Development of the High Resolution Rapid Refresh (HRRR) Version 4 and Transition to an FV3 based Rapid Refresh Forecast System (RRFS)

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Cooperative Institute for Research in Environmental Sciences

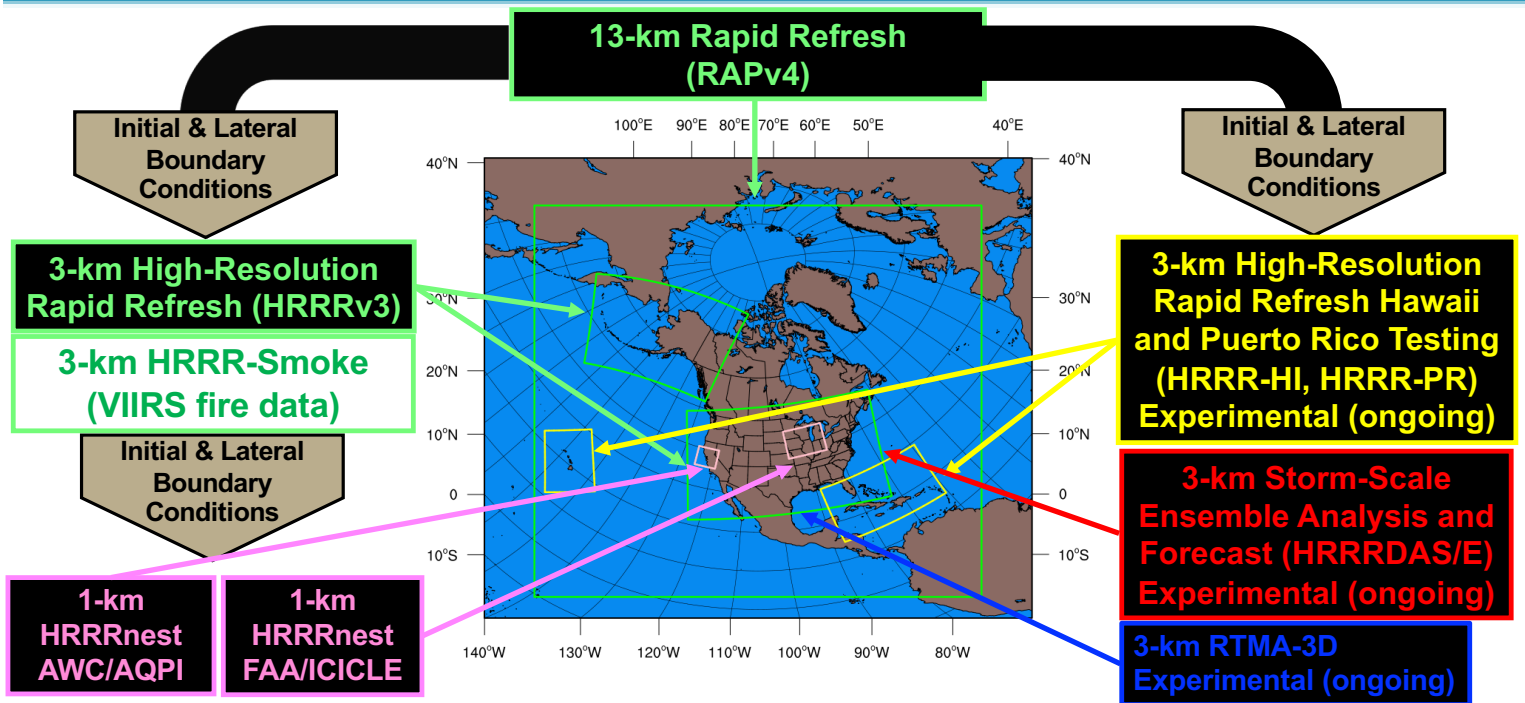NOAA/ESRL/GLOBAL SYSTEMS DIVISION

EGU Vienna   8 April 2019

RAP/HRRR Model Forecast Suite

13-km Rapid Refresh (RAPv4)

Initial & Lateral Boundary Conditions

Initial & Lateral Boundary Conditions

3-km High-Resolution Rapid Refresh (HRRRv3)

3-km HRRR-Smoke (VIIRS fire data)

Initial & Lateral Boundary Conditions

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

3-km Storm-Scale Ensemble Analysis and Forecast (HRRRDAS/E) Experimental (ongoing)

3-km RTMA-3D Experimental (ongoing)

1-km HRRRnest AWC/AQPI

1-km HRRRnest FAA/ICICLE

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Vision: High Resolution and Rapidly Updating Probabilistic Forecast Guidance for Weather Hazards

Expected Spring 2020:

