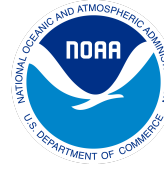UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL WEATHER SERVICE

NATIONAL CENTERS FOR ENVIRONMENTAL PREDICTION

ENVIRONMENTAL MODELING CENTER

External Review

June 6-8, 2023

EMC External Model Innovation
2019–2023

EMC-Adopted External Model Innovations (2019-2023)

Model Innovation	Source	Adoption date (if available)	Implementation Date (if applicable)	Target Operational System	Description	Benefits/Impacts
CICE/Ice Physics	CICE Consortium	2019		GFSv17, GEFSv13, SFSv1	Use CICE column physics package with CICE model	CICE models are well tested for climate applications
Cloud microphysics	GFDL	October 2016	6/12/2019, 09/23/2020	GFSv15, GEFSv12	Replace Zhao-Carr single-moment single-hydrometer MP with GFDL single-moment multiple-hydrometers MP	Better representation of cloud microphysics; Improved precipitation forecast
Cloud microphysics	Community Model (Thompson MP)			GFSv17, GEFSv13, HAFSv1, RRFSv1	Double-moment microphysics	
Cloud microphysics	OAR/NSSL (NSSL MP)			RRFSv1	Multi-physics option for RRFSv1	
CMEPS	NCAR	2023	2023	HAFSv1	Coupled Mediator for Earth Prediction Systems (CMEPS)	CMEPS built jointly by both NCAR and NOAA
Direct Radar Reflectivity DA	GSL and OU MAP			HRRRv4, RRFS1	Directly assimilate radar reflectivity observations	Improved representation of convection in analysis and short-term forecasts
Dynamical Core	GFDL	October 2016	6/12/2019, 09/23/2020	GFSv15, GEFSv12	Replace spectral dynamic core with FV3	FV3 is scalable, enabling high-resolution modeling. GSM cannot scale with grid size

Dynamical Core	GFDL	2019		GFSv17, GEFSv13, SFSv1	Add MOM6 as the ocean model component	MOM6 is a well tested model for S2S applications
Dynamical Core	CICE Consortium	2019		GFSv17, GEFSv13, SFSv1	Add CICE5/CICE6 as the Sea Ice model component	CICE models are well tested for climate applications
ESMF/NUOPC coupling	NCAR & NRL	2020	3/22/2021	GFSv16, GEFSv12	ESMF/NUOPC coupling - ESMF group	One-way coupling to waves
HYCOM ocean model	US Navy	2017 (HMON, HWRF), 2023 (HAFS)	2017 (HMON), HWRF (2017), HAFS (2023)	HMONv1, HWRFv10, HAFSv1	HYCOM ocean model coupled to HMON, HWRF and HAFS	Operational TC model coupled with HYCOM improves TC intensity forecast skills through better modeling of air-sea interaction
Incremental Analysis Update (IAU)	PSL	2018	3/22/2021	GFSv16	Method for passing increments to model and performing initialization	Improved incremental initialization
JEDI for Snow DA	JCSDA, PSL			GFSv17	New snow data assimilation scheme for GFS/GDAS	Inline snow analysis to replace direct insertion of offline products
JEDI replacement of GSI	JCSDA			GFSv18, RRFSv2, HAFSv2	Next generation DA infrastructure to enable future innovation	Replacement of legacy DA system to unified DA infrastructure to enable future innovations
JEDI-based direct radar reflectivity assimilation	OU CAPS			RRFSv2+, 3DRTMAv2+	Accelerate availability of core convective-scale DA capabilities in next gen DA framework	Improved representation of convection in analysis and short-term forecasts in JEDI
JEDI-SOCA	JCSDA	2021		GODAS, GFSv17	40 year reanalysis with JEDI-SOCA (*aka* "ng-godas")	Initial demonstration of JEDI capabilities, improved marine analysis/reanalysis and prototype for ocean monitoring. Initial

