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

HFIP Annual Meeting, 9 November 2022, Miami, FL

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# Acknowledgement

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- Maoyi Huang
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- Chris Domanti
- Farida Adimi
- Luke Peffers
- Keven Blackman
- Fredrick Gabelmann

## Platform Team
- Stylianos Flampouris
- Cam Sherrell
- Boris Acha
- Sylvia Chin
- Zach Shrader
- Jesse McFarland
- Jose Guttierez
- Marcus Delponte
- Leron Thomas
- Michael Lueken

## Advanced User Support Team
- Yi-Cheng Teng
- Jong Kim
- Jim Abeles
- Rhae Sung Kim

## Community Engagement Team
- Mark Potts
- Lauren Frederick
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- Mandy Parson
- Jamiel Farhat
- Jessica Wheeler
- Amber Jenkins
- Ben Brinkley
- Charlene Barone
- Laura Generosa
- Randii Oliver
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Hurricane Sandy (2012) Raises Public Awareness of Modeling…

How a trusted weather model fumbled the forecast for Hurricane Ian

Left-of-Track Bias in Global Models

Cycles are colored by initialization time: Lighter (Darker) colors are Older (Newer)
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

21 Independent Stand-alone Systems
- Global Weather, Waves & Global Analysis - GFS/ GDAS
- Global Weather and Wave Ensembles, Aerosols - GEFS
- Short-Range Regional Ensembles - SREF
- Global Ocean & Sea-Ice - RTOFS
- Global Ocean Analysis - GODAS
- Seasonal Climate - CDAS/ CFS
- Regional Hurricane 1 - HWRF
- Regional Hurricane 2 - HMON
- Regional High Resolution CAM 1 - HiRes Window
- Regional High Resolution CAM 2 - NAM nests/ Fire Wx
- Regional High Resolution CAM 3 - RAPv5/ HRRR
- Regional HiRes CAM Ensemble - HREF
- Regional Mesoscale Weather - NAM
- Regional Air Quality - AQM
- Regional Surface Weather Analysis - RTMA/ URMA
- Atmospheric Transport & Dispersion - HySPLIT
- Coastal & Regional Waves - NWPS
- Great Lakes - GLWU
- Regional Hydrology - NWM
- Space Weather 1 - WAM/IPE
- Space Weather 2 - ENLIL

Unified Forecast System (UFS)

UFS Applications
- Medium Range & Subseasonal
- Marine & Cryosphere
- Seasonal
- Hurricane
- Short-Range Regional HiRes CAM & Regional Air Quality
- Air Quality & Dispersion
- Coastal
- Lakes
- Hydrology
- Space Weather

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

Cloud Use

Vision: Enable the most accurate and reliable operational numerical forecast model in the world.
EPIC Innovation Flow
Creating an Environment for Co-development and Inclusion

INNOVATION PROCESS
Through User Support

User Forums
Code Repository
Documentation

Building a Community
Creating the next generation of scientists
Supporting agencies' environmental modeling mission needs
Protecting life and property
Bolstering the economy and industry

Bringing greater alignment between NOAA, academia, private industry, and research centers

Uccellini et al., BAMS, 2022
EPIC Program Budget

- **Fiscal Year (FY):** FY21, FY22
- **Budget Components:** Software Infrastructure, JEDI, JEDI-UFS, NCAR MOA, EPIC Contract
- **Dollars (x $1MM):**
  - FY21:
    - Software Infrastructure: 0.6
    - JEDI: 6.5
    - JEDI-UFS: 0.9
    - NCAR MOA: 1.6
    - EPIC Contract: 7.0
  - FY22:
    - Software Infrastructure: 0.9
    - JEDI: 1.6
    - JEDI-UFS: 1.6
    - NCAR MOA: 1.6
    - EPIC Contract: 0.9

