Assessment of Urbanization Impact On Heavy Precipitation in Istanbul, Turkey

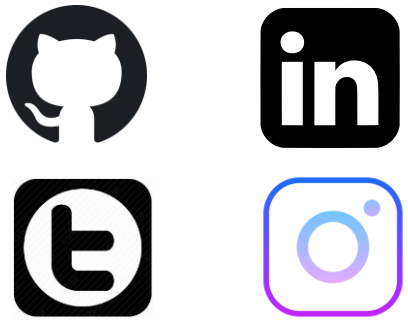
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SOCIAL MEDIA



ABSTRACT

Cities have undergone a substantial increase in urbanization over the past decades. Whether the change in land-use type and the consequent Urban Heat Island (UHI) affects the extreme precipitation was of interest and has been under investigation for various developing cities. This study pursued a similar purpose and investigated the impact of urbanization on a heavy precipitation incident that took place in Istanbul on 18 July 2017.

Two particular land-use scenarios were used to simulate the event by Weather Research and Forecasting Model (WRF). First, the control simulation (WRF-urban) was performed using the default CORINE 2018 land-use dataset. Subsequently, the test simulation (WRF-nourban) was implemented by replacing the urbanized land-use type of Istanbul with the most dominant land use category of arid cultivated area. Comparison of the WRF-urban simulation with station observations and satellite data reveal that the WRF captured the heavy precipitation event reasonably well over Istanbul.

Results showed that urbanization has a notable impact on both the magnitude and timing of heavy rainfall. Event day total precipitation amount decreased considerably over urbanized regions of Istanbul on the control run. Although the start time and location of the incident reasonably matched for both runs, the control run with urbanization advanced the rainfall quicker over Istanbul, and the heavy precipitation event took place about 1 hour earlier than the test run without urbanization. Another pronounced distinction between the simulations with and without urbanization is detected over the north of Istanbul as the maximum daily total precipitation line slightly shifted northwest on the WRF-urban run compared to the WRF-nourban run. This result indicates that urban-areas may have a substantial effect on the direction of the airflow.

Analysis of both vertical cross-sections and sensible heat fluxes on the city revealed that non-urbanized areas increased the atmospheric instability, thus caused heavier precipitation.

START

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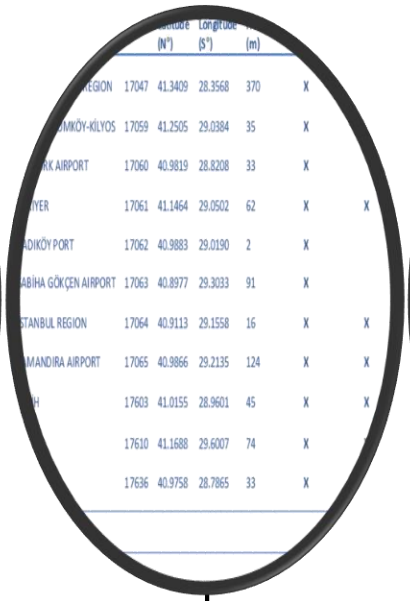
WELCOME TO THE CONTENT OVERVIEW

(You can proceed with one of the topics from below)

1

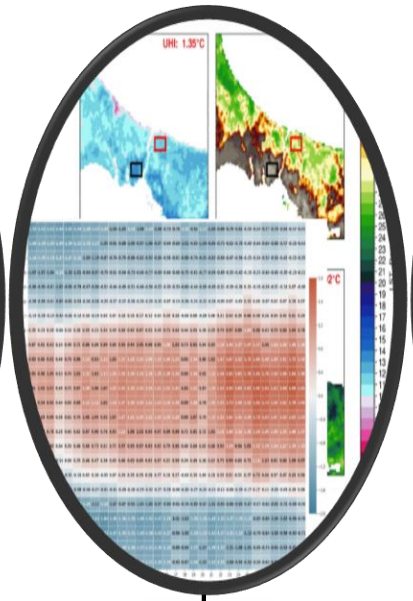


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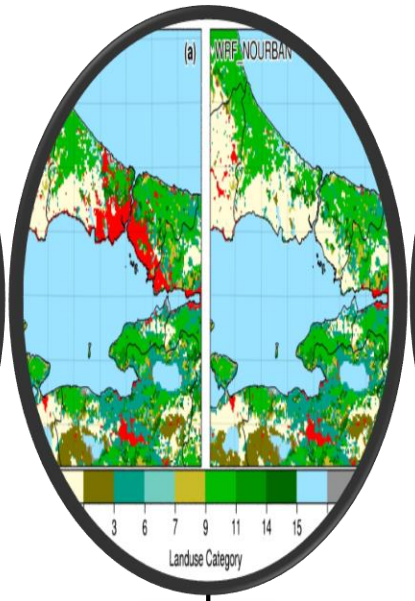


		Latitude (N°)	Longitude (S°)	(m)		
REGION	17047	41.3409	28.3568	370	X	
MKÖY-KİLYOS	17059	41.2505	29.0384	35	X	
K AIRPORT	17060	40.9819	28.8208	33	X	
IYER	17061	41.1464	29.0502	62	X	X
ADIKÖY PORT	17062	40.9883	29.0190	2	X	
ABİHA GÖKÇEN AIRPORT	17063	40.8977	29.3033	91	X	
STANBUL REGION	17064	40.9113	29.1558	16	X	X
MANDIRA AIRPORT	17065	40.9866	29.2135	124	X	X
H	17603	41.0155	28.9601	45	X	X
	17610	41.1688	29.6007	74	X	
	17636	40.9758	28.7865	33	X	

