Evaluation of 13km Global fvGFS on Hurricane Prediction
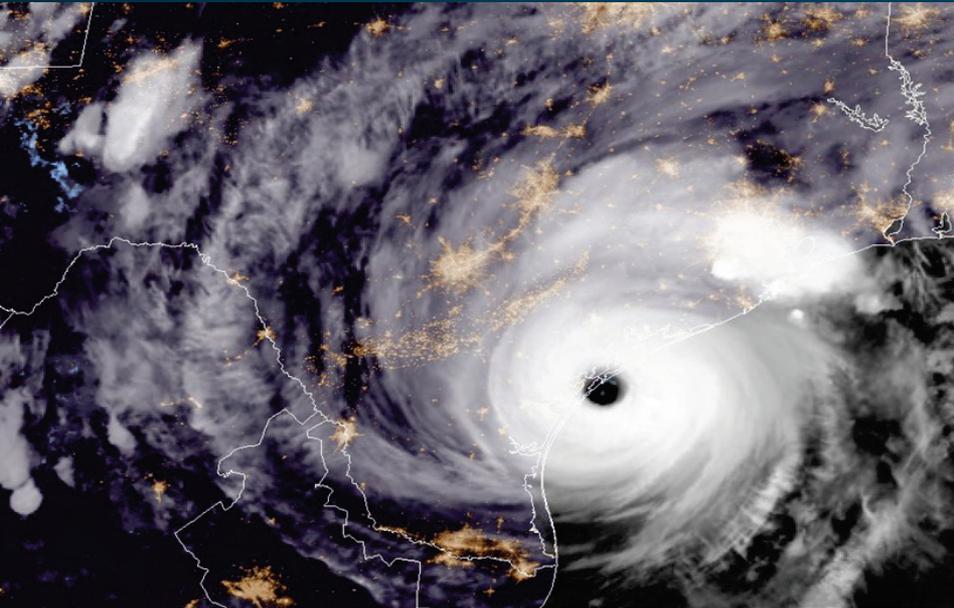

Morris Bender, Matthew Morin, Andrew Hazelton, Shian-Jiann Lin, and the GFDL FV³ Team
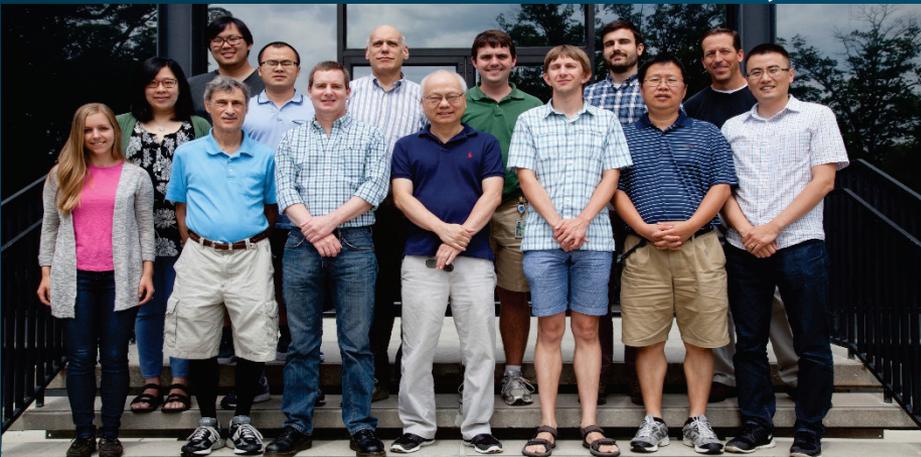
February 7th, 2018
HFIP Telecon

1

Model Setup

- Evaluation of Global 13km **fvGFS** run on the Jet Computer facility by GFDL group

- 63 Vertical Levels

- GFDL 6-class Micro-Physics replaced GFS Zhao-Carr Micro-Physics

- All forecasts started from GFS initial fields *(cold start)*

- Evaluated performance for Atlantic, East Pacific, West Pacific, Indian Ocean and Southern Hemisphere Basins and compared with operational guidance *(i.e., GFS, HWRF, ECMWF).*

- 0 and 12z Synoptic times from April 1st – December 31st, 2015, 2016, and 2017 Seasons.

- fvGFS intensity guidance diagnosed with ~ 1/8 degree grid. Operational GFS still uses coarse ¼ degree grid to diagnose intensity ! ECMWF intensity errors and bias significantly improved using high resolution output grid.

Average Track Errors (nm)
GFS vs. fvGFS

2015, 2016, 2017 SEASONS (GLOBAL)

— NWS GLOBAL GFS
— 13 km fvGFS

#CASES:	1941	1544	1196	913	692
	-3% (53%)	-4% (53%)	-4% (53%)	-3% (54%)	-1% (50%)

2015, 2016, 2017 ATLANTIC SEASONS

— NWS GLOBAL GFS
— 13 km fvGFS
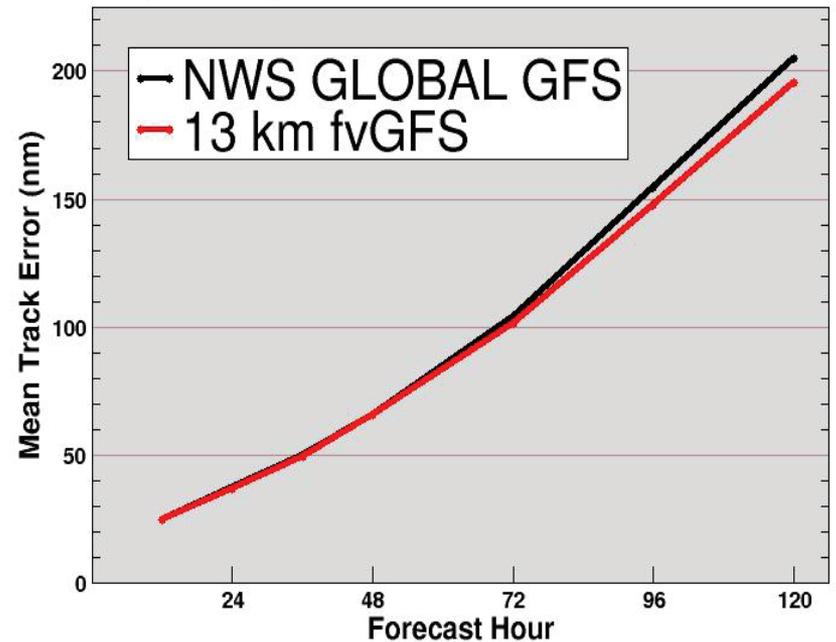
| #CASES:	402	321	251	200	161
	-2% (52%)	0% (47%)	-3% (49%)	-4% (48%)	-5% (52%)

Comparable track errors between fsGFS and the GFS.
3-4% reduced track errors 1-4 days

3

Average Track Errors (nm)
fvGFS vs. Other Guidance

7 Day Track Errors (nm)
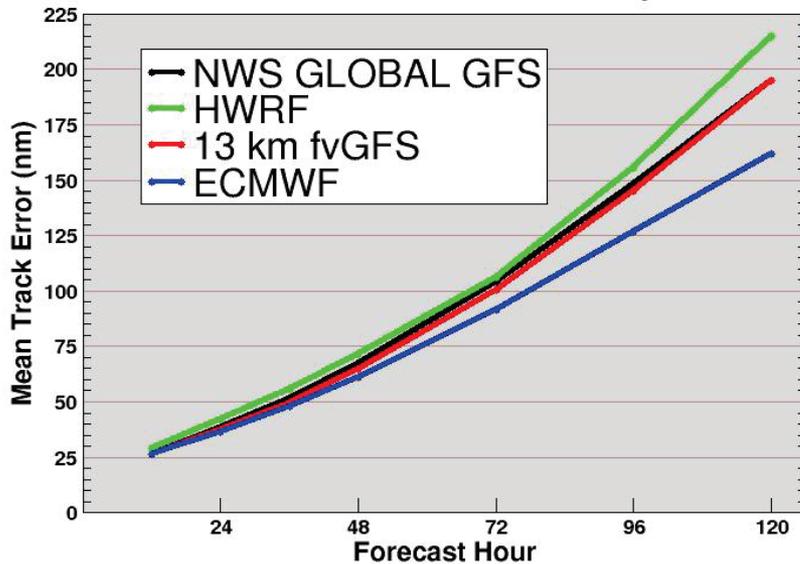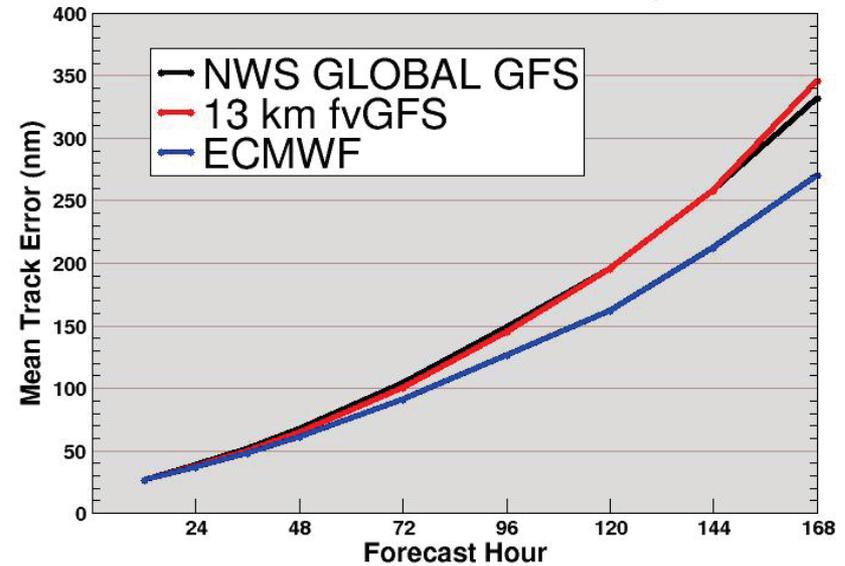
ECMWF track errors significantly lower then GFS based guidance

Days 6-7 ECMWF track errors 18-20% lower then GFS or fvGFS

Average Track Errors *(NHC Basins)*

Average Track Errors (*JTWC Basins*)
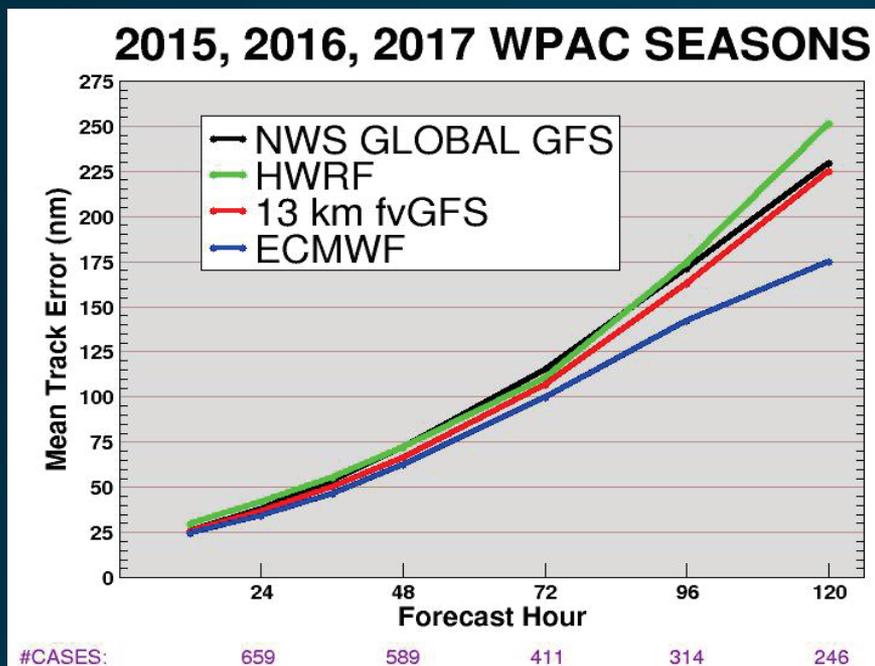

7 % reduction in fvGFS tracks errors compared to GFS at 1-4 days
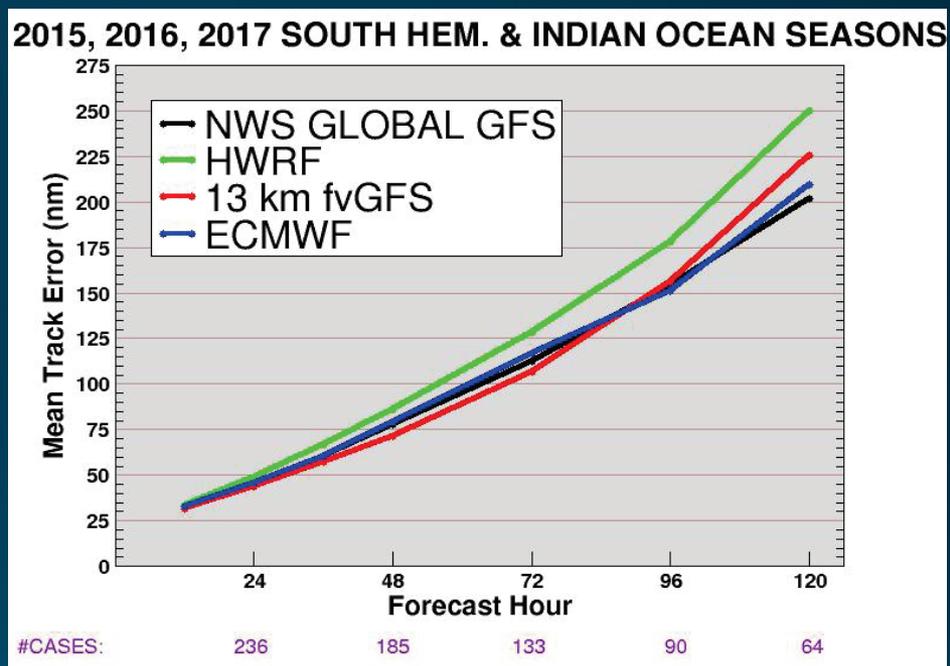
Poor track performance on weak systems for HWRF

