Climate Variability and Climate Change Impact on Agriculture and Water Resources in Jordan

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Climate versus weather

- Climate: A statistical description of the mean and variability of temperature, precipitation, wind, etc. over a period of time ranging from months to thousands or millions of years.

- Weather: The present condition of the above elements, typically over periods up to two weeks.

- Climate change: A change in the state of the mean and/or variability of these elements that can be identified statistically and that persists over a longer period, typically decades or longer.

CLIMATE CHANGE DEFINITION

UNFCCC Article 1

A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.

IPCC TAR, 2001 b

A statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). Climate change may be due to natural processes or external forcing, or to persistent anthropogenic changes in the composition of the atmosphere or in land-use.

IPCC TAR, 2001 a

Any change in climate over time, whether due to natural variability or as a result of human activity.

UN/ISDR, 2004

The climate of a place or region is changed if over an extended period (typically decades or longer) there is a statistically significant change in measurements of either the mean state or variability of the climate for that place or region. (Changes in climate may be due to natural processes or to persistent anthropogenic changes in atmosphere or in land use. Note that the definition of climate change used in the United Nations Framework Convention on Climate Change is more restricted, as it includes only those changes which are attributable directly or indirectly to human activity.)

IPCC :

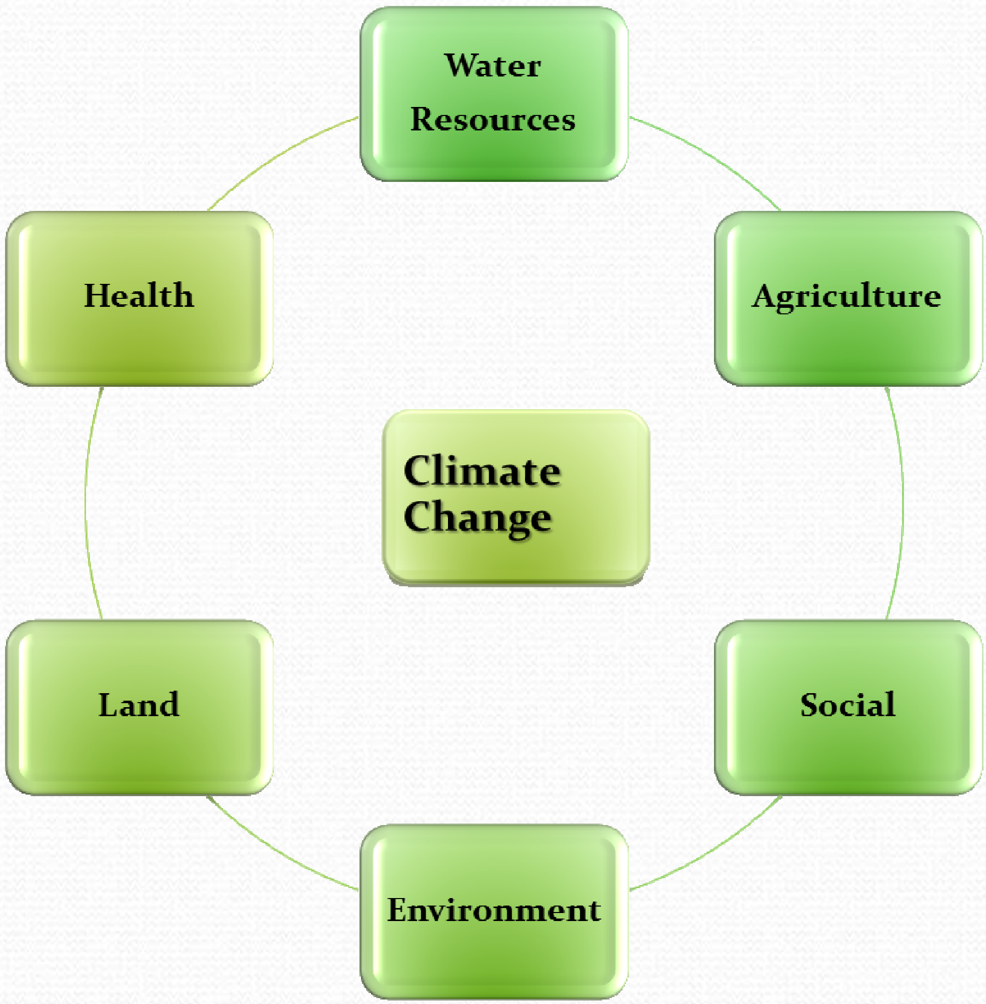
Intergovernmental Panel on Climate Change Created by World Meteorological Organisation (WMO) & United Nations Environment Programme (UNEP) in 1988.

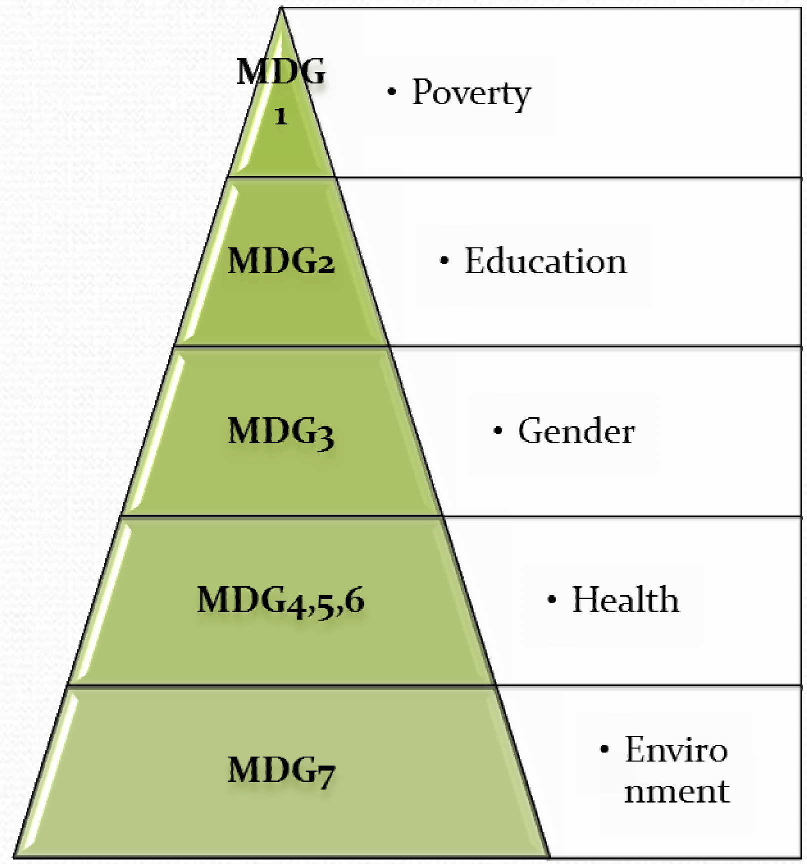
Mandate : assess the science of climate change, impacts and adaptation, mitigation options

Publishes consensus reports (1990, 1996, 2001, 2007, AR5 2014)

Website= http://www.ipcc.ch

CLIMATE CHANGE IMPACTS





What climate change means

Climate consists of averages & extremes of

- hot & cold
- wet & dry
- snowpack & snowmelt
- winds & storm tracks
- ocean currents & upwellings
- and the patterns of these in space and time.

