Climate Change and Health:
Concepts, Measures and Processes

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Overview

- Introduction to global environmental change
- Definitions: weather, climate, climate change
- Discuss evidence that humans are influencing the climate
- Characterize some changes that have occurred
- Explore likely climate change scenarios for future
Historical Perspective

- Over past 10,000 years, humans have altered their environment
  - Leading to increased population size, improved living conditions, and increased life expectancy

- Last 150+ years, gains in population health from increasing:
  - Access to safe water and sanitation
  - Food security
  - Access to simple medical care
  - Education and literacy
Epidemiology Since ~1850: Changes in Emphasis / Units of Analysis

- Population
  - Germ theory
  - Micronutrients
- Sub-groups
  - Occupational risks
- Individuals
  - Non-infectious diseases
  - Individual risk factors
  - Genetics and epigenetics

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Epidemiology Since ~1950: Changes in Emphasis / Units of Analysis

- Social Epidemiology
  - Population patterns
  - Lifecourse, complex etiology

- Complex Regional Factors
  - Environment, land use

- Individuals
  - Non-infectious diseases
  - Individual risk factors
  - Genetics and epigenetics
21st Century

- Risks populations face have become more complex, larger scale, and potentially more devastating.

- Global environmental changes require that environmental epidemiology consider current and future health risks due to changes in climate, food systems, water resources, and other factors.
Global Change Involves Many Factors

- Population
- Climate
- Economy
- Resource use
- Energy development
- Transportation
- Communication
- Land use / land cover
- Urbanization
- Globalization
- Atmospheric circulation
- Ocean circulation
- Carbon, nitrogen, water and other cycles
- Sea ice loss
- Sea-level rise
- Food webs
- Pollution
- Over fishing
- Biological diversity
- Health
Pathways from Global Change to Human Health

Global change

- Demographic change
  - Aging
  - Family structures
  - Urbanization

- Social change
  - Institutions
  - Governance

Environmental degradation, ecosystem disturbances, geophysical changes

Economic activities
  - Trade
  - Wealth creation and distribution

Human health

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Ecosystem Services and Human Health

- Regeneration of fertile land → food
- Viable fisheries → food
- Wetlands: flood storage, cleansing of surface water
- Nutrient recycling (nitrogen, phosphorus, etc.)
- Intact ecosystems: control of infectious disease vectors (mosquitoes, ticks, rodents)
- Buffering against environmental stressors (protection by forests and reefs against cyclones, storm surges, and droughts)
- Source of medicinals
- Support/inspiration for aesthetic/spiritual values

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What is Different About Studying the Health Impacts of Global Change?

- Temporal and spatial scale issues
- Not a discrete exposure
- Everyone is exposed – but not all equally
- Exposures will increase over coming decades
  - Risks will increase with increasing exposures
- Impacts operate through a wide range of pathways

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Scale and Type of Environmental Health Risks

- Global change
- Regional air pollution: Acid rain, Asian brown cloud
- Local air pollution
- Environmental tobacco smoke

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Extremes of exposures; disruption of life/health-support systems
Direct, toxic, hazard
Not Only is Environment Changing

- Worldwide emergence and re-emergence of infectious diseases since 1970s
- Increase in obesity and diabetes
- Trade and travel increasing transport of lifestyles, infectious people, hazardous materials, ....
- Export of occupational hazards to low-income countries
- Increasing income inequalities

WHO 2009
World Population: 1960

Worldmapper, 2008b, e
World Population: 2050

Worldmapper, 2008b, e
National Carbon Dioxide Emissions

Per Capita emissions of carbon dioxide from fossil fuel combustion, largest emitting countries, 2006

<table>
<thead>
<tr>
<th>Country</th>
<th>Tonnes carbon per capita</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>6.0</td>
</tr>
<tr>
<td>Canada</td>
<td>5.6</td>
</tr>
<tr>
<td>Australia</td>
<td>5.2</td>
</tr>
<tr>
<td>Republic of Korea</td>
<td>3.5</td>
</tr>
<tr>
<td>Russia</td>
<td>3.3</td>
</tr>
<tr>
<td>Japan</td>
<td>3.0</td>
</tr>
<tr>
<td>Germany</td>
<td>3.0</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>2.8</td>
</tr>
<tr>
<td>Italy</td>
<td>2.3</td>
</tr>
<tr>
<td>China</td>
<td>1.3</td>
</tr>
<tr>
<td>India</td>
<td>0.3</td>
</tr>
</tbody>
</table>

