耶鲁大学-南京信息工程大学大气环境中心

Yale-NUIST Center on Atmospheric Environment

Rainfall Modification by Major Urban Areas: Observations from Spaceborne Rain Radar on the TRMM Satellite

By J. MARSHALL SHEPHERD; HAROLD PIERCE; ANDREW J. NEGRI

Reporter: Guan Yujie

2016.3.18

Outline

1. Introduction
2. Research strategy
3. Data and methodology
4. Discussions and results
5. Conclusions

1. Introduction

There are results showed that the UHI enhances rainfall production over and downwind of the urban area. And, the model simulations suggested that stronger heat islands tended to produce more localized effects on rainfall and weaker heat islands affected rainfall at some distance downwind of the heat island.

Previous investigations that studied urban impacts on rainfall used primarily rain gauge networks, ground-based radar, or model simulations. Although useful, these studies were limited to specific cities with special observation networks or theoretical model simulations.

1. Introduction

Herein, a novel approach is introduced to correlate urbanization and rainfall modification. Satellite-based analysis of rainfall modification near urban areas is demonstrated as a viable approach to assessing this problem.

2. Research strategy

To investigate the capabilities of satellite-based measurements for identifying urban effects on rainfall, a working hypothesis was established.

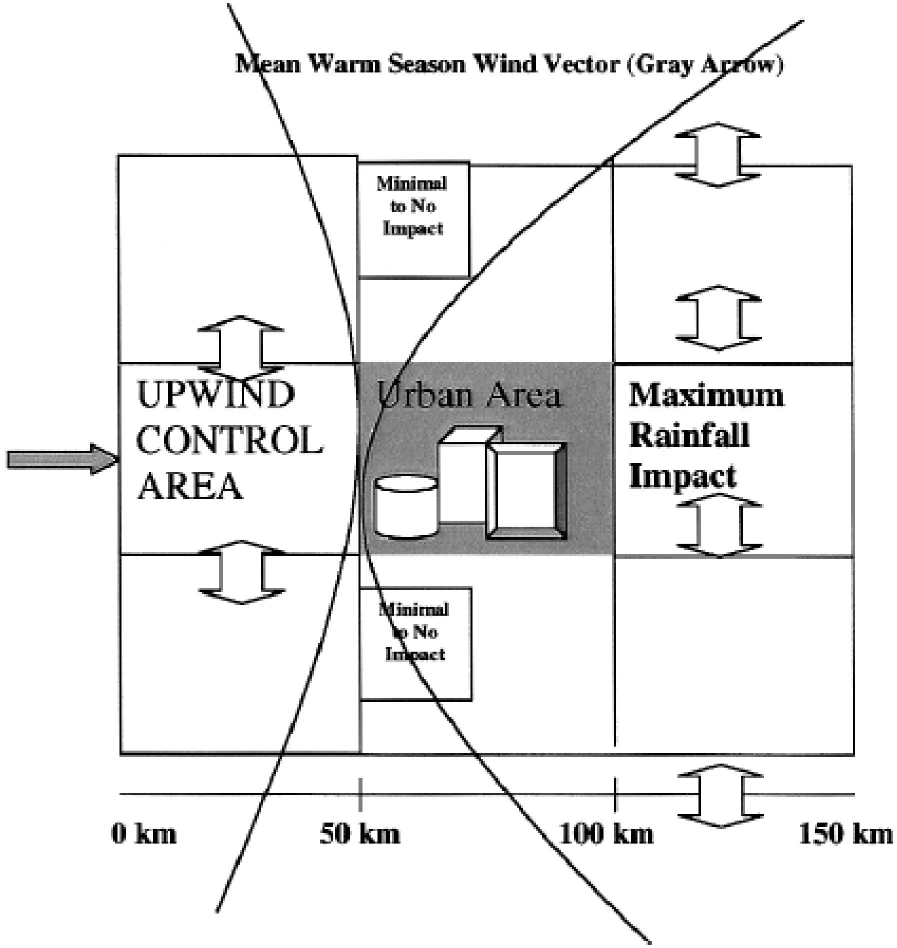

FIG. 1. Theoretical coordinate system used to define upwind control, urban, and maximum UHI-rainfall impact area. Gray arrow depicts the mean prevailing wind and defines the reference axis for the coordinate system.

2. Research strategy

TABLE 1. Mean 700-hPa wind direction (May–Sep) based on NCEP–NCAR reanalysis geopotential height climatic dataset from 1979 to 1998. Mean altitude above sea level (m) of city is also given.

City	Mean 700-hPa wind direction (°; May–Sep)	Mean alt (m) above sea level
Atlanta	273	~320
Montgomery	266	~190
Dallas	225	~140–230
Waco	210	~120–150
San Antonio	198	~100–150

2. Research strategy

An analysis of a parameter called the urban rainfall ratio (URR) was conducted, with

$$\text{URR} = R_i / R_{BG},$$

where R_i represents a given mean rainfall rate at a grid point and R_{BG} is the mean background value.

The URR is a measure of the relative magnitude of a given point to a background value, and values greater (less) than 1.0 are considered to be positive (negative) anomalies.

