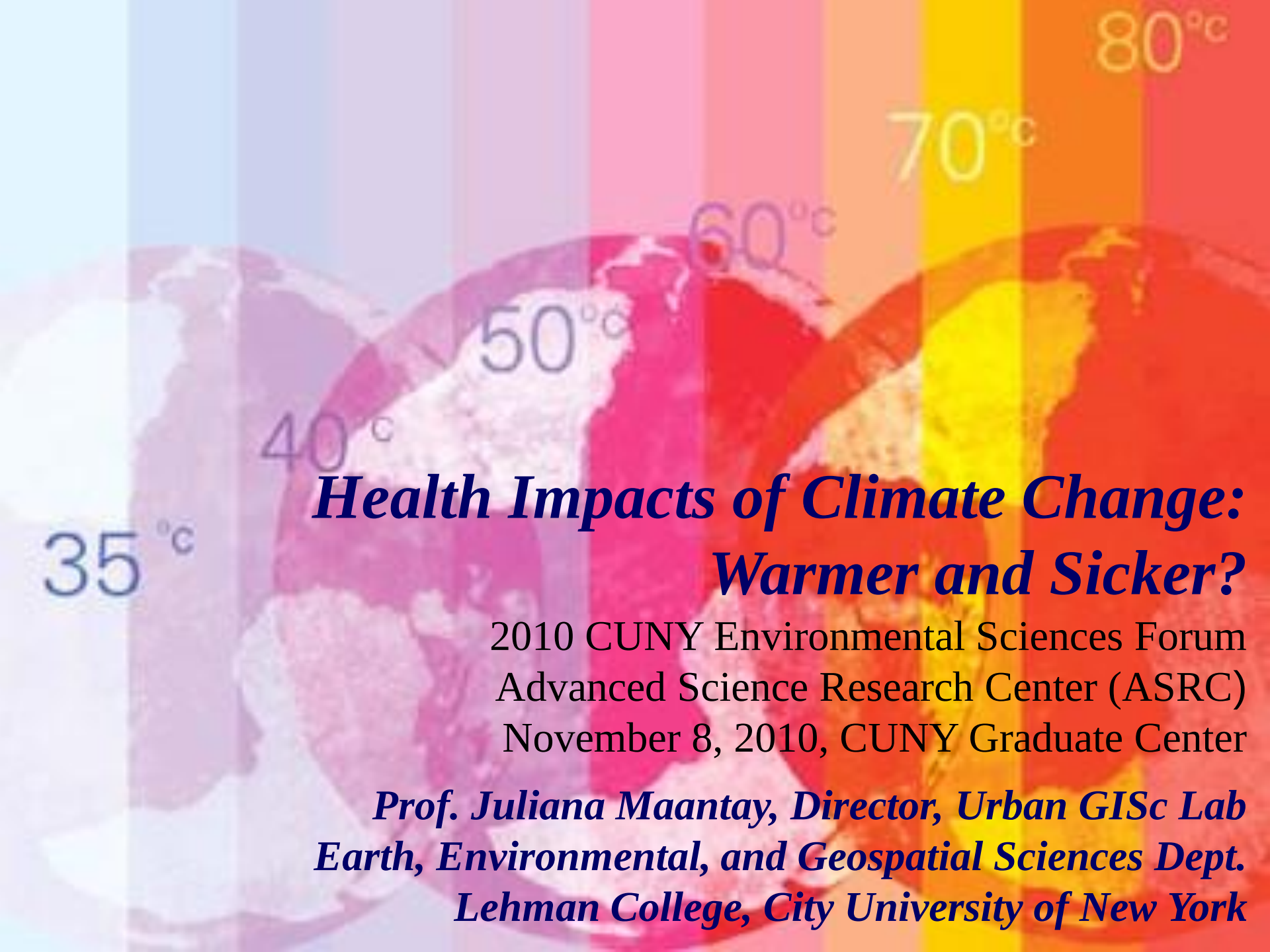
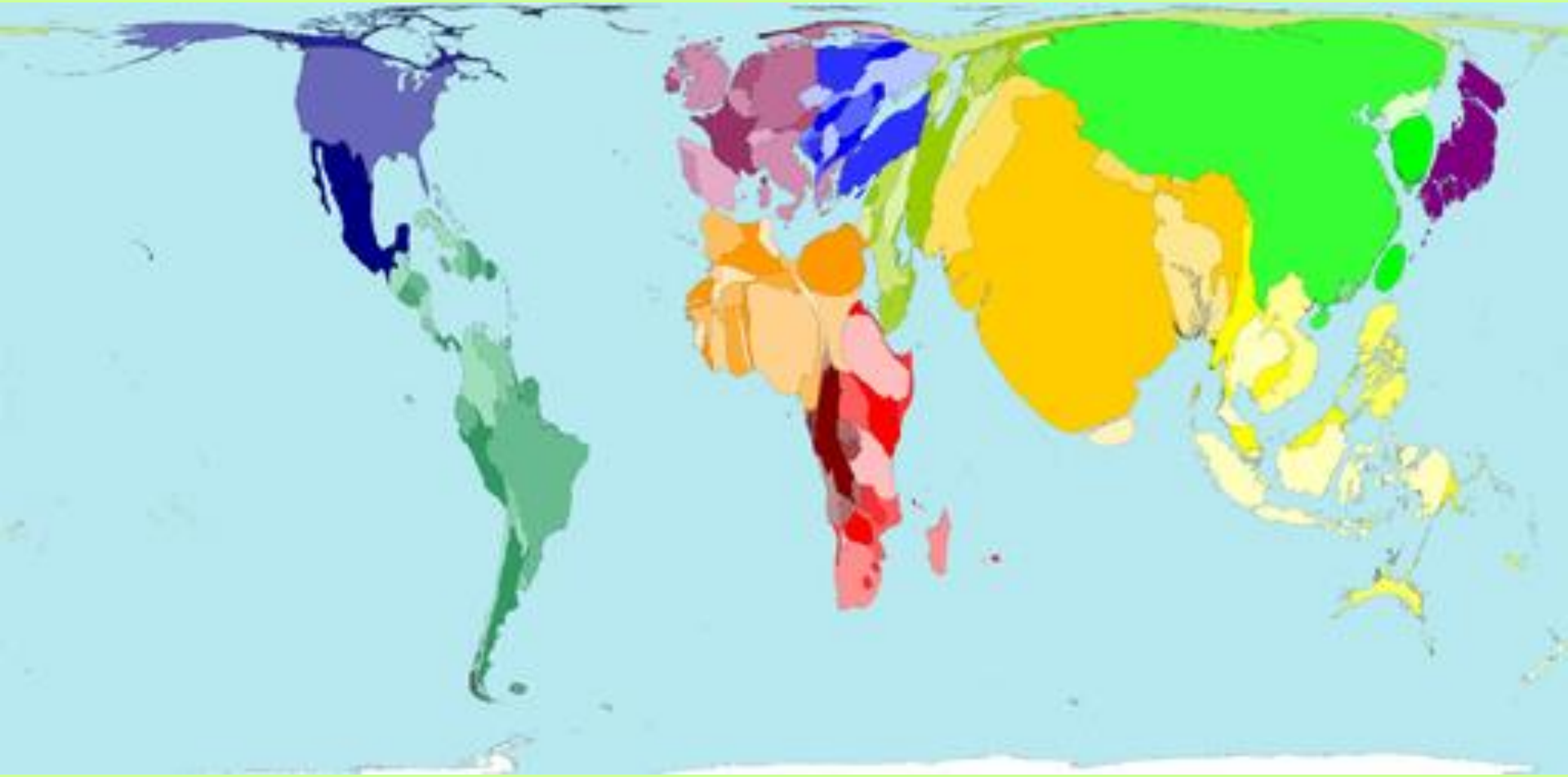


Health Impacts of Climate Change: Warmer and Sicker?

2010 CUNY Environmental Sciences Forum
Advanced Science Research Center (ASRC)
November 8, 2010, CUNY Graduate Center

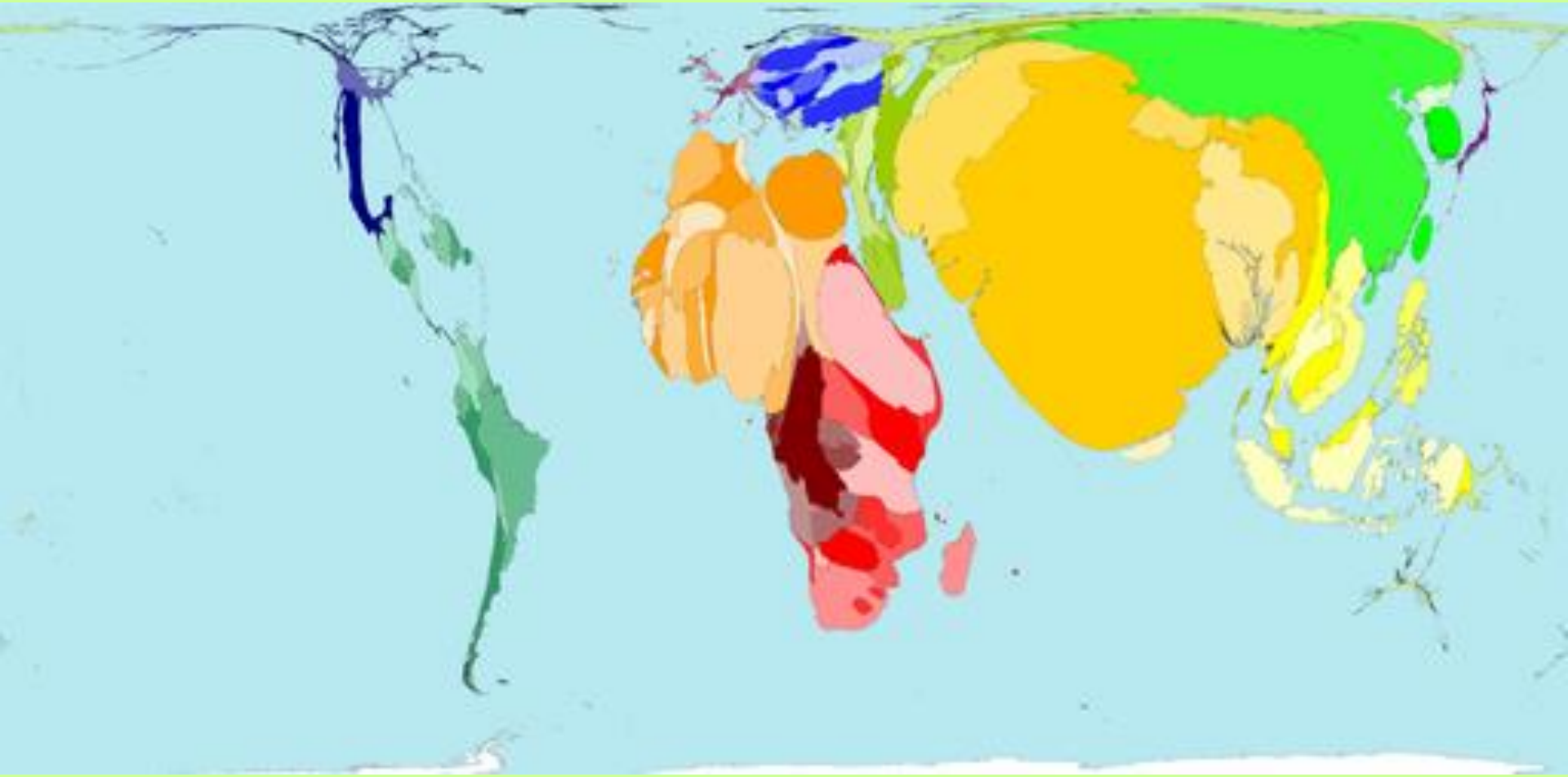
Prof. Juliana Maantay, Director, Urban GISc Lab
Earth, Environmental, and Geospatial Sciences Dept.
Lehman College, City University of New York

Total World Population – Cartogram (Value-by-Area Map)



In Spring 2000 world population estimates reached 6 billion; that is 6 thousand million. The distribution of the earth's population is shown in this map.India, China and Japan appear large on the map because they have large populations. Panama, Namibia and Guinea-Bissau have small populations so are barely visible on the map. Population is very weakly related to land area. **The size of each territory shows the relative proportion of the world's population living there.**

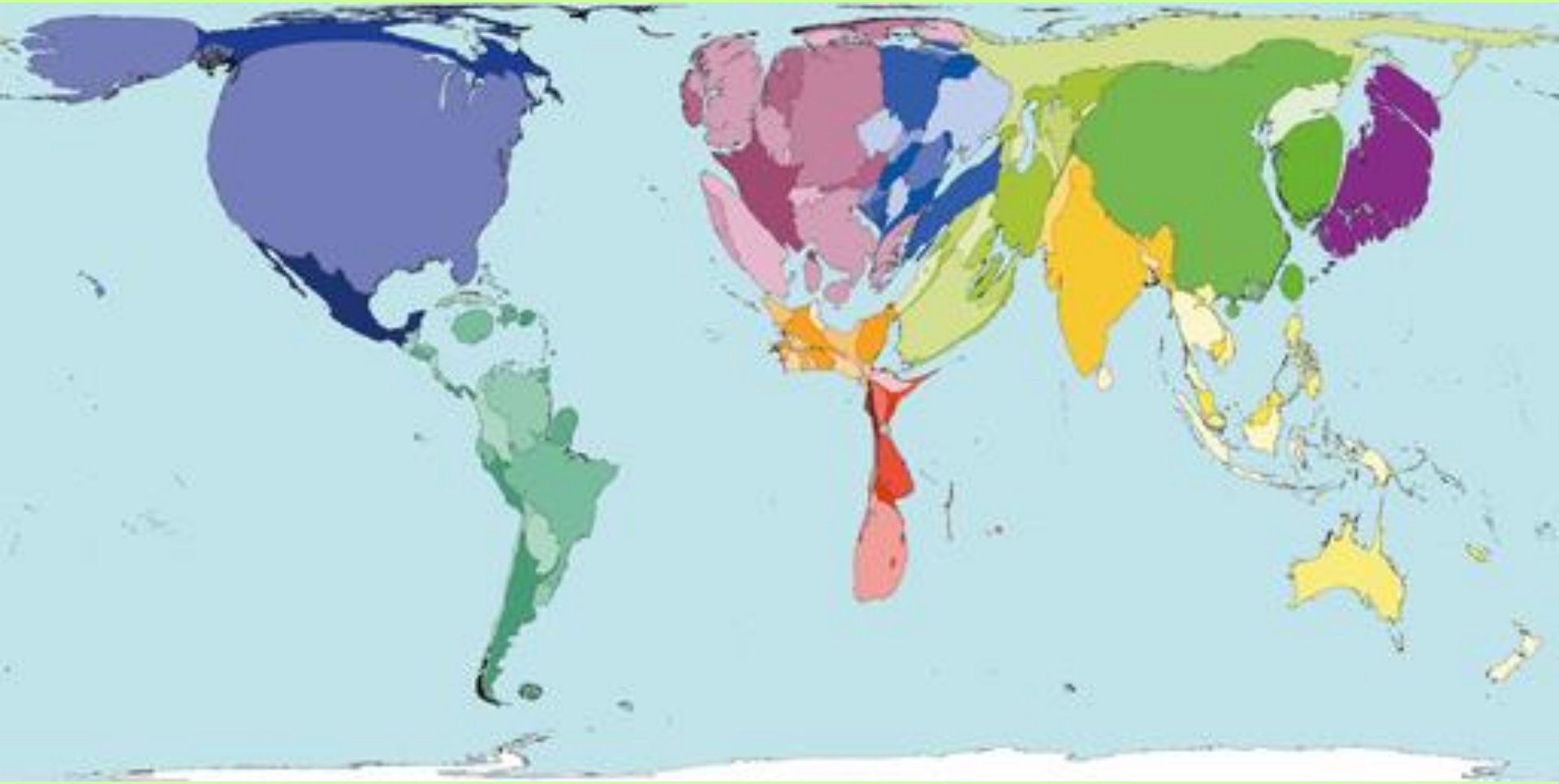
Human Poverty



Poverty is not just a financial state. Being poor affects life in many ways. The human poverty index uses indicators that capture non-financial elements of poverty, such as life expectancy, adult literacy, water quality, and children that are underweight. The 30 territories of the Organisation for Economic Cooperation and Development use a different index which includes income and long-term unemployment; and not water quality or underweight children. This implies that the poor in richer territories are materially better off.

