# The WRF Lightning Forecast Algorithm: An Update

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GLM Meeting

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Photo, David Blankenship
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# LFA Objectives

*Given LTG link to large ice, and a cloud-scale model like WRF, which prognoses hydrometeors, LFA seeks to:*

1. Create WRF forecasts of LTG threat (1-36 h), based on simple proxy fields from explicitly simulated convection
2. Construct an empirically calibrated threat that yields accurate quantitative peak flash rate densities for the strongest storms, based on LMA total LTG observations
3. Provide an *affordable yet robust* algorithm for use in making gridded proxy LTG data, and for potential uses with DA, *without need for full electrification scheme*

# WRF Configuration (LFA study)

## Prototypical Original Case

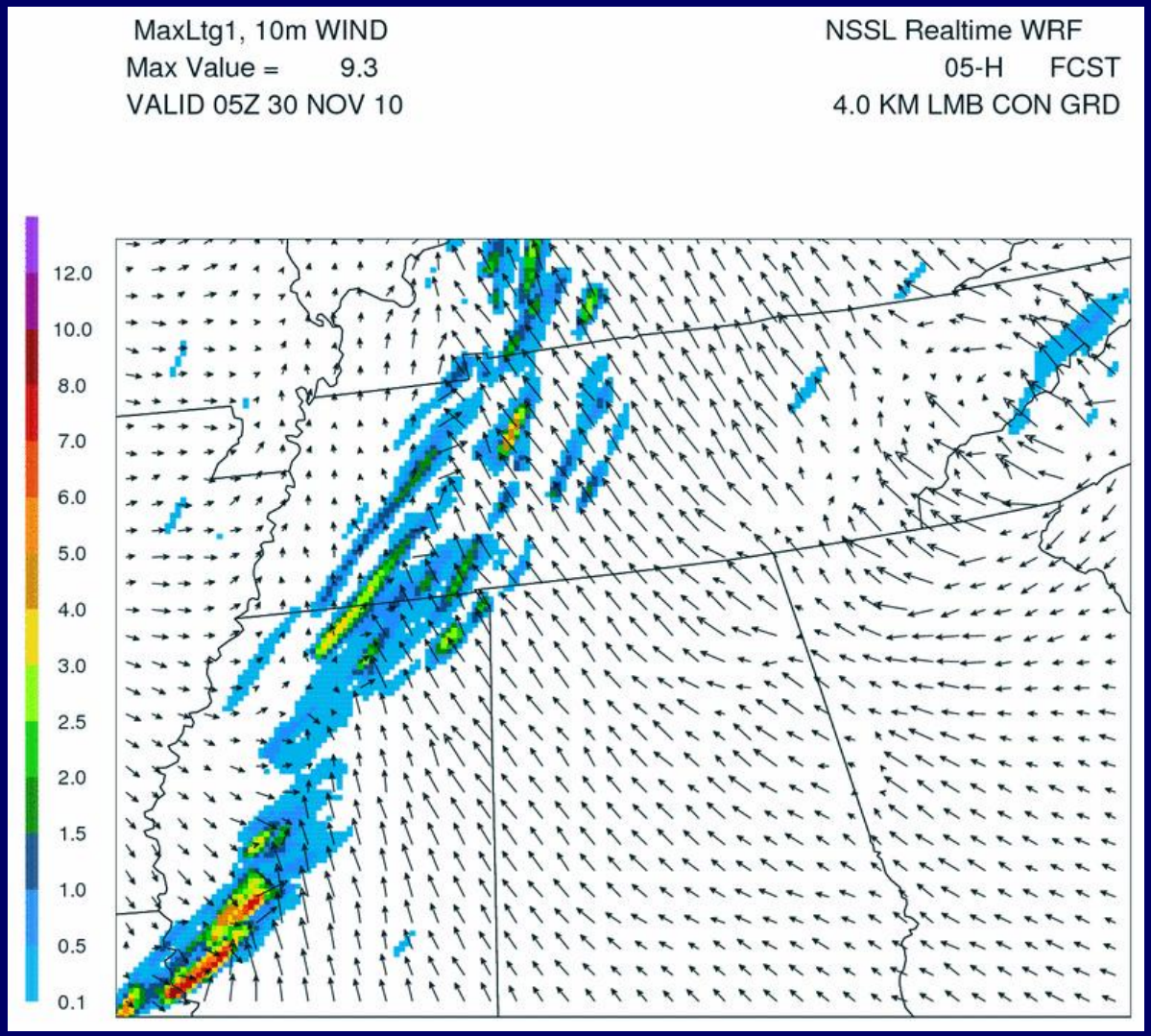
- 2-km horizontal grid mesh
- 51 vertical sigma levels
- Dynamics and physics:
  - Eulerian mass core
  - Dudhia SW radiation
  - RRTM LW radiation
  - YSU PBL scheme
  - Noah LSM
  - WSM 6-class microphysics scheme (graupel; no hail)
- 8h forecast initialized at 00 UTC with AWIP212 NCEP EDAS analysis;
- Also used METAR, ACARS, and WSR-88D radial vel at 00 UTC;
- Eta 3-h forecasts used for LBCs

