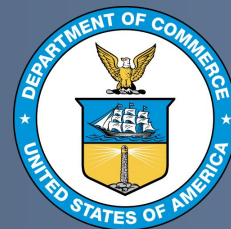


NOAA Global Systems Laboratory

# Towards the Grand Challenge: Prediction Across Scales

Curtis Alexander  
Chief, Assimilation and Verification Innovation Division

Ravan Ahmadv, Stan Benjamin, Ligia Bernardet,  
Mark Govett, Georg Grell, Joseph Olson, Steve Weygandt







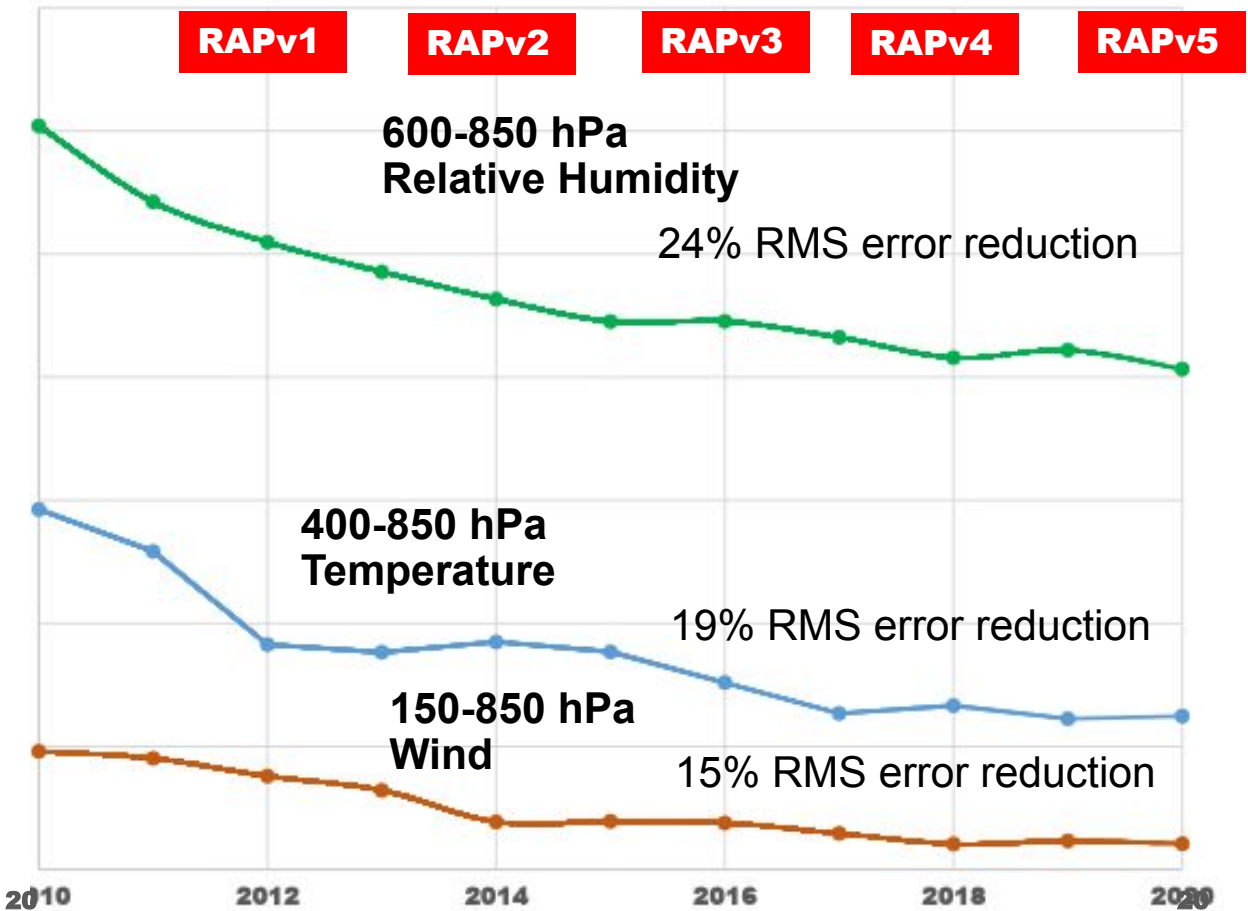
**Benefits:** improved severe weather guidance, contributes to safety

# Ongoing Improvements in RAP Forecasts

**RH** (%)  
**T** (°F)  
**wind** (m/s)

21.0 2.1 10.5  
20.0 2.0 10.0  
19.0 1.9 9.5  
18.0 1.8 9.0  
17.0 1.7 8.5  
16.0 1.6 8.0  
15.0 1.5 7.5  
14.0 1.4 7.0  
13.0 1.3 6.5  
12.0 1.2 6.0  
11.0 1.1 5.0  
10.0 1.0 5.0  
9.0 0.9 4.5  
8.0 0.8 4.0

Annual average upper-air RMS errors for 9-hour RAP forecasts

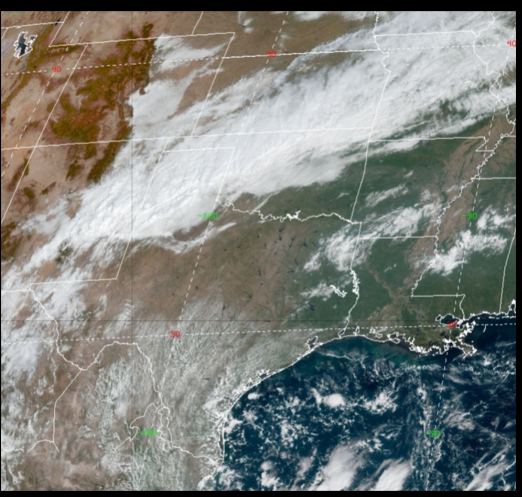


- Annual average 9-h upper-air RMS error
- Rawinsonde verification on RAP domain
- RAP implementations indicated at top
- Errors computed for GSL real-time RAP, some year-to-year variability
- Reduced errors for all three variables
- Error reduction for 10 year period shown
- Increasing role of global model partial cycling to gain further error reductions



# New Capabilities in the Most Recent HRRR

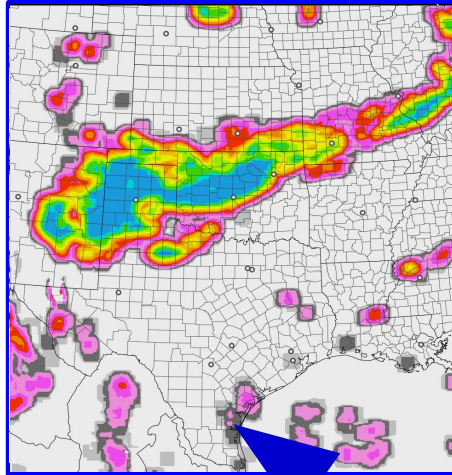
## Reality



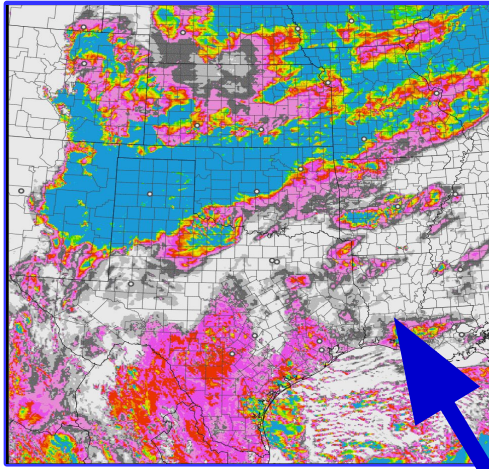
Improved cloud /  
ceiling forecast  
capability

