FV^3 at the Hazardous Weather Testbed

Lucas Harris, S-J Lin, Matt Morin,
and the GFDL FV^3 team

Special thanks to Ming Xue,
Tim Supinie, and Bill Putman

FV^3 Development Update

Development never sleeps. Keep moving forward!
Work continues on fvGFS physics (especially GFDL microphysics) and on modifying advection operators and dissipation mechanisms.

Same FV^3 dynamical core in fvGFS and NCEP FV3GFS as in GFDL AM4 climate/S2S model. **Unification in progress!**

Space weather & deep atmosphere development is beginning

Moving nested grids for hurricane prediction

Beginning development of stand-alone regional model with EMC, for university users and others with limited computing capacity

Community involvement, from day 1

Collaborating with OU-CAPS on convection-resolving model development.
Submitted fvGFS-CAPS to HWT using Thompson MP

Examination of a **very** early "**version 0**" of FV^3-powered CRM at HWT.
Get feedback from expert severe-weather forecasters and researchers from the very beginning.

Open invitation for interested parties to visit GFDL to work on fvGFS and other model development efforts. EMC has already committed three developers to visit GFDL; OU, Penn State, and AOML visitors also to come.

fvGFS Design and setup

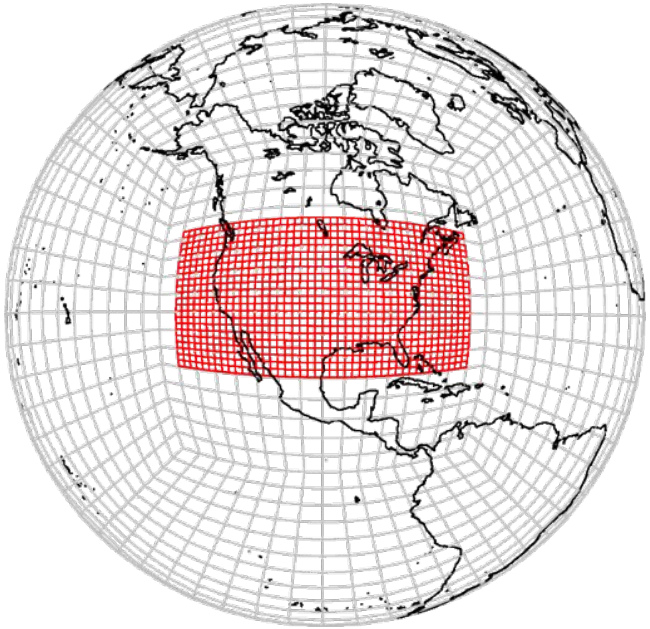
fvGFS = FV^3 + GFS Physics + NOAH land model

13-km global and 13 & 3-km CONUS nest

Replaces GFS Zhao-Carr with
six-category GFDL microphysics

Uses IPDv4 designed at GFDL:
Prepared for future physics upgrades!

Model cold-started from GFS analyses.
No regional initialization yet.



fvGFS Design and setup

fvGFS = FV^3 + GFS Physics + NOAH land model

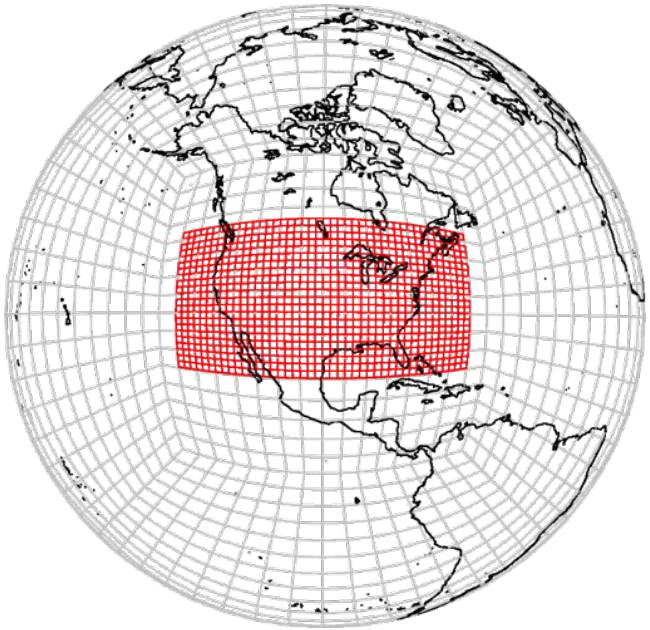
Nested-grid uses neither shallow nor deep convection (unless noted)
Global grid uses scale-aware SAS

GFS PBL mixing artificially halved and inversion mixing disabled.

Still too much mixing? Work in progress.

~19 minutes/day 3456 PEs on Gaea-c4, slightly more on xJet

Post-processed GRIB data at HWT by 09Z



fvGFS Development Strategy

13-km fvGFS has excellent global skill and shows regional improvements.

Global-to-regional refinement avoids limitations of limited-area models.
No lateral BCs from another model!

Nesting allows us to use physics with global skill in global domain,
and physics with regional skill in **targeted** regional domain.

Goal: Maintain large-scale skill while adding storm-scale information on 3-km nest

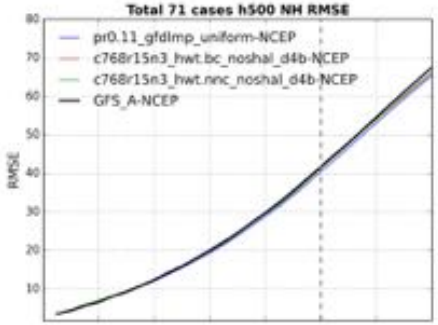
Can we get good qualitative skill for all seasons as well as useful qualitative storm-scale information??

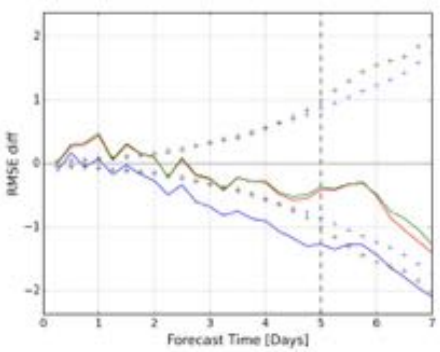
Objective Skill Scores

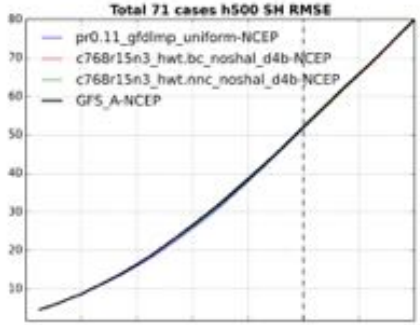
Thanks to Shannon Rees, Bill Stern,
Linjiong Zhou, and Xi Chen

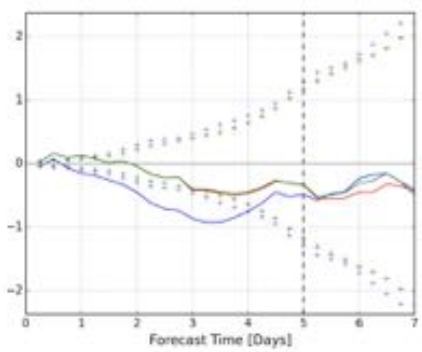
2015 Year-Round Hindcasts (71 cases)

Hemispheric RMSE (lower is better)

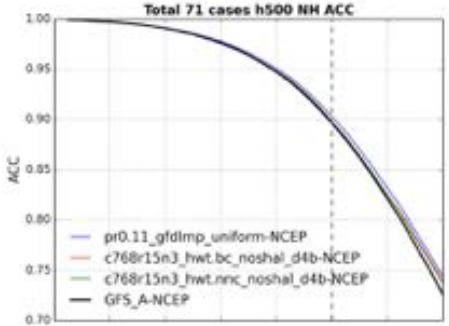


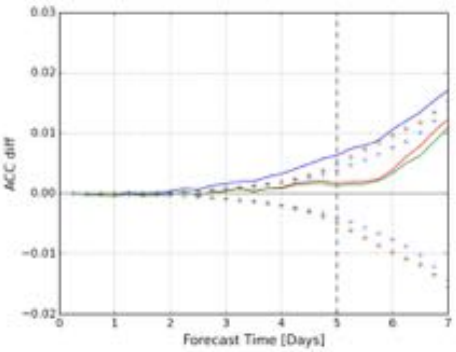


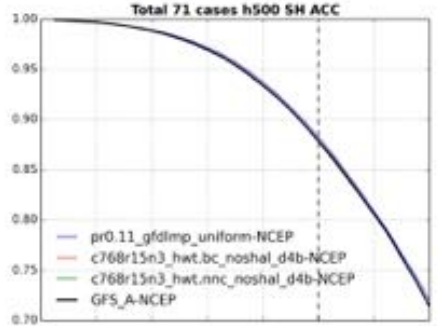


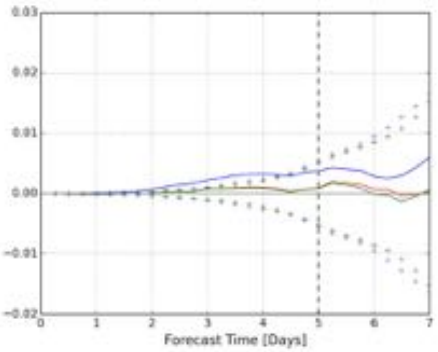


Hemispheric ACC (higher is better)









Blue: 13-km global (NUOPC 3 version)

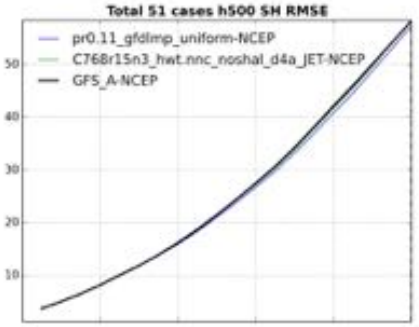
Red: 13 & 3-km global-to-CONUS Deep conv. on nest (IPDv4 version)

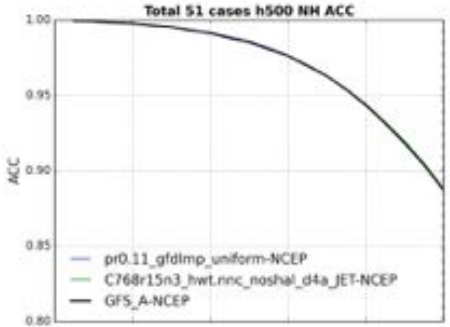
Green: 13 & 3-km global-to-CONUS NO deep conv. on nest (IPDv4 version)

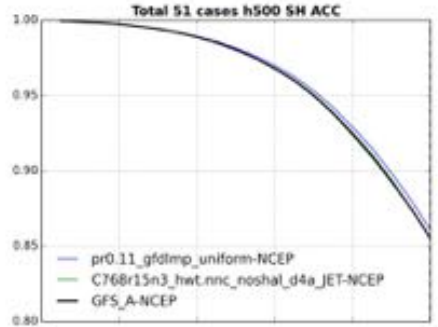
April/May 2017 HWT Forecasts (51 cases)

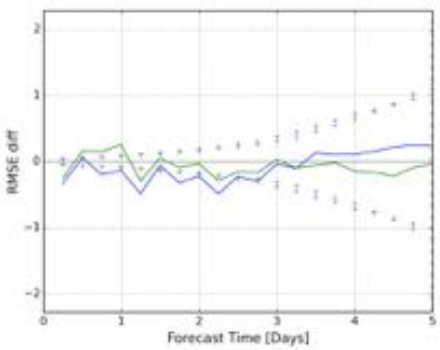
Hemispheric RMSE
(lower is better)

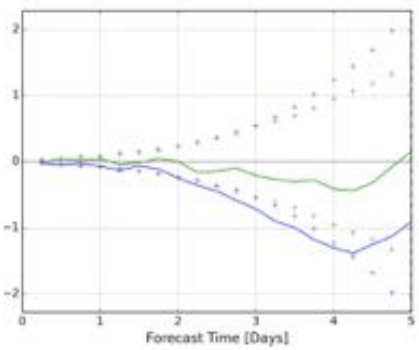
Hemispheric ACC
(higher is better)

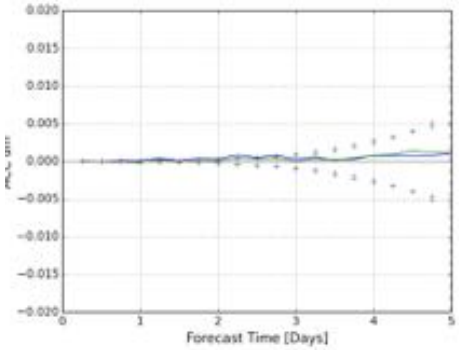


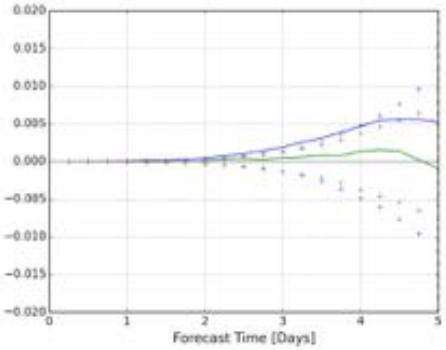








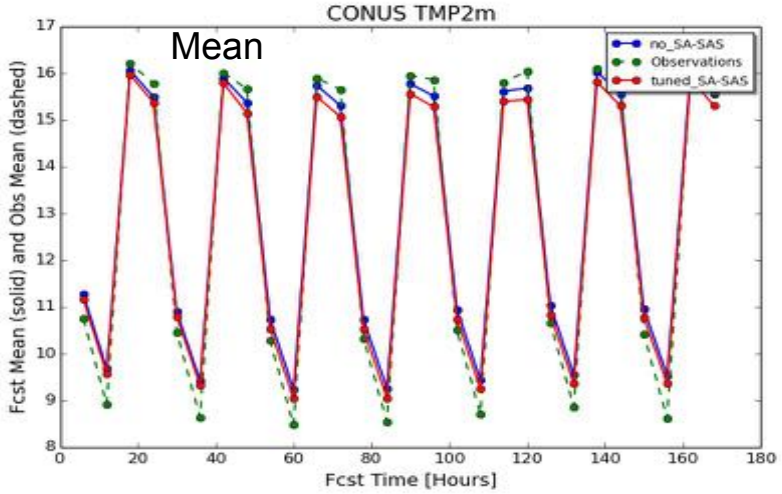


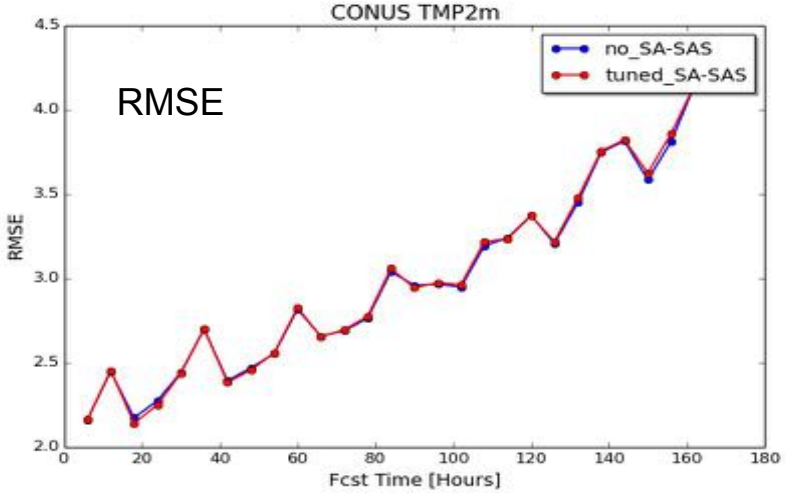


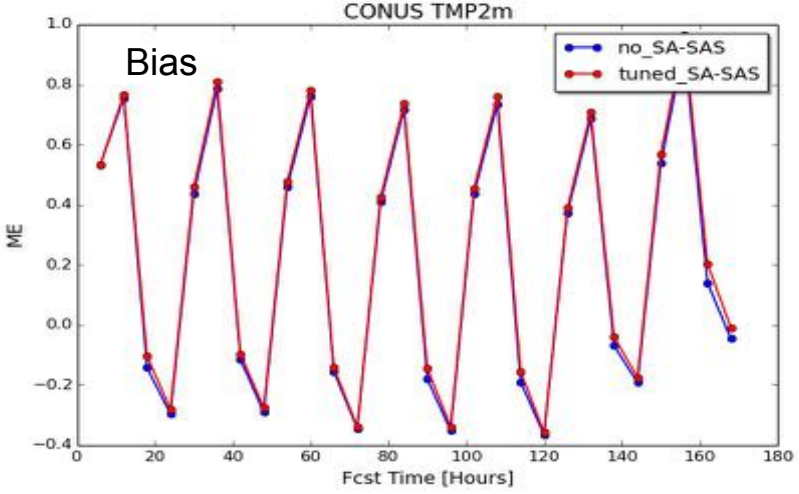
Blue: 13-km global (NUOPC 3 version)

Green: 13 & 3-km global-to-CONUS NO deep conv. on nest (IPDv4 version)

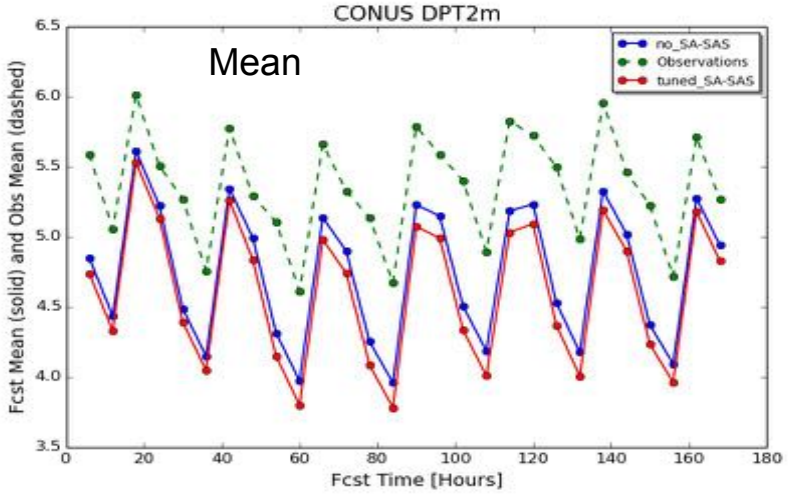
2015 Year-Round Hindcasts (68 cases)
CONUS 2-m temperature errors (degC)

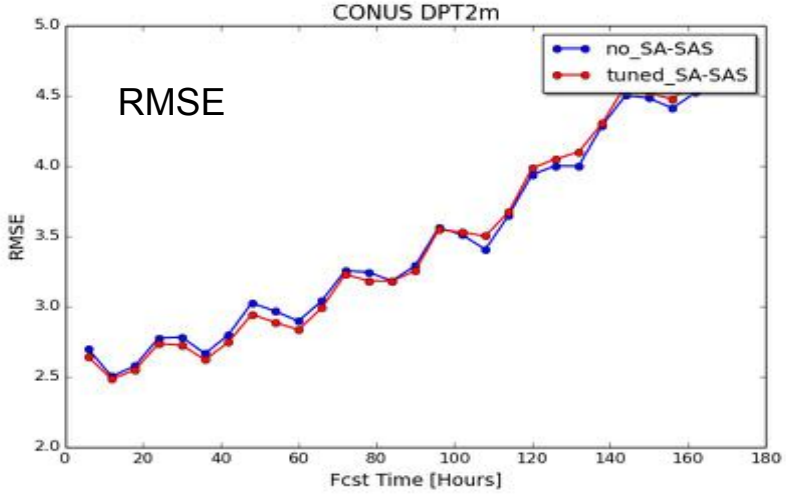


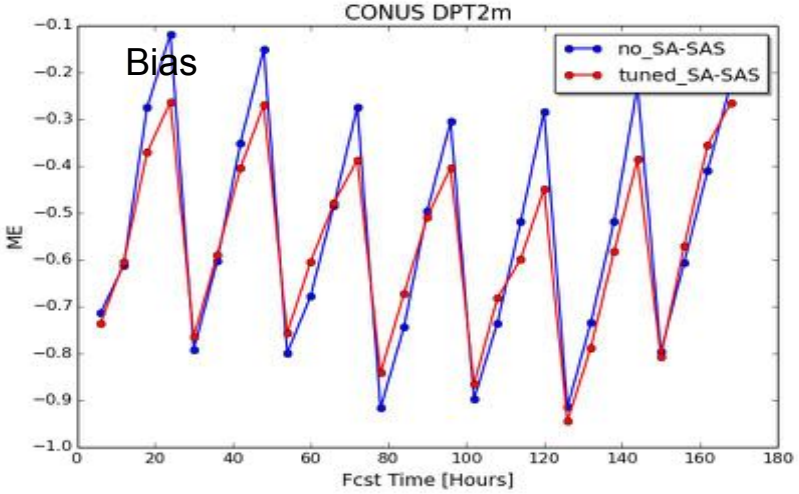




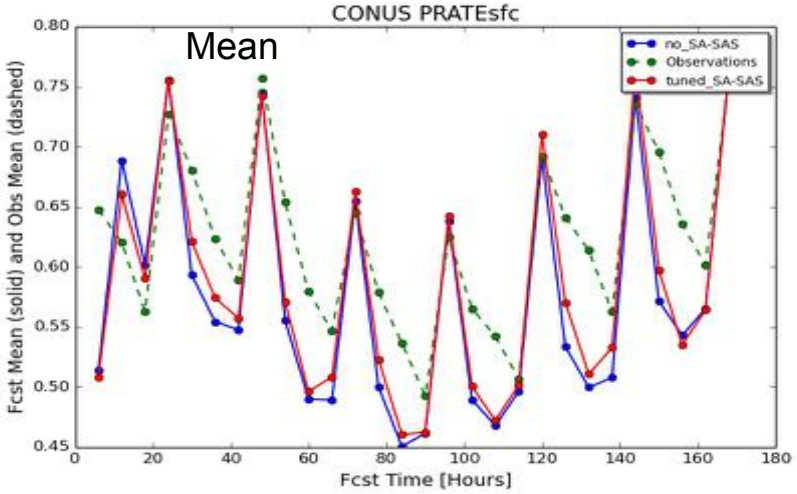
2015 Year-Round Hindcasts (68 cases)
CONUS 2-m dew point errors (degC)