The stakes in climate change

Climate governs, so climate change alters the following:

- productivity of farms, forests, & fisheries
- prevalence of oppressive heat &humidity
- geography of disease
- damages from storms, floods, droughts, wildfires
- property losses from sea-level rise
- expenditures on engineered environments
- distribution & abundance of species

Climate Change in Jordan……

Jordan is a vulnerable country in terms of climate change impact. In the latest assessment report published by the Inter-governmental Panel on Climate Change (IPCC ,2007), Jordan will suffer from reduced agricultural productivity due to more erratic rainfall patterns, reduced freshwater resources and increased temperatures.

The Initial National Communication (INC) to the United Nations Framework Convention to Climate Change (UNFCCC) foresees that over the next three decades, Jordan will witness a rise in temperature, drop in rainfall, reduced ground cover, reduced water availability, heat-waves, and more frequent dust storms.

Several studies have investigated climate change and climate variability in Jordan.

(Freiwan and Kadioglu, 2008) have studied the temporal and spatial analysis of precipitation in Jordan.

(Bani Domi, 2005; Freiwan and Kadioglu, 2008) have investigated the trends of the precipitation, temperature and other climatic variables in Jordan.

These studies show that the temperature time series exhibit increasing trends while the precipitation time series reveal decreasing trends in the majority of the meteorological stations in the country.

Table I. Station information and length of temperature and rainfall records (Years).

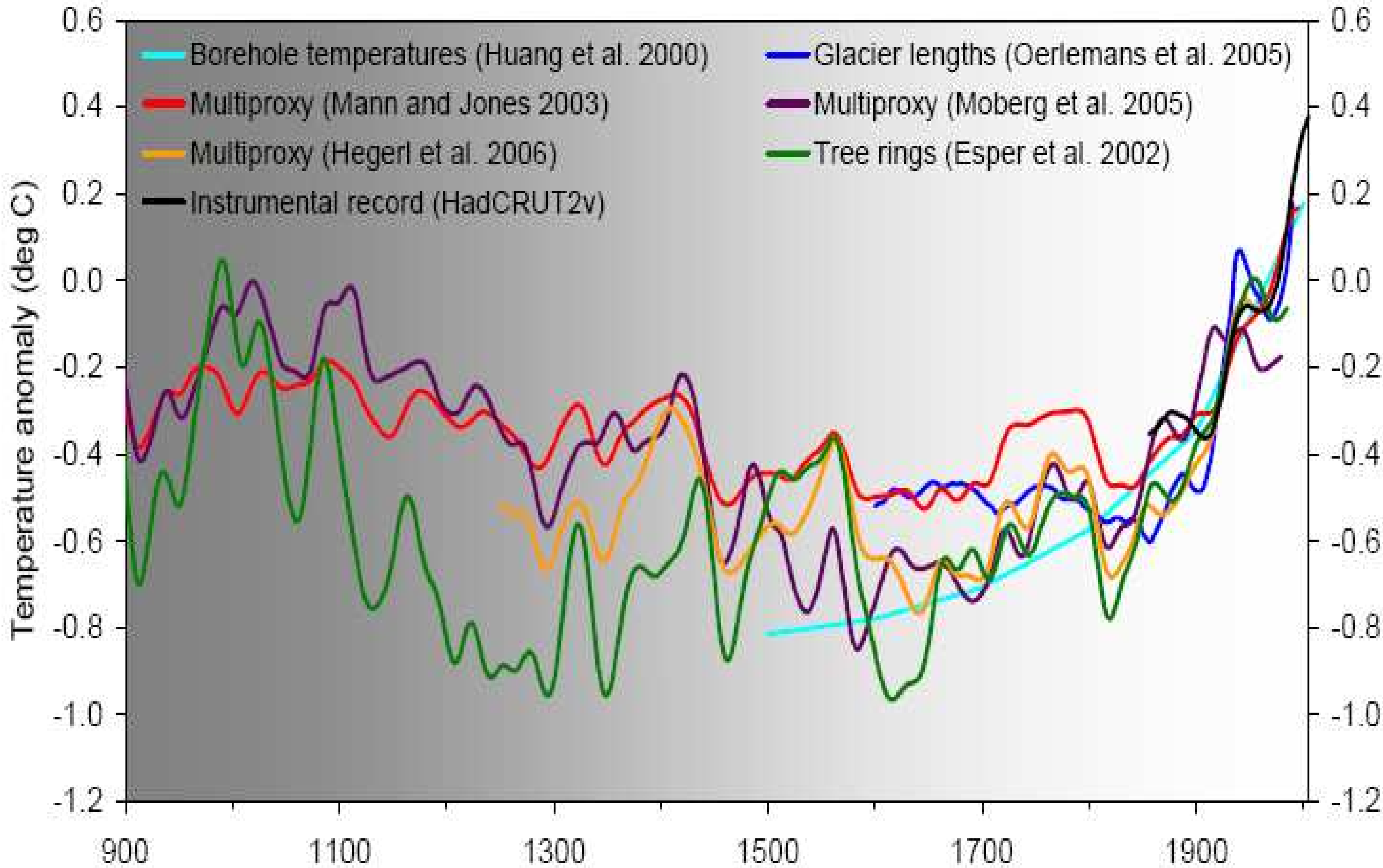
Station name	WMO No.	Lat.	Long.	Elev.	Rainfall	Temperature
Amman airport	40 270	31.98	35.98	780	1923-2000 (78)	1923–2000 (78)
Aqaba airport	40 340	29.55	35.00	51	1946–2000 (55)	1959–2000 (42)
Baqura	40 253	32.63	35.62	−170	1968–2000 (33)	1968–2000 (33)
Deir Alla	40 285	32.22	35.62	−224	1953–2000 (48)	1953–2000 (48)
Irbed	40 255	32.55	35.85	616	1938–2000 (63)	1955–2000 (46)
Ma'an	40 310	30.17	35.78	1069	1938–2000 (63)	1960–2000 (41)
Mafraq	40 265	32.37	36.25	686	1942–2000 (59)	1960–2000 (41)
QAIA	40 272	31.72	35.98	722	1952–2000 (49)	1971–2000 (30)
Rabba	40 292	31.27	35.75	920	1952–2000 (49)	1967–2000 (34)
Safawi (H5)	40 260	32.20	37.13	672	1943–2000 (58)	1964–2000 (37)
Shoubak	40 300	30.52	35.53	1365	1938–2000 (63)	1965–2000 (36)
Wadi Duleil	40 267	32.15	36.28	580	1968–2000 (63)	1968–2000 (33)
Ruwaished(H4)	40 250	32.50	38.20	683	1943–2000 (58)	1961–2000 (40)
Al Jafr	40 305	30.28	36.15	865	1948–2000 (53)	1965–2000 (36)

