NCEP Environmental Modeling Center (EMC)
3-year Implementation Plan: FY2018-2020

DRAFT, Version 1.0 (adopted Jan 25, 2018)

PURPOSE AND INTENDED BENEFITS

The purpose of this Implementation Plan is to describe the major development and implementation projects planned for the Environmental Modeling Center (EMC) over the next three years, and how those fit within the broader NOAA Strategic Vision and Roadmap for modeling, as well as how EMC projects link with other model-related projects internally within NOAA and with the broader U.S. modeling community.

The intended benefits or uses of this Implementation Plan include the following:

- Resource planning: Facilitates planning for major resource drivers:
    - **Budget**: The 3-year plan provides estimated costs for the execution during the current Fiscal Year (FY), the next budget year (next President's Budget), and the following year (under budget formulation). This allows proactive planning with the NOAA program offices that fund EMC (primarily NWS/OSTI, OAR/OWAQ, and OAR/CPO), as well as smooth transitions from one FY to the next.
    - **Personnel** (feds + contract support): Aids in formulation of requirements for level of effort and areas of expertise for both federal employee and contract support. As such, it will help align needs for hiring, training, etc.
    - **High Performance Computing (HPC):** Aligns planned development and implementation projects with HPC needs for R&D, testing and evaluation (to include retrospective runs), associated reanalyses and reforecasts, and operations. When all projects are viewed together, it also aids in identification of an overall implementation schedule and dependencies/conflicts with other model and related model infrastructure projects.
- Identify linkages with community partners: Enhances ability to collaborate with internal NOAA and external community partners by capturing linkages and dependencies with their related work. In particular, this plan will capture internal EMC-projects and how they connect with broader community projects outlined under the NOAA Strategic Implementation Plan (SIP) for unified modeling.
- Identify challenges: In addition to resource challenges, this comprehensive plan will aid in EMC to identify and plan for other key challenges, to include:
    - Basic science challenges to overcome
    - Improvements needed in the associated technologies (e.g., infrastructure) in order to achieve the science goals
    - Challenges or limitations associated with interdependencies on partner organizations (i.e., things outside of EMC's control)

STRATEGIC MOTIVATION AND APPROACH

This Implementation Plan is designed to fall under the overall modeling strategy developed by NOAA and with collaboration with the greater U.S. modeling community. In addition, it is intended to address key findings and recommendations from NOAA and community partners, to include the UCAR Community Advisory Committee for NCEP (UCACN) Modeling Advisory Committee (UMAC). Altogether, these illuminate several ***strategic drivers and motivations*** that are inherent to this plan, to include:

- **Improved science**: While not new, the improvement of science in EMC's models must continue to play a predominant role in the planning of EMC's model develop and implementations.
- **Workforce development**: Closely related to the science, EMC must also continue to place development of the workforce as a top priority, to include hiring, training, and mentoring.
- **Field requirements**: While science will drive many desired improvements to the modeling suite, EMC must continue to respond to requirements from NWS operational users and other key stakeholders and customers as we set strategic goals and priorities.
- **Simplification of NCEP Production Suite**: One of the UMAC's main findings was that the complexity and large number of models in the production suite is a key factor in limiting our effectiveness and ability to improve. As such, simplifying the production suite is a primary strategic goal.
- **Community-based modeling**: Another key limiting factor identified by UMAC and others for the U.S. to keep pace scientifically with world-leading modeling centers (such as the European Center and the UK Met Office) has been the U.S.'s fragmentation of resources and limited collaboration. Therefore another top strategic priority is to increase and better align our collaboration with the greater U.S. modeling community.

To respond to these motivations and strategic drivers, EMC and our partners have adopted the following ***strategies and approaches,*** which underlie most of the projects contained in this plan:

- **Unified modeling**: Unification of many of EMC's currently independent atmospheric models under the FV3 dynamic core within NGGPS. In addition, evolution of NGGPS (with its beginnings as a global weather model) towards a fully-coupled Earth system model and regional applications.
- **Consolidation/optimization of EMC's model suite**: In addition to migration towards a FV3-based unified modeling system, EMC will pursue incremental consolidation of EMC's mesoscale modeling systems, and consolidation/unification of EMC's related model infrastructure and upstream/downstream applications.
- **Modernization/optimization of model infrastructure**: While already mentioned in the previous item, this critical element needs to be called out separately in order to highlight the need for significant investment in this area, which has been historically under-resourced.
- **Community collaboration:** A common thread to all the above strategic drivers, community collaboration is included in several ways, to include:
    - Partnerships with individual EMC projects
    - Broad community partnerships under the Strategic Implementation Plan (SIP)
    - The pending NOAA-UCAR agreement on common infrastructure
    - Enabling collaborative research and development through the VLab repository.
    - Interacting via authoritative code repositories (one per earth system model)

MAJOR EMC PROJECTS

In order to work toward the strategic objectives described in the previous sections, EMC is planning the predominance of our development and implementation activities for this three-year period around the projects described in the remainder of this plan. The projects will be presented in four main categories, the first three of which are for major development projects, while the fourth covers routine upgrades:

- **Modeling and Data Assimilation**: major model and DA development projects that encompass significant scientific leaps forward and the improved incorporation of observation data.
- **Verification, Post-processing and Product Generation**: major unification or modernization/re-engineering projects that evolves the overall capability of these functions.
- **Software Engineering and Infrastructure**: major unification or modernization/re-engineering projects that evolves the overall system architecture, infrastructure, software engineering and supporting tools and processes.
- **Routine/recurring upgrades**: Incremental recurring upgrades that while they do not represent fundamental change like the first three categories, need to be accounted for when planning for budget, personnel and HPC resources.

Each of the projects in these four categories is described in further detail with annexes at the end of this plan. Begin this section with a brief intro paragraph, followed by a 3-year Gantt chart with WCOSS and other significant implementations by quarter. After that, break into 4 sub-sections for *the most major efforts* in each category (i.e., we should not include all).

- *Notes:*
  - *All of the following individual items for major development projects will be limited to a max of 2 pages (including the Gantt chart), which can also be circulated separately as a 1-page (front/back) fact sheet.*
    - *Do not worry about condensing the initial version of FV3-GFS and FV3-GEFS, which are currently 3 pages; leave those alone and focus on completing the other sections.*
  - *Items in the 4th section (annual/routine upgrades) limited to 1 page each).*
  - *Once all the following project sections are completed, we will insert a couple of summary Gantt charts that show the flow of planned implementations by quarter .*

1. **Model and Data Assimilation (DA) development projects**
    1.1. FV3-GFS, to include DA for FV3 system (include JEDI collaboration)
    1.2. FV3-GEFS/Sub-seasonal
    1.3. FV3-SFS
    1.4. FV3 regional/meso
    1.5. FV3 Regional Ensemble (HREFv3 vs FV3-REFS at CAM resolutions)
    1.6. FV3-Hurricane (transformation of HMON with FV3 dycore)
    1.7. 3D RTMA/URMA (3D evolution of RTMA/URMA);
    1.8. HRRRv4
    1.9. Wave model unification (multi-1 and wave ensembles)
    1.10. Wave DA development
    1.11. Advanced Scale-aware physics, with appropriate up/downscaling within a given model component (e.g. clouds/convection/radiation), and to connect different model component grids (e.g. land-atmosphere, lake-atmosphere, land-hydrology, ocean-atmosphere, etc.).
    1.12. Hierarchical model development, i.e. simple-to-more-complex/increasingly coupled components, requiring process-level validation appropriate to level of model complexity. (This is the science part: "get the right answer for the right reason", and better for community R2O.)
    1.13. Data Assimilation development (Improved DA techniques and improved use of observations)
    1.14. NCODA implementation and RTOFS
    1.15. Sea Ice Modeling and Data Assimilation (weather to seasonal scales)
    1.16. FV3-WAM/IPE (Space Weather component) and deep-atmosphere dynamics

2. **Verification, Post-processing and Product Generation development projects**
    2.1. Unification of verification capabilities under MET
    2.2. Other major verification work (MEG, marine verification packages, enhancement of MET based verification to sub seasonal and seasonal scales)
    2.3. Re-engineering/modernization of UPP (and linkage to MDL's WISPS project)
    2.4. Re-engineering/modernization of ObsProc

3. **Software Engineering and related Infrastructure development projects**
    3.1. Community Research and Ops Workflow (**CROW**): addresses EMC-NCO unification and common needs with broader community
    3.2. **NEMS/coupling architecture** (FV3-GFS/GEFS/SFS and interactions with AQ, WAM, etc.)
        Note: Necessary system architecture to accommodate hierarchical model development, e.g. easily extracted/inserted model components, single column model (SCM), SCM+ocean, SCM+ocean+waves, SCM+aerosols, etc.
    3.3. Migration of **code repositories** from Subversion to VLab Git
    3.4. **Web-site** consolidation/modernization
    3.5. Update, enhance, maintain and support the NCEP models' shared **libraries/utilities & EE**
    3.6. Update and consistency of **documentation**
    3.7. Development of integrated **PM tools/environment** on VLab

4. **Routine/recurring upgrades (note: Mention only major ones in this section of the plan, with a link to the full listing of all quads)**
    4.1. RTMA/URMA
    4.2. HREF
    4.3. NAEFS
    4.4. HWRF

4.5. HMON (annual upgrades with NMMB dycore)
4.6. WW3 (stand-alone wave models; coupling included in GEFS/SS and SFS)
4.7. Sea Ice (coupled with RTOFS and GEFS/SS and SFS)
4.8. SST (stand-alone SST; coupling included in GEFS/SS and SFS)
4.9. NWPS
4.10. Global Land Data Assimilation System (GLDAS), including hydrology-ocean and connection to the Nat'l Water Model.
4.11. Air Quality (CMAQ and HYSPLIT)
4.12. Incremental UPP capability additions (e.g., aviation products) not tied to major model upgrade (those tied to GFS or other model upgrade will be included there)

	Project	Leads	Reference
Modeling and Data Assimilation Branch			
1.1	FV3-GFS, to include DA for FV3 system (include JEDI collaboration)	Vijay Tallapragada, Shrinivas Moorthi, **Fanglin Yang**	SIP Document Annex 1, Project 1 FV3GFS Dev Quad
1.2	FV3-GEFS	Vijay Tallapragada, **Yuejian Zhu**	SIP Document Annex 1, Project 2 FV3GEFS Dev Quad
1.3	FV3-SFS	Arun Chawla, **Suranjana Saha**	SIP Document Annex 1, Project 3 FV3SFS Dev Quad
1.4	FV3 Regional/Meso	**Eric Rogers**, Tom Black, Brad Ferrier, Jack Kain	SIP Document Annex 7, Project 1 Dev Quad
1.5	FV3 Regional Ensemble (HREFv3 vs FV3-REFS at CAM resolutions)	Vijay Tallapragada, Eric Rogers, **Jun Du**, Matt Pyle, Jack Kain	SIP Document Annex 7, Project 2 Dev Quad
1.6	FV3-Hurricane (transformation of HMON with FV3 dycore)	Avichal Mehra, **Tom Black**	SIP Document Annex 4, Project 3 Need Dev Quad
1.7	3D RTMA/URMA (3D evolution of RTMA/URMA	John derber, **Jacob Carley**	SIP Document Annex 6, Project 4 Dev Quad
1.8	HRRRv4	**Geoff Manikin**	SIP Document Annex 7, Project 3 Need Dev Quad
1.9	Wave model unification (multi-1 and wave ensembles)	Vijay Tallapragada, Arun Chawla, **Jessica Meixner**	SIP Document Annex 8, Project 2c Need Dev Quad
1.10	Wave DA development in GSI	**Stylianos Flampouris,** Arun Chawla John Derber	SIP Document Annex 8, Project 2c Dev Quad
1.11	Advanced Scale-aware physics	**Shrinivas Moorthi,** Vijay Tallapragada, Jack Kain	SIP Document Annex 5, Project 2 Dev Quad
1.12	Hierarchical model development	Mike Ek, **Jack Kain**	Need Dev Quad
1.13	Data Assimilation development (Improved DA techniques and improved use of observations)	**John Derber,** Andrew Collard	Dev Quad: Techniques Dev Quad: Obs
1.14	NCODA Implementation	**Ilya Rivin** and Avichal Mehra	SIP Document Annex 8, Project 1 Dev Quad
1.15	Sea Ice Modeling and Data Assimilation (weather to seasonal scales)	**Bob Grumbine**	
1.16	FV3-WAM/IPE (Space Weather Component) and Deep Atmosphere Dynamics	**Henry Juang** and Sajal Kar	SIP Document Annex 4, Project 4 Dev Quad

Verification, Post Processing and Product Generation Branch			
2.1	Unification of verification capabilities under MET	Jason Levit, **Geoff Manikin**, Ying Lin Perry Shafran	SIP Document Annex 13, Project 1, 2 Dev Quad
2.2	Other major verification work (MEG, marine and air quality verification packages, enhancement of MET based verification to sub seasonal and seasonal scales)	Jason Levit, **Geoff Manikin**, Todd Spindler and Deanna Spindler Jeff McQueen, Perry Shafran	SIP Document Annex 13, Project 3 Marine Verification Dev Quad AQ Verification Dev Quad
2.3	Re-engineering/modernization of UPP (and linkage to MDL's WISPS project)	Jason Levit, **Hui-Ya Chuang**, Boi Vuong, Guang Ping Lou	SIP Document Annex 12, Project 1 Dev Quad
2.4	Re-engineering/modernization of ObsProc	Jason Levit, **Dennis Keyser**	Need Dev Quad
Engineering and Implementation Branch			
3.1	Community Research and Ops Workflow (CROW)	Arun Chawla, **Sam Trahan**	SIP Document Annex 3, Project 1 Dev Quad
3.2	NEMS/coupling architecture	Arun Chawla, **Mark Iredell**, Samuel Trahan	SIP Document Annex 2, Project 1c Dev Quad (NEMS) Dev Quad (coupling architecture)
3.3	Migration of code repositories from Subversion to VLab Git	Arun Chawla, **Mark Potts**	SIP Document Annex 3, Project 2 Dev Quad
3.4	Web-site consolidation/modernization	**Eric Rogers**, Kate Howard,	Dev Quad
3.5	Update, enhance, maintain and support the NCEP models' shared libraries/utilities & EE.	**Mark Iredell**, Eugene Mirvis	SIP Document Annex 3, Project 5 Dev Quad
3.6	Update and consistency of documentation	**Mark Iredell**, Valbona Kunkel	SIP Document Annex 3, Project 3 Dev Quad
3.7	Development of integrated PM tools/environment on VLab	**Farida Adimi**	Need Dev Quad
Regular Model Upgrades			
4.1	RTMA/URMA	Jacob Carley, Steven Levine	RTMA-URMA RTMA-URMA RTMA-URMA
4.2	HREF	Matt Pyle, Eric Rogers	HiResWindow/HREF
4.3	NAEFS	Yuejian Zhu, Bo Cui	NAEFS
4.4	HWRF	Avichal Mehra	HWRF
4.5	HMON	Avichal Mehra	HMON

4.6	RTOFS (stand-alone ocean model)	Avichal Mehra, Ilya Rivin	RTOFS Global RTOFS Global RTOFS Global
4.7	WW3 (stand-alone wave models; coupling included in GEFS/SS and SFS)	Arun Chawla, Henrique Alves	GLWU
4.8	Sea Ice (coupled with RTOFS and GEFS/SS and SFS)	Robert Grumbine, Arun Chawla	Sea Ice Conc
4.9	SST (stand-alone SST; coupling included in GEFS/SS and SFS)	Robert Grumbine, Arun Chawla	RTG-SST RTG-SST
4.10	NWPS	Andre VanDer Westhuysen, Arun Chawla	NWPS
4.11	Global Land Data Assimilation System (GLDAS), including hydrology-ocean and connection to the Nat'l Water Model	Mike Ek, Jesse Meng	GLDAS Dev Quad
4.11	Air Quality (CMAQ and HYSPLIT)	Jeff McQueen, Jianping Huang, Ho-Chun Huang, Barbara Stunder Daniel Tong	SIP Document Annex 10, project 1,3 CMAQ HYSPLIT CMAQ DEV HYSPLIT DEV
4.13	Incremental UPP capability additions (e.g., aviation products) not tied to major model upgrade (those tied to GFS or other model upgrade will be included there)	Hui-Ya Chuang, Yali Mao	UPP-Aviation-R2O

1. Modeling and Data Assimilation

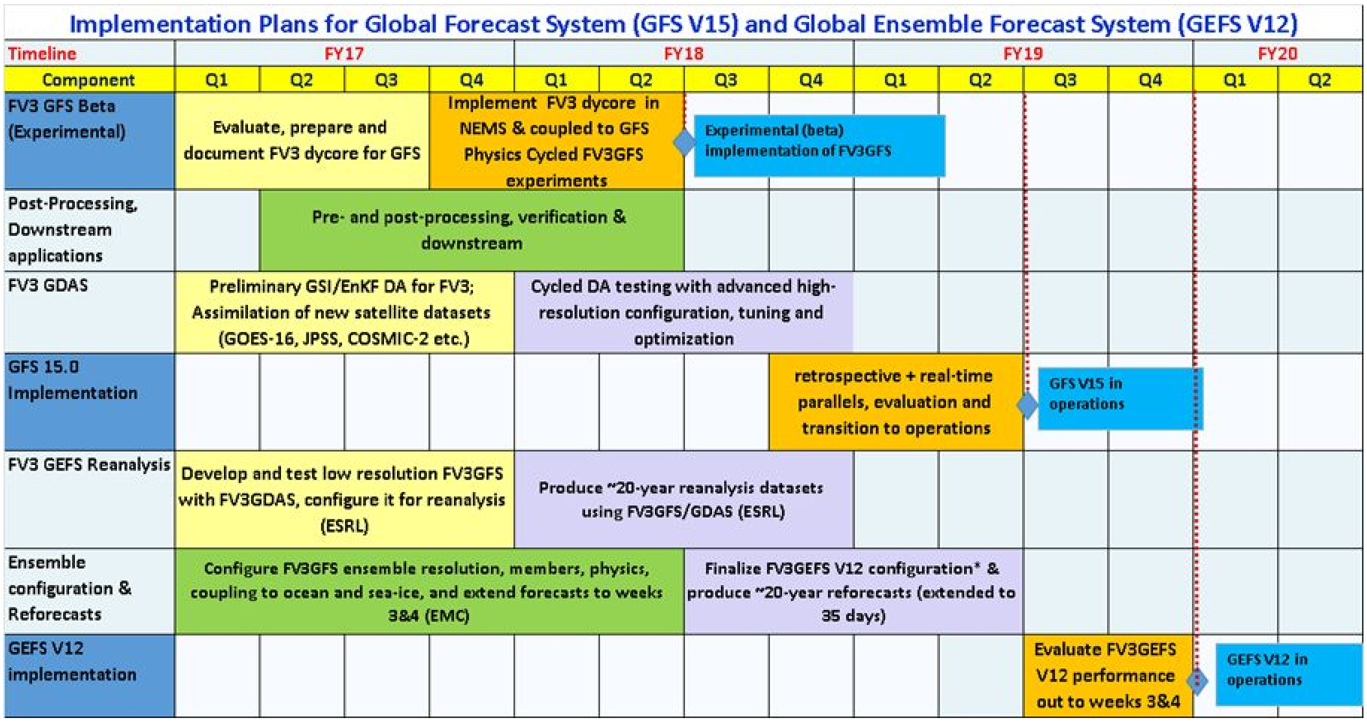
Given that NGGPS will be the foundation upon which EMC's unified modeling capabilities will be built, it is logical to begin with the planned NGGPS capabilities and timelines, and use thoseas our anchor points. Therefore the first few sections that follow will lay out the deliverables and schedule for NGGPS functionality, to be followed by other major model development projects.

The first major NGGPS model package will be to replace EMC's legacy Global Forecast System (GFS) model, based on the Global Spectral Model (GSM) dynamic core, with a new version of the GFS that is based on FV3 dynamic core. As such, this new system is referred to as FV3-GFS. There is an early prototype of the FV3-GFS planned for FY18; the first operational version of the FV3-GFS is planned for FY19, with additional upgrades planned on an annual basis starting in FY20.

The second major NGGPS model package will be to replace EMC's legacy Global Ensemble Forecast System (GEFS), based on the Global Spectral Model (GSM) dynamic core, with a new version of the GEFS that is based on FV3 dynamic core. As such, this new system is referred to as FV3-GEFS. The first operational version will follow the implementation of the first operational FV3-GFS in FY19. In addition to replacing the legacy GEFS, the forecast length for the new FV3-GEFS will be extended to approximately 35 days, therefore making it an operational ***Sub-Seasonal*** ensemble prediction system.

The third major NGGPS model package will be to replace EMC's legacy Climate Forecast System (CFS), a fully coupled seasonal-scale model based on the Global Spectral Model (GSM) dynamic core, with a new version that is based on FV3 dynamic core. Given that the old CFS name is a misnomer in that is provides predictions on *seasonal scales*, and not to long-range climate scales as the name implies, the "climate" part of the name will be dropped and replaced with the more accurate "seasonal" descriptor; as such, this new system will be referred to as the FV3-SFS.

