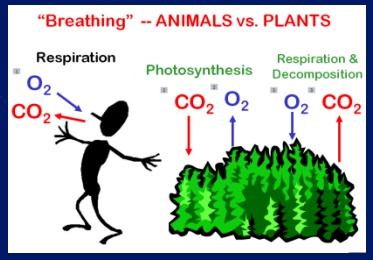
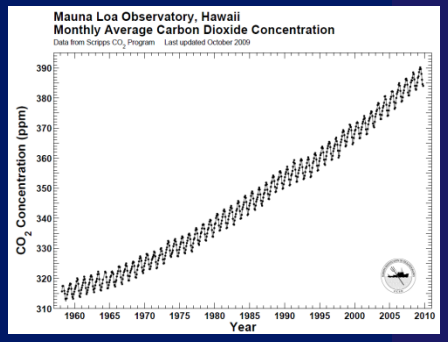
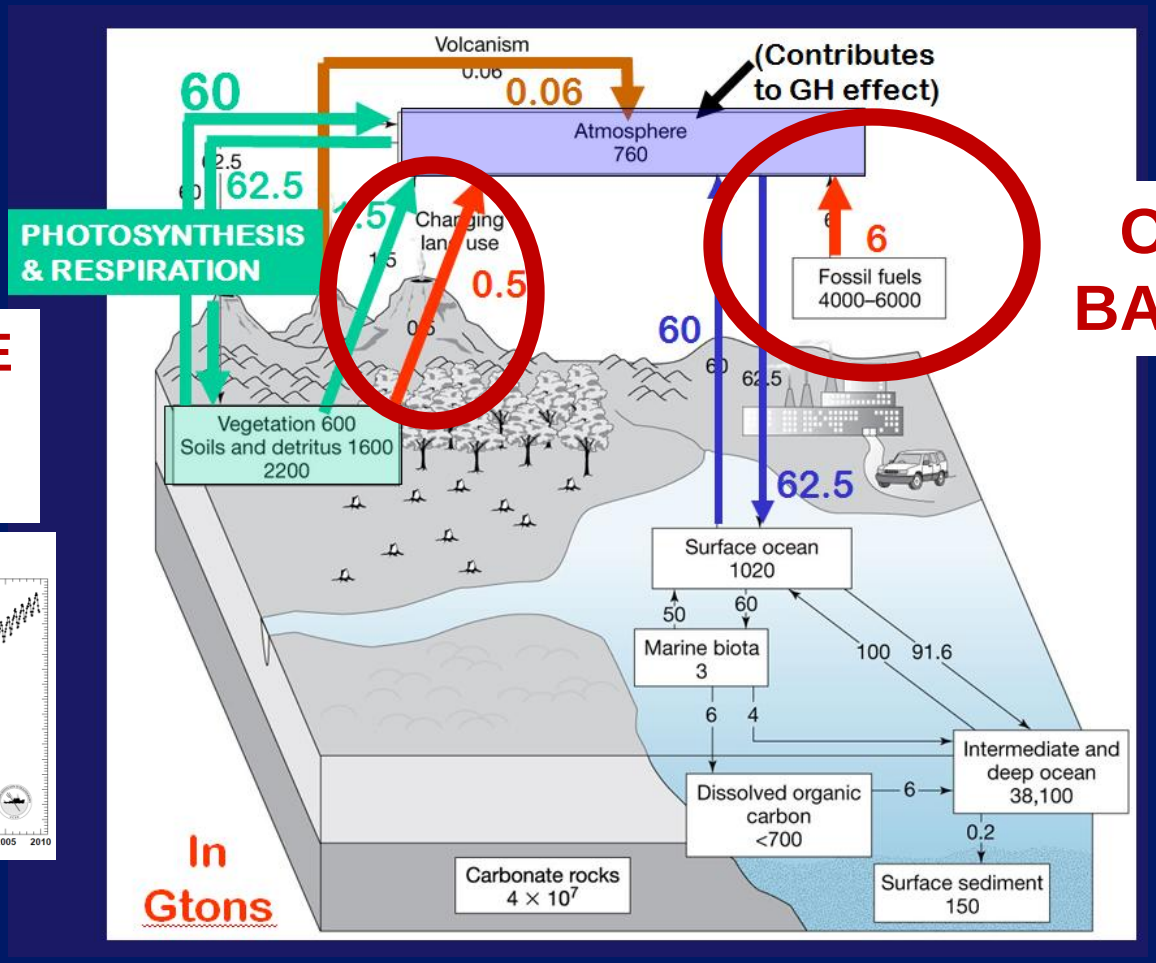
TOPIC # 15 WRAP UP:

CARBON RESERVOIRS & FLUXES

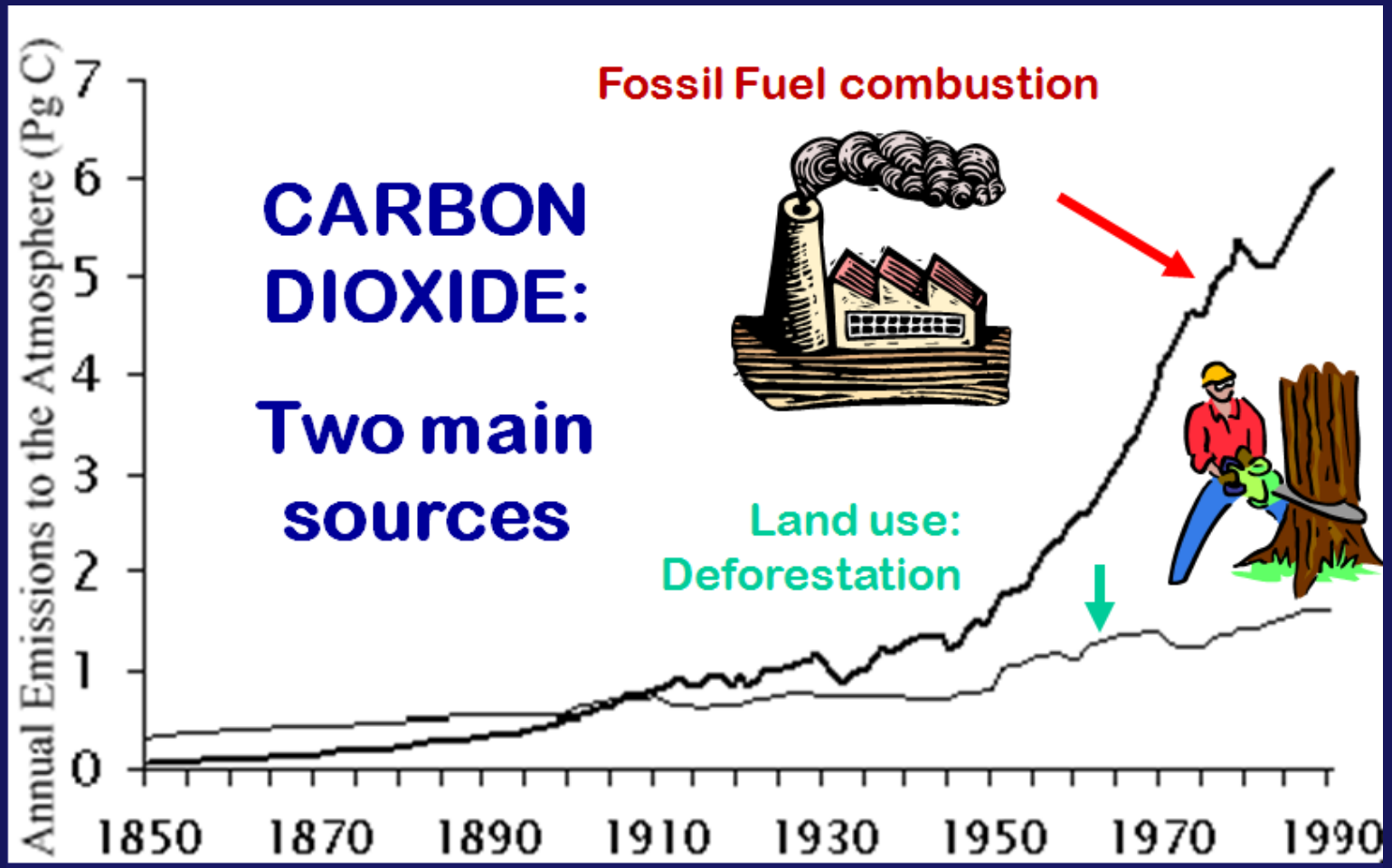


IN BALANCE until RECENTLY



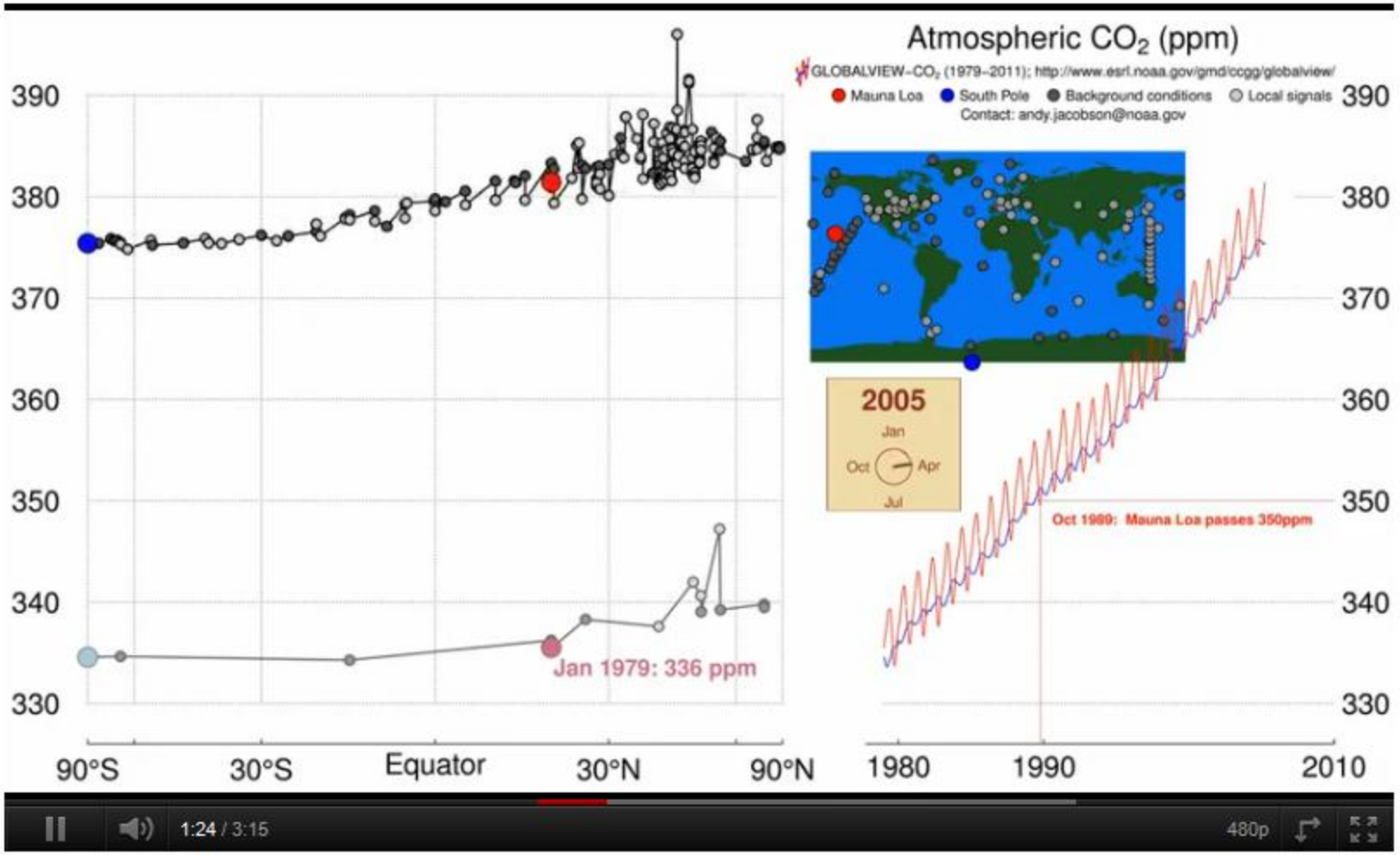


Major Carbon Fluxes IN & OUT of the atmosphere


Annual Emissions to the Atmosphere (Pg C)
0
1
2
3
4
5
6
7
1850
1870
1890
1910
1930
1950
1970
1990
CARBON DIOXIDE:
Two main sources
Fossil Fuel combustion
Land use:
Deforestation

Time history of atmospheric CO2 (2011 update)

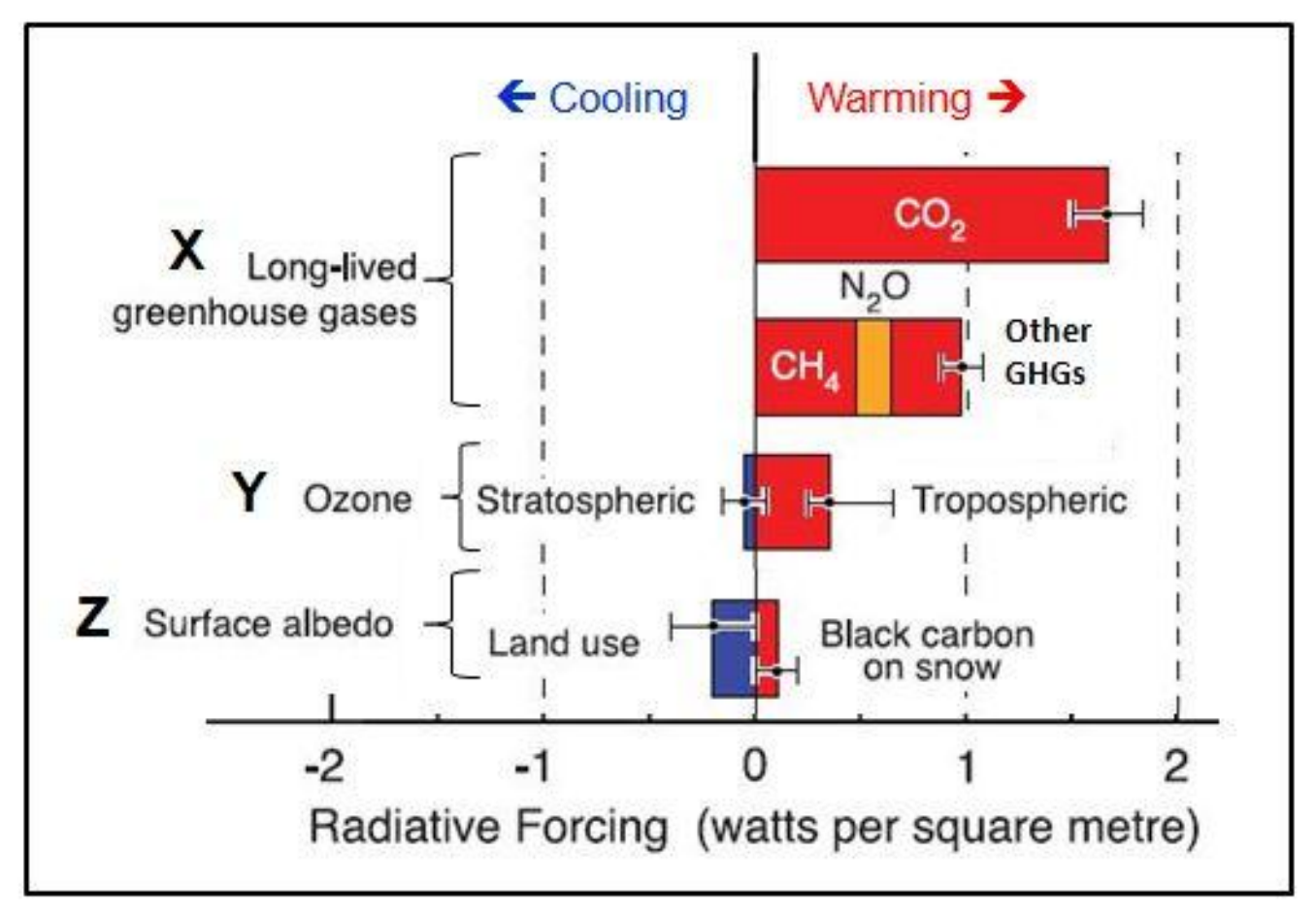
CarbonTracker 6 videos Subscribe



http://www.youtube.com/watch?v=bbgUE04Y-Xg&feature=player_embedded#!

TOPIC # 15 WRAP UP:

RADIATIVE FORCING DIAGRAM



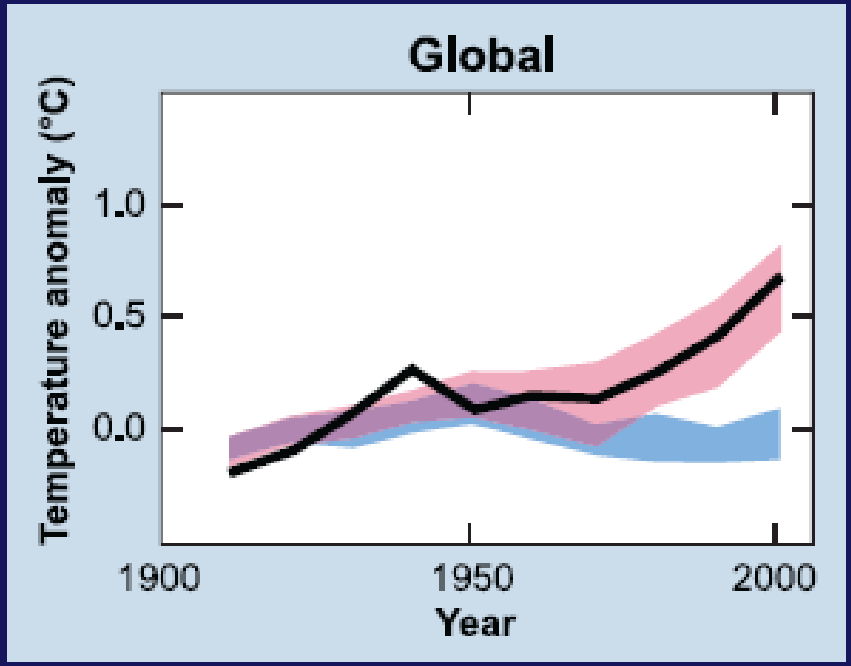
Abbreviated version of p 83

TOPIC # 15 WRAP UP
Natural vs Anthropogenic Forcing

observations

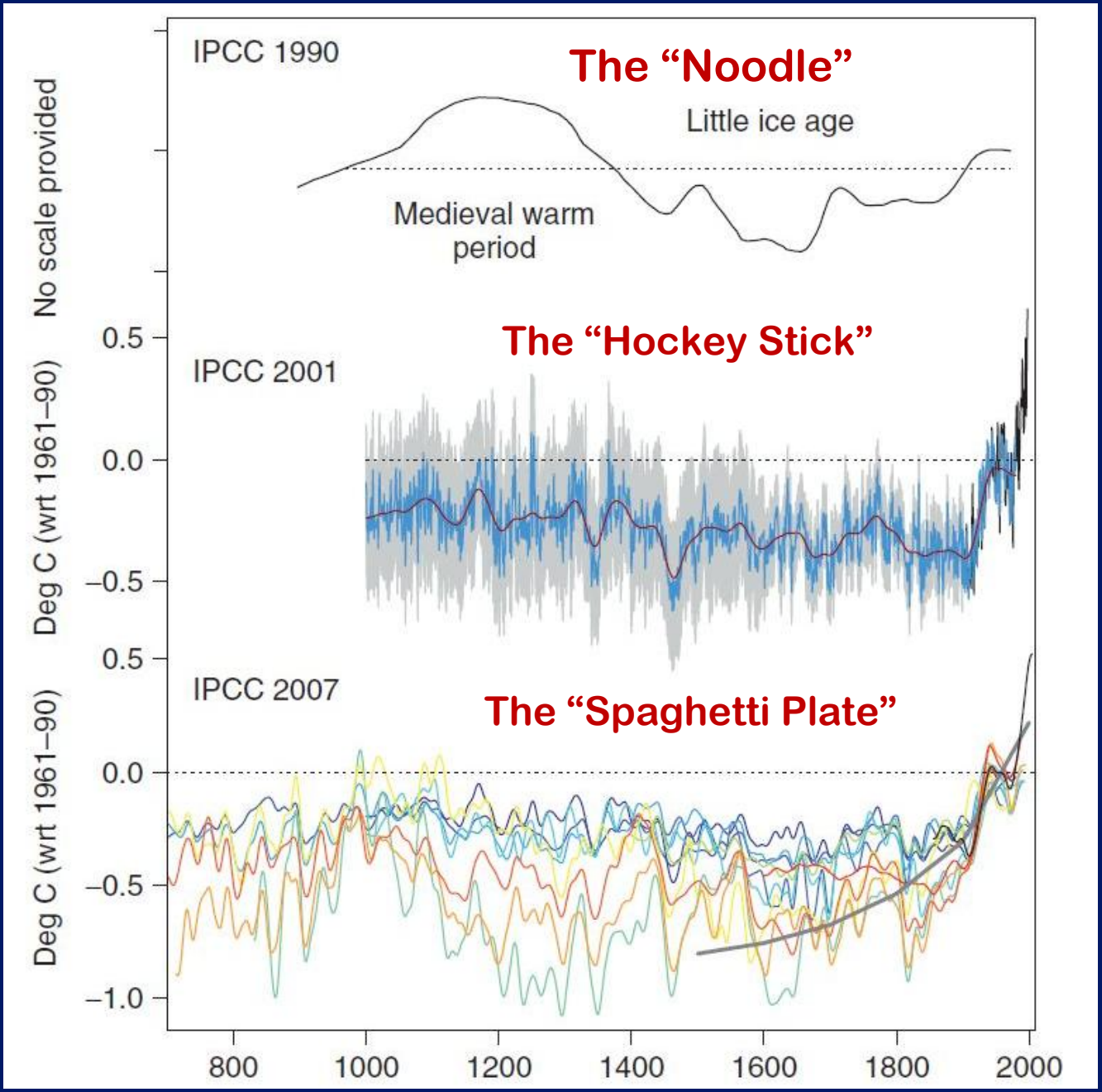
Only Natural Forcing

Natural + Anthropogenic Forcing

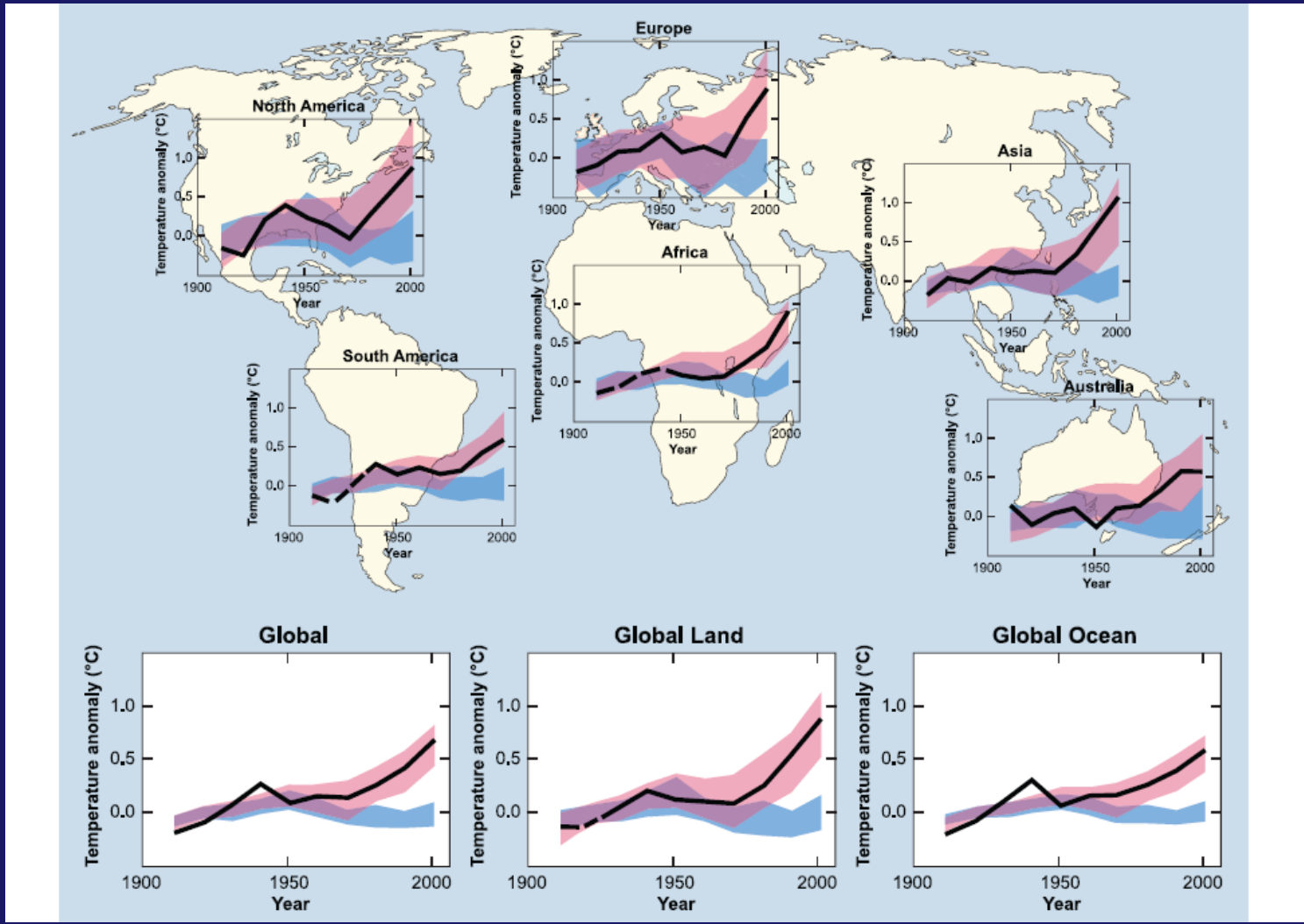


Class Notes p 85

The Scientific Process "in action"



Individual Region Model Runs showed the same results!