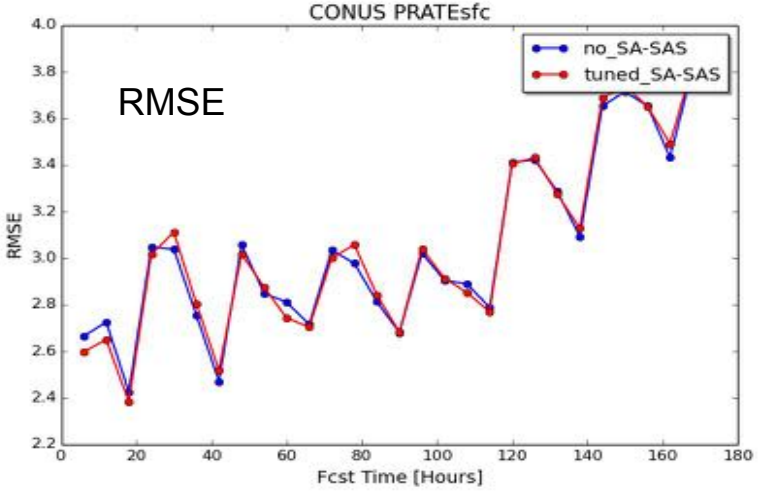


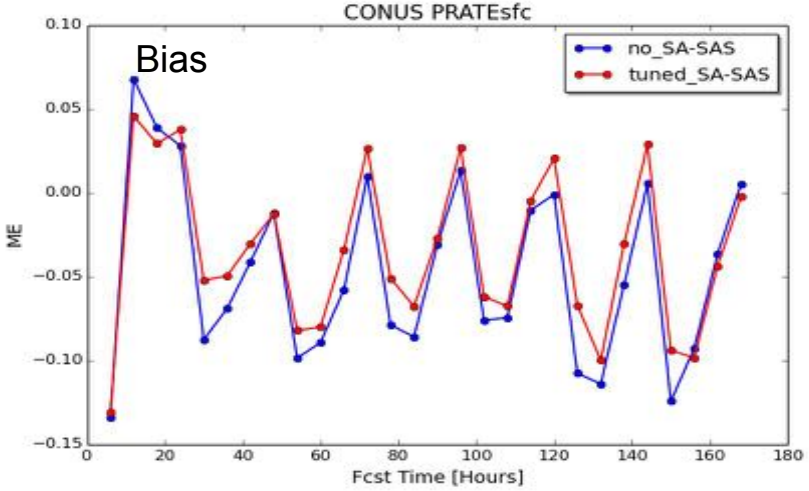




2015 Year-Round Hindcasts (68 cases)
CONUS Precipitation rate errors (mm/6 hr)

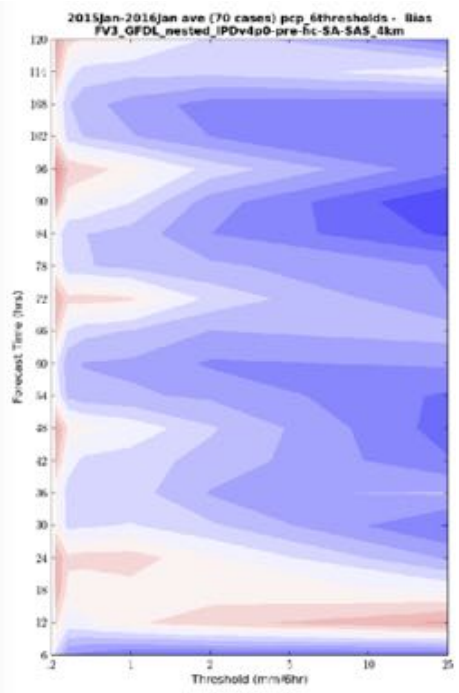




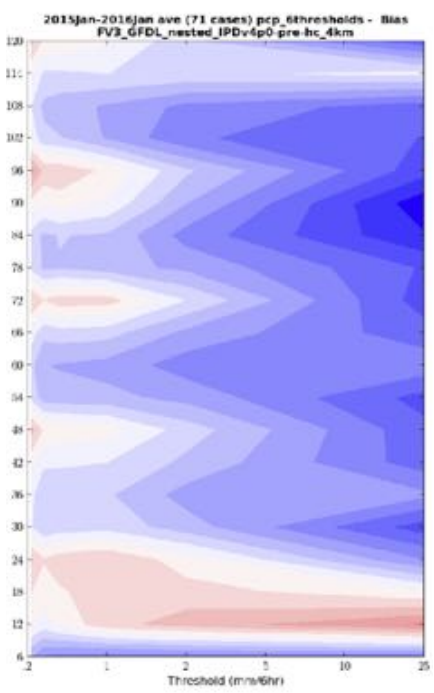


Bias Score: 3-km CONUS nest

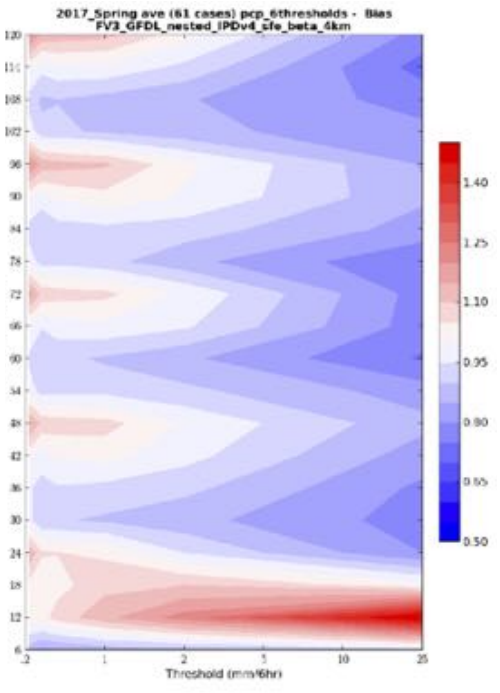
2015 year-round
Deep ON



2015 year-round
NO Deep



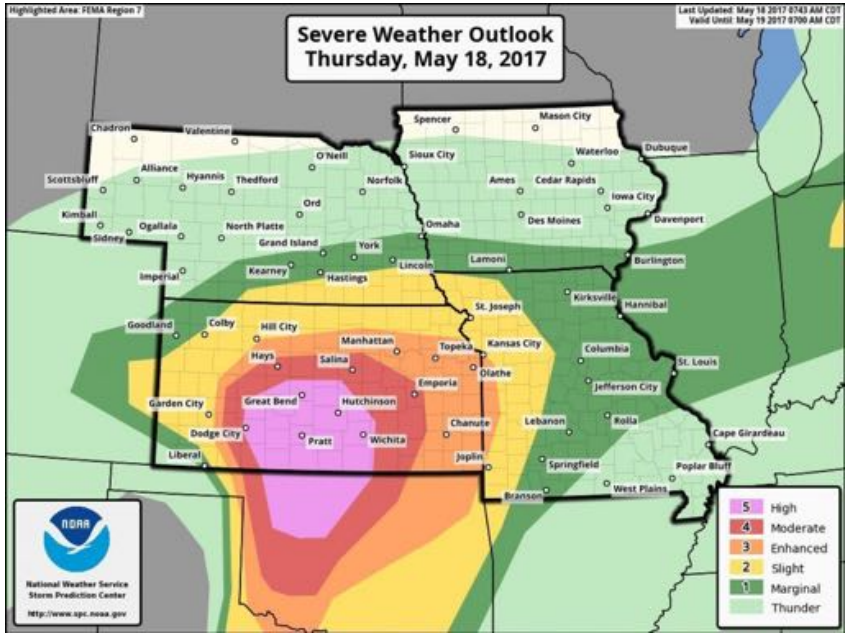
April/May 2017 HWT
NO Deep



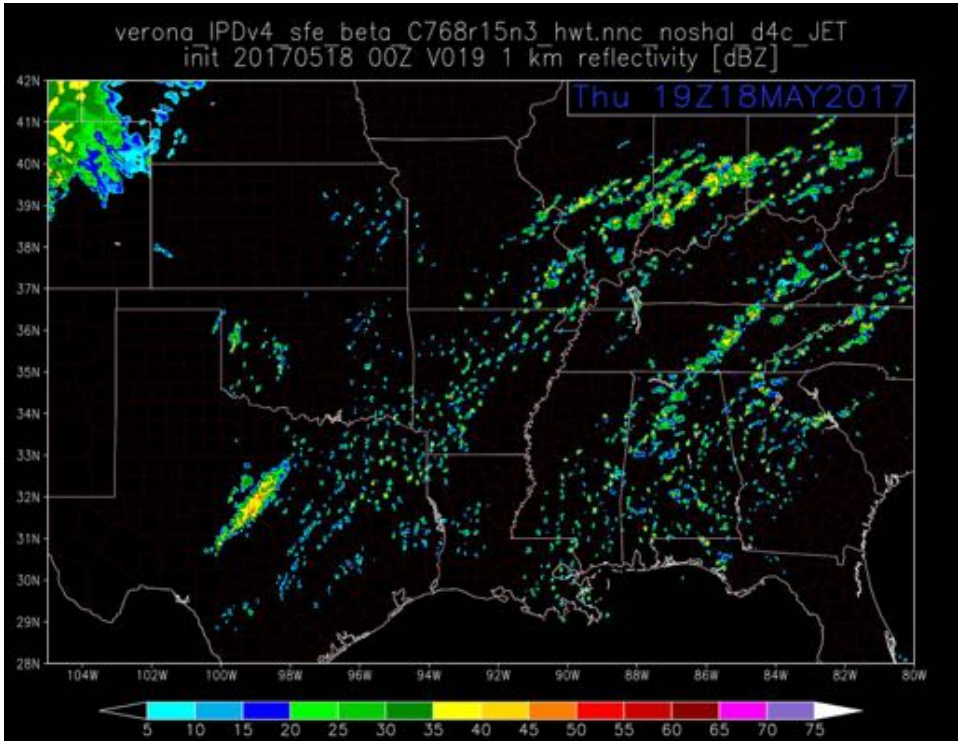
18 May OK-KS **High Risk**

GOES-16 1-min band 2 visible

(click for animation)


Highlighted Area: FEMA Region 7
Last Updated: May 18 2017 0743 AM CDT
Valid Until: May 19 2017 0700 AM CDT
Severe Weather Outlook
Thursday, May 18, 2017
Chadron
Valentine
Spencer
Mason City
O'Neill
Sioux City
Waterloo
Dubuque
Scottsbluff
Alliance
Hyannis
Thedford
Norfolk
Ames
Cedar Rapids
Ord
Iowa City
Kimball
Ogallala
North Platte
Omaha
Des Moines
Davenport
Sidney
Grand Island
York
Lincoln
Lamoni
Burlington
Imperial
Kearney
Hastings
Kirksville
St. Joseph
Hannibal
Goodland
Colby
Hill City
Manhattan
Topeka
Kansas City
Columbia
Hays
Salina
Olathe
St. Louis
Emporia
Jefferson City
Garden City
Great Bend
Hutchinson
Chanute
Lebanon
Rolla
Dodge City
Pratt
Wichita
Cape Girardeau
Liberal
Joplin
Springfield
Poplar Bluff
Branson
West Plains
National Weather Service
Storm Prediction Center
http://www.spc.noaa.gov
5 High
4 Moderate
3 Enhanced
2 Slight
1 Marginal
Thunder

SPC Storm Reports for 05/18/17
Map updated at 1329Z on 05/19/17
TORNADO REPORTS.....(28)
WIND REPORTS/HI.....(275/5)
HAIL REPORTS/LG.....(208/19)
TOTAL REPORTS.....(583)
National Weather Service
Storm Prediction Center
Norman, Oklahoma
• High Wind Report (65KT +)
▲ Large Hail Report (2" dia. +)
PRELIMINARY DATA ONLY


verona_IPDv4_sfe_beta_C768r15n3_hwt.nnc_noshal_d4c_JET
init 20170518 00Z V019 1 km reflectivity [dBZ]
Thu 19Z18MAY2017
42N
41N
40N
39N
38N
37N
36N
35N
34N
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32N
31N
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29N
28N
104W
102W
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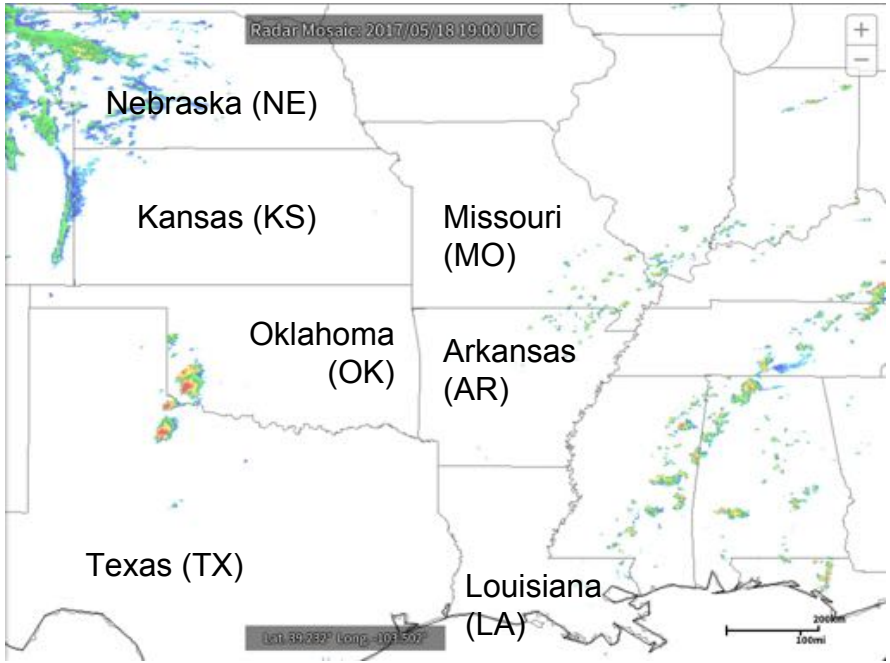
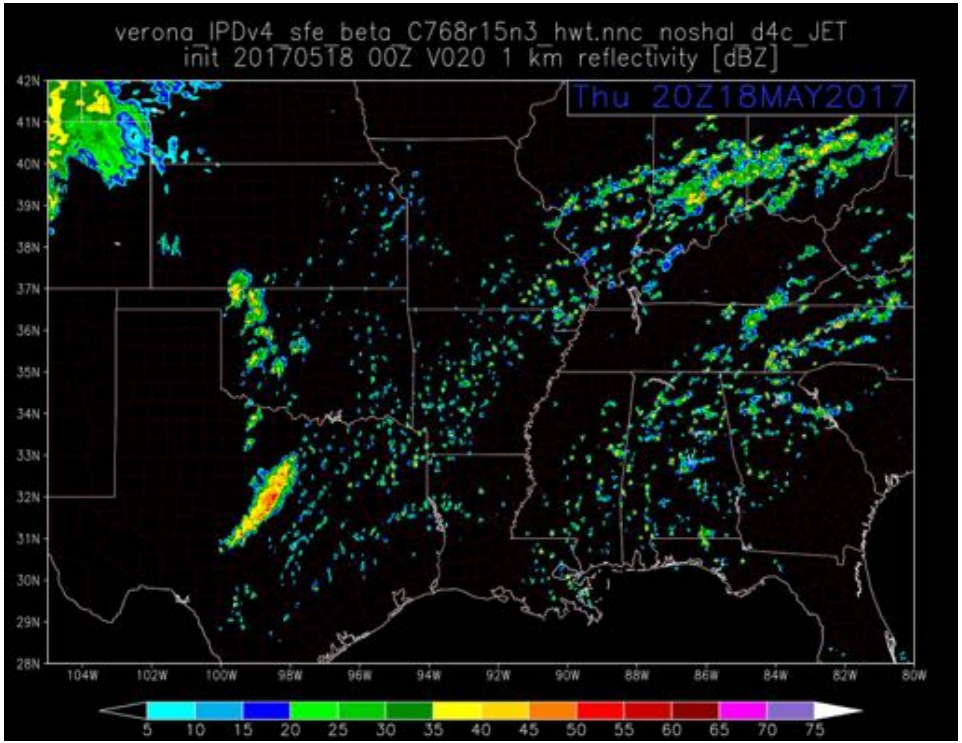

Radar Mosaic: 2017/05/18 19:00 UTC
Nebraska (NE)
Kansas (KS)
Missouri (MO)
Oklahoma (OK)
Arkansas (AR)
Texas (TX)
Louisiana (LA)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init 20170518 00Z V020 1 km reflectivity [dBZ]
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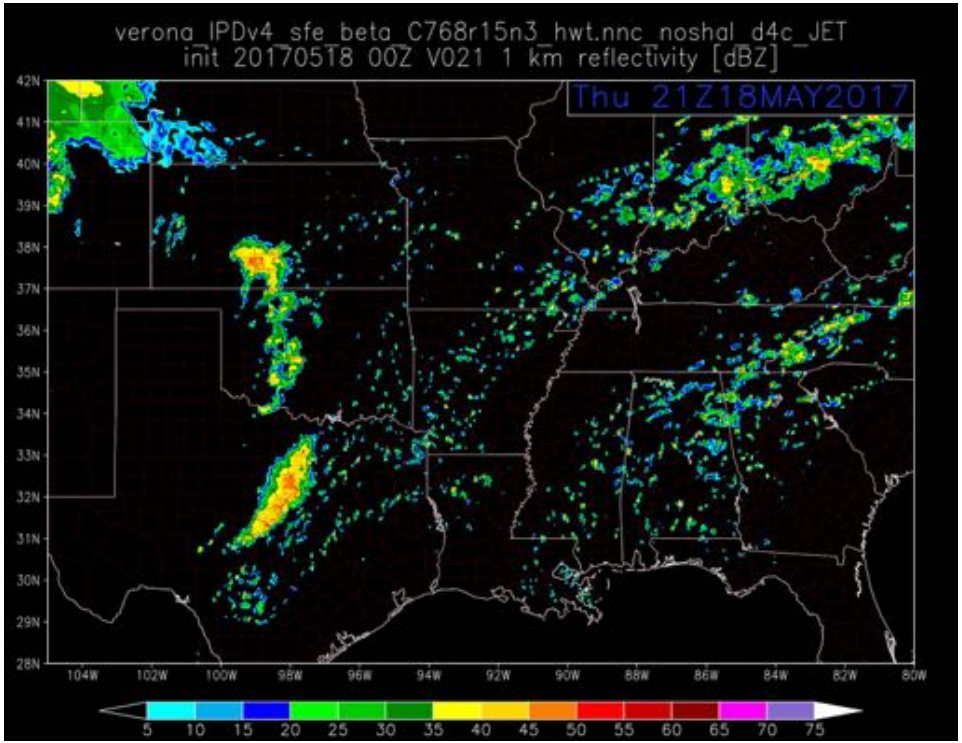
Radar Mosaic: 2017/05/18 20:00 UTC
200km
100mi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84W
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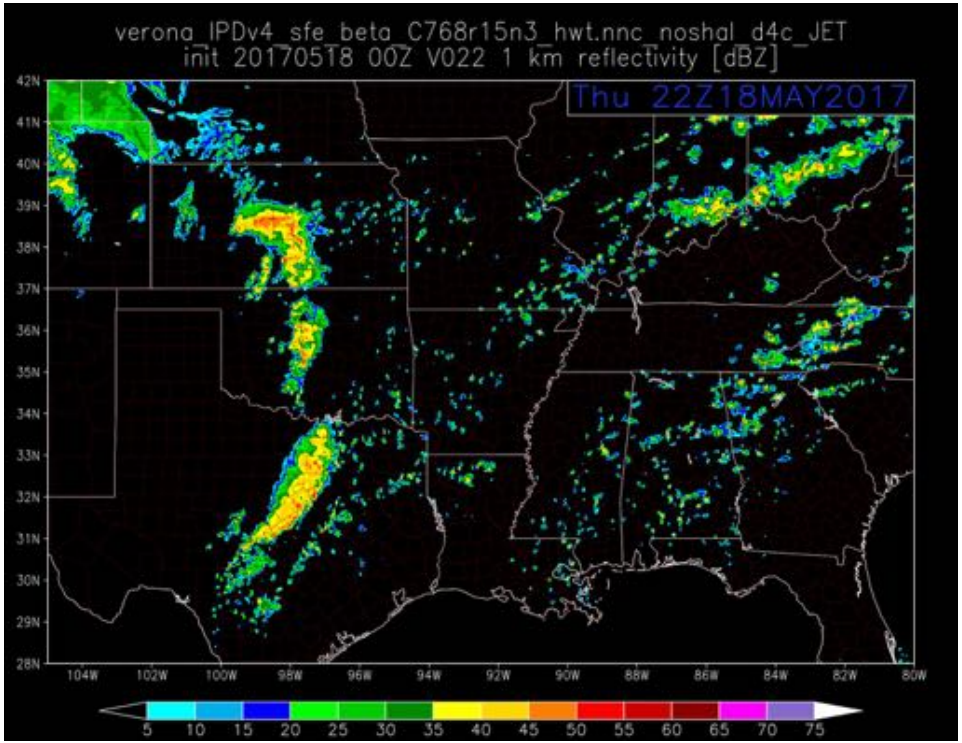
Radar Mosaic: 2017/05/18 21:00 UTC
Lat: 39.232° Long: -103.502°
200km
100mi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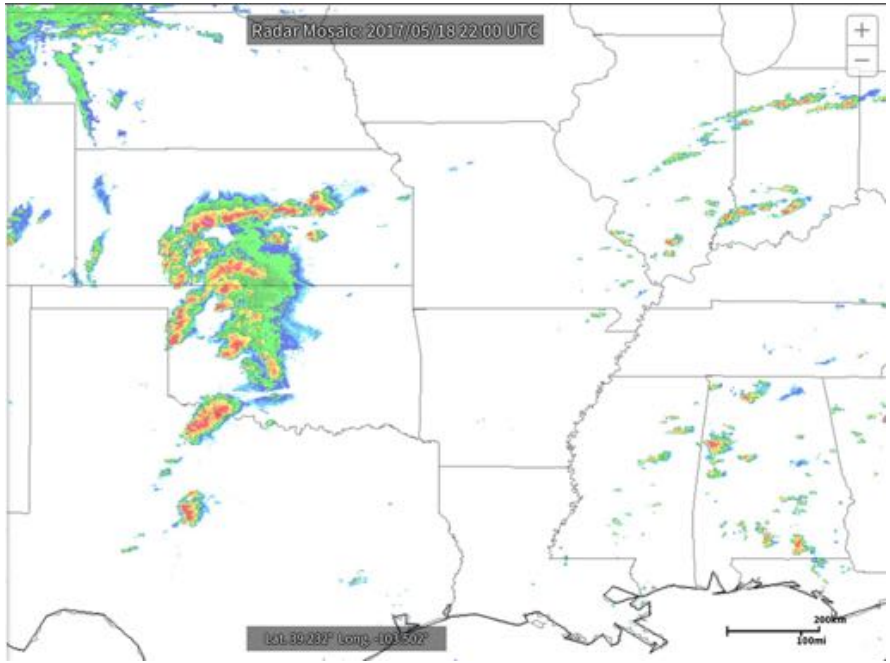
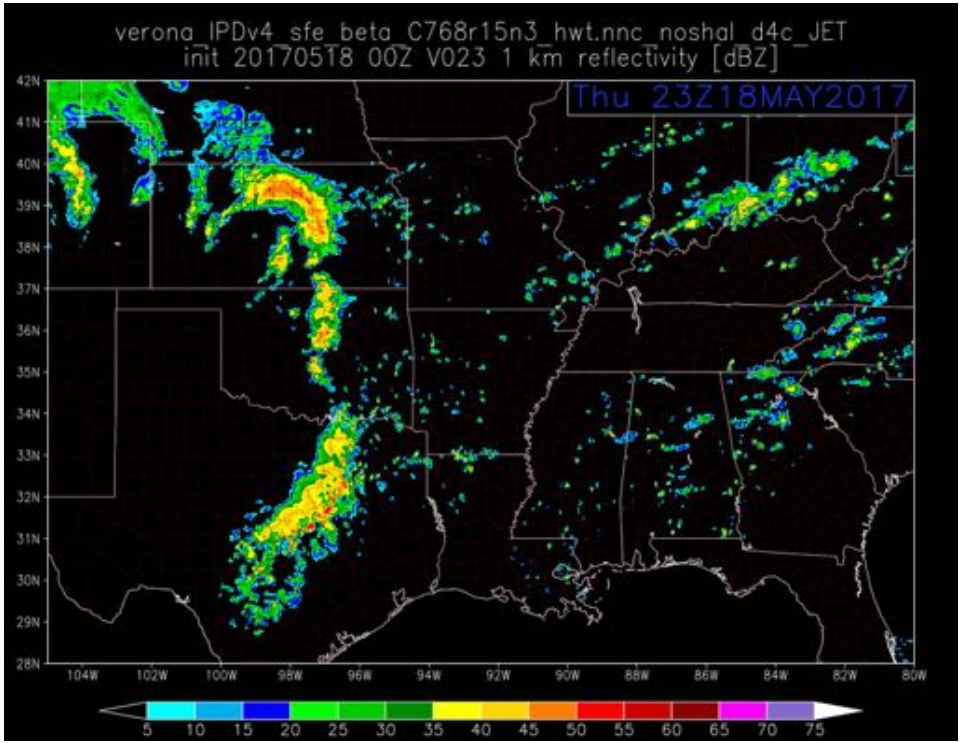

