Atmospheric dynamical core (FV3) and NOAA Next Generation Global Prediction System

Presented by

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The Next Generation Global Prediction System (NGGPS)

- The FV3 development started at NASA in early 90s and significantly improved and enhanced at GFDL.
- NOAA in 2016 selected (via competition) GFDL Finite-Volume Dynamical Core on the Cubed-Sphere (FV3) as the foundation for building the nation’s unified weather-climate prediction system for the next 10-20 years.
- The New FV3 (nu-FV3) will be breaking the traditional boundary between “dynamics” and “physics.”

Anomaly Correlation Coefficient (500-mb Height)

Day-0

Day-8

Kinetic Energy Spectra (200-mb)

- Day 10 KE spectra at 200 hPa
- 8Δ, 4Δ, 2Δ
- FV3
- MPAS
- -5/3 power law
Kinetic Energy Spectra are the *fingerprints* of the dynamics

- FV3 at C1152 (9km, roughly the same as “Euro” IFS) resolves the “-5/3” meso-beta (20-200 km) spectrum
- The “Euro” IFS has much lower energy in the meso-scale; but it does follow “-3” spectrum (synoptic scale) well
- The GFS has the least amount of energy in the meso-scale (3 orders of magnitude smaller than FV3 and the theoretical value)
fvGFS with $2-\Delta x$ flux-limiter

- Better than GFS
- GFS as the baseline
- Worse than GFS

74 cases initialized with GFS IC

73 cases initialized with IFS IC

(Courtesy of Linus Magnusson, ECMWF)

- fvGFS (FV3 with GFDL MP) initialized with GFS IC caught up with the IFS after day-9
- fvGFS with same IC as IFS is comparable to IFS up to day-7 and outperforms IFS after that
Performance of fvGFS in real-time forecasts of global tropical cyclones during 2017 (up to Oct 23)

- For all basins, FV3 is comparable in “track errors” to the best operational model in the world (the “Euro” IFS)
- For all basins, FV3 is comparable in “intensity errors” to the best intensity model in the world (HWRF)
Comparisons of track errors with operational global models

**Harvey**

**Hurricane Harvey**

- **Number of cases:** (17, 16, 14, 12, 10, 9, 9)

**NWS Global GFS**

- **GFDL Global FV3**

**ECMWF**

- **UKMET**

**IFS**

- **FV3**

**Irma**

**Hurricane Irma**

- **Number of cases:** (23, 23, 23, 22, 20, 18, 16)

**NWS Global GFS**

- **GFDL Global FV3**

**ECMWF**

- **UKMET**

**IFS**

- **FV3**

**FV3 is the best for Harvey**

**IFS is THE BEST for Irma**
Hurricane Harvey: flooding produced the most damage

Precipitation Verifications in Inches

INIT: 2017082412

OBSERVED 72h PRECIPITATION TOTALS

13 km FV3

3 km FV3

Geophysical Fluid Dynamics Laboratory Fall Science Symposium
November 2, 2017
Hurricane Irma: 3-km fvGFS vs. Radar

The Next Generation Hurricane Prediction System – a global model with regional resolution

Observed radar image (Brian McNoldy)

Nested FV3 forecast from 0906 (Andrew.Hazelton@GFDL)
The non-hydrostatic FV3-based HiRAM provided improvements over the hydrostatic (HY) HiRAM (Chen & Lin 2011).
Seasonal hurricane predictions with GFDL HiRAM

Impact of MJO on Gulf of Mexico tropical cyclones

(Kun et al., submitted)

Observation

HiRAM

Convectively enhanced MJO Phase

Blue - Tropical Storms
Red - Hurricanes

Convectively suppressed MJO Phase
Long-range prediction of Irma with GFDL HiRAM: 8 Day Lead

Physically based ensemble by time-lag and perturbed physics (Gao & Chen)
The next generation FV3 for long-range predictions: challenge and path forward

The Challenge:

- Building a GFDL global-regional prediction system with resolution high enough to resolve hurricanes & thunderstorms (via 2-way nest, next talk) and efficient enough for ensemble seasonal predictions

Path forward: the next generation “new” FV3

- Embedding Sub-Grid Orography (SGO) processes and cloud micro-physics (MP) within the FV3 – the next evolution of the “dynamical core”
  - Precise FV integration of SGO “mountain blocking” and SGO-forced “3D gravity waves” (via bottom BC in the non-hydrostatic solver of the nu-FV3)
  - Explicit consideration of SGO within the cloud MP (e.g., precip from subgrid mountain lifting)
Performance of fvGFS in retrospective forecasts of all tropical cyclones during 2015-2016

- Track errors are slightly improved over operational GFS; IFS is THE best for track prediction
- Intensity skill is as good as the best intensity model in the world (HWRF); IFS is worst in intensity

(analysed by Morris Bender)
An alternative approach to ultra-high resolution (convection permitting over CONUS)

CONUS precipitation (2015–2016, clock-wise, from upper left)

- Observation
- 13-km operational GFS
- 13-km fvGFS
- 4-40 km variable-resolution fvGFS