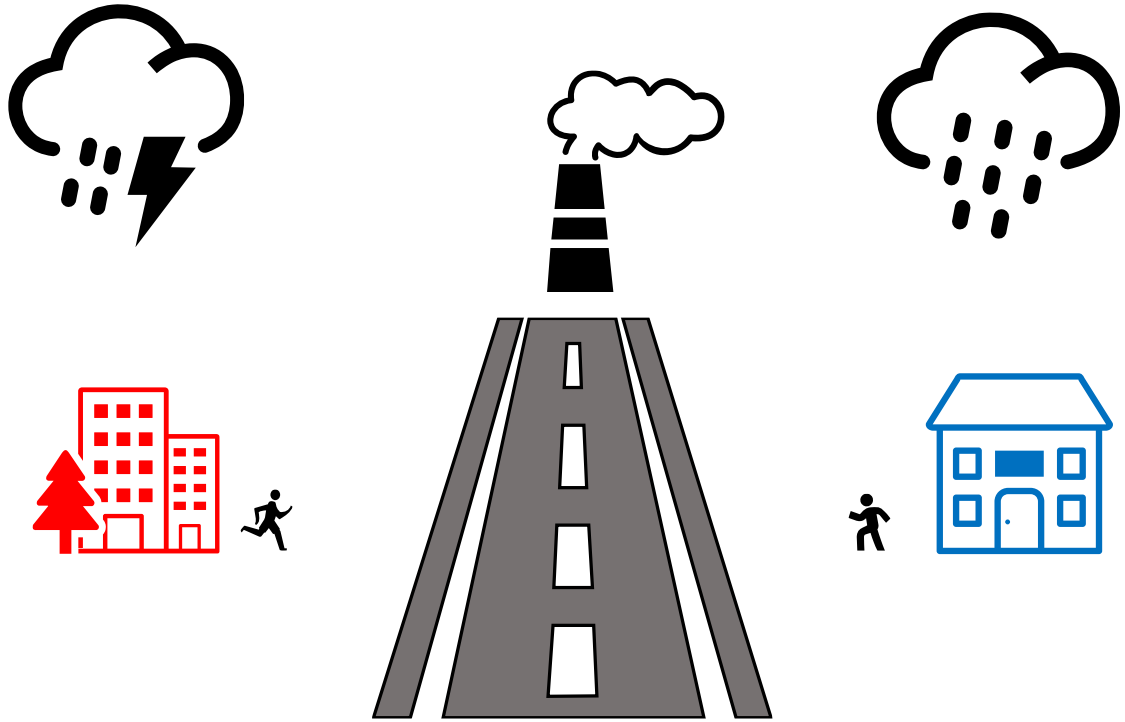
The Impact of Urban Land Use On the Springtime Frontal Precipitation Event in Ankara: A Case Study of 5 May 2014

Berkay Dönmez, Kutay Dönmez, Deniz Diren-Üstün, and Yurdanur Ünal

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Start Abstract

The Impact of Urban Land Use On the Springtime Frontal Precipitation Event in Ankara: A Case Study of 5 May 2014

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Abstract

Studies concerning the effects of urbanization on heavy precipitation events mostly focused on the summertime convective precipitation events. In these studies, the Urban Heat Island (UHI) effect was prominent over the urbanized region before the event, changing the spatial and temporal distribution of the precipitation. We aim to reveal the impact of urbanization over Ankara on the springtime frontal precipitation event of 5 May 2014, when the ground heating and UHI effects are not as strong as those in the summertime.

We performed two different simulations based on the land-use scenarios with urban (URBAN) and without urban areas (NOURBAN) over Ankara, integrating the CORINE Land Use dataset into the Weather Research and Forecasting Model (WRF v3.8) and replacing the urban areas with the dominant land use category over the region. Four sub-regions with the identical area coverages corresponding to the upwind, central, and downwind parts of the city center are defined to have a lucid spatial and temporal representation of the event. The two simulation results agreed reasonably with the observations.

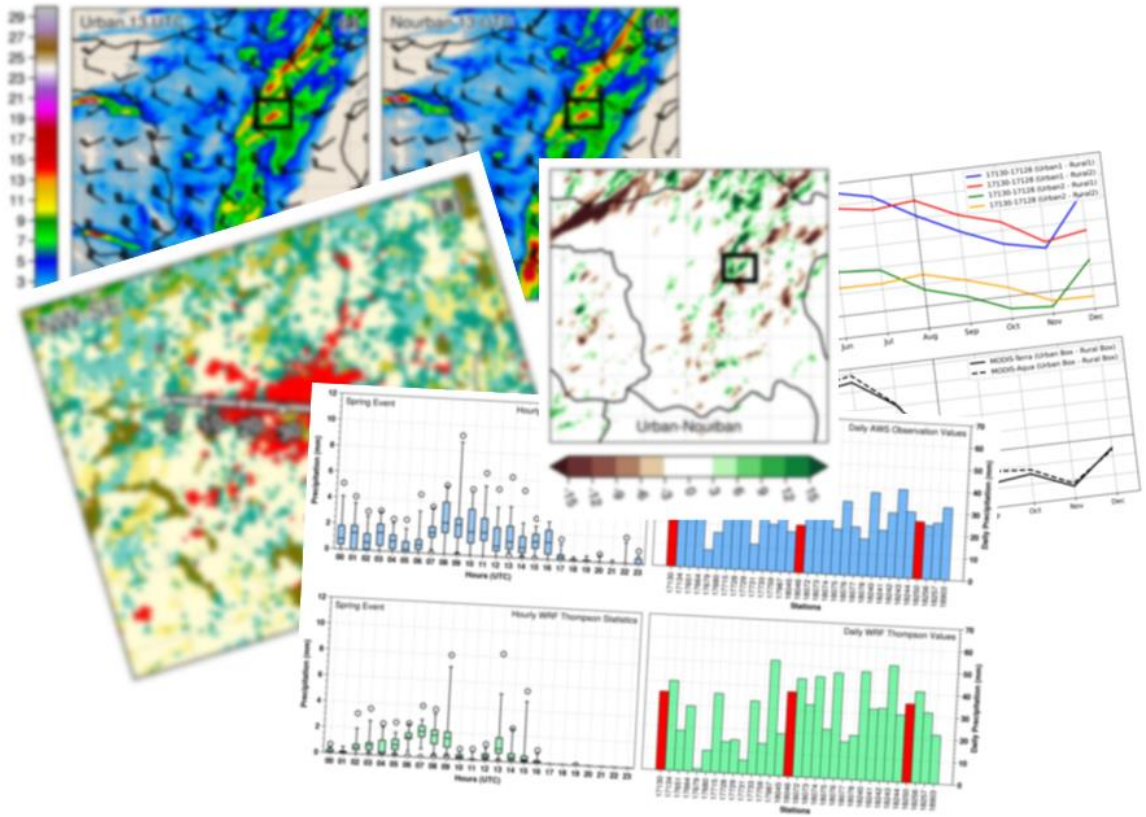
In the simulation (URBAN) with the urban land use included, the spatial average of the daily rainfall amounts over the predefined sub-regions slightly decreased, especially the sub-regions to the upwind and downwind of the highly urbanized area. However, the difference in precipitation amount in the vicinity of the urbanized area between the two different simulations is not of significance in comparison to what was observed in other summertime precipitation studies. On the other hand, the UHI effect might be crucial in determining the impact of urban land use on the distribution and magnitude of the heavy springtime rainfall. To support this idea, we performed a similar analysis for a summertime convective precipitation event over Ankara and compared the results.

