Weather Forecasts and Climate
AOSC 200

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Class Web Site: http://www.atmos.umd.edu/~tcanty/aosc200

Topics for today:

Climate
Natural Variations
Feedback Mechanisms

Lecture 27
Dec 3 2019

Numerical Weather Prediction: Assimilation

Step 2: Data Assimilation

- Data does not cover the entire globe at all times
- Data is smoothed and interpolated to model grid

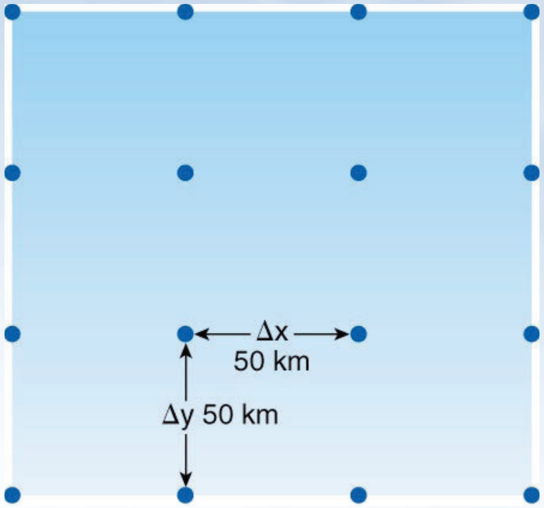

Fig 13-13 *Meteorology: Understanding the Atmosphere*

Numerical Weather Prediction: Integration

Step 3: Model Integration

- Assimilated data is used to solve equations that describe the atmosphere
- Determines state of atmosphere at next time step

● = Observations

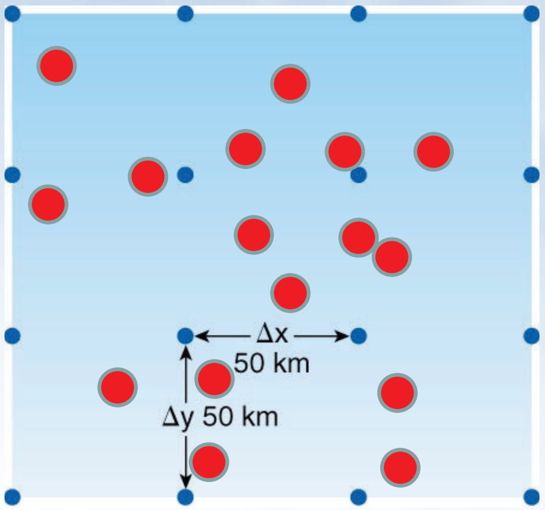

Fig 13-13 *Meteorology: Understanding the Atmosphere*

Numerical Weather Prediction: Integration

Step 3: Model Integration

- Assimilated data is used to solve equations that describe the atmosphere
- Determines state of atmosphere at next time step

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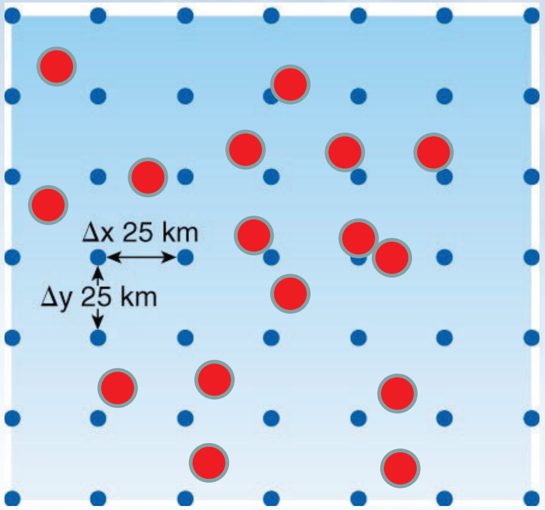


More grid points (higher resolution) yields more accurate forecasts.

Takes longer to run, though.

Fig 13-13 *Meteorology: Understanding the Atmosphere*

Numerical Weather Prediction: Tweaking

Step 4: Tweaking and Broadcasting

- Analyze model output accounting for known biases in models
- Combine model output with knowledge of local weather (small scale winds that models can't predict) to create forecasts

Forecasting (Surface Map)

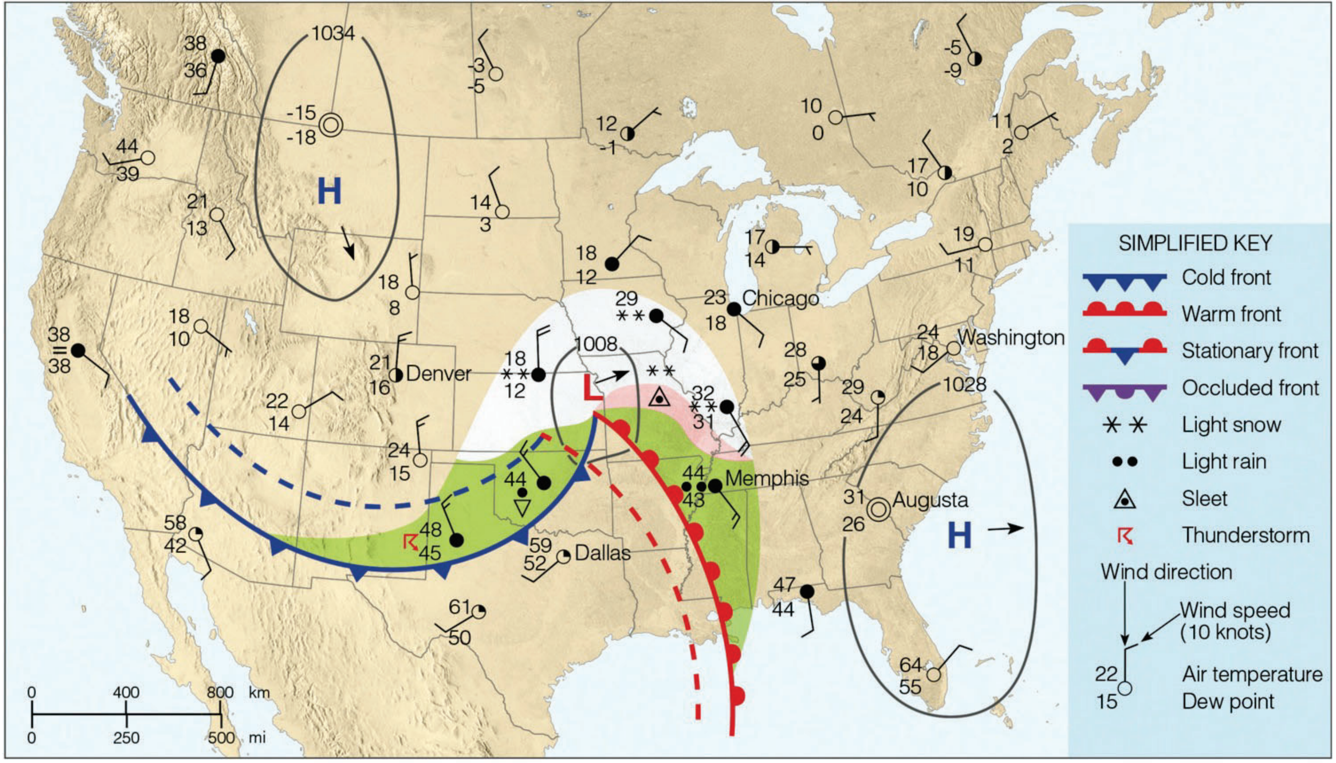
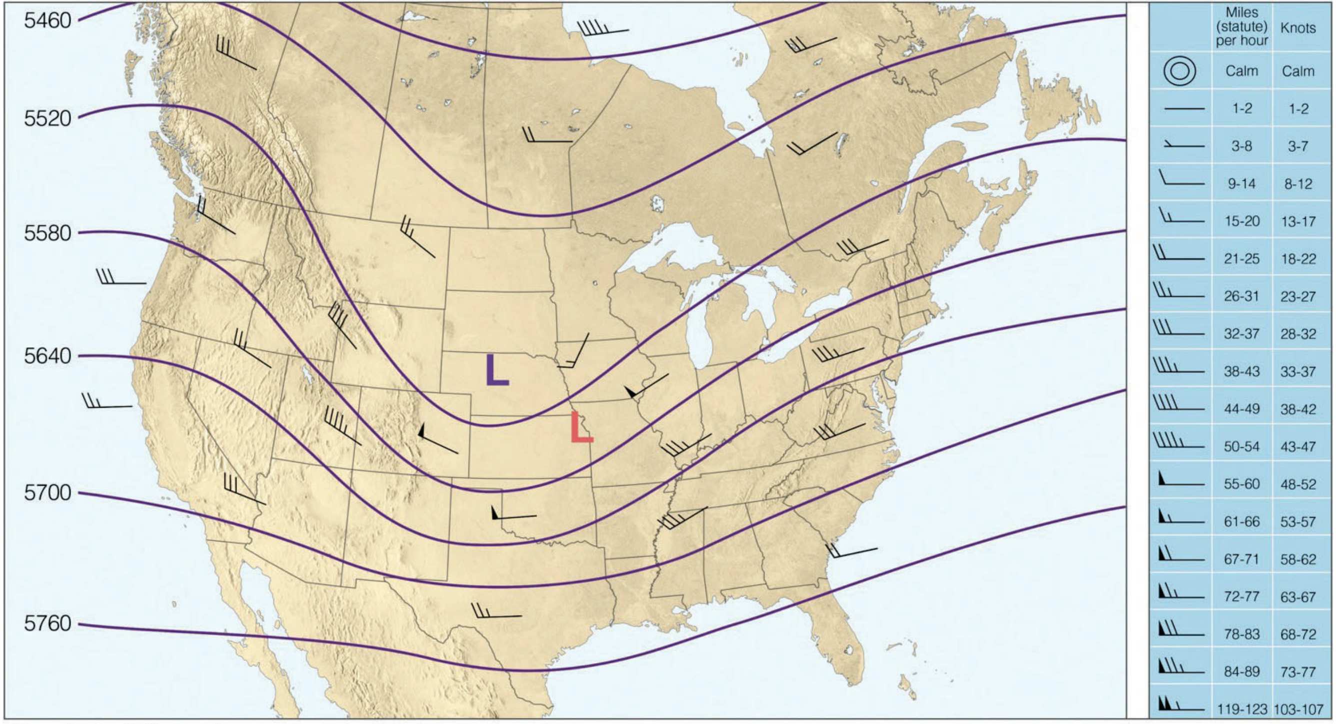


Fig 9.14: *Essentials of Meteorology*

Forecasting (500 mb Map)



Miles (statute) per hour	Knots
Calm	Calm
1-2	1-2
3-8	3-7
9-14	8-12
15-20	13-17
21-25	18-22
26-31	23-27
32-37	28-32
38-43	33-37
44-49	38-42
50-54	43-47
55-60	48-52
61-66	53-57
67-71	58-62
72-77	63-67
78-83	68-72
84-89	73-77
119-123	103-107

Fig 9.15: ***Essentials of Meteorology***

Forecasting (Future Surface)