Highlights of possible climate impacts

Temp rise (°C)	Water	Food	Health	Land	Environment	Abrupt and Large-Scale Impacts
1°C	Small glaciers in the Andes disappear completely, threatening water supplies for 50 million people	Modest increases in cereal yields in temperate regions	At least 300,000 people each year die from limate related diseases (predominantly diarrhoea, malaria, and malnutrition) Reduction in winter mortality in higher latitudes (Northern Europe, USA)	Permafrost thawing damages buildings and roads in parts of Canada and Russia	At least 10% of land species facing extinction (according to one estimate) 80% bleaching of coral reefs, including Great Barrier Reef	Atlantic Thermohaline Circulation starts to weaken
2°C	Potentially 20 - 30% decrease in water availability in some vulnerable regions, e.g. Southern Africa and Mediterranean	Sharp declines in crop yield in tropical regions (5 - 10% in Africa)	40 – 60 million more people exposed to malaria in Africa	Up to 10 million more people affected by coastal flooding each year	15 – 40% of species facing extinction (according to one estimate) High risk of extinction of Arctic species, including polar bear and caribou	Potential for Greenland ice sheet to begin melting irreversibly, accelerating sea level rise and committing world to an eventual 7 m sea level rise Rising risk of abrupt changes to atmospheric circulations, e.g. the monsoon Rising risk of collapse of West Antarctic Ice Sheet Rising risk of collapse of Atlantic Thermohaline Circulation
3°C	In Southern Europe, serious droughts occur once every 10 years 1 - 4 billion more people suffer water shortages, while 1 – 5 billion gain water, which may increase flood risk	150 - 550 additional millions at risk of hunger (if carbon fertilization weak) Agricultural yields in higher latitudes likely to peak	1 – 3 million more people die from malnutrition (if carbon fertilization weak)	1 – 170 million more people affected by coastal flooding each year	20 – 50% of species facing extinction (according to one estimate), including 25 – 60% mammals, 30 – 40% birds and 15 – 70% butterflies in South Africa Collapse of Amazon rainforest (according to some models) only	
4°C	Potentially 30 – 50% decrease in water availability in Southern Africa and Mediterranean	Agricultural yields decline by 15 – 35% in Africa, and entire regions out of production (e.g. parts of Australia)	Up to 80 million more people exposed to malaria in Africa	7 – 300 million more people affected by coastal flooding each year	Loss of around half Arctic tundra Around half of all the world's nature reserves cannot fulfill objectives	
5°C	Possible disappearance of large glaciers in Himalayas, affecting one-quarter of China's population and hundreds of millions in India	Continued increase in ocean acidity seriously disrupting marine ecosystems and possibly fish stocks		Sea level rise threatens small islands, low-lying coastal areas (Florida) and major world cities such as New York, London, and Tokyo		
More than 5°C	The latest science suggests that the Earth's average temperature will rise by even more than 5 or 6°C if emissions continue to grow and positive feedbacks amplify the warming effect of greenhouse gases (e.g. release of carbon dioxide from soils or methane from permafrost). This level of global temperature rise would be equivalent to the amount of warming that occurred between the last age and today – and is likely to lead to major disruption and large-scale movement of population. Such "socially contingent" effects could be catastrophic, but are currently very hard to capture with current models as temperatures would be so far outside human experience.					

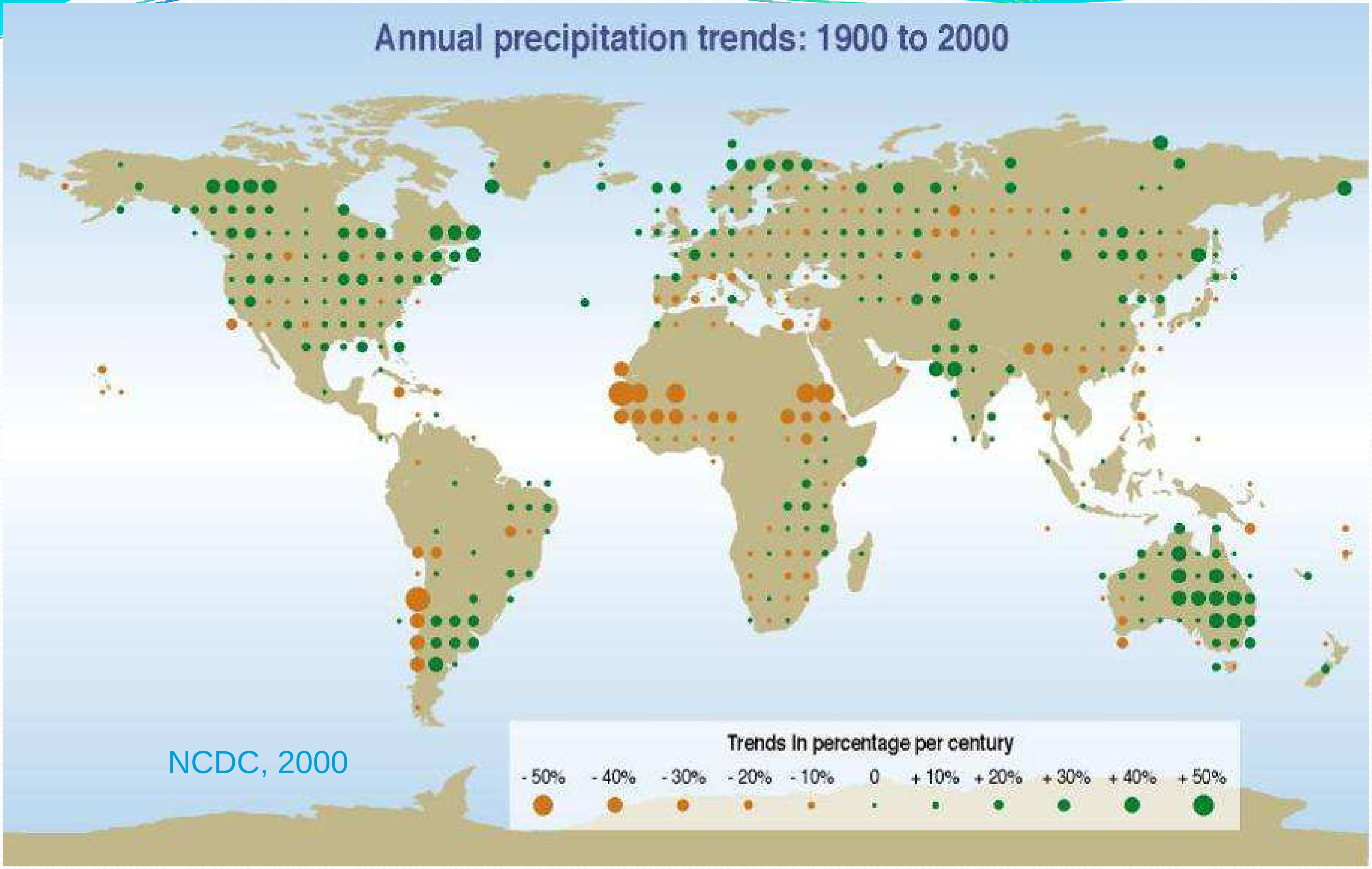
Is current climate change unusual?

