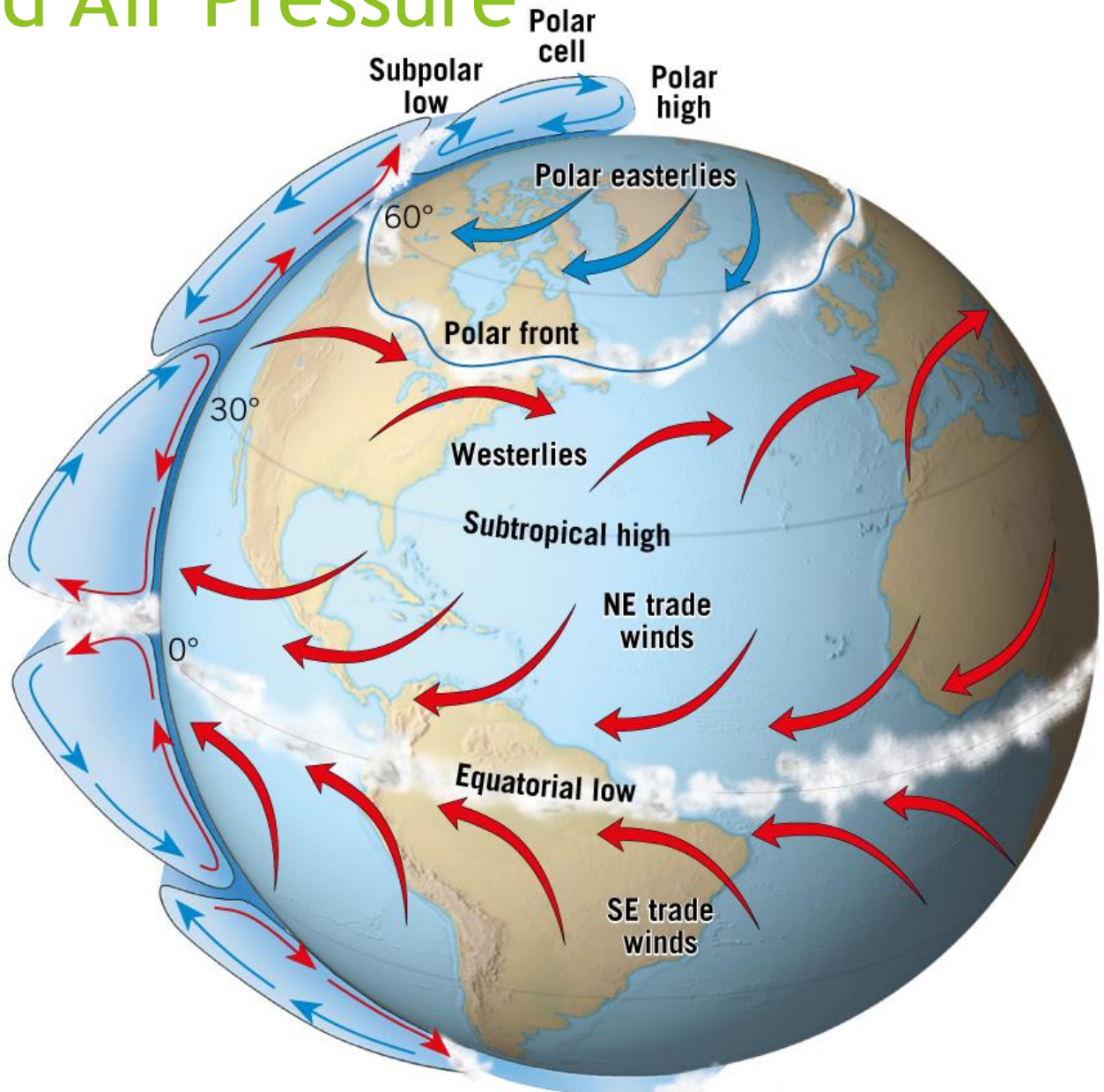
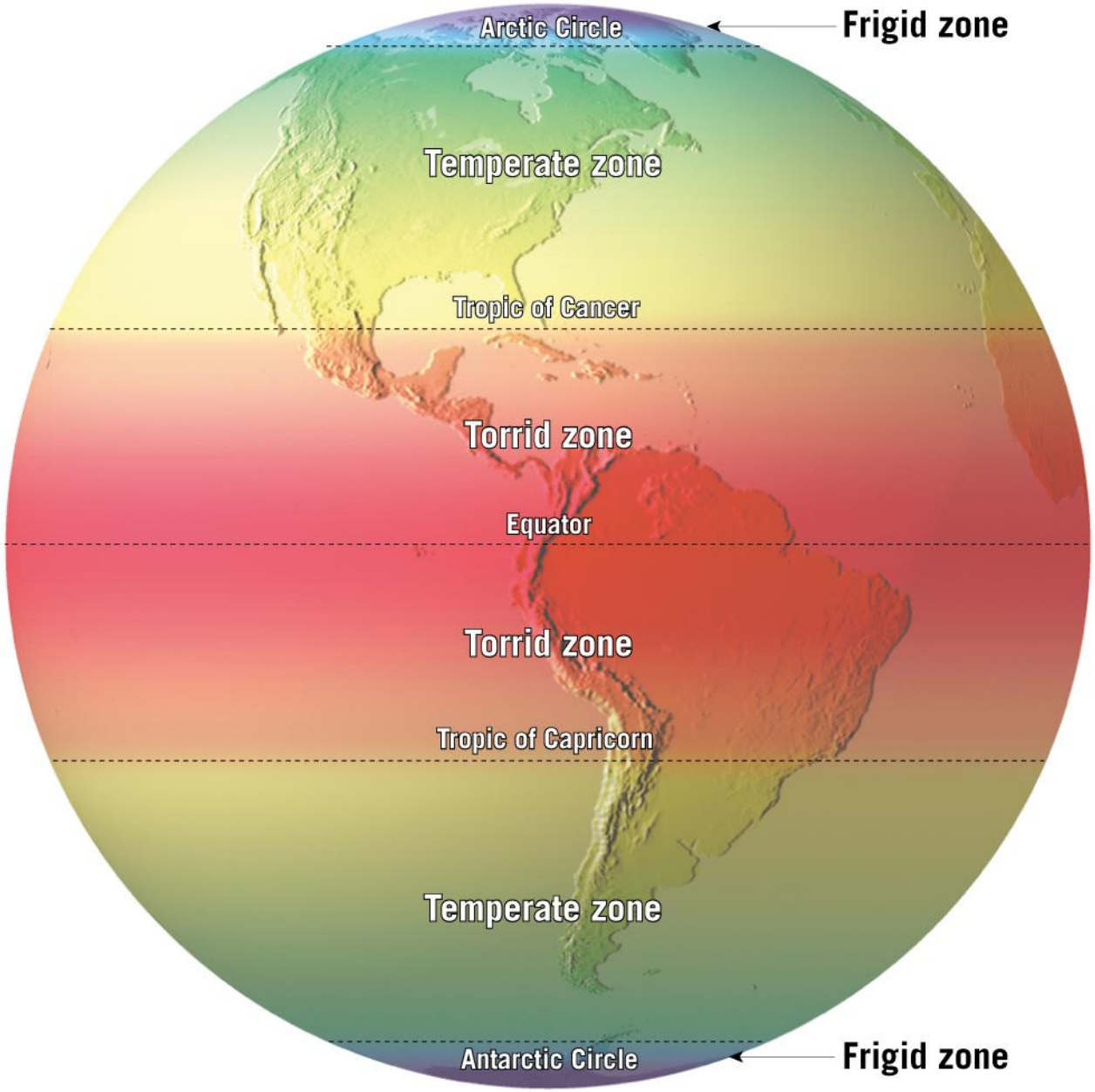
Climate and Climate Change

Weather vs Climate

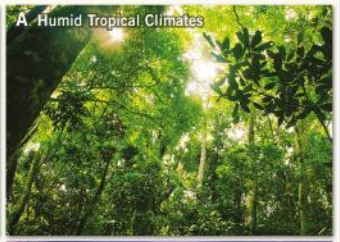
- **Weather** is the state of the atmosphere at a particular time and place.
- **Climate** is an aggregate of weather over time particular to a region.

