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

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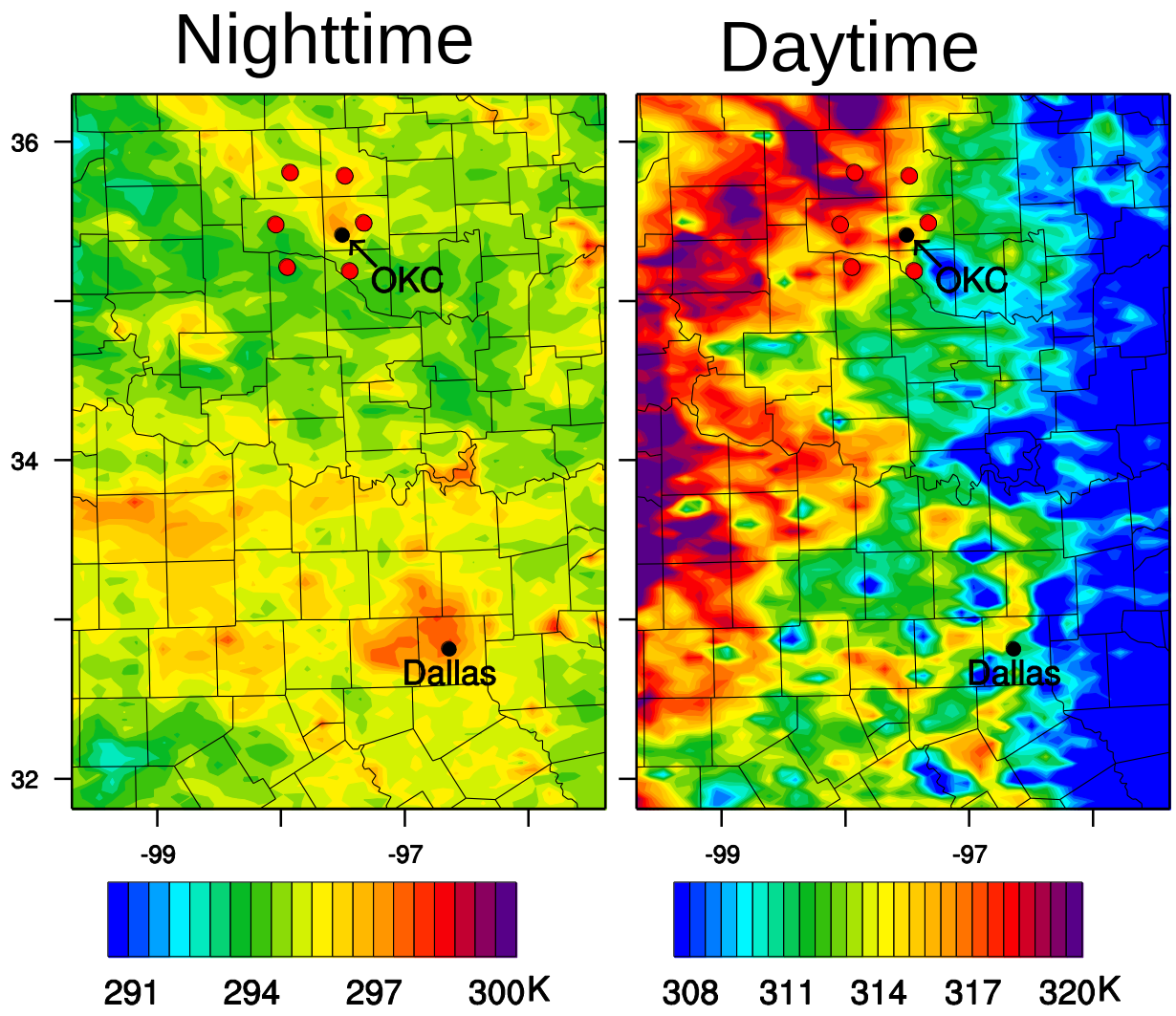
Oct. 29th 2012

