Assimilation of Lightning Observations and GOES Infrared Imagery at Convection-Permitting Scales

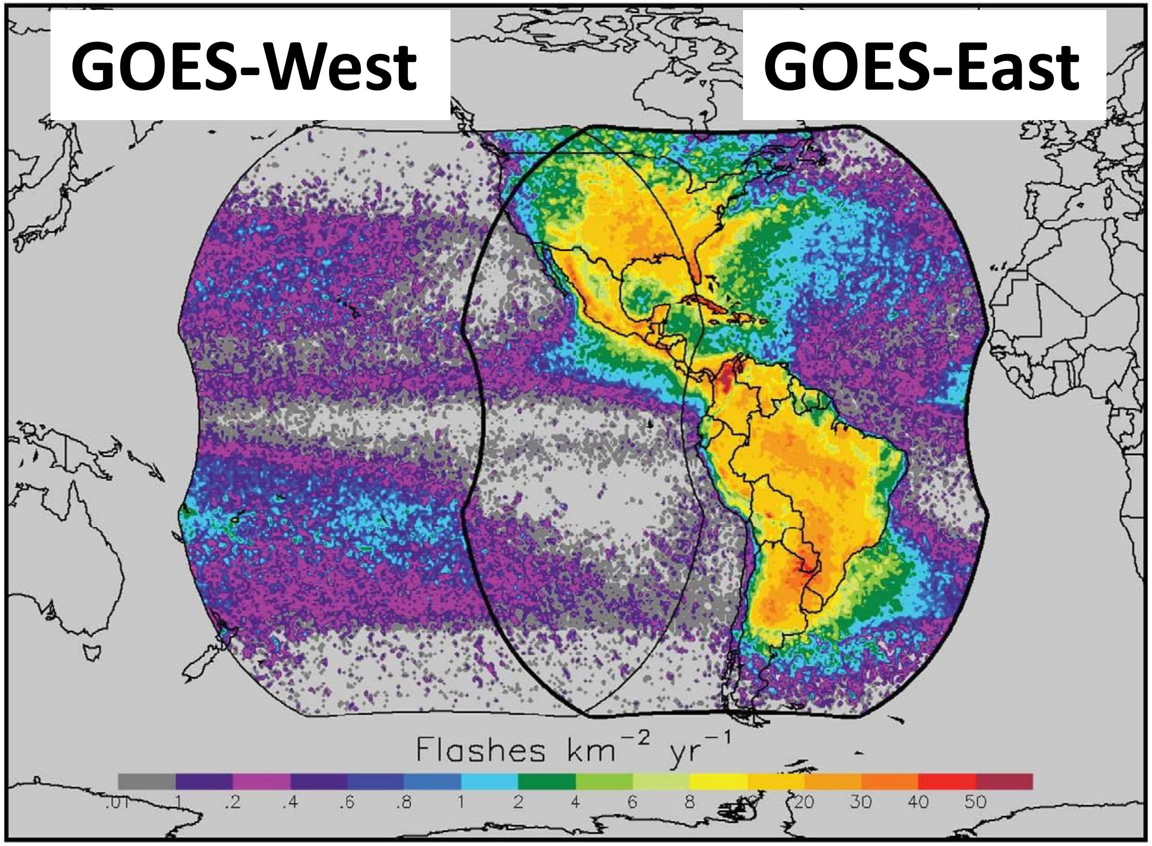
Max Marchand

Henry Fuelberg

Florida State University

GOES-R: GLM

- Geostationary Lightning Mapper
  - Continuous total lightning (IC+CG) observations
  - Scheduled launch in October 2016