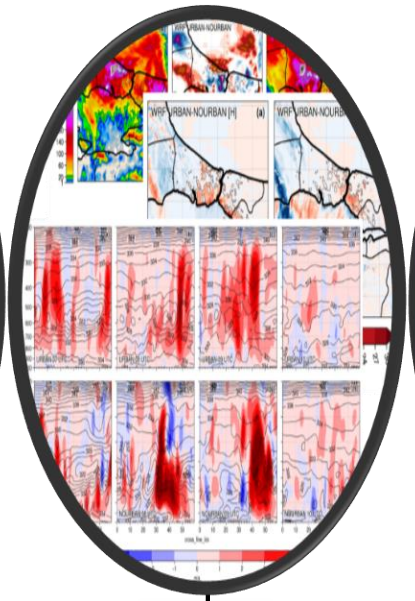
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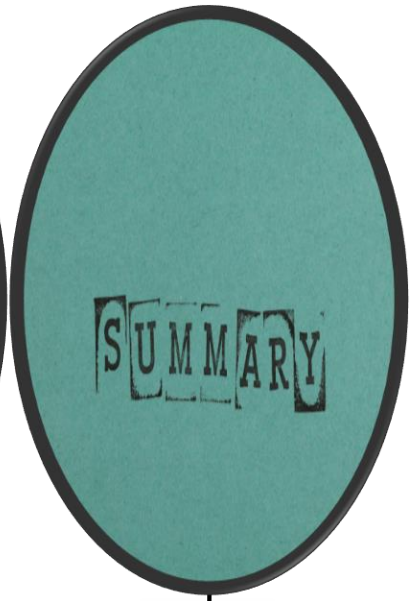
4



5



6



GLOBALLY

2018:
- 55% of population lives in urban

by 2050:
- 68 % expected to live in urban

(UN DESA, 2018)

IN ISTANBUL

2002 to 2013 annually:
- 1.2% increase in population
- 3.7% increase in urban extent

("Istanbul," n.d.)

WHAT IS OUR AIM ?

- To show how urbanization may affect heavy-precipitation events
- To provide meteorological guidance to the policy-makers in planning cities.

IN EUROPE

2018:
- ¾ of population lives in urban

by 2050:
- 85 % expected to live in urban

(United Nations Publications, 2019)

The population vulnerable to urban flooding increases at a pace !!

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Which Data We Used ?

Validation Data

- GPM Imerg Final
  - Precipitation
  - Half hourly, 0.1 x 0.1 degree
  - Obtained from GES DISC
- MODIS Terra
  - Land surface temperature/emissivity
  - Daily, 1km x 1km
  - Obtained from LP DAAC
- MGM Surface Observations

Modelling Data

- ERA5 Pressure/Single Level
  - Boundary/initial condition for WRF
  - 3 hourly, 0.25 x 0.25 degree
  - Obtained from CDS Copernicus
- Corine Land Cover 2018
  - Used on WRF Instead of USGS land-cover data
  - Much better resolution, up-to-date

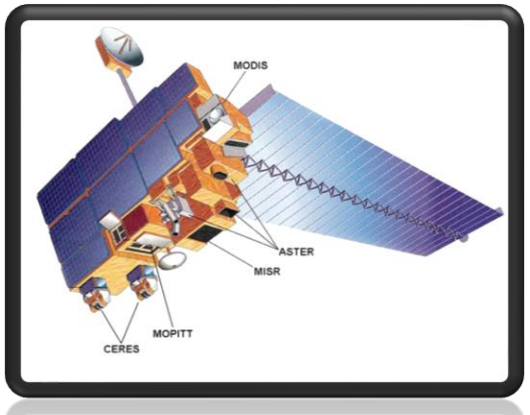
Which Model We Run ?

- The Weather Research and Forecasting Model
  - Next generation mesoscale model
  - Used in both research and forecasting areas
  - A lot of physics scheme options to integrate in the model
  - Easy to run and get results
  - In this study, dynamic core: WRF-ARW

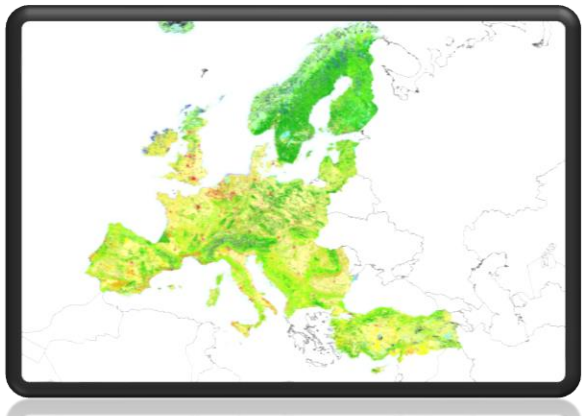
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https://gpm.nasa.gov/missions/GPM