at Chinese Academy of Meteorological Sciences

- 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



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

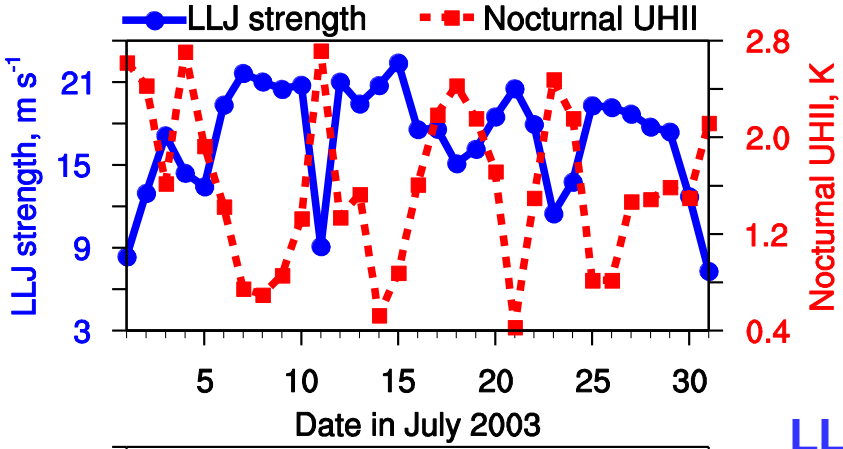
Red dots around OKC:
Six rural sites

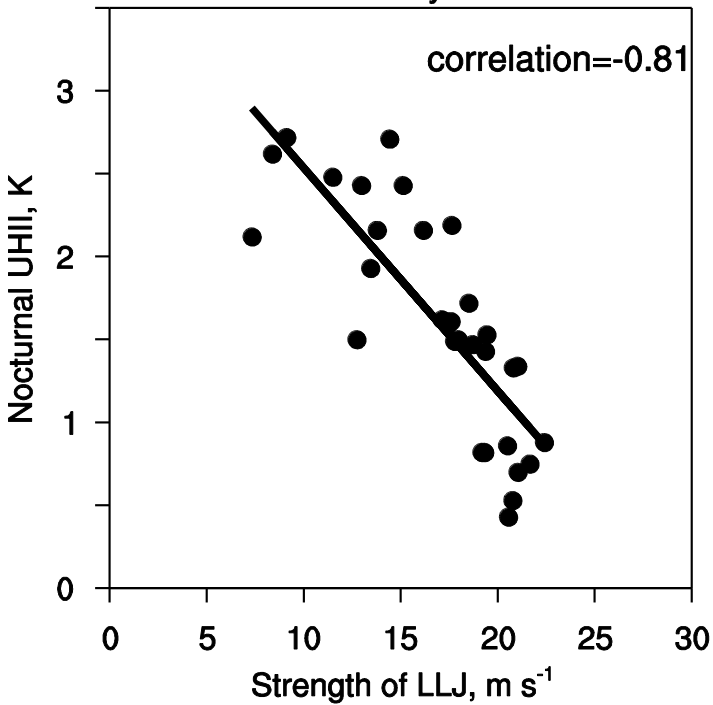
Factors affecting UHI intensity

- 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



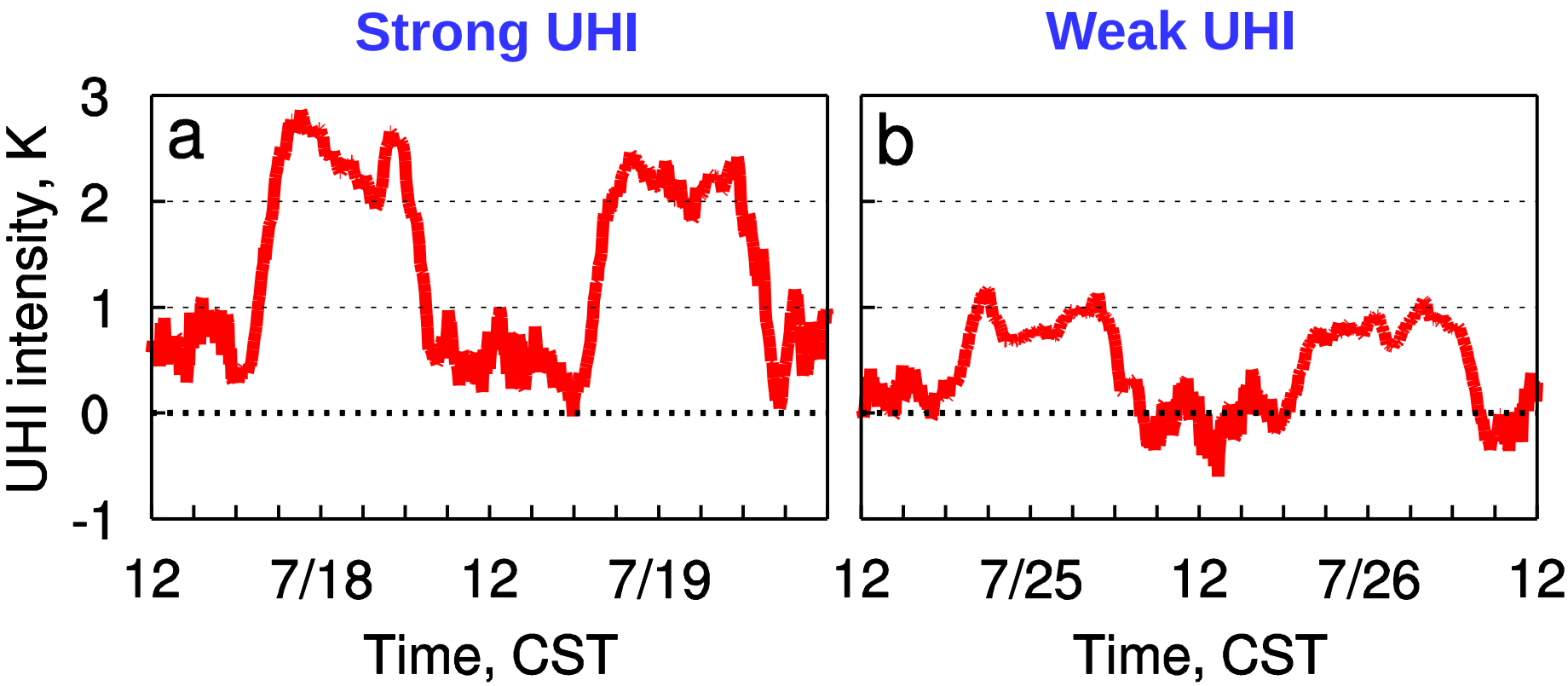


LLJ strength: maximum wind speed of a LLJ

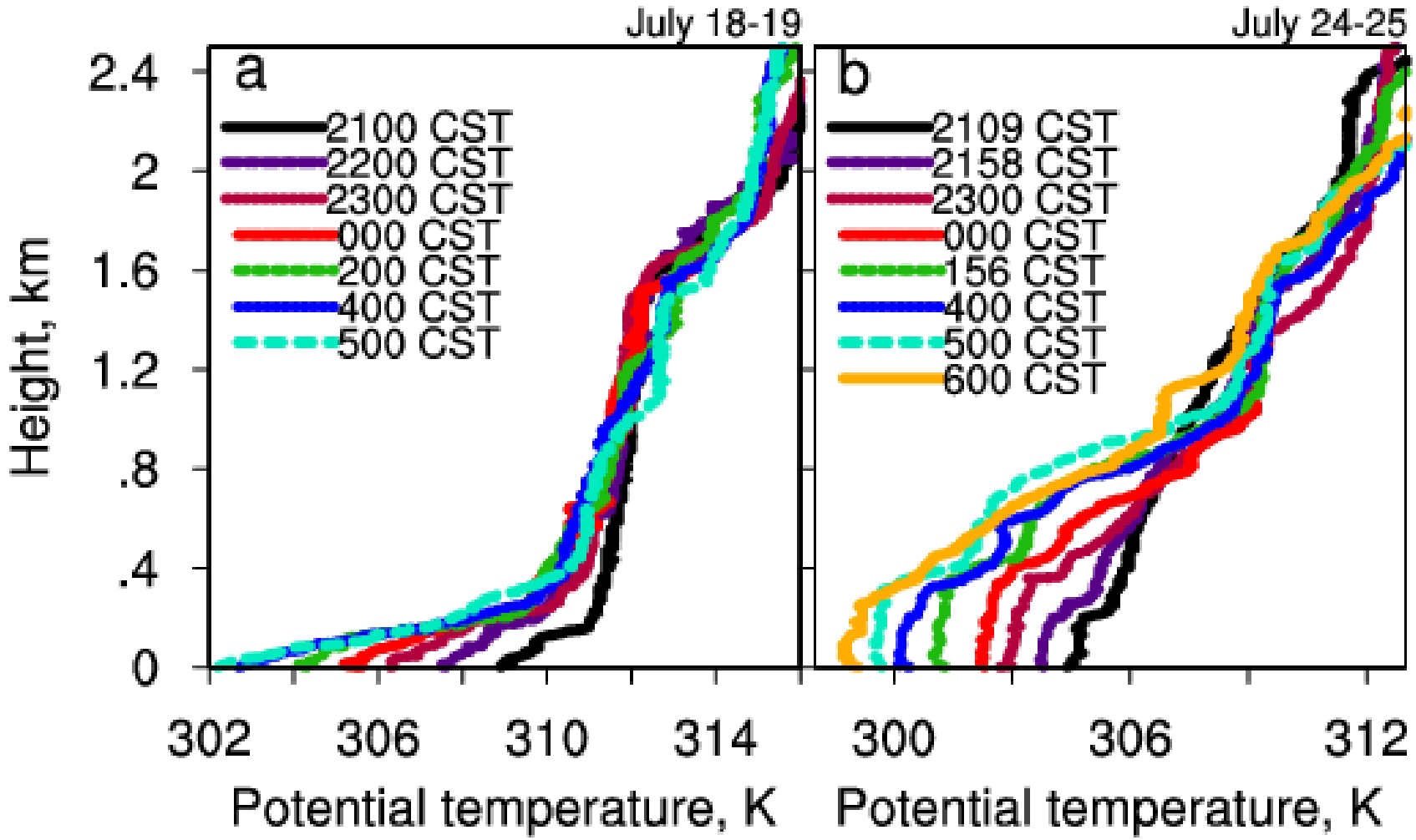
Nocturnal UHII: mean T difference between urban and rural area during nighttime

