Impact of Mountainous Terrain on Precipitation

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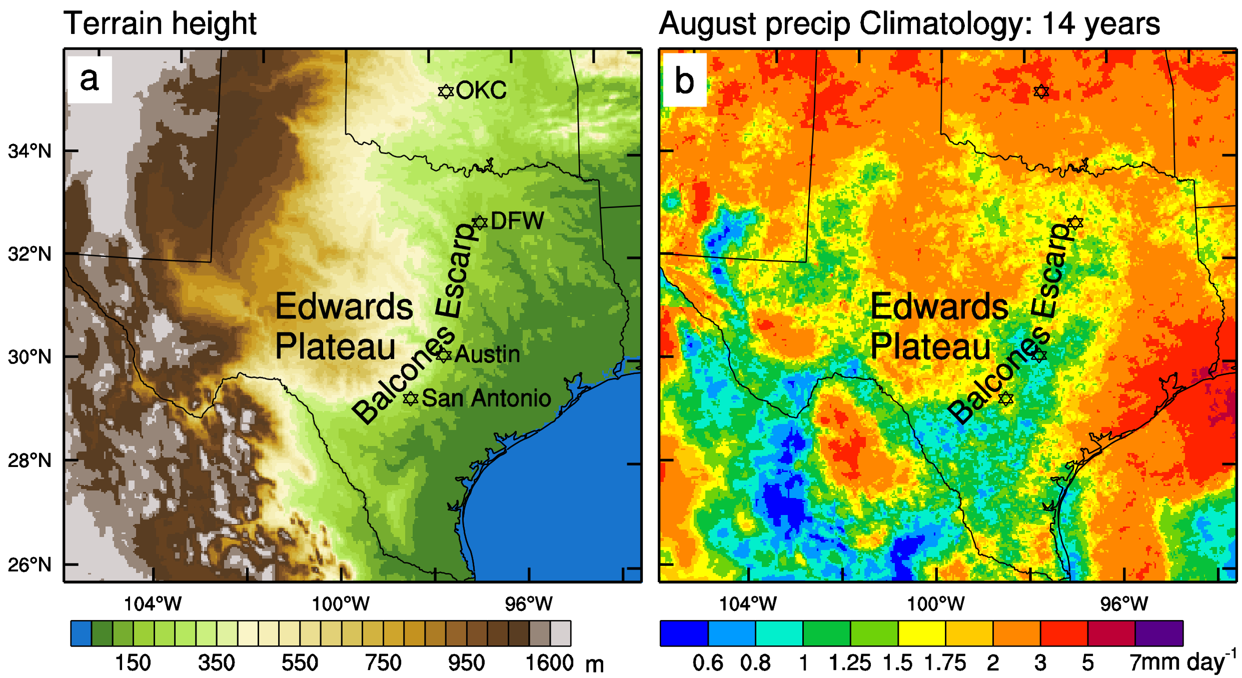
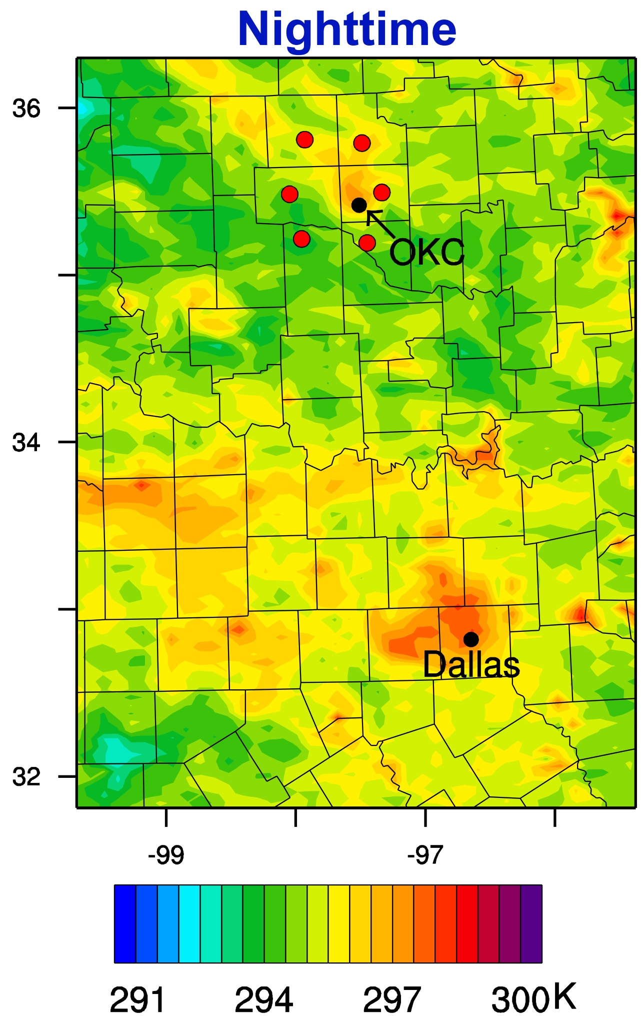
August precipitation in Texas



Thermal effects or dynamic effects?

1. **Investigates effects under dry conditions**
2. **Investigates effects under wet conditions**

MODIS-derived land surface temperature

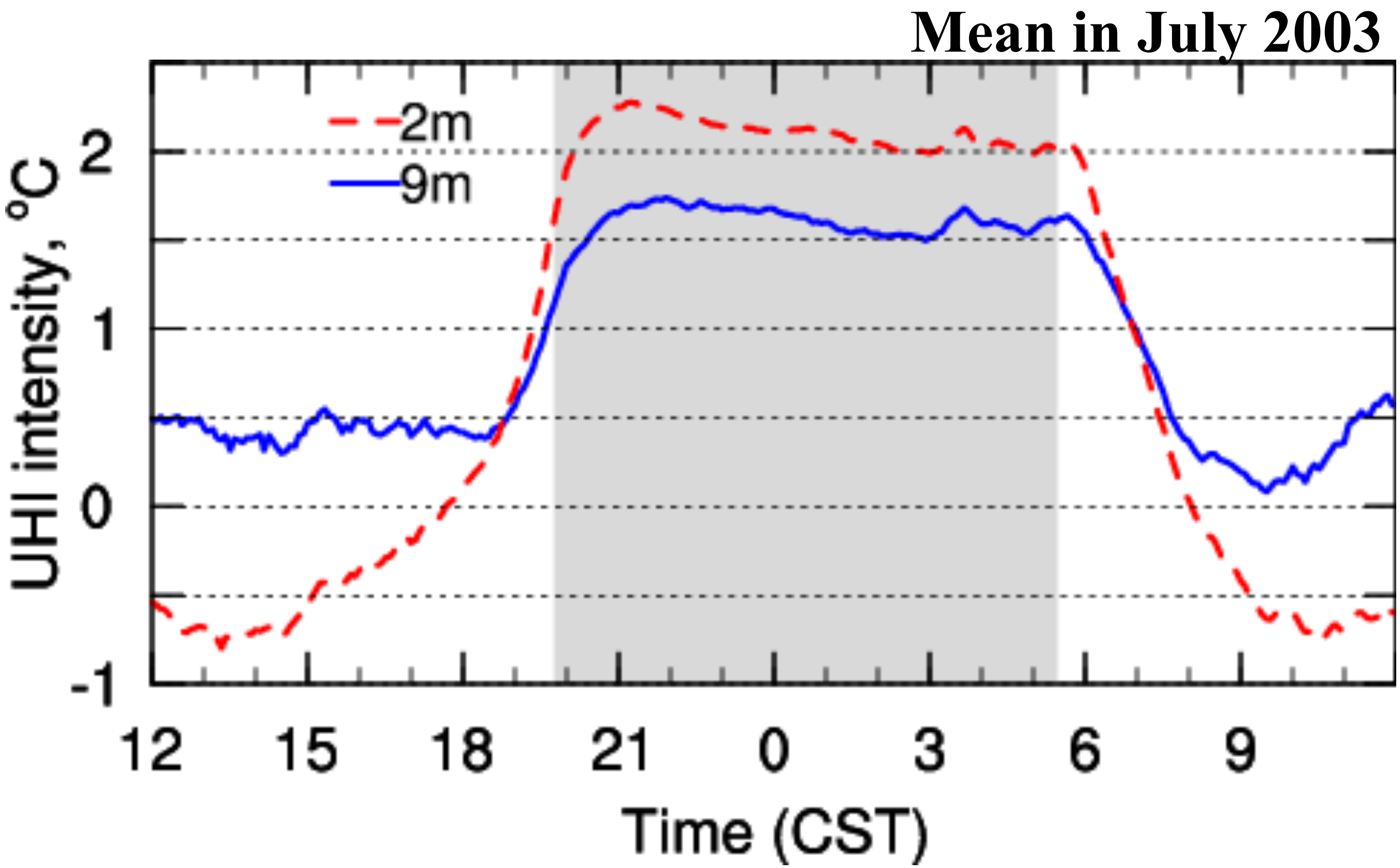


Hu et al. (2013, JAMC)

UHI is prominent during nighttime

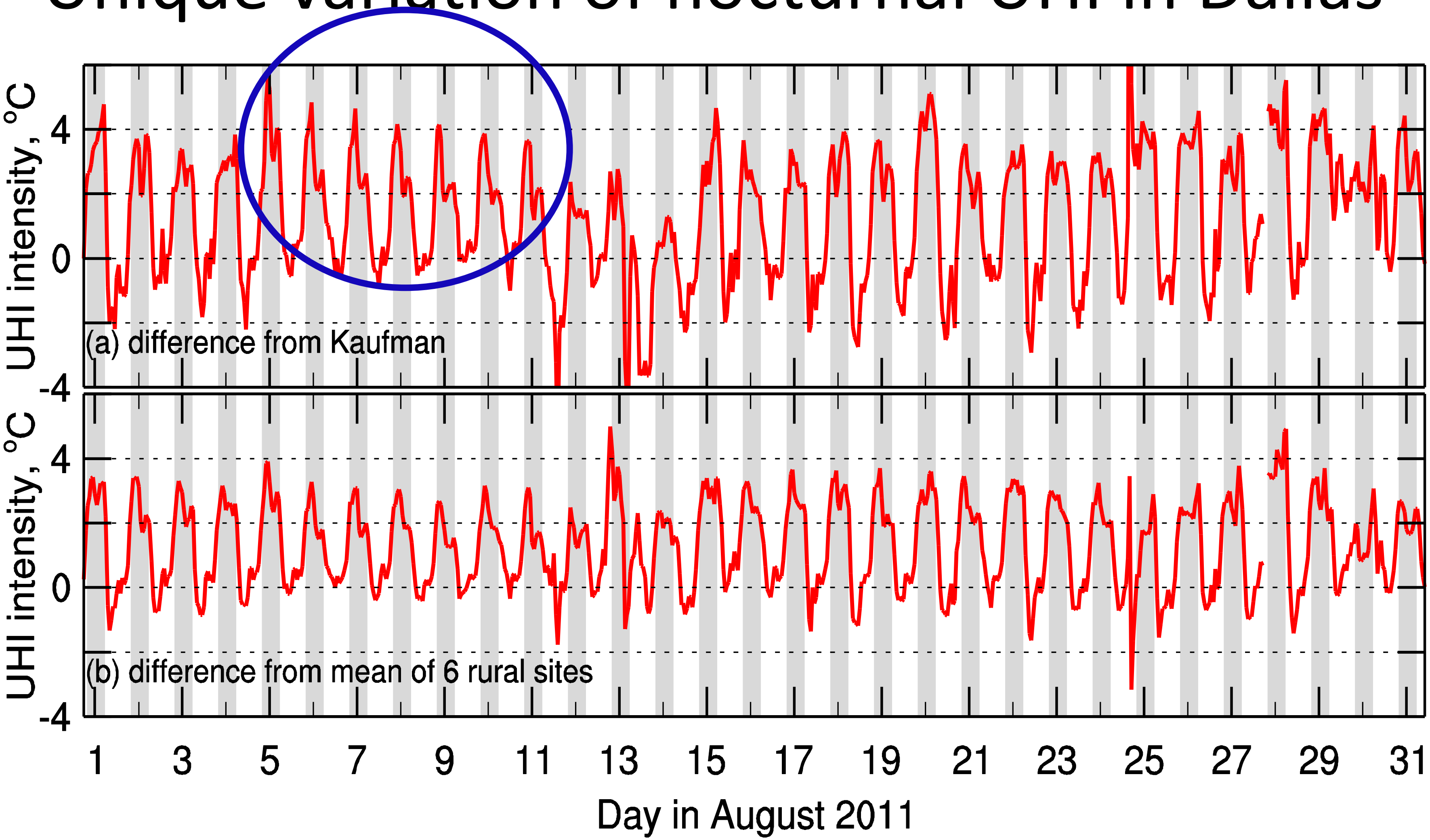
UHI intensity = T at urban location – T at rural sites

Diurnal variation of UHI intensity in OKC



UHI intensity normally increases around sunset quickly and then stays at a roughly constant level throughout the night.

