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Seasonal Variability and Trends of the Miami Urban Heat Island

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Introduction & Motivation

Urban areas tend to be consistently warmer than their rural surroundings due to altered evapotranspiration properties (Taha 1997), increased anthropogenic heat output (Oke 1982), and higher heat capacities of urban substrates (Swaid 1991). The induced horizontal temperature gradients associated with urban heat islands (UHIs) are known to influence convection and subsequent mesoscale circulations (Baik et al. 2001), thus having the potential to modify precipitation distribution within, and adjacent to, the urban center (Shepherd et al. 2002, Dixon & Mote 2002, Dou et al. 2013). Aside from confirming its existence (Debbage & Shepherd 2015, Kandel et al. 2016), relatively little work has been conducted on the Miami urban heat island. The city's unique climate and topography further increase the need for such a study. The primary goals of this study are to:

1) Further verify the presence of the Miami urban heat island
2) Assess its strength and variability
3) Evaluate its potential influence on precipitation distribution in south Florida

References:

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Data

Temperature:
- National Centers for Environmental Information (NCEI) surface station daily minimum 2-m temperature (°C)
- Livneh .06° x .06° gridded daily minimum 2-m temperature (°C) (Livneh et al. 2013)

Precipitation:
- Livneh .06° x .06° gridded daily total precipitation (mm)

Methodology

Daily minimum 2-m temperatures (T_{min}) observed at eight NCEI surface stations over the period 2002-2011 are utilized for analysis. Stations are classified as urban (Miami International Airport – MIA, Miami Beach – MIB, Hialeah – HIA, Opa-Locka Airport – OPF) and rural (Ten Mile Corner – TEN, Oasis Ranger Station – OAS, Ochopee – OCH, Raccoon Point – RAC) based on land use classifications and proximity to Census-defined urban Miami.

The daily urban-rural difference in T_{min} provides the working proxy for UHI intensity (defined as $T_{min,urban}$-$T_{min,rural}$). Each daily average T_{min} is an average of the four urban and four rural representative surface station sites, respectively. Daily UHI intensities (UHII) are then categorized by magnitude:

- Strong (> 2.78° C)
- Average (2.28° C - 2.78° C)
- Weak (0° C - 2.28° C)
- Negative (< 0° C)

and analyzed on monthly, seasonal, and yearly timescales. Gridded daily precipitation accumulation (mm) is then analyzed against daily UHII in an effort to investigate potential relationships between UHII and precipitation distribution.

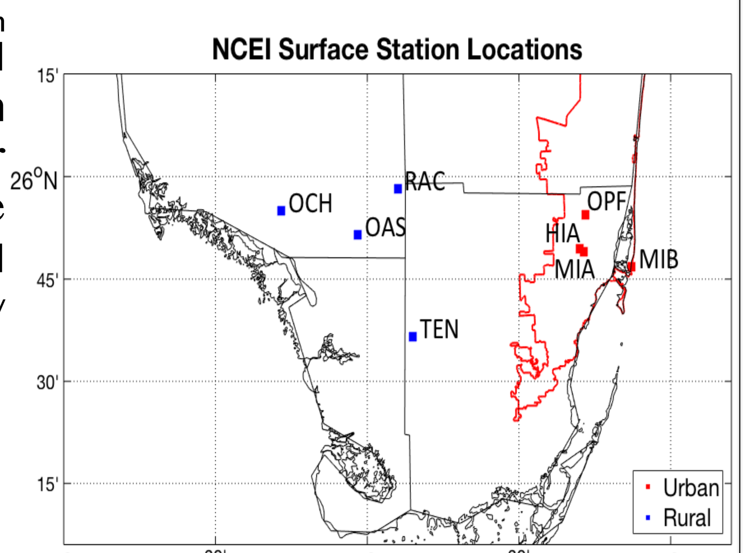

Fig 1: Locations of urban and rural NCEI surface stations utilized for analysis. Red symbols denote urban stations whereas blue symbols denote rural stations. Census-defined boundaries of urban Miami are depicted in red.