https://www.nasa.gov/mission_pages/terra/spacecraft/index.html

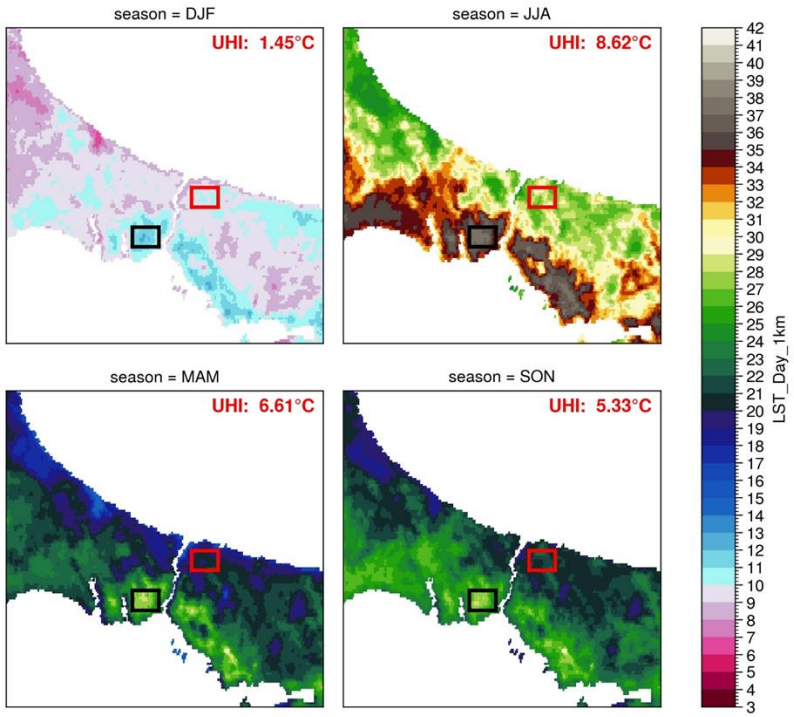


https://land.copernicus.eu/pan-european/corine-land-cover

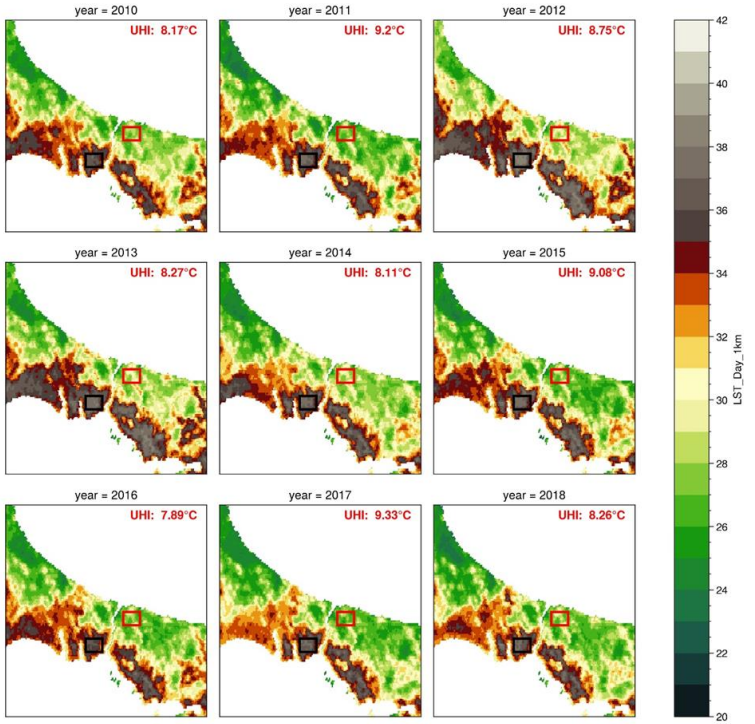
https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-pressure-levels?tab=overview

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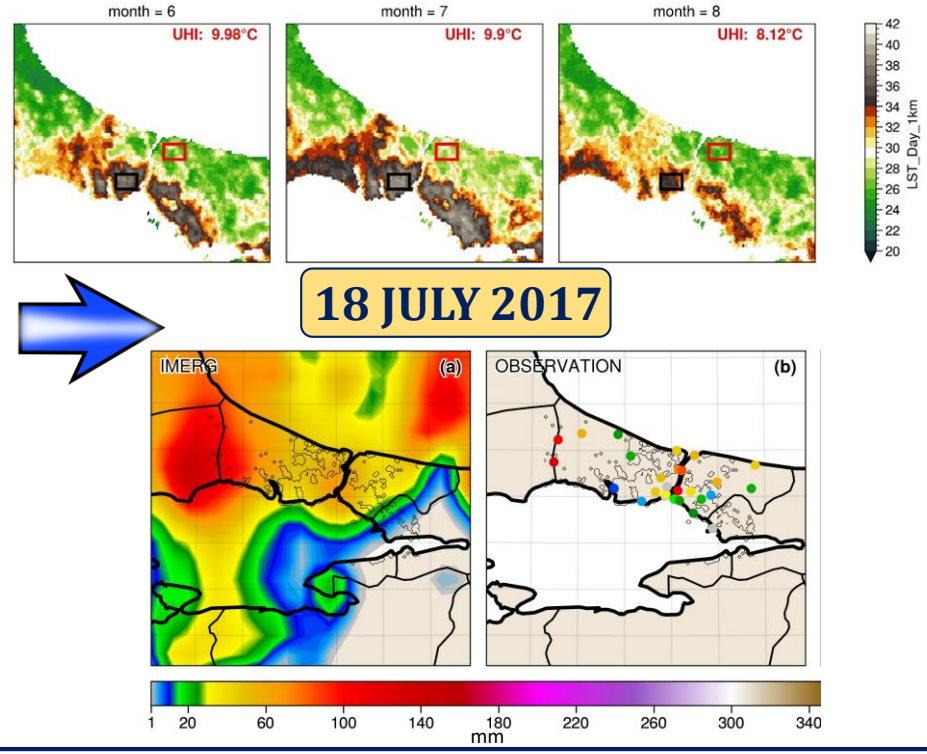
Seasonal Analysis



Yearly Analysis



Summer Analysis of 2017



What We Are Looking For ?