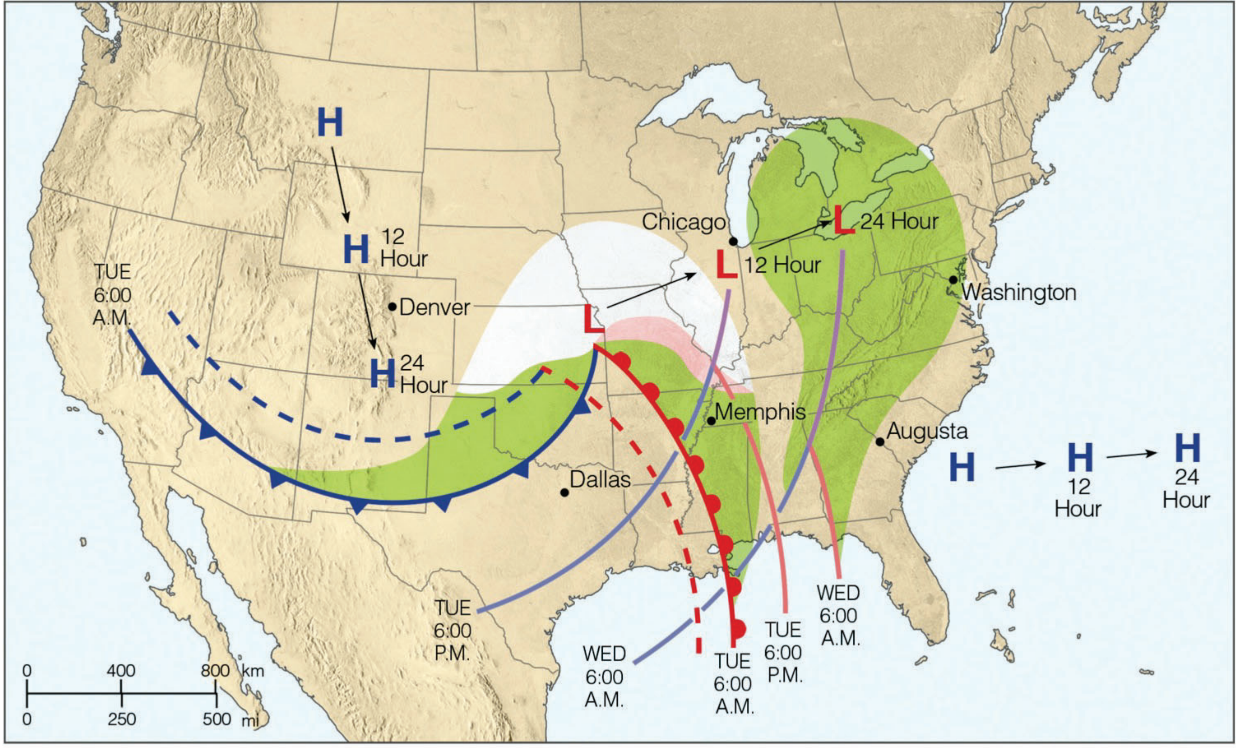


Fig 9.16: ***Essentials of Meteorology***

Actual weather (+1 day)

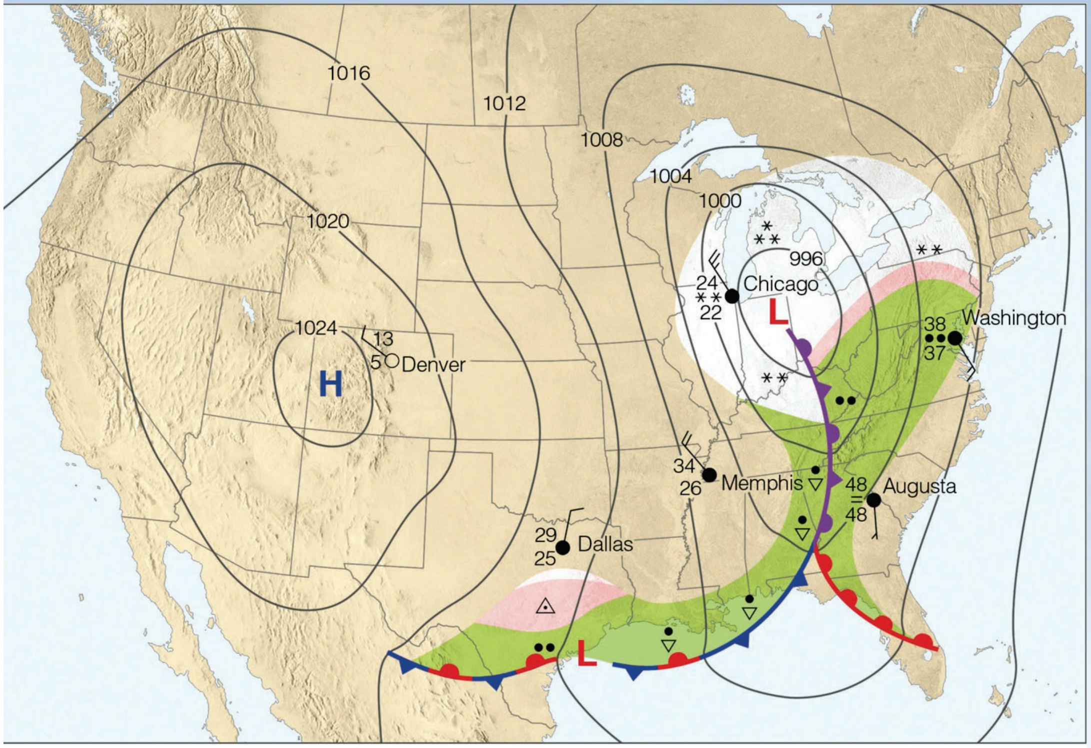


Fig 9.17: *Essentials of Meteorology*

Forecast Range

Nowcasting	**A description of current weather parameters and 0-2 hours description of forecasted weather parameters**
Very short-range weather forecasting	**Up to 12 hours description of weather parameters**
Short-range weather forecasting	**Beyond 12 hours and up to 72 hours description of weather parameters**
Medium-range weather forecasting	**Beyond 72 hours and up to 240 hours description of weather parameters**
Extended-range weather forecasting	**Beyond 10 days and up to 30 days description of weather parameters, usually averaged and expressed as a departure from climate values for that period.**
Long-range forecasting	**From 30 days up to two years**

http://www.wmo.int/pages/prog/www/DPS/GDPS-Supplement5-AppI-4.html

Ensemble Forecasts

Ensemble forecasts:

Run model numerous times for slightly different initial conditions

Perform statistical analysis of all the model runs

Ensemble Forecasts

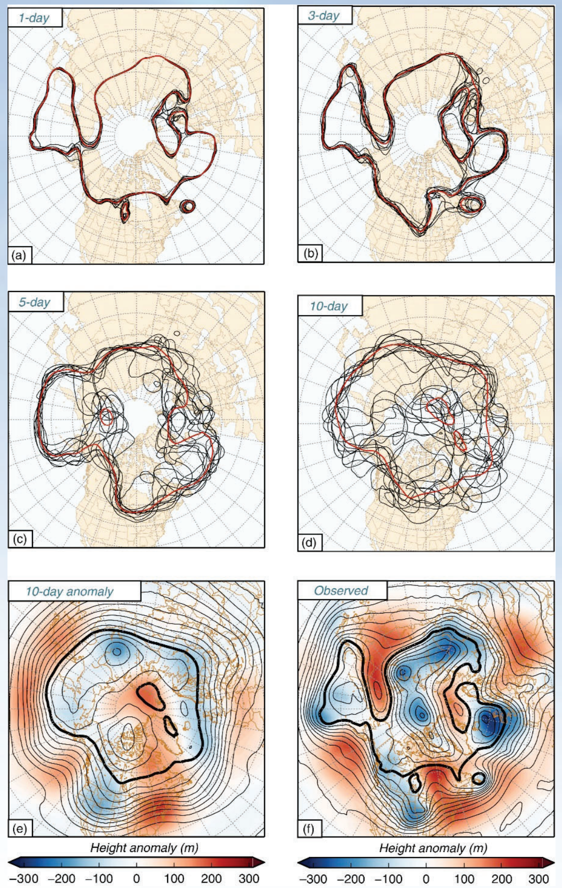


Fig 13-5 *Weather A Concise Introduction*

Why aren't forecasts perfect?