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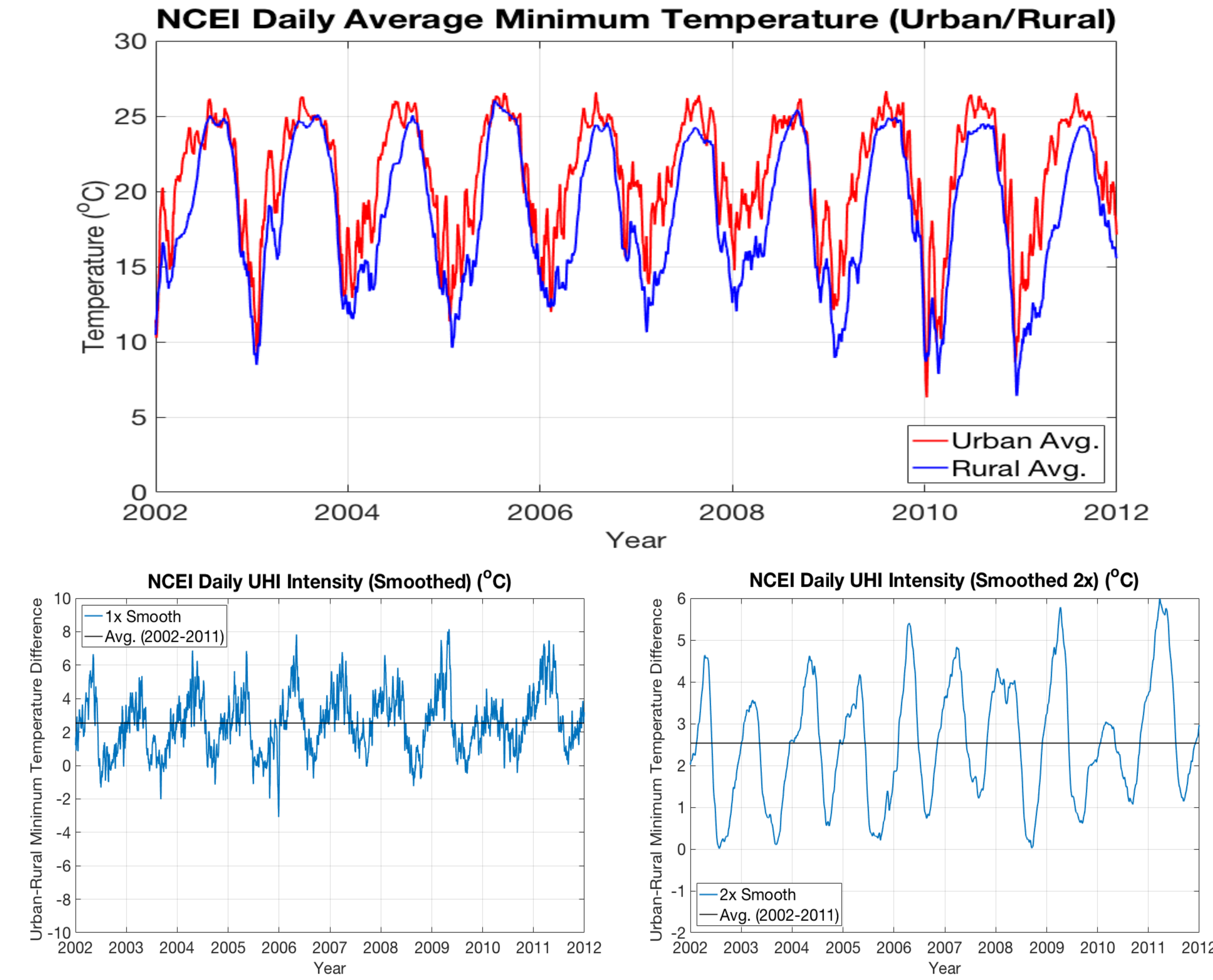
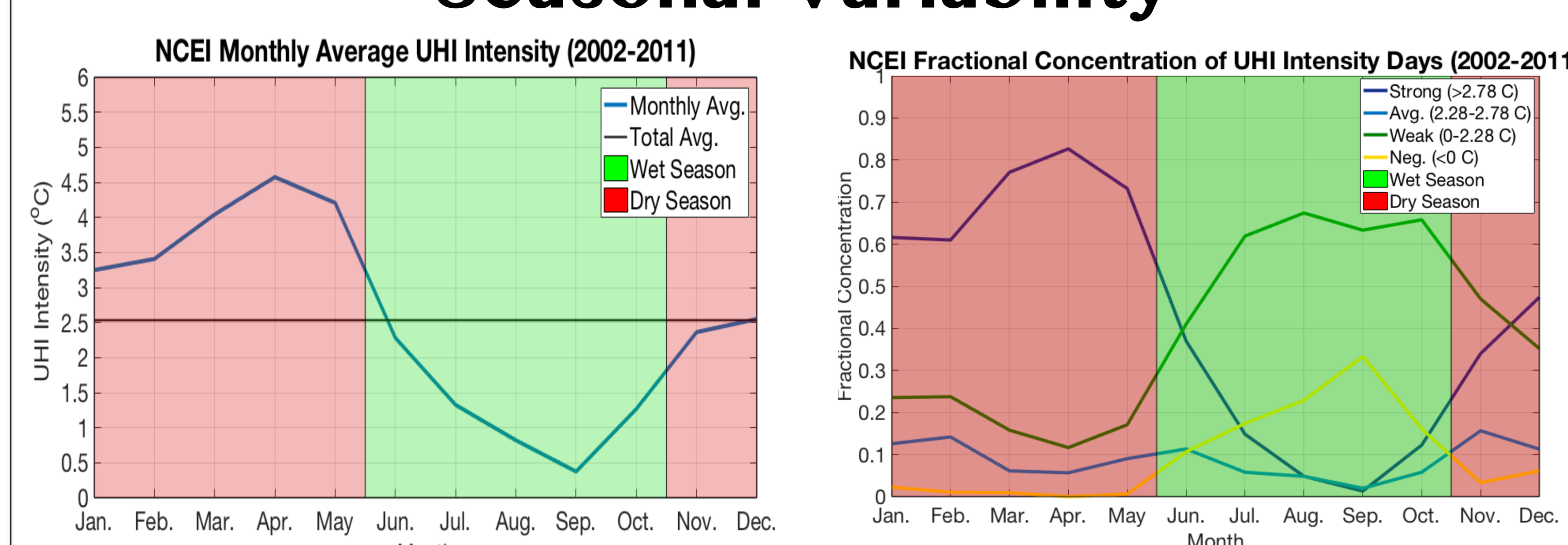
Miami Urban Heat Island: Presence and Variability