1000 years of “proxy” surface temperatures



National Research Council, 2006

Evaporation & precipitation are increasing

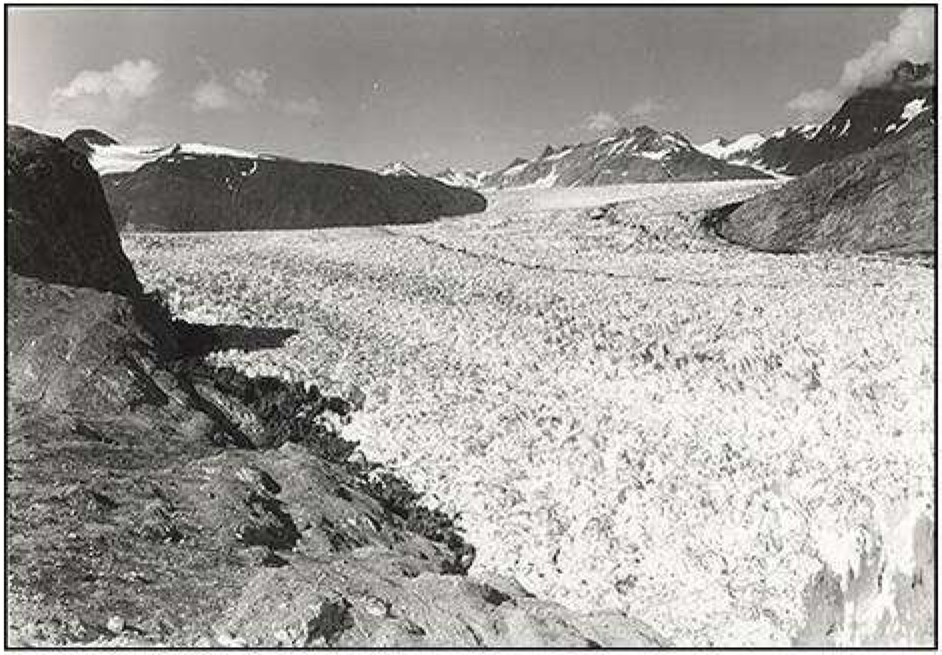


NCDC, 2000

Effect is not uniform; most places getting wetter, some getting drier.

Muir Glacier, Alaska, 1941-2004

August 1941



August 2004

NSIDC/WDC for Glaciology, Boulder, compiler. 2002, updated 2006. *Online glacier photograph database.* Boulder, CO: National Snow and Ice Data Center.

Sea ice is shrinking

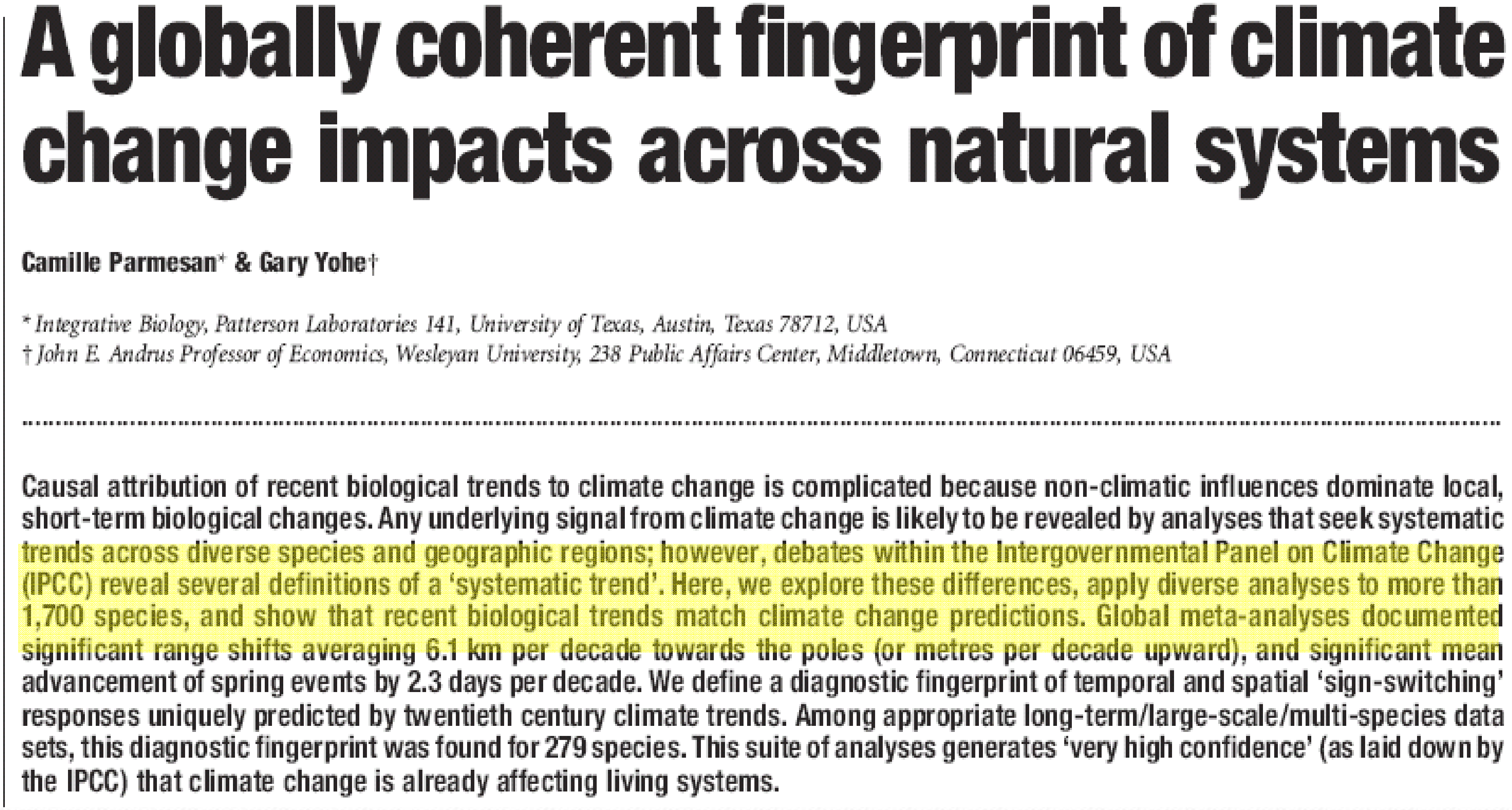
1979

2003

Extent of Arctic summer ice in 1979 and in 2003.

