Assimilation of GOES-R GLM Lightning Data and Cloud-Top Cooling Information in the High-Resolution Rapid Refresh Analysis and Forecasting System

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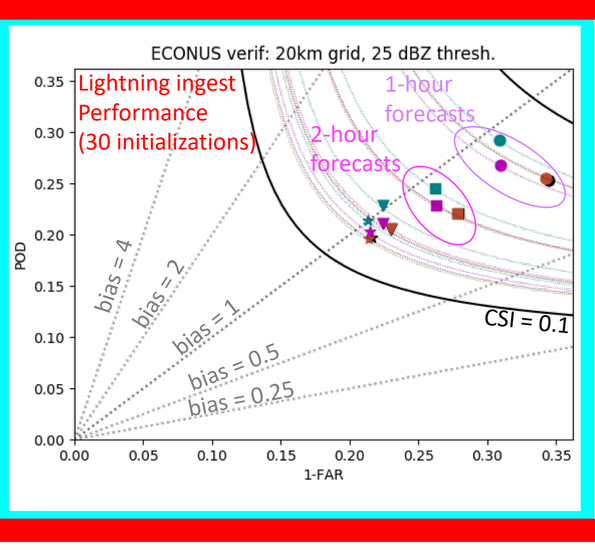
The High Resolution Rapid Refresh (HRRR) is a convection-resolving hourly-updated model run operationally by NOAA to provide detailed forecast guidance for thunderstorms and other hazardous weather. Convective weather phenomena are initialized within the HRRR via a latent-heating adjustment procedure, relying primarily on radar reflectivity observations, to provide realistic and accurate short-term severe weather forecasts. Radar reflectivity observations are augmented by lightning observations from ground-based sensing networks to enhance heating at convective cores and to supplement areas of low radar coverage.

The Geostationary Lightning Mapper (GLM) instruments onboard the GOES-16 and GOES-17 satellites provide continuous detection of total lightning throughout the HRRR domain and surrounding areas at about a 10-km resolution. The satellite data further complement reflectivity and ground-based lightning detections for storms over data sparse regions (primarily oceanic regions adjacent to North America for the RAP/HRRR systems), offering improved capability to determine the extent and intensity of storms in these areas. In experimental HRRR configurations, we augment the assimilation of ground-based lightning data with that of GLM by merging the two datasets prior to ingest.

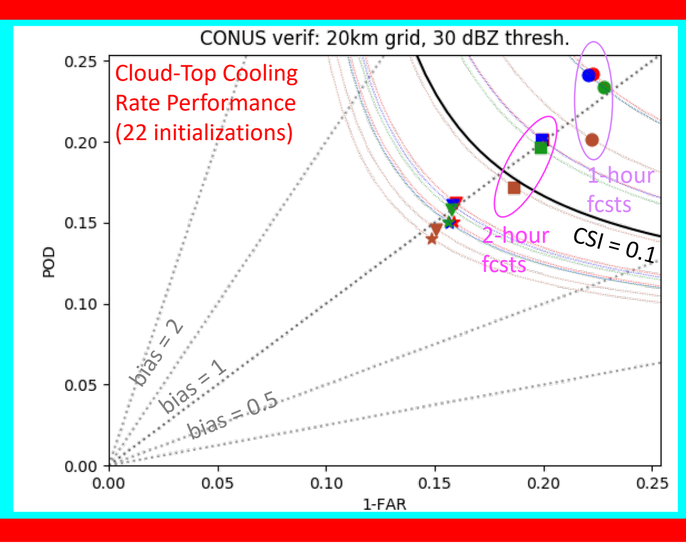
Another new source of information regarding the onset of convective weather is the SATCAST product developed at U. Huntsville. The product includes cloud object tracking and cloud-top cooling rates (CTCR) derived from GOES-R ABI products; high rate of cooling indicates rapid cloud top rise and developing convection. These data can be used to identify nascent storms earlier than high radar reflectivity or dense lightning can be observed. The CTCR data are assimilated experimentally into HRRR using the same latent-heating scheme used to assimilate radar and lightning and show benefit in representation of storms that are just initiating at analysis time.



