NOAA Satellite Science Week,
Kansas City, MS, April 30-May 4, 2012

Risk Reduction Annual Meeting
Data Assimilation and other RR Activities

Utility of GOES-R Geostationary Lightning Mapper (GLM) using Hybrid Variational-Ensemble Data Assimilation in Regional Applications

Milija Zupanski[1], Karina Apodaca[1], Man Zhang[1], Louis Grasso[1], Gregory DeMaria[1] and John Knaff[2]

[1] Cooperative Institute for Research in the Atmosphere
[2] NOAA/STAR/RAMMB
Colorado State University
Fort Collins, Colorado, U. S. A.
[http://www.cira.colostate.edu/projects/ensemble/]

Acknowledgements:

- NOAA NESDIS/GOES-R

- NOAA NESDIS/JCSDA

Goal of the project

Title: **Utility of GOES-R Geostationary Lightning Mapper (GLM) using hybrid variational-ensemble data assimilation in regional applications**

Lead:

- Milija Zupanski, CIRA

Participants:

- Louis Grasso, CIRA
- John Knaff, STAR/RAMMB
- Karina Apodaca, CIRA
- Man Zhang, CIRA

Outside Collaboration:

- Stephen Lord, NCEP/EMC

Goals:

(1) **Demonstrate the utility of the GOES-R GLM in severe weather data assimilation application**.

(2) **Use NOAA operational codes and scripts:**

- WRF-NMM
- NCEP operational observations (forward GSI, CRTM)
- additional assimilation of all-sky MW satellite radiances and lightning flash rates

Year-1 milestones and accomplishments

Year-1 Milestones:

(1) Interface the WRF-NMM based data assimilation system with NOAA operational observations and MW cloudy radiances

Status: Completed

(2) Make initial evaluation of the system in application to severe weather and make benchmark experiments (without lightning data)

Status: Completed

(3) Develop/adopt the forward observation operator for lightning data and make initial evaluations

Status: Completed

(4) Present the results on the web page, and at the conferences/ workshops

Status: Completed/ongoing

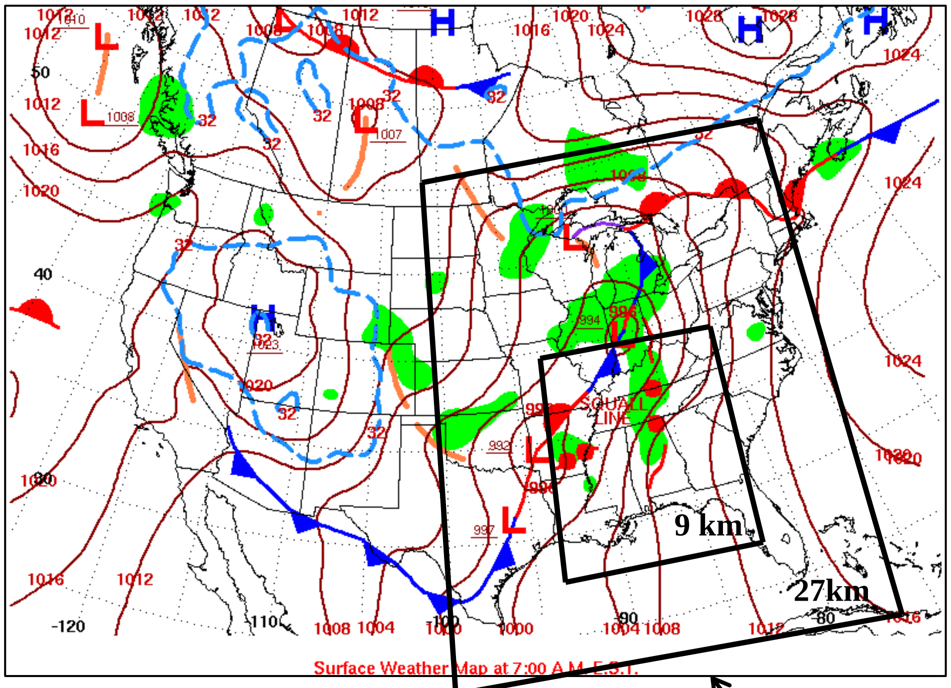
Apodaca, K., M. Zupanski, M. Zhang, M. DeMaria, L. D. Grasso, J. A. Knaff, and G. DeMaria: Evaluating the potential impact of assimilating GOES-R GLM satellite lightning observations. To be submitted to *Mon. Wea. Rev*.

