Impact of Assimilating GOES-R GLM Flash Extent Density in NSSL's Warn-on-Forecast System for Severe Weather Forecast

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Introduction

The GOES-R GLM lightning data:

- Total lightning rate with high temporal and spatial (8-12 km) resolution.

- A good indicator of deep electrified convection, and well correlated with graupel and ice content, updraft intensity, and rainfall amount in storm cells.

- Complement to ground-based networks.

The NSSL Warn-on-Forecast System (WoFS) :

- Reginal, storm scale, on-demand, rapidly-updated ensemble data assimilation (DA) and prediction system.

- GSI-EnKF; WRF model V3.8

- 15 min updates; 36 members; 250 x 250 or 300 x 300 grid, dx = 3 km

- Initial and boundary conditions: GSD's experimental HRRRE

- Microphysics: NSSL two-moment scheme; Boundary layer: MYNN, YSU, MYJ

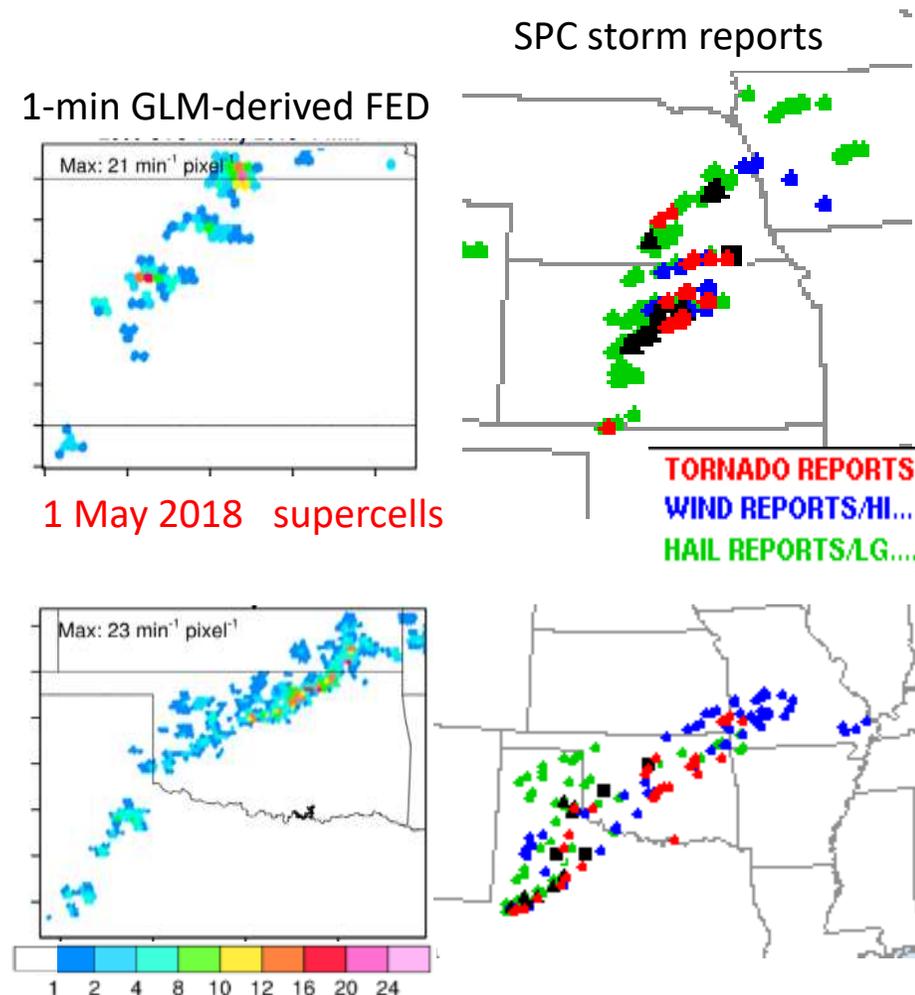- Assimilated observations: NCEP prebufr, Mesonet, satellite cloud water path, radar data

Methods

- 1-min accumulated GLM-derived flash extent density (FED) (including zero value): number of flashes passing through a grid box about 10 x 10 km^2, processed using *glmtools* package (Bruning, 2019)

- DA cycles at 15-min intervals

- **Observation operator** (Allen et al., 2019; Kong et al., 2020):

  FEDM = 0.5 $\times$ 2.088 $\times 10^{-8}$(GM).

