NGGPS

Development of NOAA' Unified Forecast System: Progress and plans for modeling advancements in NGGPS/FV3 era

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NOAA/NWS/NCEP/EMC

The 3rd Taiwan West Pacific Global Forecast System Development Workshop
Central Weather Bureau, Taipei, Taiwan, June 19-22, 2018

Outline

FV3 Dynamic Core: Central component for NOAA's Next Generation Global Prediction System (NGGPS) and Unified Forecast System (UFS)

Implementation Plans for FV3GFS; FV3GDAS; and FV3GEFS (sub-seasonal)

FV3 Dynamic Core for Regional Convective Allowing Modeling Applications (including hurricanes)

Unified Forecast System: Focus on Advanced Physics

Community Involvement

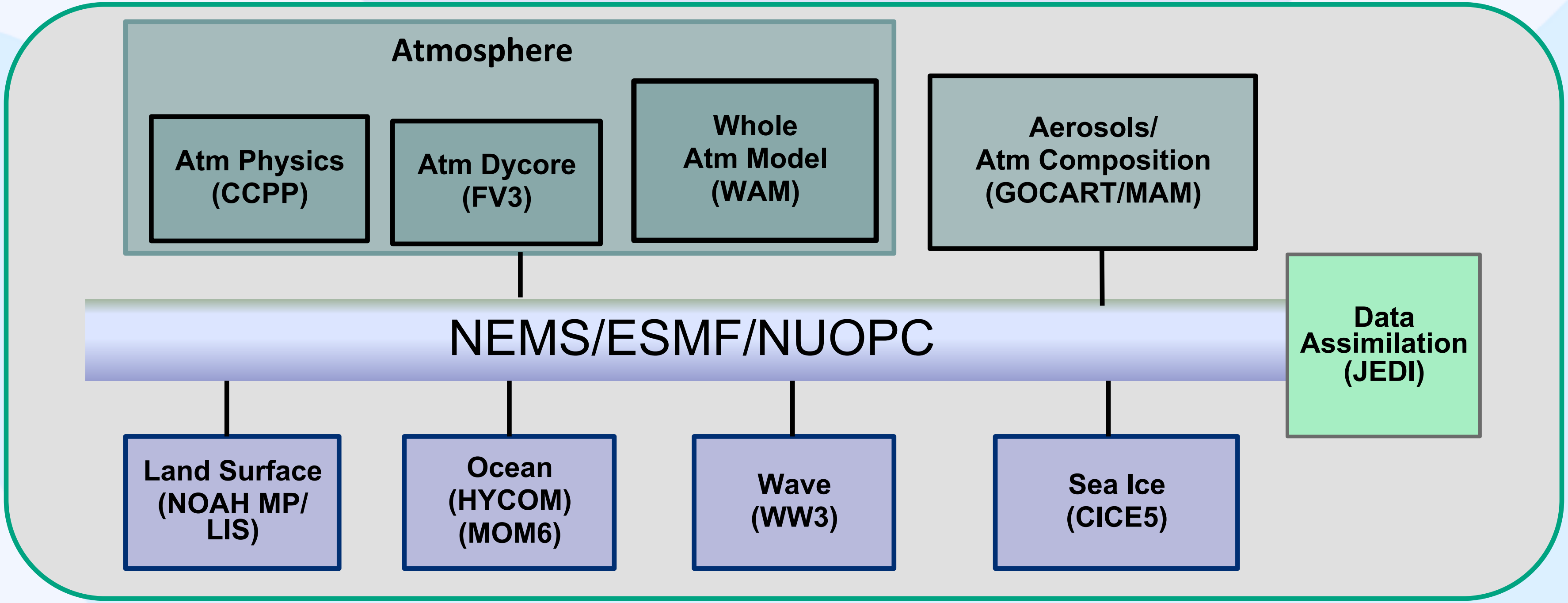
NGGPS Goals and Objectives[1]

- Design/Develop/Implement NGGPS global atmospheric prediction model
  - Non-hydrostatic scalable dynamics
- Improve data assimilation and physics
- Position NOAA NWS for next generation high performance computing
- Engage community in model/components development
- Reduce implementation time
- Increase effectiveness of product distribution
  - Post-processing, assessments, and display

World's Best Global Forecast Guidance

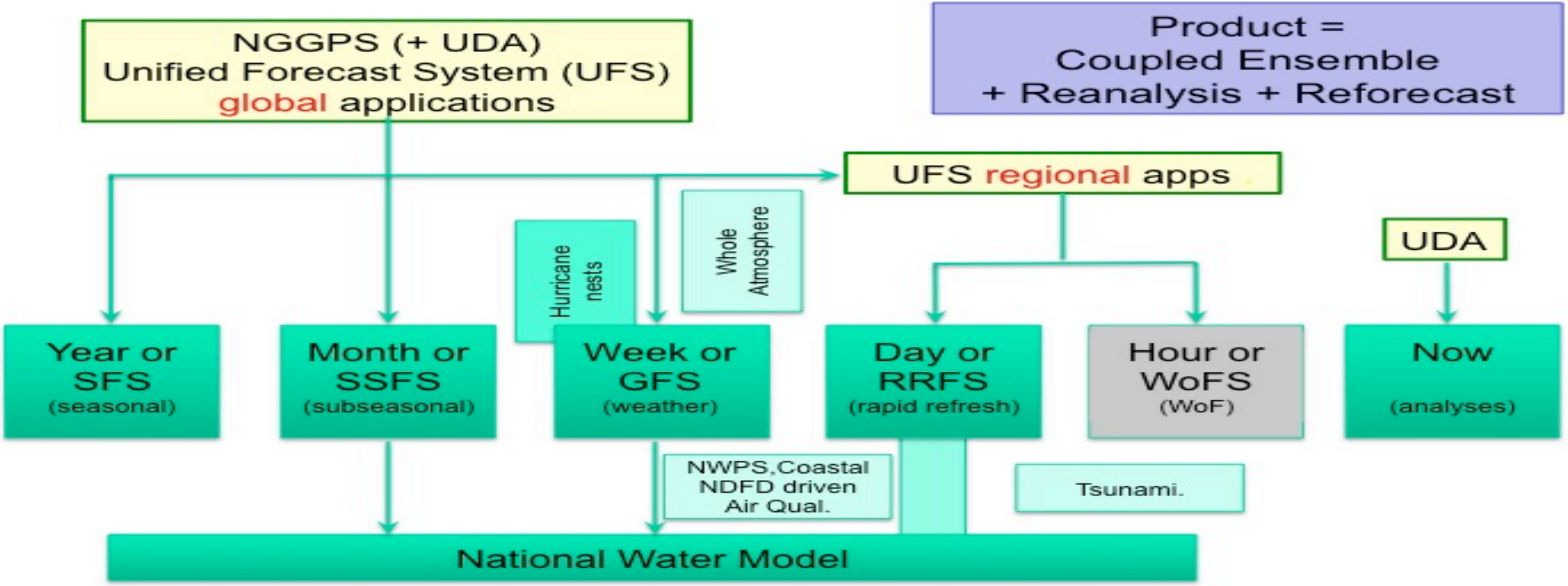
[1]From NWS Budget Initiative proposal to OMB

NGGPS Prediction Model Components



- NGGPS prediction model will consist of fully coupled components representing different parts of the Earth system.
- All components will be based on <u>community codes</u>.

Unified Forecast System NWS Operational Applications



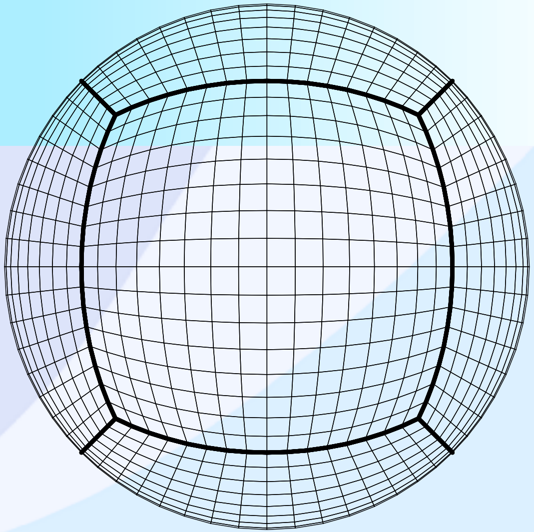
UDA: Unified Data assimilation
SFS: Seasonal Forecast System
SSFS: Subseasonal Forecast System

GFS: Weather Forecast System
RRFS: Rapid Refresh Forecast System
WoFS; Warn on Forecast System