LLJs modulate nocturnal UHI intensity

Two different episodes

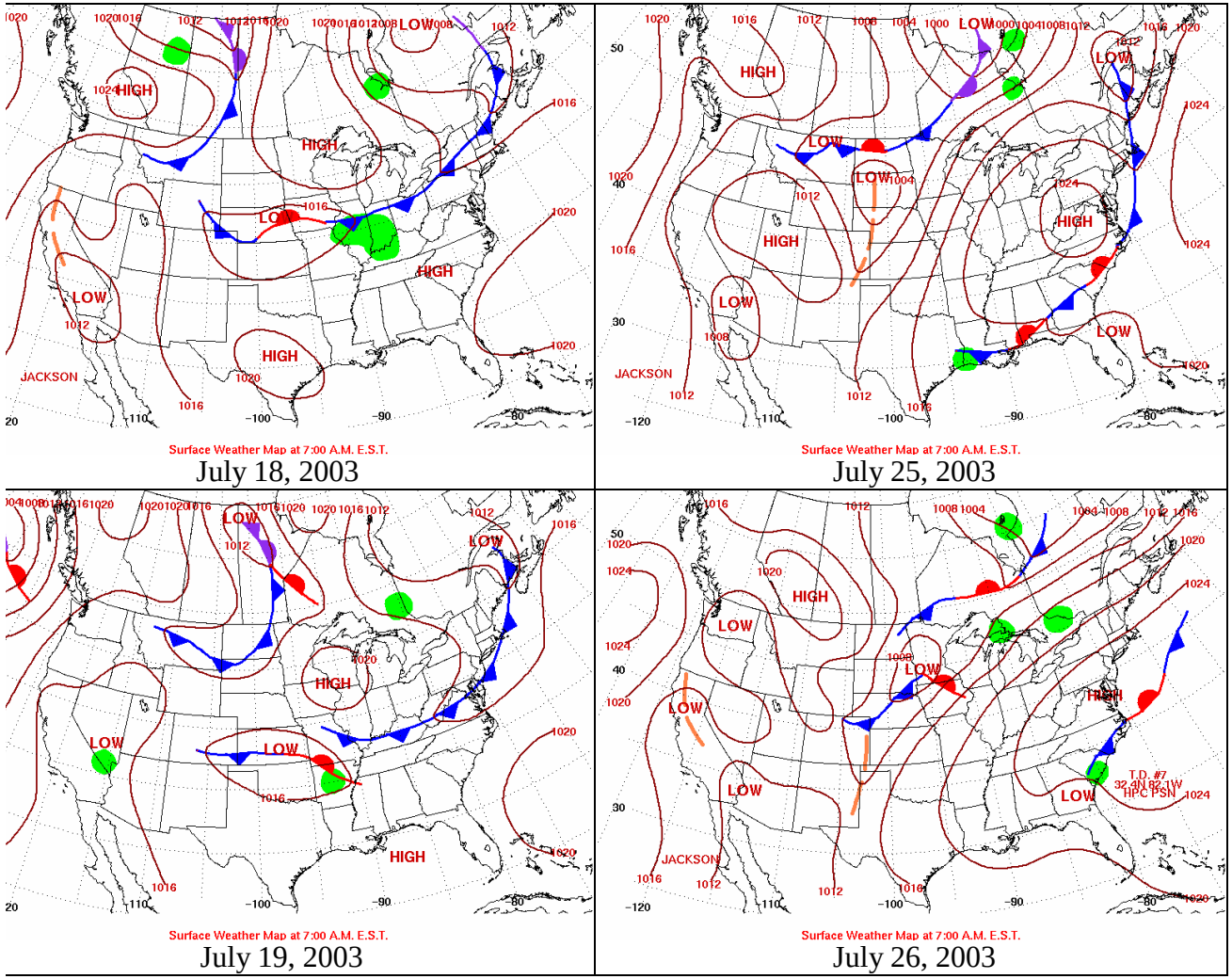


Two different episodes: temperature profiles



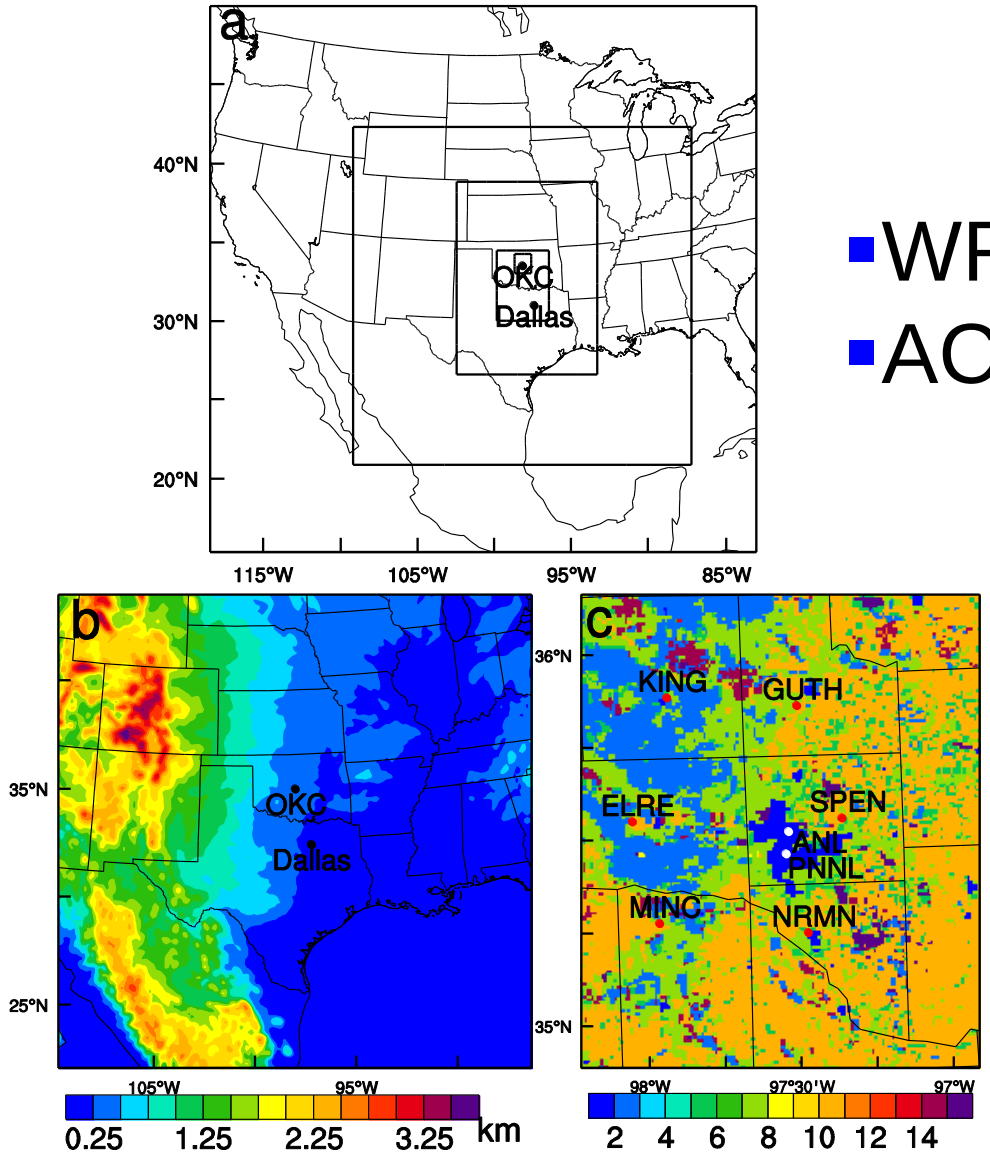
Near surface thermal structure is different, will investigate the reason and effect

Two different episodes: large scale forcing



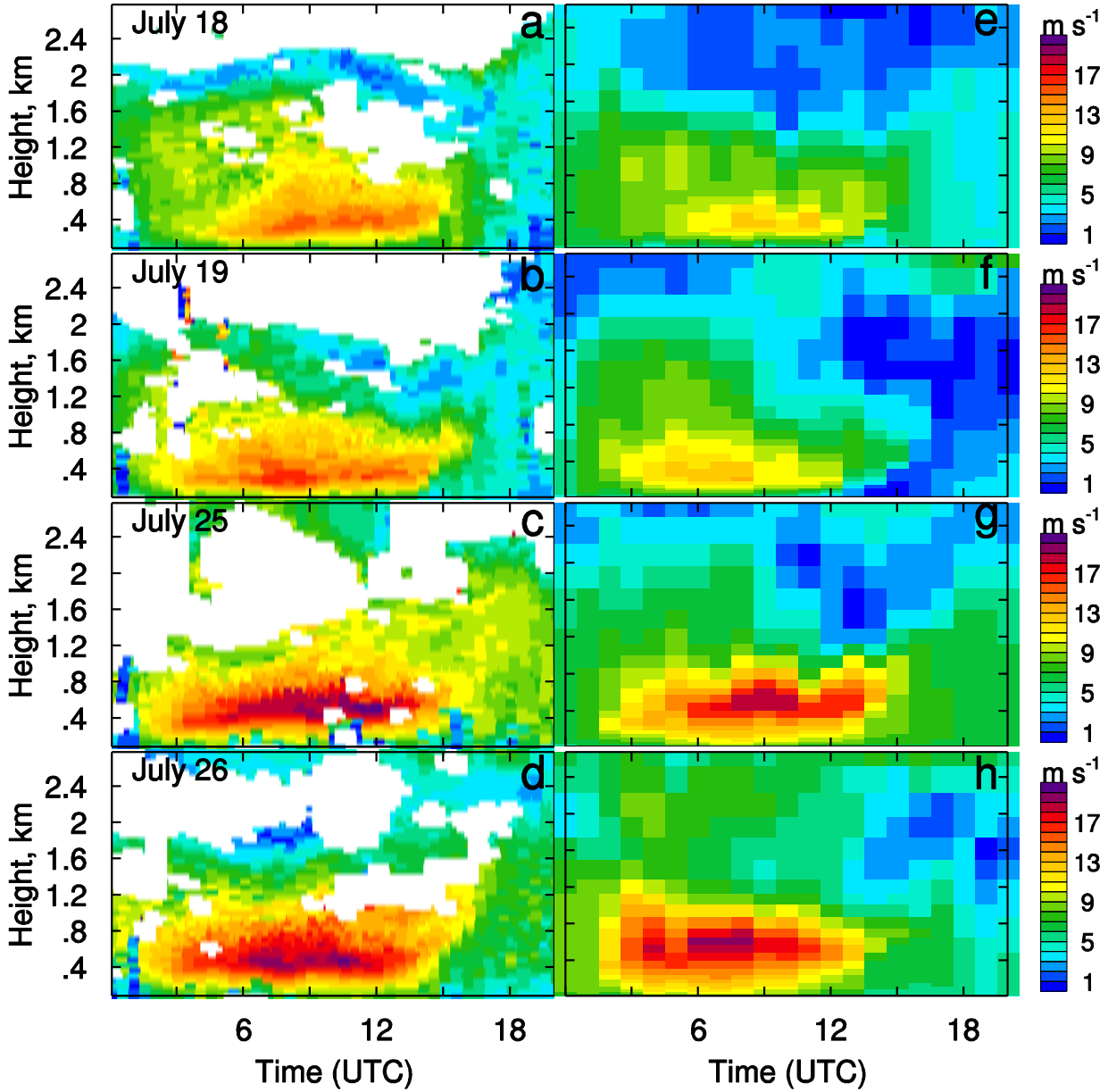
Large scale forcing plays role in the formation of LLJs