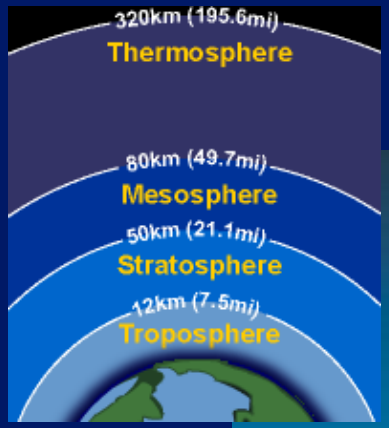
observations

models using only natural forcings

models using both natural and anthropogenic forcings

10 Indicators of a Human Fingerprint on Climate Change

Source: NOAA 's 2009 State of the Climate Report



[evidence of enhanced greenhouse effect from radiation & temperature observations at various levels in the atmosphere]

Less heat escaping to space

Shrinking thermosphere

Cooling stratosphere

Rising tropopause

The Greenhouse Signature

Cooling in the Stratosphere

Warming in the Troposphere

Less oxygen in the air

[evidence from atmospheric composition measurements]

30 billion tonnes of CO2 per year

More fossil fuel carbon in the air

[evidence from carbon isotopes]

More heat returning to Earth

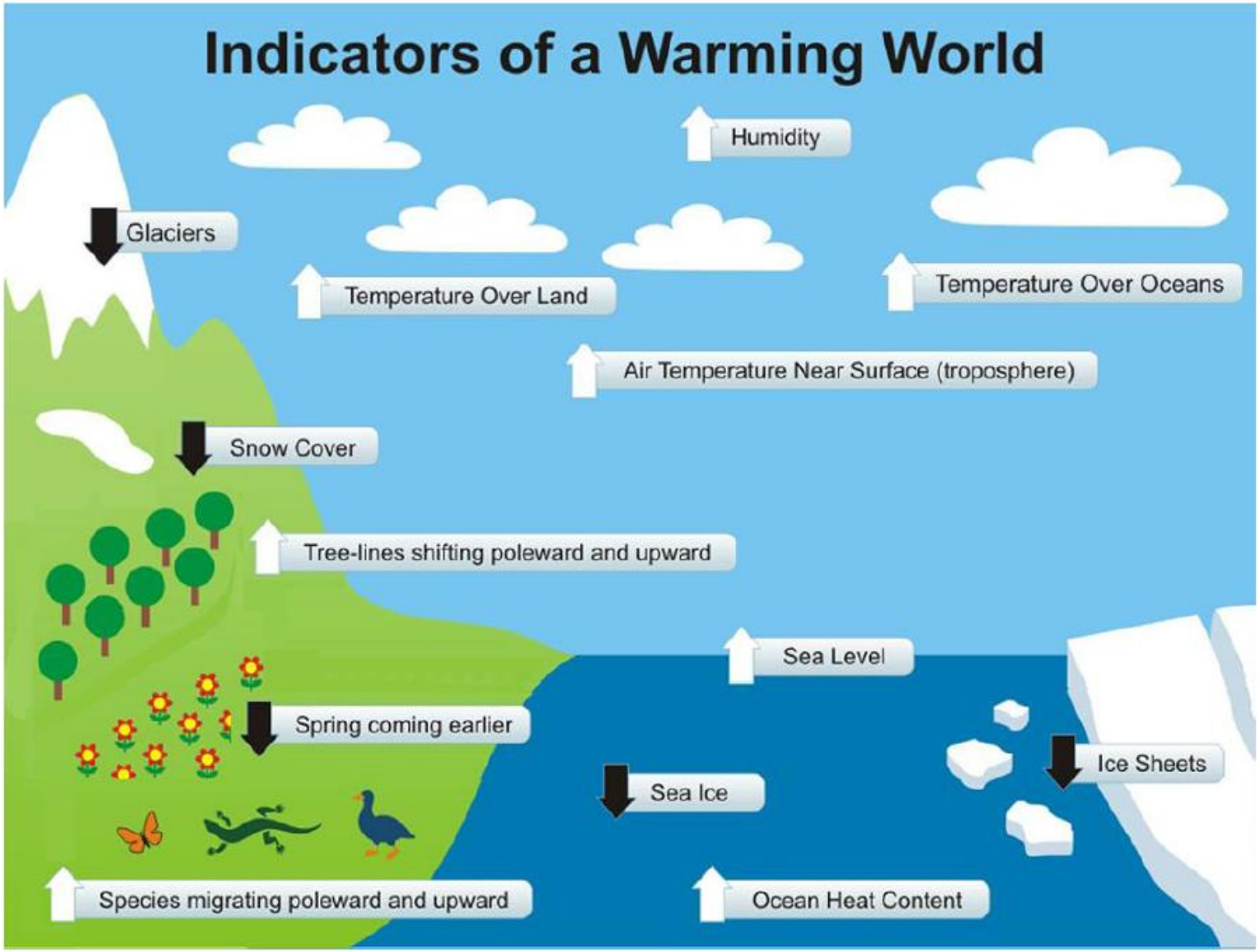
Nights warming faster than days

[evidence from surface temperature measurements]

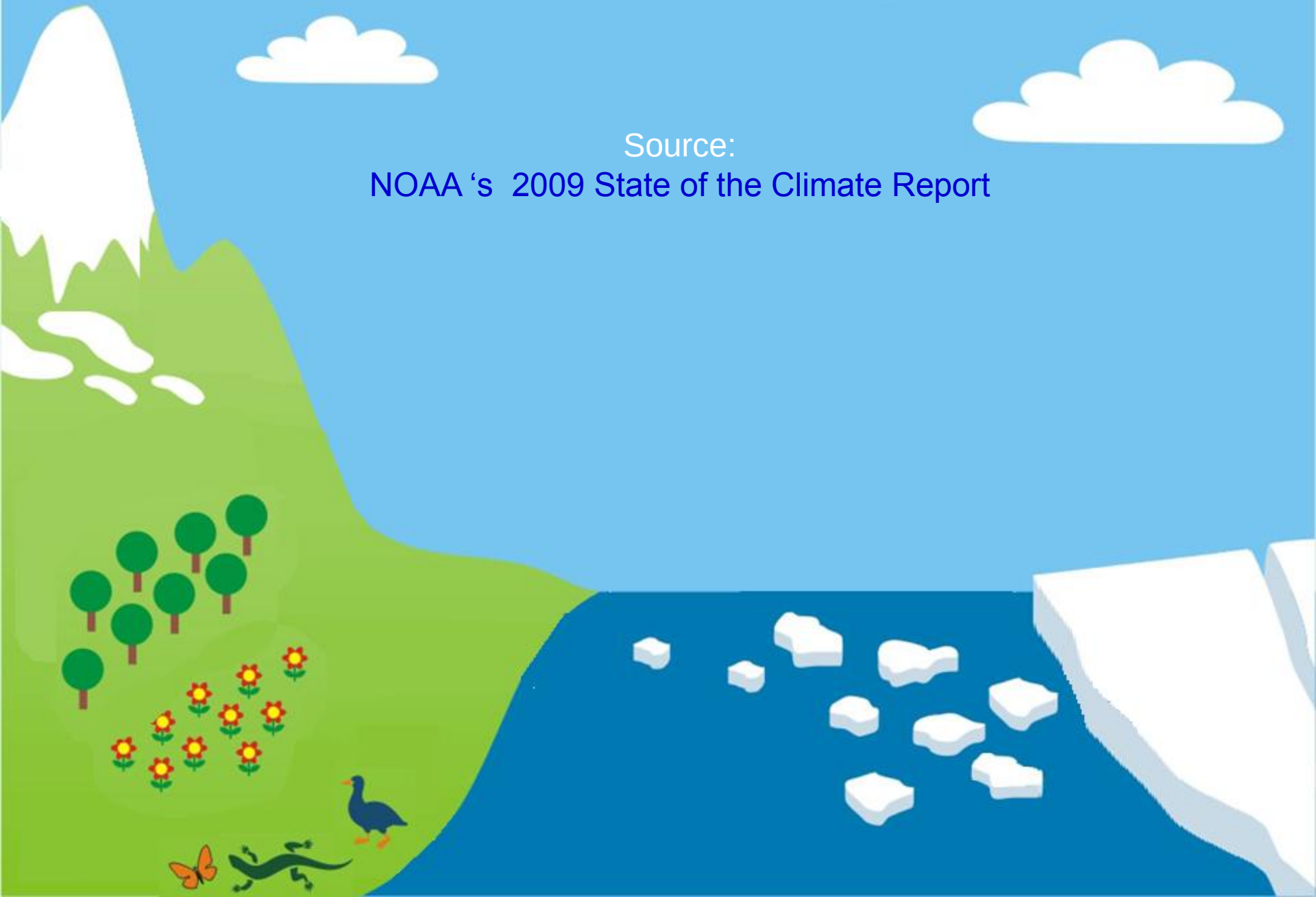
More fossil fuel carbon in coral

[evidence from carbon isotopes]

THE SUMMARY: INDICATORS RECAP



Indicators of a Warming World

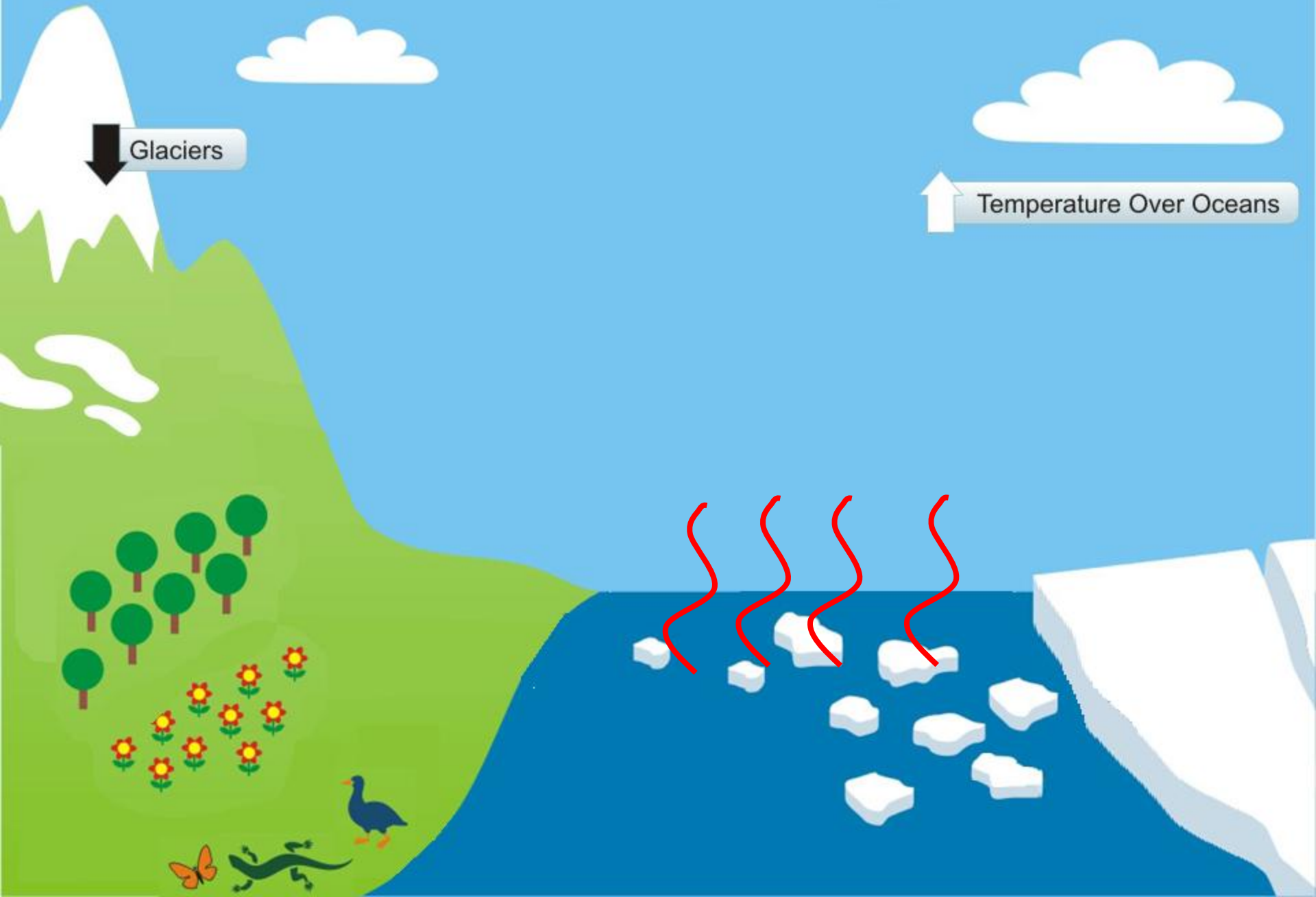


Source:
NOAA ‘s 2009 State of the Climate Report

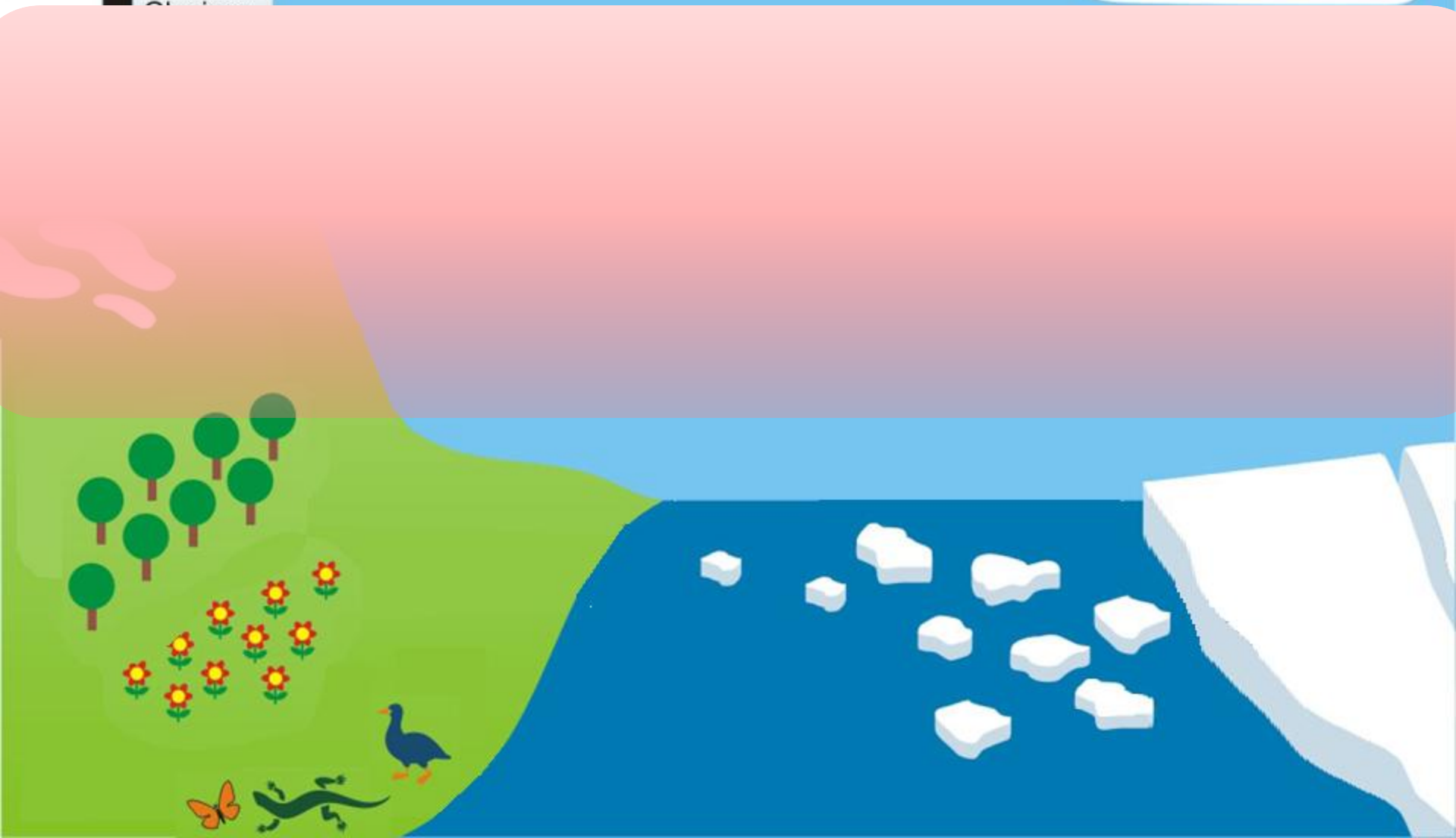
Indicators of a Warming World

Indicators of a Warming World

Indicators of a Warming World



Indicators of a Warming World



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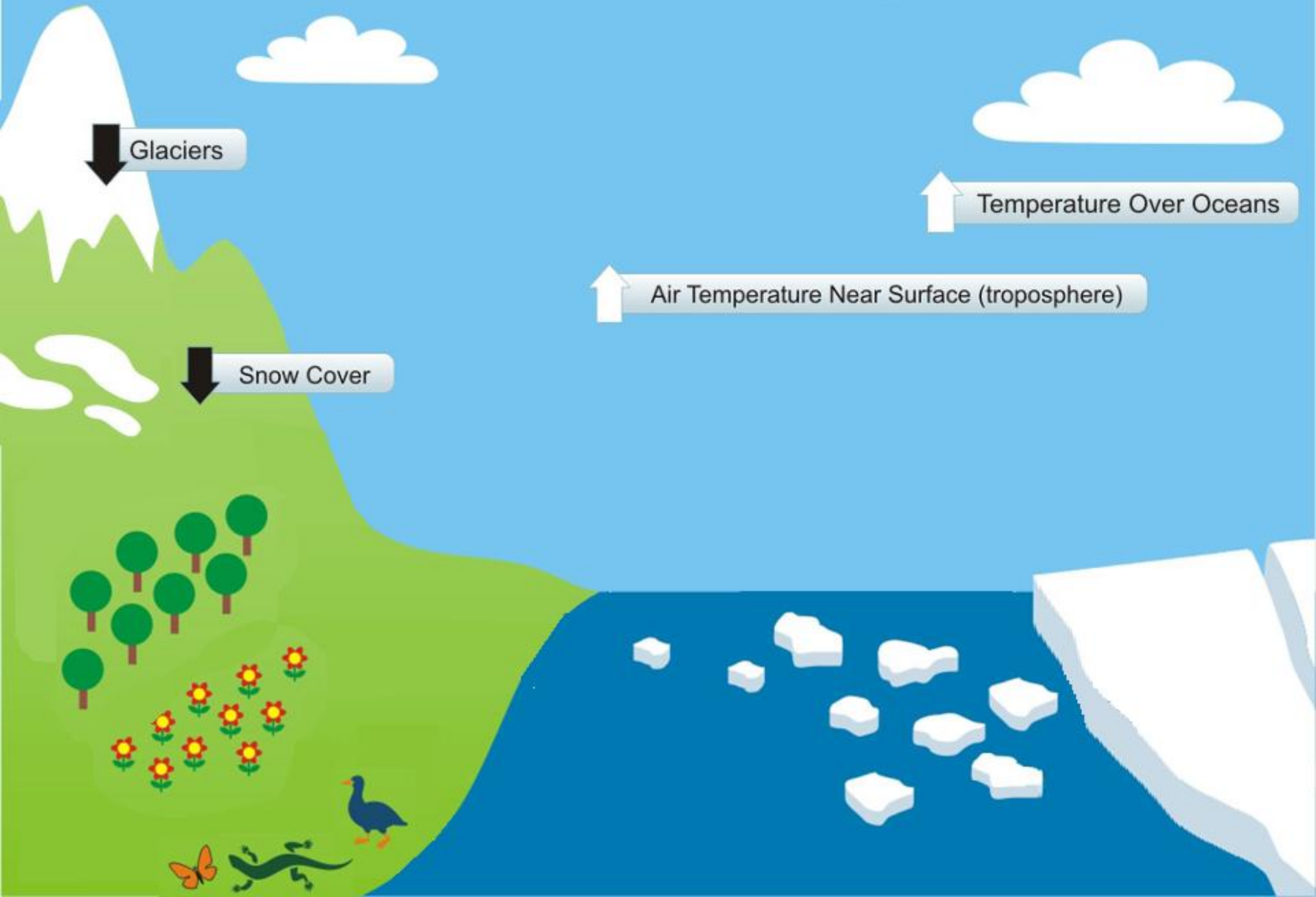

