Climate Change and Health:

Extreme Temperature Events

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Overview

- Concepts and identity of thermal extremes
- Who is vulnerable during thermal extremes
- Methods for assessing the health risk and impacts of thermal extremes
- Current health impacts of thermal extremes
- Potential impacts of climate change
- Opportunities for adaptation to minimize future health risks and impacts

Key Concepts for Evaluating Thermal Extremes

- Events vs. Seasons
  - Thermal extremes focus on relatively short lived weather conditions (generally days)
  - These are generally the days in the "tails" in distributions summarizing annual weather
- "Excess" health outcomes
  - Defined as the difference in the number/rate of outcomes during thermal extremes with longer term averages
  - The difference is assumed to reflect the health impact of the extreme temperatures, assuming all else is equal

Characteristics of Extreme Thermal Conditions

- Extreme thermal conditions should
  - Be **atypical**
    - The ordinary should not be considered “extreme”
    - These events should be considered “unusually” or “exceptionally” hot or cold conditions
    - As variations from “normal” conditions the actual conditions associated with these events can and should vary by location
  - Have a historical **association with** increases in a range of **adverse health outcomes**

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Options for Identifying Extreme Thermal Conditions

- Extreme thermal conditions can be identified by
  - Evaluating **meteorological data** against established criteria (e.g., threshold temperatures, comfort indices, historical distributions)
  - Observed **health impacts**
  - **Combined** meteorological and health impact assessment

Meteorological Options to Identify Extreme Thermal Conditions

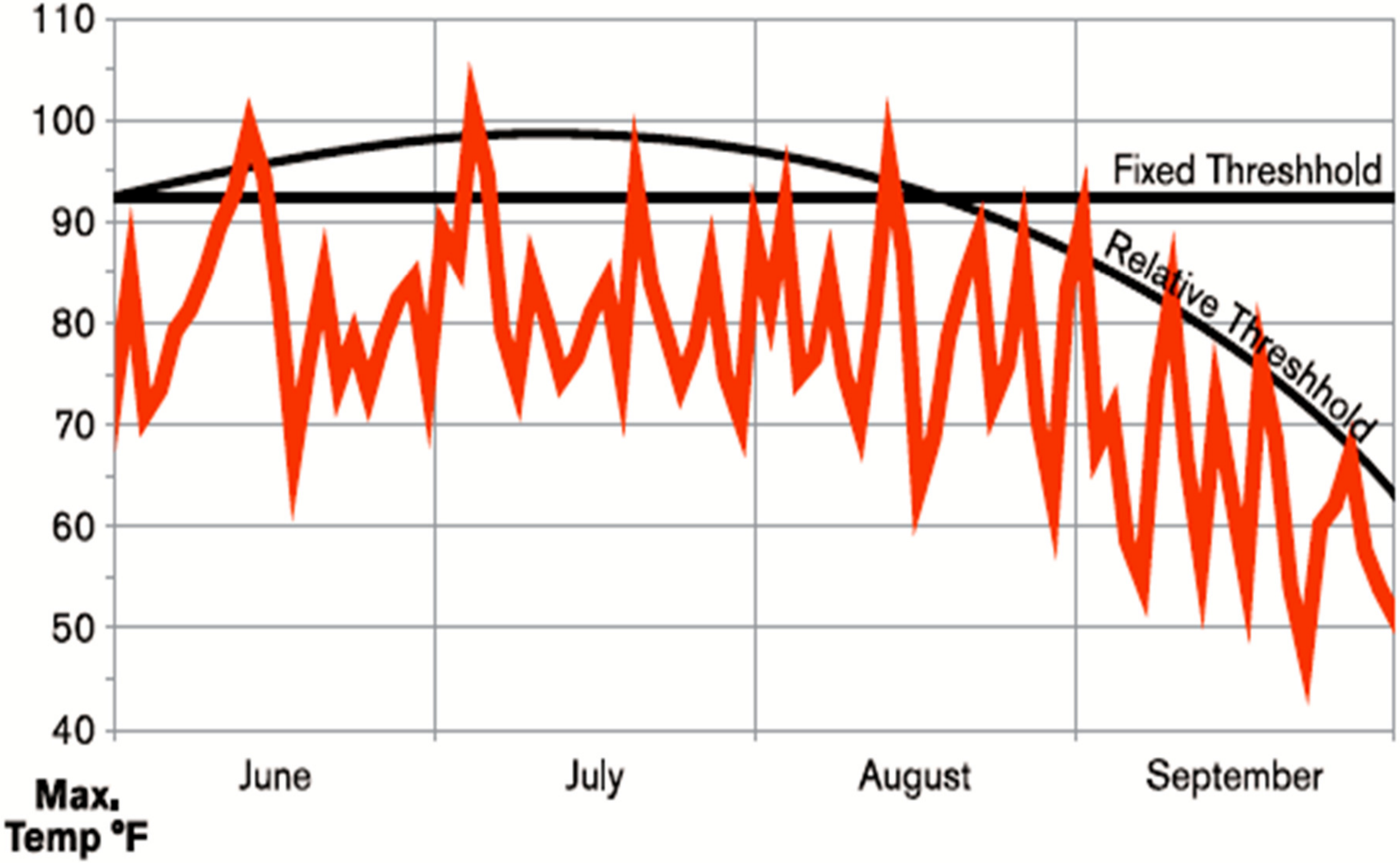
- **Fixed threshold criteria**
  - Extreme thermal conditions exist when criteria are exceeded at any point in time, for example:
    - Extreme heat if temperature > 40ºC
    - Extreme cold if temperature < -10ºC
    - Exceed a seasonal distribution value (e.g., 5th or 95th percentile)
- **Relative threshold criteria**
  - Criteria for extreme thermal conditions vary by location and/or time of season
  - Recognize that perceptions of what is exceptionally “hot” and “cold” can and should vary

Terms and Definitions for Extreme

PHENOMENON	Definition
Low-temperature days/ nights and frost days	Percentage of days with temperature (maximum for days, minimumfor nights) not exceeding some threshold, either fixed (frost days) or varying regionally (cold days/cold nights), based on the 10th percentile of the daily distribution in the reference period (1961–1990).
High-temperature days/nights	See low-temperature days/nights, but now exceeding the 90thpercentile.
Cold spells/snaps	Episode of several consecutive low-temperature days/nights.
Warm spells (heat waves)	Episode of several consecutive high-temperature days/nights.
Cool seasons/warm seasons	Seasonal averages (rather than daily temperatures) exceedingsome threshold.
Heavy precipitation events (events that occur every year)	Percentage of days (or daily precipitation amount) with precipitation exceeding some threshold, either fixed or varying regionally, basedon the 95th or 99th percentile of the daily distribution in thereference period (1961–1990).
Rare precipitation events (with return periods >~10 yr)	As for heavy precipitation events, but for extremes further into the tail of the distribution.
Drought (season/year)	Precipitation deficit; or based on the PDSI (see Box 3.1).
Tropical cyclones (frequency, intensity, track, peak wind, peak precipitation)	Tropical storm with thresholds crossed in terms of estimated wind speed and organisation. Hurricanes in categories 1 to 5, according tothe Saffir-Simpson scale, are defined as storms with wind speedsof 33 to 42 m s^{-1}, 43 to 49 m s^{-1}, 50 to 58 m s^{-1}, 59 to 69 m s^{-1}, and >70 m s^{-1}, respectively. NOAA's ACE index is a measure ofthe total seasonal activity that accounts for the collective intensityand duration of tropical storms and hurricanes during agiven tropical cyclone season.
Extreme extratropical storms (frequency, intensity, track, surface wind, wave height)	Intense low-pressure systems that occur throughout the mid-latitudes of both hemispheres fueled by temperature gradients and actingto reduce them.
Small-scale severe weather phenomena	Extreme events, such as tornadoes, hail, thunderstorms, dust stormsand other severe local weather.

