

# Earth's Changing Climate

- .What is climate?
- .What makes the climate change?
- .How has climate changed in the past?
- .Human caused climate change: the greenhouse effect.
- .Have we changed the climate?
- .What will the future climate look like?
- .How will climate change affect people?
- .Feedbacks

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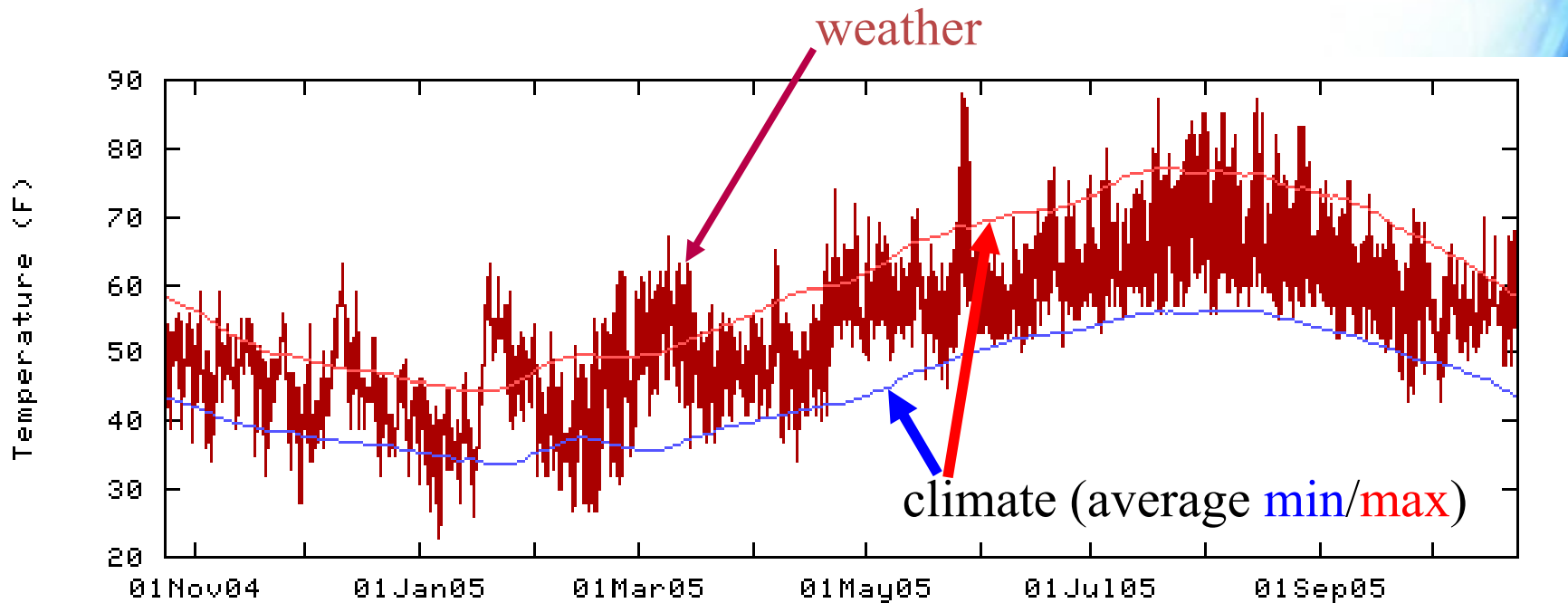
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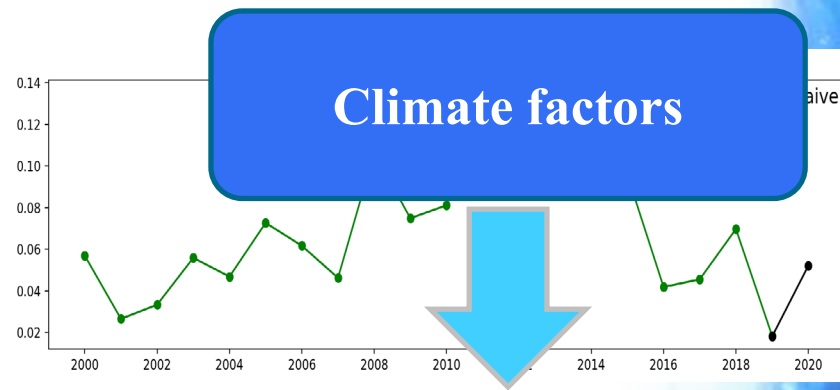
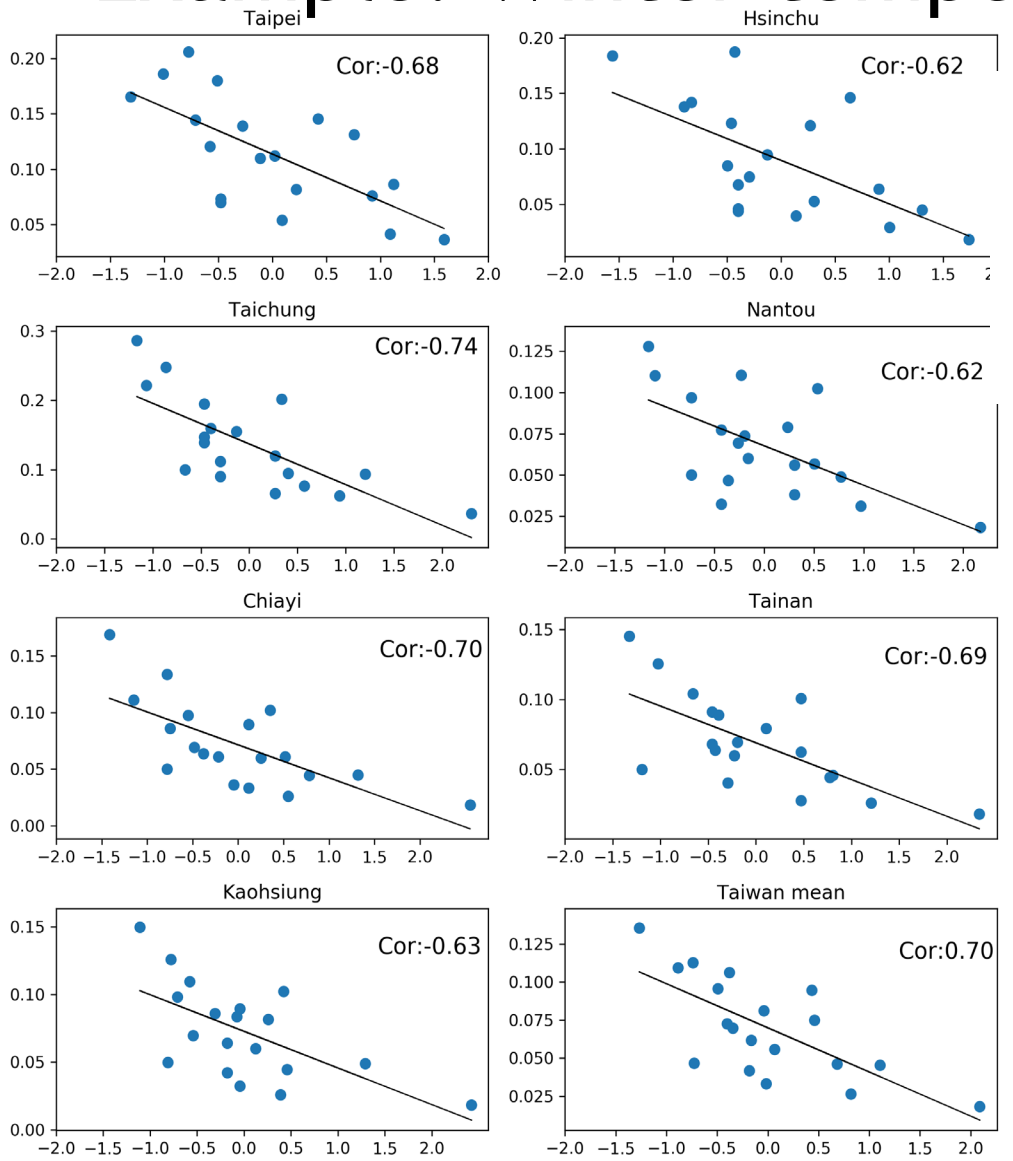
# What is climate?

Climate is an *average* of weather (Temperature, Rainfall...) over a “long” time (more than 2-3 weeks).

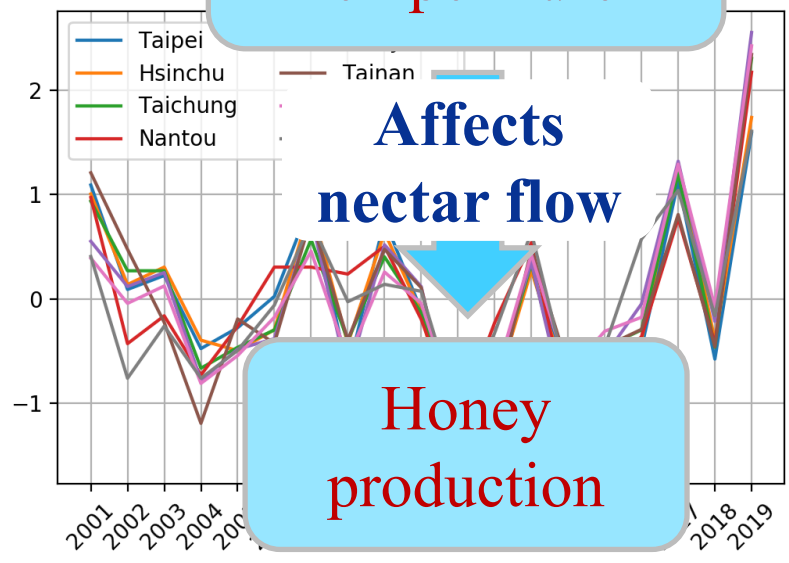
## Weather and Climate



# Example: Winter temperature in Taiwan



Taiwan winter temperature



# What makes climate change?

- Changes in the sun
- Changes in the earth's orbit
- Changes in the clouds
- Changes in ice sheets
- **Volcanic eruptions**
- Changes in the gases in the atmosphere (Greenhouse effect)
- Internal Wiggles (for example El Nino)



