# Open-innovation and Open-development Framework for the Unified Forecast System - An EPIC Approach

**HFIP Annual Meeting , 9 November 2022, Miami, FL**

**Maoyi Huang, Ph.D.,** EPIC Program Manager
Weather Program Office, Oceanic and Atmospheric Research
National Oceanic and Atmospheric Administration

EPIC

EARTH PREDICTION INNOVATION CENTER

# Acknowledgement


| Agile Train Leadership | Platform Team | | Advanced User Support Team | Community Engagement Team |
|---|---|---|---|---|
| Maoyi Huang | Stylianos Flampouris | Yi-Cheng Teng | Mark Potts | Mandy Parson |
| Henrique Alves | Cam Sherrell | Jong Kim | Lauren Frederick | Jamiel Farhat |
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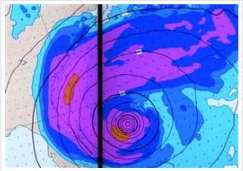
| Luke Peffers | Leron Thomas | | | Jef Dodson |
| Keven Blackman | Michael Lueken | | | |
| Fredrick Gabelmann | | | | |


NOAA WEATHER PROGRAM OFFICE

# Hurricane Sandy (2012) Raises Public Awareness of Modeling……

Nightly News | March 08, 2013

**European weather forecasts superior to US models**

The predictions from European computer models, which have 10 times the computing ability of the National Weather Service, have increasingly become more accurate than our models with the starkest example being Hurricane Sandy. NBC's Al Roker reports.

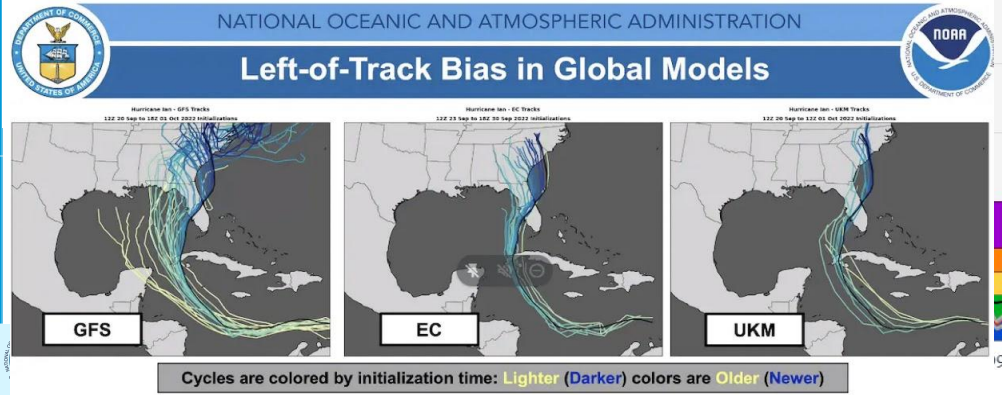
Share This:

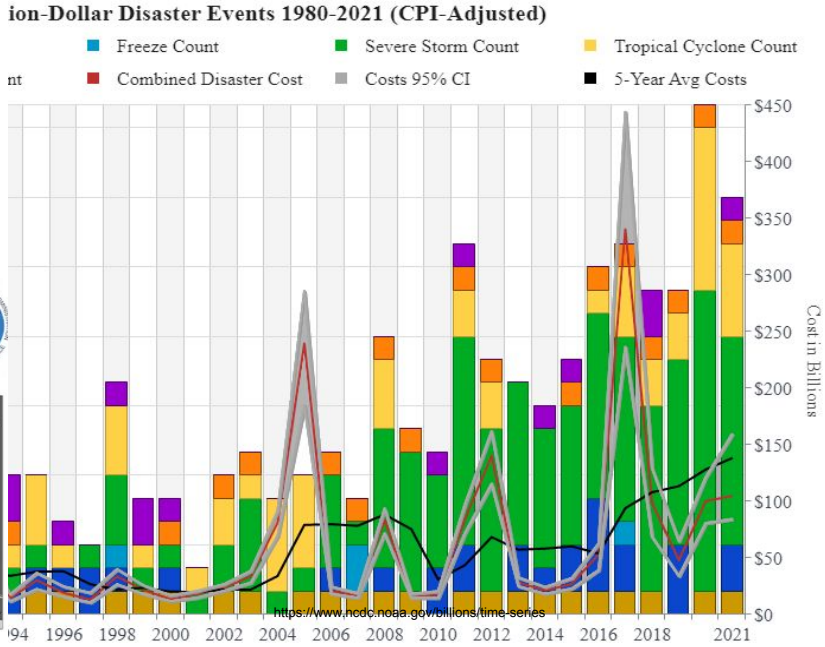
Capital Weather Gang

Why America Has Fallen Behind the World in Storm Forecasting

CAPITAL WEATHER GANG

## How a trusted weather model fumbled the forecast for Hurricane Ian



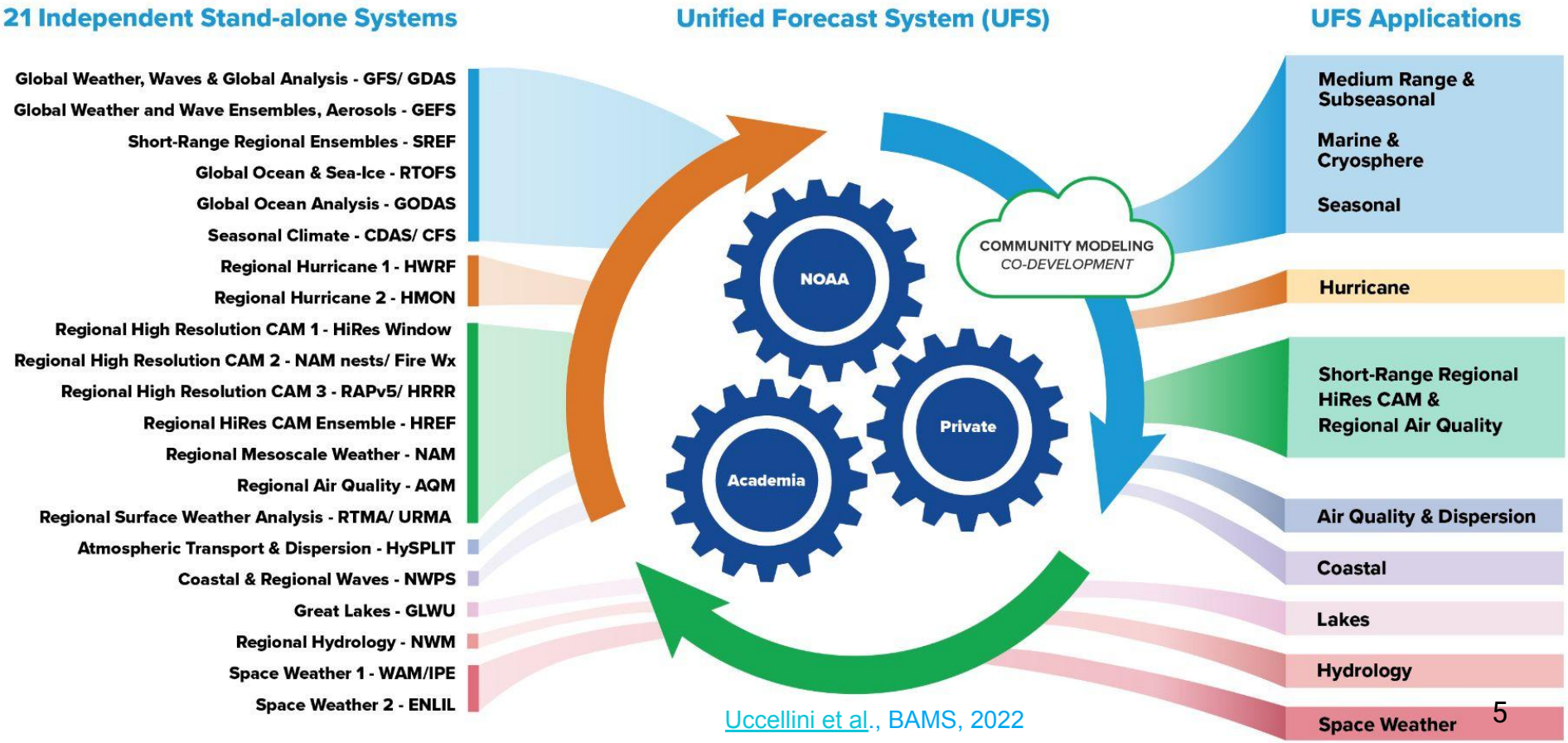
# External Review Committee for NCEP Modeling Suite

