Arbaminch Water Technology Institute (AWTI)
Faculty of Meteorology and Hydrology

Climate change Impact, adaptation &Mitigation

Course code: MHF1303.

Course credit: 6

Target group: UG3_MHS

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Climate change Impact, adaptation & Mitigation

Lecture Note5:

- **Climate change impacts**
- **Climate change mitigation**
- **Adaptation to Climate change**
- **The difference between Adaptation and Mitigation mechanisms**

Impact of Climate Change

- **What is causing climate change?**

- Certain atmospheric gases act like a greenhouse, trapping heat.
- These greenhouse gases have been accumulated in the atmosphere due to human activity.
- The elevated concentrations of these heat trapping gases is warming the planet.

- **Notes**: Let's talk about the cause of climate change.
- When sunlight reaches the Earth's surface, it can either be reflected back into space or absorbed by the Earth.
- The planet then releases some of the absorbed energy back into the atmosphere as heat.
- Certain gases are known as "greenhouse gases" because they trap the solar radiation in the Earth's atmosphere, acting much like a greenhouse.

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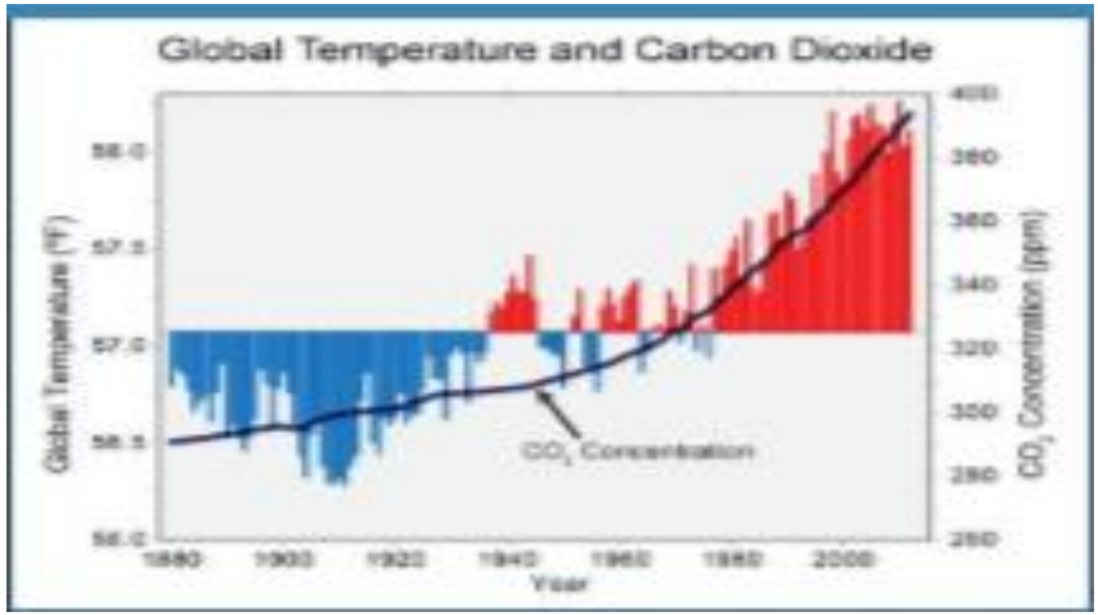
- Greenhouse gases are vital to making Earth a habitable planet, but the amounts of the gases in the atmosphere-gases such as carbon dioxide, methane, and nitrous oxide-have been accumulating.
- This accumulation of greenhouse gases is causing global average temperatures to rise.
- What is causing this rising greenhouse gases?
- Fossil fuels burned through various human activities are the primary causes of climate change as evidenced by the relationship between rising CO_2 concentrations and rising global average temperatures over the last past years.

- In the past, climate change was driven exclusively by natural factors such as volcanic eruptions that inject reflective particles into the atmosphere, natural cycles that transfer heat between the ocean and the atmosphere, and natural variations in heat-trapping gases in the atmosphere.

- But since the beginning of the *Industrial Revolution* the burning of coal, oil, and natural gas has increased the concentration of carbon dioxide in the atmosphere by more than 40 percent.

- Agriculture and other human activities have also added methane and nitrous oxide to the atmosphere.



- As you can see on this graph, there is a strong relationship between the increase in greenhouse gases and rising temperatures.

❖ Unprecedented Increases in Carbon Dioxide:

- A critical ‘greenhouse gas’ that absorbs energy and is the largest single driver of current warming .
- Increases change the Earth’s energy budget, ‘forcing’ climate to change and acidifying the oceans.
- Future emissions are erroneously correlated with atmospheric CO_2.
- Purple dashed line indicates the correct emissions path to stabilize CO_2 given the subject's estimate of net removal (figure below).

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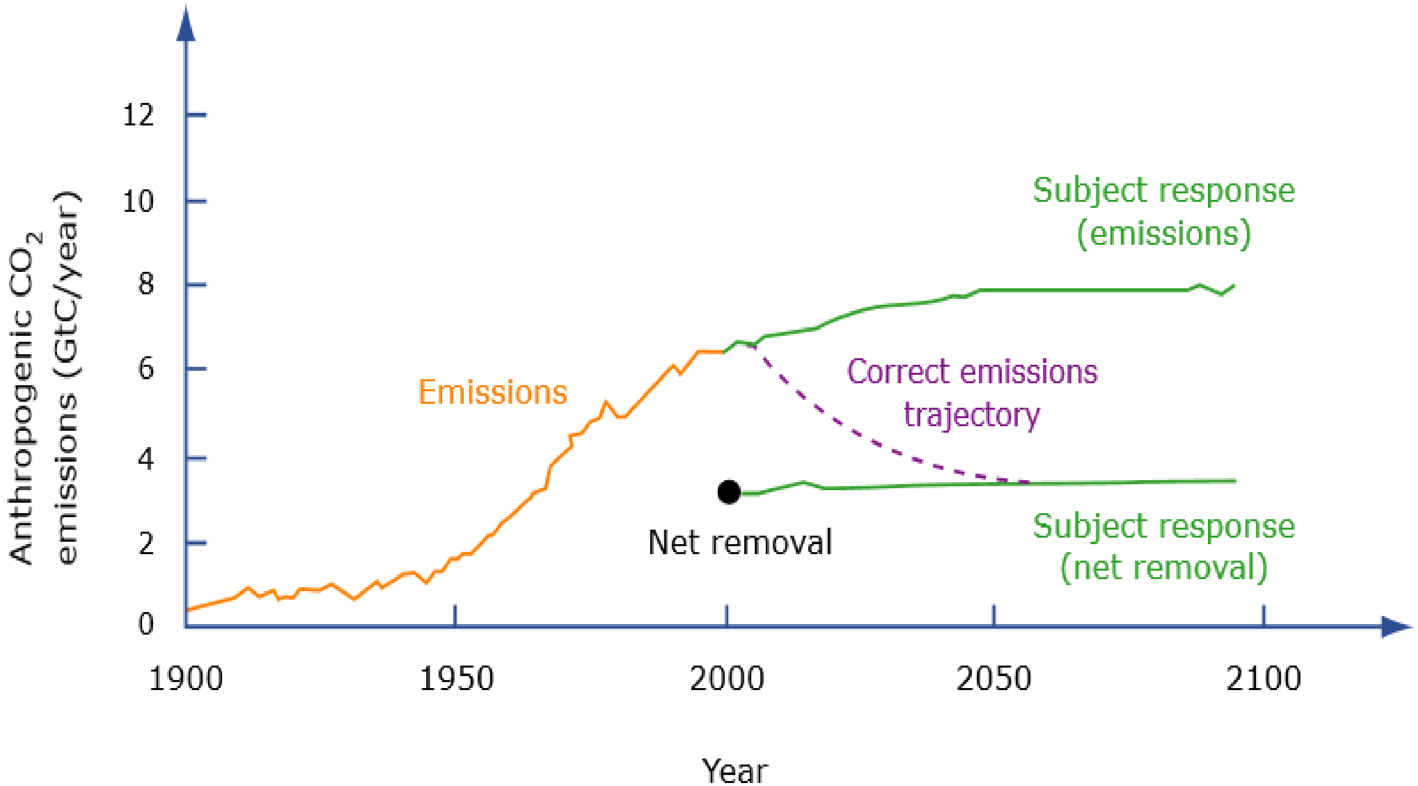