Toufiq Siddiqi, 2008

WHO 2009
THREE ECOLOGICAL FOOTPRINT SCENARIOS
1961–2100

World Wildlife Fund, 2006
The structure and functioning of the world’s ecosystems changed more rapidly in the second half of the twentieth century than over any comparable period in human history. Humans are fundamentally, and to a significant extent irreversibly, changing the diversity of life on Earth and most of these changes represent a loss of biodiversity. Most changes to ecosystems have been made to meet a dramatic growth in the demand for food, water, timber, fibre and fuel.
Water Poverty Index

The Centre for Ecology & Hydrology of the United Kingdom, 2005

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Projected Changes in Length of Growing Season, 2050

ECHam4, B1  ECHam4, B2

> 20% loss  5-20% loss  No change  5-20% gain  >20% gain

International Livestock Research Institute, 2006

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Cereal Production under GCM Scenarios

![Graph showing changes in cereal production under three different GCM equilibrium scenarios](image)

**Developed countries**
- Climate effects only
- Plus physiological effect of CO₂
- Plus adaptation level 1
- Plus adaptation level 2

**World total**
- Climate effects only
- Plus physiological effect of CO₂
- Plus adaptation level 1
- Plus adaptation level 2

**Developing countries**
- Climate effects only
- Plus physiological effect of CO₂
- Plus adaptation level 1
- Plus adaptation level 2

Notes: Level 1 adaptation included changes in crop variety but not the crop, the planting date of less than 1 month, and the amount of water applied for areas already irrigated. Level 2 adaptation additionally included changes in the type of crop grown, changes in fertilizer use, changes in the planting of more than 1 month, and extension of irrigation to previously unirrigated areas.

Source: Climate change 1995. Impacts, adaptations and mitigation of climate change: scientific-technical analyses, contribution of working group 2 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge press university, 1996.

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Food Web and Future Productivity of Ocean Fisheries Affected by

- Increasing ocean temperatures
- Ocean acidification
  - Zooplankton, crustaceans, shellfish sensitive to pH
- Over-fishing

25% of commercially exploited marine fish stocks are now seriously over-harvested

*(Millennium Ecosystem Assessment, 2005)*
Human Changes to Global Activated Nitrogen Cycle, 1900-2050

Human health risks include:

- Decreased crop yields
- Nitrogen oxides (air pollution)

Source: Millennium Ecosystem Assessment

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United Nations Environment Program (UNEP) estimates 1-2 million deaths in India annually from atmospheric pollution.

Asia’s brown haze is also altering regional weather, creating acid rain, and (perhaps) affecting forest and crop yields.

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Whose Research Task?

- Epidemiology is the study of the distribution and determinants of diseases in populations, and of ways to reduce the burden of disease.
- Some say that global environmental change is too big/too complex for epidemiologists to study.
  - Then who will ensure that population health is protected from expected impacts?
  - Epidemiology has a responsibility to address societal needs.
Definitions

Weather, Climate, Climate Variability, and Climate Change
Definitions

- **Climate** - *expected* atmospheric conditions
  - Based on 30-plus-year averages

- **Weather** - *experienced* day-to-day

- **Climate variability**
  - Short-term fluctuations (weeks-to-months) around avg. weather
  - Includes ENSO (El Nino-Southern Oscillation)

- **Climate change**
  - Operates over *decades* or longer
  - General circulation models (GCMs)
  - Scenarios, not predictions
More Definitions

- **Global climate change** - series of changes in Earth’s weather patterns driven by temperature resulting in changes in precipitation, winds, ocean currents, and storms.

- **Global warming** - emphasizes only rising temperature.

- **Global environmental change** - includes global climate change along with all the other major changes that are occurring in our global environment.

