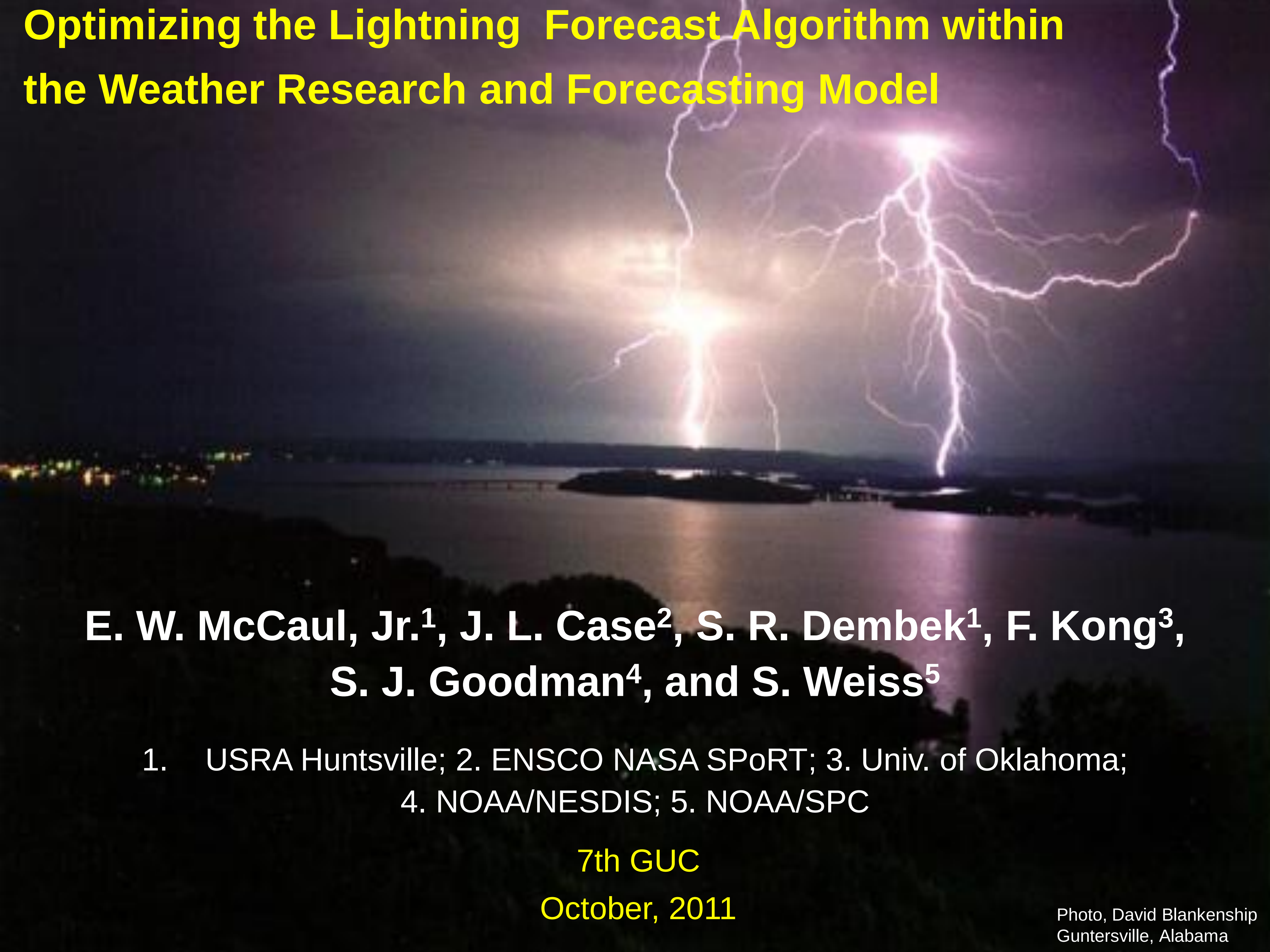

Optimizing the Lightning Forecast Algorithm within the Weather Research and Forecasting Model

