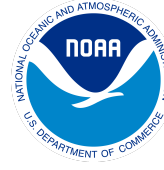UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL WEATHER SERVICE

NATIONAL CENTERS FOR ENVIRONMENTAL PREDICTION

ENVIRONMENTAL MODELING CENTER

External Review

June 6-8, 2023

EMC Model Implementations and Innovations 2019–2023

Innovations in EMC Model Implementations (2019-2023)

The following table lists the major innovations included in EMC operational systems implemented operationally between FY2019 and FY2023.

A detailed report including major and minor EMC implementations occurred between calendar years 2019 and 2023 is provided at the end of this document.

Fiscal Quarter	System Name	System Version	Implementation Innovations
FY19Q1	AQM	5.1.0	Improve bias corrected PM2.5 New bias corrected ozone product Updated emissions Inventory to NEI2014V2.
FY19Q3	GFS/GDAS	15.1.1	**Transitioning GFS from spectral dycore to the finite-volume cubed-sphere (FV3) dynamical core;** **Replacing Zhao-Carr microphysics with the more advanced GFDL microphysics;** Introduced parameterization of middle atmospheric water vapor photochemistry; Add IASI moisture channels, ATMS all-sky radiances, Megha-Tropiques SAPHIR data, ASCAT data from MetOp-B, Meteosat-11 SEVIRI channels 5 and 6, NPP OMPS profile and total column ozone. Add ability to read drifting and moored buoy data. Update quality control for GOES atmospheric motion vector (AMV) winds. Upgrade the use of CrIS radiances. **Remove digital filter and storm relocation. Increase horizontal resolution of the ensemble part of the hybrid data assimilation from 35 km to 25 km.** Update the Near Sea Surface Temperature scheme to a) apply Sea Surface Temperature climatology tendency to the foundation temperature and, b) reduce background error correlation length from 450~800 km down to 100 km.
FY19Q3	GFS/GDAS	15.1.1	Replace the Marine Fog product with the Global Forecast System (GFS) visibility output
FY20Q1	GFS/GDAS	15.2.0	**Assimilate new satellite observations** - GOES-17 Atmospheric Motion Vector (AMV): - Metop-C Advanced Microwave Sounding Unit (AMSU) and

			Microwave Humidity Sounder (MHS) - Korea Multi-Purpose Satellite (KOMPSAT-5) GPS Radio Occultation
FY20Q3	HMON	3.0.0	Expected benefits from this upgrade include improved track and intensity forecast skill for tropical cyclones in the North Atlantic, East Pacific and Central Pacific basins. There are also expected reductions in intensity bias and storm size errors.
FY20Q3	GFS/GDAS	15.1.1	Replace the variables for precipitation and vertical velocity for all World Meteorological Organization (WMO) headed data over NOAAPort and on the Global Telecommunications System (GTS)
FY20Q4	HWRF	13.0.0	Expected benefits from this upgrade include improved track and intensity forecast skill for tropical cyclones in all world ocean basins for HWRF. There are also expected reductions in intensity bias and storm size errors.
FY20Q4	GEFS	12.0.0	Removal of Products from the Global Ensemble Forecast System (GEFS) forecast data produced at 2.5 x 2.5 degree spatial resolution, 1.25 x 1.25 degree spatial resolution, and at 1.0 x 1.0 degree spatial resolution.
FY20Q4	GEFS	12.0.0	The upgrade to GEFS will include the following scientific advancements: Replace the spectral dynamical core with the Finite Volume Cubed Sphere (FV3) dynamical core. New perturbation techniques including Stochastic Perturbation of Physical Tendencies (SPPT) and Stochastic Kinetic Energy Backscatter (SKEB). Upgrade the physical parameterization schemes to those implemented with GFS v15.1 including new Geophysical Fluid Dynamics Laboratory (GFDL) microphysics. Expand the number of ensemble members from 21 to 31. Couple with the global wave ensembles (one-way). Couple with the global aerosols (control member-only). Increase model horizontal resolution to 0.25 deg. (~25 km) and maintain the same resolution out to 16 days forecast each cycle, (the current system operates at ~33 km resolution and reduces it to ~50 km after day 8). For the first time, provide the capability for weeks 3 - 4 forecast guidance once a day at 00z cycle, by extending the forecast length to 35 days with the same resolution of ~25 km.