The next few sections will cover the implementation activities of the three NGGPS global modeling systems targeted for operations at NCEP/EMC, to be followed by other model development projects.



1.1: FV3-Global Forecast System (FV3-GFS)

Project overview: The NGGPS mission and objectives include NOAA/NWS/NCEP being the world's best and most trusted provider of deterministic and probabilistic forecast guidance across all spatial and temporal scales. Fundamental and central to this mission is the FV3-GFS and associated FV3 based Global Data Assimilation System (GDAS). The NOAA Environmental Modeling System (NEMS) framework will provide the infrastructure for developing the FV3-GFS, and will become the core component of the National Unified Modeling System. Apart from providing forecast guidance over different time scales, the FV3-GFS also provides initial and boundary conditions for regional atmospheric and ocean models, space weather models, air quality models, and various other NCEP production suite applications. To properly service the customers, the forecasts must be available reliably and at the appropriate time within available resources.

Major Risks and Issues:
- Computational resources dedicated for model development and for operations
- Documentation, training, code management and access of codes by core partners and community
- Demonstration of superior performance of FV3-GFS from scientific evaluation
- Alignment with Unified Model Development strategy

Major resources requirements:
- Personnel: EMC: 21 FTE (FV3-GFS Model development, physics, and DA)
  - Partners: ESRL (2 FTE), GFDL (3 FTE), other?
- HPC for development: ~20M CPU hrs per month on WCOSS, Theia, Jet and Gaea; ~500 TB scratch space and ~2 PB HPSS storage prior to implementation

Dependencies/linkages with other projects:
- NEMS/ESMF framework advancements
- DA: JEDI; ESRL/PSD DA integration; readiness/availability of GOES-16, JPSS and COSMIC-2 data

- Physics: GFDL IPDv4; DTC/GMTB CCPP (not in the critical path); and advanced physics options
- MET based verification and validation; Refactored NCEP POST (UPP) and product generation
- Unified Workflow (CROW); Transition to VLab and Code Management/Governance

Core development partners and their roles:

- NCEP/EMC: Model development (including physics and data assimilation), integration into NEMS framework and unified workflow, code management, retrospective and real-time experiments, testing and evaluation, transition to operations
- GFDL: Utilities for FV3 Grid Structure and I/O; Model diagnostics and troubleshooting; NEMS Integration Support; Documentation and Training; Advanced physics connections to IPDv4
- ESRL/PSD and JCSDA: DA development support
- ESRL/GSD; DTC/GMTB: Physics development and T&E
- ESRL/NESII: The NOAA Environmental Software Infrastructure and Interoperability (NESII) team provides ESMF/NUOPC advances and NEMS development and integration support.
- NGGPS funded PIs for R2O

Major Milestones:

- (Q3FY17) Prepare FV3 dynamic core for GFS: Develop extensive documentation and training material, establish code management, code build and optimization procedures; assemble tools for pre-processing and post-processing tools; develop libraries and utilities;
- (Q2FY18) Implement FV3 dynamic core and physics driver into NEMS: Add FV3 cap to NEMS; develop FV3 write component; enable hourly output; develop regridding tools and NETCDF I/O
- (Q3FY18) Pre-/Post-Processing and verification/validation: Refactor UPP; transition verification software to MET; generate downstream products; evaluate impacts on production suite
- (Q3FY18) Initial performance evaluation of FV3-GFS: Couple FV3 dynamic core with IPDv4; conduct forecast experiments; code optimization; performance evaluation; and real-time demonstration. Prepare for experimental implementation of FV3-GFS (matching the current operational GFS configuration) for operations and provide real-time forecasts to the field
- (Q2FY19): Advanced model configuration of FV3-GFS for transition to operations: Increase model resolution to ~9 km 128L; implement advanced and scale-aware physics; perform retrospective and real-time evaluation of various configurations; integrate into unified workflow; conduct pre-implementation T&E; and prepare model for transition to operations

Other Milestones associated with this project:

Unified Workflow:

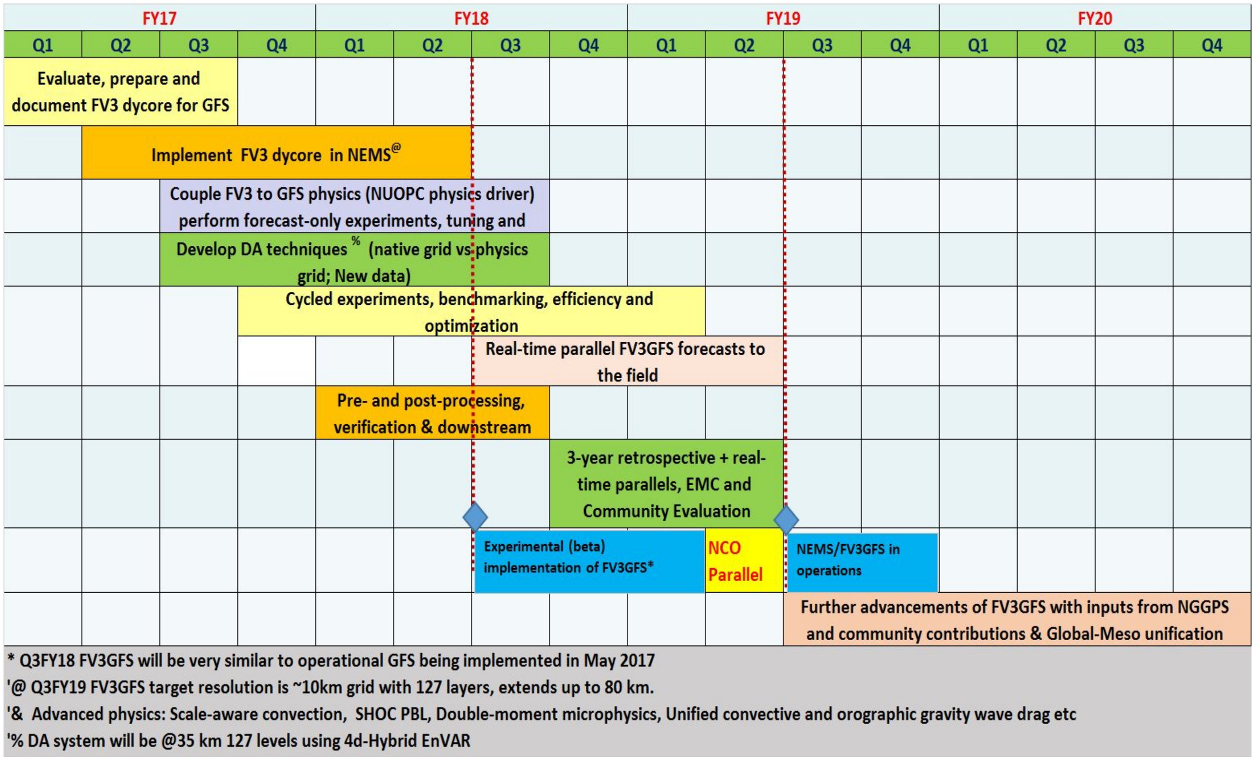
- (Q2FY19) Modular and object oriented workflow design: Develop and implement Community and Operations Workflow (CROW) with object oriented scripting and automation tools.

Unification of Global Wave model into FV3-GFS:

- (Q2FY19) Couple FV3-GFS to WAVEWATCH III: Integrate the wave model into FV3-GFS using NEMS/NUOPC coupler; test the impacts of two-way interactive wave physics; replace global wave model products with the wave coupled FV3-GFS. (See section 1.9 for details)

Unification of NCEP Global Aerosol Model into FV3-GFS:

- (Q2FY19) Couple Aerosol Model to FV3-GFS: Integrate the aerosol chemistry module (GOCART or MAM7) into FV3-GFS using NEMS/NUOPC coupler; test the impacts of two-way interactive aerosol chemistry; implement aerosol data assimilation; replace operational NGAC products with the aerosol coupled FV3-GFS



FV3-GDAS:

- (Q2FY18) Adapt 4D-Hybrid DA for FV3-GFS: Prepare tools to develop initial conditions for FV3-GFS using NEMS-GSM analysis fields; transition the 4D-Hybrid En-Var data assimilation framework for FV3-GFS; configure and optimize the cycled data assimilation experiments including EnKF and stochastic physics
- (Q2FY18) Assimilation of GOES-16, JPSS and COSMIC-2 data: Prepare FV3-GFS for assimilating new satellite datasets as they become available
- (Q2FY19) Advanced high-resolution DA for FV3-GFS: Increase the horizontal and vertical resolutions for DA configurations in support of FV3-GFS implementation.
- (Q2FY19) Integrate into JEDI framework: Transition FV3-GDAS developments into JEDI framework, and implement any available JEDI contributions into operational FV3-GDAS. Implement forward operator on native cubed-sphere grid using JEDI Unified Forward Operator (UFO).

FY17				FY18				FY19				FY20			
Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
		Adopt GDAS (4D Hybrid En-VAR) DA for FV3GFS													
Testing, Evaluation and Operational Implementation of new satellite datasets (GOES-16, JPSS, COSMIC-2 etc.)															
			Increase vertical resolution to 127 levels and increase GDAS resolution to 35 km												
					Incorporate JEDI Unified Forward Operator and Modular GSI infrastructure										
							Develop and implement DA on native cubed sphere grid								
										Further advancements of FV3GDAS Global-Meso-Marine unification (Unified DA Development)					

1.2: FV3-GEFS/Sub-seasonal

Project overview: The FV3-GEFS project will assemble, test, and prepare for the implementation of an upgraded Global Ensemble Forecast System (FV3-GEFS) which will extend the weather forecast guidance to weeks 3&4 (35 days). The FV3-GEFS implementation will be accompanied by a ~20-year reanalysis and reforecast. The FV3-GEFS will be implemented within the NEMS framework using the FV3 dynamic core and IPDv4, and is consistent with the development and implementation plans for the FV3-GFS supported by NGGPS and CPO. The FV3-GEFS project will have close coordination with the FV3-GFS project, and the ESRL/PSD reanalysis project to ensure timely execution of the reforecasts leading to implementation of FV3-GEFS in operations. The model configuration for FV3-GEFS will have possible options to include coupling the atmospheric model to Ocean (GFDL Modular Ocean Model MOM6), Sea-Ice (CICE), and Land (Noah Land Surface Model) components. The data assimilation systems for the component models will be uncoupled. The FV3-GEFS reforecast experiments will rely on ESRL/PSD's atmospheric initial conditions based on the ~20-year atmospheric reanalysis project.

Major Risks and Issues:

- Computational resources dedicated for model development, tuning, and for operations, including procurement of disk space for reanalysis/reforecast ($149K to be sent to NCO for NOMADS disk augmentation in early FY2018).
- The reanalysis planned for GEFS will be atmosphere-only and uncoupled with the ocean. It is possible that the lack of coupling may lead to sub-optimal coupled ocean forecasts with numerical transients. At the earliest possible time, tests of the coupled GEFS prediction system initialized with uncoupled atmospheric ocean and atmospheric analyses should be tested and evaluated.
- Successful development of atmos.-ocean-wave-sea ice coupled system based on FV3-GFS, MOM6, Wavewatch III, and CICE within NEMS framework and ready for testing on week 3-4 time scales.
- Coupled FV3-GEFS forecast skill for weather scales, especially for weeks 1-2, must show sufficient improvement over the uncoupled FV3-GEFS, as well as the operational GEFS V11 (and CFS V2) forecast skill in order to justify the cost of coupling. If a coupled system is not ready, we will explore alternative, simpler approaches.
- Timely execution of reanalysis/reforecast project, which depends on computational resource availability and the stability of the FV3 model and DA system. When the reanalysis is generated (using FV3), the FV3 system should be as close as possible to the eventual operational version.

Major resources requirements:

- Personnel:
  - EMC: 18 FTE (Ensemble model development, coupled system development, Reforecasts, T&E and transition to operations)
  - Partners: ESRL/PSD (~6 FTE) for reanalysis/reforecast and GEFS development in FY2017; GFDL (xx FTE); other?
- HPC for development: ~25 M of CPU per month, ~500TB of disk space, and ~5 PB of archive (tape)

Dependencies/linkages with other projects:

- NEMS/ESMF framework advancements.
- Via collaboration with DA team, a stable, agreed-upon procedure for atmospheric ensemble initialization, via presumably 4D-En-Var system, and stochastic physics. We will need resolution of whether EnKF used in 4D-En-Var will be moved from the late to the early DA cycle (or both), and then whether GEFS atmospheric initial conditions will be initialized from analysis perturbations (EnKF in early cycle) or from 6-h forecast perturbations (EnKF in late cycle).
- Via collaboration with coupling team, readiness of GFDL MOM6; CICE; and DA for component models; i.e., if a coupled ocean/ice/land/atmosphere state is expected for the forecast, the GEFS

project will depend on the existence of a stable, well-tested coupled prediction system. If a coupled prediction system is not expected, then the forecasts will have dependencies on other methodologies such as transplantation of CFSv2 forecast anomalies.

- Via collaboration with land-surface team, agreement on the procedure for control land-state initialization in the GEFS in advance of reforecast production (roughly 1 July 2018). Will the control state be supplied by the GLDAS, and if so, to what extent will GLDAS use forcing from FV3 and what approach will be used to deal with the latency of the GLDAS system.
- Reanalyses/reforecasts are available and data sent to key partners (MDL, CPC, NWC) prior to ops.
- Agreement on the procedure for initialization of land-state initial perturbations, in collaboration with ESRL/PSD.
- ESRL/PSD stochastic physics methods successfully ported, tested, and verified in the FV3/NEMS framework (ESRL/PSD in collaboration with EMC staff).
- In collaboration with physics working group, advanced physics options recommended and specifics delivered by 1 April 2018 so they can be used in reanalysis production.
- MET based verification and validation; process-oriented metrics for ensemble evaluation
- Refactored NCEP POST (UPP) and product generation
- Unified Workflow
- Transition to VLab and Code Management/Governance for coupled system components

Core development partners and their roles:

- NCEP/EMC: Ensemble Model development (including integration into NEMS framework and unified workflow), partner with NESII on development and integration of land, ocean, waves and sea-ice model components into NEMS and couple to FV3-GFS using NUOPC mediator; test various ensemble perturbation methods (SPPT, SKEB, SHUM and land surface parameter perturbations); test representation of process-level uncertainty in physics; ~20-year reforecasts including extension to weeks 3&4; determine optimal configuration for ensemble size and resolution; develop post-processing, bias corrections, and products for FV3-GEFS; conduct retrospective and real-time experiments, testing and evaluation, and transition to operations
- GFDL: MOM6 and CICE development
- ESRL/GSD (NESII): Partner in development and integration of land, ocean, waves and sea-ice model components within NEMS and coupling to FV3-GFS using NUOPC mediator.
- ESRL/PSD: Reanalysis project; development of stochastic physics methods; methods for treating land-surface related uncertainties, methods for postprocessing of model guidance in the National Blend of Models project.
- NCEP/CPC: Evaluation metrics and support for verification and validation

Major Milestones:

- (Q2FY18) Prepare FV3-GFS for reanalysis project: Develop and test low-resolution version of FV3-GFS and FV3-GDAS, and configure the model for reanalysis project.
- (Q3FY18) Determine ensemble configuration for FV3-GEFS: Configure for optimum ensemble size (# members), resolution, physics, and coupling to Ocean, Sea Ice, Land and Wave models using NEMS/NUOPC mediator; conduct testing for quality assurance and computational efficiency.
- (Q2FY19) Produce ~20-year reanalysis datasets: Mainly ESRL/PSD activity. Determine configuration of the reanalysis system; develop observational database for reanalysis; prepare observational inputs; and produce reanalysis suitable for reforecasts and calibration.
- (Q3FY19) Produce ~20-year reforecast datasets for FV3-GEFS: Finalize ensemble configuration and produce reforecasts consistent with the reanalysis data; extend the reforecast length to 35 days.
- (Q4FY19) Transition FV3-GEFS into operations: Conduct pre-implementation T&E; transition the system for operational implementation.

Other Milestones associated with this project:

MOM6 and CICE in NEMS:

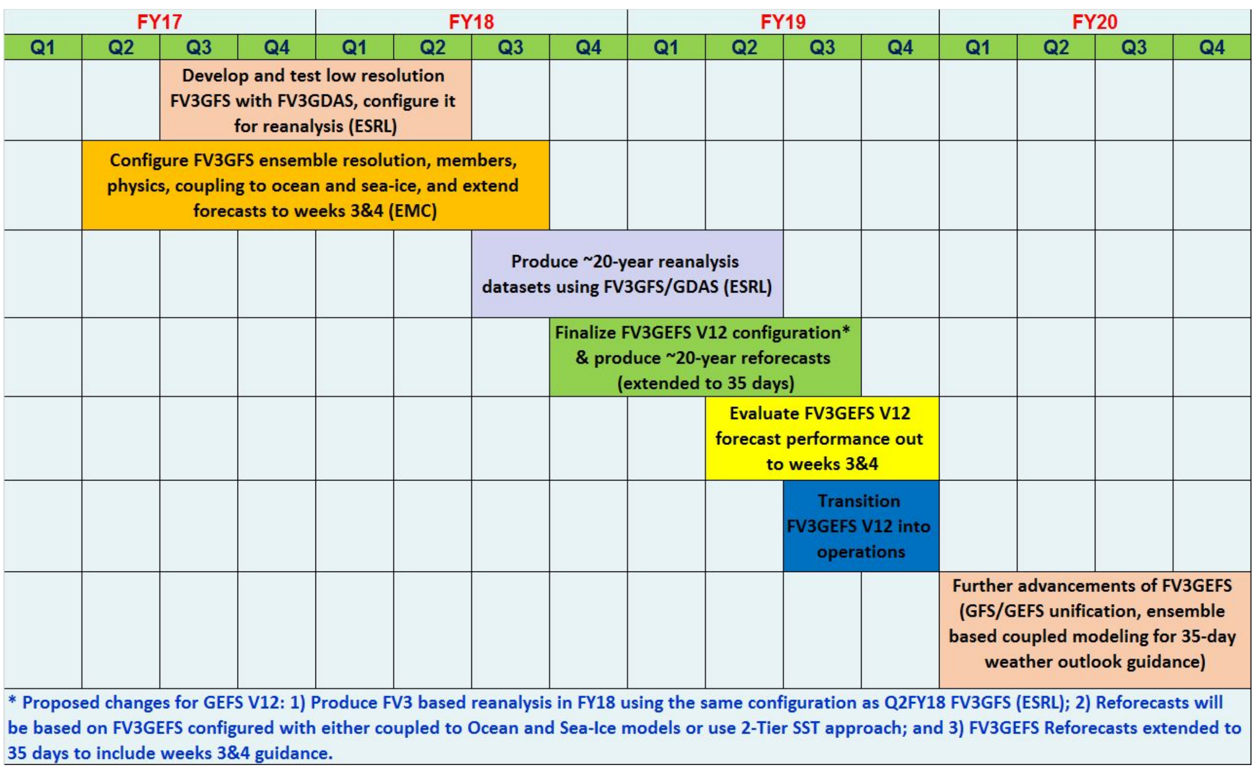
- (Q2FY18) Couple MOM6 and CICE models with FV3-GFS: Couple MOM6 and CICE models with FV3-GFS in NEMS using NUOPC mediator and caps; configure the ocean and sea ice models for weather-scale applications; test, evaluation and benchmark the coupled model performance for 0-35 days; develop data assimilation methods for the coupled components; configure the coupled FV3-GFS model for weeks 3&4 ensemble forecast applications

Unified Workflow:

- (Q2FY19) Modular and object oriented workflow design: Develop and implement Community and Operations Workflow (CROW) with object oriented scripting and automation tools for all coupled system components and the ensemble system.

Unification of Global Wave Ensembles into FV3-GFS:

- (Q2FY19) Couple FV3-GEFS to WAVEWATCHIII ensembles: Integrate the wave model ensembles into FV3-GEFS using NEMS/NUOPC coupler; test the impacts of two-way interactive wave physics; replace global wave model products with the wave coupled FV3-GEFS.



1.3: FV3-Seasonal Forecast System (SFS)

Project overview: The FV3-SFS project will develop the next generation seasonal forecast system based on the FV3 dycore. The seasonal forecast system will provide model guidance out to 9 months. FV3-SFS will include all the components that are being developed for the FV3-GEFS system (coupling between FV3, MOM6, WAVEWATCH III, CICE5LSM) with focus on processes that occur at longer time scales than those for FV3-GEFS. (Note: There is a lot of overlap in processes at the week 3-4 time scale of FV3-GEFS and the longer time scale of FV3-SFS, where developments will be leveraged for both systems). The stochastic physics will be expanded to the ocean model to provide greater spread for the coupled system. The initialization of the other components (land, aerosol waves, sea ice) will also be developed.