**Legend:**
- IIJA
- SUPPLEMENTAL
Timeline and Accomplishments

**EPIC program established under OWAQ (now WPO)**
- 2019: Release EPIC Vision Paper
- 2019: Host first EPIC Community Workshop
- 2019: Release EPIC Industry Day and Vendor Meetings
- 2019: Host EPIC Industry Day and Vendor Meetings
- 2019: Fund UFS Community Modeling Support Project (w/ JTTI)
- 2019: Release UFS Medium Range System v1.0 to Github
- 2020: Release EPIC Strategic Plan
- 2020: Release EPIC Community Workshop Report
- 2020: Align EPIC and JCSDA under same budget line item
- 2020: Award the RFP Contract to Raytheon Intelligence & Space
- 2020: Support and release JCSDA-JEDI Tools and Software
- 2020: Implement Scaled Agile, completed two program increments
- 2020: Release Final EPIC Strategic Plan
- 2021: Host EPIC Symposium at the AMS
- 2021: EPIC Short course, code sprint, and Hackathon
- 2021: Release UFS Short Range System v1.0 to Github
- 2021: Release UFS Short Range System v2.0
- 2021: WPO FY23 Innovation Competition
- 2021: UIFCW workshop
- 2021: Release EPIC Community Portal website (epic.noaa.gov)
- 2022: Support and release JCSDA-JEDI Tools and Software
- 2022: Implement Scaled Agile, completed two program increments
- 2022: Release EPIC Community Portal website (epic.noaa.gov)
- 2022: EPIC Short course, code sprint, and Hackathon
- 2022: Release UFS Short Range System v1.0 to Github
- 2022: WPO FY23 Innovation Competition
- 2022: UIFCW workshop
- 2022: WINGS Dissertation Fellowship
UFS Governance and Process

Community
Academia (research & teaching), industry, individuals, gov labs?

Innovations, new obs, etc.

Real-time Observations (BDP/data lake)

Community governance needed (CMB)

Community input on criteria (WG/SC)

NOAA-centric governance (board?)

R2O “Funnel”

Stage
Gate

Stage
Gate

Stage
Gate

R2O Project

operational code

ECM

operational code

NCO

EPIC

releases

more research

research code

more work

operational code

Code

more research

GitHub

 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

<table>
<thead>
<tr>
<th>Platform</th>
<th>Examples</th>
<th>Libraries</th>
<th>Model tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloud</td>
<td>AWS, Azure, GCP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Container</td>
<td>Docker</td>
<td>Prebuilt</td>
<td>Full</td>
</tr>
<tr>
<td>Pre-configured</td>
<td>RDHPC, Cheyenne (NCAR)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Configurable</td>
<td>Stampede, Odin</td>
<td>User builds</td>
<td></td>
</tr>
<tr>
<td>Limited Test</td>
<td>Mac or Linux box</td>
<td></td>
<td>Limited</td>
</tr>
<tr>
<td>Build Only</td>
<td>None</td>
<td></td>
<td>None</td>
</tr>
</tbody>
</table>

Laptop, cluster, HPC, cloud needed to serve needs of operations, academia, industry
# Cloud Data Management

<table>
<thead>
<tr>
<th>Cloud Data Storage</th>
<th>Cloud Data Storages Established for UFS Weather Model (UFS-WM) Regression Test (RT) datasets, SRW Application &amp; Medium-Range Weather (MRW) Application datasets</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Established requirements &amp; setup for SRW &amp; MRW cloud data storage</td>
</tr>
<tr>
<td></td>
<td>Acquired Identity Access &amp; Management (IAM) credentials from BDP</td>
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<tr>
<td></td>
<td>SRW cloud data storage contains data supporting cases unique to SRW 2.0 Release</td>
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<thead>
<tr>
<th>Cloud Data Transferring</th>
<th>Utilization of Multi-Thread Uploader program to continue transfer of UFS-WM RT data to cloud</th>
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<tbody>
<tr>
<td></td>
<td>Partitioned large files into chunks to assist in improving upload performance to cloud storage.</td>
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<tr>
<td></td>
<td>Successfully transferred UFS-WM RT datasets to cloud storage</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Data Management Support</th>
<th>Utilization of Data Tracker Bot program to continue UFS-WM data management support.</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Detects &amp; records timestamp datasets being pushed to the developing UFS-WM repository</td>
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<tr>
<td></td>
<td>Ensures UFS-WM cloud data storage is up-to-date</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Data Log Visuals</th>
<th>Creation of UFS-WM RT Log Extraction application which extracts, parses, &amp; converts UFS-WM logs into visuals.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Application parses, extracts, summarizes, &amp; displays metrics from UFS-WM RT logs into plot figures.</td>
</tr>
</tbody>
</table>