3. Data and methodology

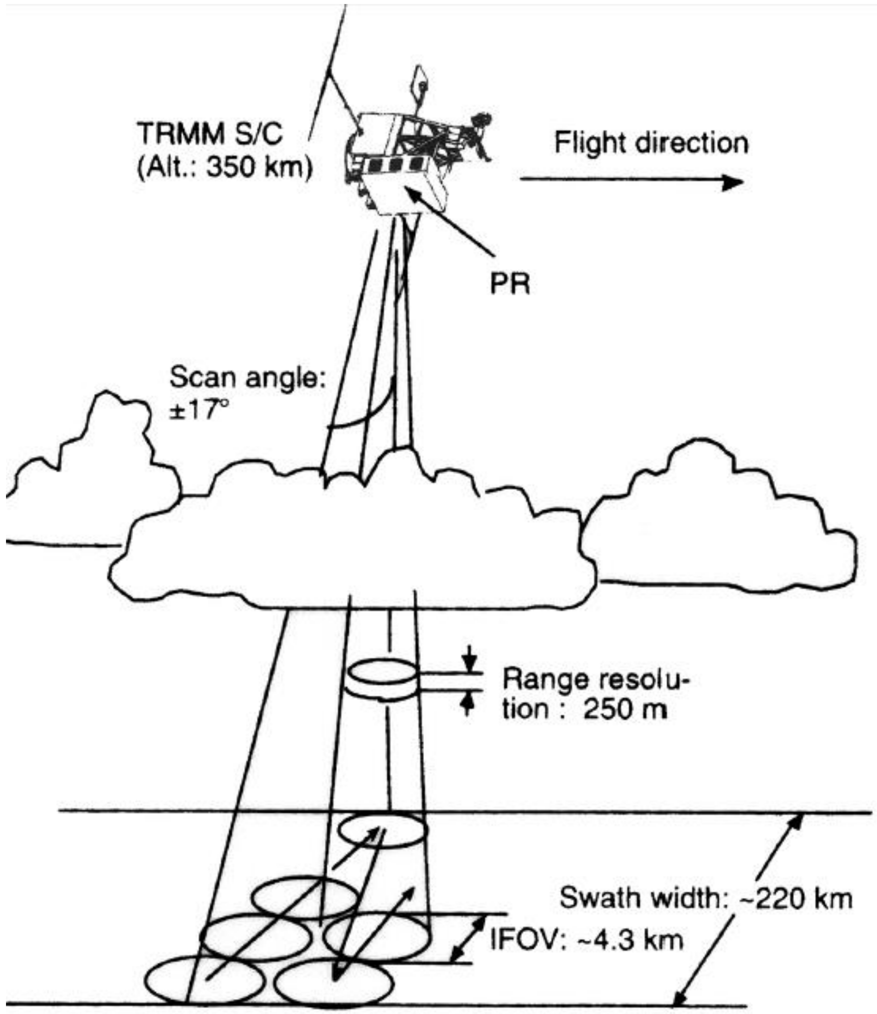

FIG. 2. Schematic of TRMM platform scan strategy (following National Space Development Agency of Japan and National Aeronautics and Space Administration 2000).

