

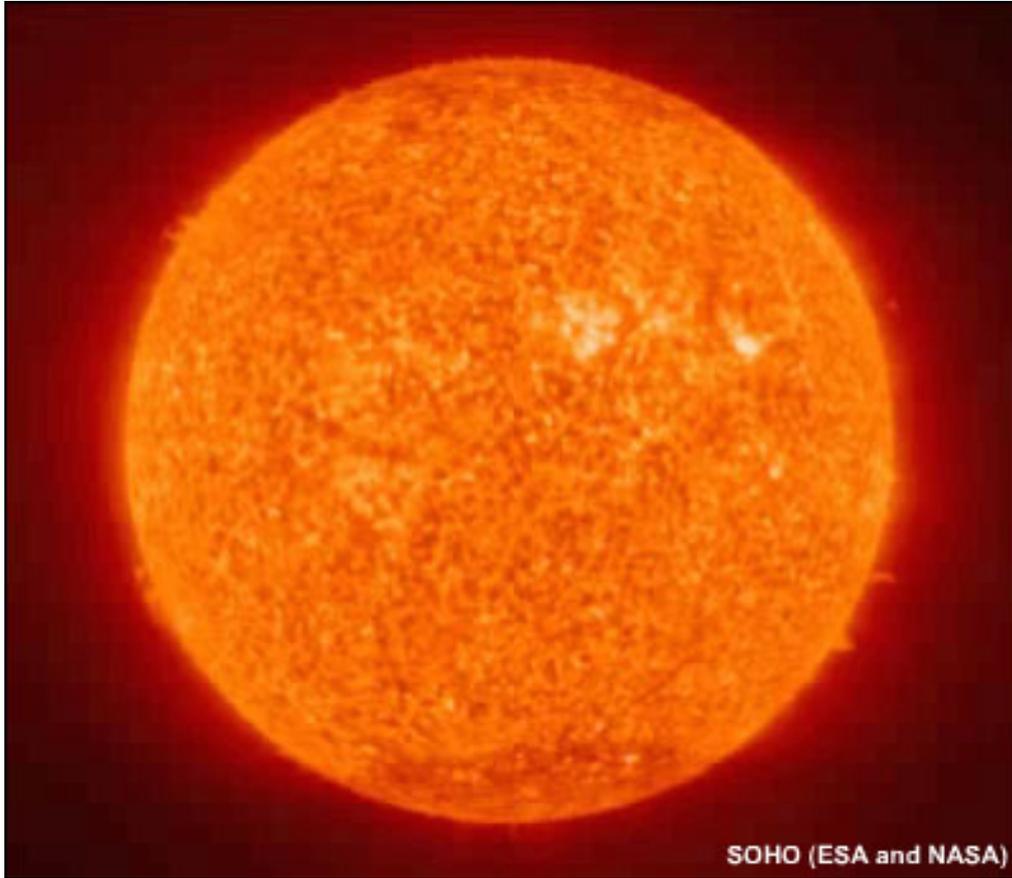
A satellite image of Earth showing the continent of South America on the left and the Atlantic Ocean on the right. The text is overlaid on the right side of the image.

Física da Atmosfera

Aula introdutória

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O Sol é a nossa fonte de energia



Sem o Sol, a temperatura na Terra seria -270°C

The Greenhouse Effect

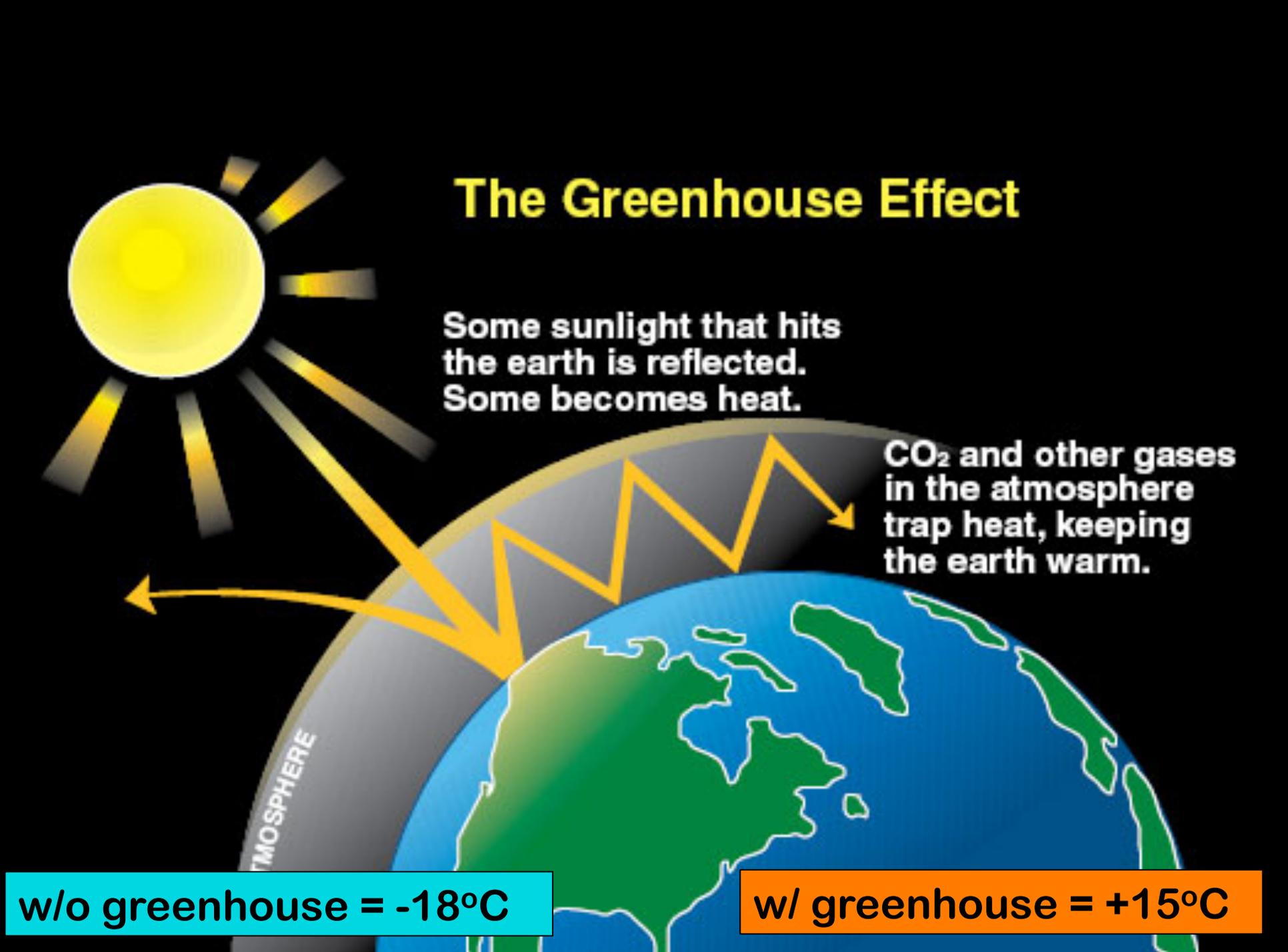
Some sunlight that hits the earth is reflected. Some becomes heat.

CO₂ and other gases in the atmosphere trap heat, keeping the earth warm.

