Hurricane Analysis and Forecast System (HAFS): A collaborative Project in UFS Framework

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Revised HFIP Goals aligned with the Weather Act

1. Reduce forecast guidance errors, including during RI, by 50% from 27
2. Produce 7-day forecast guidance as good as the 27 5-day forecast guidance
3. Improve guidance on pre-formation disturbances, including genesis timing, and track and intensity forecasts, by 20% from 27
4. Improve hazard guidance and risk communication, based on social and behavioral science, to modernize the TC product suite (products, information, and services) for actionable lead-times for storm surge and all other threats

HAFS: Hurricane Analysis and Forecast System

Goals:

- **Develop FV3 based multi-scale model and data assimilation package capable of providing analyses and forecasts of the inner core structure key to improving size and intensity predictions, as well as the large-scale environment that is known to influence the TC's motion.**

- **Provide an advanced Hurricane Analysis and Forecast System for cutting-edge research within the outlined Next Generation Global Prediction System (FV3) plans for the Unified Forecast System.**

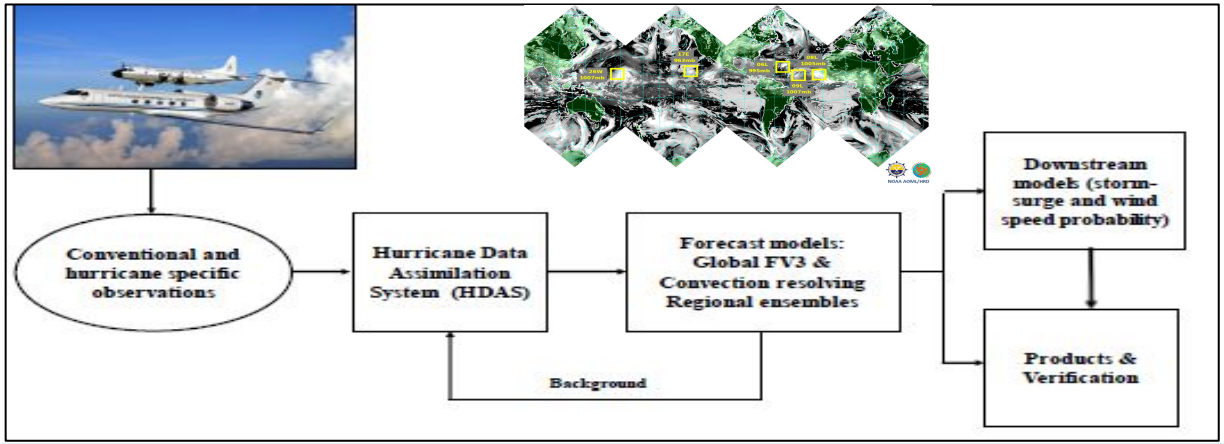
Ongoing Efforts at EMC Towards Simplified Production Suite

Modeling System	Current Status	Proposed Plans in the UFS Context
Global Deterministic	FY19: Transition FV3GFS into operations	Advancement of NGGPS/FV3GFS (biennial upgrades)
Global DA	4D-Hybrid En-Var using GSI	Migrate to JEDI
Global Ensembles (Sub-seasonal)	FV3/NEMS based reanalysis/ reforecasts	FY20: Implement FV3 GEFS for sub-seasonal weather forecasts (35 days)
Global Seasonal Climate	Develop coupled UFS and coupled DA	Implement FV3 SFS for seasonal climate forecasts (MOM6, CICE5, Noah-MP, WWIII, GOCART,JEDI)
Global Aerosols	NGAC V2 (NEMS/GSM + GOCART)	FY20: Merge with FV3 GEFS
Hurricanes	HWRF &HMON	FV3 GFS with multiple moving nests (HAFS)
Waves	Waves Multi2 merged with HWRF	FY20: Merge wave ensembles models with FV3GEFS FY21: Merge deterministic Waves with GFSv16
Ocean	RTOFS/HYCOM	MOM6 + NCODA + Marine JEDI
Meso-Scale	NAM V4 & NMMB frozen	Transition to FV3 CAM, NAM/RAP Parent domains subsumed by FV3GFS?
Short-range ens.	SREF V7.1 frozen	FY20: Replace SREF with FV3GEFS???
HREF	V2: HiRes Window + NAM Nests (SSEO)	FV3 SAR to replace poor performing HREF members
RAP/HRRR	V2/V3	FY20: V3/V4 UFS CAM (RRFS)
Products, V&V	UPP, VSDB/MET, MEG, NAWIPS	UPP+, MET+, MEG+
Collaborative Infrastructure	Various	NEMS/ESMF/NUOPC+; EE2+; CROW; Shared infrastructure and distributed development