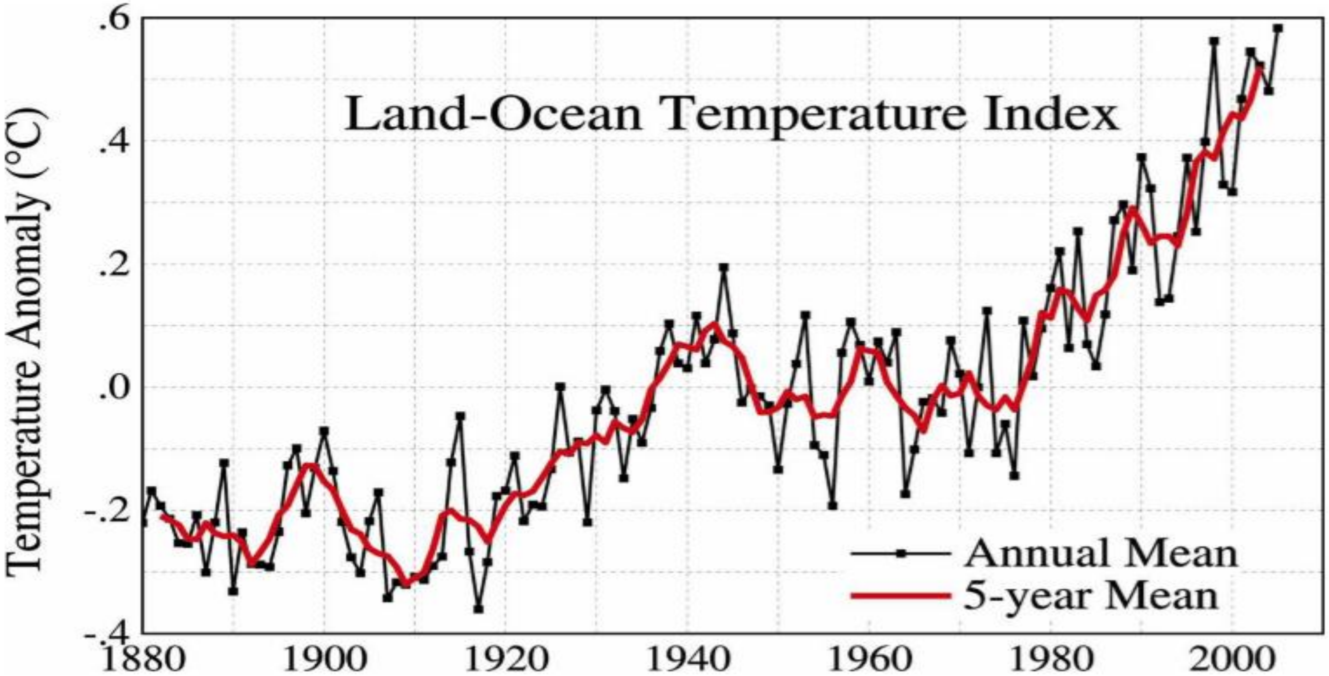
- A typical response to the climate stabilization task.

Two main effects associated with climate change:

- (1)An increase in global mean temperature (global warming).
- (2)An increase in evaporation everywhere, driven by increased greenhouse gas concentrations and increased temperatures.
- The increase in evaporation also implies an increase in precipitation, because the atmosphere can’t store water vapor indefinitely.

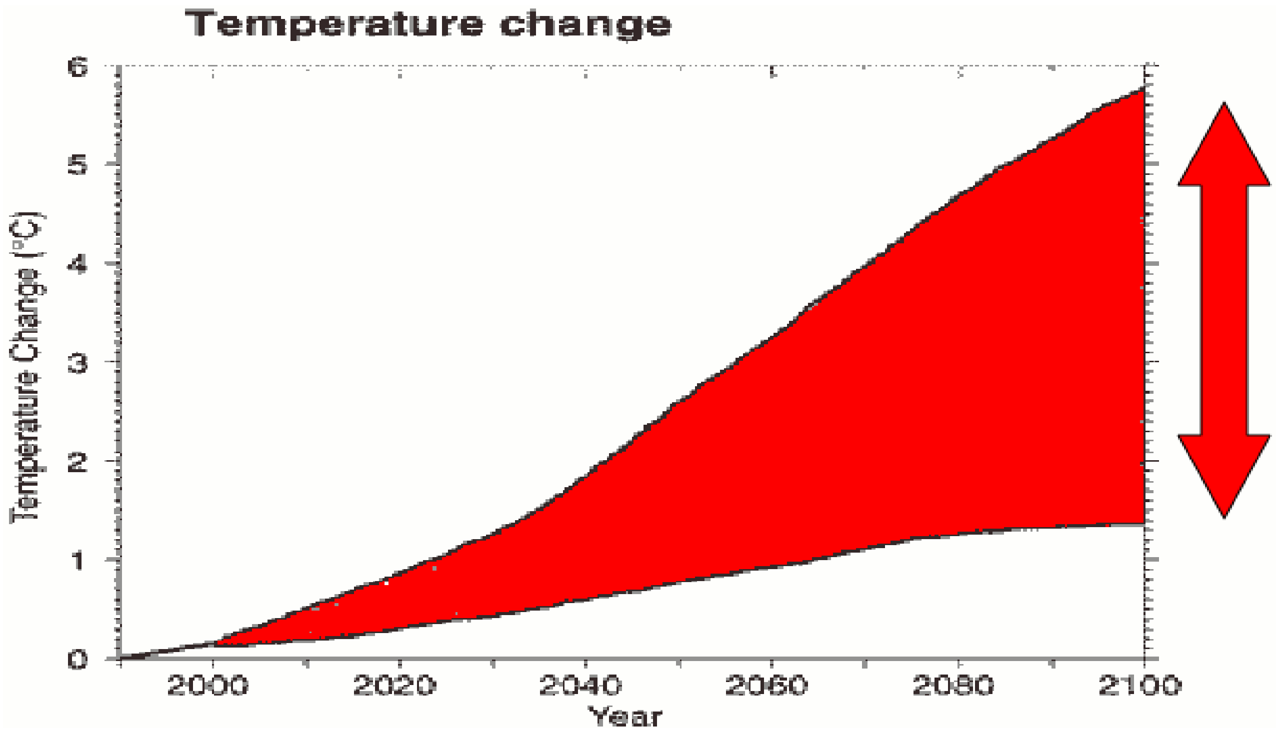
- There is no clear consensus on how the increase in precipitation will be distributed.
- However, we do know that it will not be distributed uniformly.
- This increase in evaporation and precipitation is known as the **intensification of the hydrologic cyc**le.
- Global mean surface temperature change based on surface air measurements over land and SSTs over ocean.

