Climate Change at Global and National Scales

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PMD

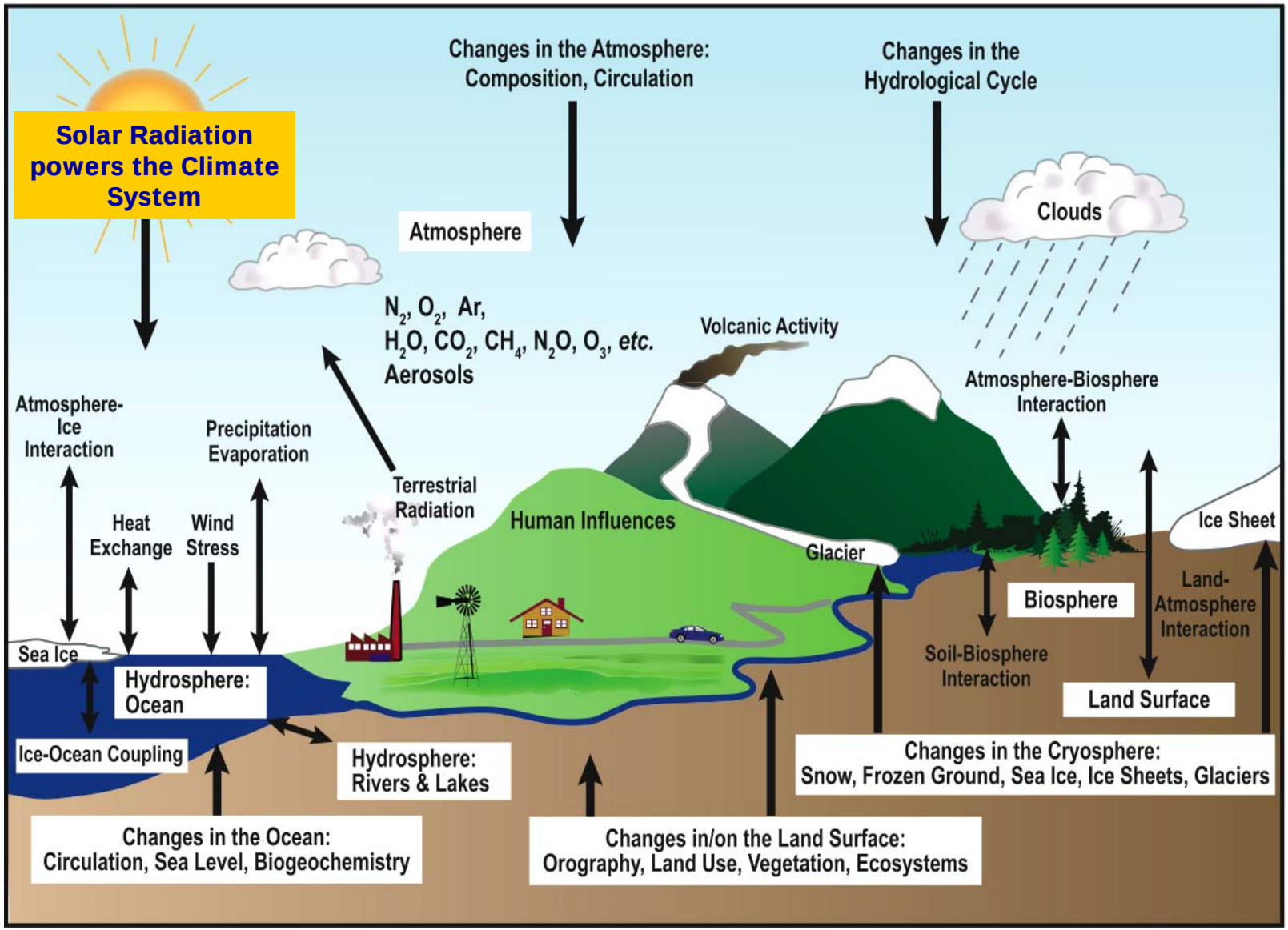
Science of Global Warming

Past and present trends

Scenarios

Impacts

Measures


Solar Radiation powers the Climate System
Changes in the Atmosphere: Composition, Circulation
Changes in the Hydrological Cycle
Atmosphere
Clouds
N_2, O_2, Ar,
H_2O, CO_2, CH_4, N_2O, O_3, *etc.*
Aerosols
Volcanic Activity
Atmosphere-Biosphere Interaction
Atmosphere-Ice Interaction
Precipitation Evaporation
Terrestrial Radiation
Heat Exchange
Wind Stress
Human Influences
Glacier
Ice Sheet
Biosphere
Land-Atmosphere Interaction
Sea Ice
Soil-Biosphere Interaction
Hydrosphere: Ocean
Land Surface
Ice-Ocean Coupling
Hydrosphere: Rivers & Lakes
Changes in the Cryosphere: Snow, Frozen Ground, Sea Ice, Ice Sheets, Glaciers
Changes in the Ocean: Circulation, Sea Level, Biogeochemistry
Changes in/on the Land Surface: Orography, Land Use, Vegetation, Ecosystems

Source: IPCC

Science of global warming

Continuous flow of energy from the sun reaches the earth as visible light

30% immediately scattered back into space, 70% penetrates the atmosphere to heat up the surface

This energy is emitted from the earth into the atmosphere as infrared light

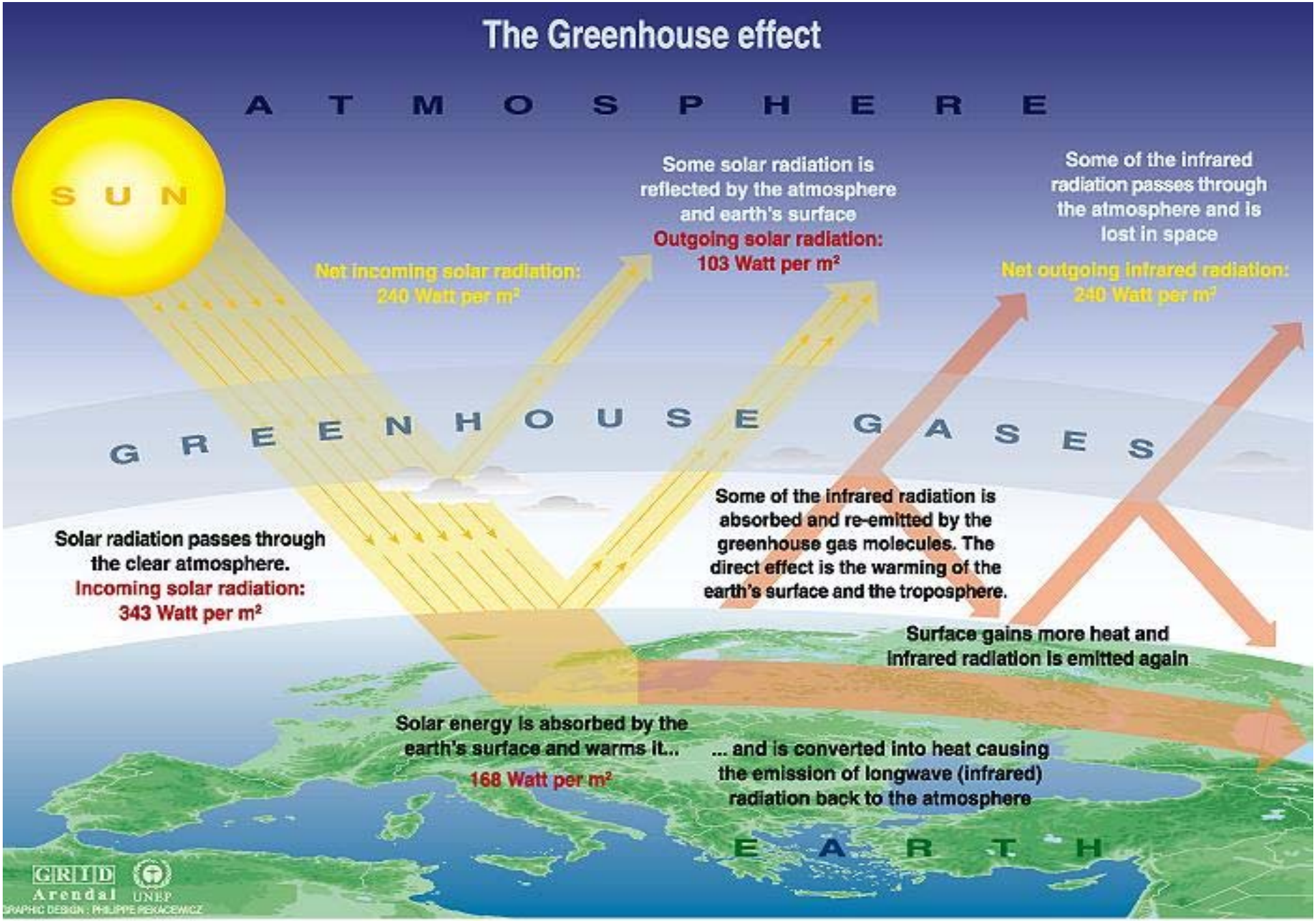
Some of this infrared irradiation is adsorbed by components in the atmosphere so called ‘greenhouse gases’

Science of global warming (cont)

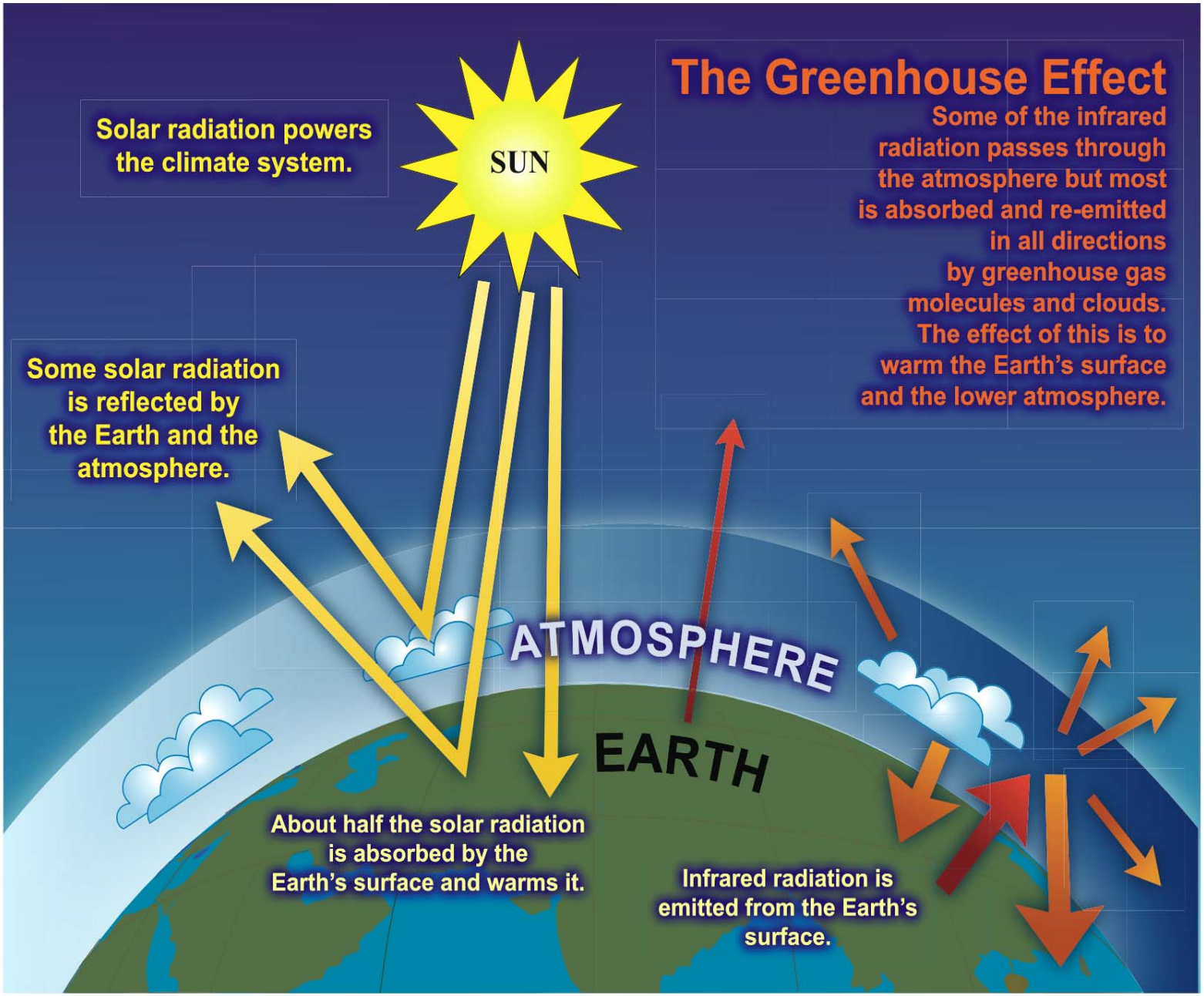
These greenhouse gases can re-emit this energy in all direction

As result of this effect the earth is kept some 30°C warmer than without these GHGs, essential for live on earth

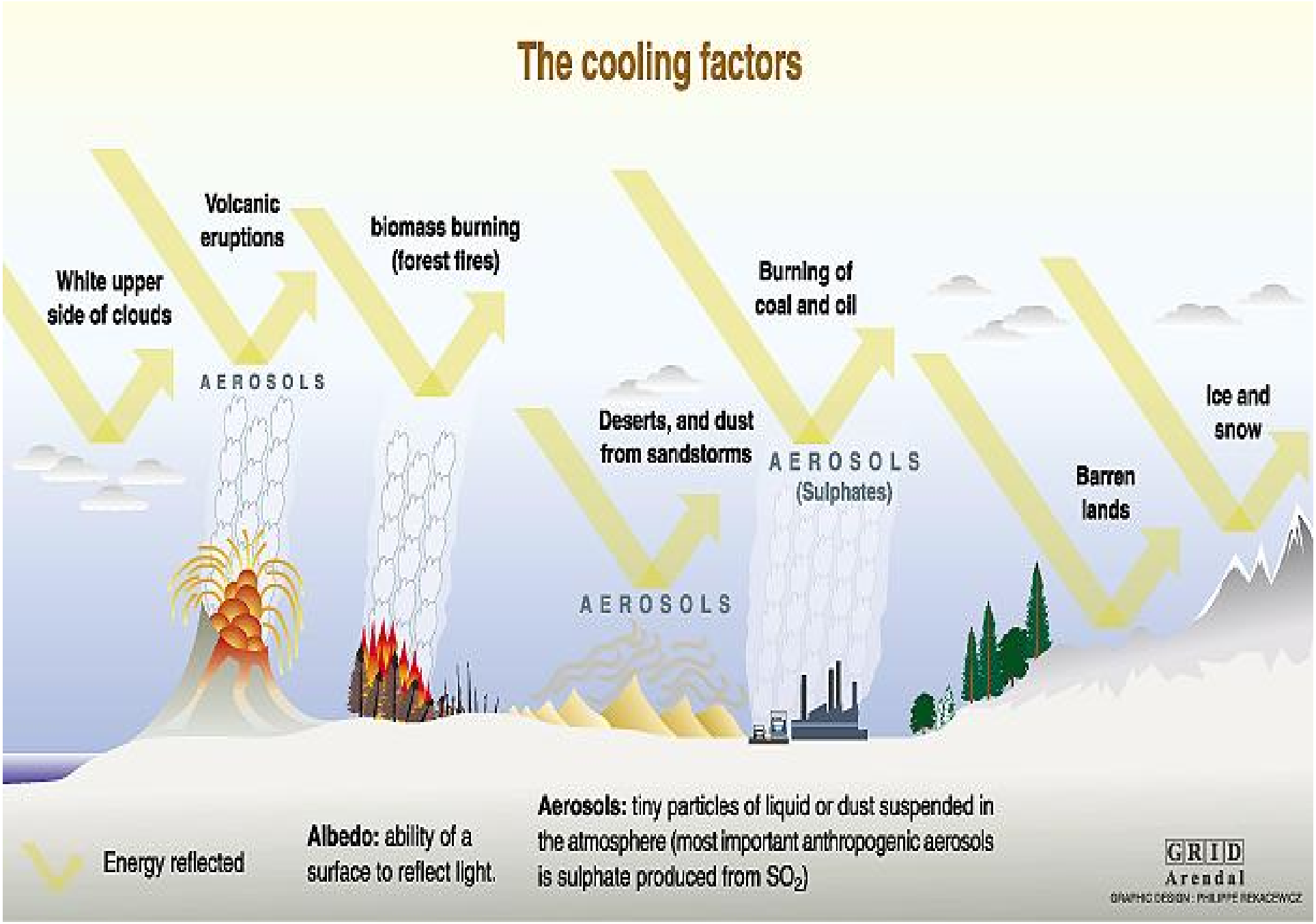
These gasses are making up only about 1% of earth atmospheric composition



Sources: Okanagan university college in Canada, Department of geography, University of Oxford, school of geography; United States Environmental Protection Agency (EPA), Washington; Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge university press, 1996.


The Greenhouse Effect
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.
Solar radiation powers the climate system.
SUN
Some solar radiation is reflected by the Earth and the atmosphere.
ATMOSPHERE
EARTH
About half the solar radiation is absorbed by the Earth's surface and warms it.
Infrared radiation is emitted from the Earth's surface.

The cooling factors



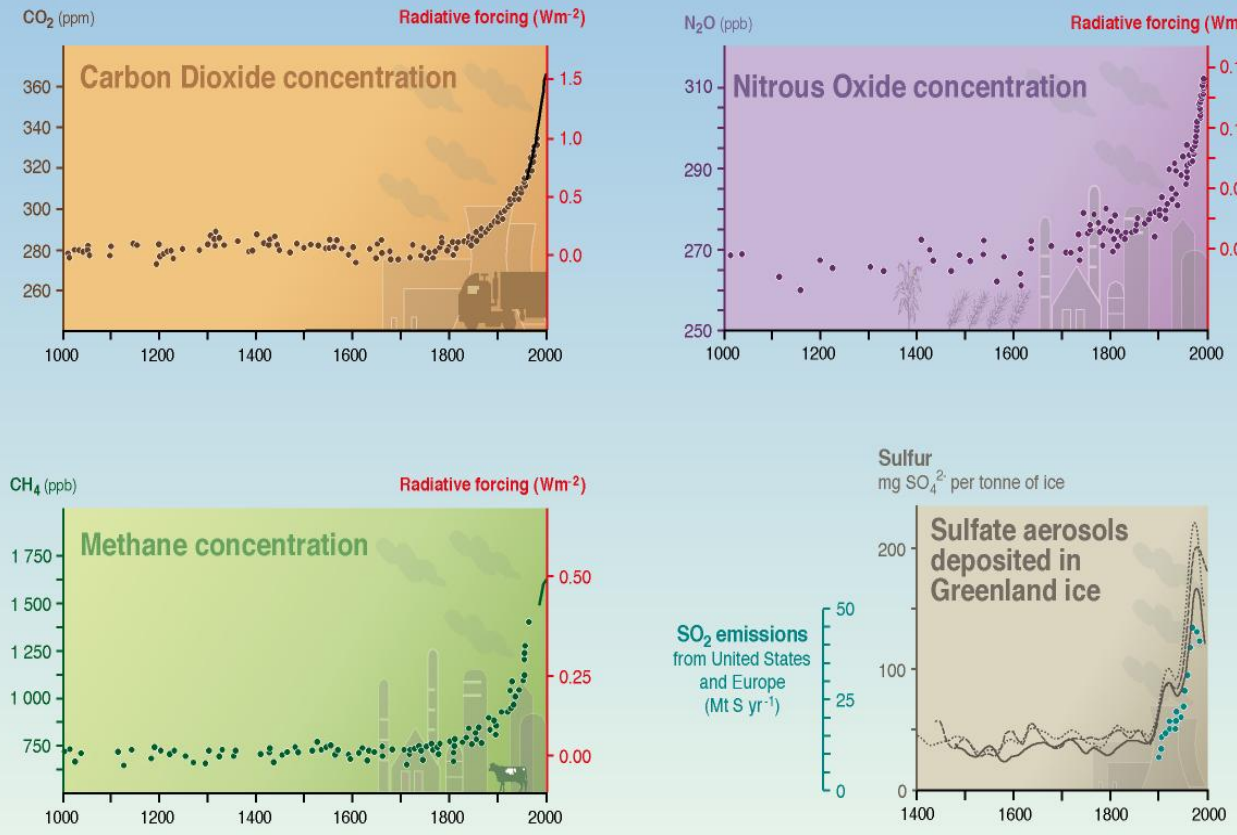
Sources: Radiative forcing of climate change, the 1994 report of the scientific assessment working group of IPCC, summary for policymakers, WMO, UNEP; L.D. Danny Harvey, Climate and global environmental change, Prentice Hall, pearson Education, Harlow, United Kingdom, 2000.

Major Greenhouse gases

Main GHGs are water vapor (H_2O), carbon dioxide (CO_2), ozone (O_3), methane (CH_4), nitrous oxide (N2O), and (hydro) chlorofluorocarbons (CFCs and HCFCs)

Apart from CFCs and HCFCs all these gases occur naturally

Indicators of the human influence on the atmosphere during the Industrial era



SYR - FIGURE 2-1
WG1 FIGURE SPM-2

Sources of GHGs

Gas	Formula	Sources
Carbon Dioxide	CO_2	• fossil fuel combustion, • gas flaring, • cement production, • land use change
Methane	CH_4	• fossil fuel • rice paddies • waste dumps • livestock
Nitrous oxide	N_2O	• fertilizer • industrial process (nylon) • combustion
CFC-12	CCl_2F_2	• liquid coolants
HCFC-22	$CHClF_2$	• production of aluminum
Sulpher hexa-fluoride	SF_6	• dielectric fluid

Science of Global Climate Change

Science of Global Warming

Past & Present Trends

Scenarios

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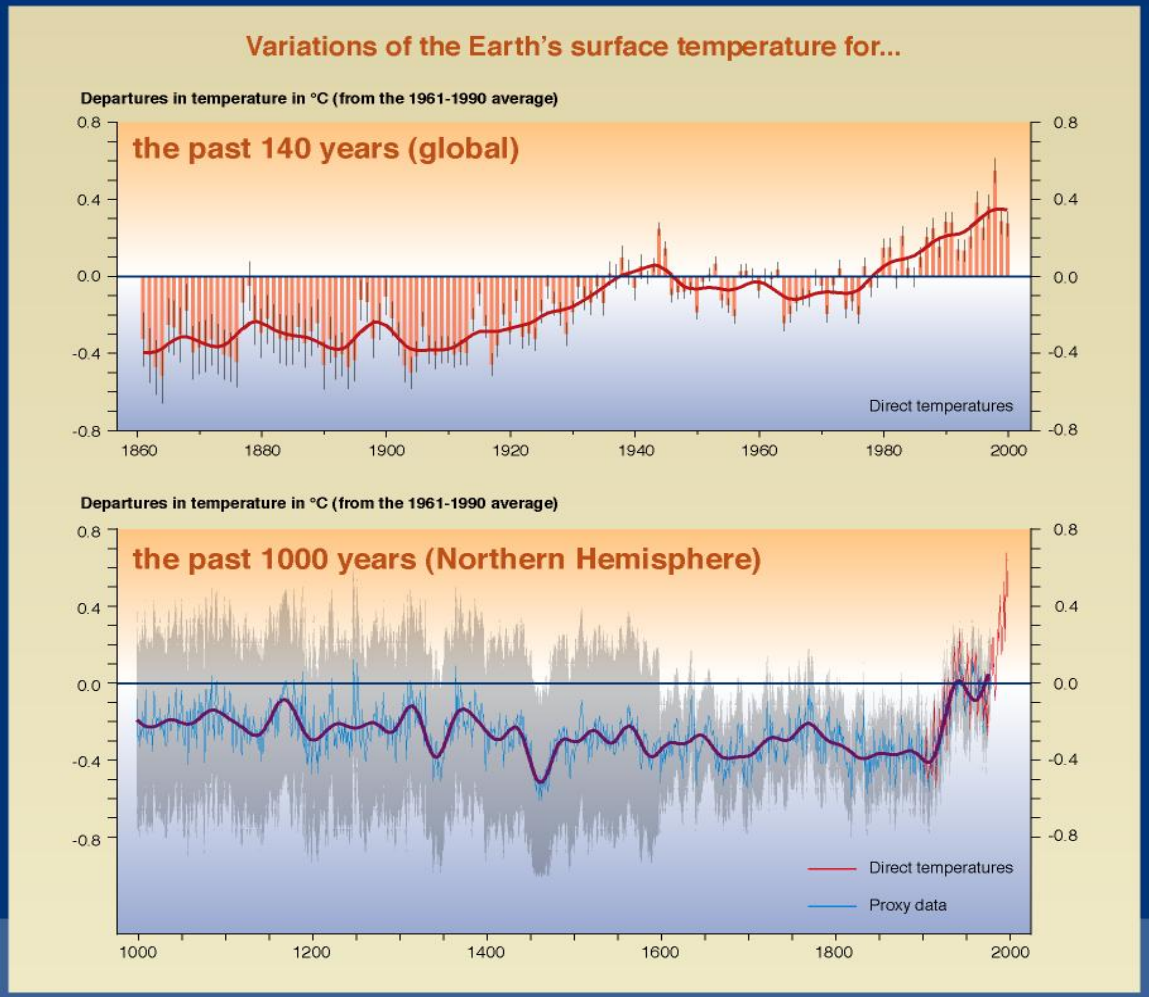
Trends and relationships

What are the trends in the concentration of the greenhouse gases in the atmosphere and is there a relation with the global temperature?

