The state of the UFS July 2024

POCs Hendrik L. Tolman (UFS) and Maoyi Huang (EPIC)
Hendrik.Tolman@NOAA.gov and Maoyi.Huang@NOAA.gov
NOAA / NWS / Office of Science and Technology Integration and NOAA / OAR / Weather Program Office

The Unified Forecast System (UFS)

The Unified Forecast System (UFS) is software stack of community-supported component environmental models and (coupling) tools that are intended for use in both operations and research at NOAA and by a broader community. Many of the tools have been developed in collaboration with NCAR. Note that the UFS is different from unitary modeling systems such as the IFS of the European Center for Medium range Weather Forecasting or the UM of the UK MetOffice, who allow only one model per type in the table below. The UFS allows for multiple component models as needed to cover both operational and research mission needs. The table below shows presents the software stack on July 15, 2024.

Type	Model	Description	Open source	Open Science	Com strength	License	Originates from	Governance
			rate 1 (low) to 5 (high)					
Infrastructure	ESMF	Earth System Modeling Framework.	5	3	5	https://github.com/esmf-org/esmf/blob/develop/LICENSE	https://earthsystemmodeling.org/organization/	https://earthsystemmodeling.org/organization/
	NUOPC	"Dictionary" to uniformly implement NUOPC	5	3	4	N/A	Started as grass-roots effort by NOAA / NRL / USACE supporting waves / coastal / ocean modeling.	This effectively becomes a "cap" on each component model, governed by its community.
	CMEPS / CDEPS	Coupler / mediator for ESMF - NUOPC coupling	5	4	4	Unknown	CMEPS is associated with NOAA-NCAR MOA 2019-2023. DMEPS is an NCAR extension.	Was joined NOAA/NCAR through the 2019-2023 MOA. MOA is being re-negotiated.
	CCPP	Unified infrastructure for physics in atmospheric models. Includes physics options.	5	4	5	Apache License, Version 2.0	Joining previous EMC and NCAR efforts under MOA.	Team governance, not formalized.
	METplus	Model Evaluation Tools	5	3	5	https://dtcenter.org/community-code/metplus/terms-use	https://dtcenter.org/community-code/metplus	METplus Advisory Board.
	UPP	Unified Post Processor	5	3	5	https://github.com/NOAA-EMC/UPP/blob/develop/LICENSE.md	https://epic.noaa.gov/unified-post-processor/	Mainly EMC
	NCEP libs / Spack Stack	There about 20+ libraries that comprise NCEP libs.	5	2	2	GNU Lesser General Public License v3.0	NCEP	Mainly EMC
	UFS Workflow	There is no single UFS workflow yet.	1	1	1		Developing a library of workflow modules rather than a single workflow.	
DA	JEDI	Joint Effort for Data Assimilation Integration, community Data Assimilation Effort	4	2	4	Apache License, Version 2.0	Joint Center for Satellite Data Assimilation (JCSDA, intergovernmental collaboration)	JSCDA
Atmosphere	FV3	Finite Volume Cubed Sphere atmospheric dynamic core	5	3	3	GNU Lesser General Public License	GFDL (as full mdel)	GFDL
	MPAS	The Model for Prediction Across Scales	5	3	3	https://github.com/MPAS-Dev/MPAS-Model/blob/master/LICENSE	Los Alamos National Laboratory (COSIM) and the National Center for Atmospheric Research.	NCAR has primary responsibility for the atmospheric model.
	CCPP	See infrastrucure section	5	4	5	Apache License, Version 2.0	See infrastrucure section	See infrastrucure section
Ocean / Coasta	HYCOM	Hybid Coordinate Ocean Model	4	3	3	MIT license	Nation Oceanographic Partnership PRogram project between NAvy and NOAA.	Developed in collaboratiopn with NRL and broader comunity.