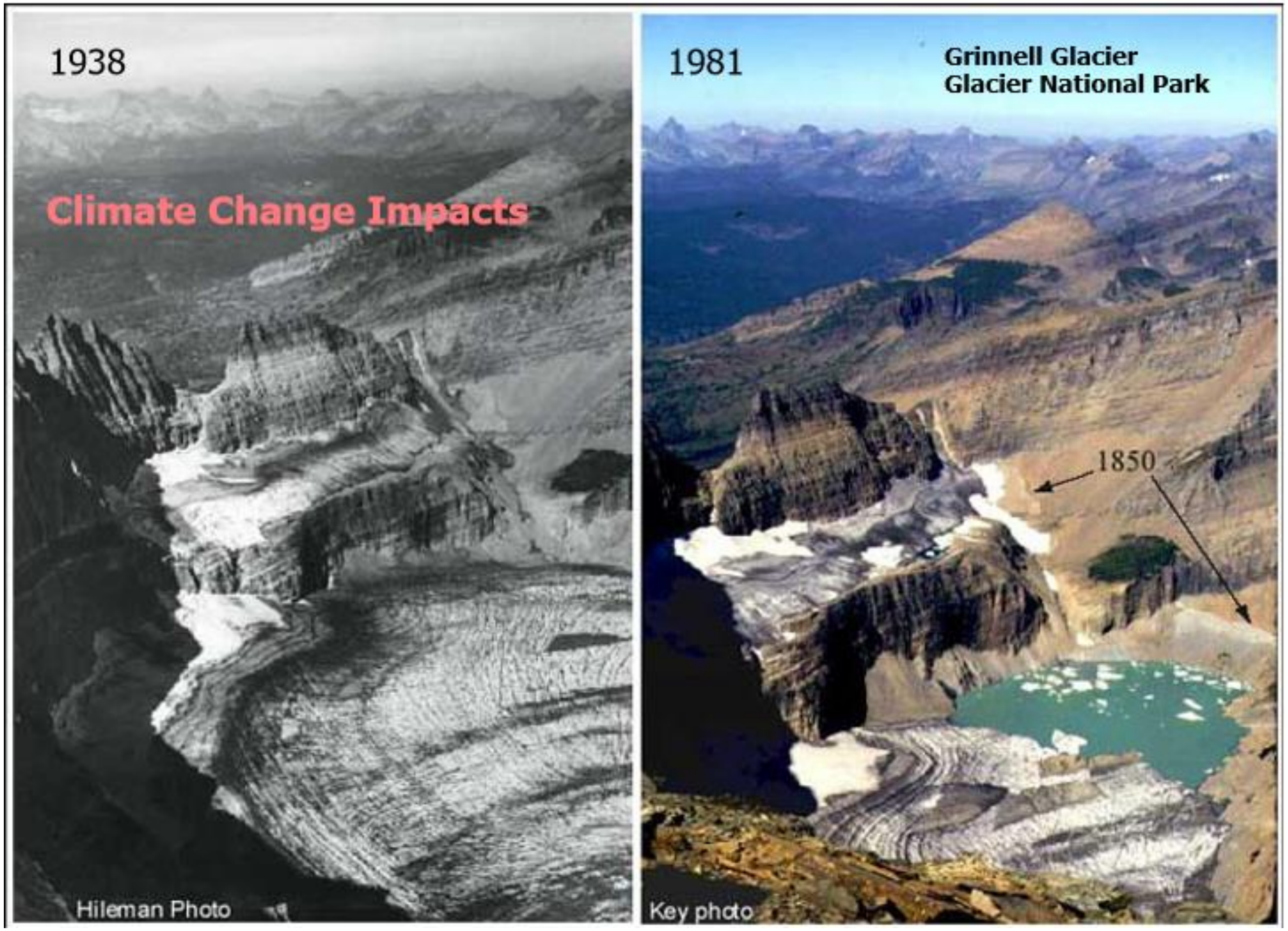
- Projection to the future? (Globe and regions)



- Uncertainty about the future:
- This plot shows the upper and lower limits of the warming over the coming century predicted by current GCM simulations.

- This range is due to two factors:
- (1) uncertainty in emissions scenarios and
- (2) different model sensitivities (i.e. different simulations of climate feedbacks).





- Mountain glaciers all over the world are in retreat.

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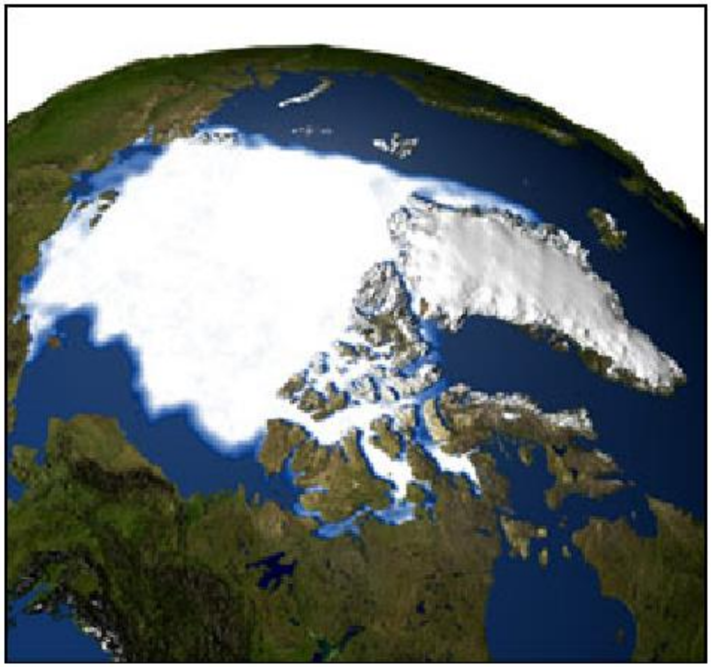
- Arctic researchers see early warning signals



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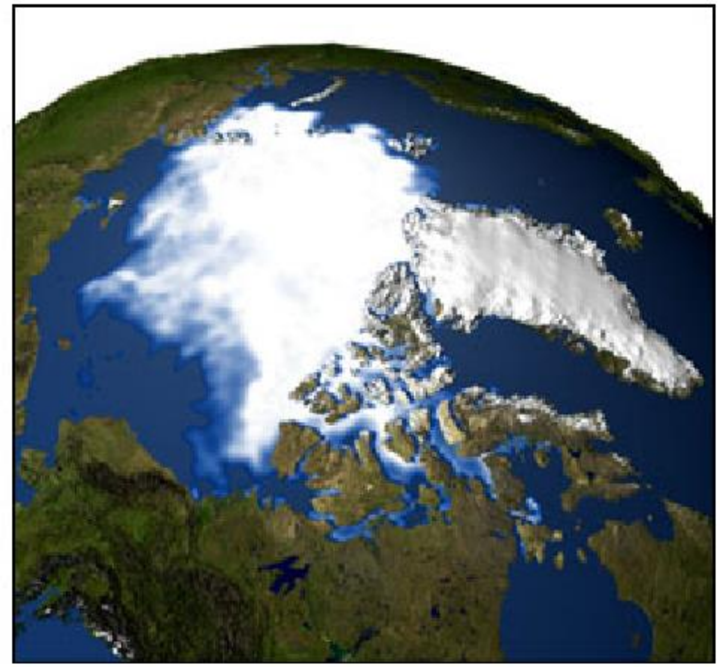
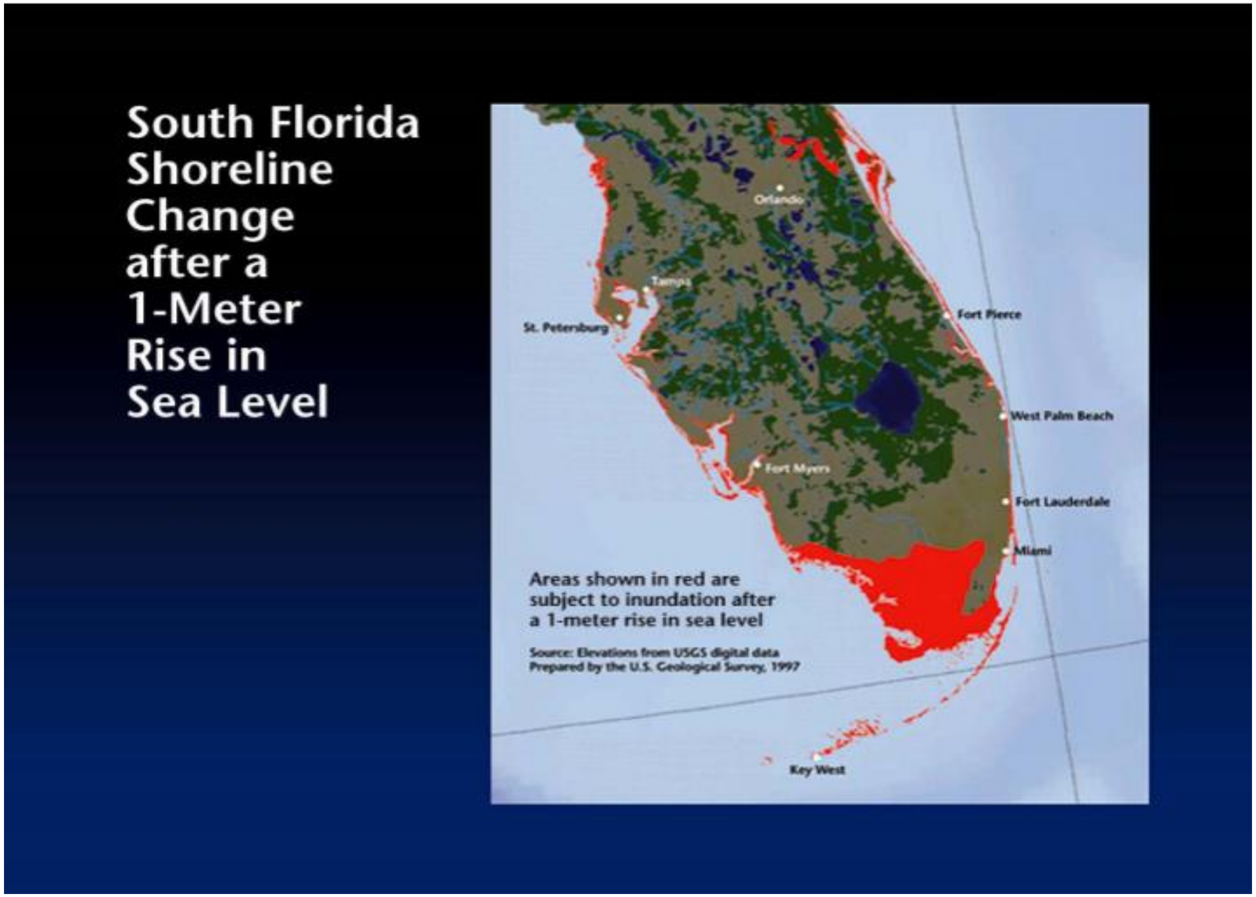