Zhang, M., M. Zupanski, M.-J. Kim, and J. Knaff, 2012: Direct Assimilation of all-sky AMSU-A Radiances in TC inner core: Hurricane Danielle (2010). To be submitted to *Mon. Wea. Rev.*

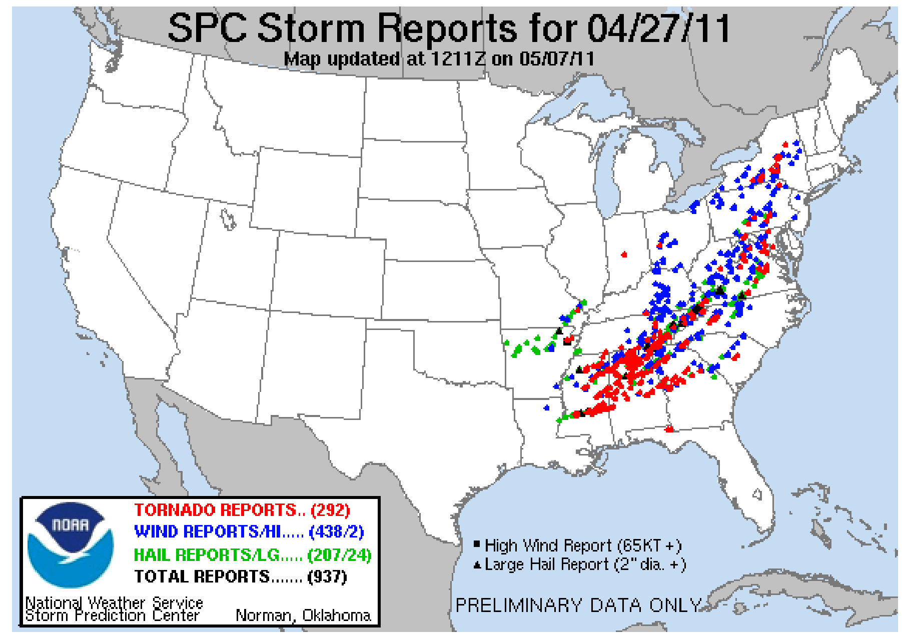
All Year-1 milestones are accomplished and the work on Year-2 milestones is underway

Severe weather outbreak over the southeastern U.S. on April 25-28, 2011

Surface map, valid 1200 UTC April 27, 2011



Tornado reports for April 27, 2011



WRF-NMM model domain and resolution

Benchmark system setup (Milestone 1)

<u>Data Assimilation system setup</u>:

- WRF-NMM model at 27km / 9km resolution
- Use Maximum Likelihood Ensemble Filter (MLEF) as a prototype HVEDAS
- 32 ensembles
- 6-hour assimilation interval
- Control variables are model predictive variables: PD, PINT, T, Q, U, V, CWM

<u>Observations</u>:

- NOAA operational observations using GSI and CRTM *forward* operators
- *All-sky AMSU-A radiances*: Use the approach originally developed by M.-J. Kim for global DA system, adapted by M. Zhang for use in regional DA system and for hurricanes

<u>Experiments</u>:

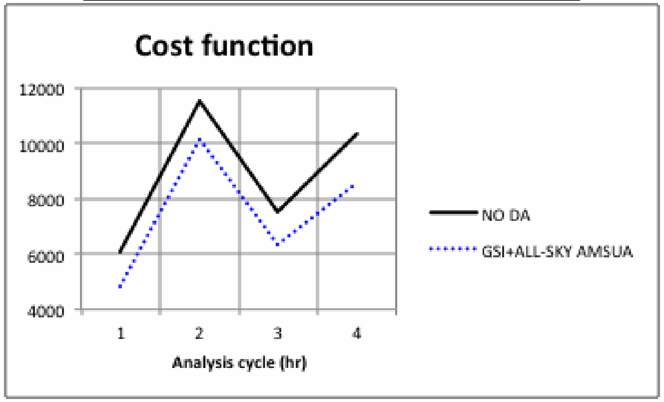
1) Benchmark experiment (without lightning observations): assimilation of NCEP operational observations AND all-sky AMSU-A MW radiances

2) Control experiment: no data assimilation

Focus on 9 km model grid

Benchmark system evaluation (Milestone 2)

