



NCEP Unified Forecast System: High-Resolution Global, Regional and Hurricane Modeling Capabilities using FV3 Dynamic Core

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Outline

FV3 Dynamic Core: Central component for NOAA's Next Gen. Prediction Systems

Progress on FV3GFS and FV3GDAS Developments and Results from Real-Time Experiments

FV3 Dynamic Core for Regional Convective Allowing Modeling Applications and moving nests for Hurricanes

Role of Community Engagement in the development of NOAA's Strategic Implementation Plan (0-3 years) and Roadmap (0-10 years)

Strategic Implementation Plan for Unified Modeling

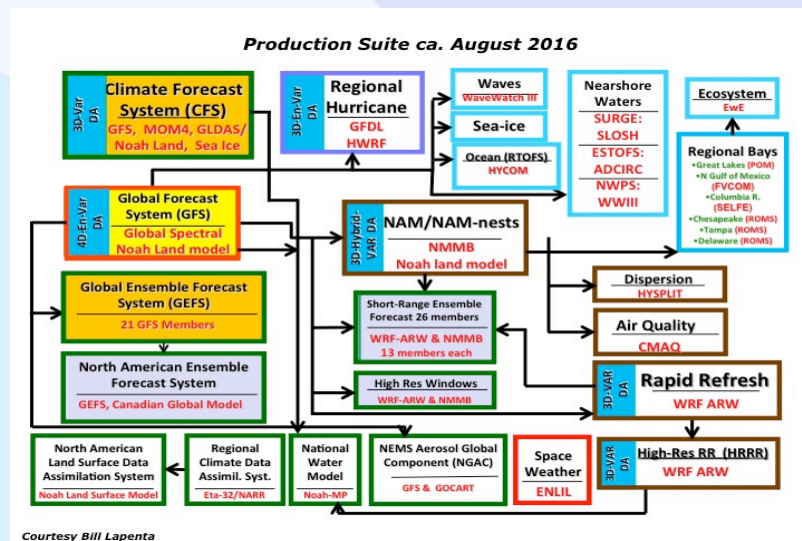
Strategic Vision for Evolution of NGGPS to a National Unified Modeling System

- Unified Modeling based on FV3 – Short term implementation plans through FY20
- Evidence based decision making process
- Community engagement from the beginning
- Working groups met at NCWCP during April 17-19, and August 1-4 2017 to draft SIP Draft V1, first draft developed
- Leading to more detailed Strategic Plan and Road Map being developed by NWS STI in collaboration with partners & community

- **Governance**
- **System architecture**
- **Infrastructure**
- **Dynamics and Nesting (including hurricanes)**
- **Model physics**

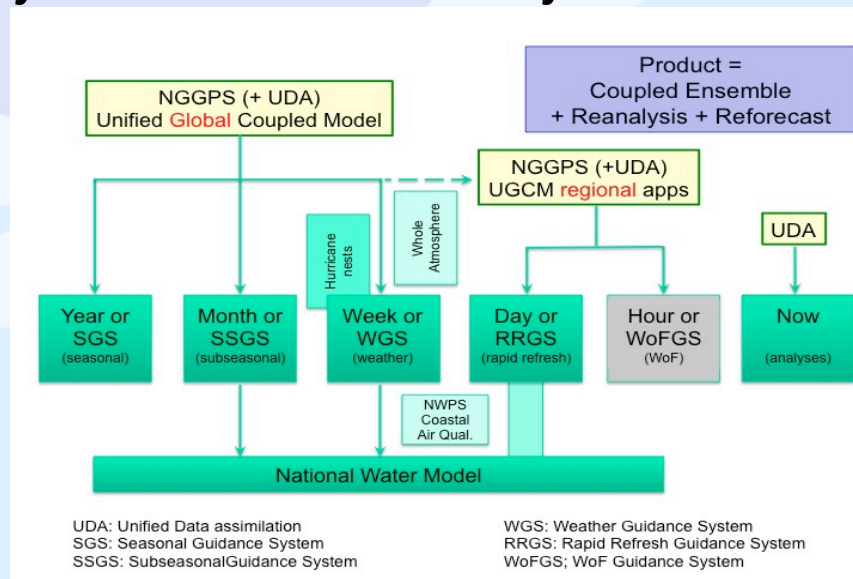
- **Data assimilation**
- **Ensembles**
- **Post Processing**
- **Verification & Validation**
- **Convective allowing models**

Strategic Vision & Roadmap



Starting from the quilt of models and products created by the implementing solutions rather than addressing requirements

... we will move to a product based system that covers all present elements of the productions suite in a more systematic and efficient way

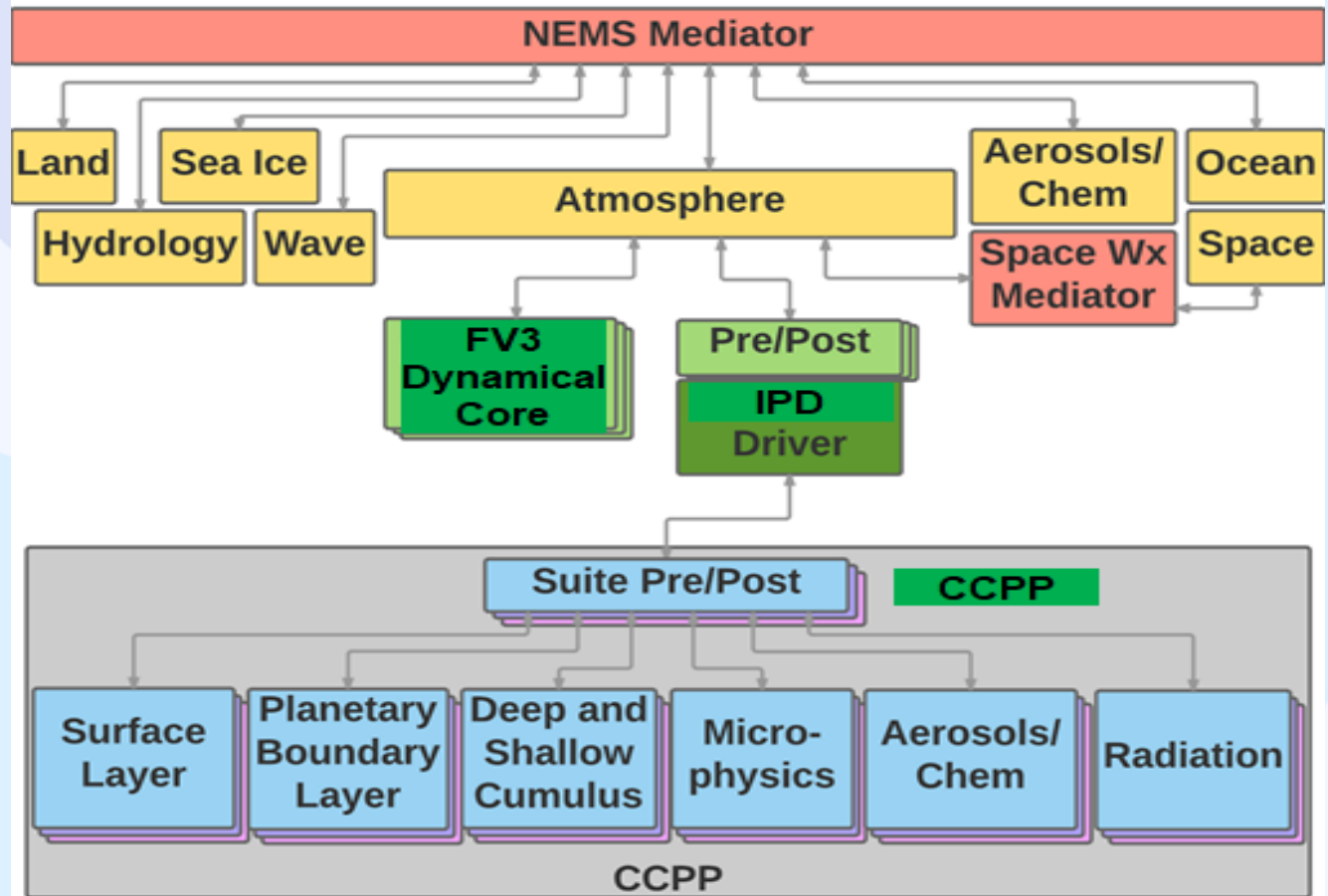


ESMF Based NEMS FV3GFS - Object Oriented Design

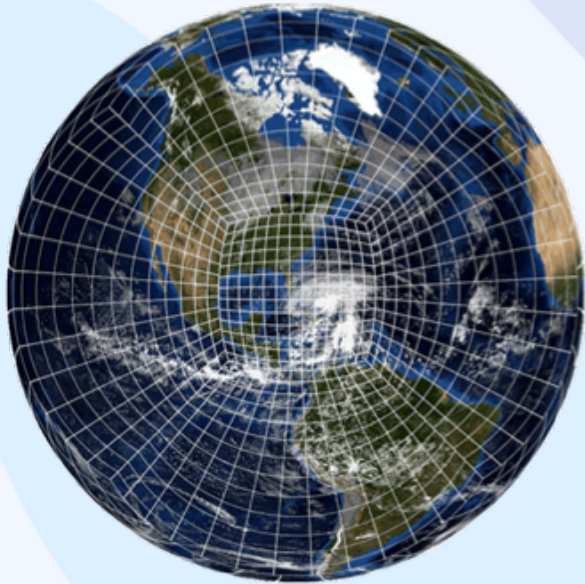
NEMS is based on **ESMF** and follows **NUOPC** convention

A numerical model in NEMS is represented by software and implemented as an ESMF grid component.

