# WARNING CITIZENS OF THE HEALTH RISK OF SEVERE WEATHER: STATUS AND PROJECTIONS

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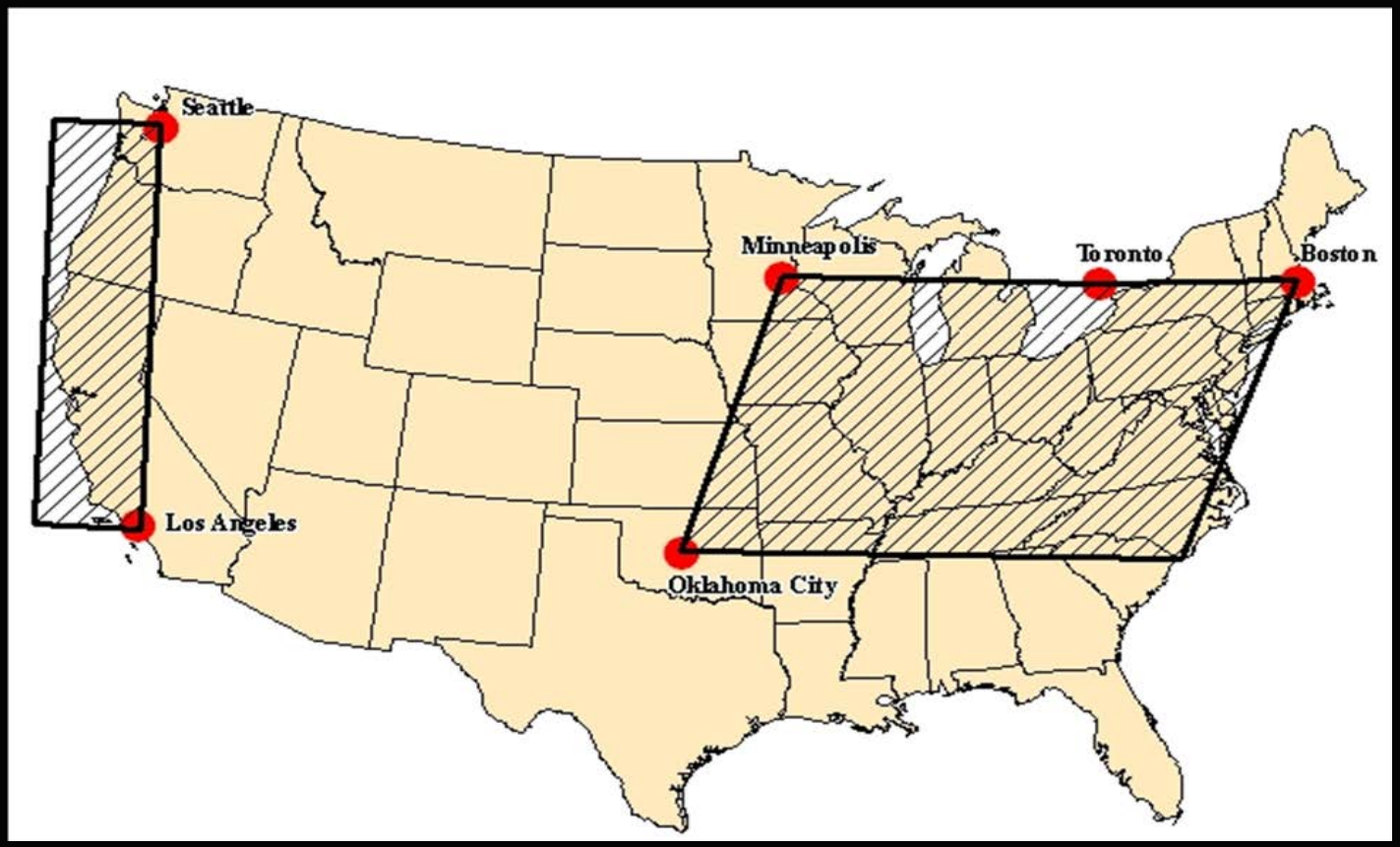
# We Have A Problem!

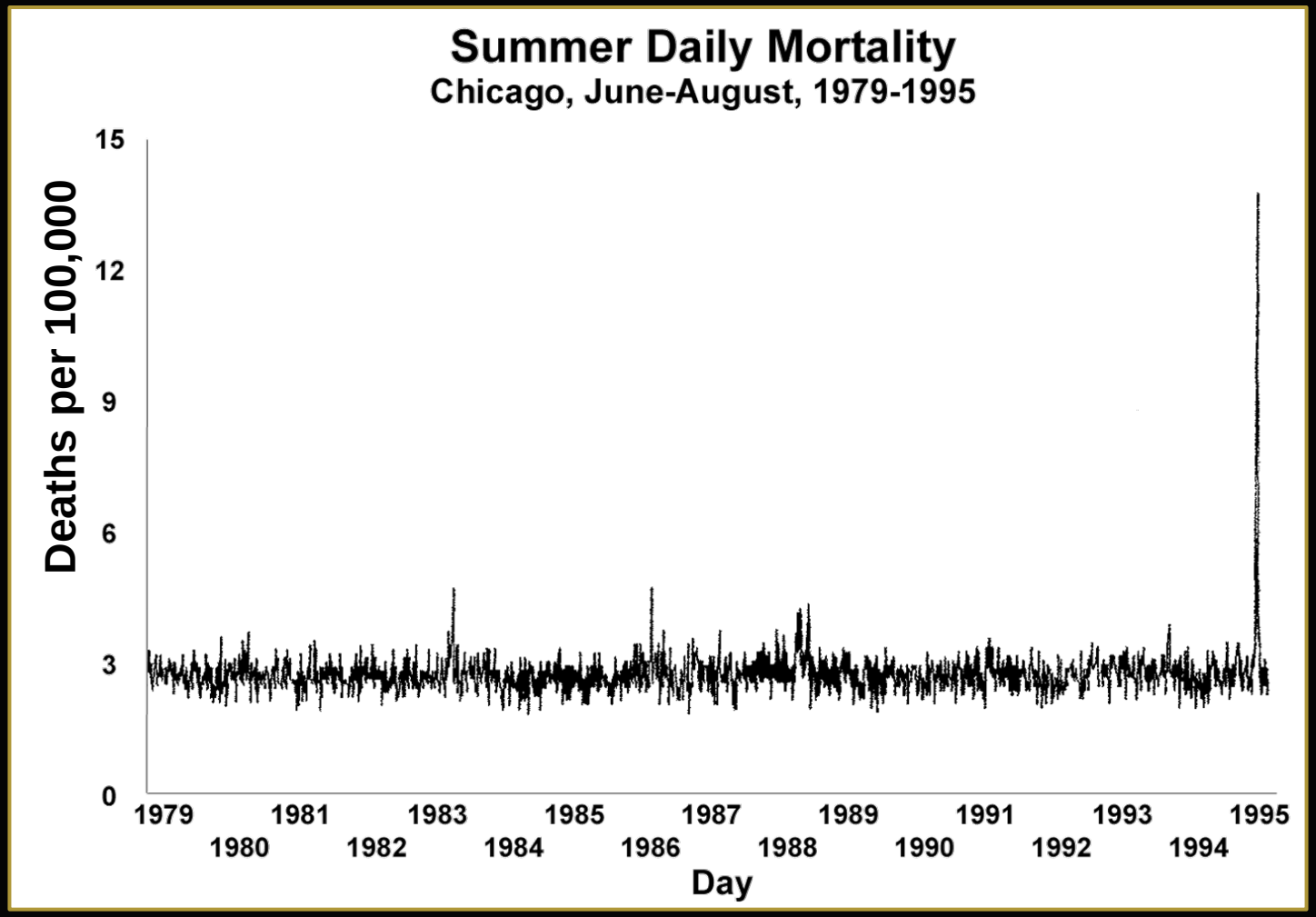
- Heat is presently the leading weather-related killer in the U.S.
- The impact of heat varies from one region to another.
- Most heat/mortality evaluations rely on simple meteorological parameters and ignore important social and physical factors.
- What will a climate change do to extreme weather/public health associations?

