SESSION-03.373: THE WRF LIGHTNING FORECASTING ALGORITHM: SENSITIVITIES TO MICROPHYSICS AND BOUNDARY LAYER PHYSICS SCHEMES

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Background

- WRF-based Lightning Forecast Algorithm (LFA) exploits the observed robust relationships between LTG flash rates and large precipitating ice in convection-permitting simulated storms
- LFA was designed to be simple and easy to implement
- LFA uses two proxy fields: graupel flux at -15°C (GFX) and vertically-integrated ice (VII); the algorithm is designed to be regime-independent and can be applied in any location
- GFX represents amplitude and time variability of LTG; VII represents areal coverage of LTG; a weighted average blend of 0.95GFX + 0.05VII gives best overall results
- Original LFA study used 2 km mesh, WSM6 microphysics, and used only North Alabama storms for which North Alabama LMA data were available for calibration; recent WRF efforts have used 3-4 km CONUS mesh, with varying microphysics
- Since LFA was designed using single-moment WSM6, and graupel amounts may vary with other microphysics options, it is necessary to examine sensitivity to model physics
- Here we document the changes of LFA diagnoses of peak flash rate density (FRD) arising from a subset of available combinations of microphysics and boundary layer packages.

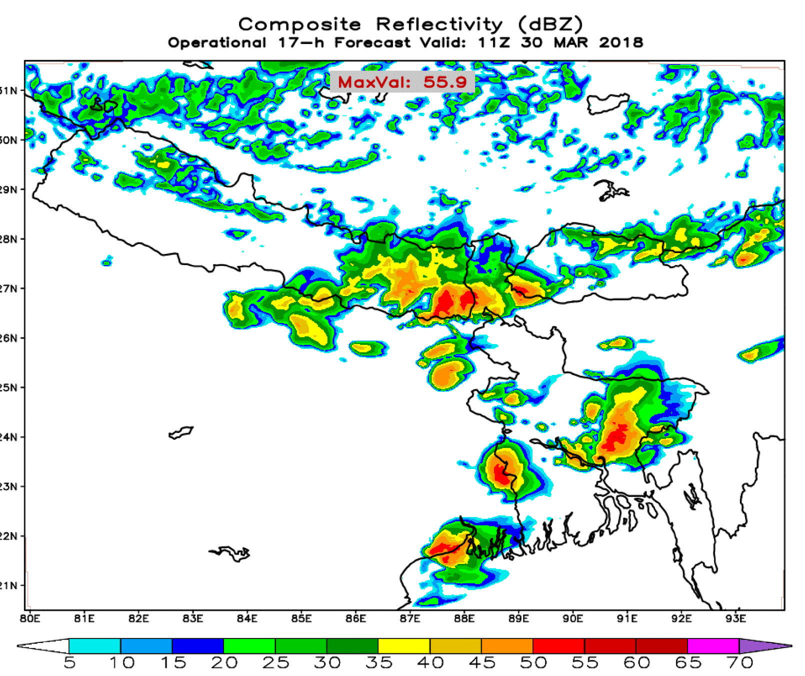
Methodology

- We apply the LFA to WRF output from daily 48-h, 4-km mesh forecast runs over Nepal-Bangladesh-NE India during the pre-monsoon 2018 severe convective season, initialized at 18z.
- Consider only 6-30 h output to align with diurnal cycle.
- A matrix of 12 WRF forecasts was executed each day, with 4 options for microphysics mated with 3 for PBL.
- The microphysics and PBL options are listed in Table below. Note that WSM6 and MYJ is configuration on which the original LFA was built. Another microphysics option of interest is Thompson 2-moment, which is used in the operational RAP/HRRR model.
- We use the WSM6/MYJ output as a proxy for ground truth (since this combination was calibrated against the North Alabama LMA), and simply compare the LFA output from the other 11 runs to this "REF" output. Metrics: peak FRD, peak area seen during daily storms; we focus on the ratios F = FRD.REF / FRD and its analog F_a for peak area.