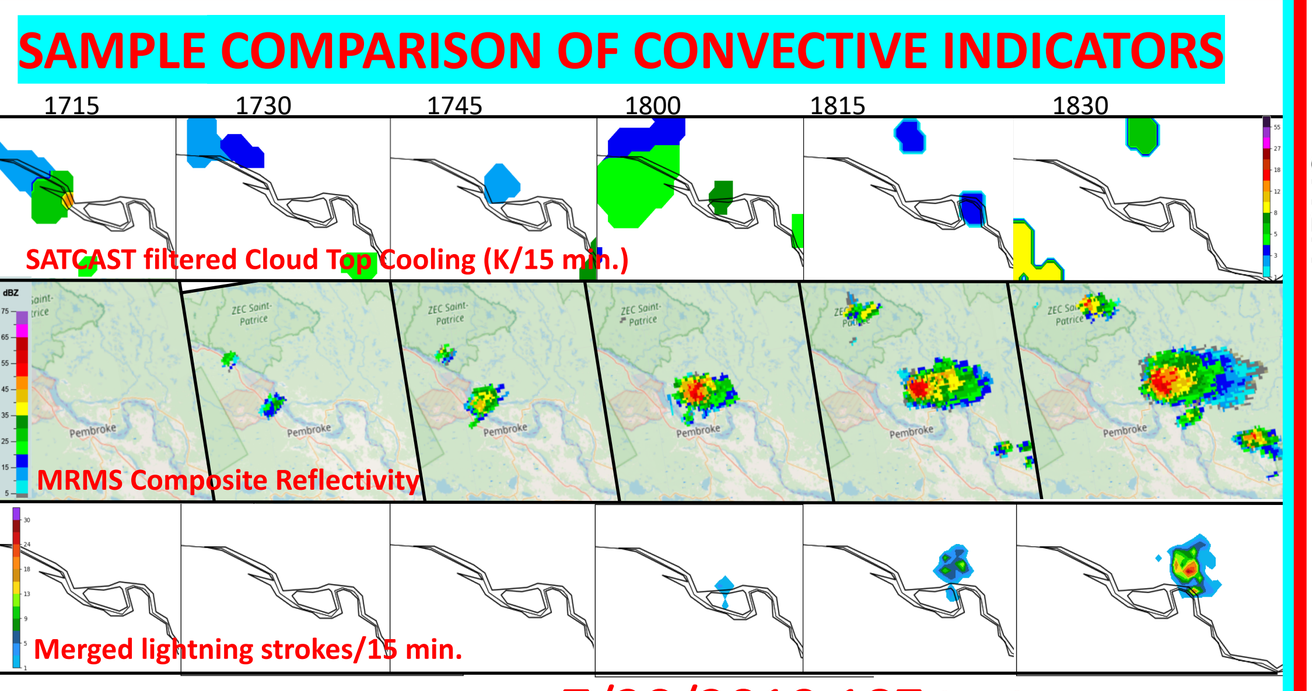
- 30 forecasts initiated 15Z -- 0Z, Jul 19-22 2019 (22 forecasts for SATCAST tests)
- Experimental configurations:

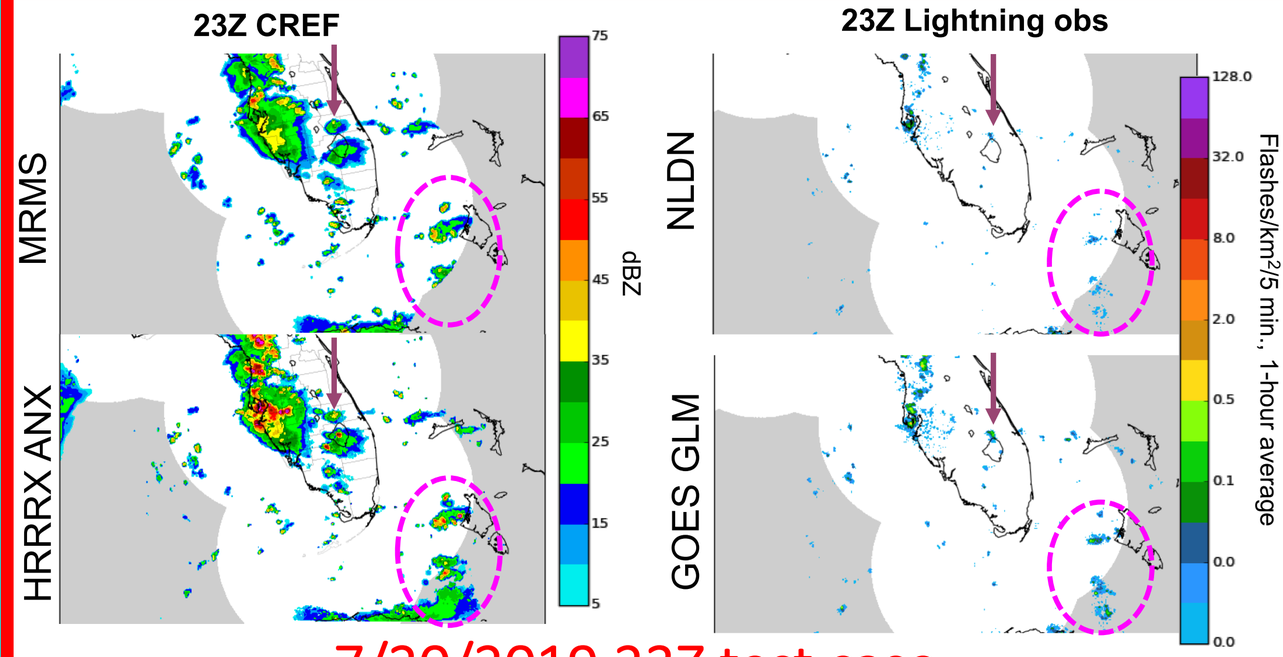
No lightning ingest	Merged NLDN+GLM	CTCR ingest, GOES-16
NLDN lightning	Merged lightning dilated to neighboring grid points	CTCR ingest, GOES 16 +17
NLDN lightning dilated to neighboring grid points		CTCR filtered by SATCAST CI prob.

- **Merged lightning** data: **Merge** GLM groups to NLDN strokes (Bitzer & Burchfield, 2016) then **cluster** into flashes
  - Merging thresholds similar to Bitzer & Burchfield and others (merging LIS to ground-based sensing networks): 20 km and10 ms
  - Flash clustering similar to Vaisala for NLDN (ground-based detections)



