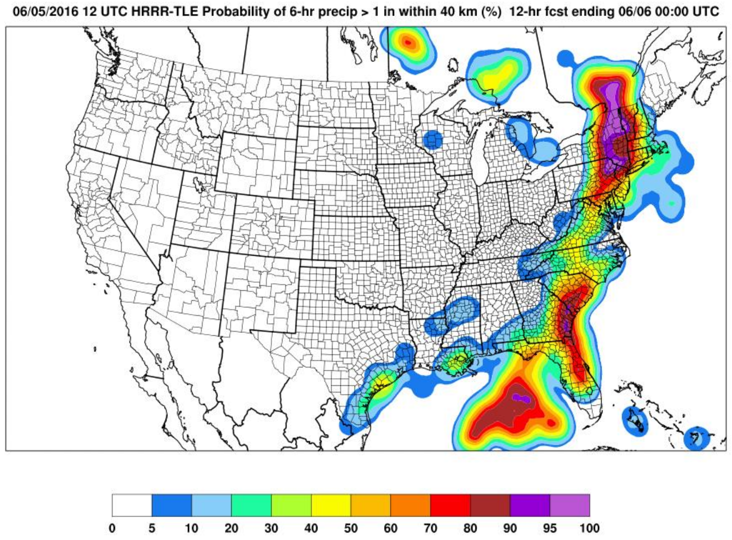
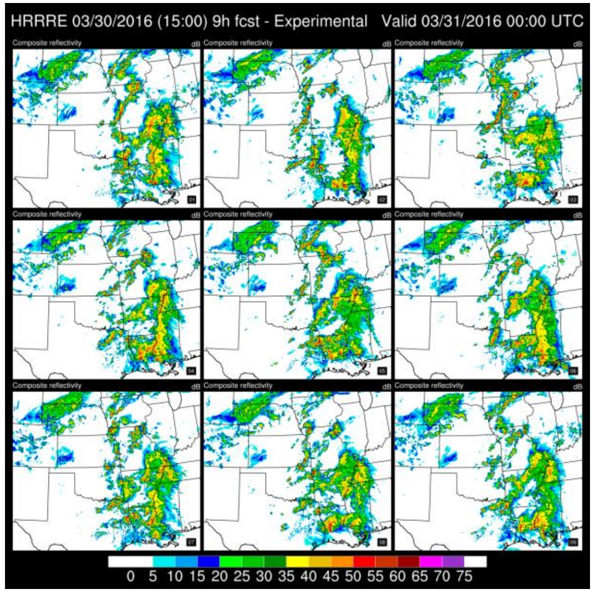
Experimental and operational RAP/HRRR forecasting of US / West Coast precipitation events



30 May 2017

Stan Benjamin, Curtis Alexander, David Dowell, Eric James, Trevor Alcott, Isidora Jankov, Terra Ladwig, Steve Weygandt, Jeff Hamilton, Georg Grell, and John Brown

Kelly Mahoney, Rob Cifelli - PSD



NOAA/ESRL/GLOBAL SYSTEMS DIVISION

RAP/HRRR: Hourly-Updating Weather Forecast Suite

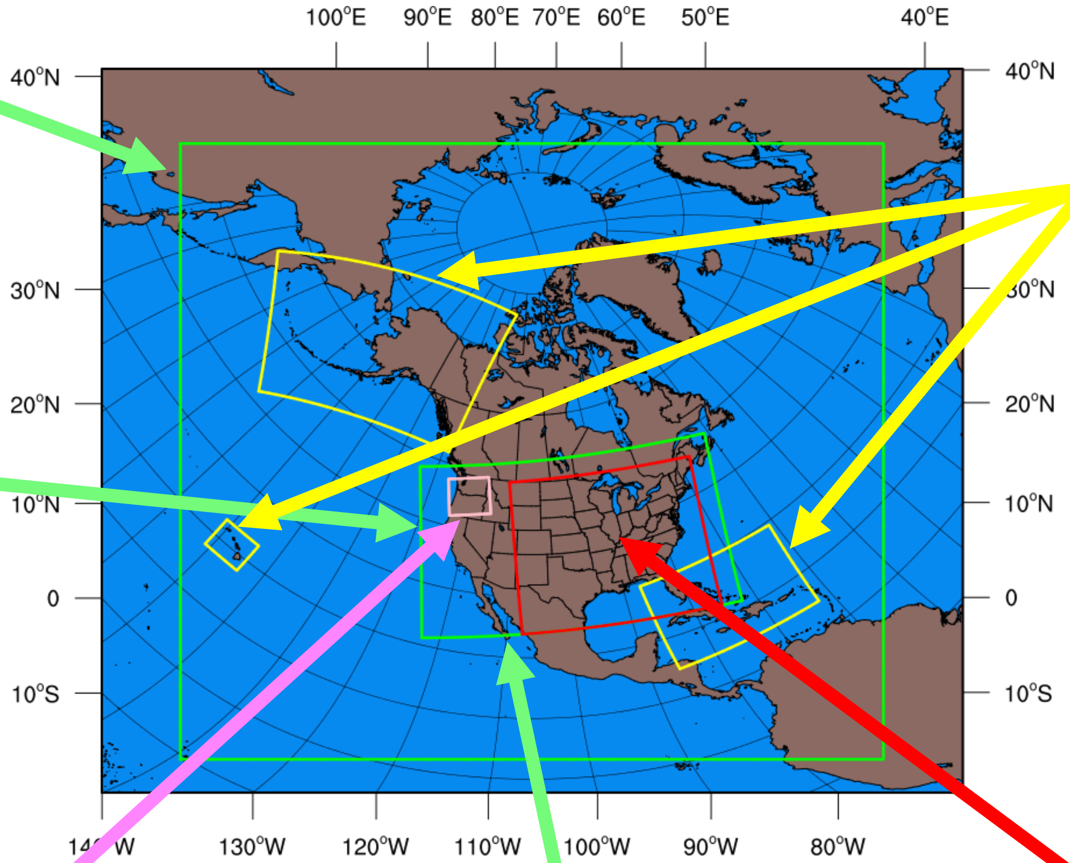
13-km Rapid Refresh (RAPv4) – to 39h (Feb 2018)

Initial & Lateral Boundary Conditions

3-km High-Resolution Rapid Refresh (HRRRv3) – to 36h (Feb 2018)

Initial & Lateral Boundary Conditions

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



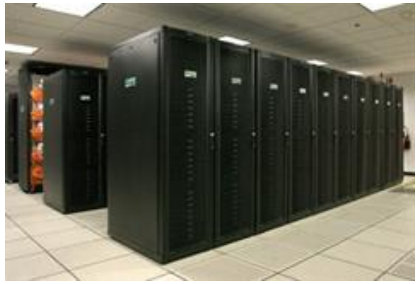
3-km High-Resolution Rapid Refresh Alaska, Hawaii and Puerto Rico Testing (HRRR-AK, HRRR-HI, HRRR-PR) Experimental (ongoing)

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

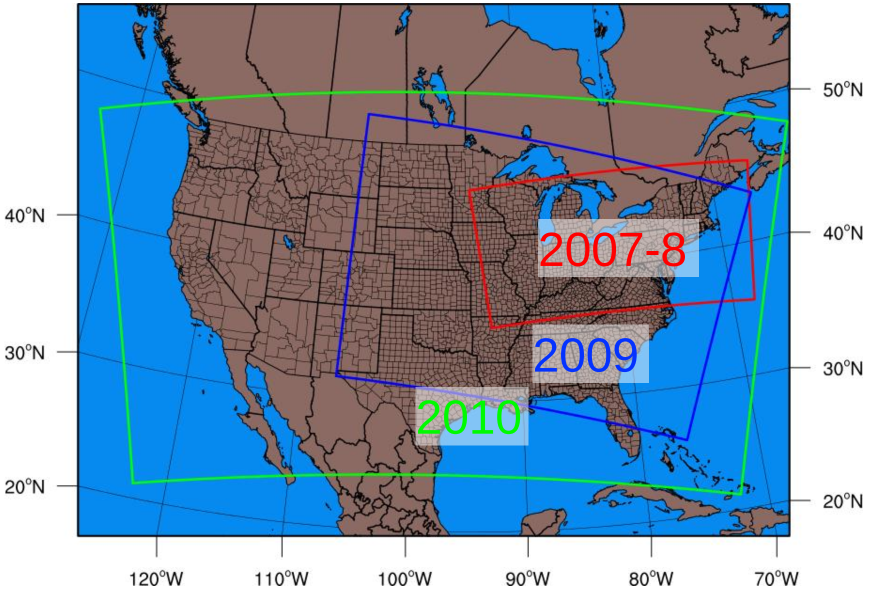
3-km HRRR-Smoke (VIIRS fire data)

3-km Storm-Scale Ensemble Analysis and Forecast (HRRRE) 55% CONUS HRRR Experimental (ongoing)

Hourly Updating Computer Weather Forecasts



Increased Supercomputing Power



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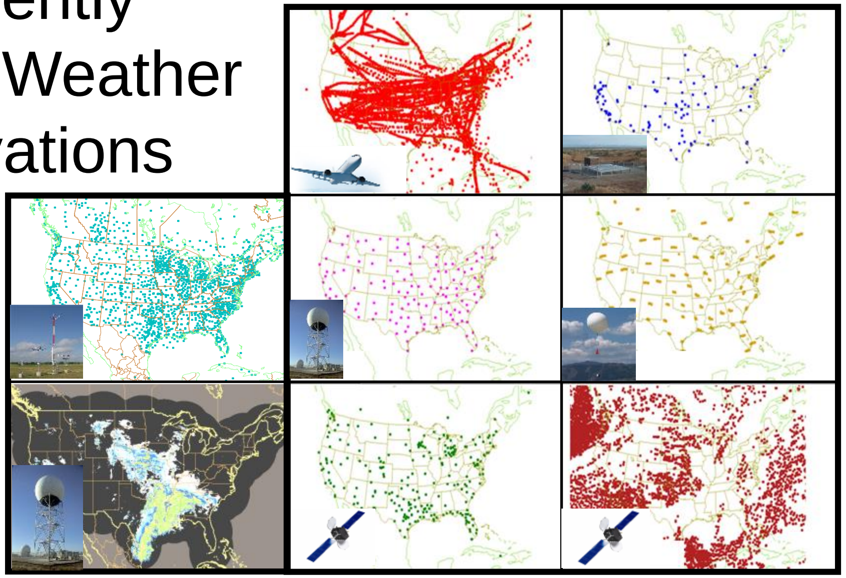
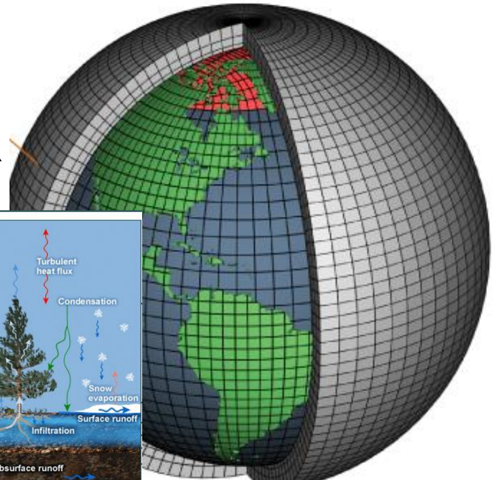
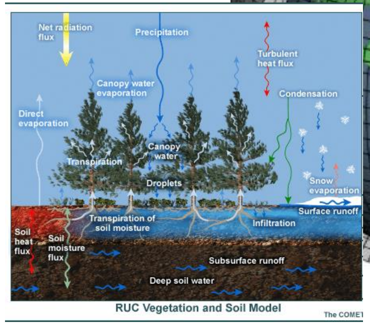
Frequently Updating Weather Observations





Accurate Computer Representation of Weather Processes



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High Powered Computer Forecast

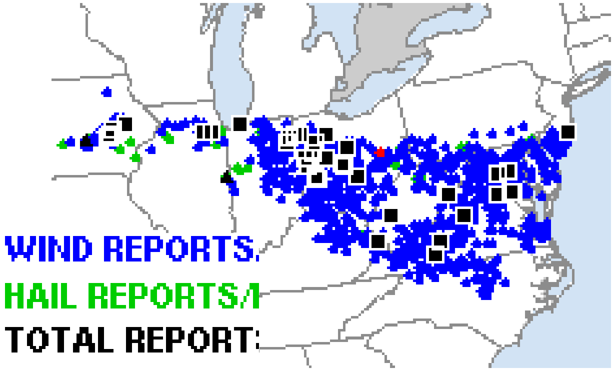
High-Resolution Rapid Refresh a.k.a. HRRR

High-Impact Weather Prediction: Wind/Precipitation

After the storm, D.C. still scrambling

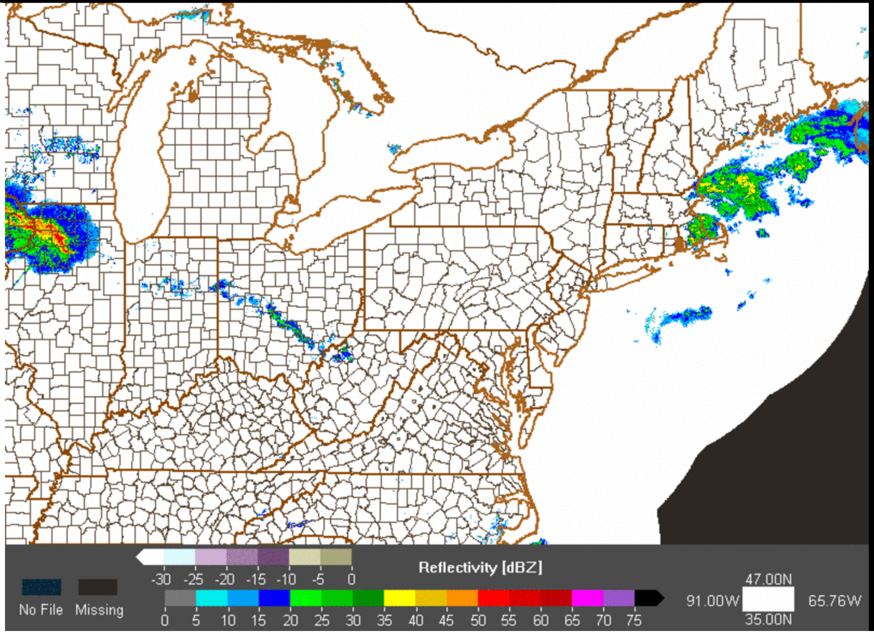
10 Like 7 Tweet 7 Share 3 Short URL Email Print

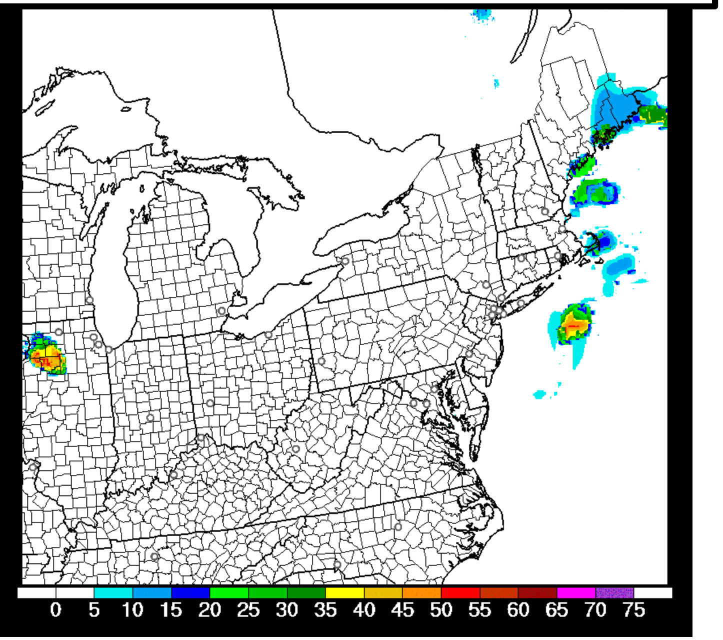
By ANDREW RESTUCCIA and DARIUS DIXON | 7/2/12 1:44 PM EDT



Fast-Moving Damaging
“Derecho” Thunderstorm Winds
June 29, 2012
11 am – 2 am EDT

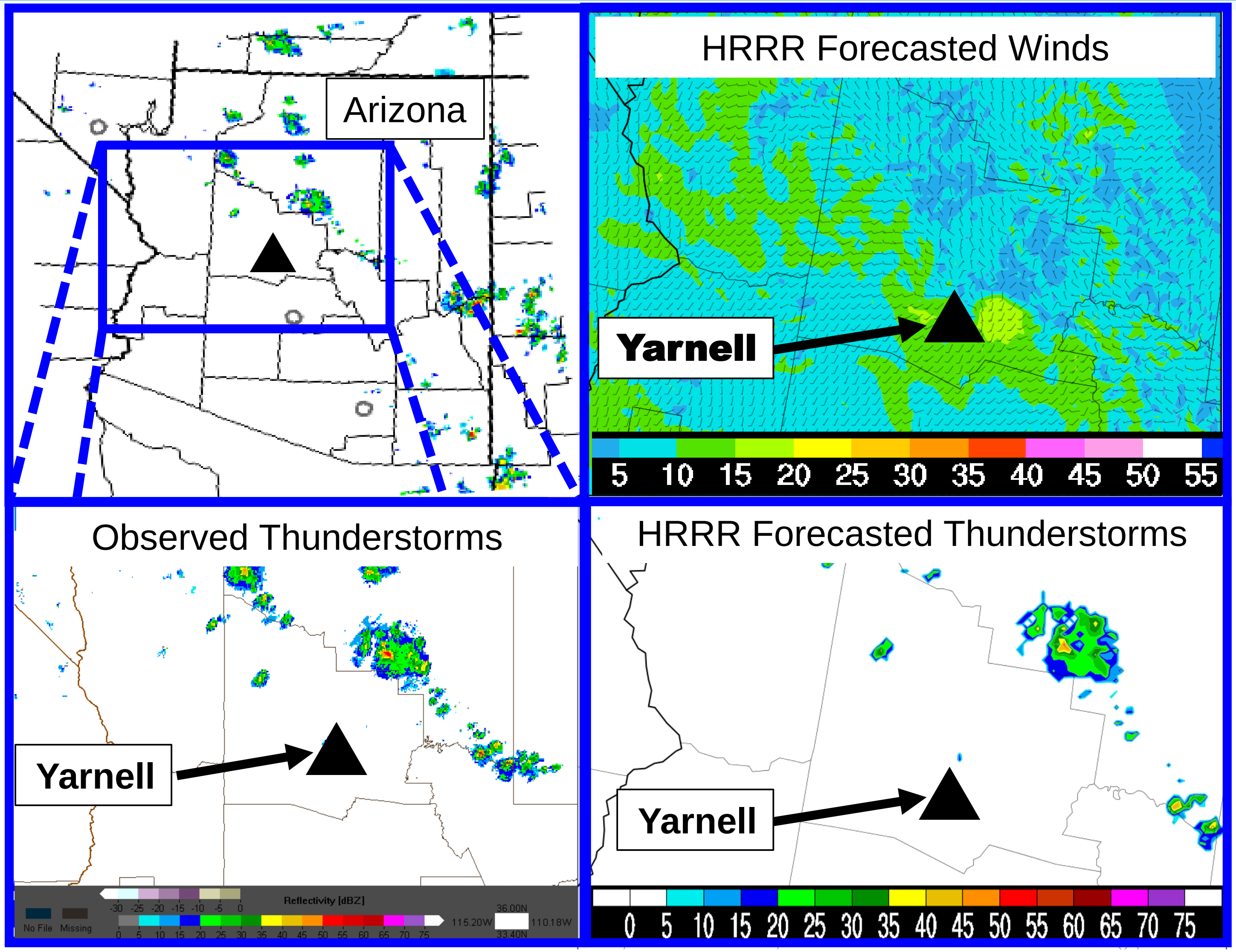
Observed Thunderstorms | 11 am HRRR Forecast





