Urban Heat Islands

GEOG/ENST 3331 – Lecture 17

Ahrens: Chapter 18; A&B: Chapter 14

Assignment 7

- Describe three environmental hazards are presented by Arctic Haze.
- Global (1.1 C)and regional warming (2 to 2.5 C in Prairies and Northern Ontario) experienced to date may seem relatively small. Why does almost all of the scientific community with atmospheric and terrestrial expertise say it is urgent to reduce emissions?
- Issued March 2 DUE March 9

Last lecture

- Arctic Haze
- Persistent Organic Pollutants
  - Bioaccumulation and biomagnification
  - Transport to the Arctic
- Stockholm Convention

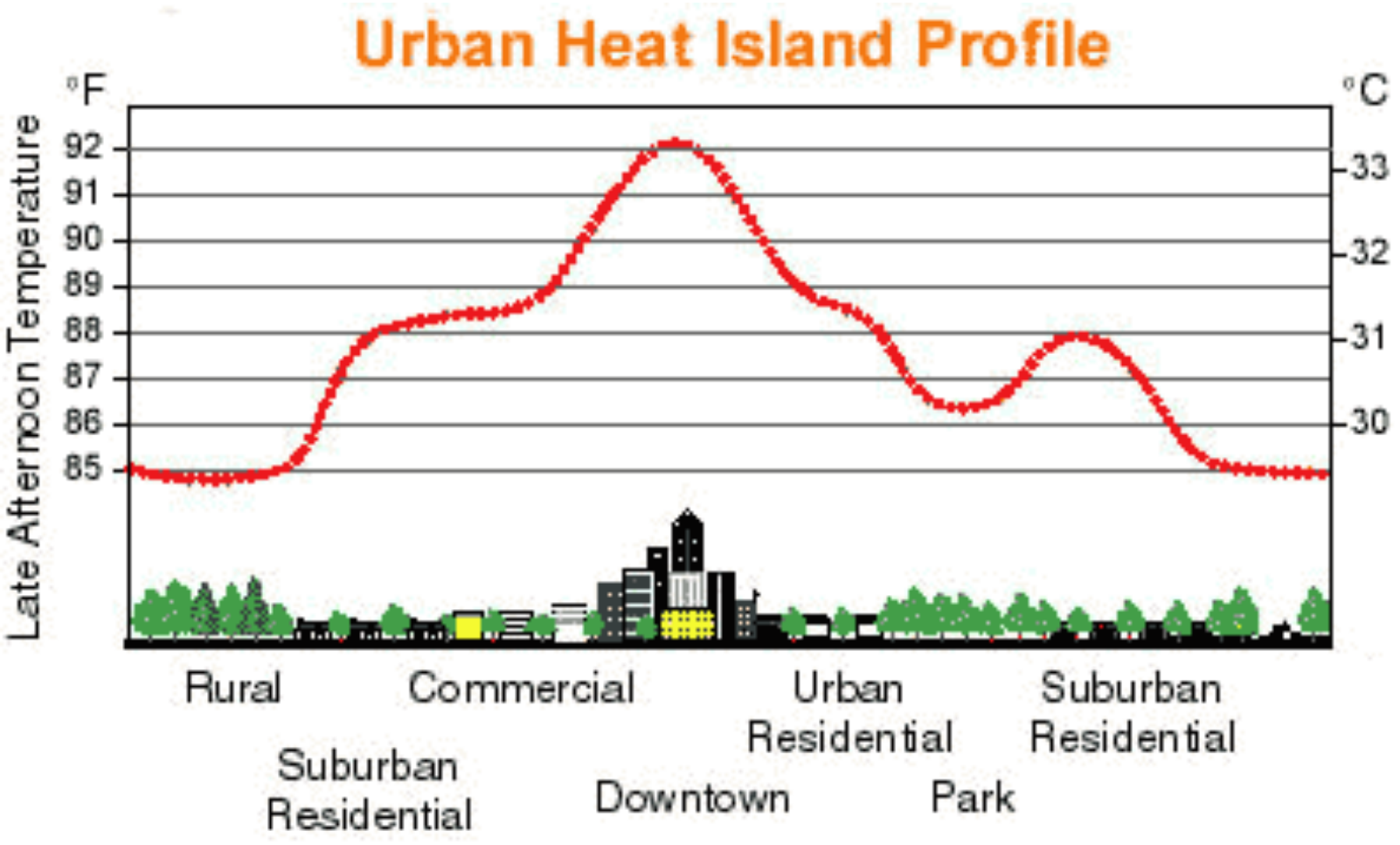
Outline for Urban Heat Islands

- **Urban heat island**
  - **Causes and Effects**
  - **Links to population, power generation**
- Heat island research
- Mitigation
- Urban heat island and climate change

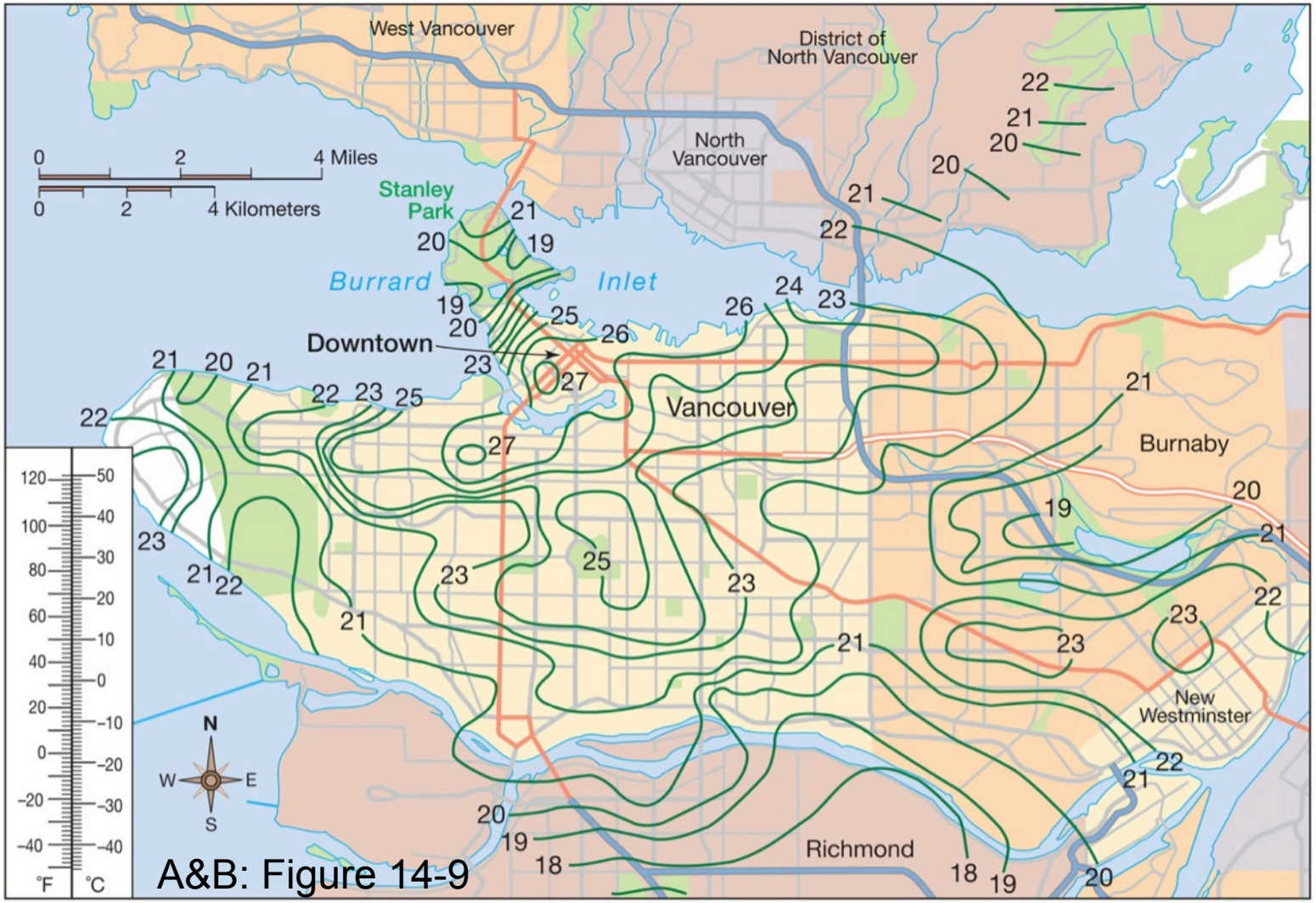
Urban Heat Island

- Most noticeable at night and in the winter months
- More intense when winds are weak or non-existent
- Typically 2-6°C warmer in city core
- Mitigated by green space, water