Some cause *bigger* changes, some cause *small* changes

Some cause *slower* changes, some cause *fast* changes

Some cause changes that *last*, some cause changes that *go away fast*

# How has climate changed in the past?

## •Ice Ages

- Big swings in climate over 100,000 yrs
- Occurred over last million years
- Advance and retreat of ice sheets
- We are in between ice ages right now



21 thousand  
years ago

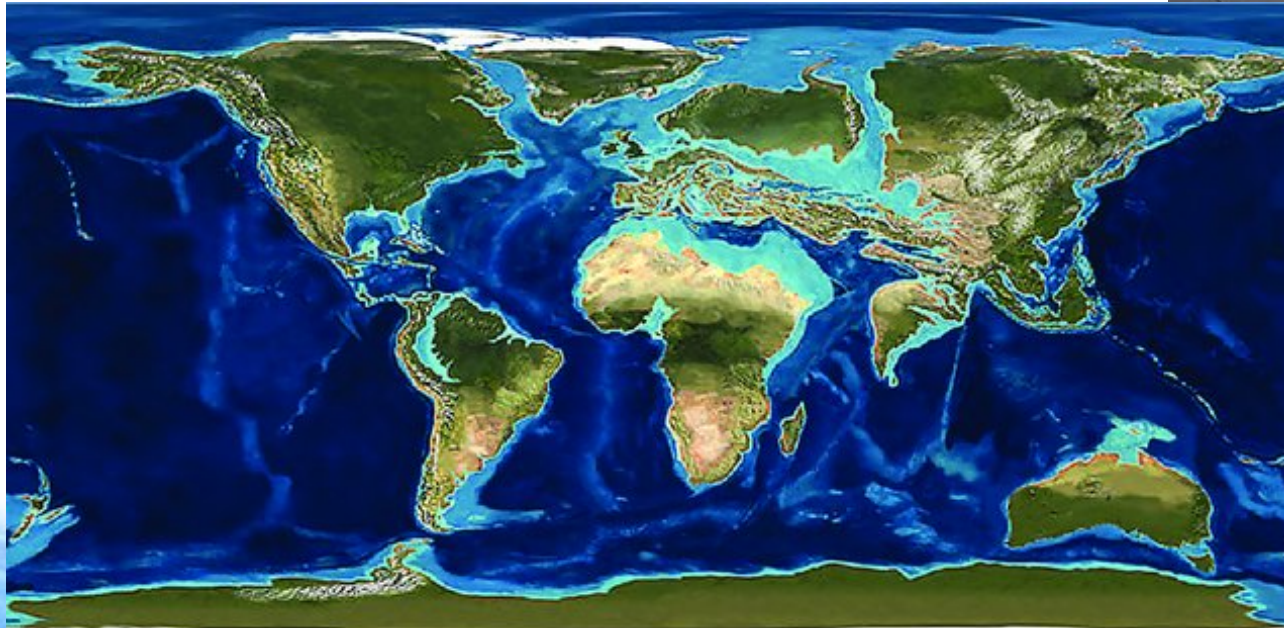


Now

# How has climate changed in the past?

## •Eocene Warm Period

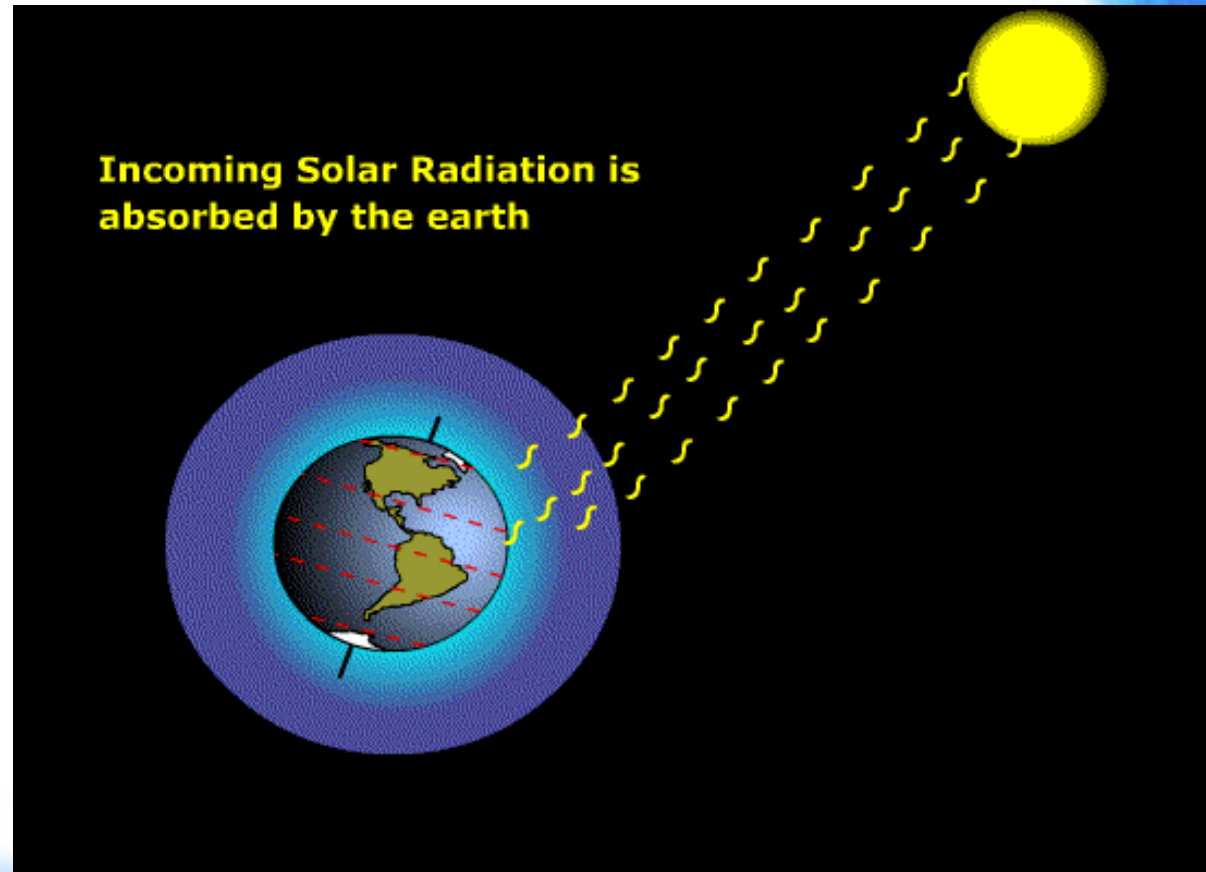
- 50 million years ago
- Palm trees in Puget Sound
- Crocodiles in the Arctic



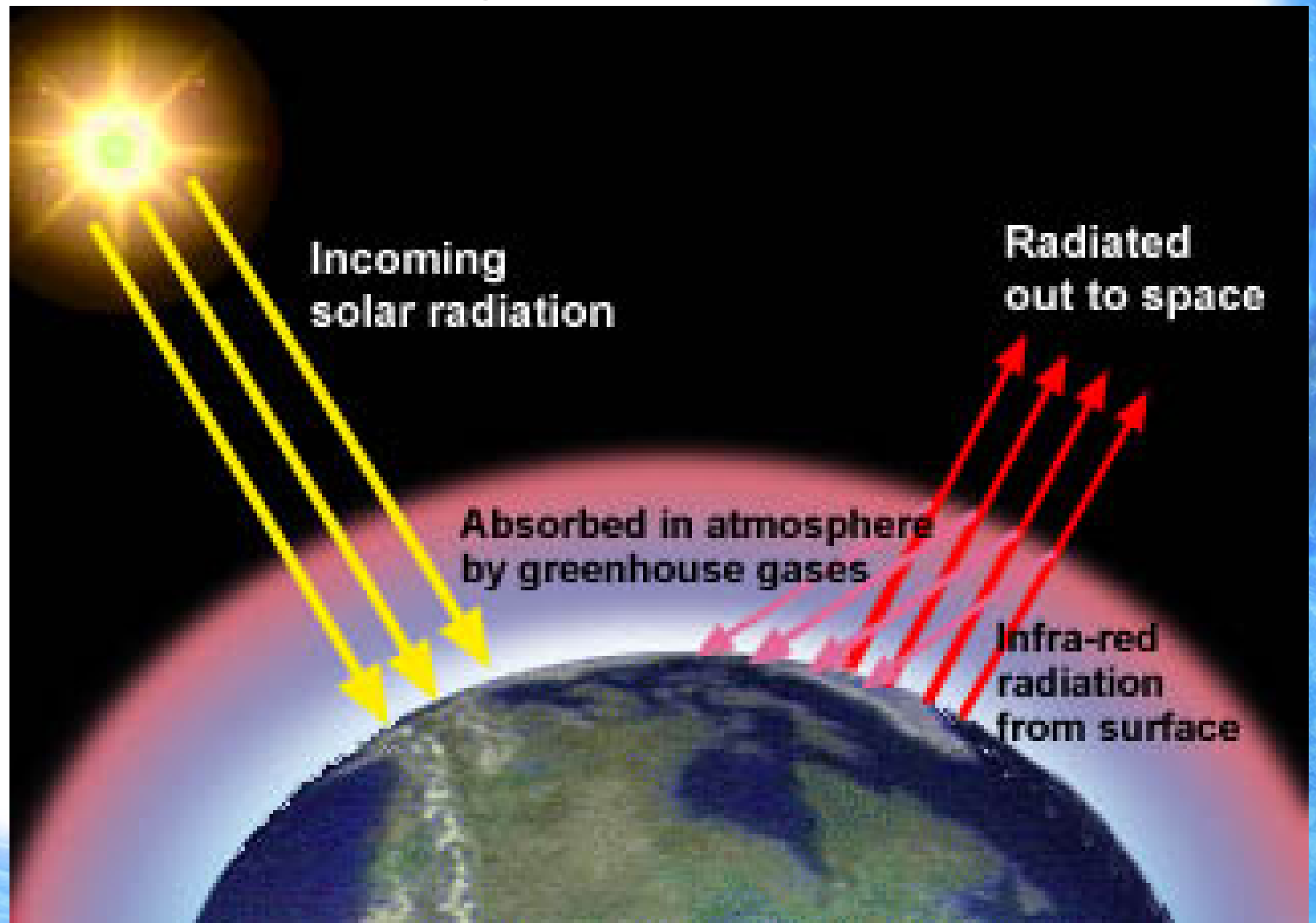
# Human-Forced Climate Change

- Climate changes can be natural or human caused.

