Pós-Graduação
Programas em Energia (PPGE) e Ciência Ambiental (PROCAM)

Mudanças Climáticas e Redução de Emissões

PCA5019

Aula 01

Pedro Luiz Côrtes
plcortes@usp.br

Pedro Roberto Jacobi
prjacobi@gmail.com

Voltando no tempo ...

A.......

de dólares.
A instabilidade do clima vem sendo prevista periodicamente com teorias que variam desde o derretimento das calotas polares e um novo dilúvio, até a entrada da terra em uma nova era glacial. Recentemente começaram a ser

Jornal O Estado de S.Paulo - 06 2 1977

Ele faz esta afirmação baseado em conclusões de climatologistas e biólogos norte-americanos e europeus, segundo os quais, "a terra está entrando em nova fase glacial, com redução das áreas de clima quente e intensificação do frio nas áreas de clima temperado".

Jornal O Estado de S.Paulo - 24 5 1977

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PROCAMUSP

30 anos depois ...

A........

UE quer regra ambiental em acordos comerciais

A União Européia (UE) decidiu incluir critérios ambientais em todos os seus acordos comerciais. A decisão já é resultado das avaliações de cientistas sobre os efeitos do aquecimento global, divulgadas sexta-feira pelo Painel Intergovernamental de Mudanças Climáticas. A diplomacia brasileira dá sinais de que não aceitará a inclusão do tema nas negociações entre Mercosul e UE. ● PÁG. A12

SUPERAGÊNCIA
A criação de uma nova agência para o meio ambiente não tem apoio irrestrito do Brasil. O governo prefere o fortalecimento do Programa das Nações Unidas para o Meio Ambiente (Pnuma), que pode ser aperfeiçoado com a regionalização. ● PÁG. A12

Jornal O Estado de S.Paulo - 05 2 2007

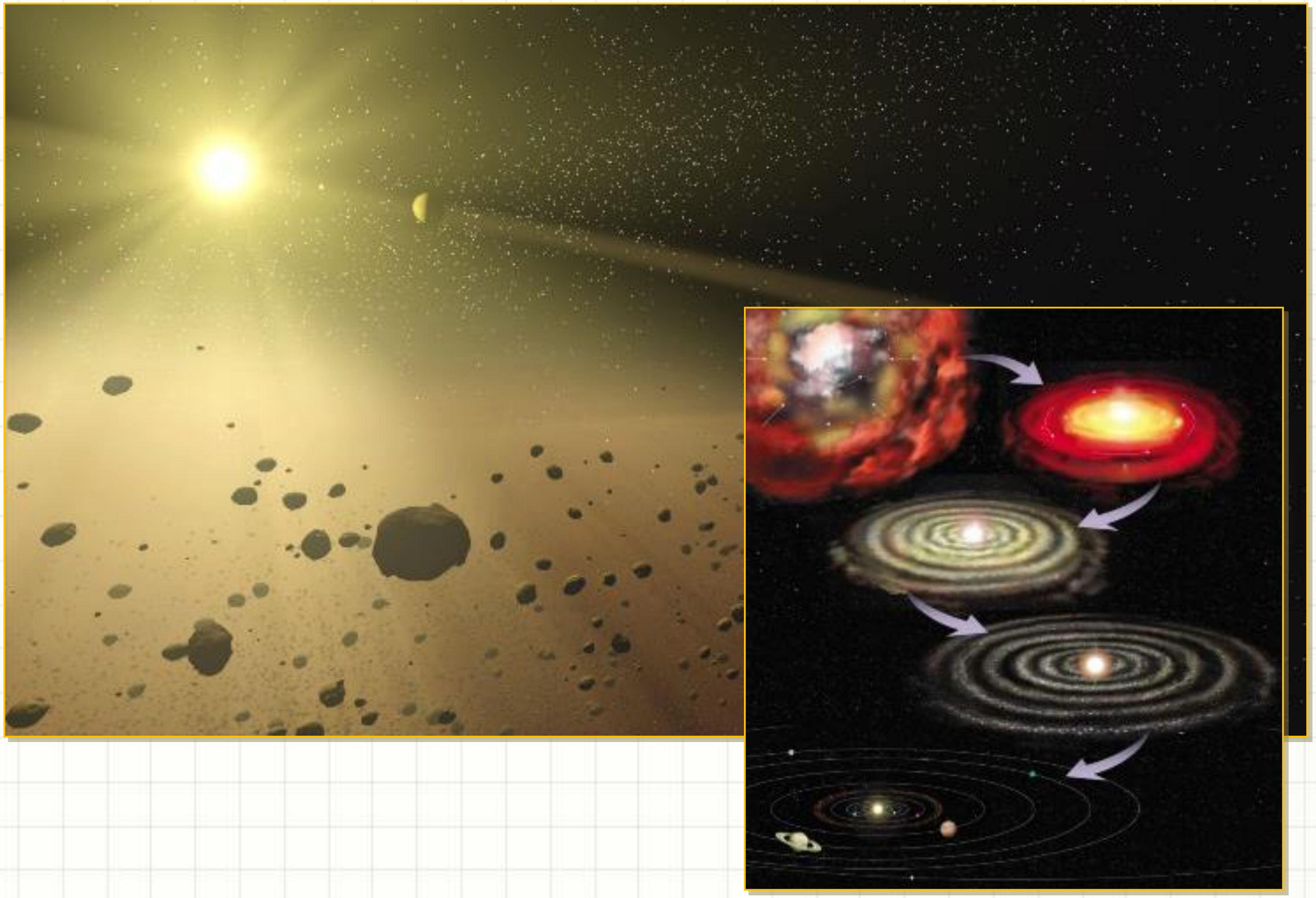
O clima está mudando?

Exemplos ... não faltam

O clima está mudando?

Na verdade, o clima sempre mudou ...

A origem da atmosfera



A origem da atmosfera

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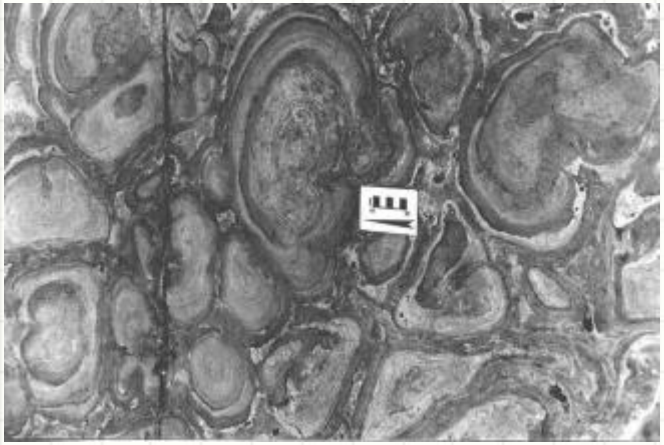
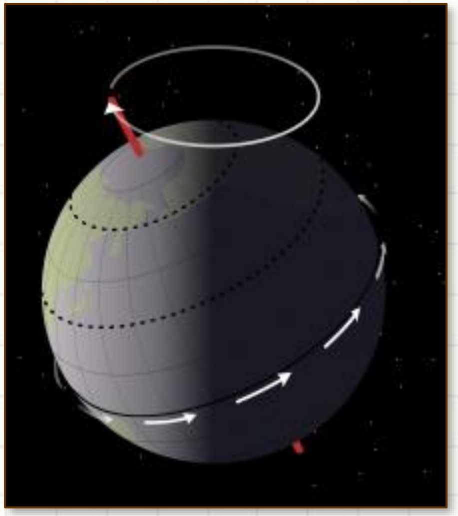