Unique variation of nocturnal UHI in Dallas



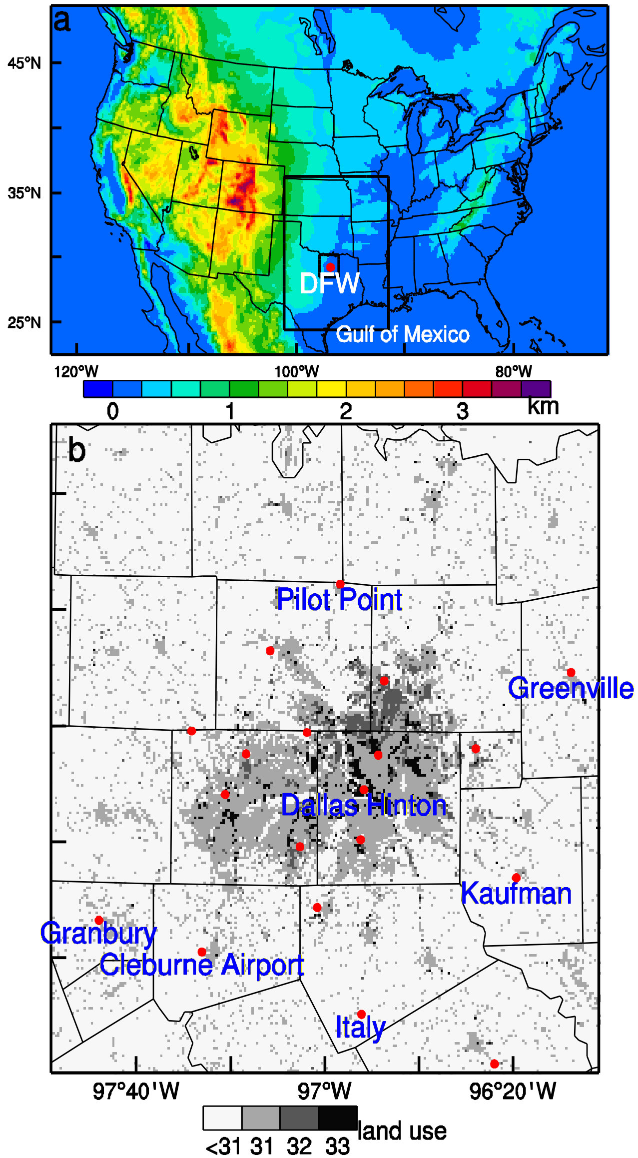
Sharp decrease ("collapse") of the nocturnal UHI intensity

Motivations/objectives of this study

Hu and Xue (2016, MWR)

- Understand such a unique temporal variation of the nocturnal UHI intensity in Dallas
  - Mountain-Plain solenoid
  - Sea breeze
  - Nocturnal warming events
- Investigate WRF model capability to reproduce UHI
- Impact on air quality

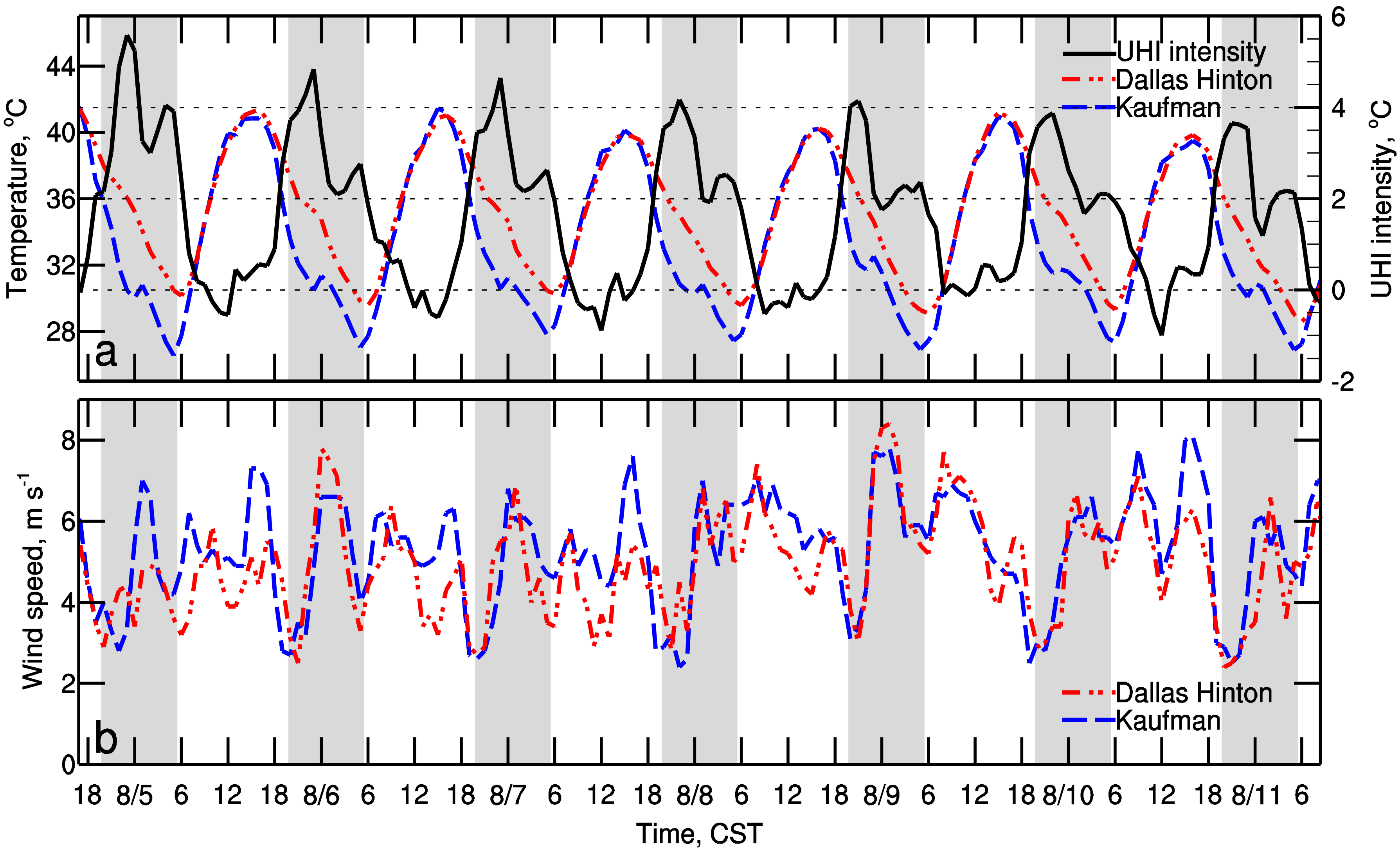
Model domains and configurations



- WRF3.6.1
- 12->4->0.8km
- NOAH+Urban canopy model
- Boundary layer scheme: YSU
- Simulation period: August 7-8 2011

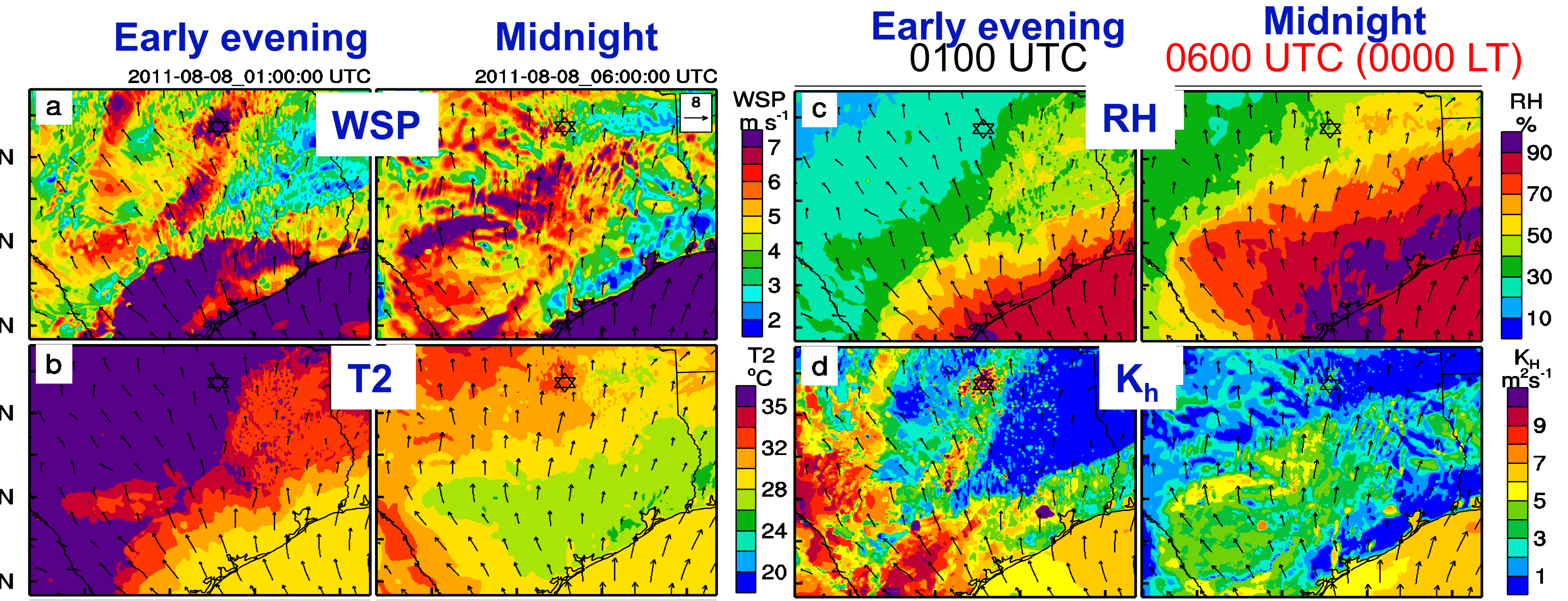
UHI intensity = T at Dallas Hinton – T at Kaufman
to be consistent with Winguth (2013, JAMC)

Observed variation of UHI, T, wind speed



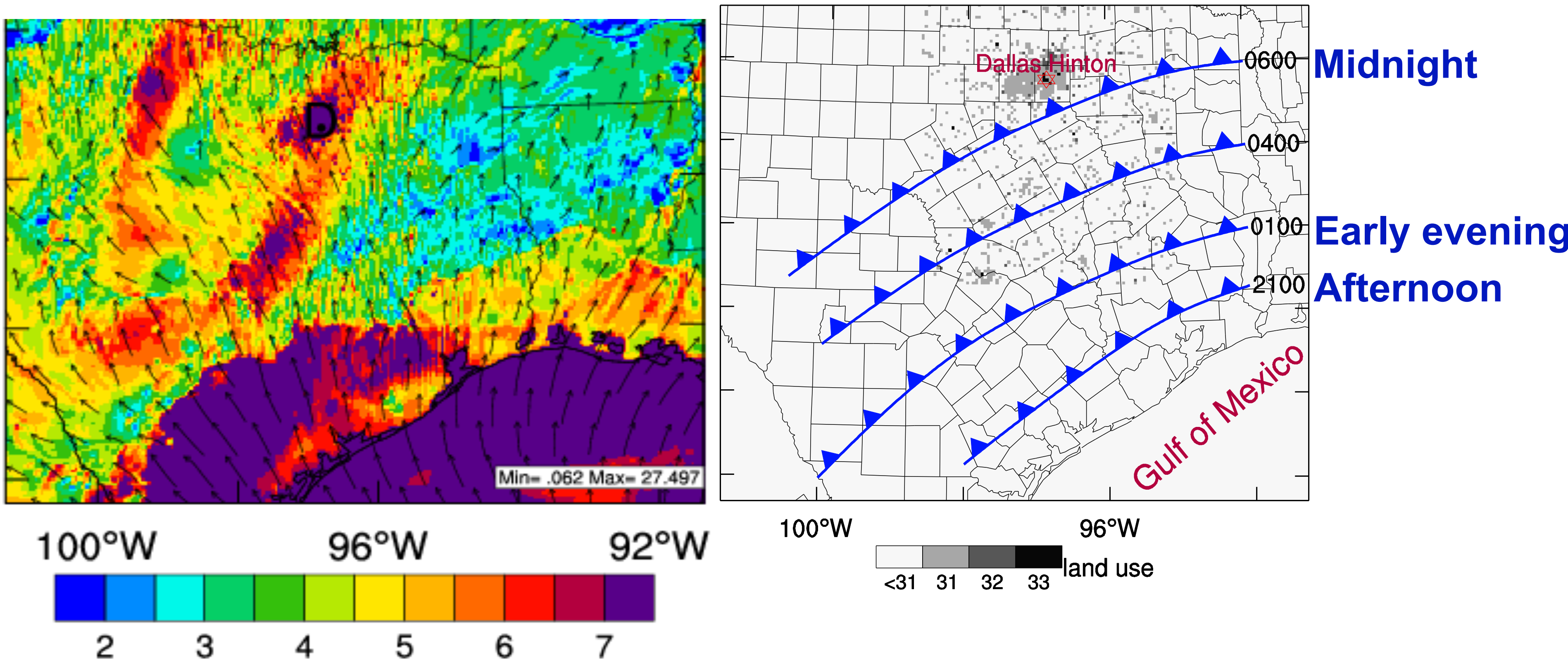
Collapses of UHI coincided with wind maximum and rural nocturnal warming events

