NATIONAL WEATHER SERVICE

NWS numerical weather prediction Research to Operations (R2O) process and perspectives

Kevin Garrett, NOAA/NWS Office of Science and Technology Integration

Youngsun Jung, Judy Ghirardelli, Sarah Perfator, Phil Shafer

Friends & Partners in Aviation Weather Spring 2023, Kansas City, MO May 16-18, 2023

NWS Mission

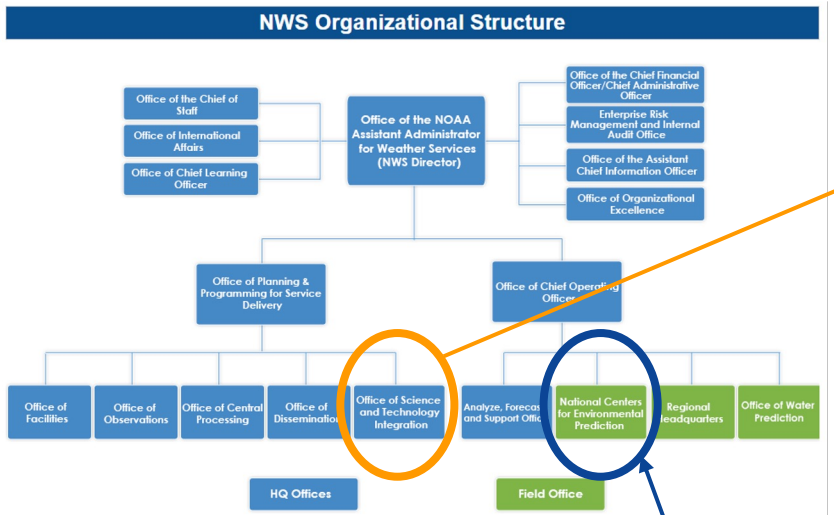
*"Provide weather, water and climate **data, forecasts, warnings, and impact-based decision support services** for the protection of life and property and enhancement of the national economy."*

What is Transition?

"The transfer of an R&D output to an operation, application, commercial product or service, or other use." - NAO 216-105B

NWS Office of Science and Technology Integration

National Weather Service



NCEP
(EMC, AWC, SPC..)

OSTI

OSTI - Mission

- Advance Operational Earth System Modeling
- Manage and accelerate the transition of research and development to NWS operations
- Develop cutting-edge tools and guidance to enhance NWS Service Delivery
- Apply Social, Behavioral, and Economic Sciences to the NWS Mission
- Foster a diverse workforce and an inclusive workplace culture