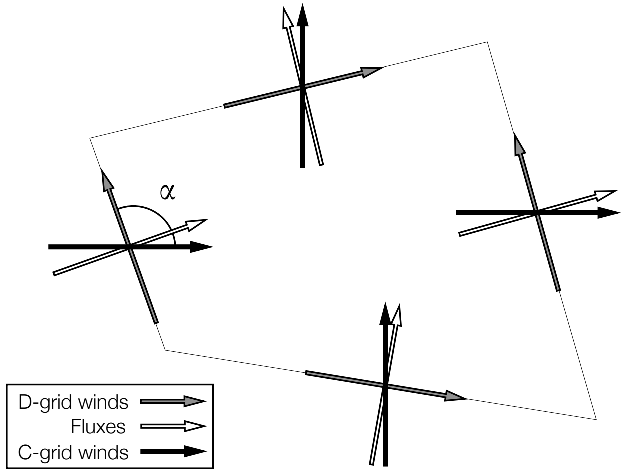
FV3 Dynamic Core: Central to UFS Applications

Courtesy: Lucas Harris, NOAA/GFDL

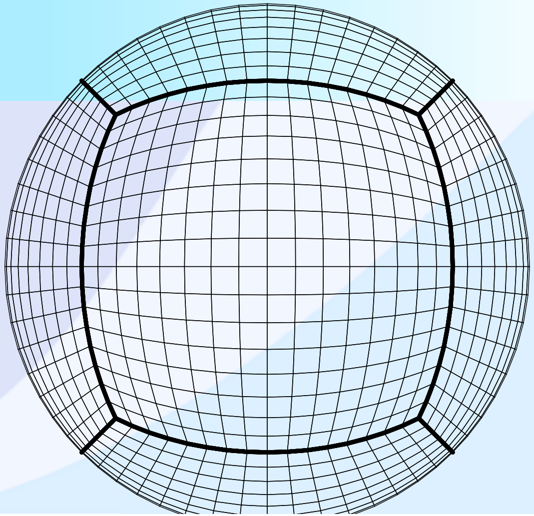
The Cubed-Sphere Grid



- Gnomonic cubed-sphere grid: coordinates are great circles
- Widest cell only √2 wider than narrowest
- More uniform than conformal, elliptic, or spring-dynamics cubed spheres
  - Tradeoff: coordinate is non-orthogonal, and special handling needs to be done at the edges and corners.



The Cubed-Sphere Grid

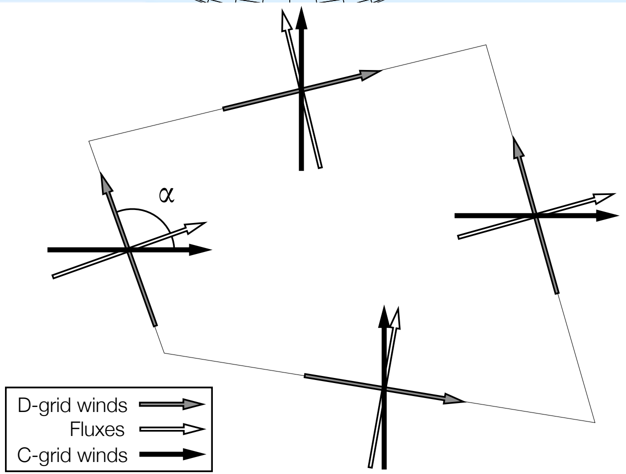


Gnomonic cubed-sphere is non-orthogonal

Instead of using numerous metric terms, use covariant and contravariant winds

- Solution winds are covariant, advection is by contravariant winds
- KE is half the product of the two

Winds u and v are defined in the local coordinate: rotation needed to get zonal and meridional components

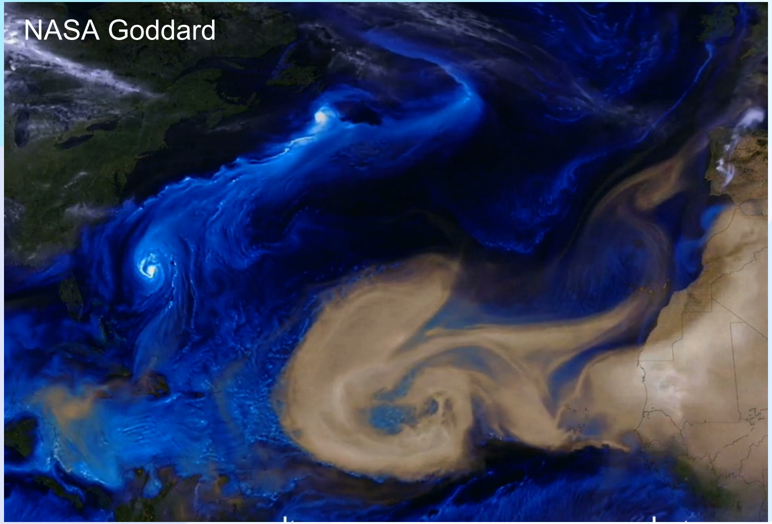


Features of FV3 Dynamics

Lagrangian Dynamics

- Eulerian in the horizontal, Lagrangian in the vertical
- Prognostic variables: u, v (D-grid), w, q_i, δz, δp, θ_v
- All variables are layer-means, no vertical staggering
- Piece-wise parabolic method for finite volume numerics (positive, monotonic, eliminates $2\Delta x$ noise, avoids too much diffusion
- Lin-Rood Finite Volume advection (flux form conservative)
- Tracer advection with sub-cycling
- C-D grid discretization and time-centered fluxes; exact computation of absolute vorticity

Many flows are vortical
Not just large-scale flows



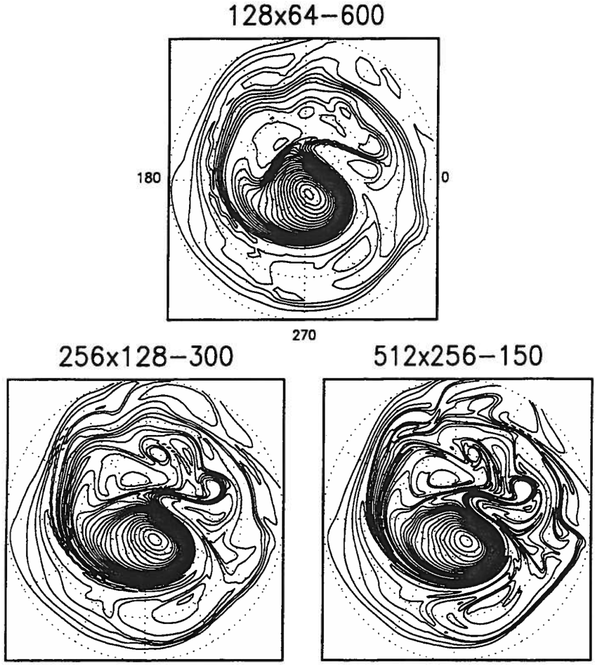
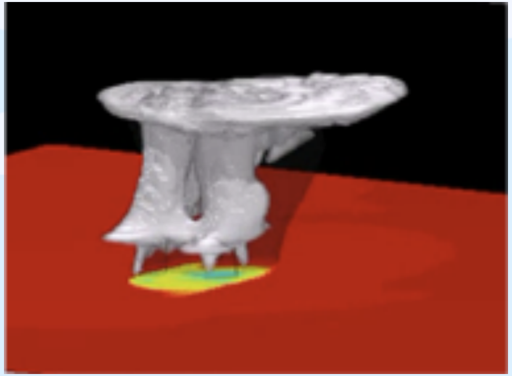
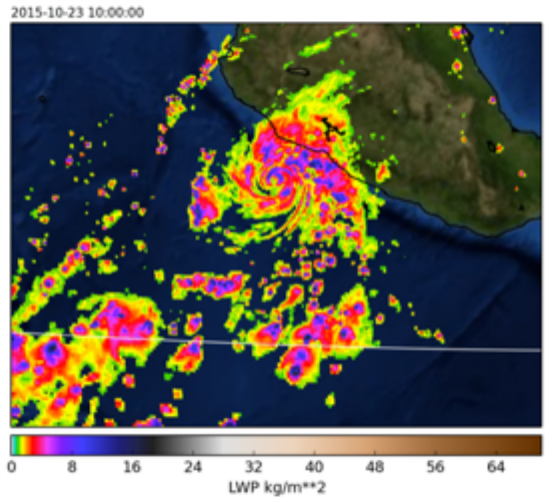


Figure 10. Polar stereographic projection (from the equator to the north pole) of the potential vorticity contours at DAY-24 in the 'stratospheric vortex erosion' test case at three different resolutions.





