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# Radar-Data Assimilation into the Rapid Refresh (RR) and High Resolution Rapid Refresh (HRRR) Models Toward Improved Convective Guidance for Aviation


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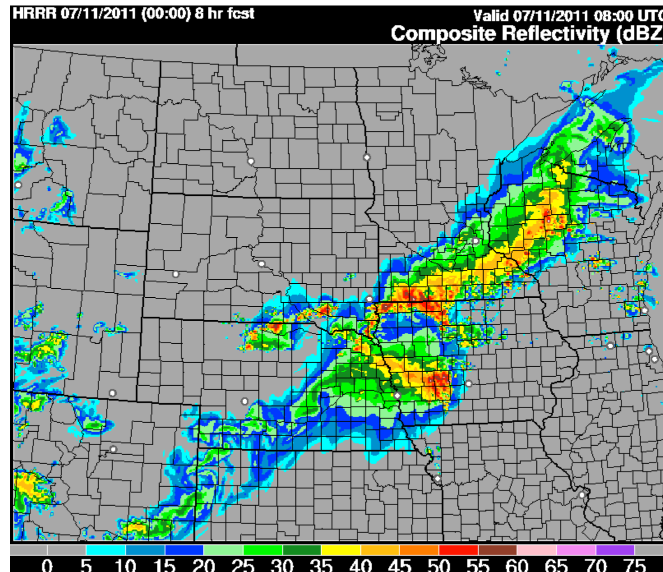


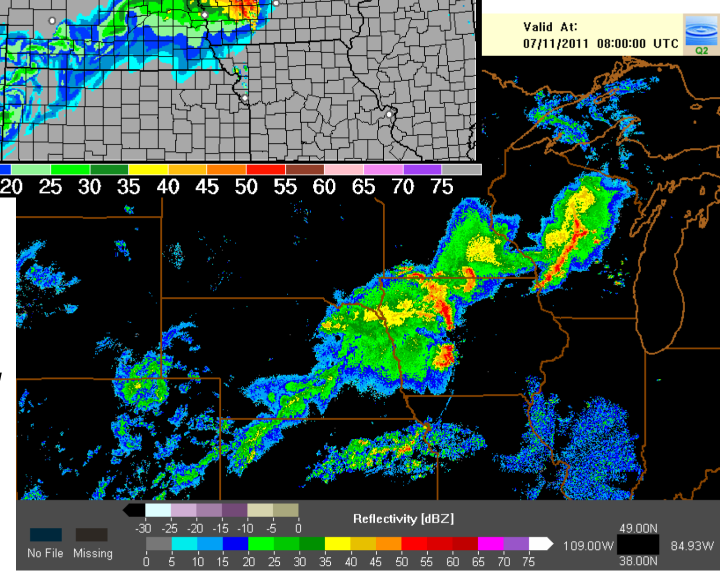



*This research is partially in response to requirements and funding by the Federal Aviation Administration (FAA). The views expressed are those of the authors and do not necessarily represent the official policy or position of the FAA.*


Earth System Research Laboratory
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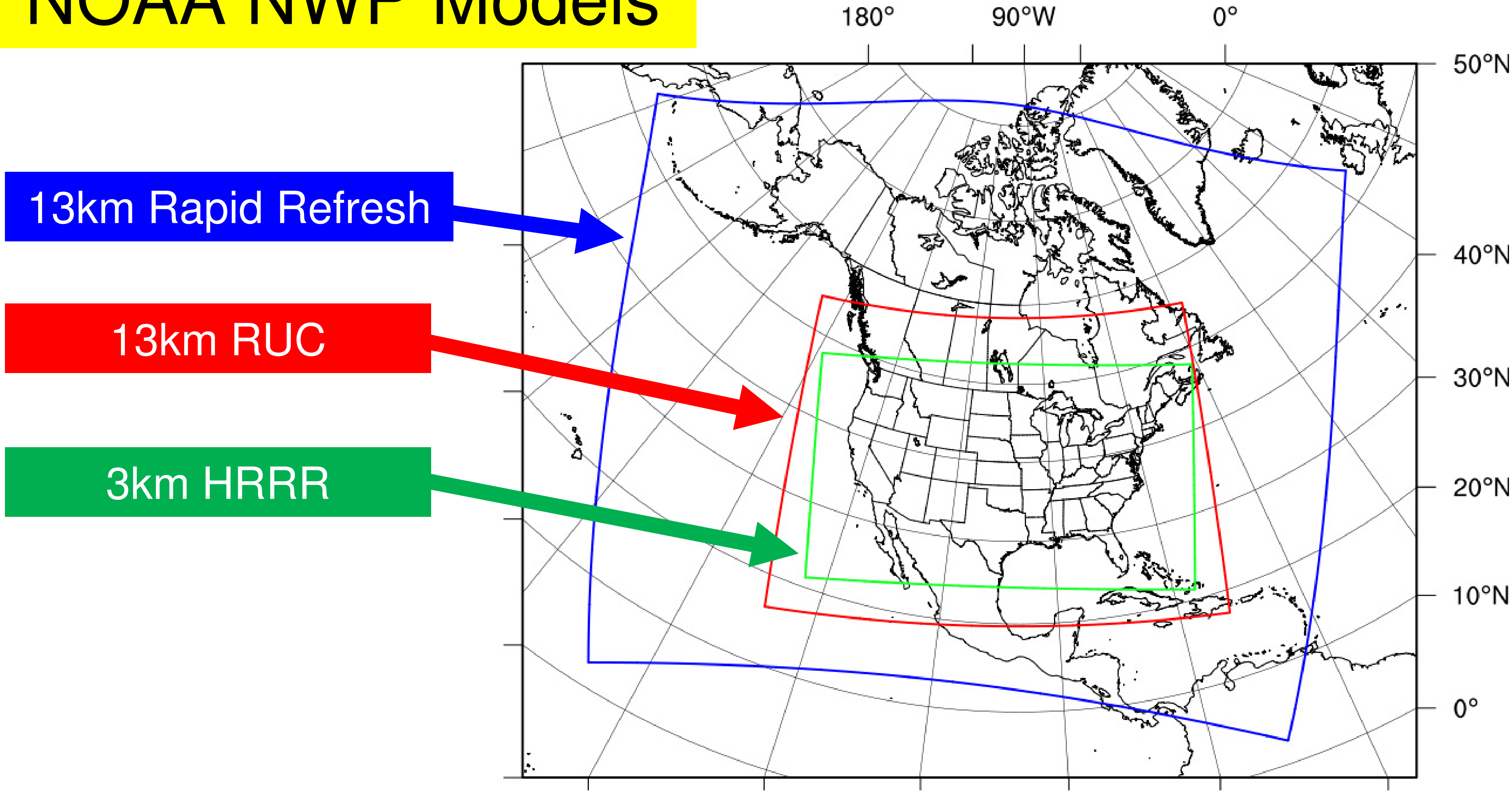
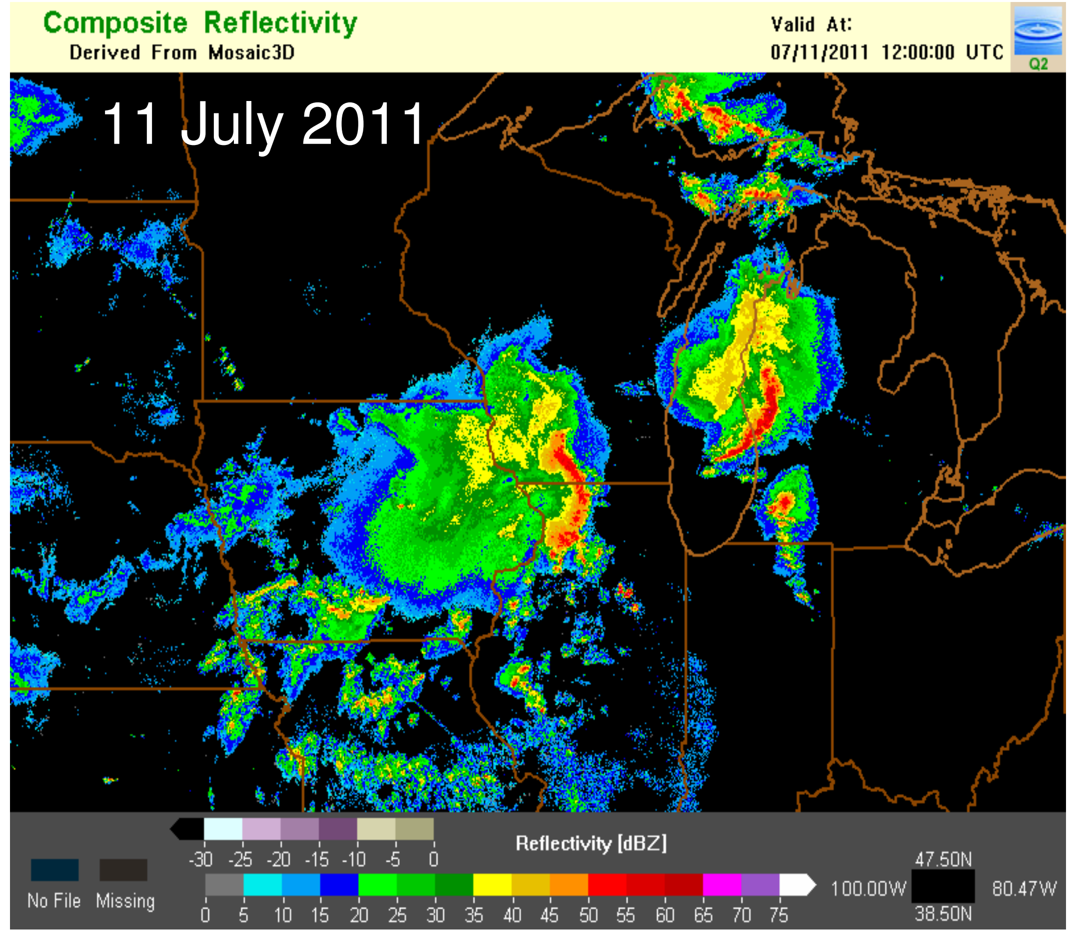
# Hourly Updated NOAA NWP Models




**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**

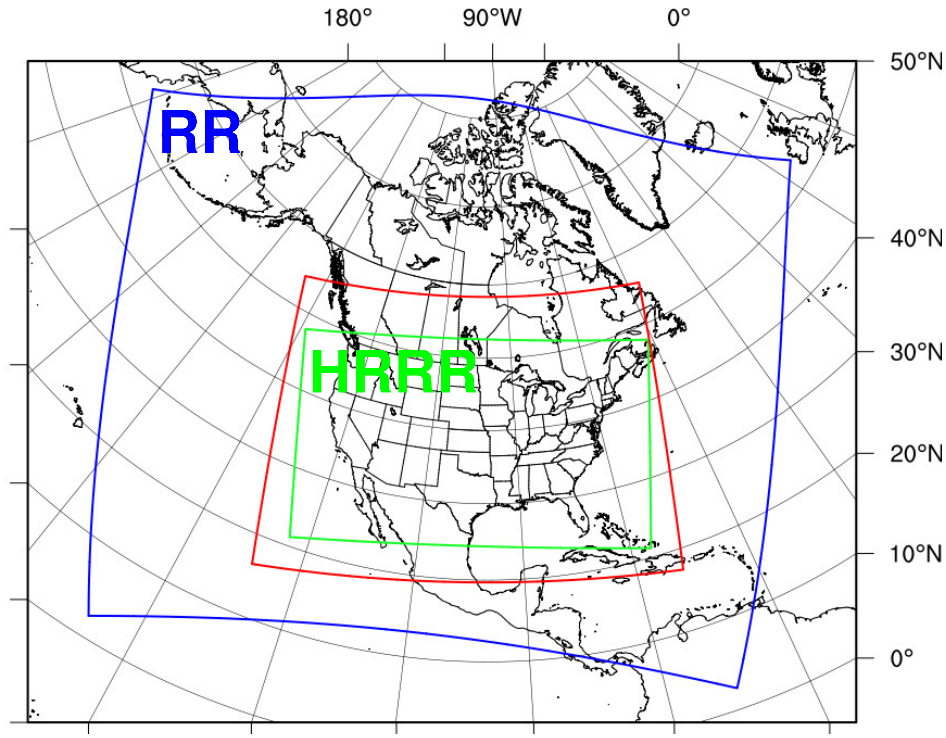
*Forecasting mesoscale convective system size, intensity, and longevity is a significant challenge for aviation, and a significant challenge for initializing NWP models.*




