Study of the Urban Heat Island and its Effect on the Planetary Boundary Layer (PBL) for the El Paso - Juarez Airshed

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November 22, 2022

Abstract

The planetary boundary layer (PBL) is a layer in the lowest part of the atmosphere where Earth's surface strongly influences temperature, moisture, and wind through the turbulent transfer of air mass. It is a key component of air pollution transport studies. An urban heat island (UHI) is a metropolitan area which is significantly warmer than its surrounding rural areas. The El Paso - Juarez Metropolitan area, with a combined population of ˜ 1.972 million (in 2010) and growing urban infrastructure, can be studied as an UHI surrounded by rural areas. In this study, we have analyzed the temperature fields for the lower levels of the troposphere for the El Paso - Juarez metropolitan area and neighboring rural areas during the day and night hours both for the summer and winter seasons. The Vaisala Boundary Layer View Software (BLView) was used to obtain the aerosol mixing layer height (ML), a proxy for the PBL height, using data from a Vaisala ceilometer, model CL31. The ceilometer is situated at the University of Texas at El Paso (UTEP) campus. The BLView analyzes the ceilometer backscatter profile data and provided the ML structure. In addition, the Weather Research Forecast Model (WRF) was used to simulate PBL heights for the El Paso - Juarez Airshed and its surrounding rural areas. The overall objective of the project is to contribute to a better understanding of the PBL structure and the effect the UHI has for the El Paso - Juarez Airshed.

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Introduction

The Urban Heat Island (UHI) is a metropolitan area which is significantly warmer than its surrounding rural area. The El Paso-Juarez metropolitan area, with a combined population of ~1.972 million (in 2010) and growing infrastructure, can be a good example of an UHI. The Earth's surface is the bottom boundary of the atmosphere. The portion of the atmosphere most affected by that boundary is called the Planetary Boundary Layer (PBL). It is directly influenced by the earth's surface and responds to heat transfer, pollutant emission and other surface forces. It is a key component of air pollution transport studies. The overall objective of the project is to contribute to a better understanding of the PBL structure and the effect the UHI has for the El Paso-Juarez airshed.

Methodology

1 - Satellite images and data from NASA's 'WORLDVIEW' are used to study the surface land and air temperature for day and night hours (worldview.earthdata.nasa.gov).

2 - The Vaisala Ceilometer CL-31 situated at the UTEP campus, measures the cloud height, vertical visibility and mixing height using the aerosol backscatter profile data. BL-view software is used to analyze the mixing height using the ceilometer data.

3 - Weather Research Forecast (WRF) simulations are used for studying PBL in the El Paso-Juarez Airshed and neighboring regions.

Results

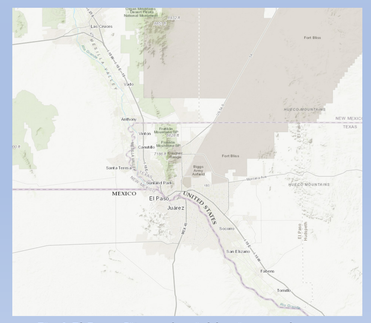

Fig.1 El Paso City and neighboring rural areas

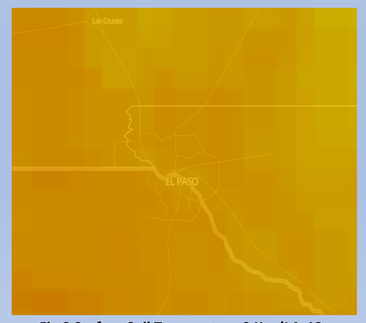

Fig.2 Surface Soil Temperature 9 Km (L4, 12z Instantaneous) SMAP / Model Value Added