Goodman et al. 2013

Lightning Data Assimilation

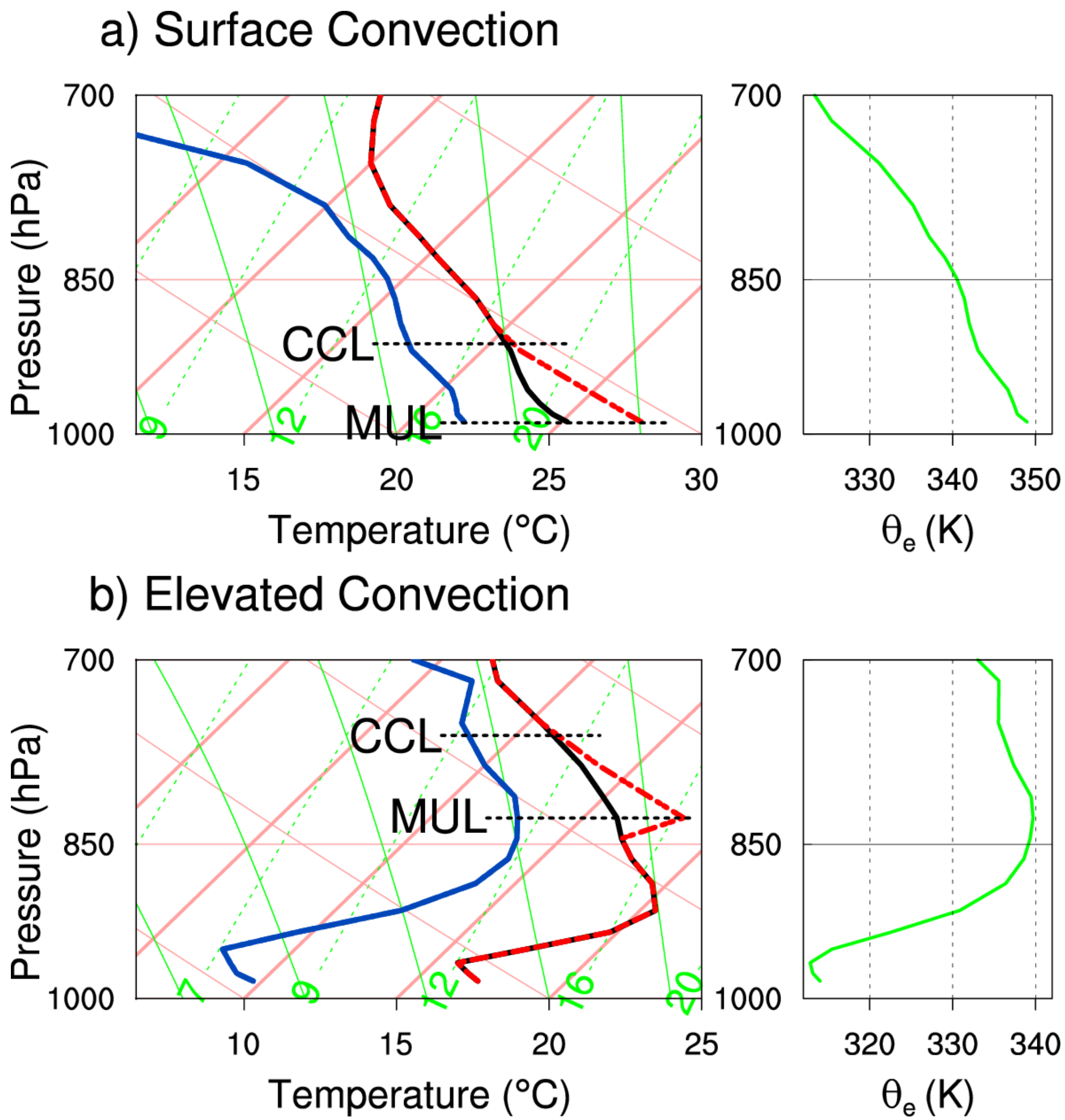
- Lightning indicates areas of deep convection
  - Related to graupel and updraft strength
- Ensemble filter and variational methods
  - Difficult to assimilate hydrometeors and vertical velocity
  - Computationally expensive
  - Mansell (2014) used EnKF at 1 km horiz. grid spacing
- Nudging
  - Typically continuous and gradual modification of model fields

Lightning Data Assimilation: Nudging

- Previous methods:
  - Increased humidity to initiate T-storms (Papadopoulos et al. 2005; Mansell et al. 2007; Fierro et al. 2012, 2014, 2015)
  - Modified mid and upper-level heating rates (Alexander et al. 1999; Chang et al. 2001; Pessi and Businger 2009; Weygandt 2008)

Marchand and Fuelberg (2014): Warming to Initiate Convection (MU)

- If maximum graupel mixing ratio < 1 g kg^{-1}, warming performed where lightning observed
- Most unstable level (MUL) accounts for elevated convection
- Generally effective at assimilating observed storms