High-Impact Weather Prediction: Wind-Driven Wildfire

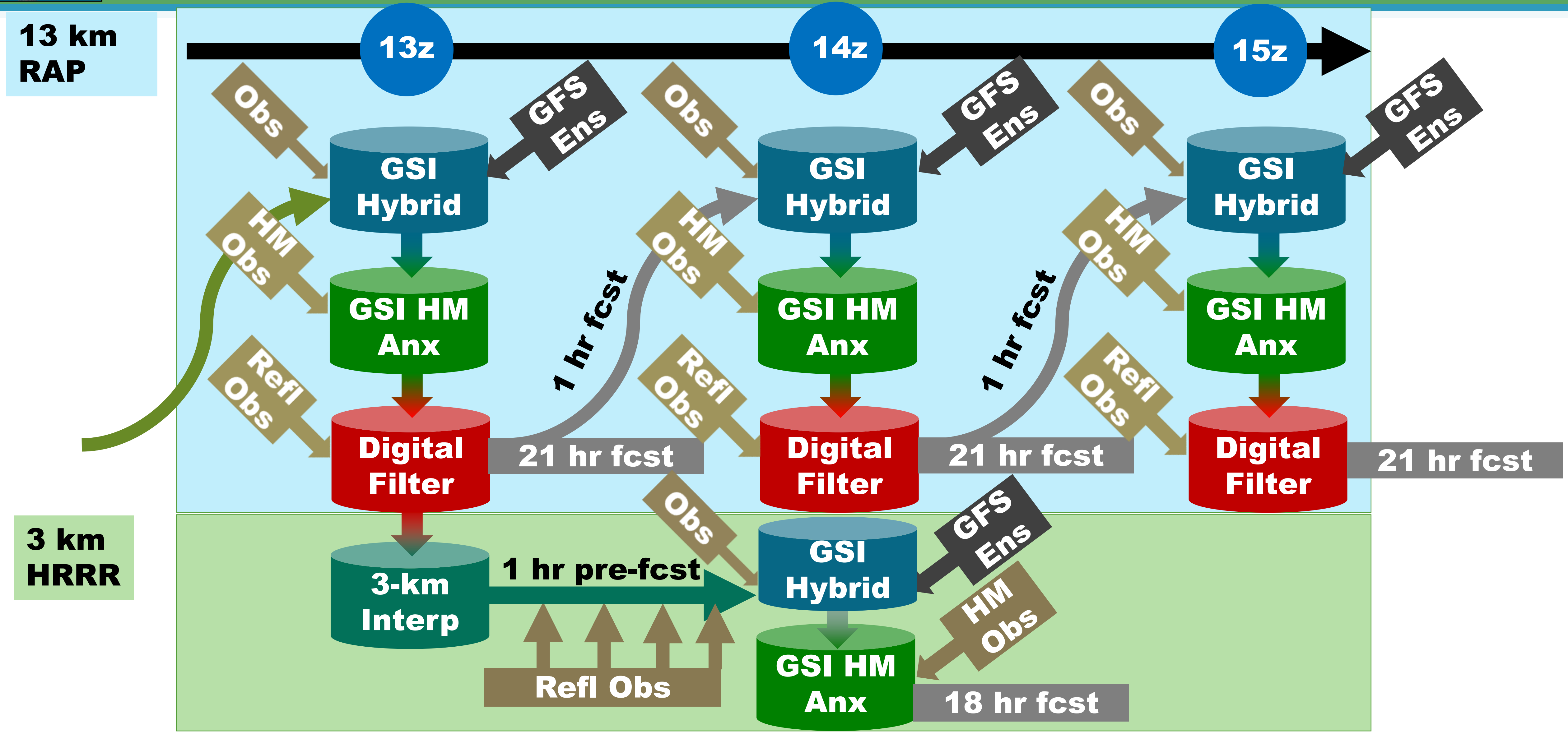
Yarnell, AZ Wildfire Driven by Thunderstorm Winds
June 20, 2013
19 Firefighter Fatalities
Contact Lost ~4:30 pm MST



HRRR forecast made at 12 pm MST

Available by 2 pm MST

HRRRv3 Initialization from RAPv4



HRRR Users and Applications

Example: National Weather Service including Storm and Weather Prediction Centers (SPC and WPC)
Aviation Weather Center (AWC) and FAA Command Center
National Severe Storms Laboratory (NSSL) and Air Resources Laboratory (ARL)
National Centers for Atmospheric Research (NCAR) and Lincoln Laboratory (LL)

General Forecasting

Renewable Energy Same-Day Decision Support

Renewable Energy Day-Ahead Decision Support

Severe Weather

Severe Weather -Watches, Convective Outlooks

Severe Weather Day 2 Outlooks

QPF / hydro

Heavy rainfall/snowfall watches, National Water Model

Heavy rainfall/snowfall Day 2 Outlooks

Aviation Tactical Planning

Aviation Strategic Planning

0–2 hr 2–8 hrs 8–15 hrs 15–24 hrs 24–48 hrs

Forecast Length

RAPv3/HRRRv2 Observation Data Assimilation Changes

New in RAPv3/HRRRv2

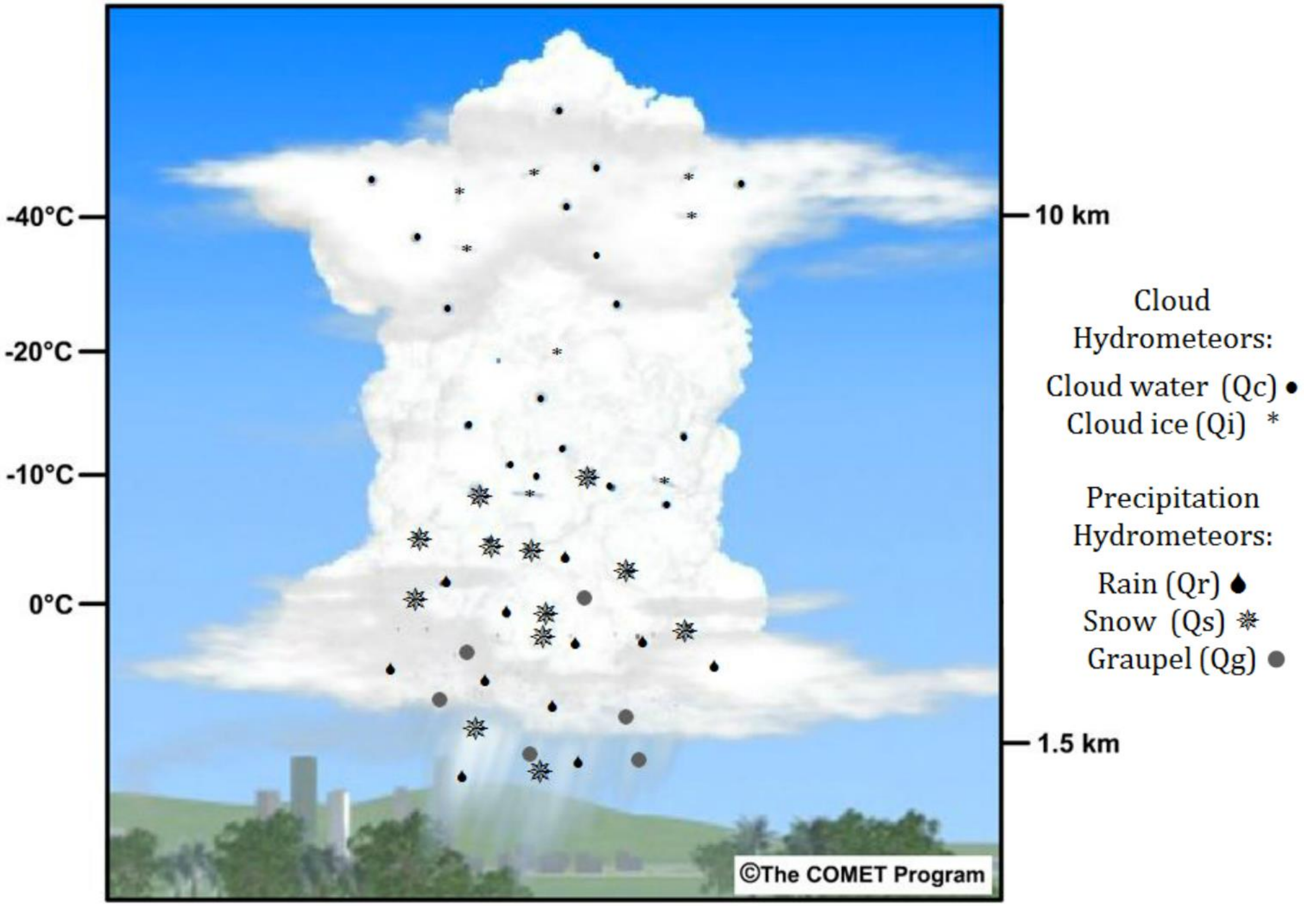
Radial Velocity (RAPv3)
Lightning (RAPv3)
Mesonet (RAPv3/HRRRv2)
RARS Radiances (RAPv3)

Hourly Observation Type	Variables Observed	Observation Count
Rawinsonde	Temperature, Humidity, Wind, Pressure	120
Profiler – 915 MHz	Wind, Virtual Temperature	20-30
Radar – VAD	Wind	125
Radar	**Radial Velocity**	**125 radars**
Radar reflectivity – CONUS	3-d refl ➔Rain, Snow, Graupel	1,500,000
Lightning	**(proxy reflectivity)**	**NLDN**
Aircraft	Wind, Temperature	2,000 -15,000
Aircraft - WVSS	Humidity	0 - 800
Surface/METAR	Temperature, Moisture, Wind, Pressure, Clouds, Visibility, Weather	2200 - 2500
Surface/Mesonet	**Temperature, Moisture, Wind**	**~5K-12K**
Buoys/ships	Wind, Pressure	200 - 400
GOES AMVs	Wind	2000 - 4000
AMSU/HIRS/MHS **(RARS)**	Radiances	1K-10K
GOES	**Radiances**	**large**
GOES cloud-top press/temp	Cloud Top Height	100,000
GPS – Precipitable water	Humidity	260
WindSat Scatterometer	Winds	2,000 – 10,000

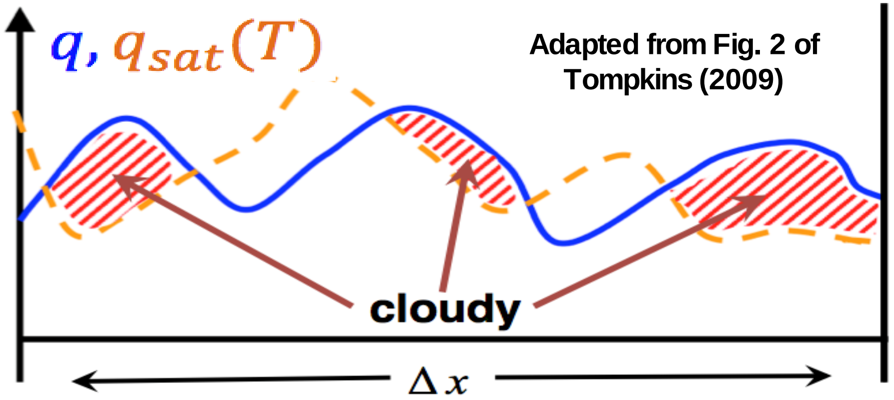
RAPv3/HRRRv2: New Model Forecast Fields

Explicit (Resolved) Clouds/Precipitation

RAP and HRRR use the Thompson microphysics scheme with 5 hydrometeor types



Sub-Grid (Unresolved) Clouds



$$Var(s) \propto Var(q) + Var(T) - Cov(q,T)$$

Assume a PDF of s (saturation ratio)

Retrieve Cloud Fraction, Cloud Condensate

Parameterize: assume subgrid PDFs for thermodynamic variables
Chaboureau and Bechtold (2002)

RAPv3/HRRRv2 Summary of Changes

Operational RAPv2/HRRRv1

Model	Run at:	Domain	Grid Points	Grid Spacing	Vertical Levels	Pressure Top	Boundary Conditions	Initialized
RAP	GSD, NCO	North America	758 x 567	13 km	50	10 mb	GFS	Hourly (cycled)
HRRR	GSD, NCO	CONUS	1799 x 1059	3 km	50	20 mb	RAP	Hourly (pre-forecast hour cycle)

Model	Version	Assimilation	Radar DA	Radiation LW/SW	Microphysics	Cumulus Param	PBL	LSM
RAP	WRF-ARW v3.4.1+	GSI Hybrid 3D-VAR/Ensemble	13-km DFI	RRTM/ Goddard	Thompson v3.4.1	G3 + Shallow	MYNN	RUC
HRRR	WRF-ARW v3.4.1+	GSI 3D-VAR	3-km 15-min LH	RRTM/ Goddard	Thompson v3.4.1	None	MYNN	RUC

Model	Horiz/Vert Advection	Scalar Advection	Upper-Level Damping	6th Order Diffusion	SW Radiation Update	Land Use	MP Tend Limit	Time-Step
RAP	5th/5th	Positive-Definite	w-Rayleigh 0.2	Yes 0.12	10 min	MODIS Fractional	0.01 K/s	60 s
HRRR	5th/5th	Positive-Definite	w-Rayleigh 0.2	No	5 min	MODIS Fractional	0.07 K/s	20 s

RAPv3/HRRRv2 Summary of Changes

Implementation RAPv3/HRRRv2

Larger RAP Domain

Model	Run at:	Domain	Grid Points	Grid Spacing	Vertical Levels	Pressure Top	Boundary Conditions	Initialized
RAP	GSD, NCO	North America	953 x 834	13 km	50	10 mb	GFS	Hourly (cycled)
HRRR	GSD, NCO	CONUS	1799 x 1059	3 km	50	20 mb	RAP	Hourly (pre-forecast hour cycle)

Newer Model Version
More Ensemble Weight
Advanced Physics

Model	Version	Assimilation	Radar DA	Radiation LW/SW	Microphysics	Cumulus Param	PBL	LSM
RAP	WRF-ARW v3.6+	GSI Hybrid Ensemble to 0.75	13-km DFI	RRTMG/ RRTMG	Thompson Aerosol v3.6	GF + Shallow	MYNN v3.6	RUC v3.6
HRRR	WRF-ARW v3.6+	GSI Hybrid Ensemble to 0.75	3-km 15-min LH	RRTMG/ RRTMG	Thompson Aerosol v3.6	None	MYNN v3.6	RUC v3.6

Seasonal Vegetation Fraction/Leaf Area Index

Model	Horiz/Vert Advection	Scalar Advection	Upper-Level Damping	6th Order Diffusion	SW Radiation Update	Land Use	MP Tend Limit	Time-Step
RAP	5th/5th	Positive-Definite	w-Rayleigh 0.2	Yes 0.12	20 min	MODIS Seasonal	0.01 K/s	60 s
HRRR	5th/5th	Positive-Definite	w-Rayleigh 0.2	Yes 0.25 (flat terr)	15 min with SW-dt	MODIS Seasonal	0.07 K/s	20 s

RAPv4/HRRRv3 Summary of Changes – Feb 2018

Implementation RAPv4/HRRRv3

Larger RAP Domain

Model	Run at:	Domain	Grid Points	Grid Spacing	Vertical Levels	Pressure Top	Boundary Conditions	Initialized
RAP	GSD, NCEP	North America	953 x 834	13 km	50	10 hPa	GFS	Hourly (cycled)
HRRR	GSD, NCEP	CONUS	1799 x 1059	3 km	50	20 hPa	RAP	Hourly (pre-forecast hour cycle)

Newer Model Version
More Ensemble Weight
Advanced Physics

Model	Version	Assimilation	Radar DA	Radiation LW/SW	Microphysics	Cumulus Param	PBL	LSM
RAP	WRF-ARW v3.9 - hyb	GSI Hybrid Ensemble to 0.75	13-km 3dLH-DFI	RRTMG/ RRTMG	Thompson Aerosol v3.9	GF + Shallow	MYNN v3.9	RUC v3.9
HRRR	WRF-ARW v3.9 - hyb	GSI Hybrid Ensemble to 0.75	3-km 15-min LH	RRTMG/ RRTMG	Thompson Aerosol v3.9	None	MYNN v3.9	RUC v3.9

Seasonal Vegetation Fraction/Leaf Area Index

Model	Horiz/Vert Advection	Scalar Advection	Upper-Level Damping	6th Order Diffusion	SW Radiation Update	Land Use	MP Tend Limit	Time-Step
RAP	5th/5th	Positive-Definite	w-Rayleigh 0.2	Yes 0.12	20 min	15” MODIS Seasonal	0.01 K/s	60 s
HRRR	5th/5th	Positive-Definite	w-Rayleigh 0.2	Yes -0.25 (slope dep)	15 min with SW-dt	15” MODIS Seasonal	0.07 K/s	20 s

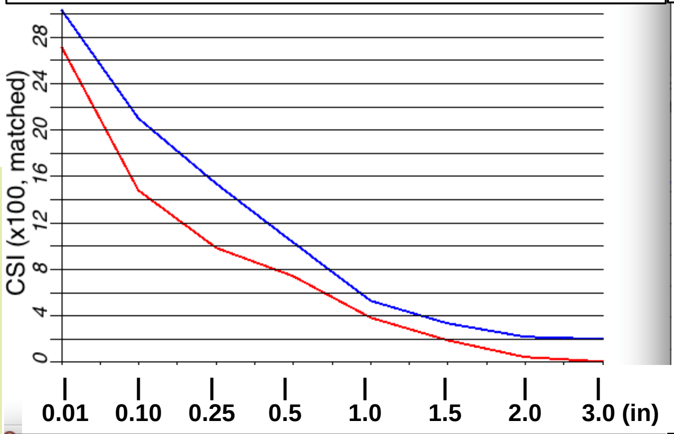
RAPv3 Retrospective Tests: Precipitation