- Humans can affect the climate by changing the gases in the atmosphere. (greenhouse effect).

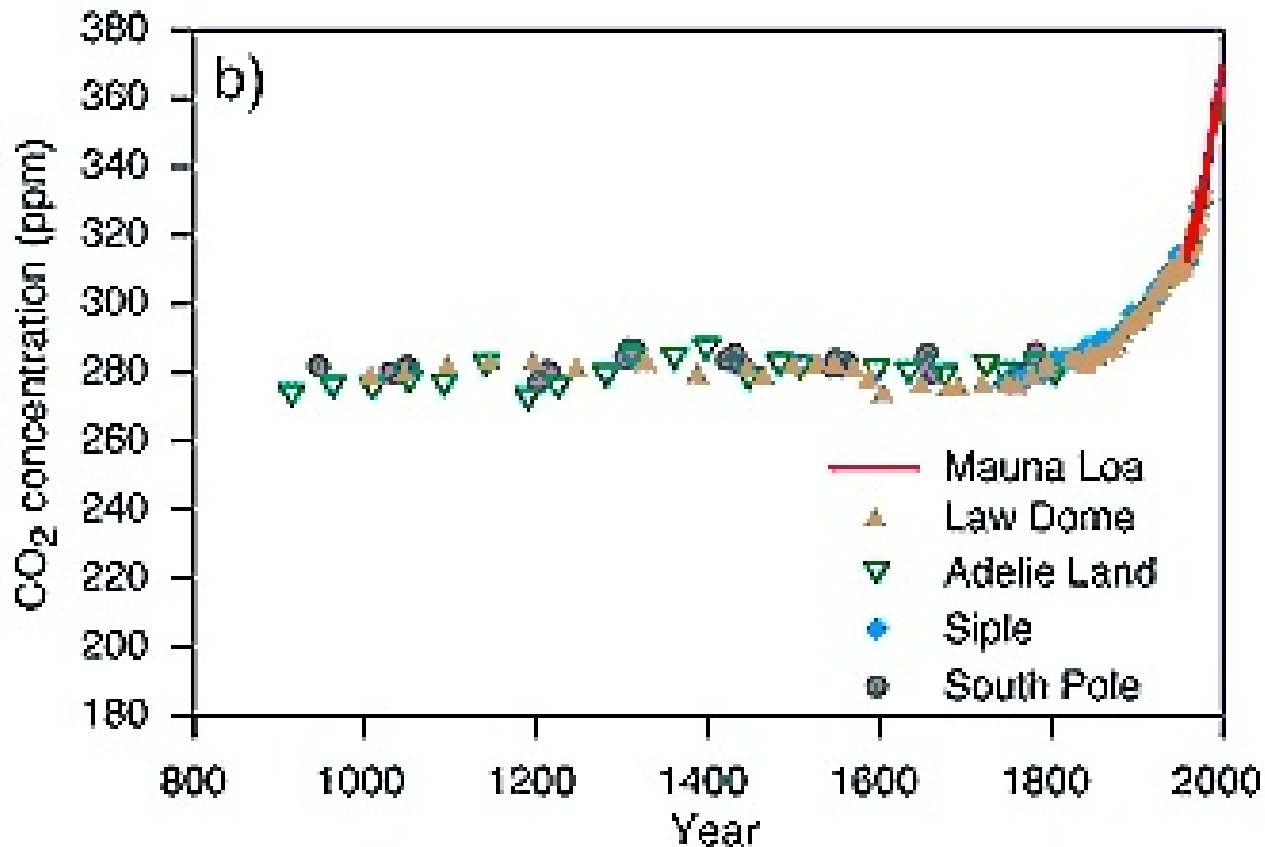


# The Greenhouse Effect



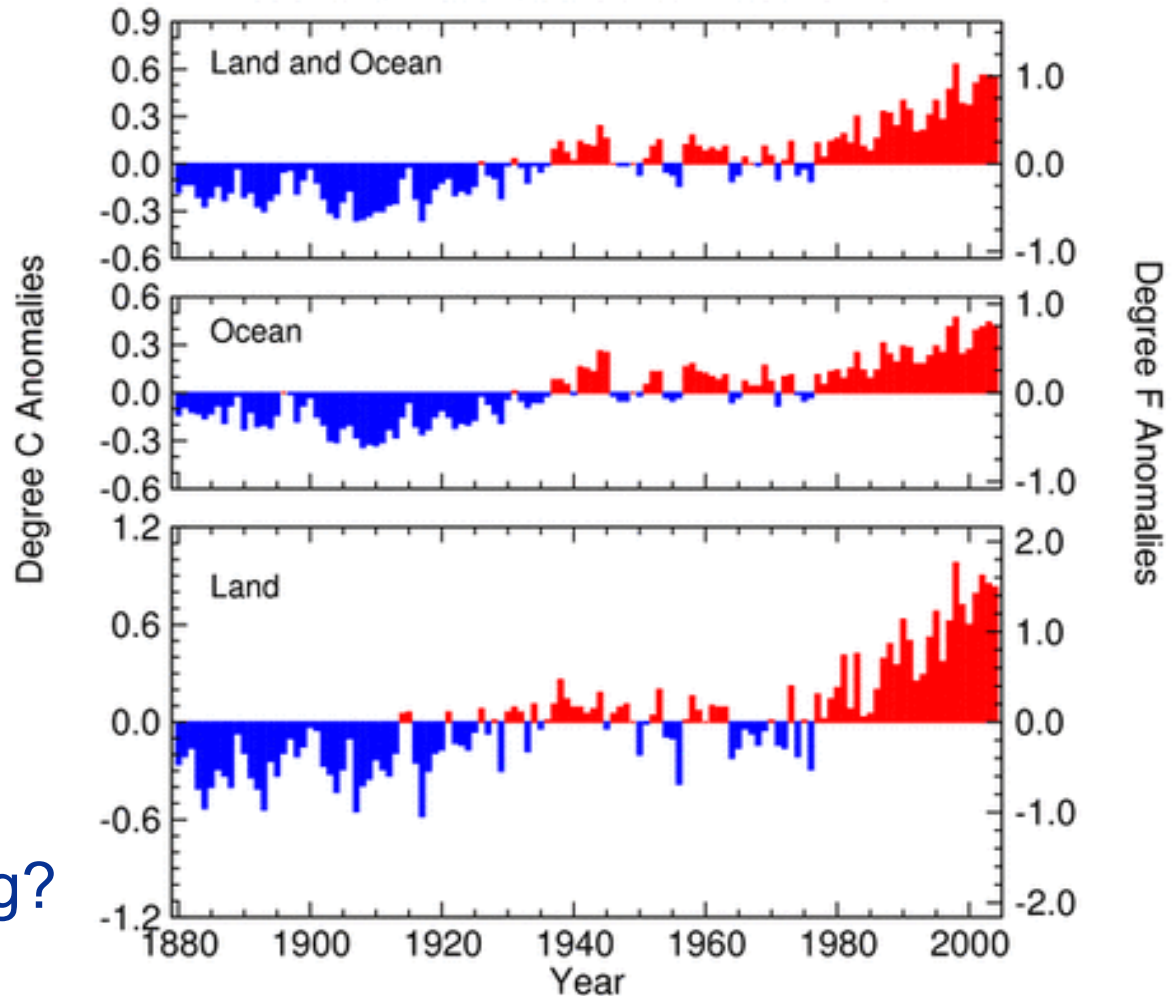
# Human influence on climate: the greenhouse effect

- Carbon Dioxide ( $\text{CO}_2$ ) is a major greenhouse gas
- Human burning of *fossil fuels*, and plants releases  $\text{CO}_2$