How to cite: Dönmez, B., Dönmez, K., Diren-Üstün, D., and Ünal, Y.: The Impact of Urban Land Use On the Springtime Frontal Precipitation Event in Ankara: A Case Study of 5 May 2014, EGU General Assembly 2021, online, 19–30 Apr 2021, EGU21-3056, https://doi.org/10.5194/egusphere-egu21-3056, 2021.

Continue

Content

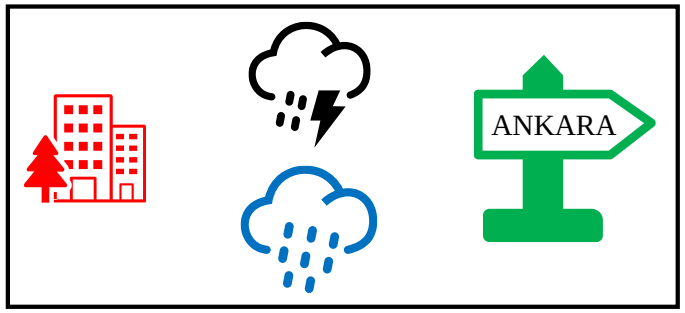
- Motivation
- Approach
- Case Selection
- Case Overview
- Validation
- Results
- Conclusion



Research Motivation

KEY QUESTION

How does **urbanization** impact the precipitation of **different characteristics** in **Ankara**?



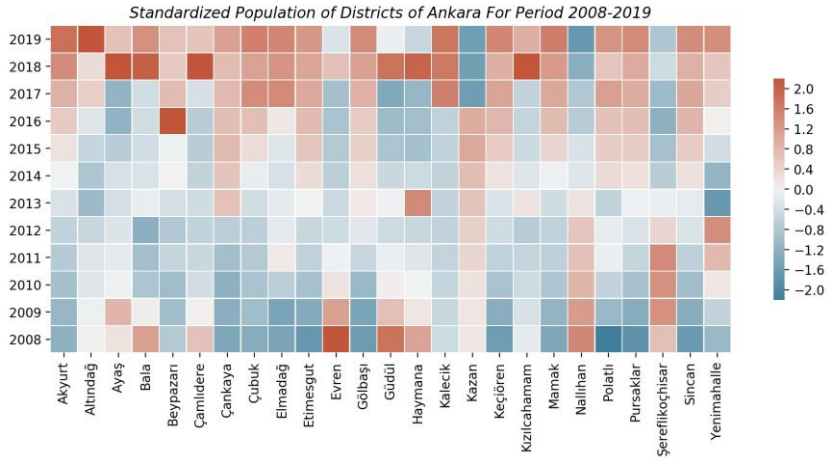
KEY TRIGGER

Do the urbanization effects in Ankara agree with the literature?

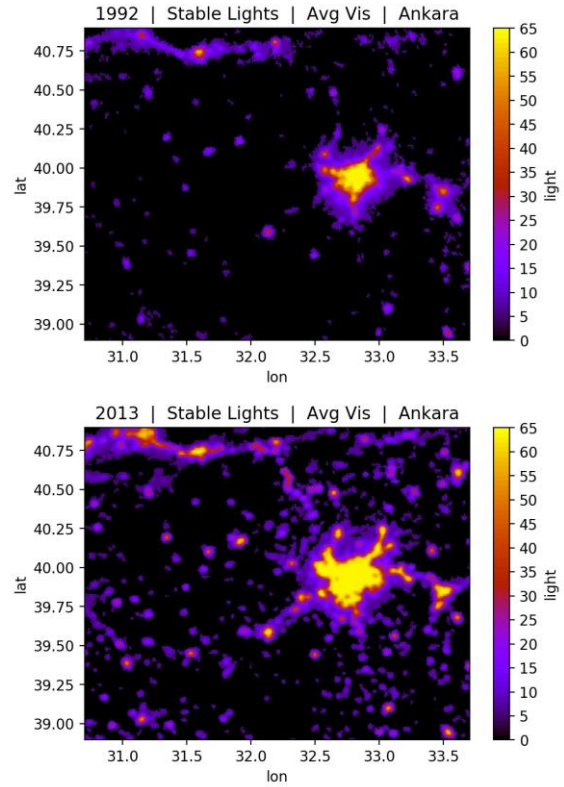
What are the similarities and differences between the current research and the literature in terms of how urbanization affects precipitation distribution?

WHY ANKARA?