Each ESMF grid component has its own internal state with internal methods



Timeline for FV3GFS Transition to Operations



Near-term Milestones

- Q1FY18: Update FV3 documentation
- Q1FY18: Complete Pre/Post processing, verification, & downstream
- **Q3FY18: Implement FV3GFS Beta version (parallel production from NCO)**
- Q4FY18: Advanced physics; increased resolution and enhanced DA
- Q1FY19: Finalize FY19 FV3GFS implementation configuration
- Q2FY19: Conduct and evaluate real-time parallels and 3-year retrospective experiments
- **Q2FY19: Implement FV3GFS into NCEP operations replacing current operational GFS (GSM)**

Timeline for FV3GEFS Transition to Operations

(extending forecasts to sub-seasonal time scales at weeks 3&4)

Version 1.1 January 2018	Implementation Plan for FV3-GEFS (FY2017-2020)																
FV3GEFS	FY17				FY18				FY19				FY20				
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	
FV3GEFS Reanalysis Development			FV3GFS with FV3GDAS, configure it for reanalysis (ESRL)														
FV3GEFS Ensemble Configuration		Configure FV3GFS ensemble resolution, members, physics, coupling to ocean and sea-ice, and extend forecasts to weeks 3&4 (EMC)															
FV3GEFS Reanalysis Production							Produce ~20-year reanalysis datasets using FV3GFS/GDAS (ESRL)										
FV3GEFS Reforecasts							Finalize FV3GEFS V12 configuration* & produce ~20-year reforecasts (extended to 35 days)										
FV3GEFS V12 Evaluation										Evaluate FV3GEFS V12 forecast performance out to weeks 3&4							
FV3GEFS V12 Implementation					current date								FV3GEFS V12 in operation				
Advancement of FV3GEFS													Further advancements of FV3GEFS (GFS/GEFS unification, ensemble based coupled modeling for 35-day weather outlook guidance)				
* Proposed changes for GEFS V12: 1) Produce FV3 based reanalysis in FY18 using the same configuration as Q2FY18 FV3GFS (ESRL); 2) Reforecasts will be based on FV3GEFS configured with either coupled to Ocean and Sea-Ice models or use 2-Tier SST approach; and 3) FV3GEFS Reforecasts extended to 35 days to include weeks 3&4 guidance.																	

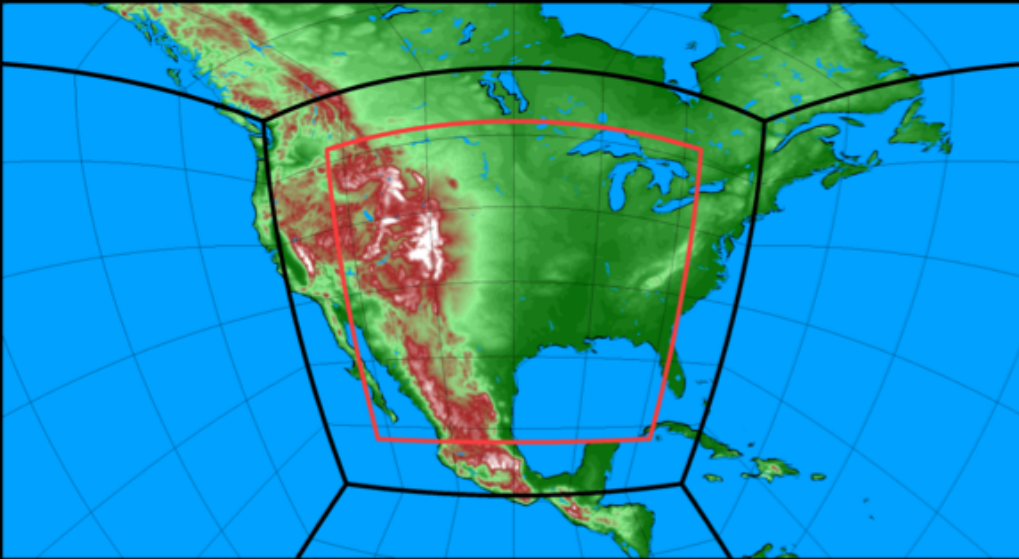
Achieving thunderstorm-resolving resolution “TODAY” in a unified meso-global prediction system

1) Grid stretching (smooth variation of grid spacing)

1) 2-way nesting (Harris and Lin 2014)

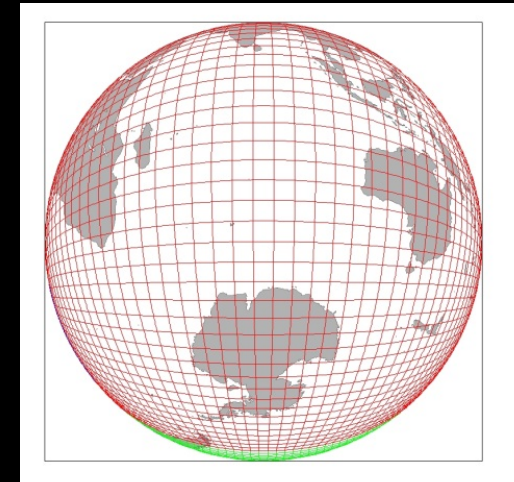
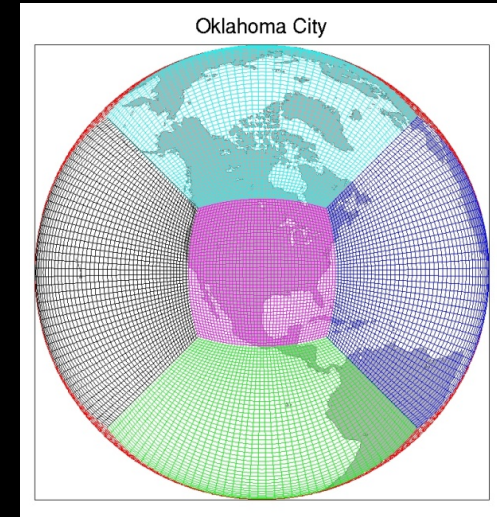
FV3 is uniquely suitable for 2-way nesting, due to the application of two-time-level Finite-Volume transport scheme

2) Optimal combination of the “stretching” and “nesting”

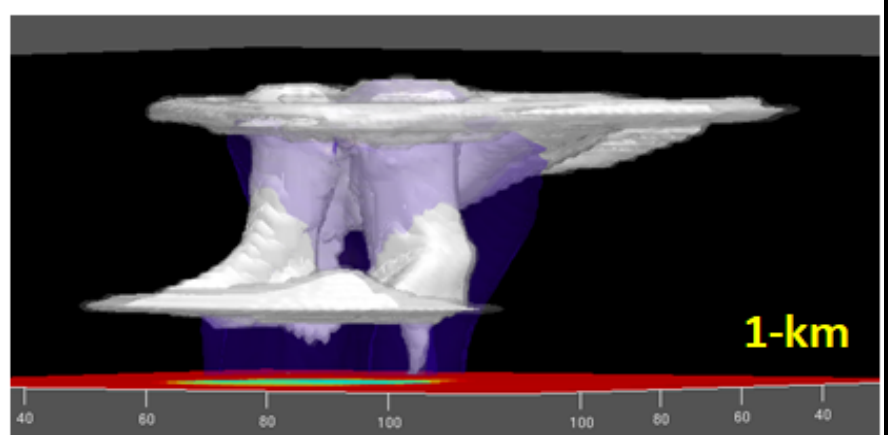
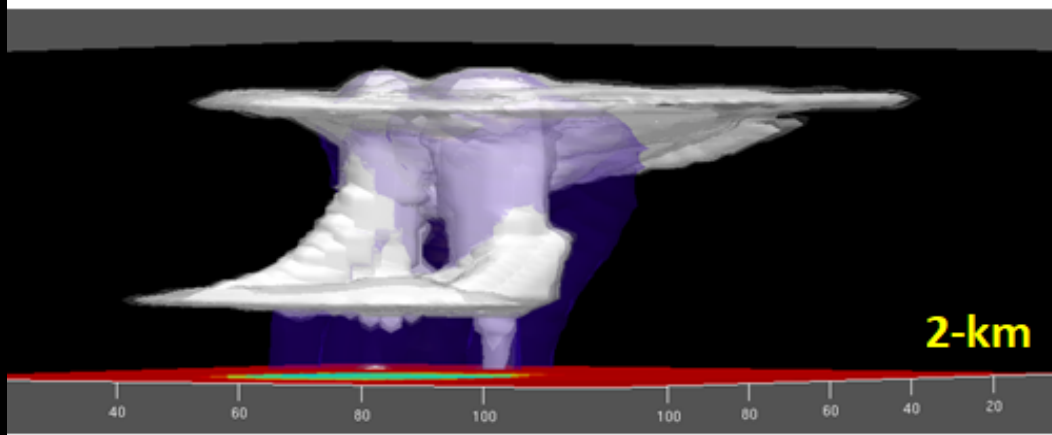
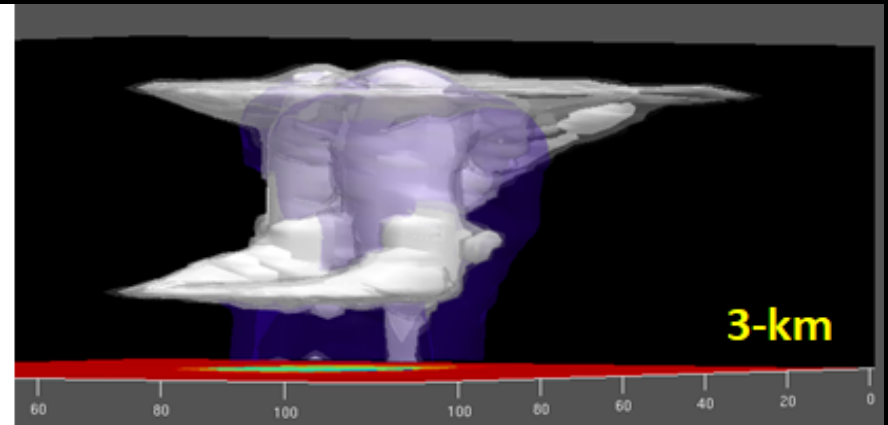
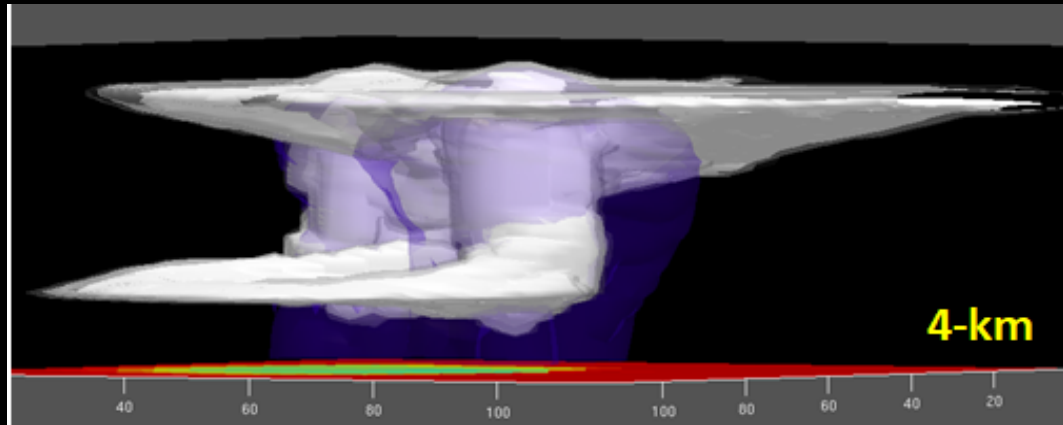