Radar Mosaic: 2017/05/18 22:00 UTC
200km
100mi


verona_IPDv4_sfe_beta_C768r15n3_hwt.nnc_noshal_d4c_JET
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Thu 23Z18MAY2017
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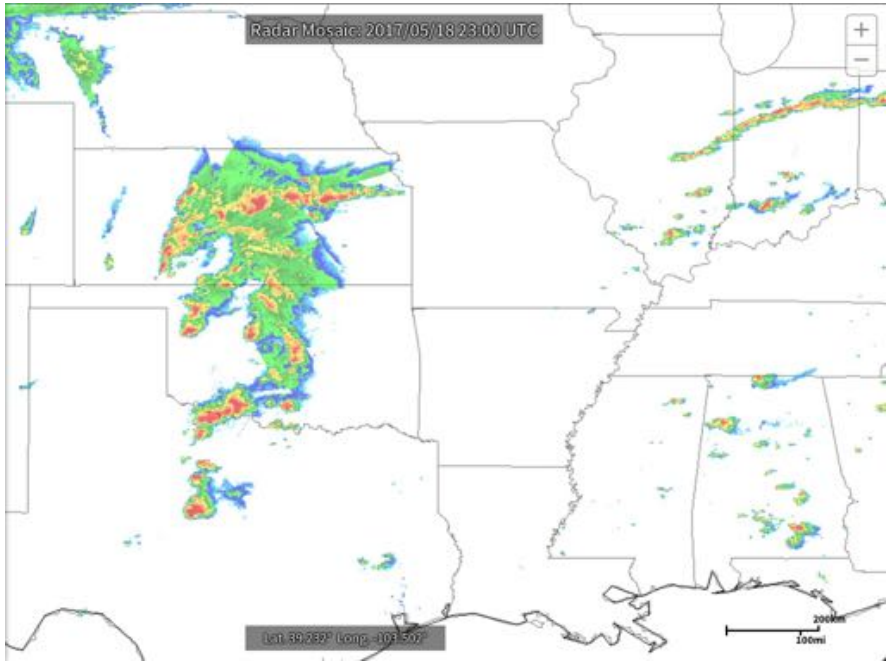
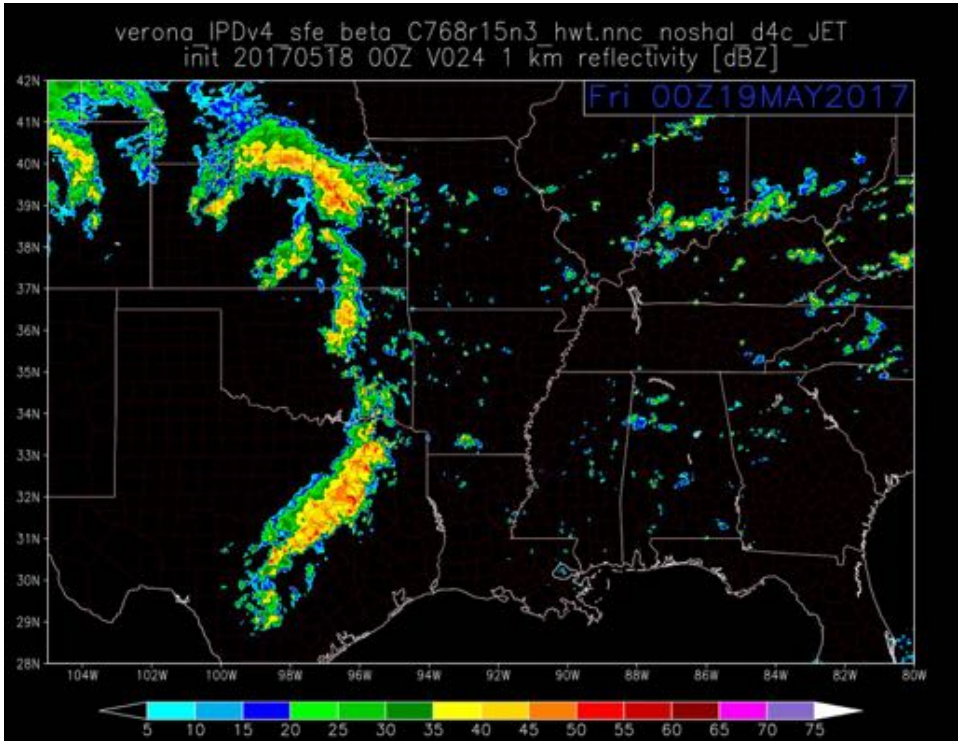

Radar Mosaic: 2017/05/18 23:00 UTC
200km
100mi


verona_IPDv4_sfe_beta_C768r15n3_hwt.nnc_noshal_d4c_JET
init 20170518 00Z V024 1 km reflectivity [dBZ]
Fri 00Z19MAY2017
42N
41N
40N
39N
38N
37N
36N
35N
34N
33N
32N
31N
30N
29N
28N
104W
102W
100W
98W
96W
94W
92W
90W
88W
86W
84W
82W
80W
5
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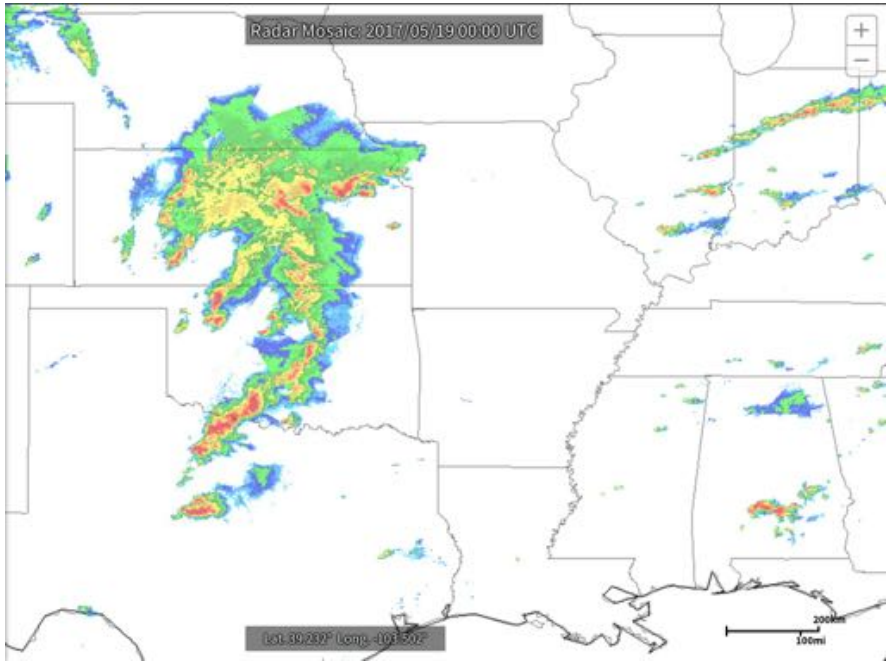
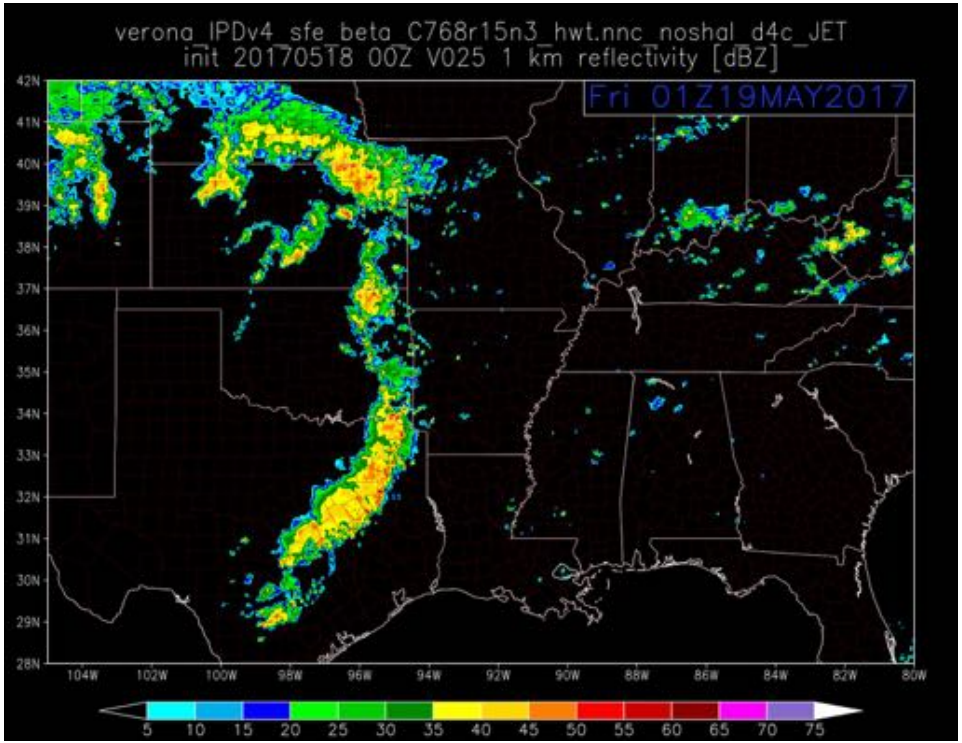
15
20
25
30
35
40
45
50
55
60
65
70
75


Radar Mosaic 2017/05/19 00:00 UTC
200km
100mi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init 20170518 00Z V025 1 km reflectivity [dBZ]
Fri 01Z19MAY2017
42N
41N
40N
39N
38N
37N
36N
35N
34N
33N
32N
31N
30N
29N
28N
104W
102W
100W
98W
96W
94W
92W
90W
88W
86W
84W
82W
80W
5
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15
20
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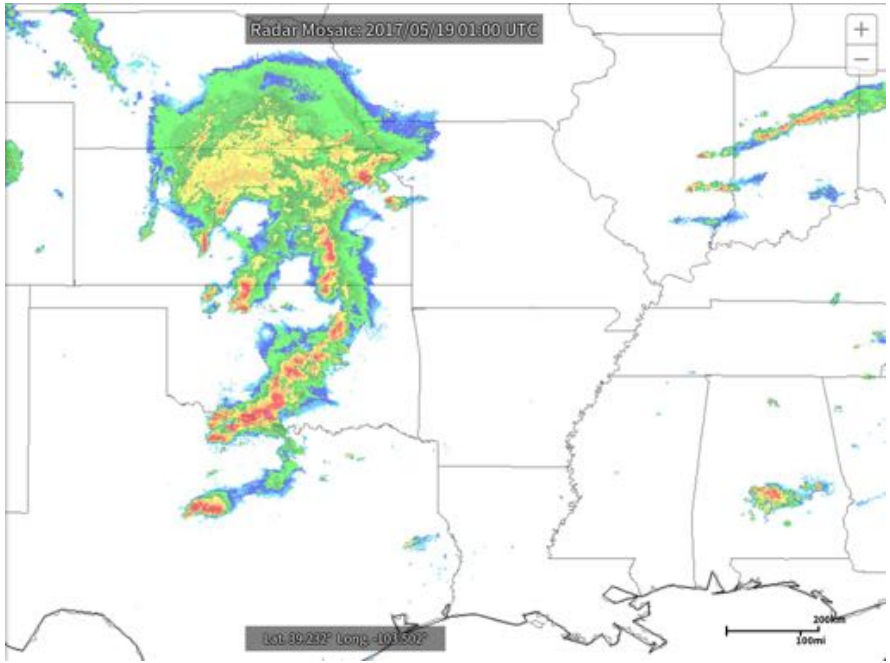
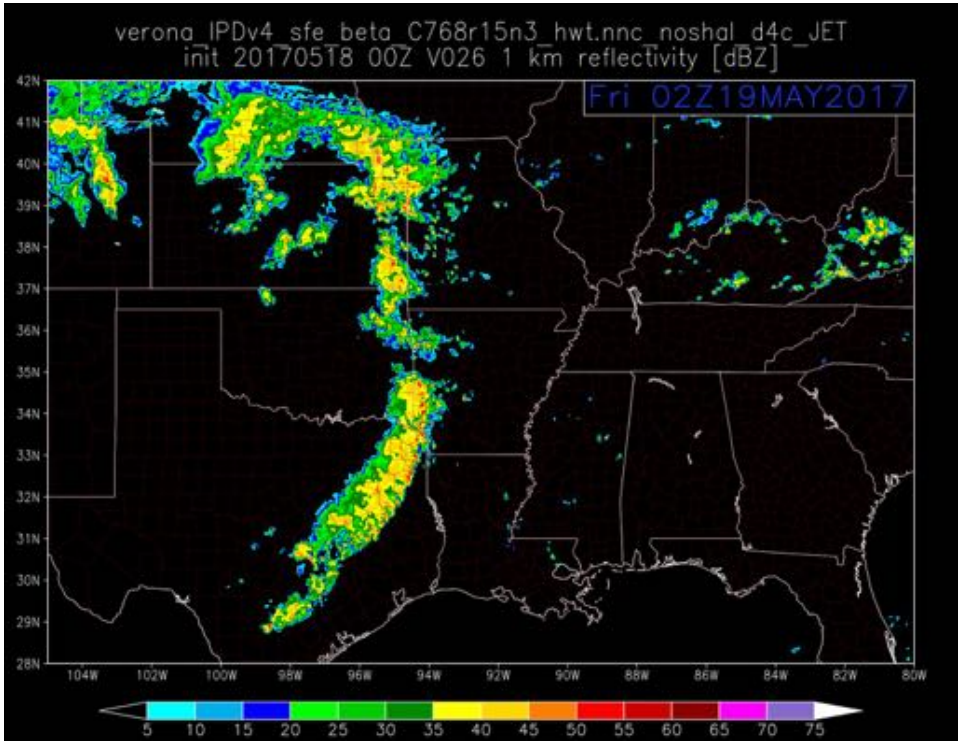
70
75


Radar Mosaic: 2017/05/19 01:00 UTC
200km
100mi


verona_IPDv4_sfe_beta_C768r15n3_hwt.nnc_noshal_d4c_JET
init 20170518 00Z V026 1 km reflectivity [dBZ]
Fri 02Z19MAY2017
42N
41N
40N
39N
38N
37N
36N
35N
34N
33N
32N
31N
30N
29N
28N
104W
102W
100W
98W
96W
94W
92W
90W
88W
86W
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82W
80W
5
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20
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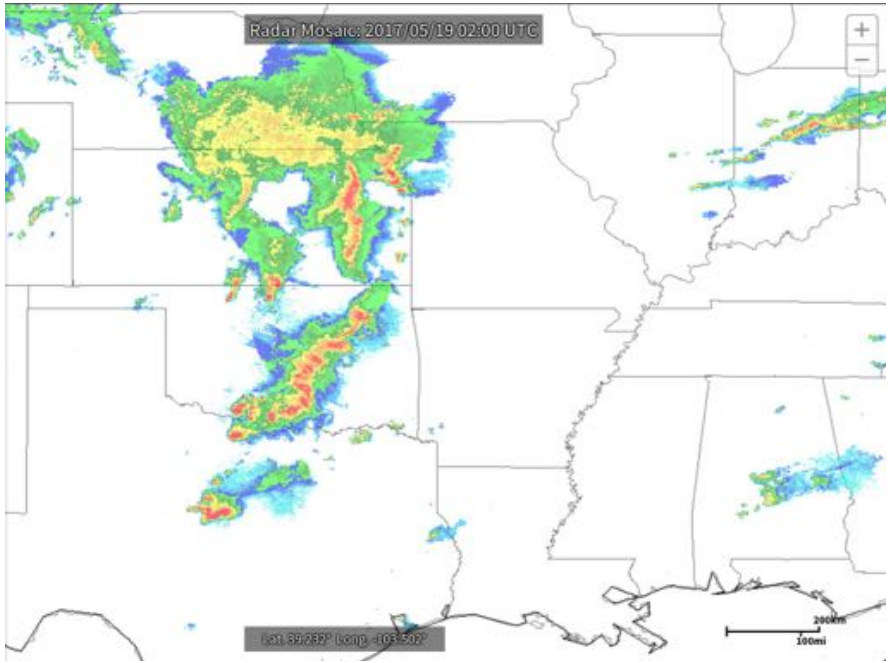
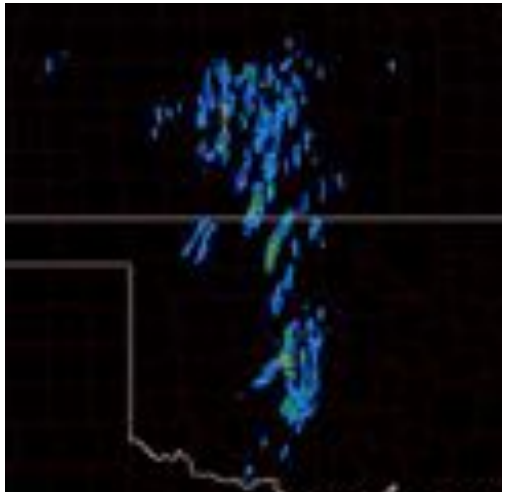
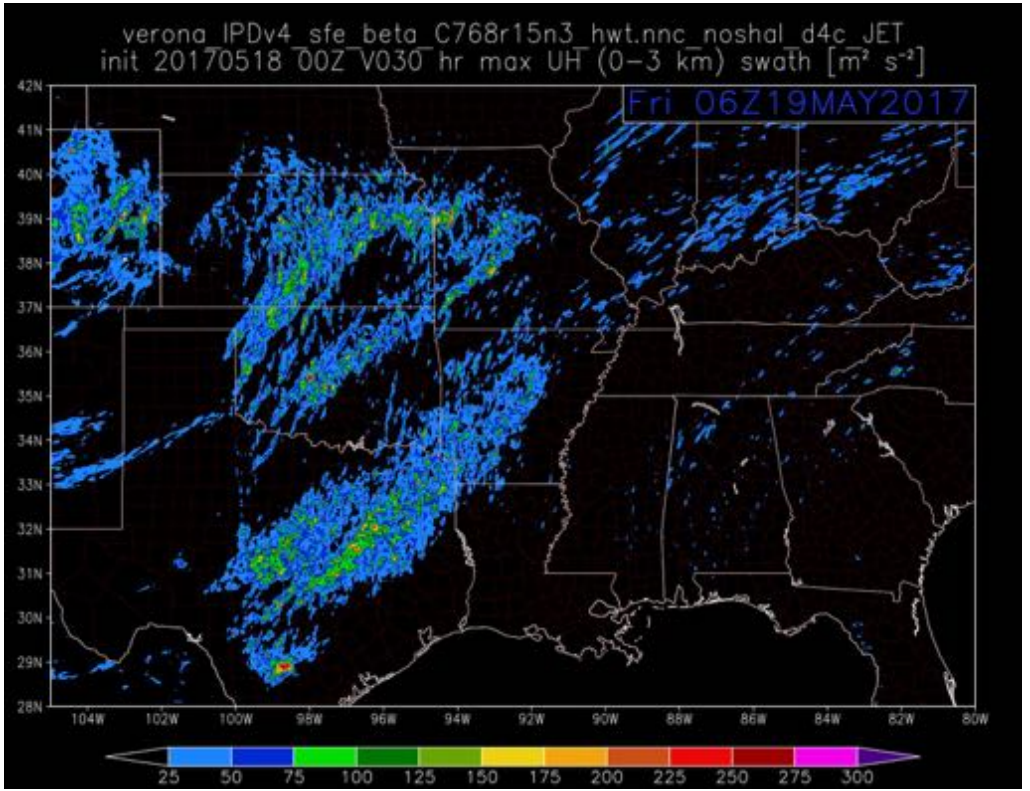
70
75