1. The **second** most populated city in Turkey.
2. The **urbanization** has been steadily increasing over the years.



Data: TUIK

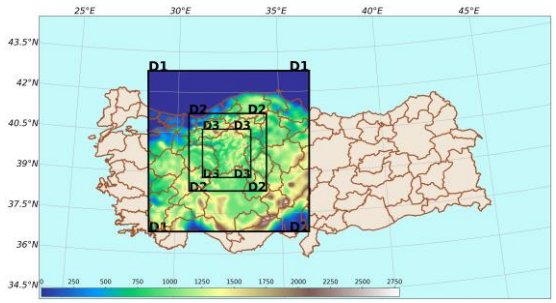


Data: DMSP-OLS Night-time Lights

Research Approach

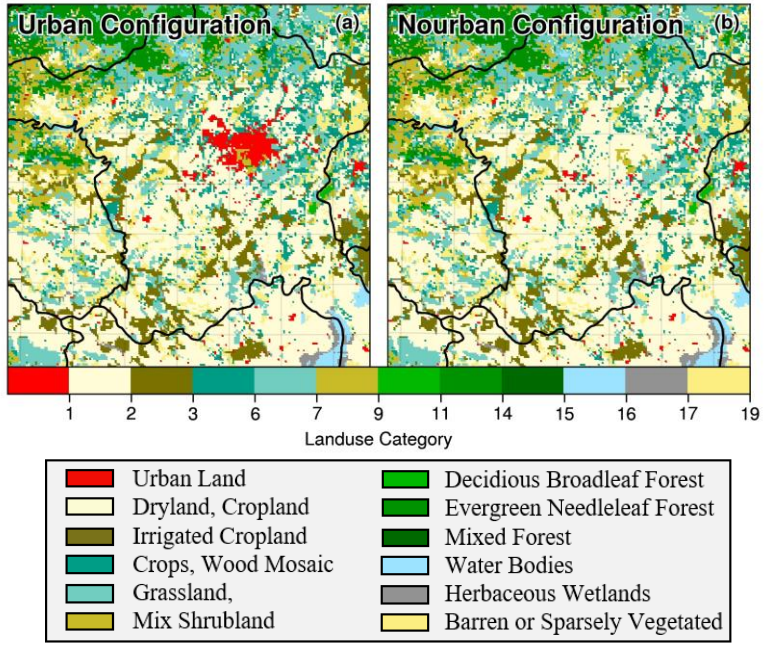
What is our strategy?

- WRF model simulation-based analysis with three different parameterization configurations for **two** precipitation cases with different characteristics.
- Analyzing the effect of urbanization on these unique precipitation events both from quantitative and physical perspectives.



What do we do?

- Model simulations with **Urban** and **Nourban** configurations.
- Using CORINE Land Use data instead of the standard USGS Land Use data.
- Comparing Urban and Nourban results with each other for both precipitation cases.



What data do we use?

- Multiple **observational** data sources:

METEOROLOJİ

→ **Automatic Weather Station (AWS) temperature and precipitation observations**

NASA

→ **GPM Imerg Final data (cite)**
→ **Modis Aqua-Terra temperature data**

ECMWF

→ **ERA5 Reanalysis data**

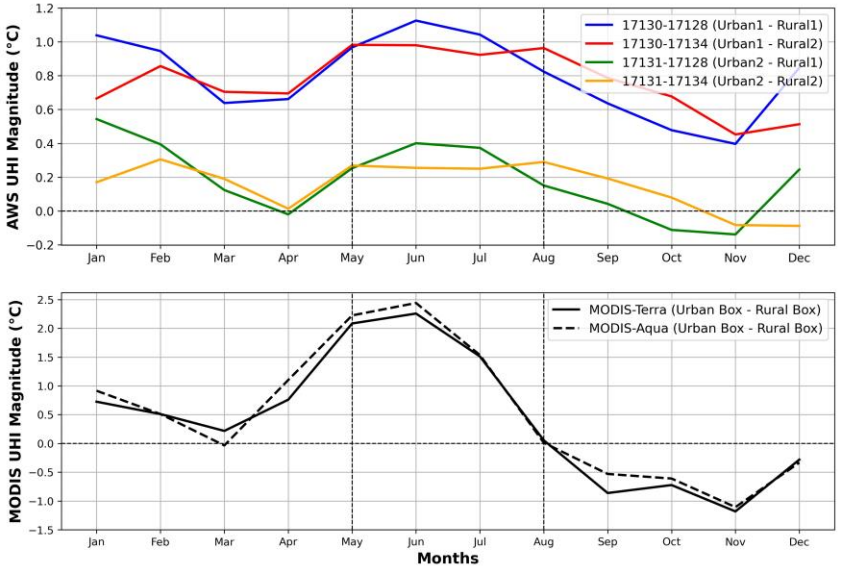
Case Selection

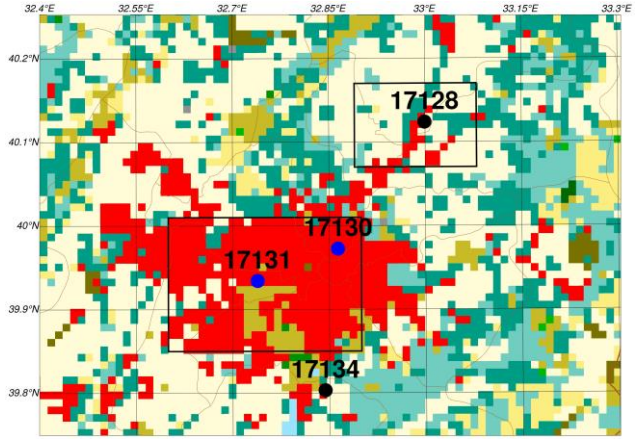
Key Notes

- **Precipitation** characteristics and **Urban Heat Island** (UHI) intensities may differ from season to season.
- Selecting **two** unique precipitation events considering **longer-term** characteristics of UHI.

How do we select?

- Finding **monthly UHI** between 2009-2018 in Ankara using:
  - → AWS data for two urban and two rural stations.
  - → MODIS Aqua and Terra temperature data spatially averaged for one urban and one rural box..
- Extracting **daily maximum** urban temperature values from the rural temperature values.





Blue Dots: Urban Station | Black Dots: Rural Station

Key Findings

- Both datasets exhibit a **similar** pattern both temporally and in magnitude.
- The seasonal variability of **UHI** is remarkable.
- Prominent among other months are **May** and **August**, whose heat island intensities are similar in the AWS data but diverging in the MODIS data.

What is our selection?