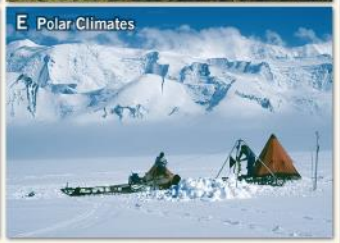
Latitude and Air Pressure





Letter Symbol 1st	2nd	3rd	
A			Average temperature of the coldest month is 18°C or higher.
	f		Every month has 6 cm of precipitation or more.
	m		Short dry season; precipitation in driest month less than 6 cm but equal to or greater than 10 – *R*/25 (*R* is annual rainfall in cm).
	w		Well-defined winter dry season; precipitation in driest month less than 10 – *R*/25.
	s		Well-defined summer dry season (rare).
B			Potential evaporation exceeds precipitation. The dry–humid boundary is defined by the following formulas: (Note: *R* is the average annual precipitation in cm, and T is the average annual temperature in °C.) When R is less than the calculated value the climate is dry. *R* < 2T + 28 when 70% or more of rain falls in warmer 6 months. *R* < 2T when 70% or more of rain falls in cooler 6 months. *R* < 2T + 14 when neither half year has 70% or more of rain.
	S		Steppe — The BS–BW boundary is 1/2 the dry–humid boundary.
	W		Desert
		h	Average annual temperature is 18°C or greater.
		k	Average annual temperature is less than 18°C.
C			Average temperature of the coldest month is under 18°C and above –3°C.
	w		At least 10 times as much precipitation in a summer month as in the driest winter month.
	s		At least three times as much precipitation in a winter month as in the driest summer month; precipitation in driest summer month less than 4 cm.
	f		Criteria for w and s cannot be met.
		a	Warmest month is over 22°C; at least 4 months over 10°C.
		b	No month above 22°C; at least 4 months over 10°C.
		c	One to 3 months above 10°C.
D			Average temperature of coldest month is –3°C or below; average temperature of warmest month is greater than 10°C.
	w		Same as under C.
	s		Same as under C.
	f		Same as under C.
		a	Same as under C.
		b	Same as under C.
		c	Same as under C.
		d	Average temperature of the coldest month is –38°C or below.
E			Average temperature of the warmest month is below 10°C.
	T		Average temperature of the warmest month is greater than 0°C and less than 10°C.
	F		Average temperature of the warmest month is 0°C or below.





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A			Average temperature of the coldest month is 18°C or higher.
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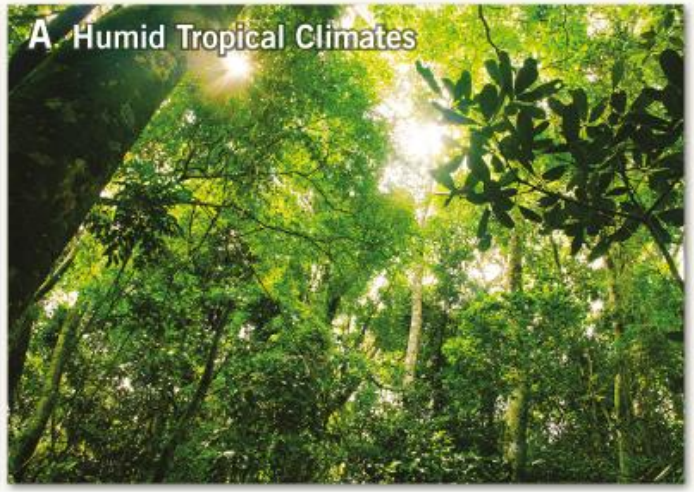

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B			Potential evaporation exceeds precipitation. The dry–humid boundary is defined by the following formulas: (Note: *R* is the average annual precipitation in cm, and T is the average annual temperature in °C.) When R is less than the calculated value the climate is dry. $R < 2T + 28$ when 70% or more of rain falls in warmer 6 months. $R < 2T$ when 70% or more of rain falls in cooler 6 months. $R < 2T + 14$ when neither half year has 70% or more of rain.
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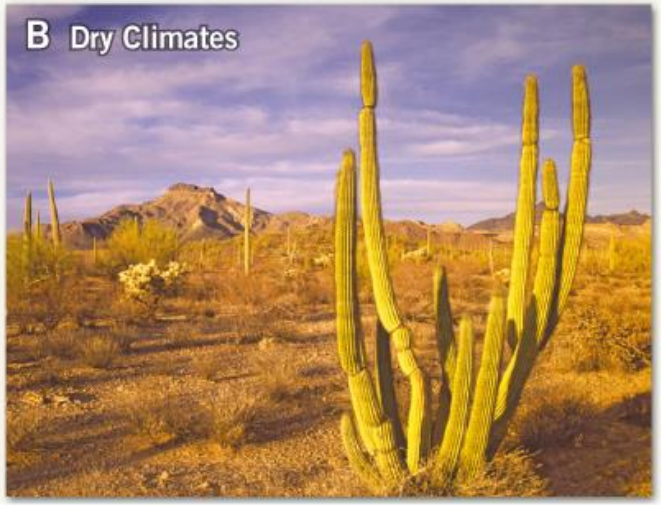

