This research is partially in response to requirements and funding by the Federal Aviation Administration (FAA). The views expressed are those of the authors and do not necessarily represent the official policy or position of the FAA.
**Hourly Updated NOAA NWP Models**

**13km Rapid Refresh**

**13km RUC**

**3km HRRR**

**Rapid Refresh (RR):**
WRF-ARW; GSI + RUC-based enhancements; new 18-h fcst every hour

**High-Resolution Rapid Refresh (HRRR):**
WRF-ARW; experimental 3-km nest inside RR; new 15-h fcst every hour
Forecasting mesoscale convective system size, intensity, and longevity is a significant challenge for aviation, and a significant challenge for initializing NWP models.

Radar Reflectivity

- Detailed information about *hydrometeors and lack thereof*, useful for initializing convective storms / systems in models
- Difficulty using these observations directly
  - Biases in model hydrometeor prediction and reflectivity computation
  - Numerous observations
- Reflectivity *assimilated indirectly in RR* (upcoming slides)
RR Cycling and HRRR Initialization

RR

13 km

t₀−2 h  t₀−1 h  t₀

HRRR

3 km
RR Cycling and HRRR Initialization

RR
13 km

fcst
$t_0 - 2$ h
$t_0 - 1$ h
$t_0$

HRRR
3 km

obs
3DVar + cloud analysis
RR Cycling and HRRR Initialization

HRRR

13 km

fcst

t₀−2 h

RR

fcst

t₀−1 h

obs

DDFI

radar data

3DVar + cloud analysis

HRRR

3 km

fcst

t₀
RR Cycling and HRRR Initialization

- RR
- HRRR
- 13 km
- fcst
- DDFI
- obs
- 3DVar + cloud analysis
- interpolation
- radar data
- HRRR
- 3 km
- t₀ - 2 h
- t₀ - 1 h
- t₀
RR Cycling and HRRR Initialization

RR
13 km

HRRR
3 km

obs
3DVar + cloud analysis

interpolation

radar data

DDFI

fcst

$\tau_0 - 2$ h

$\tau_0 - 1$ h

$t_0$

15-h fcst
Diabatic Digital Filter Initialization (DDFI)

-20 min  -10 min  Init  +10 min

Backward integration, no physics

Forward integration, full physics
Apply latent heating from radar reflectivity, lightning data

Obtain initial fields with improved balance, vertical circulations associated with ongoing convection

RR model forecast

- The model microphysics temperature tendency is replaced with a reflectivity-based temperature tendency.
  - Dynamics and microphysics respond to thermodynamic forcing.
- Analysis noise is reduced by digital filtering.
HRRR Critical Success Index (CSI): dependence on strength of reflectivity-based latent heating in RR

July 2010 retrospective HRRR forecasts

40-km verification composite reflectivity 25 dBZ

RUC parent model

RR parent model

RR parent model, 1/3 heating rate

HRRR initialized with real-time RR configuration

same, except 1/3 heating rate during RR DDFI

CSI (x100, matched)

Forecast Length (Hr)
HRRR Bias:
dependence on strength of reflectivity-based latent heating in RR

July 2010 retrospective HRRR forecasts
3-km verification composite reflectivity 25 dBZ
RUC parent model
RR parent model
RR parent model, 1/3 heating rate
Reflectivity DA on 3-km (HRRR) Grid

HRRR (3-km) grid produces convective storms explicitly
Reflectivity-based temp. tendencies are applied during sub-hourly cycling (forward model integration only, no digital filtering)

reflectivity-based temperature tendency

interpolation from RR, hydrometeor specification

HRRR composite reflectivity
Experiment Comparison

(1) HRRR initialized “without 3-km radar DA”

(2) HRRR initialized “with 3-km radar DA”
(1) HRRR initialized "without 3-km radar DA"

(2) HRRR initialized "with 3-km radar DA"
Experiment Comparison

(1) HRRR initialized “without 3-km radar DA”

(2) HRRR initialized “with 3-km radar DA”
Experiment Comparison

(1) HRRR initialized "without 3-km radar DA"