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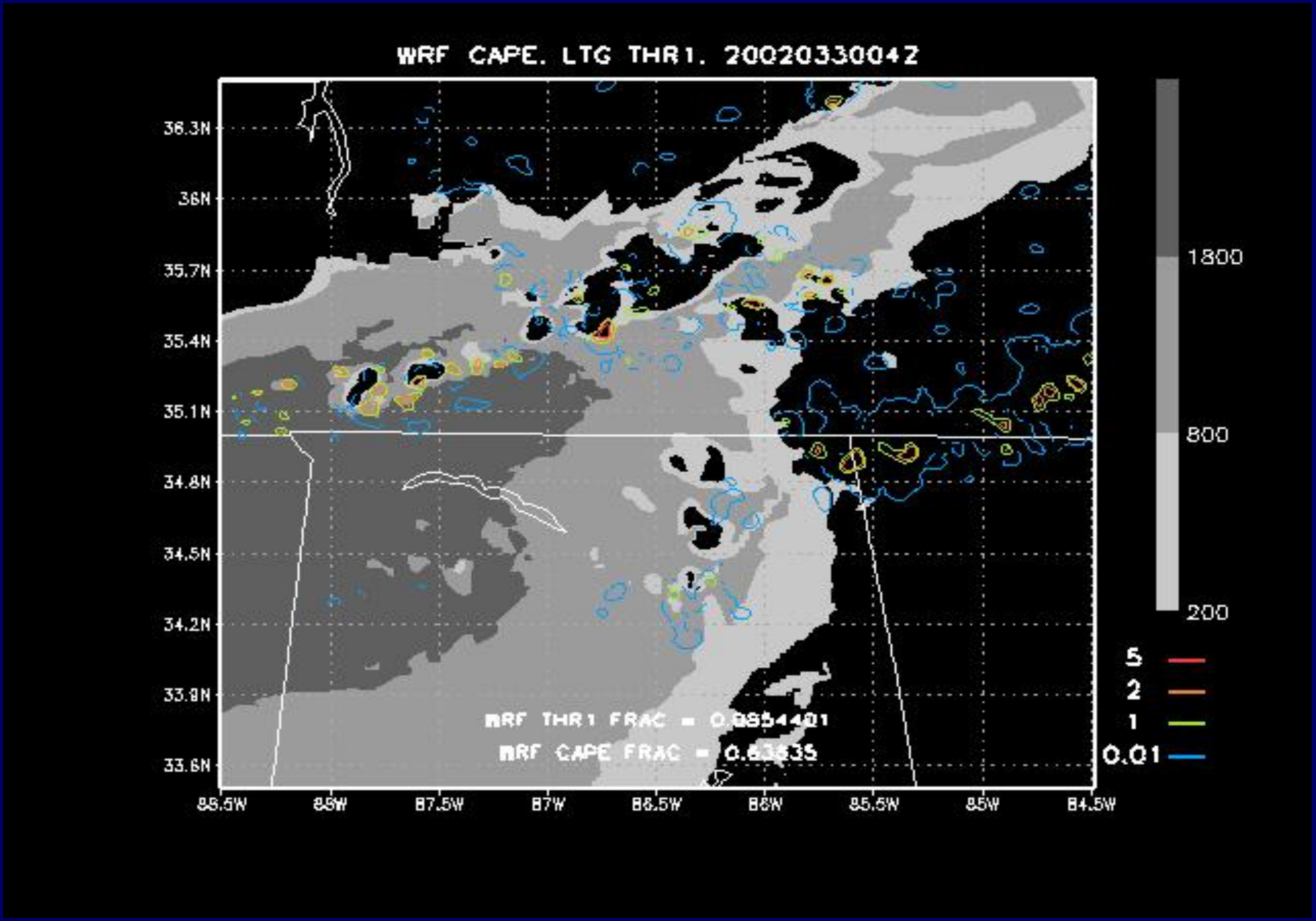
7th GUC

October, 2011

Photo, David Blankenship
Guntersville, Alabama

Motivation: Compare coverage CAPE vs LFA LTG1



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 a calibrated threat that yields accurate quantitative peak flash rate densities for the strongest storms, based on LMA total LTG observations
3. Provide robust algorithm for use in making proxy LTG data, and for potential uses with DA