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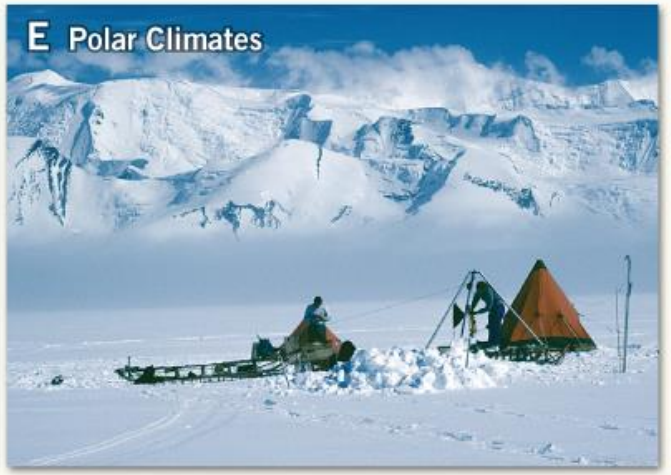
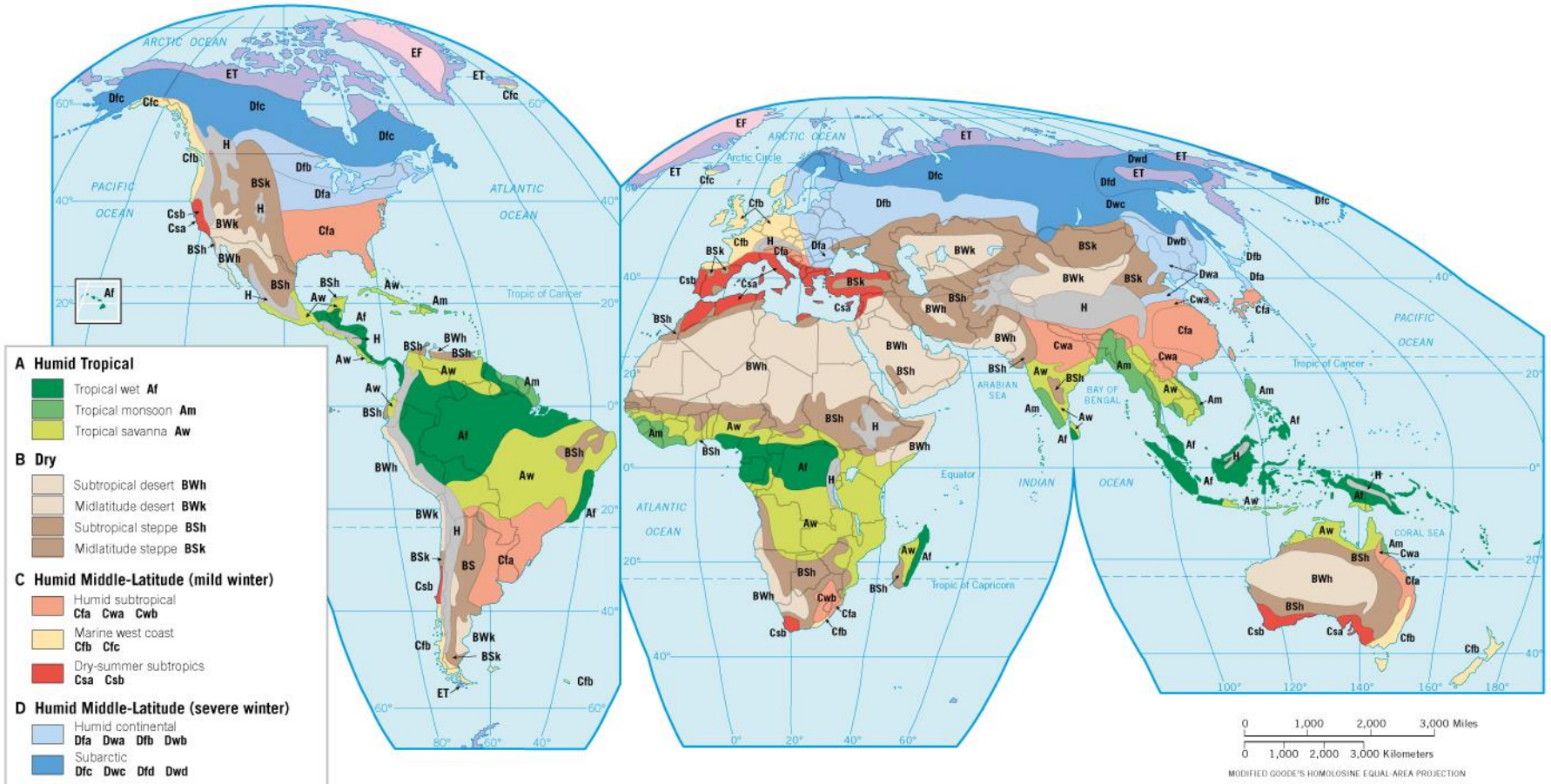
		d	Average temperature of the coldest month is –38°C or below.

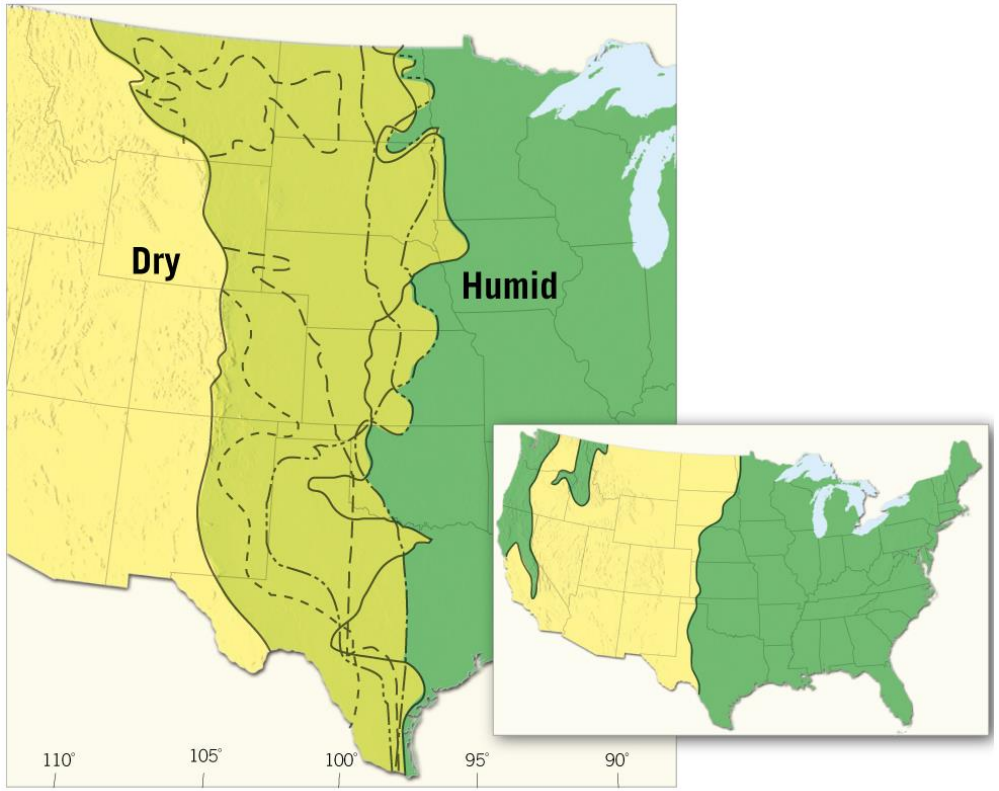
Letter Symbol 1st	2nd	3rd	
E			Average temperature of the warmest month is below 10°C.
	T		Average temperature of the warmest month is greater than 0°C and less than 10°C.
		F	Average temperature of the warmest month is 0°C or below.

