Impact of Climate Change on Society: Mitigation, Adaptation and Ethics.
The mean global surface temperature has increased by about 0.3 to 0.6°C since the late 19th century and by about 0.2 to 0.3°C over the last 40 years.
Vostok’s Ice Cores Data
450,000 years of climate variability
Potential Climate Change Impacts

- **Health Impacts**
  - Weather-related Mortality
  - Infectious Diseases
  - Air Quality-Respiratory Illnesses

- **Agriculture Impacts**
  - Crop yields
  - Irrigation demands

- **Forest Impacts**
  - Change in forest composition
  - Shift geographic range of forests
  - Forest Health and Productivity

- **Water Resource Impacts**
  - Changes in water supply
  - Water quality
  - Increased Competition for water

- **Impacts on Coastal Areas**
  - Erosion of beaches
  - Inundate coastal lands
  - Costs to defend coastal communities

- **Species and Natural Areas**
  - Shift in ecological zones
  - Loss of habitat and species
Alps - Europe
Alps - Europe

1978

1993

2002

Kilimanjaro - Africa

1993

2000
Alps - Europe

Alaska – North America

Kilimanjaro - Africa
Alps - Europe

Alaska – North America

Peru – South America

Kilimanjaro - Africa

Muir and Riggs Glaciers

1859

1941

2004

1978

1993

2002

2000
Natural vs. Anthropogenic factors in predicting global temperatures

- Observations:
  - Natural factors only
  - Human factors excluded
  - Model simulation: natural and human-induced greenhouse gases are taken into account

- THE HUMAN FACTOR
Natural vs. Anthropogenic factors in predicting global temperatures

Observations

Model simulation:
Human factors excluded

Human factors included
Pathways by which climate change affects health, and concurrent direct-acting and modifying (conditioning) influences of environmental, social and health-system factors
Human Health

An increase in the frequency or intensity of heatwaves will increase the risk of mortality and morbidity, principally in older age groups and among the urban poor.

Any regional increases in climate extremes (e.g., storms, floods, cyclones, droughts) would cause deaths and injuries, population displacement, and adverse effects on food production, freshwater availability and quality, and would increase the risks of infectious disease, particularly in low-income countries.

May cause social disruption, economic decline, and displacement of populations. The health impacts associated with such socio-economic dislocation and population displacement are substantial.

Would affect many vector-borne infections. Populations at the margins of the current distribution of diseases might be particularly affected.

Additional pressure on the world’s food supply system and is expected to increase yields at higher latitudes and decrease yields at lower latitudes. This would increase the number of undernourished people in the low-income world, unless there was a major redistribution of food around the world.

Assuming that current emission levels continue, air quality in many large urban areas will deteriorate. Increases in exposure to ozone and other air pollutants (e.g., particulates) could increase morbidity and mortality.
Health Impacts of

- Physical injury.
- Decreases in nutritional status, especially in children.
- Increases in respiratory and diarrheal diseases resulting from crowding of survivors, often with limited shelter and access to potable water.
- Impacts on mental health, which in some cases may be long-lasting.
- Increased risk of water-related diseases as a result of disruption of water supply or sewage systems.
- Release and dissemination of dangerous chemicals from storage sites and waste disposal sites into floodwaters.
Gender and Natural Disaster

Men and women are affected differently in all phases of a disaster
Natural disasters have been shown to result in increased domestic violence against, and post-traumatic stress disorders in, women
Women make an important contribution to disaster reduction, often informally through participating in disaster management and acting as agents of social change.
Direct Weather Impact

The pie chart shows the distribution of deaths for 11 hazard categories as a percent of the total 19,958 deaths due to these hazards from 1970 to 2004. Heat/drought ranks highest, followed by severe weather, which includes events with multiple causes such as lightning, wind, and rain. This analysis ended prior to the 2005 hurricane season which resulted in approximately 2,000 deaths.
Heatwave Mortality in Paris
Wind, Storm and Floods

Estimated health impact of climate change (1990–2000) by region. Calculated for Malaria, Malnutrition, Diarrhoea and Floods. DALYs are a parameter for the cumulated burden through diseases.
Flood-related Mortality Risk
Human Health Response to Climate Change