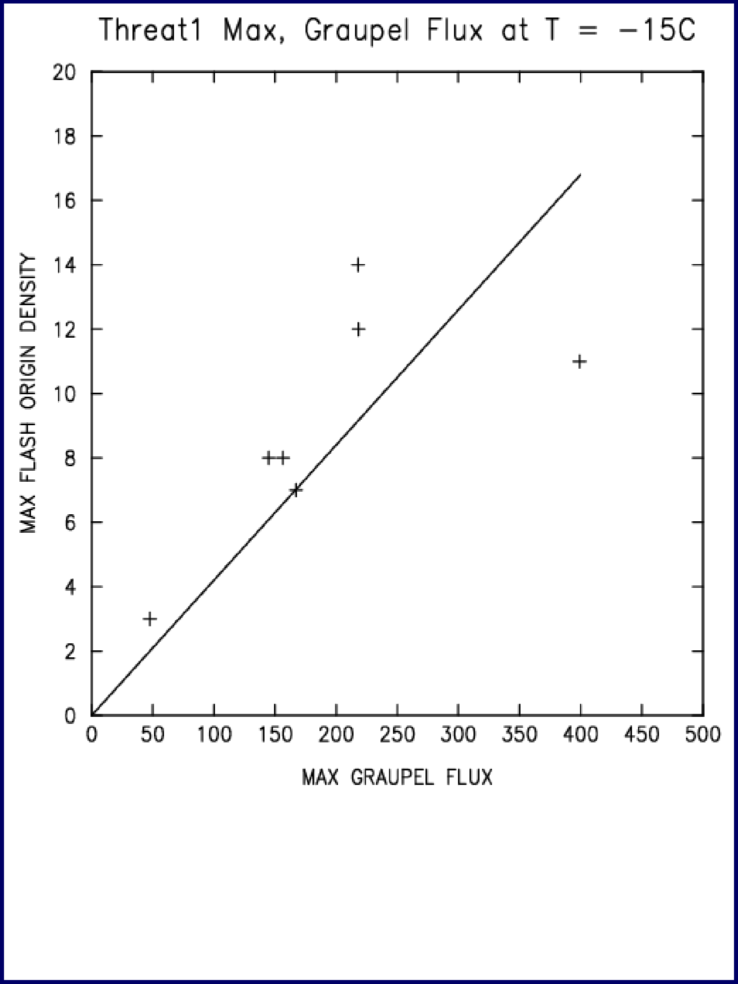
Calibration Curve

LTG1 (FLX)

$F_1 = 0.042$ FLX

$F_1 > 0.01$

$r = 0.67$



Units of F_1 are fl/km^2/5 min

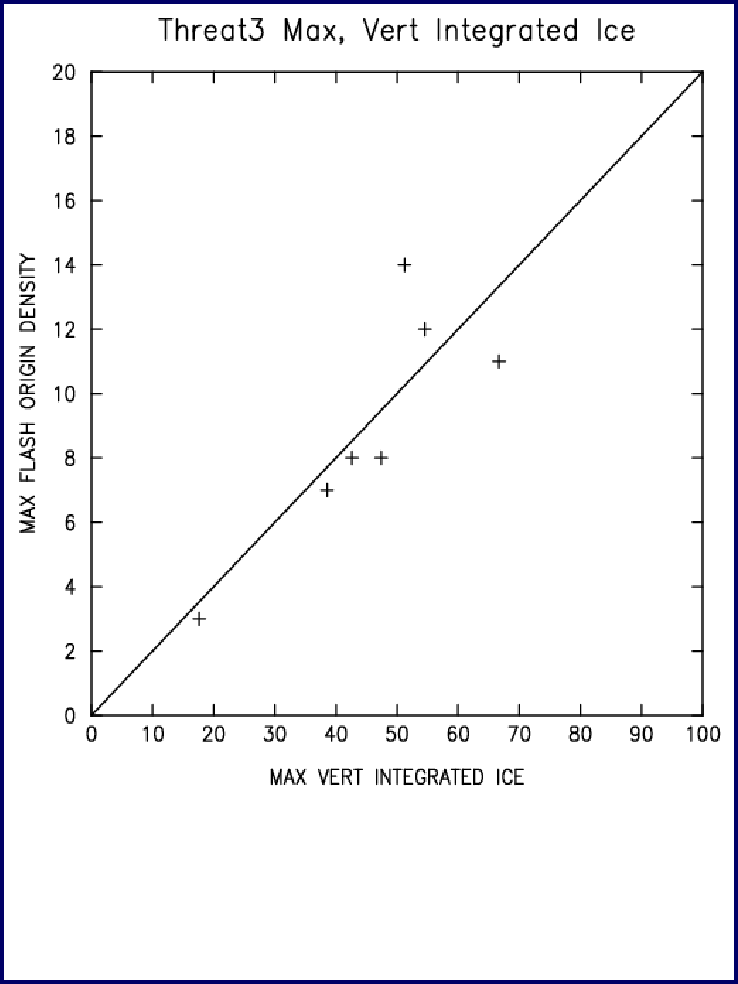
Calibration Curve

LTG2 (VII)