# Areas Most Vulnerable to Heat-Related Health Problems

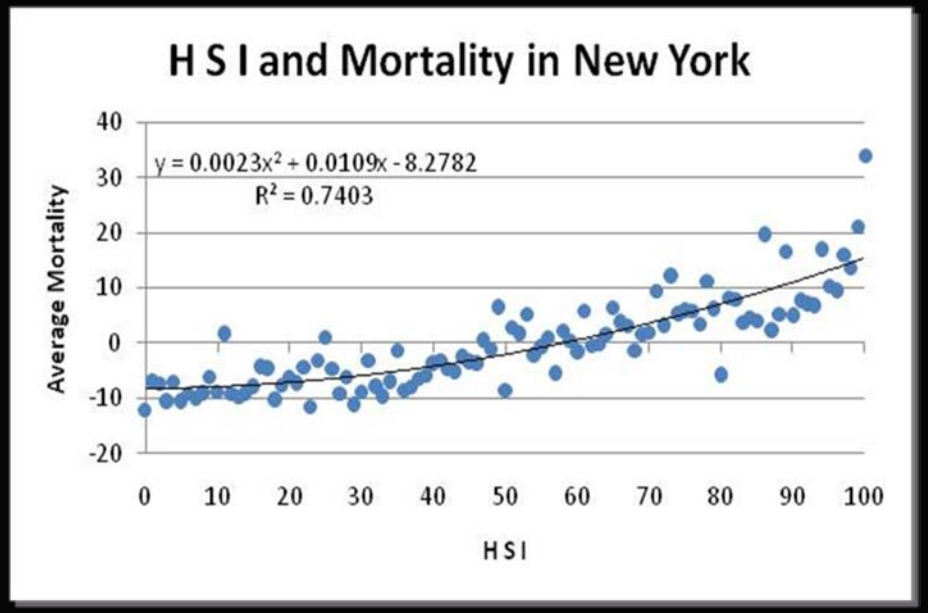


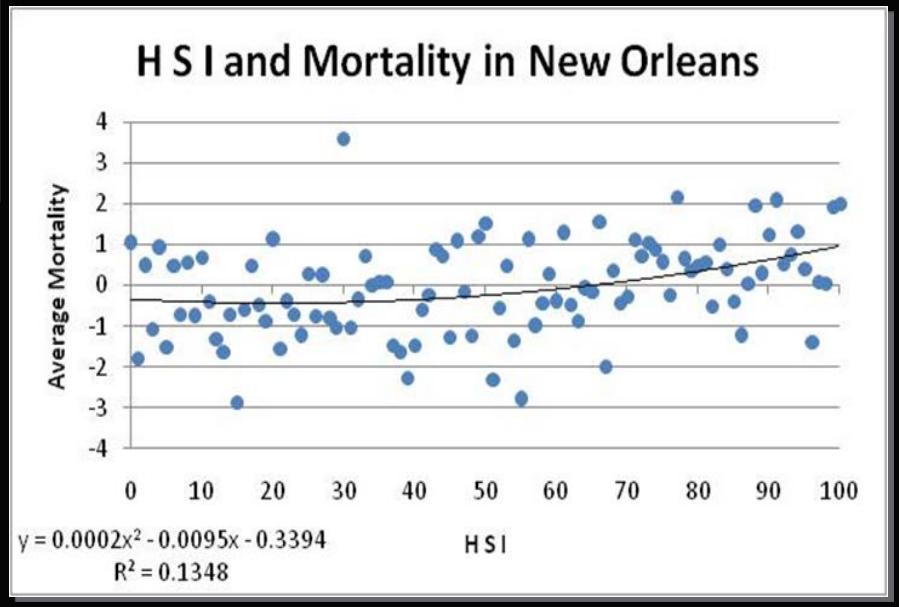

**The key: highly variable day-to-day summer weather.**

# Not a Trivial Increase!



# Comparing High and Low Variable Summer Climates

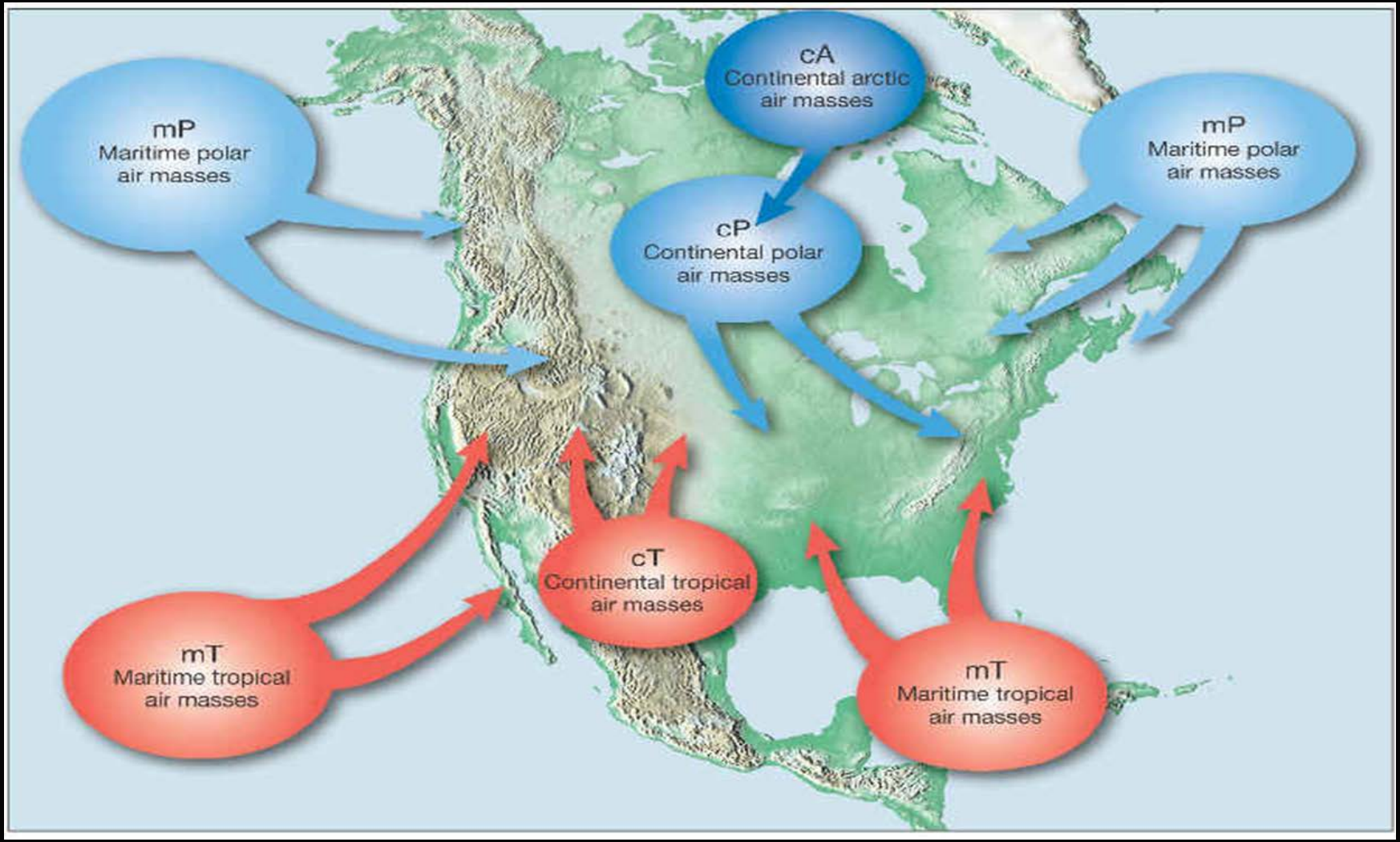


# The Air Mass-Based Approach

- Each day is assigned a particular air mass type.
- Air mass determination is based on 24 distinct variables (6 variables 4 times per day).
- The air masses are spatially cohesive.
- They lend themselves well to health-based applied studies since "offensive" air masses are statistically linked to negative health outcomes.
- They are primary input for our NWS heat-health warning systems.

# Air Mass "Source Regions"



# Our Nomenclature

| SSC Air Mass Types | |
|---|---|
| DP | Dry Polar (cP) |
| DM | Dry Moderate (Pacific) |
| **DT** | **Dry Tropical (cT)** |
| MP | Moist Polar (mP) |
| MM | Moist Moderate (Overrunning) |
| MT | Moist Tropical (mT) |
| **MT+** | **Moist Tropical Plus** |
| TR | Transition between air masses |

Sheridan, S.C., 2002: The redevelopment of a weather-type classification scheme for North American. *Int. J. Climatology,* **22**, 51-68.

