WSR88D radar data and NLDN lightning data assimilation at NCEP

Shun Liu[1,2],

Jacob Carley[1], Wan-Shu Wu[2], Eric Rogers[2], Jing He[2,3], Brad Ferrier[2], David Parrish[2], Matthew Pyle[2], Geoff DiMego[2], John Derber[2] and Xudong Liang[3]

[1]I. M. System Group, Rockville, Maryland
[2]NOAA/National Centers of Environmental Prediction, College Park, Maryland
[3] Institute of Urban Meteorology, CMA, Beijing, China
Shun.Liu@noaa.gov

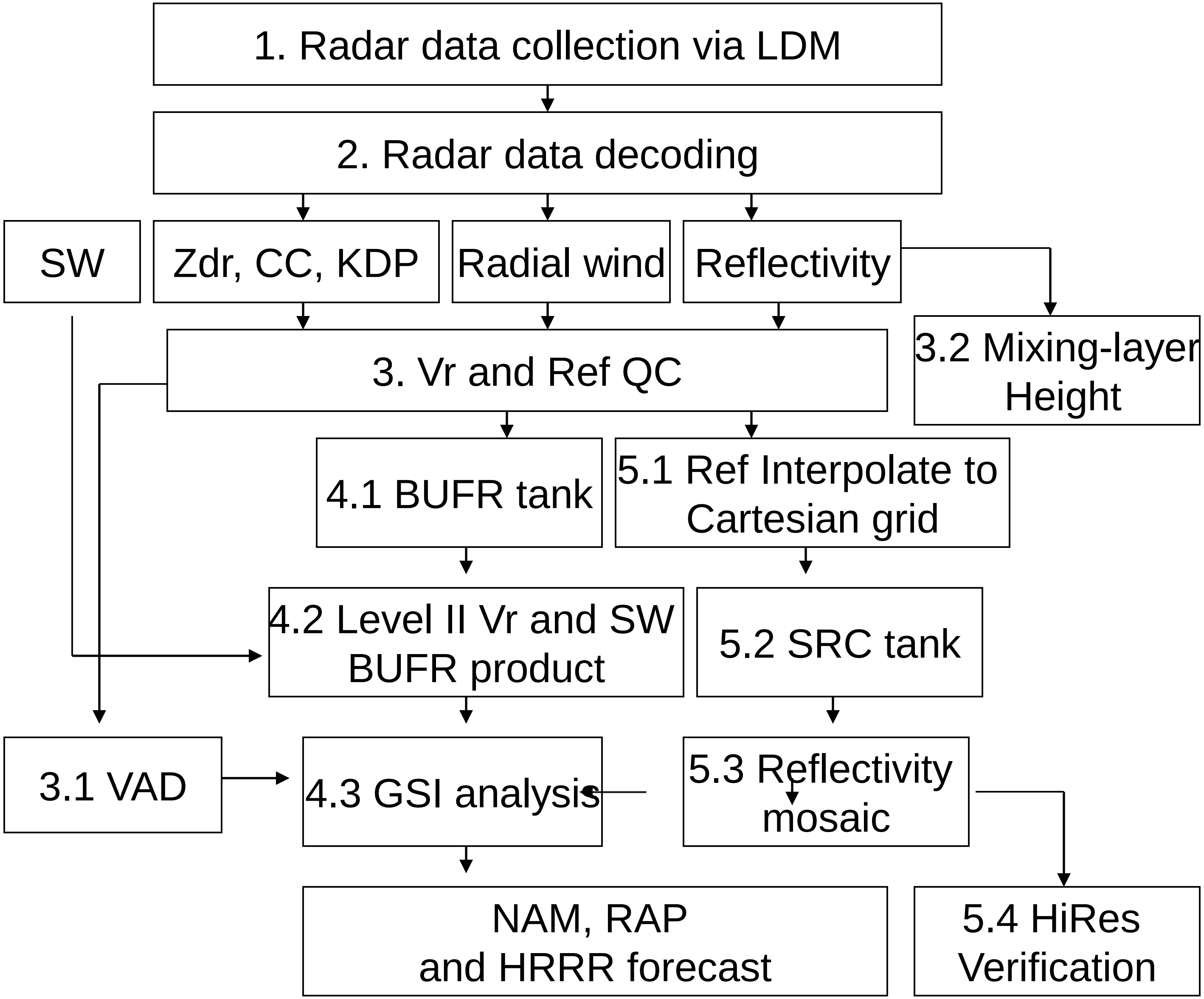
OVERVIEW

- **WSR88D radar data and Lightning data available at NCEP in operation**
- **Clear indication of convective storm**
- **Potentially improve storm scale NWP forecast with lightning observation**
- **Develop an algorithm can be used in operation**
- **Implementation of WSR-88D radar and lightning data assimilation in operational NAM (Aug, 2014) and the coming NAMv4**
- **Also see:**
  - ✓ **Rogers et al., Session 3B.4 (Mon 1/23) on NAMv4 upgrade and future scenario**
  - ✓ **Carley et al., Poster Session 3, #1204 (Wed 1/25) on NAM nest improvements**
  - ✓ **Aligo et al., Session 4B.4 (Tues 1/24) on microphysics changes**
  - ✓ **Ferrier et al., Poster Session 3, #1205 (Wed 1/25) on NMMB model changes**
  - ✓ **Lippi et al., Session TJ11.3, (Tu 1/25) on assimilation of radial wind with vertical velocity**

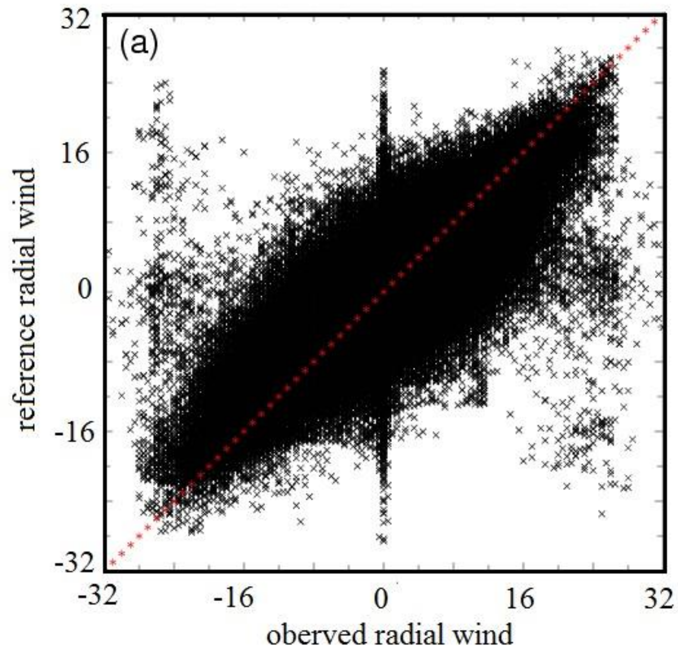
OUTLINE

- Radar data processing at NCEP
- Lightning data at NCEP
- Radar and lightning data assimilation using GSI
- Impact of DA on analysis and forecast in operation

