Impacts of Microphysics and PBL Physics Schemes on Tornado Outbreak Prediction

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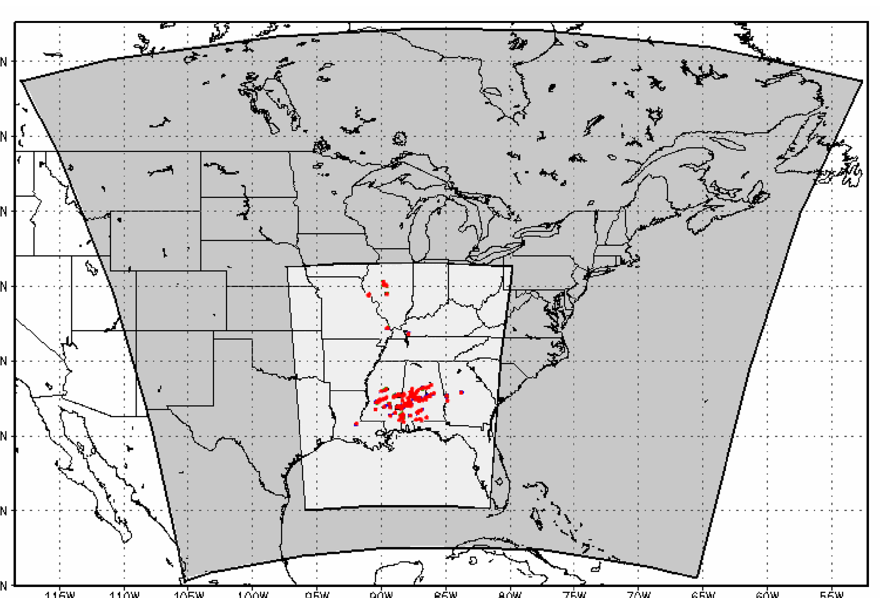
Introduction

A major tornado outbreak can be anticipated multiple days in advance in ideal outbreak setups. However, forecasts often miss the dominant severe weather mode (tornadoes, wind, hail, flooding) until the event is underway. Since nontornadic outbreaks are typically less of a threat to life and property, it is common to separate outbreak modes into tornadic and nontornadic outbreak types for such forecast applications (Shafer et al. 2010, Mercer et al. 2009). Numerous studies have examined the impact of model physics parameterization schemes on the modeling of convection processes, cloud ice production, and mesoscale weather events. However, no study has formally identified the performance of a suite of physics parameterizations in severe weather outbreak mode forecasting. Therefore, the goal of this research is to identify the individual impact of certain physics parameterization schemes on the ability to distinguish tornadic and nontornadic outbreaks within an NWP framework.

Methodology

20 tornadic and 20 nontornadic outbreaks from 2008-2011 were modeled in this study. Five microphysics schemes were selected for examination: the **Goddard**, **Morrison double-moment**, **Thompson**, **WRF double-moment 6-class (WDM-6)**, and **WRF single-moment 6-class (WSM-6)** microphysics. Three PBL schemes were chosen: the **Yonsei University**, **Mellor-Yamada-Janjic (MYJ)**, and refined **Asymmetric Convection Model (ACM2)** schemes.

WRF version 3.4.1 was used to generate the model fields. Runs were initialized at 1800 UTC the day preceding the outbreak to 1200 UTC the day after the outbreak. A two-way nested configuration was used, with the outer nest consisting of a 12-km Lambert-conformal grid and the inner nest consisting of a smaller 4-km grid centered on each outbreak.