The highest human poverty index scores are in Central Africa, the lowest are in Japan.

Emissions of Greenhouse Gases

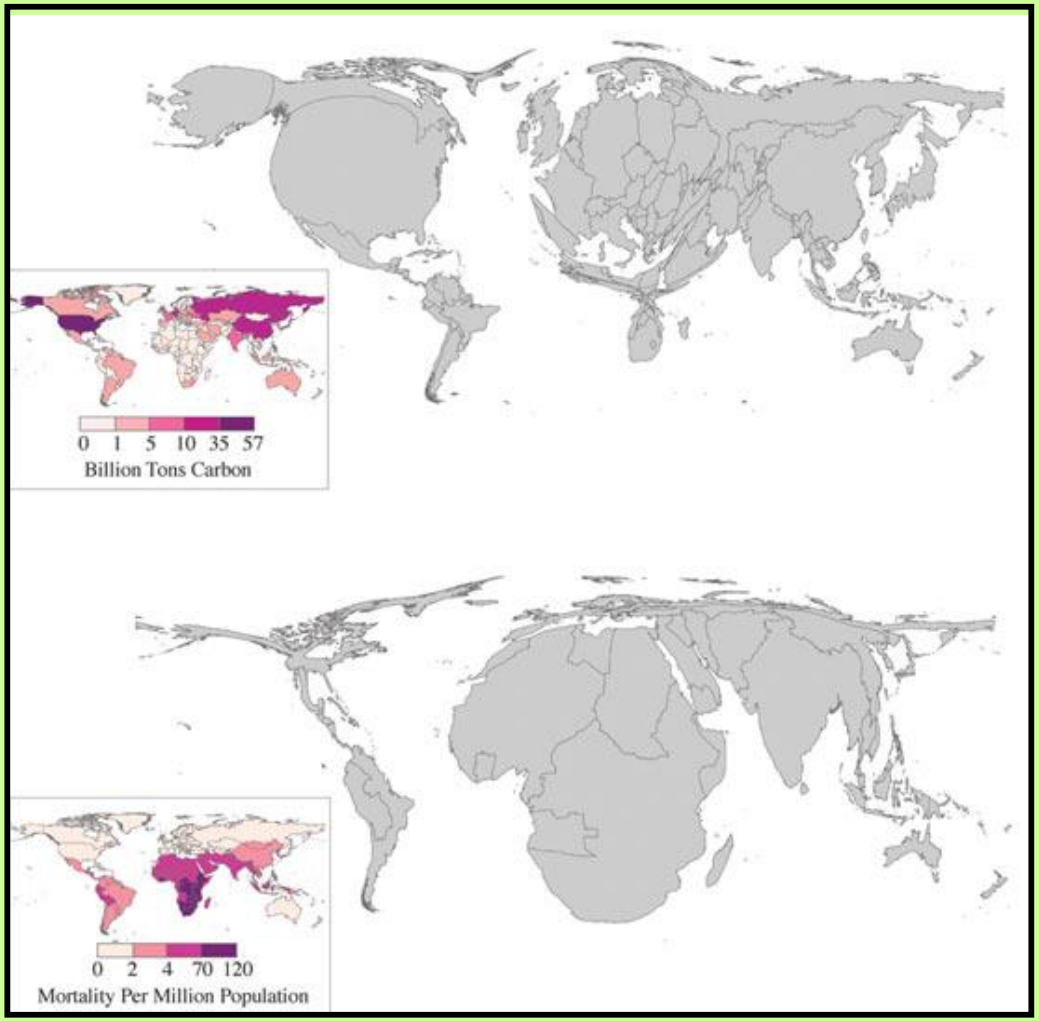


Greenhouse gases trap heat in the earth's atmosphere, causing it to warm up. The greenhouse gases shown here are carbon dioxide, methane and nitrous oxide. These gases account for 98% of the greenhouse effect. The territories that emit the most greenhouse gases are the United States, China, the Russian Federation and Japan. However, the most emissions per person are in Qatar: equivalent to 86 tonnes of carbon dioxide per year. Qatar has significant oil and gas reserves, and in 2002 was populated by 600,000 people. **Territory size shows the proportion, by their global warming potential, of all greenhouse gas emissions that come from there.**

The Ethical Dimensions of Global Climate Change

TOP MAP:
Carbon Output (in billions of tons of carbon)

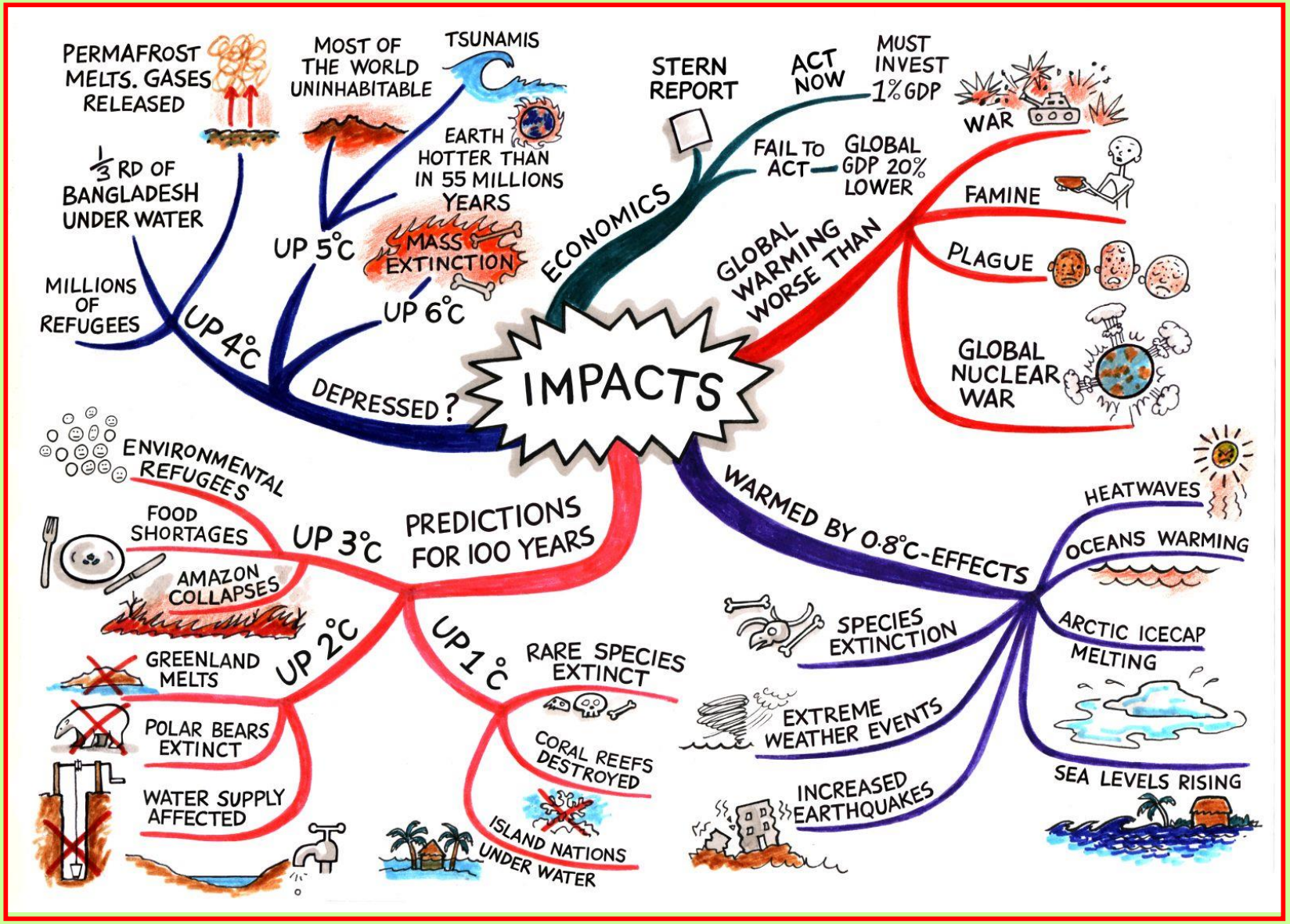
BOTTOM MAP:
Health effects of global warming (in mortality per million people)



Data Source: University of Wisconsin-Madison (2007, November 12). Health Toll Of Climate Change Seen As Ethical Crisis. *ScienceDaily*.

The two world maps schematically represent the contribution of different nations to global warming, as measured in atmospheric carbon output (top) and the health effects of global warming as measured in mortality for diseases and other effects of a warming world climate (bottom). The effort to compare and contrast such measures is one way to illustrate the ethical dimensions of global climate change. (Credit: Jeff Miller, Image courtesy of University of Wisconsin-Madison)

Mental Map of Global Warming Impacts



Data Source: "*Global Warming: A MindMapper's Guide to the Science and Solutions*," by Sharon Gennovese

The Disease Ecologic Approach – Physical Environment, Ecology, Human Culture

"Disease, any disease – and let me remind you that by disease I mean maladjustment to the environment – can never occur without the combination of three orders of factors converging in time and space, that is, there must be stimuli from the environment, there must be responses from an agent, and there must be the conglomeration of thoughts and traits that we call culture." (May, J.M. ***Studies in Disease Ecology***, 1961: xvi)

"Basic to the disease ecologic approach May presented is understanding how humanity, including culture, society and behavior; the physical world, including topography, vegetation, and climate; and biology, including vector and pathogen ecology, interact together in an evolving and interactive system, to produce foci of disease." (Mayer, J.D., 1996. The Political Ecology of Disease as One New Focus for Medical Geography. ***Progress in Human Geography*** 20(4): 441)

Potential Health Impacts from Global Climate Change

Heat Waves/UHI	More heat-related deaths and illnesses;
Air Pollution	Aggravation of cardiovascular and respiratory diseases from worsening air quality;
Terrestrial Changes	Risk of infectious diseases because of new geographic ranges and activity of disease-carrying animals, insects, and infective parasites;
Altered Marine Ecology	Changes in incidence of cholera and food poisoning from toxic algae;
Storms	Deaths and injuries from storms and floods and intestinal illnesses from flooding of sewage treatment plants;
Droughts	Rising malnutrition in some places;
Population Displacement	Injuries and increased risk of disease and conflict due to migration and crowding;
Saltwater Encroachment in Coastal Aquifers	Greater risk of intestinal illnesses from inadequate water supplies.

Direct Temperature Effects

- ***Heat Waves***: heat stroke, kidney disease, cardiovascular problems;

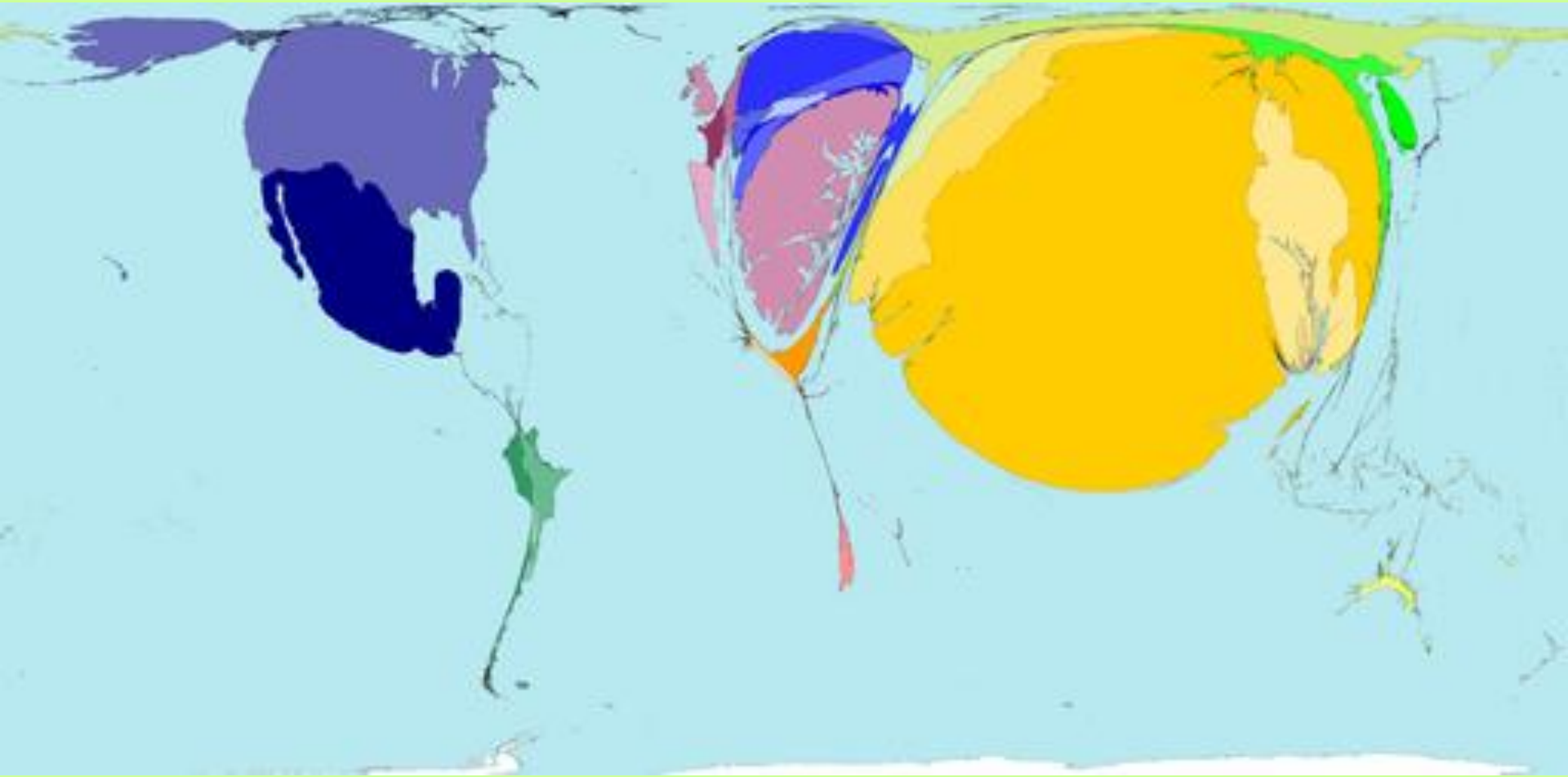
- ***Droughts:*** malnutrition, water shortages;

- ***Increased precipitation***: proliferation of vector-borne diseases;

- ***Smog***: respiratory disease;

Warmer temperatures lead to greater concentrations of ground-level ozone, which forms on hot, sunny days when pollution from cars and other sources mix. Smog can damage lung tissue, increasing respiratory and heart disease and death. Even modest increases in smog can cause asthma in children.