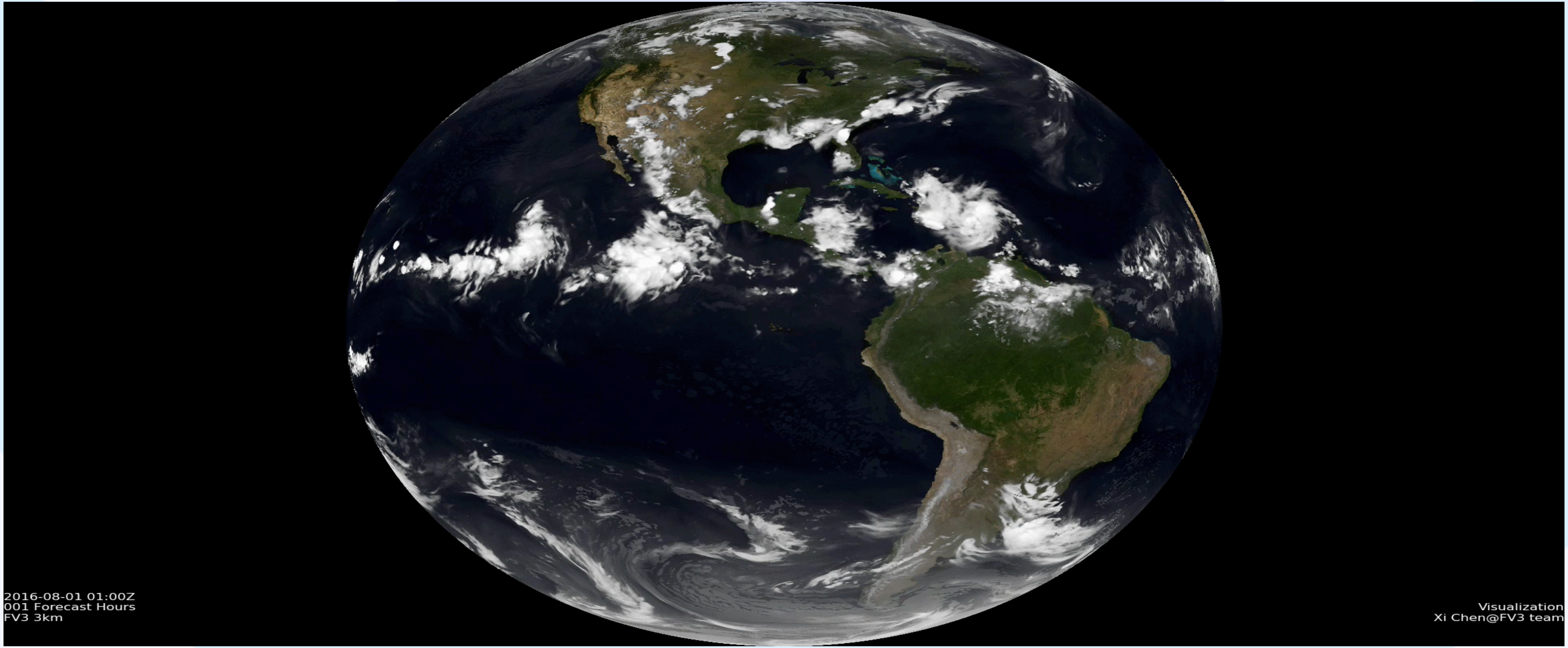
Cloud Microphysics Consistent with Dynamics

Courtesy: SJ Lin, NOAA/GFDL

GFDL Cloud Micro Physics & consistency with FV3 dynamics

S.-J. Lin & Linjiong Zhou

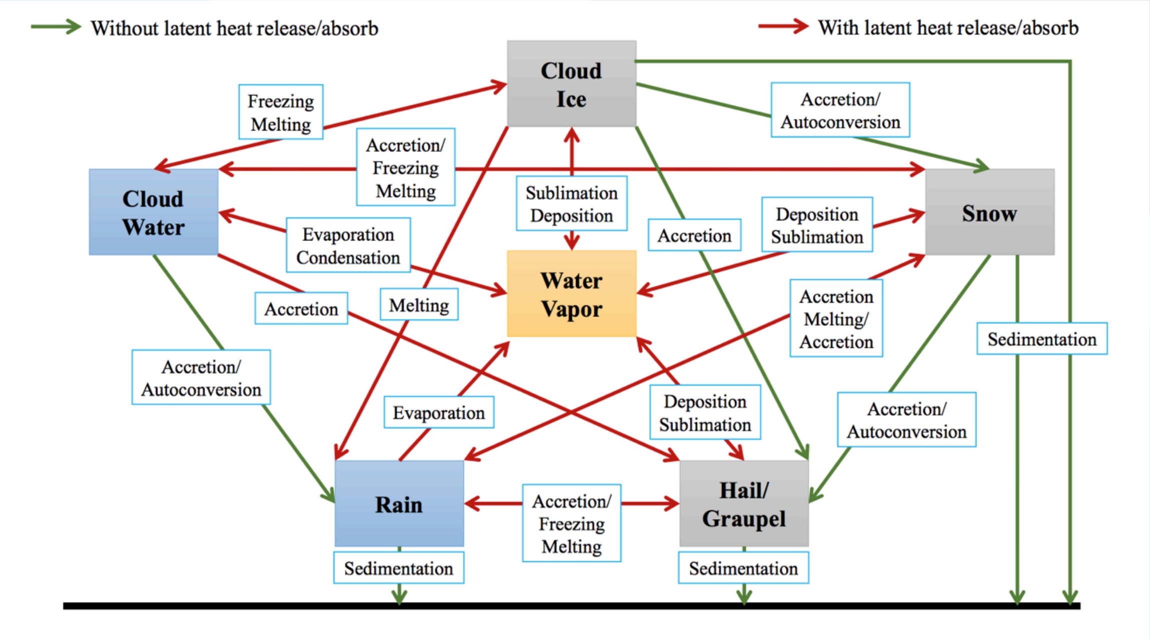
NOAA/Geophysical Fluid Dynamics Laboratory

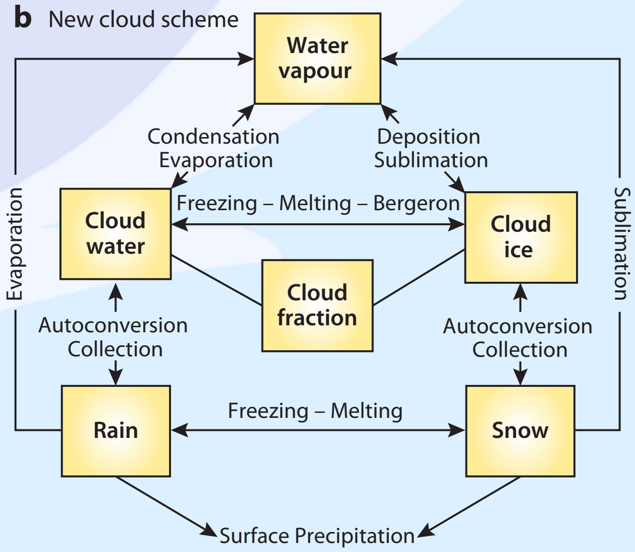


GFDL MP is simpler than double moment schemes; but …

GFDL cloud microphysics (6 species)

ECMWF cloud microphysics (5 species)

