Developing fruitful community collaborations in operational model development: Discussion and guidelines in the context of the UFS-R2O Project

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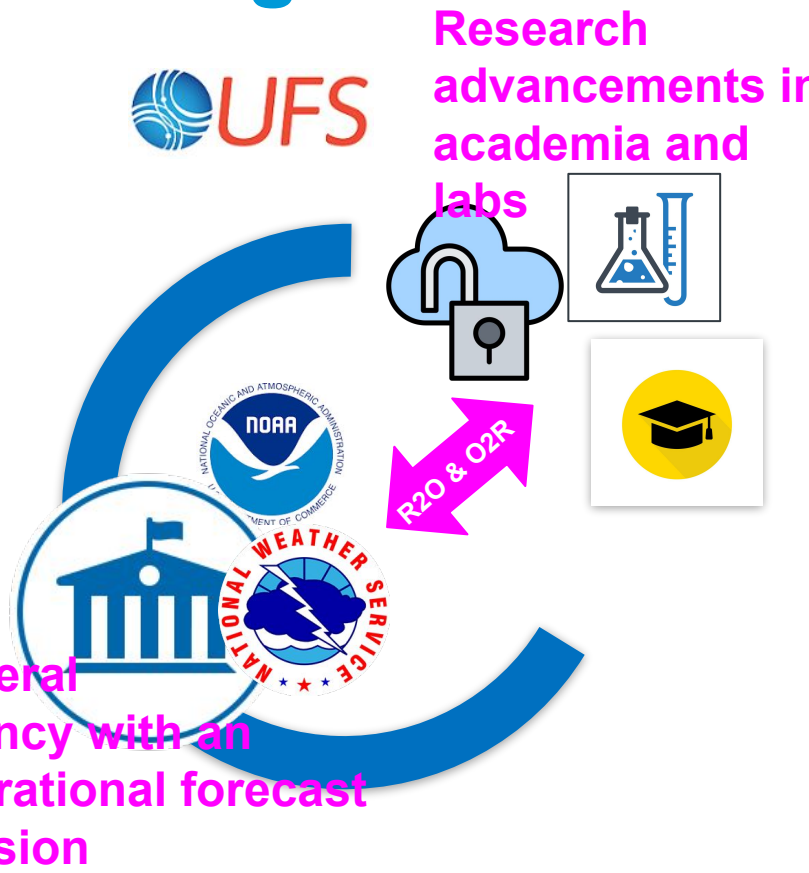
AMS Annual Meeting, Baltimore, MD
January 28 - February 1, 2024

UFS R2O

Unified Forecast System - Background

- Community-based **global coupled modeling** system with a mission to accelerate **operational model development** by incorporating timely and efficient research innovations
- Simultaneously developing a **state-of-the-art community modeling** system for research applications
- **Operational mission** makes this a unique community modeling effort



