary conditions for NEWS-e
- **Sources of ensemble spread**
 - initial condition perturbations from GFS ensemble
 - model integration
 - adaptive, multiplicative posterior inflation

HRRRE Resources

HRRRE Real-Time System on NOAA R&D “Jet”

2 May - 20 June 2016 (testing in March/April)

HRRRE ~650x550 = 357,500 grdpts

HRRR 1800x1060 = 1,908,000 grdpts

HRRRE ~ 20% HRRR (1/5th)

Ensemble Pre-Processing

LBC 64 cores ~ 15 min

IC 120 cores ~ 30 min

Ensemble 3-km Data Assimilation (20 mem)

WRF 1-hr cycle 72 cores/mem ~ 20 min

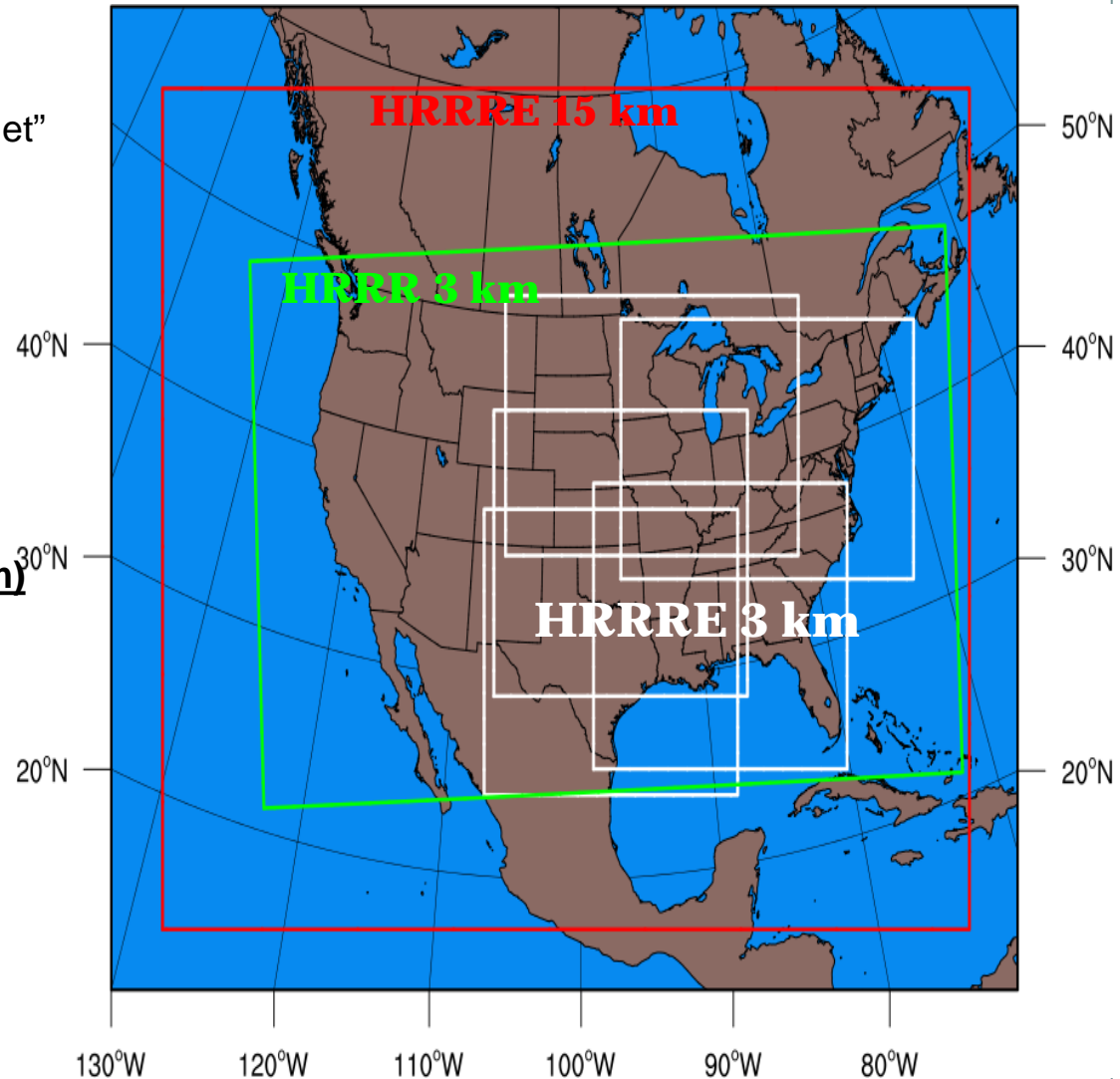
GSI-EnKF 240 cores ~ 25 min

Ensemble 3-km Forecast (3-18 mem)

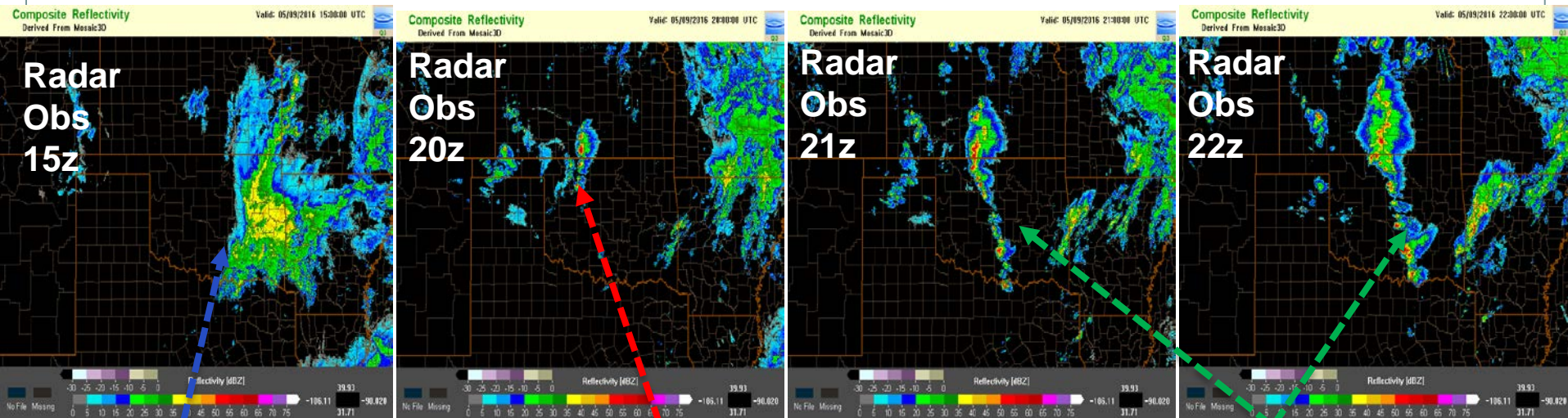
WRF 18-hr fcst 180 cores/mem ~120 min

Post-processing 16 cores/mem ~5 min

DA + FCST = ~5,000 cores (18 fcst mem)



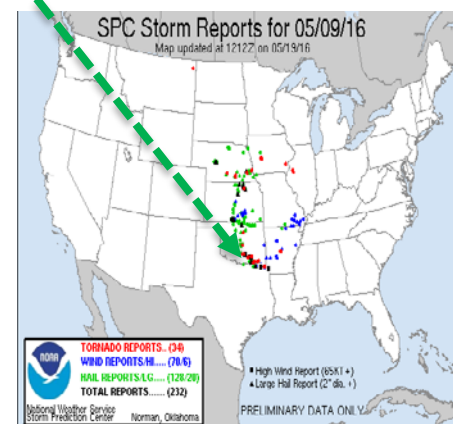
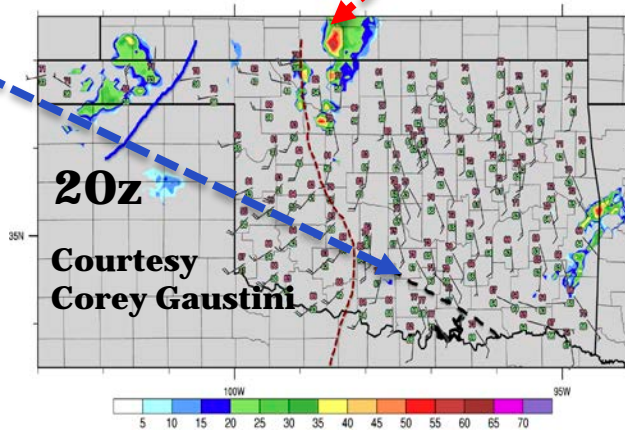
HRRRE: Case Study 09 May 2016



Rain-cooled
Boundary

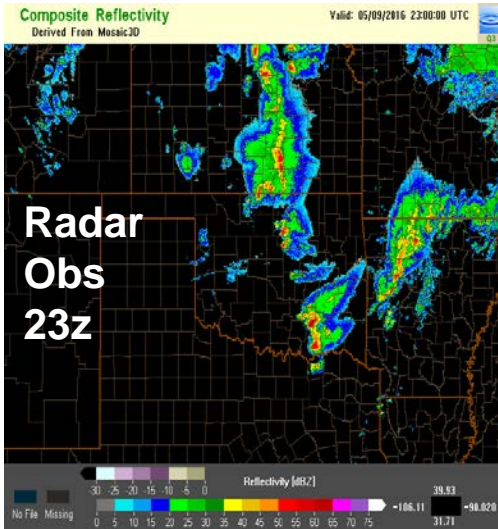
Convective initiation along dryline

Tornado supercell
development near residual
outflow boundary intersection

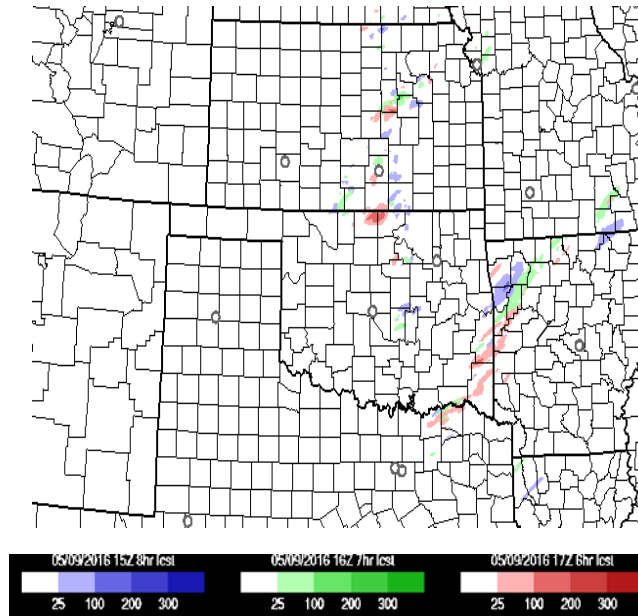


HRRRE: Case Study 09 May 2016

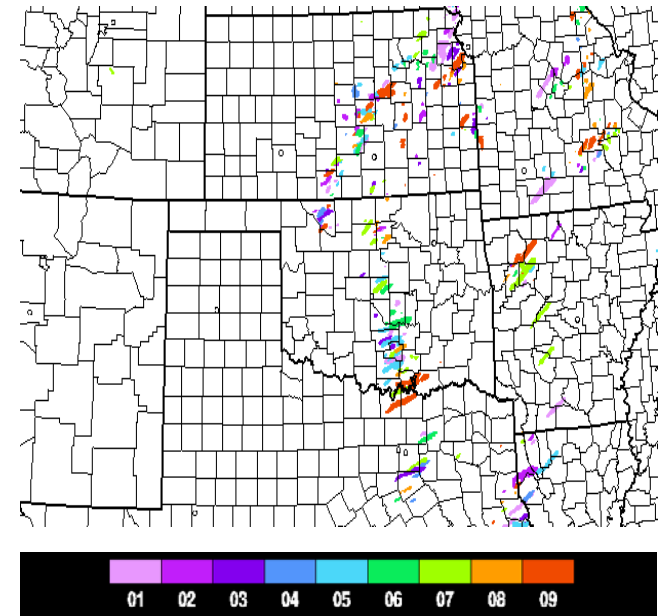
1-hr Maximum Updraft Helicity Valid 22z (colors > 25 m²/s²)



HRRRX 15z-17z initializations
Time-Lagged Ensemble



HRRRE 15z + 7hr fcst valid 22z



Effective use of the boundary observations in storm-scale ensemble data assimilation

HRRRE Observation Space Diagnostics: 1-hr cycling

Black = Observation Error

Red = Ens Bias (mean obs innovation)

Green = Total Spread (ensemble standard deviation + ob error)

Blue = Ens Forecast Error (innovation standard deviation)



Need accurate specification of observation error

Ensemble spread \ll Observation error \rightarrow Not drawn towards obs in DA

Based on results observation errors reduced for some datasets

Want total spread to track with forecast errors of the day

Ensemble spread $<$ Forecast error (green $<$ blue) \rightarrow

Underdispersive

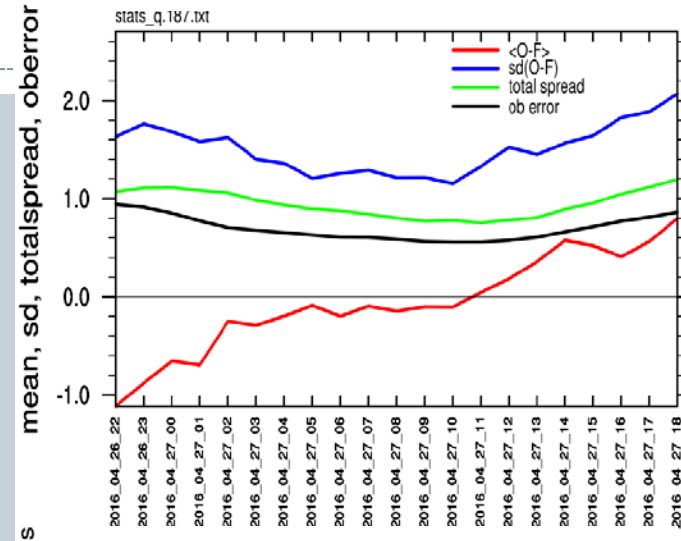
Ensemble spread $>$ Forecast error (green $>$ blue) \rightarrow

Overdispersive

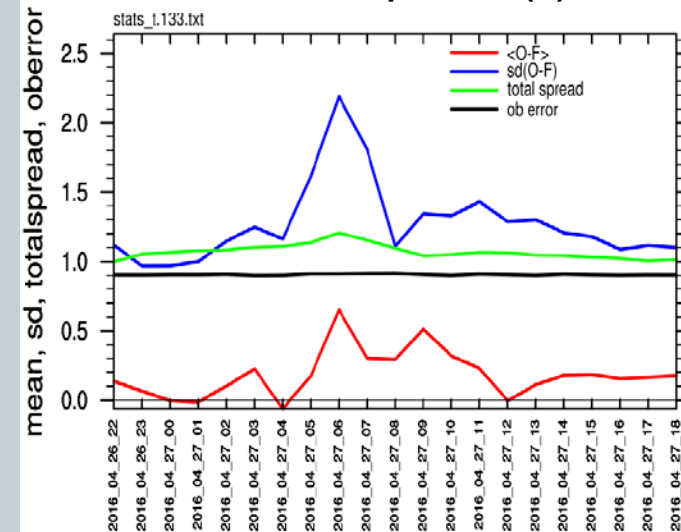
Ensemble generally underdispersive

**Ensemble design refinements planned including...
statistical post-processing**

METAR specific humidity (g kg^{-1})



ACARS temperature (K)



Stochastic physics for use in Regional/Storm Scales Ensembles

Motivation

- Issues with mixed-physics approach
 - Maintenance
 - Inconsistent ensemble system (some schemes closer related than others)
 - Each member has a unique climatology and mean error
- Compare mixed-physics approach to stochastic parameter perturbation (SPP), Stochastic Kinetic Energy Backscatter (SKEB) and Stochastic Perturbation of Physics Tendencies (SPPT).

Experiment Design

- Regional RAP model simulations
- 7 days from 2013 convective season: May 23,29; June 7, 14, 20, 28; July 4
- 24 h forecasts
- 00 and 12 Z initializations using different GEFS members
- Stochastic Parameter Perturbation, SKEB and SPPT
- Focus on convective Grell-Freitas and MYNN PBL
- Verification performed over CONUS
- Statistical significance testing by employing boot strap method with 95% confidence interval

Experiments

CU comparison

Control mixed
physics
(CU and PBL)

SPP
(CU and PBL)

PBL comparison

SPP+SKEB
(CU + PBL)

SPP+SPPT
(CU+PBL)

SPP+SKEB+SPPT
(CU+PBL)

Impact of adding SKEB and SPPT on stochastic parameter perturbation

Mixed-physics and stochastic members



Mixed-physics members	Convective	PBL	LSM
control0	OSAS	MYNN	RUC
control1	BMJ	MYNN	RUC
control2	GF	MYNN	RUC
control3	NSAS	MYNN	RUC
control4	GF	MYJ	RUC
control5	GF	YSU	RUC
control6	GF	BOULAC	RUC
control7	GF	MYNN	RUC

Stochastic	Convective	PBL	LSM
stoch0	GF-pert	MYNN	RUC
stoch1	GF-pert	MYNN	RUC
stoch2	GF-pert	MYNN	RUC
stoch3	GF-pert	MYNN	RUC
stoch4	GF	MYNN-p	RUC
stoch5	GF	MYNN-p	RUC
stoch6	GF	MYNN-p	RUC
stoch7	GF	MYNN-p	RUC

Perturbed parameters

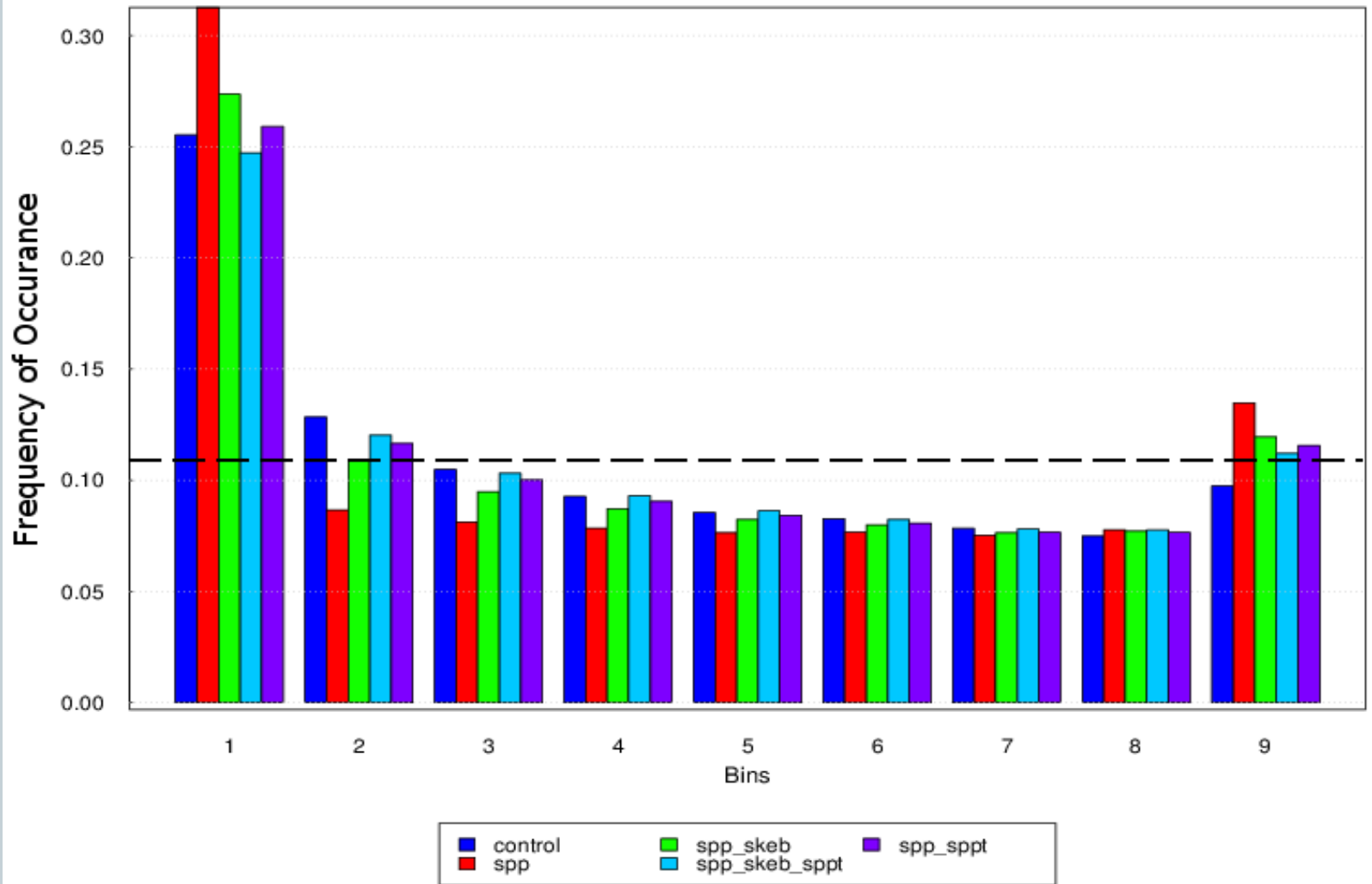
MYNN PBL: Turbulent mixing length

GF CU scheme: Closures

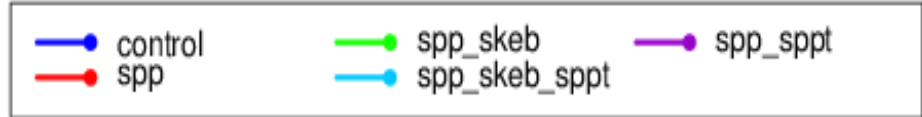
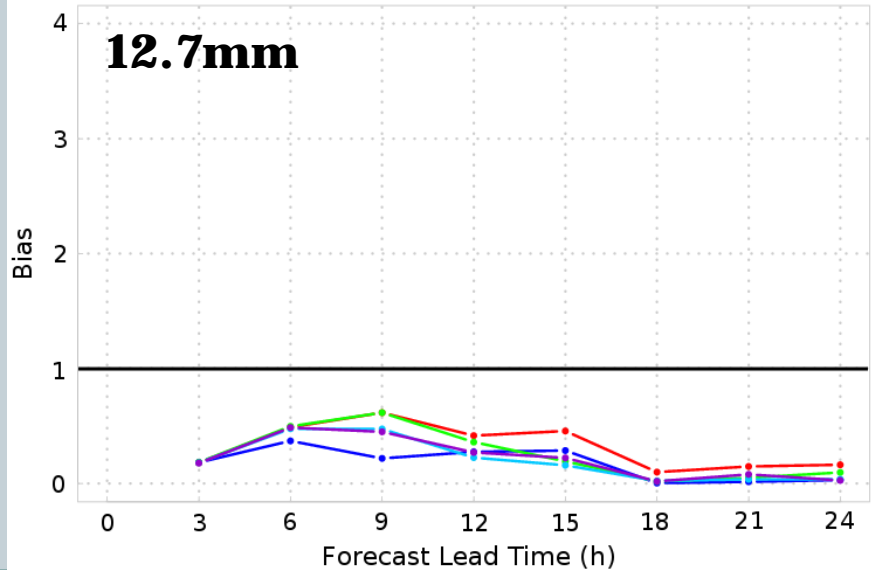
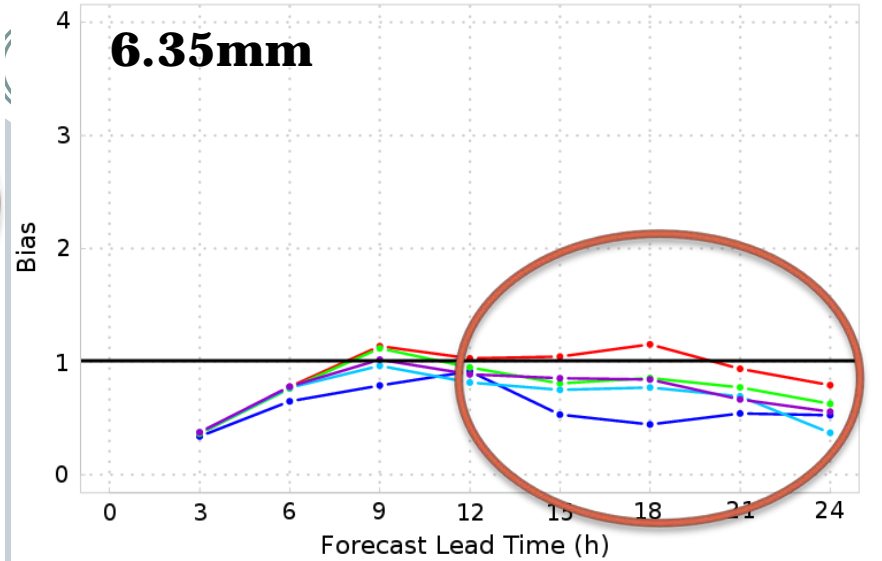
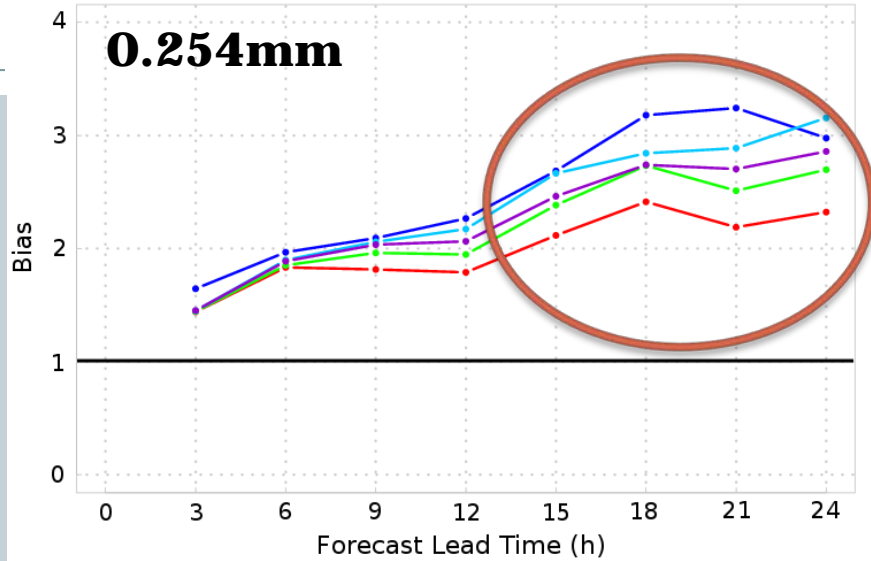
Sub-grid cloud fraction

Roughness length (T & moist.)