	MOM6	Modular Ocean Model 6	5	5	5	GNU Lesser General Public License	GFDL	Lead by GFDL
	ADCIRC	Finite elemt depth-Integrated storm surge model	5	5	5	GNU LGPL	UNC Chapel Hill Institute of Marine Sciences and UND Dept of Civil Engineering and Geological Sciences	See https://github.com/adcirc/adcirc, https://adcirc.org/, and https://wiki.adcirc.org/Main_Page
	SLOSH	A 2-D explicit, finite-differencing storm surge model	3	1	2	Private GitHub repository with custom license	NWS/OSTI/MDL/Decision Support Division	Code maintained at MDL and computational grids developed at NHC and MDL.
	ROMS	The Regional Ocean Modeling System (ROMS) i	5	5	5	MIT License	Rutgers University, University of California Los Angeles and contributors worldwide.	See https://en.wikipedia.org/wiki/Regional_Ocean_Modeling_System_
	FVCOM	The Finite Volume Community Ocean Modeling System (FVCOM).	4	5	4	MIT/X	University of Massachusetts Dartmouth and Woods Hole Oceanographic Institution.	See http://fvcom.smast.umassd.edu/wiki/index.php/About_
	SCHISM	SCHISM (Semi-implicit Cross-scale Hydroscience Integrated System Model)	5	5	5	Apache-2.0	SCHISM modeling system is a derivative work from the original SELFE model (v3.1dc as of Dec. 13 , 2014).	See https://ccrm.vims.edu/schismweb/
Hydro	NWM	National Water Model (NWM)	2	2	2	Terms and Conditions	WRF-Hydro is research code developed by NCAR. The NWM is an operational configuration of WRF-Hydro.	N/A
	NextGen	The Next Generation Water Resources Modeling Framework (NextGen)	5	5	3	Under Revision (current license linked)	Original development by the Office of Water Prediction beginning in February 2020	TBD, see https://github.com/NOAA-OWP
Sea Ice	CICE	Sea ilce Model	5	5	5		CICE started as a proprietary DOE model.	There is a formal governance with oversight, working with a community of the willing.
	MOM6	Optional ice model closely embedded in MOM6 ocean model.	5	5	5		See MOM6 ocean model.	See MOM6 ocean model.
Wind Waves	WAVEWATCH III	Wind wave modeling framework	5	5	5	GNU LGPL v3. 29	NOAA/NWS (Delft University fo Technology, GSFC)	Informal devepment group that started with a NOPP project.
	SWAN	Simlating Waves Nearshore	5	3	5	GNU GPL	Delft University of Technology	DUT manages official code.
Land	Noah-MP	Noah-MP (multiple parameterization) land surface model	5	5	4	https://github.com/NCAR/noahmp?tab=License-1-ov-file#readme	NCAR	Noah-MP Strategic Planning Committee.
	LM4	GFDL Land Model v4				GNU license	GFDL	https://github.com/ufs-community/ufs-weather-model/pull/2146
Atmospheric composition and air quality	GOCART	Atmospheric aerosols	5	4	4	Apache license (https://github.com/GEOS-ESM/GOCART/blob/main/LICENSE)	NASA Goddard	
	AQM	Air quality	5	4	5	MIT license (https://github.com/USEPA/CMAQ/blob/main/license.md)	EPA	For AQM see https://github.com/NOAA-EMC/AQM
	HYSPLIT	Atmospheric dispersion	2	3	3	N/A	NOAA OAR ARL	NOAA OAR ARL is the primary manager
Space Weather	WAM-IPE	Coupled Whole Atmosphere Model-Ionosphere Plasmasphere Electrodynamics Forecast System	5	4	2		WAM from EMC and SWPC, IPE from SWPC	SWPC is the primary repository manager (https://github.com/NOAA-SWPC)
	ENLIL	Solar wind and Coronal Mass Ejection propagation	1	1	1	No formal licensing in place	WSA from NASA Goddard Enlil from George Mason and CU CIRES	SWPC manages the operational fork of these two models