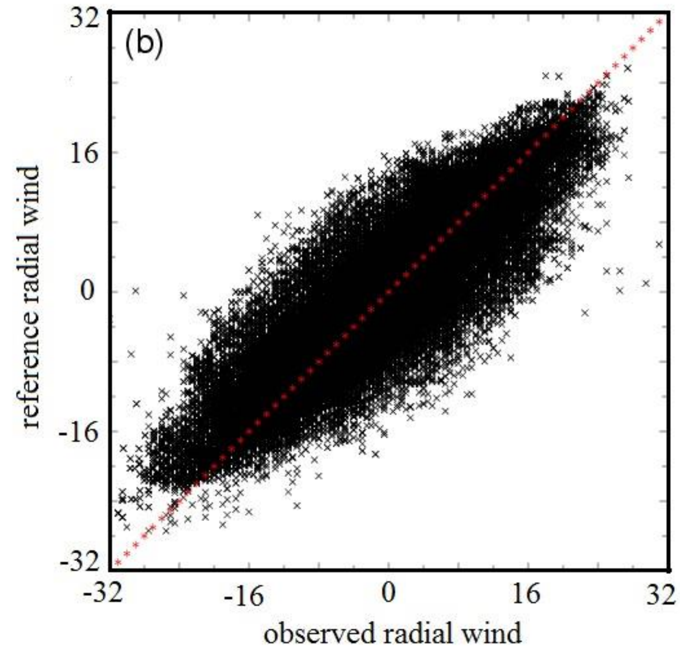
Radar data processing at NCEP



Performance of Radial Wind QC



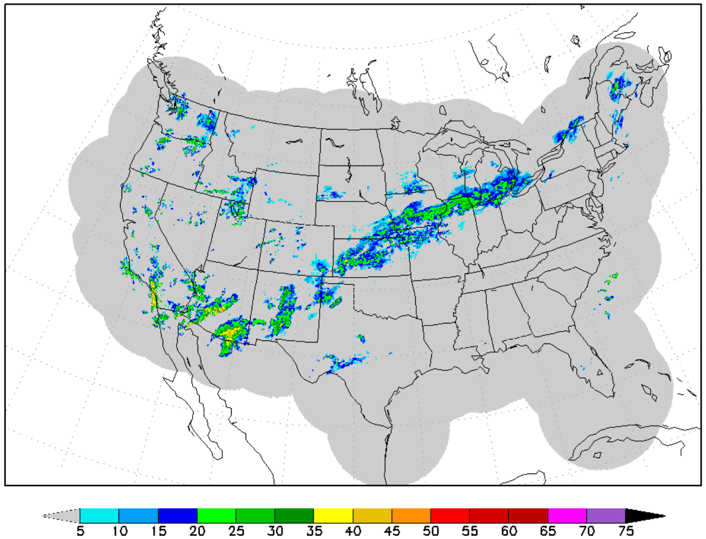
before QC



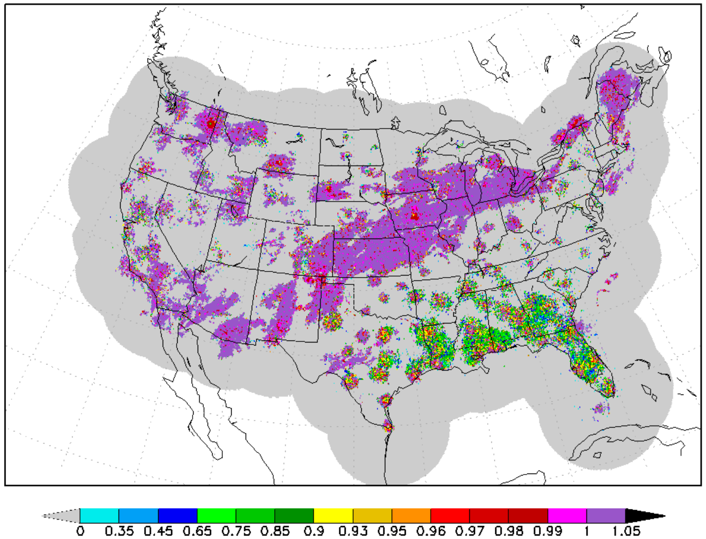
after QC

Radar Mosaic vs Satellite Product

COMPOSITE REF t01z 2014030201



COMPOSITE CC t01z 2014030201



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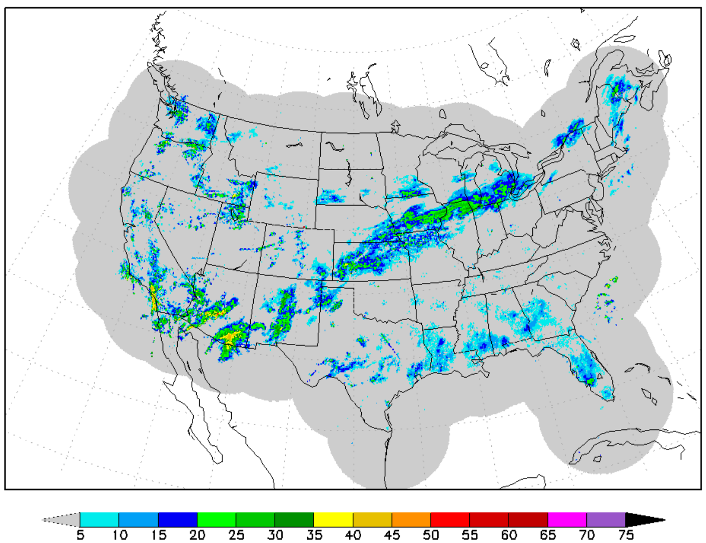
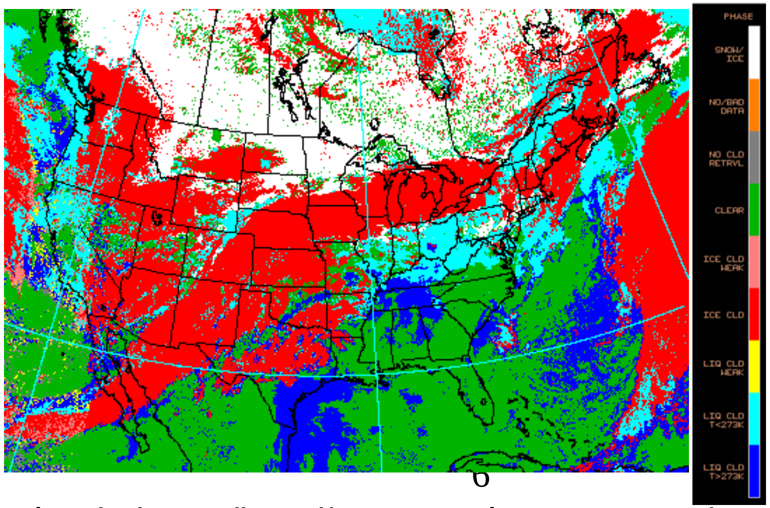
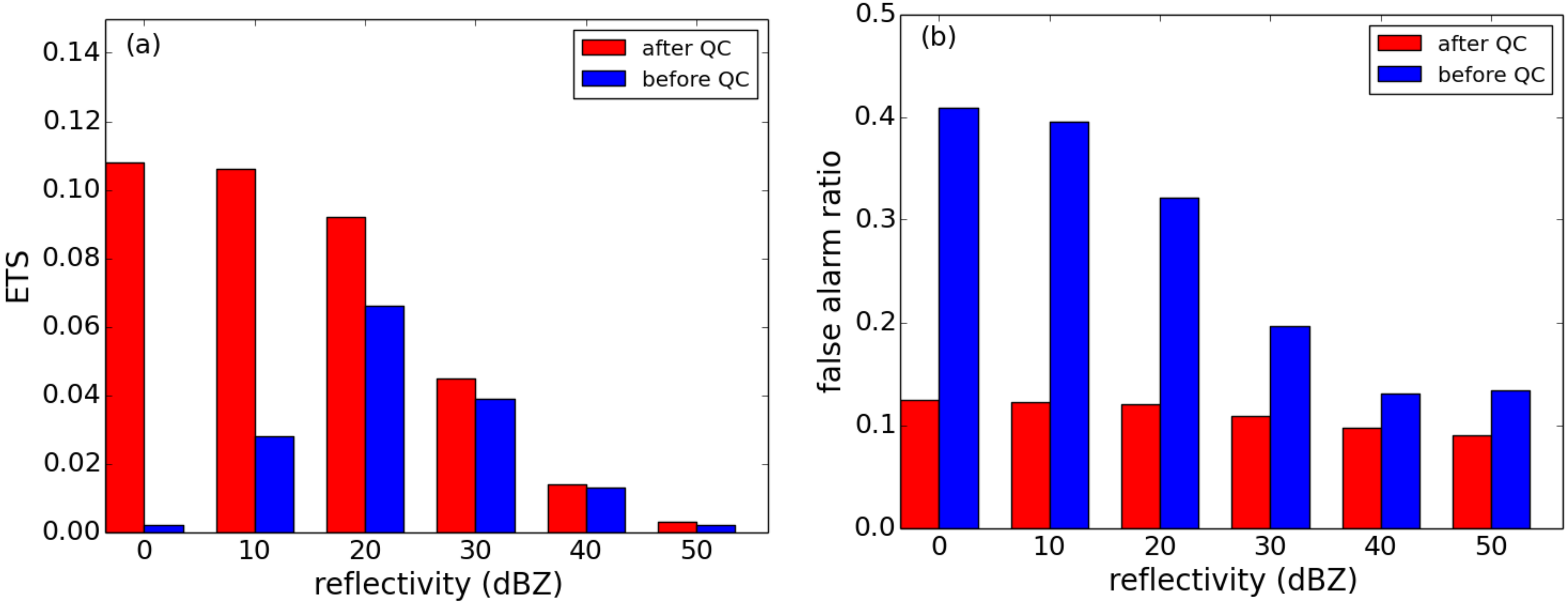




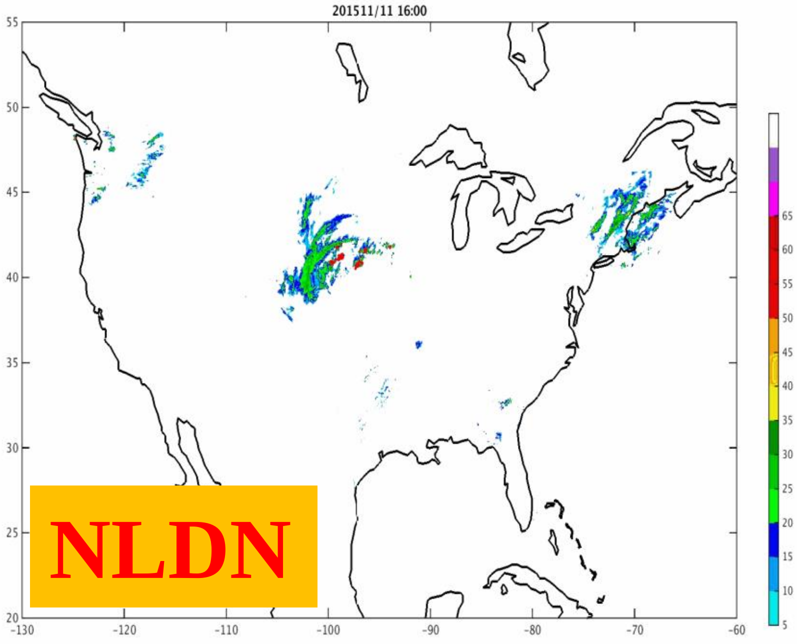
Cloud phase (http://www-pm.larc.nasa.gov)

