WRF MODELED LOW-LEVEL JET CLIMATOLOGY COMPARED TO OBSERVED CLIMATOLOGIES: WEAKNESSES AND STRENGTHS

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1. INTRODUCTION

Nocturnal low-level jets (LLJs) are common features observed in the Great Plains region of the United States. LLJs play a key factor in initiating and sustaining mesoscale convective systems and other severe convective storm modes in the Great Plains. These LLJs can also be a key source of moisture transport into the Great Plains, which could lead to severe weather development and widespread flooding. LLJs make the Great Plains wind resources more favorable for wind energy production. At the same time, the presence of LLJs can significantly modify vertical shear and nighttime turbulence environments in the vicinities of wind turbine hub height and have detrimental effects on rotors.

Several observational studies have been conducted to determine the climatology of LLJs over the Great Plains (e.g Bonner, 1968; Whiteman et al., 1997; Song et al., 2005). However, these studies are limited due to spatial restraints. Using point measurements makes it nearly impossible to determine the spatial structure of LLJs. Using a numerical weather prediction (NWP) model, on the other hand, lessens this restraint. However, grid spacing and frequency of the model output is still problematic in the case of operational forecasts.

This study investigates how well the operational Advanced Research WRF (ARW) forecasts represent the LLJ climatology of the Great Plains region. If the WRF can be shown to produce a similar climatology to that what has been observed, we gain more confidence in WRF and its planetary boundary layer (PBL) parameterizations.

It is important to know how well the WRF is representing the LLJ for pollutant transport forecasts and moisture transport in the Great Plains, which can be a key factor in thunderstorm initiation. If any deficiencies are found in predicting the LLJ climatology, improvements to current modeling approaches will be investigated.

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2. DATA AND METHODS

To evaluate if WRF is accurately representing the LLJ climatology at the ABLE site, 6 months of WRF forecasts (April – September 2006) have been collected and analyzed. To complete the LLJ climatology, the 6 months of WRF output during the cold season (October 2006 – March 2007) will be collected and analyzed. The WRF output being utilized was generated in real time at NCAR. The configuration is a 36/12 km two-way nested run (35 vertical levels) which is initialized from 40 km Eta grib data at 0000 UTC every day. The model physics options include: WSM 3-class simple ice scheme microphysics, RRTM long-wave radiation, Dudhia Shortwave radiation, YSU PBL scheme, Noah land-surface model, and Kain-Fritsch cumulization. 48 hour forecast were generated, with output every three hours. This means two separate forecasts are generated for verification at the same time (0300 – 1200 UTC), 3 to 12 hour forecasts and 27 to 36 hour forecasts. The WRF output during the warm season months were not available for 10 days, so this results in 173 days and 692 forecast times available for analysis. Analyzing these two separate forecast periods give insight on the predictability of LLJs within WRF.

Since the investigation by Song et al. (2005) includes the longest data set and uses data with a fine vertical resolution, comparison between the WRF output to this data will be done. Song et al. (2005) classified jets into four categories (LLJ0 – LLJ3) as shown in Table 1. These classifications are different from Bonner (1968) and others since the categories are not cumulative. For example, Bonner (1968) would classify a jet having a max wind speed of 14 ms^{-1} and a change in wind speed of 6 ms^{-1} as both a category 0 and 1 jet, while Song et al. (2005) will only classify it as a category 1 jet.

3. RESULTS

As seen in Table 1, both the observed and WRF climatologies have a dominant direction from the south. However, less LLJs are represented in the WRF simulations in comparison to the 6-year climatology. It is also obvious from Table 1 that the WRF output database lacks

Table 1: Criteria for LLJ categories and LLJ occurrences from (Song et al., 2005) and operational WRF forecasts

			LLJ occurrence (hours/nights)					
			Song et al. (2005)		3-12 hour forecast		27-36 hour forecast	
Category	Vmax	ΔV	Southerly	Northerly	Southerly	Northerly	Southerly	Northerly
0	≥ 10	> 5	997/82	303/41	46/15	13/5	54/20	26/5
1	≥ 12	> 6	1638/217	328/76	90/29	11/6	71/32	15/8
2	≥ 16	> 8	967/180	100/31	35/15	2/1	28/13	4/2
3	≥ 20	> 10	569/139	35/15	8/2	1/1	5/3	1/1
Total			4171/618	766/163	179/61	27/13	158/68	46/16
Percentage			37%/60%	7%/16%	26%/35%	4%/5%	23%/39%	7%/9%