Urban Heat Island



Vancouver Heat Island



A&B: Figure 14-9

Urban Heat Island

- What causes it?
  - Reduction of evaporation
  - Reduced albedo
  - Greater heat capacity
  - Generation of heat
- No dominant mechanism, city dependent

Suppression of Evaporation

- Radiant energy from the sun is used at the surface to either heat the surface or evaporate water
  - Heating the surface increases the surface temperature
  - Evaporation converts the energy into latent heat and does not increase the surface temperature

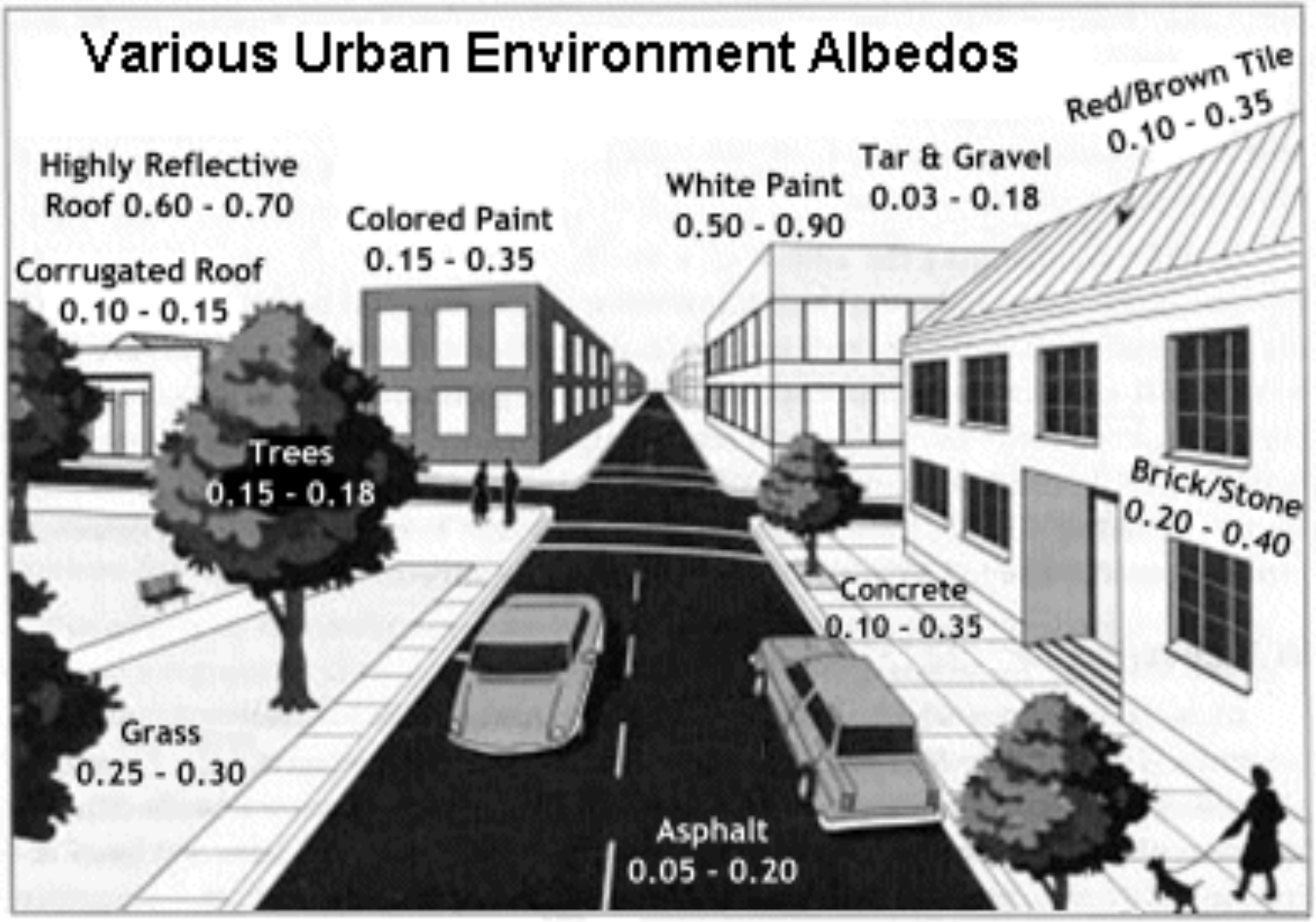
- Urban environment
  - Paved surfaces instead of bare soil
  - Lack of vegetation