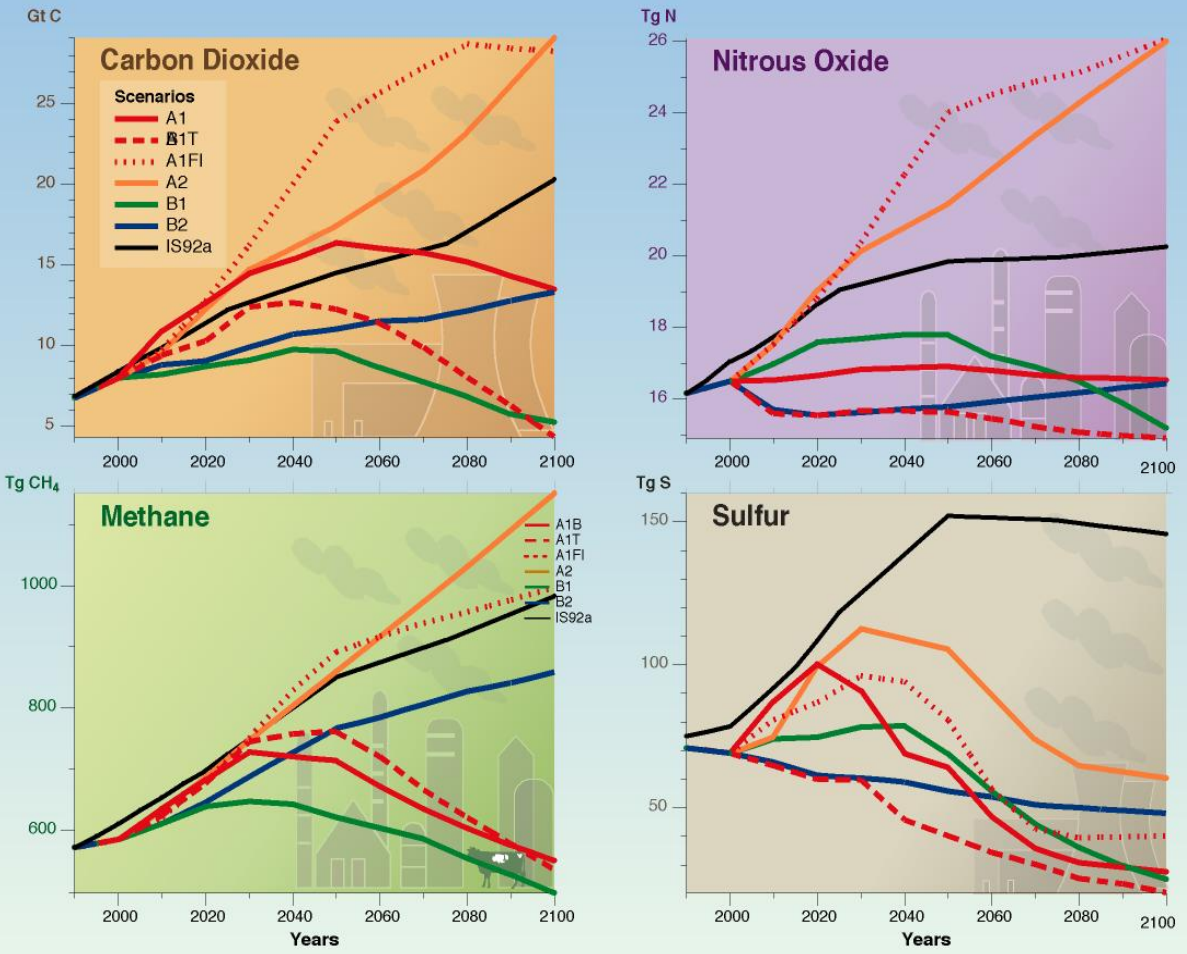
What are the sources of the greenhouse gases and and what is the trend in the emissions?

Surface temperature trend



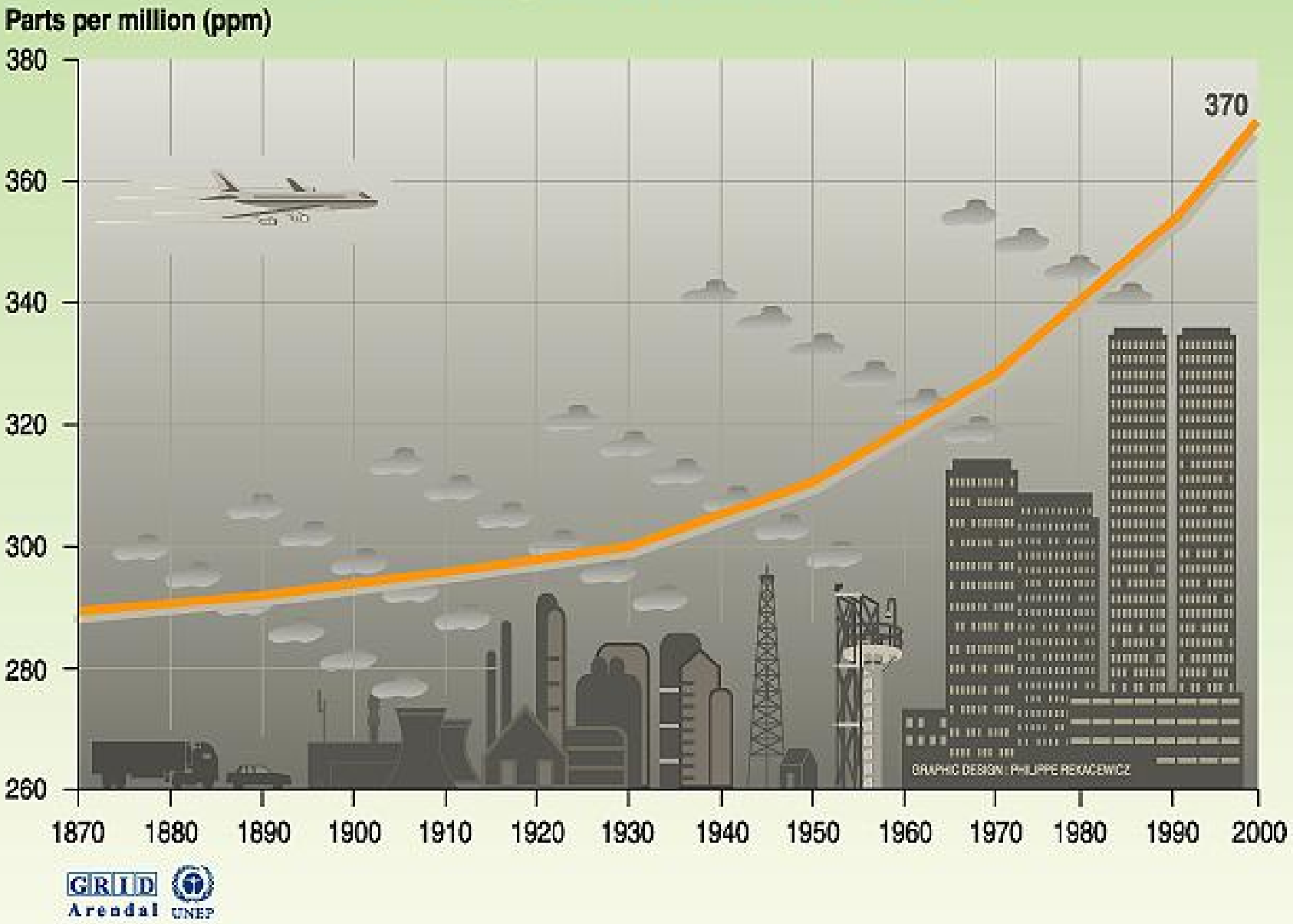
SYR - FIGURE 2-3

Anthropogenic emissions of CO_2, CH_4, N_2O and SO_2
for the six SRES scenarios



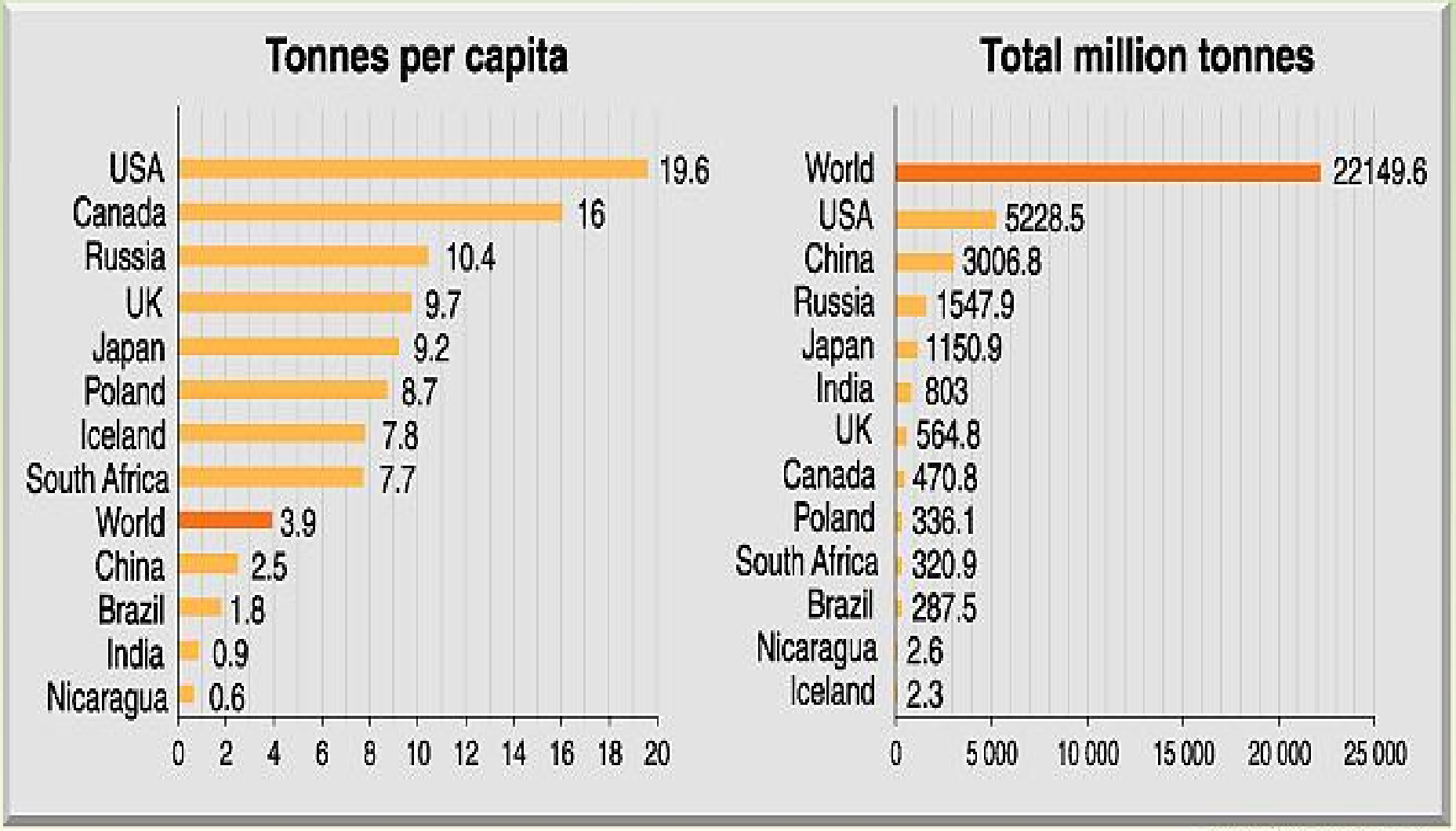
WG1 TS FIGURE 17

Global atmospheric concentration of CO_2



Sources: TP Whorf Scripps, Mauna Loa Observatory, Hawaii, Institution of oceanography (SIO), university of California La Jolla, California, United States, 1999

Emissions of CO_2 - selected countries (1995)

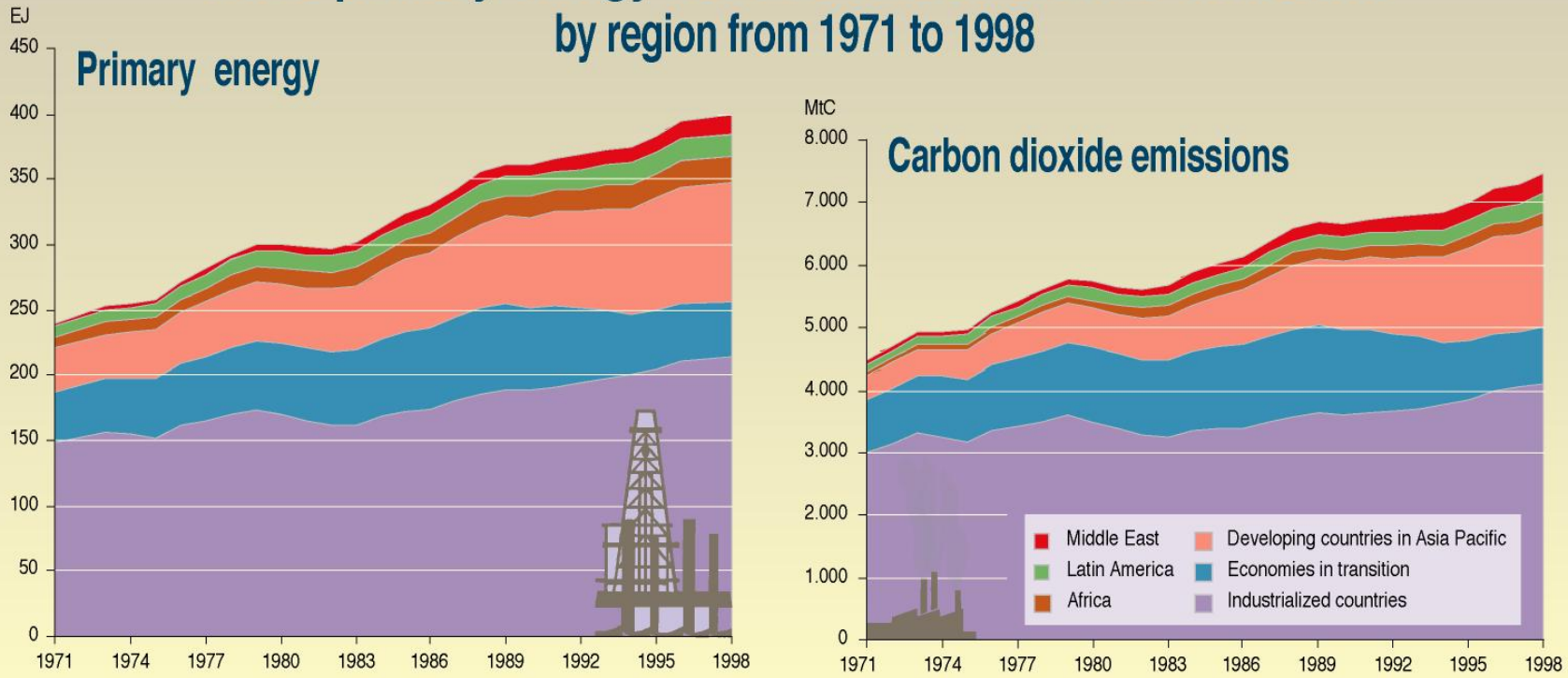


GRAPHIC DESIGN : PHILIPPE REKACEWICZ

GRID Arendal UNEP

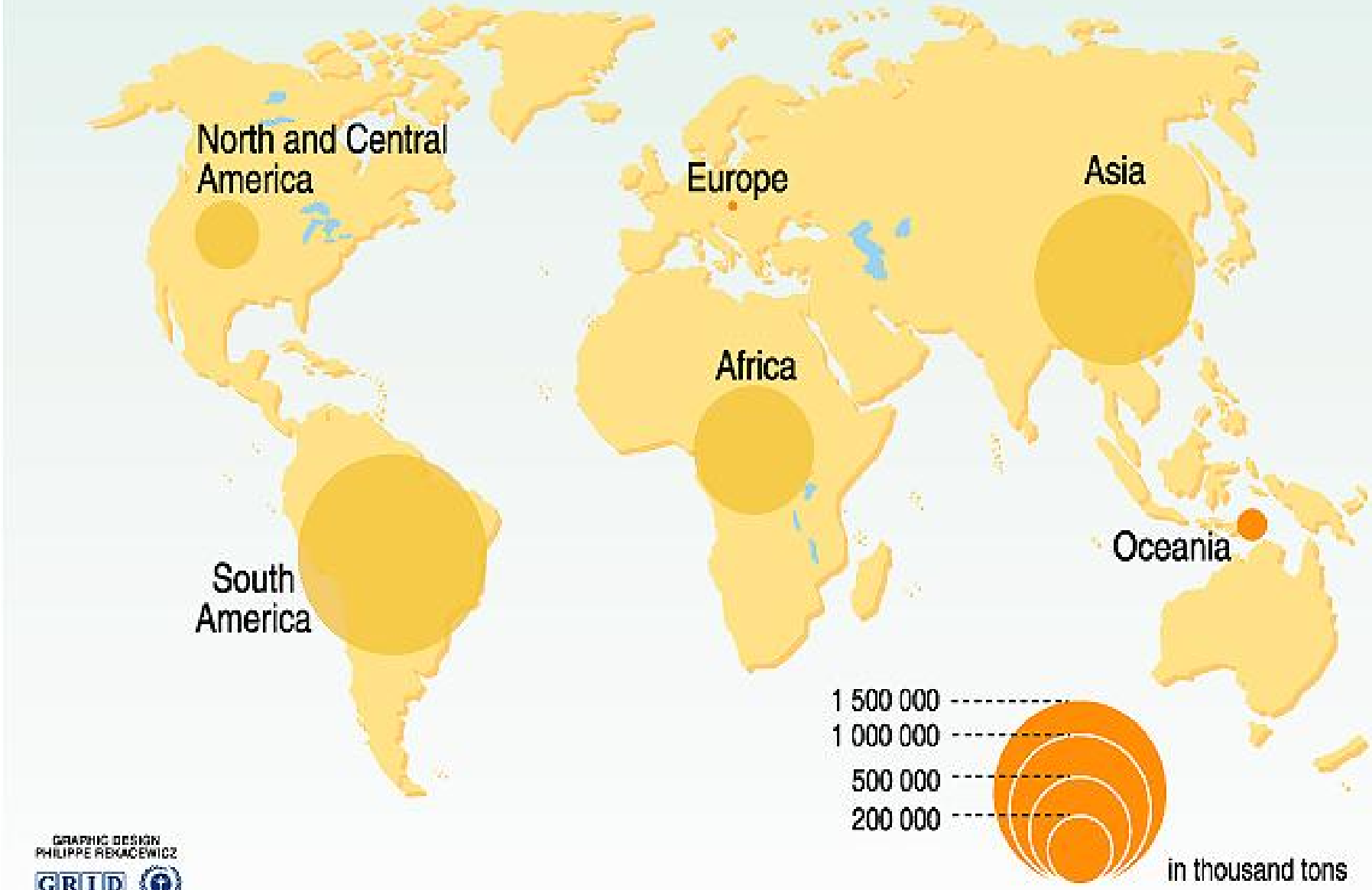
Source : International Energy Agency, 1998.

World primary energy use and carbon dioxide emissions
by region from 1971 to 1998



WG3 - FIGURE TS-3 and 4

CO_2 emissions from land use change



GRAPHIC DESIGN
PHILIPPE REKACEWICZ

GRID Arendal UNEP

Source : Climate Change Information kit, UNEP IUC, 1997.

Recent Trends in Climate Change (Pakistan)

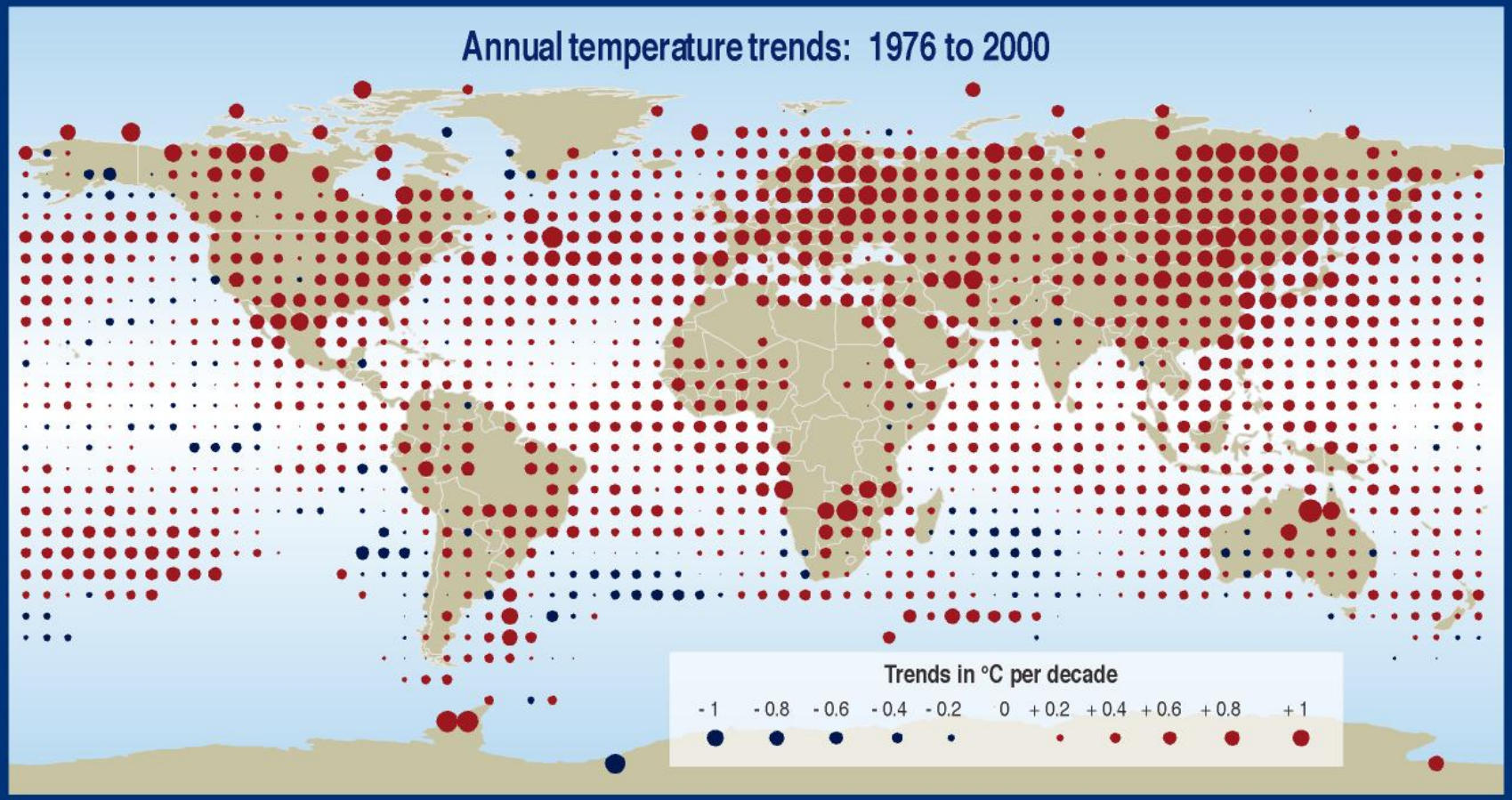
Rise in mean temp. of 0.6-1.0°C in arid coastal areas, arid mountains and hyper arid plains

10-15% decrease in both winter and summer rainfall in coastal belt and hyper arid plains

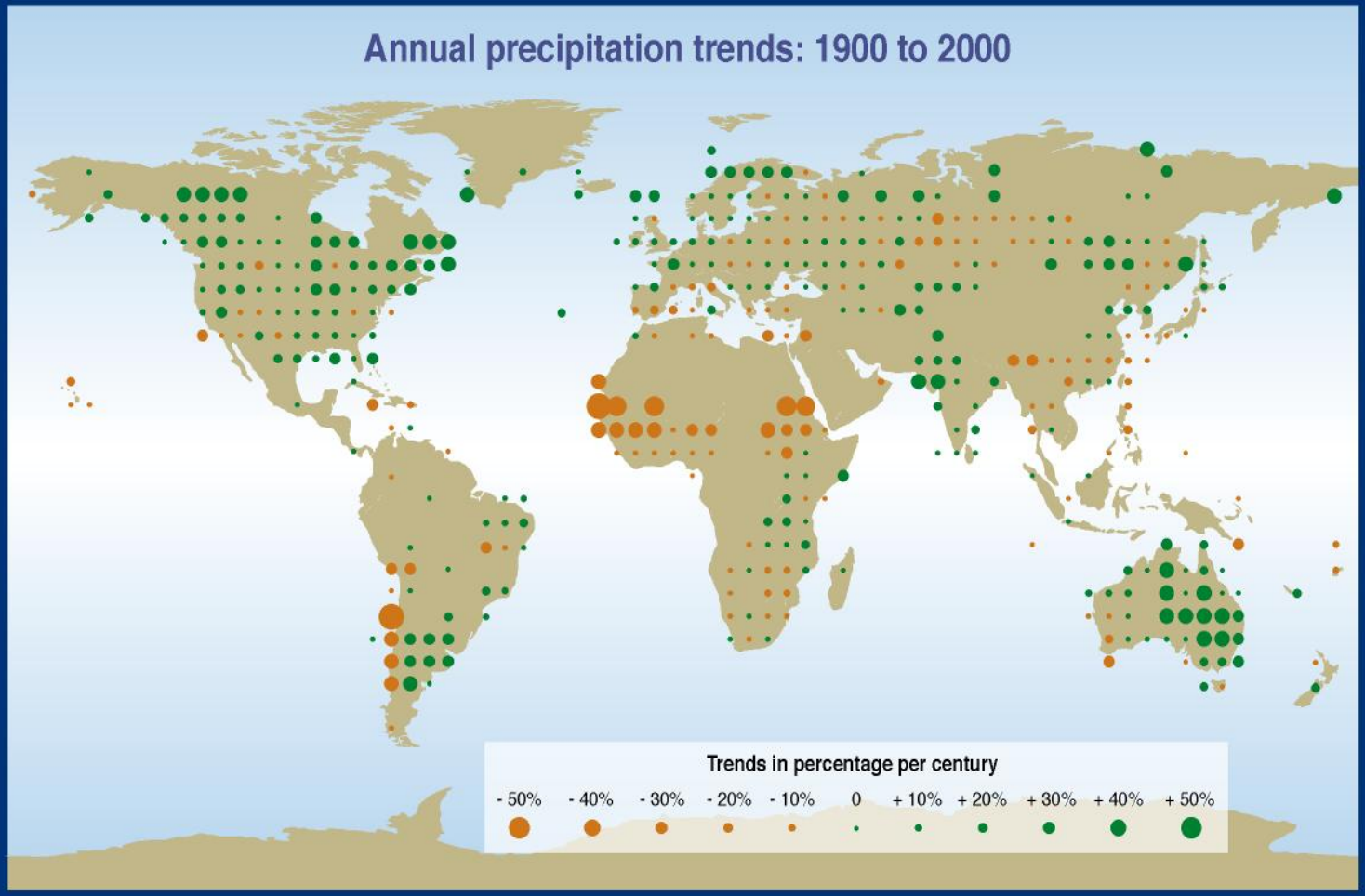
18-32% increase in rainfall in monsoon zone especially the sub-humid and humid areas.

5% decrease in relative humidity in Balochistan

0.5 to 0.7% Increase in solar radiation over southern half of country.



SYR - FIGURE 2-6b



SYR - FIGURE 2-6a

Recent Trends in Climate Change (Pakistan)

3-5% decrease in cloud cover in central Pakistan with increase in sunshine hours

3 - 5% increase in ETo due to 0.9°C temp. increase

5% Increase in net irrigation water requirement with no change in rainfall.

Expanding aridity in Northern parts outside monsoon range and arid regions

During last 100 years, 7 strong, 10 moderate and 7 weak *EL Nino* events. 17-64% departure of rainfall from normal during strong events

Recent Trends in Climate Change

Frequency of depressions and Cyclones increased over Bay of Bangal and Arabian Sea during last 50 years.

The intensity of systems also increased during last quarter of the 20th century.

Science of Global Climate Change

Science of Global Warming

Past & Present Trends

Scenarios

Impacts

Measures

Scenarios

We now know that there is a correlation between emission of greenhouse gases, their atmospheric concentration and earth global temperature, but what about the next future?

What can we expect, will the concentrations and temperature still increase?