Killed by Extreme Temperatures



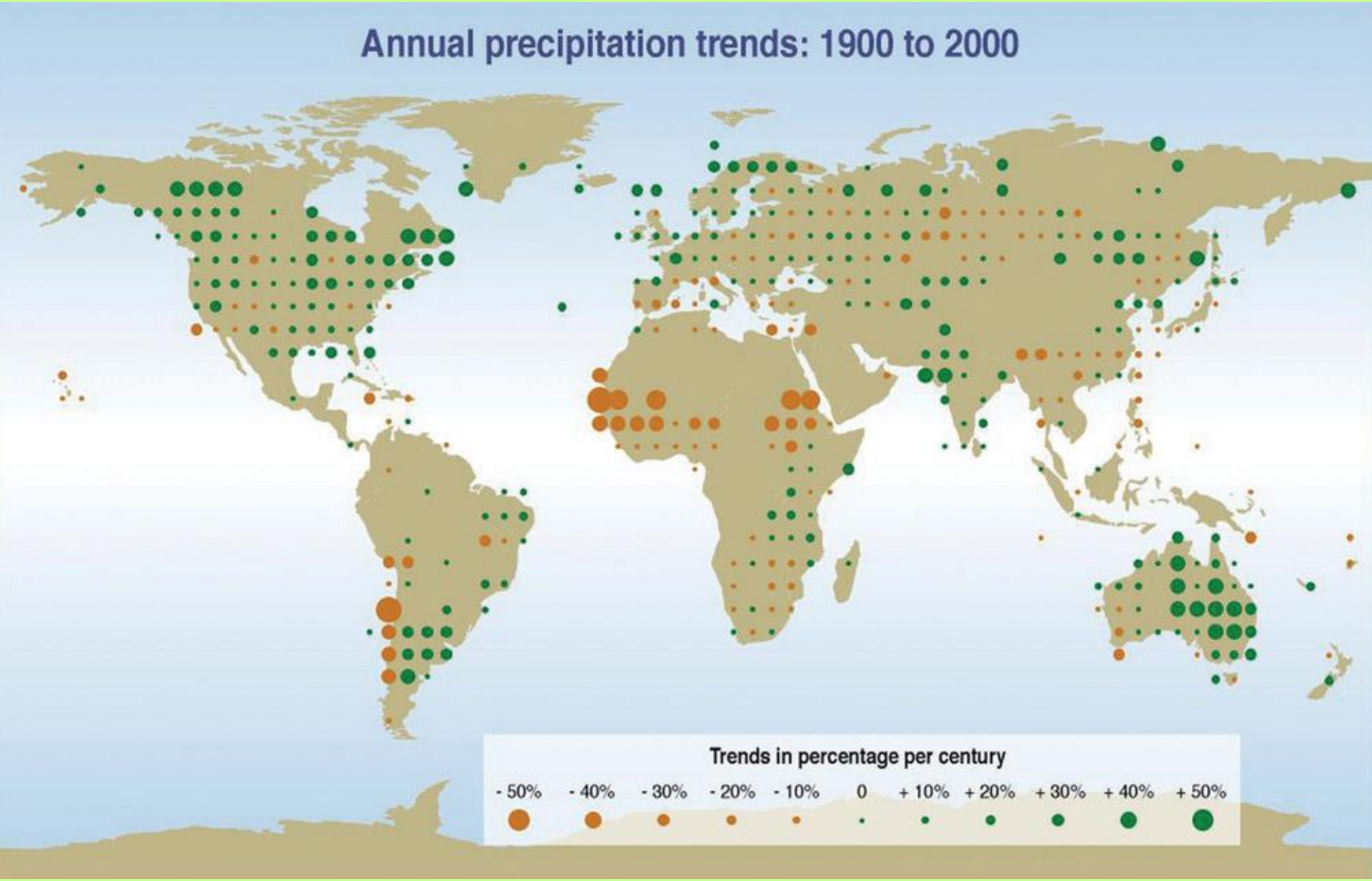
This is a map of people who have died from severe heat waves or cold waves, where the community have required help, between 1975 and 2000. Very hot and very cold temperatures can occur in the same place at different times. Extreme temperatures are most dangerous when they are unusual in that location. Over 15,000 deaths in disasters due to extreme temperatures have occurred between 1975 and 2000. The territories where the most deaths have occurred during this period are India, the United States, Greece and Mexico. **Territory size shows the proportion of all worldwide deaths in disasters due to extreme temperature that occurred there between 1975 and 2000. A disaster, here, is an event which overwhelms local resources**

Projections of Heat Wave Deaths Due to Global Warming

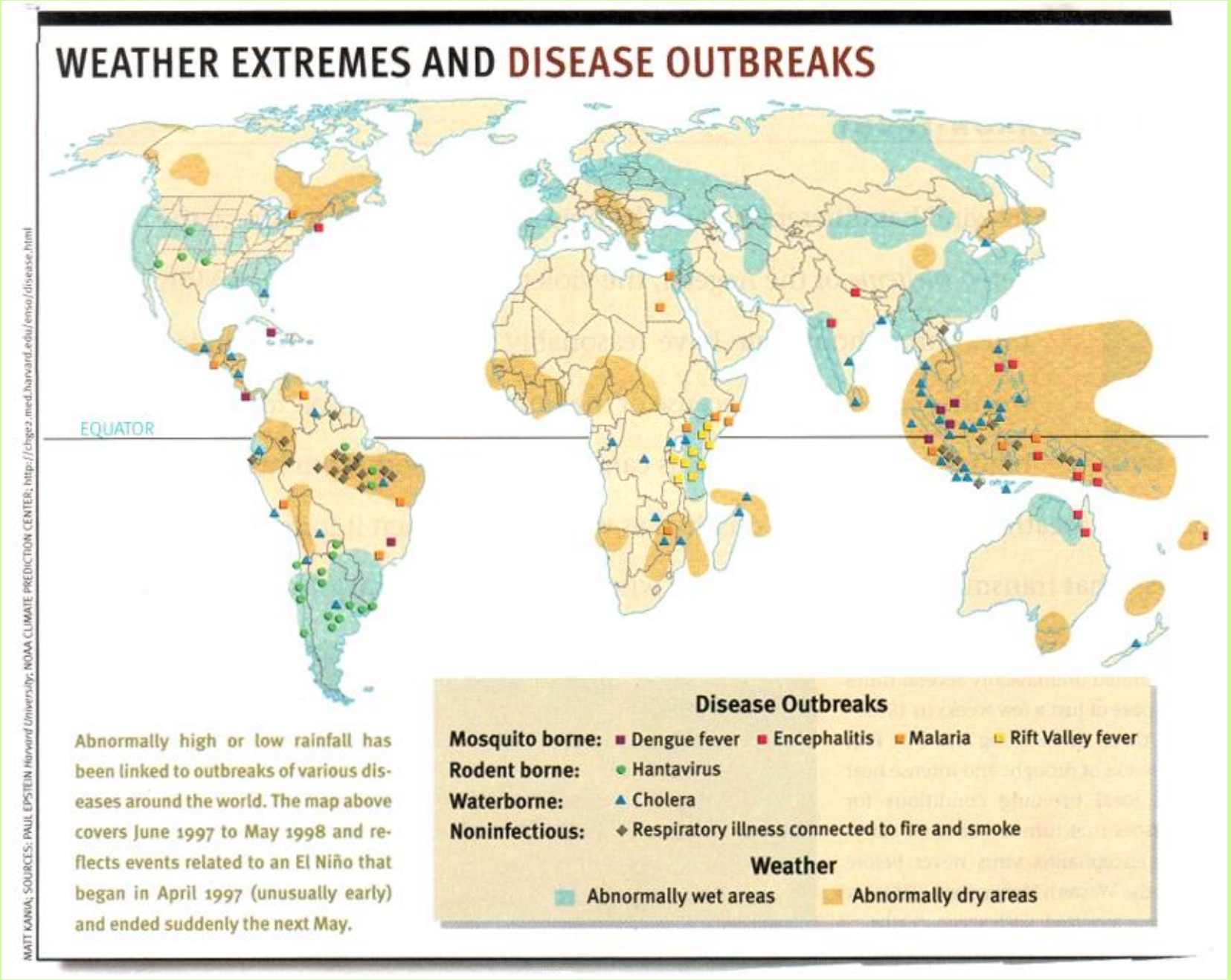
CITY	CURRENT DEATHS IN PRESENT CLIMATE	2020 *CLIMATE AVERAGE DEATHS	2050 *CLIMATE AVERAGE DEATHS
Buffalo, NY	33	34.3	55.3
Chicago,IL	191	400.7	497.3
Cleveland,OH	29	39	52.3
Detroit,MI	110	162.7	219
Indianapolis,IN	36	55.7	70
Kansas City,MO	49	115	127.3
Minneapolis,MN	59	129.3	174.7
Pittsburgh,PA	39	54	79.7
St. Louis,MO	79	160	185.3

Numbers derived from averages from three models -- United Kingdom Meteorological Model, Global Fluid Dynamics Laboratory Model, and Max Planck Institute for Meteorology Model. Population and metropolitan areas standardized to current levels. Lives spared due to warmer winters estimated to be negligible. Adapted from Laurence S. Kalkstein and J. Scott Greene.

Changing Rainfall Patterns



Weather Extremes and Disease Outbreaks (1997-1998)

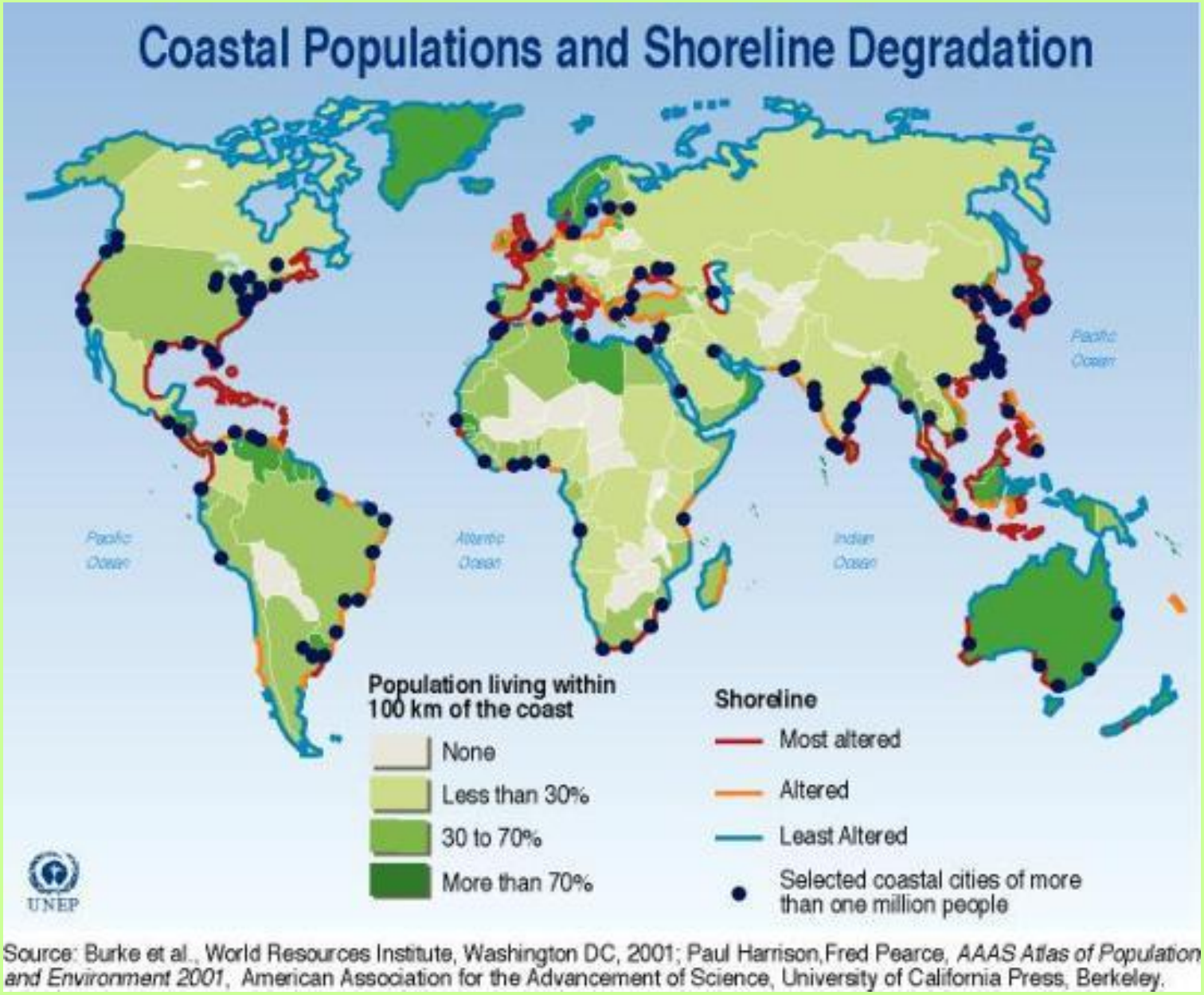


Extreme Weather Events

- ***Hurricanes***
- ***Severe Storms***
- ***Tornadoes***
- ***Flooding/storm surges***