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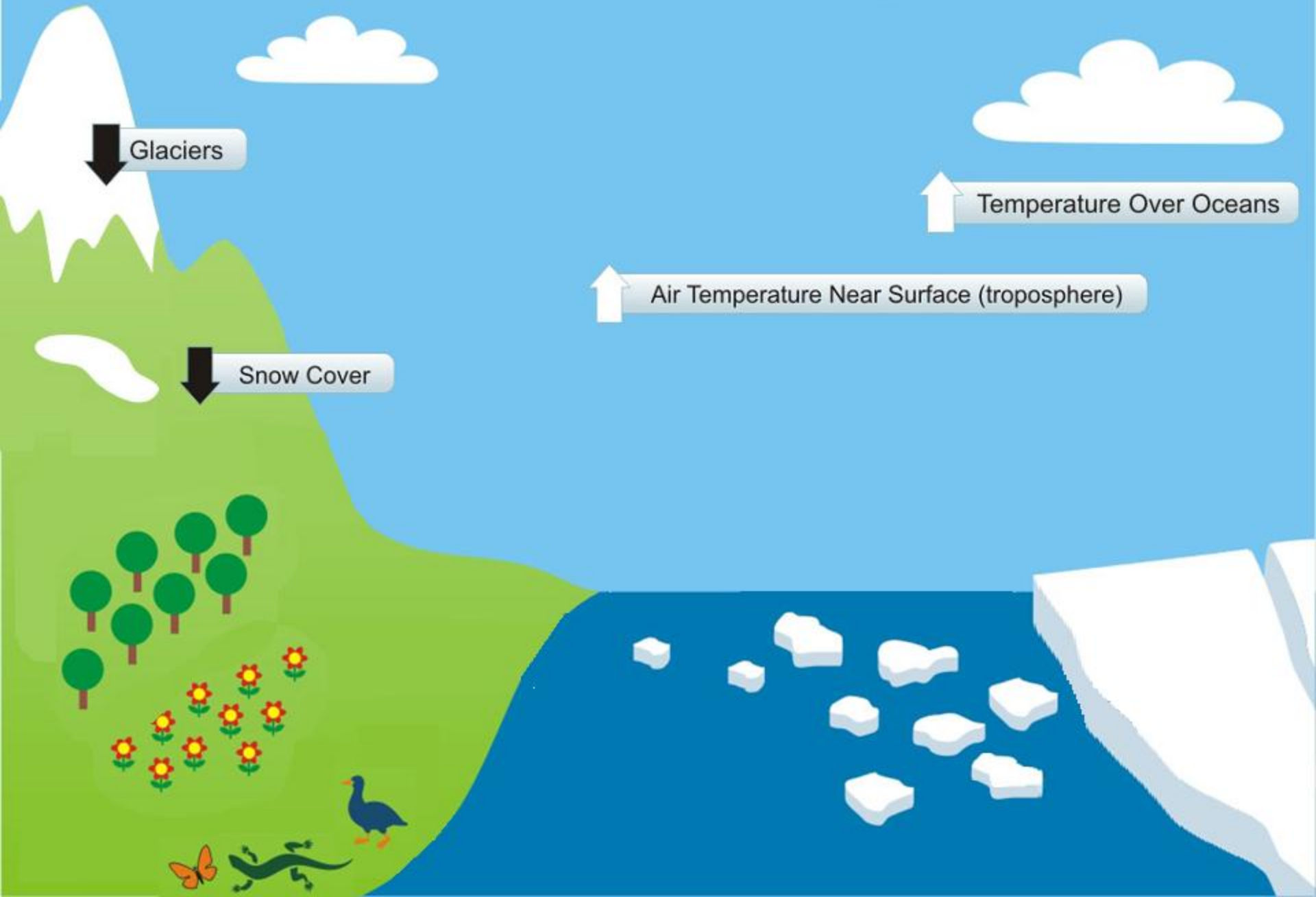
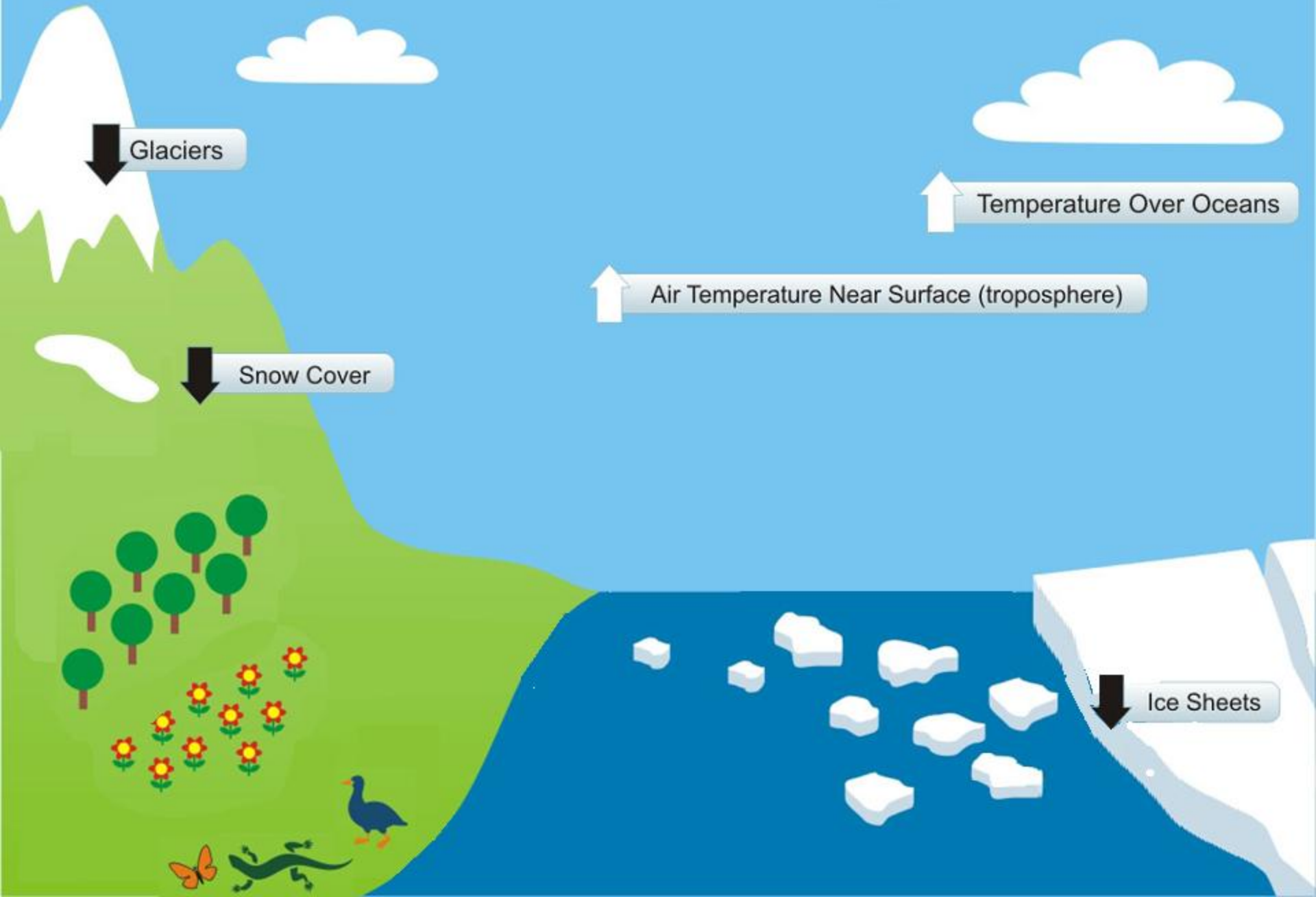


Indicators of a Warming World



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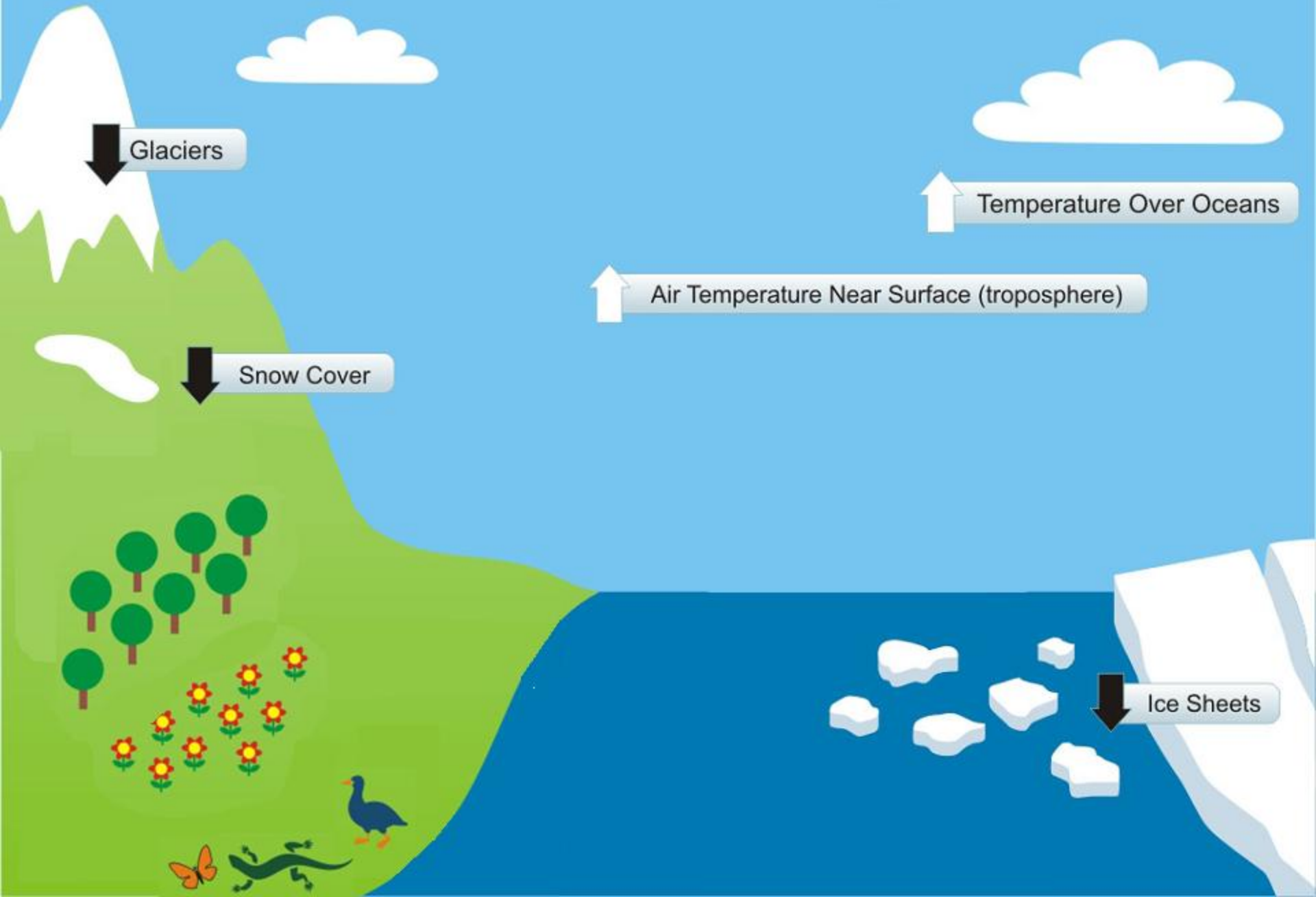

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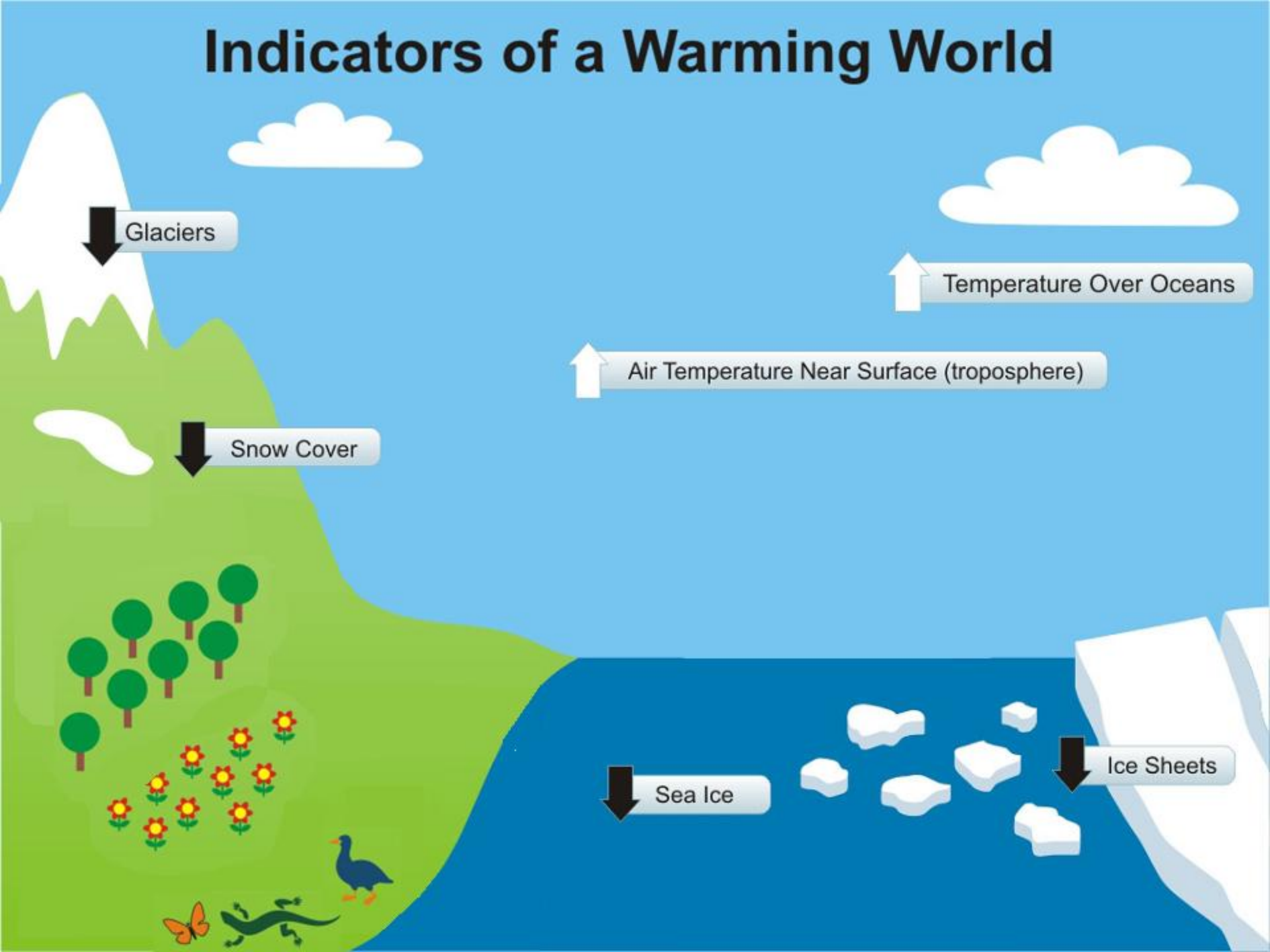
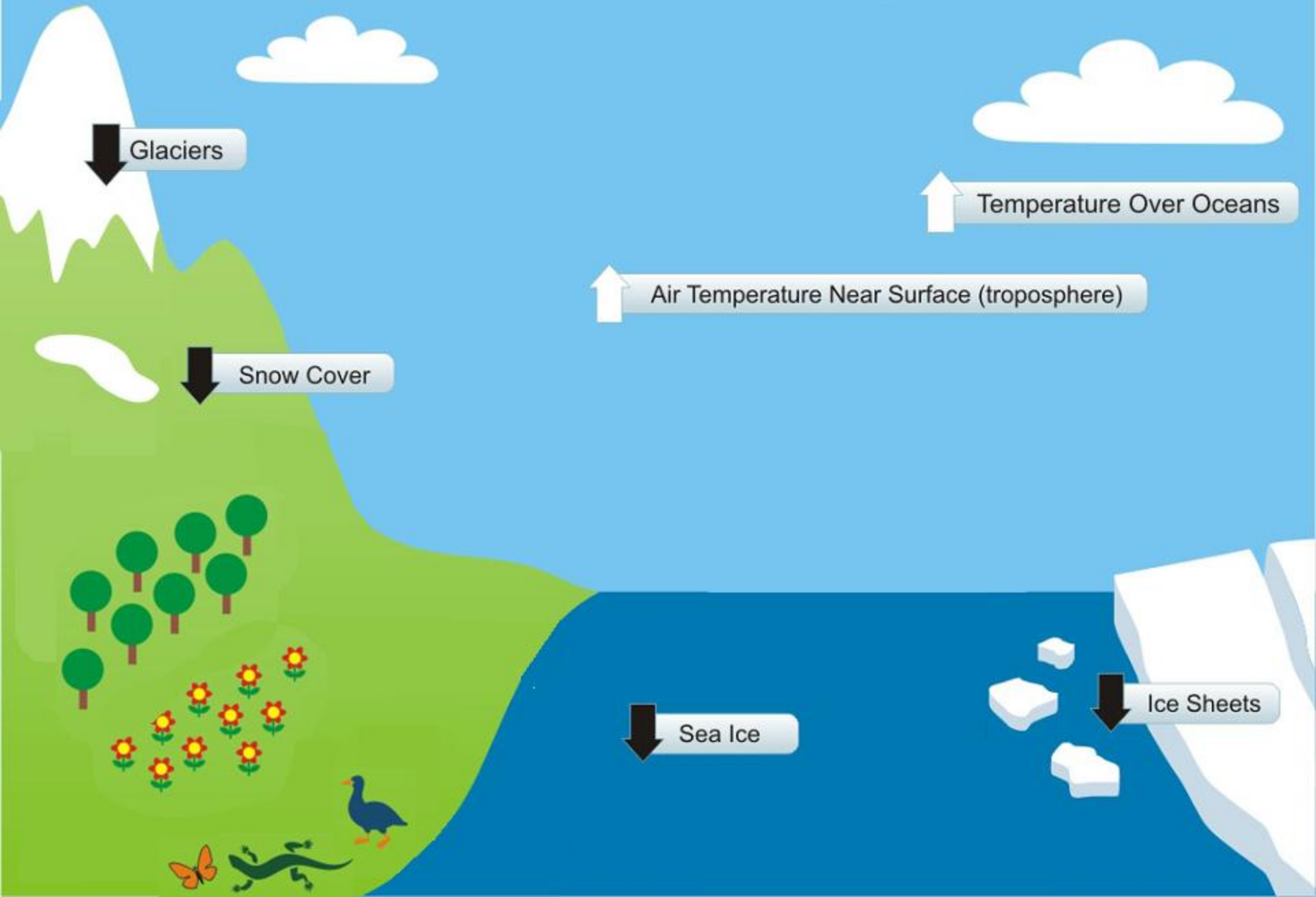
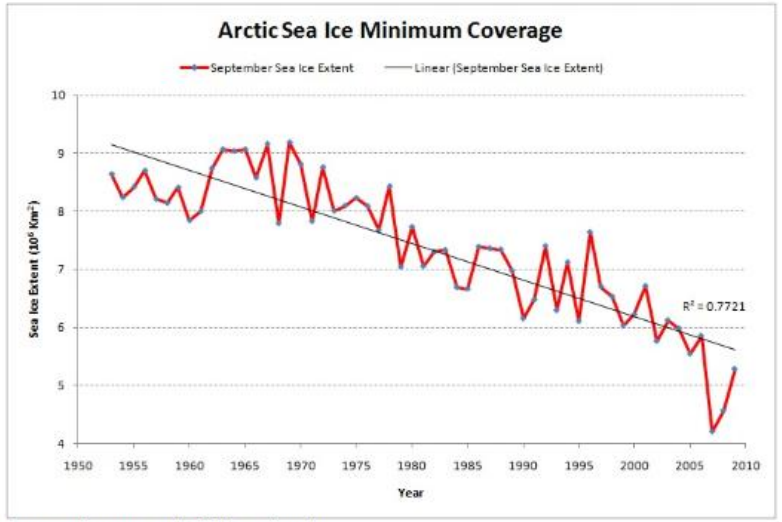
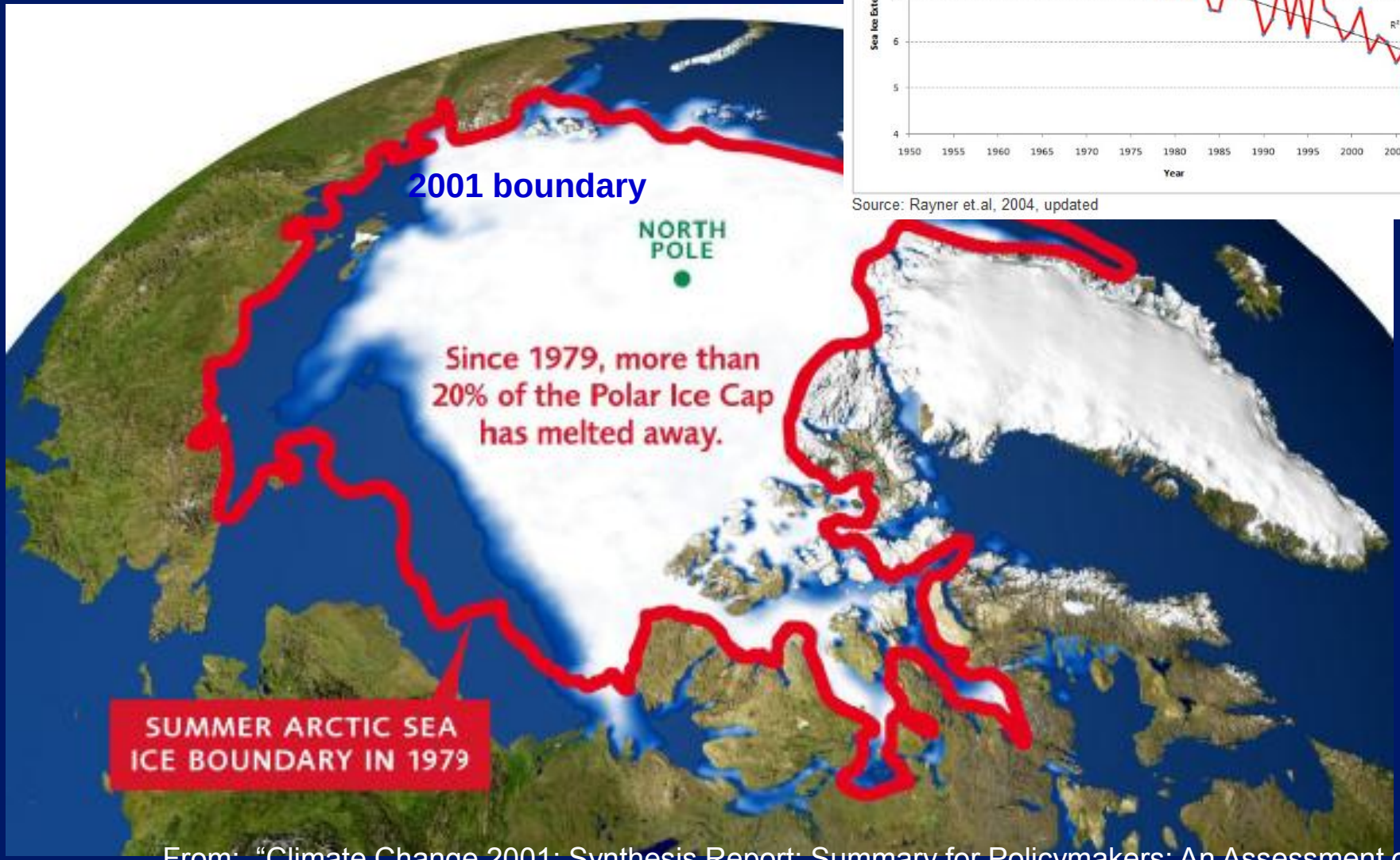


Indicators of a Warming World





Source: Rayner et.al, 2004, updated



From: "Climate Change 2001: Synthesis Report: Summary for Policymakers: An Assessment of the Intergovernmental Panel on Climate Change"

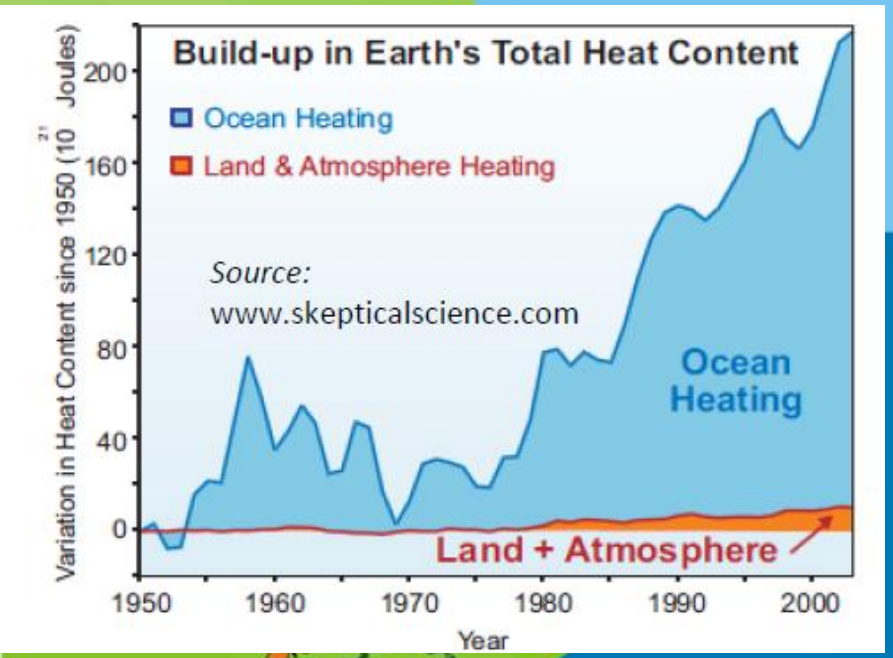
Indicators of a Warming World

Glaciers

Temperature Over Oceans

Air Temperature Near Surface (troposphere)