3. Data and methodology

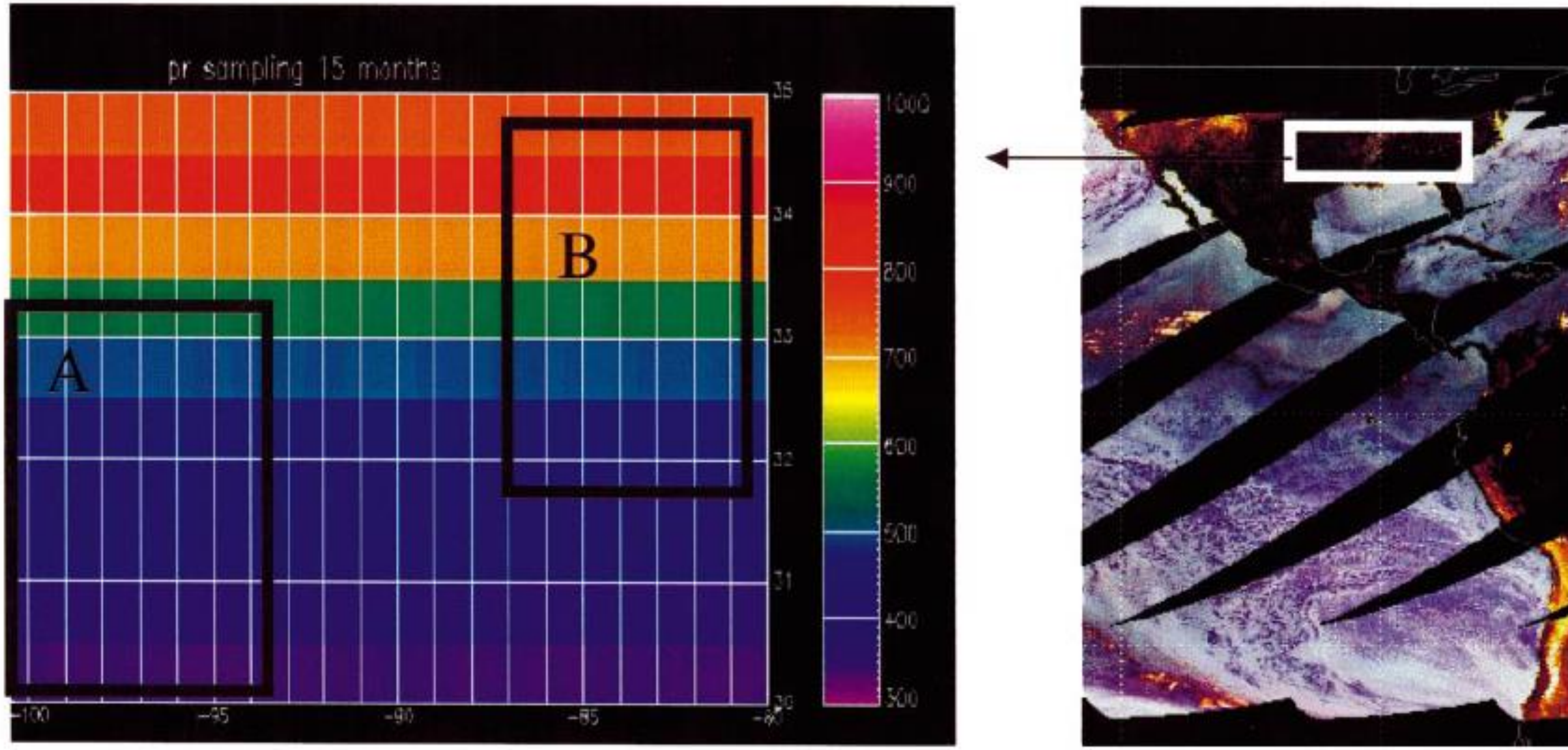

FIG. 3. A diagram illustrating the number of rainfall estimates in 0.5° -resolution cells as a function of latitude and longitude for region A (Texas region) and region B (southeastern United States) for a 15-month sample period. Sample density decreases as latitude approaches the equator.