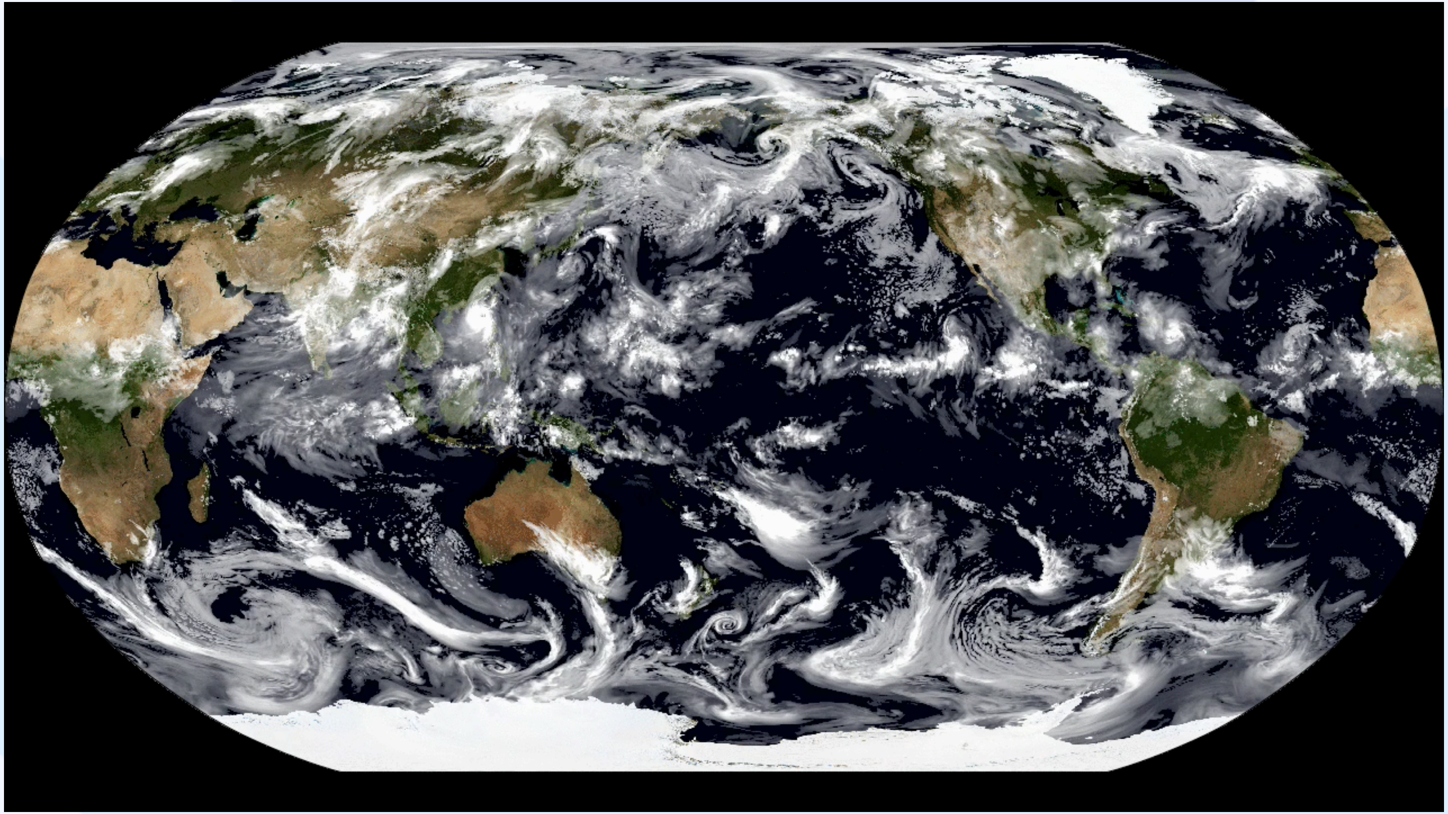




GFDL Cloud Microphysics used in the "DYAMOND" project

C1536L79 (6.5 km resolution, equivalent to 14 megapixels)

Total condensates (vertical sum of rain, cloud water, snow, graupel, and cloud ice): 20160801-20160810



UFS: Advanced Physics

Development of Advanced Physics using CCPP and HTF

Strategic plan for advanced physics development

FV3-GFSv1 (2019):

- mostly GSM physics, but with GFDL MP

FV3-GFSv2 (2020):

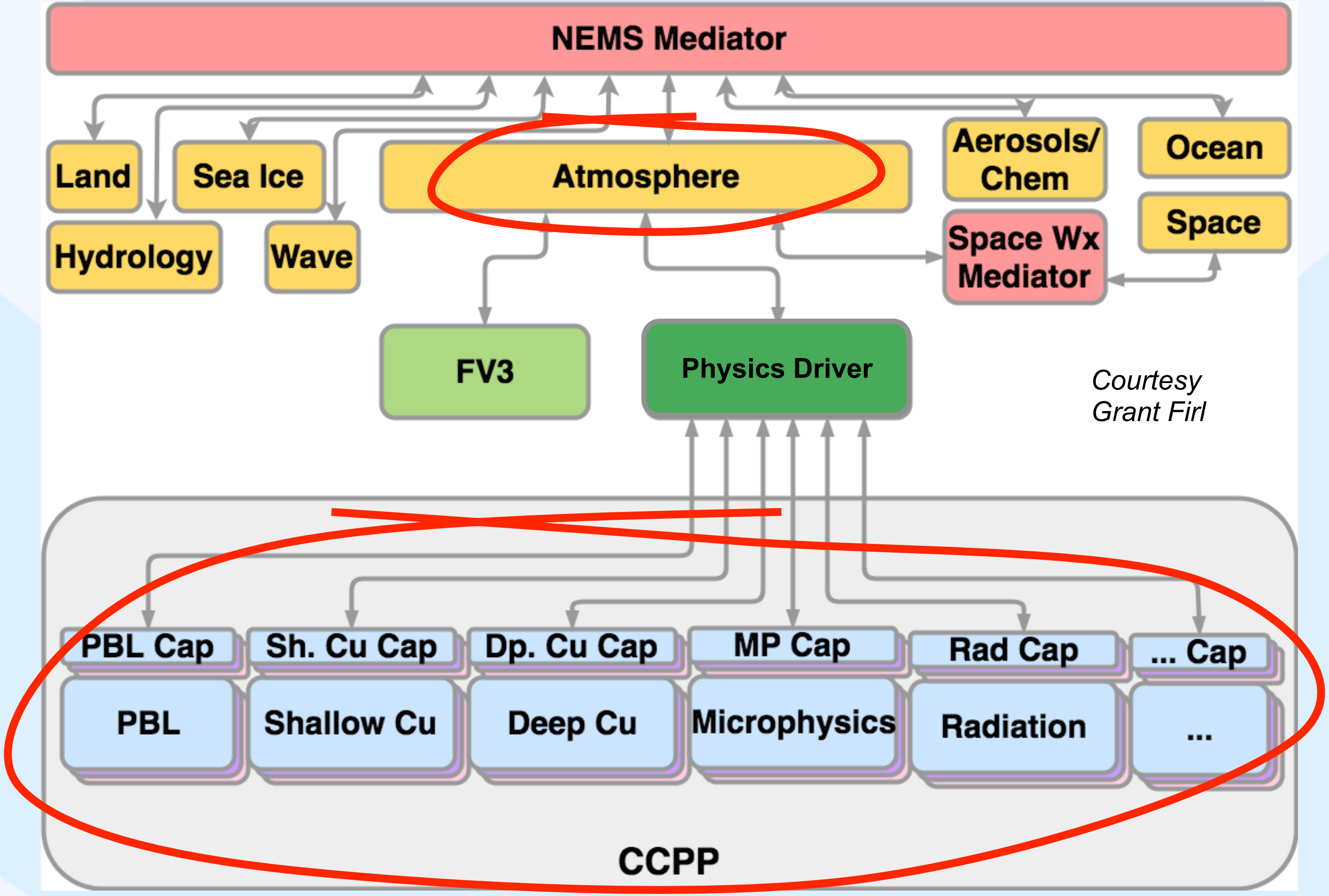
- Model Physics implemented through Common Community Physics Package (CCPP)
- Potential full-suite replacement

FV3-GFSv3+:

- Physics upgrades driven by community-supported Hierarchical Testing Framework connected to CCPP

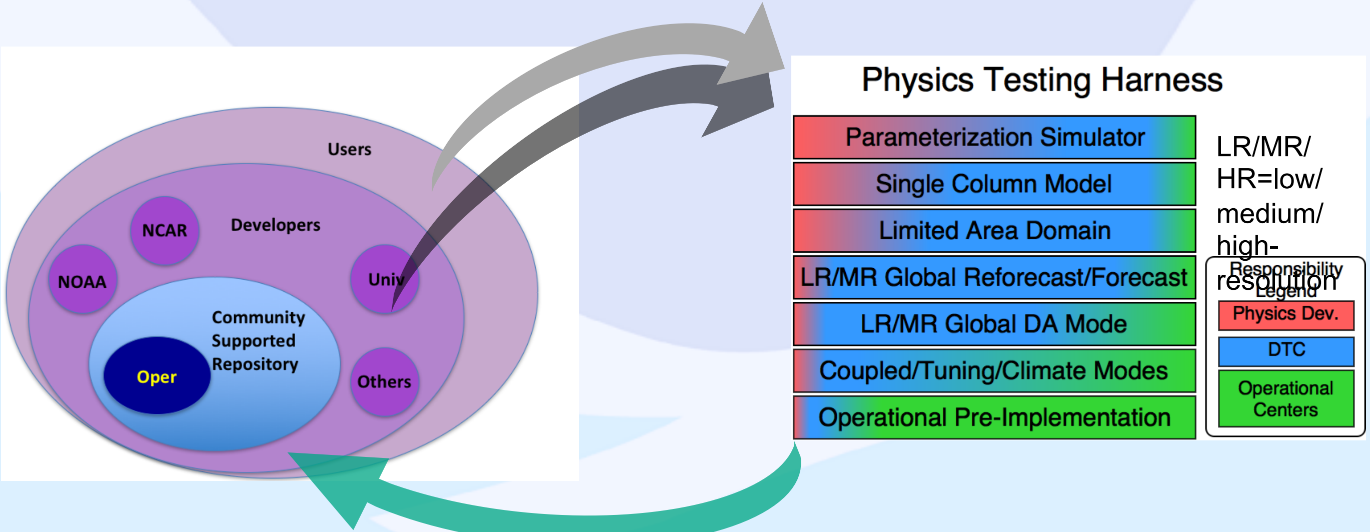
Highest Priority Physics Suite for FV3GFSv2