Precipitation Rank histograms for 00 Z initialization:

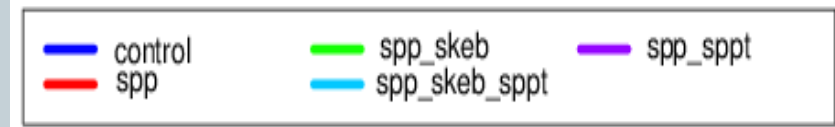
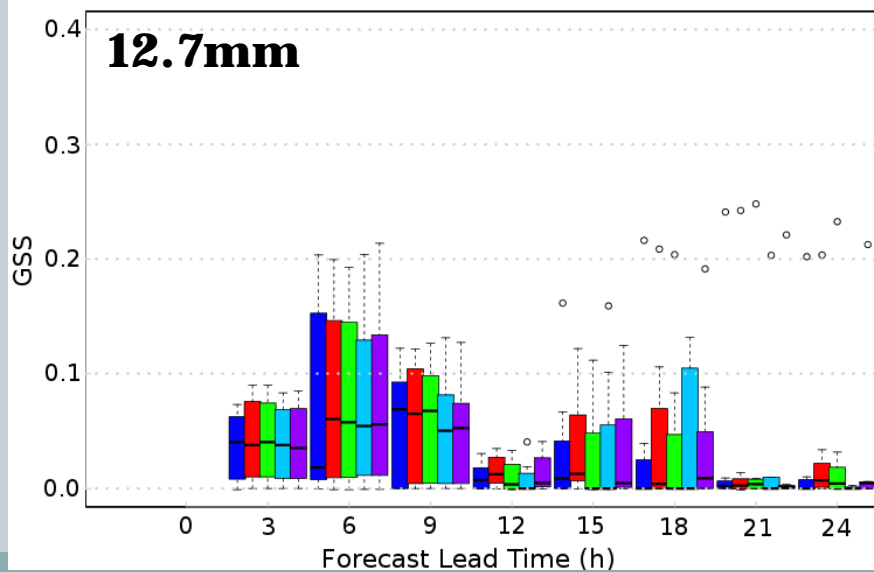
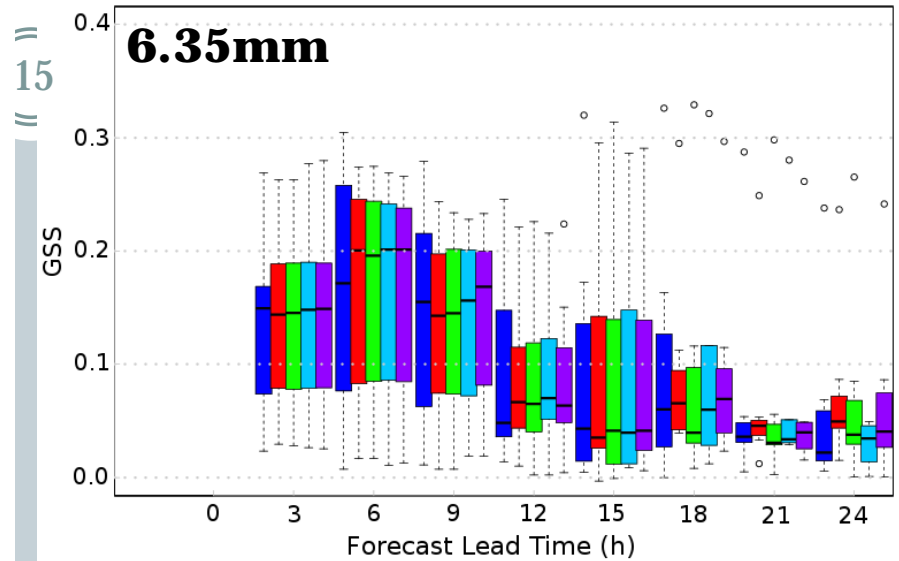
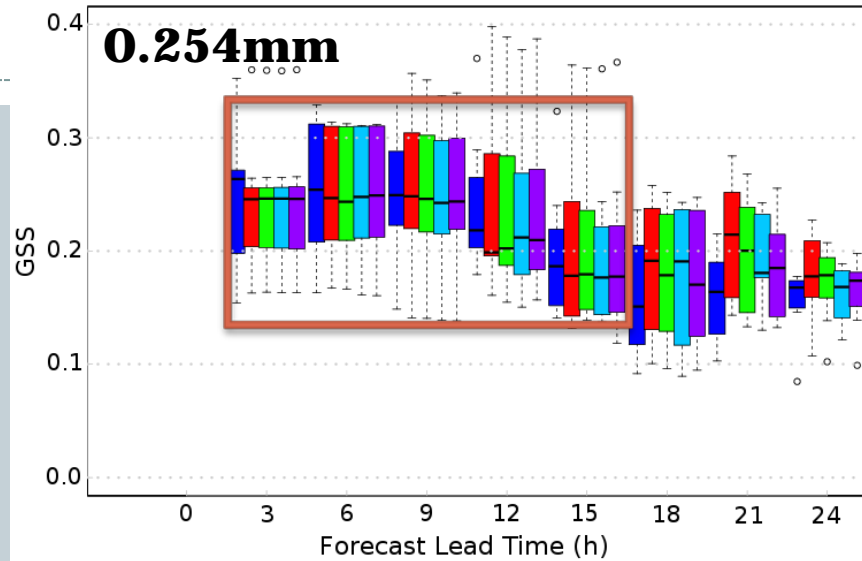


Ensemble Mean Bias – 00Z init.

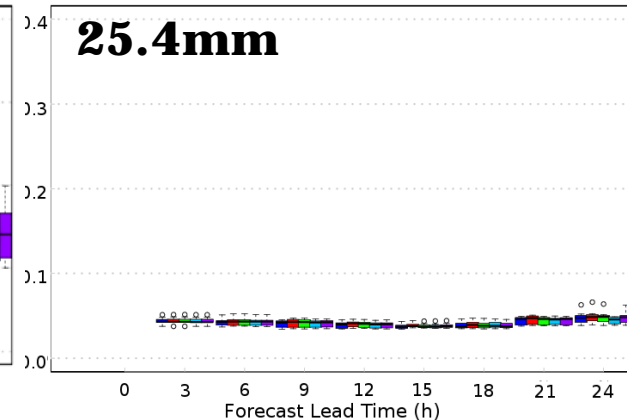
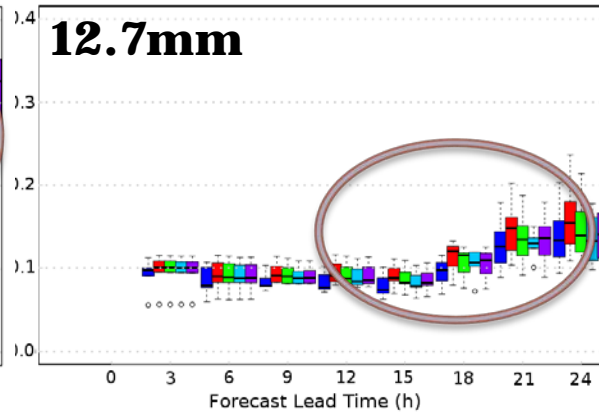
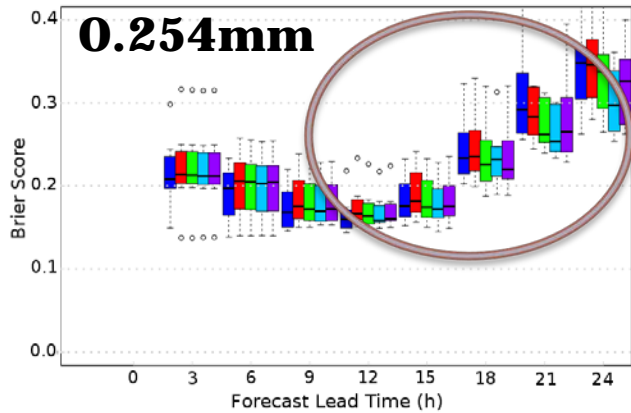


 Statistically Significant

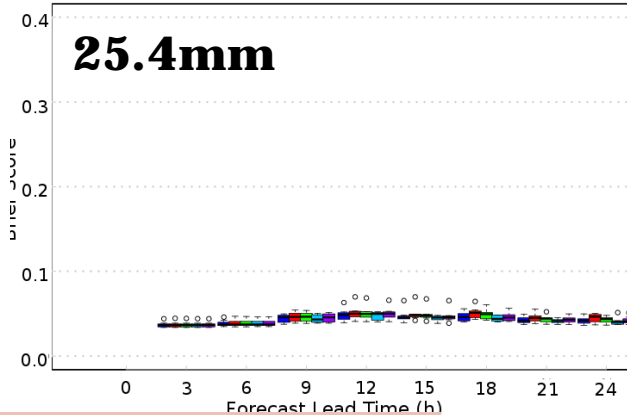
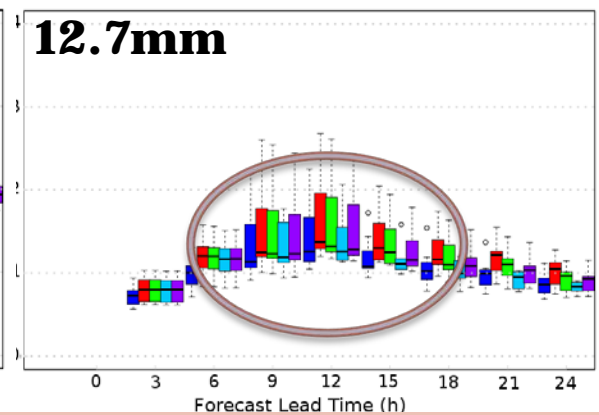
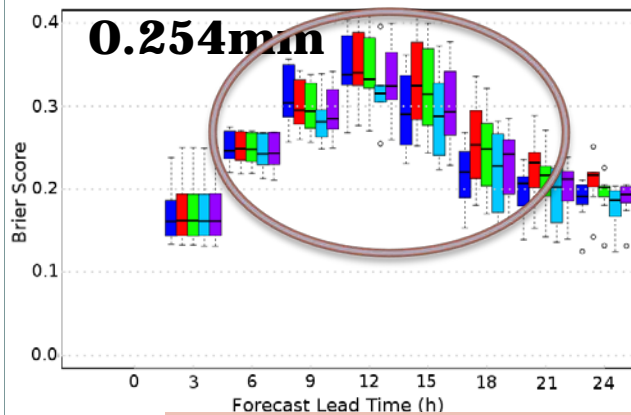
Ensemble Mean GSS – 00Z Init.



Brier Score - 00 Z initialization

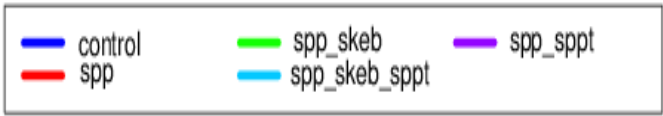
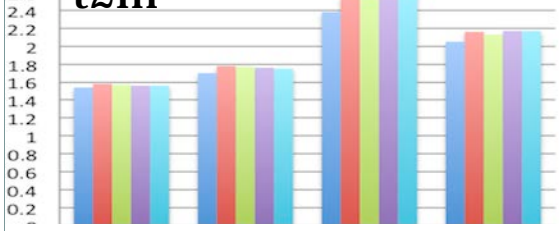


Brier Score - 12 Z initialization

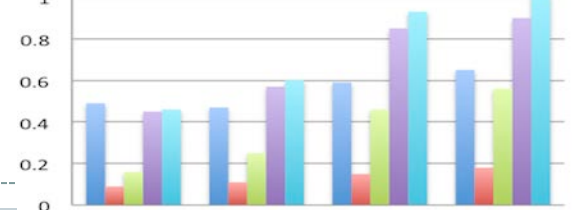


**During the day stochastic experiments significantly outperform the control.
spp_skeb_sppt significantly better than others.
Situation opposite during the night.**

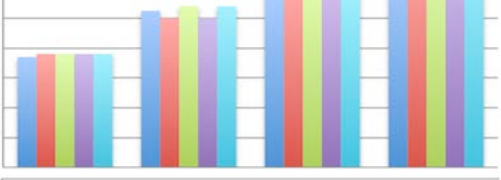
t2m **RMSE-00Z Init.**



Spread-00Z Init.



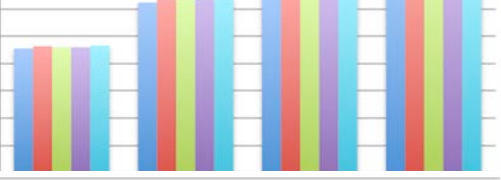
t850



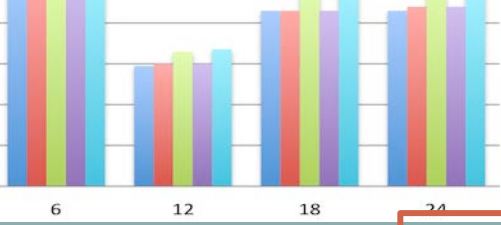
u10



u250

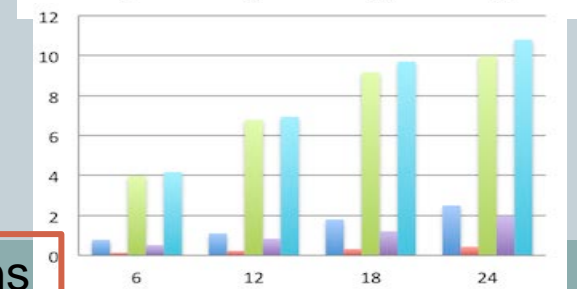
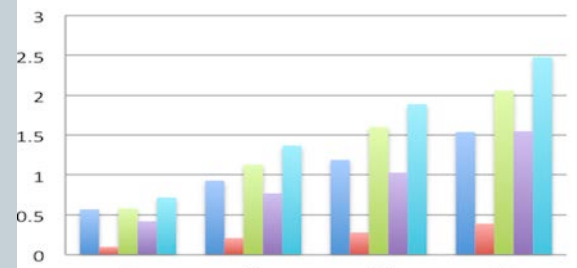
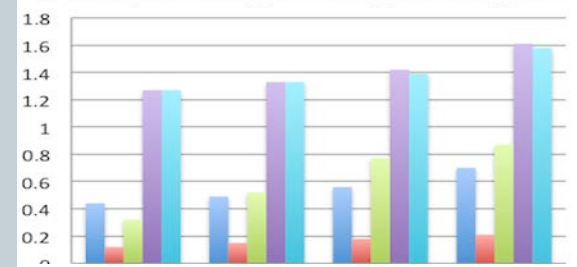
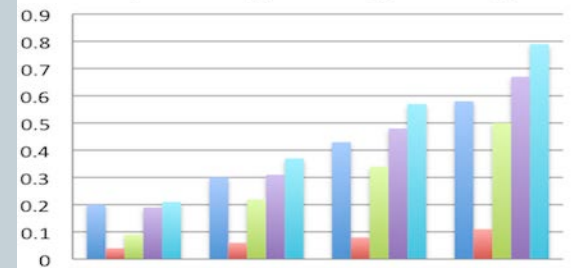


h500



spp_skeb_sppt spread significantly higher when compared to the control experiment, for most of the lead times (longer than 6hrs) and all variables.

Very similar results for 12Z simulations



CRPS for 00Z and 12Z Initi:

00Z Init.

12Z Init.

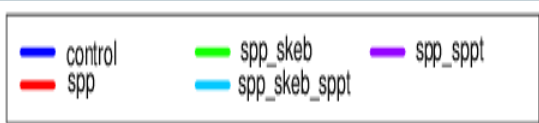
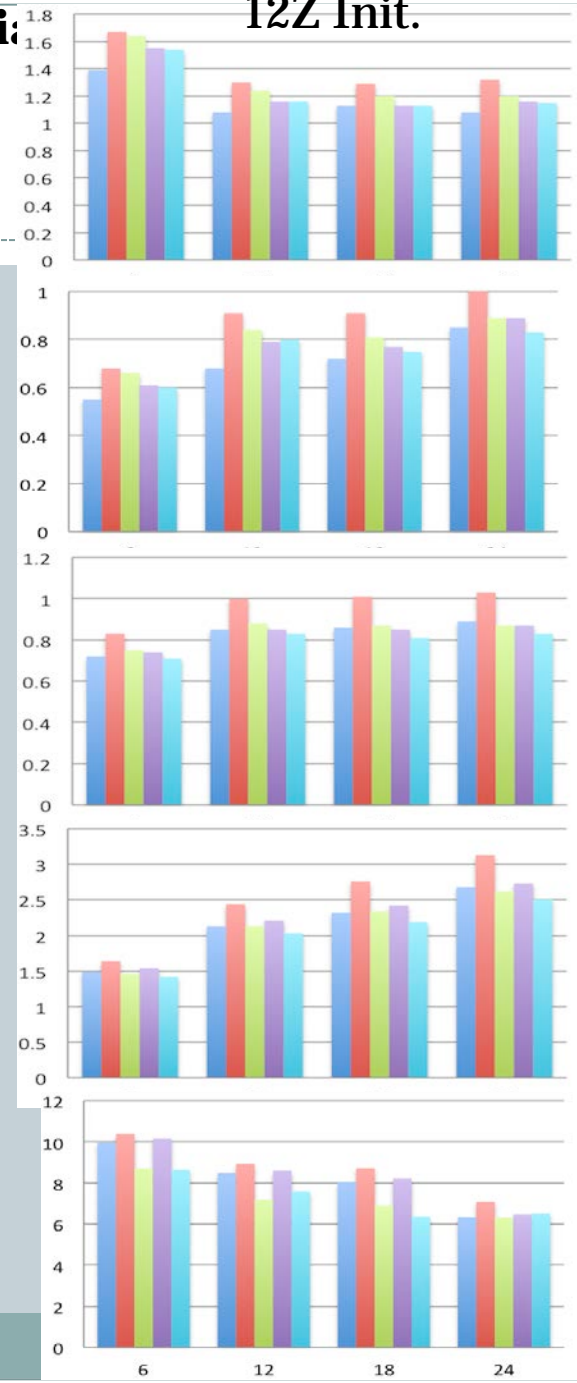
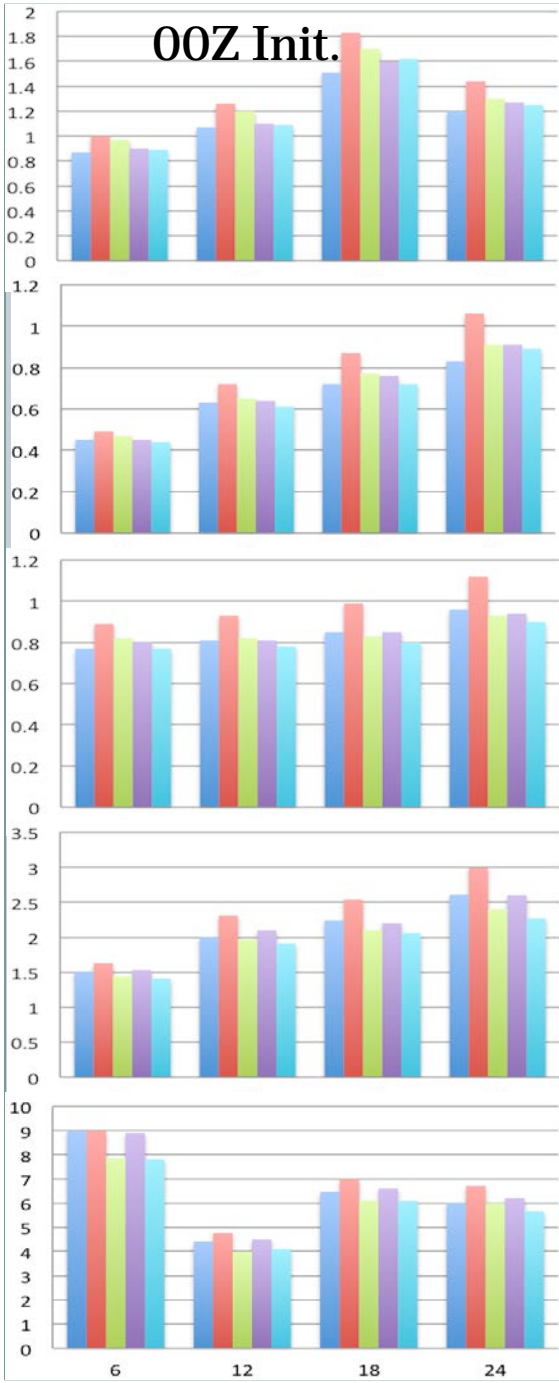
t2m

t850

u10

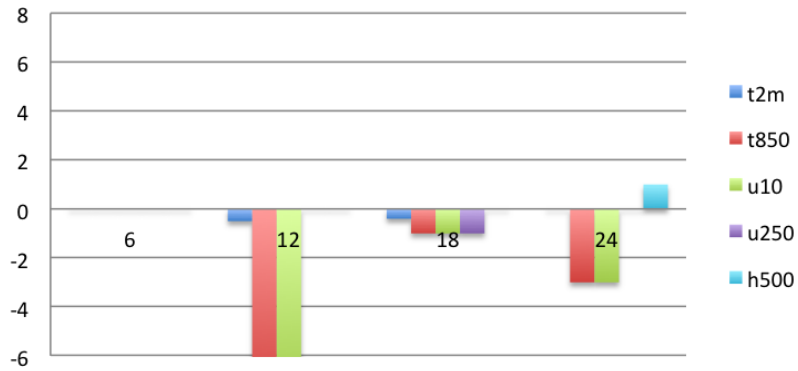
u250

h500

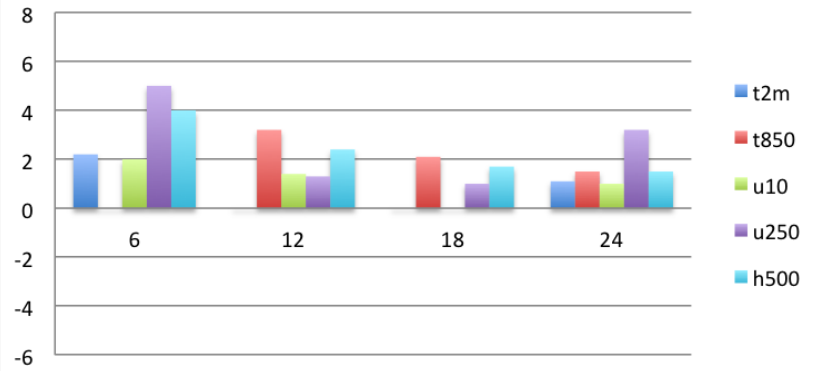


SPP+SPPT – SPPT experiments

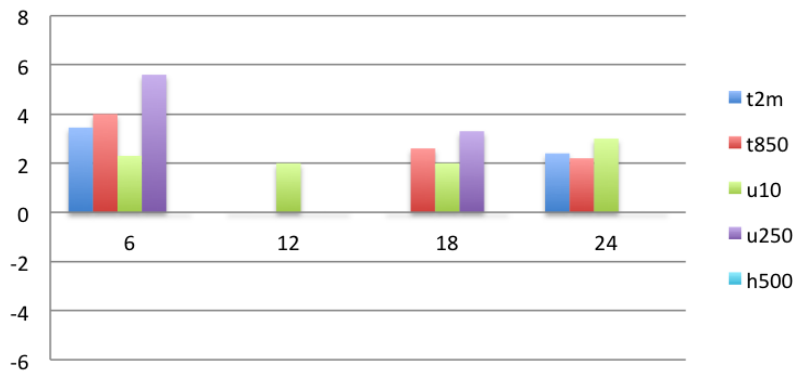
RMSE 00Z



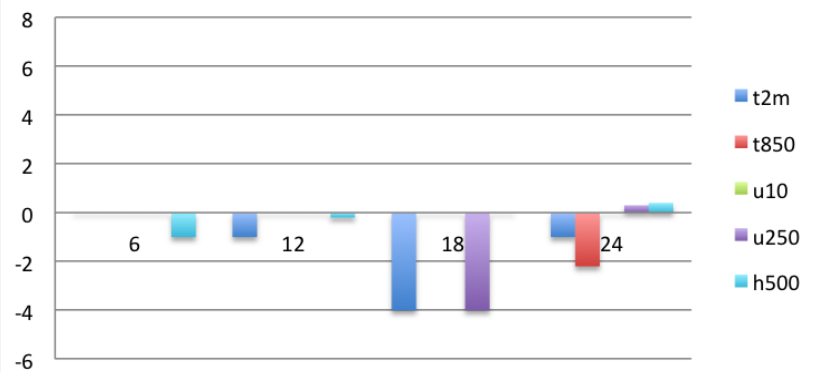
Spread 00Z



Spread/Error 00Z



CRPS 00Z



Stochastic Physics Tests Summary

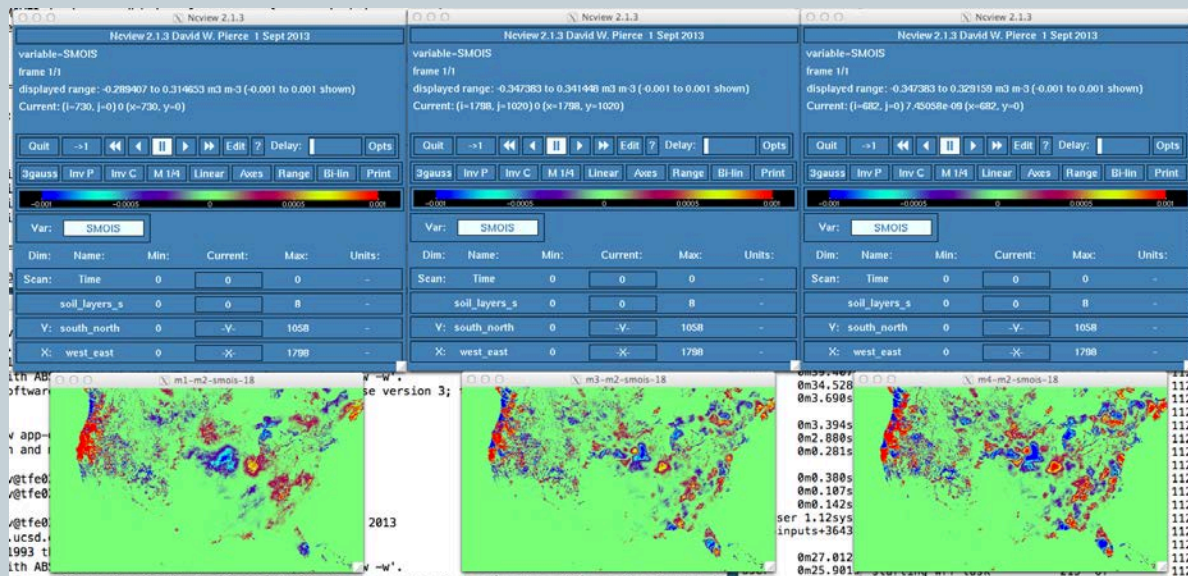
- Alone, the parameter perturbations of SPP introduce insufficient spread.
- When combined with SKEB and/or SPPT the spread is as large and for some instances even larger than for a multi-physics ensemble.
- An ensemble created by combining three stochastic approaches (SPP, SKEB and SPPT) generally outperformed the multi-physics, control ensemble for most of the examined variables, most of the evaluated lead times, and most of the employed statistics.
- SKEB made a larger impact on spread associated with upper level wind and geopotential heights, while SPPT had a larger impact on spread for near-surface temperature.
- Combining SPP with SPPT has generally a positive impact, on the order of a 2-10% improvement over an ensemble using SPPT alone.