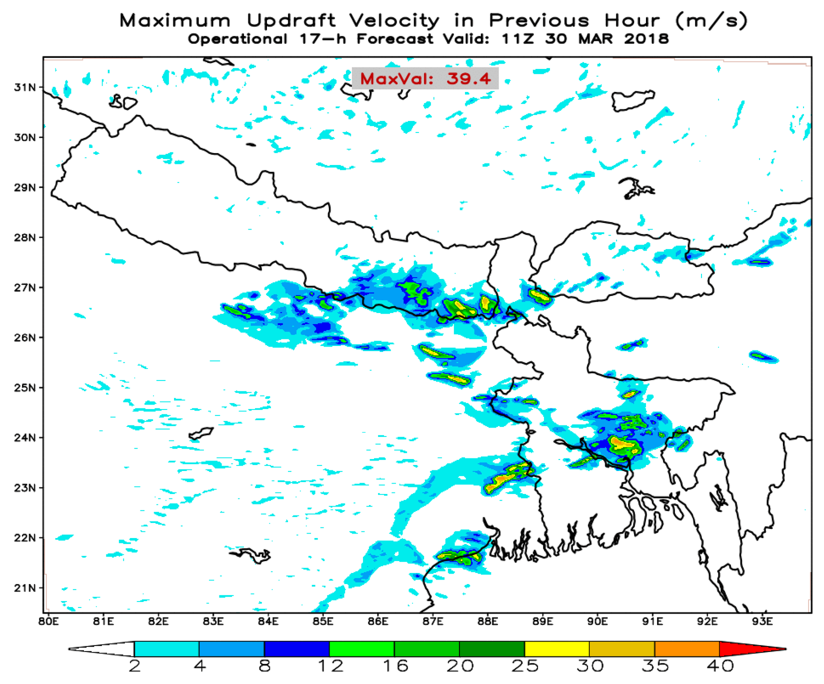
Results

- LFA F, F_a values are obtained for each of the 12 forecasts made on for 73 convective days in March to May 2018. Scatterplots of peak FRD vs. the FRD.REF are constructed, and an estimate of F is computed from the slope of the linear regression line in the scatterplots. We seek to learn if the F slopes differ significantly from 1.0. Note that for one experiment, the reference WSM6-MYJ run, all the F estimates collapse to unity, as expected. We apply the same for F_a.
- The scatterplots show that the ratio F never exceeds 1.21; differences are not significant, with only 2 exceptions.
- F values for MYNN2 exceed 1.0, with a value of 1.13 for Thompson-MYNN2 HRRR run. Thompson scheme shows relatively large F bias to REF run. F_a values differ from 1.0 by more significant margins, depending on microphysics.
- The ratios F, F_a may be applied to the LFA calibration constants to produce better results; HRRR scheme suffers from too little graupel and too little anvil ice, compared to REF scheme.
- Simulated storms and their LFA peak FRDs are also sensitive to other aspects of forecast initialization (not shown).

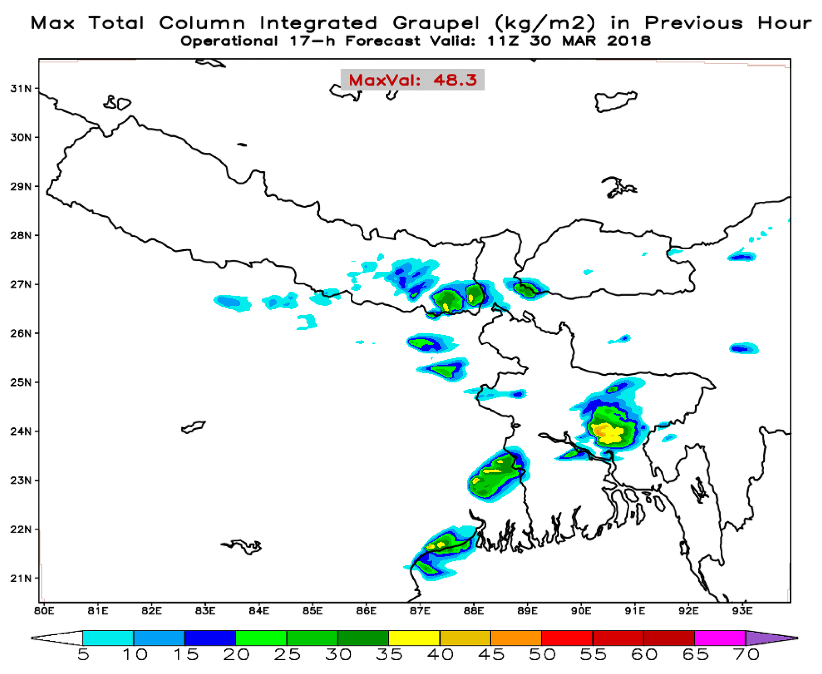
WRF composite dBZ for N. India-Bangladesh, At 11 UTC 29 March 2018:



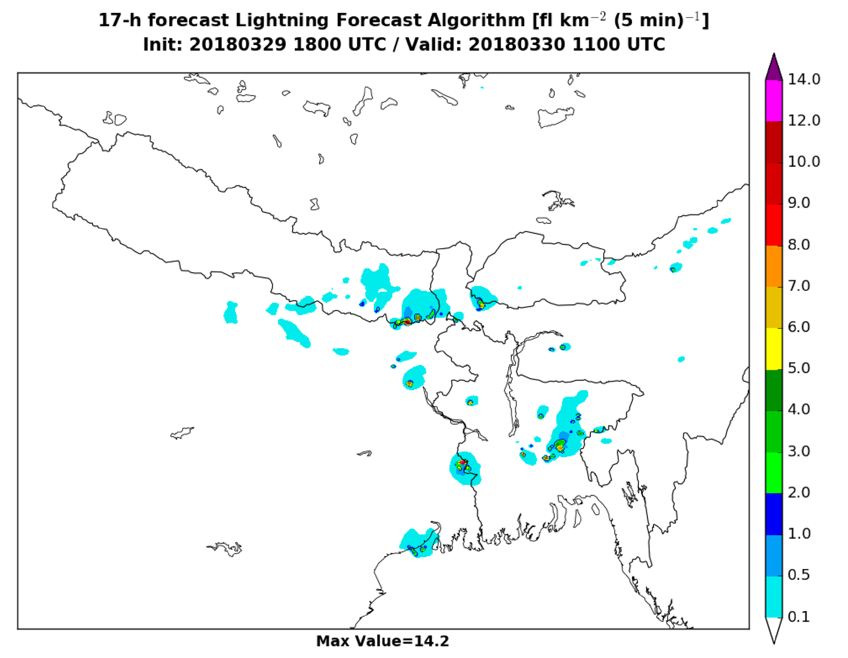
Same as above, but for 2-5 km Updraft Velocity