RAPv5 / HRRRv4

➤ **Physics improvements & smoke prediction**
➤ **HRRR ensemble data assimilation**

➤ **Better short-range cloud and storm prediction (last ARW implementation)**

## Expected in 2022:

Rapid Refresh Forecast System (RRFS)

➤ **Full CAM ensemble assimilation / prediction**
➤ **Use of NOAA Unified Forecast System**

➤ **Improved deterministic prediction**
➤ **Improved uncertainty / probability information**

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Data assimilation work

- **HRRRDAS ensemble data assimilation (HRRRv4)**

- Why do we want to use CAM ensemble data assimilation?
  - Ensemble covariances provide time- and flow-dependent information at CAM scales
- How does ensemble data assimilation help?
  - Improve initial conditions

Observation

Initial Condition Ensemble

Ensemble Analysis Mean

Ensemble Forecast Mean

1-hour Ensemble Forecast

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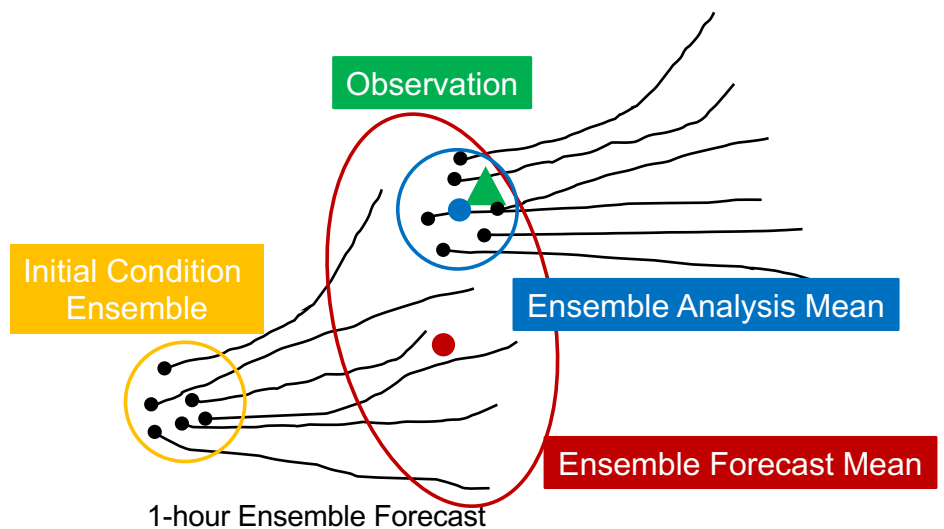
Nested 15-km and 3-km domains

36 members
- Initial mean from GFS (atmos.) and RAP-HRRR (soil)
- Atmospheric perturbations from GFS ensemble (GDAS) to initialize HRRRDAS ensemble
- Random soil-moisture perturbations

Hourly cycling with EnKF data assimilation
- 50,000 to 100,000 Conventional observations
- 100,000 Reflectivity observations 3-km domain only
- Tight localization
- Analysis variables: U, V, PH, T, MU, QVAPOR, QCLOUD, QICE, QRAIN, QSNOW, QGRAUPEL

$\Delta x = 3$ km

$\Delta x = 15$ km

Sources of Spread
- **Hourly DA (adaptive multiplicative posterior inflation)**
- **Lower boundary perturbations (soil moisture)**
- **Lateral boundary perturbations**

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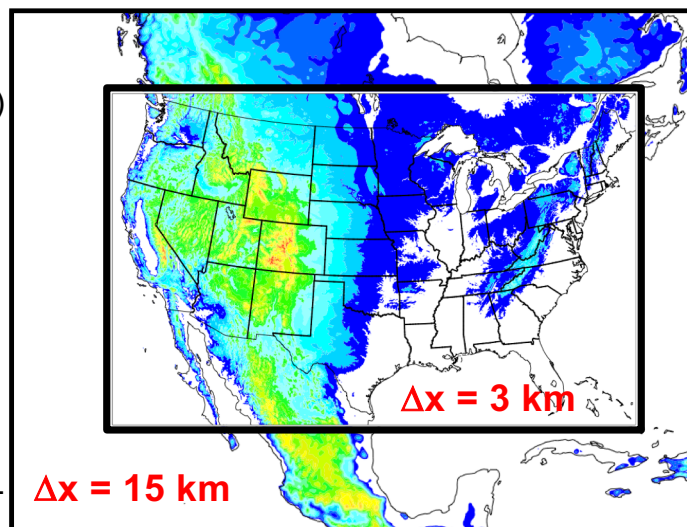
HRRR and HRRRE Member Reflectivity Forecast Skill