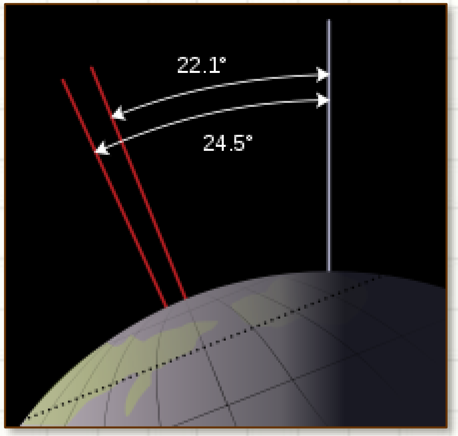
Fatores que contribuem para as variações climáticas

- Precessão dos equinócios



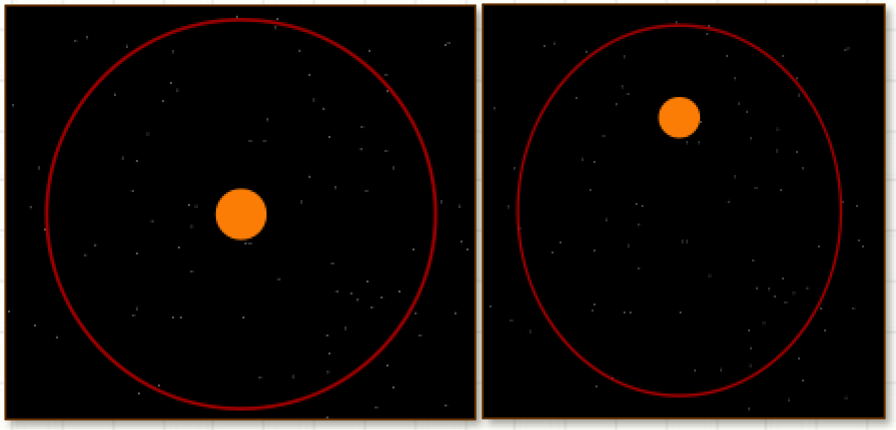
Fatores que contribuem para as variações climáticas

- Variação na inclinação do eixo da Terra



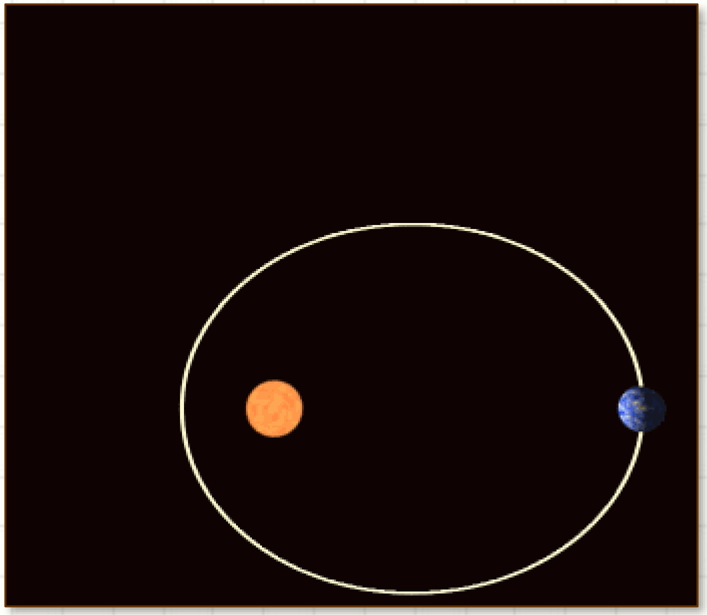
Fatores que contribuem para as variações climáticas

- Excentricidade orbital



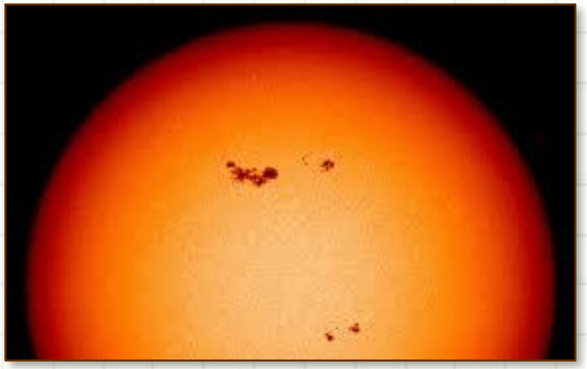
Fatores que contribuem para as variações climáticas