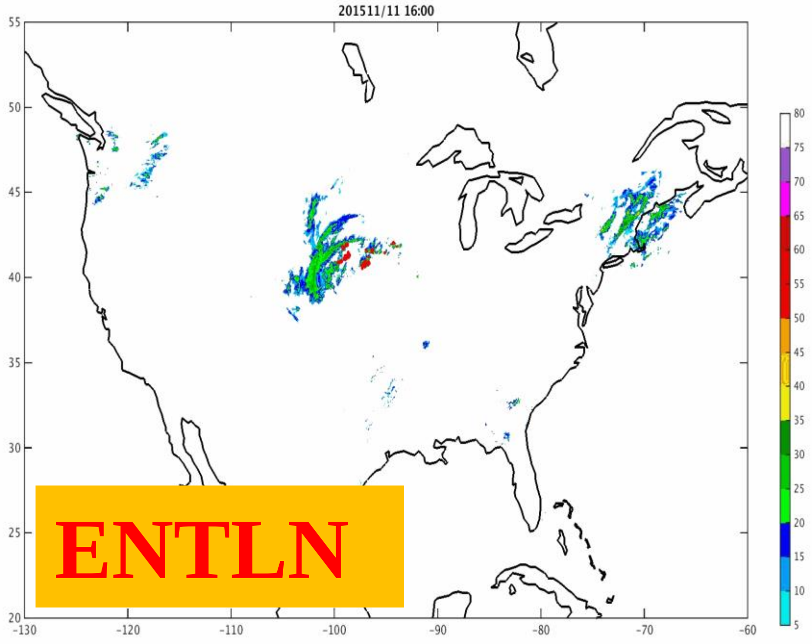
Performance of Reflectivity QC



Equitable Threat Score and False Alarm Ratio of composite reflectivity coverage against cloud coverage

Lightning data at NCEP





- **NLDN: National Lightning Detection Network**
- **ENTLN: Earth Networks Total Lightning Network**

Lightning data at NCEP

NLDN Lightning Variables and Description

004001	YEAR	2015.0	YEAR	YEAR
004002	MNTH	6.0	MONTH	MONTH
004003	DAYS	16.0	DAY	DAY
004004	HOUR	22.0	HOUR	HOUR
004005	MINU	30.0	MINUTES	MINUTES
004006	SECO	5.411	SECONDS	SECONDS
005001	CLATH	37.02378	DEGREES	LATITUDE (HIGH ACCURACY)
006001	CLONH	-89.16837	DEGREES	LONGITUDE (HIGH ACCURACY)
020117	AMPLS	6000.0	AMPS	AMPLITUDE OF LIGHTNING STRIKE
020119	PLRTS	2.0	CODE TABLE	POLARITY OF STROKE
020023	OWEP	8192.0	FLAG TABLE(5)	OTHER WEATHER PHENOMENA
013059	NOFL	1.0	NUMERIC	NUMBER OF FLASHES (THUNDERSTORM)
035200	RSRD	16.0	FLAG TABLE(5)	RESTRICTIONS ON REDISTRIBUTION
035201	EXPRSRD	MISSING	HOURS	EXPIRATION OF RESTRICTIONS ON REDISTRIBUTION

The time of the lightning strike

The location of the lightning flash

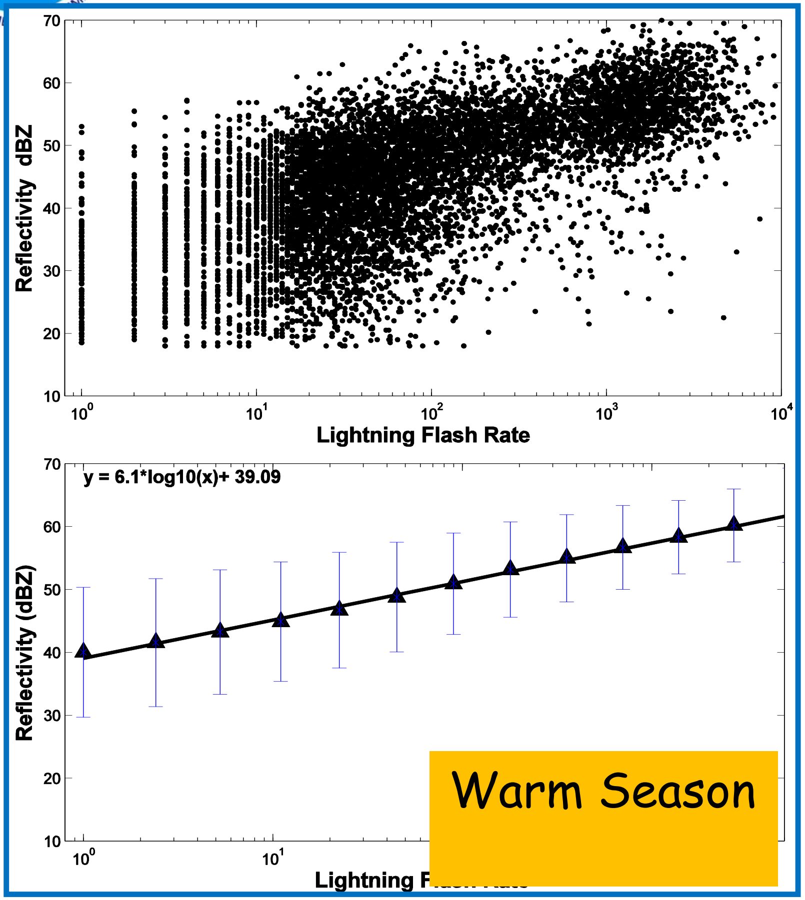
1.0 :positive lightning
2.0 :negative lightning

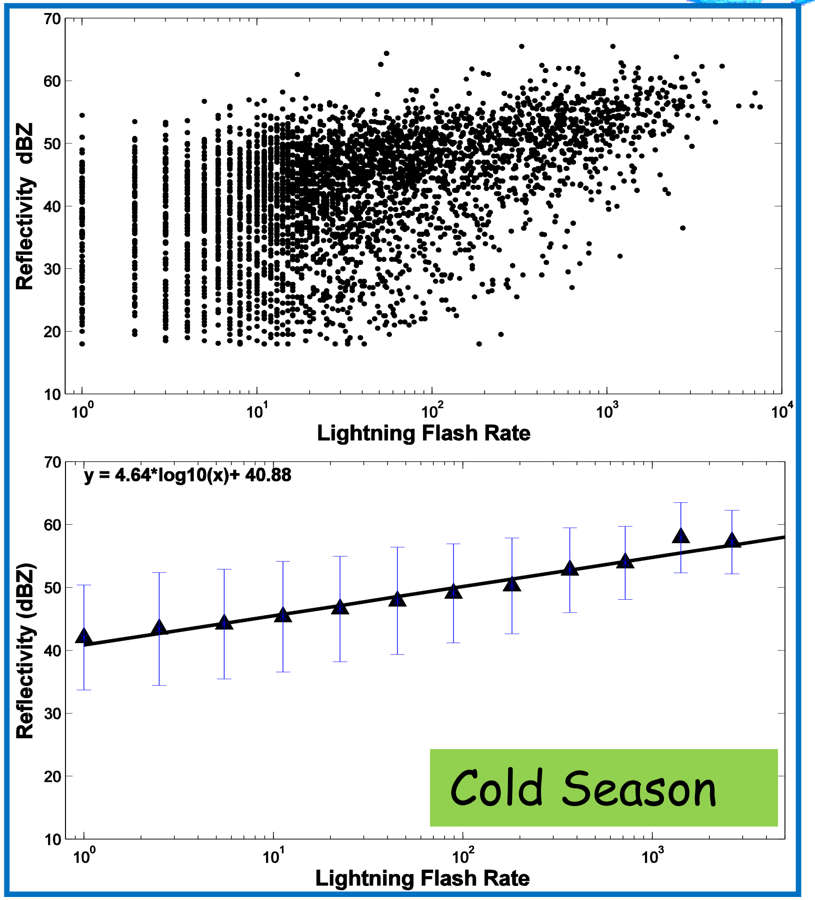
4086:Cloud-Cloud Lightning
8192:Cloud-Ground Lightning