Analysis

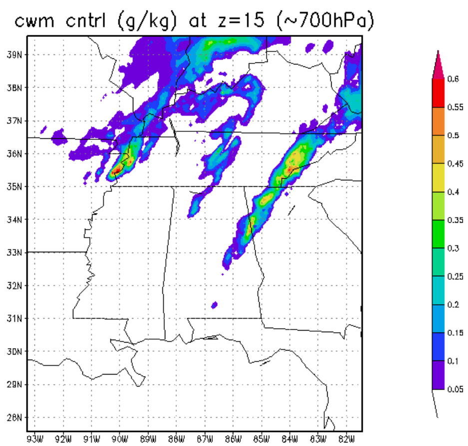


Cost function shows the combined impact of all observations

Consistent improvement in all DA cycles in the benchmark experiment

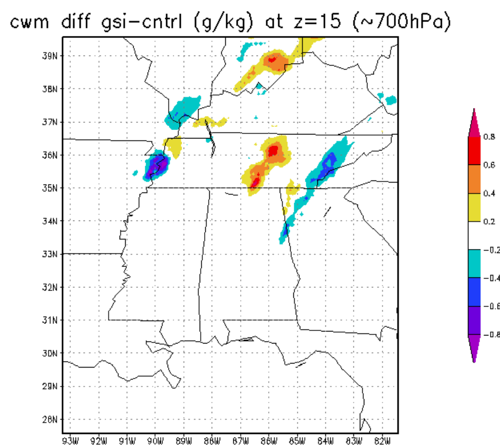
6-hour forecast (valid 0000 UTC April 28, 2011)

CWM control



GrADS: COLA/IGES

CWM difference: Benchmark - Control



GrADS: COLA/IGES

GOES-13 visible

Data assimilation indicates a strengthening of the middle cloud band, as observed

Lightning observation operator (Milestone 3)

Utilize empirical relationships between lightning flash rate and:

1- cloud properties (e.g., graupel flux, vertically integrated ice – McCaul etal. (2009))

- adequate for cloud-resolving model with explicit microphysics
- requires ensemble-based (or hybrid) DA error covariance for cloud control variables

2- maximum vertical velocity

- adequate for model with simple (e.g., bulk) microphysics or convective parameterization
- applicable to standard DA (e.g., 3D-Var) with dynamical control variables only

- **For current applications with WRF-NMM at 9 km use approach (2)**

$$f = \alpha \times w_{max}^{\beta}$$

$$\alpha = 3 \times 10^{-4} \left[\frac{hour}{km^2}\right]^{3.5}$$

$$\beta = 4.5$$

- **For future applications with HRRR WRF in high resolution use approach (1)**

LIGHTNING OBSERVATION OPERATOR (MILESTONE 3)

Observations: Create lightning flash rate “super-observations” at 0.1 degree (~10 km) resolution by calculating the number of flashes per square km per hour

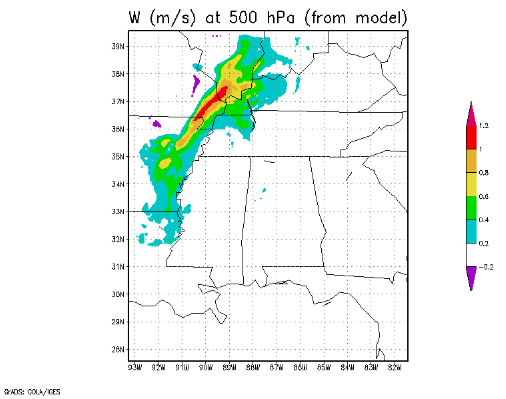
Forecast guess: Calculate w_{max} from approximate vertical velocity

$$w = \frac{1}{g}\left(\frac{\partial\Phi}{\partial t} + v\cdot\nabla_\sigma\Phi + \dot{\sigma}\frac{\partial\Phi}{\partial\sigma}\right)$$

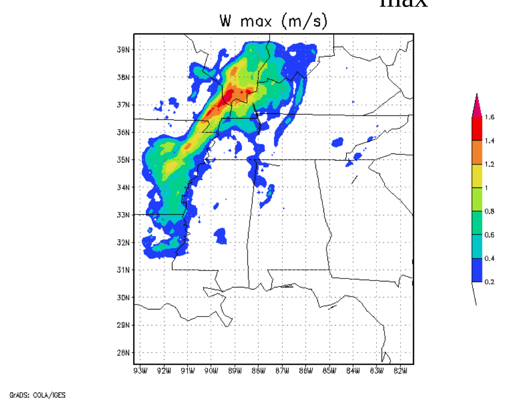
Time tendencies not calculated, used from the model output