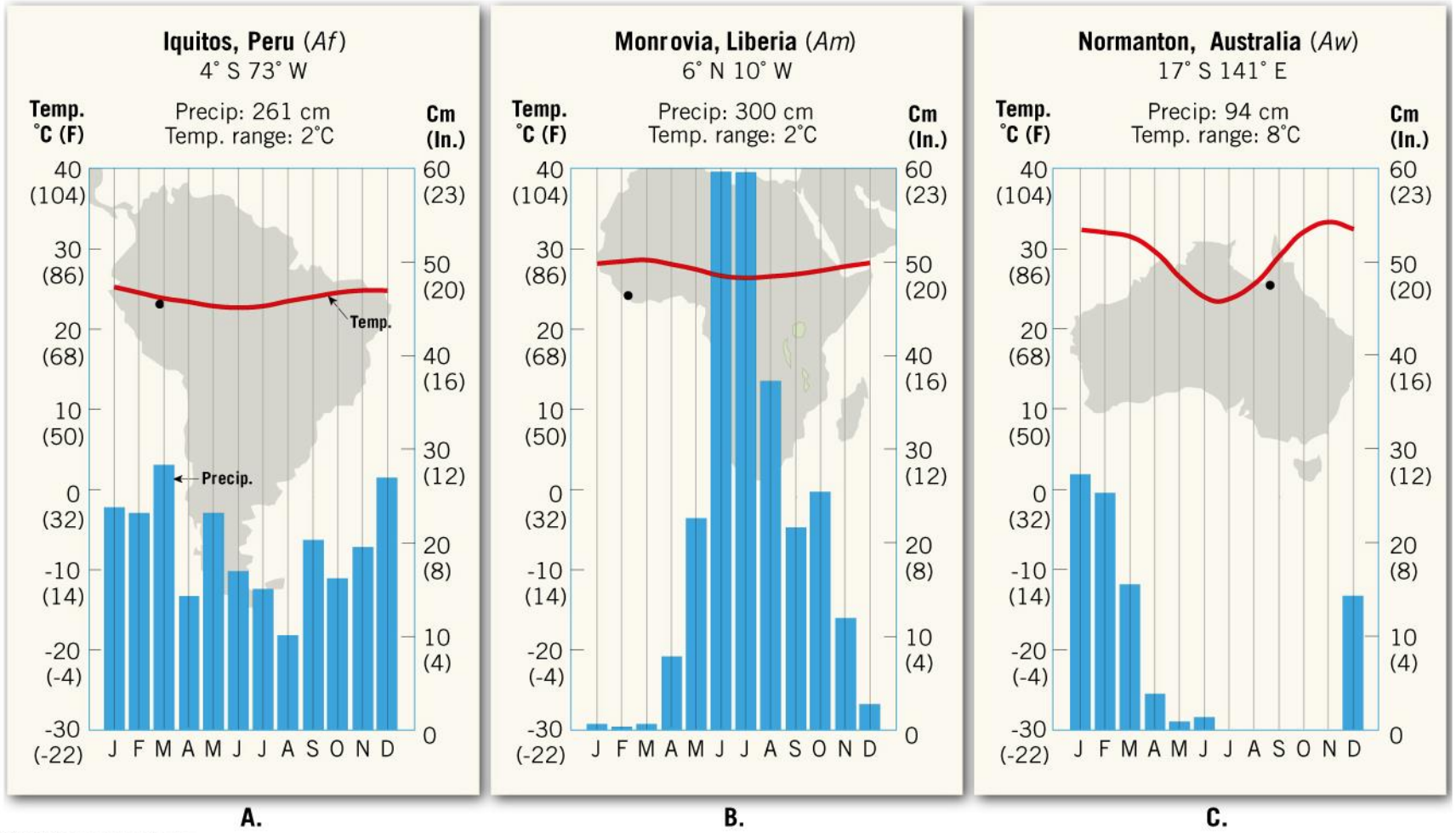




The 98th Meridian

https://www.youtube.com/watch?v=wwJABxjcvUc&t=13s

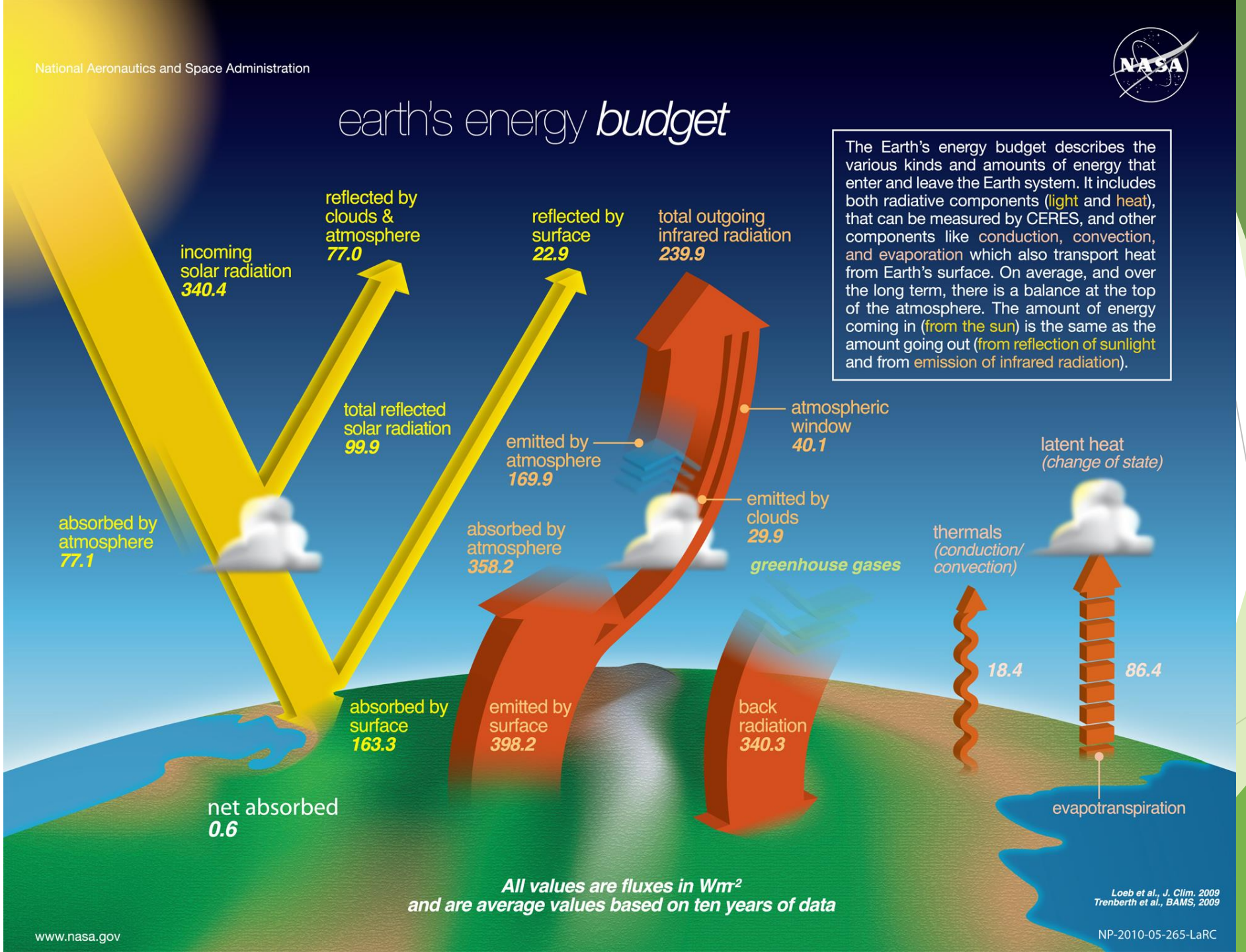


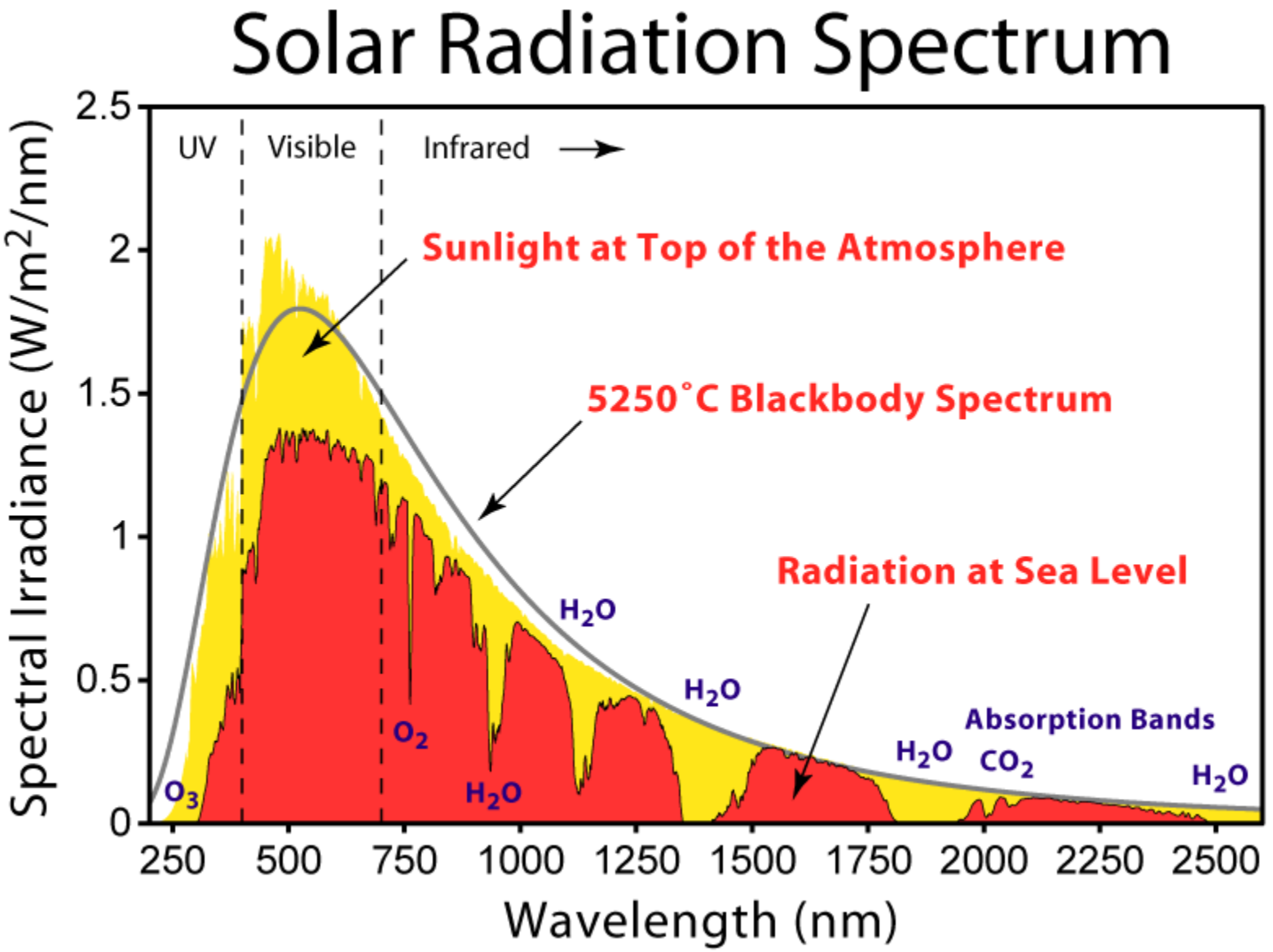


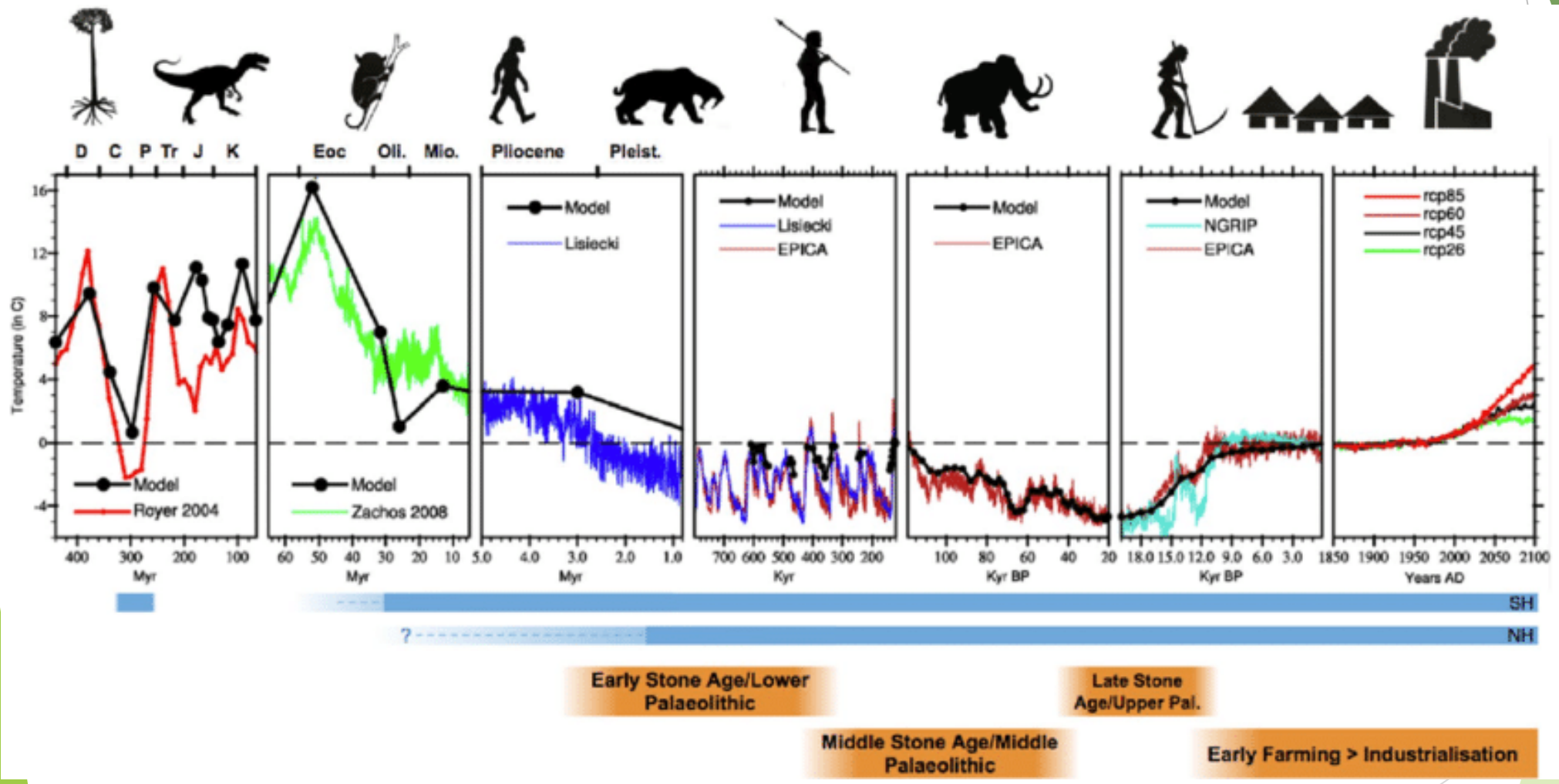
Climate Change

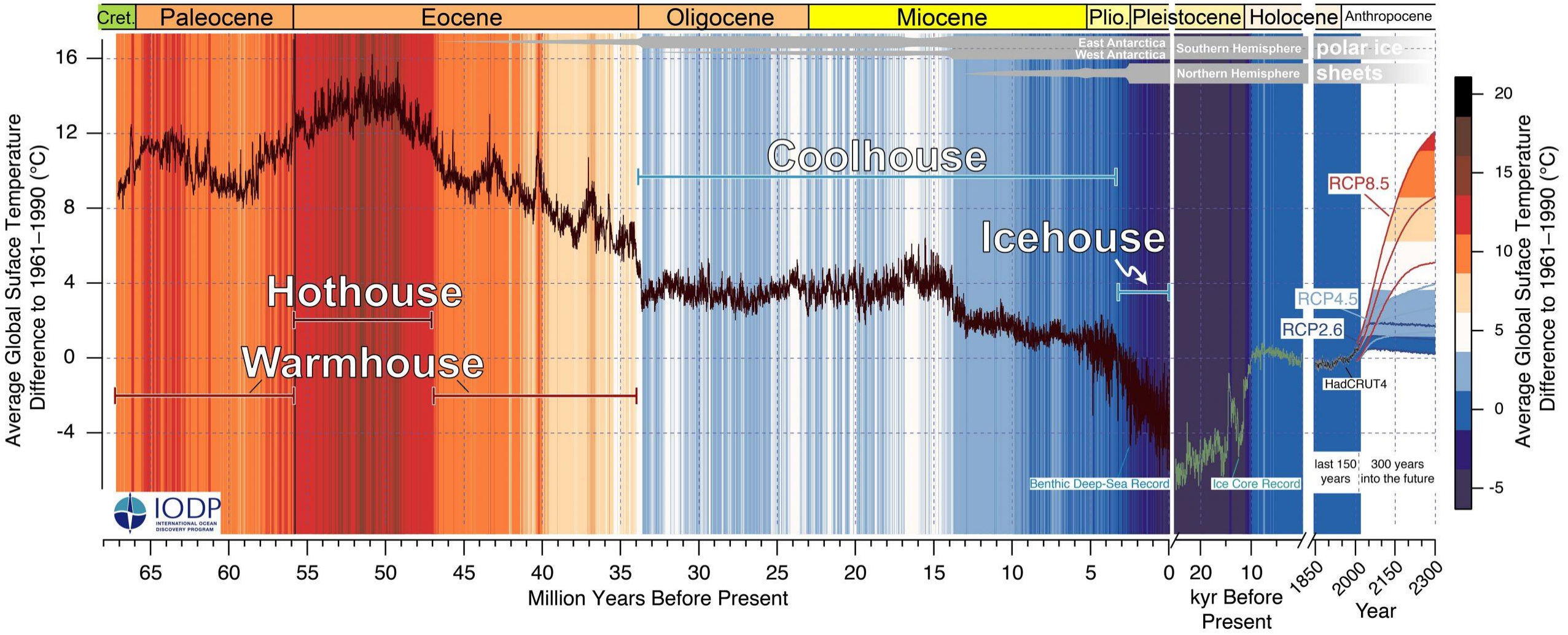
Take a Quiz

https://climate.nasa.gov/climate_resources/16/quiz-global-warming/

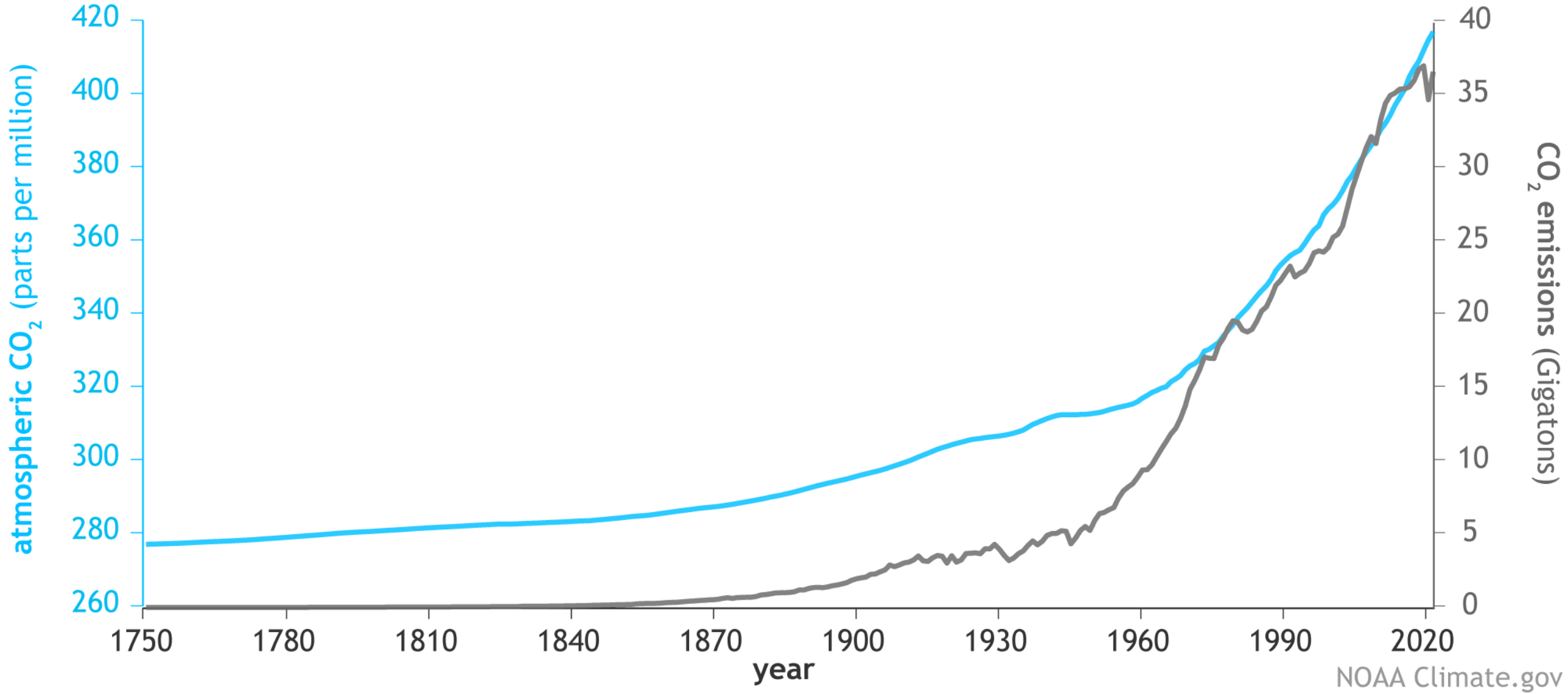

National Aeronautics and Space Administration
earth's energy budget
The Earth's energy budget describes the various kinds and amounts of energy that enter and leave the Earth system. It includes both radiative components (light and heat), that can be measured by CERES, and other components like conduction, convection, and evaporation which also transport heat from Earth's surface. On average, and over the long term, there is a balance at the top of the atmosphere. The amount of energy coming in (from the sun) is the same as the amount going out (from reflection of sunlight and from emission of infrared radiation).
incoming solar radiation 340.4
reflected by clouds & atmosphere 77.0
reflected by surface 22.9
total outgoing infrared radiation 239.9
total reflected solar radiation 99.9
emitted by atmosphere 169.9
atmospheric window 40.1
emitted by clouds 29.9
greenhouse gases
absorbed by atmosphere 77.1
absorbed by atmosphere 358.2
latent heat (change of state)
thermals (conduction/ convection)
18.4
86.4
absorbed by surface 163.3
emitted by surface 398.2
back radiation 340.3
net absorbed 0.6
evapotranspiration
All values are fluxes in Wm-2
and are average values based on ten years of data
Loeb et al., J. Clim. 2009
Trenberth et al., BAMS, 2009
www.nasa.gov
NP-2010-05-265-LaRC