	SUITE		
Physical Process(es)	**FV3-GFSv1 opnl 1/19**	**RAP/HRRR**	**Climate Process Team EMC/CSU/Utah**
MICROPHYSICS	GFDL	Thompson	Morrison-Gettelman
PBL/TURB	GFS/EDMF	MYNN/EDMF	Simplified H-O Closure (SHOC)
DEEP MOIST Cu	SA-SAS	Grell-Freitas (GF)	Chikira-Sugiyama-AW (CSAW)
SHALLOW MOIST Cu	SA-SAS	MYNN/EDMF	SHOC
RADIATION	RRTMG	RRTMG	RRTMG
LAND	Noah	RUC	Noah-MP



Courtesy Grant Firl

Physics Testbed: Hierarchical concept



Single Column Model and Global Workflow are available to community collaborators

More information at https://dtcenter.org/community-code/physics-test-harness

DTC Developmental Testbed Center

Unified Forecast System: Global Models

Global Modeling Systems:

FV3GFS; FV3GDAS; FV3GEFS (sub-seasonal); FV3SFS (Seasonal Forecast System) and FV3WAM/IPE (space-weather)

FV3GFS v1.0 Implementation Plan

May 2018	Implementation Plan for FV3-GFS (FY2017-2020)														
FV3GFS	FY17				FY18				FY19				FY20		
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	% complete
FV3 Documentation	Evaluate, prepare and document FV3 dycore for GFS														100%
FV3 Dycore in NEMS		Implement FV3 dycore in NEMS													100%
FV3 Dycore with GFS Physics + GFDL MP			Couple FV3 to GFS physics (NUOPC physics driver) perform forecast-only experiments, add GFDL microphysics, tuning and testing												100%
4D-Hybrid GSI/EnKF DA for FV3			Develop DA techniques and use new data												100%
Post Processing			Adapt post-processing & downstream codes to FV3 Dycore												100%
Fully cycled FV3GFS experiments						Cycled experiments, Real-time and 3-yr retrospective experiments, field evaluation									30%
Operational Implementation								Transition FV3GFS (GFS V15.0) to operations							0%
Advancement of FV3GFS							Further advancements of FV3GFS with inputs from NGGPS and community contributions & Global-Meso unification (Unified Model Development)						Advanced version of FV3GFS v2.0 (GFS V16.0) to operations		20%

Today

Global Data Assimilation System (GDAS) for FV3:

New Observations and changes to GSI

- **Increase in ensemble resolution from roughly 39km to 25km.**
- **Adaptation of stochastic physics parameterizations from the spectral model (except SKEB).**
- **IASI moisture channels ; ATMS all-sky radiances**
- **Near Sea Surface Temperature (NSST)**
- **An upgrade to the use of CrIS radiances: Addition of NOAA-20 CrIS and ATMS data (implemented on May 31, 2018 in current operational GFS)**
- **Addition of Megha-Tropiques Saphir data**
- **Addition of ASCAT data from MetOp-B**
- **AMVs from GOES-16 (already included) and GOES-17 when available**

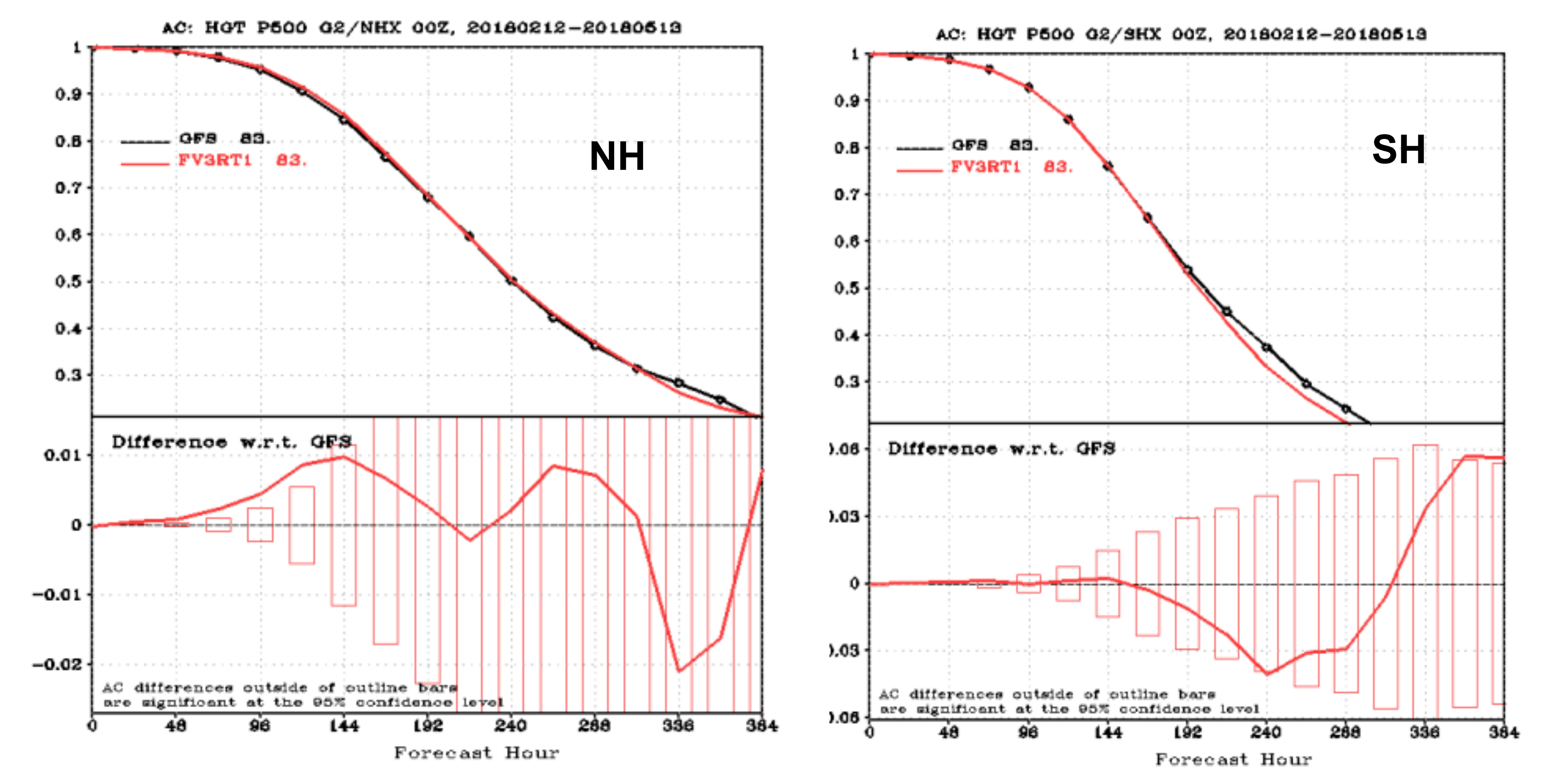
FV3GFS Configuration, Evaluation and Schedule

FV3GFS V1.0 is being configured to replace spectral model in operations in Q2FY19

Configuration:

- FV3GFS C768 (~13km deterministic); FV3GDAS C384 (~25km, 80 member ensemble);
- 64 layer, top at 0.2 hPa; Operational GFS Physics except for GFDL Microphysics
- Uniform resolution for all 16 days
- Real-Time data made available through para-NOMADS
- One-stop place for FV3GFS evaluation and other information: http://www.emc.ncep.noaa.gov/users/Alicia.Bentley/fv3gfs
- **1/24/2019: Implementation**

Real-time experiments with fully cycled FV3GFS+GFDL MP; 500-hPa HGT ACC



FV3GEFS Implementation Plan

Implementation Plan for FV3-GEFS (FY2017-2020)

June 2018

FV3GEFS	FY17				FY18				FY19				FY20				
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	% complete
FV3GEFS Reanalysis Development			Develop and test low resolution FV3GFS with FV3GDAS, configure it for reanalysis (ESRL)														100%
FV3GEFS Ensemble Configuration		Configure FV3GFS ensemble resolution, members, physics, coupling to ocean and sea-ice, and extend forecasts to weeks 3&4 (EMC)															95%
FV3GEFS Reanalysis Production							Produce ~20-year reanalysis datasets using FV3GFS/GDAS (ESRL)										15%
FV3GEFS Reforecasts								Finalize FV3GEFS V12 configuration & produce 30-year reforecasts (extended to 35 days) for calibration and validation of HEFS/OWP									0%
FV3GEFS V12 Evaluation										Evaluate FV3GEFS V12 forecast performance out to weeks 3&4							0%
FV3GEFS V12 Implementation													FV3GEFS V12 in operation				0%
Advancement of FV3GEFS													Further advancements of FV3GEFS (GFS/GEFS unification, ensemble based coupled modeling)				

Today

* Proposed changes for GEFS V12: 1) Produce FV3 based reanalysis in FY18 using the same configuration as Q2FY19 FV3GFS (ESRL); 2) Reforecasts will be based on FV3GEFS configured with 2-Tier SST approach; and 3) FV3GEFS Reforecasts extended to 35 days to include weeks 3&4 guidance.