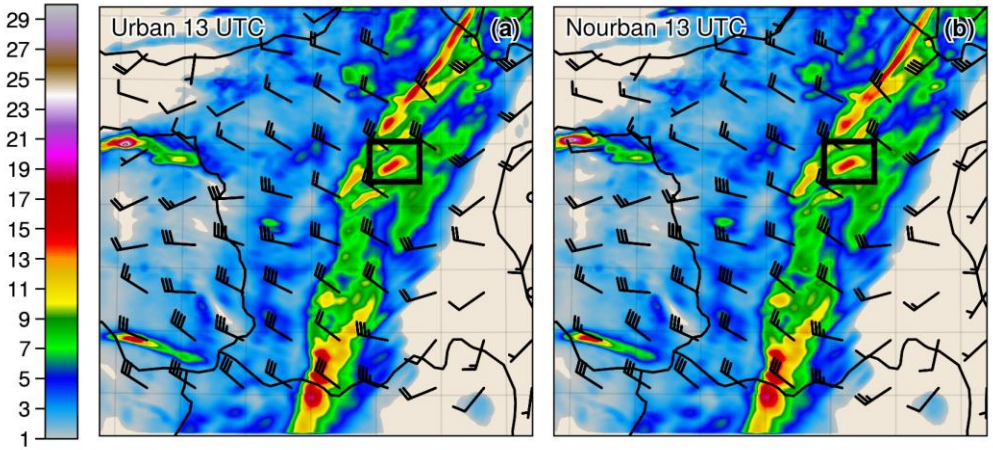
- Selecting the events from **May** and **August** for simulation since:
  - → They pose contrastive features in terms of **UHI magnitudes**.
  - → They represent the **wettest** and **driest** months, respectively, in Ankara (MGM, n.d.).

5 May 2014 — Spring Event

28 August 2016 — Summer Event

Case Overview

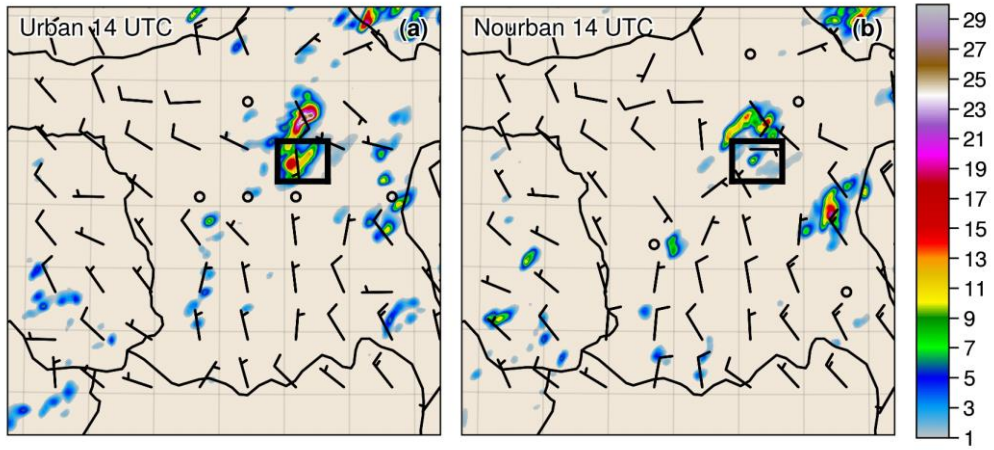
5 May 2014



Key Information

- Graphics for the **hour** at which the precipitation (mm) reached its **maximum** values
- Model results from the **Thompson** scheme for the case-demonstration purpose

28 August 2016



Key Points

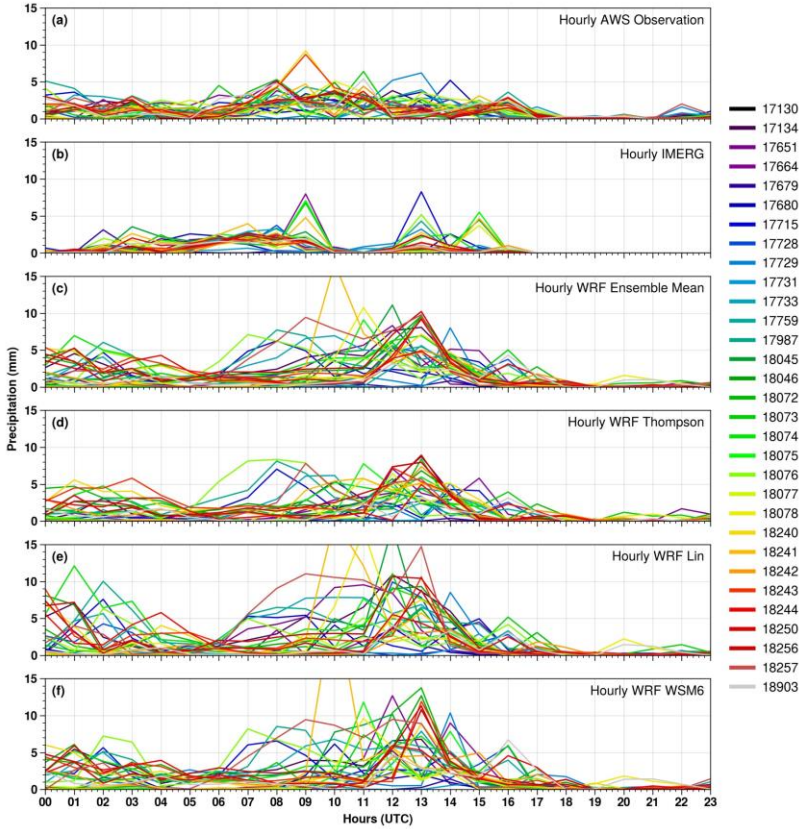
- A **springtime** heavy (relatively) precipitation event.
- The maximum precipitation is at 13 UTC.
- Characterized with a strong synoptic background (**Cold Front**).
- Encompassing a large swath across Ankara, especially to the NE-SW direction.
- Affecting highly urbanized portions (**Black Box in the middle**) of Ankara.

Key Points

- A **summertime** heavy (relatively) precipitation event.
- The maximum precipitation is at 14 UTC.
- Characterized with local and convective precipitation.
- Encompassing a smaller area compared to the spring-time event.
- Affecting highly urbanized portions (**Black Box in the middle**) of Ankara.

