Evaluation of 13km Global fvGFS on Hurricane Prediction

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HFIP Telecon
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 1/4 degree grid to diagnose intensity! ECMWF intensity errors and bias significantly improved using high resolution output grid.
Comparable track errors between fsGFS and the GFS.
3-4% reduced track errors 1-4 days
ECMWF track errors significantly lower than GFS based guidance.

Days 6-7 ECMWF track errors 18-20% lower than GFS or fvGFS.
Average Track Errors (NHC Basins)

2015, 2016, 2017 ATLANTIC SEASONS

- NWS GLOBAL GFS
- HWRF
- 13 km fvGFS
- ECMWF

Mean Track Error (nm)

2015, 2016, 2017 EPAC SEASONS

- NWS GLOBAL GFS
- HWRF
- 13 km fvGFS
- ECMWF

Mean Track Error (nm)

#CASES:

Atlantic:
- 2015: 395
- 2016: 316
- 2017: 246
- 2018: 198
- 2019: 160

EPAC:
- 2015: 5333
- 2016: 426
- 2017: 334
- 2018: 259
- 2019: 192

Forecast Hour
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)

2015, 2016, 2017 ATLANTIC SEASONS

2015, 2016, 2017 EPAC SEASONS

INTENSITY ERROR

INTENSITY BIAS
fvGFS intensity errors considerably less than GFS

Comparable intensity errors between fvGFS and HWRF for Global data set.
Average Intensity Errors (NHC Basins)

2015, 2016, 2017 ATLANTIC SEASONS

2015, 2016, 2017 EPAC SEASONS

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)

2015, 2016, 2017 WPAC SEASONS

Mean Intensity Error (knots)
Forecast Hour

- NWS GLOBAL GFS
- HWRF
- 13km fvGFS

#CASES:
700 561 435 332 257

2015, 2016, 2017 SOUTH HEM & INDIAN OCEAN SEASONS

Mean Intensity Error (knots)
Forecast Hour

- NWS GLOBAL GFS
- HWRF
- 13km fvGFS

#CASES:
243 191 137 98 67

2015-2017 WPAC SEASONS
DISTRIBUTION OF 48 HOUR INTENSITY ERRORS

FREQUENCY OF OCCURRENCES
INTENSITY INTERVAL (knots)

GFS
HWRF
13km fvGFS

2015-2017 SH & INDIAN OCEAN SEASONS
DISTRIBUTION OF 48 HOUR INTENSITY ERRORS

FREQUENCY OF OCCURRENCES
INTENSITY INTERVAL (knots)

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

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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)
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
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
Intensity Error Distribution (48 hr)

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

- More positive bias cases
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)

- 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)
- 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
Essential 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?)
RMW Error Maps (120 hr)

- 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)
Hurricane Harvey

- 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
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
Tracks generally consistent with observed
- Right bias initially
- Intensity forecasts were more problematic
- Missed RI for the most part
- Initialization near peak also difficult
- 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)
One Maria case was tested with a simple 1-d ocean model. The original run did not decay quickly enough. With a 1-d ocean model, the decay was improved by ~10 kts (still slightly high). Cooling was 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