# Have we changed the climate?

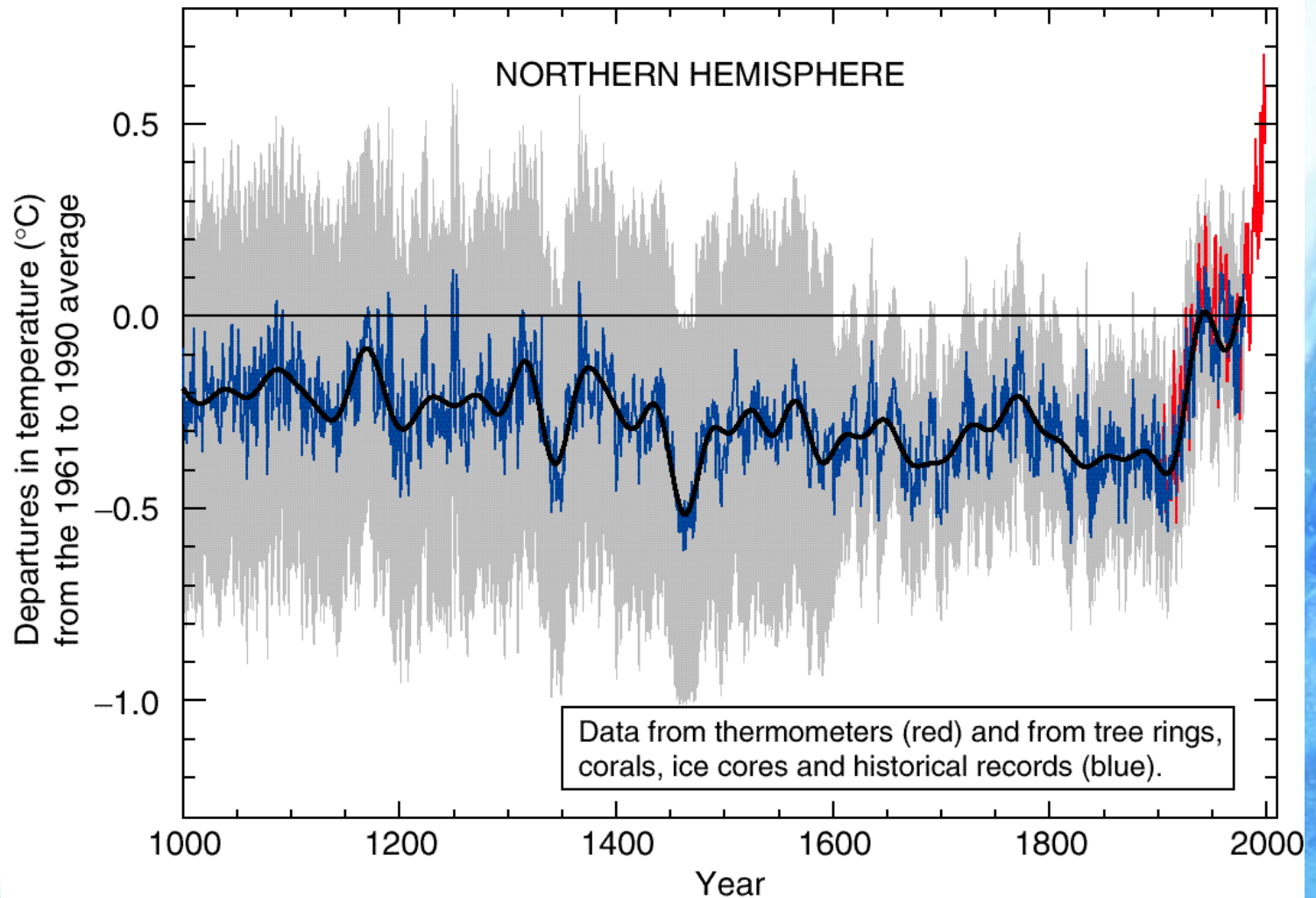
Changes in global temperature over the last 125 years



Global warming?

# Have we changed the climate?

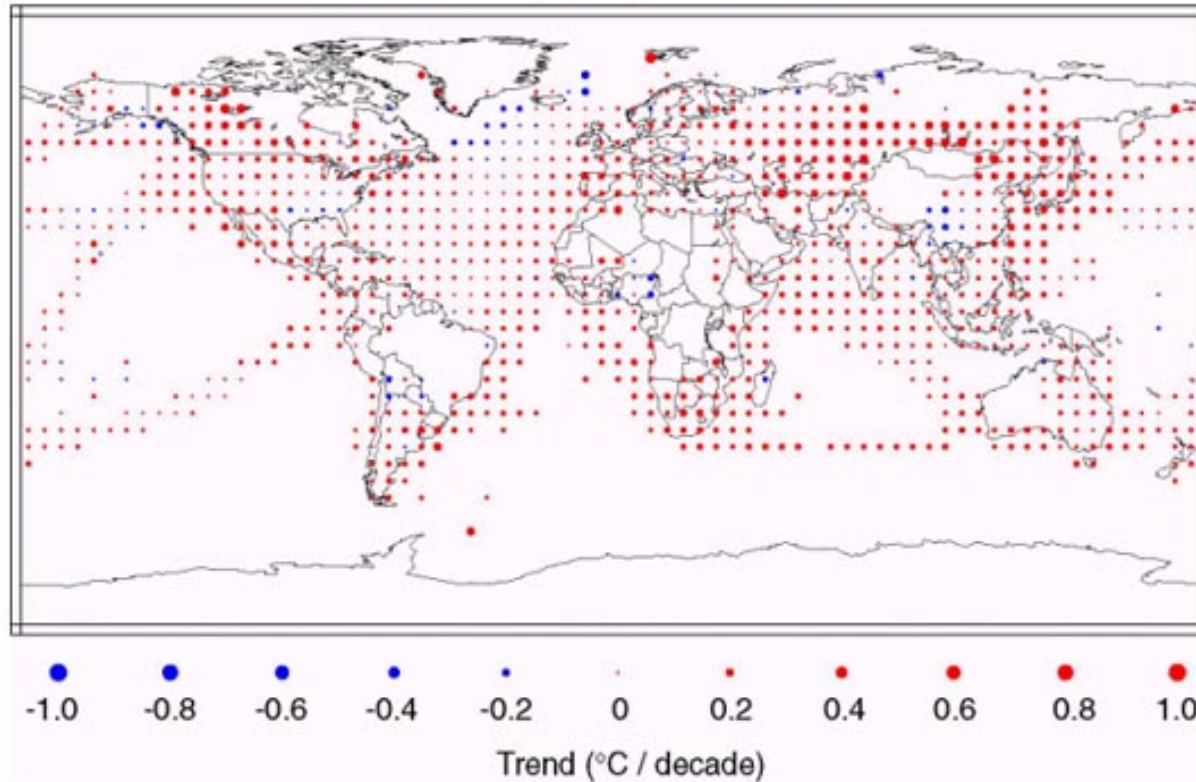
Changes in global temperature over the last 1,000 years



# Have we changed the climate?

Everywhere (almost) is warming!

**Figure 2: Annual Temperature Trends, (°C / century) 1901-1999**



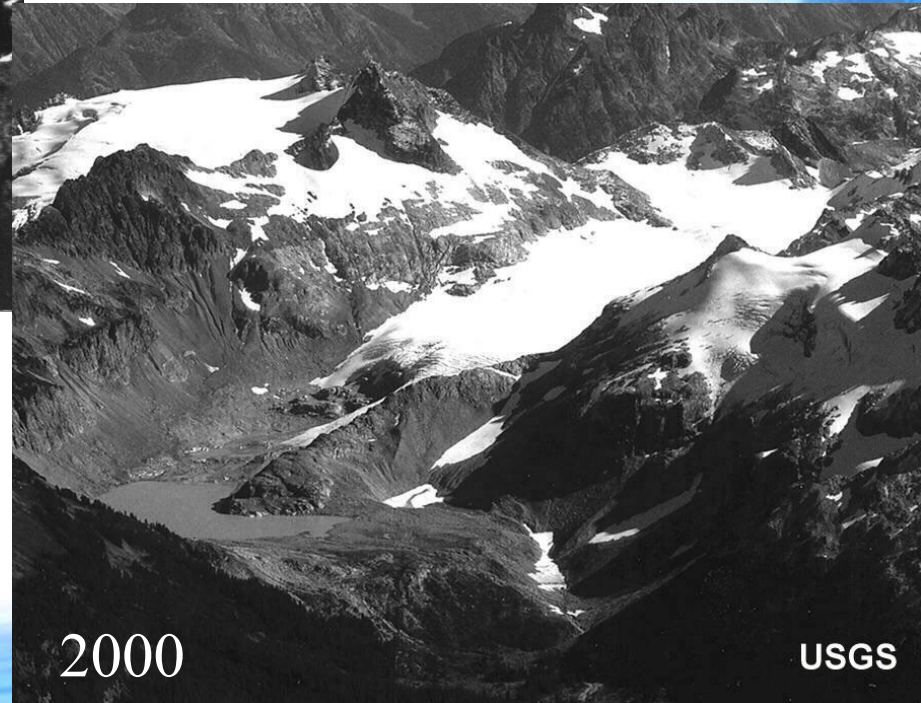
Source: P. Jones, et. al. 2000.