- A heavy-precipitation occurrence with the urbanization and UHI signature having a significant effect on altering the precipitation amount and distribution
- The seasonality prevails in UHI magnitude in Istanbul (Unal et al., 2019)
- Better to choose an event date when UHI is strongest

Which Method We Utilized ?

- Choose 2 boxes with similar topographies
- Black Box = urban; Red Box = rural
- Use 10 years of Modis Terra LST data to find the differences in grid-averaged LST between 2 boxes (upper right corners). → Highest UHI values are picked
- Execute this method initially for seasonal averages, then for yearly averages, finally for summer months averages for the year picked a step before.

What Happened On July 18, 2017 ?

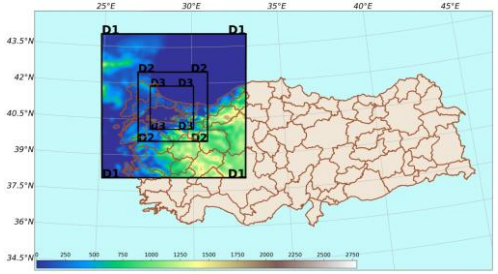
- Following the steps in the method:
  - ❑ Season found as: **Summer**
  - ❑ Year found as: **2017**
  - ❑ Month found as: **July**
- Day found as: **18 July**
  - ❑ One of the highest precipitation amounts in July in 10 years
  - ❑ 500 mb low over Istanbul
  - ❑ Lots of convective activity over and around Istanbul

2 WRF RUNS

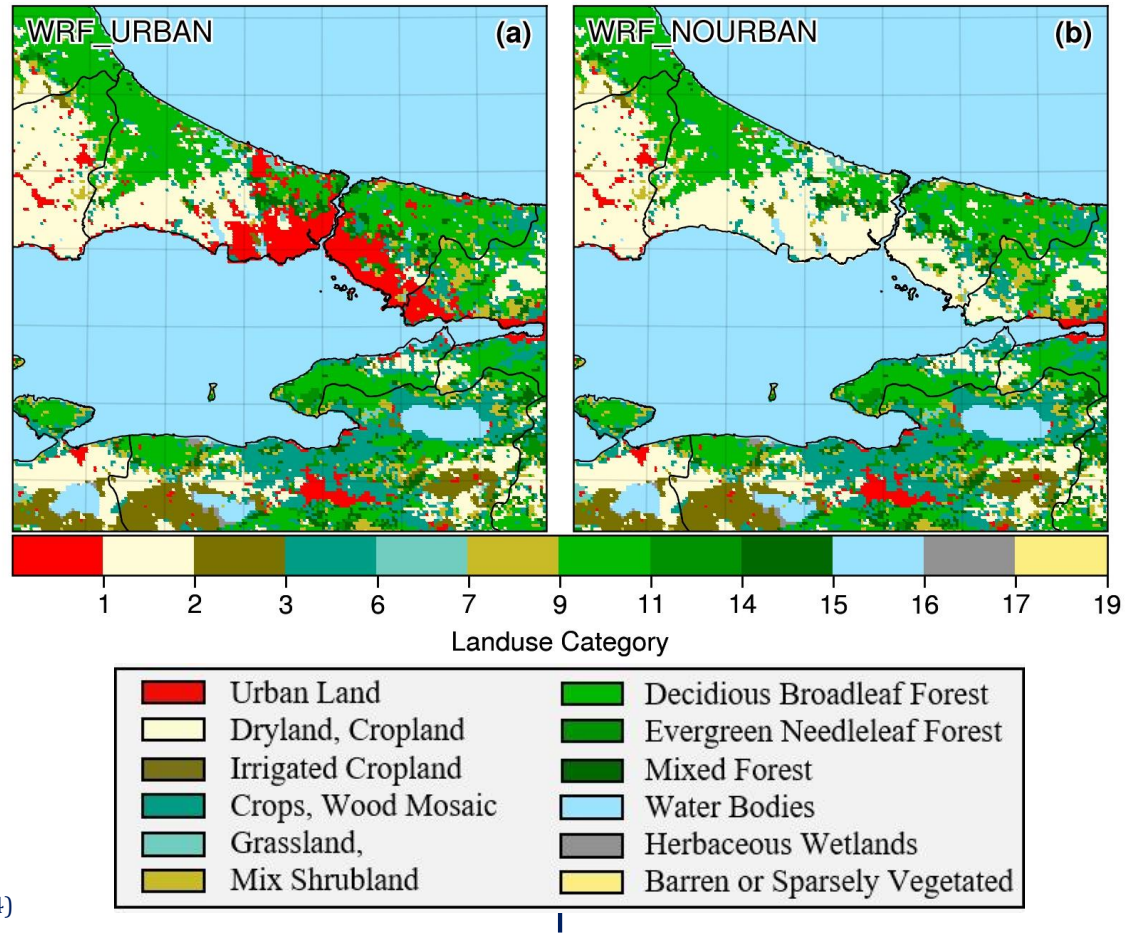
WRF_URBAN

Land Cover
- Urbanized Istanbul: **True** (Urban, Builtup Land)