**Benefits:** Aviation  
users, NWS and  
other users

**2018**  
HRRR v3 3-km

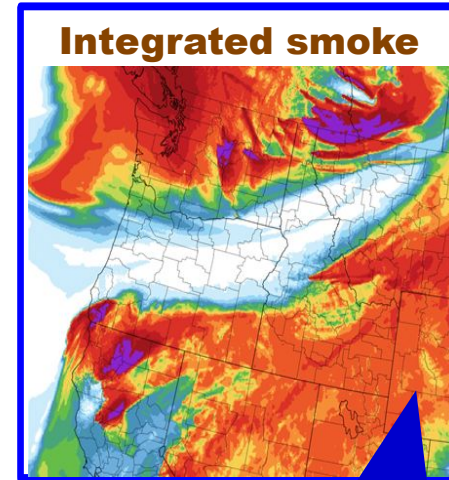


**2020**  
HRRR v4 3-km

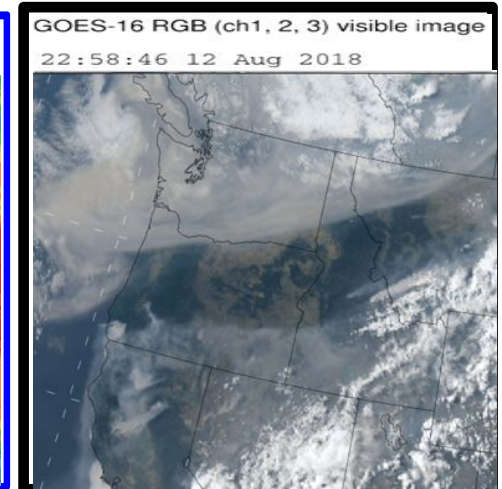


4-h forecast cloud fraction

**2020**  
HRRR v4 3-km



## Reality



Smoke prediction  
capability

**Benefits:** Many users  
including NWS, state  
and local entities, etc.

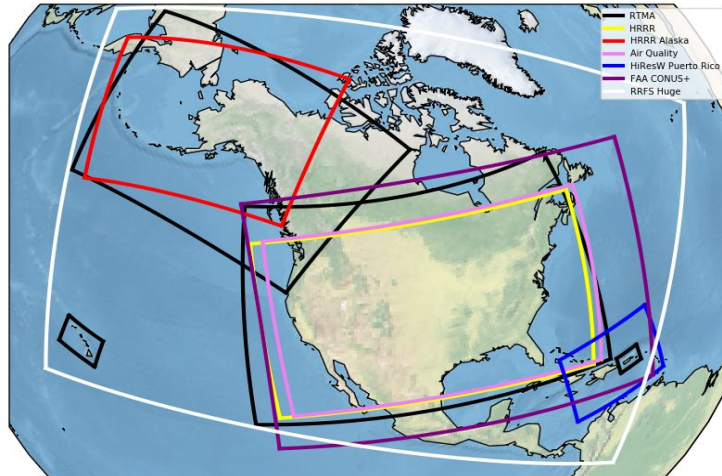
2013	2014	2015	2016	2017	2018	2019	2020
	RAPv2		RAPv3		RAPv4		RAPv5
	HRRRv1		HRRRv2		HRRRv3		HRRRv4

# GSL: Key Role in UFS Regional Development



## Rapid Refresh Forecast System (RRFS)

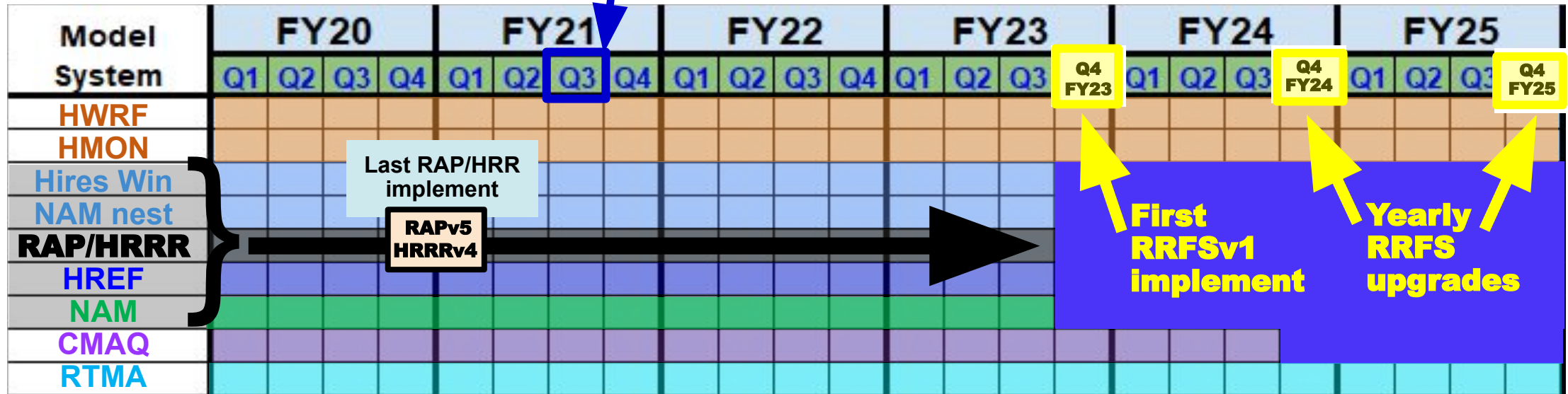
- Consolidation of all regional models
- 3-km ensemble data assimilation with JEDI (**HRRRDAS is prototype**)
- 3-km ensemble forecasts (**HRRRE is prototype**)
- GSL: key research for many RRFS capabilities (hourly cycling, radar / lightning DA, cloud analysis, use of GOES and DBnet data, smoke)