- 1. The results confirm the findings of previous studies that parameter perturbations alone do not generate sufficient spread to remedy the under-dispersion in short-term ensemble forecasts***
- 2. A combination of several stochastic schemes outperforms any single scheme. This result implies that a synthesis of different approaches is best suited to capture model error in its full complexity.***

Current and Future Work



- Adding 14 more cases to the previous study
- Experimenting with HRRR (3km grid spacing) for application in HREF
- Focus on PBL and LSM:
 - PBL-In addition to mixing length, roughness length and cloud fraction we added perturbations to mass fluxes
 - LSM-Hydraulic Conductivity is currently being perturbed



HRRR Time-Lagged Ensemble (HRRR-TLE)

Deterministic HRRR:

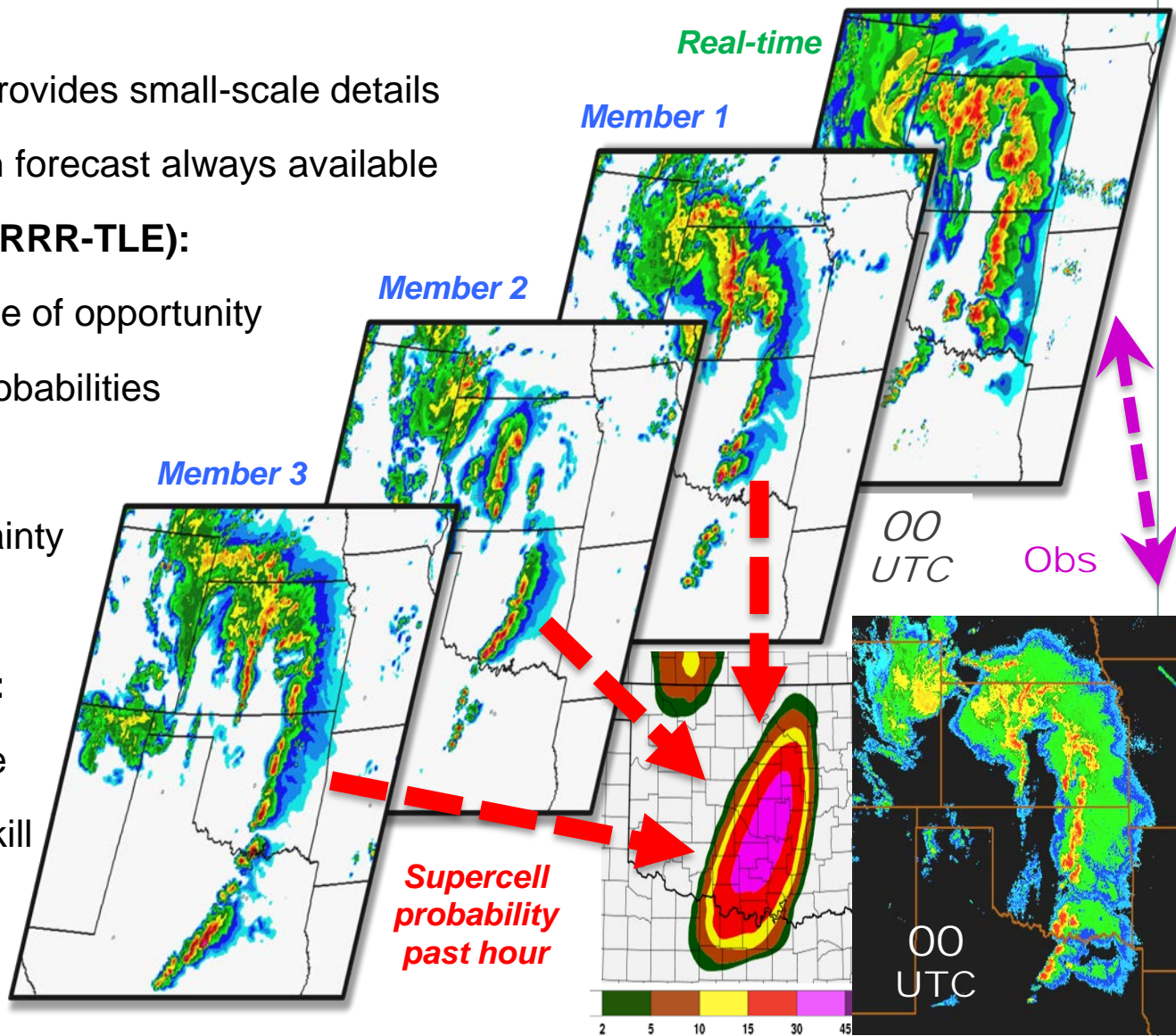
- High-resolution forecast provides small-scale details
- Hourly-updating with fresh forecast always available

Time-Lagged Ensemble (HRRR-TLE):

- Leverage runs in ensemble of opportunity
- Form hazard likelihood probabilities
- Less small-scale detail
- Proxy for confidence/certainty
- Underdispersive

HRRR Ensemble (HRRRE):

- More expensive ensemble
- More spread/dispersive/skill



HRRR-TLE Severe Weather Example

Forecasts valid 22-23z

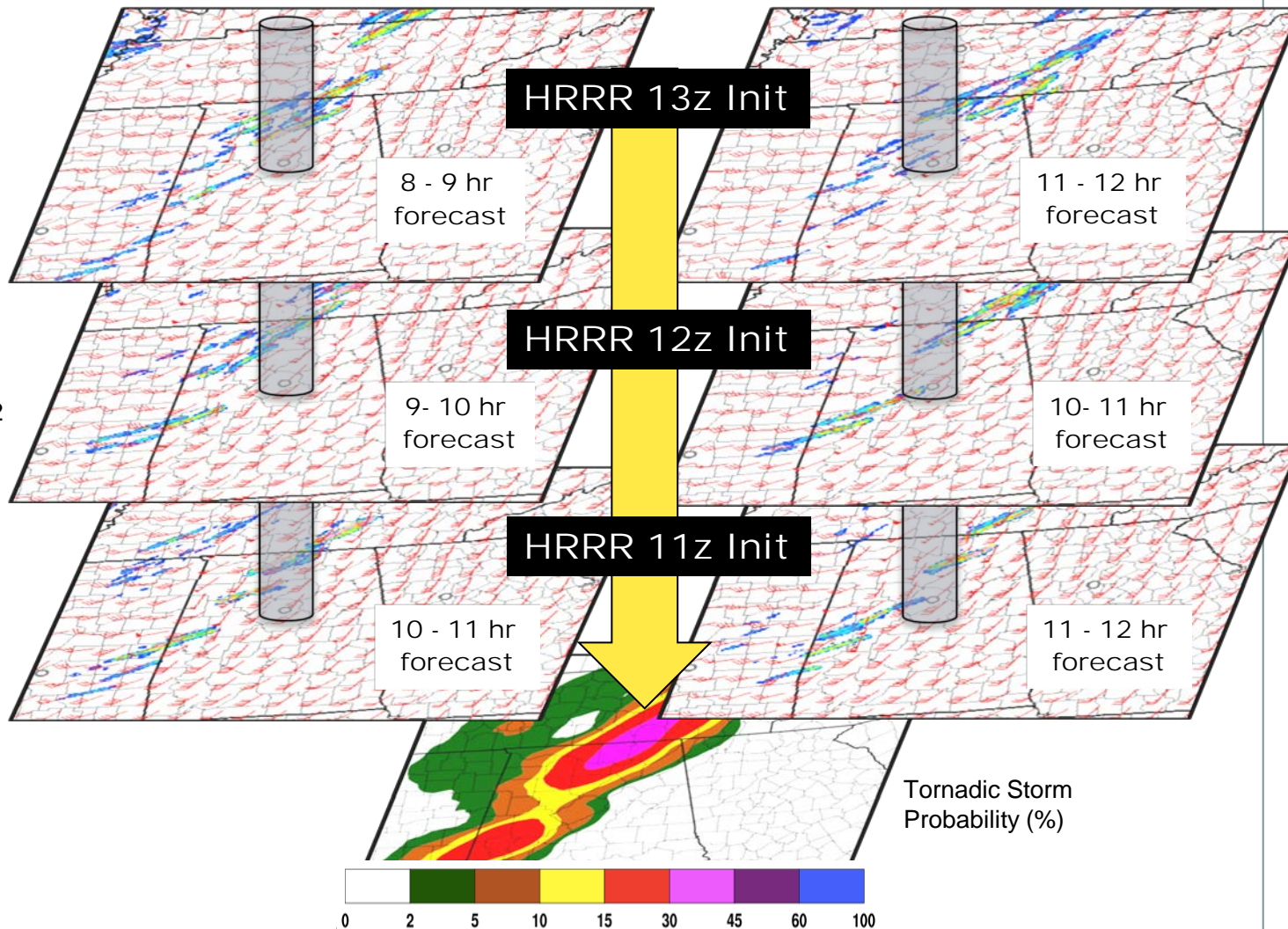
Forecasts valid 23-00z

Neighborhood Search

Point Probability

Spatial radius 45 km
Time radius 1 hr
UH threshold $25 \text{ m}^2/\text{s}^2$

All six forecasts
combined to form
probabilities valid
22z 27 April 2011



HRRR Time-Lagged Ensemble (HRRR-TLE)

Current Experimental Probability Products:

- Based on 3 HRRRX runs (equal weight)
- Starting with forecast hour two
- 40-km neighborhood probabilities
- 120-km spatial filter applied *after* identifying neighborhood hazard exceedance

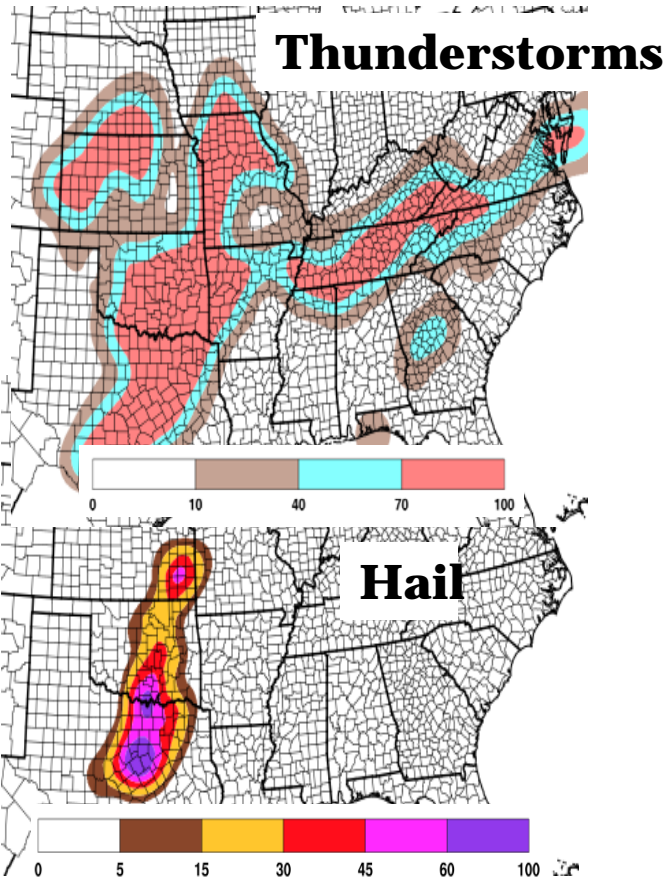
Real-Time Web Graphics (and grids via LDM/FTP)

<http://rapidrefresh.noaa.gov/hrrrtle>

HRRR Time-Lagged Ensemble - Experimental

Model: HRRRX Neighborhood Probability (Experimental) Area: Full Date: 07 Jun 2016 - 22Z

Model: HRRRX Neighborhood Probability (Experimental) Domain: Full Date: 07 Jun 2016 - 22Z



Aviation Severe Winter QPF

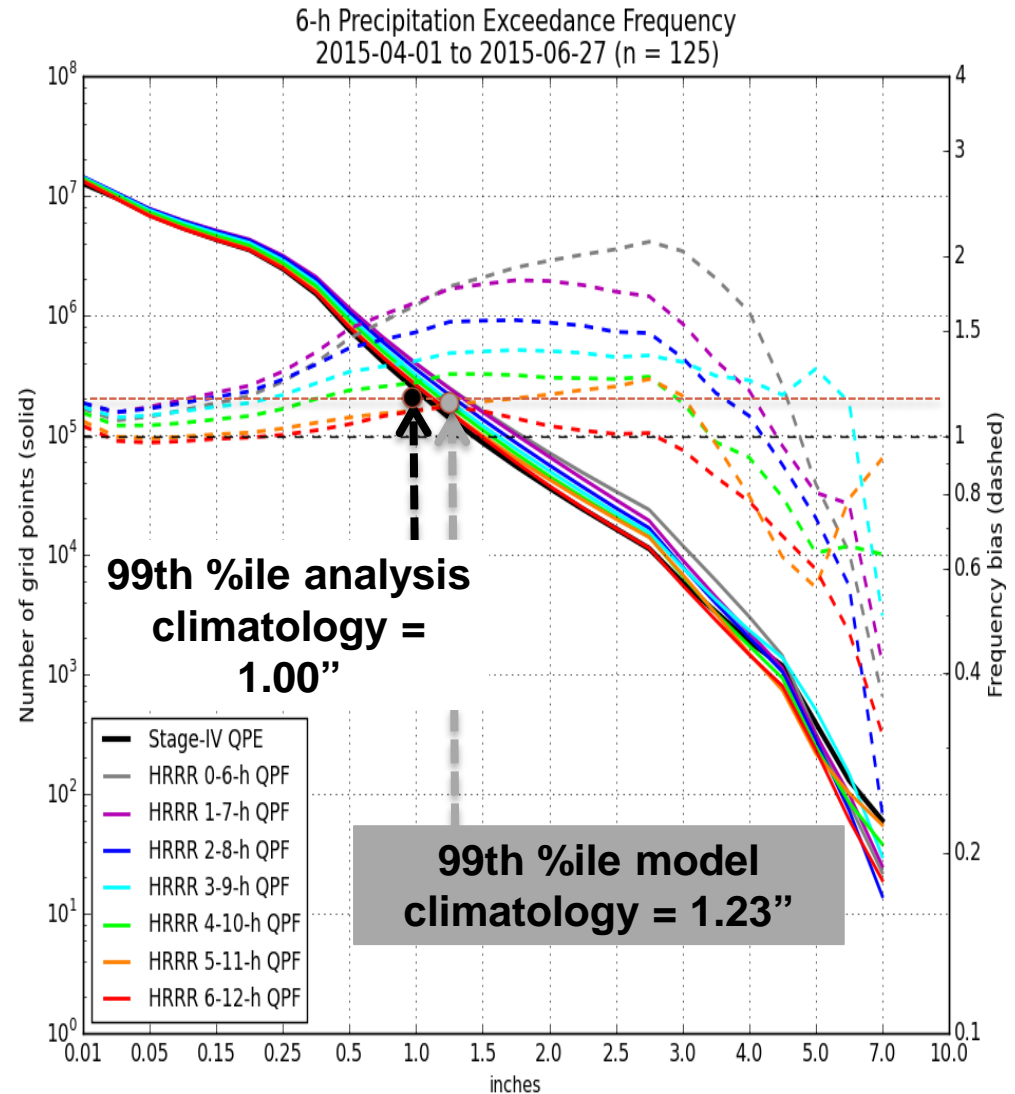
	All times	Loop	Valid Time																							
			Forecast																							
			Tue 22	Tue 23	Wed 00	Wed 01	Wed 02	Wed 03	Wed 04	Wed 05	Wed 06	Wed 07	Wed 08	Wed 09	Wed 10	Wed 11	Wed 12	Wed 13	Wed 14	Wed 15	Wed 16	Wed 17	Wed 18	Wed 19	Wed 20	Wed 21
all fields	✓	✓																								
0.50" / 1 hr precip	✓	✓																								
1.00" / 1 hr precip	✓	✓																								
2.00" / 1 hr precip	✓	✓																								
0.50" / 3 hr precip	✓	✓																								
1.00" / 3 hr precip	✓	✓																								
2.00" / 3 hr precip	✓	✓																								
3.00" / 3 hr precip	✓	✓																								
0.50" / 6 hr precip	✓	✓																								
1.00" / 6 hr precip	✓	✓																								
2.00" / 6 hr precip	✓	✓																								
3.00" / 6 hr precip	✓	✓																								
6.00" / 6 hr precip	✓	✓																								
9 hr precip > 100-yr recurrence	✓	✓																								
1.00" / 3 hr runoff	✓	✓																								
2.00" / 3 hr runoff	✓	✓																								
3.00" / 3 hr runoff	✓	✓																								
0.50" / 1 hr snowfall	✓	✓																								
1.00" / 1 hr snowfall	✓	✓																								
2.00" / 1 hr snowfall	✓	✓																								
1.00" / 6 hr snowfall	✓	✓																								
3.00" / 6 hr snowfall	✓	✓																								
6.00" / 6 hr snowfall	✓	✓																								
Thunderstorm	✓	✓																								
Wind > 50 kt in last 4 hr	✓	✓																								
Hail > 1" in last 4 hr	✓	✓																								
Tornado in last 4 hr	✓	✓																								
Visibility < 3 mi	✓	✓																								
Visibility < 1 mi	✓	✓																								
Ceiling < 3000 ft	✓	✓																								
Ceiling < 1000 ft	✓	✓																								
Ceiling < 500 ft	✓	✓																								
IFR conditions	✓	✓																								
Echo Tops > 25 kt	✓	✓																								
Echo Tops > 30 kt	✓	✓																								
Echo Tops > 35 kt	✓	✓																								

HRRR-TLE Development: Bias Correction

Frequency Bias Correction Using
“Quantile Mapping”

Model forecast climatology adjusted
to observation climatology for a
particular threshold (1 inch / 6 hrs)

Exploring modified gamma distribution
for additional refinement in bias
correction



HRRR-TLE Precipitation Products

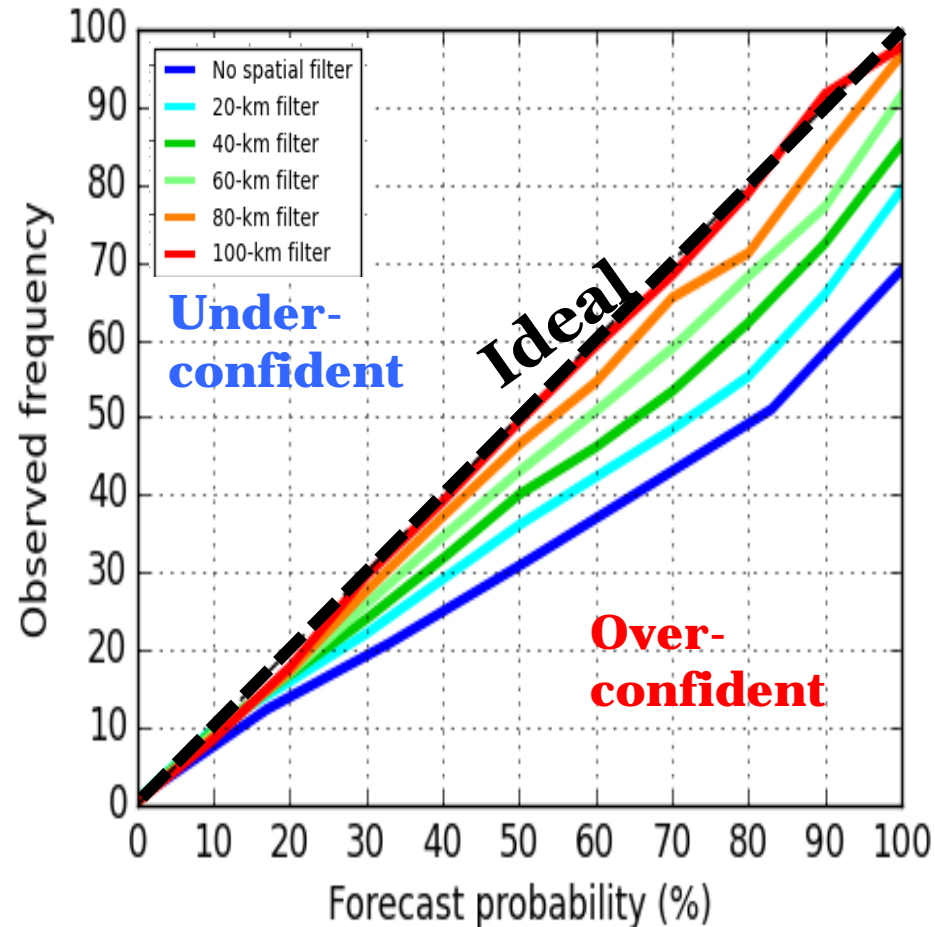
**Results: Probability of 0.5" Precipitation in 6 hours
May-Aug 2015**

With relatively small sample size (~50 forecasts)

Produce statistically reliable probabilities
60% forecasts observed 60% of the time

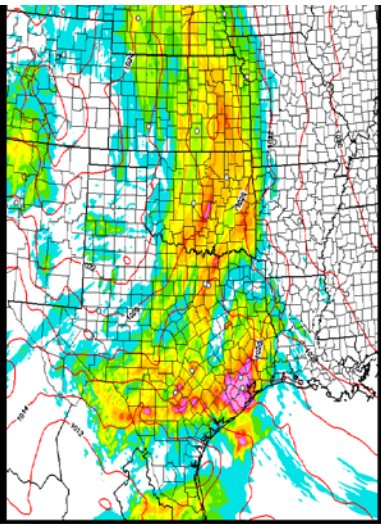
Produce probabilities with sufficient
resolution/sharpness
Large dynamic range to probabilities
including extremes

Still fundamentally underdispersive
(overconfident)

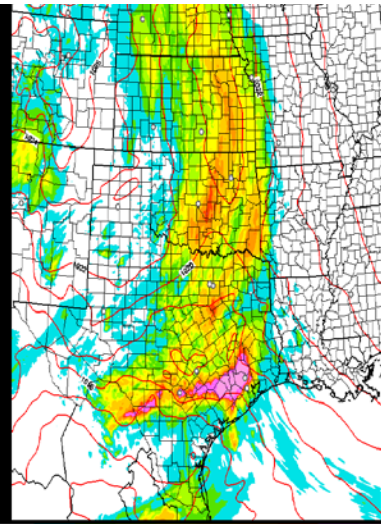


HRRR-TLE Case Study: 18 April 2016

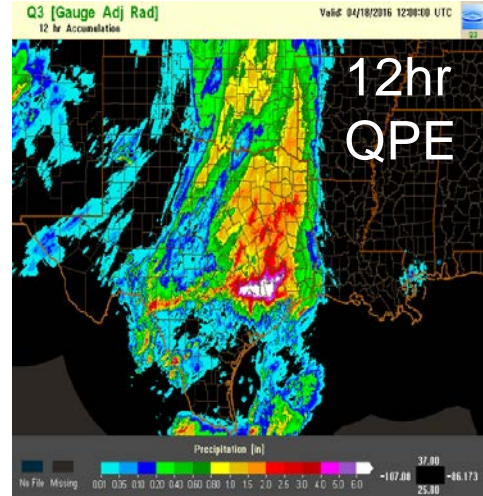
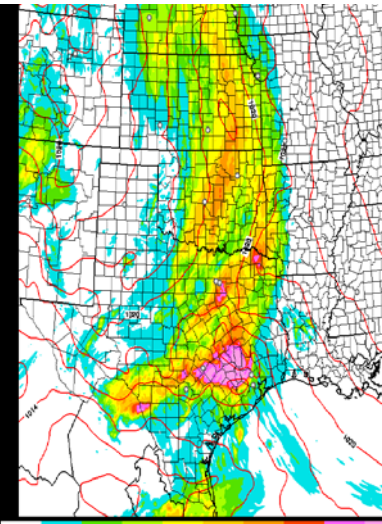
HRRR 23z 13hr pcp fcst



