Update on the Rapid Refresh Forecast System (RRFS) and related research activities
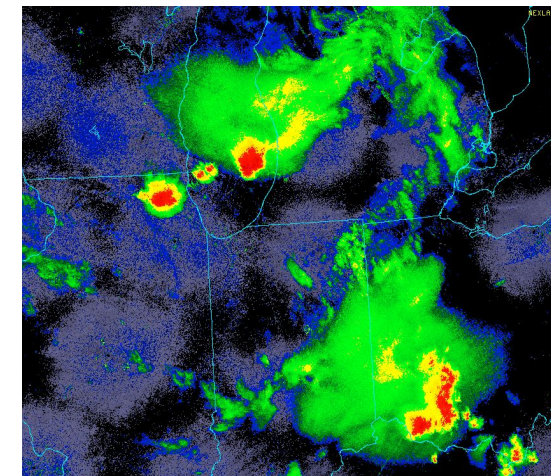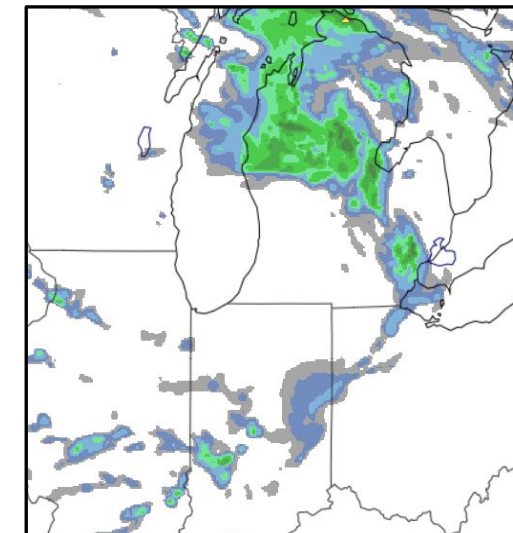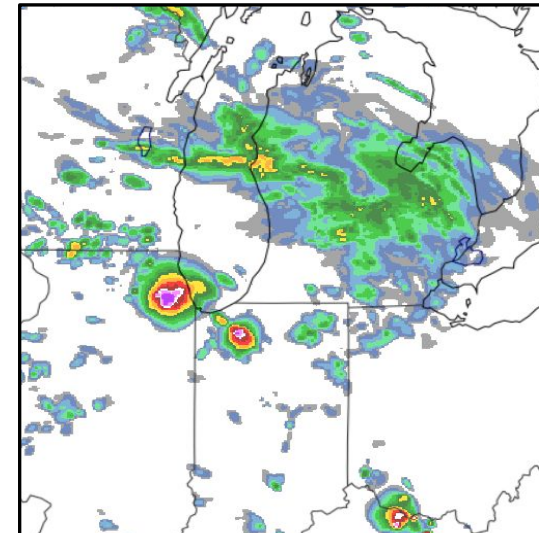
presented by Craig Hartsough[1]

Terra Ladwig[1], Steve Weygandt[1], Curtis Alexander[1], Jacob Carley[2], Matt Pyle[2]

and many developers from NOAA/GSL and NOAA/EMC

[1]NOAA/OAR/GLOBAL SYSTEMS LABORATORY
[2]NOAA/NWS/NCEP/ENVIRONMENTAL MODELING CENTER
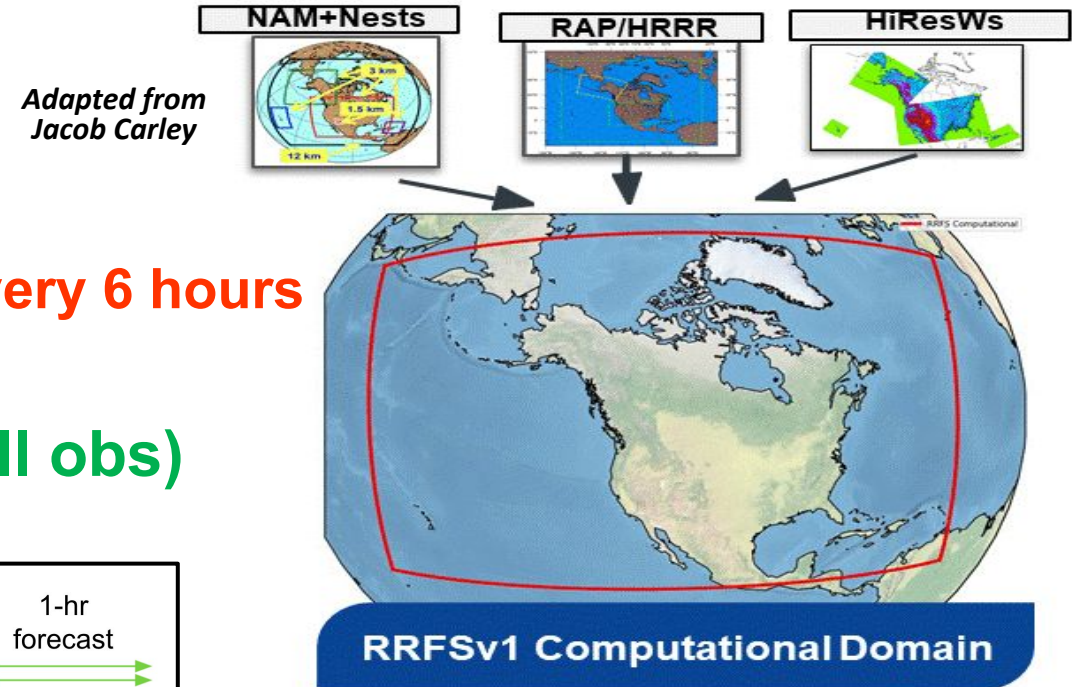
RRFS