RRFS large 3-km domain shown in white

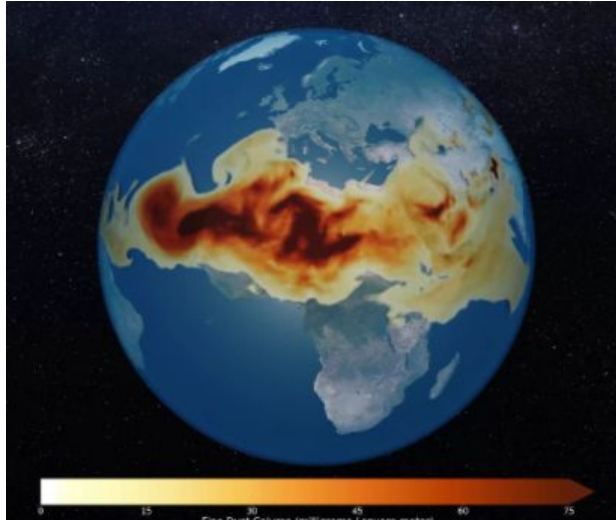
We are  
here

## Regional development and implementation schedule





# GSL: Key Role in UFS Global Development



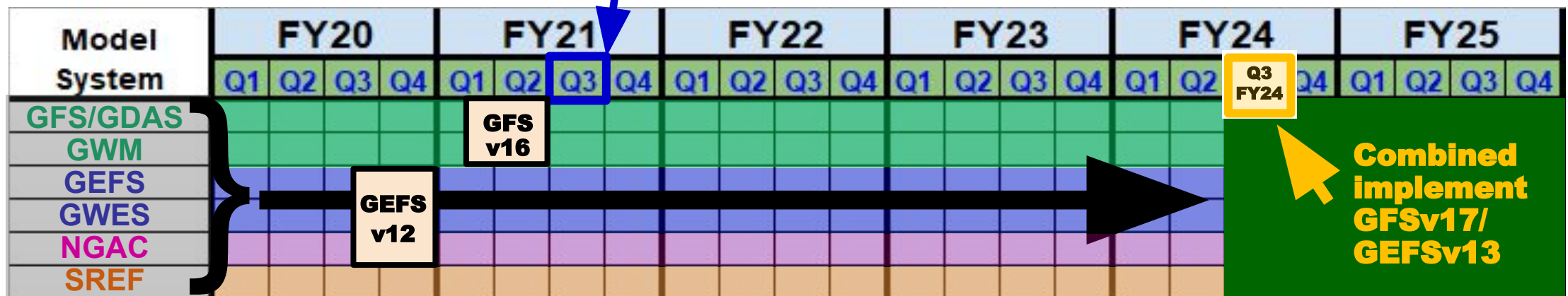
Saharan dust from GEFS-aerosol member

## Contributions to global model systems (GFS, GEFS)



- GEFS member with GOCART aerosol package (**GEFSv12**)
- Common Community Physics Package for different schemes (**CCPP**)
- Development of in-line aerosol and chemistry modules for UFS
- Development of candidate scale-aware physics suites for UFS
- Development toward improved sub-seasonal capability for UFS

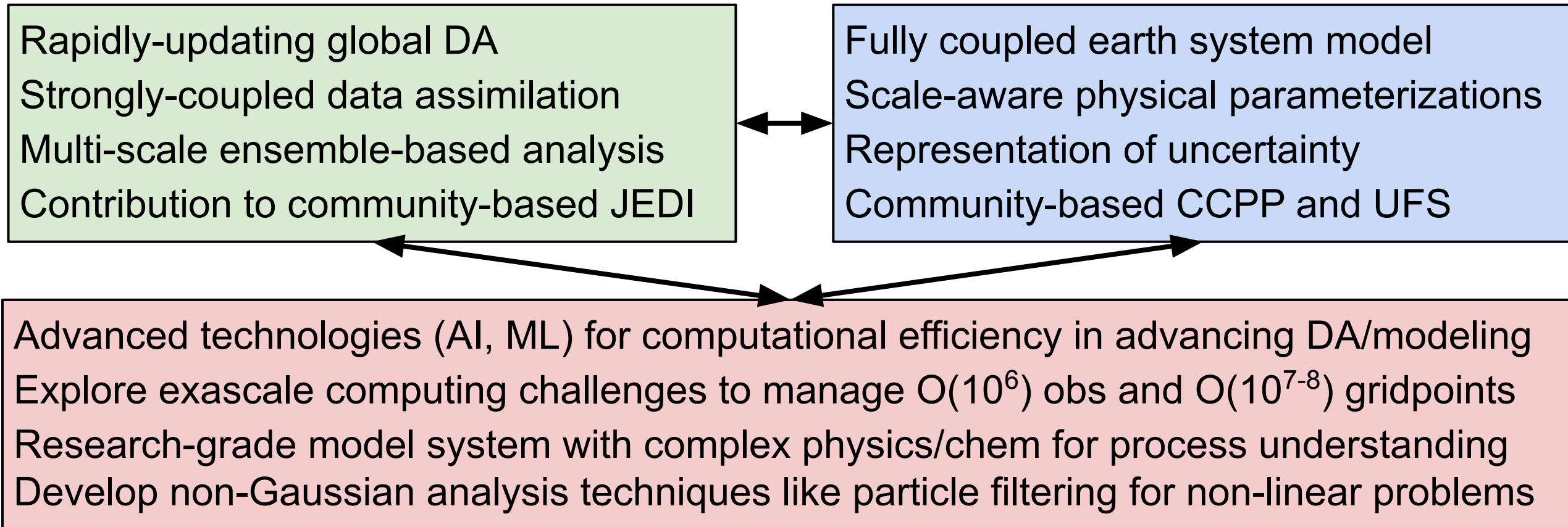
## Global development and implementation Schedule



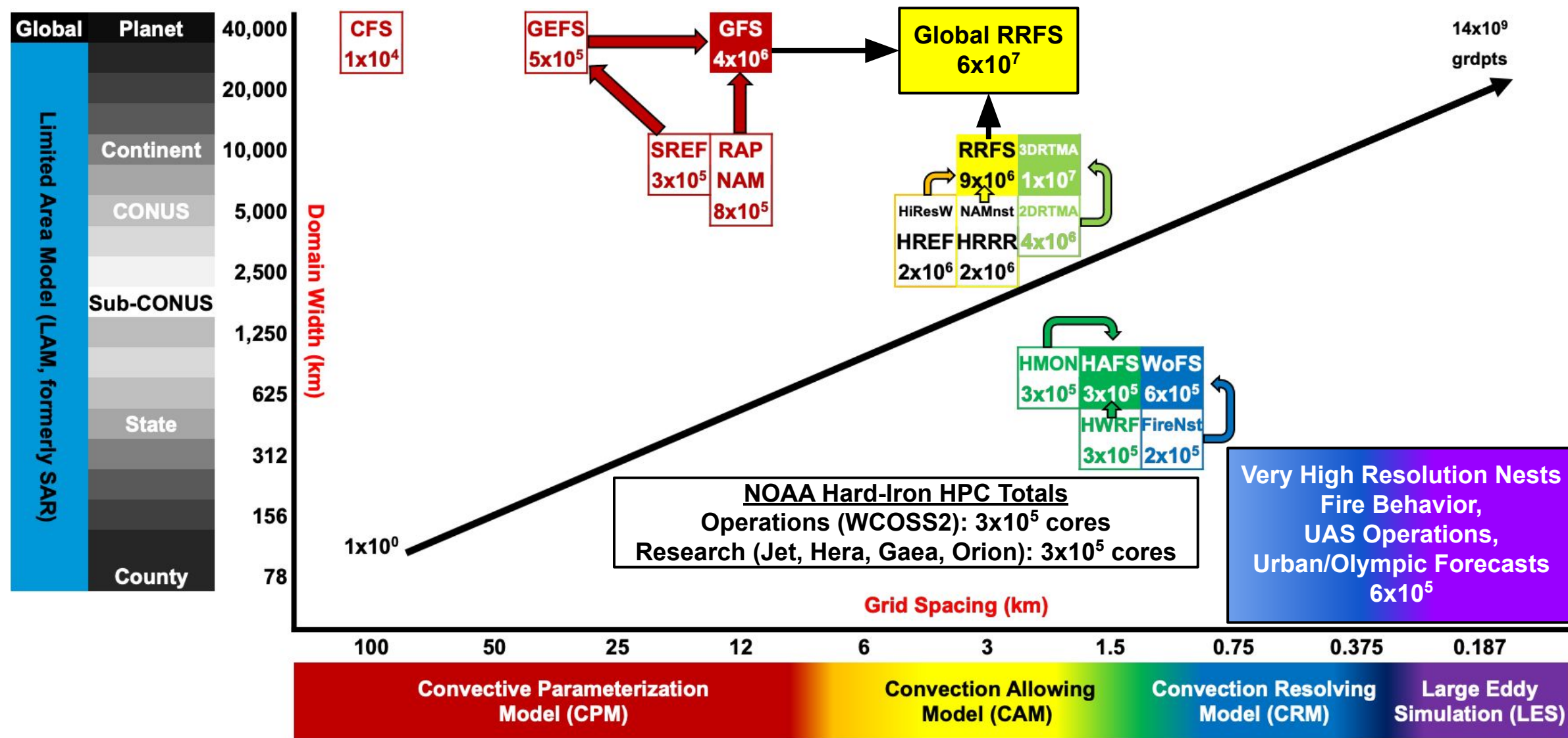
# GSL Grand Scientific Challenge

*Provide actionable environmental information through the research and development of global storm-scale prediction and innovative decision support capabilities to serve society.*