Example:

~ 3 km
without the
nest (black)
~ 1 km with a
2-way nest
(red)



Simulations of tornado-producing super-cell storms with GFDL's variable-resolution FV³



Lin and Harris (manuscript)

FV3 for convective allowing model and predictions

FV3 currently runs over a cubed sphere on which the user can place a static nest. Work is proceeding to add a regional option.

- User can select the area of interest without integrating over the entire globe.
- Nests can be embedded for further enhancement of resolution if desired.
- Mesoscale data assimilation will be done only over the limited area; no delay waiting for global data.
- Eliminate complications of nests' potentially lying on the cube's edges/corners.

Estimate for functionality without nests: **March 2018**

Capability to add nests: **Summer of 2018**

Question to be answered:

- Is the forecast quality on a regional domain with or without nests comparable to that of similar nested domains on the globe?
- Can application of resources be significantly improved by removing the coarser global portion of the integration domain?

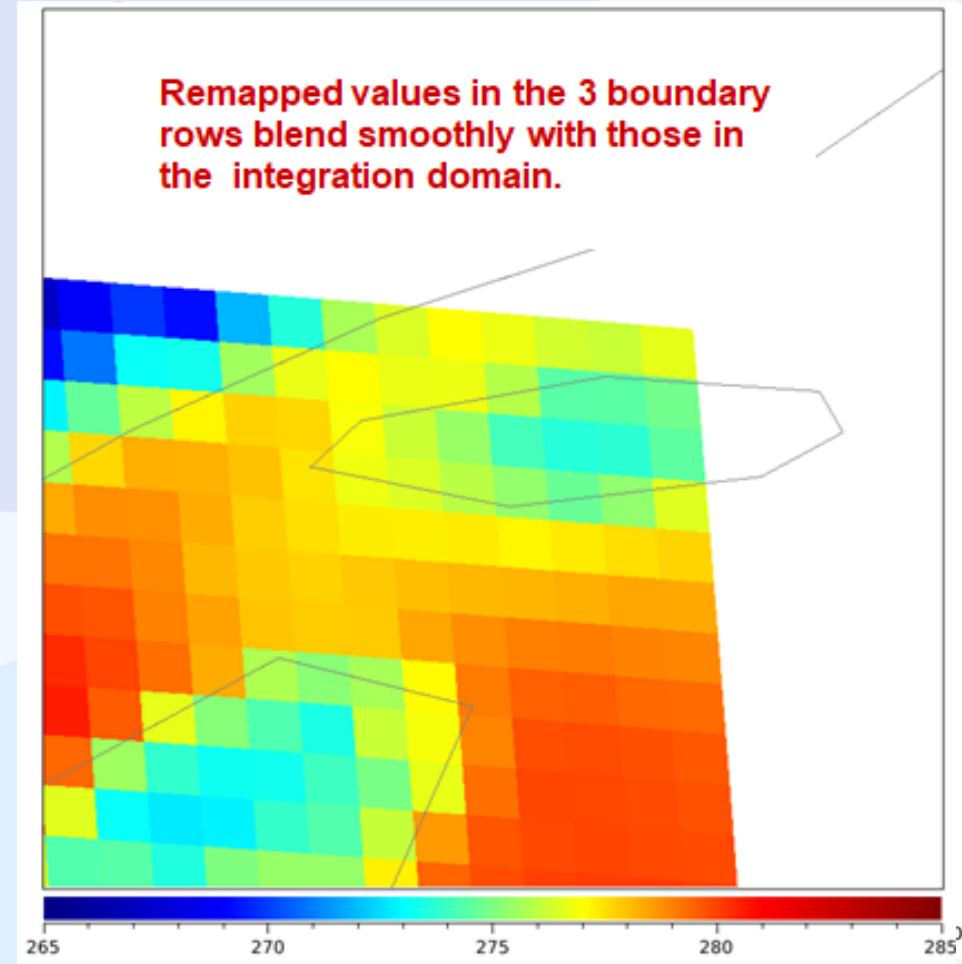
Work Completed So far:

- Initialized the integration domain from GFS input for a single FV3 tile.
- Generated the boundary data files from the GFS for a single tile
- Incorporated geographic lat/lon and orography for the full regional domain including the boundary area.
- Constructed code needed to read in the data from the BC files; vertically remap scalars and wind components in the BC data from the GFS levels to FV3's; and time interpolation of the BC data during the integration.
- Built a tool to output any variable as a netcdf file from anywhere/anytime in the model to allow numerical and visual inspection for debugging.

To be done:

- Build the time interpolation of BC data into the integration considering vertical remapping frequency, acoustic timestep, and split tracer timesteps

Stand-Alone Regional FV3 for CAM Applications



FV3GFS Release Schedule

FV3GFS Release v0 – released in May 2017

- Access by request (core developers and trusted users)
- Instructions and documentation at NCEP Vlab FV3GFS community page: <https://vlab.ncep.noaa.gov/web/fv3gfs>
- Limited capability: forecast only experiment

FV3GFS Release v1 – **planned for March 2018**


- Core developers and trusted users to get access through Vlab/Git
- Public release through **github.com**
- Full capability; including Data Assimilation and Post-Processing
- Instructions and documentation at NCEP VLab FV3GFS community page

FV3GFS Community Development Strategy

- Access FV3GFS Project on VLab
- Code repositories set up on VLab GIT
- Community Wiki page, Forums and Developers Pages on Vlab

X Next Release of FV3GFS (including DA and post-processing) planned for March 2018 through github.com





X Regional capability to core developers through VLab Git

 **VIRTUAL LAB**
WHERE GREAT IDEAS BECOME OPERATIONAL REALITY

<https://vlab.ncep.noaa.gov/web/fv3gfs>

FV3GFS / Home

FV3GFS Version 0 Release

Announcing the Version 0 Release of the FV3GFS!

NOAA users and external partners with NWS Virtual Lab access can view the release information, as well as other developmental details, in the FV3GFS Community.

NGGPS and FV3 Dynamic Core:

NOAA GFDL's Finite Volume Cubed Sphere (FV3) dynamical core was selected for the new NGGPS atmospheric model. FV3 dynamical core implementation includes incorporating FV3 into NEMS, and developing advanced physics and data assimilation techniques to match or exceed the skill of operational Global Forecast System (GFS). In addition, NWS is working with federal partners, universities, and the community to create a fully accessible community model.

NGGPS FV3-based Unified Modeling System will be a community guided system. Additional information can be found on the [Community Participation](#) page.

[Click here to view a 2016 FV3 Workshop presentation by the GFDL FV3 team.](#)

Documentation of FV3 Dynamic Core is available through various documents listed below:

FV3	A brief overview of the FV3 dynamical core	General description that is part of FV3 Documentation.
FV3	A class of the van Leer-type Transport Schemes and Its Application to the Moisture Transport in a General Circulation Model	Scientific Journal Article that is part of FV3 Documentation.
FV3	A Control-Volume Model of the Compressible Euler Equations with a Vertical Lagrangian Coordinate	Scientific Journal Article that is part of FV3 Documentation.
FV3	A finite-volume integration method for computing pressure gradient force in general vertical coordinates	Scientific Journal Article that is part of FV3 Documentation.
FV3	An explicit flux-form semi-Lagrangian shallow-water model on the sphere	Scientific Journal Article that is part of FV3 Documentation.
FV3	A Two-Way Nested Global-Regional Dynamical Core on the Cubed-Sphere Grid	Scientific Journal Article that is part of FV3 Documentation.

How to access the FV3GFS Version 0 Release

NON-NOAA USERS

Users outside of NOAA will need to obtain a VLab External Partner Account. To get an external partner account please fill out the [FV3GFS External Partner Request Form](#).

NOAA USERS AND EXTERNAL PARTNERS

FV3GFS VLab community.