IPCC AR4 2007

Identifying Thermal Extremes Using Fixed and Relative Thresholds



U.S. EPA, 2006

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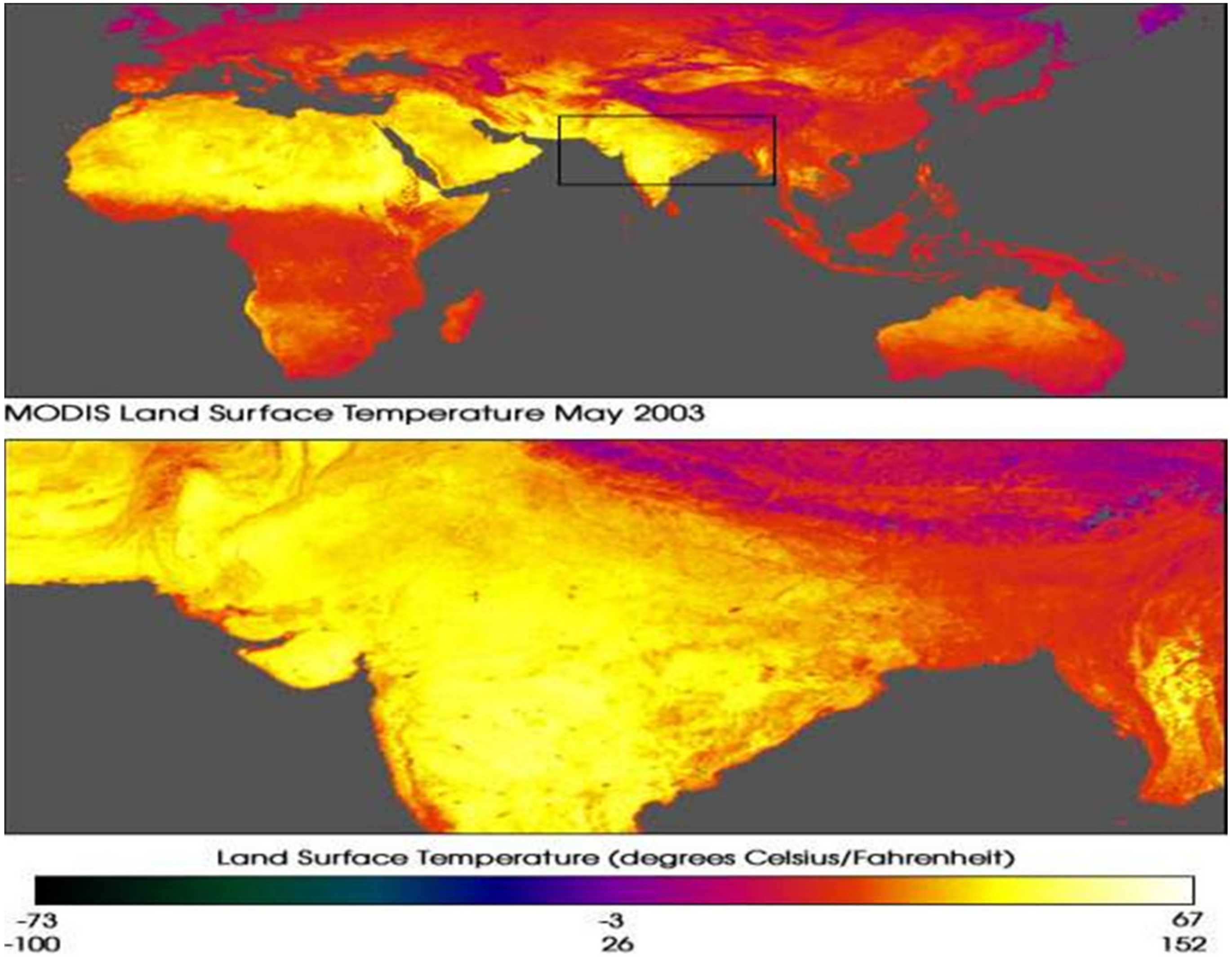
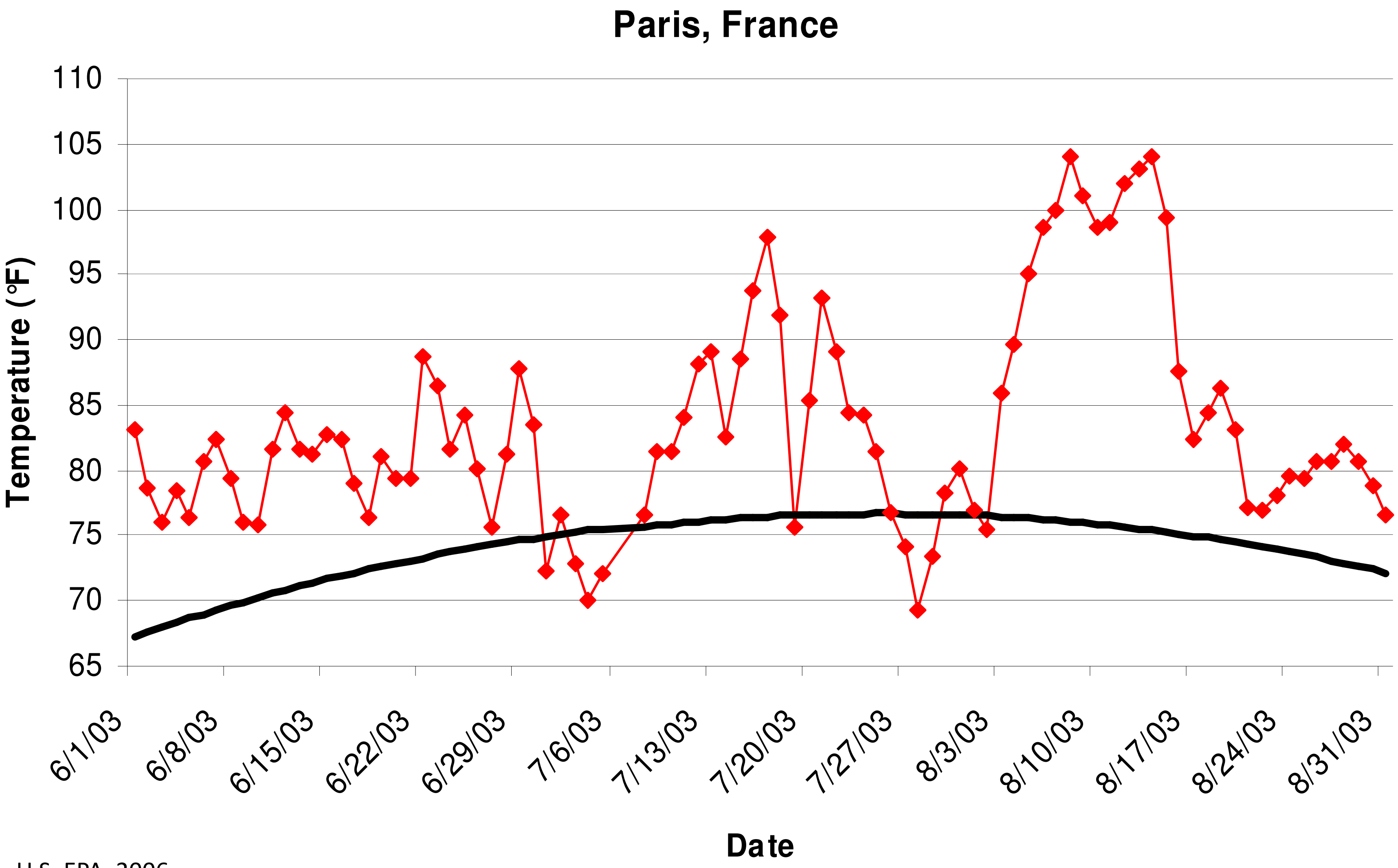
What Does Extreme Heat Look Like: Using Fixed Thresholds



NASA, 2008a

India in 2003 has the same temperature signal as the Sahara desert ≥50ºC

Extreme Heat Using Relative Thresholds: Paris 2003



U.S. EPA, 2006

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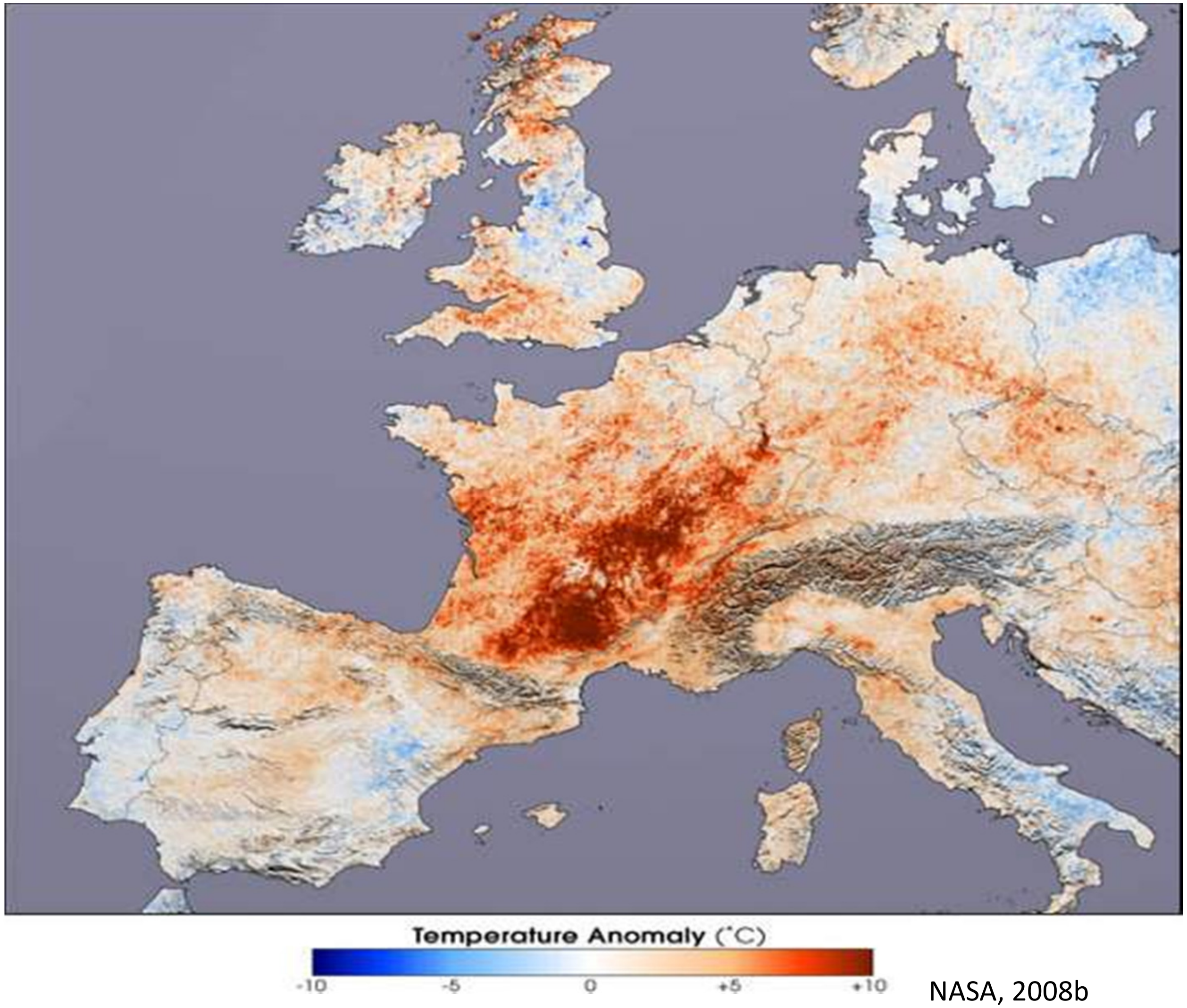
Extreme Heat Using Relative Thresholds: July 2003 in Europe