Validation

5 May 2014



The observations and model results for the hourly precipitation on the **spring-event** day at each automatic weather station in Ankara.

Colors represent the station numbers

Key Question

- Which **parameterization scheme** better simulated the results and will be used in the urban-impact analysis?

Runs	Spring Event				Summer Event			
	Precipitation (mm)		Temperature (°C)		Precipitation (mm)		Temperature (°C)	
	MAE	RMSE	MAE	RMSE	MAE	RMSE	MAE	RMSE
Lin	1.56	2.55	1.30	1.60	0.25	0.87	1.71	2.12
Thompson	**1.18**	1.82	2.11	2.36	**0.22**	**0.73**	**1.66**	**2.05**
WSM6	1.42	2.37	1.56	1.85	0.24	0.82	1.71	2.12

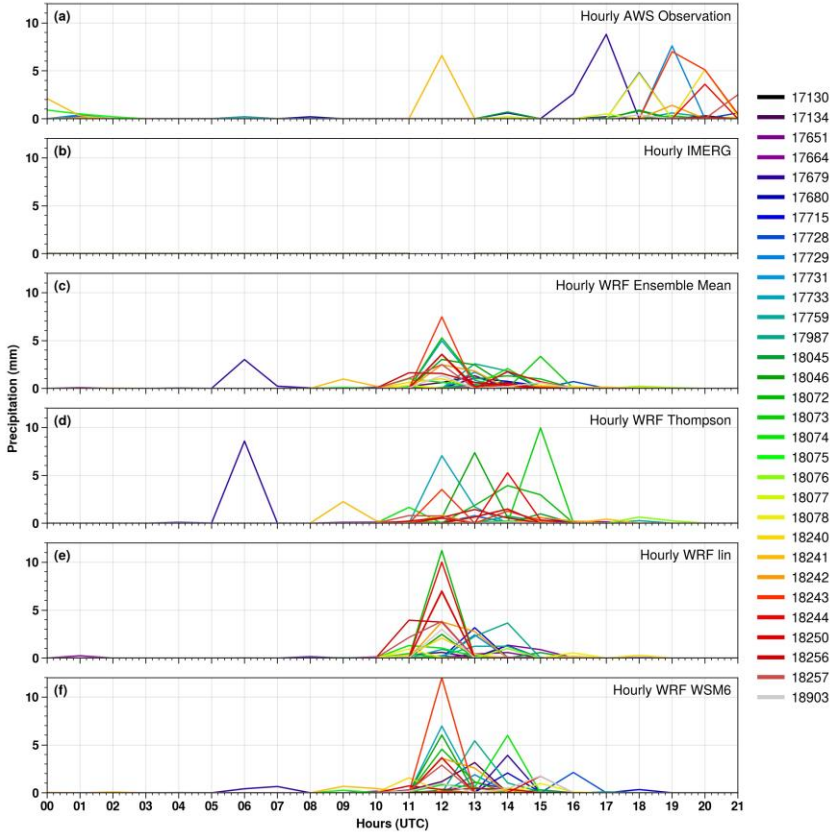
MAEs and RMSEs for the model results on the event days

Key Findings

- Model results are consistent with the observations.
- Model forecasted precipitation **earlier** than observations for the 28 August 2016 event.
- **IMERG** observation was not able to capture the event of 28 August.
- Model results with **Lin** and **WSM6** schemes exaggerated the maximum precipitation.
- **Thompson** scheme better forecasted both events.

We use **Thompson** scheme in the analysis

28 August 2016



The observations and model results for the hourly precipitation on the **summer-event** day at each automatic weather station in Ankara.

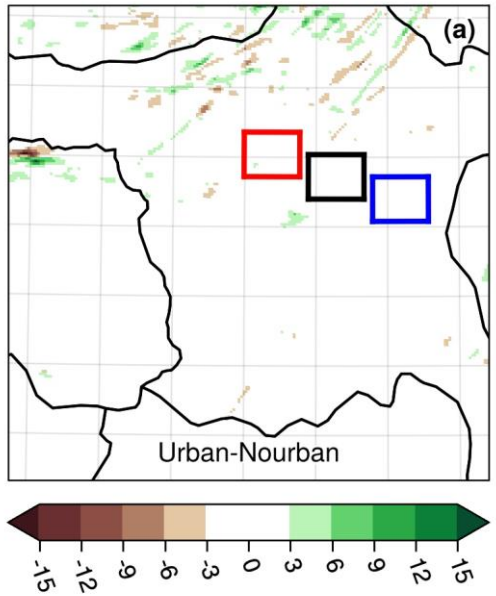
Colors represent the station numbers

Results

Part I

Go To Part II

5 May 2014



Key Information

- Differences in the daily total precipitation (mm) between **Urban** and **Nourban** configurations for **springtime** and **summertime** events.

Box-Sum Difference
(Urban-Nourban Runs)

Boxes	Spring Event		Summer Event	
	mm	%	mm	%
Upwind	-45	-0.3	55	3.4
Center	31	0.2	**1178**	**42.8**
Downwind	-103	-0.5	-130	-4.9

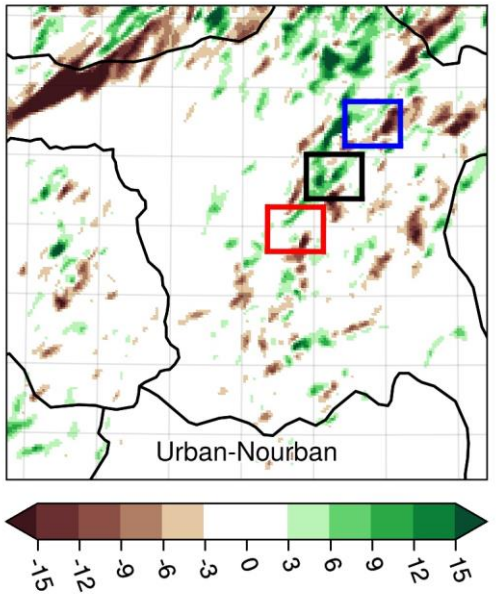
Key Findings

- No significant precipitation difference between **Urban** and **Nourban** configurations.
- In contrast to **Yang et al. (2014),** urbanization did not influence the spatial and temporal pattern of this spring **frontal precipitation** event, which was induced by a robust synoptic background.