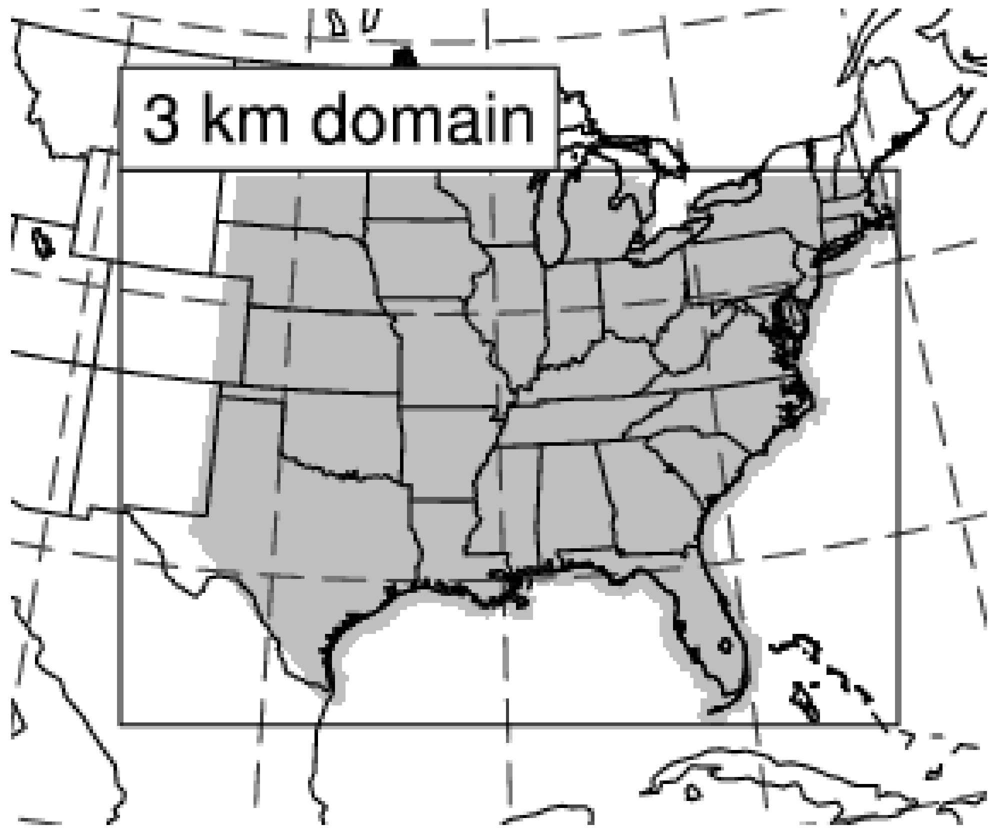


Updraft Nudging

- Lifting-based instead of heating-based thunderstorm production
- Nudging in an 10 m s^{-1} updraft for 10-15 min more effectively produced supercells than thermal bubble (Naylor and Gilmore 2012)

