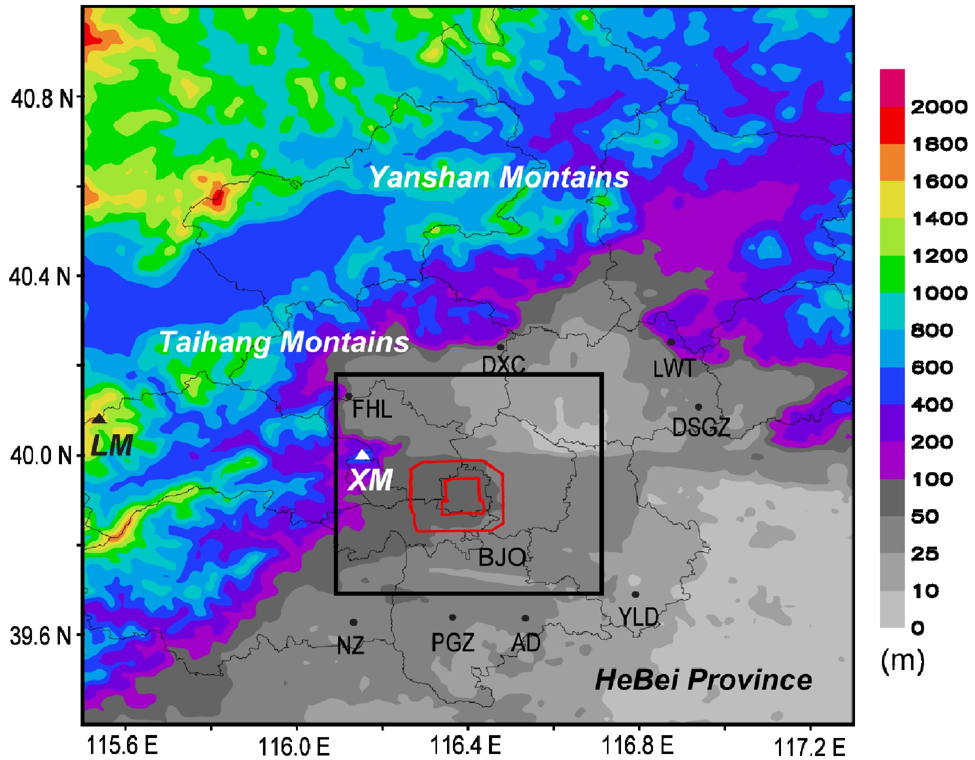
Observed Spatial Characteristics of Beijing Urban-Climate Impacts on Summer Thunderstorms

Jingjing Dou[1], Yingchun Wang[1,2],
Robert ("Bob") Bornstein[1,3], Shiguang Miao[1]

[1]Institute of Urban Meteorology (IUM), Meteorological Administration ,Beijing, China
[2]Beijing Meteorological Service (BMS), Beijing, China
[3]Dept. of Meteorology, San Jose State University, San Jose, California, USA

ICUC-9, Toulouse, France,
July 2015

Beijing area: on North China Plain



topographic-heights (m, colors)
city-district boundaries (grey lines), study area (black square)
2nd & 4th Ring Roads (RRs, inner & outer red circles, respectively)
Beijing Observatory (BJO), & rural temp-stations (black dots)

Data & Analysis (1)

- Data: June-August 2008-12
  - Rawinsonde wind from Beijing Observatory
  - Hourly (2-m) T & RH and (10-m) V at 64 AWS sites in & around Beijing

- AWS-site average day (assumed as 08-19 LT) & night (assumed as 20-07 LT) T, q, & V-values were determined

- Near-surface flows: classified as nighttime (02-08 LT)/Mt.- & daytime (12-22 LT)/valley-breezes, respectively (Cai et al. 2002)

- 09-11 & 23-01 LT: transitional periods

Data & Analysis (2)

- Prevailing flow-direction: determined at each AWS site for Mt.- & valley-breeze periods