NASA, 2008b

Note estimates for the temperature difference comes from a comparison of the region in July 2001 with July 2003

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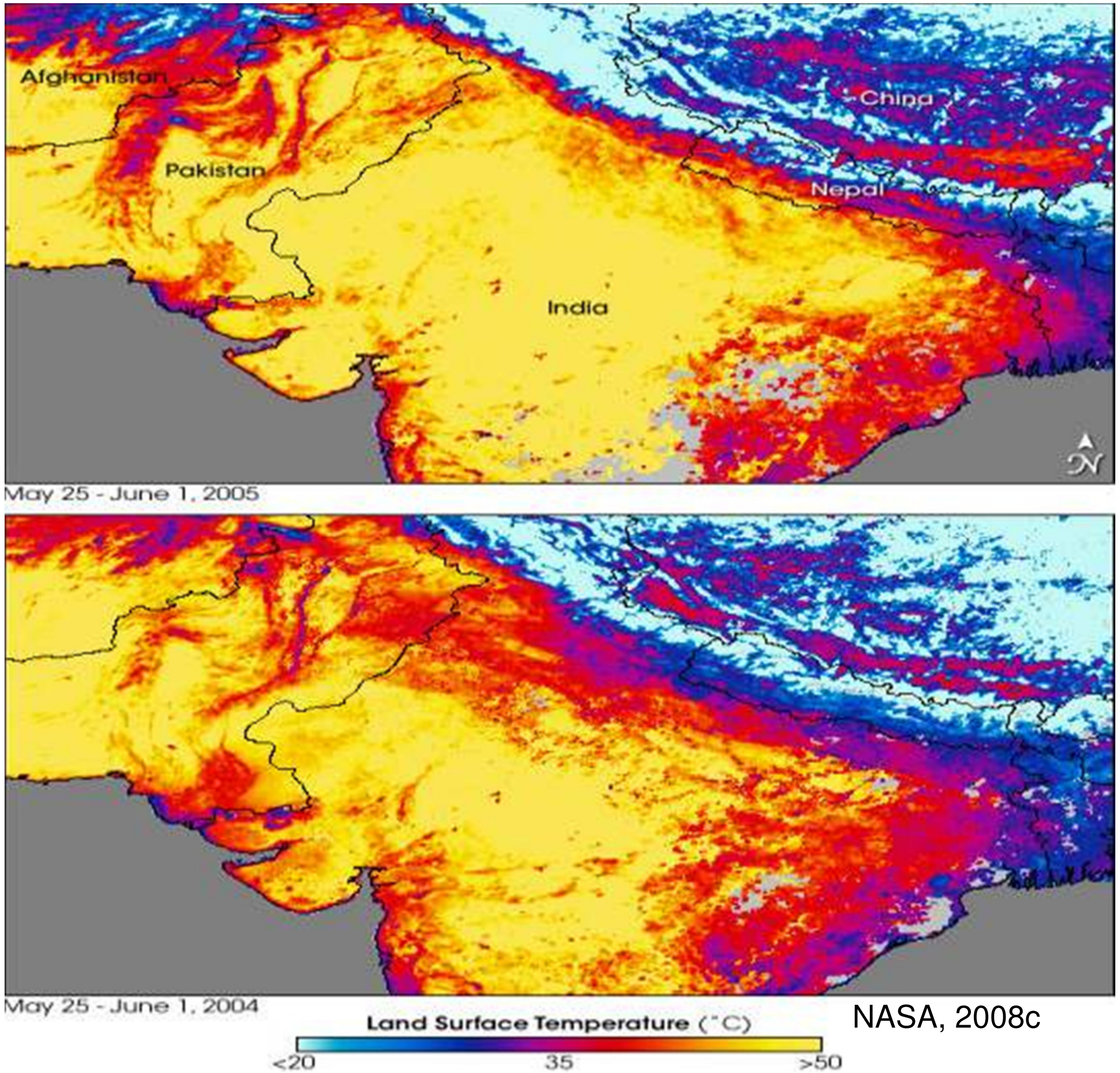
Extreme Heat Using Relative Thresholds: July 2003 in Europe



NASA, 2008c

Upper image shows start of Indian heat wave in May 2005 (upper slide) when compared with the same area at the same time in 2004 – “hot” in both

Note expanded yellow areas in top slide for 2005

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Identifying Thermal Extremes Based on Health Impacts

- “Significant” increases in health outcomes used to identify announce/recognize extreme thermal conditions or establish future criteria
- Increases should still be evaluated vs. localized norms that account for the time of year

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Using Health Impacts to Identify Thermal Extremes: Concept

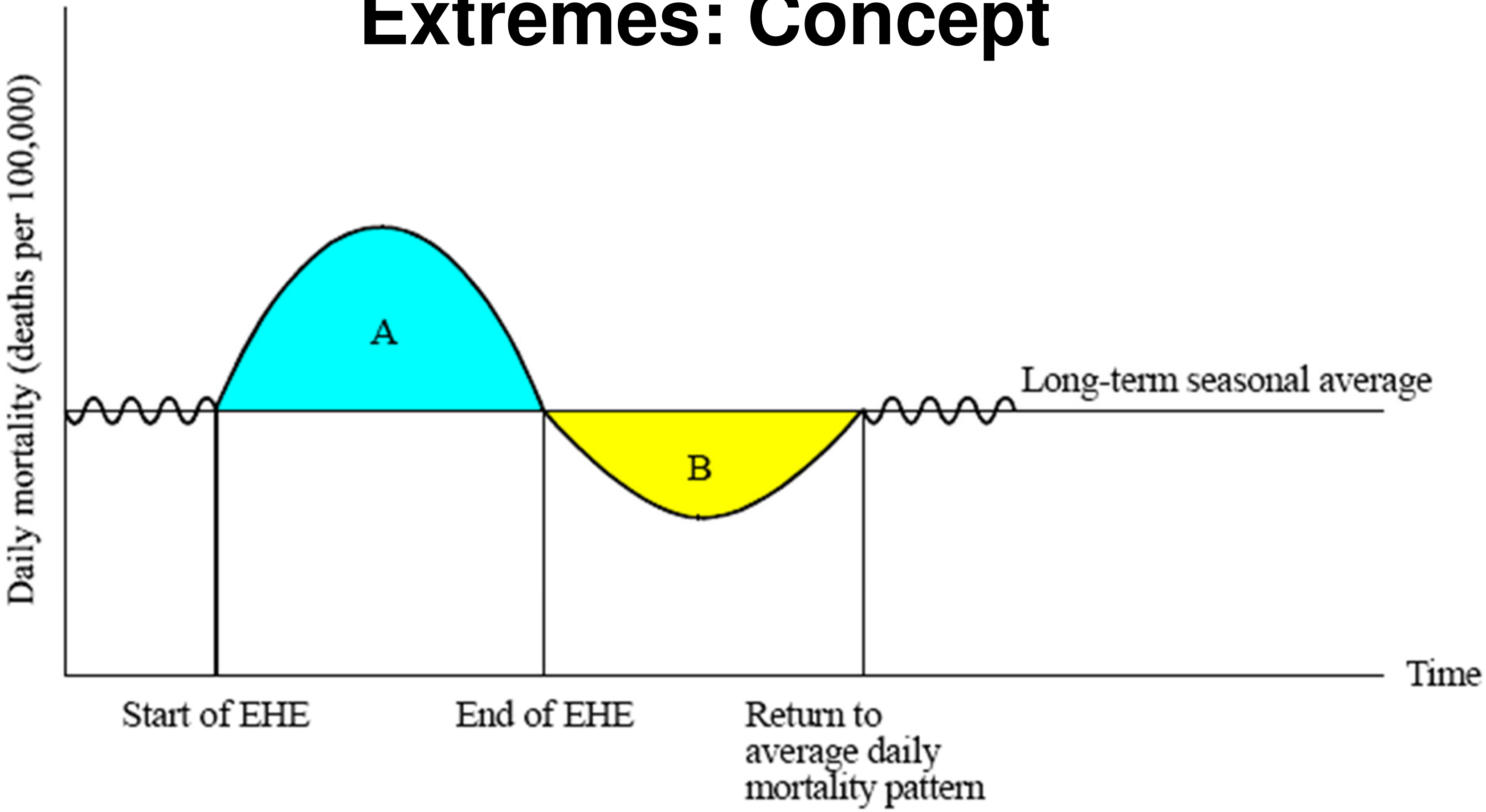

Figure 3.2. Mortality displacement in EHEs.