The strength of the Lightning

The number of the Lightning flash strike of each flash

Comparison and Relationship

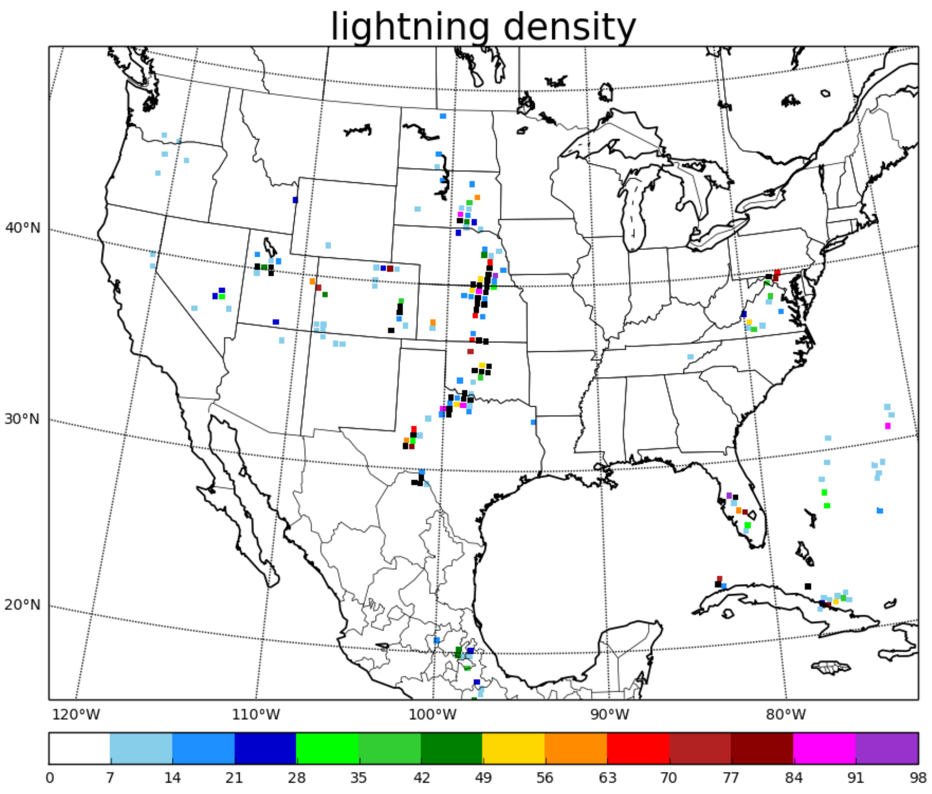


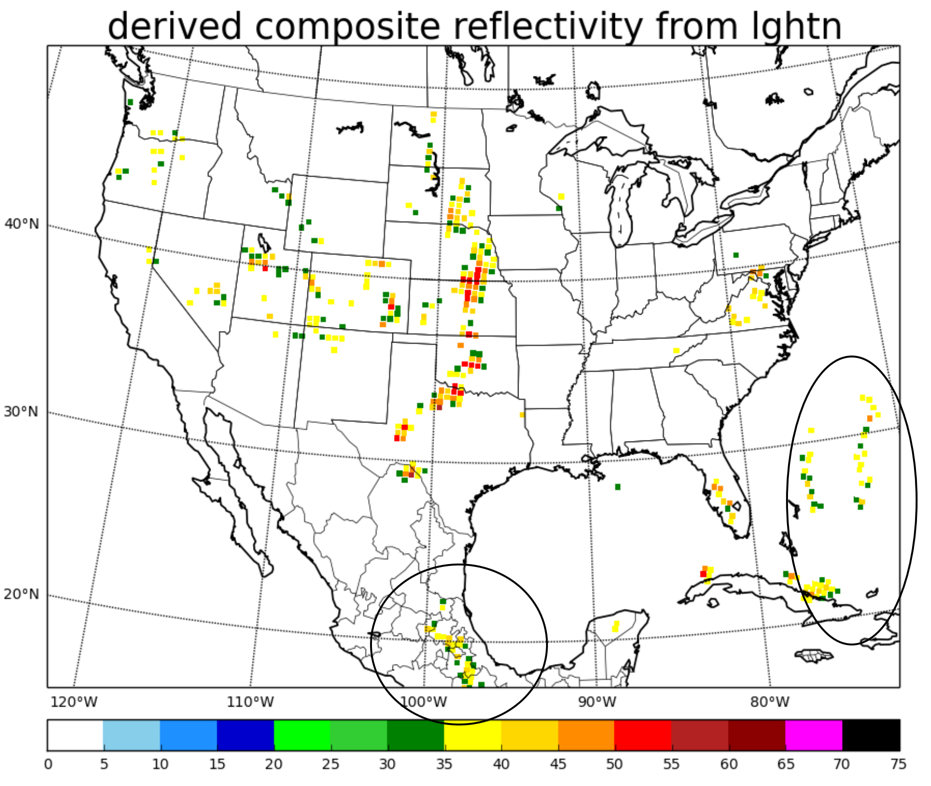


The scatter plots (top) shows the radar reflectivity increases with the increasing of lightning flash rate in both warm and cold season

The radar reflectivity is in logarithmic relationship with lightning flash rate (bottom) with the correlation coefficient exceeding 0.97

Proxy Composite reflectivity from Lighting observations





Lightning density

Proxy composite reflectivity

Assimilation of radar radial wind and VAD wind with GSI

- The radial wind and VAD wind are directly analyzed by GSI.
- Hybrid vairational-Ensemble GSI are used (Wu, et. al (2002), Wang et. al (2007), Daryl et. al (2013)).

$$J\left(x_f',\boldsymbol{\alpha}\right)=\beta_f\frac{1}{2}\left(x_f'\right)^T B_f^{-1}\left(x_f'\right)+\beta_e\frac{1}{2}\sum_{n=1}^{N}\left(\boldsymbol{\alpha}^n\right)^T L^{-1}\left(\boldsymbol{\alpha}^n\right)+\frac{1}{2}\left(Hx_t'-y'\right)^T R^{-1}\left(Hx_t'-y'\right)$$

$$x_t' = x_f' + \sum_{n=1}^{N}\left(\boldsymbol{\alpha}^n \circ x_e{}^n\right)$$

β_f & β_e: weighting coefficients for fixed and ensemble covariance respectively

$\mathbf{x}_t$': (total increment) sum of increment from fixed/static **B** ($\mathbf{x}_f$') and ensemble **B**

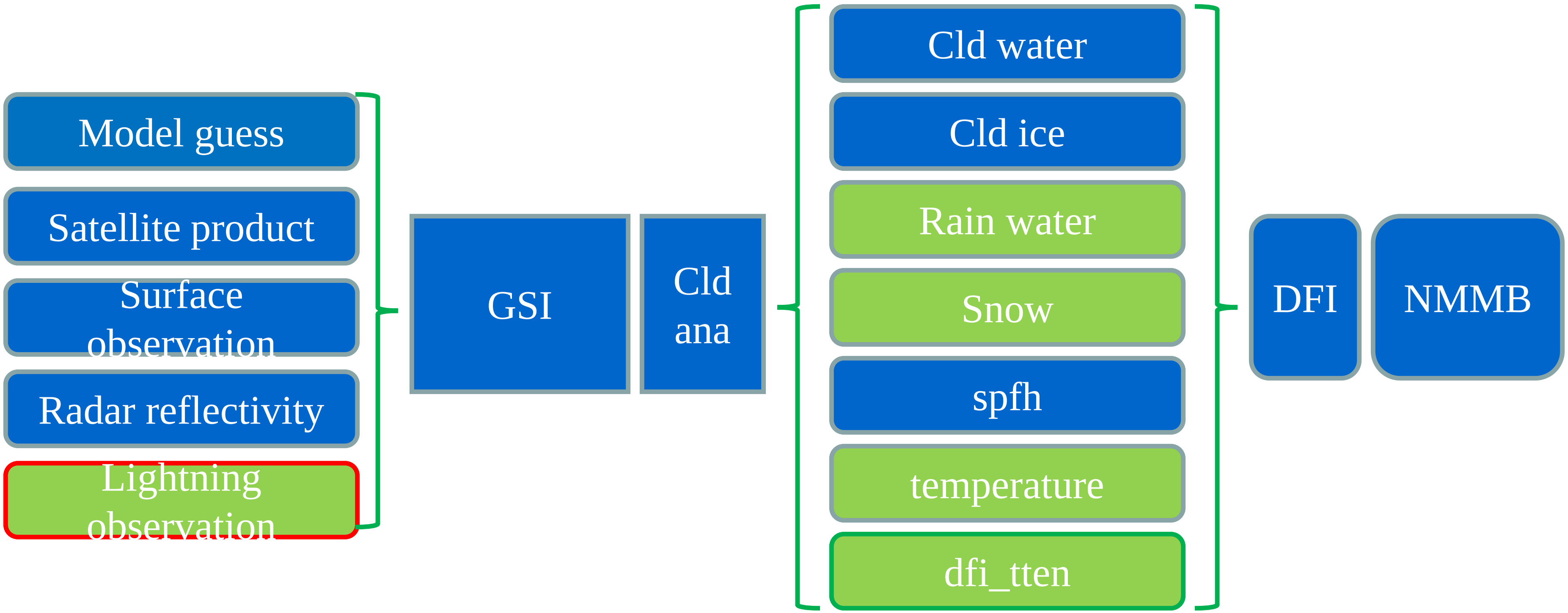
α: extended control variable; x_e:ensemble perturbations

L: correlation matrix [effectively the localization of ensemble perturbations]

Assimilation of radar reflectivity and lightning data with cloud analysis

- Cloud analysis originally developed by GSD
- Cloud analysis is used in RAP, HRRR, operational NAM and the coming NAMv4
- Cloud analysis use various of observations to update guess hydrometeors and temperature
- Satellite product, METAR data and radar reflectivity and lighting are used in cloud analysis
- Use cloud analysis for NMMB

