NATIONAL WEATHER SERVICE

Model infrastructure development in UFS weather model

JULY 24-28, 2023

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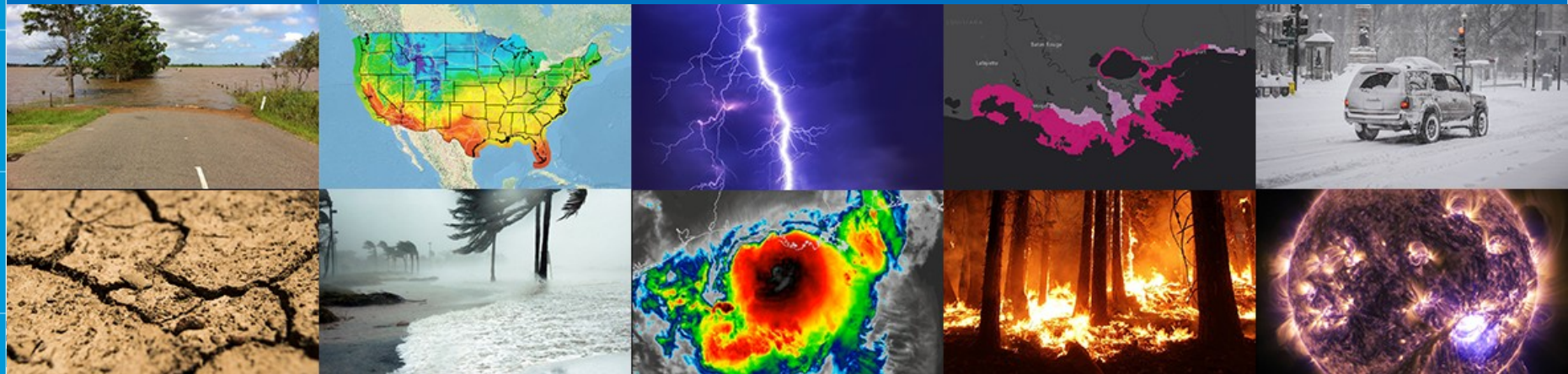
Environmental Modeling Center Review - June 6-8, 2023