Albedo Changes

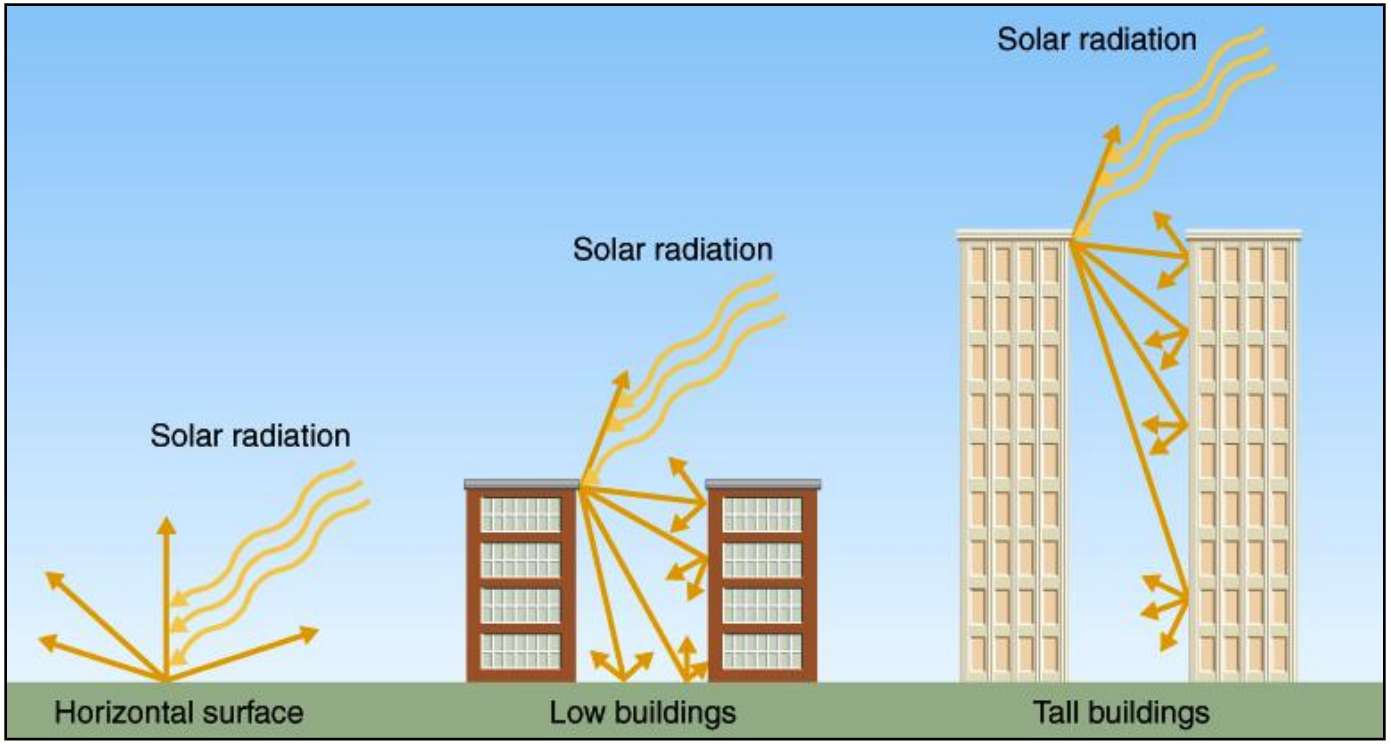
Snow has a high albedo approaching 1

In urban areas there is less snow

Snow that does fall is removed



Urban Canyons

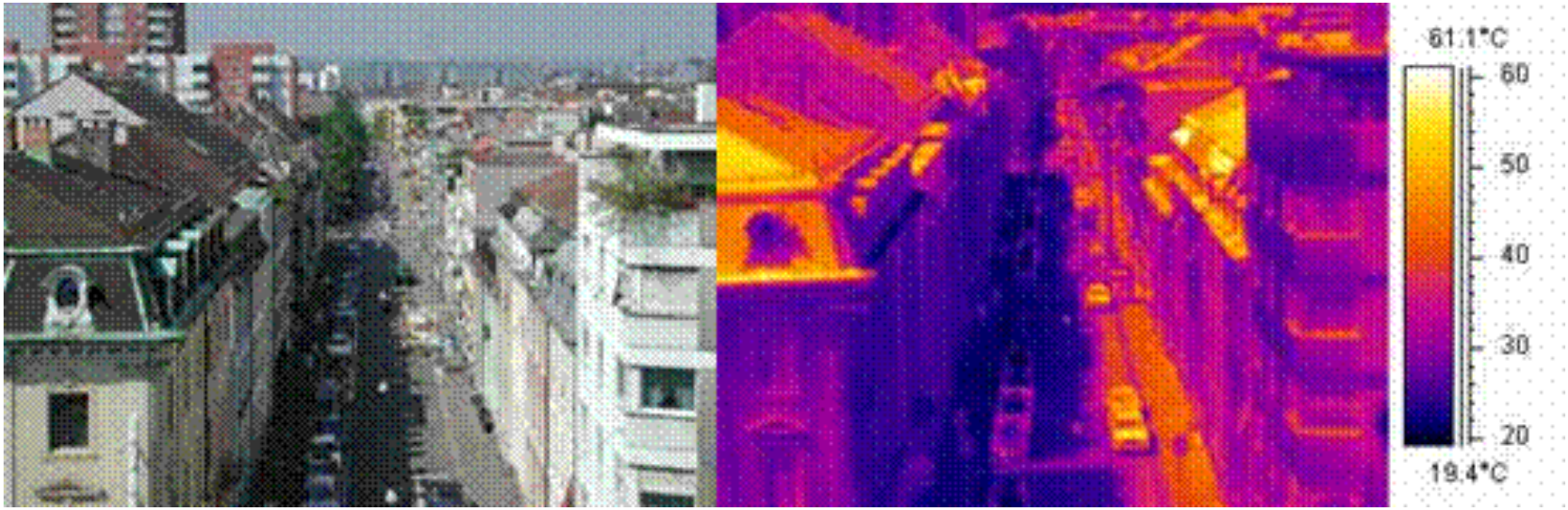


- Tall buildings create a complex geometry which helps absorb radiation (canyon effect) and alters air flow, reducing convection.

A&B: Figure 14.10

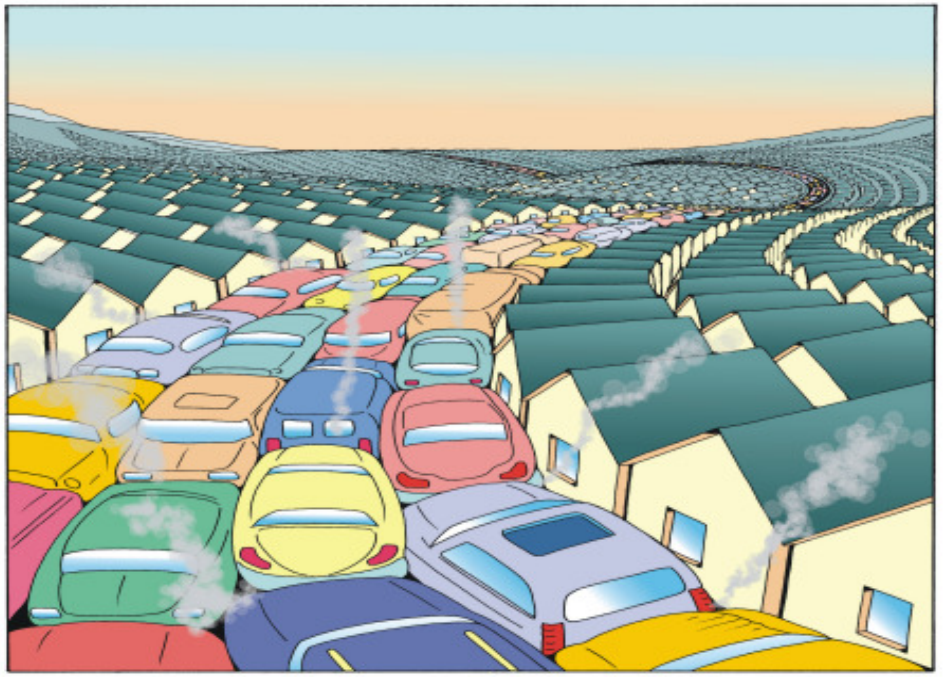
Urban Heat Capacity

- Urban environment has a large heat capacity, therefore cools more slowly at night



Urban Generation of Heat

- Industry, motor vehicles, domestic heating and air conditioning release large quantities of heat
- Urban pollution can prevent release of excess heat



Urban Versus Rural Conditions

Ahrens: Fig. 18.17

CONSTITUENTS	URBAN AREA (CONTRASTED TO RURAL AREA)
Mean pollution level	higher
Mean sunshine reaching the surface	lower
Mean temperature	higher
Mean relative humidity	lower
Mean visibility	lower
Mean wind speed	lower
Mean precipitation	higher
Mean amount of cloudiness	higher
Mean thunderstorm (frequency)	higher

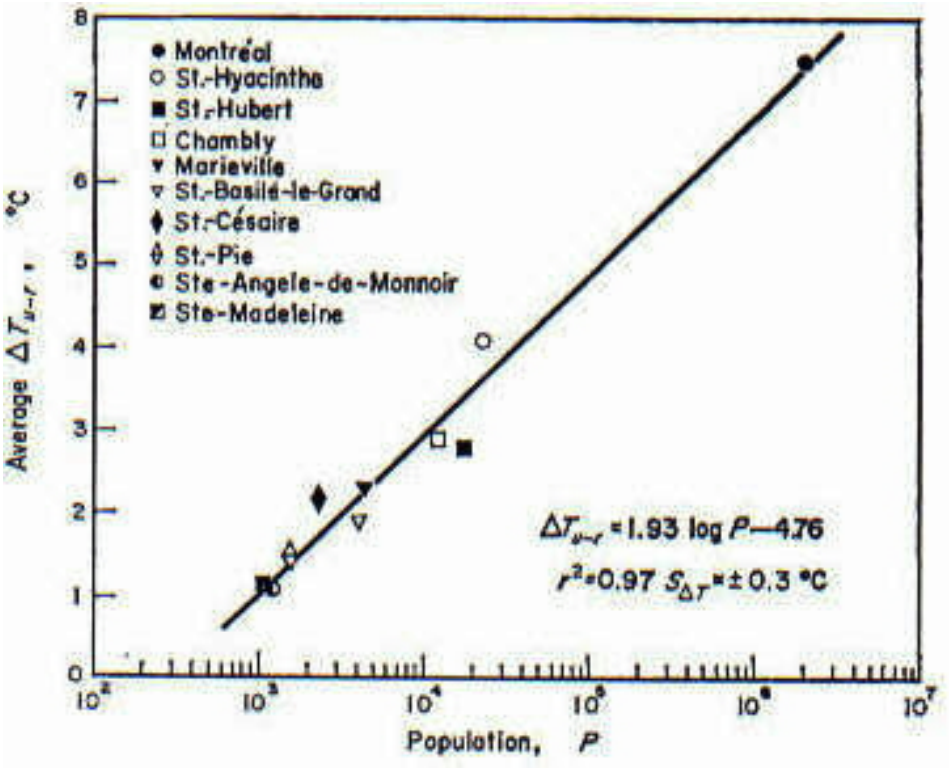
Ahrens: Table 18.4

Urban Heat Island and Population

- Tim Oke (1973) – McGill University
  - Linked heat island to population
  - Biggest difference is in daily minimum temperature

Oke (1973)

- $\Delta T = 1.93 \log(P) - 4.76$
- ΔT is the temperature difference between the urban area and the rural area
- P is the population
  - log is the base-10 logarithm



Lecture outline

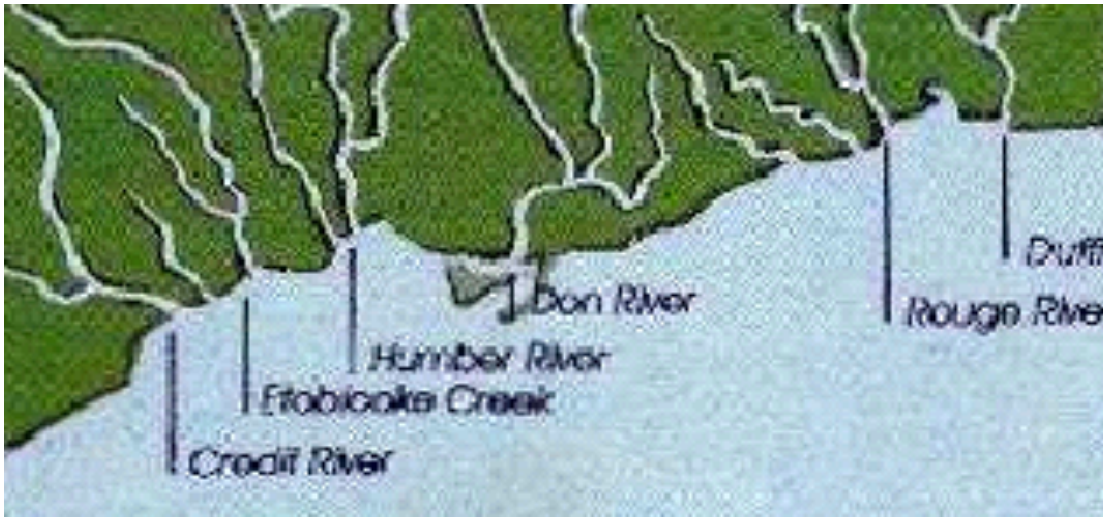
- Urban heat island
- **Heat island research**
  - **Toronto studies**
  - **Other examples**
- Mitigation
- Urban heat island and climate change