Forecast Errors

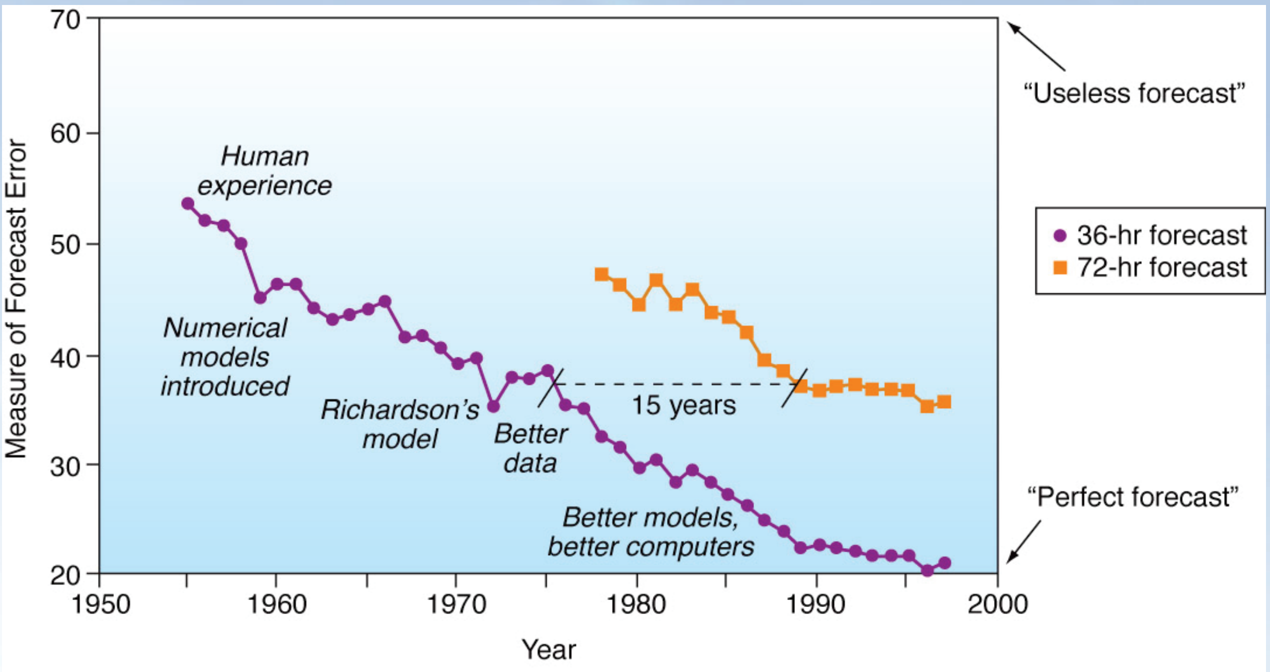


Fig 13-25 *Meteorology: Understanding the Atmosphere*

Climate

Climate: state of the atmosphere at a given place over a specified time range

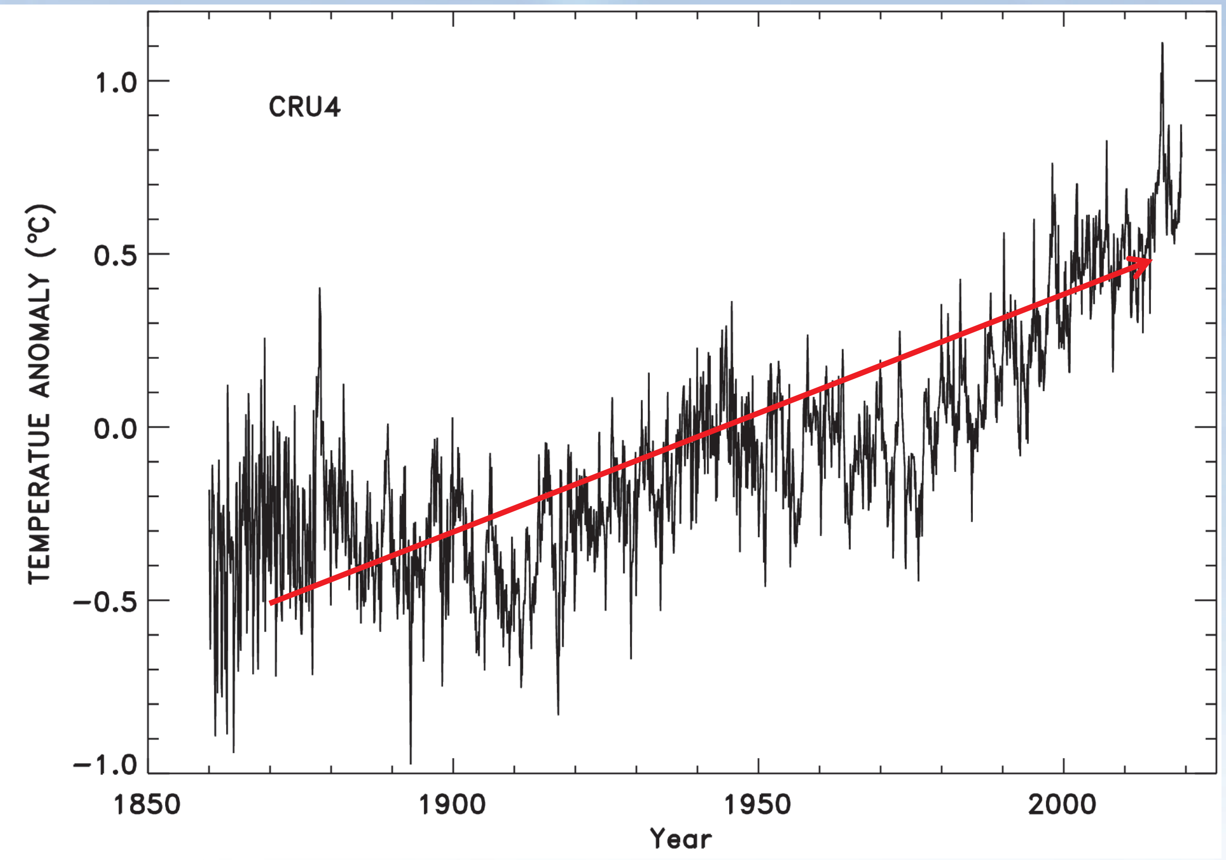
Location: can be global, regional, local, etc.

Time: long term (i.e. 30 year or more)

Can be precipitation, temperature, humidity, or other meteorological variable

"Weather is what you're wearing, Climate is what's in your closet"

Global Monthly Temperature



Climate

- Long-term behavior of global environmental system
- Have to understand the Sun, geology, oceans, ice, atmosphere, life
- Climate system consists of the atmosphere, hydrosphere, solid earth, biosphere and cryosphere
- Involves the exchange of energy and moisture among these components
- Can be modified by natural events (volcanoes, El Niño) and human activity (adding greenhouse gases)

“Climate would change even if there weren’t people on the planet!”

“Climate would change even if there weren’t people on the planet!”

Very true!!!

Past Climate

How do we know what the temperature was 100,000 years ago??

Has the climate changed in the past and, if so, how and why??

Historical Climate

Can be as simple as a cave painting….

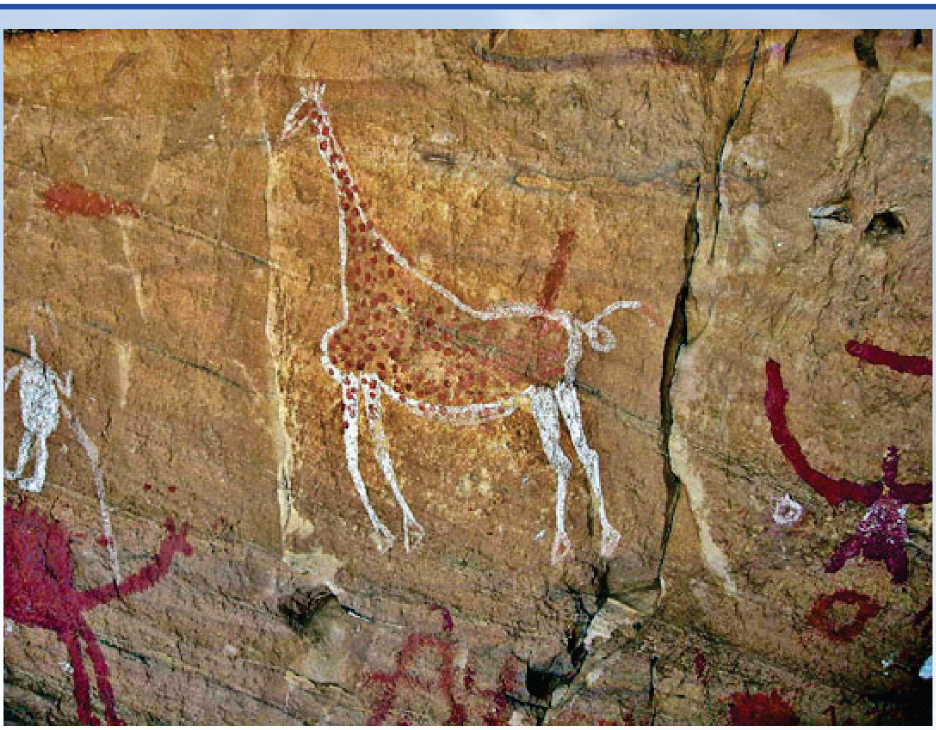


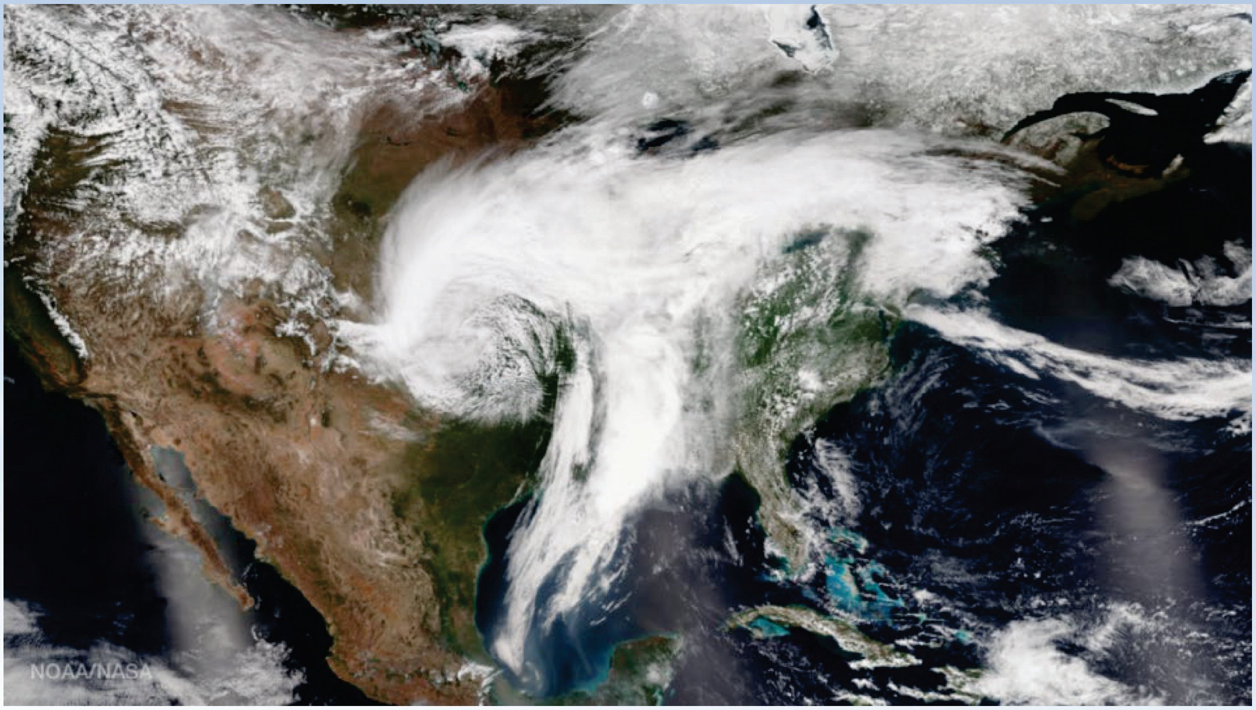
Fig 14-14 *Meteorology: Understanding the Atmosphere*

Historical Climate

Or a more modern painting….

The Thames River frozen in 1677

Historical Climate



…. or as detailed as a satellite map

https://www.nnvl.noaa.gov/imageoftheday.php

Historical Climate

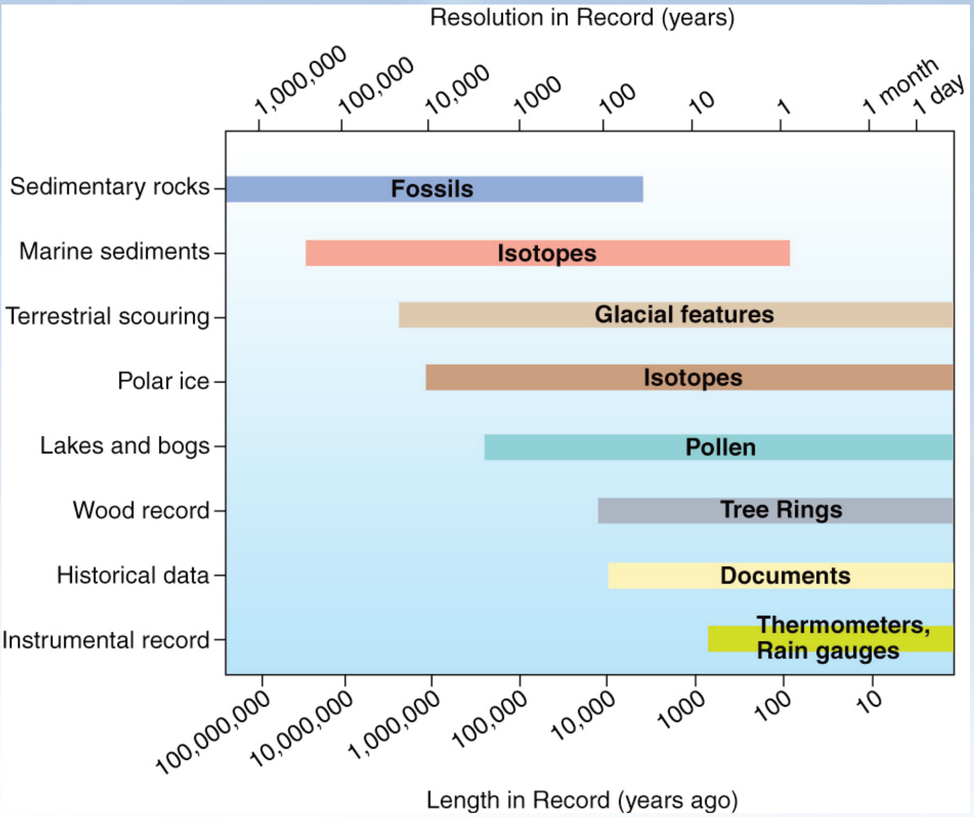


Fig 14-13 *Meteorology: Understanding the Atmosphere*

Tree Rings

Dendrochronology: study of tree rings to determine climate conditions

Trees generally grow one ring per year

- Width of ring depends on available water, temperature, and solar radiation.
- Tree species have different responses to these factors – hence the factors can be separated by looking at different species