UFS powerd by EPIC

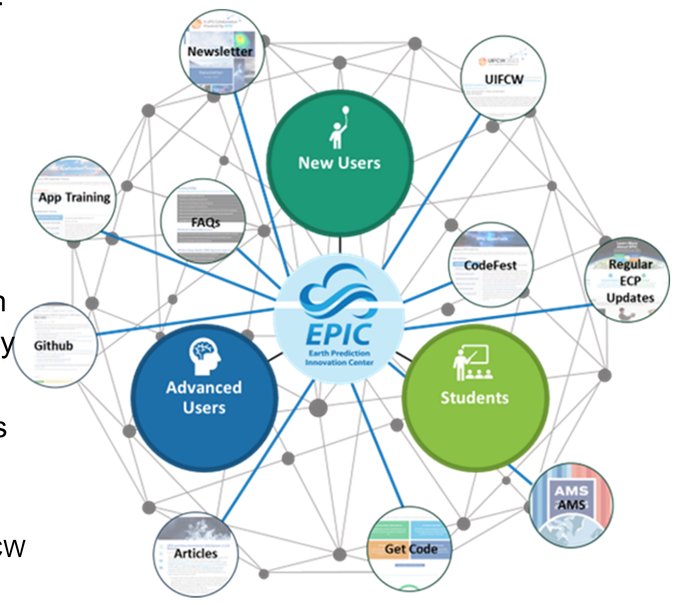
•Success Story: Academic Install was completed partnering George Mason University with EPIC. Students and professors can now build and run UFS applications on Frontera.
–We are partnering with other academic institutions with an important goal of making a universal academic set of install scripts to support a vast academia community.
•HPC Access has been a key concern to researchers getting access to resources to run numerical models. Our “Apache Packer” scripts allow you to build out the supported applications on non Tier-1 machines.

•The material being covered in tutorials, conference, and workshops is continuing to diversify as AI, DA, and RRFS capability are being supported by EPIC.

•Infrastructure: The team created the first open-source public CI/CD dashboards to bring transparency to the modeling community.

•Innovation: The Atmospheric River team completed the work for in-core data assimilation that is JEDI based. This capability is significantly faster than the legacy implementation.

•Community: The participation for EPIC tutorials and workshops continue to grow at a rate of 300% year over year.
–UIFCW Workshops in 2023 reached 50 participants. UIFCW 2024 has over 200 participants signed up.
–UIFCW is hosted by EPIC and has received over 500 participants working on differing aspects of community modeling across multiple sectors.



Big Picture UFS progress

Simplifying the production suite: reduce the complexity of the Production Suite, measured as the reduction in the number of major applications (baseline is 26 in 2016)
- 70% planned, 23% achieved

Building the community: reducing the cost of setting up GFS modeling system outside of the NOAA
- Was $15M+ for GFS, now 1 person 1 day on your computer
- NSF starting to support UFS (6 projects funded in 2023)

Improving Operations: Evidence driven, community teams
- Much larger teams supporting development

NOAA planning: 10 Year NOAA Modeling Strategy (UFS, JEDI) →

Glossary for Applications:
S2S: Subseasonal to Seasonal; GST: Graduate Student Test; MRW: Medium Range Weather; SRW: Short range Weather; UPP: Unified Post Processor; GFS: Global FS; GEFS: Global Ensemble FS; SFS: Seasonal FS; HAFS: Hurricane FS; RRFS: Rapid Refresh FS; NWPS: Nearshore Wave PS; GLWU: Great Lakes Waves; RTMA: Real Time Mesoscale Analysis; URMA: Unrestricted RMA; GODAS: Global Ocean DA System; SECOFS: Southeast Coast Operational FS; STOFS: Surge and Tide Operational FS; NECOFS: Northeast Coast Operational FS

UFS Applications

The software stack is used to build applications to fit operational and research missions. We make a distinction between

1. Applications released by EPIC
2. Applications in the NOAA Production Suite
3. R&D Applications

The number and corresponding color legend in the figure on the right are

-3	Use in Application still TBD	Dark Grey
-2	Not intended for use in App	Light Grey
-1	Other UFS component used	Yellow
0	Intended but not yet included	Red
1	Partially included	Light Green
2	Fully included	Dark Green