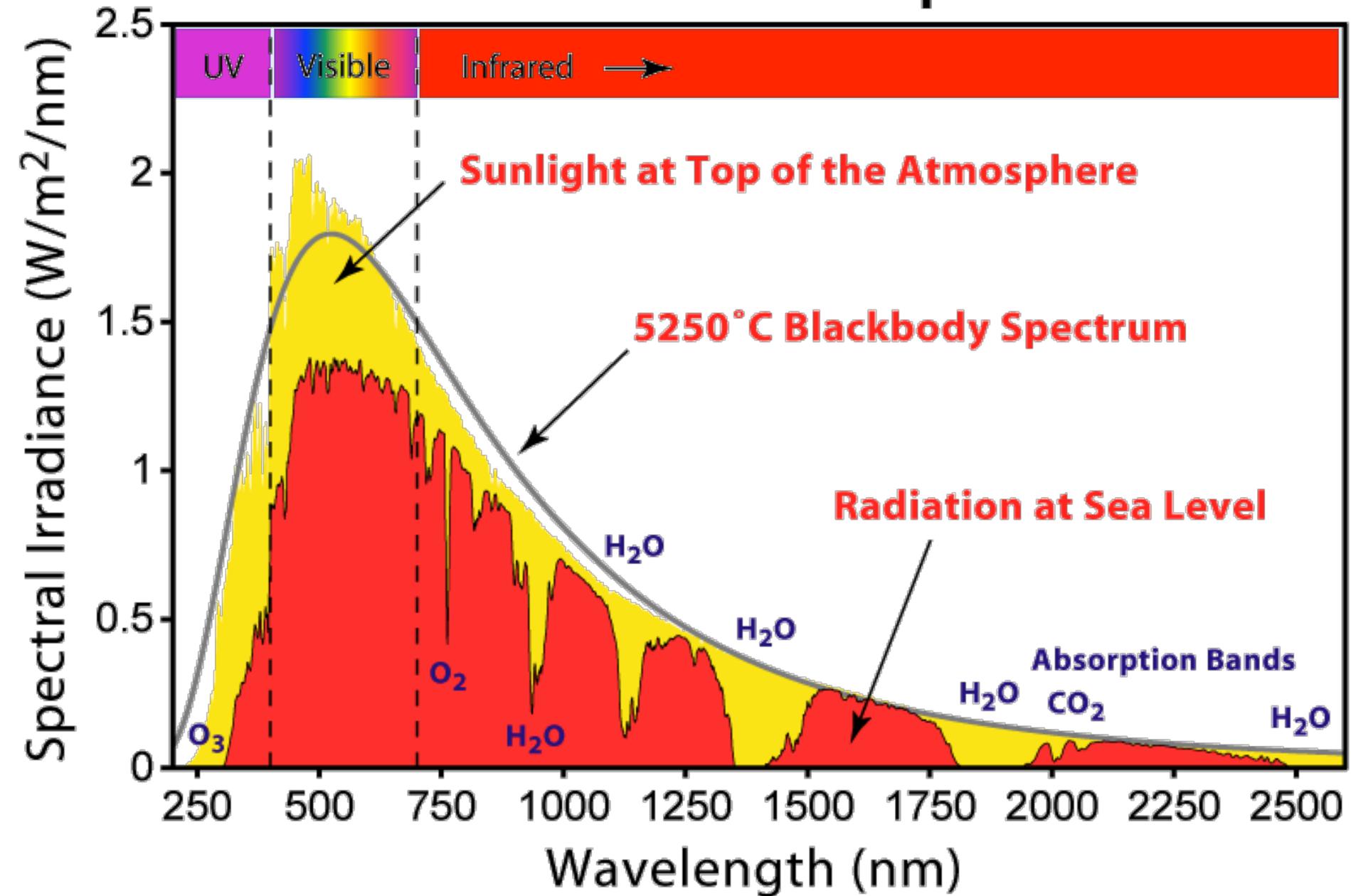
ATMOSPHERE

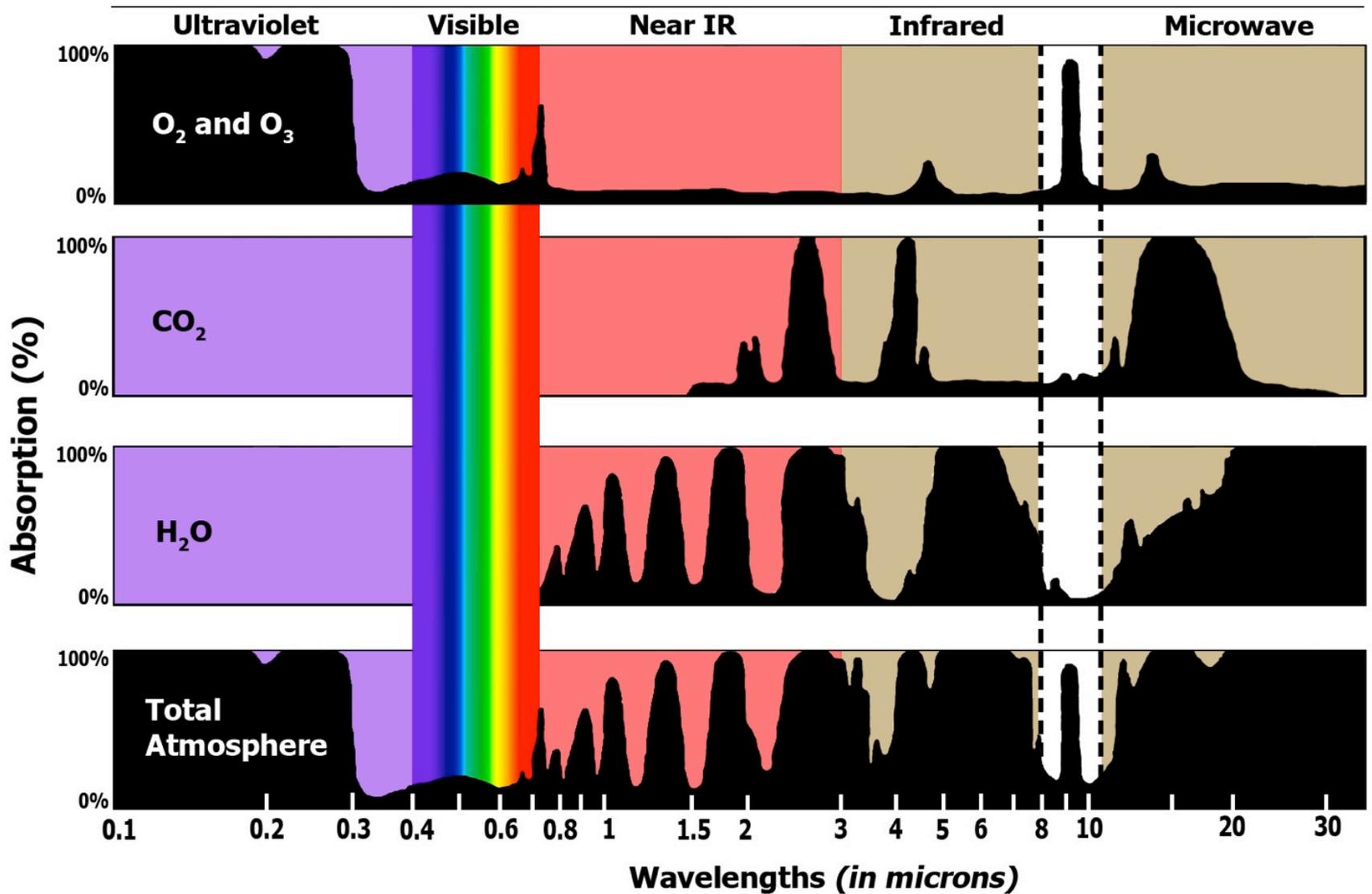
w/o greenhouse = -18°C

w/ greenhouse = +15°C



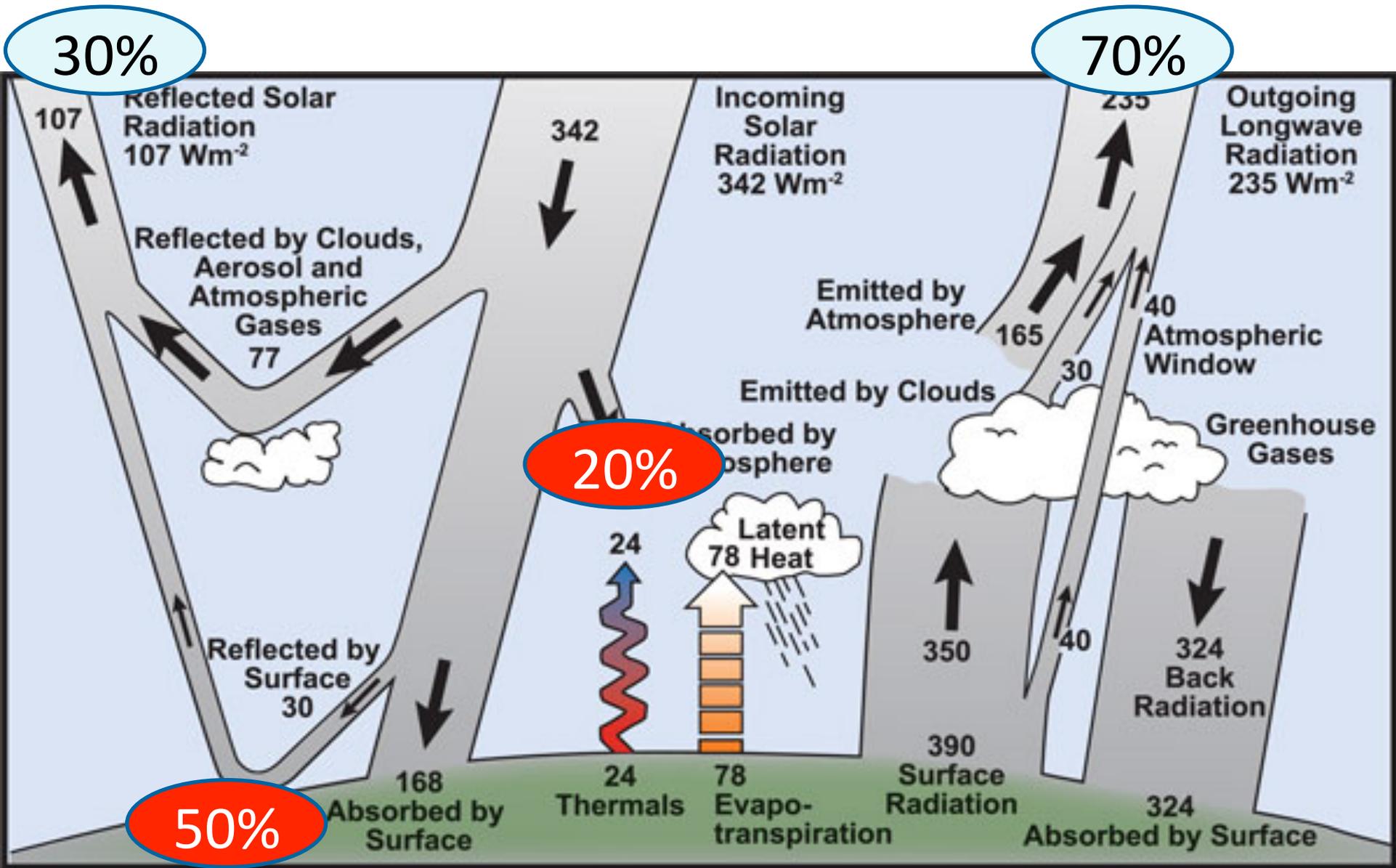
Solar Radiation Spectrum





Absorptivity as a function of the wavelength of radiation. An absorptivity of zero means no absorption while a value of one means complete absorption. The dominant absorbers of infrared radiation are H₂O and CO₂. O₂ and O₃ absorb much of the sun's ultraviolet radiation.

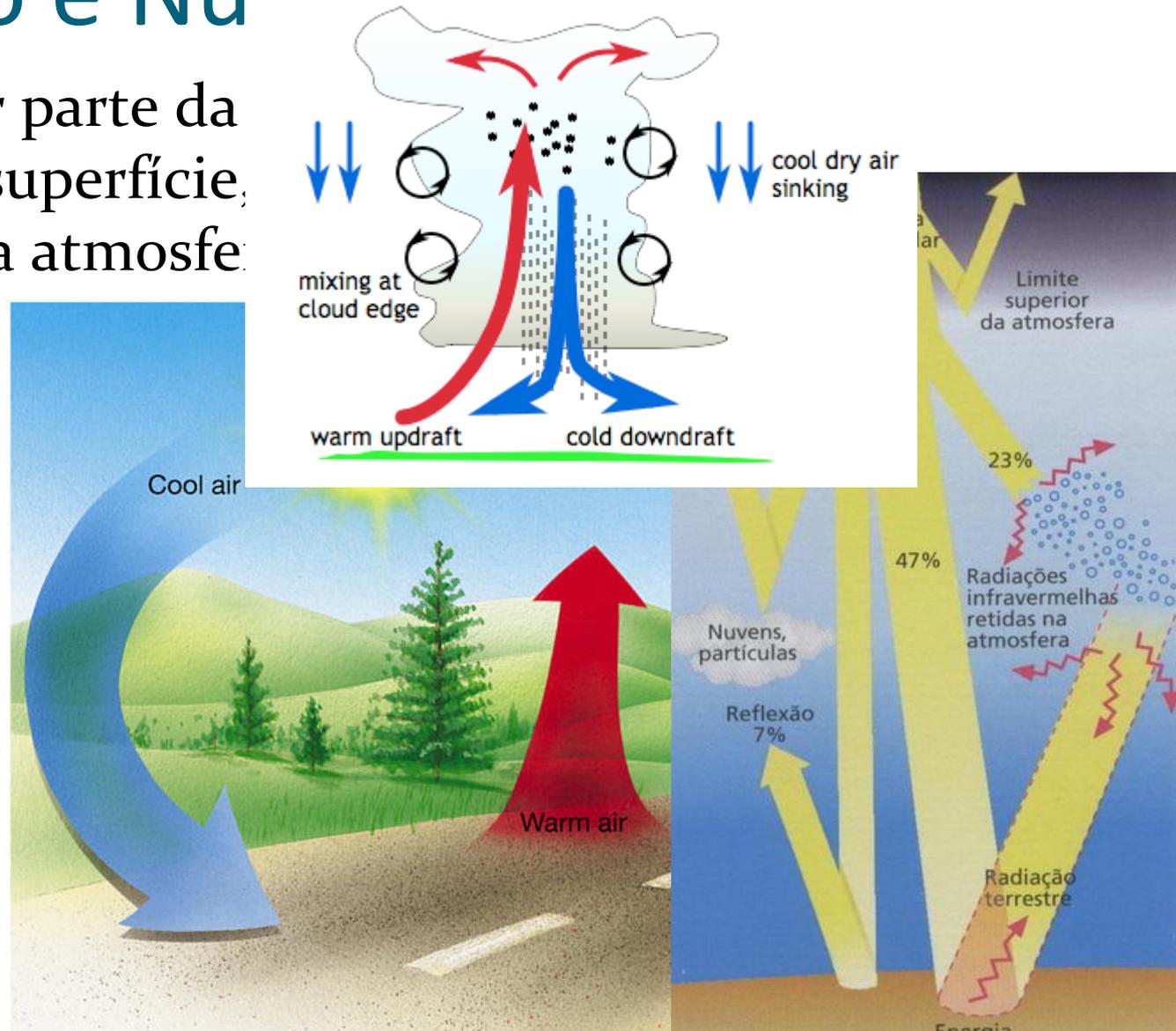
Atmospheric Energy Balance



Convecção e Nuvens

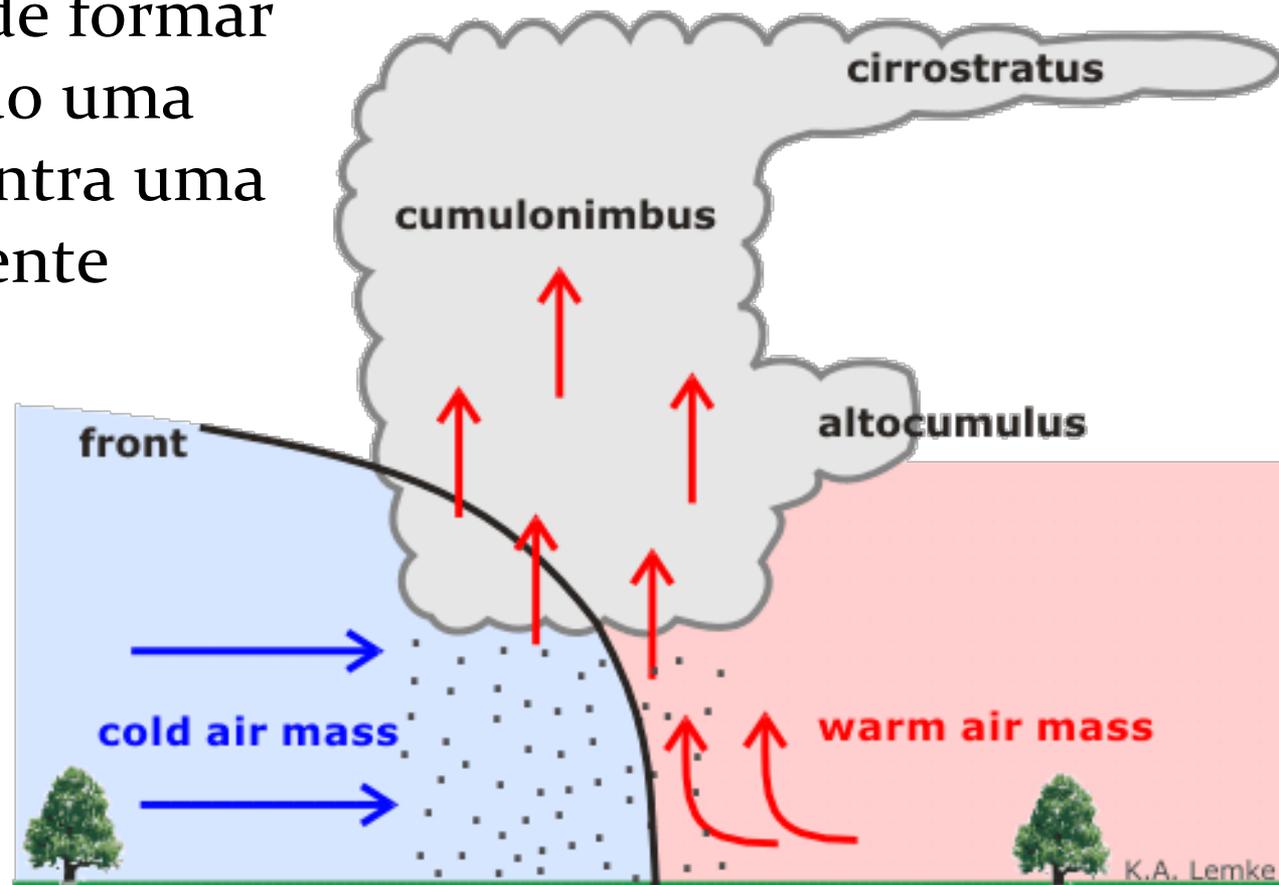
- Como a maior parte da absorvida na superfície, esquentando a atmosfera

O ar quente é menos denso e sobe, pois o ar frio que está em cima é mais pesado.



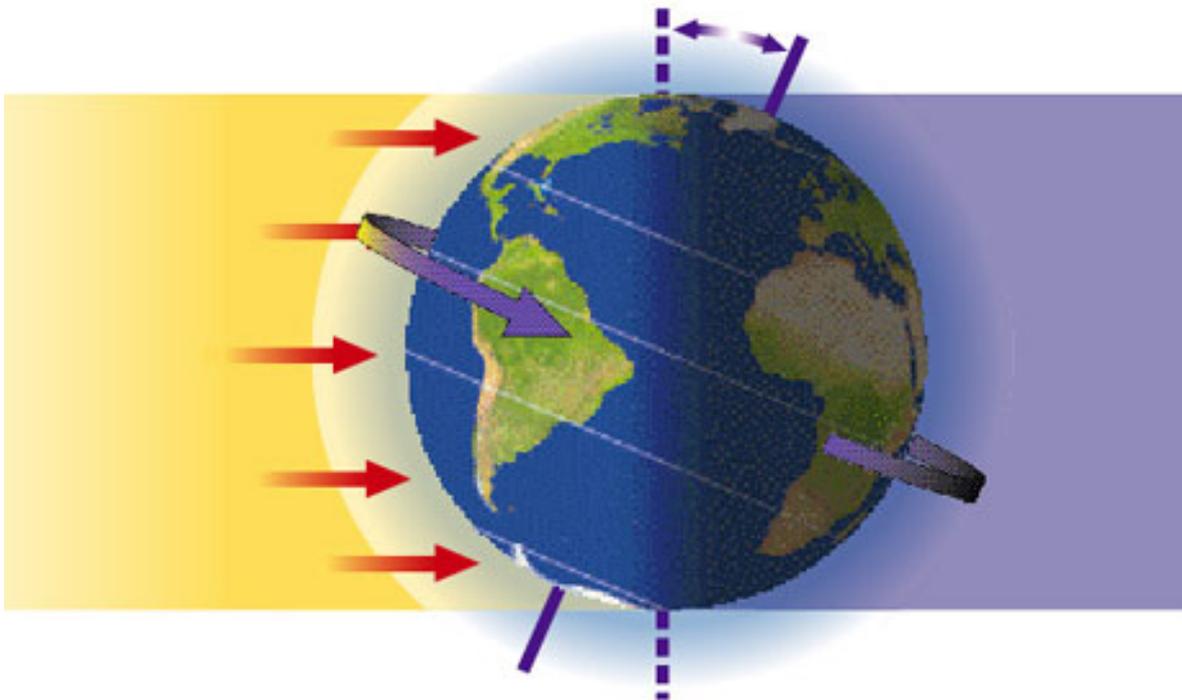
Nuvens e Frentes

- Uma outra maneira muito comum de formar nuvens é quando uma frente fria encontra uma massa de ar quente

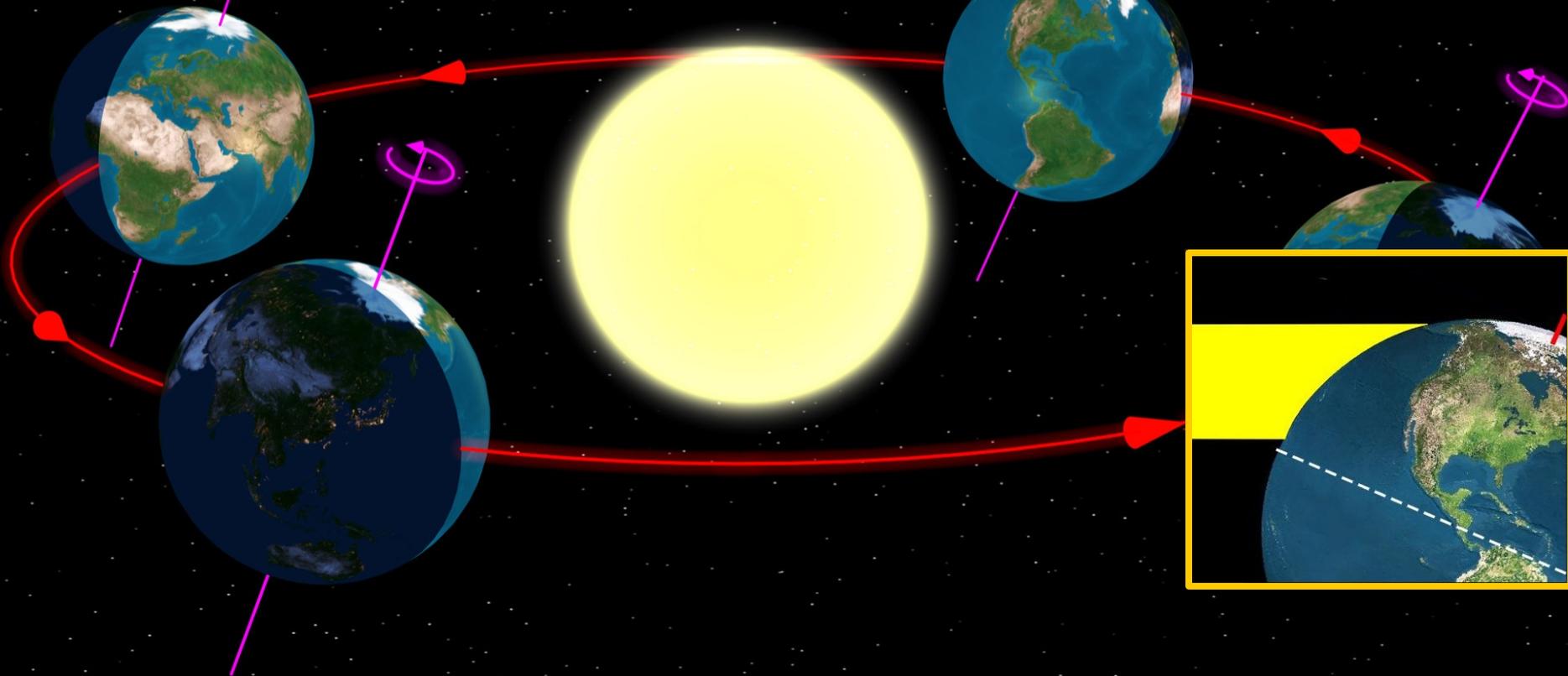


Dia e Noite

- A energia que recebemos do Sol também não é distribuída igualmente pela superfície do planeta!
 - Giro em torno do próprio eixo
 - O eixo é inclinado em relação a órbita em torno do Sol