Eastern US
15 Jul – 15 Aug 2014

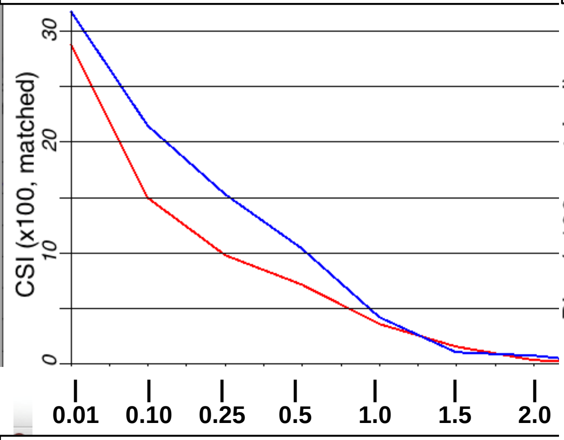
Exper RAPv3
Oper RAPv2

RAP Eastern US Precipitation 6-hr Forecast

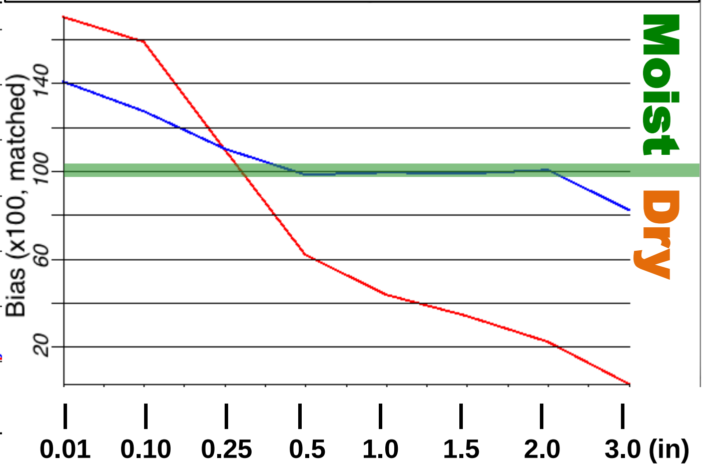
CSI 13-km



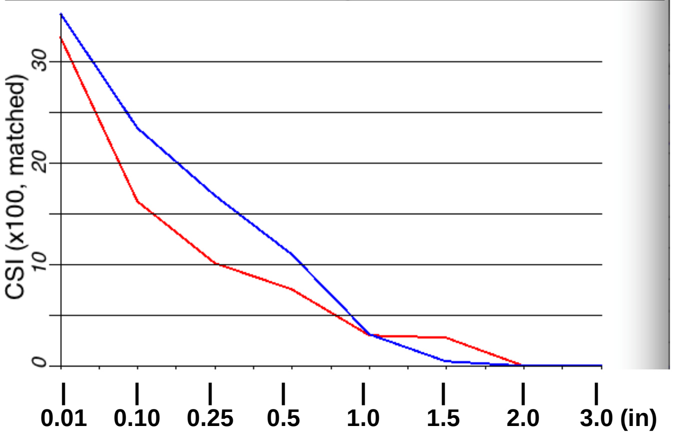
CSI 20-km



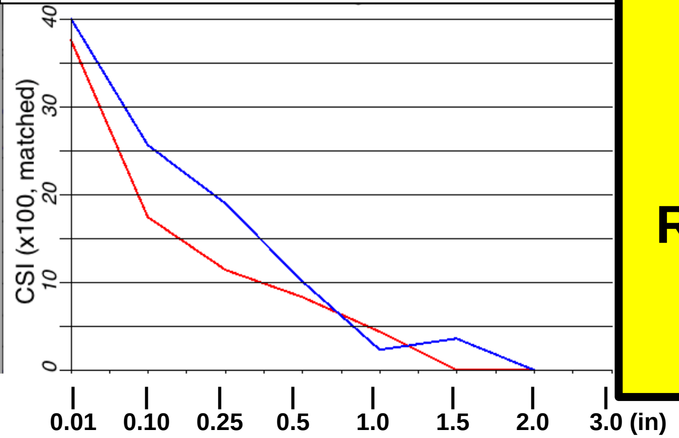
BIAS 13-km



CSI 40-km



CSI 80-km



Reduced moist bias at low precip thresholds

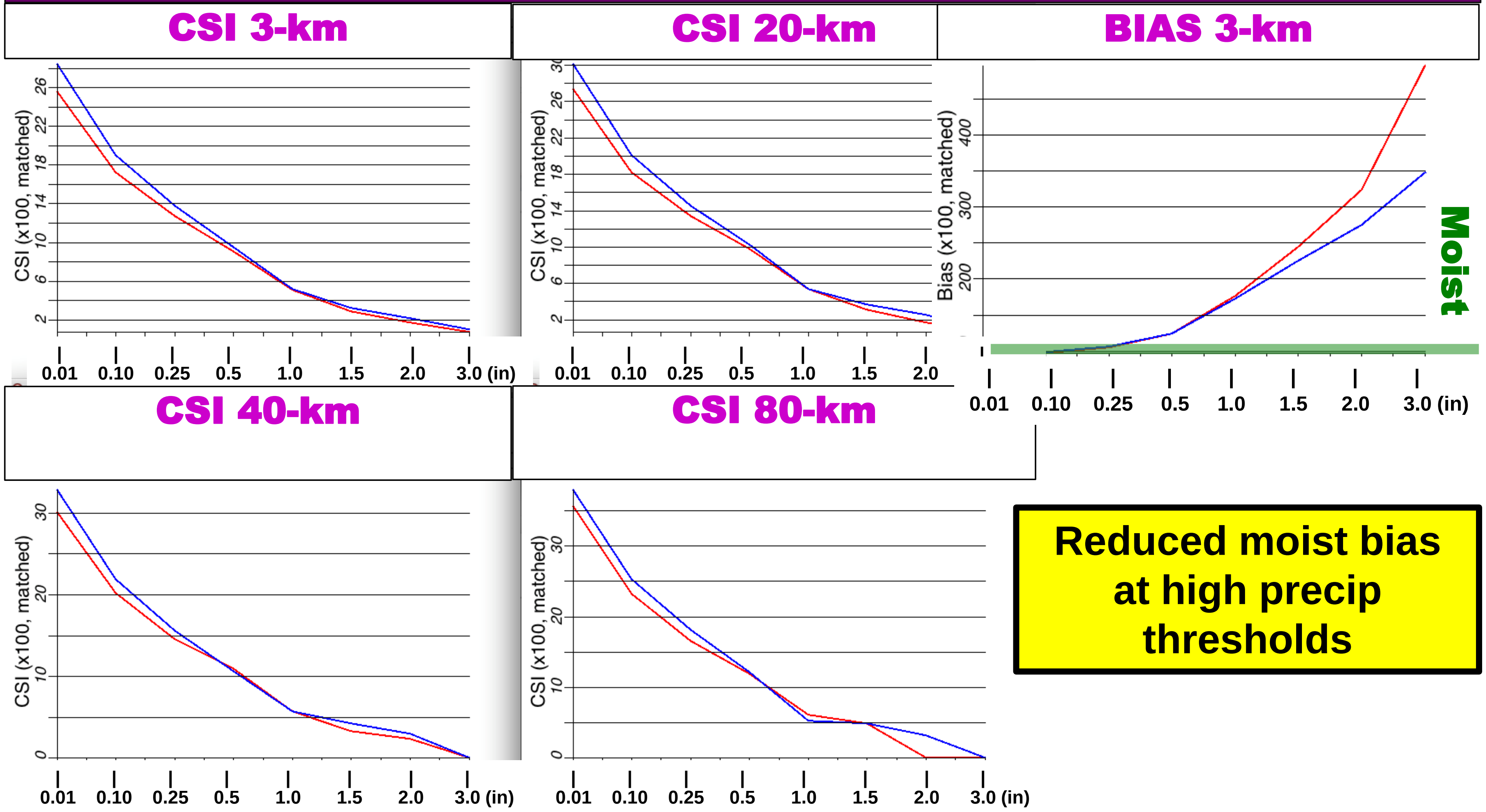
Reduced dry bias at high precip thresholds

HRRRv2 Retrospective Tests: Precipitation

Eastern US
15 Jul – 15 Aug 2014

Exper HRRRv2
Real-Time HRRRv1

HRRR Eastern US Precipitation 6-hr Forecast



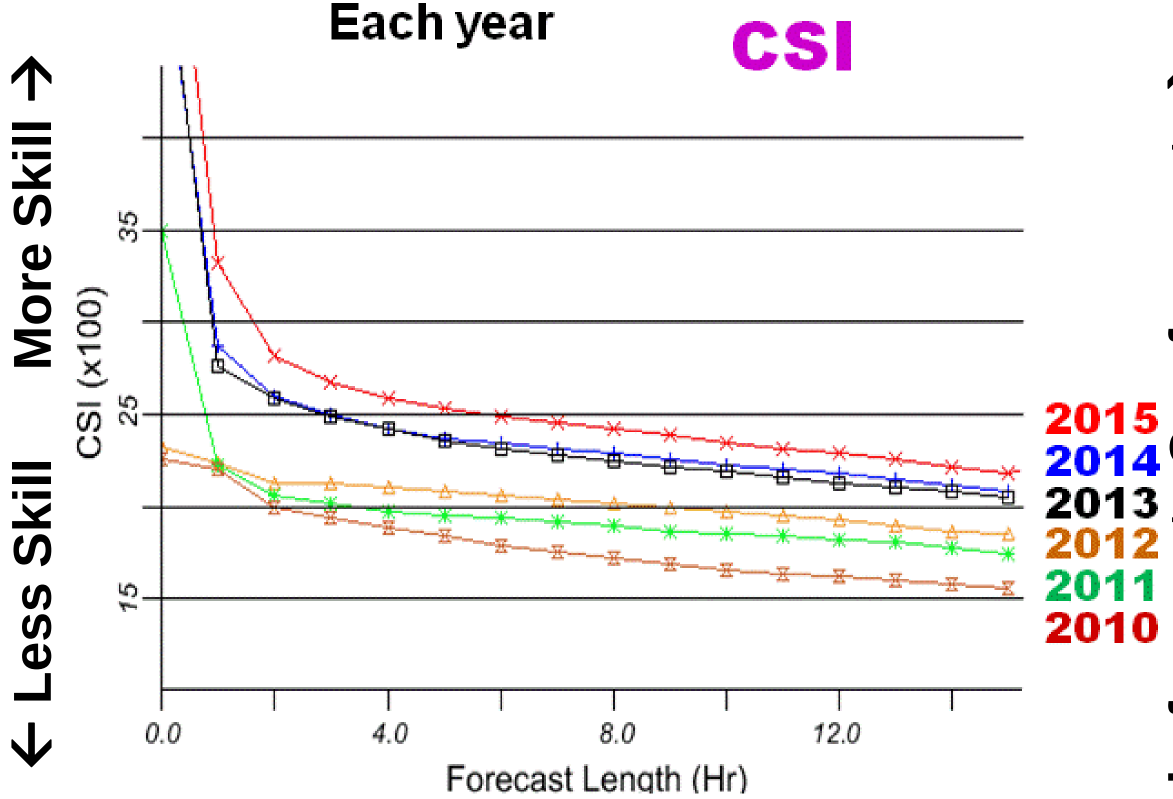
Reduced moist bias at high precip thresholds

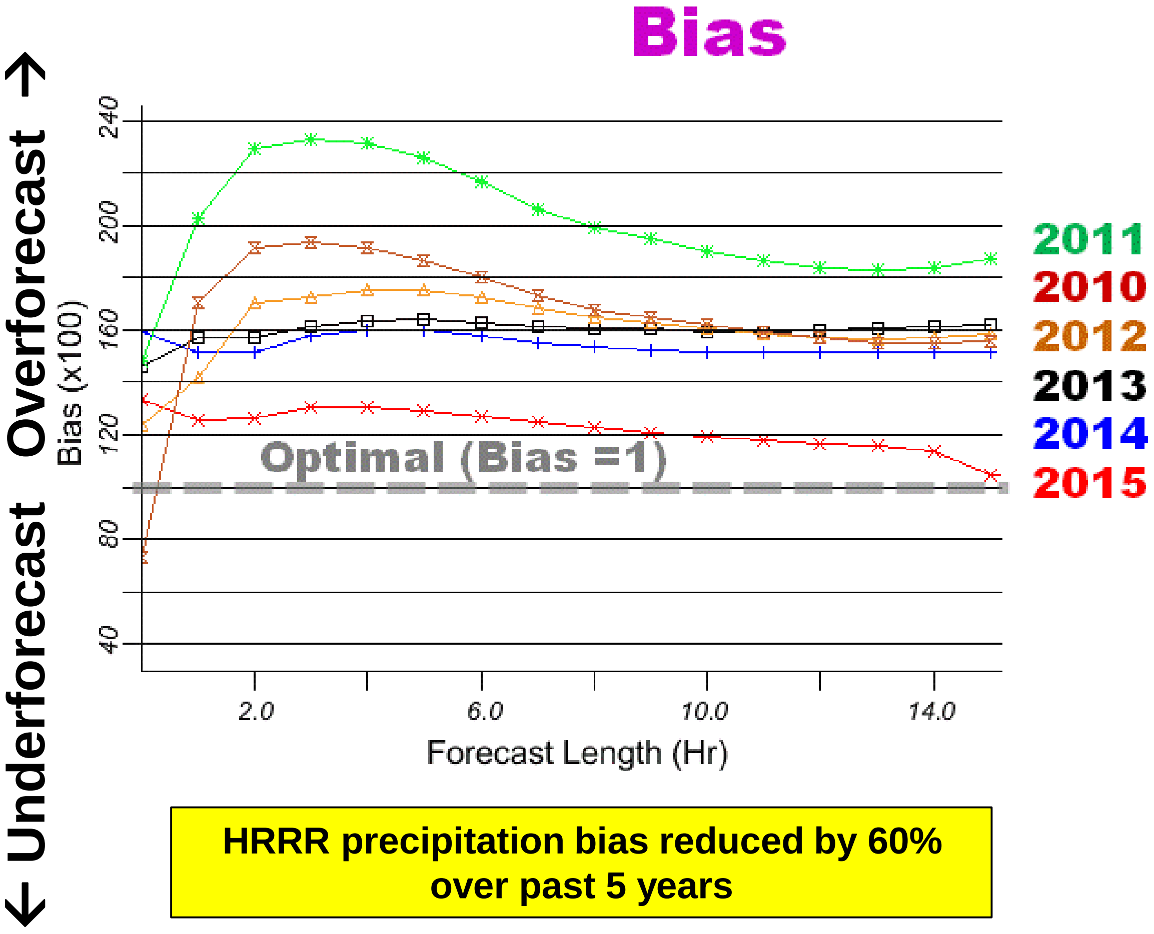
HRRR Performance History

HRRR reflectivity verification by year

CONUS
1 Jan – 31 Dec
Each year

20 dbz 20 km -- score vs. forecast length



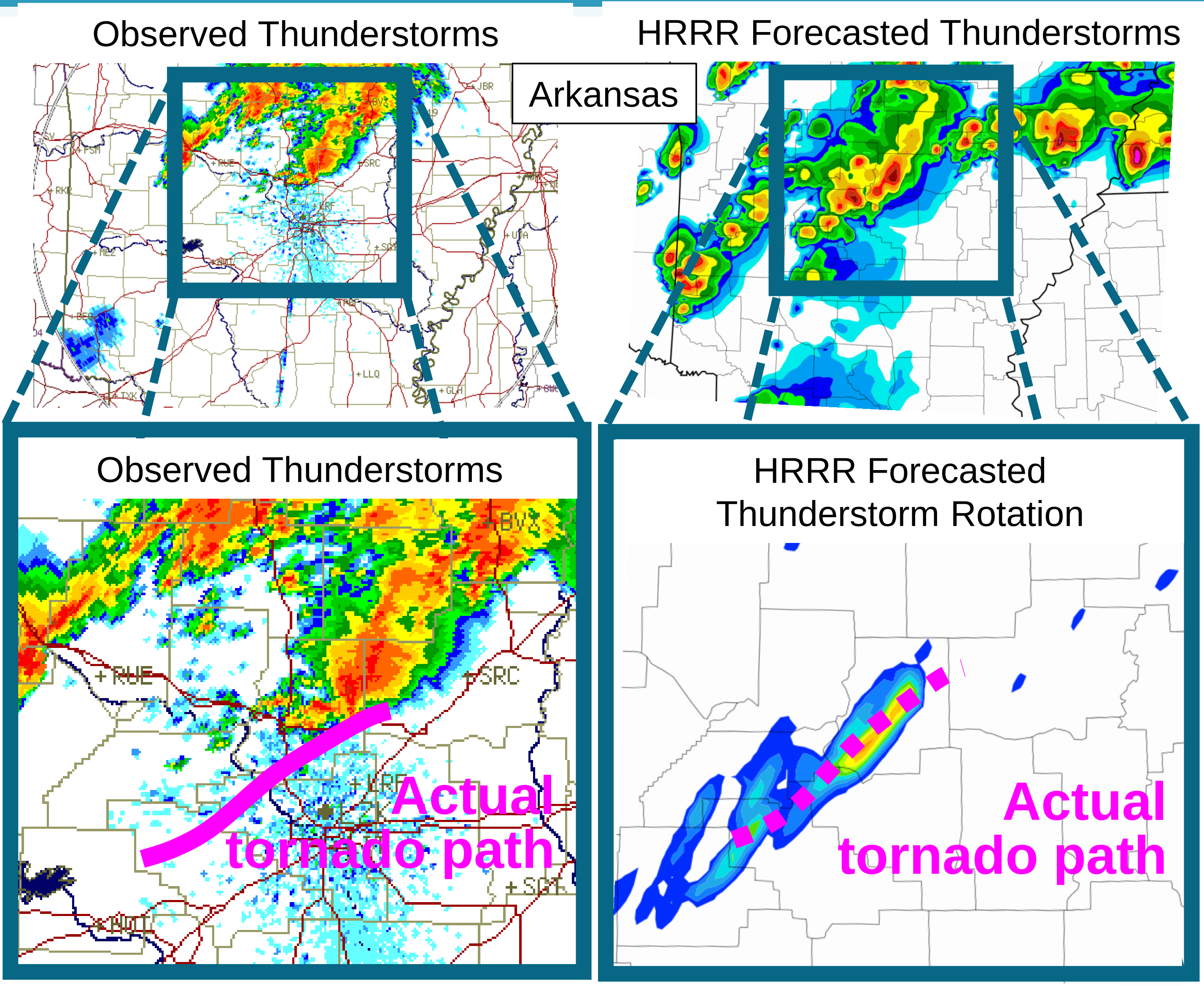


HRRR precipitation location skill improves by 50% over past 5 years

HRRR precipitation bias reduced by 60% over past 5 years

High-Impact Weather Prediction: Tornadoes

Mayflower-Vilonia, AR
Tornado and Thunderstorm
April 27, 2014
16 Fatalities



HRRR 10-hr forecast made at 10 AM

available by noon

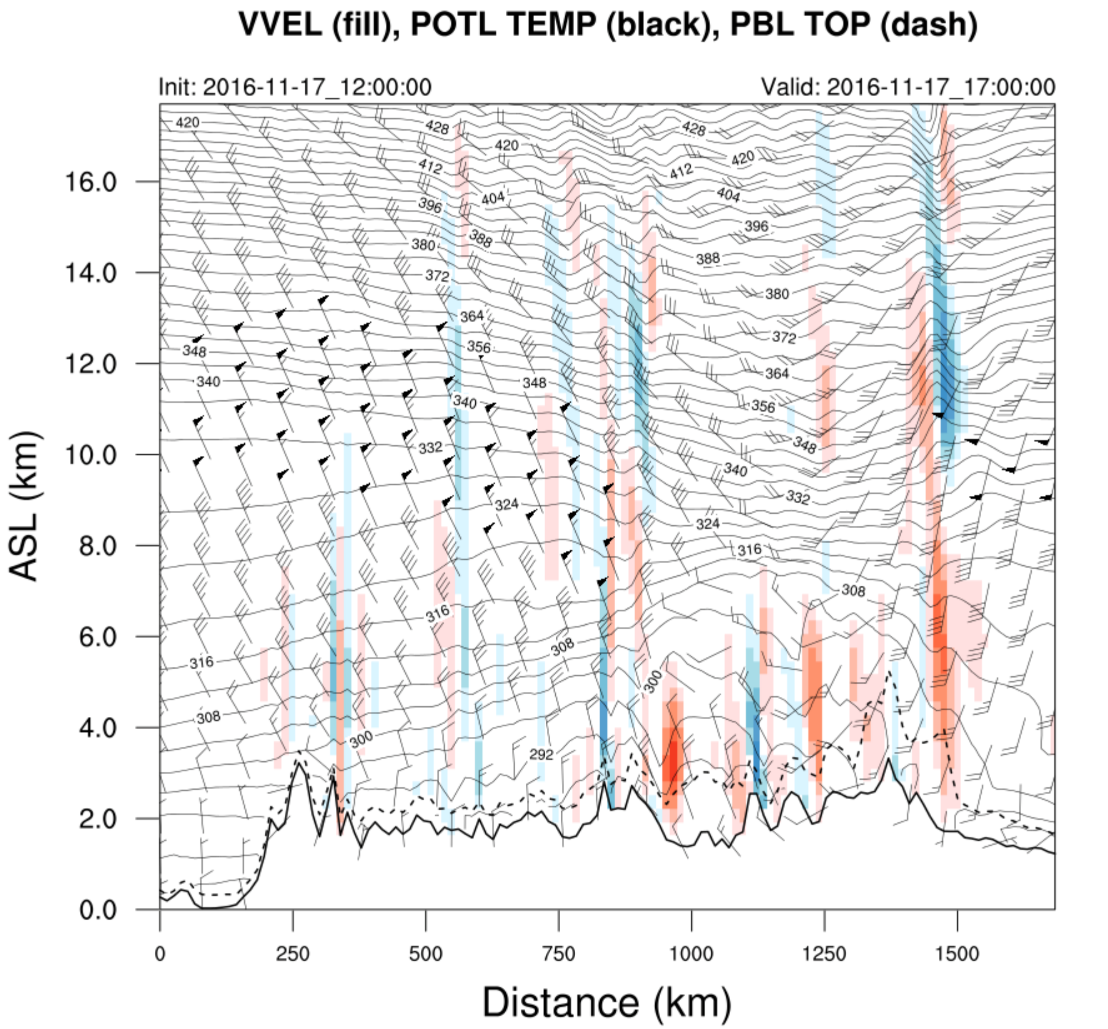
for 8 PM

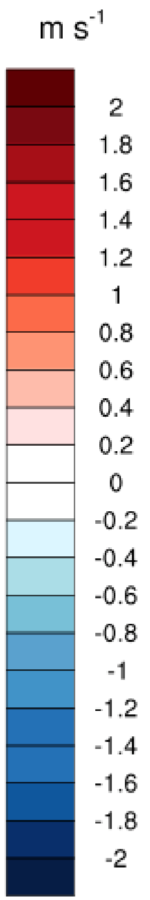
NOAA/ESRL-developed RAPv4/HRRRv3 modifications