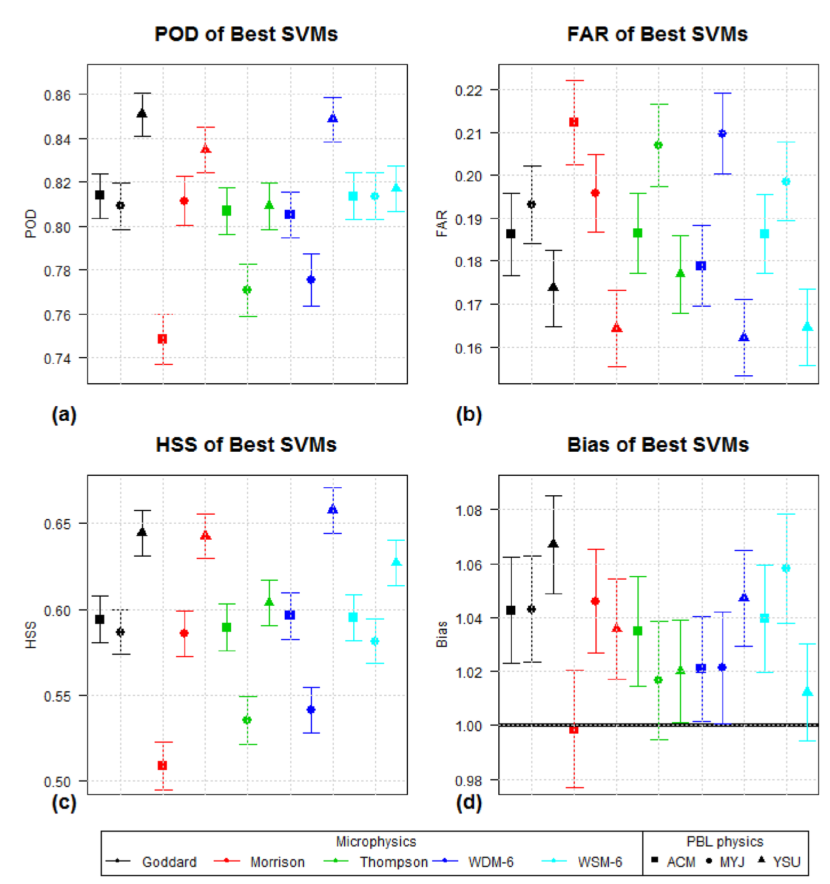


This study utilized a learning algorithm known as support vector machines (SVM) on the output of the WRF simulations to predict the type of outbreak suggested by the model run. Seven important covariates were calculated on the 4 km domains for each of the outbreaks at outbreak valid time: **0-1 km EHI**, **0-1 km storm-relative helicity**, **0-3 km SRH**, **0-1 km bulk shear**, **lifted condensation level**, **CAPE x 0-1 km bulk shear**, and **surface-based CIN.** S-mode PCA scores for each physics ensemble member were generated and input to the SVM.

To determine the impact of model physics on each type of outbreak, an average composite of all 20 covariate fields for each outbreak type was formulated for each of the physics runs. The contrasts in these composites help demonstrate the exact impacts of model physics variation on the simulations.

Results & Discussion

Contingency statistics for the SVMs indicated that the use of the WRF double-moment 6-class microphysics scheme (WDM-6) and Yonsei University PBL physics produced the highest skill.

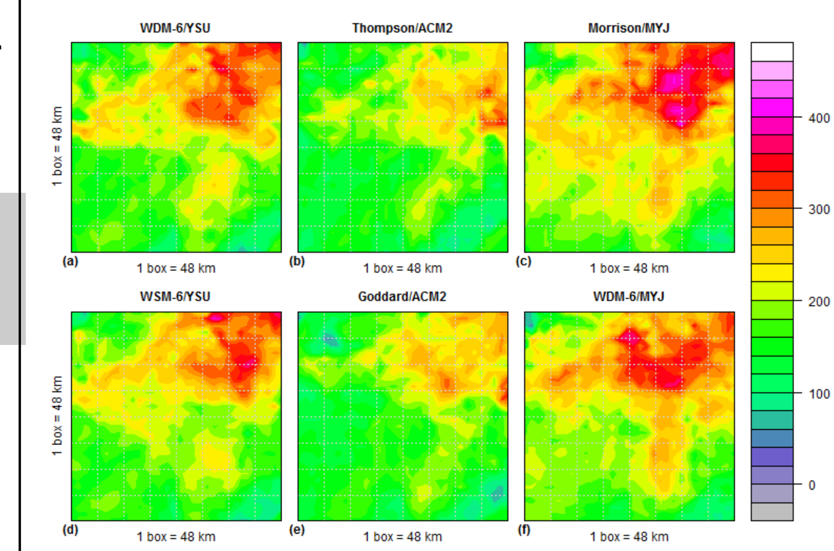


PBL physics had a strong impact on FAR. The Yonsei University scheme produced the lowest FAR of the PBL parameterizations for every microphysics option.