Example reflects extreme thermal conditions that result in excess mortality (A) followed by depressed mortality (B) indicating "harvesting"

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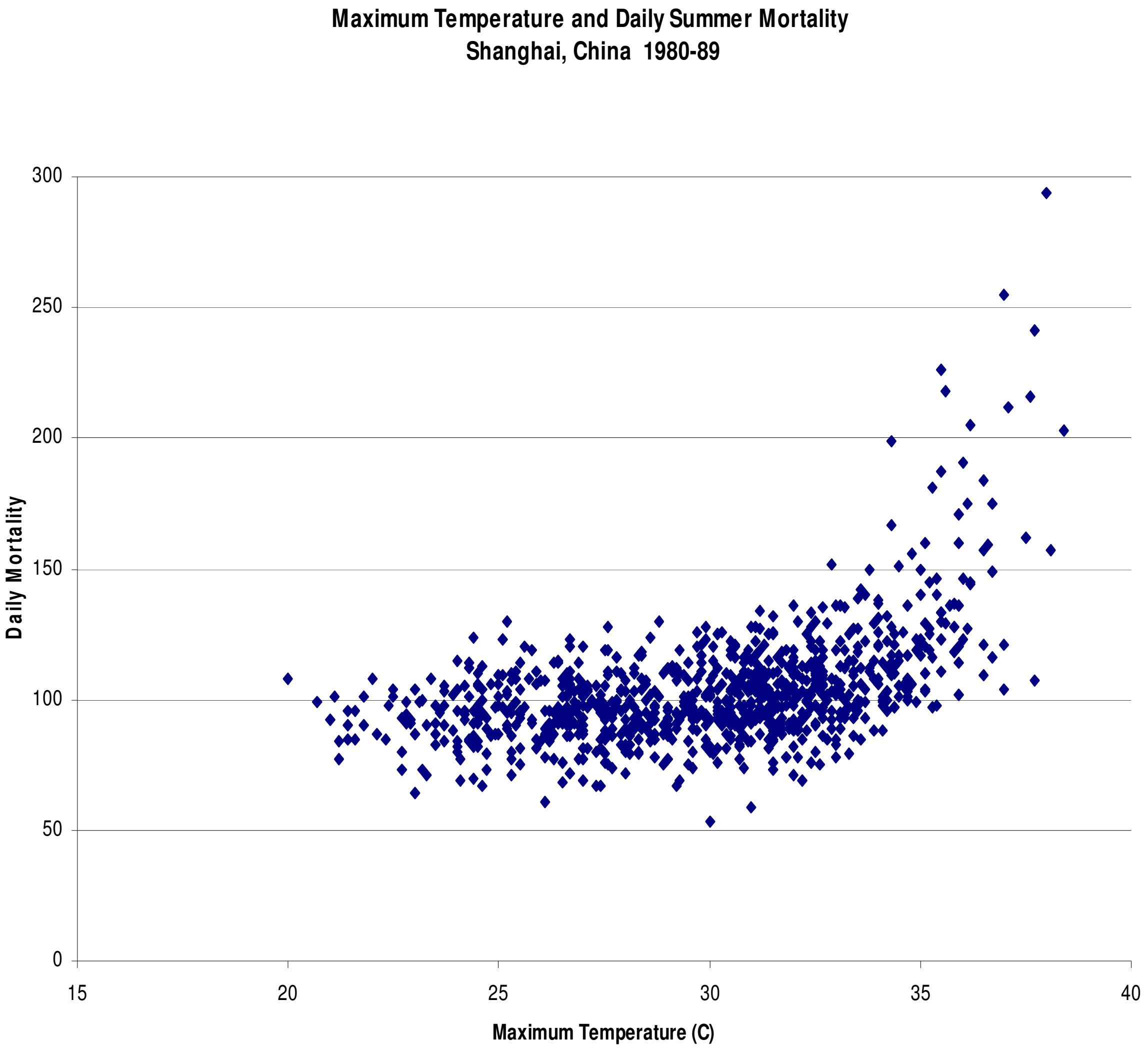
Identifying Thermal Extremes Using Meteorology and Health Impacts

- Evaluate how the historical relationship between weather and health outcomes (e.g., daily mortality) to establish criteria for extreme conditions

Identifying Thermal Extremes Using Meteorology and Health Impacts



(L. Kalkstein, personal communication, 2002)

Scatter plot of daily maximum temperature and total mortality to help identify possible summertime threshold temperatures for extreme heat in Shanghai, China based on the mortality impact

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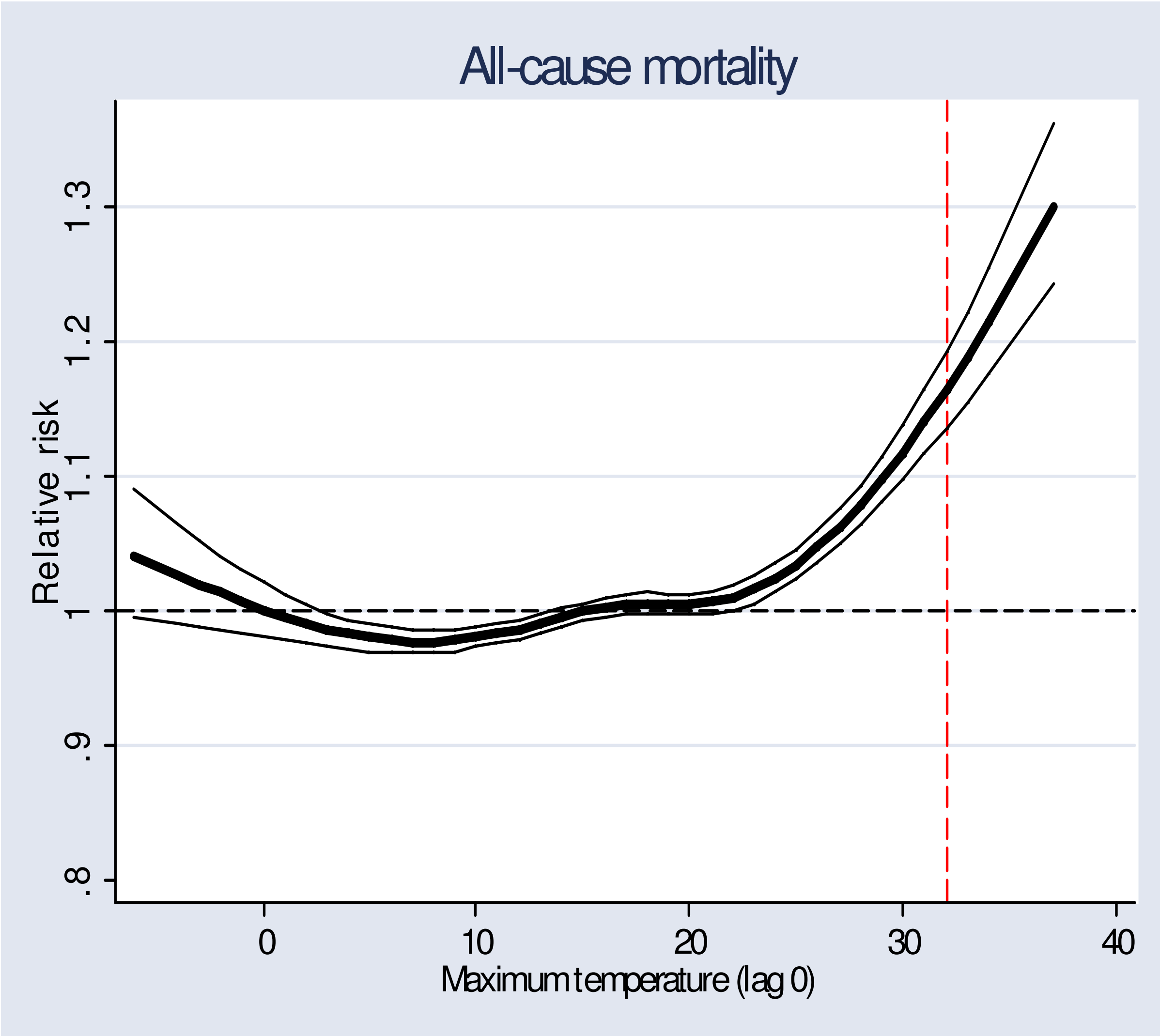
Thermal Extremes from Meteorology and Health Impacts Assessment



Marie O'Neill, pers comm, 2008

Hypothetical example of mortality and temperature risk results from epidemiological study of annual mortality

Note the J- or U-shape for the curve

Comparing Options for Identifying Extreme Thermal Conditions

- **Meteorological criteria:**
  - **Strengths**
    - Can be easy to set
    - Understandable if based on simple measures
    - Can be used proactively with weather forecasts to provide advance warning of impending conditions
  - **Weaknesses**
    - Generally don't vary by time of season (doing so can cause confusion with public)
    - Fail to account for whether the criteria have a link with the changes in health risk or impacts

Comparing Options for Identifying Extreme Thermal Conditions (cont.)

- **Using observed health outcomes:**
  - **Strengths:**
    - Certain: if you observe “significant” impacts you know extreme thermal conditions exist
  - **Weaknesses**
    - Reactive: need to rely on real-time data to identify dangerous conditions
    - Requires accurate, comprehensive, and timely health outcome reporting systems
    - Lagged notification and response – outcomes a result of exposure so dangerous conditions already being experienced before warning is provided
    - Short term resource commitment to monitoring vs. response might be better balanced

Comparing Options for Identifying Extreme Thermal Conditions (cont.)

