Evaluating the Boundary Layer Environment and Convective Storm Evolution from FV3-SAR Simulations

Tomer Burg

EMC Mentor: Logan Dawson
NCEP is transitioning its modeling suite to the **Finite-Volume Cubed-Sphere (FV3)** Dynamical Core.

*Image credit: GFDL*
Unified Forecast System (UFS)

NCEP is transitioning its modeling suite to the **Finite-Volume Cubed-Sphere (FV3)** Dynamical Core

The Global Forecast System (GFS) model was upgraded from v14 to v15 on 12 June 2019, implementing the **FV3 core**
Limited Area FV3-SAR

- The current FV3-nest configuration requires the global model to run in conjunction with a convection allowing 3-km nest. **Computationally expensive!**

- EMC developed a stand alone regional (SAR) model capability for the FV3.

- The FV3-SAR is run over the continental U.S. while ingesting boundary conditions from the global GFS.
## Model Configuration

<table>
<thead>
<tr>
<th>Component</th>
<th>Details</th>
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</thead>
<tbody>
<tr>
<td>Horiz. Resolution</td>
<td>3-km</td>
</tr>
<tr>
<td>ICs</td>
<td>GFSv15</td>
</tr>
<tr>
<td>LBCs</td>
<td>GFSv15</td>
</tr>
<tr>
<td>MP Scheme</td>
<td>GFDL</td>
</tr>
<tr>
<td>PBL Scheme</td>
<td>Hybrid EDMF</td>
</tr>
<tr>
<td>Land Surface Model</td>
<td>NOAH</td>
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<tr>
<td>Radiation</td>
<td>RRTMG</td>
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<tr>
<td>Model Core</td>
<td>FV3</td>
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</tbody>
</table>
Every spring, the SPC & NSSL run a testbed to evaluate emerging technologies from research to operations.

In 2019, the EMC ran FV3-SAR simulations for evaluation alongside other operational & experimental models.

SPC = Storm Prediction Center
NSSL = National Severe Storms Laboratory

Image credit: SPC
2019 Hazardous Weather Testbed

- 2019 has been one of the most active severe weather years on record, producing many candidate cases for evaluation.
The PBL is defined as “the bottom layer of the troposphere that is in contact with the surface of the earth.”

Typically at its highest during the day as solar heating results in a growing mixed turbulent layer.

Minimized at night when a radiative inversion develops at the surface.

The FV3-SAR inherits the same PBL scheme from GFSv15 and GFSv14.
This project seeks to address the following questions:

1. How does the GFS PBL scheme affect the pre-convective environment within the FV3-SAR?

2. How does the FV3-SAR represent convective mode & evolution compared to observations?
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- How does the GFS PBL scheme affect the pre-convective environment within the FV3-SAR?

- How does the FV3-SAR represent convective mode & evolution compared to observations?
OUTLINE

Methodology

Results
- FV3-SAR Systematic Biases
- Case Studies

Conclusions
## Methodology

### CASE SELECTION

<table>
<thead>
<tr>
<th>Date Range</th>
<th>18 May 2019 - 29 May 2019</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initialization</td>
<td>0000 UTC Daily</td>
</tr>
<tr>
<td>Forecast Hours</td>
<td>Hour 12 (1200 UTC) &amp; Hour 24 (0000 UTC)</td>
</tr>
</tbody>
</table>
| Data Sources     | Model: FV3-SAR simulations  
                  | Observation: RAOB radiosondes |
| Criteria         | 3 RAOB sites within the warm sector for each initialization with verification soundings available for both hours 12 & 24  
                  | Both model & observed soundings are not convectively contaminated for both hours 12 & 24, but are downstream of convection |
## Analysis Methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
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<tr>
<td>Skew-T Soundings</td>
<td>MetPy python package (py3.7)</td>
</tr>
<tr>
<td>Severe Indices</td>
<td>SHARPpy python package (py2.7 converted to py3.7)</td>
</tr>
</tbody>
</table>
| PBL Metrics                 | • **PBL Height**: First identifiable height at which the virtual potential temperature is greater than the surface value + 0.5  
                                • **PBL Integral**: Vertical integral of dewpoint depression throughout the PBL |
In theory, practice equals theory, but in practice, practice does not equal theory...”