**RECOMMENDATIONS**

- Reduce complexity of the NCEP Production Suite
- Create a unified collaborative strategy for model development across NOAA
- Leverage the capabilities of the external community
- Continue to enhance High Performance Computing capabilities
- Execute strategic and implementation plans based on stakeholder requirements

# Simplifying NOAA's Operational Forecast Suite

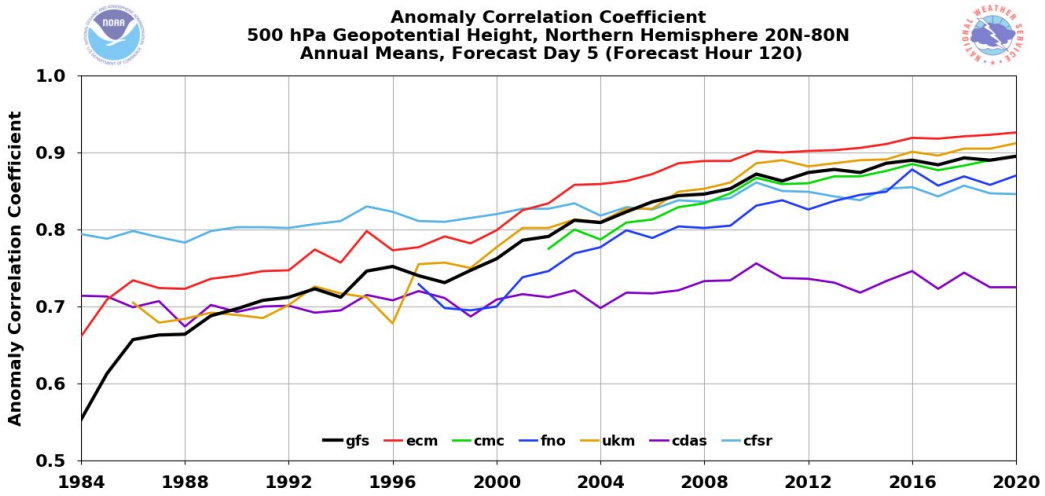
## Reducing the 21 Stand-alone Operational Forecast Systems into Eight Applications




Uccellini et al., BAMS, 2022

# Why is EPIC needed

- Access to **integrated development environment** that is platform-agnostic
- Access to **external expertise in modeling**
- Common UFS infrastructure that **shares components**
- **Clarify** research and operational priorities
- Increase and **accelerate** the rate of **Innovation** into operations and applications




# EPIC

Partnering with the community for the benefit of the nation

***Vision:*** *Enable* the most accurate and reliable operational numerical forecast model in the world.

***Mission:*** To be the *catalyst* for community research and modeling system advances that continually inform and accelerate advances in our nation's operational forecast modeling systems.

***What EPIC is….***

- A virtual community model development environment
- Management of cloud- ready code
- Community access to NOAA observations, data & tools
- Community support & engagement
- Clear research & model transition to operations priorities
- Expected expansion to other additional model components
- EPIC: focus on the Unified Forecast System (UFS)