Deaths from climate change

Figure 3.8 WHO estimates of extra deaths (per million people) from climate change in 2000

<table>
<thead>
<tr>
<th>Disease/Illness</th>
<th>Annual Deaths</th>
<th>Climate change component (death / % total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diarrhoeal diseases</td>
<td>2.0 million</td>
<td>47,000 / 2%</td>
</tr>
<tr>
<td>Malaria</td>
<td>1.1 million</td>
<td>27,000 / 2%</td>
</tr>
<tr>
<td>Malnutrition</td>
<td>3.7 million</td>
<td>77,000 / 2%</td>
</tr>
<tr>
<td>Cardiovascular disease</td>
<td>17.5 million</td>
<td>Total heat/cold data not provided</td>
</tr>
<tr>
<td>HIV/AIDS</td>
<td>2.8 million</td>
<td>No climate change element</td>
</tr>
<tr>
<td>Cancer</td>
<td>7.6 million</td>
<td>No climate change element</td>
</tr>
</tbody>
</table>

Source: WHO (2006) based on data from McMichael et al. (2004). The numbers are expected to at least double to 300,000 deaths each year by 2030.
Heat Stress in US Cities

Average Annual Excess Weather-Related Mortality for 1993, 2020 and 2050 Climate

Sources: Kalkstein and Green (1997); Chestnut et al. (1995)

Note: Includes both summer and winter mortality. Assumes full acclimation to changed climate. Includes population growth.

GFDL Climate Change Scenario
Plasmodium vivax, with the Anopheles mosquito as a vector, is an organism causing malaria. The main climate factors that have bearing on the malarial transmission potential of the mosquito population are temperature and precipitation.
A warmer climate increases occasions of vector borne tropical diseases. The figure depicts weeks of potential dengue transmission under current temperature and 2°C and 4°C warming.
Economy

Agriculture

Insurance Premiums/Claims

Fisheries

Health

Engineering
Climate Change and the Gross Domestic Product

Global mean temperature (above pre-industrial)

% loss in GDP per capita

Baseline climate, market impacts + risk of catastrophe
High climate, market impacts + risk of catastrophe
Baseline climate, market impacts + risk of catastrophe + non-market impacts
High climate, market impacts + risk of catastrophe + non-market impacts
Yearly economic losses from large events increased 10.3-fold from US$4 billion in the 1950s to US$40 billion per year in the 1990s (all in 1999 US$). The insured portion of these losses rose from a negligible level to US$9.2 billion annually during the same period, and the ratio of premiums to catastrophe losses fell by two-thirds. Notably, costs are larger by a factor of 2 when losses from ordinary, noncatastrophic weather-related events are included. The numbers generally include "captive" self-insurers but not the less-formal types of self-insurance.
25% increase in peak gust causes almost seven-fold increase in building damages.
2011 Tornado Reports

U.S. Tornadoes: Daily Count and Running Annual Trend*

*Preliminary tornadoes from NWS Local Storm Reports (LSRs)
Daily and annual averages are based on preliminary LSRs, 2005-2010
Insurance Claims

The graph illustrates the relationship between average temperature (F) and the number of insurance claims. The data points are color-coded by year, with different symbols representing different years:

- Green diamonds: 1991
- Purple circles: 1992
- Red squares: 1993
- Blue triangles: 1994
- Orange diamonds: 1995

The x-axis represents the number of insurance claims, while the y-axis shows the average temperature. The trend appears to show a positive correlation, indicating that higher temperatures correlate with an increased number of insurance claims.
Definitions

**Sensitivity**: rate of change of the outcome variable per unit change in the input

Population **vulnerability**: a function of the extent to which a health outcome in that particular environmental-demographic setting is sensitive to climate change and the capacity of the population to adapt to new climate conditions

**Adaptation**: adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities

**Mitigation**: action to decrease the intensity of radiative forcing in order to reduce the potential effects of global warming

Understanding a population's capacity to adapt to new climate conditions is crucial to realistic assessment of the potential impacts of climate change
Integrated Assessment Framework

- Models
- Scenario analysis
- Simulation gaming/policy
- Qualitative assessment
Why Adaptation?
Example: Mitigation and Adaptation

Selecting Key Vulnerability

- magnitude of impacts,
- timing of impacts,
- persistence and reversibility of impacts,
- likelihood (estimates of uncertainty) of impacts and vulnerabilities, and confidence in those estimates,
- potential for adaptation,
- distributional aspects of impacts and vulnerabilities,
- importance of the system(s) at risk.