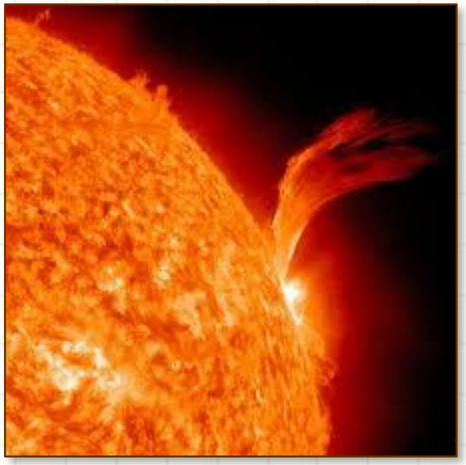
- Precessão (rotação) orbital

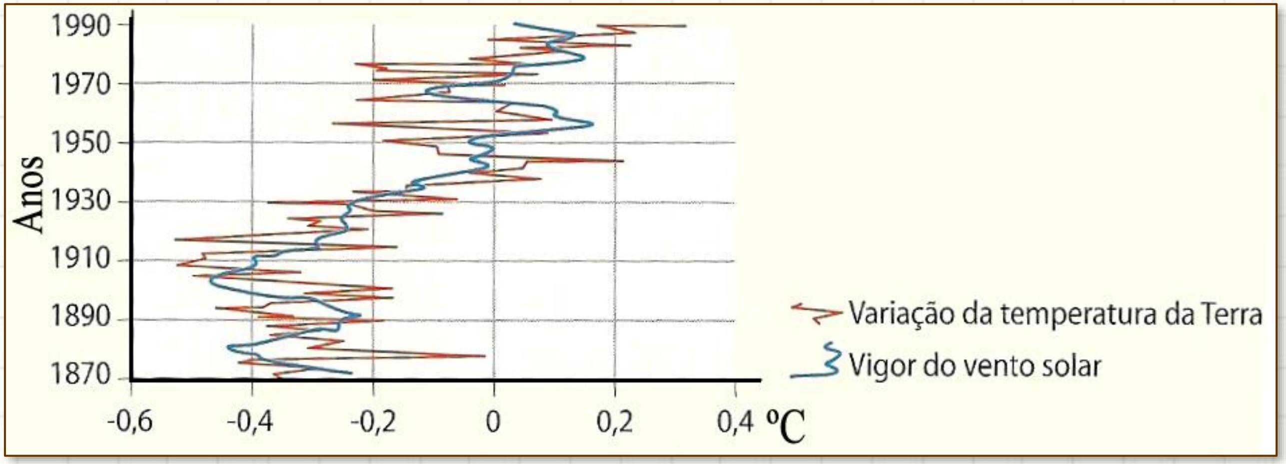


Fatores que contribuem para as variações climáticas

- Manchas solares

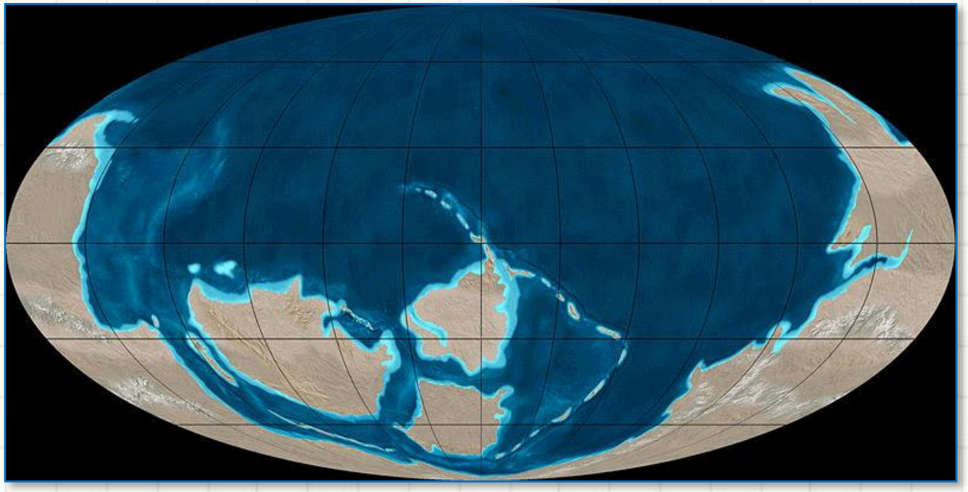






Fatores que contribuem para as variações climáticas

- Movimento dos continentes



Fatores que contribuem para as variações climáticas

- Vulcões

Vulcão Puyehue (Chile), junho de 2011

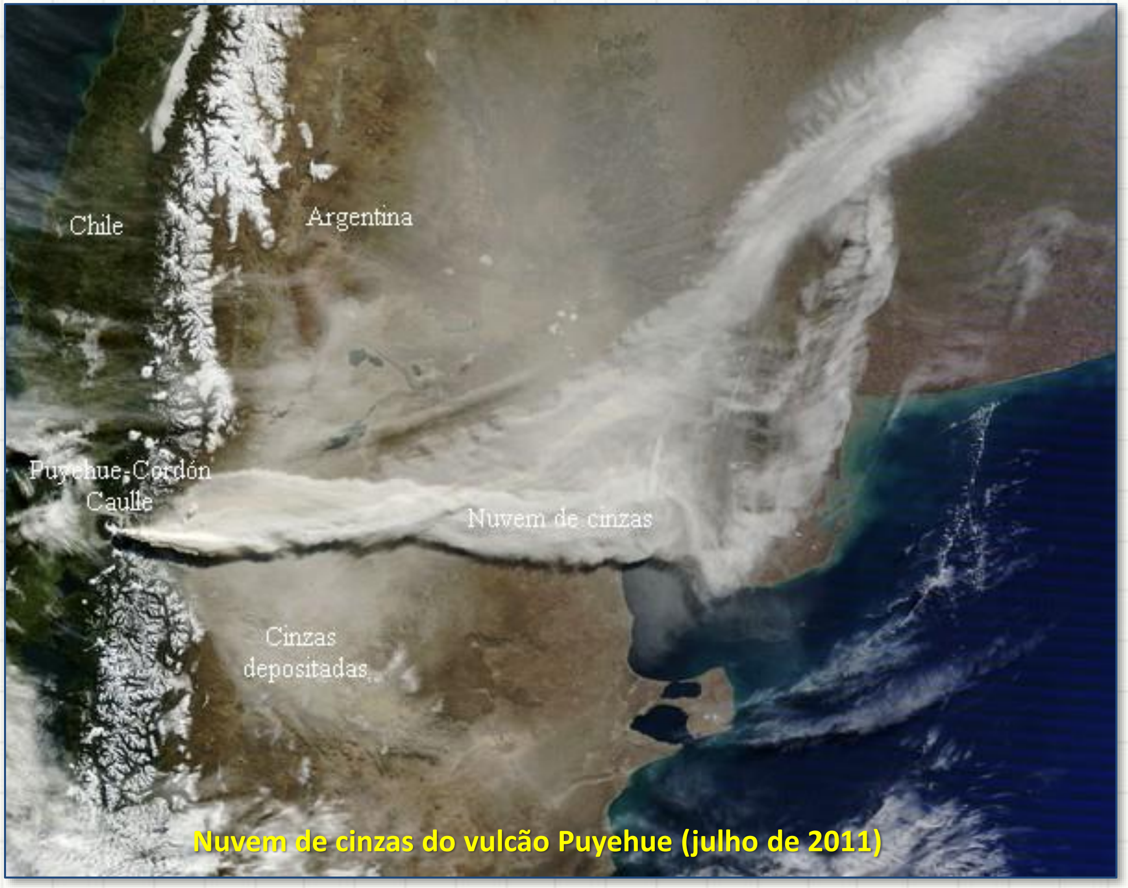
Fatores que contribuem para as variações climáticas

- Vulcões

Cinzas do vulcão Puyehue cobrindo a cidade de San Martin de los Andes (Argentina)