**EPIC POC: Sylvia Chin**
Cloud Data Management, cont'd

<table>
<thead>
<tr>
<th>Data Mapping for Data Ingestion Support</th>
</tr>
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<tbody>
<tr>
<td>• Maps will allow users to distinguish between data files required for a given UFS application-to-physics suite build, UFS component, &amp; regression test.</td>
</tr>
<tr>
<td>• Maps categorize &amp; detail each UFS data files into their associated …</td>
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</table>

<table>
<thead>
<tr>
<th>Data Analytics &amp; Data Maintenance</th>
</tr>
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<tbody>
<tr>
<td>• Perform feature extraction (parse, extract &amp; preprocess the UFS data filenames), feature engineering, &amp; exploratory data analysis against the UFS datasets</td>
</tr>
<tr>
<td>• Provides details regarding the UFS input and baseline datasets</td>
</tr>
<tr>
<td>• Can continue to assist NOAA in the cleaning of current data structure.</td>
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</tbody>
</table>

EPIC POC: Sylvia Chin
UFS Data Buckets

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

<table>
<thead>
<tr>
<th>Cloud Data Storage Information: UFS-WM RT Datasets</th>
<th>Cloud Data Storage Information: SRW Datasets</th>
<th>Cloud Data Storage Information: MRW Datasets</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description</strong></td>
<td>Unified Forecast System Weather Model (UFS-WM) Regression Tests Data</td>
<td>Unified Forecast System Short-Range Weather (UFS SRW) Application Data</td>
</tr>
<tr>
<td><strong>Resource Type</strong></td>
<td>S3 Bucket</td>
<td>S3 Bucket</td>
</tr>
<tr>
<td><strong>Amazon Resource Name (ARN)</strong></td>
<td>noaa-ufs-regtests-pds</td>
<td>noaa-ufs-srw-pds</td>
</tr>
<tr>
<td><strong>AWS Region</strong></td>
<td>us-east-1</td>
<td>us-east-1</td>
</tr>
</tbody>
</table>

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
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

#### Unit Test:
- **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]

#### Component Test:
- **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]

#### Integration Test:
- **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]

### UFS-case Test (Scientific evaluation):  

<table>
<thead>
<tr>
<th>Test</th>
<th>Description</th>
<th>Status</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/4</td>
<td>Test #1: ocn_unit_test</td>
<td>Passed</td>
<td>0.75 sec</td>
</tr>
<tr>
<td>2/4</td>
<td>Test #2: ocn_scm_test</td>
<td>Passed</td>
<td>11.09 sec</td>
</tr>
<tr>
<td>3/4</td>
<td>Test #3: datm_ocn_test</td>
<td>Passed</td>
<td>248.82 sec</td>
</tr>
<tr>
<td>4/4</td>
<td>Test #4: ufs_case_test</td>
<td>Passed</td>
<td>370.78 sec</td>
</tr>
</tbody>
</table>

- **Total Test time (real):** 12.20 sec
- **0%** tests passed, 0 tests failed out of 4

The following tests **FAILED**:
1. ocn_unit_test (Failed)
2. ocn_scm_test (Failed)
3. datm_ocn_test (Not Run)
4. ufs_case_test (Not Run)
Prototype of UFS HTF (2019 Hurricane Barry, ufs-case-study, DTC)

Prototype HTF repo for UFS short-range weather Application

Build HTF test for the UFS Short-Range Weather App

cctest (for Hierarchical Testing Framework, HTF)

Currently, the following configurations are supported/tested:

<table>
<thead>
<tr>
<th>Machine</th>
<th>Orion</th>
<th>NOAA Cloud (AWS &amp; GCPv2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Intel, GNU</td>
<td>Intel</td>
</tr>
</tbody>
</table>

Ctest + containerized test case

[Yi-cheng.Teng@awsnoaa-1 test] $ cctest
Test project /lustre/ufs-srweather-app/build/test
1/5 Test #1: test_ccpp_scn_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) = 10080.64 sec
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 907.00 sec
- **Start 2:** get_ufs_fix_data

- **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

- **Short-Range Weather**
- **Medium-Range Weather**

Additional assessments to expand the UFS scope beyond weather scales

- **Cryosphere**
- **Coastal & Maritime**
- **Space**
- **Subseasonal-to Seasonal**
- **Hydrology**
- **Hurricane**
- **Atmospheric Composition**

- **Plan scope of work for product/code integrations**
- **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