HAFS Strategies

1. Advance operational hurricane analysis and forecast system (HAFS)

- R&D for HAFS to advance deterministic and ensemble prediction capabilities
- R&D for fusion of modeling, data assimilation and observations to produce an analysis of record
- R&D for ensemble post-processing to extract guidance and uncertainty information

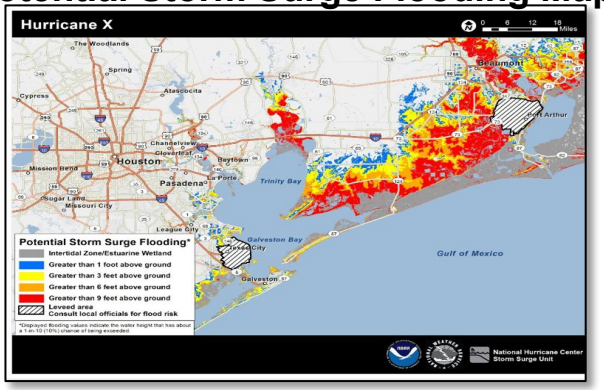


HAFS: Guidance & Products

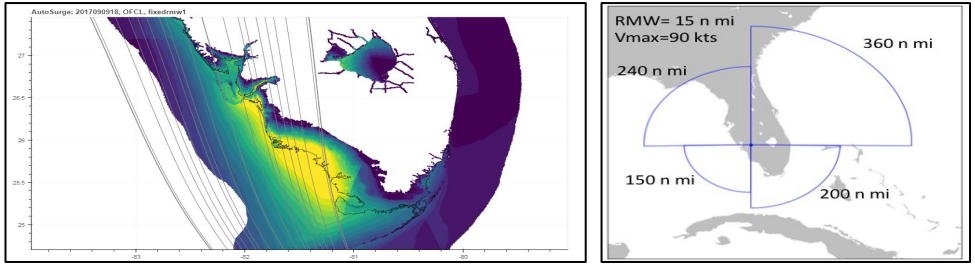
2. Improve probabilistic guidance

- Calibrate guidance with HAFS
- Incorporate dynamically-based uncertainty into hazard models and products
- R&D for hazard-specific products from HAFS

Potential Storm Surge Flooding Map



Planned improvements to P-Surge to Improve the Potential Storm Surge Flooding Map

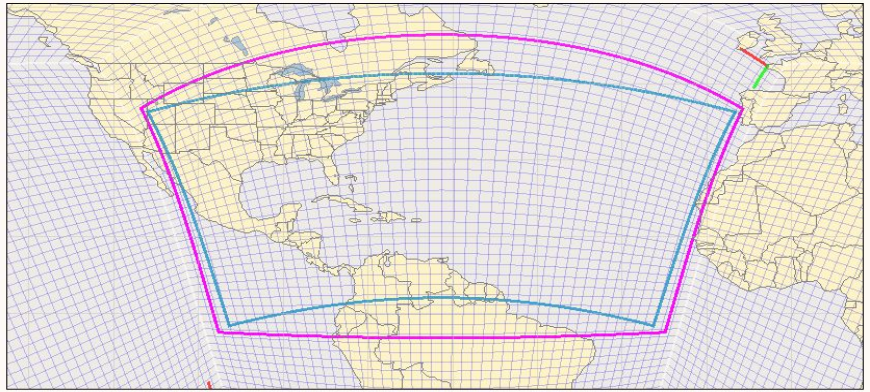


3. Enhance communication of risk and uncertainty

- Evaluate TC products for the effective communication of risk
- Modernize TC products as informed by social and behavioral science