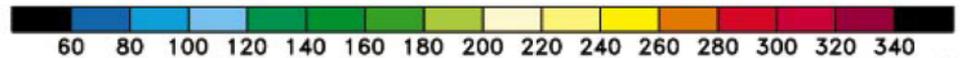
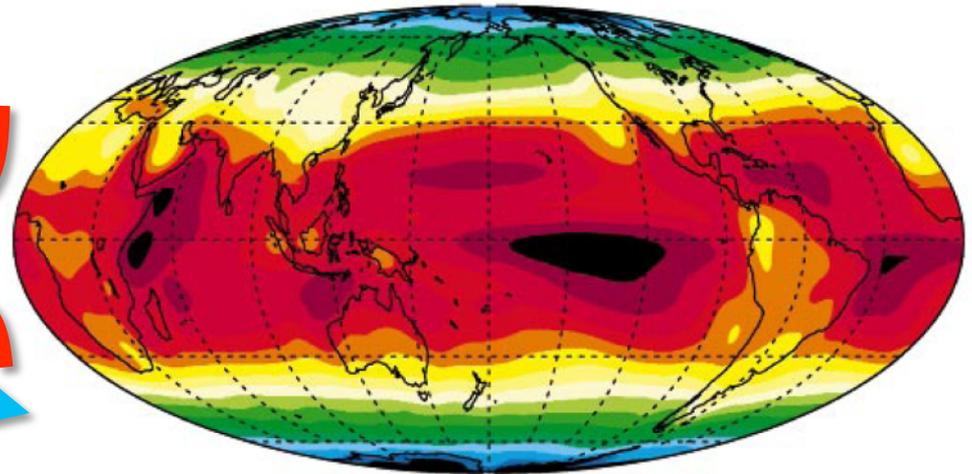
Estações do ano



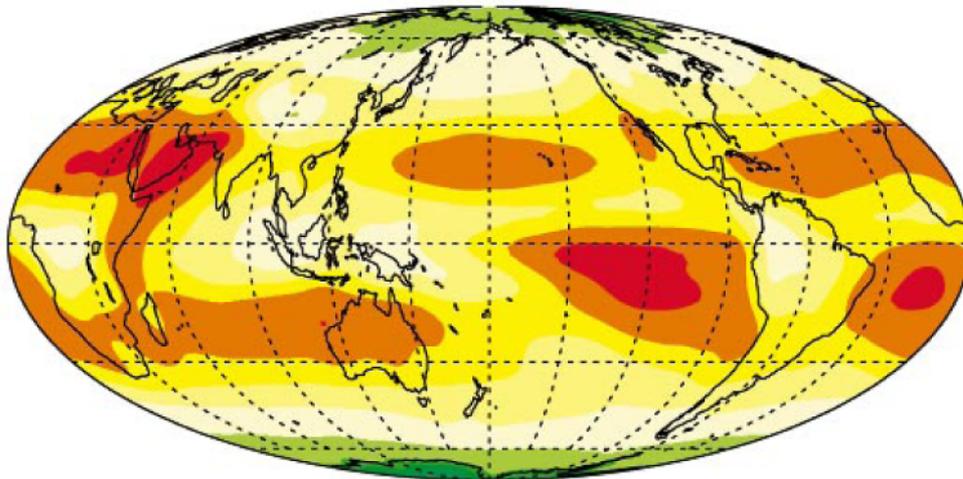
Distribution on the Earth

Hot air rises at the equator

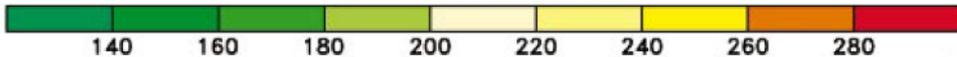
Cold dry air descends at high latitudes



Annual mean solar radiation budget at top (W/m²)

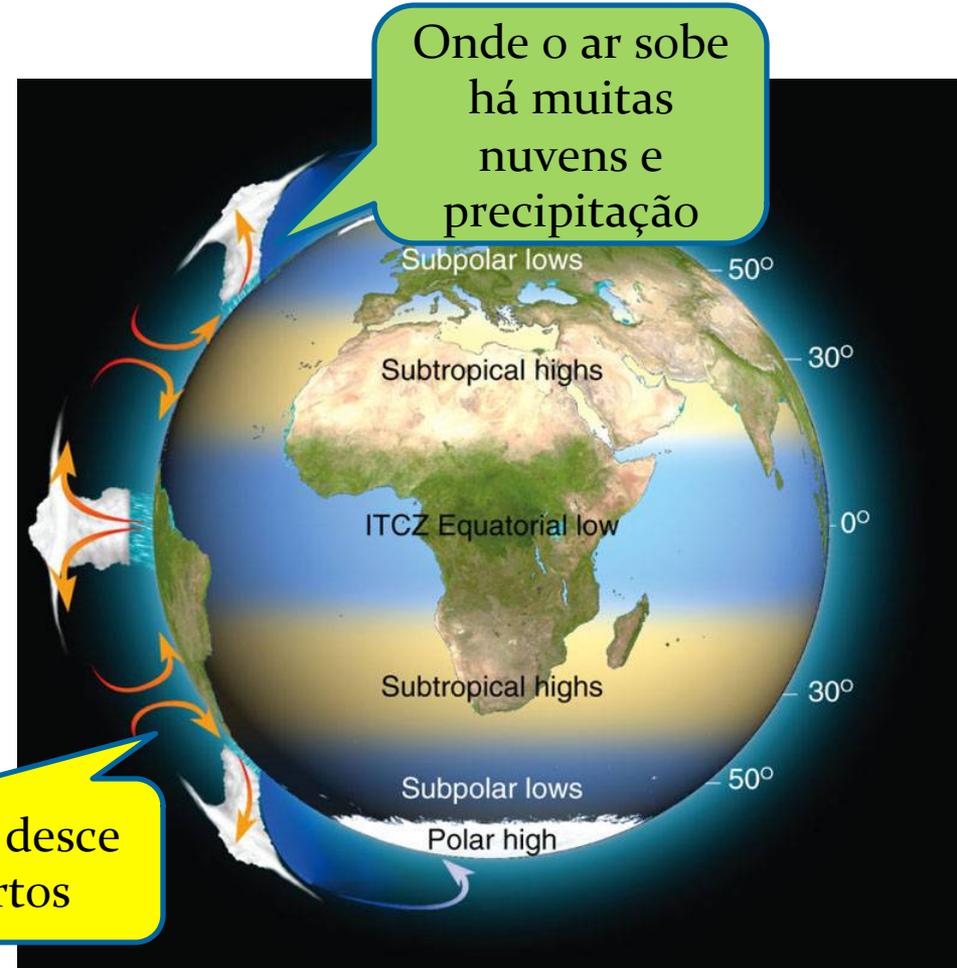
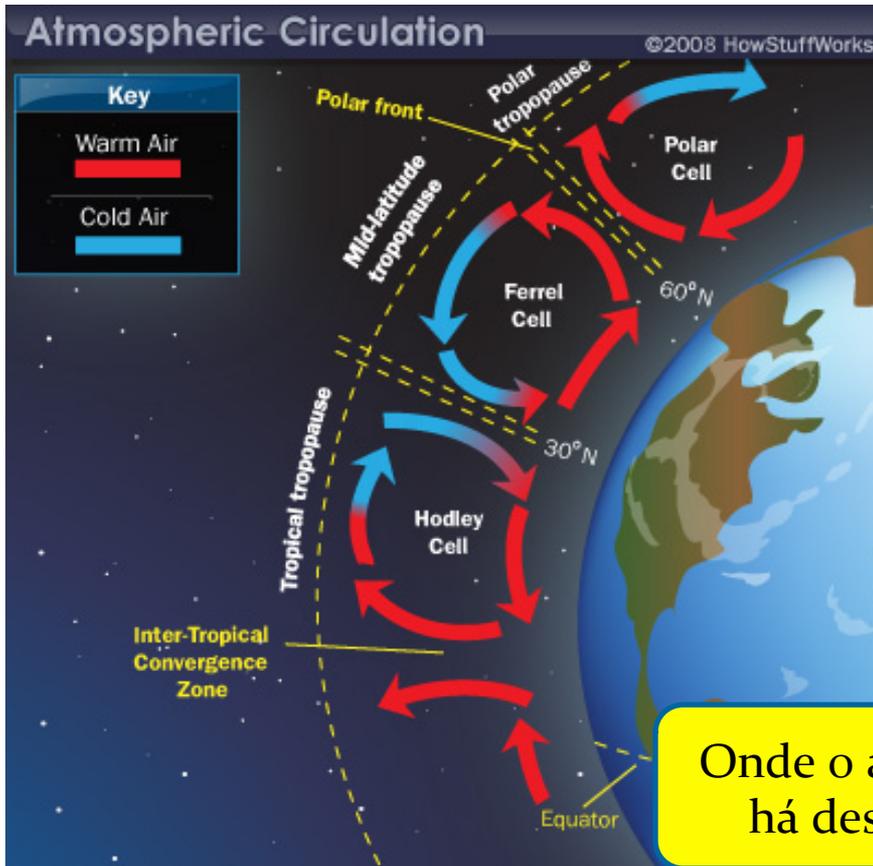


Annual mean outgoing long wave radiation at top (W/m²)



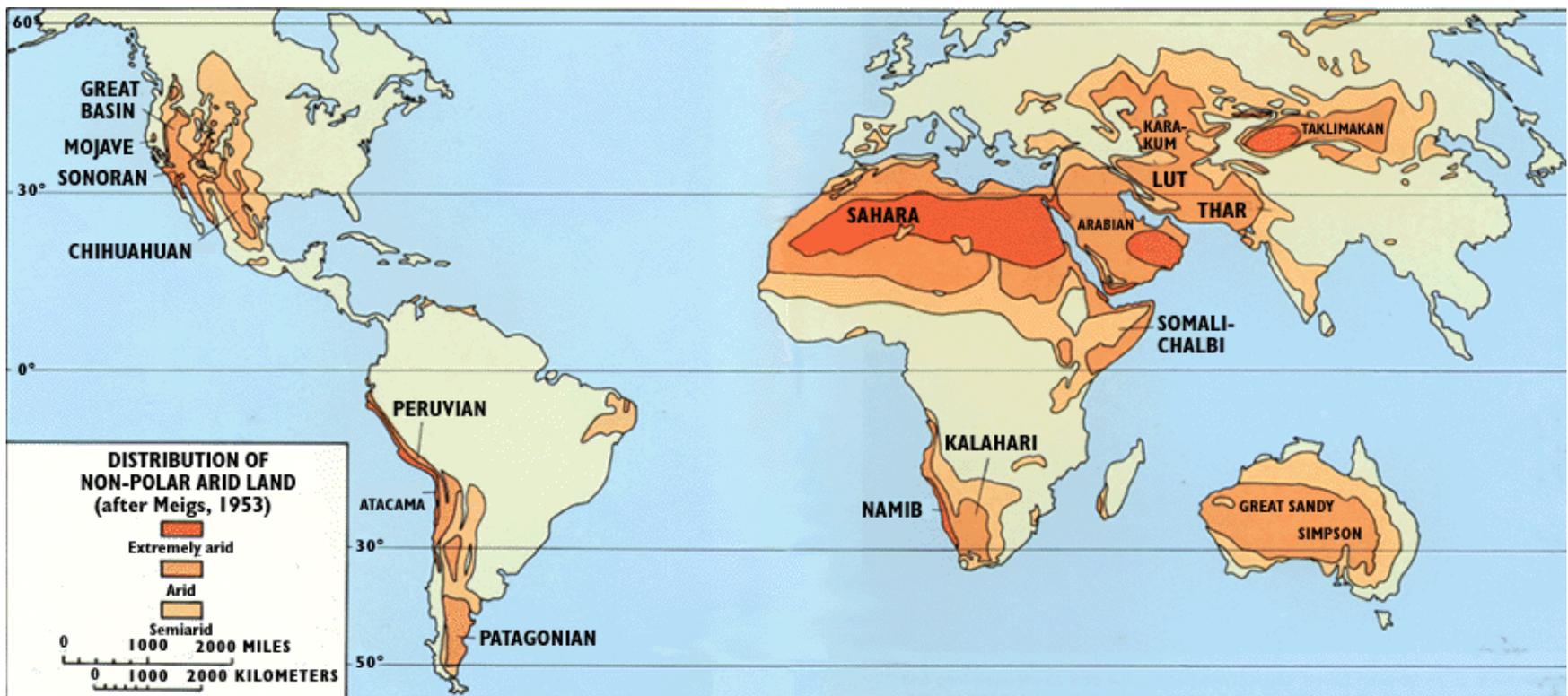
Trenberth and Stepaniak, J. Clim. (2003)

Circulação de grande escala



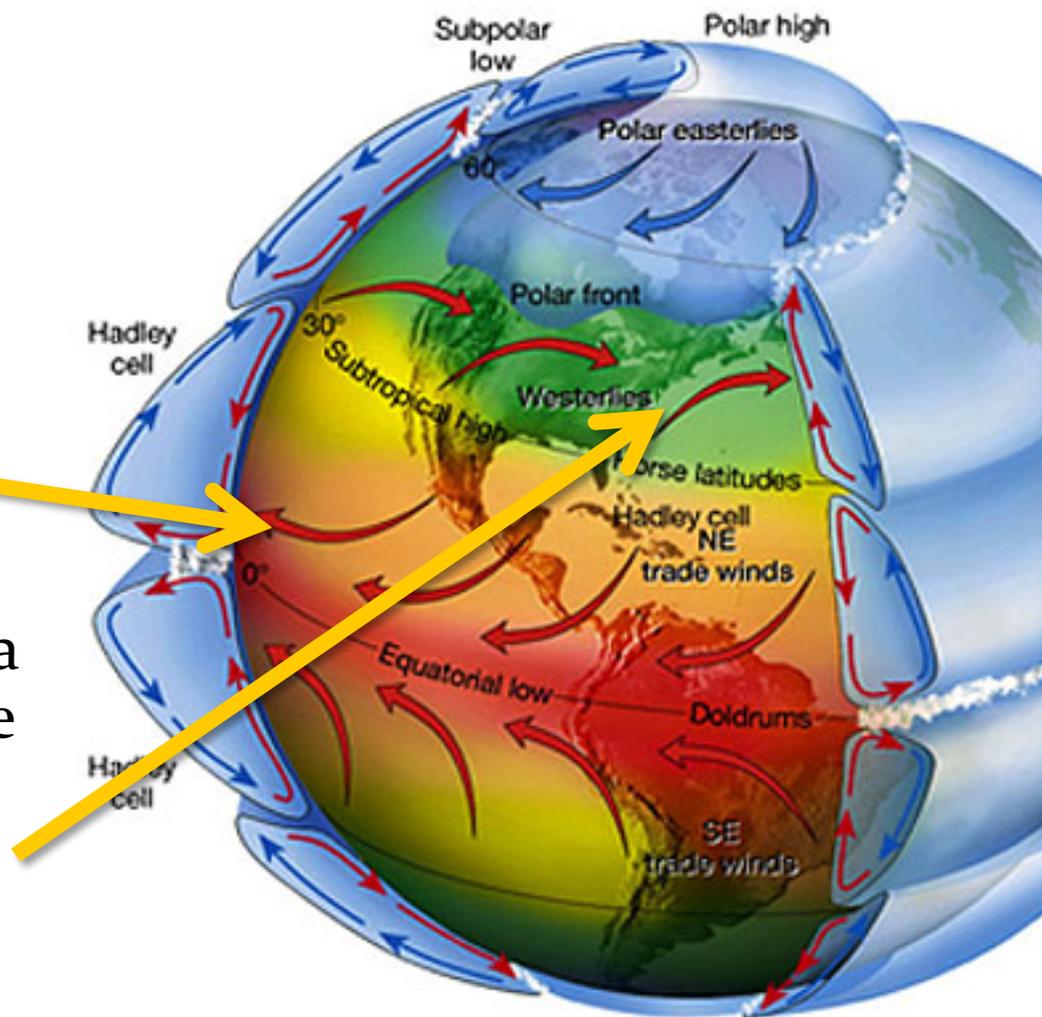
Localização dos grandes desertos

- Nas latitudes onde o ar desce seco e frio, há precipitação é pouco e as regiões são desérticas.