Radar Mosaic: 2017/05/19 02:00 UTC
200km
100mi

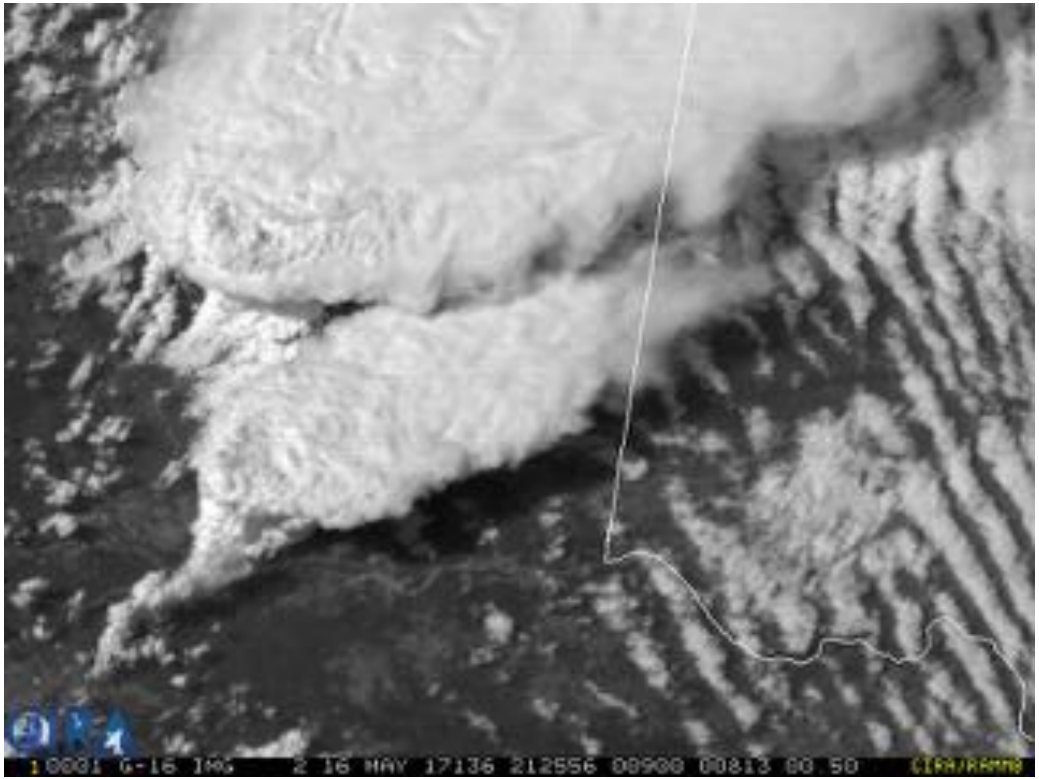


22Z



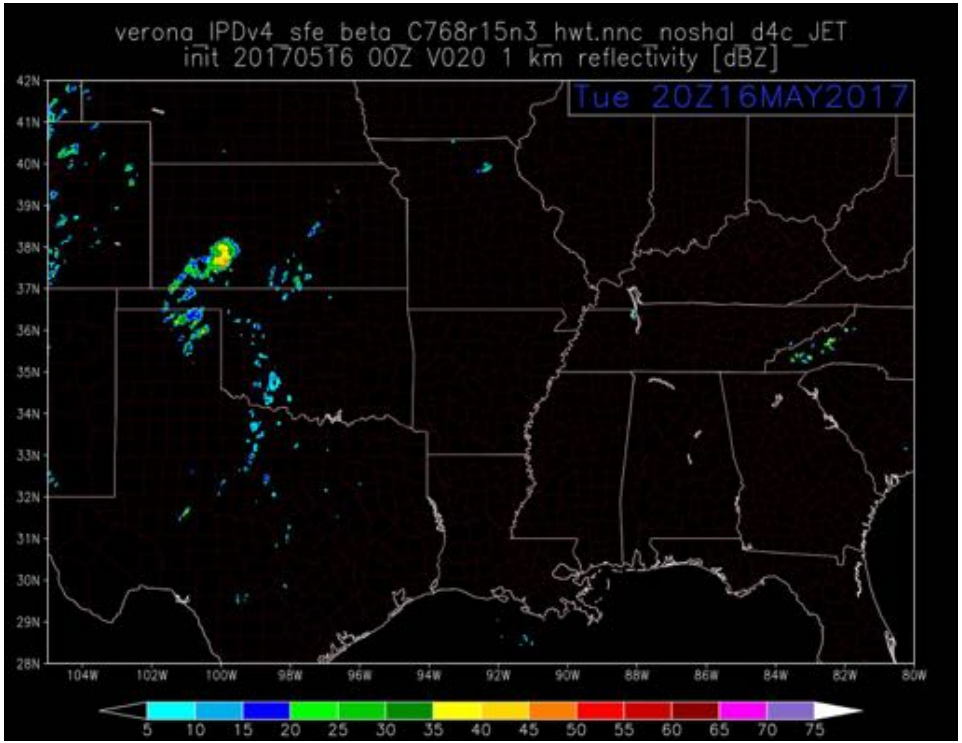
0-3 km UH; 2-5 km (HWT website) are more intense

16 May TX-OK outbreak



(click for animation)

GOES-16 1-min band 2 visible:
Rotating supercells and roll clouds


verona_IPDv4_sfe_beta_C768r15n3_hwt.nnc_noshal_d4c_JET
init 20170516 00Z V020 1 km reflectivity [dBZ]
Tue 20Z16MAY2017
42N
41N
40N
39N
38N
37N
36N
35N
34N
33N
32N
31N
30N
29N
28N
104W
102W
100W
98W
96W
94W
92W
90W
88W
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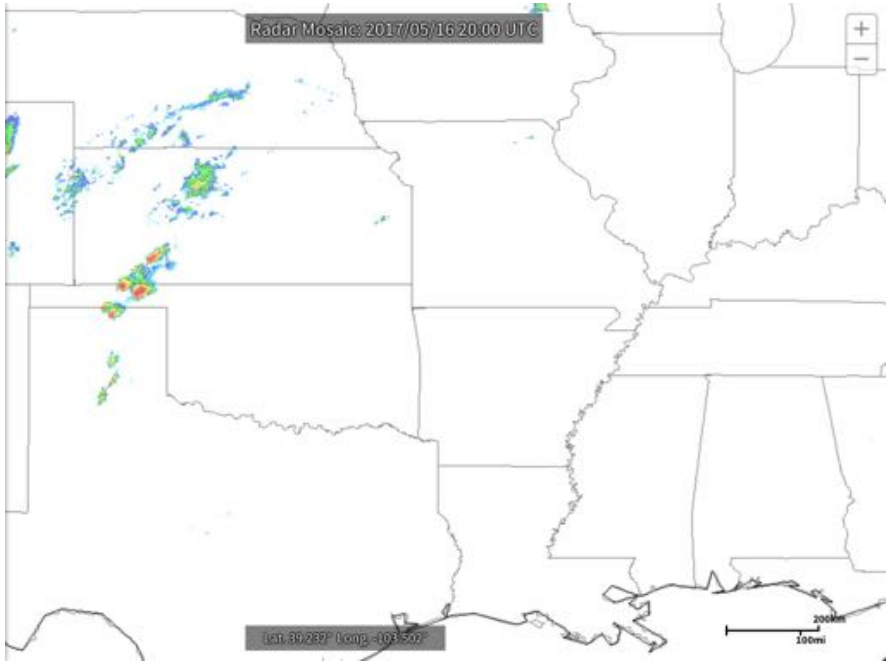
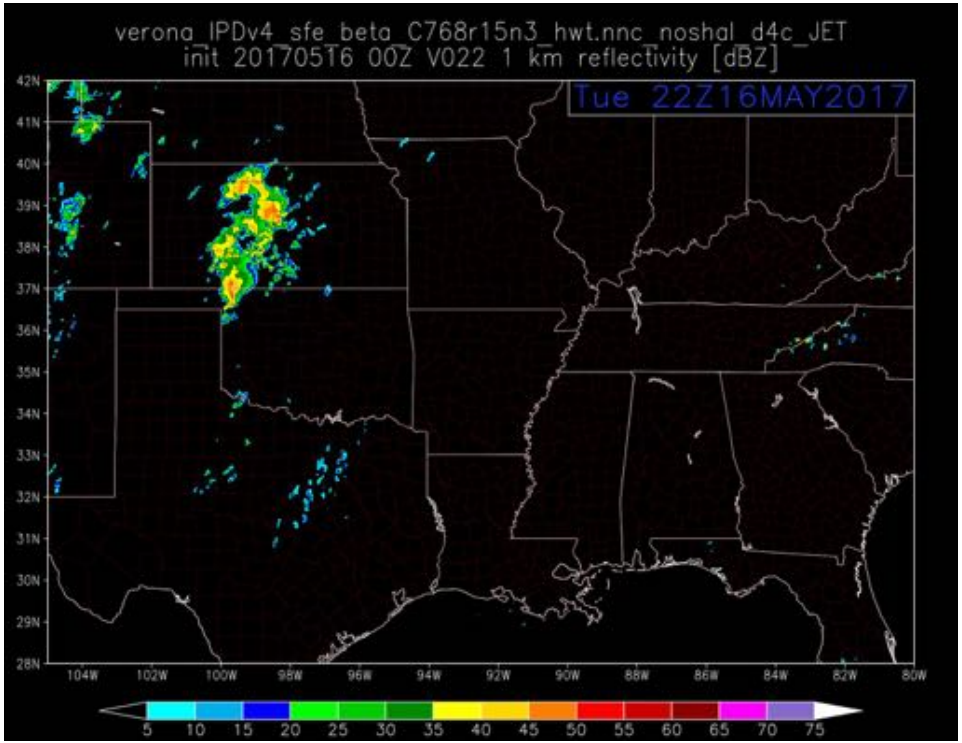
75


Radar Mosaic: 2017/05/16 20:00 UTC
200km
100mi


verona_IPDv4_sfe_beta_C768r15n3_hwt.nnc_noshal_d4c_JET
init 20170516 00Z V022 1 km reflectivity [dBZ]
Tue 22Z16MAY2017
42N
41N
40N
39N
38N
37N
36N
35N
34N
33N
32N
31N
30N
29N
28N
104W
102W
100W
98W
96W
94W
92W
90W
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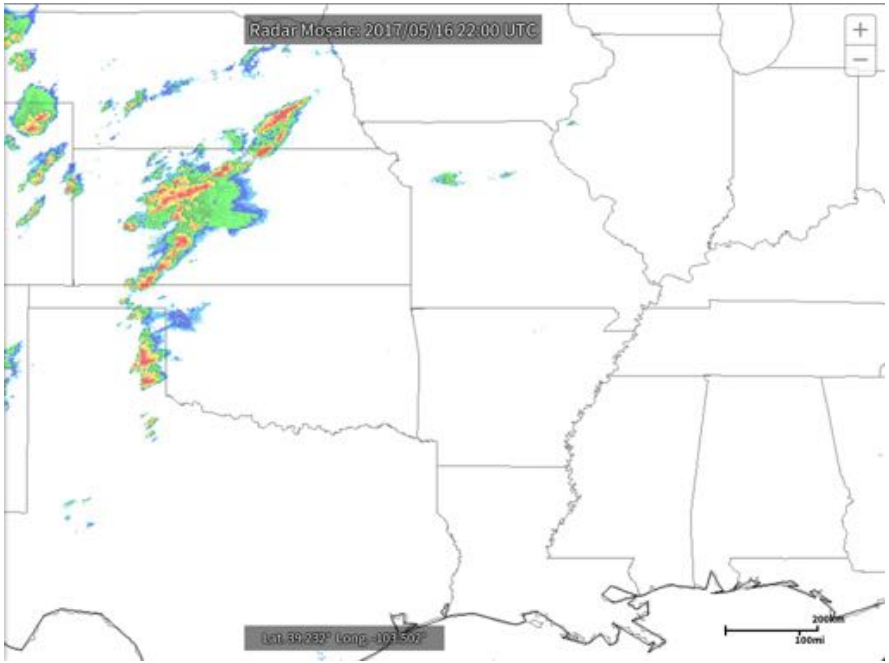
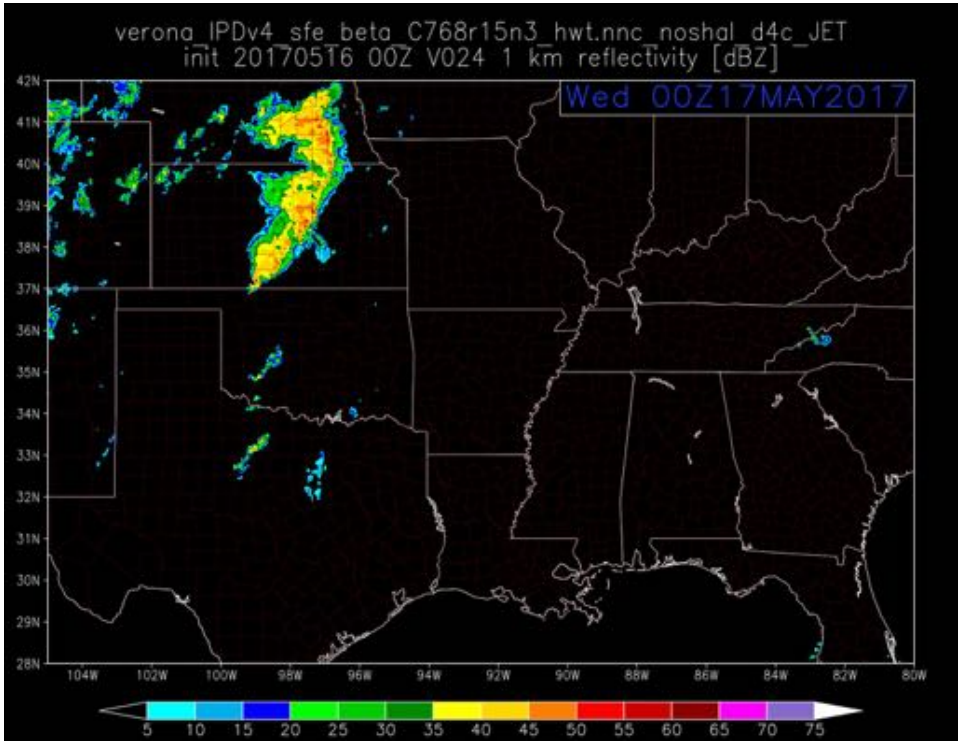
70
75


Radar Mosaic: 2017/05/16 22:00 UTC
200km
100mi


verona_IPDv4_sfe_beta_C768r15n3_hwt.nnc_noshal_d4c_JET
init 20170516 00Z V024 1 km reflectivity [dBZ]
Wed 00Z17MAY2017
42N
41N
40N
39N
38N
37N
36N
35N
34N
33N
32N
31N
30N
29N
28N
104W
102W
100W
98W
96W
94W
92W
90W
88W
86W
84W
82W
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5
10
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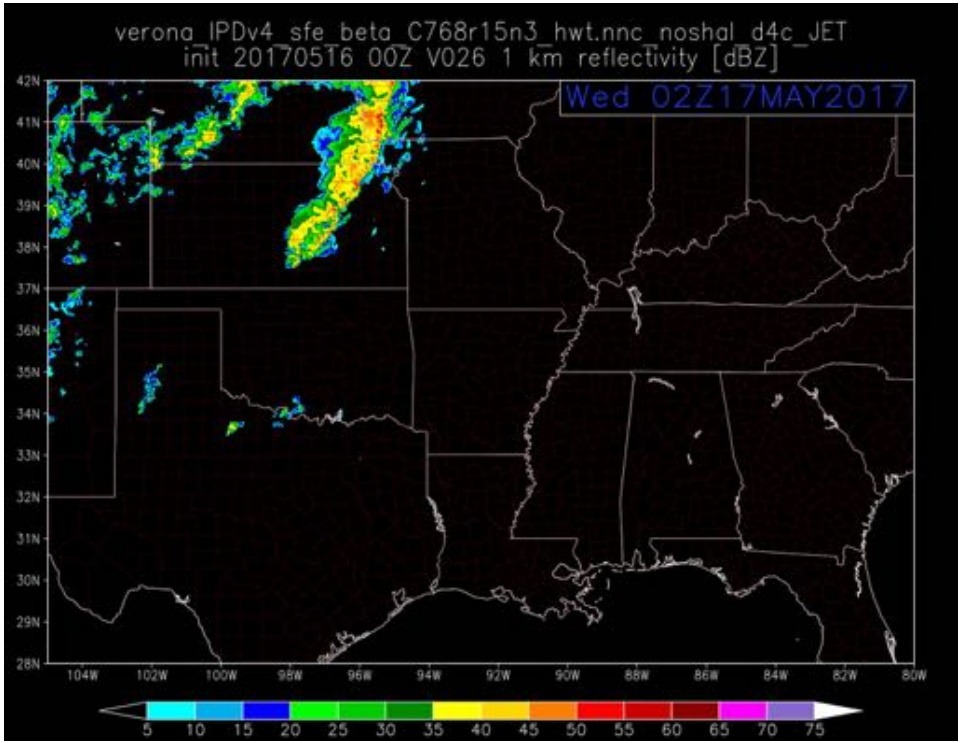
75

Radar Mosaic: 2017/05/17 00:00 UTC
200km
100mi


verona_IPDv4_sfe_beta_C768r15n3_hwt.nnc_noshal_d4c_JET
init 20170516 00Z V026 1 km reflectivity [dBZ]
Wed 02Z17MAY2017
42N
41N
40N
39N
38N
37N
36N
35N
34N
33N
32N
31N
30N
29N
28N
104W
102W
100W
98W
96W
94W
92W
90W
88W
86W
84W
82W
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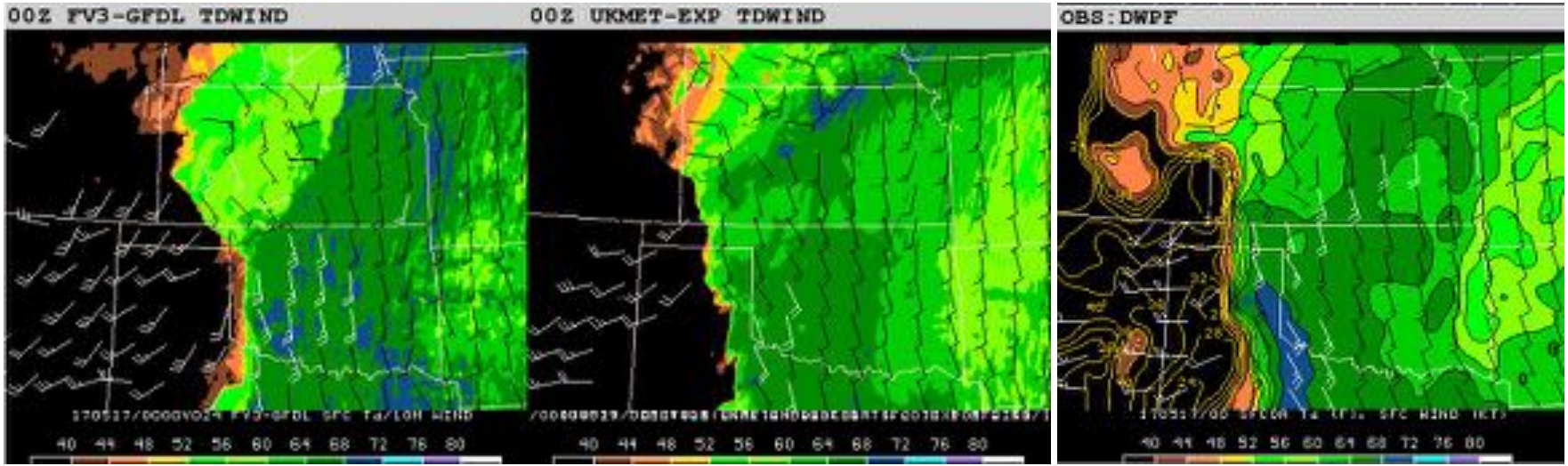
Radar Mosaic: 2017/05/17 02:00 UTC
200km
100mi



Dryline erodes very quickly in fvGFS.
Likely a deficiency in PBL scheme.

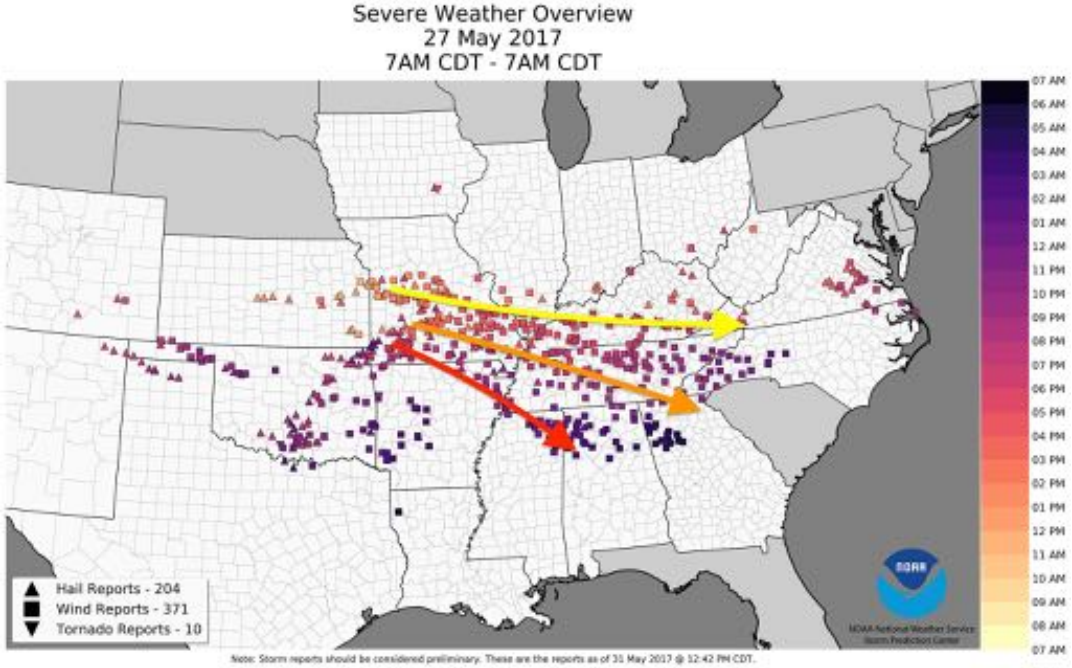
NASA GEOS-5 at C3072 (*Global* 3-km)

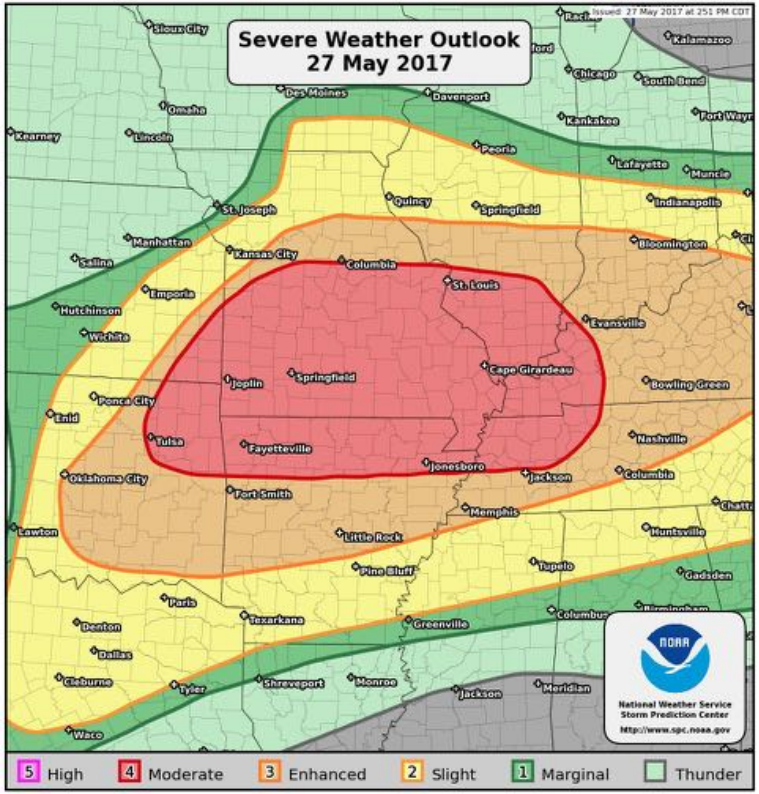
GEOS-5: NASA's FV^3-powered weather & climate model