NWS/OSTI Modeling Program

Programs

Projects

UFSR20

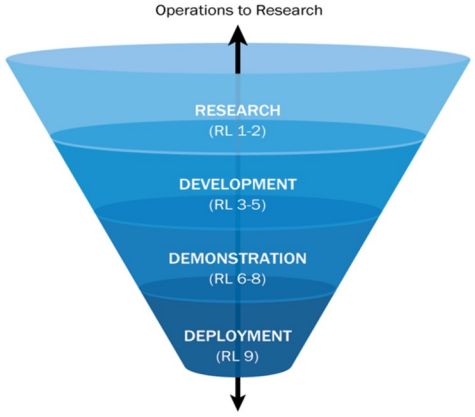
NOAA MODELING PROGRAM GRANTS

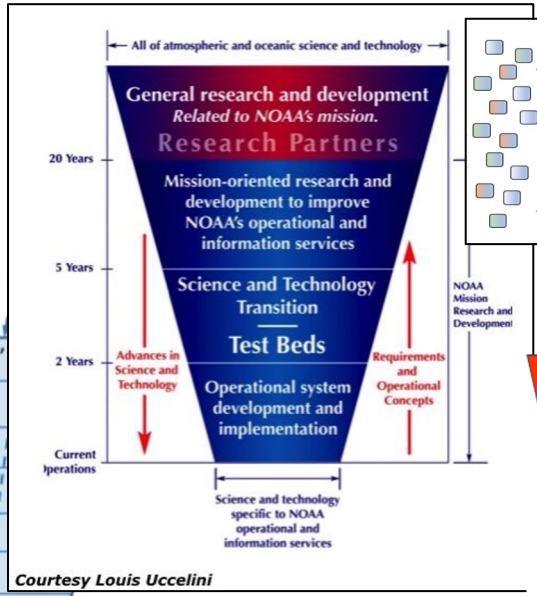

Cloud Computing

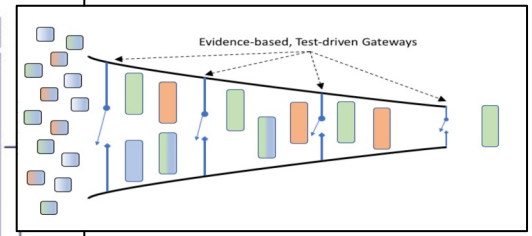

Land Modeling

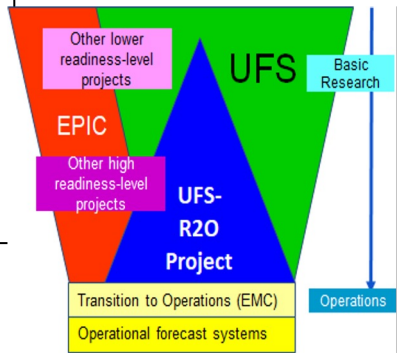
- Support NWS modeling and research initiatives to accelerate operational model development and improve forecast accuracy (*transitioning to the Unified Forecast System, UFS*)
- Foster collaboration among NOAA research scientists, federal labs, operational forecasters and the academic community

Research to Operations (R2O) Process (NOAA has 'funnel-itis')

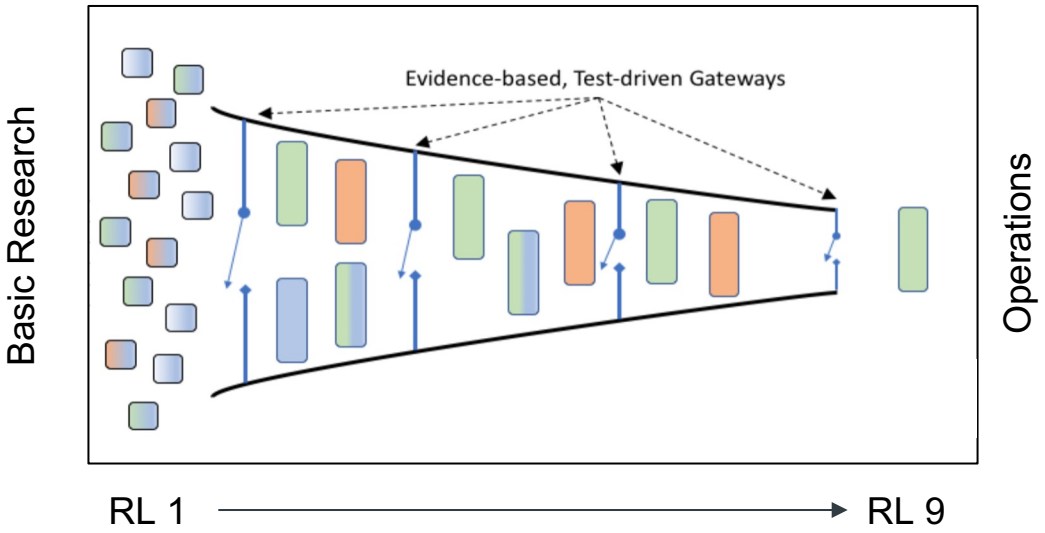








R2O In (Basic) Theory



- Capture needs/requirements
- Identify solution space
- Begin development (Readiness Levels (RLs) 1-5)
- Advance through RLs (stages and gates)
- Operational acceptance
- Operational transition

R2O In Detail

Initial Development

- Map user requirements to possible solutions
- Develop requirements of the system
- Engage Modeling community (Academia, OAR)
- Begin system development

Prototypes

- Establish metrics and benchmarks
- Hierarchical Testing
- Development and Operational communities interface
- Engage operational forecasters
- Transition plans