	Model	Data Assimilation
RAPv4 (13 km)	WRF-ARW v3.9 incl. physics changes ***Physics changes:*** Thompson microphysics – improved upper-level clouds MYNN PBL update – better sub-grid clouds LSM update – 15” MODIS data – better lower boundary VIIRS-based real-time greenness vegetation fraction ***Numerics changes:*** Improved terrain (cell avg) – better winds /turbulence Hybrid vertical coordinate from NCAR	Merge with GSI trunk – last updated in Mar 2017 ***New Observations for assimilation:*** NCEP new VAD wind retrievals Add AMVs over land and TAMDAR ***Assimilation Methods:*** Revised PBL pseudo-obs – reduce RH bias More ensemble weight in hybrid DA (0.85/0.15) Cloud building – smaller qc/qi, cloud CCN now specified, GOES/METAR consistent (<1200m AGL) Aircraft temperature bias correction Add IASI, CrIS, SEVIRI, GOES-R (incl ltg) satellite
Larger impact for QPF **HRRR v3 (3 km)**	WRF-ARW v3.9 incl. physics changes ***Physics changes:*** Thompson microphysics – improved upper-level clouds MYNN PBL update – better sub-grid clouds LSM update – 15” MODIS data – better lower boundary VIIRS-based real-time greenness vegetation fraction (delay to HRRRv4 - Add smoke with VIIRS fire radiative power) ***Numerics changes:*** Hybrid vertical coordinate from NCAR	***New Observations for assimilation:*** GOES cloud-top cooling rates – convection proxy Add new VAD wind, AMVs over land and TAMDAR Radar radial velocity Cloud building – smaller qc/qi, cloud CCN now specified, GOES/METAR consistent (<1200m AGL) ***Assimilation Methods:*** More ens weight in hybrid DA (0.85/0.15) 3km ensemble DA (40 members out to 1h) – effective in 2017 test but DELAY to HRRRv4

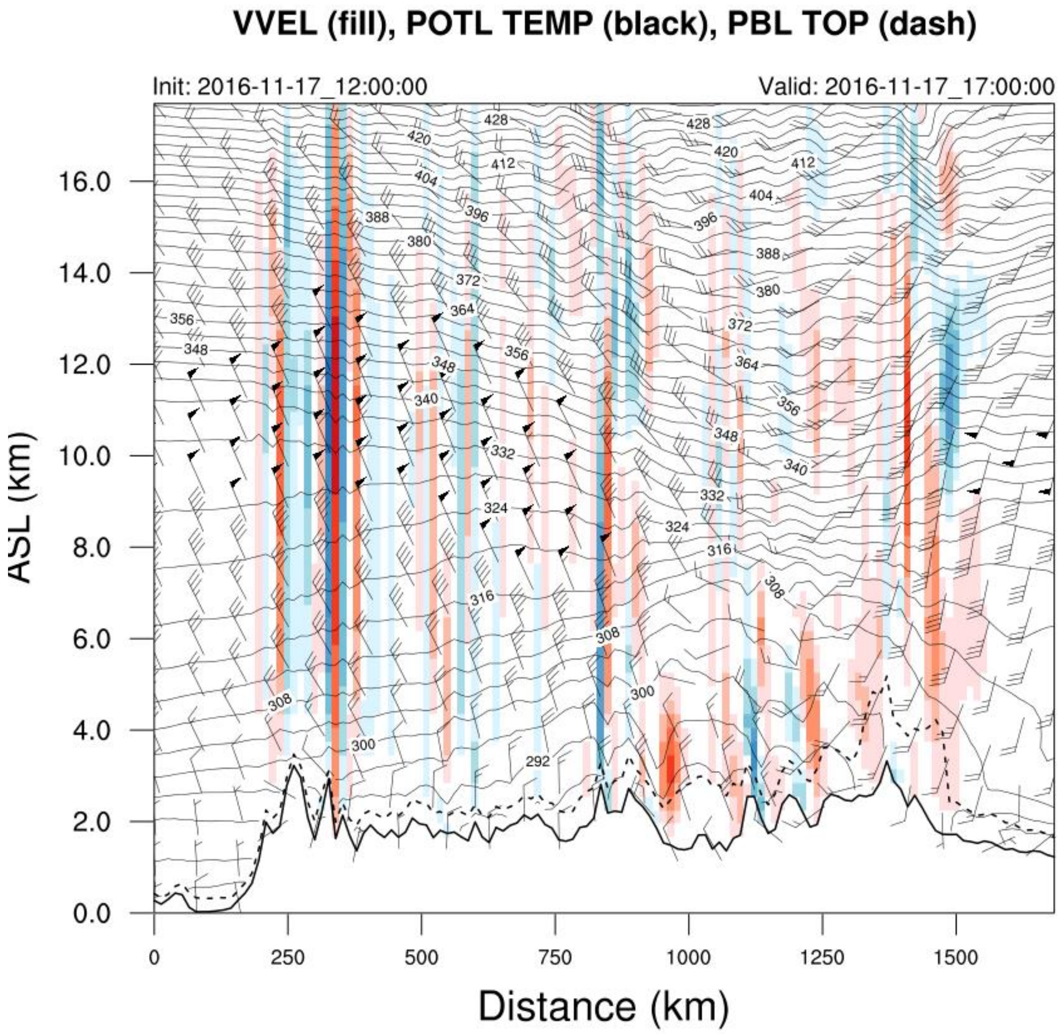
New RAP/HRRR Vertical Coordinate

Hybrid coordinate





Terrain-following coordinate



RAP / HRRR: Implementation Schedule

RAPv3 – Reduced warm / dry bias → NCEP Implement Aug 2016

- Improved PBL, LSM, cu-parm, DA
- Thompson/NCAR aerosol-aware microphysics

HRRRv2 – Improved convection → NCEP Implement Aug 2016

- Initialized by RAP (v3)
- Improved radar assimilation, hybrid assimilation, PBL/cloud physics

RAPv4 – GSD testing 2016 /17 → NCEP Implement Feb 2018

- 3D cloud fraction, better coupling to radiation scheme, better ceiling

HRRRv3 – GSD testing 2016 /17 → NCEP Implement Feb 2018

- Reduced precipitation/convection bias 0-3 hrs
- Improved retention of clouds

HRRRE – GSD testing in 2016/17 → NCEP implement 2019?

- ***Storm-scale ensemble forecast component***

HRRR Time-Lagged Ensemble (HRRR-TLE)

Deterministic HRRR:

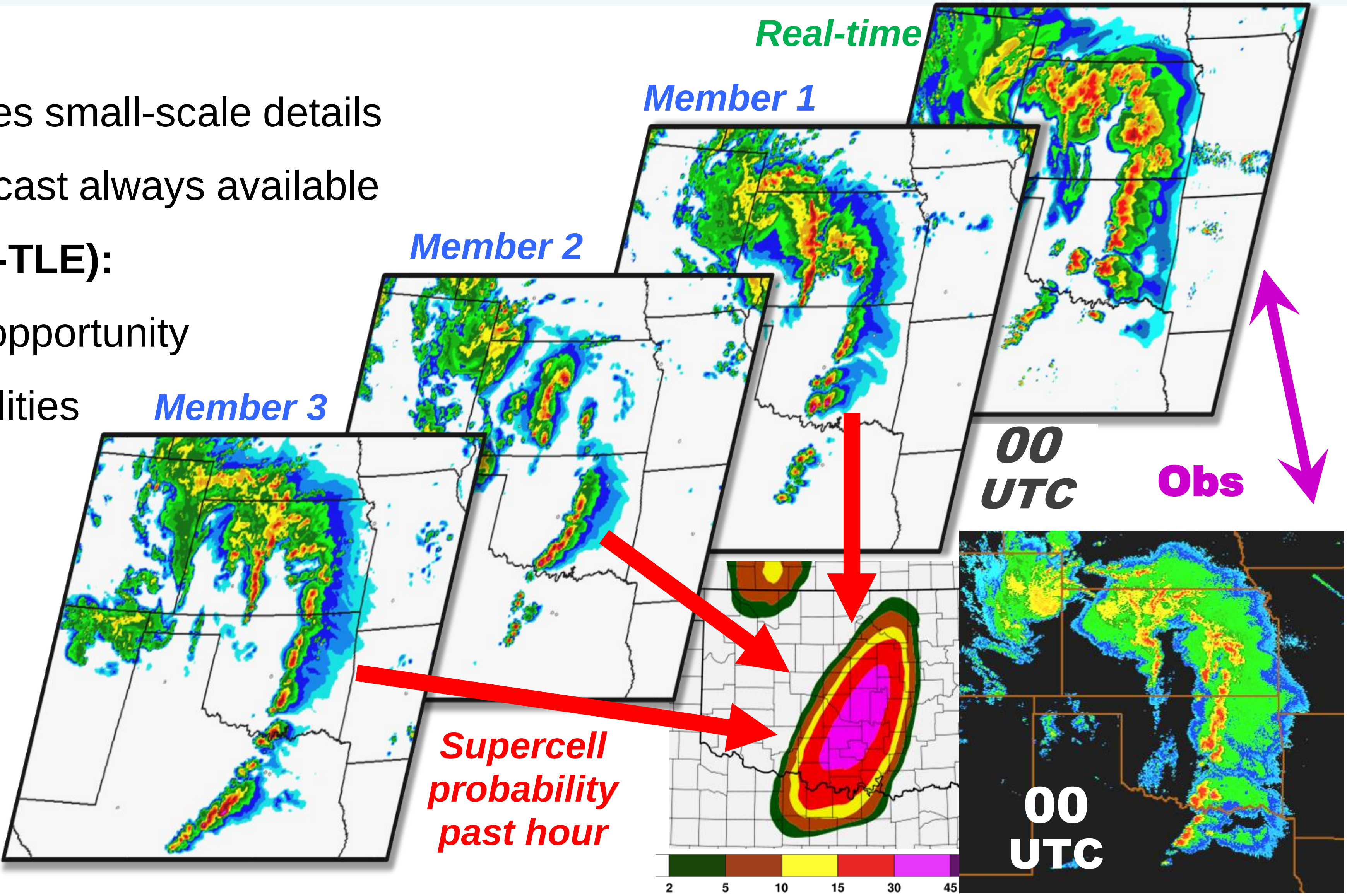
- High-resolution forecast provides small-scale details
- Hourly-updating with fresh forecast always available

Time-Lagged Ensemble (HRRR-TLE):

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

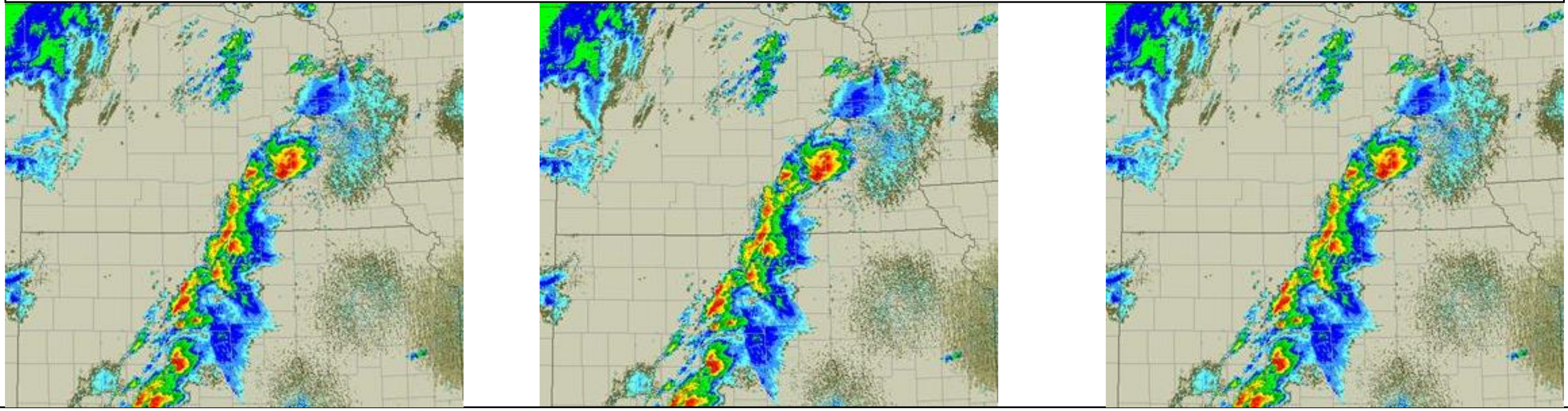
HRRR Ensemble (HRRRE):

- More expensive ensemble
- More spread/dispersive/skill

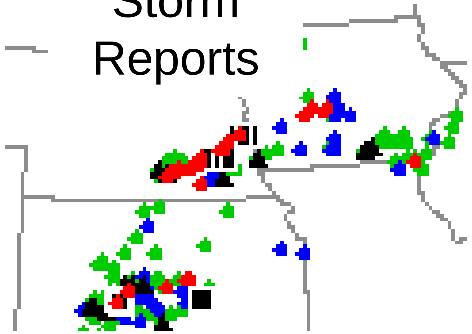


HRRR Forecast Consistency Example

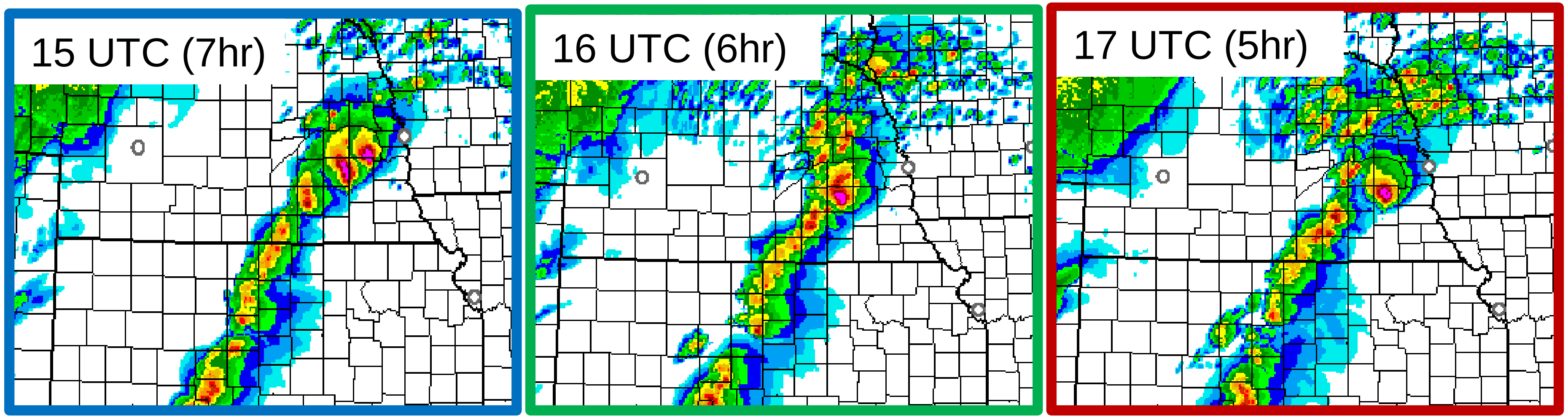
Radar Obs at 2200 UTC



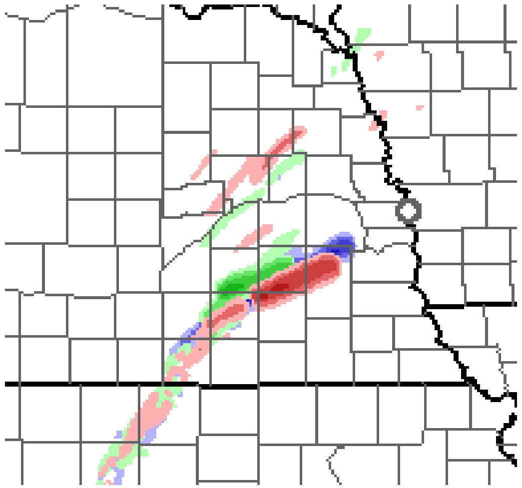
11 May 2014



HRRR Forecasts valid at 2200 UTC



Updraft Helicity
Time-Lagged Ensemble



HRRR Time-Lagged Ensemble: HRRR-TLE

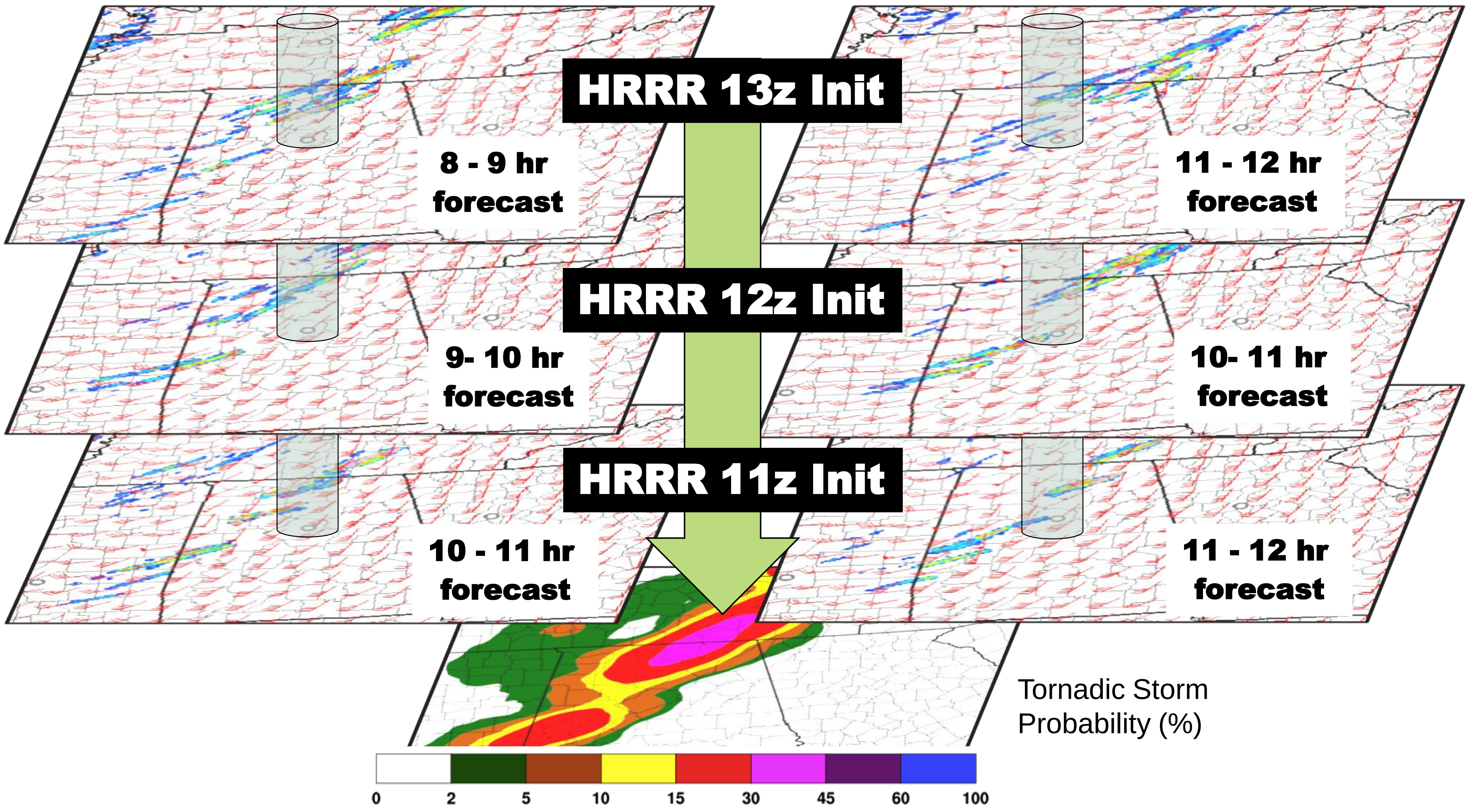
Neighborhood Search

Point Probability

Spatial radius 45 km
Time radius 1 hr
UH threshold 25 m^2/s^2

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

Forecasts valid 22-23z **Forecasts valid 23-00z**



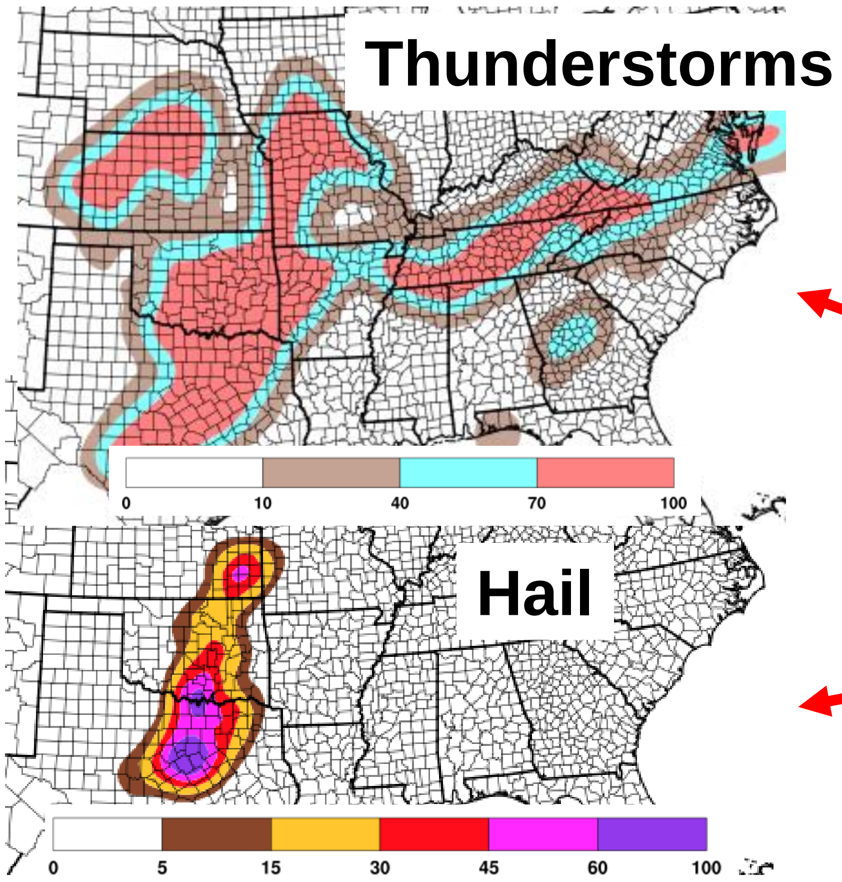
HRRR Time-Lagged Ensemble (HRRR-TLE)