→ **Predict Earth-system seamlessly across space and time scales**



# Scales of Prediction Systems

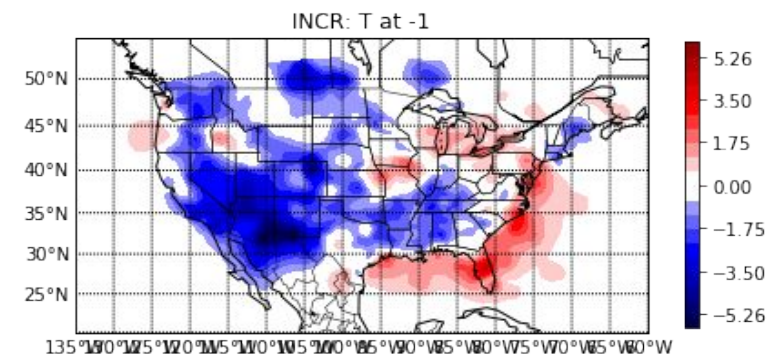
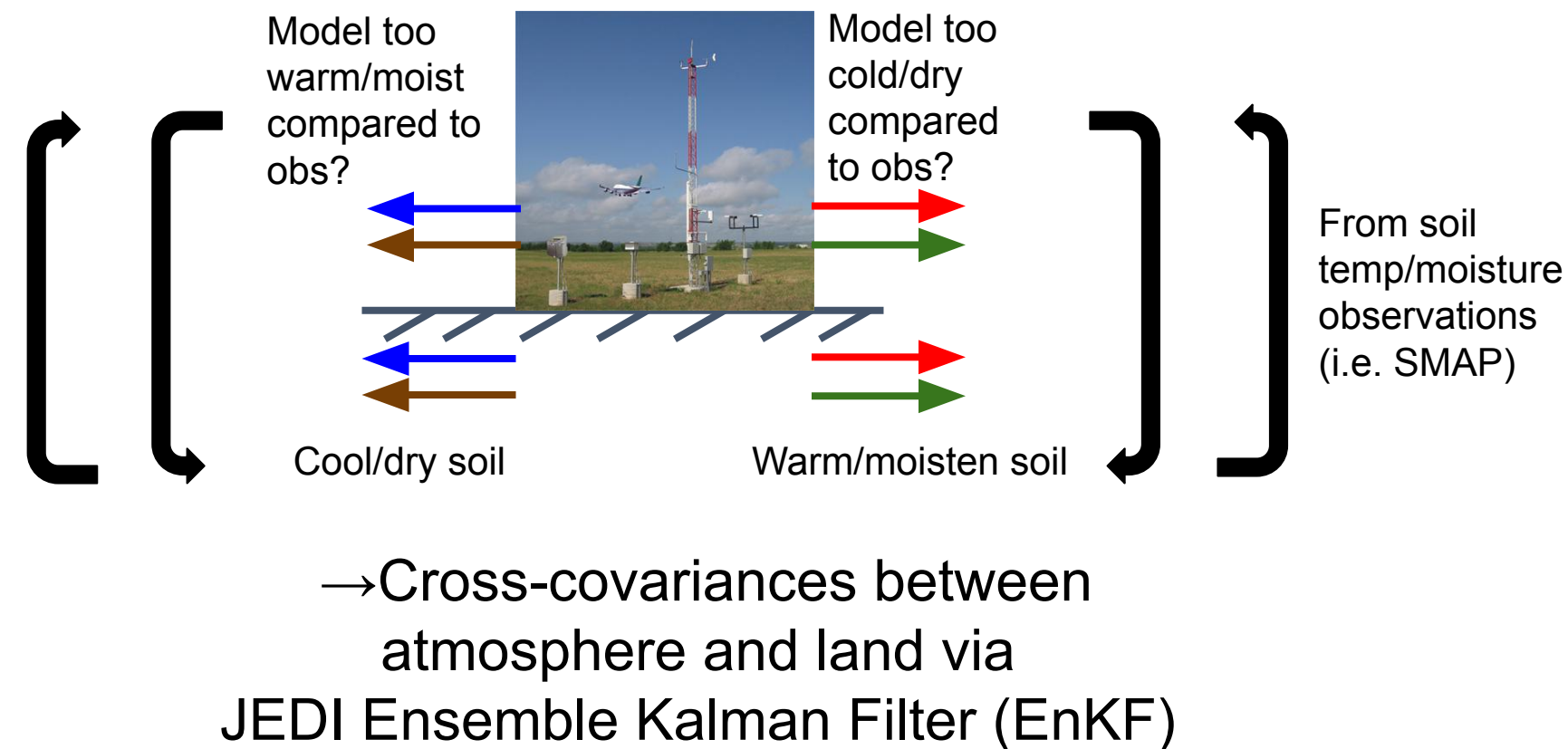




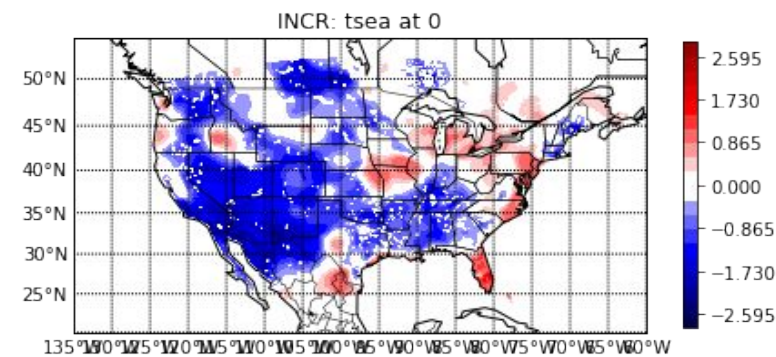
# A Global Rapidly Updating Storm-Scale Model

Effective DA using surface (and other) observations including coupled data assimilation

## RAP/HRRR 1-way coupled DA Soil Adjustment



Atmos Temp Increment (K)



Soil Temp Increment (K)