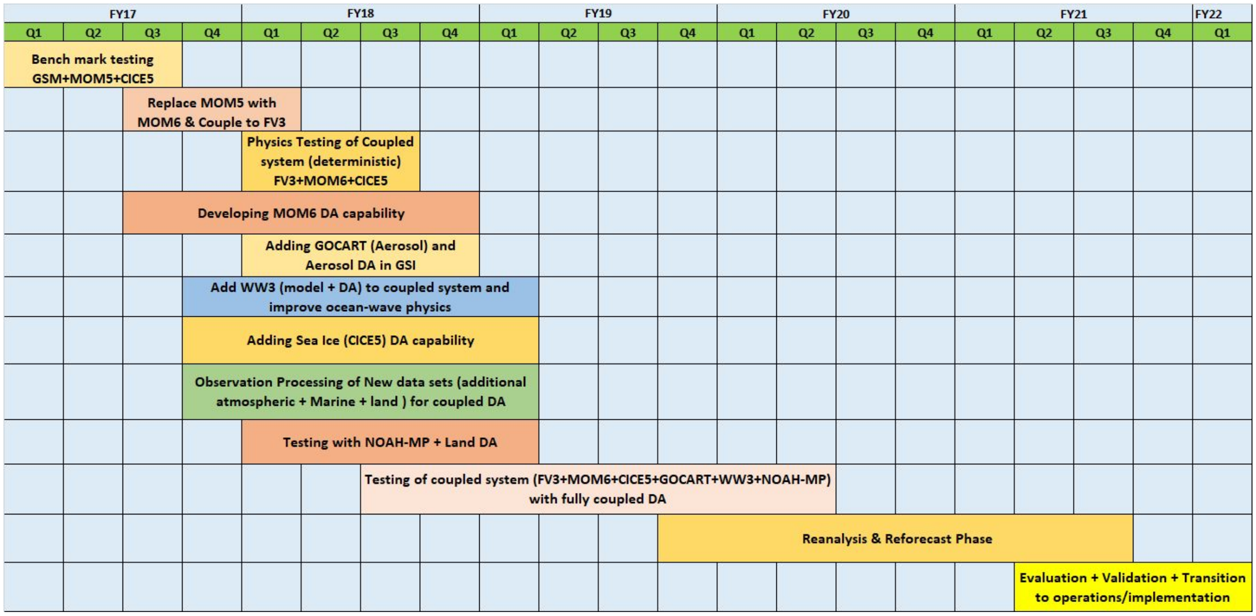
Major Risks and Issues:
- Computational resources for model development
- New physics algorithms for coupled systems require extensive testing
- Data assimilation techniques for sea ice still at early stage of development

Major resources requirements:
- Personnel:
  - EMC: xx FTE (tasks….)
  - Partners: GFDL (~xx FTE) for xxx; other?
- HPC for development: xx???

Dependencies/linkages with other projects:
- Development for FV3-GEFS will feed into this system
- NEMS / NUOPC infrastructure for the component models needs to be ready; requirements need to be communicated

Core development partners and their roles:
- NCEP/EMC: Partner with ESRL/GSD (NESII) to develop the coupled system in the NEMS framework including coupling the MOM6, WAVEWATCH III, CICE5 and GOCART components; develop DA framework for each of the components; test new physics algorithms for coupled systems
- GFDL: Partner with EMC to develop wave and ocean coupled mixing parameterization. GFDL will also provide expertise in FV3 development and ocean modeling. The FV3-SFS development has numerous similarities with the CM4 model being developed by GFDL, and as such GFDL will provide their expertise knowledge in coupling FV3 with MOM6.
- ESRL/GSD (NESII): Partner with EMC and GFDL to develop the coupled system in the NEMS framework. The NESII team led development of the NEMS mediator and previous coupling of atmosphere, MOM5, CICE5, and WAVEWATCH III.

Major Milestones:
- (Q3FY18) Prototype coupled system with FV3-MOM6-WAVEWATCHIII-NOAH-CICE5 with initialization for the individual components
- (Q4FY18) Upgrade to NOAH-MP land model
- (Q4FY19) Include new physics processes for coupled components, including testing alternative atmospheric algorithms for seasonal scales
- (Q1FY20) Freeze system and begin 30 year reanalyses and reforecasts
- (Q1FY21) Final validation and evaluation; and preparation for transition to operations
- (Q1FY22) Operational implementation of FV3-SFS


FY17
FY18
FY19
FY20
FY21
FY22
Q1
Q2
Q3
Q4
Bench mark testing GSM+MOM5+CICE5
Replace MOM5 with MOM6 & Couple to FV3
Physics Testing of Coupled system (deterministic) FV3+MOM6+CICE5
Developing MOM6 DA capability
Adding GOCART (Aerosol) and Aerosol DA in GSI
Add WW3 (model + DA) to coupled system and improve ocean-wave physics
Adding Sea Ice (CICE5) DA capability
Observation Processing of New data sets (additional atmospheric + Marine + land) for coupled DA
Testing with NOAH-MP + Land DA
Testing of coupled system (FV3+MOM6+CICE5+GOCART+WW3+NOAH-MP) with fully coupled DA
Reanalysis & Reforecast Phase
Evaluation + Validation + Transition to operations/implementation

1.4: FV3 Regional/Meso

Project overview: As part of the NWS commitment to move towards a National Unified Modeling System, NCEP's Regional/Mesoscale Modeling Suite will transition to use a high-resolution version of the FV3 dynamic core (FV3-Regional), both for the modeling and data assimilation components (FV3-Regional DA). The precise configuration of the regional/mesoscale system using FV3 is still under consideration. As of this writing, a regional "standalone" system using FV3 is under development by EMC, with the assistance of GFDL scientists. In addition, NSSL and SPC will compare performance of global FV3/3 km CONUS nest to emerging stand-alone regional FV3 in daily real-time forecasts to ensure internal consistency. The milestones and decision points for the way forward are presented below. The goal of the project is to establish a viable and scientifically robust Regional FV3 modeling and data assimilation system at convective-allowing scales, which will be provided to related EMC implementation projects to provide high-resolution deterministic and ensemble guidance at convective-allowing scales. To properly service the customers, the forecasts must be available reliably and at the appropriate time within available HPC resources.

Major Risks and Issues:

- Adequate computational resources for FV3-Regional for development
- Documentation, training, code management and access of codes by core partners
- Demonstration of superior performance of FV3-Regional from scientific evaluation
- Alignment with Unified Model Development strategy

Major resources requirements:

- Personnel: EMC: 9.0 FTE (FV3-Meso Model Development (nesting), physics, DA)
- Partners: ESRL (3 FTE), GFDL (2 FTE), NSSL (2 FTE)
- HPC for development: ~300 nodes per run (assume full set of 3 km CONUS/Alaska/Hawaii/Puerto Rico runs, plus a Fire Weather-like nest); ~5 TB scratch space per run, ~ 5 TB per day of HPC disk space

Dependencies/linkages with other projects:

- FV3 Regional DA, ESRL/PSD DA integration
- NEMS/ESMF framework requirements
- Availability of EMC and ESRL/GSD mesoscale physics for use with FV3 dynamics
- MET based verification and validation
- Refactored NCEP POST (UPP) and product generation
- Unified Workflow

Core development partners and their roles:

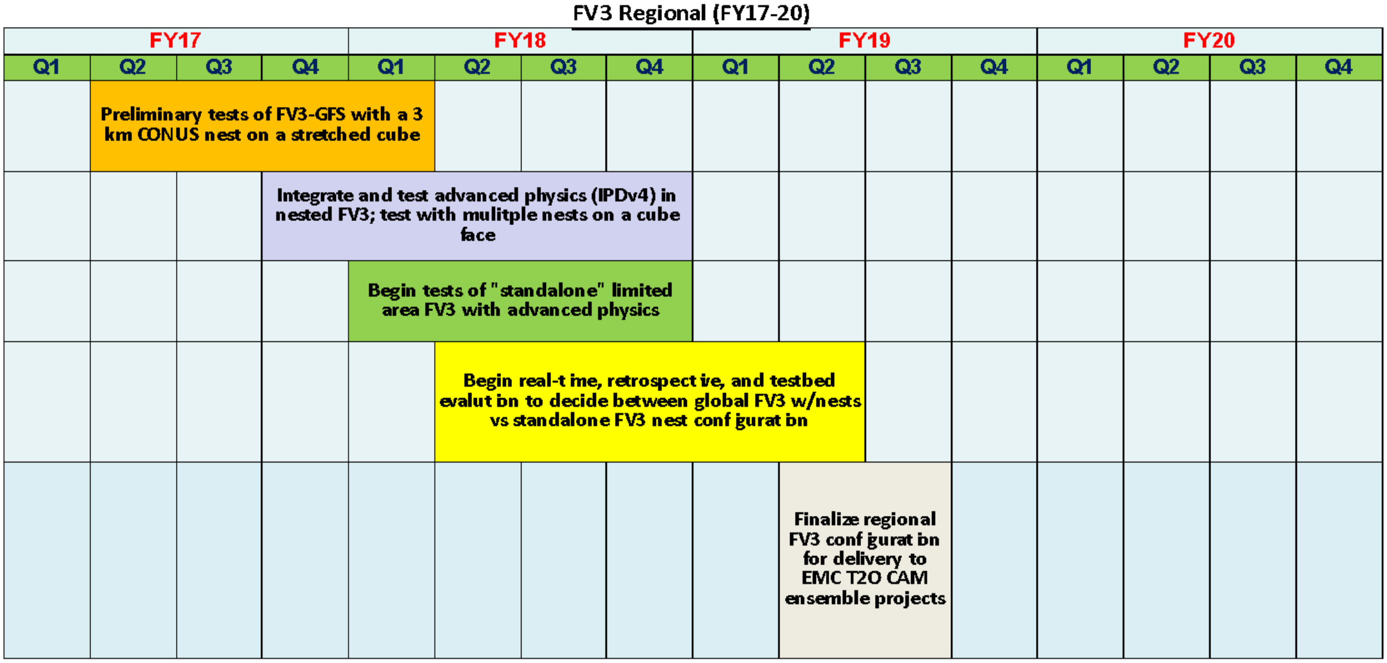
- NCEP/EMC: Model development (including physics and data assimilation), integration into NEMS framework and unified workflow, code management, retrospective and real-time experiments, testing and evaluation, transition to operations
- ESRL/GSD: Model development including physics and DA; retrospective and real-time experiments, testing and evaluation
- NSSL and SPC: Daily real-time forecasting and evaluation based on applications for severe-weather prediction at SPC and elsewhere

- GFDL: Utilities for FV3 Grid Structure and I/O; Model diagnostics and troubleshooting; NEMS Integration Support; Documentation and Training; Advanced physics connections to IPDv4
- ESRL/PSD and JCSDA: DA development support

Major Milestones:

- (Q1FY18) : Preliminary tests of global FV3GFS with a 3 km CONUS nest on a stretched cube
- (Q4FY18) : Tests with multiple nests on a cube face; FV3 "standalone" limited area capability
- (Q4FY18) : Advanced physics in the regional FV3 nests
- (Q2FY19) : Complete real-time/retrospective/testbed evaluations of different advanced physics options in FV3 3km nest under three different configurations: 1) Regional FV3 parent with 3km nests; 2) Global FV3 parent with 3km nests; 3) "Standalone" 3km runs with no FV3 parent
- (Q2FY19) : Decision on which regional FV3 nest configuration gives the best results and optimizes HPC
- (Q2FY19) : Final version to delivered to FV3 CAM ensemble projects for further development, testing and operational implementation

FV3 Regional (FY17-20)



1.5: FV3 Regional Ensemble Forecast System (REFS)

Project overview: Another aspect of the National Unified Modeling System is to replace NCEP's Regional/Mesoscale Modeling Suite with regional ensemble-based systems that provide probabilistic guidance. During the FY18-20 period, two configurations of a "day 2-3" CAM ensemble will be considered to replace HREFv2 (the operational baseline). The first configuration will test whether to continue to run different model cores and operational physics packages as with the current HREFv2, but adding both FV3 CAM runs and extended HRRR v3 runs, increasing the number of members and/or keeping only the best performing model components. The second configuration will test a regional FV3 CAM ensemble made up of either nested runs inside a global parent or as standalone limited-area domains. Initial condition perturbations will be provided from the FV3-GEFS and (if available) from an FV3-based regional EnKF data assimilation system. Multiple stochastic physics methods (STTP, SKEB, etc.), random soil moisture and temperature perturbations in the land states, and multiple physics will be evaluated. The project will collaborate closely with the FV3-GEFS effort, as well as a joint EMC-ESRL effort to develop a higher-resolution, shorter-range global FV3 ensemble.

The determination of forecast improvements will be an enormous effort that will involve objective verification statistics, and for the ensemble systems in this project that includes probabilistic verification statistics. The MET verification system will serve as a common tool used by different development groups. Experimental forecasts from each of the systems will also be evaluated through forecaster feedback in NCEP testbeds, EMC MEG reviews, and MEG-STI activities.

Major Risks and Issues:

- Computational resources dedicated for model development and for operations.
- Successful development of FV3-GFS, FV3-CAM and FV3-NCEP Post.
- Failing to outperform the SREF and HREF.
- Identifying a set of generally agreed upon metrics for making evidence-based decisions.
- Insufficient development and test resources to support the simultaneous co-development of both regional and global ensemble systems.

Major resources requirements:

- Personnel:
  - EMC: 3.0 FTE (Ensemble configuration and testing, ensemble product, evaluation and transition to operation)
  - Partners: ESRL/GSD, ESRL/PSD, GFDL
- HPC for development: For each run, ~144 nodes per member on WCOSS-Cray

Dependencies/linkages with other projects:

- FV3 regional/meso, new HRRRE (including the FV3 regional rapidly updated ensemble DA), FV3-GFS/GEFS, FV3-HRGEFS (high resolution GEFS)
- ESRL/PSD stochastic parameterization methods to treat model uncertainty.
- Advanced physics options
- MET based verification and validation
- NCEP POST (UPP) and product generator
- Unified Workflow

Core development partners and their roles:

- NCEP/EMC: Ensemble Model development and testing (IC, physics and possibly land surface perturbations) , ensemble products, ensemble evaluation, and transition to operation
- ESRL/GSD: Model development including physics; ensemble products and evaluation, retrospective experiments, testing and evaluation
- GFDL: Providing necessary technical support
- ESRL/PSD: Development of stochastic parameterization methods, testing of global ensemble predictions.
- NSSL, SPC, WPC, AWC: Various testbed evaluations

Major Milestones:

- Q4FY18: Complete build a beta version of the regional FV3 CAM ensemble (second configuration), include one or more regional FV3 runs in the multi-core ensemble (first configuration).
- Q2FY19. Evaluate the forecast performance of the two configurations to determine the most skillful system.
- Q4FY19: Provide forecasts from the most skillful configuration for evaluation by various NCEP testbeds.
- Q4FY20: Real-time and retrospective testing of the most skillful configuration for possible operational implementation

<u>FV3 Regional Ensemble (FY17-20)</u>

<table>
<tr><th colspan="4">FY17</th><th colspan="4">FY18</th><th colspan="4">FY19</th><th colspan="4">FY20</th></tr>
<tr><th>Q1</th><th>Q2</th><th>Q3</th><th>Q4</th><th>Q1</th><th>Q2</th><th>Q3</th><th>Q4</th><th>Q1</th><th>Q2</th><th>Q3</th><th>Q4</th><th>Q1</th><th>Q2</th><th>Q3</th><th>Q4</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2">Build prototype regional FV3 ensemble</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="3">Compare forecast performance to multi-core version</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="3">Evaluate in NCEP testbeds and real-time parallels</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2">Evaluate for operations</td></tr>
</table>

1.6: FV3 based hurricane model developments: Building and testing moving nests within the FV3 framework with coupling to oceans and waves

Project Overview: Moving nests in the operational HWRF and HMON hurricane forecast systems are associated with their parent domains in such a way that the nests always remain oriented to the same map projection as that of the parent. A critical result of this is that immediately following a shift in position only the leading edge of the nest must be regenerated through interpolation of all the dynamical and physical fields whereas the vast majority of the nest's area needs no interpolation to account for the shift. Interpolation can lead to degradation so minimizing it when nests move is a very important feature provided by so-called parent-oriented nests. In addition the cost of generating new interpolation weights following shifts is limited to only those few points along the leading edge. Given the inherent benefit of this type of parent-nest association and that EMC developers have considerable experience with it through HWRF and HMON, EMC proposes using this same fundamental approach for building a moving nest capability in FV3.

The existing nesting framework in FV3 successfully uses FMS for all interactions between static nests and their parents. The same can then be done for moving nests and parents after completion of upcoming FMS enhancements that include allowing multiple nests on a parent as well as permitting a nest to lie on edges and corners of FV3's cubed sphere. A parent-oriented moving nest crossing an edge will then lead to nothing more than following the change in orientation that occurs at every edge of the cubed sphere. Crossing a cube's corner will lead to a concave kink in the nest domain which of course disappears as the nest domain moves beyond the corner (Rancic et al., 2015).

When coupling an atmospheric parent-nest system to other earth system component models (e.g., ocean, sea ice, waves, land, storm surge) FMS could also be used. It provides the capability to couple various earth system component models lying on different logically rectangular grids and is designed to conserve fluxes between those systems (including mass and momentum flux adjustments). An alternative to FMS for coupling would be to explore use of NEMS (NOAA Environmental Modeling System) which provides an infrastructure underlying a coupled modeling system that supports predictions of Earth's environment at a range of time scales. Coupling of other earth system components to FV3 would then be accomplished using the NEMS mediator. Any NUOPC enabled physics package (IPDv4) would also be available for parent/child nest applications.

Major Risks and Issues:

- Computational resources for model development
- Adequate funding for personnel from NESII and GFDL
- Delays in Meso/regional FV3 developments and NEMS/Coupling Architecture projects

Major resources requirements:

- Personnel: 3 FTE per year (EMC: 2 FTE; NESII: 0.5 FTE; GFDL 0.5 FTE)
- HPC for development: 2M hrs per month, 100 TB of storage

Dependencies/linkages with other projects:

- Developments for Global FV3
- Static FV3 nests (CAM WG)
- FMS and/or NEMS framework support is highly required

Core development partners and their roles:

- EMC (Lead, moving nest alternatives in FV3)
- GFDL: Implementation of required functionality in FV3, including additional flexibility for nest placement (multiple nests, telescoping nests, nests over cube edges/corners).
- NSSL (Static Nests within FV3)
- AOML (Moving nests in FV3)
- NESII/GSD (support for ESMF and NUOPC/NEMS functionality)

Major Milestones:

- Q3FY18: Identify/transfer relevant static nest initialization routines to moving nest integration routines (assumes personnel is available to begin this work in Q2FY18).
- Q1FY19: Complete methods for updating moving nest boundaries.
- Q4FY19: Complete methods for updating full fields in moving nests.
- Q2FY20: Complete handling of moving nests crossing edges and corners of FV3 cube.

<u>Project 3: Moving Nests for FV3 (EMC Approach, includes development of DA and coupling to ocean/waves for hurricanes) (FY17/18-20)</u>

<table>
<tr><th colspan="17">Implementation Plan for Moving Nest for FV3 Hurricane Applications (EMC Approach) (FY2017-2020)</th></tr>
<tr><th rowspan="2">Milestone</th><th colspan="4">FY17</th><th colspan="4">FY18</th><th colspan="4">FY19</th><th colspan="4">FY20</th></tr>
<tr><th>Q1</th><th>Q2</th><th>Q3</th><th>Q4</th><th>Q1</th><th>Q2</th><th>Q3</th><th>Q4</th><th>Q1</th><th>Q2</th><th>Q3</th><th>Q4</th><th>Q1</th><th>Q2</th><th>Q3</th><th>Q4</th></tr>
<tr><td>Reuse static nest components for moving nest</td><td colspan="7">Identify/transfer static nest initialization routines to moving nest integration routines</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Boundary conditions for moving nests</td><td></td><td colspan="8">Complete methods for updating moving nest boundaries.</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Choice of FMS/ NEMS or hybrid</td><td></td><td></td><td colspan="6">Determine use of FMS and/or NEMS or a hybrid framework (similar to NGGNF) for developing moving nest</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Update full fields in moving nests</td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="6">Complete methods for updating full fields in moving nests.</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Nests crossing edges and corners of FV3 cube</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="6">Complete handling of moving nests crossing edges and corners of FV3 cube</td><td></td><td></td></tr>
<tr><td>Extending coupling for moving nests</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="7">Develop/extend coupling to ocean, waves etc. For mioving nests</td></tr>
</table>

1.7: 3D Rapid Updating RTMA/URMA Systems

Project overview: This project is a collaborative effort among scientists from ESRL/GSD, NCEP/EMC, JCSDA, and NSSL, who will extend the existing 2-D Real-Time Mesoscale Analysis (RTMA) and UnRestricted Mesoscale Analysis (URMA) to three dimensions, assimilate in-situ and remote observations from a variety of platforms with a high-resolution very-short- range model background, and synthesize the output to produce new 3-D analysis products with a short latency and very frequent sub-hourly updates. Furthermore, this project is intended to facilitate the unification of NOAA nowcasting capabilities to meet needs for situational awareness information and forecast verification.