Key Citations

- Extreme precipitation events with strong UHI present in the urbanized area intensifies the precipitation regardless of the synoptic background and seasons (**Wu et al., 2019**).
- Urbanization is capable of affecting the local heavy precipitation distribution for events that have a robust synoptic background (**Yang et al., 2014**).
- Urbanization, located along the coastal regions, weakens the extreme precipitation (EP), while urbanization, located in inland regions, intensifies the EPs (**Lin et al., 2020**).
- Urbanization supports an increase in local precipitation (**Su et al., 2021**).

28 August 2016



Key Findings

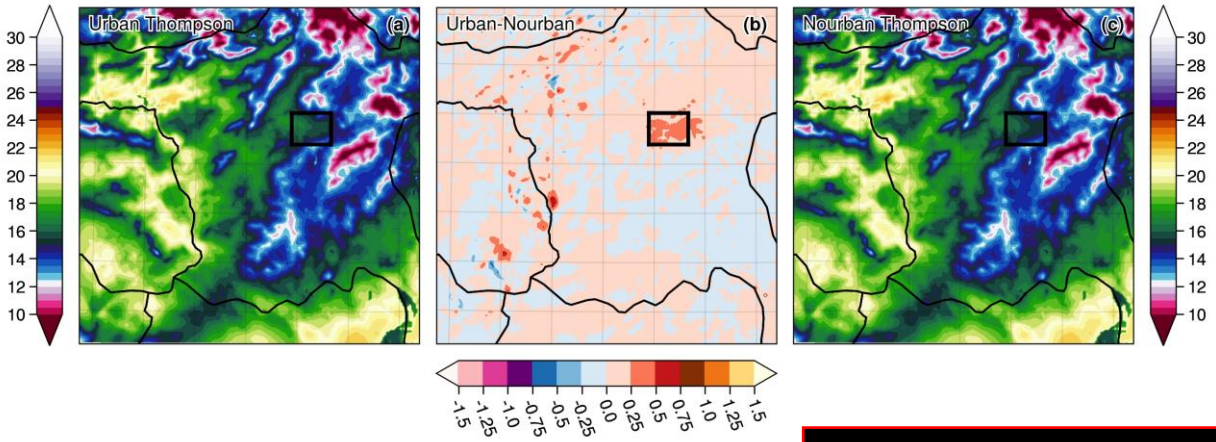
- Precipitation changes are prominent between **Urban** and **Nourban** configurations.
- In accord with **Su et al. (2021) and Lin et al. (2020),** urbanization induced a change, especially in the urban center (42.8%), in this **local and convective precipitation** event.

Return To Part I

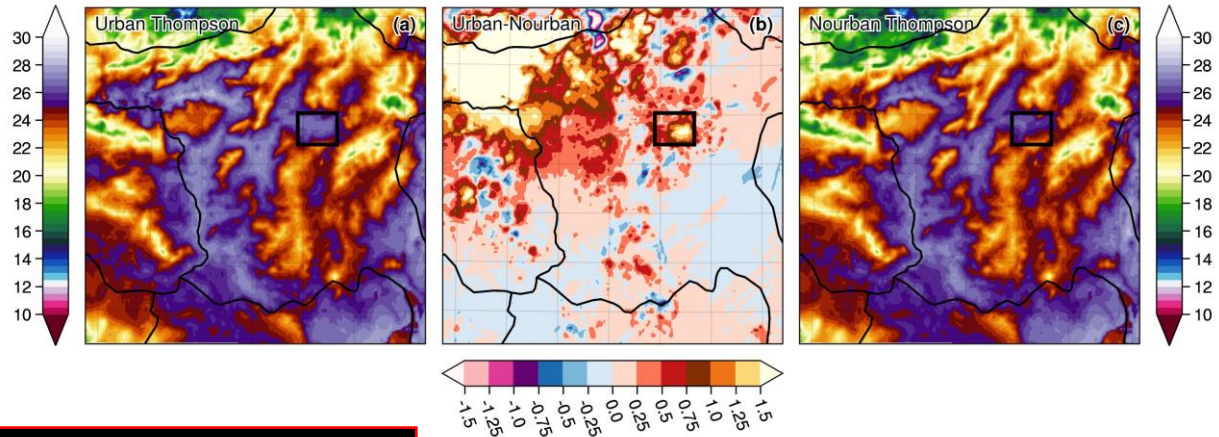
Results Part II

Go To Part III

5 May 2014



28 August 2016



Key Information

- Differences in the temperatures (°C), averaged over the four hour before the strongest rainfall, between **Urban** and **Nourban** configurations for **springtime** and **summertime** events.

Key Findings

- Temperature increase, characterized with the UHI, is prominent in the Urban configuration before the hour of the heaviest rainfall.
- Interestingly, the temperature increase in the urban configuration for the **spring event** was not strong enough to influence the precipitation pattern (see the previous slide).
- **Strong synoptic** characteristics of the **spring event** masked the effect imposed by the temperature increase over the urbanized area.

Key Citations

- Temperature extremes are more likely to be observed over urban canyons since the urbanized areas absorb larger radiative energy and are characterized by a decrease in cloud cover and soil dryness (**Lin et al., 2020**).
- There is observed warming over a particular region when its land cover is converted from Cropland to Urban Land (**Sertel et al., 2009**).

Key Findings

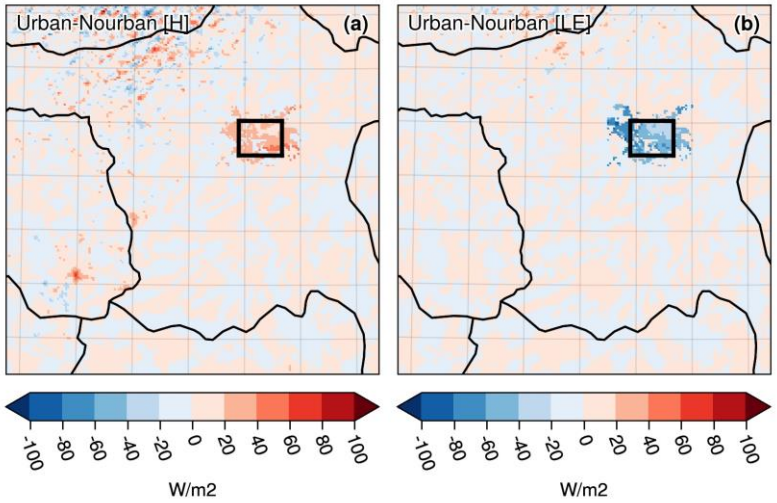
- Temperature increase induced by **urban land use** is more for the **summer event** (~ 1.5 °C) than the **spring event** (~ 0.5 °C).
- **Cropland** to **Urban Land** conversion resulted in warming, as in Sertel et al. (2009).
- Strength of the **UHI** before the heaviest rainfall might be crucial to assess whether the urbanization will affect the precipitation or not.