Cloud analysis in NAMv3 and NAMv4

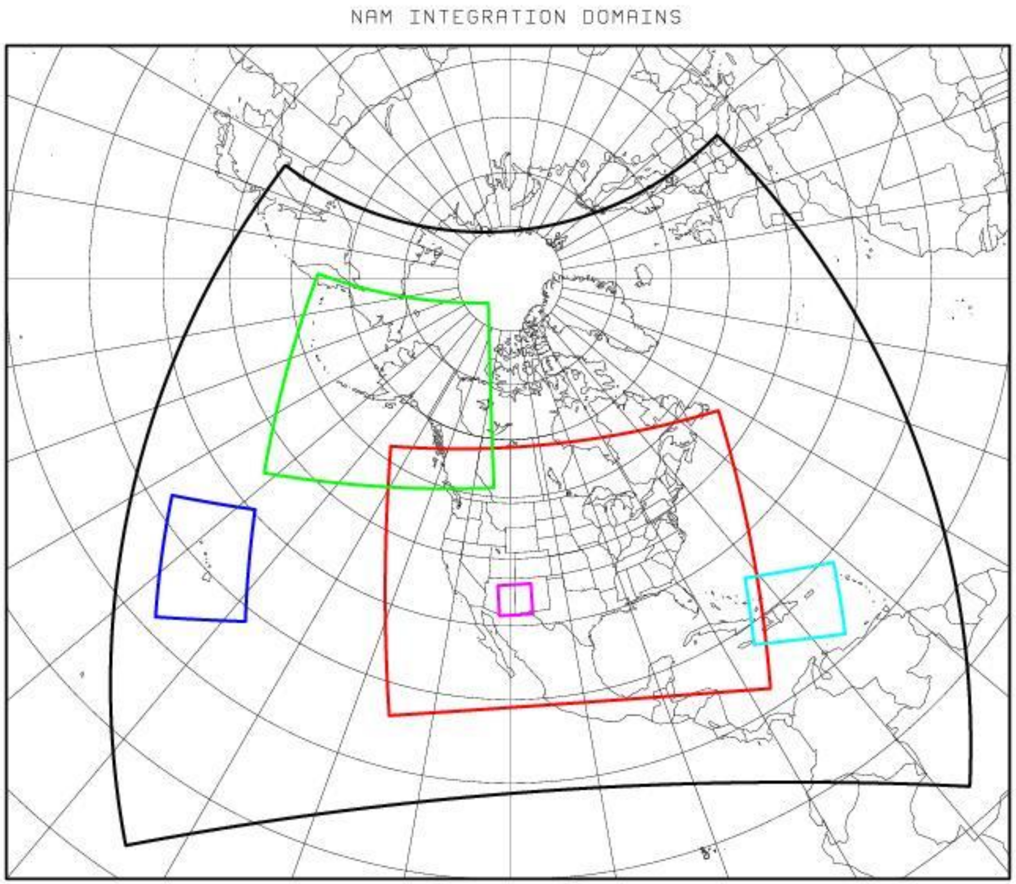


Forecast Initialization

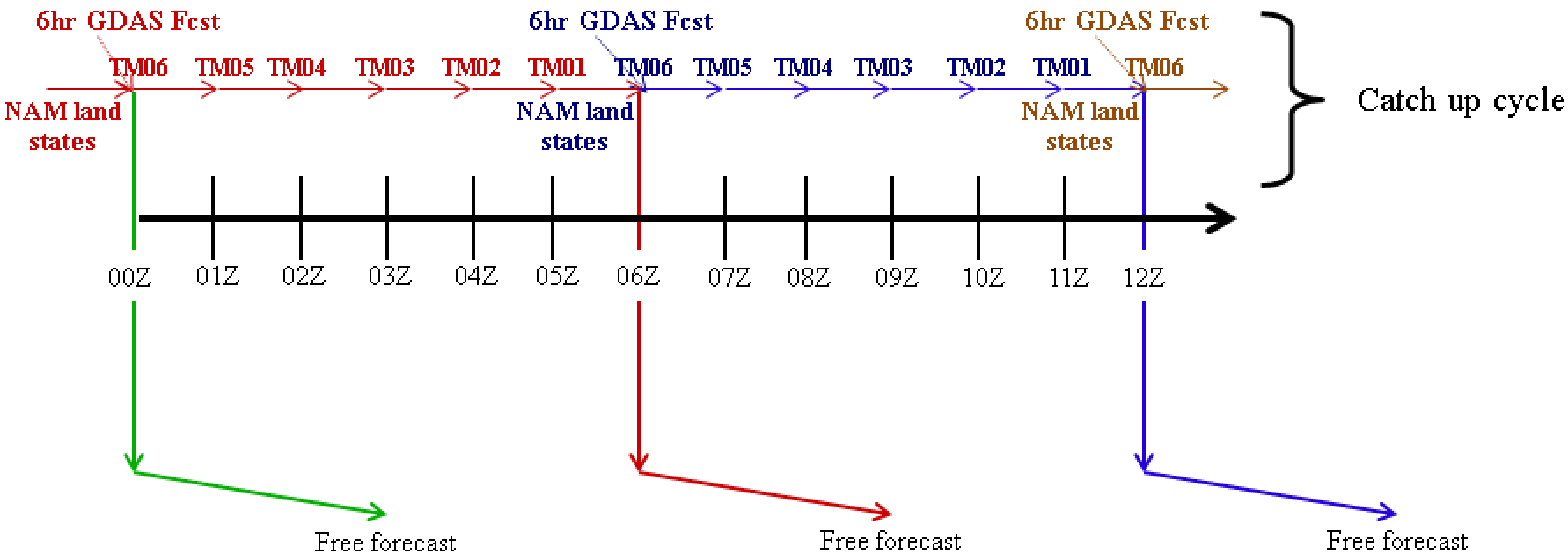
NAM: North American Model
NDAS: NAM Data Assimilation