Snow Cover

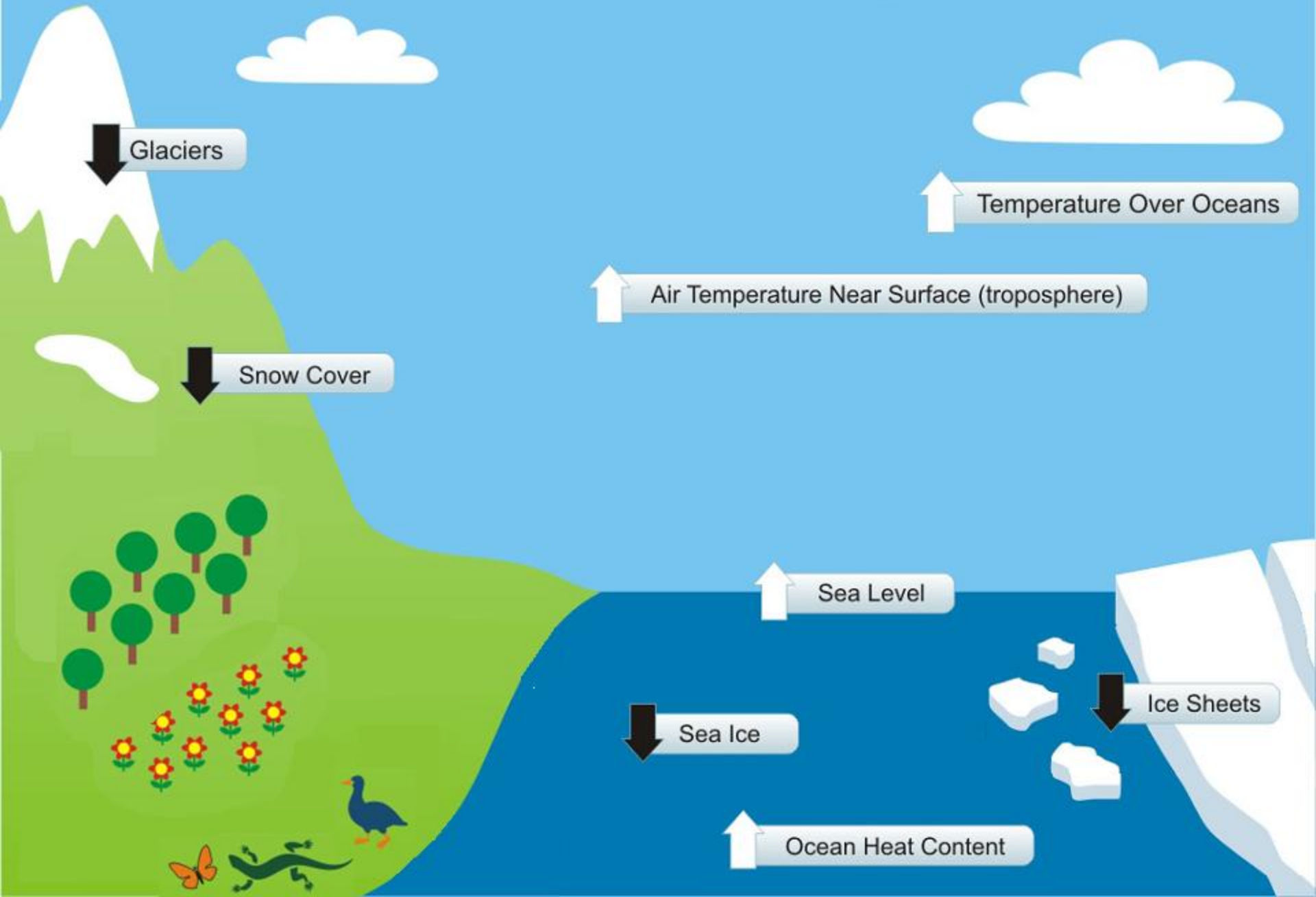


Sea Ice

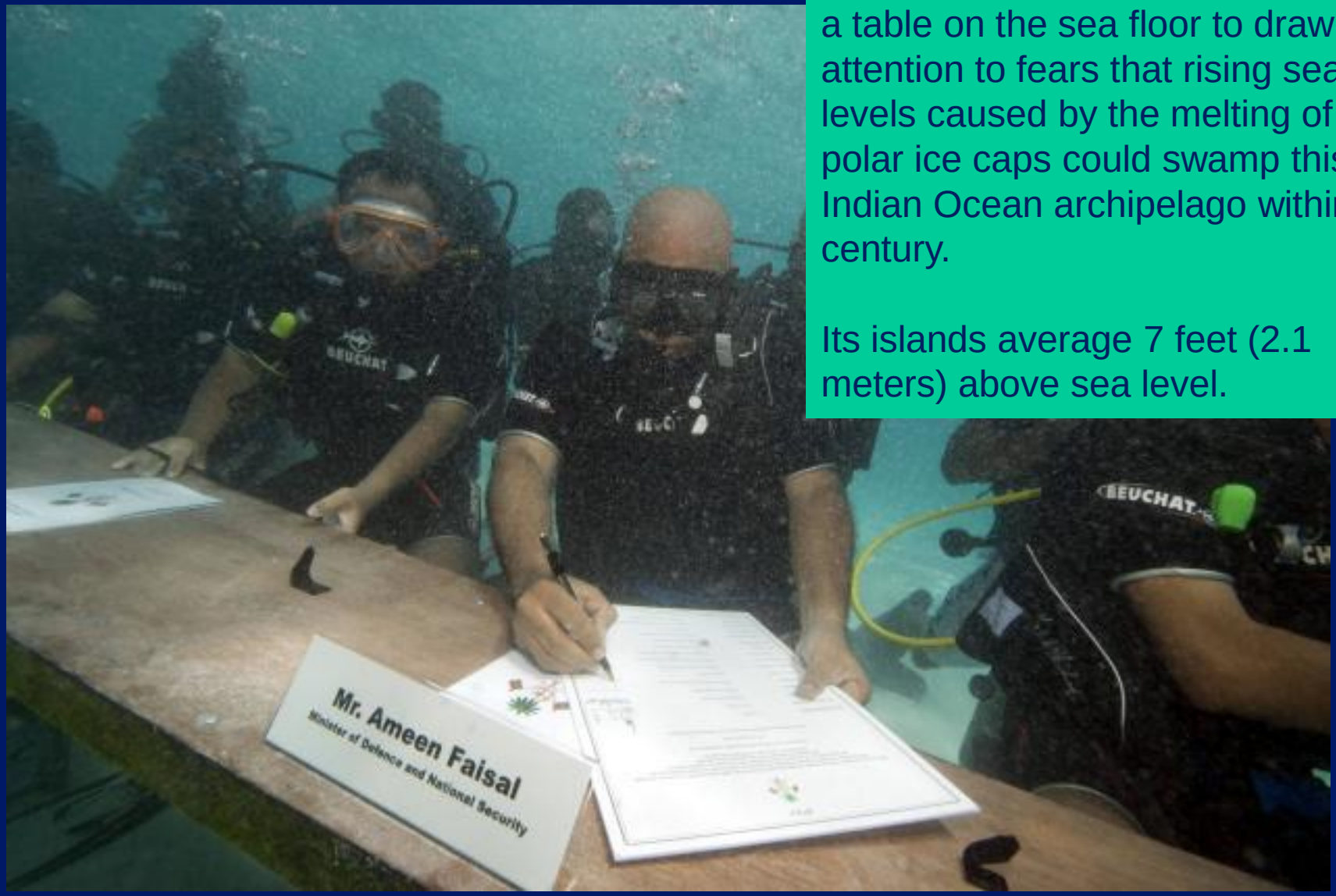
Ice Sheets

Ocean Heat Content

Indicators of a Warming World



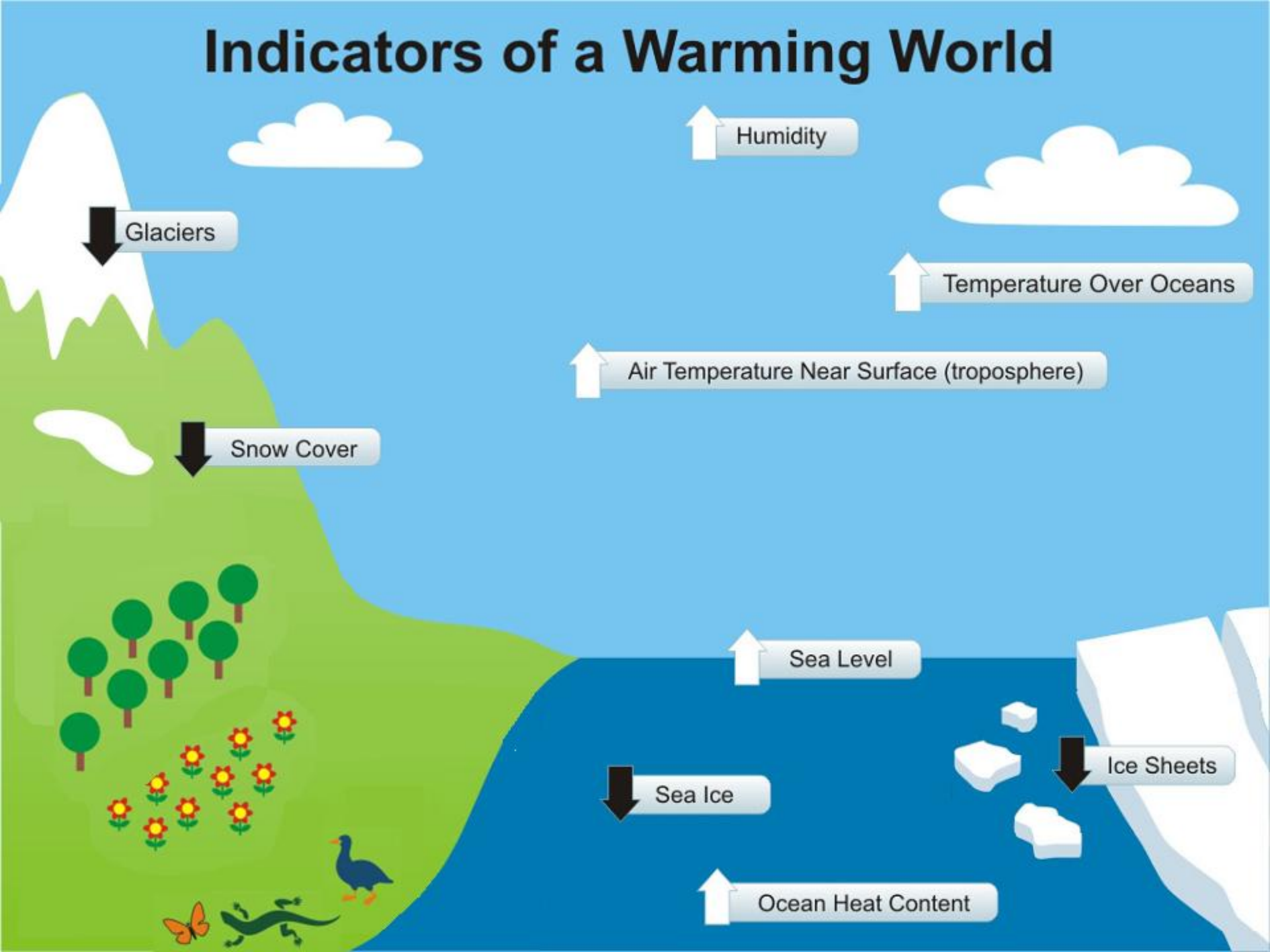
Global concerns about sea level rise:



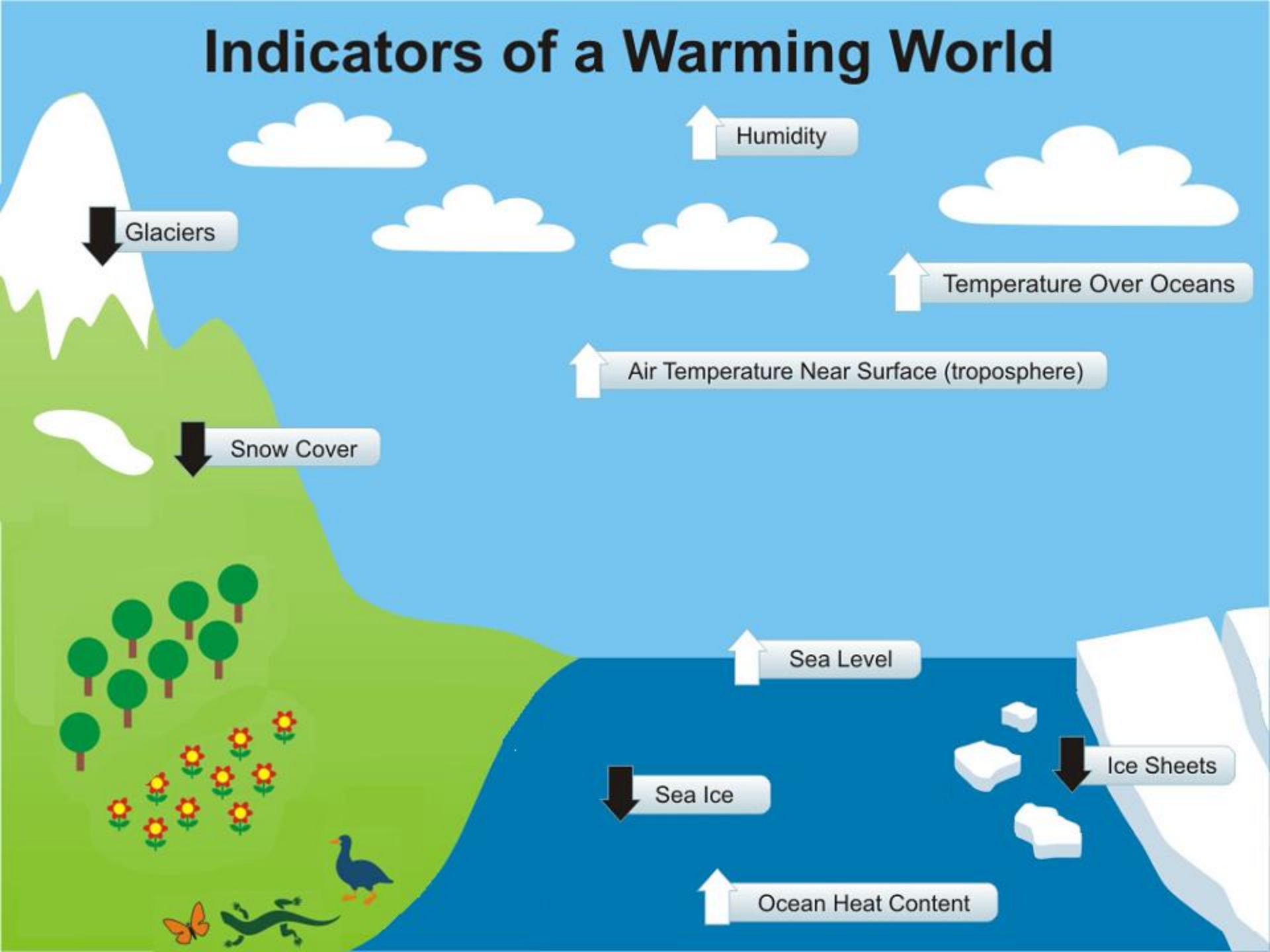
The president of the Maldives and 13 other government officials submerged and took their seats at a table on the sea floor to draw attention to fears that rising sea levels caused by the melting of polar ice caps could swamp this Indian Ocean archipelago within a century.

Its islands average 7 feet (2.1 meters) above sea level.

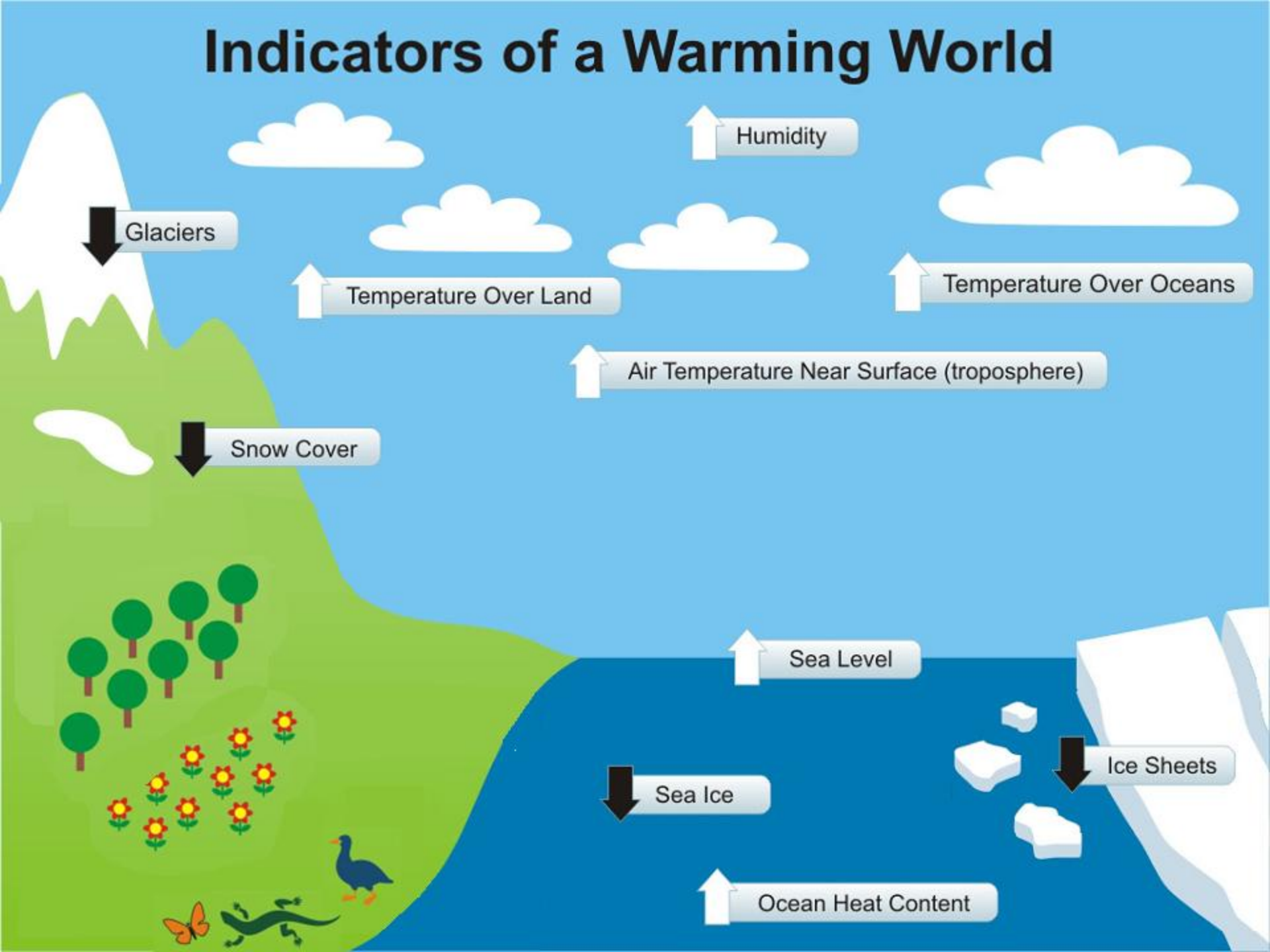
Indicators of a Warming World



Indicators of a Warming World



Indicators of a Warming World



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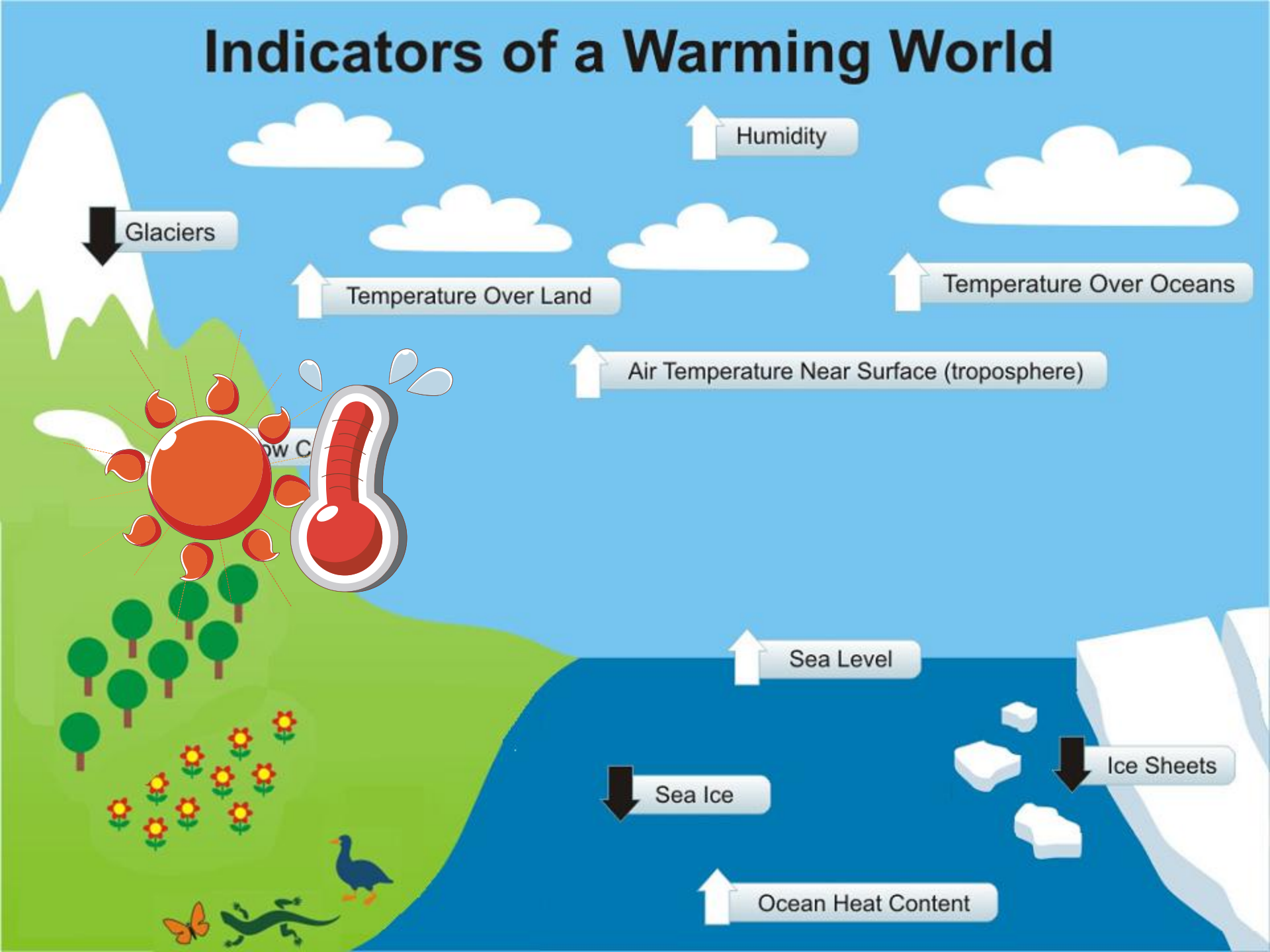