NOAA users and external partners with VLab access: 1) click "Sign In" on top right of this page, 2) once signed in click on "All Available Communities" in the "My Communities" portlet on the left side, 3) scroll down the list to find the "FV3GFS" community and 4) click "Join" next to the community. Then navigate to the community home page through your "My Communities" list at the top or by this link:

<https://vlab.ncep.noaa.gov/group/fv3gfs/>

FV3GFS Redmine & Git repository:

(access requested through form in FV3GFS VLab community)

<https://vlab.ncep.noaa.gov/redmine/projects/comfv3>

EMC SVN repository:

(users with pre-established access to EMC SVN server)

<https://svnemc.ncep.noaa.gov/trac/nems/>

Documents and Media Display

Release Version 0 Documents

Last Updated 5/15/17 5:22 PM | 0 Subfolders | 6 Documents

Documents

- Limited support from EMC to run FV3GFS forecast only experiments on WCOSS, Theia and Jet; expanded support to come with CROW (planned for March 2018)
- Broader community support mechanism is planned for September 2018

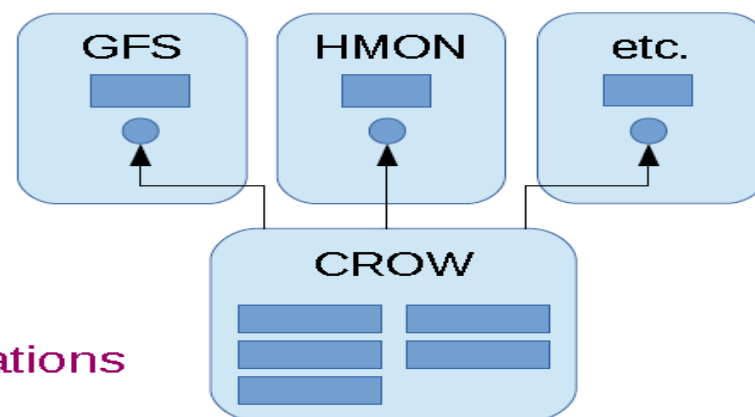
Unified Workflow for Research and Operations

CROW

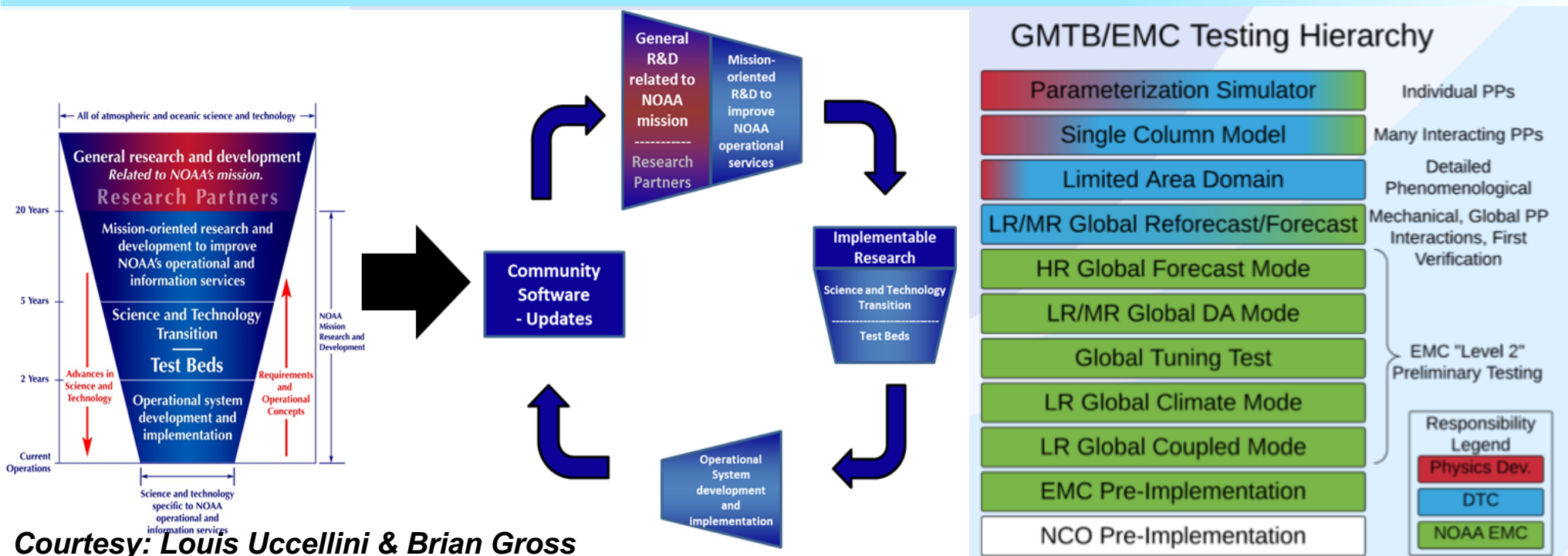
Common Research and Operational Workflow

Scope by ~12 months

- Integrated build & workflow system.
 - Umbrella build system
 - Unified workflow system
- For all use cases:
 - Production, Parallels, Research
 - Easy transition of code to and from operations
- System can be subsetted:
 - Researchers needs do not include DBNet, nor GFS faxes.
 - Production needs do not include scientific data visualization
- Initial target: FV3 Global Models (GFS, GDAS, GEFS)



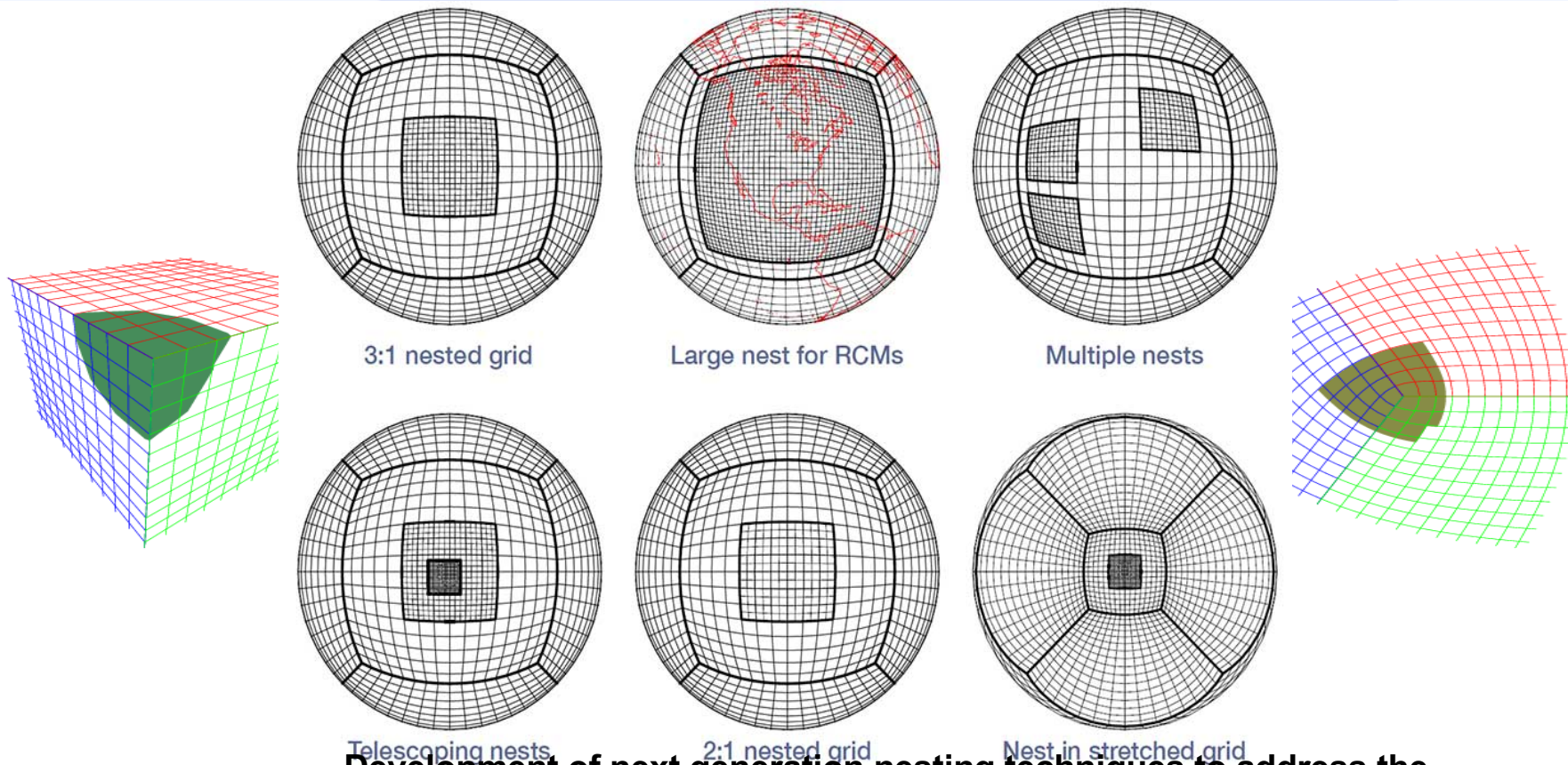
Rethinking R2O Strategy



Courtesy: Louis Uccellini & Brian Gross

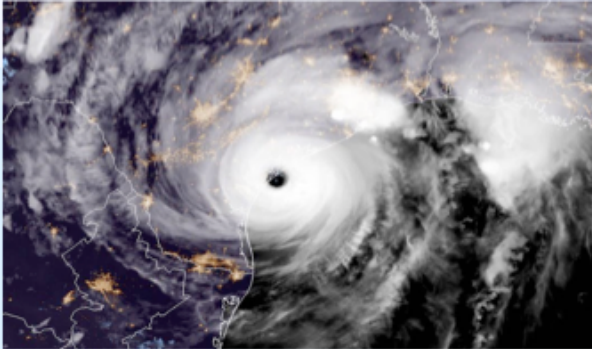
- Community Governance for Unified Forecast System
- Improved communications and outreach
- Alignment among NOAA Labs towards SIP/SV/RM
- Evidence based decision making process
- NGGPS/HFIP/JTTI FFOs focused on R2O
- Incentivize participation from community
- NCEP/DTC/UCAR Visiting Scientist Programs
- Expanded international collaborations

Tropical Cyclone Forecasts in FV3



Development of next generation nesting techniques to address the tropical cyclone forecast problem within the global model

Hurricanes:



Two FV3 configurations:

1. The standard (uniform resolution) C768L63
2. Stretched C768L63 with a **3-km Atlantic Basin nest**

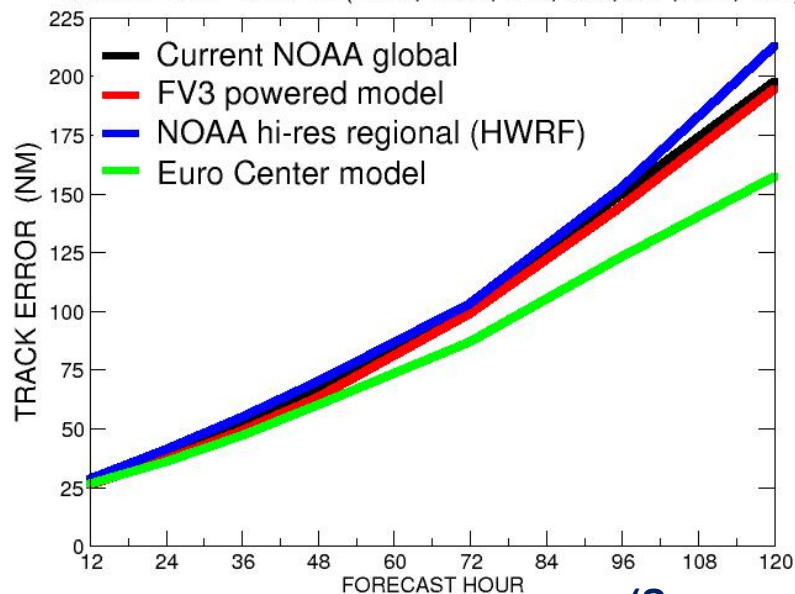
Both configurations running quasi-real-time on Jet (Gaea as the backup)

Statistics for 2-year period: 2015 & 2016

C768L63 (13-km) for all basins

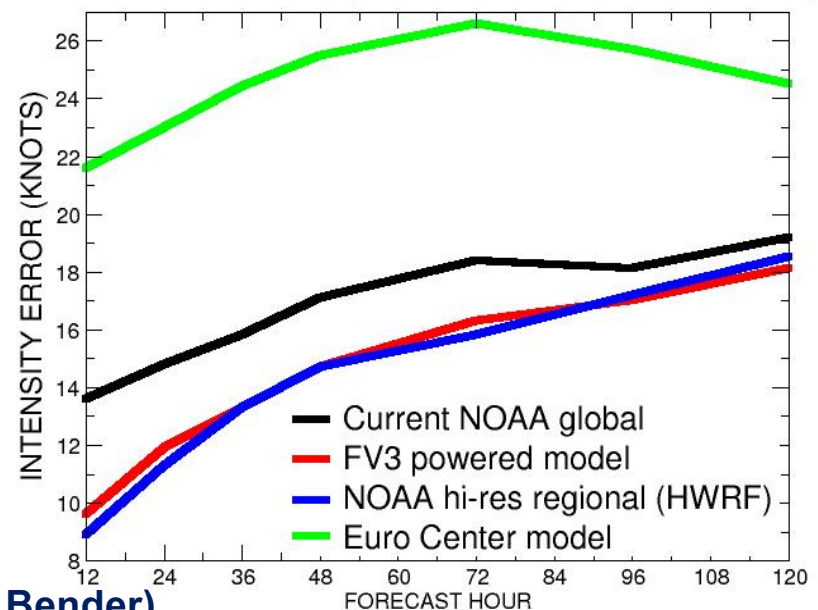
Lower
Errors
better

2015 & 2016 ATLANTIC, EAST PACIFIC, WEST PACIFIC
NUMBER OF CASES: (1217, 1102, 995, 890, 697, 547, 420)



(Source: Morris Bender)

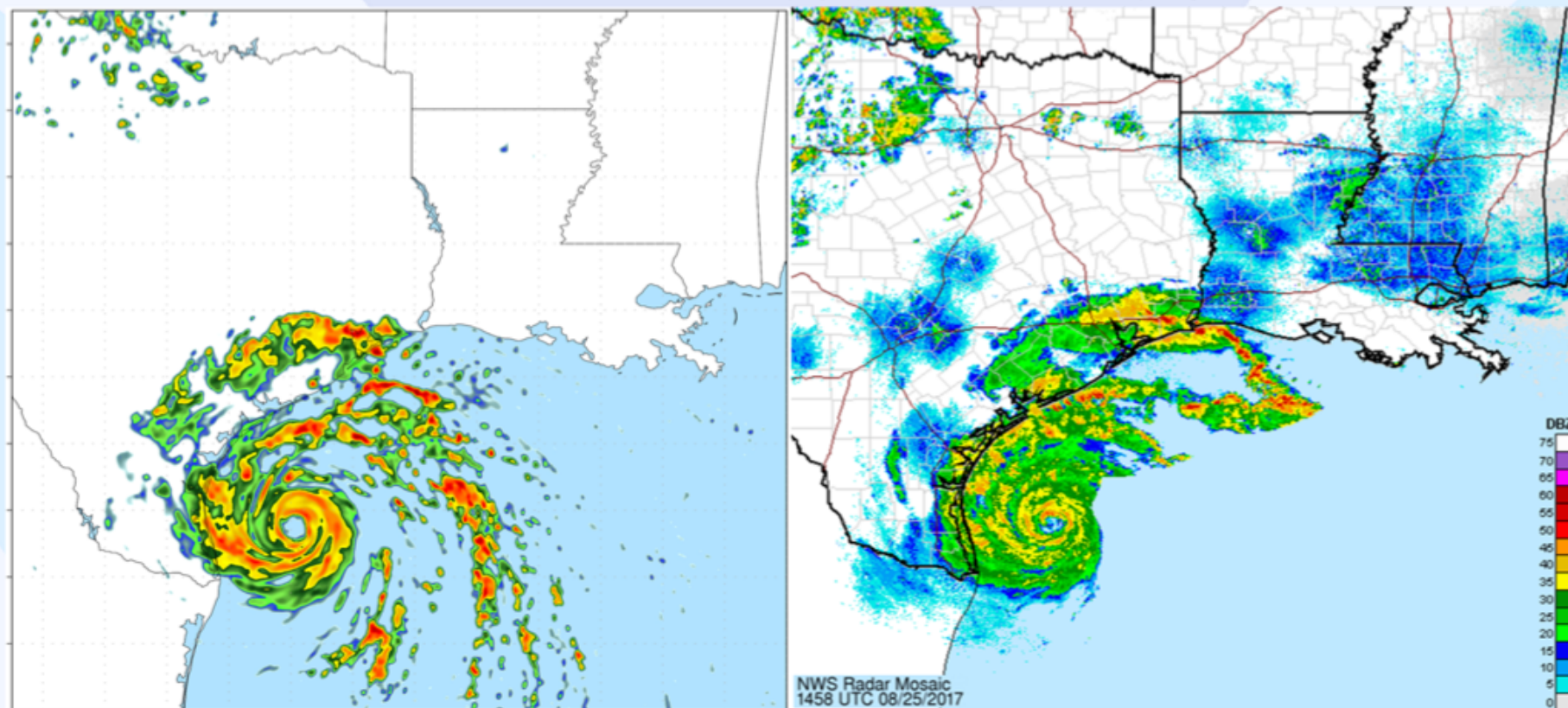
2015 & 2016 ATLANTIC, EAST PACIFIC, WEST PACIFIC
NUMBER OF CASES: (1217, 1102, 995, 890, 697, 547, 420)



Intensity skill is as good as HWRF

Forecast Reflectivity Structure vs. NEXRAD Observations

fvGFS Initialized 18 UTC August 24, 2017
21-hour Forecast Radar Reflectivity (Left)
and Observed Ground-Based NEXRAD Radar (Right) at 15 UTC (10 AM CDT) August 25, 2017



(Source: Andrew Hazelton)

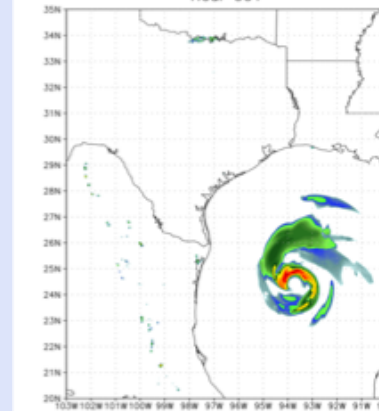
Spin-up From GFS (13-km) ICs

-At hour 1, core is starting to spin up, but looks very low-res

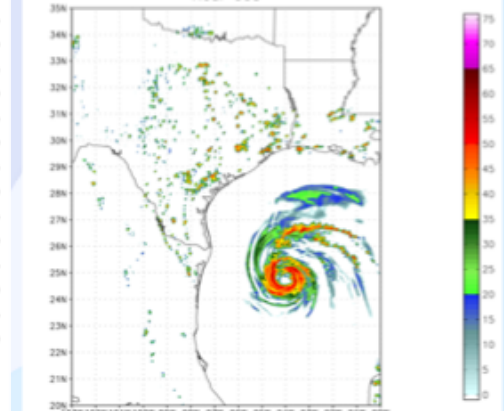
-At hour 3, isolated cells over Texas and rain bands are well-developed; Core still looks somewhat too coarse

-By hour 6 the core appears to me mostly spun up

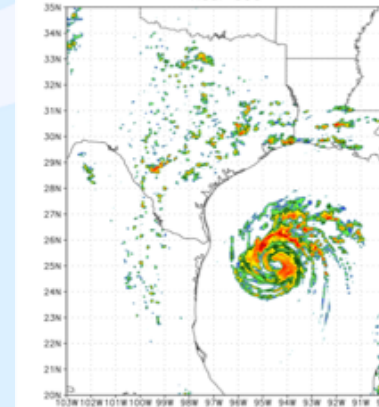
fvGFS Initialized 2017082418 1-km Reflectivity (dBZ)
Hour 001