Average Intensity Errors (knots)

Intensity Guidance
All Basins

2015, 2016, 2017 SEASONS (GLOBAL)
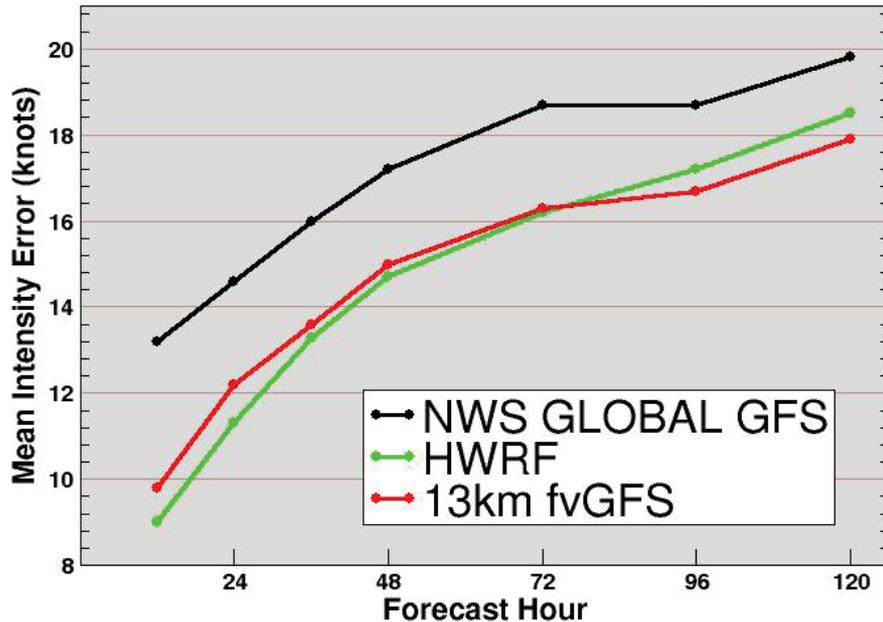
fvGFS intensity errors considerably less then GFS

Comparable intensity errors between fvGFS and HWRF for Global data set.

Average Intensity Errors *(NHC Basins)*
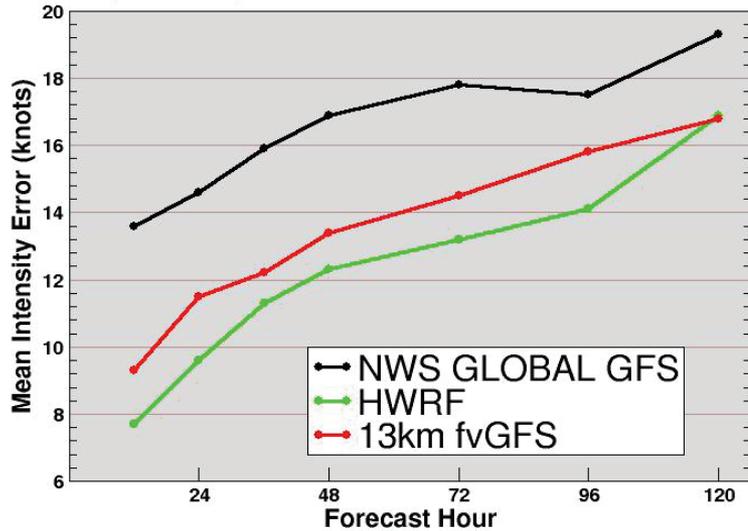
2015, 2016, 2017 ATLANTIC SEASONS
#CASES: 400 320 250 200 161

2015, 2016, 2017 EPAC SEASONS
#CASES: 546 436 342 265 195
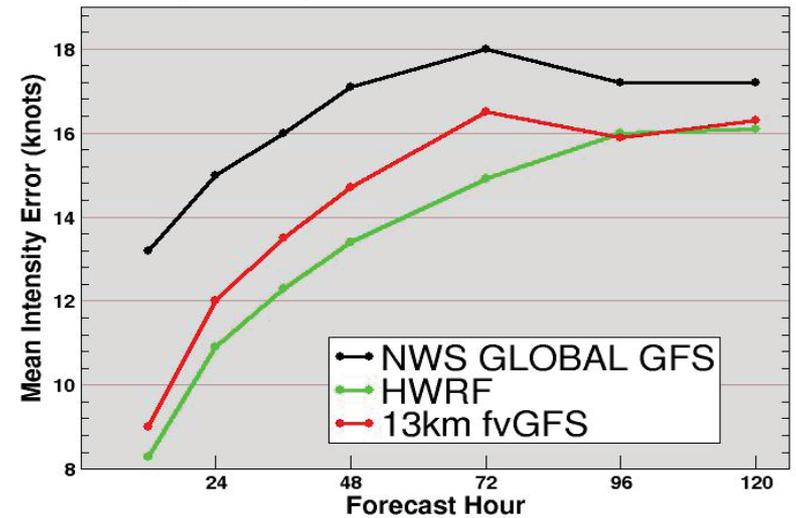
2015-2017 ATLANTIC SEASONS
DISTRIBUTION OF 48 HOUR INTENSITY ERRORS
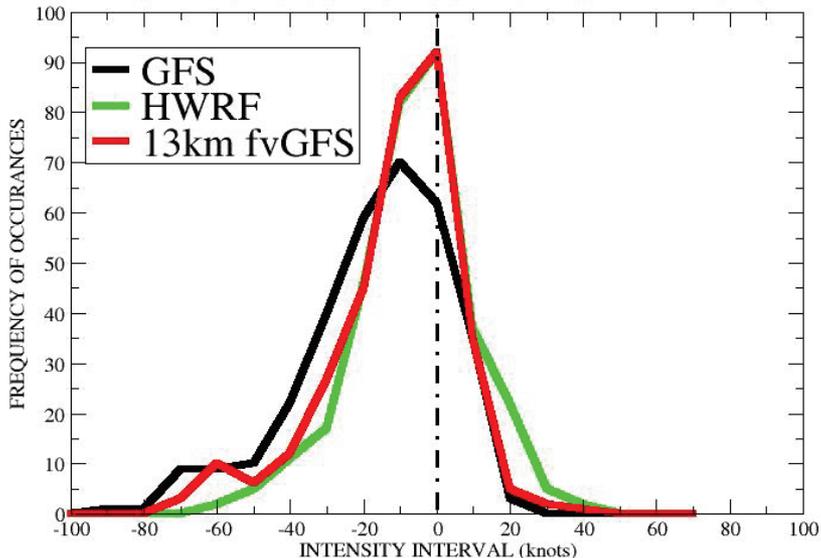
2015-2017 EPAC SEASONS
DISTRIBUTION OF 48 HOUR INTENSITY ERRORS
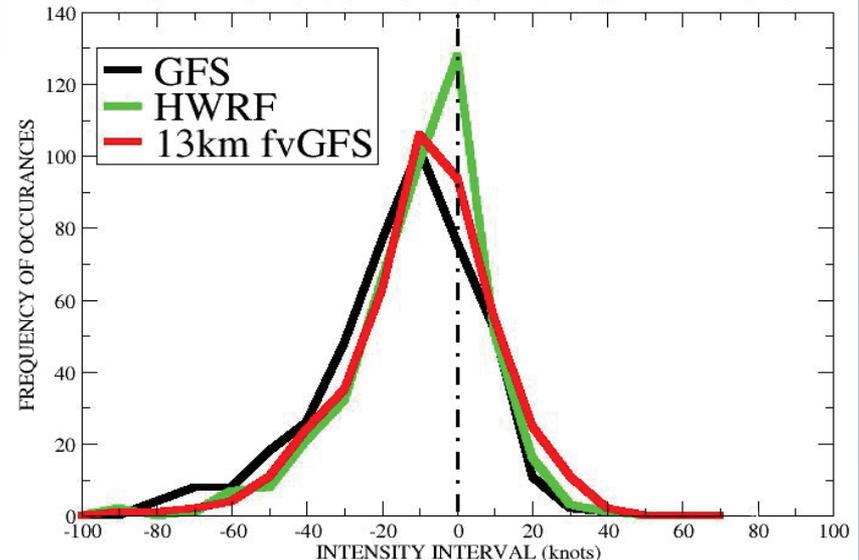
Average Intensity Errors (*JTWC Basins*)

Top left: **2015, 2016, 2017 WPAC SEASONS** — Mean Intensity Error (knots) vs Forecast Hour. Legend: NWS GLOBAL GFS, HWRF, 13km fvGFS. #CASES: 700, 561, 435, 332, 257.
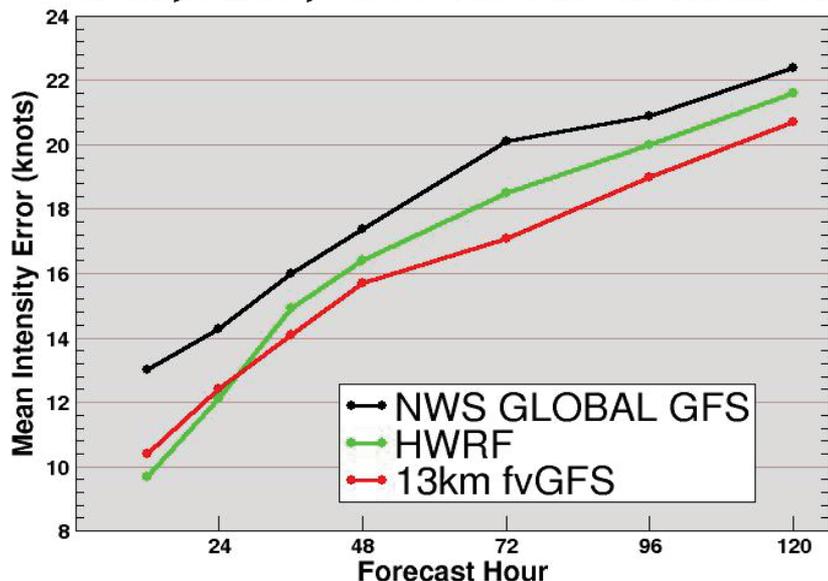
Top right: **2015, 2016, 2017 SOUTH HEM & INDIAN OCEAN SEASONS** — Mean Intensity Error (knots) vs Forecast Hour. Legend: NWS GLOBAL GFS, HWRF, 13km fvGFS. #CASES: 243, 191, 137, 98, 67.
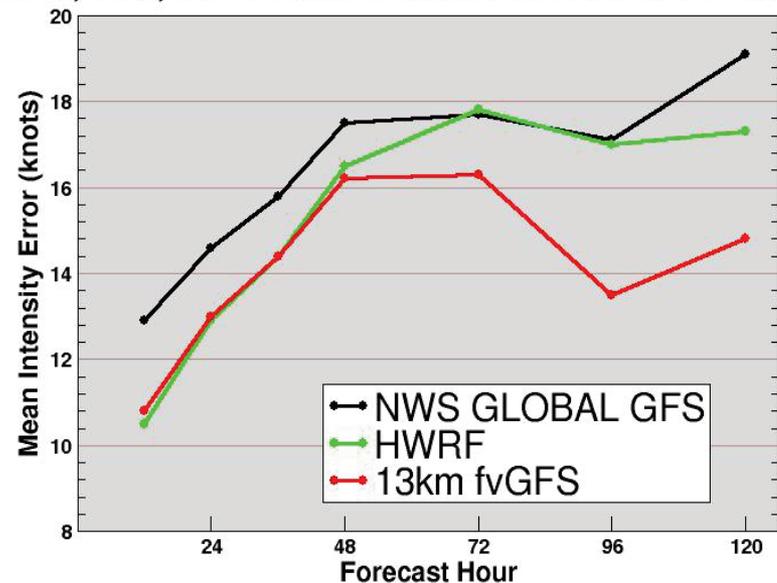
Bottom left: **2015-2017 WPAC SEASONS — DISTRIBUTION OF 48 HOUR INTENSITY ERRORS**. Legend: GFS, HWRF, 13km fvGFS.
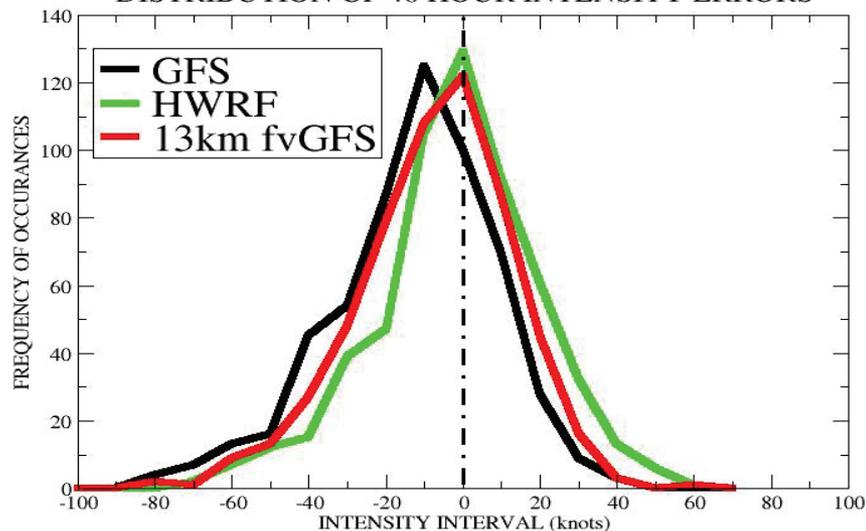
Bottom right: **2015-2017 SH & INDIAN OCEAN SEASONS — DISTRIBUTION OF 48 HOUR INTENSITY ERRORS**. Legend: GFS, HWRF, 13km fvGFS.
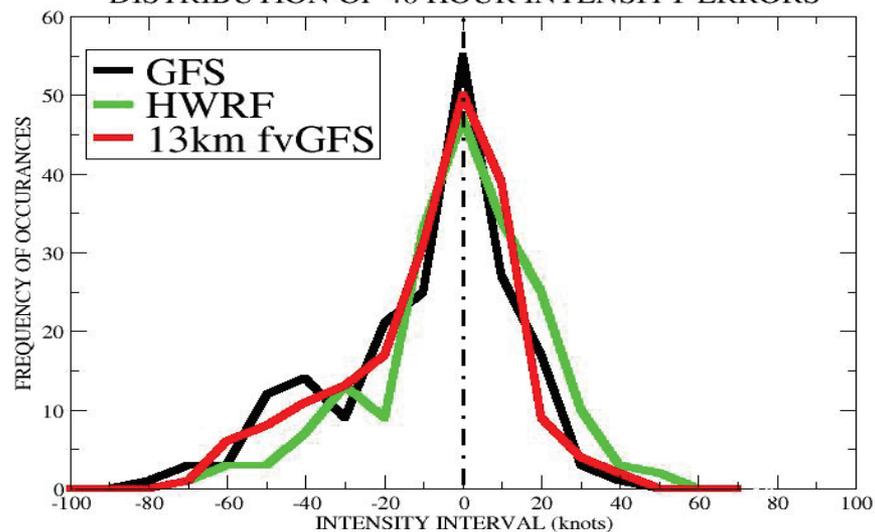
Conclusions

- Track skill of 13 km fvGFS exhibited only slightly improved skill compared to the operational GFS
(~ 3-4 % reduced track errors at 1-4 day forecast lead times)

- Large intensity improvement over operational GFS, however results were likely impacted with the coarser output grid used to compute GFS maximum winds.