Return To Part II

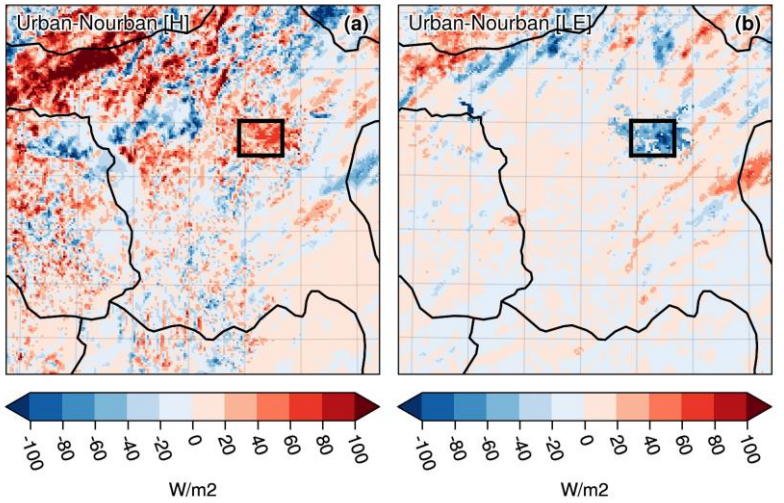
Results Part III

Go To Part IV

5 May 2014



28 August 2016



Key Information

- Differences in the **Sensible Heat (H)** and **Latent Heat (LE),** averaged over the four hours before the heaviest rainfall, between **Urban** and **Nourban** configurations for **springtime** and **summertime** events.

Key Findings

- In Accord with **De Meij & Vinuesa (2014)**, the **urban configuration** have increased the Sensible Heat (H) amounts but have decreased the Latent Heat (LE) amounts over the urbanized region (black box).
- H and LE changes might affect the dynamical and thermodynamical characteristics over a particular region which was not the case for the 5 May **springtime** frontal precipitation event.

Key Citations

- There is a complexity between urbanization and how it affects the precipitation processes (**Kug & Ahn, 2013**).
- Changes in the spatial distribution of the precipitation relative to the urban center are related to the dynamical and regional heating rates (**Niyogi et al., 2017**).
- In their study, **De Meij & Vinuesa (2014)** observed higher (lower) sensible (latent) heat flux values when urban (non-urban) land cover is used.
- Urbanization has a more prominent effect in summer (**Kug & Ahn, 2013**).

Key Findings

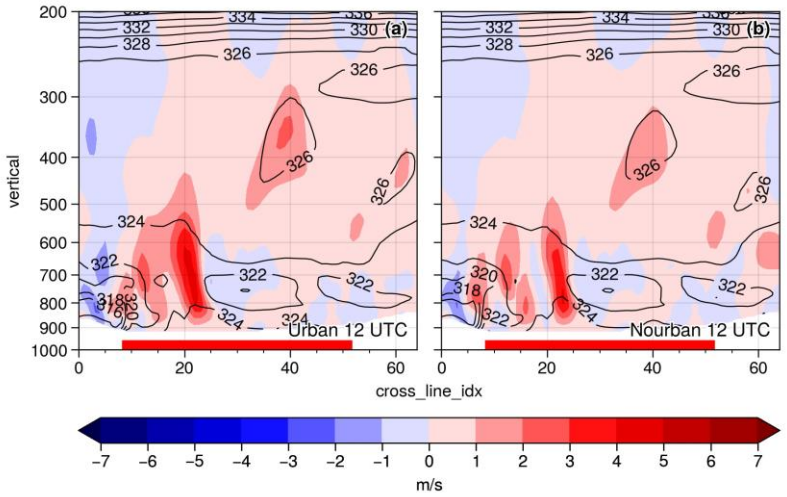
- Changes induced by urbanization in **H** and **LE** values are more obvious in the summer compared to the spring.
- Up to 80 (100) W/m2 increase (decrease) in Sensible (Latent) Heat in the **urban** configuration.
- Strength of the observed **heat change** before the heaviest rainfall might be crucial to assess the **urban effect** on precipitation.