Implementation Overview

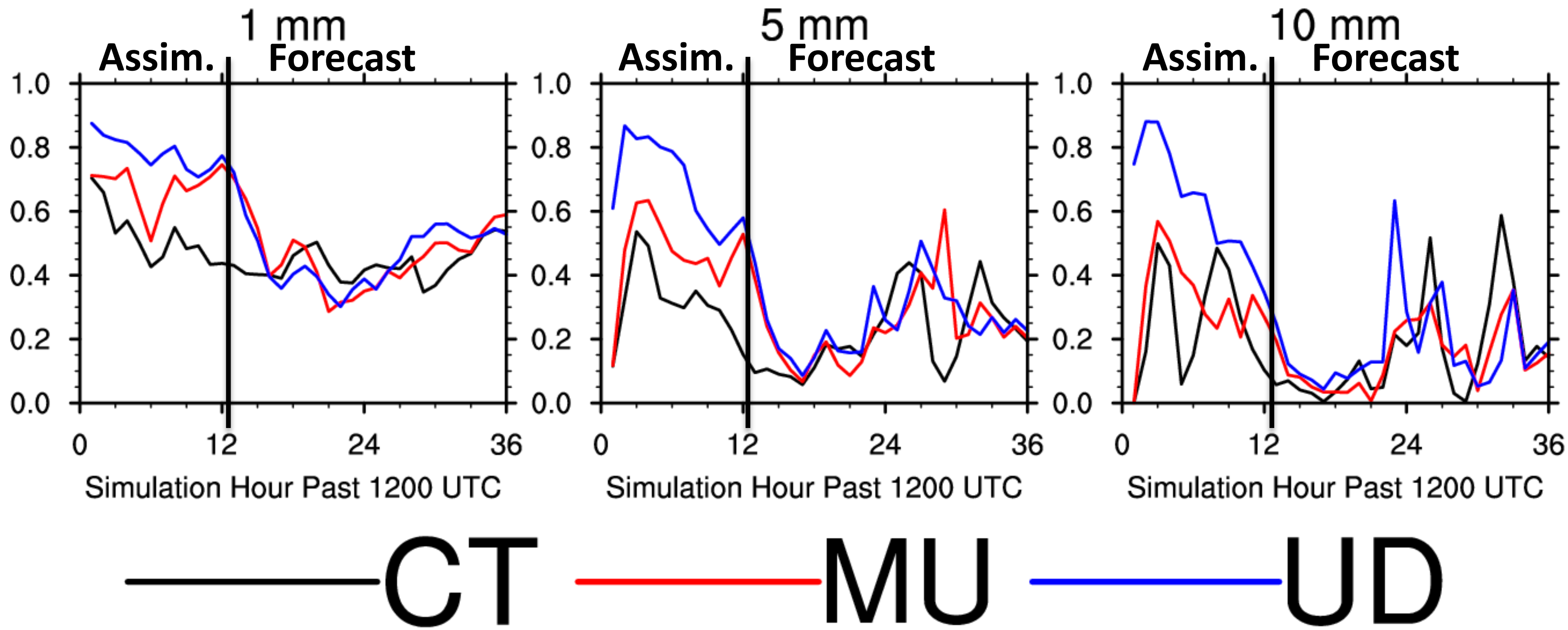
- Use of WRF-ARW numerical model with RAP ICs
- 3 domains: 27, 9, 3 km horizontal grid spacing
- ENTLN data mapped on 9 km domain (± 5 min window)
- Nudging and Verification on 3 km domain
- Comparison of hourly simulated precipitation with observed (~ 4 km NCEP Stage IV dataset)



Our Updraft Nudging Method (UD)

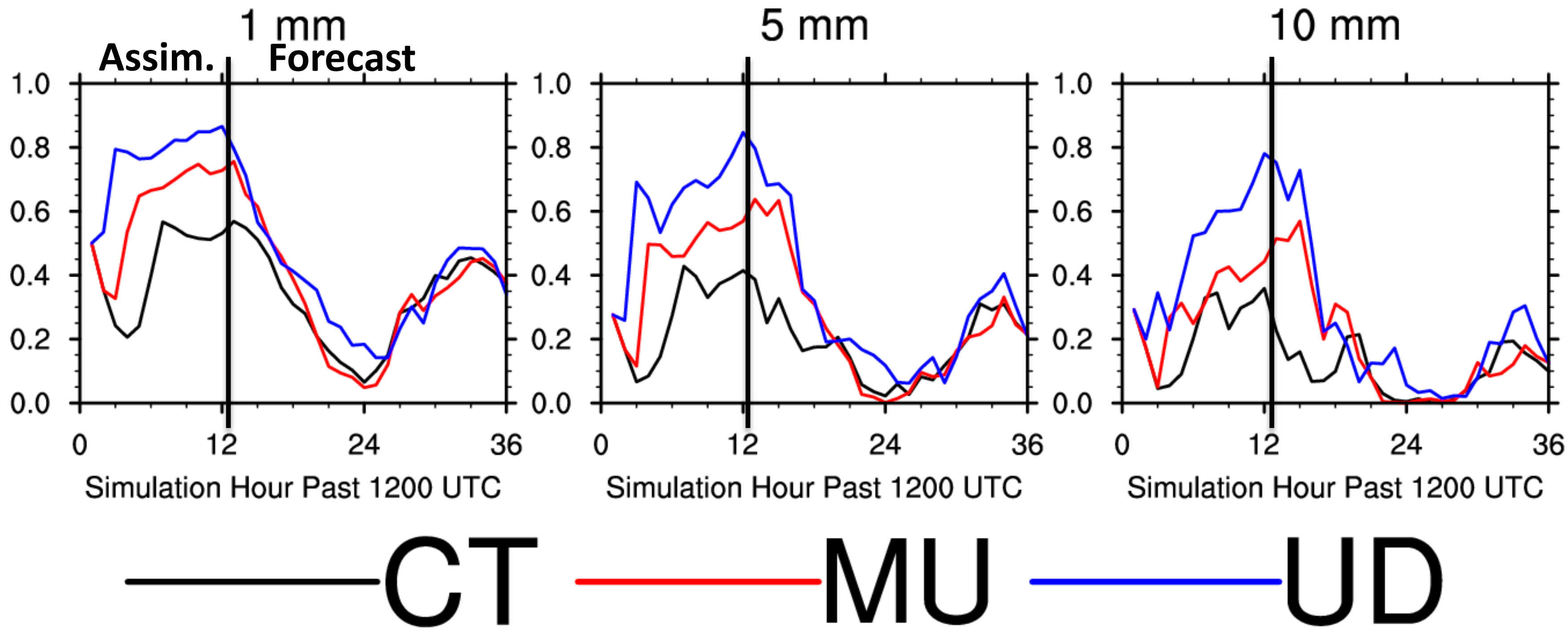
- w (in m/s) = 2.0 + 0.03*F + 0.2*$\sqrt{2\text{CIN}}$
  - where **F** is flash rate per 9 km × 9 km per 10 min
  - **CIN** is convective inhibition
- Nudge 10 model levels (~150-200 hPa) above most unstable level (MUL)
- If maximum graupel mixing ratio < 1 g kg^{-1}, nudging performed where lightning observed
- Relaxation time scale: 2 s
  - Warming method (MU) used 100 s