- fvGFS intensity errors are comparable with the 2km HWRF globally, with higher errors in the Atlantic and East Pacific, but significantly reduced intensity errors in the JTWC basins of responsibility (e.g., West Pacific, Souther Hemisphere)

- Although HWRF significantly improved prediction of RI, comparable intensity performance resulted from reduced positive bias with fvGFS.

Nested fvGFS Forecasts of the 2017 Atlantic Hurricane Season

Andrew Hazelton[1], Morris Bender[1], Matt Morin[2], Lucas Harris[3], S-J Lin[3], and the FV3 Team
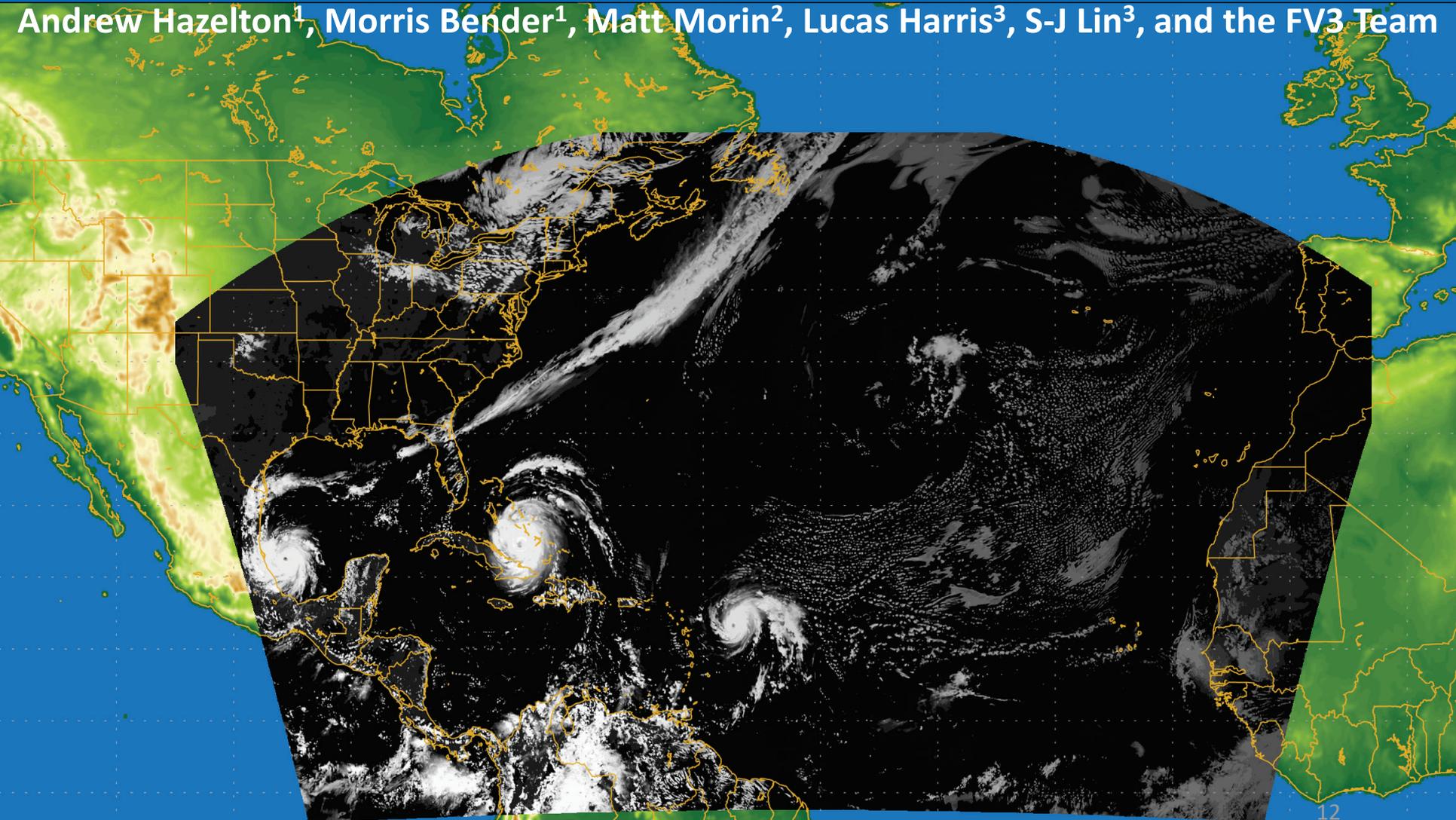
[1]Princeton University, [2]UCAR, [3]NOAA GFDL

Introduction

- FV3 core has applications on a variety of scales

- FV3 with GFS physics (fvGFS) used for weather prediction

- High-resolution nested version capable of TC track, intensity, structure prediction

- 2017 Atlantic hurricane season featured a large variety of cases, including RI and extreme impacts

- Perfect testing set for new model

Model Description and Cases

- FV3 dynamical core

- 3-km nest within 13-km global grid

- GFS physics
  -Includes scale-aware convection

- GFDL microphysics

- No ocean coupling

- 10 cases from 2017 (Franklin through Ophelia)

fvGFS 2017 Atlantic TC Grid
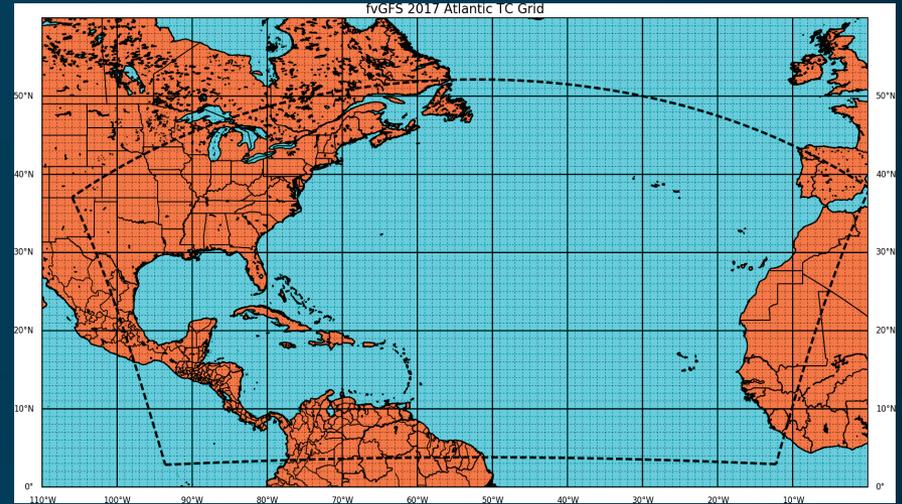
Cases Used

fvGFS 2017 Atlantic TC Forecasts
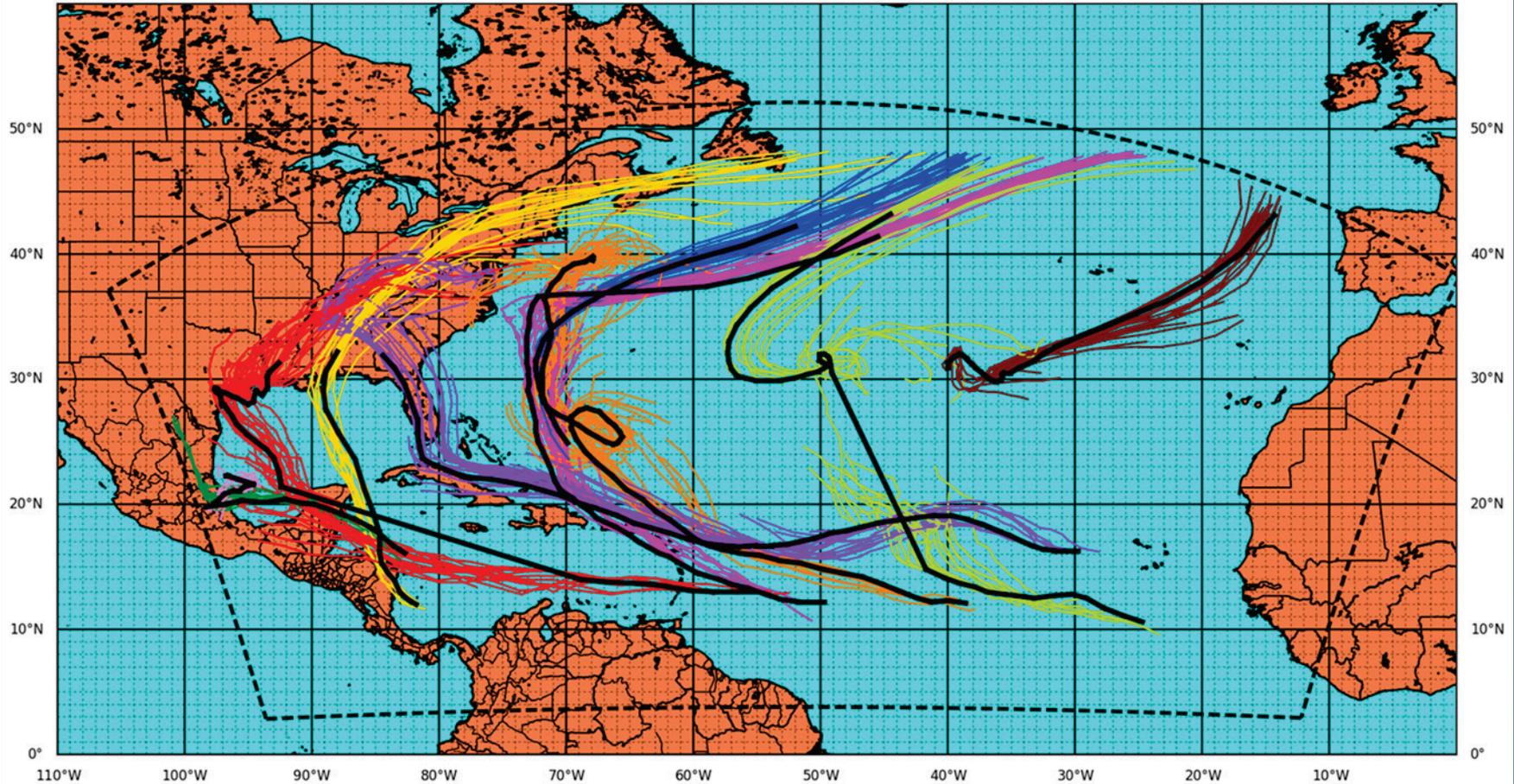
Franklin Gert Harvey Irma Jose Katia Lee Maria Nate Ophelia