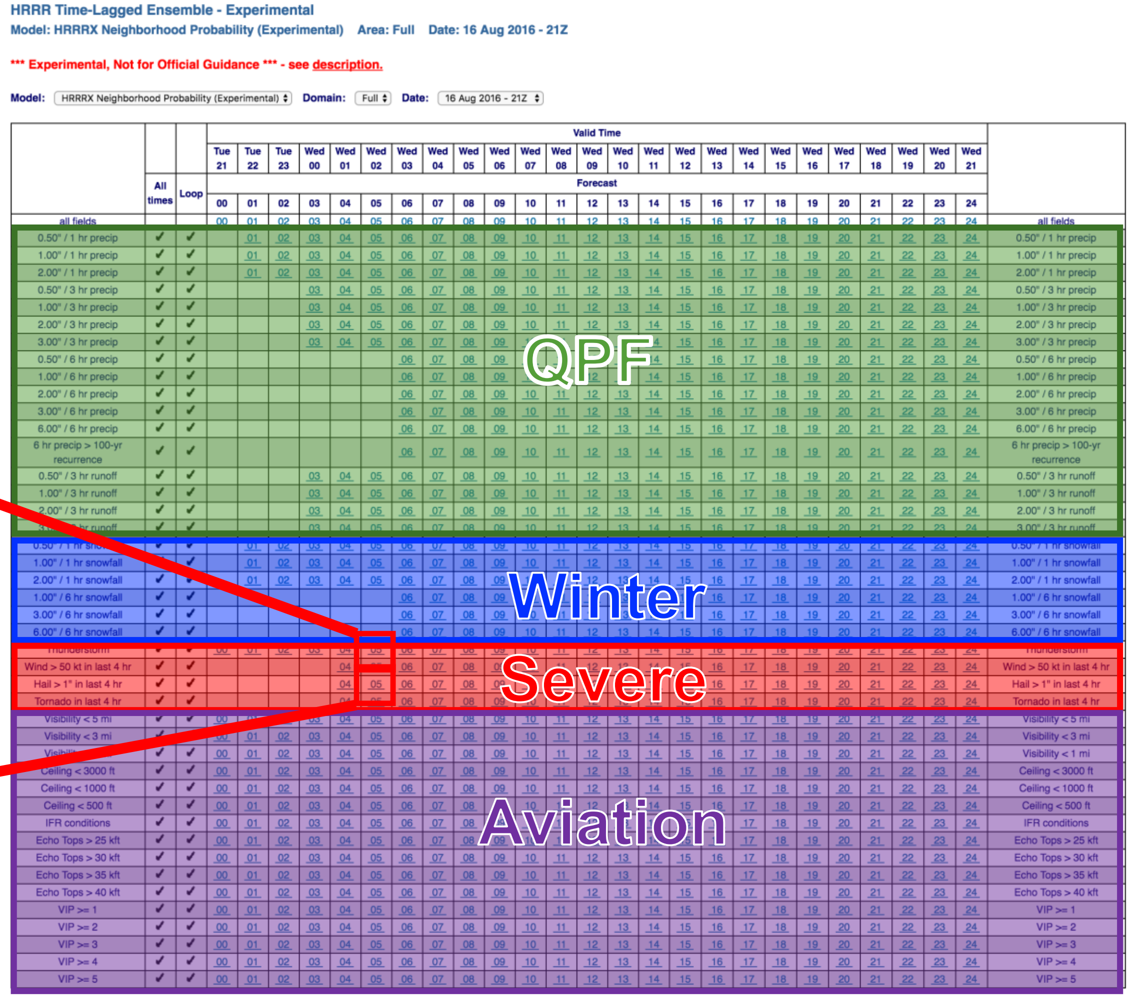
Current Experimental Probability Products:

- **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/hrrr/hrrrtle



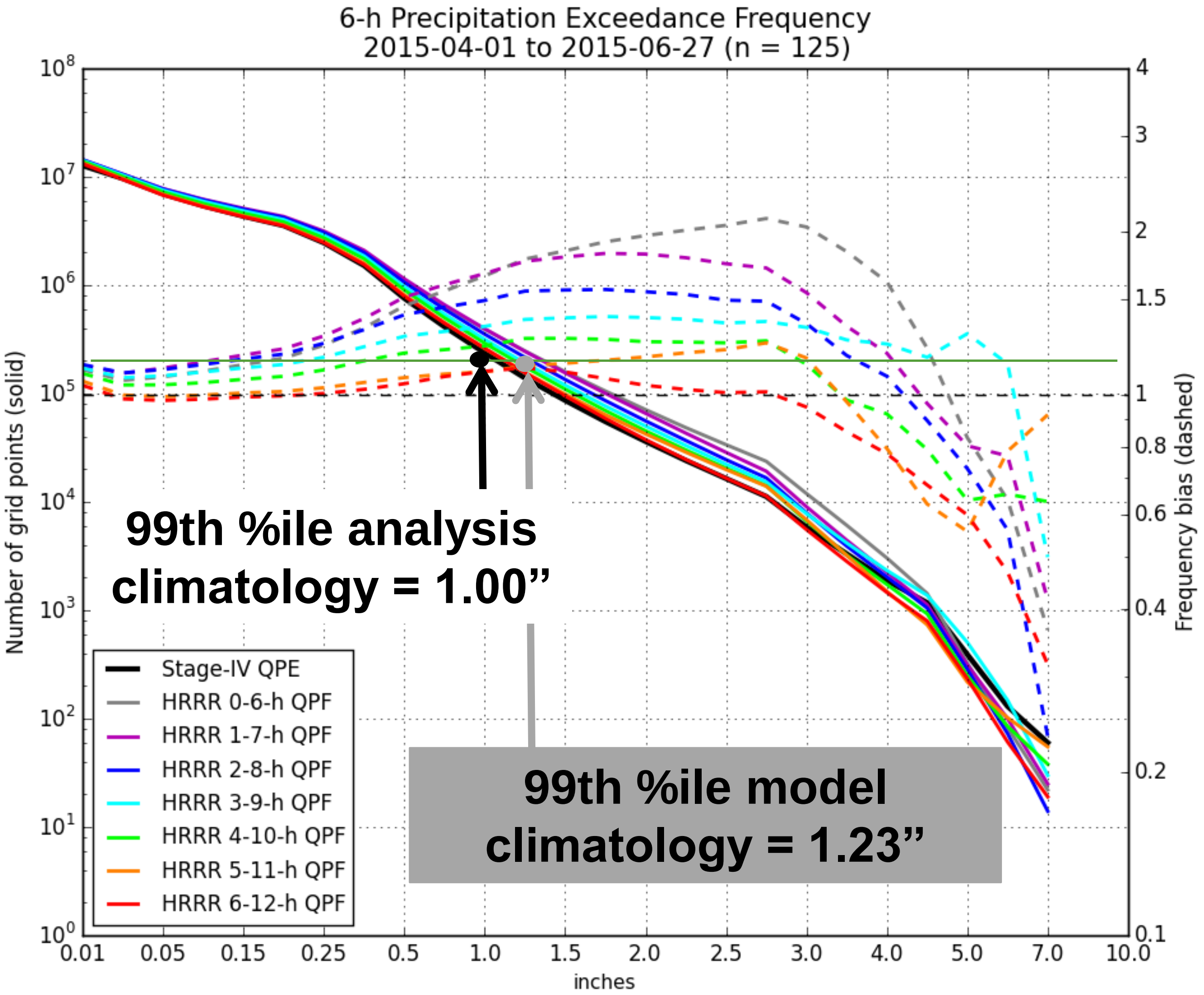


HRRR-TLE Development: Bias Correction

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

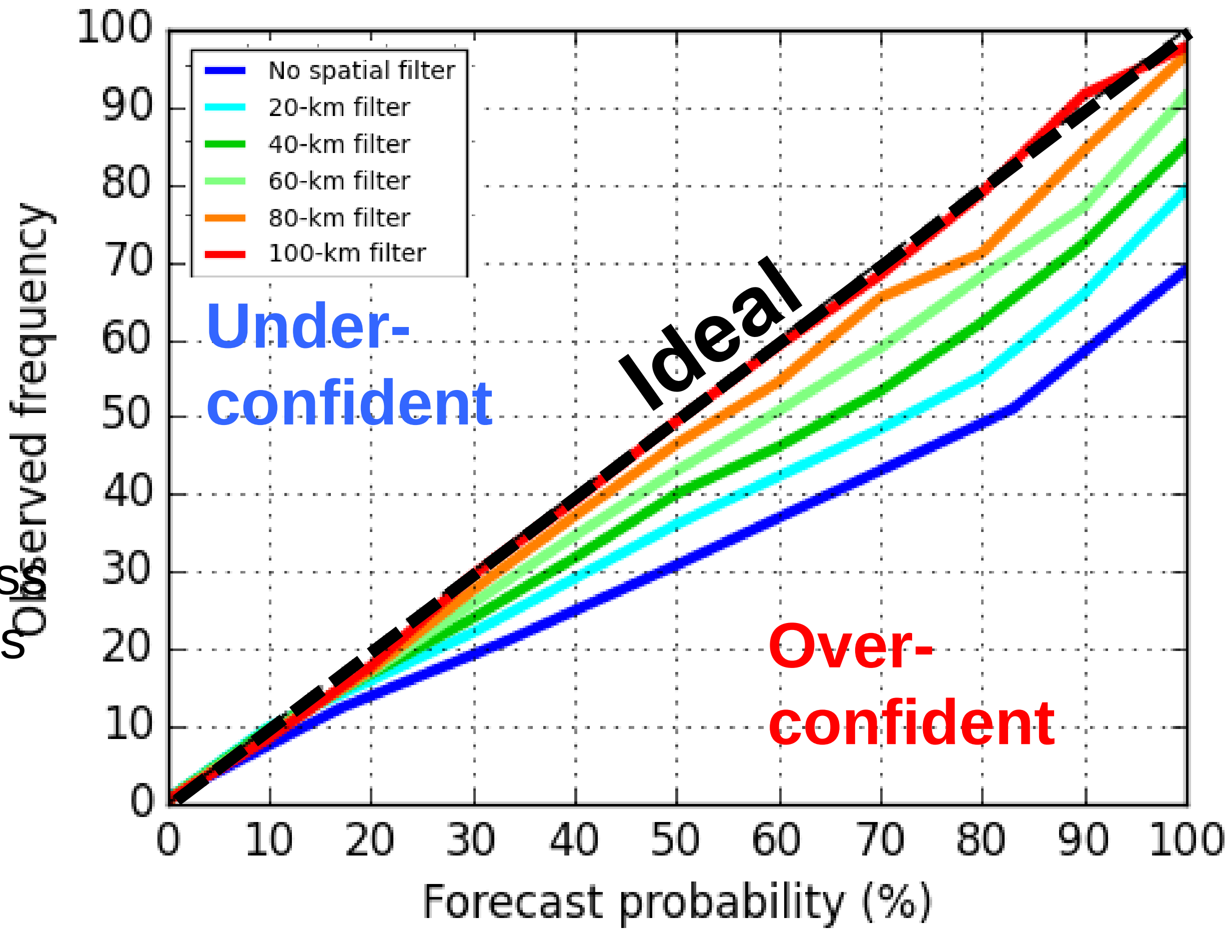
Results: Probability of 0.5" Precipitation in 6 hours
May-Aug 2015

With relatively small sample size (~50 forecasts)

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

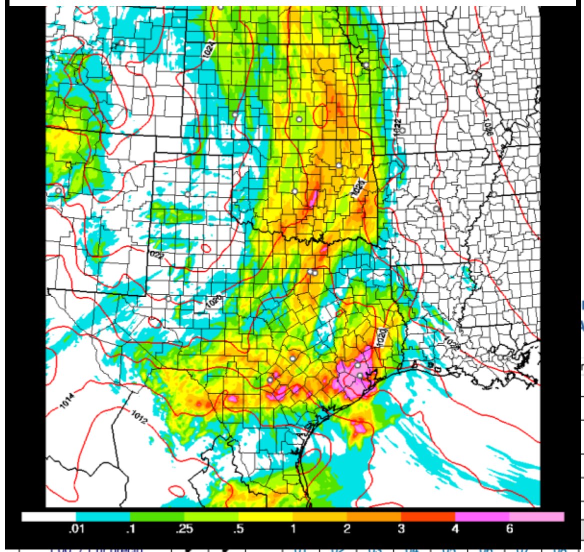
Produce probabilities with sufficient resolution/sharpness
Large dynamic range to probabilities including extremes

Still fundamentally underdispersive (overconfident)

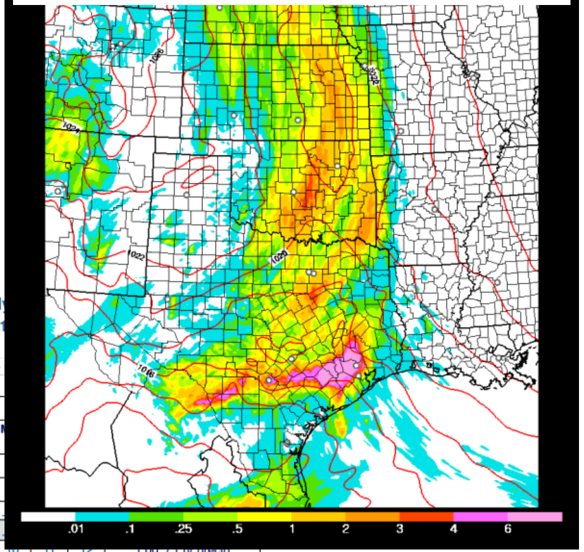


HRRR-TLE Case Study: 18 April 2016

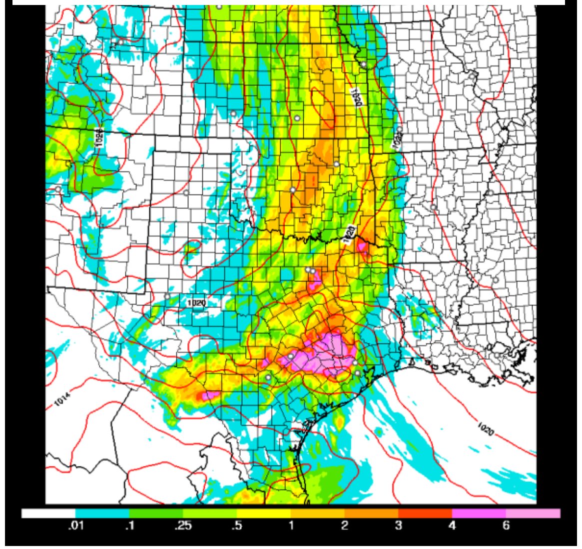
HRRR 23z 13hr pcp fcst

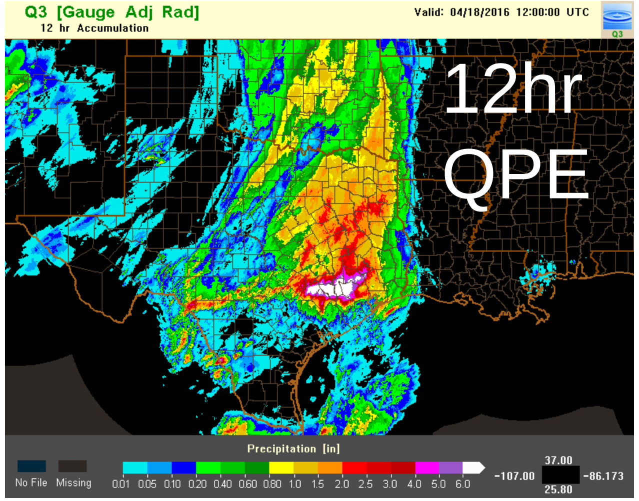


HRRR 00z 12 hr pcp fcst

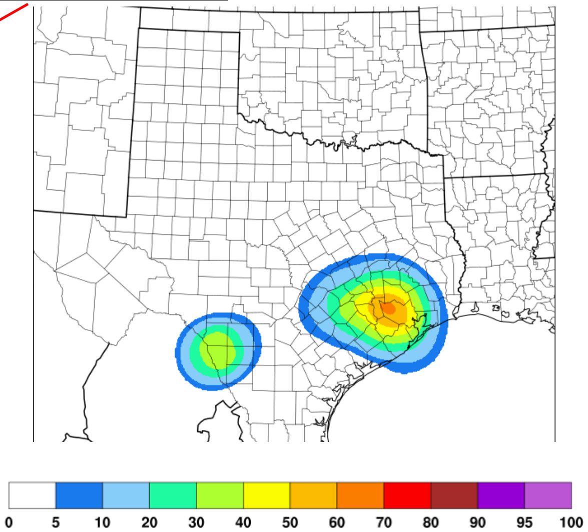


HRRR 01z 11 hr pcp fcst



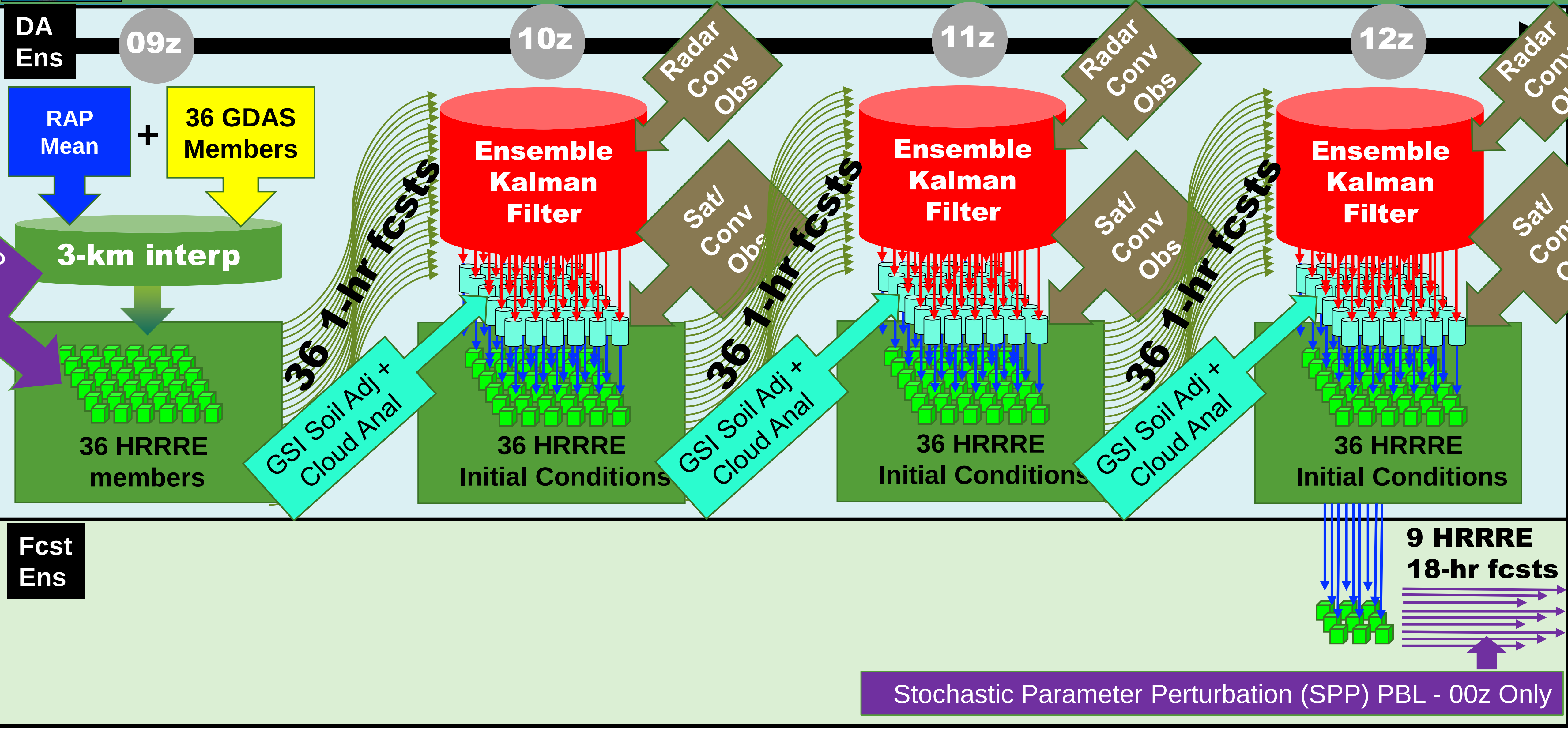


2.00" / 1 hr precip	✔	✔		01	02	03	04	05	06	07	08	09	10	11	12	2.00" / 1 hr precip
0.50" / 3 hr precip	✔	✔				03			06			09			12	0.50" / 3 hr precip
1.00" / 3 hr precip	✔	✔				03			06			09			12	1.00" / 3 hr precip
2.00" / 3 hr precip	✔	✔				03			06			09			12	2.00" / 3 hr precip
3.00" / 3 hr precip	✔	✔	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