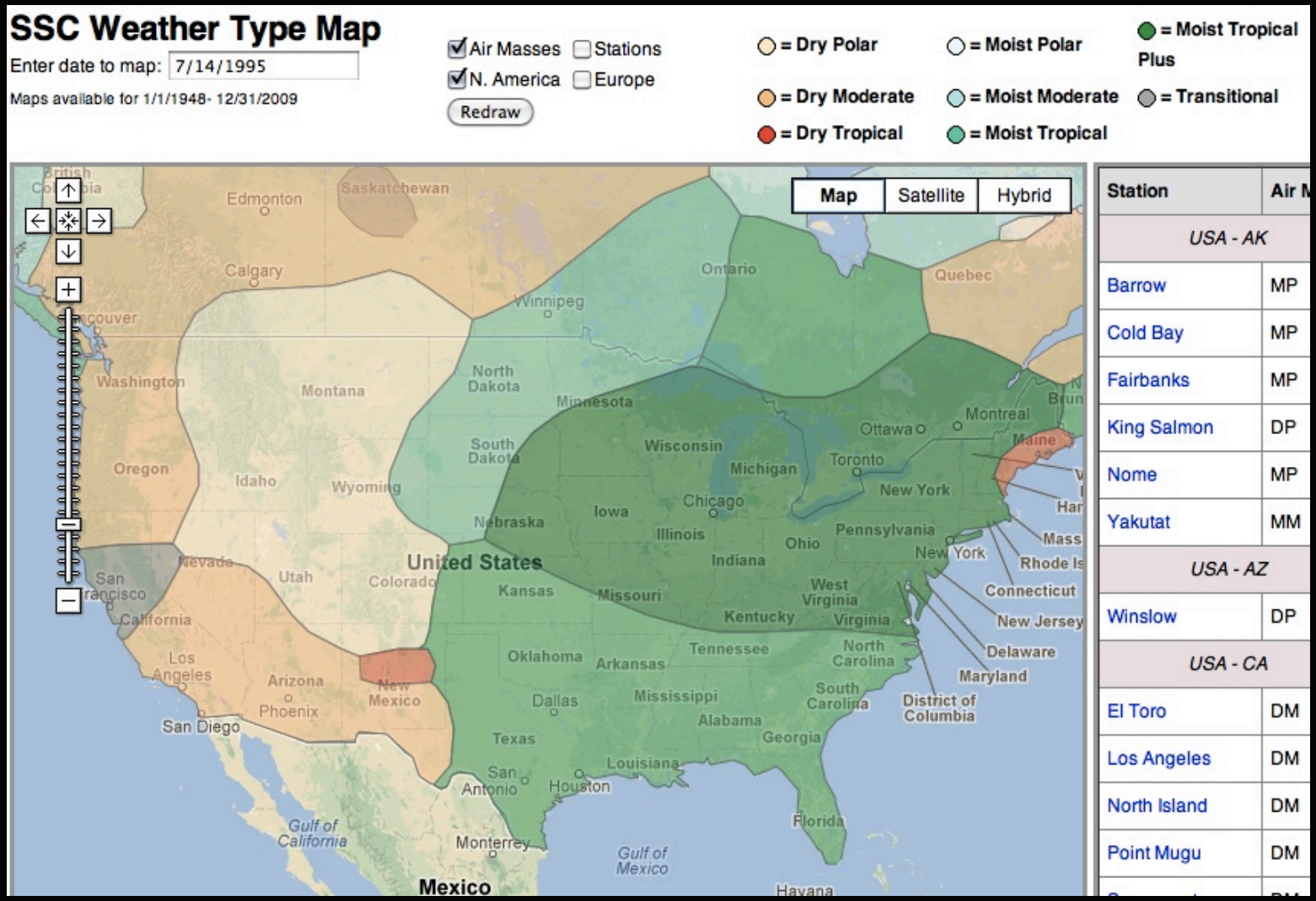
Kalkstein, L. S., Greene, S., Mills, D. M., & Samenow, J. 2011: An evaluation of the progress in reducing heat-related human mortality in major US cities. *Natural Hazards*, ***56***(1), 113-129.

# Characteristics of Chicago Summer Air Mass Types

| Air Mass | 5pm Air Temp (°C)* | 5pm Dew Pt Temp (°C)* | 5am Air Temp (°C)* | Frequency |
|---|---|---|---|---|
| DP | 23.9 | 11.7 | 14.4 | 15% |
| DM | 28.9 | 15.0 | 16.7 | 24% |
| DT | 34.4 | 17.2 | 22.2 | 4% |
| MP | 19.4 | 15.0 | 16.7 | 5% |
| MM | 25.0 | 18.3 | 20.0 | 19% |
| MT | 29.4 | 19.4 | 21.1 | 18% |
| MT+ | 33.3 | 22.2 | 25.0 | 8% |
| TR | 26.1 | 16.1 | 19.4 | 7% |

*Mean temperature from June 1st to August 31st

# A Map of Daily U.S. Air Masses




http://sheridan.geog.kent.edu/ssc.html

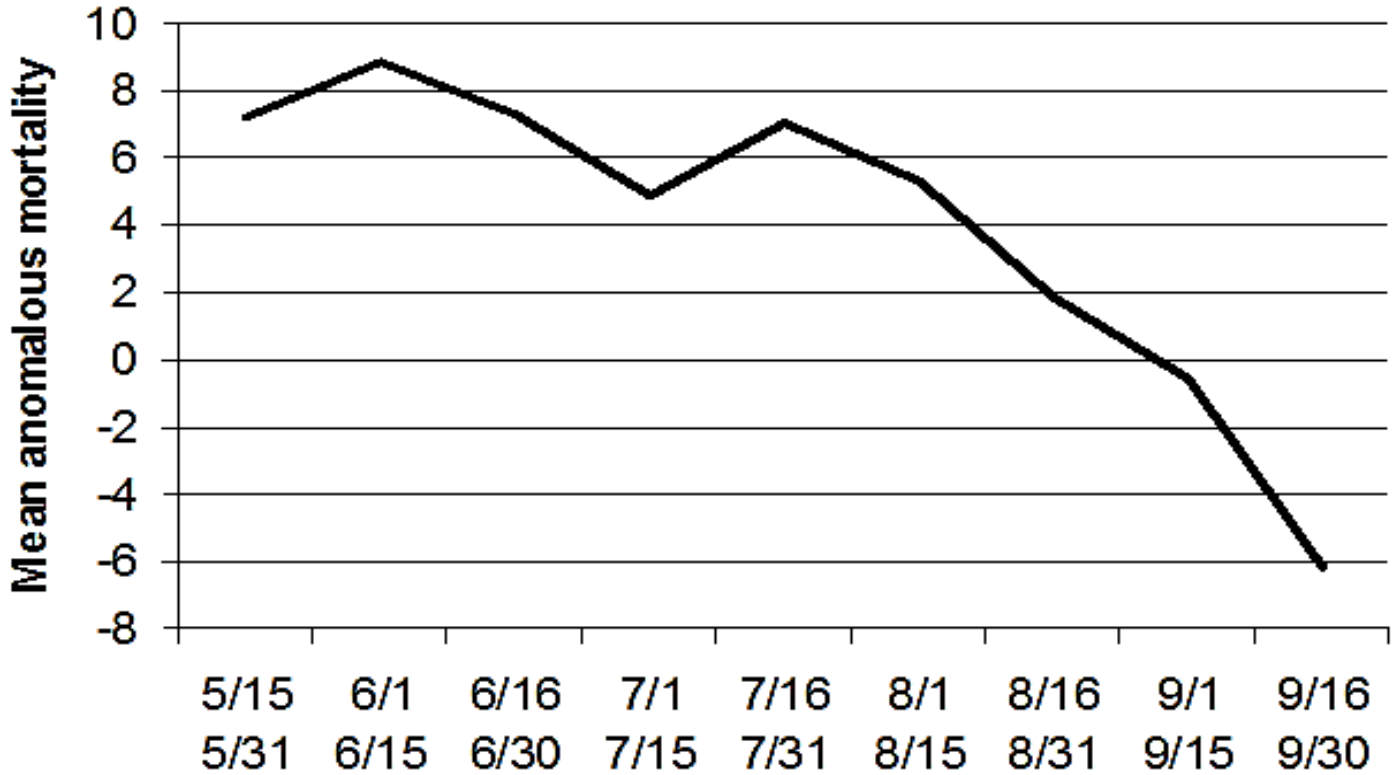
# Mean Mortality Increases Within Offensive Air Mass Types

| City (% frequency JJA) | DT Mortality (% Inc) | MT+ Mortality (% Inc) |
|---|---|---|
| Seattle (6%)[#] | +3.7 (8%) | +4.7[a] (10%) |
| **New York (11%)** | **+16.6 (7%)** | **+16.9% (7%)** |
| Washington (11%) | +0.9 (4%) | +1.7 (7%) |
| New Orleans (2%) | None | +3.7% (9%) |
| Phoenix (1%) | +2.7[b] (7%) | None |
| Rome (11%) | +6.2 (14%) | +5.0 (12%) |
| Shanghai (11%) | None | +42.4 (10%) |
| Toronto (7%) | +4.2 (11%) | +4.0 (10%) |