FV3-GEFS V12 Configuration

- Model configuration
  - C384 (25km) horizontal resolution and 64 hybrid vertical levels
- Ensemble size
  - **30+1** members per cycle (preferred, depends on resources availability)
- Frequency
  - 0000; 0600; 1200 and 1800UTC
- Forecast lead-time
  - 16 days for every cycle, except for
  - 35 days once per day at 00UTC
- Output
  - 3 hourly at 0.25d out to 10 days (25% additional cost for hourly output)
  - 6 hourly at 0.5d from 10 to 35 days.
- NPS Unification
  - Atmosphere forced wave ensembles
  - NEMS GFS Aerosol Component

- Reforecast configuration: The same as real-time GEFSv12 (C384L64)
- Period of reforecasts: 30 years (1989 – 2018)
- Frequency and ensemble size
  - Configuration: 30 years, initialized at 00UTC for every day; runs 5 members out to 16 days, except for 11 members out to 35 days every 5 days.
- Output data
  - 3 hourly out to 10 days at 0.25 degree resolution
  - 6 hourly beyond 10 days at 0.5 degree resolution
- Timeline to complete
  - One year (Q4FY18 – Q4FY19)

FV3-GEFS V12 Configuration (Cont.)

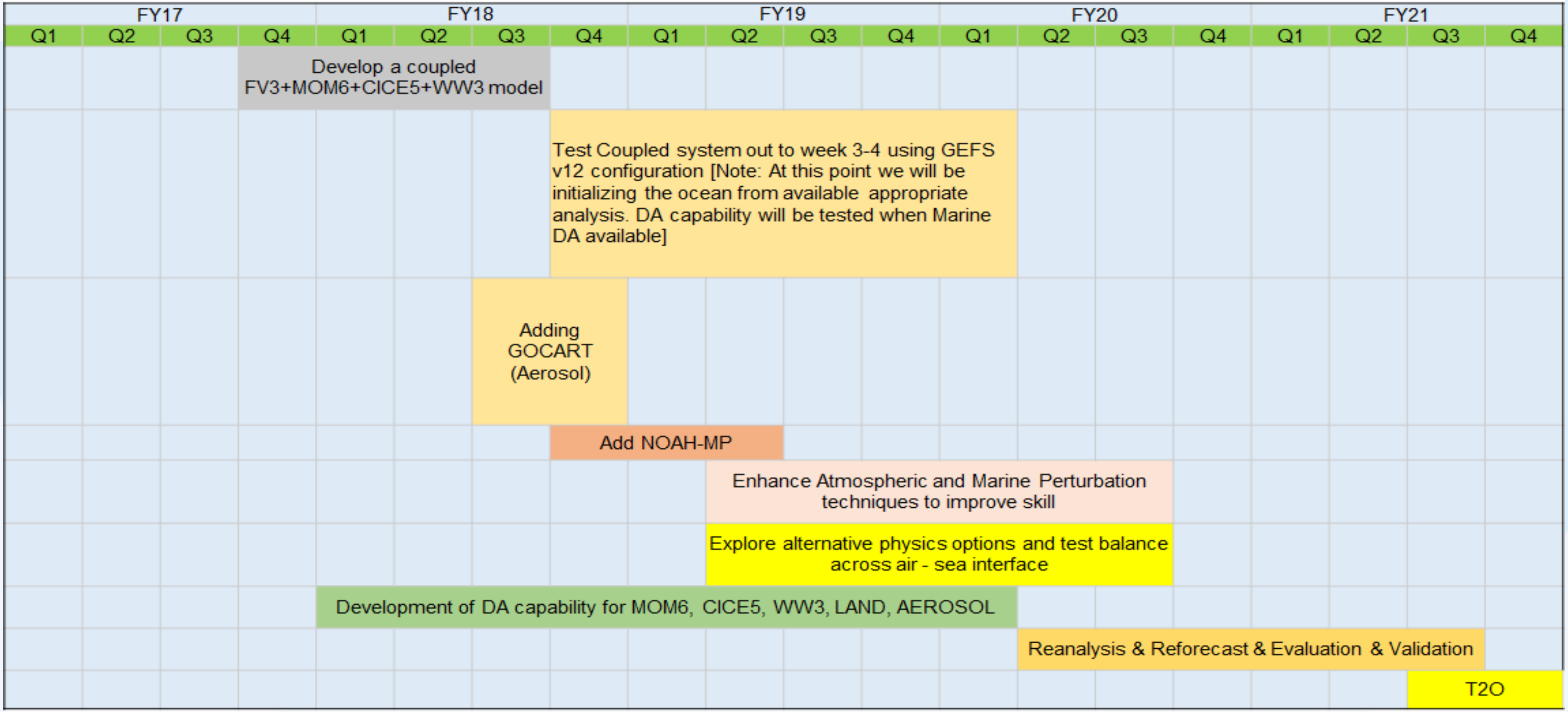
- Model
  - FV3GEFS (C384L64) with GFDL MP
- Initial perturbations
  - FV3EnKF analysis (early run) or FV3EnKF f06
  - No TS relocation for FV3EnKF
- Stochastic perturbations for atmosphere
  - SKEB, SPPT (5-Scales) and SHUM (0.004)
- Stochastic perturbations for land
  - No stochastic perturbations
- Boundary forcing for weeks 3&4 forecast
  - 2-tiered SST approach
- **Timeline for finalizing configuration – Q4FY18**

FV3 based Coupled System for S2S (UFS: Target GEFS v13 and SFS V1.0)

- UFS system consists of the following components
  - NOAA's Environmental Modeling System (NEMS) for coupling infrastructure
  - FV3 Dycore with CCPP
  - MOM6 ocean model
  - WW3 wave model
  - CICE5 ice model
  - GOCART aerosol model
  - Noah MP land model
- Each component has its own community repository. NEMS infrastructure allows flexibility to connect instantiations of the repositories together to create a coupled modeling system.

- Q3 FY18 -- Complete technical development of FV3-MOM6-CICE5-WW3 system
- Q3 FY18 - Q1FY20 -- Detailed science testing in deterministic mode.
- Q2FY19 - Q1FY20 -- Test alternative physics and perturbation techniques
- Q1FY18 - Q1FY20 -- DA development
  - DA development for the atmosphere will rely on GSI (and any subsequent transition to JEDI)
  - DA group working on a marine DA in JEDI (DA for MOM6, WW3 and CICE5). Separate development plan

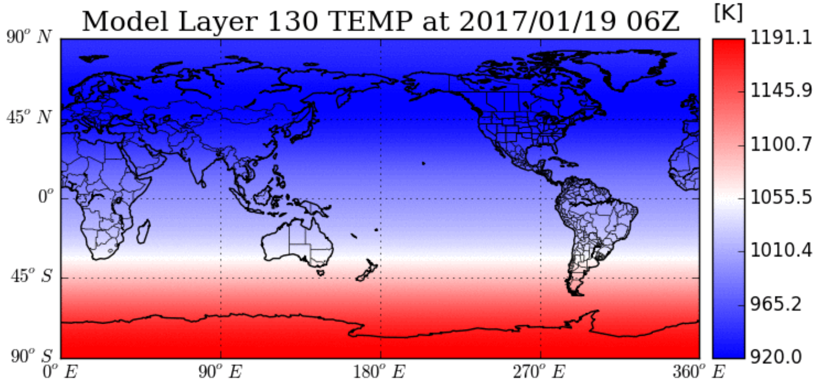
UFS/S2S Development Timeline



FV3 based Deep Atmosphere Dynamics for WAM/IPE

Joint development plan for Space Weather Applications: (EMC/GFDL/SWPC/CU Collaboration)

- Extend FV3 vertical domain to be the same as GSM WAM
- Adiabatic mode of FV3
- Extend to WAM domain with WAM cold-start IC
- Use GFS physics with Rayleigh damping
- Add diffusivity, conductivity, viscosity for upper-layer integration
- Add WAM physics and multi gases thermodynamics
- Add deep-atmosphere dynamics
- Couple to IPE using NUOPC mediator