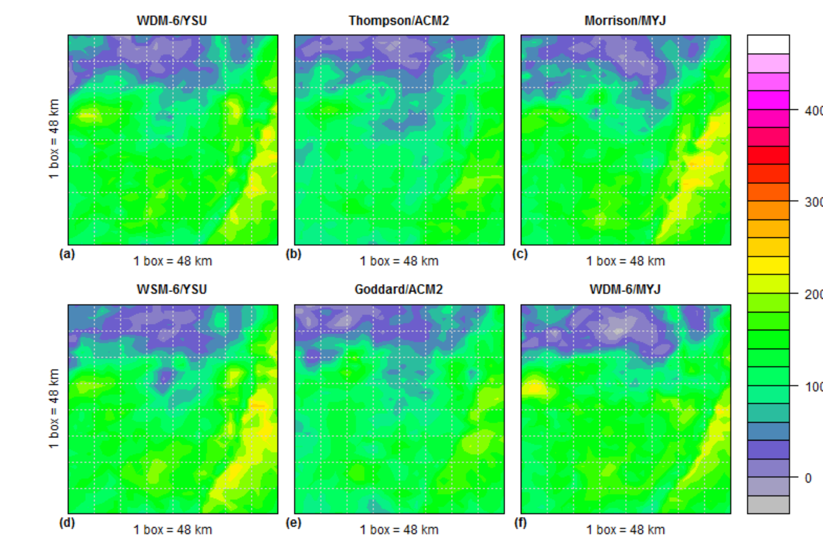
To determine the specific physical impact of physics on each type of outbreak, an average composite of CIN, 0-1 km SRH, and 0-1 km bulk shear for each outbreak type was formulated for the runs. A sample of these composites is shown here.

For 0-1 km SRH and 0-1 km bulk shear in tornado outbreaks, pronounced differences are apparent among the PBL parameterizations. MYJ PBL physics generated the highest values of 0-1 km SRH and 0-1 km bulk shear. Of the two MYJ runs examined in the composites, Morrison microphysics displayed higher values of both covariates than WDM-6. In tornado outbreaks, the CIN fields appear largely randomly dispersed, though a visual similarity does exist in the examined runs among WDM-6/Yonsei, WSM-6/Yonsei, and Thompson/ACM2.

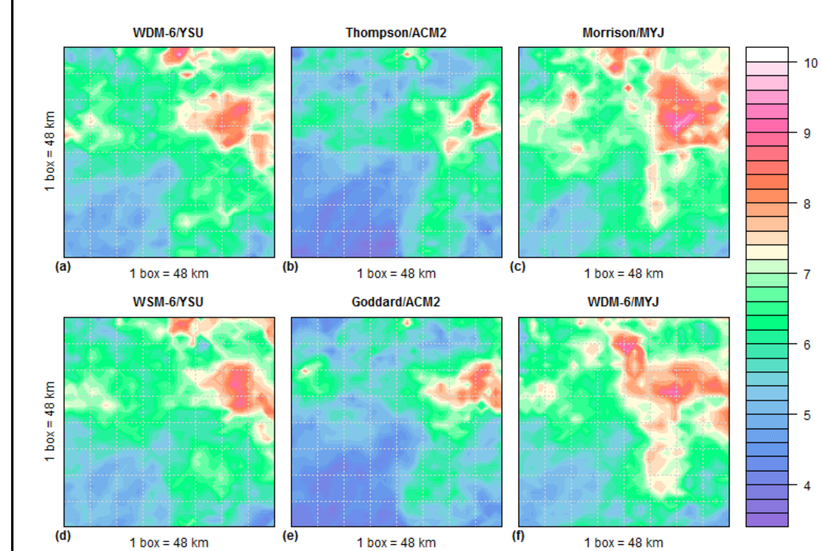
0-1 km SRH and 0-1 km bulk shear for the nontornadic outbreaks also displayed a strong PBL physics-based distinction. As was the case with the tornado outbreaks, ACM2 PBL physics decreased values of 0-1 km SRH and 0-1 km bulk shear relative to the other two PBL physics parameterizations. The role of microphysics in 0-1 km SRH and 0-1 km bulk shear nontornadic outbreak variations was very difficult to discern. CIN fields for nontornadic outbreaks exhibited a random pattern similarly to the tornado outbreaks, though with higher values. For the nontornadic outbreaks, PBL physics appeared to influence the spatial location of certain features, though not the magnitude of these features. In the Yonsei and MYJ composites, a small region of field-relative higher CIN oriented southwest to northeast was present in the center-right area of the composites. This feature was not discernible in the ACM2 composites.