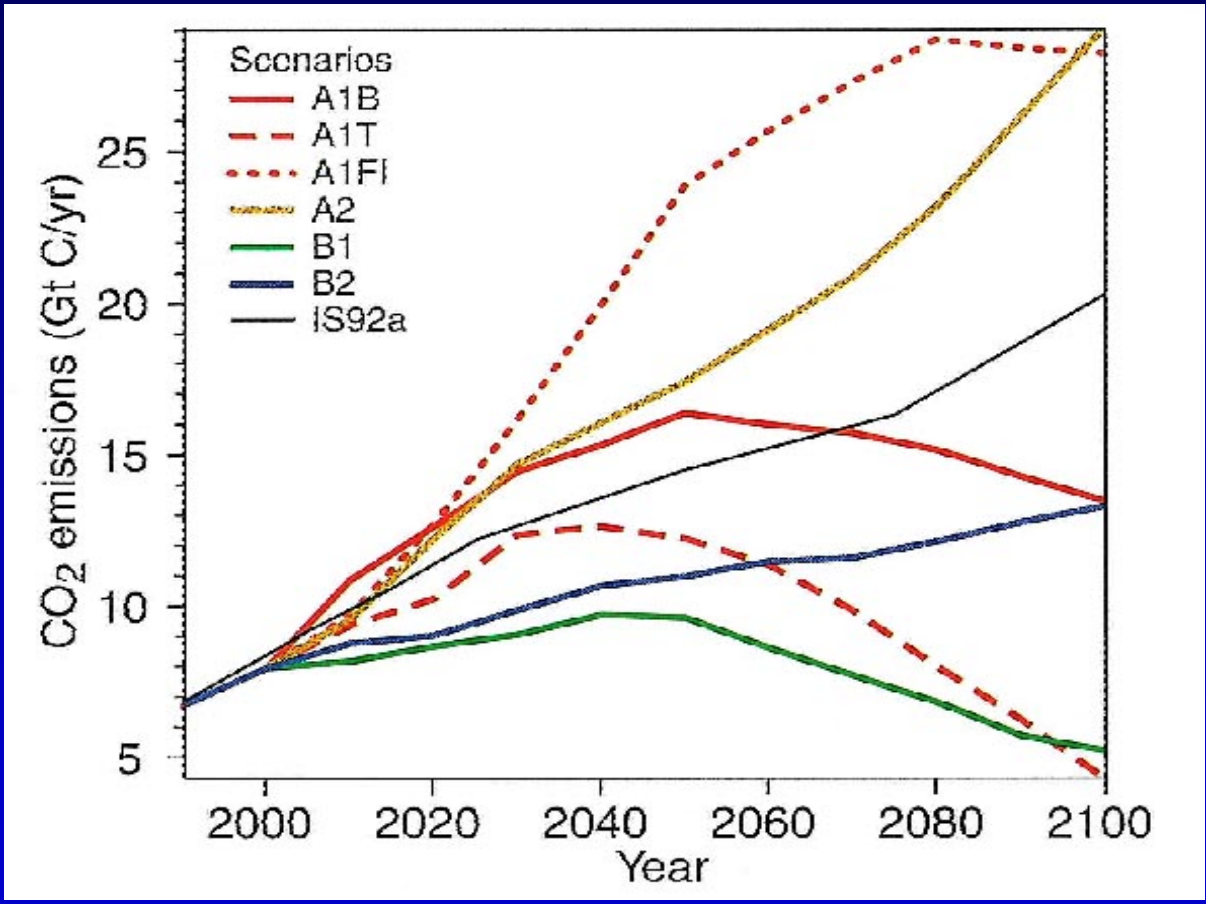
Scenarios

With help of scenarios we get a feeling what might happen.

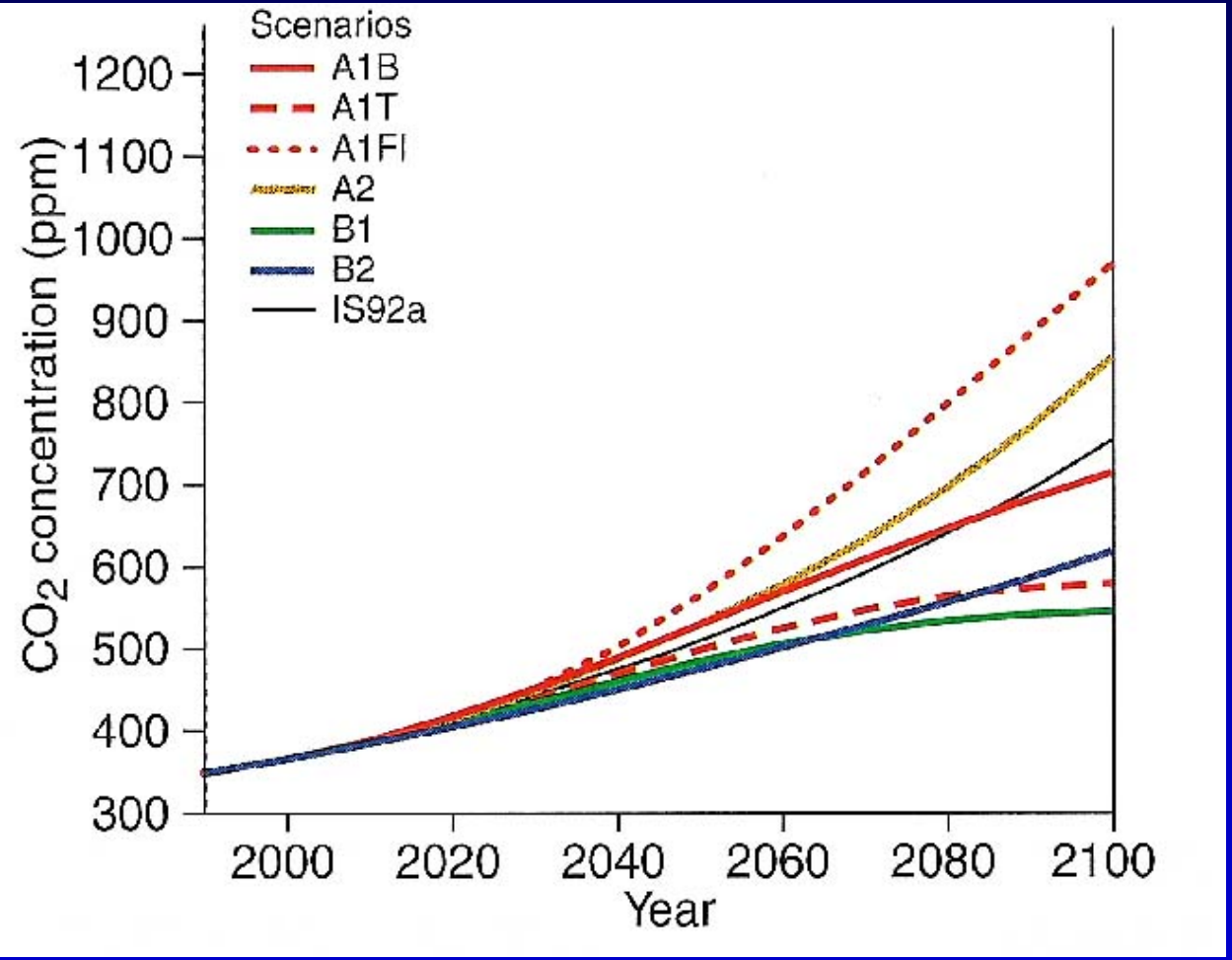
Specific scenarios were developed under the IPCC program