HRRR

17z +6h forecasts

**Radar observations**
23z 23 June 2022

From 2022 AWC Aviation Weather Testbed retrospective test case

Rapid Refresh Forecast System (RRFS)

- **Based on the FV3 dynamical core**
- **~3 km grid spacing, 65 vertical layers**
- **Deterministic forecasts to 18h every hour**
- **Deterministic and Ensemble forecasts to 60h every 6 hours**
- **HRRR-type physics components**
- **Hourly updating ensemble assimilation (all obs)**

Adapted from Jacob Carley

RRFSv1 Computational Domain

Component	Scheme
Land-Surface:	RUC Land Surface Model
Lake Model	CLM (small lakes)
Surface Layer:	MYNN
PBL + shallow convection:	MYNN-EDMF
Drag:	Unified Drag Suite
Radiation:	RRTMG
Microphysics:	Thompson Aerosol-aware

Advanced HRRR physics

Advanced ensemble data assimilation
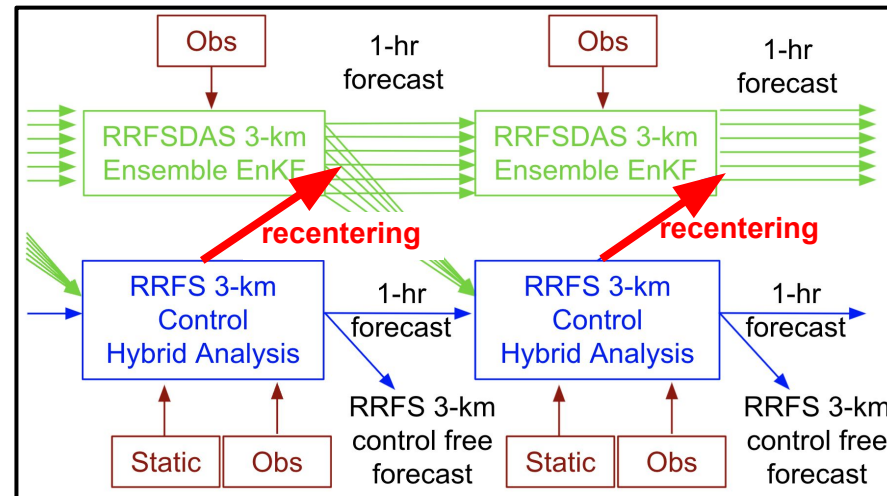
RRFS will provide consolidation of several different NCEP regional model systems, allowing for enhanced capabilities

Current RRFSv1 Implementation Timeline

Phase (overlapping)	Event	NOW: 18 May 2023	Start	End / Chg
Science Freeze	**Identify release branches/repositories**		09/28/23	10/26/23
	Finalize science package	**5 months**	10/26/23	**10/26/23**
Pre-Implementation Finalization/Evaluation	**Confirm all products for stakeholders**		01/20/23	**05/25/23**
	Confirm products for downstream operational applications (e.g. RTMA suite)		01/20/23	05/25/23
	Contact ADMAC (AWIPS Data Management & Activation Committee) to coordinate any changes/updates to AWIPS/SBN products		05/26/23	06/01/23
	EMC Issues PNS Statement		11/02/23	11/22/23
	Brief HPCRAC for RRFS resource requirements		09/28/23	11/08/23
	Finalize RRFSv1 package for evaluation		10/26/23	**10/26/23**
	Environmental Equivalence coordination/review with NCO		11/09/23	12/20/23
	Retrospective testing	**3 months**	**10/27/23**	**01/19/24**
	Real time testing		**01/22/24**	**05/24/24**
	Field Evaluation	**4 months**	01/22/24	05/24/24
	EMC Change Control Board Briefing		05/24/24	05/24/24
	NCEP OD Brief		05/24/24	**05/24/24**
Implementation Procedure	Hand off to NCO		05/27/24	05/27/24
	Work with SPAs to establish in NCO parallel		05/28/24	08/19/24
	Issue SCN		08/20/24	08/21/24
	IT Stability		08/22/24	09/23/24
	IT Briefing	**4 months**	09/23/24	09/23/24
	Implementation		09/26/24	**09/26/24**
Legacy Retirement	**Legacy Shutoff**	**6 months**	Q1FY25	Q2FY25

RRFSv1 Workflow of Grids

RRFS runs on a special grid **(yellow box)**

RRFS output is mapped to a rotated lat-lon grid **(red box)** and the Unified Post-Processor (UPP) is run on that grid