Model domains and configurations

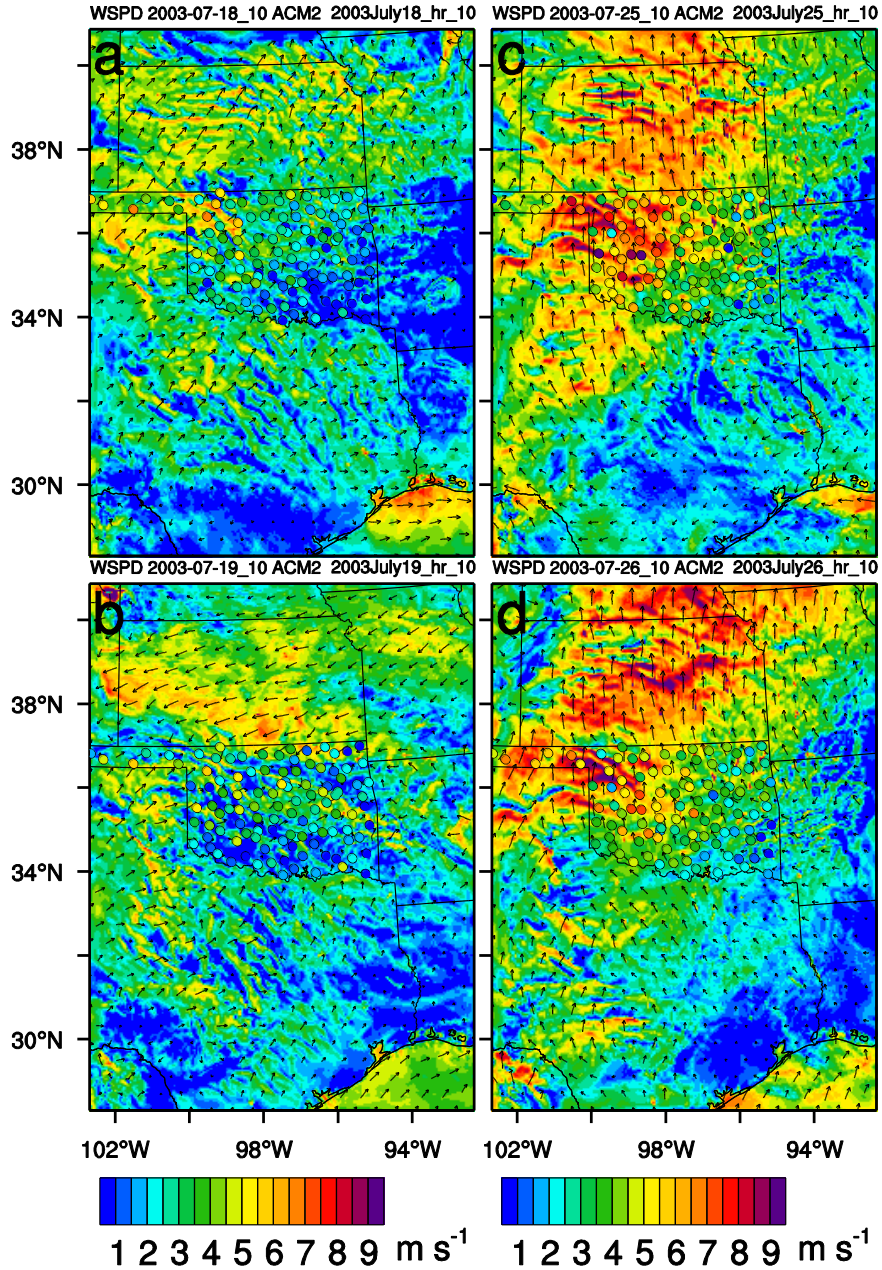


- WRF3.4
- ACM2 PBL scheme

Time-height diagram of wind speeds

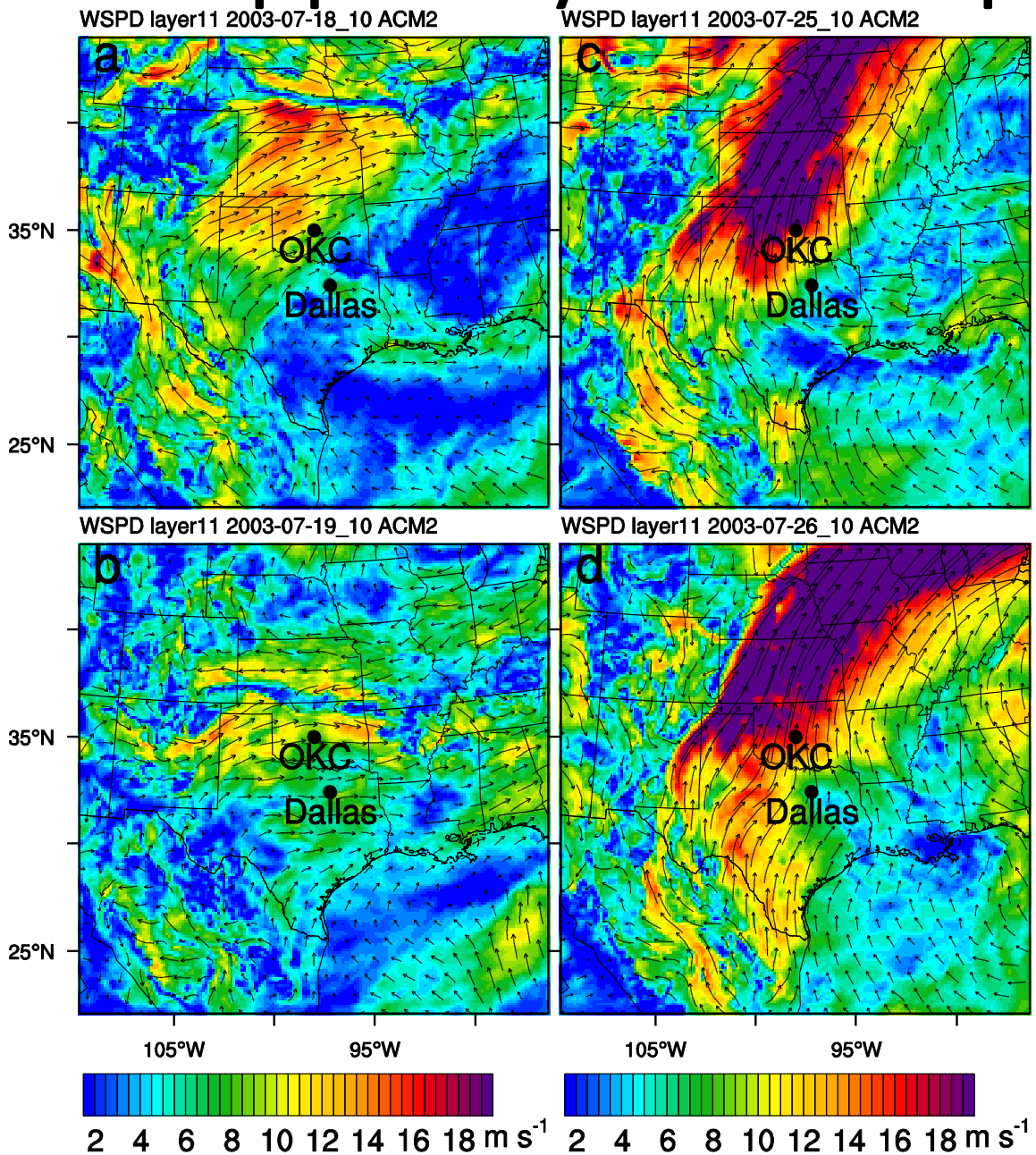


Surface wind speeds at 0400 LT

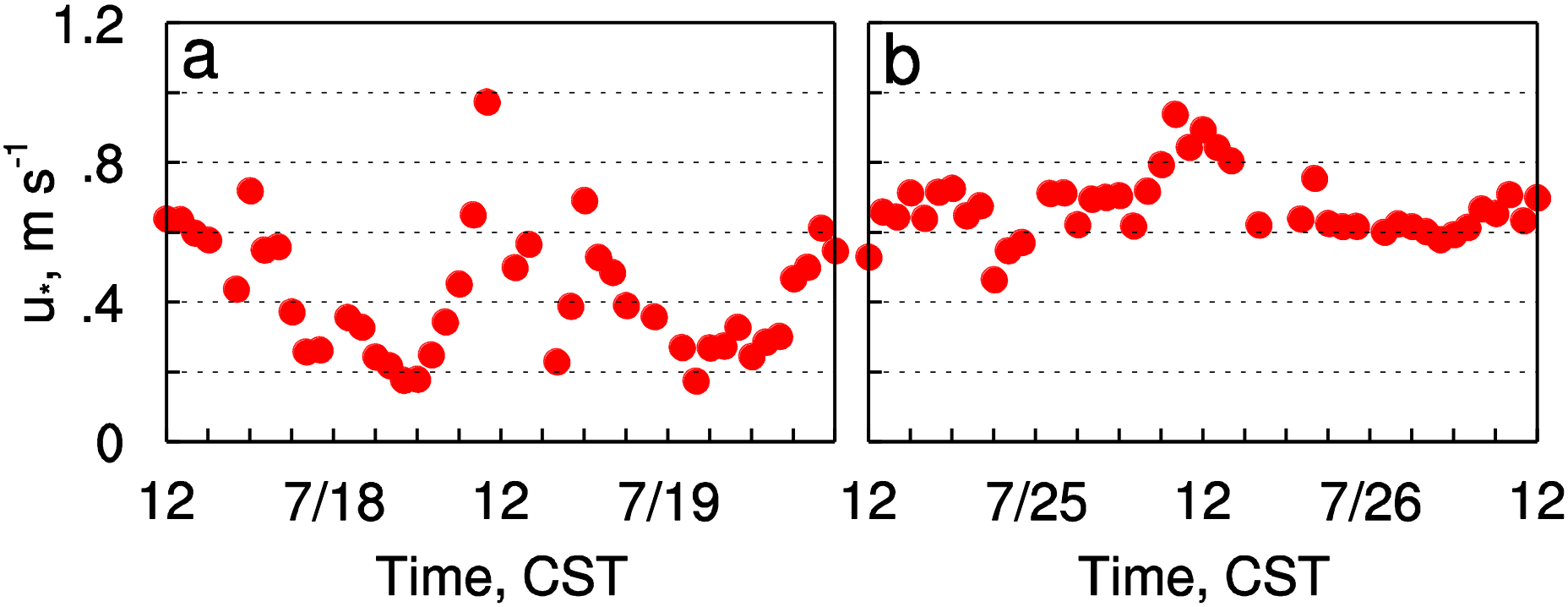


Stronger surface wind is related to LLJs

Upper layer wind speeds

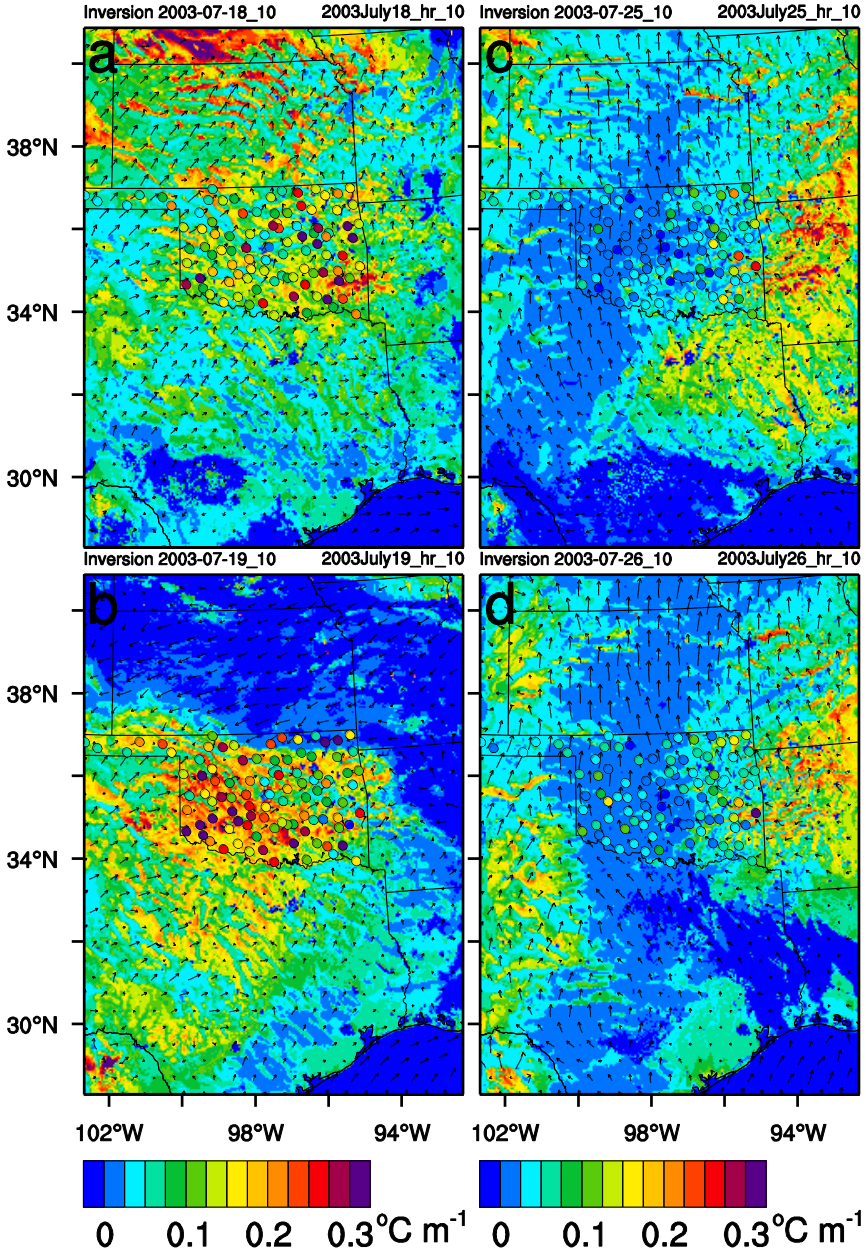


Observed frictional velocity