Effects on CO_2 concentration, temperature and sea level rise are given

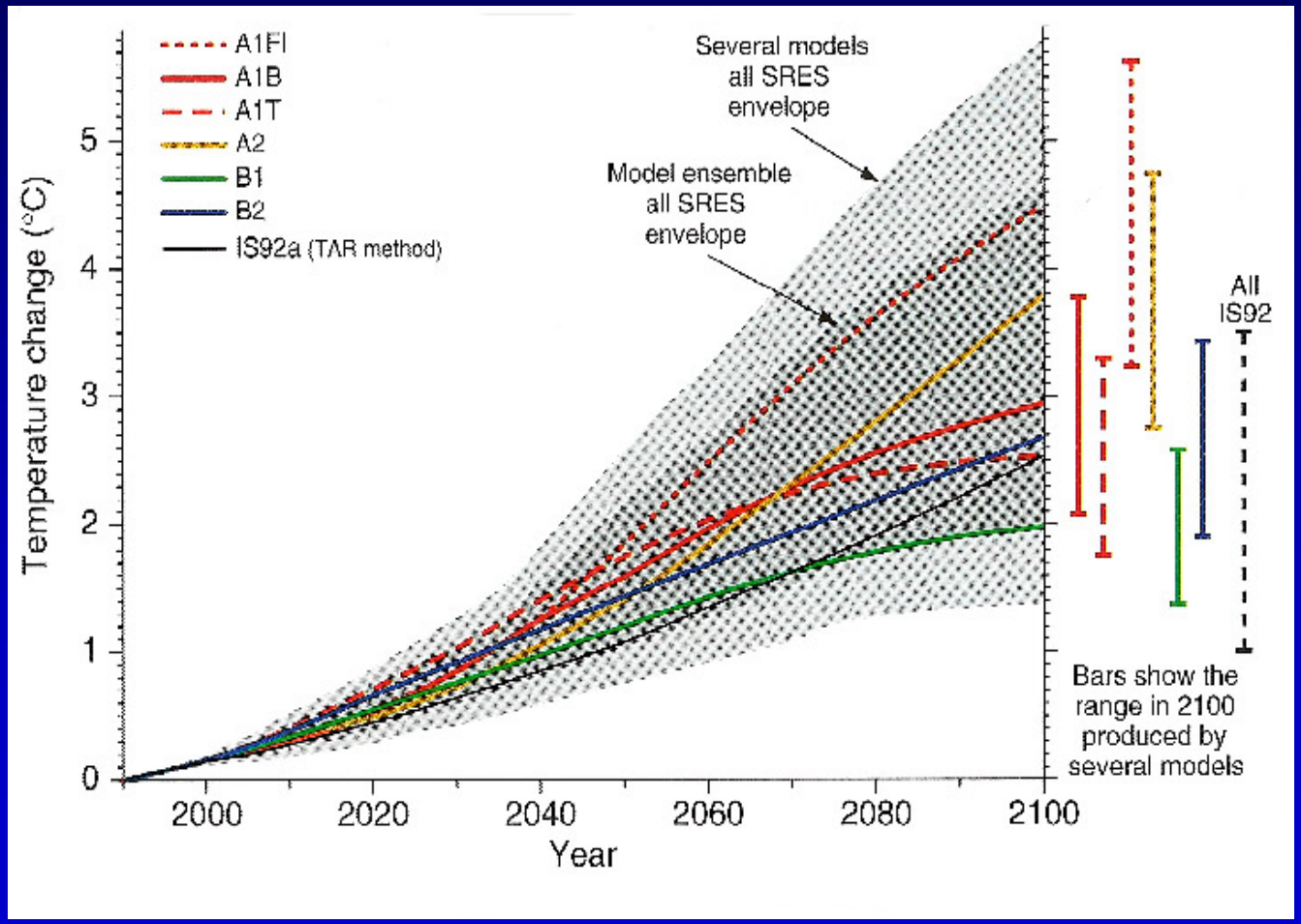
Projected CO_2 emissions



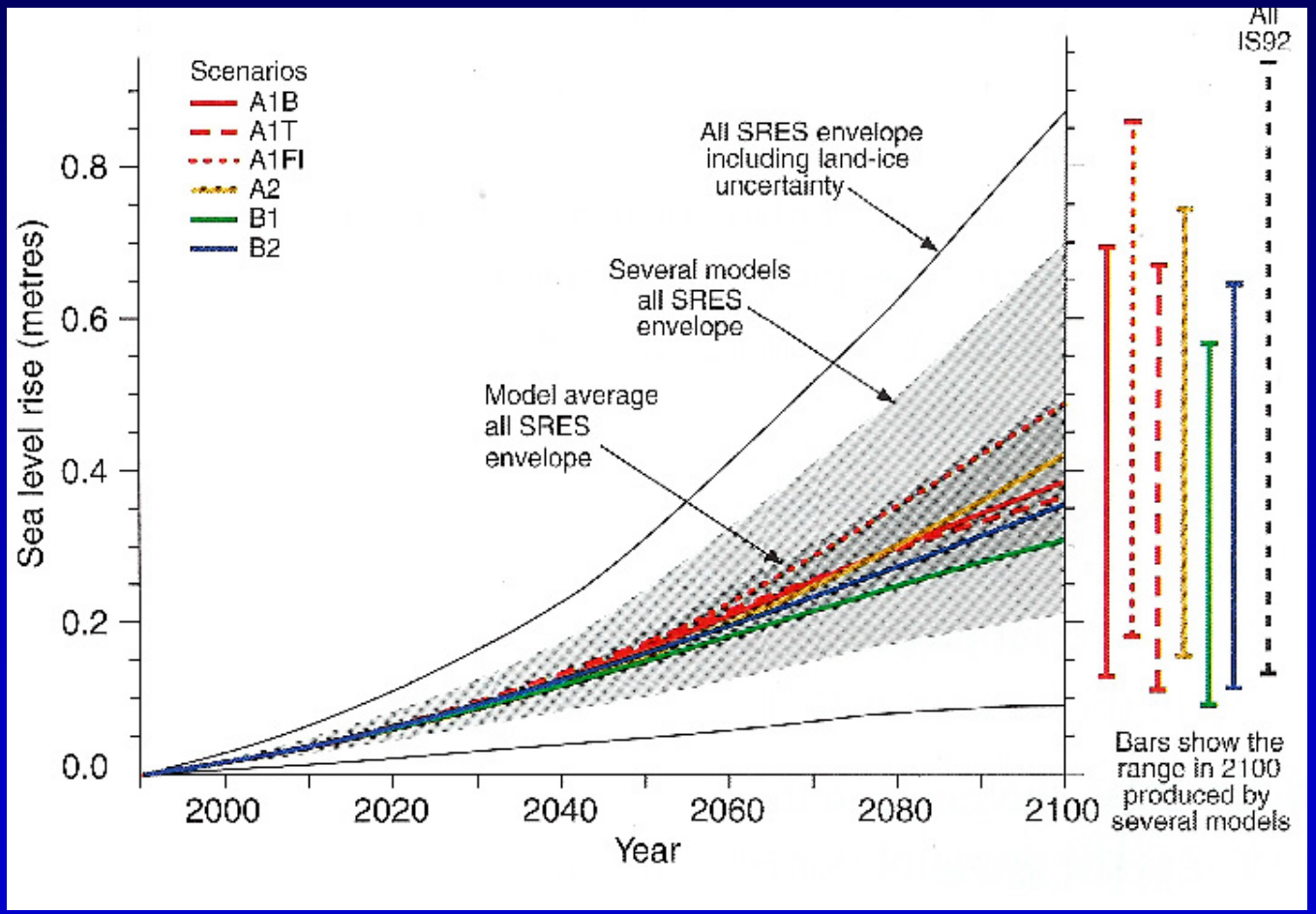
Projected CO_2 concentrations



Projected temperature change

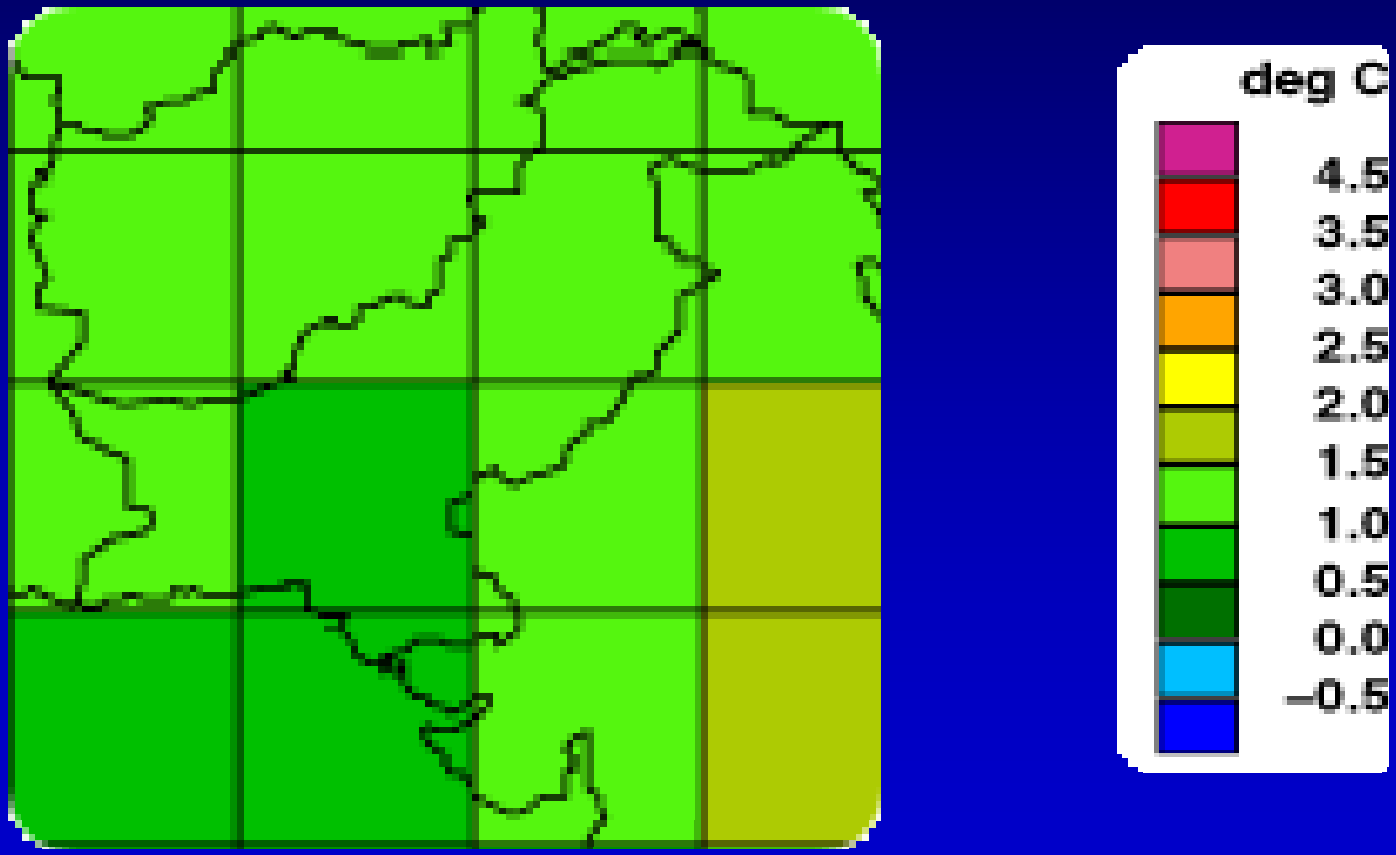


Projected sea level rise



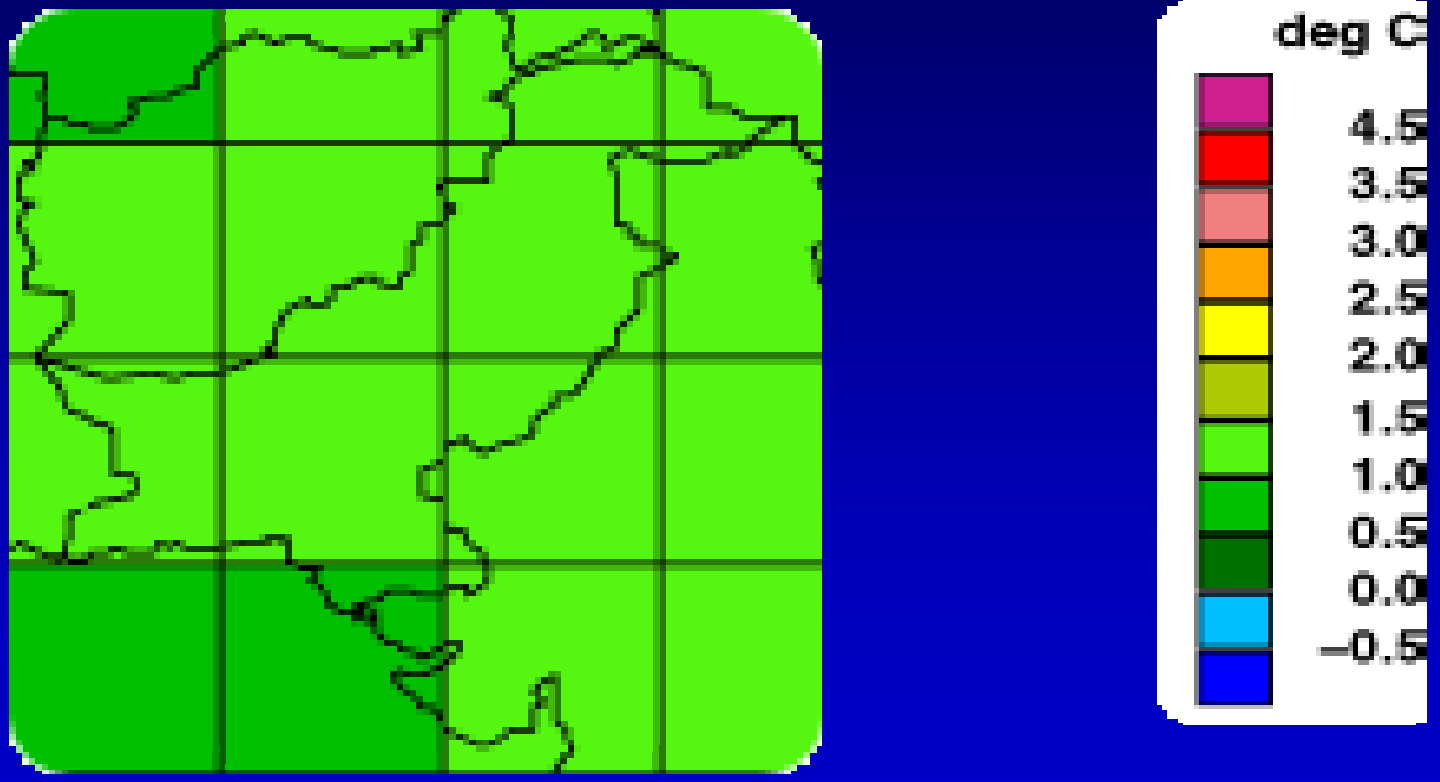
Climate Scenario in 2025

Temperature Change during Monsoon period



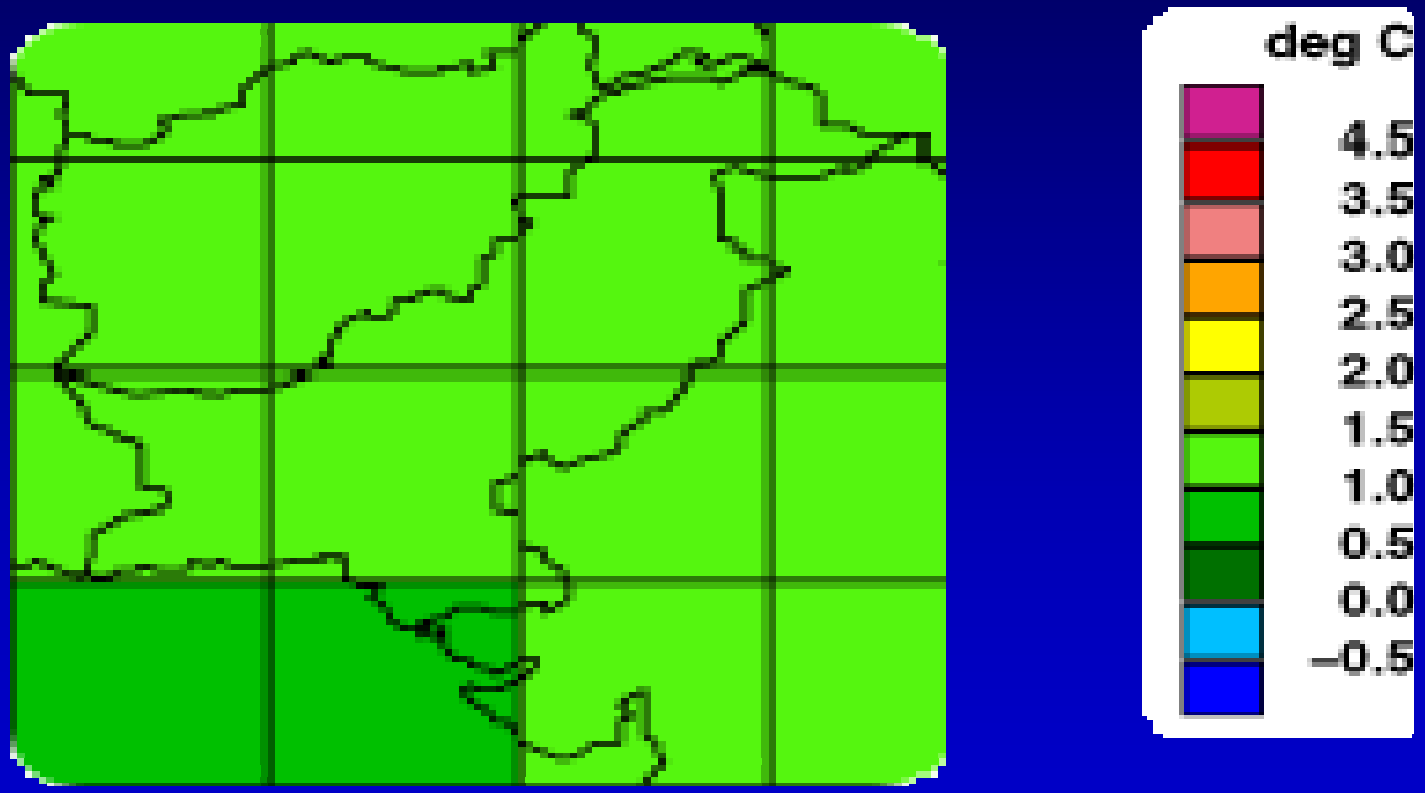
Climate Scenario in 2025

Temperature Change during Winter period



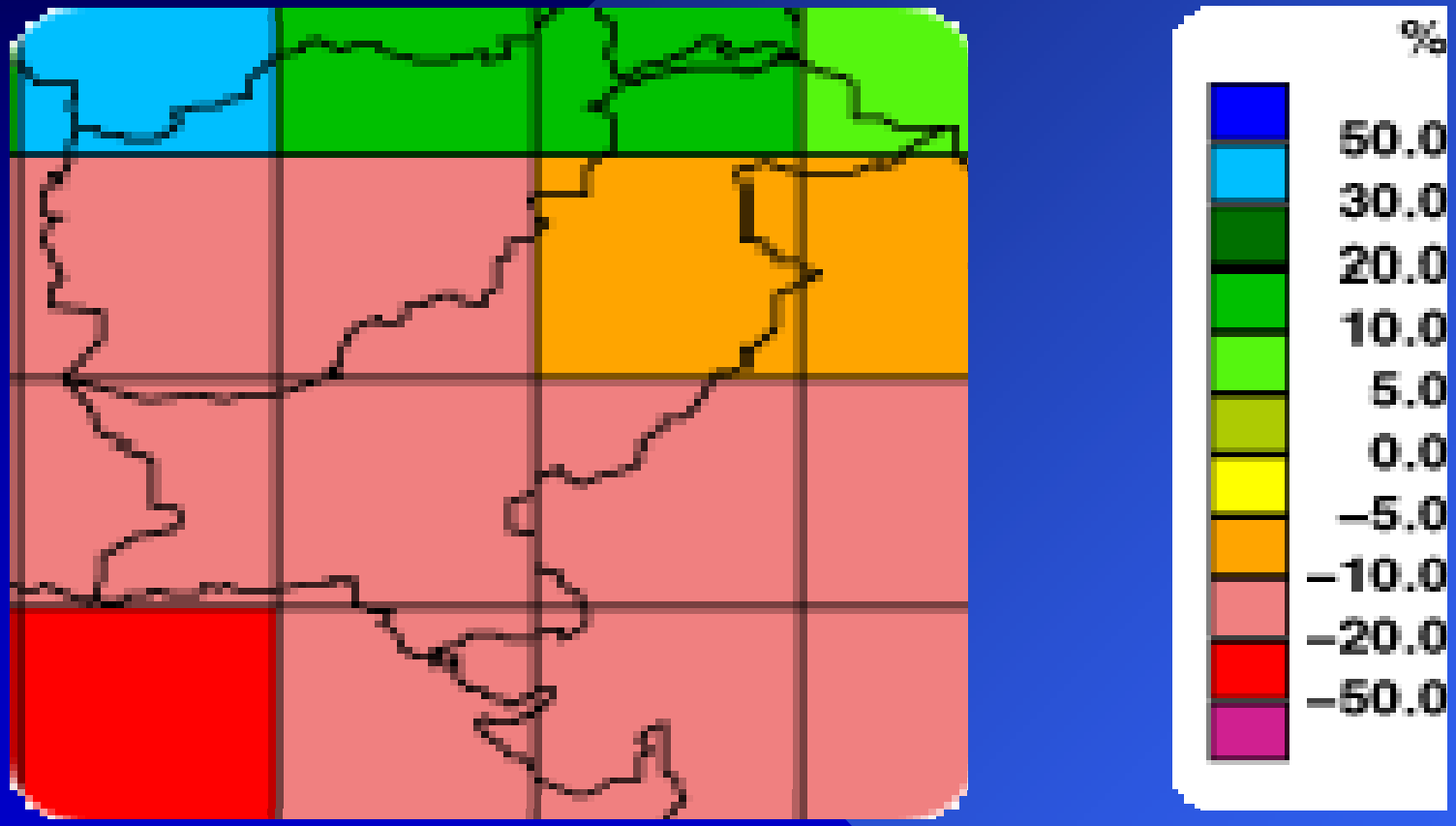
Climate Scenario in 2025

Temperature Change during Annual period



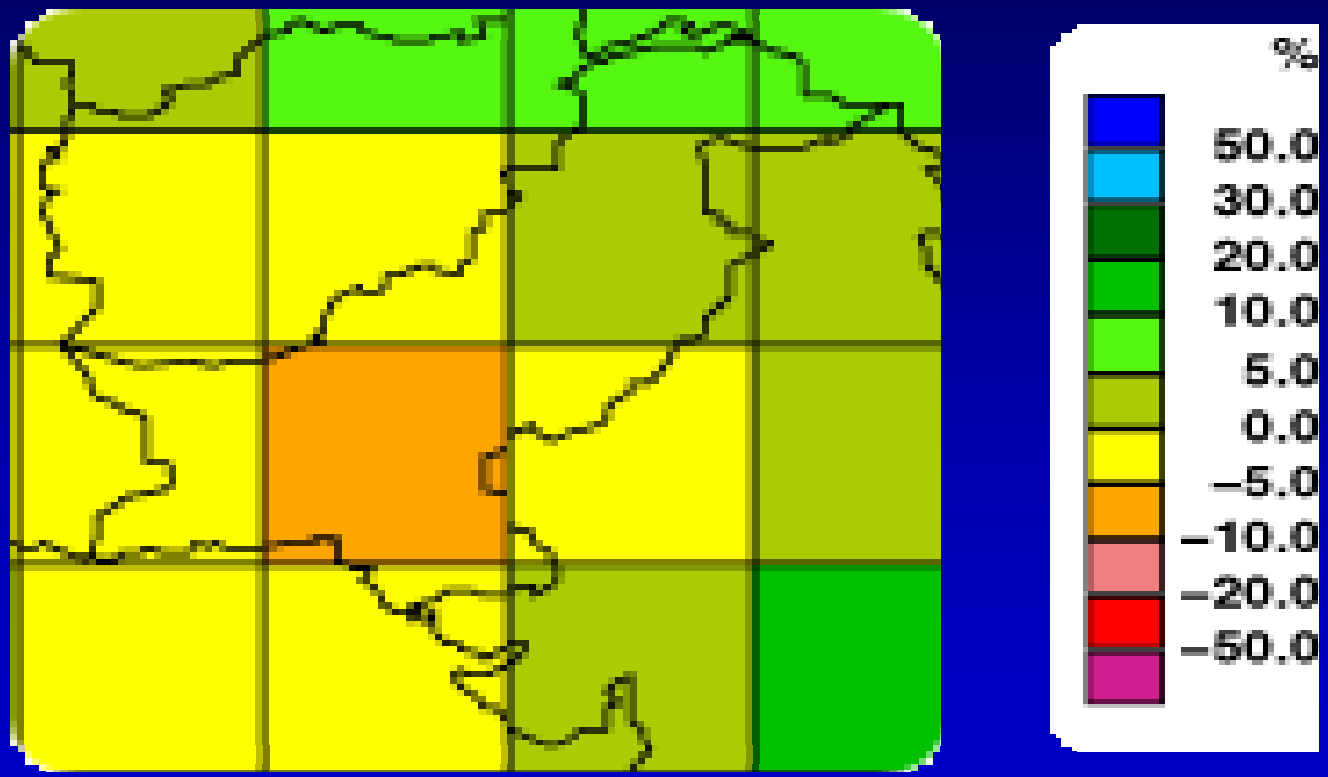
Climate Scenario in 2025

Precipitation Change during Monsoon period



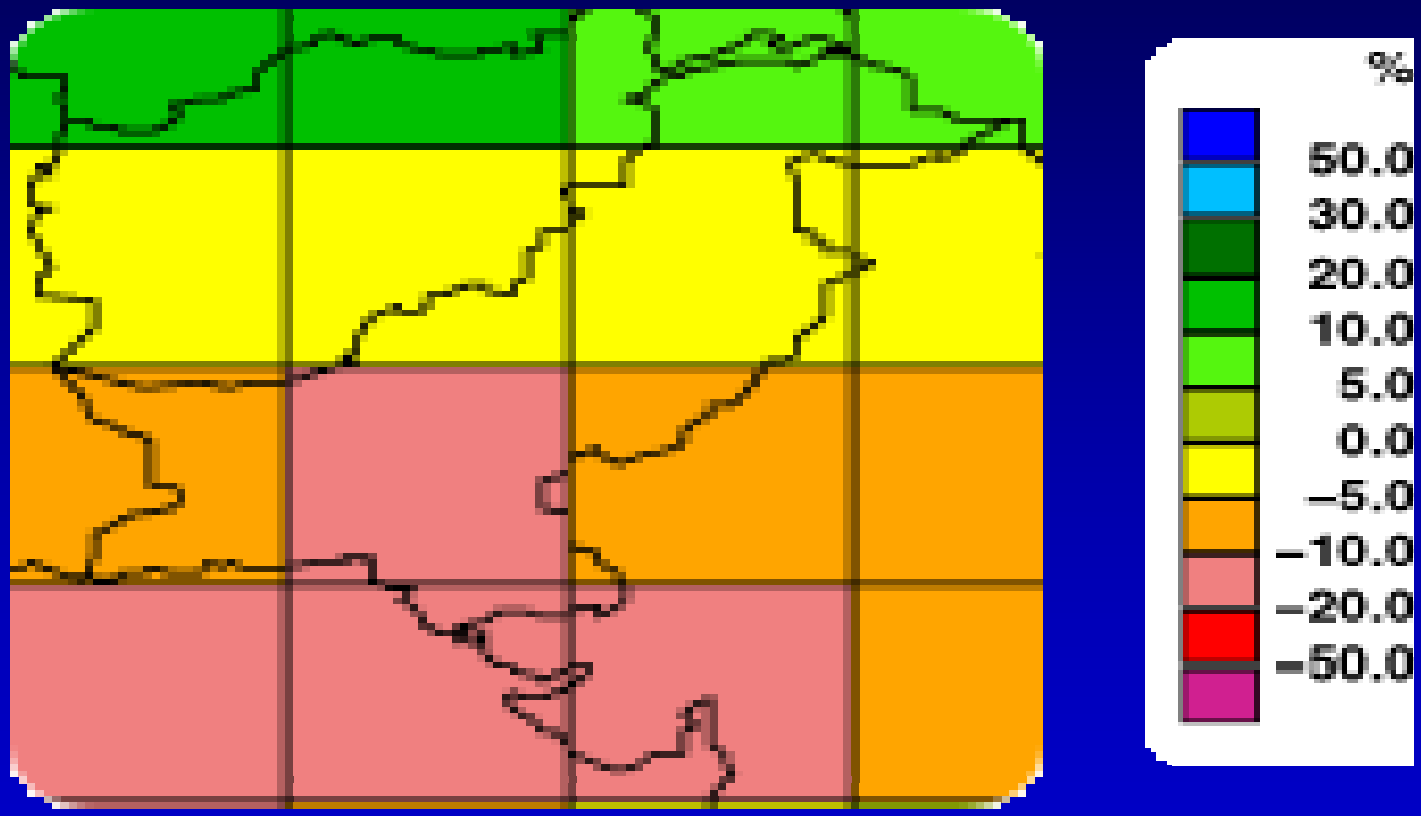
Climate Scenario in 2025

Precipitation Change during Winter period



Climate Scenario in 2025

Precipitation Change during Annual period



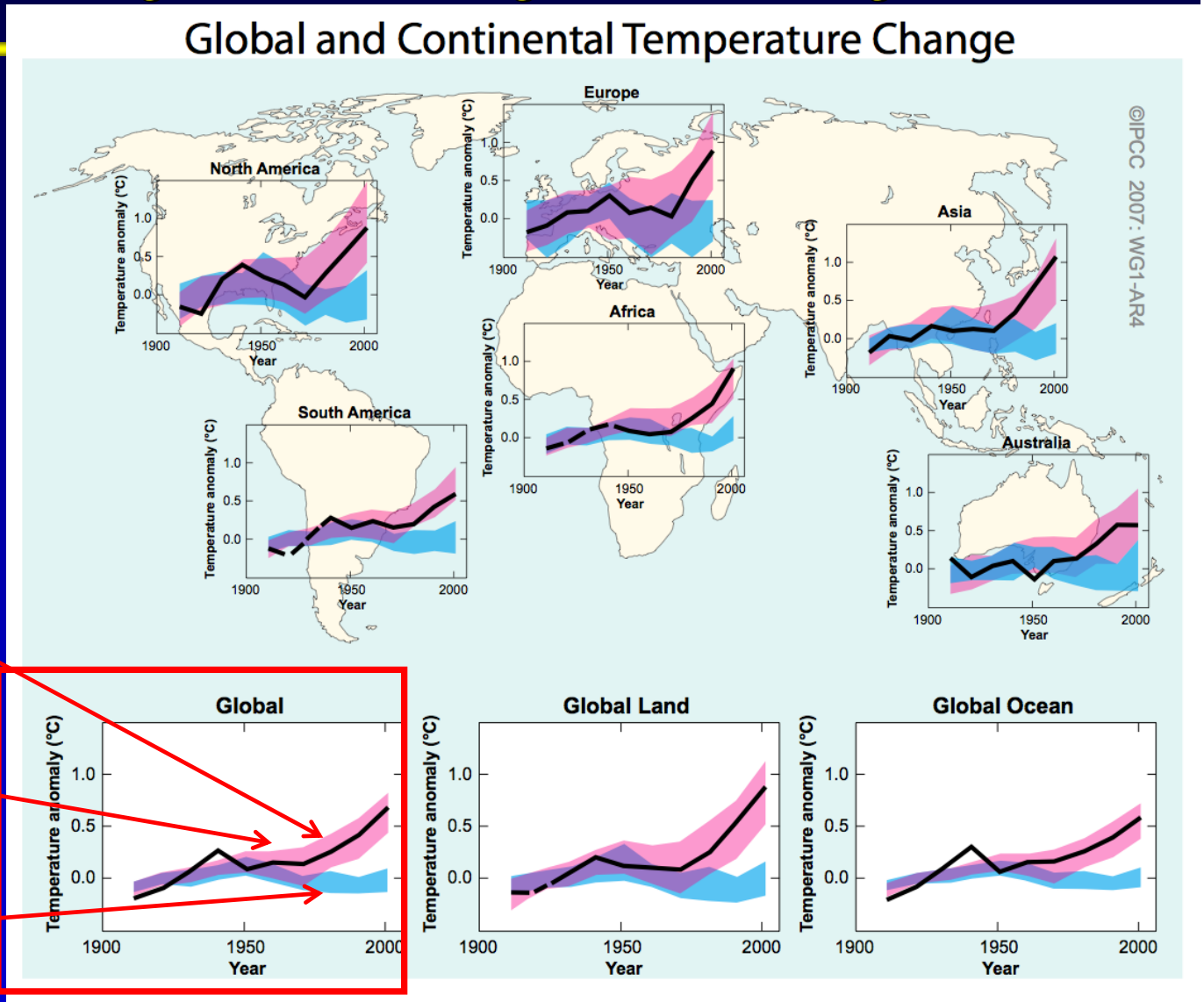
Understanding and Attributing Climate Change

Anthropogenic warming is likely discernible on all inhabited continents

Observed

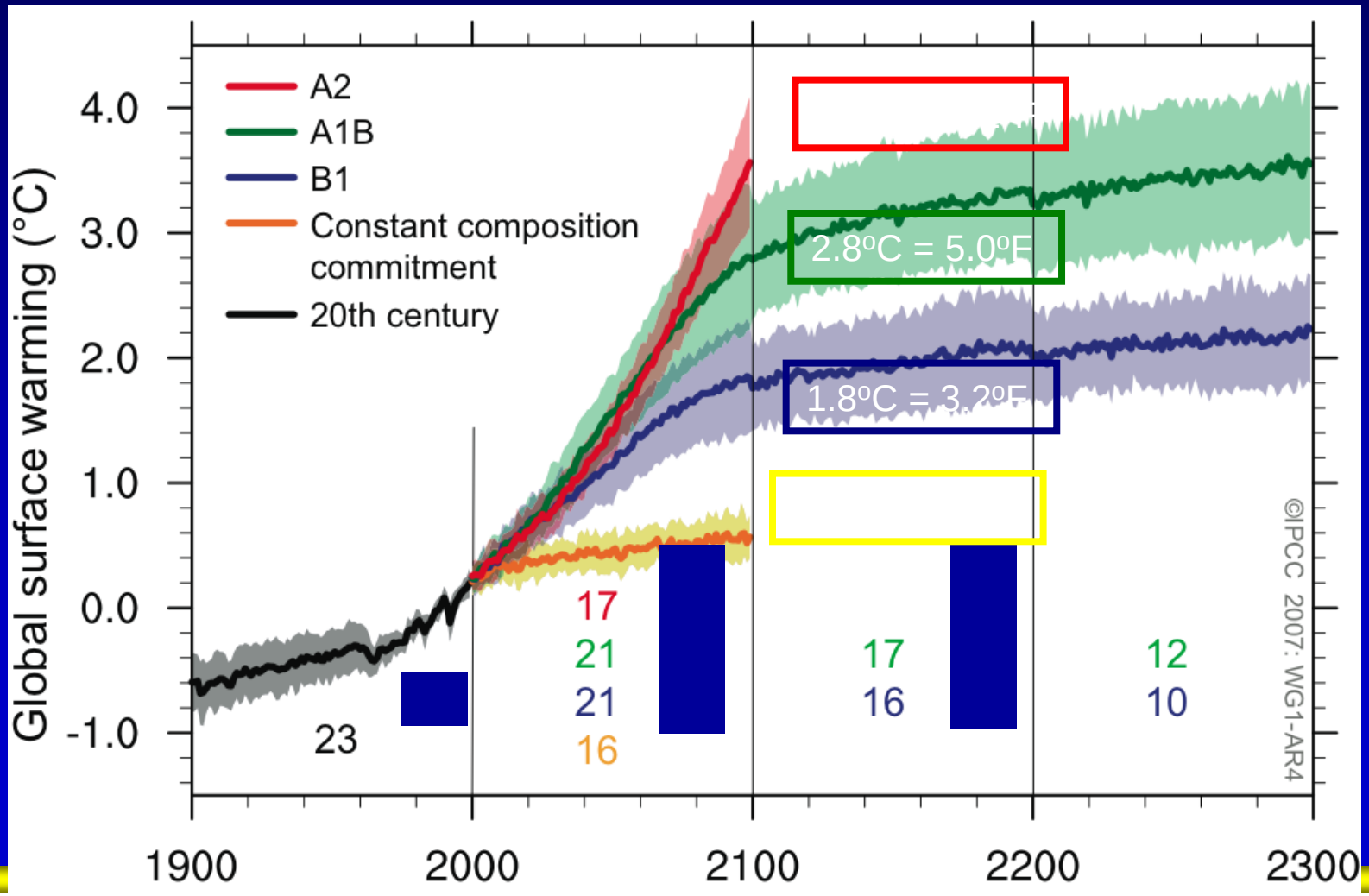
Expected for all forcings

Natural forcing only



What's in the pipeline and what could come

Warming will increase if GHG increase. If GHG were kept fixed at current levels, a committed 0.6°C of further warming would be expected by 2100. More warming would accompany more emission.



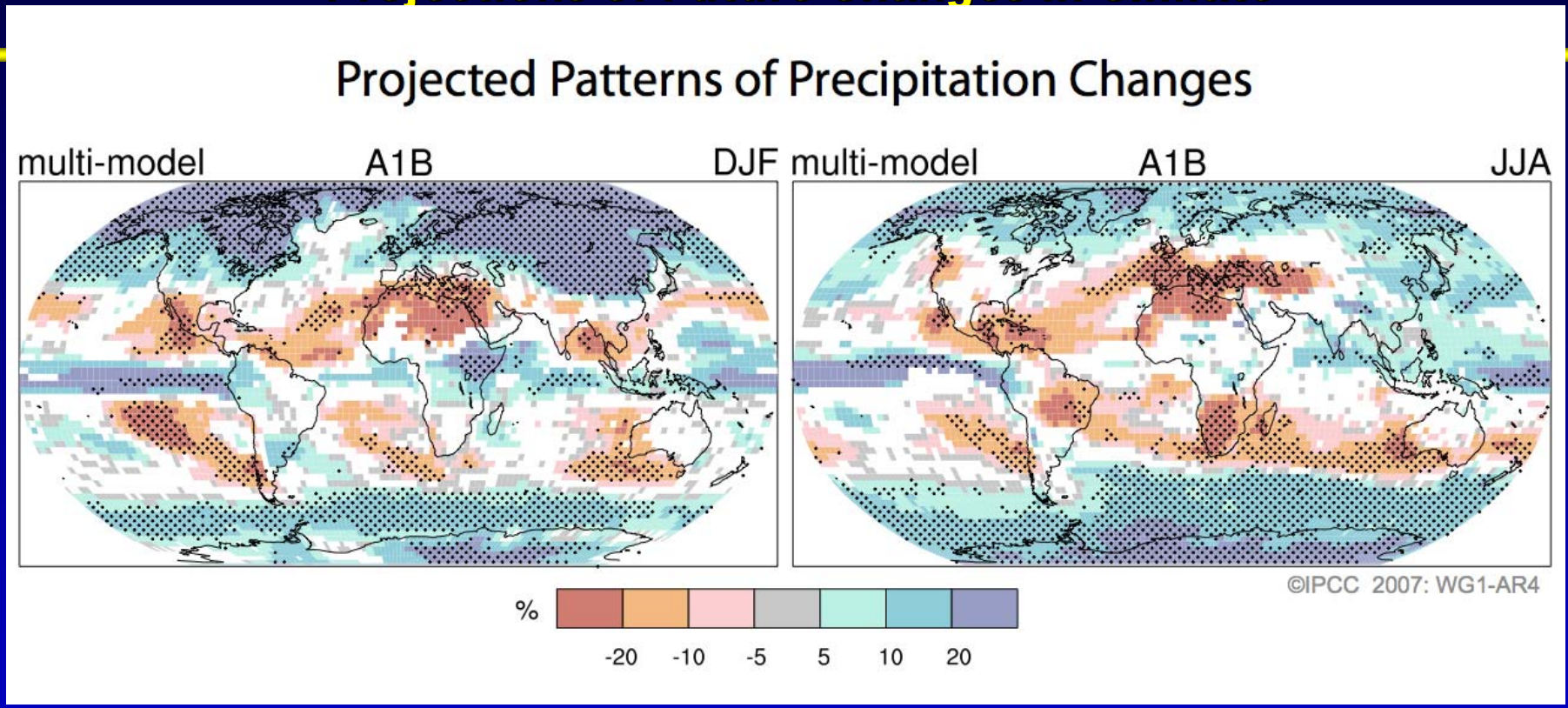
CO2 Eq

850

600

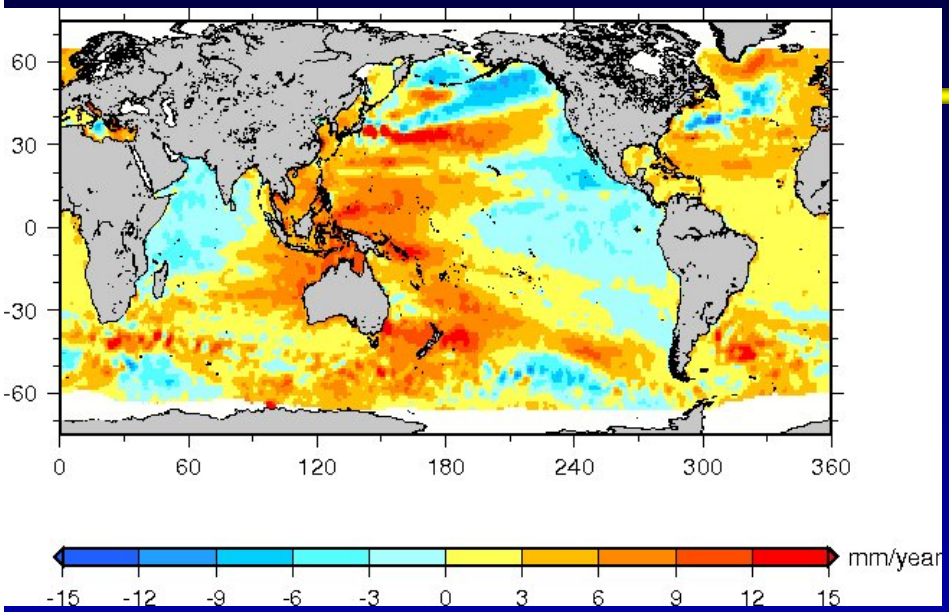
400

Projections of Future Changes in Climate



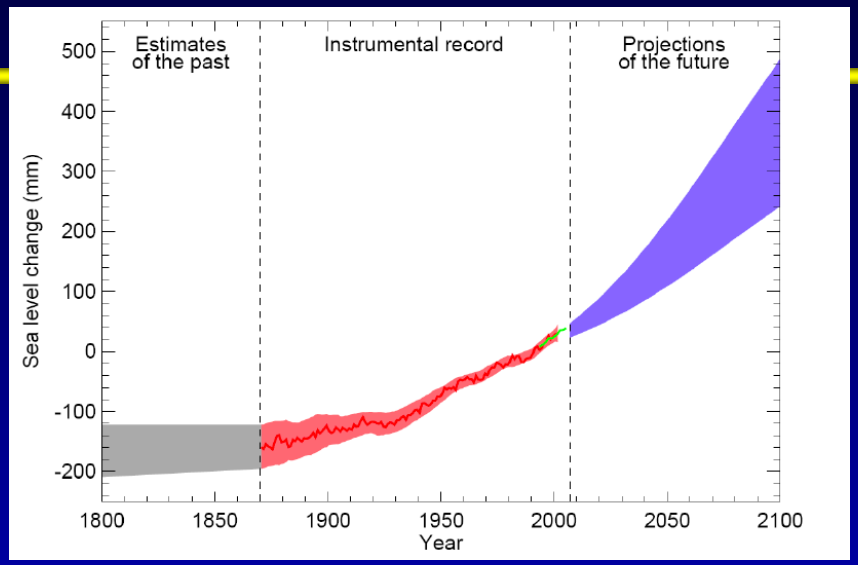
New in AR4: **Drying in much of the subtropics**, more rain in higher latitudes, continuing the broad pattern of rainfall changes already observed.

What else happens in a hotter world?



Observations of sea level rise from satellites, 1993-2003.

The global average SLR for the 20th century was about 6 inches (0.17m), mostly from expansion of the hot ocean, and with contributions from glacier melt (Alaska, Patagonia, Europe….).



Future changes just from these processes could be up to 1.5 feet (0.5 m) by 2100, and up to 3 feet (1 meter) within about 2-3 centuries, depending on how much GHGs are emitted.

But what about other processes? Rapid ice flow?

Sea level rise is one of the surest consequences of a warmer climate.

However, the quantitative answer is elusive. It depends on thermal expansion and melting ice on land, and on instabilities that are difficult to model and predict.

Destabilizing large ice sheets, if it happens, is extremely serious. We don't know yet how likely this is.

So, even with the best-case scenario (with a lot of regulations and incentives by governments) when the CO_2 emissions will decrease, the temperature will still go up and the sea level will still rise.

It can be concluded from these scenarios that climate will change. In some scenarios it will be quite drastic, be still - do we need to care?

What might potential impacts look like? Are we going to suffer?