The sub-hourly 3D RTMA/URMA system will build upon the operational 2D, hourly RTMA/URMA system, which is currently limited to fields that correspond to official National Weather Service (NWS) gridded forecasts, mostly surface fields. Extending the 2D hourly RTMA/URMA to three dimensions allows for the creation of highly useful nowcasting products, including full-column representation of standard meteorological fields such as temperature, water vapor, and wind, as well as hydrometeors (i.e., clouds, precipitation of all forms), and eventually aerosols. The 3D system will also include 2-D land-surface diagnostics (e.g., soil moisture, snow state from multi-level land-surface fields), and convective (e.g., hail size, supercell rotation tracks) fields, developed through collaboration with the Office of Water Prediction (OWP) and National Severe Storms Laboratory (NSSL), respectively. This effort will also lead to improved analysis fields that will benefit NOAA's National Blend of Models (NBM) project.

As a pathway to the 3D system, this effort will focus initially on improvements to the 2D RTMA/URMA system in Year 1 to meet outstanding issues in support of the NBM. Such advancements will also benefit the 3D system. The 3D RTMA/URMA and near-term 2D RTMA/URMA enhancement are critical for quality of NOAA's National Blend of Models (NBM).

Major Risks and Issues:

- HPC priority for fast, low latency turn-around for real time products
- Science issues with model errors and limited observational network may limit quality of 3-D analysis, potentially limiting usefulness
- Governance/oversight for effective unification of a variety of products

Major resources requirements:

- Personnel:
    - EMC: 9 FTE (Data assimilation, workflow, obs processing, QC, background errors, validation/verification, implementations)
    - ESRL: 3 FTE (Data assimilation, QC, background errors)
- HPC for development: 500K CPU hrs per month on WCOSS, Theia, and Jet; 50 TB scratch space and 500 TB HPSS storage prior to implementation

Dependencies/linkages with other projects:

- NBM
- AWC C&V Project and Helicopter Emergency Medical Services
- Observation Processing
- An available convection-allowing ensemble for DA

- An available convection-allowing model for background
- Satisfactory evaluations from stakeholders and partners
- Unified Workflow (CROW)
- Transition to VLab and Code Management/Governance
- JEDI

Core development partners and their roles:

- EMC - Co-lead: (Data assimilation, workflow, obs processing, QC, background errors, validation/verification, implementations)
- ESRL/GSD - Co-lead: Data assimilation, QC, background errors

Major Milestones:

- (Q1FY18-Q4FY18) Enhance 2D RTMA/URMA to Support NBM: Continue introducing enhancements to existing 2D RTMA/URMA via improvements in quality control, specification of background errors, etc.
- (Q1FY18-Q3FY19) 3D RTMA/URMA for CONUS: Develop initial operating capacity of 3D RTMA/URMA with sub-hourly updates over CONUS. Run in experimental mode and compare against existing RTMA/URMA.
- (Q3FY18-Q3FY19) 3D RTMA/URMA for AK: Extend 3D RTMA/URMA to Alaska and test/evaluate.
- (Q3FY18-Q1FY20): Evaluate 3D RTMA/URMA Systems: Pursuant to comparable or better performance relative to existing 2D RTMA/URMA, consider implementing 3D RTMA/URMA system(s).
- (Q4FY19-Q4FY20): Evaluate EnVar Approach to 3D RTMA/URMA: If available, test and evaluate available convection-allowing ensemble hybrid 3D RTMA/URMA analysis.

Development Plan for 3D RTMA/URMA (FY2018-2020)

RTMA/URMA	FY18				FY19				FY20			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Enhance 2D RTMA/URMA to Support NBM	Enhance existing 2D RTMA/URMA via improved OBS QC, specification of background errors, etc.											
3D RTMA/URMA for CONUS	Initial 3D RTMA/URMA with sub-hourly updates in development/testing											
3D RTMA/URMA for AK			Extend 3D RTMA/URMA to AK and test									
Evaluate 3D RTMA/URMA Systems			Evaluate 3D system and compare to 2D system(s). Refine and update 3D system(s) as needed. Consider implementation.									
Evaluate EnVar Approach to 3D RTMA/URMA								Given an available, pre-existing convection-allowing ensemble, develop and test EnVar in 3D RTMA/URMA				

1.8: RAPv5/HRRRv4

Project overview: During FY18-20, an hourly-updating HRRR (WRF-ARW) 3-km ensemble will be tested using storm-scale ensemble data assimilation. Cycling of roughly 40 CAM members using a GSI-based Ensemble Kalman filter will assimilate conventional, radar, satellite, and other observations each hour. A nine-member HRRR ensemble will produce 18-h “day 1” forecasts over CONUS. Multiple stochastic physics methods (STTP, SKEB, etc.), random perturbations in the land surface states (soil moisture and temperature), lateral boundary perturbations, and inflation during the cycled data assimilation will promote spread and represent both initial condition and model forecast uncertainties. A RAPv5 deterministic mesoscale system will serve to provide periodic re-centering to the hourly-cycling CAM ensemble mean for inclusion of larger-scale information as well as providing HRRR ensemble lateral boundary conditions. Ensemble-based post-processing methods will produce probabilities of weather hazards for all seasons. The 40-member data assimilation ensemble will also be used in hybrid ensemble/variational data assimilation to initialize a HRRRv4 for hourly-updating 3-km deterministic prediction. The RAPv5/HRRRv4 storm-scale data assimilation and forecast ensemble will be delivered to EMC in Q3FY19 for a Q2FY20 operational implementation, pending evidence-based support from testbeds and other objective verification measures along with sufficient computing resources. This hourly-updating ensemble system would also provide the foundation for future Warn-on-Forecast (WoF) capabilities. If resources do not permit or if the evaluation does not validate the ensemble forecast component, the HRRRv4 will still have the storm-scale ensemble data assimilation but will retain a deterministic forecast component. At this time, it is unclear whether HRRR-Alaska will become an ensemble system.

Major Risks and Issues:

- Computational resources dedicated for model development and for operations
- Successful development of FV3-GFS, FV3-CAM, FV3-NCEP Post
- Successful development of stand-alone regional FV3
- Performances (to outperform SREF, HREF, and HRRRv3)

Major resources requirements:

- Personnel:
  - ESRL/GSD: 8 FTE (Ensemble configuration and testing, ensemble product, evaluation and transition to operation)
  - EMC: 3 FTE (Operational transition + evaluation)
  - NSSL: (?)
  - GFDL: (?)
  - Others: (?)
- HPC for development: 800 nodes on WCOSS-Cray

Dependencies/linkages with other projects:

- FV3-GFS/GEFS and other FV3-regional projects
- ESRL/PSD stochastic-based ensemble perturbation methods
- Advanced Physics options recommended by SIP Physics Working Group
- Integration of mesoscale physics packages into IPD
- Interaction with data assimilation testing at PSU and OU/NSSL/CAPS
- MET based verification and validation; process-oriented metrics for ensemble evaluation
- NCEP POST (UPP) and product generator
- Unified Workflow

- Transition to VLab and Code Management

Core development partners and their roles:

- ESRL/GSD: Model development including data assimilation, physics; ensemble products and evaluation, retrospective experiments, testing and evaluation

- NCEP/EMC: Ensemble Model development and testing (IC, physics and possibly land surface perturbations) , ensemble products, ensemble evaluation, and transition to operation
- GFDL: Providing necessary technical support
- ESRL/PSD: Development of stochastic perturbation methods
- SPC/NSSL: Evaluation in the Spring Experiment
- WPC: Evaluation in Winter Weather and Flash Flood experiments
- AWC: Evaluation in winter and summer aviation testbeds

Major Milestones:

- Q1FY18: Begin running cold-start FV3 global at CAM-scale once per day
- Q2FY18: Operational implementation of RAPv4/HRRRv3 including 36 hr forecasts for member inclusion in HREFv3
- Q2-Q4FY18: Provide RAPv5/HRRRv4 deterministic and ensemble forecasts for evaluation by various NCEP testbeds, such as WPC's Winter Weather and Flash Flood experiments, SPC/NSSL's Spring Experiment, and AWC's winter and summer aviation experiments.
- Q1FY19: Begin testing the FV3-based CAM ensemble data assimilation
- Q3FY19: Code delivery of RAPv5/HRRRv4 deterministic and ensemble system to EMC
- Q2FY20: Conditional implementation of RAPv5/HRRRv4 including hourly-updating storm-scale ensemble data assimilation and forecasts pending science evaluation
- Q2FY20: Freeze RAP/HRRR systems and put all RAP/HRRR resources into transitioning them to FV3-based systems
- Q4 FY20: Complete tests of the FV3-based CAM ensemble data assimilation

1.9: Waves in GFS / GEFS

Project Overview: The goal of this project is to develop a coupled atmosphere-wave system, running the multi-grid WAVEWATCH III (WW3) model coupled (two-way, if appropriate) in NEMS, including both GFS and GEFS. This coupled model will become part of the next-generation operational global forecast system at NCEP. We will start by evaluating the skill of a two-way coupled FV3-WW3 model. To complete the cycled tests, we will incorporate the needed components for coupling and WW3 pre- and post-processing, into the existing GFS workflow for FV3. This model will only use a single wave grid and subsequent milestones will add the capabilities within the WW3 ESMF/NUOPC cap to run the full multigrid WW3 system within NEMS. Optimal settings for wave physics parameterizations will need to be determined for both the one- and two-way coupled FV3-WW3 models, which will be achieved via the development of an objective framework for model tuning. Simultaneously, we will determine an optimal configuration of grids for the multigrid wave model, which will likely involve a redesign of the current wave multigrid mosaic.

Major risks and issues:

- Two way coupling may deteriorate physics skill scores (will resort to one way coupling in that case)

Resource requirements:

- Personnel: 2 FTE
- HPC for development

Core development partners and their role:

- Naval Research Laboratory: Development of NUOPC cap for Multi-grid version of WAVEWATCH-III

Major milestones:

- Include WW3 and wave verification in the GFS workflow (Q2FY2018)
- Perform cycled runs to evaluate skill with coupling (Q3FY2018)
- Fix load balancing issue with multi-grid partitions (Q2FY2018)
- Add capability for multiple import grids for wave model NEMS cap (Q3FY2018)
- Full multi_1 wave model in NEMS for forecast (one-way coupling) (Q4FY2018)
- Two-way coupling of weather model, if appropriate (Q1Y2019)
- Create internal WW3 export grid for wave model NEMS cap (Q4FY2019)
- Determine optimal configuration/redesign grids and physics for multigrid wave model in coupled mode (Q4FY2019)

1.10: Wave DA development

Project Overview: The JEDI data assimilation system is being developed for use for general data assimilation. The plan is to evolve all EMC data assimilation systems to the JEDI system over time. The goal of the present project is to include the wave data assimilation components in the same JEDI DA framework. As the first wave data assimilation approach integrated into JEDI, the development strategy is: 1. to add the necessary capabilities to accommodate the requirements for the wave DA and 2. To leverage the existing capabilities of the system.
With respect to these two fundamental principles, the following components have to be implemented: Import into JEDII the five dimensional (physical space: longitude, latitude, time; spectral space: frequency and direction) output fields of the wave model , the prefered data format is GRIB2. Import and pre-process the in-situ and satellite wave field observations; prefered data format is BUFR and prepBUFR. Add the appropriate wave forward operators. Add the appropriate models of error covariances for spectral wave models and wave observations. Export the analysis fields to format compatible with the model.
The new components will be model-agnostic, so they can be used for different applications with inputs from different wave models and observations, to be flexible and easy-to-update. The development will happen in two major steps: 1. Using the diagnostic variables of the wave model, e.g. significant wave height and 2. Using the prognostic variables, wave spectra. The final product will provide analysis based on variational, Ensemble Kalman Filters and hybrid approaches.

Major Risks and Issues:

- Adding the Wave DA features to JEDI will depend on JEDI development schedule
- Wave DA may not improve skill scores

Resource requirements:

- Personnel: 1 FTE
- HPC for Computing

Core development partners and their role:

- UKMO, IFREMER, Environment Canada: Developing alternative approaches to convert diagnostic variables to prognostic variables in the community WAVEWATCH III code that can be leveraged to compare model skill

Major milestones:

(Note: Code delivery for operations will be in coordination with GSI schedule)

- Grib2 I/O and Observations I/O (Q2FY2018)
- Additional code for waves DA, e.g. handling sea/land (Q2FY2018)
- Customize covariance models and update model restart files (Q3FY2018)
- Test JEDI-3-D Variational (Q4FY2018)
- Transition to operations (Q1FY2019)
- Test JEDI-EnKF (Q2FY2019)
- Test JEDI-Hybrid (Q3FY2019)
- Transition to operations (Q1FY2020)

1.11 Advanced scale-aware physics development and implementation

Project overview: The NOAA/NWS/NCEP/EMC's mission would be to continuously improve both the deterministic and probabilistic forecast guidance across all spatial and temporal scales from diurnal and meso scales to seasonal and global scales. Fundamental to achieving this goal is the continuous improvements to the numerical model that approximates the earth system, the state of which we want to predict. A major component of this prediction system that needs continuous improvement is the way in which physical processes are treated in a mathematical model approximating the system. Fundamental to the atmospheric prediction is the treatment of atmospheric physics, both resolved and unresolved. Physical parameterization development has been a critical driver of increased forecast accuracy of global and regional models, as more and more physical processes are accounted for with sophistication appropriate for the model's resolution in all three dimensions. Key atmospheric processes that are parameterized in current global models include subgrid turbulent mixing in and above the boundary layer, cloud microphysics and 'macrophysics' (subgrid cloud variability), cumulus convection, radiative processes, and subgrid scale gravity wave drag. Parameterizations of surface heat, moisture, and momentum fluxes over both ocean and land, subgrid mixing within the ocean due to top and bottom boundary layers, gravity waves and unresolved eddies, land surface and sea ice properties are also important on weather and seasonal time scales.

The advanced scale-aware project attempts to fill some of the gap we have in the treatment of physics in the current operational GFS. In this project we are attempting to improve microphysics (Morrison-Gettleman, Thompson, WSM6 etc), scale-aware convection (Chikira-Sugiyama with Arakawa-Wu extension, RAS, Scale-aware SAS, Grell-Freitas etc.), improved boundary layer and shallow convection treatment (Simplified Higher Order Closure – SHOC and Moist EDMF/TKE based new boundary layer scheme), stationary and non-stationary gravity wave drag, land surface model improvements , advanced treatment of radiation (RRTMGP), improved photochemistry parameterization for stratospheric ozone, and new simple parameterization to represent methane oxidation of water vapor in the stratosphere/mesosphere, and interactive aerosols. Advanced physics development goes hand in hand with the resolution both horizontal and vertical.

Major Risks and Issues:

- Computational resources (including CPU and storage) dedicated to the development and testing and evaluation for prediction at various scales
- Documentation, training, code management and access of codes by core partners and community
- Need to demonstrate the superiority of performance at multiple scales - Needs unified metrics.
- Alignment with Unified Model Development strategy
- Need to test as a coupled system
- Community involvement and support

Major resources requirements:

- Personnel: EMC: ?? FTE
- Partners: ESRL (2 FTE), GFDL (3 FTE), U. Utah, CSU, U. Washington, GMAO, SUNY ???
- HPC for development: ~20M CPU hrs per month on WCOSS, Theia, Jet and Gaea; ~500 TB ?? scratch space

Dependencies/linkages with other projects:

- NEMS/ESMF framework advancements

- Availability of post processing and verification software that can handle advanced physics

with appropriate documentation, training and user support.

- Support all other libraries and support in using/modifying FV3 dynamical core with new physics.
- Unified Workflow (CROW); Transition to VLab and Code Management/Governance and support to the physics developers.
- Availability of fast, easy to use CCPP and IPD, if the physics developer need to use these packages.
- Availability of coupled model test harness with user friendly workflow including evaluation and verification modules.

Core development partners and their roles:

- NCEP/EMC: Advanced physics development, integration into NEMS framework and unified workflow, code management, retrospective and real-time experiments, testing and evaluation
- GFDL: Utilities for FV3 Grid Structure and I/O; Model diagnostics and troubleshooting; NEMS Integration Support; Documentation and Training; Advanced physics connections to IPDv4
- ESRL/GSD; DTC/GMTB: Physics development and T&E
- ESRL/NESII: The NOAA Environmental Software Infrastructure and Interoperability (NESII) team provides ESMF/NUOPC advances and NEMS development and integration support.
- NGGPS/CPO funded PIs for R2O

Major Milestones:

- (Q4FY17) Install a version SHOC, CSAW, RAS, MG, Thompson, and WSM6microphysics schemes in to NEMS/FV3 IPDv4. Perform initial forecast only tests and do some tuning at different resolutions.
- (Q2FY18) Do further test, tune and evaluate various suites of physics components by making forecast only and/or cycled experiments. Also start testing in coupled mode at least some of the physics packages to evaluate in the seasonal prediction mode.
- (Q3FY18) Test and evaluate promising physics suites with higher horizontal and vertical resolutions in preparation for pre-implementation parallel testing and perform the sensitivity tests and tuning of the system for optimal performance.
- (Q2FY19): Advanced model configuration of FV3-GFS for transition to operations: Increase model resolution to ~10km 127L; implement advanced and scale-aware physics; perform retrospective and real-time evaluation of various configurations; integrate into unified workflow; conduct pre-implementation T&E; and prepare model for transition to operations

FY17				FY18				FY19				FY20			
Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Implement hierarchical physics tests, define initial metrics for evaluation															
		MYNN/EDMF (from HRRR physics) using IPDV4													
			Development of model versions suitable for testing												
	testing new physics parameterizations for the medium-term ('evolved') physics suite														
		Tuning and evaluation of Thompson, GFDL, and Morrison-Gettelman microphysics in FV3-GFS													
			Tuning and evaluation of RRTMGP radiation and evolved GFS EDMF boundary layer scheme												
			Testing and evaluation of the unified gravity wave drag physics												
			Testing and evaluation of the NRL ozone photochemistry and stratospheric water vapor parameterizations												
				Testing and evaluation of advanced convection parameterizations and representations of clouds and boundary layers											
							Transition advanced physics package for final T&E and T2O								
						Testing and tuning of proposed advanced physics suite in collaboration with EMC									

1.12: Hierarchical model development

Project overview: Hierarchical model development (HMD) is not a model/DA or ObsProc/post-processing/product-generation project, rather, it is development that follows a simpler-to-more-complex approach. This then requires the EMC Engineering and Implementation Branch (EIB) and partners to develop an overarching “architecture” for HMD, with primary emphasis on model physics. A focus on individual model components (and even sub-components within a given parameterization) allows problems to be confined to processes that can be observed and properly parameterized. This requires forcing and validation data sets to drive and validate parameterizations, where observations, model, and/or synthetic/idealized data sets provide the forcing to allow for a number of investigative tests. This allows one to examine the “phase space” for a given parameterization in response to a range of geophysical conditions, also allowing one to "stress test" parameterizations. Under HMD, individual components are increasingly coupled to test their interactions, again, requiring various forcing and validation data sets, up to Single Column Model (SCM) testing. Subsequently, tests include limited-area, regional and finally global and fully coupled atmosphere-ocean-land-etc modeling systems. In HMD, appropriate benchmarks must be passed and evaluation metrics must be assessed to validate individual parameterizations to more complex coupled systems, in their ability to represent processes. The set of benchmarks/metrics increase with the complexity of the system; for example, a benchmark for performance of the “offline” land model (e.g. surface bowen ratio) must also then be “passed” in global model tests that also include “large-scale” performance metrics (e.g. 500mb A.C. scores). This is the principle behind the NCAR/NOAA Global Model Test Bed (GMTB), and should be increasingly leveraged as a development partnership with NCEP/EMC (and others), where much of individual component development is higher in the R2O “funnel” (and less in the domain of EMC development), but this approach provides a better connection up the R2O funnel.

Major Risks and Issues:

· The traditional approach of making an educated scientific “guess” about the source of a given model bias and the corresponding change to a given model parameterization (or, “try something and see if it works”) does not allow for a comprehensive and robust solution to those model biases. The HMD approach maximizes use of resources, both personnel and compute, leveraging the often under-utilized data sets from field programs and other measurement networks.

· Model architecture must allow for “extraction” of many pieces of model code, enabling the various research partners easier access to those parts of the model code most relevant (to their research), making the R2O process more efficient for EMC and our partners.

Major resources requirements:

· Personnel:

· EMC: the EMC EIB should lead the development of the HMD system, making the HMD tools/procedures available to all development personnel working on model/DA development, internal to EMC and externally.

· Partners: NCO TBD.

· HPC for development: quite minimal for individual component development/testing, increasing for e.g. SCM and limited-area testing, prior to the “normal” model resources used to test operational models and their parallel systems, and potentially especially useful as an efficient procedure for fully-coupled models development with multiple earth system model components (atmosphere/aerosols, ocean, land-hydrology, sea-ice, waves).

Dependencies/linkages with other projects:

· All "upstream" R2O model development (primarily model physics) can be done under this paradigm.

Core development partners and their roles:

· NCEP/EMC: HMD system and tools, integration into NEMS framework, HMD code management.