						development for future marine component of coupled assimilation system
Land Model	OAR/GSL (RUC)			RRFSv1	Legacy land model inherited from HRRR/RAP	
Land Model	Community Model (NOAH-MP)			GFSv17, GEFSv13	More advanced land model than NOAH LSM, which is no longer supported by the community	
Linearized Observation Operator	PSL		3/22/2021	GFSv16	A cost efficient way to compute the forward operator for the ensemble	Reduces ensemble DA run time, allows for further innovations in the EnKF
METplus	NCAR/DTC	2019	2019	All EMC models and product systems	Model Evaluation Tools (MET), used for verification of EMC's Earth System Models	
Modulated-ensemble LETKF	PSL		3/22/2021	GFSv16	Replaces the EnSRF for the ensemble update and provides model space localization in the vertical	Allows the computation of analysis increments across the time window simultaneously, enabling the use of IAU
Moving nest and telescopic moving nests	AOML/HRD	2007 (HWRF), 2020 (HAFS)	2012 (HWRF), 2023 (HAFS)	HWRFv5, HAFSv1	Moving nest and telescopic moving nest capability in WRF and FV3 framework	The high-resolution storm-following moving nest capability helps to improve TC track and intensity forecast skills, and better describe TC structure with limited computer resources
Navy's Coupled Ocean Data	Naval Research	2020	12/20/2020	RTOFS	Ocean and Sea Ice coupled data assimilation build by US Navy for HYCOM	

Assimilation (NCODA)	Lab					
Nonstationary Gravity-Wave drag parameterization	SWPC/CIRES (collaboration with EMC)	October 2016	3/22/2021	GFSv16	Parameterize unresolved gravity waves from convection, wind shear, etc.	
Overlapping windows	PSL			RRFSv2+, GDASv18+	Collaboration between PSL, GSL, and EMC	Assimilate more observations with wider DA windows, leading to improved forecasts and less complex cycling system
Radiation	AER/ Columbia Univ (RRTMGP)	2020		GFSv18, GEFSv14, HWRFv13	More accurate radiative transfer calculation, especially in the middle atmosphere	
Scale-dependent blending	NCAR			RRFSv2+		
Scale-dependent Localization	JMA, Oklahoma			GFSv17, RRFSv1-2	Collaborative effort to expand EnVar assimilation to utilize scale-dependent localization	Improved background error covariance
Scattering look-up-tables	Penn State University	2021	11/1/2022	GFSv16.3, GFSv17+	Use microphysics scheme-specific, scattering look-up-tables for CRTM to enable tailored all-sky assimilation of MW radiances	Improved all sky MW radiance assimilation
Stochastic Physics (SPPT, SKEB, SHUM)	PSL	2015	11/2015, multiple subsequent upgrades	GFS/GDAS	Use of STTP, SKEB, and SHUM to drive system uncertainty estimate in GDAS to assist in prescription of enemble based estimates of background error	Improved ensemble representations of background error used in Hybrid EnVar -- replaced more ad-hoc additive inflation

Stochastic Physics (SPPT, SKEB)	PSL	2016	9/23/2020	GEFSv12	Replace STTP (stochastic total tendency perturtbation) with SPPT (stochastic perturbed physical tendency) and SKEB (stochastic kinetic-energy backscatter)	Significantly improved ensemble spread especially in the tropics
Tropical Cyclone Tracker	GFDL	2018, 2020, 2023	Multiple	HWRF, HMON, HAFS	Automated vortex tracker for tropical cyclones	Objective, automated method for scanning NWP output and creating TC forecast guidance on metrics such as: predicted track; minimum sea level pressure (MSLP); maximum near-surface wind speed; and near-surface wind structure diagnostics
Unified Gravity Wave Parameterization	OAR/GSL collaboration with EMC)			GFSv17, GEFSv13, HAFSv1, RRFSv1	More advanced and accurate GWD parameterization. Unified for global and regional models at all spatial and temporal resolutions	
Unstructured grid capabilities	Aron Roland	2017	2018, 2020, 2023	GLWUv1, NWPSv1.3, GLWUv2	Unstructured grids for WW3	Allow for much higher resolution of coastlines and coastal grids, benefiting WFOs
Water Vapor Photochemistry	NRL	December 2018	6/12/2019, 09/23/2020	GFSv15, GEFSv12	Predicted water vapor in the middle atmosphere	Improve radiative transfer and water vapor data assimilation
Wave-Ocean coupling	GFDL	2019	3/22/2021	GFSv16, GEFSv12	Impact of ocean currents on waves	Account for non-linear wave-current interactions.
Wavewatch Grids	NRL	2020	3/22/2021	GFSv16, GEFSv12	Computational grid system following Navy's example and using Navy-implemented features	
Wind-Wave-Current DA	UCONN			3DRTMAv1-v2		