- Rawinsondes: twice daily (08 & 20 LT) during June, & thrice daily (08, 14, 20 LT) during July & August

- June to August has 80% of Beijing annual precip

- 850 hPa wind-velocity prior to each rainfall-event (defined below): its storm "steering" velocity

Data & Analysis (3)

- Rainfall-event: concurrent-rain at least two AWS sits, each with hourly accumulation > 0.1 mm
- Minimum of 3-h between events was required; 333 events
- Each event: classified by storm “steering” velocity
- Southwesterly flows: 134 cases (40% of all events); southerly: second (51 cases); others: only 14-33 events
- Thus only southwesterly flows studied: to avoid confusion between up- & down-wind (the key point in any urban climatology study)

Data & Analysis (4)

- Hourly-average Beijing UHI-intensity: average temp-values at all 26 urban stations (within Fourth RR) minus corresponding rural value (average of seven stations)

- Thunderstorm-cases: classified by its "event" UHI-value, i.e., the max of the three pre-event hourly UHI-values

- Average calculated 2008-12 Beijing summer-UHI: 1.25^0C

- Event-UHIs above or below 1.25^0C: strong- & weak-UHIs, re-spectively

- 35 of 61 strong-UHI were nighttime (20-07 LT) & 53 of 73 weak-UHIs were daytime (08-19 LT)

Data & Analysis (5)

- Regional-normalized rainfall-amount NR (%): eliminates large-scale effects, highlighting local impacts

- Site-NR: calculated as its total study-period rainfall minus the all-site average (producing a positive or negative deviation) divided by (i.e., normalizing) the all-site average

- Results: DOU*, WANG, BORNSTEIN, & MIAO (2015) in JAMC

- * Her M. S. thesis

- Bob Bornstein will give Wed plenary on urban impacts on precip, which will put this study into a larger context