3. Data and methodology

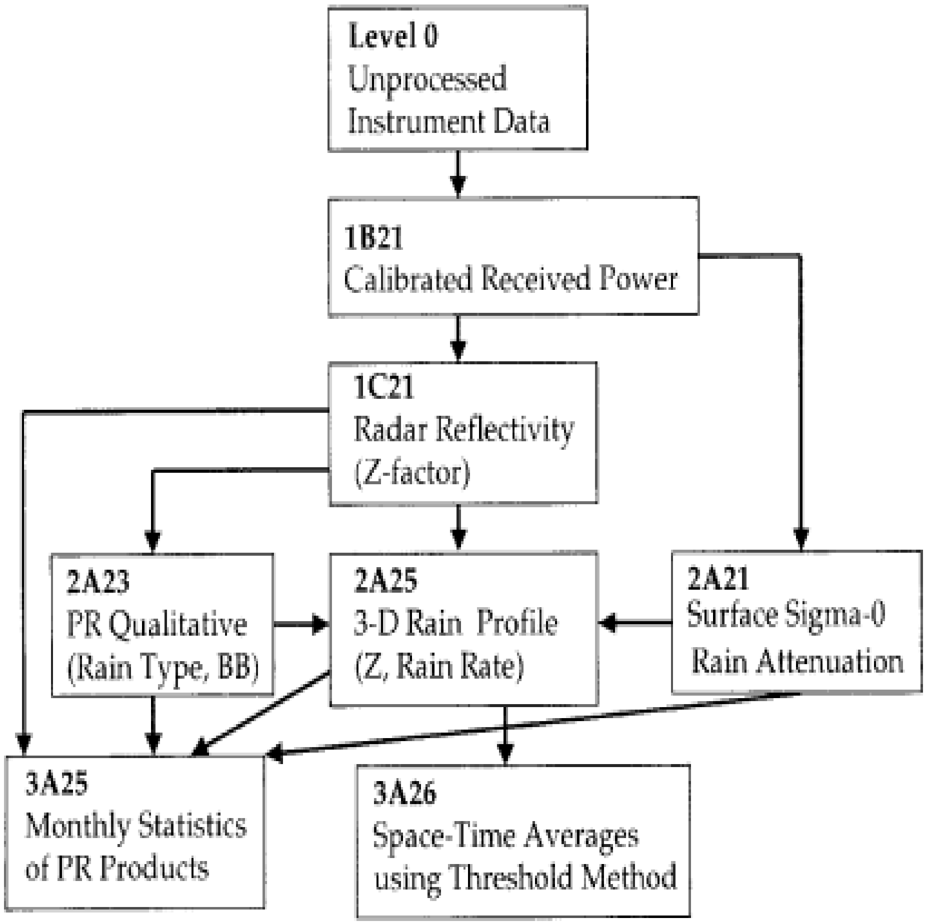

FIG. 4. TRMM algorithm flow chart

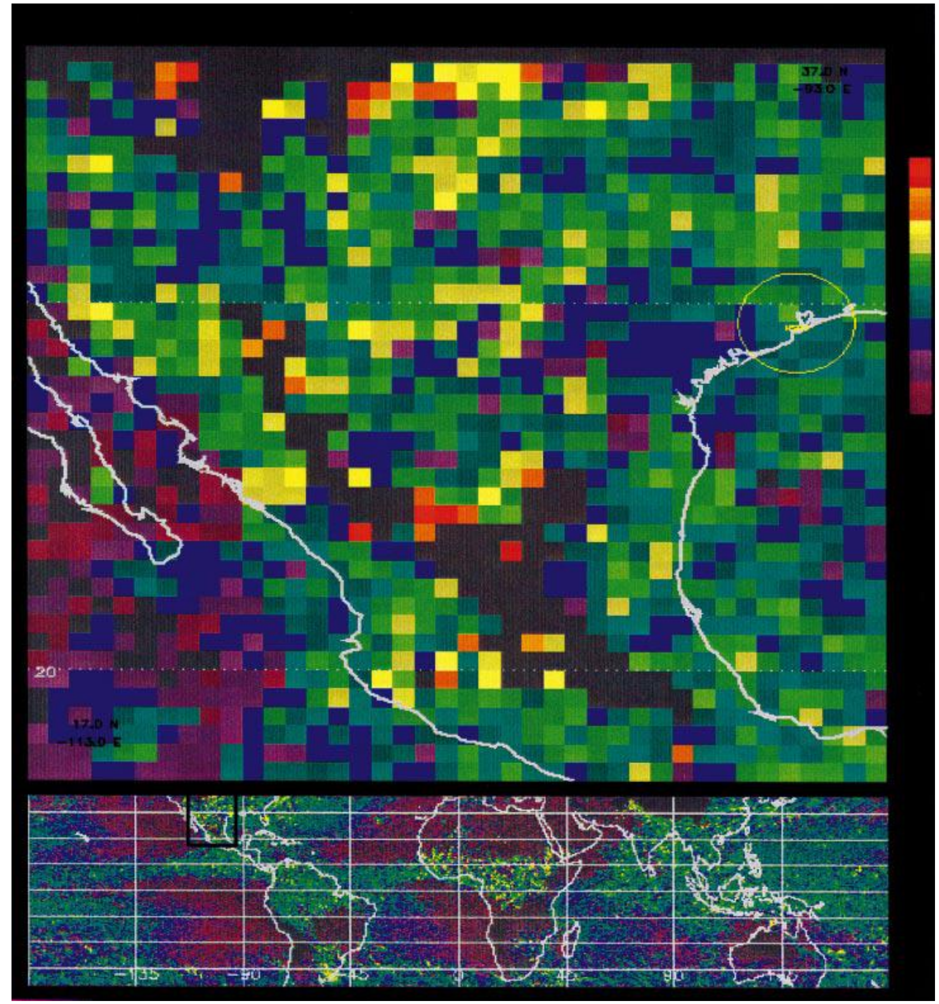

FIG. 5. Mean rainfall rates at a height of 2.0 km.

4. Discussions and results

(1) Region B (southeastern United States cities)