- Robert Fovell, SUNY Albany, many times in 2019
Python Problems

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THEORY

Python 3.7

- Run jupyterhub
- Parse grib2 file
- Generate soundings
- Make radar maps

End
Python Problems

“In theory, practice equals theory, but in practice, practice does not equal theory…”

- Robert Fovell, SUNY Albany, many times in 2019

**THEORY**

- Python 3.7
  - Run jupyterhub
  - Parse grib2 file
  - Generate soundings
  - Make radar maps
  - End

**PRACTICE**

- Python 3.7
  - Parse grib2 file
  - Make radar maps
  - Generate soundings with edited SHARPpy

- Python 2.7
  - Run jupyterhub
  - Make radar maps

- Local desktop
  - Run jupyterhub

- NCL
  - Parse grib2 file
  - End?
OUTLINE

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Conclusions
1200 UTC Temperature Biases

- 1200 UTC (Hour 12)
- Surface exhibits slight warm bias
- 925-850 hPa exhibit cool bias
1200 UTC Temperature Biases

- 1200 UTC (Hour 12)
- Surface exhibits slight warm bias
- 925-850 hPa exhibit cool bias

Morning slight warm bias
1200 UTC Temperature Biases

FV3SAR vs. Observed Sounding for KSGF Forecast Hour 12

Init: 00 UTC 22 May 2019
Valid: 12 UTC 22 May 2019

MRM5 Seamless Hybrid Scan Reflectivity (dBZ) 1200 UTC 22 May 2019

Observed

Forecast

FV3SAR Hybrid Reflectivity (dBZ) Hour 12
Init: 0000 UTC 22 May 2019
Valid: 1200 UTC 22 May 2019
1200 UTC Temperature Biases

Inversion is stronger than modeled
FV3-SAR tends to depict smaller inversions than observed.

The FV3-SAR is often biased too cold in the top of the inversion layer.
• 0000 UTC (Hour 24)
• Surface exhibits cold bias
• 925-850 hPa also exhibit cold bias, but less so than surface
0000 UTC Temperature Biases

- 0000 UTC (Hour 24)
- Surface exhibits cold bias
- 925-850 hPa also exhibit cold bias, but less so than surface

Evening cool bias
0000 UTC Temperature Biases

FV3SAR vs. Observed Sounding for KSGF
Forecast Hour 24

Init: 00 UTC 22 May 2019
Valid: 00 UTC 23 May 2019

MRMS Seamless Hybrid Scan Reflectivity (dBZ)

Observed

Forecast
0000 UTC Temperature Biases

FV3SAR vs. Observed Sounding for KSGF Forecast Hour 24

Init: 00 UTC 22 May 2019
Valid: 00 UTC 23 May 2019

PBL is less moist than modeled
0000 UTC PBL Systematic Biases

- #1: FV3SAR modeled PBL integral, and sometimes height, is too small compared to observation
• #2: FV3SAR appears to decouple the boundary layer too quickly in the evening
0000 UTC PBL Systematic Biases

- Both PBL height and PBL integral are biased too low for 0000 UTC soundings
- Associated with surface cool bias decreasing with height
Convective Available Potential Energy (CAPE)

“The maximum buoyancy of an ... air parcel, related to the potential updraft strength of thunderstorms.”