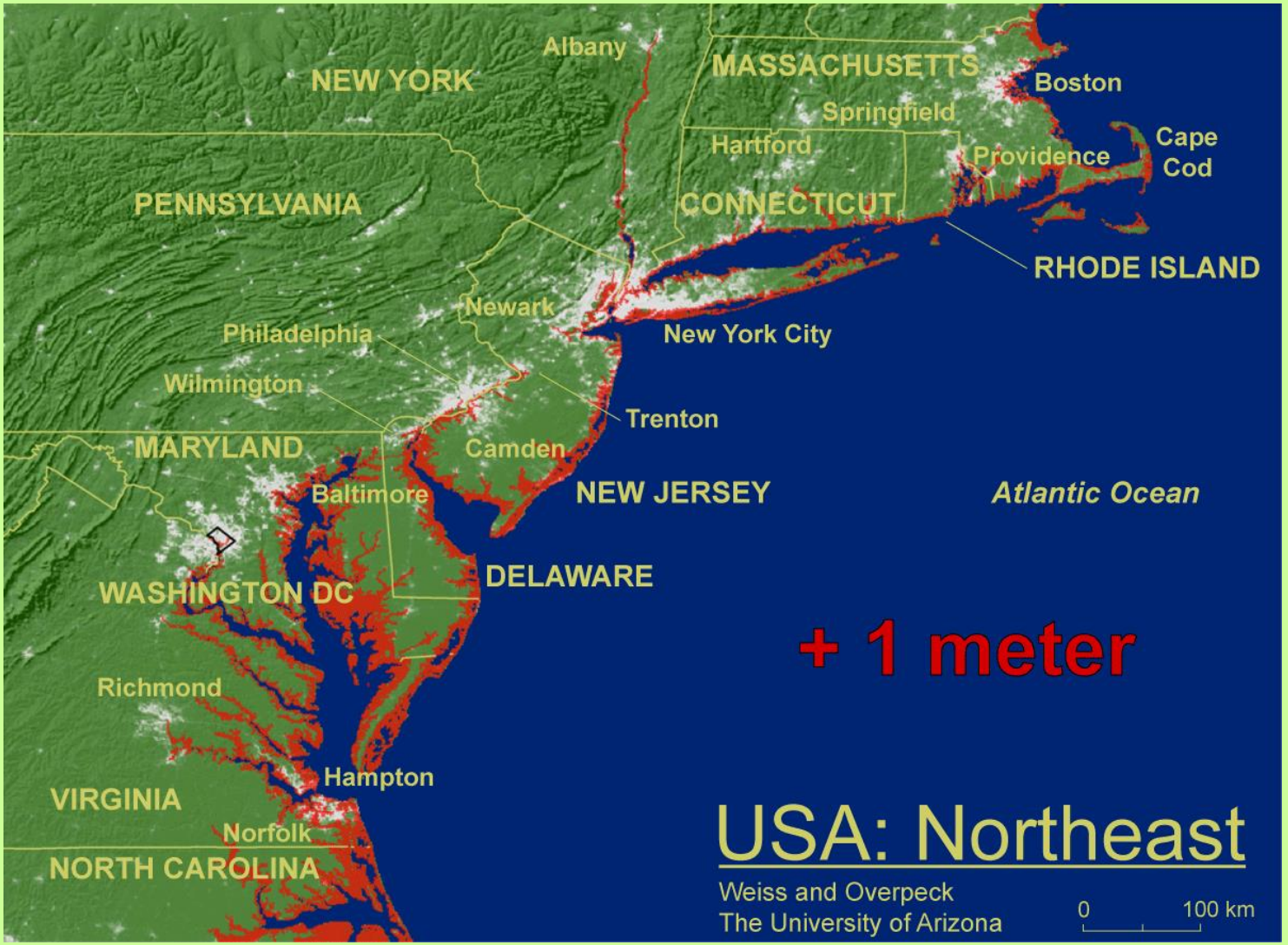
Floods could lead, in addition to deaths, to the spread of infectious diseases because of crowded living conditions in shelters, exposure to fecal material because of impaired sewage treatment, exposure to toxic chemicals from heavier runoff from agricultural lands and urban stormwater systems, and hazardous exposure from ingesting contaminated water and fish.

Sea Level Rise / Flooding



Data Source: United Nations Environmental Programme – GRID-Arendal

Sea-Level Rise / Flooding



Data Source: Department of Geosciences, Environmental Studies Lab – University of Arizona, Tucson, AZ

Sea Level Rise / Flooding

3 meter sea level rise; Population: 1,537,195

Data source: Architecture 2030

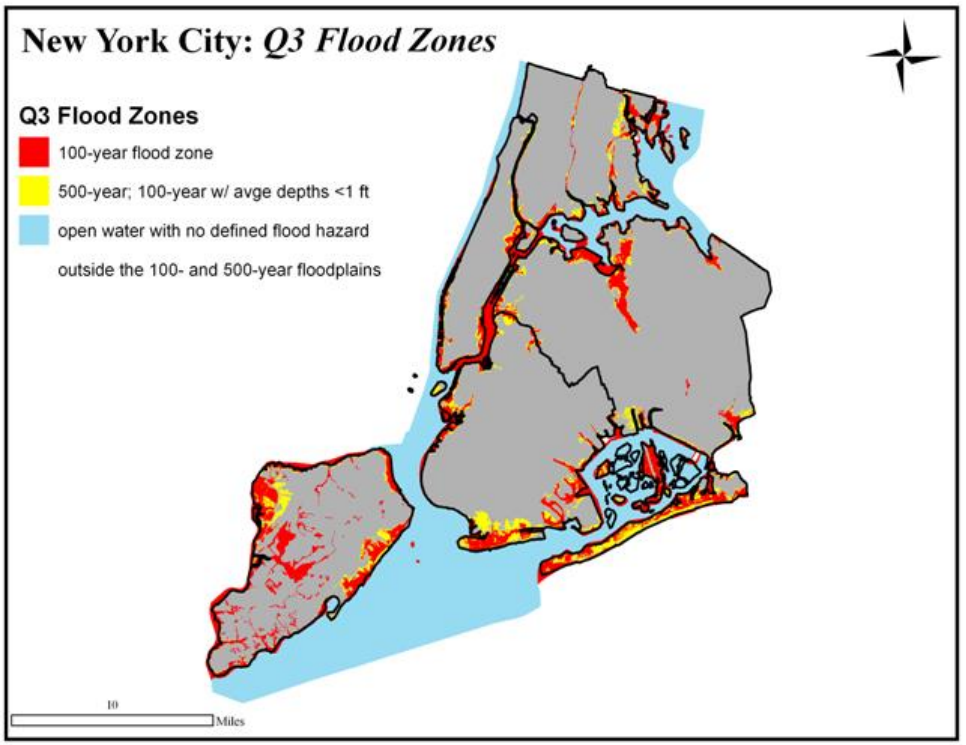
Data Source: USGS 10M NED

Maps are based on LIDAR data, USGS 10m NED.

Maps are illustrative; areas in blue depict various potential inundation scenarios.

Map accuracy is dependent on the accuracy of the geospatial data.

Health-Related Impacts of Floods



Data Source: Maantay, J.A.and Maroko, A., 2008. Mapping Urban Risk: Flood Hazard , Race, and Environmental Justice in New York City, *Applied Geography*, 29 (1):111-124. Map by A.R. Maroko.

Data Source: US EPA, Office of Policy, Planning, and Evaluation, 2000, "*Potential Health Impacts from Global Climate Change*"

Health-Related Impacts of Mississippi River Flood of 1993

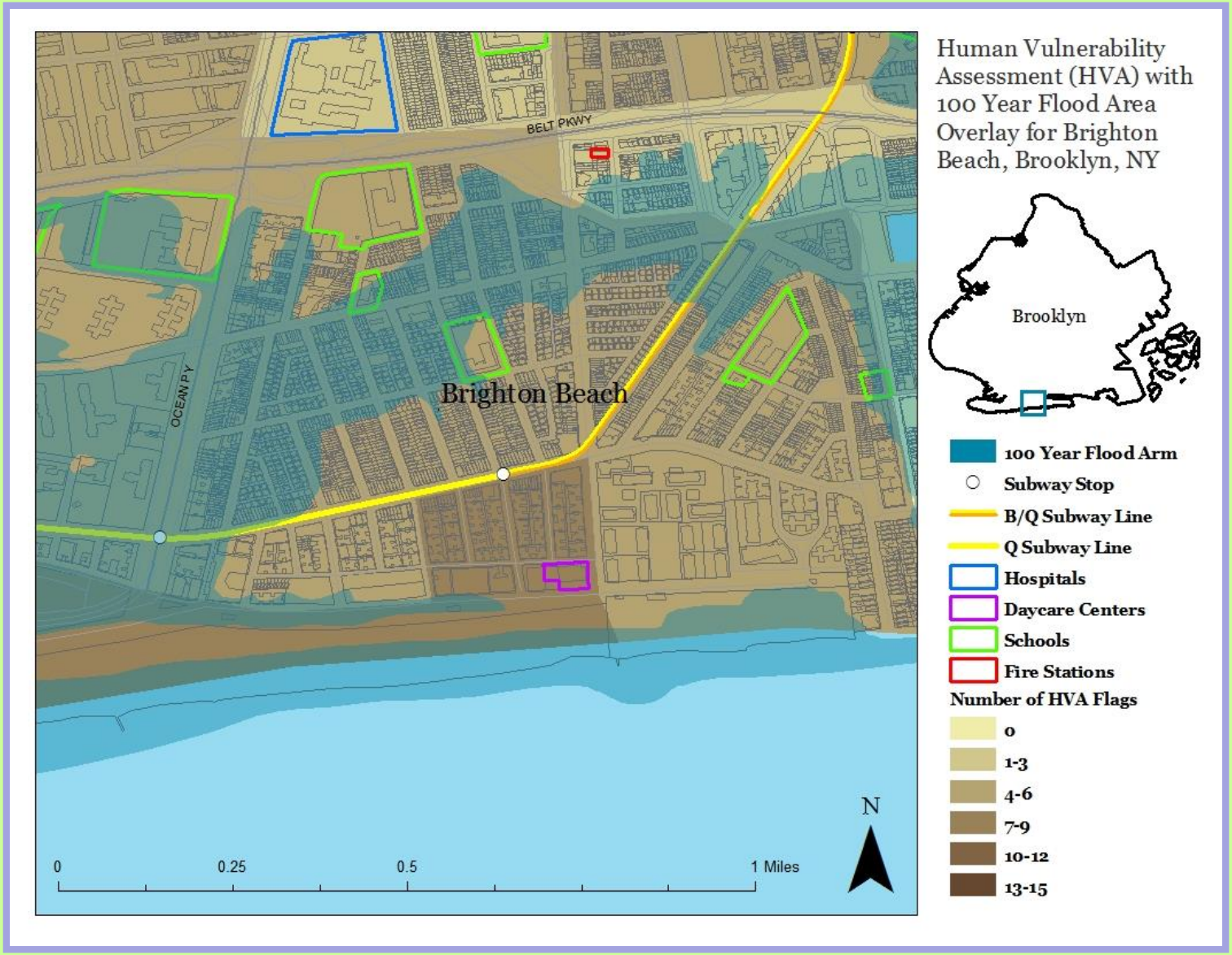
Fatalities	48
Health-Related Impacts	
Displaced Missourians (increased exposure to risk of disease)	60,000
Injuries and illnesses in Missouri*	483
Hospital emergency room patients in Missouri*	234
Hospitalizations in Missouri*	32
Potential Health-Related Impacts	
Closures of primary-care physician offices in Iowa**	14% of population affected
Interruptions in public health services in Iowa**	24% of population affected
Loss of operating public water system in Des Moines, Iowa	250,000 people affected for 12 days
Loss of operating public sewer systems in Iowa***	35% of population affected
More reports of mosquitoes and rats in Iowa**	53% of population affected

* Emergency room flood-related data reported to CDC for July 16–September 3.

** CDC survey for July 15–16.

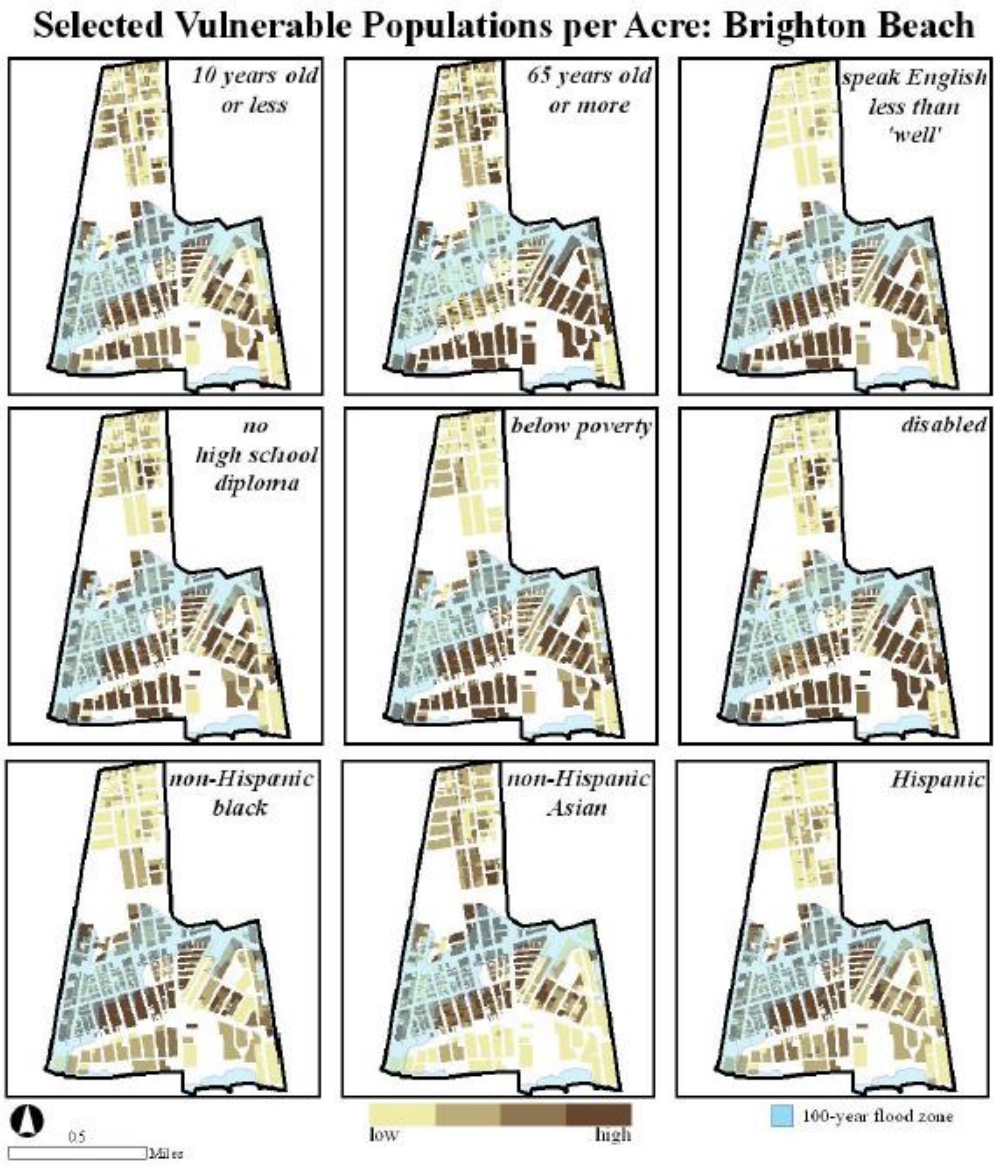
*** CDC survey for week of July 18–24.