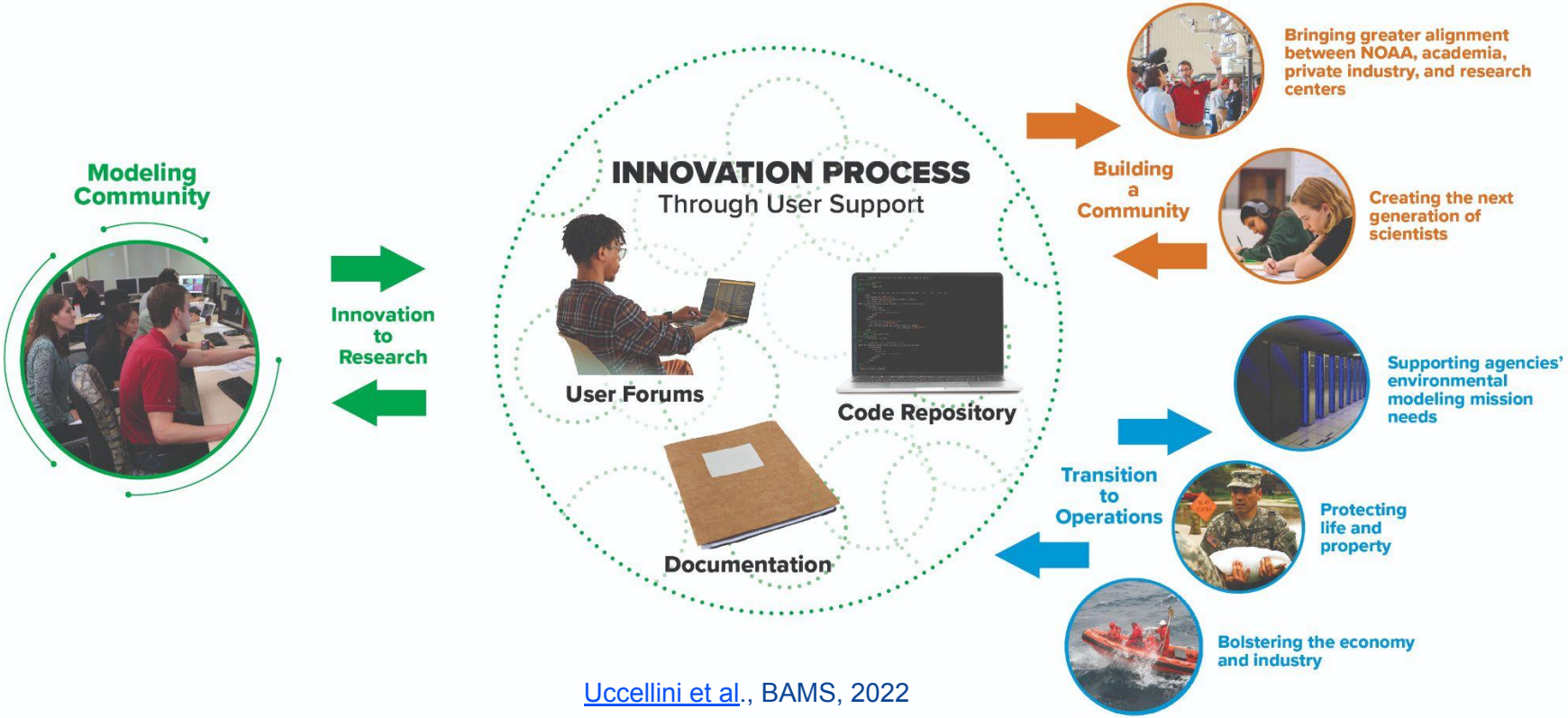
**Community Engagement**

UFS
UNIFIED FORECAST SYSTEM

**Cloud Use**

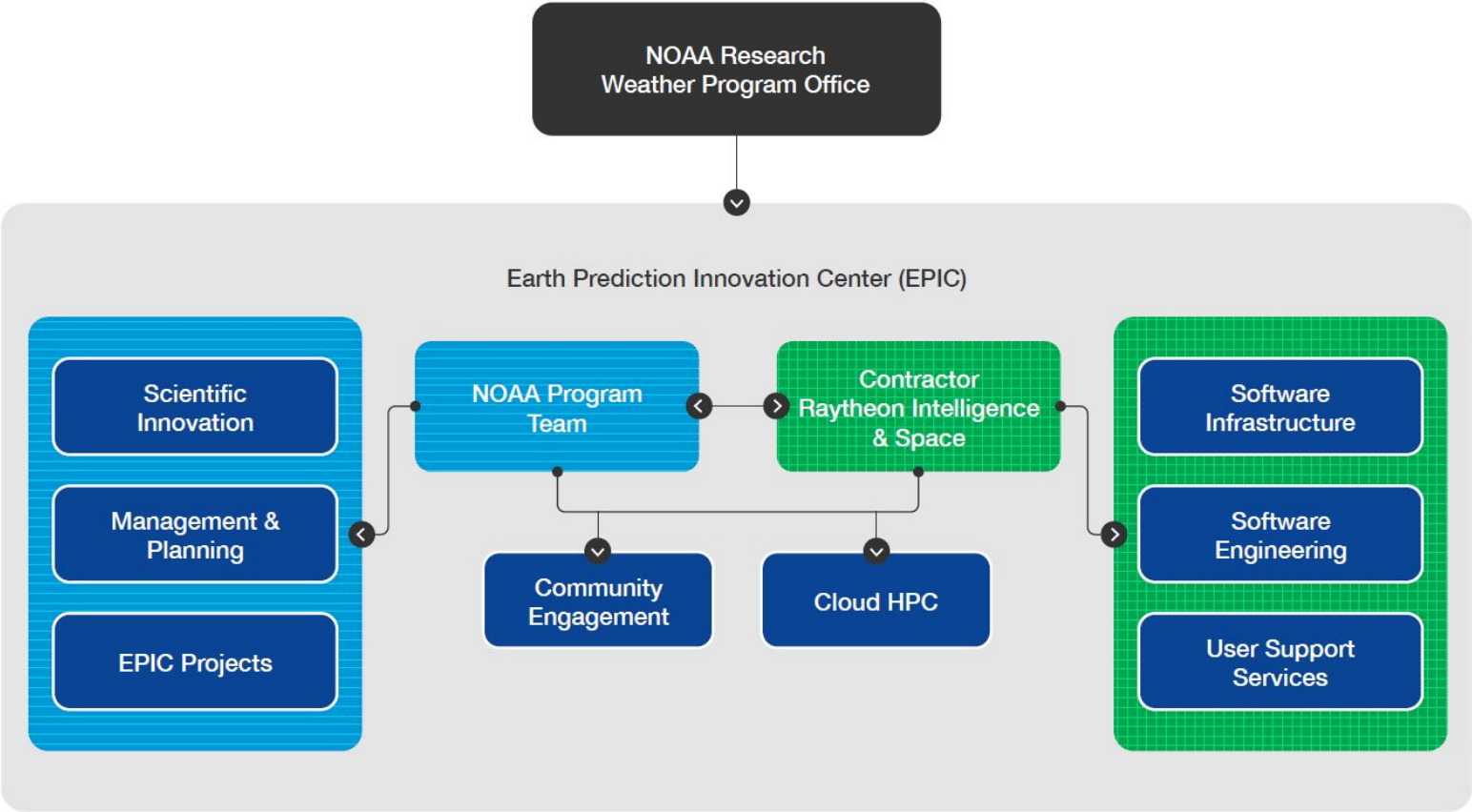
# EPIC Innovation Flow

## Creating an Environment for Co-development and Inclusion

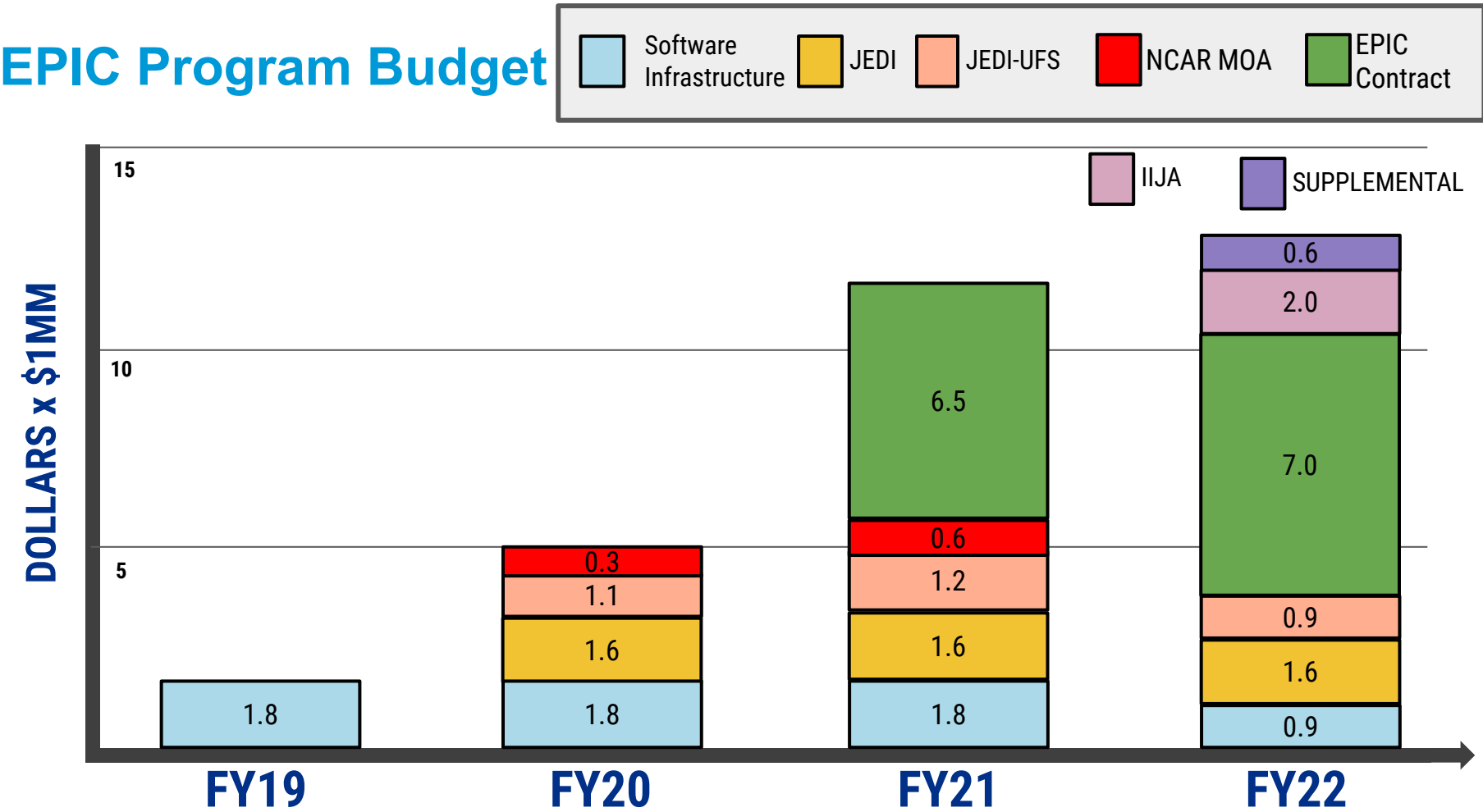



Uccellini et al., BAMS, 2022

# EPIC Organization



# EPIC Program Budget



# Timeline and Accomplishments

EPIC
Earth Prediction Innovation Center

**2019**

- EPIC program established under OWAQ (now WPO)
- **Release EPIC Vision Paper**
- **Host first EPIC Community Workshop**
- Host EPIC Industry Day and Vendor Meetings
- Release EPIC Community Workshop Report
- Fund UFS Community Modeling Support Project (w/ JTTI)

**2020**

- **Release EPIC Strategic Plan**
- Release EPIC Request For Proposals
- Align EPIC and JCSDA under same budget line item
- **Release UFS Medium Range System v1.0 to Github**