RRFS UPP output is then mapped to all existing NCEP output domains **(green)**
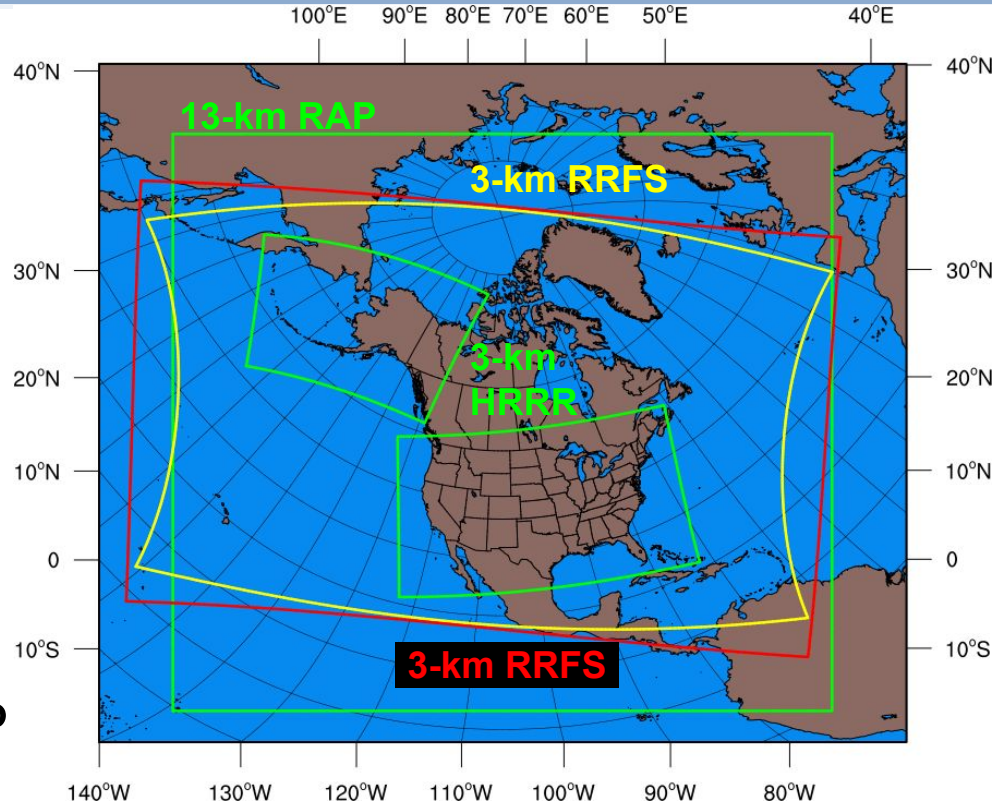
All RRFS products will be available on all the same existing output domains

HRRR-CONUS 3-km
1799x1059x50
(1,905,141)x50
800MB/3Dnative file
Lambert Conformal

HRRR-AK 3-km
1299x919x50
(1,193,781)x50
500MB/3Dnative file
Polar Stereographic

RAP 13-km
953x834x50
(794,802)x50
300MB/3Dnative file
Rotated Lat-Lon

RRFS 3-km
7912x5412x65
(42,819,744)x65
Extended Schmitt Gnomonic (ESG)

→ Model Interp →

RRFS 3-km Output
4881x2961x65
(14,452,641)x65
Rotated Lat-Lon

→ UPP Diagnostics Algorithms →

GRIB2 3-km
4881x2961x65
Nat, Prs, Sfc
10GB/3Dnative file

→ wgrib2 Interp →

GRIB2 Cutouts:
HRRR-CONUS (3 km)
NAM-AK (3 km)
NAM-HI (2.5 km)
NAM-PR (2.5 km)
RAP-like (13 km)
130-like (13 km)

Ongoing RRFS testing and refinement

- **"RRFS_A" real-time prototype running on NCEP WCOSS computer**

  - Fully vetted code, high run reliability, grids to AWT, HWT, FFaIR
  - Deterministic and ensemble runs on CONUS domain (also some NA deterministic runs)
  - Expansion to full North American domain planned for July