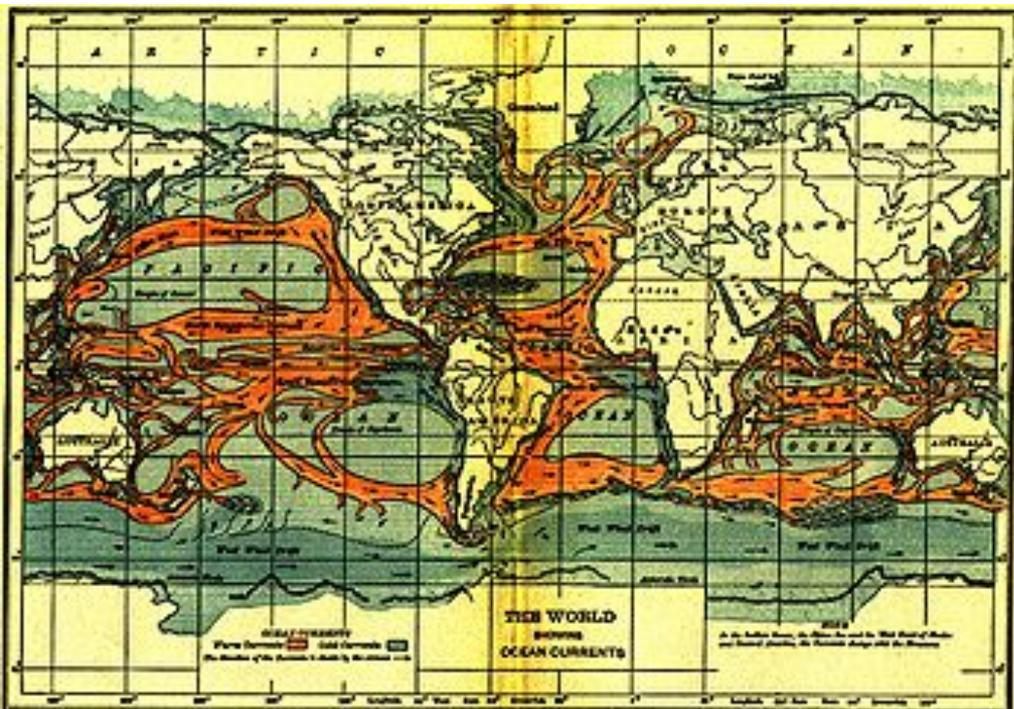
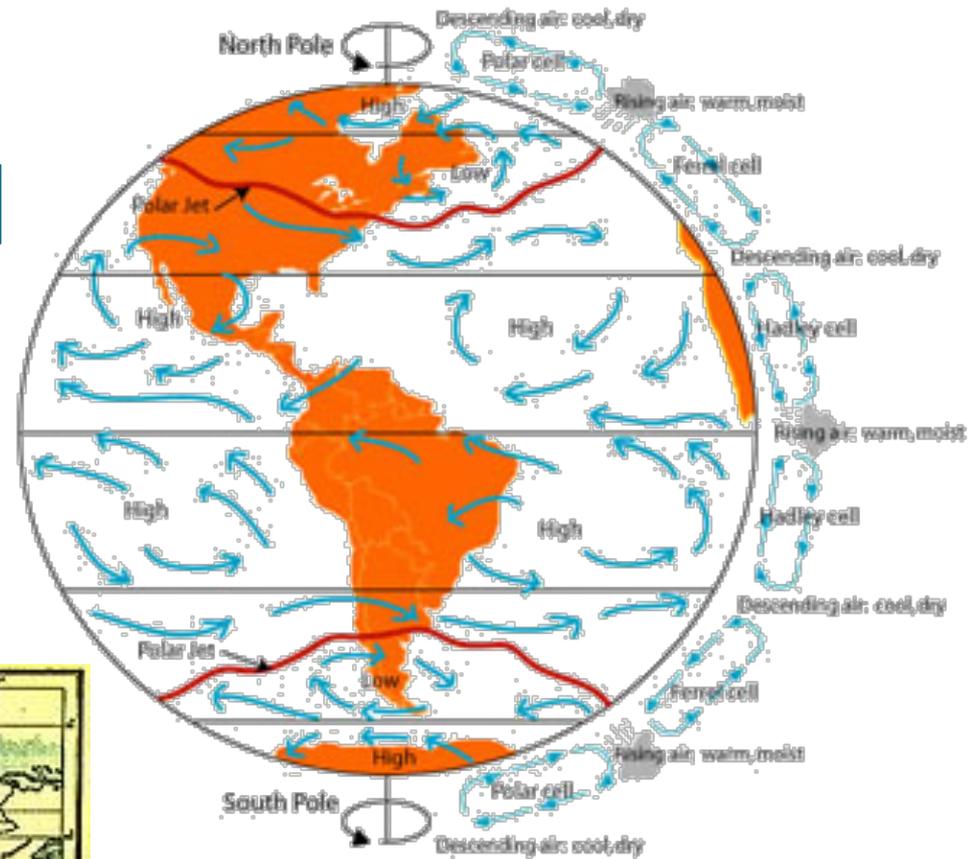
Circulação global

- Como a terra gira, por inércia, a atmosfera acaba ficando para traz.
 - A célula de Hadley fica inclinada no equador, formando os **Alísios**.
 - Já o ar que desce em latitudes mais altas está girando mais rápido que a chão (ele estava no EQ), e a circulação é ao contrário



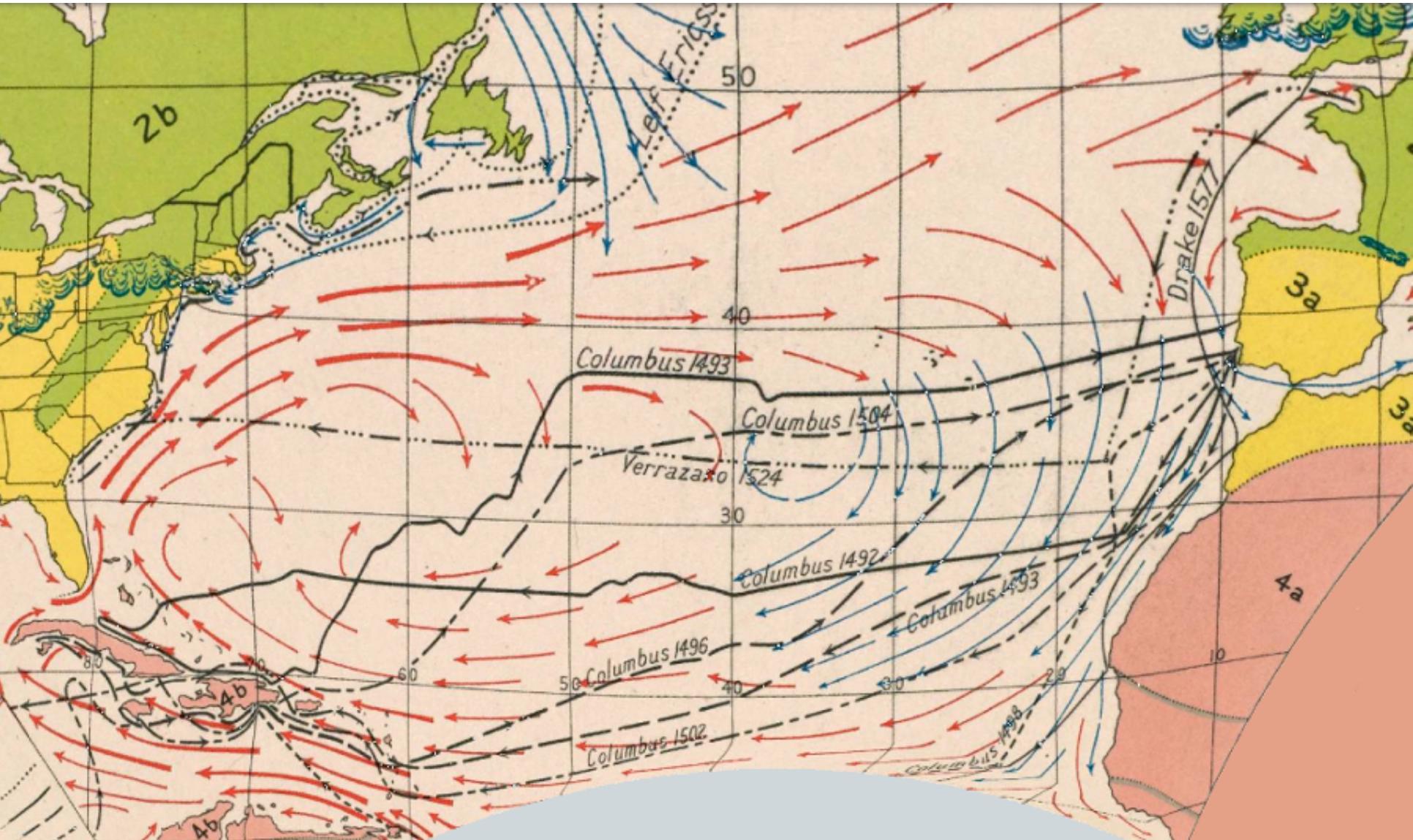
Circulação Global

- Os ventos próximos da superfície forçam o surgimento de correntes oceânicas

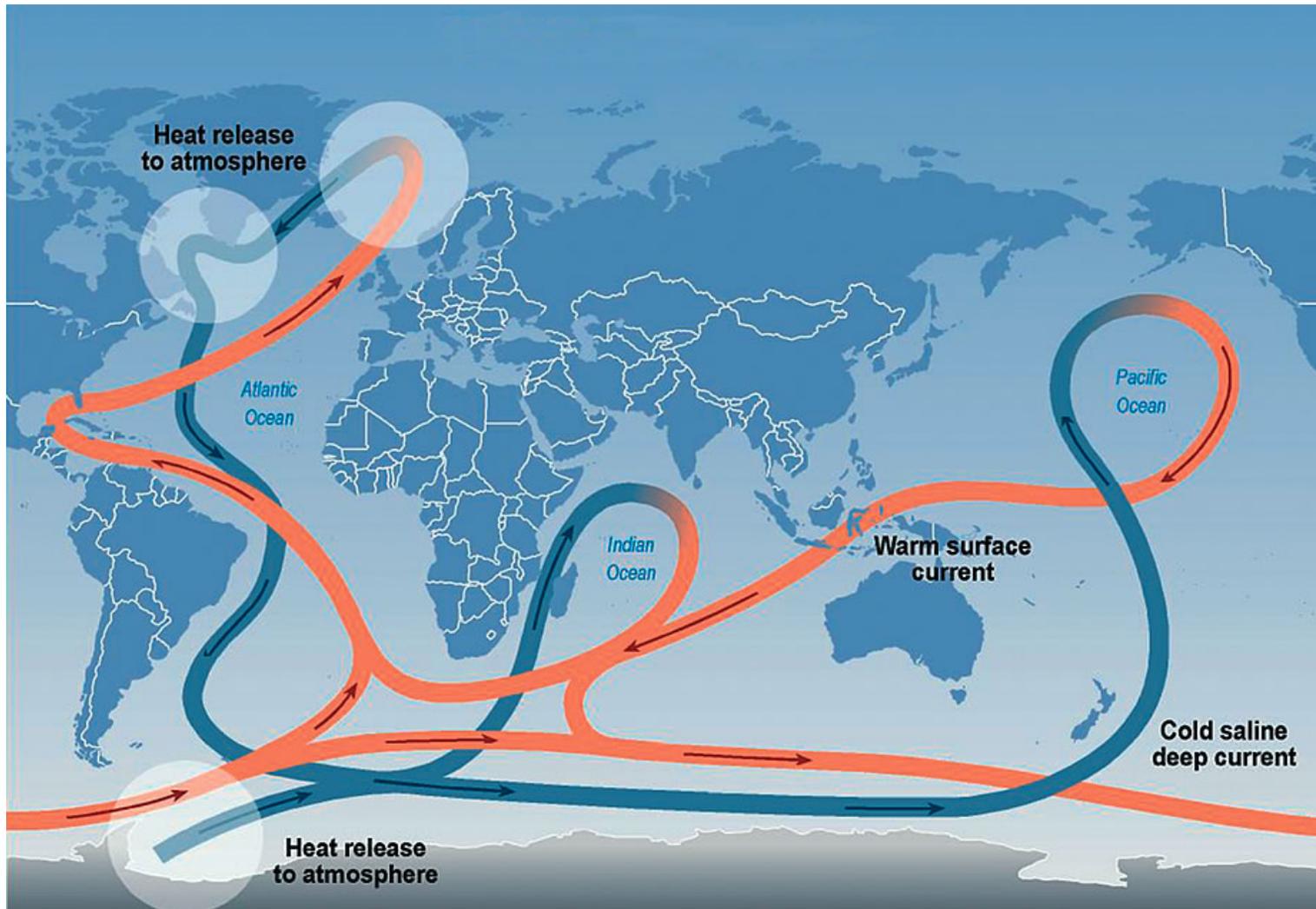


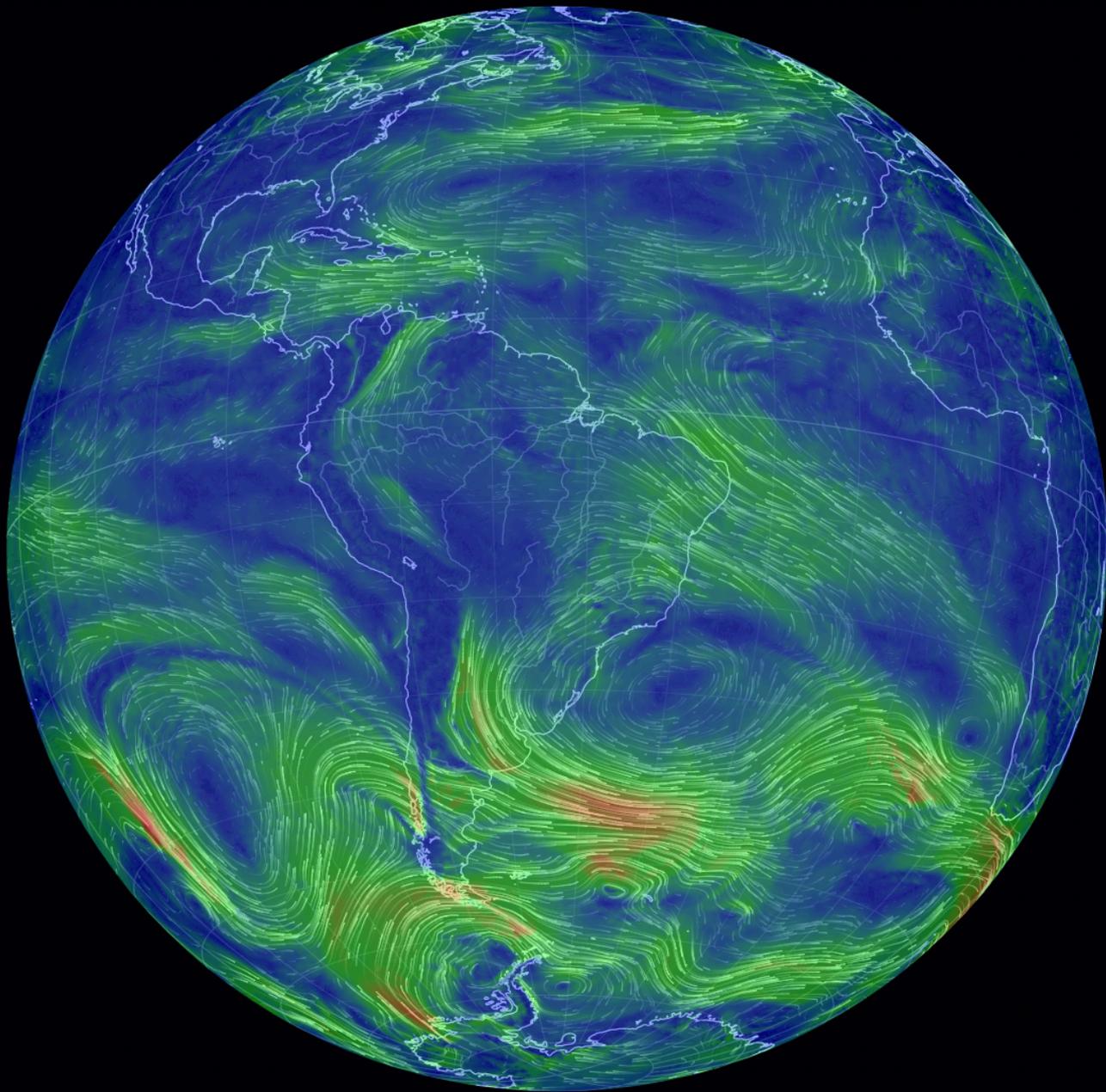


In the first two centuries of Spanish colonization in the New World, the Chesapeake Bay (red X) was on the edge - far from the focus of Spanish settlements that stretched from Mexico into South America. Source: Library of Congress, *Americae sive quartae orbis partis nova et exactissima descriptio* (Diego Gutierrez, 1562)