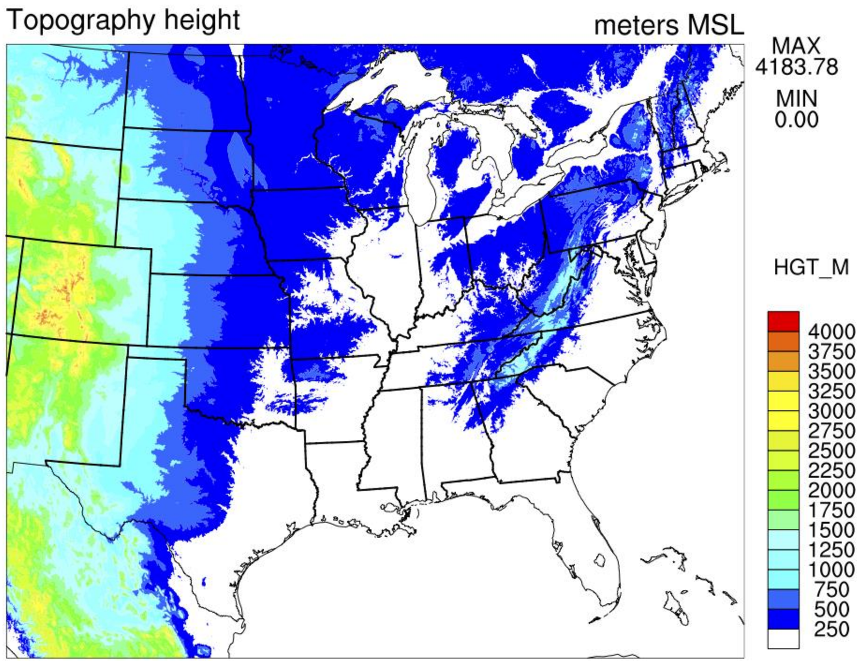
HRRR-TLE forecasts > 60% probability of 6hr QPF exceeding 100 year average return interval (ARI) in Houston,TX area based on ATLAS14

HRRRE 2017 Design



HRRRE 2017 (01 March – 30 June 2017)

55% CONUS HRRR



Proof-of-concept
Real-time demonstration
With NSSL Experimental
WoF System for ensembles
“NEWS-e”

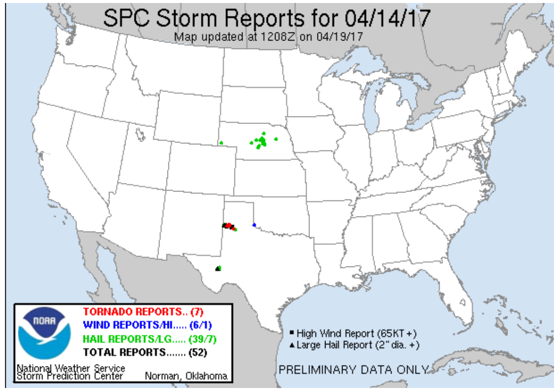
Real-Time Web Graphics
https://rapidrefresh.noaa.gov/hrrr/HRRRE

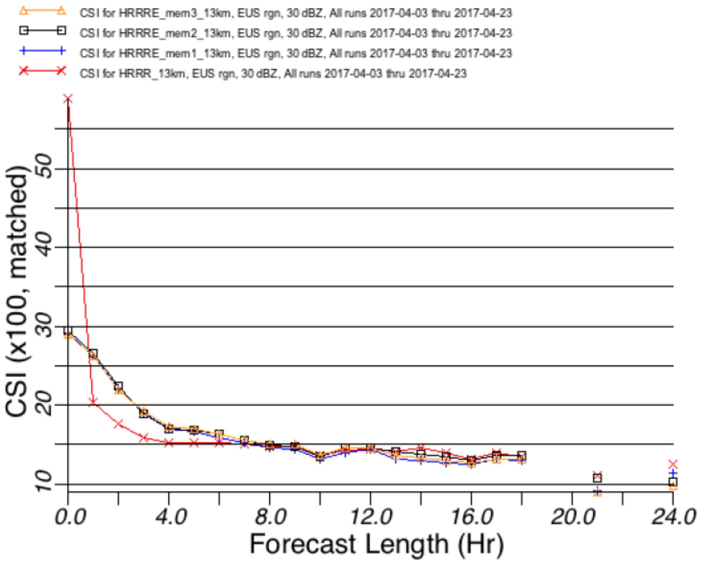
- Single core (ARW)
- Ensemble DA (DART and GSI-EnKF)
- RAP mean + GDAS perturbations w/more inflation
- Conventional observations
- Radar reflectivity observations
- Stochastic physics
- Cloud analysis
- Soil adjustments
- HRRR-TLE post-processing

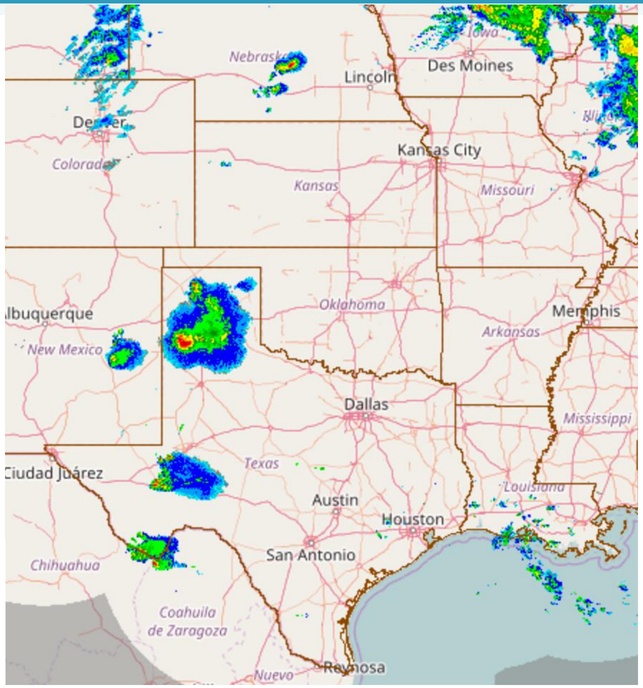
Assimilation	Forecast
36 members	12z – Nine members to 18 hrs
1 hr cycling	15z – Nine members to 18 hrs
15 fcsts / day	18z – Nine members to 18 hrs
Start 09z day one	21z – Nine members to 18 hrs
End 00z day two	00z – Nine members to 36 hrs

Ensemble Forecast Challenge: Spread vs Error

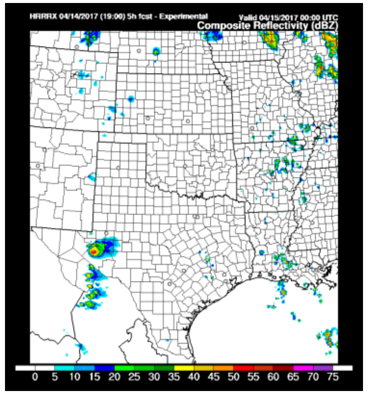
Isolated Supercell
00z 15 April 2017

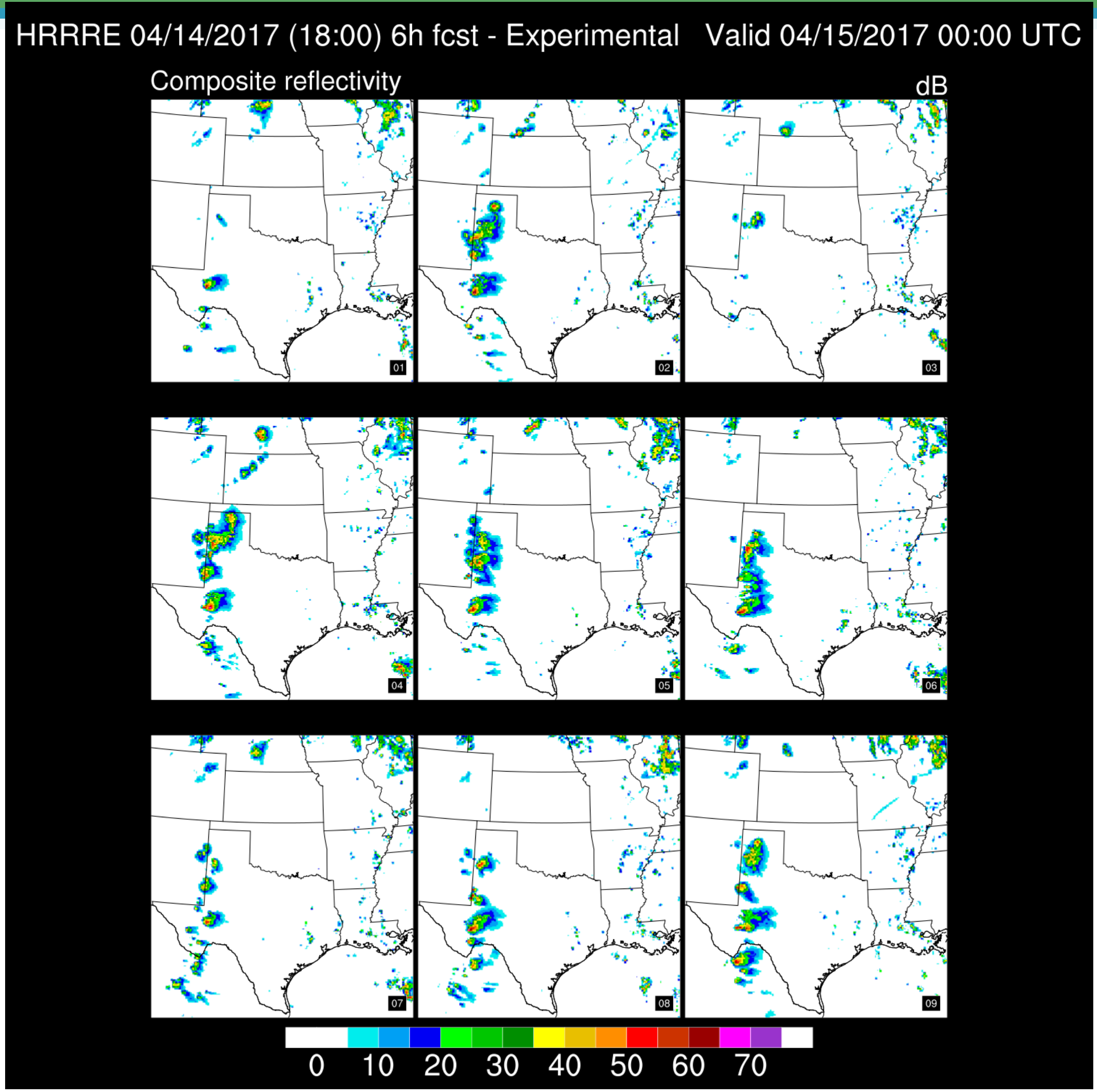






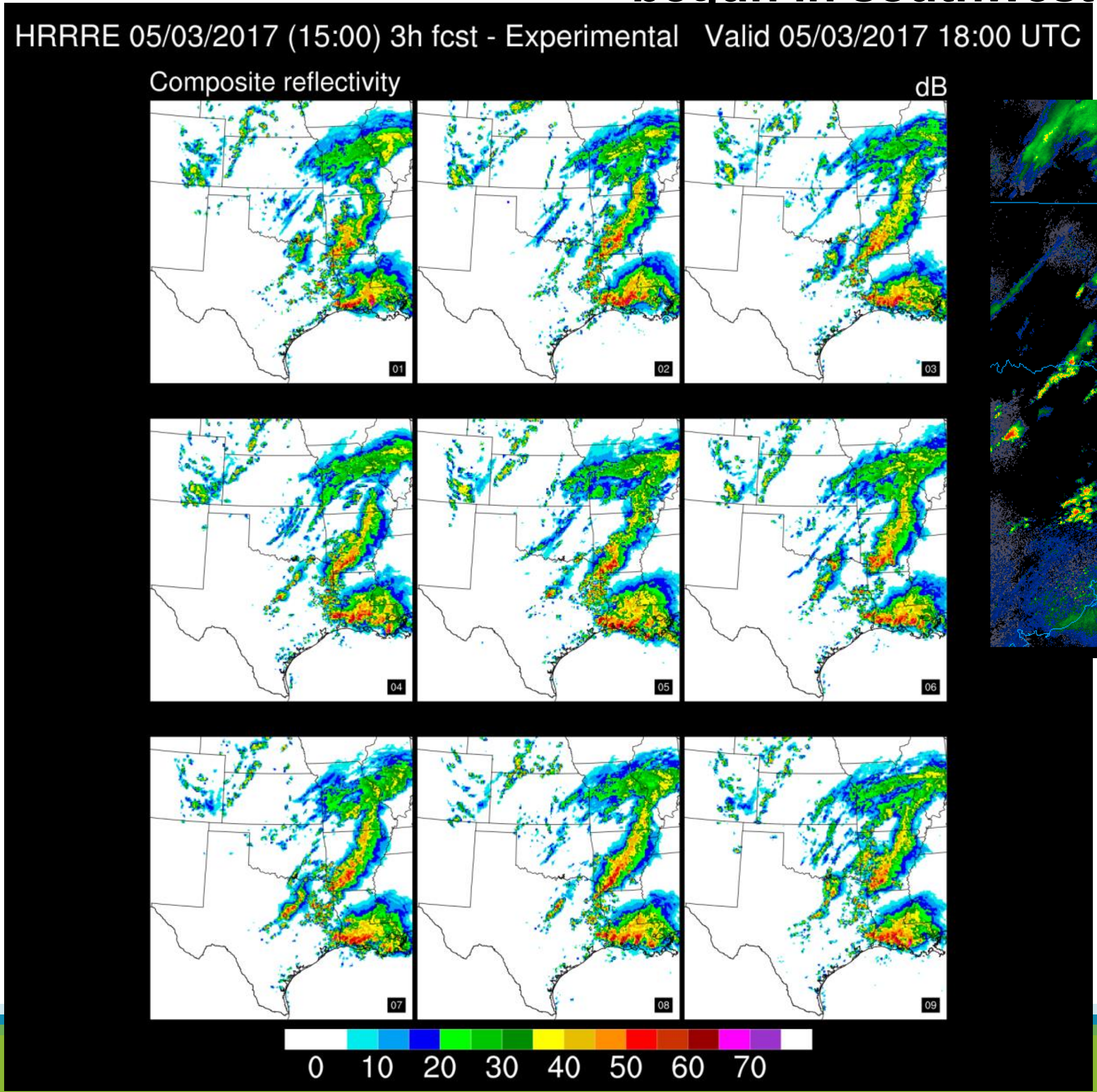
Deterministic HRRR 6-hr Forecast

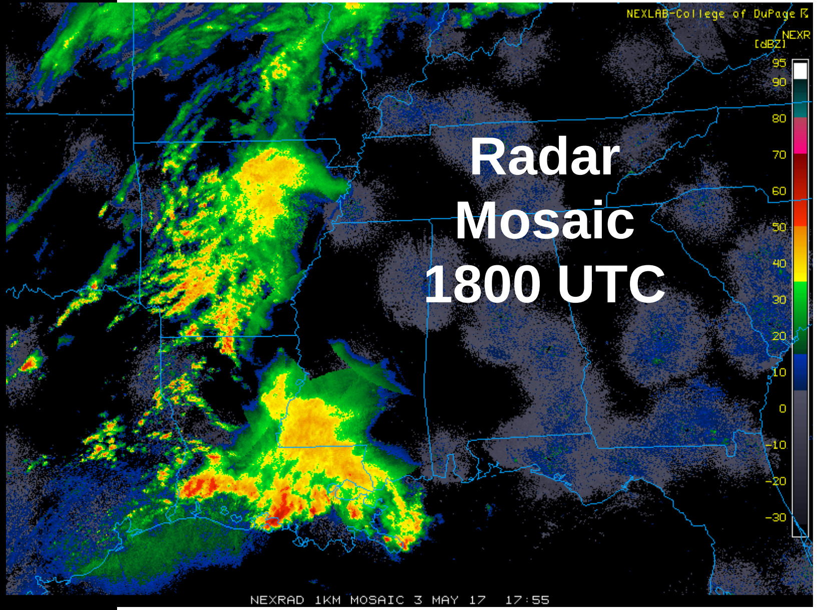




Louisiana heavy rain 3-4 May 2017

HRRRE forecast was initialized at 1500 UTC 3 May, when convective storms had just begun in southwest Louisiana.