# WRF Configuration (NSSL)

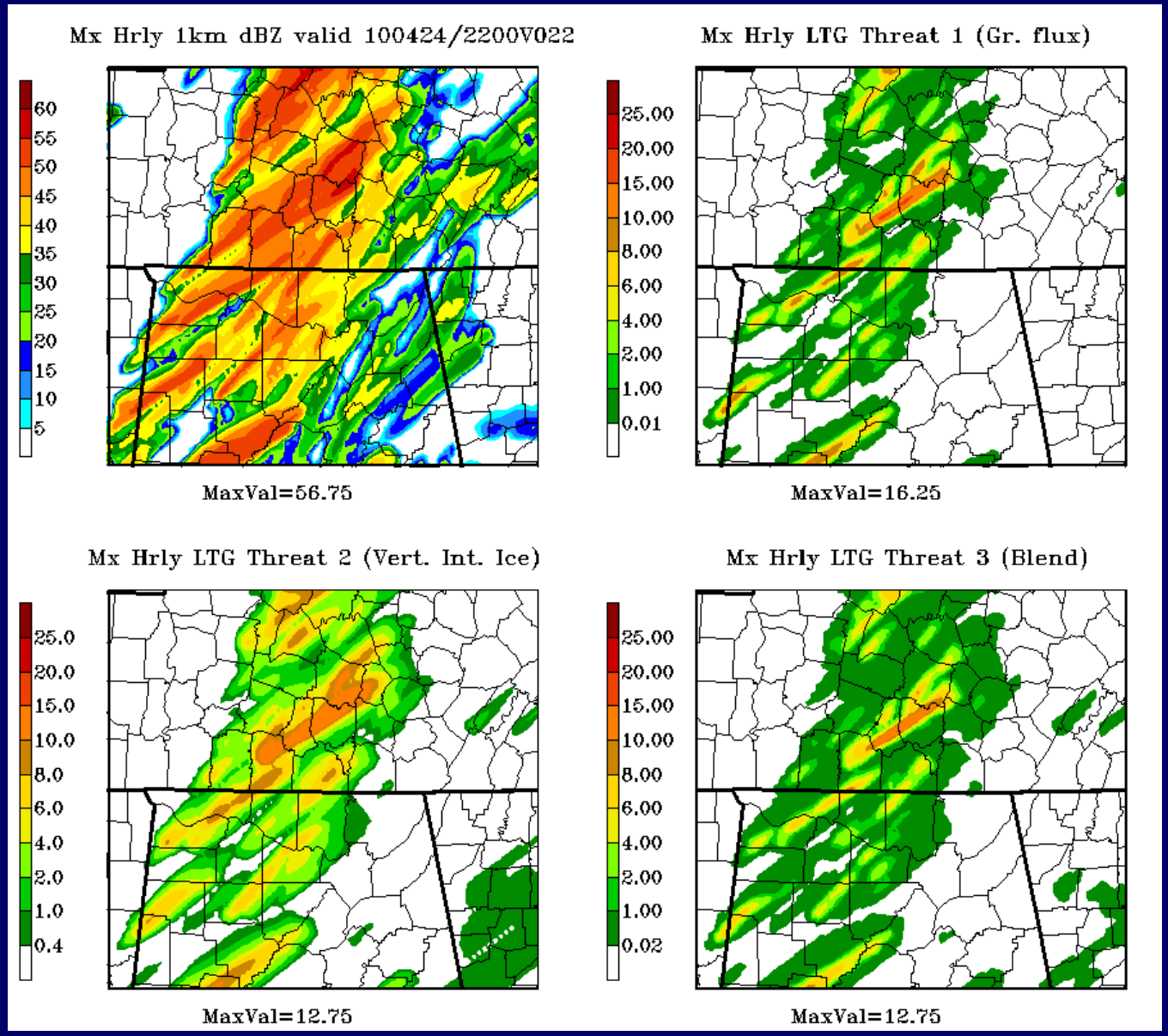
## Typical Operational Case

- 4-km horizontal grid mesh
- 35 vertical sigma levels
- Dynamics and physics:
  - Eulerian mass core
  - Dudhia SW radiation
  - RRTM LW radiation
  - MYJ PBL scheme
  - Noah LSM
  - WSM 6-class microphysics scheme (graupel; no hail)
- 36h forecast initialized at 00 UTC with AWIP212 NCEP EDAS analysis on 40 km grid;
- 0-36-h NAM forecasts used for LBCs