Map of wind, T2, RH, K_h at 00 and 06 UTC



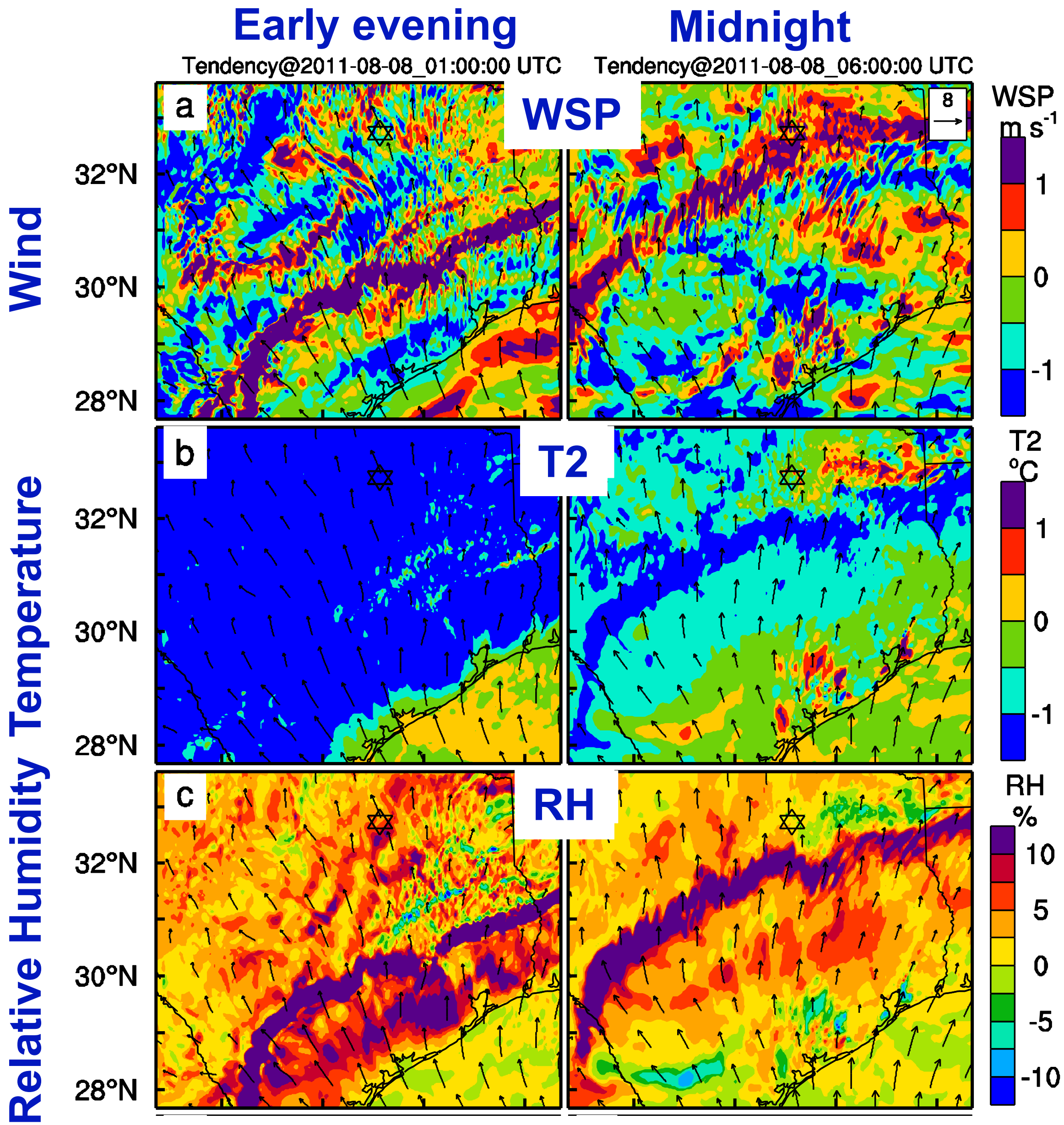
Indications of a sea breeze front:
Cooler and moister air behind the front with stronger momentum and vertical mixing

Inland penetration of the sea breeze front



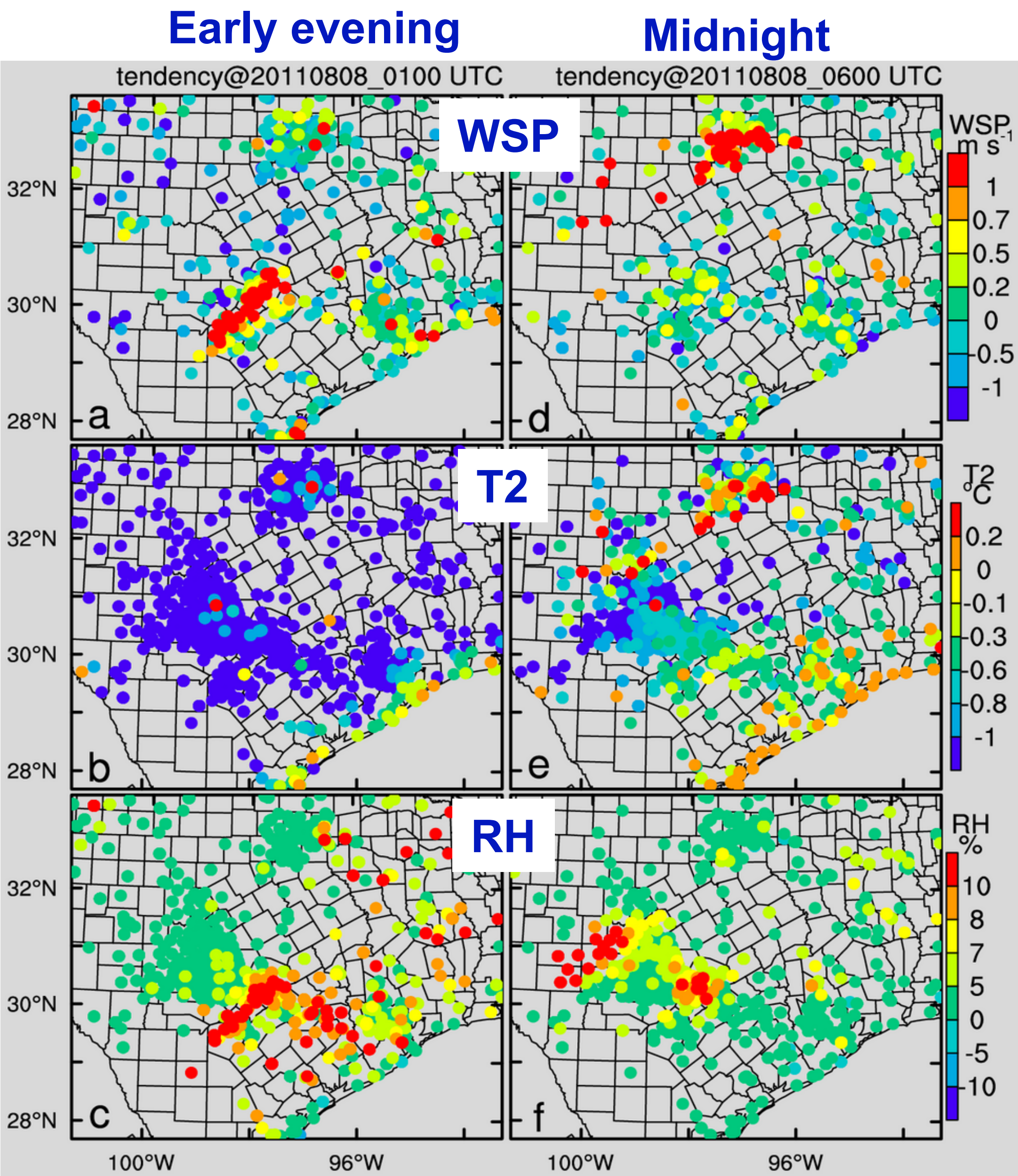
The sea breeze front approached Dallas around midnight (0600 UTC)

Tendency: difference between current and next hours



The inland penetration of sea breeze front can be clearly illustrated in the tendency of WSP, T2, RH.

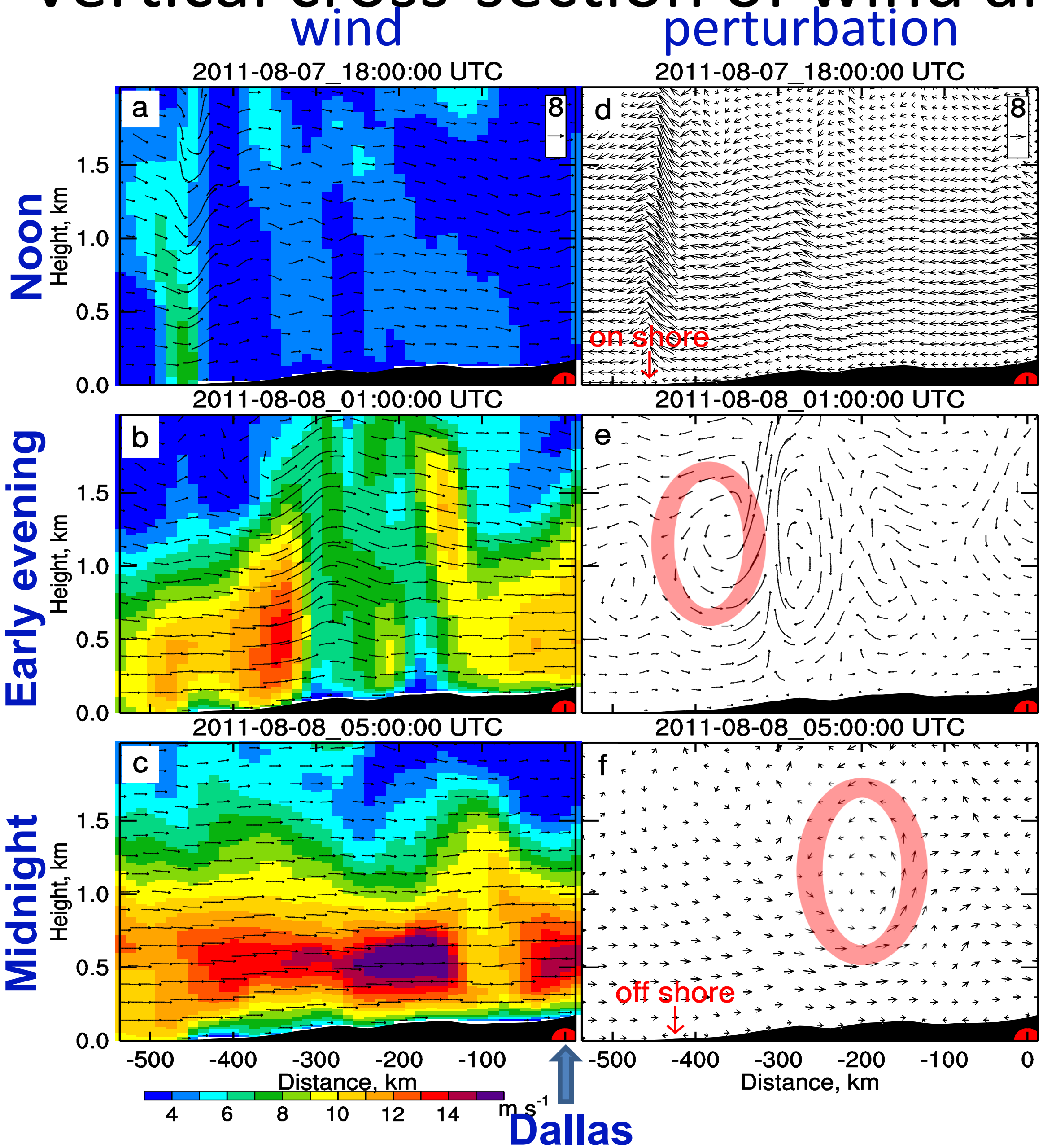
Observed tendency in MADIS data



MADIS integrated data from many providers

In the spatial distribution of tendency, the small scale local heterogeneity in instantaneous values is removed and only the spatial information of temporal variation is remaining.