CSI 30-dbz Threshold
Eastern US
0000 UTC Forecasts

HRRR

HRRRE mem1
HRRRE mem2
HRRRE mem3
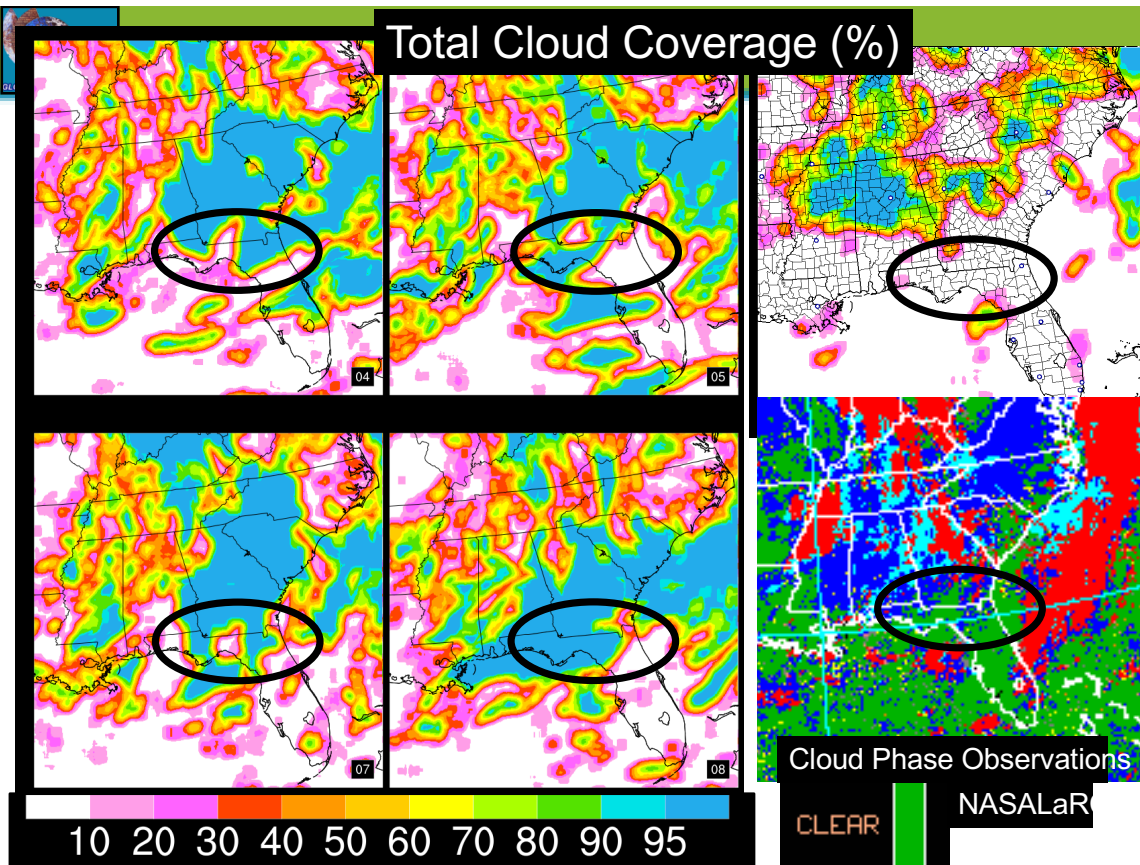
3-h cycling before forecast