FY21Q1	RTOFS	2.0.6	The following changes will be implemented in RTOFS v2.0: -The daily ocean and ice analysis, which for RTOFS v1 is done through the Navy Coupled Ocean Data Assimilation (NCODA) at the Naval Oceanographic Office (NAVOCEANO), will be done instead at the Environmental Modeling Center (EMC) with a similar but upgraded data assimilation system, RTOFS-DA. -The coupled ocean-sea ice model, hycom_cice, will also be upgraded.
FY21Q2	NWPS	1.3.7	Improved algorithm for wave system tracking guidance. Resolved low-frequency limit lowered to 0.035 Hz. For 12 Weather Forecast Office (WFO) domains, computation on unstructured domain meshes with variable resolution of 5 km to 200 m. For 9 WFO domains, the addition of rip current and runup (erosion/overwash) guidance. For WFOs KEY and GUM, only rip current guidance is added. Improved blending of P-Surge (Probabilistic Storm Surge) and ESTOFS (Extratropical Surge and Tide Operational Forecast System) water level inputs. Inclusion of wave field transect output graphics.
FY21Q2	GFS/GDAS	16.0.7	**Increase the number of model vertical layers from 64 to 127 and extend the model top from the upper stratosphere (~55 km height) to the mesopause (~80 km height).** Usea new scale-aware turbulent kinetic energy based moist eddy-diffusivity mass-flux vertical turbulence mixing scheme to better represent the planetary boundary layer processes. Merge the operational standalone global deterministic WAVEWATCH III based wave model Multi_1 (wave_multi_1.v3.3) into the GFS system. **Replace the Ensemble Square Root Filter with the Local Ensemble Kalman Filter (LETKF).** **Implement 4-Dimensional Incremental Analysis Update (4D-IAU) technique.** Turn on stochastic kinetic energy backscattering (SKEB) perturbations in ensemble forecast used in constructing background error covariances. Update variational quality control. Apply Hilbert curve to aircraft data. Use correlated observation error for Cross-track Infrared Sounder (CrIS) over sea surfaces and Infrared Atmospheric Sounding

			Interferometer (IASI) over sea and land. **Change the format of forecast output history files from NEMSIO (binary) to compressed netCDF.**
FY21Q4	AQM	6.0.6	Update to CMAQ Version 5.3.1 Update to National Emissions Inventory (NEI 2016) Repalce NAM with GFS as the forcing meterology data Extended AQ forecasts from 48 to 72 hours
FY21Q4	GEFS	12.1.2	Improved interpolation of grib2 files from the model's native Gaussian grid: Use bilinear interpolation to replace the current nearest neighbour interpolation for the land-sea mask (LAND). Inclusion of a new variable to the list of 0.25degree output products onto NCEP web servers: MSLET (Mean Sea Level Pressure with Eta model reduction).
FY22Q2	GFS/GDAS	16.1.6	To begin assimilating Global Navigation Satellite System radio occultation (GNSS-RO) data from GeoOptics on March 29, 2022
FY22Q4	RTOFS	2.3.0	Upgrades include: Applying bias corrections to the equatorial regions . Adjustments for new and deprecated satellite data inputs
FY23Q1	GEFS	12.3.1	- Fengsha dust parameterization bug fix - Update to anthropogenic emissions from CEDS-2014 to CEDS-2019 base year - Fix a bug in Unified Post Processor(UPP) Aerosol Optical Depth (AOD) calculation that resulted in overestimates of AOD - Adjust aerosol physics (aerosol large-scale precipitation and convective wet scavenging removal) to improve aerosol quality forecasts in the Operational GEFS-Aerosol version 12 - Improvement in the GBBEPx smoke Organic Carbon emission process
FY23Q1	GFS/GDAS	16.3.3	Updating UPP and WAFS products for improving the internal flight planning and global aviation safety; Ameliorating the snow depth prediction; Advancing the overall global analysis and forecast by improving the use of observations and adding newly available ones
FY23Q1	HYSPLIT	8.0.0	Ensemble dispersion capability to predict and quantify Volcanic Ash plume uncertainty
FY23Q3	AQM	6.1.8	Update AQM to ingest GBBEPx v4

FY23Q3	GLWU	2.0.6	This upgrades include: 1. Expansion of the model to include Lake Champlain . 2. Increase in Sea Ice Concentration Resolution. 3. Upgrade to Wave Model Core GLWUv2 will also introduce a new version of the WAVEWATCH III wave model core. This version features improvements in the physics, new capabilities for pre- and post-processing utilities, increased efficiency on highperformance computing platforms, and includes multiple bug fixes.