Species are moving

articles


A globally coherent fingerprint of climate change impacts across natural systems

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Causal attribution of recent biological trends to climate change is complicated because non-climatic influences dominate local, short-term biological changes. Any underlying signal from climate change is likely to be revealed by analyses that seek systematic trends across diverse species and geographic regions; however, debates within the Intergovernmental Panel on Climate Change (IPCC) reveal several definitions of a 'systematic trend'. Here, we explore these differences, apply diverse analyses to more than 1,700 species, and show that recent biological trends match climate change predictions. Global meta-analyses documented significant range shifts averaging 6.1 km per decade towards the poles (or metres per decade upward), and significant mean advancement of spring events by 2.3 days per decade. We define a diagnostic fingerprint of temporal and spatial 'sign-switching' responses uniquely predicted by twentieth century climate trends. Among appropriate long-term/large-scale/multi-species data sets, this diagnostic fingerprint was found for 279 species. This suite of analyses generates 'very high confidence' (as laid down by the IPCC) that climate change is already affecting living systems.

Serious impacts are <u>already</u> occurring

- Frequency of major floods, droughts, heat waves, & wildfires is up all over the world…as predicted by theory & models.

- Heat stress from ocean warming is impacting coral reefs worldwide, exacerbated by increasing acidity from CO_2 uptake.

- Most tropical forests are drying out & burning.

- World Health Organization estimates direct health impacts of climate change already amount to ≥150,000 premature deaths/yr.

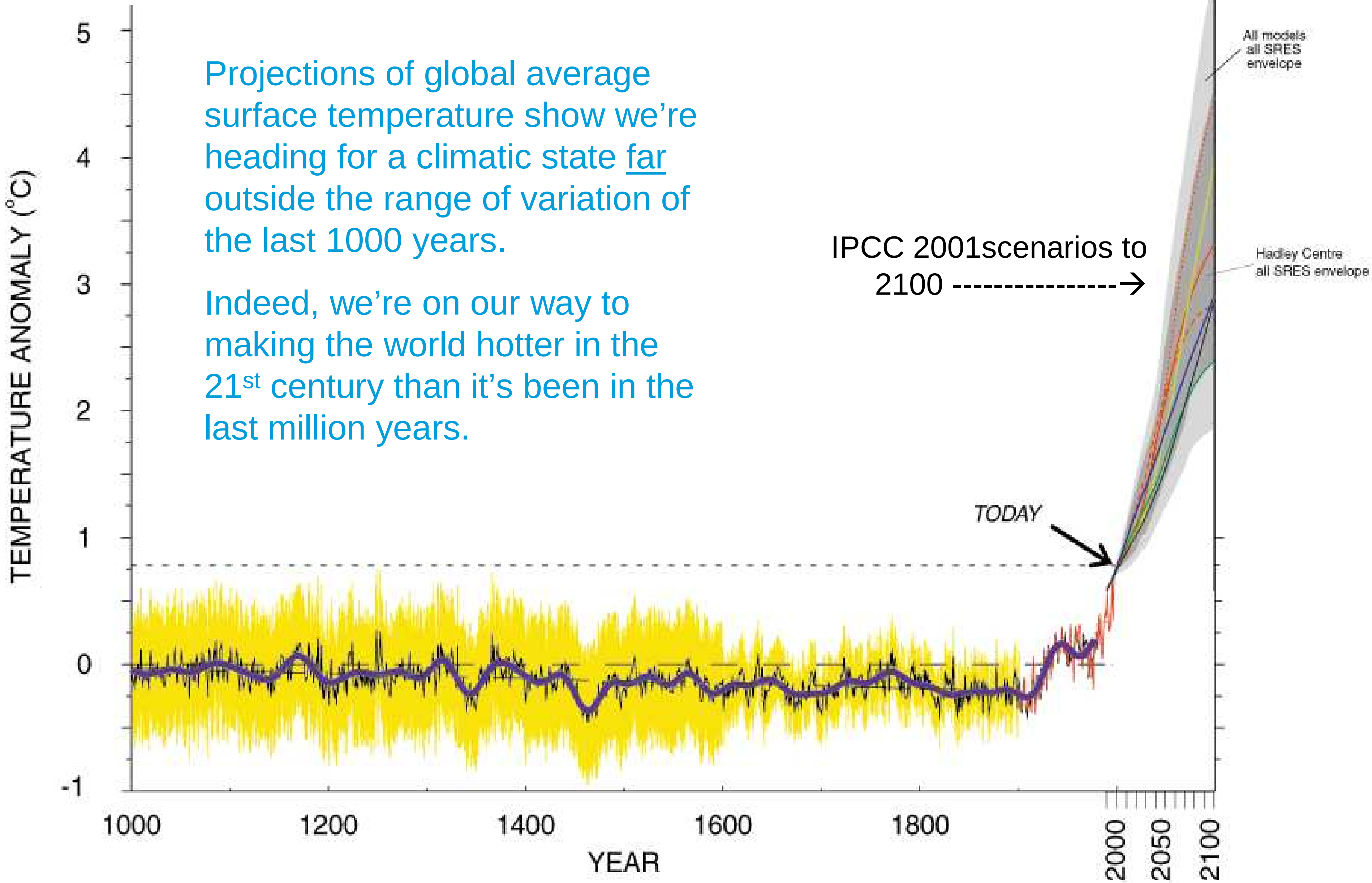
Where are we headed?

The next 100 years compared to the last 1000

Projections of global average surface temperature show we're heading for a climatic state far outside the range of variation of the last 1000 years.

Indeed, we're on our way to making the world hotter in the 21st century than it's been in the last million years.

IPCC 2001scenarios to 2100 ---------------→



Impacts of BAU climate change

Consequences expected with <u>high likelihood</u> include…

- reduced agricultural productivity in many regions at $\Delta T_{avg} \approx$ 2-3°C; nearly everywhere at $\Delta T_{avg} >$ 3°C;
- increasing devastation from droughts, heat waves, wildfires, powerful storms, and floods;
- accelerating loss of biodiversity from its two greatest reservoirs: tropical forests and coral reefs
- expanded geographic ranges of malaria, cholera, fevers, and other diseases whose vectors or pathogens are temperature- or moisture-dependent;