Oceanic circulation

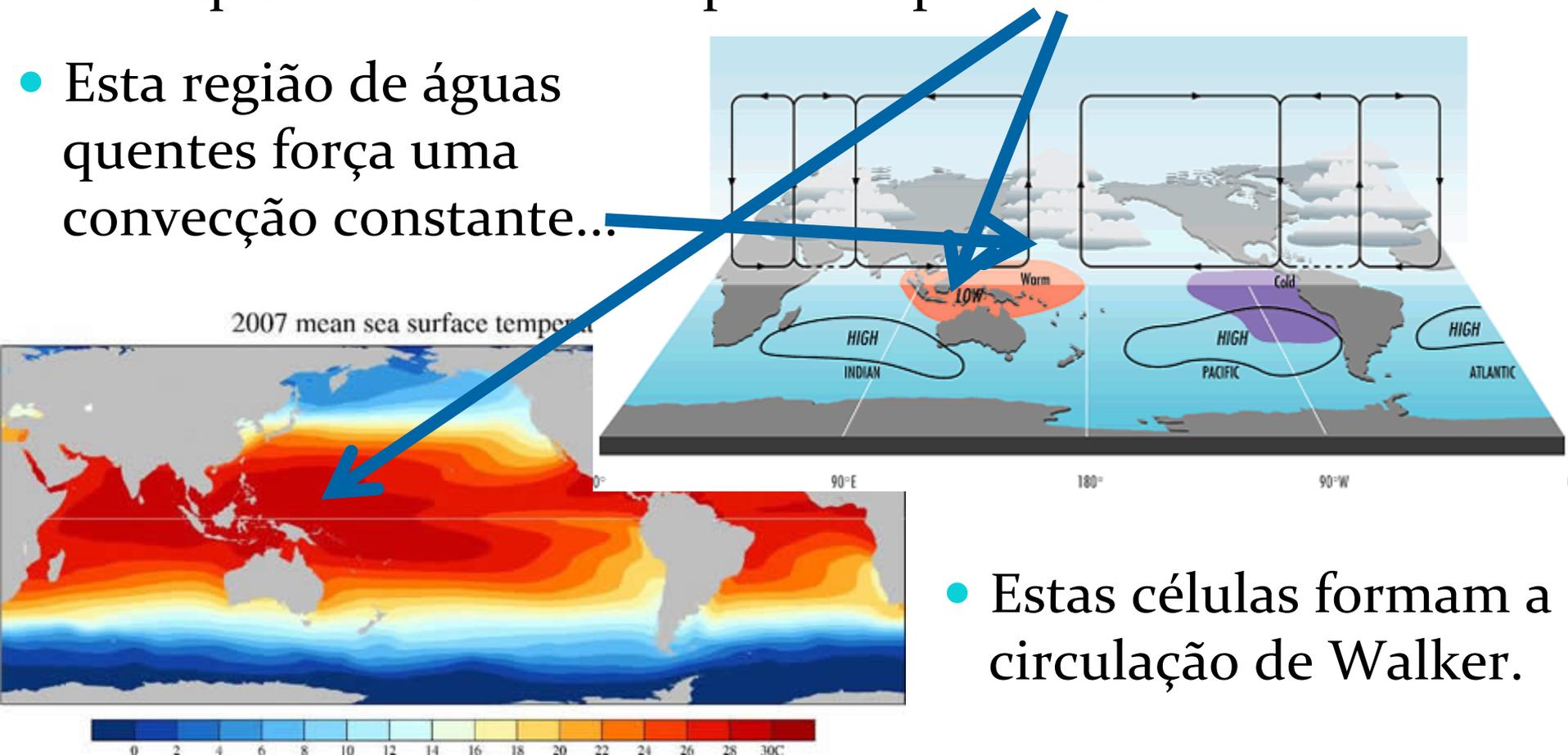




<https://earth.nullschool.net/#current/wind/isobaric/850hPa/orthographic=-53.20,-15.02,519>

Circulação de Walker

- Devido a presença constante dos ventos alísios, a água mais quente vai sendo empurrada para oeste.
- Esta região de águas quentes força uma convecção constante...

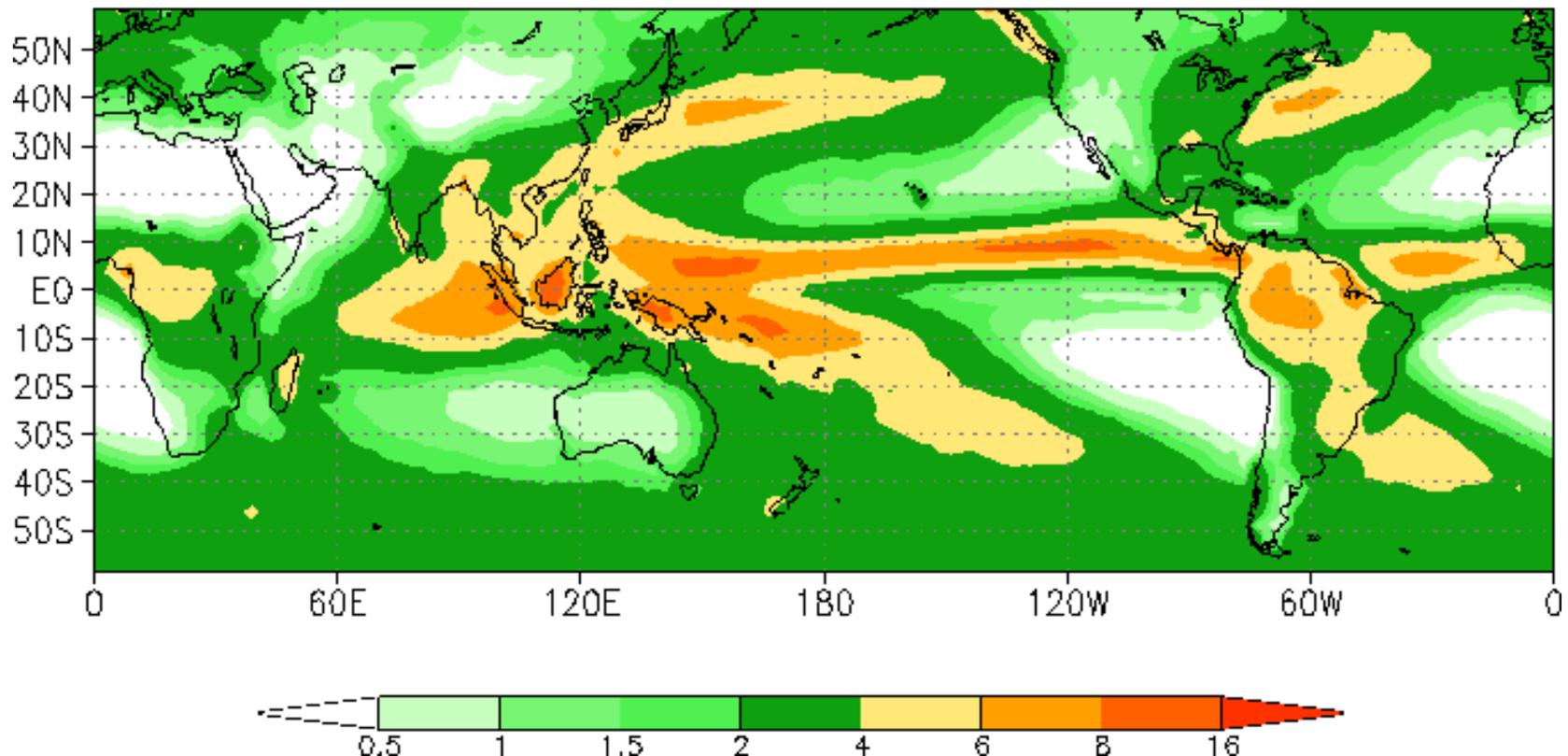


- Estas células formam a circulação de Walker.

Precipitação

- A distribuição global dos ventos, e principalmente de onde eles sobem e descem, determinam em grande parte a distribuição da precipitação

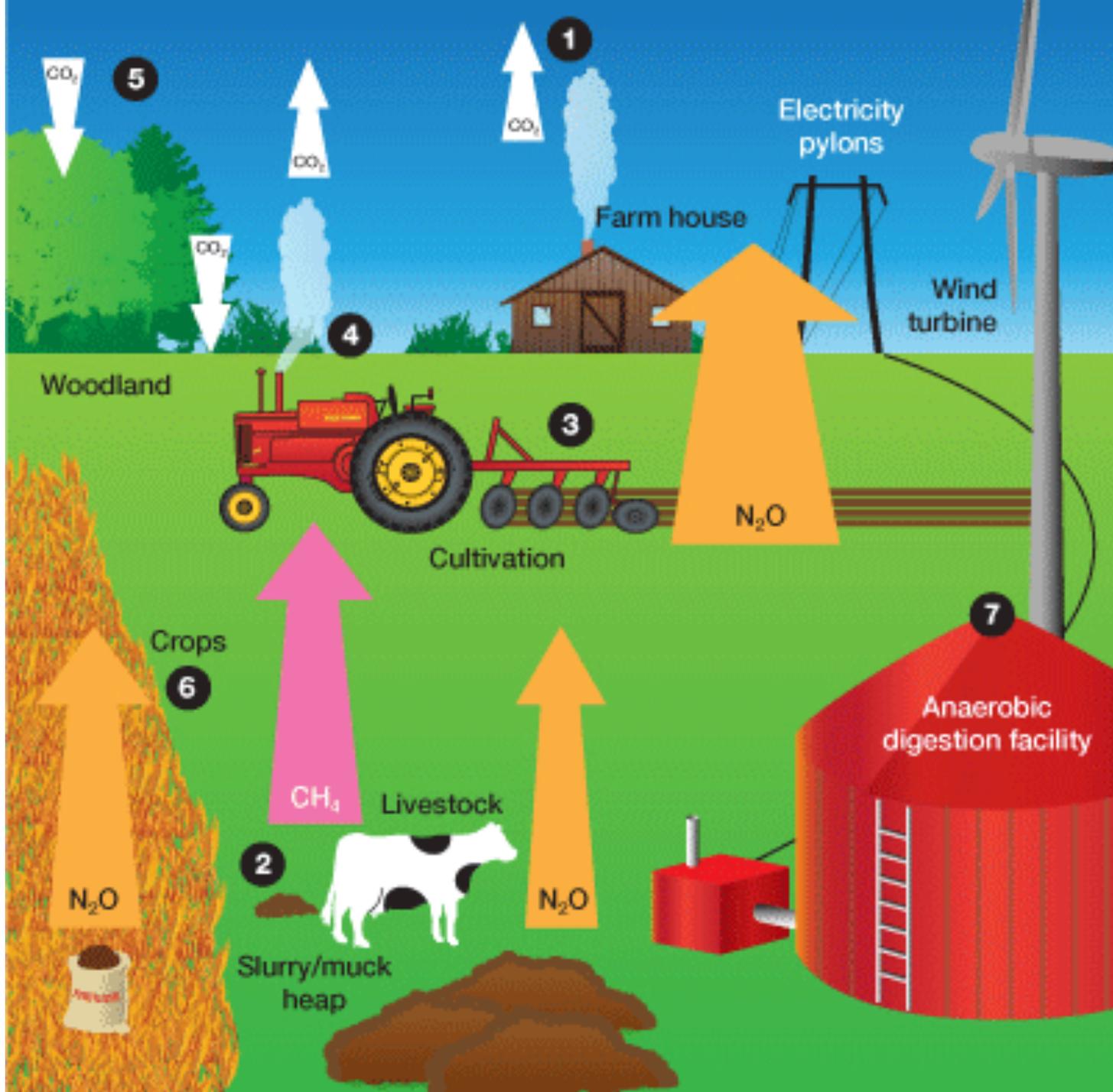
Pentad mean Precipitation (mm/day): Annual mean