Engaging with an Operational UFS Project

Operational requirements

Evaluation metrics

Forecasters Priorities

EMC

Downstream Products

NCO

OSTI

UFS

NCEP

WPO

MEG

UFS Applications

R2O Funnel

UFS-R2O

EPIC

T2O

NOFO

METPlus

Headline scores

Readiness Levels

JTTI

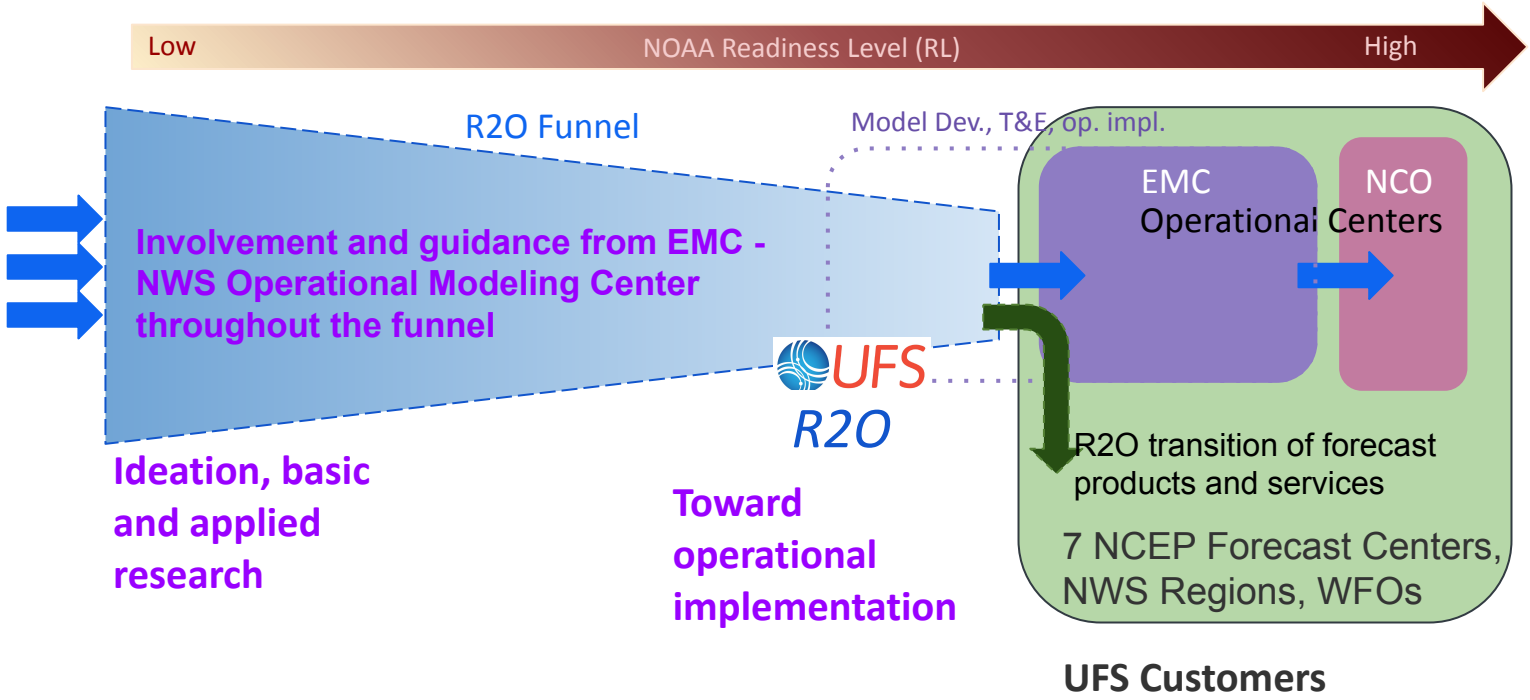
R2O Stages and Gates

Customers and stakeholders

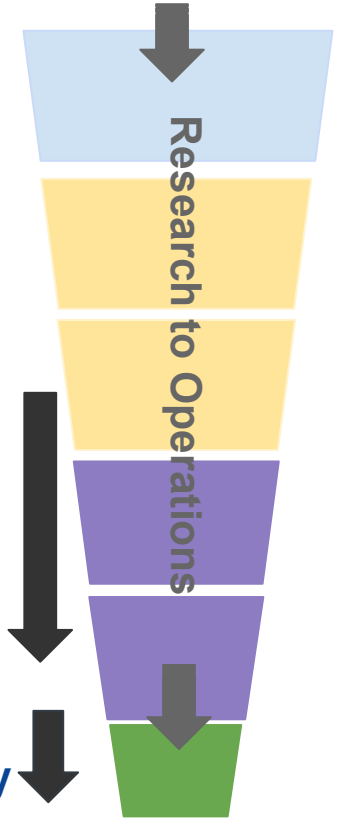
Objectives

- Provide an overview of Research to Operations (R2O) transitions
- Discuss operational requirements and expectations from external collaborators
- Discuss pathways to engage with R2O for existing and potential collaborators from research and academia.