HAFS Experimental Configurations

HAFS domains



Blue: Global with 3km static nest

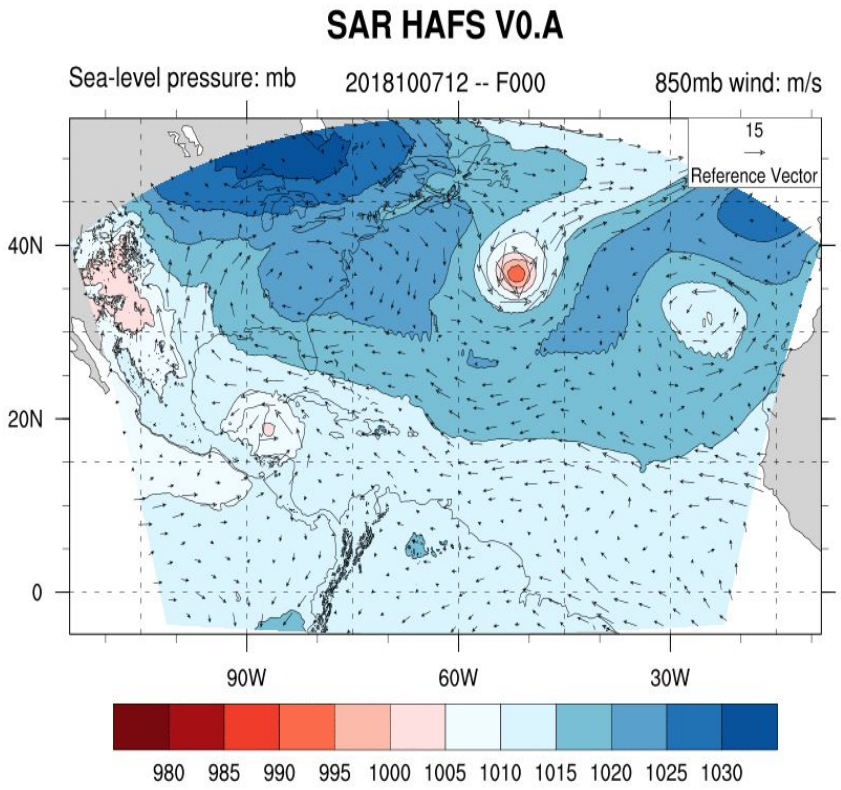
Purple: 3km Stand-Alone Regional Model

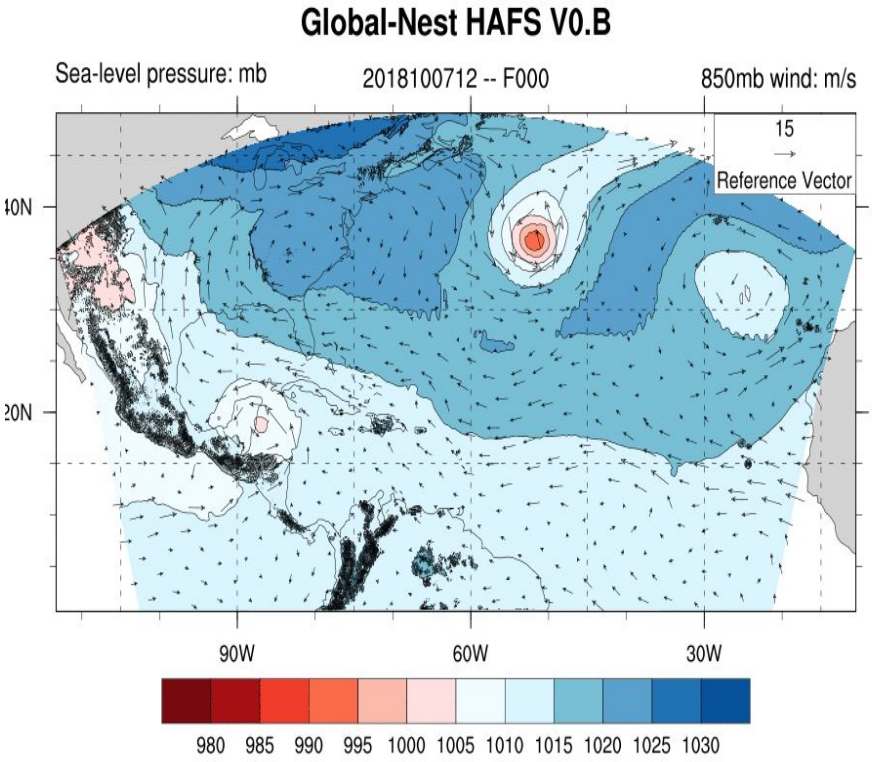
HAFS 0.A:
The NATL basin focused standalone regional domain configuration

- C768 with a refinement ratio of 4
- the regional domain size: 2880x1920 (~85x56deg)