- **"RRFS_B" real-time experimental system running at GSL**

  - Testing additional code updates, lower run reliability, grids not disseminated
  - Deterministic runs only on CONUS domain (also running controlled retrospective runs)
  - No ensemble DA or ensemble forecasts, testing physics and other refinements
  - Current retrospective and RRFS_B tests focusing on use of cumulus scheme to help modulate intense convective cores sometimes seen in RRFS
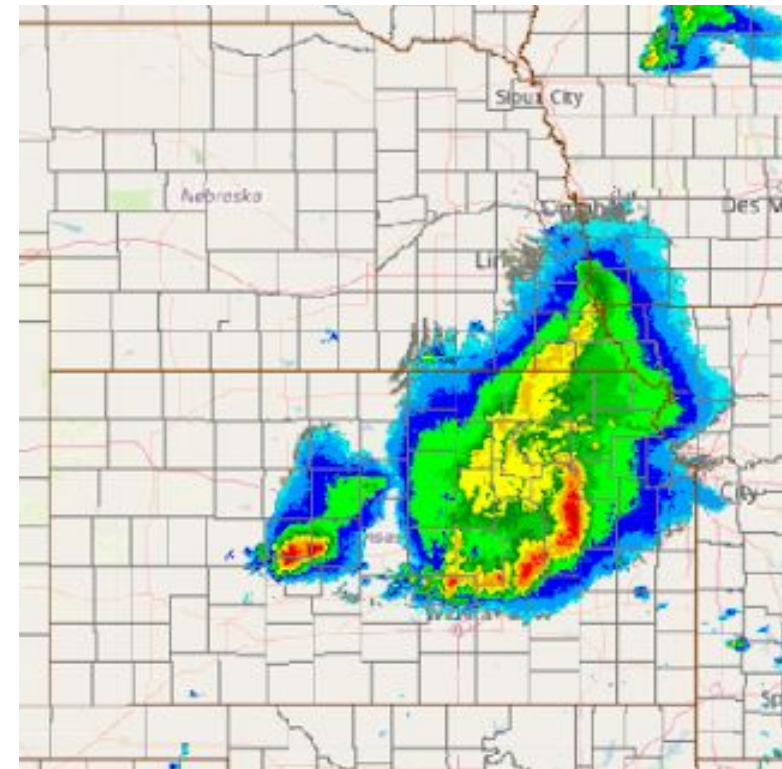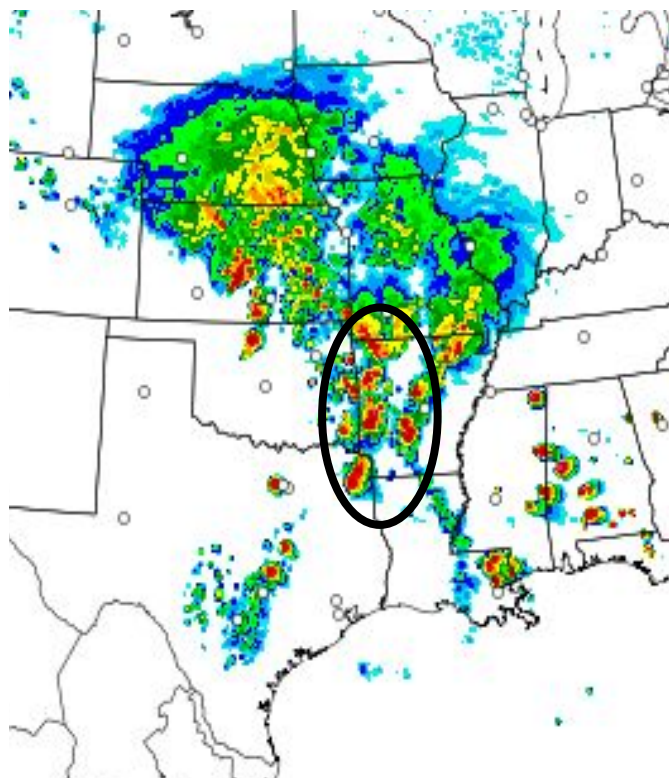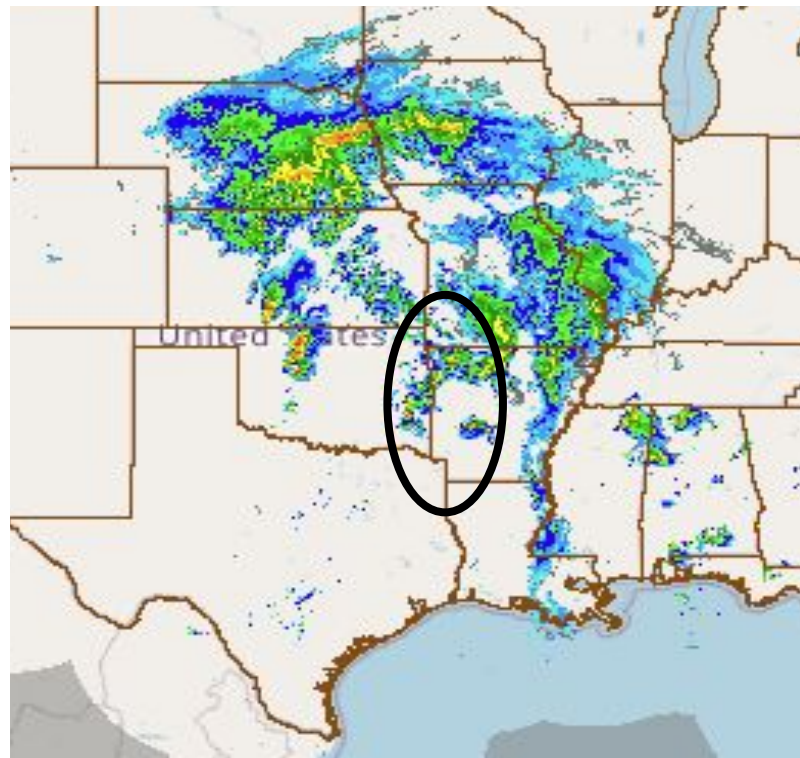
Recent sample RRFS_A vs. HRRR comparison
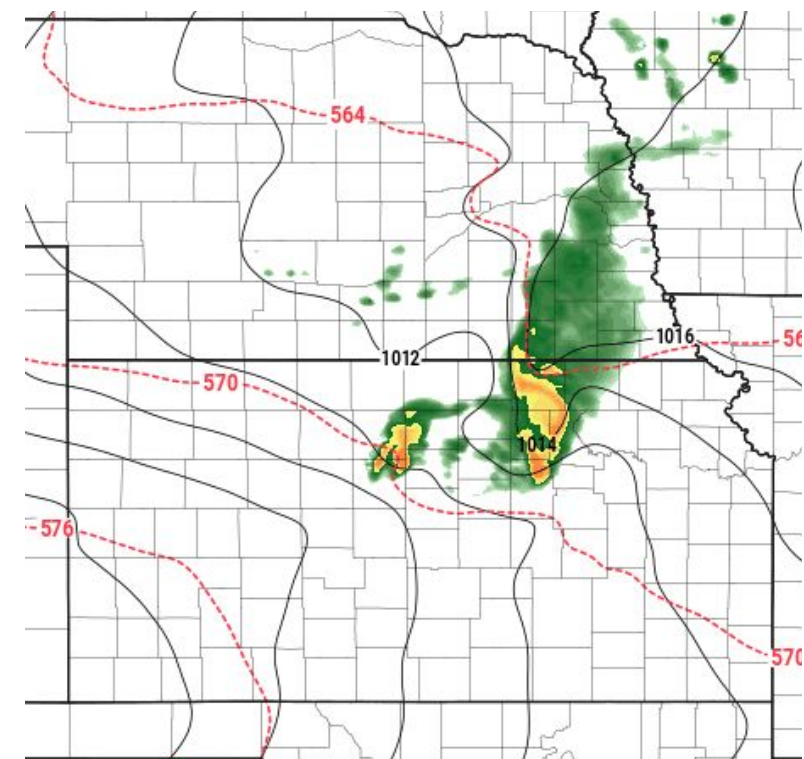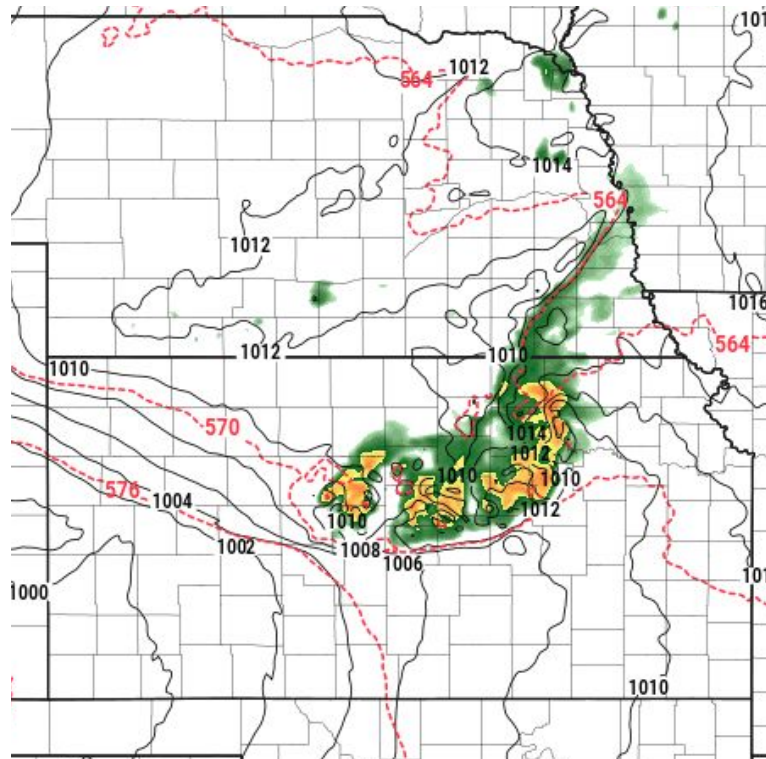
HRRR RRFS_A MRMS