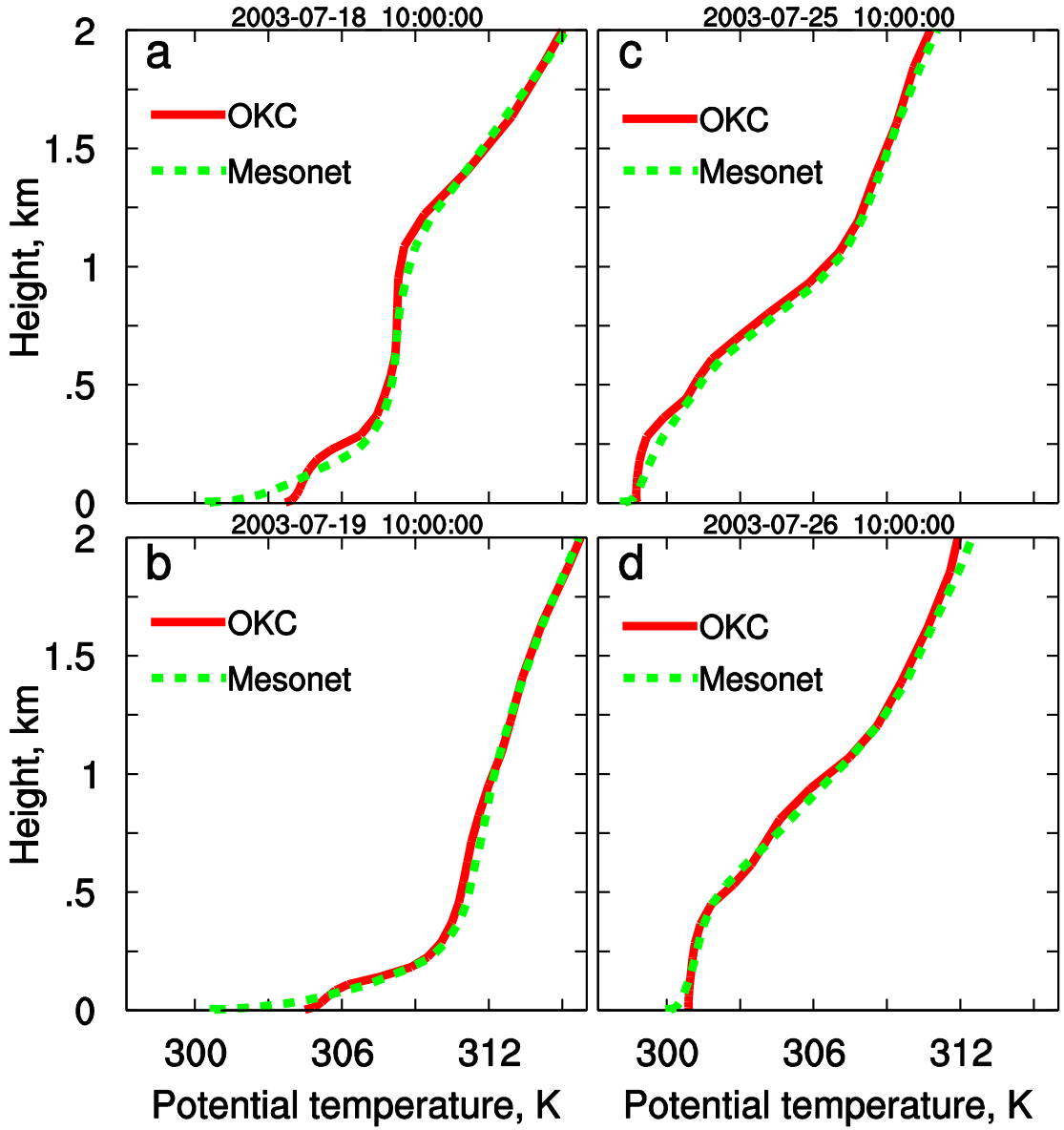
LLJs generate stronger turbulence during nighttime, thus reducing its diurnal variation

Near surface vertical T gradient



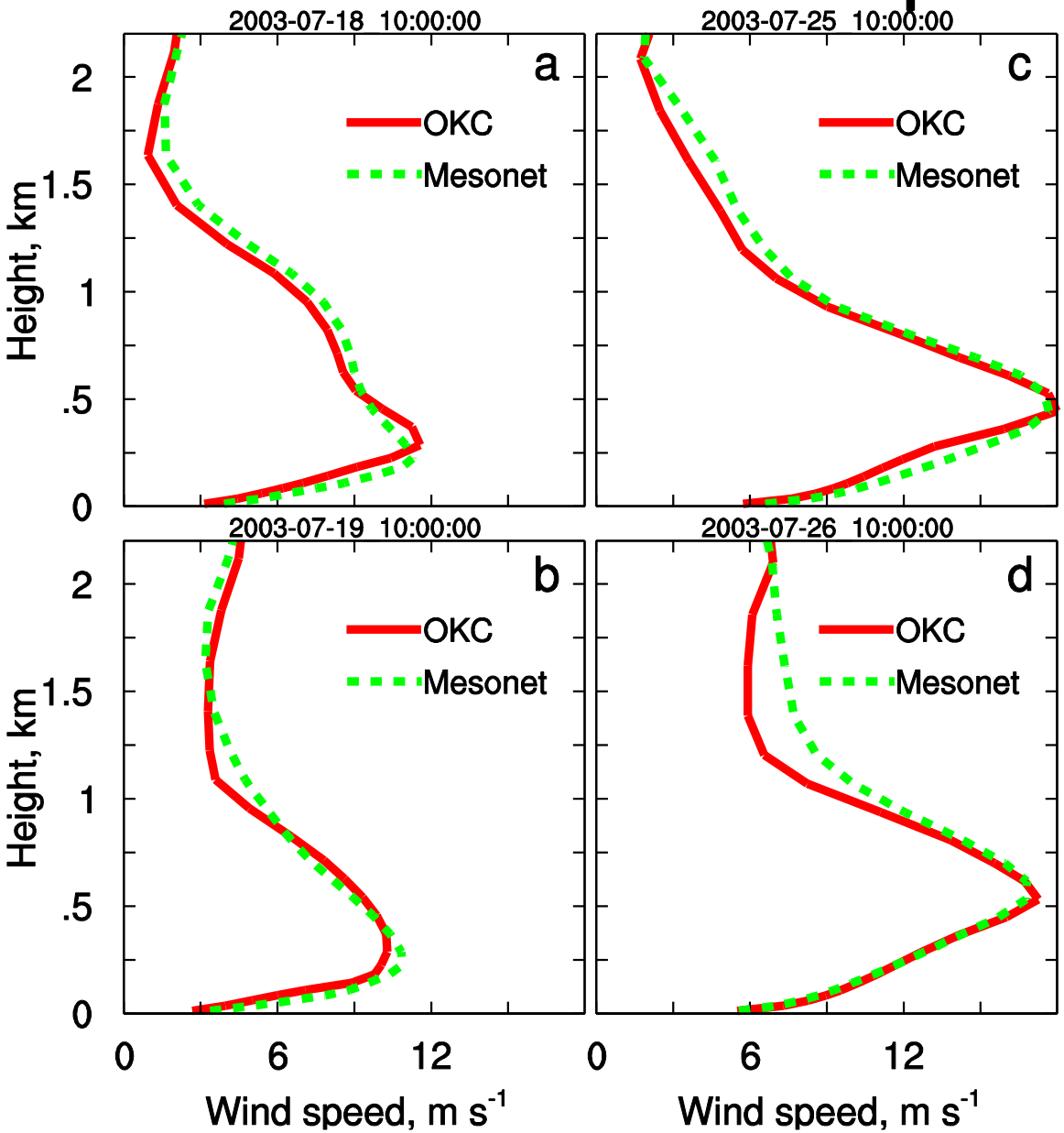
Stronger turbulence induced by LLJs reduced near surface T gradient

Different vertical T gradients dictate UHI intensity



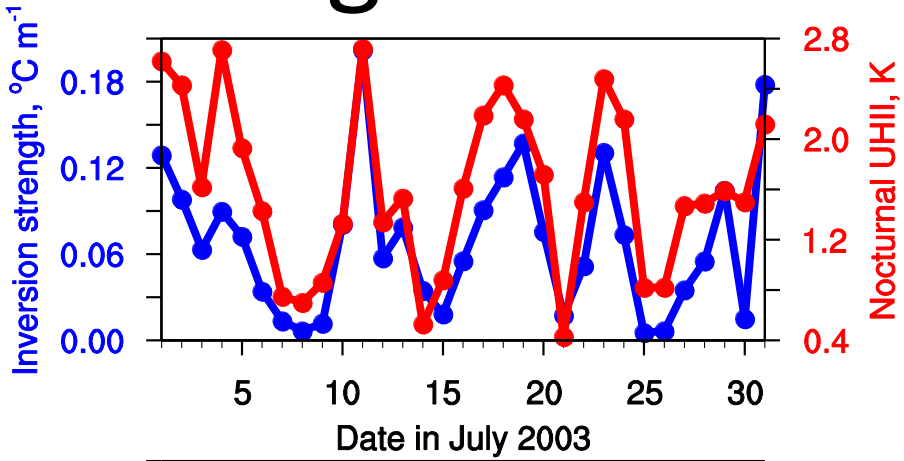
Stronger vertical T gradients lead to larger UHI intensity