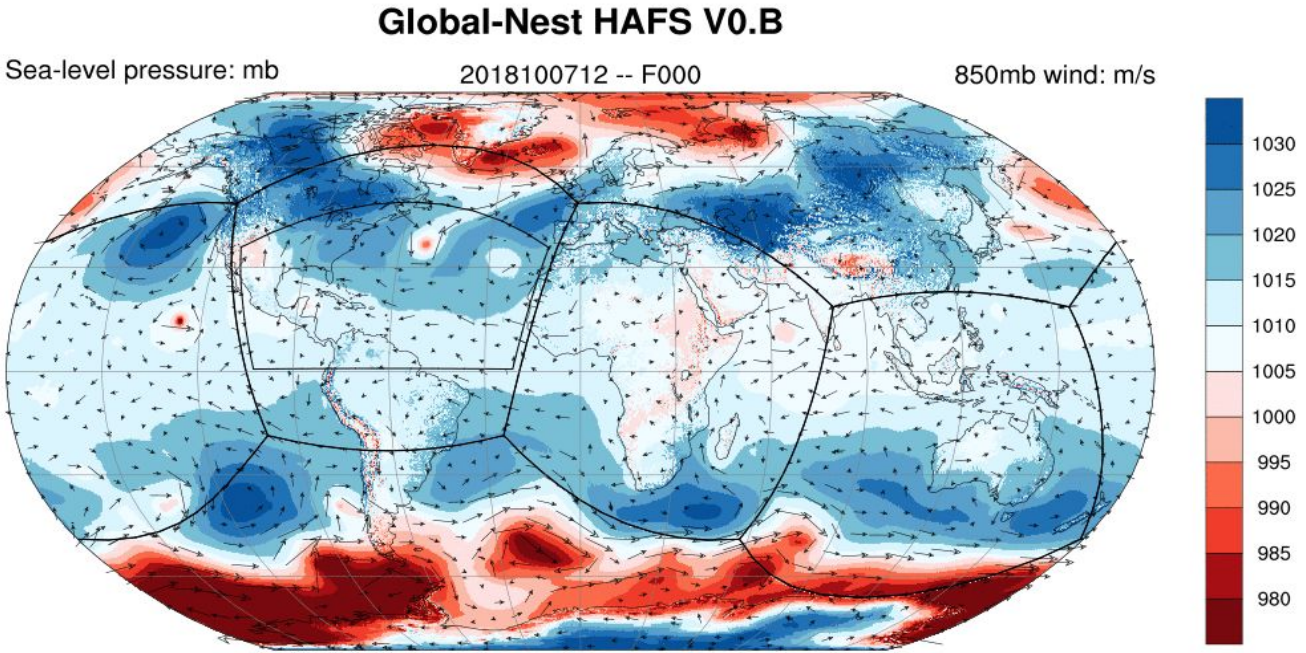
HAFS 0.B:
The NATL basin focused global-nesting domain configuration

- C768 with a refinement ratio of 4
- the nested domain size of 2880x1536 (~85x45deg)


SAR HAFS V0.A
Sea-level pressure: mb
2018100712 -- F000
850mb wind: m/s
15
Reference Vector
40N
20N
0
90W
60W
30W
980 985 990 995 1000 1005 1010 1015 1020 1025 1030


Global-Nest HAFS V0.B
Sea-level pressure: mb
2018100712 -- F000
850mb wind: m/s
15
Reference Vector
90W
60W
30W
980 985 990 995 1000 1005 1010 1015 1020 1025 1030

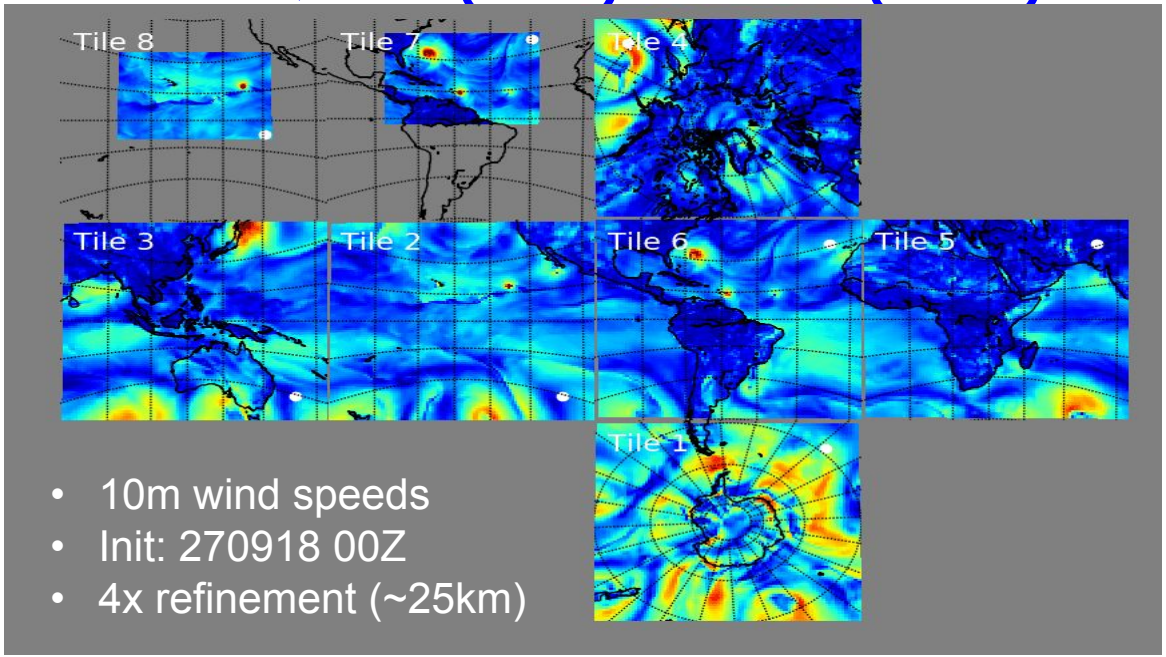
Hurricane Moving Nest
Single 3km Nest on Global Parent