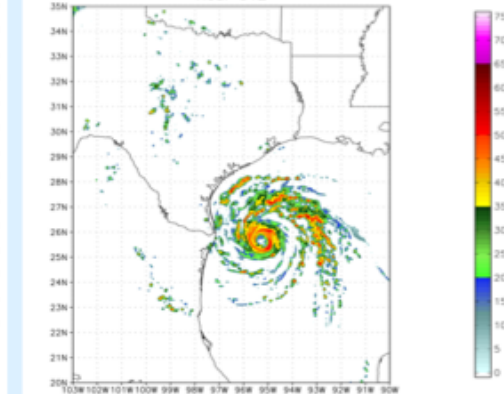
fvGFS Initialized 2017082418 1-km Reflectivity (dBZ)
Hour 003



fvGFS Initialized 2017082418 1-km Reflectivity (dBZ)
Hour 006



fvGFS Initialized 2017082418 1-km Reflectivity (dBZ)
Hour 012



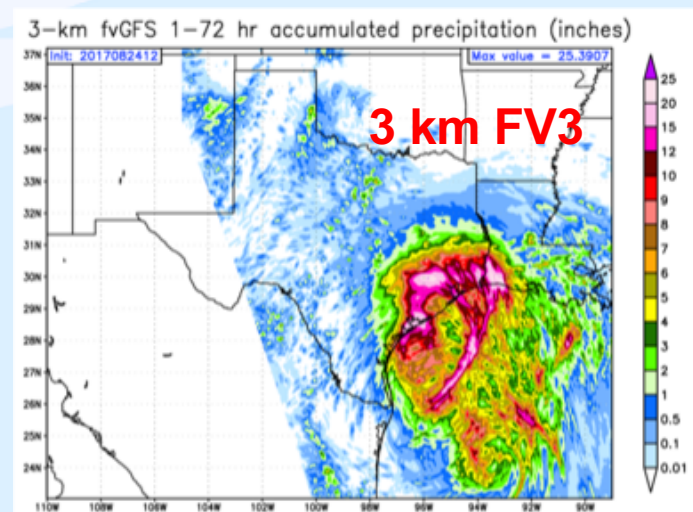
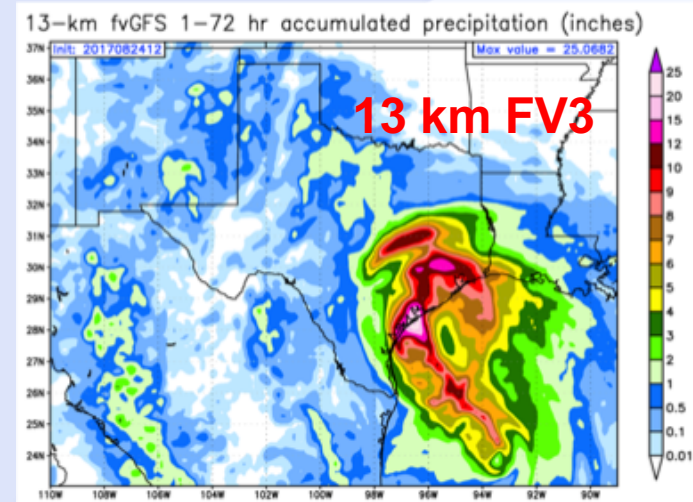
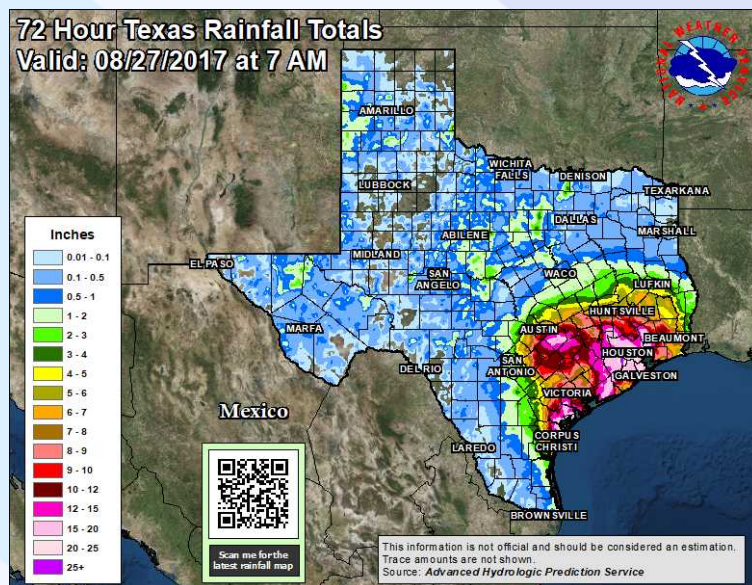
(Source: Andrew Hazelton)

Precipitation Verifications in Inches

(from Thursday 8am through Sunday 8am)

INIT: 2017082412

OBSERVED 72h PRECIPITATION TOTALS

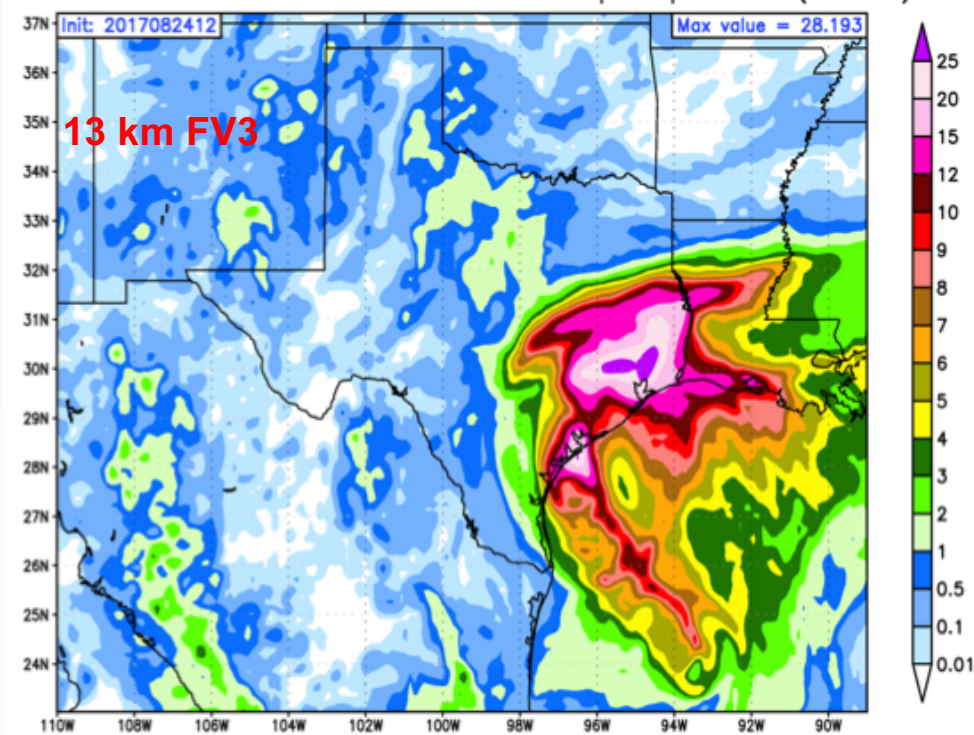


INIT: 2017082412

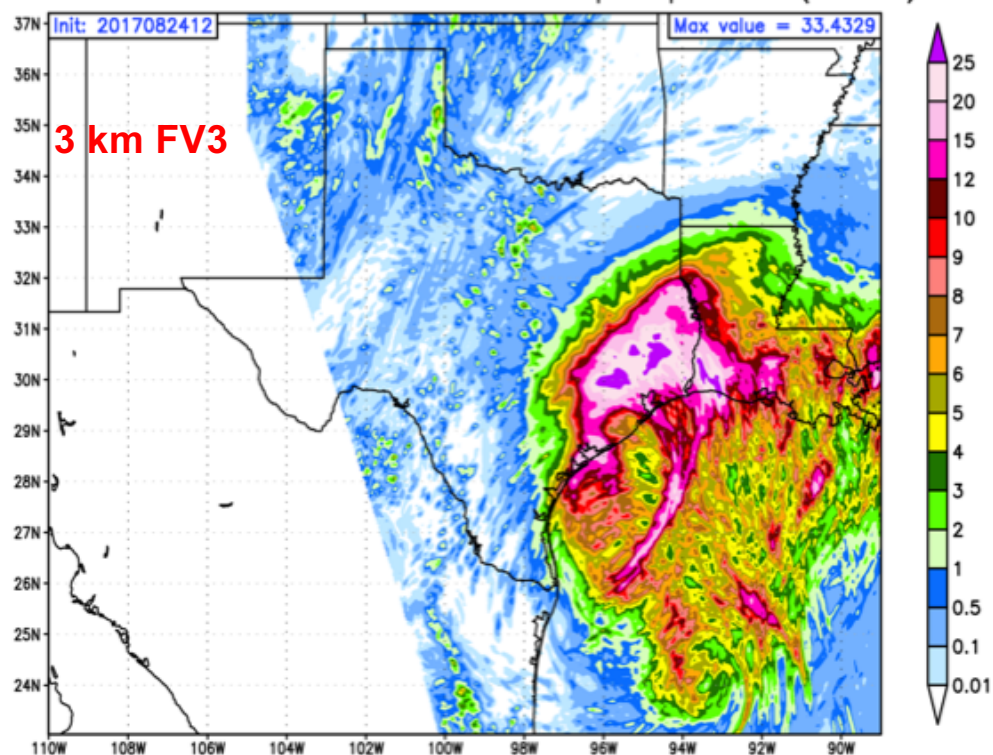
5 day Total Precipitation in Inches

(from Thursday 8am through Tuesday 8am)

13-km fvGFS 1-120 hr accumulated precipitation (inches)