12z 9 May 2023 + 9hr forecasts valid 21z

Example of RRFS_B retrospective with and without G-F cumulus scheme
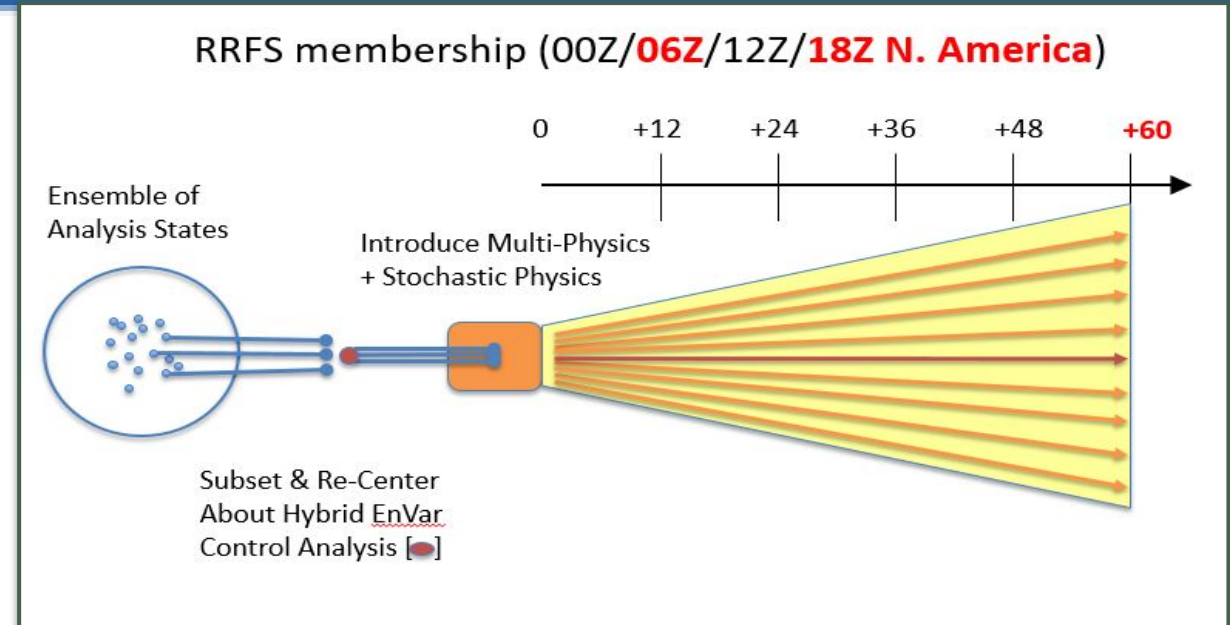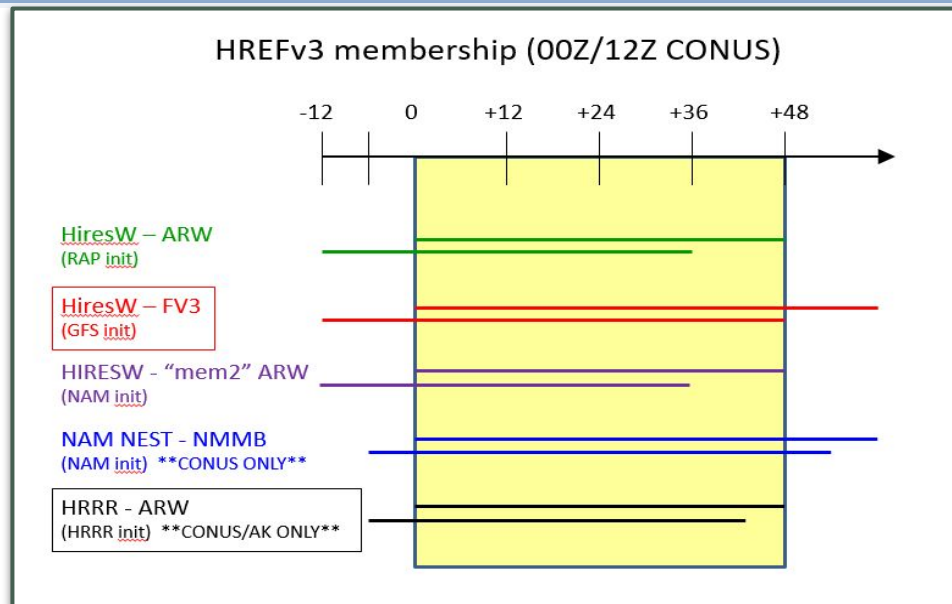
RRFS - No cumulus scheme   **MRMS - observations**   **RRFS - With cumulus scheme**

RRFSv1 Forecast Ensemble Design

HREFv3 membership (00Z/12Z CONUS)

HiresW – ARW (RAP init)

HiresW – FV3 (GFS init)

HIRESW - "mem2" ARW (NAM init)

NAM NEST - NMMB (NAM init) **CONUS ONLY**

HRRR - ARW (HRRR init) **CONUS/AK ONLY**

RRFS membership (00Z/**06Z**/12Z/**18Z N. America**)

Ensemble of Analysis States

Introduce Multi-Physics + Stochastic Physics

Subset & Re-Center About Hybrid EnVar Control Analysis [●]

- 5 on time members + 5 time lagged
- 48H forecast length 2x per day
- Multi-dycore (3)
- ICs from NAM + nests, RAP, HRRR, GFS
- Multiphysics

- 9 members + control member (complete N. America coverage)
- 60H forecast length 4x per day
- Single dycore
- IC perturbations subset from 30-40 member EnKF
- Multiphysics+stochastic physics

- Single core & physics CAM ensembles designed *to date* have typically been under-dispersive vs. HREF
- RRFSv1 ensemble design leveraging HRRRE development and HIWT, DSUP, UFS-R2O projects to incorporate methods of representing uncertainty (multiphysics, SPP, etc.)
- Goal: Skillful spread & error relationship.
  - RRFSv2 will converge toward single physics to facilitate fundamental reductions in forecast error

RRFS Ensemble forecast output available on AWS

https://noaa-rrfs-pds.s3.amazonaws.com/index.html#rrfs_a/rrfs_a.20230513/12/multi_physics/mem0001/

RRFS Spring 2023 Forecast Experiment at HWT

Hazardous Weather Testbed 8 May 2023
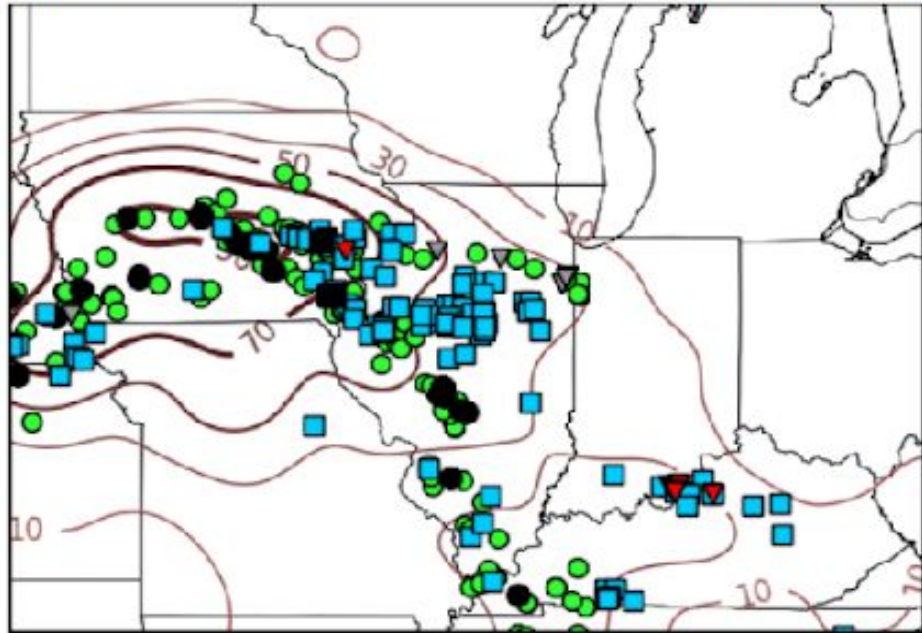**Spring Forecast Experiment Demonstration**