  GM: vertically integrated graupel mass in a 15×15 km^2 box

- **observation error**: 0.5 flash min^{-1} pixel^{-1} ; FED height: 6.5 km

- **Additive noise**: add random perturbation in and near the regions where FED > 1 min^{-1} pixel^{-1}

- 3-hr forecasts

Experiment	Data being assimilated
CTRL	NCEP prebufr, Mesonet, satellite cloud water path
GLM	same as "CTRL", but additional GLM FED
RAD	same as "CTRL", but additional radar data
RAD+GLM	same as "RAD", but additional GLM FED

	DA window	Forecast window
1 May 2018	1800–0300 UTC	2100–0300 UTC
20 May 2019	1700–0100 UTC	1900–0100 UTC

1-min GLM-derived FED

SPC storm reports

Max: 21 min^{-1} pixel^{-1}

1 May 2018   supercells

TORNADO REPORTS
WIND REPORTS/HI....
HAIL REPORTS/LG....

Max: 23 min^{-1} pixel^{-1}
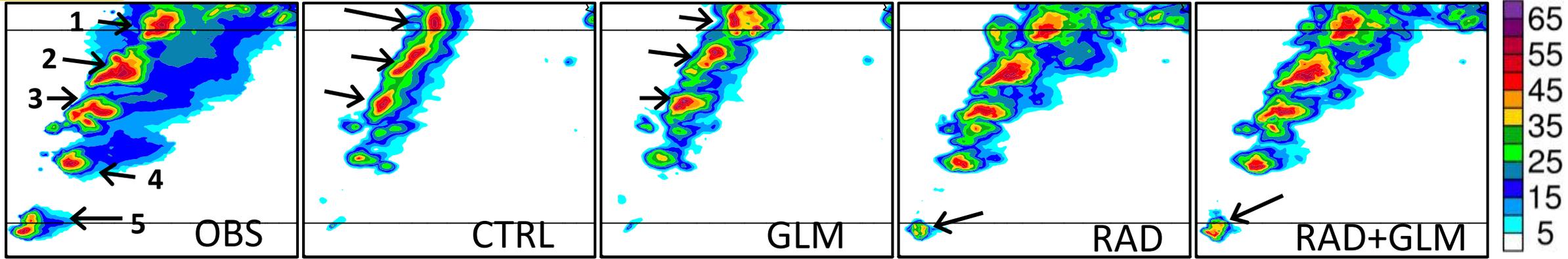
1   2   4   8   10 12 16 20 24

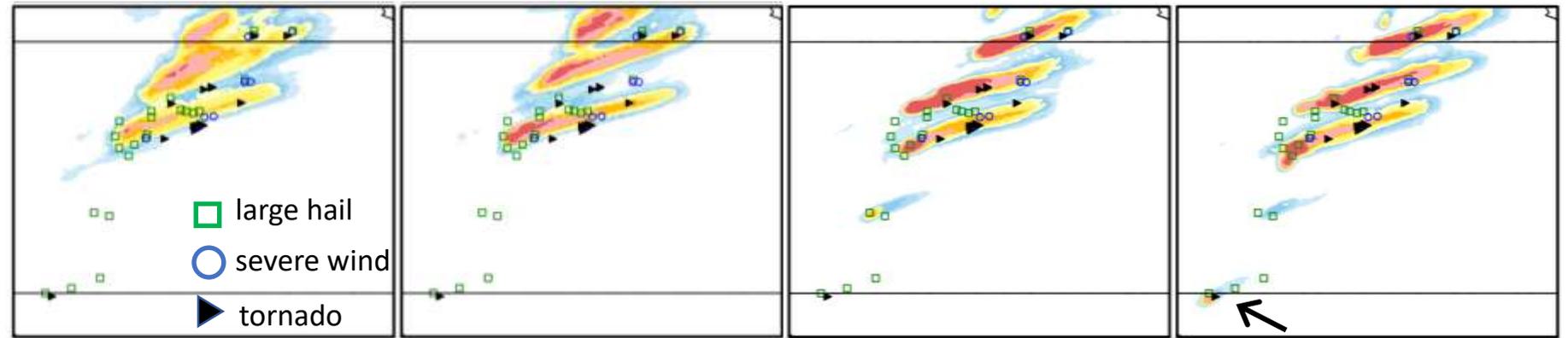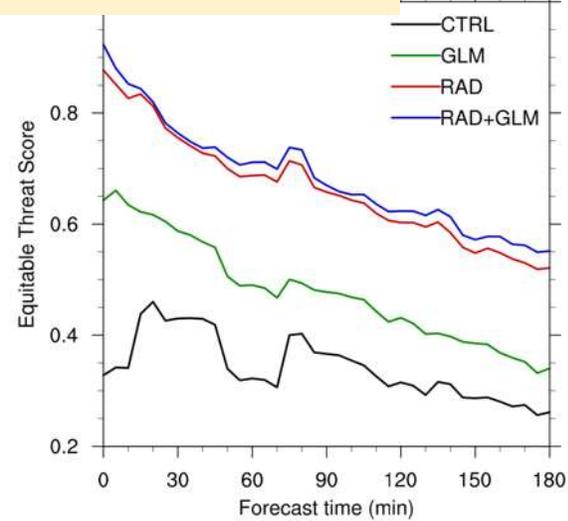20 May 2019 Mesoscale convective system (MCS)