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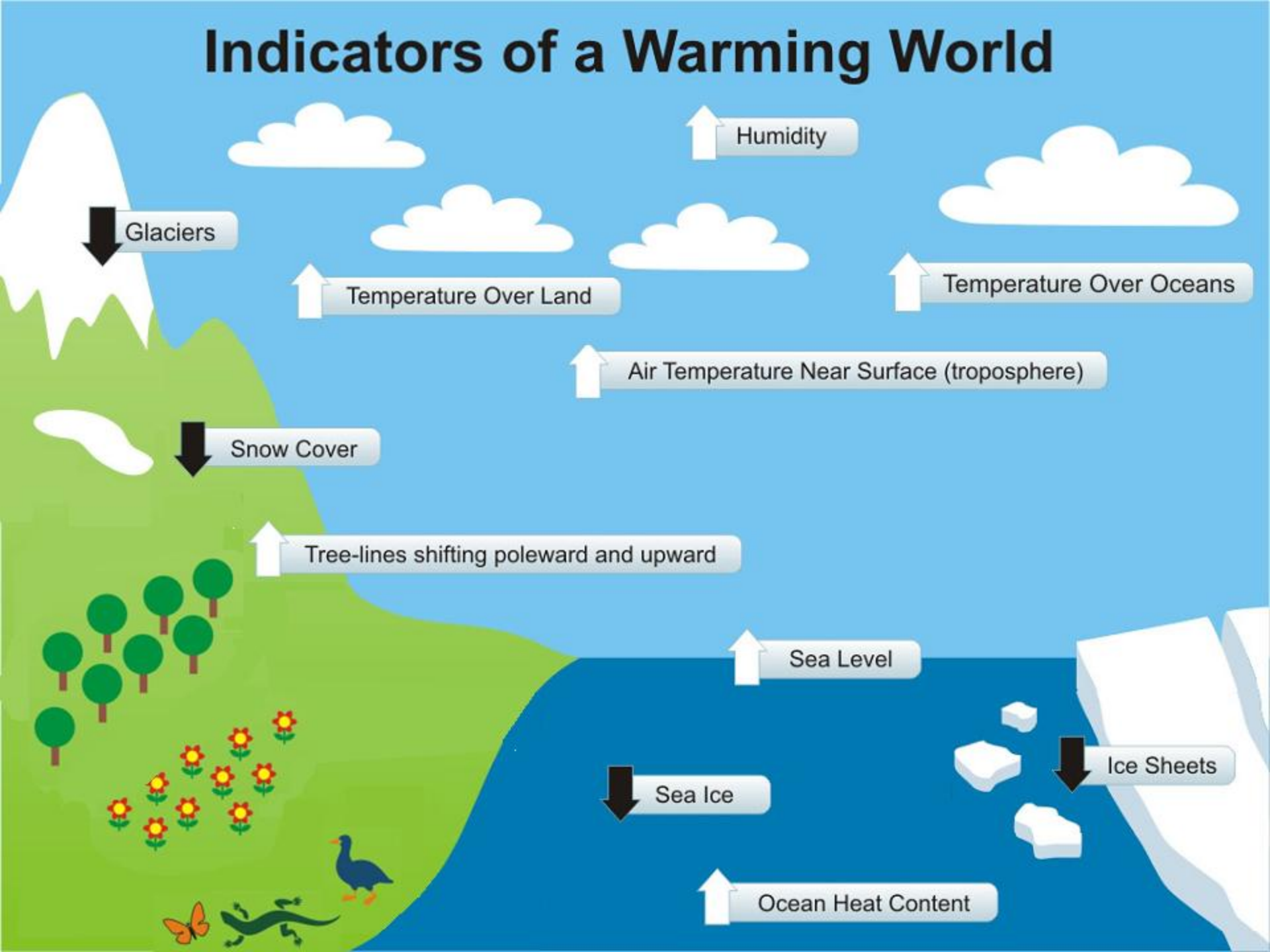
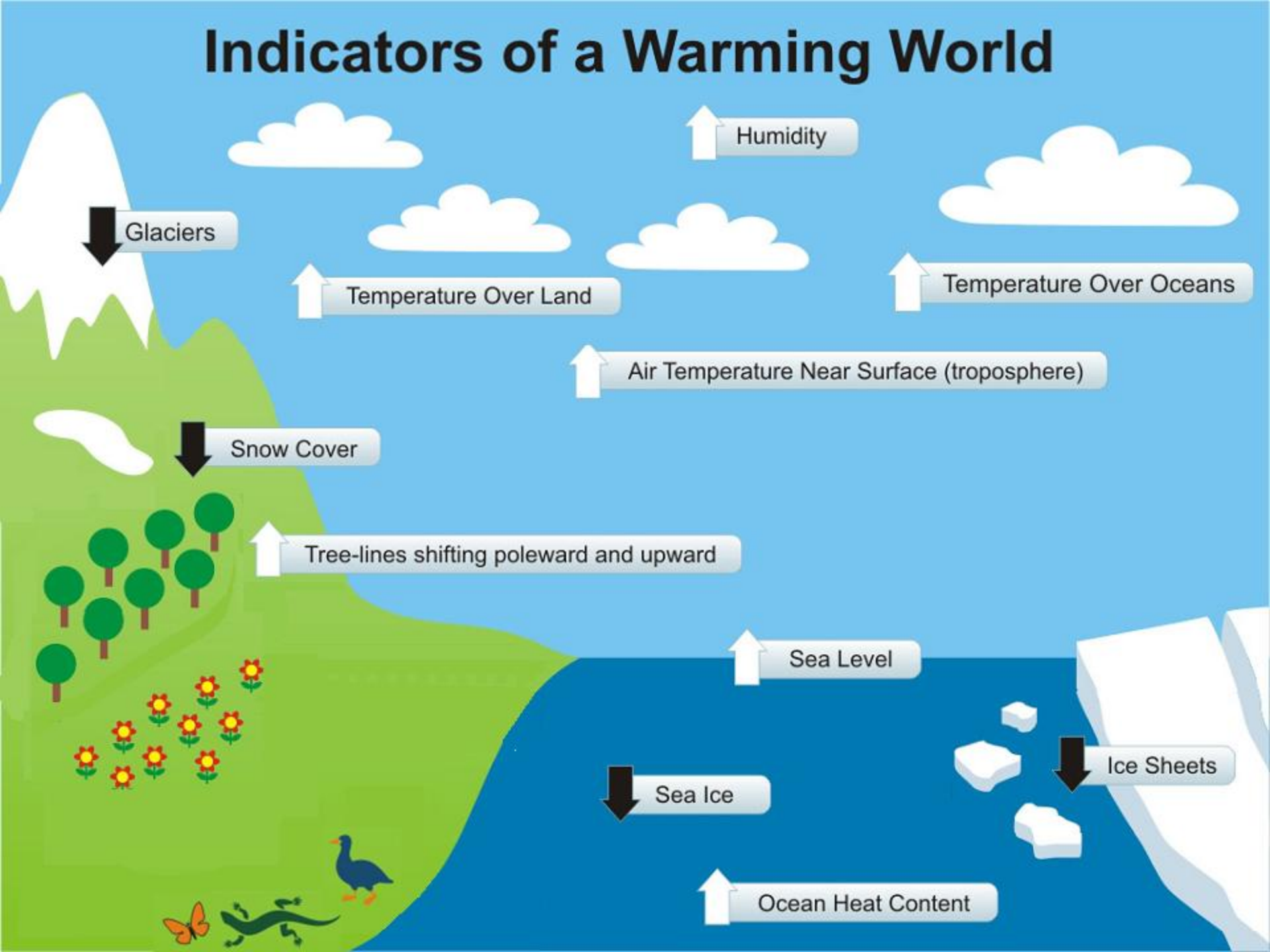
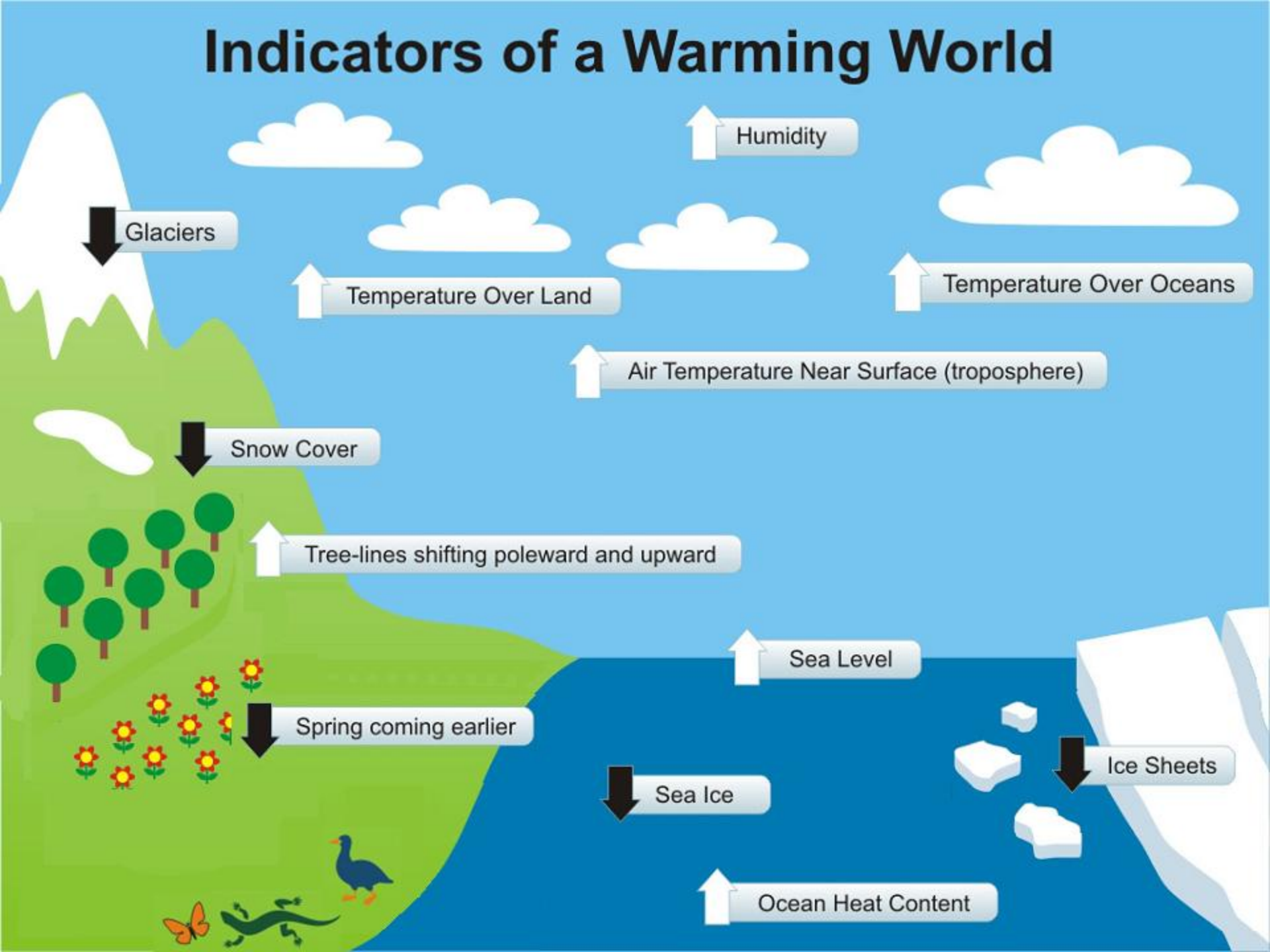


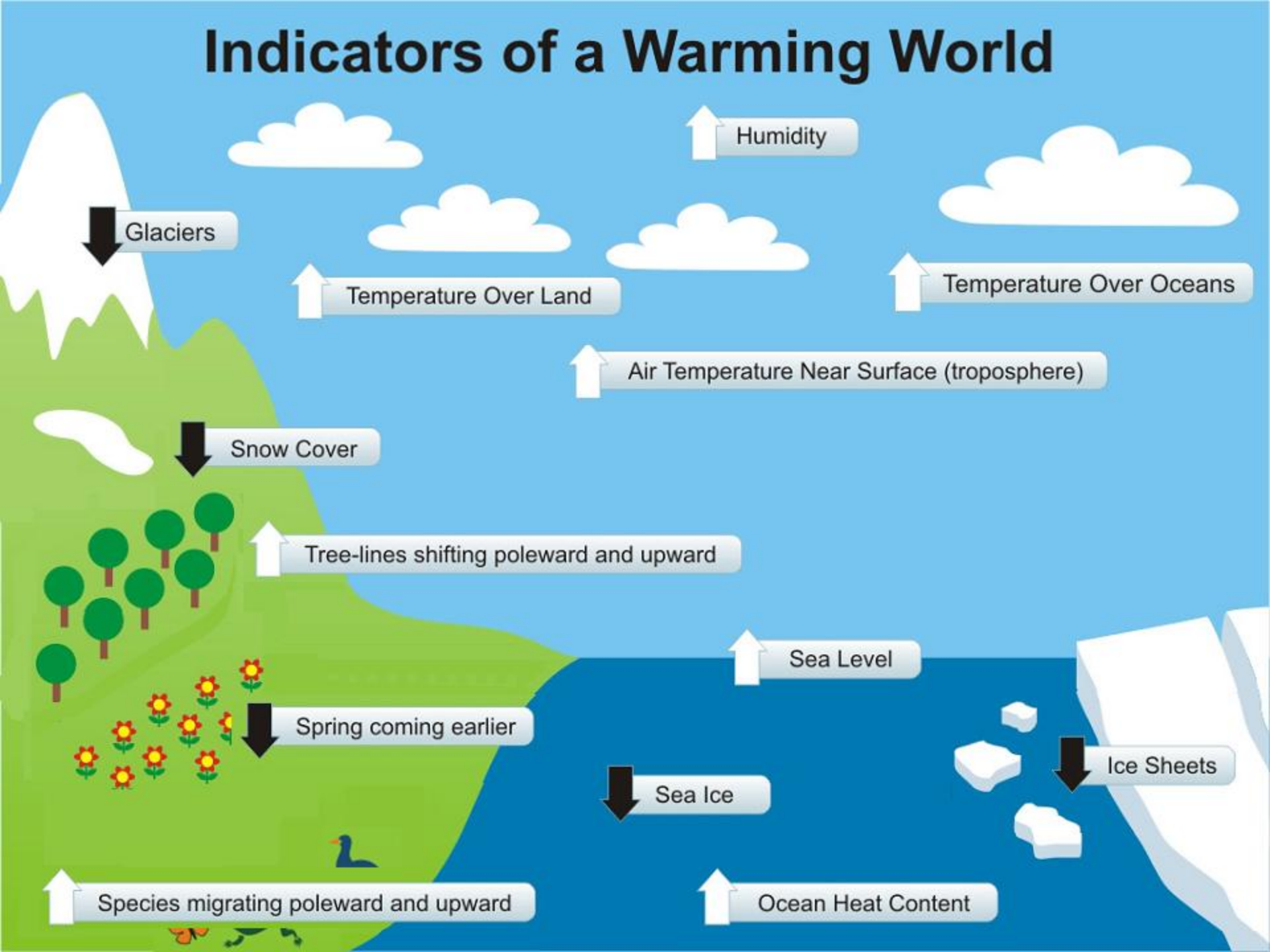
Indicators of a Warming World



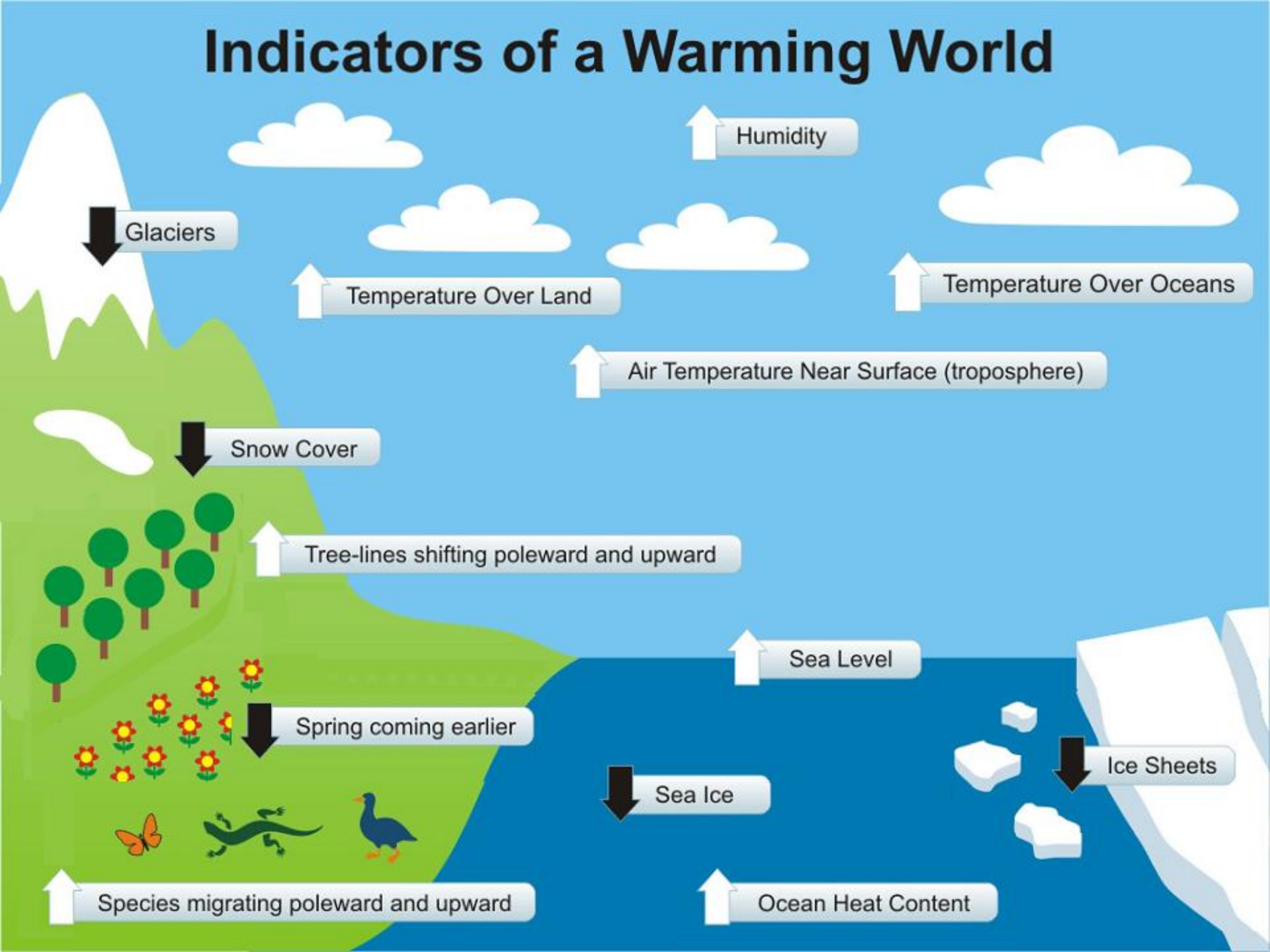
Indicators of a Warming World

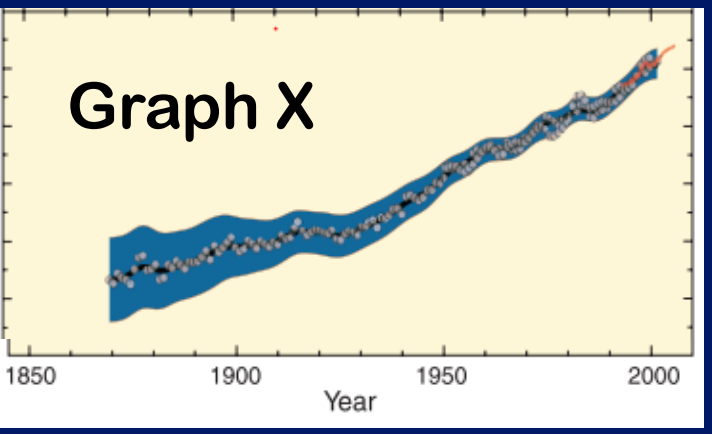


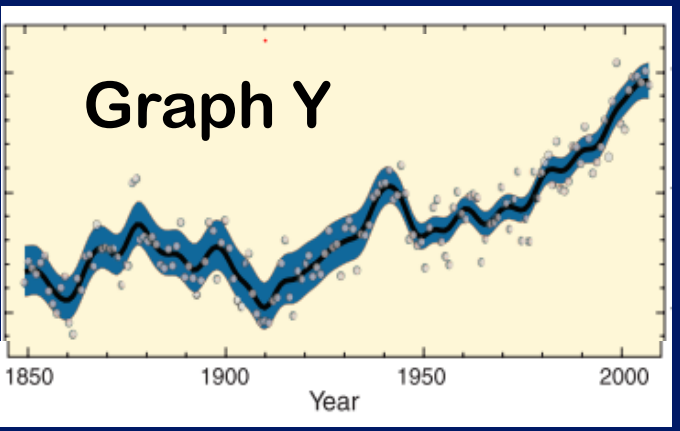
Indicators of a Warming World

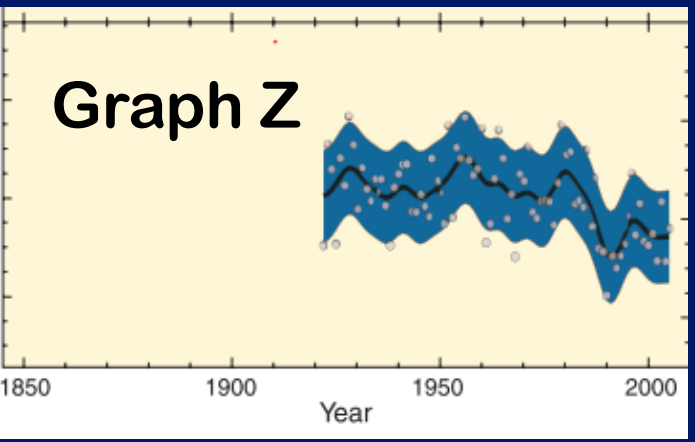


Indicators of a Warming World







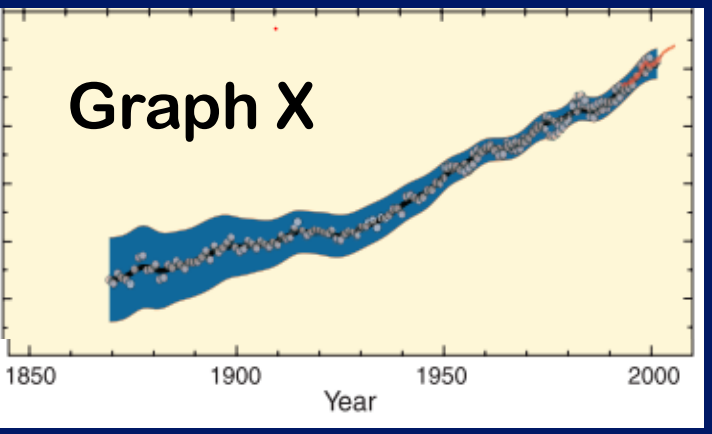


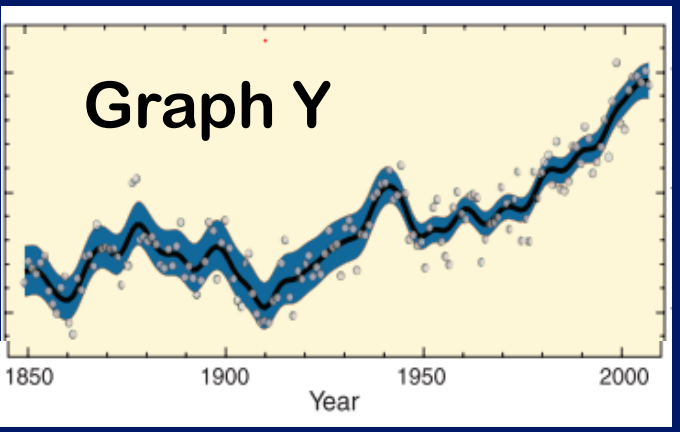
Q - Which choice below presents the correct LABELS for Graphs X, Y & Z?