Tested in Operational-like System

- Integrate Testing and Evaluation in Testbeds
- Engage operational forecasters
- Engage users and stakeholders
- Refine and iterate

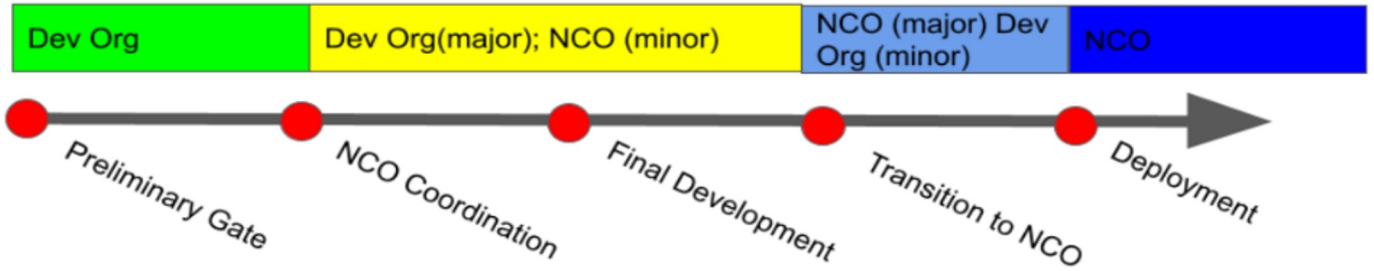
Operations

- Rollout plan
- Public notices and feedback period
- NCEP acceptance
- Service change notice
- Operational integration
- Production

Constants: standards, QC, documentation, open development

T2O Timeline

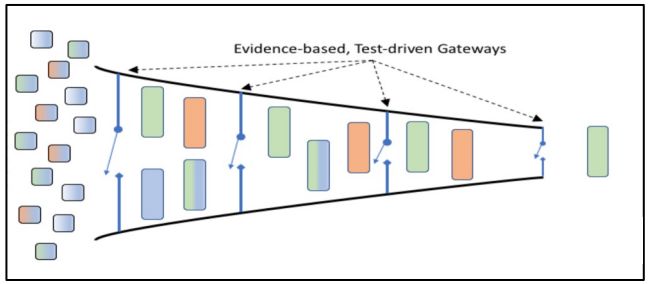
- Preliminary Gate: 1-3 years Prior To Implementation (PTI)
- NCEP Central Operations (NCO) Coordination Gate: 1 year PTI
- Final Development Gate: 6-12 month PTI
- NCO Deployment Gate: 0-3 months PTI
- Postmortem Gate: Optional, 1 month after implementation
- *Considerations: Computational cost, production timelines, data flows and archive*



Source: EMC Implementation Plan FY23-27

What's missing?

Basic Research



Operations

Downstream applications and services

Model upgrades can be trivial, or major.

User/stakeholder engagement is needed to prepare downstream applications *well in advance*

Applies both internal and external to NOAA

- Data format
- Data Dissemination
- Products (new or removed)
- Error characteristics

What else is missing?