Fatores que contribuem para as variações climáticas

- Vulcões

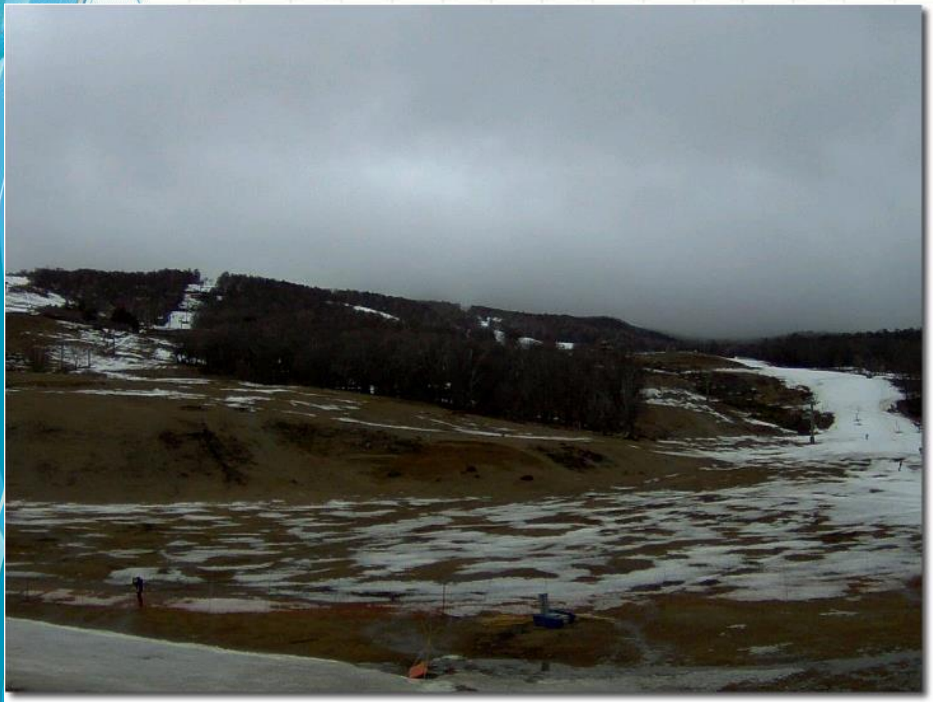


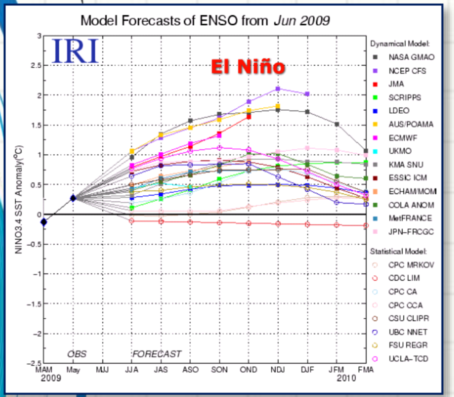
Nuvem de cinzas do vulcão Puyehue (julho de 2011)

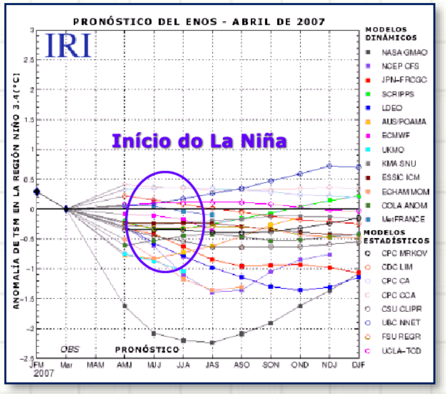
Fatores que contribuem para as variações climáticas

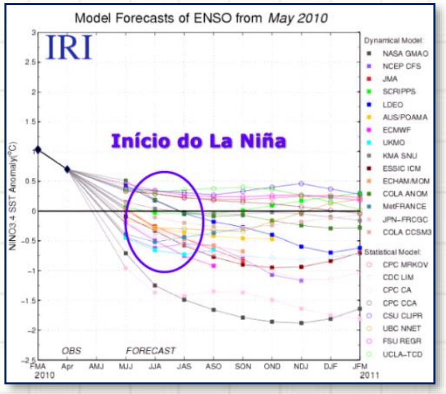
- Vulcões

Nuvem de cinzas do vulcão Cinzas do vulcão Grimsvötn




Model Forecasts of ENSO from Jun 2009
IRI
El Niño
OBS
FORECAST


PRONÓSTICO DEL ENOS - ABRIL DE 2007
IRI
Início do La Niña
OBS
PRONÓSTICO


Model Forecasts of ENSO from May 2010
IRI
Início do La Niña
OBS
FORECAST

- Qual a temperatura na Lua?

Curiosidades...

- Qual a temperatura na Lua?
  - -233 °C no lado escuro (noite)
  - +123 °C no lado iluminado (dia)

Curiosidades...

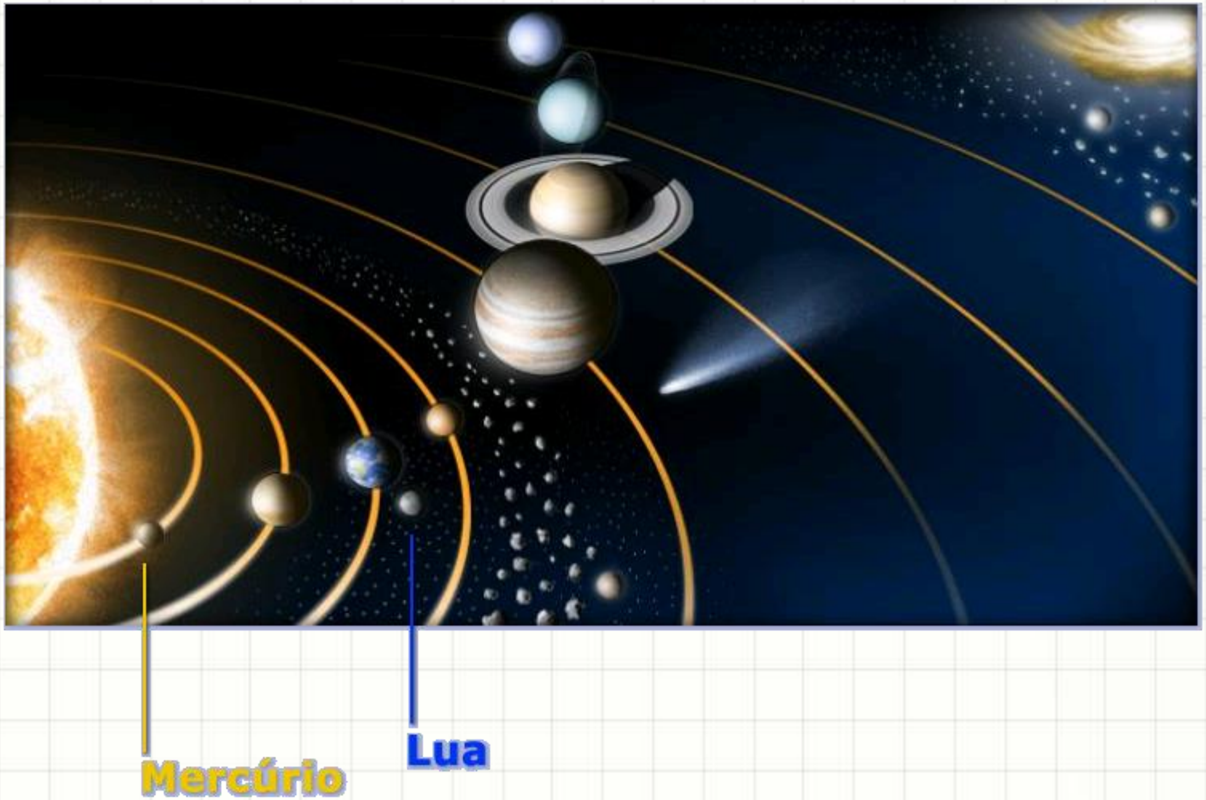
- Qual a temperatura em Mercúrio?

Curiosidades...

- Qual a temperatura em Mercúrio
  - -173 ^{o}C no lado escuro (noite)
  - +427 ^{o}C no lado iluminado (dia)

Curiosidades...

- Por que essa diferença tão grande?



Curiosidades...