Advection terms calculated using reduced WRF-NMM codes

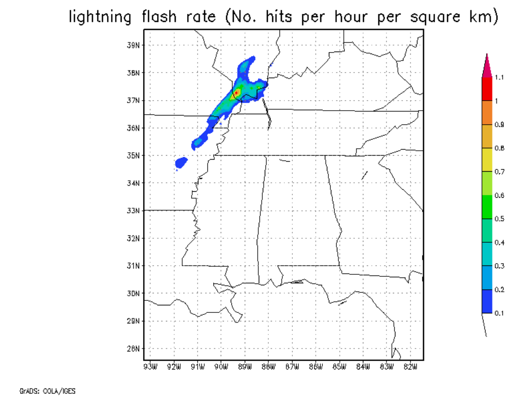
Model-produced w at 500 hPa



Calculated w_{max}



Lightning flash rate



Calculated w_{max} agrees with the actual WRF-NMM model output

ACCOMPLISHMENTS ANTICIPATED AT END OF YEAR 2

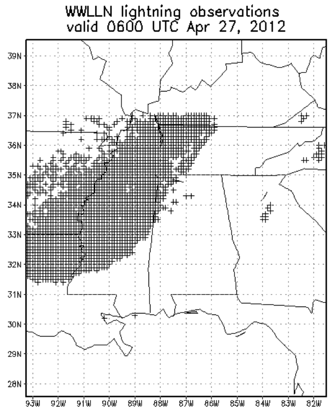
(1) **Combine all components into a complete HVEDAS, including the lightning observations, and compare the complete system with the benchmark system.**

(2) **Evaluate the impact of GOES-R GLM observations in severe weather.**

(3) **Produce lightning forecast using WRF-NMM.**

Preliminary results: **Assimilation of WWLLN lightning observations using WRF-NMM**

WWLLN Observations



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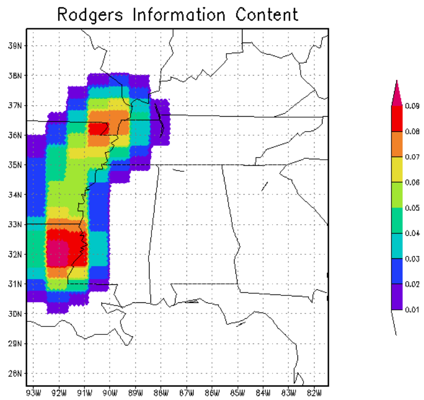
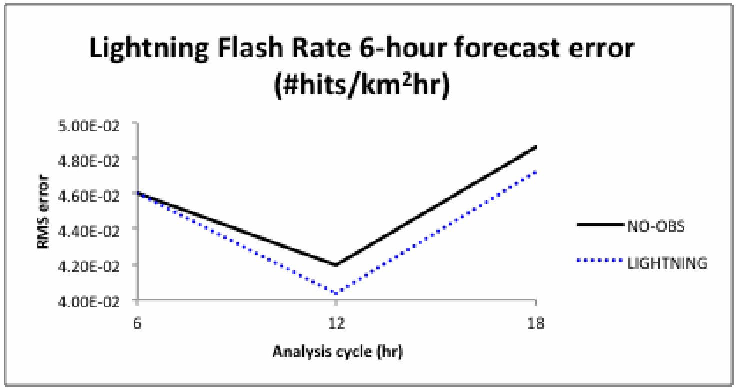
Information content



Forecast RMS error



- **Information content shows the utility of lightning observations in the analysis**
- **6-hour WRF-NMM forecasts improved due to lightning observations**

What could be accomplished with a 3rd year of funding?

1- Possibility of utilizing GLM lightning observations in operational data assimilation:

- Vertical velocity in WRF-NMM is a function of standard model predictive variables
- This means that lightning observations impact PD, T, Q, U, V initial conditions
- Straightforward application with current operational GSI
- Operational use of lightning observations is straightforward, it does not require complex new development!

❖ **Great opportunity to add lightning observations to current operational data assimilation!**

2- Prepare for future assimilation of GLM and the use with HRRR WRF

- Use lightning observation operator based on cloud microphysics (McCaul etal.)
- Adjust DA for new (e.g., cloud) control variables

Summary

- WRF-NMM model with regional prototype HVEDAS
  - assimilated operational observations
  - assimilated all-sky AMSU-A radiances
  - forward GSI and CRTM

- Assimilation of WWLLN lightning flash rate observations
  - positive impact on the 6-hour WRF-NMM forecast
  - opportunity for immediate applications in operations

Future Work

- Demonstrate the utility of GLM (proxy) observations in regional DA
  - in-depth experiments with assimilation of all available data, including lightning and all-sky radiances
  - include assimilation of lightning observations in hurricane DA (HWRF)

- Prepare for possible use in current operational DA (in collaboration with NOAA)
  - enhance GSI (and HVEDAS) capability by adding lightning observations
  - assist NOAA in preparation for assimilation of lightning assimilation

- Prepare for future GLM assimilation with HRRR WRF
  - add cloud microphysics-based lightning observation operator