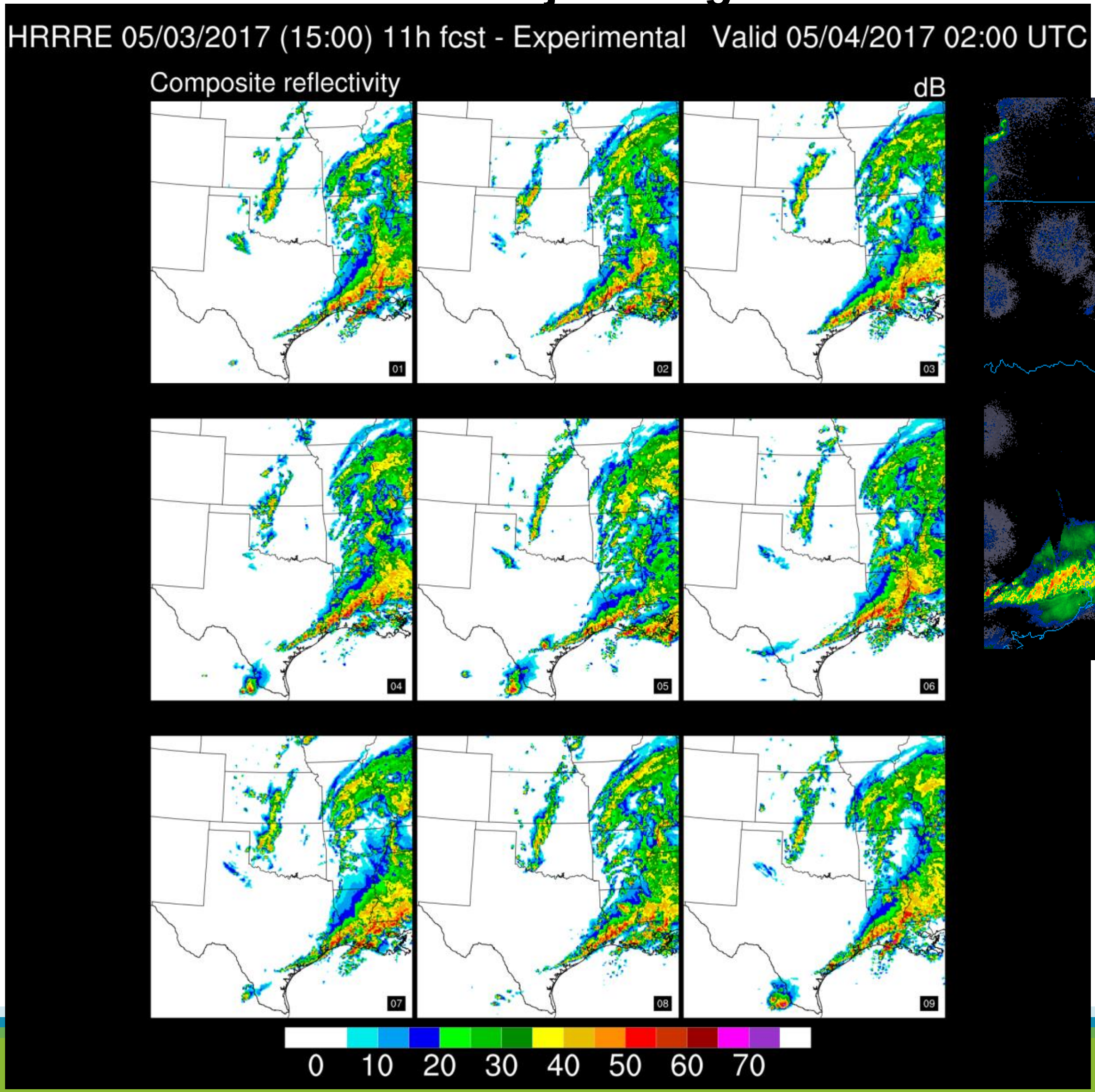


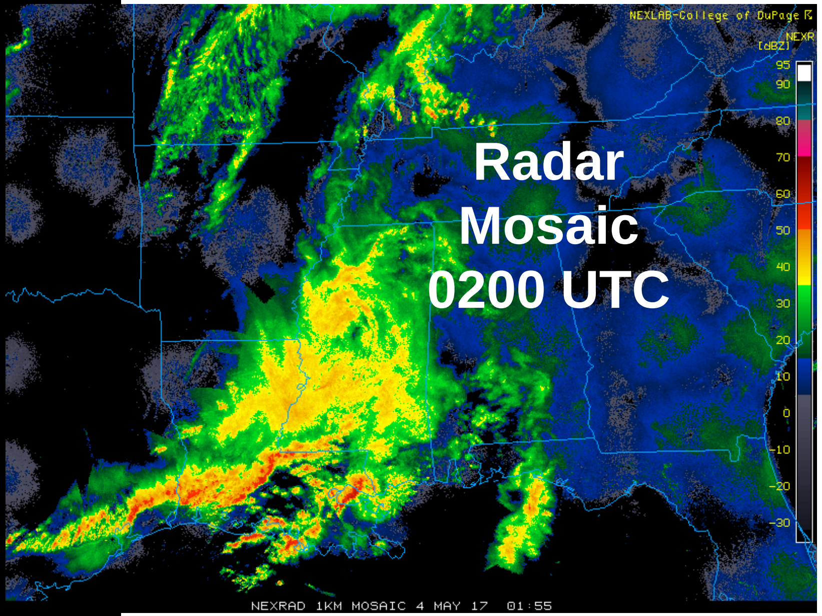


3-h forecast members agree and provide good representation of southern Louisiana convective system.

Louisiana heavy rain 3-4 May 2017

HRRRE forecast was initialized at 1500 UTC 3 May, when convective storms had just begun in southwest Louisiana

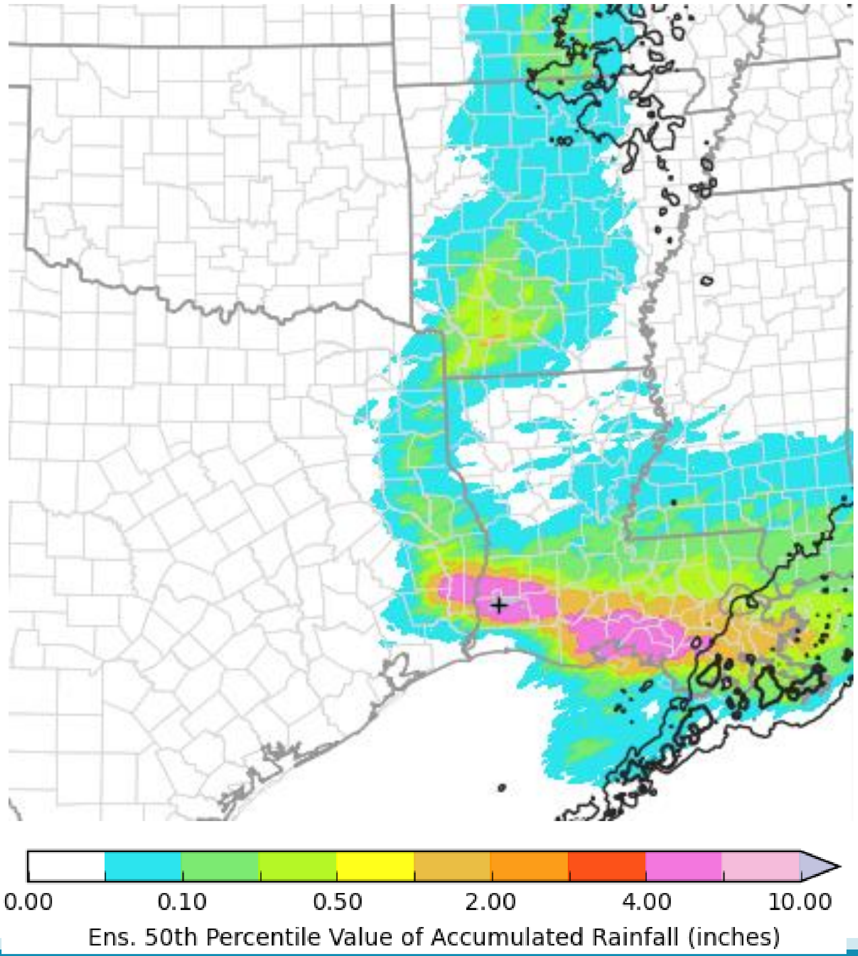




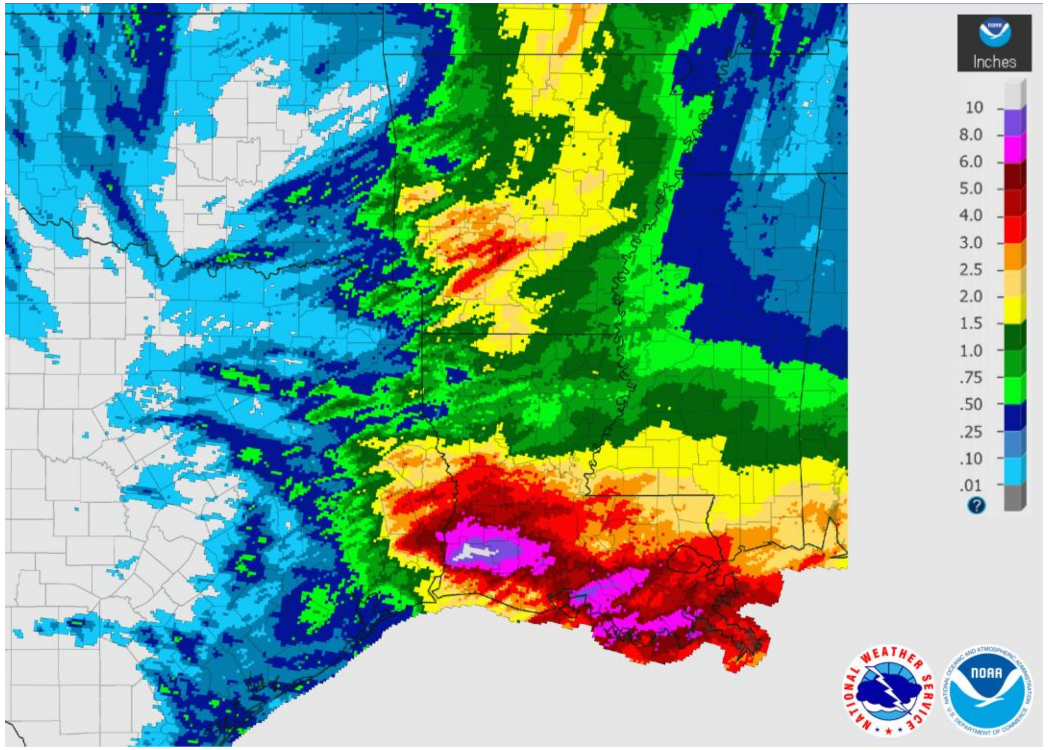
11-h forecast members indicate a second wave of convective storms in southern Louisiana, with some variability in details.

Louisiana heavy rain 3-4 May 2017

HRRRE 50% percentile rainfall, 0-18 h forecast for period ending 0900 UTC 4 May

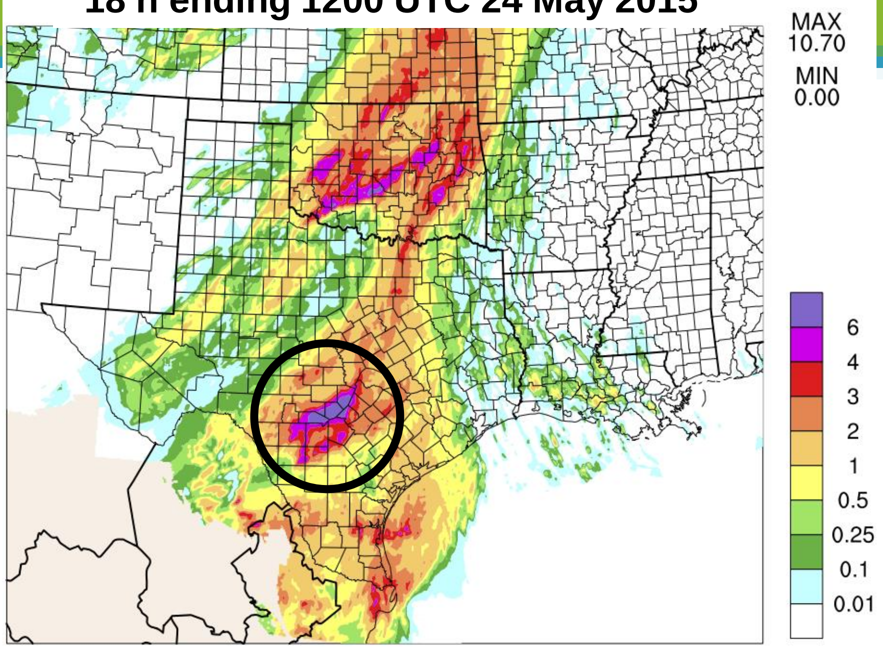


24-h QPE for period ending 1200 UTC 4 May



Texas Hill Country Flood
23-24 May 2015

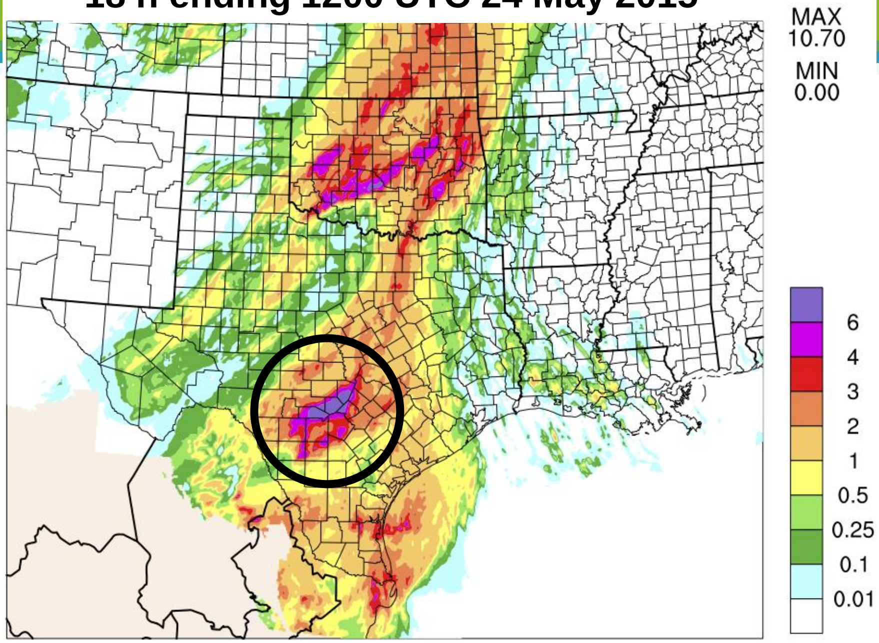
Stage 4 precip (in)
18 h ending 1200 UTC 24 May 2015

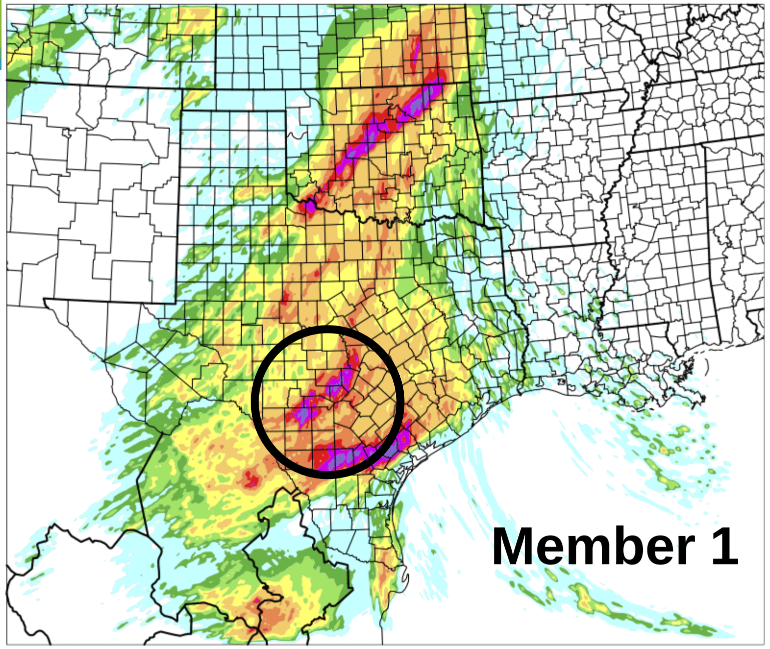


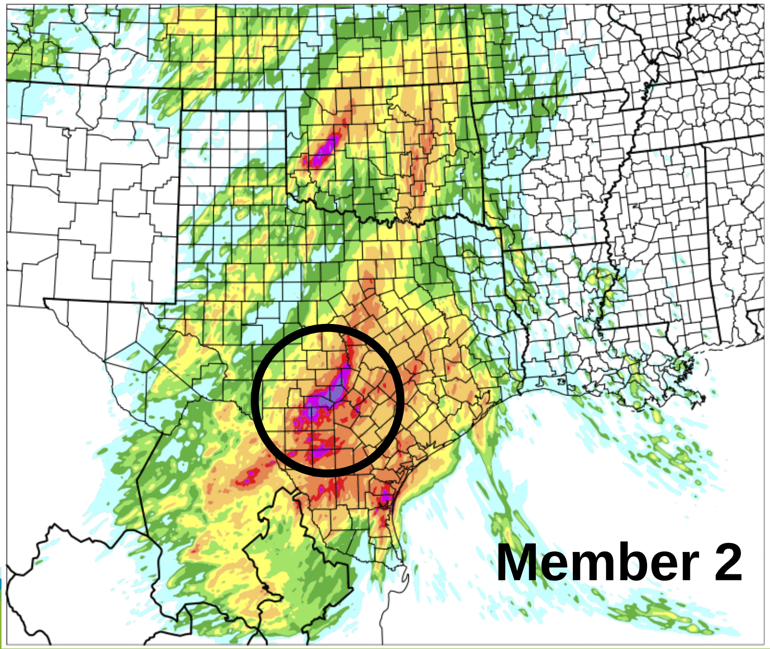
Stage 4 precip (in)

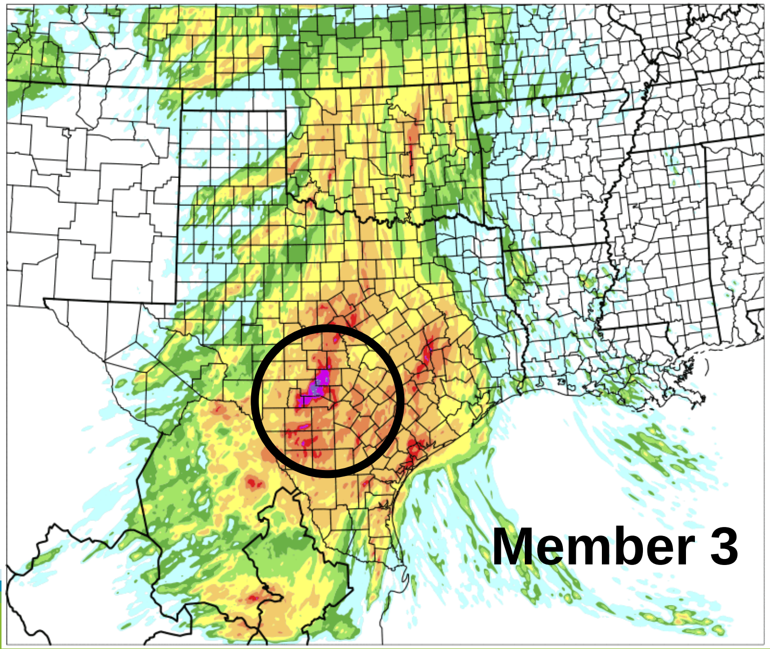
18 h ending 1200 UTC 24 May 2015

HRRRE 2100 UTC init, 15-h fcst









RAP / HRRR: Implementation Schedule

RAPv3 – Reduced warm / dry bias → NCEP Implement Aug 2016
- Improved PBL, LSM, cu-parm, DA
- Thompson/NCAR aerosol-aware microphysics

HRRRv2 – Improved convection → NCEP Implement Aug 2016
- Initialized by RAP (v3)
- Improved radar assimilation, hybrid assimilation, PBL/cloud physics

RAPv4 – GSD testing 2016 /17 → NCEP Implement Feb 2018
- 3D cloud fraction, better coupling to radiation scheme, better ceiling

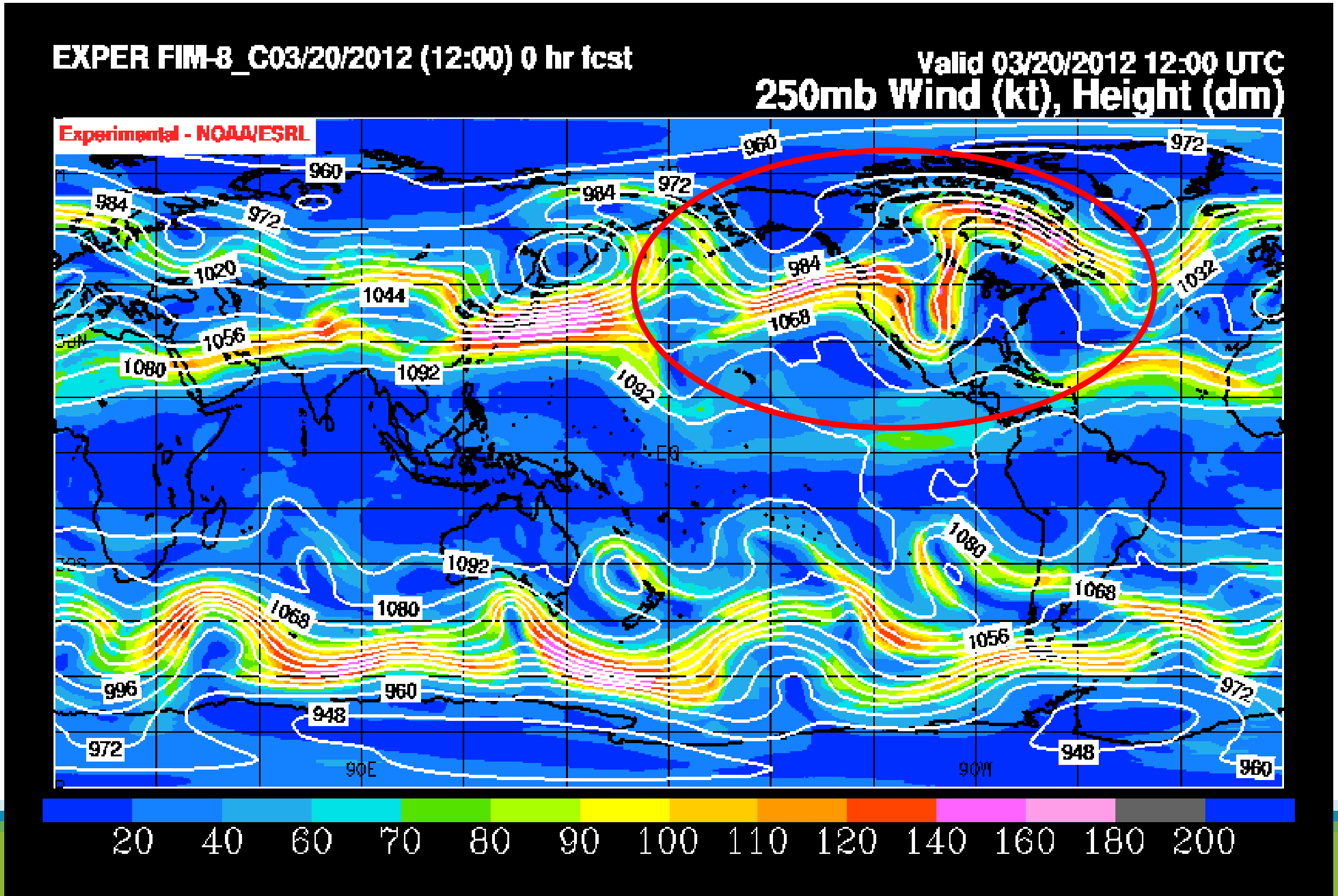
HRRRv3 – GSD testing 2016 /17 → NCEP Implement Feb 2018
- HRRR – Addition of 36h forecasts, Alaska domain
- Reduced precip bias, improved retention of clouds