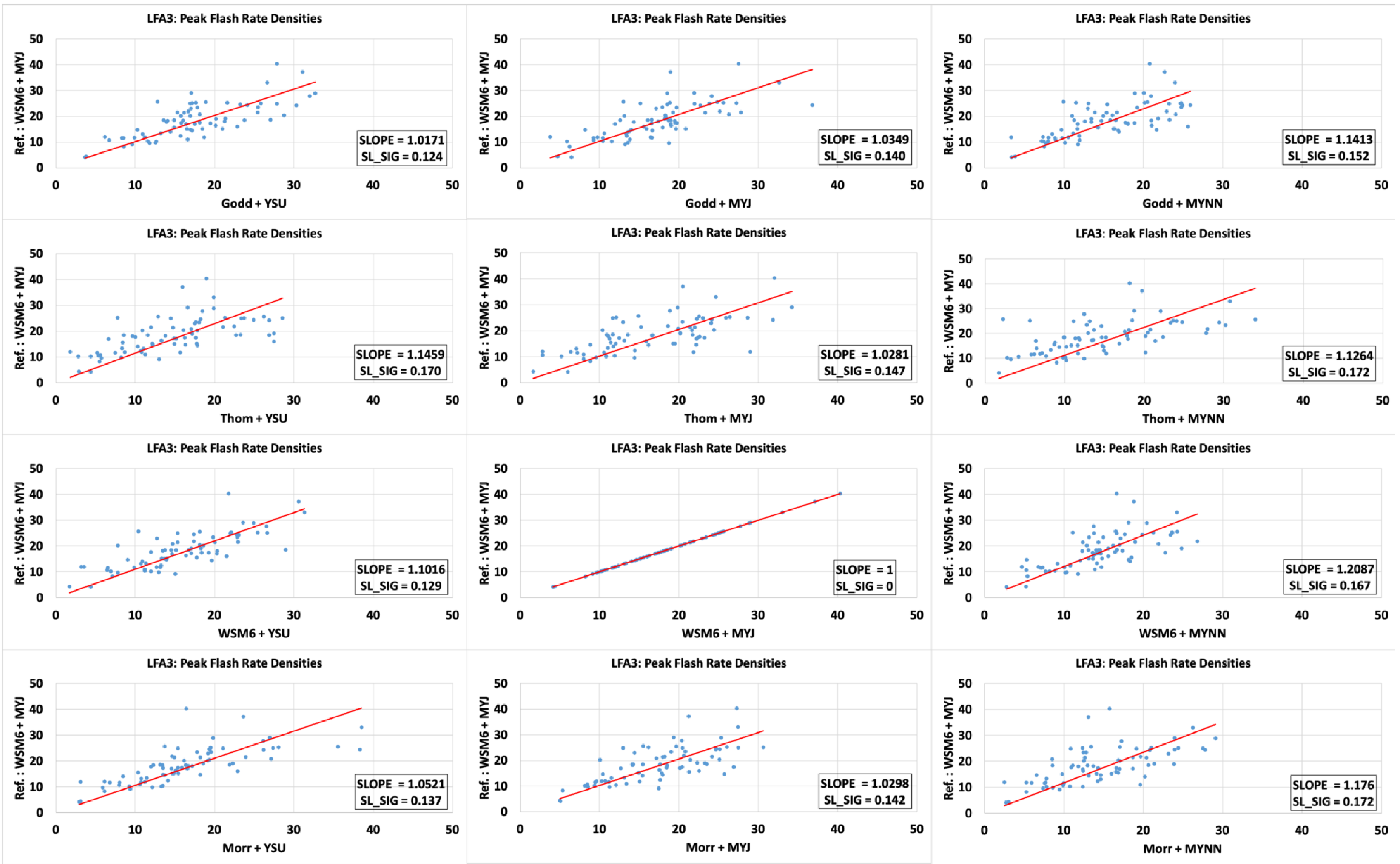


Same as above, but for 2-5 km Column Graupel



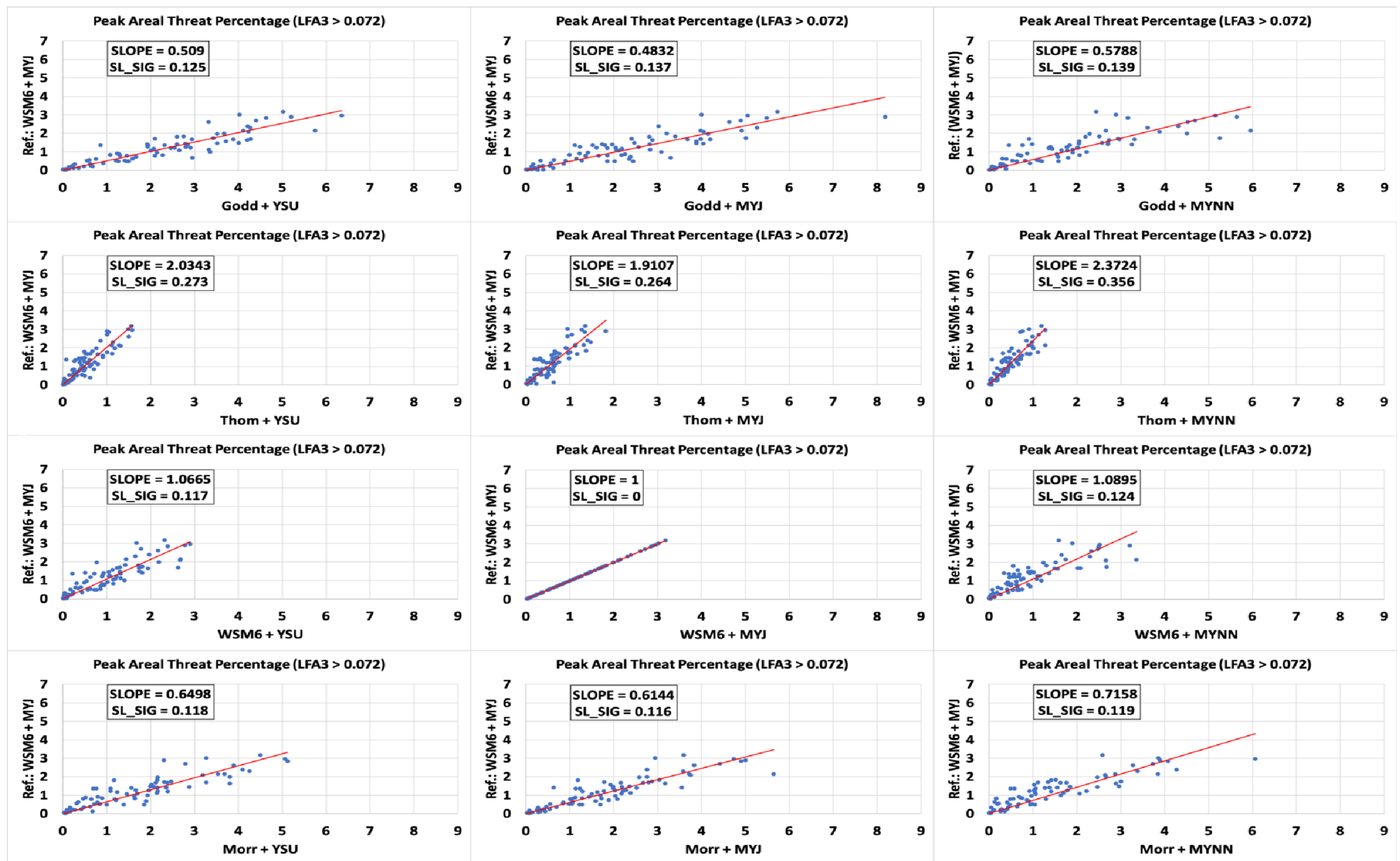
Same as above, but for LFA flash rate density





Scatterplots: Peak Flash Rate Densities

Note all slopes FRD.REF / FRD are > 1.0, except for REF scheme; thus all schemes produce less FRD than the REF. This implies under-production of graupel ice hydrometeor species. Statistical analysis shows only two MYNN2 schemes exceed 1.0+SL_SIG and differ significantly from REF scheme.



Scatterplots: Peak Threat Area Fraction

Here, slopes for each microphysics scheme other than WSM6 differ from 1.0 by amounts > SL_SIG, indicating statistical significance. Thom needs area boost by about 2.0 (too little cloud ice/snow in anvils). PBL scheme impacts are minor.

Table of Schemes

- Microphysics schemes (4 tested):
  - Goddard (GODD)
  - Thompson quasi double-moment (THOM)
  - WRF Single moment 6 Species (WSM6)
  - Morrison double-moment (MORR).
- PBL Physics schemes (3 tested):
  - Yonsei University (YSU)
  - Mellor Yamada Janjic (MYJ)
  - Mellor Yamada Nakanishi Niino 2.5 (MYNN2)
- 4x3 = 12 combinations tested; infeasible to test the myriad of others physics combinations. Results here are therefore NOT exhaustive.

Summary

- As with WRF model simulated convection in general, LFA output is sensitive to cloud and PBL physics.
- WRF convection is also sensitive to model initialization uncertainties and unresolved errors.
- Large sensitivity exists in HRRR-like Thompson microphysics and PBL, for which original LFA calibration constant needs to be multiplied by 1.13 to give proper FRD amplitudes.
- Thompson microphysics scheme also shows poorest correlations relative to reference data, suggesting low predictability of HRRR LFA output.
- Need to validate HRRR LFA against GLM observations.

Acknowledgments

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