Results

Case 1 May 2018 supercell

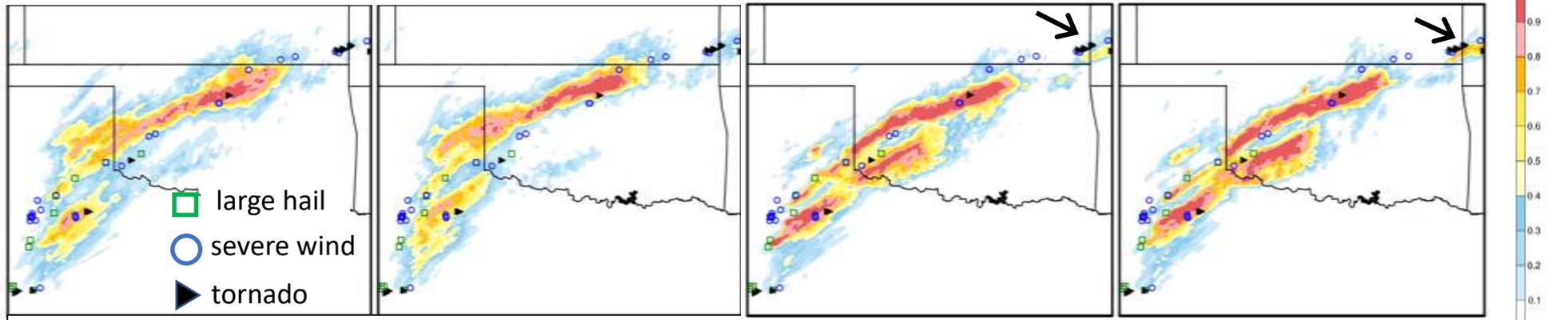Analyzed PMM composite reflectivity at 2300 UTC