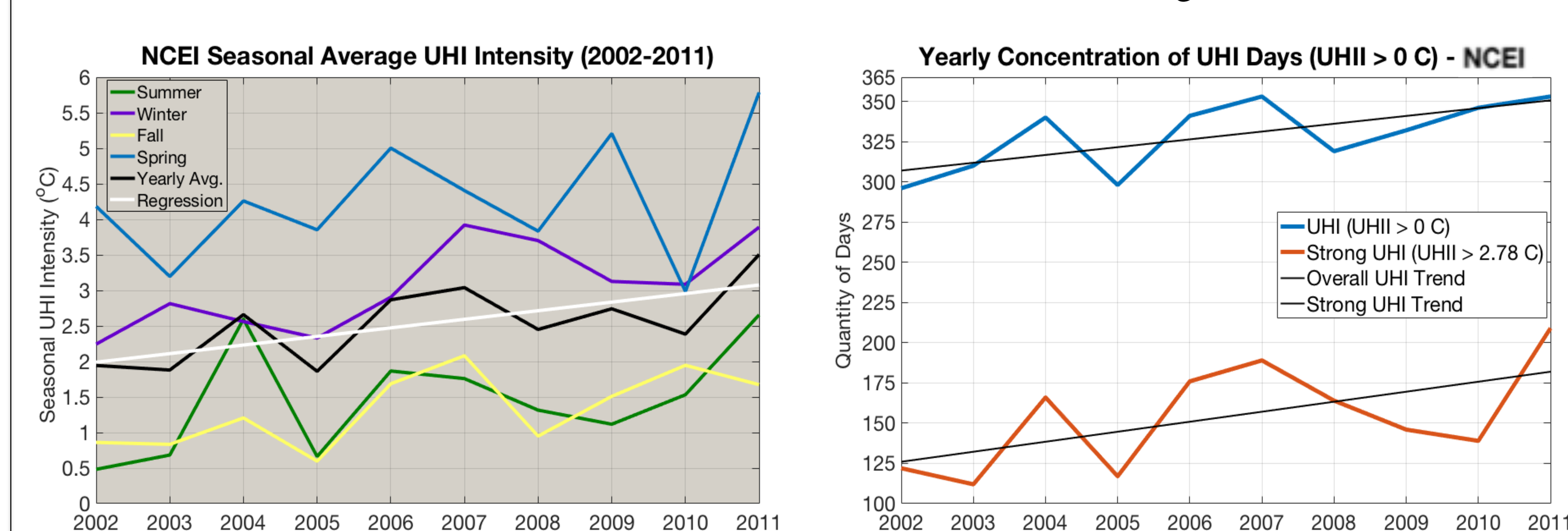
Figs. 2-4: Daily average NCEI minimum temperatures over the period of 2002-2011. Daily UHI intensities at different levels of data smoothing (moving average). 2-m temperatures were obtained from NCEI surface station observations. Each daily average minimum temperature is the average of four urban and rural representative surface station sites.