Results-1: 2-m temps

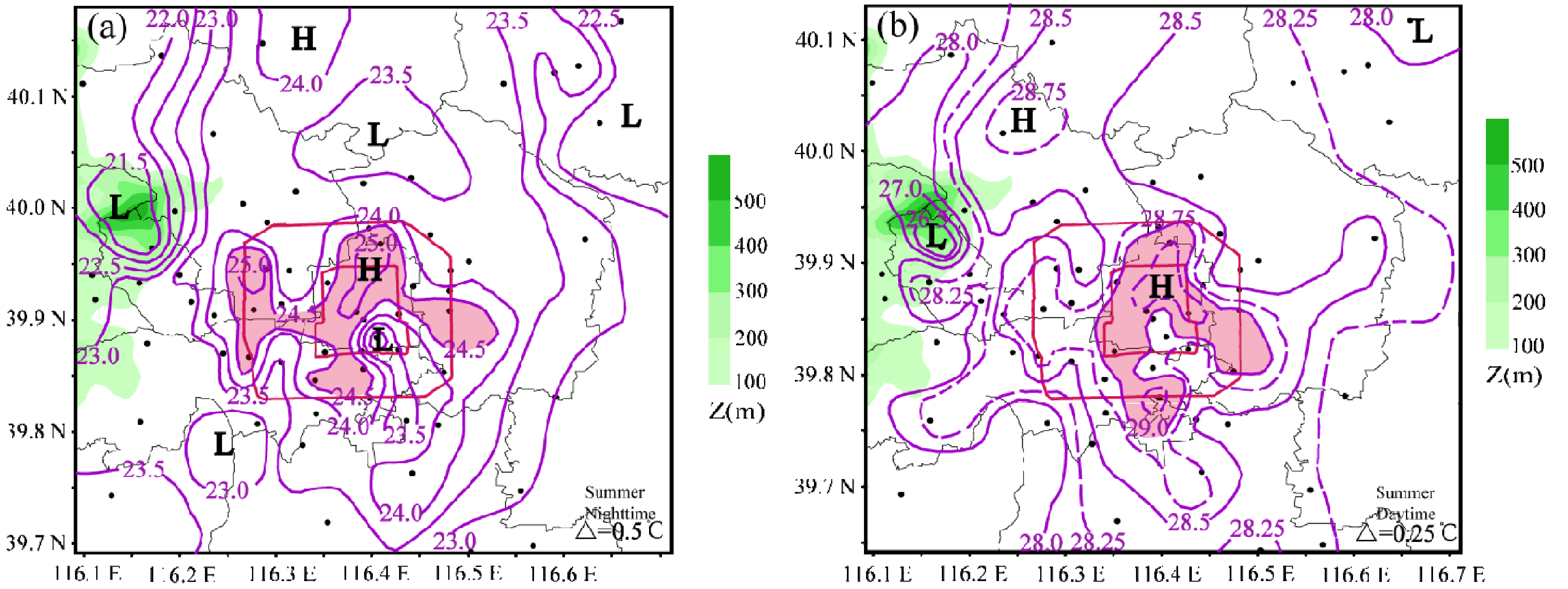


Fig.2. Average Beijing-area 2-m temps (°C)
showing high (H, shaded in red) & low (L) temp areas
Note: smaller (0.25 vs 0.5 °C) day isotherm-increment
Results: (a) cooler nights & (b) warmer days (of course), but with
(c) stronger night than day average-UHI (1.7 vs. 0.8°C)