## 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



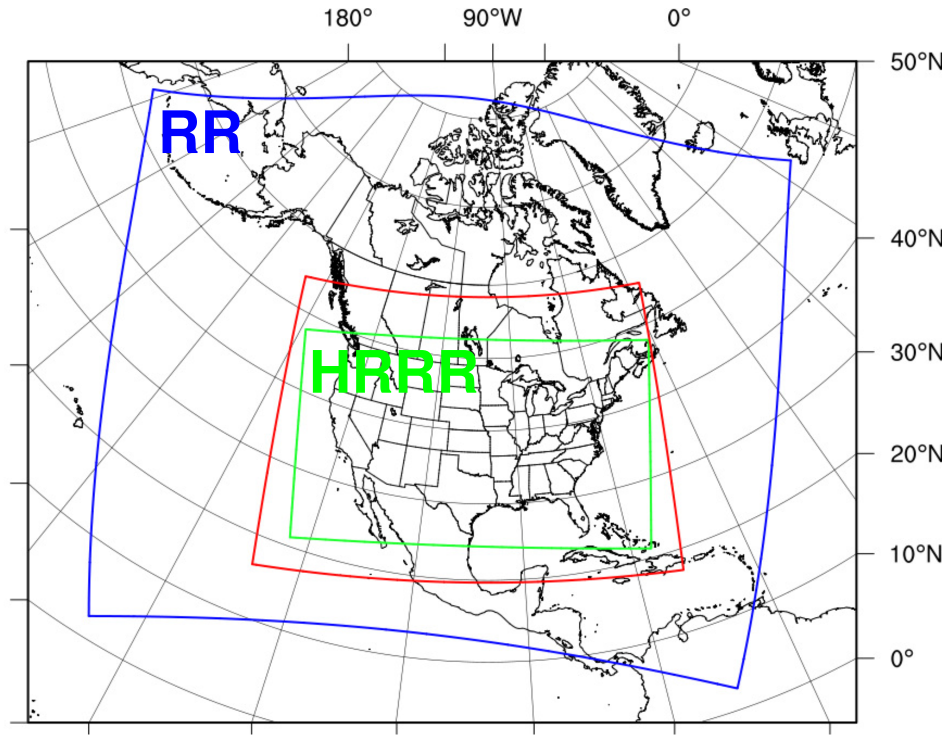

*RR*
*13 km*

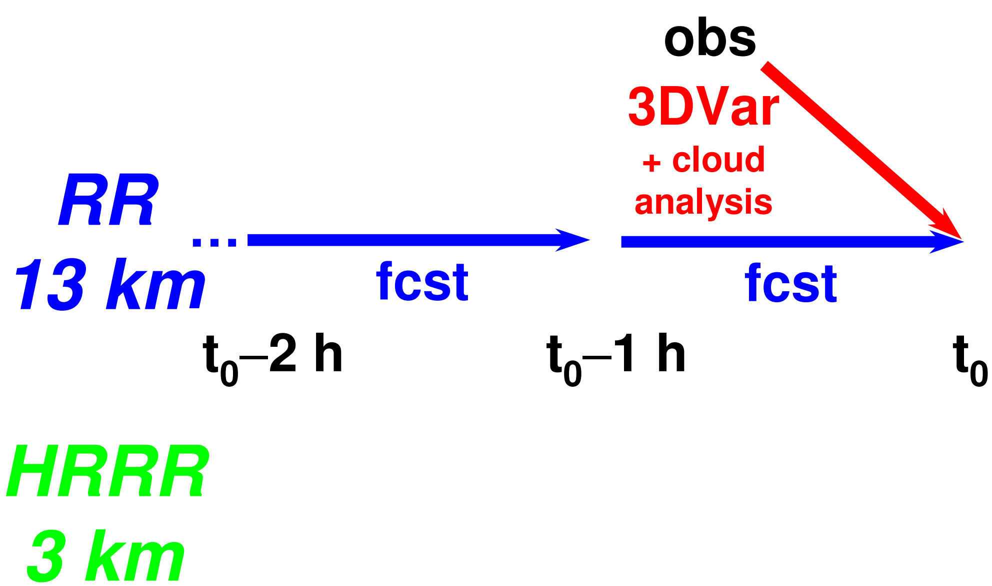
... fcst fcst

$t_0$–2 h $t_0$–1 h $t_0$

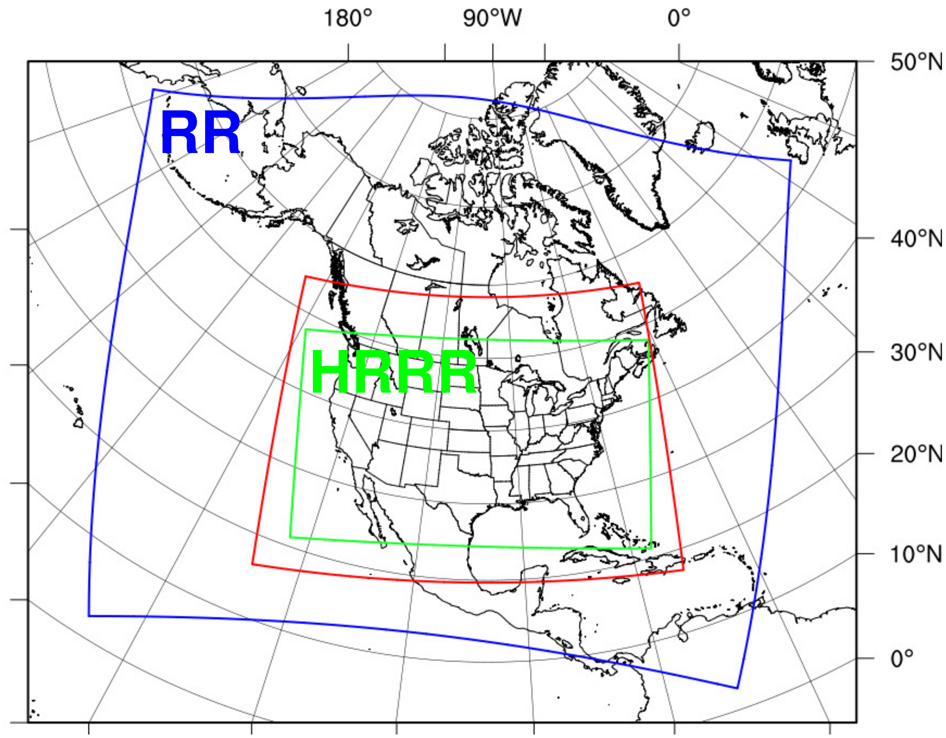
*HRRR*
*3 km*

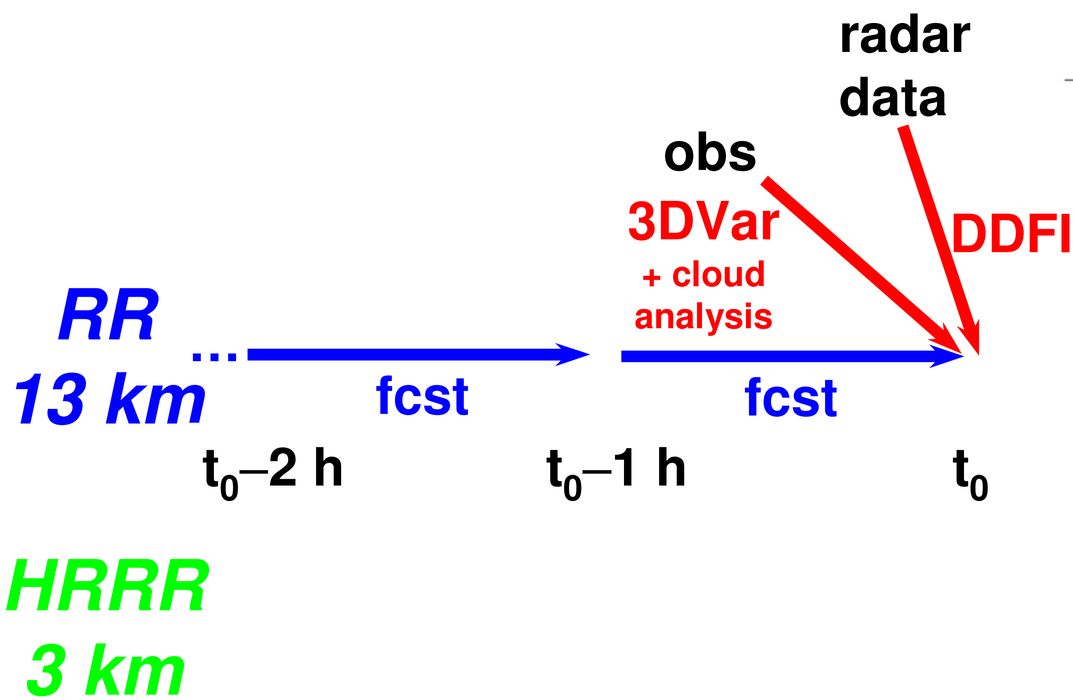
# RR Cycling and HRRR Initialization



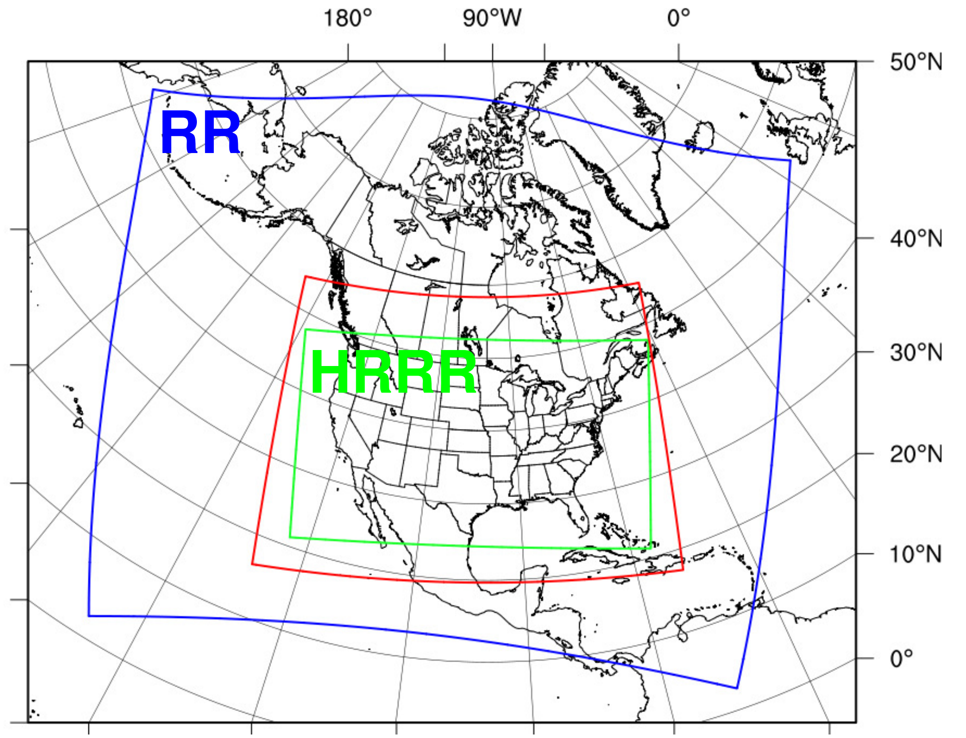



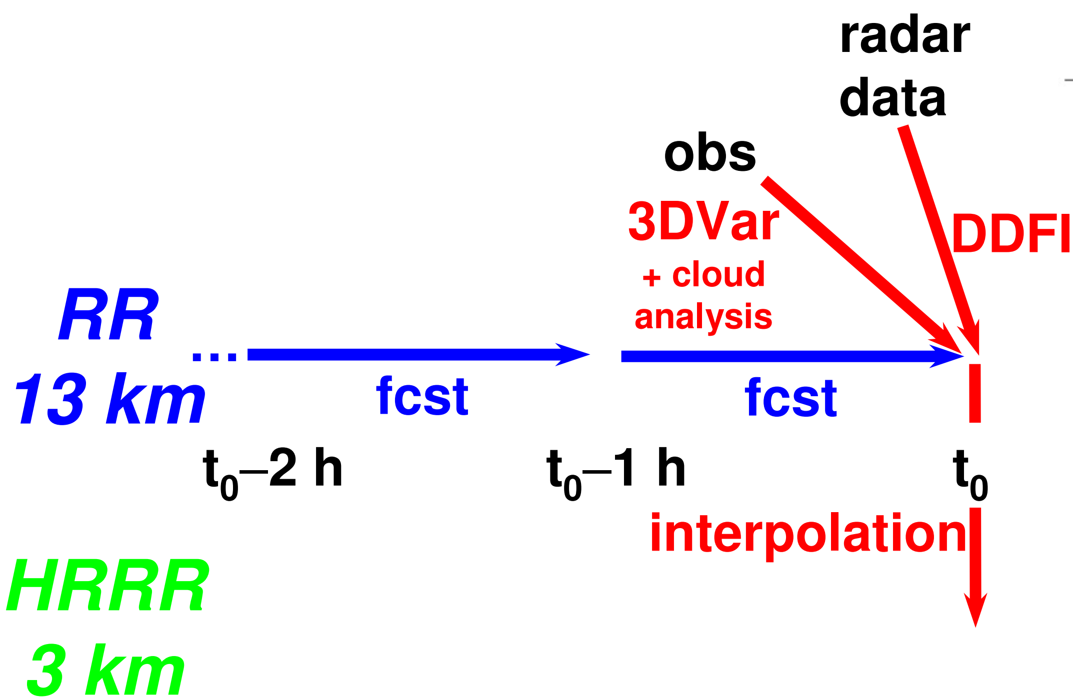
# RR Cycling and HRRR Initialization



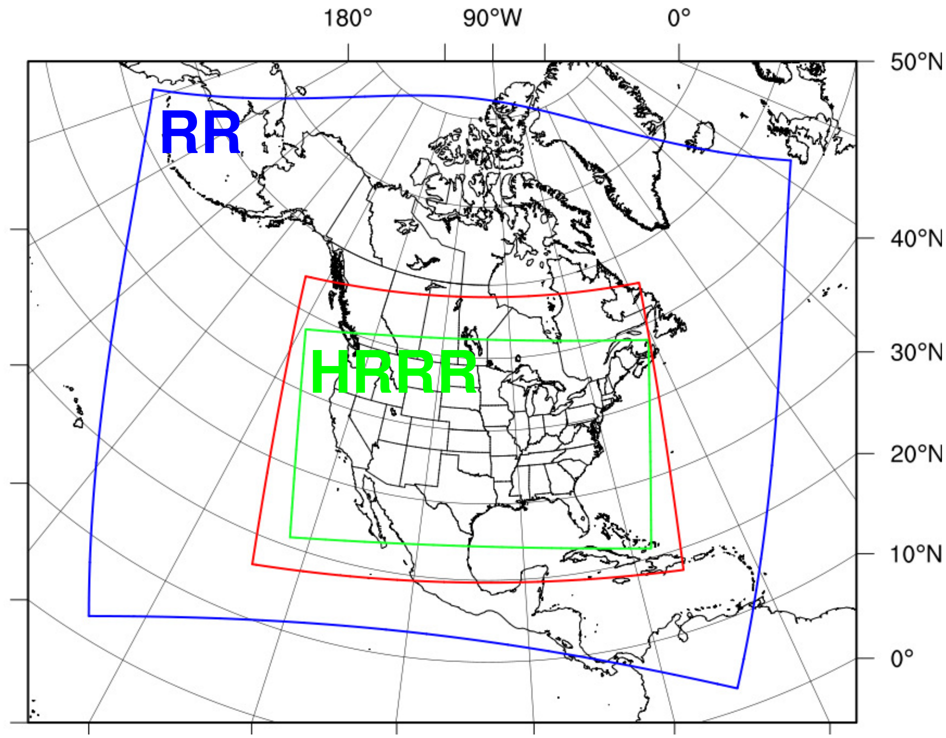



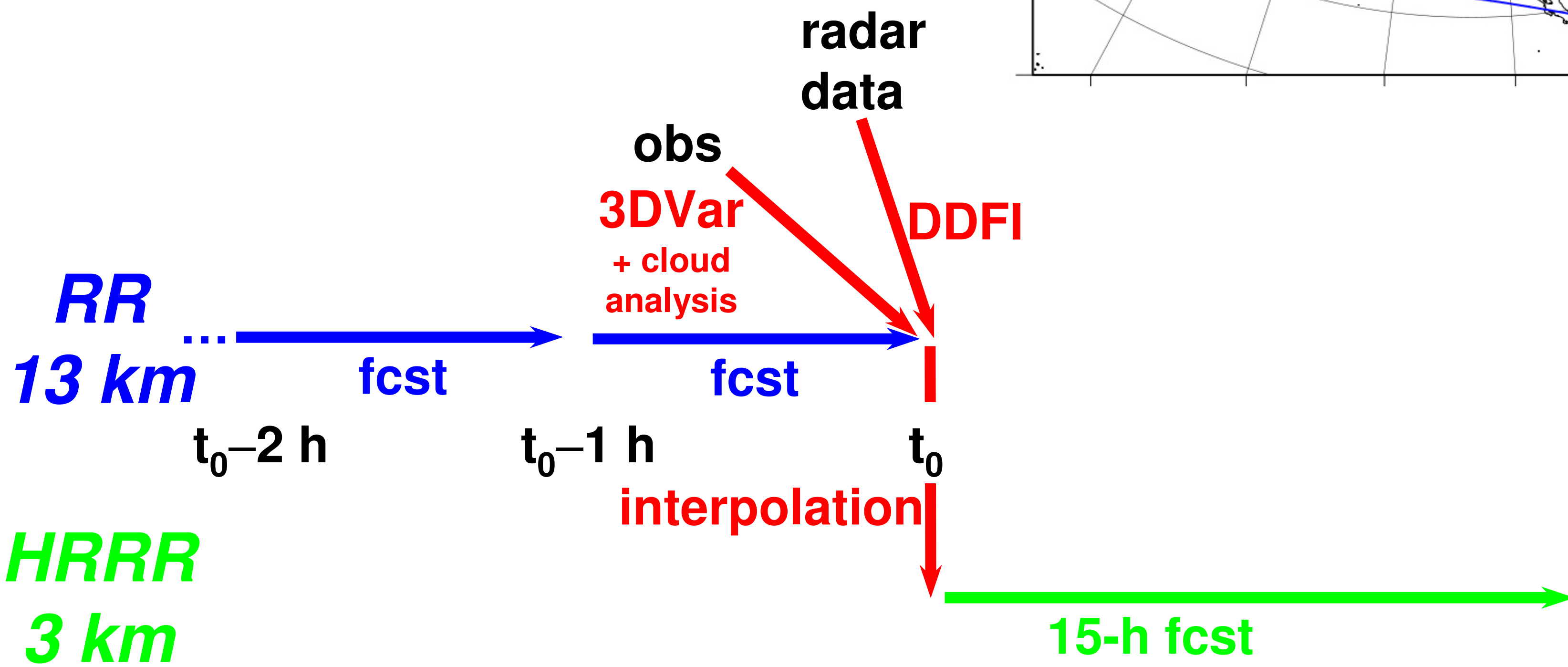
# RR Cycling and HRRR Initialization



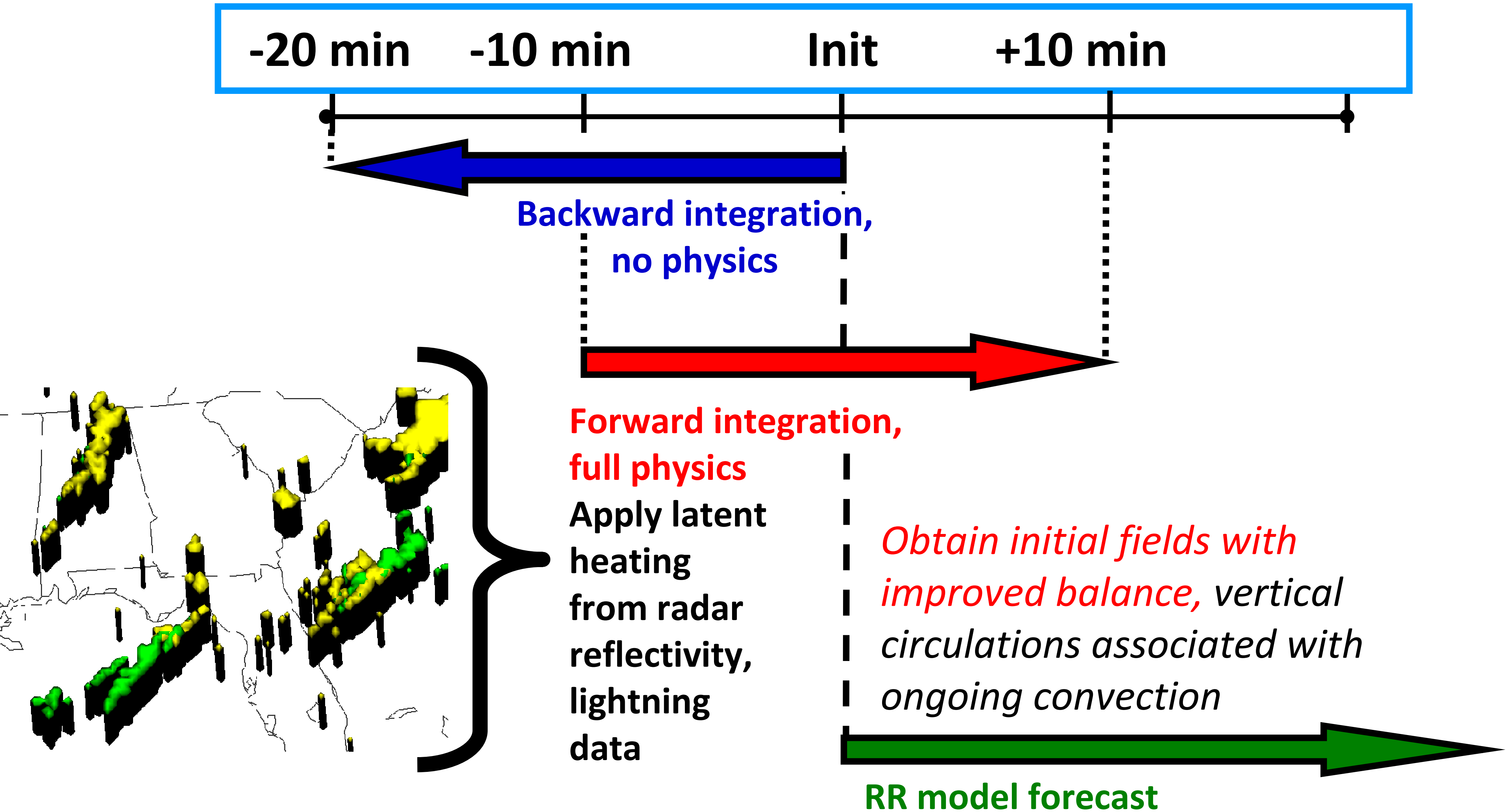



# RR Cycling and HRRR Initialization



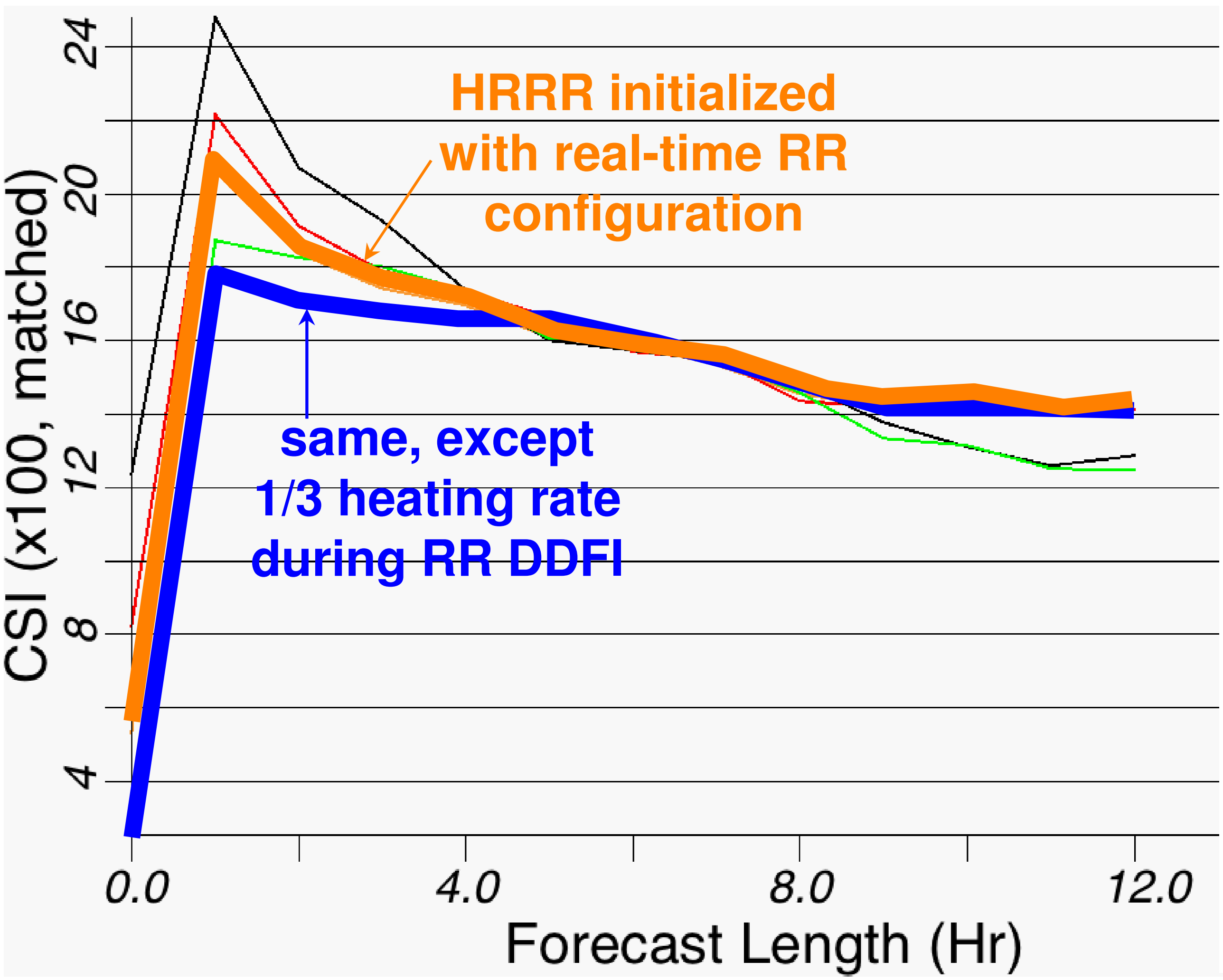