Seasonal Variability



Figs. 5-6: Monthly average NCEI UHI intensity over the period of 2002-2011 (blue) and complete analysis period average (black). Monthly fractional concentration of UHI "category" days (see methodology) (strong: purple, average: blue, weak: green, negative: yellow). Approximate positions of Florida's distinct wet (green) and dry (red) seasons are overlaid.

Interannual Variability



Figs. 7-8: Yearly average UHI intensity (black) and average seasonal UHI intensity (summer: green, winter: purple, fall: yellow, spring: blue) over the period of 2002-2011. Yearly concentration of UHI days (UHI intensity > 0° C, blue) and yearly concentration of strong UHI days (UHI intensity > 2.78° C, red).

Key Takeaways

1) Urban Miami has a tendency to behave as an urban heat island (corroborating the findings of Debbage & Shepherd 2015, Kandel et al. 2016). **On average, the city retains a positive daily minimum temperature anomaly of +2.53° C.**
2) The Miami urban heat island exhibits distinct seasonal variability. It is **strongest in the spring (+4.27° C) and winter (+3.06° C)**, corresponding to Florida's dry season (~November through ~April). It is **weakest in the summer (+1.47° C) and fall (+1.33° C)**, corresponding to Florida's wet season (~May through ~October). Distinct seasonal differences in soil moisture content may act to modulate UHI intensity, as moist soil has a much higher heat capacity (comparable to that of concrete) than dry soil.
3) Over the complete analysis period, there are **distinct upward trends in**:
   - **Overall urban heat island intensity: +.17° C/year**
   - **Seasonal urban heat island intensity: summer: +.24° C/year, winter/spring: +.18° C/year, fall: +.09° C/year**
   - **Urban heat island days (UHI intensity > 0° C): +6.3 days/ year**
   - **Strong urban heat island days (UHI intensity > 2.78° C): +9.7 days/year**