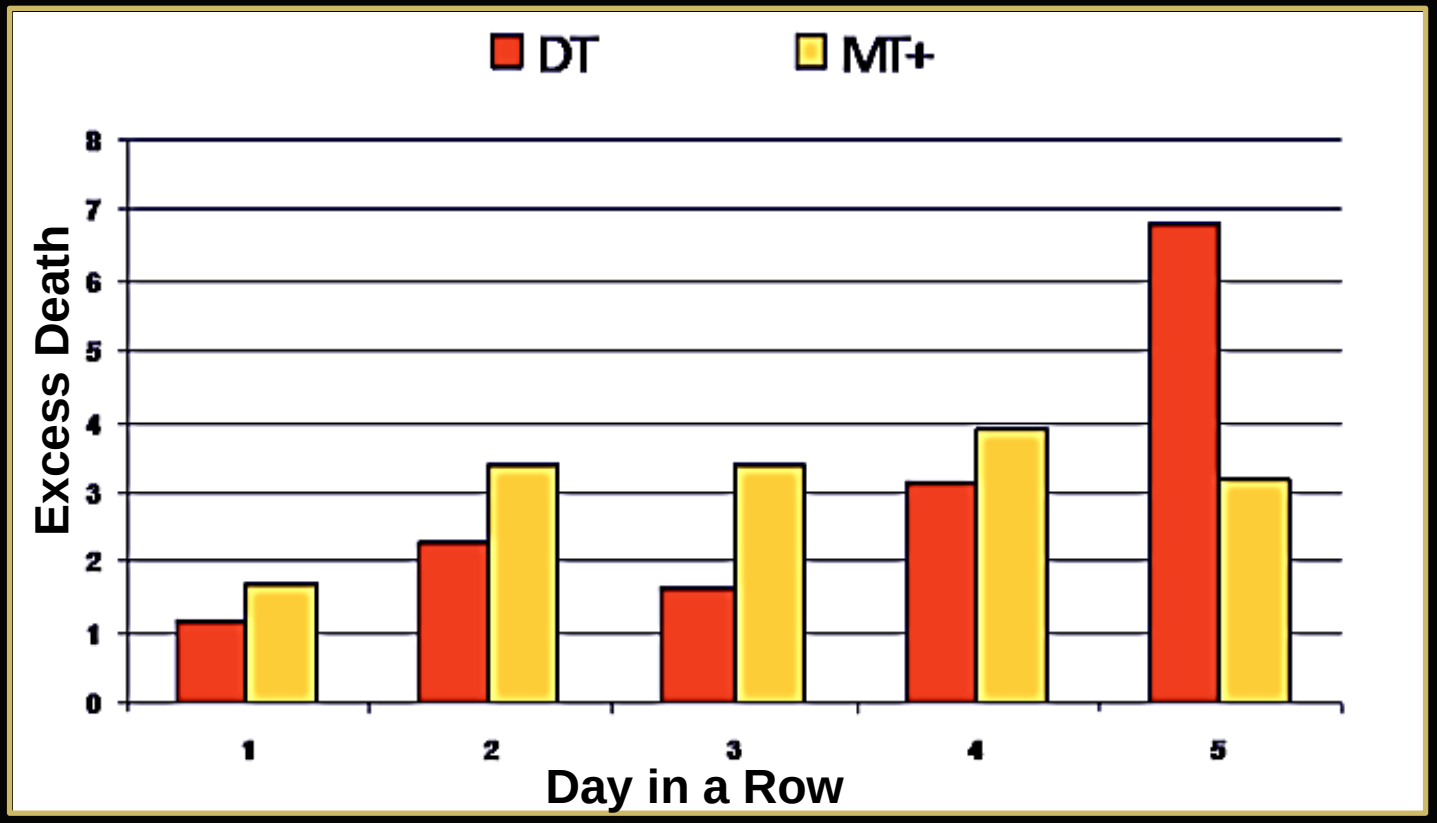
[#] *Seattle called its first heat advisory ever in 2005, thanks to the new system*
[a] MT+ does not occur in Seattle; the moist air mass that is present is MT.
[b] DT+ air mass for Phoenix.

# Development of Forecast Algorithms: Within-Air Mass Category Mortality Variations

# Impact of Acclimatization and Mortality Displacement: MT+ Air Mass in Rome



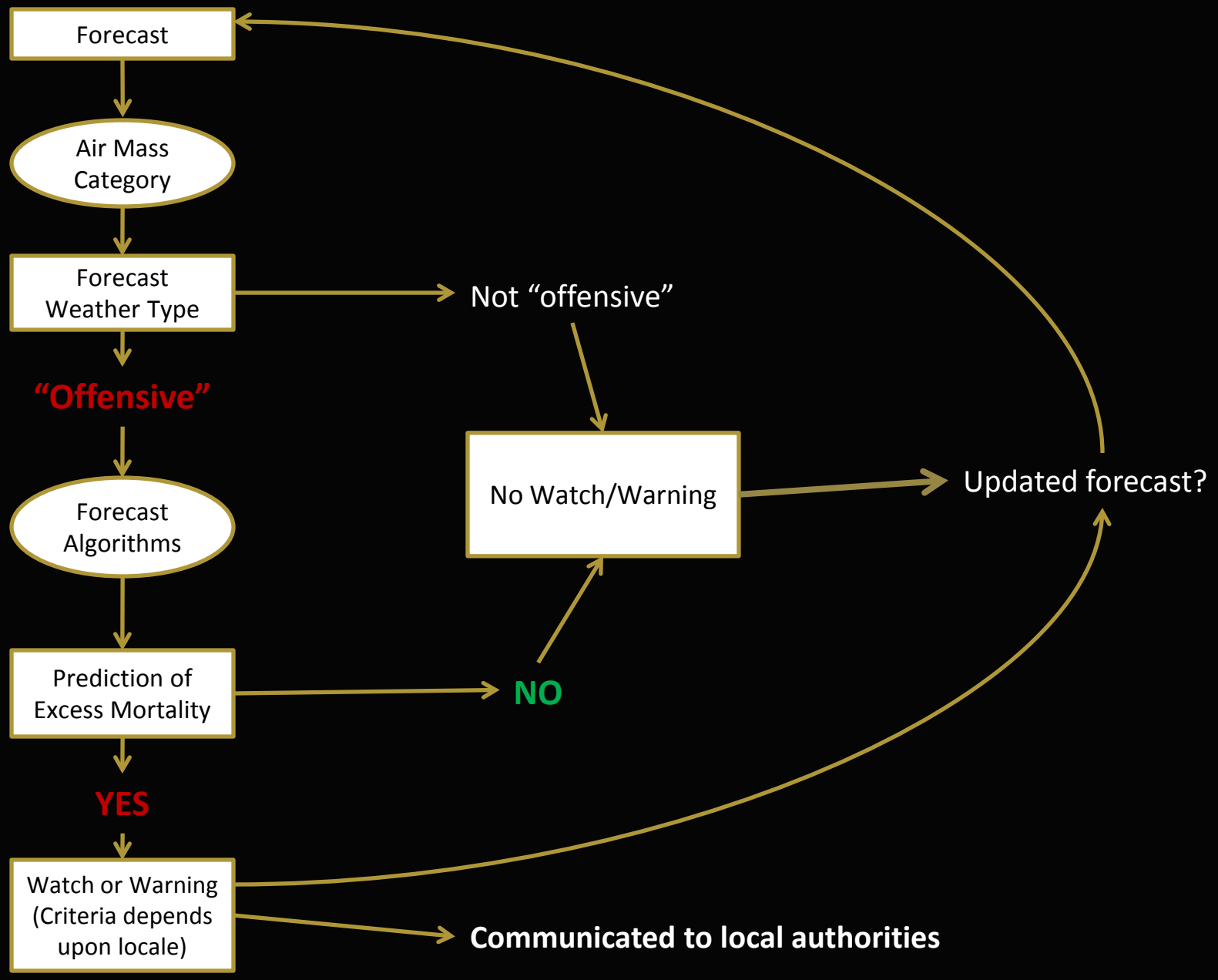
# Impact of Consecutive Days of "Offensive" Air Masses: Detroit



# New York City Mortality Algorithm

- **Mortality = -37.4 + 8.82 DIS + 1.425 ATP - 0.11 TOS**
  - For either MT+ or DT
  - DIS = day in sequence
  - TOS = time of season (May 1st = 1, May 2nd = 2…)
  - ATP = 5 pm Apparent temperature °C
- **Website URL:** **http://sheridan.geog.kent.edu/hwws/**
- **Username:** health **Password:** stress

# Criteria for Calling a Watch or a Warning



# HHWS Password-Protected Website

## Synoptic Health Watch-Warning Network

Synoptic heat-health (and cold-health) watch-warning systems are available real-time for the following cities online:

- (LOT) Chicago
- (ILN) Cincinnati, Columbus, and Dayton
- (FWD) Dallas-Fort Worth
- (DTX) Detroit
- (HGX) Houston
- (JAN) Jackson and Meridian
- (LCH) Lake Charles and Alexandria
- (LZK) Little Rock and Pine Bluff
- (MEG) Memphis and Tupelo
- (MPX) Minneapolis-St. Paul
- (LIX) New Orleans and Baton Rouge
- (PHI) Philadelphia
- (PSR) Phoenix and Yuma
- (PQR) Portland
- (LSX) Saint Louis
- (MTR) San Francisco and San Jose (SSC)
- (MTR) San Francisco and San Jose (Temperature)
- (SEW) Seattle
- (SHV) Shreveport and Monroe
- (LWX) Washington and Baltimore
- Toronto and Peel Region
- Seoul, South Korea

***Note these sites are NOW password-protected- with a different password from previous websites. If you are a party that has had access, please contact Scott Sheridan (ssherid1@kent.edu) or Larry Kalkstein (larryk@udel.edu) for the password.***

Synoptic systems are also presently employed in 8 cities in Italy; Shanghai, China; and will be implemented in South Korea beginning in 2008.