Animation of August-October 2017
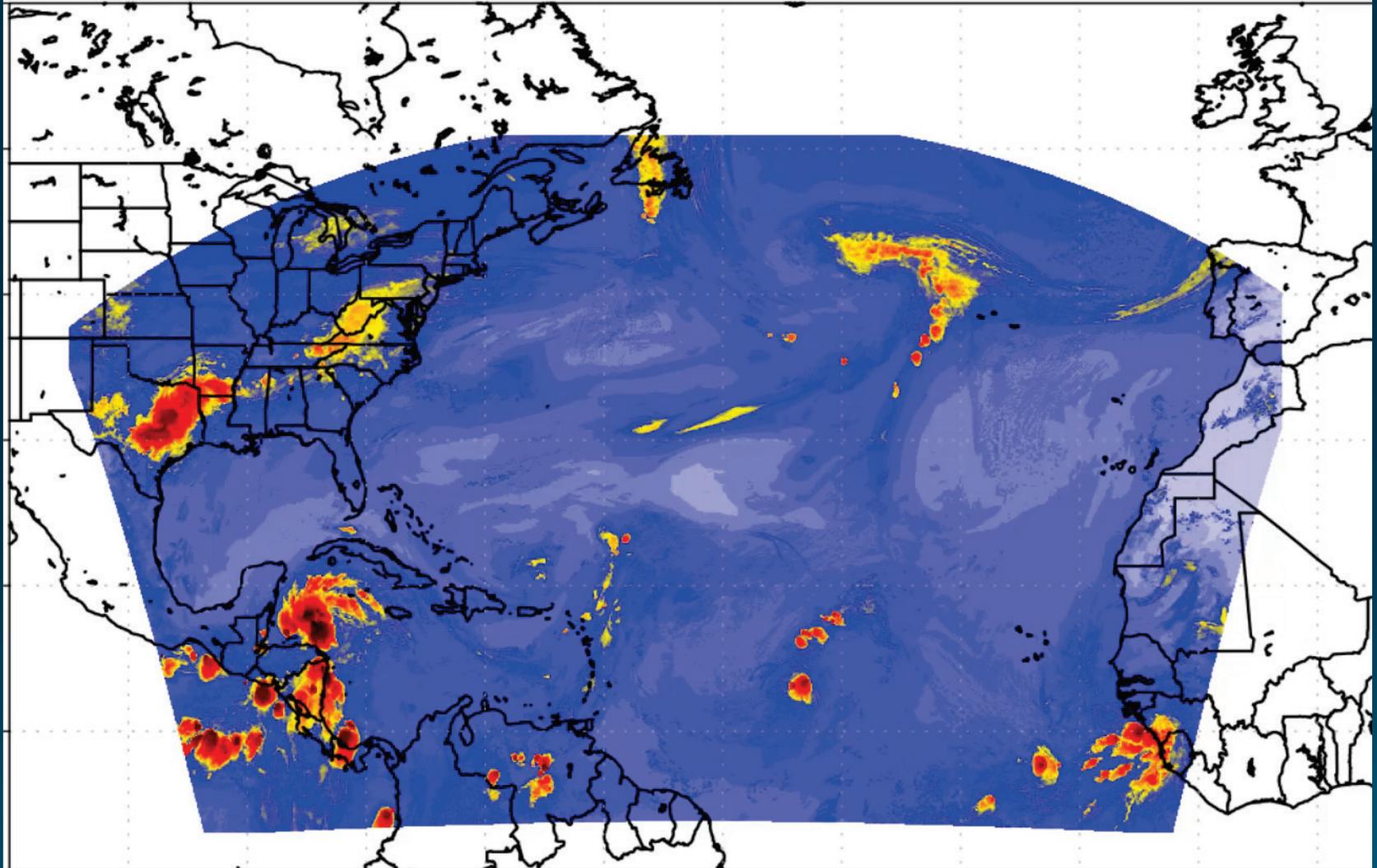
- All 12-hour fvGFS forecasts (simulated IR imagery)

Track Forecast Skill

-Similar track skill to GFS and HWRF at all leads

-Skill peaks around hour 48
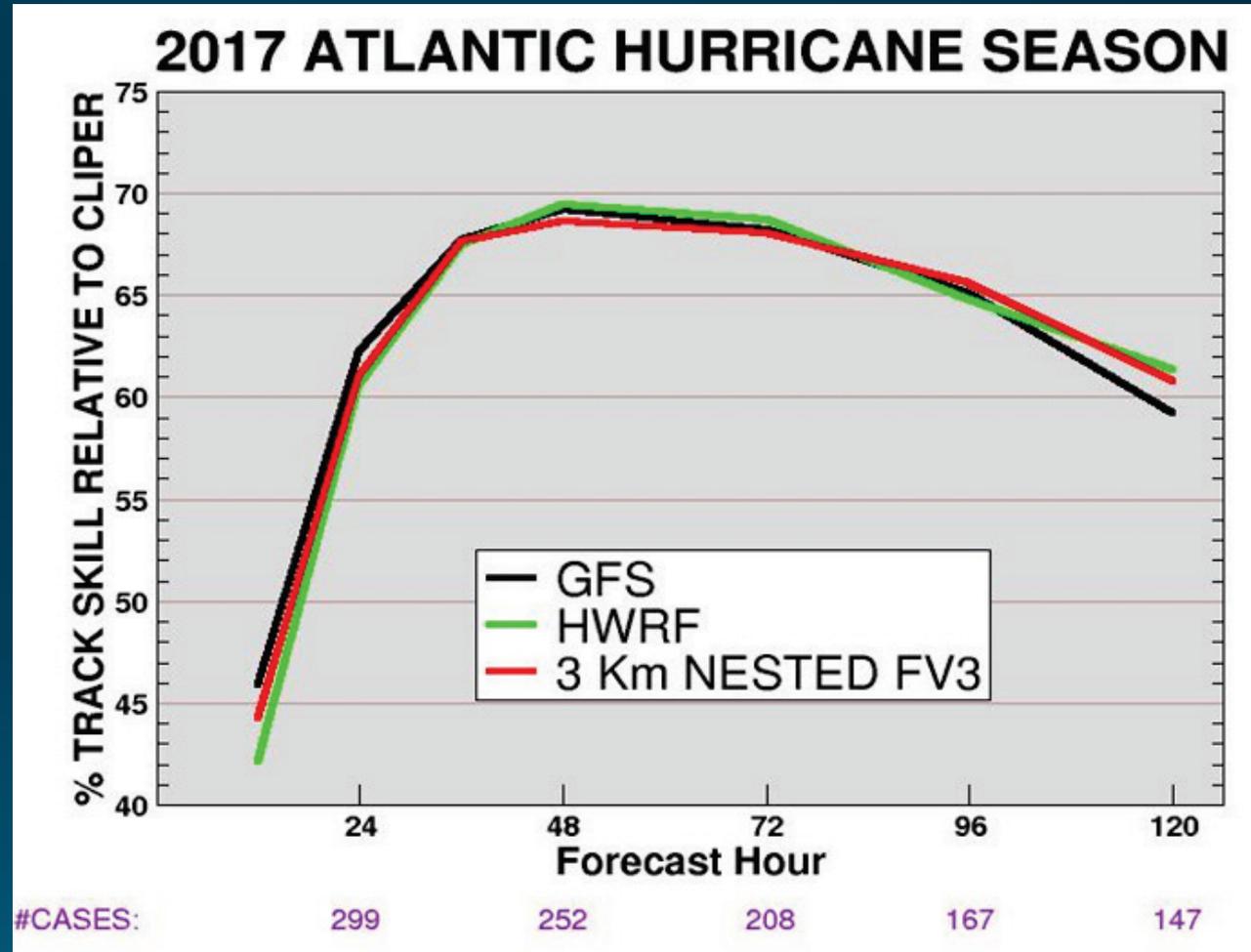
Track Errors Map (48,120 hour)
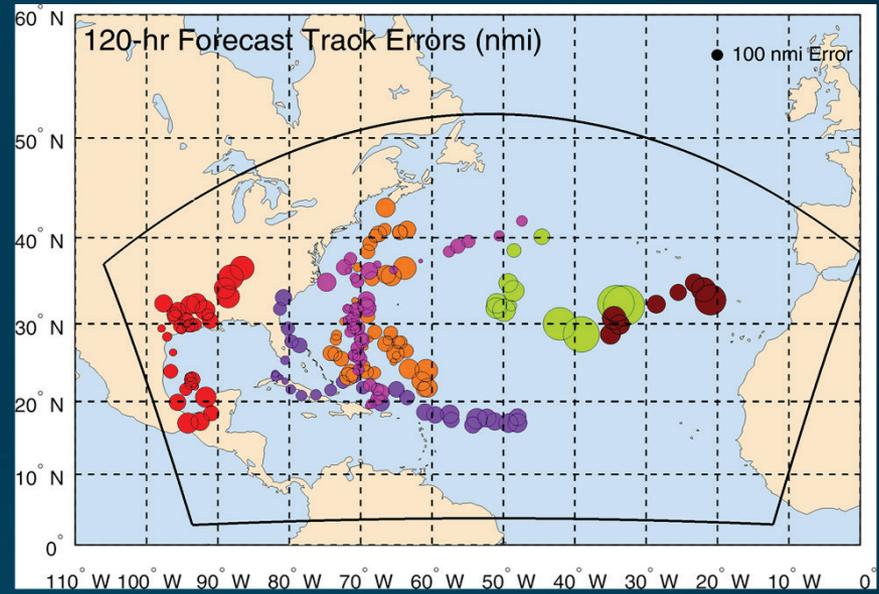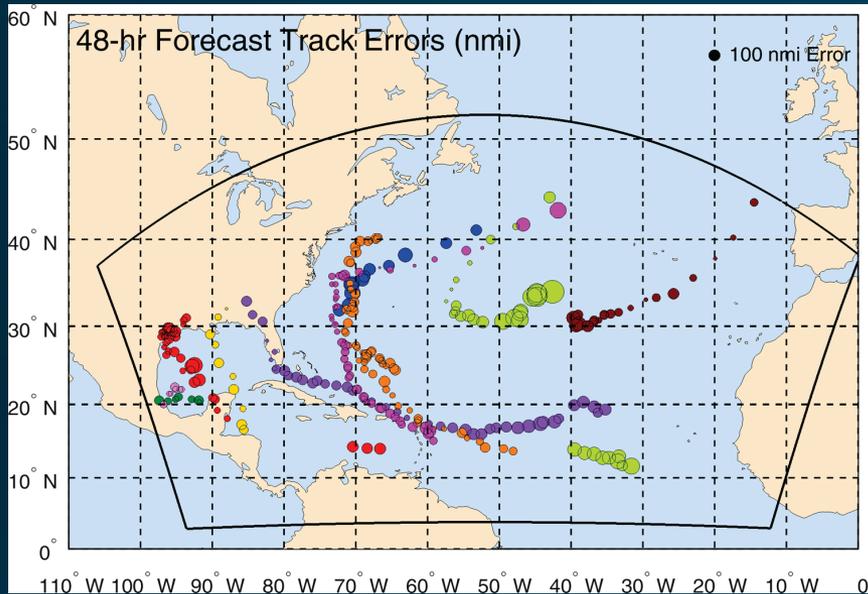
Franklin **Gert** **Harvey** **Irma** **Jose** **Katia** **Lee** **Maria** **Nate** **Ophelia**

-Largest errors during erratic motion of Lee/Jose

-Recurving Harvey/Ophelia also had issues (speed?)

-Western Atlantic cases moving NW had smaller errors

Intensity Forecast Skill

-fvGFS generally more skillful than GFS, but worse than operational HWRF

-Skill peaks around hour 72

-Sharp dropoff Day 5

2017 ATLANTIC HURRICANE SEASON

% INTENSITY SKILL RELATIVE TO SHIFOR

GFS
HWRF
3km NESTED FV3

Forecast Hour

#CASES: 299   252   208   167   147
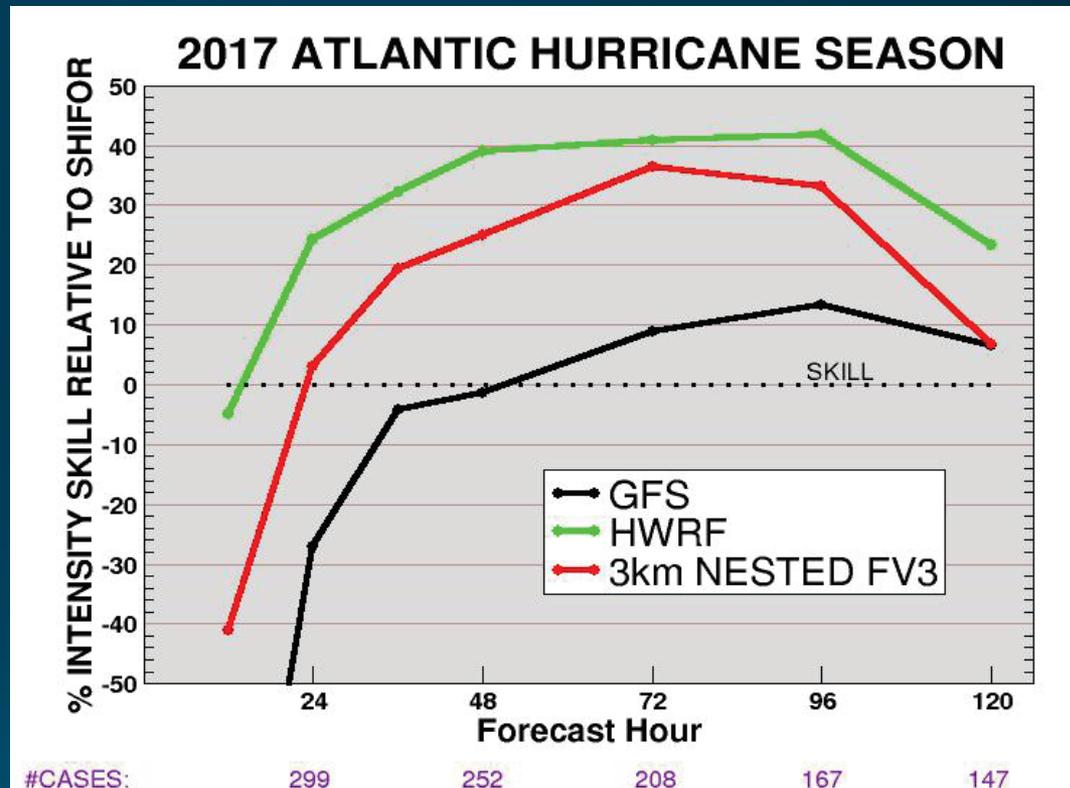
Intensity Error Distribution (48 hr)

-More extreme negative bias cases than HWRF (but much fewer than GFS)

-More positive bias cases

DISTRIBUTION OF 48 HOUR INTENSITY ERRORS

Legend: GFS, HWRF, 3km NESTED FV3

Intensity Error Maps (48 hr)