FV3 based Regional Convection Allowing Models

Development of FV3 based Stand-Alone Regional Model

FV3 for Convection Allowing Models: Stand-alone regional configuration

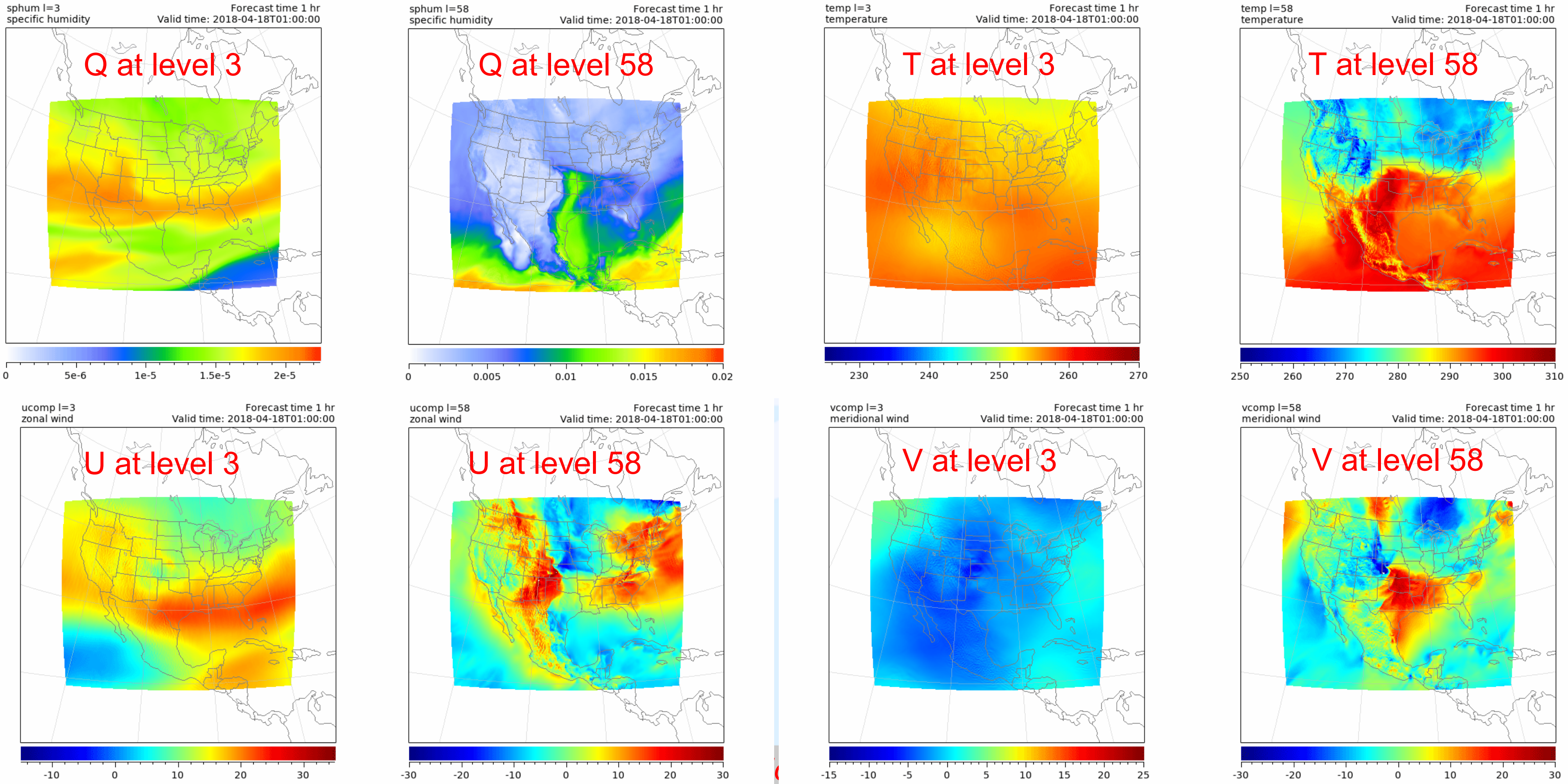
Completed

- Q3FY17: Initial concept ensemble test case with FV3 nesting on a stretched cube (manually run)
- Q1FY18: More testing with global FV3 with a 3 km CONUS nest on a stretched cube including ensemble display tools
- Q3FY18: Develop a standalone regional FV3 capability, share codes with GSD and NSSL

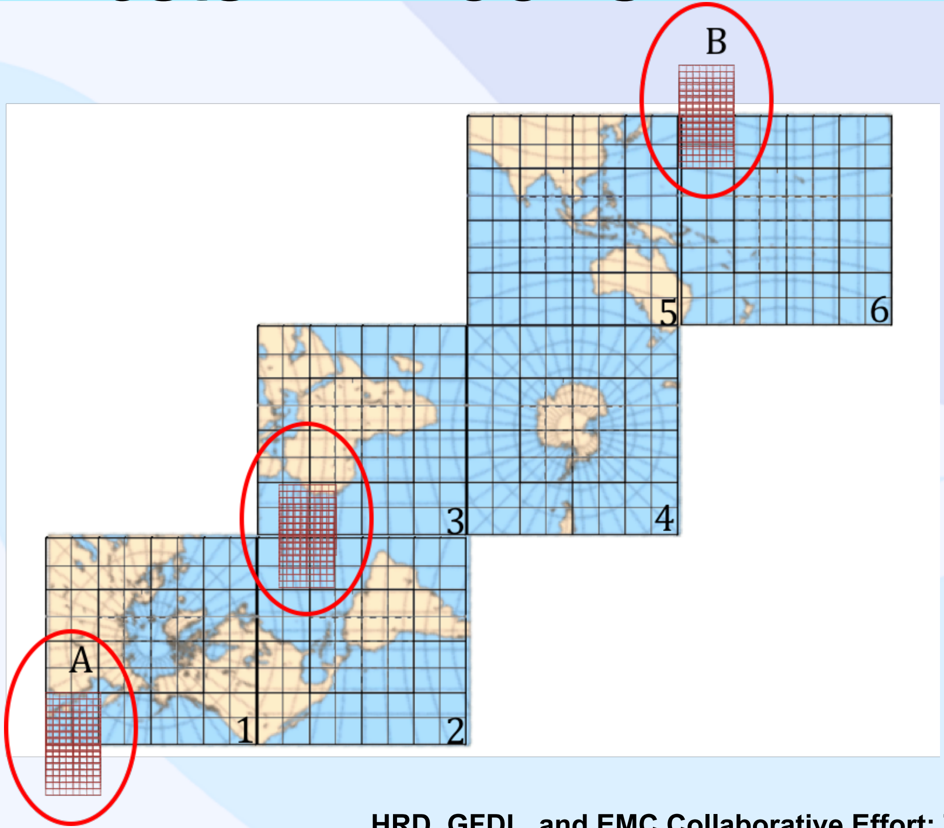
Near-term Milestones

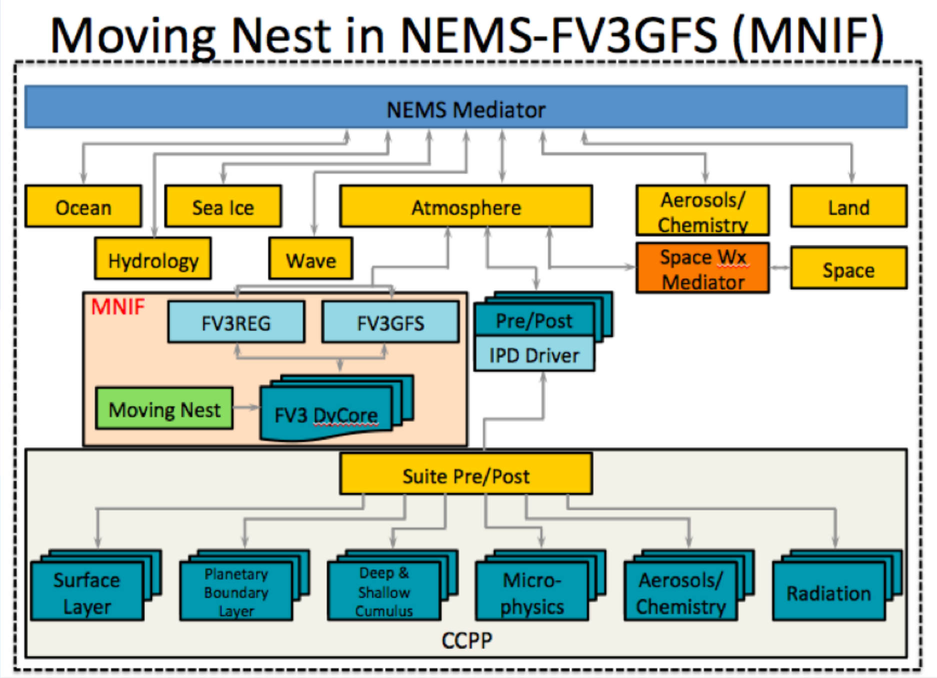
- Q4FY18: Static nests running in standalone regional FV3
- Q4FY18: Integration/testing of advanced physics in nested FV3
- Q4FY18: Early adopters workshop on standalone regional FV3
- Q2FY19: Compare pure FV3-based HREF with multi-model HREF

