Vertical mixing induced by Low-Level Jets (LLJs), observations and simulations

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• Part 1: Impacts of LLJs on the Nocturnal Urban Heat Island (UHI)

• Part 2: Improved performance by WRF3.4.1
UHI is prominent during the nighttime

Nighttime

Daytime

LLJs occur frequently in this region, must play some roles.

Red dots around OKC:
Six rural sites
Factors affecting UHI intensity

• Intrinsic characteristics of a city
  – E.g., canyon geometry, thermal properties of the fabric, anthropogenic heat

• External meteorological factors
  – E.g, cloud, wind, radiation

This study will demonstrate the dominant effect of LLJs on UHI intensity in the Oklahoma City (OKC) metro area
Relationship between LLJs and nocturnal UHI intensity

LLJ strength: maximum wind speed of a LLJ

Nocturnal UHII: mean T difference between urban and rural area during nighttime

LLJs modulate nocturnal UHI intensity
Two different episodes

![Graph showing two different episodes of UHI intensity.](image)
Two different episodes: temperature profiles

Near surface thermal structure is different, will investigate the reason and effect
Two different episodes:
large scale forcing

July 18, 2003
July 25, 2003
July 19, 2003
July 26, 2003

Large scale forcing plays role in the formation of LLJs
Model domains and configurations

- WRF3.4
- ACM2 PBL scheme
Time-height diagram of wind speeds
Surface wind speeds at 0400 LT

Stronger surface wind is related to LLJs
Upper layer wind speeds
Observed frictional velocity

LLJs generate stronger turbulence during nighttime, thus reducing its diurnal variation.
Near surface vertical T gradient

Stronger turbulence induced by LLJs reduced near surface T gradient
Different vertical T gradients dictate UHI intensity

Stronger vertical T gradients lead to larger UHI intensity
Vertical wind speed profiles

LLJs determine the boundary layer thermal structure
Relationship between inversion strength and UHI intensity

Inversion strength is a good indicator of UHI intensity.
Conclusions

1. LLJs play an important role in modulating the Nocturnal UHI intensity.
2. Temperature inversion in the surrounding rural area can be used as an indicator for UHI intensity.
Part 2: Improvement in WRF3.4.1
Three PBL schemes in WRF
MYJ, YSU, ACM2

- MYJ: local, down gradient
- YSU, ACM2: local+non-local

YSU in WRF3.4 was found to destroy LLJs

YSU: the Yonsei University scheme
MYJ: the Mellor–Yamada–Janjic scheme
ACM2: the asymmetric convective model scheme, v2
Nighttime problems associated with the old YSU

- Underestimation of LLJs strength
- Overestimation of near surface wind during the nighttime.
- Overestimation of near surface temperature

Hu et al. (2012)
Update of YSU in WRF3.4.1

\[ \phi_m = 1 + 5z/L \cdot h'/h, \quad h'/h = 0.05 \]

\[ \phi_m = 1 + 5z/L \]

\[ K_m / \kappa \cdot u \cdot h \]
Improvement of near surface wind

2003-07-18 08:00:00

WSP @ 2003July18_hr_08 3.4

2003-07-18 08:00:00

3.4 with YSU3.4.1

2003-07-18 08:00:00

3.4.1

1 2 3 4 5 6 7 8 9 m s⁻¹

1 2 3 4 5 6 7 8 9 m s⁻¹

1 2 3 4 5 6 7 8 9 m s⁻¹
The update in YSU only affects nighttime
Improvement in vertical wind profiles
Improvement in vertical temperature profiles
Alleviate the T overestimation problem during the nighttime
Conclusions

1. The update of YSU in WRF3.4.1 improved its performance during the nighttime.
2. Some of the long-lasting problems associated with old YSU scheme are solved.
References


Links