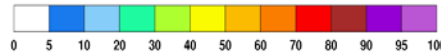
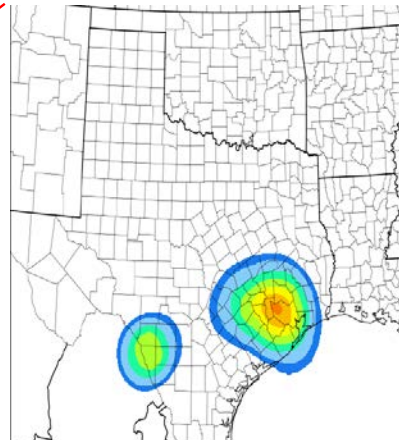
HRRR 00z 12 hr pcp fcst



HRRR 01z 11 hr pcp fcst



	01	02	03	04	05	06	07	08	09	10	11	12			
2.00" / 1 hr precip	✓	✓	01	02	03	04	05	06	07	08	09	10	11	12	
0.50" / 3 hr precip	✓	✓	01	02	03	04	05	06	07	08	09	10	11	12	
1.00" / 3 hr precip	✓	✓	01	02	03	04	05	06	07	08	09	10	11	12	
2.00" / 3 hr precip	✓	✓	01	02	03	04	05	06	07	08	09	10	11	12	
3.00" / 3 hr precip	✓	✓	01	02	03	04	05	06	07	08	09	10	11	12	
0.50" / 6 hr precip	✓	✓	01	02	03	04	05	06	07	08	09	10	11	12	
1.00" / 6 hr precip	✓	✓	01	02	03	04	05	06	07	08	09	10	11	12	
2.00" / 6 hr precip	✓	✓	01	02	03	04	05	06	07	08	09	10	11	12	
3.00" / 6 hr precip	✓	✓	01	02	03	04	05	06	07	08	09	10	11	12	
6.00" / 6 hr precip	✓	✓	01	02	03	04	05	06	07	08	09	10	11	12	
6 hr precip > 100-yr recurrence	✓	✓	01	02	03	04	05	06	07	08	09	10	11	12	
1.00" / 3 hr runoff	✓	✓	01	02	03	04	05	06	07	08	09	10	11	12	
2.00" / 3 hr runoff	✓	✓	01	02	03	04	05	06	07	08	09	10	11	12	
3.00" / 3 hr runoff	✓	✓	01	02	03	04	05	06	07	08	09	10	11	12	
0.50" / 1 hr snowfall	✓	✓	01	02	03	04	05	06	07	08	09	10	11	12	
1.00" / 1 hr snowfall	✓	✓	01	02	03	04	05	06	07	08	09	10	11	12	
2.00" / 1 hr snowfall	✓	✓	01	02	03	04	05	06	07	08	09	10	11	12	
1.00" / 6 hr snowfall	✓	✓	01	02	03	04	05	06	07	08	09	10	11	12	
3.00" / 6 hr snowfall	✓	✓	01	02	03	04	05	06	07	08	09	10	11	12	
6.00" / 6 hr snowfall	✓	✓	01	02	03	04	05	06	07	08	09	10	11	12	
Thunderstorm	✓	✓	00	01	02	03	04	05	06	07	08	09	10	11	12
Wind > 50 kt in last 4 hr	✓	✓	04	05	06	07	08	09	10	11	12				
Hail > 1" in last 4 hr	✓	✓	04	05	06	07	08	09	10	11	12				
Tornado in last 4 hr	✓	✓	04	05	06	07	08	09	10	11	12				



HRRR-TLE forecasts > 60% probability of 6hr QPF exceeding 100 year average return interval (ARI) in Houston, TX area based on ATLAS14

HRRR-TLE: Product Development

Product
Development
Methodology

<u>Hazard</u>	<u>Proxy</u>	<u>Truth</u>
Heavy rainfall	QPF	Stage-IV / MRMS
Snowfall rate	Microphysics-based	ASOS visibility
Precipitation type	Microphysics-based	ASOS type
Accumulating snow	Explicit snow depth	Point observations
Severe wind	80-m hourly max wind or 10-m gust	METAR/mesonet observations
Large hail	Column graupel, updraft speed, ?	MESH
Tornado*	Updraft helicity	Post-processed MRMS rotation tracks
Lightning	Lightning flash algorithm	GLD360/NLDN
Visibility/Ceiling	Post-processed field in development	ASOS or future CIMSS technique
General Convection	Vertical motion, stability, reflectivity	MRMS reflectivity

HRRR-TLE: Project Timeline

Product Development Timeline

Engage National Center Testbeds

Organization/Experiment	Hazards	Platform	Timeline
WPC WWE	PQPF, Snowfall, Snow Rate	NAWIPS and web site	January 2016
NSSL/SPC EFP/EWP	Tornadoes, Hail, Wind	NAWIPS and AWIPSII	May 2016
WPC FFaIR	Refined PQPF and FF guidance	NAWIPS	June 2016
AWC Summer Experiment	Initial aviation hazards: ceiling, visibility, convection	NAWIPS	August 2016
WPC WWE	Refined winter hazards and PQPF	NAWIPS	January 2017
AWC Winter Experiment	Ceiling and visibility	NAWIPS	February 2017
NSSL/SPC EFP/EWP	Refined severe weather guidance	NAWIPS and AWPSII	May 2017
WPC FFaIR	Refined FF guidance	NAWIPS	July 2017
AWC Summer Experiment/OPG	Refined aviation hazards	NAWIPS and AWPSII	August 2017
Initiate NCO 'on-boarding'	All	IDP	Late 2017 or 2018

HRRRE Future Work

Refine ensemble data assimilation and forecasting

- Install radar reflectivity data assimilation
- Stochastic physics (parameter perturbation, tendencies for both DA and forecasting)
- Apply HRRR-TLE statistical post-processing
- Include lagged members?

Real-Time Status

Resume real-time HRRRE runs in Oct/Nov 2016 after ending 20 June 2016
HRRR-TLE runs continually available

Together (EMC, ESRL, NSSL, NCAR, ...) work toward building a national real-time storm-scale ensemble system (and eventually a global storm-scale ensemble system)

Using the CRTM and GOES Observations to Improve Model Microphysics

Dan Lindsey

NOAA Center for Satellite Applications and Research, CIRA, Ft. Collins, CO

**Louie Grasso, Yoo-Jeong Noh, Steve Miller, Curtis Seaman,
Chris O'Dell**

Cooperative Institute for Research in the Atmosphere, Ft. Collins, CO

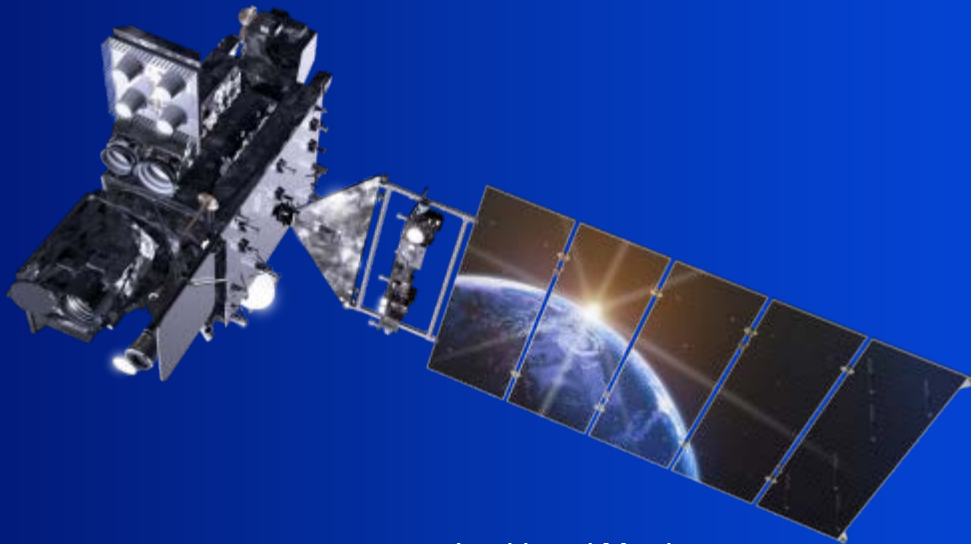


Outline

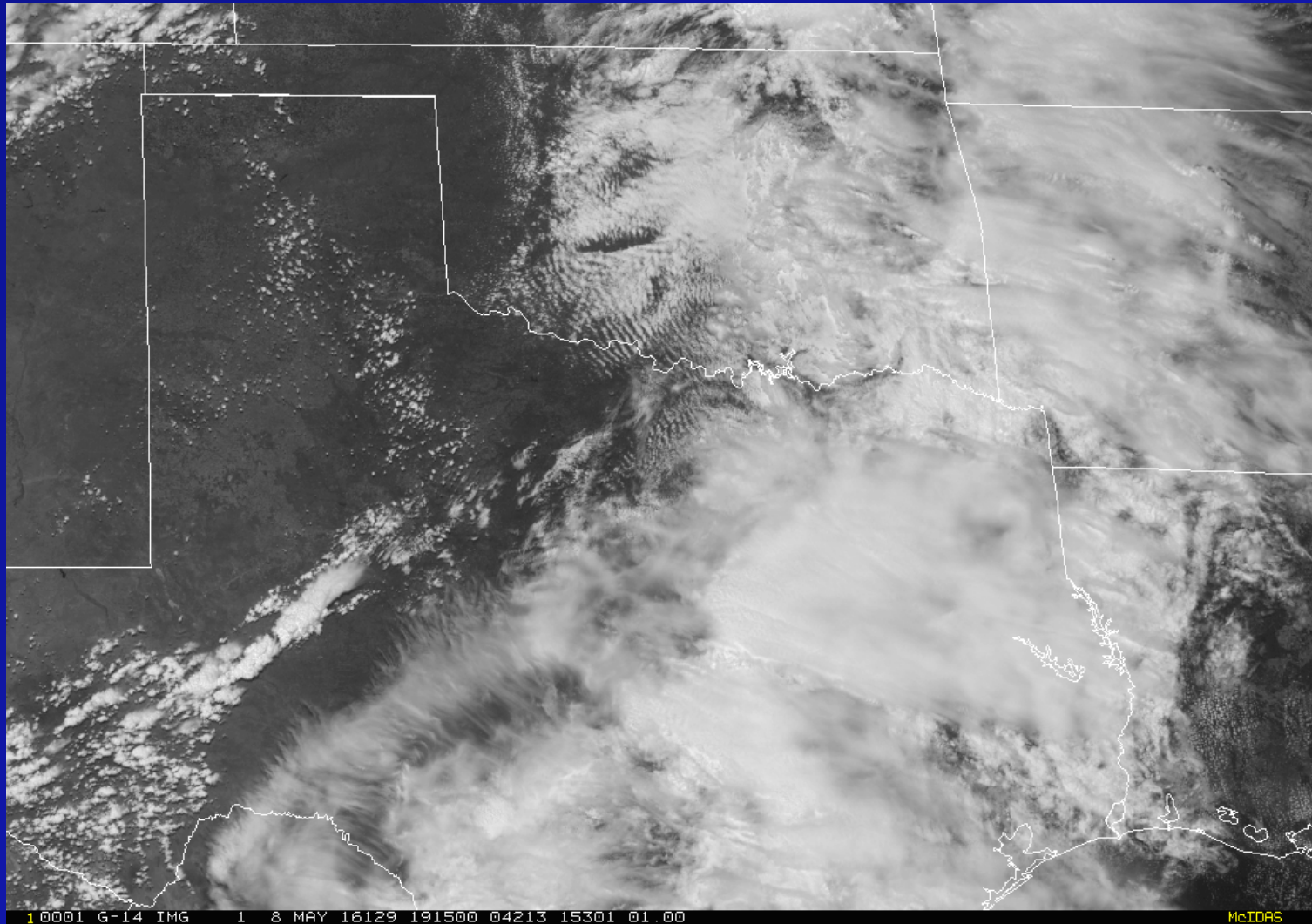
1. New Satellite Observations

2. Synthetic Satellite Imagery

3. CRTM Improvements

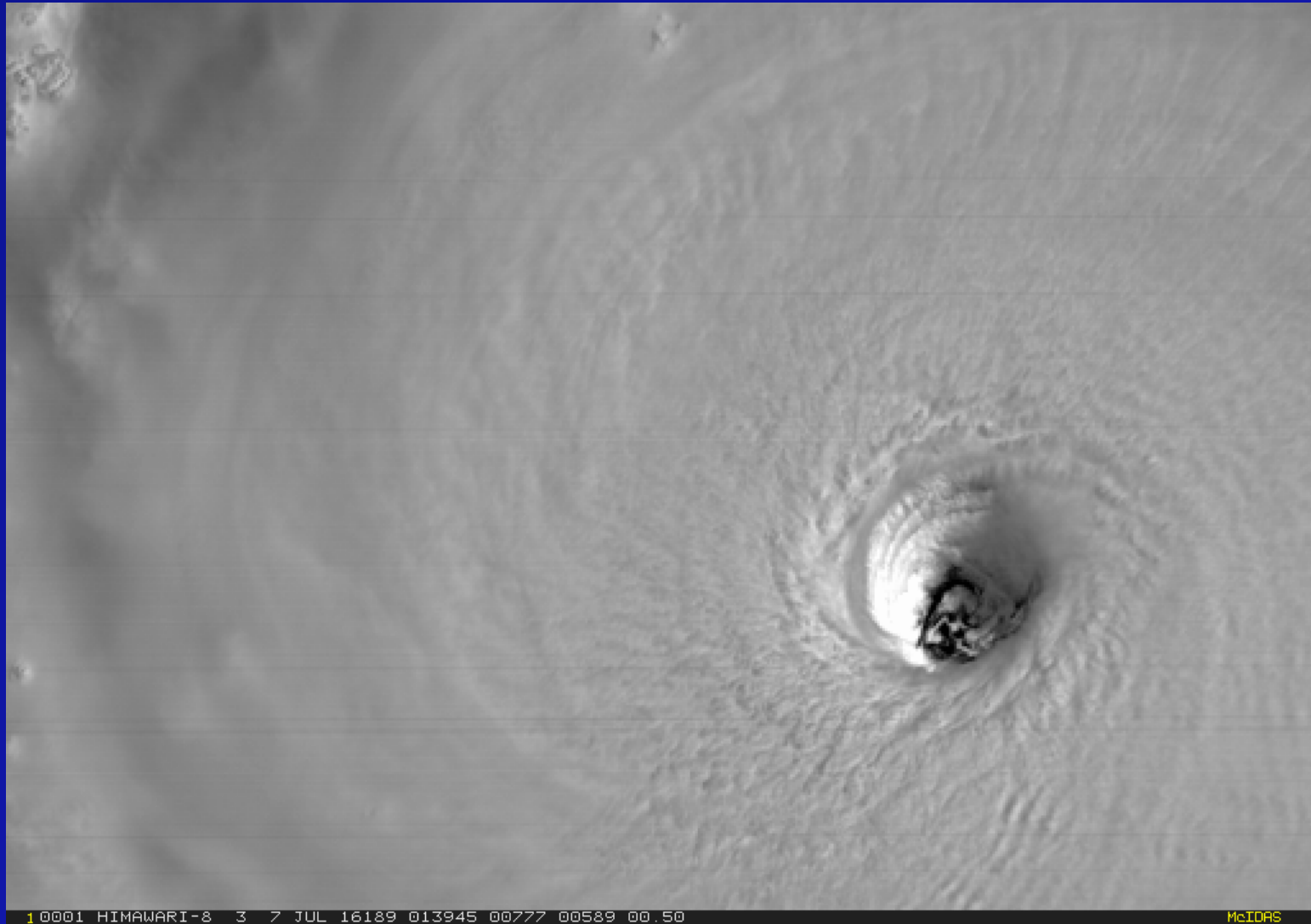


New Satellite Observations



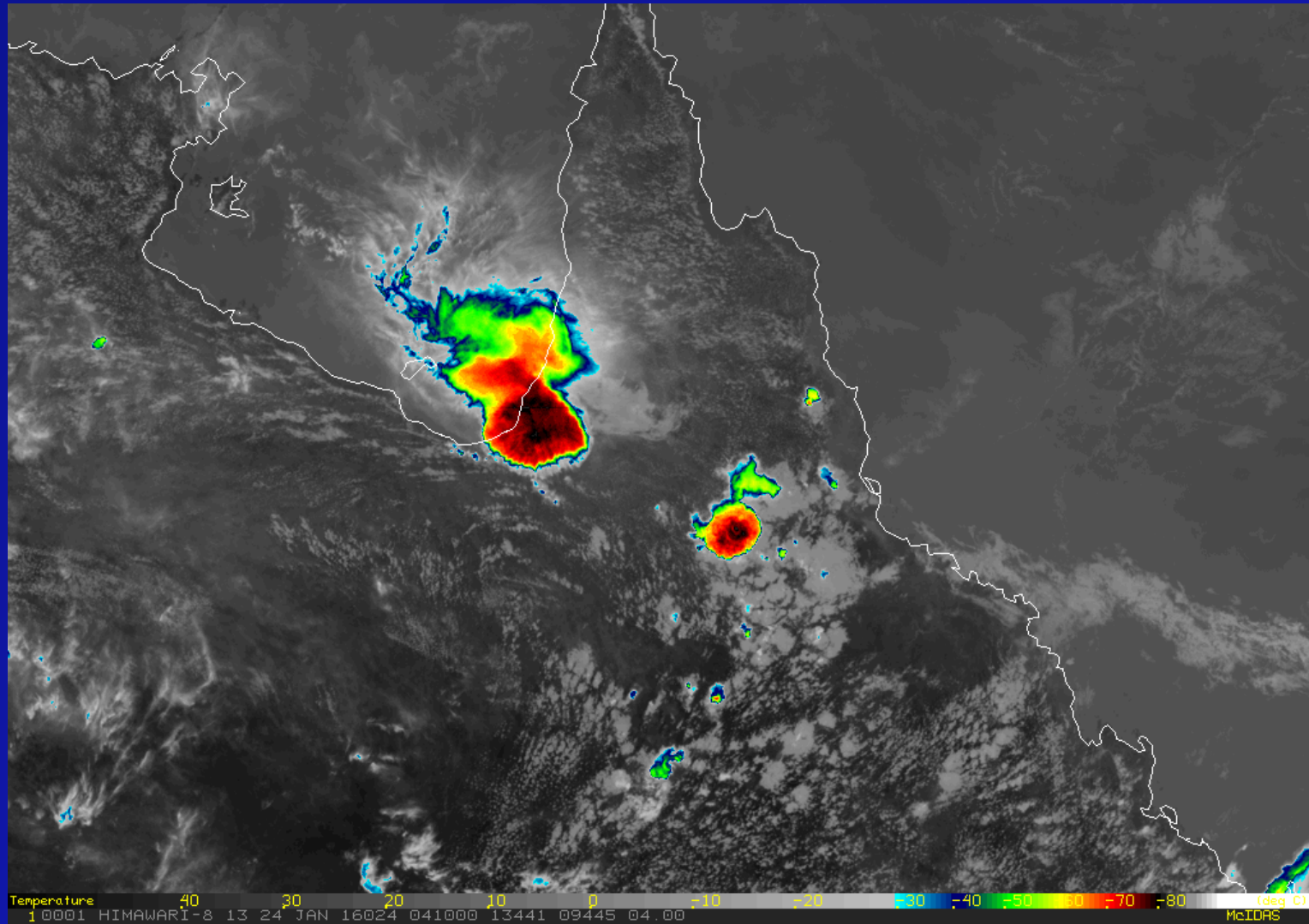
GOES-R will provide 1-min imagery over two mesoscale sectors. GOES-14 has been collecting occasional 1-min data for several years. This example is from 8 May 2016. GOES-R 1-min imagery will have four times better spatial resolution.

New Satellite Observations



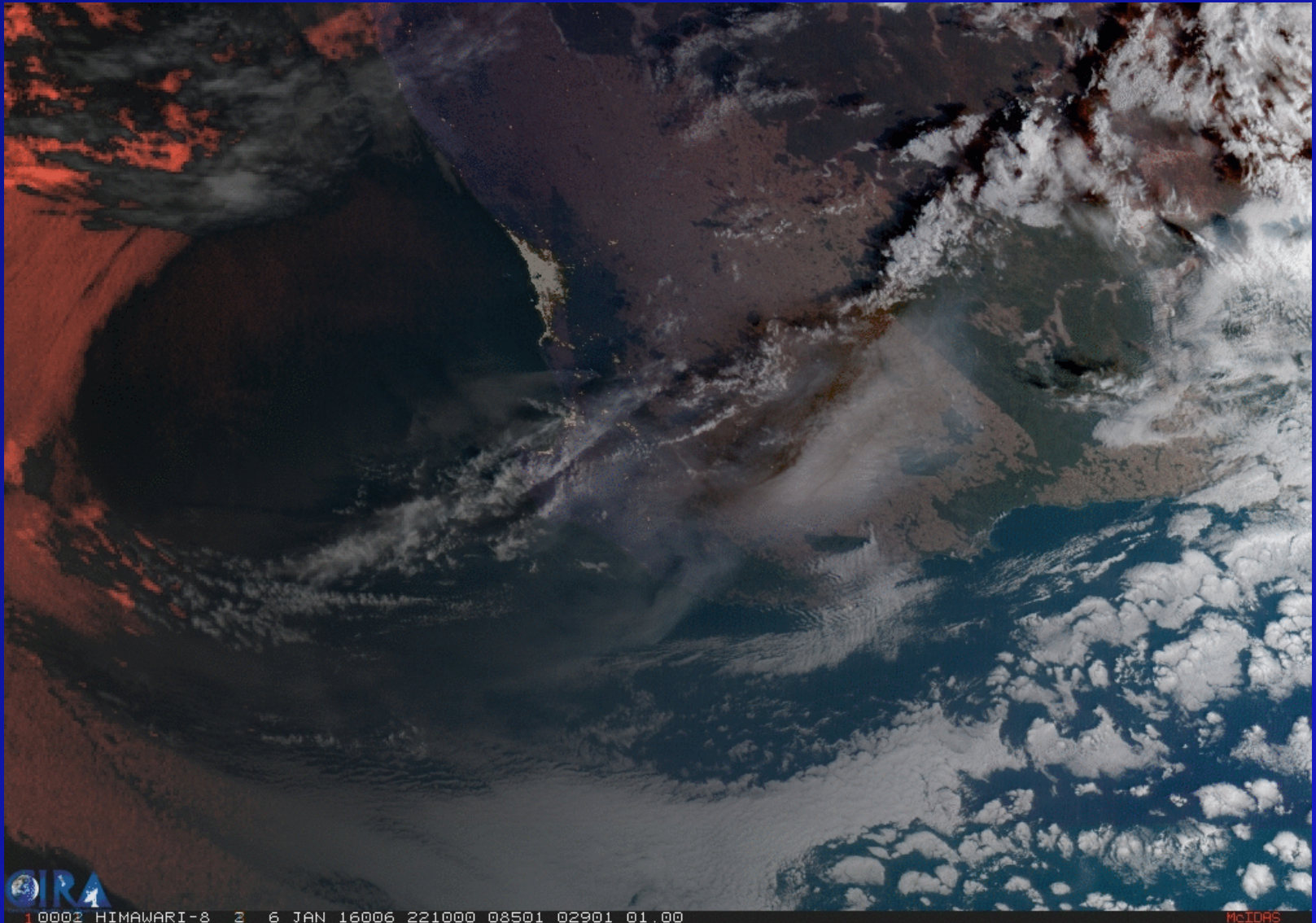
Himawari-8 was launched by the Japanese Meteorological Agency in late 2014. Its imager is quite similar to the GOES-R ABI, and therefore provides the closest proxy to what we'll have over the western Hemisphere in less than a year. This example shows 2.5-min imagery at 500-m resolution of Super Typhoon Nepartak from a couple weeks ago.

New Satellite Observations



This examples shows the Himawari 10.4 μm window IR band (2-km resolution) from 24 Jan. 2016 over northeast Australia

New Satellite Observations



Himawari-8 allows for true color imagery every 10 mins during the day. This example is CIRA's Geocolor product over southwestern Australia on 6 Jan. 2016.