Results-2: 10-m wind speeds

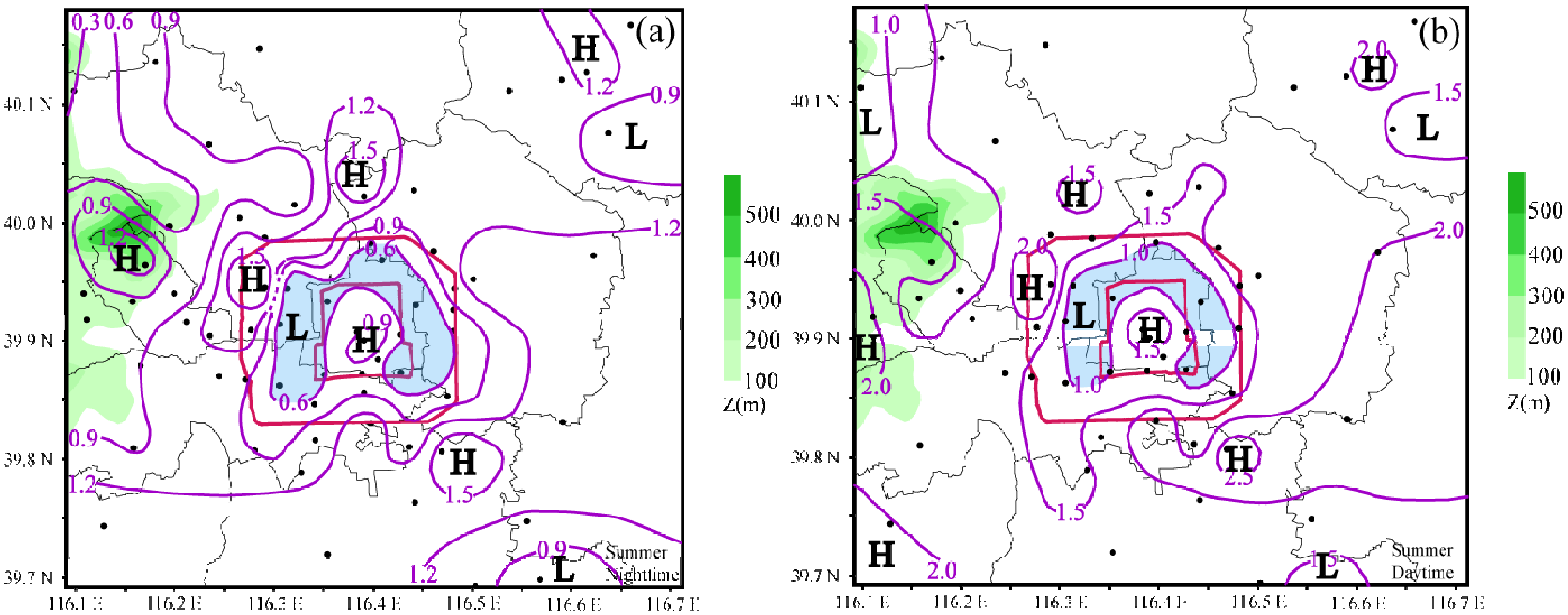


Fig.3. Average Beijing-area 10-m wind speeds (m/s) showing high (H) & low (L, shaded in blue) speed areas

Note: smaller (0.3 vs 0.5 m/s) night isotach-increment

Results: low-speed belt between 2nd & 4th RR, the max build-up urban area

Results-3: 10-m wind direction

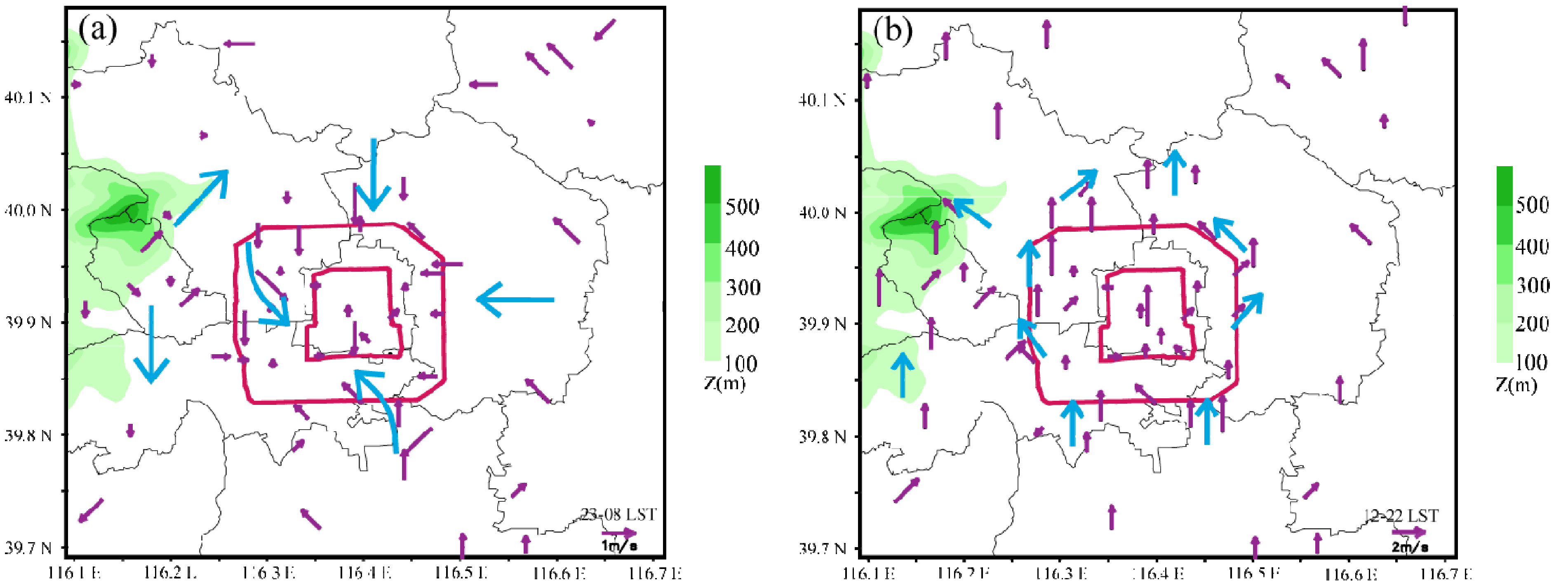


Fig.4. Same as Fig. 2, but for 10-m prevailing -winds for (a) Mt. (02-08 LT) & (b) valley (12-22 LT) breeze periods