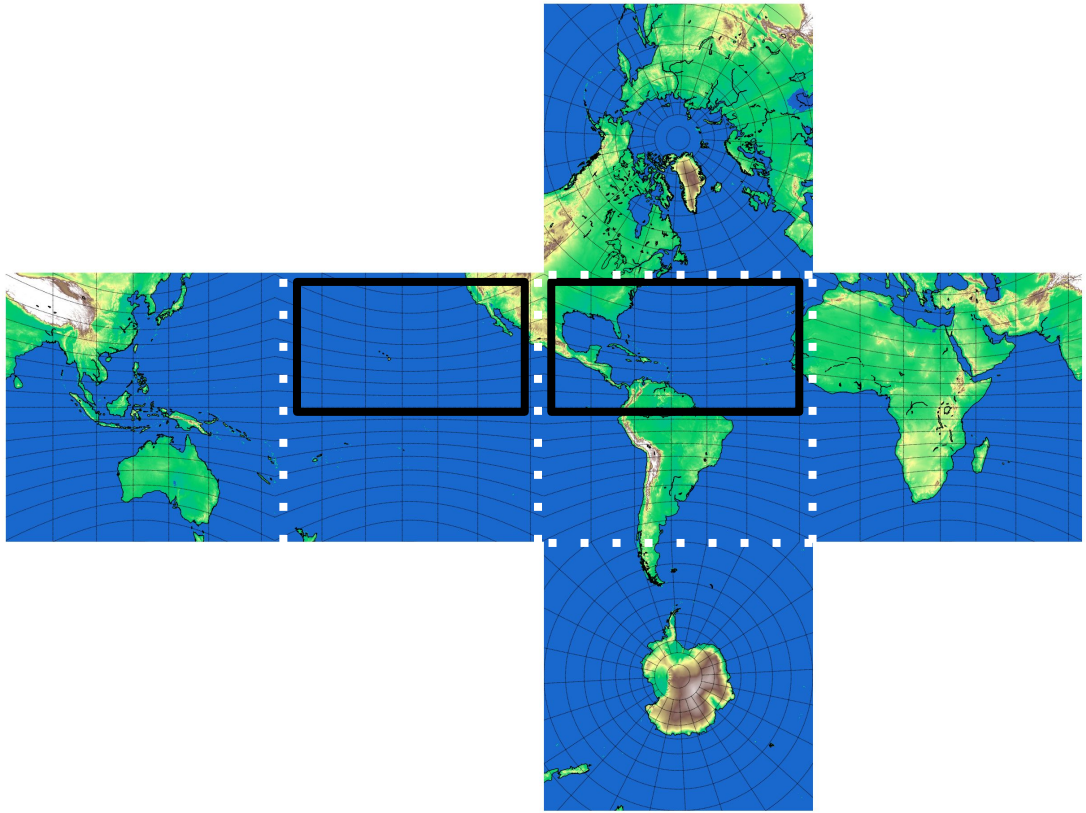


Hurricane Moving Nest
Two Static Nests on Two Tiles

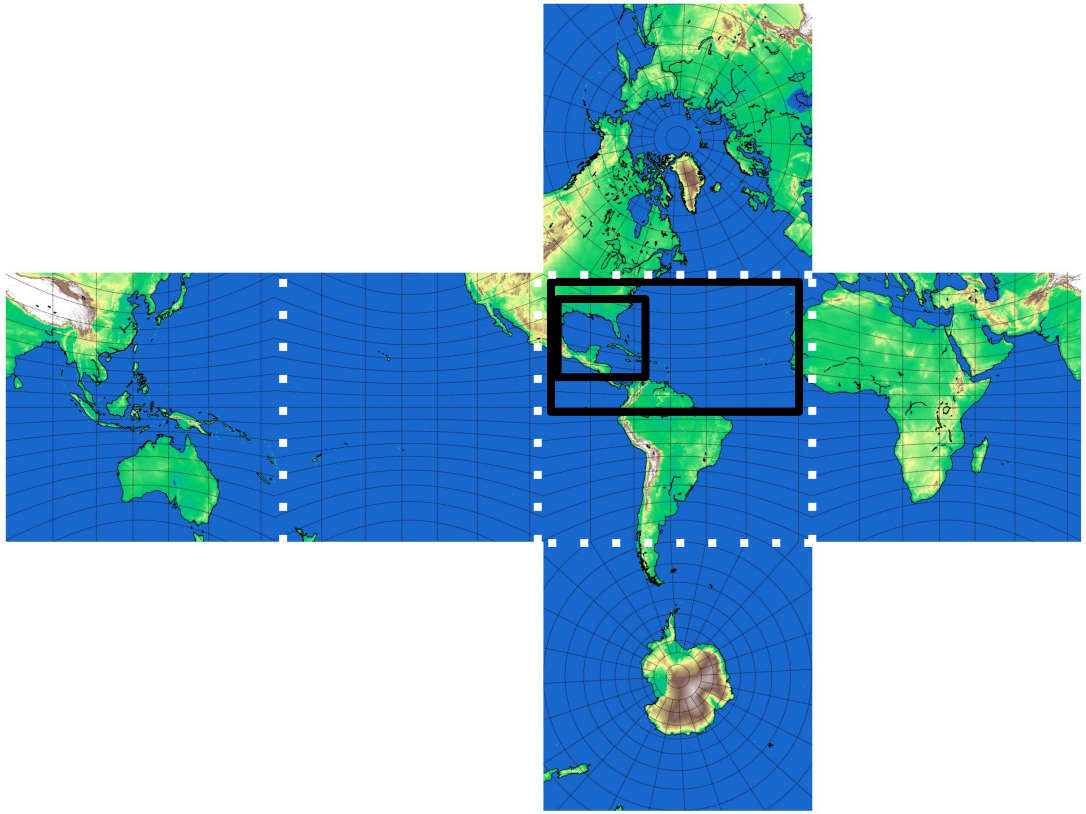
- Stable runs to 96 hours
- Scalable performance
- 24 (12) cores global (nest)
- 1 nest:36 cores: 1:29
- 2 nests:48 cores: 1:32
- Validation underway
- Original single nest results identical
- Multiple nests alter forecast in expected ways

Maria, Jose (NATL) and Otis (EPAC)