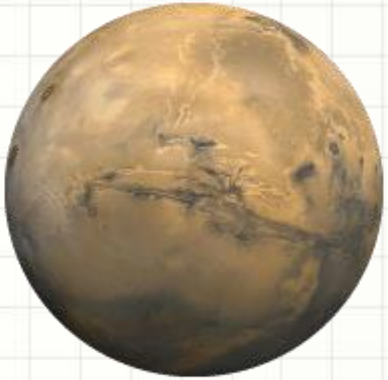
- Qual a temperatura em Venus?

Curiosidades...

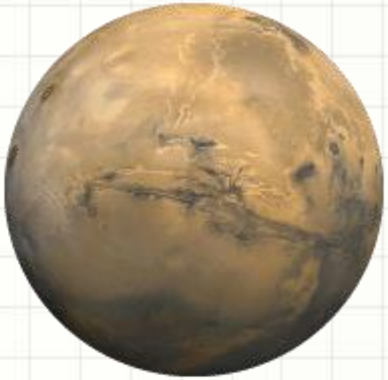
- Qual a temperatura em Venus?
  - +462 ^{o}C no lado escuro (noite)
  - +462 ^{o}C no lado claro (dia)

Curiosidades...

- Qual a temperatura em Marte?



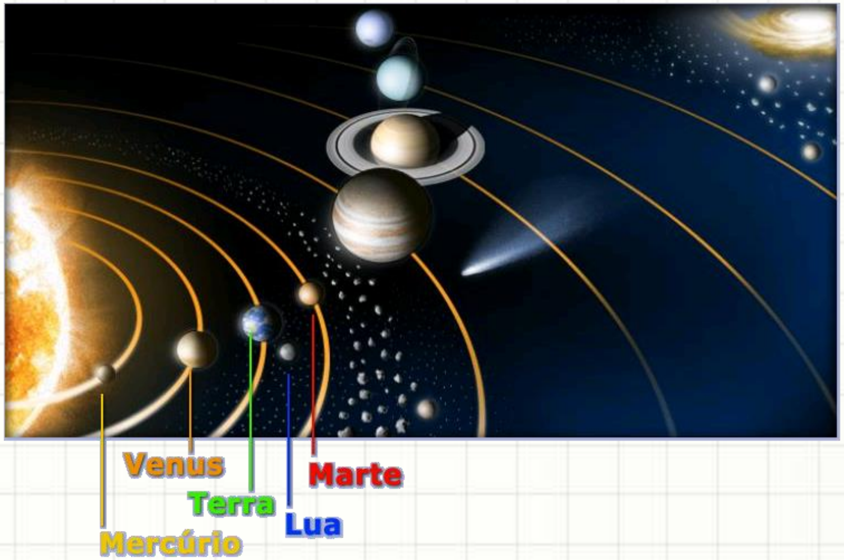
Curiosidades...



- Qual a temperatura em Marte?
  - -60ºC no lado escuro (noite)
  - 0 ºC no lado claro (dia)
  - Latitudes médicas

Curiosidades...

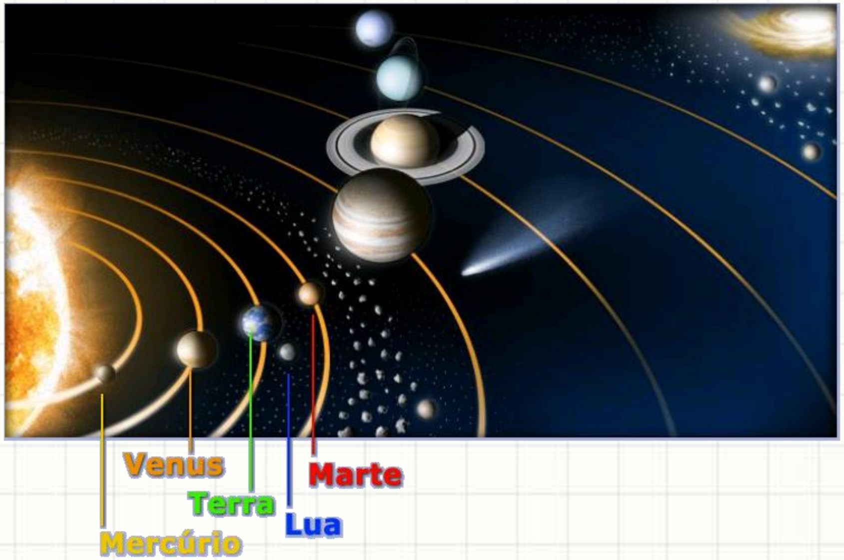
- Resumindo



Planeta ou satélite	Temp. mínima – ºC	Temp. máxima - ºC
Mercúrio	- 173	+ 427
Venus	+ 462	+ 462
Terra	+ 5	+ 20
Lua	-233	+ 123
Marte	- 60	0

Curiosidades...

- Resumindo



Planeta ou satélite	Temp. mínima – ºC	Temp. máxima - ºC	Diferença
Mercúrio	- 173	+ 427	600ºC
Venus	+ 462	+ 462	0ºC
Terra	+ 5	+ 20	15ºC
Lua	-233	+ 123	356ºC
Marte	- 60	0	60ºC