Domain
- Resolutions: **9km x 3km x 1km**
- Horizontal Grids: **202 x 202**
- Vertical Grids: **Manual 61 layers**
- Initial/Boundary: **3 hourly ERA5 0.25 °**
- Simulation Start: **17 July 2017 00 UTC**
- Simulation End: **19 July 2017 18 UTC**
- Integration : **45 sec. for outermost domain**



Parametrization
- Microphysics: **WSM6** (Hong and Lim, 2006)
- Longwave: **RRTM** (Mlawer et al., 1997)
- Shortwave: **Dudhia** (Dudhia, 1989)
- Land Surface: **Unified Noah Land** (Tewari et al., 2004)
- Surface Layer: **Revised MM5** (Jimenez et al., 2012)
- PBL: **YSU** (Hong et al., 2006)



LAND-USE DATA: CORINE 2018

WRF_NOURBAN

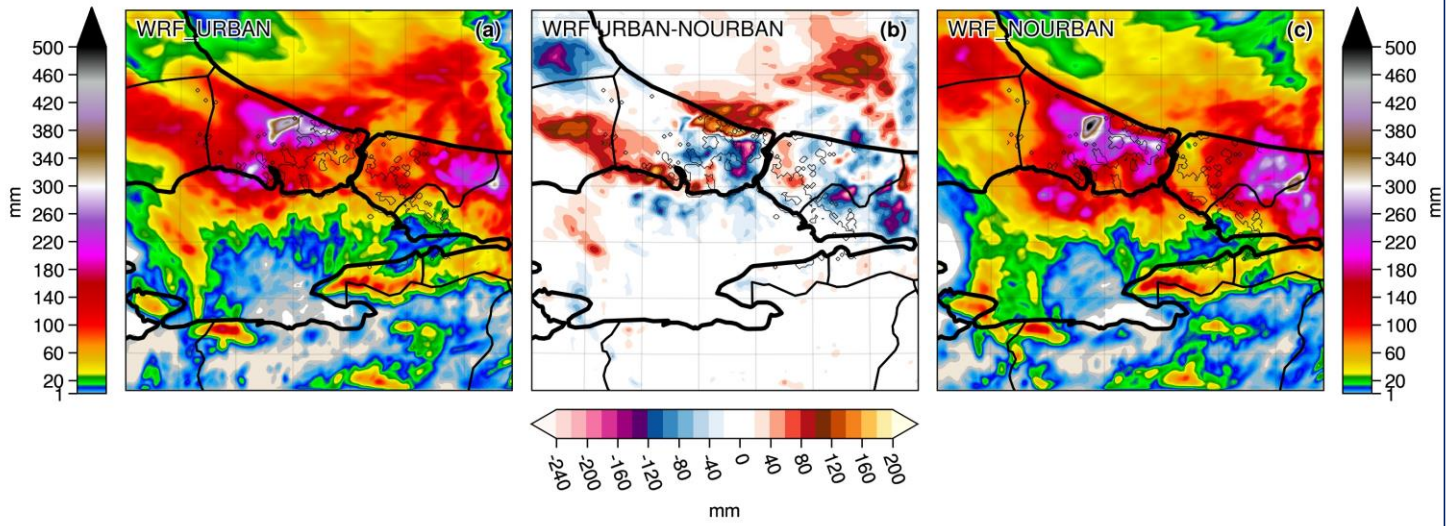
Land Cover
- Urbanized Istanbul: **False** (Dryland, Cropland)

Domain
- SAME AS WRF_URBAN

Parametrization
- SAME AS WRF_URBAN

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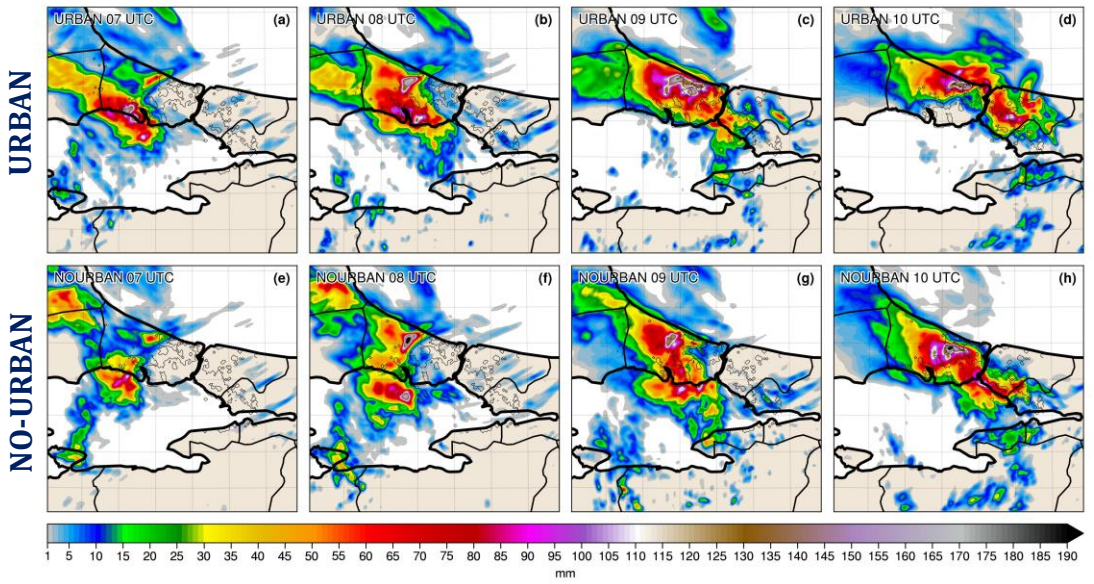
Event Day Total