Overview of R2O Funnel



(Operational) Readiness Levels



R2O Projects typically transition to Level 8

RL 8 to 9 is carried out by EMC

- RL1 - Basic Research
- RL2 - Applied Research
- RL3 - Proof of Concept
- RL4 - Validation of System in a Lab or Equivalent
- RL5 - Validation of System in a Relevant Environment
- RL6 - Demonstration in a Test Environment
- RL7 - Demonstration in a Relevant Environment
- RL8 - Demonstration in an Actual Environment
- RL9 - Deployment and Regular Use

RL break-down from R. Certner, L. Newcomb and G. Matlock, 2018

Customers and Development Priorities

- **Customers of UFS Applications**
  - NWS Forecasters
    - NCEP Forecast Centers
    - NWS Regional HQs, Local WFOs
- **Development priorities**
  - Forecasters requirements
  - Model biases impacting operational mission
  - Scientific priorities developed collectively by the community (NOAA operations, NOAA research and non-NOAA research)

UFS Evaluation Metrics

FIELD	LEVEL	DETERMNISTIC METRIC	ENSEMBLE METRIC	PROBABILISTIC METRIC	TEMPORAL ATTRIBUTE	NOTABLE THRESHOLDS	REGION	VERIFICATION APPROACH	VALIDATION SOURCE
TIER 1									
Heights	Profile	BCRMSE + Bias	RMSE of Ens. Mean + Ensemble Spread	ROC + Reliability + BSS	3-Hourly		Full Domain	Grid-to-obs	Raobs + Aircraft
Temperature	Profile	BCRMSE + Bias	RMSE of Ens. Mean + Ensemble Spread	ROC + Reliability + BSS	3-Hourly	0°C for 850 temps, 12°C for 700 temps	Full Domain	Grid-to-obs	Raobs + Aircraft
U and V Wind Components	Profile	BCRMSE + Bias	RMSE of Ens. Mean + Ensemble Spread	ROC + Reliability + BSS	3-Hourly	30, 40 kt at 700-hPa 50 kt at 850-hPa	Full Domain	Grid-to-obs	Raobs + Aircraft
Specific Humidity	Profile	BCRMSE + Bias	RMSE of Ens. Mean + Ensemble Spread	ROC + Reliability + BSS	3-Hourly	15 g/kg at 850 and 925-hPa	Full Domain	Grid-to-obs	Raobs + Aircraft
TIER 2									
Precipitation	Surface	Total Interest (MODE), FSS, and Contingency Table Counts	FSS + CTC + Rank Histogram	Reliability Diagram	Hourly to f24 and then 3-hourly, also 24-hourly	3h: 0.25", 0.5", 1" (include 0.1" in winter) and 24h: 1" and 2" (include 0.5" in winter)	CONUS divided into fourths + Alaska	Grid-to-grid, grid-to-obs	CCPA
Temperature	Sfc/2-m	BCRMSE + Bias	RMSE of Ens. Mean + Ensemble Spread + Ranked	ROC + Reliability + BSS	Hourly to f24 and then 3-hrly	0°C, 60°F (when paired with high Td)?	CONUS divided into fourths + Alaska	Grid-to-obs	METARS + some mesonet + marine obs
Wind	Sfc/10-m	BCRMSE + Mean Error Bias	RMSE of Ens. Mean + Ensemble Spread + Ranked Histogram	ROC + Reliability + BSS	Hourly to f24 and then 3-hrly		CONUS divided into fourths + Alaska	Grid-to-obs	METARS + some mesonet + marine obs
Dew Point	Sfc/2-m	BCRMSE + Threshold Bias (do not compute stats for low values)	RMSE of Ens. Mean + Ensemble Spread	ROC + Reliability + BSS	Hourly to f24 and then 3-hrly	50, 60, 70°F (possibly 40 and 50 in the west?); need lower threshold for fire wx	CONUS divided into fourths + Alaska	Grid-to-obs	METARS + some mesonet + marine obs