UKMO Lock (conv)
& EC Louis (stable) PBL
Bacmeister MP

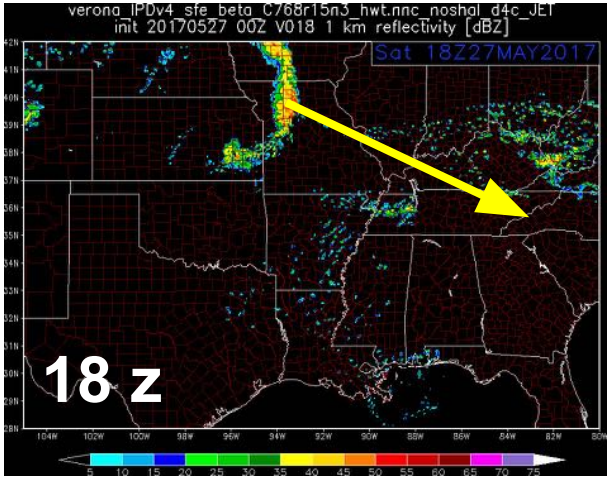
(click for animation)

27 May
Triple Derecho





SPC 26 May Day 2 outlook:
“Some high-res solutions show two bowing line segments moving east-southeastward across the enhanced risk area...This environment should support a wind-damage threat with multicell line segments that can become organized.”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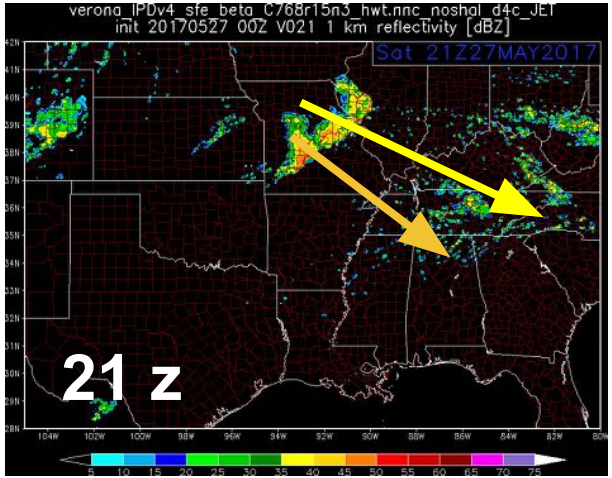
init 20170527 00Z V018 1 km reflectivity [dBZ]
Sat 18Z27MAY2017
18 z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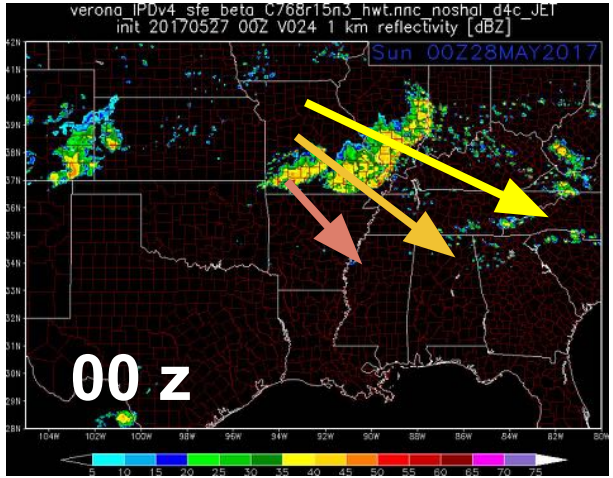
init 20170527 00Z V021 1 km reflectivity [dBZ]
Sat 21Z27MAY2017
21 z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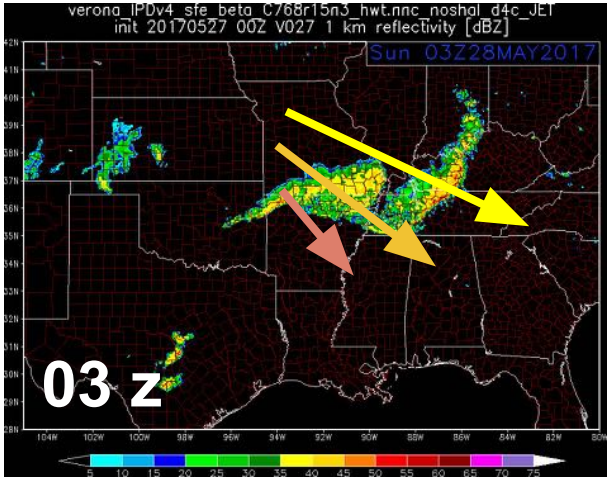
init 20170527 00Z V024 1 km reflectivity [dBZ]
Sun 00Z28MAY2017
00 z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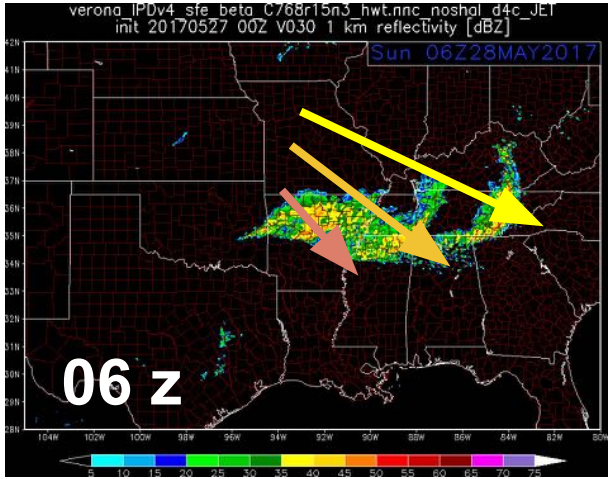
init 20170527 00Z V027 1 km reflectivity [dBZ]
Sun 03Z28MAY2017
03 z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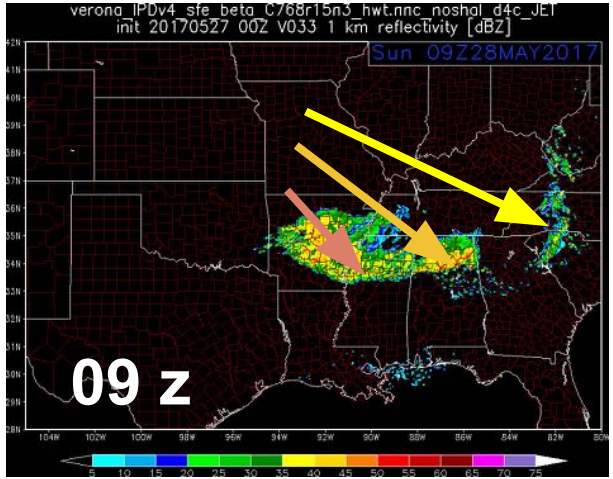
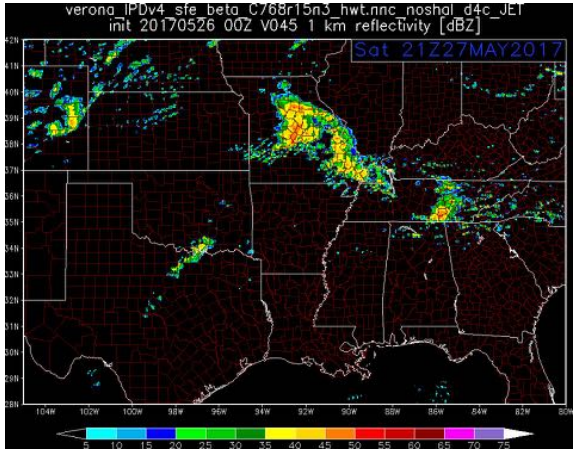
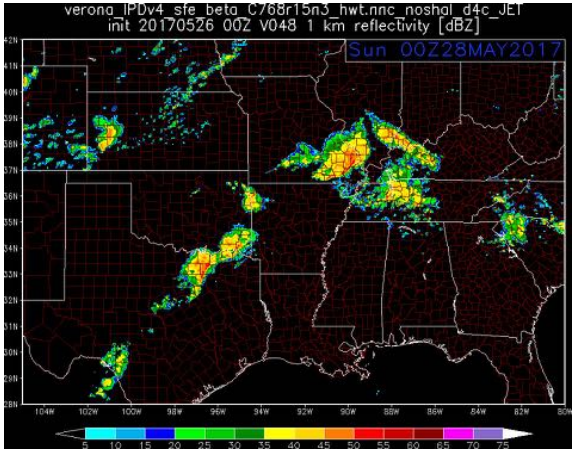
init 20170527 00Z V030 1 km reflectivity [dBZ]
Sun 06Z28MAY2017
06 z


verona_IPDv4_sfe_beta_C768r15n3_hwt.nnc_noshgl_d4c_JET
init 20170527 00Z V033 1 km reflectivity [dBZ]
Sun 09Z28MAY2017
09 z

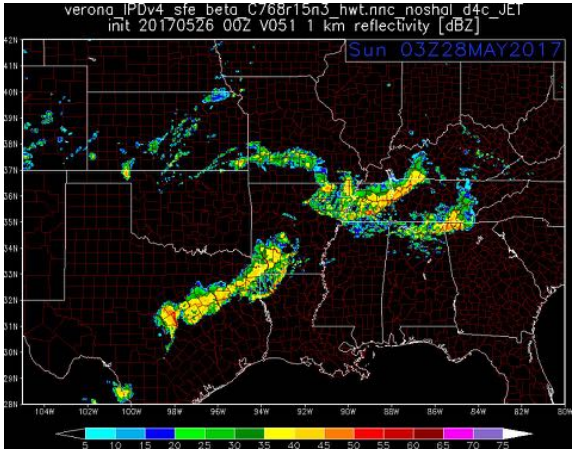
+45 hr Init 0526



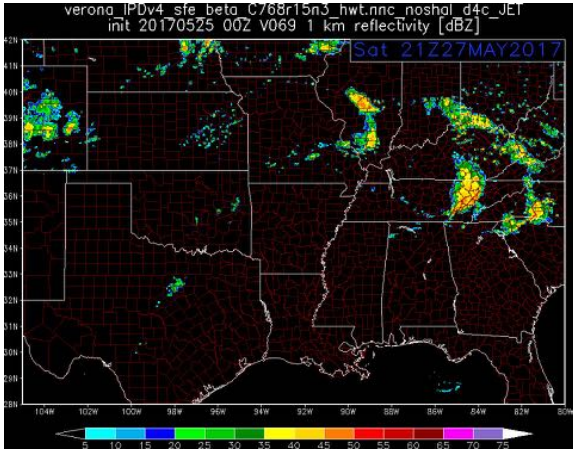
+48 hr Init 0526



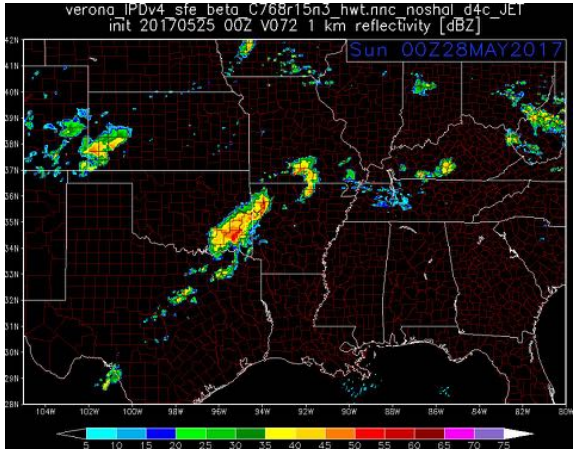
+51 hr Init 0526



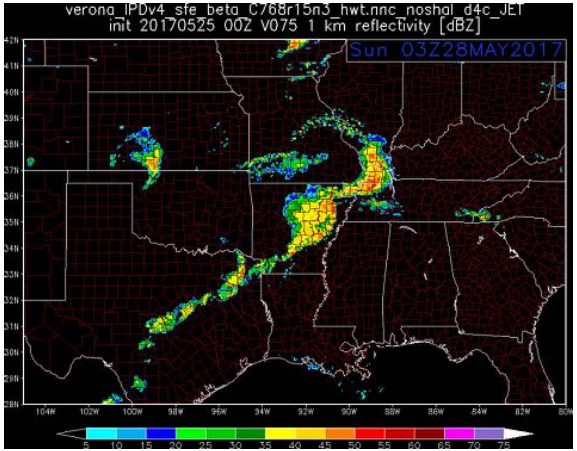
+69 hr Init 0525



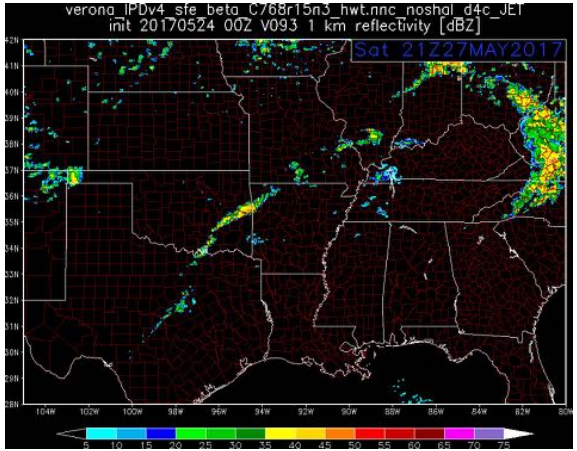
+72 hr Init 0525



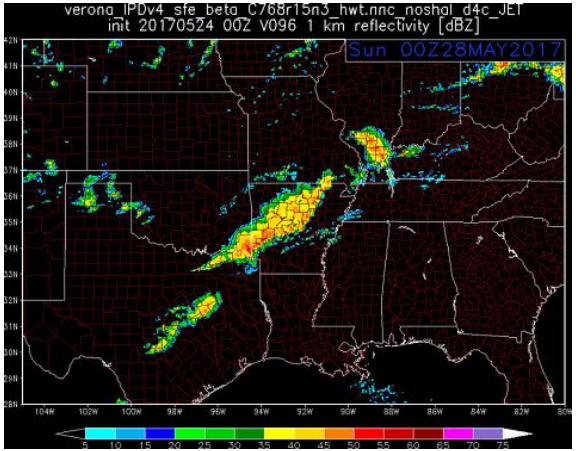
+75 hr Init 0525



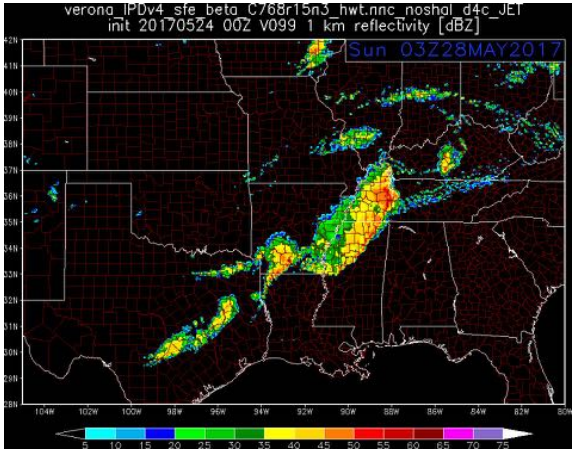
+93 hr Init 0524



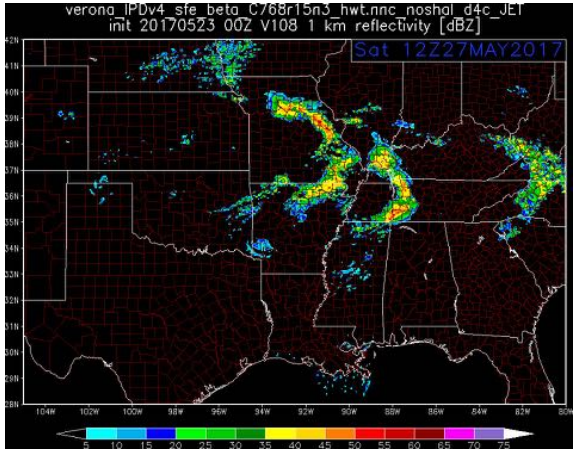
+96 hr Init 0524



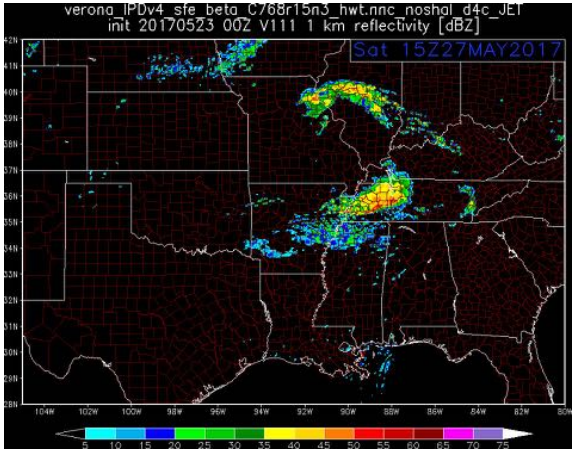
+99 hr Init 0524



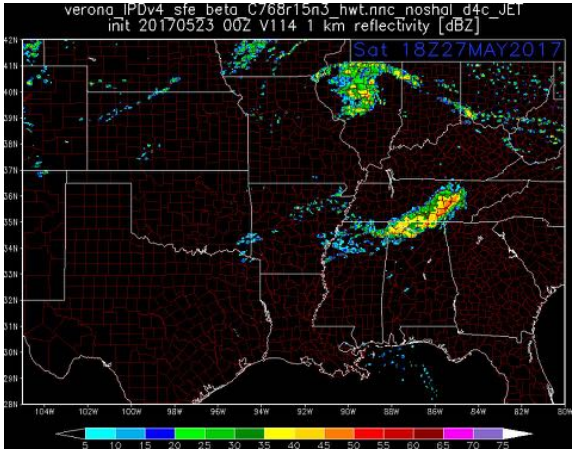
+108 hr Init 0523



+111 hr Init 0523



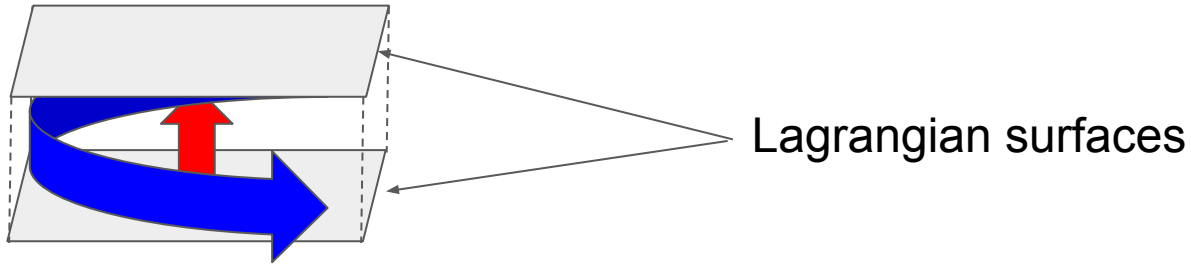
+114 hr Init 0523



Updraft Helicity in FV^3

FV^3 design is *optimal* for representing Updraft Helicity

Vertical vorticity and ***vertical wind*** are co-located
as “vertically Lagrangian” Finite-Volume mean



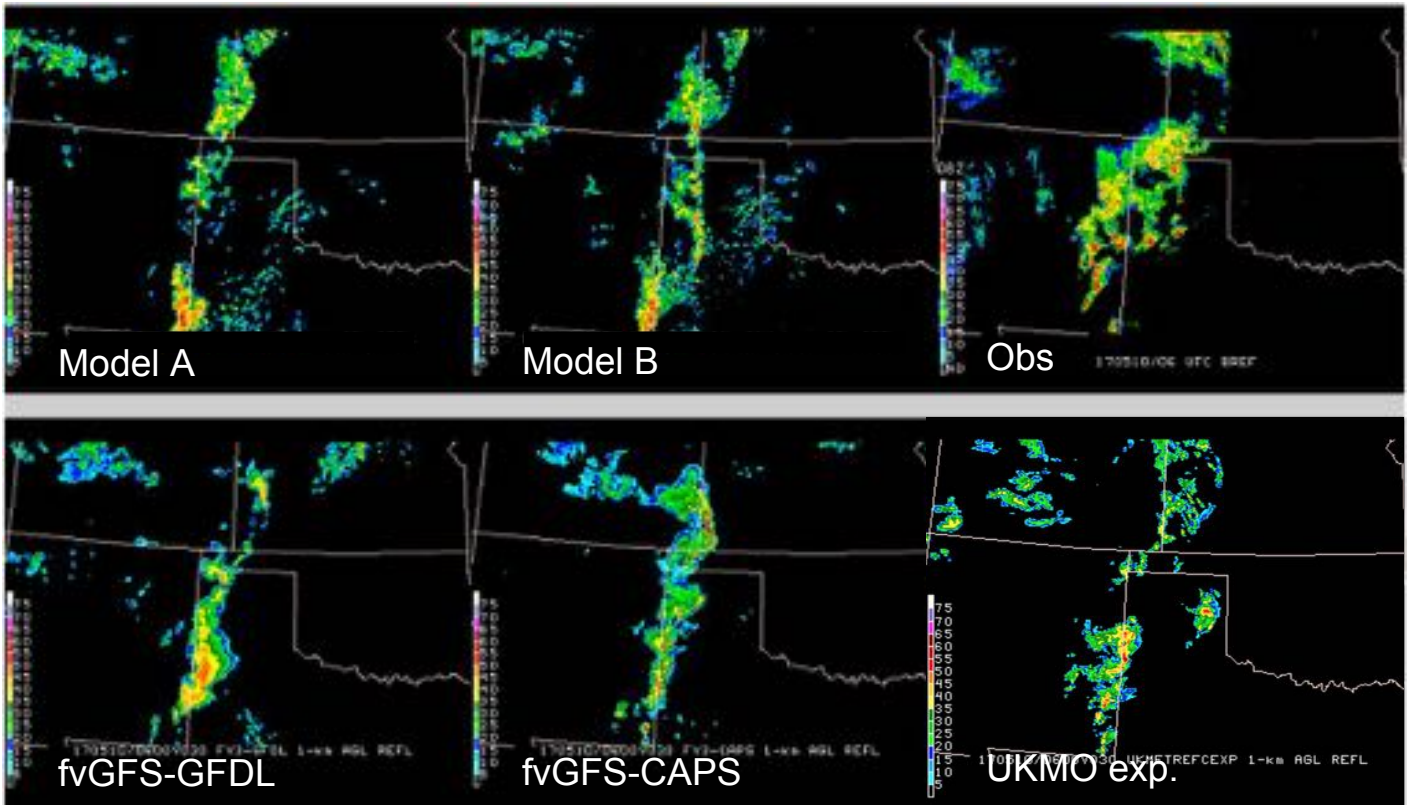
The Lagrangian control-volume is bounded vertically by Lagrangian surfaces