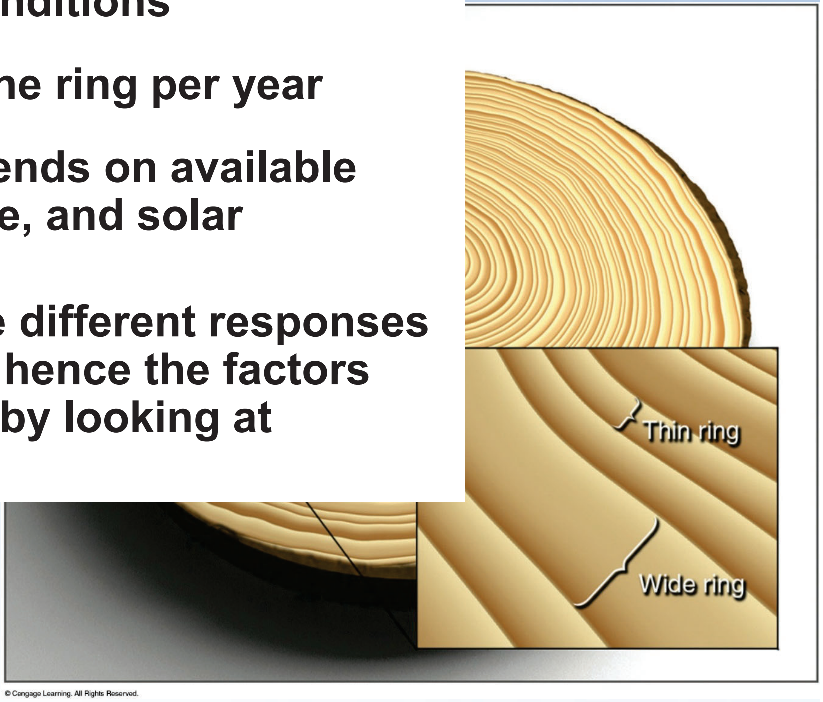


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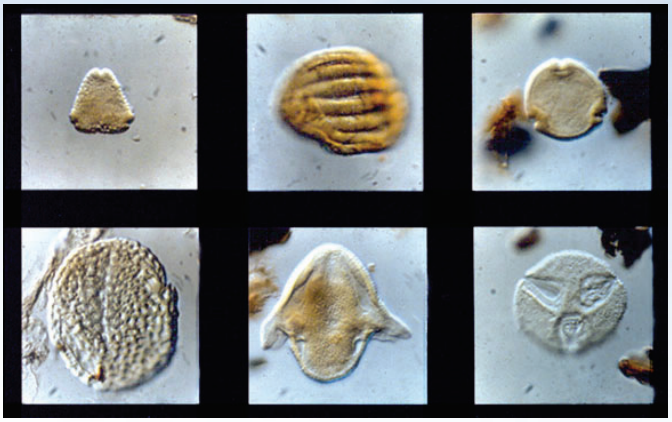
Fig 13-4 *Essentials of Meteorology*

Pollen Records

Palynology: study of prehistoric pollen to determine climate conditions

Each species has a different shape

- Can determine types of plants that were most abundant when the pollen was deposited
- Can use carbon dating to determine age of pollen

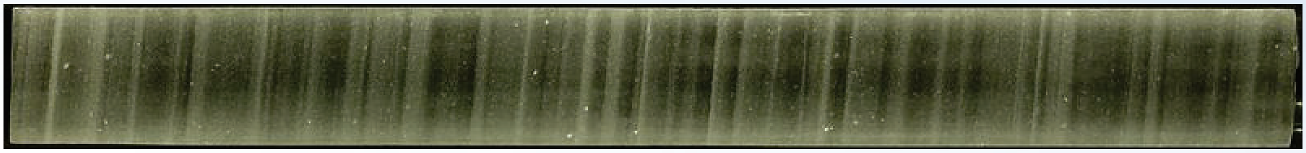


Ice Core Records

Air bubbles trapped in ice sheets provide record of atmospheric composition

Dust trapped in ice provides a record of volcanic activity and of dry, windy conditions

- Carbon dioxide (CO_2), Methane (CH_4), Water Vapor (H_2O), Sulfate (SO_4^{2-}), aerosols, etc.
- Can be used to reconstruct temperature, atmospheric circulation strength, precipitation, ocean volume, atmospheric dust, volcanic eruptions, solar variability, marine biological productivity, sea ice and desert extent, and forest fires.