2000

- Based on satellite data, these images show Arctic sea ice.
- The ice cover shrunk by 9 percent a decade over that time.

Why will sea level rise as the climate warms?

- Sea level will rise as the climate warms due to the thermal expansion of seawater, i.e., the fact that seawater expands as it warms.



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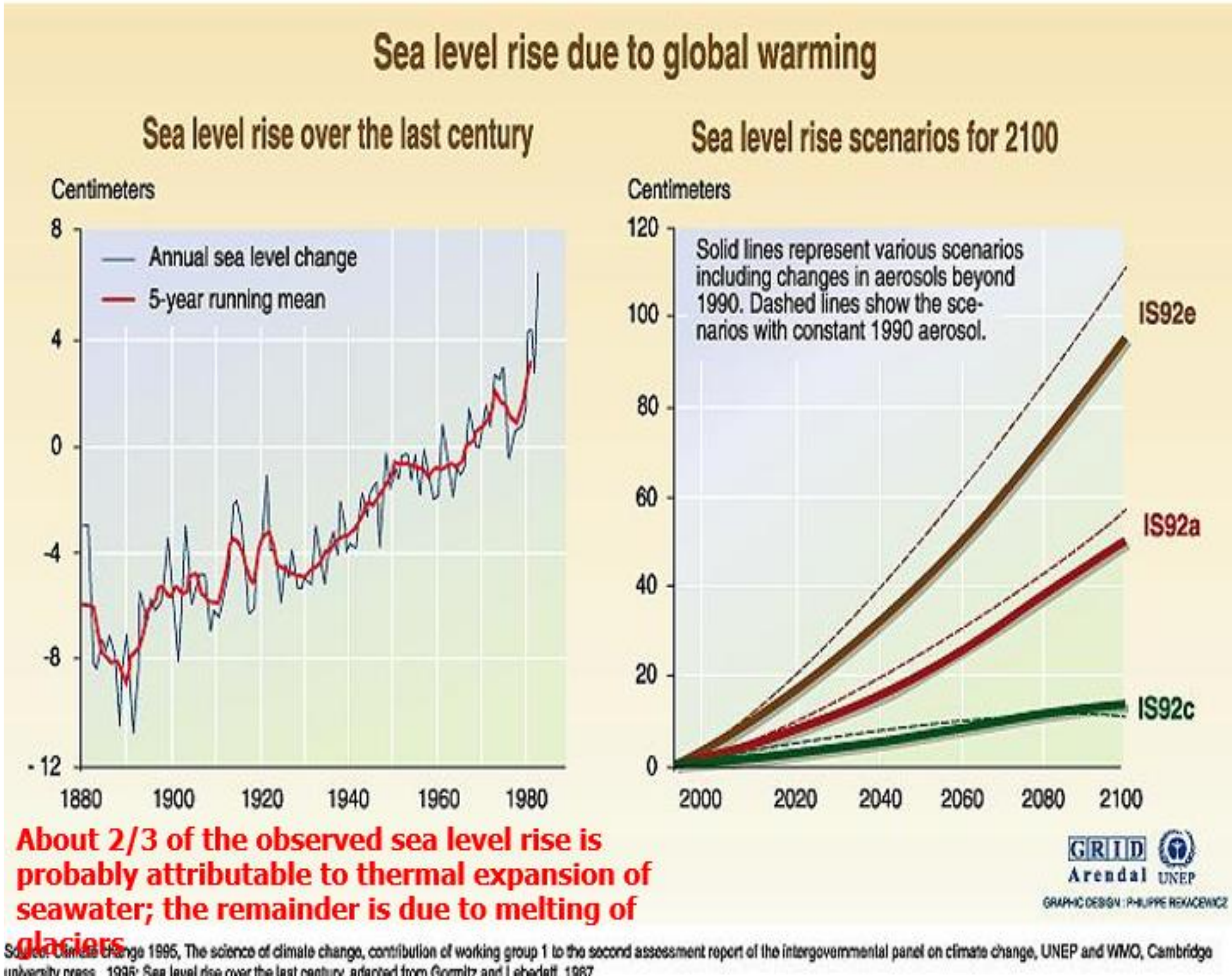

About 2/3 of the observed sea level rise is probably attributable to thermal expansion of seawater; the remainder is due to melting of glaciers


Another important issue: The
intensification of the hydrologic cycle

HYDROLOGIC CYCLE INTENSIFICATION

Increase in greenhouse gases means more longwave radiation reaches the

Increase in temperatures favors loss of surface heat through evaporation rather than sensible heat

Increase in evaporation (fairly uniform globally)

Increase in precipitation (not uniform)

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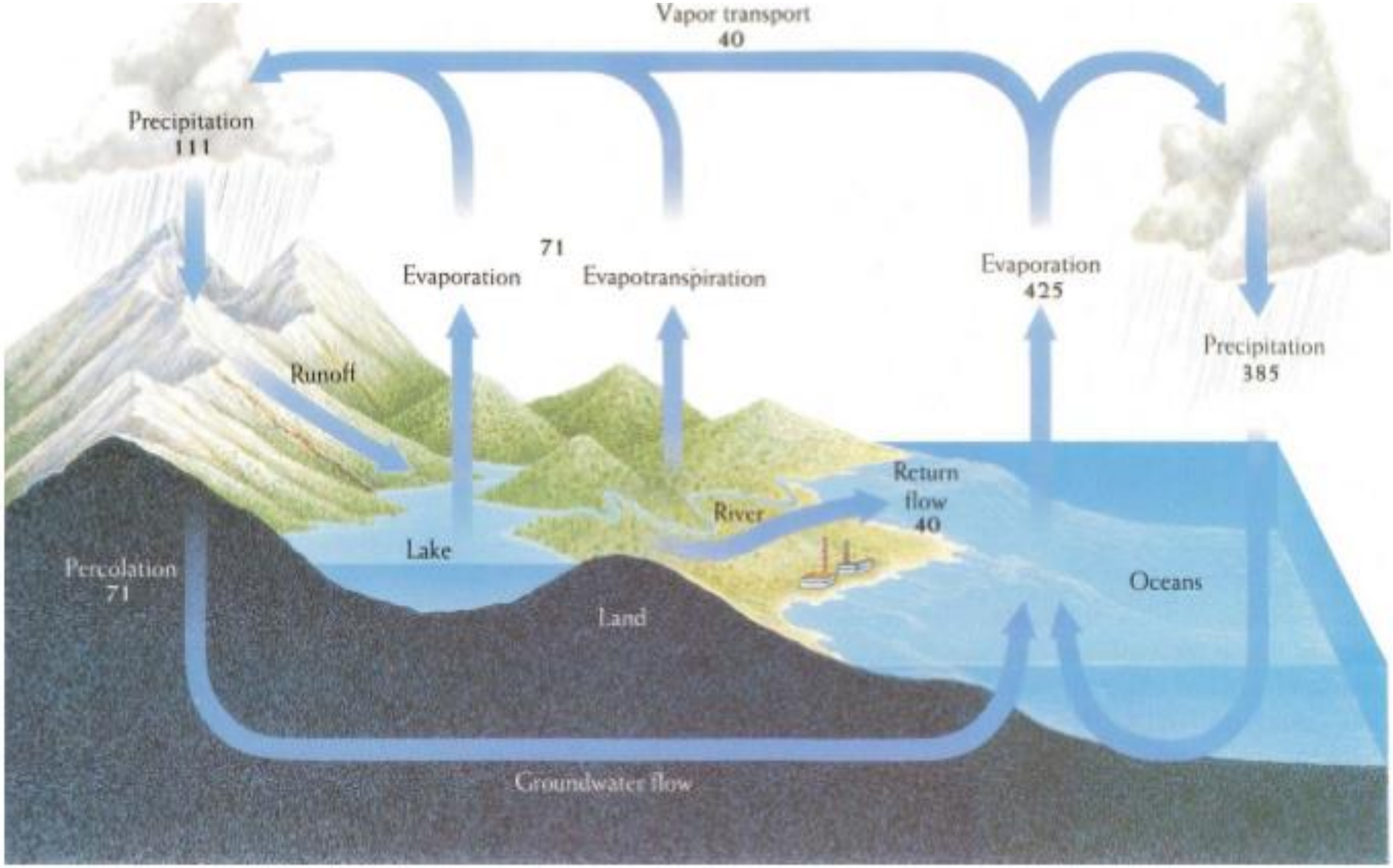