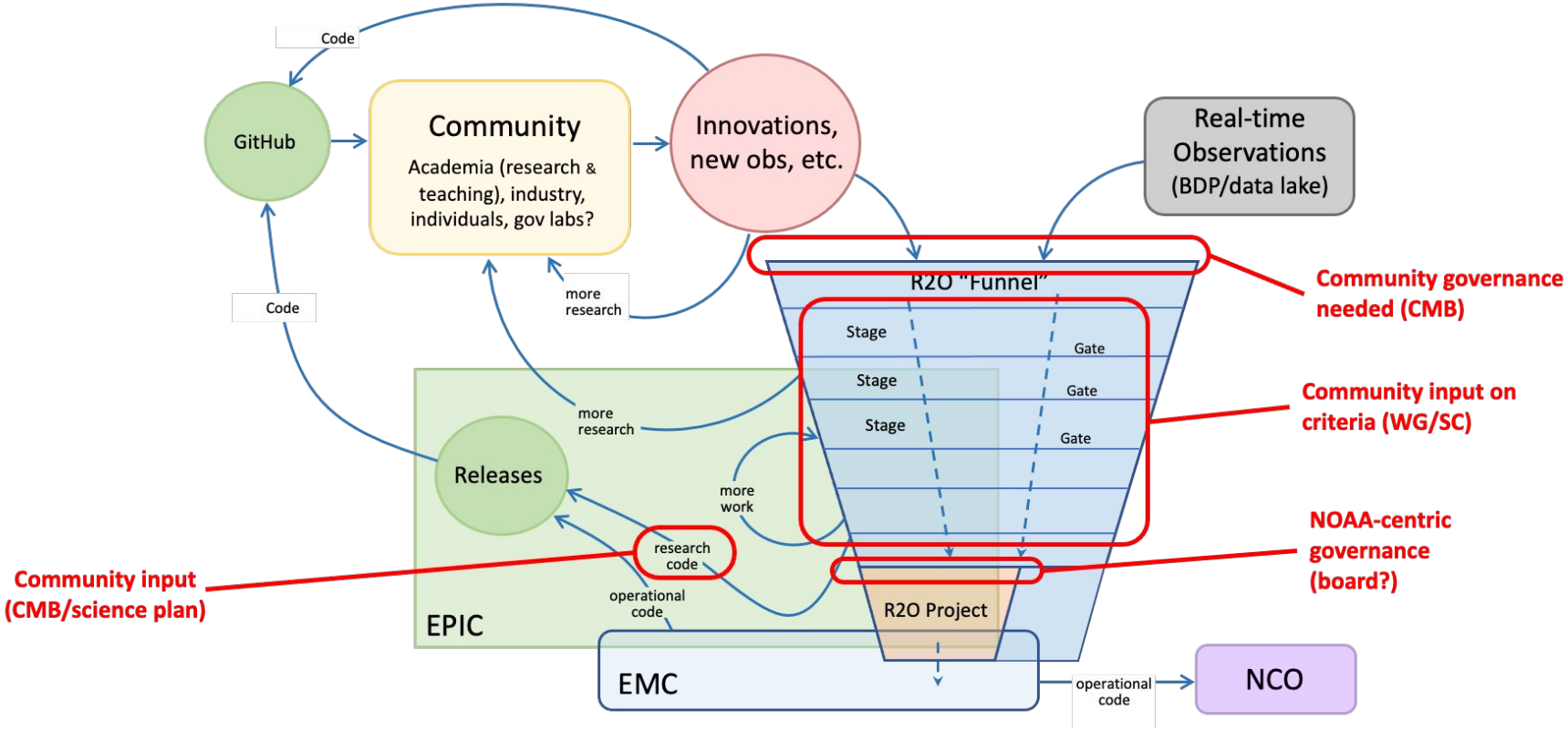
**2021**

- **Release UFS Short Range System v1.0 to Github**
- **Award the RFP Contract to Raytheon Intelligence & Space**
- Support and release JCSDA-JEDI Tools and Software
- Implement Scaled Agile, completed two program increments
- **Release Final EPIC Strategic Plan**

**2022**

- **Release EPIC Community Portal website (epic.noaa.gov)**
- Host first EPIC Symposium at the AMS
- EPIC Short course, code sprint, and Hackathon
- **Release UFS Short Range System v2.0**
- UIFCW workshop
- **WPO FY23 Innovation Competition**
- **WINGS Dissertation Fellowship**

# UFS Governance and Process




*Courtesy of the UFS Steering Committee*

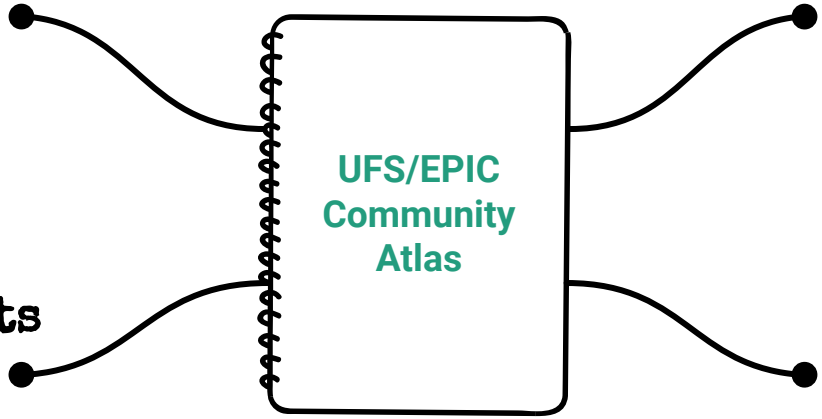
# What's happening in the UFS community?

## Everyone

Websites (EPIC portal and UFScommunity.org), GitHub, forums, FAQs, governance, webinars

## New Users & Students

Hackathons, code sprints, short courses, coming soon: training videos and tutorials




## Developers

UFS Working Groups, UFS R2O Project including Application Teams and Cross-Cutting Development Teams

## Super User

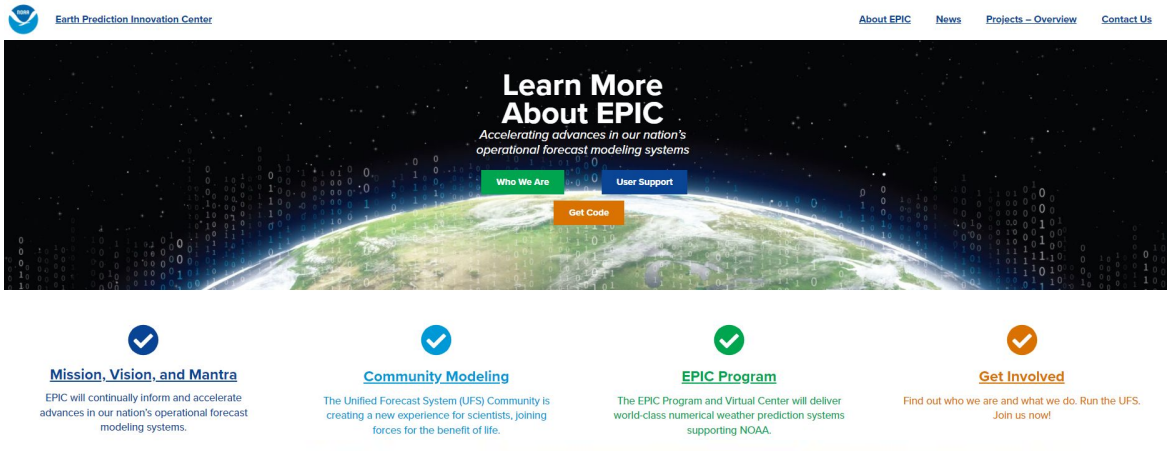
Coming soon: CI/CD pipeline access, use cases on cloud, ticketing system

# EPIC Community Portal

https://www.epic.noaa.gov

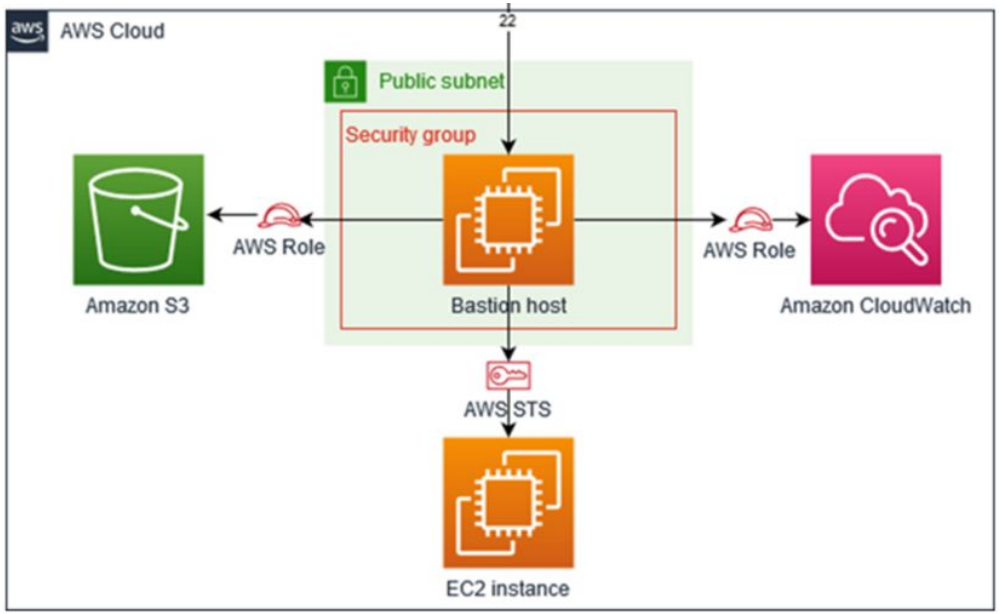
- Github forums
- User support
- News
- Events
- Get code
- Metrics
- Cloud Cost Estimator