15-h cycling before forecast
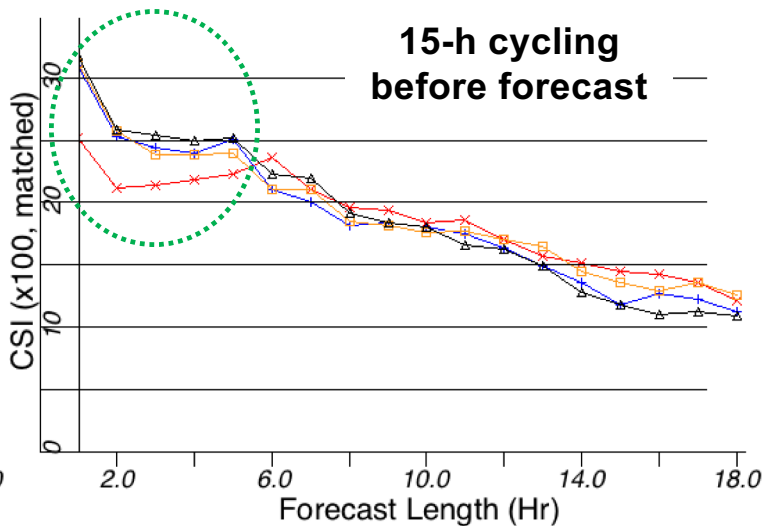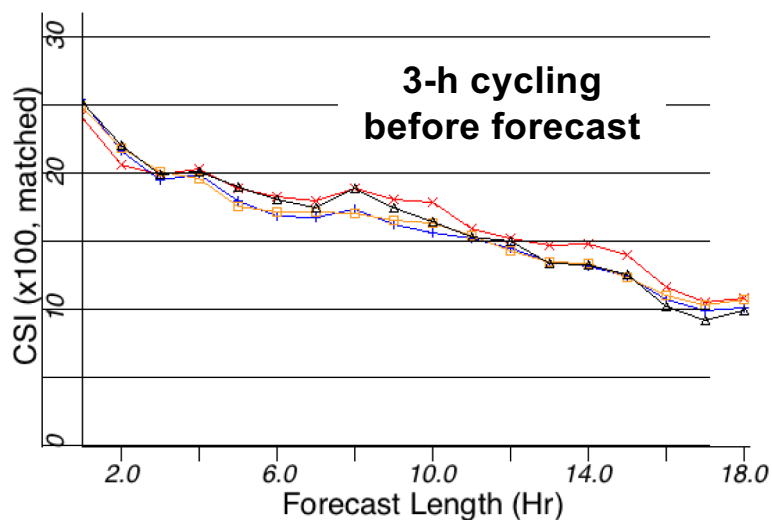
Total Cloud Coverage (%)

Aug 20th 2018
3-h Fcst @ 15 UTC
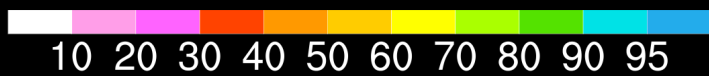
HRRRE has Larger Amounts & Greater Coverage of Clouds

Cloud Phase Observations

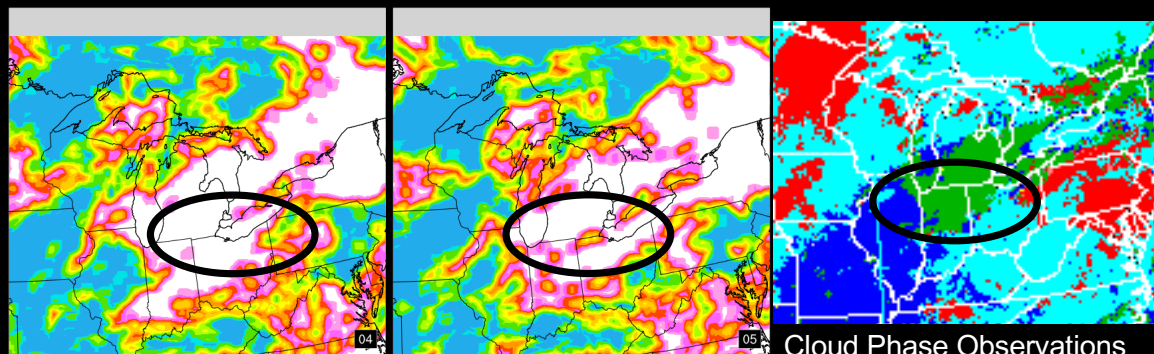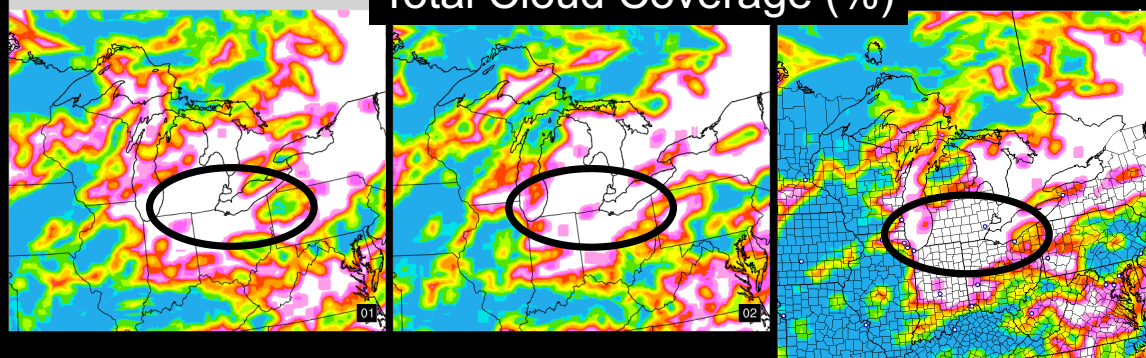CLEAR

NASALaRC

10 20 30 40 50 60 70 80 90 95

Hydrometeor Analysis

The model hydrometeors are updated based on cloud and precipitation observations to provide a high resolution analysis.