Solar Radiation Spectrum
Spectral Irradiance (W/m²/nm)
2.5
2
1.5
1
0.5
0
UV
Visible
Infrared
Sunlight at Top of the Atmosphere
5250˚C Blackbody Spectrum
Radiation at Sea Level
O3
O2
H2O
H2O
H2O
H2O
CO2
H2O
Absorption Bands
250
500
750
1000
1250
1500
1750
2000
2250
2500
Wavelength (nm)


D C P Tr J K
Eoc Oli. Mio.
Pliocene
Pleist.
Temperature (in C)
Model
Royer 2004
Model
Zachos 2008
Model
Lisiecki
Model
Lisiecki
EPICA
Model
EPICA
Model
NGRIP
EPICA
rcp85
rcp60
rcp45
rcp26
Myr
Myr
Myr
Kyr
Kyr BP
Kyr BP
Years AD
SH
NH
?
Early Stone Age/Lower Palaeolithic
Middle Stone Age/Middle Palaeolithic
Late Stone Age/Upper Pal.
Early Farming > Industrialisation


Cret.
Paleocene
Eocene
Oligocene
Miocene
Plio.
Pleistocene
Holocene
Anthropocene
East Antarctica
West Antarctica
Southern Hemisphere
Northern Hemisphere
polar ice sheets
Coolhouse
Icehouse
Hothouse
Warmhouse
RCP8.5
RCP4.5
RCP2.6
HadCRUT4
Benthic Deep-Sea Record
Ice Core Record
last 150 years
300 years into the future
IODP
INTERNATIONAL OCEAN DISCOVERY PROGRAM
Average Global Suface Temperature Difference to 1961–1990 (°C)
16
12
8
4
0
-4
65
60
55
50
45
40
35
30
25
20
15
10
5
0
20
10
1850
2000
2150
2300
Million Years Before Present
kyr Before Present
Year
20
15
10
5
0
-5
Average Global Suface Temperature Difference to 1961–1990 (°C)

Atmospheric carbon dioxide amounts and annual emissions (1750–2021)