Earth's water budget. The units of the water flows are thousands of cubic kilometers per year.

Effect on Ecosystems

- Ecosystems will be forced to adapt to climate change for two reasons:

- (1) Temperatures will be warmer.
- (2) Precipitation will be distributed differently.
- One easily anticipated effect of climate change is species migration to higher latitudes.
- For example, a warmer climate may have significant effect on forests composition.

- Deciduous forests will probably move northwards and to higher altitudes, replacing coniferous forests in many areas.
- Some tree species will probably be replaced altogether, jeopardizing biological diversity.
- Species would also migrate to higher altitudes.

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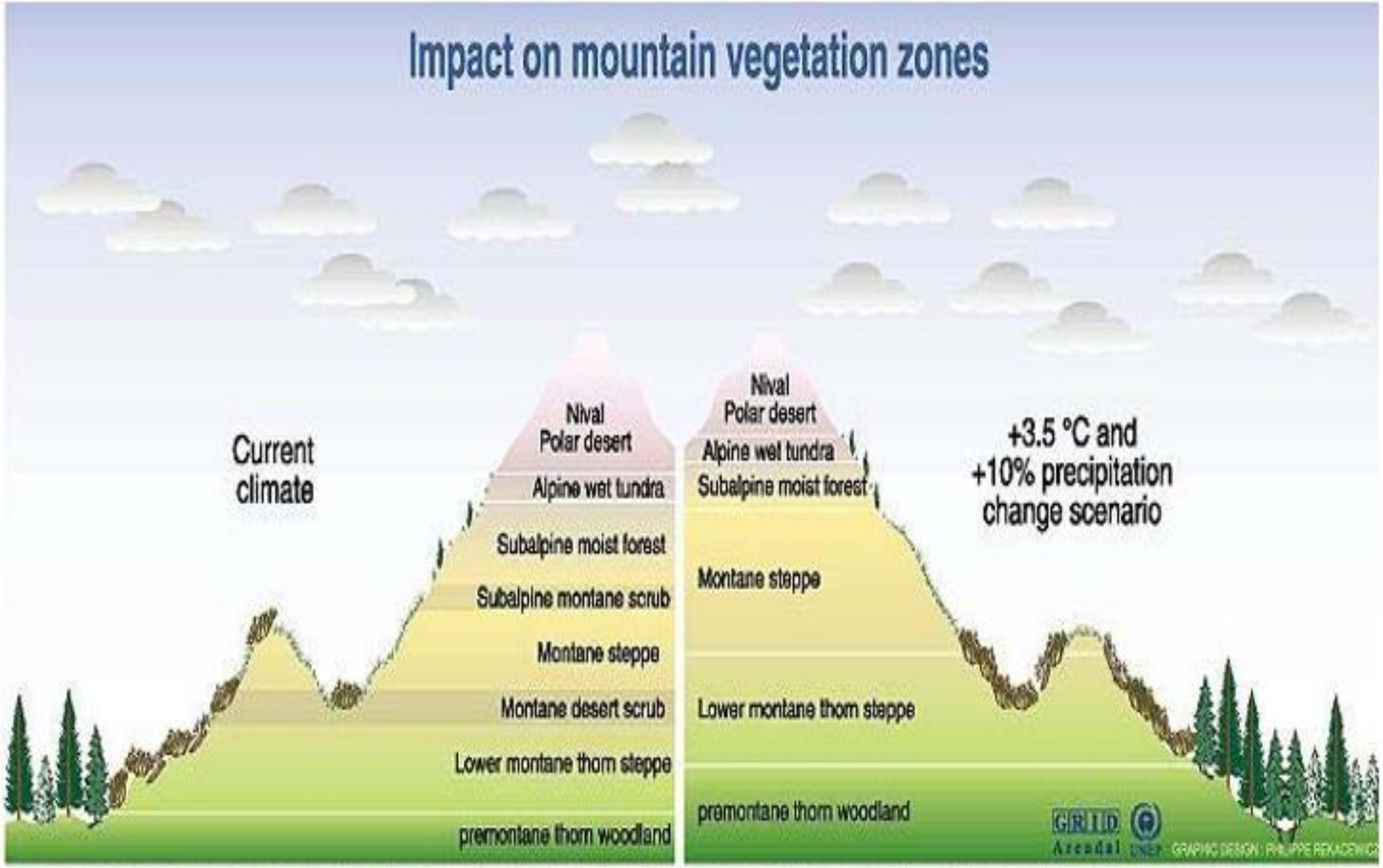
- The figure below shows a comparison of current vegetation zones at a hypothetical dry temperate mountain site with simulated vegetation zones under a climate-warming scenario.



- Species and ecosystems with limited climatic ranges could disappear.

Climate Change Mitigation

- Mitigation refers to a technological change and substitution that reduce resource inputs and emissions per unit of output.
- Although several social, economic and technological policies would produce an emission reduction, with respect to climate change,
- mitigation means implementing policies to reduce greenhouse gas emissions and enhance sinks.

- The United Nations Framework Convention on Climate Change (UNFCCC) identifies two responses to climate change:
- Mitigation of climate change by reducing greenhouse gas emissions and
- Enhancing sinks, and adaptation to the impacts of climate change.
- Most industrialized countries have committed themselves, as signatories to the UNFCCC and the Kyoto Protocol, to adopting national policies and taking corresponding measures on the mitigation of climate change and to reducing their overall greenhouse-gas emissions.

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- The international climate policy community has become aware that energy policy alone will not suffice in the quest to control climate change and limit its impacts.
- Climate policy is being expanded to consider a wide range of options aimed at sequestering carbon in vegetation, oceans and geological formations,
- at reducing the emissions of non-CO2 greenhouse gases,
- and at reducing the vulnerability of sectors and communities to the impacts of climate change by means of adaptation.

Mitigation methods (options)

- **What is a “Wedge”?**

- A “*wedge*” is a strategy to reduce carbon emissions that grows in 50 years from zero to 1.0 GTC/yr.

- The strategy has already been commercialized at scale somewhere.

- The “*stabilization wedges*” concept is a simple tool for conveying the emissions cuts that can be made to avoid dramatic climate change.