18 JULY 2017

Event Day Hourly

18 JULY 2017 | 07-10 UTC
4 Most Intense Hours



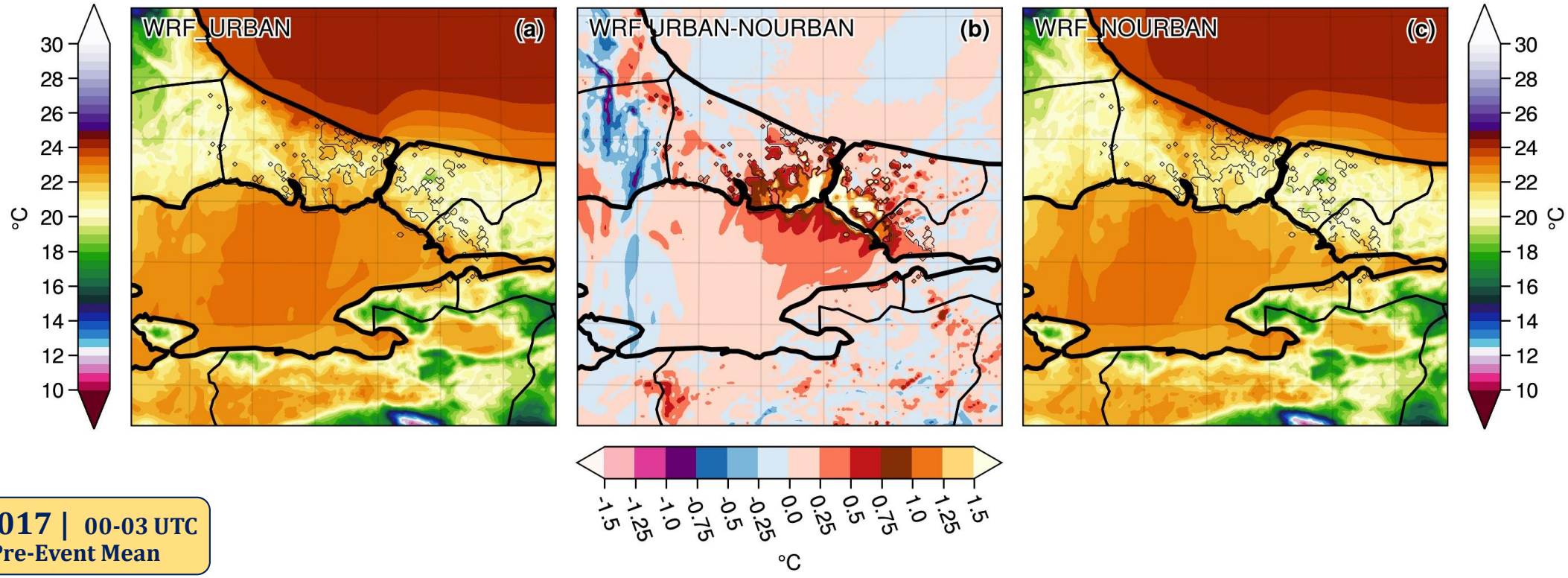
KEY NOTES

- Growing urbanization in coastal areas may suppress precipitation owing to the urban dry island (UDI) (Lin et al., 2020).
- Urbanization may relocate the highest precipitation from above the urban to the rural-urban border (Niyogi et al., 2020; Niyogi et al., 2017).
- With lower UHI, oncoming precipitation bifurcates on the upwind of the urban and follows the side paths (Zhang et al., 2017).

KEY RESULTS

- Decrease in event-day total precipitation amount in *wrf_urban* over most of the urbanized regions of Istanbul (Left panel)
- Shiftment of maximum daily total precipitation line slightly to the north-northwest of Istanbul in *wrf_urban*, a possible indicator of bifurcation of oncoming rainfall on the urban upwind (Left panel)
- Increase in event-day total precipitation amount on the downstream rural-urban border in *wrf_urban* (Left panel).
- Increase in event-day total precipitation amount on the near-upwind of Istanbul in *wrf_urban*
- 1 hour earlier advancement of precipitation in *wrf_urban* (Right panel)