UFS Releases (Apps) | Production Suite | <------ "Rainbow diagram target end ------> | Prototypes + products outside of Productions Suite

Type	Model	S2S	MRW	SRW	(wm)	(wm)	Weather Model	Land DA		UPP		GFS	GEFS	SFS	HAFS	RRFS		Hysplit	NWPS	GLWU	ENLIL	RTMA	URMA	COASTAL ACT	Coupled Global System (UFS Weather Model)								GODAS reanalysis	3D RTMA	Hurricane Surge	SECOFS	ROMS RTs	STOFS-3D AK	STOFS-2D
		GST	1.0.0	1.0.0	2.0.0	2.1.0	2.2.0	1.1.0	1.2.0	2.1.0	2.2.0	v15	v16	v12	v1	v1	v1	v2		8.0.5	v1.4	v2		v3.0	v3.0		v1	v2	v3	v4	v5	v6	v7	v8	HR			v0	v0	v0	v0	
		2019	2020/03	2020/10	2021/03	2022/6	2022/11	2023/10	2023/05	2023/12	2022/05	2022/6	2019/06	2021/3	2020/09	TBD	2023/06	2025	20287	2022/12		2023/02		2025/06	2025/06	2019				2022	2022				mv8							
Infrastructure	ESMF	2	-2	-2	-2	-2	2	2	-2	-2	-2	-2	2	2	2	2	2	2	2	-2	-2	-2	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	NUOPC	2	-2	-2	-2	-2	2	2	-2	-2	-2	-2	2	2	2	2	2	2	2	-2	-2	-2	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	CMEPS / CDEPS	2	-2	-2	-2	-2	2	2	-2	-2	-2	-2	-2	1	0	2	2	-2	-3	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
	CCPP	2	2	2	2	2	2	2	-2	-2	-2	-2	1	2	0	2	2	2	2	-2	-2	-2	-2	2	2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
	METplus	0	0	0	0	2	2	2	0	0	-2	-2	0	1	0	2	0	2	2	-2	-2	-2	-2	2	2	-2	-2	-2	-2	-2	-2	-2	-2	0	2	-3	-3	-3	-3	-3
	UPP	0	2	2	2	2	2	2	0	0	2	2	2	2	2	2	2	2	2	-2	-2	-2	-2	2	2	-2	-2	-2	-2	-2	-2	-2	-2	-2	2	-3	-3	-3	-3	-3
	NCEP libs / Spack Stack	0	0	0	2	2	2	2	2	2	2	2	1	2	0	2	0	0	-3	-2	-2	-2	-2	0	0	-2	-2	-2	-2	-2	-2	-2	-2	-2	2	-3	-3	-3	-3	-3
	UFS Workflow	1	1	1	1	1	1	1	1	1	1	1	0	0	0	2	0	0	2	-2	1	1	-2	0	0	-2	-2	-2	-2	-2	-2	-2	-2	-2	2	-2	-2	-2	-2	-2
DA	JEDI	0	0	0	0	0	0	0	2	2	-2	-2	2	2	2	2	2	2	2	-2	-2	-2	-2	2	2	-2	-2	-2	-2	-2	-2	-2	-2	-2	2	-2	-2	-2	-2	-2
Atmosphere	FV3	2	2	2	2	2	2	2	-2	-2	-2	-2	2	2	2	2	2	2	2	-2	-2	-2	-2	2	2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
	MPAS	-1	-1	-1	-1	-1	-1	-1	-1	-1	-2	-2	-1	-1	0	2	-2	-2	-3	-2	-2	-2	-2	-1	-1	-2	-1	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
	CCPP	2	2	2	2	2	2	2	-2	-2	-2	-2	2	2	0	2	2	2	2	-2	-2	-2	-2	2	2	-2	-2	-2	-2	-2	-2	-2	-2	-2	2	-2	-2	-2	-2	-2
Ocean / Coasta	HYCOM	-1	-2	-2	-2	-2	-2	-2	2	2	-2	-2	0	0	0	-1	2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-1	-2	-2	-2	-2	-2	-2	-2	-2	-1	-1	-1	-1	-1
	MOM6	2	-2	-2	-2	-2	-2	-2	2	2	-2	-2	0	0	0	2	0	-2	-2	-2	-2	-2	-2	-2	-2	-2	-1	-2	-2	-2	-2	-2	-2	-2	-2	-1	-1	-1	-1	-1