Blue arrows: subjective representative flow-directions

Note: vector-scale is double for (faster) day winds

Results: (a) urban convergence during night strong-UHIs & (b) (Some) urban bifurcation during day weak-UHIs

Results-4: Rainfall amount (all cases)

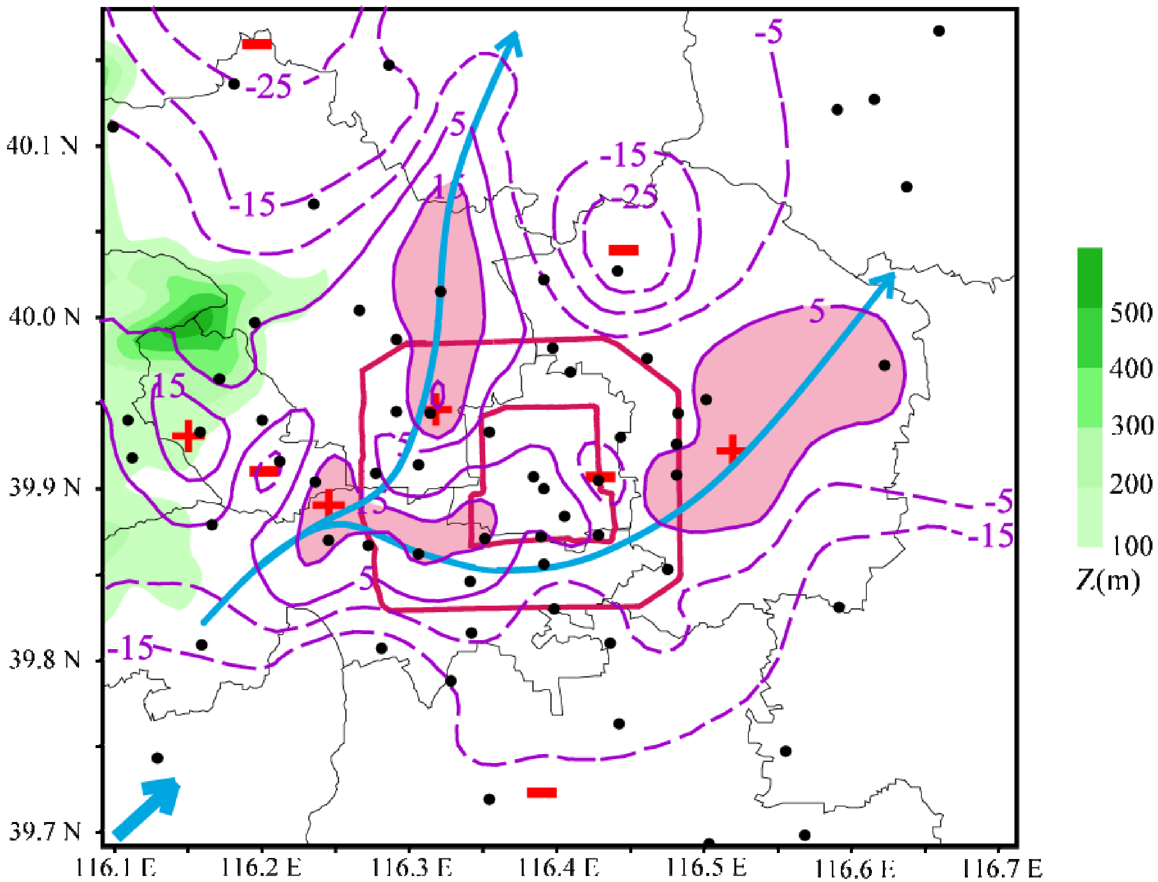


Fig.5. Same as Fig. 2, but for normalized rainfall-amounts N (%)
for all cases, where high urban-precip areas are shaded red
& thin blue-lines show a bifurcating streamline
Results: weak N-extremes (1) decreases over & downwind (>25%) of city
& (2) increases in lateral-areas (>15%) around city