A atmosfera e o efeito estufa

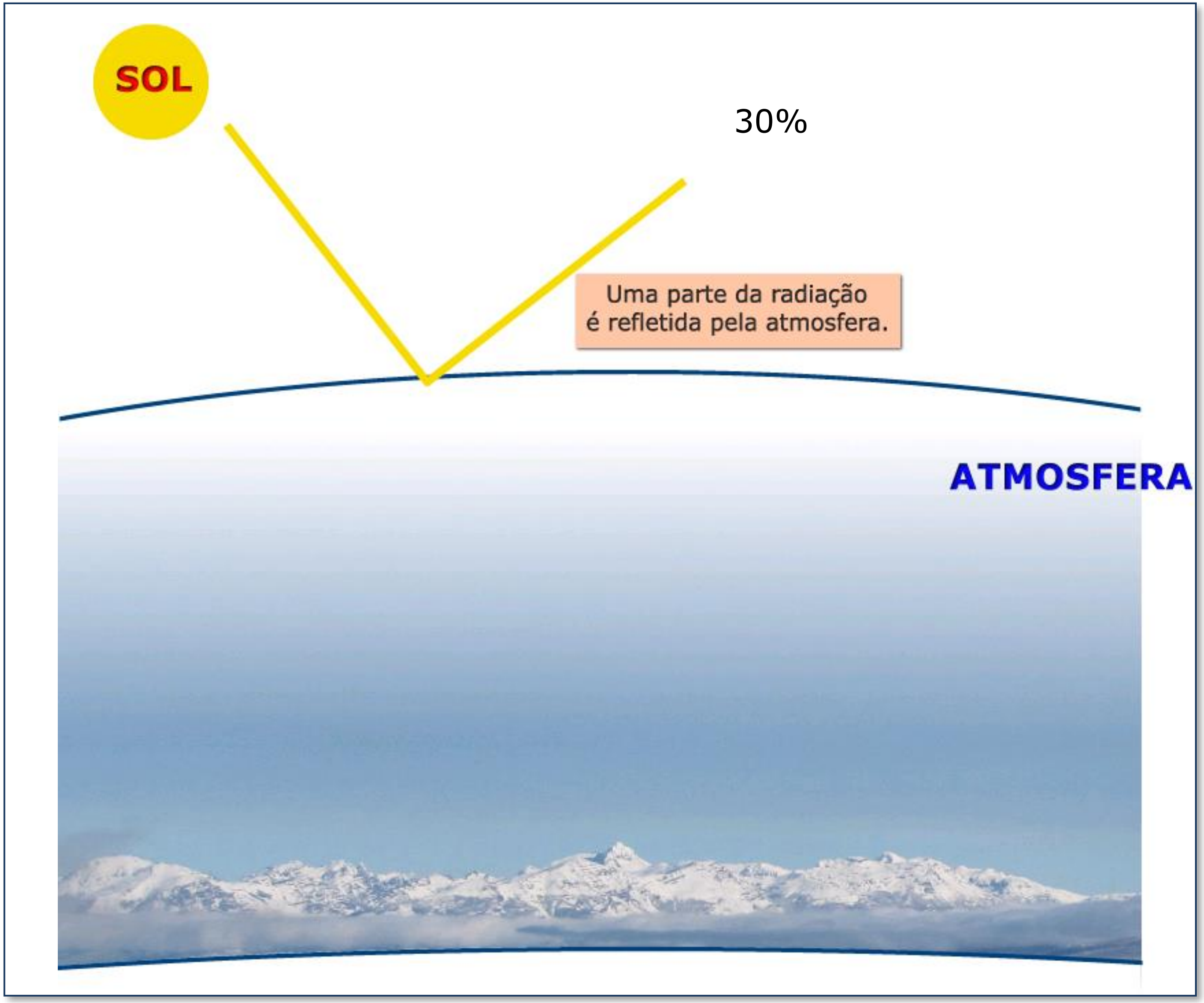
Planeta ou satélite	Temp. mínima – ºC	Temp. máxima - ºC	Diferença	Atmosfera
Mercúrio	- 173	+ 427	600ºC	Não tem
Venus	+ 462	+ 462	0ºC	Muito densa
Terra	+ 5	+ 20	15ºC	Normal
Lua	-233	+ 123	356ºC	Não tem
Marte	- 60	0	60ºC	Pouco densa

A atmosfera e o efeito estufa

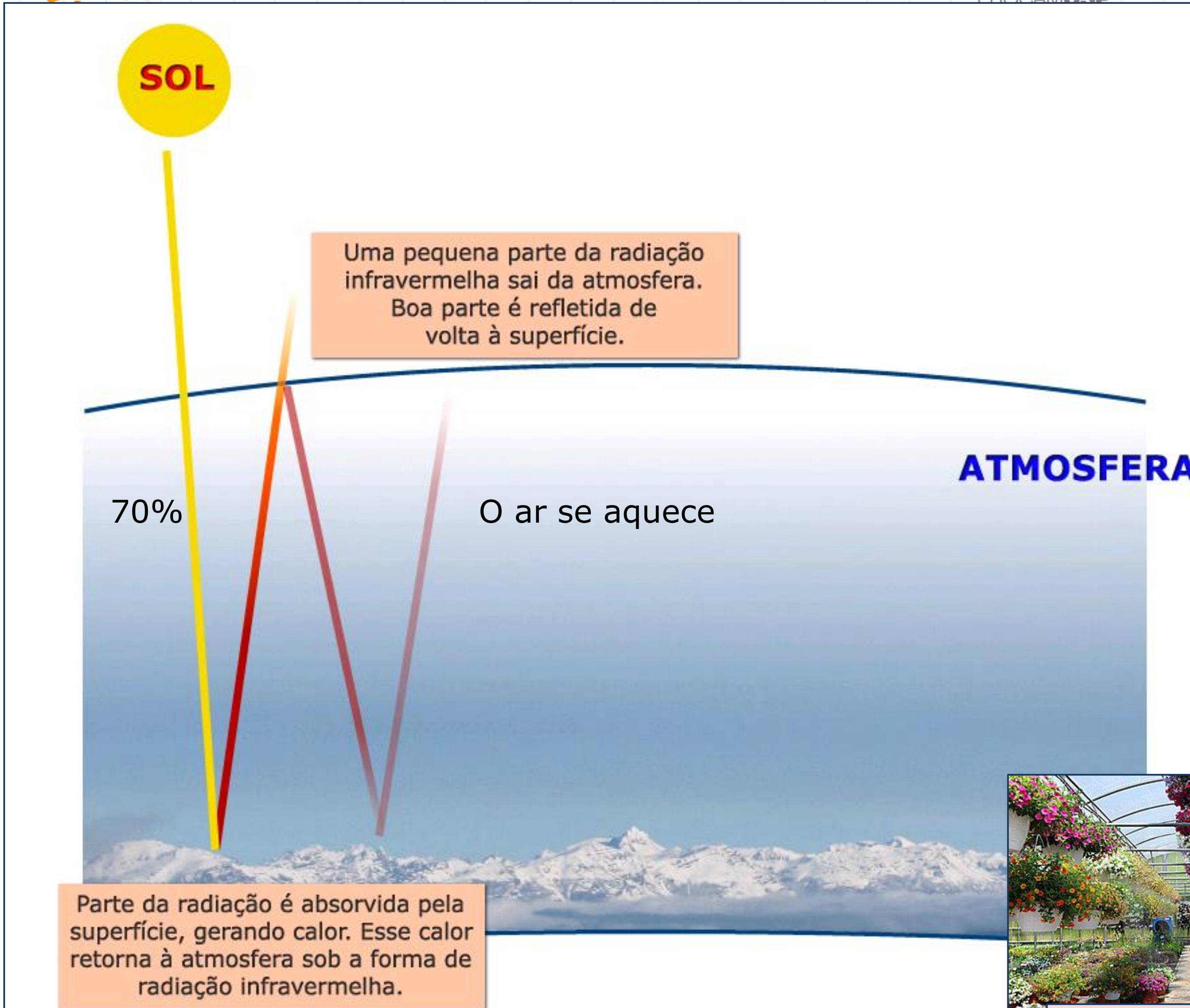
Sem atmosfera

•Durante o dia, o planeta aquece rapidamente. Parte do calor retorna ao espaço sob a forma de raios infravermelhos.

•Durante a noite, o planeta resfria rapidamente, pois não há atmosfera que ajude a reter o calor gerado durante o dia.