48-hr Forecast Negative Vmax Errors (kt)

48-hr Forecast Positive Vmax Errors (kt)
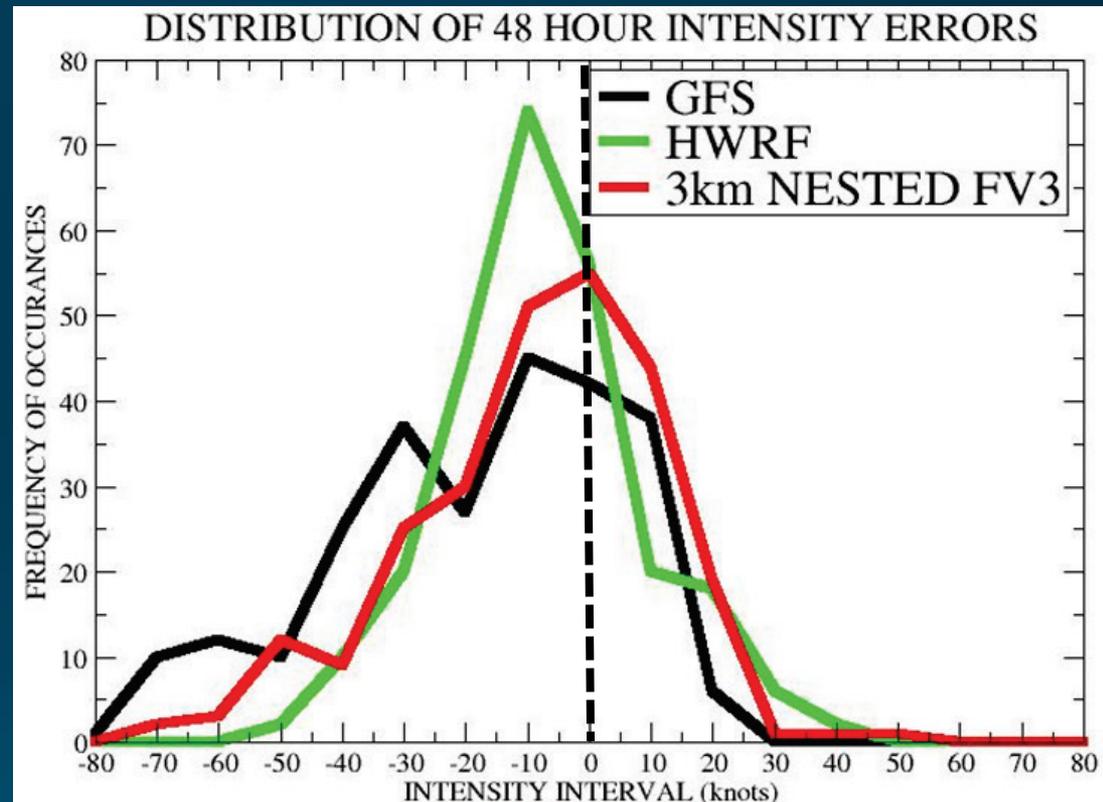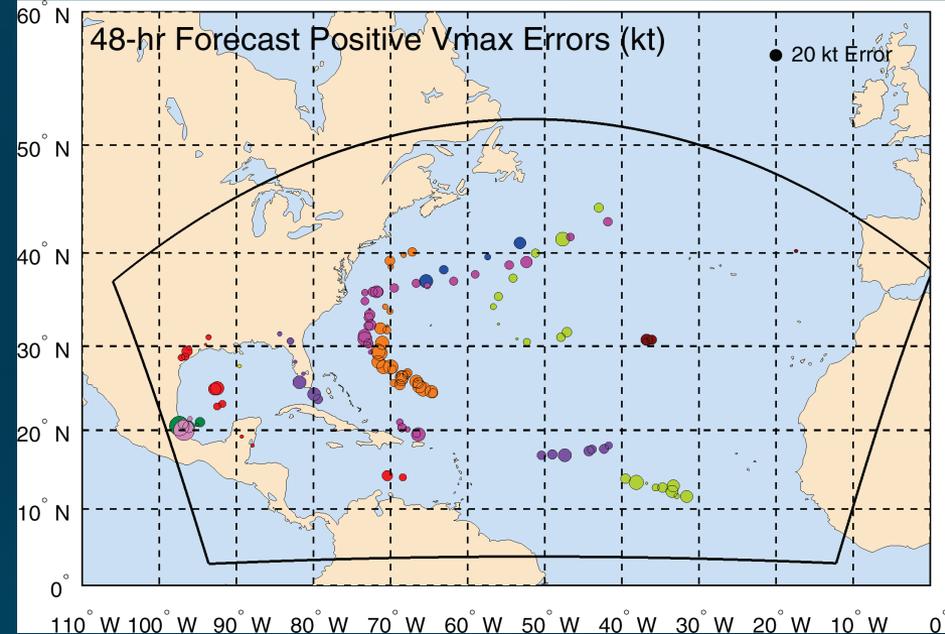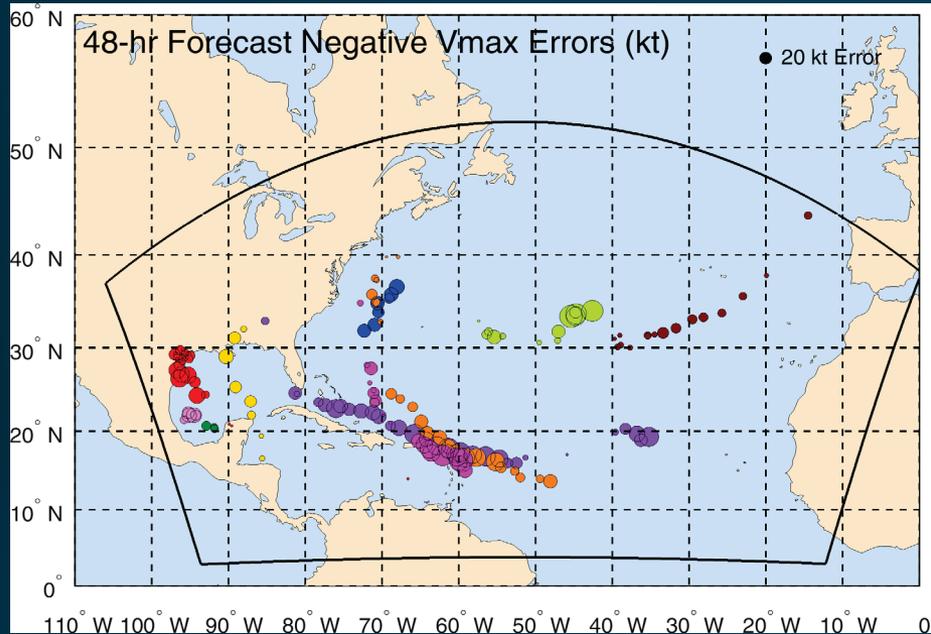
Franklin **Gert** **Harvey** **Irma** **Jose** **Katia** **Lee** **Maria** **Nate** **Ophelia**

-More negative bias cases than positive

-RI of Maria, Irma near peak intensity, Lee all had large negative bias

-Jose and Ophelia smaller negative bias

-Most positive errors were during recurve (ocean coupling?)

Intensity Error Maps (120 hr)
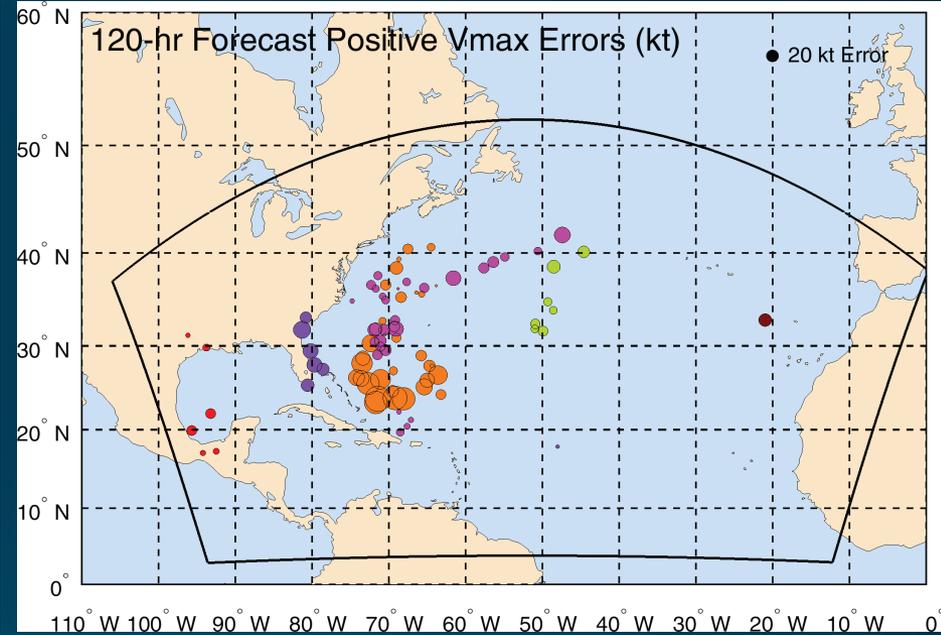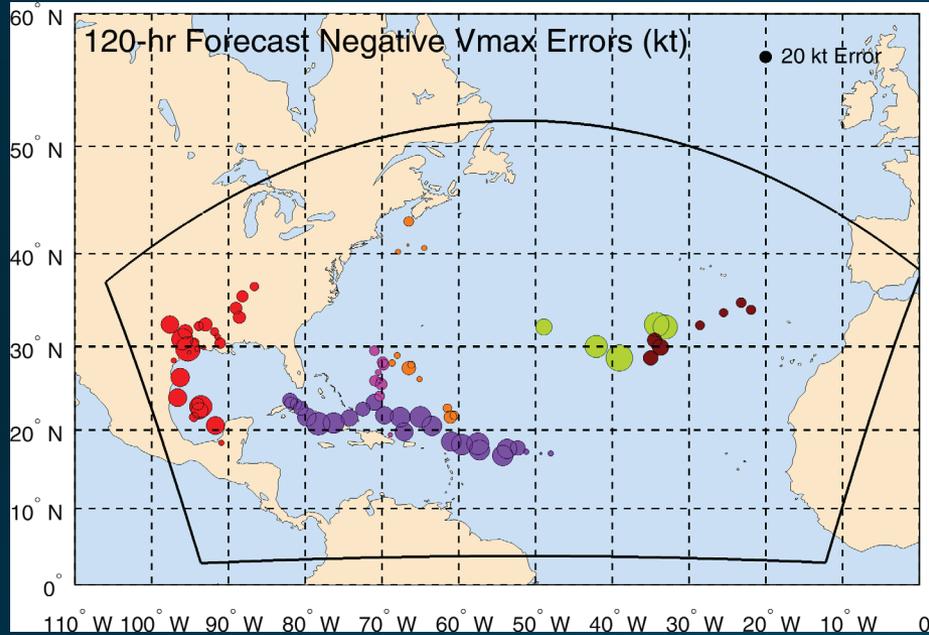
**Franklin Gert Harvey Irma Jose Katia Lee Maria Nate Ophelia**

-Negative biases larger than the positive
-Negative biases dominated by Irma (~150-160 kts for days)
-Positive biases dominated by Jose (looping over cold wake, no coupling)

Intensity Comparison vs. Global fvGFS
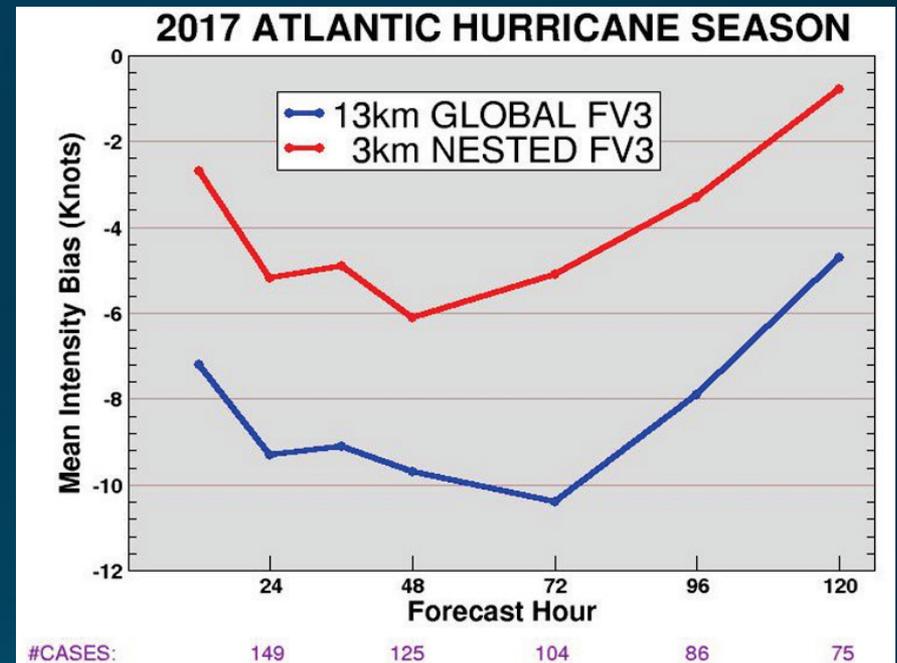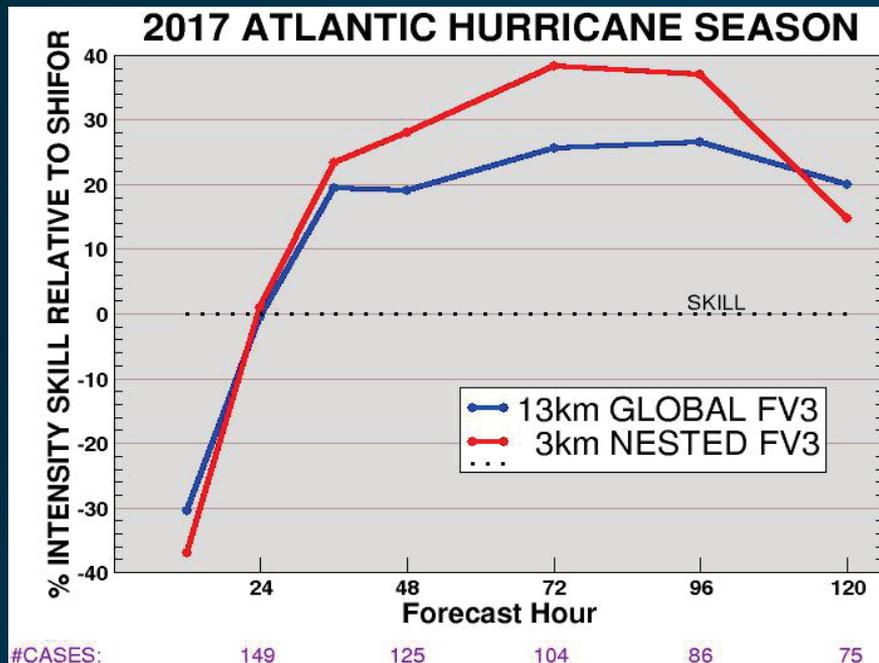
-After spin-up from global ICs (~24 hr), nested model shows large increase in skill relative to global (except at hour 120)