New Satellite Observations

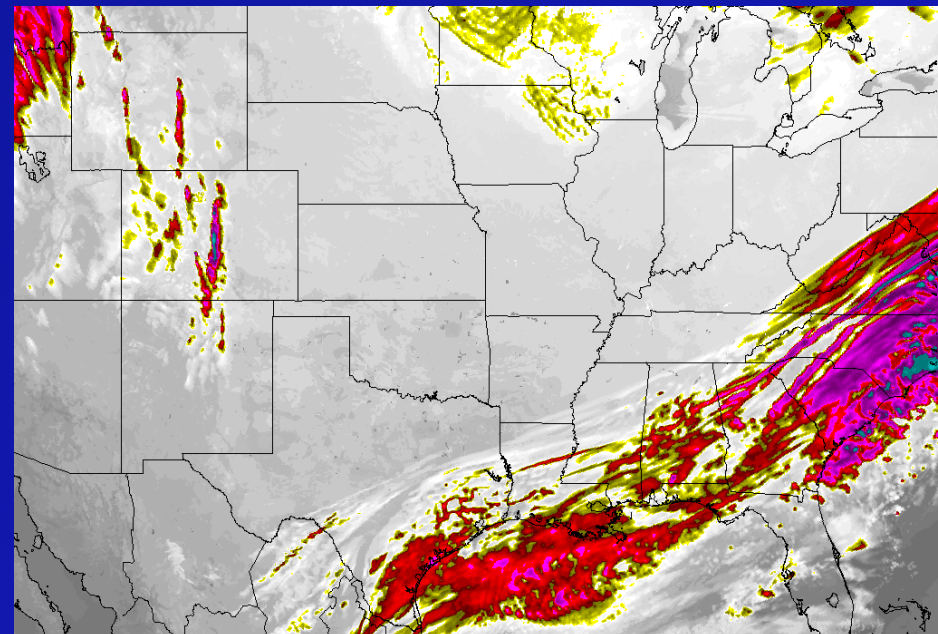
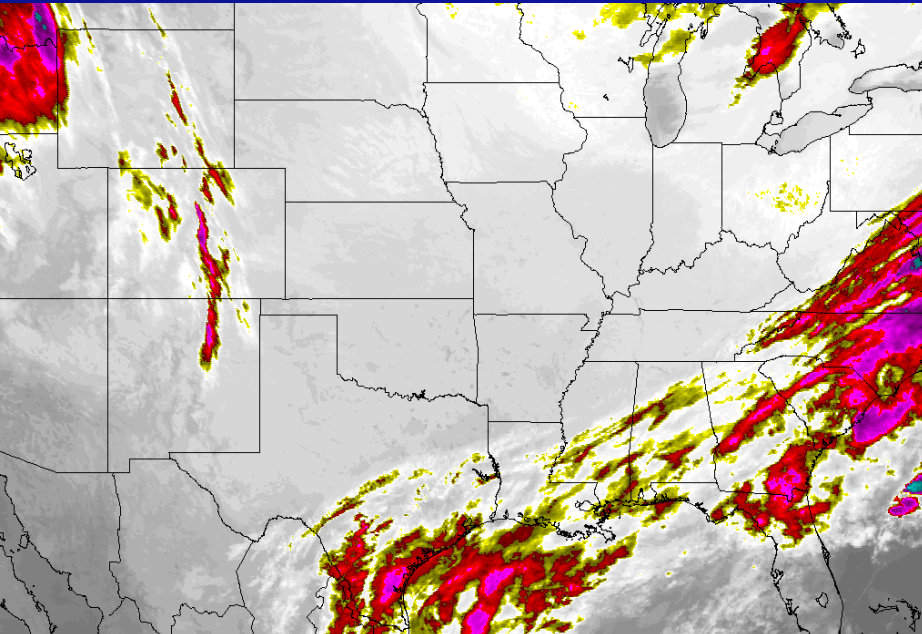
The big question is this:

In addition to using these amazing new satellite observations in a qualitative manner, how can they be used *quantitatively* to improve forecasts?

One possible answer: Data Assimilation

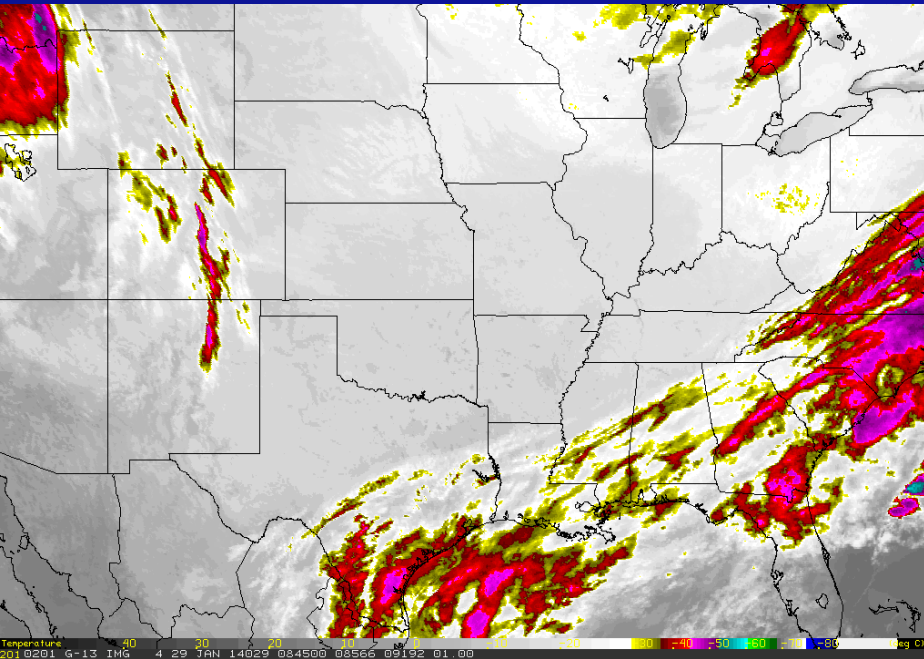
- This requires use of a radiative transfer model to simulate what radiance the satellite would see given a particular model-forecast state
- It is critical that the RTM and the model “play well” together

Synthetic Satellite Imagery

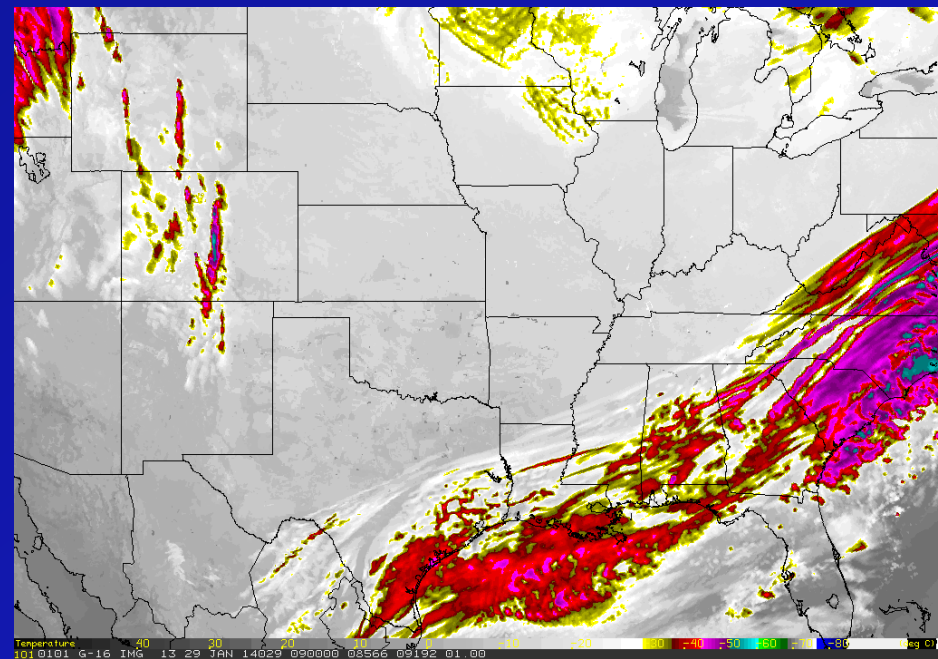


Which of these loops is actual satellite data, and which is simulated imagery based on a model forecast?

Synthetic Satellite Imagery

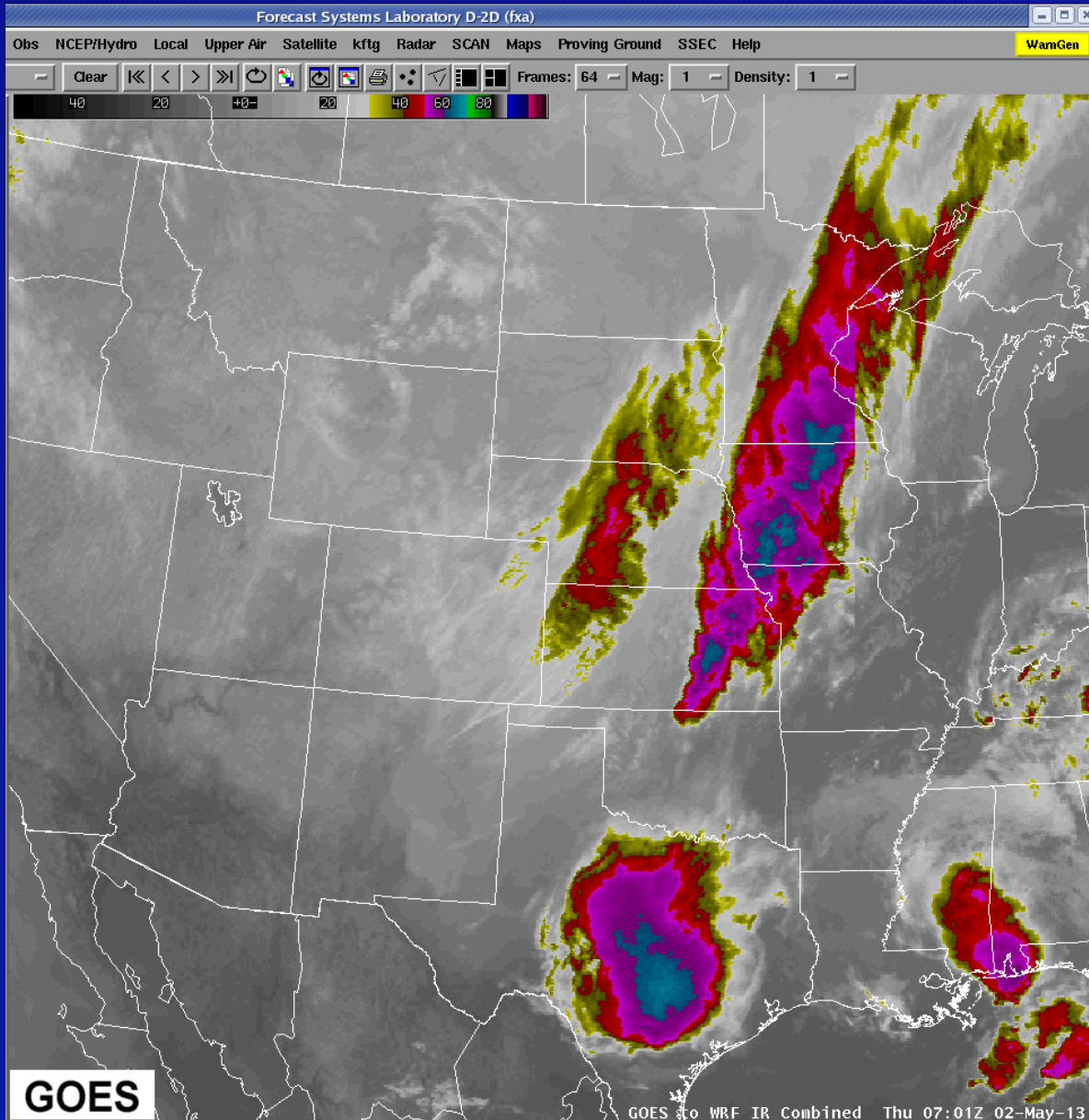


Observed GOES-13 data



Simulated IR Imagery based on a 9- to 23-hour forecast from the NSSL WRF-ARW

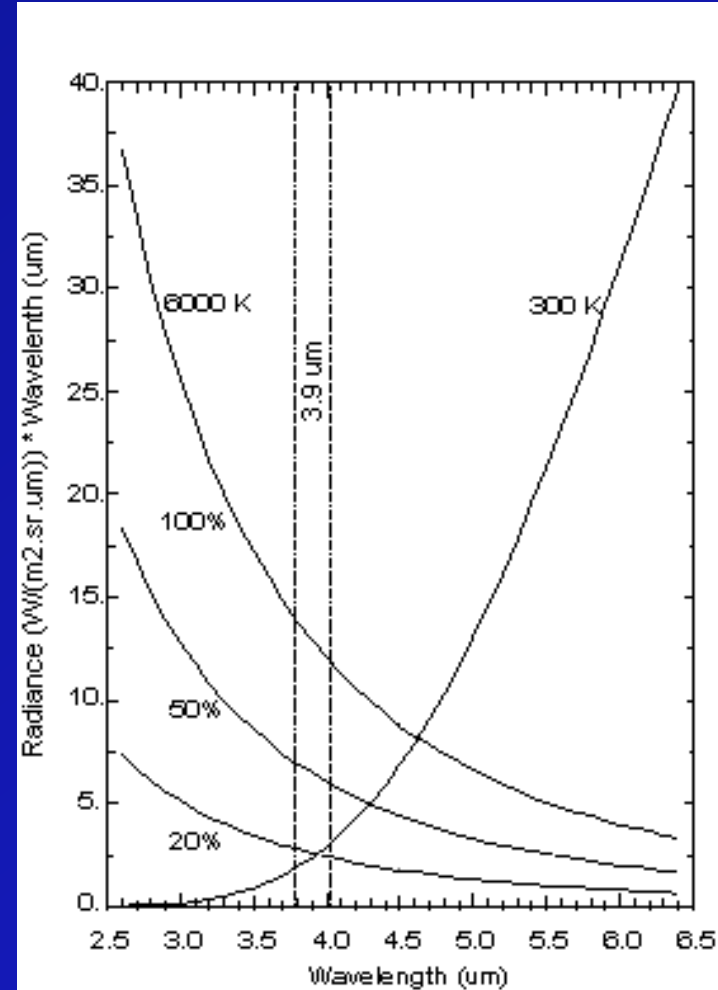
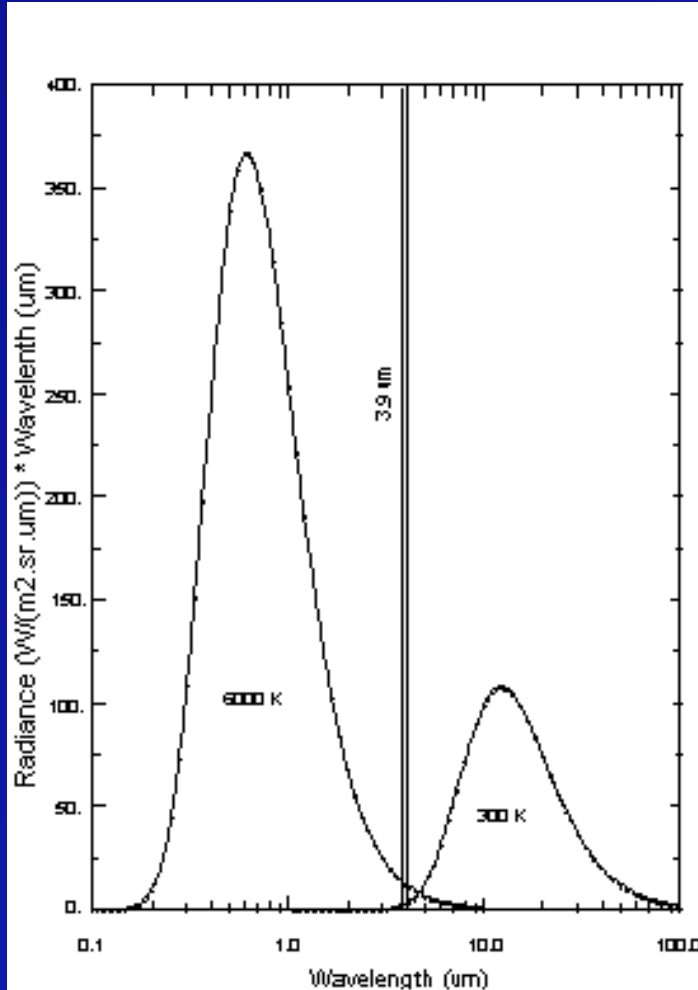
Synthetic Satellite Imagery



- Running a radiative transfer model using high resolution NWP output to generate synthetic satellite imagery has several applications
- From a forecaster's perspective, the most useful is the ability to view model-forecast clouds in terms of how it would look from GOES

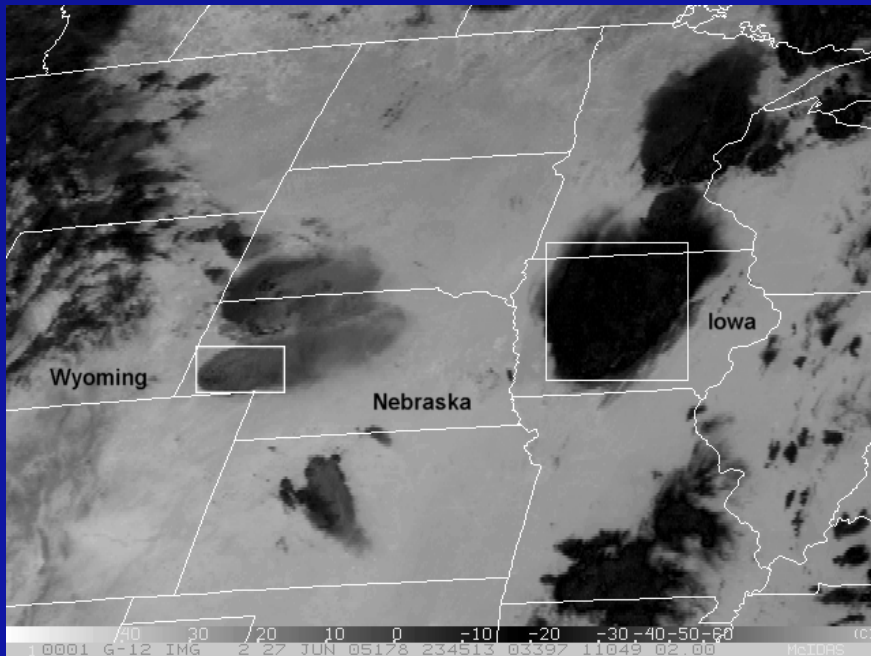
Synthetic Satellite Imagery

The GOES 3.9 μm Band

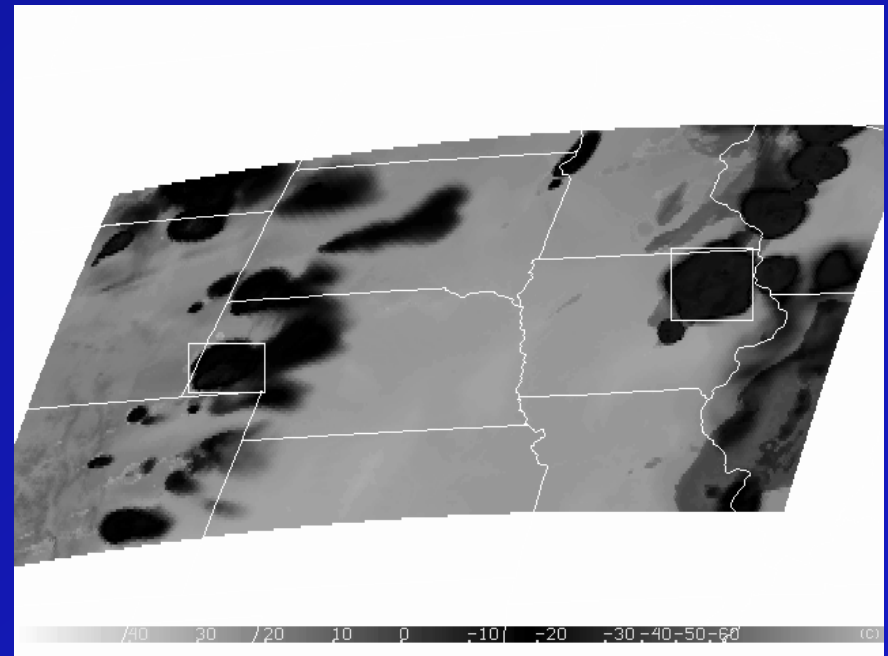


Synthetic Satellite Imagery

- A second benefit of synthetic imagery is to help evaluate NWP microphysics schemes



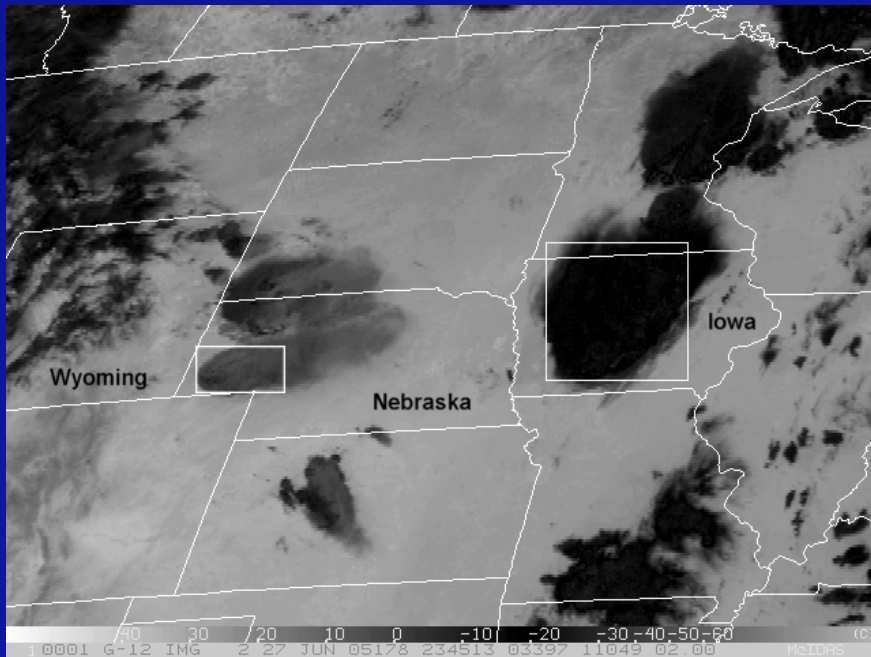
GOES-12 Observed 3.9 μm , 27 June 2005, 2345 UTC



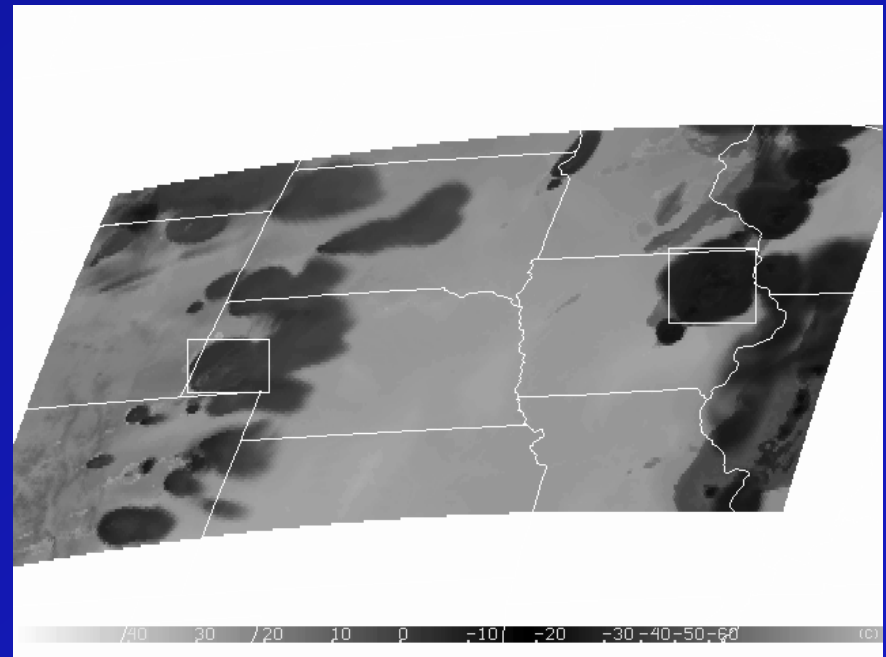
Simulated 3.9 μm based on a RAMS simulation of the 27 June 2005 case, using CIRA's RTM

Synthetic Satellite Imagery

- A second benefit of synthetic imagery is to help evaluate NWP microphysics schemes



GOES-12 Observed 3.9 μm , 27 June 2005, 2345 UTC



Simulated 3.9 μm based after fixing the bug discovered in the RAMS microphysics

The Community Radiative Transfer Model (CRTM)

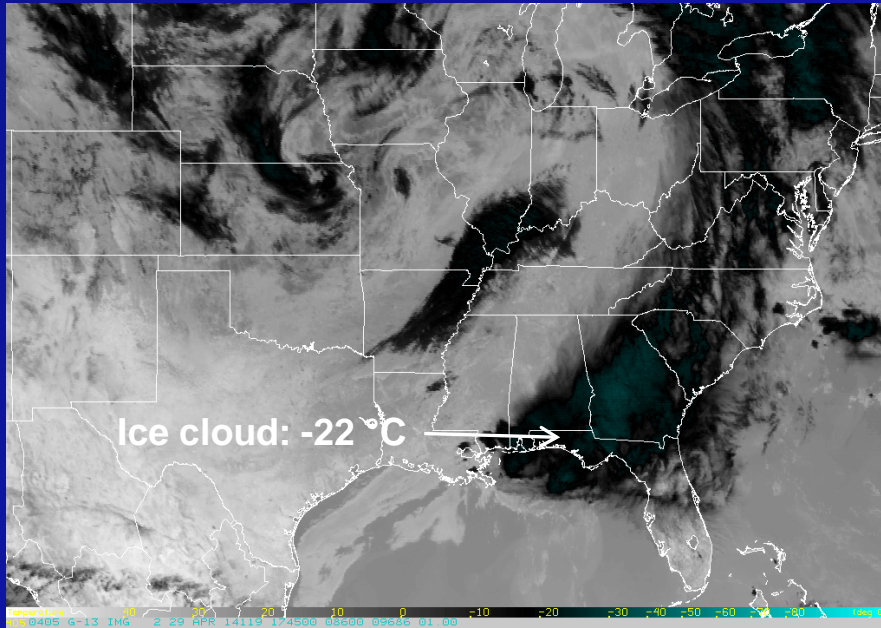
- The CRTM is currently used as part of GSI, the operational data assimilation system used by NCEP
- Although all-sky (including clouds) radiance assimilation is not yet being done in operations, it likely will be in the future
- It is therefore critical that the NWP microphysical output is consistent with that expected by the CRTM – here we investigate this connection

Comparisons between the CRTM (V2.1.3), and GOES-13 Observations

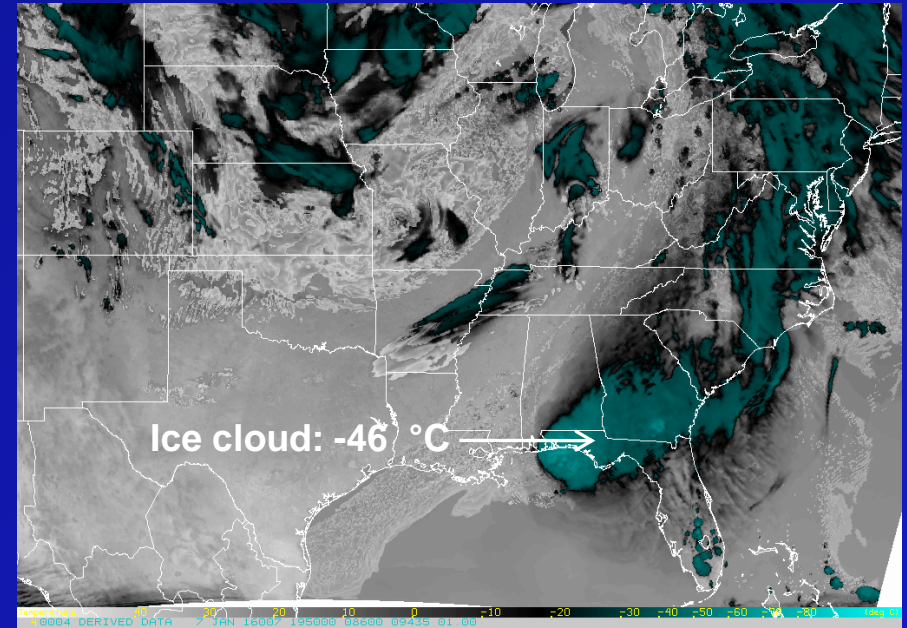
29 April 2014 – 18 Z – based on WRF forecast – Morrison microphysics

3.9 μm ABI band

GOES-13 Observations



CRTM



- The CRTM simulated 3.9 μm band is about $25\text{ }^{\circ}\text{C}$ too cold
- Not enough solar 3.9 μm radiation is being reflected by ice clouds

So why are the CRTM simulated brightness temps too cold?