Vertical cross-section of wind and its perturbation



Sea breeze develops in the morning and is advected by Low-Level Jet at night

Synoptic sea breeze

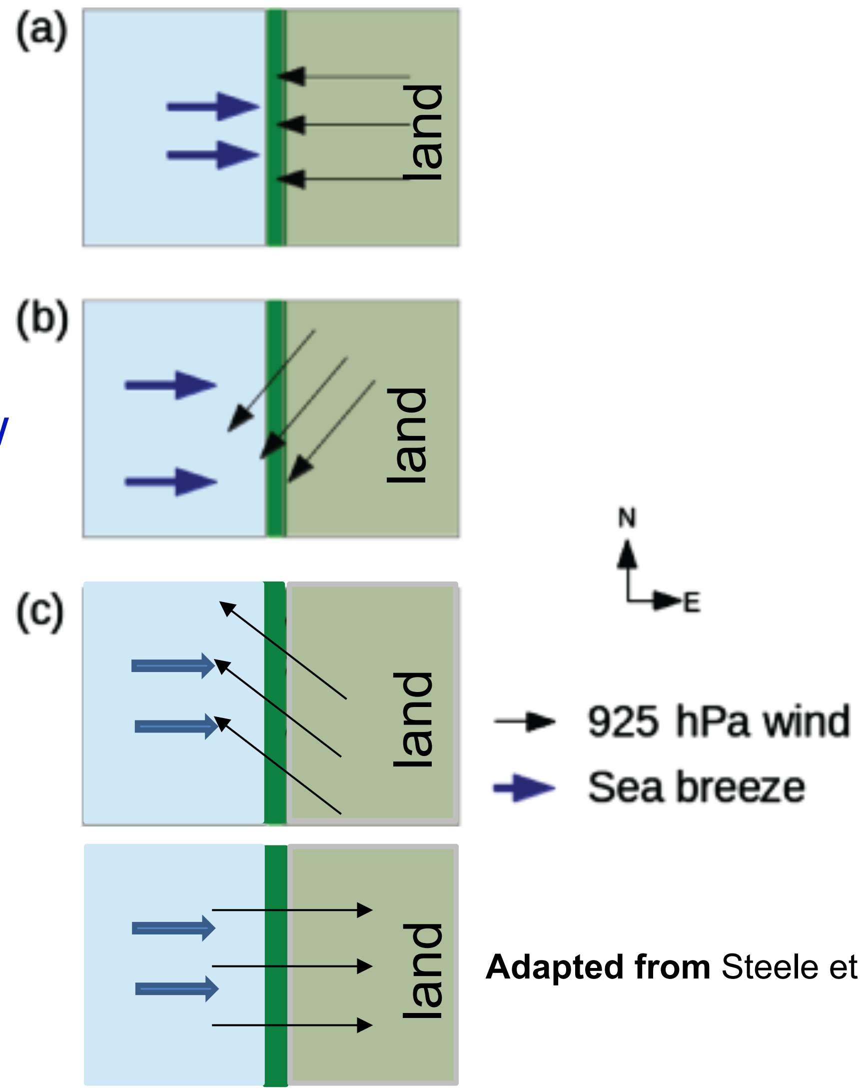
Categories of Sea Breeze

Pure

Corkscrew

Backdoor

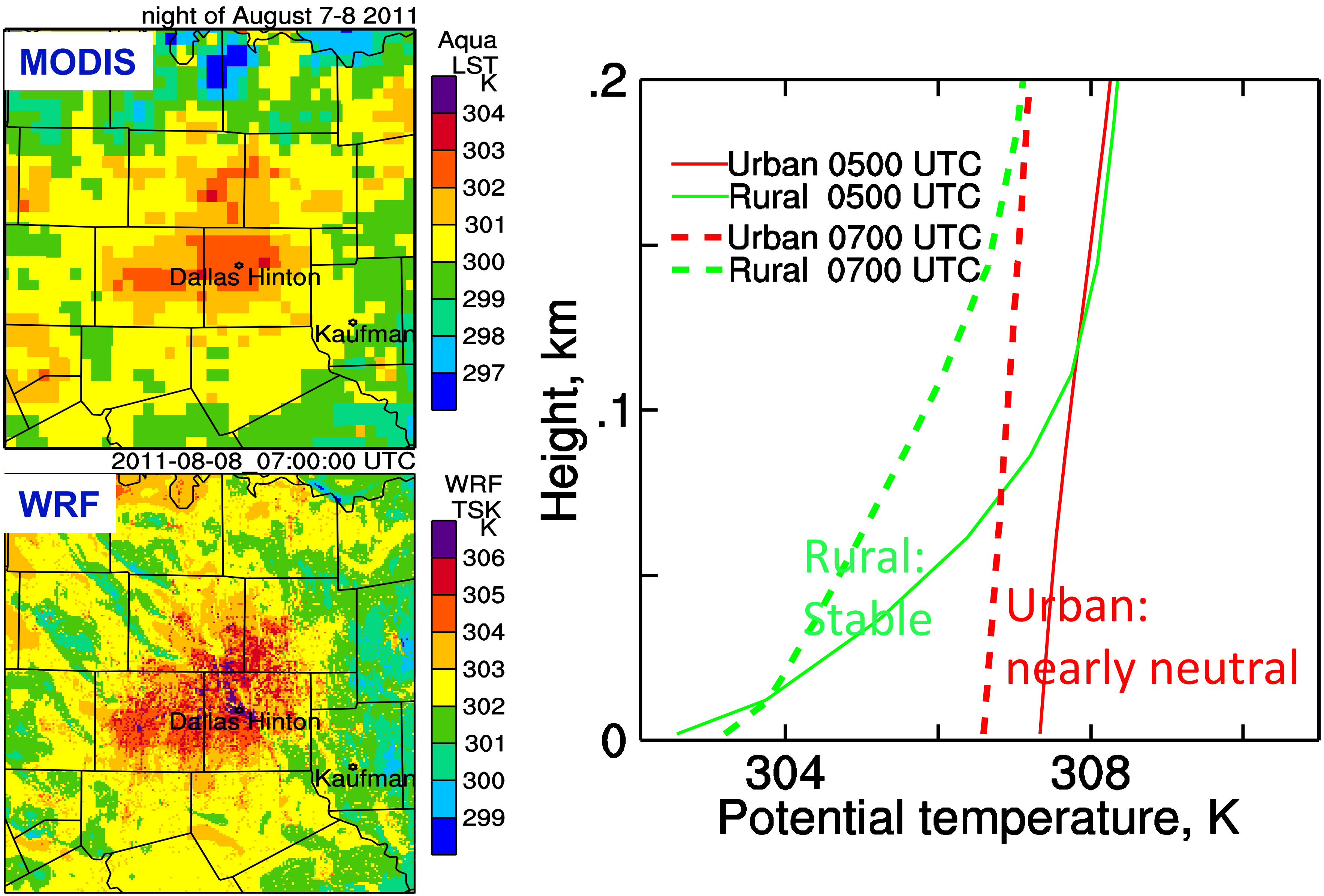
Synoptic



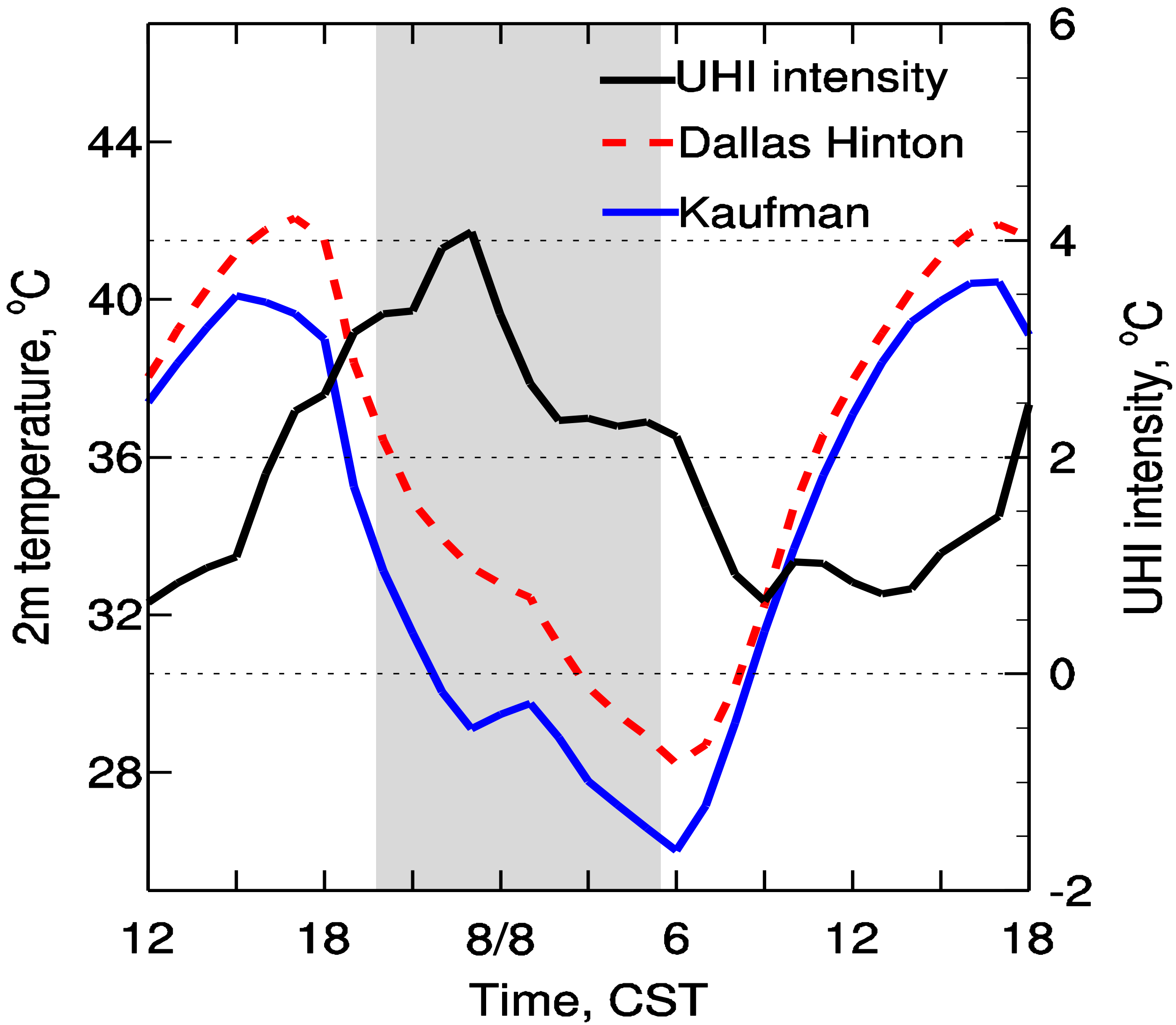
Adapted from Steele et al. (2014, QJ)