8 April 2015 Case: FSS (r=60 km)



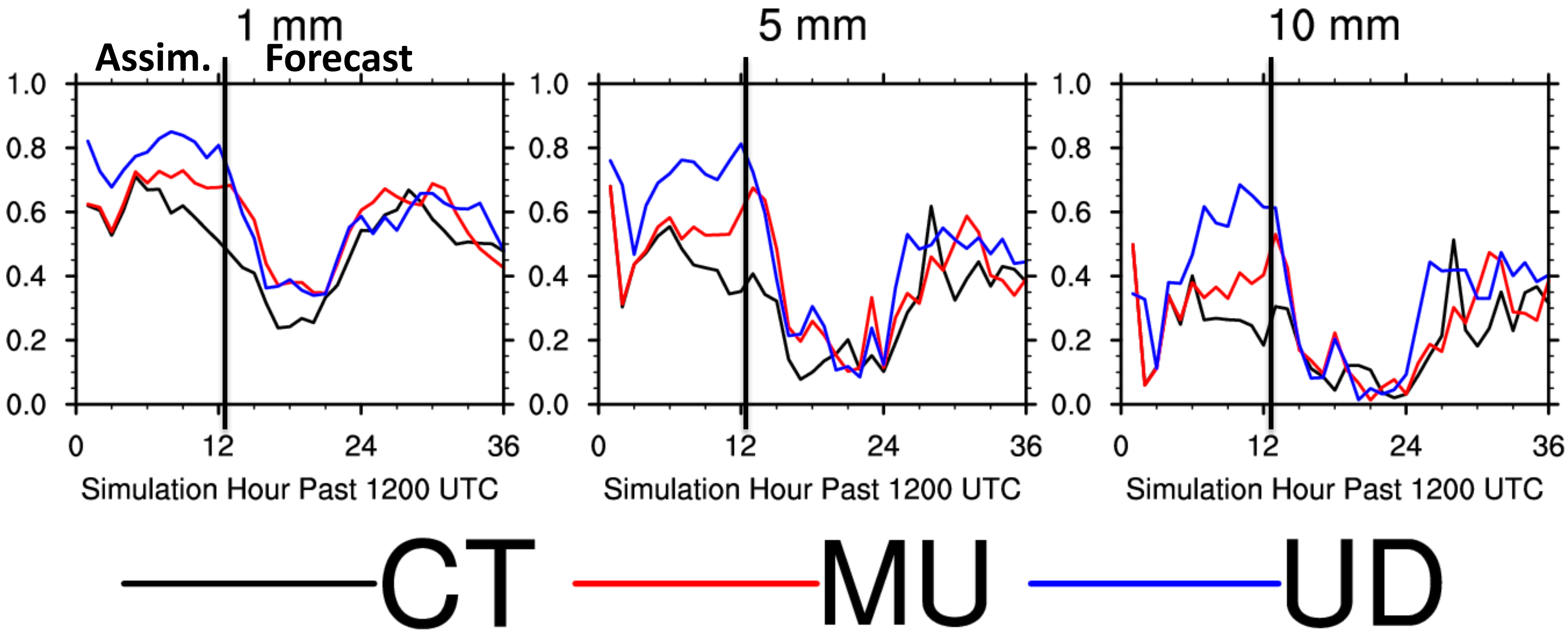
- Fractions skill score
  - Neighborhood verification method for precipitation
  - Penalizes small displacement errors less than threat score
- UD better than MU during assimilation
- MU generally better than CT during assimilation

