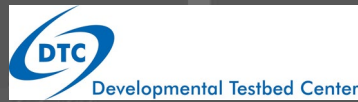




**GLOBAL
SYSTEMS
LABORATORY**



Progress in Expanding the Unified Forecast System to Multiple Dynamical Cores

Ligia Bernardet, NOAA GSL
June 10, 2025



Forecast systems that deliver solutions

Contributions from Developmental Testbed Center

Dustin Swales (NOAA GSL)- technical lead

Grant Firl (CSU/CIRA at NOAA GSL)

Vanderlei Vargas (CSU/CIRA at NOAA GSL)

Soren Rasmussen (NCAR RAL)

Lulin Xue (NCAR RAL)

Contributions from NOAA GSL

Clark Evans (NOAA GSL) - Physics Branch chief

Terra Ladwig (NOAA GSL) - AVID chief

Several NOAA GSL contributors



UFS: For research and NOAA Operations

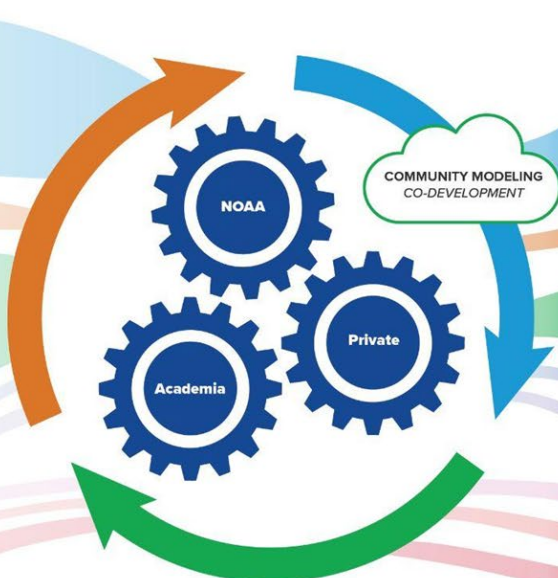
Simplifying NOAA's Operational Forecast Suite

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)



