FV3 LAM Testing

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Content contributions from EMC, NSSL, SPC and WPC

NOAA/GLOBAL SYSTEMS LABORATORY
NOAA Model Operational Implementation Timeline to FY24

Unified Forecast System (UFS) Applications

- **Global Systems**
  - ~10-13 km grid spacings

- **Regional Systems**
  - ~1-3 km grid spacings

**Rapid Refresh Forecast System (RRFS)**
- Consolidation of regional models NAM/RAP/HRRR/HREF
- Carry forward data assimilation and physics research and development
RRFS Domain Development

Larger 3-km domain of coverage
- More observation-sparse oceanic regions
- More reliance upon satellite observations
Experimental Real-Time Integration/Output:
CONUS: 3-km, 1800x1060 (approx), 65 levels, 20 mb top (1,908,000 grid cells)
Alaska: 3-km, 1440x1080 (approx), 65 levels, 20 mb top (1,555,200 grid cells)
NA: 13-km, 953x834 (approx), 65 levels, 15 mb top (794,802 grid cells)

Operational Candidate:
North America (NA): 3-km, 3000x3000 (approx), 65 levels (minimum), 2 mb top
Approximately 9,172,000 grid cells compared to 3,538,944 grid cells in GFS (2.5X more)

RRFS Design Options:
(1) 13-km (ish) GFS and 3-km RRFS NA domains
   • GFS would supply lateral boundary and partial cycled initial conditions directly to RRFS
   • Eliminates the complexity and resources of a three-tiered model system (global, meso regional, CAM)
   • Requires more accurate meso environment from GFS through data assimilation and physics improvements
   • Scale-separation with data assimilation may still be needed along with “cleaner” LBC perturbation method

(2) 13-km (ish) GFS and 13-km and 3-km RRFS NA domains
   • 12-km RRFS would supply lateral boundary and partial cycled initial conditions directly to RRFS
   • Retains the complexity and resources of a three-tiered model system (global, meso regional, CAM)
   • Provides intervening layer for meso environment limiting the impact of GFS inputs
Two-way coupled deterministic and ensemble forecast system
Deterministic analysis benefits from ensemble “flow-dependent” covariance information
Ensemble benefits from hybrid analysis through recentering of ensemble mean
CAM Physics Development: Estimated Scales of Impact

- Local PBL mixing: mixing length revision, z-less
- Non-local PBL: mass-flux component
- PBL: 1D→3D turbulence scheme
- Drag: GWD and form drag
- Surface Layer: 3D stresses
- Wind Farm: momentum drag
- Numerics: Hybrid Vertical Coordinate
- Numerics: IBM
- Microphysics: subgrid clouds

△x=kilometers

RAP
HRRR
HRRR-nest
Subgrid-Scale (SGS) Clouds

Key Idea: thermodynamic variability within a grid volume may produce small areas of saturation (clouds)

Variability is subgrid (unresolved): must be parameterized

Key Changes for RAPv5 / HRRRv4:

- Mixing ratio ($q_{cldwat}$ and $q_{cldice}$) of SGS clouds:
  - Removed constraints on $q_x$ for stratiform SGS
  - Increased coverage of convective SGS via MYNN mass-flux approach

- Cloud fraction:
  - Stratiform: slightly reduced, except in high grid-scale RH

- Effective radii ($r_e$) of SGS clouds:
  - Water: use Turner et al. (2007)
  - Ice: use Mishra et al. (2014)
From binary to continuous cloud fraction – next DA step

4-h HRRR Forecast
Init: 1200 UTC 3 Oct 2019
Valid: 1600 UTC 3 Oct 2019

Old method – smoothed explicit (qc/qi>0) cloud
New method – quasi-progn cloud fraction – MYNN PBL

HRRR cloud-ellite definitions:
low: below 642 hPa (~12 kft MSL)

GOES Visible
Comparison of SW-up at top of atmosphere

18 UTC 06 June 2019

Initialized 12 UTC 05 June
Fcast hr 30:
3km HRRR model – 6h forecast
Downward shortwave radiation bias vs. NOAA SURFRAD radiation network. (daytime 15z-21z)