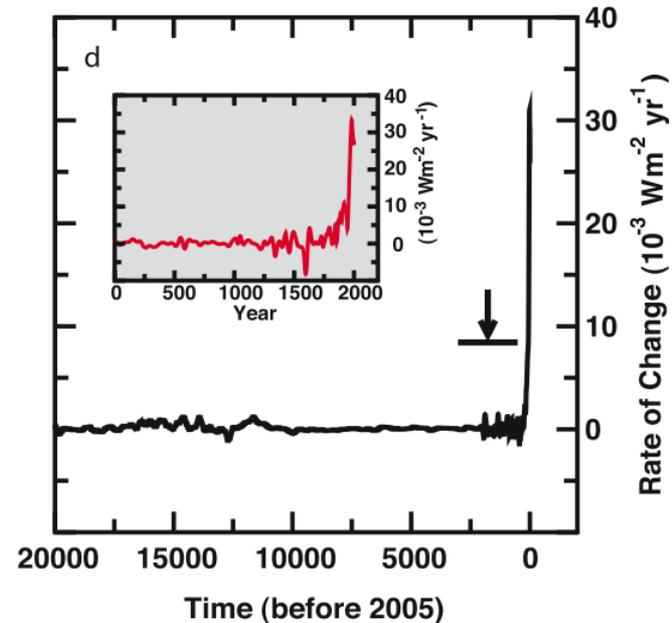
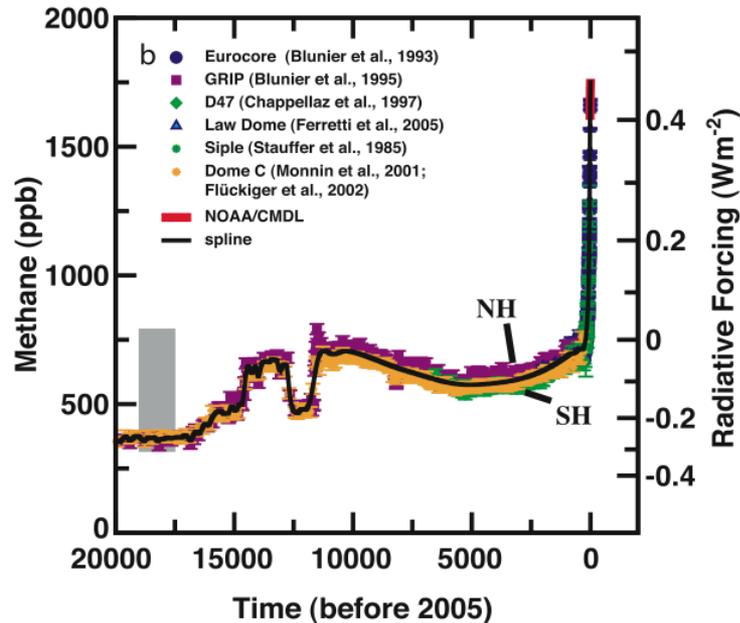
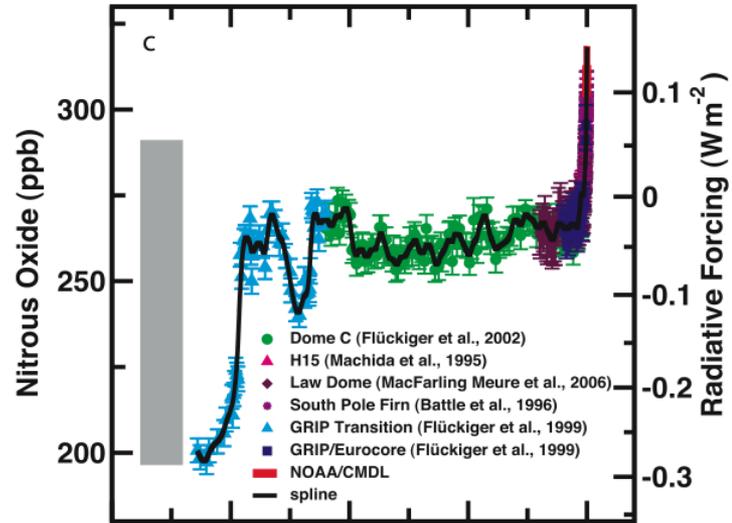
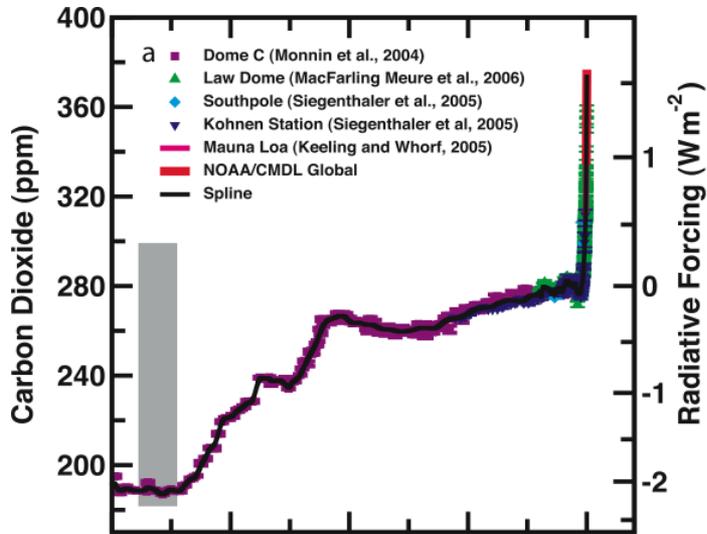
Circulação da Atmosfera

- A terra recebe energia do sol, a maior parte chega na região tropical e é absorvida na superfície.
- Esse aquecimento desigual força o surgimento de ventos na atmosfera e de correntes no oceano.
- Esta circulação redistribui a energia

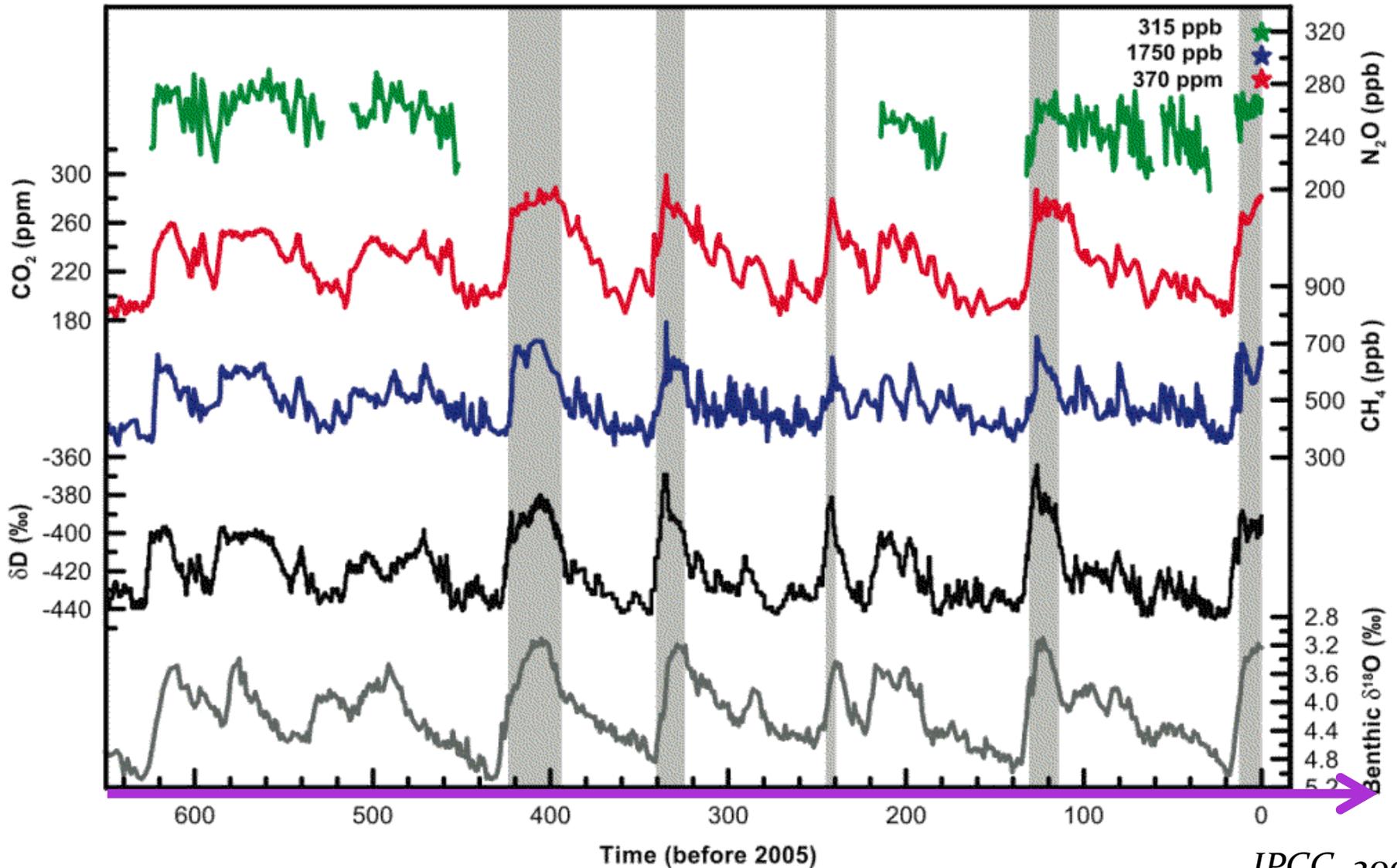
A teoria que explica o movimentos dos fluídos é chamada de dinâmica dos fluídos.



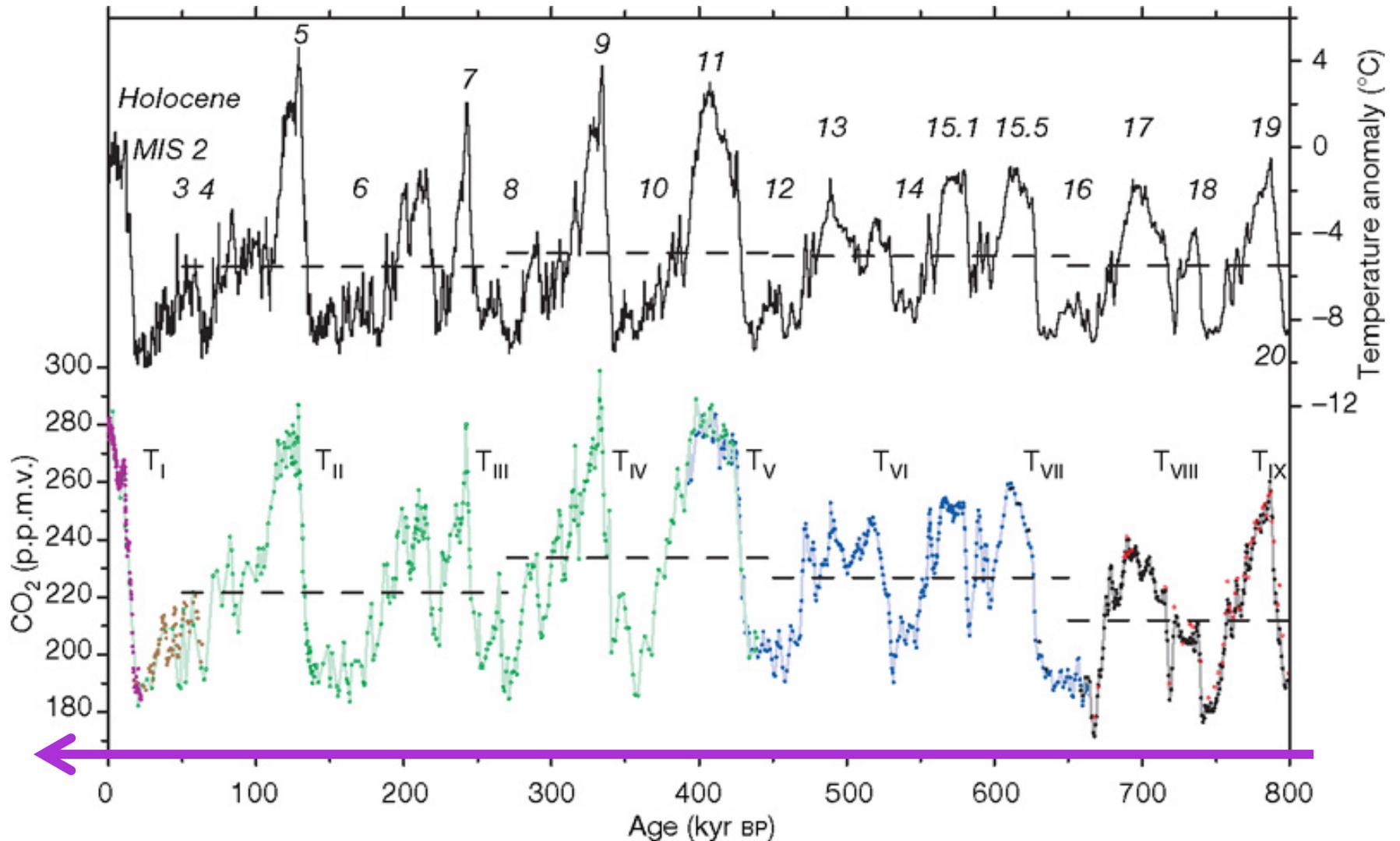
Antropogenic? Yes!



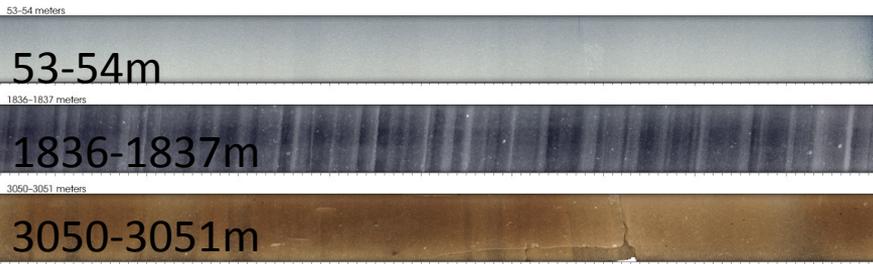
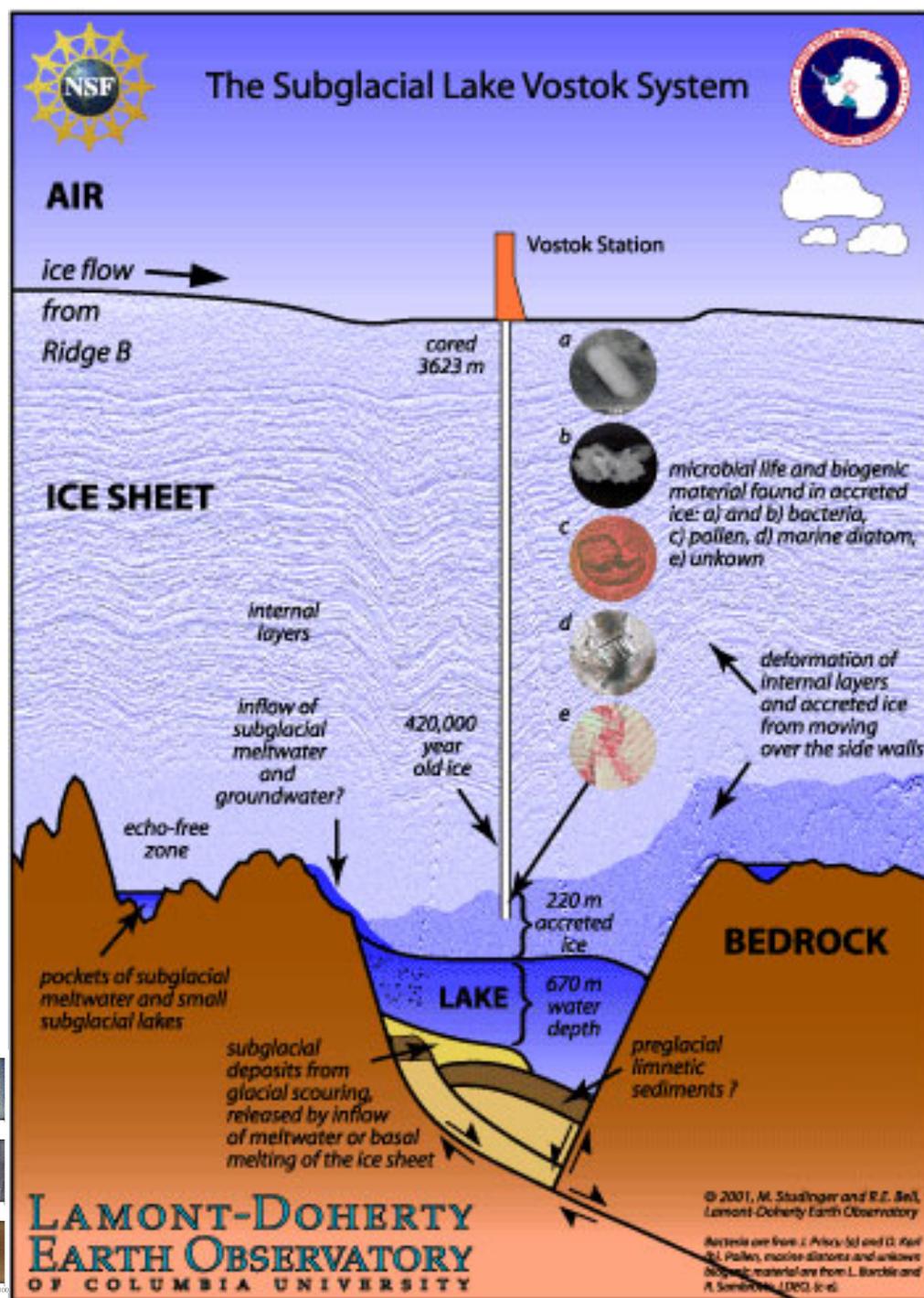
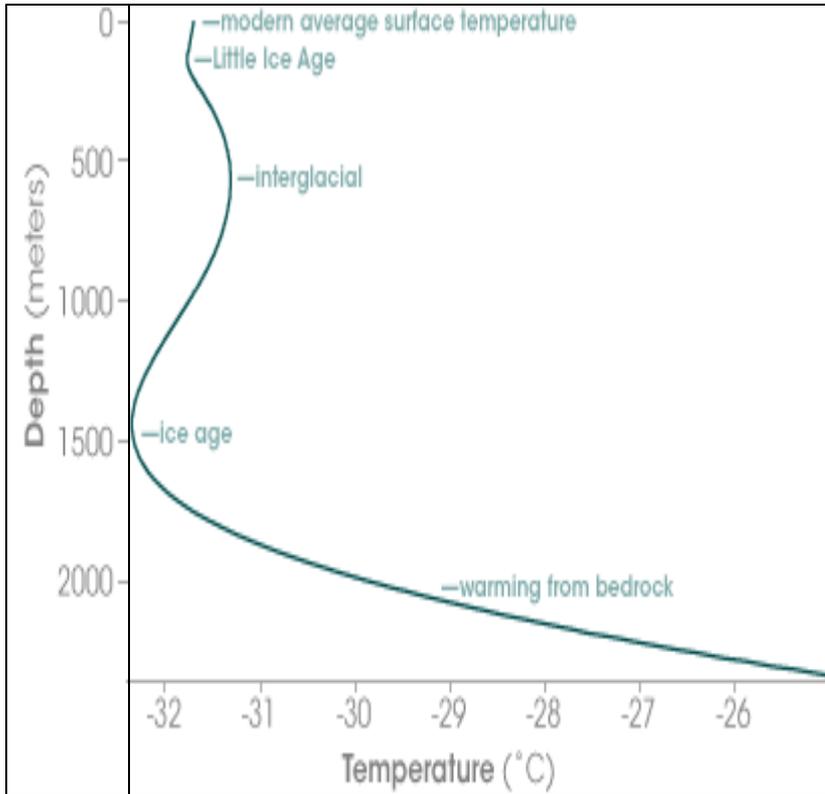
Vostok (650ky)



