# The Anthropogenic Urban Heat Island Effect in Nuuk, Greenland


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## Research Question

**Has urbanization impacted the local climate in Nuuk, Greenland?**

## Background

- Greenland is urbanizing, as emigration from villages to cities increases.
- Today, 85% of Greenlanders live in cities.
- Greenland's capital and largest city, Nuuk, has experienced major growth.
- It is projected that by 2025, 50% of Greenlanders will reside in Nuuk (2013, 29%).
- Nuuk's population and mean annual temperatures steadily increased.

*A view of Nuuk from the past*
*Photo Credit: http://edamberg.skysite.dk/*

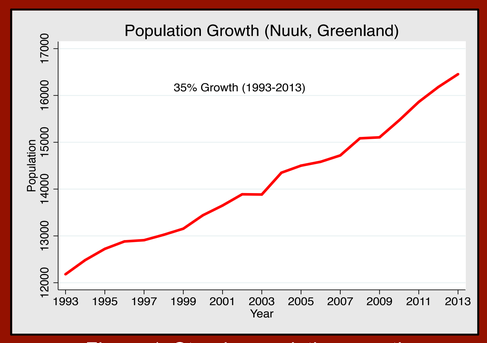


*Figure 1. Steady population growth*

*A view of Nuuk today*

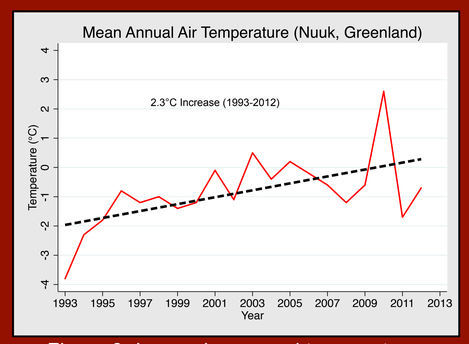


*Figure 2. Increasing annual temperatures*

## The Urban Heat Island (UHI) Effect

- Is among the best expressions of human impact on local climate, and describes the temperature difference between an urban area and its surrounding rural areas.
- The net flux of heat into the atmosphere, known as anthropogenic heat release, results from the concentration of buildings and other impervious surfaces, and the use of fossil fuels to generate power for buildings, vehicles and other activities.
- The UHI magnitude (UHIM) is defined as the temperature difference between the urban (u) area and rural (r) area, or $\Delta T_{u\text{-}r}$, examined at different temporal scales.
- High-latitude cities provide a unique opportunity to evaluate anthropogenic UHI:
  - UHI exhibits maximum development and intensity in the winter,
  - anthropogenic influences on local warming are isolated because solar contributions are negligible during cold, dark arctic winters, and
  - summer energy demands are minimal, compared to lower latitude cities where air conditioning is required, thus exhibiting a weak or nonexistent UHI in summer.

## UHI and Energy Consumption for Heat

| Season | Winter | Spring | Summer | Fall | 2005-2010 |
|---|---|---|---|---|---|
| UHIM (°C) | 0.5 | 0.1 | -0.4 | 0.2 | 0.1 |

*Table 1. Seasonal UHIM (2005-2010)*

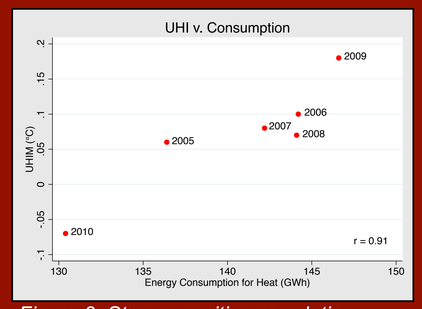


*Figure 3. Strong, positive correlation between UHIM and annual energy consumption for heat*

- Seasonal and annual UHIM ($\Delta T_{u\text{-}r}$) were calculated using temperature data from two local weather observation stations; WS 4250 near the city center (u) and WS 4254 at the airport (r).
- On average, between 2005 and 2010*, temperatures near the city center were slightly warmer than outside the city; maximized in winter (*See Table 1*).
- Annual UHIM exhibits a strong, positive correlation ($r$ = 0.91) with annual energy consumption for heating (*See Figure 3*).