GOES

Provided by NASA Langley

Clear model hydrometeors

Add precip hydromet

Add cloud hydrometeors

WSR-88D

ceilometeors

Total Cloud Coverage (%)

10 20 30 40 50 60 70 80 90 95
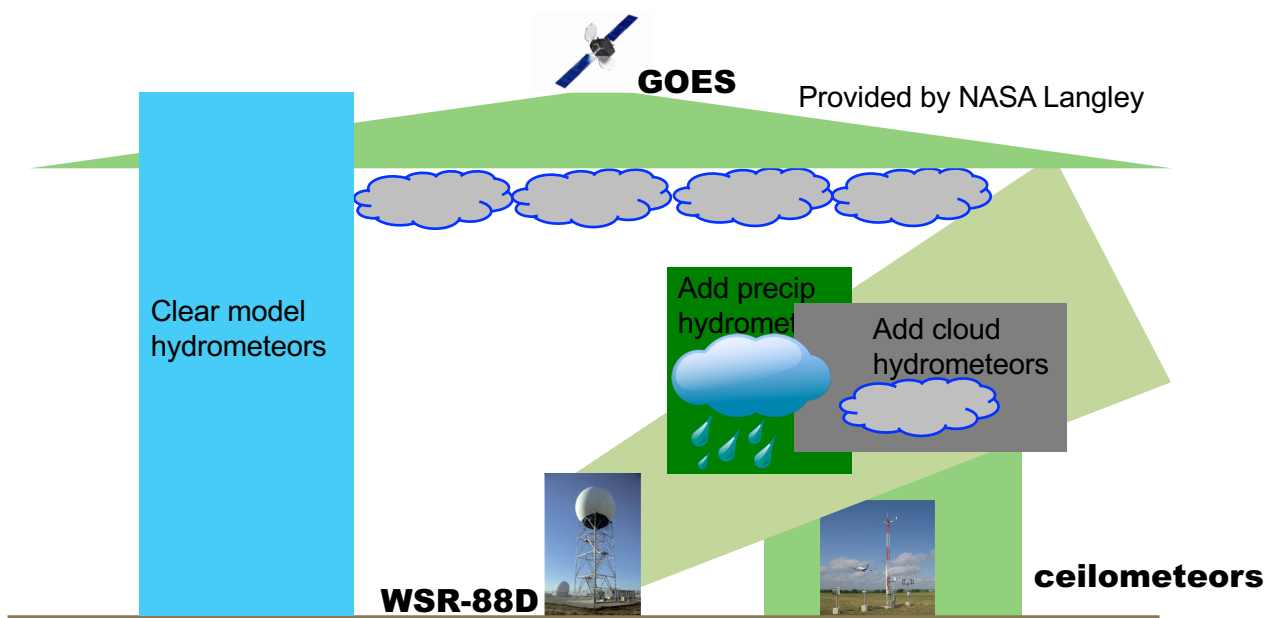
Cloud Phase Observations