**POC: Mandy Parson**



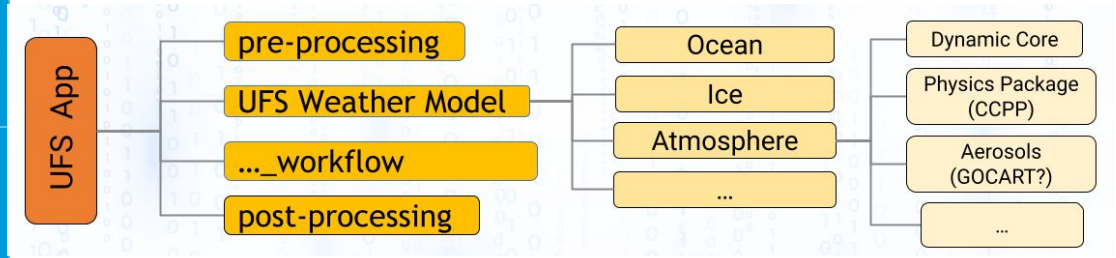

# EPIC Cloud Sandbox

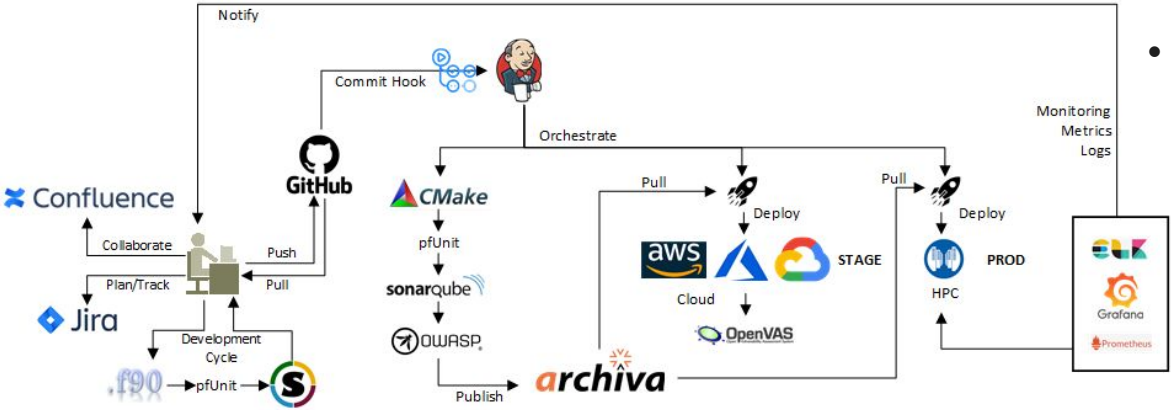
- The EPIC Cloud Sandbox is an AWS environment that is accessible by non-NOAA users, for EPIC-related purposes.
- It has been used by attendees of June 2022 AMS Short Course, code sprints and hackathons, to configure, run  and evaluate the SRW Container developed by the EPIC Program.
- Discussing with CSPs to extent the sandbox to a multi-cloud environment.




**POC: Keven Blackman**

# EPIC Configuration Management




- EPIC leads the management of UFS Weather Model and SRW App
  - **Jong Kim** (UFS WM Lead CM )
  - **Michael Lueken** (SRW Lead CM)
  - Coordination with MRW and HAFS App teams and CI of component repos
- Automated build pipeline on NOAA Multi-Cloud Platform using Jenkins and Static code analysis to ensure quality, security, and coding standards using SonarQube
  - **Jessie McFarland**
  - **Keven Blackman**

# EPIC Supported Platforms

| Platform | Examples | Libraries | Model tests |
|---|---|---|---|
| **Cloud** | AWS, Azure, GCP | Prebuilt | Full |
| **Container** | Docker | | |
| **Pre-configured** | RDHPC, Cheyenne (NCAR) | | |
| **Configurable** | Stampede, Odin | User builds | |
| **Limited Test** | Mac or Linux box | | Limited |
| **Build Only** | None | | None |

Laptop, cluster, HPC, cloud needed to serve needs of operations, academia, industry

# Cloud Data Management

| | |
|---|---|
| ***Cloud Data Storage*** | **Cloud Data Storages Established for UFS Weather Model (UFS-WM) Regression Test (RT) datasets, SRW Application & Medium-Range Weather (MRW) Application datasets**<br>• Established requirements & setup for SRW & MRW cloud data storage<br>• Acquired Identity Access & Management (IAM) credentials from BDP<br>• SRW cloud data storage contains data supporting cases unique to SRW 2.0 Release |
| ***Cloud Data Transferring*** | **Utilization of Multi-Thread Uploader program to continue transfer of UFS-WM RT data to cloud**<br>• Partitioned large files into chunks to assist in improving upload performance to cloud storage.<br>• Successfully transferred UFS-WM RT datasets to cloud storage<br>**Creation of Multi-Thread Uploader program to transfer SRW data to cloud**<br>• Partitioned large files into chunks to assist in improving upload performance to cloud storage.<br>• Successfully transferred SRW datasets to cloud storage & up-to-date |
| ***Data Management Support*** | **Utilization of Data Tracker Bot program to continue UFS-WM data management support.**<br>• Detects & records timestamp datasets being pushed to the developing UFS-WM repository<br>• Ensures UFS-WM cloud data storage is up-to-date |
| ***Data Log Visuals*** | **Creation of UFS-WM RT Log Extraction application which extracts, parses, & converts UFS-WM logs into visuals.**<br>• Application parses, extracts, summarizes, & displays metrics from UFS-WM RT logs into plot figures. |

**EPIC POC: Sylvia Chin**

# Cloud Data Management, cont'd

***Data Mapping for Data Ingestion Support***

- Maps will allow users to distinguish between data files required for a given UFS application-to-physics suite build, UFS component, & regression test.
- Maps categorize & detail each UFS data files into their associated …

| UFS Application-to-Physics Suite Build |
|---|
| Regression Test |
| UFS Component |
| Data File Format |
| Test Type |
| Resolution (if applicable) |

| Data File Type |
|---|
| Coupled (if applicable) |
| Applicable Compiler |
| File Size |
| Hierarchical Nodes Relative to Root Location |
| File Source Location |

- Maps will also allow users to distinguish between UFS RT configuration files & test parameters required for a given UFS application-to-physics suite builds' regression test.

***Data Analytics & Data Maintenance***

- Perform feature extraction (parse, extract & preprocess the UFS data filenames), feature engineering, & exploratory data analysis against the UFS datasets
- Provides details regarding the UFS input and baseline datasets
- Can continue to assist NOAA in the cleaning of current data structure.

**EPIC POC: Sylvia Chin**

# UFS Data Buckets

**On AWS, work in progress to deploy and stage data across all CSPs.**

| Cloud Data Storage Information: UFS-WM RT Datasets | |
|---|---|
| **Description** | Unified Forecast System Weather Model (UFS-WM) Regression Tests Data |
| **Resource Type** | S3 Bucket |
| **Amazon Resource Name (ARN)** | noaa-ufs-regtests-pds |
| **AWS Region** | us-east-1 |
| **AWS URL** | https://noaa-ufs-regtests-pds.s3.amazonaws.com/index.html |

| Cloud Data Storage Information: SRW Datasets | |
|---|---|
| **Description** | Unified Forecast System Short-Range Weather (UFS SRW) Application Data |
| **Resource Type** | S3 Bucket |
| **Amazon Resource Name (ARN)** | noaa-ufs-srw-pds |
| **AWS Region** | us-east-1 |
| **AWS URL** | https://noaa-ufs-srw-pds.s3.amazonaws.com/index.html |

| Cloud Data Storage Information: MRW Datasets | |
|---|---|
| **Description** | Unified Forecast System Medium-Range Weather (UFS MRW) Application data |
| **Resource Type** | S3 Bucket |
| **Amazon Resource Name (ARN)** | noaa-ufs-mrw-pds |
| **AWS Region** | us-east-1 |
| **AWS URL** | https://noaa-ufs-mrw-pds.s3.amazonaws.com/index.html |