**Note: 2010 was a record warm year, requiring less consumption of heating energy, resulting in a nonexistent UHI effect.*

## Improving the Analysis, 2011 UHI Study

For improved representation of temperatures in the city center, data from two additional weather observation stations was included to calculate spatially averaged temperatures.

**Weather Station Locations**

(rural) WS 4254 Airport
(urban) WS 4250
(urban) WS 522
(urban) WS 500


| Month* | Urban $T_{avg}$ (°C) | Rural $T_{avg}$ (°C) | UHIM $\Delta T_{(u\text{-}r)}$ (°C) |
|---|---|---|---|
| January | -4.3 | -5.0 | 0.7 |
| February | -8.6 | -9.7 | 1.1 |
| May | 0.2 | -0.2 | 0.4 |
| June | 4.6 | 4.6 | 0.0 |
| July | 8.0 | 8.2 | -0.2 |
| August | 6.2 | 6.2 | 0.0 |
| September | 2.9 | 2.4 | 0.5 |
| October | -0.9 | -1.6 | 0.7 |
| November | -4.1 | -5.0 | 0.9 |
| December | -6.3 | -7.1 | 0.8 |
| **Annual** | **-0.2** | **-0.7** | **0.5** |
| **Winter** | **-6.5** | **-7.4** | **0.9** |
| **Summer** | **6.3** | **6.3** | **0.0** |

*Table 2. Monthly UHIM (2011)*

**Note: March and April omitted due to a significant amount of missing data for one station*

Table 2, demonstrates that on average temperatures around the city center were 0.5°C warmer than temperatures at the airport in 2011. The monthly UHIM reached a maximum of 1.1°C in February. July exhibited a negative UHIM value indicating the presence of an "inverse heat island" or "cold island" often attributed to shading effects and minimal nocturnal heat loss during the summer in high-latitude cities. The UHIM was 0.9°C in winter and nonexistent in summer. The maximum daily UHIM reached 2.3°C on 17 February.

## UHI and Heating Need

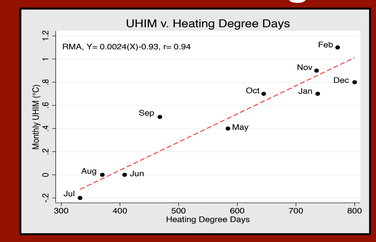


*Figure 4. Strong, positive correlation between UHIM and heating degree days*

One measure of winter severity and heating need utilizes heating degree days (HDD). This is a measure of the amount of energy needed to maintain building interiors at a comfortable level (19° C for Greenland). Figure 4 shows the relation between average monthly UHIM in 2011 and monthly HDD, based on reduced major axis (RMA) analysis. A strong positive relation ($r$ = 0.94) exists between heating need and the magnitude of the UHI. Additionally, calculating freezing degree days (FDD), using a base of 0°C, the city center accumulated 13% fewer FDD than the airport area. Warmer urban air has the potential to alter snow accumulation or accelerate the ablation of snow cover.

## Discussion and Conclusions

- This study demonstrates the existence of an urban heat island effect in Nuuk. On average, the city center was warmer than the less developed airport area.
- Energy used to heat buildings eventually escapes into the atmosphere creating warmer temperatures in urban areas. Urban warming in Nuuk displays a strong, positive relation to anthropogenic heat release, using energy consumption for heating and heating degree days as proxies.
- The UHI has a strong seasonal component. The UHI exhibits maximum development and intensity during winter months and is nonexistent during summer months.
- The effects of climate change coupled with social, political and economic influences will continue Greenland's trends of urbanization and emigration from villages to cities.
- A better understanding of the environmental impacts of urbanization may enhance planning and policies and facilitate more sustainable urban development.

### References


Hinkel, K.M., et al. (2003). The Urban Heat Island in Winter at Barrow, Alaska. *International Journal of Climatology*, 23(15), 1889-1905.


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