- 12 km resolution for parent domain

- 3 km resolution for CONUS nest



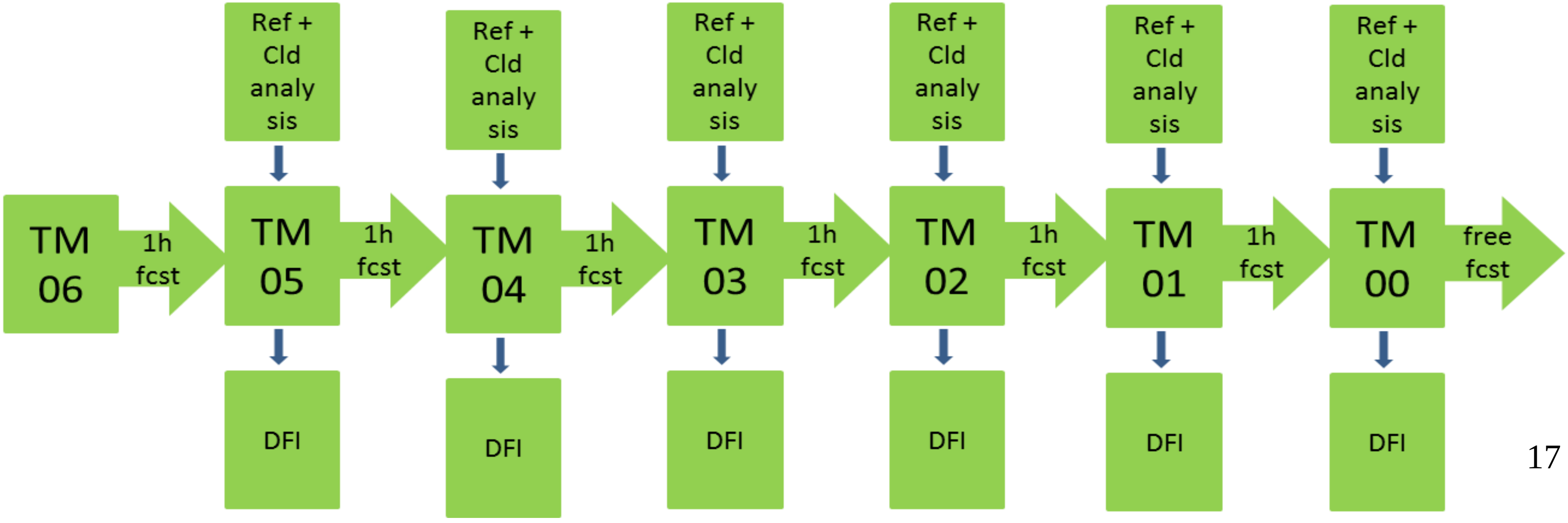
NAMv4

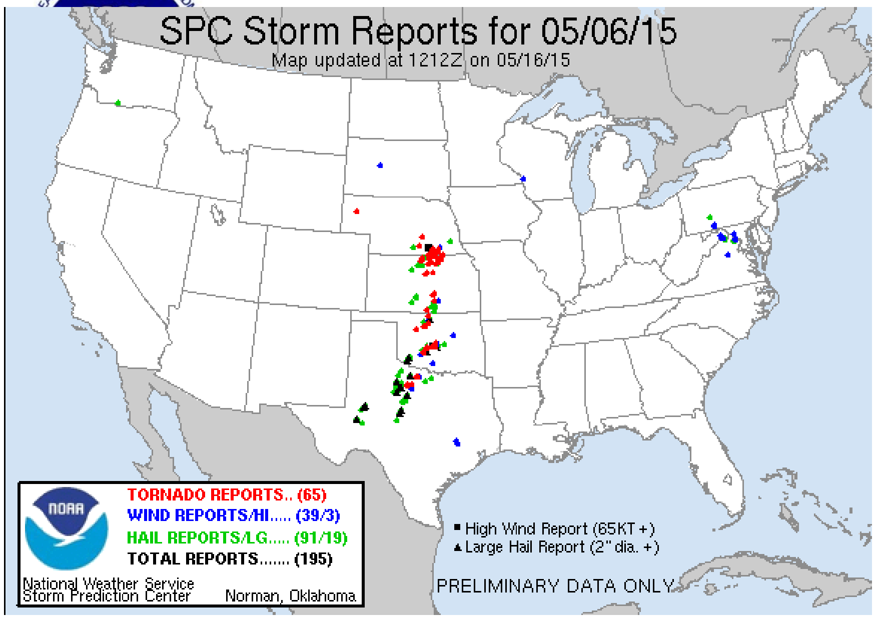


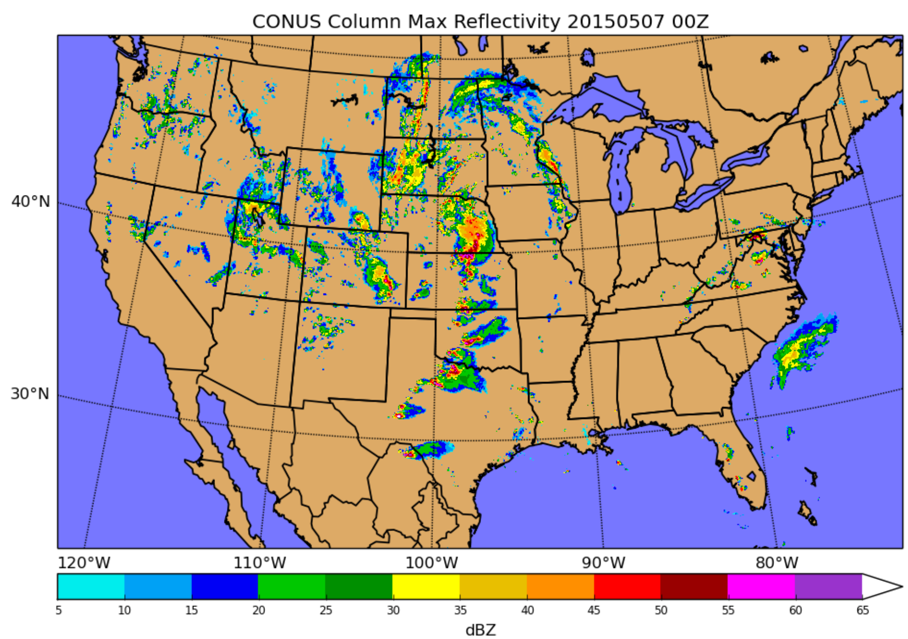
- TMXX= Cycle time minus XX hours.
- Colors denote a continuous thread of cycling which begins by using the land states from the previous catchup cycle and a 6 hour forecast from the GDAS as the first guess for the atmospheric state at TM06.

Assimilation radar and lightning in NAMv4

- Hybrid varational-Ensemble GSI are used (Wu, et. al (2002), Wang et. al (2007), Kleist et. al (2013)).
- The radial wind is directly analyzed by GSI.
- GSD cloud analysis + DFI is used to assimilate radar reflectivity
- METAR and Satellite products are used in cloud analysis to detect cloud.
- Latent heat rate estimated from reflectivity.
- Wind, cloud water and cloud ice mixing ratio and specific humidity are upgraded.
- Free forecast from 00Z, 06Z, 12Z and 18Z
- Assimilation in parent domain and CONUS nest