Upcoming Investigation

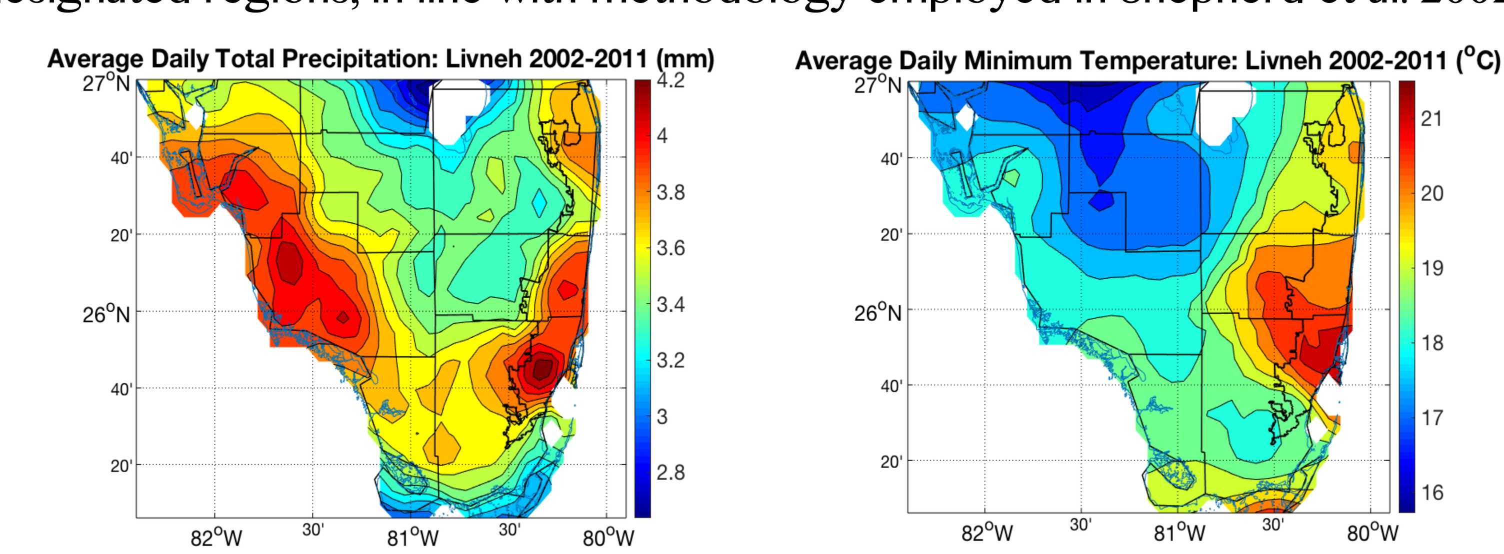
Future analysis will employ several additional datasets and analysis techniques to further our understanding of the behavior of the Miami urban heat island and evaluate potential relationships between its magnitude, mesoscale wind patterns, and precipitation distribution in South Florida on daily, seasonal, and yearly timescales. Datasets we will employ include:

Precipitation:
- North American Regional Reanalysis (NARR) .03° x .03° gridded daily total precipitation (kg/m²)
- South Florida Water Management District (SFWMD) 2 km. x 2 km. gridded daily total precipitation estimates (in.) (NEXRAD-derived)

Temperature:
- Livneh .06° x .06° gridded daily minimum 2-m temperature (°C)
- Moderate Resolution Imaging Spectroradiometer (MODIS) .05° x .05° gridded monthly average Land Surface Temperatures (LST) (K)

Wind Velocity:
- NARR .03° x .03° gridded daily wind velocities (m/s)

Livneh 2-m gridded temperature data and MODIS LST data will be utilized to assess the validity of station-derived UHI analysis. Urban and rural representative grids will be defined to assist quantitative analysis of urban heat island magnitude and precipitation distribution with respect to upwind and downwind designated regions, in line with methodology employed in Shepherd et al. 2002.



Figs. 9-10: Livneh average daily total precipitation (mm) and average daily minimum temperature (°C)

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