# Diabatic Digital Filter Initialization (DDFI)




- 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**

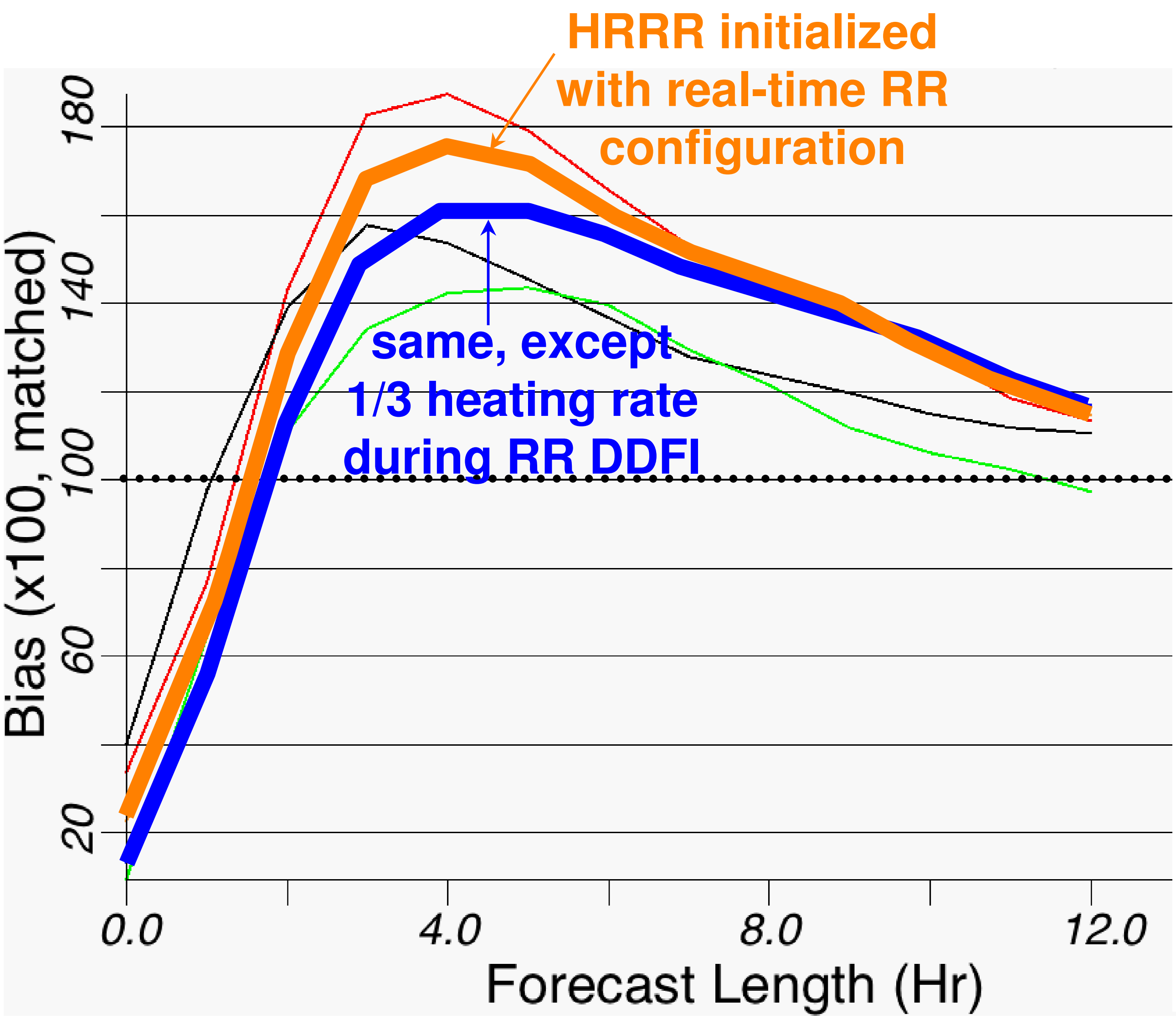
**40-km verification composite reflectivity 25 dBZ**

RUC parent model

**RR parent model**

**RR parent model, 1/3 heating rate**

# HRRR 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

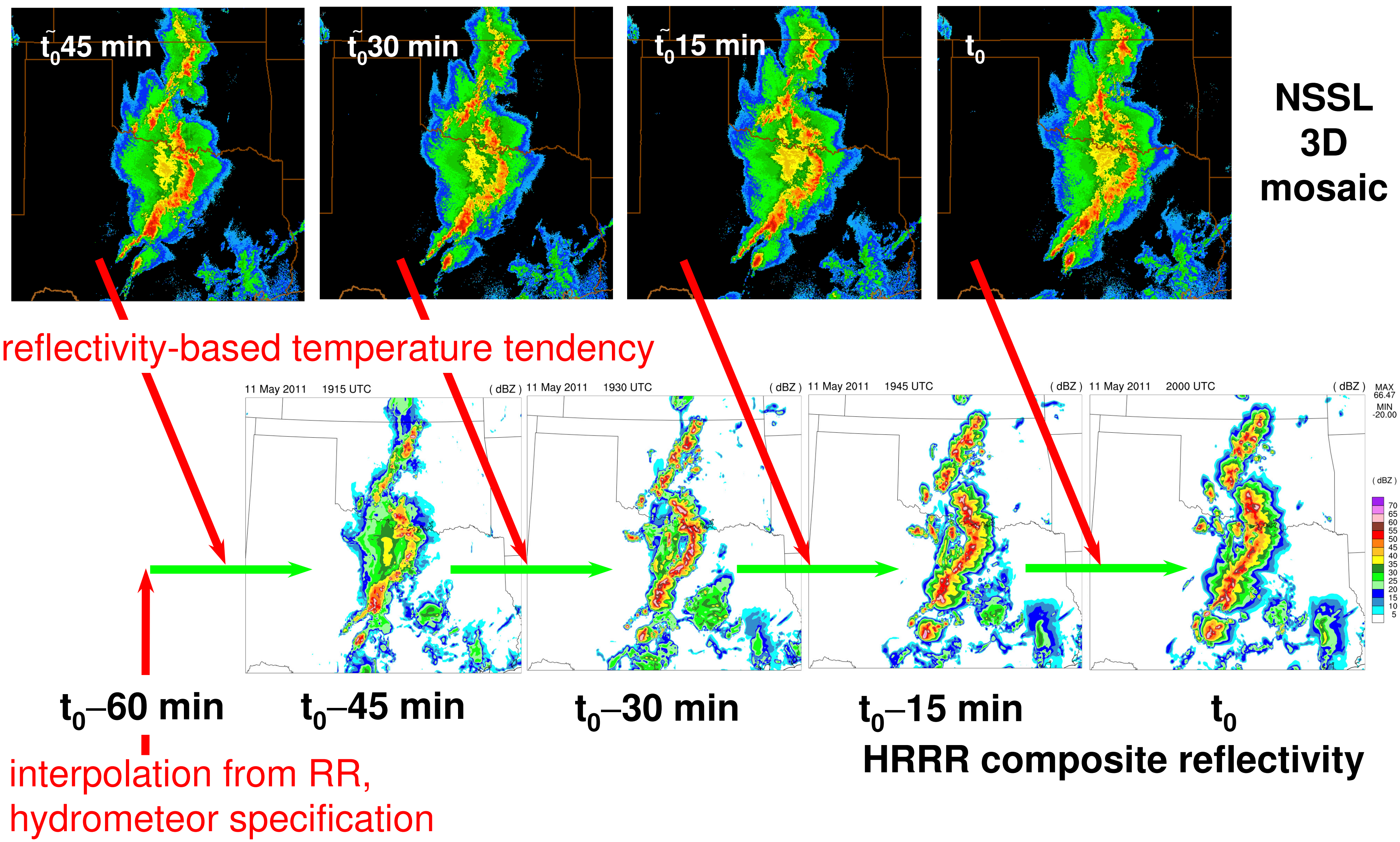
**RR parent model**

**RR parent model, 1/3 heating rate**

# Reflectivity DA on 3-km (HRRR) Grid

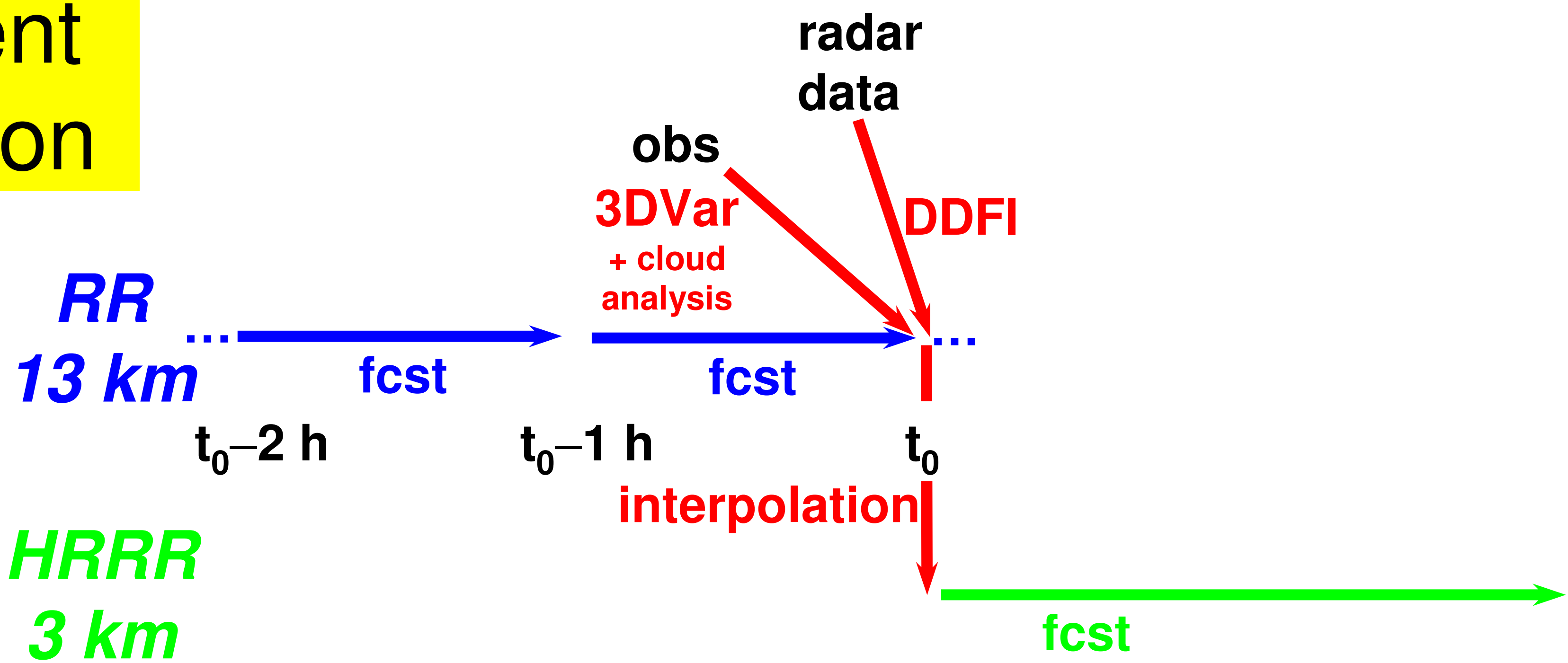
HRRR (3-km) grid produces convective storms explicitly

Reflectivity-based temp. tendencies are applied during sub-hourly cycling (forward model integration only, no digital filtering)