<table>
<thead>
<tr>
<th>(1) HRRR initialized</th>
<th>RR 13 km</th>
<th>$t_0-2$ h</th>
<th>fcst</th>
<th>DDFI</th>
<th>obs</th>
<th>3DVar + cloud analysis</th>
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<tbody>
<tr>
<td></td>
<td>HRRR 3 km</td>
<td>$t_0-1$ h</td>
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<td></td>
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<td>$t_0$</td>
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(2) HRRR initialized "with 3-km radar DA"

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<th>(2) HRRR initialized</th>
<th>RR 13 km</th>
<th>$t_0-2$ h</th>
<th>fcst</th>
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<td>$t_0$</td>
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Interpolation
Experiment Comparison

(1) HRRR initialized "without 3-km radar DA"

HRRR 13 km

RR

t₀ − 2 h

interpolation

3DVar + cloud analysis

DDFI

obs

radar data

fcst

t₀ − 1 h

HRRR 3 km

fcst

Interpolation

(2) HRRR initialized "with 3-km radar DA"

HRRR 13 km

RR

t₀ − 2 h

interpolation

3DVar + cloud analysis

DDFI

obs

radar data

fcst

t₀ − 1 h

HRRR 3 km

fcst
Initial Temperature at Lowest Model Level

(1) HRRR initialized without 3-km radar DA

(2) HRRR initialized with 3-km radar DA

2000 UTC 11 May 2011
convection develops quickly (RR cycling, DDFI)

11 May 2011  2100 UTC

1-h fcst without 3-km radar DA

11 May 2011  2100 UTC

1-h fcst with 3-km radar DA
Composite Reflectivity
2100 UTC
11 May 2011

more accurate representation of system maturity

1-h fcst without 3-km radar DA

1-h fcst with 3-km radar DA
Composite Reflectivity
2100 UTC
11 May 2011

obs
spurious convection

1-h fcst without 3-km radar DA

1-h fcst with 3-km radar DA
Composite Reflectivity
0200 UTC
11 May 2011

12 May 2011  0200 UTC
MAX 64.78
MIN -20.00

12 May 2011  0200 UTC
MAX 63.50
MIN -20.00

more accurate forecast of convective system propagation

6-h fcst without 3-km radar DA

6-h fcst with 3-km radar DA
Composite Reflectivity
0300 UTC
11 July 2011

2-h fcst with 3-km radar DA

2-h fcst without 3-km radar DA

stronger convective system
Composite Reflectivity
0700 UTC
11 July 2011

better representation of convective system coverage and orientation

11 July 2011 0700 UTC

6-h fcst without 3-km radar DA

6-h fcst with 3-km radar DA
Composite Reflectivity
0700 UTC
11 July 2011

better indication of merging convective systems

11 July 2011 0700 UTC
6-h fcst with 3-km radar DA

11 July 2011 0700 UTC
6-h fcst without 3-km radar DA
SUMMARY

- Reflectivity data assimilation into the RR through DDFI effectively initiates convective storms in the HRRR.
  - forecast skill depends significantly on reflectivity-based heating rate
- Reflectivity data assimilation into the HRRR through sub-hourly cycling has a minor influence on convective forecasts for most convective events but a significant influence for some events.
  - convective storm evolution typically controlled by larger scales?
  - room for improvement in assimilation method?

FUTURE WORK

- Situation-dependent latent-heating profiles
  - Elevated / surface-based convection
  - New isolated storm / long-lived convective system
- Doppler-velocity data assimilation into HRRR
- Full cycling on 3-km (HRRR) grid
HRRR Critical Success Index (CSI):
with and without 3-km radar DA

limited number of cases
May and July 2011

40-km verification
composite reflectivity
35 dBZ

with 3-km radar DA
without 3-km radar DA
HRRR Bias: with and without 3-km radar DA

limited number of cases
May and July 2011

3-km verification composite reflectivity 35 dBZ

with 3-km radar DA
without 3-km radar DA