References on the heat warning systems:

Progress in heat watch-warning system technology Scott Sheridan and Laurence Kalkstein, Bulletin of the American Meteorological Society, 2004

The development of analog European heat waves for U.S. cities to analyze the impacts on heat-related mortality Laurence Kalkstein, Scott Greene, Dave Mills, Alan Perrin, Jason Samenow, Jean-Paul Cohen. Bulletin of the American Meteorological Society, 2007

**Current alerts:**
Dallas - Ft Worth : Warning (14) Watch (15)
Yuma : Advisory (14) Watch (15)
Portland : Warning (14) Watch (15) Outlook (16)
Phoenix : Advisory (14)
Seattle : Outlook (16)

# Dallas/Ft. Worth HHWS Page

## Synoptic Health Watch-Warning Network

Dallas-Fort Worth (FWD)

System levels:

**EXCESSIVE HEAT WARNING**
Dangerous heat stress conditions, which historically have led to excess mortality, are forecast to occur within the next 24 hours.

**HEAT ADVISORY**
Heat stress conditions, which might be associated with excess mortality, are forecast to occur within the next 24 hours.

**HEAT WATCH**
Potentially life-threatening heat stress conditions are forecast to occur in the next 24 to 48 hours.

**HEAT OUTLOOK**
Potentially life-threatening heat stress conditions are forecast to occur in the next 48 to 120 hours.

**NO ADVISORY**
Weather conditions are not forecast to be oppressive.

The synoptic-based heat-health watch warning network is based on evaluating the negative health impact of oppressive air masses, as expressed by excess mortality, in each locality. Forecast data, as defined by PFMs, are compared to historical meteorological conditions that have led to such mortalty increases, and advisories, watches, and warnings are called accordingly.

These systems utilize the Spatial Synoptic Classification, about which more can be learned here. Where oppressive conditions are forecast to occur, the consecutive day run of such conditions will appear in parentheses following the SSC type.

**Copyright 2008.** This webpage was developed and is maintained by Scott Sheridan, Kent State University (ssherid1@kent.edu). This network of systems has been developed by Laurence Kalkstein, University of Miami (larryk@miami.edu) and Scott Sheridan.

*DFW forecast issued 08/04/2009 16:20:02*

| Time | 09Z | 15Z | 21Z | 03Z |
|---|---|---|---|---|
| August 5 | | | | Dry Tropical ( 3) |
| **WARNING ( 3 deaths forecast)** | | | | |
| Temperature / Dew Point | 80 / 69 | 86 / 69 | 103 / 64 | 88 / 65 |
| August 6 | | | | Dry Tropical ( 4) |
| **WATCH ( 4 deaths forecast)** | | | | |
| Temperature / Dew Point | 81 / 68 | 87 / 68 | 103 / 64 | 88 / 65 |
| August 7 | | | | Moist Tropical ( 3) |
| **NO ADVISORY** | | | | |
| Temperature / Dew Point | 82 / 69 | 95 / 66 | 95 / 64 | 82 / 66 |
| August 8 | | | | Moist Tropical ( 2) |
| **NO ADVISORY** | | | | |
| Temperature / Dew Point | 77 / 68 | 94 / 67 | 94 / 65 | 82 / 68 |
| August 9 | | | | Moist Tropical ( 1) |
| **NO ADVISORY** | | | | |
| Temperature / Dew Point | 78 / 70 | 92 / 69 | 92 / 67 | 81 / 69 |

Click here for archived forecasts. Explanation of the archive file can be found here.

# Intervention Procedures in Philadelphia & Toronto when a warning is issued

**Table 3.1.** Summary of confirmed EHE program elements in Philadelphia and Toronto

| Program elements | Philadelphia[5] | Toronto[6] |
|---|---|---|
| **Prediction** see 3.1.1, p. 23 | | |
| Ensure access to weather forecasts capable of predicting EHE conditions 1-5 days in advance | ✓ | ✓ |
| **Risk assessment** see 3.1.2, p. 23 | | |
| Coordinate transfer and evaluation of weather forecasts by EHE program personnel | ✓ | ✓ |
| Develop quantitative estimates of the EHE's potential health impact | ✓ | ✓ |
| Use the broader criteria to identify heat-attributable deaths | ✓ | ✓ |
| Develop information on high-risk individuals | ✓ | |
| Develop an accessible record on facilities and locations with concentrations of high-risk individuals | ✓ | ✓ |
| **Notification and response** see 3.1.3, p. 24 | | |
| Coordinate public broadcasts of information about the anticipated timing, severity, and duration of EHE conditions and availability and hours of any public cooling centers | ✓ | ✓ |
| Coordinate public distribution and broadcast of heat exposure symptoms and tips on how to stay cool during an EHE | ✓ | ✓ |
| Operate informational phone lines that can be used to report heat-related health concerns | ✓ | ✓ |
| Designate public buildings or specific private buildings with air conditioning as public cooling shelters and provide transportation | ✓ | ✓ |
| Extend hours of operation at community centers with air conditioning | ✓ | |
| Arrange for extra staffing of emergency support services | ✓ | |
| Directly contact and evaluate the environmental conditions and health status of known high-risk individuals and locations likely to have concentrations of these individuals | ✓ | ✓ |
| Increase outreach efforts to the homeless and establish provisions for their protective removal to cooling shelters | ✓ | ✓ |
| Suspend utility shutoffs | ✓ | ✓ |
| Reschedule public events to avoid large outdoor gatherings when possible | ✓ | |
| **Mitigation** see 3.1.4, p. 26 | | |
| Develop and promote actions to reduce effects of urban heat islands | Not evaluated | |

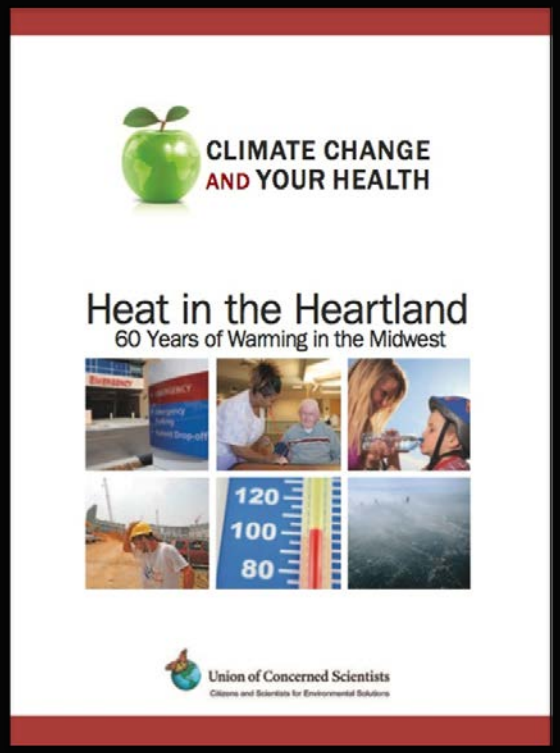
5. NOAA, 1995; Kalkstein, 2002.
6. Kalkstein, 2002; personal communications, M. Vittiglio and N. Day, Toronto Public Health, 2005.

# Positive Outcomes Resulting from System Implementation

- **Lives have been saved**[A]
- **Effectiveness can be checked**
  - Forecasting effectiveness (false positives or negatives)
  - Accuracy in estimating health impacts of offensive weather[B]
  - Is the system saving lives?
- **Inter-agency collaboration has increased**
  - EPA/NOAA guidebook on intervention activities[C]
- **Increased NWS/Stakeholder cooperation**
  - More sophisticated intervention activities developed.


[A] Ebi, KL, 2004. Heat watch warning systems save lives. *Bull. Am. Met. Soc.* 85:1067-74
[B] Michelozzi, P. 2004. Impact of heat waves on mortality - Rome. *J. of Am. Med. Assn.* 291:2537-38
[C] Mills, D, Kalkstein, L, Perin, A. 2006. Excessive Heat Events Guidebook. U.S. EPA: Washington, D.C., 65pp.

# Air Masses and Climate Change




- ❑ Determine changes in air mass frequency and character over the past six decades in five large Midwestern cities.

- ❑ Focus on trends in those air masses that have historically been associated with negative health impacts.