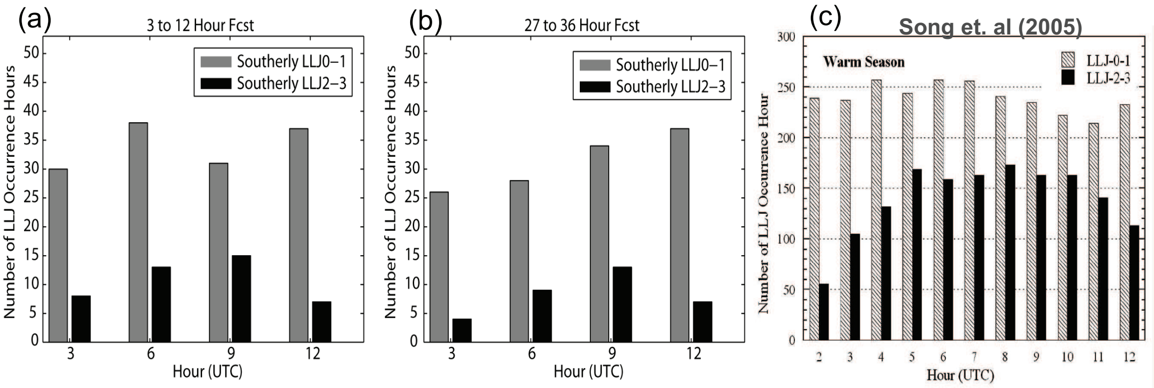

Figure 1: Nocturnal variations in southerly LLJ occurrences during the warm seasons for (a) 3-12 hour WRF forecast, (b) 27-36 hour WRF forecast, and (c) Song et al. (2005) 6-yr hourly dataset.

stronger LLJ events, as majority of the LLJs in WRF are classified as LLJ1s. This discrepency significant and reasons for this will be investigated.

There appears to be a distinct difference between the number of hours and nights of LLJ events between the two WRF datasets, 3-12 and 27-36 hour forecasts. This may be due to the fact 10 days of WRF output was not available. This results in different days being represented in the two data sets. The difference might also be an indication of how sensitive the predictability of LLJs are. This could indicate as simulation time increases, accurately simulating LLJs can be significantly affected.

Similar nocturnal trends are displayed in both the WRF and profiler-based observations, with both having a nocturnal dominance. Fig. 1 show that the stronger jets occur more frequently during the middle of the nights, while there are no clear trends for weaker jets.

The monthly distribution between the WRF and observed climatology agree fairly well for both northerly and southerly jets (Fig. 2). Both the observed and WRF show a peak in LLJ events between June – August, though the distribution in the 27-36 hour forecast data set does not match as well. This again may be due to the fact that 10 days of WRF output was not available, resulting in different days being represented in the two data sets. This again could indicate issues with the model spin-up time or the predictability limit of LLJs.

The average height of the LLJs from WRF are also around 300 – 400 meters too high (Fig 3). It also appears that the strong jets from WRF are higher than what has been observed. Vertical resolution and the performance of the PBL scheme are key and will be discussed more later.

4. CONCLUSIONS AND FUTURE WORK

WRF shows promising signs of being able to represent LLJs across the Great Plains, though the need for improvement is evident. The nocturnal and southerly dominance is present in both the WRF and observed climatology. Why fewer jets are being represented in WRF than is typically observed needs to be investigated. The lack of LLJs could be due to the diffusion in the PBL scheme, or a product of the vertical resolution.

Since the preliminary LLJ climatology indicate that the LLJ heights are higher than the observed climatol-

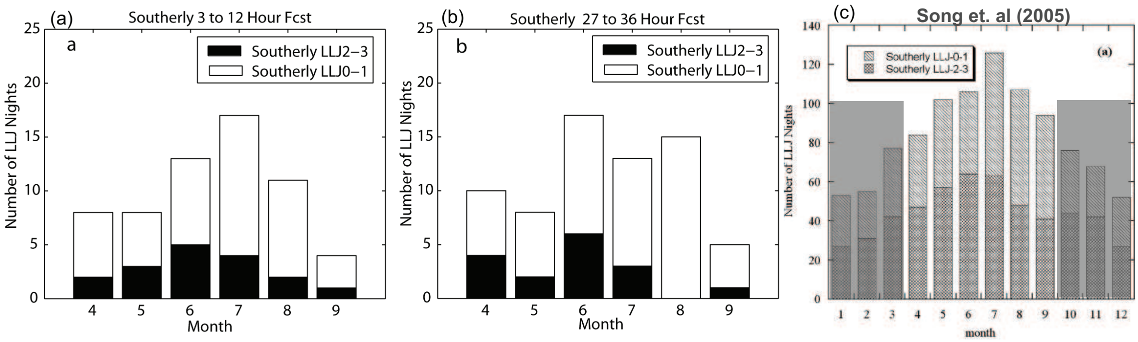

Figure 2: Variations in monthly occurrence of southerly LLJs for (a) 3-12 hour WRF forecast, (b) 27-36 hour WRF forecast, and (c) Song et al. (2005) 6-yr hourly dataset.

ogy, detailed investigation of selected cases will be done. The same model configuration and input used at NCAR will be used, with the exception of the vertical resolution. The resolution will be increased within the lower levels to determine if this will improve the LLJ height location. The use of LES or 1-D codes may be done too to help determine if the YSU PBL scheme is problematic. Again, it is possible that the YSU PBL scheme has excessive diffusion to accurately represent LLJs. Furthermore, the ARW-MYJ PBL scheme will be evaluated as a viable alternative.