American Meteorological Society glossary

- Larger CAPE results from:
  - Large magnitude of positive buoyancy
  - Deep layer of positive buoyancy

- Used as a metric to assess instability in pre-convective environments

- Higher CAPE, when combined with vertical wind shear & ascent, contributes to severe thunderstorms
Convective Available Potential Energy (CAPE)

SBCAPE
Surface-Based CAPE
CAPE for parcel lifted from the surface
Convective Available Potential Energy (CAPE)

**MLCAPE**

Mixed Layer CAPE

CAPE for a parcel representative of the average of lowest 100mb
- Surface-based CAPE is biased too low as a result of the evening cool bias
- Mixed layer CAPE significantly improves this bias by removing the impact of the surface decoupling
- MLCAPE is still biased slightly low due to the background low tropospheric cool bias
FV3-SAR Temperature Systematic Biases

FV3SAR Hour 12 Temperature Bias
Valid 1200 UTC

FV3SAR Hour 24 Temperature Bias
Valid 0000 UTC
FV3-SAR Temperature Systematic Biases

Morning slight warm bias

Evening cool bias
FV3-SAR Temperature Systematic Biases

Systematic cool bias just aloft
Case Study #1

- 27 May 2019 Dayton, OH Tornadoes
- Analysis Location: Wilmington, OH (KILN)
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Case Study #1

- FV3SAR hour 12 underestimated the inversion magnitude
- FV3SAR hour 24 depicted an inversion not observed
Case Study #1

• CAPE bias is substantially reduced when using MLCAPE vs. SBCAPE

Surface Based CAPE:

- **FV3-SAR**: 260 J/kg
- **Observed**: 1799 J/kg

Mixed Layer CAPE:

- **FV3-SAR**: 632 J/kg
- **Observed**: 601 J/kg
Case Study #1 Conclusions

- Surface temperature bias & SBCAPE biases don’t appear to have a major detrimental impact on convective mode & evolution

- A possible impact of lower PBL height & more PBL moisture could be more widespread convective initiation
Case Study #2

- 20 May 2019 Oklahoma & Texas Tornadoes
- Analysis Location: Norman, OK (KOUN)

Hour 12 | 1200 UTC 20 May 2019
Case Study #2

- 20 May 2019 Oklahoma & Texas Tornadoes
- Analysis Location: Norman, OK (KOUN)
Case Study #2

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- 20 May 2019 Oklahoma & Texas Tornadoes
- Analysis Location: Norman, OK (KOUN)
Case Study #2 Conclusions

- Too much convection was already ongoing at forecast hour 12 compared to observations.
- Spurious modeled convection resulted in faster upscale growth & propagation than observed, shifting the boundary for subsequent supercell initiation in Texas too far east.
- Discrete cells developed east of the dryline in Texas in the FV3-SAR, but rapidly merged with the modeled QLCS over Oklahoma rather than remaining discrete.
Conclusions

How does the GFS PBL scheme affect the pre-convective environment within the FV3-SAR?

- FV3-SAR exhibits a **cold bias aloft** for hours 12 & 24
- FV3-SAR exhibits a surface **slight warm bias** at hour 12 & **cold bias** at hour 24
- PBL height and PBL integral are **biased low** compared to observations
- Surface cool bias results in SBCAPE low bias; calculating MLCAPE mostly **eliminates this bias**
Conclusions

How does the FV3-SAR represent *convective mode & evolution* compared to observations?

- FV3-SAR has a more “blobby” reflectivity structure compared to observations
- In a majority of cases the FV3-SAR exhibited more convection than observed, in some cases spurious
Acknowledgements

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- EMC
- Fellow interns
- NCEP
Extra Slides
FV3-SAR Systematic Biases

- FV3-SAR has a well documented cold bias
FV3-SAR Systematic Biases

- FV3-SAR has a well documented cold bias

![CONUS 850 mb Temperature Bias and BCRMSE: 15 March – 16 July 2019](image)

*Image credit: Logan Dawson*
NCEP is transitioning its modeling suite to the **Finite-Volume Cubed-Sphere (FV3)** Dynamical Core.

The FV3 is a global model with the capability of inserting a nested higher resolution grid.