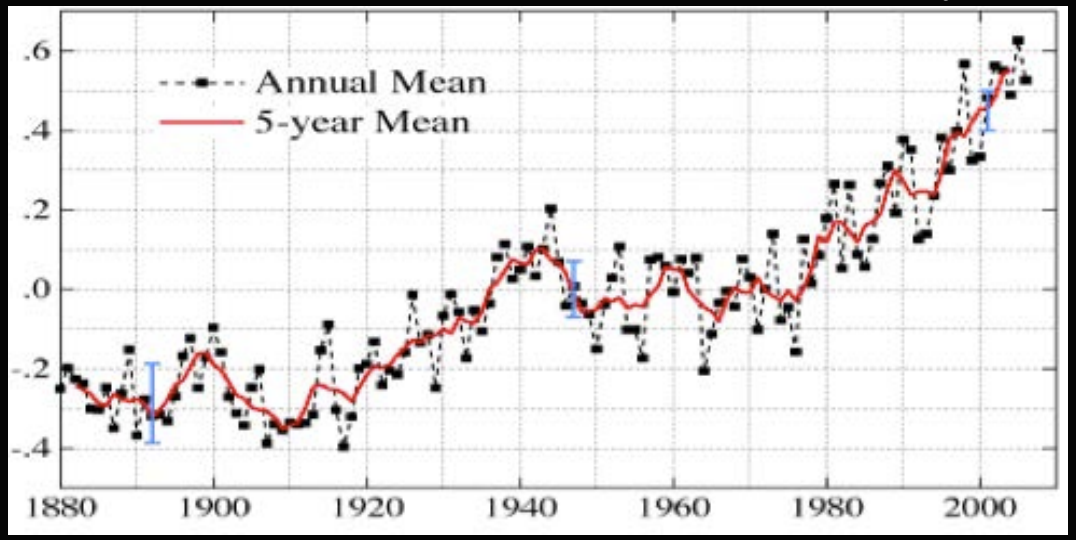
- ❑ Estimate contributions from generalized climate change and urban heat island effects. Did not investigate if trends are human-caused or not.

# Evaluated Meteorological Attributes

- Air mass frequency = changes in the number of days within the summer season.
- Air mass character = changes in 3AM and 3PM temperature and 3AM dewpoint.
- Consecutive day evaluation = changes in numbers of three day offensive air mass episodes.
- Trends over a 60+ year period, including determination of statistical significance.

# Generalized Climate Change Since 1880

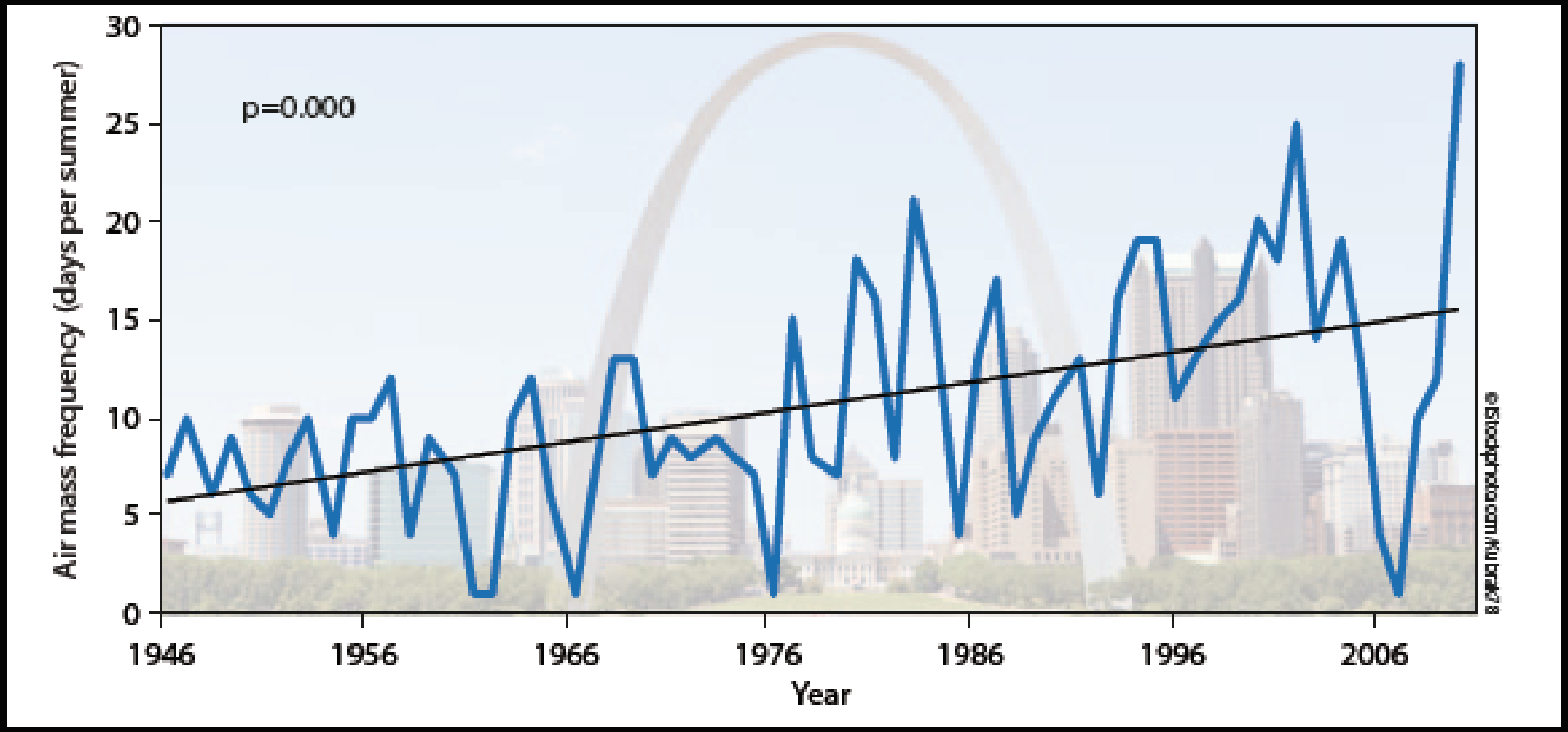
Global Mean Surface Temperature Anomaly (°C)




This familiar graph shows an increase of about 1°C over the past 130 years. The trend is not statistically significant.

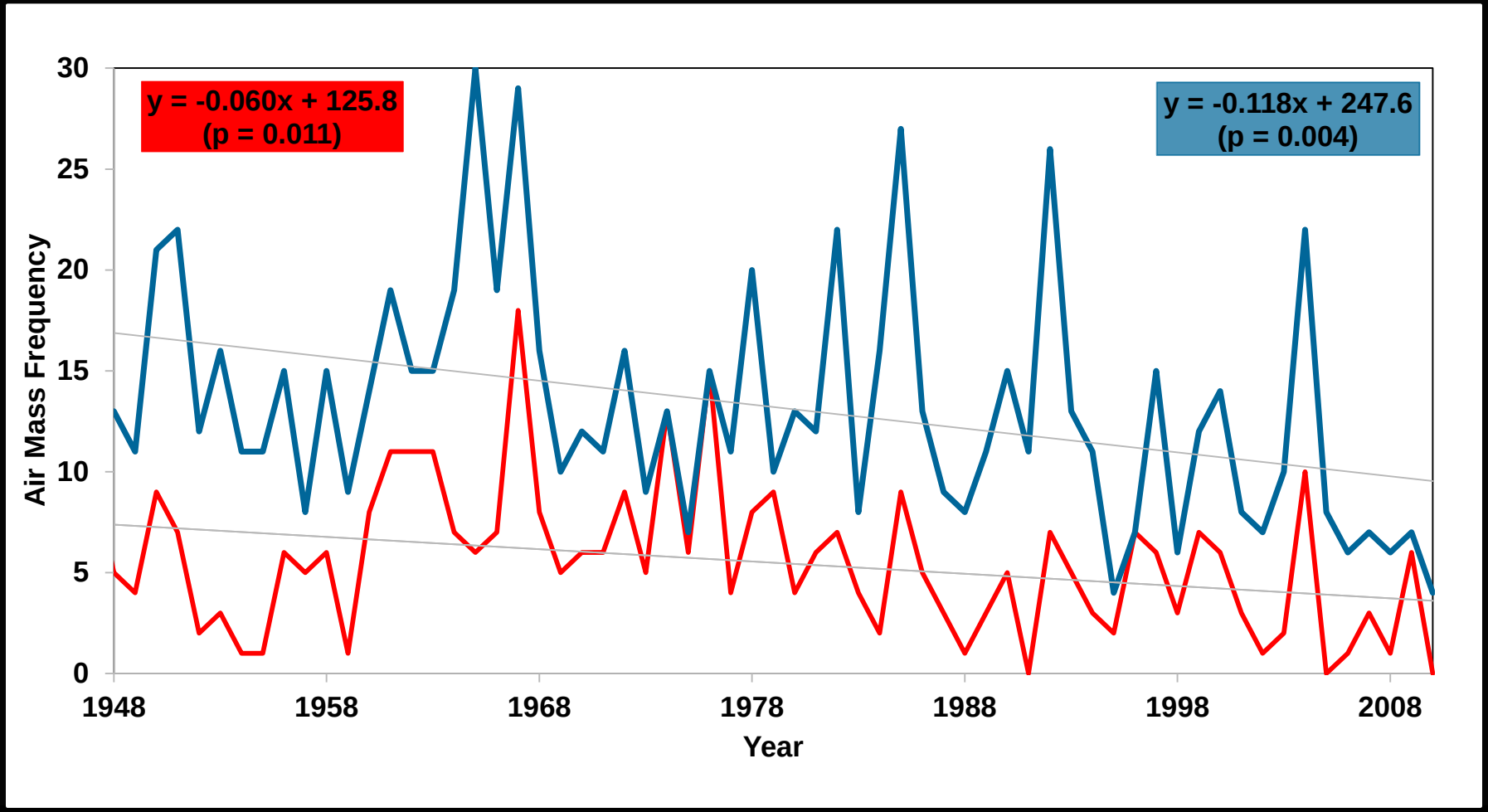
The graph encompasses all weather situations combined. Our approach confines itself to climate changes within only those air masses that are known contributors to negative health outcomes. Thus, we can pinpoint which air masses contribute most to a generalized climate change.