Ice Core Records: Composition/Temperature

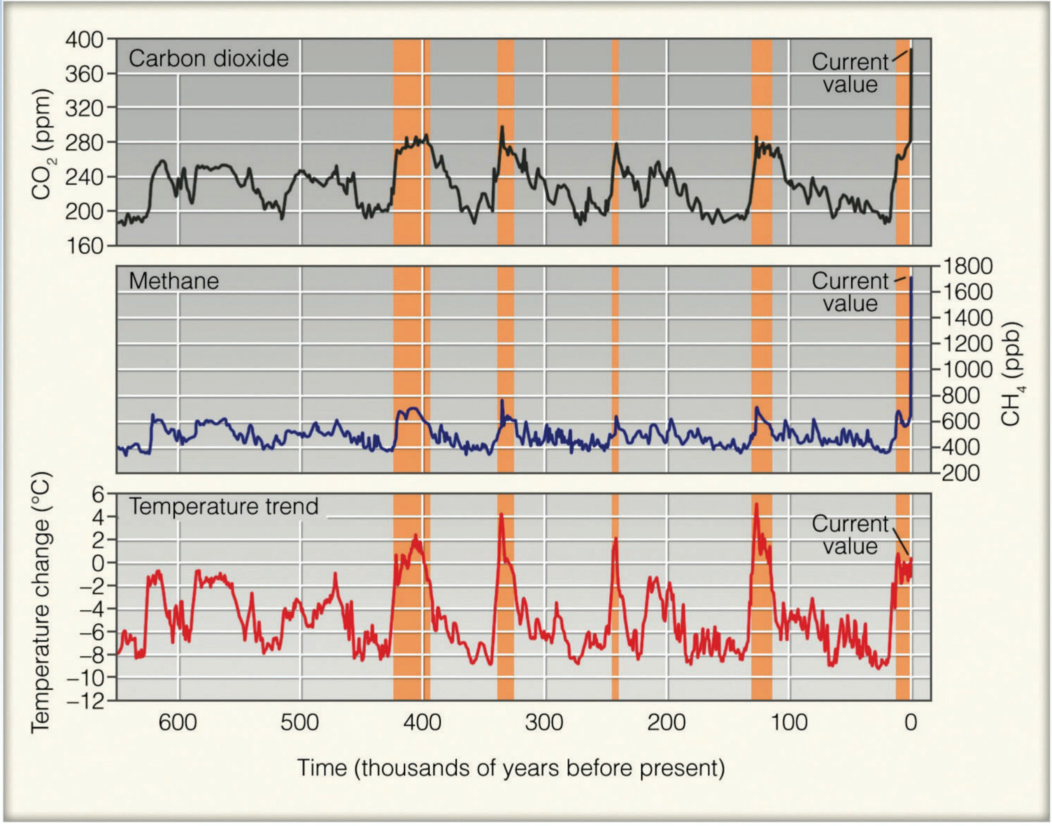


Fig 13-13 *Essentials of Meteorology*

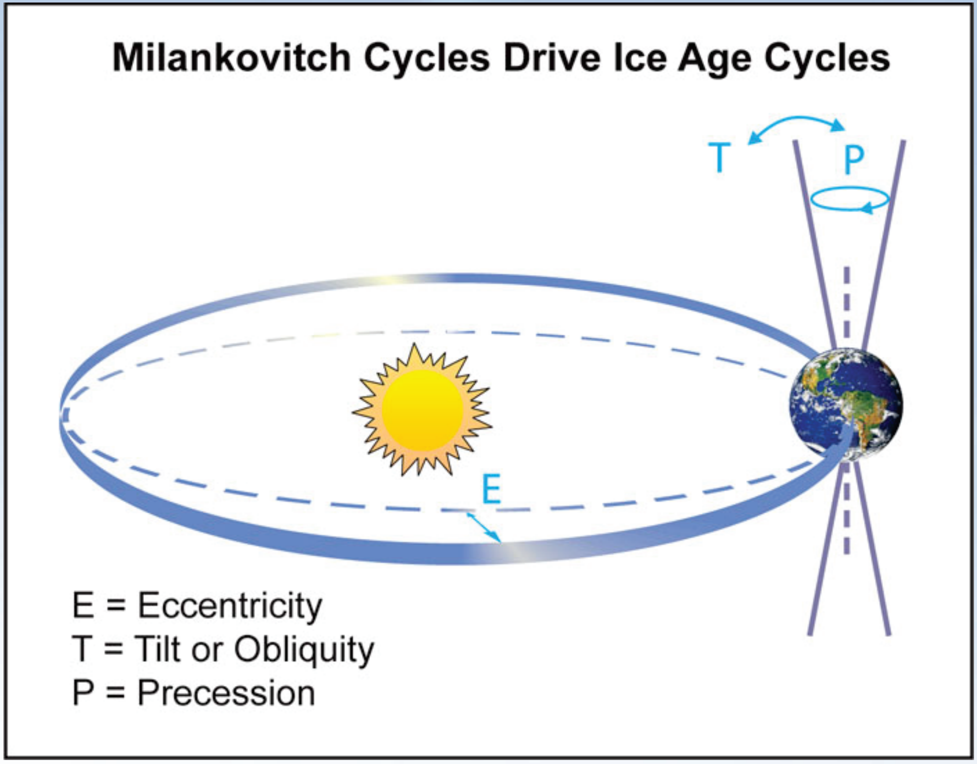
Natural Influences on Climate

To try and predict future climate, we need to understand past climate

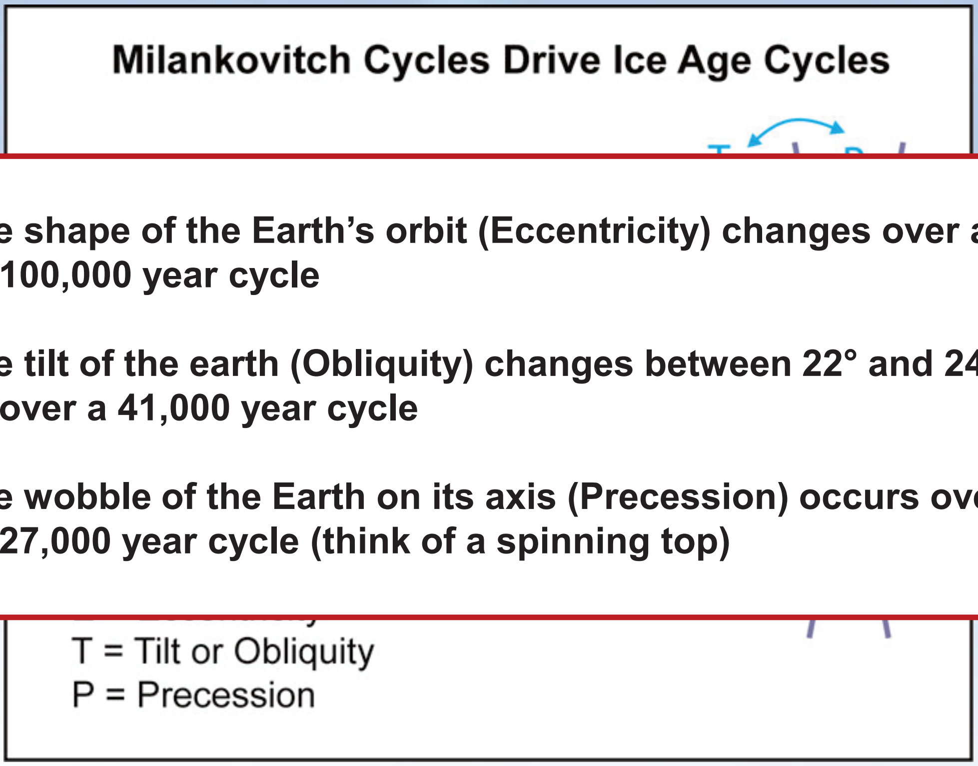
Understanding past climate allows us to separate natural changes in climate from human-made (anthropogenic)

Need to understand how changing climate can lead to further changes (feedback mechanisms)

Milankovitch Cycles



Milankovitch Cycles



The shape of the Earth’s orbit (Eccentricity) changes over a 100,000 year cycle

The tilt of the earth (Obliquity) changes between 22° and 24.5 ° over a 41,000 year cycle

The wobble of the Earth on its axis (Precession) occurs over a 27,000 year cycle (think of a spinning top)

Solar Variation

Solar output follows an 11 year cycle which, historically, has been tracked through sunspot observations

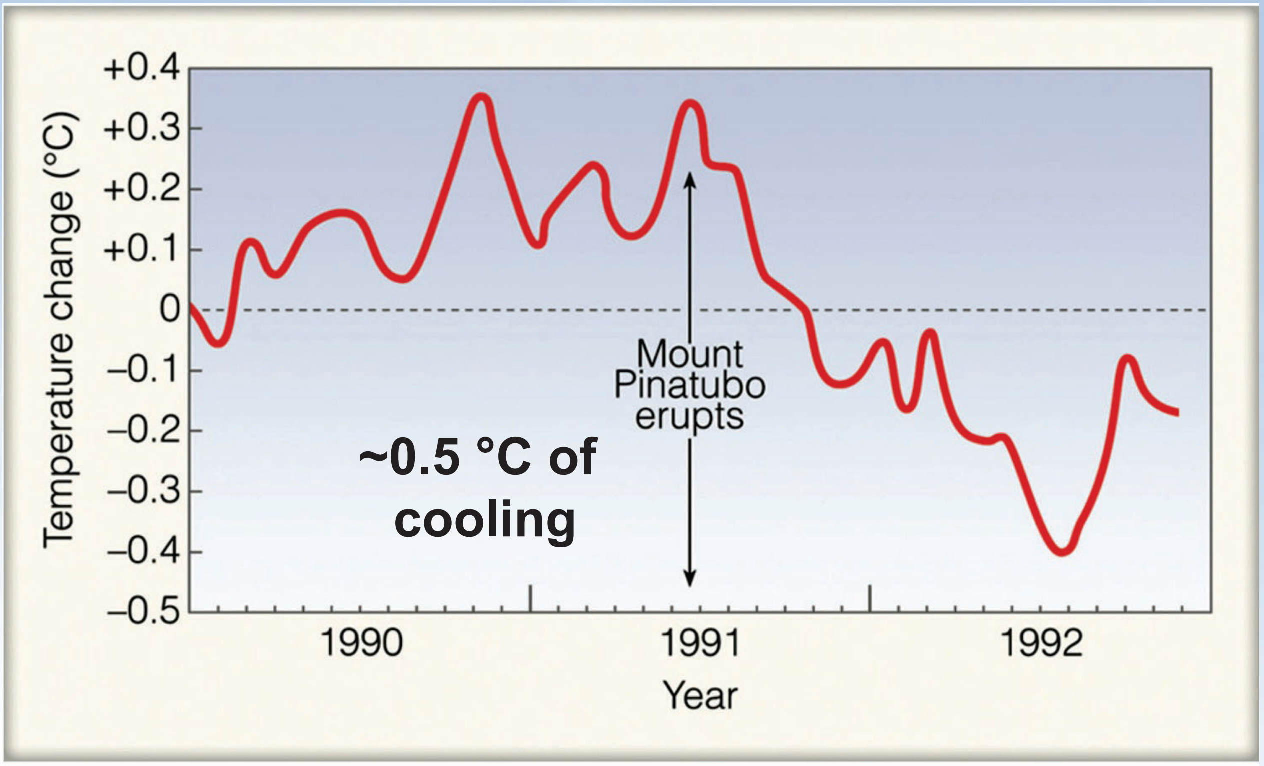
Sun spots have been observed directly by telescope since the 1600’s

Prior to this, Chinese astronomers recorded observations as early as 364 BC

Volcanoes

USGS

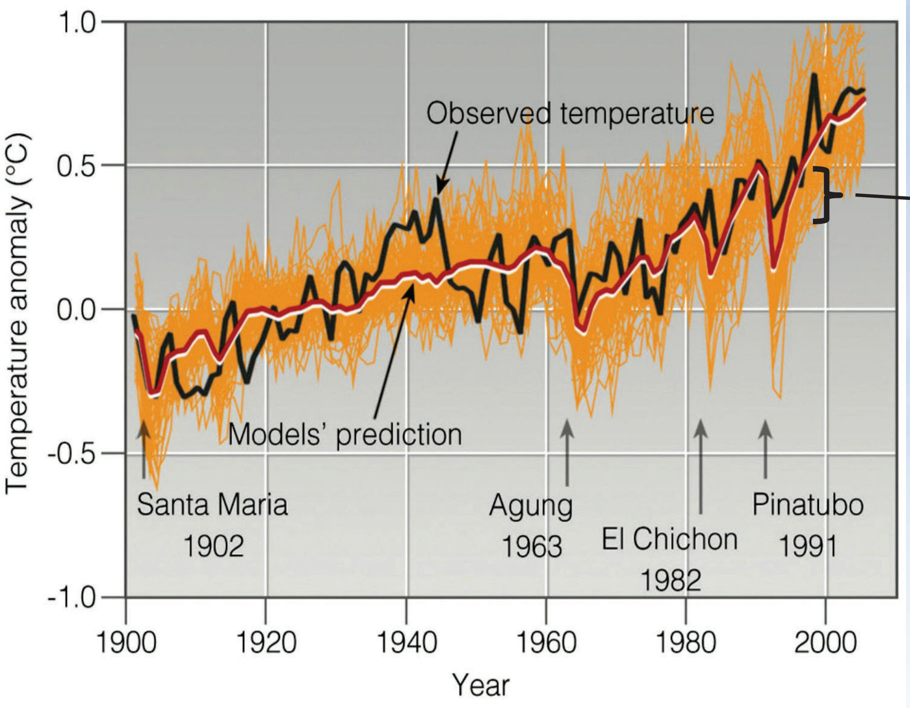
Volcanoes



~0.5 °C of cooling

Fig 13-16 *Essentials of Meteorology*

Volcanoes



(b) Natural and human forcing agents.

~0.5 °C of cooling?

Fig 13-18 *Essentials of Meteorology*

Plate Tectonics

The slow movement of the Earth's land masses can affect climate on long time scales

As land moves to the poles, the amount of solar radiation absorbed by the planet at these latitudes decreases

Currently, majority of land is in the Northern hemisphere

300 million years ago, all land masses joined together as on supercontinent called Pangea

As continents separated and collided together forming mountain ranges

Plate Tectonics

Geologic record indicates prior location of land masses

Coal from Appalachians contain fossil remains of ferns

Ferns requires a warm moist climate, such as at the equator

So, Appalachian mountains had to have been closer to the equator when the organic material (i.e. ferns) that became the coal was deposited

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Plate Tectonics

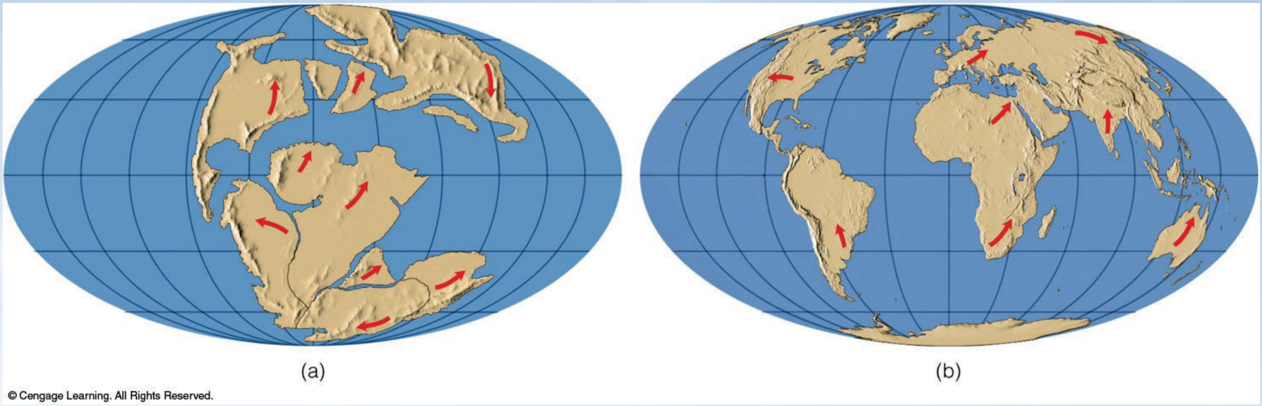

Fig 13-9 *Essentials of Meteorology*

Human Influences on Climate

To try and predict future climate, we need to understand past climate

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Need to understand how changing climate can lead to further changes (feedback mechanisms)