**Example:**
temperature increase of 2°C => **11.6% increase** in residential per capita electricity use in Florida, but **7.2% decrease** in Washington DC
Examples of Adaptation

**Strategy #1**: Shore Protection

**Strategy #2**: Planned retreat
<table>
<thead>
<tr>
<th>Cost of Adaptation</th>
<th>1°C</th>
<th>2°C</th>
<th>3°C</th>
<th>4°C</th>
<th>5°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>Increasing potential of crop yields in selected countries</td>
<td>Failing crop yields</td>
<td>Loss of agricultural lands due to sea level rise</td>
<td>Delay in current cropping schedule</td>
<td></td>
</tr>
<tr>
<td>Water Resources</td>
<td>Increasing population under water stress</td>
<td></td>
<td>Increased water runoff</td>
<td>Decreasing quality of aquifer and ground water resources</td>
<td></td>
</tr>
<tr>
<td>Forestry and Ecosystem</td>
<td></td>
<td>Tropical forest gradually replaced by tropical savannas and shrub lands</td>
<td>Loss of small islands</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Health</td>
<td></td>
<td>Coral bleaching</td>
<td></td>
<td>Increased respiratory and cardiovascular diseases due to thermal stress</td>
<td></td>
</tr>
<tr>
<td>Extreme Weather Events</td>
<td></td>
<td></td>
<td>Outbreak of vector born diseases (malaria and dengue)</td>
<td>Increased frequency and intensity of extreme weather events (heat waves and drought, flooding, and tropical cyclones)</td>
<td></td>
</tr>
</tbody>
</table>
Potential Adaptation:

1. Human Health
2. Sea Level Rise
3. Agriculture and Forestry
4. Ecosystems and Wildlife
5. Water Resources
6. Energy
Potential Adaptation: Human Health
Potential Adaptation: Human Health

- Adequate financial and human public health resources: training, surveillance and emergency response, and prevention and control programs.
- Urban tree planting
- Weather advisories
- Grain storage, emergency feeding stations
- Adjusting clothing and activity levels, increasing fluid intake
Potential Adaptation: Sea Level Rise
Potential Adaptation: Sea Level Rise

- Developing county-scale maps depicting which areas will require shore protection (e.g. dikes, bulkheads, beach nourishment) and which areas will be allowed to adapt naturally
- Analyzing the environmental consequences
- Promoting techniques that do not destroy all habitat
- Identifying land use measures to ensure that wetlands migrate as sea level rises in some areas
- Engaging state and local governments
- Improving early warning systems and flood hazard mapping for storms
- Protecting water supplies from contamination by saltwater
Potential Adaptation: Agriculture and Forestry
Potential Adaptation: Agriculture and Forestry

- Altering the timing of planting dates
- Altering cropping mix and forest species that are better suited to the changing climatic conditions
- Breeding new plant species and crops that are more tolerant to changed climate condition
- Promoting fire suppression practices
- Controlling insect outbreaks
Potential Adaptation: Ecosystems and Wildlife
Potential Adaptation: Ecosystems and Wildlife

- Protecting and enhancing migration corridors
- Identifying management practices that will ensure the successful attainment of conservation and management goals
- Promoting management practices that confer resilience to the ecosystem
Potential Adaptation: Water Resources
Potential Adaptation: Water Resources

- Altering infrastructure or institutional arrangements
- Changing demand or reducing risk
- Improving water use efficiency, planning for alternative water sources (treated wastewater or desalinated seawater), and making changes to water allocation
- Conserving soil moisture through mulching and other means
- Protecting coastal freshwater resources from saltwater intrusion
Potential Adaptation: Energy
Potential Adaptation: Energy

- Increasing energy efficiency
- Protecting facilities against extreme weather events
- Diversifying power supply in the event of power plant failures due to excess demand created by extreme heat, or by extreme weather events
A1: very rapid economic growth, low population growth, and the rapid introduction of new and more efficient technologies.