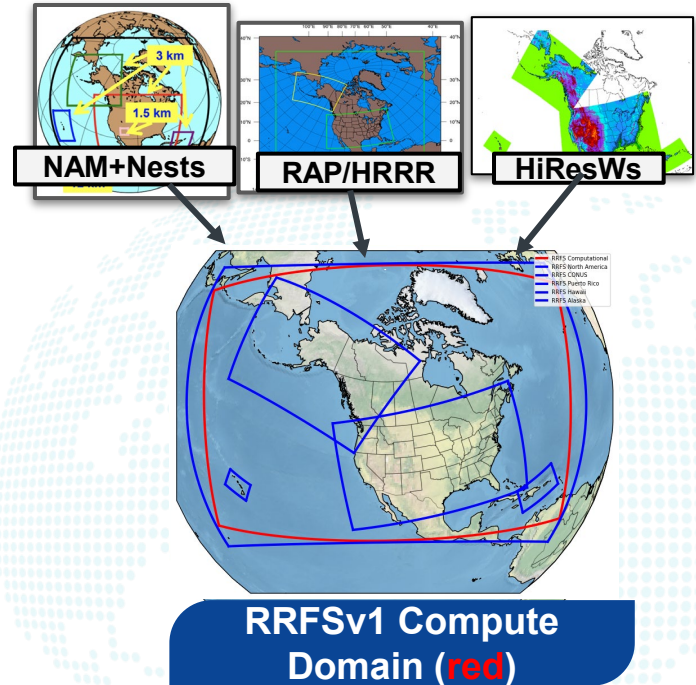
UFS Applications

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

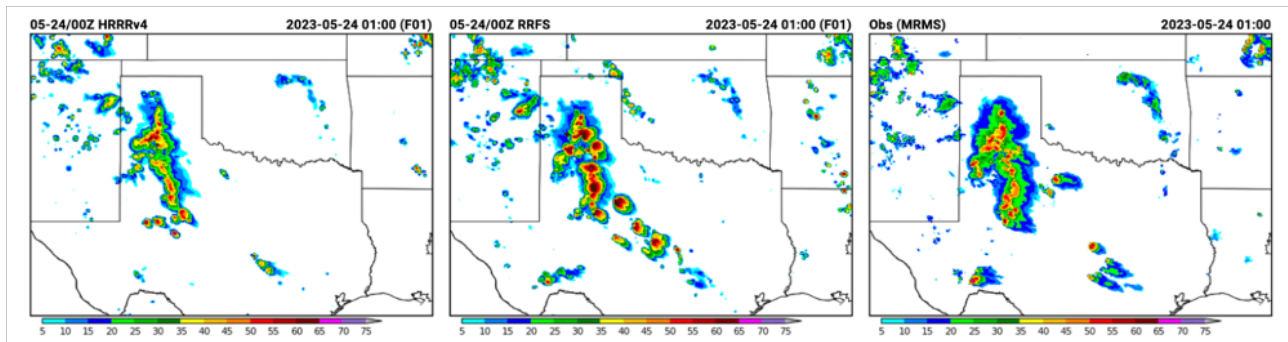
From Uccellini et al. (2022)

Rapid Refresh Forecast System (RRFS) v1

- FV3 dynamical core (limited area model)
- Hourly updated
- 3-km grid spacing over North America
- 65 vertical layers
- Hybrid 3DVar data assimilation
- Includes smoke and dust



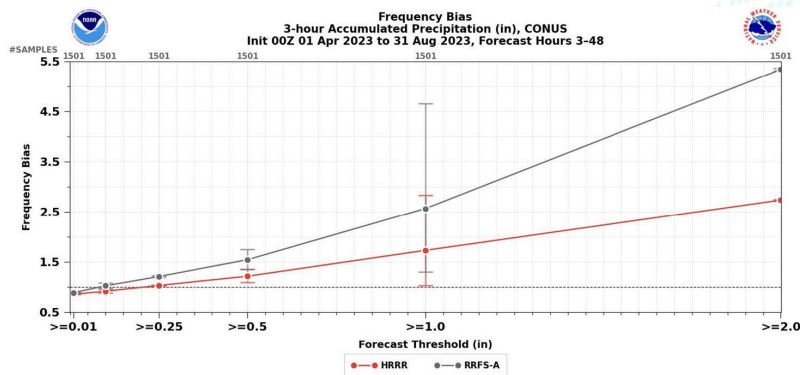
RRFS Springtime Challenges



Difficulty with springtime convective storms (too big, too much precipitation)

Recommendation to use MPAS dycore for RRFS v2

Wang, J. et al. (2023).
[Integration of MPAS dycore into UFS.](#)