-Bias is lower for nested model for all forecast hours

-Introduction of the nest reduces the negative bias but does introduce some high bias, particularly at longer leads

RMW Prediction

-Model RMW compared with Best Track

-Subject to observational uncertainty

-"Blockiness" due to BT binning every 5 n mi

-RMW tends to be slightly too large, especially for observed small RMW

-Consistent with a smaller set of cases from 2010-2016 verified using HRD radar data (Hazelton et al. 2018, WAF)

-More evenly distributed bias at the higher end

fvGFS RMW vs. Best Track Density Plot
Binned Every 5 km

RMW Error Maps (48 hr)

48-hr Forecast Negative RMW Errors (nmi) — 25 nmi Error

48-hr Forecast Positive RMW Errors (nmi) — 25 nmi Error
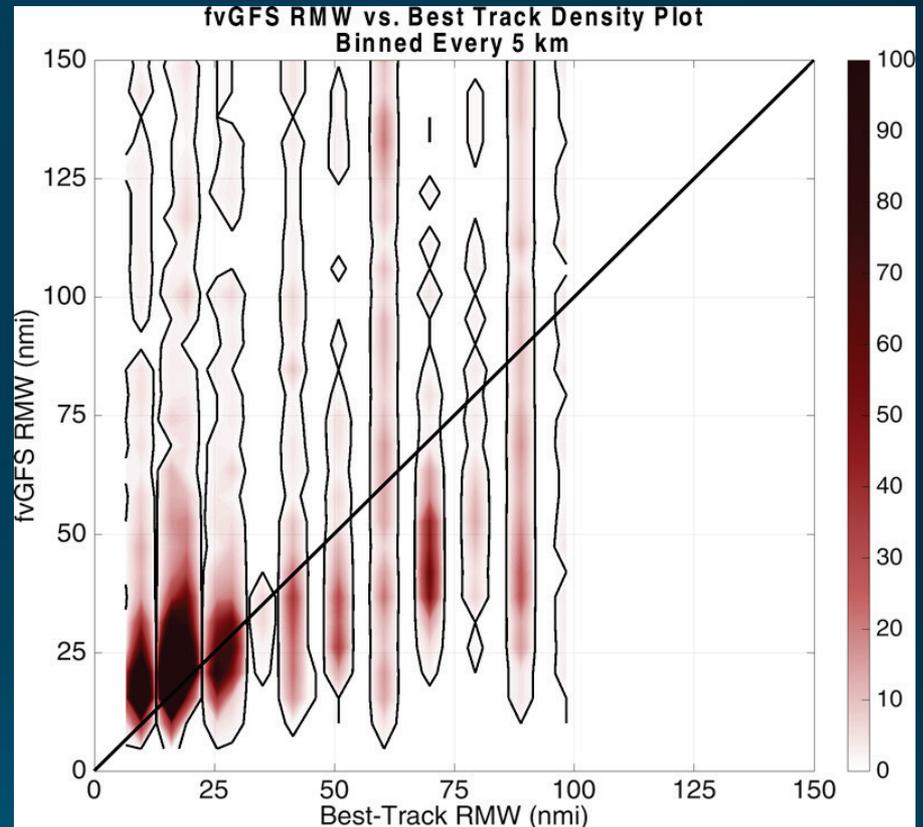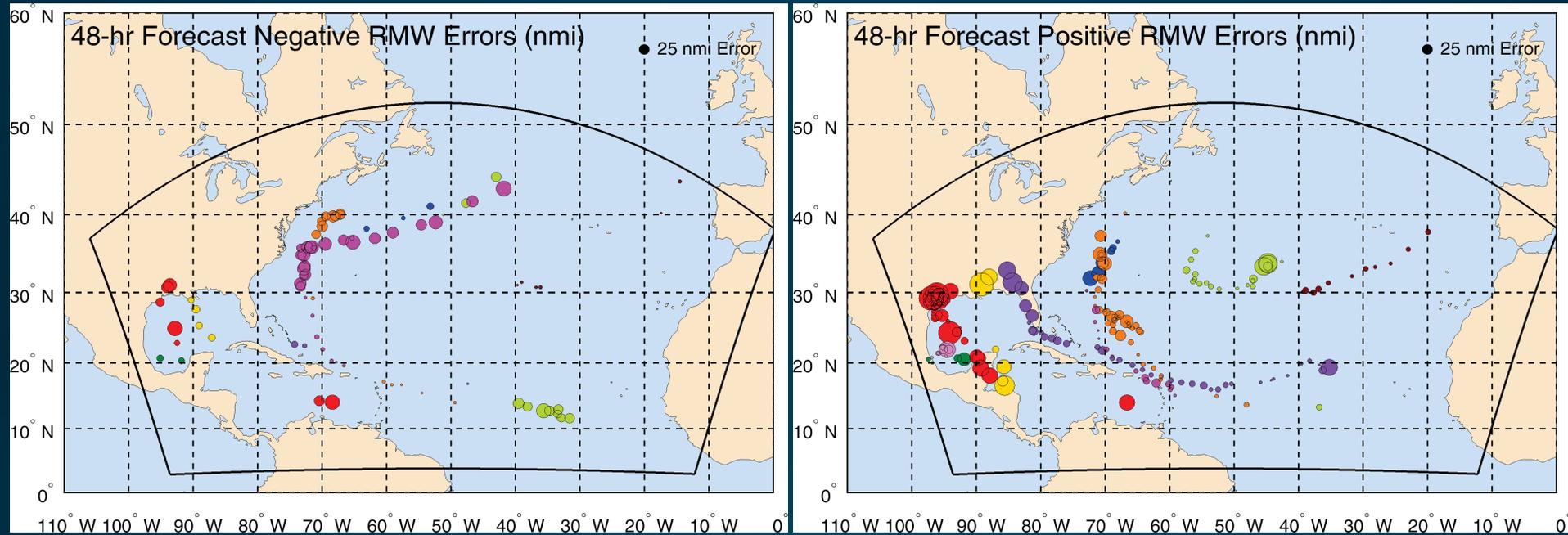
Franklin Gert Harvey Irma Jose Katia Lee Maria Nate Ophelia

-Essentially the opposite pattern of the intensity errors
-Positive errors (RMW too large) more common, larger than negative
-Most negative errors during recurve (ET?)
-Largest negative errors seem to be near Harvey, Irma landfalls (track error?)

25

RMW Error Maps (120 hr)

120-hr Forecast Negative RMW Errors (nmi)

120-hr Forecast Positive RMW Errors (nmi)
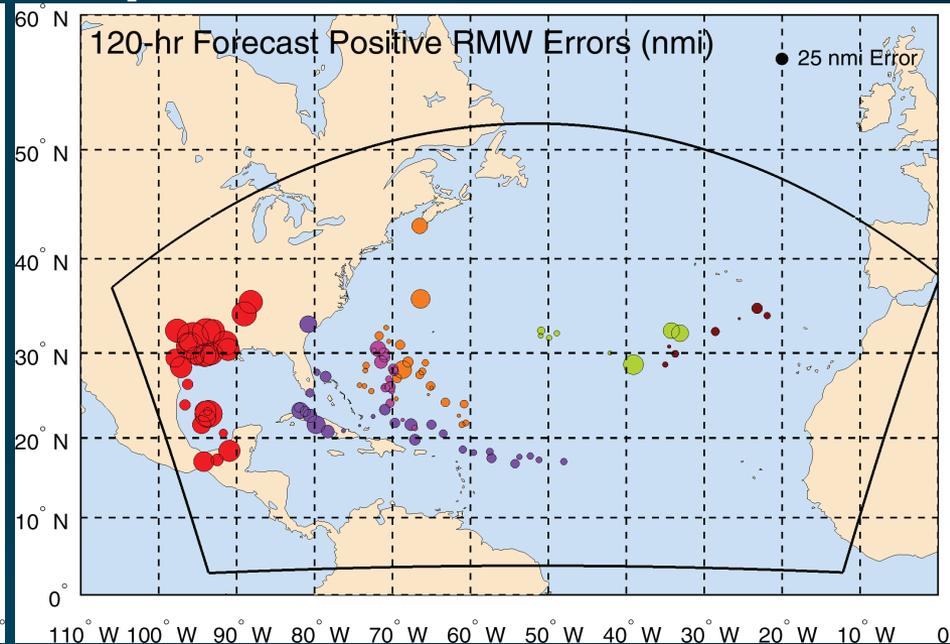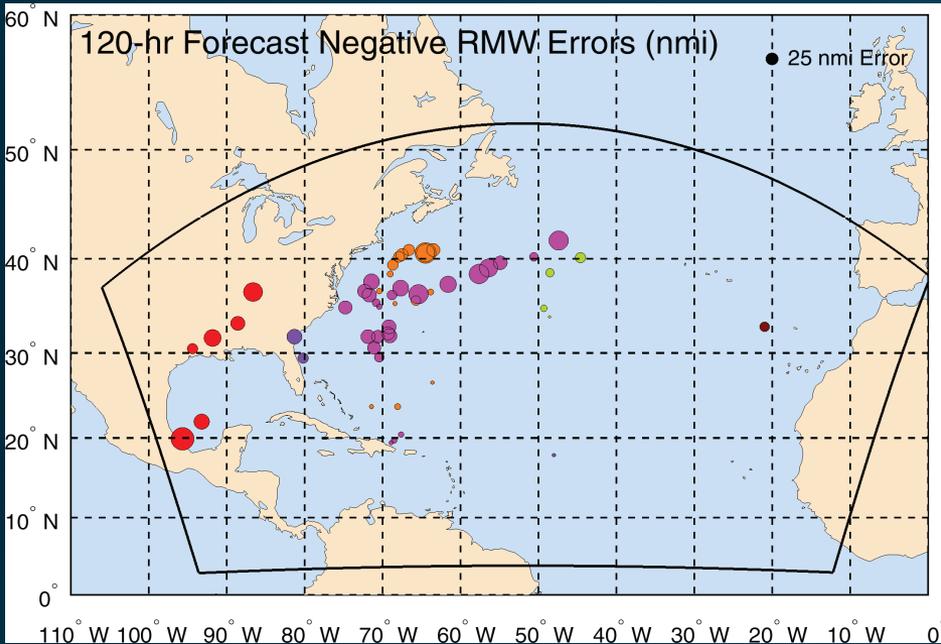
Franklin Gert Harvey Irma Jose Katia Lee Maria Nate Ophelia

- Negative RMW bias at 120 hr almost all from Maria and Jose (ocean coupling?)
- Irma had many positive biases, but most were small
- Cases with large error were from Harvey along the Texas coast (track error)

Case Studies (Harvey and Maria)

fvGFS AL09 Initialized 2017082412
Simulated Infrared Brightness Temperature (C) Hour 036
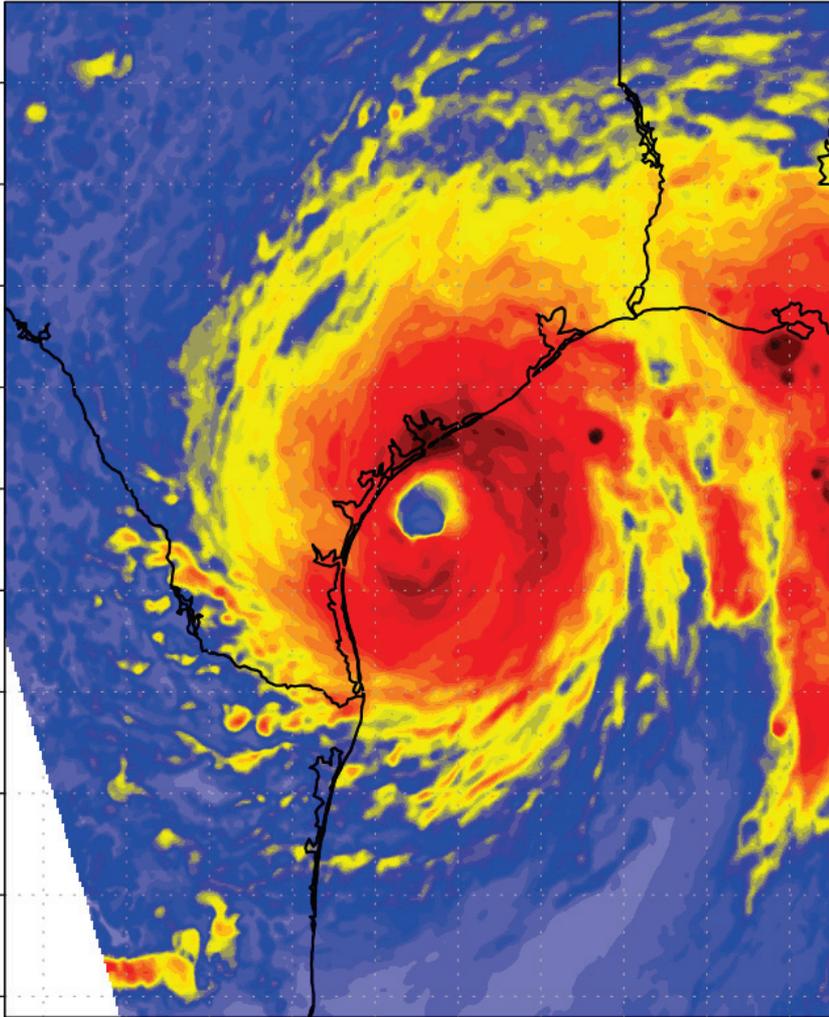
fvGFS AL15 Initialized 2017091800
Simulated Infrared Brightness Temperature (C) Hour 024