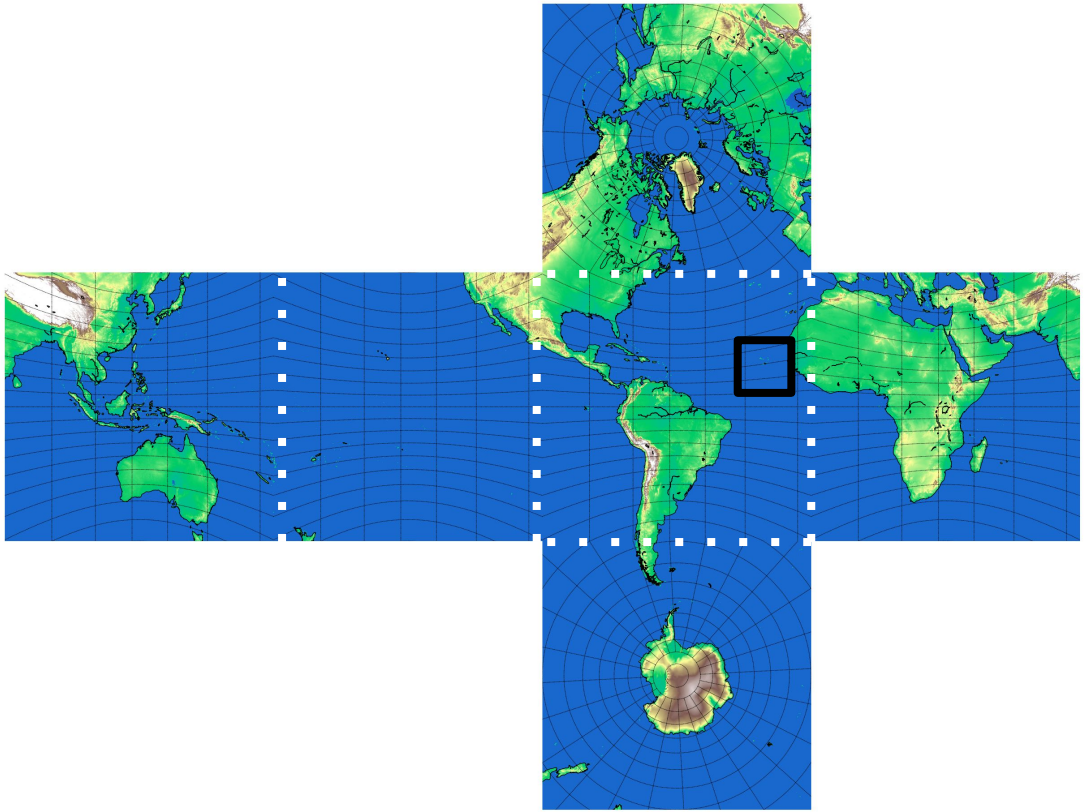




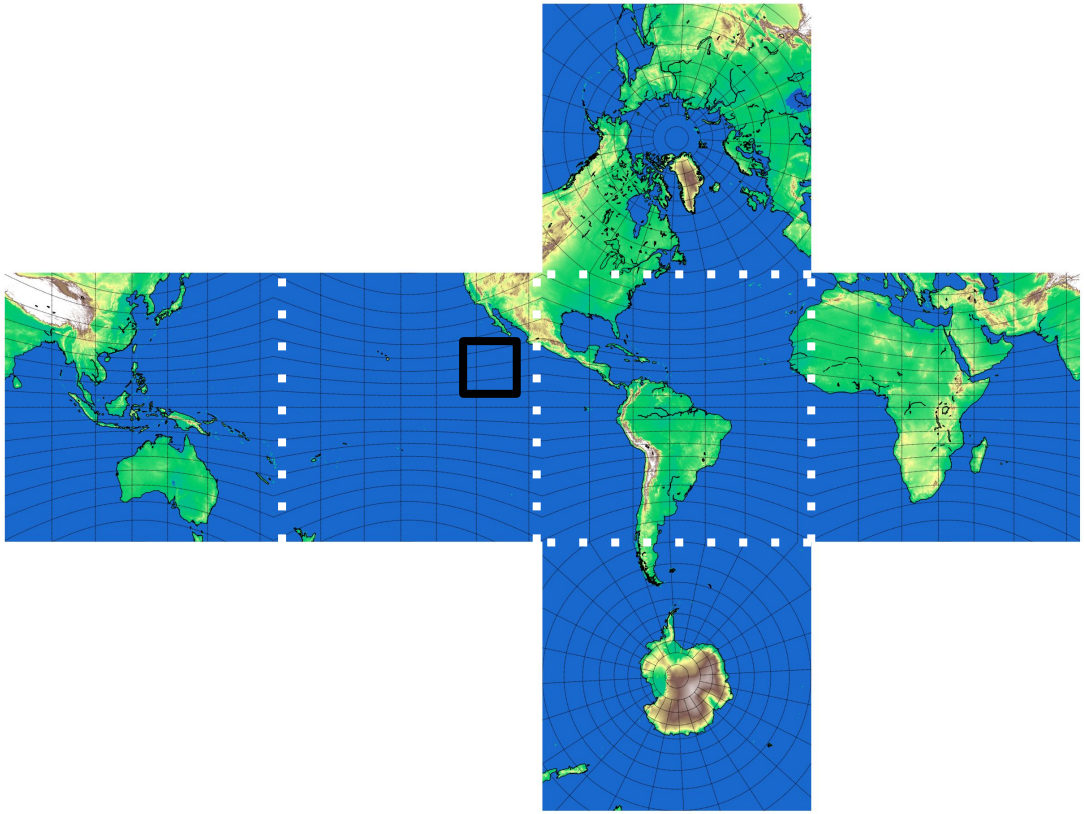
- Incremental approach to nest development:
  - **Two static nests (almost done)**