Health-Related Impacts of Floods



Data Source: Maantay, J.A., Maroko, A.R. and Culp, G., 2009. Using Geographic Information Science to Estimate Vulnerable Urban Populations for Flood Hazard and Risk Assessment in New York City, in Showalter, P., and Lu, Y. eds., *Geotechnical Contributions to Urban Hazard and Disaster Analysis*, pp. 71-97, Springer-Verlag. Map by G. Culp.

Health-Related Impacts of Floods



Selected Vulnerability Variables – Persons per Acre – Each map represents a variable whose individual data range has been classified by quartiles.

Data sources: US Census, 2000; LotInfo, 2003; NYC Parks and Recreations Dept.; FEMA, Q3, 2006.

Data Source: Maantay, J.A., Maroko, A.R. and Culp, G., 2009. Using Geographic Information Science to Estimate Vulnerable Urban Populations for Flood Hazard and Risk Assessment in New York City, in Showalter, P., and Lu, Y. eds., *Geotechnical Contributions to Urban Hazard and Disaster Analysis*, pp. 71-97, Springer-Verlag. Map by G. Culp.

Climate-Sensitive Diseases

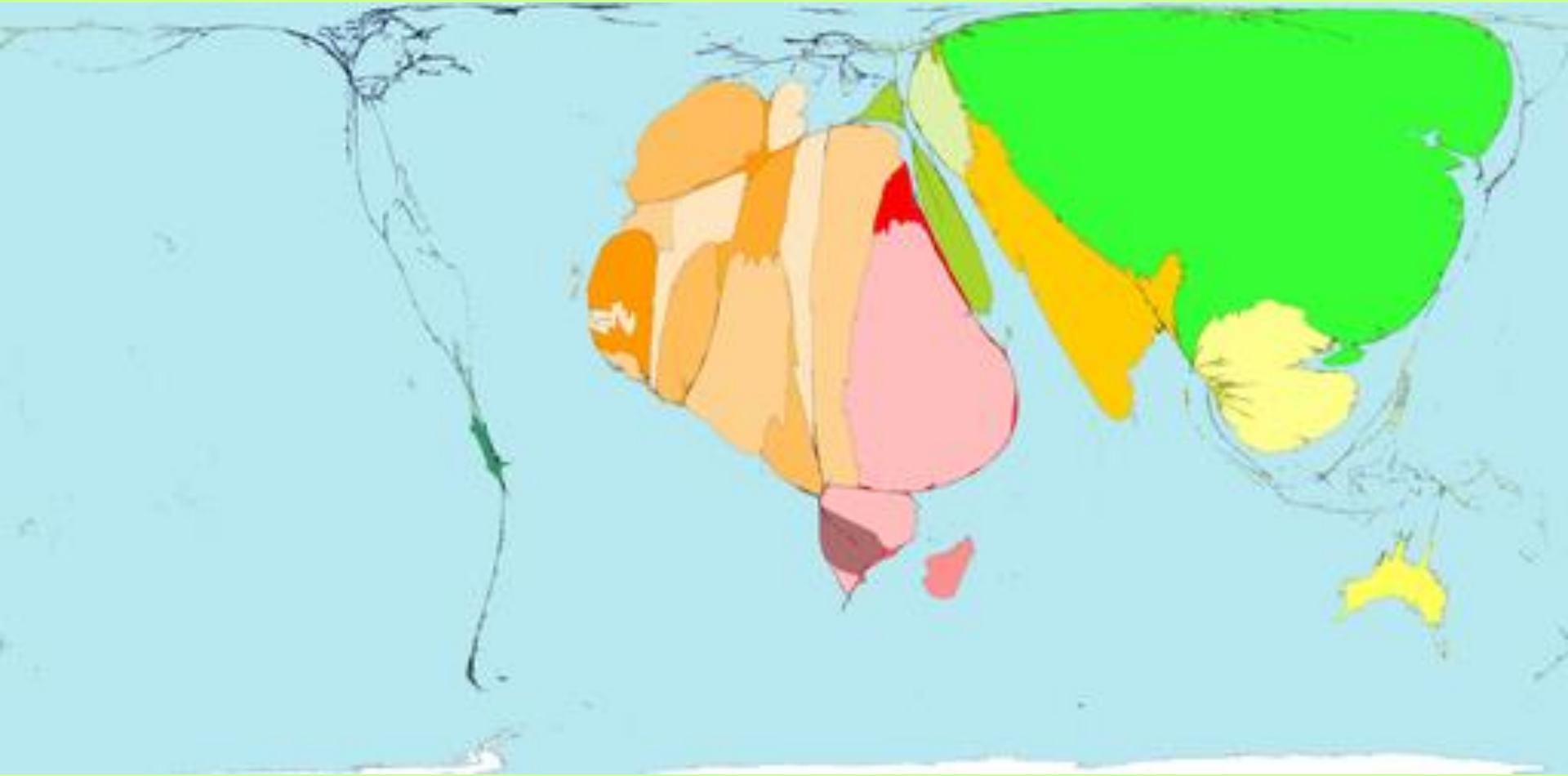
Vector-borne diseases – mosquitoes, ticks, rats and other vermin: Malaria, West Nile virus, Dengue Fever, Lyme disease, Encephalitis.

Allergens - Pollen, another air contaminant, is likely to increase as temperatures and carbon dioxide levels rise. A doubling of the atmospheric carbon dioxide levels stimulated ragweed-pollen production by more than 50 percent, a study showed. In another, ragweed grew faster, flowered earlier and produced significantly more pollen in urban locations.

Heavier rainfall – water-borne diseases

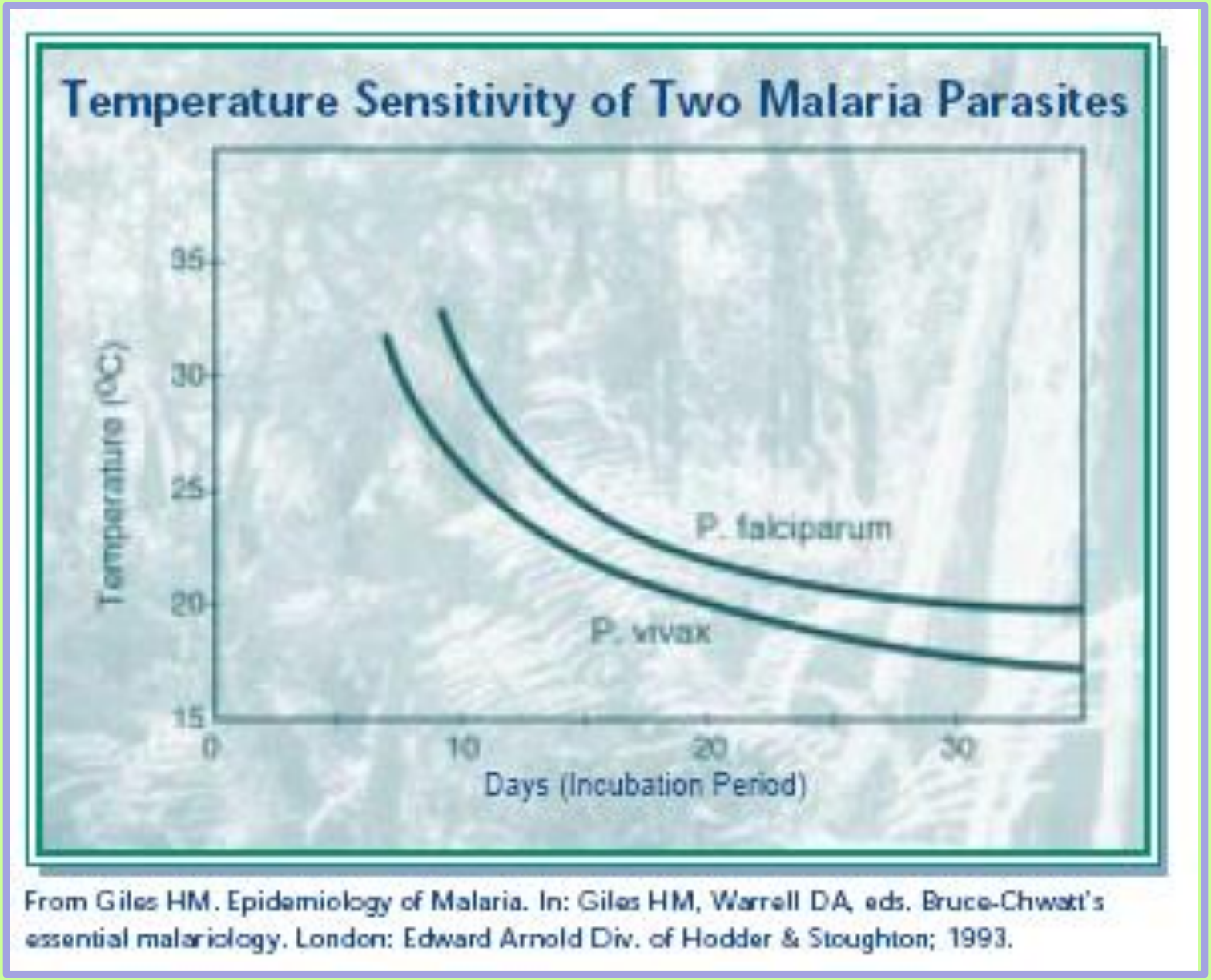
Climate-change projections show an increase in the intensity of rainstorms, which create opportunities for pathogens to move around, such as Salmonella, Cholera, Cryptosporidium, Giardia, E. coli infection, Dysentery, Typhoid.

Affected by Insect Infestation



The disasters mapped here are caused by insects, or in one case, rats. The main insects are various locusts, grasshoppers and army worms (insect larvae). Disasters occur when numbers are so large as to cause widespread devastation. Insect and vermin infestations are shown here only when they were so severe that the local population required external assistance to survive. The three territories where the largest populations affected by insect infestations live are China, Ethiopia and India. However, the highest proportions of population affected live in Northern African territories. **Territory size shows the proportion of all people worldwide affected by disasters due to infestations, usually by insects, between 1974 and 2004, who lived there. A disaster, here, is an event which overwhelms local resources.**

Temperature and Malaria



From Giles HM. Epidemiology of Malaria. In: Giles HM, Warrell DA, eds. Bruce-Chwatt's essential malariology. London: Edward Arnold Div. of Hodder & Stoughton; 1993.

Data Source: US EPA, Office of Policy, Planning, and Evaluation, 2000, "*Potential Health Impacts from Global Climate Change*"

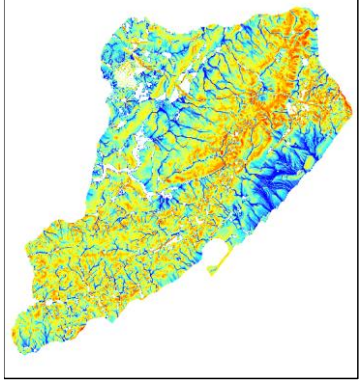
Malaria Cases

Of all the people living with malaria, 92% live in African territories. Parts of Mediterranean Africa have very low numbers of malaria cases. In contrast, almost half the people living in Uganda suffer from malaria. Uganda also has the most cases of malaria in the world. Most territories are barely visible due to the low number of malaria cases found there.Malaria is a parasitic infection that is spread between people by mosquitoes. Incidence can be reduced by mosquito control and anti-malarial prophylaxis in some cases. It is treatable but drug resistance and loss of immunity occur. 7.2 million cases of malaria were recorded worldwide in 2003. **Territory size shows the proportion of all people living with malaria worldwide, that live there.**

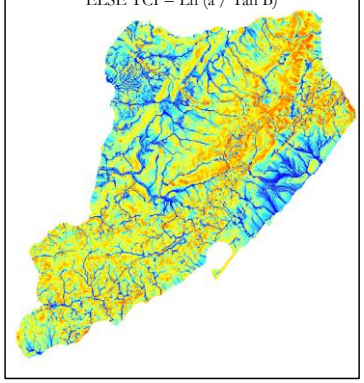
West Nile Virus in Metro New York – Characterizing the Mosquito Vector Habitat

Comparison of Four Equations Showing Topographic Convergence Index in Staten Island, NY

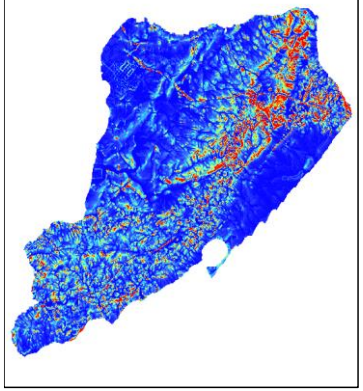
Traditional:
TCI = Ln (a / Tan B)



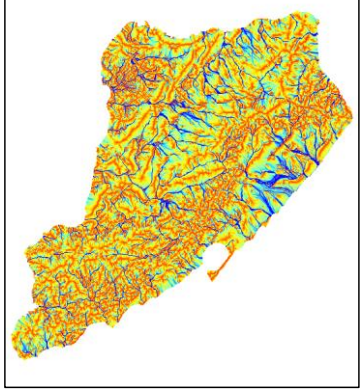
Conditional:
If Tan B = 0, THEN TCI = Ln(a / 0.001)
ELSE TCI = Ln (a / Tan B)



Inverse:
TCI = ln (Tan B / a)



Modified:
TCI = Ln ((a+ 1)/ (Tan B + 1))



high
low

Miles
0 2.5 5

a = contributing area
Tan B = slope
TCI = Topogrphic Convergence Index
Elevation data from USGS 30m DEM
Maps compiled by Andrew Maroko 4/15/05

Exploratory Spatial Data Analysis -Change in Mosquito Abundance-

Change in Connecticut Mosquito Counts
(6/10/05 - 6/26/05 to 6/27/05 - 7/11/05)
as described by
NDVI (16-day composite, 6/10/05 - 6/26/05)
Change in NDVI (6/10 - 6/26 to 6/27 - 7/11)
Temperature (6/10/05 - 6/26/05)
Elevation
Topographic Convergence Index

The **local R-square** data shows the amount of varience explained at each individual regression point, located at each mosquito trapping site in the study. The **Change in NDVI Parameter Estimate**, and the **NDVI Parameter Estimate**, quantifies the relationship between the respective value and the mosquito count.

Note that the **Temperature** and **NDVI** represent conditions from the 16-day period *preceeding* the mosquito count data (dependent variable).