UHI in Toronto

- Downtown / Pearson comparison
- Toronto / Vineland comparison
- Attribution

Toronto's Heat Island

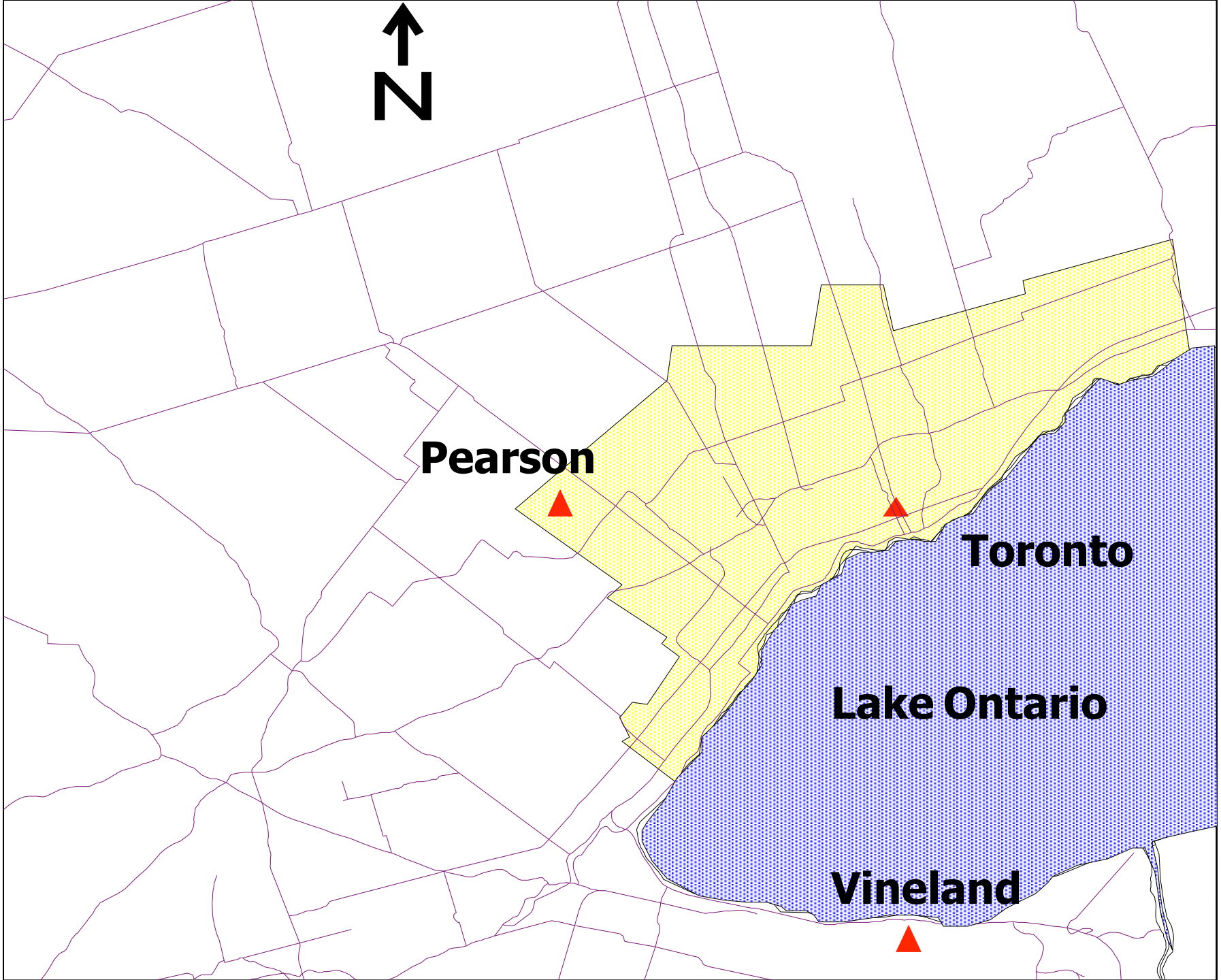
- Ted Munn – University of Toronto
  - 1967 - First thorough examination of Toronto's micro-climate
- Discovered a well defined heat island focused on the downtown
  - Modified by wind and topography
  - UHI shaped by cool air intrusion from Lake Ontario flooding up the Humber, Don and Rouge Valleys