Improved short wave radiation forecasts

Experimental HRRR worse / better

8/29/18 subgrid-cloud change

HRRRv4 with subgrid cloud changes

Bias improved by 30-80 W/m²
Prototyping Grid Configurations for 12-km/3-km FV3 LAM DA

FV3 LAM (81 combined vertical levels)
FV3 LAM (81 smoothed vertical levels)

HRRR

GFS

12-km FV3 LAM Forecast Grid
12-km GSI Analysis Grid

3-km FV3 LAM Forecast Grid
3-km GSI Analysis Grid
Interfacing Data Assimilation with the FV3 LAM

Soil temperature adjustments (lower right) in FV3 LAM derived from atmospheric analysis increments (upper right) through GSI
GSL: Testing of Latent Heat Forcing in the FV3 LAM

Observed MRMS Reflectivity Interpolated to FV3 LAM Analysis Grid

Reflectivity Transformed to Convective Promotion/Suppression Map

Column Maximum Temperature Tendency in FV3 LAM Analysis Grid

1-hr Forecast Difference (With Minus Without Temperature Tendency Specifications)

Composite Reflectivity (dBz)

Unmodified Suppress Promote

Composite Reflectivity Difference (dBz)

Temperature Tendency (K/s)

00z 23 June 2020 Test Case
EMC: Ongoing Radiance DA Development

- **Hourly** assimilation of radiances
  - Same data as GFS
  - Using radiance data through Regional ATOVS Retransmission Service (RARS) to reduce the data latency
  - Bias corrections for all satellite instruments are estimated within the regional system

GOES-16 O-Bs and O-As *with bias correction*

*Material courtesy of X. Zhang*
Advancing ensemble methods, including (hybrid) EnVar
Evaluating combining regional + global members in the ensemble B

- **3DEnVar:**
  - Global Ens
  - 3 km Reg Ens
  - Glob+Reg

- **Single T ob:**
  - 4K innovation
  - 1K ob error
  - 700 hPa

*Material courtesy of T. Lei*

**F48 hr**

**StaticGSI:** 3DVar
**HybRegEns:** 20, 3-km members
**HybMixEns:** 20, 3-km members + 80 global members

**Material courtesy of T. Lei**
Verification against ADPUPA (upper level obs) and surface observation with METplus

The benefit of HybMixEns over HybRegEns through 12 hours for temperature; No improvement found for wind forecast (at this time);
### FV3 LAM Testing in SPC/NSSL HWT SFE

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<th>LBCs</th>
<th>Micro-physics</th>
<th>PBL</th>
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EMC and NSSL: Real-Time Demonstration of FV3 LAM in SPC/NSSL Hazardous Weather Testbed

FV3 LAM 22hr Forecasts of Composite Reflectivity from 00z 27 May 2020
Valid 22z 27 May 2020 (obs in right columns)

EMC and NSSL demonstrating FV3 LAM forecast sensitivity to differences in physics and use of data assimilation

GSL demonstrating FV3 LAM forecast sensitivity to differences in initial/boundary conditions and use of different horizontal advection options
Regional FV3 Testing in SPC/NSSL HWT SFE

Graphics courtesy of NSSL/SPC

23 hr reflectivity forecasts
Valid 23z 05 May 2020

“Hord 5” dynamics suite options seem to produce improved storm-structure, but results very preliminary and sample size is small

Initial conditions appear to have the largest influence
Regional FV3 Testing in SPC/NSSL HWT SFE

May 2020 CONUS RAOB Verification
Temperature RMSE

12 hr forecasts

36 hr forecasts

HRRRv3
HRRRv4
GFS IC (hord 5)
GFS IC (hord 6)
HRRR IC (hord 5)
HRRR IC (hord 6)
Regional FV3 Testing in SPC/NSSL HWT SFE

May 2020 CONUS RAOB Verification
Wind RMSE

12 hr forecasts

36 hr forecasts

HRRRv3
HRRRv4
GFS IC (hord 5)
GFS IC (hord 6)
HRRR IC (hord 5)
HRRR IC (hord 6)
Regional FV3 Testing in SPC/NSSL HWT SFE