# Have we changed the climate?

Glaciers are retreating all over the world



The South Cascade glacier  
retreated dramatically in the  
20th century

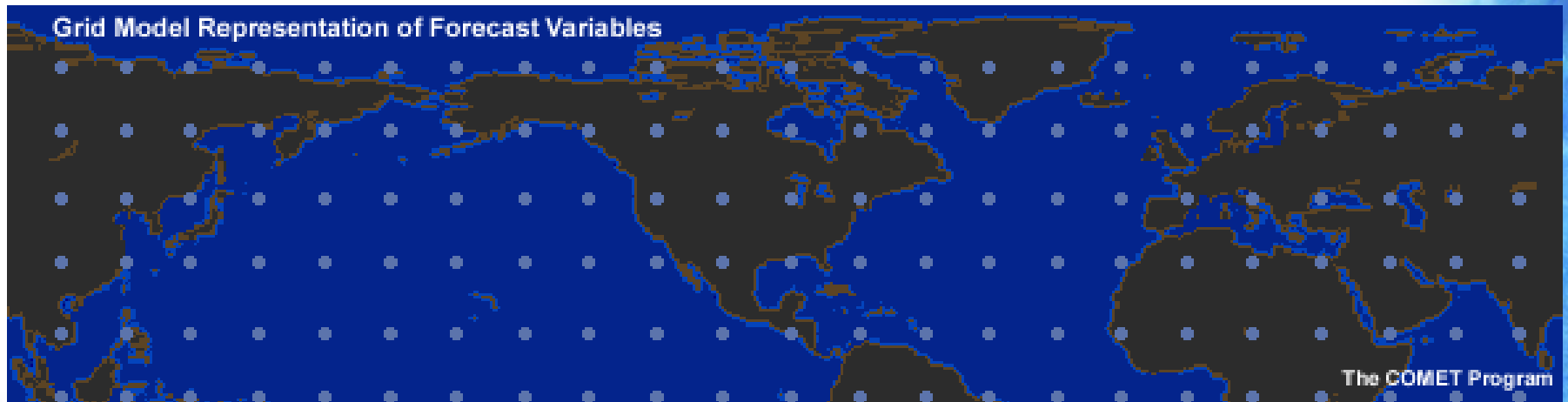


Courtesy of the USGS glacier group

# Have we changed the climate?

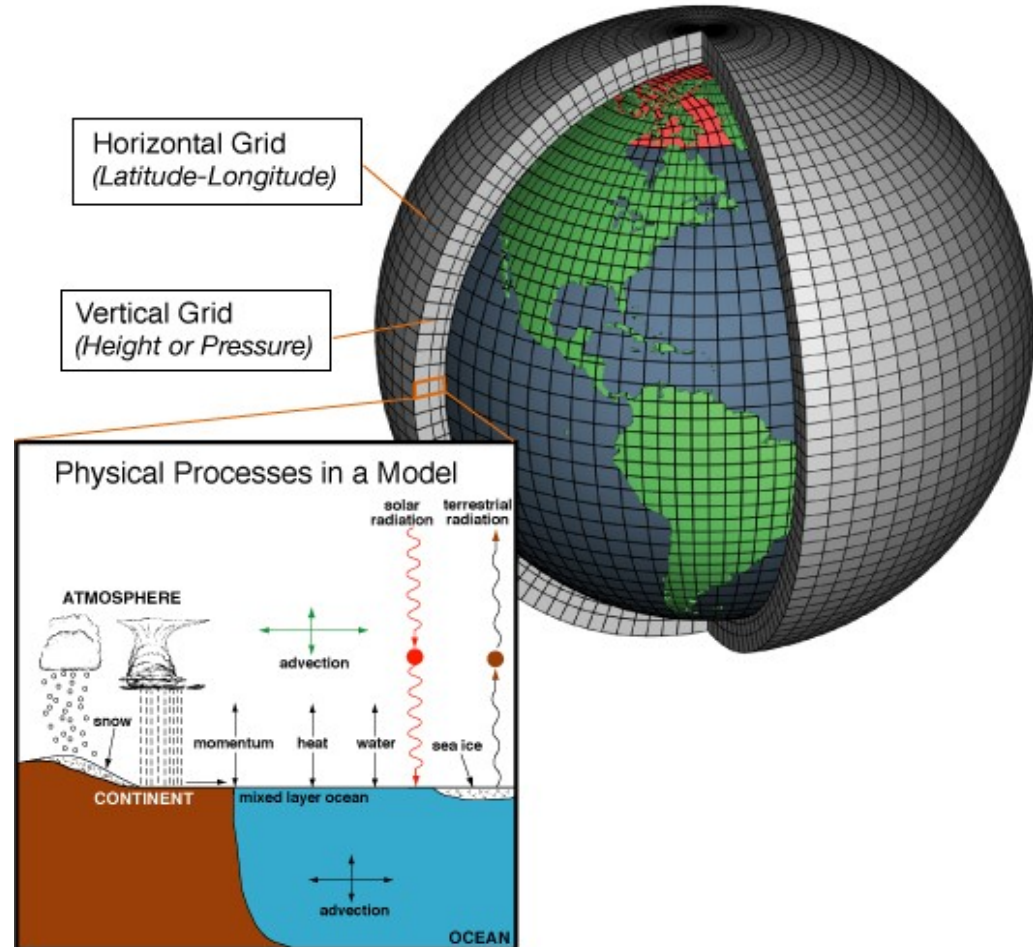
## Global Climate Models (or Earth System Models)

- Use a computer to make a “model” of the earth
  - Tell the computer how to force the climate
  - Use science to come up with equations at points on the earth that tell what the Temperature, Winds,.. are and how they change
  - Change things around and see what happens!!!

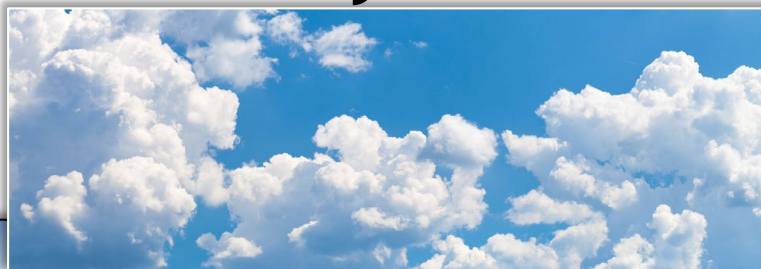


# Global Earth System Models

- The models use physical equations to simulate key fields and processes in the atmosphere, ocean, land, and sea-ice.
- Build on our understanding of processes from observations and highly-detailed models (e.g., process models, large eddy simulations).
- Processes that remain below the grid resolution need to be parameterized.



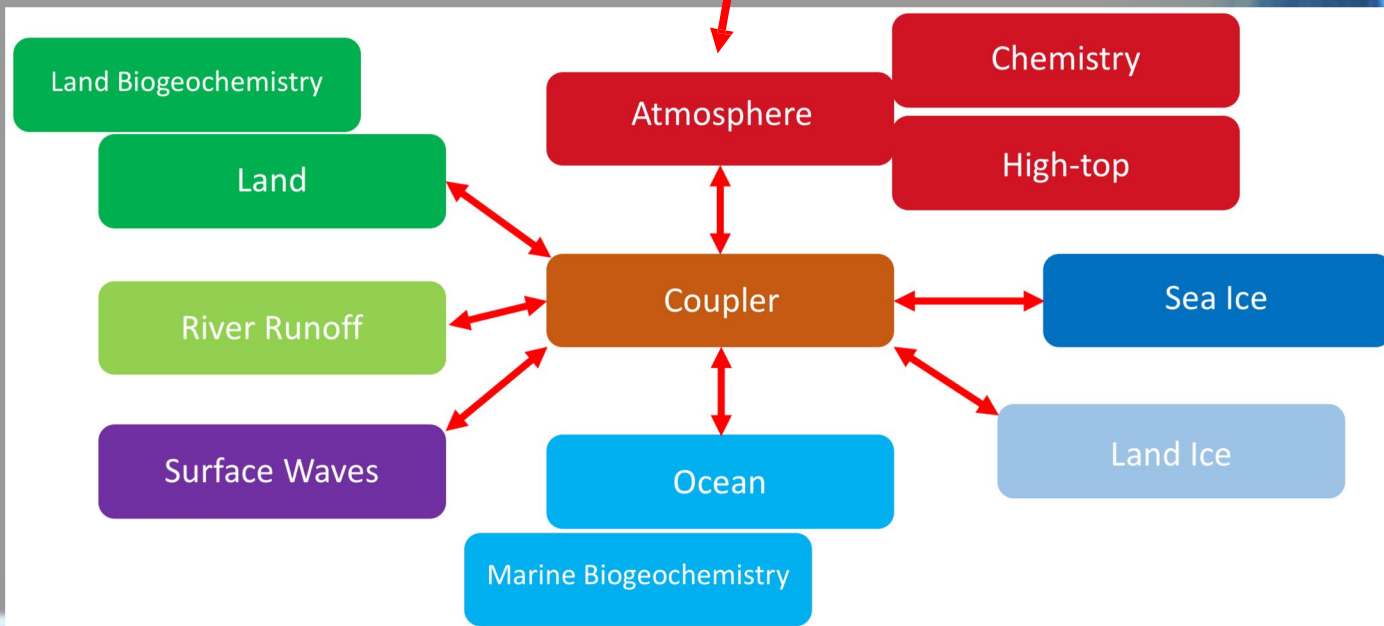
# Global Earth System Models



## Forcings:

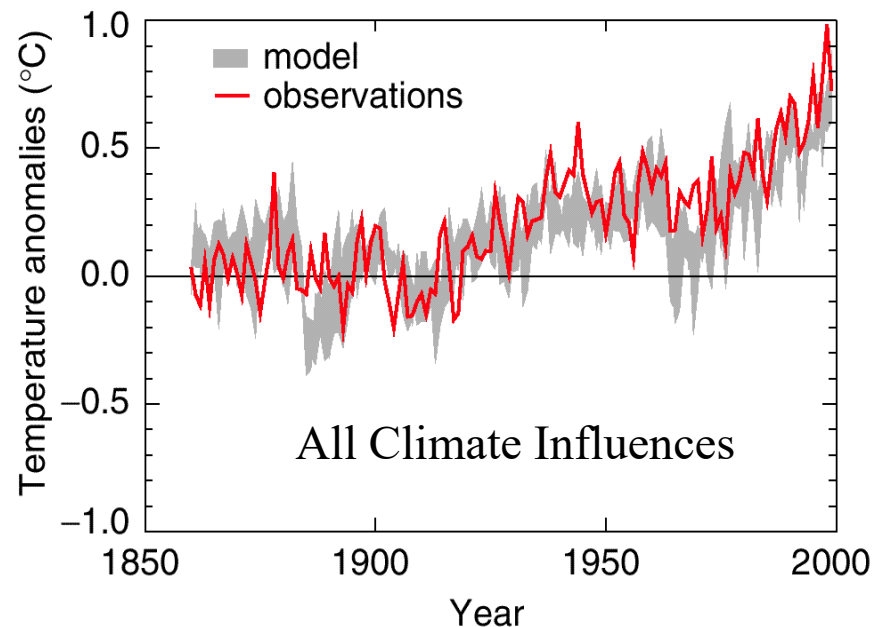
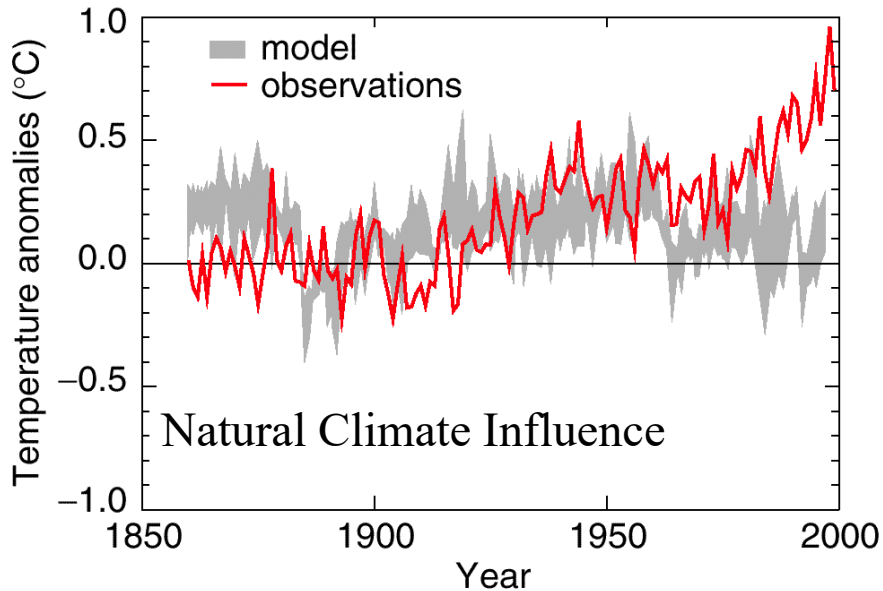
- Greenhouse gases
- Anthropogenic aerosols
- Volcanic eruptions
- Solar variability