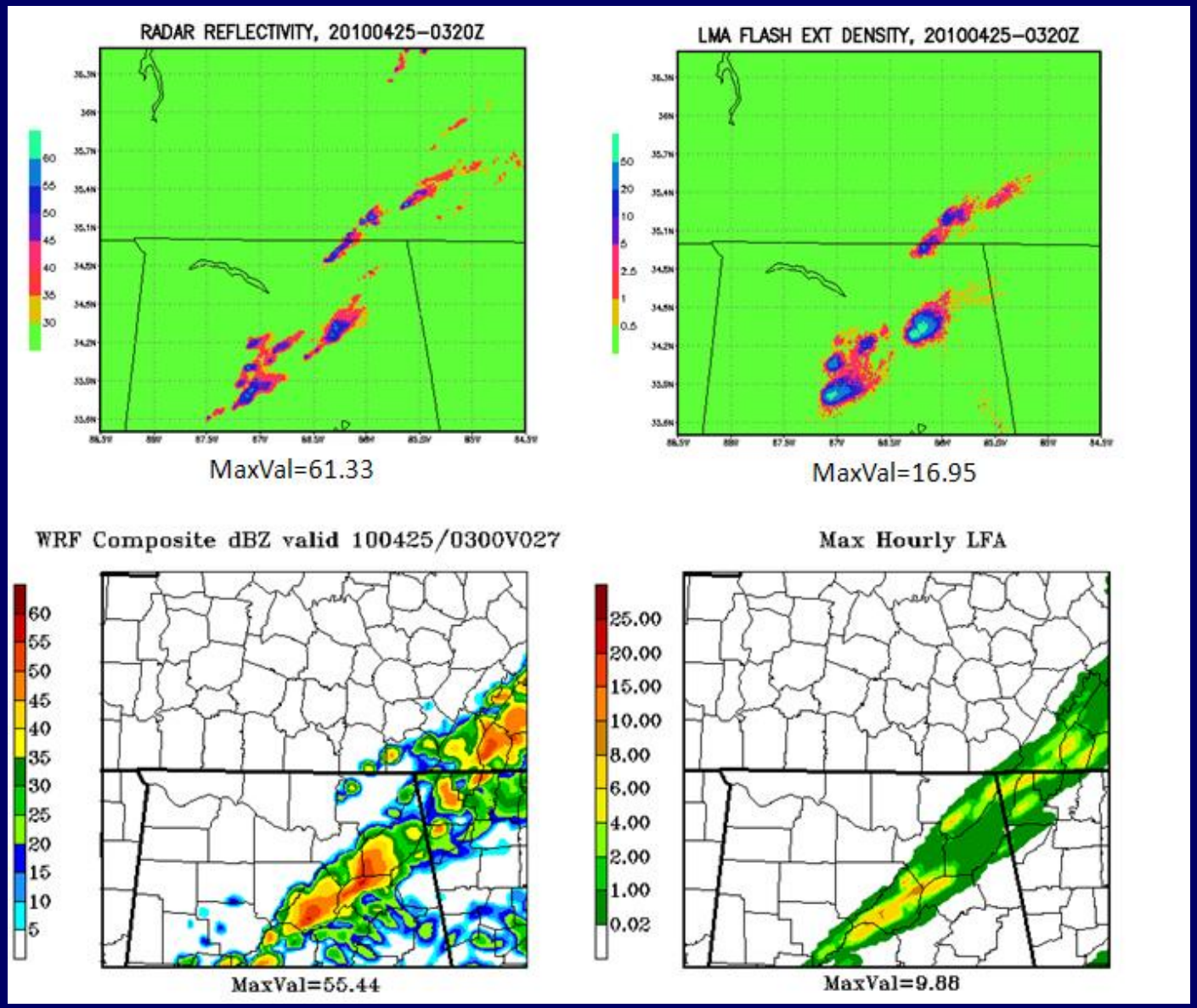
# Sample of NSSL LFA output, 20101130 (see www.nssl.noaa.gov/wrf)



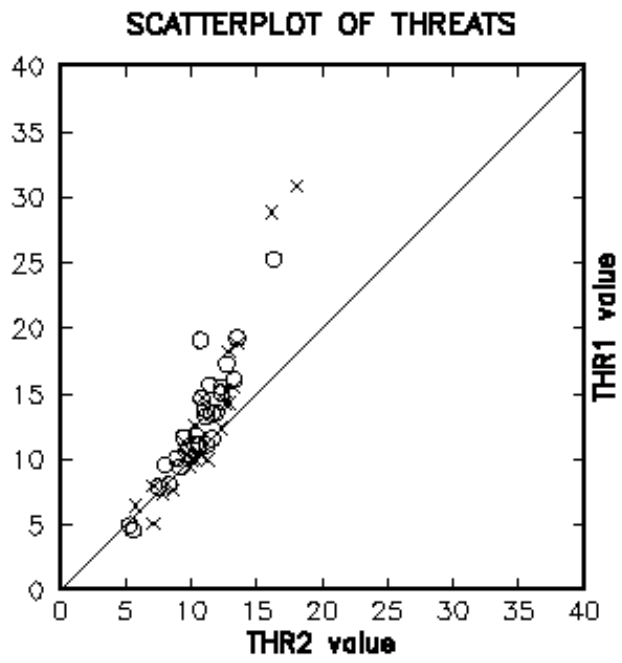
# NSSL WRF data: 24 April 2010



# Obs, NSSL WRF data: 25 April 2010



# Scatterplot of selected NSSL WRF output for LTG1, LTG2 (internal consistency check)




Threats 1, 2 should cluster along diagonal; deviation at high flash rates indicates need to check calibration

# Year-1 LFA studies, NSSL WRF, 2010-2011:

***(examined to test robustness in larger sample of model runs)***

1. Obtained NSSL WRF daily output for full 2010-2011 for three regions: HUN, OUN, USA
2. HUN region examined (preliminary)
3. OUN, USA regions to be examined soon
4. Metric used in statistics scoring: did LTG occur in WRF LFA and/or in LMA obs, within the regions, in 4-24 h periods?
5. Preliminary inspection of results shows:
   -frequent spurious activation of LFA in wintertime stratiform
   -occasional divergent LTG1, LTG2 values in high FRD cases, with LTG1 always > LTG2 (should be equal)
6. Thus: need to reevaluate LFA for *very low, very high* FRDs

# Year-1 LFA studies, NSSL WRF, 2010-2011:

***(examined to test robustness in larger sample of model runs)***

**Preliminary findings for winter weather, JFMD2010,JFM2011**

1. HUN region examined only (others to be examined later)
2. First findings, for ***winter weather (very low FRDs)***:
   - LFA produces 77 d of false alarms from LTG2
   - LFA gives only 40 d of false alarms from LTG1
   - no TSSN hits in HUN 2010; one in Jan 2011 (LTG1,LTG2)
   - if require LTG1>0.01, could reduce winter FA days by ~50%
   - if require LTG1>1.5, reduce FA days from 40 to 6 (85%)
   - use of LTG1 threshold too large might adversely affect deep convection; 3 of 6 FA events are for sleet, and these kinds of FA are impractical to eradicate