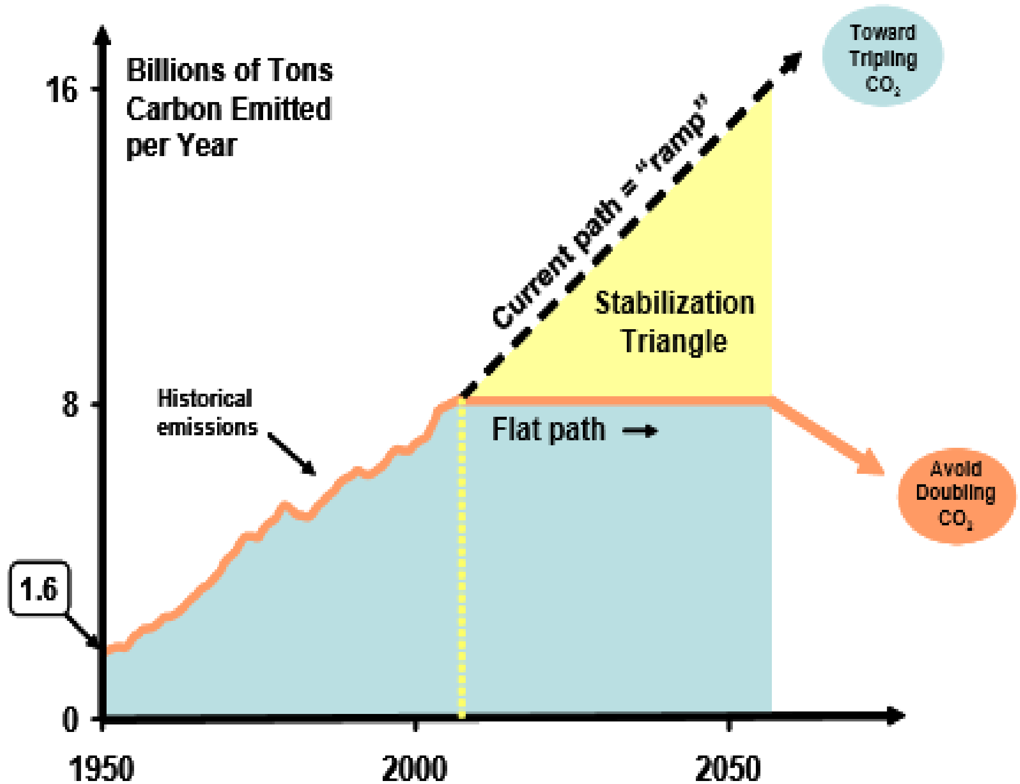


Figure 1. Two possible emissions scenarios define the "stabilization triangle."

- We consider two futures - **allowing emissions to double versus keeping emissions at current levels** for the next 50 years **(**Figure1).

- The emissions-doubling path (black dotted line) falls in the middle of the field of most estimates of future carbon emissions.
- The climb approximately extends the climb for the past 50 years, during which the world's economy grew much faster than its carbon emissions.
- Emissions could be higher or lower in 50 years, but this path is a reasonable reference scenario.

- **The emissions-doubling path is predicted to lead to significant global warming** by the end of this century.
- This warming is expected be accompanied by decreased crop yields, increased threats to human health, and more frequent extreme weather events.
- The planet could also face rising sea-level from melting of the West Antarctic Ice Sheet and Greenland glaciers and destabilization of the ocean's thermohaline circulation that helps redistribute the planet's heat and warm Western Europe.

- **In contrast, we can prevent a doubling of CO2 if we can keep emissions flat for the next 50 years**, then work to reduce emissions in the second half of the century (Figure 1, orange line).
- This path is predicted to keep atmospheric carbon under 1200 billion tons (which corresponds to about 570 parts per million (ppm)),
- allowing us to skirt the worst predicted consequences of climate change.

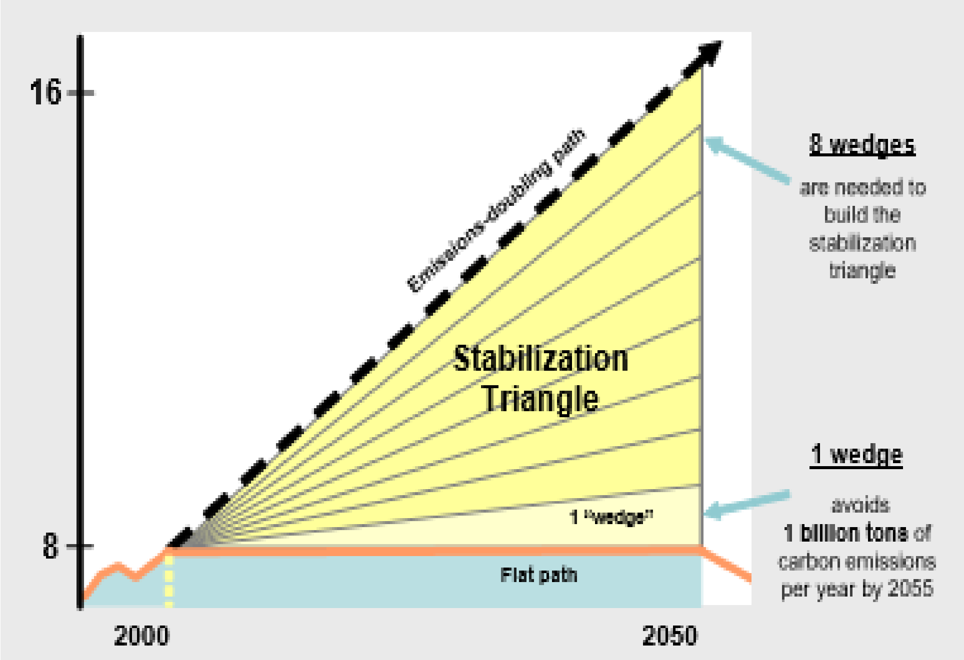
- **Keeping emissions flat will require cutting projected carbon output by about 8 billion tons per year** by 2060,
- keeping a total of ~200 billion tons of carbon from entering the atmosphere (see yellow triangle in Figure 1).
- This carbon savings is what we call the "**stabilization triangle**."

- To make the problem more tractable, we divided the stabilization triangle into **eight "wedges**."

- A wedge represents a carbon-cutting strategy that has the potential to grow from zero today to avoiding 1 billion tons of carbon emissions per year by 2060, or one-eighth of the stabilization triangle (Figure2).

- The wedges can represent ways of either making energy with no or reduced carbon emissions

- (like nuclear or wind-produced electricity), or storing carbon dioxide to prevent it from building up as rapidly in the atmosphere (either through underground storage or bio storage).



- Figure 2. The eight "wedges" of the stabilization triangle

Wedge Strategies Currently Available

- The following 15 strategies already available that could be scaled up over the next 50 years to reduce global carbon emissions by 1 billion tons per year, or one wedge.
- They are grouped into four major colored categories.

Nuclear Energy

- Nuclear electricity

Renewables and Biostorage

- Wind-generated electricity
- Solar electricity
- Wind-generated hydrogen fuel
- Biofuels
- Forest storage
- Soil storage

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Efficiency & Conservation

- Increased transport efficiency
- Reducing miles traveled
- Increased building efficiency
- Increased efficiency of electricity production

Fossil-Fuel-Based Strategies

- Fuel switching (coal to gas)
- Fossil-based electricity with carbon capture & storage (CCS)
- Coal synfuels with CCS
- Fossil-based hydrogen fuel with CCS

- Each strategy can be applied to one or more sectors, indicated by the following symbols:

= Electricity Production, =Heating and Direct Fuel Use, =Transportation, = Biostorage

Increased Efficiency & Conservation

1. Transport Efficiency

- A wedge of emissions savings would be achieved if the fuel efficiency of all the cars projected for 2060 were doubled from 30 mpg to 60 mpg.(mpg= miles per gallon).
- Efficiency improvements could come from using hybrid and diesel engine technologies,
- as well as making vehicles out of strong but lighter materials.

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2. Transport Conservation

- A wedge would be achieved if the number of miles traveled by the world’s cars were cut in half.
- Such a reduction in driving could be achieved
- if urban planning leads to more use of mass transit
- and if electronic communication becomes a good substitute for face-to-face meetings.

3. Building Efficiency

- Today carbon emissions arise about equally from providing electricity, transportation, and heat for industry and buildings.
- Cutting emissions by 25% in all new and existing residential and commercial buildings would achieve a wedge worth of emissions reduction.

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4. Efficiency in Electricity Production

- Today's coal-burning power plants produce about one-fourth of the world's carbon emissions,
- so increases in efficiency at these plants offer an important opportunity to reduce emissions.
- Producing the world's current coal-based electricity with doubled efficiency would save a wedge worth of carbon emissions.