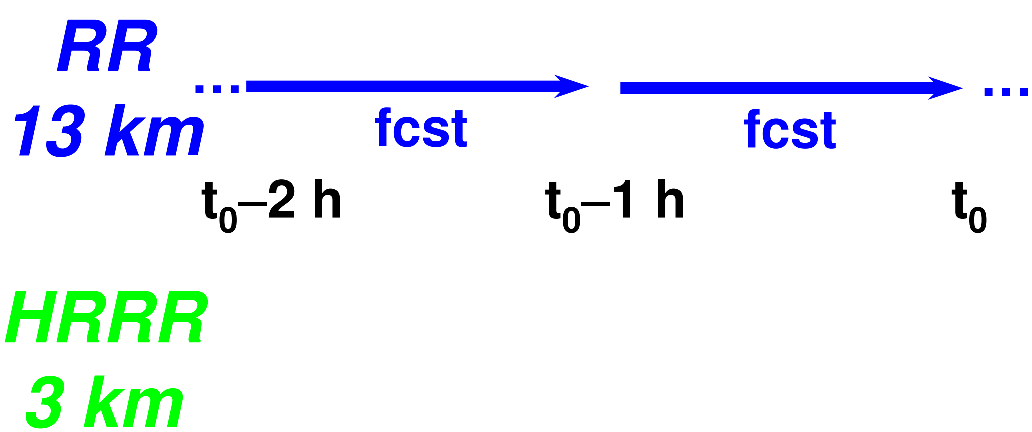


# Experiment Comparison

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




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



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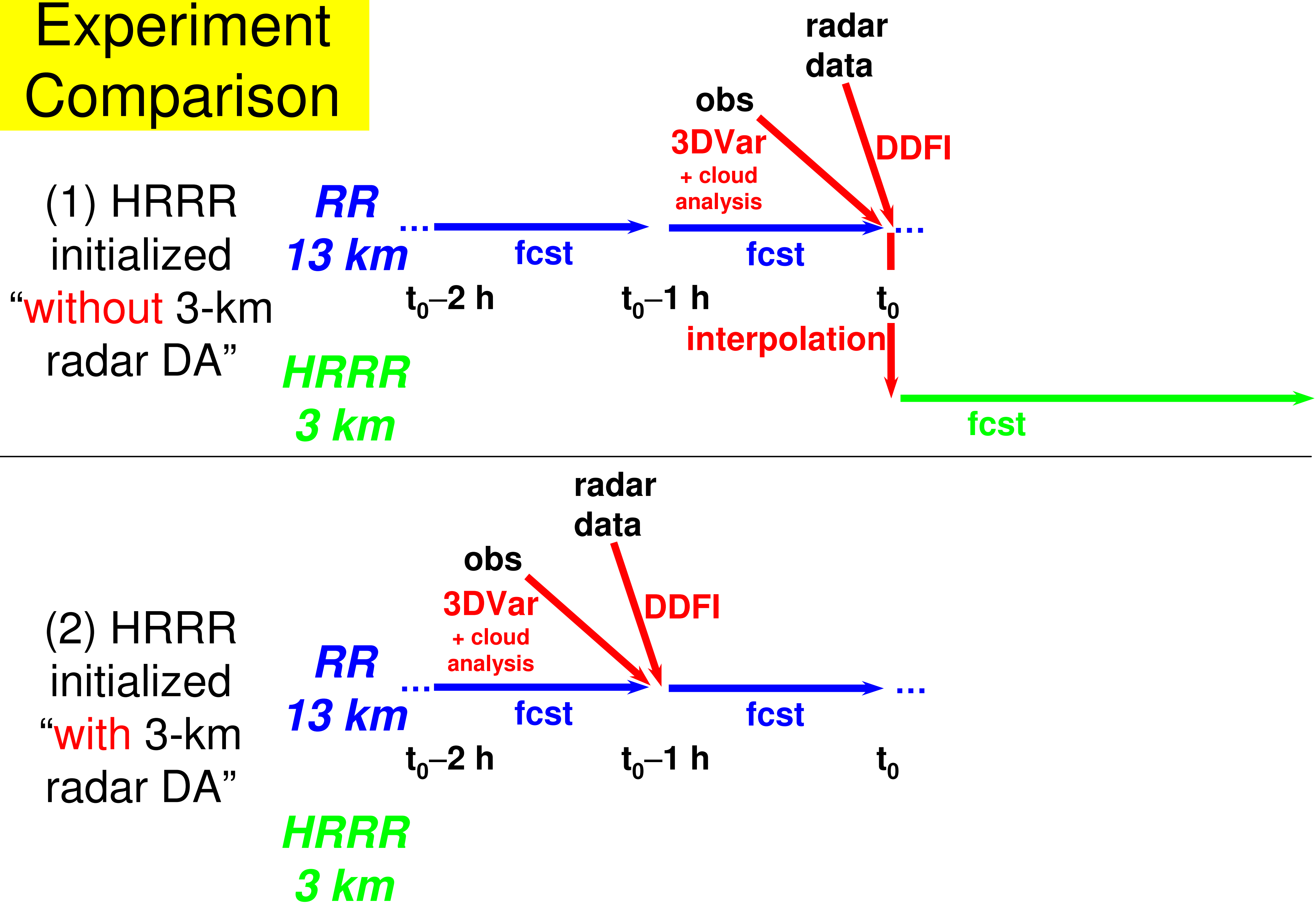

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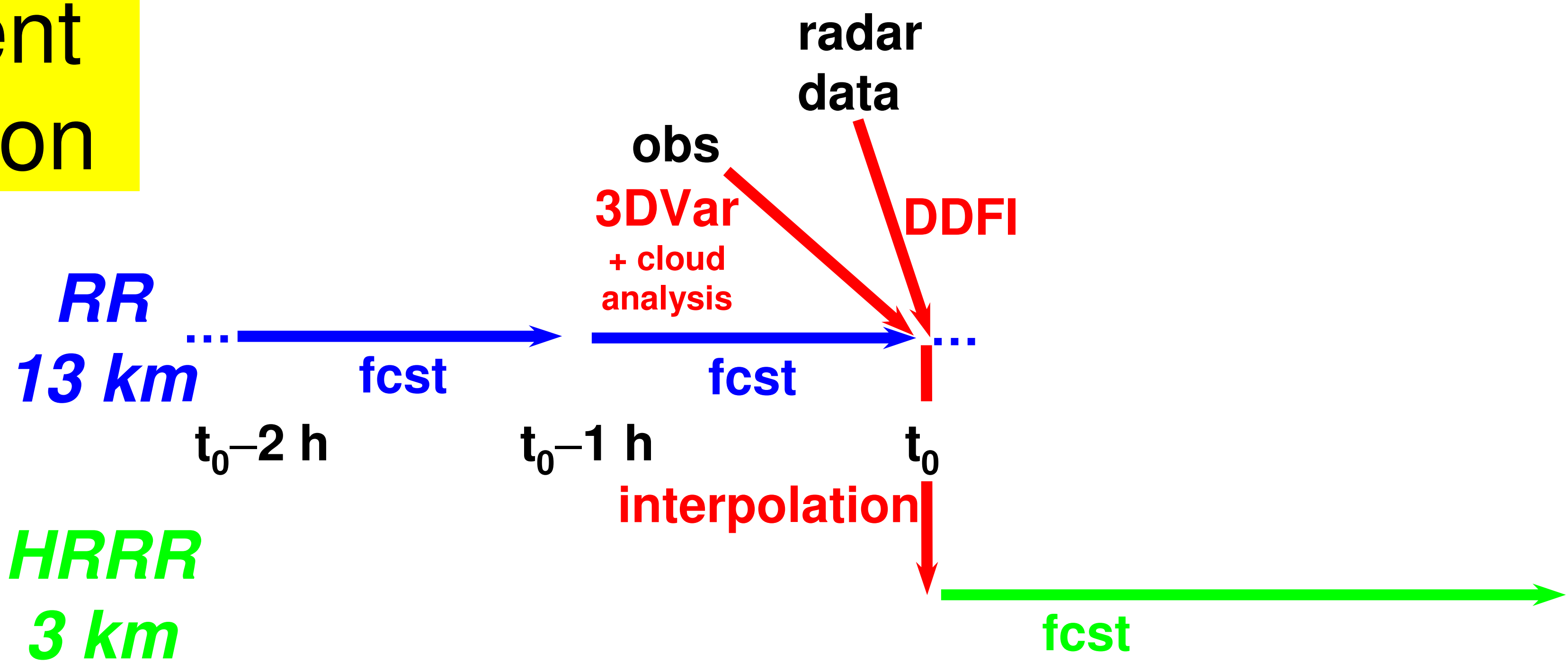


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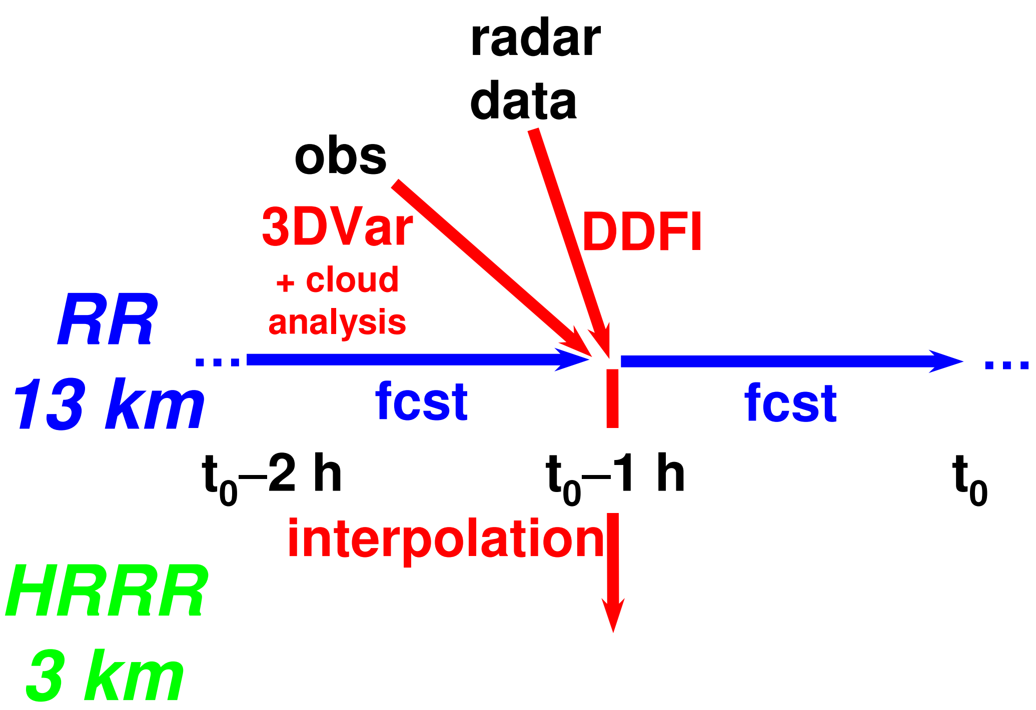

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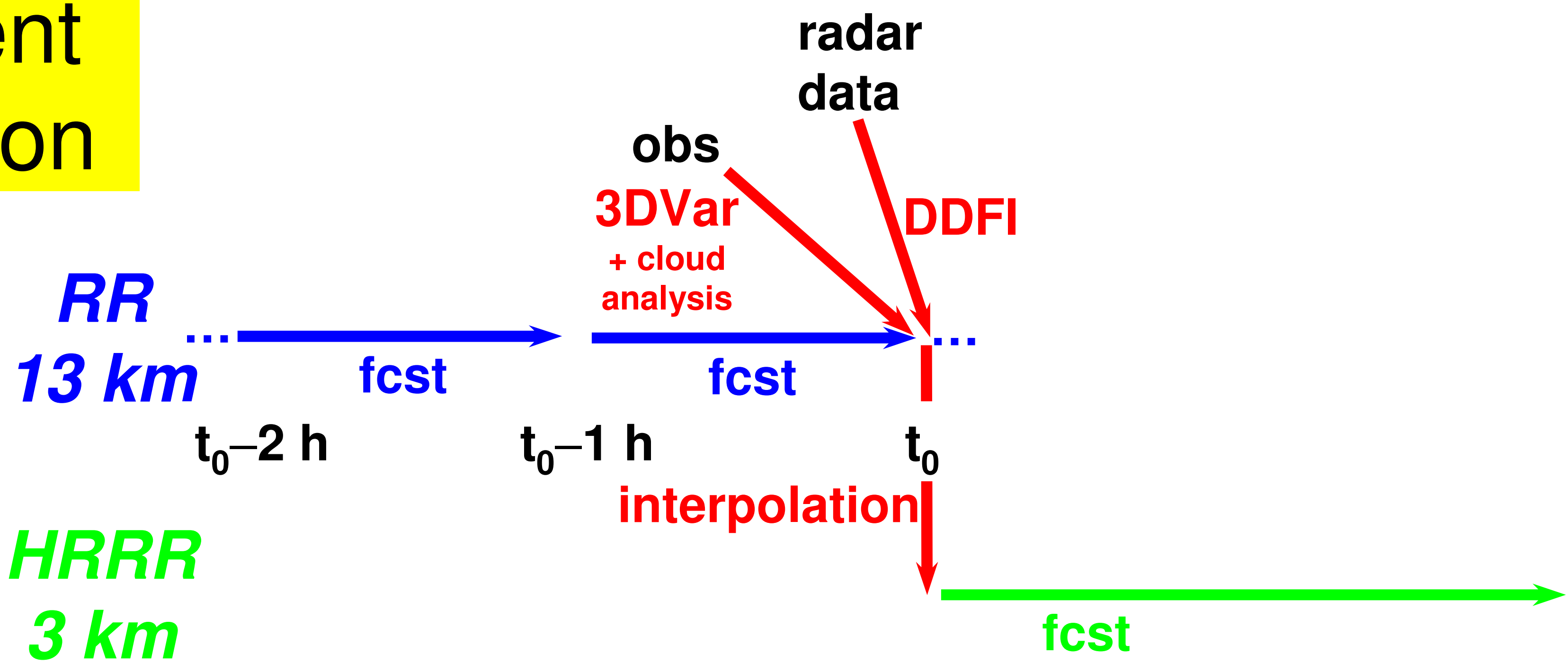


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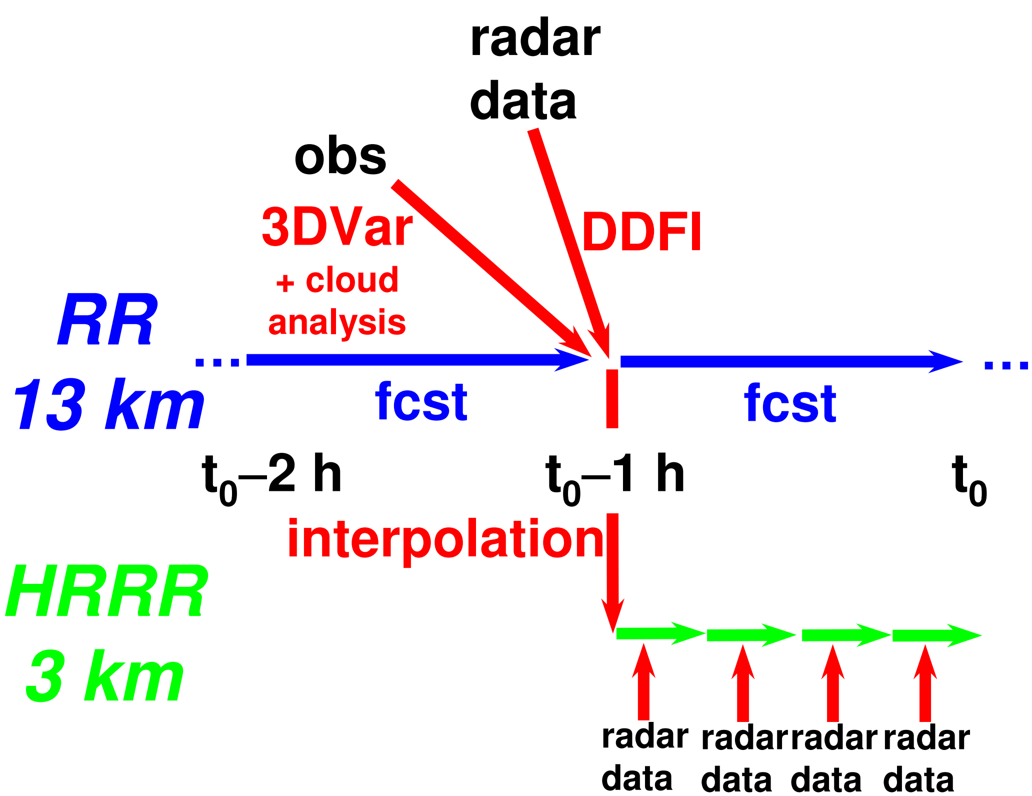

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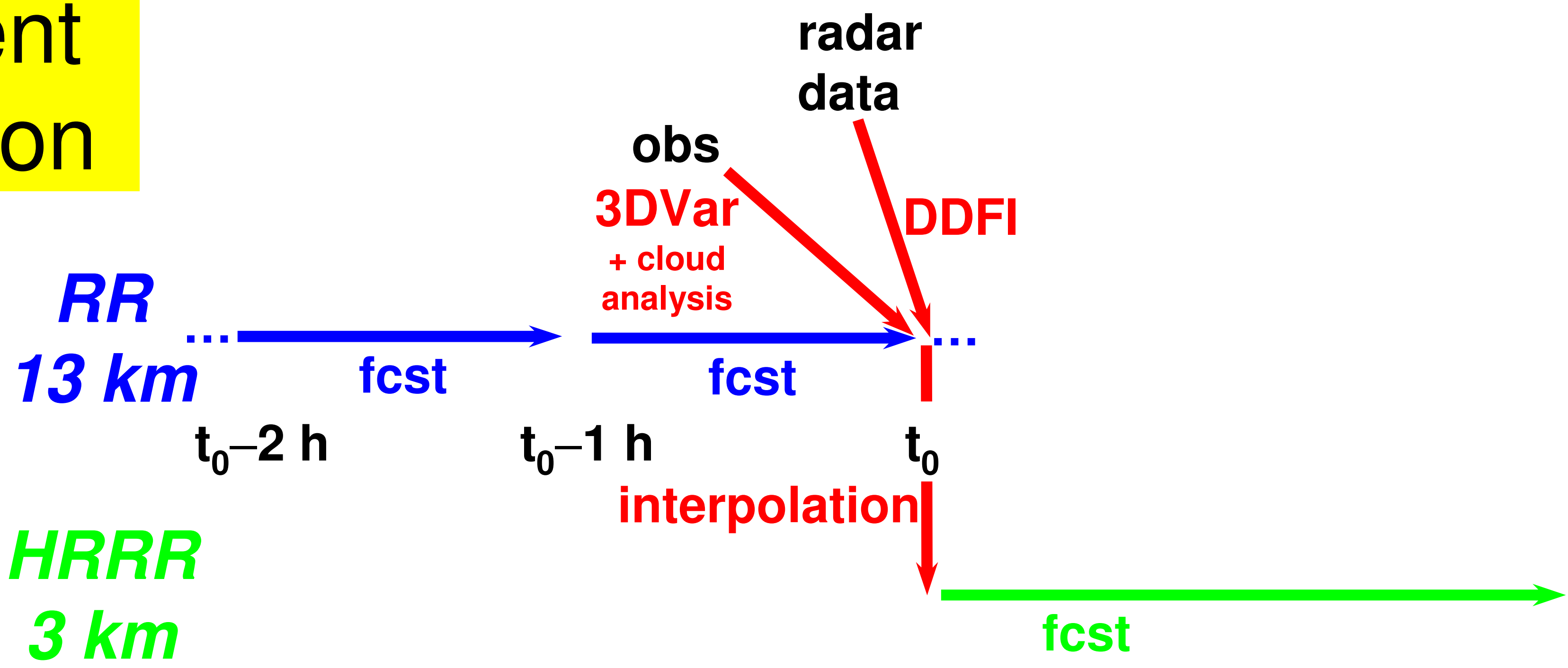