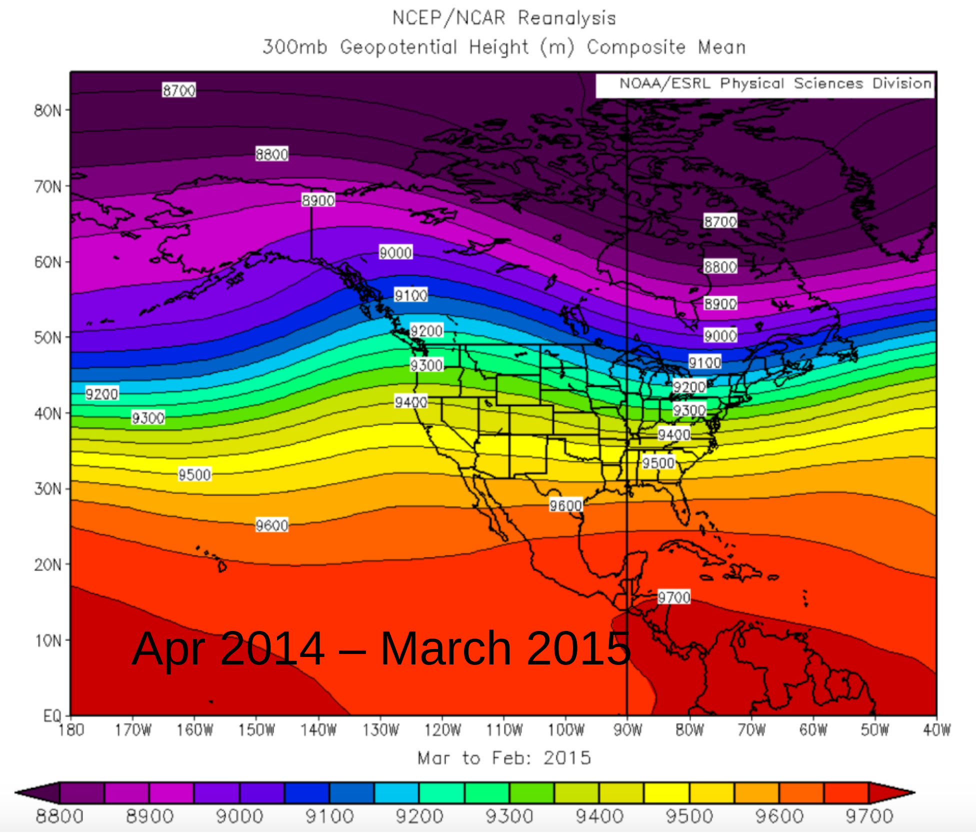
HRRRE – GSD testing in 2016/17 → NCEP implement 2019?
- **Storm-scale ensemble forecast component**

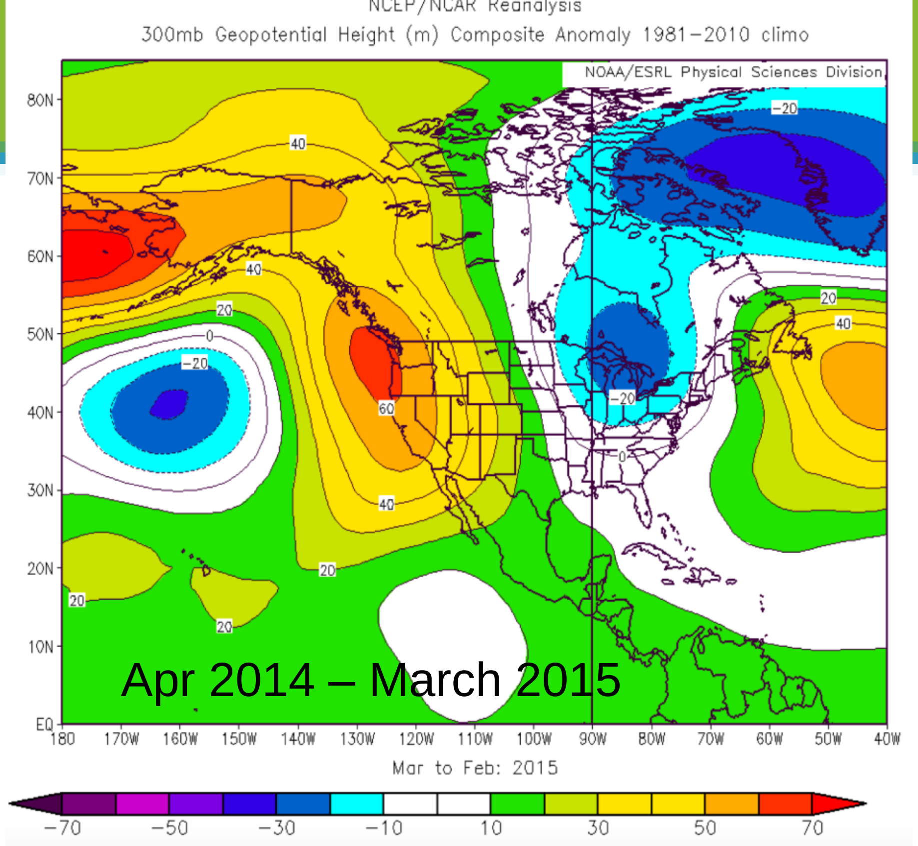
Episodic Weather Extremes from Blocking

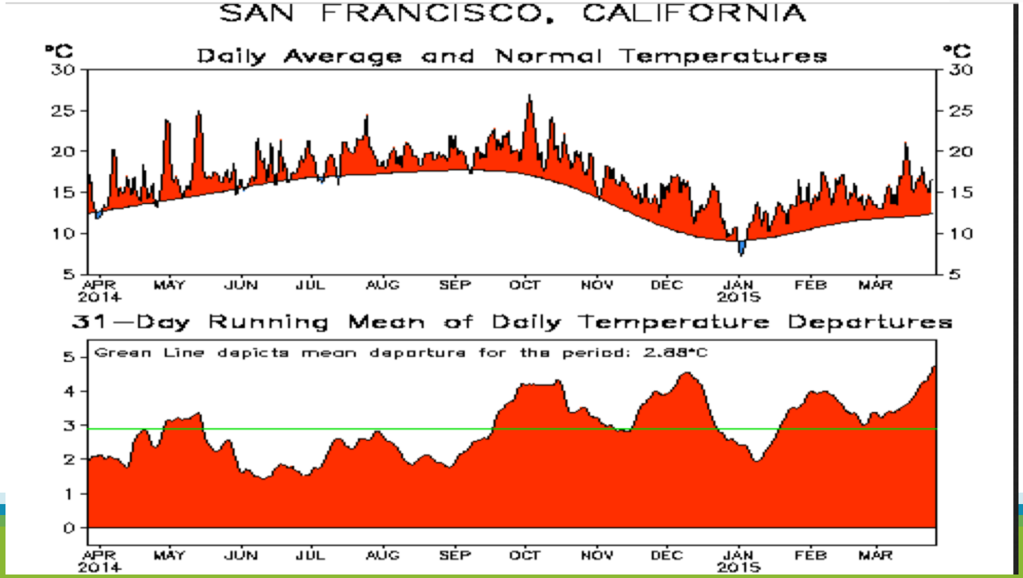
Longer-term weather anomalies from atmospheric blocking -Defined here as either ridge or trough quasi-stationary events with duration of at least 4 days to 2+ months

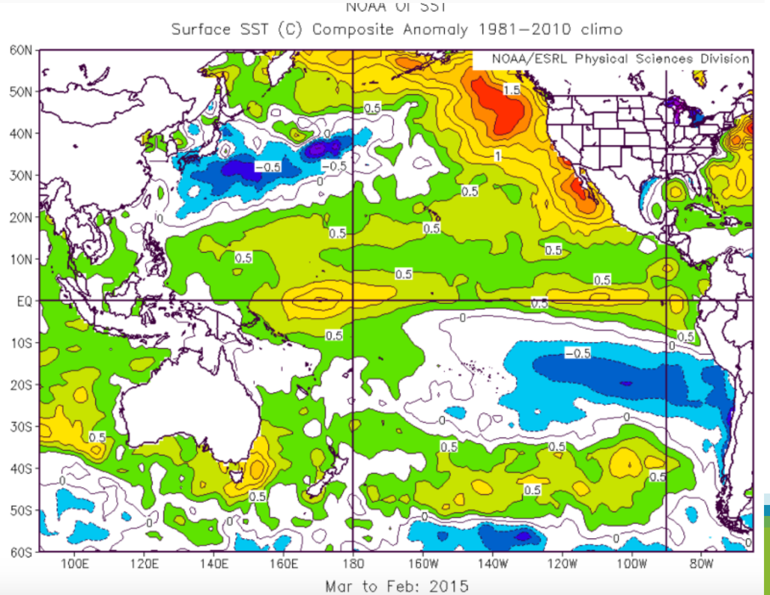
ESPC focus area #1 target: improved 0.5-6 month forecasts of blocking and related weather extremes




NCEP/NCAR Reanalysis
300mb Geopotential Height (m) Composite Mean
NOAA/ESRL Physical Sciences Division
Apr 2014 – March 2015
Mar to Feb: 2015
8800 8900 9000 9100 9200 9300 9400 9500 9600 9700

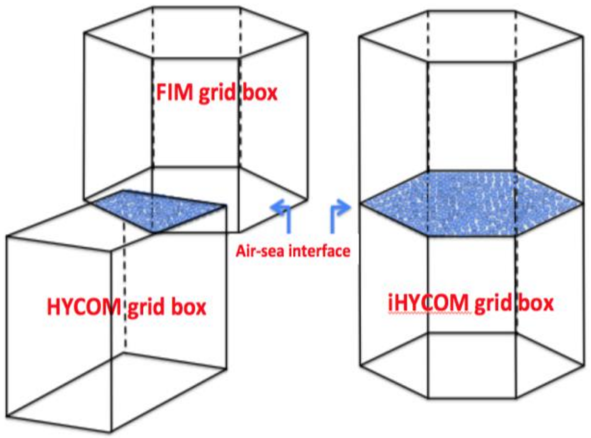

NCEP/NCAR Reanalysis
300mb Geopotential Height (m) Composite Anomaly 1981–2010 climo
NOAA/ESRL Physical Sciences Division
Apr 2014 – March 2015
Mar to Feb: 2015
–70 –50 –30 –10 10 30 50 70


SAN FRANCISCO, CALIFORNIA
Daily Average and Normal Temperatures
31–Day Running Mean of Daily Temperature Departures
Green Line depicts mean departure for the period: 2.88°C


NOAA OI SST
Surface SST (C) Composite Anomaly 1981–2010 climo
NOAA/ESRL Physical Sciences Division
Mar to Feb: 2015

NOAA Subseasonal Experiment (SubX)

Multi-Model Ensemble – Week 3-4



Coupled FIM-HYCOM

- *atmosphere-ocean model*
- *testing down to 15km*

Component of Earth System Prediction Capability – ESPC

- NOAA, Navy, DoD
- NOAA SubX working with International S2S Project

Subseasonal S2S NMME

GLOBAL SYSTEMS DIVISION

	Time-range	Resol.	Ens. Size	Freq.	Hcsts	Hcst length	Hcst Freq	Hcst Size
ECMWF	D 0-32	T639/319L91	51	2/week	On the fly	Past 18y	2/weekly	11
UKMO	D 0-60	N96L85	4	daily	On the fly	1989-2003	4/month	3
NCEP	D 0-45	N126L64	4	4/daily	Fix	1999-2010	4/daily	1
EC	D 0-35	0.6x0.6L40	21	weekly	On the fly	Past 15y	weekly	4
CAWCR	D 0-60	T47L17	33	weekly	Fix	1981-2013	6/month	33
JMA	D 0-34	T159L60	50	weekly	Fix	1979-2009	3/month	5
KMA	D 0-60	N216L85	4	daily	On the fly	1996-2009	4/month	3
CMA	D 0-45	T106L40	4	daily	Fix	1992-now	daily	4
Met.Fr	D 0-60	T127L31	51	monthly	Fix	1981-2005	monthly	11
CNR	D 0-32	0.75x0.56 L54	40	weekly	Fix	1981-2010	6/month	1
HMCR	D 0-63	1.1x1.4 L28	20	weekly	Fix	1981-2010	weekly	10
FIM/HYC	**0-32**	**30kmL64 OL32**	**10**	**weekly**	**Fix**	**1999-2014**	**weekly**	**4**

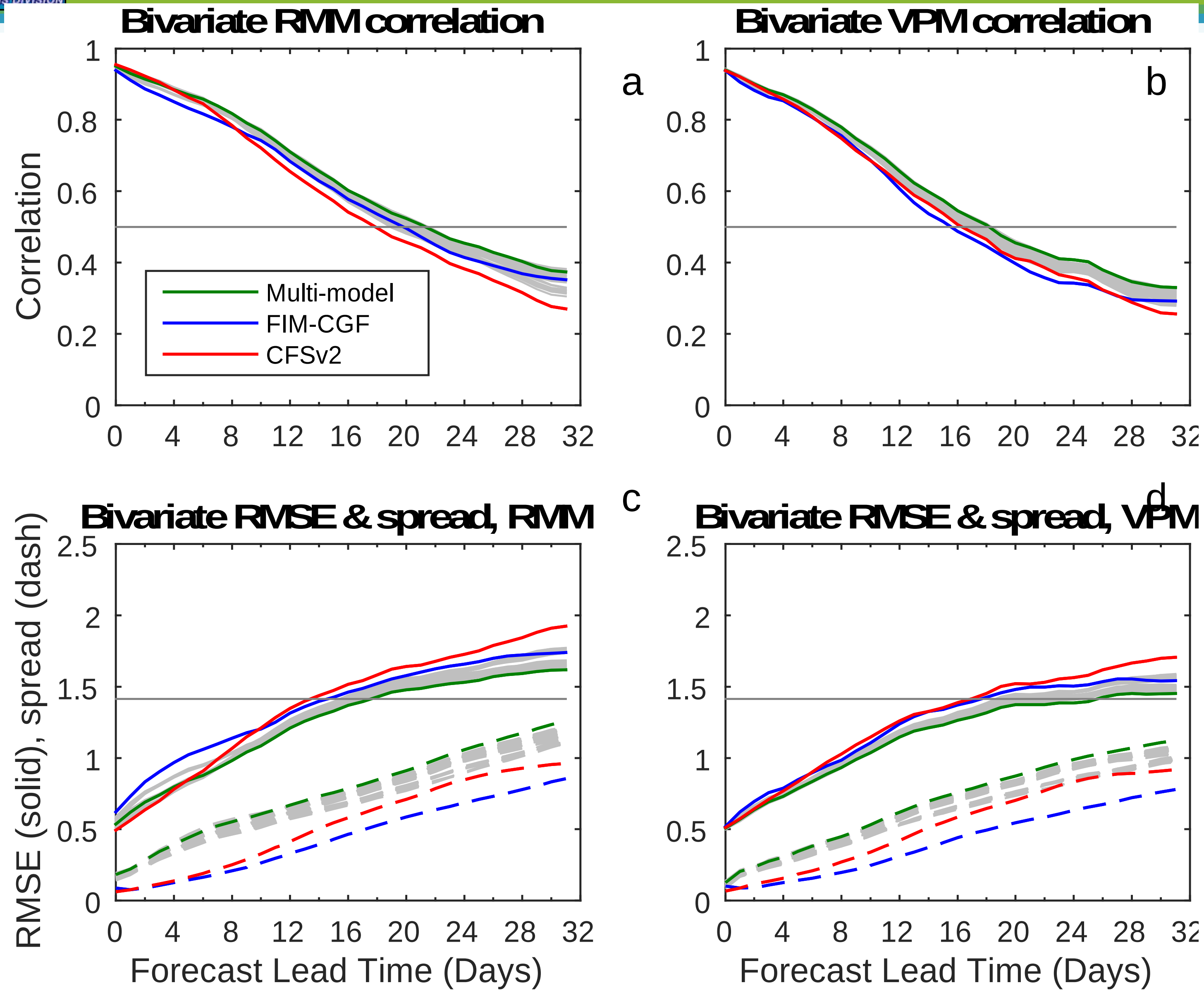
2020-22 – FV3 NOAA model for future Climate Forecast System (CFS)

Mergers of multi-agency components for earth system models

Attribute / Model	**CFS v2** **Implemented March 2011**	**FIM/iHYCOM**
Analysis resolution	38 km (T382)	Use CFSv2 initial conditions
Atmosphere model - resolution	100km (T126 – spectral) / 64 levs (sigma-p)	30km/60km (icosahedral) / 64 levs (hybrid isentropic-sigma) - ALE
Model physics	GFS-2007/CFS - Variable CO2 AER SW and LW radiation Prognostic clouds and liquid water Retuned mountain blocking Convective gravity wave drag	Similar but updated to 2015 GFS physics suite including hybrid EDMF PBL Also with Grell-Freitas (2014) deep cum. **(upcoming – test with HRRR/RAP physics)**
Ocean model	MOM-4 –global ¼ x ½ deg - tripolar Assimilation depth – 4737m	HYCOM – global (hybrid-isopycnal) - ALE (collaboration with Navy, NOAA/NCEP) 30/60km icosahedral – matched w/ atmos grid
Land-surface model (LSM) and assimilation	Noah LSM with USGS/CFS land-use, initialized with daily GLDAS . Ice - prognostic sea ice within MOM4	Noah LSM - Same as GFS MODIS land-use Ice - HYCOM energy loan
Coupling frequency	30 minutes	Every physics time step (3 min)

Similar / Different

MJO forecasts – 1999-2014: CFSv2 + FIM-CGF skill and spread



- Top: Bivariate correlation
- Bottom: RMSE and spread
- Left: RMM; Right: VPM
- Gray: 8 choose 4 = 70 combinations of 4-member multi-*model* ensembles
- Interesting points:
  - Multi-model ensemble of CFSv2 + FIM-CGF always beneficial: increased skill, decreased RMSE, increased spread
  - Improvement from multi-model ensemble is **not** simply due to increased ensemble size: see gray lines

Future direction for NOAA/ESRL modeling

- Develop and demonstrate advanced earth system modeling/assimilation components for research and NOAA/NWS operations.
- Improve understanding of earth processes with advanced models and observations.
- Focus on 2 scales: global model and storm-scale regional model
  - FV3 for global model – working with NWS, NCEP, GFDL, other laboratories. Build off experience with FIM and its physics/ocean/chem applications.
  - HRRR-WRF-ARW for regional storm-scale model – working with NCEP, NCAR, other labs
    - Lead storm-scale physics development and storm-scale assimilation (w/ radar, cloud, sat, etc.)
    - Testing of FV3 for detailed convective storm evolution for possible application at storm-scale – with NSSL, NCEP, GFDL and others
- Development of coupled models – ocean/water, chemistry/fire/aerosols, process studies, application to subseasonal-seasonal prediction

ESRL Focus: Earth-system prediction for situational awareness (hourly) to medium-range NWP to subseasonal.