a b

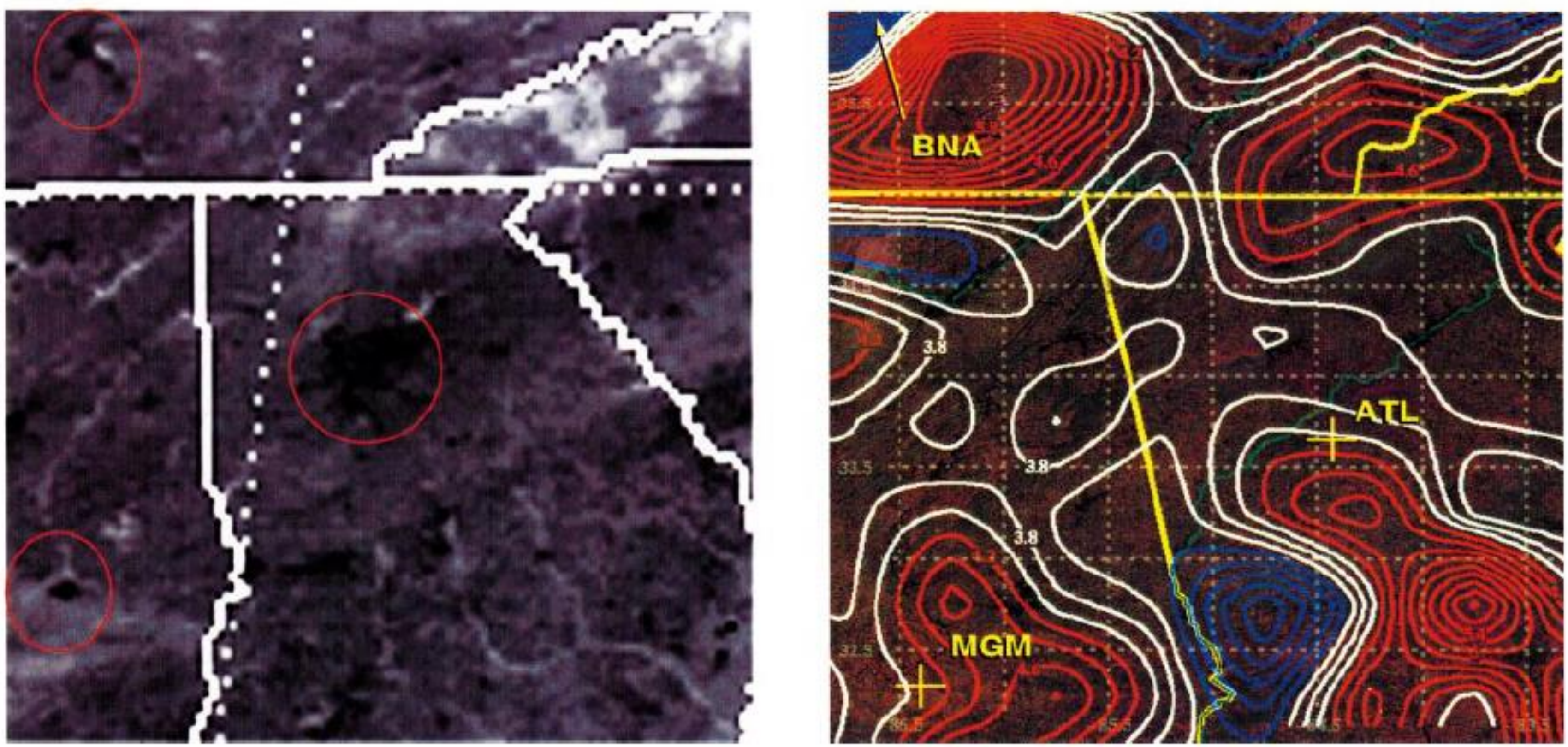

FIG.6 . (a) A GOES IR 3.9-μm image of the Southeast. Urban heat islands for Nashville, Montgomery, and Atlanta are indicated as dark warm regions in the circles. (b) A contour plot of the 15-month, warm-season mean rainfall rates at a height of 2.0 km using 0.5° -resolution TRMM PR data. Values in red are greater than or equal to 4.2 mm/h. Values in blue are less than or equal to 3.6 mm/h.