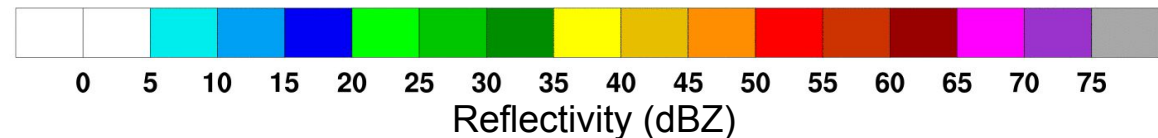
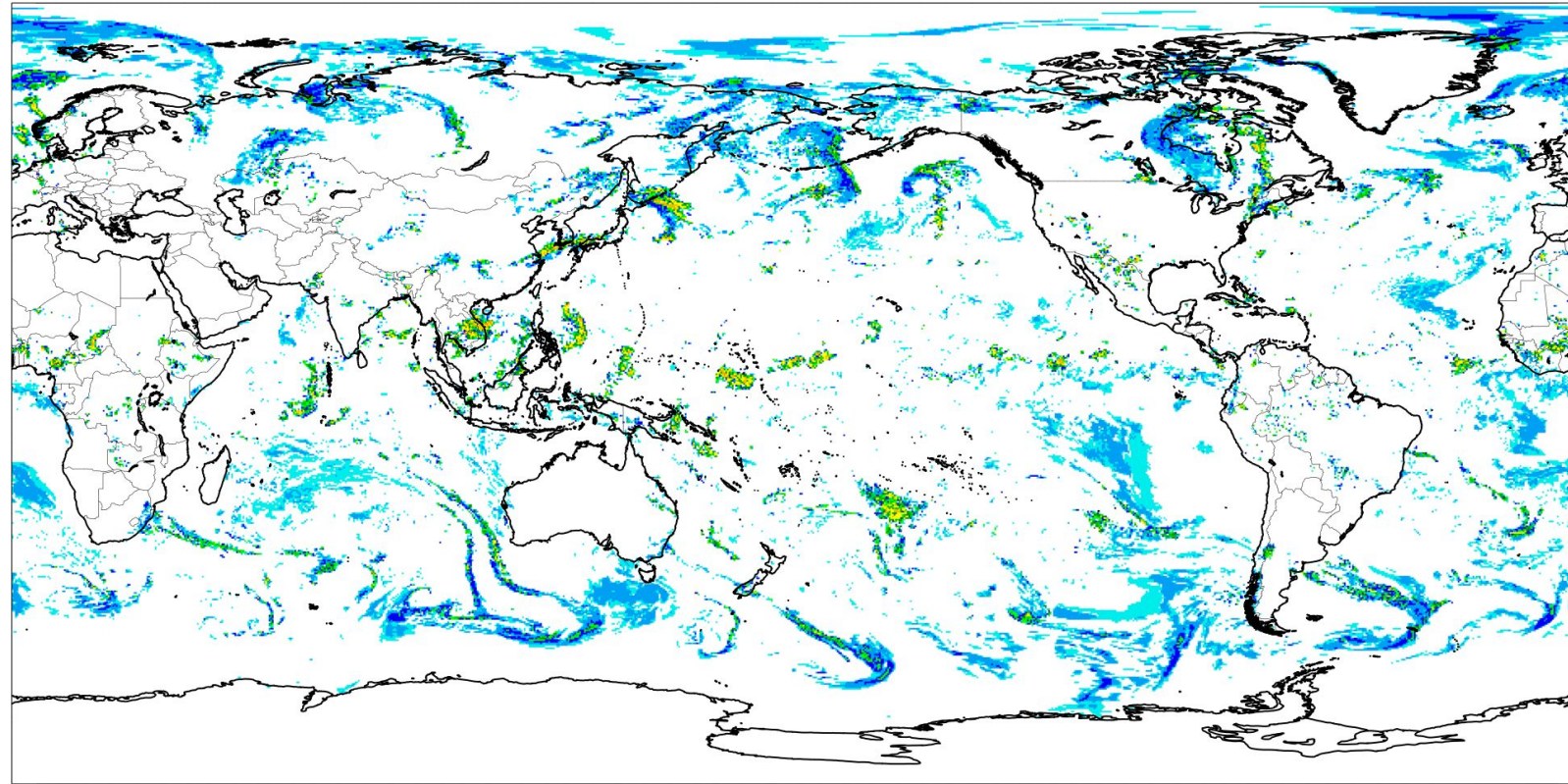
# A Global Rapidly Updating Storm-Scale Model

Global storm-scale (3 km) forecasts with scale-aware physics suite:

- SW/LW Radiation: RRTMG
- Microphysics: Thompson
- Boundary Layer: MYNN
- Surface Layer: GFS
- Land Surface Model: Noah

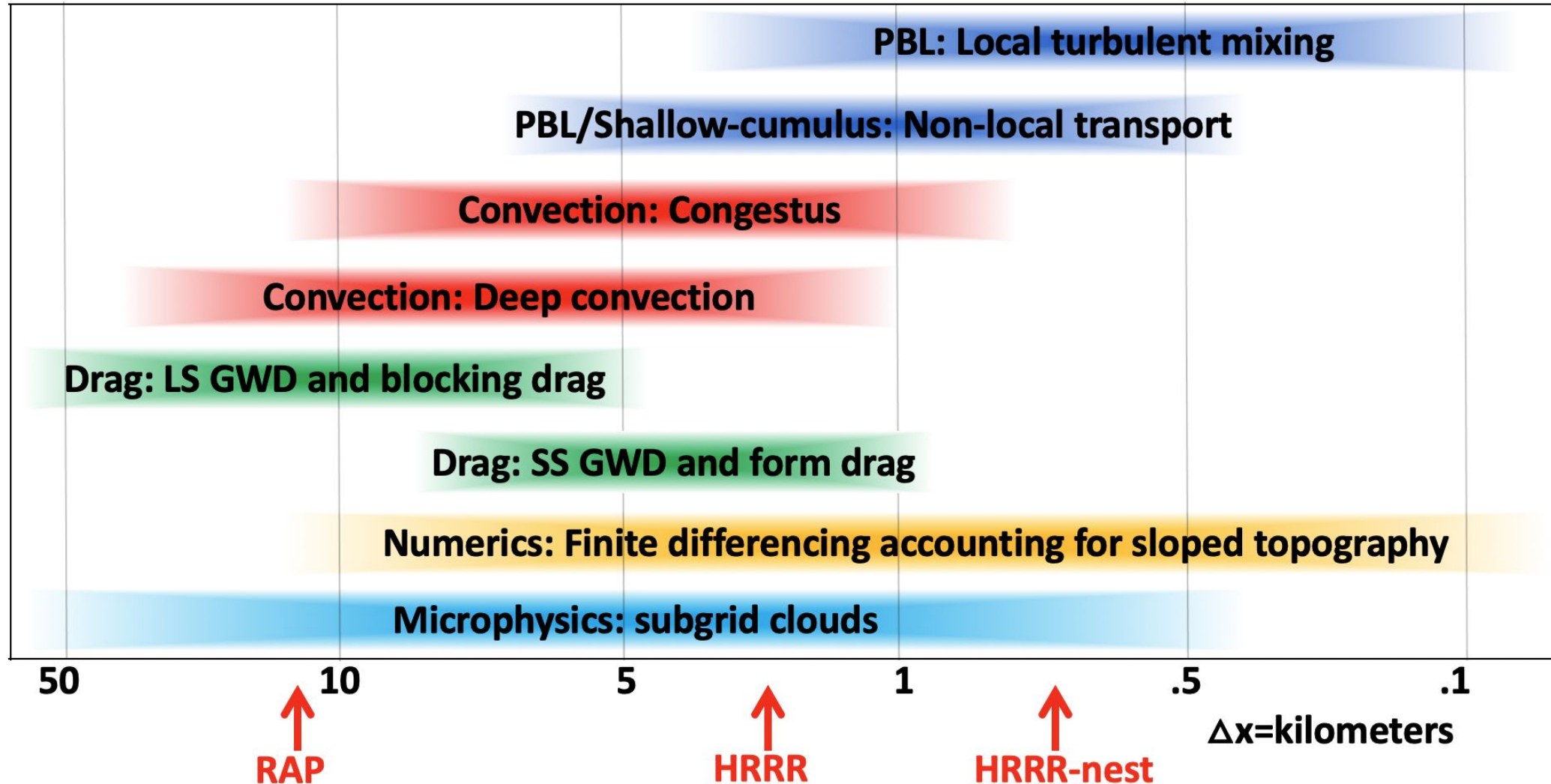
96 hr (4 day) global 3 km fcst  
13,068 processors (363 nodes)  
6 hrs of wall clock time per 24 hr fcst

