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Simulation of Nocturnal LLJs with a WRF PBL Scheme Ensemble and Comparison to Observations from the ARM Project

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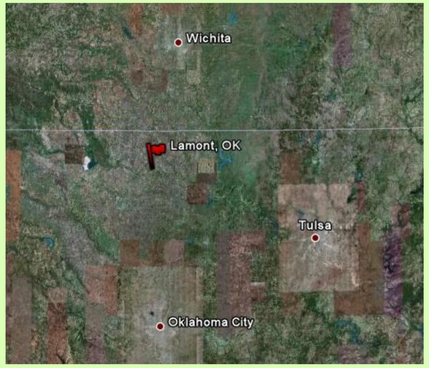
Introduction

- Low Level Jets (LLJs) –
  - Common weather phenomenon in Central US
  - Important for evolution of mesoscale convective systems
  - Roughly 50% of peak winds occur below 500m (Whiteman et al. 1997, Appl. Meteor., **36**:1363–1376.)
- Accurate forecasting of LLJs becoming even more important as taller turbines are used to generate wind power

Data and Methodology

- LLJs simulated using 10 km grid spacing Weather Research and Forecasting (WRF) model
- Six Planetary Boundary Layer (PBL) schemes were used:
  - Mellor Yamada Janjic (MYJ)
  - Yonsei University Scheme (YSU)
  - Quasi Normal Scale Elimination (QNSE)
  - Pleim or Asymmetric Convective Model (ACM2)
  - Mellor Yamada Nakanishi Nino 2.5 and 3.0 (MYNN 2.5 and MYNN3.0)
- Global Forecast System (GFS) used for initial/boundary conditions
- Lamont, OK profiler site from DOE Atmospheric Radiation Measurement (ARM) project used to validate ensemble
  - data availability below 500m
  - vertical resolution of 60m below 2,462m
- Thirty cases selected from June 2008 to May 2010
  - cases chosen based on nocturnal LLJ presence at site
  - mix of strong and weak LLJ cases used



Location of Lamont site. (Image from Google Earth)

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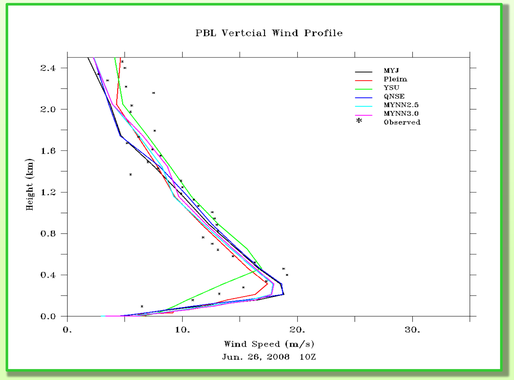
Results



Comparison of observed data from the Lamont, OK site to WRF runs with six PBL schemes at 10Z (4am CDT) June 26, 2008

Table 1: Average Peak Wind Speed

MYJ	Pleim	YSU	QNSE	MYNN2.5	MYNN3.0	Ensemble	OBS
19.0m/s	18.2m/s	16.3m/s	19.1m/s	18.2m/s	17.9m/s	18.1m/s	22.7m/s

Table 1: Average peak wind speed for each PBL scheme and the observed data from all 30 cases. All six PBL schemes under-predicted the observed data with the QNSE scheme producing the best results.

Table 2: Average Height of LLJ Max

MYJ	Pleim	YSU	QNSE	MYNN2.5	MYNN3.0	Ensemble	OBS
371.2m	427.0m	538.3m	344.5m	365.3m	340.3m	397.8m	553.0m

Table 2: Average height of low level jet maximum for each PBL scheme and the observed data from all 30 cases. Notice all six PBL schemes under-predicted the observed data.

Duration Calculation

- Duration determined from graphical display of LLJ event
  - Duration starting hour marked by beginning of LLJ event
  - Duration end hour marked by end of LLJ event or hour in which LLJ was one half peak wind speed

Table 3: Average Duration

MYJ	Pleim	YSU	QNSE	MYNN2.5	MYNN3.0	Ensemble	OBS
10.6hrs	10.4hrs	10.3hrs	10.6hrs	10.6hrs	10.6hrs	10.5hrs	11.1hrs

Table 3: Average duration of the LLJ event for each PBL scheme and the observed data from all 30 cases. The duration of simulated LLJ events was roughly 11 hours, matching observed data.