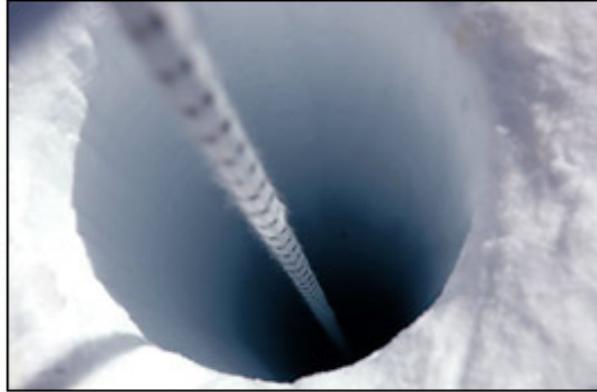
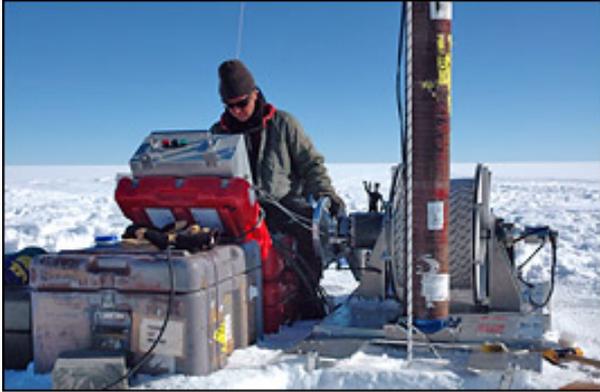
Dome C (800ky)



Ice Cores



Ice Cores

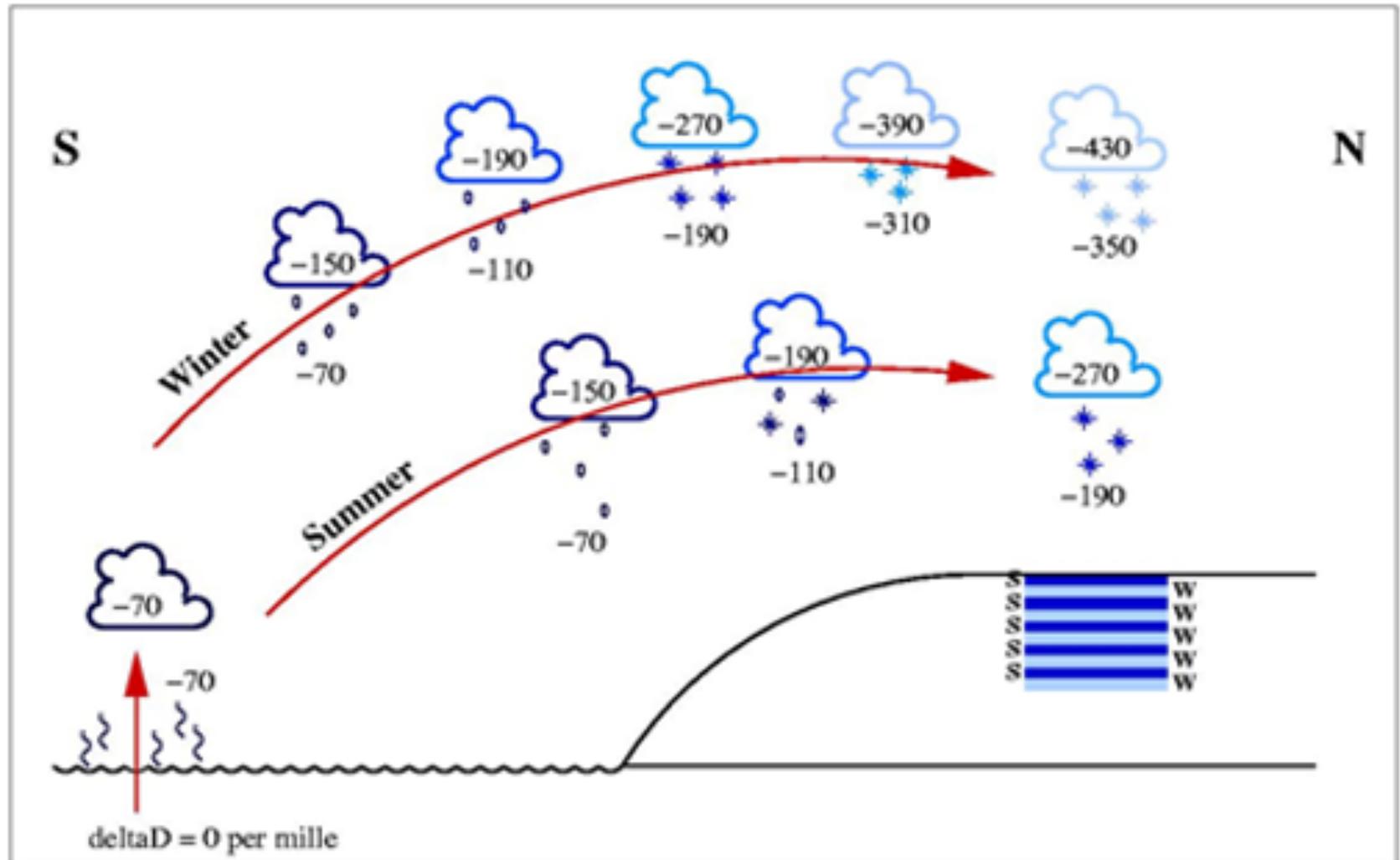


Dating ice

1. Counting layers
 - From temperature
 - From solar radiation
2. Pre dated tracers
 - Other ice cores
 - Volcanic sediments
3. Radioactive elements

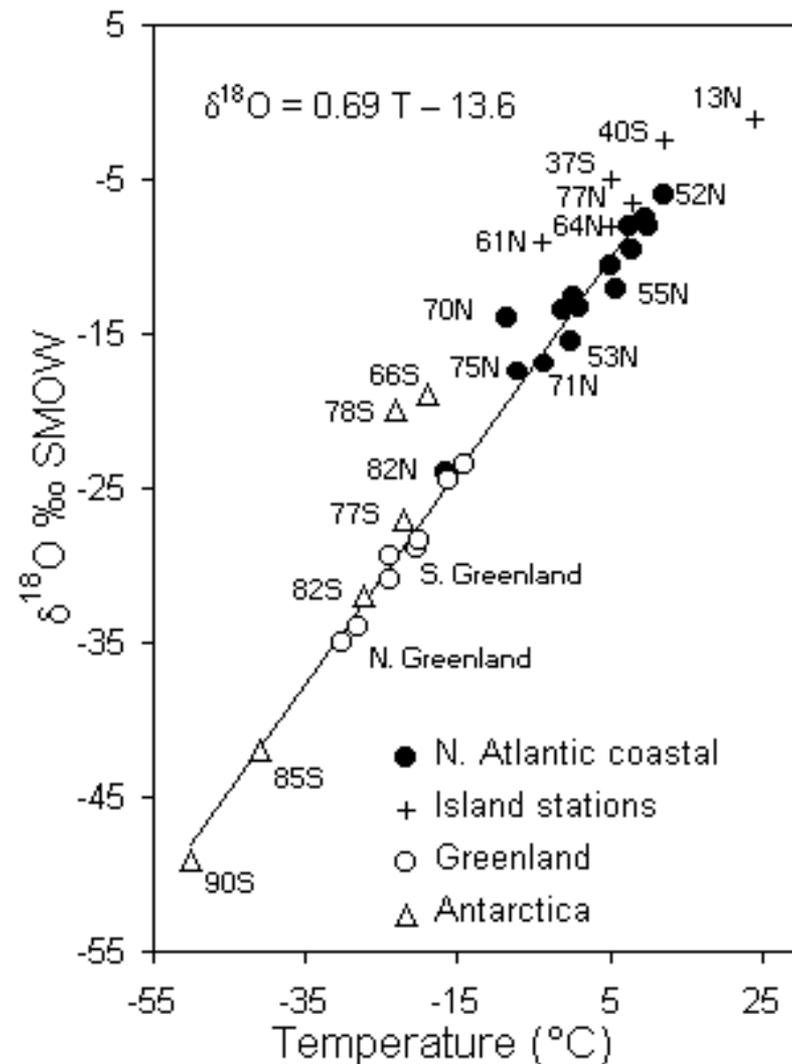
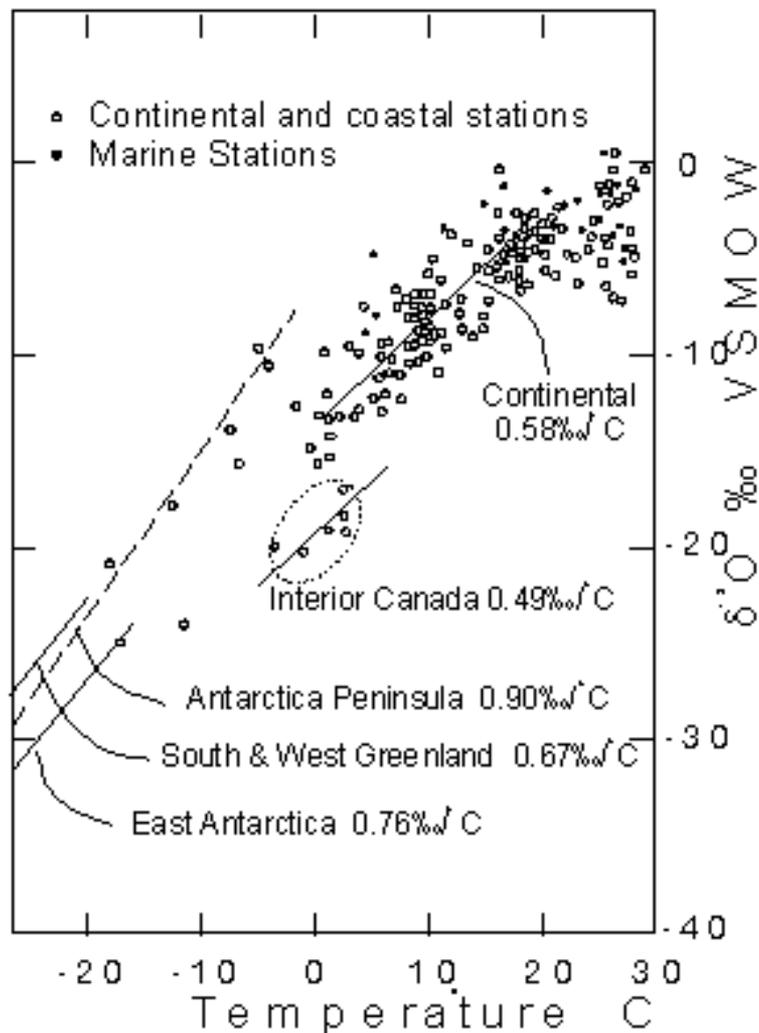


One way



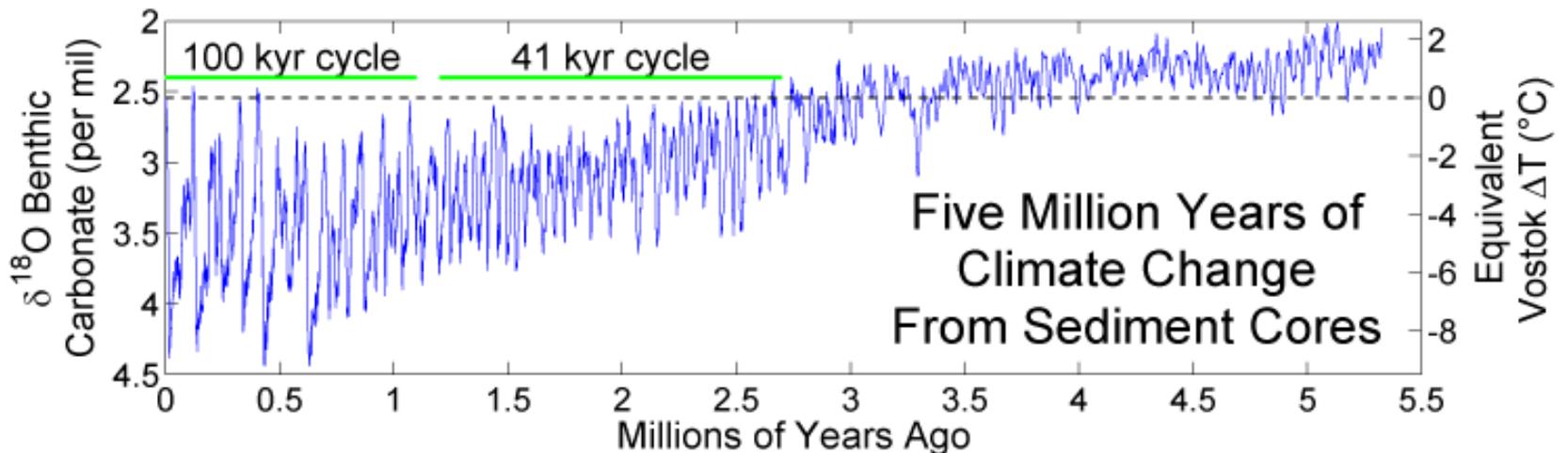
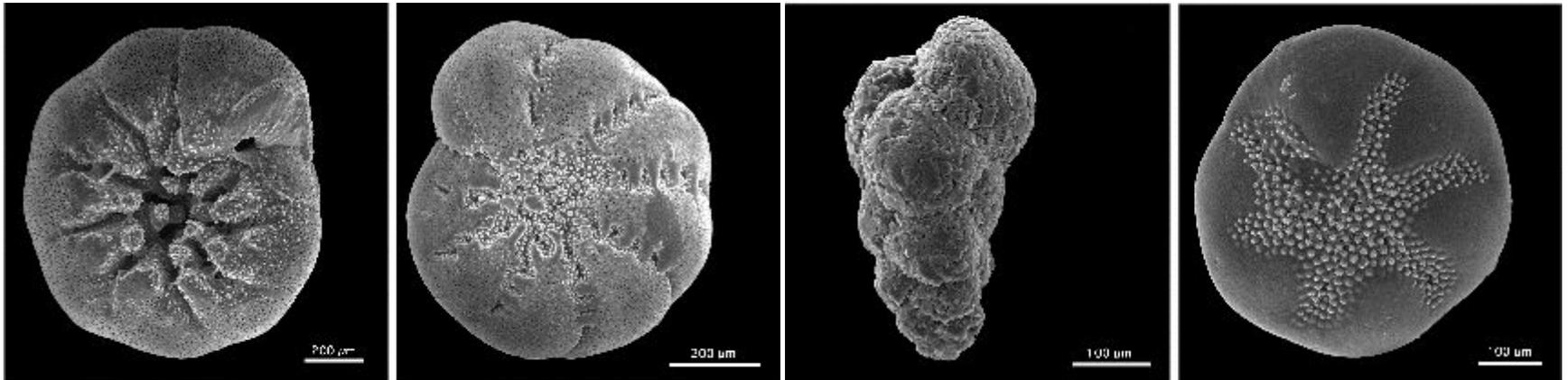
Temperature dependency

$$\delta^{18}O = \left(\frac{\left(\frac{^{18}O}{^{16}O} \right)_{sample}}{\left(\frac{^{18}O}{^{16}O} \right)_{standard}} - 1 \right) * 1000 \text{ ‰}$$