## Community Earth System Model



# Have we changed the climate?

Climate models capture the last 100 year's warming only if we include the human effects

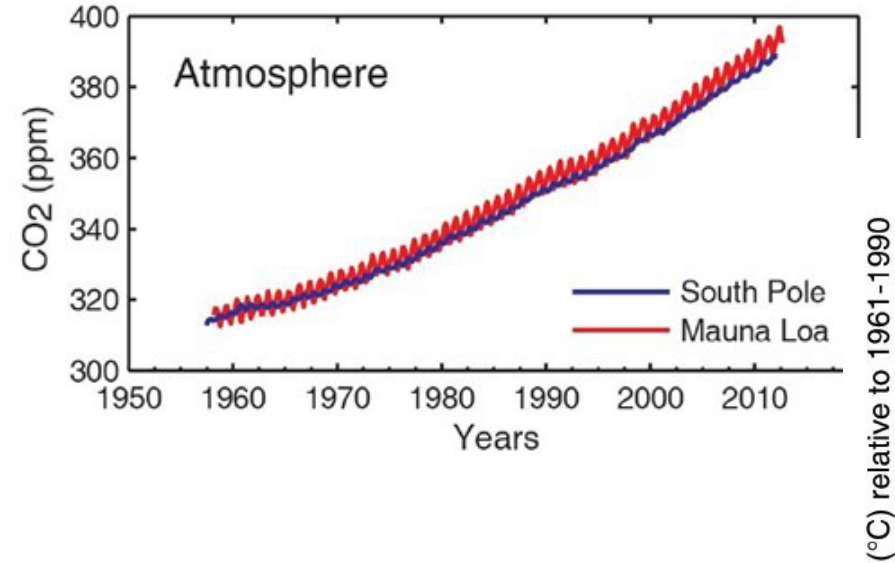


# What will the future climate look like?

- Global warming due to greenhouse gases will continue for many years even if we stop releasing CO<sub>2</sub>
- How much warming occurs depends on what societies and businesses decide about how much fuel they burn
- We use climate models to predict what might happen in different cases

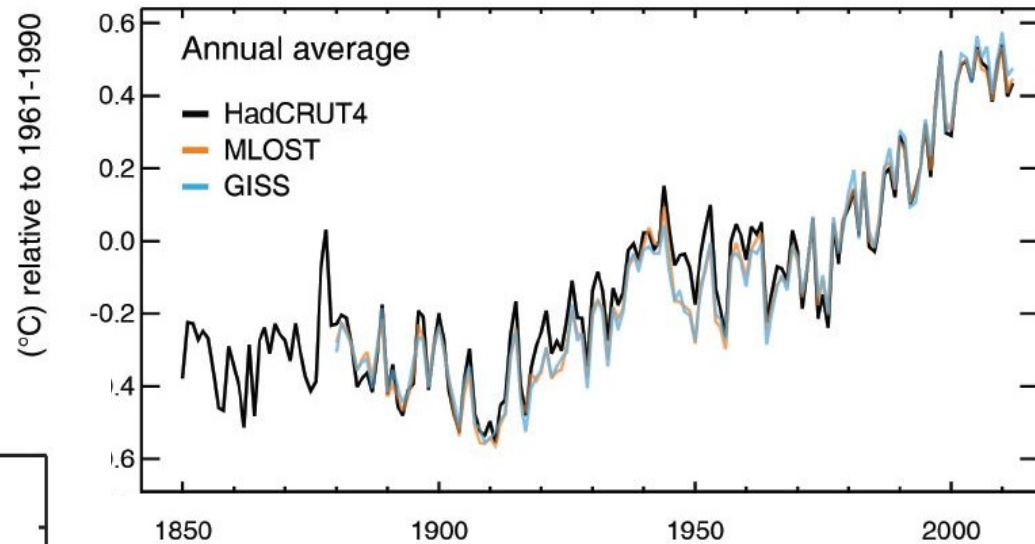
# What will the future climate look like?

## Atm. Carbon Dioxide

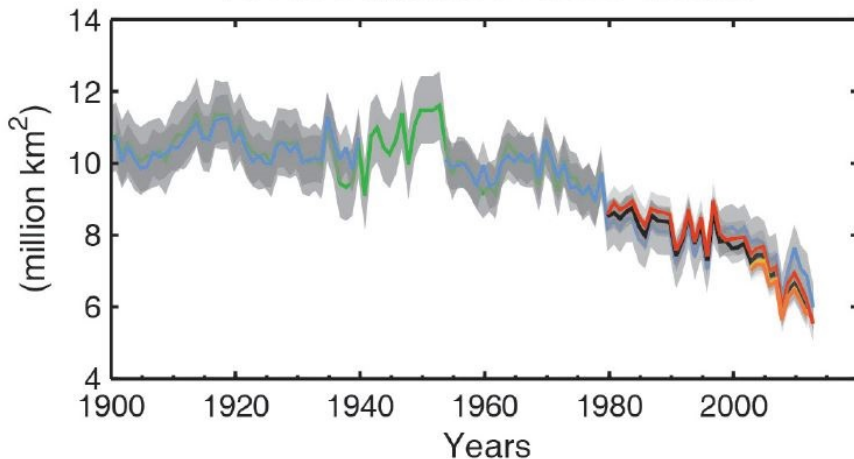


## Warming surface temperature

Global surface temperature timeseries



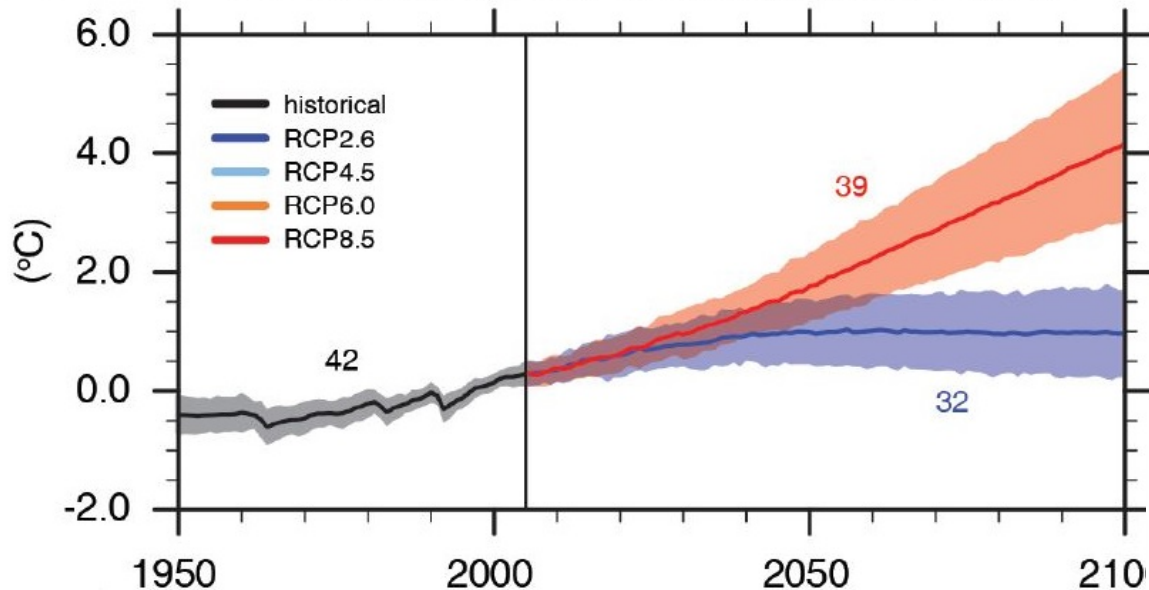
## Arctic summer sea ice extent



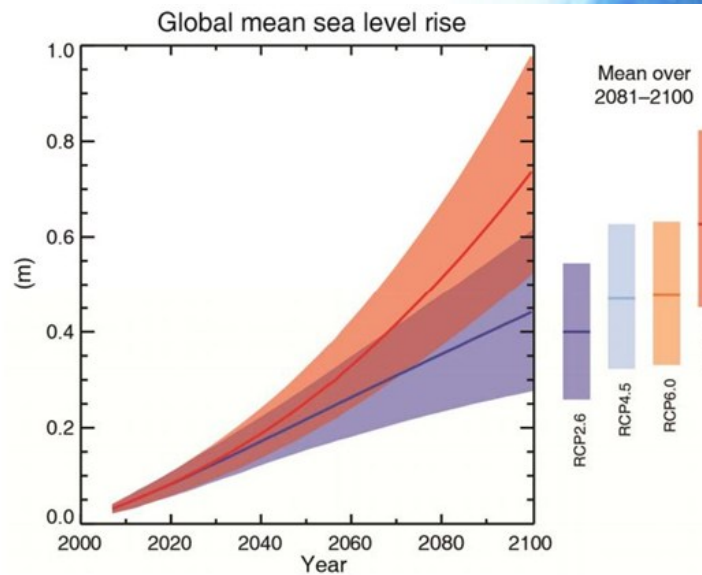
# What will the future climate look like?