Prelim storm reports (box=wind, circle=hail, triangle=tornado) along with 24-H forecast updraft helicity probs

HREF

RRFS-E

Sample RRFS Ensemble

vs.

HREF ensemble

RRFS Spring 2023 Forecast Experiment at HWT

Hazardous Weather Testbed 11 May 2023
Spring Forecast Experiment Demonstration

Prelim storm reports (box=wind, circle=hail, triangle=tornado) along with 24-H forecast updraft helicity probs

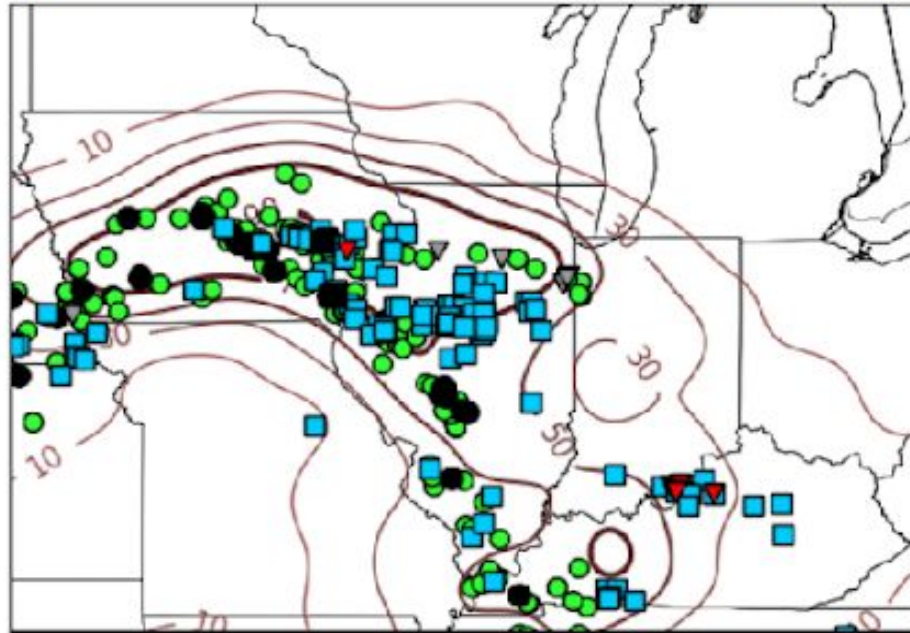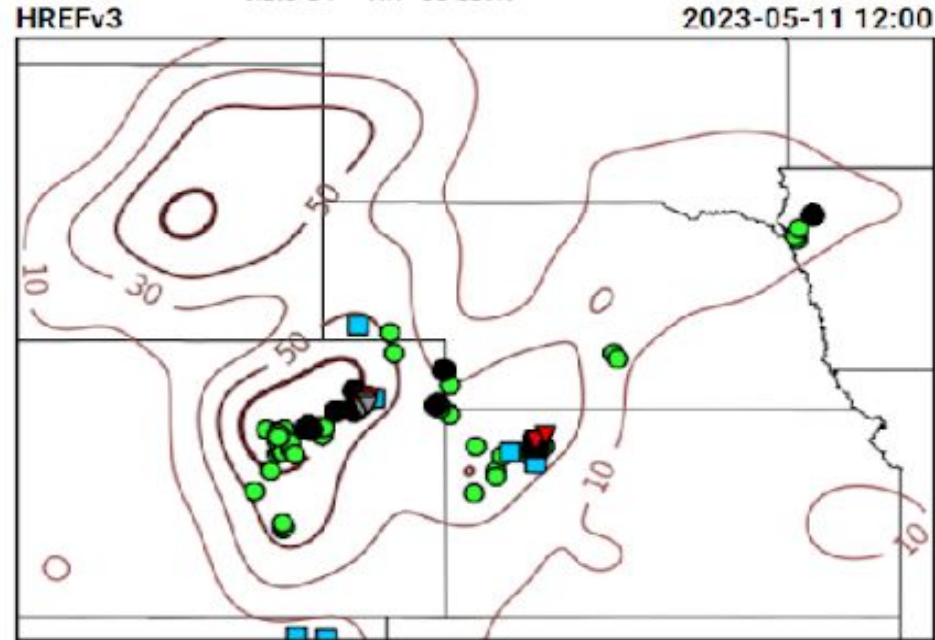Dataset: E1. CLUE: 00Z RRFS vs. HREF   Comparison: Updraft Helicity (24-h)   Date: 2023-05-10   Sector: Daily Primary