A2: very heterogeneous world. Self-reliance and Preservation of local identities, high population growth. Economic development is regionally oriented and per capita economic growth and technological change are more fragmented and slower than in other storylines.

B1: convergent world with the same low population growth as in the A1 storyline, but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies.

B2: emphasis is on local solutions to economic, social, and environmental sustainability. It is a world with moderate population growth, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines.
Adaptation costs

Sea-level rise protection costs in 2080 as a percentage of GDP for most-affected countries under the four SRES world scenarios (A1FI, A2, B1, B2)

<table>
<thead>
<tr>
<th>Protection costs (%GDP) for the 2080s</th>
<th>A1FI</th>
<th>A2</th>
<th>B1</th>
<th>B2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micronesia</td>
<td>7.4</td>
<td>10</td>
<td>5</td>
<td>13.5</td>
</tr>
<tr>
<td>Palau</td>
<td>6.1</td>
<td>7</td>
<td>3.9</td>
<td>9.1</td>
</tr>
<tr>
<td>Tuvalu</td>
<td>1.4</td>
<td>1.7</td>
<td>0.9</td>
<td>2.2</td>
</tr>
<tr>
<td>Marshall Islands</td>
<td>0.9</td>
<td>1.3</td>
<td>0.6</td>
<td>1.7</td>
</tr>
<tr>
<td>Mozambique</td>
<td>0.2</td>
<td>0.5</td>
<td>0.1</td>
<td>0.8</td>
</tr>
<tr>
<td>French Polynesia</td>
<td>0.6</td>
<td>0.8</td>
<td>0.4</td>
<td>1</td>
</tr>
<tr>
<td>Guinea-Bissau</td>
<td>0.1</td>
<td>0.3</td>
<td>0</td>
<td>0.6</td>
</tr>
<tr>
<td>Nauru</td>
<td>0.3</td>
<td>0.4</td>
<td>0.2</td>
<td>0.6</td>
</tr>
<tr>
<td>Guyana</td>
<td>0.1</td>
<td>0.2</td>
<td>0.1</td>
<td>0.4</td>
</tr>
<tr>
<td>New Caledonia</td>
<td>0.4</td>
<td>0.3</td>
<td>0.2</td>
<td>0.4</td>
</tr>
<tr>
<td>Papua New Guinea</td>
<td>0.3</td>
<td>0.3</td>
<td>0.2</td>
<td>0.4</td>
</tr>
<tr>
<td>Kiribati</td>
<td>1.2</td>
<td>0</td>
<td>0.3</td>
<td>0</td>
</tr>
<tr>
<td>Maldives</td>
<td>0</td>
<td>0.2</td>
<td>0</td>
<td>0.2</td>
</tr>
<tr>
<td>Vietnam</td>
<td>0.1</td>
<td>0.1</td>
<td>0</td>
<td>0.2</td>
</tr>
<tr>
<td>Cambodia</td>
<td>0</td>
<td>0.1</td>
<td>0</td>
<td>0.1</td>
</tr>
</tbody>
</table>
Adaptation costs and Benefits: Water management S Africa

Establishment of an efficient water market
Increase in water storage capacity through the construction of a dam

Under efficient water markets, the costs of not adapting to climate change that does occur outweigh the costs of adapting to climate change that does not occur.
Insurance Premiums Response

Relative ratio of global weather-related losses to total property/casualty premiums

Least-squares trend

Index: 1980 = 100
The Ethics of Climate Change

Science of climate change will never be sufficient to tell humanity what to do. Considerations of fairness, equity, and justice must also inform any successful international agreement, Example ” 1987 Montreal Protocol on Substances that Deplete the Ozone Layer” (dealing with CFCs)

Three major ethical dilemmas:

➢ How to balance the rights and responsibilities of the developed and developing world

➢ How to evaluate geo-engineering schemes designed to reverse or slow climate change

➢ How to assess our responsibility to future generations who must live with a climate we are shaping today
Climate Change and its differential impact on distinct economies
The Politics of Climate Change

The blunt truth about the politics of climate change is that no country will want to sacrifice its economy in order to meet this challenge, but all economies know that the only sensible long term way of developing is to do it on a sustainable basis.