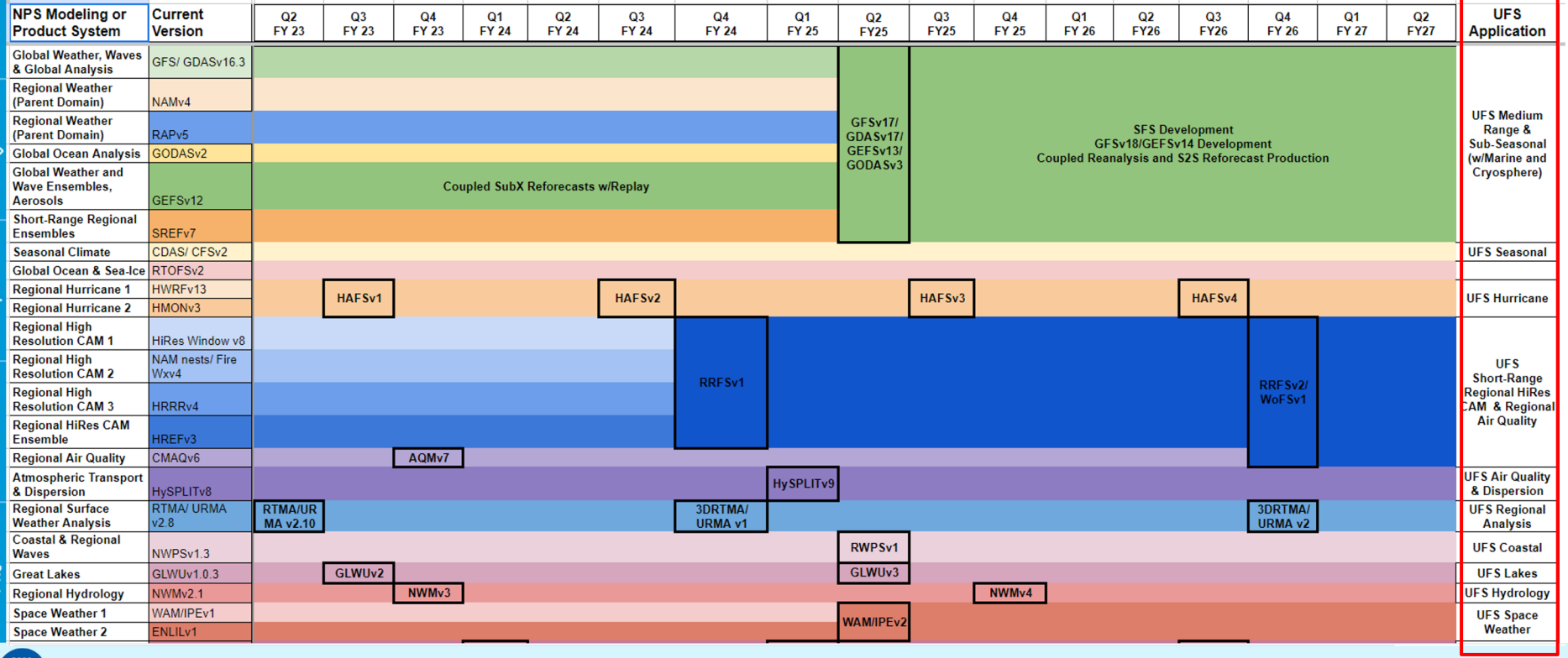
Code retirement

The objective is to develop applications with shared components and infrastructure
(see transition to UFS)

Legacy systems will be retired
(not scalable to meet NWS mission needs)
(there are not enough resources to sustain O&M of multiple systems)
(more compute is needed for next generation, high resolution, coupled, ensemble systems)

Example: Rapid Refresh Forecast System
(will replace RAP/HRRR, NAM, HiRes Window/HREF, AQM)

5-Year Transitioning NCEP Production Suite to UFS Application (Notional!!)

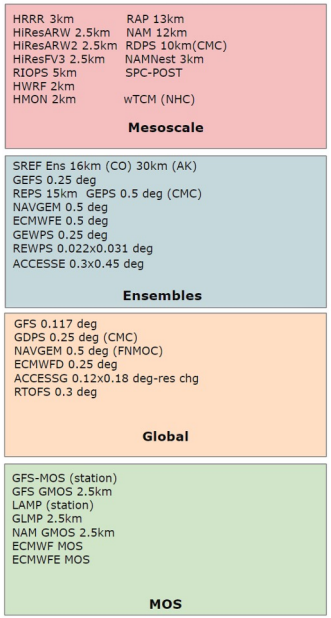


R2O Governance/Directives

- 10-102: Products and Services Change Management
  - Development, demonstration, review, implementation
- 10-103: Capabilities and Requirements Decision Support (CaRDS) Process
  - Acquiring and Validating Field Requirements
  - Request (need, idea, or opportunity) should be validated as “Requirements.”
  - Originator may be Internal (NWS), or External (Executive / Legislative Branch, International, Partner, other organization or agency)
  - Validated by the Mission Delivery Council (MDC)
  - Development of the necessary capability to meet the validated requirement is based on priority and resource availability