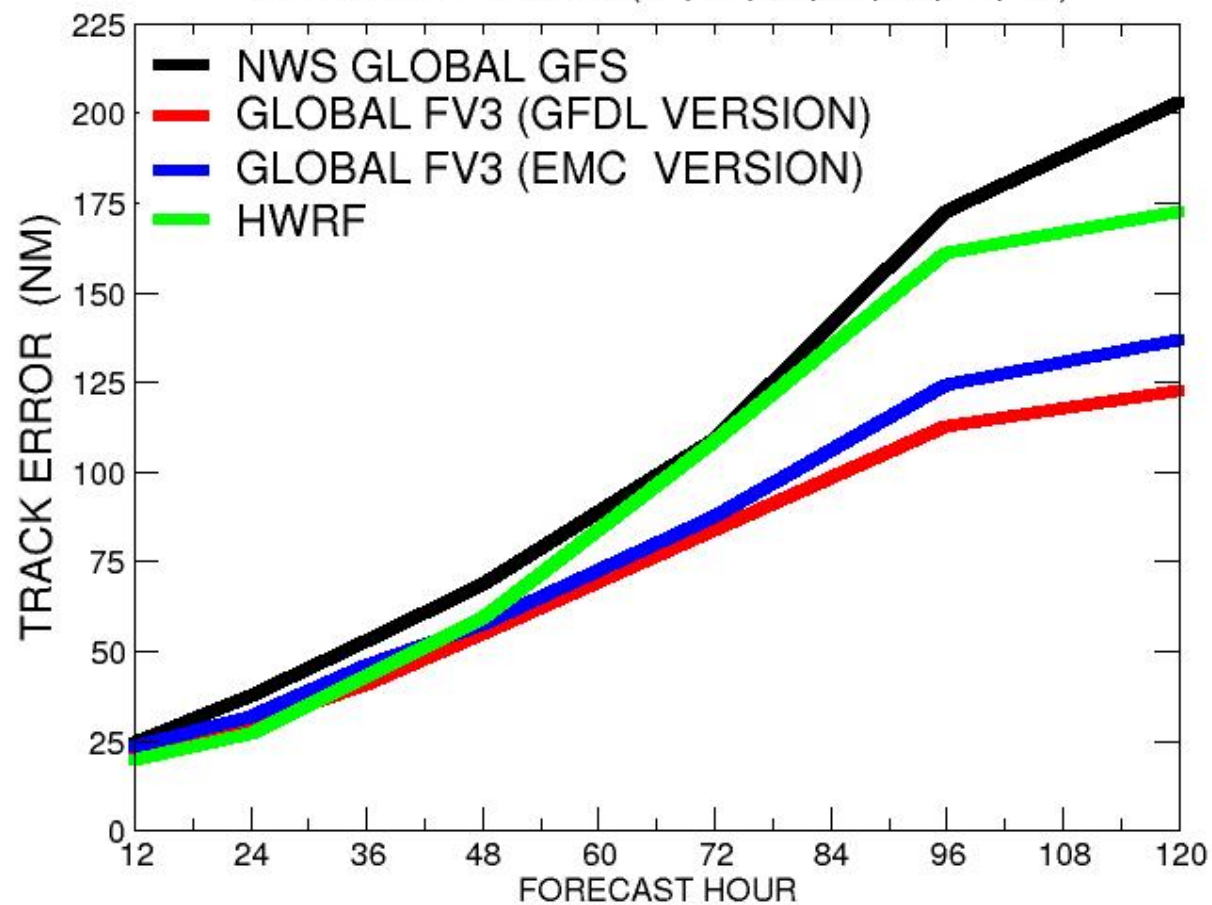


3-km fvGFS 1-120 hr accumulated precipitation (inches)



HURRICANE HARVEY (LATE GUIDANCE)

NUMBER OF CASES: (37, 33, 29, 25, 20, 17, 16)

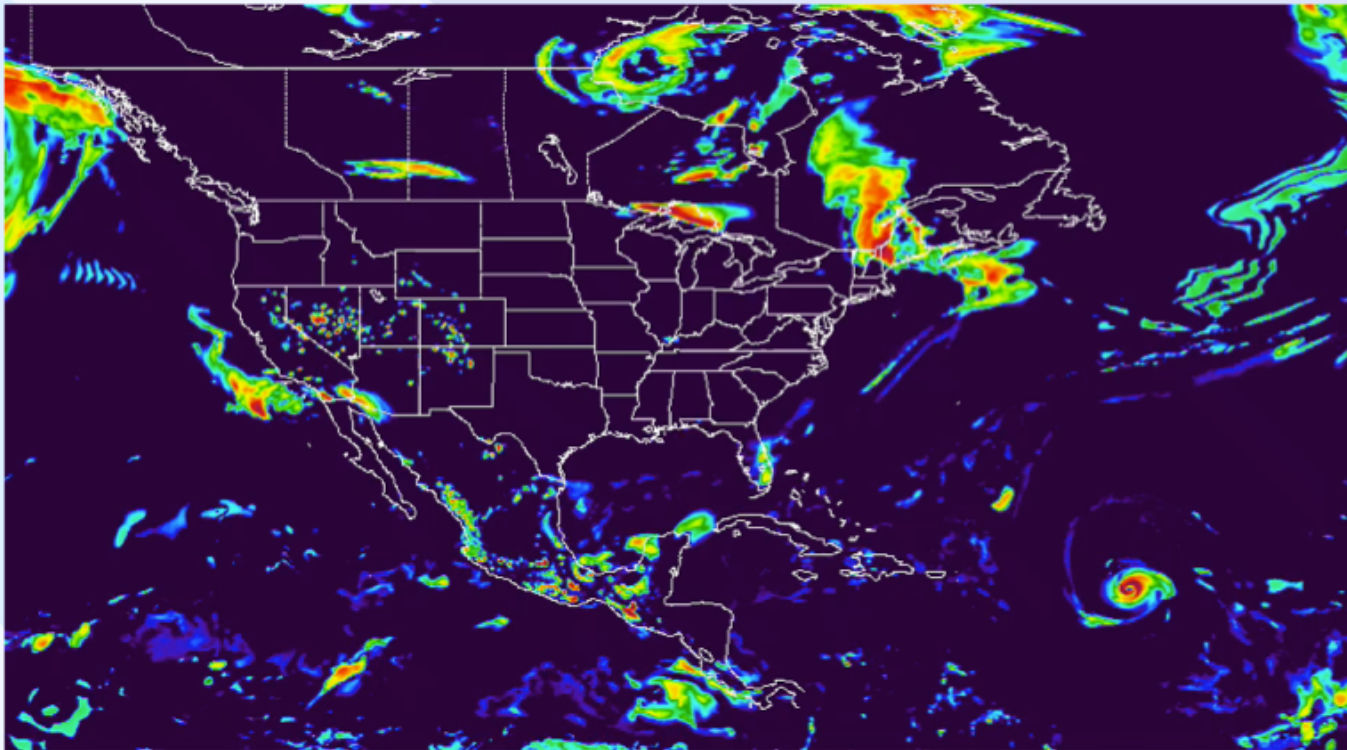


(Source: Morris Bender)

Hurricane Irma

Simulated Composite Radar Reflectivity

INIT: 00Z_20170904 fvGFS C768L63

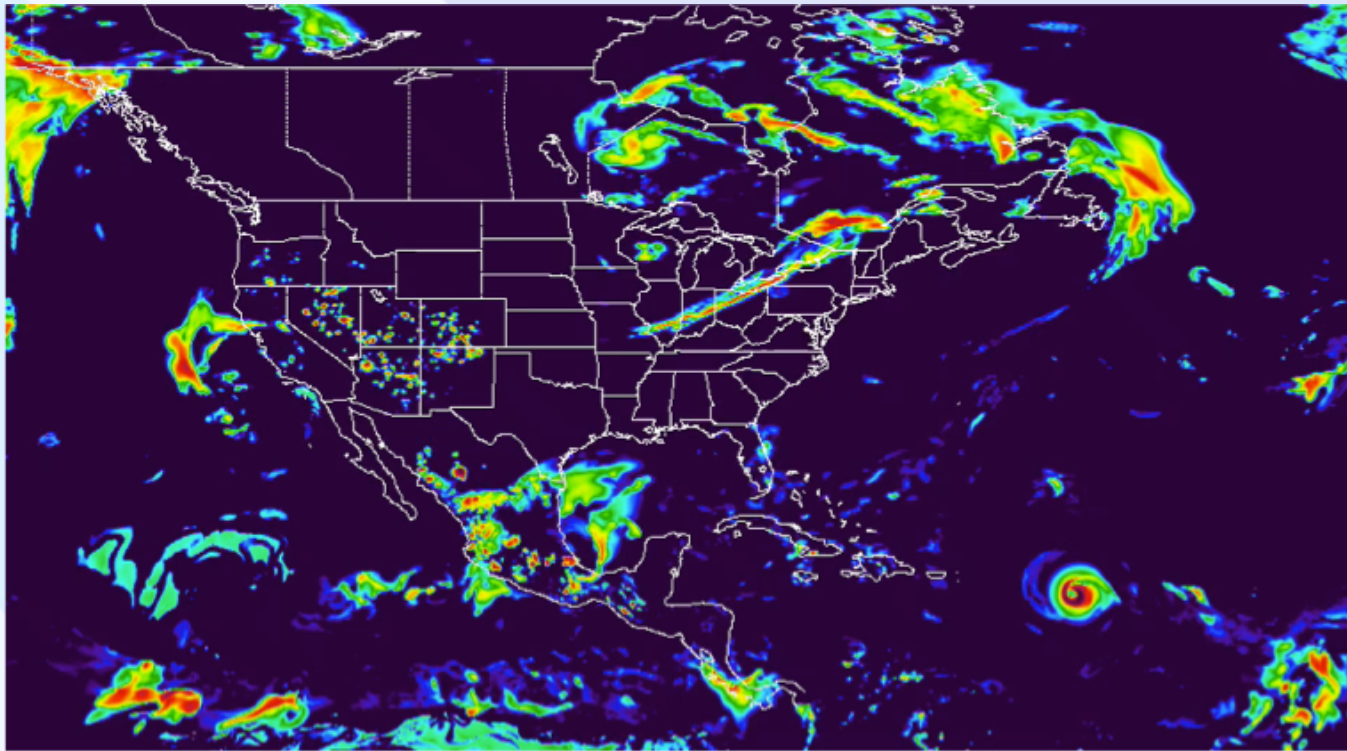


- ncview “rainbow” color with min=-20, max=54 (dBz)
- fvGFS at C768L63 with GFDL MP