Vertical wind is defined as volume-mean with edge values computed by a conservative cubic-spline reconstruction

Vertical component of vorticity is also volume-mean by Stokes’ theorem

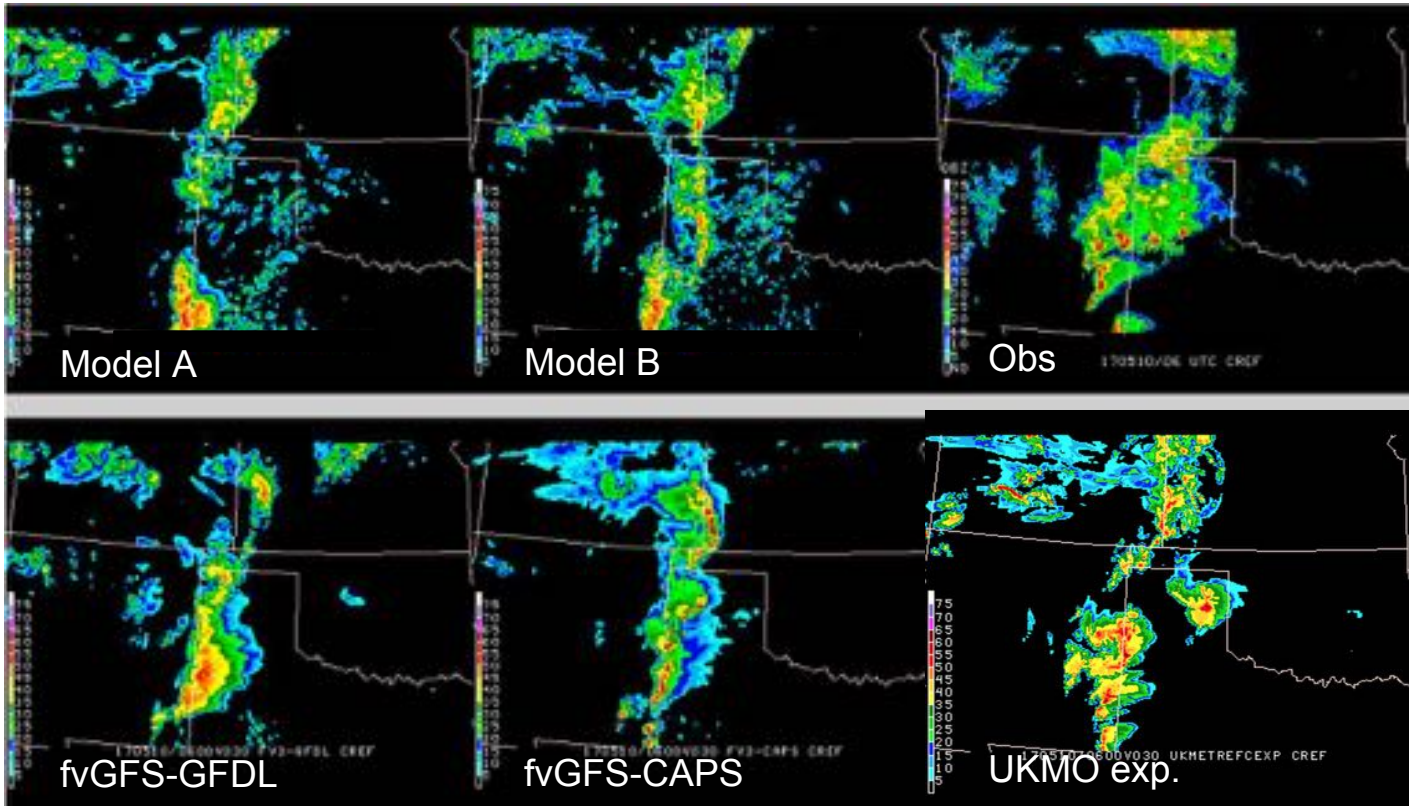
Base Reflectivity

+30 hr, init 00z 0509



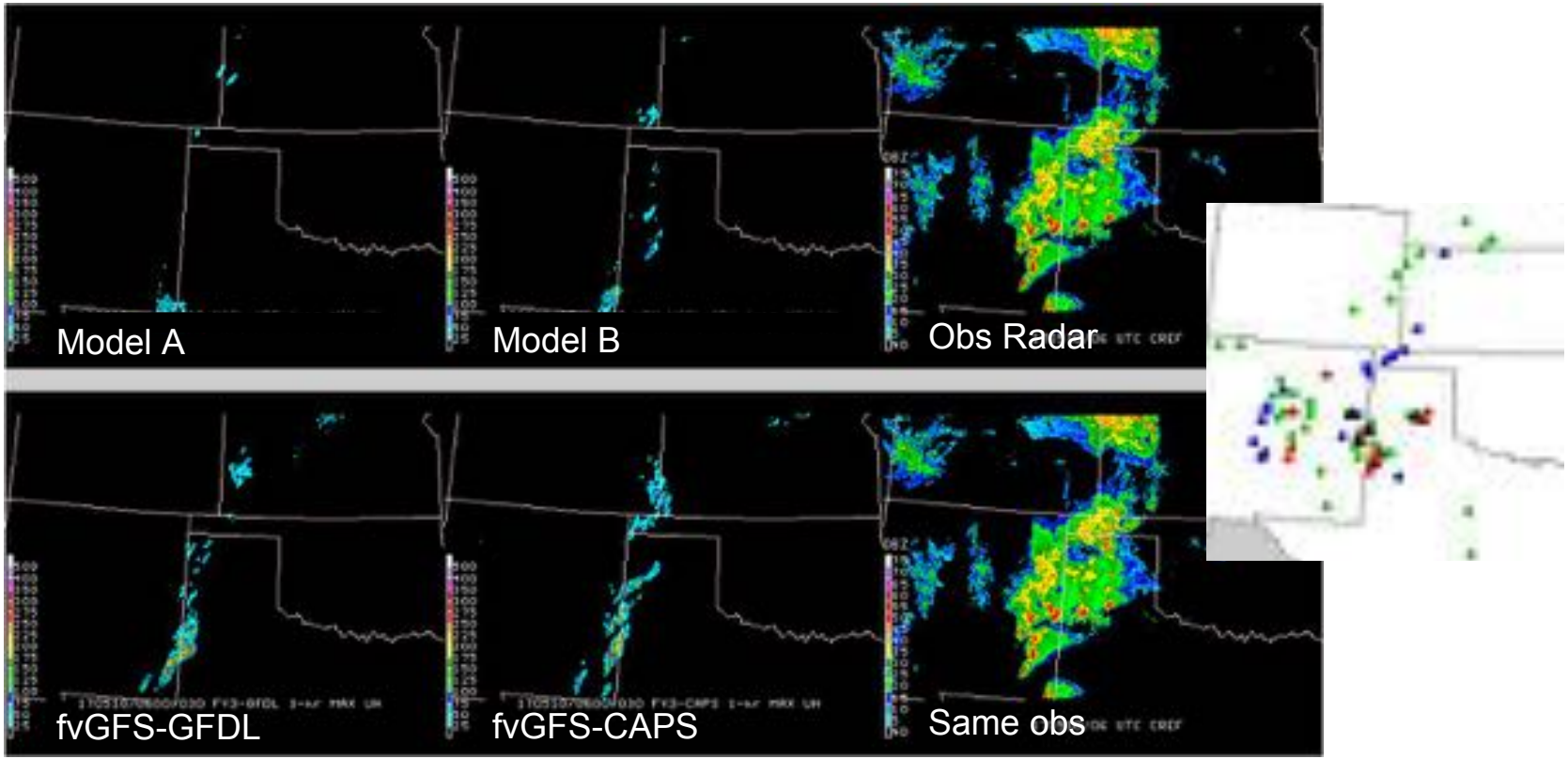
Composite reflectivity

+30 hr, init 00z 0509

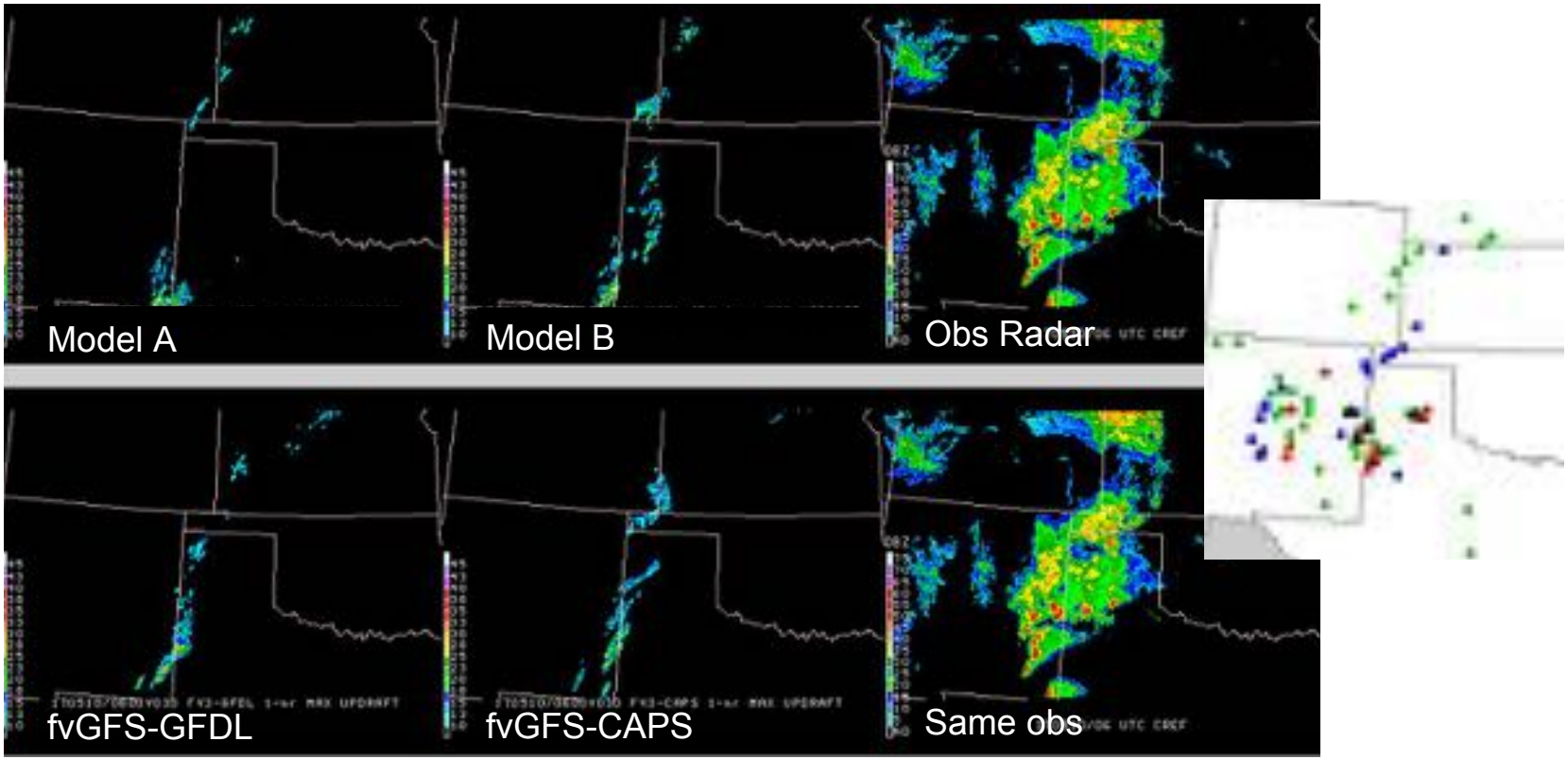


Hourly-max 2–5 km Updraft Helicity

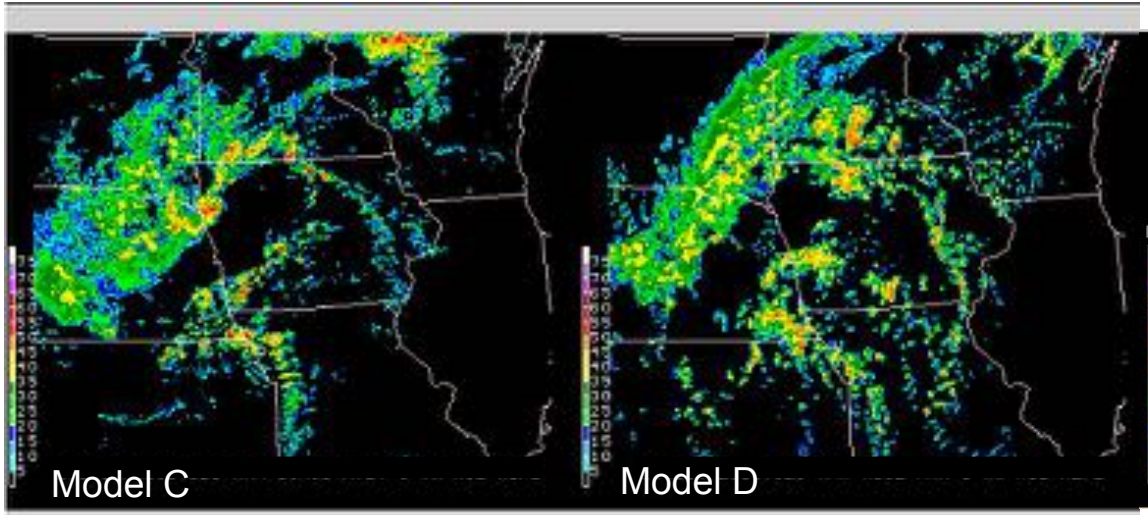
+30 hr, init 00z 0509

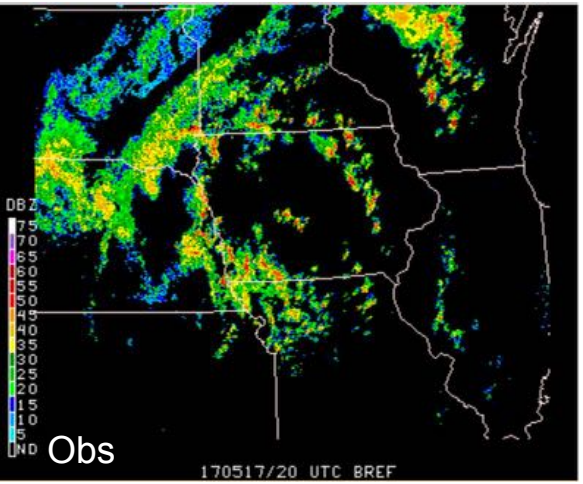


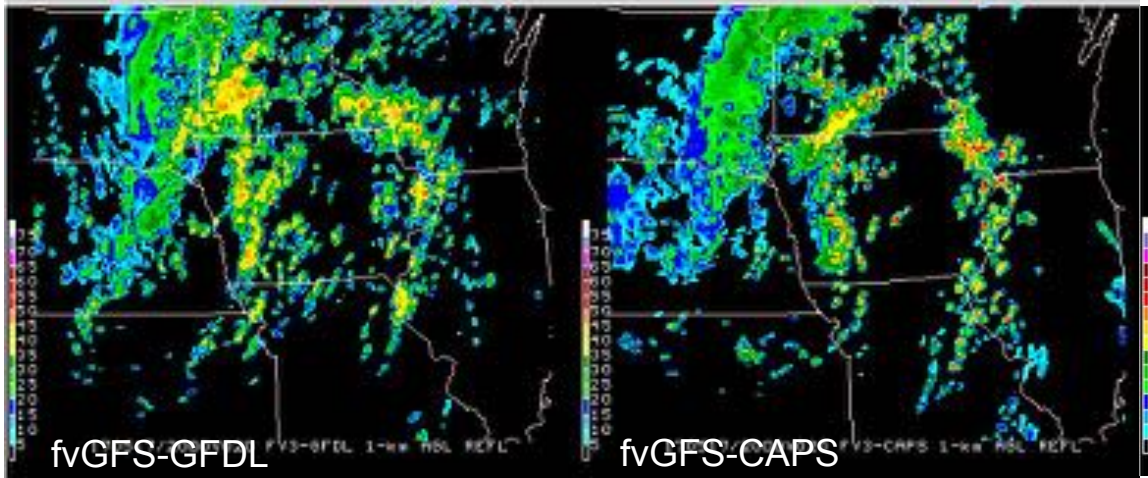
Hourly- and column-maximum updraft +30 hr, init 00z 0509