- **Global Change** - Multiple factors in many domains. More than just climate and environment, involving populations, economies, food production, etc.
What is climate change? Climate variability?

Average Trend (solid line)

Unchanging Average, Unchanging Extremes

Actual Measure (dashed line)
What is climate change? Climate variability?

Unchanging Average, **Increasing** Extremes

*Average Trend (solid line)*

*Actual Measure (dashed line)*
What is climate change? Climate variability?

**Increasing Average, Unchanging Extremes**

- **Average Trend** (solid line)
- **Actual Measure** (dashed line)

Environmental Variable

Present  Time  Future
What is climate change? Climate variability?

Different Rates of Increasing Averages

Average Trend (solid line)

Actual Measure (dashed line)

Environmental Variable

High

Present

Time

Future
What is climate change? Climate variability?

Increasing Average, Greater Extremes

Average Trend (solid line)

Actual Measure (dashed line)
What is climate change? Climate variability?

Increasing Rate of Increasing Average, Unchanging Extremes

Average Trend (solid line)

Actual Measure (dashed line)
What is climate change? Climate variability?

Increasing Rate of Increasing Average, Greater Extremes

Average Trend (solid line)

Actual Measure (dashed line)
Global Temperature Variations on Three Time Scales

- Last million years
- Last 10,000 years
- Last 1,000 years

Folland et al. 1990
Temperature over Greenland over Past 17,000 Years

Alley 2000
1,000 Years of Changes in Carbon Emissions, CO$_2$ Concentrations, and Temperature
150 Years of Changes in Temperature, Sea Level, and Northern Hemisphere Snow Cover
Temperatures are Rising at an Increasing Rate

Increasing temperature (°C) per decade at Earth's Surface and Troposphere

Temperatures are increasing at an increasing rate during recent times

IPCC 2007b
Temperature Rise due mostly to Human Factors
Temperature Rise Occurring Globally

IPCC 2007b
The Greenhouse Effect

Solar radiation powers the climate system.

Some solar radiation is reflected by the Earth and the atmosphere.

About half the solar radiation is absorbed by the Earth's surface and warms it.

Infrared radiation is emitted from the Earth's surface.

Some of the infrared radiation passes through the atmosphere but most is absorbed and re-emitted in all directions by greenhouse gas molecules and clouds. The effect of this is to warm the Earth's surface and the lower atmosphere.
The Greenhouse Effect

- Natural greenhouse effect keeps the Earth warm enough (average about 15C, 60F) to be **habitable**
- Greenhouse gases (e.g. carbon dioxide, methane, nitrous oxide) and water vapor trap heat and **warm the earth’s surface**
- Basic principles of greenhouse effect **well understood**
- For a given concentration of greenhouse gases, the resulting amount of **radiative forcing** (or heat trapping of energy) can be **predicted with precision**
- Exactly how the Earth’s **climate will respond** to enhanced greenhouse gases also depends on **complex interactions** between the atmosphere, oceans, land, ice, and biosphere
Concentrations of Greenhouse Gases over the Last 10,000 Years

Figure 2.3. Atmospheric concentrations of CO₂, CH₄ and N₂O over the last 10,000 years (large panels) and since 1750 (inset panels). Measurements are shown from ice cores (symbols with different colours for different studies) and atmospheric samples (red lines). The corresponding radiative forcings relative to 1750 are shown on the right hand axes of the large panels. {WGI Figure SPM.1}
Concentrations of Greenhouse Gases in the Past 2,000 Years

IPCC 2007b
Atmospheric CO$_2$ Concentration and Temperature Change

Projected concentrations of CO$_2$ during the 21st century are 2-4 times pre-industrial levels.
Greenhouse Gases are Increasing

- Atmospheric concentrations of greenhouse gases have increased significantly since industrial revolution
- Carbon dioxide +30%; Methane +100%; Nitrous oxide +15%
- Greenhouse gas concentrations projected to reach double pre-industrial levels by about 2060
- Many greenhouse gases remain in atmosphere for a long time (decades to centuries)
- Projected CO$_2$ concentration levels are significantly higher than any observed over the past 160,000 years
Global Average Surface Temperature

IPCC 2007b
Surface Temperature Anomalies
Projected Surface Temperatures

IPCC 2007b
Land Areas Warm More than Oceans with Greatest Warming at High Latitudes

Annual mean temperature change, 2071 to 2100 relative to 1990. Global average in 2085 = 3.1°C.
IPCC 2007b
Effect of Extreme Temperatures When Mean Temperature Increases

IPCC 2007b
Observed, Modeled, and Projected Precipitation

IPCC 2007b
Some Areas are Projected to Become Wetter, Others Drier

Annual mean precipitation change: 2071 to 2100 relative to 1990.