Crop yields in tropics start dropping at $\Delta T \geq 1\text{-}1.5℃$

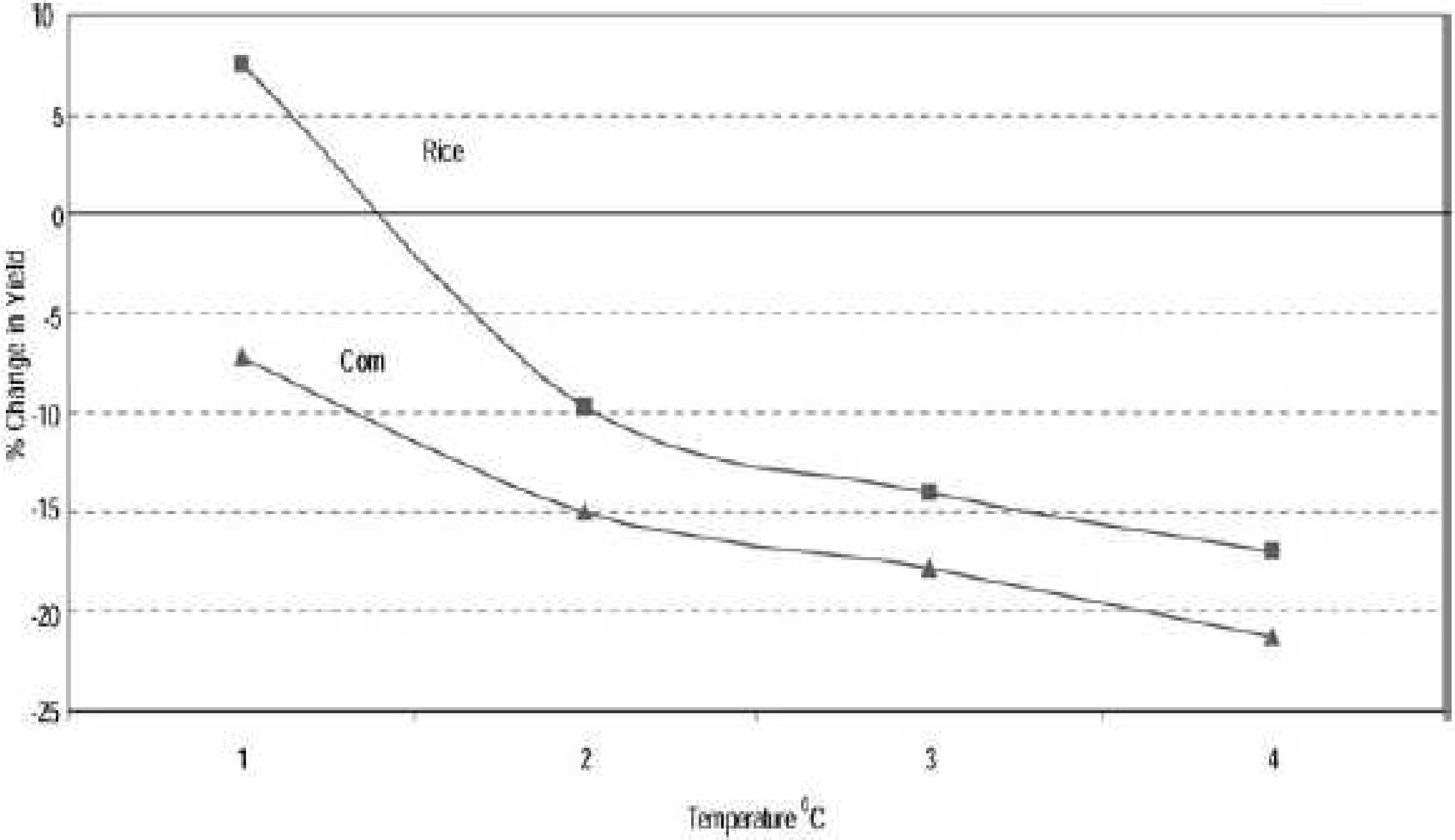
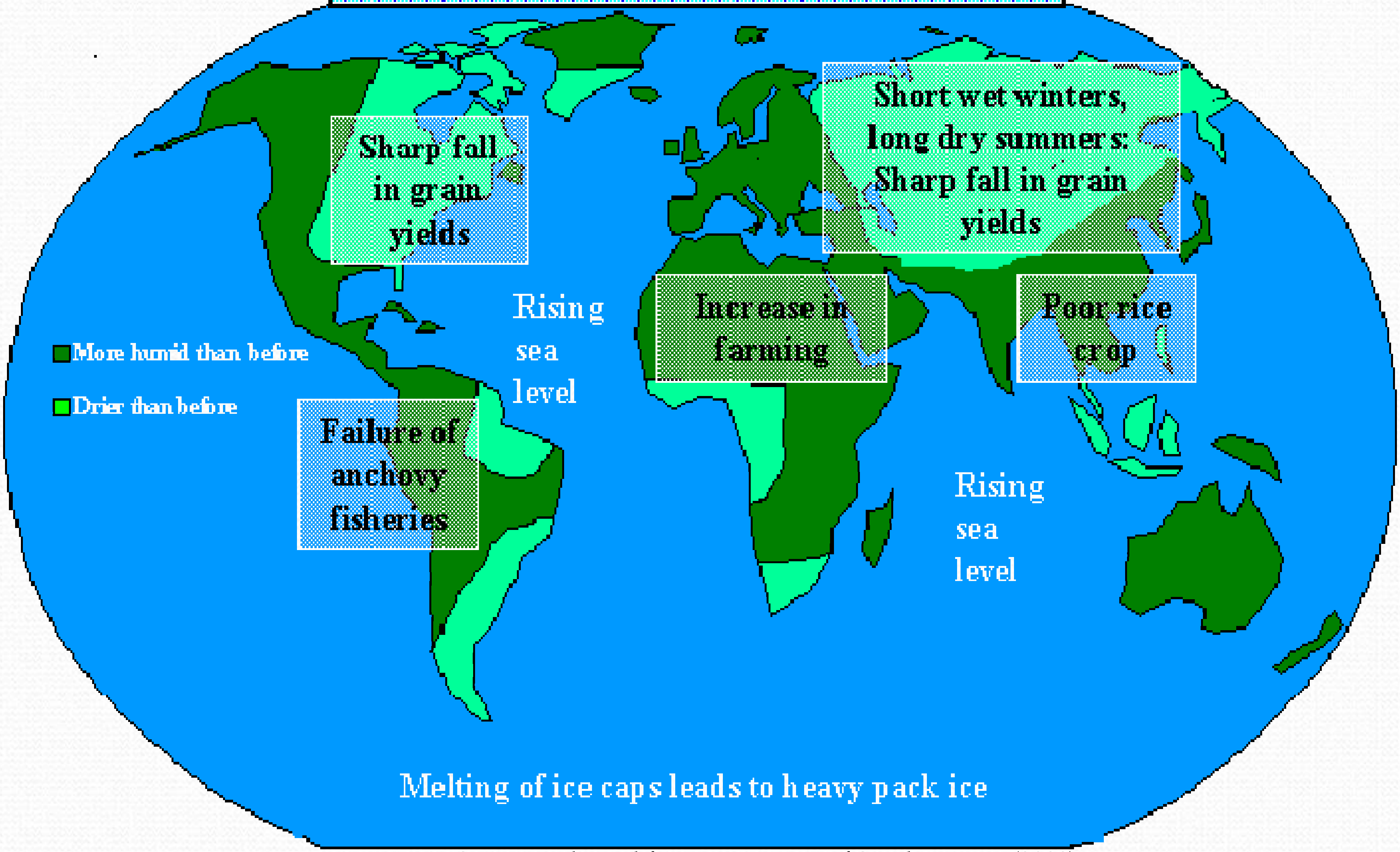


Figure 1. Corn and Rice yields versus temperature increase in the tropics averaged across 13 crop modeling studies. All studies assumed a positive change in precipitation. CO_2 direct effects were included in all studies.

