Impact of Sea Breeze Fronts on Urban Heat Island & Air Quality in Texas

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MODIS-derived land surface temperature

Nighttime

UHI is prominent during nighttime

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

Hu et al. (2013, JAMC)
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 (2015, MWR, conditionally accepted)

— 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)

WRF/Chem for air quality impact
Collapses of UHI coincided with wind maximum and rural nocturnal warming events
Indications of a sea breeze front:
Cooler and moister air behind the front with stronger momentum and vertical mixing
Mountain-Plain Solenoid induced wind maximum band

- Wind speed
- Terrain height
- Vertical velocity
- PBLH
Mountain-Plain Solenoid was prominent in Aug. 2011
Confirmed by 2D idealized simulations

Two circulation cells along a heated slope simulated using a 2D model from Qian et al. (2012, JAS)
The Plateau acts as a heated source in Summer (Hu et al., 2014, STE)

Similar as North China Plain?

Terrain height

T@850hPa

T@550hPa
Impact of Mountain-Plain solenoid on boundary layer development and enhance air pollution (Hu et al., 2014, STE)
Mountain-Plain Solenoid induced wind maximum band

Wind speed

Terrain height

Vertical velocity

PBLH
Inland penetration of the sea breeze front

The sea breeze front approached Dallas around midnight (0600 UTC)
The inland penetration of sea breeze front can be clearly illustrated in the tendency of WSP, T2, RH.
Observed tendency in MADIS data

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.
Vertical cross section of tendency of WSP, $K_h$, T.
Different response to the front in rural and urban areas.

Urban: nearly neutral

Rural: Stable

Urban: nearly neutral
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
Nocturnal warming events reported previously

Induced by sea breeze

Induced by *synoptic cold fronts* (Nallapareddy et al., 2011)
T2 and vertical mixing coefficient at the leading edge of a cold front

Enhanced vertical mixing associate with cold fronts led to surface warming (Hu, 2013, JGR)
Nocturnal warming events and $\text{O}_3$ maximum induced by a cold front

$\text{O}_3$ increased by 40 ppb when the nocturnal warming event occurred (Hu, 2013, JGR)
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.
Unique temporal variation of nocturnal $O_3$

Nighttime $O_3$ maxima associated with collapse of UHI

Night peak

Wind peak
Induced by sea breeze frontal passage? tendencies

Mesonet observations

WSP

EPA AQS observations

O3_obs tendency

20110830_23LT

Mesonet data at 20110831_0500
windSpeed tendency

Mesonet data at 20110831_0500
temperature tendency
Impact of sea breeze fronts on \( \text{O}_3 \) in the afternoon

**WRF/Chem 3.7**

**Emission:**
- NEI2011
- MEGAN

**IC/BC:**
- NARR
Impact of sea breeze front on $O_3$ at night
Impact of Hurricane on $O_3$?
Weak wind zone around Dallas?

Aug 28, 2010

Surface Weather Map at 7:00 A.M. E.S.T.
References