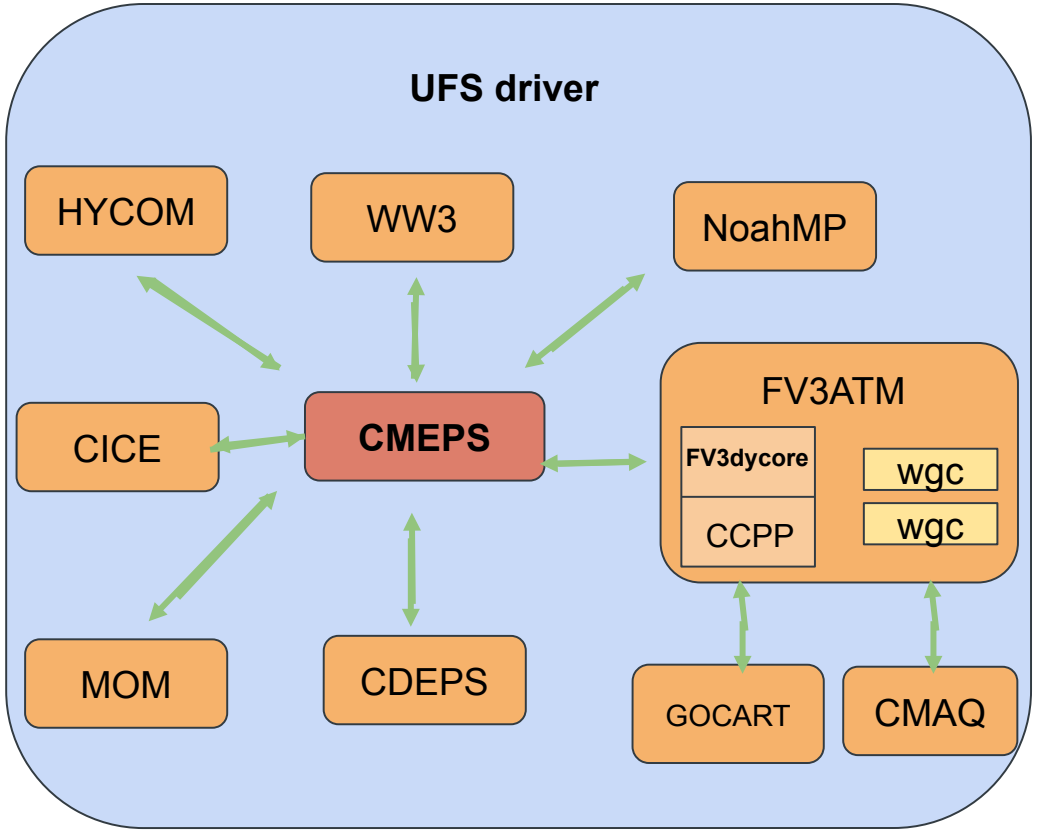


Overview

- Fully coupled capability
- Build system
- Computational performance
- Open source and open development with the community

Develop fully coupled ufs-weather-model with community

- The UFS weather model is **open source** software supporting both **research and operational** developments. It contains:
  - **17 authoritative** repositories
  - **9 major flagship** model components
  - **Community mediator** and 9 **sharable** NUOPC caps
- **Model infrastructure** has been developed as the foundation to build the unified system:
  - Coupled model prototypes
  - GFSv17/GEFSv13
  - RRFSv1
  - AQMv7
  - HAFSv1
  - FV3/JEDI
  - Marine DA forecast model

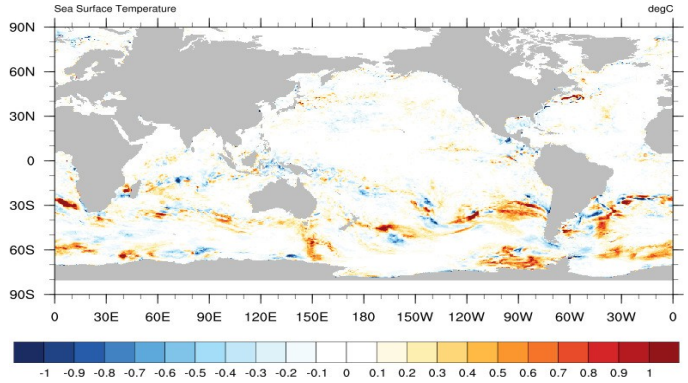


CMEPS- Community Mediator for Earth Prediction Systems

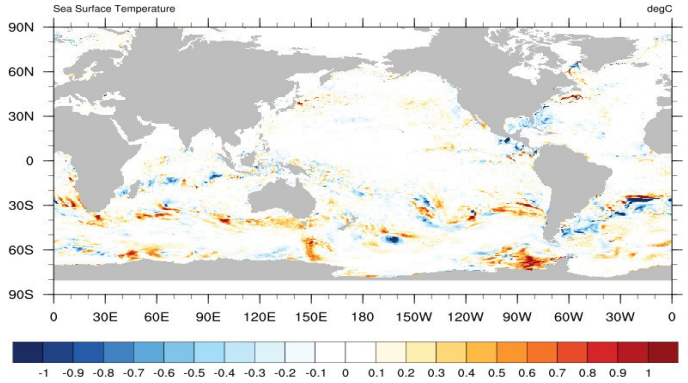
- Transition from in-house NEMS Mediator to CMEPS
  - Active development includes latest ESMF features
  - Contains diagnostic capabilities for water and energy budgets
  - Mapping between components is "expensive"; CMEPS uses multiple methods to reduce cost

- Community development and testing helps ensure robustness across multiple applications
  - Code structured as a set of reusable modules, with single system (UFS, CESM) dependent file
  - Provides for separation of concerns but also interoperability