Possibilities include:

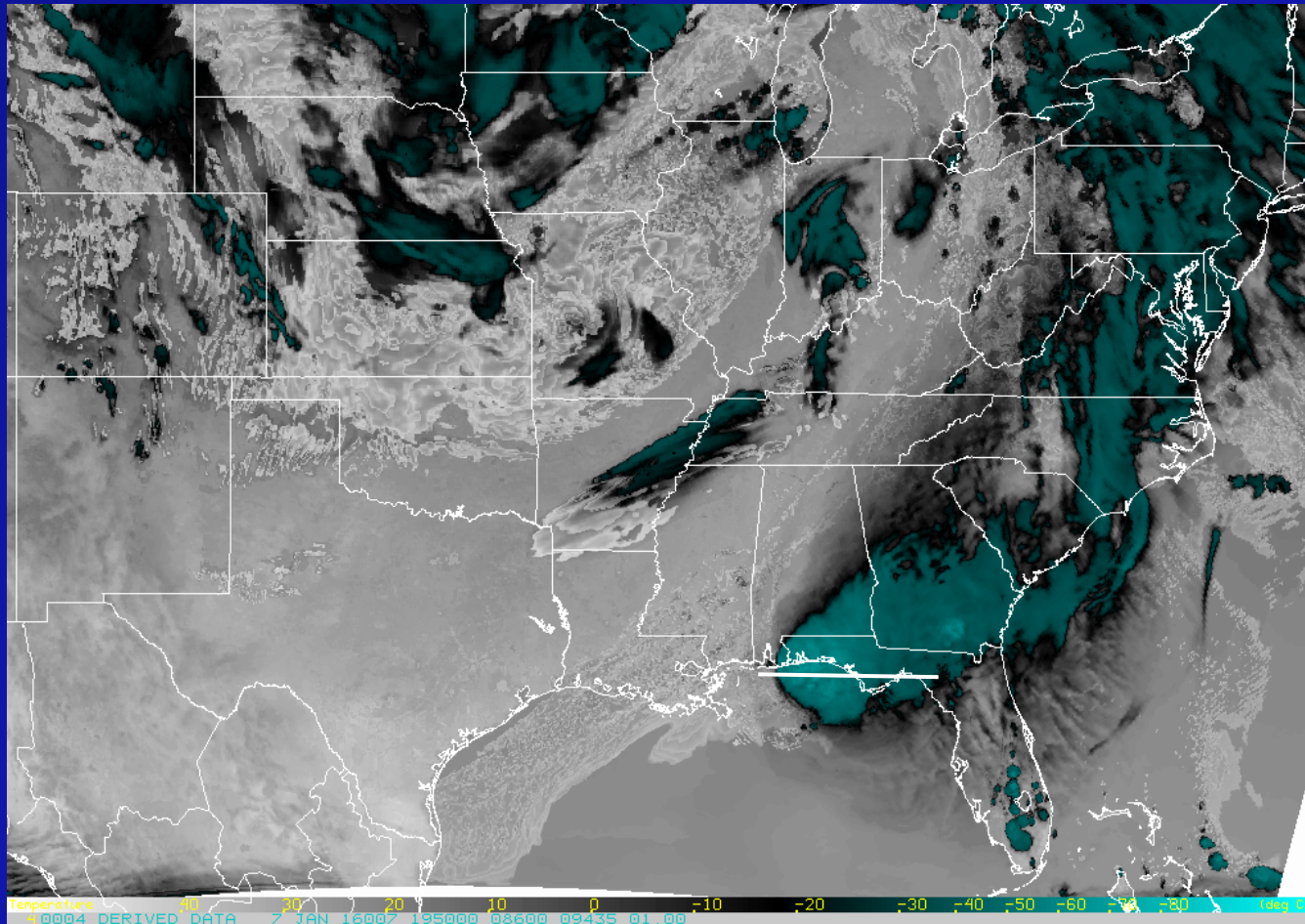
- 1) Incorrect optical properties of frozen hydrometeors used by the CRTM
- 2) Model microphysics output inconsistent with the optical properties expected by the CRTM
 - Particles may be too large – that would lead to lower 3.9 μm brightness temps
 - Distribution of the water mass among the ice species may not be supported by observations
- 3) A bug in the CRTM solar reflection code

1) Incorrect optical properties of frozen hydrometeors used by the CRTM?

- The CRTM ice scattering table has entries at 3.67 μm and 4.5 μm , but nothing at 3.9 μm . Since the GOES 3.9 μm bandwidth is 3.8-4.0 μm , perhaps interpolation between 3.67 and 4.5 μm is leading to errors
- Tests were performed in which we used recent ice scattering properties from Ping Yang centered at exactly 3.9 μm , and the simulated brightness temps increased by about 3 $^{\circ}\text{C}$, not enough to match observations
- It's unlikely that incorrect assumed ice scattering properties is solely responsible for the differences between simulations and observations

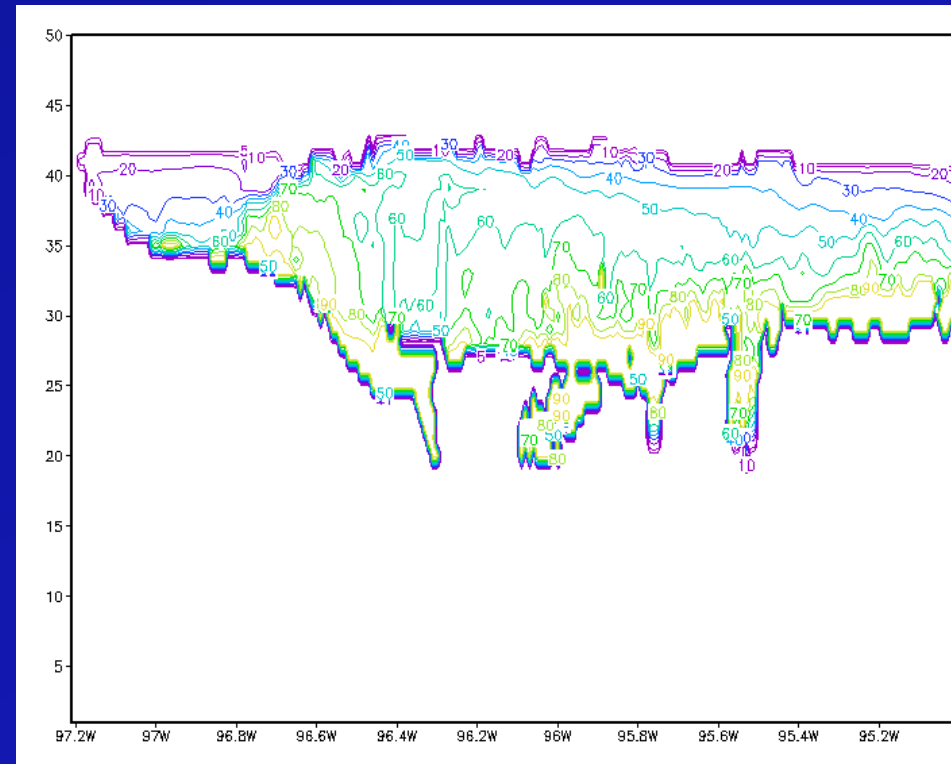
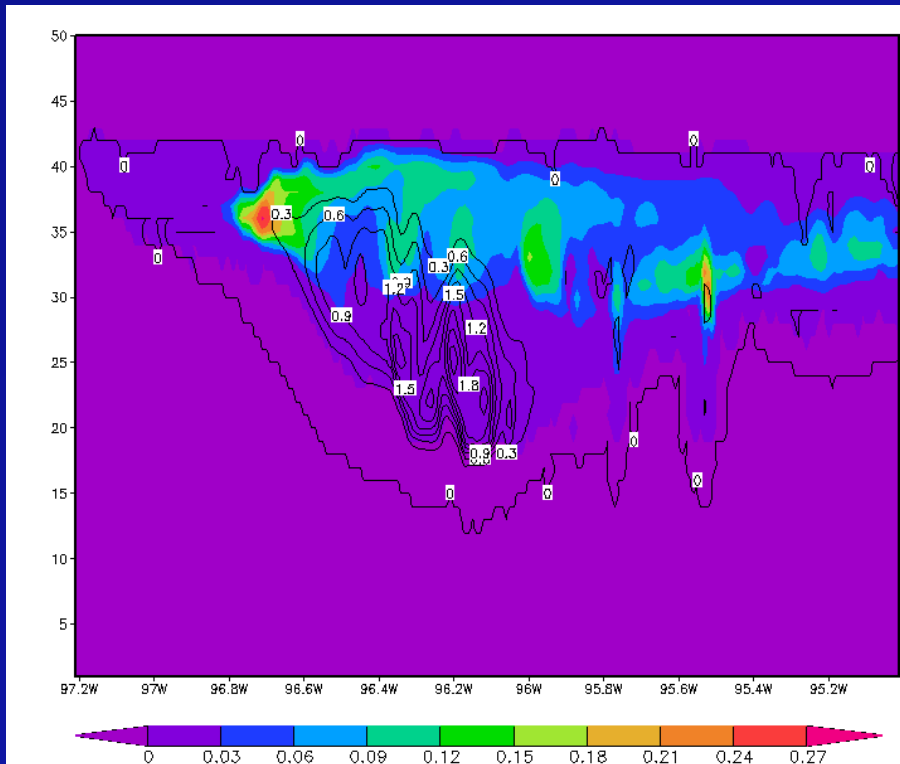
2) Model microphysics output inconsistent with the optical properties expected by the CRTM?

WRF output from the run using the Morrison scheme



2) Model microphysics output inconsistent with the optical properties expected by the CRTM?

WRF output from the run using the Morrison scheme



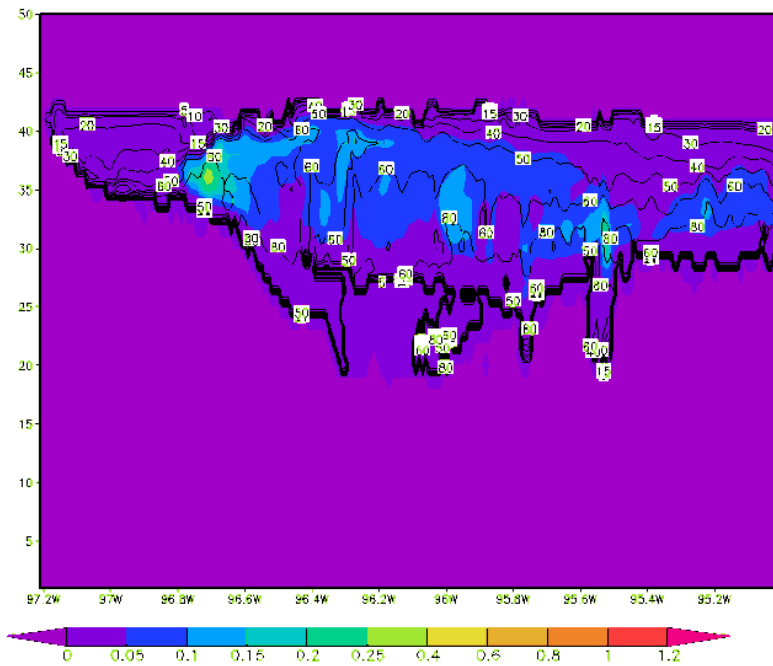
Ice mass mixing ratio (colors)
Snow mass mixing ratio (contours)

Both in g/kg

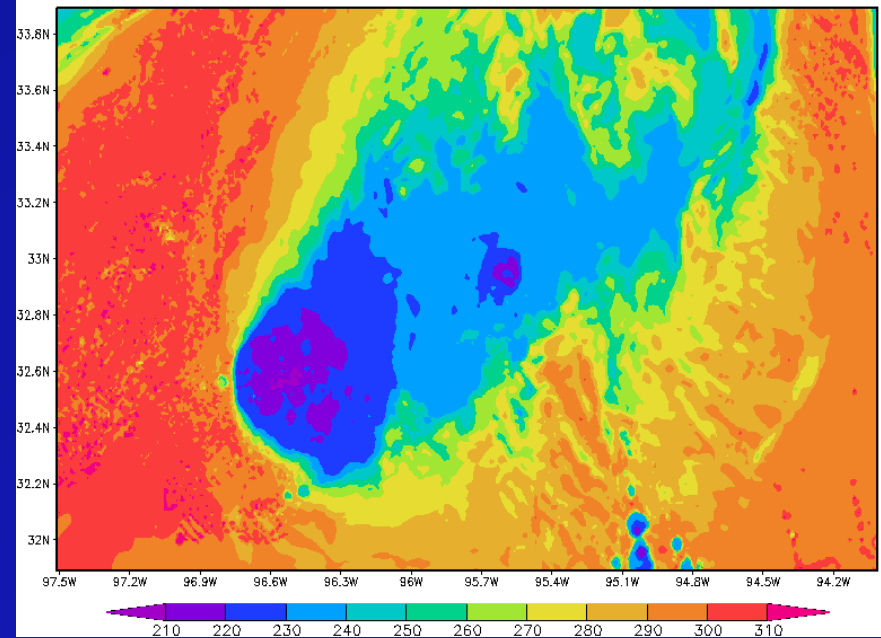
Ice effective radius (μm)

2) Model microphysics output inconsistent with the optical properties expected by the CRTM?

Original Run



Ice mass mixing ratio (colors, g/kg)
Ice Effective Radius (contours, μm)

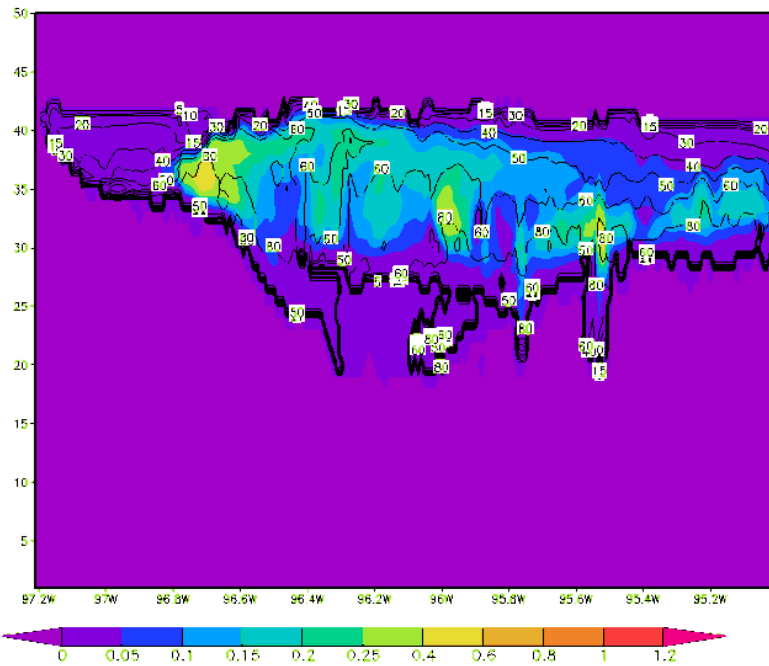


CRTM Simulated Brightness
Temperature (K)

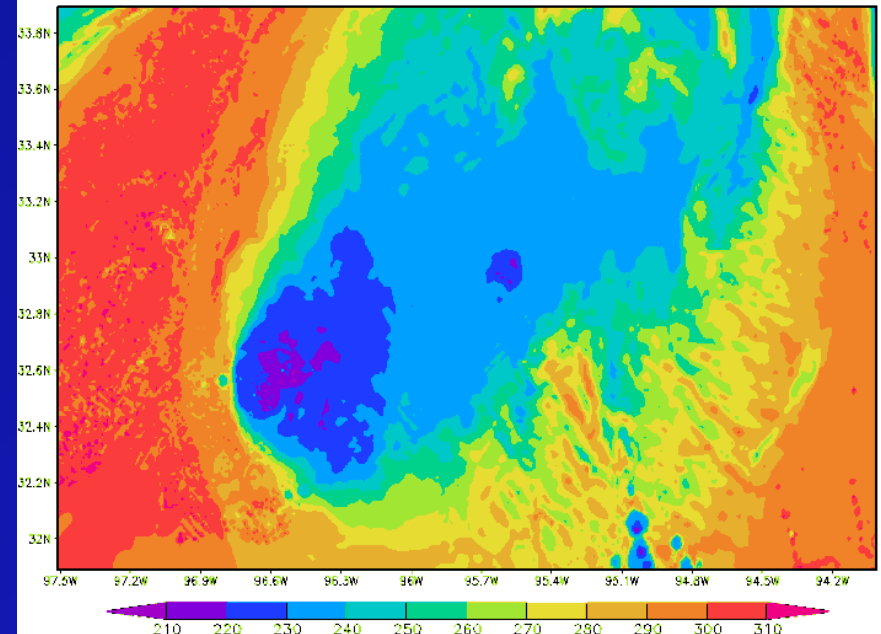
GOES Observations: ~ 250 K

2) Model microphysics output inconsistent with the optical properties expected by the CRTM?

Double the Ice Mass



Ice mass mixing ratio (colors, g/kg)
Ice Effective Radius (contours, μm)

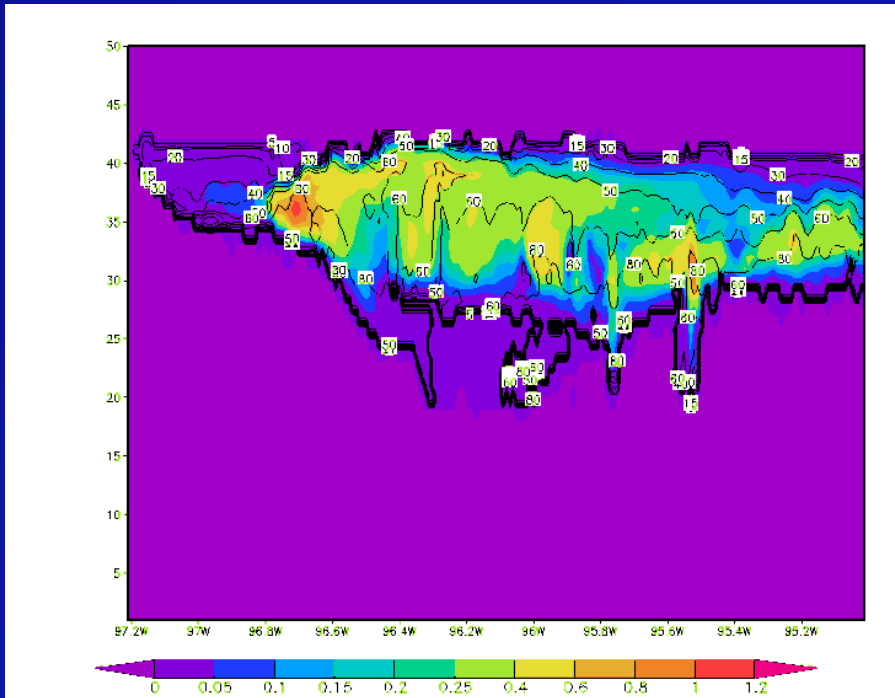


CRTM Simulated Brightness
Temperature (K)

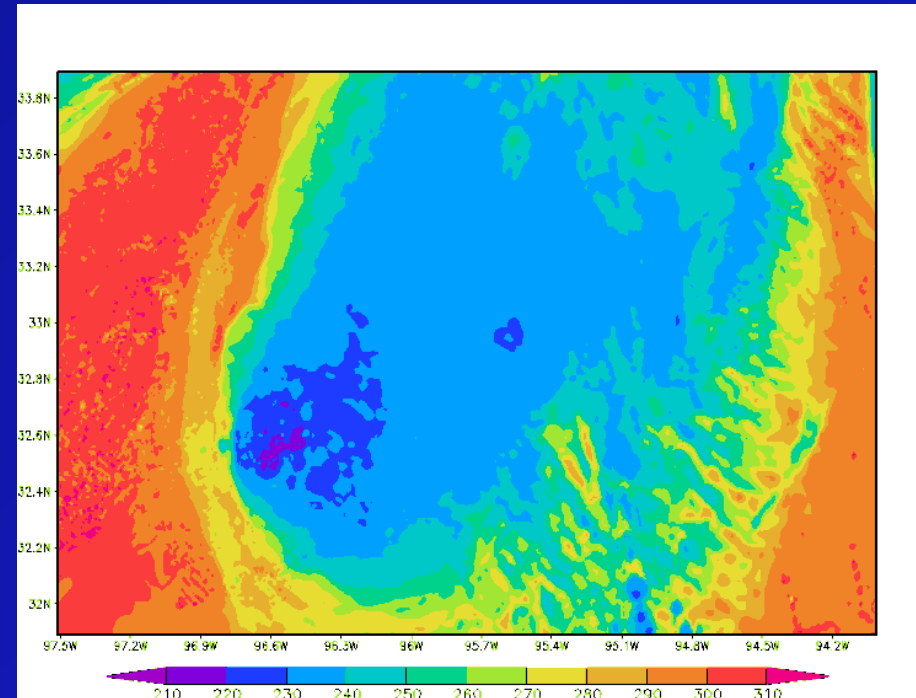
GOES Observations: ~ 250 K

2) Model microphysics output inconsistent with the optical properties expected by the CRTM?

4x the Ice Mass



Ice mass mixing ratio (colors, g/kg)
Ice Effective Radius (contours, μm)

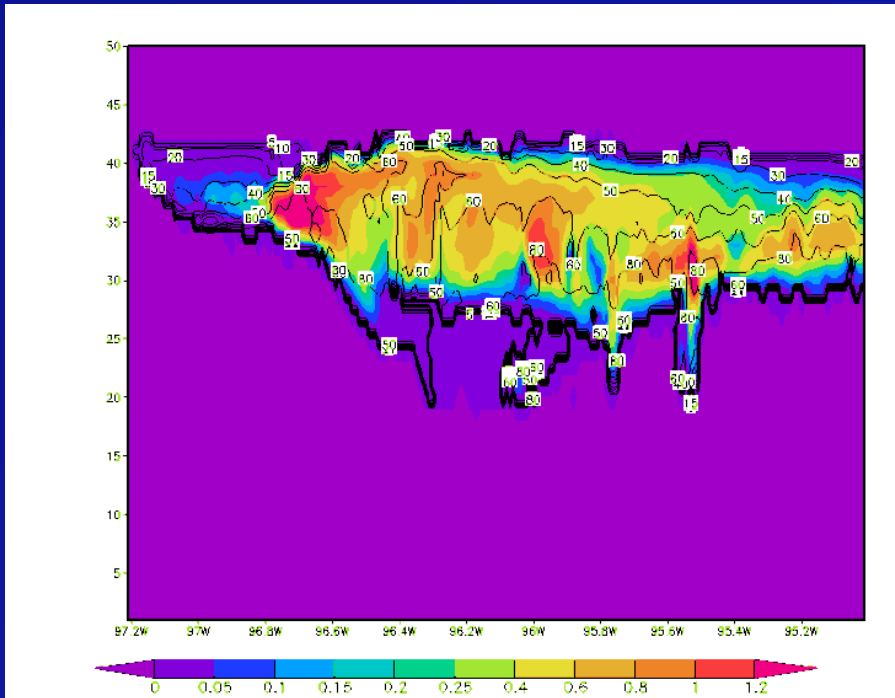


CRTM Simulated Brightness
Temperature (K)

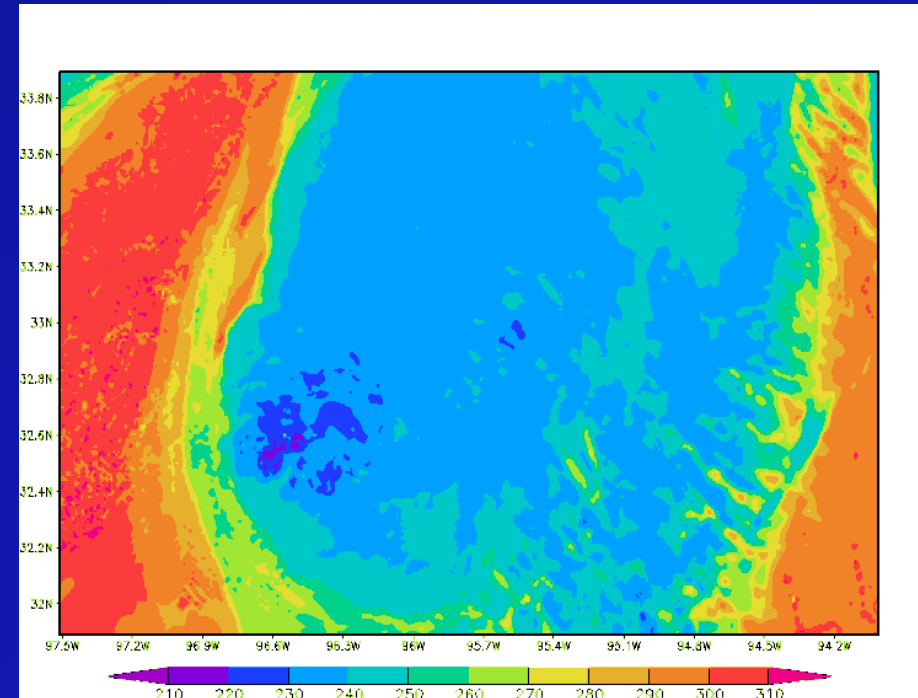
GOES Observations: ~250 K

2) Model microphysics output inconsistent with the optical properties expected by the CRTM?