Easterling and Apps, 2005

Consequences of 1°C rise in worlds temperature



Source: Adapted from University of Southampton (2000)

What's Very Likely?

- The Intergovernmental Panel on Climate Change (IPCC) has stated "Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations" (IPCC, 2007).

- In short, a growing number of scientific analyses indicate, but cannot prove, that rising levels of greenhouse gases in the atmosphere are contributing to climate change (as theory predicts).

- In the coming decades, scientists anticipate that as atmospheric concentrations of greenhouse gases continue to rise, average global temperatures and sea levels will continue to rise as a result and precipitation patterns will change.

What's Not Certain?

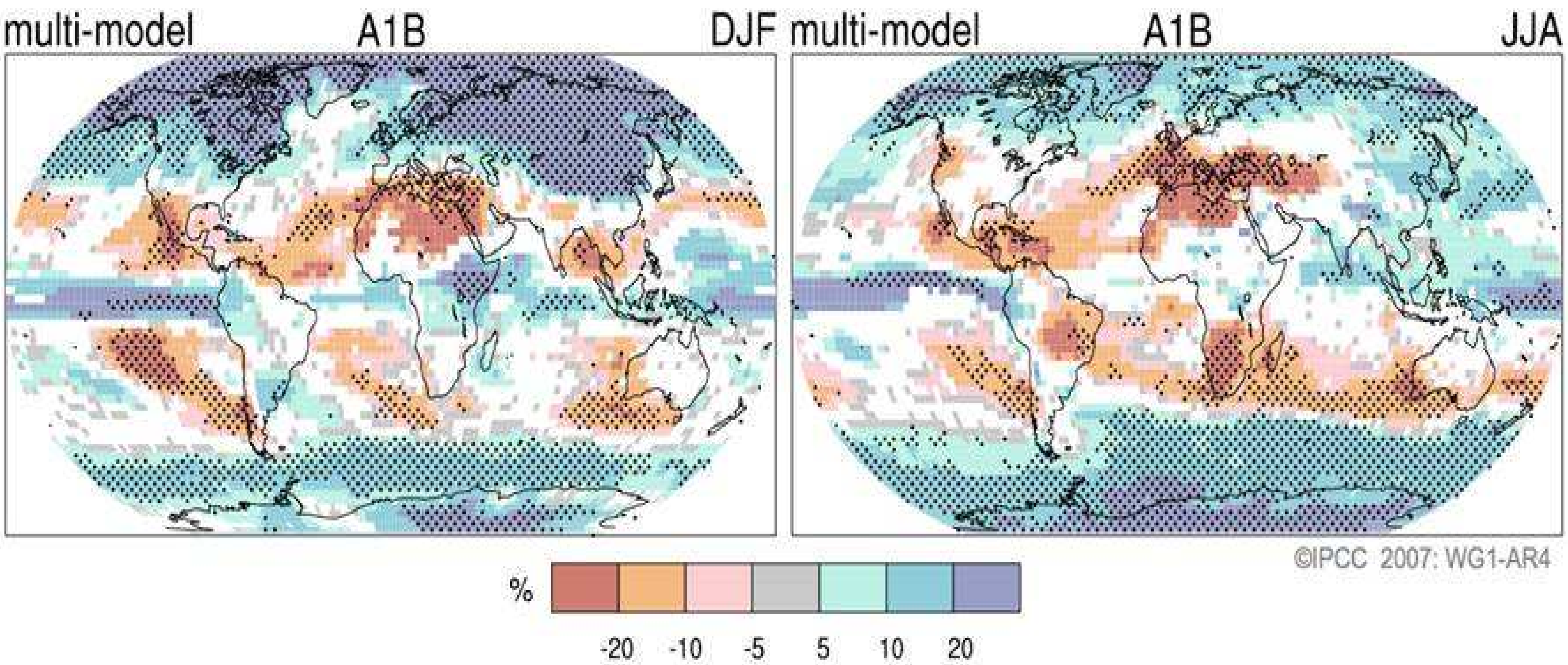
Important scientific questions remain about how much warming will occur, how fast it will occur, and how the warming will affect the rest of the climate system including precipitation patterns and storms.

Answering these questions will require advances in scientific knowledge in a number of areas:

- Improving understanding of natural climatic variations, changes in the sun's energy, land-use changes, the warming or cooling effects of pollutant aerosols, and the impacts of changing humidity and cloud cover.

- Determining the relative contribution to climate change of human activities and natural causes.

Projected Patterns of Precipitation Changes



Precipitation increases *very likely* in high latitudes

Decreases *likely* in most subtropical land regions

Climate change and water resources

Climate change impact estimation of water resources is complex because of the interaction of various climate as well as non-climate factors.

Factors promoting demand for water include population growth, rise in per capita income, urbanization, industrial development, and levels of agricultural development.

With decreased precipitation and increased evaporation from higher temperatures, average spring flow in Jordan and underground aquifers decreased.

The resulting soil erosion, salinization, and loss of vegetation will further increase surface runoff.

Underground water recharge will be reduced, and many springs throughout the country will dry up. This reduces the availability of water, especially for agriculture.

Recent studies expects a reduction of at least 25% in water availability by the end of the 21st century. Reduction in water availability in Jordan up to 2100 would be 25% or more.

Reductions in water supply will coincide with an increase in demand as households require more drinking water because of high temperatures and farms require more irrigation water because of hotter, drier conditions.

- Increased surface runoff will reduce aquifer recharge.

- The quality of stored water will degrade due to salinization, and the increased surface runoff will transport dissolved pollutants and soil sediments to waters reservoirs.

- This will gradually reduce the water storage capacity of the dams, which reduce the economic age of these reservoirs.

- Accordingly, in 2030 irrigation demand would increase by 5% due to 10% decrease in rainfall and 9% increase in crop water requirements due to increase in temperature by 1 degree C, resulting in 14% increase in demand.

- For the year 2050, the numbers would be 10% for decreasing rainfall by 20% and 18% increase in crop water requirements due to temperature increase by 2 degrees C, resulting in a total of 28% increase in demand.

Impacts of Climate Change on Agriculture

Climate change impacts can be roughly divided into **two groups**:

1- Biophysical impacts:

- physiological effects on crops, pasture, forests and livestock (quantity, quality);
- changes in land, soil and water resources (quantity, quality);
- increased weed and pest challenges;
- shifts in spatial and temporal distribution of impacts;
- sea temperature rise causing fish to inhabit different ranges.

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2- socio-economic impacts:

- decline in yields and production;
- reduced marginal GDP from agriculture;
- fluctuations in world market prices;
- changes in geographical distribution of trade regimes;
- increased number of people at risk of hunger and food insecurity;
- migration and civil unrest

Plant Response to Temperature

General Response

- Crop species differ in their critical temperature range for life cycle development. There is a base temperature for vegetative development, at which growth commences, and an optimum temperature, at which the plant develops as fast as possible.

- Increasing temperature generally accelerates progression of a crop through its life cycle phases, up to a species-dependent optimum temperature. Beyond this optimum temperature, development (node and leaf appearance rate) slows.