# Year-1 LFA studies, NSSL WRF, 2010-2011:

**Contingency table findings for HUN winter stratiform weather**
**format: n(JFMD2010) + n(JFM2011) = total**
**uses LTG1 threshold = 0.01 fl km$^{-2}$/(5 min)**

| hit days | false alarm days |
|---|---|
| 0 + 1 = 1 | 23 + 17 = 40 |
| **miss days** | **true null days** |
| 0 + 0 = 0 | 75 + 43 = 118 |

# Year-1 LFA studies, NSSL WRF, 2010-2011:

**Contingency table findings for HUN winter stratiform weather**
**format: n(JFMD2010) + n(JFM2011) = total**
**uses LTG1 threshold = 1.50 fl km$^{-2}$/(5 min)**

| hit days | false alarm days |
|---|---|
| 0 + 1 = 1 | 3 + 3 = 6 |
| **miss days** | **true null days** |
| 0 + 0 = 0 | 95 + 57 = 152 |

# Year-1 LFA studies, NSSL WRF, 2010-2011:

## Contingency table findings for HUN winter stratiform weather

(HUN area: 32.3<lat<36.7; -91.6<lon<-82.1)

- winter stratiform regimes are dominated by large WRF bias; many low-grade false alarms, but few "hits," and no "misses"
- using forecast day-scale performance as the metric, we find:

| *LTG1>0.01:* | *LTG1>1.50:* |
|---|---|
| POD = 1.00 | POD = 1.00 |
| FAR = 0.98 | FAR = 0.86 |
| CSI = 0.02 | CSI = 0.14 |
| BIAS = 41.0 | BIAS = 7.0 |
| TSS = 0.75 | TSS = 0.96 |
| HSS = 0.04 | HSS = 0.24 |

Increasing the LTG1 threshold helps, but rarity of hits a problem

# Year-1 LFA studies, NSSL WRF, 2010-2011:

***(examined to test robustness in larger sample of model runs)***

**Preliminary findings for convective weather, JJA 2010-2011**

1. HUN region examined only (others to be examined later)
2. First findings, for ***convective weather*** in HUN region, regarding ***general statistical behavior*** of LFA:
   - WRF has spinup problems in hours 0-4; exclude them
   - To eliminate double-counting, exclude WRF data after 24h
   - WRF output missing on 3 of 184 days in JJA 2010-11
   - WRF predicts LTG in HUN for all 181 days in JJA 2010-11
   - LMA observes LTG in HUN for 169 days in JJA 2010-11
   - LFA produces only 11 d of false alarms (FAR=0.07)
   - LFA produces zero false null (miss) days (POD=1.00)
   - LFA has more false alarm days in transitional months

# Year-1 LFA studies, NSSL WRF, 2010-2011:

**Contingency table findings for HUN convective weather**
**format: n(JJA2010) + n(JJA2011) = total**
**uses LTG1 threshold = 0.01 fl km$^{-2}$/(5 min)**

| | |
|---|---|
| **hit days** | **false alarm days** |
| **86 + 83 = 169** | **3 + 8 = 11** |
| **miss days** | **true null days** |
| **0 + 0 = 0** | **0 + 1 = 1** |

# Year-1 LFA studies, NSSL WRF, 2010-2011:

**Contingency table findings for HUN convective weather**
**format: n(JJA2010) + n(JJA2011) = total**
**uses LTG1 threshold = 1.50 fl km$^{-2}$/(5 min)**

| | |
|---|---|
| **hit days** | **false alarm days** |
| **86 + 83 = 169** | **3 + 6 = 9** |
| **miss days** | **true null days** |
| **0 + 0 = 0** | **0 + 3 = 3** |

# Year-1 LFA studies, NSSL WRF, 2010-2011:

## Contingency table findings for HUN convective weather

## (HUN area: 32.3<lat<36.7; -91.6<lon<-82.1)

- convective regimes are dominated by large WRF hit rate; few false alarms, but some are big; again no "misses"
- using forecast day-scale performance as the metric, we find:

| *LTG1>0.01:* | *LTG1>1.50:* |
|---|---|
| POD = 1.00 | POD = 1.00 |
| FAR = 0.07 | FAR = 0.05 |
| CSI = 0.94 | CSI = 0.95 |
| BIAS = 1.07 | BIAS = 1.05 |
| TSS = 0.08 | TSS = 0.25 |
| HSS = 0.15 | HSS = 0.38 |

Increasing the LTG1 threshold helps, but rarity of nulls a problem

# Year-1 LFA studies, NSSL WRF, 2010-2011:

## Contingency table findings for HUN Springtime weather

## (HUN area: 32.3<lat<36.7; -91.6<lon<-82.1)

- Spring (AM) convective regimes feature large WRF hit rate; some nulls and false alarms; again no "misses"
- using forecast day-scale performance as the metric, we find:

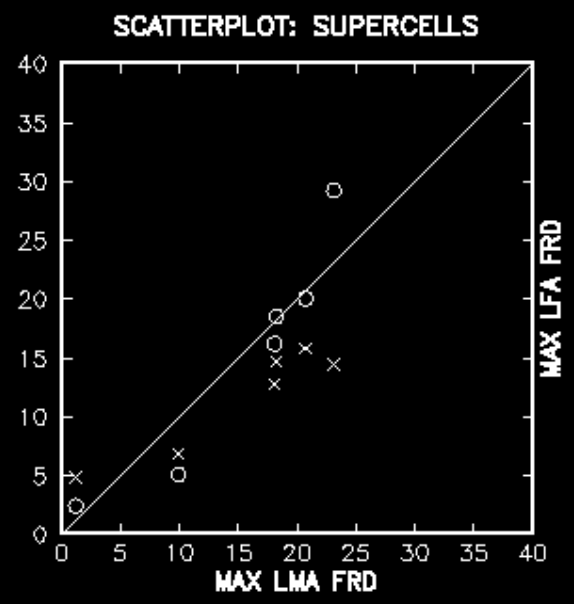
| *LTG1>0.01:* | *LTG1>1.50:* |
|---|---|
| POD = 1.00 | POD = 1.00 |
| FAR = 0.28 | FAR = 0.21 |
| CSI = 0.72 | CSI = 0.79 |
| BIAS = 1.39 | BIAS = 1.27 |
| TSS = 0.42 | TSS = 0.60 |
| HSS = 0.46 | HSS = 0.65 |

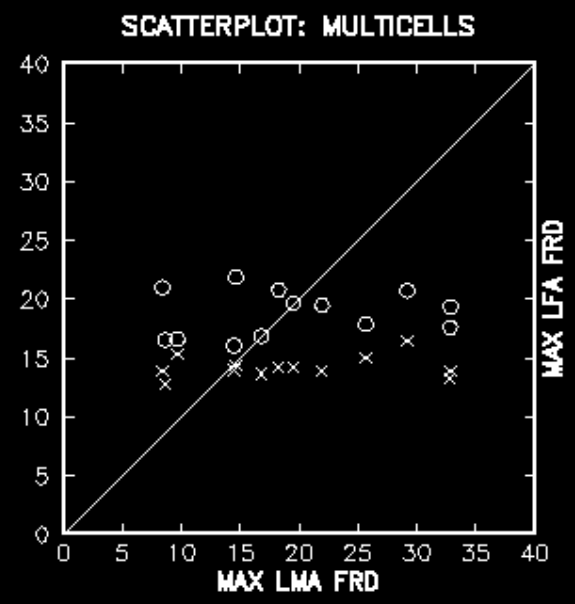
Increasing the LTG1 threshold helps, but scores already good

# Convective regimes - predictability:

1. Supercell cases well handled quantitatively by LFA;
2. Multicell cases are predicted by LFA, but handled less well quantitatively;
3. LFA seems to provide best results for convective regimes that are most predictable;
4. LFA relies heavily on accurate forecasts of midlevel w; WRF seems to have difficulty in unsheared, multicell regimes, where it may not always represent midlevel updraft speeds accurately;
5. LTG rates are to some extent proxies for midlevel updraft; thus real-time comparison of LFA FRD with LMA FRD says something about realism of WRF forecasts of storm w.