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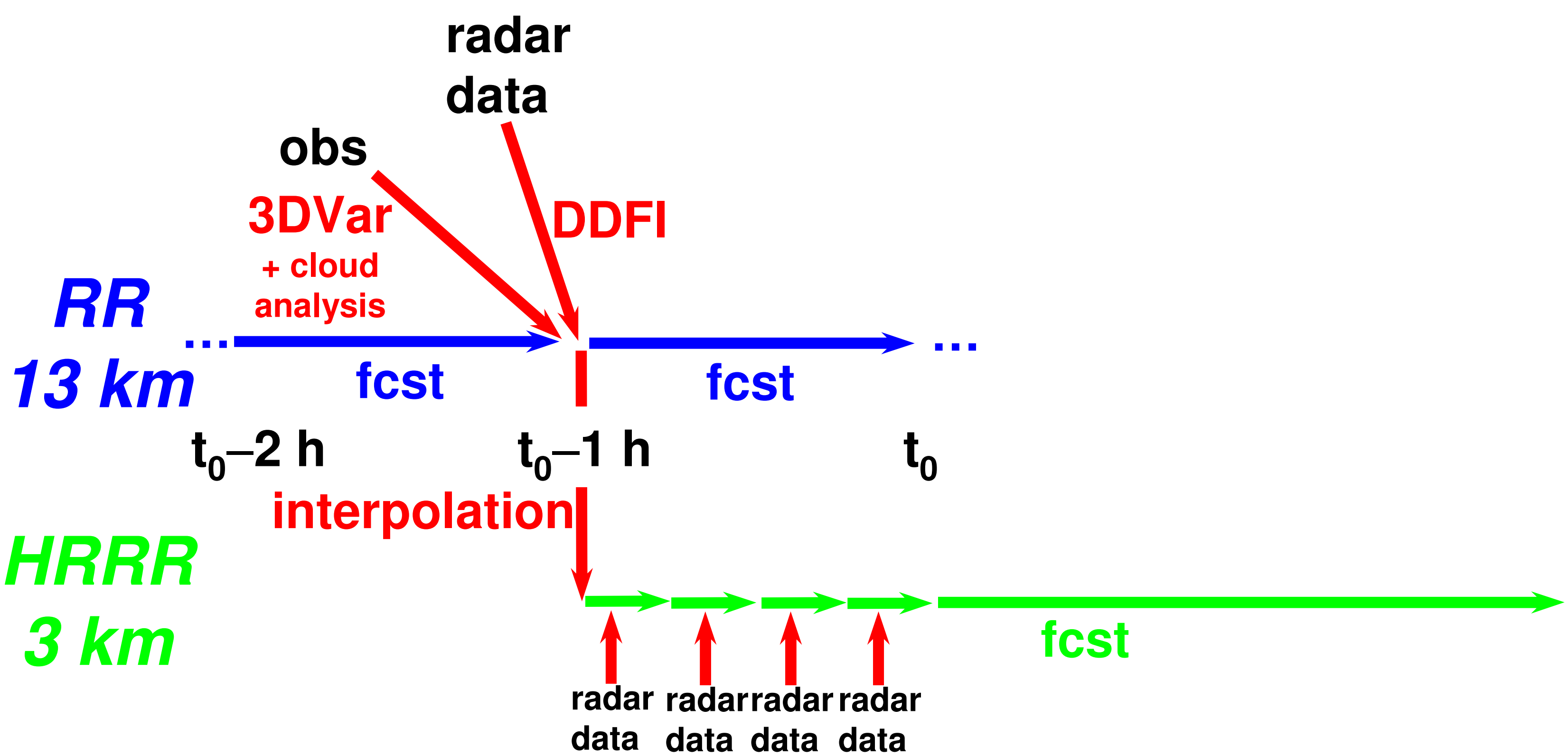
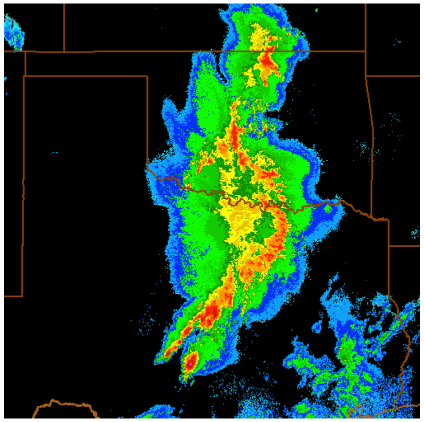
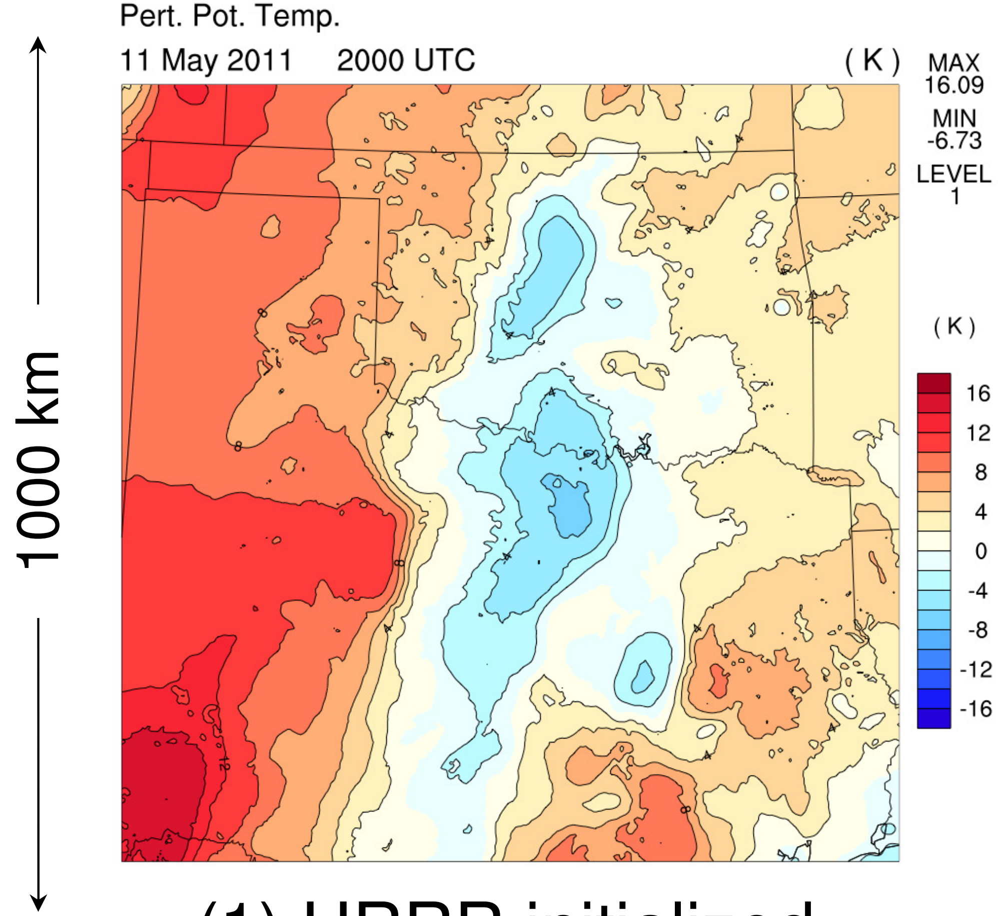