ETS of Refl>40 dBZ
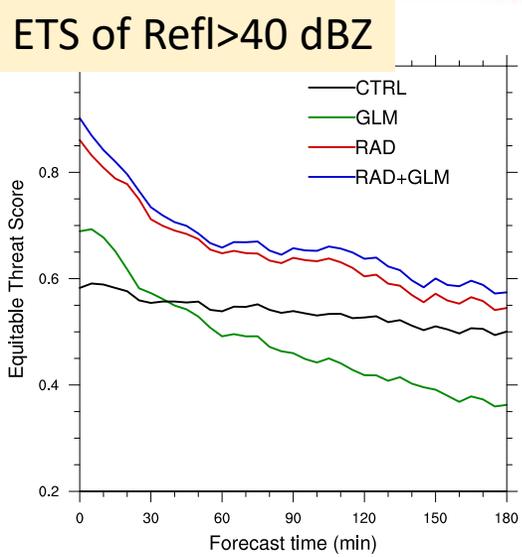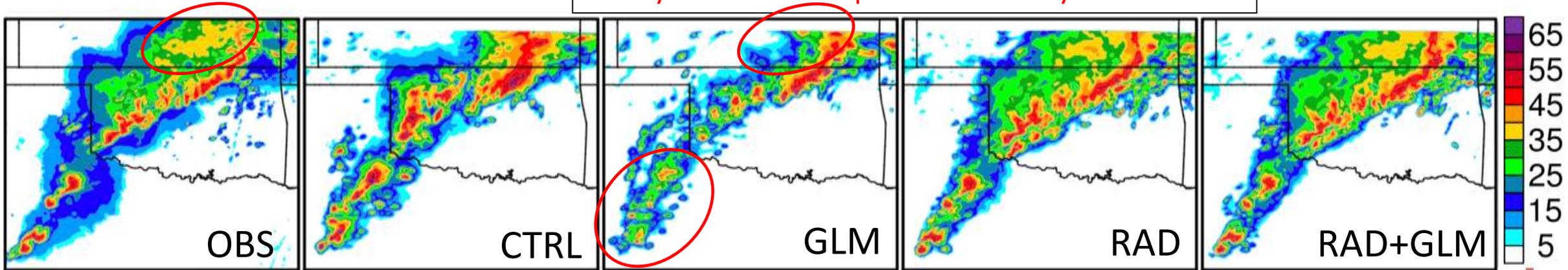
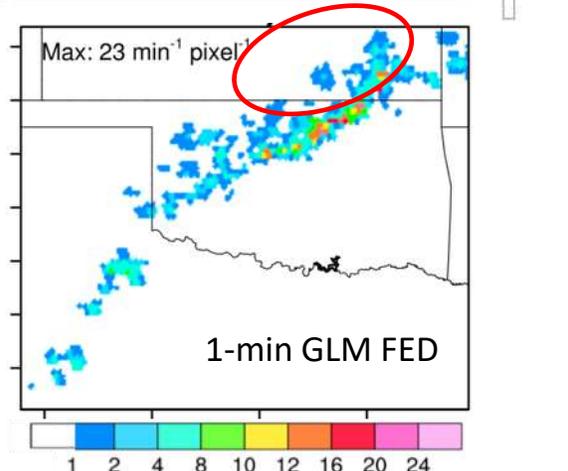Probability of 2-5 km UH >60 $m^2 s^{-2}$ from 3-hr forecast initiated at 2300 UTC

- ➢ **With or without radar data, assimilating GLM data better captures the features of individual supercells.**
- ➢ **Assimilating GLM data better predicts the storm tracks.**
- ➢ **Radar data improves the analyses and forecasts more significantly.**

Case 20 May 2019 MCS

Analyzed PMM composite reflectivity at 0000 UTC

OBS   CTRL   GLM   RAD   RAD+GLM

ETS of Refl>40 dBZ

- large hail
- severe wind
- tornado

Probability of 2-5 km UH > 60 m² s⁻² from 3-hr forecasts initiated at 2100 UTC
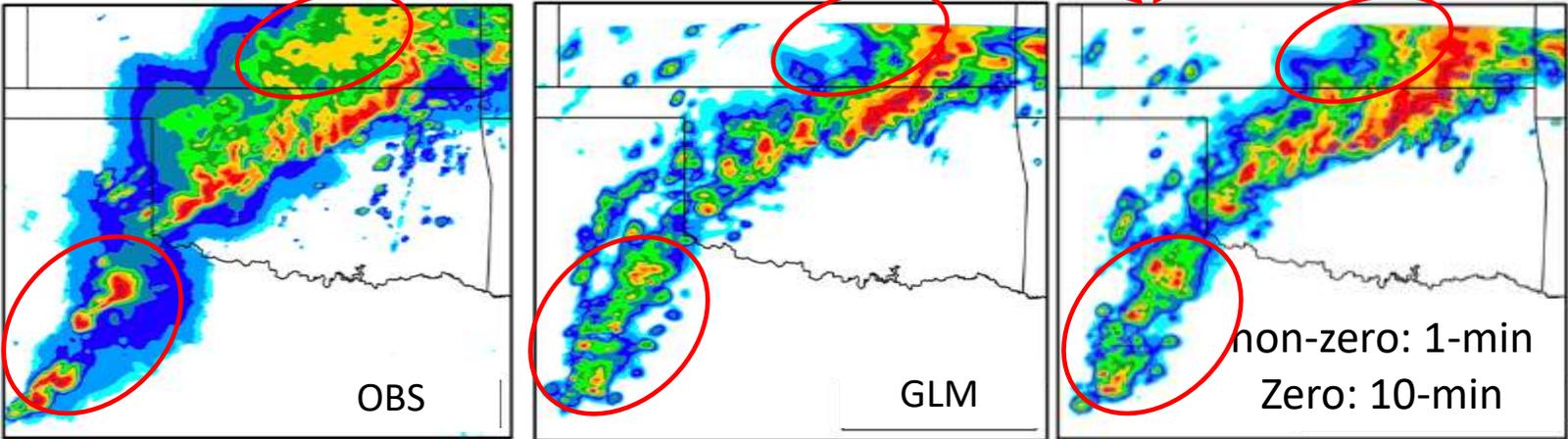