# St. Louis Air Mass Frequency Trends
# Hot Moist Weather Type – Moist Tropical + (MT+)




- **Moist Tropical:** 9.5 *more* MT+ days today than in the 1940's

# Chicago & St. Louis Air Mass Frequency Trends
# Cold Weather Type - Dry Polar (DP)




- Chicago: 7.3 *less* DP days today than in the 1940's
- St. Louis: 3.7 *less* DP days today than in the 1940's

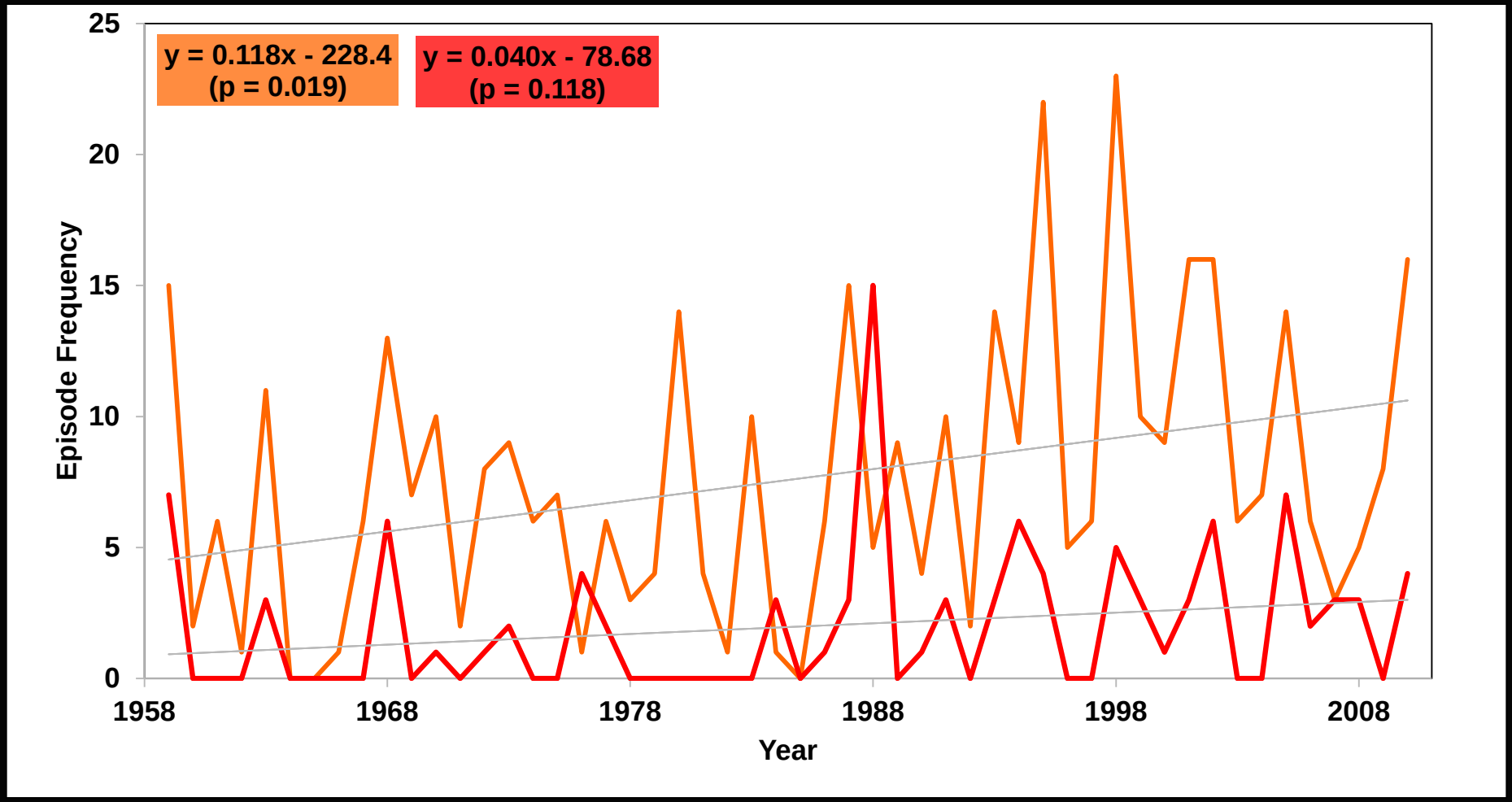
# Weather Type Frequency Trends

| | Moist Tropical+ | Dry Tropical | Dry Polar |
|---|---|---|---|
| Chicago | Increased 62% 2.5 Days | Increased 79% 1.5 Days | Decreased* 44% 7+ Days |
| Detroit | Increased^ 172% 3.5 Days | Increased^ 338% 3 Days | Decreased* 70% 10.5 Days |
| Minneapolis | Increased 55% 1.5 Days | Increased 45% 3 Days | Decreased^ 32% 4.5 Days |

| | Moist Tropical+ | Dry Tropical | Dry Polar |
|---|---|---|---|
| St. Louis | Increased* 200% 10 Days | No Change | Decreased* 43% 4 Days |
| Cincinnati | Increased^ 208% 2 Days | Decreased 45% 2 Days | Decreased 26% 2 Days |

- Dangerously hot days are becoming more prevalent in the Midwest
  - MT+ in all cities
  - DT in three of the five cities
- The coolest summer weather type (DP) is becoming less frequent

# Detroit Consecutive Three Day Runs: MT and MT+/DT



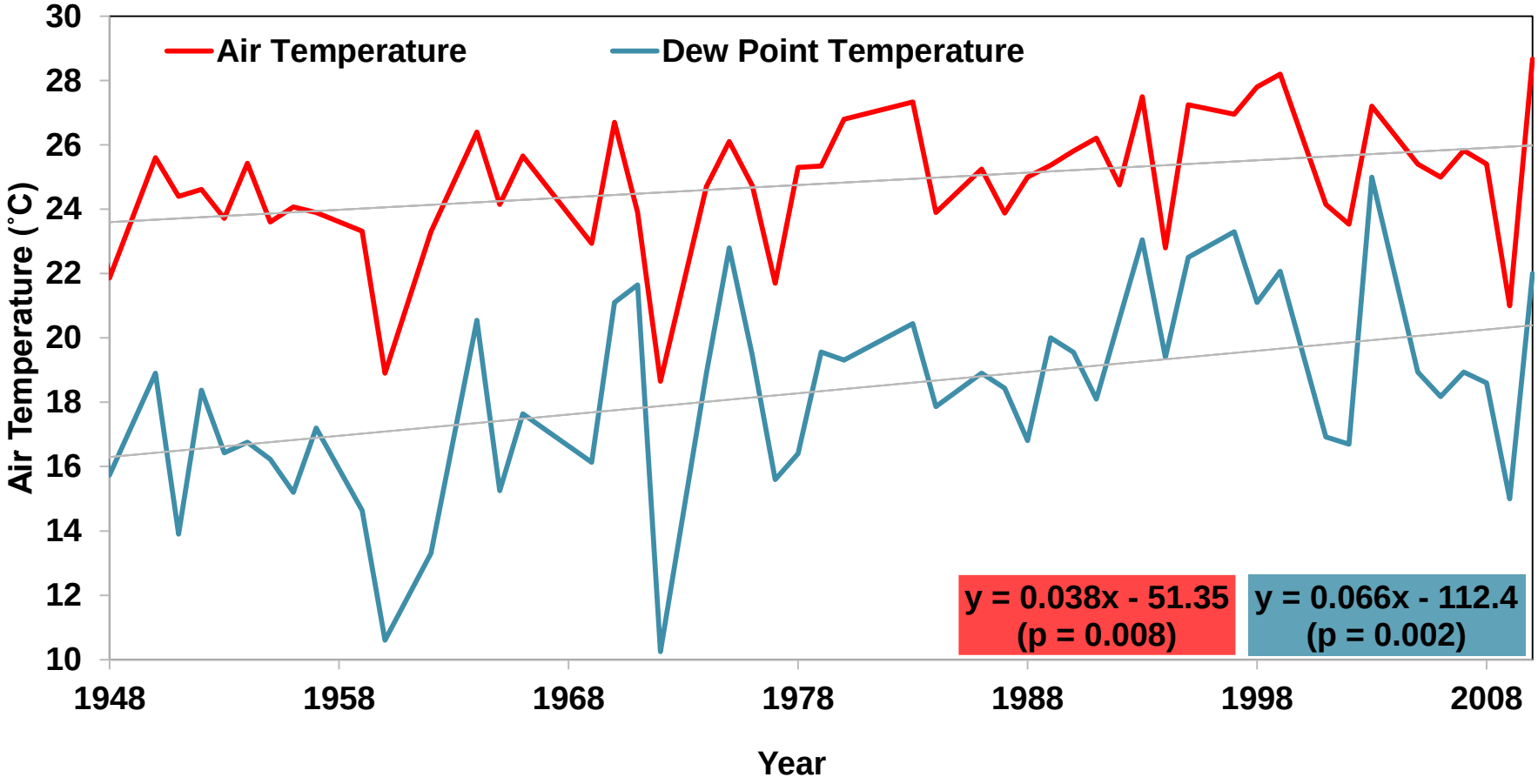

- 6 more MT episodes per summer than 5 decades ago
- 2 more MT+/DT episodes than 5 decades ago

