THE WRF LIGHTNING FORECAST ALGORITHM: REFINEMENT AND INCORPORATION INTO CONVECTIVE ENSEMBLE FORECASTS

Eugene W. McCaul Jr.[1], Jonathan L. Case[2], Scott R. Dembek[3], Fanyou Kong[4], Steven J. Goodman[5], and Steven J. Weiss[6]

[1]USRA / NASA Short-term Prediction Research and Transition (SPoRT) Center, Huntsville, AL
[2]ENSCO, Inc. / NASA SPoRT Center, Huntsville, AL
[3]USRA, Kennett Square, PA
[4]CAPS, Univ. of Oklahoma, Norman, OK
[5]NOAA/NESDIS, Silver Spring, MD
[6]NOAA/Storm Prediction Center, Norman, OK

Background

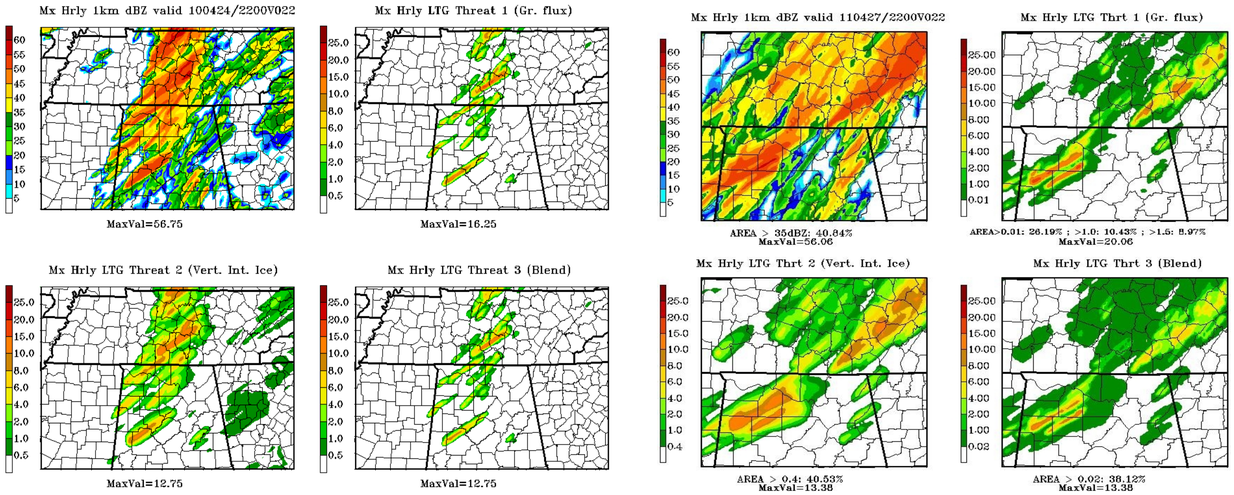
- WRF-based Lightning Forecast Algorithm (LFA) was developed based on observed robust relationships between LTG flash rates and large precipitating ice in storms
- LFA was designed to be entirely empirical, easy to implement
- LFA uses two proxy fields: graupel flux at -15°C (GFX,=LTG1), and vertical ice integral (VII, =LTG2)
- GFX represents amplitude, time variability of LTG; VII represents amplitude, areal coverage of LTG; a weighted average blend, Threat 3, gives best overall results
- Original LFA study used 2 km mesh, WSM6 microphysics, and was based on storm cases from only North Alabama for which NALMA data were available for calibration; recent WRF efforts have used 4 km CONUS mesh, varying microphysics
- Output from LFA resembles gridded LTG flash data processed from prospective platforms like upcoming GOES-R GLM, and can be used to test assimilation of LTG data
- Here we test WRF LFA on explicit convection models having more diversity of physics and grid meshes, since data assimilation efforts will not all use one model configuration

Methodology

- Applied WRF LFA code to WRF models at NSSL, CAPS, HRRR and AWC to gain CONUS-wide experience
- Assessed peaks of GFX, VII threats over HUN, OUN and CONUS areas for all 2010 and 2011; compared with LMA when available; validation and calibration work is ongoing
- Using first 24 h of each day's runs, tallied POD, FAR, CSI and other skill statistics of LFA across various seasons
- Tested various GFX thresholds to find ways to lower FAR
- Checked threshold for blended threat to ensure areal coverage remains accurate
- For CAPS ensemble runs, assess rms variability of LFA output from standard (non-customized) LFA code
- Compile list of significant cases that need detailed study

Results

- LFA has been successfully incorporated into WRF runs at NSSL, CAPS, HRRR and AWC
- LFA output appears generally reasonable and useful
- Highest LFA flash rates occur in summer storms (pulse and supercell); LMA shows similar peak flash rate density (FRD) values; graupel flux threat usually exceeds VII in such cases
- Supercell events well handled by LFA, but pulse storm events seen by LMA show more range of variation than do those predicted by WRF and LFA (predictability issues?)
- Cold stratiform clouds often trigger LFA false alarms in winter
- To reduce winter false alarms, set GFX=0 when max < 1.50
- To eliminate errors at high, low FRD, force VII threat to match peak of GFX threat before doing blend step
- Revised LFA should reduce FAR by 85%, handle high FRD cases better



LFA statistics, NSSL WRF, 2010-2011
contingency tables, HUN winter stratiform weather
using LTG1 threshold = 0.01 fl km^{-2}/(5 min)
format: n(JFMD2010) + n(JFM2011) = total

Hit days: 0 + 1 = 1	False alarm days: 23 + 17 = 40
Miss days: 0 + 0 = 0	True null days: 75 + 43 = 118