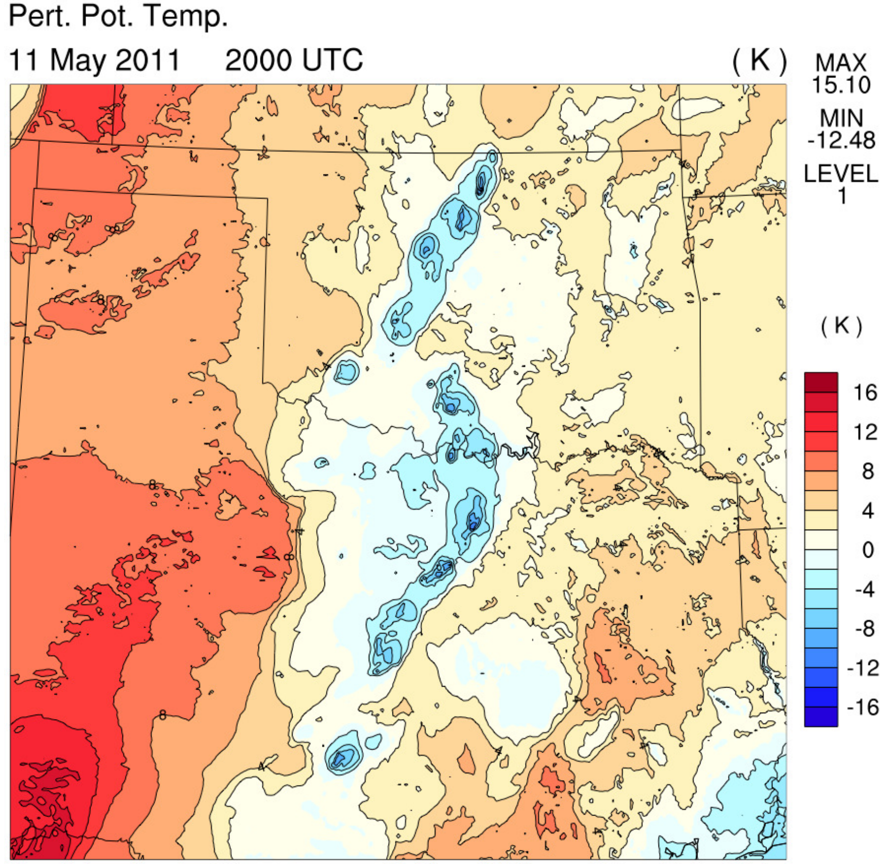
# 2000 UTC 11 May 2011

## Initial Temperature at Lowest Model Level



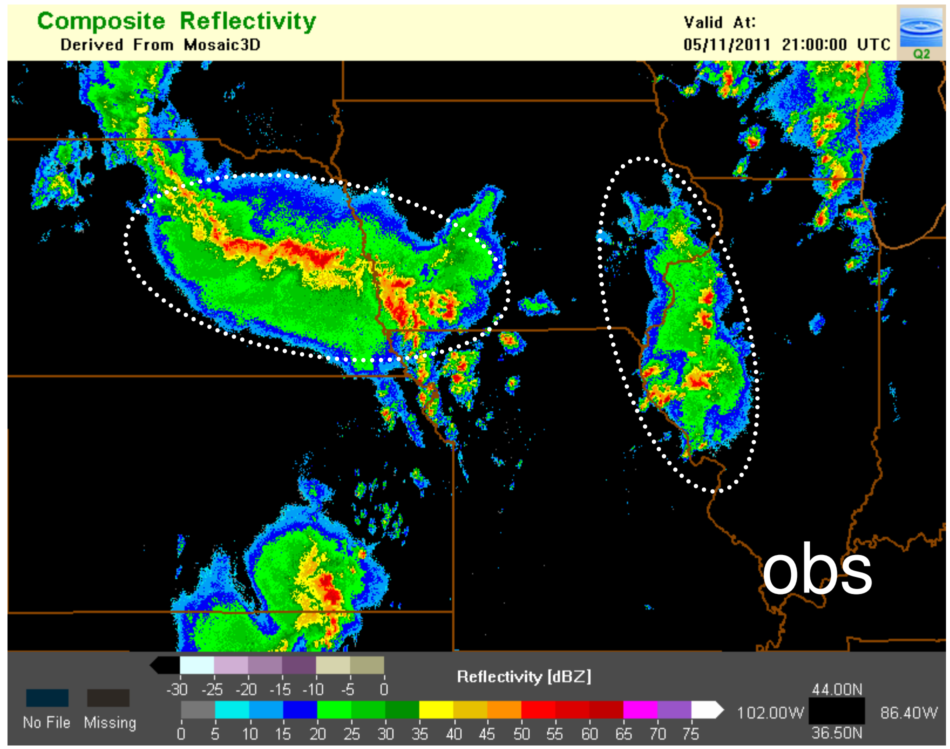



(1) HRRR initialized without 3-km radar DA

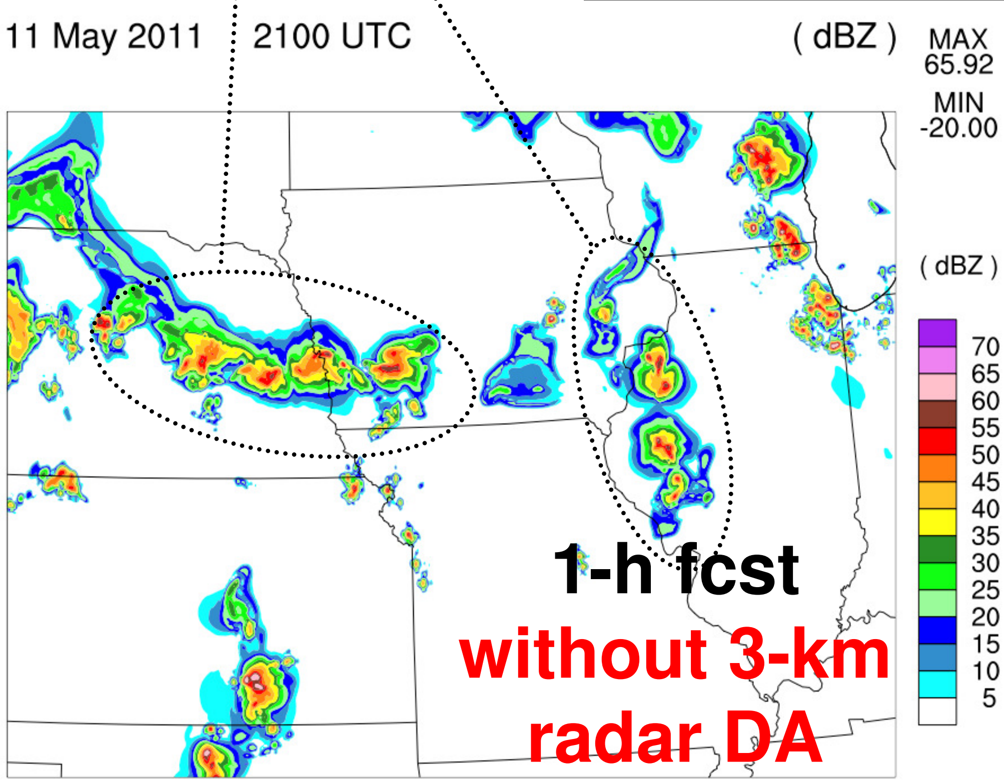


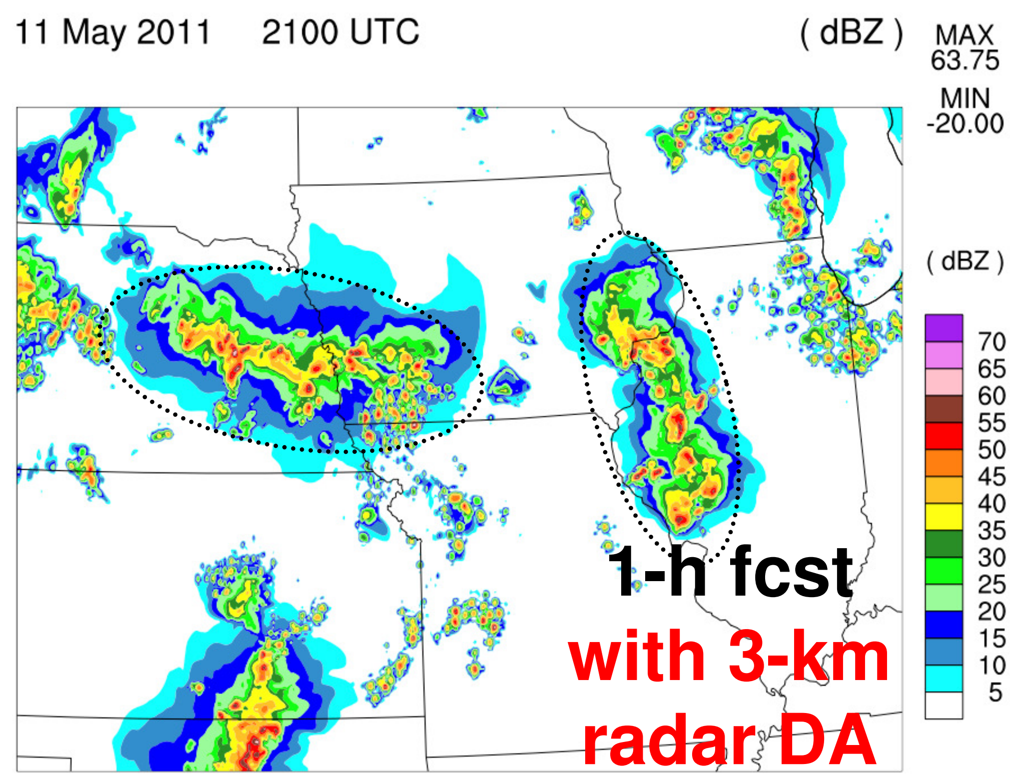

(2) HRRR initialized with 3-km radar DA

# Composite Reflectivity 2100 UTC 11 May 2011

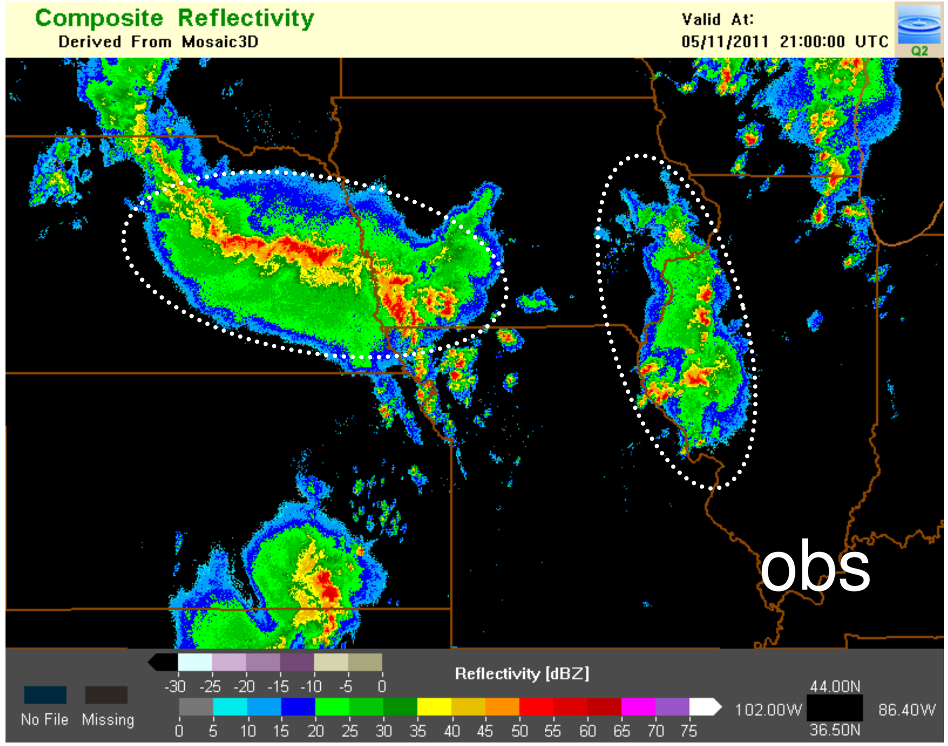



convection develops quickly (RR cycling, DDFI)

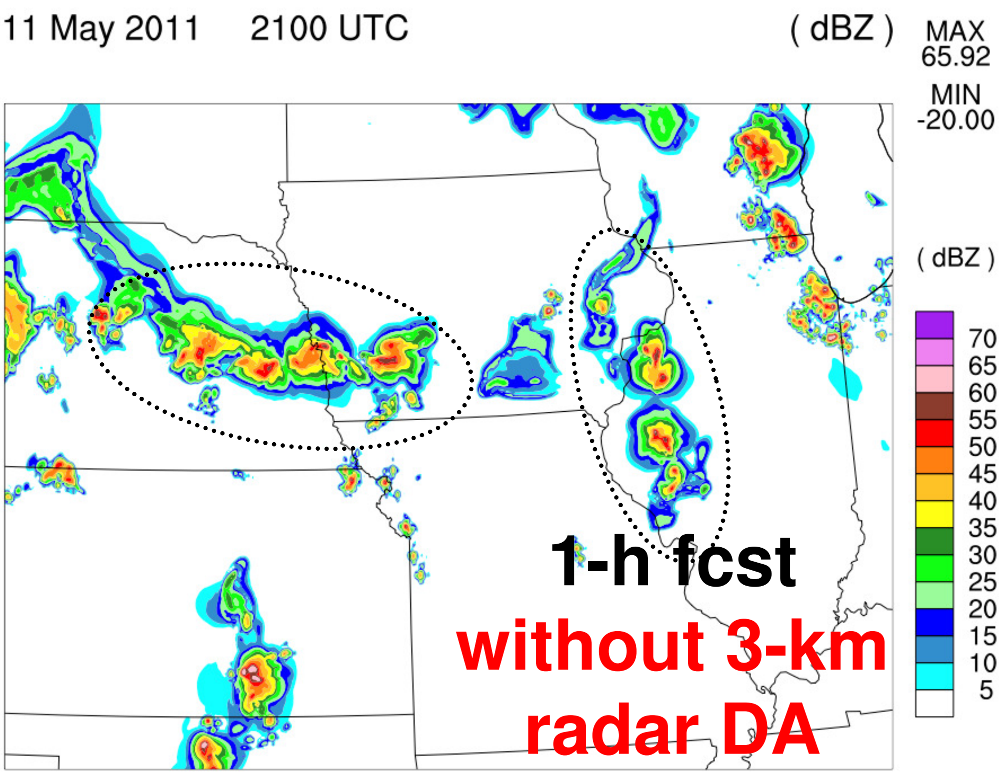


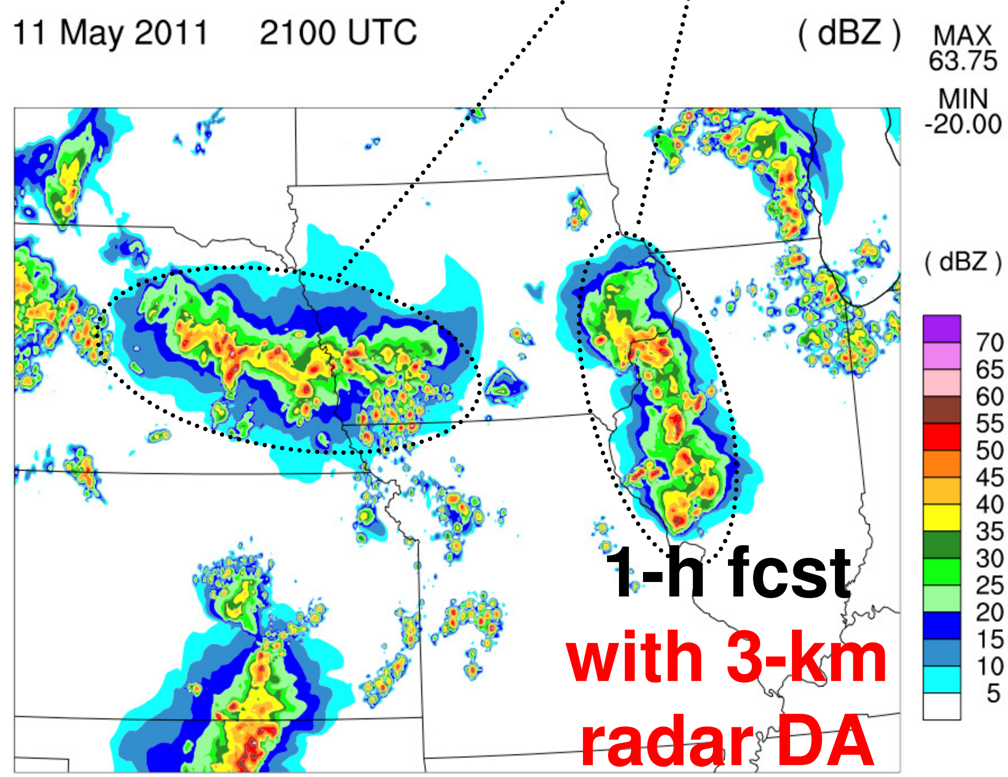



# Composite Reflectivity 2100 UTC 11 May 2011

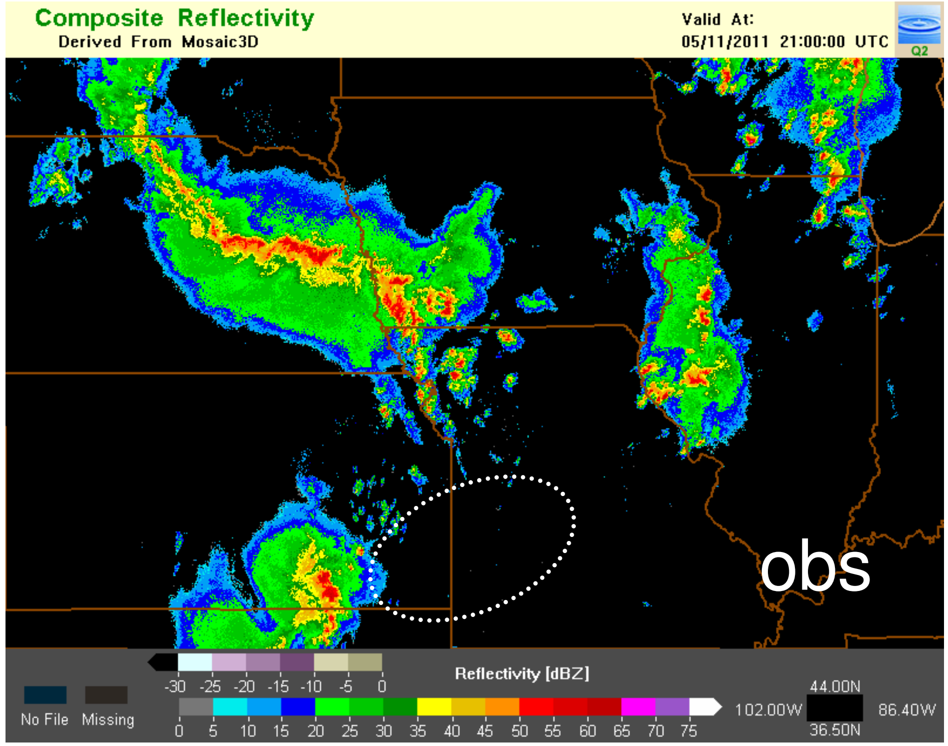


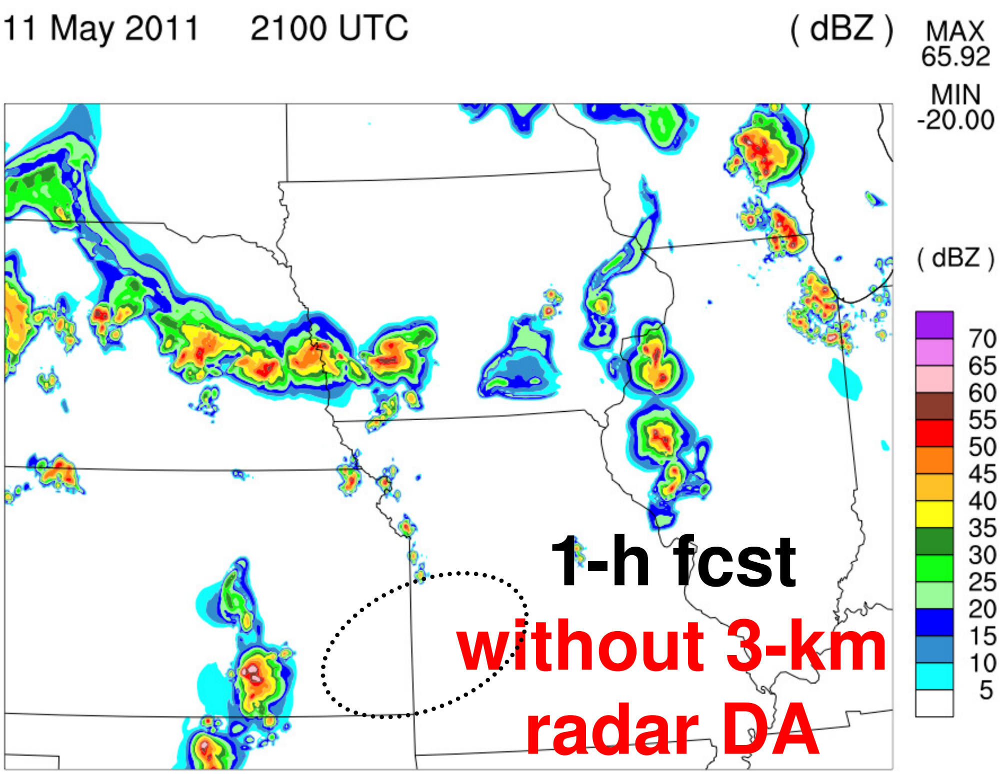

more accurate representation of system maturity

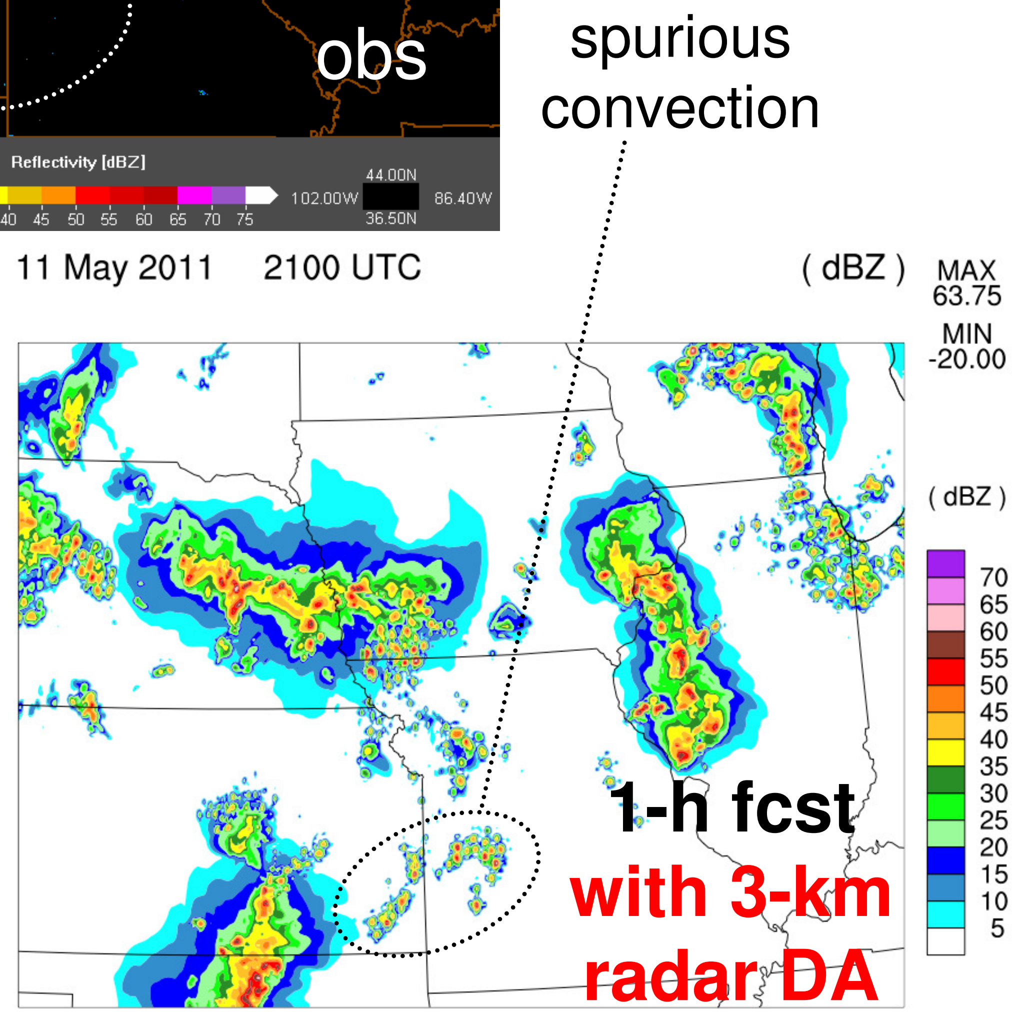


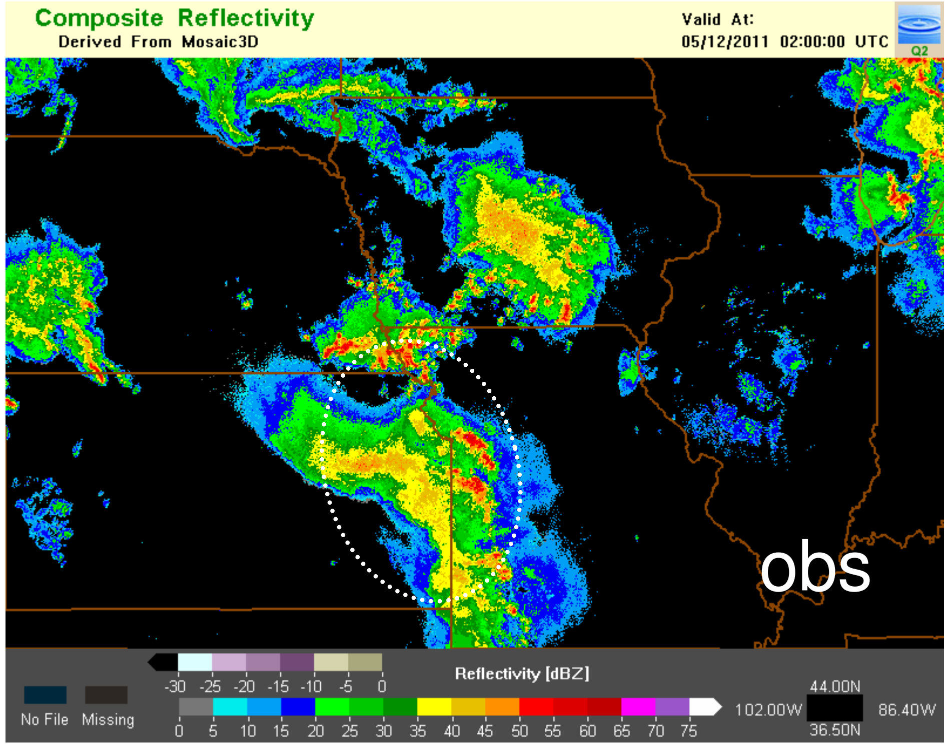
# Composite Reflectivity
# 2100 UTC
# 11 May 2011