2021 DTC UFS Evaluation Metrics Workshop and Community driven metrics for UFS R2O transitions

4 tiers of metrics for all UFS Applications for deterministic and probabilistic verifications with suggested obs data sources

Tara Jensen (DTC/NCAR), Jason Levit (EMC), UFS V&V Co-leads

Supporting Programs and Projects
(Pathways to Engage with R2O)

NOAA Operations

NOAA/NWS /OSTI

- NGGPS
- Weeks 3-4 /S2S
- HFIP
- Air Quality

NOAA Research

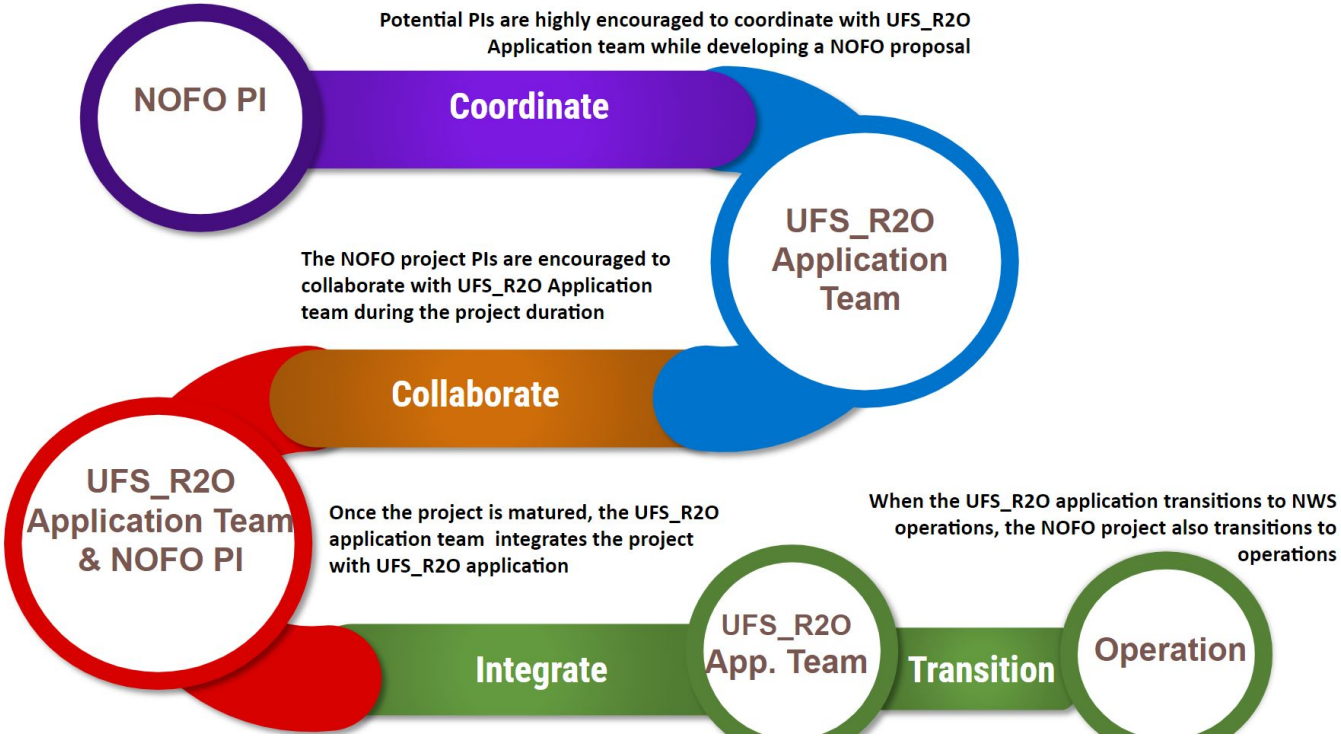
NOAA/OAR /WPO

- JTTI
- EPIC
- S2S

- **Funded UFS-R2O efforts**
- **In-kind collaboration with UFS-R2O**
- Competitives calls (**NOFO**) from **NWS and OAR** that collaborate with UFS-R2O Team
- **Calls from other funding agencies in lower RLs (e.g., NSF Call, April 2023)*