NOAA Climate.gov

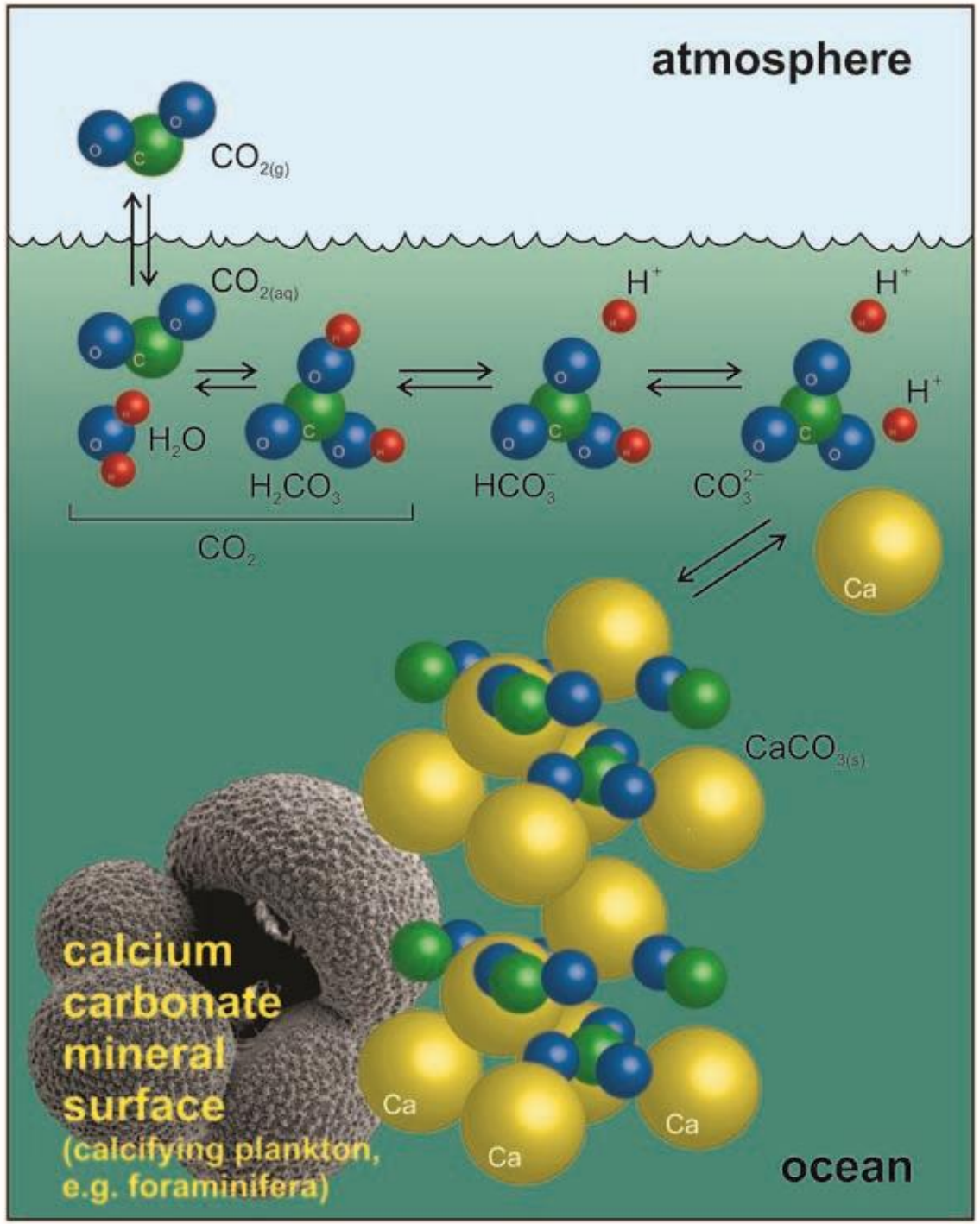
Data: NOAA, ETHZ, Our World in Data

Melting Ice

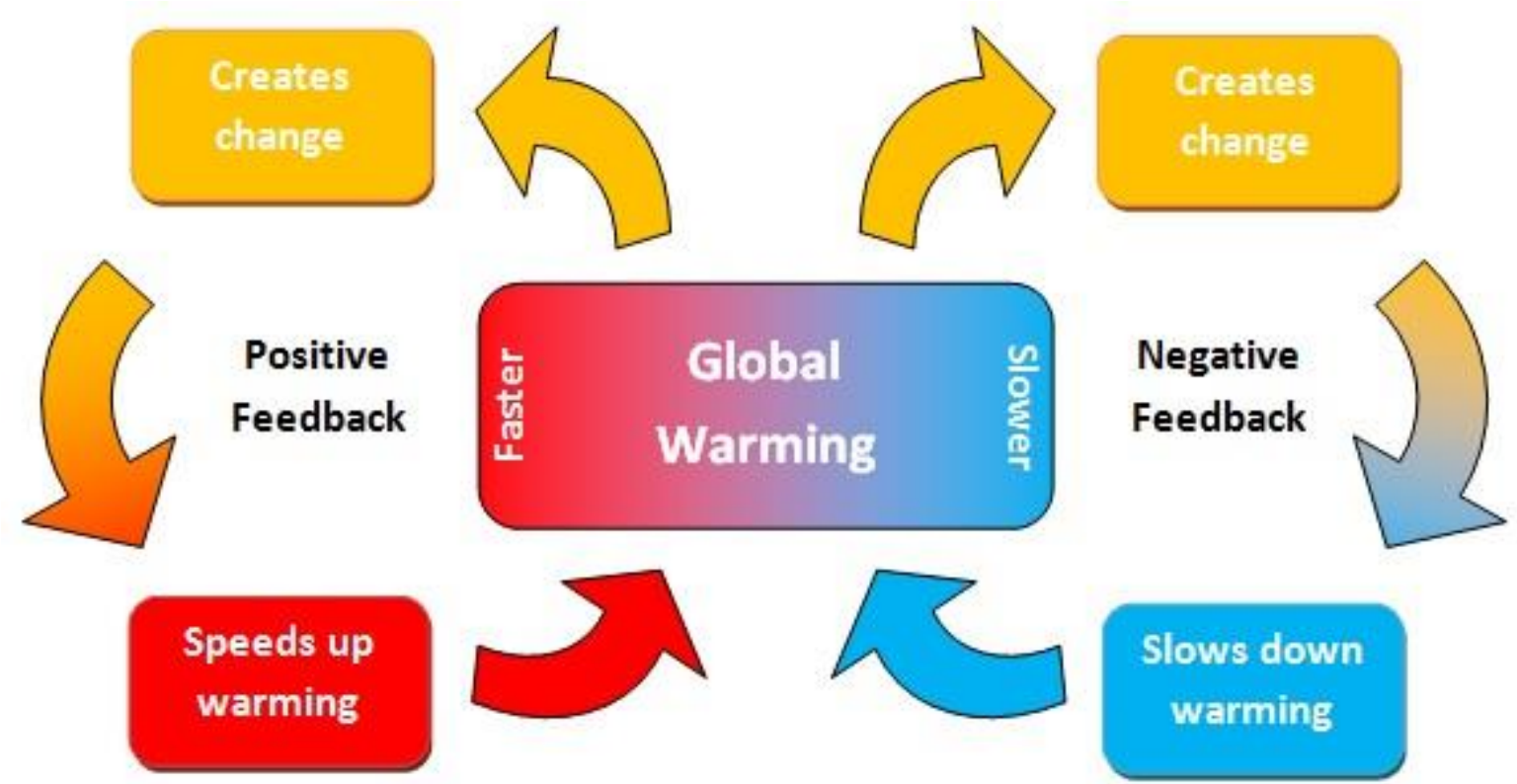
The Antarctic Ice Sheet measures nearly 4.9 kilometers (3 miles) at its thickest point and contains about 30 million cubic kilometers (7.2 million cubic miles) of ice. If the entire Antarctic Ice Sheet melted, sea level would rise about 60 meters (200 feet).

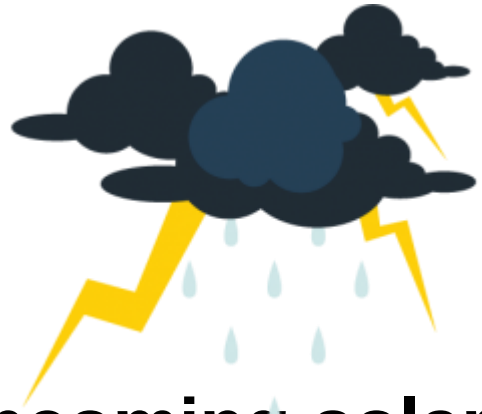

1 m
10⁰
(human scale)
meter
1 m


1 km
kilo
10^3
(mountain size)
kilometer
1000 m
Created by: Álvaro


atmosphere
$CO_{2(g)}$
$CO_{2(aq)}$
H_2O
H_2CO_3
HCO_3^-
CO_3^{2-}
H^+
H^+
H^+
CO_2
Ca
$CaCO_{3(s)}$
calcium carbonate mineral surface
(calcifying plankton, e.g. foraminifera)
Ca
Ca
Ca
ocean

Feedback Loops





Increased cloudiness reflects more incoming solar radiation

As ice sheets melt, this could increase cloudiness with more water vapor in the atmosphere.

Because clouds reflect 1/3 of incoming solar radiation , there would be less heat absorption on Earth's surface. This is a _____(positive, negative) feedback loop.

Permafrost melt sparks methane release

In the Arctic tundra, permafrost melt will trigger methane release in the atmosphere. Because methane is a more potent greenhouse gas than CO_2.

This type of _____ (positive, negative) feedback loop could be a tipping point for our climate. Currently, there are only about 5 gigatons of methane in the atmosphere.

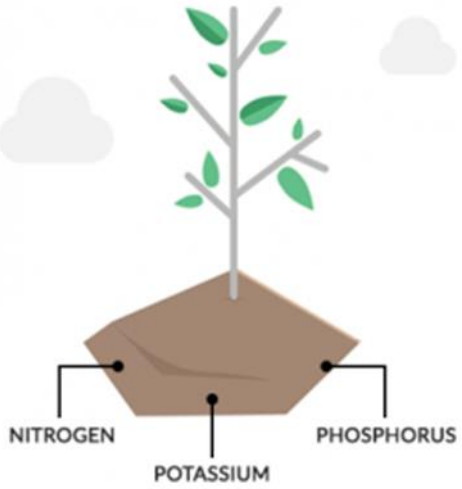
But the amount of methane in the Arctic is in the hundreds of gigatons.

Wetland Methane Release

Wetlands are the largest natural source of methane in the world. Climate change is concerned with their health because heating can cause bogs to release methane. This creates a _____ (positive, negative) feedback loop.

The amount of methane production is dependent on a number of factors: soil temperature, oxygen availability, and average temperatures.

Net primary productivity increase



As higher concentrations of CO_2 enter the atmosphere, plants have more material to photosynthesize. If you isolate a single plant ın a laboratory, then adding CO_2 makes Earth greener for now. But this fertilization effect diminishes with time. This is an example of _____ (positive, negative) feedback.

But plants can't grow indefinitely with rising CO_2. This is because plants require other factors like nitrogen in the nutrient cycle. And if temperature rises, this can negatively influence plant growth.

More Examples

- Air Pollution
- Wildfires
- Deforestation (Tree cutting)
- Volcanic Eruptions

https://www.noaa.gov/climate

https://climate.gov

https://www.youtube.com/watch?v=pEt6-jA2UE4 (84 minutes)

https://www.youtube.com/watch?v=uynhvHZUOOo (16 minutes)