# NALMA, LFA Scatterplots by regime:



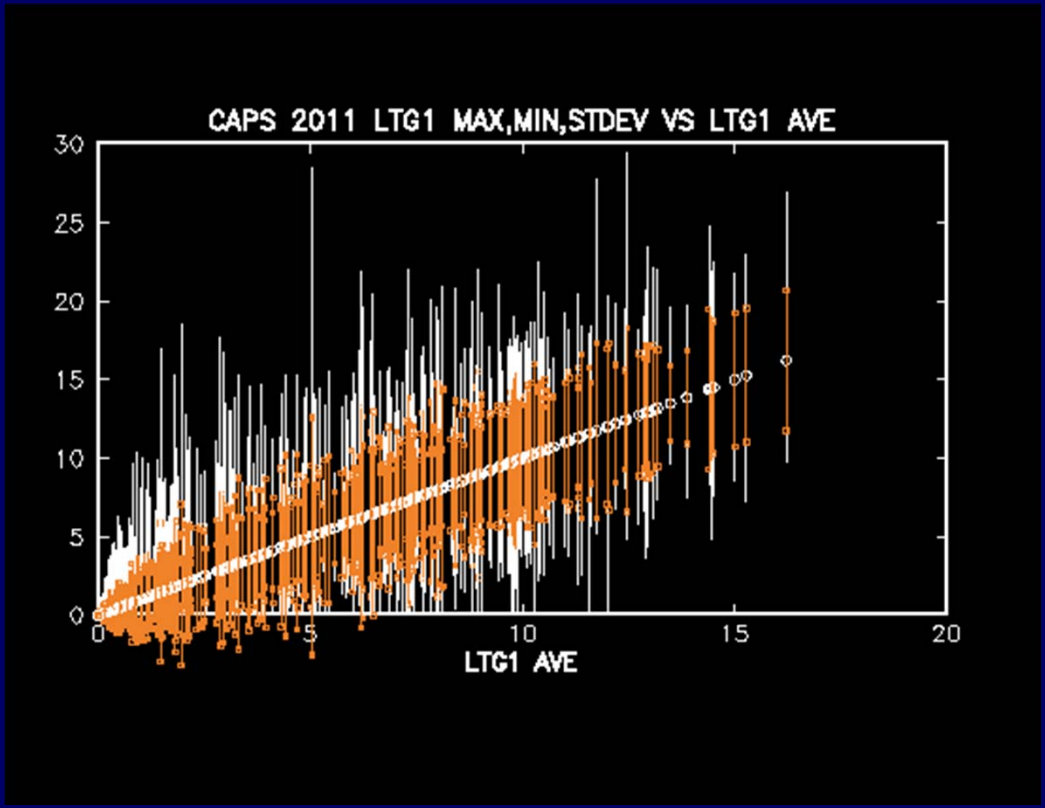
# CAPS 2011 Experiments

| Model | IC (arw_cn+) | BC | micro | LSM | PBL |
|---|---|---|---|---|---|
| S4cn | +00zARPSa | 00zNAMf | Thompson | Noah | MYJ |
| S4m4 | +em-p1 pert | 21zSREF em-p1 | Morrison | RUC | YSU |
| S4m5 | +em-p2 pert | 21zSREF em-p2 | Thompson | Noah | QNSE |
| S4m6 | +nmm-p1 pert | 21zSREF nmm-p1 | WSM6 | RUC | QNSE |
| S4m7 | +nmm-p2 pert | 21zSREF nmm-p2 | WDM6 | Noah | MYNN |
| S4m8 | +rsm-n1 pert | 21zSREF rsm-n1 | Ferrier | RUC | YSU |
| S4m9 | +eKF-n1 pert | 21zSREF eKF-n1 | Ferrier | Noah | YSU |
| S4m10 | +eKF-p1 pert | 21zSREF eKF-p1 | WDM6 | Noah | QNSE |
| S4m11 | +eBMJ-n1 prt | 21zSREF eBMJ-n1 | WSM6 | RUC | MYNN |
| S4m12 | +eBMJ-p1 prt | 21zSREF eBMJ-p1 | Thompson | RUC | MYNN |
| S4m13 | +rsm-p1 pert | 21zSREF rsm-p1 | M-Y | Noah | MYJ |
| S4m14 | +em-n1 pert | 21zSREF em-n1 | Ferrier+ | Noah | YSU |
| S4m15 | +em-n2 pert | 21zSREF em-n2 | WSM6 | Noah | MYNN |
| S4m16 | +nmm-n1 pert | 21zSREF nmm-n1 | Ferrier+ | Noah | QNSE |
| S4m17 | +nmm-n2 pert | 21zSREF nmm-n2 | Thompson | Noah | ACM2 |
| S4m18 | +rsm-p2 pert | 21zSREF rsm-p2 | WSM6 | Noah | MYJ |
| S4m19 | +rsm-n1 pert | 21zSREF rsm-n1 | M-Y | Noah | MYJ |
| S4m20 | +rsm-n2 pert | 21zSREF rsm-n2 | M-Y | RUC | ACM2 |