$F_2 = 0.2$ VII

$F_2 > 0.4$

$r = 0.83$



Units of F_2 are fl/km^2/5 min

LTG Threat Methodology: Advantages

- Methods based on LTG physics; should be robust and regime-independent
- Can provide quantitative estimates of flash rate fields; use of thresholds allows for accurate threat areal coverage
- Methods are fast and simple; based on fundamental model output fields; no need for complex electrification modules

LTG Threat Methodology: Disadvantages

- Methods are only as good as the numerical model output; models usually do not make storms in the right place at the right time; saves at 15 min sometimes miss LTG jump peaks
- Small number of cases, lack of extreme LTG events means uncertainty in calibrations
- Calibrations should be redone whenever model is changed, or error bars acknowledged regarding sensitivities to grid mesh, model microphysics (to be addressed here and in future)

WRF Configuration (typical)

Sample Case Study

- 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 30 March 2002 with AWIP212 NCEP EDAS analysis;
- Also used METAR, ACARS, and WSR-88D radial vel at 00 UTC;
- Eta 3-h forecasts used for LBC's

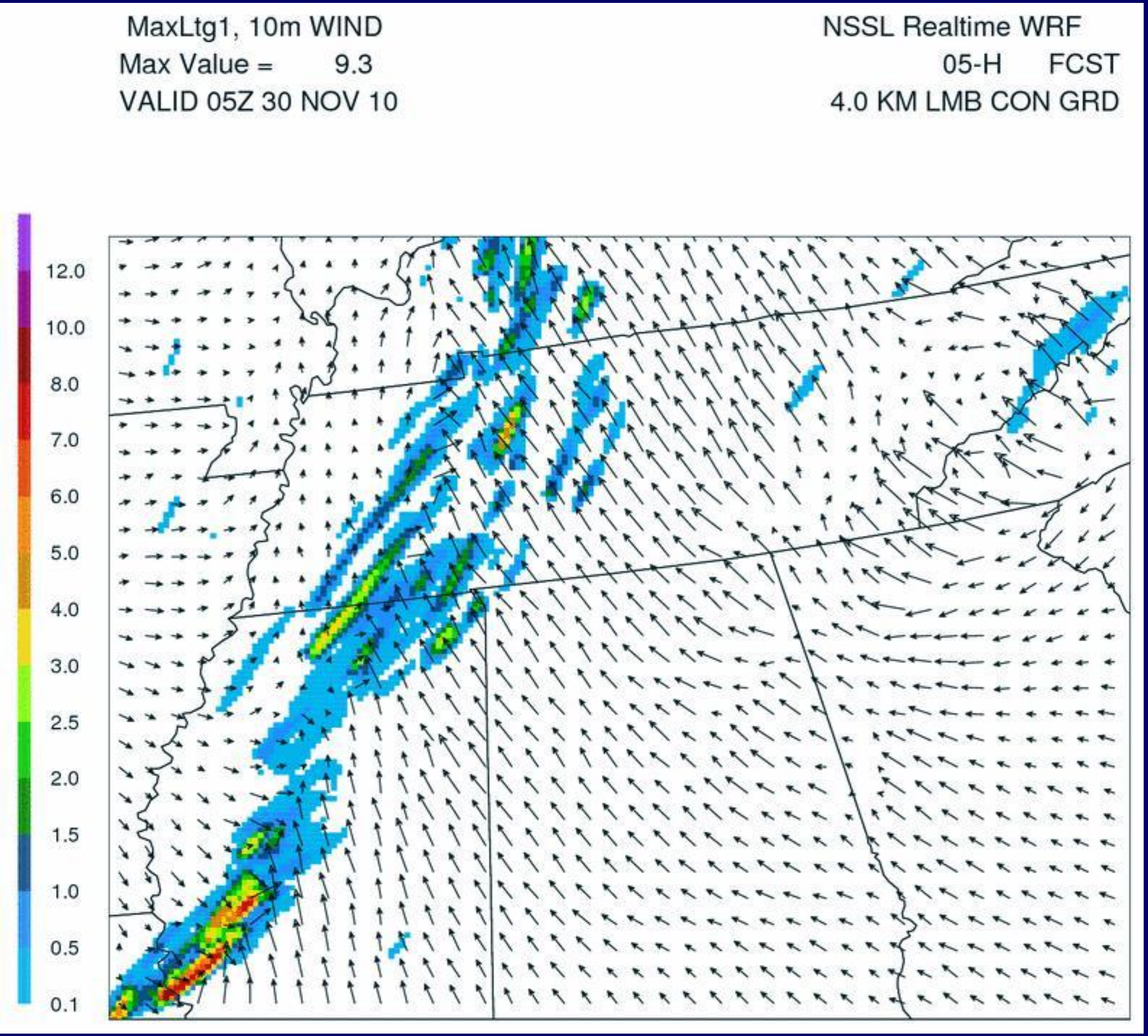
Construction of blended threat:

1. LTG1 and LTG2 are both calibrated to yield correct peak flash densities
2. The peaks of LTG1 and LTG2 also tend to be coincident in all simulated storms, but LTG2 covers more area
3. Thus, weighted linear combinations of the 2 threats will also yield the correct peak flash densities
4. To preserve most of time variability in LTG1, use large weight w_1
5. To preserve areal coverage from LTG2, avoid very small weight w_2
6. Tests using 0.95 for w_1, 0.05 for w_2, yield satisfactory results
7. Thus, set LTG3 = 0.95*LTG1 + 0.05*LTG2

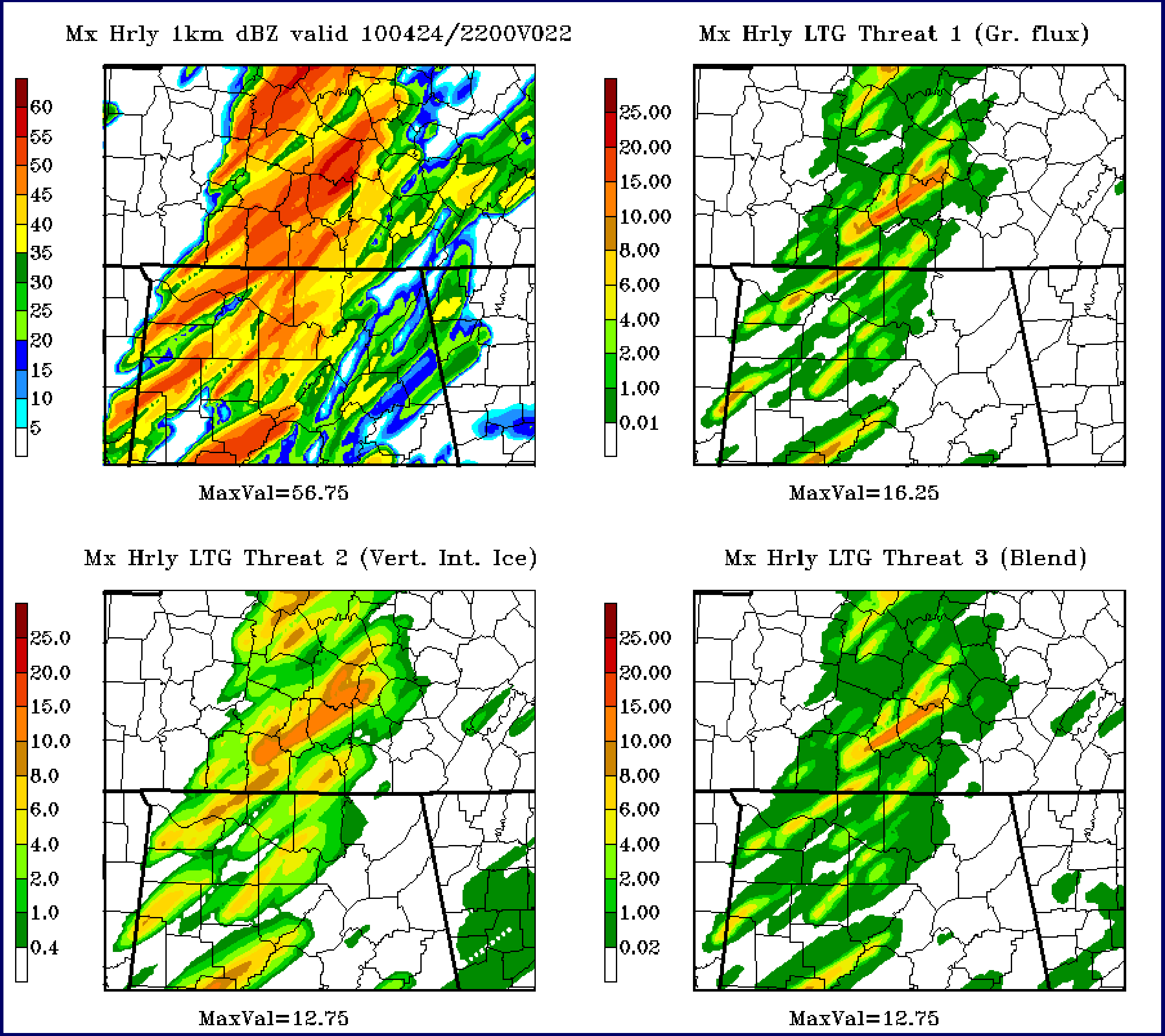
General Findings:

1. LTG threats LTG1 and LTG2: reasonable peak flash rates
2. LTG threats provide more realistic spatial coverage of LTG than that suggested by coverage of positive CAPE, which overpredicts threat area, especially in summer
   - in AL cases, CAPE coverage ~60% at any t, but our LFA, NALMA obs show storm coverage typically only ~15%
   - in summer in AL, CAPE coverage almost 100%, but storm time-integrated coverage only ~10-30%
   - in frontal cases in AL, CAPE coverage 88-100%, but squall line storm time-integrated coverage is 50-80%
3. Blended threat retains proper peak flash rate densities, because constituents are calibrated and coincident
4. Blended threat retains temporal variability of LTG1, and offers proper areal coverage, thanks to LTG2

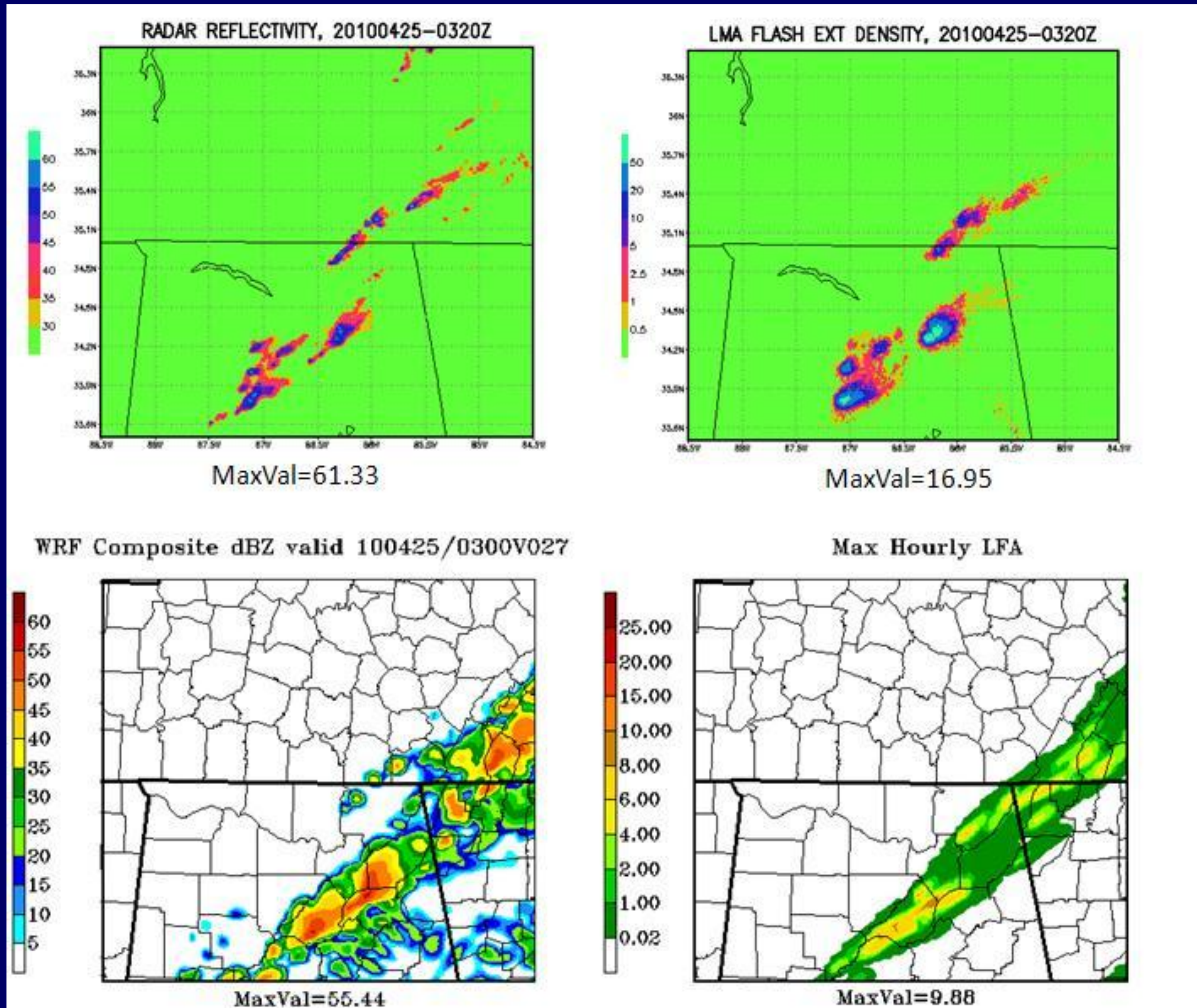
Sample of NSSL WRF output, 20101130 (see www.nssl.noaa.gov/wrf)