*no direct interface with UFS-R2O

Integration of JTTI NOFO projects with UFS-R2O



Slide courtesy: **Chandra Kondragunta, JTTI Program Manager**

What to Expect during a High RL R2O Project

- Typically high RL R2O projects are 2-3 years long with **specific deliverables and milestones**
- Expect to **work closely with NWS operational centers** and model developers with the operational or similar codebases
- **Regular meetings** (monthly, weekly) and reporting, **project management and tracking**
- **Webinars and discussion forums** - EMC Model Evaluation Group (MEG weekly webinars, UFS, Weeks 3-4, S2S All-hands
- **Stay tuned for questions until the technology transfer to operations is complete**, answer questions
- Final adoption of the code is dependent on **NCO guidelines**

An Example of a Successful R2O Transition

NOAA RESEARCH

National Centers for Environmental Prediction
Environmental Modeling Center (EMC)

06/2019-05/2021	06/2021-05/2022	06/2022-05/2023	06/2023-11/2023	12/2023-05/2024	06/2024
~4 years - Dev, T&E			~6 months after IOC		
HAFSv0.1 prototype and development	HAFSv0.2 development and real-time demo	HAFSv0.3 configuration, retro forecasts & IOC	HAFSv1 IOC implementation and real-time operations	HAFSv2 baseline, development, and upgrades	New impl'n
Create HAFS prototype version; Development essential capabilities	T&E the integrated HAFS in real-time forecasts	Create and implement HAFS IOC; T&E HAFS in real-time forecasts	Operate HAFS in real-time forecasts	Develop and upgrade HAFS for the next cycle of implementation	

Slide courtesy: **Xuejin Zhang (AOML), Zhan Zhang (EMC), UFS-R2O Hurricane Application Team Co-Leads**

Further Information and Links

- **Projects and sponsoring programs**
  - UFS-R2O (Project Plan, Applications and Leads and contact info)
  - NWS Programs - NGGPS, Weeks 3-4, HFIP, Air Quality
  - OAR Programs - JTTI, EPIC, S2S
- **Overall guidance on R2O transitions**
  - Research to Operations processes and examples and case studies
  - NOAA's guidance on R2O transitions (more on Readiness Levels)
- **Model development priorities**
  - Forecasters priorities (MRW/S2S and SRW)
  - UFS Strategic Plan (Science priorities)
- NCEP Operational implementation and software standards
- **Model evaluation standards**
  - UFS model evaluation metrics

Areas that Need Continued Progress

- Access limitations of **NOAA HPC** by non-NOAA researchers
- **Access to data** - observations and model runs (high res, ensemble)
- Continuing focus on **science publications** for active academic collaborations