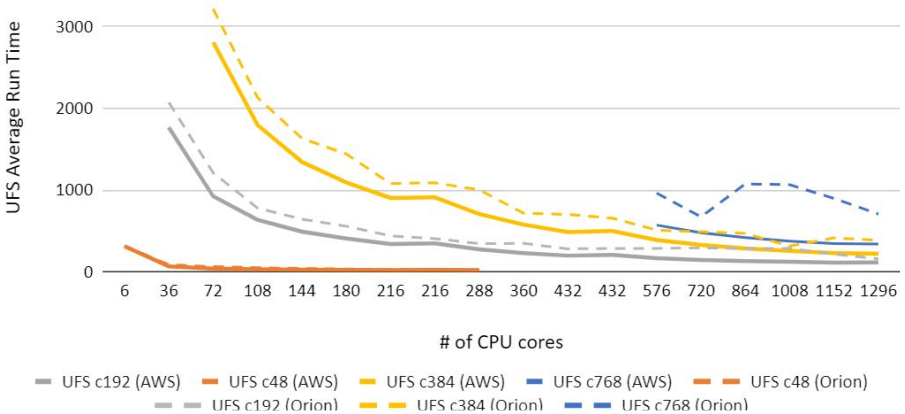
**EPIC POC: Sylvia Chin, Keven Blackman**

# Performance & Scalability

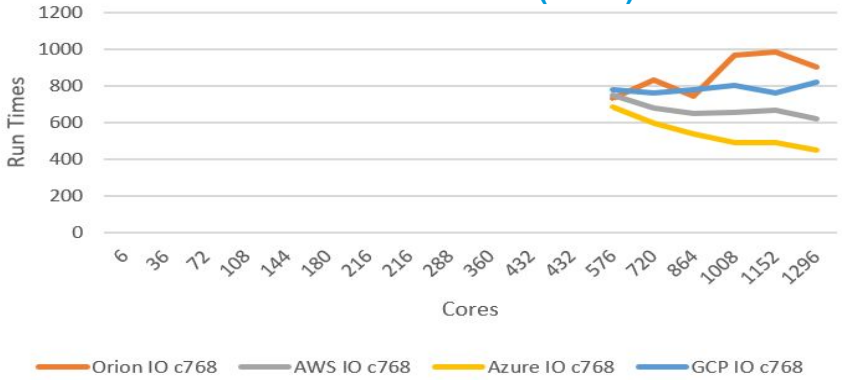
- Benchmark tests for the UFS-WM were performed on Cloud Platforms: AWS, Azure GCP and on-premise systems: Orion; with Intel and GNU compilers and at the typical model resolutions;
- The model performance and scalability on all the cloud platforms were similar;
- Computational performance on cloud platforms is comparable to or sometimes outperforms that on on-premise systems.

**EPIC POC: Luke Peffers and Zachary Shrader**

## Change of average runtime with cores
### AWS vs. Orion




## CSPs vs. Orion (c768)

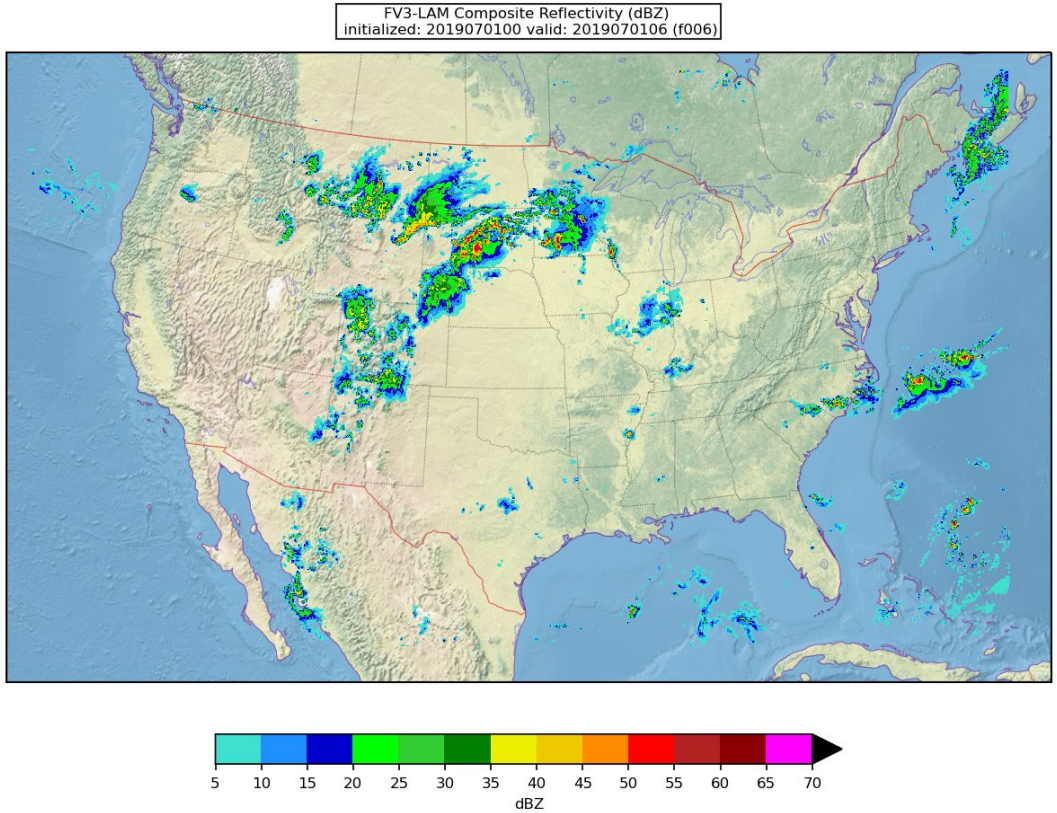


# UFS SRW Releases

- SRW2.0 Released in June of 2022, with a Singularity based SRW Container that runs on a single node.
- Upcoming v2.1 release scheduled on November 16, 2022.
  - A scalable container that can be run across multiple HPC nodes has been developed for running the SRW workflow using Rocoto inside the container
  - Getting ready for a RRFS-on-cloud release