Early results from stand-alone FV3CAM



UFS for Hurricanes: Next Generation Moving Nests in FV3GFS





HRD, GFDL and EMC Collaborative Effort: Target 2021 Implementation

Community Engagement

NGGPS supported activities; Access to FV3 Repositories and Training

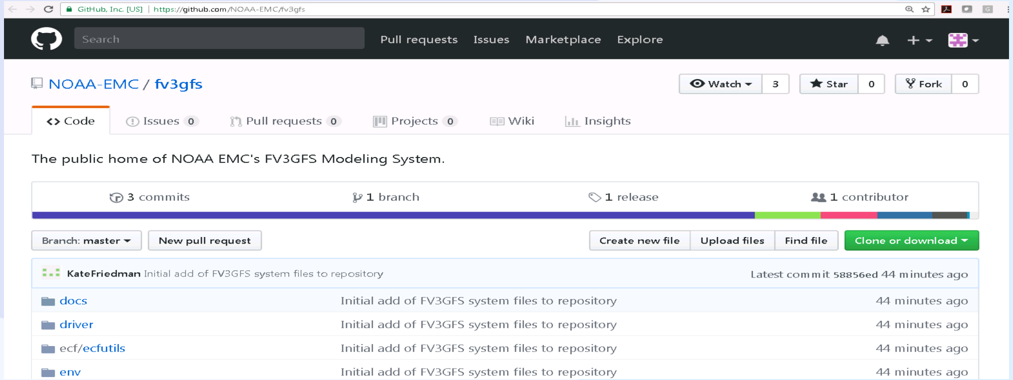
Community engagement: FV3GFS V1 Code Public Release on March 30, 2018 through Github.com and NOAA Virtual Lab (VLab)

- ➢ Access FV3GFS Project on VLab
- ➢ Code repositories set up on **Github.com & VLab GIT**
- ➢ Community Wiki page, Forums and Developers Pages on VLab
- ➢ ICs for Canned Cases:

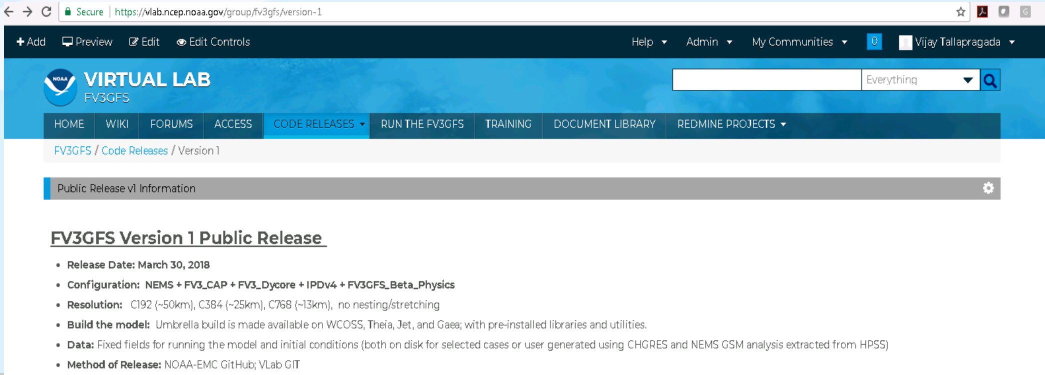
August 17, 2017 **Hurricane Harvey**
February 10, 2016 **Atmospheric River**
February 28, 2018 **East Coast Noreaster**

- ➢ Capability to generate ICs for any case
- ➢ Limited support from EMC
- ➢ Model Resolutions: C192 (**~50km**), C382 (**~25km**) or C768 (**~13km**)

https://github.com/NOAA-EMC/fv3gfs - Public Version



https://vlab.ncep.noaa.gov/web/fv3gfs - Developers Version



FV3 Training at NCWCP: June 12-14, 2018

WELCOME TO THE FV3GFS VLAB COMMUNITY!

FV3GFS Announcements:

Upcoming FV3 Training

GFDL and EMC are pleased to announce an initial FV3 training targeted towards technical developers; the goal of this initial training is to focus on the detailed description of the FV3GFS forecast model (dynamic core, solver and physics) and various utilities, and testing of the FV3GFS for global atmospheric applications. A demo on how to run FV3GFS using the FV3GFS workflow including post processing and verification will also be part of this training.

The training will be held at NCWCP/NCEP in College Park, Maryland June 12th through 14th. More information will be available soon on the following community page: https://vlab.ncep.noaa.gov/web/fv3gfs/training

FV3 Training at CWB: June 19-22, 2018

The 3rd Taiwan West Pacific Global Forecast System Development Workshop

第三屆臺灣與西北太平洋全球預報系統發展研討會

CWB, Taipei, Taiwan, June 19 - 22, 2018

CWB conference room 310, 617

PROGRAM

Day 1 - Tuesday, June 19 (room 310)		
Opening Session *Chair：Chia-Ping (Mark) Cheng 程家平, Director, Meteorological Information Center, CWB, Taiwan*		
09:00-09:05	*Tien-Chiang Yeh 葉天降* *Director General,* *CWB, Taiwan*	Welcome Remarks
09:05-09:15	*Ming-Dean Cheng 鄭明典* *Deputy Director General,* *CWB, Taiwan*	Objective of the 3rd TWPGFS Development Workshop / Invitee (Panel) introduction
09:15-09:55	*Brian Gross* *Director,* *EMC/NCEP/NWS/NOAA,USA*	Directions of agency and community modeling efforts, pathways for CWB to engage in collaborative research and development
09:55-10:10	Group Photo and Tea Break	
Section 1：The EMC NGGPS and its New Physics Processes *Chair：Jen-Her Chen 陳建河, Senior Meteorologist, Meteorological Information Center, CWB, Taiwan*		
10:10-10:50	*Vijay Tallapragada* *Global Branch Chief,* *EMC/NCEP/NWS/NOAA,USA*	Development of non-hydrostatic unified modeling system, progress and plan for development of advanced physics in NGGPS era (NGGPS/FV3)
10:50-11:00	Tea Break	
11:00-11:30	*Rui Yu Sun* *Senior Scientist* *EMC/NCEP/NWS/NOAA,USA*	Testing of alternate cloud microsphysics schemes in NGGPS/FV3
11:30-12:00	*FangLin Yang* *Senior Scientist* *EMC/NCEP/NWS/NOAA, USA*	The installation and evaluation of FV3 dycore and advancement physics in GFS for Q1FY19 operational implementation
12:00-13:30	Lunch Break (room 311)	

Day 2 - Wednesday, June 20 (room 310)		
Section 3：The EMC Ensemble Prediction, Data Assimilation, and Postprocesses *Chair：Jyh-Wen Hwu 胡志文, Associate Researcher, R&D Center, CWB, Taiwan* *Hui-Lin Chang 張惠玲, Senior Meteorologist, R&D Center, CWB, Taiwan*		
09:00-09:30	*Yuejian Zhu* *Ensemble lead* *EMC/NCEP/NWS/NOAA,USA*	Update on FV3-based GEFSv12, plans for weeks 3-4
09:30-10:00	*Philip Pegion* *Senior Scientist* *ESRL/NOAA,USA*	Development and testing of stochastic parameterizations for use in data assimilation and ensemble prediction systems
10:00-10:10	Tea Break	
10:10-10:40	*Daryl Kleist* *Senior Scientist* *EMC/NCEP/NWS/NOAA,USA*	Enhancements to Hybrid 4DEnVar through shifting/lagging, scale-dependent localization, and expanding all-sky capabilities with new GFDL MP
10:40-11:10	*Catherine Thomas* *Senior Scientist* *EMC/NCEP/NWS/NOAA, USA*	Update on data assimilation activities for NGGPS/FV3: impacts on data assimilation within context of new microphysics scheme, cloud analysis, and plans for higher vertical resolution
11:10-11:20	Tea Break	
11:20-11:50	*Jason Levit* *Postprocess and verification lead* *EMC/NCEP/NWS/NOAA,USA*	Current and Future Strategies for Verification and Post-Processing of Numerical Weather Prediction Models at the NOAA Environmental Modeling Center
11:50-12:20	*Jun Wang* *Senior Scientist* *Engineering and Implementation Branch* *EMC/NCEP/NWS/NOAA,USA*	An overview of the NOAA Environmental Modeling System infrastructure

Day 3 - Thursday, June 21 (room 617)		
Section 5：EMC modeling infrastructure and NGGPS Tutorial		
09:00-10:30	Tutorial Course (1)	
10:30-10:40	Tea Break	
10:40-12:00	Tutorial Course (2)	

NGGPS/UFS: Next Steps

Continue integration and implement FV3 dynamical core

- Accelerate evolution of model physics
- Implement improved data assimilation (adapt to the new model with FV3 dynamical core and add data sets)
- Develop enhanced post-processing, ensemble methods; verification and validation; visualization tools and techniques

- Foster a community involvement in:
  - UFS Governance
  - Model environment with GMTB, JCSDA
  - Testing and evaluation of components and systems
  - Planning and development through NGGPS/UFS Working Groups and SIP

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