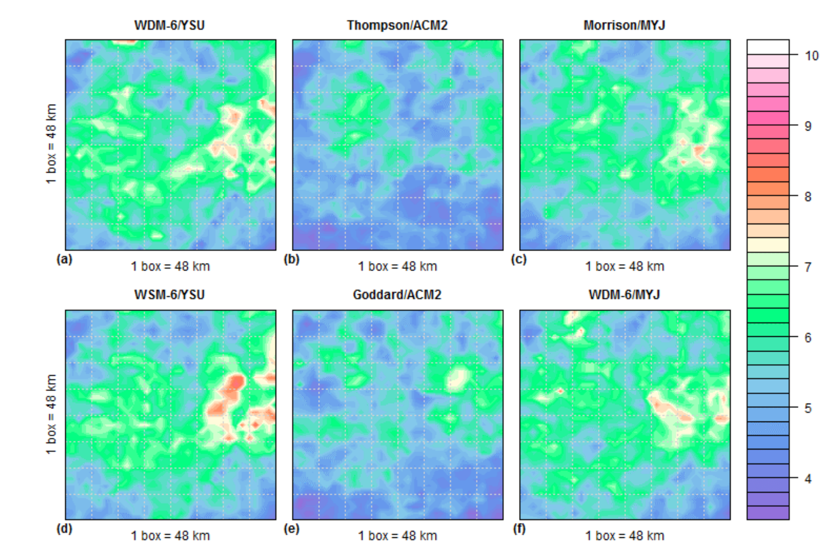
Tornadic outbreak composites of 0-1 km SRH



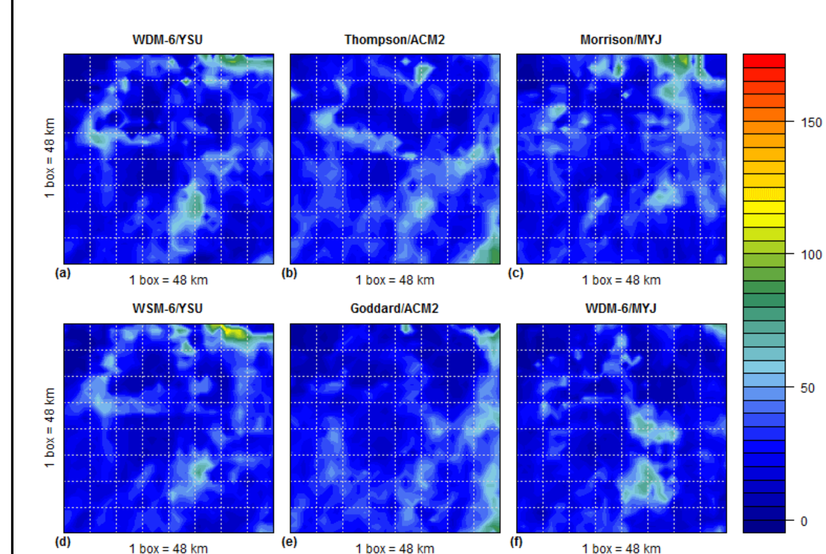
Nontornadic outbreak composites of 0-1 km SRH



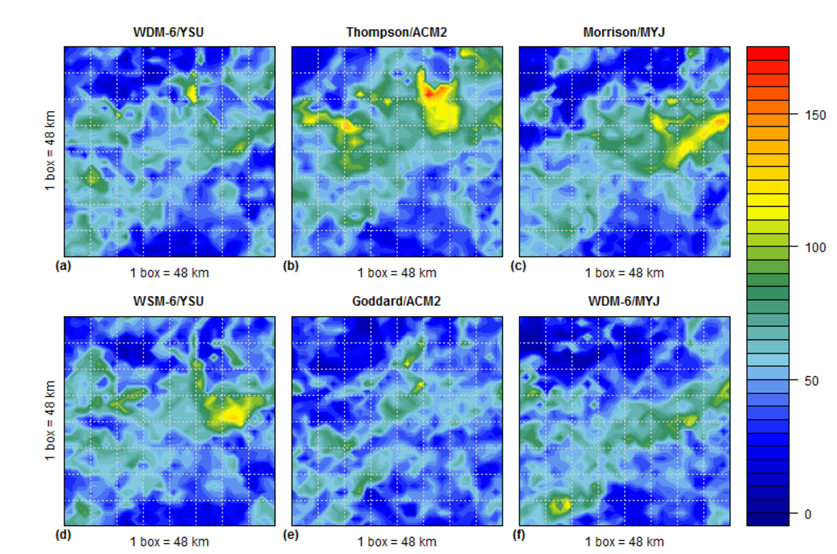
Tornadic outbreak composites of 0-1 km bulk shear



Nontornadic outbreak composites of 0-1 km bulk shear



Tornadic outbreak composites of CIN



Nontornadic outbreak composites of CIN

References

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Shafer, C. M, and C. A. Doswell III, 2010: A multivariate index for ranking and classifying severe weather outbreaks. *E-Journal of Severe Storms Meteorology,* Vol. 5, No. 1