Science of Global Climate Change

Science of Global Warming

Past & Present Trends

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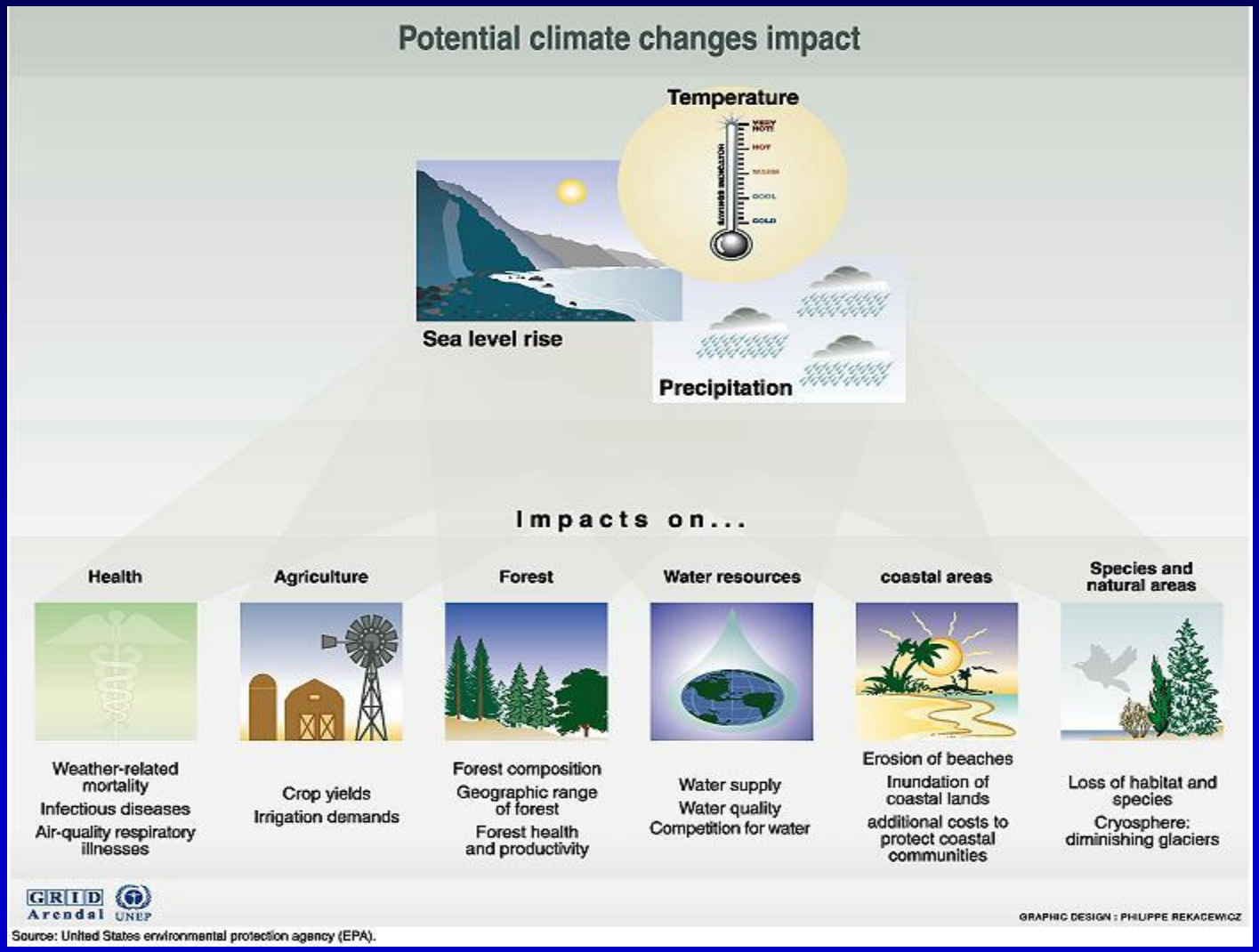
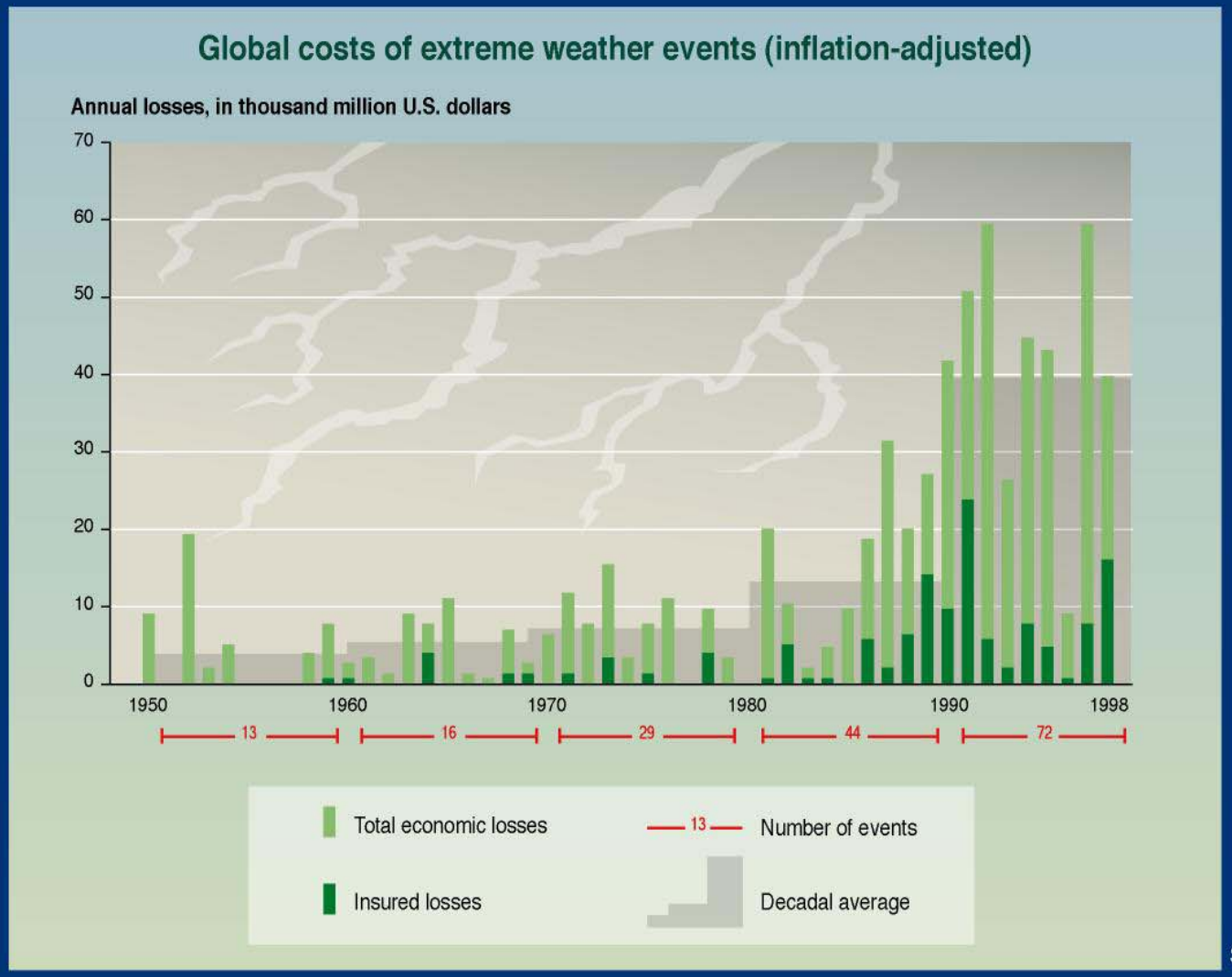
Potential impacts

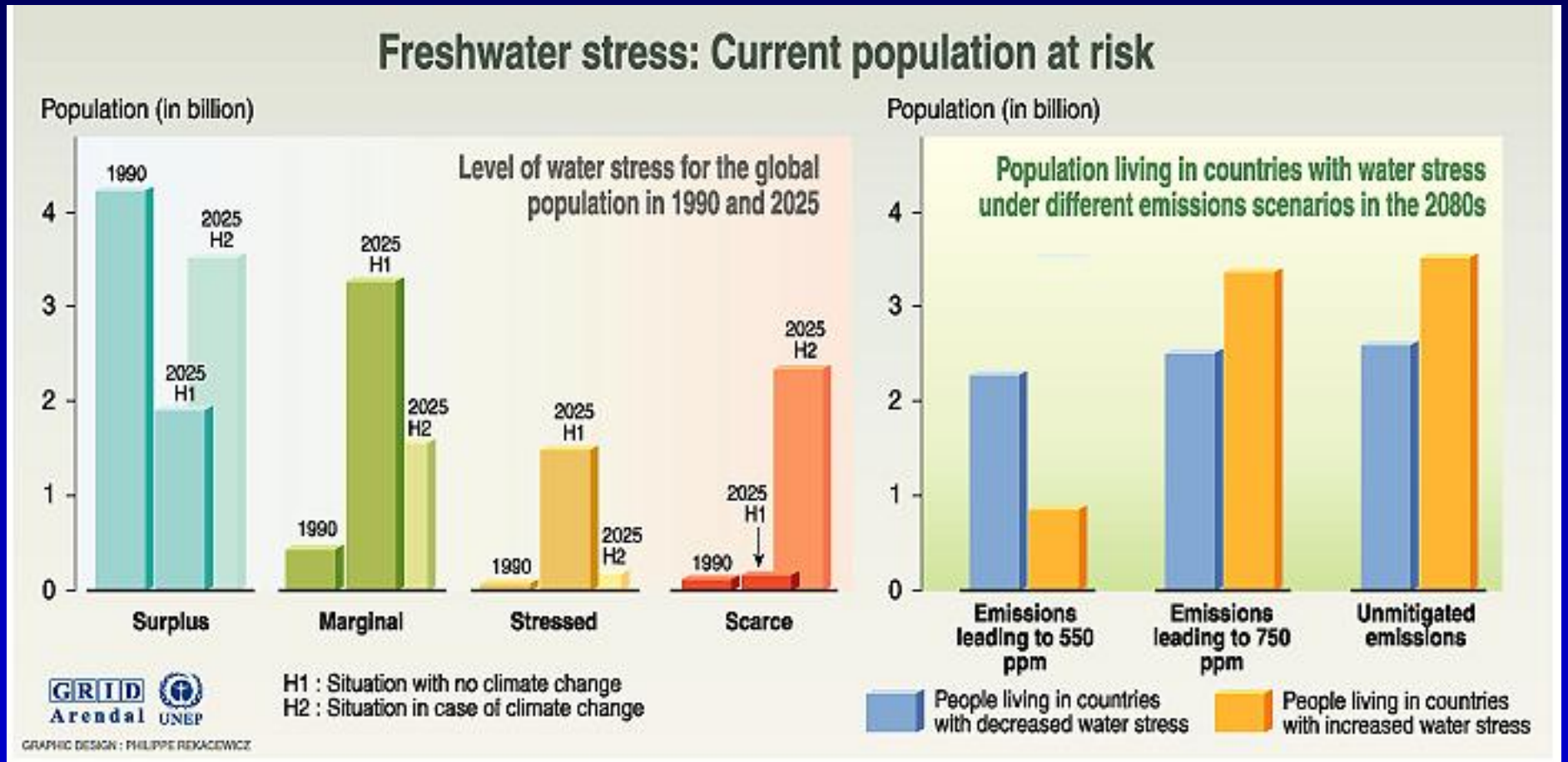


Potential impacts



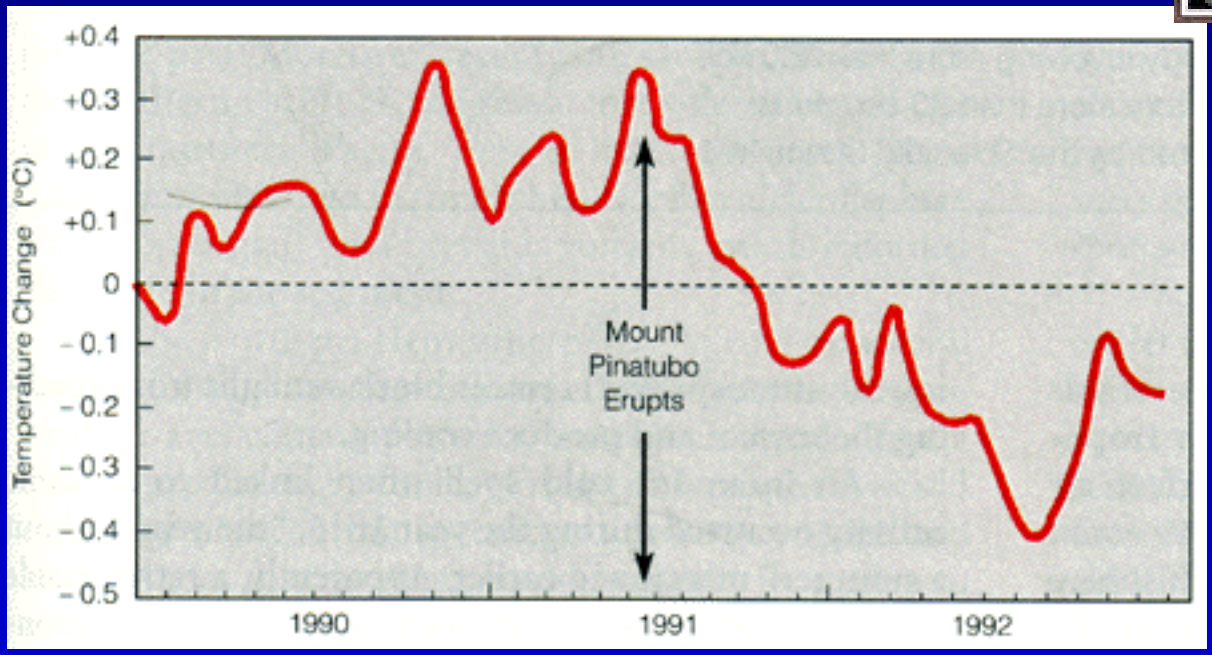
SYR - FIGURE 2-7

Potential impacts



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; Climate change and its impacts, stabilisation of CO2 in the atmosphere, Hadley centre for climate prediction and research,the meteorological office, London, 1999.

Explosive Volcanic Eruptions: Proof of Fast-Response Climate Change Due to Forcing



Changing forcing changes the temperature (and water vapor, etc.).

If volcanoes can cool, then GHG must warm….

Warming is Unequivocal

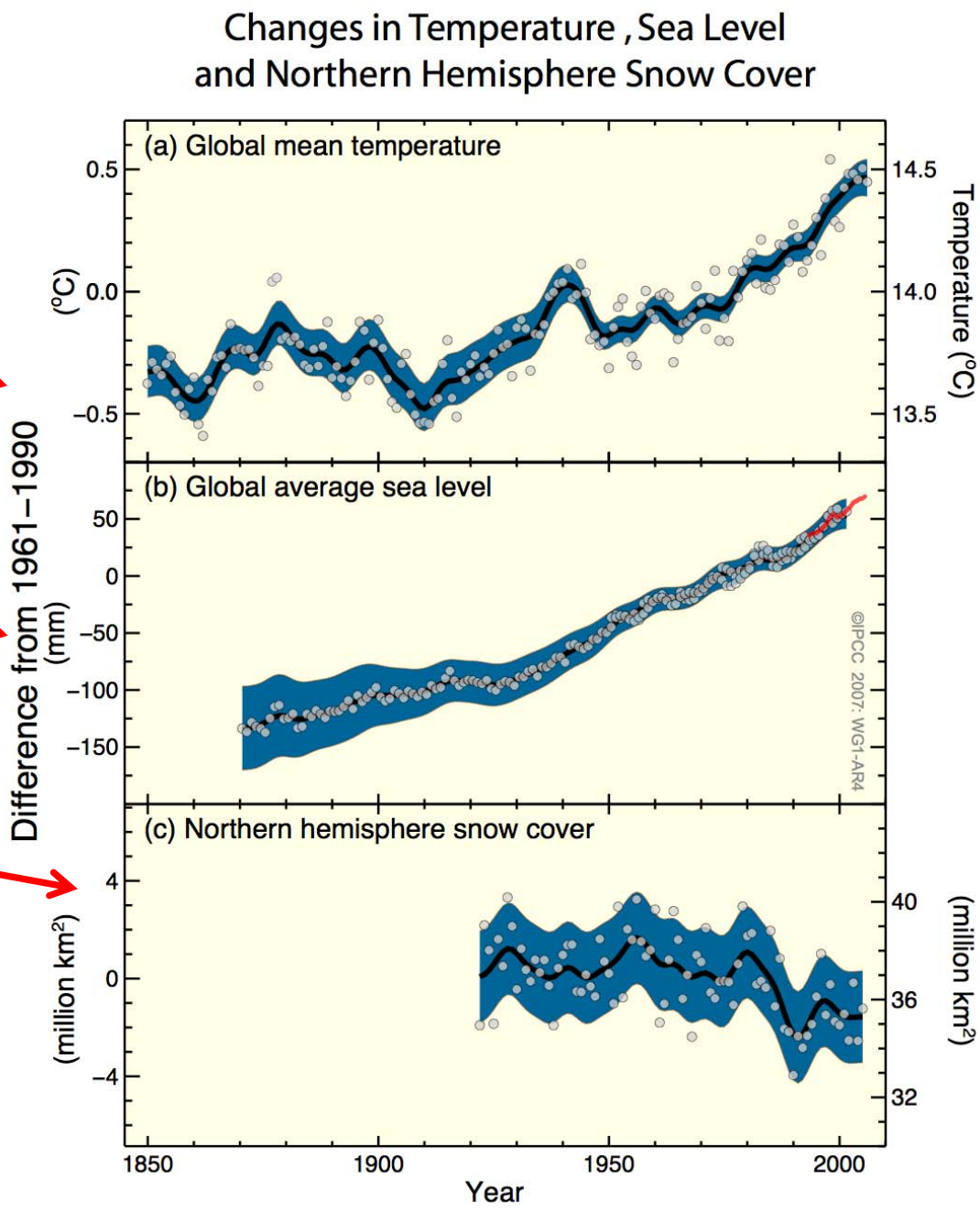
Rising atmospheric temperature

Rising sea level

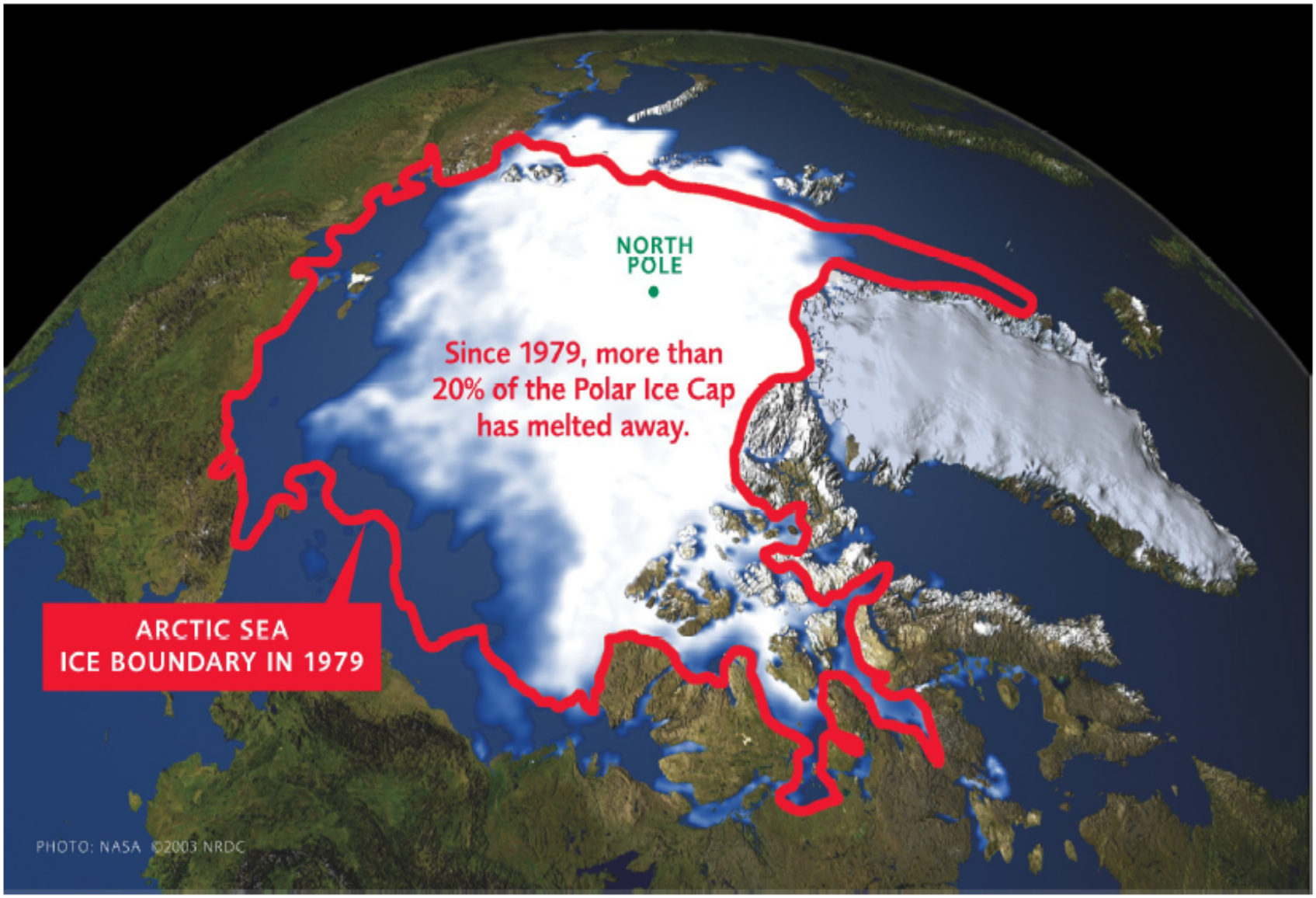
Reductions in NH snow cover

And oceans..

And upper atmosphere….



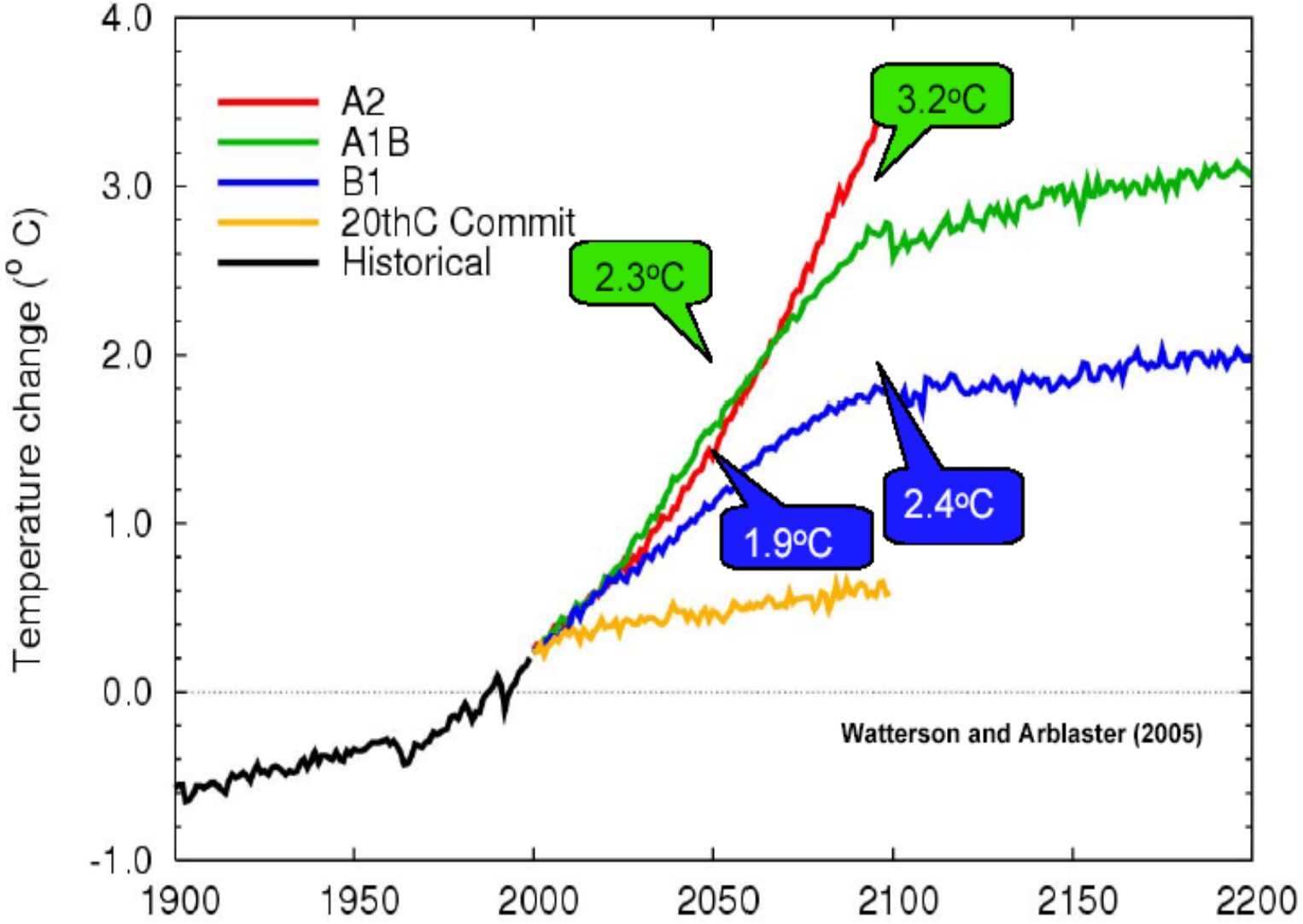
The Earth is de-glaciating



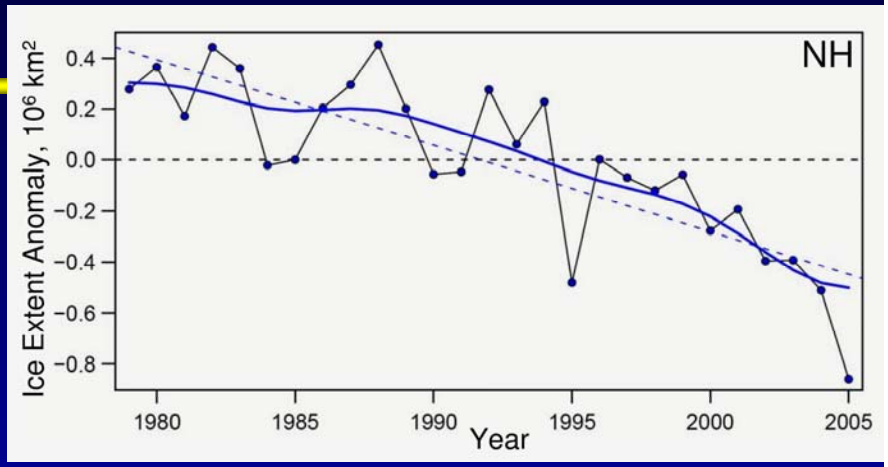
The Earth is de-glaciating

The Earth is de-glaciating

Global warming relative to 1980-1999
17-model average, 4 emission futures



A different world in the Arctic: present and future



The Arctic was also warm in the period 1925-1940, but the extent of warmth was not global at that time.

Large future changes in Arctic sea ice are very likely.

Changes in sea ice don't significantly affect sea level because this ice is already floating. Changes in land ice (glaciers, ice caps, and ice sheets) do affect sea level.

Clear decreases in Arctic sea ice extent.