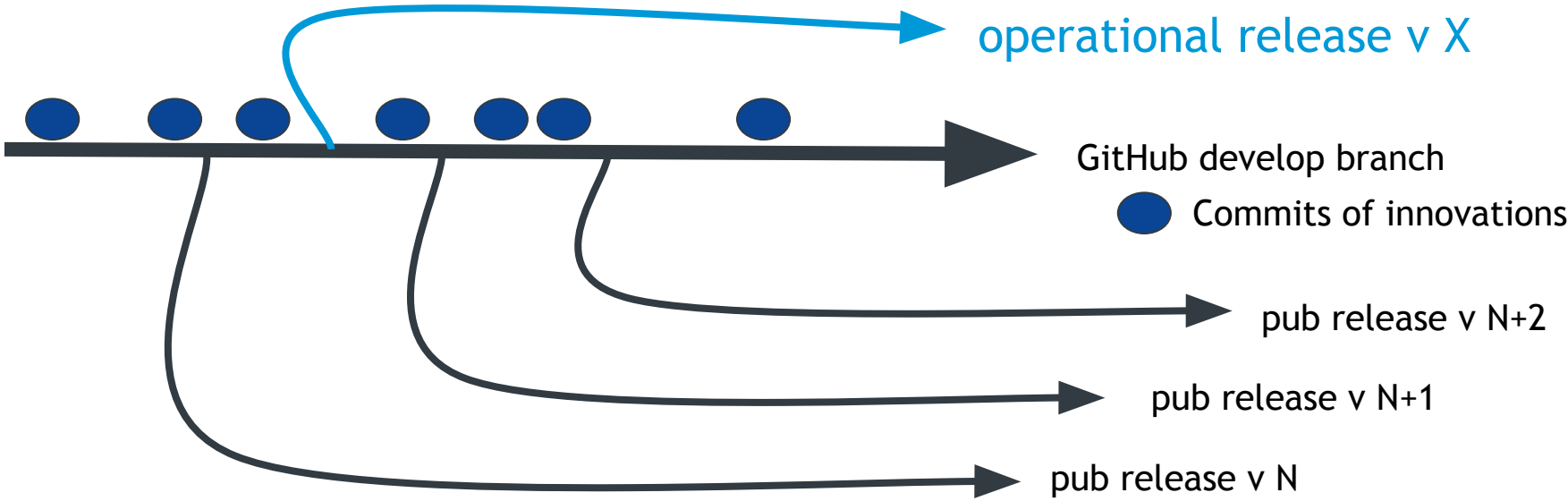
**Contributors**

- NOAA: EMC, EPIC, GSL
- DTC
- CIRES
- NCAR




**EPIC POC: Mark Potts**

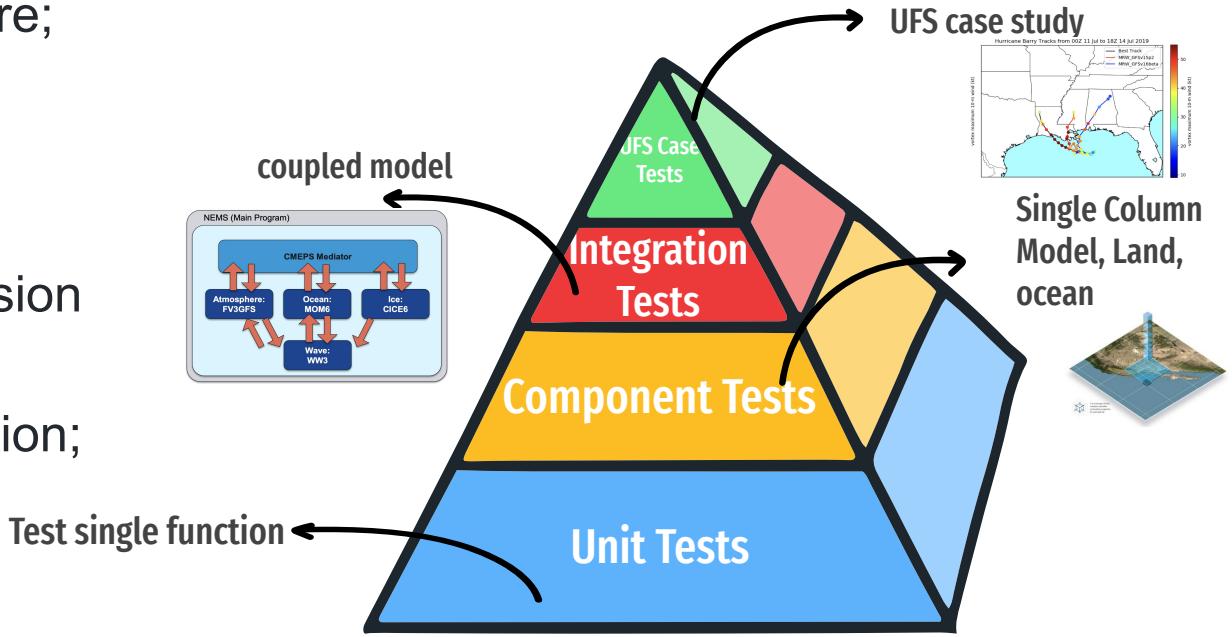
# UFS Releases Based on a Common Code Base




**Courtesy of UFS Release Coordination WG (POC: Ligia Bernardet and Mark Potts)**

# UFS Hierarchical Testing Framework (HTF)

- A common infrastructure;
- Simple-to-complex;
- Optimized testing
- Scientific case study;
- Evidenced-based decision making;
- Accelerate R2O transition;
- user-friendly and well-documented




**EPIC POC:** Yi-Cheng Teng and Stylianos Flampouris

# UFS Hierarchical Testing Framework (HTF), cont'ed

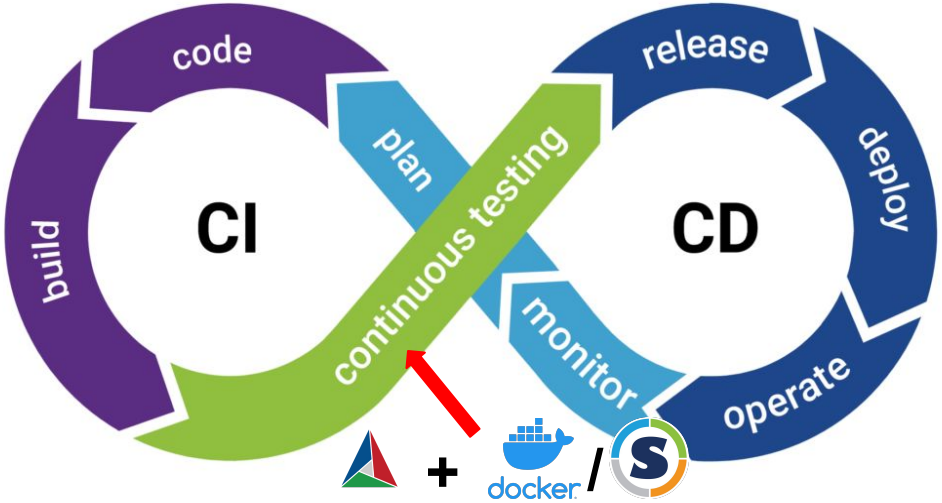
**EPIC is developing a testing infrastructure based on Ctest and container technology**

## Pros of CTest:

- Ctest is the CMake test driver;
- Easy to add new tests in Ctest;
- Has potential to integrate with JEDI DA Ctest framework directly.

## Pros of Container:

- Portability;
- No need worry about library dependencies;
- Ensure bitwise identical results, regardless of different computing systems.



# UFS HTF examples

## UFS-case Test (Scientific evaluation):

```
    Start 1: ocn_unit_test
1/4 Test #1: ocn_unit_test ...................   Passed    0.76 sec
    Start 2: ocn_scm_test
2/4 Test #2: ocn_scm_test ....................   Passed   11.37 sec
    Start 3: datm_ocn_test
3/4 Test #3: datm_ocn_test ...................   Passed  251.14 sec
```

```
    Start 1: ocn_unit_test
1/4 Test #1: ocn_unit_test ....................   Passed    0.75 sec
    Start 2: ocn_scm_test
2/4 Test #2: ocn_scm_test .....................   Passed   11.09 sec
    Start 3: datm_ocn_test
3/4 Test #3: datm_ocn_test ....................   Passed  248.82 sec
    Start 4: ufs_case_test
4/4 Test #4: ufs_case_test ....................   Passed  370.78 sec

100% tests passed, 0 tests failed out of 4
```

```
    Start 4: ufs_case_test
Failed test dependencies: datm_ocn_te
4/4 Test #4: ufs_case_test ..........

0% tests passed, 4 tests failed out o

Total Test time (real) =   0.76 sec

The following tests FAILED:
          1 - ocn_unit_test (Failed)
          2 - ocn_scm_test (Not Run)
          3 - datm_ocn_test (Not Run)
          4 - ufs_case_test (Not Run)
Errors while running CTest
```

```
Total Test time (real) =  12.20 sec

The following tests FAILED:
          2 - ocn_scm_test (Failed)
          3 - datm_ocn_test (Not Run)
          4 - ufs_case_test (Not Run)
Errors while running CTest
```

# Prototype of UFS HTF (2019 Hurricane Barry, ufs-case-study, DTC)

**Prototype HTF repo for UFS short-range weather Application**

Build htf passing

## Build HTF test for the UFS Short-Range Weather App

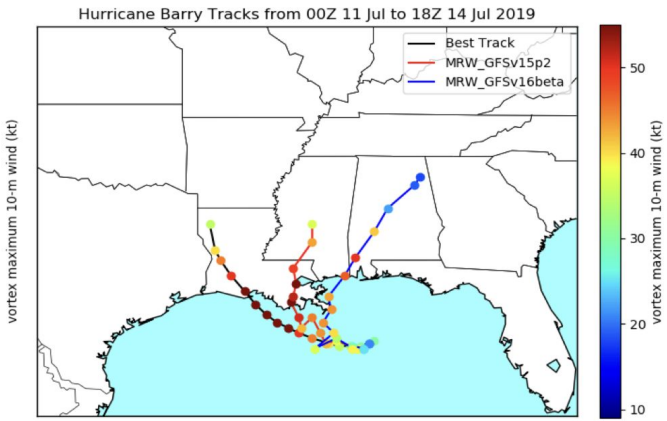
### ctest (for Hierarchical Testing Framework, HTF)

Currently, the following configurations are supported/tested:

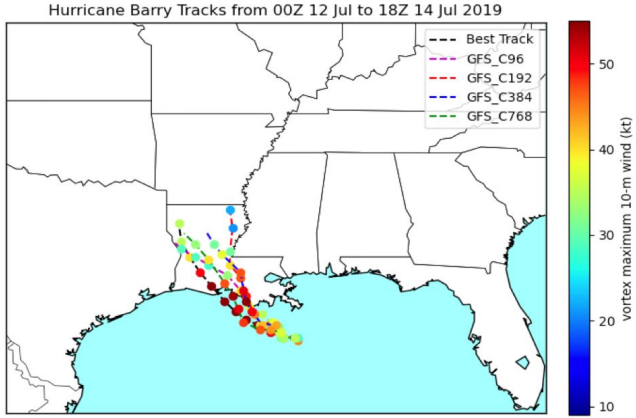
| Machine | Orion | NOAA Cloud (AWS & GCPv2) |
|---|---|---|
| Compiler(s) | Intel, GNU | Intel |