Atmospheric Absorption

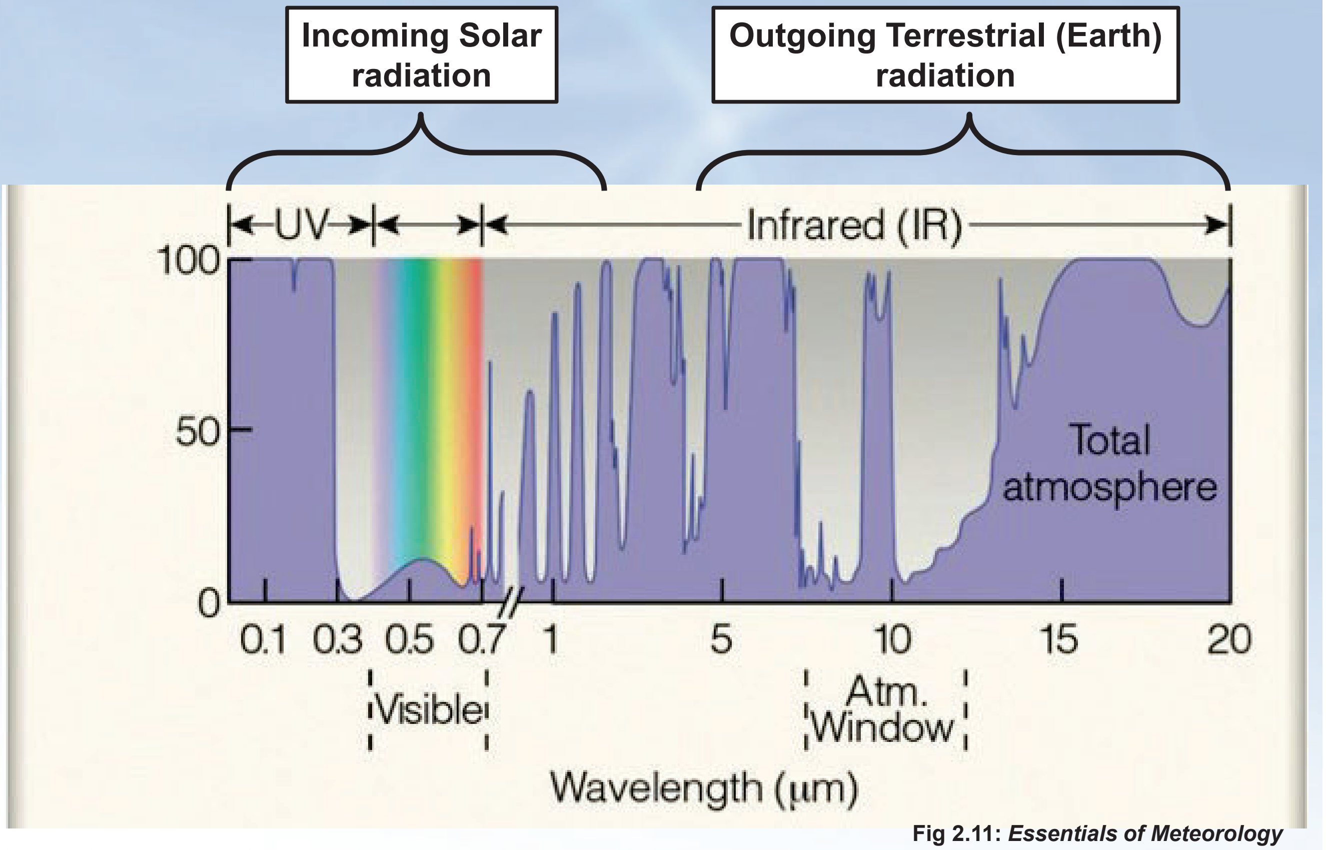
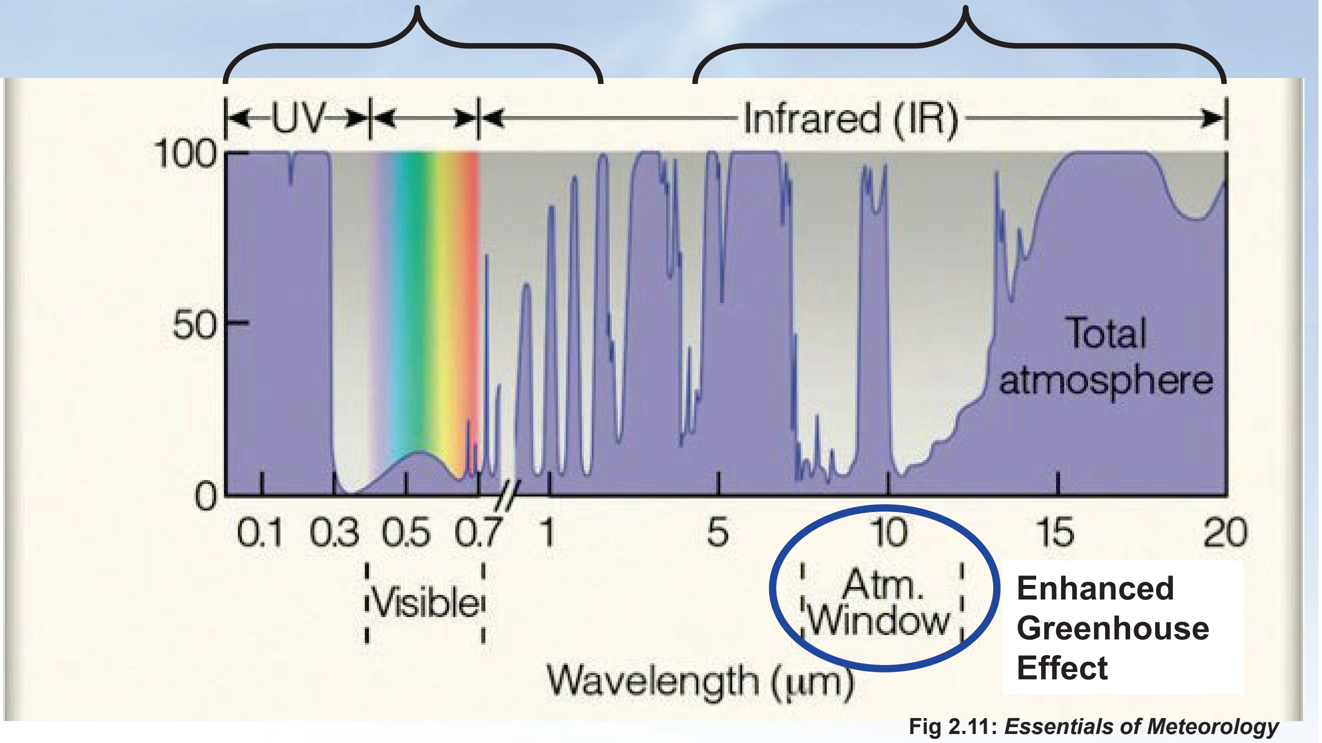


Fig 2.11: *Essentials of Meteorology*

Atmospheric Absorption

Incoming Solar radiation

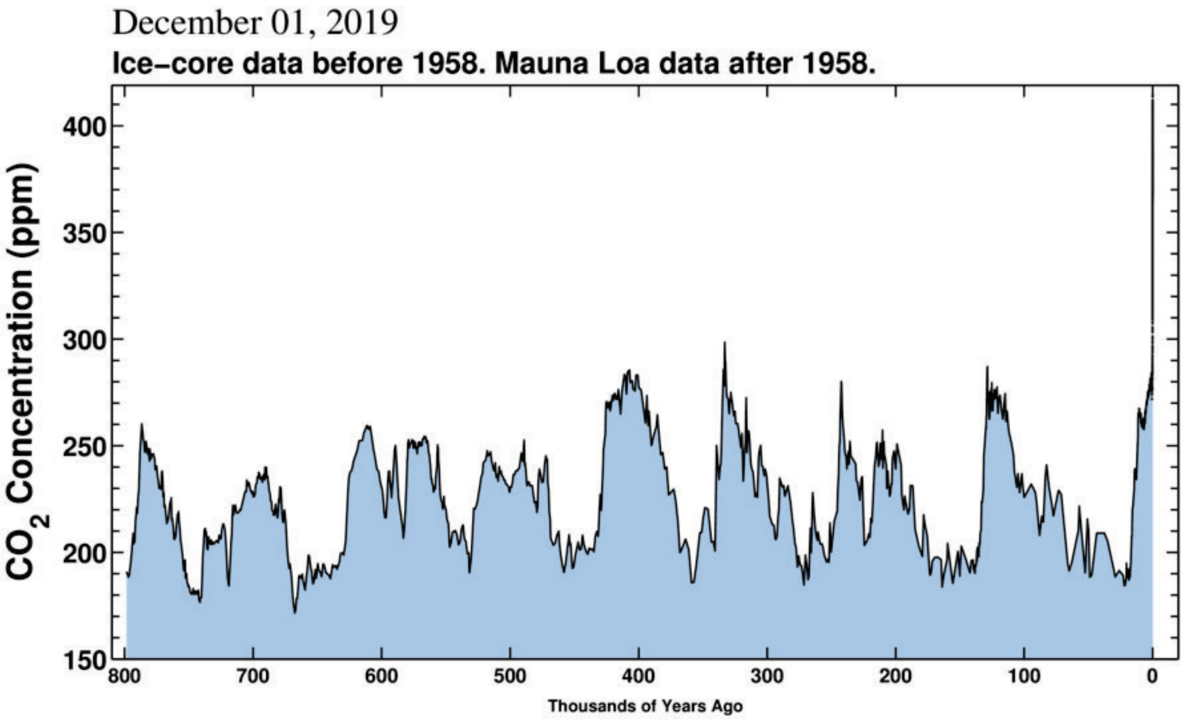
Outgoing Terrestrial (Earth) radiation



Enhanced Greenhouse Effect

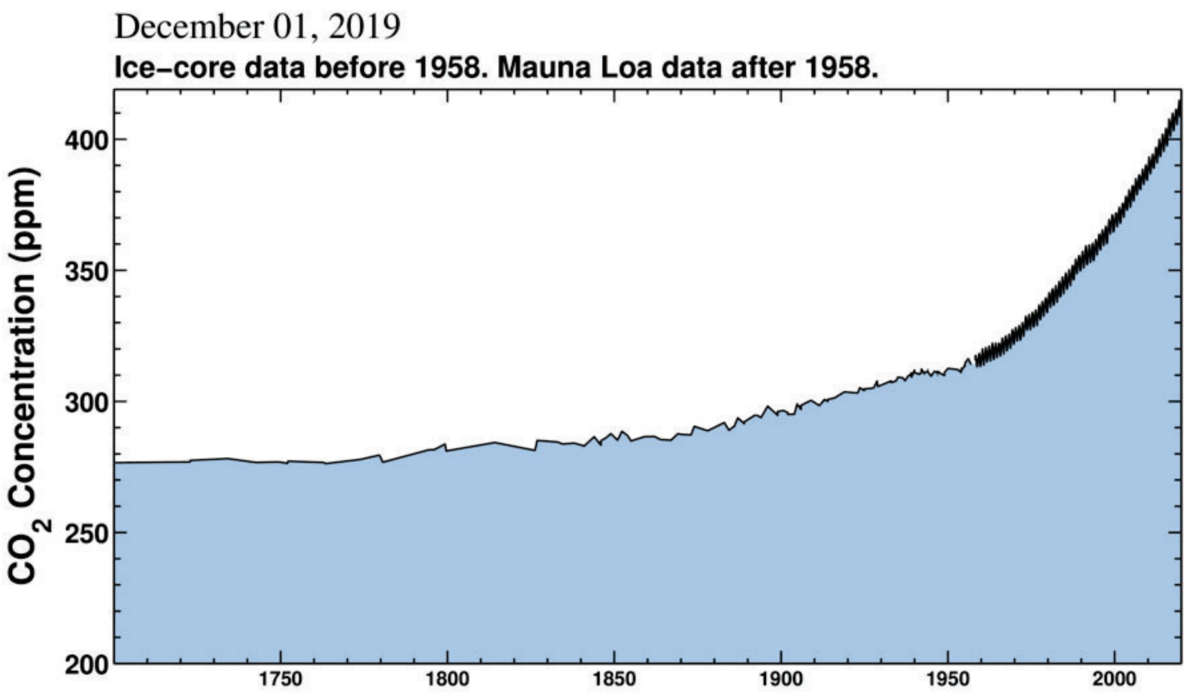
Fig 2.11: ***Essentials of Meteorology***