Global Regression:
Coefficient of Determination = 0.185

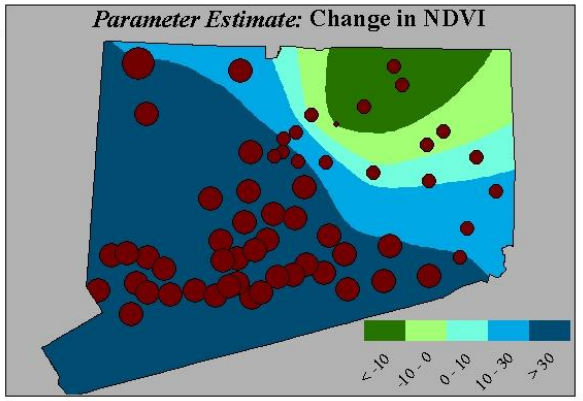
GWR:
Coefficient of Determination = 0.437

Local R^2
- < .20
- 0.21 - 0.40
- 0.41 - 0.60
- 0.61 - 0.80

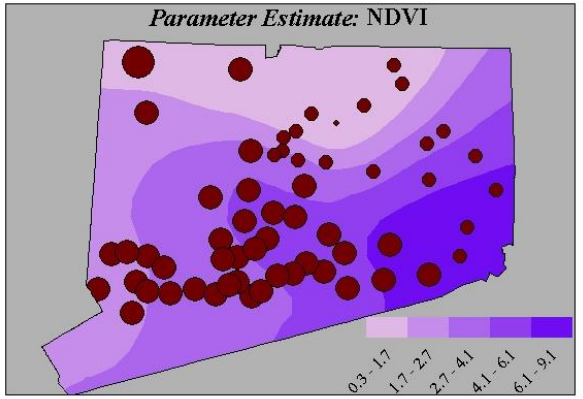
Data Sources:
Mosquito Counts: Connecticut Agricultural Experiment Station
NDVI and Temperature: MODIS via EOS Data Gateway
TCI and Elevation: USGS
State Boundary: U.S. Census, 2000

GIS executed using ArcGIS 9 software
GWR executed with GWR3 software
Map Compiled by Andrew Maroko, 2006

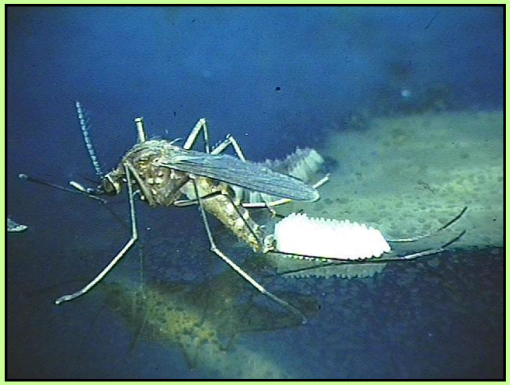
Parameter Estimate: **Change in NDVI**



Parameter Estimate: **NDVI**



Culex mosquito laying eggs



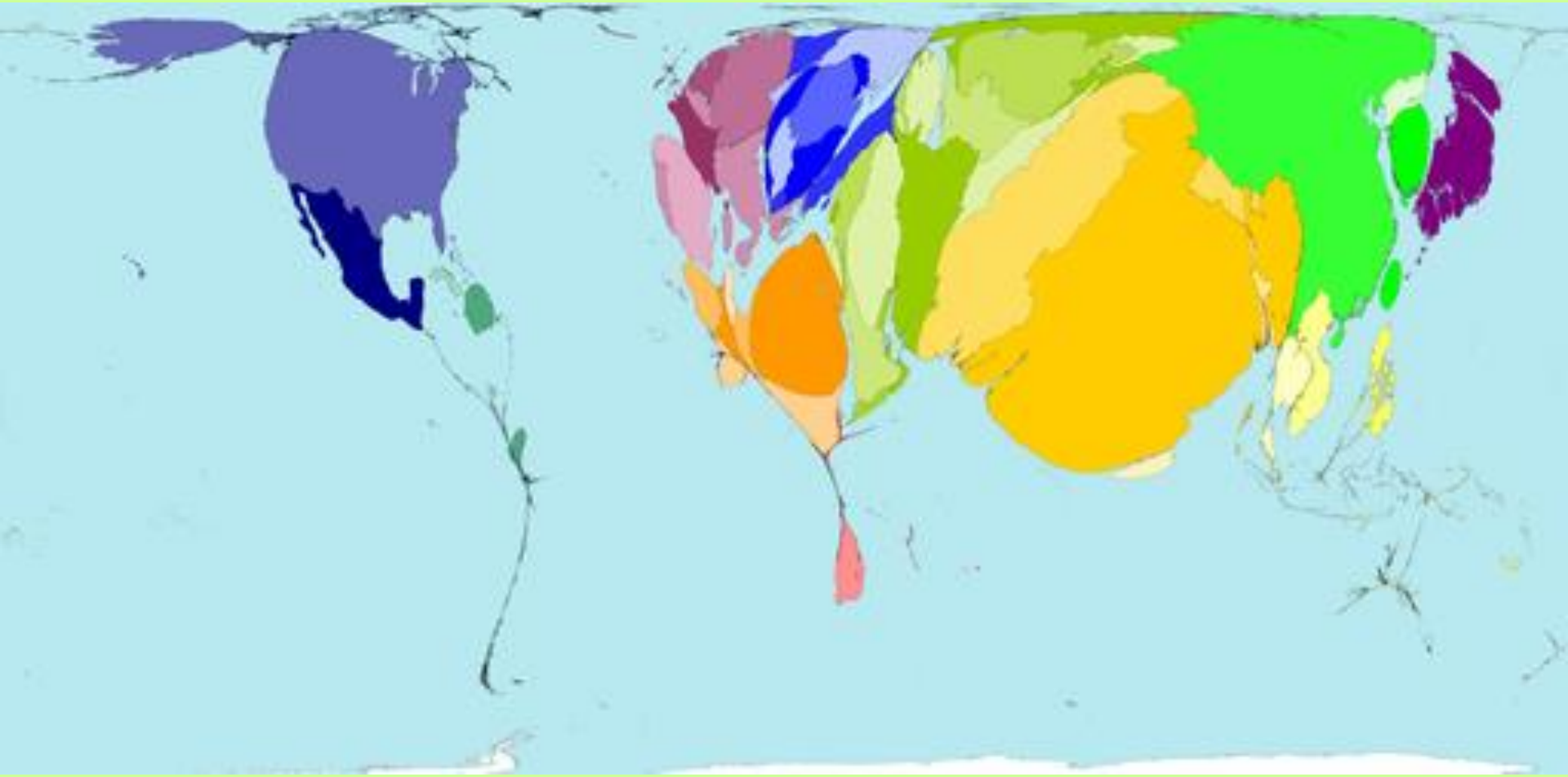
Water Quality – Health-Related Problems

- *Water shortages*
- *Reduced water quality/water contamination*
- *Water-borne diseases: Cholera, Dysentery, Typhoid, etc.*
- *Growth of organisms in the ocean that cause foodborne seafood poisoning*

Water Quality – Deaths from Cholera

Cholera deaths result from severe dehydration caused by diarrhoea. This is treatable: in 2004 the number of cholera deaths was only 2.5% of the number of cholera cases that year.. **Territory size shows the proportion of worldwide deaths from cholera that occurred there in 2004 or most recent year available.**

Water Shortages / Water Depletion



This map shows those territories that use much of their internal water resources, measured with a threshold of people using more than 10% of renewable water resources. Each territory is resized based on the volume of water used beyond 10%. **Territory size shows the proportion of all water used that is more than 10% of the renewable internal freshwater resources of that territory**

Air Quality

New York City Smog

Air Quality – Acute Episodes of Air Pollution (Killer Smog)

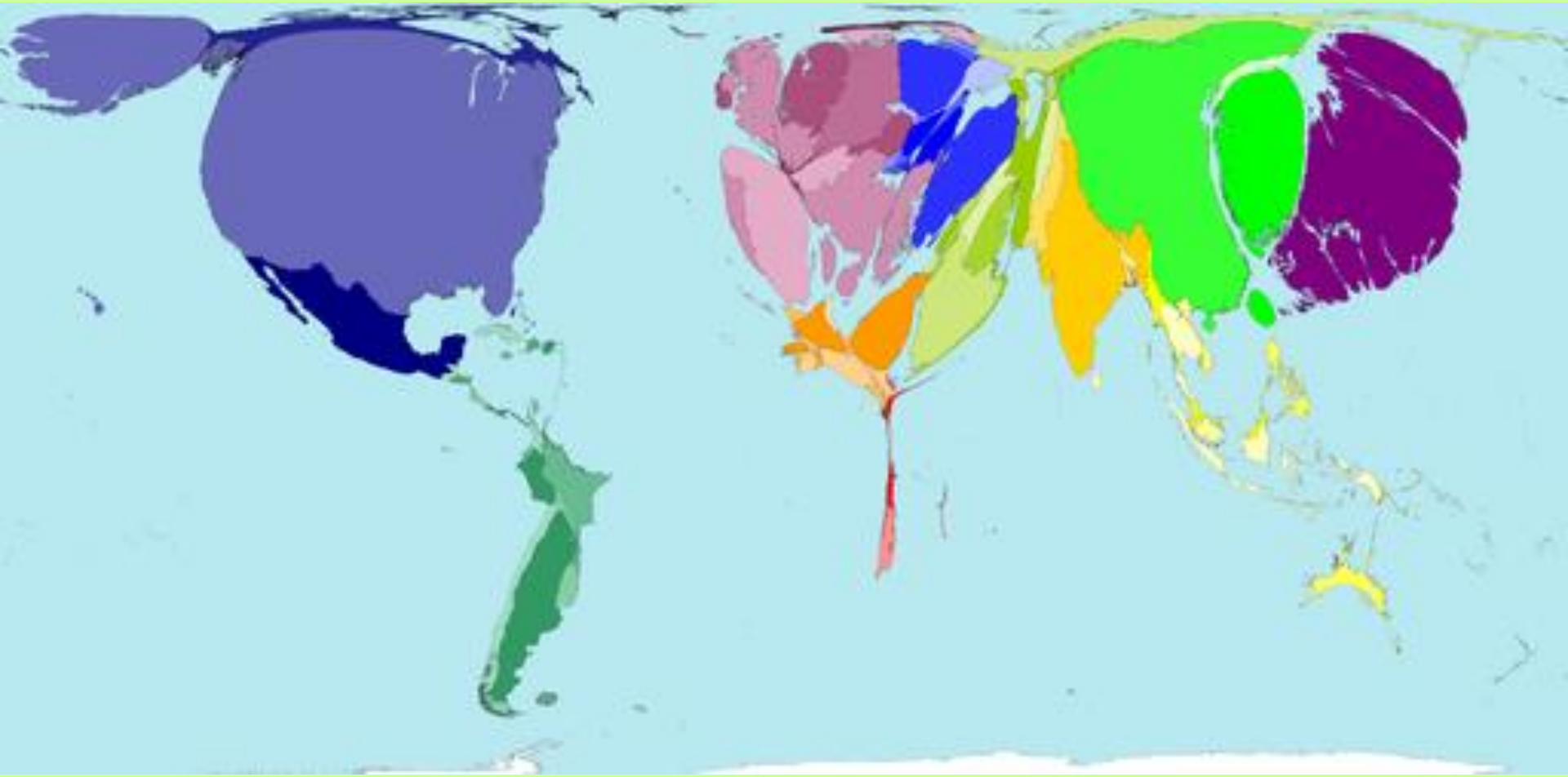
Acute Episodes of Air Pollution

Location	Year	No. of Fatalities or Illnesses
Glasgow, Scotland	1909	1,063 deaths
Meuse Valley, Belgium	1930	63 deaths and 6,000 people sick
Donora, Pennsylvania	1948	20 deaths and 1,190 people sick*
London	1952	4,000 to 8,000 fatalities
New York City	1953	175 to 260 fatalities

*Almost 43 percent of the area's population.

Data Source: US EPA, Office of Policy, Planning, and Evaluation, 2000, "*Potential Health Impacts from Global Climate Change*"

Air Quality - Particulate Matter (PM_{10}) Damage

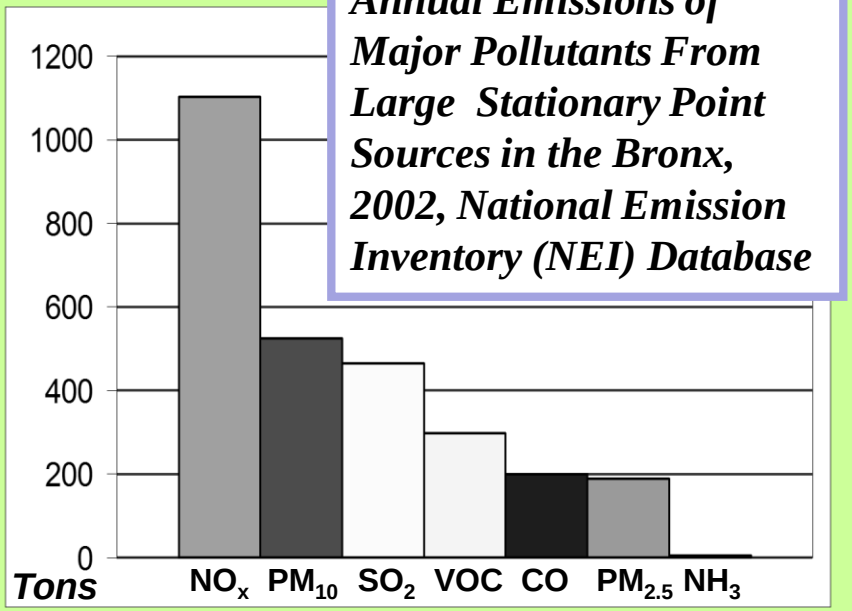


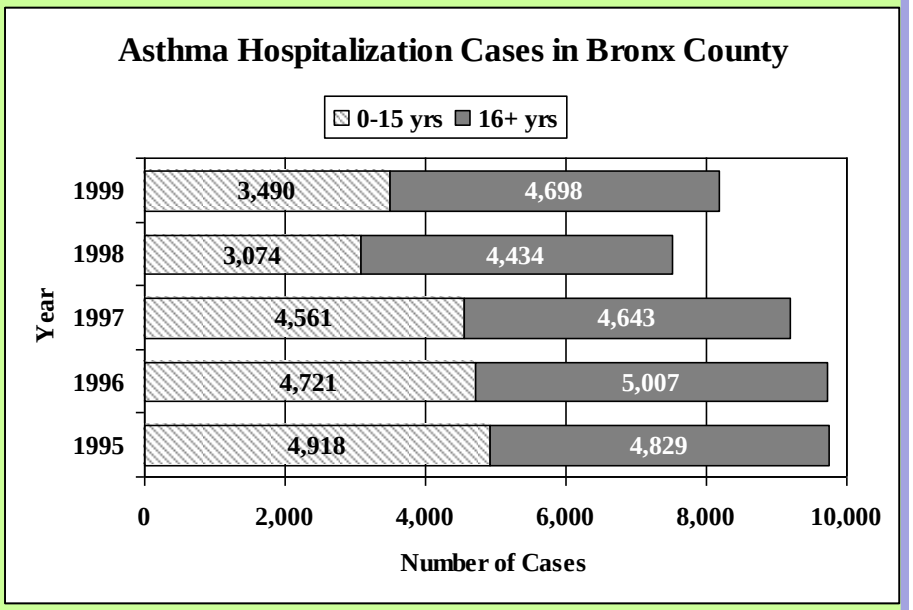
Particulates are dusts under 10 microns in diameter. They are linked to cardiopulmonary disease, lung cancer and acute respiratory infections. Their main sources are fossil-fuel power plants, vehicles, heating systems and industrial processes. Mapped is a measure of the costs of improving air quality to prevent avoidable deaths attributed to particulate emissions.. **Territory size shows the proportion of all particulate damage there. This is measured as the estimated cost to pay to avoid deaths caused by particulates there.**