**Ctest + containerized test case**

```
[Yi-cheng.Teng@awsnoaa-1 test]$ ctest
Test project /lustre/ufs-srweather-app/build/test
    Start 1: test_ccpp_scm_fv3
1/5 Test #1: test_ccpp_scm_fv3 ................   Passed    6.78 sec
    Start 2: test_fv3_regional_noquilt
2/5 Test #2: test_fv3_regional_noquilt ........   Passed   74.70 sec
    Start 3: test_fv3_regional_upp
3/5 Test #3: test_fv3_regional_upp ............   Passed   70.53 sec
    Start 4: test_fv3_regional_stoch
4/5 Test #4: test_fv3_regional_stoch ..........   Passed   72.39 sec
    Start 5: test_regional_workflow
5/5 Test #5: test_regional_workflow ...........   Passed  856.20 sec

100% tests passed, 0 tests failed out of 5

Total Test time (real) = 1080.64 sec
```



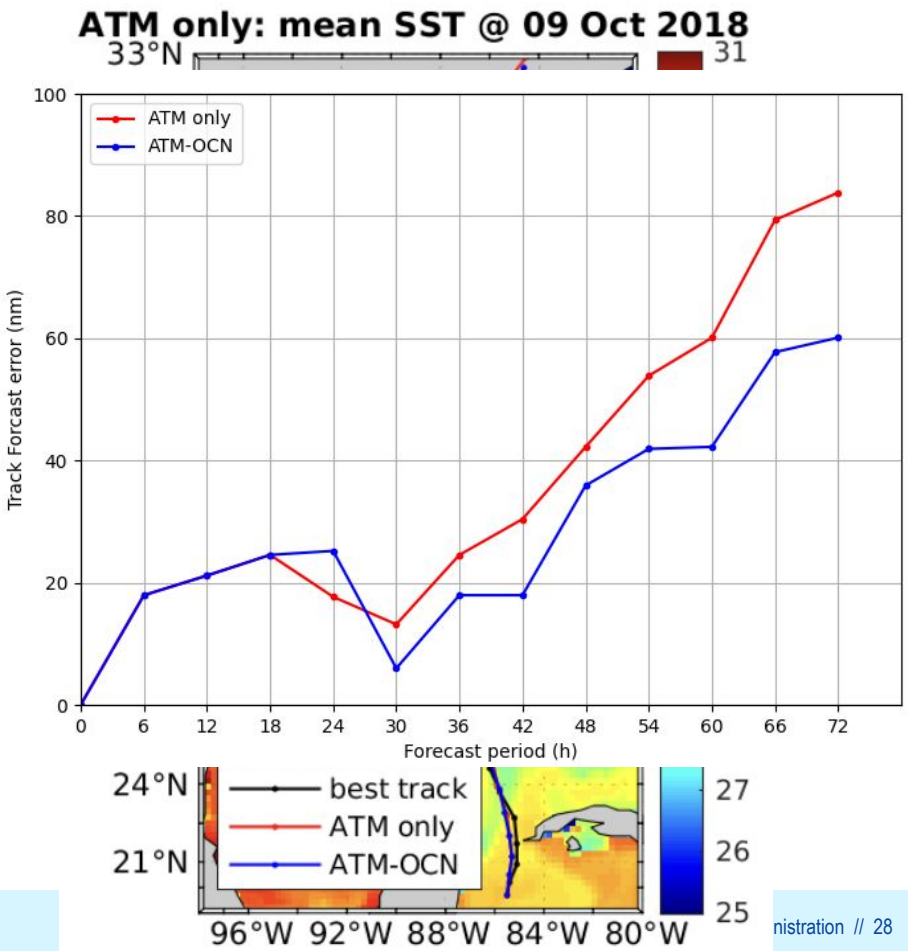

**2019 Barry with different CCPP Physics Parameterizations**




**2019 Barry with different grid resolutions**

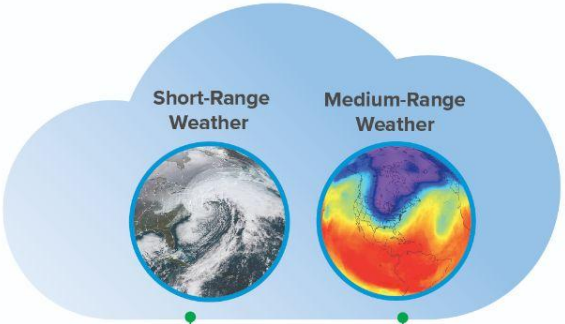
# Prototype UFS HTF for coupled model (2018 Hurricane Michael, ufs-case-study, DTC)

```
Test project /work/noaa/epic-ps/ycteng/case/20220828/ufs-htf/build/test
    Start 1: build_ufs
1/9 Test #1: build_ufs ..........................   Passed  907.80 sec
    Start 2: get_ufs_fix_data
2/9 Test #2: get_ufs_fix_data ...................   Passed    0.08 sec
    Start 3: ATM_c96_Michael
3/9 Test #3: ATM_c96_Michael ....................   Passed  1226.49 sec
    Start 4: S2S_c96_Michael
4/9 Test #4: S2S_c96_Michael ....................   Passed  1273.41 sec
    Start 5: S2SW_c96_Michael
5/9 Test #5: S2SW_c96_Michael ...................   Passed  1329.12 sec
    Start 6: S2SWA_c96_Michael
6/9 Test #6: S2SWA_c96_Michael ..................   Passed  1771.19 sec
    Start 7: Plot_track_err
7/9 Test #7: Plot_track_err .....................   Passed   28.91 sec
    Start 8: model_vrfy
8/9 Test #8: model_vrfy .........................   Passed   66.50 sec
    Start 9: fcst_only_S2S_c96_Michael
9/9 Test #9: fcst_only_S2S_c96_Michael ..........   Passed  821.40 sec

100% tests passed, 0 tests failed out of 9

Total Test time (real) = 7424.93 sec
```



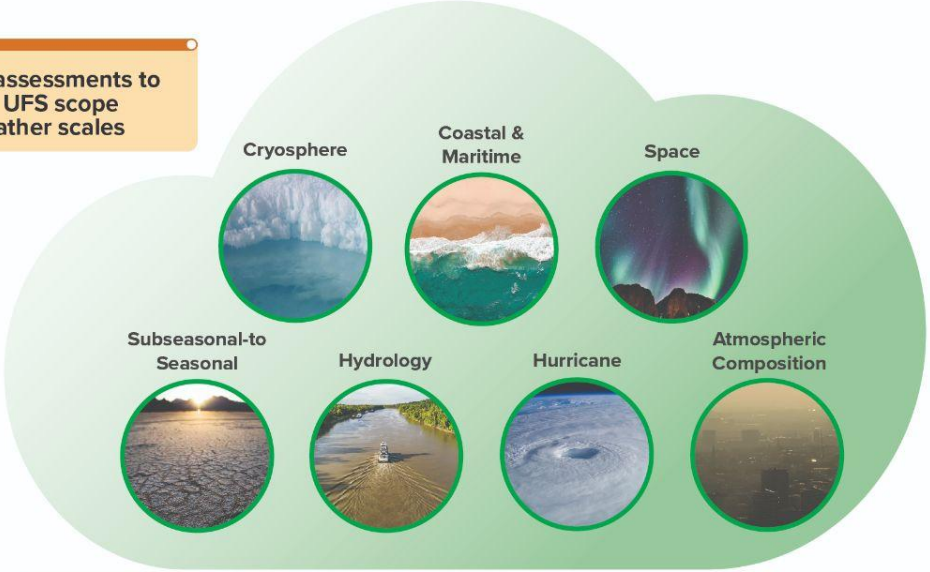
# UFS Model and Infrastructure Ports to Cloud Service Providers

## User Support and Community Engagement to Accelerate Innovation




Plan scope of work for product/code integrations

Additional assessments to expand the UFS scope beyond weather scales




Build cloud-based community modeling infrastructure

Build EPIC Community Portal

Continued development of community modeling infrastructure

Adapt modeling portal as new modeling developments are implemented

Provide continuous community engagement and user support

ONGOING

FUTURE WORK

# Thank you!

**Contact: epic.wpo@noaa.gov**
**maoyi.huang@noaa.gov**