11

4. Discussions and results

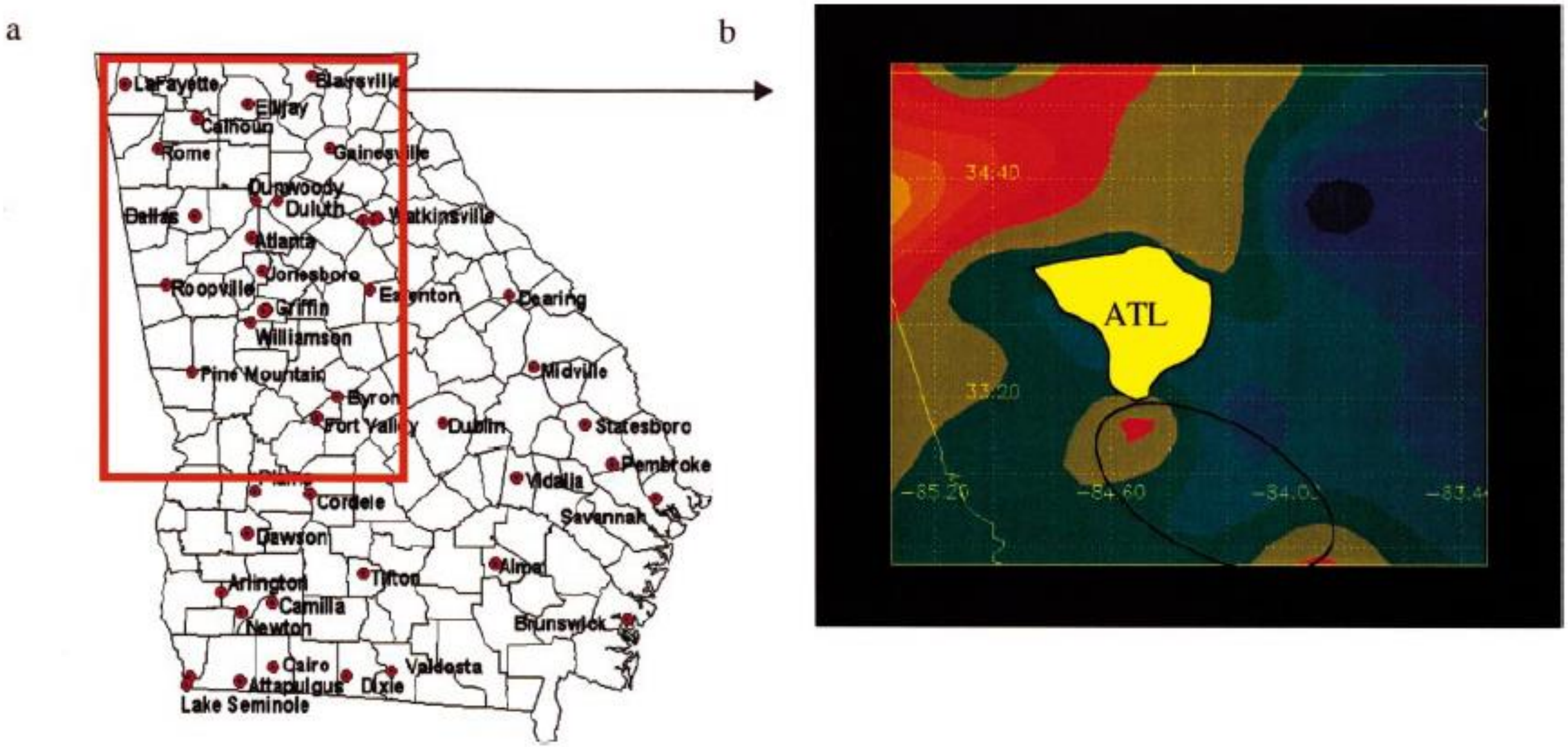

FIG. 7. (a) The Georgia AEMN network of rain gauge stations. The red box represents the inset in (b). (b) An analysis of the mean rainfall amount from May to Sep (1998–2000). The redder colors are values greater than 3.0 in. (maximum value: 3.71), and bluer colors are values less than 3.0 in. (minimum value: 2.41). The values in the black oval represent possible rainfall anomalies identified by TRMM in Fig. 6b (although these values are mean total amounts, not rainfall rate).

4. Discussions and results

(2) Region A (Texas cities)

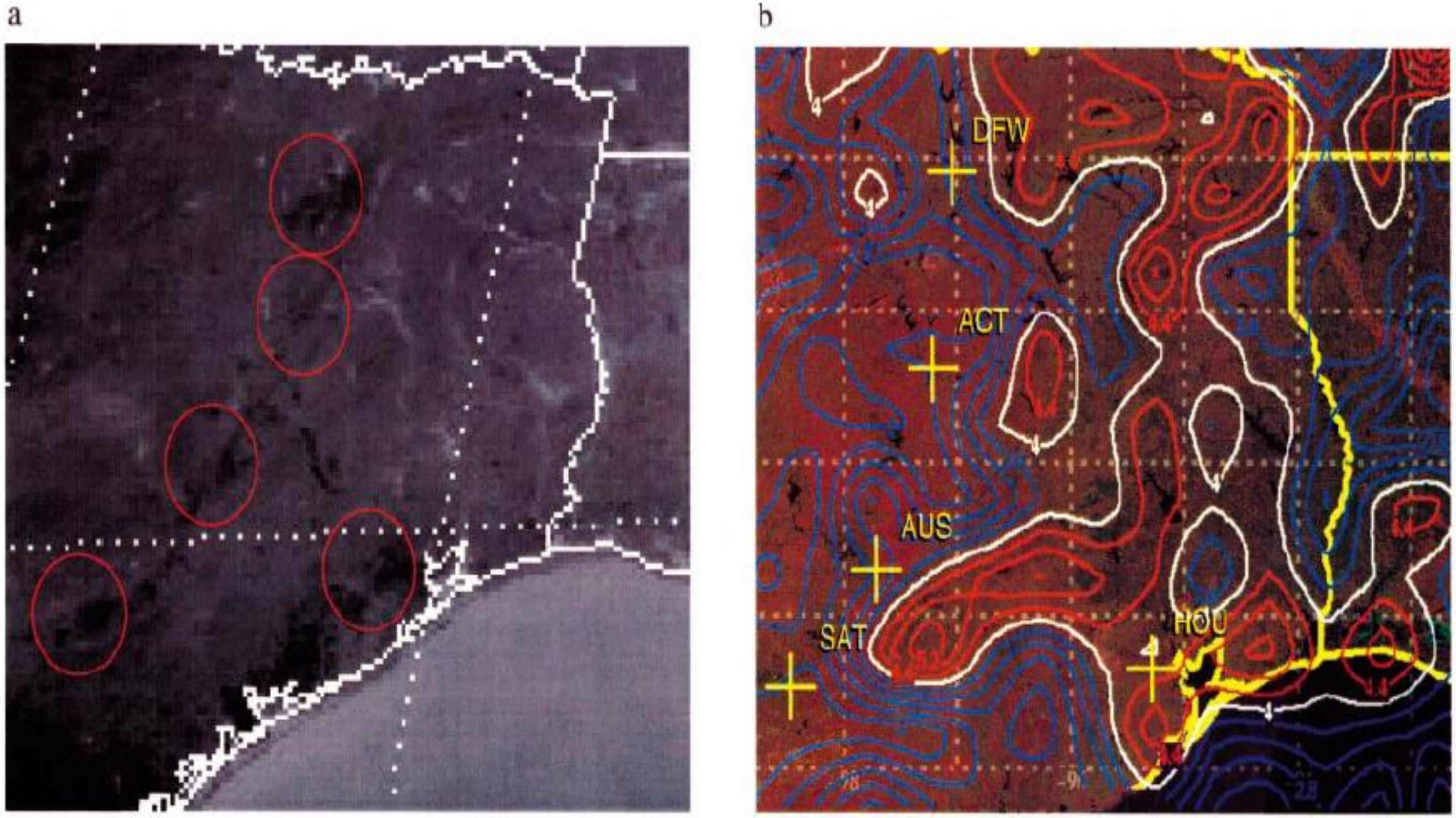

FIG. 8. (a) A GOES IR 3.9-μm image of Texas. Urban heat islands for Dallas, Waco, Austin, San Antonio, and Houston are indicated as warm, dark regions in the circles. (b) A contour plot of the 15-month, warm-season analysis of mean rainfall rates at a height of 2.0 km using the 0.5° -resolution TRMM PR data. Values in red are greater than or equal to 4.2mm/h. Values in blue are less than or equal to 3.6 mm/h.