Impact of NWP upgrades downstream

- Examples
  - GFSv16.3 -> WAFS products
  - HYSPLITv8 -> Ensemble dispersion capability (volcanic ash)
  - RAPv4/HRRRv5 -> NBM, LAMP
- Systems need to be robust in handling changes to upstream models



National Blend of Models Inputs

Downstream impacts example (LAMP)

- Model upgrade impacts on Localized Aviation MOS Program (LAMP)
  - Retrospective data are needed to assess impact on LAMP. Retrospective LAMP data would need to be created, verified, and the impact assessed. The majority of the impacts have been minor historically, with some impacts requiring later redevelopment.
  - Sometimes, model improvements lead to LAMP improvements without redevelopment.
  - Redevelopment is not an agile process (i.e., it is time-consuming and resource intensive). To mitigate this, LAMP has now developed in a two step process, with the more changeable HRRR incorporated in the second, broader development step, which makes the process more agile when redevelopment is needed (i.e., only the second step may need to be redeveloped).
  - Long term goals are to create a self-updating system using AI/ML techniques.

In short, changes to input models can have both positive and negative impacts on LAMP guidance

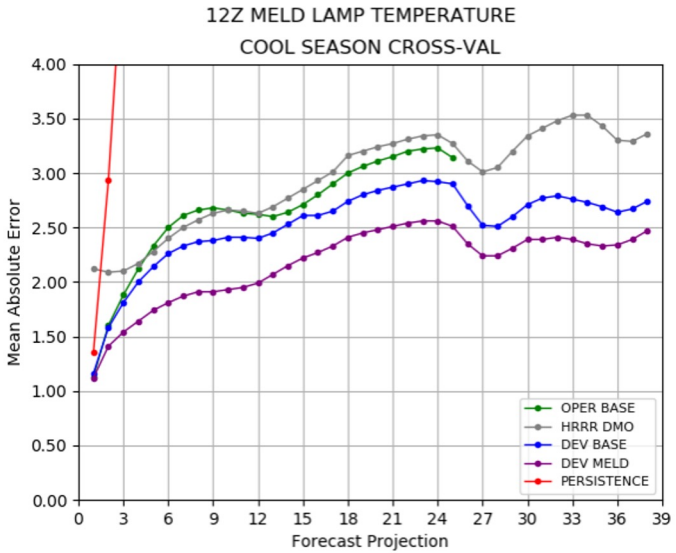
Example of a recent LAMP upgrade to incorporate the HRRR and updated GFS MOS

- LAMP v2.5*: Updated station-based temperature (T), dew point (Td), wind speed (WS), wind direction (WD), and wind gust (WG) guidance. Redeveloped to:
  - incorporate recently redeveloped GFS MOS,
  - incorporate input from the High Resolution Rapid Refresh (HRRR) model,
  - extend forecast projections from 25 hours out to 38 hours,
  - and incorporate input from the Rapid Refresh (RAP) model for stations outside the CONUS

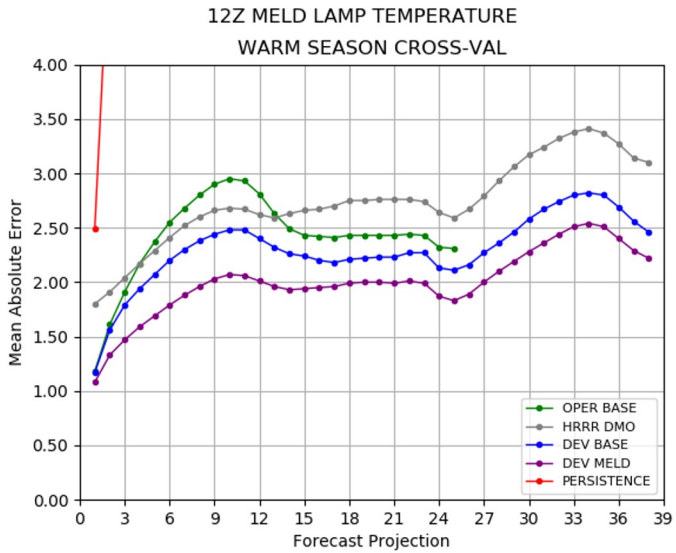
*LAMP/GLMP v2.5 is scheduled to be implemented on June 6, 2023