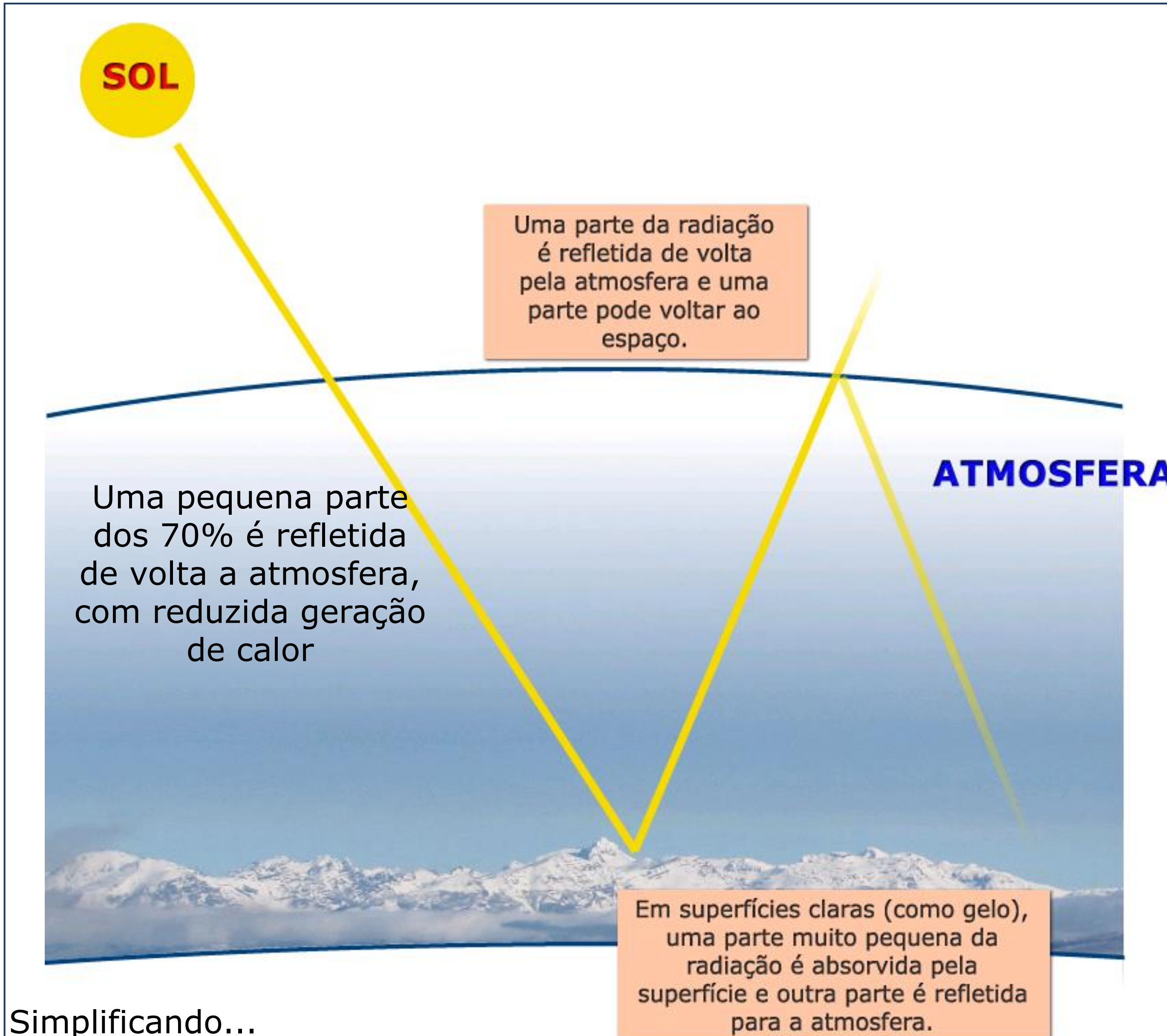
Simplificando...

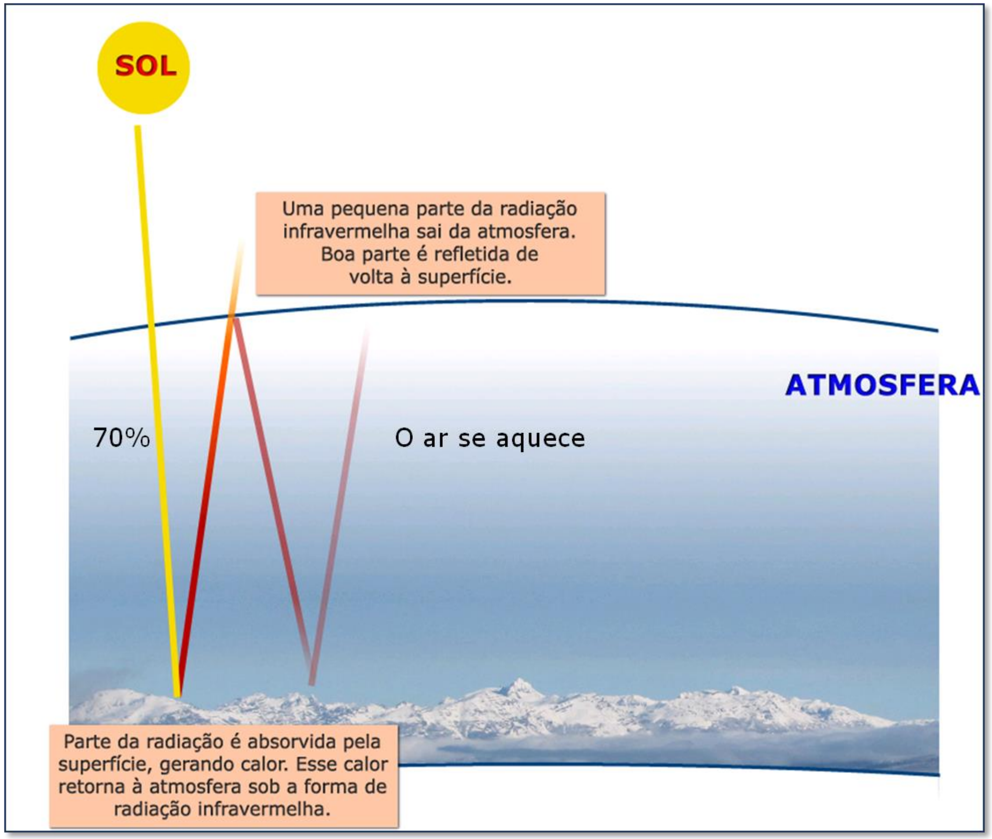


Simplificando...

Pense em uma estufa

A atmosfera e o efeito estufa





Simplificando...