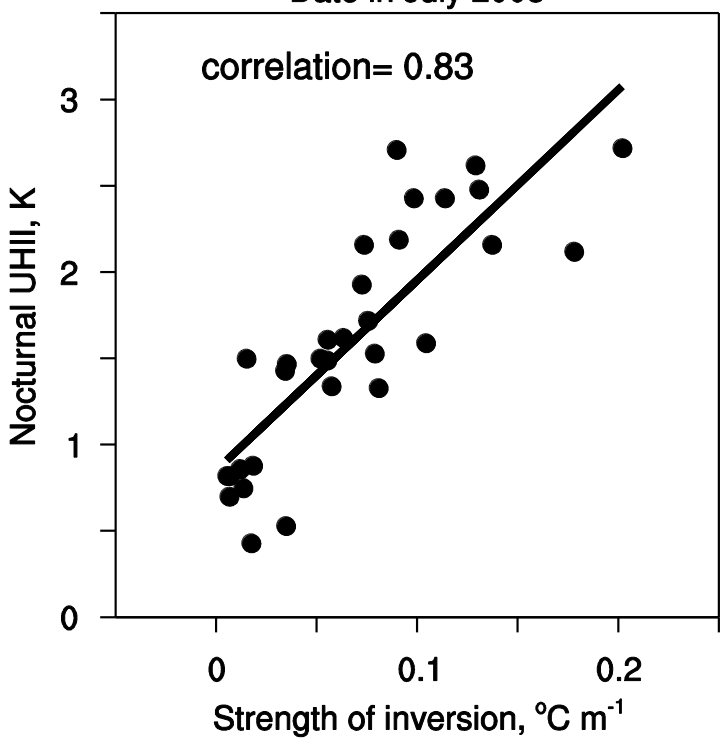
Vertical wind speed profiles



LLJs determine the boundary layer thermal structure

Relationship between inversion strength and UHI intensity





Inversion strength is a good indicator of UHI intensity

Conclusions

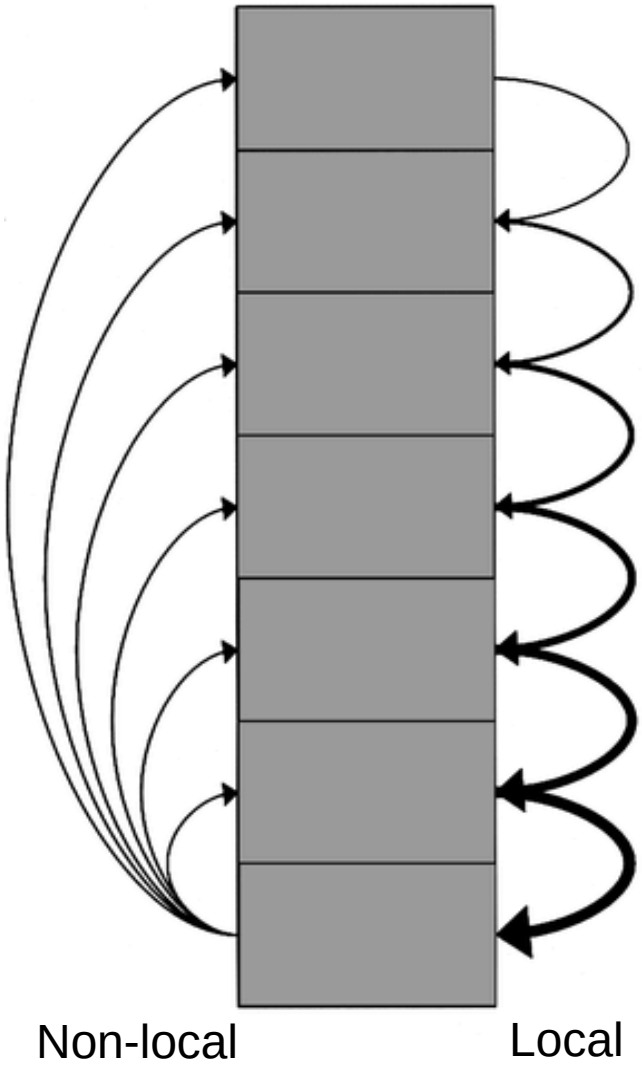
1. LLJs paly an important role in modulating the Nocturnal UHI intensity.
2. Temperature inversion in the surrounding rural area can be used as an indicator for UHI intensity

- 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



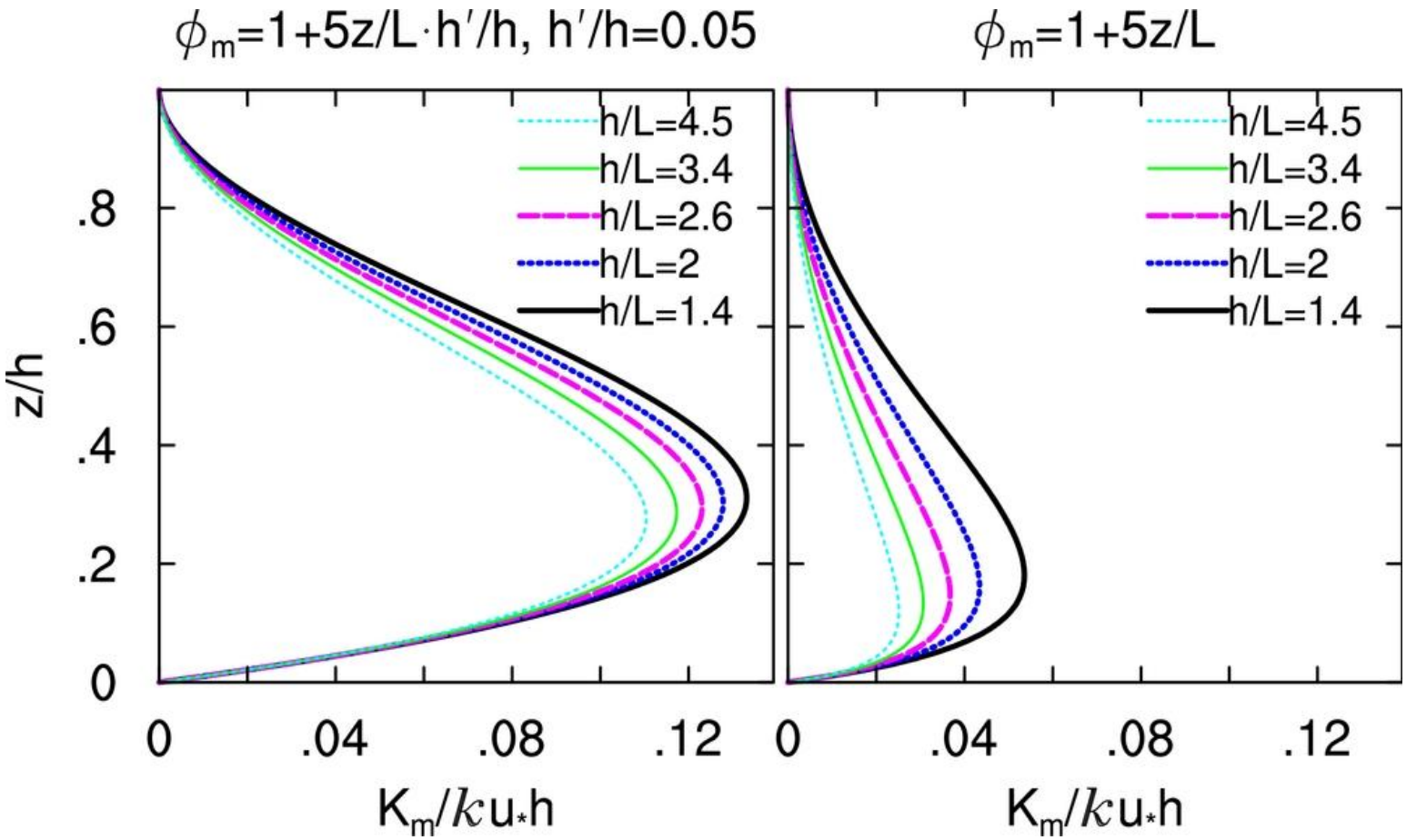
YSU: the Yonsei University scheme
MYJ: the Mellor–Yamada–Janjic scheme
ACM2: the asymmetric convective model scheme, v2