Hurricane Harvey

2017 Tropical Cyclone Tracks
Storm: AL0917 (HARVEY)

Forecasts: Beginning 2017082212 for AFVN model
Observed: Beginning 2017082212, every 12 hours

Intensity (kt)

Aug 22nd   Aug 25nd   Aug 28th
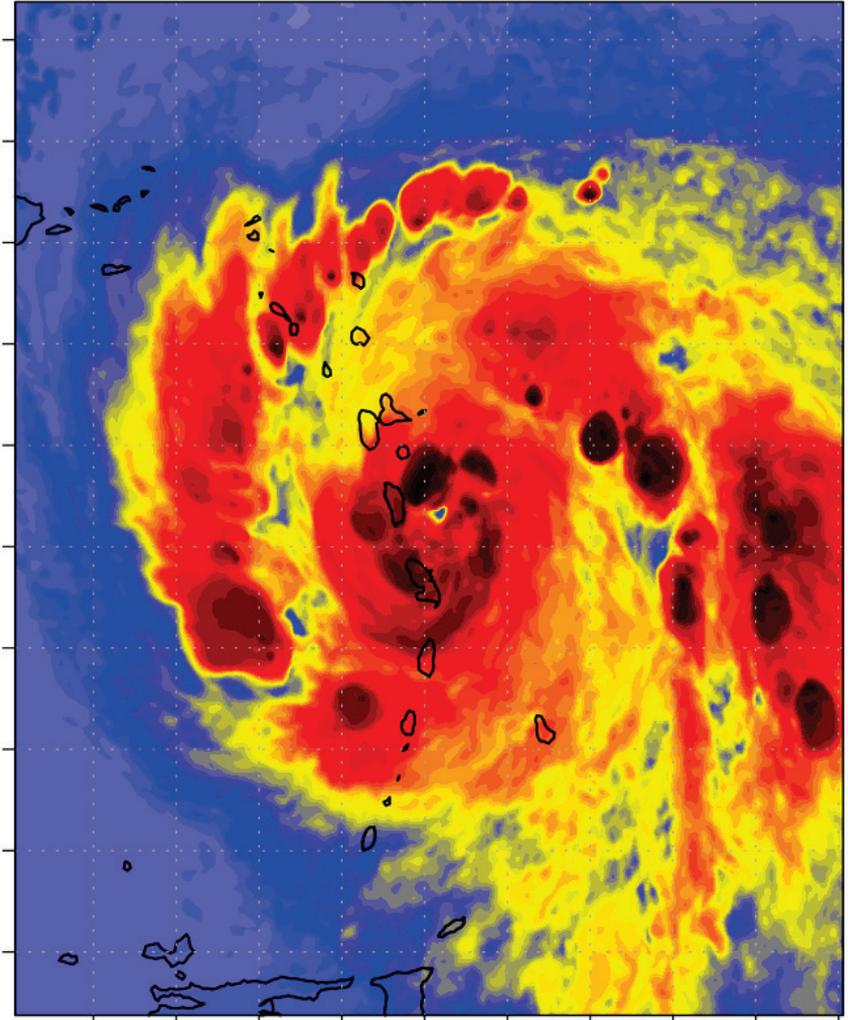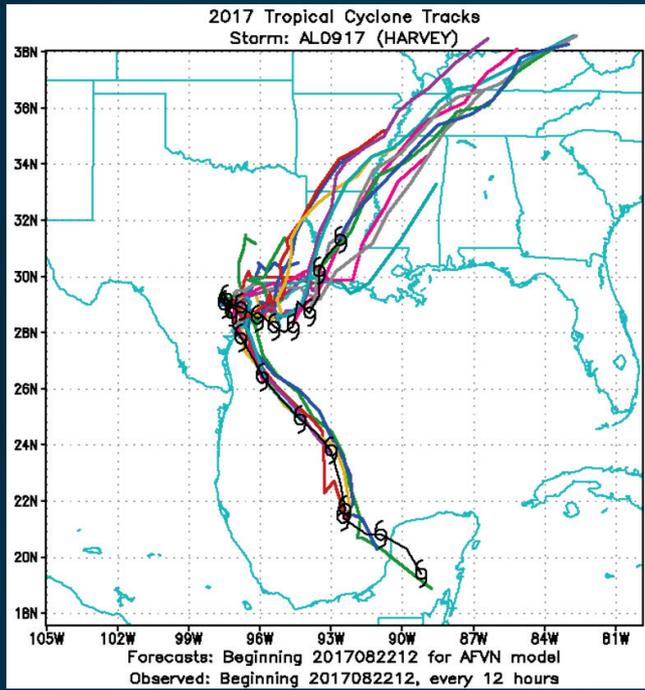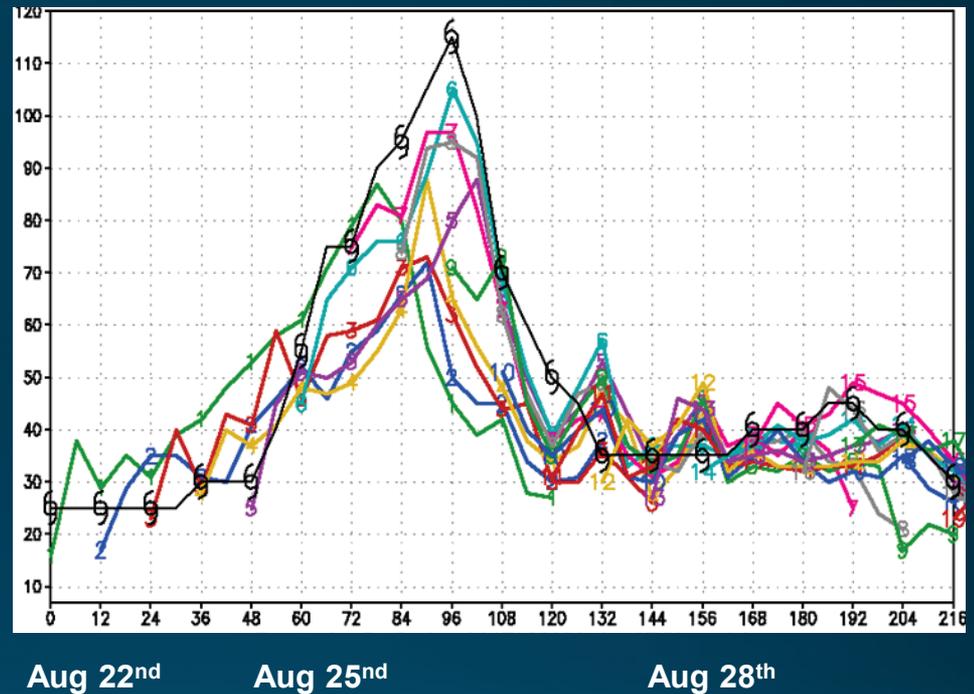
-fvGFS did well with initial track, landfall location
-Some forecasts went NE too quickly
-Earliest forecasts did not capture RI perfectly
-Many forecasts from August 23-24 did show RI to a major hurricane

Hurricane Harvey
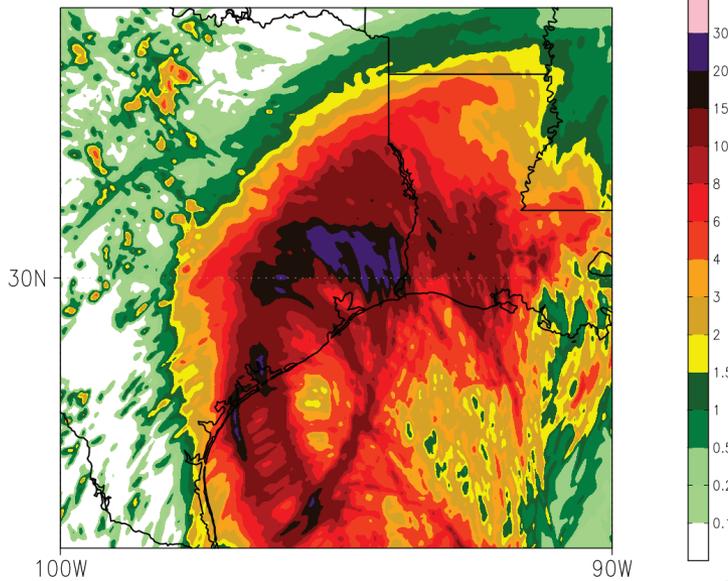
-General rainfall pattern well predicted

-Max near Houston, secondary max near landfall

-Some areas over 20" predicted, but maximum values not perfectly forecast
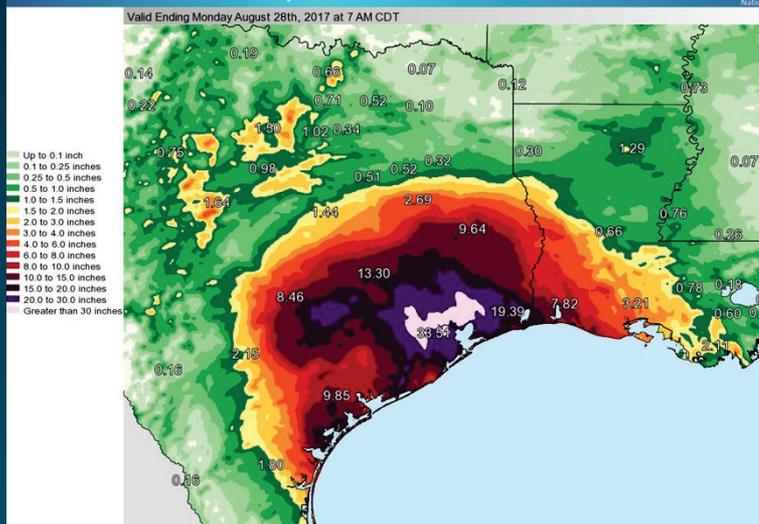
# Hurricane Harvey

-Harvey was initially broad and tilted

-Blue is 500-hPa wind, green is 850-hPa wind

-Convection led to vortex becoming stacked and consolidated

-This consolidation due to convection noted in TC report (Blake and Zelinsky 2018)

-RI commenced

-Process well-represented in this fvGFS run

Hurricane Maria

2017 Tropical Cyclone Tracks
Storm: AL1517 (MARIA)
Forecasts: Beginning 2017091612 for AFVN model
Observed: Beginning 2017091612, every 12 hours