Wheat

Grain-filling period of wheat and other small grains shortens dramatically with rising temperature. The optimum temperature for photosynthesis in wheat is 20-30ºC. This is 10ºC higher than the optimum (15ºC) for grain yield and single grain growth rate.

Any increase in temperature beyond the 25-35ºC range that is common during grain filling of wheat will reduce the grain filling period and, ultimately, yields.

Effects of higher temperature

- In middle and higher latitudes, global warming will extend the length of the potential growing season, allowing earlier planting of crops in the spring, earlier maturation and harvesting. When temperatures exceed the optimal for biological processes, crops often respond negatively with a steep drop in net growth and yield.

- If nighttime temperature minima rise more than do daytime maxima--as is expected from greenhouse warming projections-heat stress during the day may be less severe than otherwise, but increased nighttime respiration may also reduce potential yields.

- Another important effect of high temperature is accelerated physiological development, resulting in hastened maturation and reduced yield.

Available water

- Agriculture of any kind is strongly influenced by the availability of water. Climate change will modify rainfall, evaporation, runoff, and soil moisture storage. Changes in total seasonal precipitation or in its pattern of variability are both important.

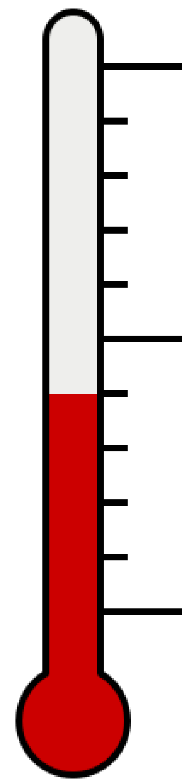
- The occurrence of moisture stress during flowering, pollination, and grain-filling is harmful to most crops.

- Increased evaporation from the soil and accelerated transpiration in the plants themselves will cause moisture stress; as a result there will be a need to develop crop varieties with greater drought tolerance.

- The demand for water for irrigation is projected to rise in a warmer climate, bringing increased competition between agriculture and urban as well as industrial users.
- Peak irrigation demands are also predicted to rise due to more severe heat waves. Additional investment for dams, reservoirs, canals, wells, pumps, and piping may be needed to develop irrigation networks in new locations.
- Finally, intensified evaporation will increase the hazard of salt accumulation in the soil.

Extreme meteorological events, such as spells of high temperature, heavy storms, or droughts, disrupt crop production in areas where certain varieties of crops are grown near their limits of maximum temperature tolerance.

For example, barley grown in the marginal lands (steppe zone) where heat spells can be particularly detrimental.

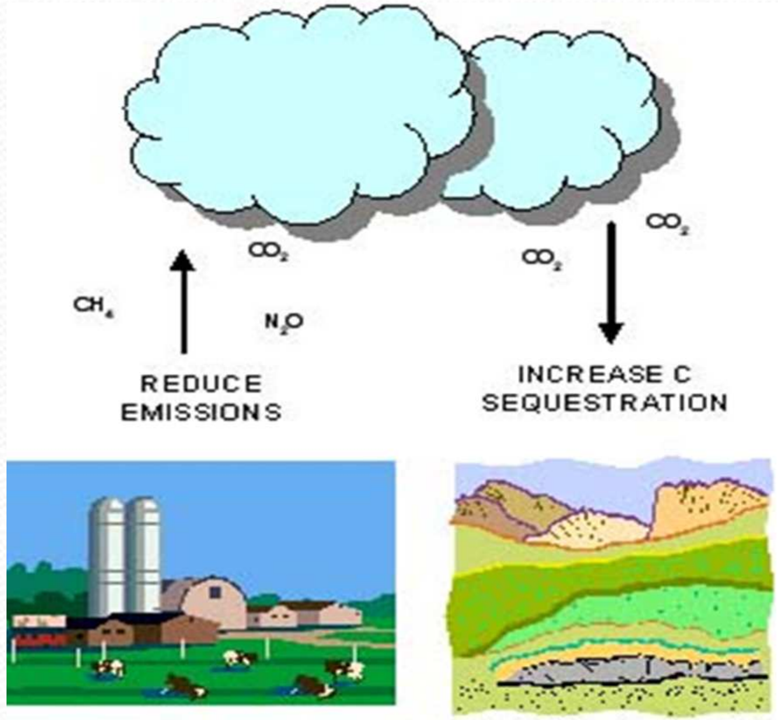


Similarly, frequent droughts not only reduce water supplies but also increase the amount of water needed for plant transpiration.

Carbon sequestration to mitigate climate change

- Carbon sequestration implies transferring atmospheric CO_2 into long-lived pools and storing it securely so it is not immediately re-emitted. Thus, soil C sequestration means increasing SOC and soil inorganic carbon stocks through appropriate land use and recommended management practices.

- Some of these practices include conservation tillage, agro-forestry and diverse cropping systems, cover crops and integrated nutrient management, including the use of manure, compost, improved grazing, and forest management.



Forages

- Increased temperature will hasten development and increase the length of the growing season.

- Impact on forage quality.

Fruits trees

- Warmer temperatures will cause earlier bud break or flowering in the spring.

- Warmer temperatures will cause faster development.

- Warmer temperatures could impact chilling requirements for many plants.

Animals

- Optimum temperature is a very narrow range (thermo-neutral zone) in which animal does not need to alter behavior or physiological function to maintain core temperature.

- Responses include panting (breath problems), shivering, reduced feed intake, increased (cold) or decreased (warm) metabolic rates.

- Any of these responses will impact productivity (meat, milk, or reproduction).

Rangeland Responses;

- Directional shifts in the composition of vegetation occur most consistently when global change treatments alter water availability.

- Weedy and invasive plant species likely will be favored by CO_2 enrichment and other global changes because these species possess traits (rapid growth rate, abundant seed production) that permit a large growth response to CO_2 .

- CO_2 enrichment will likely accelerate the rate of successional change in species composition following overgrazing or other severe disturbances.

Changes in extreme events (temperature)

- Higher maximum temperatures, more hot days and heat waves over nearly all land areas *(Very likely)*

- Increased heat stress in livestock and wildlife

- Increased risk of damage to a number of crops

- Higher [Increasing] minimum temperatures,

- fewer cold days, frost days and cold waves over nearly all land areas *(Very likely)*

- Decreased damage to a number of crops, and increased risk to others Extended range and activity of some pest and disease vectors

Changes in extreme events (hydrological)

- More intense precipitation events (*Very likely*, *over* many areas)
- Increased flood, landslide, avalanche, and mudslide damage
- Increased soil erosion
- Increased flood runoff could increase recharge of some floodplain aquifers
- Increased summer drying over most mid-latitude continental interiors and associated risk of drought *(Likely)*
- Decreased crop yields Decreased water resource quantity and quality Increased risk of forest fire

Impacts of climate change are likely to be the greatest in the developing world

- Current degradation of natural resources
- Poor access to technologies
- Low investments in production