Max: 23 min⁻¹ pixel⁻¹

1-min GLM FED

➤ **Without radar data, assimilating GLM data degrades the forecast skills by overly suppressing convection.**

➤ **With radar data assimilated, assimilating GLM data slightly improve the forecast skill of composite reflectivity and storm tracks.**
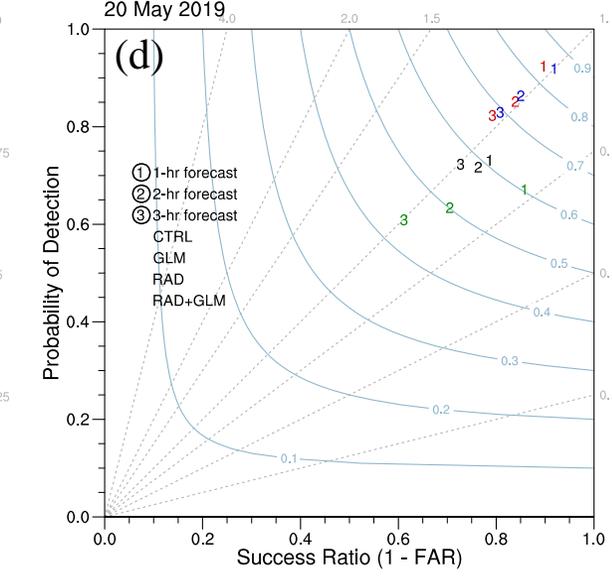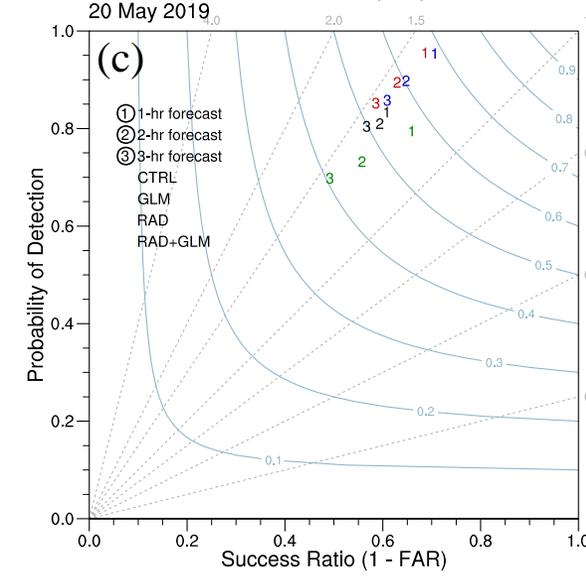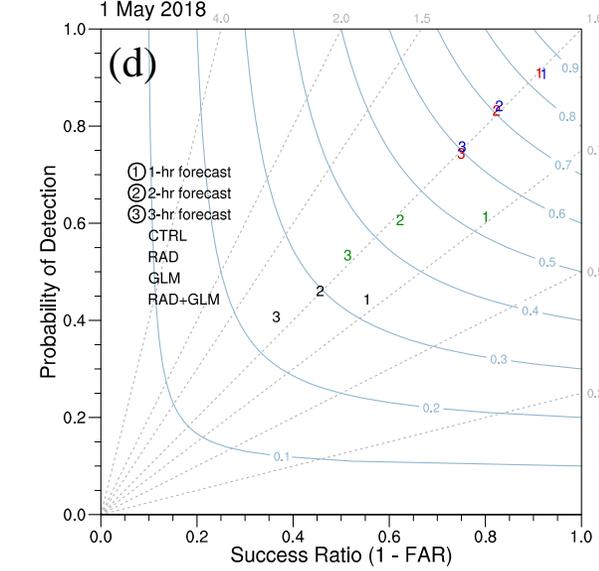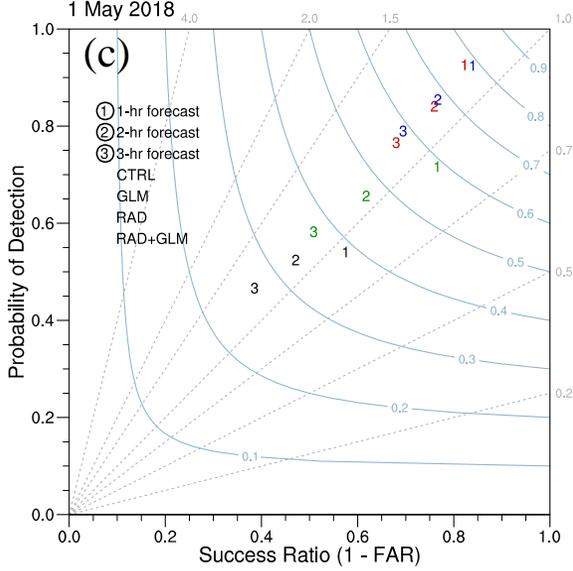
Case 20 May 2019 MCS