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Science of Global Warming

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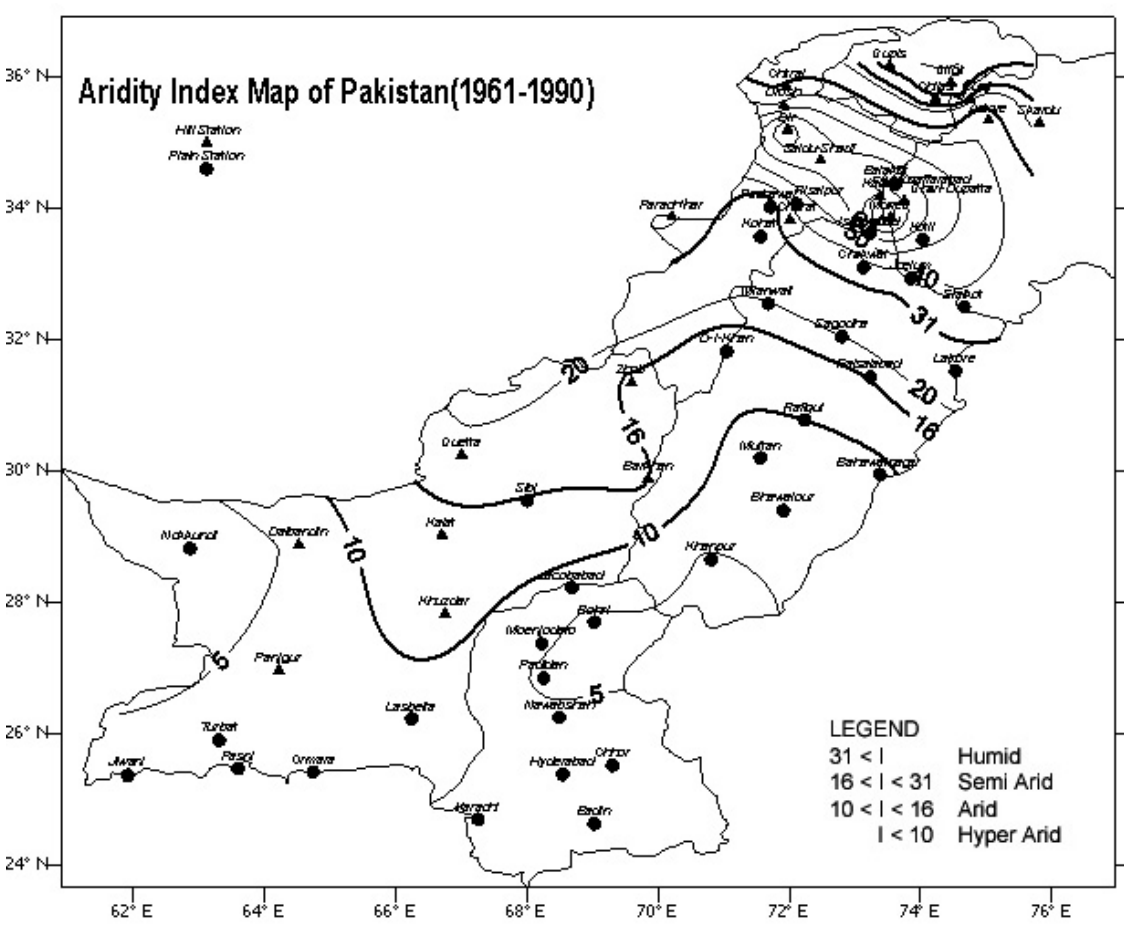
Climate change: complex & interdisciplinary

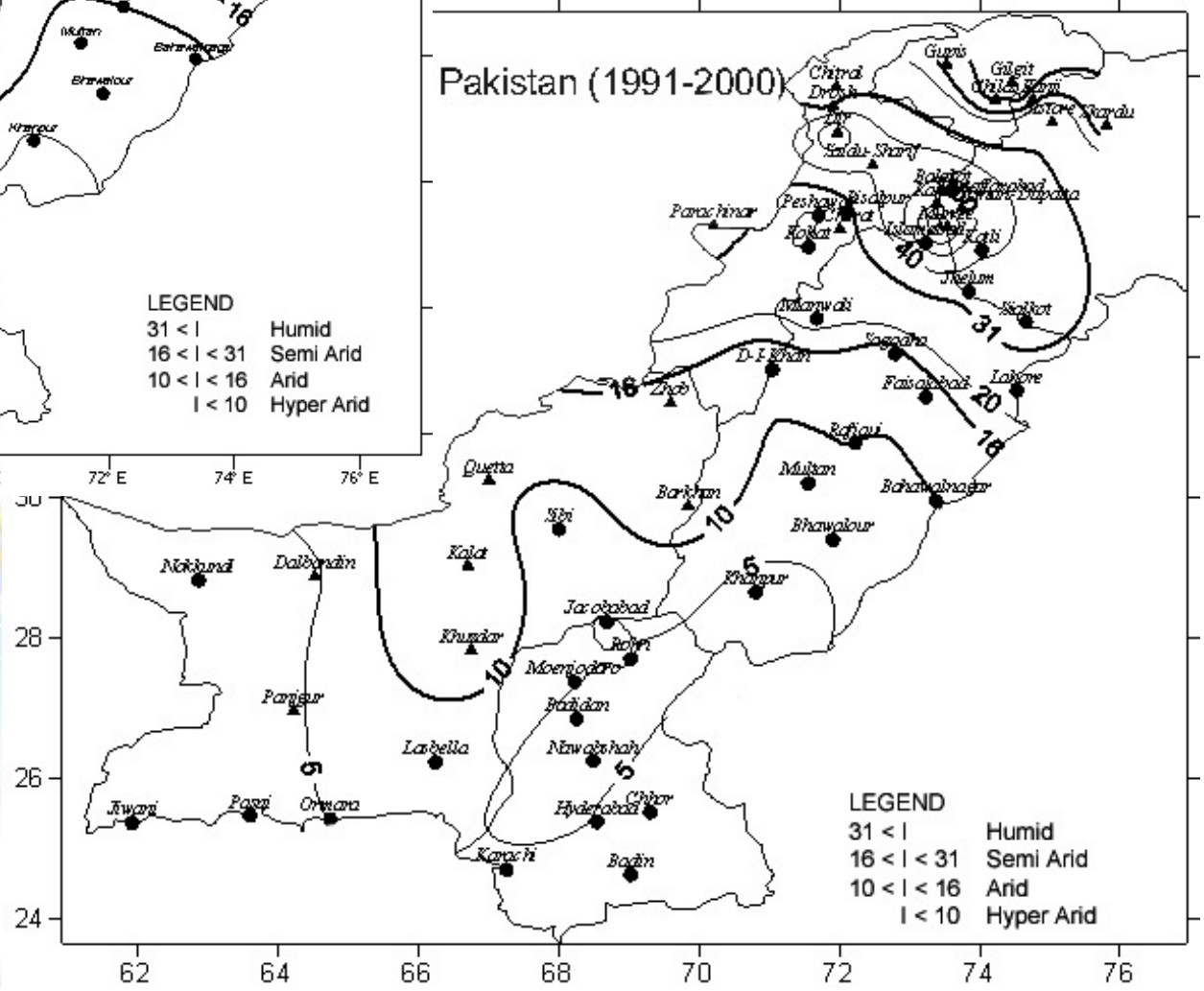
- Global climate change is the most dangerous environmental problem humans have ever created.
- It is also the most difficult environmental problem humans have ever created.
- But there is much that individuals, firms, & governments can do to reduce the danger.

CLIMATE CHANGE

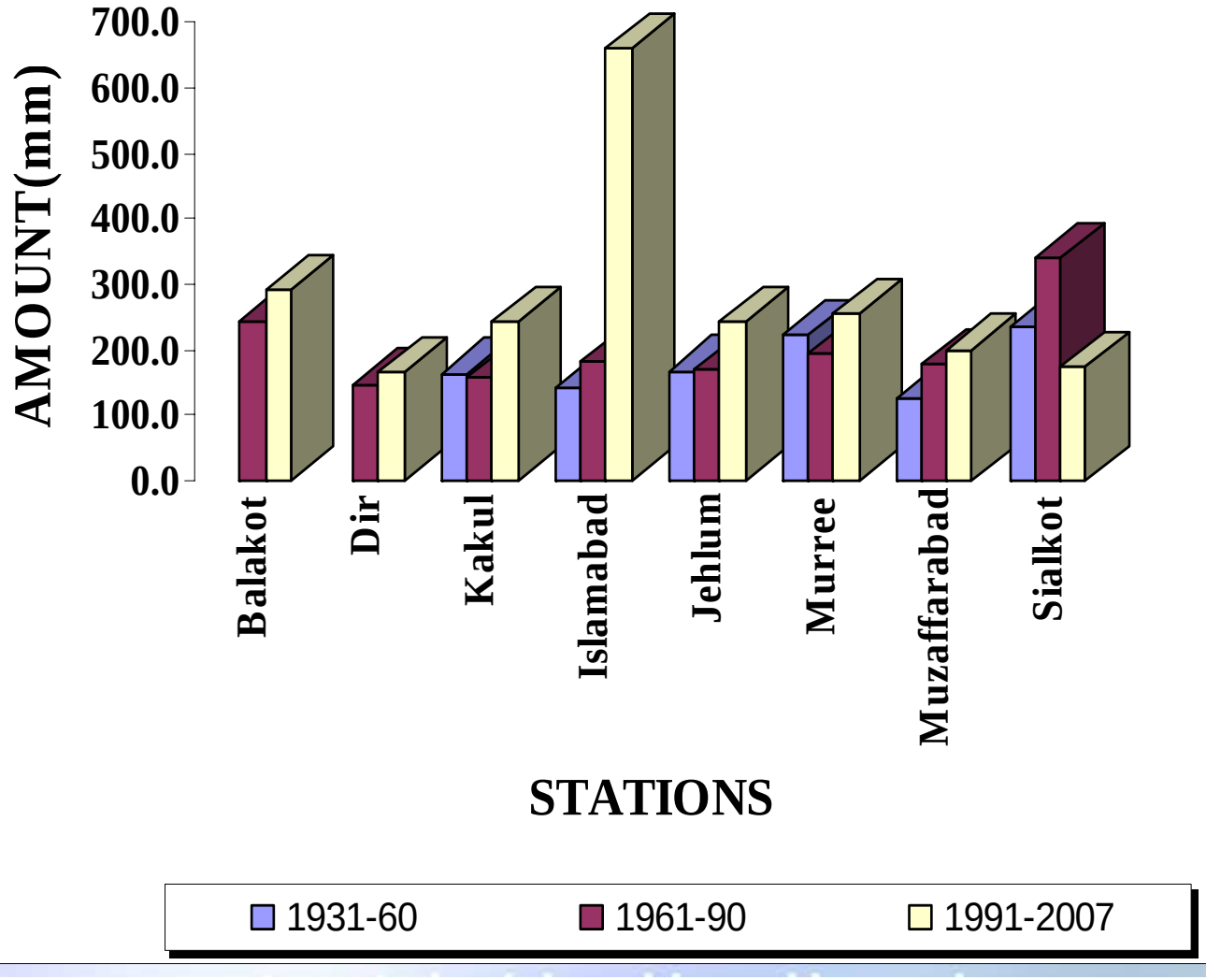
Precipitation Changes 1951-2000

Precipitation Changes	On annual basis	Monsoon Season (Jun – Sep)	Winter Season (Dec – Mar)
Coastal areas	Negative	Negative	Positive
Quetta region & SE Sindh	Positive	Positive	Positive
Western Balochistan around Nokkundi	Negative	Negative	Negative
Monsoon belt	Positive	Positive	Mostly positive
Northern Mountains	Positive	Positive	Negative

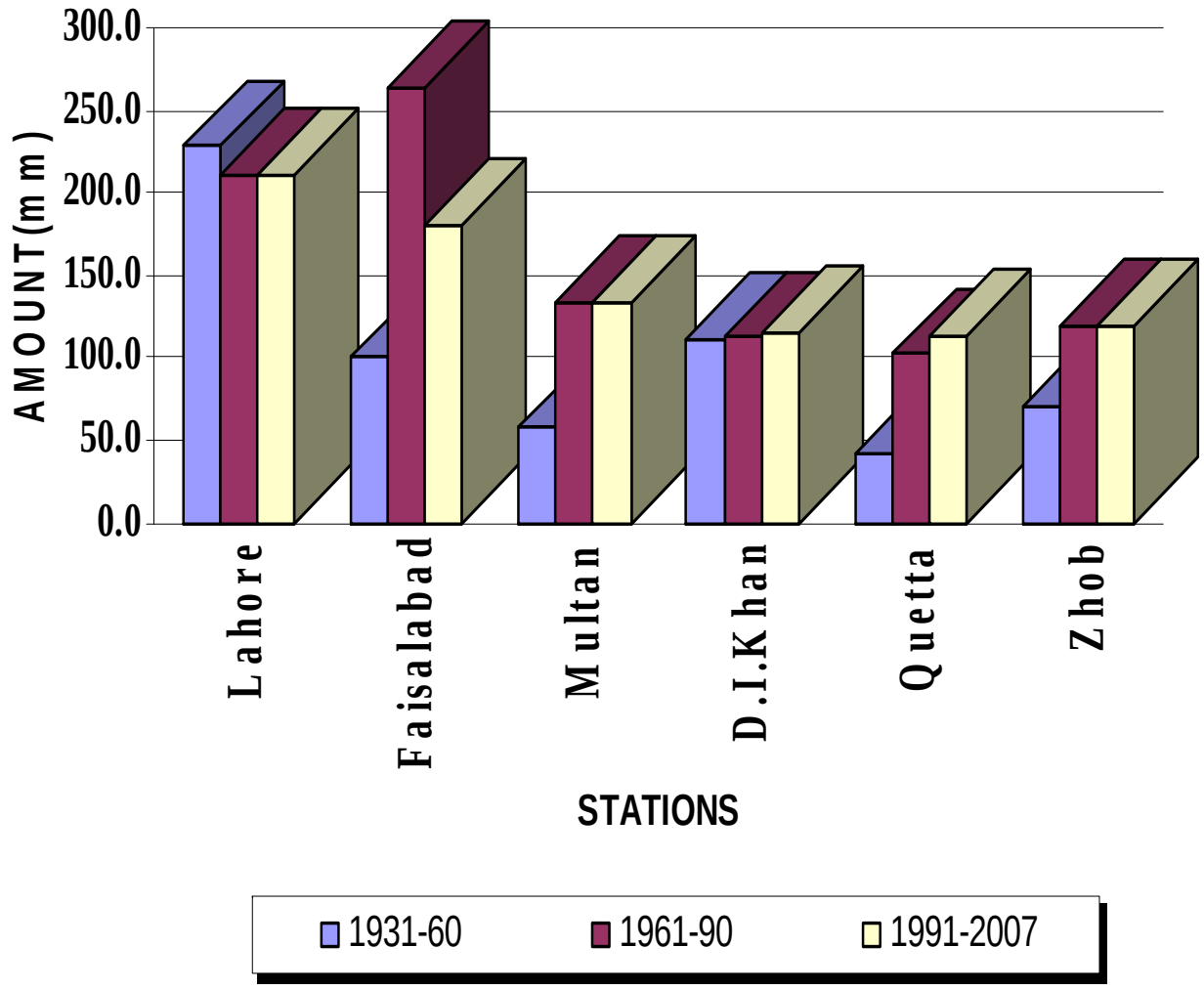

Aridity Index Map of Pakistan(1961-1990)
Hill Station
Plain Station
LEGEND
31 < I Humid
16 < I < 31 Semi Arid
10 < I < 16 Arid
I < 10 Hyper Arid


Pakistan (1991-2000)
LEGEND
31 < I Humid
16 < I < 31 Semi Arid
10 < I < 16 Arid
I < 10 Hyper Arid

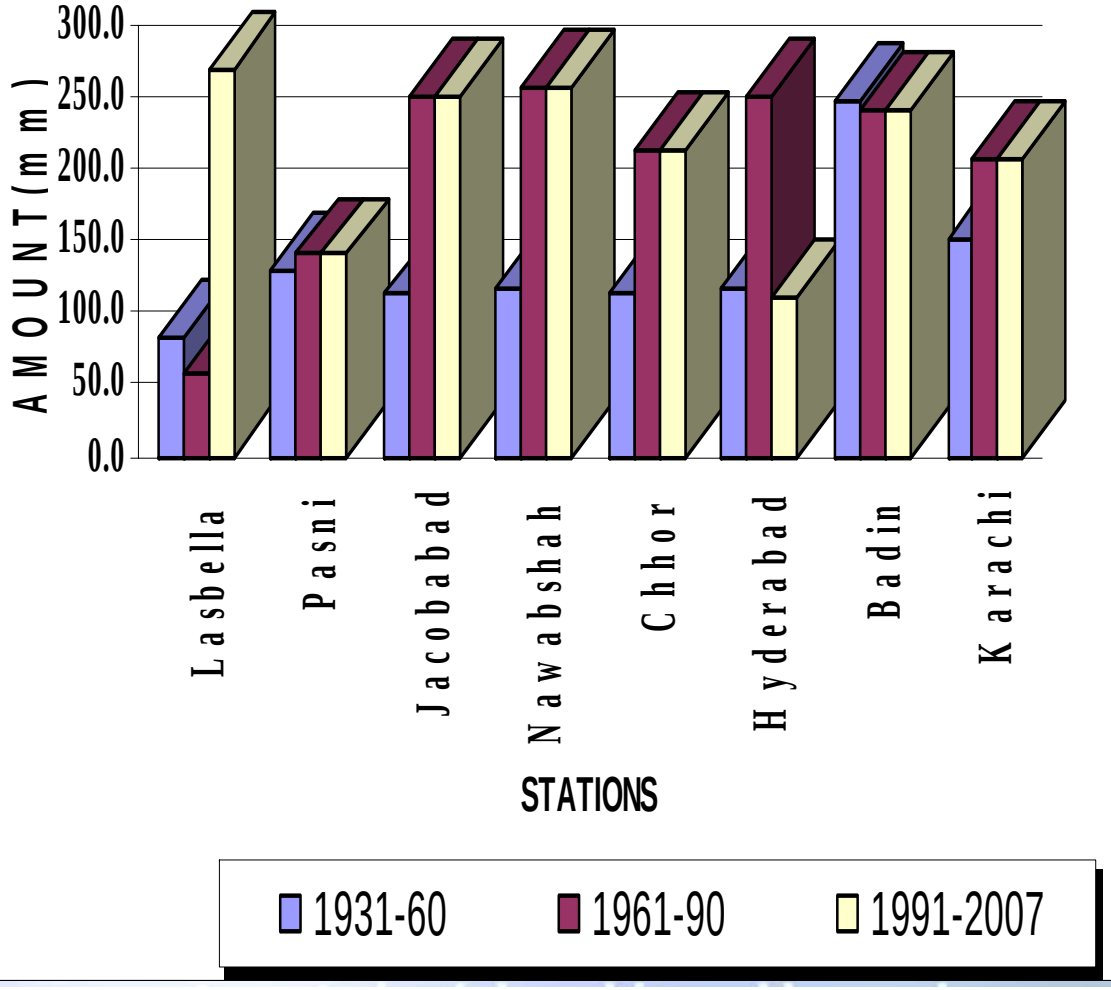
Maximum daily precipitation (mm) trend in northern parts of Pakistan from 1931-2007



Maximum daily precipitation (mm) trend in Central parts of Pakistan from 1931-2007



Maximum daily precipitation (mm) trend in Southern parts of Pakistan from 1931-2007



Impact of ENSO on hydro-meteorological resources of country

Over the closing decades of the twentieth century, the term ENSO has become synonymous with social, economic and environmental crises in many parts of the globe.

ENSO signals a major departure from the normal climate patterns, particularly those affecting tropical regions.

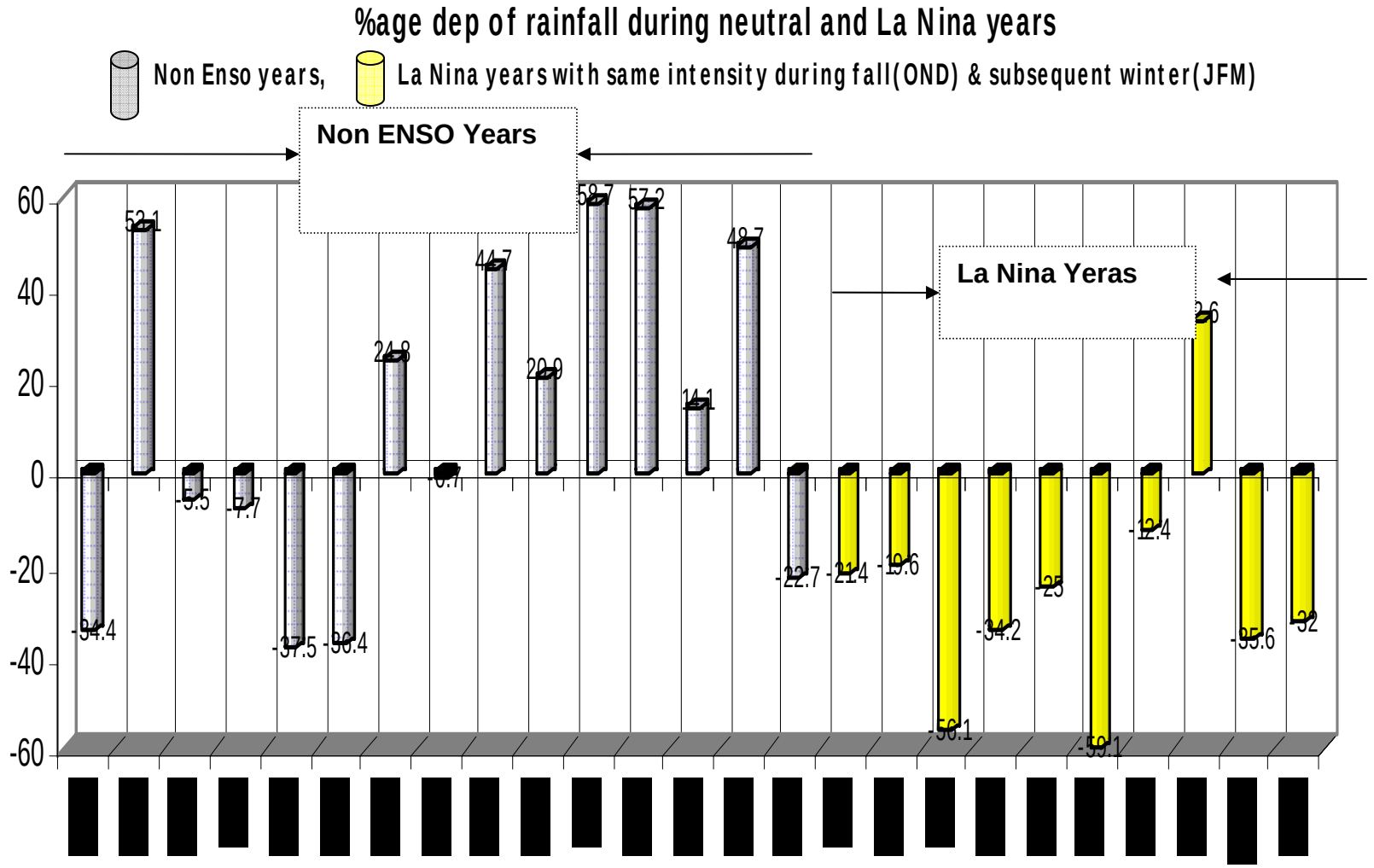
Impact of ENSO on hydro-meteorological resources of country

Analysis of all Pakistan Monsoon Rainfall depicts that;

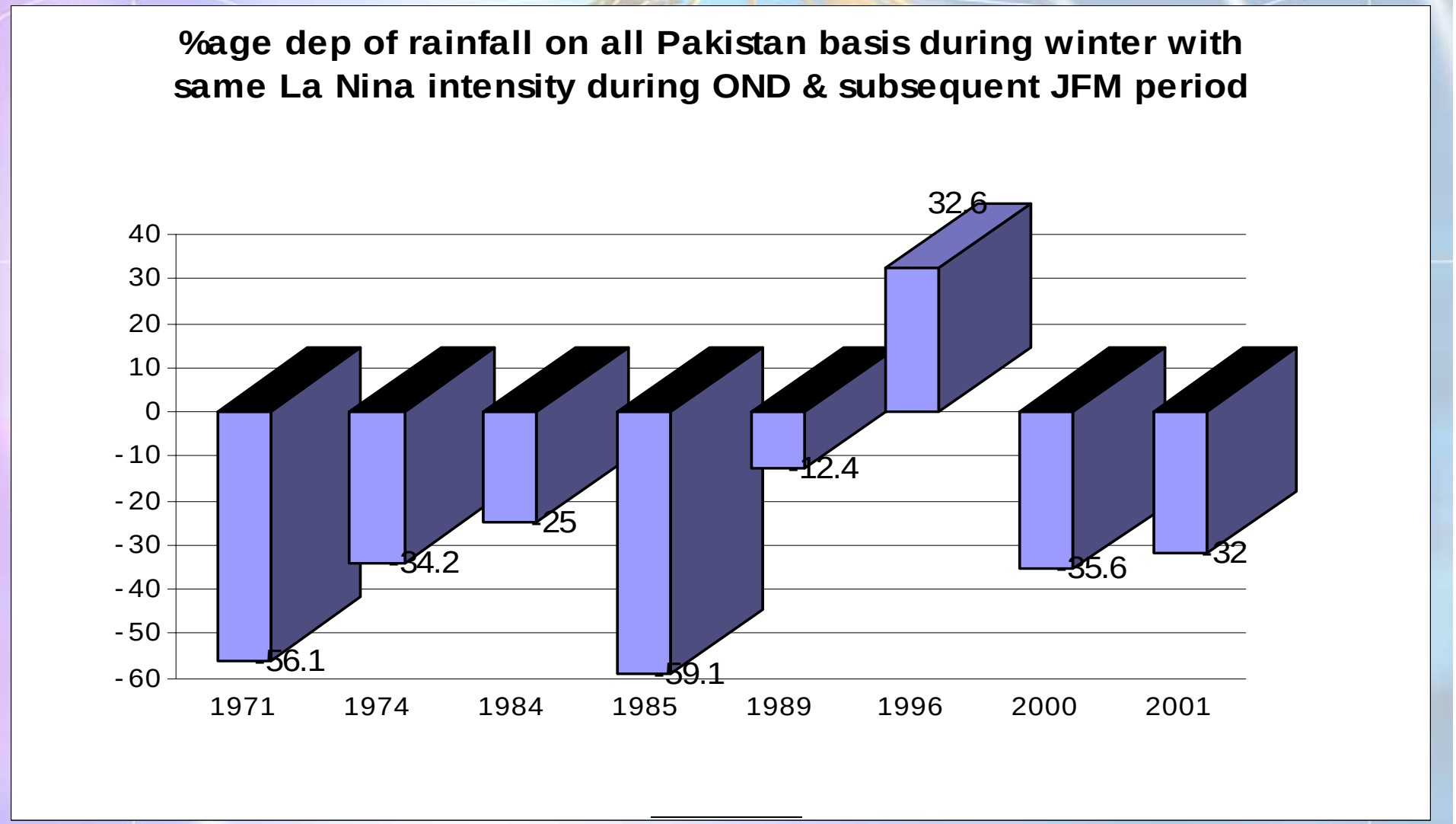
During the 8 strong El Nino events identified during the last 100 years period, monsoon rainfall was largely deficit in all the cases.

In the case of moderate/weak El Nino events also, the rainfall is generally normal/below normal on most of the occasions except on one to two occasions.