- **Using combined meteorological and health impact assessments**
  - **Strengths**
    - **Accurate**: any criteria will be based on periods of interest where weather significantly increased health impacts
    - **Flexible**: various assessment methods can be used depending on available data (visual evaluation, regression)
    - **Proactive**: with criteria established can evaluate weather forecasts for dangerous conditions
  - **Weaknesses**
    - Approach can be difficult to explain
    - Outreach and education messaging can be complicated

Personal Characteristics and Thermal Extreme Vulnerability

- **Factors that increase personal vulnerability to extreme thermal conditions**
  - Extreme age: both older and younger individuals
  - Poverty
  - Low level of fitness
  - Physical or mental impairment
  - Restricted mobility
  - Social isolation
  - Chronic conditions/use of specific medications
  - Extended direct exposure to ambient heat

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Evaluating the Health Risks and Impacts of Thermal Extremes

- How should the health impact of thermal extremes be quantified?
  - Develop and use estimates of “excess” outcomes instead of counts based on listed medical condition codes for thermal exposure

Options for Quantifying the Health Risk of Thermal Extremes

- **Epidemiologic studies**
  - Evaluate the historical association of weather conditions with adverse health outcomes
  - Can generate odds ratios or relative risk estimates for changes in thermal measures or combinations of meteorological conditions
  - Conditional results can be generated (e.g, risk by age of persons affected, by thermal threshold)

Options for Quantifying the Health Risk of Thermal Extremes (cont.)

- **Air mass-based studies**
  - Air masses capture distinctions in weather considering multiple meteorological variables (e.g., temperature, humidity, wind speed)
  - Map the air masses over the time period of interest in the area of interest
  - Compare health outcomes, by air mass, with longer term averages
  - Air masses with elevated outcome rates may identify extreme thermal conditions
  - Regression analysis can be used to predict health outcomes given conditions in an air mass

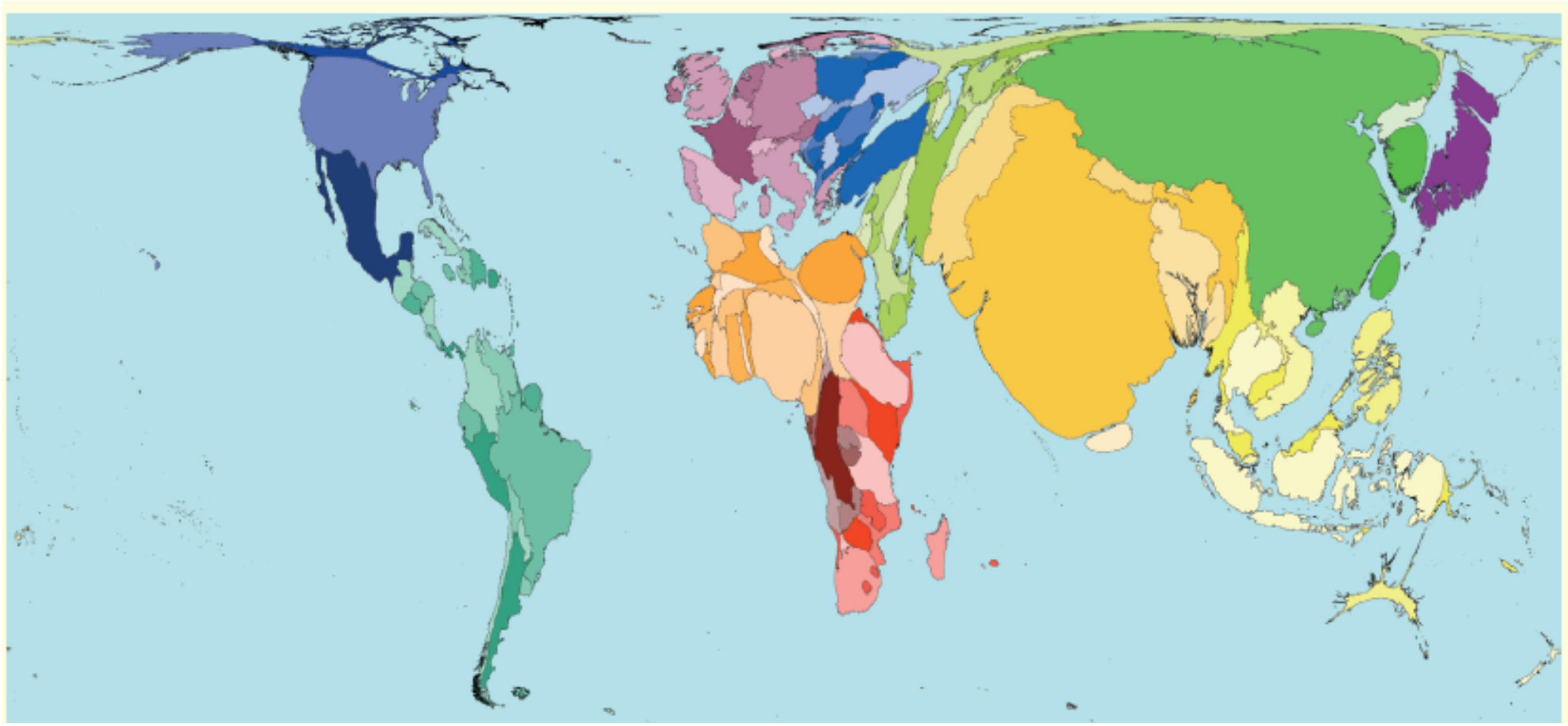
Options for Quantifying the Health Risk of Thermal Extremes: Summary

- Different study methodologies exist for identifying and quantifying impact of thermal extremes
- Epidemiological and air-mass based studies end up focusing on, and have their results driven by, the same set of acute events
- Availability of historical and forecast data may shape the appeal of pursuing one approach or the other

Current Impacts of Thermal Extremes: Cartogram Results

- **Cartograms**
  - Re-weight a country's land area as a percentage of the variable in question
  - For health outcomes
    - Larger countries/regions account for more of the health impact in question (e.g., deaths from a cause or cases of an illness)
    - For evidence of a relatively high or disproportionate impacts compare cartograms for the health outcome with cartograms of population

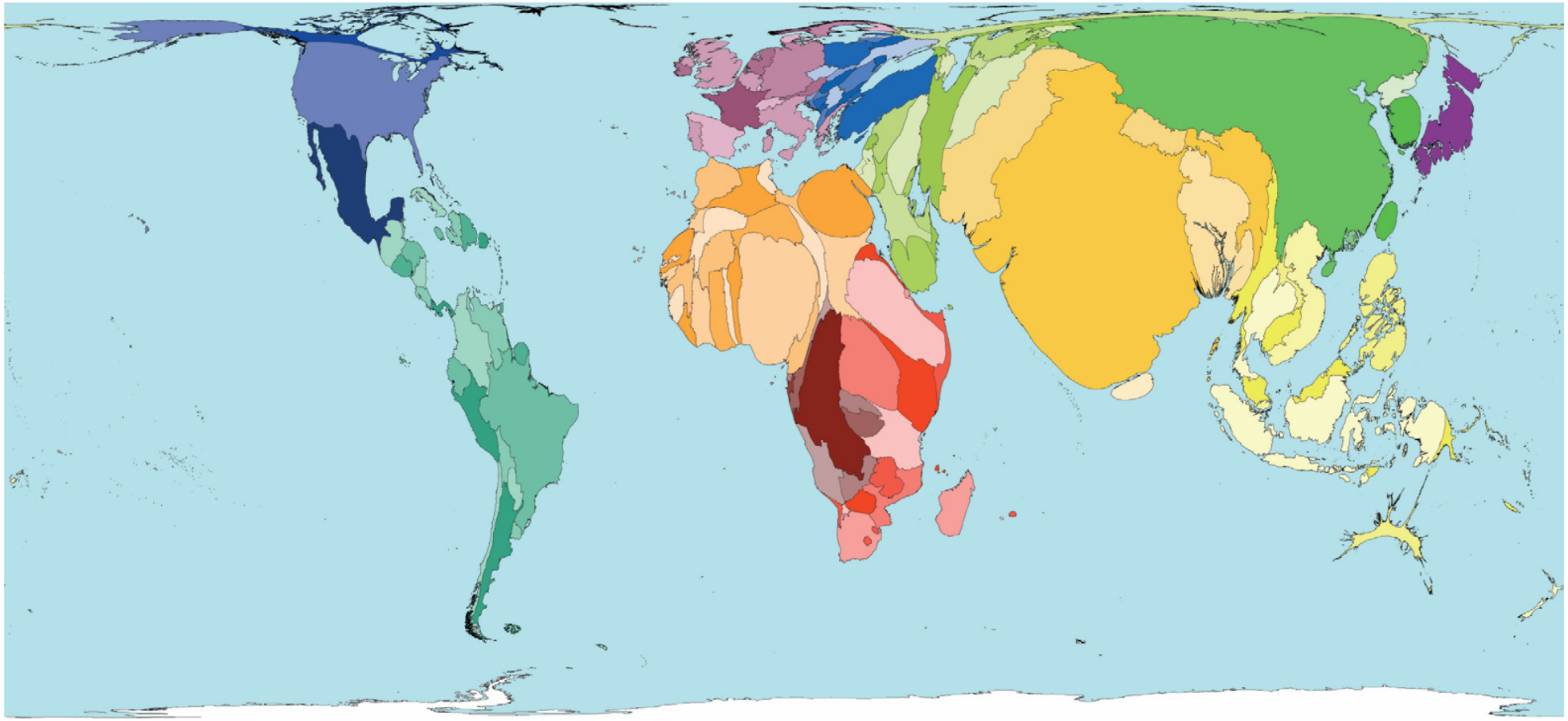
Cartogram Baseline Now: World Population in 2000