# CAPS 2011 results

## Mean, range, SD vs. LTG1, all stormy hours

Variations are large for weak lightning, in a relative sense

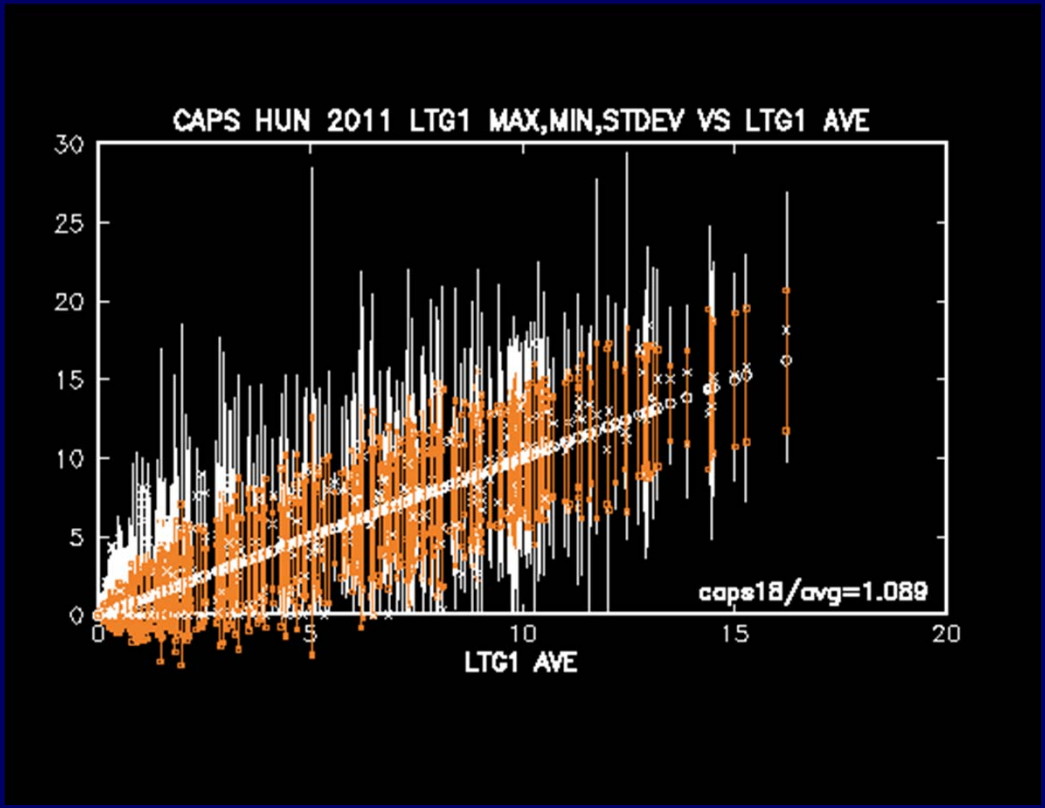



Variations slowly Increase as LTG increases

# CAPS 2011 results

## Mean, range, SD vs. LTG1, x = expt 18, WSM6

CAPS 2011 had four WSM6 expts

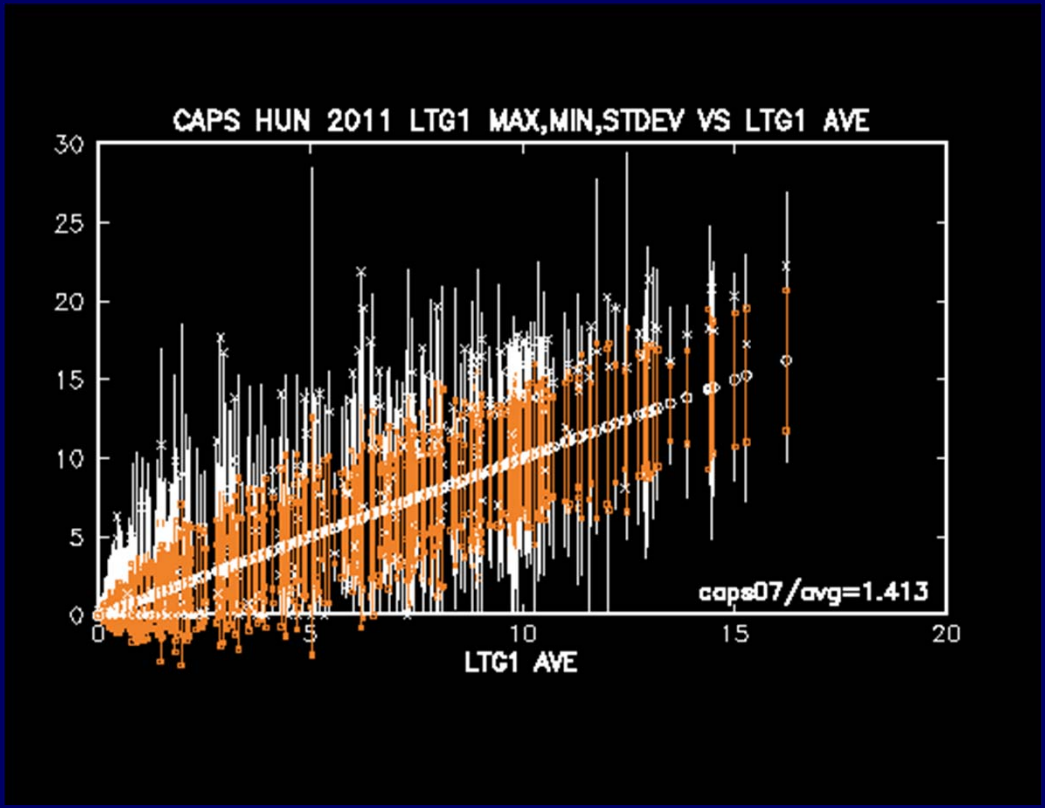



Mean relative to overall avg = 1.09

# CAPS 2011 results

Mean, range, SD vs. LTG1, x = expt 7, WDM6

CAPS 2011 had two WDM6 expts

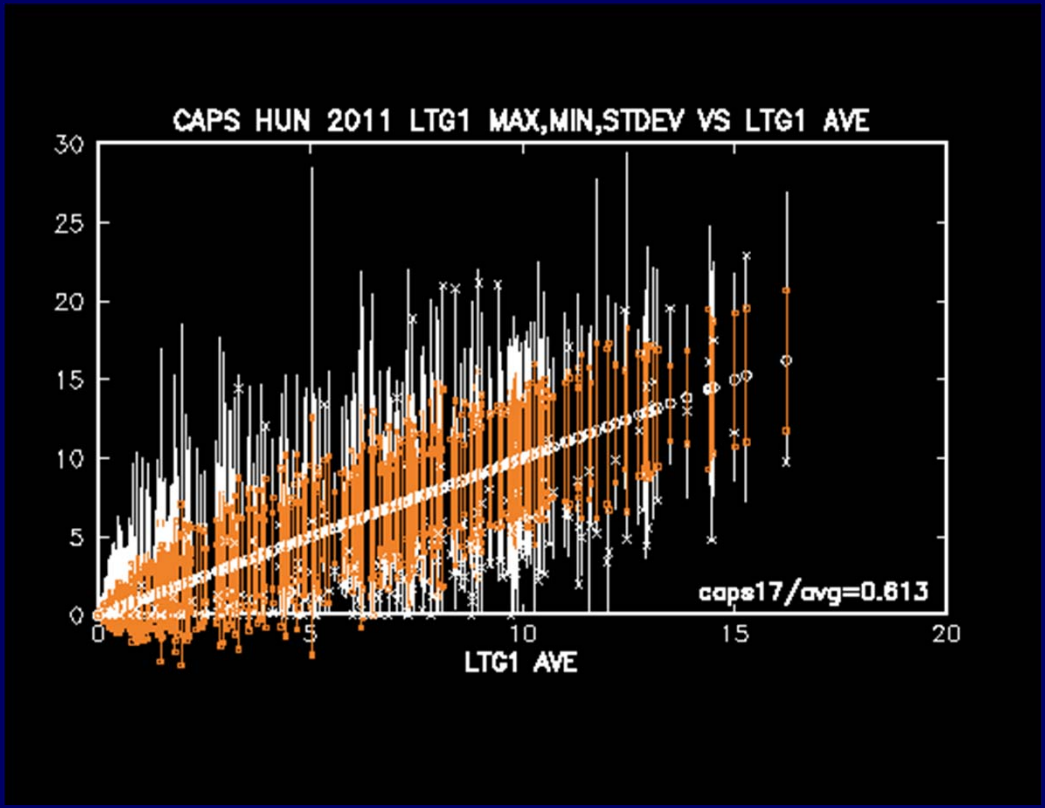



Mean relative to Overall avg = 1.57

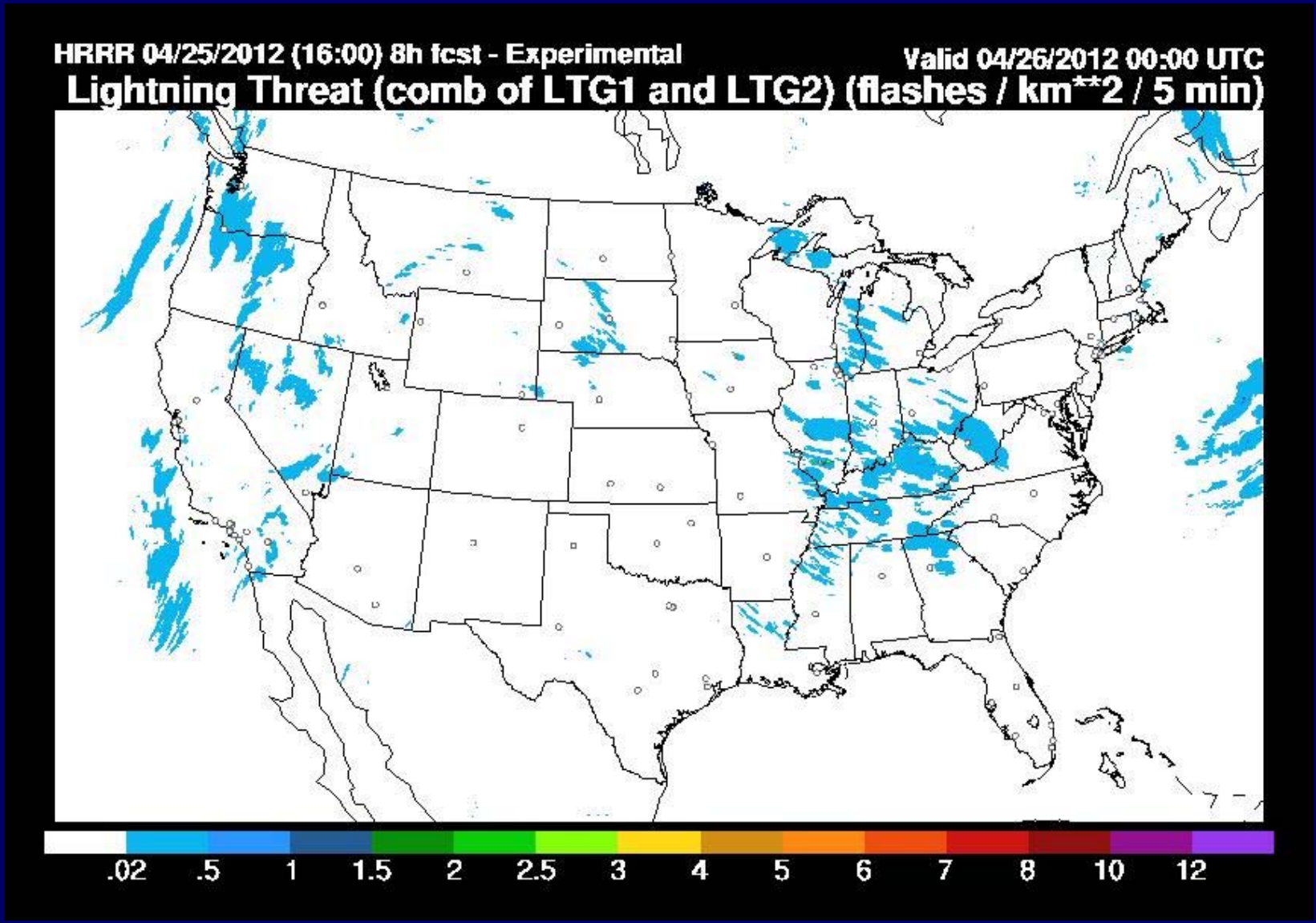
# CAPS 2011 results

Mean, range, SD vs. LTG1, x = expt 17, Thompson

CAPS 2011 had three Thompson expts




Mean relative to overall avg = 0.67


HRRR 04/25/2012 (16:00) 8h fcst - Experimental
Valid 04/26/2012 00:00 UTC
Lightning Threat (comb of LTG1 and LTG2) (flashes / km**2 / 5 min)
.02
.5
1
1.5
2
2.5
3
4
5
6
7
8
10
12

# Future Work:

1. Continue collaborations with NSSL, CAPS, HRRR, AWC to implement, test revised LFA;
2. Complete study of LMA cases from 2010, 2011 NSSL and 2011 CAPS WRF runs; examine 2012 data (in progress);
3. Evaluate revised LFA for 2012 low-FRD, high-FRD cases; use NALMA, OKLMA as needed; check accuracy of LFA areal coverage;
4. Study performance of revised LFA in CAPS ensembles under varying model configurations; perform custom recalibration of LFA for WRF with Thompson 2-moment microphysics;
5. Assess LFA for dry summer LTG storms in w USA;
6. Examine HWRF runs (by others) to assess LFA in TCs;
7. Assist efforts to use LFA output in LTG DA for GOES-R

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***McCaul, E. W., Jr., S. J. Goodman, K. LaCasse and D. Cecil, 2009: Forecasting lightning threat using cloud-resolving model simulations. Wea. Forecasting, 24, 709-729.***