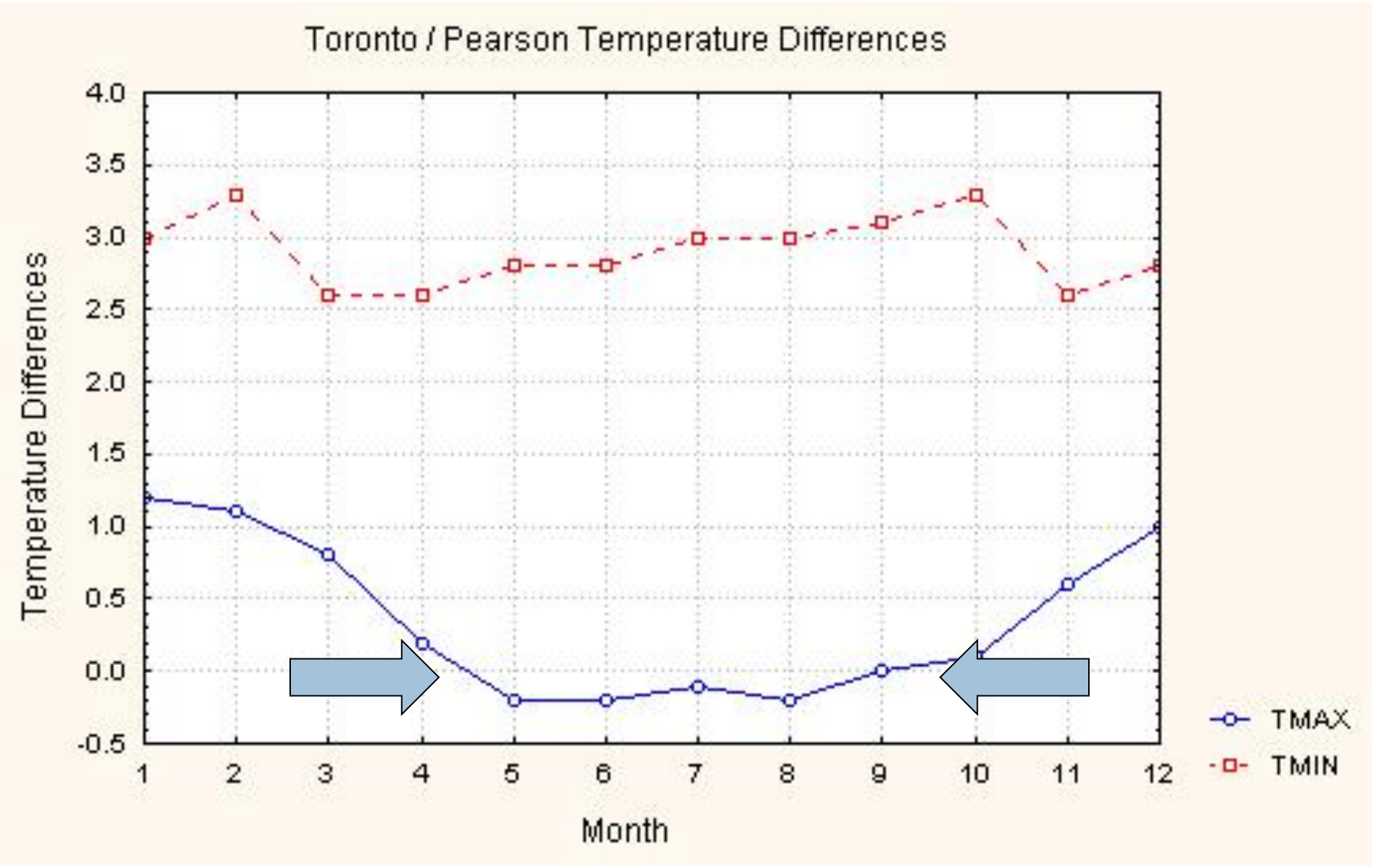


Toronto, Ontario

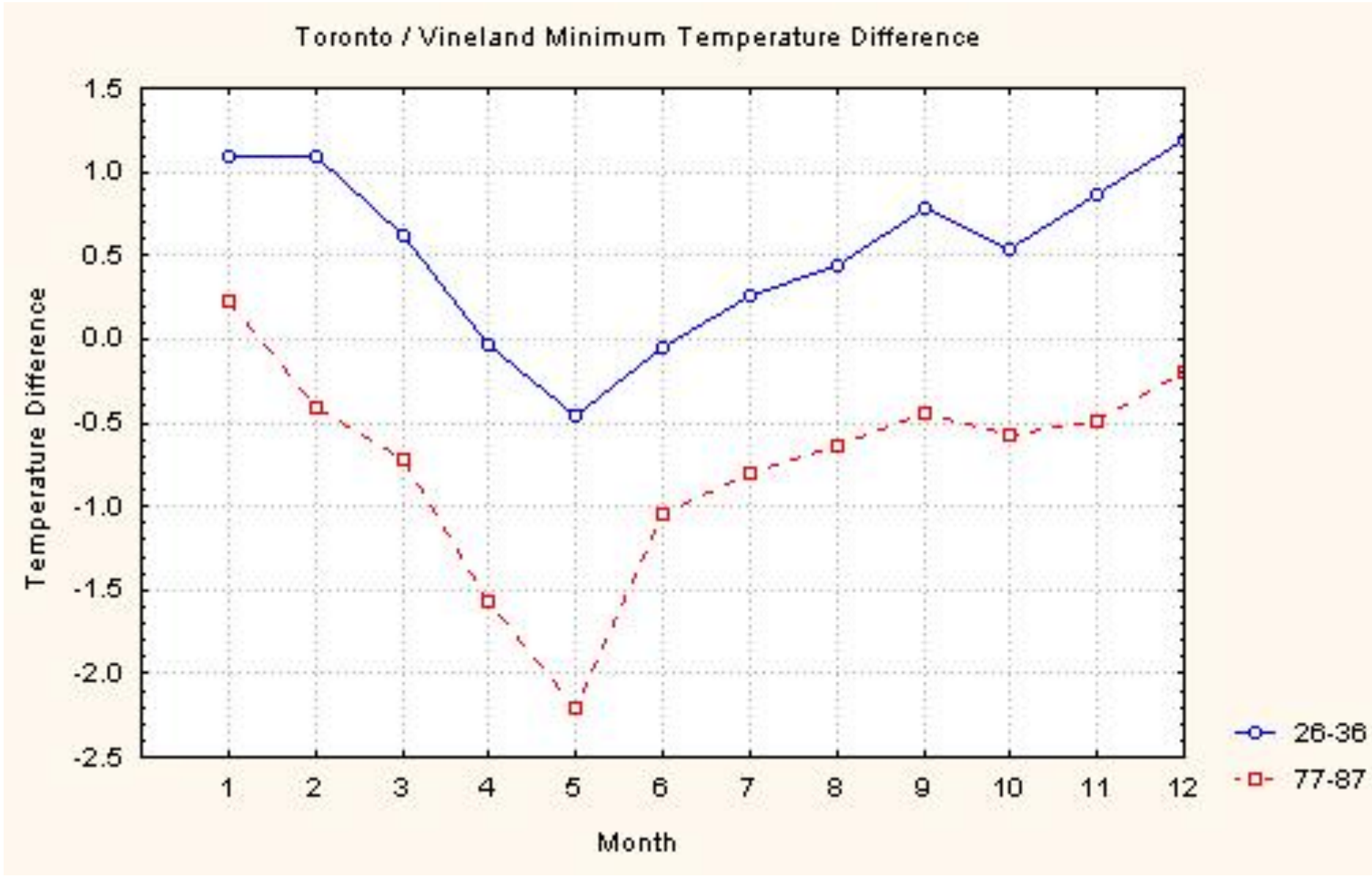
Gough and Rozanov (2001)

- Using climate normals, Urban Heat Island was assessed for Toronto, Ontario
- Current comparison: downtown Toronto with “rural” site at Pearson Airport
- Long-term comparison: with Vineland, Ontario


N
Pearson
Toronto
Lake Ontario
Vineland



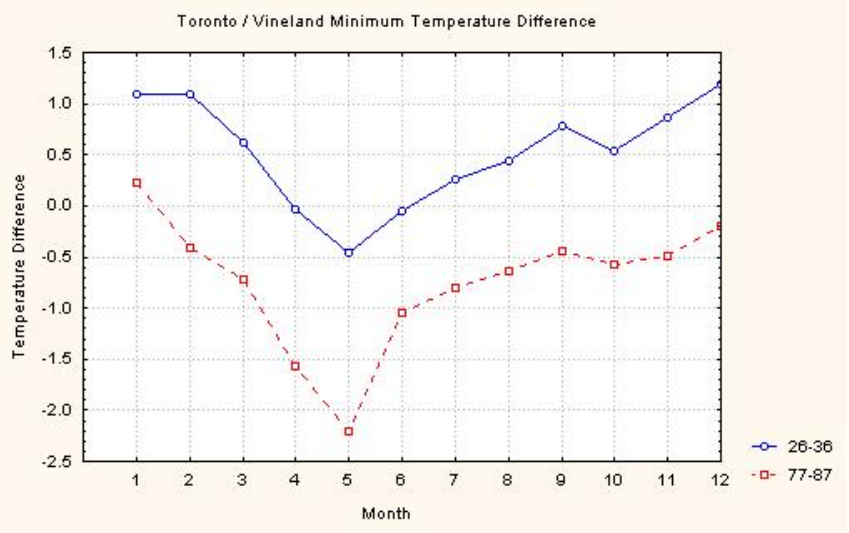
Toronto T (°C) – Pearson T (°C)



Vineland *T* (°C) – Toronto *T* (°C)

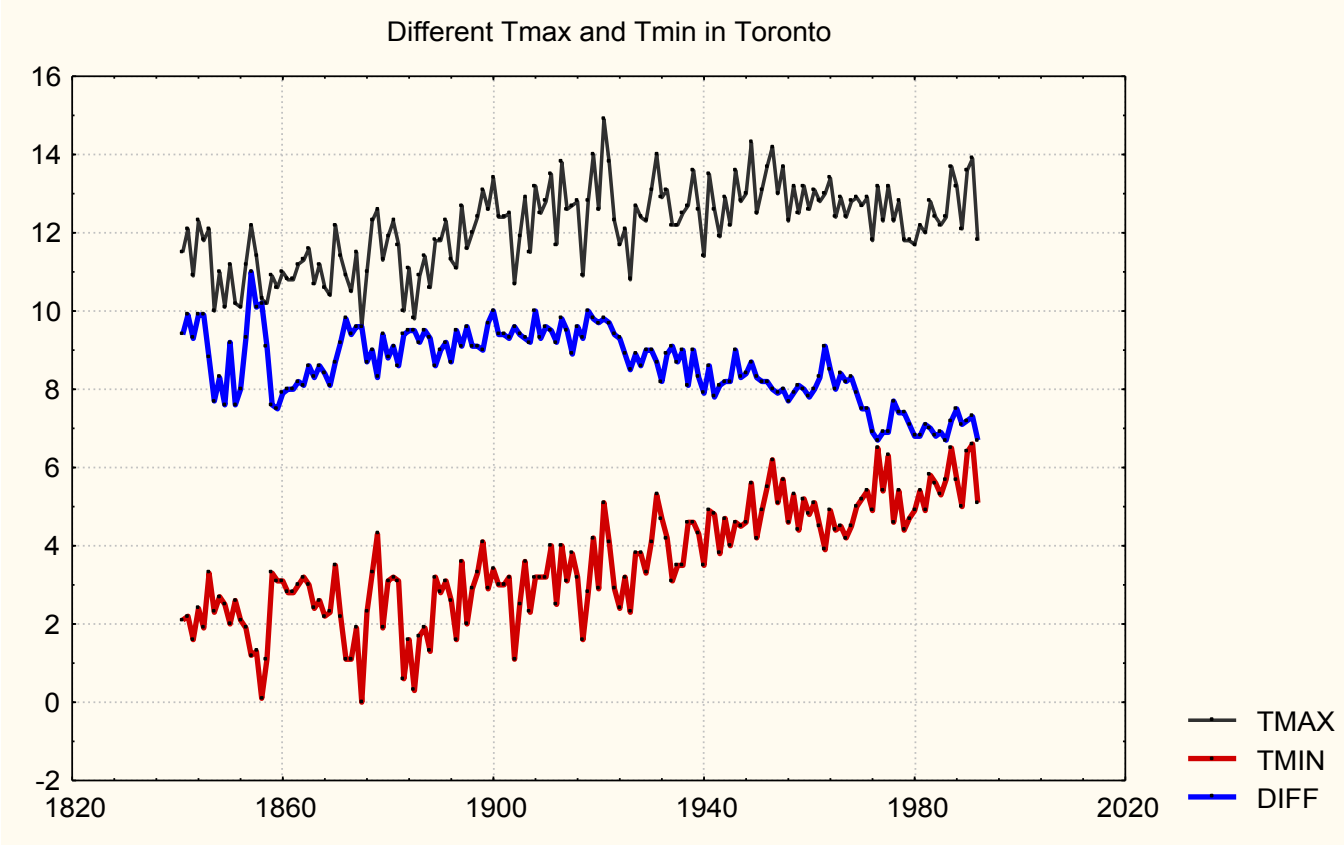
Gough and Rozanov (2004)