SST difference from NEMS on two platforms



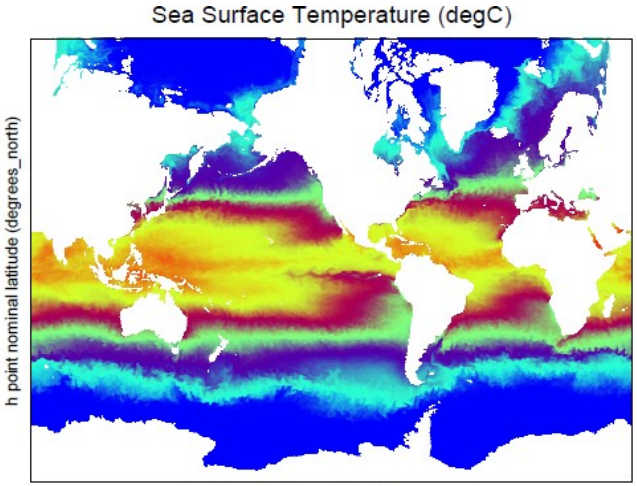
SST difference between CMEPS and NEMS



CDEPS - Community Data Models for Earth Predictive Systems

- **New data model** component
  - Feature rich, flexible data model replacement for ATM, OCN, ICE, WAV or LND component
  - CDEPS reads external observational data or model outputs at available time or resolution
  - Interpolates in time and space and sends the data to the CMEPS mediator as stand-in replacement for active component
- Allows **isolation of feedbacks** between components
- Adds capability of **hierarchical testing** of components models

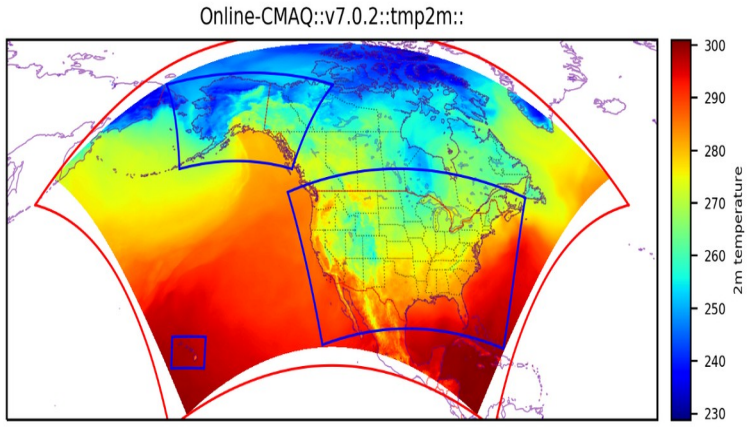
DATM-MOM6-CICE6 configuration used for NG-GODAS



Forecast SST on day 20. The SST range is: -1.89-32.83C.

Air Quality Model (AQM) v7.0 Implementation

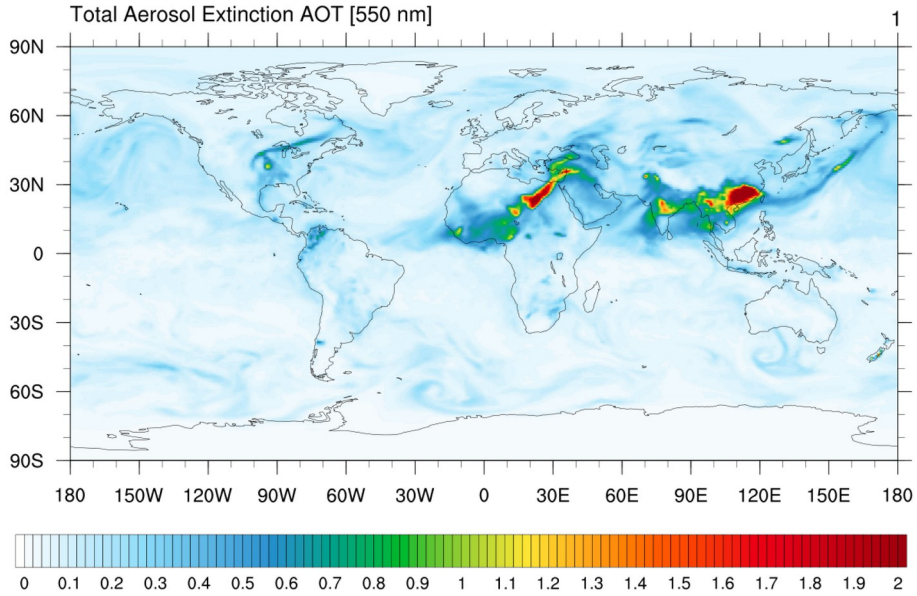
- FV3-CMAQ coupled using ESMF connectors with **new CMAQ NUOPC Cap**
- Fengsha windblown dust emission scheme and CMAQ scavenging and wet removal in resolved clouds
- Regional configuration added to UFS



Red box: AQM v7.0 computation domain; Shaded area: AQM v7.0 model output grid; Three blue boxes: operational model domains.