HFIP/HAFS Testbed

May 2020 METAR RMSE
2m Temperature

May 2020 METAR RMSE
2m Dewpoint

May 2020 METAR RMSE
10m Wind

HRRRv3
HRRRv4
GFS IC (hord 5)
GFS IC (hord 6)
HRRR IC (hord 5)
HRRR IC (hord 6)
• The GSL LAMs are generally clustered together

• LAM3 and LAM4 typically have a higher CSI than LAM1 and LAM2

• LAM3 and LAM4 have similar CSI but LAM3 almost always has a bias closer to 1 than LAM4 has
FV3 LAM Testing Diagrams in WPC FFaIR 24 h QPF

Noted high QPF bias

High reflectivity bias at higher thresholds (not shown) also observed

Related to large/deep UVVs in 3-km FV3 LAM?

Figures courtesy of NCEP/WPC
Comparison of HRRRv4 and RRFS (HRRR init)

HRRRx (v4) +5h forecast
Valid 17z
10 Aug. 2020

RRFS (HRRR-init) +5h forecast
Valid 17z
10 Aug. 2020

HFIP/HAFS  RRFS

19 Nov 2020  24
Comparison of HRRRv4 and RRFS (HRRR init)

HRRRv4 (v4) +5h forecast
Valid 17z 10 Aug. 2020

RRFS (HRRR-init) +5h forecast
Valid 17z 10 Aug. 2020
GSL: Development and Testing of 3-km FV3 LAM Ensemble

9-member 18-hr forecast valid 18z 10 Aug 2020 from initial condition perturbations (GDAS)
9-member 12-hr forecast valid 18z 10 Aug 2020 from stochastically perturbed physics tendencies (SPPT)
EMC: Technical documentation for FV3 LAM

EMC: Development of post-processing tools

- Outlines of the technical document
- FV3-LAM users are classified into three groups:
  - Beginner level: runs existing FV3-LAM cases without any other assistance.
  - Intermediate level: creates a new regional case and run it on HPCs.
  - Expert level: modifies the source code for advanced applications.

- The workflow section currently describes EMC workflows, but it will be updated once the EMC and community workflows are merged.
- The workflow part for DA, and code development section will be written soon.
- The post-processing section mainly describes the python scripts to plot input files of FV3-LAM now. Python scripts for output files are under development.
- Appendix will describe how to use GitHub and transfer data between HPCs.
Ensuring reproducibility (1): Diagnostics

- Some diagnostic prints are done in a way that produces different results depending on the MPI layout
- Not a model issue - but may give the false appearance of one to a developer
- Fixed by using more appropriate MPI routines

Ensuring reproducibility (2): Dynamics and LBCs

- Look into model dynamics
- Examination of MPI tasks and tiles + interaction with LBCs
- Issue discovered at corner grid points of a few MPI tiles
- Updated code to correct missing boundary halo exchange → fixed!

Ensuring reproducibility (3): Physics

- Results are now bit reproducible when using GFS v15 physics suite in LAM!
- However - when testing with RRFS beta suite we encounter non-reproducible results with varying task counts
- Isolated to interface between model physics and dynamics
- Once complete, and assuming there are no further issues, this will translate into: Fixed code in UFS model repo, new regression suite for LAM, and reduced likelihood of this kind of future issue(s)
UFS Short Range Weather (SRW/CAM) Application Release

- Limited Area Model (LAM) FV3 Capability
- No Data Assimilation
- Extended Schmidt Gnomonic (ESG) Grid
- 3-km, 13-km, 25-km CONUS-type configurations
- GFS/NAM/RAP/HRRR GRIB2 Initializations
- Regional Workflow
- Physics Suite Definitions (SDFs):
  - RRFSv1alpha (RRTMG radiation, Thompson MP, MYNN PBL, GFS GWD/SL, NoahMP LSM)
  - GFSv15

<table>
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<tr>
<th>Date</th>
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<tr>
<td>09 Oct 2020</td>
<td>Code slush for preliminary pre-release testing</td>
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<tr>
<td>30 Nov 2020</td>
<td>Code freeze for final testing</td>
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<tr>
<td>Dec 2020</td>
<td>Documentation finalized</td>
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<tr>
<td>Dec/Jan 20/21</td>
<td>Target release ready</td>
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