Thank You

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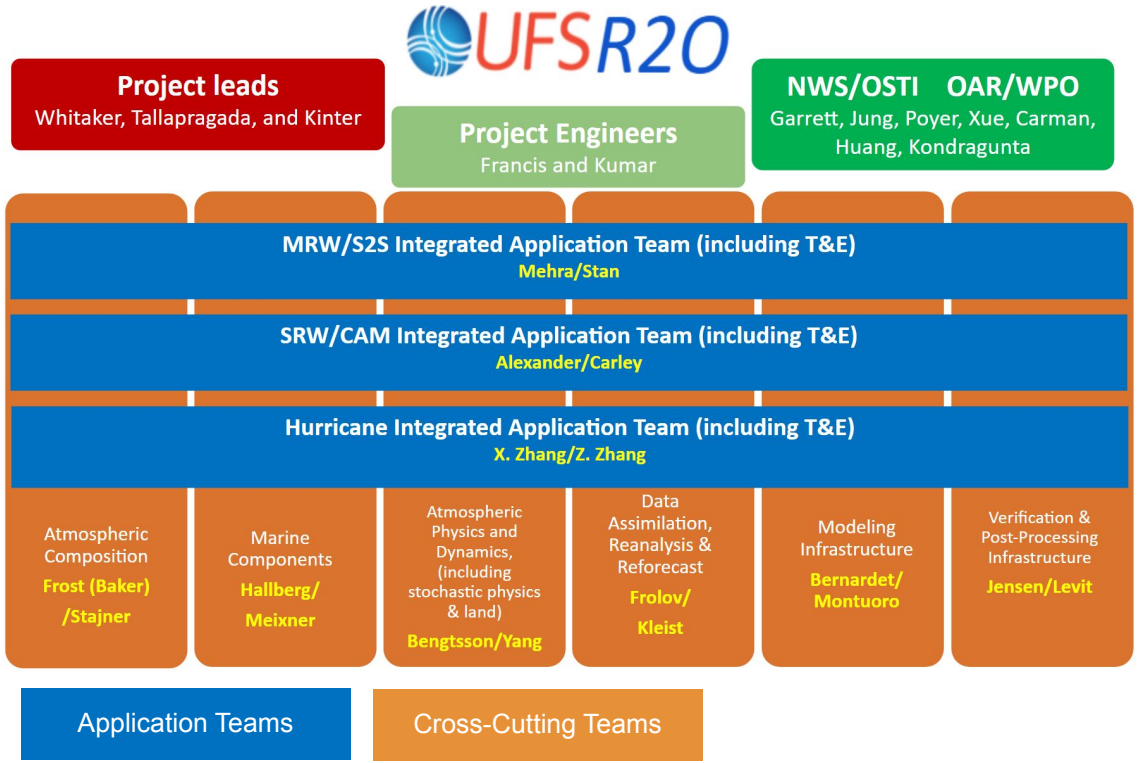
Types of R2O Transitions

- **Systems level transitions**
  - A major aspect of the UFS is selected from a community-based model repository. Relatively infrequent event - Occurs when a new application is brought in - or as part of a long-term strategy to address a basic model shortcoming. E.g., Introduction of FV3 dynamical core. Timeline for transition - ~5 years
- **Application level transitions**
  - Significant changes to a model component - E.g., advancing Atmospheric model Physics. Timeline - months to 2 years
- **Incremental level transitions**
  - More frequent. Target narrow changes to an existing operational system. Can be scientific, technical, and/or engineering improvements. E.g., Investigation of sensitivity of the forecast to grid-scale mixing parameterizations. Relatively less time consuming.

UFS-R2O - A High RL UFS Project



Funded by both NOAA Operations and Research

Co-led by scientists at operational centers, research labs, and universities

Non-NWS partners work closely with NWS in transitioning research innovations to operational models

Transition to Operations (T2O) at EMC

- **Assembling and optimizing**
  - Hierarchical testing and evaluation to **finalize the configuration** of individual components that are included in the upgrade.
  - Work with the developers to optimize the performance of each component
  - Assemble all components together to conduct experiments that involve only the forecast system or only the data assimilation system, further **optimize the forecast and data assimilation system respectively**
  - **Combine the forecast and data assimilation systems** together to perform cycled experiments, further optimize the entire system.
  - To prepare for implementation, carry out official **retrospective and real-time parallel experiments,** and evaluate the system performances.
- The Transition Team often consists of community collaborators, EMC model developers and system engineers

Transition to Operations (T2O) at EMC

- **Transition to Operations**
  - Code freeze
  - Model runs start for real-time EMC parallel, retrospectives and case studies. Evaluations by MEG start at this stage.
  - Evaluations from other NCEP centers and field due. Some perform their own (e.g., CPC in the case of GEFS, most draw their conclusions from weekly MEG briefings), Downstream Products evaluation
  - Briefing before EMC CCB (Change Control Board) - by Technical lead
  - Briefing before NCEP Office of the Director (OD) - by Overall Project Manager
  - Code hand-off to NCO and NCO 30-day IT Test
- **Implementation**