CLEAR   NASALaRC

Oct 14th 2018
3-h Fcst @ 15 UTC

HRRRE has
Reasonable
Cloud
Coverage

Any Cloud Ceiling Bias

HRRRE Member 1

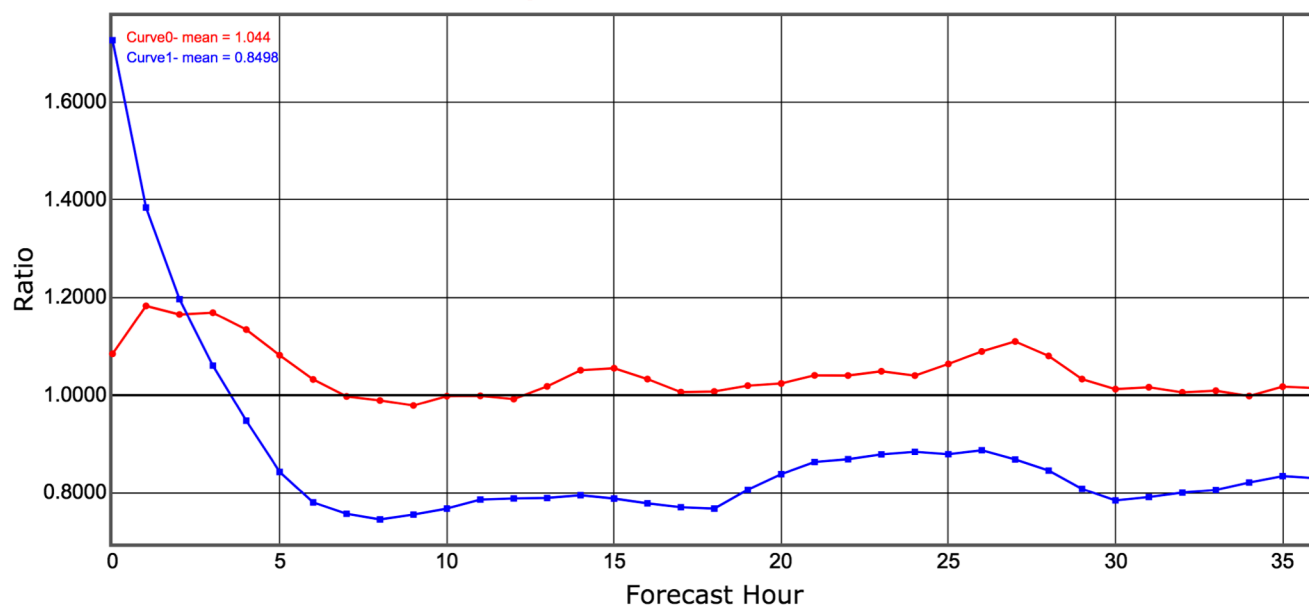August Forecasts – no cloud DA

September Forecasts – with cloud clearing

HRRRE Member 1

August Forecasts – no cloud DA
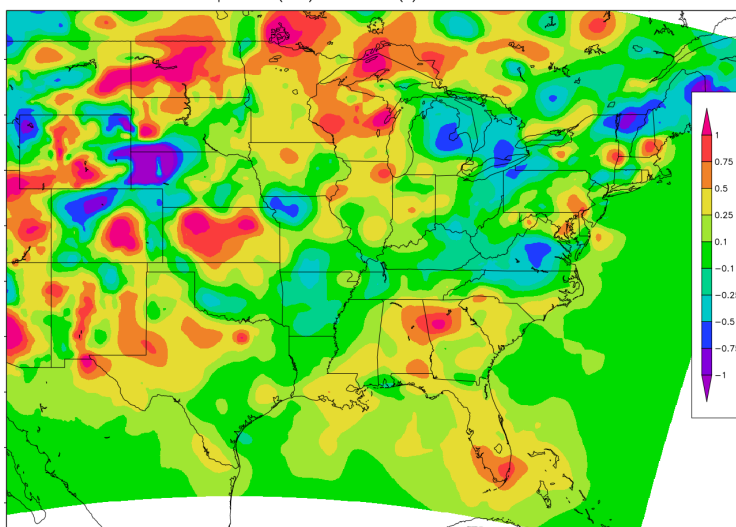
September Forecasts – with cloud clearing

HRRRv4 – Using CAM covarainces
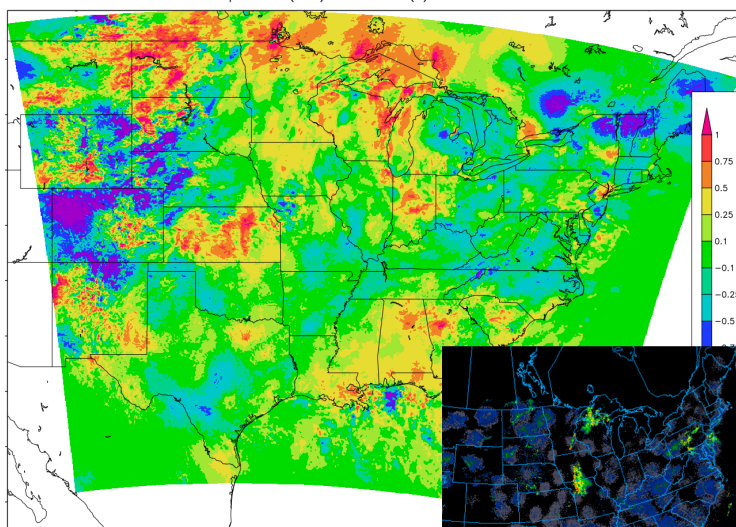## Analysis Increment: T at lowest model level
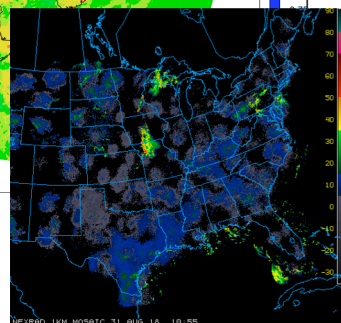
HRRRX temperature (z=0) increments (K) at 1100 UTC 31 AUG 2018