Carbon Dioxide (CO_2)

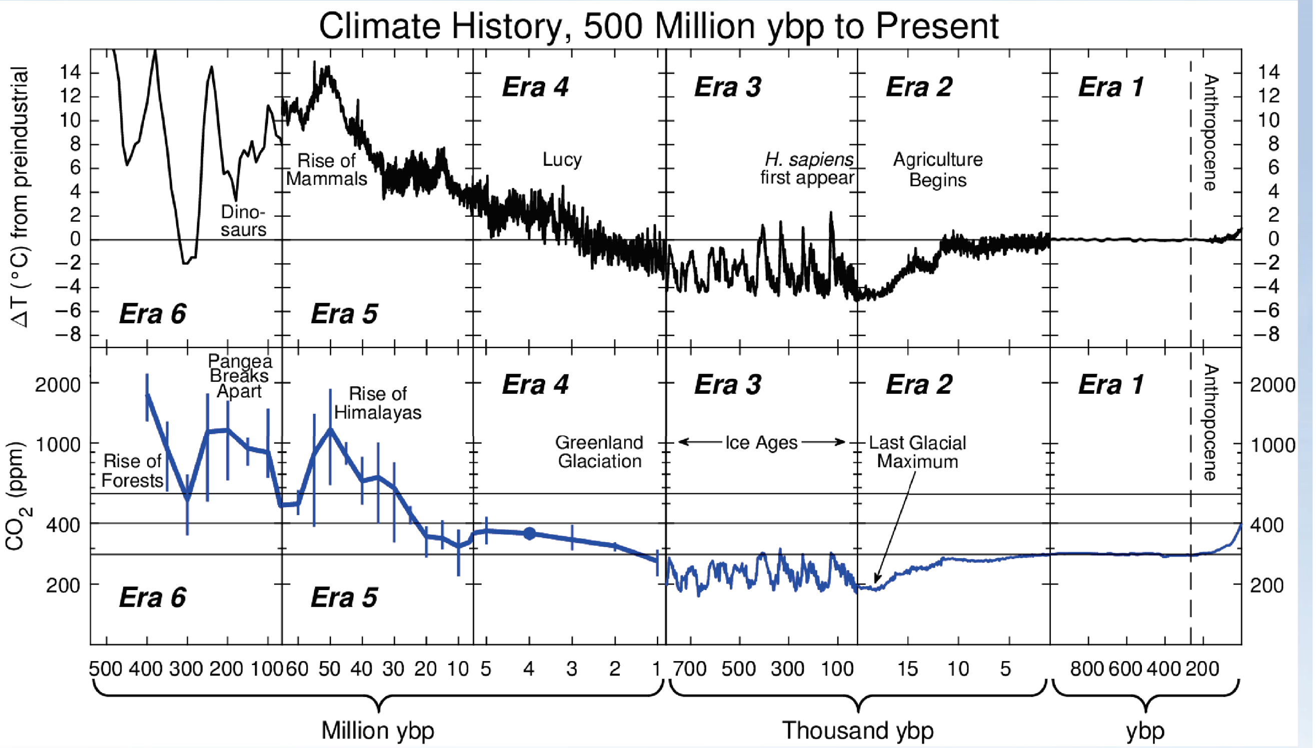


http://keelingcurve.ucsd.edu/

Carbon Dioxide (CO_2)

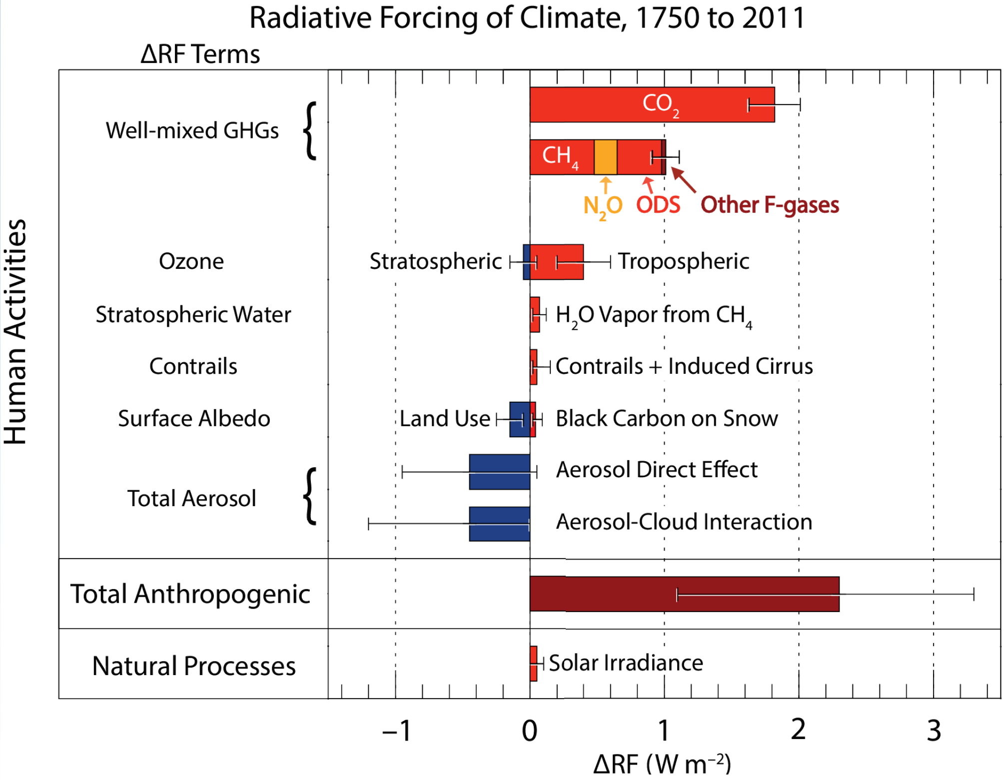


http://keelingcurve.ucsd.edu/



http://parisbeaconofhope.org

Total Radiative Forcing



Radiative Forcing: the change in the Earth's energy budget due to changes in these variables

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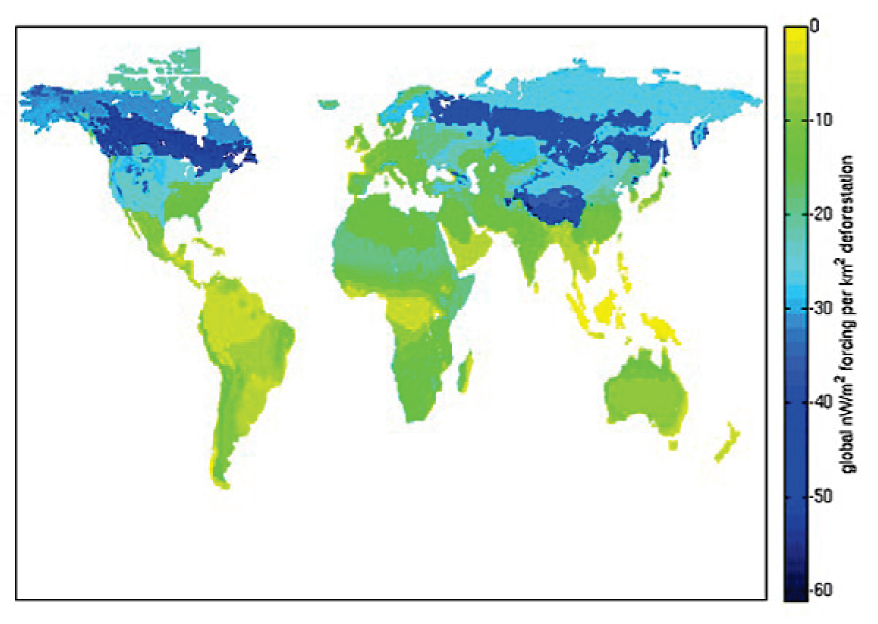
Land use change

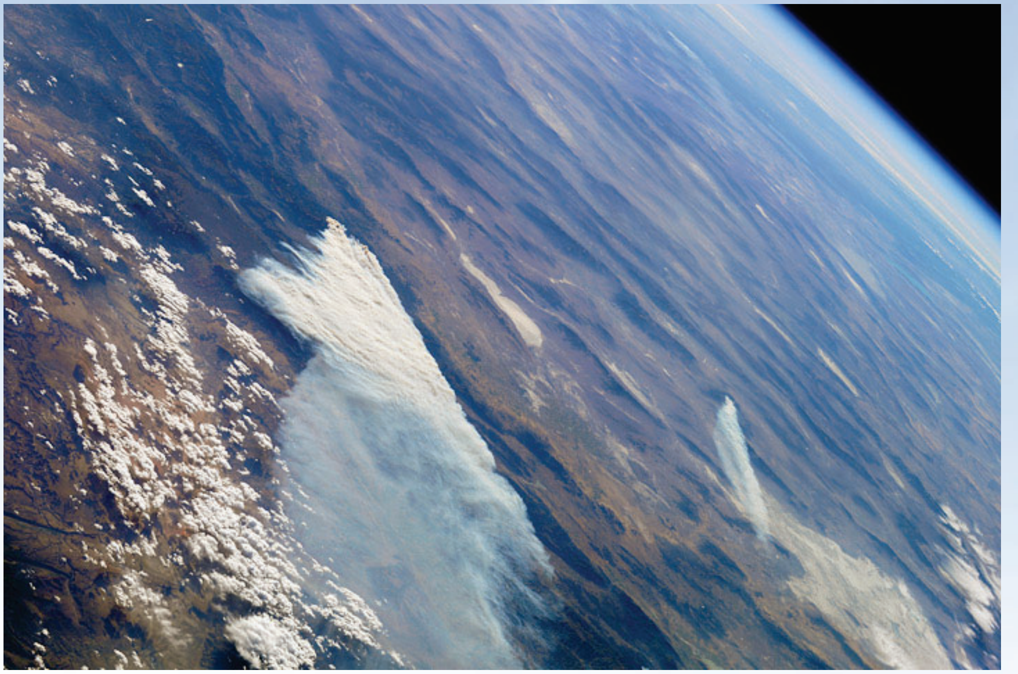
Converting forests to land for agriculture may decrease radiative forcing (cooling). Albedo increases as snow on the ground is more reflective than snow on trees.



http://esd.lbl.gov/radiative-forcing-albedo-in-land-use-scenarios/

Aerosol: Direct Climate Effect

Aerosols are often brighter than the surface and reflect incoming solar radiation. This leads to cooling.