· Partners: NCAR/NOAA GMTB/DTC, and other R2O partners, i.e. academic, other NOAA labs (e.g. GFDL), other agencies and institutes (e.g. NASA, our various university partners), including international collaborators and programs (e.g. ECMWF, UKMO; WMO WWRP/WCRP). HMD tools can be particularly useful for those external partners that have as their focus specific model parameterizations of interest, e.g. land-hydrology, boundary-layer turbulence, convection, cloud-radiation interaction, etc. Such a paradigm would provide a consistent and robust framework for development with EMC partners. Relevant to this is the NGGPS-supported work by GMTB/DTC in their design and development a Common Community Physics Package (CCPP) based on the current operational GFS physics package, including enabling an Interoperable Physics Driver (IPD).

Upgrade schedule:

· (Q1FY18-Q4FY19) Working with EMC's EIB, GMTB and other partners, establish the Model Development Hierarchy paradigm, e.g. code "extraction", benchmarks/metrics, forcing/validation data sets. Specific details TBD.

· (Q1FY20) HMD paradigm in place and utilized by EMC and partner model developers.

Gantt Chart: TBD working with EIB, GMTB, and other partners.

1.13: Data Assimilation development (Improved DA techniques and improved use of observations)

Project overview: The initial conditions for a model forecast are specified through a data assimilation system. In this system, the model is integrated forward for a short period and then adjusted based on the information in observations. By repeating this multiple times, the model forecast and adjusted analysis become close to reality. The primary focus to improve this process can be divided into 2 main components: Improving the data assimilation techniques (How the model solution is adjusted to the information in the observations) and the improved use of observations (What observations are used and how they are compared to the model solution). The focus of this project over the next three years will be on improving the data assimilation through various components of the assimilation technique (e.g., stochastic physics, details of the use of ensembles such as localization techniques, balance constraints, bias correction of the background, incremental analysis update and other components) and through the use of additional observations and improving the use of current observations with the development of advanced forward models, improve quality control schemes, improved specification of observational error, bias correction, thinning or super-ob dense observations, and other details. In the longer term, the atmospheric DA system will become a part of the unified EMC DA system built on the JCSDA JEDI infrastructure.

Major Risks and Issues:

- Basic science for all issues has not been sufficiently developed.
- Insufficient resources for adequate testing.
- Shifting priorities from higher levels of management
- Availability of data due to issues upstream
- Observations are not available or delayed.
- Unrealistic expectations for the impact of observations.

Major resources requirements:

- Personnel: EMC: 3 Fed, 21 contractors (observations - including obsproc)
- Personnel: EMC: 1.9 Fed, 5.4 contractors (DA infrastructure and technique development)
- HPC for development: infinite

Dependencies/linkages with other projects:

- Stochastic physics - Ensemble forecasting
- Appropriate initial conditions for ensembles - Ensemble forecasting
- Model biases and errors - Model physics and dynamics
- JCSDA (including JEDI project)
- GMAO development

Core development partners and their roles:

- NCEP/EMC: Obsproc, DA techniques, and use of observations
- PSD: Ensemble physics and techniques
- JCSDA - JEDI development
- JCSDA - Use of observations (including CRTM)
- GMAO - System development

Major Milestones:

- Will map into model implementations.
- Q2FY18: Implementation of new observations from JPSS-1 (CrIS,ATMS) and GOES-16 (AMVs). Potential components for this implementation are here.
- Q2FY18: Implement hybrid 4DEn-Var in parallel version of FV3GFS.

- Q2FY19: Increase vertical and horizontal resolution of GDAS to 127 levels and 35km.
- Q2FY20: Incorporate JEDI infrastructure and DA on native cube-sphere grid.

<table>
<tr><th colspan="4">FY17</th><th colspan="4">FY18</th><th colspan="4">FY19</th><th colspan="4">FY20</th></tr>
<tr><th>Q1</th><th>Q2</th><th>Q3</th><th>Q4</th><th>Q1</th><th>Q2</th><th>Q3</th><th>Q4</th><th>Q1</th><th>Q2</th><th>Q3</th><th>Q4</th><th>Q1</th><th>Q2</th><th>Q3</th><th>Q4</th></tr>
<tr><td></td><td></td><td colspan="4">Adopt GDAS (4D Hybrid En-VAR) DA for FV3GFS</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="6">Testing, Evaluation and Operational Implementation of new satellite datasets (GOES-16, JPSS, COSMIC-2 etc.)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td colspan="7">Increase vertical resolution to 127 levels and increase GDAS resolution to 35 km</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td colspan="9">Incorporate JEDI Unified Forward Operator and Modular GSI infrastructure</td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="7">Develop and implement DA on native cubed sphere grid</td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="6">Further advancements of FV3GDAS Global-Meso-Marine unification (Unified DA Development)</td></tr>
</table>

1.14 Ocean Data Assimilation (NCODA) to support RTOFS (FY17/FY18-FY20)

Project overview:

Currently, NCEP is providing eight days global ocean numerical forecasts by Real-Time Ocean Forecast System (RTOFS), based on HYbrid Coordinate Ocean Model (HYCOM). In the following three years, the major development will be introducing an ocean data assimilation system (NCODA) and providing, in addition to ocean forecasts, NCEP's global ocean numerical analysis. Development of a unified EMC data assimilation system through the JEDI project will eventually replace the NCODA system.

In 2013, EMC signed a Memorandum of Understanding (MOU) with Navy Research Laboratory (NRL) to port Navy Coupled Ocean Data Assimilation System (NCODA) to EMC. Having NCODA implemented at EMC will eliminate the need for a daily data feed from NRL to EMC to initialize RTOFS, as well as the need for EMC to remain in lockstep with NAVO/NRL with respect to core ocean forecast model development (currently HYCOM). The eventual transition to a unified DA system based on JEDI for real-time ocean analysis at NCEP will allow support of applications in the planned unified modeling framework, and the development of coupled ocean-atmosphere-sea ice data assimilation.

Major Risks and Issues:

- System delivered from NRL was with missing documentation, test cases, operational protocols, scripts and supporting codes
- NCEP is under-resourced for marine observation processing

Major resources requirements:

- Personnel: 3.5 FTE per year (EMC), 1 FTE (NRL)
- HPC for development: (2 Million CPU-hours on WCOSS, 50 TB of disc)

Dependencies/linkages with other projects:

- ANNEX 6 (Data Assimilation) Processing of marine/ocean observations
- ANNEX 6 (Data Assimilation) Monitoring/evaluation of ocean observations

Core development partners and their roles:

- US Navy (to support transitioning of NCODA capabilities to NCEP/EMC)

Major Milestones:

- FY18: Implement NCODA at EMC: 1) Develop and test NCEP data ingest into NCODA and NCODA QC. 2) Implement global NCODA+HYCOM; test and cycle using canned data as input.
- FY19: Transition development to unified EMC based on JEDI DA infrastructure.

Gantt chart:

Implementation Plan for NCEP NCODA (FY18 - 20)										
	FY18				FY19				FY20	
NCODA	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2

NCODA QC	Develop and test interface between NCEP operational data tanks and QC.									
NCODA 3DVAR	Implement global NCODA+HYCOM; test and cycle using canned data as input									
Real-time experiment, evaluation			Implement global NCODA+HYCOM; test and cycle using canned data as input							
Pre-operational testing					Transition to NCO					
Advanced DA								Transition to JEDI based DA system for ocean, including new data sources		

<u>1.15: Sea Ice Modeling and Data Assimilation (weather to seasonal scales)</u>

Project Overview: Sea ice modeling has been used in the NCEP modeling suite as part of CFSv2 (the current operational seasonal forecast system) since 2011. The latest upgrade of RTOFS will provide ice model guidance at weather scales using CICE4. Separately, CICE5 is being added to our coupled seasonal and sub-seasonal systems (see Sections 1.2 and 1.3). The sea ice group is involved in validating skill from the weather to seasonal scales, developing new physics packages to improve skill scores, and developing a Data Assimilation capability for sea ice especially as an ice/ocean assimilation problem. A component of the unified EMC DA development for sea ice in the JEDI framework is underway

Major Risks and Issues:
- Computational requirements
- Software support for NEMS/NUOPC, CICE, ESMF, other coupled models (e.g. MOM6, FV3) coupling with sea ice models (CICE, KISS), job control / work flow (CROW)
- Community needs to be heavily involved in the CICE consortium to develop a common community physics package for sea ice modeling.

Major resources requirements:
- Personnel: EMC: 3 FTE (sea ice modeling, model coupling, sea ice DA)
  - Partners:
  - CICE Consortium
  - JCSDA/JEDI (1 FTE) (Sea ice DA in/with JEDI framework)
- HPC for development: include ~ 2M CPU hrs/year, ~30 Tb disk space, ~ 300 Tb HPSS/year storage, etc.

Dependencies/linkages with other projects:
- NEMS, NUOPC, ESMF, CICE, FV3, Hycom, MOM6, CROW, JEDI, GSI, NCODA
- YOPP -- Year of Polar Prediction -- these efforts are a NOAA contribution to the international program
- Verification and Validation Group
- NGGPS

Core development partners and their roles:
- NCEP/EMC: Sea ice model adaptation/development, coupled air/sea/ice model development and evaluation, sea ice DA (SIDA) evaluation
- CICE Consortium: CICE ice model support
- JCSDA: JEDI support + implementation of DA codes, sea ice and coupled ice/ocean data assimilation development, …
- UMD College Park: sea ice and coupled ice/ocean DA
- NESDIS: Sea ice satellite-derived products, development, distribution and evaluation

Major Milestones:
- (Q1FY18) Run coupled air/sea/ice model 35 days, for arbitrary start dates
- (Q3FY18) Evaluation of sea ice prediction skill at weather to seasonal time scales
- (Q3FY18) Test SIDA using NEMS version of CICE/atm/MOM6
- (Q4FY19) SIDA for concentration to be transitioned to operations
- (Q1FY20) Begin 30 year sea ice reanalyses and reforecasts with the SFS

1.16: Development of Deep Atmospheric Dynamics (DAD) for FV3 for Whole Atmosphere Model (WAM) and coupling to Ionosphere Plasmasphere and Electrodynamics Model (IPE)

Project overview:

FV3 is a non-hydrostatic dynamics model, beyond non-hydrostatic dynamics is non-approximated deep-atmosphere dynamics. Developing deep-atmosphere dynamics (DAD) for FV3 is an essential step which is not only to move model dynamic into fully non-approximation to benefit all applications including weather and climate but also to support SWPC on whole atmosphere modeling to couple with SWPC IPE. The implementation of our DAD emphasizes on accuracy on top of non-approximation, especially starting from generalized multiple-constituent formulation for thermodynamics. Due to the consideration of accurate thermodynamics and DAD hydrostatic relation etc, the relation formulation used in model physics, data assimilation, pre-processing, and post processing etc have to be modified for DAD ready, which leads to a DAD modeling in parallel development on WAM for SWPC IPE. In other words, while DAD works on model physics for WAM, DAD modeling benefit to improve accuracy of thermodynamics in model physics, the same for data assimilation and post processor etc. Thus, the DAD modeling will eventually provide non-approximated, accurate, and better dynamics for all other components on weather and climate modeling.

Major Risks and Issues:

- Deep-atmosphere dynamics involves dynamic core modification, though the idea of scaled prognostic variable (the so-called smile space) minimizes the changes of the dynamic core, the stability of the deep-atmosphere dynamic core has to be examined and tested (e.g., tolerance to T>2000, V ~1000 m/s, W ~100 m/s; impact of non-hydrostatics on IPE). Further numerical techniques may be necessary.
- Vertical extension from 60km to 600km requires implementation of WAMGSM column physics, e.g., radiation, diffusion, ion drag, etc., and stability tests.
- Implement implicit 2D horizontal diffusion in dynamical code (explicit may be an option of very small timesteps ~1-10 s are tolerated).
- IPE couple issues ---Modify existing WAM-IPE ESMF mediator and 3D re-gridding, develop FV3WAM-CAP, implement one-way and possible two-way coupling.
- Data assimilation issues – implement IAU and existing 6-hr cycling. Extend GSI to 100 km, and implement 1-hr cycling window.

Major resources requirements:

Personnel: EMC (1 FTE for development, 2FTE for testing)

SWPC (1 FTE for development, 2 FTE for testing);

GFDL (Xi Chen for discussion and unified code management)

HPC for development: 250K CPU per month on Theia and 50 TB disk space

Dependencies/linkages with other projects:

- ANNEX 3 (system architecture): requires coupling techniques through NESII group with NEMS/NUOPC and ESMF modification of existing coupling scheme (mediator)
- ANNEX 5 (model physics): requires deep-atmosphere physics with physics project– import WAM column physics using IPD.

- ANNEX 6 (data assimilation): requires data assimilation project – higher cadence and extended altitude range.
- ANNEX 10 (aerosol and composition): requires to link to atmospheric composition on applying multiple- gases thermodynamics
- ANNEX 12 (post processing): requires to modify post-processor for deep-atmosphere dynamics.
- ANNEX 13 (verification): requires verification including deep-atmosphere dynamics, WAM, and IPE related capabilities.

Core development partners and their roles:

- including multiple gases and deep-atmosphere dynamics
- extension vertical domain with physics modification with implementation and tuning GW parameterization and others.
- data assimilation – extend GSI to 100 km resolution, 1-hr cycling.
- couple with IPE– one and possible two-way coupling through NESII NEMS.

Major Milestones:

- Q4FY17: add multiple-constituent treatment into thermodynamics equation
- Q1FY18: extending vertical domain to WAM and updated physics for WAM
- Q2FY18: implement 2D implicit horizontal diffusion
- Q3FY18: add deep-atmosphere dynamics
- Q4FY18: validate standalone WAMFV3 against WAMGSM at similar resolution
- Q1FY19: data assimilation -- implement IAU into WAMFV3 and test cycling
- Q2FY19: WAMFV3-IPE one-way coupling, validate against WAMGSM-IPE
- Q1FY20: WAMFV3-IPE two-way coupling
- Q4FY20: data assimilation with 1-hr cycling and extended altitude range; implement space weather drivers; test.

<u>Project 4: Development of Deep Atmospheric Dynamics for FV3 for Whole Atmosphere Model (WAM) and coupling to Ionosphere Plasmasphere and Electrodynamics Model (IPE) (FY17/18-20)</u>

<table>
<tr><th colspan="17">Deep Atmospheric Dynamics (DAD) Development for FV3 (WAM and coupling to IPE) (FY2017-2020)</th></tr>
<tr><th rowspan="2">Milestone</th><th colspan="4">FY17</th><th colspan="4">FY18</th><th colspan="4">FY19</th><th colspan="4">FY20</th></tr>
<tr><th>Q1</th><th>Q2</th><th>Q3</th><th>Q4</th><th>Q1</th><th>Q2</th><th>Q3</th><th>Q4</th><th>Q1</th><th>Q2</th><th>Q3</th><th>Q4</th><th>Q1</th><th>Q2</th><th>Q3</th><th>Q4</th></tr>
<tr><td>Modifications to thermodynamic equation</td><td></td><td></td><td colspan="4">Add multiple-constituent treatment into thermodynamics equation</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Extend vertical domains</td><td></td><td></td><td></td><td colspan="4">extending vertical domain to WAM and updated physics for WAM</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Horizontal Diffusion</td><td></td><td></td><td></td><td></td><td colspan="4">implement 2D implicit horizontal diffusion</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Add DAD & validateFV3 WAM</td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="6">add deep-atmosphere dynamics & validate standalone WAMFV3 against WAMGSM at similar resolution</td><td></td><td></td><td></td><td></td></tr>
<tr><td>DA for FV3 WAM</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="6">implement GSI and IAU into WAMFV3 and test cycling</td><td></td><td></td></tr>
<tr><td>FV3 WAM - IPE one-way coupling</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="6">WAMFV3-IPE one-way coupling, validate against WAMGSM-IPE</td><td></td></tr>
<tr><td>FV3 WAM - IPE two-way coupling</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="5">Develop WAMFV3-IPE two-way coupling</td><td></td></tr>
<tr><td>Testing and Evaluation of FV3 WAM</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="5">data assimilation with 1-hr cycling and extended altitude range; implement space weather drivers; test</td></tr>
</table>

2.1: UNIFICATION OF VERIFICATION EFFORTS UNDER MET

Project overview: The transition of EMC to a MET+ based system requires replication of some critical functionality within the system. Verification procedures addressed with this project include those for global to meso- to storm scale phenomena, cyclones (both tropical and extra-tropical), and atmospheric composition and air quality, and others represented by the other 12 SIP working groups. This process began in FY17 and requires additional development to meet the expected timelines. The transition is needed to establish a unified system and free up resources to define the optimal verification methods and tools to enact the critical evaluation of the NGGPS. Several of the components (e.g. Marine, Hydrology, Land Surface Model, Sub-Seasonal to Seasonal) have well established packages that need to be integrated into MET+. If the method is not currently available in MET+, enhancements to the system will be made to ensure that the capability exists. This effort will also expand to validation of the fully coupled system, including visual inspection of high-frequency data (i.e. fluxes), process oriented methods. Effort will be made to include these capabilities in the next 3 years but this will likely require additional effort beyond FY20.

METViewer is the companion database and display system to the MET verification package. It reads in both MET statistics files as well as legacy EMC Verification Statistics Database (VSDB) files. A prototype system has been established by NCO on the Interactive Data Protocol (IDP) development framework. Some initial needed improvements have been identified prior to METViewer going through the formal IDP on-boarding procedure.

Additionally, this project will examine using data created from MET+ to organize and consolidate the EMC verification web pages, and to determine where the METViewer is adequate for verification data visualization, or if web-based graphics are a more appropriate solution.

Major Risks and Issues:

- MET+ may become difficult to compile/configure and hence unwieldy
- Lengthy list of development tasks – need sufficient resources for development and training
- Several components already have well established pkgs
- Lengthy list of milestones that may be difficult to track on a quad chart – may need to determine how to break into 2 projects
- MetViewer server: EMC needs to keep decades of data on disk for plotting of historical performance, so an efficient solution must be found to achieve this goal
- Developers would benefit greatly from METViewer batch engine capability on HPCs such as WCOSS/Theia – need to figure out how

Major resources requirements (per year):

- Personnel: EMC 2 or 2.5 FTE

  NCAR 2.5 FTE

  ESRL 2.0 FTE

  NSSL 1.0 FTE

- HPC for development: MET+ is designed to run on a single processor and be “parallelized” through a workflow manager such as Rocoto or ECFlow. There is minimal HPC requirement.

- Disk space: 2-5 TB per year for near-term archives

Dependencies/linkages with other projects:

- MET-based verification and validation for the FV3-GFS
- MET-based verification and validation for the FV3-GEFS with process-oriented metrics for ensemble evaluation
- MET-based verification and validation for convection-allowing ensembles
- MET-based verification and validation for aerosols and atmospheric composition models
- MET-based verification and validation for marine models
- MET-based verification and validation for land-surface models and hydrology
- MET-based verification for Space-Weather
- MET-based verification for S2S Prediction
- MET-based verification for Seasonal Prediction
- JEDI/IODA

Core development partners and their roles:

- NCAR - provide MET development and enhancement, based on needs of the verification community.
- EMC - verification branch will lead verification and evaluation efforts for the FV3 applications. The Model Evaluation Group will lead evaluations of individual modeling systems.
- ESRL - provide additional MET and MET+ development
- NSSL - provide metric and process development efforts related to CAM verification
- WPC, SPC, OPC, CPC - provide additional MET+ tools and visualization capability

Major Milestones:

- Q2FY18: Initial real-time MET+ system running on WCOSS in parallel to VSDB system
- Q3FY18: MET+ accepted for FV3 verification
- Q3FY18: Establish Cython API for MET+ to allow MET C++ code to communicate with python scripts
- Q4FY18: MET+ accepted for FV3 aerosol, atmospheric composition and air quality verification
- Q3FY19: MET+ accepted for FV3 CAM verification and linked to Marine, Land Surface Model, Hydrology and Sub-Seasonal packages
- Q4FY20: MET+ major release with coupled system requirements met, including basic evaluation capability for space weather

Project 1: Unified verification and validation system based on MET+

MET+	FY17	FY18				FY19				FY20			
	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
	Initial real-time MET+ system running on WCOSS in parallel to VSDB system												
		MET+ accepted for FV3 verification											
		Establish Cython API for MET+ to allow MET C++ code to communicate with python scripts											
			MET+ accepted for FV3 aerosol, atmospheric composition and air quality verification										
					MET+ accepted for FV3 CAM verification and linked to Marine, Land Surface Model, Hydrology and Sub-Seasonal packages								
								MET+ development for major release with coupled system requirements met, including basic evaluation capability for space weather					

2.2: OTHER MAJOR VERIFICATION WORK

Project overview:

This project covers EMC verification projects for which the MET+ capabilities will not exist in sufficient time to support those efforts. It also covers the formal evaluation efforts of parallel systems. This project will also entail continuing to engage the community both independently and through the Governance and Communications WG of the SIP to determine a set of methods and common metrics that can be used in all verification efforts. Ultimately, there will be an established and well-documented T&E testing procedure that may be executed using the MET+ system.