Results-5: Rainfall (strong- vs. weak-UHIs)

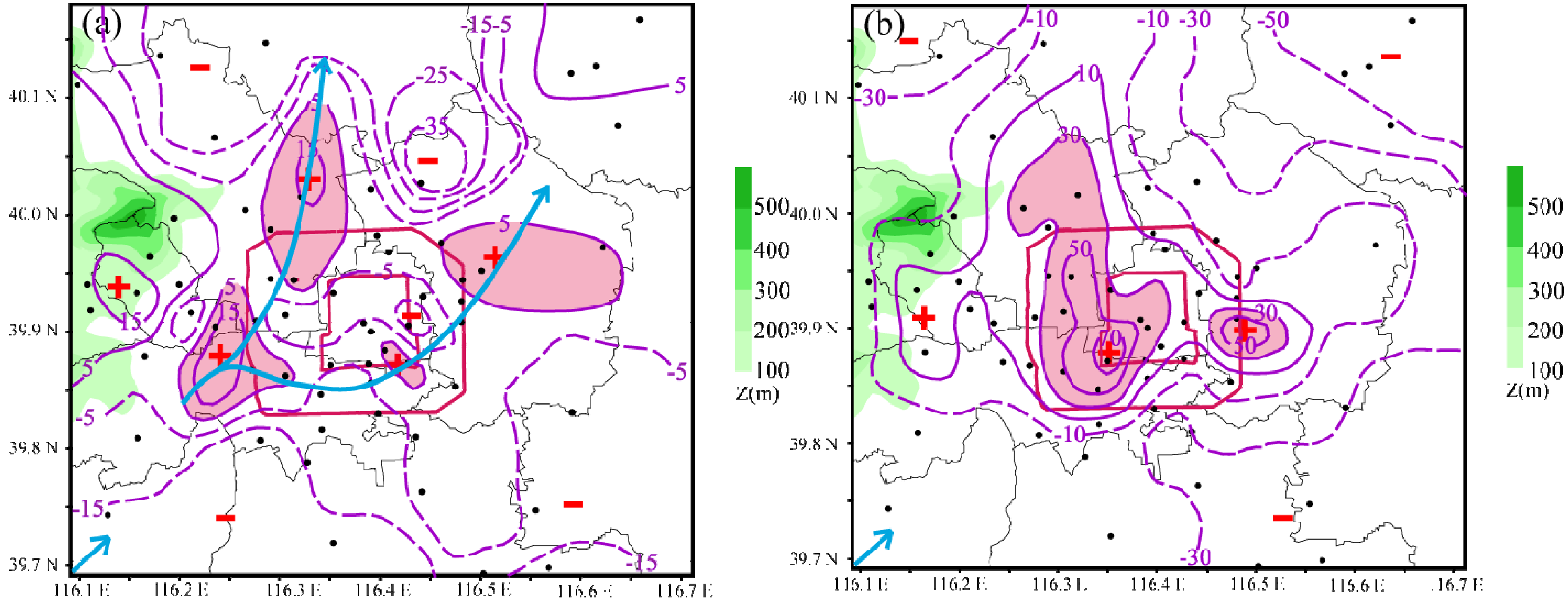


Fig 6. Same as Fig. 5, but for weak (L) vs. strong (R) UHIs

Note: strong-UHIs have larger (20 vs. 10%) isoterm-increment

Results: (1) weak-UHIs (on L): downwind N-decrease is larger (>35 vs. >25 %) than in Fig. 5 (i.e., for all cases together)