2017 Tropical Cyclone Tracks
Storm: AL1517 (MARIA)
Forecasts: Beginning 2017091612 for AFVN model
Observed: Beginning 2017091612, every 12 hours
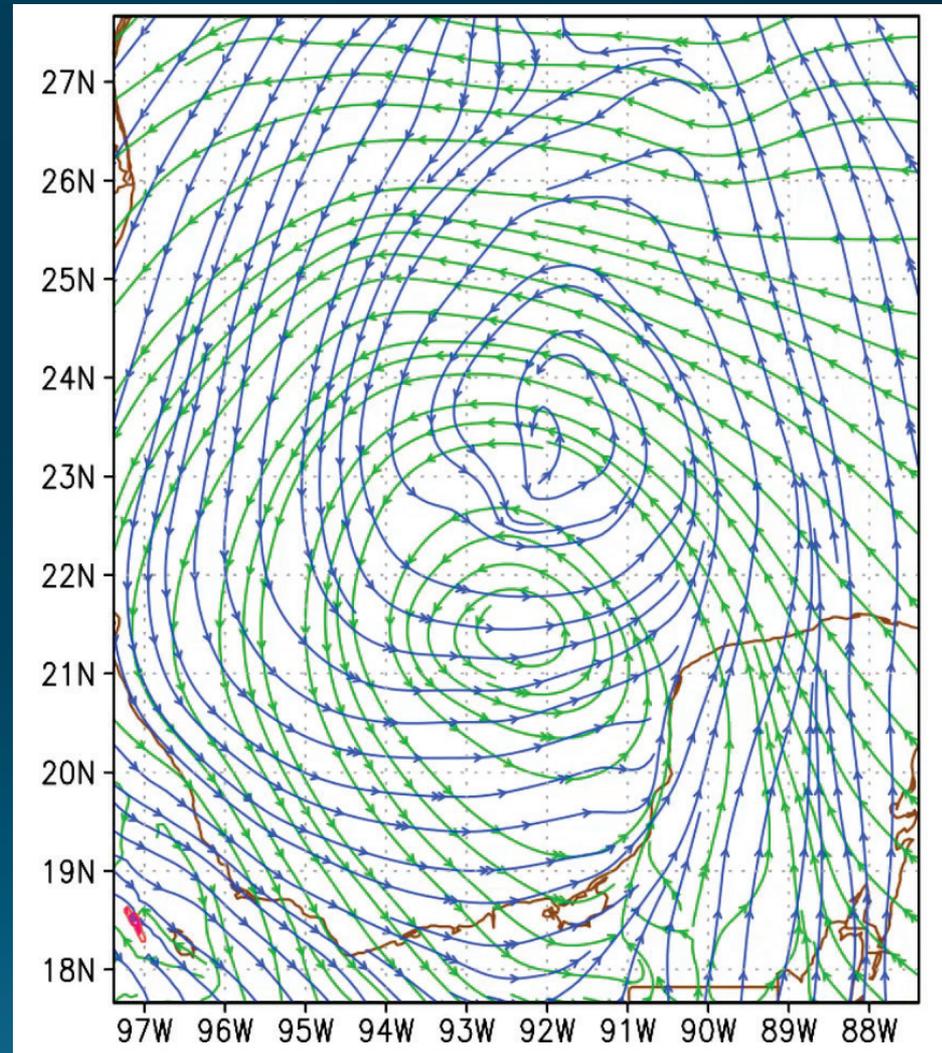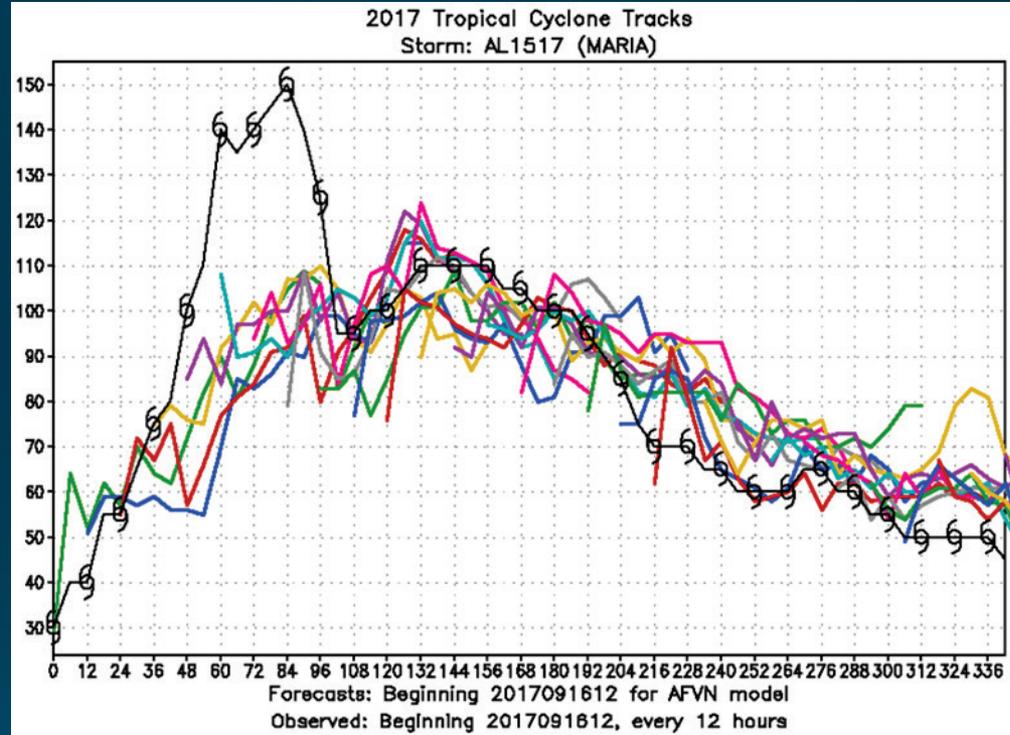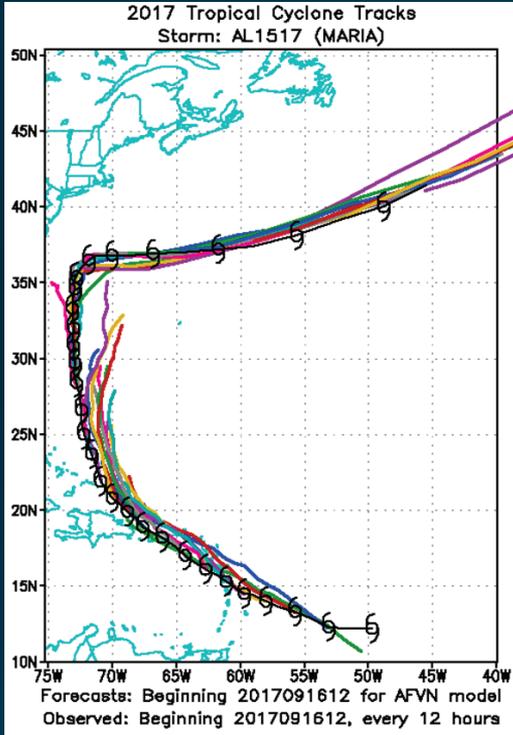
-Tracks generally consistent with observed
-Right bias initially
-Intensity forecasts were more problematic
-Missed RI for the most part
-Initialization near peak also difficult

Hurricane Maria

12-hr
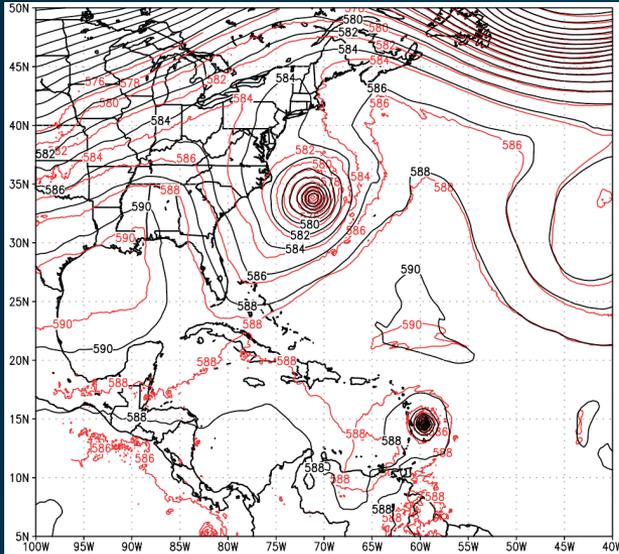
24-hr
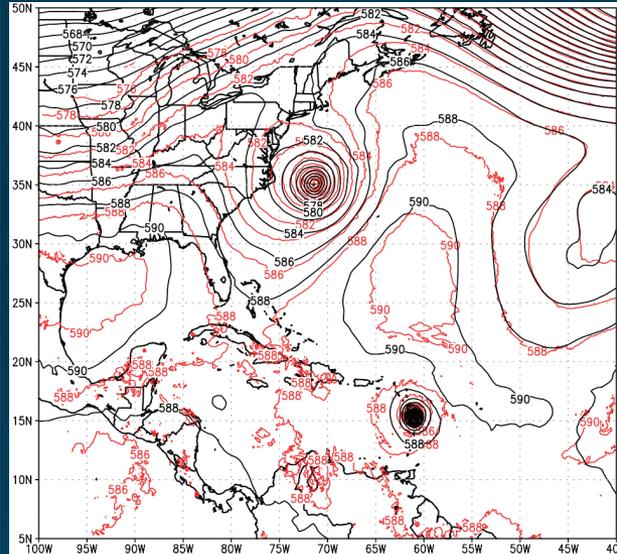
48-hr
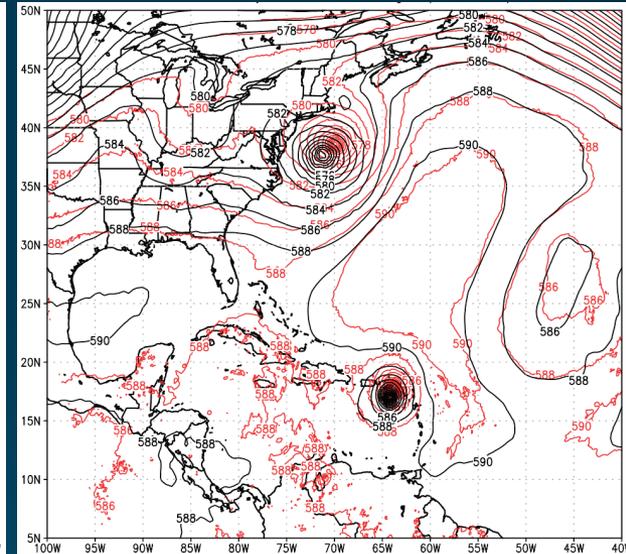

-Red is forecast z500, black is analysis

-Ridge too weak even at 12, 24 hour forecasts

-Likely explanation for right bias (seen in other GFS-based models too)

Hurricane Maria

2017 Tropical Cyclone Tracks
Storm: AL1517 (MARIA)

BT
fvGFS Original
fvGFS Coupled
HWRF

Forecasts: Beginning 2017092312
Observed: Beginning 2017092312, every 12 hours

fvGFS Initialized 2017092312
96-Hour Forecast SST − Initial SST (C)

AVHRR SST 20170927−20170923 (C)
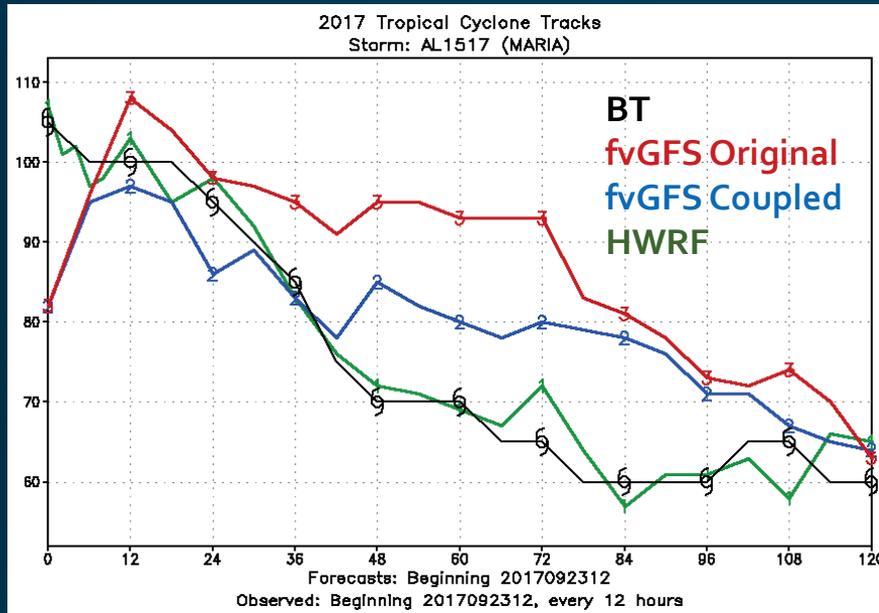
-One Maria case was tested with a simple 1-d ocean model
-Original run did not decay quickly enough
-With 1-d ocean model, improved by ~10 kts (still slightly high)
-Cooling reasonable as well (width imperfect)
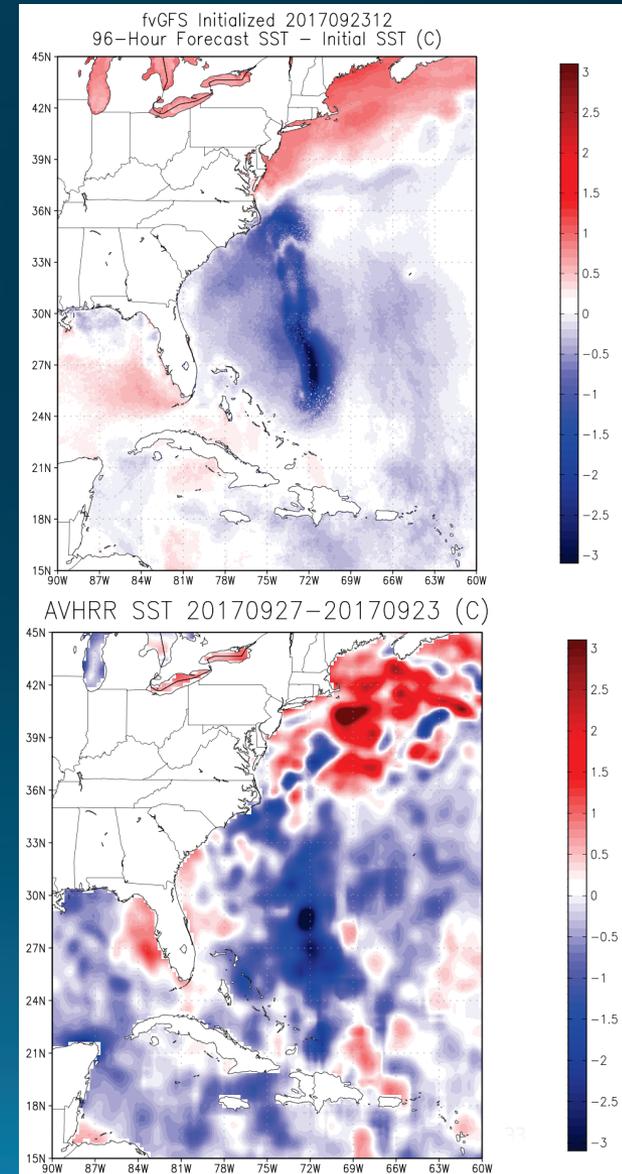
Conclusions

- Nested fvGFS has similar or better track skill than GFS

- Large intensity improvement over global fvGFS

- Some issues with forecast/init of extreme cases, although structure evolution leading to RI predicted in Harvey

- High bias at longer leads

- Ocean coupling needed (simple 1-d model shows promise, in development)

- Better init/DA needed for track bias/vortex initialization