Tony Blair
Riots, instability spread as food prices skyrocket

“Also, said Sachs, "climate shocks" are damaging food supply in parts of the world.”
Meeting Kyoto Targets

Many countries are making progress towards their Kyoto commitments, but even the agreed targets fall far short of stabilizing greenhouse gas emissions at levels considered to be safe.

**Progress Towards Kyoto Targets**

Changes in aggregate emissions of major greenhouse gases including changes in land-use that affect CO\textsubscript{2} absorption

- **percentage change 1990–2003**
- **Kyoto target for 2008–12 as percentage of base year (variable)**

**Kyoto targets**

Signatory Annex I countries have individual targets, and target years ranging from 2008 to 2012. The EU-15 agreed to develop a distribution of greenhouse gas reductions among themselves, which equals an 8% overall reduction. Allowances were made for less developed European countries to increase emissions with economic growth. In fact, countries making the transition from a communist to a market economy have seen their emissions drop as their economies have suffered.

**EU industrialized**

- Austria: 42.2
- Belgium: 4.8
- Denmark: 1.1
- Finland: 24.7
- France: 25.0
- Germany: 31.8
- Greece: 27.0
- Ireland: 15.0
- Italy: 8.3
- Luxembourg: 1.4
- Netherlands: 24.4
- Portugal: 0.0
- Spain: 0.0
- Sweden: 4.0
- UK: 0.0
- Canada: 57.5
- Iceland: 0.0
- Japan: 0.0
- New Zealand: 0.0
- Norway: 0.0
- Switzerland: 0.0

**Non-EU industrialized**

- Bulgaria: 0.0
- Croatia: 0.0
- Czech Republic: 0.0
- Estonia: 0.0
- Hungary: 0.0
- Latvia: 0.0
- Lithuania: 0.0
- Poland: 0.0
- Romania: 0.0
- Russia: 0.0
- Slovakia: 6.9
- Slovenia: 0.0
- Ukraine: 0.0

**Economies in transition**

- Australia: 49.9
- USA: 20.3
- Australia: 4.9
- USA: 8.0
- Australia: 20.3
When and How to Act?

Dec 2007: UN sponsored conference in Bali: By 2050 DHGs emission should be cut by 50% below 1990 levels, CO2 levels < 450 ppm (agreement was not reached)

Differing perspectives of developed and developing nations: Current vs Future responsibilities

Geo-engineering to counter human-caused climate change
- Addictive
- Create additional problems
- Eliminates only part of the problem (i.e. increasing earth reflectivity does not change oceans acidification)

Delaying Mechanisms of Climate system: Benefit from using cheap fossil fuels => sentencing next generation to coping with consequences
What it will take to reach that goal of CO2 stabilized 350 ppm

Learning tool: Understand the long-term climate effects (CO$_2$ concentrations, global temperature, sea level rise) of various customized actions to reduce fossil fuel CO$_2$ emissions, reduce deforestation, and grow more trees.

Activity:

2. Read Instructions
3. Run 2-3 different simulations (don’t forget to name them)
4. Do comparative analysis of your runs
5. Present your findings and recommendations
Main Greenhouse Gases:
- CO2 (carbon dioxide)
- CH4 (methane)
- Nitrous Oxide (N2O)
- CFCs (Chloro fluoro compounds)
Over the last 400,000 years the Earth's climate has been unstable, with very significant temperature changes, going from a warm climate to an ice age in as rapidly as a few decades. These rapid changes suggest that climate may be quite sensitive to internal or external climate forcings and feedbacks.
Carbon Concentration in the World Ocean

Sea-surface DIC [mmol C kg\(^{-1}\)]

1.8  1.85  1.9  1.95  2  2.05  2.1  2.15  2.2
Carbon Concentration in the World Ocean

Southern Ocean reaching SATURATION (LaQuerre, 2007)
Total emissions in 2000: 42 GtCO₂e.

Energy emissions are mostly CO₂ (some non-CO₂ in industry and other energy related). Non-energy emissions are CO₂ (land use) and non-CO₂ (agriculture and waste).