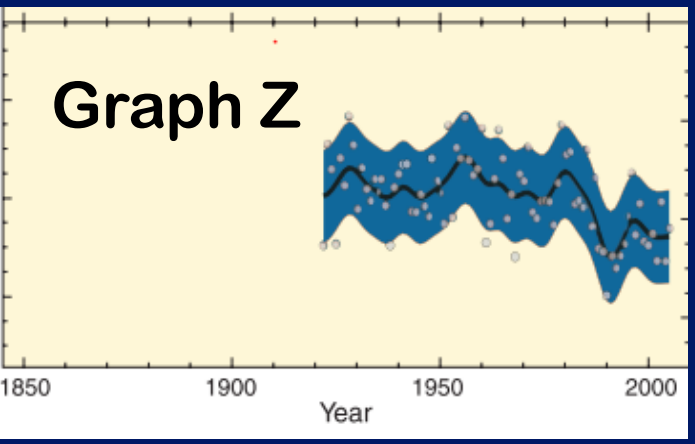
(1) X = Global Temperature
Y = N. Hemisphere Snow Cover
Z = Global Sea Level

(2) X = Global Temperature
Y = Global Sea Level
Z = N. Hemisphere Snow Cover

(3) X = Global Sea Level
Y = Global Temperature
Z = N. Hemisphere Snow Cover







Q1 - Which choice below presents the correct LABELS for Graphs X, Y & Z?

(1) X = Global Temperature
Y = N. Hemisphere Snow Cover
Z = Global Sea Level

(2) X = Global Temperature
Y = Global Sea Level
Z = N. Hemisphere Snow Cover

(3) X = Global Sea Level
Y = Global Temperature
Z = N. Hemisphere Snow Cover

TOPIC #16

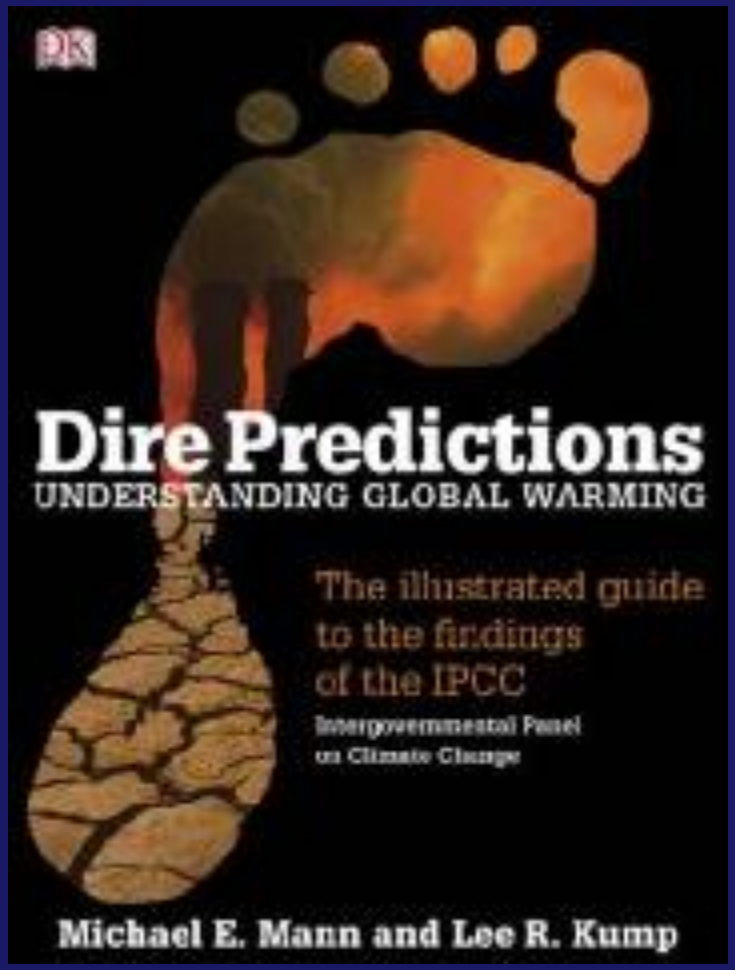
CLIMATE CHANGE: IMPACTS & ISSUES – THE IPCC FINDINGS & WHAT LIES AHEAD

starts on p 89 in Class Notes

There is a paradoxical gulf between the importance of Earth's climate and the level of public interest in it . . . .

We're in the middle of a large uncontrolled experiment on the only planet we have.

- Donald Kennedy
editor-in-chief of the journal Science



"The Illustrated Guide to the findings of the IPCC"

The most comprehensive source of information on Global Climate Change -- the IPCC

WMO INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE UNEP

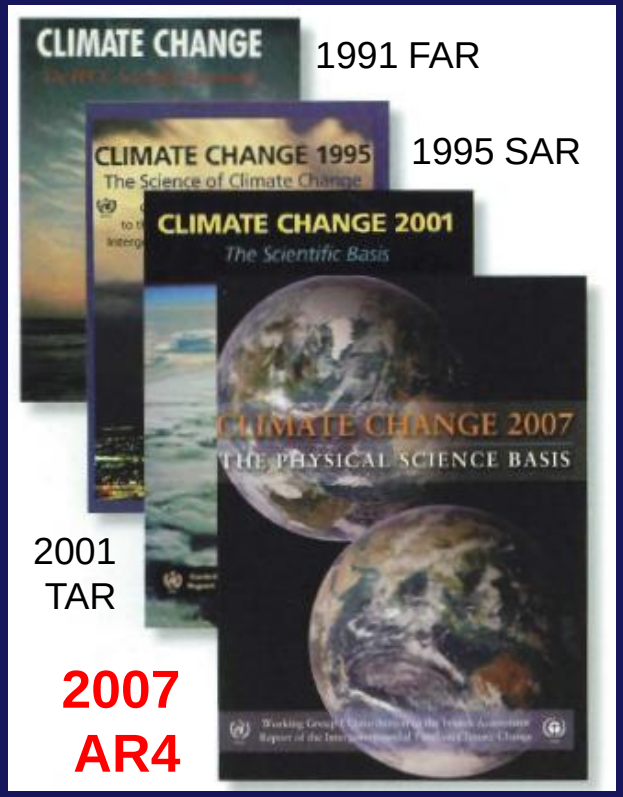
- Established by World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) in 1988 as an objective source of information for decision-makers, etc.

"to provide the world with a clear scientific view on the current state of climate change and its potential environmental and socio-economic consequences" (IPCC 2007)

- The IPCC does not conduct any research on its own, nor does it monitor climate related data or parameters.

Began with:

The "First Assessment Report" (FAR) in 1991



Most recent:

"Assessment Report 4" (AR4) in 2007 (now working on AR5)

- Its role is **to assess on a comprehensive, objective, open and transparent basis** the latest **scientific**, **technical** and **socio-economic** literature produced worldwide relevant to the understanding of:
  - the **risk** of human induced climate change
  - its **observed and projected impacts** and
  - options for **adaptation and mitigation.**

http://www.ipcc.ch/publications_and_data/publications_and_data_reports.htm#1

- The **IPCC** is a **scientific body**

- **Thousands of scientists** from all over the world contribute to the work of the IPCC on a voluntary basis.

- **PEER REVIEW** is an essential part of the IPCC process, to ensure an objective and complete assessment of current information.

- **Differing viewpoints** existing within the scientific community are reflected in the IPCC reports.

AR4 (IPCC 2007)

• **The IPCC is an intergovernmental body,** and it is open to all member countries of UN and WMO.

• Because of its scientific and intergovernmental nature, the IPCC embodies a **unique opportunity to provide rigorous and balanced scientific information to decision makers**.

• By endorsing the IPCC reports, **governments acknowledge the authority of their scientific content.**

• The work of the organization is **therefore policy-relevant and yet policy-neutral, never policy-prescriptive**.

AR4 (IPCC 2007)

Small, low income, vulnerable people & nations:
They are least responsible,
yet likely to be impacted the most!

The IPCC has 3 "working groups," a Task Force (and various other subcommittees):

Working Group I (WGI):
Physical Science of climate and climate change.

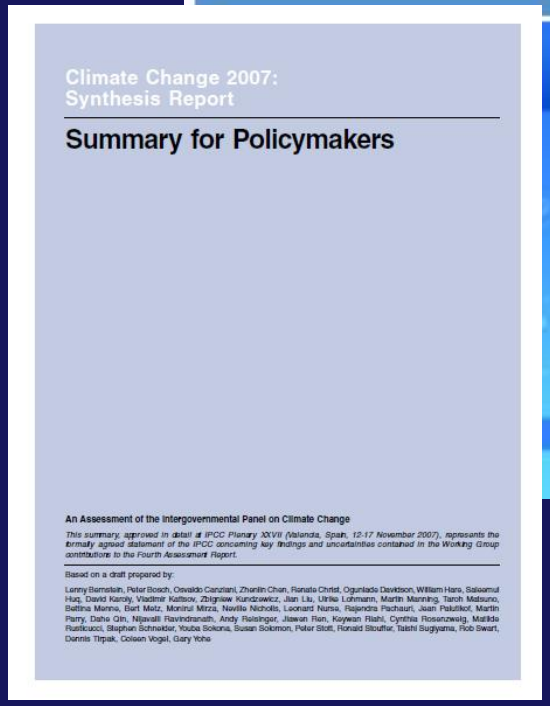
Working Group II (WGII):
People & Climate – Impacts, Vulnerability of people and natural systems to climate change, & Adaptation options)

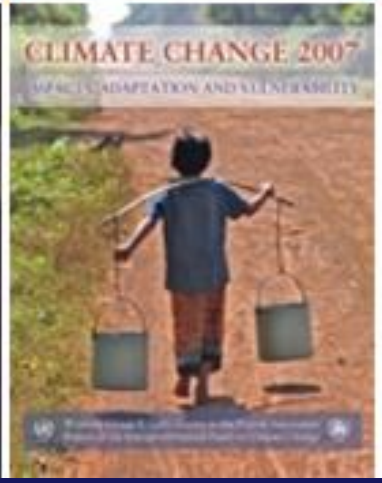
Working Group III (WGIII):
Mitigation - options for limiting GHG emissions

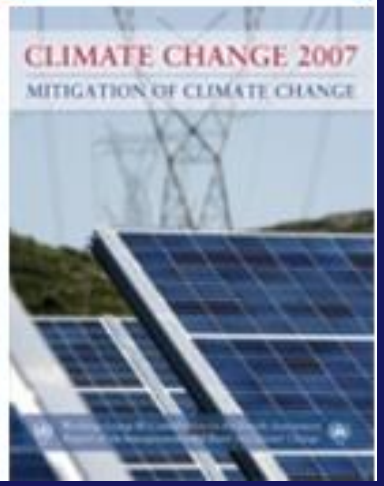
Plus: A Task Force that oversees the National Greenhouse Gas Inventories Program

The **Fourth Assessment Report (AR4)** was released in 2007, and it consists of four volumes: the three IPCC Working Groups (WGs) Reports and a Synthesis Report (SYR)

The AR4 Synthesis Report	WG I The Physical Science Basis	WG II Impacts, Adaptation and Vulnerability	WG III Mitigation of Climate Change

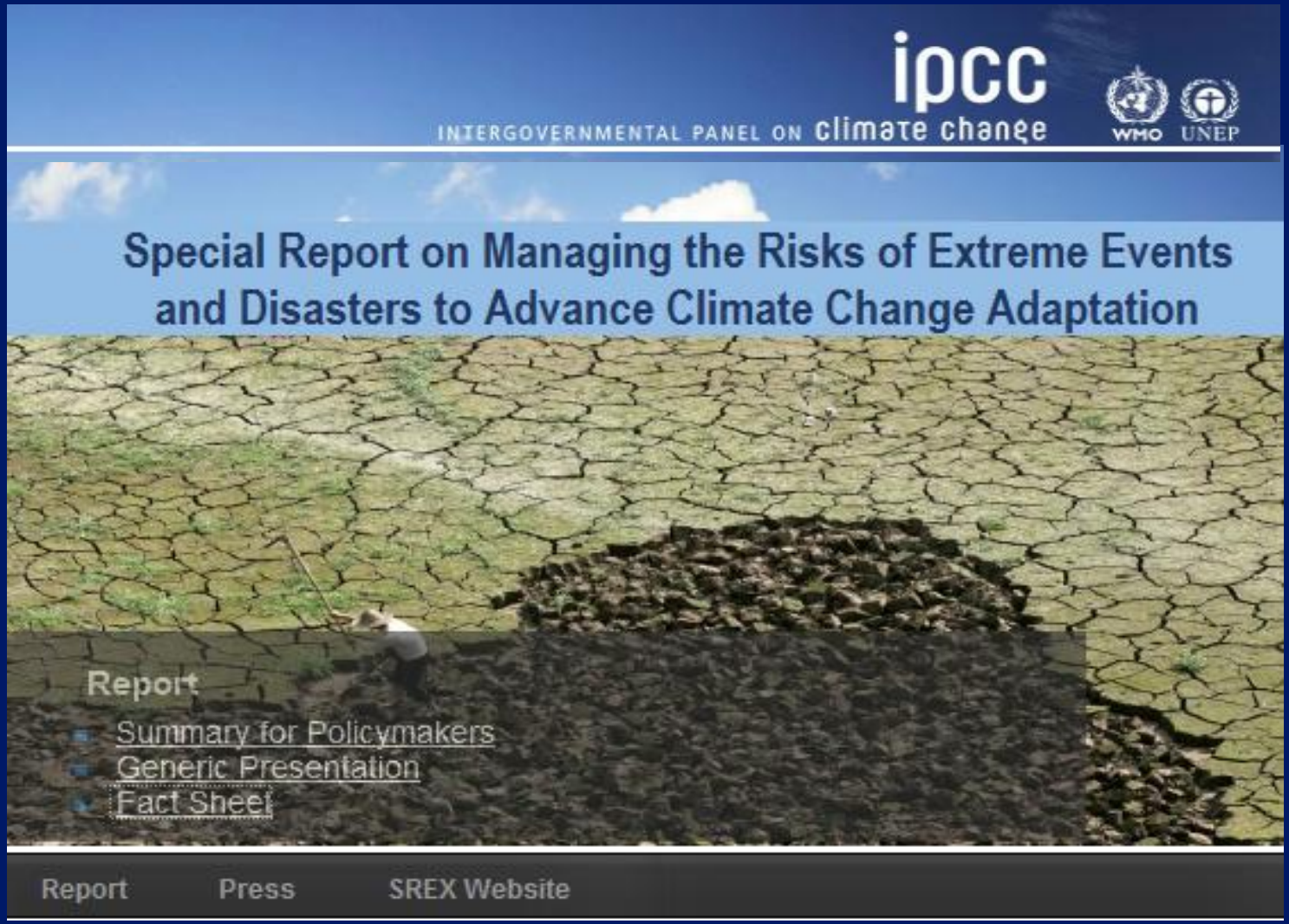






http://www.ipcc.ch/

. . . And SPECIAL REPORTS:

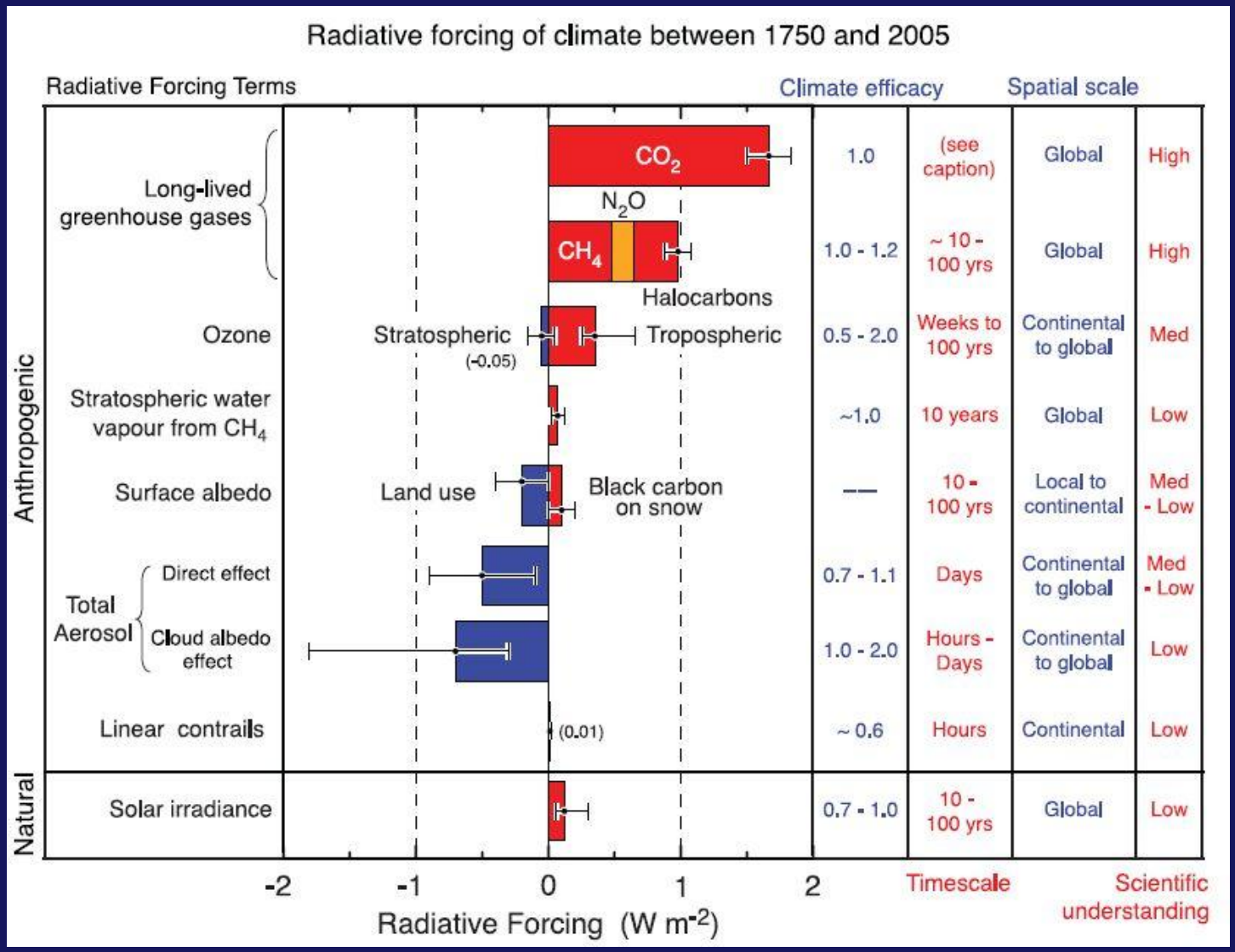


What was **NEW** in the most recent reports:

Estimates of confidence in the report's results / conclusions:

- **virtually certain** (greater than 99% chance that a result is true)
- **very likely** (90-99% chance);
- **likely** (66-90% chance);
- **medium likelihood** (33-66% chance);
- **unlikely** (10-33% chance);
- **very unlikely** (1-10% chance);
- **exceptionally unlikely** (less than 1%) chance).

More accurate assessment of magnitude of individual RADIATIVE FORCINGS :



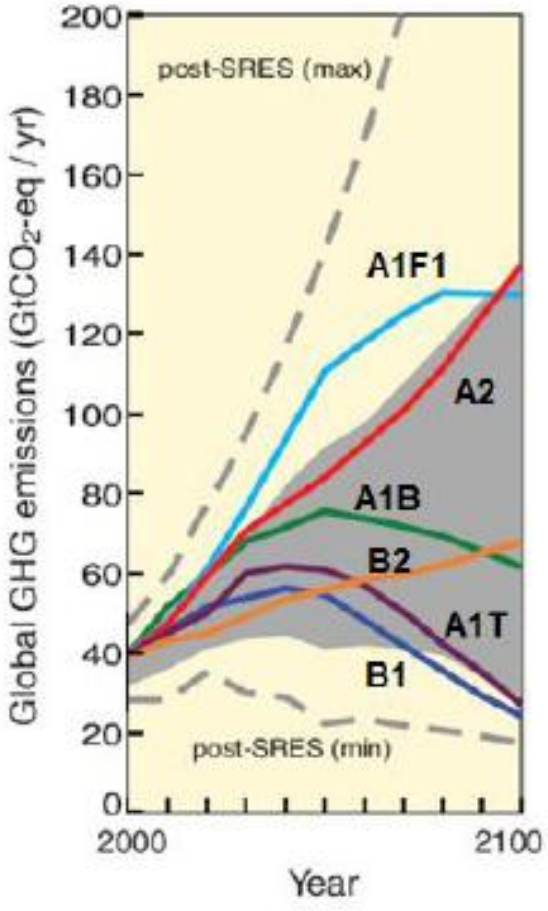
SOURCE: IPCC 2007 WG-1 Synthesis Report Summary for Policymakers

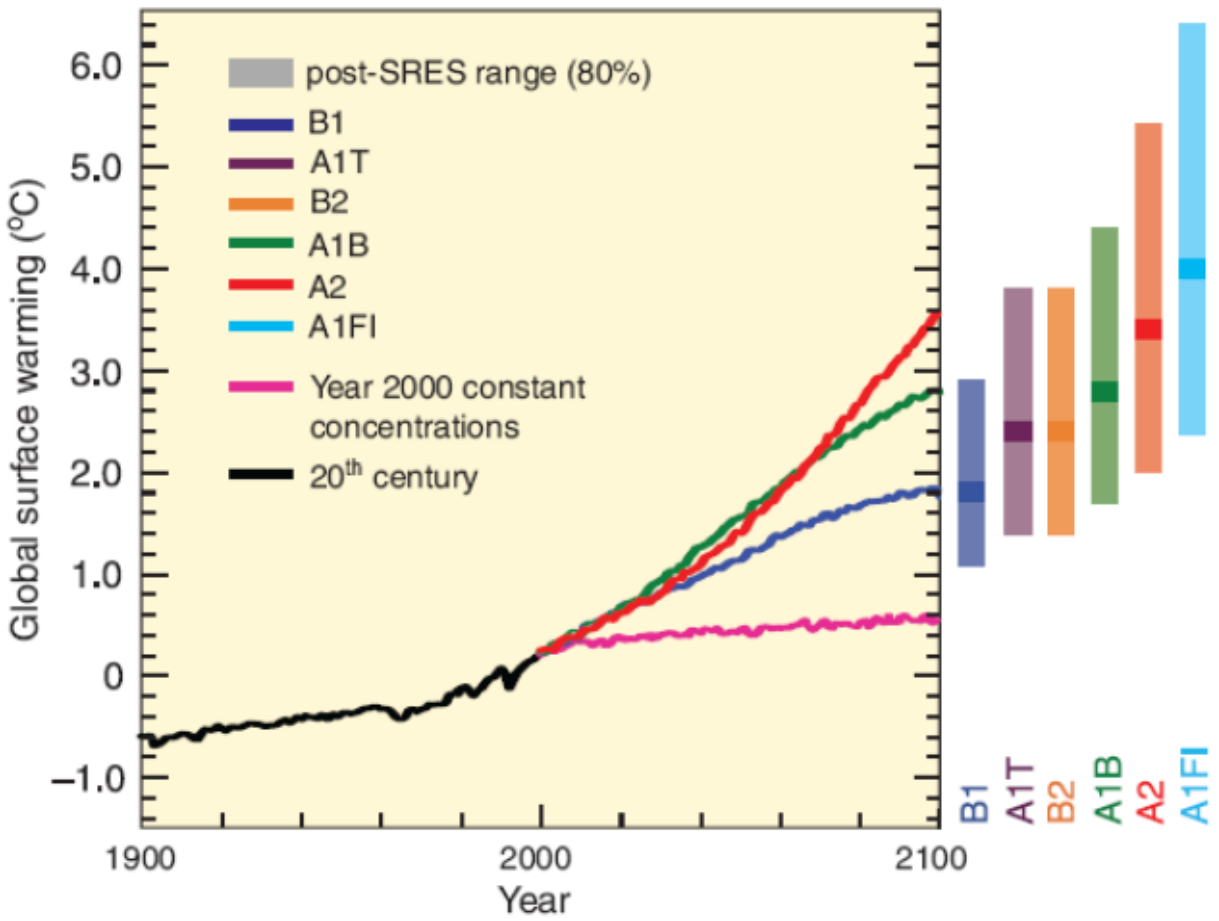
review

New Projections of Climate Change based on **state-of-the-art computer model results** and **revised SCENARIOS:**