4. Discussions and results

(3) General summary of results

TABLE 2. Mean rain rates (mm/h) from TRMM precipitation radar data (2.0-km height). The data are averaged over specified upwind, downwind, and urban area for the warm season (May–Sep) for 1998–2000. The percentage change from the upwind control area is given for the maximum impact and urban center areas.

City	Mean rain rate in MIA (mm h^{-1})	Mean rain rate in UCA (mm h^{-1})	Mean rain rate over urban center (mm h^{-1})	Percentage change in MIA from UCA (%)	Percentage change in urban center area from UCA (%)
Atlanta	4.23	3.54	3.81	19.5	7.8
Montgomery	4.39	3.83	4.39	14.6	9.9
Dallas	4.00	3.03	3.78	32.0	24.7
Waco	3.33	2.17	2.49	51.1	14.7
San Antonio	3.29	2.63	1.90	25.0	−27.7

Mean percentage change in maximum impact area=28.4%.
Mean percentage change in urban center=5.8%.

4. Discussions and results

To evaluate the significance of the differences in warm-season rainfall rates between the upwind control area and hypothesized effect areas, statistical *t* tests were applied. It is customary to establish that if this probability is less than 0.05, the difference is significant and not caused by chance.

a. major impact area versus upwind control, probability=0.034;

b. urban area versus upwind control, probability=0.805.

These findings suggest that differences between the MIA and the upwind control area are significant and likely is not due to random chance.

4. Discussions and results

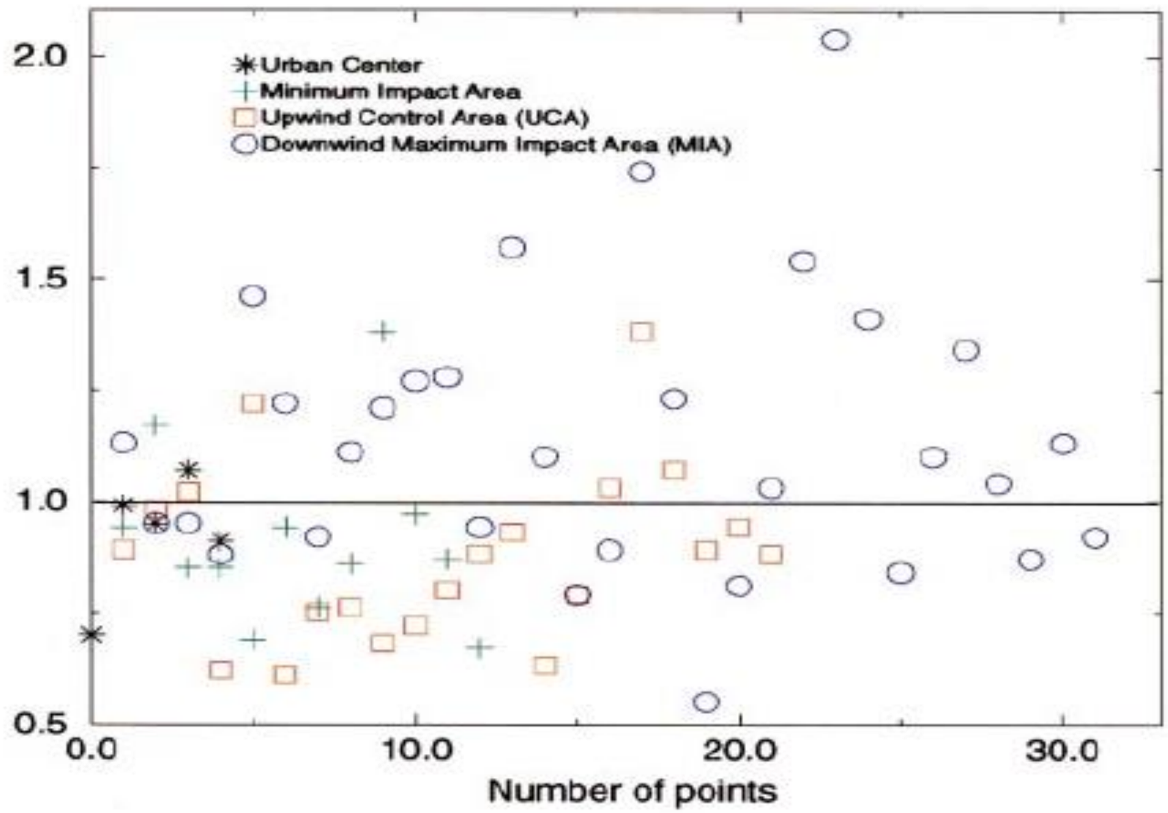

FIG. 9. URRs for the control coordinate system for five cities in the study. Blue circles are URR values in the downwind MIA. Red squares are URR values in the UCA. Green plus marks are URR values in minimum impact areas. Black asterisks are URR values over the urban area (see Fig. 1).