HRRRdev3 temperature (z=0) increments (K) at 1100 UTC 31 AUG 2018

**HRRRX (GDAS
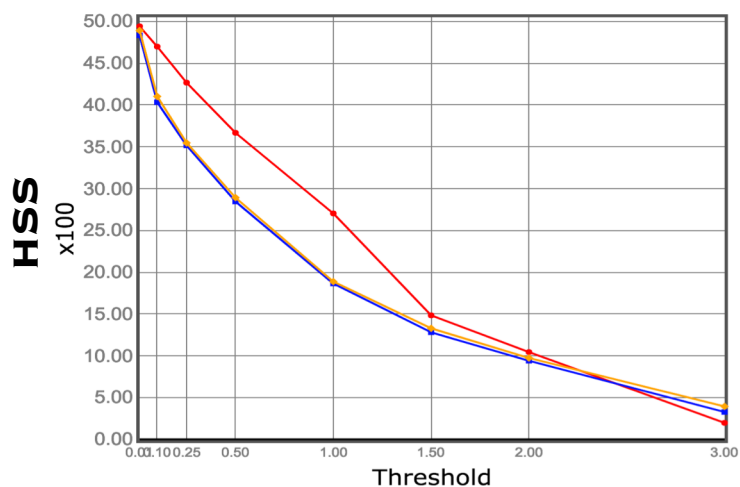ensemble background)**
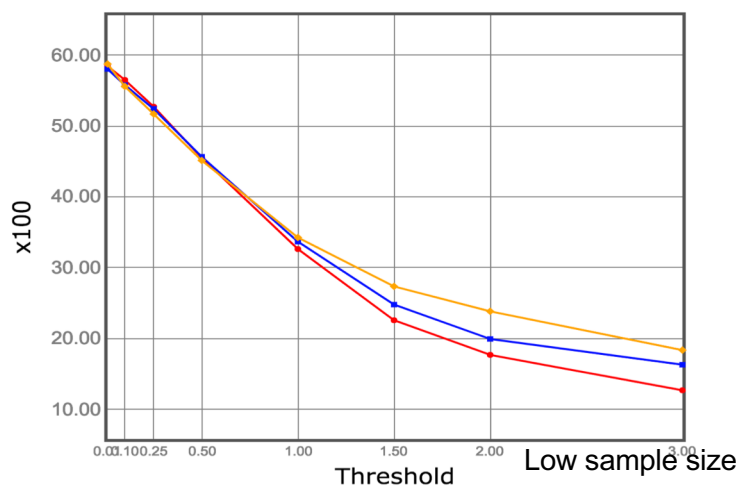
**HRRRdev3 (HRRRDAS
ensemble background)**

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Precipitation Verification in Eastern US

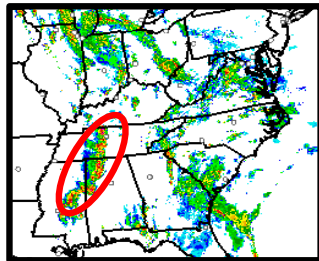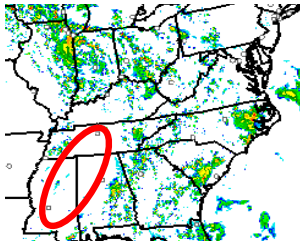**6-HOUR PRECIP**

12-HOUR PRECIP

HRRRX + HRRRDAS   Improved precip skill in first 6 hrs
HRRRX
HRRRv3

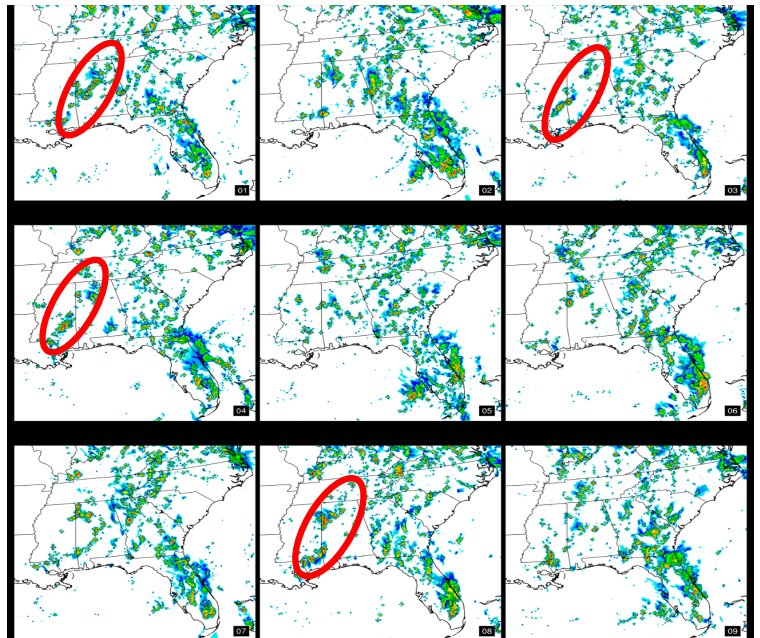Low sample size

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Benefits of HRRRE information for aviation