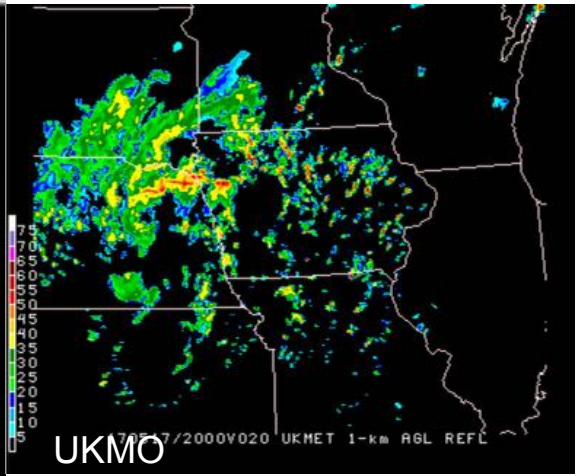


Base Refl. +20 hr init 00z 0517

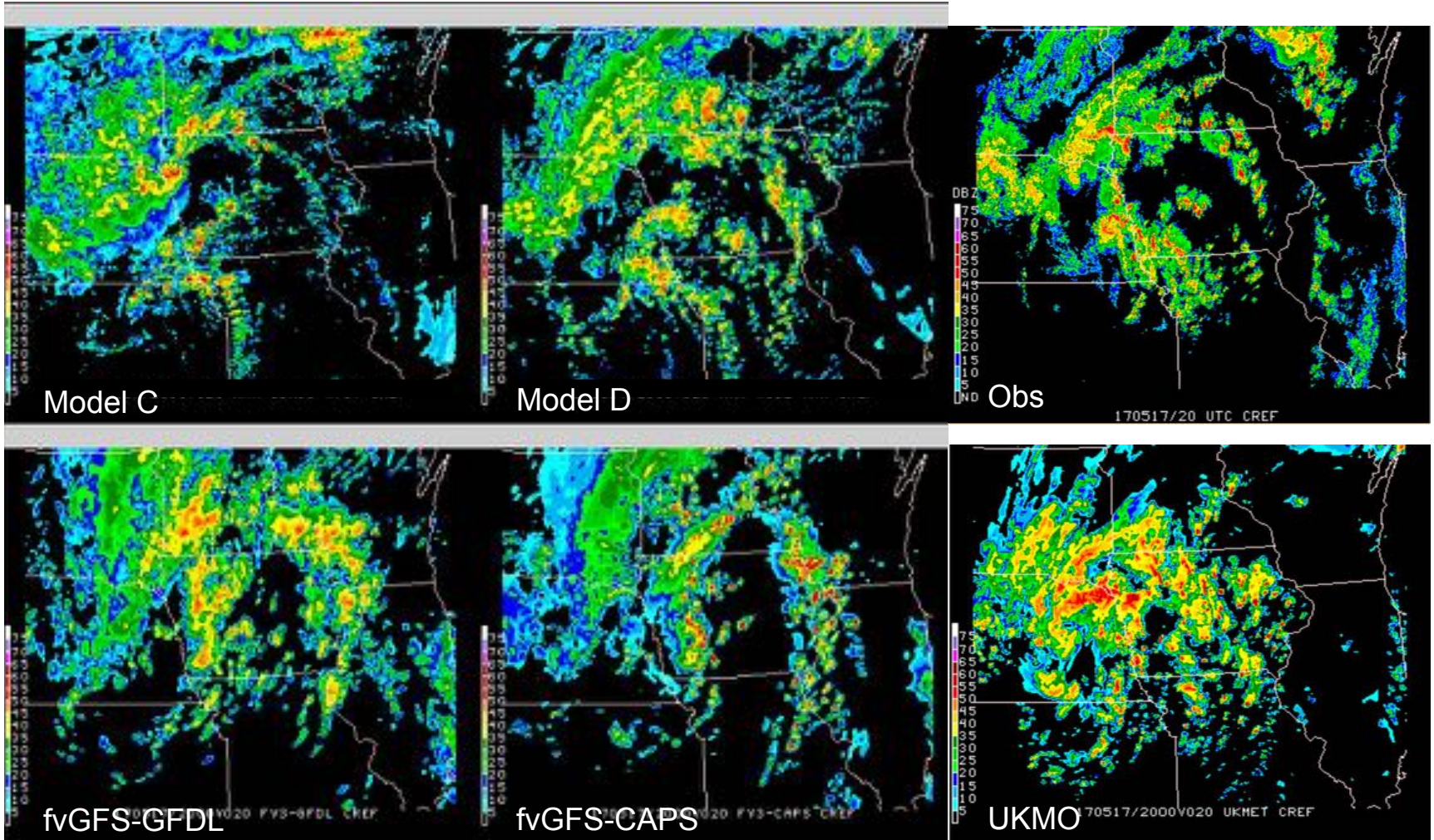




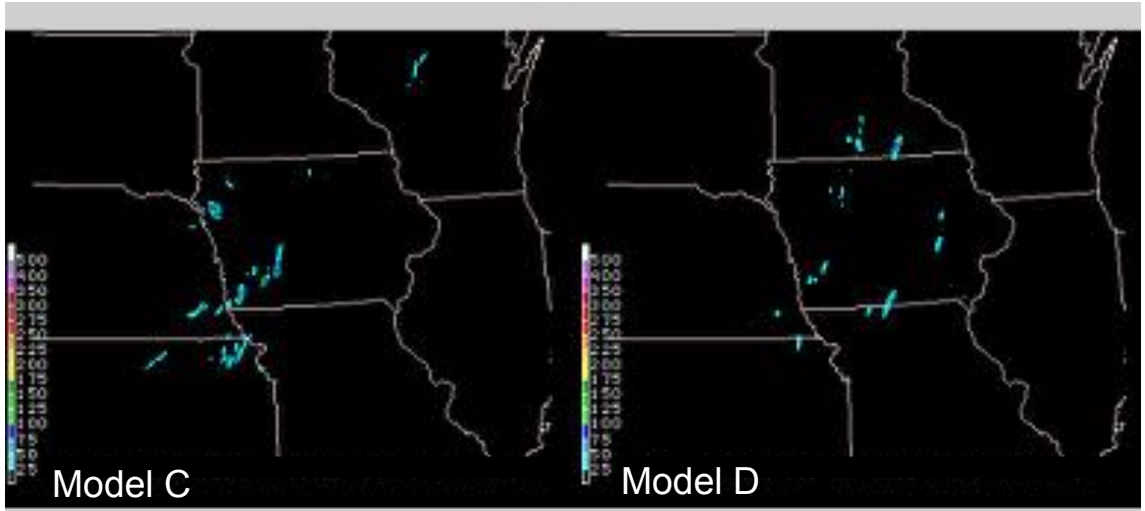


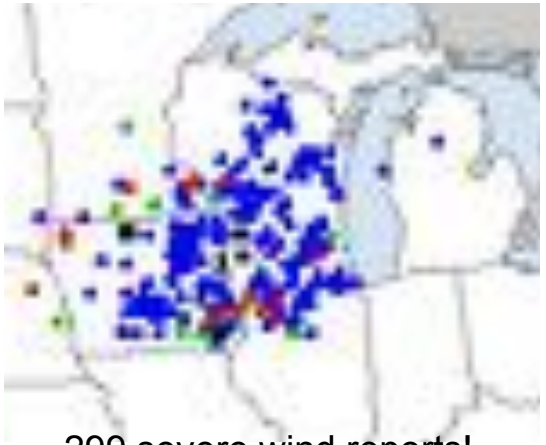


Composite Refl. +20 hr init 00z 0517

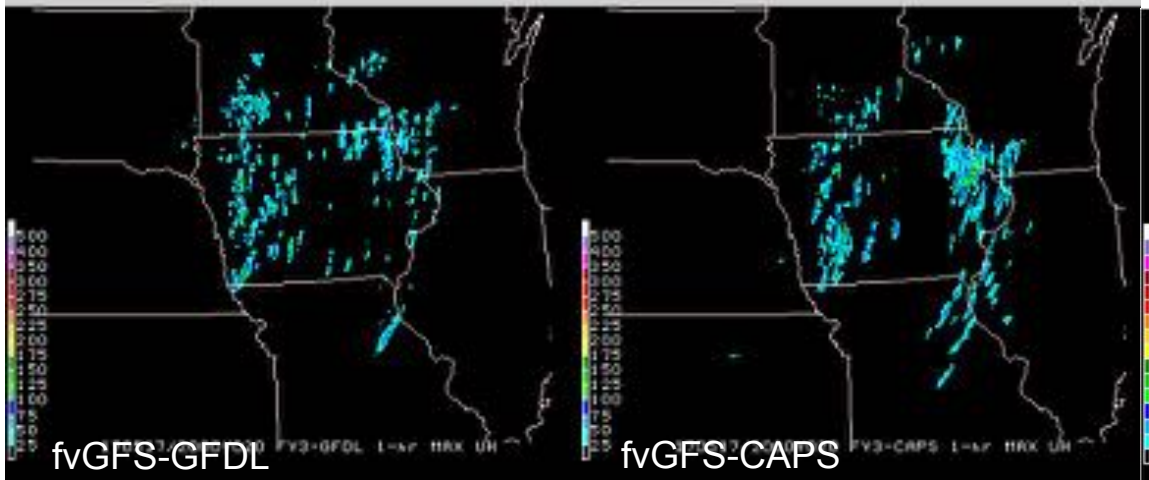


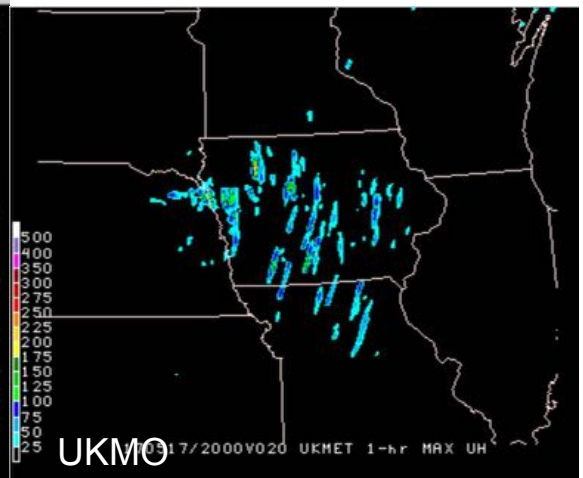
Hourly max 2–5 km UH +20 hr init 00z 0517



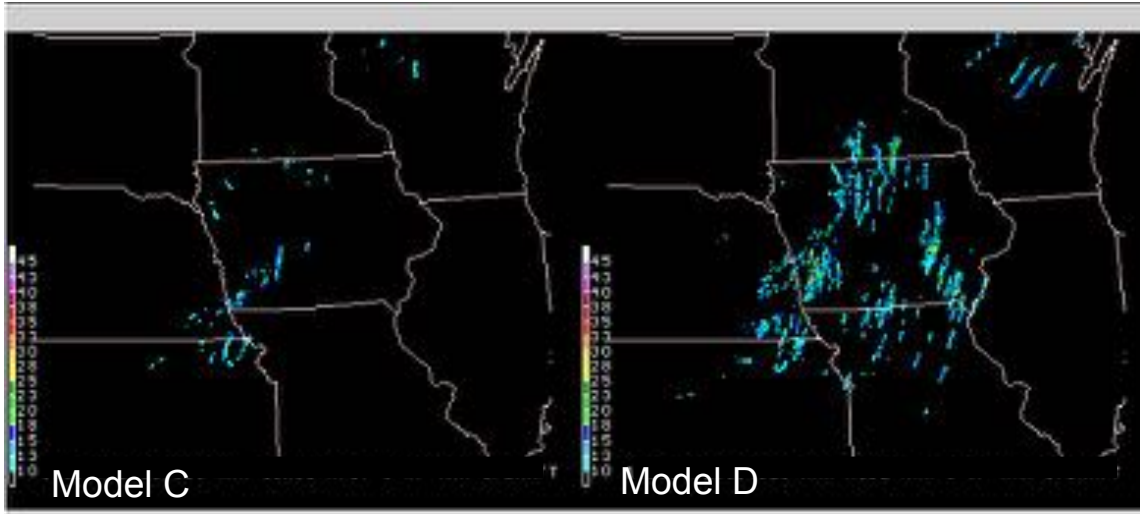


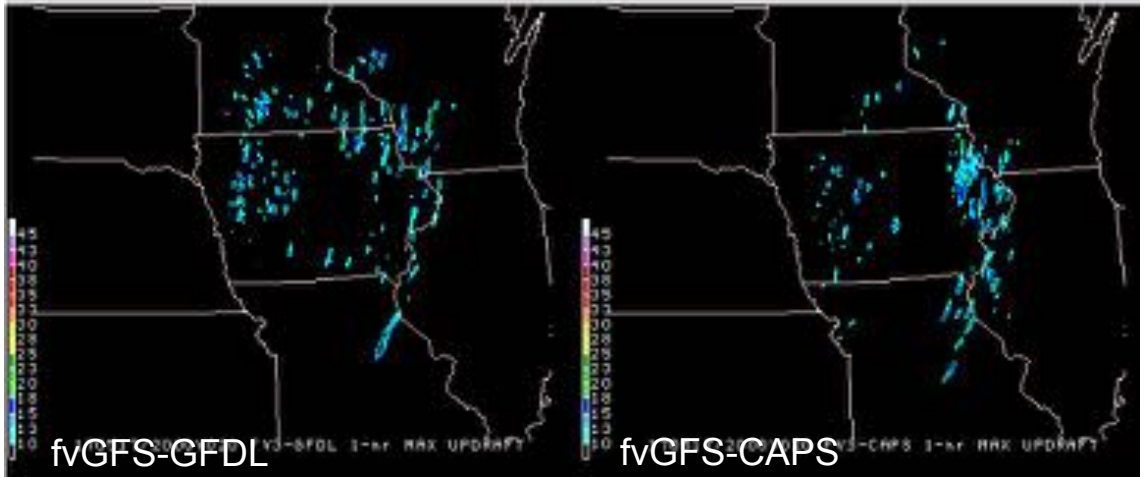
299 severe wind reports!





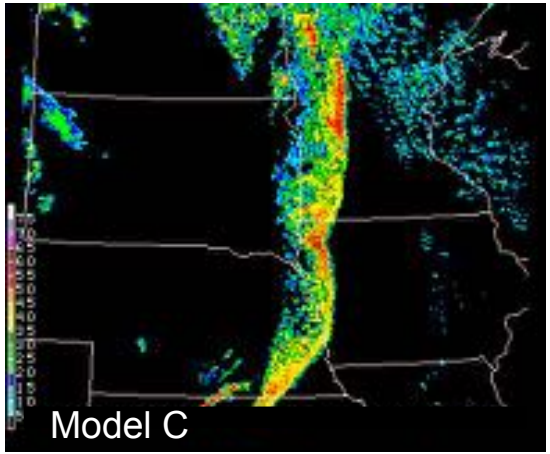
Hourly max 2–5 km updraft +20 hr init 00z 0517

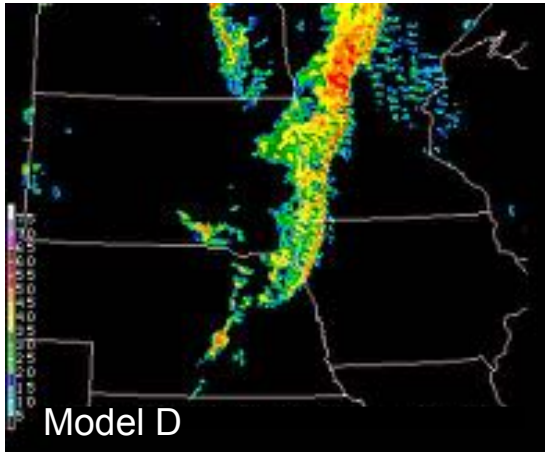




Base Reflectivity

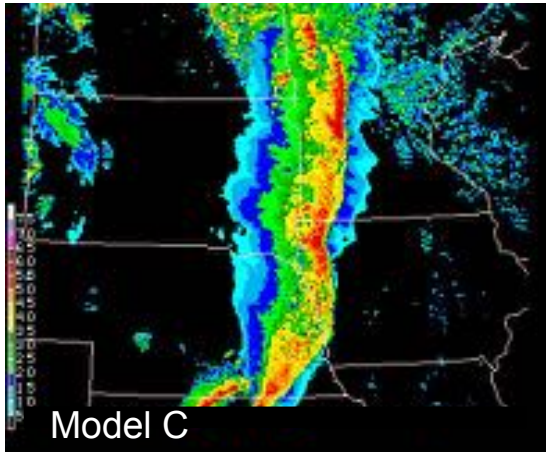
+26 hr, init 00z 0613

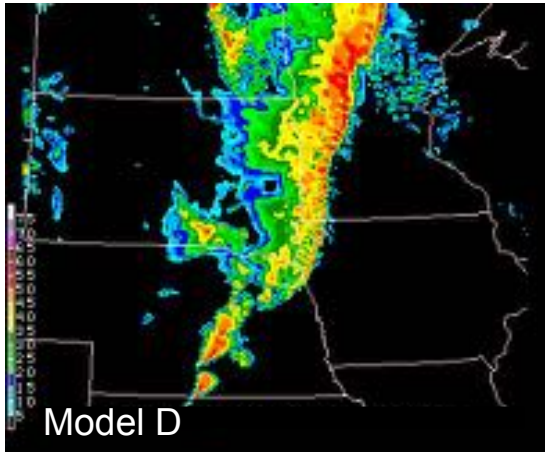




Composite Reflectivity

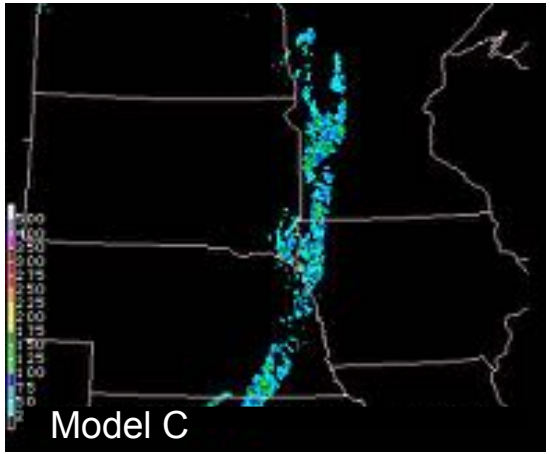
+26 hr, init 00z 0613

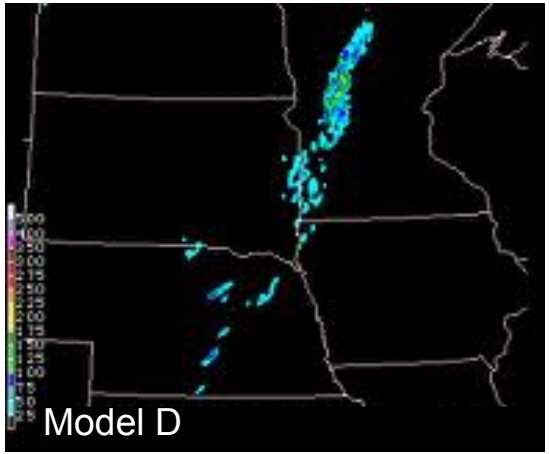


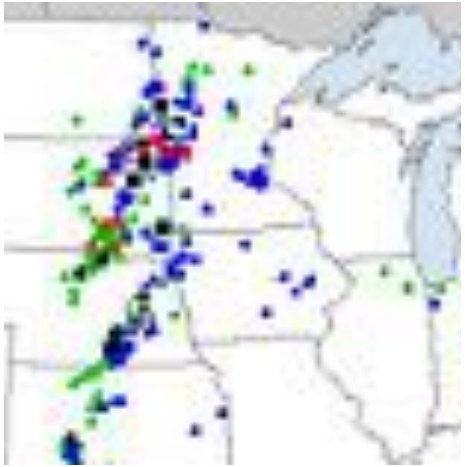


Hour-max 2–5 km UH

+26 hr, init 00z 0613

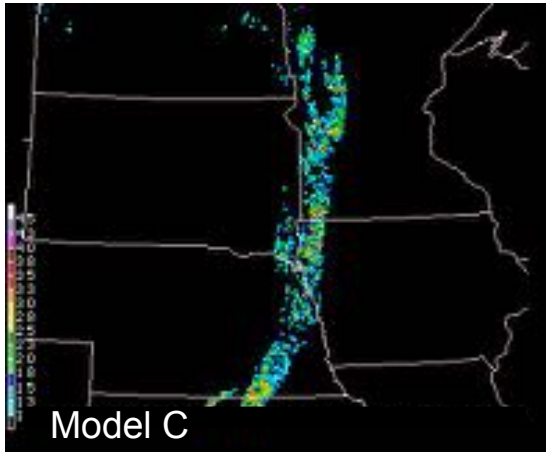


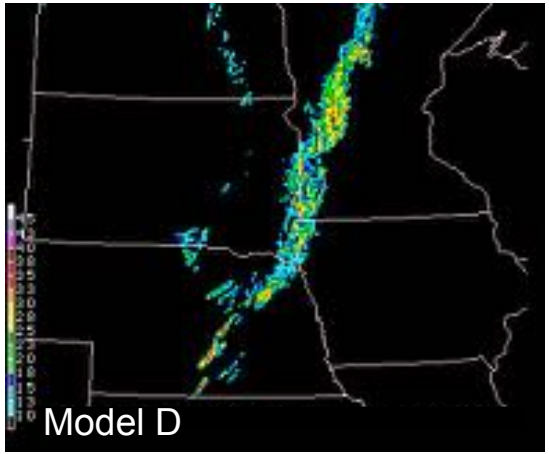




Hour-max updraft

+26 hr, init 00z 0613





GFDL MP: reflectivities are biased low.

But precipitation rate, UH, and updraft velocity are not.

Towards a global-to-regional CRM

Building community collaborations: EMC, OU, AOML, NASA, and Penn State

Better PBL scheme a **must**; the GFS PBL is suboptimal for CONUS.
CAPS is implementing YSU PBL.

Thompson MP (fvGFS-CAPS) has beautiful, intense cores!
GFDL MP yields good stratiform regions but intensities need improving

Initialization: Radar & satellite DA work proposed by OU and Penn State for 2018

➔ fvGFS is a drastically new regional-global modeling system, which may require a drastically new DA strategy (**NoRUC**, a **N**est-**o**nly **R**apid **U**pdate **C**ycle)

Naive proposal for rapidly-updating multiple-cadence unified DA

All runs are unified two-way global-to-regional with at least one (CONUS) nest—both global and regional models stand to benefit

:00—:05 : Assimilate US radar (and satellite) in fvGFS once available
Begin nowcast-timescale global-to-CONUS-to-WoF run(s)

:05–:15 : Assimilate global satellite and surface obs data once available
Begin SREF/HREF-length global-to-CONUS runs

:15–:60 : Assimilate remaining slow global surface and radiosonde data
Begin medium-range/extended-range run

Towards new global *and* regional thinking

FV^3's variable-resolution capabilities creates possibilities for powerful new modeling techniques, and new challenges.

Global-to-regional unified/seamless modeling has great promise for extended-range explicit prediction of extreme weather, especially hurricanes

We must not be constrained to current limited-area thinking. We must take advantage of these new capabilities if US modeling is to be second-to-none.

How to design a model that does best at all scales?
Even at 3 km, global models raise problems not faced by CONUS modeling.

Think outside of the (limited-area) box.

Summary

"Suitability" of FV^3 for convective-scale forecasts has been demonstrated. Global-to-regional 2-way nesting maintains global skill while providing mesoscale and storm-scale detail

Current FV^3-based CRM is still primitive. Much much more work needs to be done, especially on the **physics** (cloud MP and PBL) and **DA** -- **these are areas where the community can make great contributions!**

fvGFS shown to mimic a regional model, using a refined global grid. This removes the need for BCs and is more efficient than some operational regional models

Unified model approach: systematic year-round evaluation will be crucial. **Cannot tune for just one season for only one type of events.** Must also consider TCs, winter storms, floods, etc.

Extended range prediction
10 May Storms

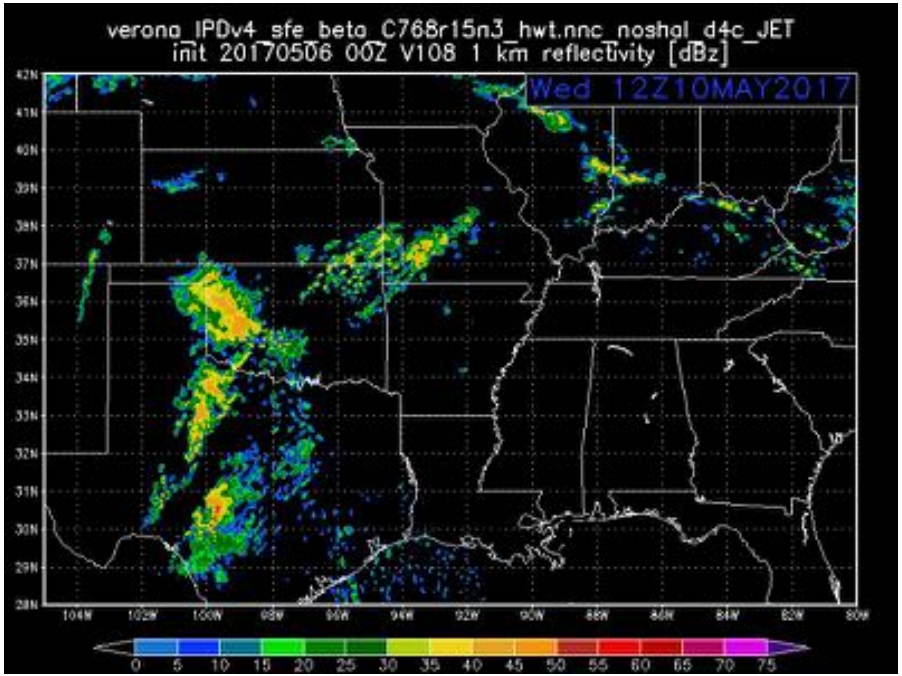
Radar validation

12UTC 10 May 2017

00 UTC 11 May 2017

Init 0506 00Z

12UTC 10 May 2017 +108h



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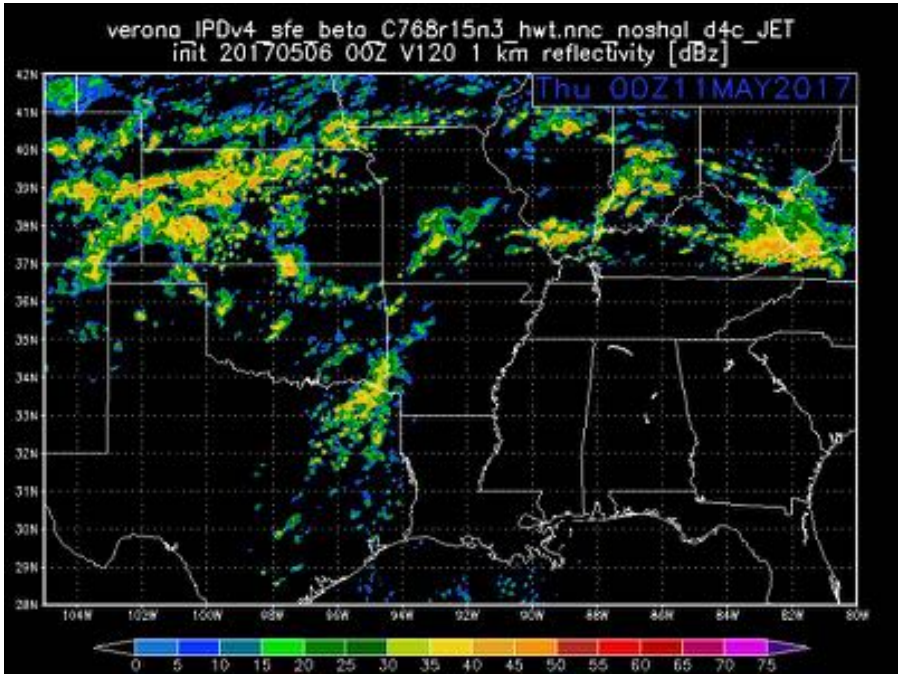