4. Discussions and results

TABLE 3. Maximum 3-yr warm-season rain rate (mm/h) found in the maximum impact area. The table provides information on the distance from the urban center to the value in column 1.

City	Max rain-rate value in MIA ($mm\ h^{-1}$)	Percentage change in max value in MIA from UCA (%)	Distance downwind of max rain-rate value from urban center area (km)
Atlanta	5.86	65.0	~60
Montgomery	5.69	48.5	~25
Dallas	4.52	49.1	~20
Waco	4.74	116.0	~50
San Antonio	5.45	107.0	~40

Maximum rain-rate value is found in the maximum impact area at a mean distance of 39 km from the edge of the urban center (or 64 km from the exact center).

5. Summary and conclusions

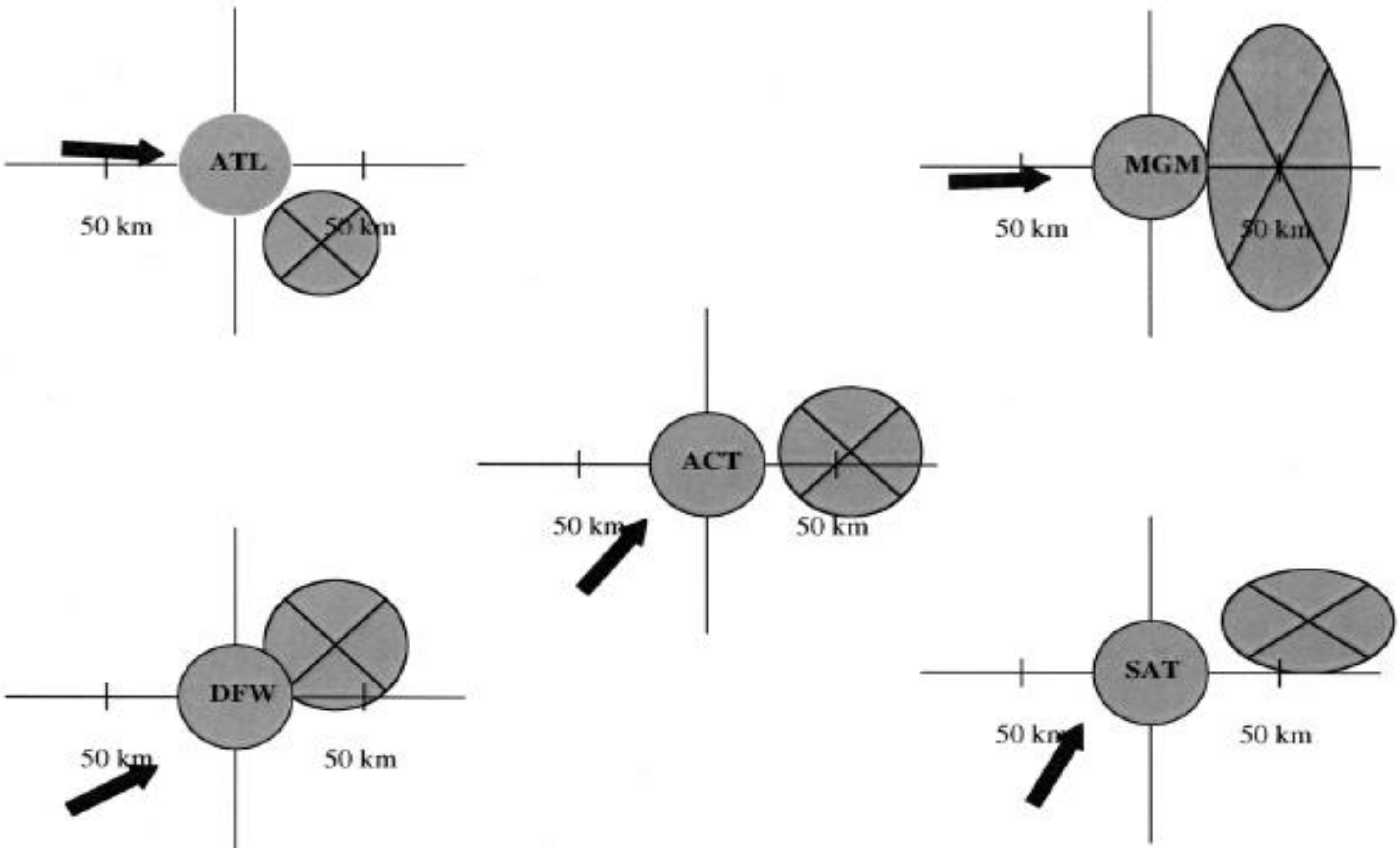

FIG. 10. Summary of the downwind locations for the cities experiencing the most significant urban-impacted rainfall (shaded cross region) in the warm-season months. The arrows represent the mean prevailing wind direction at 700 hPa as determined by the NCEP–NCAR reanalysis climatic dataset.

5. Summary and conclusions

- The study establishes that a 3-yr, warm-season analysis of mean rainfall rates from the TRMM PR could be used to identify urban-induced rainfall anomalies.
- The study demonstrated the potential capability to study urban rainfall modification on a global scale and over longer time periods.
- Such research has implications for weather forecasting, urban planning, water resource management.

Thanks