Thu 05/11

1200 UTC

F36

HREFv3   2023-05-11 12:00

RRFS   2023-05-11 12:00
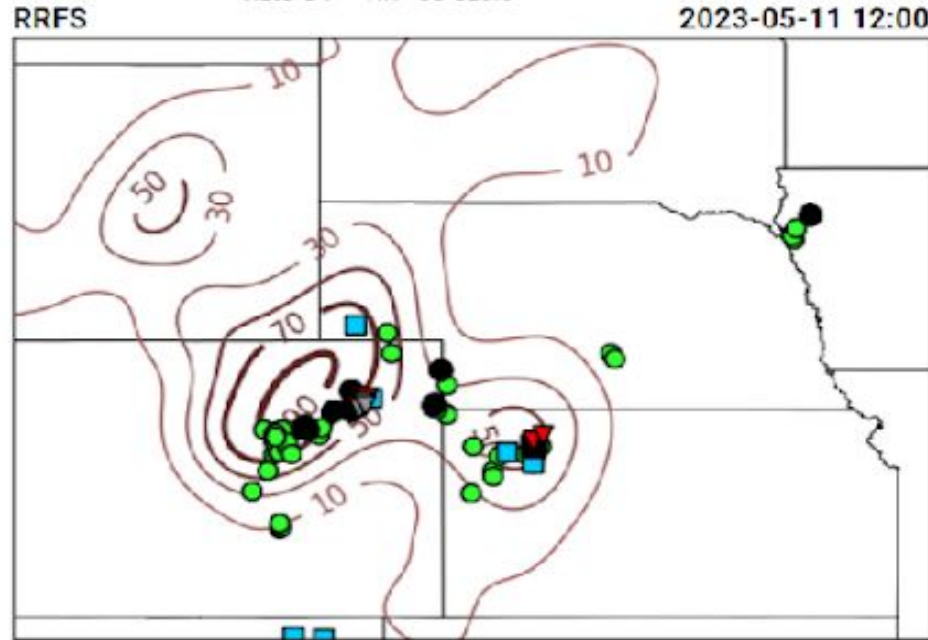
HREF   **RRFS-E**

Sample RRFS Ensemble

vs.

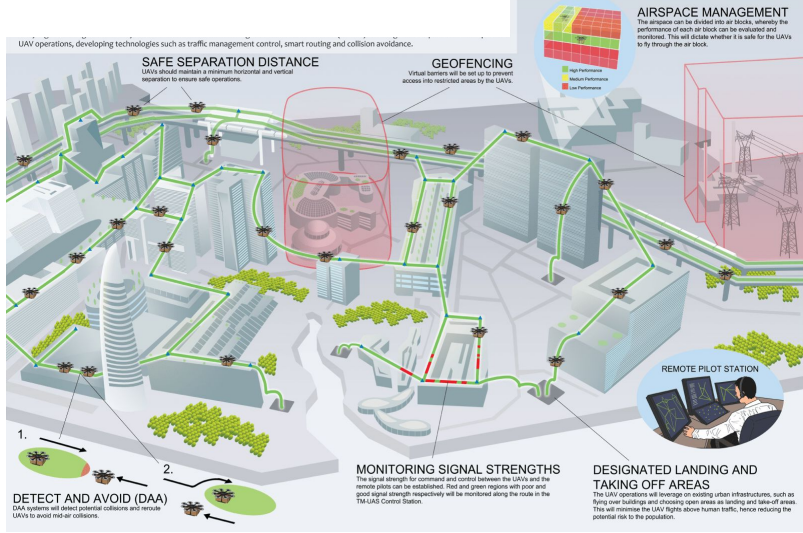HREF ensemble

RRFSv1 Status Summary

- **RRFS is a major upgrade over HRRR (bigger domain, longer forecast length, ensemble forecasts)**

- **RRFS scheduled for September 2024 operational implementation**

- **RRFS code freeze fall 2023, Science evaluation winter/spring 2024**

- **RRFS deterministic forecasts (hourly to 18h, 6-hourly to 6h), ensemble forecasts (6-hourly to 60h)**

- **RRFS has advanced scale-aware physics, storm-scale ensemble data assimilation, smoke prediction**

- **Planned inclusion of some aviation hazard products in RRFS Unified Post-Processor (UPP)**

- **Significant improvement in RRFS deterministic forecast skill over past two years, now similar to HRRR**

- **Significant improvement in RRFS Ensemble skill compared to HREF, both in "placement" and "spread"**

- **Users (especially aviation) continue to provide a KEY feedback loop in RRFS development and refinement**

GSL Aviation Weather Applications

- HRRR (and RRFS) will continue to provide **key aviation weather guidance** (widespread use, input to many hazard tools)

- Scale-aware physics, near-continuous data assimilation development are enabling **higher-resolution models** to meet future needs for **urban-scale weather hazard prediction**

- Higher-resolution models with ensemble output will require more **model post-processing work** to optimize communication of detailed, complex, and uncertain weather hazard information

3-km grid

Newark Airport

LaGuardia Airport

JFK Airport

1-km grid

Newark Airport

LaGuardia Airport

JFK Airport

Sample schematic UAS flow routing for complex urban landscape

Images: Shawn Murdzek, GSL NRC post-doc