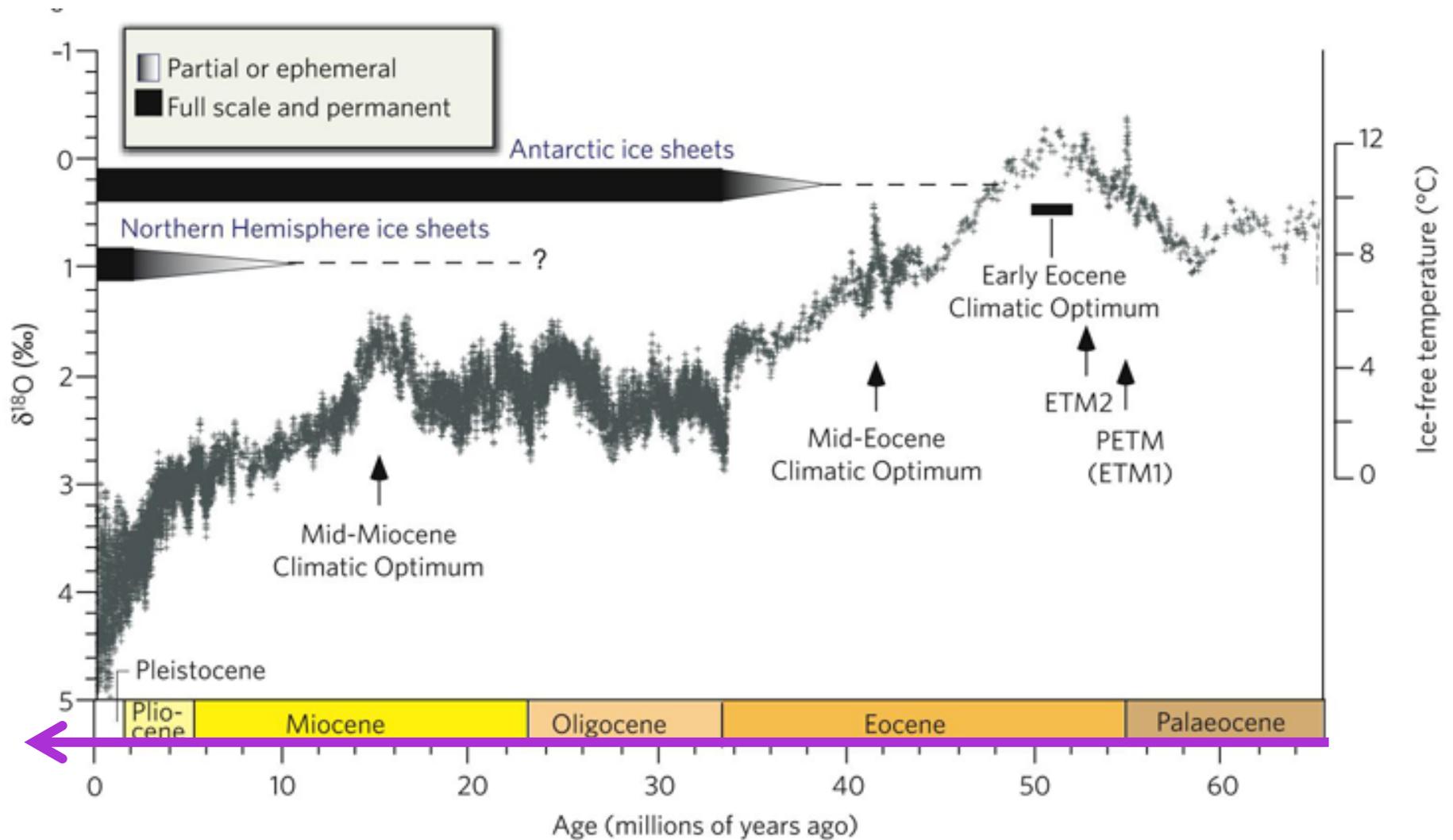
Same thing now on ocean sediments

Shell of Foraminifera's is made of CaCO_3



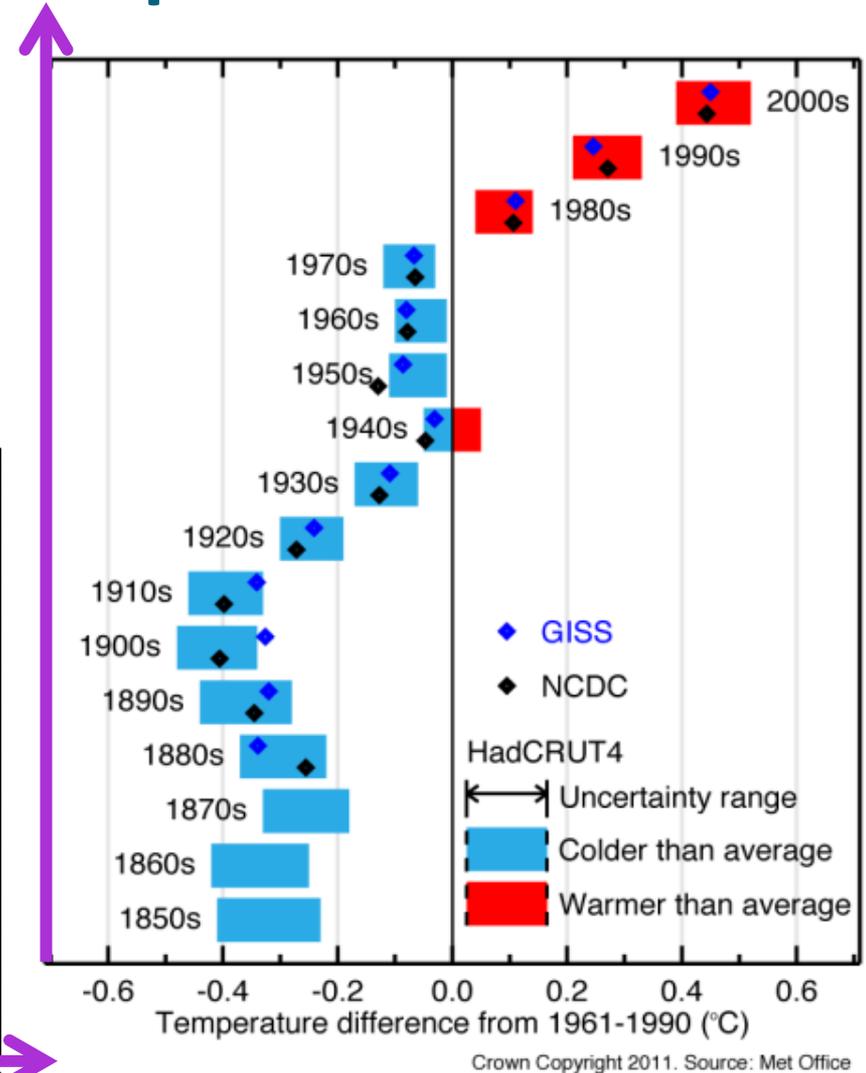
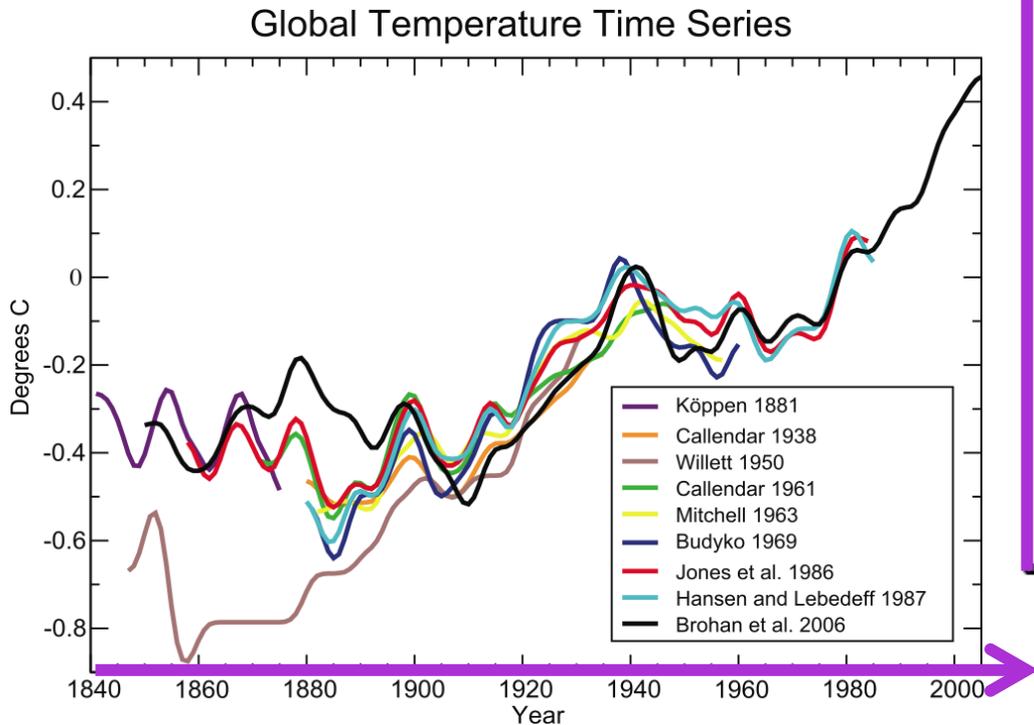
Lisiecki and Raymo (Paleoceanography, 2005).

Even deeper

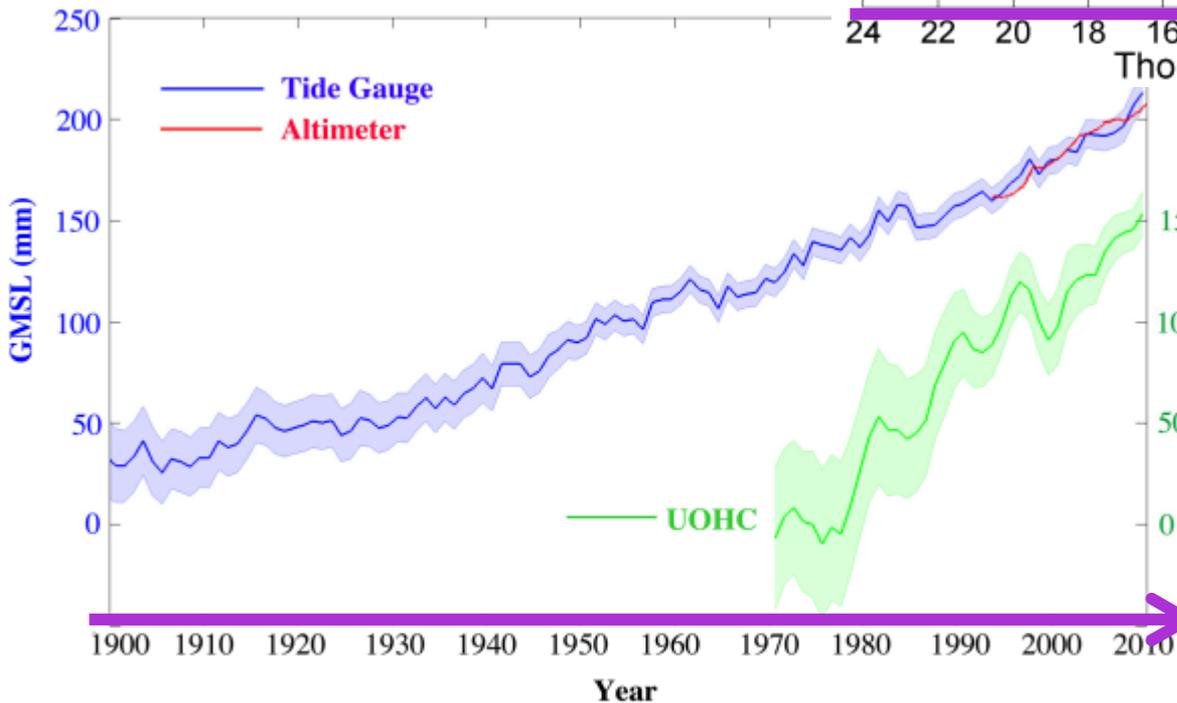
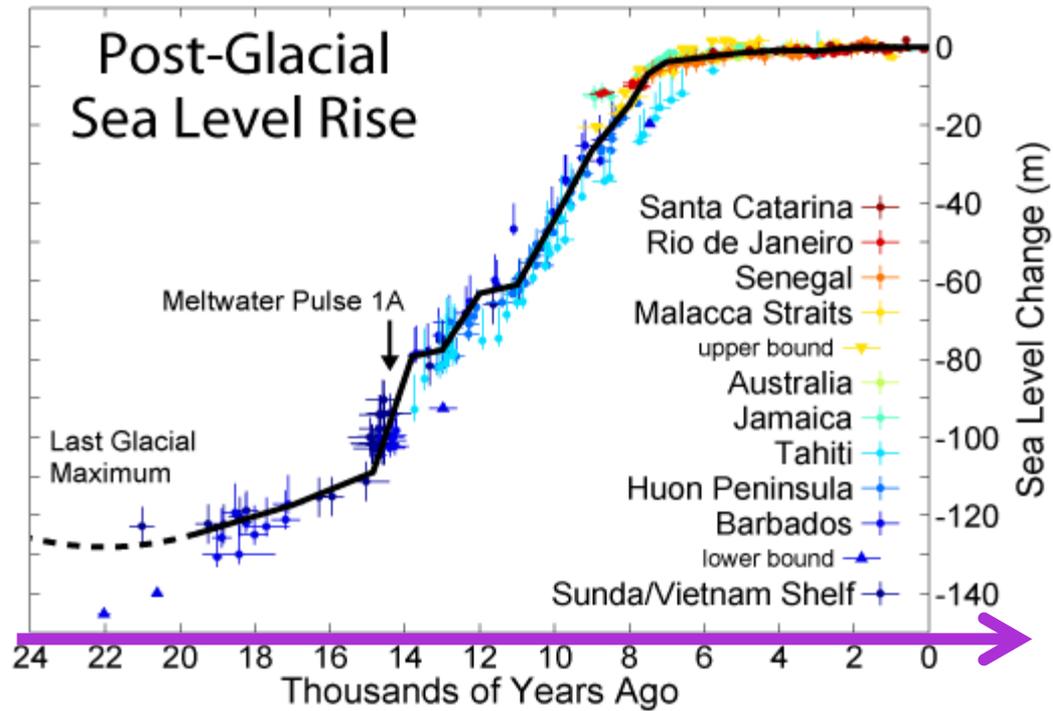


Zachos et al. (Nature, 2008)

Observation of Temperature Increase



(2) Sea level



Church and White, 2011;
Jevrejeva et al., 2008;
Nerem et al., 2010