Countries' areas are re-weighted according to the size of their population: note India and China

Worldmapper, 2008a

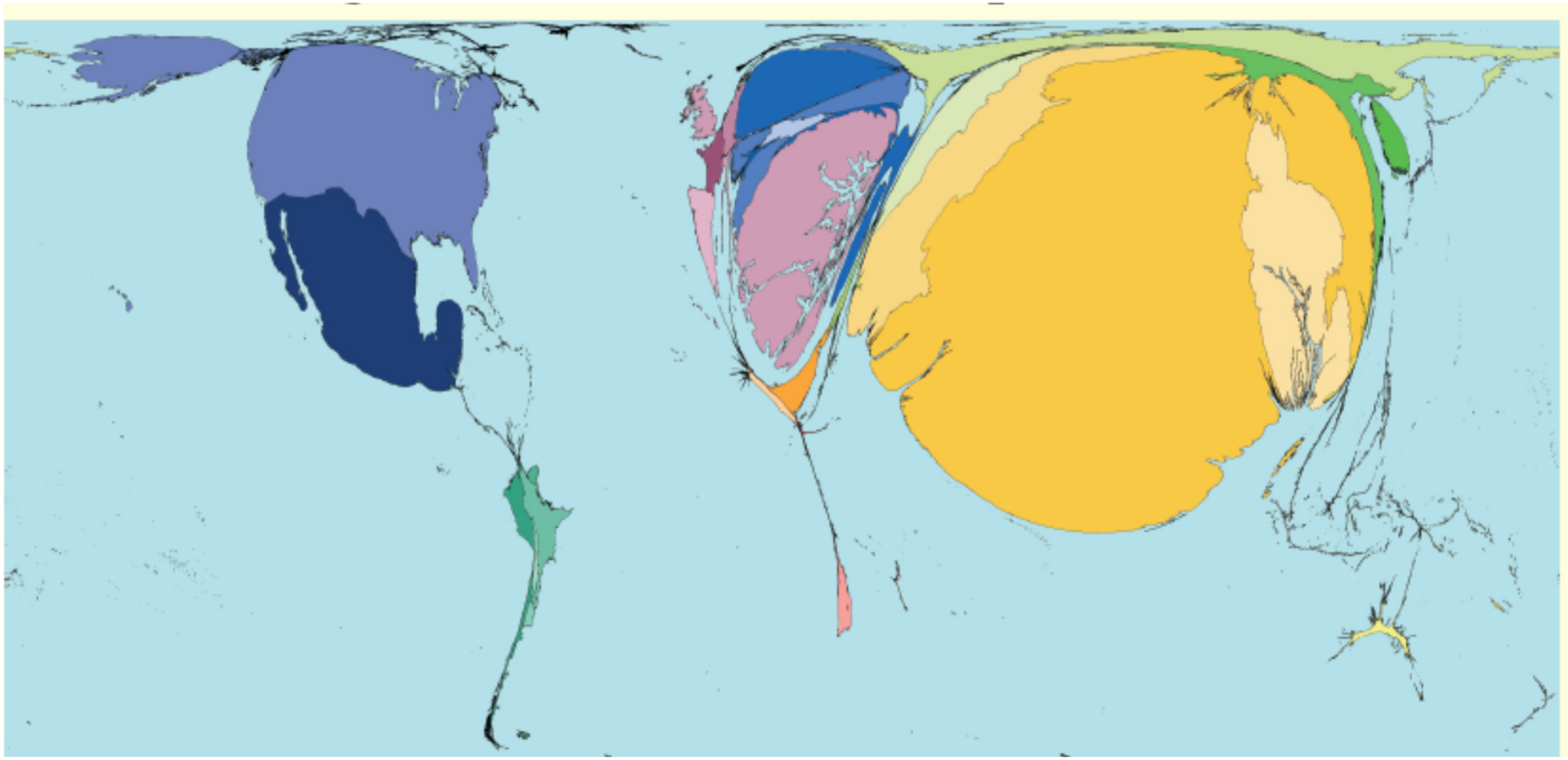
Cartogram Baseline Now: World Population in 2050



Countries' areas re-weighted according to the size of 2050 populations, this is a period relevant for climate change

Worldmapper, 2008a

Current Impact of Thermal Extremes – 1975-2000 Cartogram



Country size proportional to share of total deaths from thermal extremes for years 1975-2000, Note India and Bangladesh

Worldmapper, 2008c

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Mortality Impacts of Thermal Extremes: Vulnerable Countries

MOST PEOPLE KILLED BY EXTREME TEMPERATURE DISASTERS

Rank	Territory	Value	Rank	Territory	Value
1	Greece	3.8	11	India	0.26
2	Cyprus	2.7	12	Pakistan	0.20
3	Albania	0.8	13	Russian Federation	0.18
4	Mexico	0.4	14	Romania	0.18
5	Afghanistan	0.4	15	Serbia & Montenegro	0.15
6	Lithuania	0.4	16	Jordan	0.11
7	Poland	0.4	17	Kyrgyzstan	0.08
8	Croatia	0.3	18	Uruguay	0.08
9	United States	0.3	19	Spain	0.07
10	Bangladesh	0.3	20	Peru	0.06

*people killed per million people per year 1975-2000**

SEA member countries among those with a recent history of significant heat-related mortality

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Impacts of Thermal Extremes

It's too hot to work for cart pullers in New Delhi

CBS News, 2002

The health impacts of thermal extremes are not limited to mortality

BBC News, 2000

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Climate Change in South East Asia Region: Impact on Thermal Extremes

- Expected warming of region under climate change scenarios evaluated in recent IPCC reports (IPCC, 2007a)
- Expect more extreme heat events in the SEA, and also Indian Ocean region