	ADCIRC	-1	-2	-2	-2	-2	-2	-2	-1	-1	-2	-2	-3	-3	-2	-1	-3	-2	-2	-2	-3	-2	-2	-2	-2	2	-1	-1	-1	-1	-1	-1	-1	-1	-2	-2	-1	-1	-1	-1
	SLOSH	-1	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-1	-2	-2	-2	-2	-3	-2	-2	-2	-2	-1	-2	-2	-2	-2	-2	-2	-2	-2	-2	-1	-1	-1	-1	-1
	ROMS	-1	-2	-2	-2	-2	-2	-2	-1	-1	-2	-2	-2	-2	-2	-1	-2	-2	-2	-2	-3	-2	-2	-2	-2	-1	-2	-2	-2	-2	-2	-2	-2	-2	-2	-1	-1	2	-1	-1
	FVCOM	-1	-2	-2	-2	-2	-2	-2	-1	-1	-2	-2	-3	-3	-2	-1	-3	-2	-2	-2	-3	-2	-2	-2	-2	-1	-1	-1	-1	-1	-1	-1	-1	-1	-2	-1	-1	-1	-1	-1
	SCHISM	-1	-2	-2	-2	-2	-2	-2	-3	-3	-2	-2	-3	-3	-2	-1	-3	-2	-2	-2	-3	-2	-2	-2	-2	-1	-1	-1	-1	-1	-1	-1	-1	-1	-2	2	2	-1	2	-1
Hydro	NWM	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	0	-3	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	0	1	0	0	0
	NextGen	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	0	-3	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	0	0	0	0	0
Sea Ice	CICE	2	-2	-2	-2	-2	-2	-2	2	2	-2	-2	0	0	0	2	-2	-2	-2	-2	-2	-3	-2	-2	-2	-2	1	-2	-2	-2	-2	-2	-2	-2	2	-2	-2	-2	1	-2
	MOM6	2	-2	-2	-2	-2	-2	-2	2	2	-2	-2	-2	-2	0	-1	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-1	-2	-2	-2	-2	-2	-2	-2	-2	-2	-1	-2	-1	-2
Wind Waves	WAVEWATCH III	0	-2	-2	-2	-2	-2	-2	2	2	-2	-2	0	2	2	-3	2	-2	-3	-2	-1	2	-2	2	2	2	0	0	0	2	2	2	2	2	-2	1	2	2	2	2
	SWAN	-2	-2	-2	-2	-2	-2	-2	-1	-1	-2	-2	-2	-1	-2	0	-1	-2	-2	-2	2	-1	-2	-2	-2	-2	-1	-2	-2	-2	-2	-2	-2	-2	-2	-1	-1	-1	-1	-1
Land	Noah-MP	1	1	1	1	1	1	1	1	1	2	2	1	1	1	2	0	-1	2	-2	-2	-2	-2	0	0	-2	-1	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
	LM4	-2	-1	-1	-1	-1	-1	-1	-1	-1	-2	-2	-1	-1	-1	-1	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	1	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
Atmospheric composition and air quality	GOCART	0	-2	-2	-2	-2	-2	-2	2	2	-2	-2	0	1	1	-3	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-1	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
	For AQM see https://github.com/NOAA-EMC/AQM	0	-2	-2	-2	-2	-2	-2	2	2	-2	-2	0	-1	-1	0	-3	0	2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
	HYSPLIT	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	0	-3	-2	-2	2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
Space Weather	WAM-IPE	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	0	-3	-2	-2	-3	-2	-2	2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
	ENLIL	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	0	-3	-2	-2	-3	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2