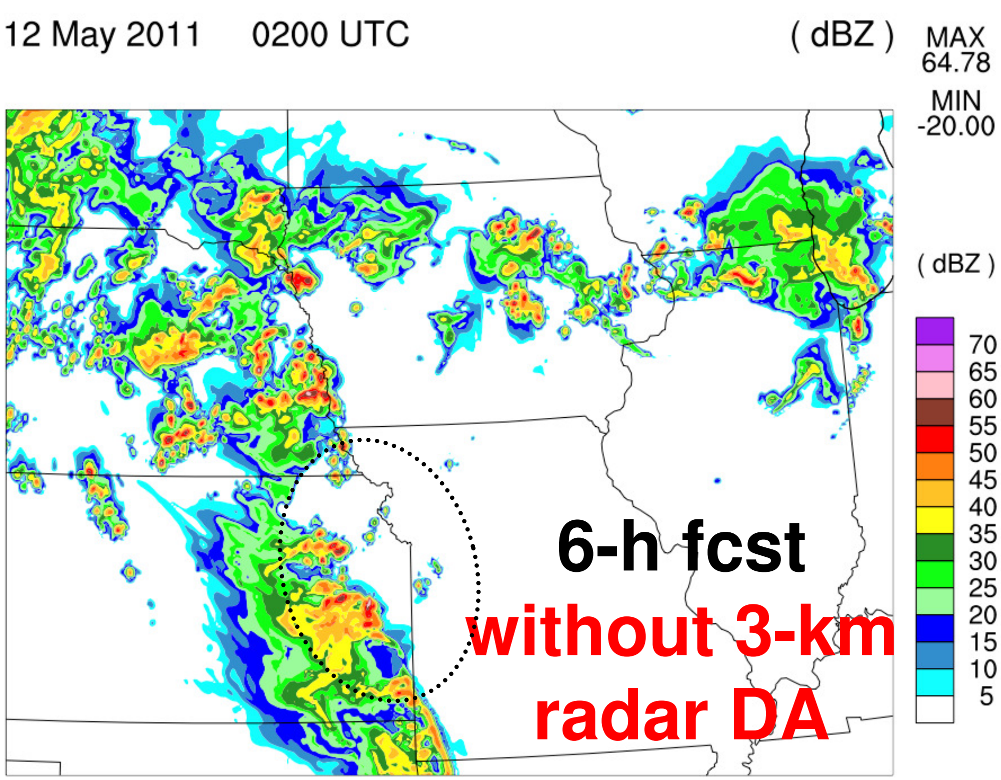



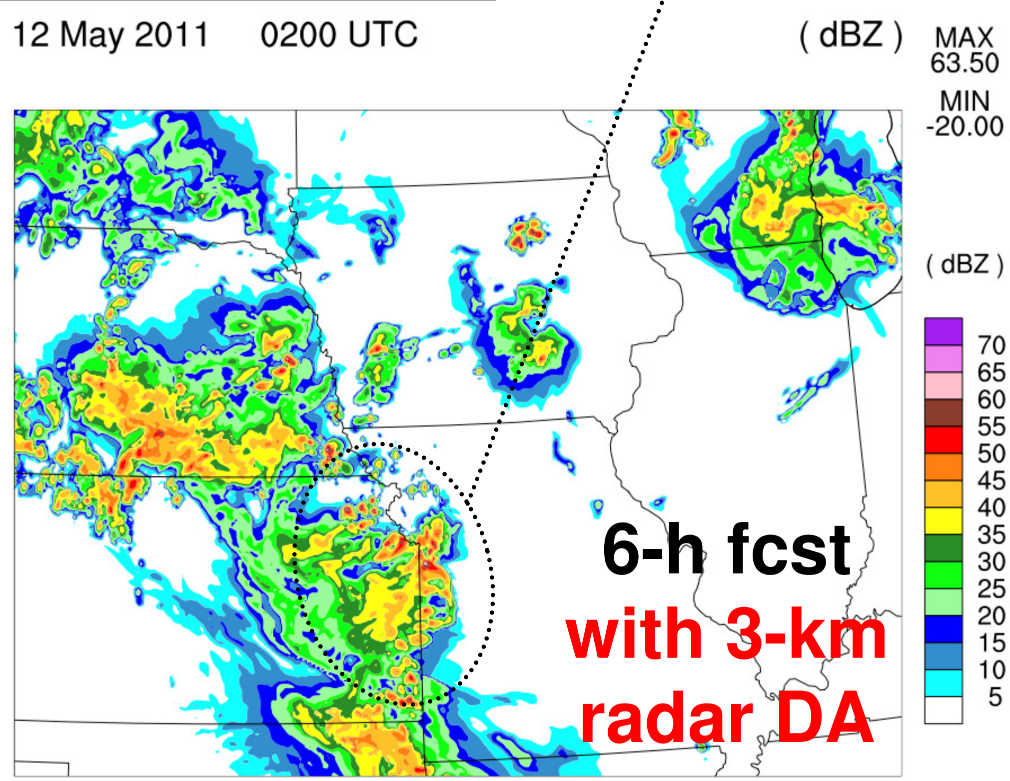



# Composite Reflectivity 0200 UTC 11 May 2011

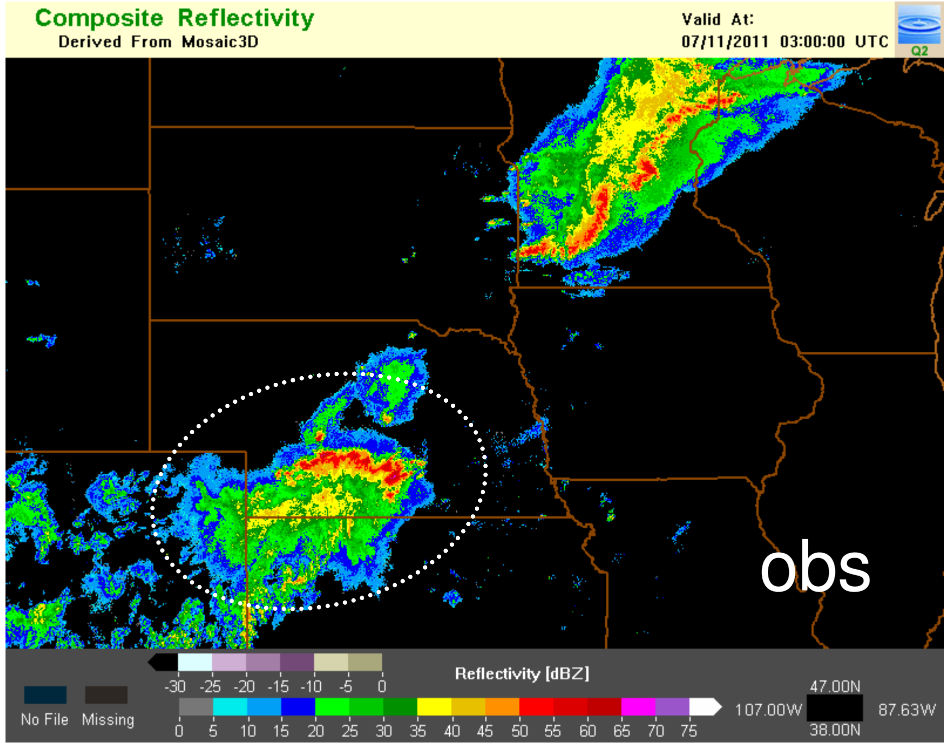


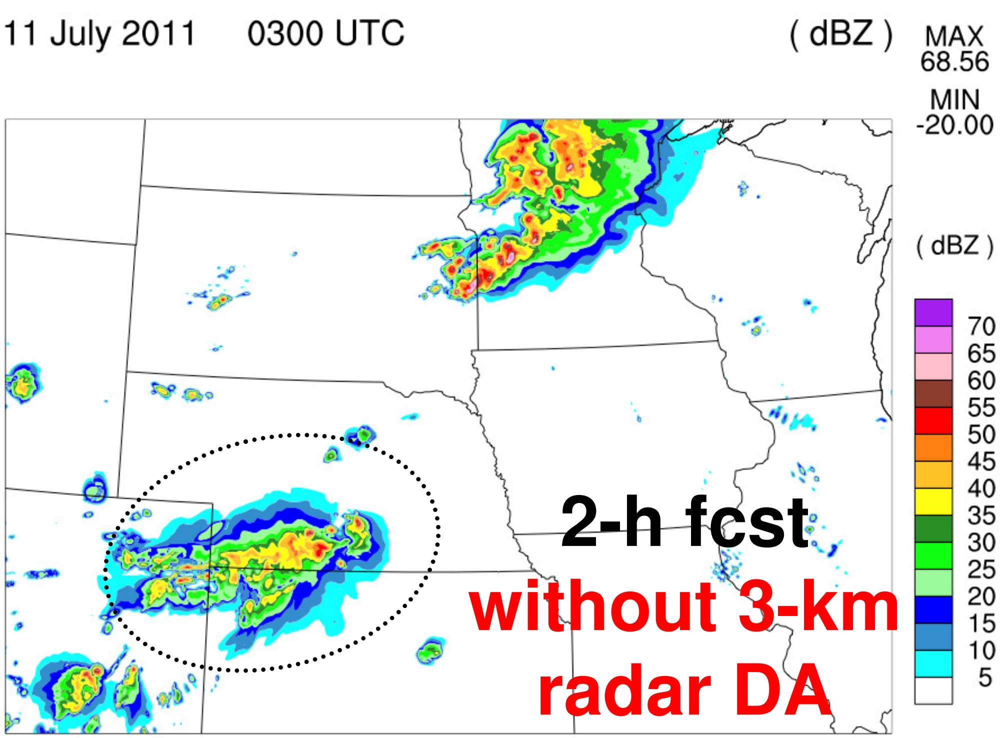

more accurate forecast of convective system propagation



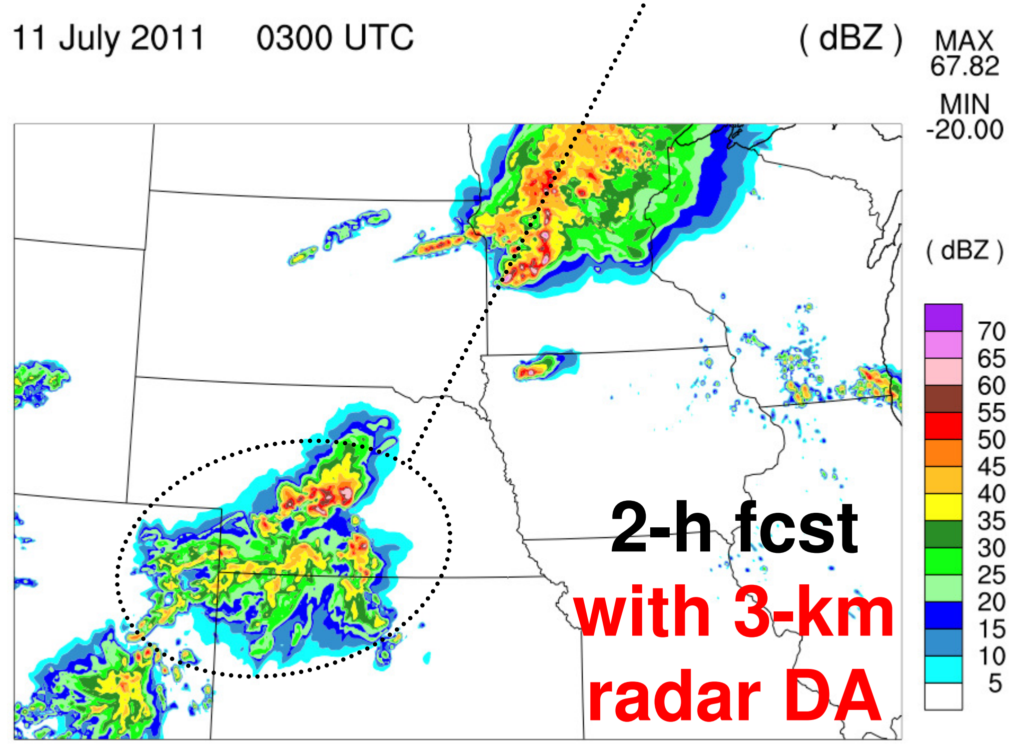



# Composite Reflectivity 0300 UTC 11 July 2011

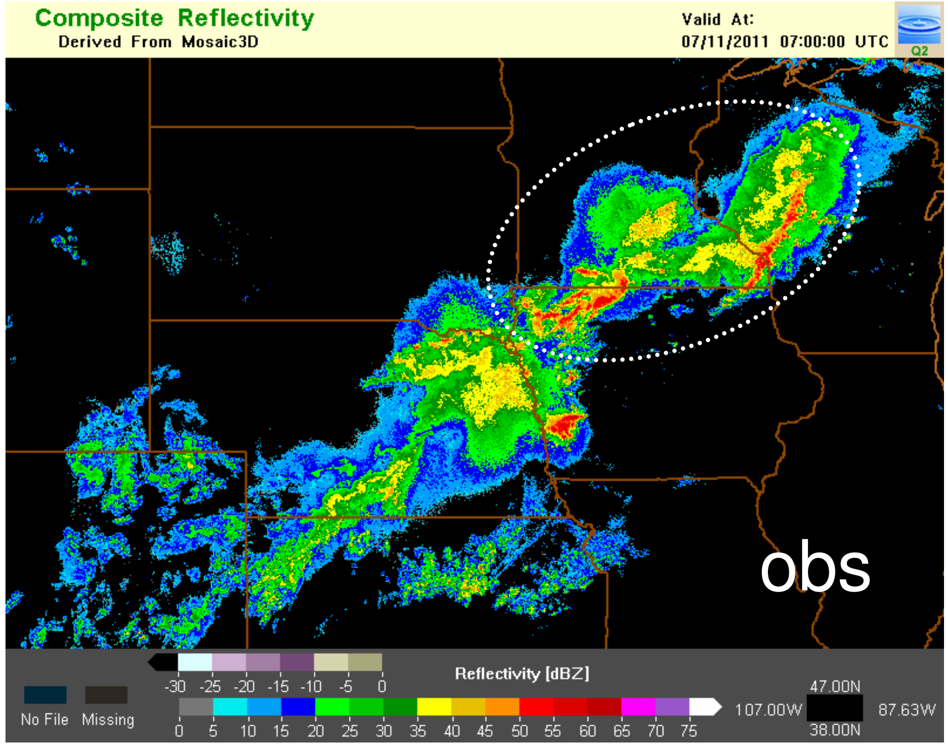


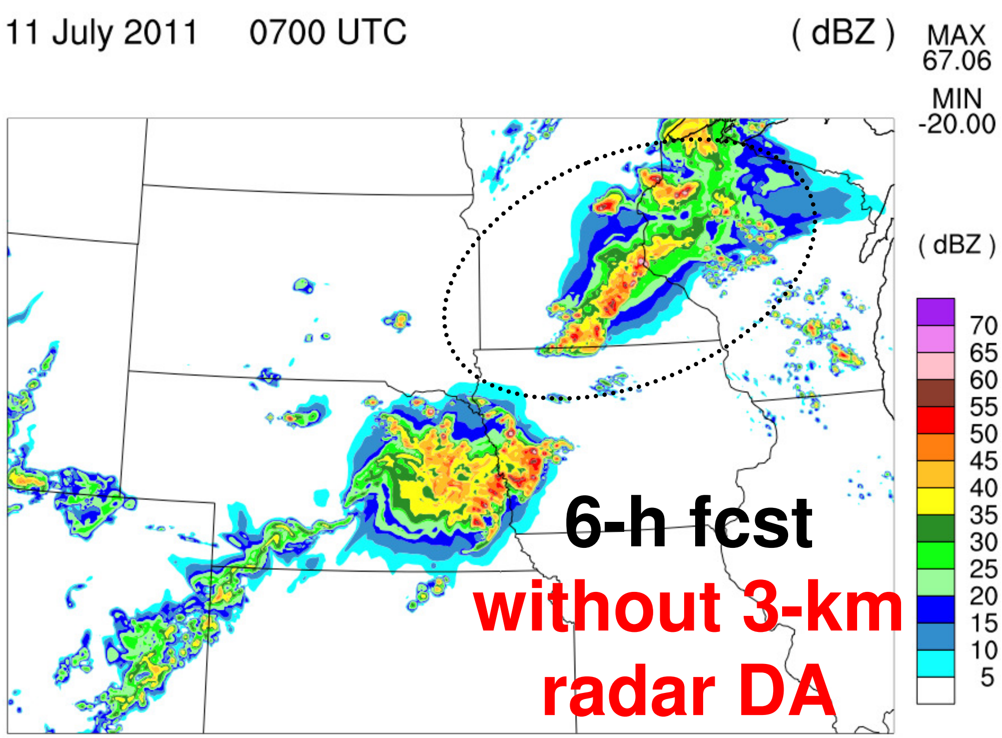

stronger convective system

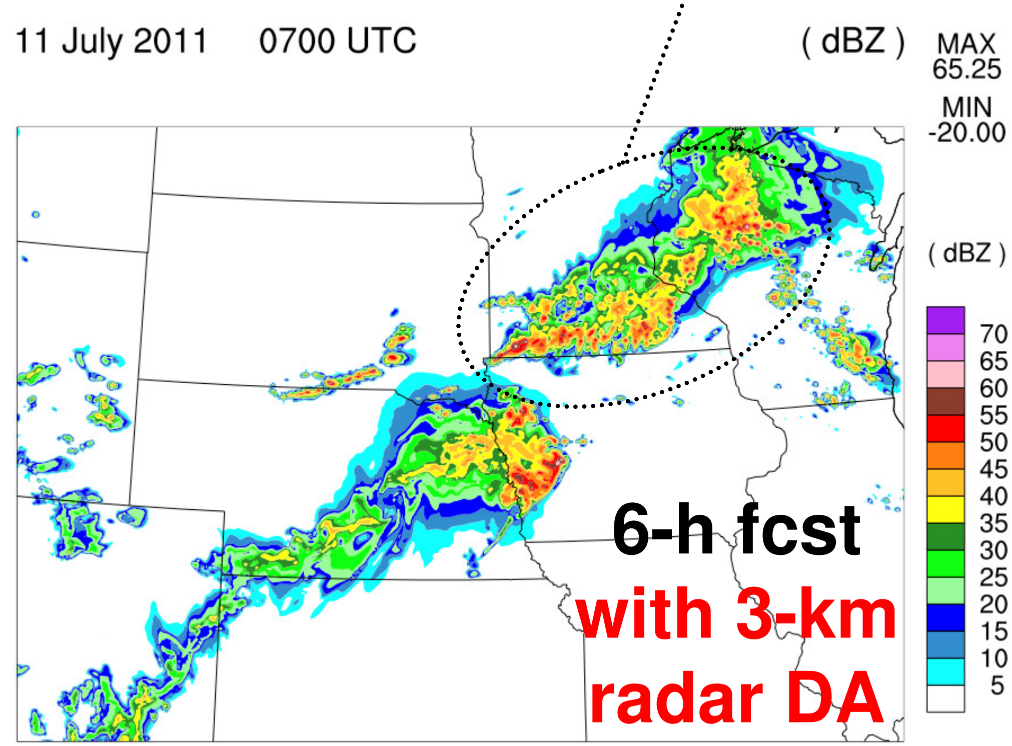