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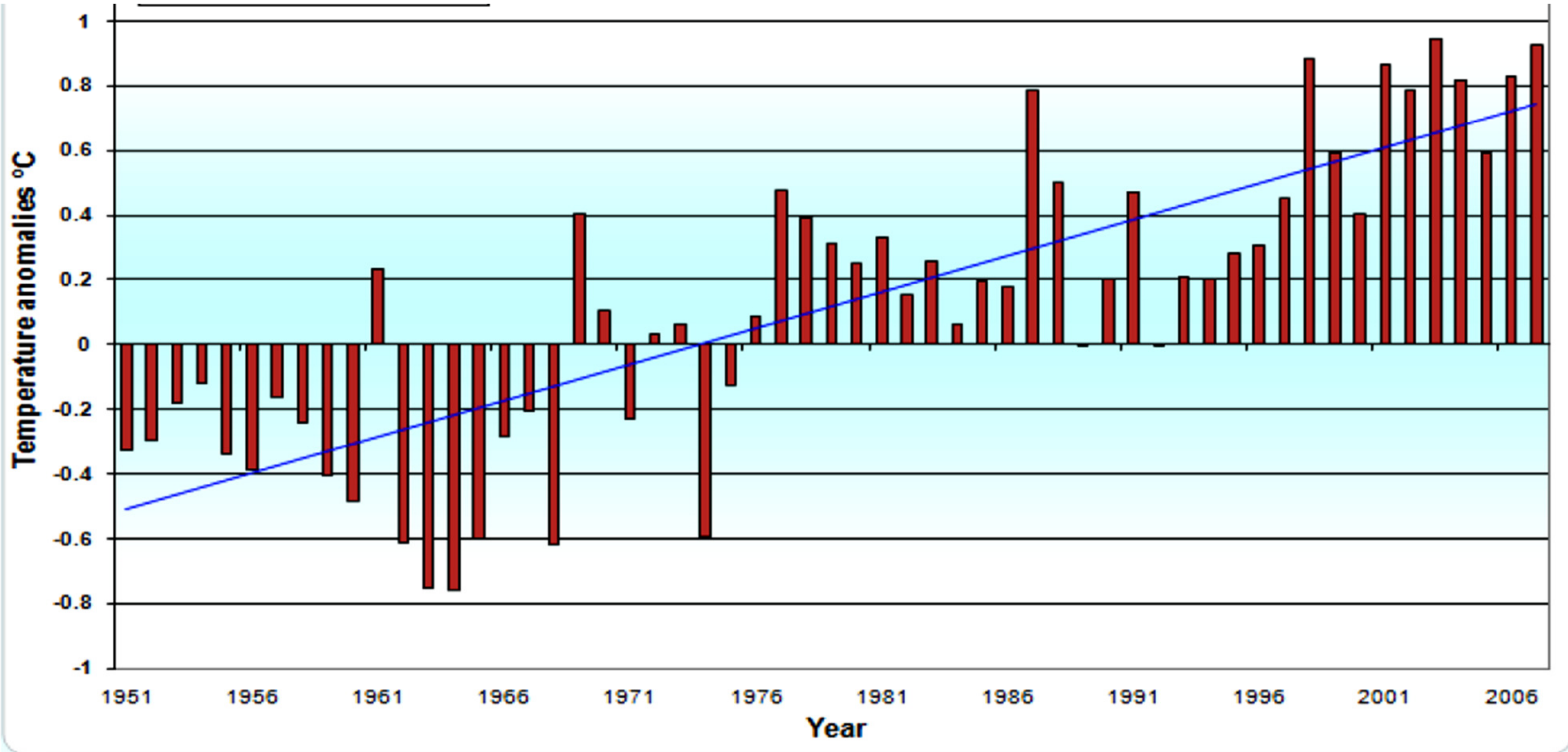
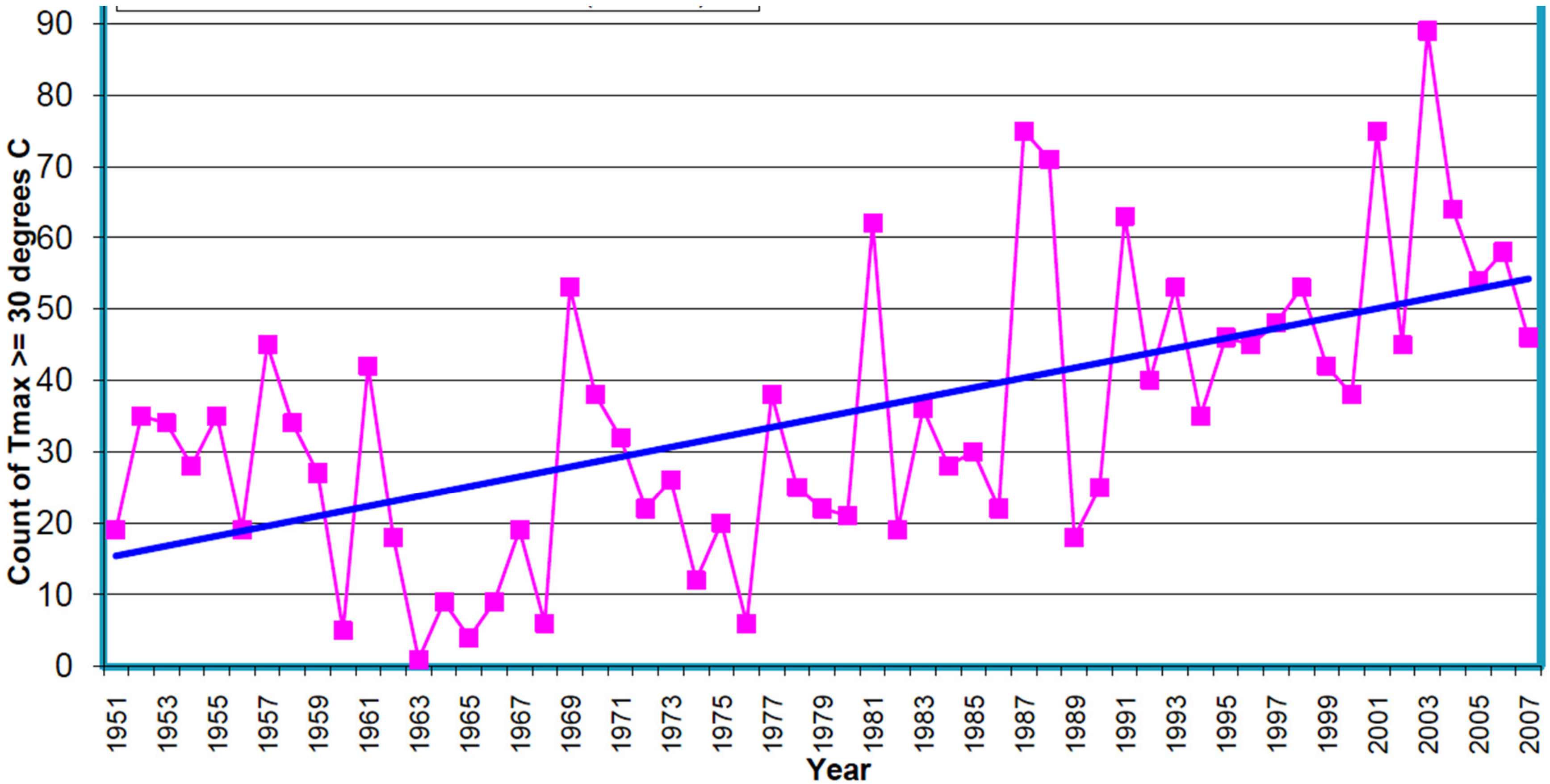
Mauritius (Plaisance) Avg. Temperature Anomaly (1951-2007)



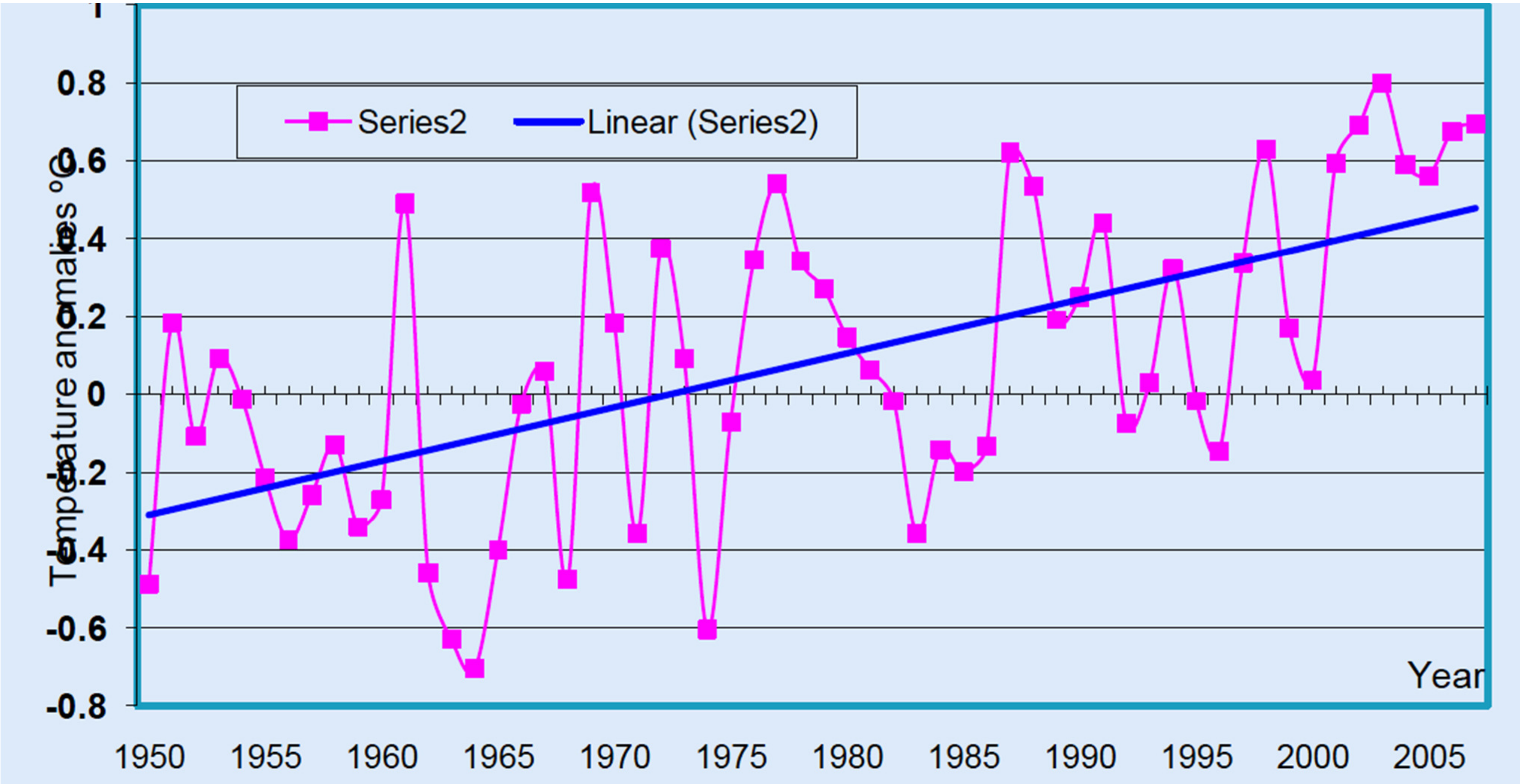
Second National Communication of the Republic of Mauritius under UNFCCC 2010