Carbon Capture & Storage (CCS)

- If the CO2 emissions from fossil fuels can be captured and stored, rather than vented to the atmosphere, then the world could continue to use coal, oil, and natural gas to meet energy demands without harmful climate consequences.
- The most economical way to pursue this is to capture CO2 at large electricity or fuels plants, and then stores it underground.
- This strategy, called carbon capture and storage

5. **CCS Electricity**

- A wedge would be achieved by applying CCS to 800 large (1 billion watt) baseload coal power plants or 1600 large baseload natural gas power plants in 50 years.
- As with all CCS strategies, to provide low-carbon energy the captured CO2 would need to be stored for centuries.

6. CCS Hydrogen

- Hydrogen is a desirable fuel for a low-carbon society because when it's burned the only emission product is water vapor.
- Because fossil fuels are composed mainly of carbon and hydrogen they are potential sources of hydrogen,
- but to have a climate benefit the excess carbon must be captured and stored.

7. CCS Synfuels

- When coal is heated and combined with steam and air or oxygen, carbon monoxide and hydrogen are released and can be processed to make a liquid fuel called a “synfuel.”
- A wedge is an activity that, over 50 years, can capture the CO2 emissions from 180 such coal-to synfuels facilities.

Fuel Switching

8. Fuel-Switching for Electricity

- Because of the lower carbon content of natural gas and higher efficiencies of natural gas plants, producing electricity with natural gas results in only about half the emissions of coal.
- A wedge would require 1400 large (1 billion watt) natural gas plants displacing similar coal-electric plants.

Nuclear Energy

9.Nuclear Electricity

- Nuclear fission currently provides about 17% of the world's electricity, and produces no CO2.
- Adding new nuclear electric plants to triple the world's current nuclear capacity would cut emissions by one wedge if coal plants were displaced.

Renewable Energy & Biostorage

10. Wind Electricity

- In the past wind produces less than 1% of total global electricity, but wind electricity is growing at a rate of about 30% per year.
- To gain a wedge of emissions savings from wind displacing coal-based electricity,
- current wind capacity would need to be scaled up by a factor of 10.

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"On Sunday, for a brief, shining moment, renewable power output in Germany reached 90 percent of the country's total electricity demand."

The 4th Largest Economy In The World Just Generated 90 Percent Of The Power It Needs From Renewables

The total output of German solar, wind, hydropower, and biomass reached 55 gigawatts this weekend.

11.Solar Electricity

- Photovoltaic (PV) cells convert sunlight to electricity, providing a source of CO_2-free and renewable energy.
- The land demand for solar is less than with other renewables, but installing a wedge worth of PV would still require arrays with an area of two million hectares, or 20,000 km^2.
- The arrays could be located on either dedicated land or on multiple-use surfaces such as the roofs and walls of buildings.

12. Wind Hydrogen

- Hydrogen is a desirable fuel for a low-carbon society because when it’s burned the only emission product is water vapor.
- To produce hydrogen with wind energy, electricity generated by wind turbines is used in electrolysis, a process that liberates hydrogen from water.
- Wind hydrogen displacing vehicle fuel is only about half as efficient at reducing carbon emissions as wind electricity displacing coal electricity

Renewables & Biostorage (cont'd)

13. **Biofuels**

- Because plants take up carbon dioxide from the atmosphere, combustion of biofuels made from plants like corn and sugar cane simply returns "borrowed" carbon to the atmosphere.
- Thus burning biofuels for transportation and heating will not raise the atmosphere's net CO2 concentration.
- **One wedge of** biofuels savings would require increasing today's global ethanol production by about 12 times, and making it sustainable.

14. Forest Storage

- Land plants and soils contain large amounts of carbon.
- Today, there is a net removal of carbon from the atmosphere by these “natural sinks," in spite of deliberate deforestation by people that adds between 1 and 2 billion tons of carbon to the atmosphere.
- Evidently, the carbon in forests is increasing elsewhere on the planet.
- Halting global deforestation in 50 years would provide one wedge of emissions savings.

15. Soil Storage

- Conversion of natural vegetation to cropland reduces soil carbon content by one-half to one-third.
- A wedge of emissions savings could be achieved by applying carbon management strategies to all of the world’s existing agricultural soils.

Technical measures for methane emissions

1. Extended recovery of **coal mine** gas
2. Extended recovery and flaring (instead of venting) of associated gas from production of **crude oil and natural gas**
3. Reduced **gas leakage** at compressor stations in long-distance gas transmission pipelines.
4. Separation and treatment of biodegradable **municipal waste** through recycling, composting and anaerobic digestion.

5. Upgrading primary **wastewater treatment** to secondary/tertiary treatment with gas recovery and overflow control.

6. Control of methane emissions from **livestock**, mainly through farm-scale **anaerobic digestion** of manure from cattle and pigs with liquid manure management.

7. Intermittent aeration of continuously flooded **rice paddies.**

Technical measures for black carbon

1. Replacing **traditional coke ovens** with modern recovery ovens, including the improvement of end-of-pipe abatement measures (in developing countries).
2. Replacing **traditional brick kilns** with vertical shaft kilns and Hoffman kilns where considered feasible (in developing countries).
3. **Diesel particle filters** for road vehicles and off-road mobile sources (excluding shipping).
4. Particle control at **stationary engines**
5. **Improved stoves** in developing countries in residential sector.

ADAPTATION TO CLIMATE CHANGE: INTERNATIONAL POLICY OPTIONS

- From its inception, the international climate effort has focused predominantly on mitigation—reducing greenhouse gas (GHG) emissions to prevent dangerous climate change.
- The next stage of the international effort must deal squarely with adaptation—coping with those impacts that cannot be avoided.

I. Adaptation: An Evolving Challenge

- Adaptation to climate is not a new phenomenon.
- Indeed, throughout human history, societies have adapted to natural climate variability by altering settlement and agricultural patterns and other facets of their economies and lifestyles.
- Human-induced climate change lends a complex new dimension to this age-old challenge.

Vulnerability of Key Sectors

- The impacts of global climate change will be felt across economies and societies
- **Human Health:** Infectious diseases may become more prevalent as their reach increases and seasonality expands;
- the frequency and intensity of heat waves and natural hazards such as droughts, floods, and cyclones may increase, causing adverse health effects; and levels of air pollution may increase.

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- **Agriculture:** The production of food crops is the most climate-dependent economic activity.
- Changes in climate can be expected to have significant impacts upon crop yields through changes in both temperature and moisture.
- As climate patterns shift, changes in the distribution of plant diseases and pests may also have adverse effects on agriculture.

- **Water Resources:** Climate change is expected to have significant impacts on water supplies— creating or exacerbating chronic shortages—and on water quality.
- There is already widespread acceleration of glacial retreat and in many areas stream flow is shifting from spring to winter peaks.
- **Coastal Resources**: One of the most certain effects of a warmer climate is sea-level rise.

- **Ecosystems and Biodiversity:**
- Changes in natural ecosystems are among the first observable impacts of climate change.
- Changes in plant flowering dates and bird migrations and distributions have already been widely recorded.

II. Adaptation Policy: Needs and Issues

- To be most effective, adaptation must proceed at several levels simultaneously.
- Adaptation is in fundamental ways inherently "local"—the direct impacts of climate change are felt locally, and response measures must be tailored to local circumstances.
- However, for these efforts to be robust—or, in many cases, even possible—they must be guided and supported by national *policies* and *strategies*.

- Collectively, these efforts must meet a wide range of interrelated needs.

- Briefly, these include:

- **Information**—Effective strategies must rest on the best available data on the nature and
- severity of likely impacts over different time frames in given locales, and
- on the cost and efficacy of possible response measures.

- **Capacity**—an overriding priority is strengthening capacities in the technical and planning disciplines most relevant to understanding potential climate impacts and devising response strategies.
- **Financial Resources**—poorer countries will require resources to improve capacity, undertake specific adaptation measures, and cope with impacts as they occur.

- **Institutions**—while adaptation must be integrated across existing institutions, focal points are needed at the national and international levels.
- **Technology**—as in climate mitigation, adaptation success depends in part on access to—and, in some areas, development of—technologies suited to the specific needs and circumstances of different countries.