28 May 2015 Case: FSS (r=60 km)



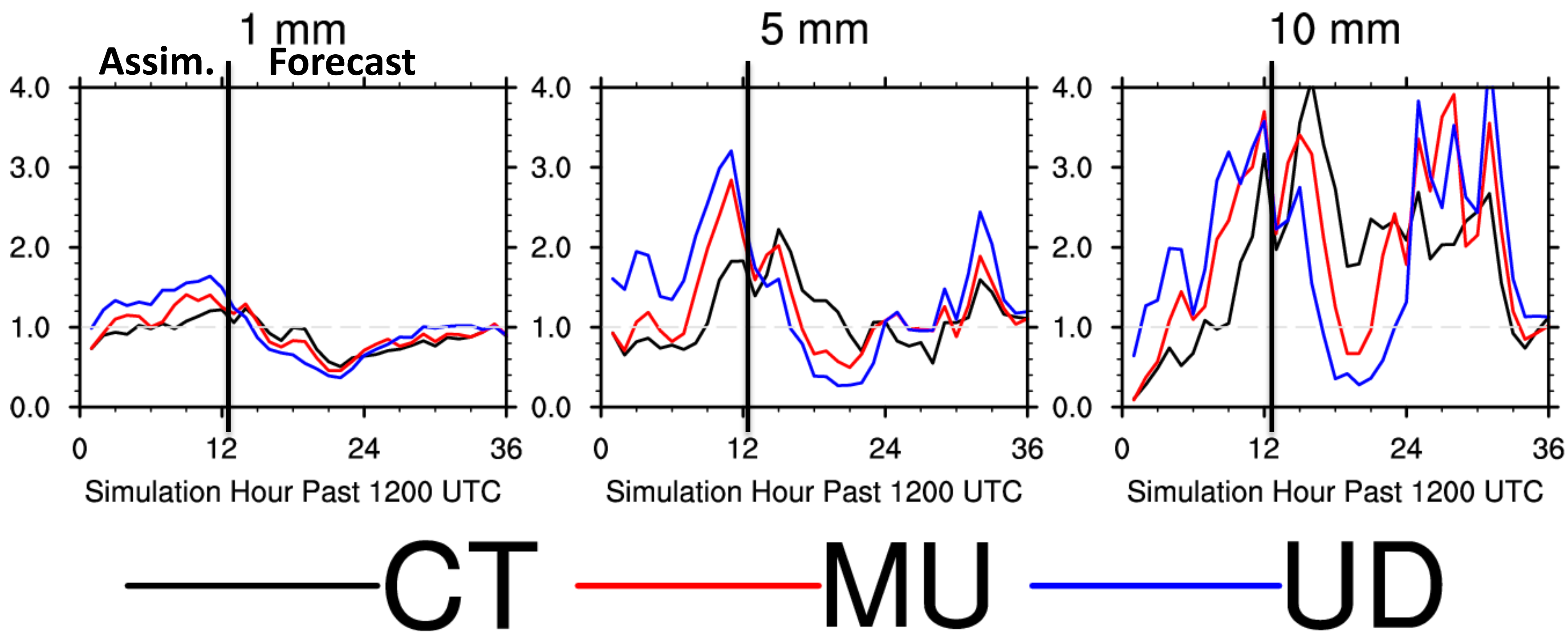
- UD better than MU during assimilation
- MU better than CT during assimilation
- Longer lasting improvement during forecast period

8 June 2015 Case: FSS (r=60 km)



- UD better than MU during assimilation
- MU generally better than CT during assimilation
- Improvement wanes after ~8 h for 1 and 5 mm

8 April 2015 Case: Bias



- UD overpredicts precipitation during assimilation
- UD underpredicts after assimilation for ~12 h
- UD near CT during last 12 h
- Similar pattern for other cases