The marine verification package will convert marine verification scripts and codes into python-based packages, with a long-term goal of plugging these capabilities into the MET package. The air quality verification package update includes a transition of the CMAQ/HYSPLIT verification to use GOES-16 AOD, dust and smoke masks, including available ceilometer data for PBL and PM profile verifications, and incorporating VIIRS and AERONET AOD into a MET+ verification package.

With the recent paradigm shift to model evaluations occurring much earlier in the implementation schedule. EMC's Model Evaluation Group (MEG) has taken on the role of leading evaluations of major model upgrades. Evaluations had previously been performed by NCEP and NWS stakeholders over a short 30-day period immediately prior to NCEP director approval immediately prior to the operational implementation, but this was found to be an insufficient time period and also allowed for the possibility of NCO building their parallel system only to have the evaluators reject the proposed upgrade.

The new paradigm for most implementations has the developers running an early parallel system and the MEG leading the evaluation with frequent updates given to developers, researchers and forecasters at the group's weekly webinars. The evaluations consist of a combination of statistical evidence as well as case studies and reviews of daily inspections of critical forecast parameters. Statistical evidence and forecast examples from retrospective runs are also presented. As part of an STI initiative, there are also two MEG sub-teams, consisting of members from the NCEP and NWS SOO community. One is tasked with assisting with evaluations of global and high-resolution FV3 runs and to help with the challenge of disseminating parallel data to the field, and other other assists with evaluations of CAMs and CAM-based ensemble systems. These STI teams play a critical role in providing neutrality and forecast expertise in assessing the day-to-day forecast utility of the new systems.

The MEG will lead the writing of the test plan for the FV3-based systems with input from the community and organizations such as the Developmental Testbed Center (DTC), Global Model Test Bed (GMTB) and Community Earth System Modeling (CESM) group. The test plan will not only be based on statistics and metrics but also on subjective evaluations by the EMC MEG, the MEG-STI groups, NWS Regions, NCEP Centers, and other customers and stakeholders. The metrics will not be unified across all scales, and engagement with the forecaster and verification community will be critical in identifying scale-appropriate metrics for each system. Once written, the test plan will be used to conduct the formal evaluations by the MEG, the listed organizations, and the community.

Major Risks and Issues:

- Reaching consensus on the correct fields, measures and display methods as well as the minimum sample size for effective T&E will be challenging.
- There is potential for evaluations of multiple major modeling systems to be needed simultaneously, which will severely tax limited MEG resources.

Major resources requirements (per year):

- Personnel: 7.3 EMC + two STI SOO-based teams

  NCAR 0.25 + GMTB staff

  ESRL GMTB staff
- There is minimal HPC requirement.

Dependencies/linkages with other projects:

- All EMC projects for metrics that are meaningful within each specific group
- Formal evaluations of all modeling system updates (and new systems) are required
- MET+ extension to read AIRNOW, GOES, VIIRS, AERONET, Ceilometer data
- This project links to all EMC modeling systems

Core development partners and their roles:

- NCAR - provide MET development and enhancement, based on needs of the verification community.
- EMC - Model Evaluation Group will lead the evaluations/validations of major modeling systems and web page consolidation/organization; marine modeling personnel will work on marine verification; air quality group will work on air quality verification

Major Milestones:

- Q2FY18: Identify new MET capabilities needed to assist with evaluation efforts
- Q2FY18: Develop unified python package for wave model systems (real time) and prototype verification package for ocean DA
- Q3FY18: Transition AOD, smoke/dust mask verification with GOES-16 & MET+
- Q3FY18: Begin AIRNOW O3/PM and AERONET AOD CMAQ verification with MET+
- Q4FY18: Couple VIIRS AOD data to MET+ for verification and begin VIIRS volcanic ash verification of HYSPLIT
- Q4FY18: Test plan for NGGPS identified for use in evaluation
- Q1FY19: Create multi-month verification records from retro FV3-R-AQ and from FV3-R-HYSPLIT
- Q2FY19: Complete FV3-GFS evaluation as part of transition to operations
- Q2FY19: Convert existing ocean verification products to python
- Q4FY19: Complete FV3-GEFS evaluation as part of transition to operations
- Q4FY19: Complete RAPv5/HRRRv4 evaluation as part of transition to operations
- Evaluations of other major upgrades can be added

2.3: FV3 Transition and Re-engineering of UPP and other Post Processing Packages as well as linkage to MDL's WISPS project

Project overview: NOAA is required to support existing operational products during each model upgrade and that includes the transition to FV3. EMC is building new interfaces within model write grid components to efficiently interpolate FV3 model output from a cube-sphere grid onto regular orthogonal grids. The objective is to have minimal changes to post processed output which will then facilitate a smooth transition from GFS to FV3 for NOAA's internal (e.g., MDL, SPC, and WPC) and external (e.g., AWI and academia) users.

Modernization and reengineering of UPP will enhance future development and collaboration, although it is not required to support transition to FV3. The UPP will be re-structured to define variable dependency and to become more modular to be used as a library. The advantage of having a UPP library is that it can be used by MET and other packages so that diagnostic variables can be computed the same way across different components. EMC will also use this opportunity to consolidate its ~20 downstream packages.

EMC will also work more closely with MDL, specifically through MDL's WISPS project, to share and possibly unify data formats, scientific algorithms, and softwares. Both EMC and MDL have identified NetCDF with CF conventions for storing data to improve conformance with community standards. EMC will work toward outputting native model output in NetCDF, or by developing software to convert NEMSIO to NetCDF, but GRIB2 post processed output will also continue. EMC and MDL will work on unification of commonly used algorithms and software, such as interpolation, smoothing, map projection and computation of diagnostic functions. Software systems will need to be tested, with some migration to Python expected as MDL's WISPS project is primarily written in Python.

The Post Processing group also recommends testing and evaluating new post processing techniques that have potentials to be implemented into NOAA operations, as outlined in Annex 12, Project 4. DTC is proposed to be the main testbed for Phase I. However, EMC may be able to facilitate simple testing while transitioning and re-engineering all EMC's post processing packages to support FV3, pending approval from EMC management.

Major Risks and Issues:

- Lack of familiarity with netCDF format at EMC
- Coupling python with FORTRAN and other software languages
- Lack of knowledge and training with Python
- FV3 output may not satisfy all operational requirement
- Re-engineered post may run slower (some modern Fortran operation is known to be slower than its Fortran 77 counterpart), and Python code could be slower than FORTRAN
- Consolidate downstream packages can lead to delay delivery
- Connection with WISPS may be difficult due to difference in organizational culture and customer requirement
- NetCDF with CF convention output is desired by the global weather enterprise, but finding disk space to distribute data in real-time (via NOMADS or other means) could be challenging

Major resources requirements:

- Personnel: EMC: 4 FTE (Model write grid component, UPP and Bufr sounding interface with FV3 output, UPP reengineering, downstream consolidation testing)
  - Partners: NOAA organizations testing their downstream packages off new FV3 output
  - MDL: 1 FTE to work on unification and consolidation of post processing algorithms with EMC
- HPC for development: include 200 CPU hrs/per month, minimal disk space and HPSS storage

Dependencies/linkages with other projects:

- Annex 12, Project 2 (Unify model and post-processing data formats).
- Annex 12, Projects 3 and 4
- Annex 1, Projects 1, 2, 3
- Annex 3, Project 1
- Annex 4, Projects 1 and 4
- Annex 7, Projects 1, 2, 3
- Annex 10, Project 1
- Annex 13, Project 4
- MDL's WISPS project

Core development partners and their roles:

- EMC will Update UPP and Bufr sounding to interface with FV3 output
- EMC will test its downstream packages
- EMC will provide FV3 output to NOAA organization for testing in their downstream applications as soon as possible
- GFDL will provide assistance in writing out all model output necessary to support existing operational products.
- MDL, AWC, CPC, SPC, and WPC will test FV3 output provided by EMC in their downstream applications and adjust their algorithms if necessary
- EMC and MDL will work on better connection of post processed products and consolidation of post processing algorithms

Major Milestones:

- (Q1FY18) EMC Modifies UPP and Bufr sounding to read new FV3 GFS output
- (Q1FY18) EMC modifies UPP to read regional/nested FV3 output
- (Q2FY18) EMC tests all GFS downstream packages on new GFS FV3 post processed output
- (Q2FY18) EMC distributes FV3 GFS output to MDL, AWC, CPC, SPC, and WPC for testing their downstream applications and for evaluating new products
- (Q3FY18) MDL, AWC, CPC, SPC, and WPC provide feedback about their evaluation results on FV3 GFS
- (Q3FY18) Run UPP inline on model quilt server
- (Q4 FY18) Re-design UPP to 1)define variable dependency, 2) clean up redundancy, 3) become more modular to be used as library for MET or physics
- (Q4 FY18) Consolidate GFS downstream packages
- (Q4 FY18) EMC outputs model in NetCDF format with CF convention consistent with MDL

- (Q4 FY19) EMC and MDL has agreed-upon plan to consolidate post processing algorithms that can be shared with community

FV3 Transition and Re-engineering of UPP and other Post Processing Packages as well as linkage to WISPS															
FY17				FY18				FY19				FY20			
Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
		EMC modifies UPP and Bufr sounding to read new FV3 output													
				EMC tests its own downstream packages											
					EMC distributes FV3 GFS output to NOAA downstream users for testing and evaluation										
					RUN UPP inline on Model quilt servers										
					Deliver first draft of re-enginerred UPP										
						Consolidate all GFS downstream packages									
						EMC outputs model in NetCDF format									
								EMC and MDL has agreed-upon plan to consolidate post processing algorithms							

2.4: Reengineering/modernization of ObsProc

Project overview: A complete set of good quality observations is essential to establishing accurate initial conditions in the NCEP Data Assimilation systems. The purpose of this project is to redesign the existing ObsProc workflow such that it can more effectively handle the processing of observational data used in the DA systems. This is especially important with the huge amount of satellite radiance data coming in now which will grow even larger over the next 3-5 years, among other observational data sets which continue to grow in size. The current ObsProc system is based on a patchwork of updates going back to the 1990's. It is written almost entirely in Fortran (even Fortran 66/77 in many places) and it uses sequential data basing, with all observation types in BUFR. The ObsProc system needs to be optimized and it needs to take full advantage of parallel processing and other features now available on the WCOSS systems, including possible changes to using Python for rapid development, prototyping, and changes to existing and new decoders.

Major project efforts include:

1. Updating existing Fortran codes to streamline processing of conventional data in the PREPDATA processing which reads in BUFR data from dump files and outputs PREPBUFR for the GSI.
    a. Split up processing by obs-type.
    b. Combine mass and wind.
    c. Remove legacy logic which was designed to use ON29 look-alike interface from dump files.
2. Test the conversion of Fortran codes to Python scripts to speed code development and consolidate resources.
3. Develop a software re-engineering plan that identifies core algorithms and workflows, and create common software libraries that handle main tasks.
4. Streamline Fortran code, if a conversion to Python is deemed difficult or where Python cannot be used.
5. Use a non-BUFR path for some data (e.g., satellite data). We could save considerable wall time by not encoding in BUFR and or re-encoding in BUFR, but staying in the native format (e.g., HDF).
6. Exploring the use of a relational database (e.g., mySQL) to allow for more flexibility in the interface with observations.
7. Exploring storing observational data in netCDF using CF conventions and linked data with standards (OGC/ISO) metadata.
8. Investigate optimization of observation processing through software or hardware parallelism.
9. Coordination with the to-be-defined JEDI/IODA data base.
10. Inclusion of additional metadata (e.g., instrument heights, etc.).
11. Enhanced operational scripting (e.g., handling multiple files at once).
12. Quality control advancements (esp. aircraft, ship, surface data). Improved use of radiation correction.
13. Data Mining: Improved methods for discovering and looking into use of new/exotic data types.
14. Exploring the use of the new CROW system for operational unified workflows.
15. Exploring the development of web-based dashboards to indicate the current status of real-time data processing.

Major Risks and Issues:

- ObsProc is a sustainment project. Legacy system will need to be updated and maintained even while new system is re-engineered. Several high priority obs types (e.g., GOES-16, JPSS-1) and responses to upstream changes (e.g., NESDIS DDS to PDA migration) must be implemented soon. Lack of resources may become an issue.
- Lack of knowledge of Python and interfacing with Fortran algorithms and libraries.
- Insufficient staffing resources and personnel movement between projects.
- Availability of data due to issues upstream.
- Attaching re-engineering project milestones to timelines of other obsproc development efforts within internal projects and the global weather enterprise (CROW, JEDI, GSD).
- Python BUFR libraries have not been tested locally, and support is unknown.
- Contractor staff access to WCOSS and compute resources with long security clearance wait times.

Major resources requirements:

- Personnel: EMC: 3 Fed, 7 contractors
- HPC resources, but minimal

Dependencies/linkages with other projects:

- RTMA/URMA Systems
- Data Assimilation development
- JCSDA - JEDI/IODA development
- Ocean Data Assimilation
- This project links to all EMC modeling systems

Major Milestones:

- Q2FY18: Implement BUFR-feed for upper-air (radiosonde, pibal, dropsonde) data, synoptic and marine (ship, buoy) systems. TAC feed will be retained where BUFR is not yet present.
- Q2FY18: Identify key priorities and requirements for new observation processing software system, including potential linkages with JEDI/IODA, and areas needed for improvement or optimization.
- Q3FY18: Determine new (if any) data types targeted for storage upgrades (netCDF, HDF, etc.).
- Q3FY18: Begin re-coding efforts for obs proc using Python, or, in FORTRAN where appropriate
- Q2FY19: New observation processing system executing in full test mode.
- Q1FY20: Implement new observation processing system into operations, running in parallel with legacy systems.
- Q4FY20: Remove legacy systems, ensure internal and external partners are using any new data sets or databases created via new obs proc system.

[add Gantt chart]

3.1. Community Research and Ops Workflow (CROW)

Project overview: The purpose of this project is to replace the existing myriad of model dependent workflows currently used in production by a single unified system that is reusable for multiple models in operations and serves the needs of the research community. The key features of this new system will have to include:

1. The ability to be run in research mode (with minimal arguments) in non-NCEP environments
2. The ability to handle all use cases : operations, serial and parallel computing environments, multiple compilers, batch systems for single and multi-component tests, large scale retrospectives, case studies, one off experiments
3. Use only high-reliability, cross-platform, software
4. Any software must have source code provided, or be available via a vendor (for future portability)
5. be seamlessly integratable (and removable) from the NCEP operational environment

The workflow project is a major undertaking at EMC and its development will use the agile development environment where rapid prototyping will be done in parallel with developing use cases and requirements gathering (both within and outside EMC). The starting point for this workflow is the current existing workflow for the NEMS-FV3GFS forecast system [initial condition creation; build system (acquire source & compile); run configuration; workspace creation; forecast with offline DA; post-processing; product delivery; configuration capture (insertion into database)] and will then evolve into adding more systems.

One key aspect of this project is the scripting language to be used. Using the criteria of portability and versatility the unanimous opinion of the SIWG was that this workflow should be based on Python 3. It should be emphasised that at this moment EMC has a development plan, not a final design. For a final design that is simple, modular and flexible enough to serve the operational (and experimental) needs of both EMC and their research partners, it is critical that the workflow development team remains engaged with the community. This can either be done through the SIWG or as a separate Working Group established and tasked to provide guidance.

Major Risks and Issues:

- Insufficient use cases and input by user communities could lead to a poor system design that can worsen our current situation.
- Insufficient support or maintenance personnel can make even a good design unusable.
- If a technology underlying the system is no longer supported, or no longer actively maintained, the system may need to be redesigned to use other technology.

Major resources requirements:

- Personnel:
  - 4-6 quasi-permanent core developers
  - 0-12 short-term subject matter experts to implement portions of system

- HPC for development:
  - july-oct: 200k core-hours/month, 10 TB disk
  - nov-feb: 1200k core-hours, 40 TB disk

Dependencies/linkages with other projects:

- Software Architecture Working Group
- Ensembles Working Group
- Post-Processing Working Group

Core development partners and their roles:

- NCAR, NCO, GMTB, GFDL and representatives of SIWG or its counterpart Working Group

Major Milestones:

- Mid august 2017 - requirements document
- Mid august 2017 - technology prospects document
- Late september 2017 - prototype system suitable for widespread use
- Late oct 2017 - umbrella build system that compiles all executables and dependencies except software found on typical HPC clusters (e.g. netcdf libraries)
- Mid december 2017 - full-featured workflow system
- Late april 2018 - transition to NCO for operational parallel
- Mid-late 2018 - community release of system (exact date will be discussed with stakeholders)
- 2019 - operational GFS system and begin incorporation into other modeling systems

3.2: NEMS/coupling architecture

Project overview: NEMS (NOAA Environmental Modeling System) consists of the superstructure for model coupling and the infrastructure for shared model tasks. The NEMS support team provides maintenance, development and design for the NEMS project. The coupling architecture encompasses using NEMS to couple all Earth modeling systems, including atmosphere, ocean, sea ice, wave, surge and inundation, land, hydrology, aerosols, chemistry, and ionosphere. There must also be capabilities to support ensembles and nesting. The coupling architecture team develops and improves the coupled model capabilities.

Major Risks and Issues:
- Complexity of the total Earth system likely to interact unpredictably.
- Dependence on many components from many sources carries challenges.
- Need ESMF and NUOPC mediator support at EMC for operational support

Major resources requirements:
- Personnel: ~12 FTE at EMC
- HPC resources: substantial

Dependencies/linkages with other projects:
- Dependent on all components within NEMS, including atmosphere, ocean, sea ice, wave, surge and inundation, land, hydrology, aerosols, chemistry, and ionosphere.
- Dependent on data assimilation and workflow projects for cycled applications.

Core development partners and their roles:
- NCEP/EMC: Continue developing the NUOPC mediator and adding / testing earth system components. Develop moving nest capability
- GFDL: Provide support to build NUOPC interfaces for GFDL models. Guidance in building the exchange grid capability for the mediator
- ESRL/NESII: PRovide ESMF support and development of new features like moving nest capability and other support (e.g. optimization of libraries and mediator etc.)

Upgrade schedule:
- Documentation of the NEMS system (Q1FY18)
- Adding FV3 to NEMS coupled infrastructure (Q1FY18)
- Refactor build system and a regression test suite (Q2FY18)
- Consistent regridding / flux calculation under masks (Q2FY18)
- Unified workflow for NEMS Applications (Q1FY19)
- Development of moving nests for hurricane applications (Q1FY19)
- Inclusion of GFDL style exchange grid capability (Q1FY19)
- Higher order conservative interpolation (Q1FY19)
- Transition of coupled systems into operations (Q1FY19 and beyond)
- Adding chemistry models to coupled systems (Q1FY20)

3.3: Migration of code repositories from Subversion to VLab Git

Project overview: The purpose of this project is to migrate all existing active subversion repositories within EMC to new hosting on the VLab servers using git. There are several advantages to hosting the repositories on Vlab which include:

1. Enables better community-based collaboration due to more open access on VLab.
2. Switches from subversion-based repositories to much more common and modern git-based repositories.
3. Incorporates tools such as Gerrit, Redmine, and Jenkins to formalize the code-review procedures used across EMC.
4. Adds fine-graned access controls to each repository that can be controlled at the code manager level.
5. Enables a potential adoption of tools such as GitHub or Bitbucket for hosting.

Major Risks and Issues:

- Many repositories currently housed in subversion contain large binary files that are not suited for repositories in general, and for git in particular.
- Network bandwidth requirements may be higher than those currently seen on the EMC subversion servers.
- Because git provides an entire copy of a cloned repository, storage requirements on NOAA HPC systems may be higher than under subversion.

Major resources requirements:

- Personnel: 2 FTE
- VLab space requirements: 2 TB of storage

Dependencies/linkages with other projects:

- Vlab tools and support

Core development partners and their roles:

- VLab personnel are supporting training on Git, Gerrit, and Redmine.

Major Milestones:

- June 2017—Identify all repositories to be moved to VLab
- September 2017--Transition GSI to Vlab
- September 15, 2017--Begin transitioning other repositories to VLab
- August 2017--Conduct training for developers and code managers
- December 2017--Complete transition of all active EMC codes to Vlab
- January 2017--Restrict svn repositories to read-only access

3.4: EMC Website Consolidation/Modernization

Project overview: The project plan calls for aligning the EMC public website with the new EMC organization/mission to allow for better communication with shareholders on model testing, implementation, and documentation. The plan calls for 1) implementing a new public EMC frontpage design at www.emc.ncep.noaa.gov and reorganizing the model and user directory structure on the EMCRZDM server and 2) develop an EMC Community Development Site on Vlab with documentation of all NCEP models, workflow, and software infrastructure components. The EMC Community Development Site will serve as a point of entry for stakeholders to request access to EMC code repositories and other development tools, and serve as a area for collaborative discussions.