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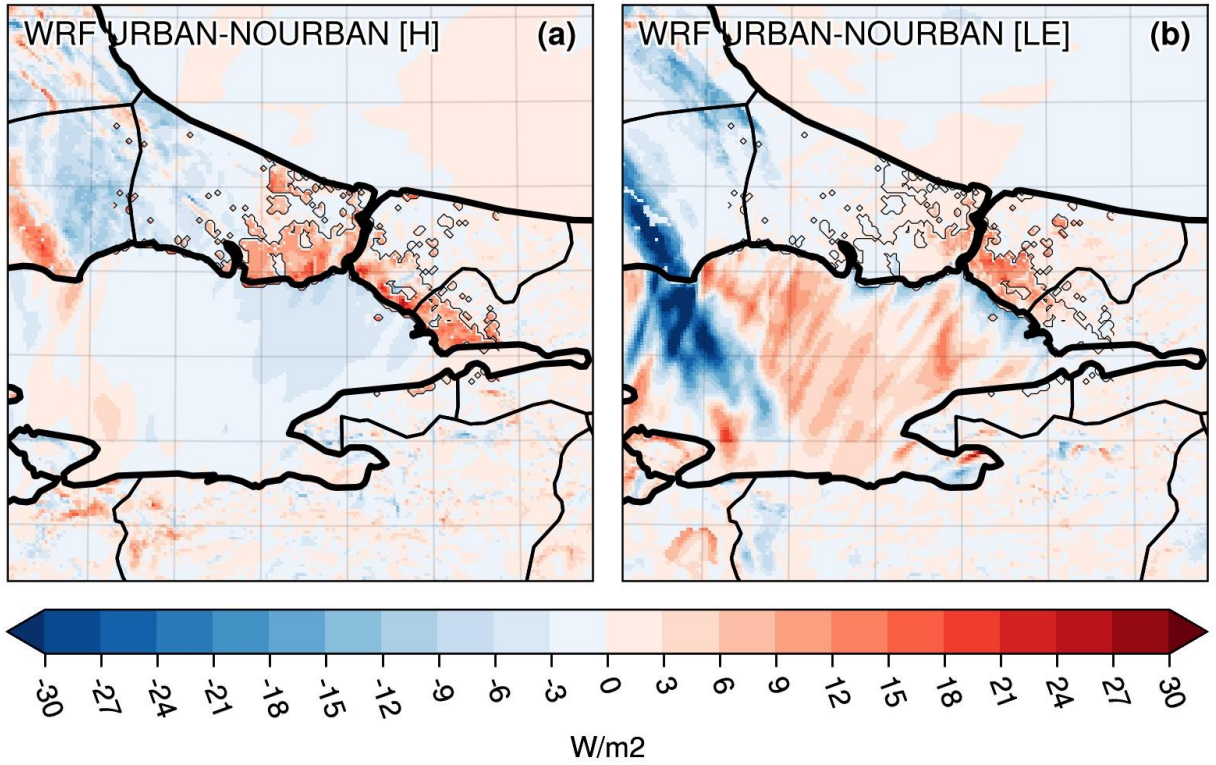
18 JULY 2017 | 00-03 UTC
4 Hours Pre-Event Mean

KEY NOTES

- Urbanization increases the temperature (Su et al., 2021; Lin et al., 2020; Kug & Ahn, 2013)
- In terms of max. temperature, the most robust UHI magnitude is found in July in Istanbul (Kartal) (Unal et al., 2019)
- Utilizing high-resolution land cover datasets carries utmost concern in representing UHI accuracy (De Meij et al., 2018).

KEY RESULTS

- 0.75 to 1.5 °C increase in 2m air temperature over the urbanized regions of Istanbul in *wrf_urban* (mid-panel)
- 0.50 to 1.5 °C increase in 2m air temperature on the near-offshore in *wrf_urban* (mid-panel)
- Accurate representation of land-use over urbanized regions have a prominent effect on 2m air-temperature



18 JULY 2017 | 00-03 UTC
4 Hours Pre-Event Mean

KEY NOTES

- Higher urban representation increases the sensible heat flux (De Meij & Vinuesa, 2014), reduces the latent heat flux (De Meij & Vinuesa, 2014; Sertel et al., 2009) above urban region.
- On the WRF model, using up-to-date Corine land-use data contributes to greater accuracy of the heat fluxes (De Meij et al., 2018).

KEY RESULTS

- Up to 20 to 30 W/m2 increase in 4 hours pre-event average of upward sensible heat flux due to heat trapped inside the urbanized region in wrf urban. (Left panel)
- In contrast to other studies in literature, there is an increase in 4 hours pre-event average of upward latent heat flux possibly due to increase in temperature and thus evaporation in *wrf urban* (No significant change observed in soil moisture between *wrf urban* and *wrf nourban* – not shown)