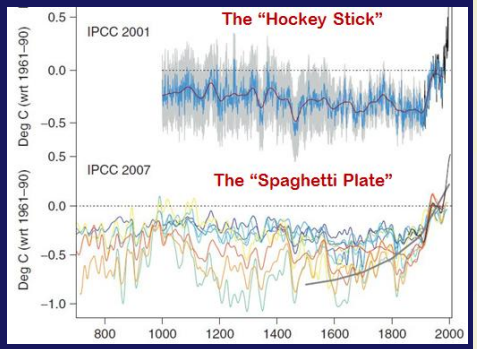
Projected Climate Change for Different Scenarios of GHG Emissions

Scenarios for GHG emissions from 2000 to 2100 (in the absence of additional climate policies) and projections of surface temperatures

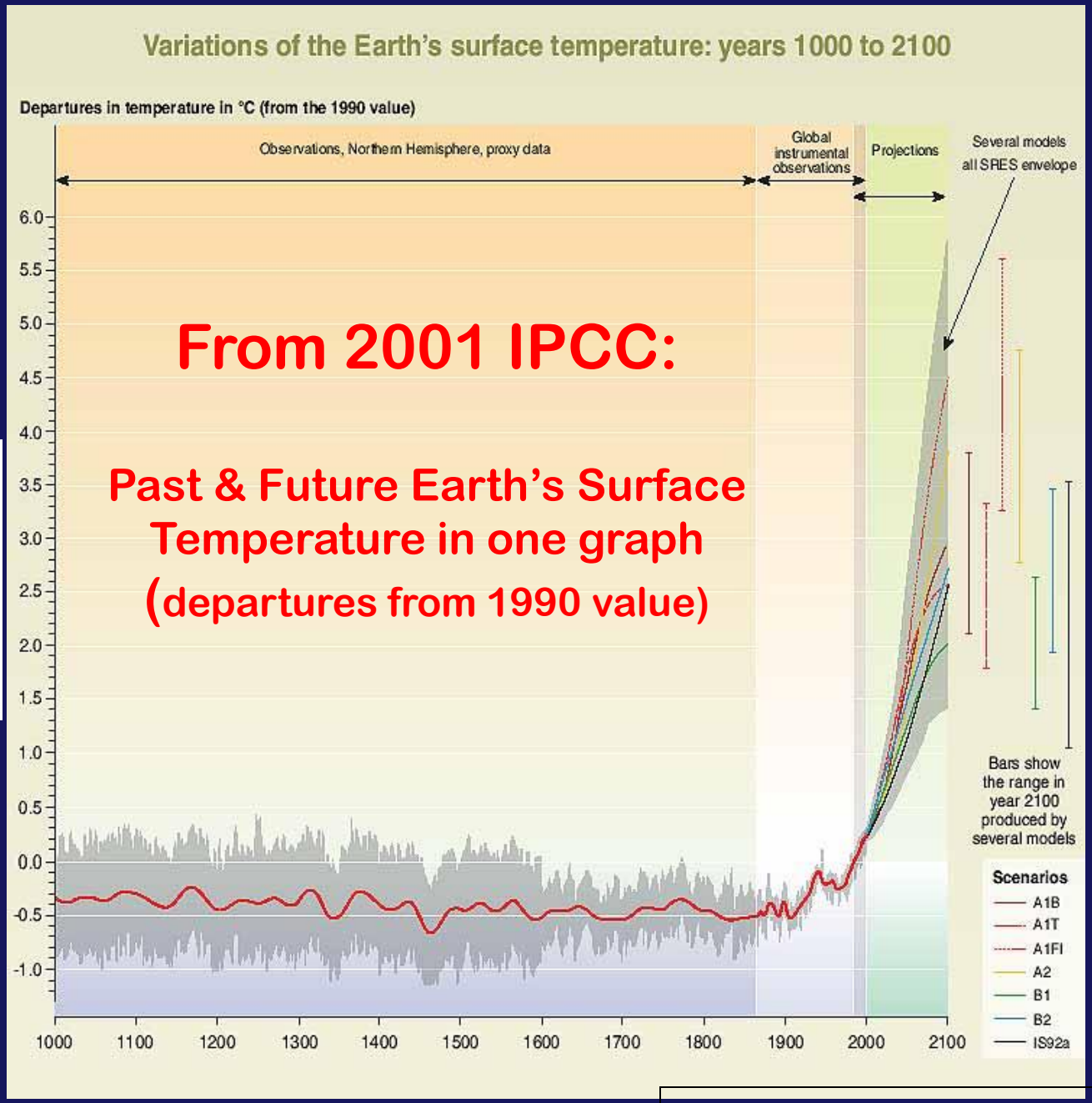




Improved "Hockey Stick" (from 2001 Third Assessment) ➔ Spaghetti Plate



GLOBAL SURFACE TEMPERATURE CHANGE (° C) (compared to 1990 value)

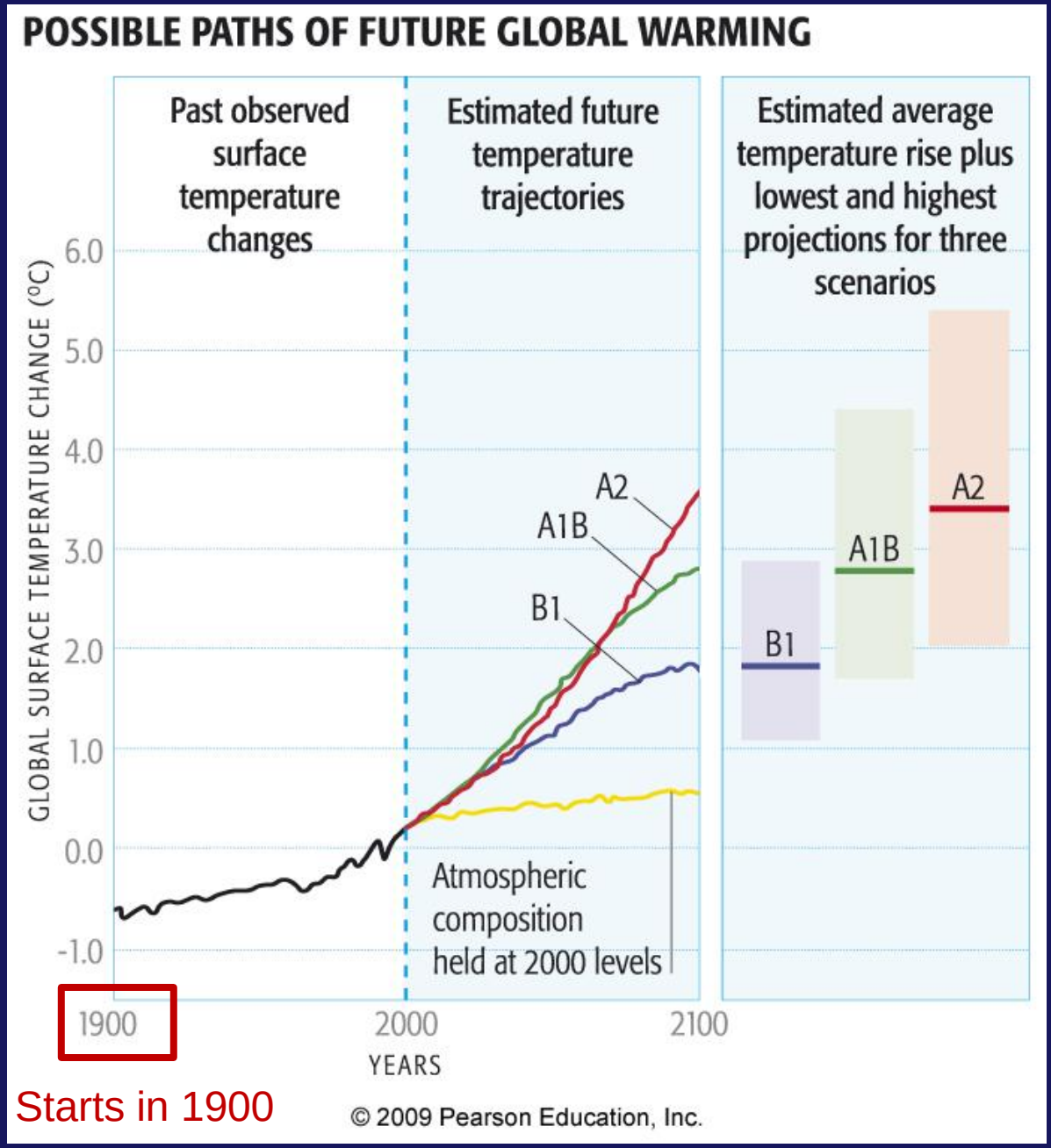


From Self test 8

Updated version in AR4:

2007 IPCC FOURTH ASSESSMENT REPORT

GLOBAL SURFACE TEMPERATURE CHANGE (° C)
Compared to 1980-1999 period



Starts in 1900

From *Dire Predictions* (p 20)

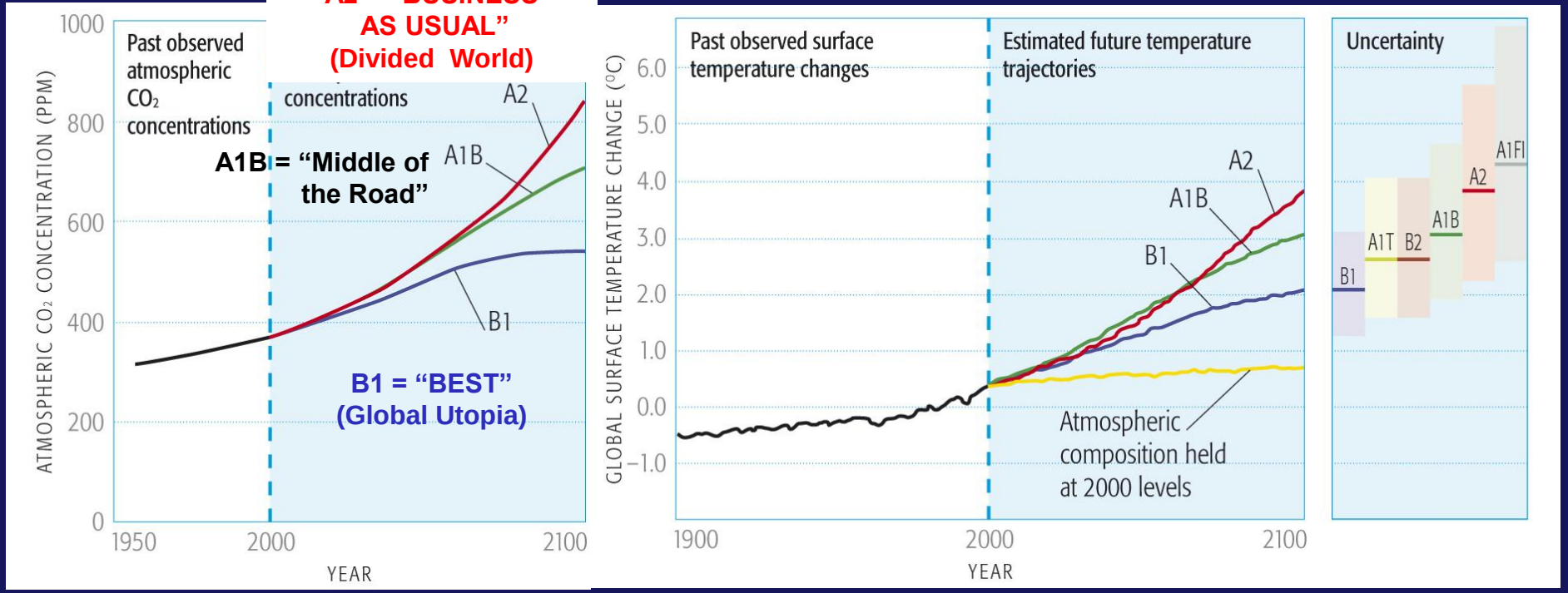
RANGE OF POSSIBLE TRAJECTORIES FOR FUTURE CLIMATE CHANGE

CO2 in ATMOSPHERE
(due to emissions)

RESULTING WARMING: TEMPERATURE INCREASE

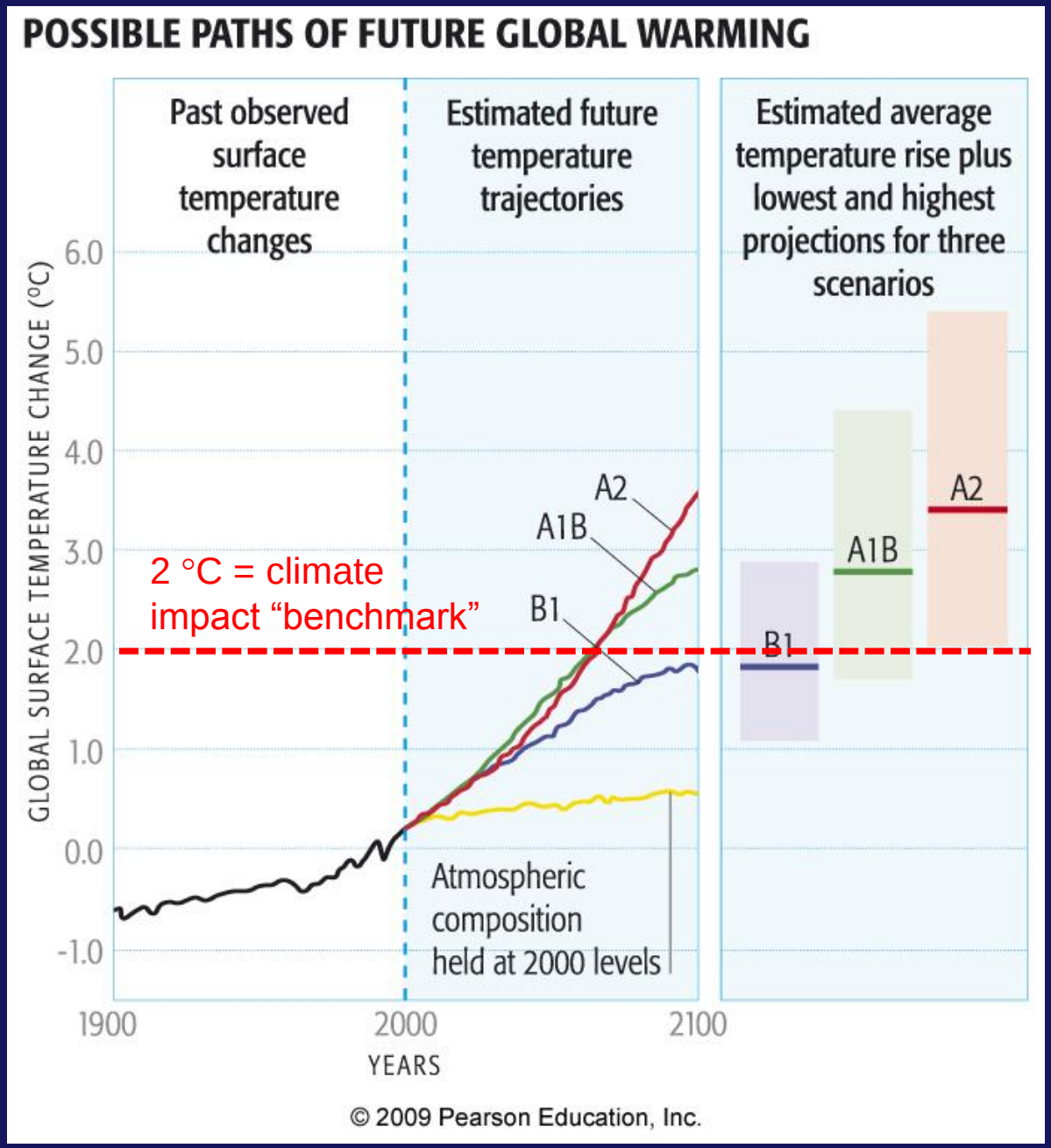
Spread of results due to:

(a) which future emission scenario used
(b) variations among different climate models



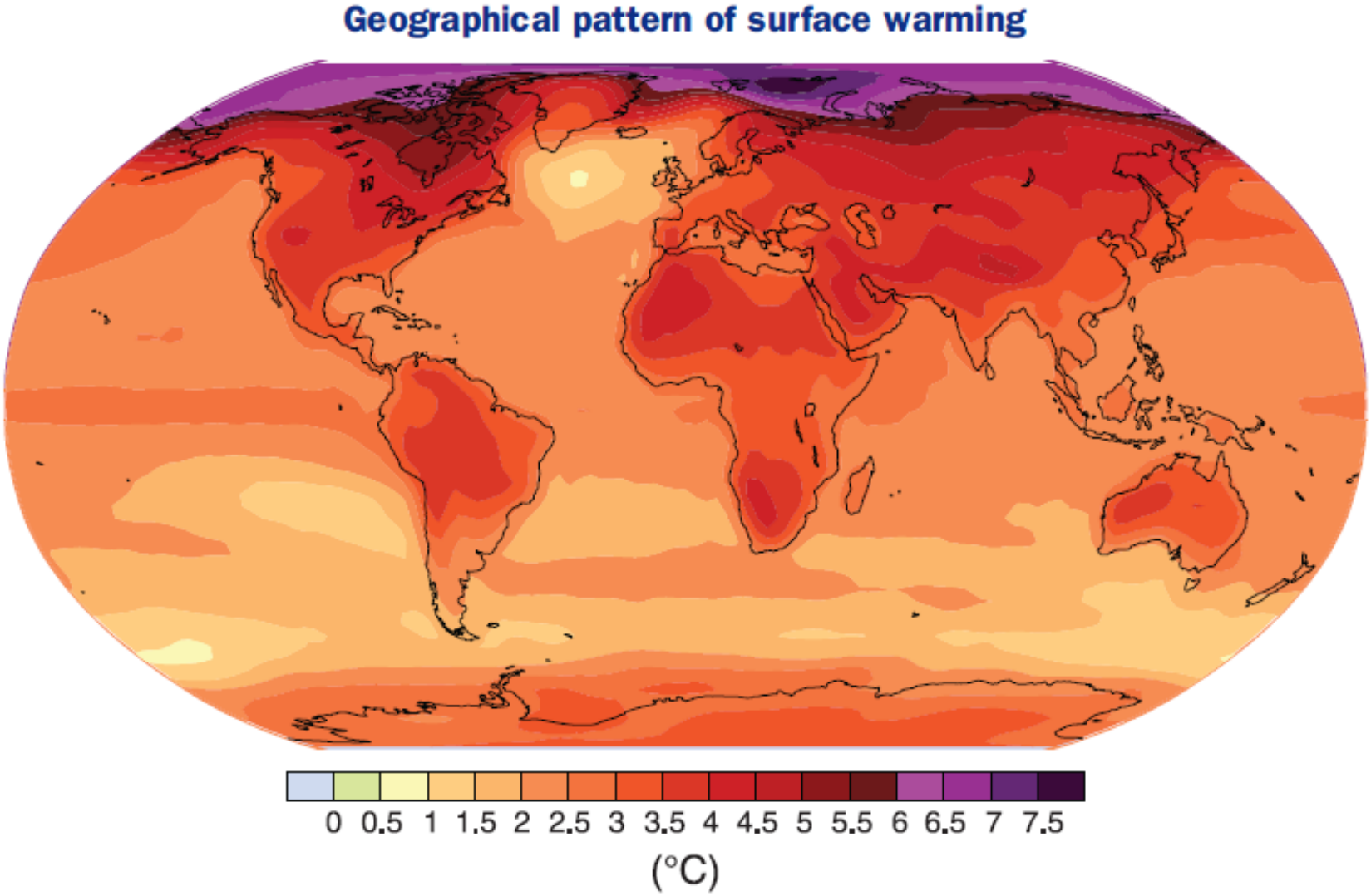
From *Dire Predictions* (p 88)

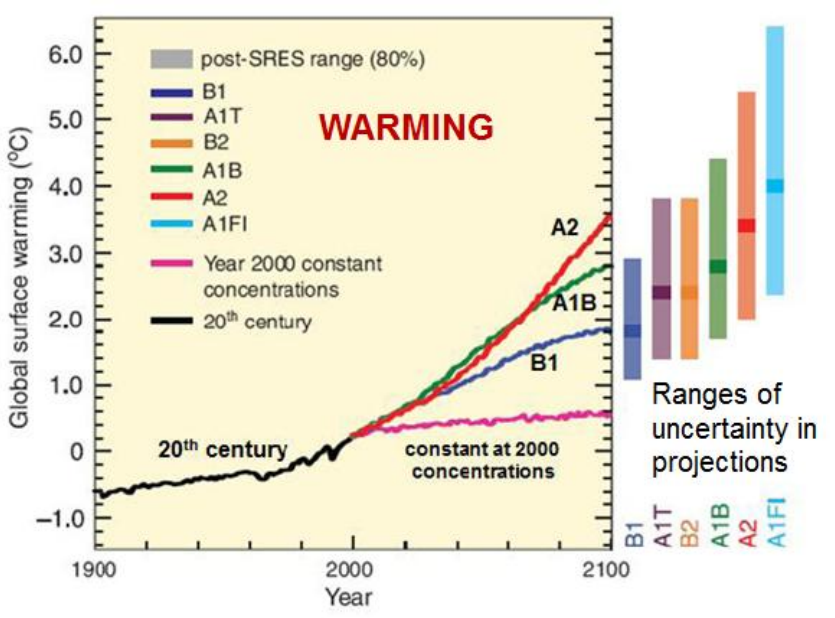
GLOBAL SURFACE TEMPERA-TURE CHANGE (° C)



From *Dire Predictions* (p 20)

Projected Warming by Late 21st Century (2090-2099) based on the A1B "Middle of the Road" Scenario





The TABLE below shows the computer model estimates of temperature change for each of the scenarios on ← this graph

Table SPM.1. Projected global average surface warming and sea level rise at the end of the 21st century. {Table 3.1}

Case	Temperature change (°C at 2090-2099 relative to 1980-1999) [a, d]		Sea level rise (m at 2090-2099 relative to 1980-1999)
	Best estimate	*Likely* range	Model-based range excluding future rapid dynamical changes in ice flow
Constant year 2000 concentrations[b]	0.6	0.3 – 0.9	Not available
B1 scenario	1.8	1.1 – 2.9	0.18 – 0.38
A1T scenario	2.4	1.4 – 3.8	0.20 – 0.45
B2 scenario	2.4	1.4 – 3.8	0.20 – 0.43
A1B scenario	2.8	1.7 – 4.4	0.21 – 0.48
A2 scenario	3.4	2.0 – 5.4	0.23 – 0.51
A1FI scenario	4.0	2.4 – 6.4	0.26 – 0.59

We are already on a path that is close to the A2 scenario or WORSE!!

← This is much faster than was expected when the 2007 IPCC first came out!