SAMPLE COMPARISON OF CONVECTIVE INDICATORS

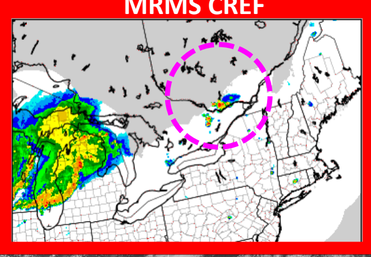


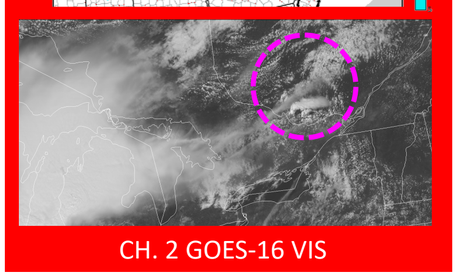


7/20/2019 18Z test case

19Z Observations

MRMS CREF

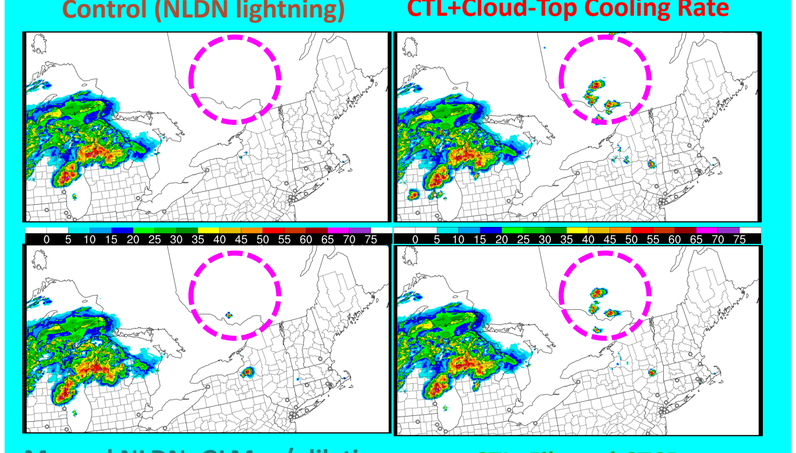




CH. 2 GOES-16 VIS

1 hour forecast CREF valid 19Z

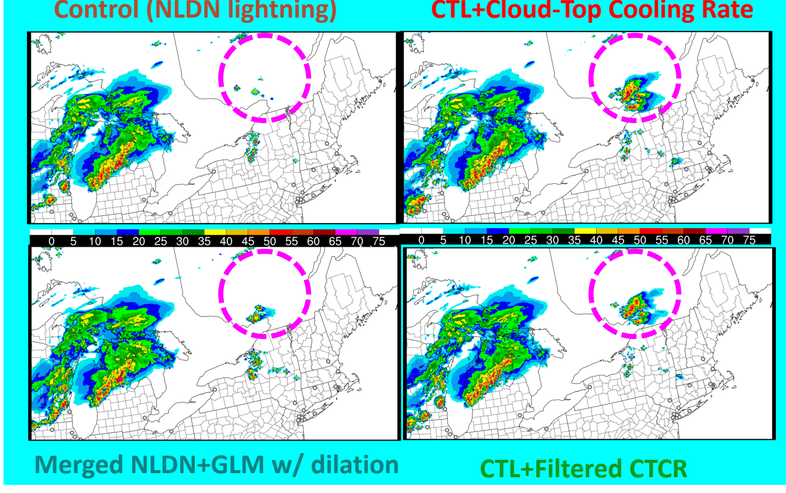
Control (NLDN lightning) | CTL+Cloud-Top Cooling Rate



Merged NLDN+GLM w/ dilation | CTL+Filtered CTCR

3 hour forecast CREF valid 21Z

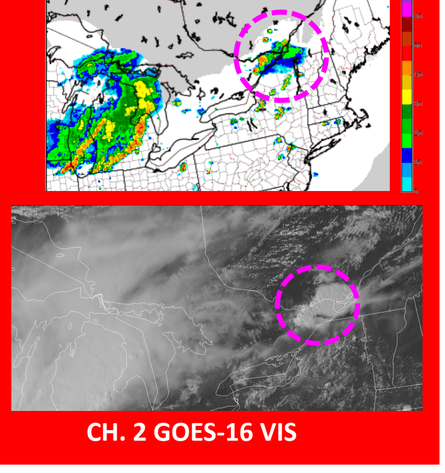
Control (NLDN lightning) | CTL+Cloud-Top Cooling Rate