# Composite Reflectivity 0700 UTC 11 July 2011

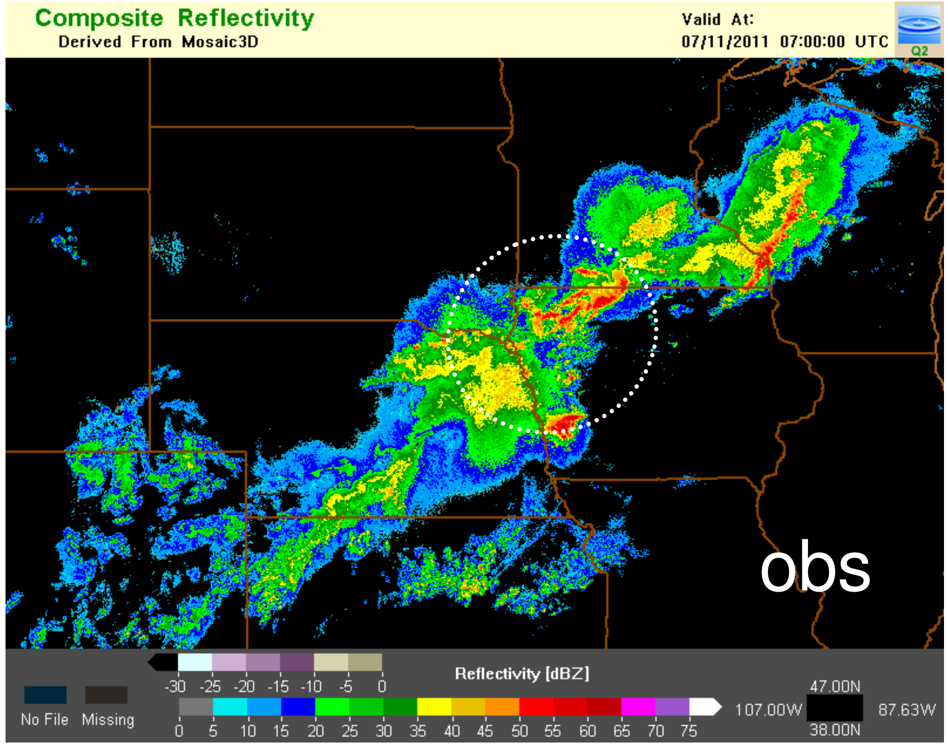



better representation of convective system coverage and orientation

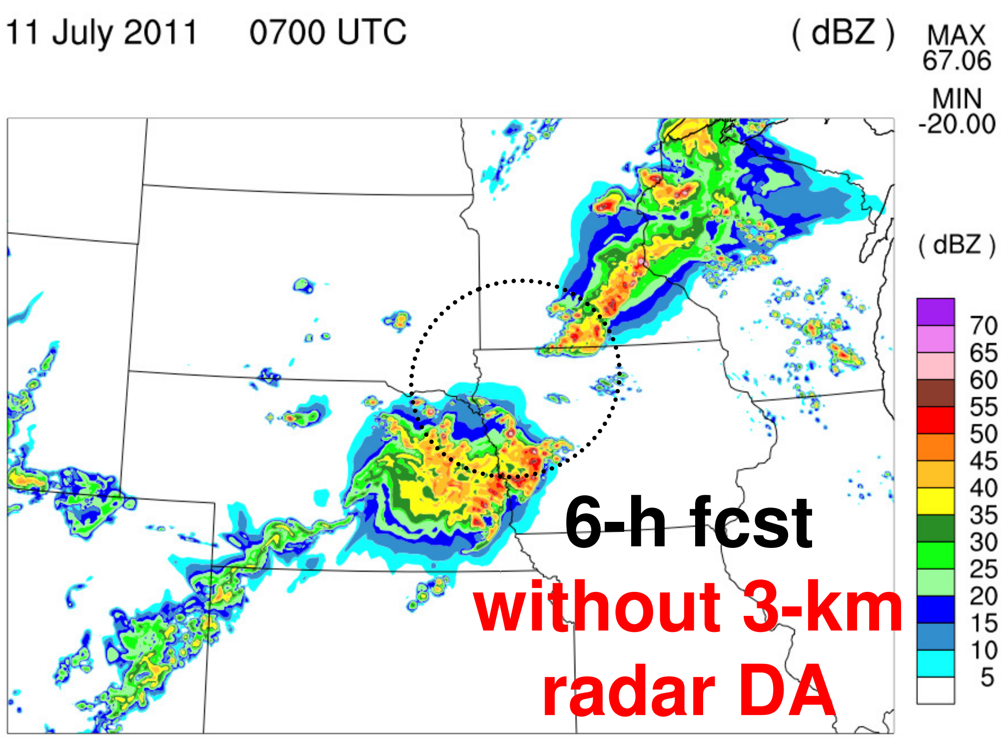


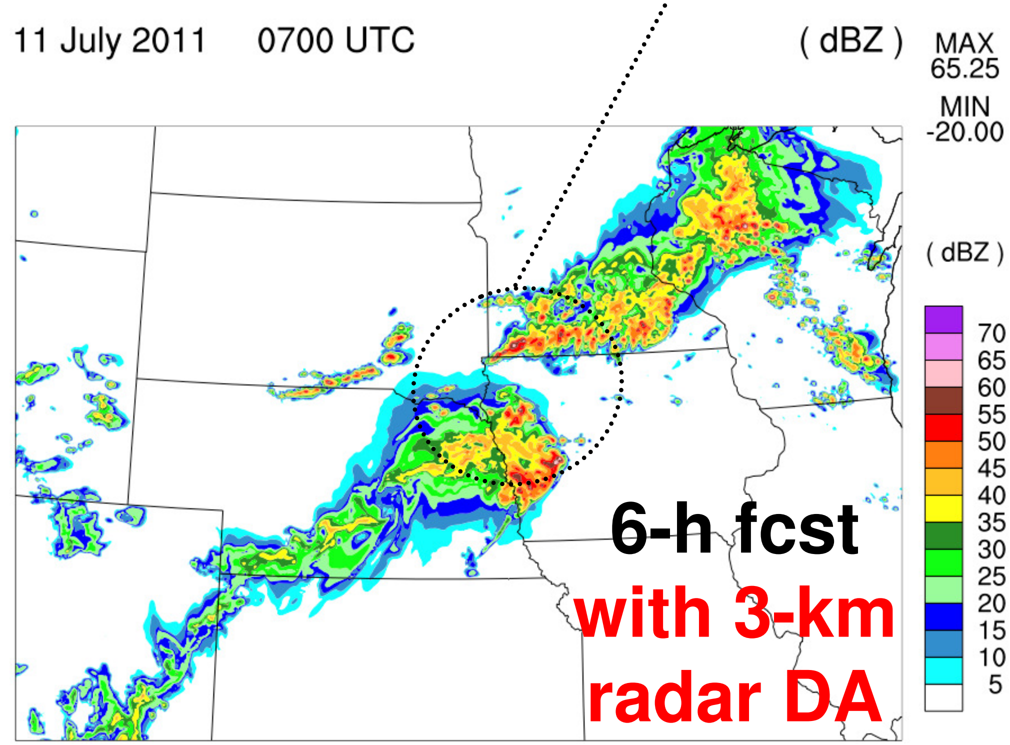



Composite Reflectivity
0700 UTC
11 July 2011




better indication of merging convective systems



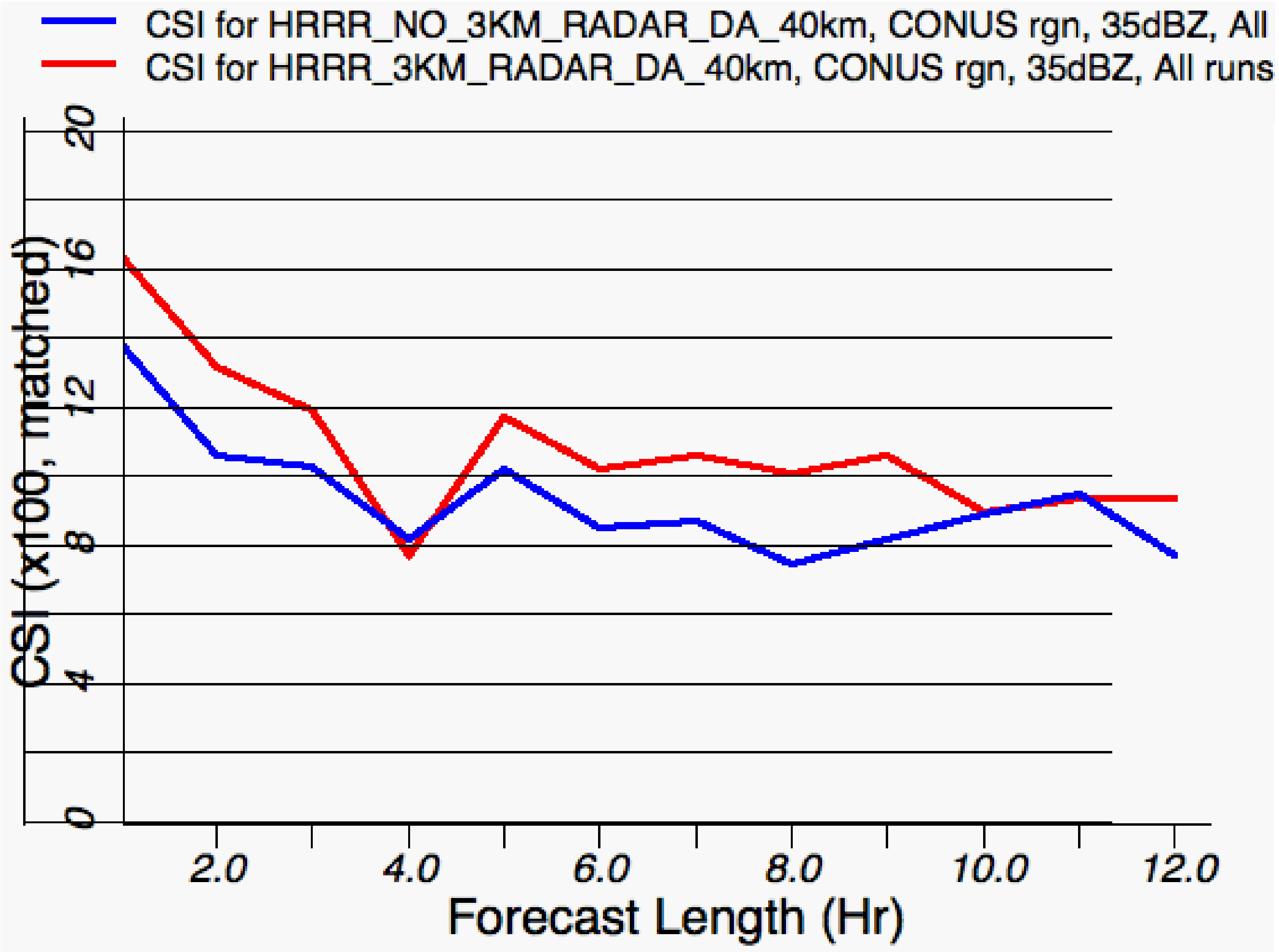
## SUMMARY

- 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



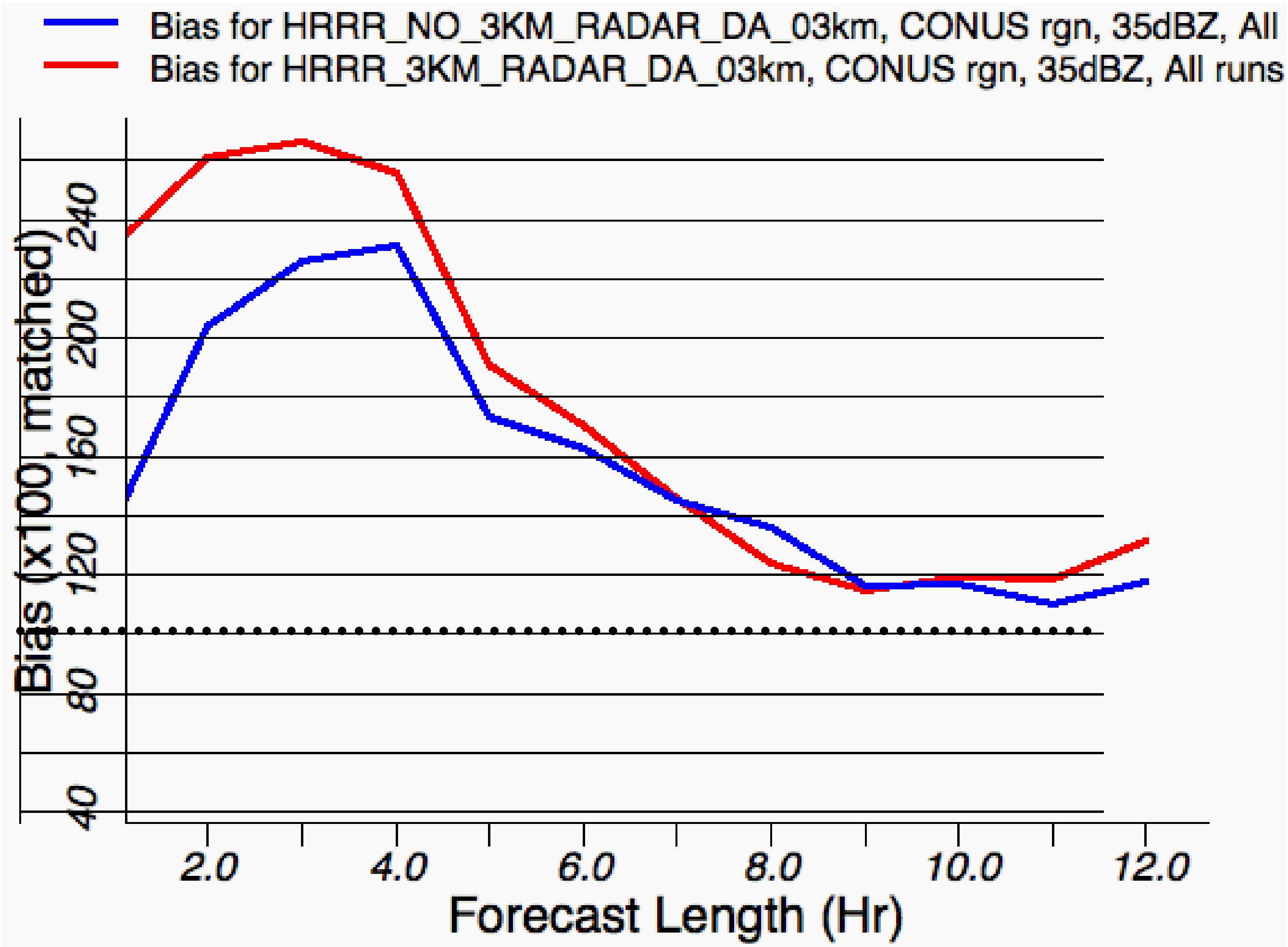

**limited number of cases**
**May and July 2011**

**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**