- Does the urban heat island change with time?
- Vineland results suggest that it has
- Further investigation



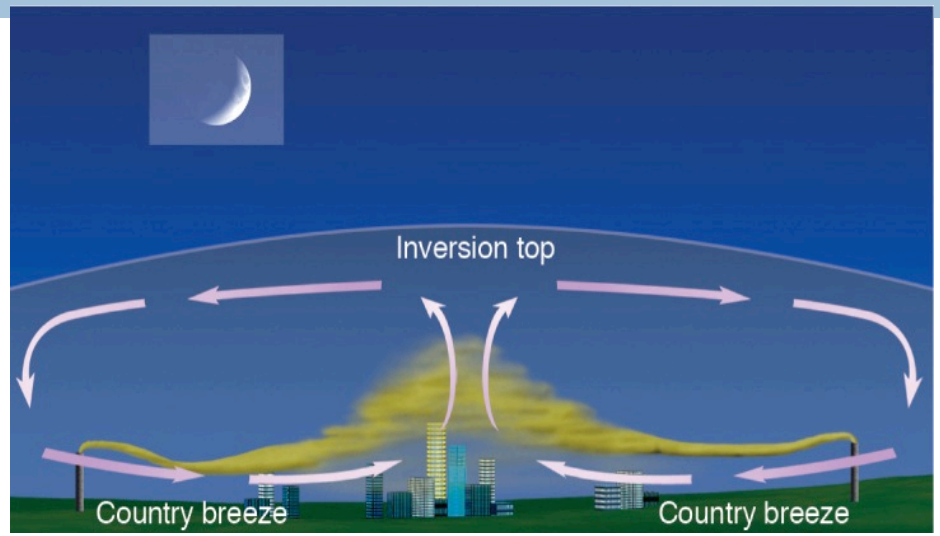
Diurnal Temperature Range

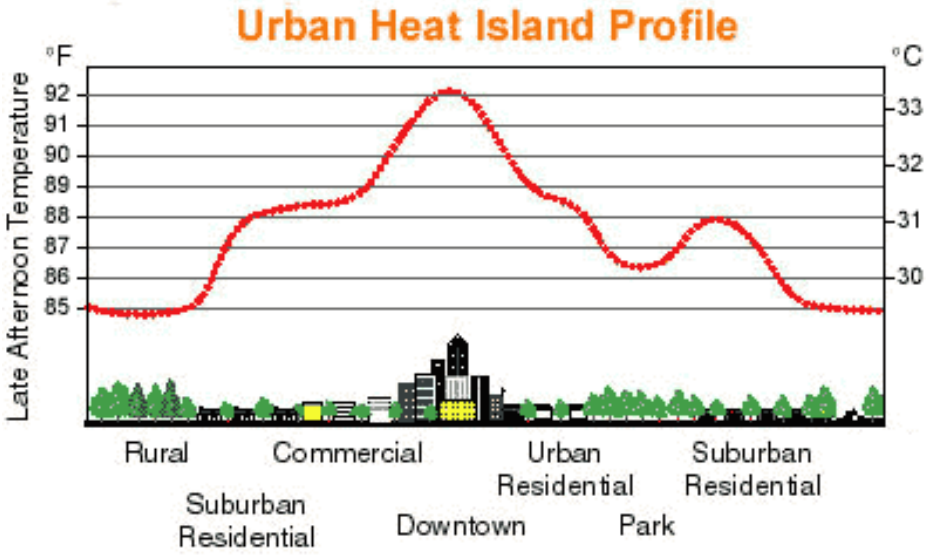
Time series from downtown Toronto station 1840-2000



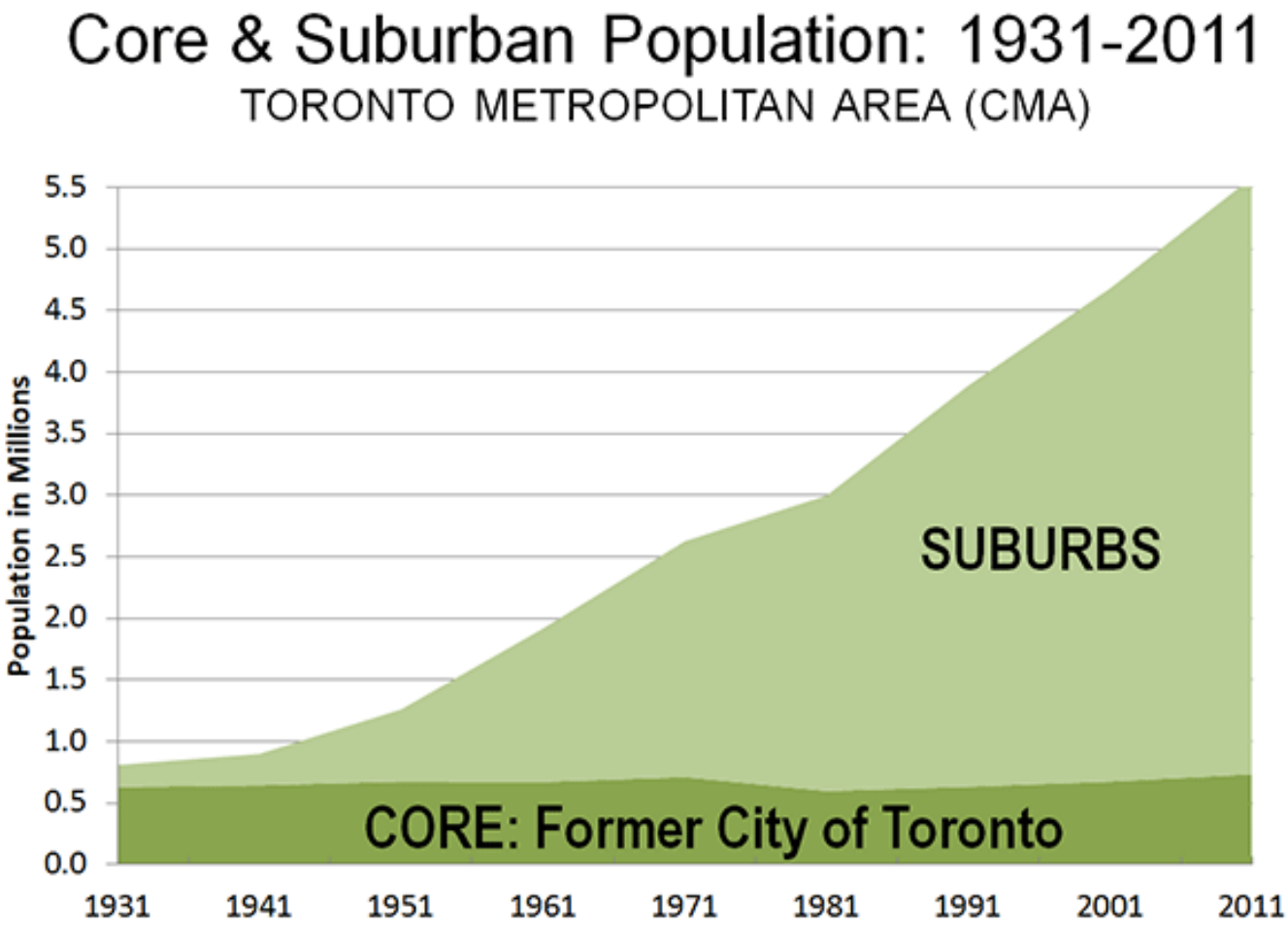
Diurnal Temperature Range

- Hypothesis: country breeze is no longer cooling the city at night
- Urban sprawl has spread far beyond downtown
- Now a "suburban" breeze