Nighttime problems associated with the old YSU

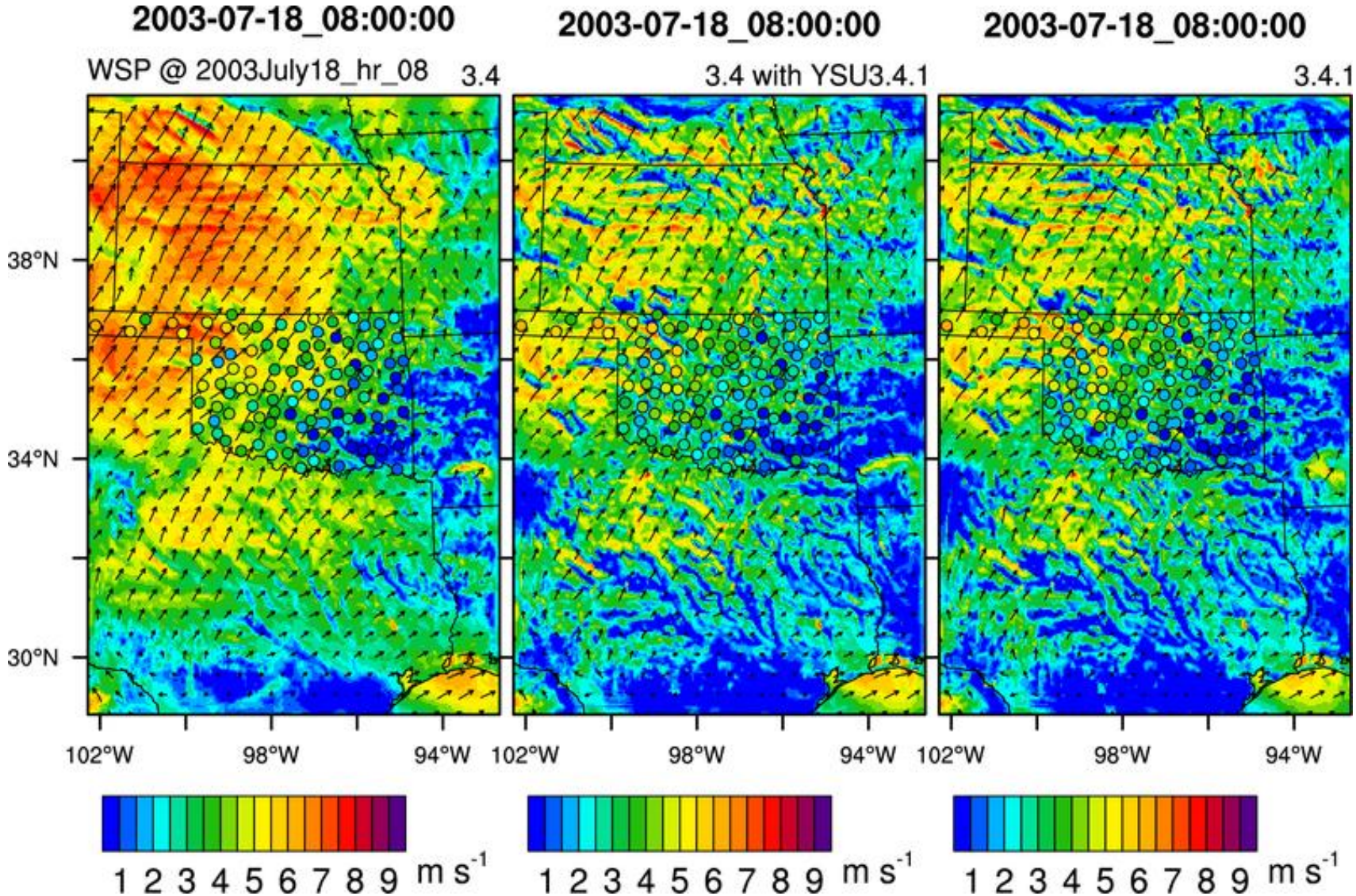
- Underestimation of LLJs strength
- Overestimation of near surface wind during the nighttime.
- Overestimation of near surface temperature

Hu et al. (2012)