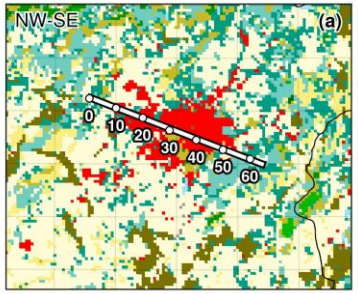
Return To Part III

Results

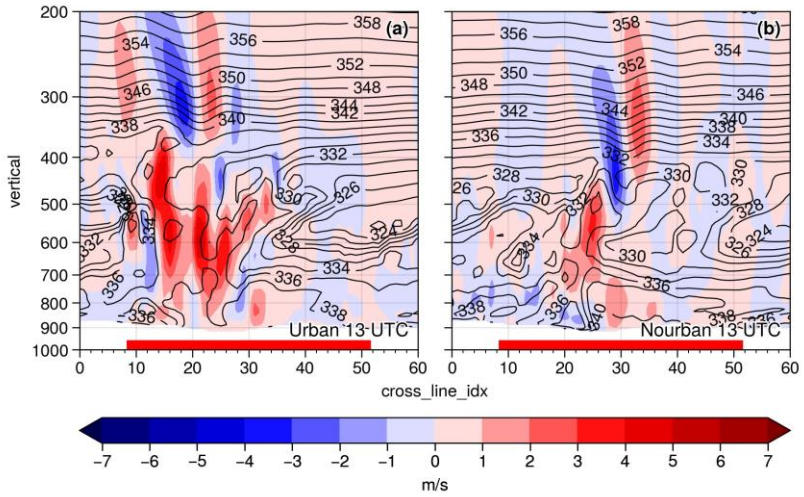
Part IV

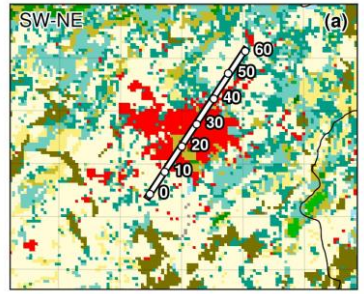
5 May 2014





28 August 2016





Key Information

- **Vertical Velocity** (shade) and **Theta-e** (contour) Cross-Section (CS) graphics for **Urban** and **Nourban** configurations one hour before the heaviest rainfall.
- The red line on the x-axis represents the urban area.
- CS directions are shown below.

Key Citations

- In their research, **Niyogi et al. (2011)** has revealed that the urbanization increases both the **boundary layer height** and **vertical velocity**.

Key Findings

- In Accord with the findings of **Niyogi et al. (2011)**, urbanization has increased the vertical velocity over the **upwind parts** of the urban center.
- However, the synoptic background again suppressed any change in the precipitation pattern over the urban region.

Key Findings

- The increase in the **vertical velocity** is more prominent in the **summer event** than the **spring event**.
- This increase coupled with the observed changes in temperature, sensible heat, and latent heat resulted in a change in the precipitation pattern for the **Urban** configuration.

Conclusion

Key Importance

- Testing the **impact of urbanization** on the precipitation with **different characteristics** in Ankara exploiting the WRF model.
- Using **two precipitation cases** characterized with a robust synoptic background and local convection, respectively.

Urbanization has impacts on the temperature, sensible heat, latent heat, and vertical velocity variables in Ankara.

However, these observed changes do not necessarily suggest a change in the **spatial** and **temporal** pattern of a precipitation event.

The characteristics (i.e., **synoptic background**, **locality**) related to the formation of the rainfall should also be included in the analysis.

Urbanization did not affect the precipitation pattern of the **spring event** (characterized with a **strong synoptic background**), whereas it impacted the distribution of the rainfall in the summer event (characterized with **local convection**).

The strength of the **UHI** and **heating** related to the urbanization **before** the heaviest rainfall might be crucial to determine how the urbanization will affect the precipitation.

Variables	Yes/No Table			
	Has urbanization affected the variables?			
	Spring Event (5 May 2014)		**Summer Event (28 August 2016)**	
	Strong Synoptic Background		Local Convectivity	
T (°C)	Yes	AWL	Yes	AWL
H (W/m^2)	Yes	AWL	Yes	AWL
LE (W/m^2)	Yes	AWL	Yes	AWL
W (m/s)	Yes	AWL	Yes	AWL
P (mm)	No	PAWL	Yes	AWL

T: Temperature, **H**: Sensible Heat, **LE**: Latent Heat, **W**: Vertical Velocity, **P**: Precipitation

AWL: Agrees With the Literature | **PAWL**: Partially Agrees With the Literature

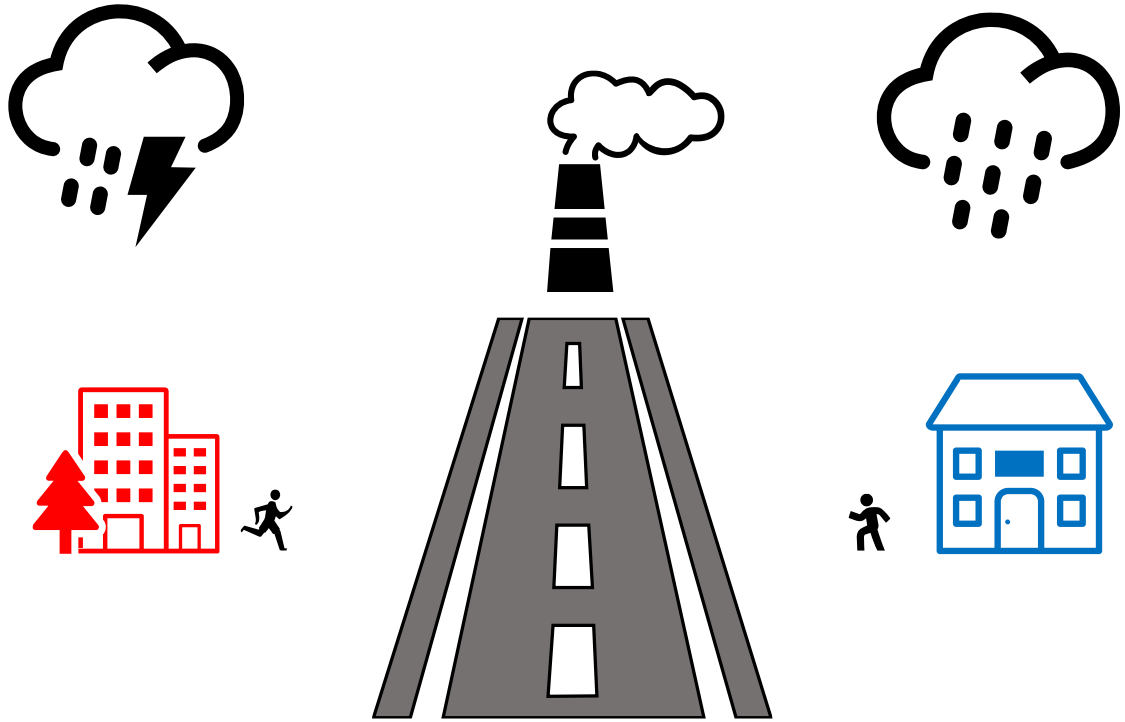
Limitations and Suggestions

- This study utilizes the **best parameterization scheme** out of **three** model configurations. However, later studies can emphasize the uncertainty of the results by exploiting the **ensemble averages**.
- The **topography** might mask or exacerbate the rate at which urbanization affects the distribution of the precipitation and should be included in the later studies.

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Thank You!

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