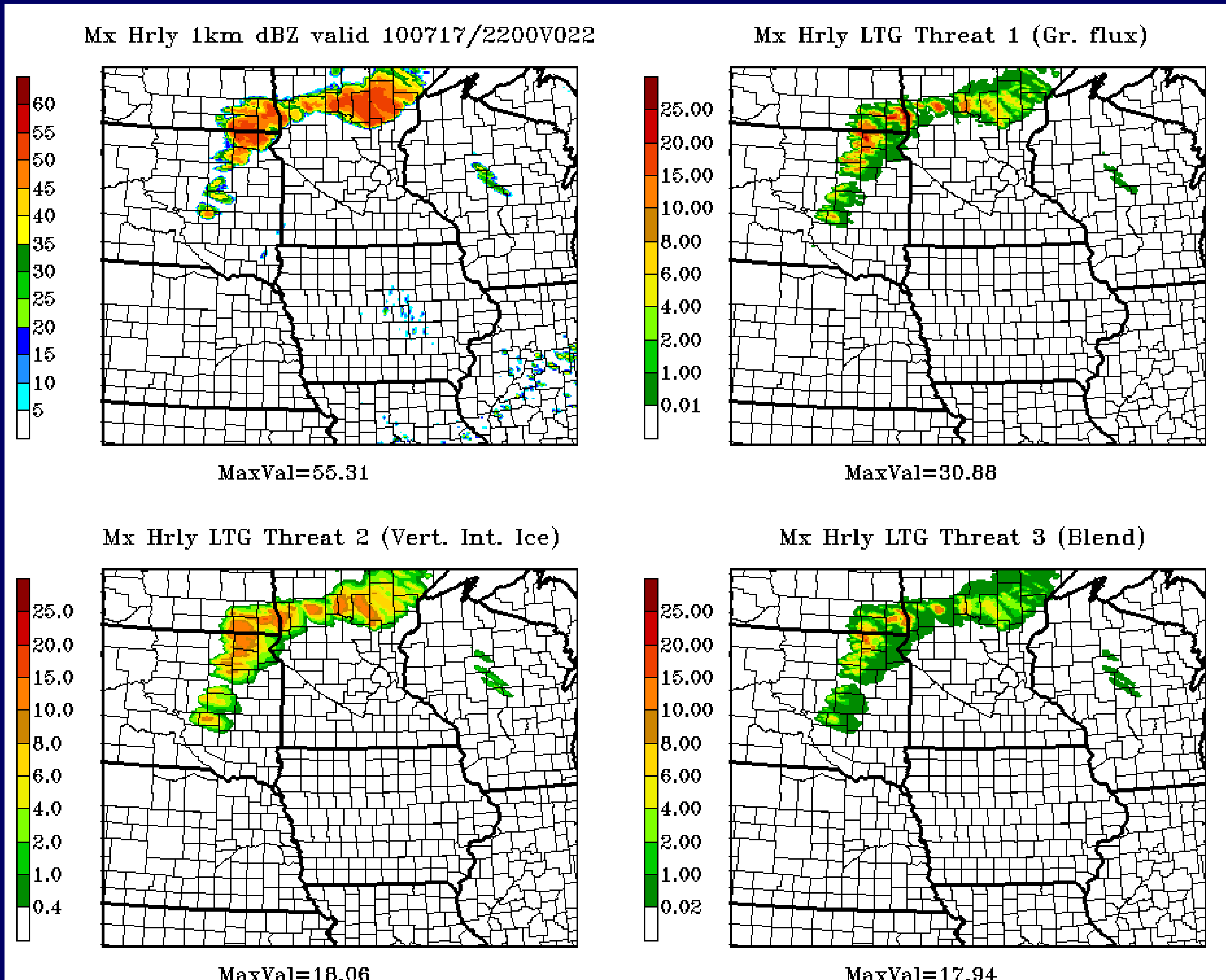
NSSL WRF data: 24 April 2010



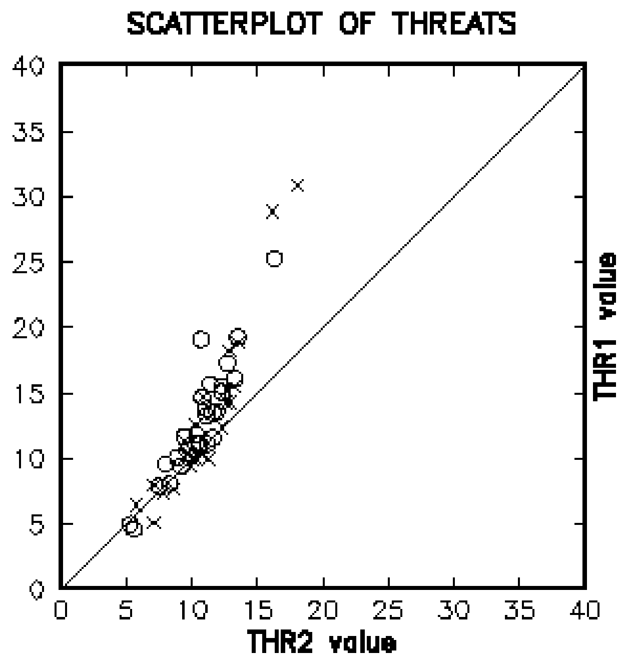
NSSL WRF data: 25 April 2010



NSSL WRF output: 17 July 2010



Scatterplot of selected NSSL WRF output for threats 1, 2 (internal consistency check)



Threats 1, 2 should cluster along diagonal; deviation at high flash rates indicates need for recalibration

Recent LFA studies, NSSL WRF, 2010-2011:
(examined to test robustness in larger sample of model runs)

1. Obtained NSSL 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. May consult DCLMA because of OKLMA downtime issues
5. Metric used in statistics scoring: did LTG occur in WRF LFA and/or in LMA obs, within the regions, in 0-24 h periods?
6. 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)
7. Thus: need to reevaluate LFA for *very low, very high* FRDs

Recent 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 LTG hits in HUN in 2010; one in Jan 2011 by LTG1,LTG2
   - if require LTG1>0.01, could reduce winter FA d by ~50%
   - if require LTG1>1.5, reduce FA d from 40 to 6 (85%)
   - use of LTG1 threshold > 1.5 might adversely affect true convection; 3 of 6 FA events are for sleet, and these kinds of FA are impractical to eradicate

Recent 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

Recent 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

Recent 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 170 days in JJA 2010-11
   - LFA produces only 11 d of false alarms (FAR=0.061)
   - LFA produces zero false null (miss) days (POD=1.000)
   - LFA has more false alarm days in transitional months

Recent LFA studies, NSSL WRF, 2010-2011:

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

Preliminary findings for convective weather

3. Other findings, for ***convective weather*** in HUN region, regarding ***high FRD (>20 fl/km^2/5 min) behavior*** of LFA:
   - in HUN, high FRD cases mostly occur in JJA (weak shear)
   - LFA produces LTG1 FRD>20 on 37 days in JJA 2010-11
   - Max LTG1=43.75, max LTG2=20.44 (4 Aug 2010)
   - if exclude 0-4 h spinup, LTG1 FRD>20 on 23 days total
   - Max LTG1=29.25 (3 Aug 2011), max LTG2=17.06
   - LMA analyses underway to check observed FRDs, compare prognosed vs. observed areal threat coverage

Recent 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

Recent 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

Ensemble studies, CAPS cases, 2011:
(examined to test robustness under varying grids, physics)

1. Examining CAPS ensemble output for HUN, OUN, and USA areas, as data become available.
2. CAPS runs start 16 April 2011, end 10 June 2011.
3. Statistics will be accumulated on max, min, mean, SD and mean-normalized SD of ***peak LFA FRD***, using each CAPS run (typically 14 LFA-containing members each day). These statistics will show degree of sensitivity of LFA output to model physics, IC, LBC changes.
4. Additional statistics will be obtained on thresholded envelopes of LFA areal coverage, and reliability relative to actual storms (may have to use NLDN to assess this)

Future Work:

1. Examine data from 2010, 2011 NSSL and 2011 CAPS WRF runs;
2. Compile list of intense storm cases, and use NALMA, OKLMA data to recheck calibration curves for nonlinearities, or apply changes to calibration factors; finalize threshold needed for LTG1 (>0) to minimize spurious winter activation of LFA
3. Assess performance of LFA in CAPS 2011 ensembles under varying model configurations:
   - other physics schemes;
   - other combinations of hydrometeor species;
4. Assess LFA for dry summer LTG storms in w USA;
5. Examine HWRF runs (by others) to assess LFA in TCs;

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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.