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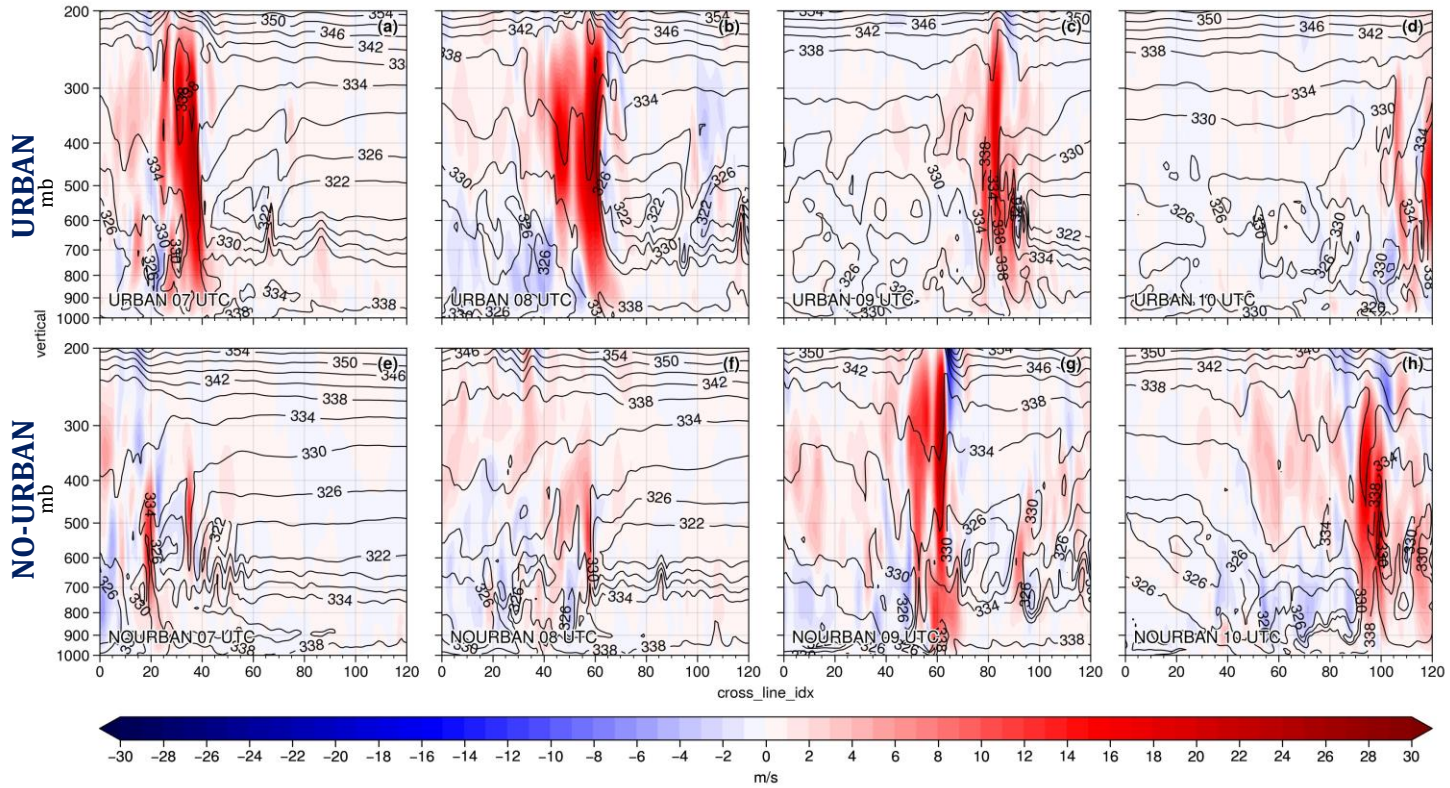
KEY NOTES

- In their study, urbanization enhanced the magnitude of vertical velocity and the height of the boundary layer (Niyogi et al., 2011).

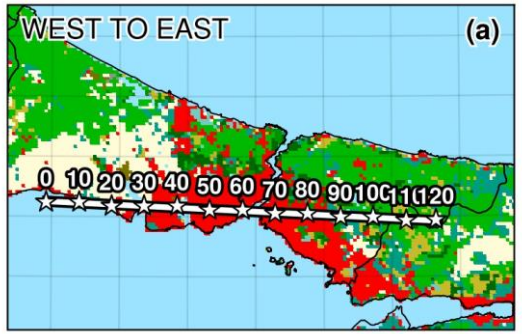
« Upper panel shows a vertical cross-section of vertical velocity and equivalent potential temperature. The index numbers in the upper panel x-axis correspond to the numbers lined in the lower panel and indicates where the cross-section is taken. »

KEY RESULTS

- Excessive increase in upward vertical velocity over the entrance (~ index 30) of the urbanized region in *wrf urban* at 07 UTC
- Equivalent potential temperature (Theta-e) intersects the urbanized ground at an angle of almost 90 degrees in *wrf urban*
- Another excessive increase in upward velocity both in *wrf urban* (08 UTC) and *wrf nourban* (09 UTC) originates from the effect of the Istanbul Bosphorus (~ index 60 to 70).



18 JULY 2017 | 07-10 UTC
4 Most Intense Hours



X-AXIS OF CROSS SECTION

Previous | Vertical Cross Section

MOTIVATION | DATA AND MODEL | CASE SELECTION | EXP. DESIGN | RESULTS | CONCLUSION

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SOCIAL MEDIA

URBANIZATION

1. has a notable impact on both the magnitude and timing of heavy rainfall.
2. decreased precipitation amount over the urban area.
3. increased precipitation amount on the downstream rural-urban border.
4. caused increase in upward vertical velocity over the entrance of the urbanized region

Variables	**Yes/No Table**	
	Has urbanization affected the variables?	
T (°C)	Yes	AWL
H (W/m^2)	Yes	AWL
LE (W/m^2)	Yes	NAWL
W (m/s)	Yes	AWL
P (mm)	Yes	AWL

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

AWL: Agrees With the Literature | **NAWL**: No Agrees With the Literature

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LACKING PARTS AND SUGGESTIONS

1. An ensemble modeling study is required to get the general idea regardless of physics parametrization used *(Which is my current thesis topic)*
2. Results of only one case-study may not neccessarily apply for other cases. So there is a need for evaluation of multiple cases

REFERENCES

MOTIVATION | DATA AND MODEL | CASE SELECTION | EXP. DESIGN | RESULTS | CONCLUSION