00 UTC 29 Aug 2019 1 km AGL Simulated Radar Reflectivity 0-96 hr 3 km Forecast

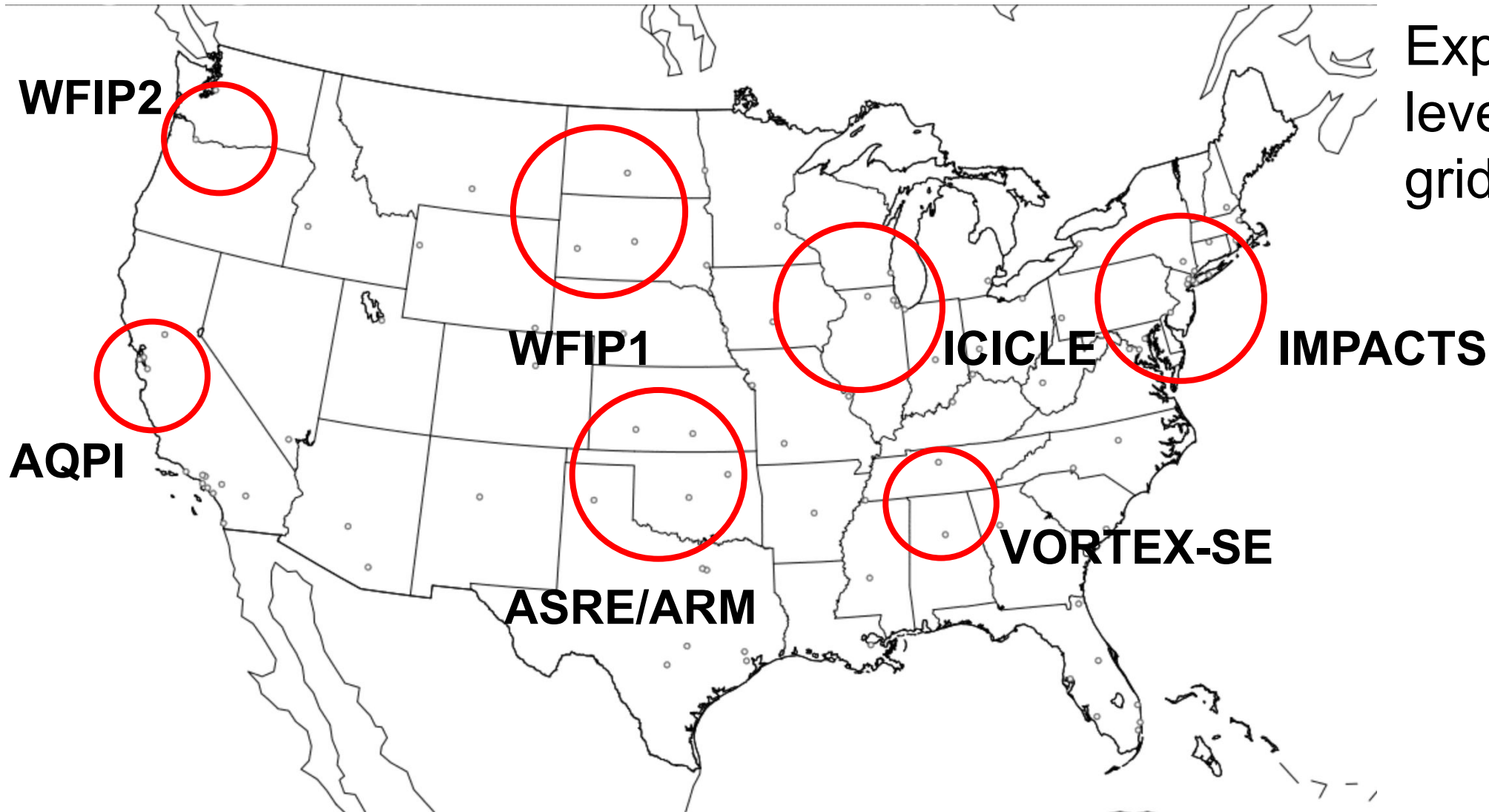




# Spatial Scales of Varying Scheme Behavior



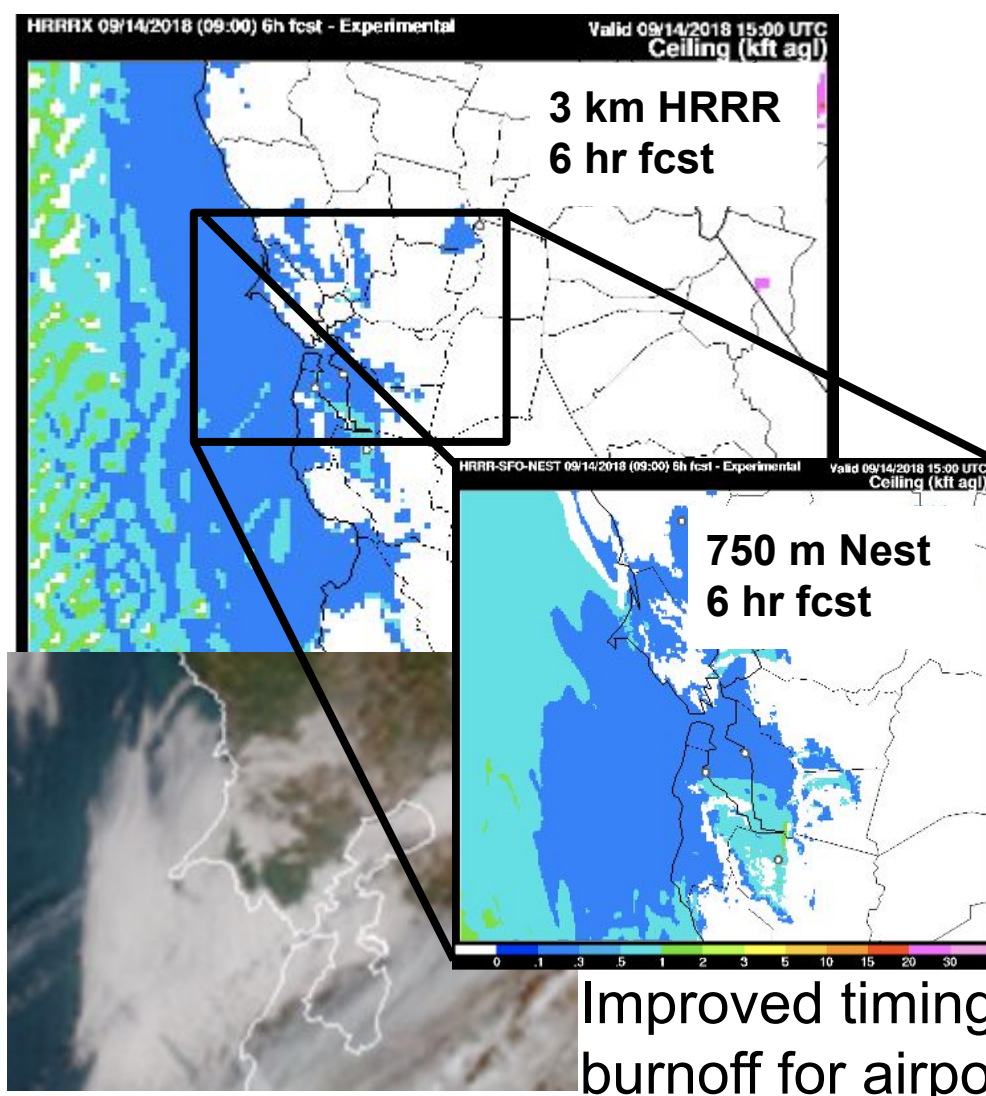
# Very High Resolution ( $\leq 1$ km) Nesting Research