Surface Urban Heat Island (SUHI) intensity = $\Delta T_{Urban - Rural}$

($\Delta T_{Urban - Rural}$) Summer ≈ 4 - 5 ^{o}C

($\Delta T_{Urban - Rural}$) Winter ≈ 2 - 3 ^{o}C

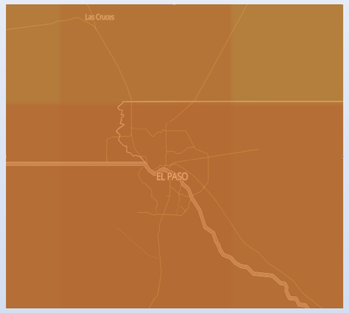

Fig.3 Surface Air Temperature (Night, Monthly) Aqua/AIRS

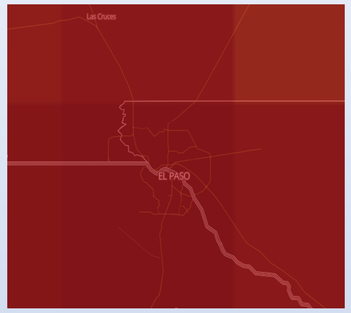

Fig.4 Surface Air Temperature (Day, Monthly) Aqua / AIRS

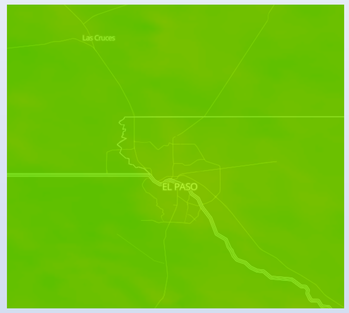

Fig.5 Land Surface Temperature (Night) Aqua / MODIS

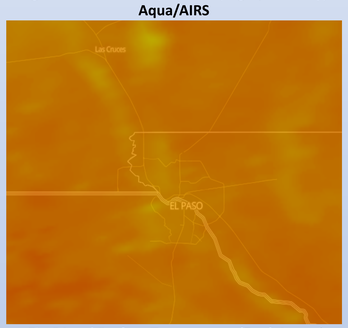

Fig.6 Land Surface Temperature (Day) Aqua / MODIS

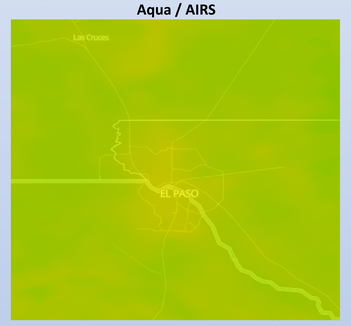

Fig.7 Land Surface Temperature (Night) Terra / MODIS

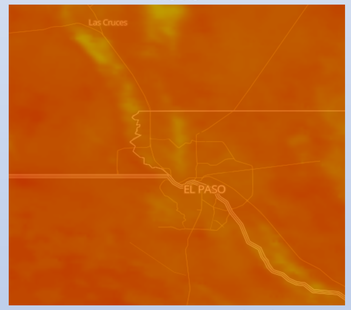

Fig.8 Land Surface Temperature (Day) Terra / MODIS

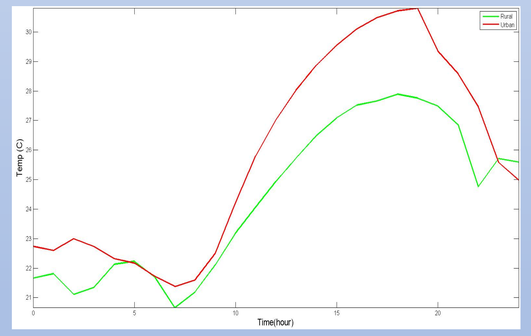

Fig.9 Temperature comparison for Urban and Rural region

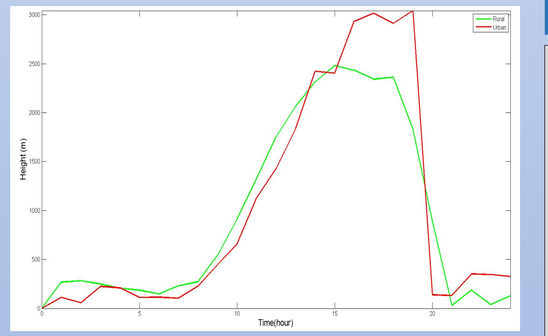

Fig.10 PBLH comparison for Rural and Urban region

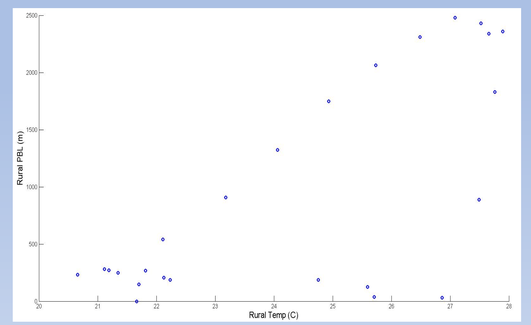

Fig.11 Correlation coefficient of Rural PBL and Temperature (0.7038)

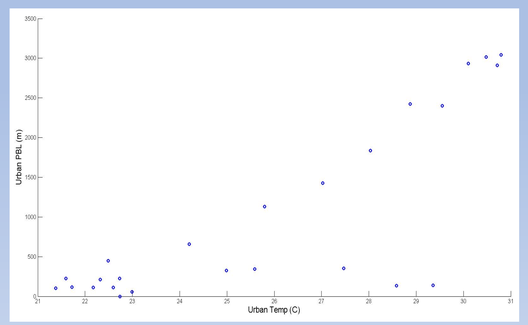

Fig.12 Correlation coefficient of Urban PBL and Temperature (0.8051)

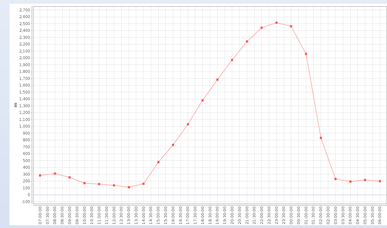

Fig.13 PBL in El Paso-Juarez region, 06/07/2017 using the (WRF) Simulations