Urban sprawling



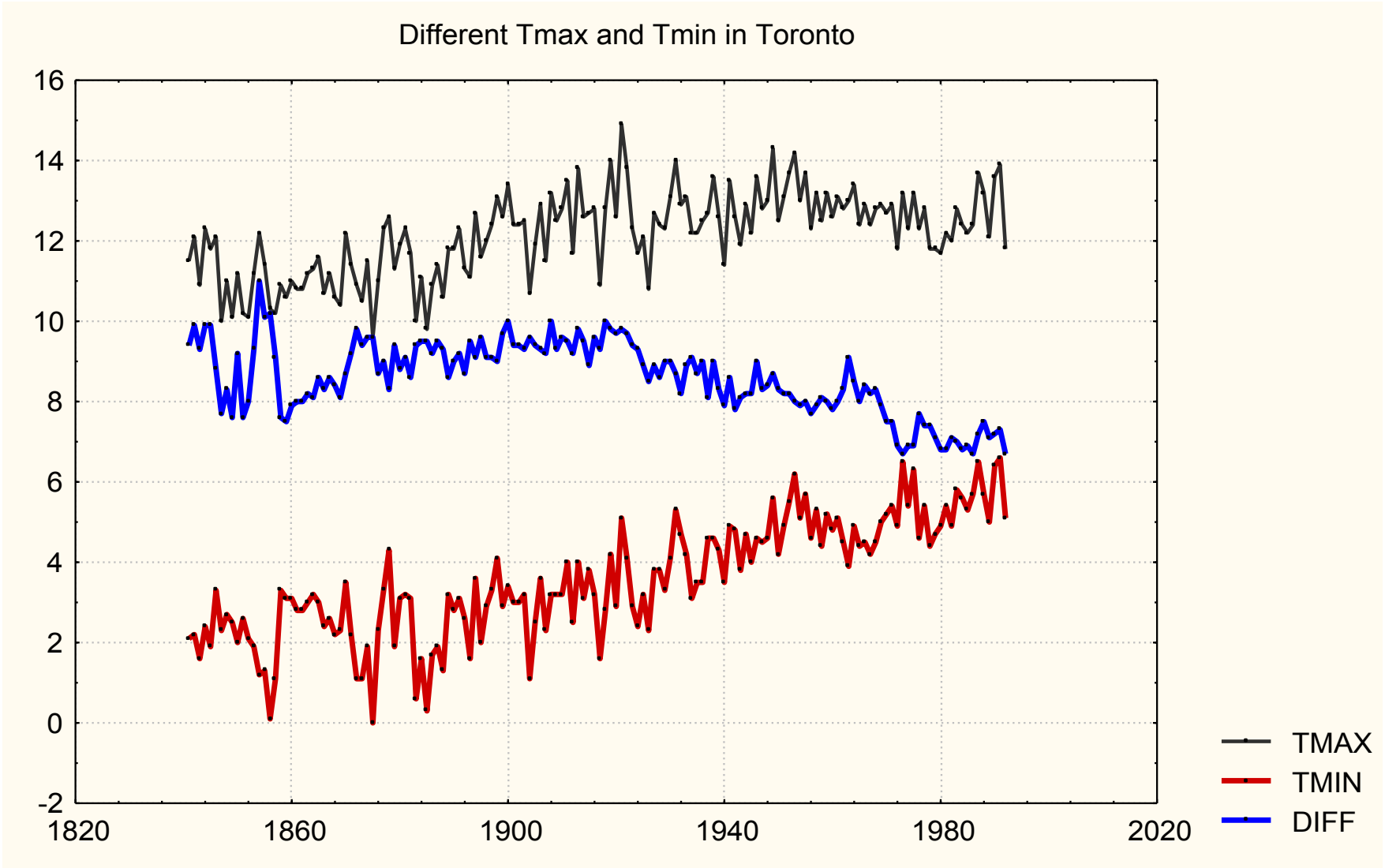
Source: NewGeography.com, Statistics Canada

Correlation vs. Causality

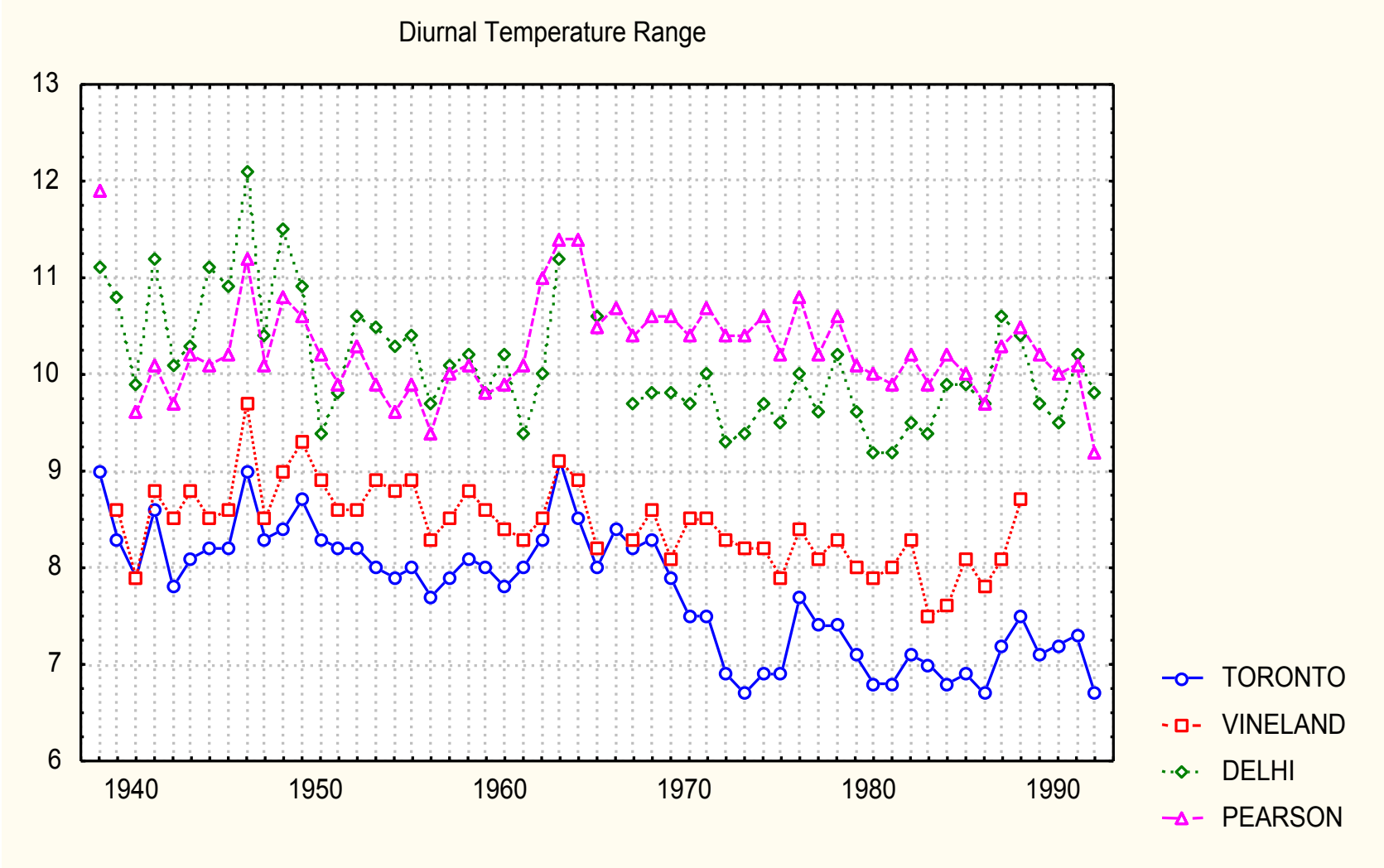
- Two changes happening at the same time does not necessarily indicate that one caused the other

- Alternate hypothesis: global warming
  - GHGs lead to constant heat trapping
  - Aerosol pollution has a cooling effect during the day *but not at night*
  - Therefore the diurnal temperature range is reduced

Revisit Data



Rural Comparison



Coincidence vs. Causality

- Decreases in diurnal temperature range:
  - Toronto: 1.2 C°
  - Vineland: 0.6 C°
  - Delhi: 0.6 C°
  - Pearson: invalid due to station relocation
- Similar results from comparison of Montréal with nearby Oka, Québec

Summary

- Intensifying UHI in Toronto
- Changes in diurnal temperature range
  - Influence of expanding urbanization
  - Suppression of the country breeze
  - Also influenced by global climate change

Other Examples

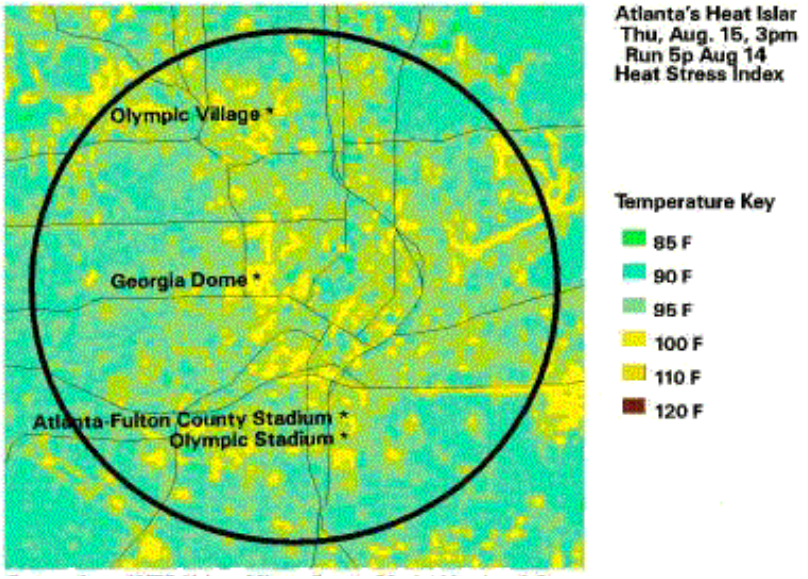
- Sacramento, California
- Atlanta, Georgia
- Thunder Bay?