## Surface continue warming

Global average surface temperature change

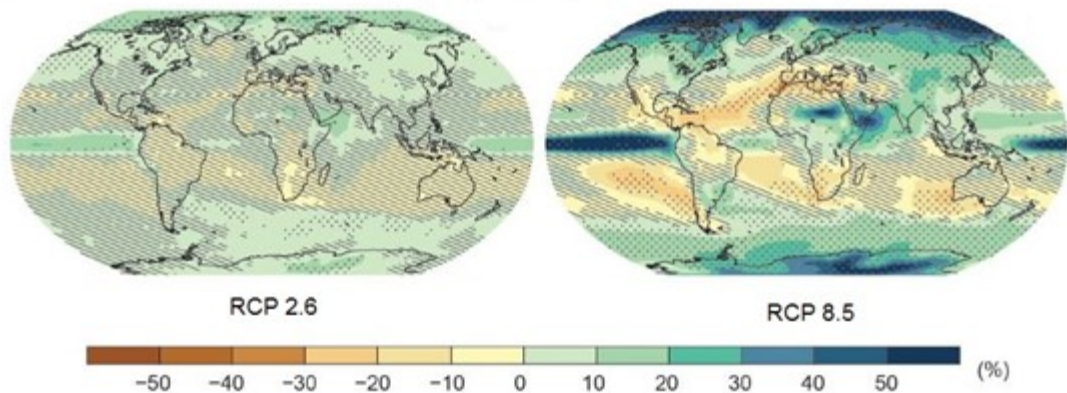


## Sea levels rise



## Rainfall patterns change

Change in average precipitation (1986-2005 to 2081-2100)



# What will the future climate look like?

- Changes are greater in far north / south
- Changes in rain and snow are likely, but not as well understood

## Surface temperature response in the climate model

<https://www.youtube.com/watch?v=l8M901ft20c>

# How will climate change affect people?

Understanding: Good

Everywhere:

- Sea-level rise
- Ecosystem change
  - effect on species
  - effect on farming
- Melting of polar ice
  - effect on shipping
  - effect on wildlife
- Coral death

local:

- Less mountain snow
- Less water to go around in the summer
- Coastal flooding (Olympia)
- Harder for Salmon to survive in freshwater



# How will climate change affect people?

Understanding: Medium

## Everywhere:

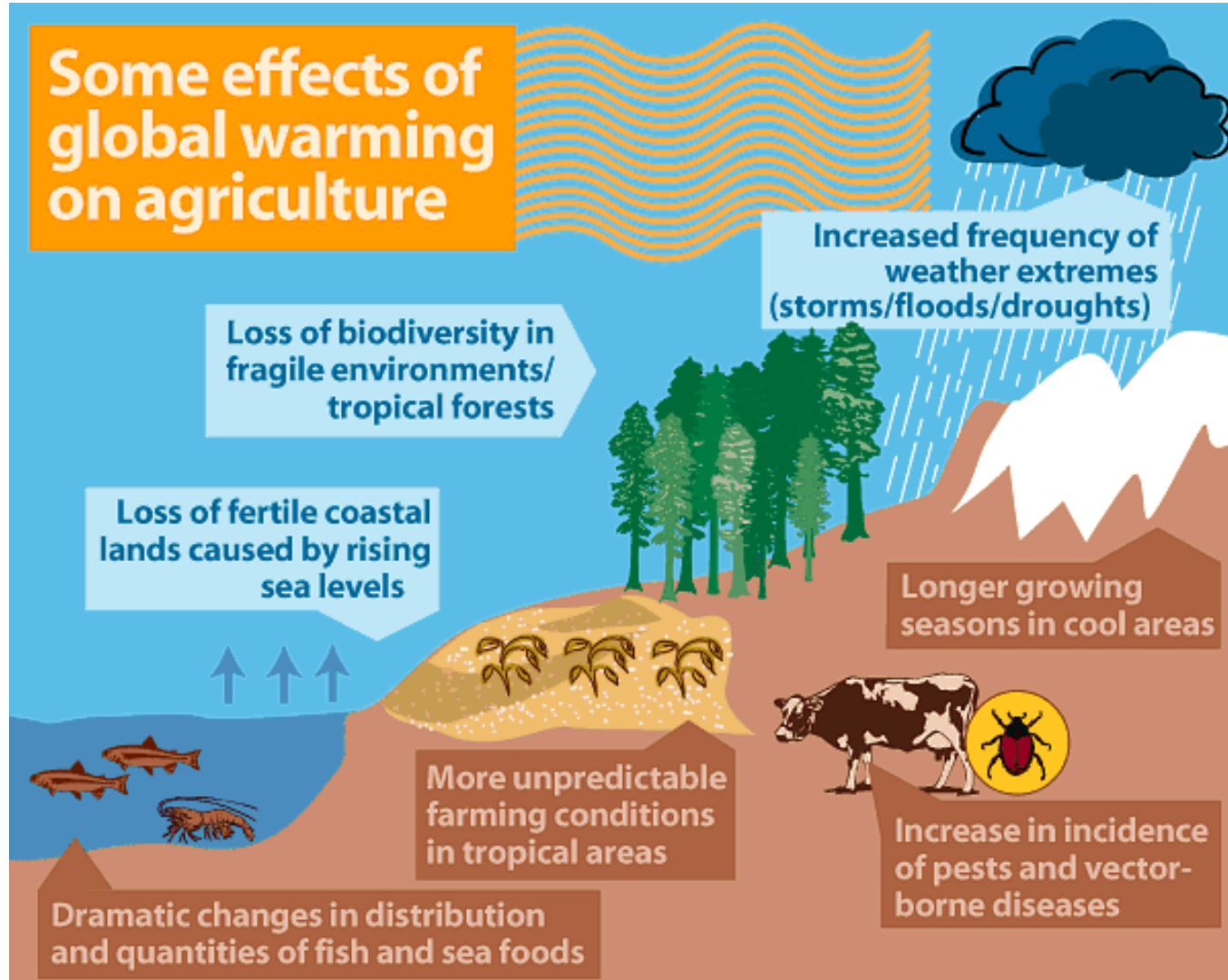
- Increase in intensity of hurricanes
- Increase in droughts in some places
- Increase in intense rain in some places

## Local:

- Changes in how well forests grow
- Increased habitat for pests
- Farming: some crops will grow better, some will grow worse



## Some effects of global warming on agriculture



*Long-term fluctuations in weather patterns could have extreme impacts on agricultural production, slashing crop yields and forcing farmers to adopt new agricultural practices in response to altered conditions.*

# How will climate change affect people?

Understanding: Low

## Everywhere:

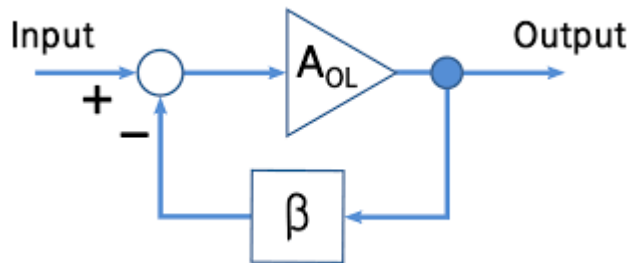
- How will humans react
- Surprise changes

## Local:

- Increased winter flooding
- Increased landslides
- Overall forest health
- Coastal erosion



- **Feedback** describes the situation when output from an event or phenomenon in the past will influence an occurrence or occurrences of the same event / phenomenon in the present or future.



Feedback is used in many applications, and here are a some examples:

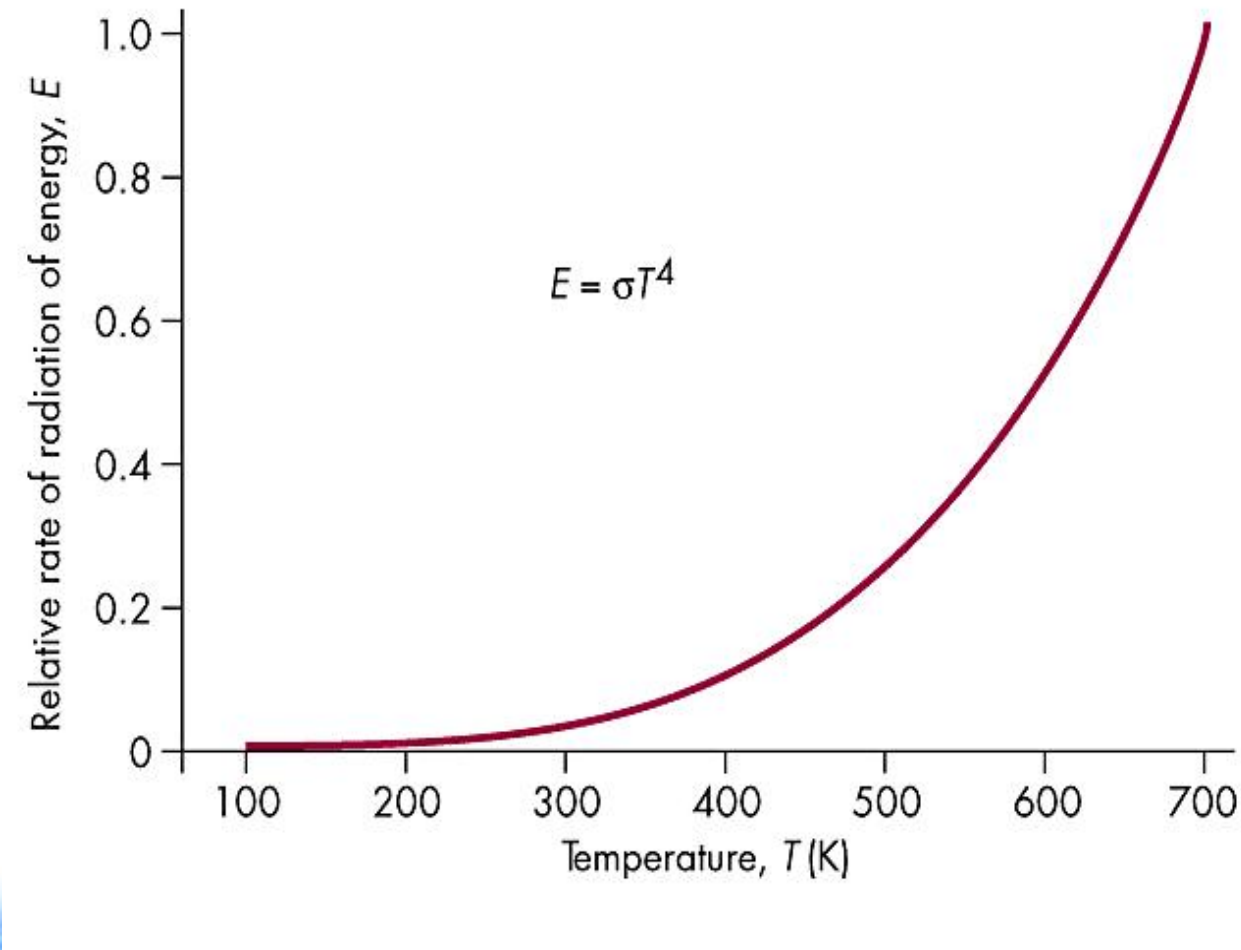
1. Biology
2. Engineering
3. Computing systems
4. Social Sciences
5. **Climate Science**

## Feedback Mechanisms

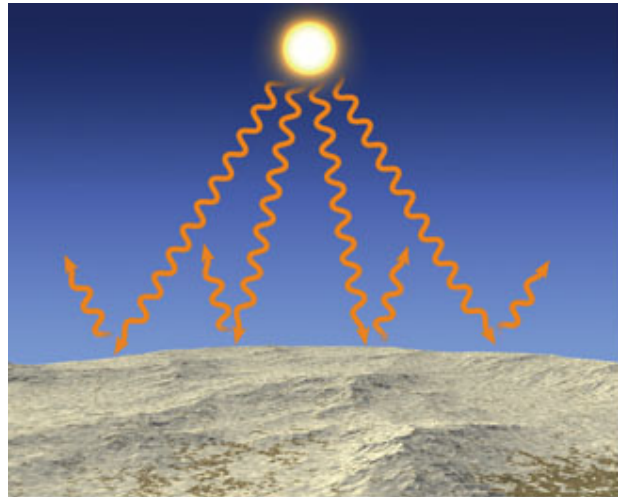
- Infrared radiation (-)
- Snow-albedo feedback (+)
- Water vapor-greenhouse gas feedback (+?)
- Cloud feedback (+ or - ?)

# Stefan-Boltzmann (Infrared Radiation)

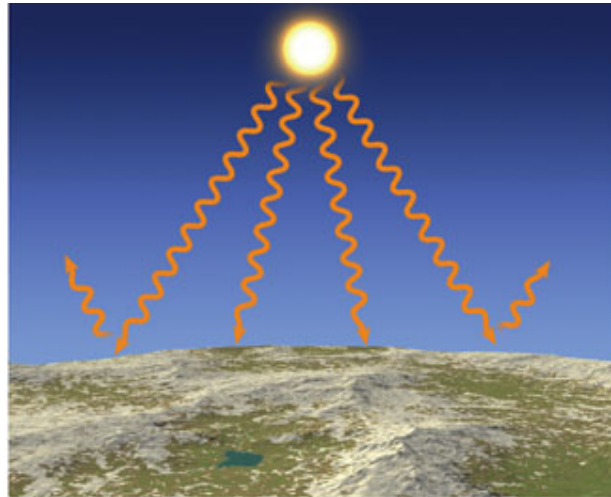
Feedback:  
Negative



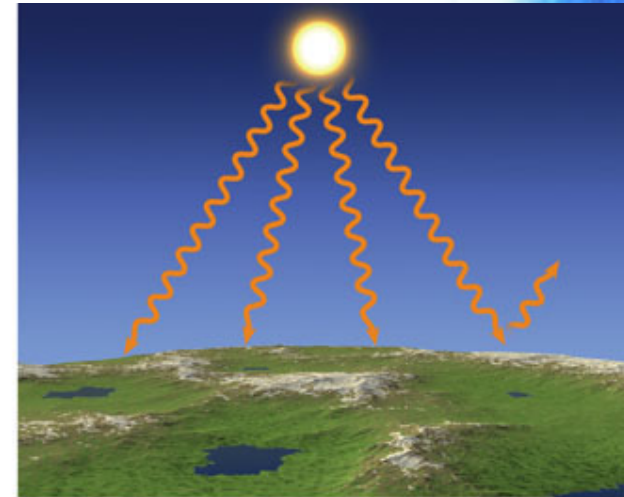
# Snow Albedo Feedback Mechanism: Positive



- (a)
- High surface albedo
  - Low absorption of sunlight
  - Gradual surface warming

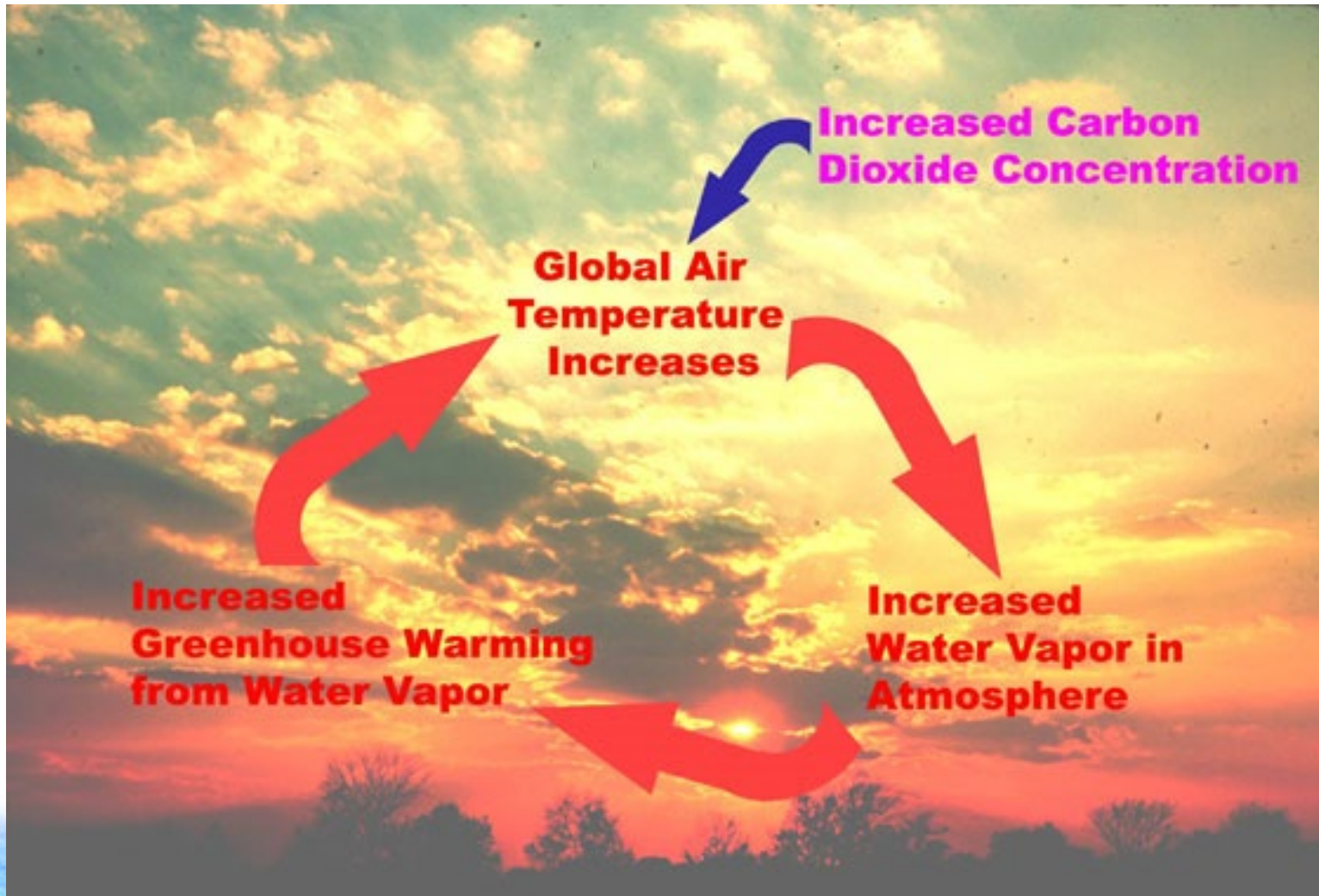


- (b)
- Lower surface albedo
  - Higher absorption of sunlight
  - Surface warming increases



- (c)
- Very low surface albedo
  - Much higher absorption of sunlight
  - Surface warming enhanced

Water Vapor Feedback Mechanism:  
Thought to be positive by climate models and most climatologists



# Cloud Feedback Mechanism: Sign of feedback basically unknown