LAMP Meld (V2.5) Independent Verification
1-38 h Temperature MAE 12 UTC cycle

Cool Season



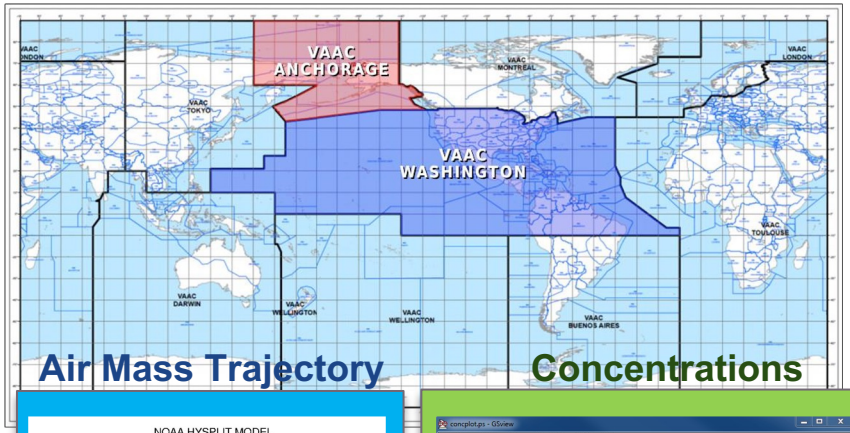
Warm Season

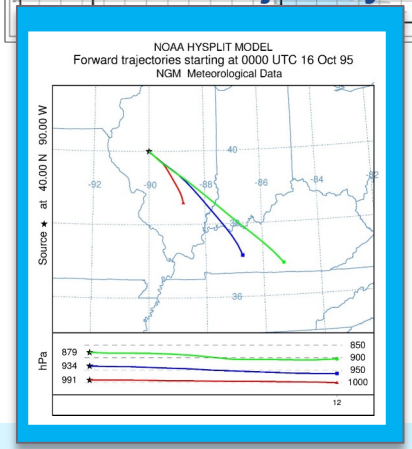


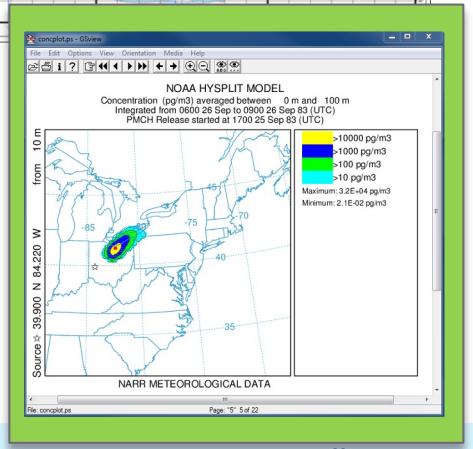
NEW LAMP Meld (purple) shows improvement over Base LAMP (blue) and Operational LAMP (green) and HRRR (gray)

Volcanic Ash Forecasting (HYSPLIT)

- Support volcanic ash advisory centers (VAACs)
- To support improved volcanic emissions advisories and warnings for aviation
- Ensemble-based volcanic ash -> quantitative probabilistic forecast
- Future enhancements
  - Incorporation of satellite data