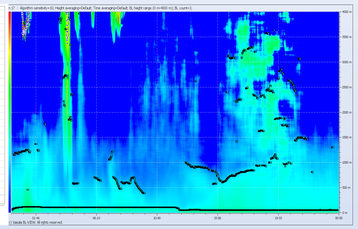

Fig.14 BL-view mixing layer height plot in El Paso-Juarez region, 06/07/2017 using the data from ceilometer CL-31

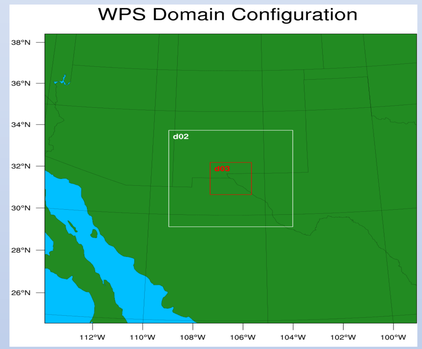

Fig. 15 WRF Simulations domain configuration

Fig. 16 Vaisala Ceilometer CL-31 @ UTEP

Conclusion

- Remote sensing data confirms that El Paso-Juarez airshed is warmer (≈ 4 - 5 ^{o}C) during summer and (≈ 2 - 3^{o}C) during winter than its surrounding rural region.
- High average wind speed especially during the summer, may contribute to lower surface urban heat island intensity.
- PBL and mixing heights are studied for the first time for El Paso-Juarez region. It is observed that both heights follow the expected diurnal cycle.
- PBL heights varies between 75 – 2700 meters. Its higher for the urban region compared to the surrounding rural regions.
- Urban correlation coefficient (0.8051) is higher than rural correlation coefficient (0.7038).

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Acknowledgements:

NCAS-M is funded by NOAA/EPP Cooperative Agreement #NA16SEC4810006.

One of the authors wishes to thank UTEP's Environmental Science and Engineering and Computational Science Program for their support.