# Three-day Consecutive Runs of Harmful Weather Types: MT+/ DT

| | | |
|---|---|---|
| **Chicago** | Increased 1 per year | Increased 1 per summer |
| **Detroit** | Increased 2 per year | Increased 2 per summer |
| **Minneapolis** | Increased 1 per year | Increased 1 per summer |
| **St. Louis** | Increased* 4 per year | Increased 4 per summer |
| **Cincinnati** | No Change | No change |

- More consecutive day runs of offensive air masses in 4 of the 5 large cities
- People respond poorly to consecutive day episodes

# St. Louis Overnight (3AM) Air & Dew Point Temperature Trends: DT Air Mass




- 3AM Air Temperature: +2.4°C warmer on average, than the 1940s
- 3AM Dew Point Temperature: +4.1°C warmer on average, than the 1940s

# Nighttime (3am) Character Trends: Hot Weather Types (DT and MT)

| | DT Air | DT Dew Pt | MT+ Air | MT+ Dew Pt |
|---|---|---|---|---|
| Chicago | Increased^ 1.7°F | Increased 0.8°F | Increased 2.6°F | Increased 2.8°F |
| Detroit | Increased* 2.1°F | Increased* 2.5°F | Increased* 4.3°F | Increased 1°F |
| Minneapolis | Increased^ 1.6°F | Increased* 2.2°F | Decreased 0.8°F | Decreased 1.4°F |

| | DT Air | DT Dew Pt | MT+ Air | MT+ Dew Pt |
|---|---|---|---|---|
| St. Louis | Increased* 2.1°F | Increased 0.6°F | Increased* 4.4°F | Increased* 7.7°F |
| Cincinnati | Increased 0.2°F | Decreased 0.7°F | Increased 0.6°F | Decreased 1.1°F |

- Hot air masses are hotter, especially at night
- Overnight air and dew point temperatures are increasing in all cities in the DT weather type
- Difference between daytime and nighttime temperatures narrowing

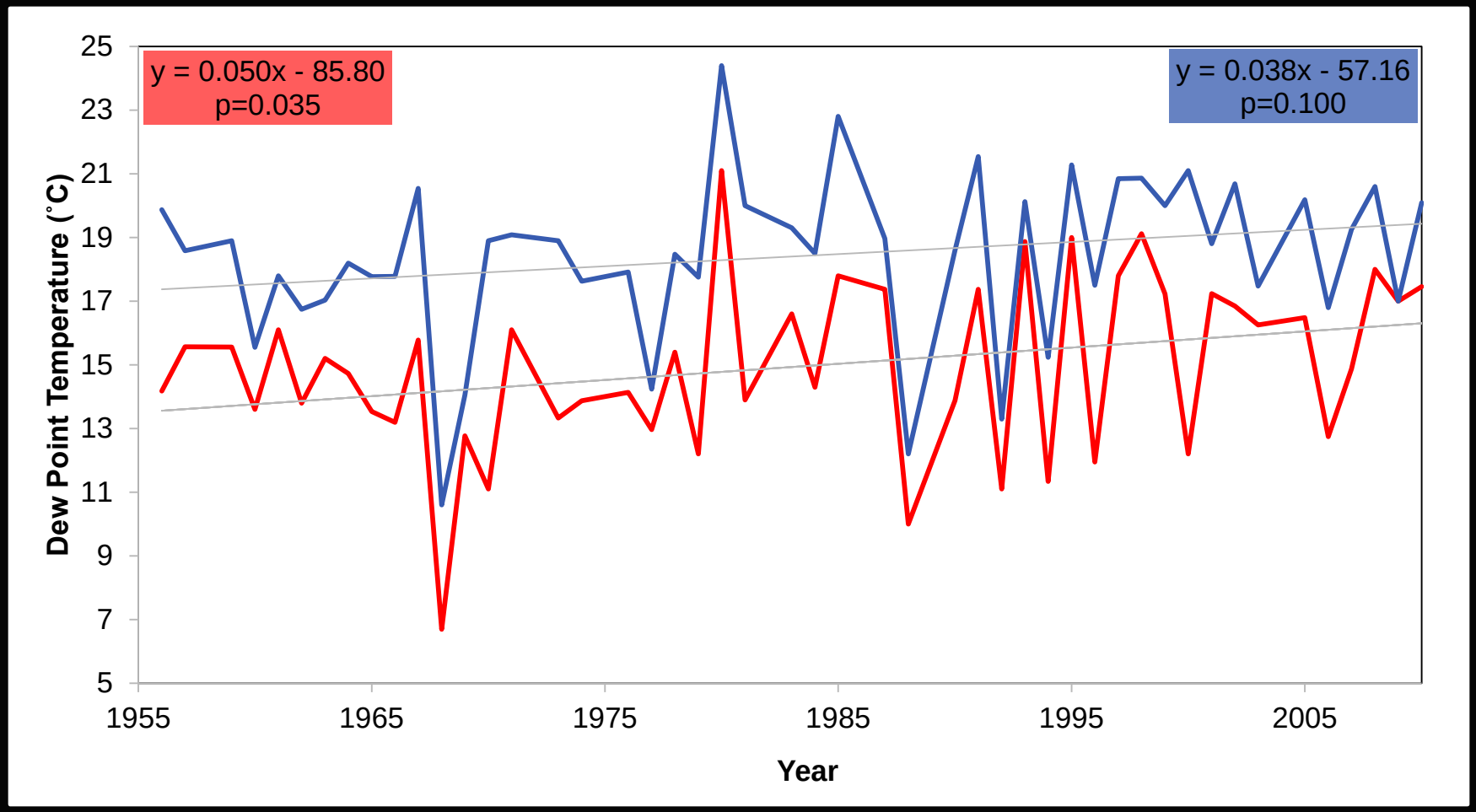
# Pairing Smaller cities with the Larger cities

# Airport Locations

Airport Weather Stations were on average 10 – 20 miles from downtown

- UHI effects were assumed to be minimal – surrounded by rural areas; however they cannot be completely eliminated

# Results: Rising Overnight Air & Dew Point Temperatures (Toledo Example)




- Air Temperatures = 2.2°C rise
- Dew Point Temperatures = 2.8°C rise

Suggestion: results aren't due solely to an urban heat island effect on major cities. More rural neighboring locations showed similar increases in hot summer air masses.

# Peoria Trends - Overall Results and Comparisons with Chicago

| Peoria | Frequency | 3pm Air Temp | 3pm Dew Point | 3am Air Temp | 3am Dew Point |
|---|---|---|---|---|---|
| DP | -0.069* | 0.011 | 0.016 | 0.023* | 0.030* |
| DT | 0.010 | -0.004 | -0.019 | 0.026 | 0.010 |
| MT+ | 0.094* | -0.007 | 0.021^ | 0.013* | 0.018* |

**sig at p <0.05. ^sig at p< 0.10.*

- *Slope agreement with trend in Chicago*
- *Slope greater than in Chicago*

- Very good agreement in results with Chicago
- Large DP decreases and MT+ increases; 3PM dewpoint increased to a greater extent (red boxes)

**OVERALL (all cities)**

- Smaller population neighboring locations showed similar increases in hot summer air masses, and decreases in cool summer air masses
- this suggests that higher temperatures are **NOT** primarily due to UHI effects

# Conclusions

- Significant air mass changes in the last 60+ years:
  - hot humid air mass days have **increased** most rapidly in frequency **(MT, MT+)**
  - hot dry air mass days have **increased** most rapidly in temperature **(DT)**
  - cool dry air mass days have **decreased** rapidly in frequency **(DP)**
  - hot air masses have become hotter and more humid during nighttime hours
  - greater prevalence of heat waves lasting three days or more
  - many of these results are statistically significant

# Conclusions *con't*

- Small population areas generally mirror overall trends of nearby large cities
- Results suggest that air mass frequency and character changes are primarily due to a generalized climate change rather than a UHI effect
- Cannot determine from this study whether this generalized trend is due to anthropogenic causes

# Take Home Messages

- Air mass-based approaches have great utility in climate-health analyses, heat wave evaluation, and climate change trend detection.
- Permits concentration on those weather situations that create stress in human populations.
- Midwest climate change study needs expansion to remainder of country.
- Expectations: strong differences in response across regions, but intraregional similarities will emerge.