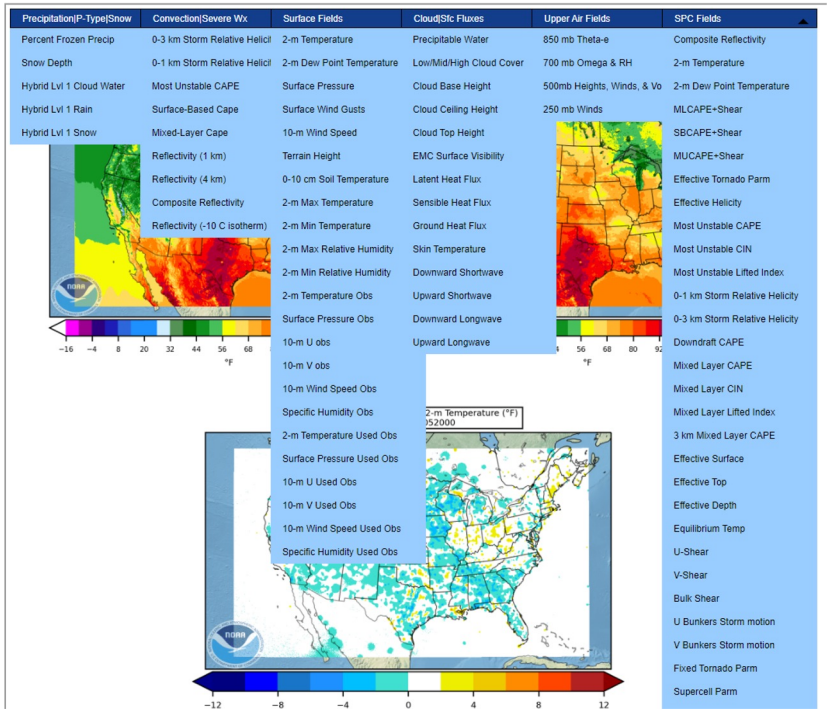


Planned Enhancement with RRFS

- Based on the FV3 dynamical core Limited Area Model (LAM) capability
- Rapidly updated
- Convection-allowing (~3 km grid spacing)
- 65 vertical layers
- Hybrid 3DEnVar assimilation (30-36 members)
- Deterministic forecasts to 18h every hour
- Ensemble forecasts to 60h every 6 hours
- Implementation: ~Q4 FY24

RRFSv1 Computational Domain

Planned Enhancement with 3D RTMA



- 3-Dimensional analysis
- More variables
- Improved Obs processing and QC
- Implementation: ~Q1 FY25

Summary and other thoughts

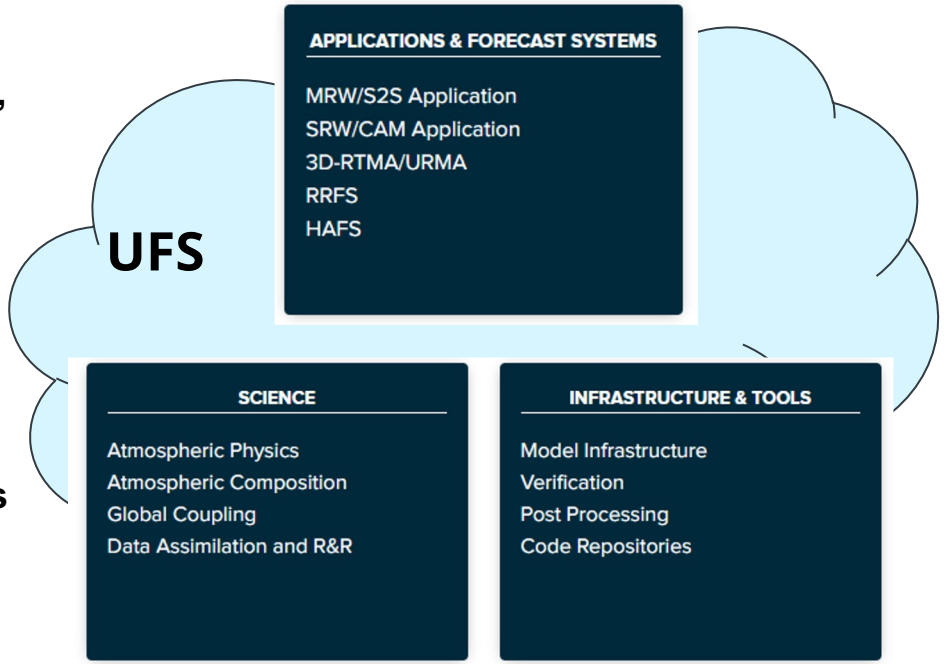
- Requirements are important- drive model development
  - Close coordination across NOAA line offices, forecasters, external users/stakeholders
- Principles based on community modeling
  - Criteria for advancing toward operations needs to be well known and resourced
- Testbeds play a critical role in model T&E
  - Need more coordination across testbeds, and ensure users/stakeholders have adequate lead time
- The R2O process for models (even minor upgrades) is thorough, but long
  - Need agility to accelerate innovation into operations

Backup slides

What is the *UFS-R2O* project?