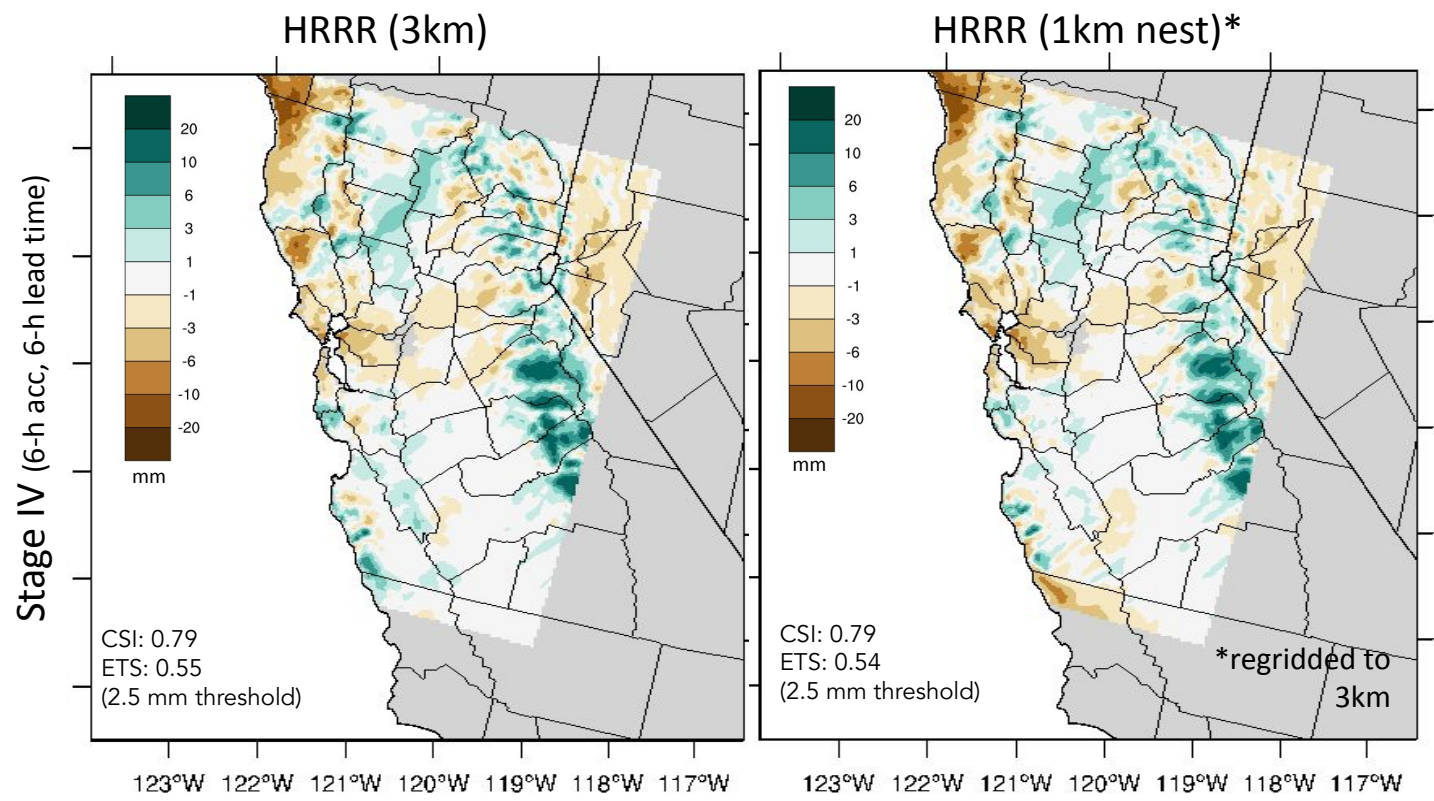
Experiments  
leveraging  $\leq 1$ -km  
grid nests



# Very High Resolution ( $\leq 1$ km) Nesting Research



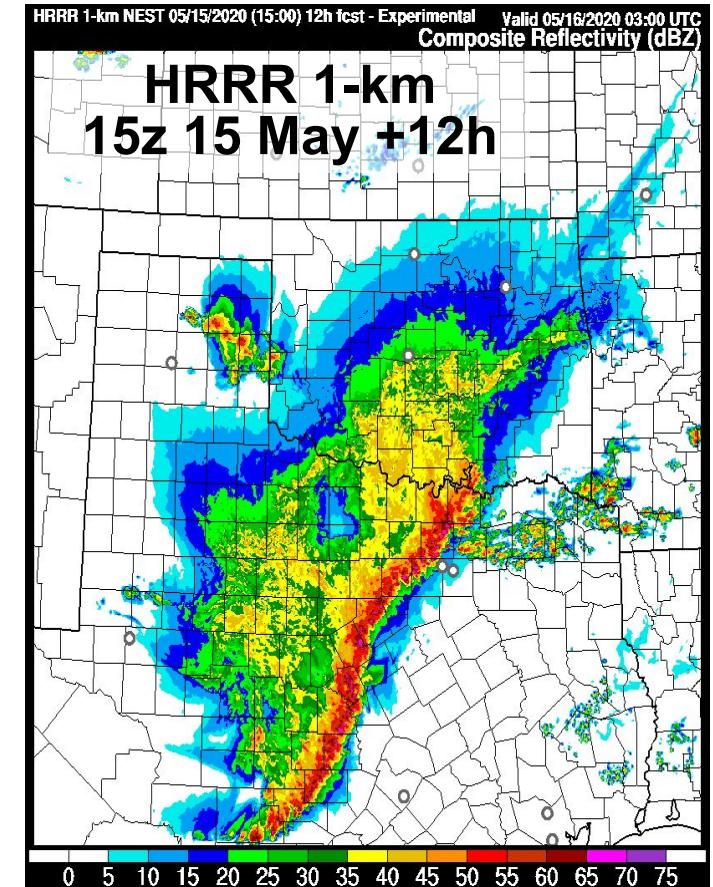
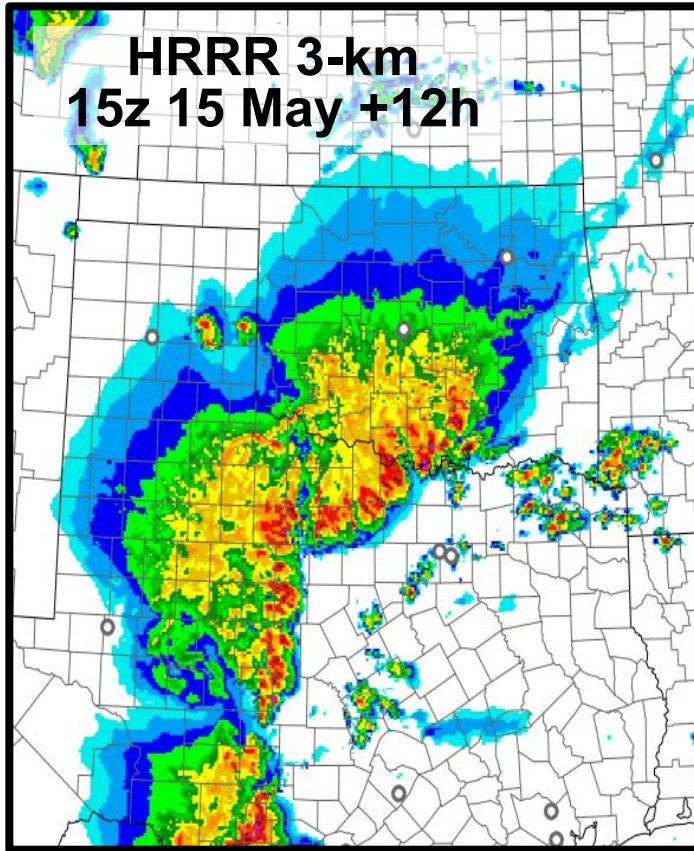
Improved timing of SFO fog burnoff for airport operations