Aerosol: Direct Climate Effect

Some aerosols are darker and lead to regional warming. May explain retreat of Himalayan glaciers.

http://www.nature.com/climate/2007/0709/full/climate.2007.41.html

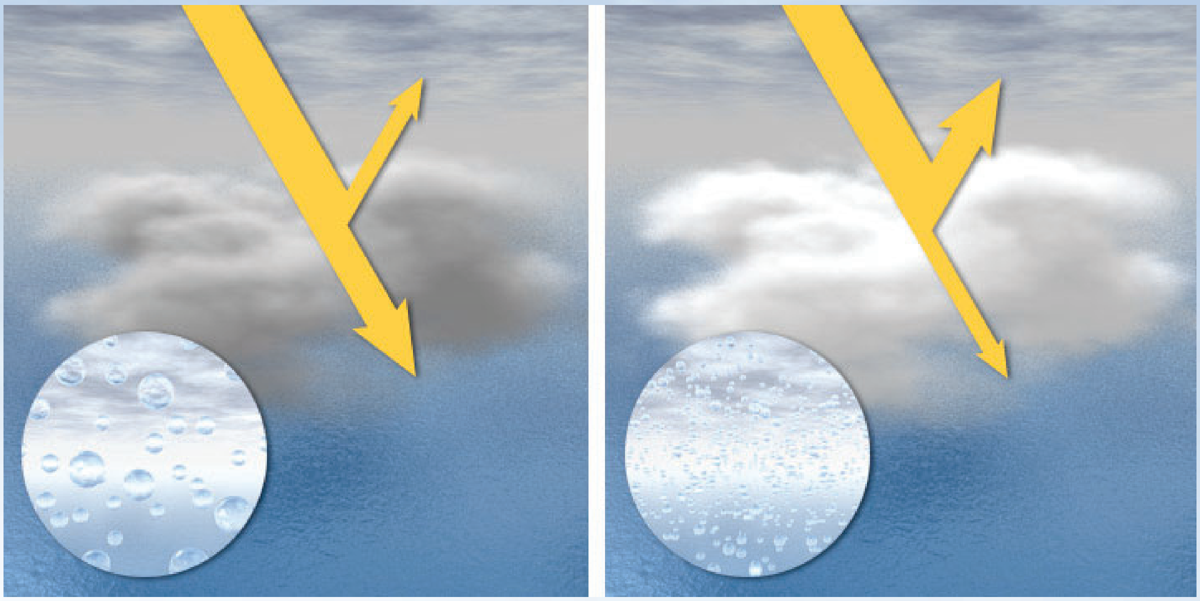
Aerosol: Direct Climate Effect

Dark aerosols on snow will decrease albedo and lead to increased absorption of solar energy and snow melt.

http://earthobservatory.nasa.gov/Features/Aerosols/page3.php

Aerosol: Indirect Climate Effect

Aerosols = cloud condensation nuclei



Clean air: clouds made of fewer, larger drops. Cloud is darker

Dirty air: clouds made of many smaller drops. Cloud is brighter

Influences on Climate

To try and predict future climate, we need to understand past climate

Understanding past climate allows us to separate natural changes in climate from human-made (anthropogenic)

Need to understand how changing climate can lead to further changes (feedback mechanisms)

Climate Feedback

A climate feedback mechanism is a climate response to an initial change

Positive Feedback: amplifies the initial change

Negative Feedback: diminishes the initial change

Feedback mechanisms are one of the big "unknowns" in climate research

Understanding climate feedbacks vital to predicting climate trends.

Ice-Albedo Feedback

A rise in temperature, caused by increasing greenhouse gases like CO_2, will cause a further increase in temperature

How will this affect ice?

Ice-Albedo Feedback

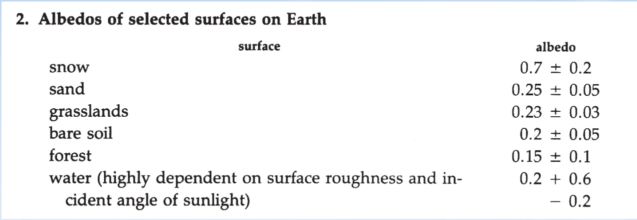
Initial Action:
Humans Release CO_2

Initial Response:
$T_{SURFACE}$ and T_{OCEAN} Rise

Secondary Response:
Ice Melts

Consequence:
Albedo Falls

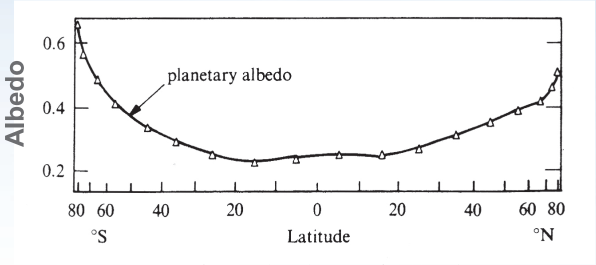
Response to Consequence:
⇨ $T_{SURFACE}$ Increases



2. **Albedos of selected surfaces on Earth**

surface	albedo
snow	0.7 ± 0.2
sand	0.25 ± 0.05
grasslands	0.23 ± 0.03
bare soil	0.2 ± 0.05
forest	0.15 ± 0.1
water (highly dependent on surface roughness and incident angle of sunlight)	0.2 + 0.6 − 0.2

Harte, *Consider a Spherical Cow: A Course in Environmental Problem Solving*, 1988.

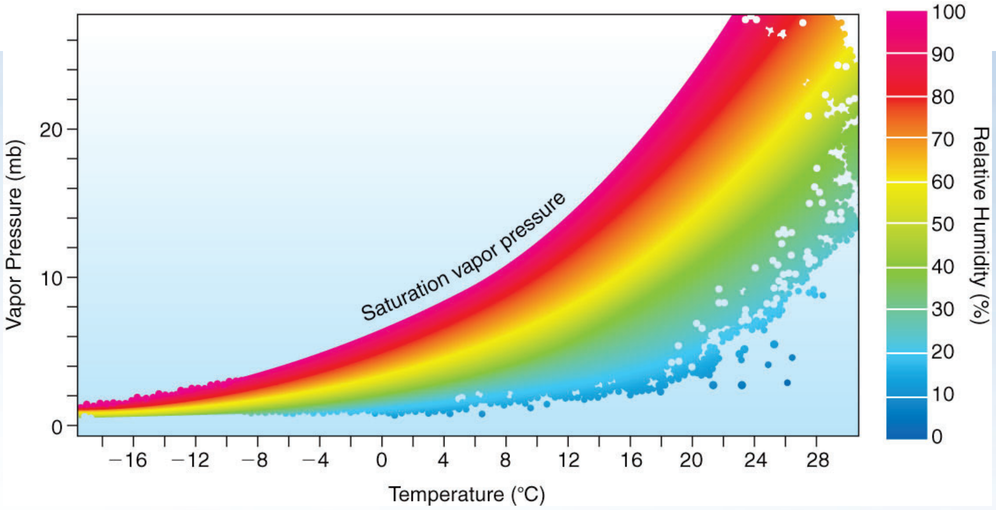


Houghton, *The Physics of Atmospheres*, 1991.

Water Vapor Feedback

A rise in temperature caused by increasing greenhouse gases, like CO_2, will cause an increase in temperature

How will this affect H_2O vapor?



Water Vapor Feedback

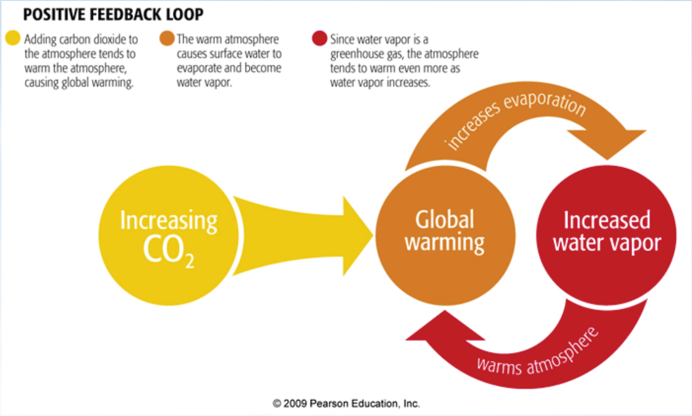
Initial Action:
Humans Release CO_2

Initial Response:
$T_{SURFACE}$ rises

Secondary Response:
Surface water evaporates

Consequence:
Increased water vapor

Response to Consequence:
⇨ $T_{SURFACE}$ Increases



POSITIVE FEEDBACK LOOP

Adding carbon dioxide to the atmosphere tends to warm the atmosphere, causing global warming.

The warm atmosphere causes surface water to evaporate and become water vapor.

Since water vapor is a greenhouse gas, the atmosphere tends to warm even more as water vapor increases.

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CO_2 Feedback: Plants

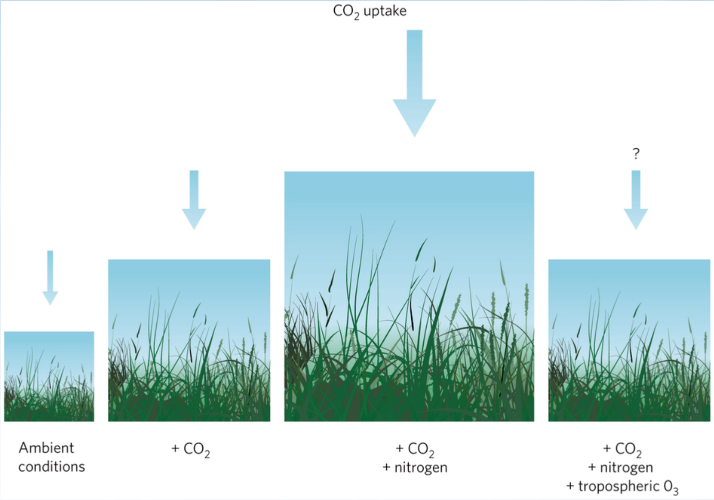
Initial Action:
Humans Release CO_2

Initial Response:
$T_{SURFACE}$ rises

Secondary Response:
Increased plant growth due to more CO_2

Consequence:
CO_2 decreases

Response to Consequence:
⇨ $T_{SURFACE}$ decreases



This is a negative feedback

http://www.nature.com/nclimate/journal/v3/n3/full/nclimate1841.html

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Cloud Feedback

Increased temperatures can increase the amount of water vapor which, in turn, can lead to an increase in clouds

How will clouds affect temperatures?

This one's tricky?

Clouds can either lead to more warming or more cooling

Cloud feedback is one of the largest uncertainties in climate science