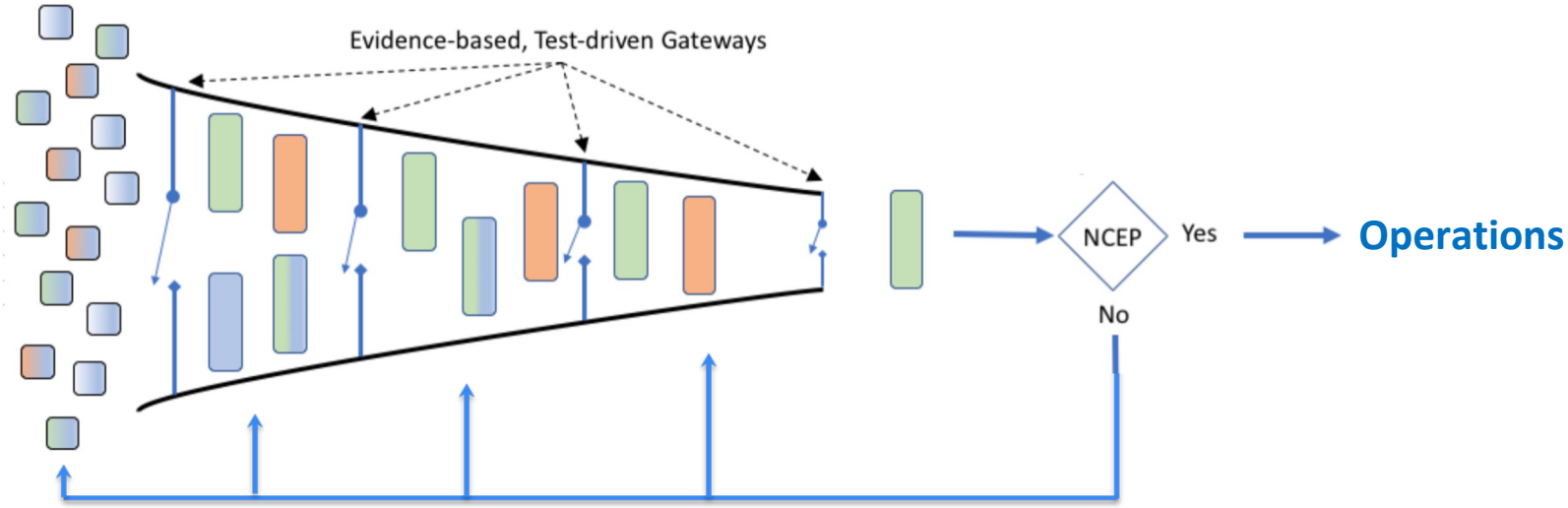
UFS R2O

- ➔ **Formal kickoff in 2020**
- ➔ **Transition UFS applications, components, and infrastructure into NWS operations (integrated, fully-coupled Earth system model)**
- ➔ **Direct partnerships with UFS community members and Earth Prediction Innovation Center (EPIC)**
- ➔ **Focus on high readiness-level capabilities**
- ➔ **Co-managed by NWS/Office of Science and Technology Integration and OAR/Weather Program Office**



SCIENCE & TECHNOLOGY INTEGRATION -MODELING · WEATHER PROGRAM OFFICE · EMC · GFDL · EARTH SYSTEM RESEARCH LABORATORIES · DTC · GEORGE MASON UNIVERSITY · NCAR UCAR · U.S. NAVAL RESEARCH LABORATORY · UNIVERSITY OF MICHIGAN · CIRES · CIMSS

Stages and Gates



Schematic adapted from 'Describing R2O Interface' by UFS-SC, SIP WGs

Research to Operations Process