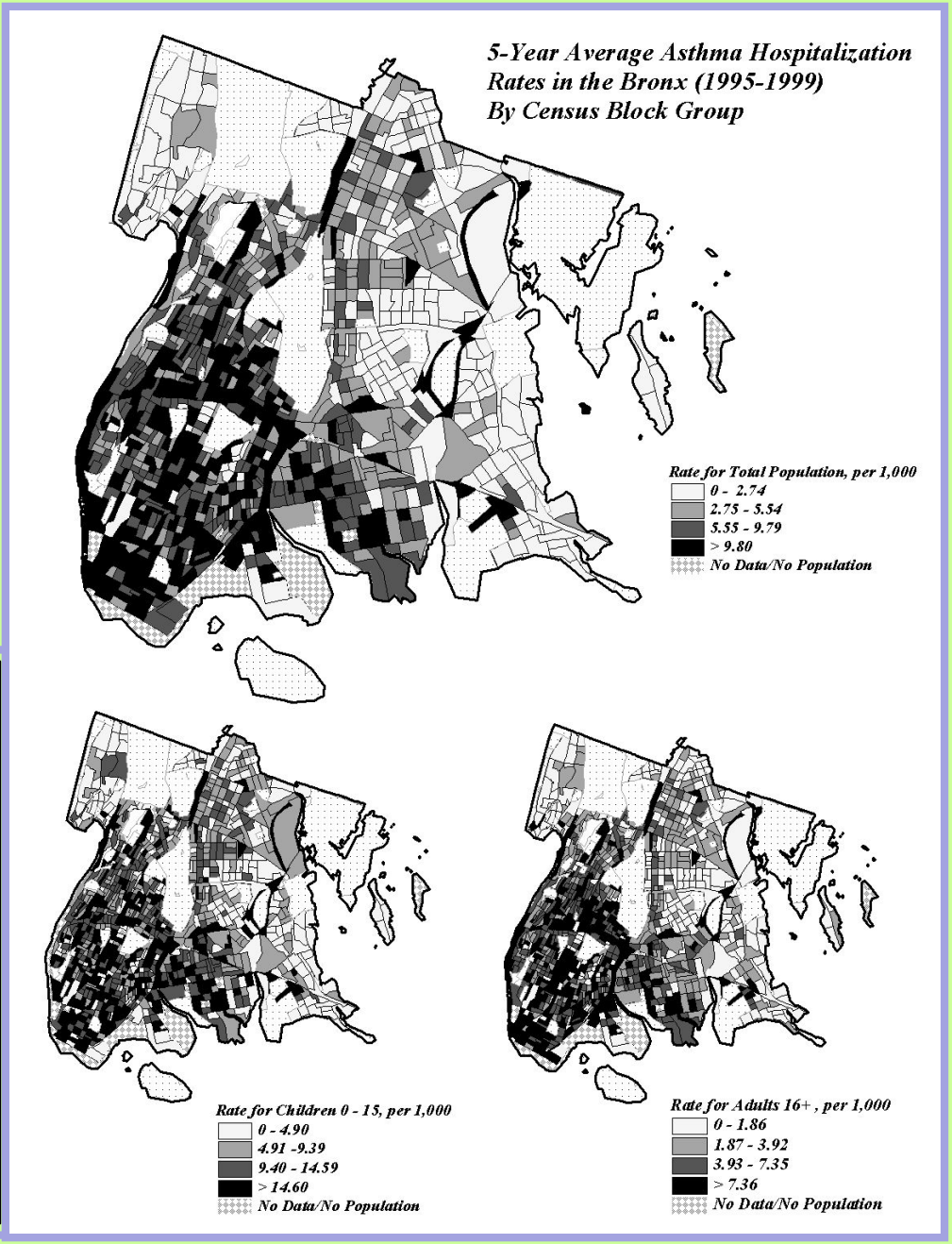
Air Quality – Health-Related Problems

- ***Air Pollution*** – respiratory disease, cardiovascular disease
- ***UV Radiation*** – skin cancer, weakened immune system, eye problems
- ***Acid Rain*** – species damage, cultural artifact destruction

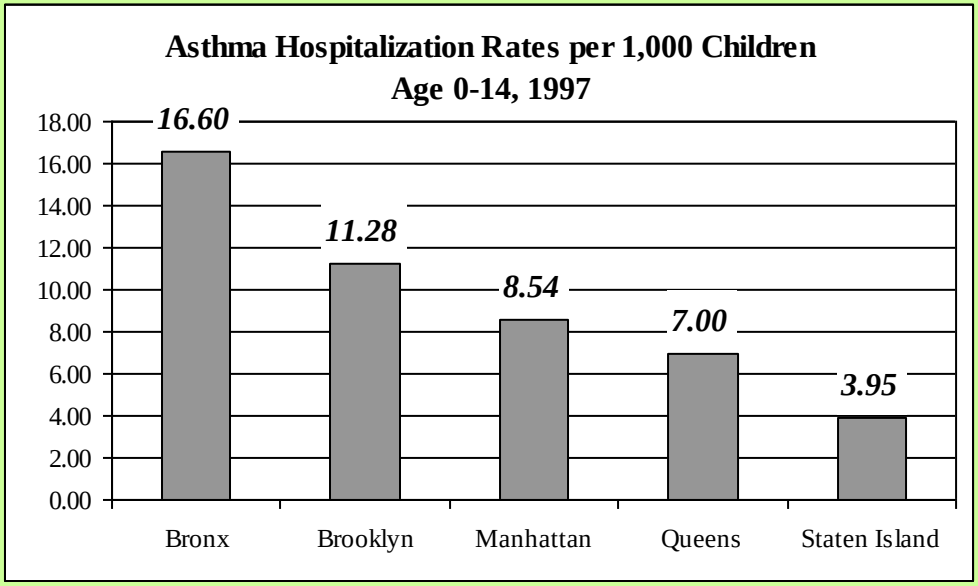
Air Quality – Asthma in the Bronx, New York City

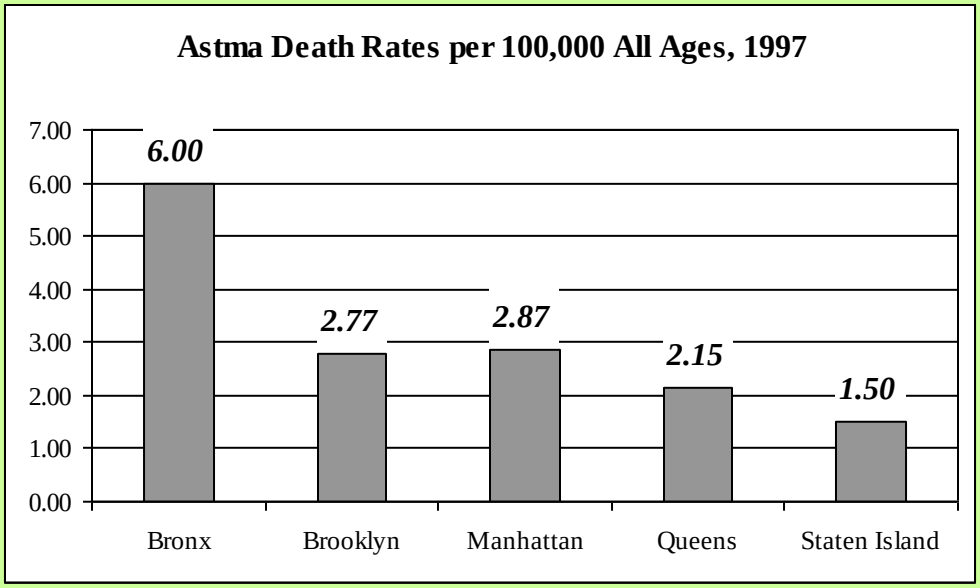






Air Quality – Asthma in the Bronx, New York City

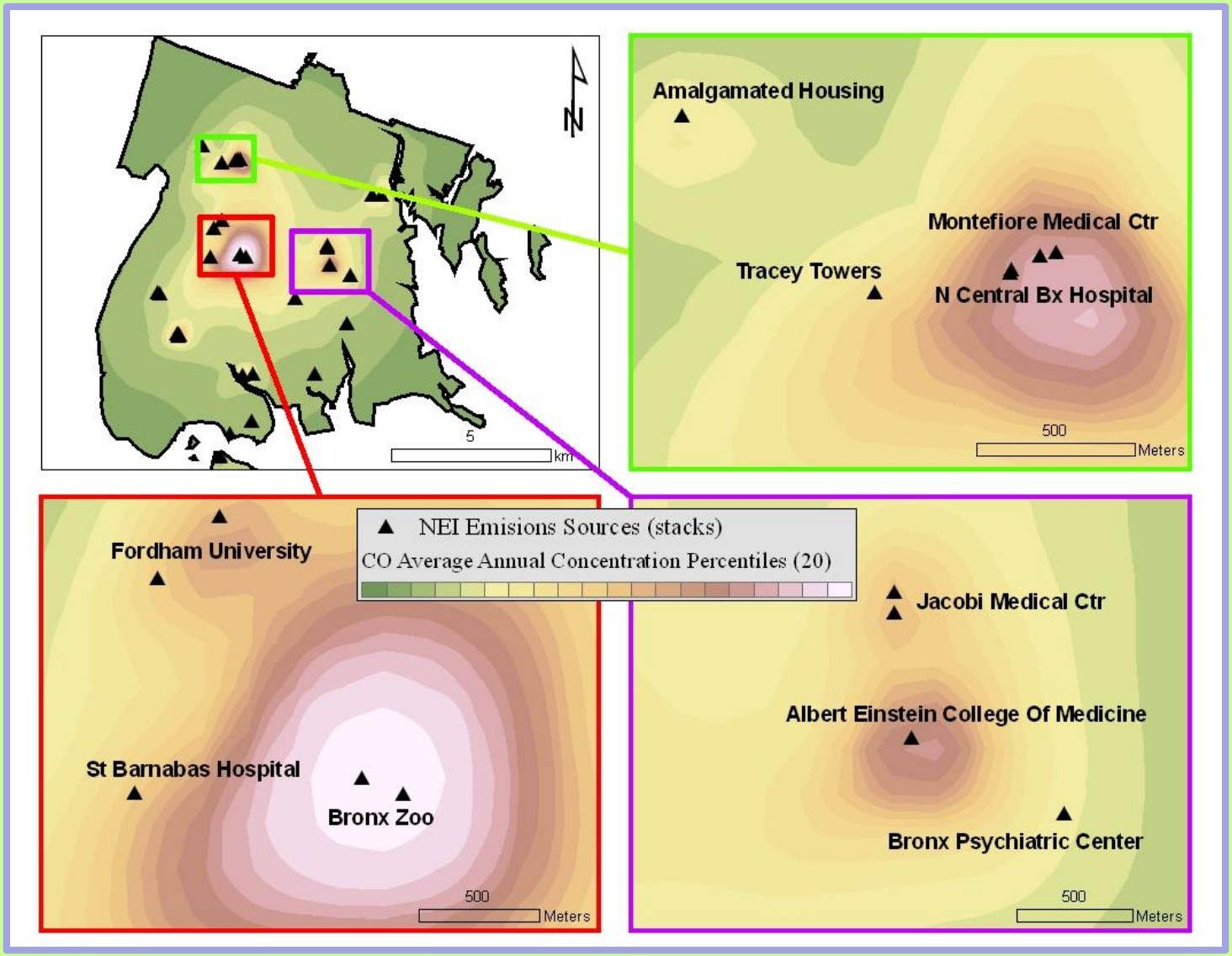




Data Source: NYC DOH, 2003, ***Asthma Facts, 2nd Edition.*** Graphs by A. Maroko, Lehman College Urban GISc Lab, in: Maantay, J.A., 2005. Asthma and Air Pollution in the Bronx: Methodological and Data Considerations in Using GIS for Environmental Justice and Health Research, ***Health and Place***, Volume 13, pp. 32-56. Special issue: *Linking Population Health, Critical Theory, and Geographical Information Science.*

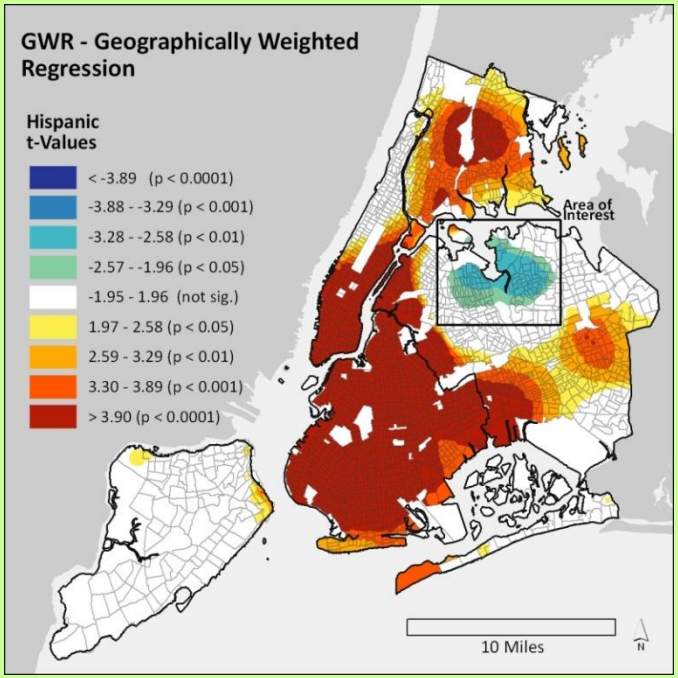
Data Sources, Previous Slide, from upper left, clockwise: (1) US EPA NEI, chart by J.C. Saborio, Lehman College Urban GISc Lab; (2) NYS SPARCS Data, Map by J.A. Maantay, Lehman College Urban GISc Lab; (3) NYC DOH, Graph by J.C. Saborio/A.R. Maroko, all in: ***GIS for the Urban Environment***, Maantay and Ziegler, 2006, ESRI Press, Redlands, CA.