Hurricane Irma

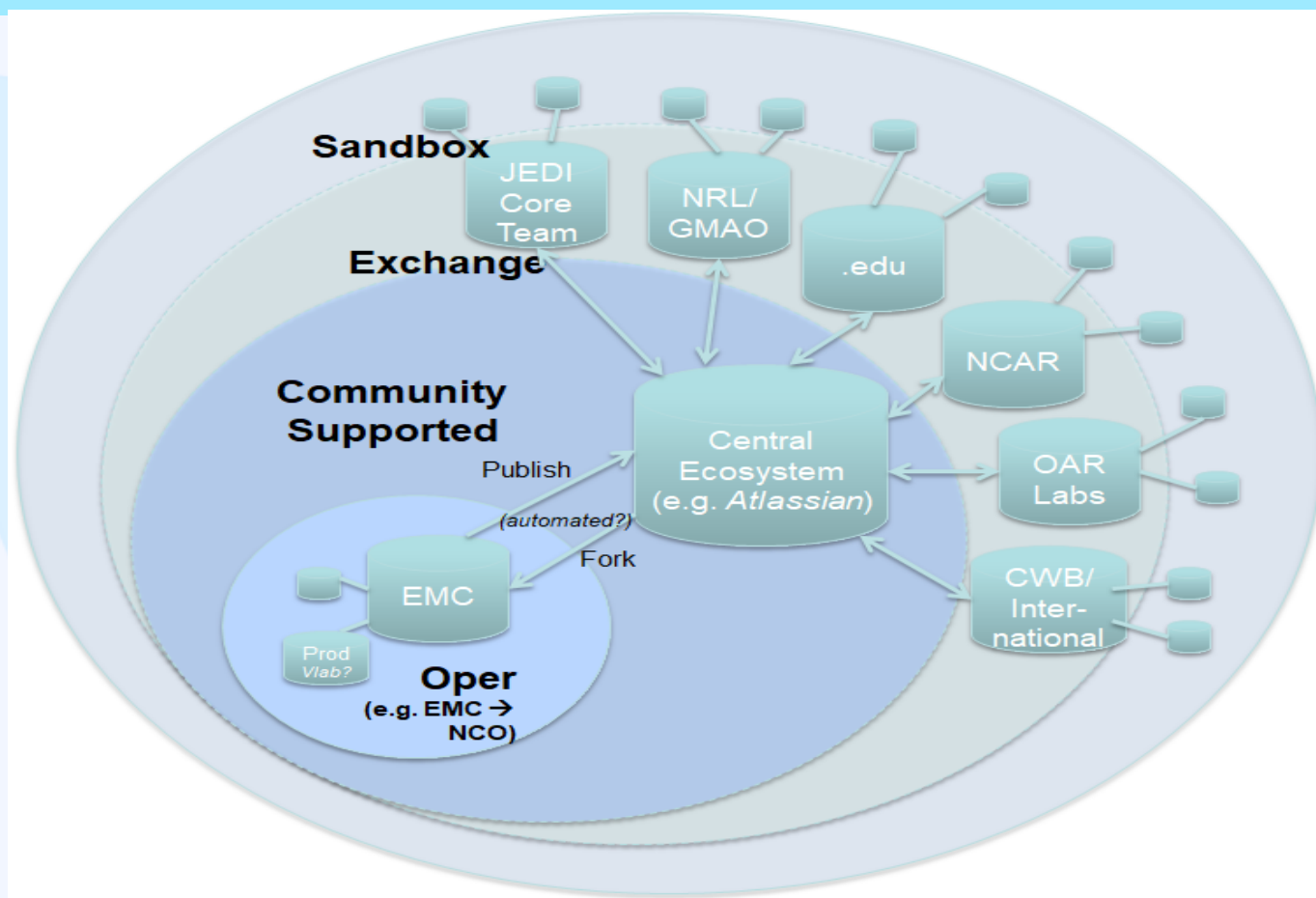
Simulated Composite Radar Reflectivity

INIT: 00Z_20170905 fvGFS C768L63



- ncview “rainbow” color with min=-20, max=54 (dBz)
- fvGFS at C768L63 with GFDL MP

Community Collaborations from NOAA Operations Point of view



Ecosystem
= **collaborative
environment**

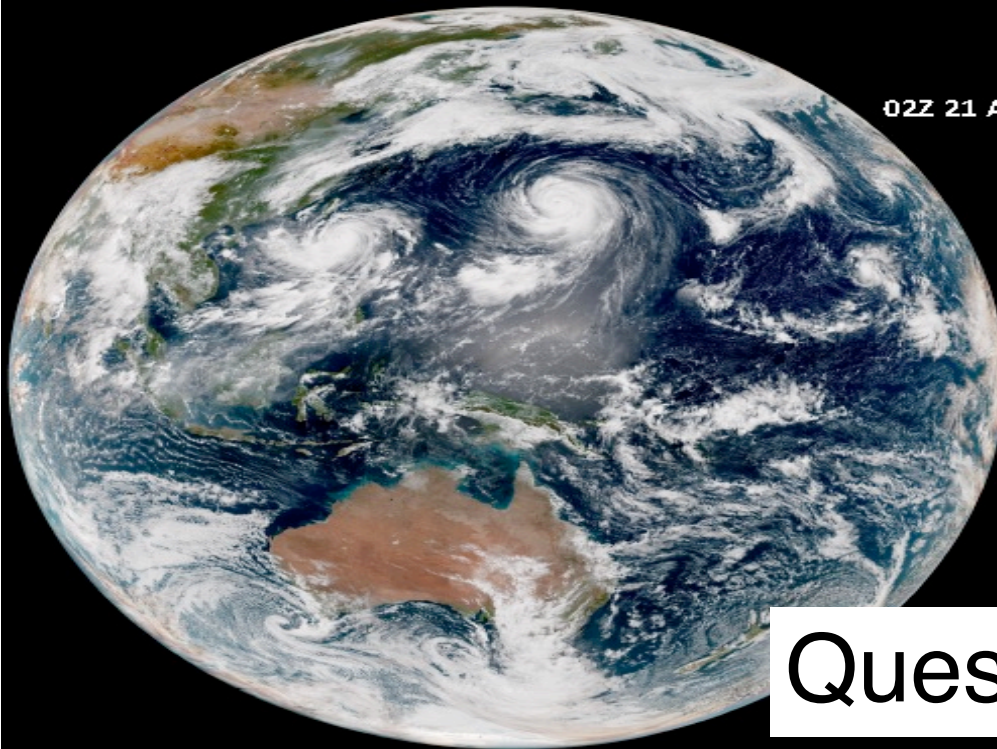
- Code repo & Reviews (*Bitbucket*)
- Issue tracking (*JIRA*)
- Testing (*Bamboo*)
- Documentation (*Confluence*)
- Support (*JIRA Helpdesk*)
- Governance
 - Identify code utility
 - Define interfaces
 - Specify roles + authorities
 - Allocate resources

A glimpse into the future of NWP

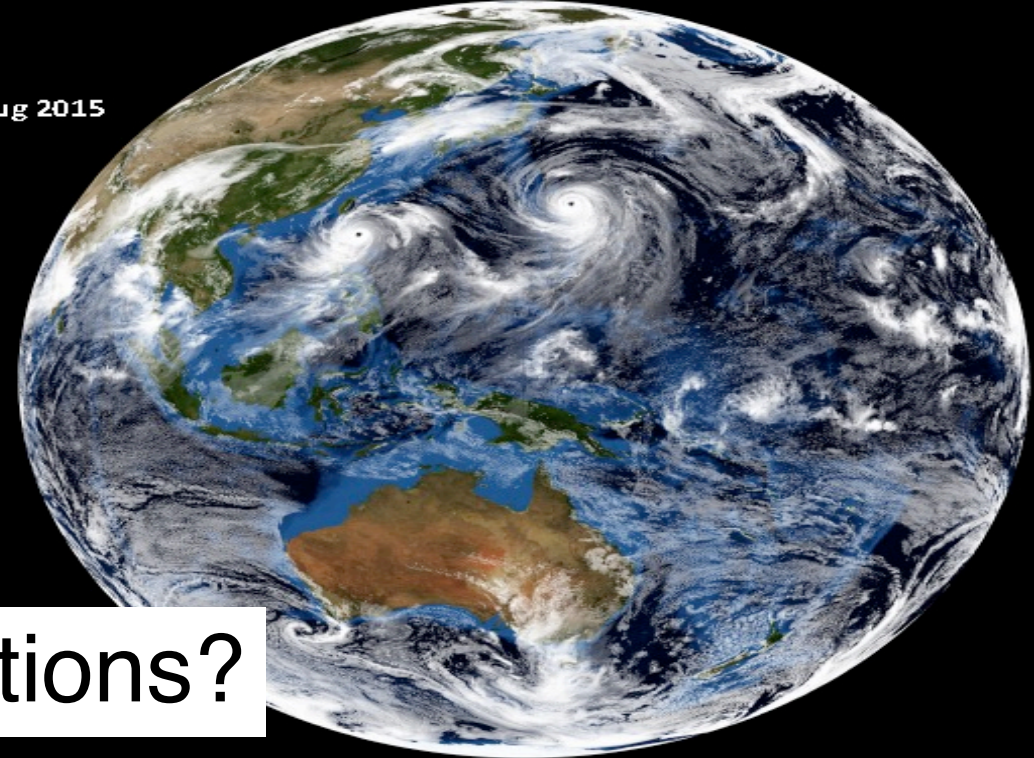
Global cloud-resolving prediction with FV3-powered NGGPS

Himawari Satellite

50-hour prediction (INIT: 00Z 19AUG 2015)



02Z 21 Aug 2015



Questions?

Courtesy: SJ Lin, GFDL

FV3 initialized with IFS IC (courtesy of Linus Magnusson, ECMWF)