IPCC 2007b
Palmer Drought Severity Index

IPCC 2007b
Recent Trends in Climate Sensitive Indicators

- Air Temperature
- Sea Ice
- Frozen Ground
- Snow Cover
- Glacier Mass
- Sea Ice Anomaly
- Temp Anomaly

IPCC 2007b
Tropical Atlantic Sea Surface Temperature Anomalies (°C)

IPCC 2007b
Sea Level Rise

IPCC 2007b

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## IPCC Conclusions

<table>
<thead>
<tr>
<th>Phenomenon and Direction of Trend</th>
<th>Likelihood that trend occurred in 20th Century</th>
<th>Likelihood of a Human Contribution to Observed Trend</th>
<th>D</th>
<th>Likelihood of Future Trend Based on Projections for 21st Century</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warmer and fewer cold days and nights over most land areas</td>
<td>Very likely</td>
<td>Likely</td>
<td>*</td>
<td>Virtually certain</td>
</tr>
<tr>
<td>Warmer and more frequent hot days and nights over most land areas</td>
<td>Very likely</td>
<td>Likely (nights)</td>
<td>*</td>
<td>Virtually certain</td>
</tr>
<tr>
<td>Warm spells / heatwaves: frequency increases over most land areas</td>
<td>Likely</td>
<td>More likely than not</td>
<td></td>
<td>Very likely</td>
</tr>
<tr>
<td>Heavy precipitation events: frequency (or proportion of total rainfall from heavy falls) increases over most areas</td>
<td>Likely</td>
<td>More likely than not</td>
<td></td>
<td>Very likely</td>
</tr>
<tr>
<td>Area affected by droughts increases</td>
<td>Likely in many regions since 1970s</td>
<td>More likely than not</td>
<td>*</td>
<td>Likely</td>
</tr>
<tr>
<td>Intense tropical cyclone activity increases</td>
<td>Likely in many regions since 1970s</td>
<td>More likely than not</td>
<td></td>
<td>Likely</td>
</tr>
<tr>
<td>Increased incidence of extreme high sea level</td>
<td>Likely</td>
<td>More likely than not</td>
<td></td>
<td>Likely</td>
</tr>
</tbody>
</table>
RISING IMPACTS OF GLOBAL WARMING

With continued intensive reliance on fossil-fuels and emissions increases:

- Extinction of more than 40% of known species
- Global economic losses of up to 5% GDP
- Commitment to at least partial melting of Greenland and W. Antarctic Ice Sheets, eventually raising sea-level 13-20 feet
- Substantial burden on health services
- Global food production decreases
- About 30% of global coastal wetlands lost

Major changes in natural systems cause predominantly negative consequences for biodiversity, water and food supplies:

- Widespread coral mortality
- Millions more people face flooding risk every year

Increased risk of extinction for 20-30% of known species:

- Most corals bleached
- Increasing mortality from heat waves, floods and droughts

Decreasing water availability, increasing drought in many regions:

- Increasing wildfire risk, increased flood and storm damage
- Increasing burden from malnutrition, diarrhoeal, cardio-respiratory and infectious diseases

Source: IPCC Fourth Assessment Report, Working Group II Summary for Policymakers. Timing of temperature increases based on IPCC scenarios that assume continued intensive reliance on fossil-fuels and emissions increases. Emissions reductions would reduce the amount and rate of warming. Conversion of temperature increases—Celsius to Fahrenheit: 1°C = 1.8°F; 2°C = 3.6°F; 3°C = 5.4°F; 4°C = 7.2°F.

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