EMC Operational Implementations, 2019-2023
Comprehensive list

Implemented Date	Implemented FY Quarter	Code Handoff Dates	PNS	SCN	System Name	System Version	Current (Ops)
2/26/2019	FY19Q2			19-12	GFS/GDAS	15.0.0	16.3.7
6/12/2019	FY19Q3	10/1/18, 4/4/19	18-15	19-40	GFS/GDAS	15.1.1	16.3.7
6/12/2019	FY19Q3			19-39	GFS/GDAS	15.1.1	16.3.7
6/12/2019	FY19Q3	10/30/2017		19-38	HYSPLIT	7.5.0	N/A
6/12/2019	FY19Q3			19-47	Multi_1		
6/12/2019	FY19Q3			19-41	NAM Nest, HIRESW		
11/7/2019	FY20Q1			19-84	GFS/GDAS	15.2.0	16.3.7
1/17/2020	FY20Q2		N/A	20-09	RTOFS	1.x	2.3.2
2/25/2020	FY20Q2			20-11	NAM, GFS, RAP, HRRR, SREF, Hi-ResW		
6/11/2020	FY20Q3	3/18/2020	20-13	20-51	HMON	3.0.0	3.2.3
6/16/2020	FY20Q3			20-48A	GFS/GDAS	15.1.1	16.3.7
7/23/2020	FY20Q4		N/A	20-59	HRRR	3.0.0	4.1.5
7/28/2020	FY20Q4	12/20/2019		20-45	RTMA/URMA	2.8.2	2.10.4/ 2.10.3
8/5/2020	FY20Q4		20-15	20-54	HWRF	13.0.0	13.2.5
9/23/2020	FY20Q4		19-37	20-75	GEFS	12.0.0	12.3.5
9/23/2020	FY20Q4	5/22/2020	20-07	20-75	GEFS	12.0.0	12.3.5
12/2/2020	FY21Q1	9/30/2020		20-46	HRRR	4.0.5	4.1.5
12/2/2020	FY21Q1	9/30/2020		20-46	RAP	5.0.4	5.1.7
12/10/2020	FY21Q1	8/9/2020, 8/30/2020	20-32	20-105	RTOFS	2.0.6	2.3.2
12/10/2020	FY21Q1		20-41	20-105	RTOFS	2.0.6	2.3.2
2/3/2021	FY21Q2		20-26	20-116	NWPS	1.3.7	1.4.8
3/22/2021	FY21Q2	10/9/2020	20-17	21-20	GFS/GDAS		

3/22/2021	FY21Q2	10/9/2020	20-44	21-20	GFS/GDAS	16.0.7	16.3.7
3/22/2021	FY21Q2			21-21	GFS/GDAS	16.0.7	16.3.7
3/22/2021	FY21Q2	10/9/2020	20-33	21-20	Multi_1		
4/13/2021	FY21Q3			21-28	NAM, GFS, GDAS		
5/4/2021	FY21Q3			21-39	CCPA	4.x	4.2.0
5/11/2021	FY21Q3	2/5/2021	20-24	21-38	HIRESW	8.0.4	8.1.8
5/11/2021	FY21Q3	2/5/2021	20-24	21-38	HREF	3.0.2	3.1.4
5/18/2021	FY21Q3			21-52	GFS/GDAS	16.1.1	16.3.7
5/26/2021	FY21Q3			21-48	GEFS	10.x	
7/20/2021	FY21Q4	4/12/2021	21-13	21-60	AQM	6.0.6	6.1.8
7/20/2021	FY21Q4			21-61	GEFS	12.1.2	12.3.5
8/10/2021	FY21Q4			21-72	RTMA, RAP, NAM, GFS and GDAS		
8/24/2021	FY21Q4			21-76	GEFS	12.x	12.3.5
9/8/2021	FY21Q4			21-80	HIRESW	8.x	8.1.8
12/21/2021	FY22Q1			21-86	HRRR	4.x	4.1.5
12/21/2021	FY22Q1			21-86	RAP		5.1.7
3/29/2022	FY22Q2			22-48	GFS/GDAS	16.1.6	16.3.7
6/28/2022	FY22Q3			22-40	All		
6/28/2022	FY22Q3		21-70	22-42	HYSPLIT, RAP		
7/19/2022	FY22Q4			22-54	RAP		5.1.7
8/2/2022	FY22Q4			22-71	RTOFS	2.3.0	2.3.2
9/13/2022	FY22Q4			22-89	HREF	3.1.3	3.1.4
10/19/2022	FY23Q1	7/8/2022	22-34	22-90	GEFS	12.3.1	12.3.5
10/19/2022	FY23Q1	7/8/2022	20-20	20-75	GWES		
11/29/2022	FY23Q1			22-103	NAM, RAP, RTMA, URMA, GFS, GDAS, CDAS obsproc		
11/30/2022	FY23Q1	8/29/2022	22-46	22-104	GFS/GDAS	16.3.3	16.3.7
12/6/2022	FY23Q1	7/19/2022	22-35	22-106	HYSPLIT	8.0.0	N/A
2/7/2023	FY23Q2	11/1/2022	N/A	23-02	RTMA/URMA	2.10.4/ 2.10.3	2.10.4/ 2.10.3

4/1/2023	FY23Q3				AQM, HRRR, RAP, NOSOFS for the new NDE GVF-WKL-GLB_v3r0 * NPP and J01 and GOES-18 products.		
4/26/2023	FY23Q3	3/28/2023			AQM	6.1.8	6.1.8
5/9/2023	FY23Q3	1/24/2023	22-67	23-35	GLWU	2.0.6	2.0.6
7/3/2023	FY23Q4	4/10/2023	22-70	TBD	HAFS	1.0.0	N/A
8/22/2023	FY23Q4	5/26/2023	23-17	TBD	AQM	7.0.0	6.1.8