

Comparison of the urban heat island signatures of two Texas cities: Dallas and Houston

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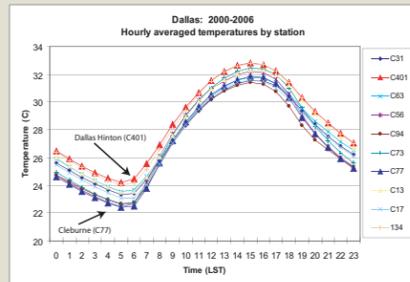
Dallas



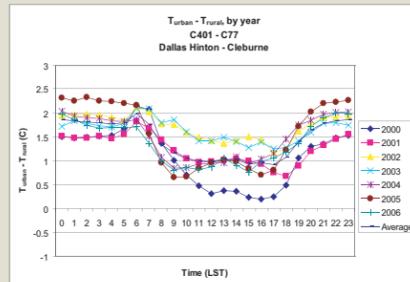
Urban site – Dallas Hinton (C401)



Rural site – Cleburne (C77)



Time series of hourly-averaged surface temperatures for 10 stations in Dallas that were in operation throughout the summers of 2000 – 2006. All data between 1 June and 30 September of each year are included, regardless of weather conditions. The timing of the diurnal cycle of the temperatures is uniform among the stations. Dallas Hinton (C401) was consistently warmer than all other stations. Cleburne (C77) was consistently coolest at night.



$T_{urban} - T_{rural}$ for each of the 7 years analyzed, and the average for all years. Note that the year 2000 had the smallest daytime $T_{urban} - T_{rural}$ difference and 2002 & 2003 had the largest daytime $T_{urban} - T_{rural}$ difference.

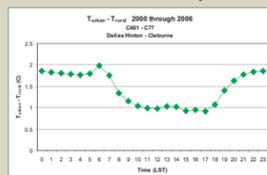
Summary for Dallas Urban Heat Island (UHI)

Strongest nighttime UHI (midnight to 0600 LST): 2005
 Weakest nighttime UHI (midnight to 0600 LST): 2001
 Strongest daytime UHI (1000 – 1800 LST): 2002
 Weakest daytime UHI (1000 – 1800 LST): 2000

On average, Dallas Hinton was 1.4° C warmer than Cleburne.

The average maximum $T_{urban} - T_{rural}$ temperature difference of ~2.0° occurred at 0600 LST.

The average minimum $T_{urban} - T_{rural}$ temperature difference of 0.9° occurred at 1700 LST.



Summary for Houston UHI

Strongest nighttime UHI (midnight to 0600 LST): 2005
 Weakest nighttime UHI (midnight to 0600 LST): 2001
 Strongest daytime UHI (1000 – 1800 LST): 2001
 Weakest daytime UHI (1000 – 1800 LST): 2005

On average, Houston Regional Office was 1.1° C warmer than Conroe.

The average maximum $T_{urban} - T_{rural}$ temperature difference was 2.2° C at 0500 LST.

The average minimum $T_{urban} - T_{rural}$ temperature difference was 0.06° C at 1500 LST.

For Houston, a station's proximity to water can have more of an impact on temperature than the urban/rural difference, particularly during the daytime.



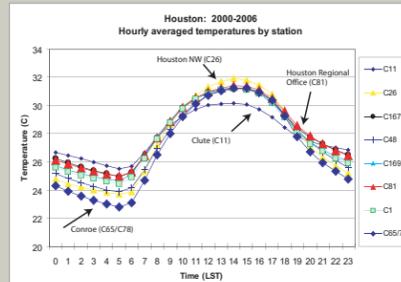
Houston



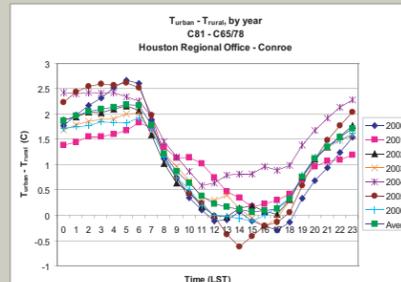
Urban site – Houston Regional Office (C81)



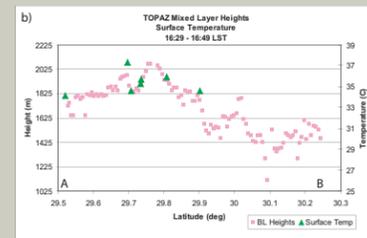
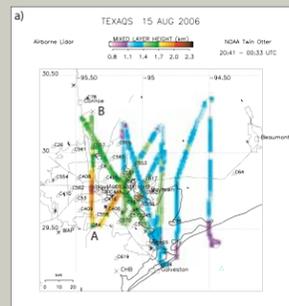
Rural site – Conroe (C65/C78)



Time series of hourly-averaged surface temperatures for 8 stations in Houston that were in operation throughout the summers of 2000 – 2006. All data between 1 June and 30 September of each year are included, regardless of weather conditions. Note the difference in the diurnal cycle pattern between Clute (C11) and the rest of the stations. Clute is closer to the Gulf coast, so the diurnal cycle of the temperature is modified by the station's proximity to the water. Houston NW (C26) is to the northwest of the city, and is not an urban station, but was consistently warmer in the afternoon due to the cooling effect of the sea breeze on the urban/metropolitan stations. The analysis is complicated by the fact that there is no true "downtown" Houston station, and many stations in the Houston metropolitan area are in parks.