Impact of ENSO on hydro-meteorological resources of country

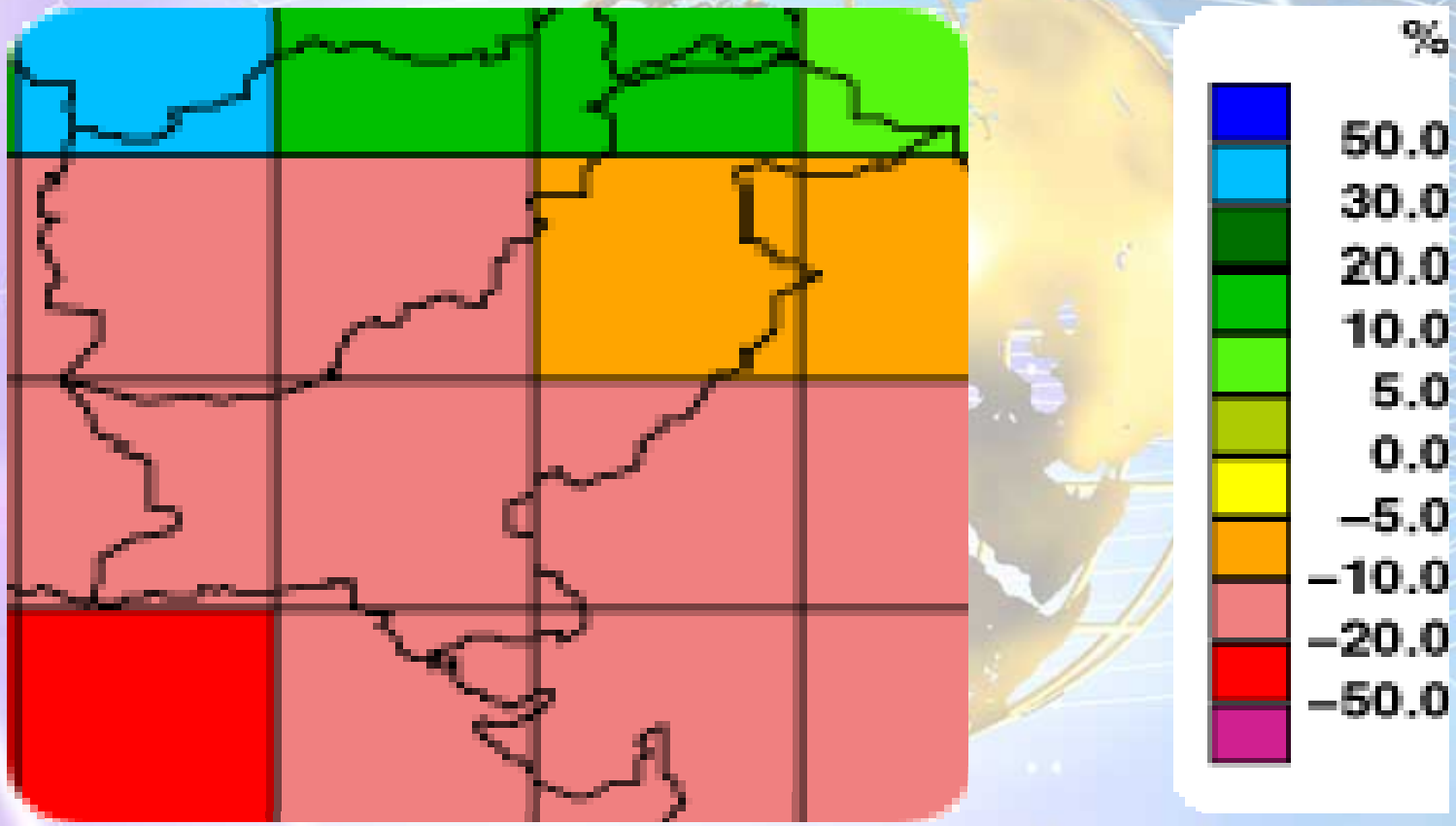


Impact of ENSO on hydro-meteorological resources of country



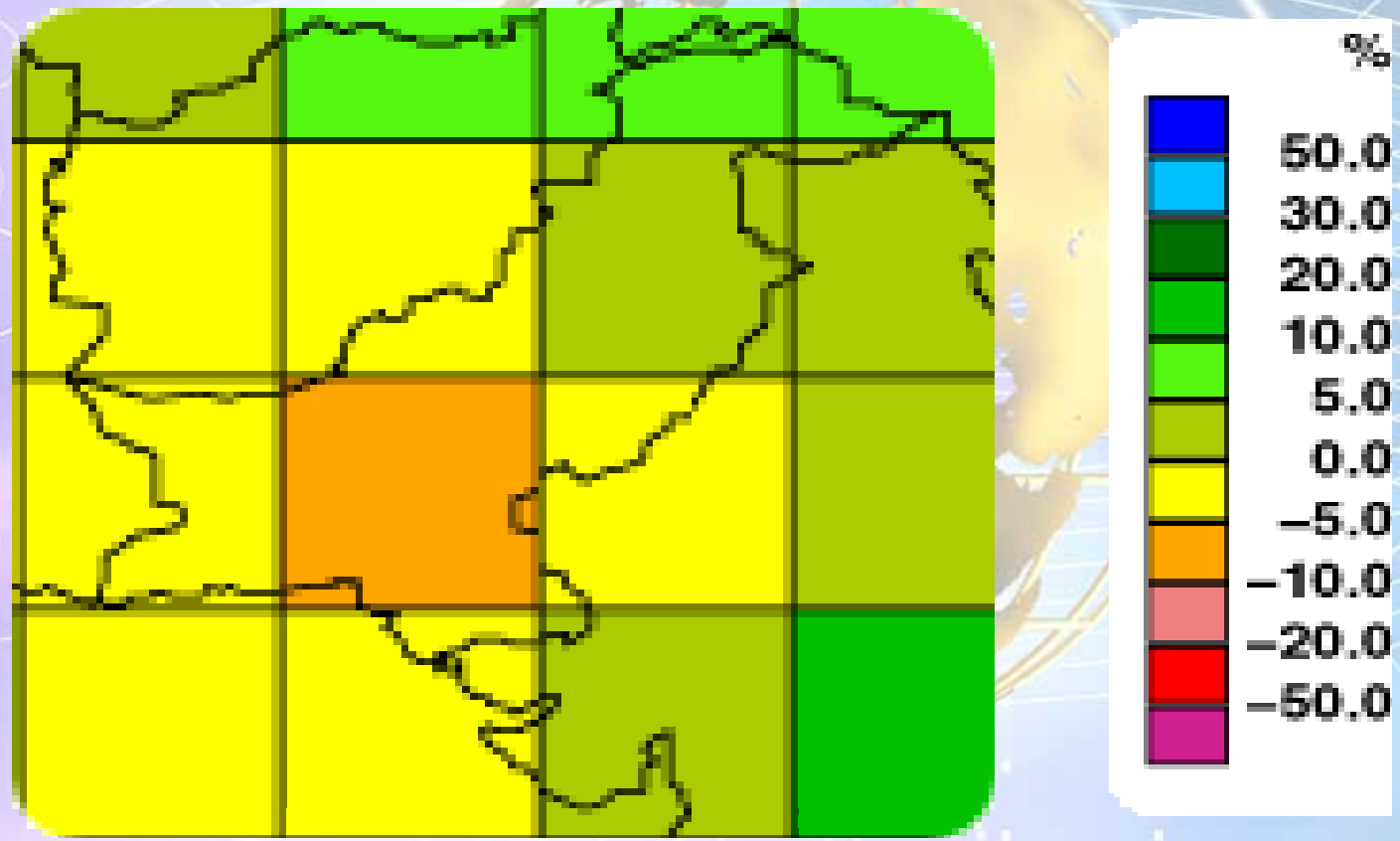
Climate Scenario in 2025

Precipitation Change during Monsoon period



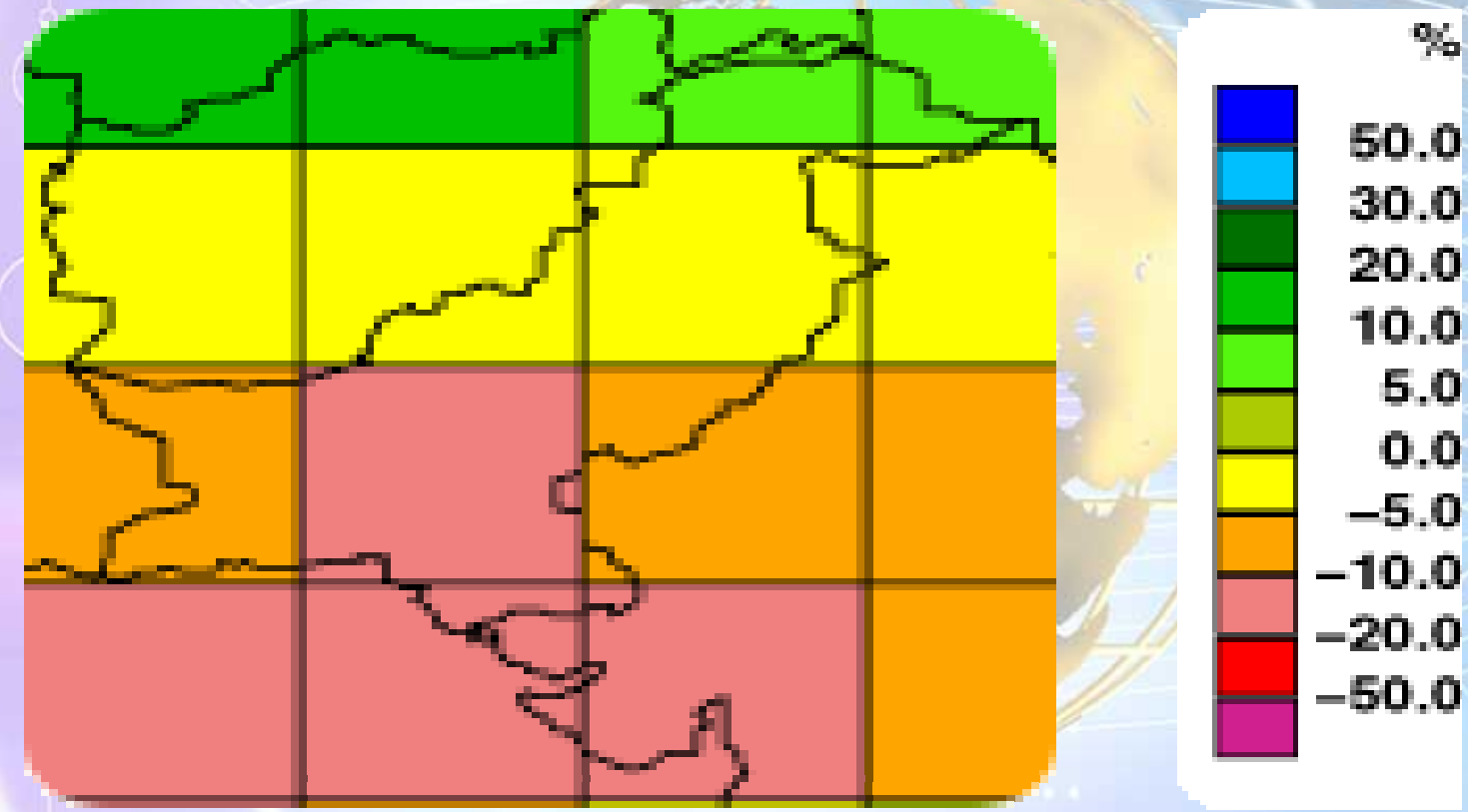
Climate Scenario in 2025

Precipitation Change during Winter period



Climate Scenario in 2025

Precipitation Change on Annual basis



RCM's Projection

Temperature Projections are nearly same as per GCMs out based on Hadley's Centre Model HadCAM2

However RCMs analysis depicts a bit different results in relation to precipitation.

Southeast Sindh and Cholistan depicts a positive change during next half century on annual basis

Relationship between inflows and rainfall pattern in catchments areas

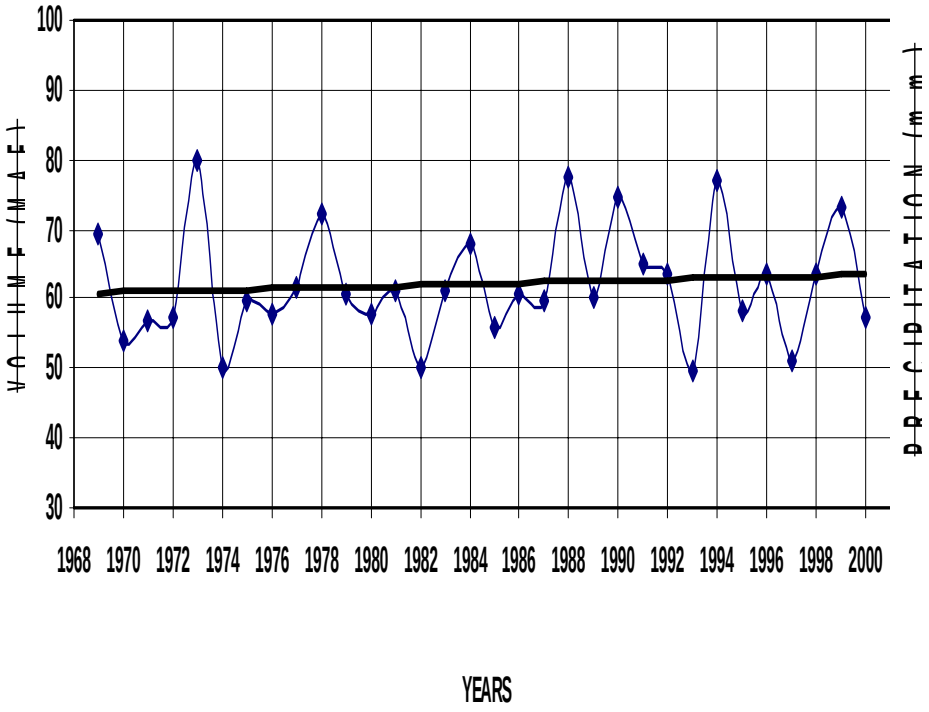
Analysis of Data shows a direct relationship between precipitation and inflows.

However during drier and warm winter months, inflows show a negitive trend

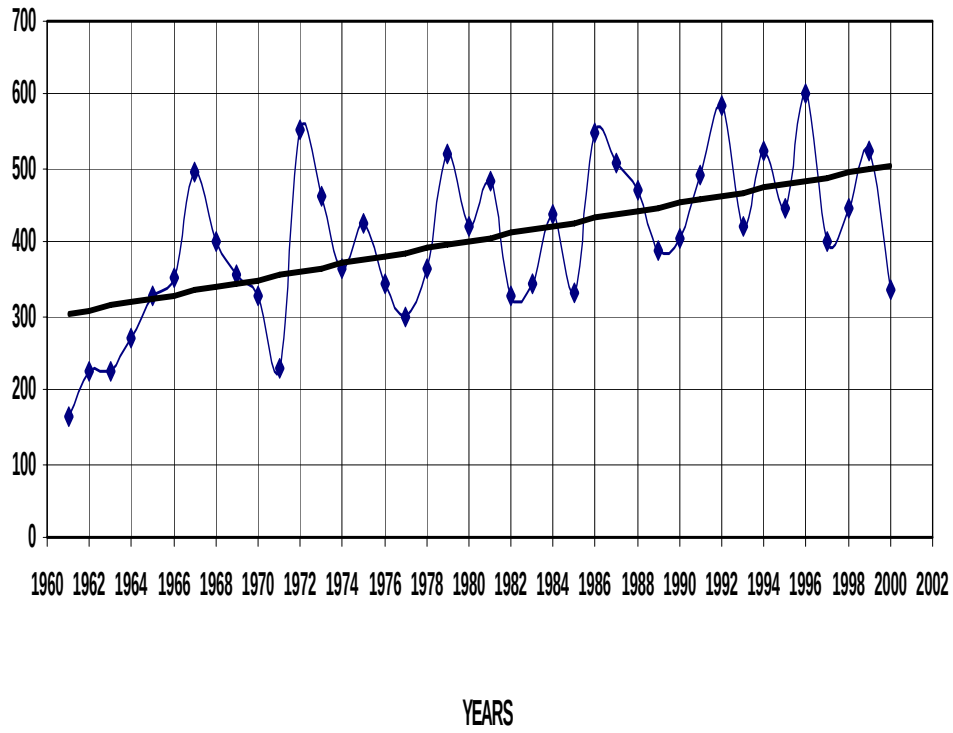
This indicates that glacier melt contribution is diminished, and the basins have entered a potentially long-term trend of declining flows.

Relationship between inflows and rainfall pattern in catchments areas

WATER FLOW AT QILA BESHAM



RAINFALL PATTERN IN NORTHERN AREAS DURING (1961-2000)



Pakistan Meteorological Department

IMPACT ON WATER RESOURCES AND ECONOMY

- Less snowfall, slow deposits & glacierization
- Reduced river flows
- Reduction in storage of water in dams
- Less rainfall in arid areas, prolonged droughts

IMPACT ON WATER RESOURCES AND AGRICULTURE

- Extreme weather events pose serious threat to Agriculture productivity.

- Farmer are more concerned to extreme events. They realize that not the 364 days of normal weather that scares them, but the one day of flash flooding.

Evidence of Climate Change in Recent Past

1992	**History's worst floods in Jhelum river in Pakistan**
1996	**Severe urban storm flooding in Lahore, Pakistan due to 500 mm rainfall in 24 hours on 20th July**
1998	**Dokriani glacier in Himalayas, India retreated at a record pace. The glacier retreated 66 feet in 1998 despite severe winter.**

Evidence of Climate Change in Recent Past

1998	**The Gangorti glacier is retreating 98 feet per year. At this rate scientists predict the loss of all central and eastern Himalayan glaciers by 2035**
1999	**Severe Cyclonic Storm hit the coastal areas of Pakistan and India**
1998-2001	**History's worst drought in Pakistan**
2001	**621 mm rainfall in Islamabad during 10 hours in the month of July causing history's worst flash floods in twin cities**

Evidence of Climate Change in Recent Past

Feb 2003	**On 17th Feb, four to five inches of rain fell in Hyderabad region. The storms acted like a mini tornado and damaged infrastructure. 9 people were reported dead.**
Feb 2003	**On 19th Feb, 2 to 4 inches of rain associated with a suction vortex affected eastern Punjab which uprooted trees & electric poles, threw away heavy equipment**
July 2003	**Hundreds of villages of lower Sindh were affected by flash floods.**

Evidence of Climate Change in Recent Past

Winter 2005	**Record heavy snowfall in northern areas caused havoc and resulted in loss of lives and damage to property.** **Also heavy rains in Balochistan caused flash flooding and damage to properties and loss of lives.** **More than 5 million people affected and 832 people died due to extreme weather conditions.**

IMPACT ON WATER RESOURCES AND AGRICULTURE

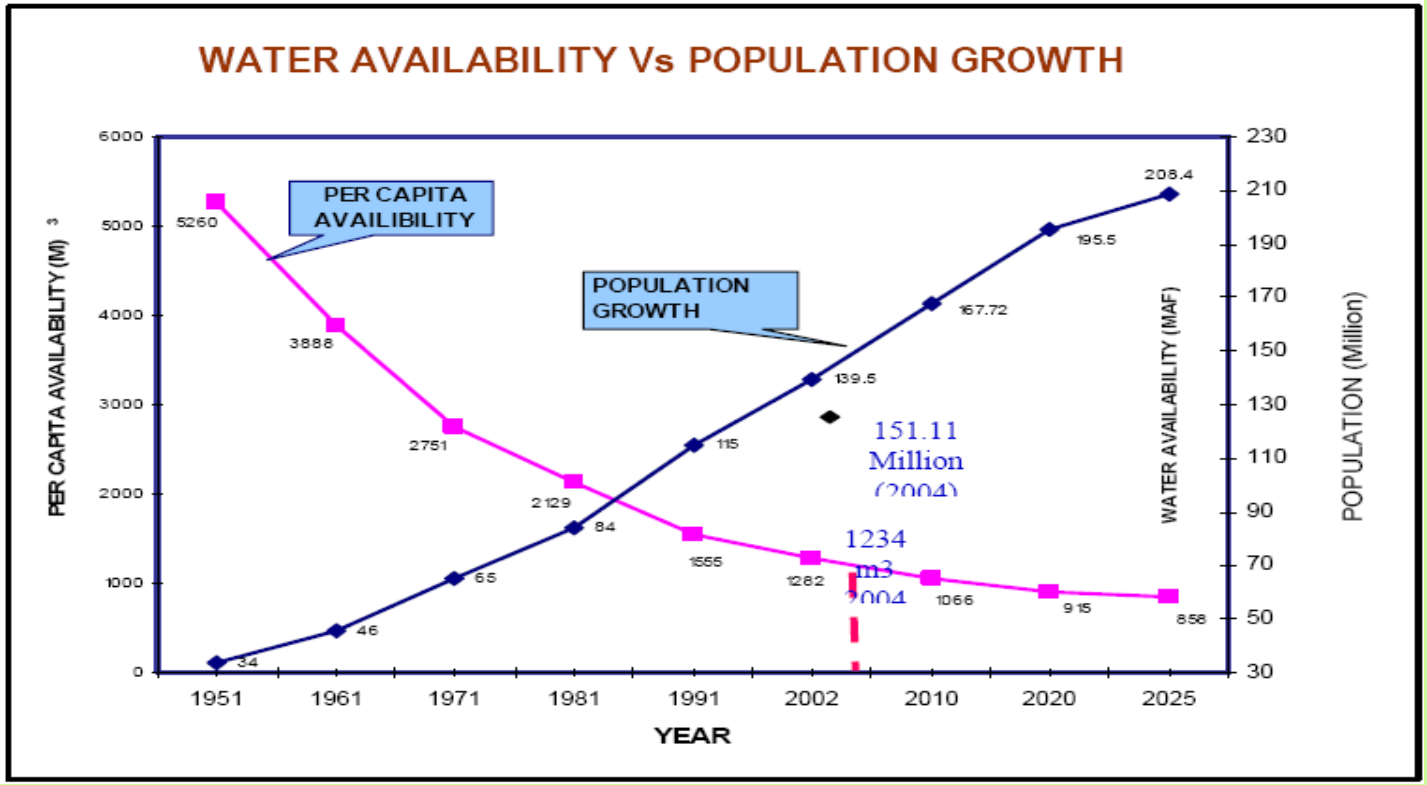
- Heat-wave in sub-continent in 2005, reduced agricultural yields in affected countries by between 10 to 40% of the harvests for that year

IMPACT ON WATER RESOURCES AND AGRICULTURE

- As per the warning within the IPCC's prediction, even ignoring extreme weather, food production in the tropics will decline due to warming.

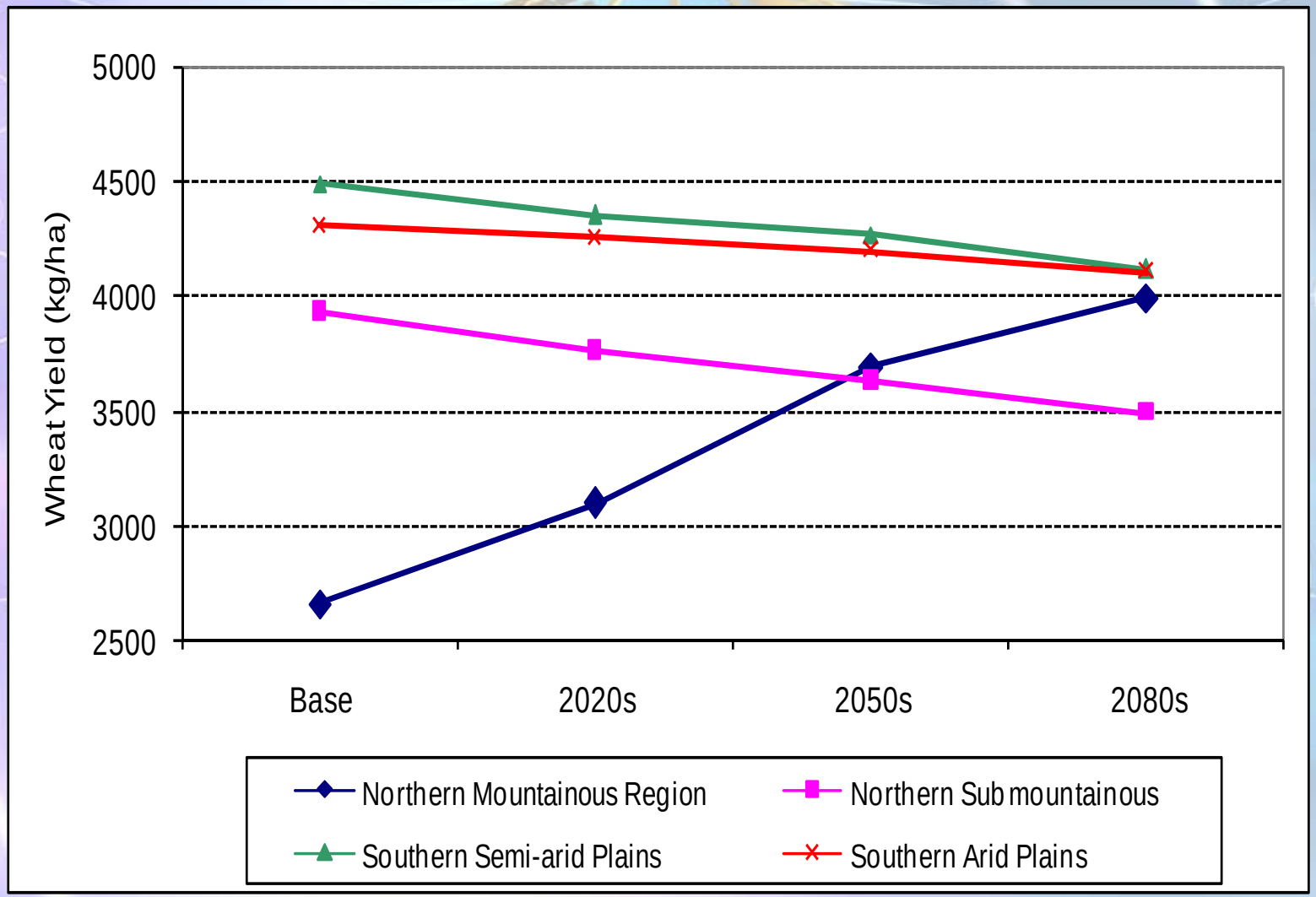
Water Availability Situation

- **Gross per capita water availability in Pakistan will decline from ~ 1350 m^3/yr in 2001 to as low as ~ 858 m^3/yr in 2025**



Source: WAPDA

Wheat Yield in different agro-climatic zones of Pakistan under A2 Scenarios (Base data 1960-2004)

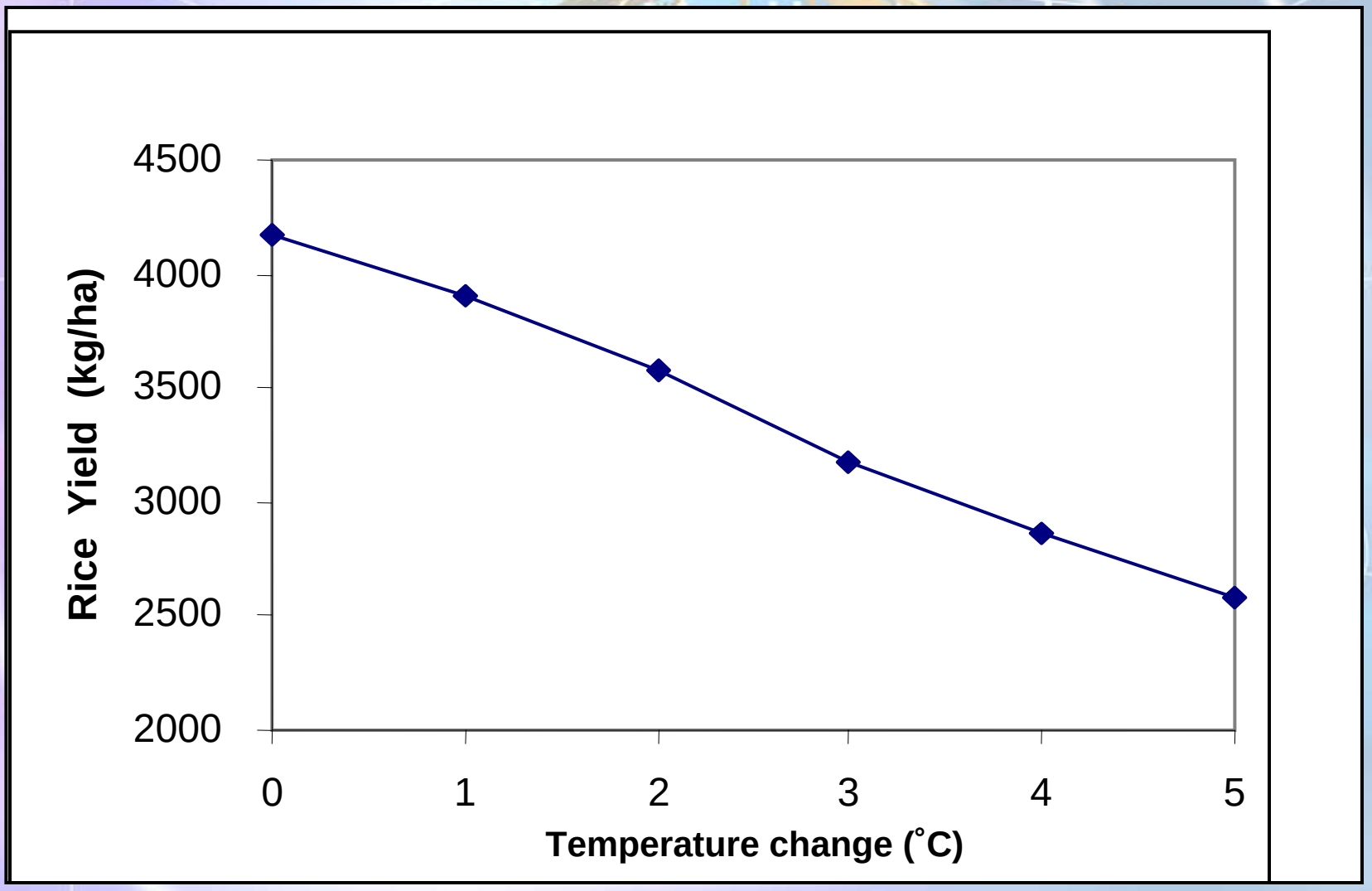


Climate Change Impact on Wheat Production in Pakistan by 2085 (A2 and B2 Scenarios)