Conclusions

- Updraft nudging effective at producing observed storms
- UD generally outperforms MU (greater FSS)
- UD still produces wet bias
- Low-level warming (MU) produces storms 25-40 minutes after initial assimilation
- Updraft nudging (UD) produces storms 10-20 minutes after initial assimilation

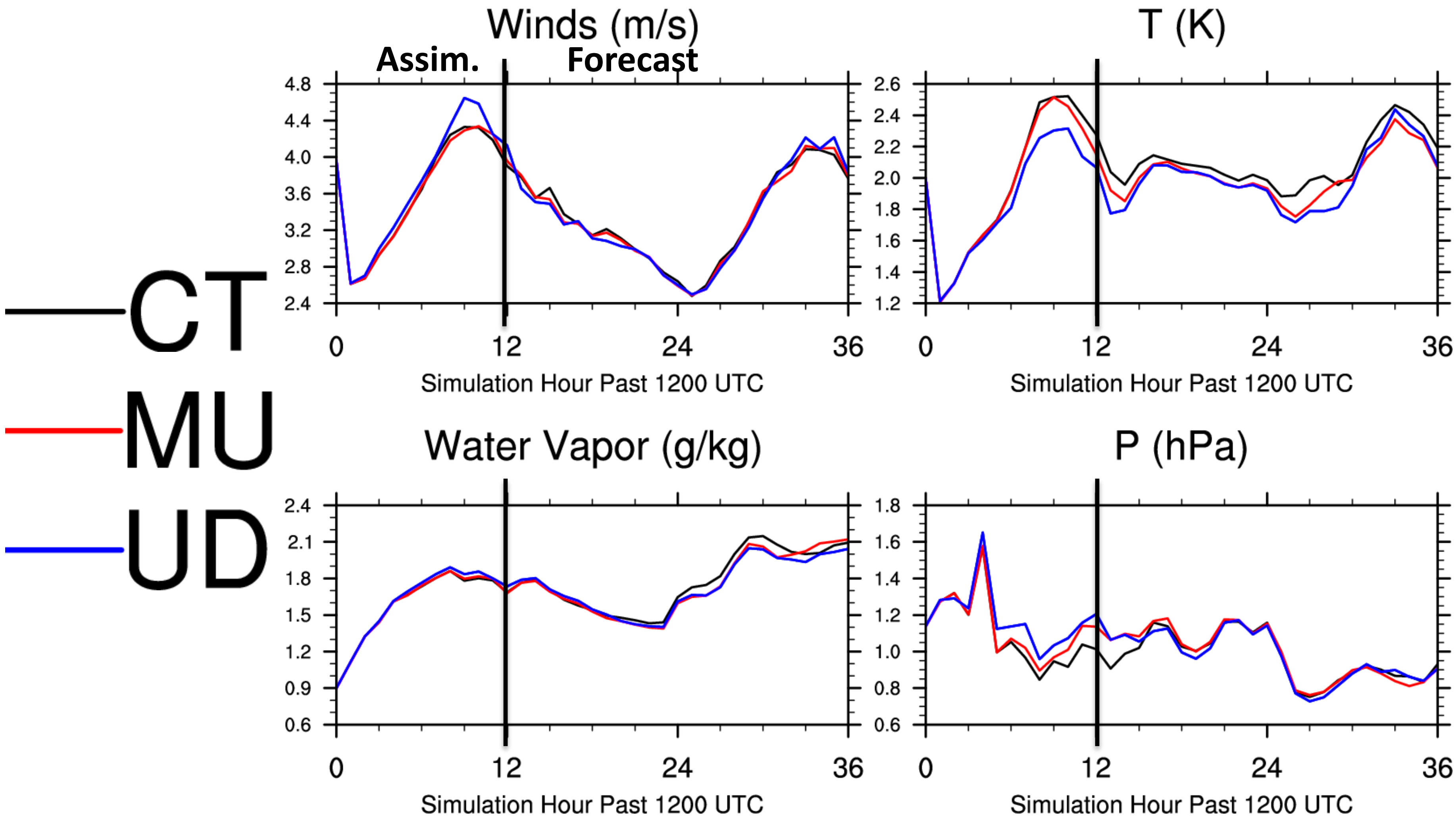
Acknowledgement

JCSDA for access to JIBB computing system

Questions?

Email: mrm06j@my.fsu.edu

8 June 2015 Case: METARs (RMSE)



- UD produces greater wind/pressure errors
- Errors disappear after assimilation