Merged NLDN+GLM w/ dilation | CTL+Filtered CTCR

21Z Observations

MRMS CREF

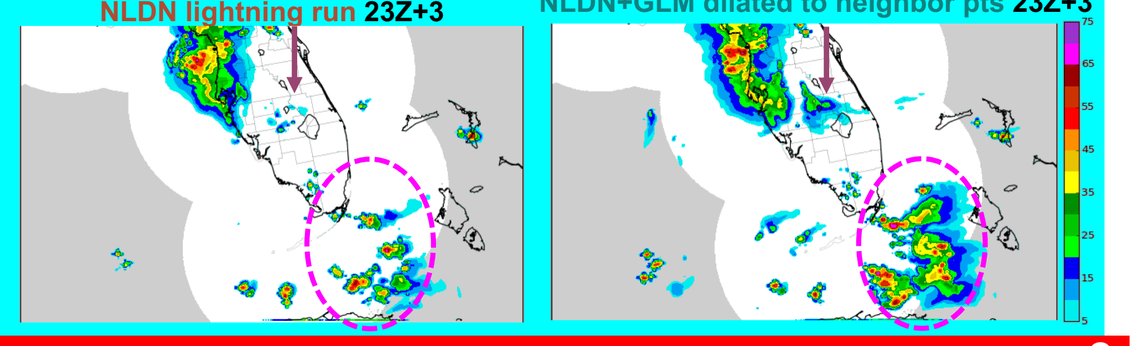


CH. 2 GOES-16 VIS

7/20/2019 23Z test case

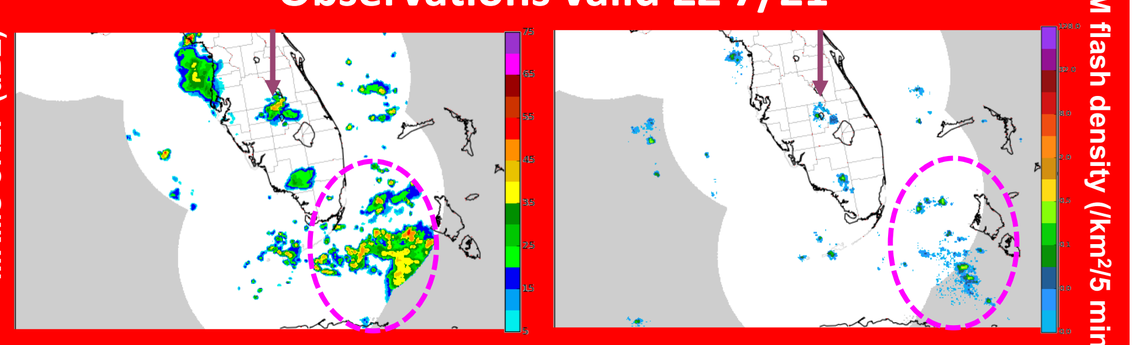
3 hour forecast CREF valid 2Z 7/21

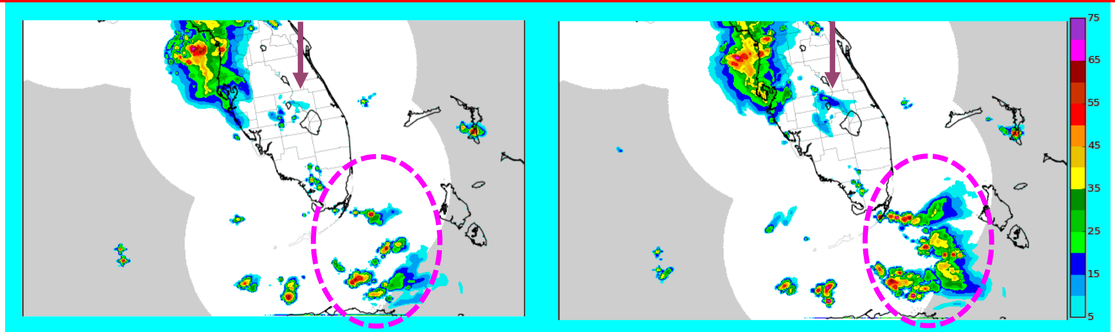
NLDN lightning run 23Z+3 | NLDN+GLM dilated to neighbor pts 23Z+3



Observations valid 2Z 7/21

MRMS CREF (dBZ) | GLM flash density (/km²/5 min)





NO lightning run 23Z+3 | NLDN dilated to neighbor pts 23Z+3

SUMMARY

- Experiments conducted assimilating novel satellite-based convection indicators into the High Resolution Rapid Refresh over a 3 day period, July 2018 using latent heating adjustment procedure
- Quantitative verification indicates both observation types increase forecast skill
- Cases studied show **GLM lightning detections improve storm representation outside radar range**
- Cases studied show **SATCAST cloud-top cooling rate improves storm representation earlier than radar detections**

FUTURE WORK

- Currently conducting experiments to further illustrate skill for other seasons and regions of CONUS
- Real-time ingest in experimental HRRR maintained by NOAA/ESRL to commence shortly
- Finalizing parameters for GLM merging/dilation
- Evaluating alternatives to latent heating scheme for future operational implementations
- **GLM and CTCR ingest capabilities transition to operations with 1st operational RRFS implementation (~2023)**

FURTHER READING

Bitzer, P.M. and Burchfield, J.C., 2016. Bayesian techniques to analyze and merge lightning locating system data. *Geophysical Research Letters*, *43*(24), pp. 12,605-12,613.

Mecikalski, J. R. and Bedka, K. M., 2006. Forecasting Convective Initiation by Monitoring the Evolution of Moving Cumulus in Daytime GOES Imagery. *Monthly Weather Review*, 134(1), pp. 49-78.

Thanks to E. Szoke and D. Bikos (CIRA) for GOES-16 ABI imagery