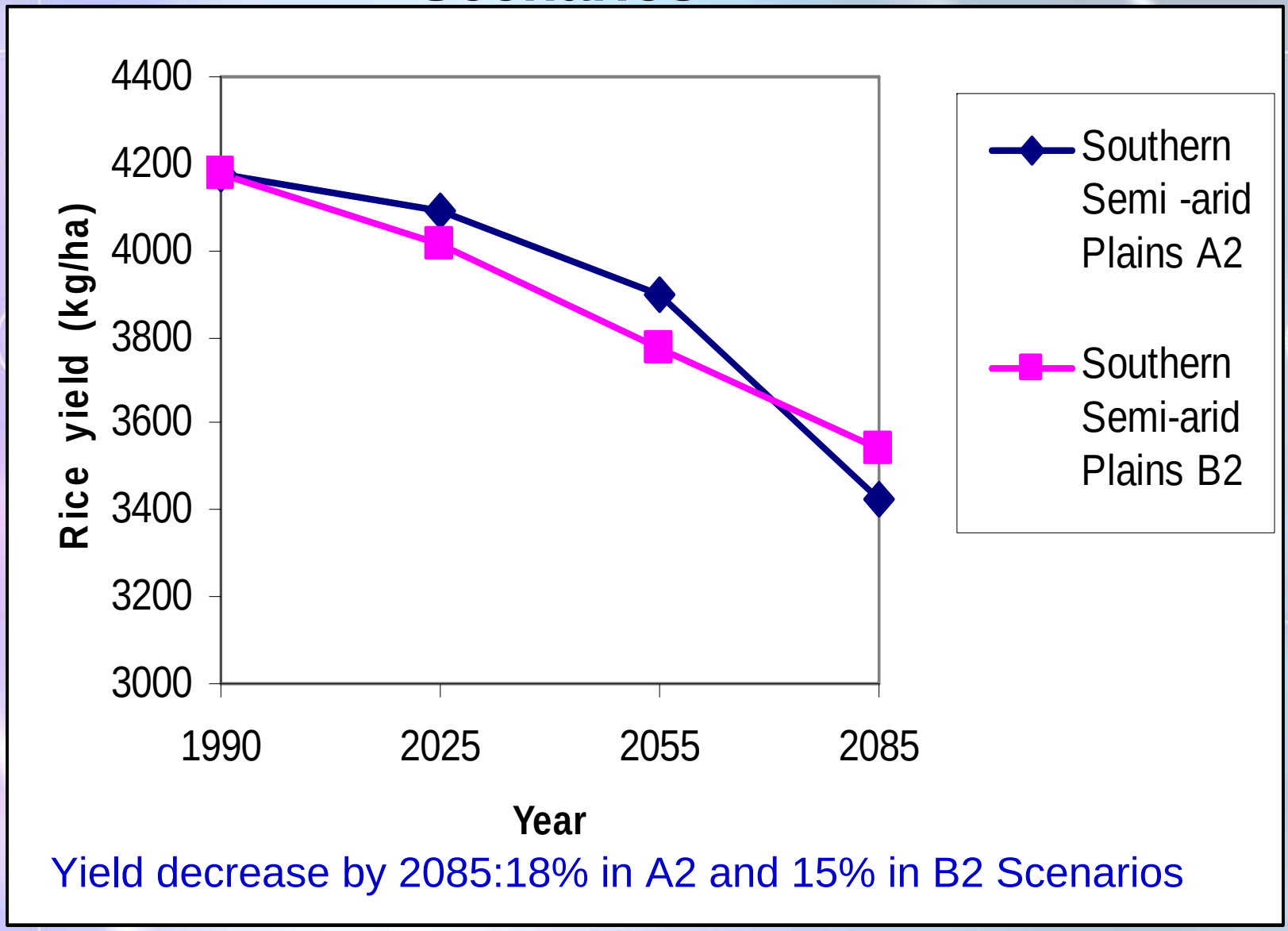
Region	Share in National Production (%)	Baseline Yield (kg ha^{-1})	% Change in yield in 2080	
			A2 Scenario	B2 Scenario
Northern Mountainous	2	2658	+50	+40
Northern Sub-mountainous	9	3933	-11	-11
Southern Semi arid Plains	42	4306	-8	-8
Southern Arid Plains	47	4490	-5	-6
Pakistan	100	4326	-5.7	-6.4

Effect of rise in temperature on Basmati rice yields in Southern Semi-arid Plains of Pakistan

(other factors remaining constant)



Basmati Rice Yield in Southern Semi-arid Plains of Pakistan under A2 and B2 Scenarios



Yield decrease by 2085:18% in A2 and 15% in B2 Scenarios

Food insecure regions and countries at risk by climate events

Phenomenon	Region/Country	Projected impact
• Hot days & nights • Warm spells /heat waves over most land areas	Countries of arid and semi-arid and sub-tropical Asia, Sub-Saharan Africa	• Decreased crop and livestock yields due to water and heat stress
Extreme events - Droughts - Floods	Semi-arid and sub-humid South Asia Low-lying areas, deltas, river valleys & lake basins of Asia	• Land degradation, crop damage and failure leading to lower yields • Increased livestock deaths • Damage to crops & food stores • Soil erosion, inability to cultivate land due to water logging

POSSIBLE IMPACTS OF CC ON Agriculture (IPCC 4th Assessment Rep.)

ASIA

- By 2050, crop yields could decrease up by up to 30% in South Asia
- By 2050, freshwater availability in South and South-East Asia, particularly in large river basins is projected to decrease by 12-20%.

RESPONDING TO CLIMATE CHANGE

- **There are two key ways of responding to climate change:**

  - Adapt to the changes

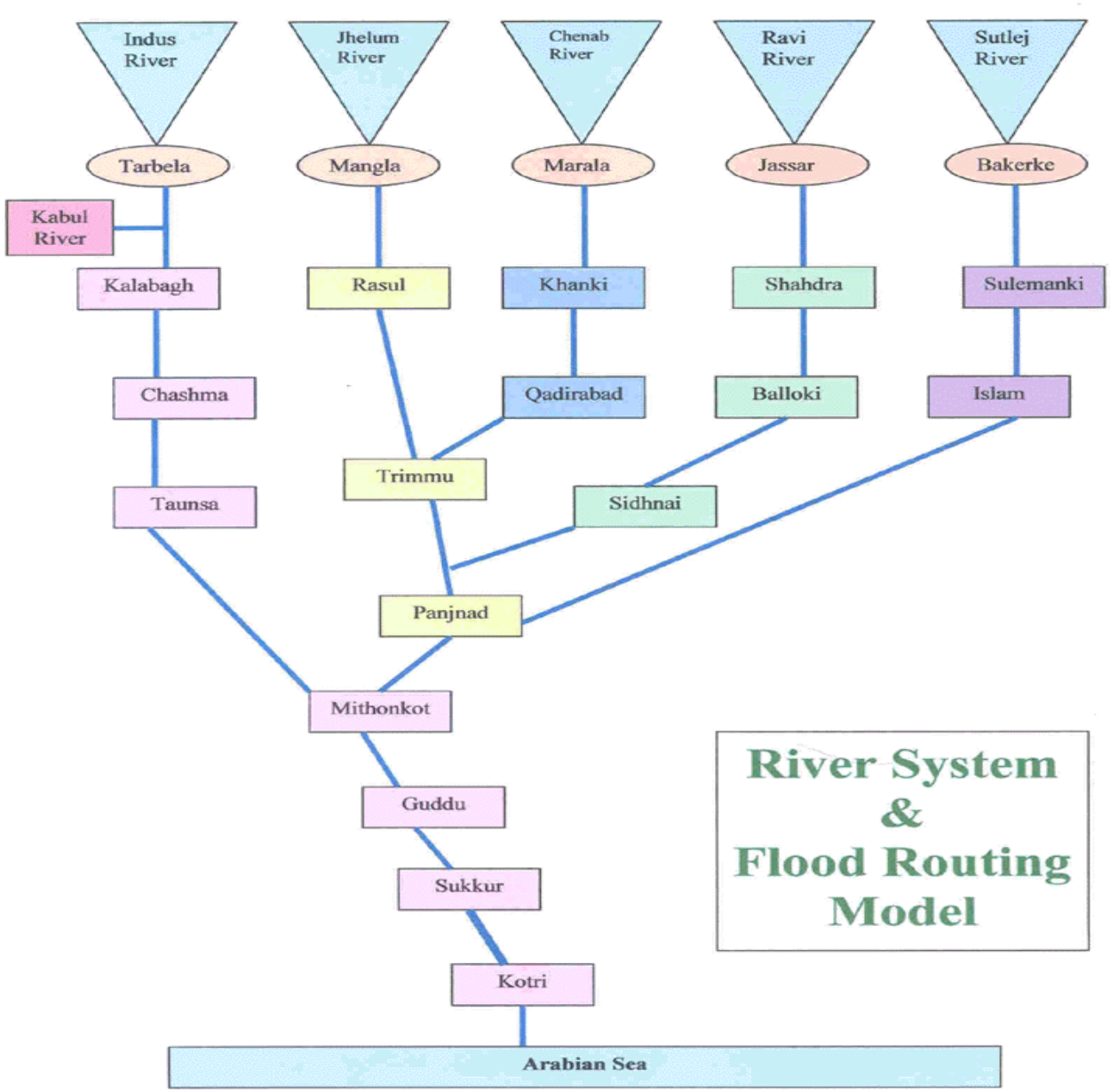
  - Reduce through mitigation measures the sources (emission abatement) or enhance the sinks (sequestration) of GHG

Thank you

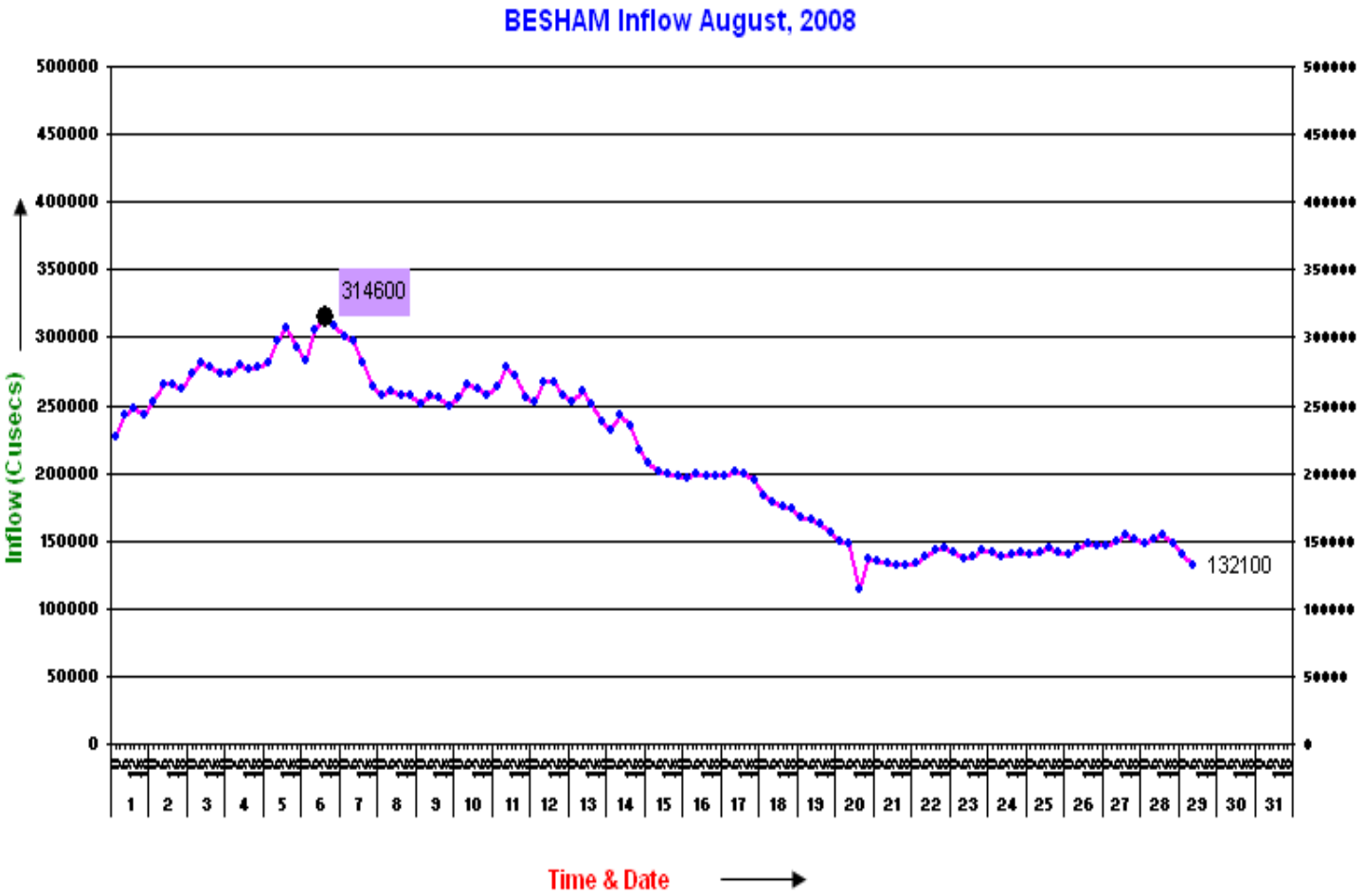
Economic benefits of Hydrological And Meteorological Services

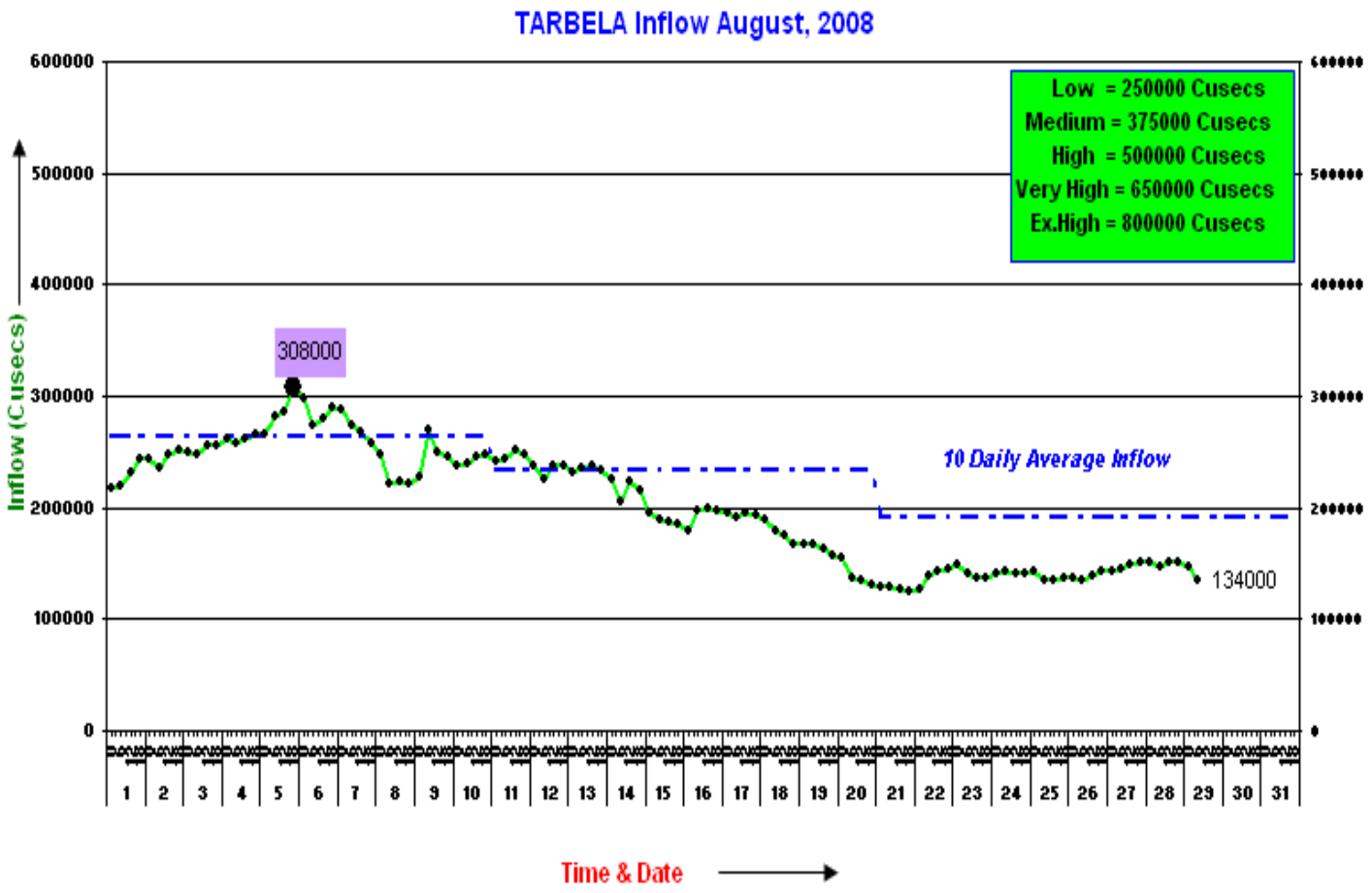
Effective Hydrological And Meteorological Services are increasingly being utilized for minimizing Economic Losses across the globe.

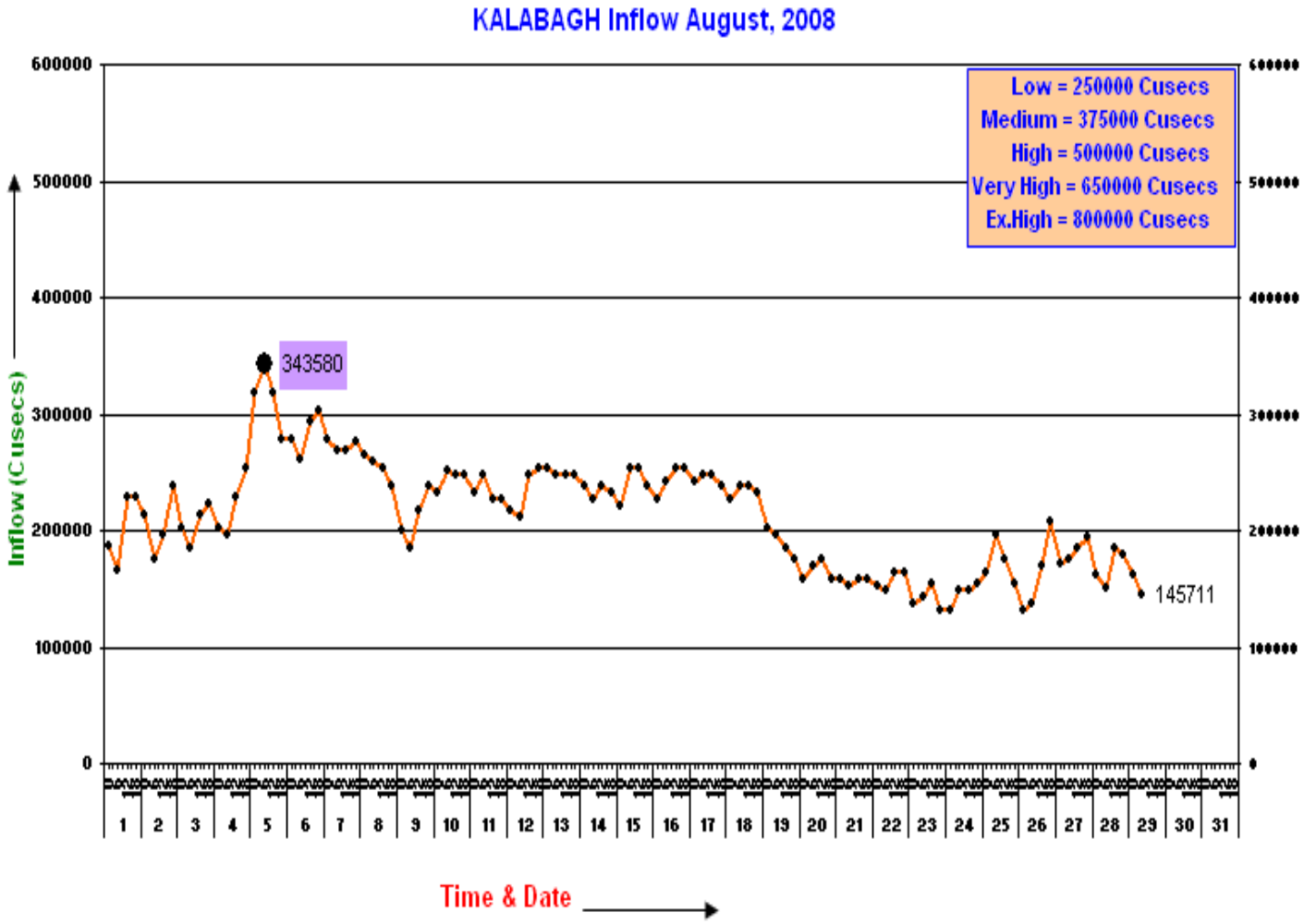
Agriculture, power sector, water management , construction firms, etc all are directly benefited from precise early warnings.

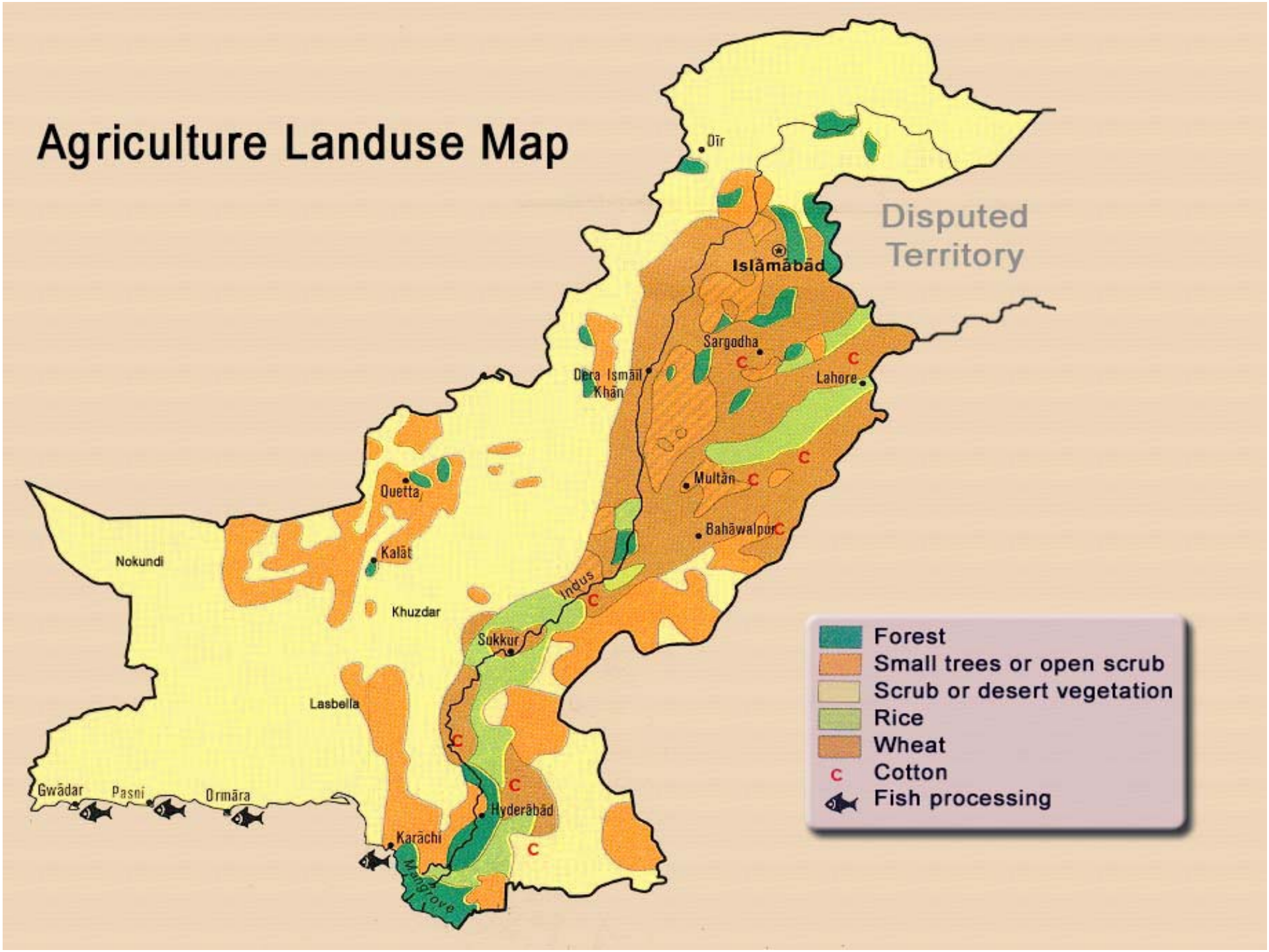


Source: Flood Forecasting Division,
Pakistan Meteorological Department


BESHAM Inflow August, 2008
Inflow (Cusecs)
500000
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
314600
132100
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Time & Date


TARBELA Inflow August, 2008
Low = 250000 Cusecs
Medium = 375000 Cusecs
High = 500000 Cusecs
Very High = 650000 Cusecs
Ex.High = 800000 Cusecs
Inflow (Cusecs)
600000
500000
400000
300000
200000
100000
0
308000
134000
10 Daily Average Inflow
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Time & Date


KALABAGH Inflow August, 2008
Low = 250000 Cusecs
Medium = 375000 Cusecs
High = 500000 Cusecs
Very High = 650000 Cusecs
Ex.High = 800000 Cusecs
343580
145711
Inflow (Cusecs)
600000
500000
400000
300000
200000
100000
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Time & Date


Agriculture Landuse Map
Dīr
Disputed Territory
Islāmābād
Sargodha
Dera Ismāil Khān
Lahore
Multān
Bahāwalpur
Quetta
Kalāt
Nokundi
Khuzdar
Indus
Sukkur
Lasbella
Gwādar
Pasni
Ormāra
Hyderābād
Karāchi
Mangrove
C
Forest
Small trees or open scrub
Scrub or desert vegetation
Rice
Wheat
Cotton
Fish processing