- **In considering how best to address these needs**,
- the international community faces a host of difficult issues stemming from the underlying characteristics of climate risk.
- **These issues include:**
- The appropriate balance between "reactive" and "proactive" approaches;

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- The proper coupling of specific adaptations and stronger adaptive capacity;
- The difficulty of distinguishing climate change impacts from those due to natural climate variability; and
- Adaptation’s intersection with a broad range of other policy areas and priorities.

Reactive and Proactive Adaptation

❖ Adaptation can be said to be "reactive" or "proactive" in two different senses.

- One distinction turns on the stimulus for adaptation whether an action is in response to observed climate impacts, or in anticipation of future climate change.
- In this sense, adaptation historically has been largely if not entirely reactive.
- Human-induced climate change presents societies for the first time with the challenge of adapting to climatic changes forecast but not yet experienced.

III. International Adaptation Efforts to Date

- In principle, adaptation was established as a priority at the very start of the international climate effort.

- In the UNFCCC, all parties committed generally to undertake national adaptation measures and to cooperate in preparing for the impacts of climate change.

- The Convention also calls for full consideration of the specific needs and concerns of developing countries
- —especially the least developed—arising from the adverse effects of climate change.
- More concretely, developed countries committed to help "particularly vulnerable" countries meet the costs of adaptation.

IV. Options Going Forward

- As is true on the mitigation side of the climate equation, an effective adaptation response requires a wide array of measures and strategies.

- Three broad approaches are described here:

- **Adaptation under the UNFCCC**—strengthening mechanisms and support for *proactive adaptation* under the Convention by facilitating comprehensive national strategies and committing reliable funding for high-priority implementation projects.

- **Integration with development**—Factoring adaptation into development assistance through measures such as mandatory climate risk assessments for projects financed by multilateral and bilateral lenders.
- **Climate “insurance**”—Committing funds to support climate relief or insurance-type approaches in vulnerable countries for losses resulting from both climate change and climate variability.

- The two previous approaches are largely proactive; they aim to reduce climate risk.
- As such measures, even if robust, are unlikely to be fully effective, reactive approaches are also needed to help vulnerable countries cope with the risks that remain.
- Climate “insurance”—identified in both the Framework Convention and the Kyoto Protocol as one means of adaptation—could take many forms.

- **Two possibilities are described here:**

- **International response fund**—Donor countries would commit to regular contributions to a multilateral fund to assist countries suffering extreme and/or long-term climate impacts.
- **Insurance "backstop**"—Donor countries support the introduction or expansion of insurance-type instruments in vulnerable countries by
- committing funds to subsidize premiums or to reinsure governments or primary insurers.

Insurance-Type Instruments

- The insurance industry and developing country governments are exploring or testing a number of insurance-type approaches to cover climate-related risks. Examples include:
- **Pooling Cash Reserves.** As a form of collective self-insurance,
- the Eastern Caribbean Central Bank is accumulating cash reserves through mandatory contributions by member governments, which can then draw loans if struck by natural disasters.

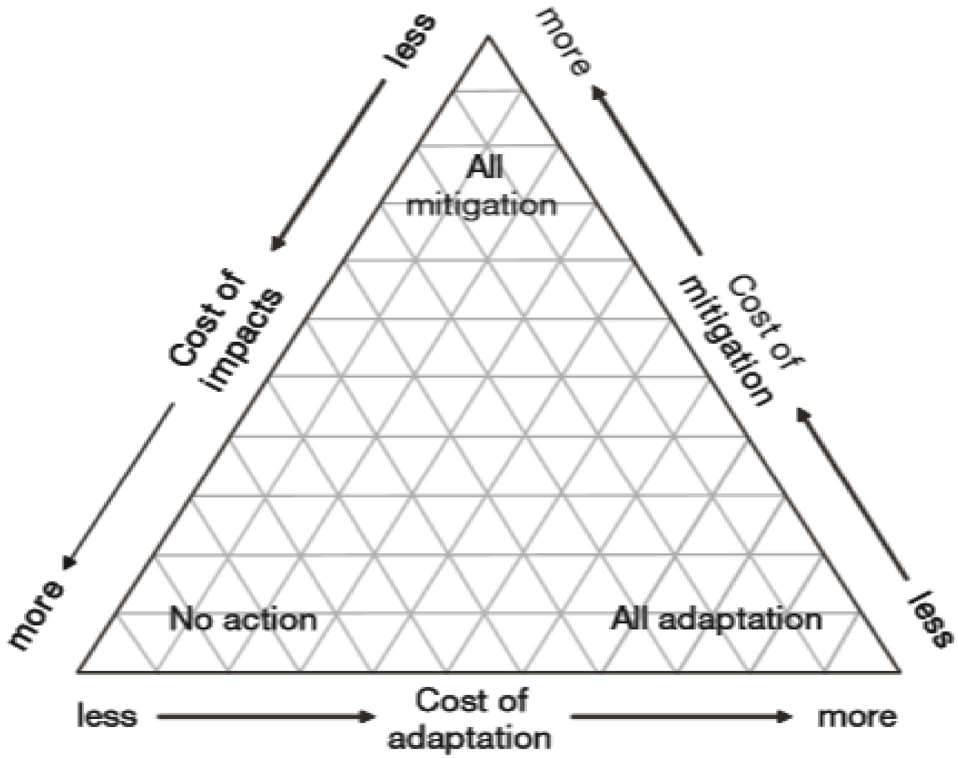
- **Indemnifying Debts.** The Commonwealth and Smaller States Disaster Management Scheme provide insurance to risk-prone governments,
- **Indexed Insurance for Agriculture.** These contracts, also known as weather derivatives, provide payments to farmers under predetermined conditions (such as number of days with temperatures above a set threshold) without requiring proof of loss.
- The World Bank is studying their feasibility in Ethiopia, Morocco, Nicaragua, and Tunisia.

Differences, similarities and complementarities b/n adaptation and mitigation.

- The IPCC TAR used the following definitions of climate change mitigation and adaptation.
- **Mitigation**: An anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases.
- **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.

- It follows from these definitions that mitigation reduces all impacts (positive and negative) of climate change and thus reduces the adaptation challenge,
- whereas adaptation is selective; it can take advantage of positive impacts and reduce negative ones.
- The two options are implemented on the same local or regional scale, and may be motivated by local and regional priorities and interests, as well as global concerns.

- Mitigation has global benefits (ancillary benefits might be realized at the local/regional level),
- although effective mitigation needs to involve a sufficient number of major greenhouse-gas emitters to foreclose leakage.
- Adaptation typically works on the scale of an impacted system, which is regional at best,
- but mostly local (although some adaptation might result in spill-overs across national boundaries,



- Figure3 . A schematic overview of inter-relationships between adaptation, mitigation and impacts.

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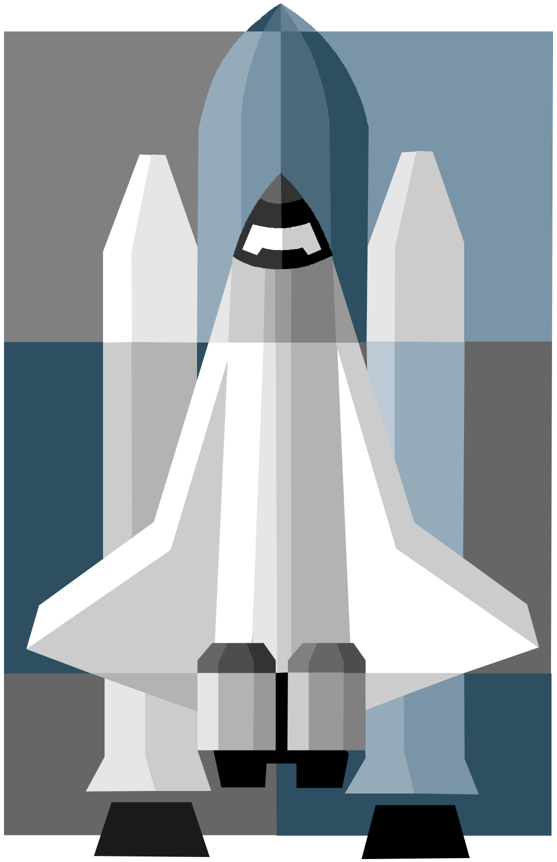

Thank You for attention !!!

Have a nice exam & time !!!!