Evaluation of QPF biases with finer orographic detail (English et al. 2021)



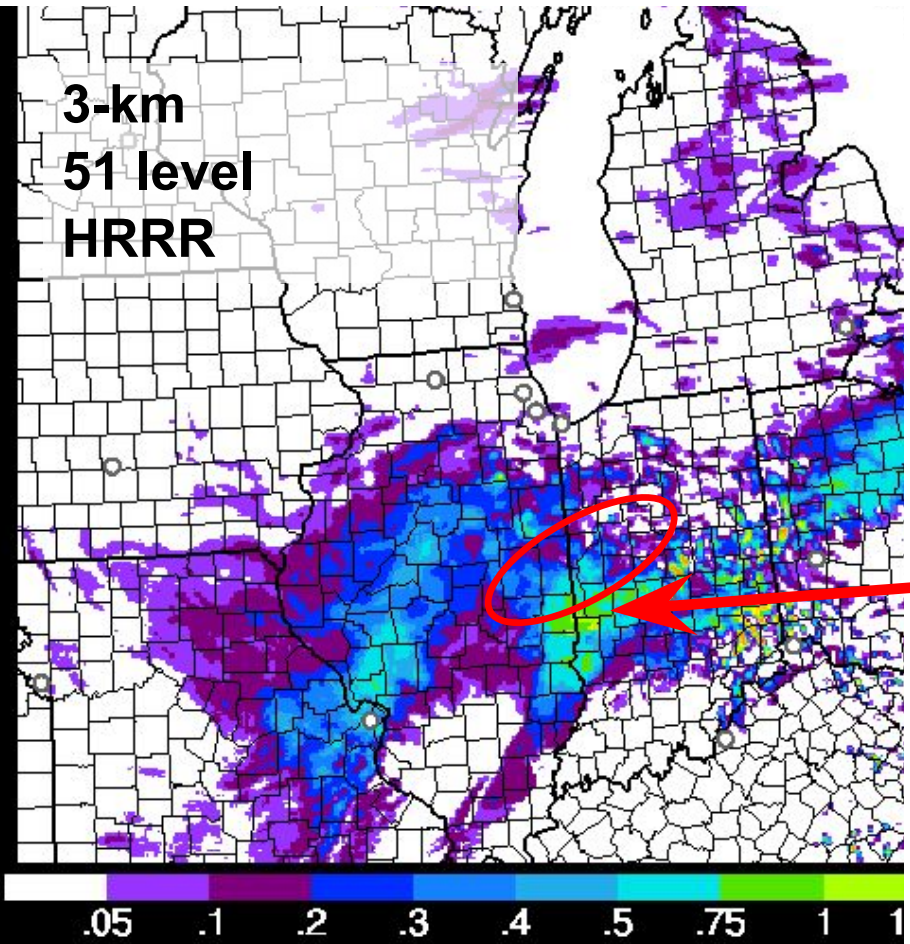
# Very High Resolution ( $\leq 1$ km) Nesting Research



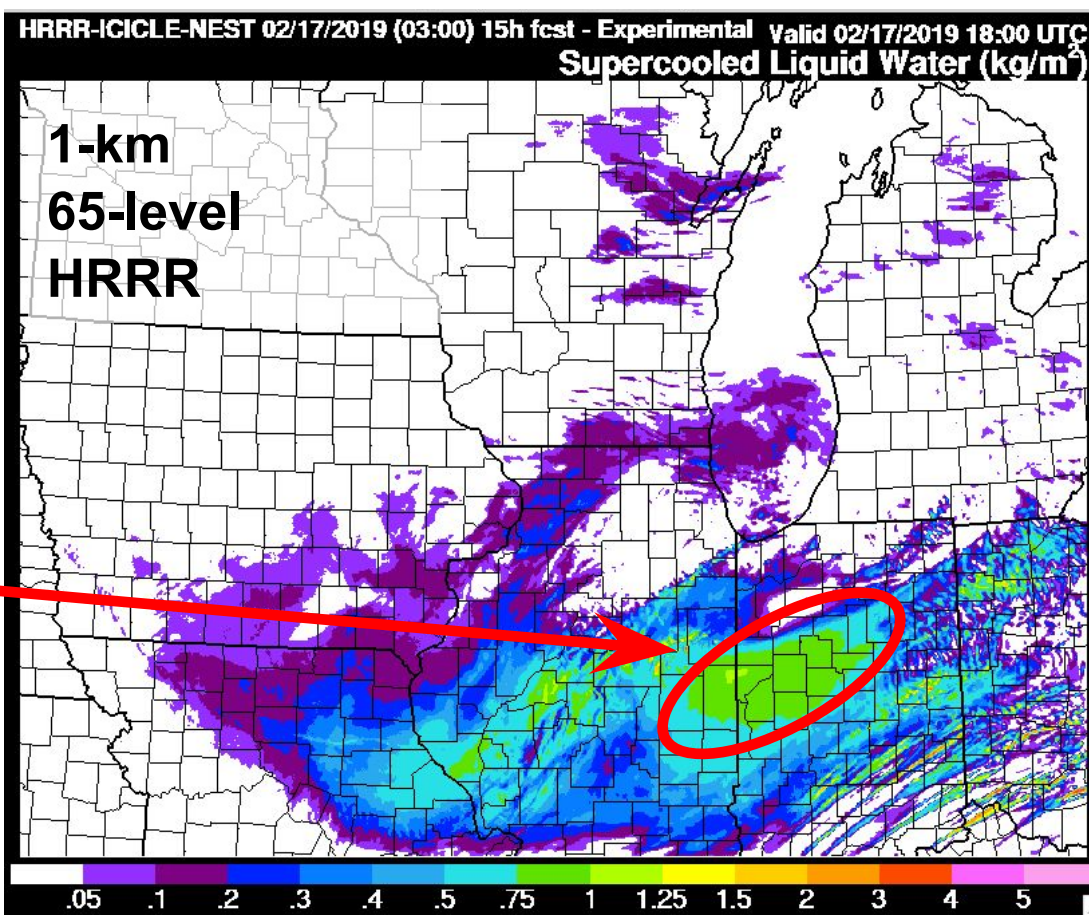
Convection impacts including more accurate initiation and system evolution at 1 km



# Very High Resolution ( $\leq 1$ km) Nesting Research



SLW  
*Improved  
county-scale  
location of  
SLW from  
1-km 65-level  
HRRR run*



In-flight icing potential from increased supercooled liquid water (SLW)/banding at 1 km

# Future Direction Earth System Predictions

- Now (0-2 years)
  - Complete evolution to FV3LAM, JEDI and CCpp
  - Develop synergistic deterministic and ensemble CAM
  - Develop storm-scale 3D analysis-of-record and uncertainty
- Now and Next (0-5 years)
  - Research with very high-resolution LAM ( $\leq 1$  km grid) for UAS
  - Develop global 13 km rapid refresh (hourly-cycled DA)
  - Develop global high-resolution (3 km) rapid refresh forecasts
- Now, Next and Later (0-10+ years)
  - Research into complex physical process understandings
  - Develop towards a global high-resolution ensemble
  - *Grand challenge: Provide actionable environmental information through the research and development of global storm-scale prediction and innovative decision support capabilities to serve society.*

R20 with EMC

HAFSv1 ● FY23

RRFSv1 ● FY23

RTMA3Dv1 ● FY24



GFSv17 ● FY24

GFSv18? ● FY26?



GEFS/GFSv20? ● FY30?