1-min GLM FED

10-min GLM FED

Non-zero + Zero

OBS

GLM
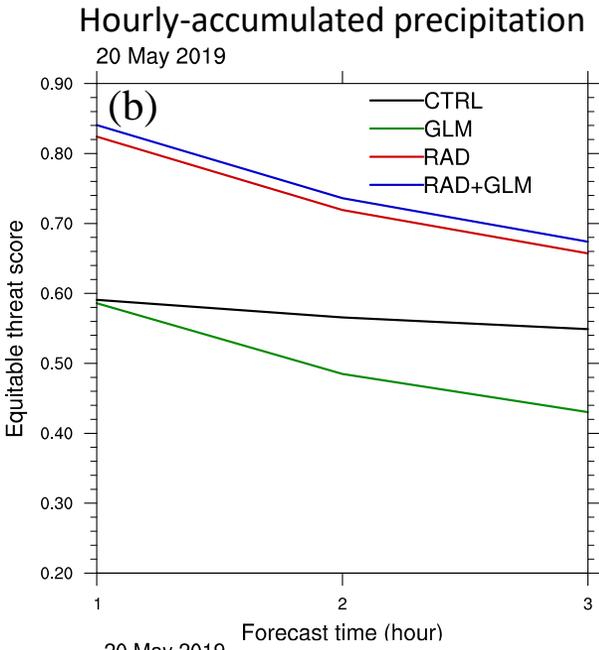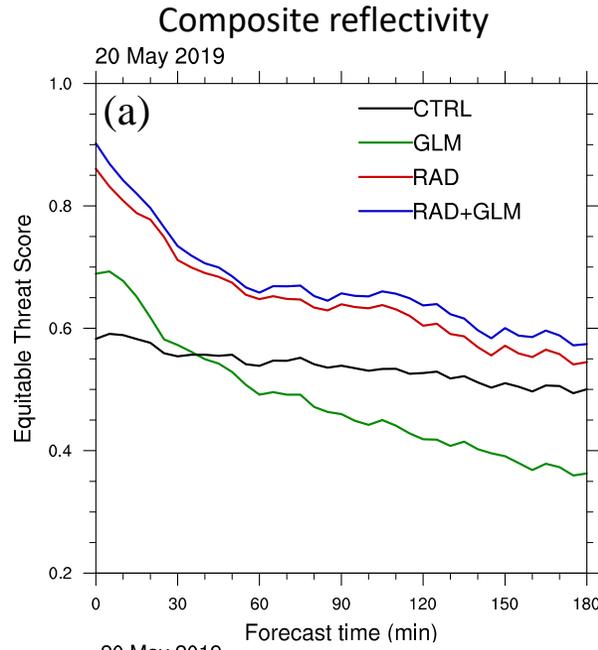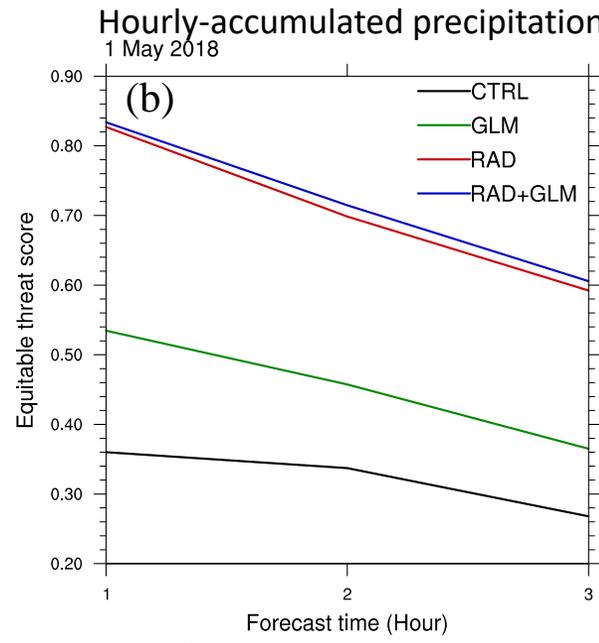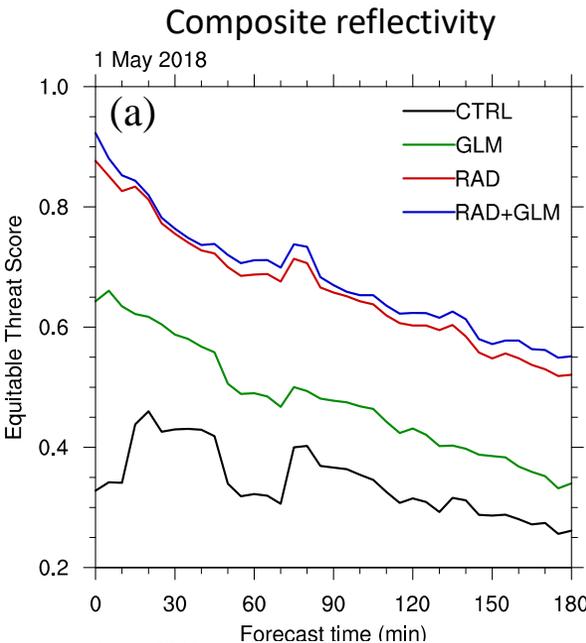
non-zero: 1-min
Zero: 10-min
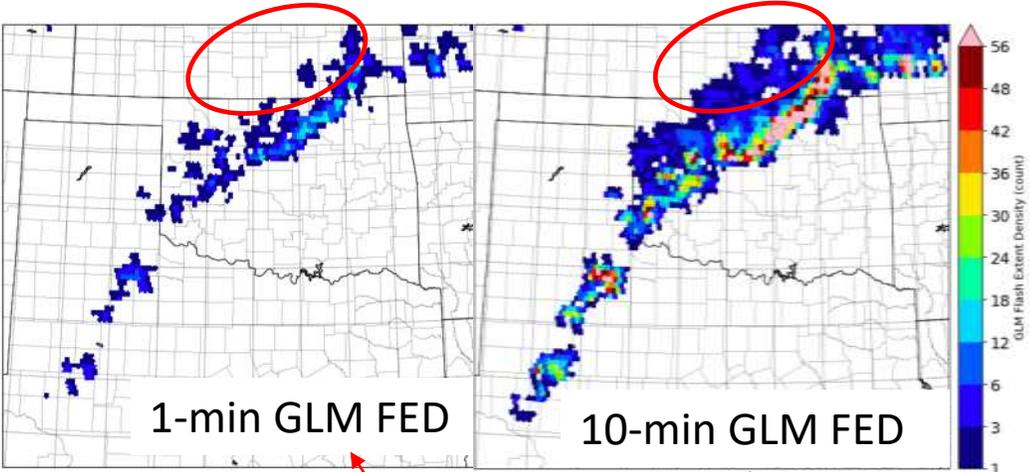
Conclusions

- Assimilating GLM FED observations with/without radar data into the WoFS has the potential to improve the short-term forecast skills by better capturing the features of individual supercells, as well as better predicting storm tracks.

- The MCS with broad trailing stratiform region has low flash rate. Assimilating zero or low GLM flash rate in the absence of radar data might degrade the forecast skills of reflectivity field.

- Future work: adjust the observation operator to better adapt to different storm types.

Backup slides for questions...

Case 20 May 2019 MCS

Analyzed FED at 0000 UTC

(a) OBS   (b) CTRL   (c) GLM_1min

RAD   RAD+GLM

0.25 0.5 1 2 4 8 10 12 16 20 24