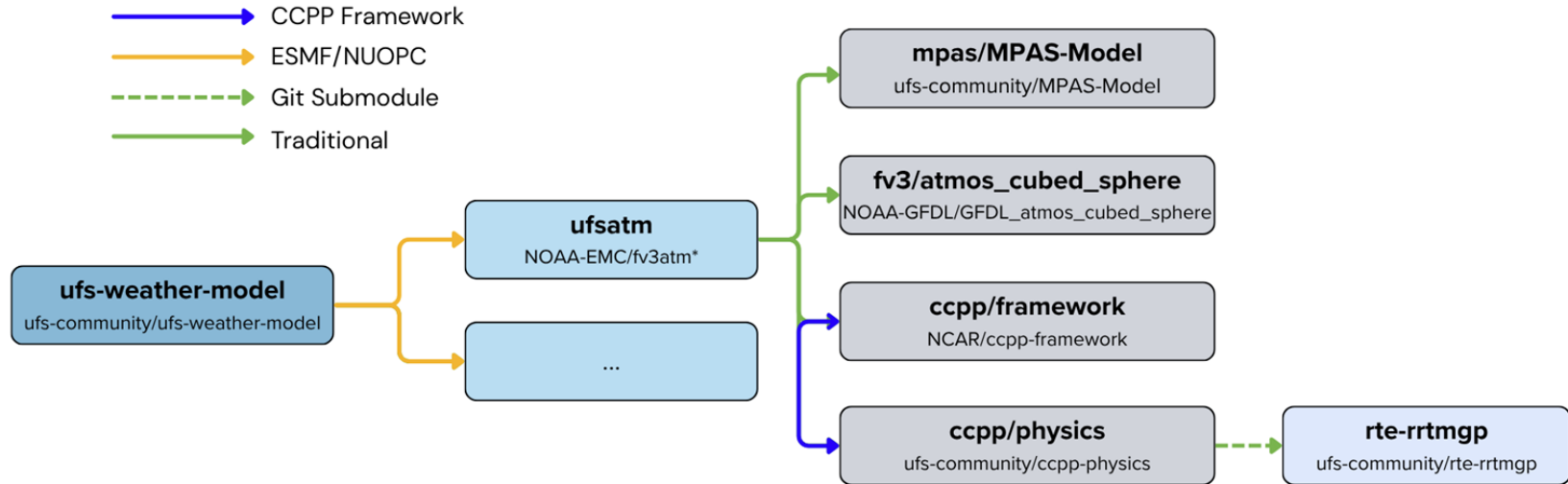


Carley, Jacob et al. (2023). Mitigation Efforts to Address Rapid Refresh Forecast System (RRFS) v1 Dynamical Core Performance Issues and Recommendations for RRFS v2.

<https://doi.org/10.25923/ccgj-7140>



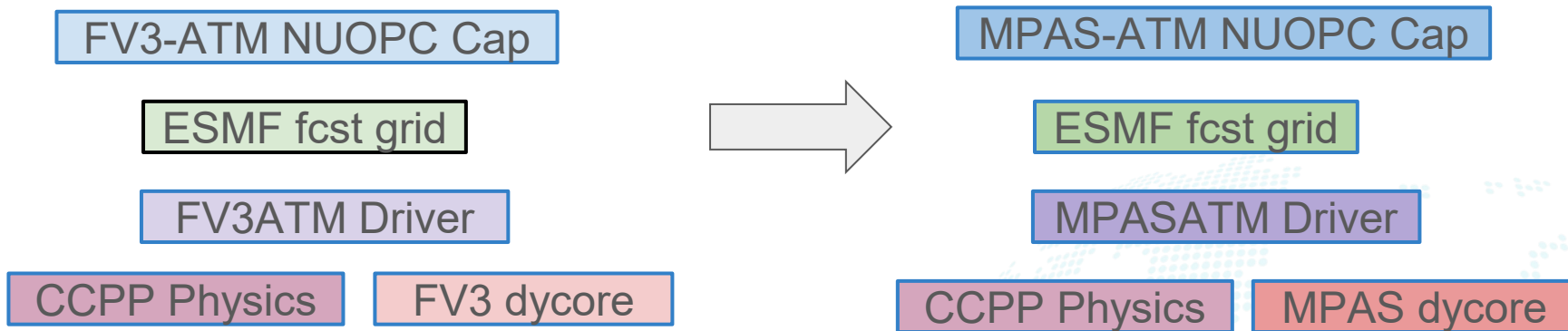
UFS Weather Model Architecture with two dycores



Step 1: Generalized FV3ATM -> UFSATM
Step 2: Included MPAS dycore (submodule)



Stub ESMF Infrastructure in Place for MPAS

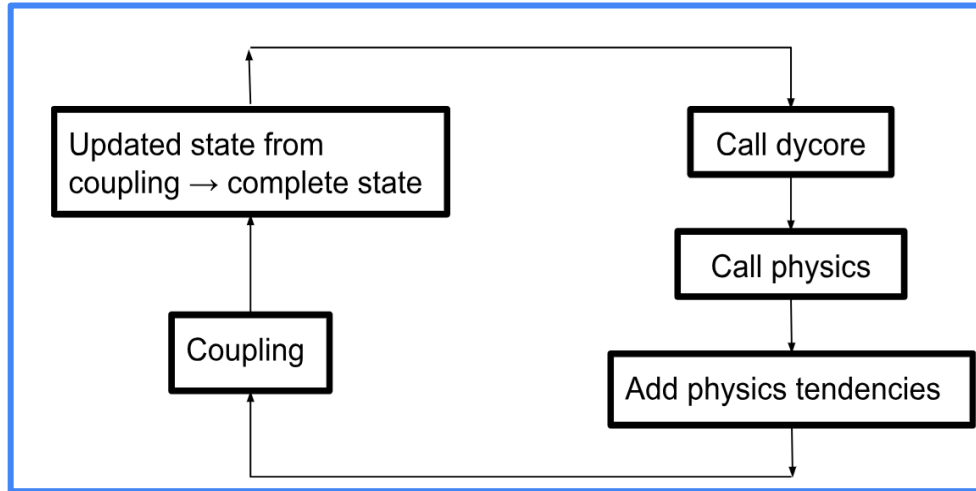


New capabilities:

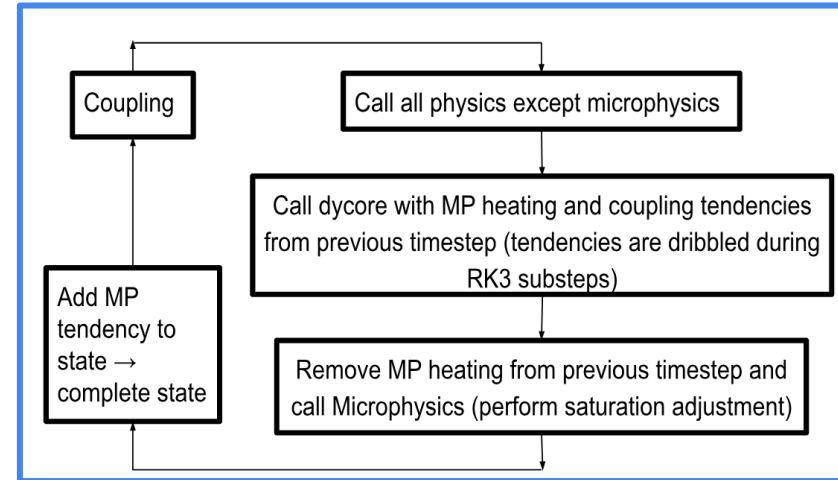
- Initialize and advance dycore
- Initialize and advance a “hello world” CCPP Physics scheme

Revised PhysicsDynamics Coupling (P2D) Needed

FV3



MPAS



MPAS-UFS atmospheric driver has to be built to call the physics, dynamics, and coupling in specific order (which differs from FV3-UFS)

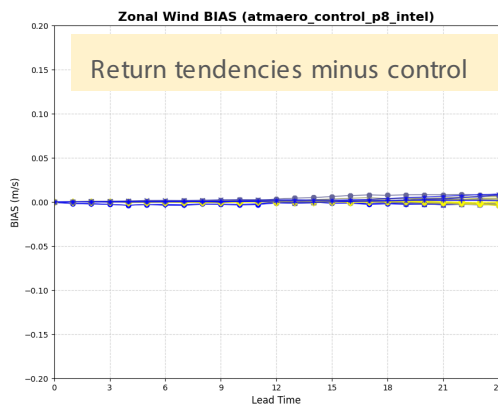
MPAS P2D Requires Parameterizations to Return Tendencies

FV3-UFS uses a mix of process- and time-split

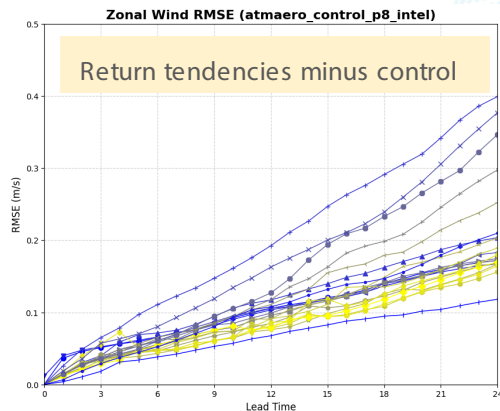
All CCPP parameterizations can now return tendencies. Time split is done by host model controlling state updates.