8x the Ice Mass



Ice mass mixing ratio (colors, g/kg)
Ice Effective Radius (contours, μm)

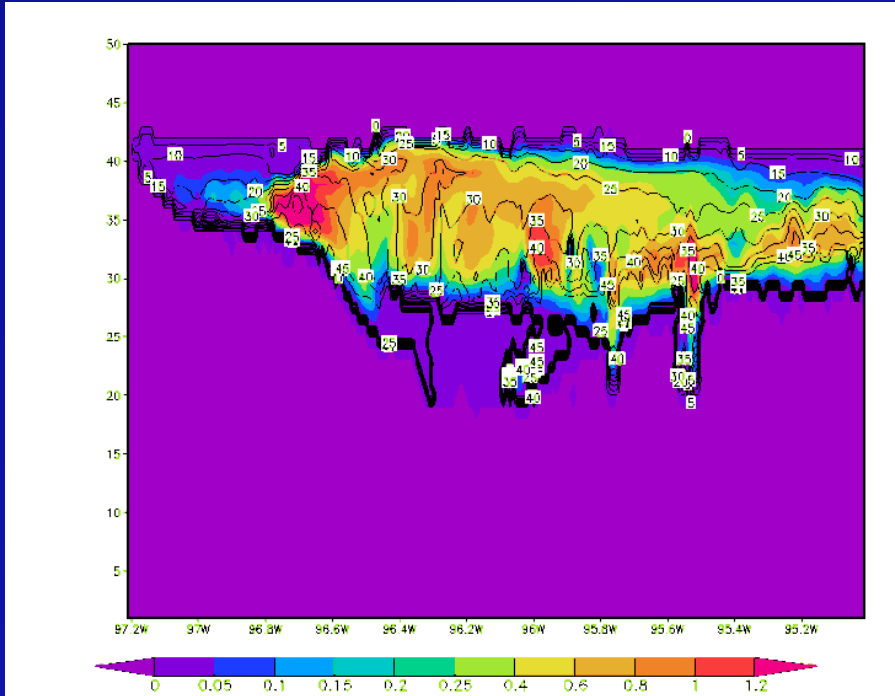


CRTM Simulated Brightness
Temperature (K)

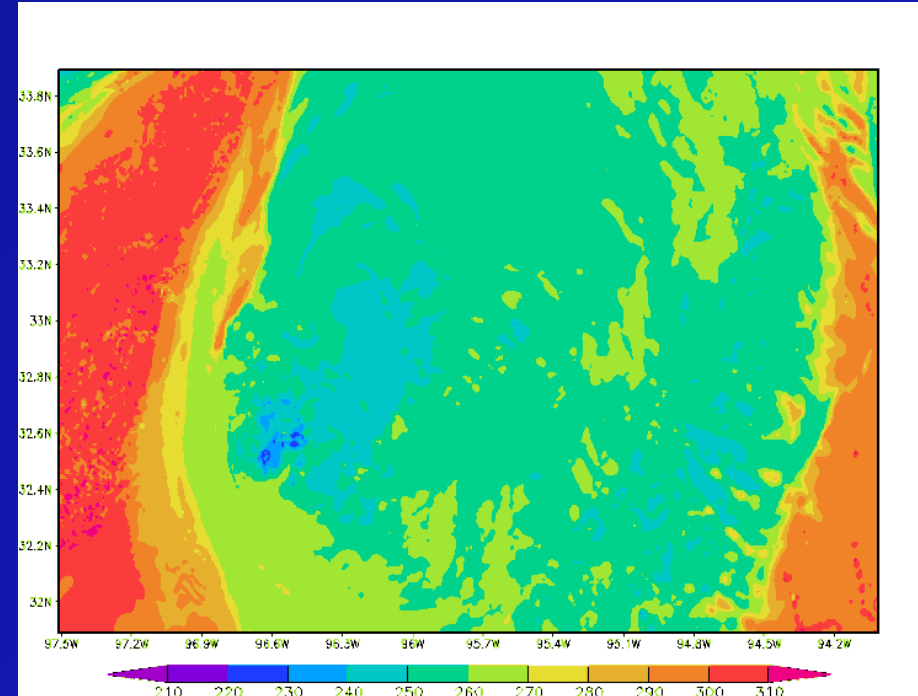
GOES Observations: ~ 250 K

2) Model microphysics output inconsistent with the optical properties expected by the CRTM?

8x the Ice Mass, Half the Ice size



Ice mass mixing ratio (colors, g/kg)
Ice Effective Radius (contours, μm)

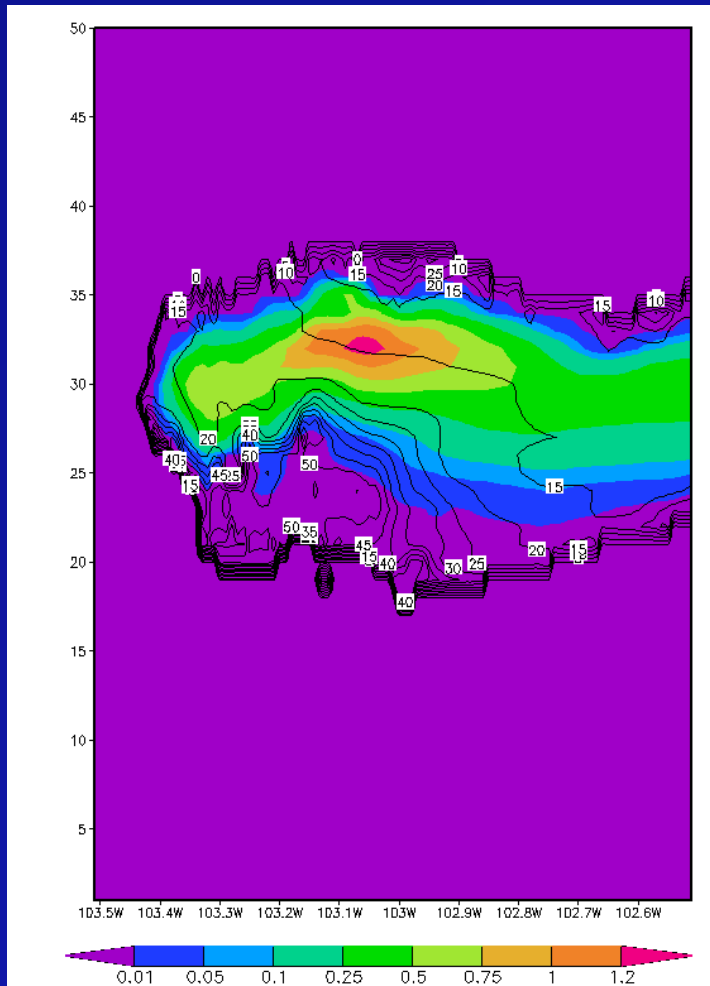


CRTM Simulated Brightness
Temperature (K)

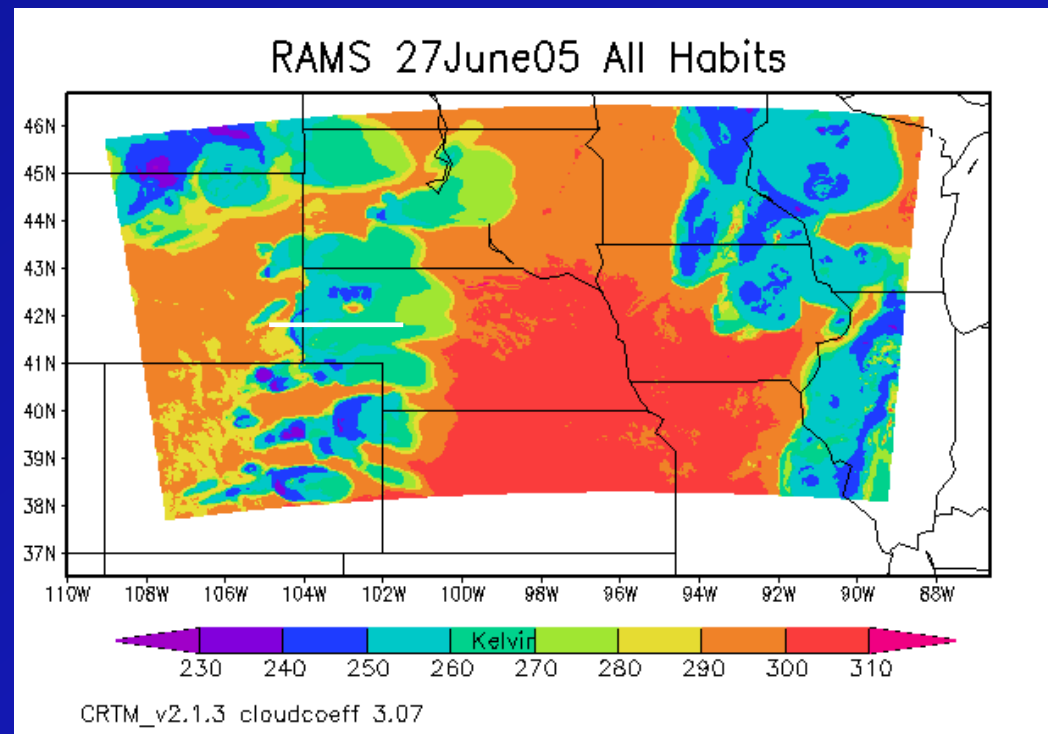
GOES Observations: ~ 250 K

2) Model microphysics output inconsistent with the optical properties expected by the CRTM?

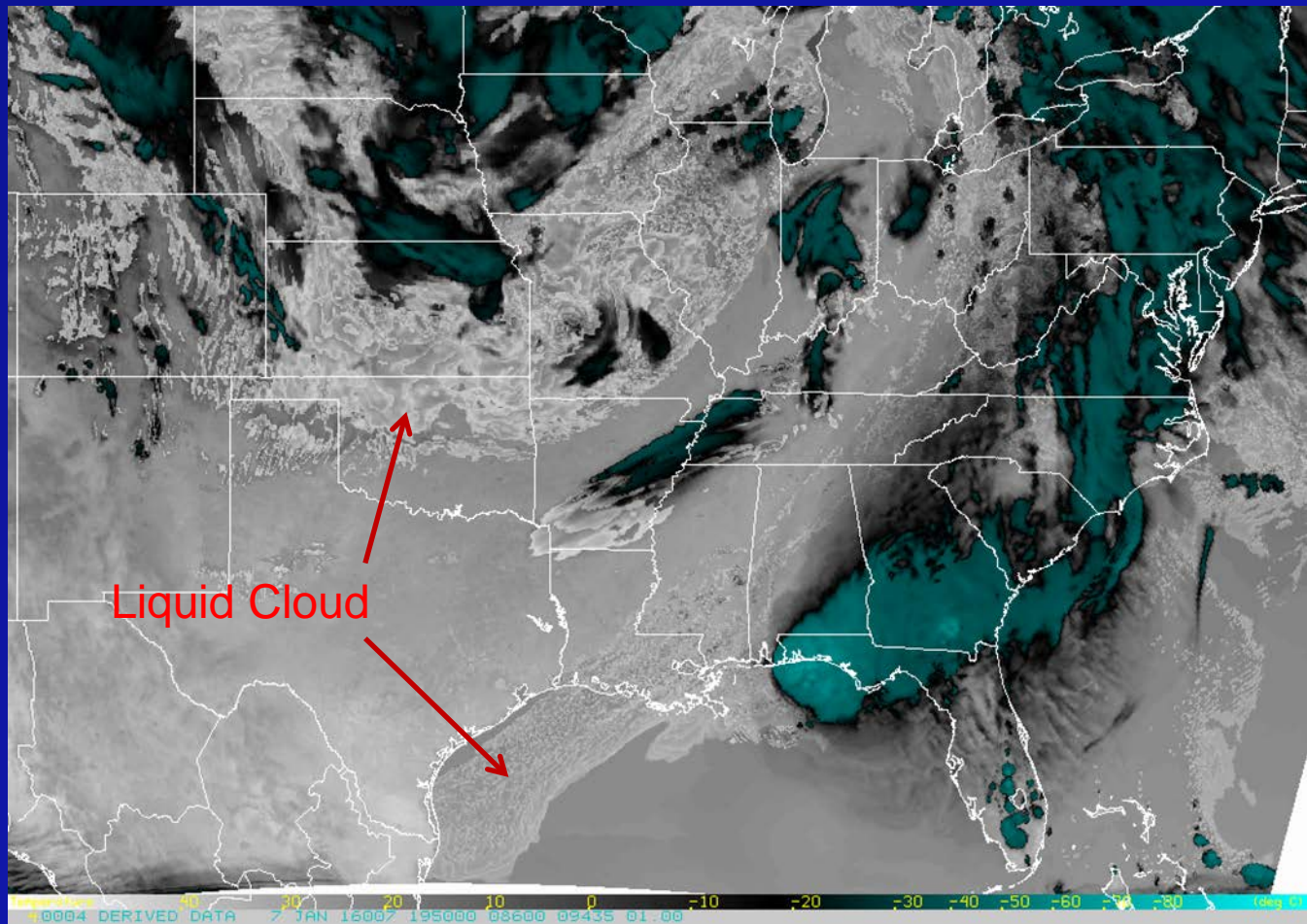
Vertical cross-section through the storm indicated on the right



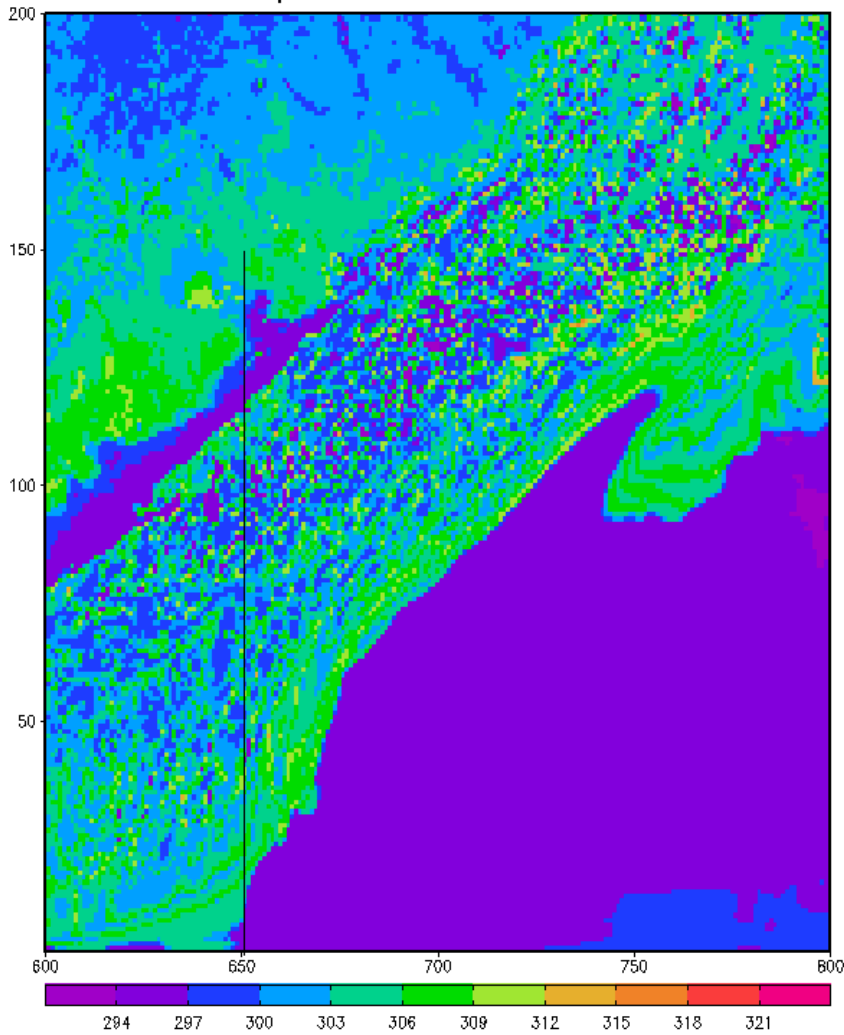
CRTM Simulated 3.9 μm Brightness Temp



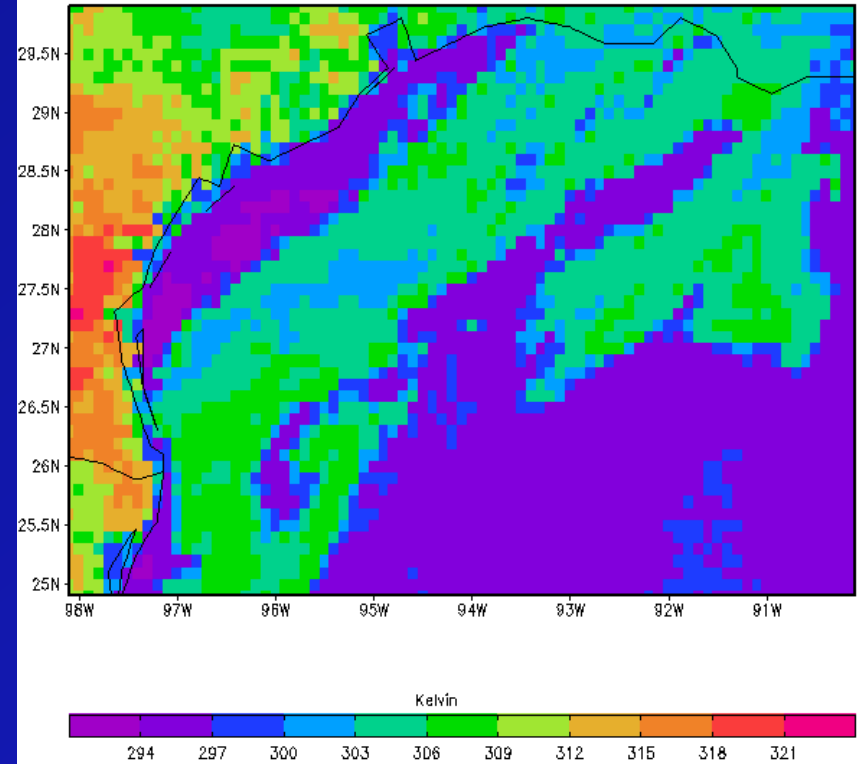
- Ice mass mixing ratio (colors, g/kg)
- Ice radius (contours, μm)



29Apr2014 18z MORR ch2

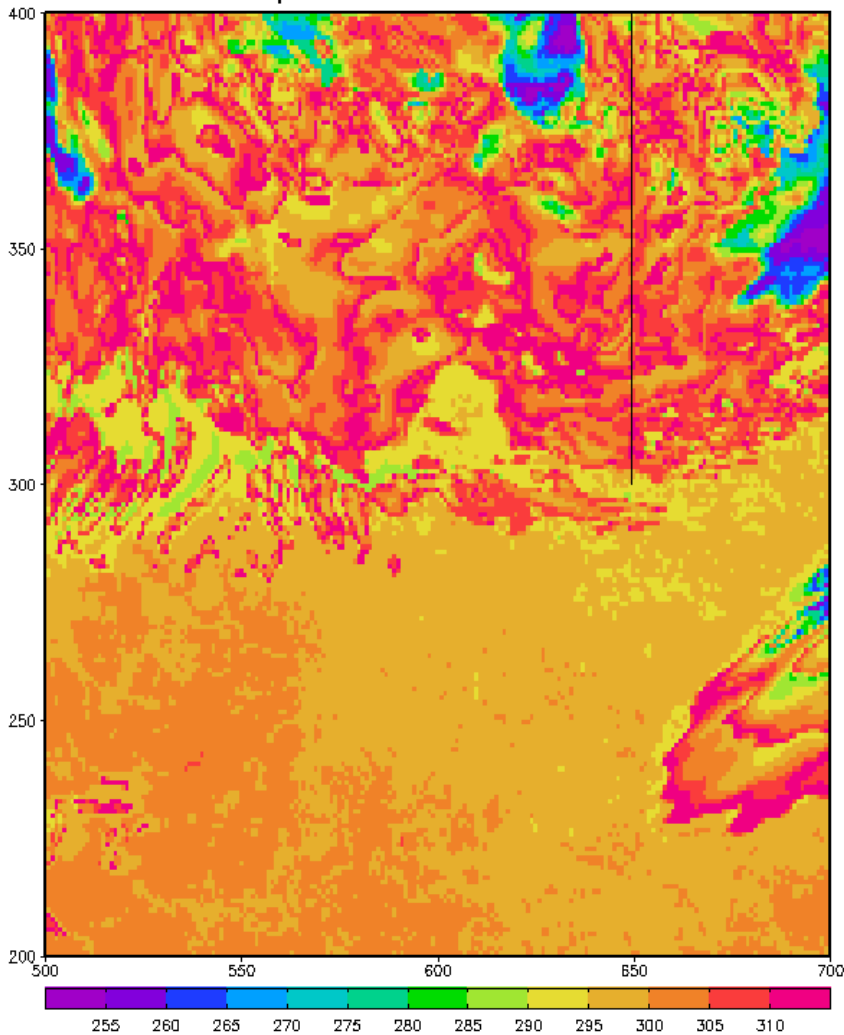


29Apr2014 18z GOES-13 ch2

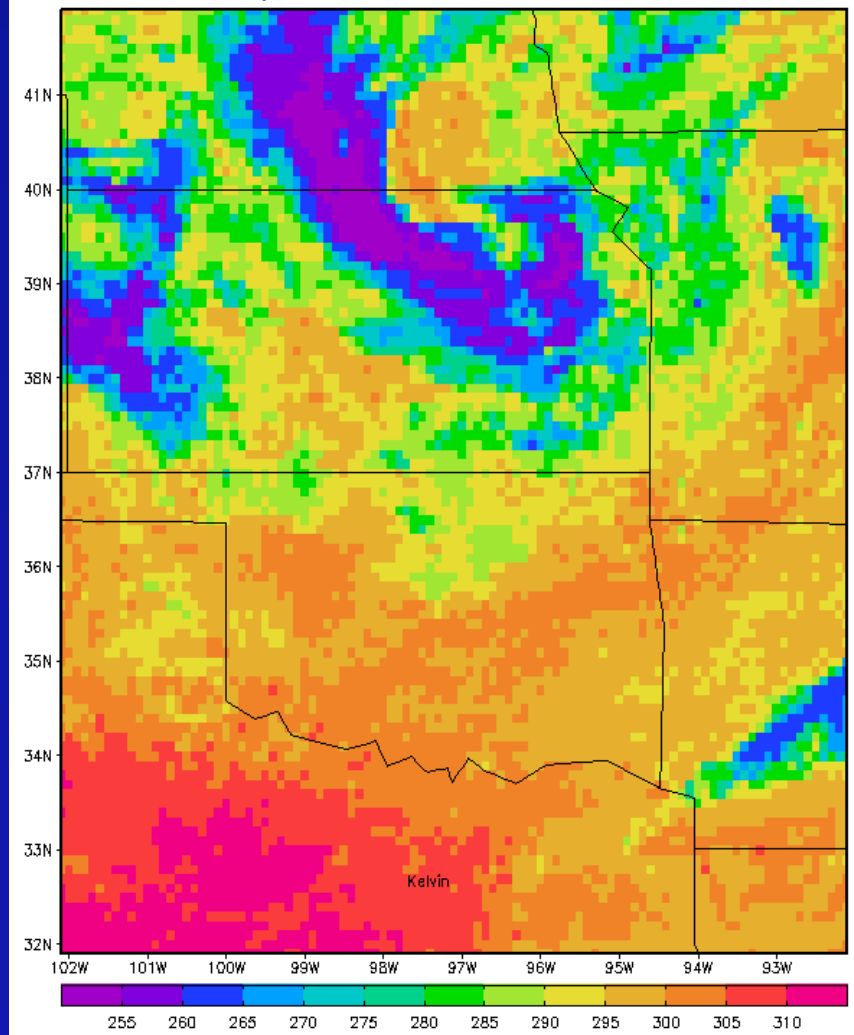


Synthetic (left) and observed (right) GOES-13 imagery at 3.9 of the liquid water cloud just off the Texas coast. Observations supports the CRTM generated brightness temperatures of the liquid water cloud layer. Black vertical line at x=650 (left) is the location of a vertical cross section to be shown very soon.