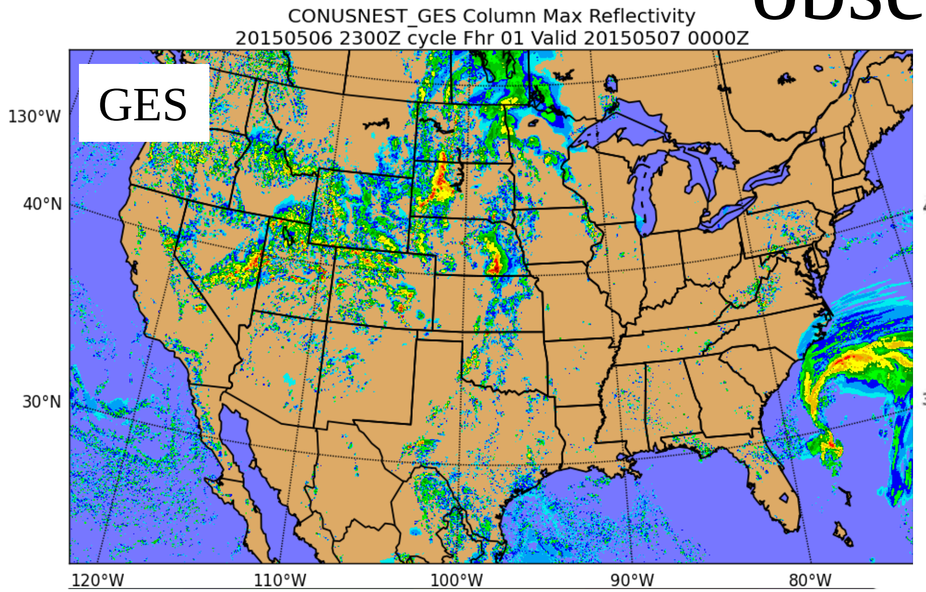


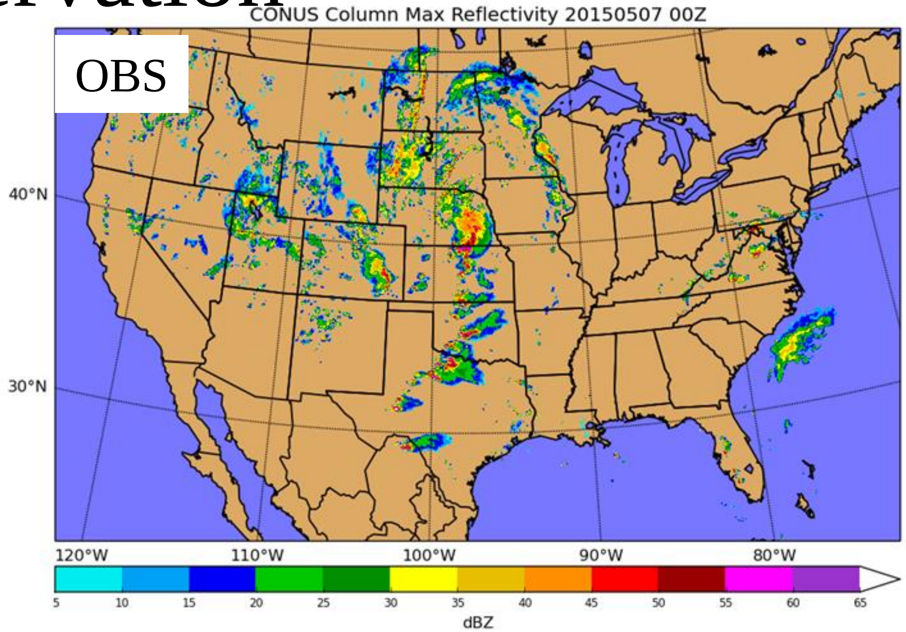


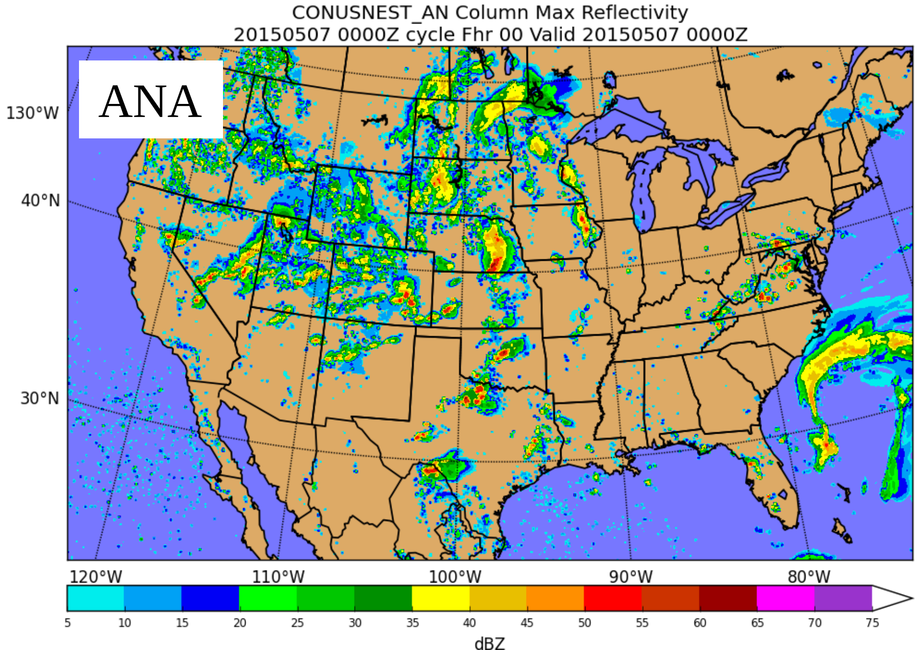


0020 2 SE MUNDEN
REPUBLIC KS 3989 9751 CONE
SHAPED TORNADO REPORTED BY STORM CHASER.
CONFIRMED 2 SOUTHEAST OF MUNDEN. (TOP)
0030 3 NE JAMESTOWN CLOUD
KS 3963 9782 TORNADO ON THE
GROUND WAS MOVING NORTHEAST. NO MORE SPECIFIC
INFORMATION ON VISUAL SHAPE OR DAMAGE. (TOP)
0035 7 SW ANTHONY HARPER
KS 3709 9812 BRIEF TORNADO
OBSERVED BY OFF-DUTY NWS EMPLOYEE (ICT)
0049 4 SE TUTTLE GRADY
OK 3525 9776 ROOF DAMAGE WAS
OBSERVED AT ONE HOME AND TREES WERE DAMAGED.
(OUN)
0056 4 NNE REYNOLDS
JEFFERSON NE 4012 9731 (OAX)
0110 4 SE DAYKIN
JEFFERSON NE 4028 9724 (OAX)
0111 4 ENE TUTTLE GRADY
OK 3531 9775 A STORM CHASER
OBSERVED A TORNADO DEVELOP APPROXIMATELY 4 MILES
EAST-NORTHEAST OF TUTTLE. THE TORNADO MOVED
SOUTHEAST AND PRODUCED DAMAGE NORTH OF BRIDGE
CREEK ... PERHA (OUN)
0120 5 W ALLIANCE BOX
BUTTE NE 4210 10297 BRIEF
TOUCHDOWN REPORTED JUST WEST OF ALLIANCE. (CYS)
0138 4 S MINNEAPOLIS OTTAWA
KS 3906 9771 TORNADO WAS
CONFIRMED ON THE GROUND. (TOP)
0141 3 SSE OKLAHOMA CITY
OKLAHOMA
OK 3543 9749 *** 12 INJ ***
UPDATED. EF3 TORNADO. TORNADO DEVELOPED NEAR
VALLEY BROOK AT 841 PM AT SOUTHEAST 59TH STREET AND

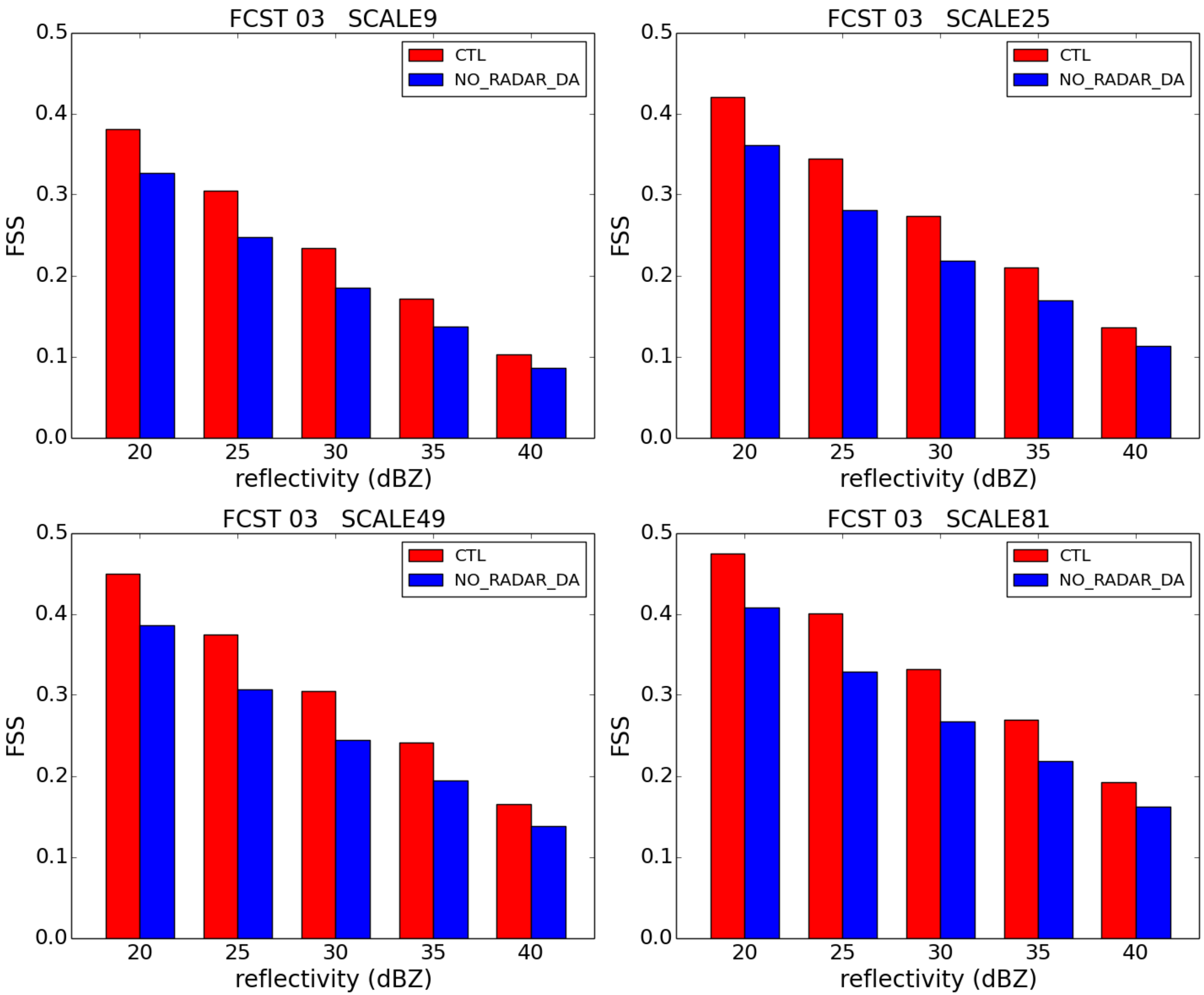
Model guess, analysis and reflectivity observation