12z+11h HRRR Ensemble forecasts

Four of nine HRRRE ensemble members captured a squall-line (with high aviation impact) that was COMPLETELY MISSED by the single deterministic HRRR run

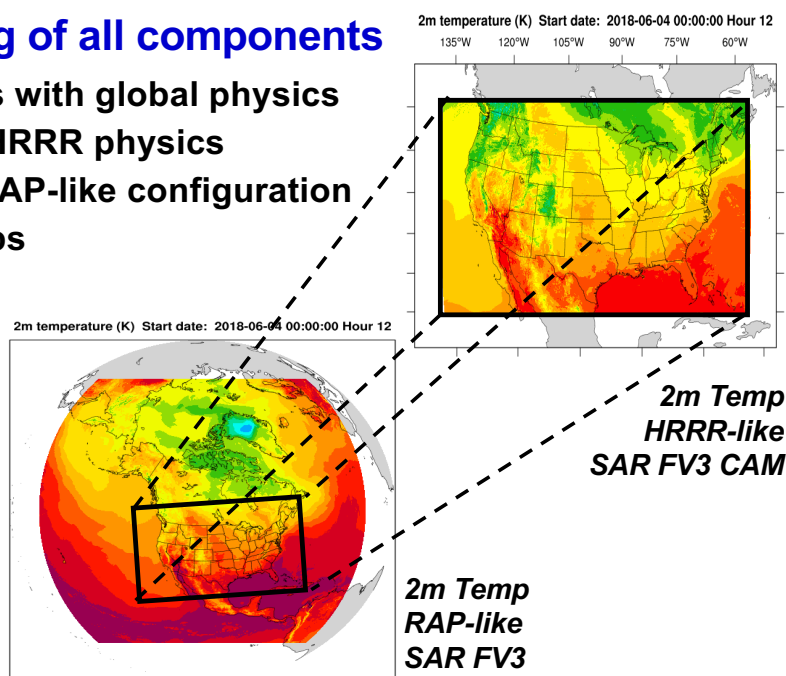## Deterministic
11z+12h   **23z anx**

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Ongoing / planned sequential testing of all components

-- Cold start RAP and HRRR configurations with global physics

-- Cold start each configuration with RAP/HRRR physics

-- Initialize HRRR-like configuration from RAP-like configuration

-- Add in GSI analysis with conventional obs

-- Add in satellite and radar observations

-- Add in pre-forecast / cycling

-- Add in ensemble data assimilation

-- Add in ensemble prediction

Key question:

When will global prediction grids
be sufficient to directly initialize
HRRR-like SAR FV3-CAM from them?
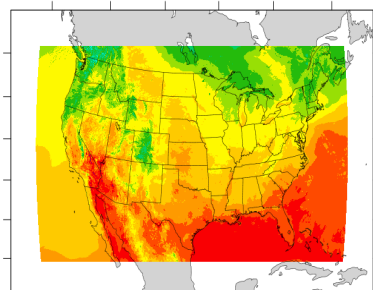
2m temperature (K) Start date: 2018-06-04 00:00:00 Hour 12

*2m Temp
HRRR-like
SAR FV3 CAM*

2m temperature (K) Start date: 2018-06-04 00:00:00 Hour 12

*2m Temp
RAP-like
SAR FV3*

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Evolution from RAPv5 / HRRRv4 to RRFSv1

	2018				2019				2020				2021				2022			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4

RAPv5/HRRRv4 R&D

RAPv5/HRRRv4 T2O

RRFS R&D

RRFS T2O

Final WRF-ARW (v4.0) HRRR ensemble DA RAP/HRRR-smoke

First Regional FV3
"Rapid Refresh Forecast System"
Transition all existing RAPv5/HRRRv4 design/capabilities to FV3 core likely with single model storm-scale ensemble forecasts

2m temperature (K) Start date: 2018-06-04 00:00:00 Hour 12

2m T forecast from HRRR configuration of stand-alone regional (SAR) FV3 CAM

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email: Terra.Ladwig@noaa.gov

Benjamin – clous&precip   -- 915 today – AS1.1
Smirnova – snow-HRRR   – 1400 today - CR3.04
Ahmadov – HRRR-smoke   – Friday – AS1.15
Grell – aerosols/convection – Friday – AS4.25