WRF shows promising capabilities to investigate in detail forcing mechanisms of LLJs, which is still not well known at this time. Once WRF can represent most LLJs accurately, improvements in moisture transportation and subsequently thunderstorm initiation should be a by-product.

Six months of WRF output during the cold season (October 2006-March 2007) has been collected and is being analyzed to complete the one-year climatology. This will give insight if there is any bias between the WRF warm and cold season months.

5. ACKNOWLEDGMENTS

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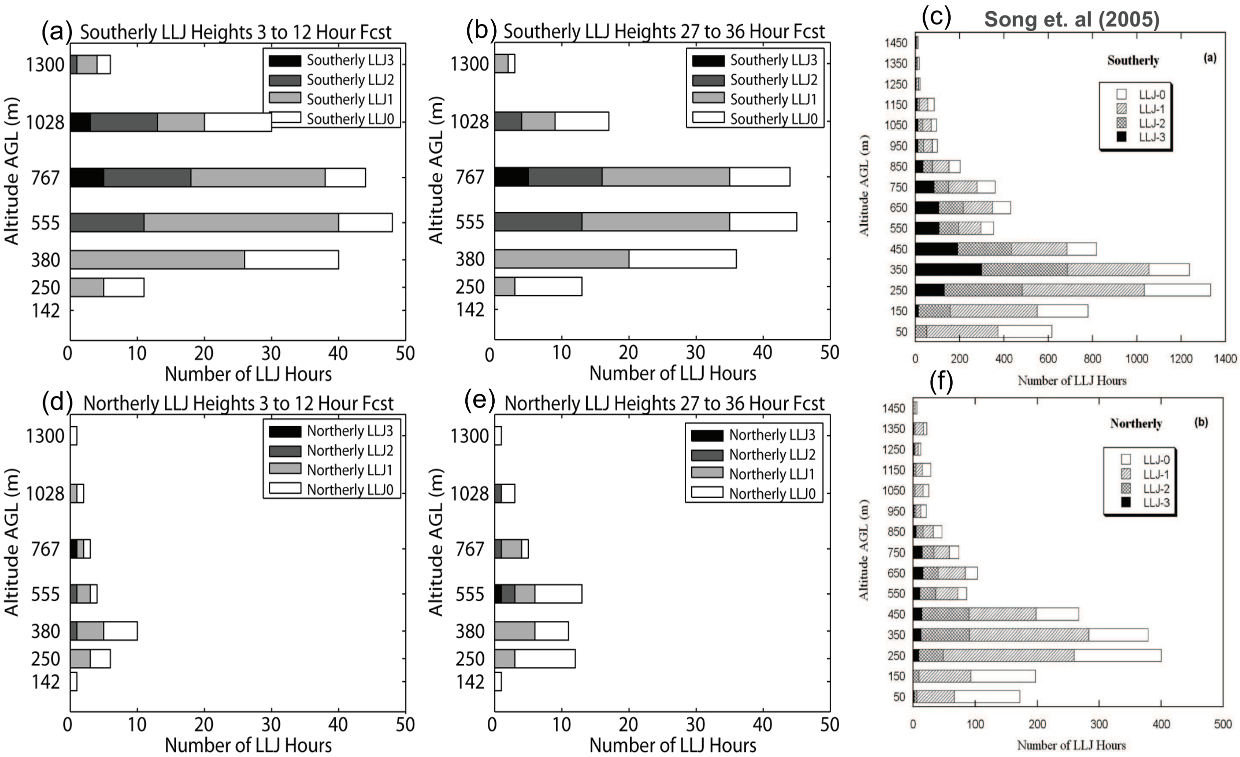

Figure 3: Vertical distributions of WRF LLJs for (a) southerly 3-12 hour forecast, (b) southerly 27-36 hour forecast (c) Song et al. (2005) southerly (d) northerly 3-12 hour forecast, (e) northerly 27-36 hour forecast, and (f) Song et al. (2005) northerly LLJs at the Beaumont site in the WRF data set and 6-yr hourly dataset.