Synoptic sea breezes were less studied previously

Different response to the front in rural and urban

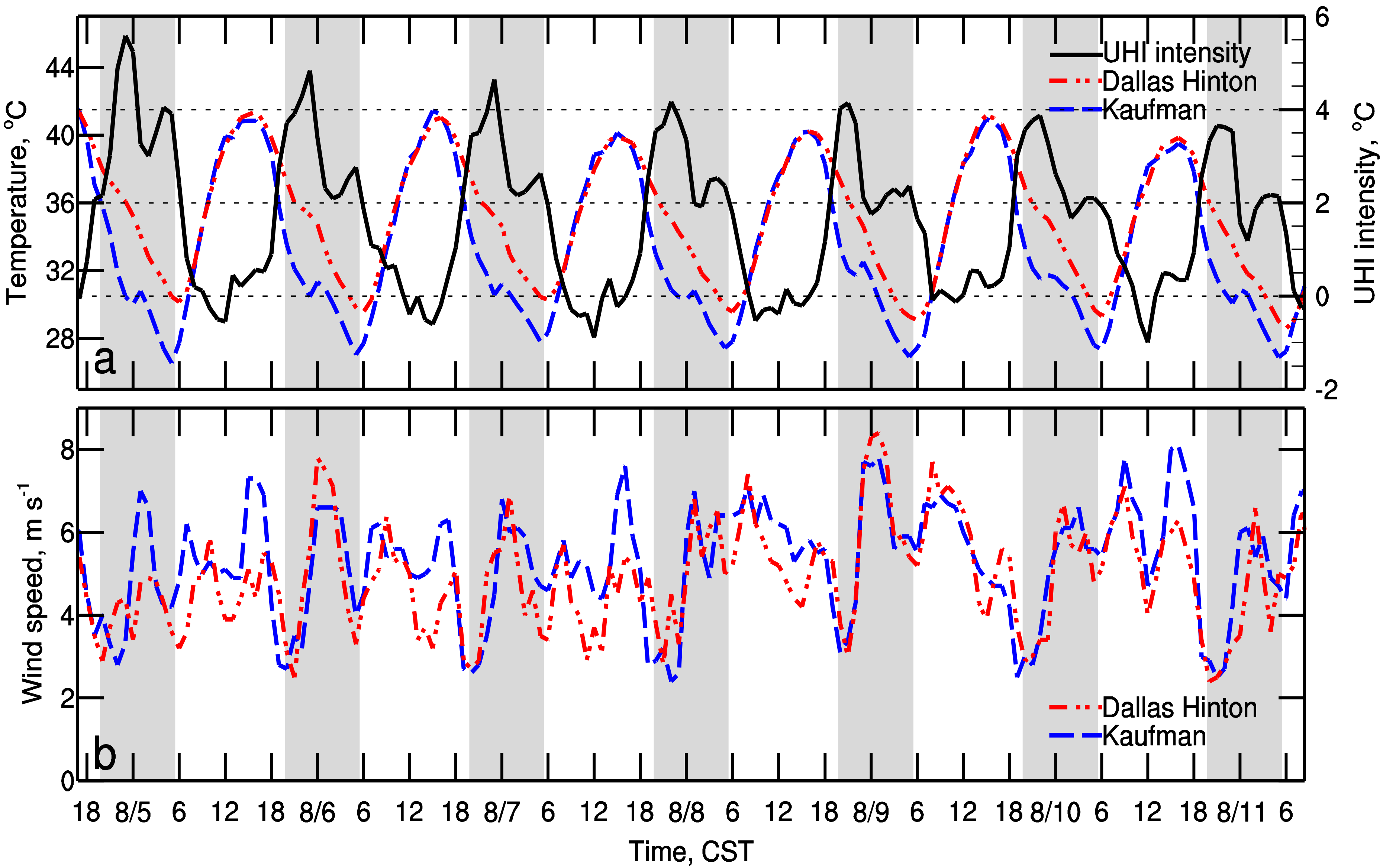


Simulated variation of T, and UHI intensity



Nocturnal warming in rural and non-warming in urban led to collapse of UHI

Observed variation of UHI intensity in Dallas



Conclusions

1.“collapse” of nocturnal UHI intensities occurred frequently around midnight in August 2011 in Dallas.

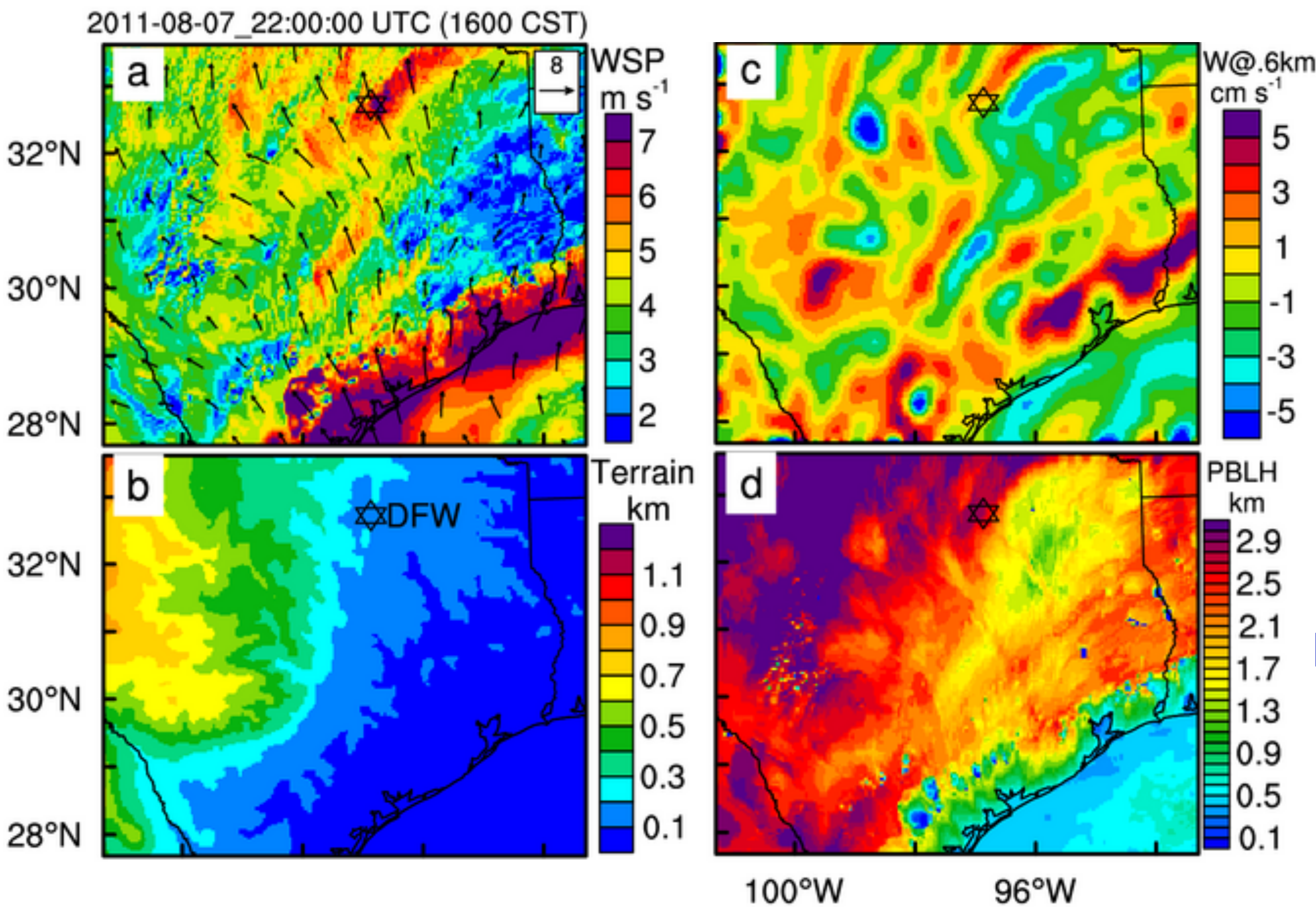
2. Synoptic sea breeze circulation cells can be advected to Dallas and influence its UHI, such a sea breeze category is rarely studied in the past.

Conclusions

3. Sea breeze frontal passage induced nocturnal warming events in rural area, while it did not alter urban boundary layer much, leading to collapse of UHI.

Nocturnal warming events were reported before, but as a result of synoptic cold fronts. In both cases the mechanism is similar, i.e., enhanced vertical mixing associated with momentum fronts plays a dominant role.

Mountain-Plain Solenoid induced wind maximum band?