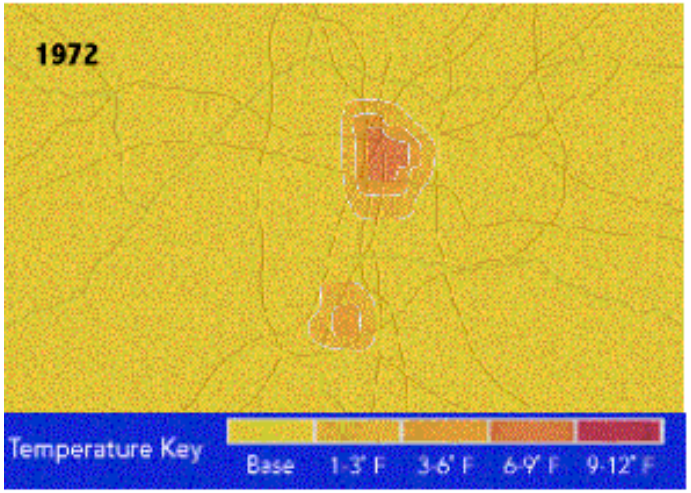
Sacramento, California

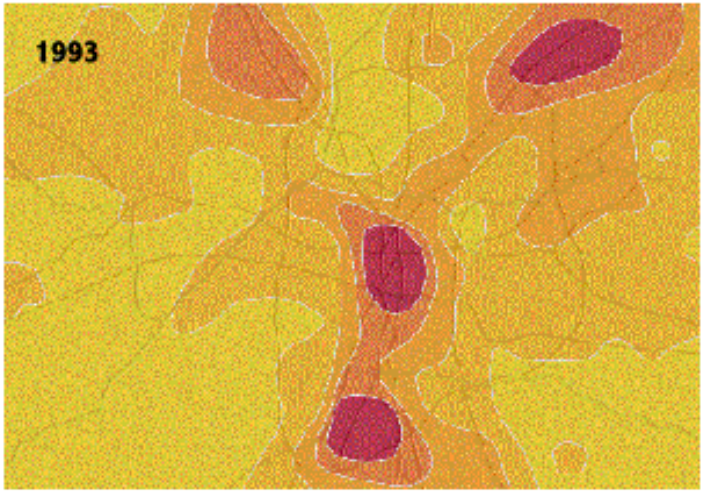
- Satellite image of Sacramento, California
- White is warmest, blue is coolest

Atlanta, Georgia

- Rapidly growing city
- Greatly enhanced UHI from 1972 to 1993







Lecture outline

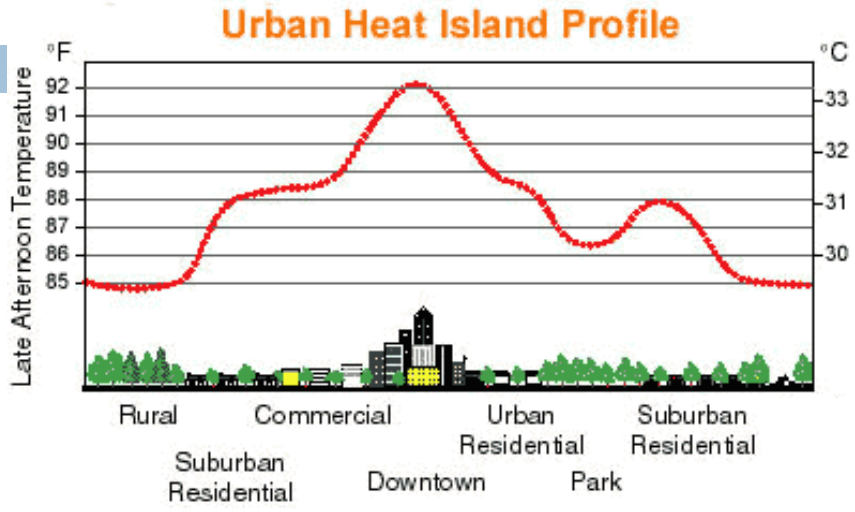
- Urban heat island
- Heat island examples
- **Mitigation**
- Urban heat island and climate change

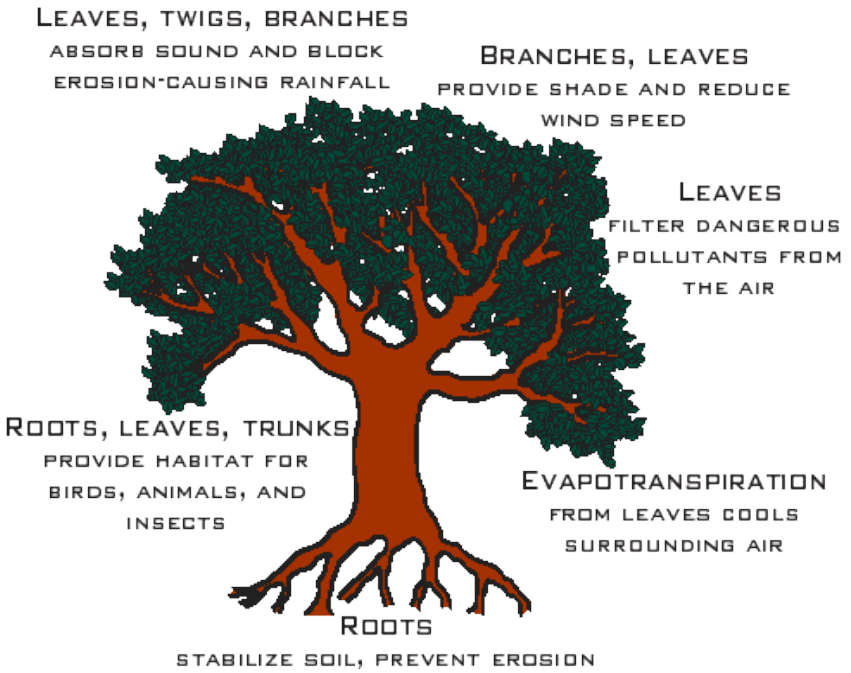
Mitigation

- Why?
  - Energy demand (air conditioning)
  - Extra precipitation (snow clearing)
  - Runoff (thermal pollution)
  - Heat waves (human health and comfort)

Mitigation Efforts

- Reduction of urban sprawl
- Introduction of green spaces
  - 1 urban tree is worth 16 in the bush:
    - Provides shade
    - Changes albedo
    - Reduces need for air conditioning
- 'Green roofs'
  - Albedo modifications to make roofs more reflective
  - Increased latent heat loss from evaporation
  - Can be applied to pavement and building materials





Lecture outline

- Urban heat island
- Heat island examples
- Mitigation
- **Urban heat island and global climate change**

Urban Heat Island and Climate Change

- Global warming
  1. How much of the overall global warming is actually from urban heat islands, rather than general increase in greenhouse gases?
  2. Some of the stations used in the global assessment of climate change come from urban areas which have changed in size and population and therefore have a stronger UHI. Does this affect that assessment?

Urban Heat Island and Climate Change

- Intergovernmental Panel on Climate Change (IPCC)
- 1997 Conclusions:
  - UHI has an impact on global temperature rise
  - Estimate using urban/rural comparisons indicate that warming due to urbanization accounts for *at most* 0.05°C of the observed globally warming of about 0.6°C (a little under 10%)
  - Deforestation is a bigger influence than urbanization, causing a slight global co*oling* due to increased albedo

UHI and Climate Change

- Do increasing UHIs distort the observed temperature record?
- No:
  - Typically observation stations are located outside cities (parks, airports, etc.)
  - Studies that exclude urban stations show the same trend
  - UHI changes can be corrected for

Next lecture

- Depletion of ozone in the stratosphere