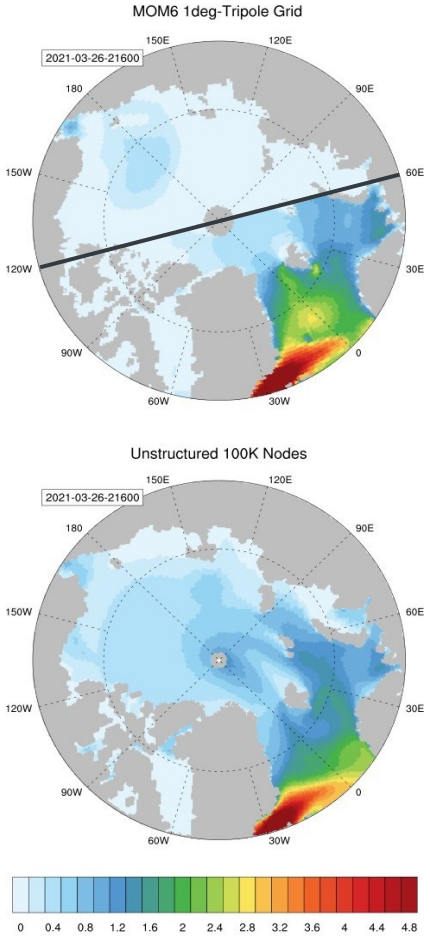
FV3atm-GOCART coupling

- Extension of both FV3 and GOCART NUOPC caps
- **FV3 coupled to GOCART** at each forecast time
- Radiative impact of aerosols for global coupled system



Mesh-based NUOPC cap for WW3

- Utilizes a **mesh** in place of a grid in Cap
  - Meshes can be either structured or unstructured, making them more flexible than grids
- **Coupled through CMEPS** instead of direct connectors
  - Provides restart reproducibility for WW3 coupled applications
  - Allows flexible run sequences since exchanged fields can be accumulated and averaged
- Mesh-based cap accommodates **unstructured** WW3 meshes
  - unstructured WW3 meshes have significant advantages in scalability and coastal resolution
  - permits wave fields to be continuous across MOM6 tripole seam



UFS-weather-model build system

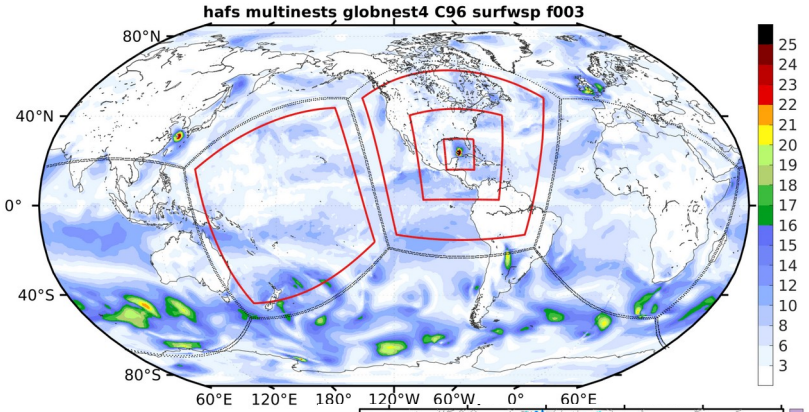
- The **ufs weather model** supports applications with various levels of complexity and is used by operational implementations and research community developments
- **Supported configurations** are: ATM, ATMAERO, ATMW, ATMWM, S2S, S2SW, S2SWA, HAFS, HAFSW, HAFS-ALL, NG-GODAS, and UFSAQM using cmake.
- Several **physics configurations** (CCPP physics suite files) can be built and run with **same executable** for configuration comparison testing. Several executables can be **built simultaneously** with different configurations including different components

Configurations	FV3atm	MOM6	HYCOM	CICE6	WW3	AERO	AQM	CDEPS	CMEPS	Stochy Phys
ATM	●									●
S2SWA	●	●		●	●	●			●	●
HAFS	●		●		●			●	●	●
UFSAQM	●						●			●
GODAS		●		●				●	●	●

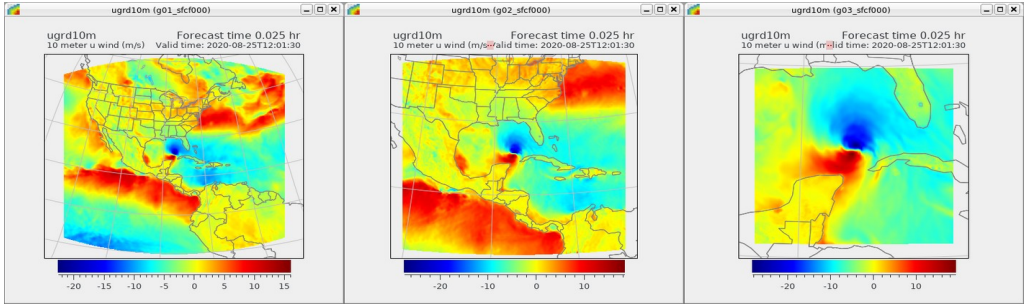
Moving Nests (HAFS)