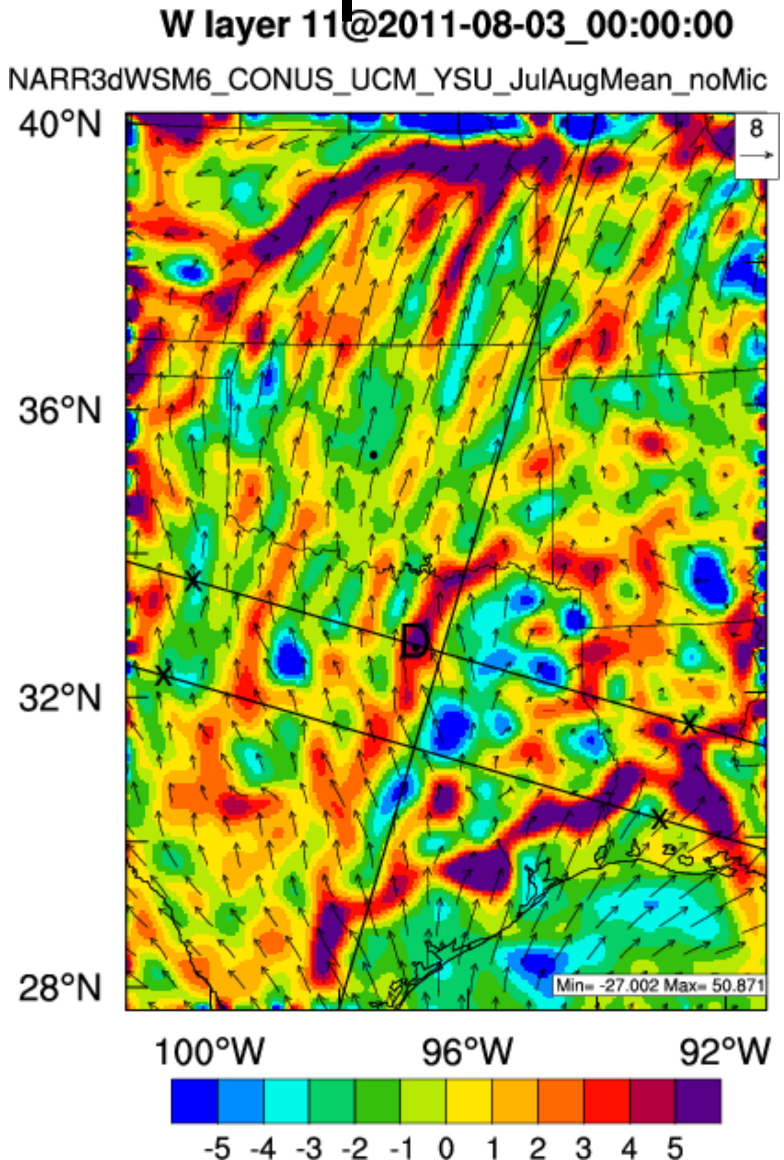
Wind speed

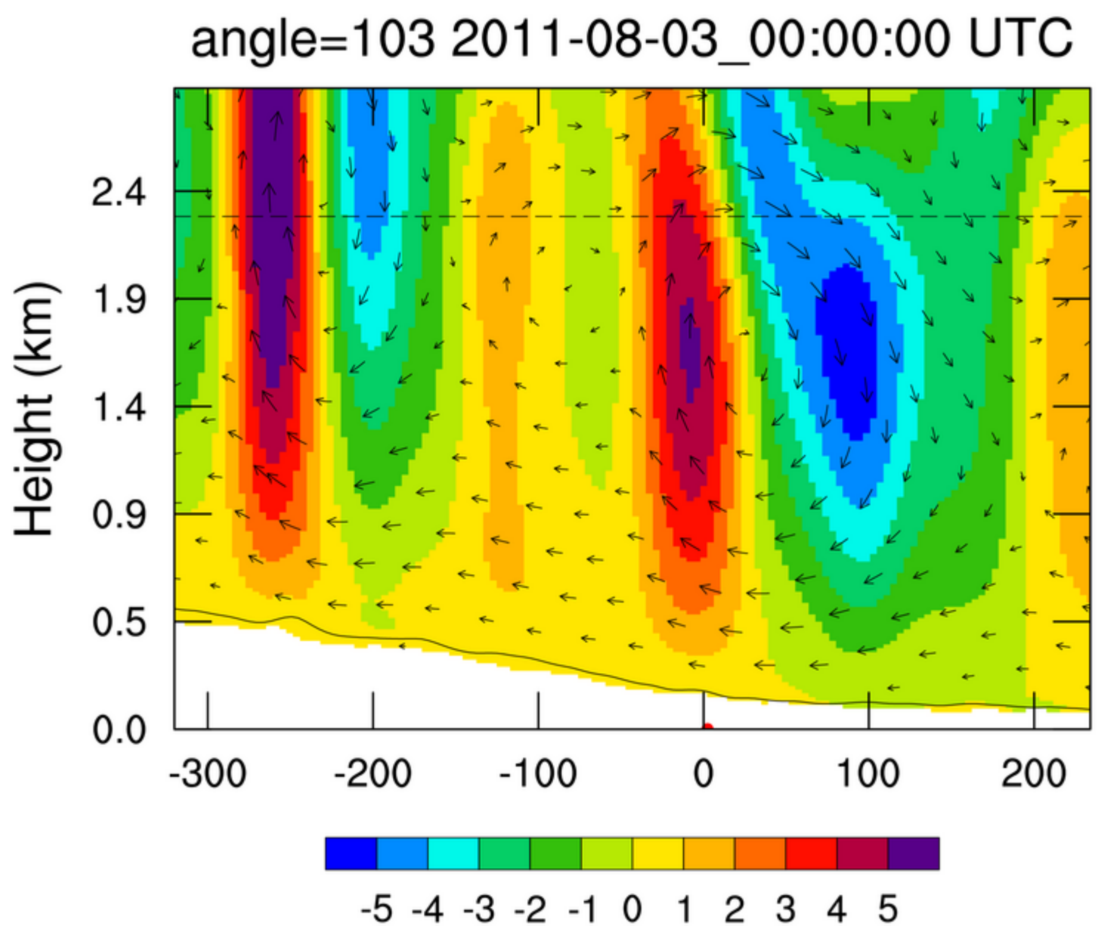
Terrain height

Vertical velocity

PBLH

Mountain-Plain Solenoid was prominent in Aug. 2011





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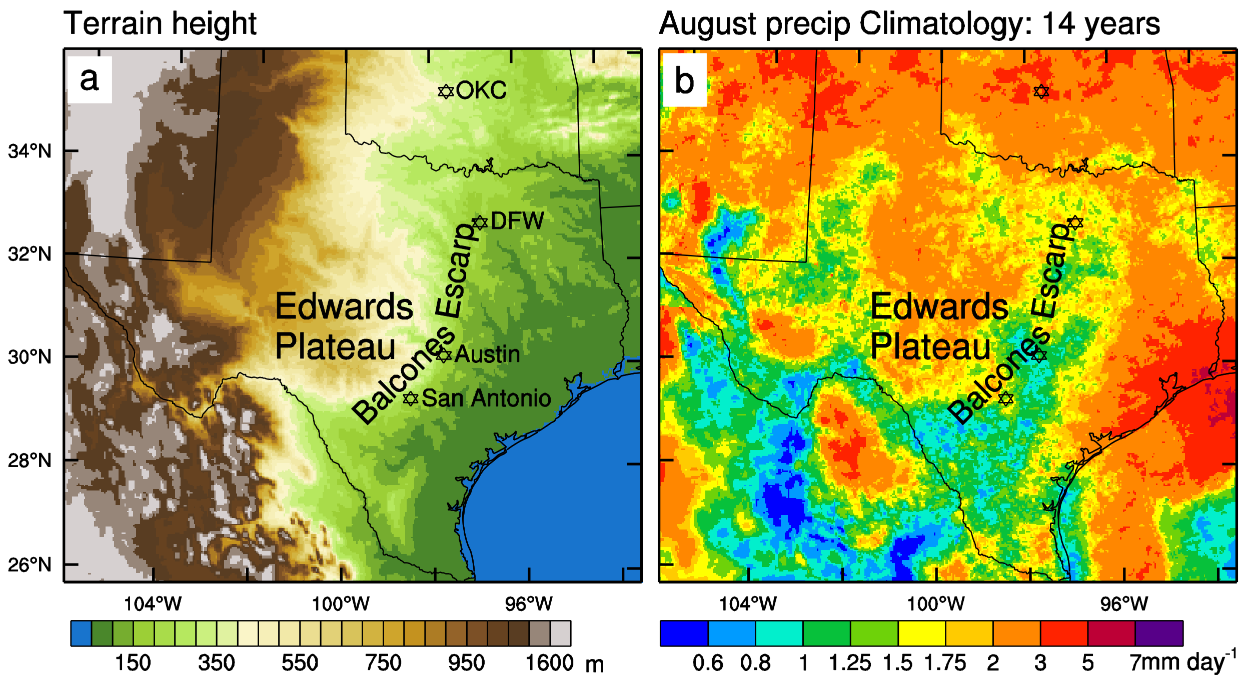
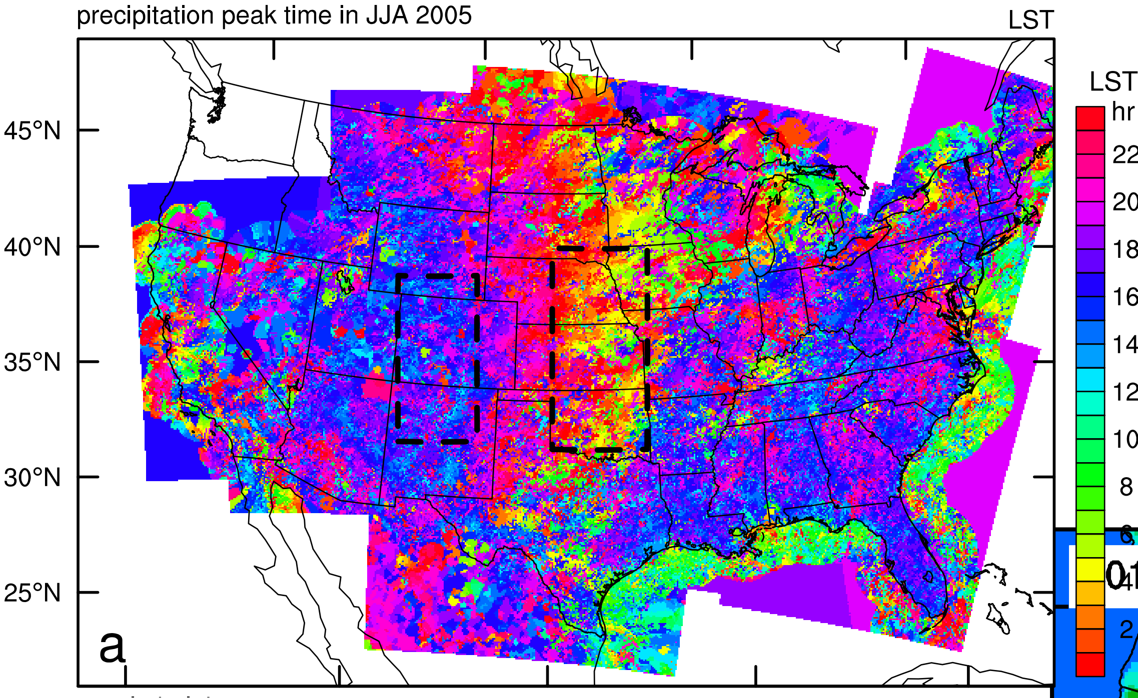
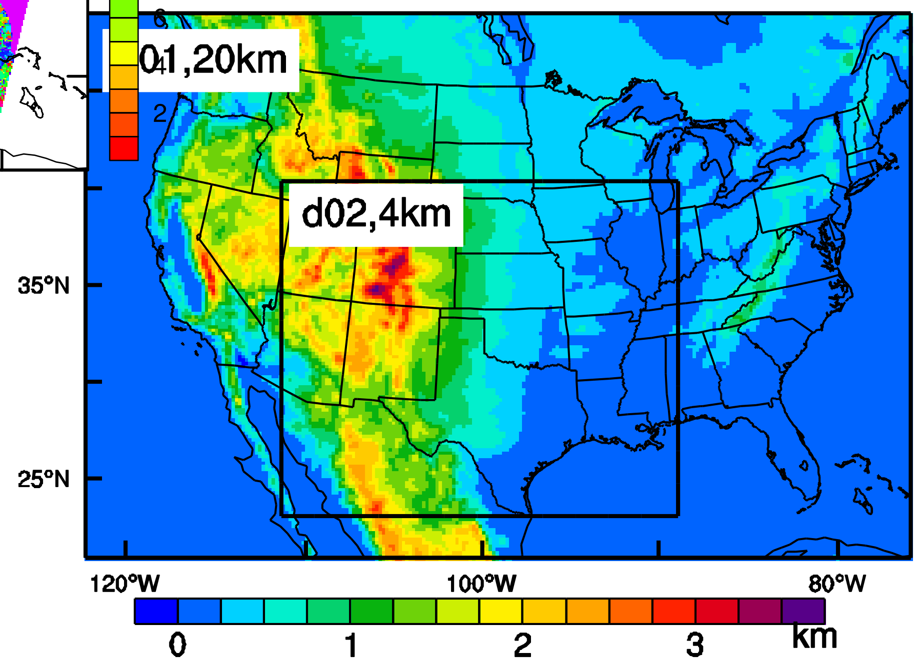
August precipitation in Texas