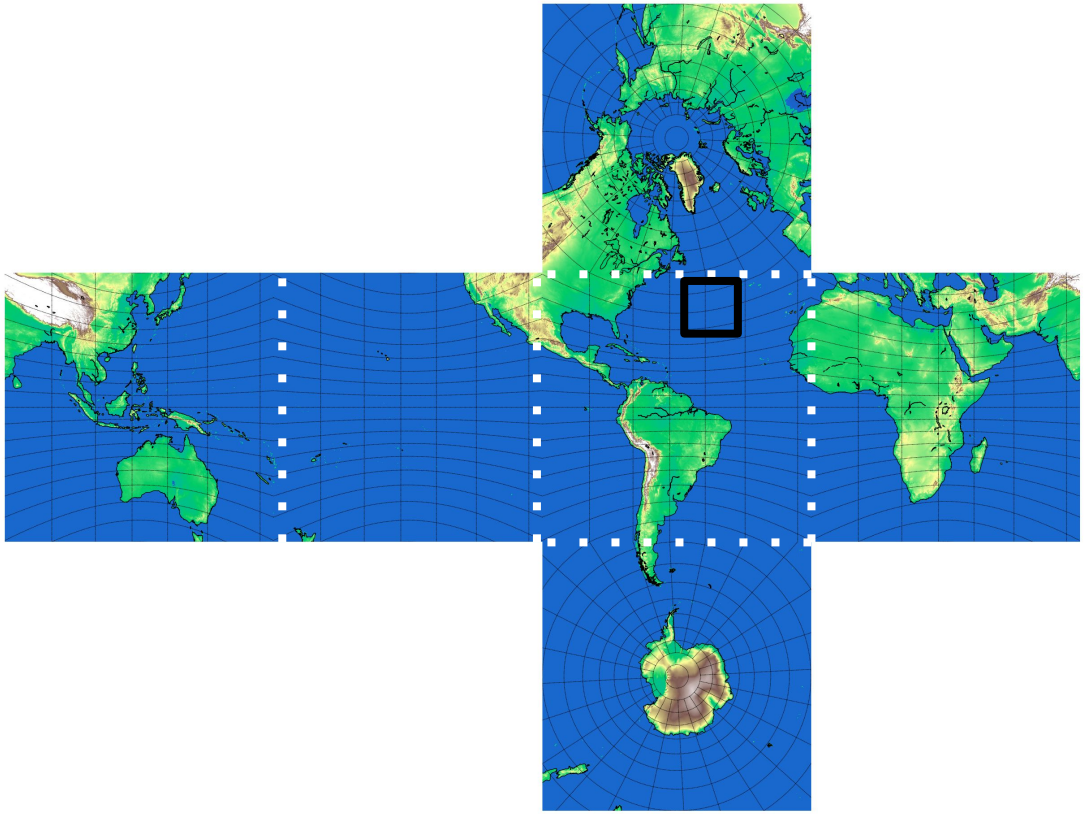
- Incremental approach to nest development:
  - Two static nests (almost done)
  - **Telescoping static nests**



- Incremental approach to nest development:
  - Two static nests (almost done)
  - Telescoping static nests
  - **Nest moving within one tile**



- Incremental approach to nest development:
  - Two static nests (almost done)
  - Telescoping static nests
  - Nest moving within one tile
  - **Nest moving across an edge (likely needed for recurving cases and long tracks)**



- Incremental approach to nest development:
  - Two static nests (almost done)
  - Telescoping static nests
  - Nest moving within one tile
  - Nest moving across an edge (likely needed for recurving cases and long tracks)
  - **Nest crossing a corner (hopefully less frequent but needs to be dealt with)**

HAFS Sub-Projects

- Reproduce HWRF/HMON functionality with FV3 based HAFS
- Accelerate multiple, moving nest implementations in FV3
- FV3 nests coupling to ocean and waves using NEMS/CMEPS NUOPC
- Implement vortex initialization for FV3
- Implement inner-core Hybrid En-VAR DA
- Implement HWRF Physics in FV3 using CCPP
- Coupling advanced LSM, hydrology, inundation and surge models (future)

Major sub-tasks for HAFS in the first year

Task ID	Subtasks	Start Date	Completion Date	Lead	Dependencies	Collaborators	Project
1.1	Implement HWRF physics in FV3 through CCPP	*July 2019*	June 2020	EMC (85K)	None	GMTB/GSD (90K)	3A.2
1.6	DA capability in the regional stand-alone FV3	*June 2019*	May 2020	EMC (170K)	EMC's ongoing regional DA project	AOML	3A.2
1.9	Vortex initialization and storm relocation for FV3	June 2019	May 2020	EMC (170K)	None	AOML	3A.2
1.12	Develop hurricane specific model diagnostic products for HAFS v0.A and v0.B	*July 2019*	June 2020	AOML	None	GFDL, EMC	3A.1
1.18	Advance moving nest framework for existing idealized/semi-idealized vortex (without physics)	*June 2019*	May 2020	AOML	Task 1.7	GFDL, EMC	1A.4
1.20	Prepare and Run HAFSv0.A and HAFSv0.B experiments, document performance and the importance of global parent	*June 2019*	November 2019	EMC (170K)	Tasks 1.1, 1.2 and 1.9	AOML	3A.2

HAFS Development Coordination

- Bi-weekly HAFS Development Meetings (HFIP)
- Published HAFS user/developer guide materials
- **HAFS Developer Guide; Quick Start for HAFS Developers; Quick Start for HAFS Users**
- HSupp activities to gain momentum once funding in place and staff hired
- Need dedicated HPC resources (MSU, Cloud?? Others?)

Questions?