29Apr2014 18z MORR ch2

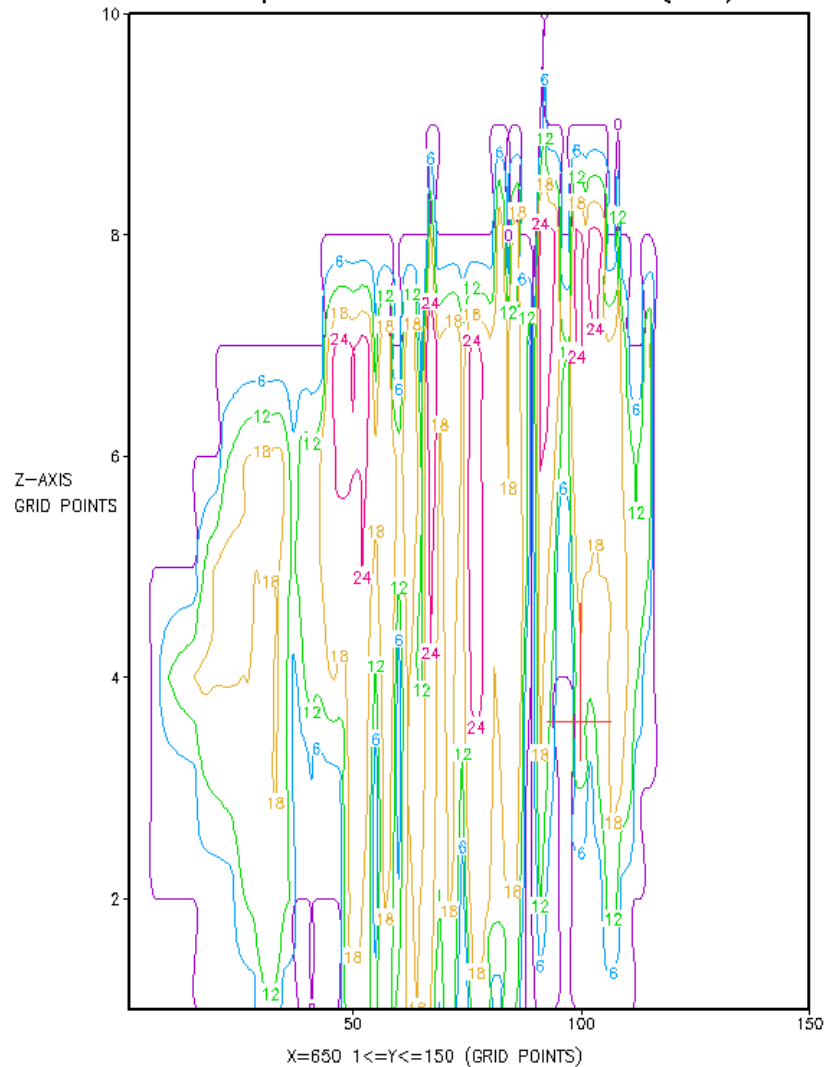


29Apr2014 18z GOES-13 ch2

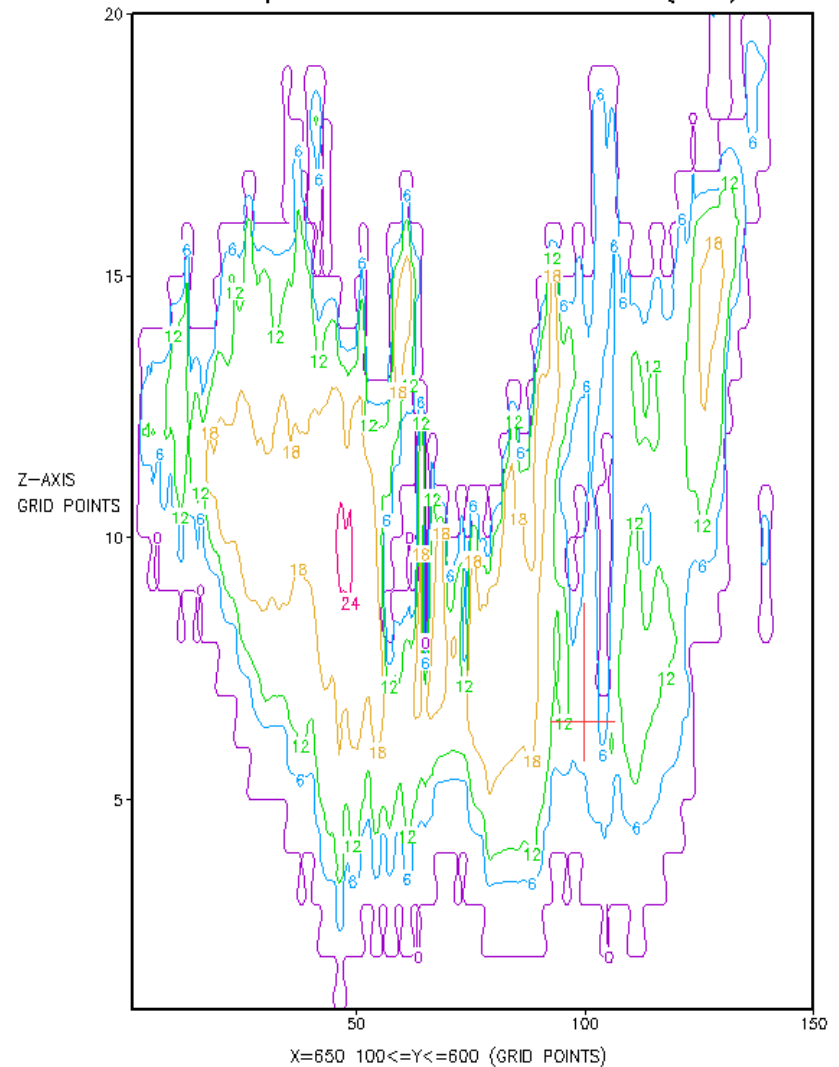


Synthetic (left) and observed (right) GOES-13 imagery at 3.9 of the liquid water cloud in the central plains. Observations does not support CRTM generated brightness temperatures of the liquid water cloud layer. Black vertical line at x=650 (left) is the location of a vertical cross section to be shown next.

29Apr2014 18z MORR DIAC(um)



29Apr2014 18z MORR DIAC(um)



Vertical cross section of simulated cloud droplet diameters (um) for cloud layer located off the Texas coast (left) and the central plains (right). Cloud diameters are smaller at cloud top in the central plains and may be the cause of larger brightness temperatures compared to observations.

Conclusions

- GOES-R will provide unprecedented spatial, spectral, and temporal resolution data
- Data assimilation is necessary to best incorporate some of this information into NWP models
- It's important that the microphysical output from the models is consistent with the fields expected in the CRTM
- Some microphysics schemes tend to make larger ice particles and spread the water mass among other microphysics hydrometeors, like snow
- It appears that the majority of schemes have ice particle sizes that are too large – this can lead to simulated brightness temps that differ from observations

Backup Slides

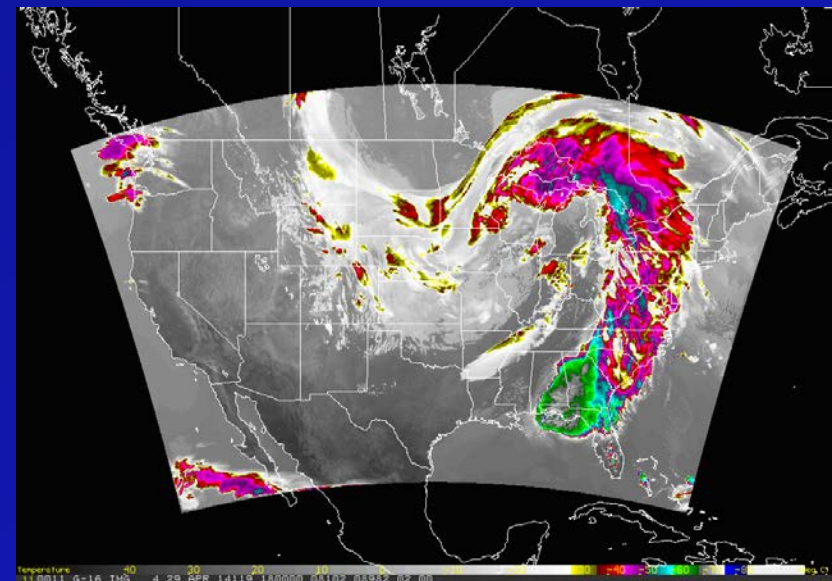
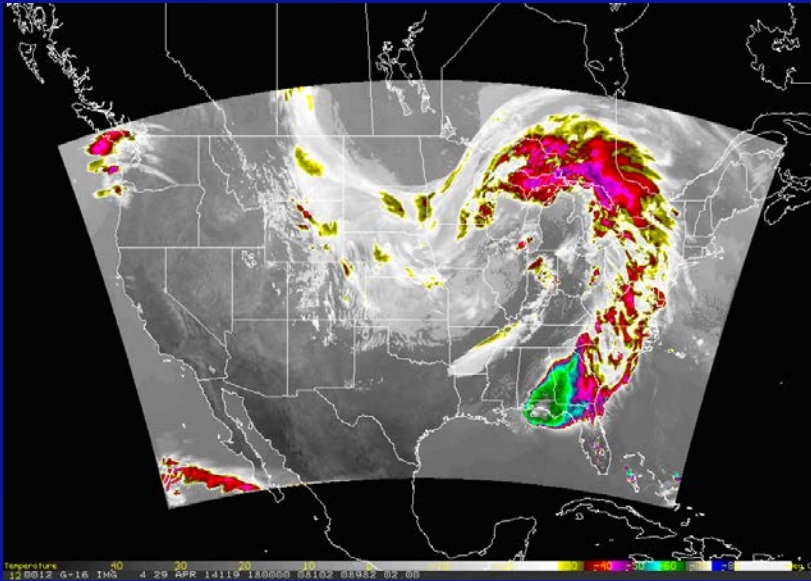
Comparisons between the CRTM (V2.1.3), the CIRA Observational Operator (CIRA-OO), and Observations

29 April 2014 – 18 Z – based on WRF forecast – Thompson microphysics

CIRA-OO

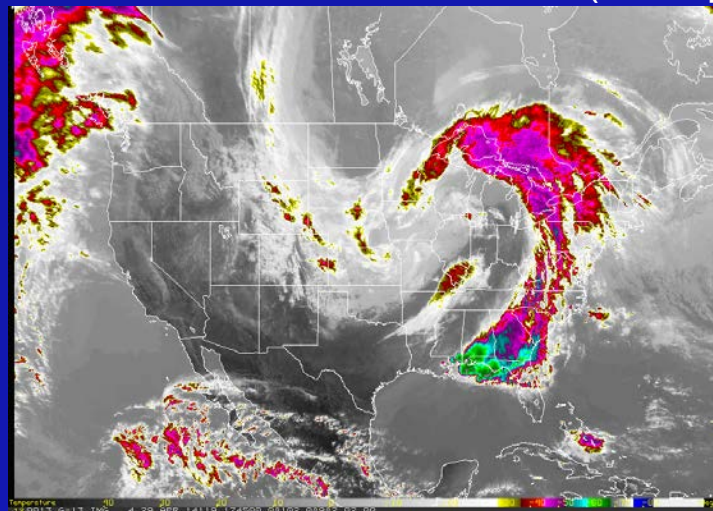
10.35 μm ABI band

CRTM

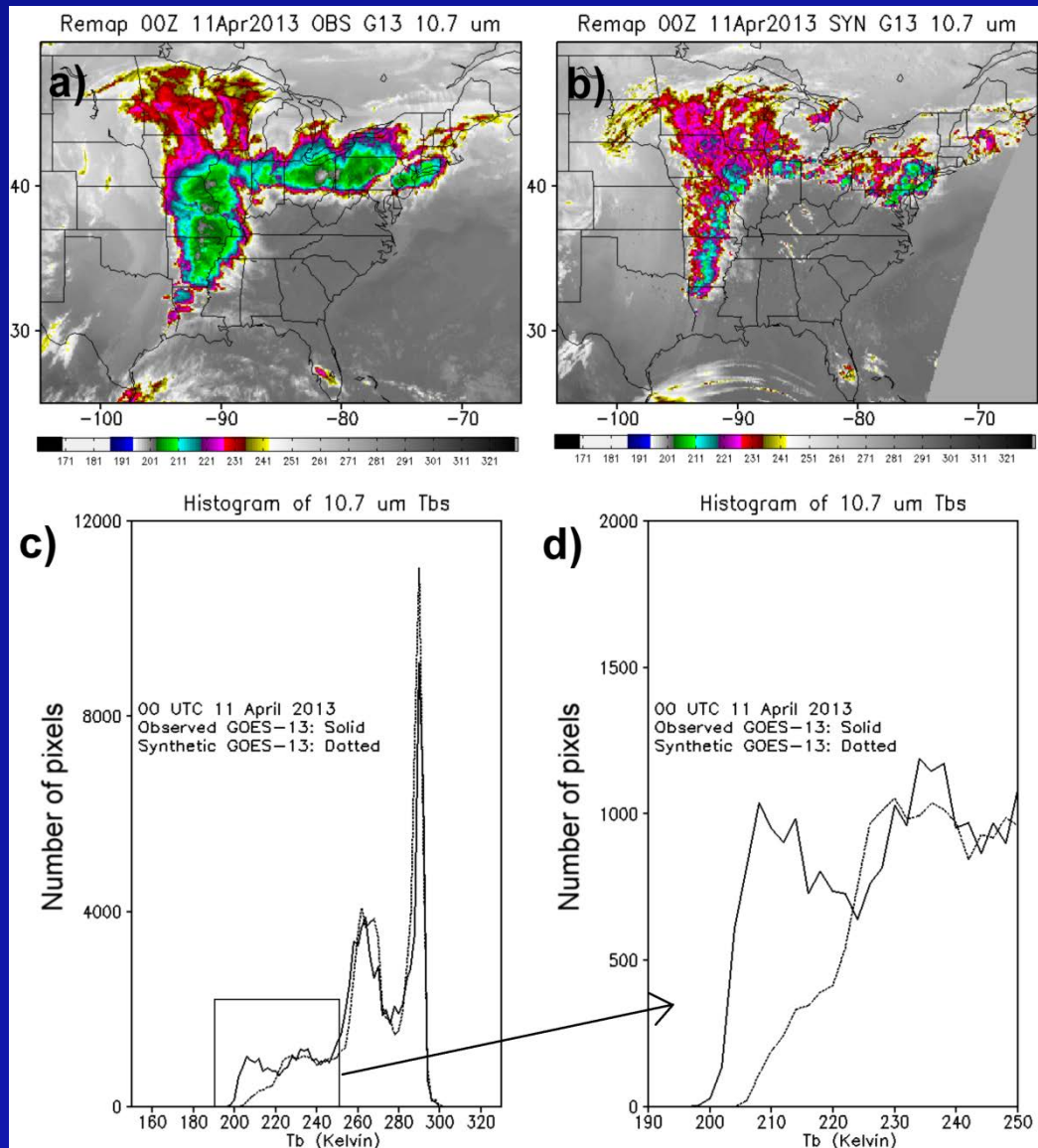


GOES-13 Observations (10.7 μm)

- CIRA-OO and CRTM produced very similar output, and both compare well with GOES observations



Background



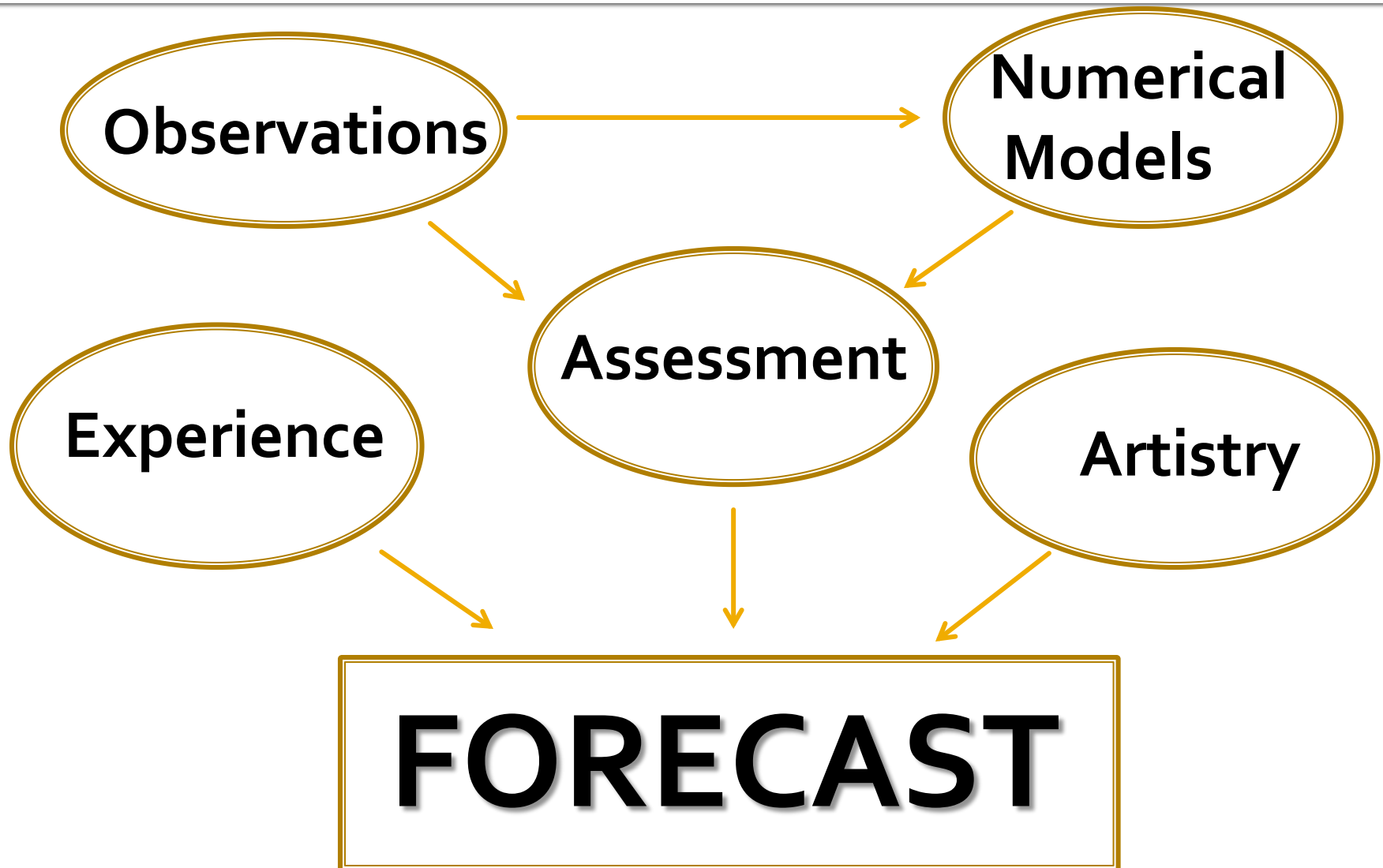
Data and Information Streams

A Rapidly Changing Environment in the Forecast Office

Nezette Rydell
National Weather Service Forecast Office
Boulder, CO



Forecast Production



INCOMING ...

- METARS
- AWOS
- Radar
 - Non-88D radars
- Upper air soundings
- ACARS
- Profilers
- Satellite
 - Images
 - Sounder and derived products
- Co-op mesonet
- Citizen weather
- Stream gauges
- Hydro networks
- CoCoRaHS
- WebCams
- Social Media
 - Tweets, FB, mPing
- Chat Rooms
- Bulletin Boards (WebEOC)
- Impact Catalog
- RWIS
- Automobiles
- Wind Farms
- Situational Awareness Screens
- State Radio/NAWAS
- Telephone
- Snotel
- RAWS
- School networks
- Ham radio reports
- ACARS
- Lightning
- Ship reports
 - Moving/stationary
- Buoys
- Dart buoys
- Tide gauges
- Numerical models – NCEP
- Numerical models – non-NCEP
- Numerical models – experimental
- Analogs

Integration

- Integrated displays
 - If it's geo-tagged and time stamped we can integrate it
- Local Analysis
 - On the fly and up to the minute analyses and short term forecasts
- Multi-perspective view
 - plane vs multi-level / 3-D
- Satellite Broadcast Network (SBN)
- MADIS - database/aggregator
- LDM/LDAD – individualized needs
- Integration crucial for automated processes
 - Non-integrated data is still used
 - **We can't afford to build systems that can't easily deliver data in standard format/pathway**

Numerical Models

- 12 + on any given day
 - Multiple runs per day
 - HRRR
- Ensembles
- Experimental
 - Usually Internet-based
 - Stuff down the hall
 - Stuff from your place!
- Analogs
- Extreme Event Awareness

Select Percent of Current Models

ADJECE 0	ADJECEBC 0	ADJECM 0	ADJECMBC 0	ADJECS 0	ADJECSBC 0	ADJLAV 0	ADJLAVBC 0	ADJMAV 0	ADJMAVBC 0	ADJMEN 0	ADJMENBC 0
ADJMET 0	ADJMETBC 0	ADJMEX 0	ADJMEXBC 0	AIIBlend 0	BCAIIBlend 0	CONSAII 0	BCCONSAII 0	CONSMOS 0	BCCONSMOS 0	CONSRaw 0	BCCONSRaw 0
CONSShort 0	BCCONSShort 0	DGEX 0	DGEXBC 0	ECMWF 0	ECMWFBC 0	GEMnh 0	GEMnhBC 0	GEMreg 0	GEMregBC 0	GFS 0	GFS40BC 0
HIRESarw 0	HIRESarwBC 0	HIRESnmm 0	HIRESnmmBC 0	HRRR 0	HRRRBC 0	MOSGuide 0	MOSGuideBC 0	NAM12 0	NAM12BC 0	NamDNG 0	NAMNest 0

RUC13 0	RUC13BC 0	ShortBlend 0	SREF 0	SREFBC 0	SuperBlend 0	WModel 0	WPCGuide 0	WPCGuideBC 0
Fcst 0	Official 0	Obs 0	LAPS 0	RTMA 0				

Select Percent of Previous Models

ADJECE 0	ADJECEBC 0	ADJECM 0	ADJECMBC 0	ADJECS 0	ADJECSBC 0	ADJLAV 0	ADJLAVBC 0	ADJMAV 0	ADJMAVBC 0	ADJMEN 0	ADJMENBC 0
ADJMET 0	ADJMETBC 0	ADJMEX 0	ADJMEXBC 0	AIIBlend 0	BCAIIBlend 0	CONSAII 0	BCCONSAII 0	CONSMOS 0	BCCONSMOS 0	CONSRaw 0	BCCONSRaw 0
CONSShort 0	BCCONSShort 0	DGEX 0	DGEXBC 0	ECMWF 0	ECMWFBC 0	GEMnh 0	GEMnhBC 0	GEMreg 0	GEMregBC 0	GFS 0	GFS40BC 0
HIRESarw 0	HIRESarwBC 0	HIRESnmm 0	HIRESnmmBC 0	HRRR 0	HRRRBC 0	MOSGuide 0	MOSGuideBC 0	NAM12 0	NAM12BC 0	NamDNG 0	NAMNest 0

RUC13 0	RUC13BC 0	ShortBlend 0	SREF 0	SREFBC 0	SuperBlend 0	WModel 0	WPCGuide 0	WPCGuideBC 0
Fcst 0	Official 0	Obs 0	LAPS 0	RTMA 0				

Obs/LAPS/RTMA offset (days-hours)
 1-24 2-48 3-72 4-96 5-120
 6-144 7-168 8-192 9-216
 10-240

Curr Obs
hours offset
0

Prev Obs
hours offset
0

Curr LAPS
hours offset
0

Prev LAPS
hours offset
0

Curr RTMA
hours offset
0

Prev RTMA
hours offset
0

Use weighted
average?

Yes
 No

Go
 Stop

A Paradigm Shift

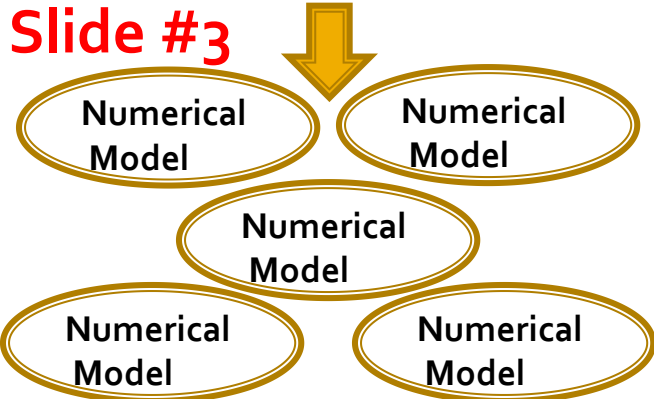
- Len Snellman – Mother Nature always integrates the equations correctly.
 - Over reliance on the model is akin to meteorological cancer. (1977)
 - This reliance can lead to the 20% human input shrinking to near zero in the 1990s. (1991)
- Data streams outstripped human capability for analysis in the middle 90s.
- **There's more to the forecast than a deterministic grid can represent.**

Blended Approach

- National Blend of Models – National First Guess
- Consistent starting point for forecast – A Blend
 - Static or dynamic based on performance?
- Coordinated and collaborated changes
- Set(s) of algorithms to create derived parameters
- Set(s) of algorithms to incorporate local expertise

Operational Forecasting 2016

Slide #3



Slide #3



Slide #3



Slide #3



Changes in the Data Environment

- Congressional mandate to NOAA – data collection with a private sector partner (satellite) by October 2016
- We already buy some data
 - TAMDAR (aircraft obs - Panasonic)
 - Lightning – Vaisala , EarthNetworks
 - ECMWF
- Implications for weather data sharing – WMO
- Private Sector NWP - Panasonic
- Spectra management/sales
 - Upper Air, DCPs, Hydronets,
 - GOES-R

Questions ?

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Meteorology Career Skill Sets

- Meteorology
 - GS-1340 Requirements
- Communications
 - Written, Verbal, Graphics
- Technology
 - Basic computer skills
 - Basic understanding/appreciation of networks and systems
 - Social media/evolving communication technologies