LFA statistics, NSSL WRF, 2010-2011
contingency tables, HUN winter stratiform weather
using LTG1 threshold = 1.50 fl km^{-2}/(5 min)
format: n(JFMD2010) + n(JFM2011) = total

Hit days: 0 + 1 = 1	False alarm days: 3 + 3 = 6
Miss days: 0 + 0 = 0	True null days: 95 + 57 = 152

Statistics, HUN winter stratiform weather

- *Using LTG1 > 0.01:*
- POD = 1.00
- FAR = 0.98
- CSI = 0.02
- BIAS = 41.00
- TSS = 0.75
- HSS = 0.04

- *Using LTG1 > 1.50:*
- POD = 1.00
- FAR = 0.86
- CSI = 0.14
- BIAS = 7.00
- TSS = 0.96
- HSS = 0.24

LFA statistics, NSSL WRF, 2010-2011
contingency tables, HUN summer convective weather
using LTG1 threshold = 0.01 fl km^{-2}/(5 min)
format: n(JJA2010) + n(JJA2011) = total

Hit days: 86 + 83 = 169	False alarm days: 3 + 8 = 11
Miss days: 0 + 0 = 0	True null days: 0 + 1 = 1

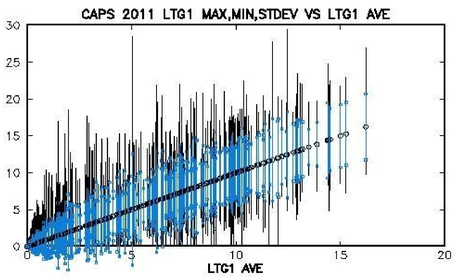
LFA statistics, NSSL WRF, 2010-2011
contingency tables, HUN summer convective weather
using LTG1 threshold = 1.50 fl km^{-2}/(5 min)
format: n(JJA2010) + n(JJA2011) = total

Hit days: 86 + 83 = 169	False alarm days: 3 + 6 = 9
Miss days: 0 + 0 = 0	True null days: 0 + 3 = 3

Statistics, HUN summer convective weather

- *Using LTG1 > 0.01:*
- POD = 1.00
- FAR = 0.07
- CSI = 0.94
- BIAS = 1.07
- TSS = 0.08
- HSS = 0.15

- *Using LTG1 > 1.50:*
- POD = 1.00
- FAR = 0.05
- CSI = 0.95
- BIAS = 1.05
- TSS = 0.25
- HSS = 0.38

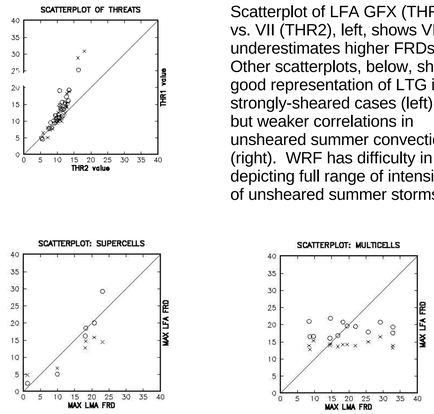


Means, ranges and sd , left, of GFX (=LTG1) flash rate density from 14 LFA-enabled CAPS WRF members in Spring 2011, sorted by interexperiment mean peak GFX flash rate density. SD is drawn in blue. Note slow increase in sd as flash rates increase, and presence of occasional outliers. This suggests absolute errors increase as flash rates increase, but relative errors decrease under similar conditions.

Statistics, HUN spring convective weather

- *Using LTG1 > 0.01:*
- POD = 1.00
- FAR = 0.28
- CSI = 0.72
- BIAS = 1.39
- TSS = 0.42
- HSS = 0.46

- *Using LTG1 > 1.50:*
- POD = 1.00
- FAR = 0.21
- CSI = 0.79
- BIAS = 1.27
- TSS = 0.60
- HSS = 0.65



Scatterplot of LFA GFX (THR1) vs. VII (THR2), left, shows VII underestimates higher FRDs. Other scatterplots, below, show good representation of LTG in strongly-sheared cases (left), but weaker correlations in unsheared summer convection (right). WRF has difficulty in depicting full range of intensity of unsheared summer storms.

Summary

- WRF LFA appears to provide useful, reliable results in NSSL, CAPS, HRRR WRF runs
- Analysis of 2010-2011 data suggest changes to LFA that will improve performance; these have been added to NSSL, CAPS, HRRR:
- GFX threat yields higher accuracy in very high and very low (winter) flash rate cases, so rely on GFX threat for estimating the amplitude of peak FRD in all cases; force VII to match GFX peak value before blending
- Boosting GFX threshold reduces winter FAR without compromising summer performance
- LFA predictions appear more accurate for sheared storms than for less-sheared ones; WRF has trouble distinguishing intensity of weakly sheared "pulse" CBs
- CAPS ensembles show RMS errors of LFA are about 3-4 fl/km2/(5 min), which are only weakly increasing with FRD; there are some occasional outliers
- CAPS ensembles show that LFA errors are larger in *absolute* sense at high FRD, but larger in *relative* sense at small FRD

Future Work

- Assess performance of revised LFA in new NSSL, CAPS, HRRR runs; collaborative visit to HRRR office planned in 2012
- Optimize LFA performance in HRRR model, and examine LFA use in AWC research
- Examine utility of LFA for lightning initiation & cessation work
- Compare LFA prognoses of LTG threat for wildfires from dry western storms to NLDN observations
- Examine LFA behavior in hurricane HWRF simulations, to assess realism and ability to predict rapid intensification of Tcs
- Assist, consult with DA teams as they test LFA proxy data in anticipation of GOES-R