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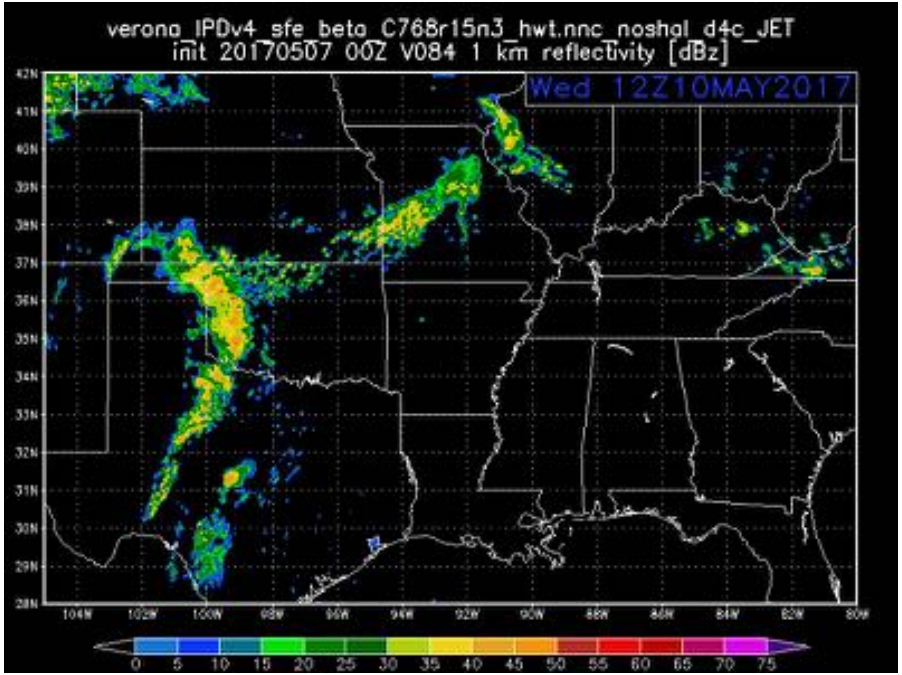

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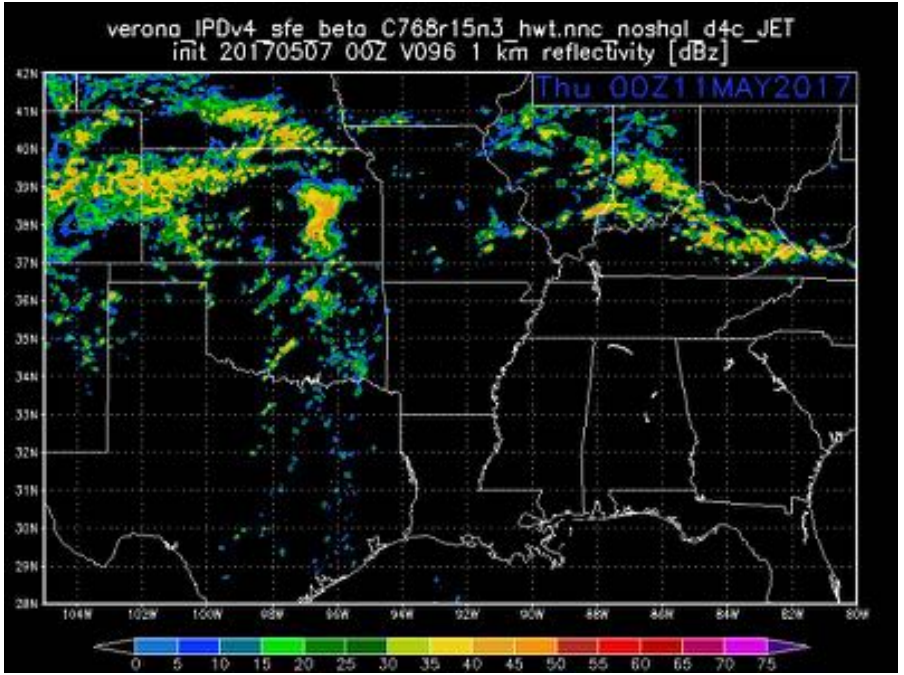

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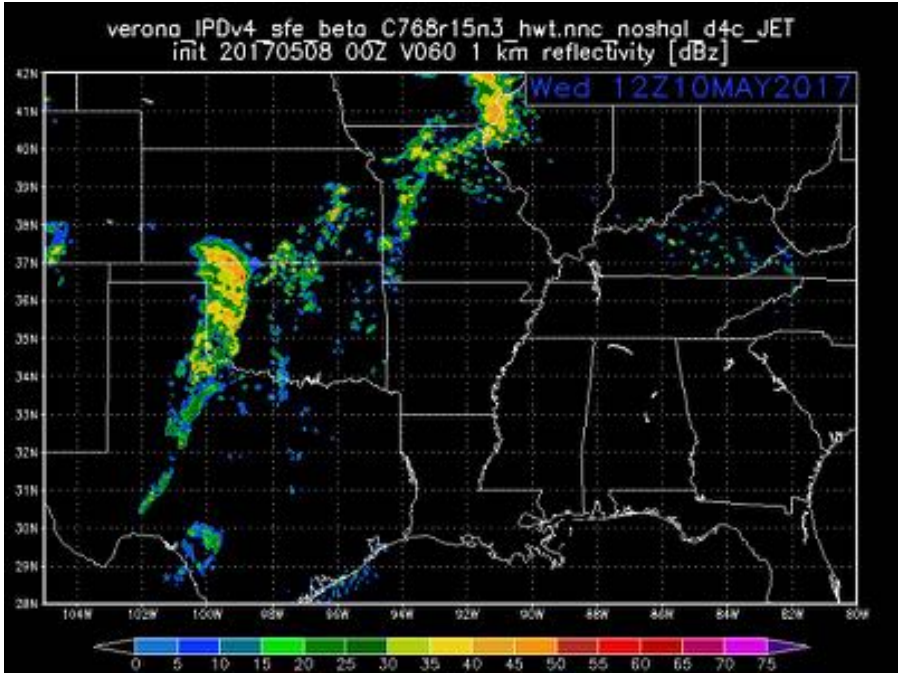

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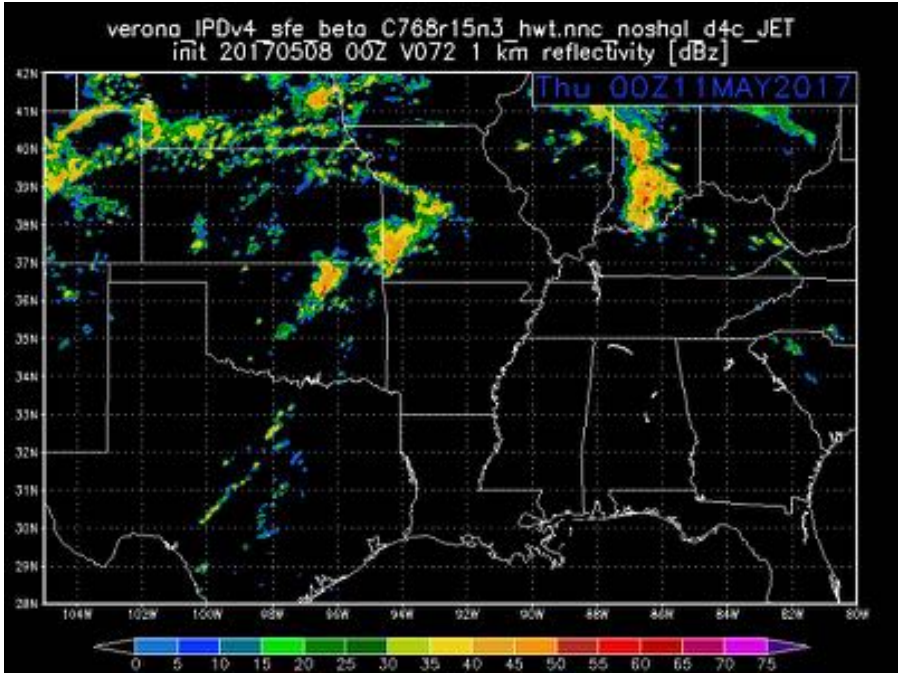

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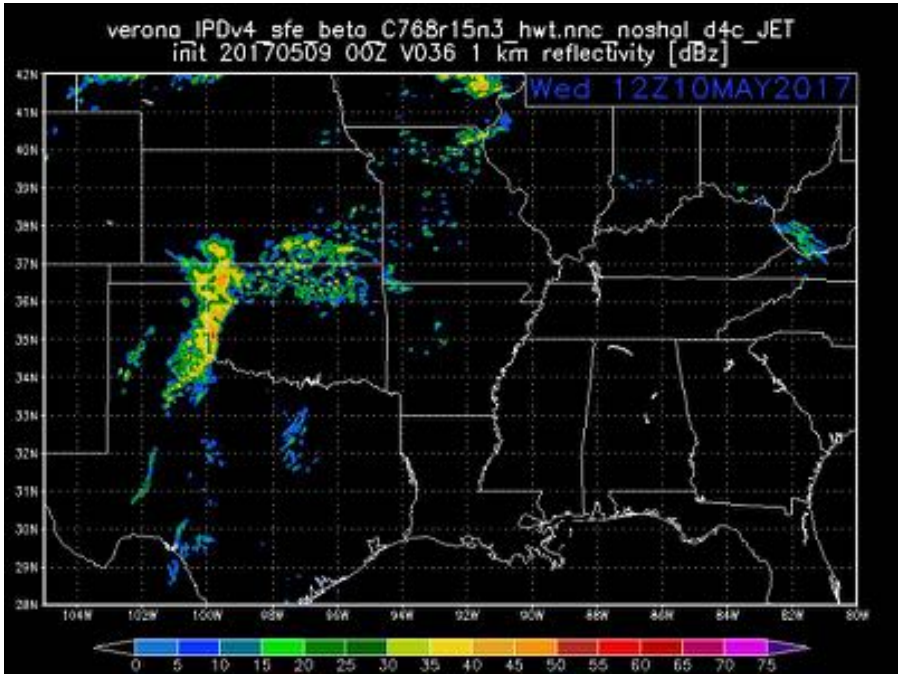
12UTC 10 May 2017 +036h



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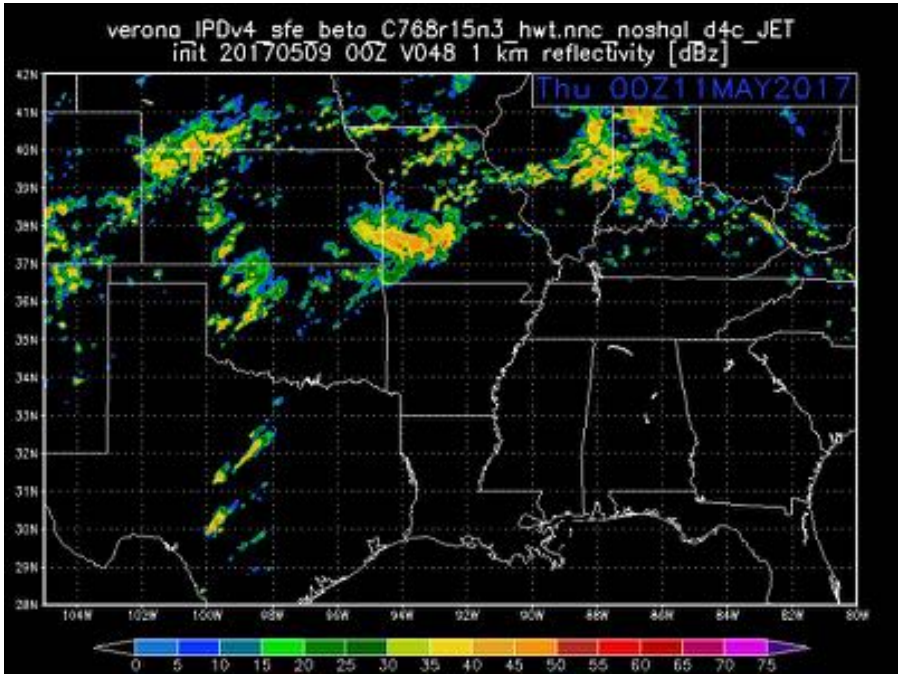

Init 0509 12Z

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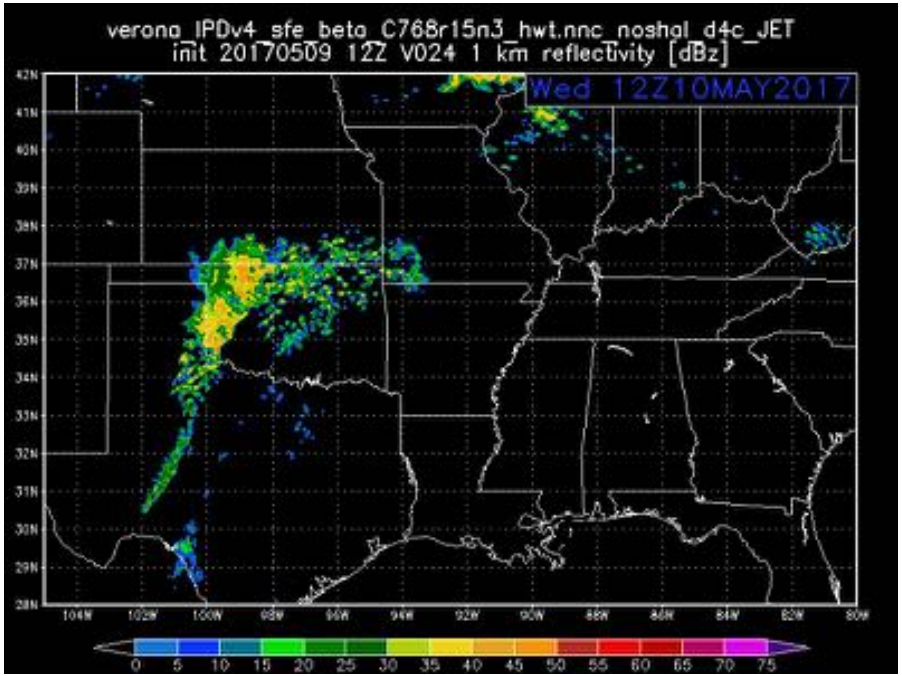

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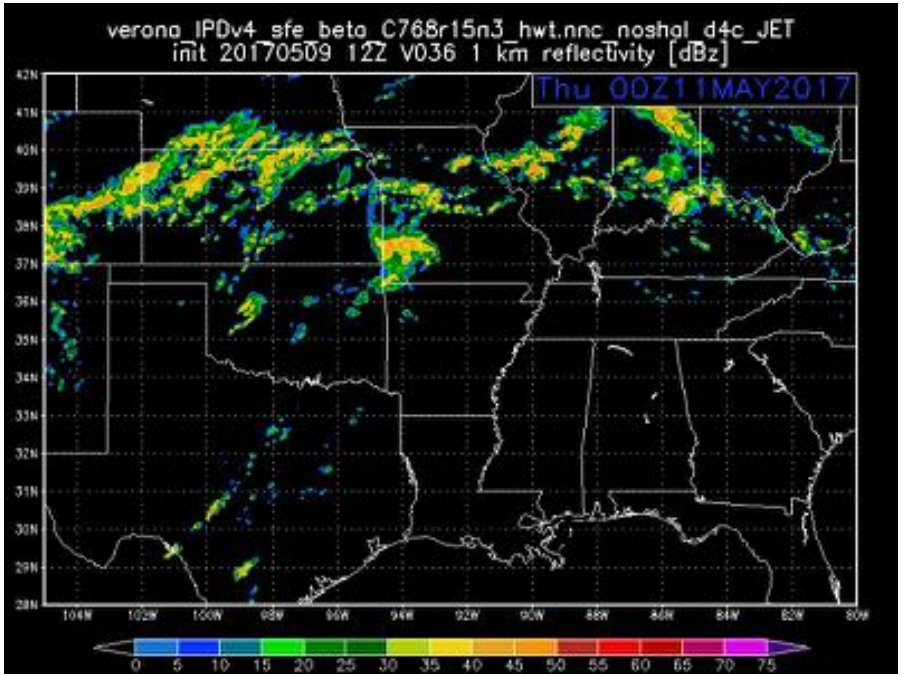

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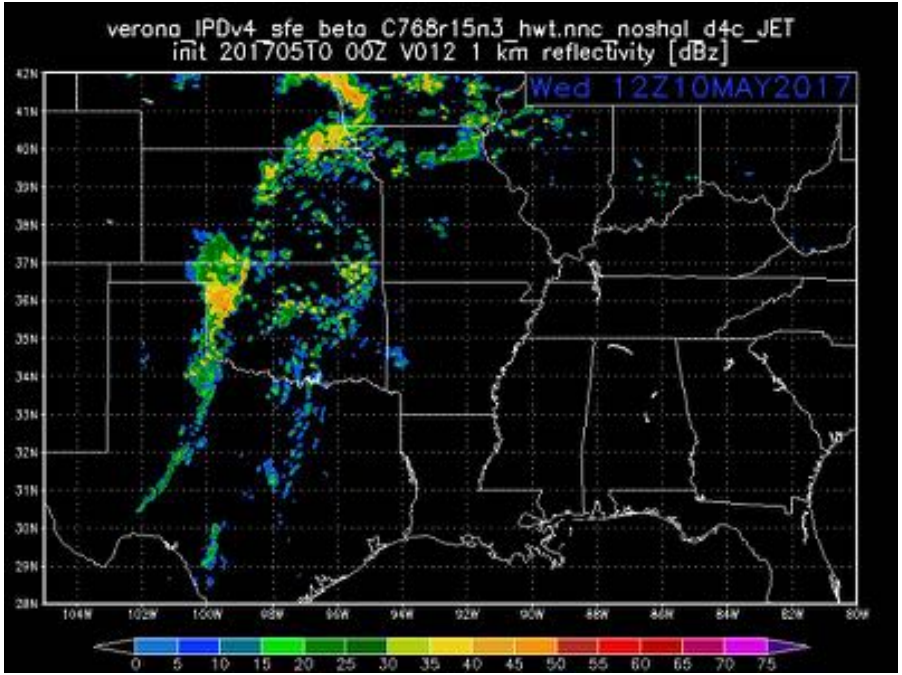

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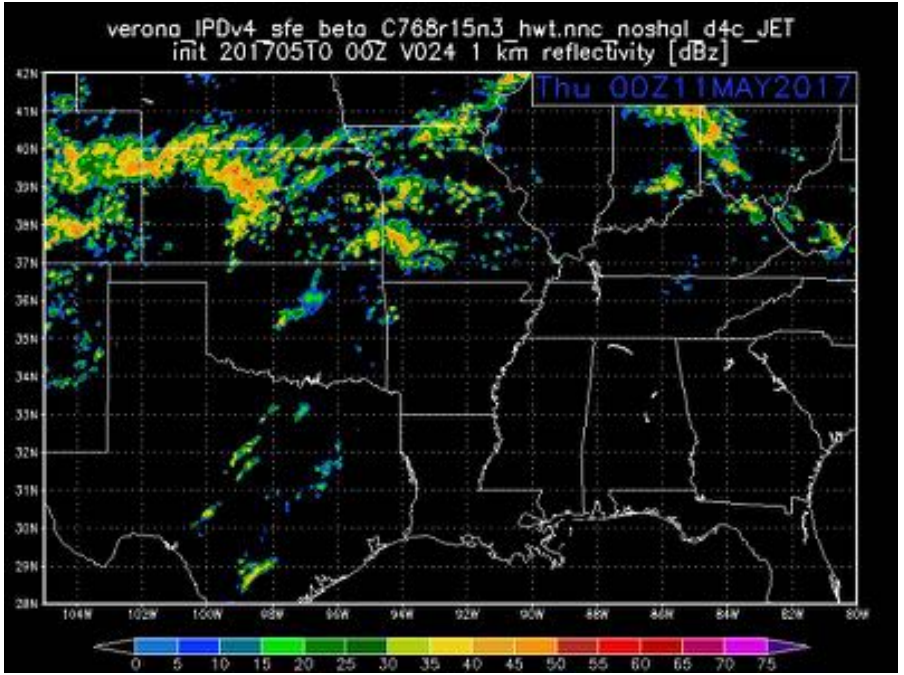
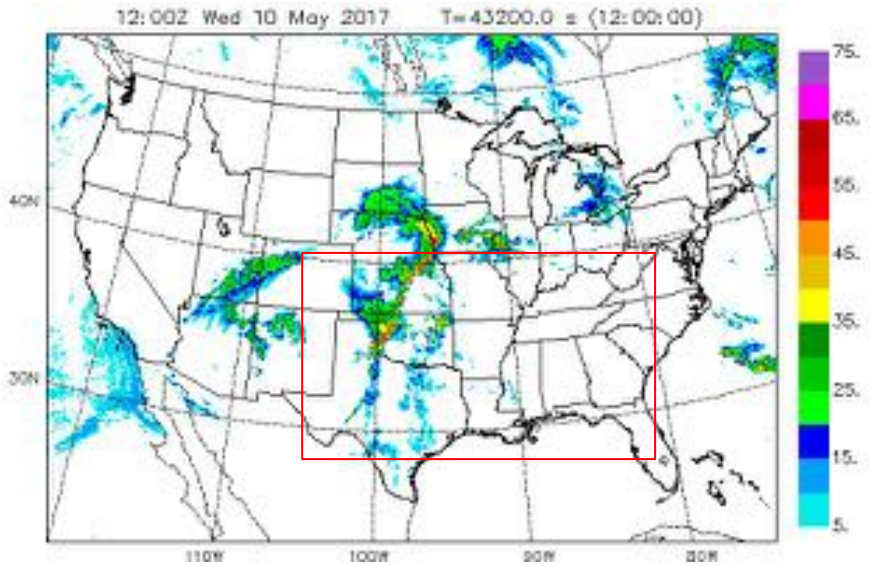
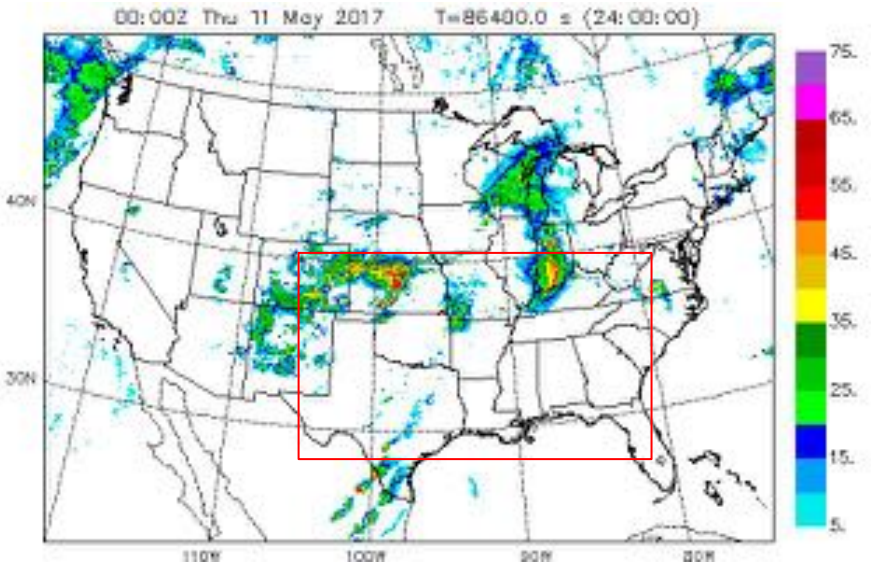


Composite Reflectivity from FV3-CAPS

Using Thompson MP: init 0510 00Z

12UTC 10 May 2017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