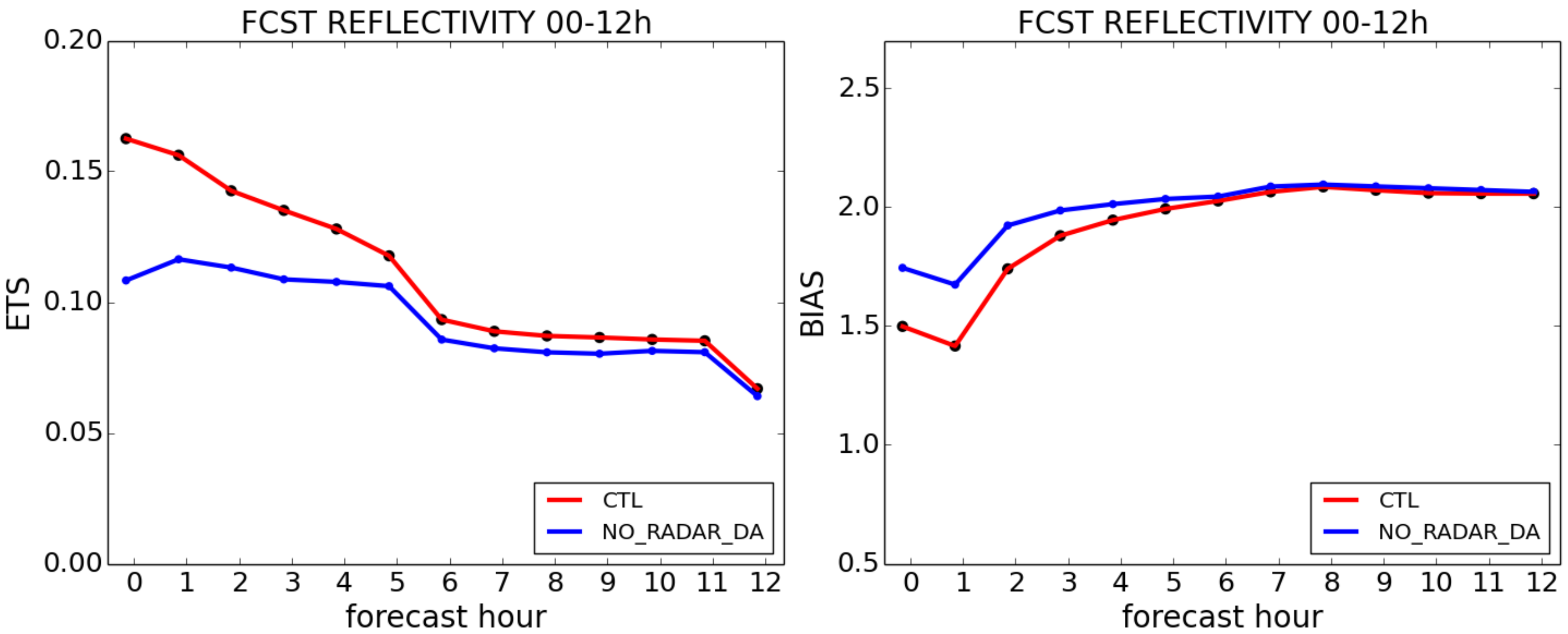


3 km CONUS nest FCST Reflectivity Verification



2015050600 - 2015051200

3 km CONUS nest FCST Reflectivity Verification



2015050600 - 2015051200 REF > 25 dBZ

CTL: NAMv4

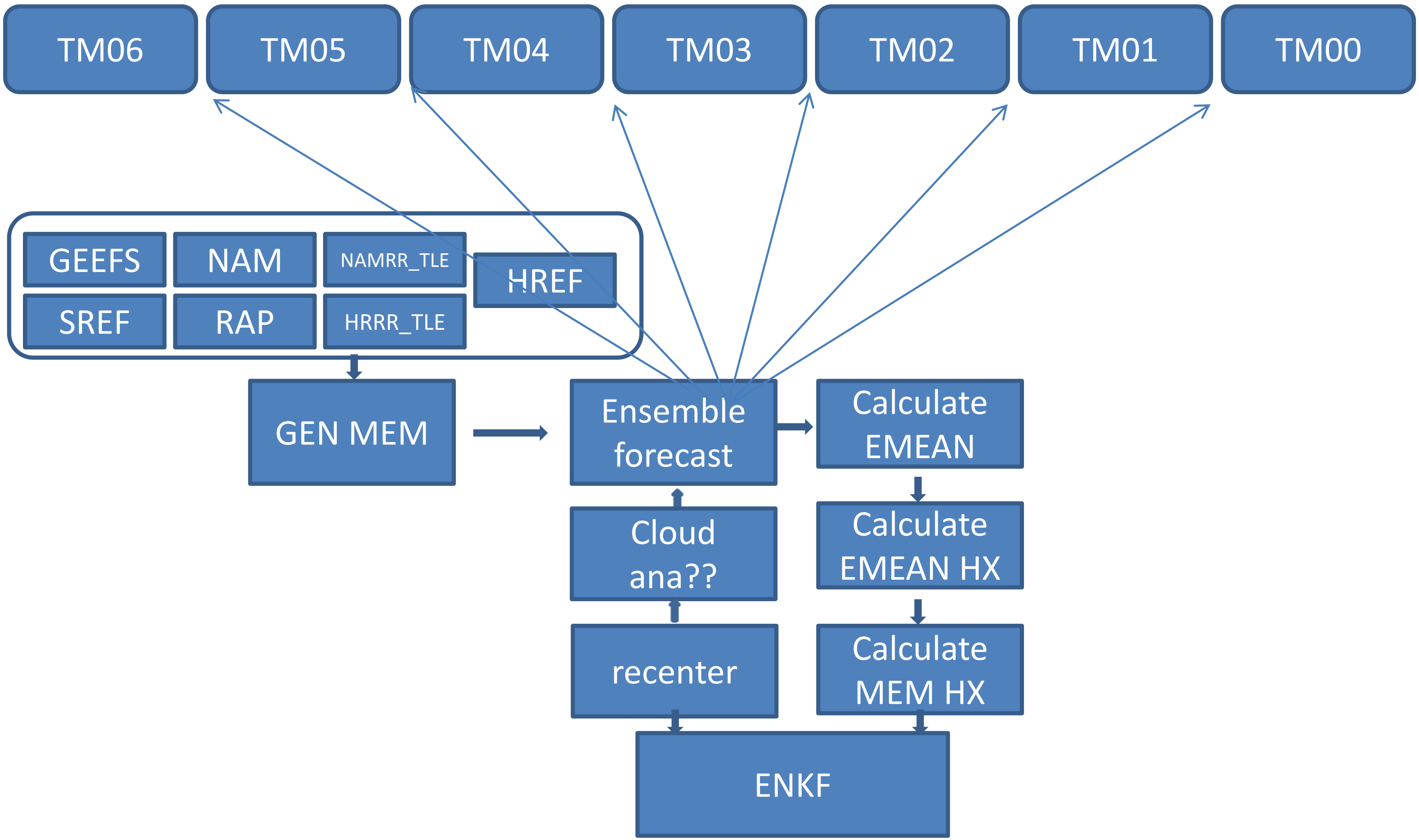
Summary and Future Plan

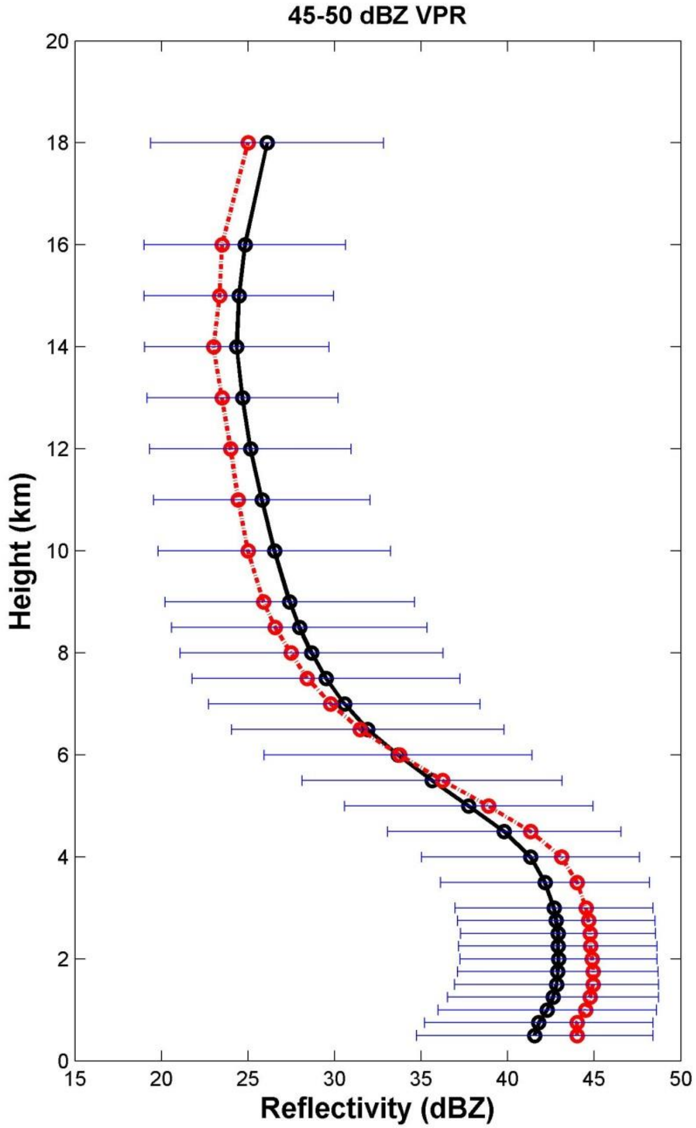
- Radar data and lightning DA algorithm is developed and was implemented in the operational NAM and will be in the coming NAMv4 system at NCEP.
- Assimilation of radar and lightning data can significantly improve short-term forecast.
- Use global lightning data in NAM domain and may potentially improve NWP forecast.
- Explore the method of assimilating radar and lighting under variational DA framework
- Test radar and lightning data assimilation with hybrid EnKF system.
- Test the whole radar and lightning data assimilation in FV3

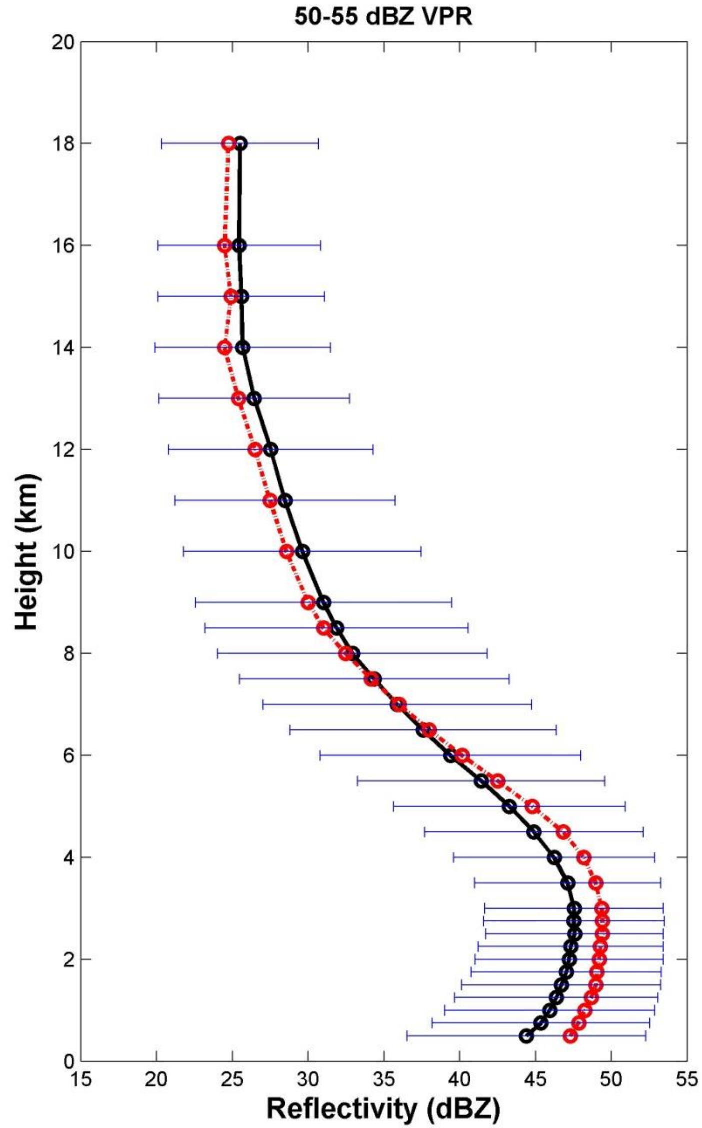
Thanks to Dr. Geoff DiMego for his many years of great leadership in NAM project

He happily retired on Jan 3, 2017

Improve regional analysis with regional ensemble member




45-50 dBZ VPR
Height (km)
Reflectivity (dBZ)
0
2
4
6
8
10
12
14
16
18
20
15
20
25
30
35
40
45
50


50-55 dBZ VPR
Height (km)
Reflectivity (dBZ)
0
2
4
6
8
10
12
14
16
18
20
15
20
25
30
35
40
45
50
55