- Results are slightly different (tested one suite, one 24-h forecast)

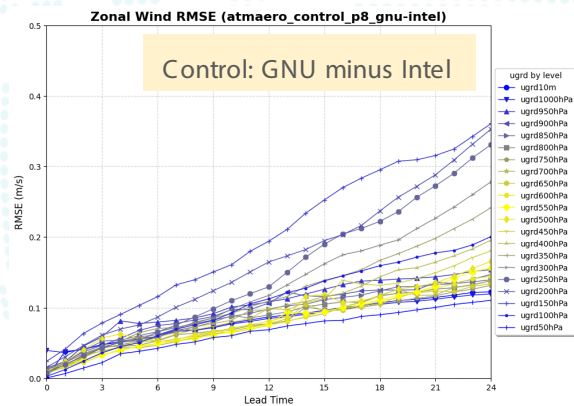
U bias is ~ zero



U RMSE is small



U RMSE ~ differences introduced by compilers



Additional Physics-to-Dynamics Coupling Work

	MPAS dycore	CCPP
Array layout	k,i	i,k
Vertical coordinate	height	pressure
Vertical ordering	bottom-up	top-down
Thermodynamics	dry, constant volume	moist, constant pressure



I/O: Hopefully Upcoming Work on (by NOAA/EMC and ESMF)

- **Background**
 - MPAS has PIO but not asynchronous I/O
- **Needs**
 - Speed up I/O
 - Output on necessary grids
- **Solutions**
 - Create MPAS-compatible ESMF write grid component
 - Extend NUOPC cap to call the forecast and write grid components

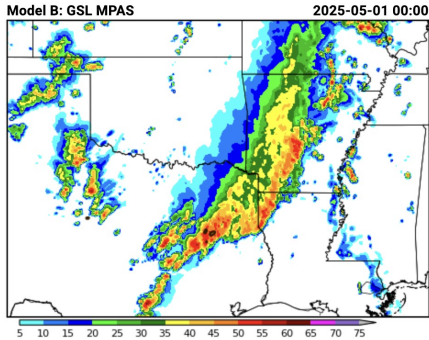


Coupling: Hopefully Upcoming Work on (NCAR/CGD/ESMF)

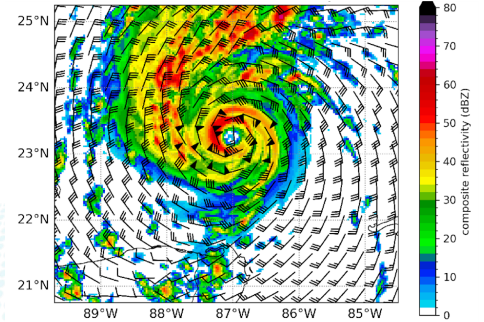
- **Background**
 - GSL/DTC auspices targeted at atmosphere-only forecasts
- **Needs**
 - Expand coupling capabilities to ocean, chemistry, etc.
- **Solutions**
 - Generalize coupling



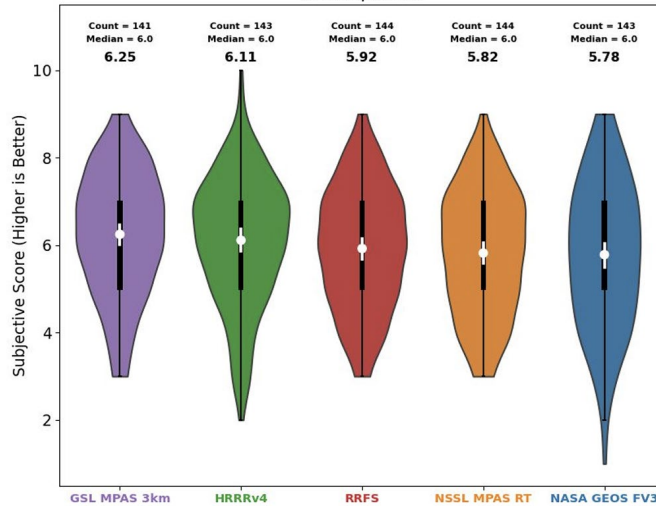
Meanwhile... NOAA GSL engaging with MPAS



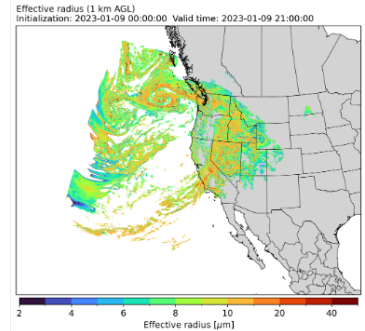
Updated physics
 Realtime research
 Testbed engagements