Bonner Classification Breakdown

- Used Bonner criteria to classify wind speed and intensity of LLJ
  - Criteria 1 – Peak wind speed must equal or exceed 12 m/s and must decrease by at least 6 m/s by 3km
  - Criteria 2 – Peak wind speed must equal or exceed 16 m/s and must decrease by at least 8 m/s by 3km.
  - Criteria 3 – Peak wind speed must equal or exceed 20 m/s and must decrease by at least 10 m/s by 3km

Table 4: Bonner Criteria 1

	Avg Peak Wind Speed	Avg Height of LLJ Max	Avg Duration
MYJ	15.2m/s	270.0m	7.7hrs
Pleim	14.5m/s	490.0m	5.3hrs
YSU	13.7m/s	583.3m	5.7hrs
QNSE	15.8m/s	463.3m	8.0hrs
MYNN2.5	15.1m/s	436.7m	8.0hrs
MYNN3.0	14.3m/s	403.3m	8.0hrs
Ensemble	14.6m/s	441.1m	7.1hrs
OBS	13.9m/s	366.7m	11.3hrs

Table 4: Results for all cases classified as Bonner Criteria 1. The schemes over-predicted the peak wind speed and height of LLJ maximum; however, the schemes under-predicted the duration.

Table 5: Bonner Criteria 2

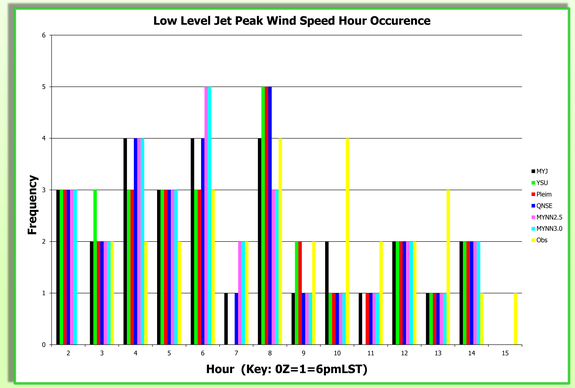
	Avg Peak Wind Speed	Avg Height of LLJ Max	Avg Duration
MYJ	19.4m/s	365.0m	12.0hrs
Pleim	18.1m/s	414.0m	11.9hrs
YSU	17.7m/s	538.0m	11.6hrs
QNSE	19.0m/s	352.0m	12.0hrs
MYNN2.5	18.3m/s	373.0m	12.0hrs
MYNN3.0	17.8m/s	373.0m	11.9hrs
Ensemble	18.4m/s	402.5m	11.9hrs
OBS	21.7m/s	592.0m	10.2hrs

Table 5: Results for all cases classified as Bonner Criteria 2. The schemes under-predicted peak wind speed and height of LLJ maximum; however, duration was over-predicted by the schemes.

Table 6: Bonner Criteria 3

	Avg Peak Wind Speed	Avg Height of LLJ Max	Avg Duration
MYJ	20.2m/s	410.9m	10.5hrs
Pleim	19.7m/s	441.3m	10.4hrs
YSU	16.7m/s	548.1m	10.4hrs
QNSE	20.5m/s	369.1m	10.4hrs
MYNN2.5	19.7m/s	400.0m	10.5hrs
MYNN3.0	19.3m/s	358.1m	10.5hrs
Ensemble	19.4m/s	421.3m	10.5hrs
OBS	25.8m/s	575.0m	12.0hrs

Table 6: Results for all cases classified as Bonner Criteria 3. The schemes under-predicted peak wind speed, height of LLJ max, and the duration.



Frequency of hour in which the peak wind speed took place for both the simulations and observed data. Note the schemes showed the peak wind speed in the late night hours while the observations showed the peak wind speed in the early morning hours.

Conclusions

- Average peak wind speeds were under-predicted by all ensemble members
- All schemes except YSU under-predicted the average height of LLJ max by more than 150 m.
- Duration of LLJ events agreed well with observed data
- Bonner Criteria 1:
  - Peak wind speed and height of LLJ max over-predicted by models
  - Duration under-predicted observed cases by almost 4 hours
- Bonner Criteria 2:
  - Models under-predicted peak wind speed and average height of LLJ max
  - Models over-predicted duration
- Bonner Criteria 3:
  - Models under-predicted average wind speed with larger difference than Bonner Criteria 1 or 2
  - Models under-predicted average height of LLJ max and duration
- Models showed peak wind speed occurrence during late night, disagreeing with observed peak in early morning

Example of a wind profiler. (Image from NOAA)

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