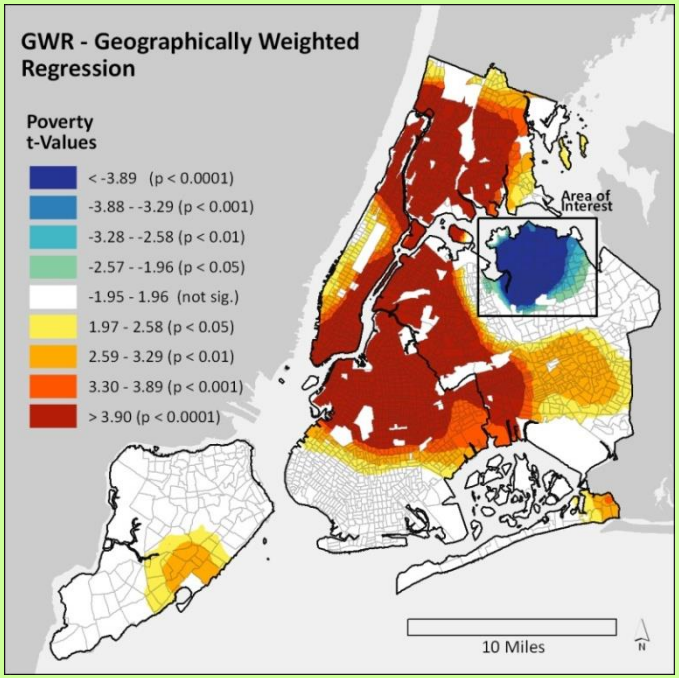
Air Quality – Asthma in the Bronx, New York City – Air Dispersion Modeling



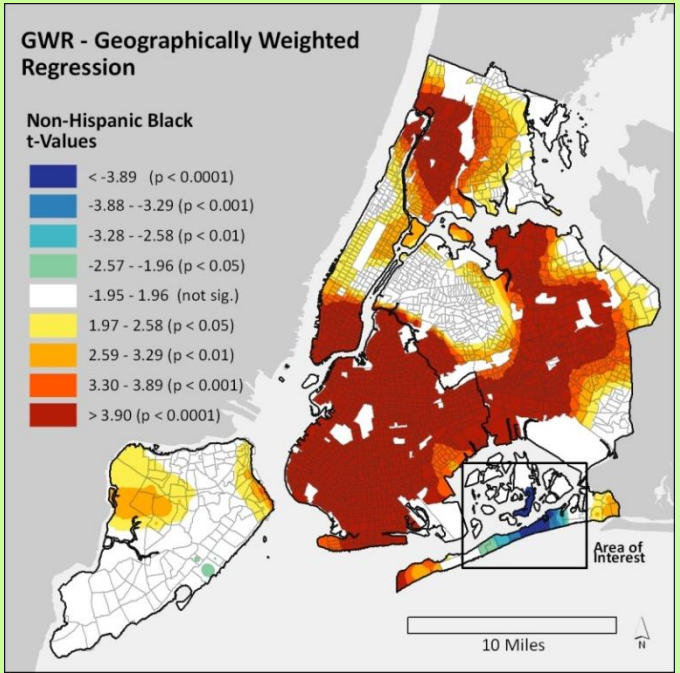
Source: Maantay, J.A., Maroko, A.R., Strelnick, A.H., Feinberg, M., 2010. Geographic Information Systems, Environmental Justice, and Health Disparities: An Interdisciplinary Approach to Adverse Health Outcomes and Pollution in the Bronx, New York. *NIEHS Environmental Justice Conference*, Research Triangle Park, NC.

Cardiovascular Diseases and Air Pollution – Geographically Weighted Regression





Source: Maroko, A.R., Maantay, J.A., and Grady, K. Using Geovisualization and Geostatistics to Explore Respiratory Disease and Environmental Health Justice in New York City, in Maantay, J.A., and McLafferty, S., eds., *Geospatial Analysis for Environmental Health*, Springer-Verlag, in press, 2010.

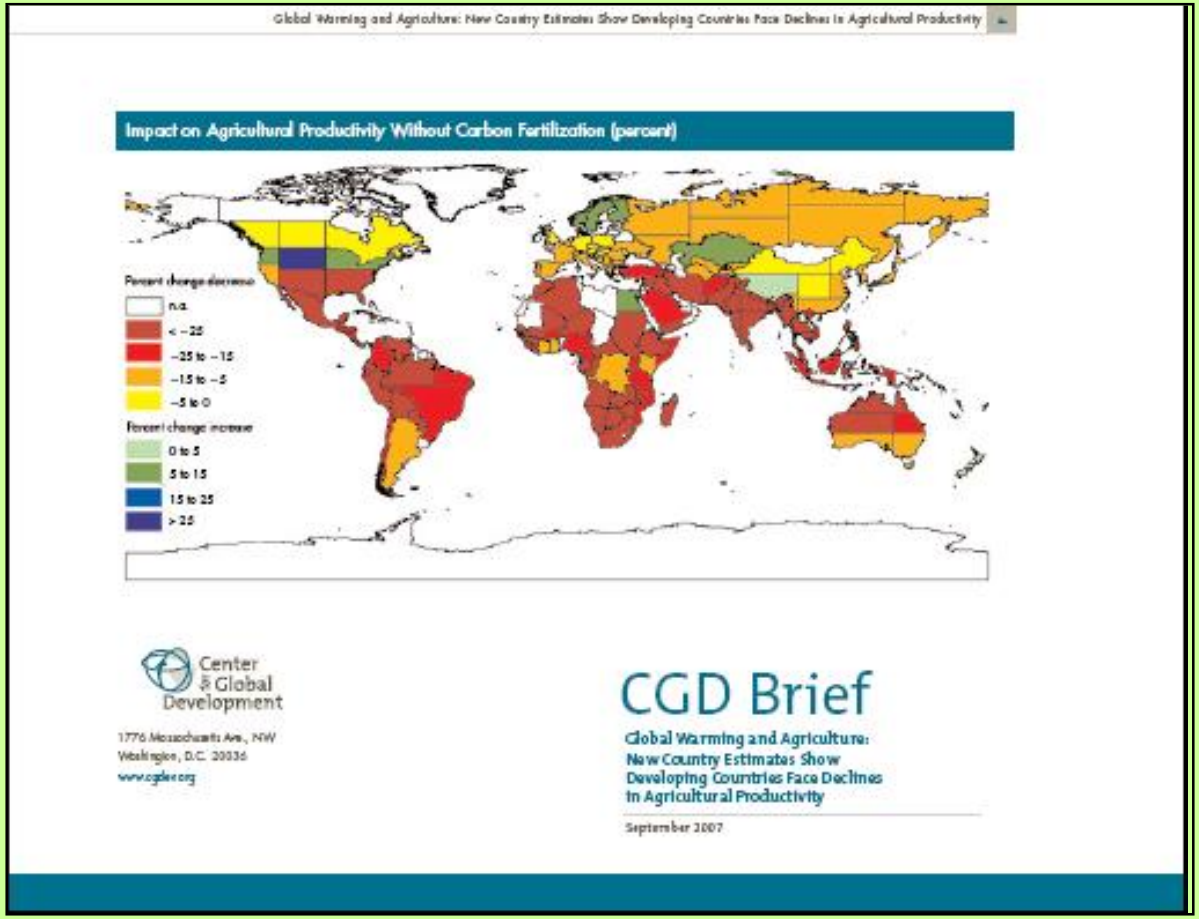


GWR performs many local regressions, each of which is influenced by the surrounding data, resulting in a set of summary statistics for each regression point. Each local regression utilizes surrounding data, with nearby data being weighted more heavily than distant data (e.g., distance decay). In this way, GWR is able to show local variations in the relationships and is able to account for potential spatial non-stationarity (local variation in parameter estimates). The majority of NYC follows the classic environmental health justice trend that census tracts with higher proportions of racial and ethnic minorities are more likely to have elevated hospitalization rates for heart failure.

Other Global Warming-Health Linkages

Reductions in Agricultural Yields:

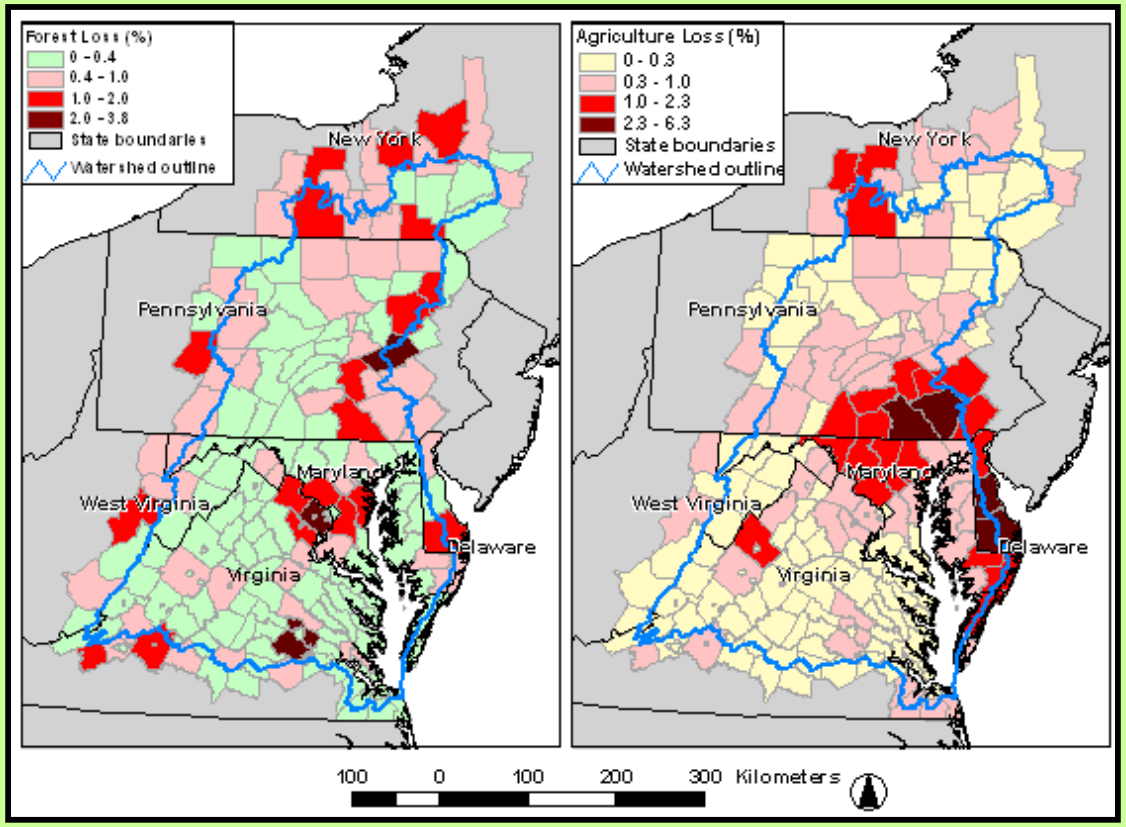
- Food shortages
- Undernourishment
- Social disruption/Conflict/War
- Economic decline
- Population displacement



Data Source: Center for Global Development, 2007, "*Global Warming and Agriculture: Developing Countries Face Decline in Agricultural Productivity*"

Loss of Land due to Sea Level Rise and Flooding:

- Overcrowding and conflict
- Population displacement
- Social disruption/Conflict/War
- Environmental infrastructure failure, leading to contaminated water, water shortages, water-borne diseases



Data Source: Woods Hole Research Center, 2007, "*Resource Land Loss in the Chesapeake Bay watershed*"

Paradise Lost?

The Urban GISc Lab, Lehman College, City University of New York

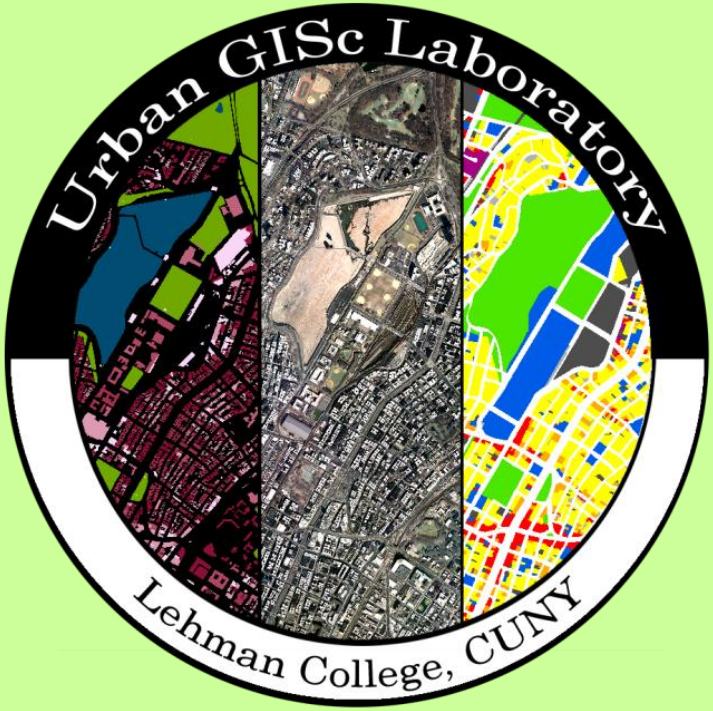
Urban GISc Laboratory

Lehman College, CUNY

Standing, left to right: ***Brian Morgan***, GISc Lab Manager; ***Rosa Perez***, NOAA-CREST Fellow, and GISc Graduate Student; ***Juliana Maantay,*** Professor and Director, Urban GISc Lab; ***Andrew Maroko***, Assist. Prof., MPH Program; ***Kristen Grady***, USDA Fellow, EES doctoral student.

Absent from photo: ***Rachael Weiss,*** DPH Program doctoral student; ***Keith Miyake***, EES Program doctoral student; ***Michelle Ottmann***, Visiting Scientist-in-Residence.

Acknowledgements:



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- National Oceanic and Atmospheric Administration;
- US Environmental Protection Agency;
- US Department of Agriculture;
- National Center for Minority Health and Health Disparities;
- South Bronx Environmental Justice Partnership;
- NYC Dept. of Parks and Recreation;
- Bronx CREED - Center to Reduce and Eliminate Ethnic and Racial Health Disparities;
- Albert Einstein College of Medicine/Yeshiva University;
- Montefiore Medical Center;
- For A Better Bronx;
- Lehman College, CUNY;
- The CUNY Graduate Center.

NIEHS
National Institute of Environmental Health Sciences

NOAA
National Oceanic and Atmospheric Administration
US Department of Commerce

United States Environmental Protection Agency

The City University of New York
The Graduate Center

EINSTEIN
Albert Einstein College of Medicine
of Yeshiva University

For A Better Bronx

USDA

National Center on Minority Health and Health Disparities
NCMHD

MONTEFIORE

Bronx CREED

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Cartograms courtesy of the WorldMapper project, Daniel Dorling and the WorldMapper team, Centre for Urban and Regional Development Studies & Housing and Society Research Group, University of Newcastle-upon-Tyne, UK; Department of Social Medicine, University of Bristol; Geography Department, University of Sheffield, UK; and University of Michigan, MI, USA.

New Book! "*Geospatial Analysis of Environmental Health*"

Related Projects/Publications:

Journal of Applied Geography **– Special Health Geographics Issue on "Health Impacts of Global Climate Change: A Geographic Perspective." Guest Editors: Juliana Maantay and Stefan Becker. March/April, 2011.**

Geospatial Analysis of Environmental Health**, by Juliana Maantay and Sara McLafferty, eds. Springer-Verlag, February 2011. Foreword by Rushton, with chapter contributions by Chakraborty, Emch, Hanchette, Margai, Cromley, Christakos, Root, Downey, and others.**

Websites:

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www.lehman.cuny.edu/deannss/geography

Earth, Environmental, and Geospatial Sciences Department:
www.lehman.cuny.edu/deannss/eggs