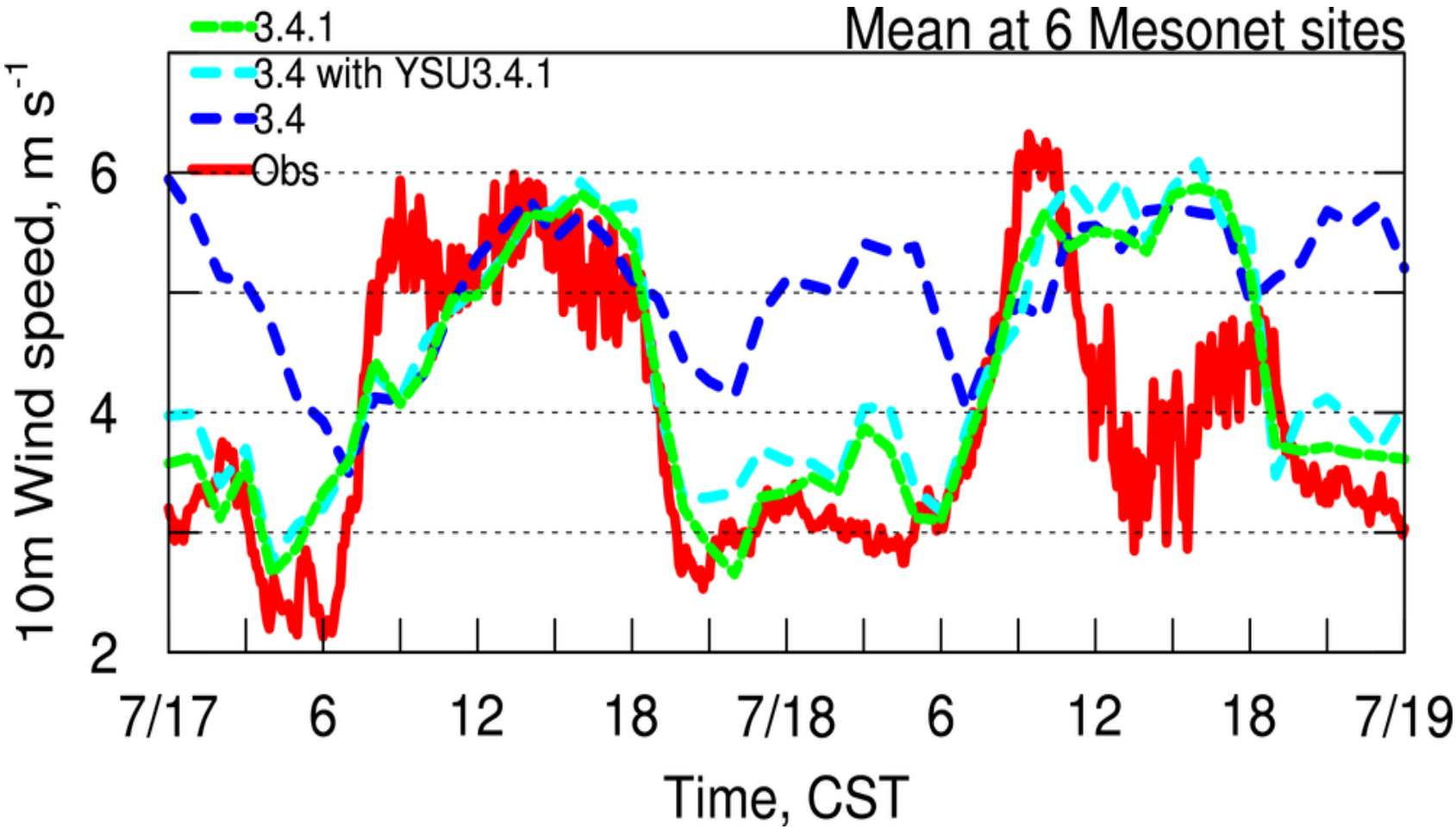
Update of YSU in WRF3.4.1



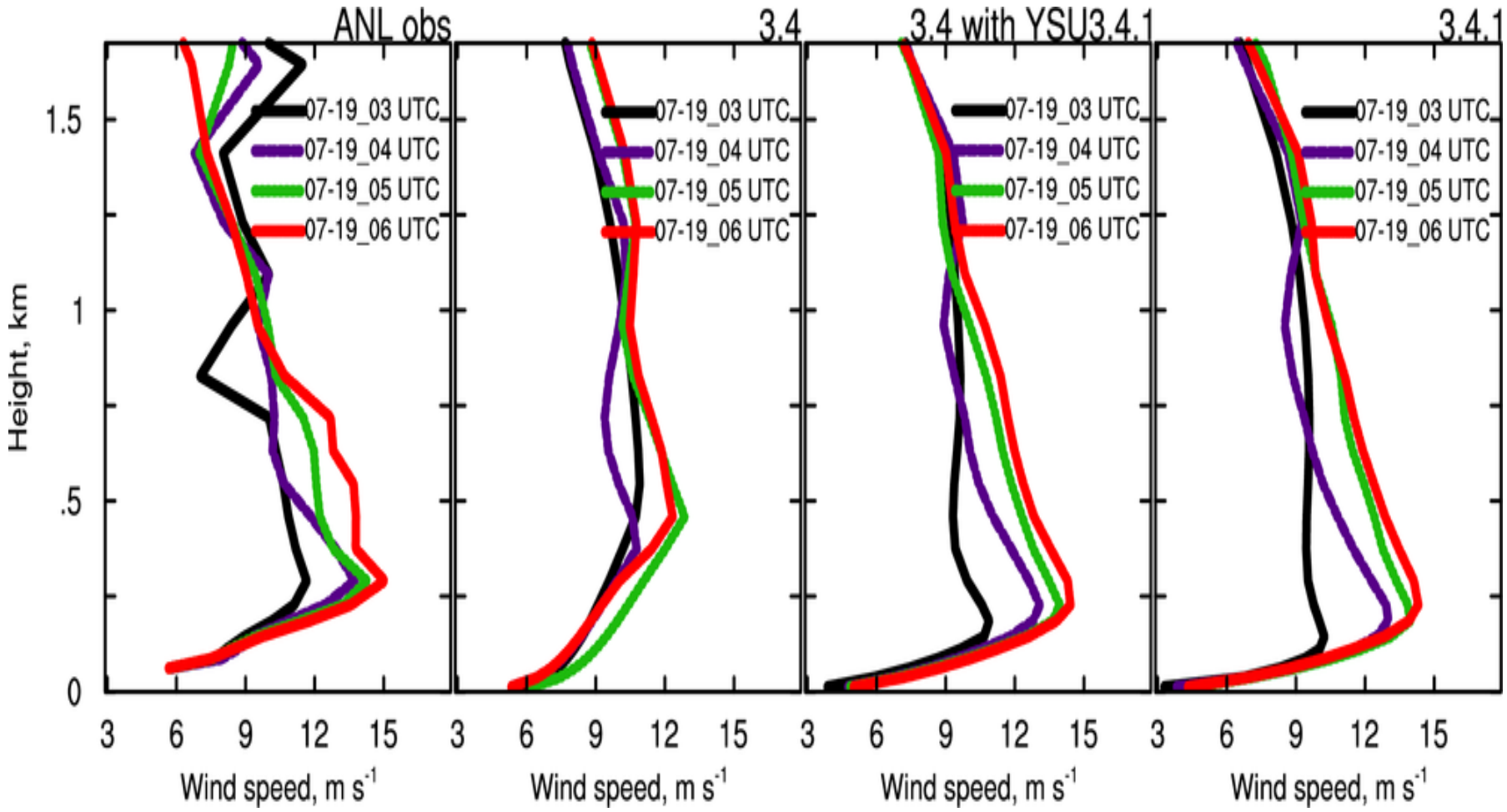
Improvement of near surface wind



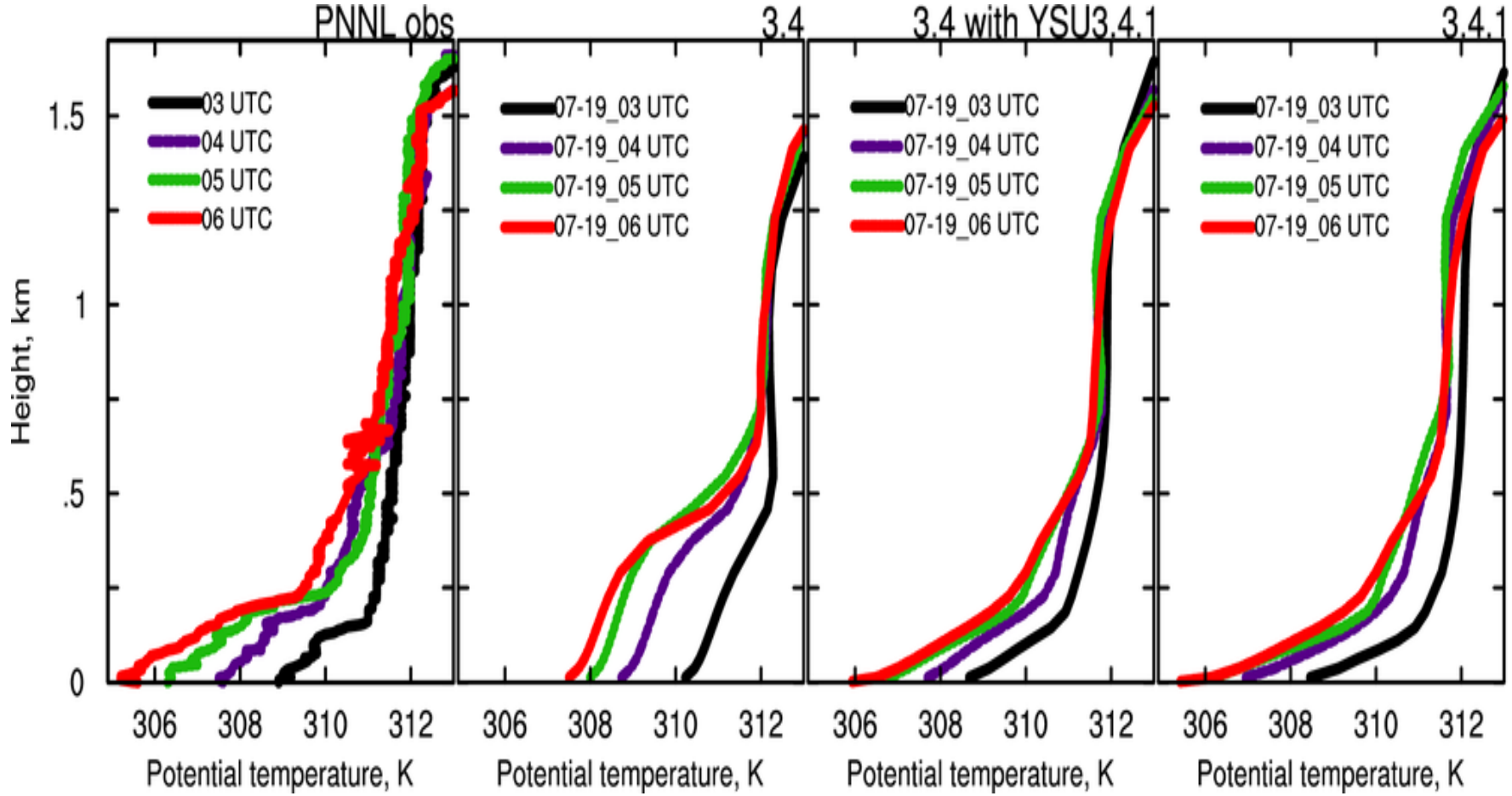
The update in YSU only affects nighttime



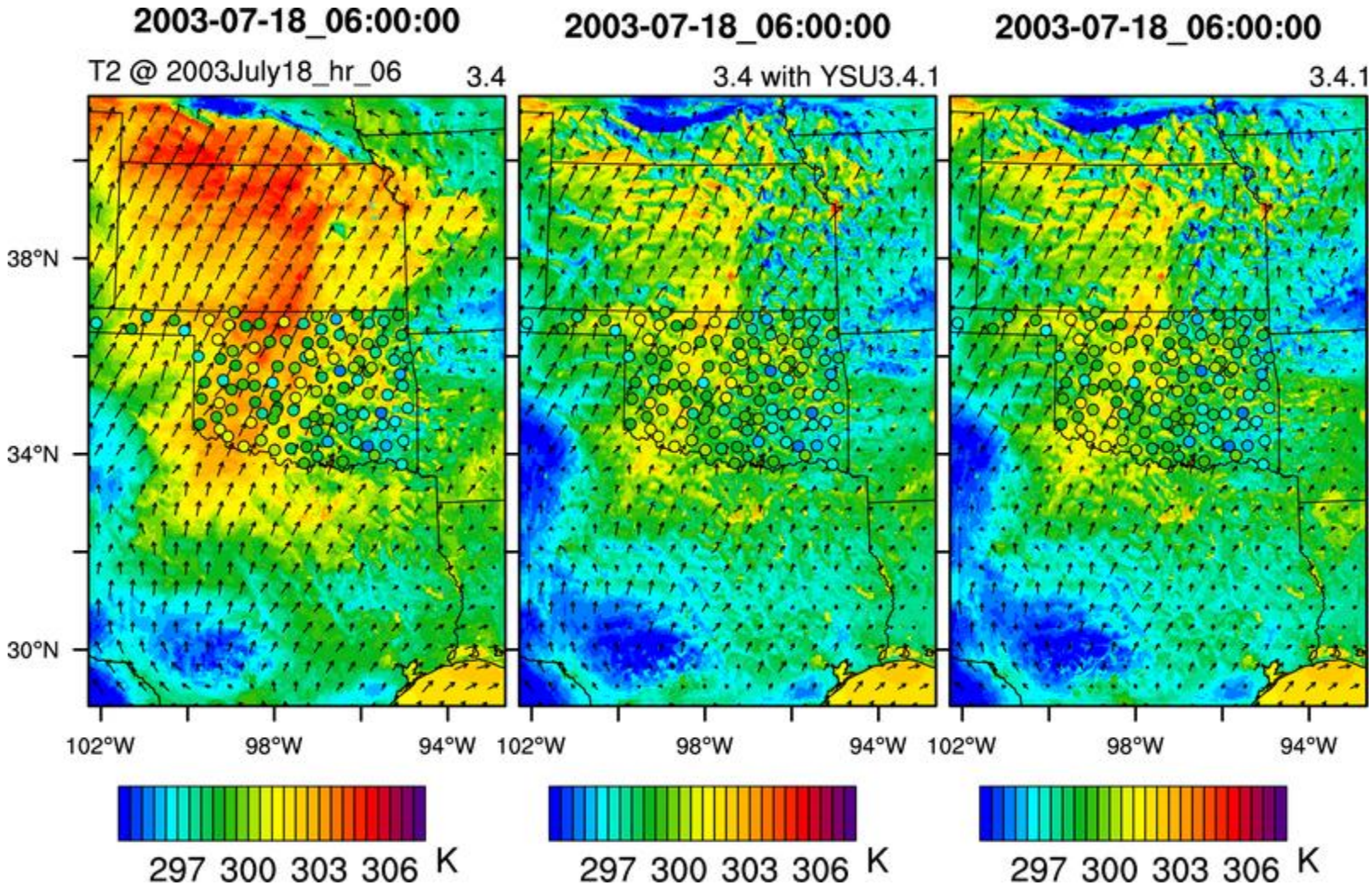
Improvement in vertical wind profiles



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

1. **Hu, X.-M.**, J. W. Nielsen-Gammon, and F. Zhang (2010), Evaluation of Three Planetary Boundary Layer Schemes in the WRF Model, *J. Appl. Meteor. Climatol.*, 49, 1831–1844.
2. Nielsen-Gammon, J. W., **X.-M. Hu**, F. Zhang, and J. E. Pleim (2010), Evaluation of Planetary Boundary Layer Scheme Sensitivities for the Purpose of Parameter Estimation, *Mon. Wea. Rev.*, 138, 3400–3417.
3. **Hu, X.-M.** , F. Zhang, and J. W. Nielsen-Gammon (2010), Ensemble-based simultaneous state and parameter estimation for treatment of mesoscale model error: A real-data study, *Geophys. Res. Lett.*, 37, L08802, doi:10.1029/2010GL043017.
4. **Hu, X.-M.**, P. M Klein, M. Xue, J. K. Lundquist, F. Zhang, and Y., Qi, 2012: Impact of Low-Level Jets on the Nocturnal Urban Heat Island Intensity in Oklahoma City. *J. Appl. Meteor. Climatol.*, submitted.
5. **Hu, X.-M.** , P. M. Klein, M. Xue (2012) Impacts of the update in the YSU planetary boundary layer scheme on the prediction of nighttime boundary layer and implications for air pollution simulations, to be submitted.

Links

1. http://faculty-staff.ou.edu/H/Xiaoming.Hu-1/
2. http://journals.ametsoc.org/doi/abs/10.1175/2010JAMC2432.1
3. http://journals.ametsoc.org/doi/abs/10.1175/2010MWR3292.1
4. http://www.agu.org/pubs/crossref/2010/2010GL043017.shtml