Major Risks and Issues:

- Issues with current EMC web site (dead/obsolete links, security, chronically short of disk space)
- Use of EMC development server for new web page template delayed due to NCO help desk staffing shortages and the need for NCO to maintain legacy PHP software on the server

Major resources requirements:

- Personnel: EMC: 1.7 FTE
- HPC for development: N/A

Dependencies/linkages with other projects:

- Migration of EMC code repositories to VLab Git
- Development of integrated **PM tools/environment** on VLab

Core development partners and their roles:

- NCEP/EMC: Build and deploy new EMC web pages using web development template; clean up and reorganize EMC web pages to match new organizational structure; create and maintain EMC Community Development Website on VLab

Major Milestones:

- (Q1FY18) : Create prototype for new main EMC web page
- (Q1FY18) : Connect existing EMC web pages to prototype EMC main web page
- (Q2FY18) : Clean up legacy EMC web pages; reorganize user directories and connect to prototype
- (Q2FY18) : Implement new EMC web page
- (Q3FY18) : Implement EMC Community Development page on VLab

FV3 Website Consolidation/Modernization (FY17-20)

FY17				FY18				FY19				FY20			
Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
	Create prototype for new EMC main public web page														
			Connect existing web pages to prototype main EMC page												
				Clean up EMC legacy web pages; reorganize user directories and connect to prototype; implement new EMC public page											
				Implement EMC Community Development Site on Vlab											

3.5: Update, enhance, maintain and support the NCEP models' shared libraries/utilities & portable EE (equivalent environment).

Project overview: This project (NCEPLIBS) serves the goal to unify, organize the source codes and integrate the development, maintenance and support of all shared scientific libraries, utilities and associated computational HPC environments.

Several dozen libraries and utilities, with several versions of each, are developed and maintained by NCEP on several platforms, supporting critical NOAA projects from operations to the research community. This complex mission requires development of a multi-level testing suite from unit tests to regression and stress tests. The NCEPLIBS group has tasks ranging from troubleshooting, model implementations, pre-implementation parallel models test and evaluation, planned NCEPLIBS developments and enhancements, refactoring and restructuring, O2R2O collaborative development, code distribution, and documentation, training, and helpdesk.

Major Risks and Issues:

- Dependency on collaboration with different organizations and people who are working on other projects can lead to delayed delivery
- NCEPLIBS problem occurrence and fixing typically has urgency and resource uncertainties as well as multi-models and multi-platforms verification needs
- General risk of using shared libraries and utilities is possible increased work from effects of upgrades on every application that needs them
- Meeting NCEPLIBS requirements of model implementations depends on model implementation schedule

Major resources requirements:

- Personnel: 3.7 FTE at EMC for project management, tech leadership, and code managers
- HPC resources: relatively small (10K-30K cpu/hrs) but growing on each WCOSS 1,2,3 Cray, Theia, Jet, Gaea. Archive: 2-5 TB on every system

Dependencies/linkages with other projects:

- Most of the EMC projects, including GFS, GEFS, GSI, SREF, NCEP_POST etc. depend on this project. There are ~ hundreds of dependencies on each library from NCEPLIBS

Core development partners and their roles:

- NCEP/EMC: EMC NCEPLIBS group and colleagues
- NCO/SPA – users/collaborators/participants;
- MDL, ESRL, CPC, NCEPLIBS users group/listings @ TRAC.
- VLAB team / collaborators;
- NCAR/DTC – distributors;

Upgrade schedule:

- (Q1FY18) operational support: Port NCEPLIBS libraries and common user environment to new operational WCOSS Venus and Mars platforms
- (Q3FY18) portability and automation Phase I: Build-all-at-once interface and verification
- (Q2FY19) portability and automation Phase II: Site oriented auto-verification code, builds and EE
- (Q3FY20) portability and automation Phase III: Fully automated OPS mirroring and nwprods/dev control on all EMC machines, plus expanding test and evaluation suite for NCEPLIBS
- (Q4FY20) Community version of NCEPLIBS.

3.6: Documentation project

Project overview:

The Documentation project goals are to document the end-to-end workflow as well as individual components and parameterizations of NCEP developments. The project also develops training materials for both developers and users. The documentation and training are shared by both internal EMC developers and the outside scientific community.

Major Risks and Issues:

- Dependency on collaboration with different organizations and people who are working on other projects can lead to delayed delivery
- Emergency or frequent code updates sometimes leave documentation behind

Major resources requirements:

- Personnel: 1 FTE at EMC, plus subject matter experts from various partners as needed
- Negligible HPC resources

Dependencies/linkages with other projects:

- Dependent on all EMC development project and collaboration from all projects that require documentation and training

Core development partners and their roles:

- NCEP/EMC: coordination, development and maintenance of NCEP development documentation and training
- GFDL: major contributor of documentation
- GMTB/DTC: coordination of community documentation and training

Upgrade schedule:

- (Q2FY18) developmental FV3 GFS documentation and training package
- (Q3FY19) operational FV3 GFS documentation and training package
- (Q1FY20) full coupled NEMS and components and libraries and workflow documentation

3.7: Project Management System Development

Project overview:

Explore and identify project management tools that can be adopted to build an EMC project management system to facilitate project tracking and improves communication between project leads, collaborators, and managers. The PM system should be able to manage all aspects of the project, such as: milestones, deliverable, risks, issues, dependencies, and resources associated with each project. In addition, the PM system will serve as communication platform to coordinate activities between the internal and external collaborators to better manage expectation.

Major Risks and Issues:

- Most Project Management tools do not provide the capability to manage and track all aspects of the project

Major resources requirements:

- Personnel: STI: 0.3 FTE (explore/select PM tools and implement a project management system)
    - Partners: VLAB or external vendors (TBD)
- HPC for development: None

Dependencies/linkages with other projects:

- EMC development and Implementation plan
- Availability and maturity of the PM tools from Vlab or external vendors
- Funds to purchase PM tools if needed

Project development partners and their roles:

- NWS/STI: project lead; explore and recommend PM tools, customize, and implement
- NCEP/EMC: stakeholder and decision maker
- VLAB or external vendors: support the customization and Implementation of the PM tools

Major Milestones:

- Q1FY18: Submit recommendation for PM tools and strategy for customizing these tools to implement a PM system

- Q2FY18: Build a baseline version of a PM system with basic capabilities and incorporate a selected set projects
- Q3FY18: Upgrade the PM system with additional capabilities and incorporate the remaining set of projects
- Q4FY18 and onward: Maintain and sustain the PM system by incorporating additional capabilities and new projects as needed

FY18		
Q1	**Q2**	**Q3**
Explore and identify Project Management tools		
Submit PM tools recommendation		
	Build an EMC PM system	
	Incorporate selected projects into the EMC PM System	
		Upgrade the PM tools with new capabilities as needed
		Incorporate the remaining set of projects

4.1: RTMA/URMA

Project overview: The Real Time Mesoscale Analysis (RTMA) and the UnRestricted Mesoscale Analysis system (URMA) are 2DVar analysis systems that provide analyses of National Digital Forecast Database parameters for CONUS, Alaska, Hawaii, Puerto Rico, and Guam. The RTMA is run hourly for these domains (except Guam, which is 3 hourly) to provide situational awareness. The URMA is also run hourly but with a six hour time delay to capture late arriving data at NCEP. While RTMA is considered for situational awareness, and heavily relied upon by FAA partners, the URMA is considered for verification/validation. The URMA also serves as a critical component in the National Blend of Models (NBM) program, as it is used for bias correction and validation. The success of the NBM relies upon a high quality analysis from the URMA system.

Major Risks and Issues:
- HPC priority for fast, low latency turnaround for development and evaluation of real time products
- Upstream dependencies on a variety of modeling systems
- Science issues model errors, issues with observation QC, and limited observational network

Major resources requirements:
- Personnel: EMC: 8.2 FTE (data assimilation, workflow, observation processing, post processing, product development, implementations, field coordination, downscaling, verification/validation, algorithms)
- HPC for development: ~100k CPU hrs per month, ~20 TB disk space, ~200 TB HPSS storage

Dependencies/linkages with other projects:
- RAP/HRRR, NAM and nests, GFS, and WW3 for background fields for various domains
- Observation Processing
- GSI
- National Blend of Models project

Core development partners and their roles:
- NCEP/EMC: Data assimilation, workflow, observation processing, post processing, product development, implementations, field coordination, downscaling, verification/validation, algorithms

Upgrade schedule:
- (Q1FY18) RTMA/URMA version 2.6: GLERL observation adjustment. Significant wave height analysis in URMA. min/max RH product for URMA. Implement updated unified terrain for HI, PR, and CONUS domains. Add ceiling analysis to AK. Introduce and implement the 15 min CONUS RTMA with Rapid Updates (RTMA-RU). Introduce hourly QPE for CONUS and PR URMAs.
- (Q3FY18) RTMA/URMA version 2.7: Improve RTMA-RU product latency. Expand ceiling and sky analysis to OCONUS (obs permitting). Introduce provider-specific obs QC. Improve C&V analysis via updated algorithm. Fill gaps in QPE analysis near CONUS coastlines. Update background error for closer fit to data. Update AK terrain. Discontinue AK QPE by AK region's request.
- (Q3FY19) RTMA/URMA version 2.8: Add hourly Guam RTMA to support NBM. Add hurricane model background (e.g. HWRF) and assimilate SMFR and dropsonde data for improved TC analysis. Update obs QC. Bring in new observations. Assimilate satellite radiances for improved temperature analysis. introduce AK-HRRR background for AK domain. Add sky cover and/or lowest cloud base analysis to RTMA-RU.
- (Q3FY20) RTMA/URMA version 3.0: Introduce 3D RTMA/URMA if ready for CONUS/AK.

4.2: HREF

Project overview: The High-Resolution Ensemble Forecast (HREF) system takes advantage of existing operational NCEP convection-allowing model (CAM) forecasts to create ensemble products. Currently HREF uses current and time-lagged forecasts from the HiresWindow system (48-h WRF-ARW and NEMS-NMMB runs over CONUS, Alaska, Hawaii, Puerto Rico). For the CONUS HREF, forecasts from the 3 km NAM CONUS nest run are also used in the creation of ensemble products. The HREF, first implemented officially in 2015, is considered a “prelude” to a future true high-resolution convection-allowing ensemble system which will have the FV3 Regional model as a prime component.

Major Risks and Issues:

- Lack of computing resources to adequately test the two proposed HREFv3 options and the proposed HRRRv4 upgrade (HRRR ensemble)
- Science and personnel resource challenges related to addressing model/initial condition uncertainty
- Science and personnel resource challenges related to multiscale data assimilation

Major resources requirements:

- Personnel: EMC: 0.8 FTE of Q1FY18; future TBD
- Partners: ESRL, NSSL
- HPC for development: Current HREF (as of Q1FY18) : minimal, ensemble product generation only as HREFv2 leverages off of existing NCEP systems

Dependencies/linkages with other projects:

- Current : HIRESW, NAM (CONUS nest only)
- Future : FV3 Regional, FV3-GEFS, FV3 DA/GSI, HRRRv3/v4

Core development partners and their roles:

- NCEP/EMC: Historical development/implementation of HIRESW and NAM (both systems now frozen as HREF evolves into a true ensemble system)
- ESRL : Long-term development/implementation of HRRR
- SPC/NSSL/WPC/AWC/WFOs: Real-time evaluation based on applications for extreme weather predictions

Upgrade schedule:

- (Q1FY18) HREFv2 / HIRESWv7 : Transform HREF into an operational version of the “Storm-scale Ensemble of Opportunity (SSEO) with the addition of a second WRF-ARW member (NSSL configuration); unify model resolution of HREF components at ~3 km; add hourly products and new OCONUS products.
- (Q4FY20) HREFv3 : Two scenarios for possible implementation: 1) Continue with multi-core membership, adding one or more 3 km FV3 runs and extended 36-h HRRR forecasts; 2) Full CAM FV3 ensemble (either standalone regional or coupled to FV3-GEFS under a unified framework).

4.3: NAEFS

Project overview: Background - The North American Ensemble Forecast System (NAEFS) is to **1)** Recognizing the importance of scientific and technical international cooperation in the field of meteorology for the development of approved global forecast models; **2)** Considering the great potential of model diversity to increase the accuracy of one to fourteen day probabilistic forecasts; **3)** Noting the significant international cooperation undertaken to develop and implement an operational ensemble forecast system for the benefit of North American and surrounding territories.

The NAEFS combines state of the art weather forecast tools, called ensemble forecasts, developed at the US National Weather Service (NWS) and the Meteorological Service of Canada (MSC). When combined, these tools (a) provide weather forecast guidance for the 1-14 day period that is of higher quality than the currently available operational guidance based on either of the two sets of tools separately; and (b) make a set of forecasts that are seamless across the national boundaries over North America, between Mexico and the US, and between the US and Canada. As a first step in the development of the NAEFS system, the two ensemble generating centers, the National Centers for Environmental Prediction (NCEP) of NWS and the Canadian Meteorological Center (CMC) of MSC started exchanging their ensemble forecast data on the operational basis in September 2004. First NAEFS probabilistic products have been implemented at NCEP in February 2006. The enhanced weather forecast products are generated based on the joint ensemble, which has been undergone, a statistical post-processing to reduce their systematic errors.

The NAEFS has been upgraded 5 times in past 10 years. NAEFS v6 is planning to be implemented in December 2017

Major Risks and Issues:

- Limited bandwidth to exchange high resolution data in real time to satisfy user request for adding new fields.

Major resources requirements:

- Personnel: EMC: 2.5 FTE (ensemble system development, process data exchange, post processing, product development, implementations, downscaling, verification/validation, algorithms)
- HPC for development: ~50k CPU hrs per month, ~10 TB disk space, ~50 TB HPSS storage

Dependencies/linkages with other projects:

- NCEP GEFS
- CMC GEFS

Core development partners and their roles:

- NCEP/EMC: NCEP UPP, workflow, ensemble system development, statistical post processing, statistical downscaling, product development, implementations, verification/validation, algorithms

Upgrade schedule:

- (Q2FY18) NAEFS version 6 will introduce higher resolution raw (CMC) and bias corrected (NCEP and CMC) global ensemble forecast. Improve methodology (hybrid of decaying and reforecast) for bias correction. Introduce calibrated Probabilistic Quantitative Precipitation Forecast (PQPF) and downscaling PQPF for CONUS. Introduce extreme forecast products, which include both anomaly forecast (AN) and extreme forecast index (EFI), which based on bias corrected forecast.
- (Q4FY19) NAEFS upgrade will coordinate to GEFS v12 implementation. It will include: 1). add variables for data exchange; 2). extend forecast leads to cover sub-seasonal; 3). generate

ensemble BUFR data to cover Northern American and OCONUS (Mexico, CONUS, OCONUS, and Canadian); 4). improve forecast bias (include week 3&4) through new reanalysis/reforecast. NAEFS upgrade will support WPC, CPC, WFOs, MDL's forecast guidance, and private sectors.

4.4: Annual HWRF Upgrades

Project overview:

Consider 3-way HWRF-Ocean-Wave coupling with appropriate changes for data assimilation, physics and other system upgrades for future HWRF versions

.

Major Risks and Issues:
If higher resolutions and upgrades are expensive, minimize additional costs by considering alternate configurations.

If 3-way coupling degrades forecast skill, revert back to a two-way coupled system

Major resources requirements:

- 10 FTE (EMC), GFDL (0.5 FTE), AOML (? FTE)
- HPC for development: 25M cpu hours per month for 6 months, 200 TB

Dependencies/linkages with other projects:

- Moving nests in FV3
- Coupling infrastructure/NEMS
- Future DA development will be done in terms of the JEDI infrastructure.

Core development partners and their roles:

- NCEP/EMC: Test all system, physics and DA upgrades using retrospectives
- GFDL: Tracker improvements
- AOML: Physics and DA developments

Upgrade schedule:

- (Q2FY18) HWRF v12.0.0: Introduce 3-way coupling, improved system, physics and DA.
- (Q2FY19) HWRF v13.0.0: Improved system, physics and DA.
- (Q2FY20) HWRF v14.0.0: Transition to use of Global/regional FV3 and NEMS coupler.

4.5: HMON Annual Upgrade

Project overview: System, physics and data assimilation upgrades for future HMON versions.

Major Risks and Issues:
If higher resolutions and upgrades are expensive, minimize additional costs by considering alternate configurations.

Major resources requirements:
- Personnel: EMC: 6 FTE (retrospective testing)
- HPC for development: 15M cpu hours per month for 6 months, 100 TB

Dependencies/linkages with other projects:
- Moving nests in FV3
- Coupling infrastructure/NEMS
- Future DA development will be done in terms of JEDI infrastructure.

Core development partners and their roles:
- NCEP/EMC: Test all system, physics and DA upgrades using retrospectives

Upgrade schedule:
- (Q2FY18) HMON v 2.0.0: Improved system, physics and DA.
- (Q2FY19) HMON v3.0.0: Improved system, physics and DA, NEMS based coupler.
- (Q2FY20) HFV3 v1.0.0: Transition to nests in Global/regional FV3

4.6: WW3 (stand-alone wave models; coupling included in GEFS/SS and SFS)

Project overview: The following stand-alone wave models are currently running at NCEP providing operational wave guidance to the US National Weather Service: global wave deterministic (Multi_1); global wave ensemble (GWES), which includes a probabilistic wave-height product (NFCENS) combining GWES and US Navy wave ensemble data; Great Lakes wave deterministic (GLWU) and the Nearshore Wave Prediction System (NWPS), which is covered in a section 4.10.

Both Multi_1 and GWES will be merged with the GFS and GEFS systems respectively in the NEMS environment in FY2019 (see section 1.9 for details) following which they will cease to exist as stand alone wave modeling systems. (Note: The stand alone hurricane wave model has already been stopped by coupling with the HWRF system). The following science developments will also be considered as part of the NEMS upgrade : optimization of existing physics parameterizations, wave - current and wave - ice interactions. If necessary and schedule permits these physics upgrades might be considered in an earlier implementation prior to the coupling with the global atmospheric models.

GLWU will remain stand-alone within the framework of the current development plan. Upgrades to GLWU include increasing resolutions of nearshore regions to support the development of beach hazards products, improved intake of ice concentrations using higher resolution ice data provided by the National Ice Center (NIC), and optimized physics tuning.

Major resources requirements:

- Personnel:
    - Multi_1: 1.5 EMC FTE (Q1FY18-Q1FY19)
    - GWES: 0.5 EMC FTE (Q1-Q3FY18)
    - GLWU: 1 EMC FTE (Q1FY18-Q1FY19)
- HPC for development: include ~CPU hrs, disk space, ~HPSS storage, etc. as applicable

Dependencies/linkages with other projects:

- Multi_1
    - Dependencies: GFS, Ice analysis (sice product), RTOFS,
    - Linkage with 1.1: FV3-Global Forecast System (FV3-GFS) and 1.9: Waves in GFS / GEFS
- GWES
    - Dependencies: GEFS, Ice analysis (sice product)
    - Linkage with 1.2: FV3-GEFS/Sub-seasonal and 1.9: Waves in GFS / GEFS
- GLWU
    - Dependencies: NDFD winds provided by MDL, Ice analyses provided by NIC.

Core development partners and their roles:

- Multi_1
    - NCEP/EMC: development, operational support, support to forecasters.
- GWES
    - NCEP/EMC: development, operational support, support to forecasters.
    - UN Navy FNMOC: provider of wave ensemble data for NFCENS product.
- GLWU
    - NCEP/EMC: development, operational support, support to forecasters.
    - MDL: provides wind forcing data consolidated onto NDFD files,
    - Great Lakes Marine WFOs: provide raw wind forcing data for creating NDFD mosaic.

Project milestones:

- (Q2FY18) wave_multi_1.v3.3.0: operational implementation, Arctic grid upgrade.

- (Q2FY18) wave physics optimization framework completed, first generation of objective tuning provided for Multi_1, GWES and GLWU stand-alone systems,
- (Q3FY18) wave_gwes.v3.1.0: operational implementation, Arctic grid, extension to 16-day forecasts, improved physics tuning.
- (Q3FY18) wave_glwu.v1.1.0: upgrade to using higher-resolution 500m NIC ice concentrations.
- (Q4FY18) wave_multi_1.v3.4.0: inclusion of wave-current interactions, upgrade of wave-ice interactions source-terms, optimized physics tuning. System providing base wave package for first-generation NEMS-coupled weather model.
- (Q1FY19) Extension to physics optimization to wave component in NEMS, HWRF, GLWU.

4.7: Sea Ice Analysis

Project overview: Many different models and analyses require information about the sea ice cover. Since 1997, a succession/collection of passive microwave instruments have been used to provide an operational sea ice concentration analysis (direct satellite algorithm). Originally an L3 product at 25.4 km resolution with an L4 at 0.5 degree, in 2004 the analysis resolution was improved to 12.7 km for L3 and 5 arcmin for L4. While 5 arcmin remains adequate for global models, mesoscale models now require information at approximately the NDFD resolution of 2.5 km. The efforts over the next three years will focus on acquiring more and higher resolution satellite information, improving data flow methods and formats to assist with development of sea ice and coupled ice/ocean DA. The DA development will be done in terms of the JEDI infrastructure.