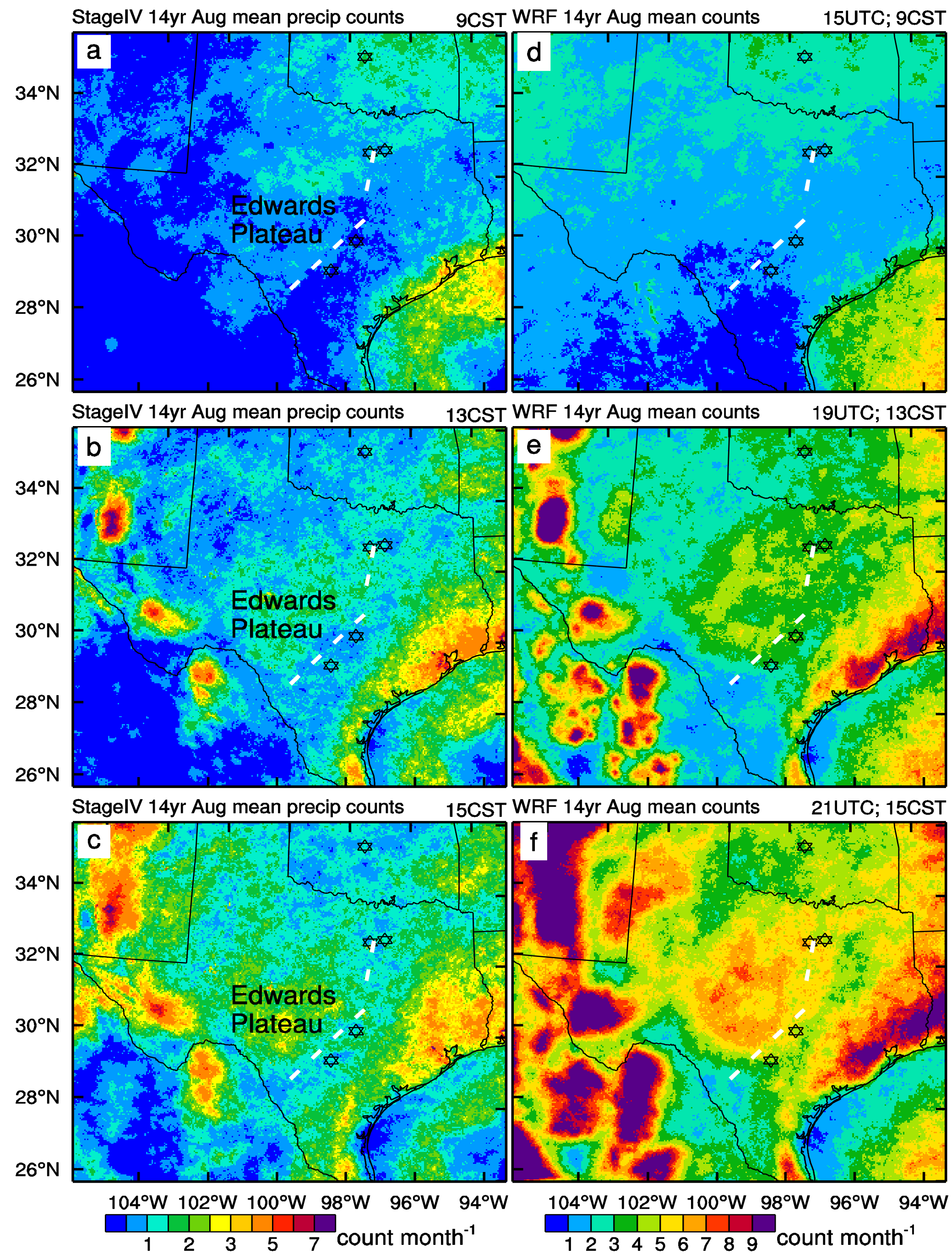


Configuration of dynamic downscaling

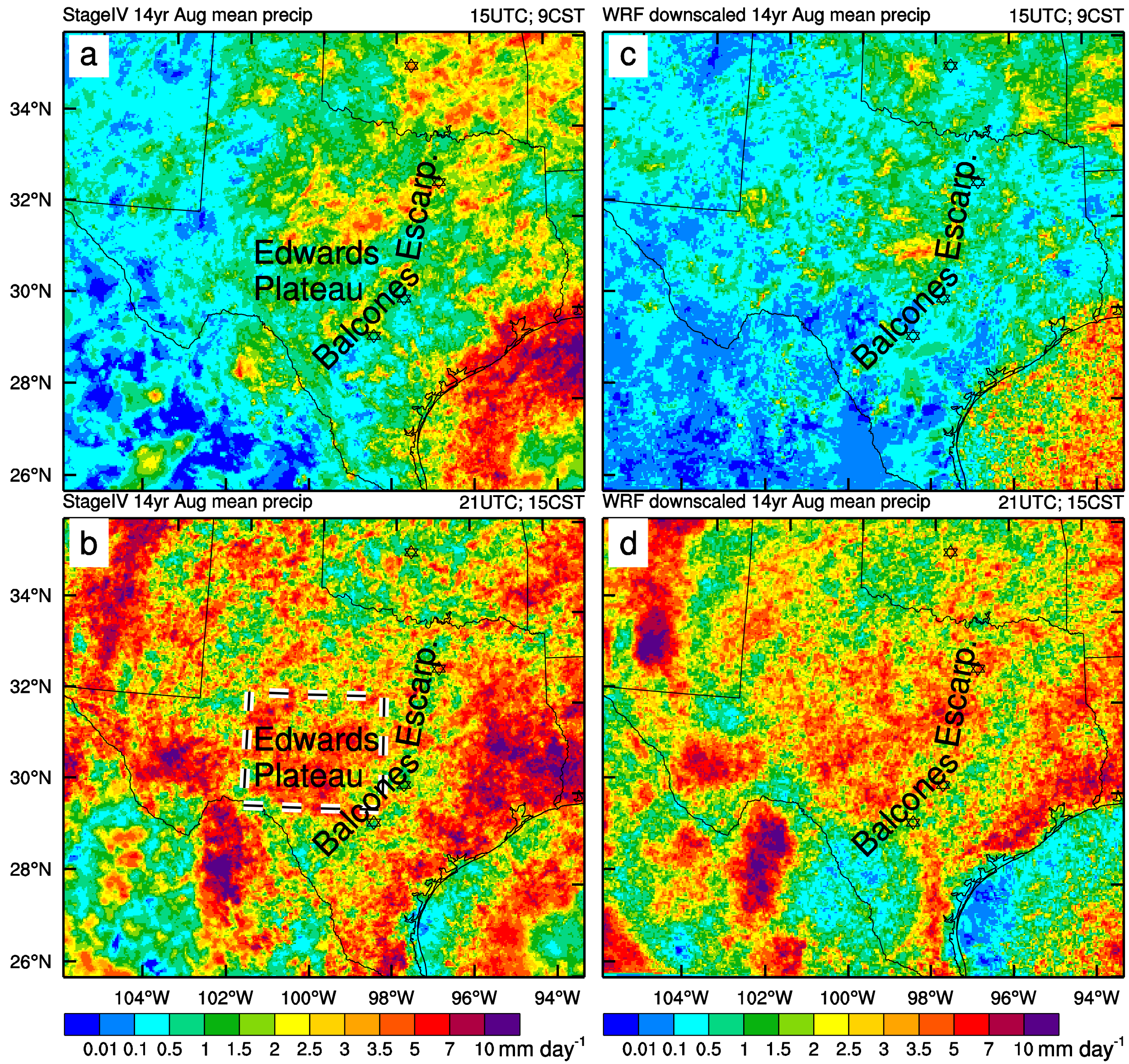




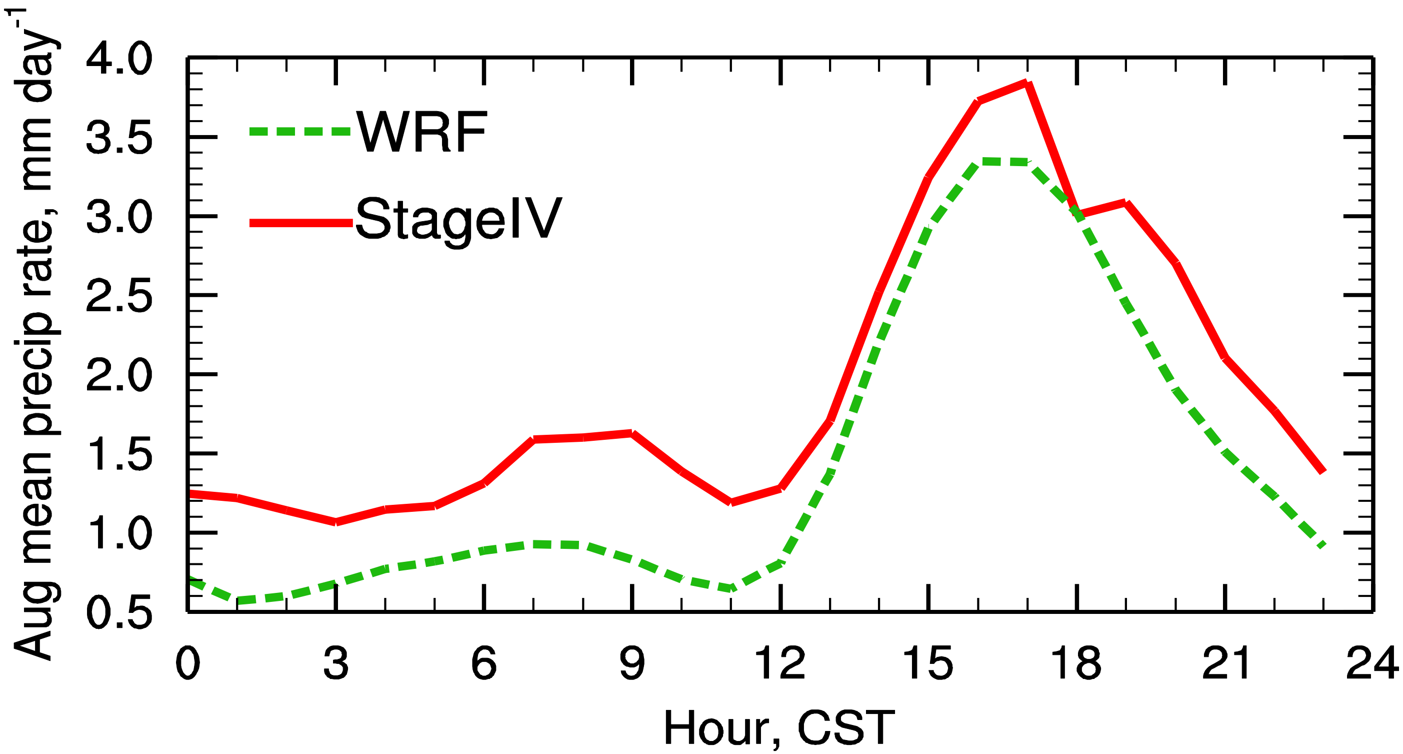
Precipitation Frequency



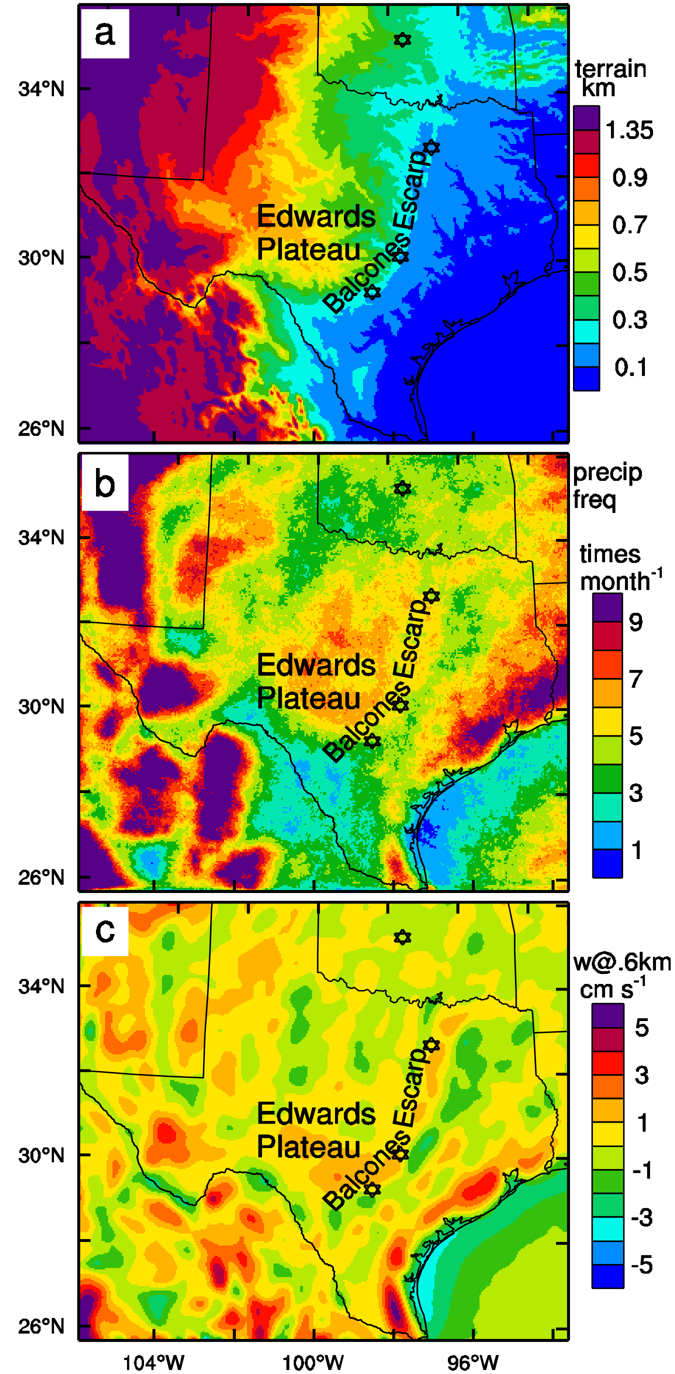
Precipitation amount



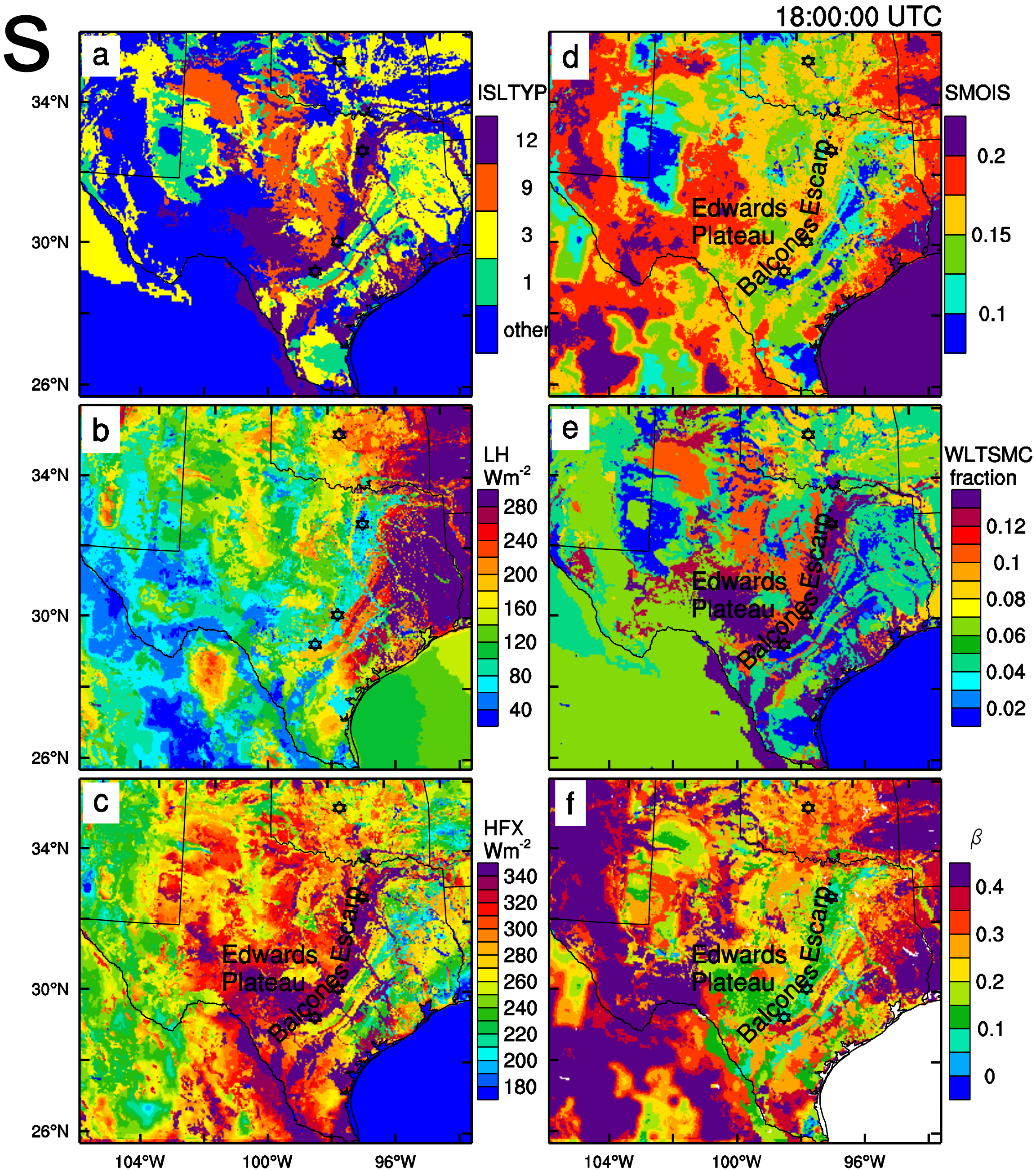
Diurnal variation of precipitation



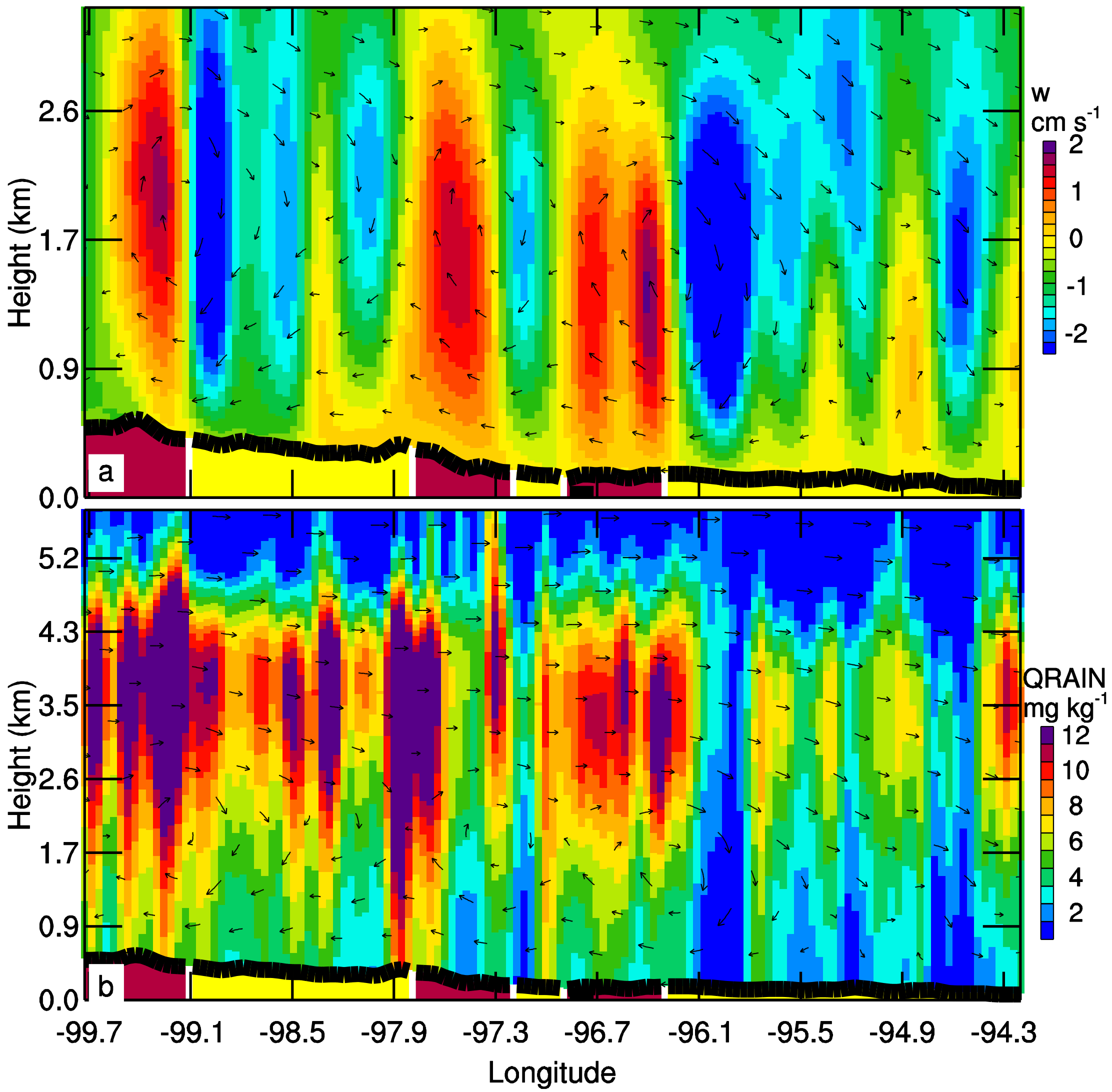
Likely causes: enhanced upward motion



Likely causes soil types



Clay enhanced vertical motion



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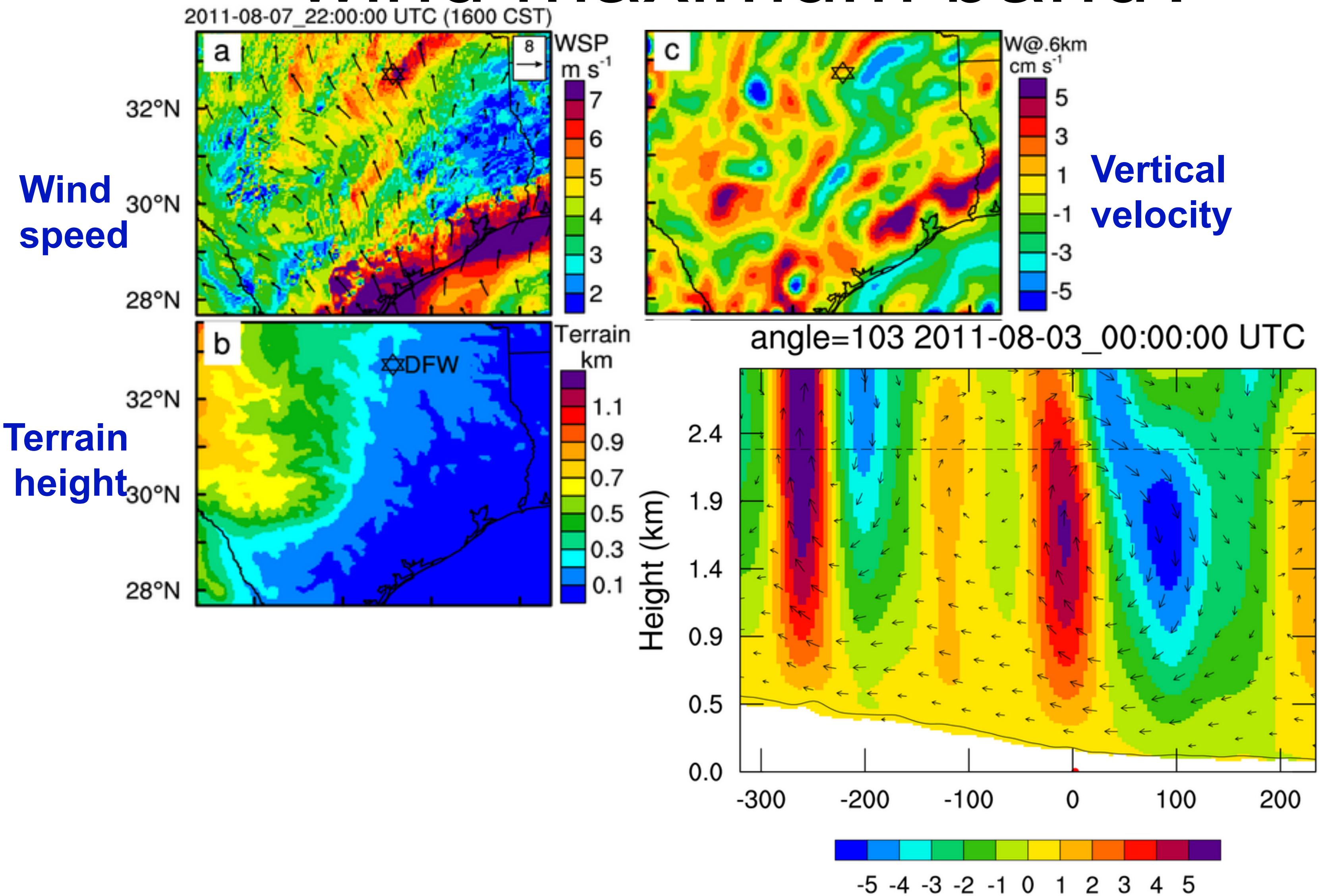
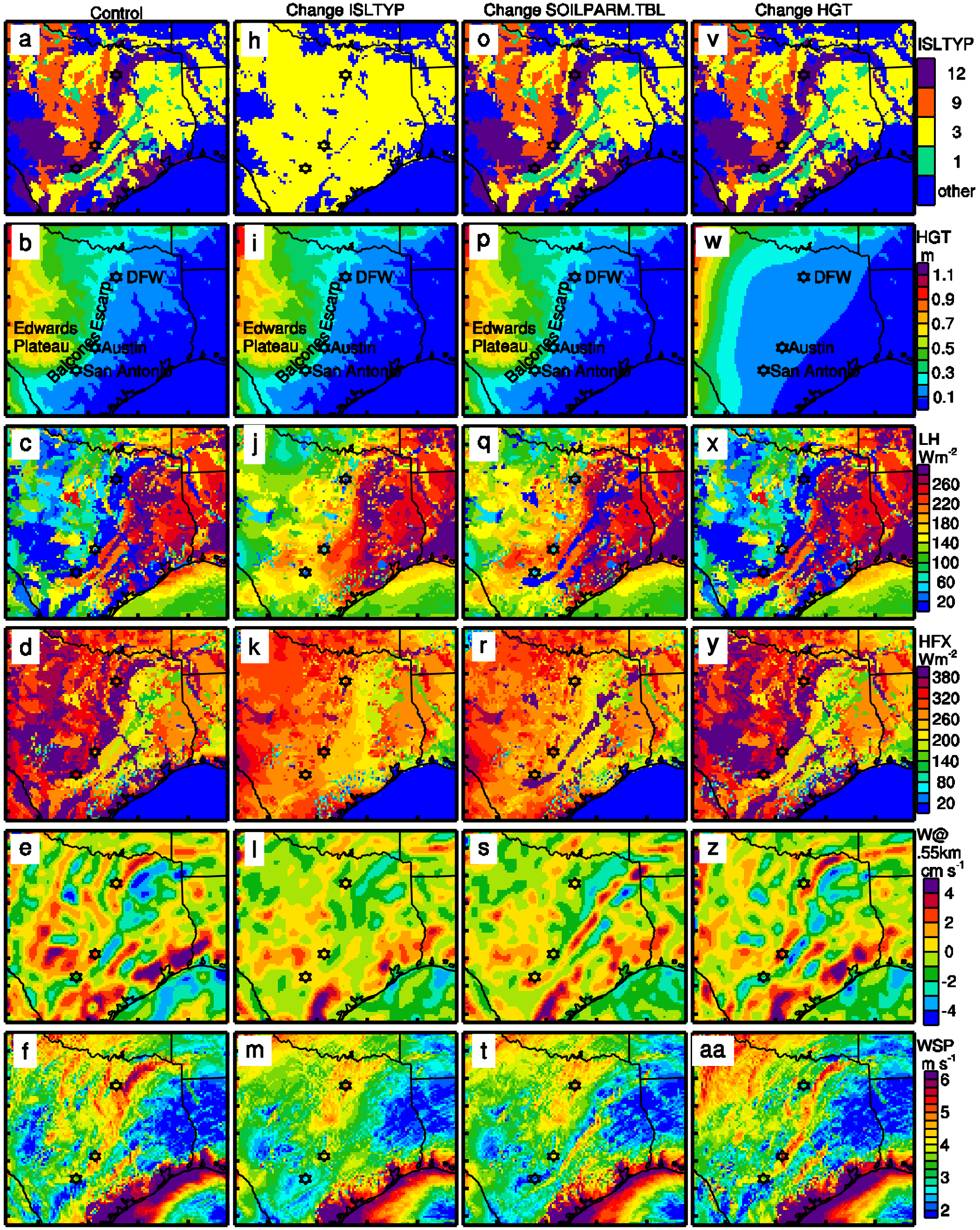


Further confirmation



Conclusions for precipitation

1. Plateau enhanced precipitation, not due to mountain-plain solenoid circulation, but due to clay soil type.
2. Clay tends to retain soil moisture, thus enhancing sensible heat fluxes and triggering upward motions.
3. Soil-type breezes are triggered due to different soil types

References

1. **Hu, X.-M.**, X. Li, M. Xue, D. Wu et al. (2016a), The Formation of Barrier Winds East of the Loess Plateau and their Effects on Dispersion Conditions in the North China Plains, Bound.-layer meteor., DOI:10.1007/s10546-016-0159-4
2. **Hu, X.-M.**, and M. Xue (2016b), Influence of synoptic sea breeze fronts on the urban heat island intensity in Dallas-Fort Worth, Texas, *Mon. Wea. Rev.*, doi:10.1175/MWR-D-15-0201.1.
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6. **Hu, X.-M.**, et al. (2013), Impact of Low-Level Jets on the Nocturnal Urban Heat Island Intensity in Oklahoma City. *J. Appl. Meteor. Climatol.*, 52, 1779–1802.
7. **Hu, X.-M.**, et al. (2013), Enhanced vertical mixing associated with a nocturnal cold front passage and its impact on near-surface temperature and ozone concentration, *J. Geophys. Res.*, 118, 2714– 2728.