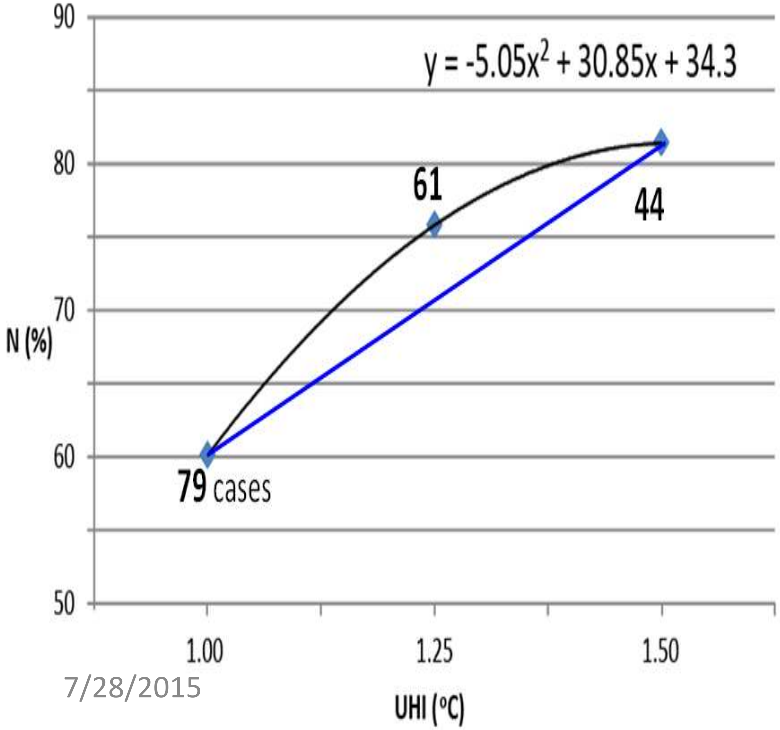
(2) strong-UHIs (on R): urban-center N-increase is now >70%

(3) Fig. 5 shows weak-UHI bifurcation domination of "all-cases"

Normalized precip-change N (%) vs. UHI-threshold (°C) for over-urban max-increases (as in Fig. 5) where

(a) over-urban max increased-precip is sensitive to UHI-magnitude (its driving mechanism), rising (non-linearly) from 60 to 81% as UHI-threshold increased from 1.00 to 1.50°C (see below)

(b) downwind max-decreased precip: not sensitive to UHI-magnitude (not shown), as it's not its driving mechanism; values changed only from -32 to -36% over this UHI-range



UHI-threshold (°C)	1.00	1.25	1.50
Max over-urban precip-increase N(%)	60	76	81
Cases with stronger-than threshold UHIs	79	61	44

Summary of summer urban-precip impacts

- All SW-flow cases together: urban-precip impacts were relatively small
- When cases are divided into weak- & strong-UHI cases: two strong conflicting-patterns emerged
  - Weak-UHIs: building-barrier induced storm-bifurcation, with (1) downwind lateral high-precip areas & (2) over-city & downwind rain-shadow min-precip areas
  - Strong-UHIs: UHI-induced convergence & a precip-max, both over the urban-center
- These conflicting effects:
  - first hypothesed by Bornstein & LeRoy (2000) and Bornstein (2011), but neither used UHI-magnitude to divide cases (they assumed results showed this)
  - This is first study to demonstrate this UHI-magnitude impact

中国气象局北京城市气象研究所
Institute of Urban Meteorology,CMA,Beijing

Observed Spatial Characteristics of Beijing Urban-Climate Impacts on Summer Thunderstorms

Jingjing Dou[1], Yingchun Wang[1,2], **Robert Bornstein[1,3]**, Shiguang Miao[1]

[1]Institute of Urban Meteorology (IUM), Meteorological Administration ,Beijing, China
[2]Beijing Meteorological Service (BMS), Beijing, China
[3]Dept. of Meteorology, San Jose State University, San Jose, California, USA

Thanks!! Questions?