Major Risks and Issues:

- All satellites currently in use (DMSP F-15, F-17, F-18) are past their design life. Implementation cdf made 8/2017 is for AMSR2, which will be past design life before NCO implementation (currently not scheduled)
- May be frozen in favor of eventual sea ice data assimilation analysis

Major Resource requirements:

- Personnel -- has been carried by a fraction of 1 EMC person, 0.125 FTE.
- Small requirement for computing and archiving, approximately 2 Gb/day of data at this point. May increase if VIIRS, GOES-16, or JPSS1 ice analyses become available.

Dependencies/Linkages with other Projects:

- Analysis is used by most models in EMC
- Also used by all known DA systems (though currently only as filters in many)
- Will feed ocean and sea ice coupled DA as that is developed
- Obsproc for data flow
- JEDI infrastructure development

Core development partners and their roles:

- JCSDA sea ice DA and JEDI infrastructure.
- NASA-GSFC, NSIDC -- passive microwave ice analysis analysis methods
- NESDIS, UW-CIMMS -- visible+IR ice analyses and methods

Project Milestones:

- Include AMSR2 ice analysis Q4FY17 (cdf)
- Include VIIRS ice analysis once operational in NESDIS
- Include Canadian Ice Services lake ice analysis
- Improve IMS ice mask usage
- Include GOES-16 ice analysis when available (not before Q2FY18)
- Include JPSS-1 ice analysis when available (not before Q1FY19)

4.8: SST (stand-alone SST; coupling included in GEFS/SS and SFS)

Project overview: Geophysical (Stand-alone) SST remains a need even in an era of assimilated SST (such as NSST in GFS, GSI, or an NCODA analysis) due to requirements for the highest accuracy and resolution SST analysis possible, particularly in support of mesoscale NWP and RTMA/URMA needs. This need extends to small lakes which are not considered water in a global land mask, or which are not part of the ocean (NCODA). A long term plan is being developed to fold this into the JEDI infrastructure for DA.

Major Risks and issues:

- Discontinuation of effort in favor of coupled NSST from global assimilation

Major Resource requirements:

- 1 FTE contractor (code management, implementation, testing)
- Part of FTE civil servant (scientific direction and development)
- Computer cpu, disk, archive

Dependencies/Linkages with other Projects:

- Consumer of sea ice concentration analysis
- Used by high resolution NWP models and sea ice concentration analysis
- Obproc supplies data flow

Core development partners and their roles:

- NESDIS STAR -- SST analysis product and method development
- NESDIS OSPO -- SST analysis delivery, formatting, …
- GRSST, JCSDA,
- NCODA

Project Milestones:

- VIIRS implementation (Q4FY17)
- AMSR2 SST retrievals implementation
- Sync with GSI physical retrievals handoff (periodic)
- Update to include active aerosols in physical retrievals
- Include NSST in physical retrieval process
- Himawari-8 ABI implementation handoff
- GOES-16 ABI implementation handoff (not before Q3FY18)
- JPSS1 implementation handoff (not before Q2FY19)

4.9: NWPS

Project overview: The Nearshore Wave Prediction System provides on-demand, high-resolution (5 km – 200 m) downscaling of ocean waves from the WW3 Multi1 model. It is triggered by coastal Weather Forecast Offices (WFOs) in real time, and forced by their official forecast wind grids. Additional model forcings include water levels (tide+surge) from ESTOFS and P-Surge, and surface currents from Global RTOFS. The system uses the wave model core SWAN, and is deployed for all 36 coastal WFOs in the CONUS, Alaska, Hawaii, Puerto Rico and Guam. As of Nov 2017 (v1.2) the system will produce hourly wave parameter guidance out to 6 days. The major developmental drive for NWPS in FY18-20 is to complete the transition from a set of regular nested grids for each WFO to a single variable-resolution unstructured mesh per WFO. This has the duel benefits of describing the wave physics more accurately, while simplifying the NWPS production suite considerably. In model v1.2 (Nov 2017) a total of 10 WFOs have been transferred to these unstructured meshes, and it is proposed to continue this transition at a rate of 10/year during FY18-20. Utilizing the high coastal resolution of these unstructured meshes, new rip current and erosion/overwash guidance will be introduced in FY18 through FY20, in lockstep with the unstructured mesh roll-out at individual WFOs. Other important milestones for FY18-20 include the improvement of wave partitioning and tracking using machine learning techniques, incorporation of high-resolution current fields in major estuaries from the NOS's OFS systems (e.g. CREOFS), changing the model core from SWAN to WW3, improvement of wave-current interaction physics, and the inclusion of state-of- the-art wave-ice interaction physics (Alaska Region).

Major Risks and Issues:

OPSNet LDM network used for transmission of GFE wind grids from WFOs to WCOSS pose outage risk. Consider transitioning input data stream to AWIPS network.

Major resources requirements:

- Personnel: EMC: 1 FTE (maintenance, system development) + 0.25 FTE (mesh building)
- HPC: 36 nodes reserved for on-demand use.

Dependencies/linkages with other projects:

- Receive forcings and boundary conditions from GFE (WFOs, via OPSNet LDM), WW3_Multi1, ESTOFS, P-Surge, RTOFS, and in future NOS OFS systems.
- NOAA Rip Current project, NOAA Total Water Level initiative (erosion/overwash).

Core development partners and their roles:

- NCEP/EMC: Develop system, physics and test upgrades using retrospectives.
- NOS/CO-OPS: Development of rip current guidance algorithms.
- NWS/MDL: Rip current model observational data collection and validation.
- USGS (St. Petersburg, FL): Erosion/overwash data collection and model validation.

Upgrade schedule:

- (Q4FY18) NWPS v 1.3.0: Unstructured meshes for 20 WFOs, rip current and erosion/overwash guidance, improved wave partitioning/tracking, high-res current fields.
- (Q4FY19) NWPS v1.4.0: Unstructured meshes for 30 WFOs, transition to WW3 model core.
- (Q4FY20) NWPS v1.5.0: Unstructured meshes for all 36 WFOs, improved wave-current and wave-ice physics.

4.10: Global Land Data Assimilation System (GLDAS)

Project overview: The objective of the GLDAS project is to test and implement an upgrade of the current operational GLDAS by implementing the updated LIS7 infrastructure. This implementation includes the advanced Noah land surface model physics, land surface data sets, and land data assimilation module. This GLDAS upgrade supports NGGPS with improved land surface analysis. GLDAS also serves as a land surface modeling and data assimilation testbed that provides infrastructure and protocol for coupled and uncoupled land surface modeling and data assimilation developments to support the weather, climate, and hydrological prediction products of NCEP and NWS. As a longer term development, the land data assimilation will be integrated into the unified EMC DA system based on the JEDI infrastructure

Major Risks and Issues:

· This implementation focuses on the upgrades in the uncoupled system. Fully-coupled system performance and readiness for operational atmospheric predictions is beyond project scope.

· The integrity of the GLDAS products relies on the realtime operational availability of the CPC 0.125 degree global gauge and satellite blended precipitation analysis. Action has been taken to communicate with CPC POC Pingping Xie.

Major resources requirements:

· Personnel:

· EMC: 2.0 FTE (Jesse Meng 1.0 FTE, Jiarui Dong 1.0 FTE; Helin Wei 0.5 FTE; GLDAS/LIS7 development, execution, and evaluation, operational implementation and maintenance)

· Partners: NCO TBD

· HPC for development: ~1 M of CPU per month, ~1TB of WCOSS disk space, and ~1TB of HPSS archive

Dependencies/linkages with other projects:

· NGGPS

· FV3-GFS

· FV3-GDAS

. JCSDA JEDI project.

Core development partners and their roles:

· NCEP/EMC: Model development (including physics and data assimilation), integration into NEMS framework and unified workflow, code management, retrospective and real-time experiments, testing and evaluation, transition to operations.

· NASA/GSFC LIS developers: consult and troubleshooting for LIS infrastructure.

. JCSDA data system development

Upgrade schedule:

· (Q1FY18) Retrospective and realtime executions and evaluation

· (Q2FY18) Freeze system code and operational ready scripts

· (Q3FY18) Conduct CCB and deliver final system to NCO

· (Q4FY18) Deliver Technical Information Notice to NCO

· (Q4FY18) NCO 30-day pre-operational IT testing and evaluation

·	(Q1FY19) Operational implementation

4.11: Atmospheric Composition Modeling (CMAQ & HYSPLIT):

Project overview: The Next Generation Atmospheric Composition Model (NGACM) should address a full range of scales from from high-resolution, convective-resolving to global, and be applicable to forecasting needs from short-range forecasts (hours-days) to the seasonal to subseasonal scales (weeks-months).

The NGACM should maintain and improve upon the quality of current operational products/services from the NWS operational atmospheric composition modeling suite:

1. Global Aerosols: NEMS Global Aerosol Capability: T126 2x/day to 5 days: GOCART aerosols (dust, smoke, sea salt, sulfate), Lu, et al. (2016)
2. Global stratospheric ozone in GFS: T1534, 4x/day,
3. Ozone/PM: NAM-CMAQ: regional 12 km, 2x/day to 72 hrs, 155 species
4. Dispersion: NAM/GFS-HYSPLIT Smoke: 0.2°, 06z to 72 hrs, 1 specie; Dust: 2x/day CONUS; Volcanic Ash, radiological Global; chemical emergencies, CONUS

The following identifies the key component projects that should be addressed for developing a general unified atmospheric composition modeling system. These projects will evolve to account for current and anticipated future applications related to aerosols and atmospheric composition. Key projects include the development of system architecture and a chemistry component that allows for coupling with model dynamics and physics, development of aerosol and atmospheric composition data assimilation capabilities, provision of anthropogenic and natural sources of emissions, verification and postprocessing. These projects would address the needs of aerosol and atmospheric composition model development for global, regional, high resolution air quality modeling and atmospheric dispersion modeling. Plans for global air quality modeling using the FV3 Unified Modeling Suite was addressed in the NCEP Strategic Implementation Plan (FY18-20).

Project 4.11.1. Regional Air Quality Modeling.

The Regional air quality modeling system would transition from NAM-CMAQ to FV3-Chem. To do this, a generic atmospheric composition component would be developed using a NUOPC cap to enable integration into the unified model system architecture for two-way interactive coupling with atmospheric physics and consistent coupling with dynamics. Some AC capabilities are already built in modular form and take advantage of ESMF infrastructure to couple with physics and dynamics. ESMF coupling would enable the atmospheric composition component to be self-contained (emissions, 1-D chemistry, deposition), allow ease of code maintenance and optimization as well as sharing of the code among users with different interests, including operations, development and research for either standalone applications or inclusion in the Earth System model with close interactions with other components. ESMF-based coupling provides a proven efficient mechanism for coupling chemical components to the FV3 dynamics and physics as evidenced by the GEOS-5 implementation at NASA GSFC. There are other critical functionalities that requires fine-scale features in order to predict high-impact weather and pollution events, such as extreme stagnation, cold pool, wildfires, dust storms, urban heat island and sea breeze. Dispersion and air chemistry driven by such fine resolution physics are important in regional FV3 and nested global FV3 implementations.

Major Risks and Issues:

- Timeliness of NUOPC cap & chemistry (5x increase) for in-line coupling.
- Operational efficiency vs range of complexity necessary for research applications.
- Computational resources for higher resolution in-line global aerosol and regional air quality predictions
- Regional FV3 meteorology development
- Demonstration of superior performance compared to current operations
- Documentation, training, code management and access of codes by core partners and community

Major resources requirements:

- Personnel:
- NCEP/EMC: 2.6 FTEs
- NOAA/ARL: 2.8 FTE
- NOAA/GSD: 1.5 FTE
- U.S EPA: 1 FTE
- NOAA/CSD: 1 FTE
- HPC for development: include 100,000 CPU hrs, 40 PB disk space, 20 PB HPSS storage per year

Dependencies/linkages with other projects:

- System Architecture WG for NUOPC FV3 cap development, coupler support and future maintenance
- NOAA/GSD & EPA for inclusion of CMAQ chemistry in FV3 on-line component
- Physics and Dynamics coupler protocols
- Physics for coupling chemistry with advanced physics options (e.g., aerosol-aware physics)
- GMTB/CCPP & infrastructure documentation and training
- Verification for including atmospheric composition variables in MET based verification
- Post-Processing for extending NCEP post for atmospheric composition parameters
- Transition to VLab and Code Management/Governance

Core development partners and their roles:

- NCEP/EMC to help develop coupler for atmospheric composition component and transitioning chemistry modules in the AC component to operations; detailed evaluations of developed systems
- NOAA/ESRL/GSD and NOAA/ARL for developing and transiting the EPA CMAQ chemistry modules into the AC component and for providing aerosol aware physics packages
- NOAA/ARL and NOAA/CSD to develop, test and transition regional emissions and model evaluation
- ESRL/PSD for bias correction development and testing
- NCAR for providing aerosol aware physics packages

Major Milestones:

- **Q2FY18: Develop & transition common chemistry component coupler template for FV3-Chem**
- Q3FY18: Develop chemistry based pre (emissions) and post-processing capabilities;
- **Q4FY18: Move atmospheric composition verification to MET; include GOCART aerosols, regional CMAQ in FV3-Chem component**
- Q2FY19: Compare the decided regional-model driven air composition to that by NAQFC
- **Q3FY19: Optimization, testing, retrospective and real time evaluation of FV3-Chem**
- Q4FY19: Perform regional FV3-chem retrospective and real-time. Evaluate regional in-line carbon bond chemistry at ~9 km L35; test regional aerosol interactions with radiation and microphysics
- **FY20: Integrate regional atmospheric composition (CB-VI) configuration into workflow; conduct pre-implementation T&E and prepare regional AC capabilities for transition to operations**

Implementation Plan for Regional AQ (FY2017-2020)

	FY17				FY18				FY19				FY20			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
U.S. NAM-CMAQ V5.1 DT&E			DT&E Regional NAM-CMAQ V5.1 updated emissions, EC smoke, ozone bias correction													
Transition & Implement CMAQ V5.1/ update emissions						NCO para & implement V5.1				Emission update						
FV3-Chem Development			Develop NEMS coupler and chem component and test FV3-Chem													
FV3- Chem Regional configuration						Optimize emiss/chem config										
FV3-Chem Regional test							Test offline vs inline FV3-CMAQ for 1 summer and 1 winter month									
Reg FV3-Chem Evaluation								Finalize FV3-Chem configuration* & perform retros and real-time runs								

Advancement of FV3-Chem													**Further advancements of FV3-Chem and implementation of Regional FV3-Chem (9 km)**
	*** Proposed changes for Reg FV3-chem(CB-VI): 1) Couple with advanced physics with reg. stand-alone FV3; 2) Test inline and offline approaches; 3) Update emissions to current year**												

Project 4.11.2. Atmospheric Dispersion Modeling.

The Atmospheric Dispersion Modeling system would transition from NAM/GFS-HYSPLIT to FV3-HYSPLIT. Currently, HYSPLIT is run for radiological releases (WMO RSMC), volcanic ash (IAEA VAAC), Hazardous Materials (HAZMAT, run on WOC server with NCEP SDM backup) , Comprehensive Test Ban Treaty Organization(CTBTO) source attribution and regional smoke & dust applications. HYSPLIT will transition to be driven by both regional and global FV3 in an off-line fashion for incident/emergency response. There are critical functionalities that requires fine-scale features in order to predict high-impact weather and pollution events, such as extreme stagnation, cold pool, wildland-fires, dust storms, urban heat island and sea breeze. Dispersion and air chemistry driven by such fine resolution physics are important in regional FV3 and/or nested global FV3 implementations. The Transfer Coefficient Matrix approach to provide flexible source term inputs will be developed and implemented for radiological and volcanic ash approaches. Tests with ensembles and ash data assimilation will begin. HYSPLIT applications for wildland-fire smoke and dust will be frozen as these processes will be included in FV3-Chem (project 1).

Major Risks and Issues:

- Operational efficiency vs range of complexity necessary for research applications.
- Computational resources for higher resolution global and regional dispersion model predictions
- Demonstration of superior performance compared to current operations
- Documentation, training, code management and access of codes by core partners and community

Major resources requirements:

- Personnel:
- NCEP/EMC: 1 FTEs
- NOAA/ARL: 2 FTE for contribution to develop and test FV3 coupler for both regional and global models; improvements to HYSPLIT (e.g.: Transfer Matrix Coefficient technique)
- HPC for development: include 10,000 CPU hrs, 1 PB disk space, 500 TB HPSS storage per year

Dependencies/linkages with other projects:

- System Architecture for off-line coupling development, coupler support and future maintenance
- Regional and global FV3 development

- Physics for driving dispersion with advanced physics options
- GMTB/CCPP & infrastructure documentation and training
- Verification for including volcanic ash & smoke from fires in MET based verification
- Post-Processing for extending NCEP post for providing needed inputs for dispersion modeling
- Transition to VLab and Code Management/Governance

Core development partners and their roles:

- NCEP/EMC to help develop offline coupler for atmospheric dispersion and transitioning to operations; detailed evaluations of developed systems
- NOAA/ARL for developing and transitioning HYSPLIT dispersion model and coupling to FV3

Major Milestones:

Project 2 Development of FV3 HYSPLIT and coupler (FY17/18-20)

- Q4FY18: HYSPLIT coupled off-line to global FV3
- Q4FY18: Move HYSPLIT verification to MET
- Q1FY19: Optimization and retrospective testing HYSPLIT off-line coupling with global FV3 (hybrid and P levels)
- Q2FY19: Implement HYSPLIT coupled to global FV3 (coincide w/ global FV3 implement)
- Q4FY19: Optimization, testing, retrospective and real time evaluation of regional FV3-HYSPLIT
- FY20: conduct pre-implementation T&E and prepare regional HYSPLIT capabilities for transition to operations

Implementation Plan for FV3-HYSPLIT (FY2017-2020)

	FY17				FY18				FY19				FY20			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
HYSPLIT V7.5 DT&E and implement		Update libs, couple HRRR & ¼ deg GFS, dev. volc. Trajs & implement														
FV3-HYSPLIT Development					Hybrid and pressure-level FV3 global output needed. Develop offline coupler for FV3-HYSPLIT. Test TCM for RSMC.											
NCO parallel & implement global										Transitio n /implem						

FV3-HYS										**GLB HYS and TCM/RSMC**						
FV3-HYSPLIT regional testing							**Hybrid and pressure level FV3-regional output needed. Couple & Test Reg FV3-HYSPLIT applications**									
Reg FV3-HYSPLIT Evaluation								**Finalize Regional FV3-HYSPLIT configuration* & perform retros and real-time runs**								
NCO Parallel & implement Regional FV3-HYSPLIT											**Transition to NCO /implementation of Regional FV3-HYSPLIT**					
Advancement of FV3-HYSPLIT													**Further advancements of FV3-HYSPLIT (HREF/GEFS ensembles, DA)**			
	*** Proposed changes for FV3-HYSPLIT: 1) Couple with advanced physics with global and regional FV3;2)Transfer Coefficient Matrix approach for volcanic ash applications**															

4.12: Incremental UPP capability additions (e.g., aviation products) not tied to major model upgrade (those tied to GFS or other model upgrade will be included there)

Project overview: UPP has been used as a R2O tool to transition many research scientific algorithms into NCEP operations. Particularly, UPP has been used to generate improved Global aviation products for World Area Forecast System (WAFS). The WAFS was established by International Civil Aviation Organization (ICAO) to improve Global flight safety and planning. This is especially important for developing countries which do not have capability to develop numerical weather guidance .

Recently, FAA also funded EMC to improve CONUS aviation products through UPP. Although EMC has been able to bundle aviation product upgrades with major model upgrades to meet timelines posed by ICAO most of times, it may be necessary in the future to have just a separate UPP upgrade sometime. This is especially true now that UPP will also be used to upgrade CONUS aviation products and RAP is only upgraded every two years.

Major Risks and Issues:

- Delay in delivery of algorithms from NCAR and other collaborators will cause delay in operational product upgrade.
- Delay in verification of experimental products by GSD and other collaborator may cause delay in operational product upgrade.
- NCO may not accept UPP only upgrade due to resource limitation or other reasons.
- Run time in research algorithms, such as GTG, may be too long to meet operational requirement.

Major resource requirements:

- Personnel: EMC: 2 FTE (WAFS maintenance and upgrade, CONUS aviation R2O upgrade)

  Partners: NCAR will migrate to use UPP, modify appropriate components within UPP, and deliver UPP to EMC for R2O transition
- HPC resources: Requires disk space for the models and observations. Cloud computing may be helpful for phase 2.

Dependencies/linkages with other projects:

- Verification and calibration from GSD and NCAR WGs
- Annex 12, project 1

Core development partners and their roles:

- EMC integrates aviation algorithms to UPP, generates experimental products, and deliver experimental products to NCAR, GSD, and AWC for evaluation.
- GSD performs statistical validations based on the experimental products provided by EMC.
- NCAR does case validations, combines efforts from GSD then re-calibrates algorithms.
- EMC works with NCAR to merge re-tuned algorithms into UPP and prepares UPP for operational implementation.

Upgrade schedule:
- (Q4FY18) implement GTG as operational WAFS turbulence product with FY18 GFS upgrade
- (Q4FY18) implement CONUS GTG product to be generated by UPP as a separate upgrade
- (Q4FY19)implement CONUS Icing product to be generated by UPP.