November 3, 2011

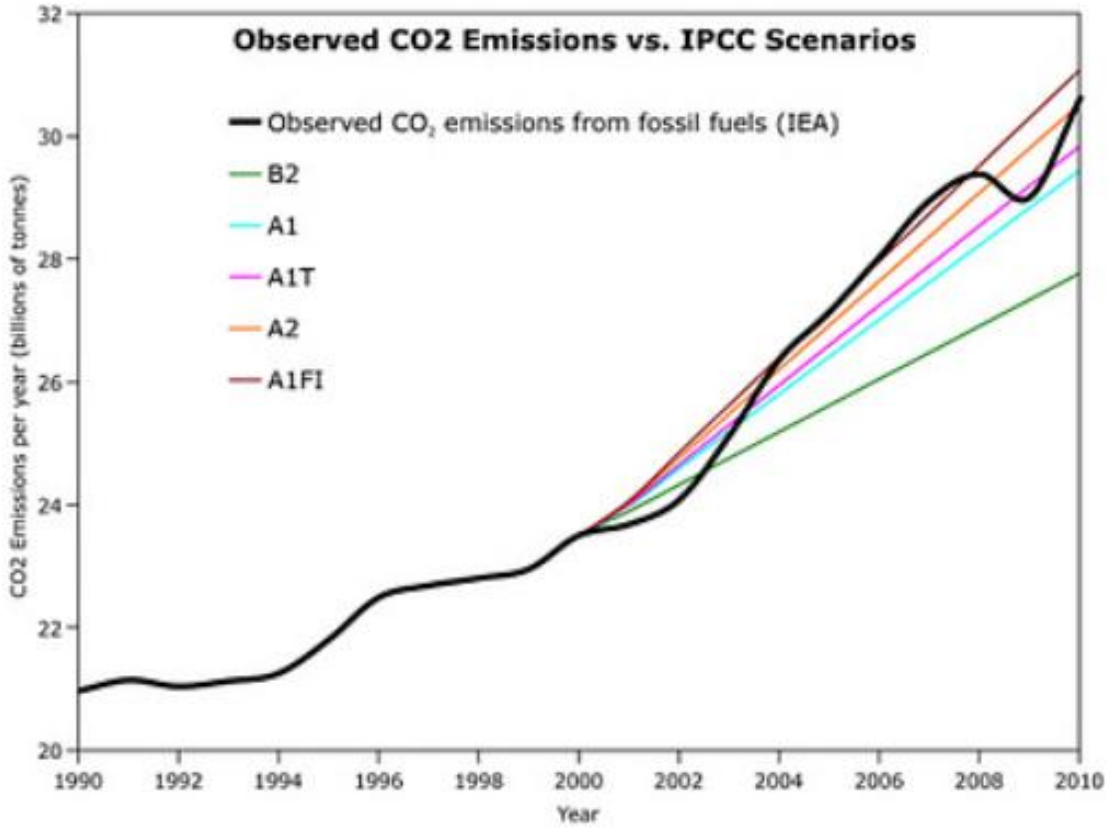
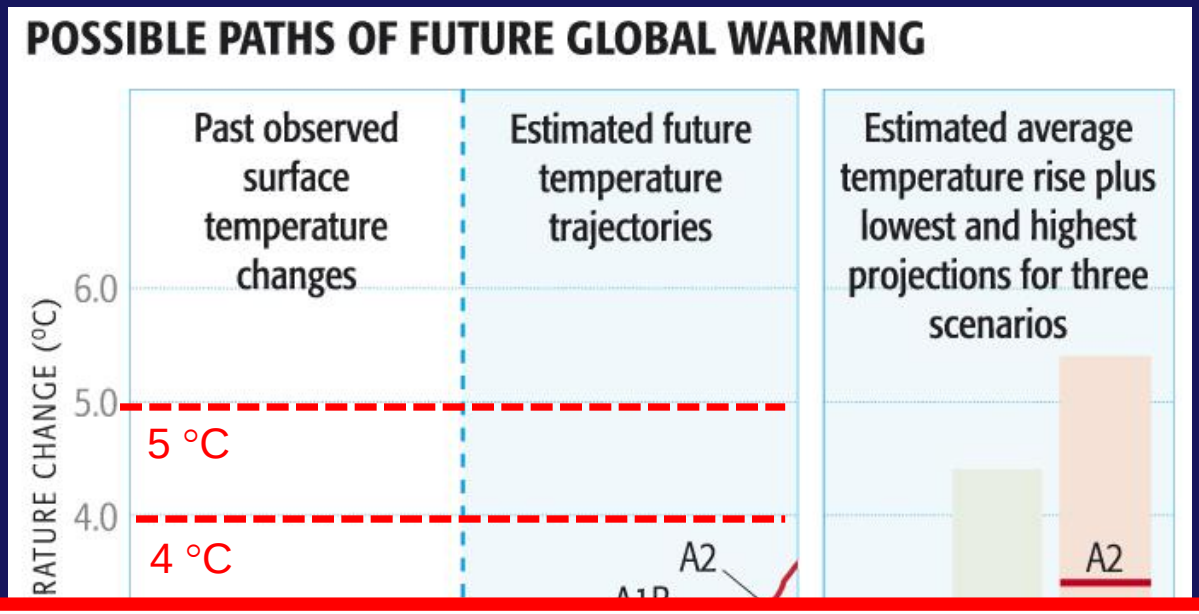


Figure 1: IEA global human CO2 annual emissions from fossil fuels estimates vs. IPCC SRES scenario projections. The IPCC Scenarios are based on observed CO2 emissions until 2000, at which point the projections take effect.

http://www gases/

The latest figures put global emissions on track with the worst case projections from the Intergovernmental Panel on Climate Change (IPCC) 2007 report.



GLOBAL SURFACE TEMPERATURE CHANGE (° C

"This means that **we will have no choice but to adapt to a change in climate**"

- even if our mitigation actions place us on a low emissions pathway (such as B1) or . . .
- even if emissions are stopped entirely (which would be impossible)

Lesson 4 Climate Science Basics Tutorial

Pacific Institute for Climate Solutions
Knowledge. Insight. Action.

The I-2D LESSON 4 ONLINE TUTORIAL

has an excellent section that will help you understand these graphs!

And now . . .

the DIRE PREDICTIONS based on the science summarized by the IPCC

(with probability / likelihood assigned to each projected future impact)

IPCC PROJECTIONS FOR THE 21ST CENTURY

▪ Cold days and nights will be warmer and less frequent over most land areas ▪ Hot days and nights will be warmer and more frequent over most land areas	VIRTUALLY CERTAIN **99%**
▪ If the atmospheric CO_2 level stabilizes at double the present level, global temperatures will rise by more than 1.5°C ▪ The warming over inhabited continents by 2030 will be about double the observed variability during the 20th century ▪ There will be an observed increase in methane concentration due to human activities ▪ The rate of increase in atmospheric CO_2, methane, and nitrous oxide will reach levels unprecedented in the last 10,000 years ▪ The frequency of warm spells and heat waves will increase ▪ The frequency of heavy precipitation events will increase ▪ Precipitation amounts will increase in high latitudes ▪ The ocean's conveyor-belt circulation will weaken or shut down abruptly	VERY LIKELY **90%**
▪ If the atmospheric CO_2 level stabilizes at double the present level, global temperatures will rise by between 2°C and 4.5°C ▪ The future increase in global average surface temperature will be between –40% and +60% of the values predicted by climate models ▪ Areas affected by drought will increase ▪ The number of frost days will decrease, and growing seasons will lengthen ▪ Intense tropical cyclone activity will increase, with greater wind speeds and heavier precipitation ▪ Extreme high-sea-level events will increase, as will ocean wave heights of mid-latitude storms ▪ Precipitation amounts will decline in the subtropics ▪ The loss of glaciers will accelerate in the next few decades ▪ Climate change will promote ozone-hole expansion, despite an overall decline in ozone-destroying chemicals	LIKELY **66%**
▪ The West Antarctic ice sheet will pass the melting point if global warming exceeds 5°C	ABOUT AS LIKELY AS NOT **35–50%**
▪ Antarctic and Greenland ice sheets will collapse due to surface warming	UNLIKELY
▪ The ocean's conveyer-belt circulation will suffer an abrupt transition ▪ If the atmospheric CO_2 level stabilizes at double the present level, global temperatures will rise by less than 1.5°C	VERY UNLIKELY **10%**

0 10 20 30 40 50 60 70 80 90

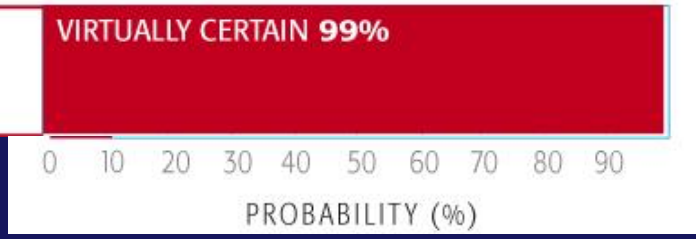
PROBABILITY (%)

From *Dire Predictions* (p 21)

IPCC PROJECTIONS FOR THE 21ST CENTURY

VIRTUALLY CERTAIN 99%

- Cold days and nights will be warmer and less frequent over most land areas
- Hot days and nights will be warmer and more frequent over most land areas



- **Over most land** areas:

HOT DAYS & NIGHTS will be WARMER;
and MORE FREQUENT

Recurrence Interval = measure of frequency

An event happening "once in 50 years"
in the future, might happen "once in 10 years"
(or have a "1 in 10" chance of occurring in any year)

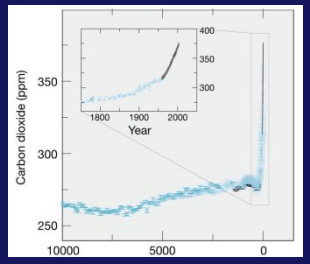
IPCC PROJECTIONS FOR THE 21ST CENTURY

VERY LIKELY 90%

- If the atmospheric CO_2 level stabilizes at double the present level, global temperatures will rise by more than 1.5°C
- The warming over inhabited continents by 2030 will be about double the observed variability during the 20th century
- There will be an observed increase in methane concentration due to human activities
- The rate of increase in atmospheric CO_2, methane, and nitrous oxide will reach levels unprecedented in the last 10,000 years
- The frequency of warm spells and heat waves will increase
- The frequency of heavy precipitation events will increase
- Precipitation amounts will increase in high latitudes
- The ocean's conveyor-belt circulation will weaken or shut down abruptly

VERY LIKELY **90%**

- **the RATE of increase of GHG's will be UNPRECEDENTED in past 10,000 yrs**



- **Frequency of HEAVY PRECIPITATION EVENTS will INCREASE**

IPCC PROJECTIONS FOR THE 21ST CENTURY

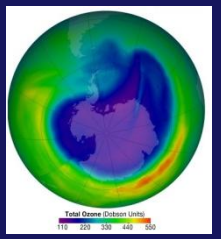
LIKELY 66%

- If the atmospheric CO_2 level stabilizes at double the present level, global temperatures will rise by between 2°C and 4.5°C
- The future increase in global average surface temperature will be between –40% and +60% of the values predicted by climate models
- Areas affected by drought will increase
- The number of frost days will decrease, and growing seasons will lengthen
- Intense tropical cyclone activity will increase, with greater wind speeds and heavier precipitation
- Extreme high-sea-level events will increase, as will ocean wave heights of mid-latitude storms
- Precipitation amounts will decline in the subtropics
- The loss of glaciers will accelerate in the next few decades
- Climate change will promote ozone-hole expansion, despite an overall decline in ozone-destroying chemicals

- **Extreme HIGH SEA LEVEL events will increase**

- **SUBTROPICS (that's us!) will experience PRECIPITATION DECLINE**

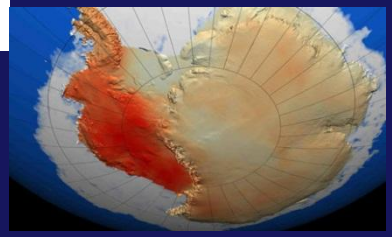
- **Stratospheric cooling ➔ ozone hole persistence even WITH ban of CFC's!**



IPCC PROJECTIONS FOR THE 21ST CENTURY

AS LIKELY AS NOT 35 - 50%

▪ The West Antarctic ice sheet will pass the melting point if global warming exceeds 5°C	ABOUT AS LIKELY AS NOT **35–50%**



- **W. ANTARCTIC ICE SHEET MELTING (if Temp > 5° C)**

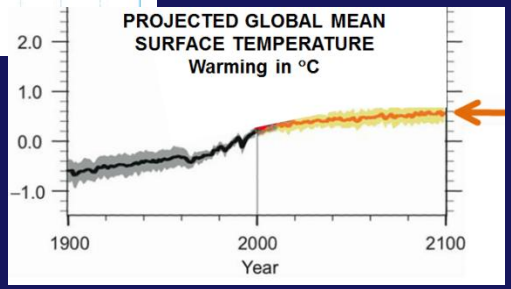
UNLIKELY 35%

▪ Antarctic and Greenland ice sheets will collapse due to surface warming	UNLIKELY

- **ANTARCTIC & GREENLAND ICE SHEETS COLLAPSE**

VERY UNLIKELY10%

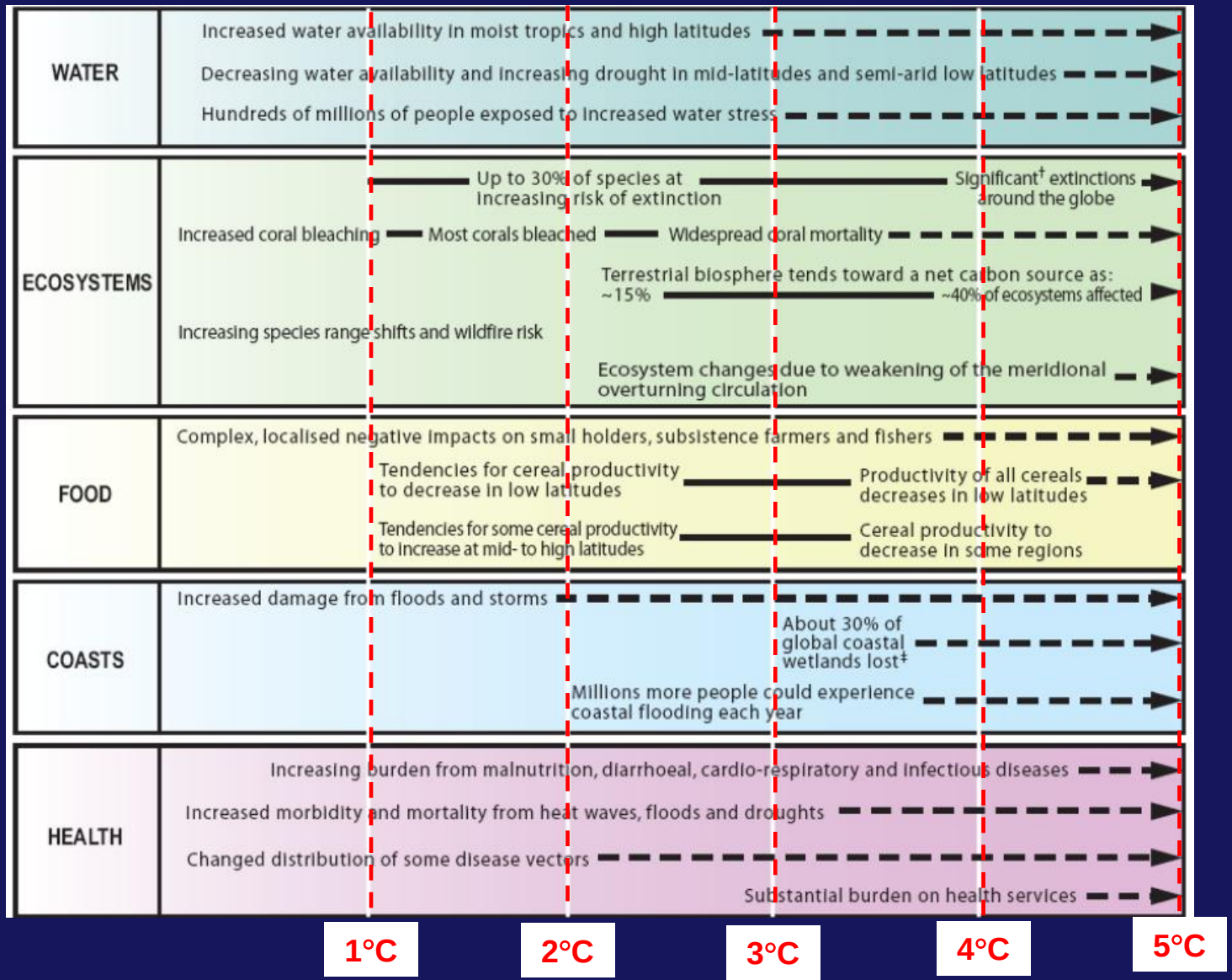
▪ The ocean's conveyer-belt circulation will suffer an abrupt transition ▪ If the atmospheric CO_2 level stabilizes at double the present level, global temperatures will rise by less than 1.5°C	VERY UNLIKELY **10%**



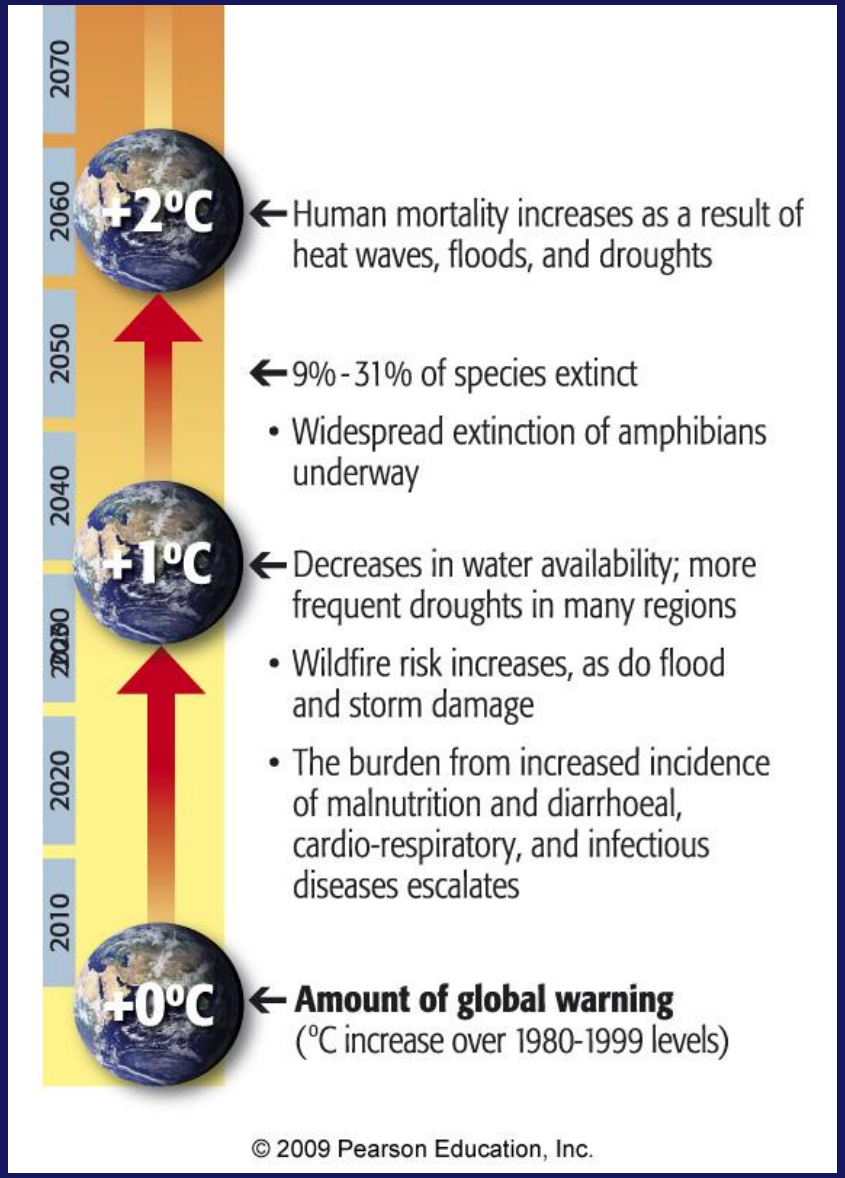
- **GLOBAL TEMPERATURES will rise by LESS than 1.5° C (if CO_2 stabilizes at 2x)**

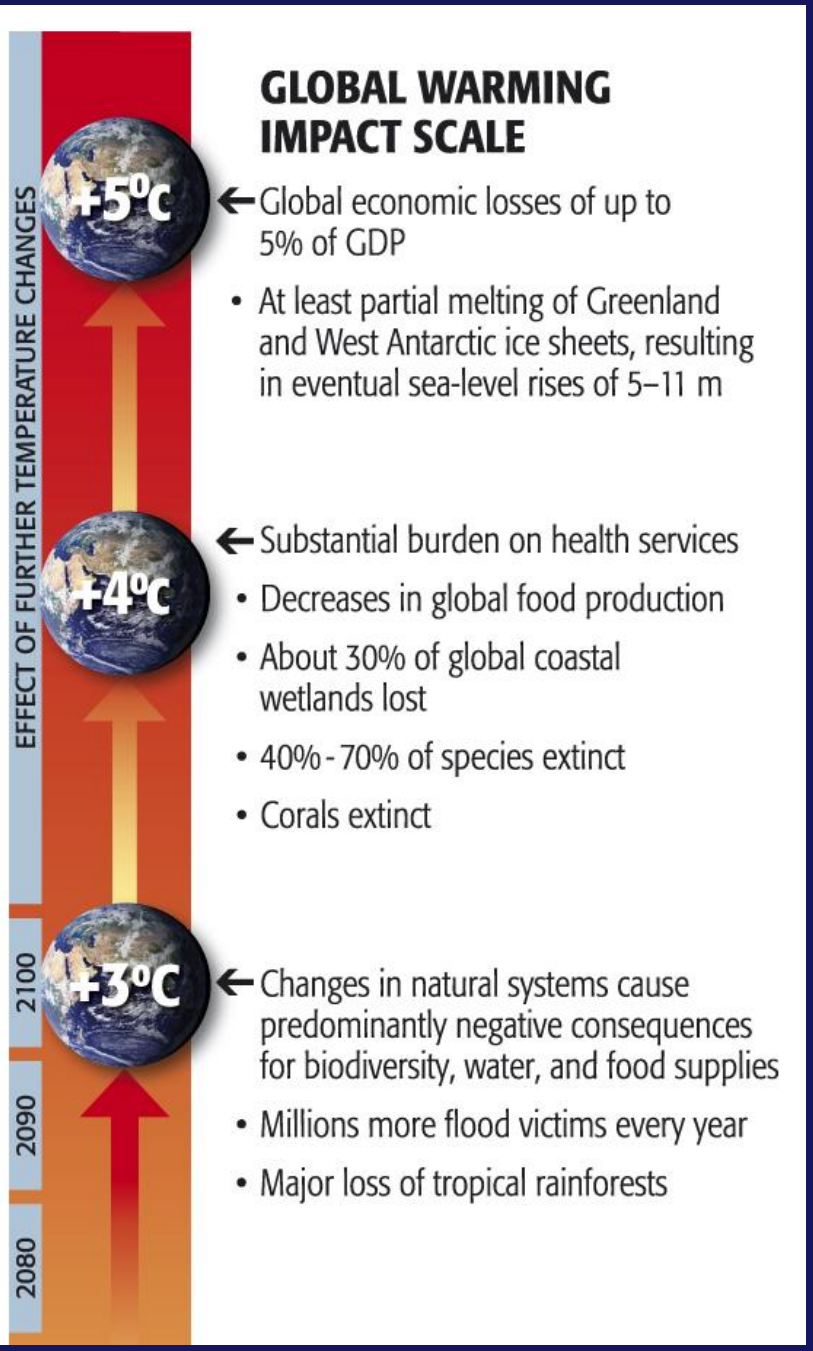
Examples of IMPACTS associated with global average annual temperature change

(relative to 1980-1999 average temperature)



GLOBAL WARMING IMPACT SCALE





From *Dire Predictions* (p 108)

So what do we do about it???

NEXT: ADAPTATION, MITIGATION & SOLUTIONS

POLICIES & POSSIBLE ACTIONS TO SLOW GLOBAL WARMING . . .