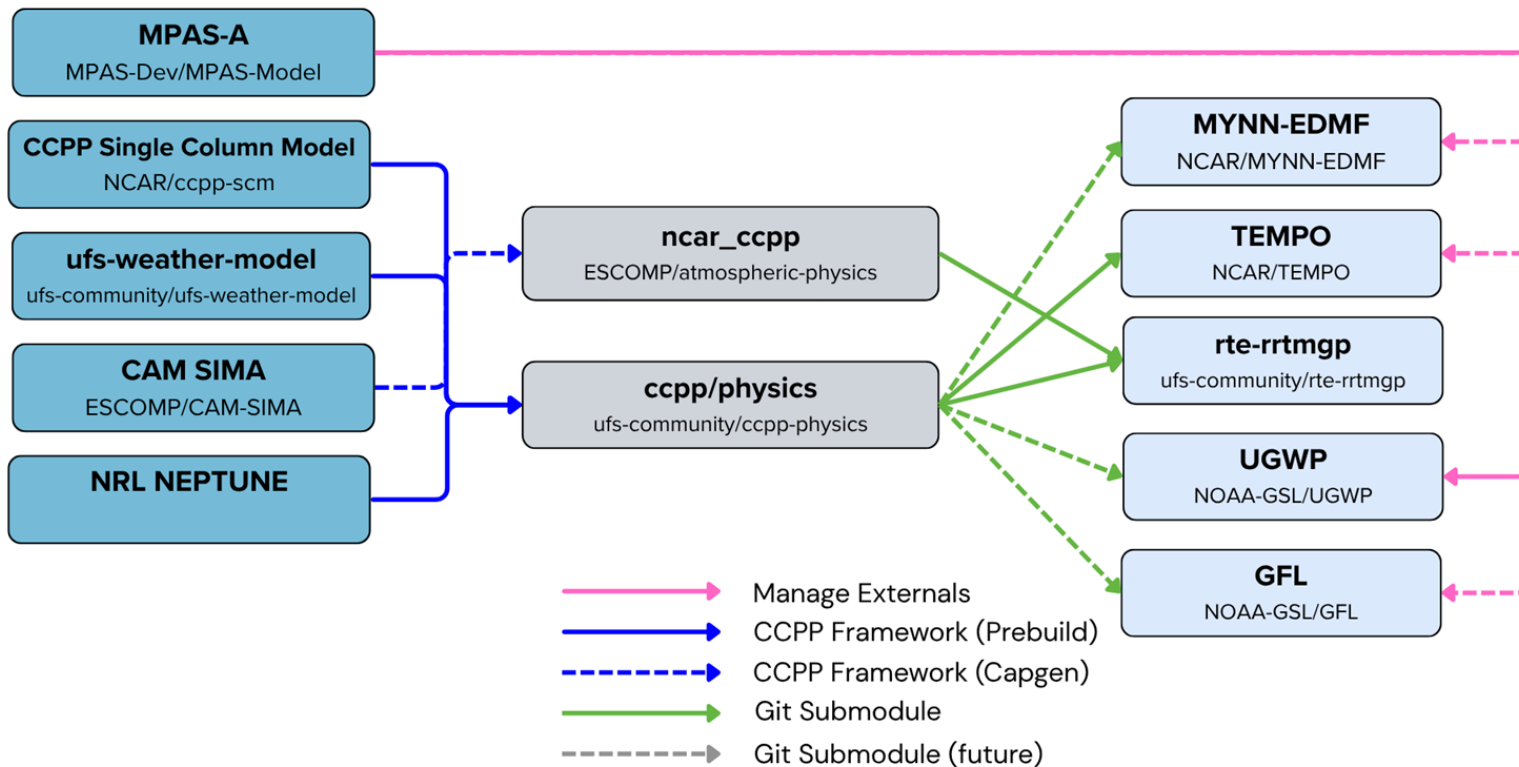
00z Day 1 Flagship Models: Composite Reflectivity & UH
 All Responses



Updated 20250530 14:40:41 UTC



Managing GSLed Physics for MPASA and CCPP



Take-Away Messages

Much progress has been made

- Stub capability in place

Plans and (partial) funding secured to continue

Upcoming work will focus on P2D, I/O, and coupling to other components

Meanwhile...science marches forward with MPAS-A

- Strategies needed for the efforts of to be synergistic and avoid divergence