- Collaboration of 4 Organizations

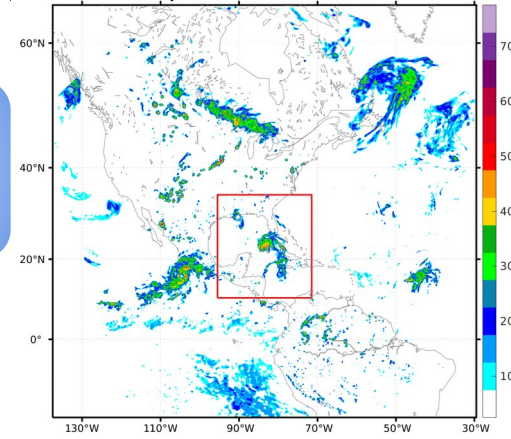
GFDL – Global Parent and Telescopic Nests



EMC & NCAR – Asynchronous I/O



AOML – Regional Parent and Moving Nests

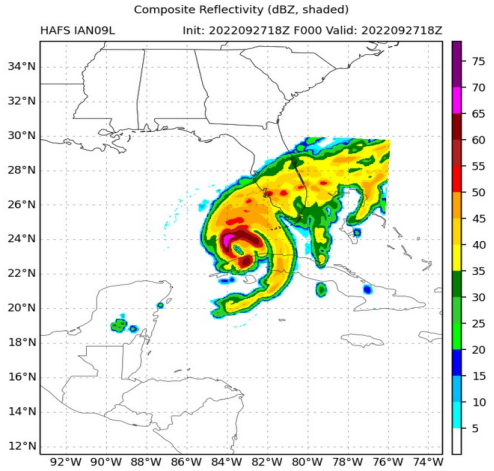


Inline Post

- Using the inline post **saves computational time (80% for high resolution runs)**

experiments	C96L64 (6 tasks)	C192L64 (12 tasks)	C768L127 (84 tasks)
Single master file size	51MB	180MB	2.5GB
Inline post time	4s	7s	39s
Offline post time	12s	17s	211s

- Inline post capability has been **extended to support multiple grid** moving nest applications
- The results have been verified in the **HAFS moving nest application**



Data compression with parallelization in operations

C768L127 fcst output	Nemsio No compression	Netcdf No compression	Netcdf Lossless (deflate=1,nbit=0)	Netcdf Lossy (deflate =1, nbit=20)	Netcdf Lossy(deflate=1,nbit=14)	Netcdf Lossy (deflate=1, nbits=14),parallel writing, default decomposition chunksize	Netcdf Lossy (deflate=1, nbits=14),parallel writing Layer chunkcsize
A 3D file size, (total fcst)	33.6GB (7TB)	33.6GB (7TB)	23.6GB (5TB)	13.5GB (2.8TB)	6.3GB (1.3TB)	6.3GB (1.3TB)	6.3GB (1.3TB)
Write Time	79s	300s	960s	680s	400s	43s	34s

- **GFSv16 could NOT be implemented** without this feature!
- **Collaborated with Unidata and PSL**, testing, release and deployment in operations in under two months

Open Source and Open Develop with community

https://github.com/ufs-community/ufs-weather-model

- ~200 forks
- ~140 developers
- >1700 issues and pull requests
- >10K files
- 4.3M LoC
- Support **operational and R&D platforms** including laptops and Cloud
- **Close collaboration** with entities in UFS **community**

Courtesy: Sam Trahan

Summary

- The **coupling infrastructure** capability is developed to support earth components coupling including atmosphere, ocean, sea ice, wave, aerosol and chemistry and land

- UFS weather model is **built consistently** with various configurations and currently supports previous and upcoming operation models

- **IO** performance is **critical**. Reading, writing and processing data that have been increasing exponentially become a bottleneck for operational implementation

- The UFS weather model is **open source** and **open develop** through **collaboration** with the community. Code integration procedure has been developed.