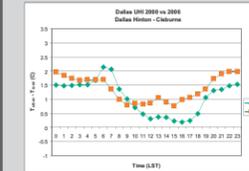
$T_{urban} - T_{rural}$ for each of the 7 years analyzed, and the average for all years. Some years, on average, have a change in sign in $T_{urban} - T_{rural}$ in the afternoon. It is suspected that these years had more sea breeze activity, and therefore more extensive cooling of the downtown stations than during other years. 2000 had the largest $T_{urban} - T_{rural}$ temperature difference of all the years at 0500 LST.



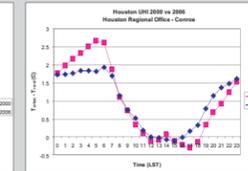
a) Mixed layer heights calculated from TOPAZ backscatter data (15 August 2006). Note the highest mixed layer heights are directly over the Houston downtown area (leg AB). b) Time series of the mixed layer heights for leg AB (pink squares). Surface temperatures from stations close to the flight track are overlaid (green triangles). c) Time series of $T_{urban} - T_{rural}$ for 15 August 2006 shows that TOPAZ measured the enhanced mixed layer heights over the city after the peak in the UHI for this day. The sea breeze caused the urban station to become cooler than the rural station.



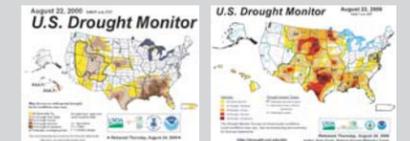
2000 vs 2006



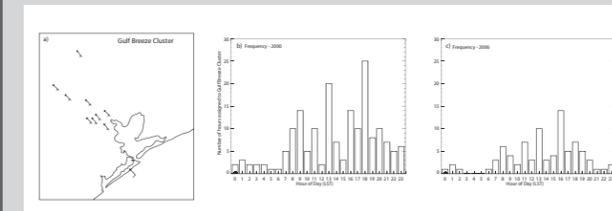
For Dallas, on average, the differences in the urban and rural areas were similar between 2000 and 2006, with the average difference 0.3° smaller in 2000. The average variability was similar between the two years.



Houston had the same average $T_{urban} - T_{rural}$ temperature difference in 2000 and 2006, but had more variability in 2000. The standard deviation for $T_{urban} - T_{rural}$ temperature differences in 2000 was 1.0° C vs 0.77° C in 2006.

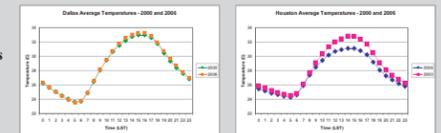


In mid-August 2000, drought conditions over most of Texas ranged from abnormally dry to extreme, with Houston experiencing a severe drought, while Dallas was in a first-stage drought. In mid-August 2006 conditions were much worse, with the mid-section of the United States, including Dallas, experiencing drought conditions running from abnormally dry to exceptional. Houston, however, was spared drought conditions at this time.

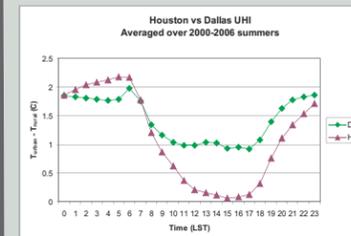


(a) Cluster analysis of the winds for the combined 7 summers yielded a wind pattern representing a Gulf breeze. Houston had more instances of Gulf breeze activity in 2000, as shown in the comparison of frequency-of-occurrence plots for this cluster between 2000 (b) and 2006 (c).

There was very little difference in the average temperatures for Dallas between 2000 and 2006. Houston temperatures were cooler throughout all hours in 2006 compared to 2000. The drought conditions in 2000 caused higher surface temperatures, which then enhanced the land/water temperature difference that drives the sea breeze.



Houston vs Dallas



Both Dallas and Houston, Texas have comprehensive networks of surface meteorology and chemistry sensors. The similarities of the networks and lack of terrain in Dallas and Houston allow for the comparison of their urban heat islands (UHI). The Dallas UHI, unperturbed by thermal flows driven by the land/sea temperature difference, is a well-defined phenomenon over the summers of 2000-2006. Including all weather conditions, the average nighttime $T_{urban} - T_{rural}$ temperature difference was between 1.5° and 2.0° C and the average daytime difference was ~1.0° C. Analysis of Houston temperature data, however, revealed a different picture due to the bay and gulf breezes. While the Houston UHI was a distinct phenomenon, even when including all weather conditions, the bay or gulf breeze modified the Houston UHI by cooling the city. Average nighttime $T_{urban} - T_{rural}$ temperature differences in Houston were between 1.75° and 2.75° C. However, during the day, the rural areas to the north and west of the city were often warmer than the downtown area during afternoon hours as a result of the sea breeze. Averaging the Houston $T_{urban} - T_{rural}$ temperature differences over the summers of 2000-2006 indicated a very small urban-rural temperature difference between 1400 to 1600 LST. In some individual years, such as 2000, 2003, 2005 and 2006, the urban areas were actually cooler than the rural areas, on average, in the mid-afternoon. These years had more bay breeze/gulf breeze activity to cool the urban area.

Future Work

Incorporate vertical sounding data.
 Incorporate cluster analysis of the winds to cull out wind patterns to categorize days for further UHI analysis.
 Evaluate what, if any, of the UHI characteristics contribute to ozone exceedances.