Mauritius (Plaisance) Annual Number Days with Tmax >= 30°C



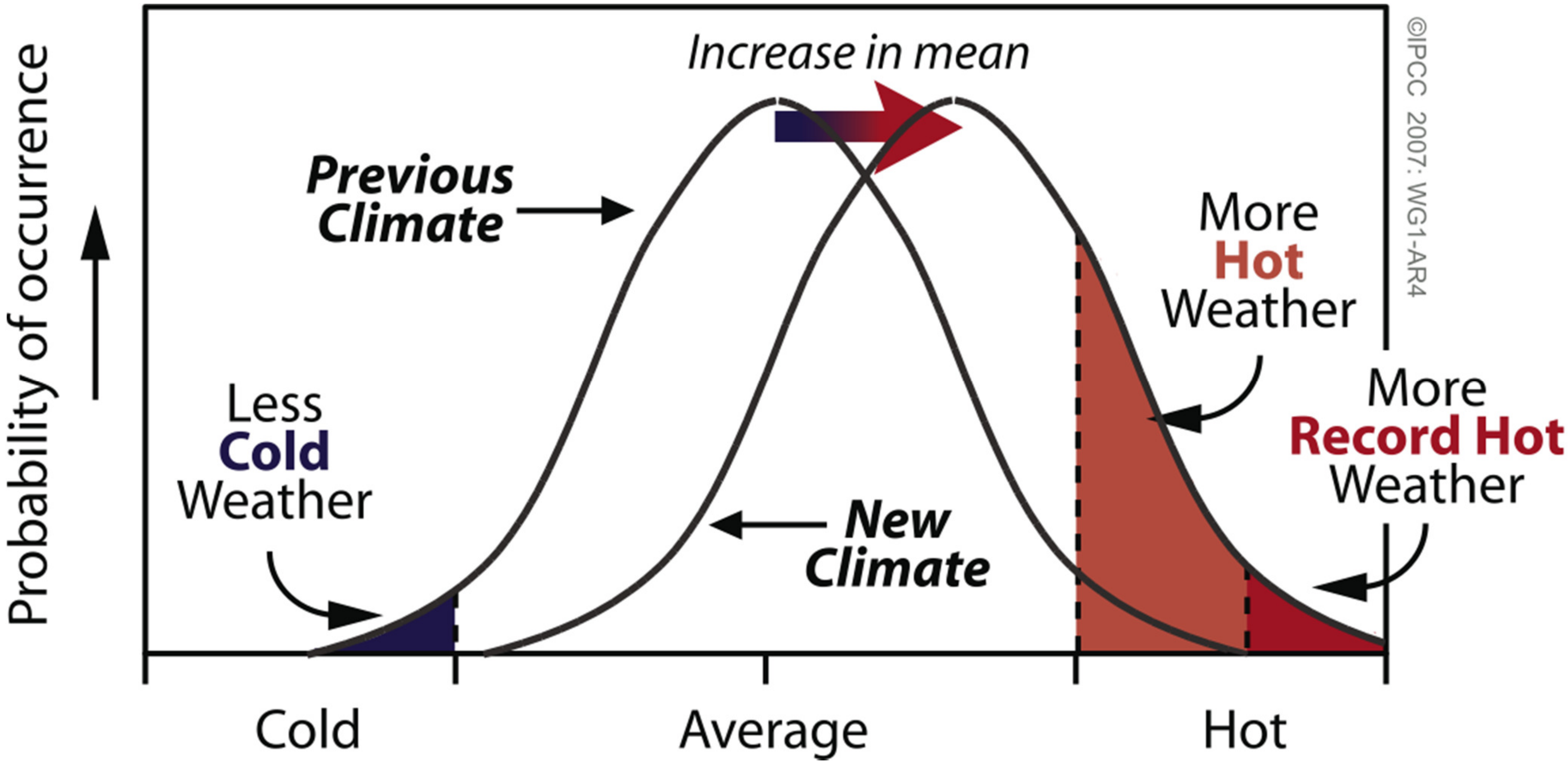
Second National Communication of the
Republic of Mauritius under UNFCCC 2010

Mauritius (Vacaos) Avg. Annual Temperature Variation and Trend (1950-2007)



Second National Communication of the Republic of Mauritius under UNFCCC 2010

Climate Change: Temperature Distribution Shift to More Heat



IPCC, 2007b

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Future Impacts of Thermal Extremes with Climate Change

- Factors increasing overall risk
  - Larger populations
  - More people in elevated risk groups (**old, young, poor**)
  - Expect more and more **severe extreme heat** events
  - May be reaching important **exposure thresholds** without adaptation

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Health Impacts of Thermal Extremes with Climate Change

- **Factors mitigating overall risk and impacts**
  - Anticipated increase in **standard of living**
  - Conditions can be accurately **forecast**
    - Provides time to implement notification and response programs
  - **Adaptive responses** could help minimize future impacts
    - Increasing knowledge about successful heat notification and response programs
    - Increased adoption of heat notification and response programs

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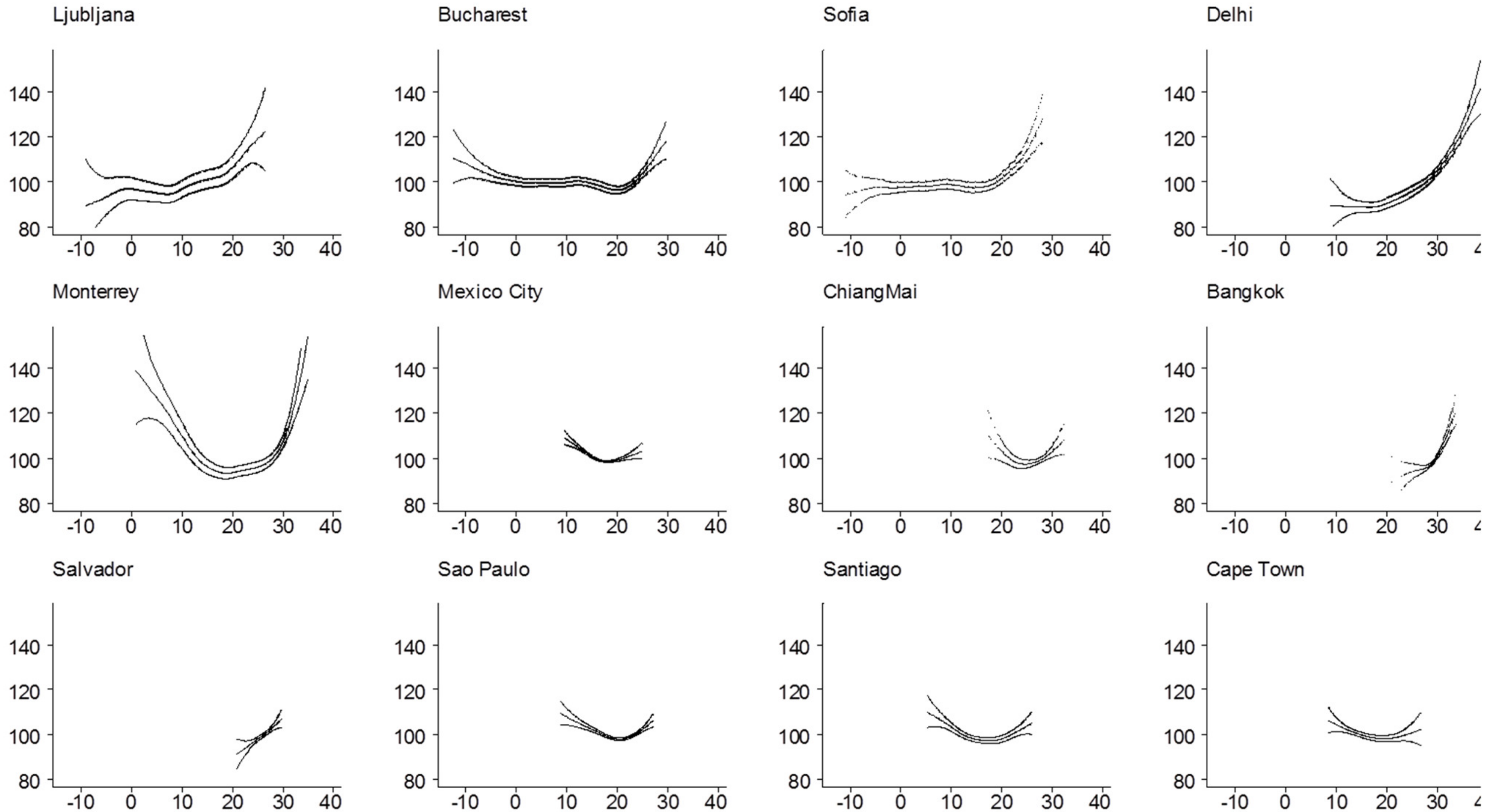
Isothurm Results: Climate Change and the Adaptation Challenge



McMichael et al., 2008b

How quickly can/will a location's heat-mortality response function respond with/to socio-economic and climate changes?

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Extreme Heat Adaptation Programs: Elements of Success

- **Active evaluation** of weather forecasts using results from health impact studies
- Provide **clear advice** in terms of actions to take and avoid
- Know who and where the **most vulnerable** people are
- Help **provide relief** from the heat

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Extreme Heat Adaptation Programs: Elements of Success (cont.)

- Provide opportunities to request assistance/evaluation for self and others
- Be creative in use of available resources
  - Short term assignment changes for some public sector staff
- Review response to events to identify successes and areas for improvement
- Revise program as needs/opportunities change

Conclusions

- Evaluate extreme thermal event conditions and impacts **against local baselines**
- Both hot and cold extreme thermal events, already have a significant public health impact in the SEA region. Questions remain for Mauritius
- In addition to health, events likely produce significant adverse **social impacts** with reduced worker productivity
- Climate change is likely to increase the health risks of these events with more and potentially more severe **extreme heat events**

Conclusions

- **Larger and older** populations could increase the risk for additional adverse health outcomes from these events in the future
- **Adaptation**, notably notification and response programs, might help control anticipated increases in these outcomes
- The cost of successful adaptation is the **lost potential** to address other issues with limited resources
- There is "**no free lunch**" with adaptation

Discussion

Questions?

Thoughts?

Concerns?

Suggestions?

http://thefuturebuzz.com/2008/10/13/stunning-images-flickr-creative-commons/

Acknowledgements

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