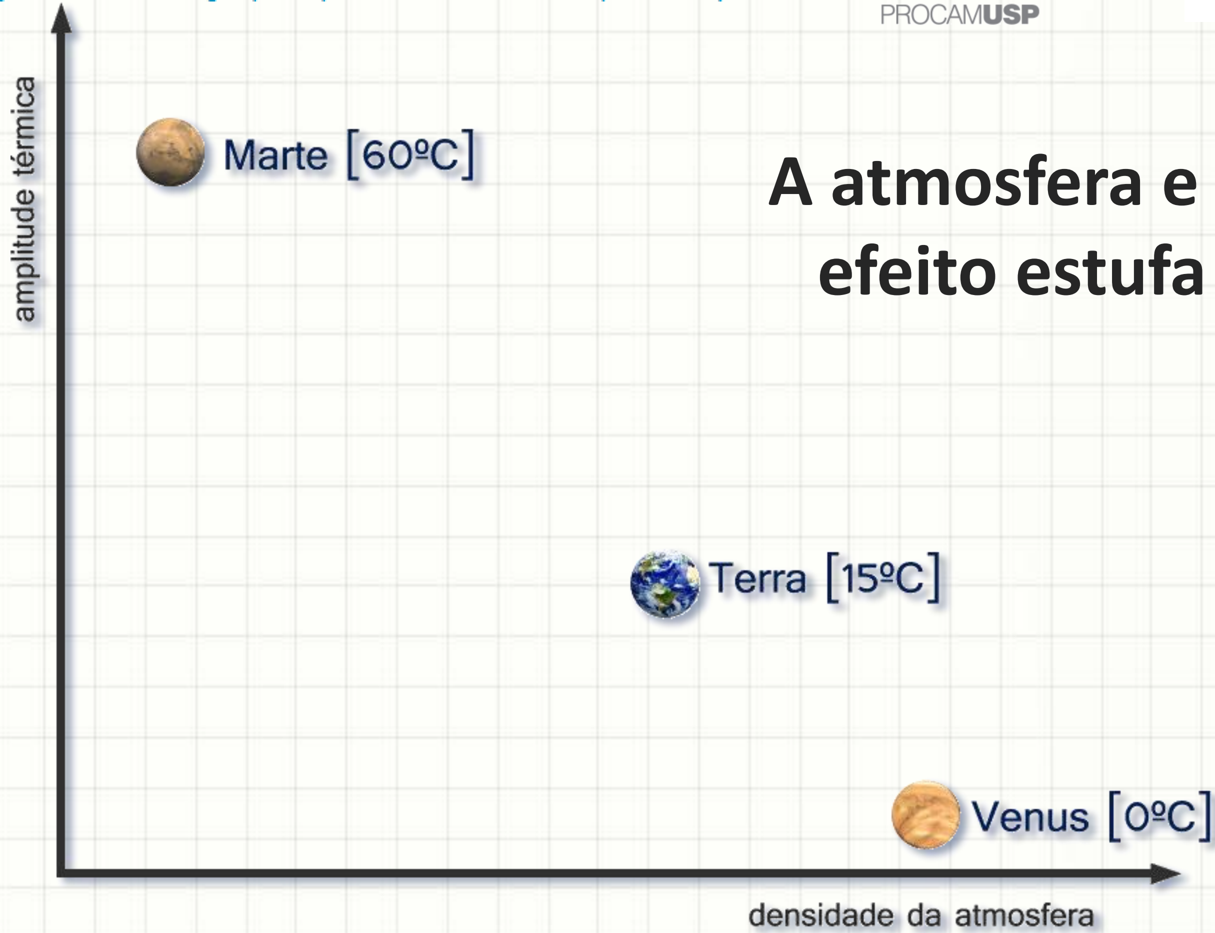

Efeito Estufa

Com atmosfera

•Durante o dia, a atmosfera funciona como um filtro, evitando que o planeta superaqueça ou aqueça rapidamente.

•Durante a noite, a atmosfera evita que o planeta resfrie rapidamente, retendo parte do calor gerado durante o dia.

A atmosfera e o efeito estufa



Planeta ou satélite	Temp. mínima – ºC	Temp. máxima - ºC	Diferença	Atmosfera
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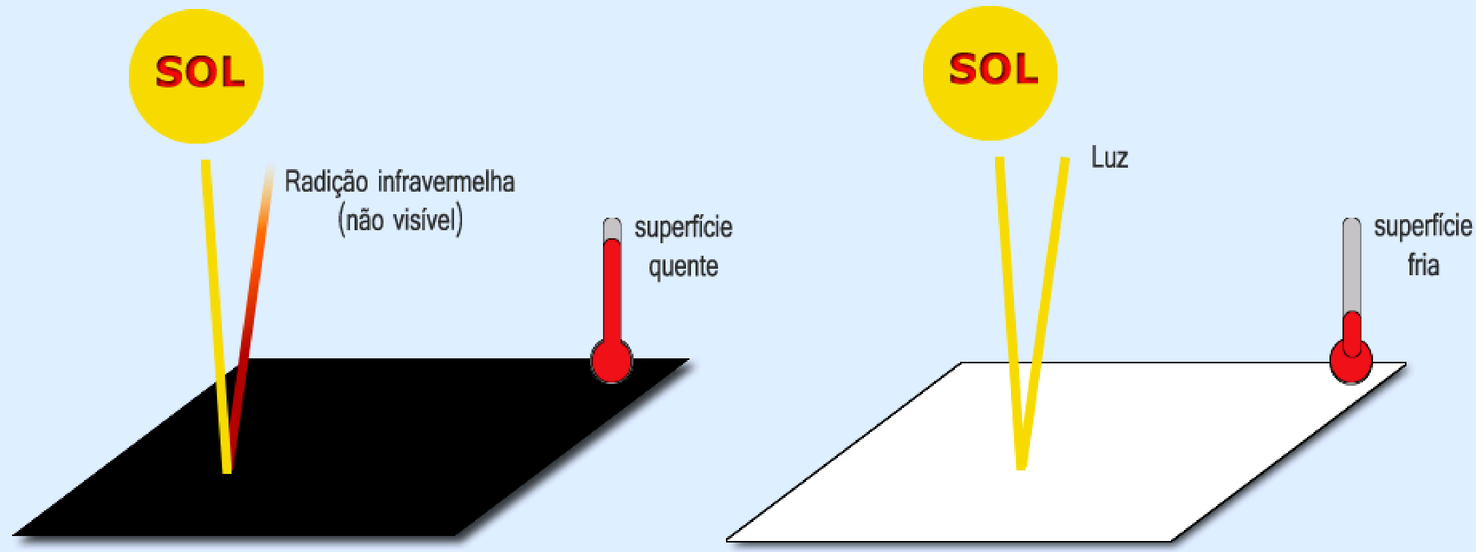
Marte	- 60	0	60ºC	Pouco densa

No verão, em um dia de sol, qual camiseta você usaria?

Albedo



Superfície preta: alta absorção de luz, que é transformada em calor. Esse calor é irradiado sob a forma de raios infravermelhos.

Superfície branca: baixa absorção de luz. Boa parte da luz recebida é refletida de volta. Há baixa emissão de raios infravermelhos.

Albedo é uma medida relativa da quantidade de luz refletida pelas superfícies de maneira direta ou difusa.
É uma relação expressa em porcentagem.

Geocronologia

- C_{14} -> C_{12}
- C_{13} -> C_{12}
- Entre os isótopos instáveis do carbono, o carbono-14 é aquele que apresenta a maior meia-vida.
- A cada 5730 anos, aproximadamente, metade do C_{14} se transforma em C_{12}.
- Verificando a proporção entre eles, é possível datar um fóssil, por exemplo.
- Este é apenas um exemplo. há diversos métodos para datação de rochas.

Absorção de CO_2 pelos oceanos

- C_{14} -> C_{12}
- C_{13} -> C_{12}
- Comparando a proporção entre os isótopos 14 e 12 e 13 e 12 em plantas terrestres e material marinho, é possível verificar quanto CO_2 está sendo absorvido pelos oceanos

Carbon Dioxide Exchange Between Atmosphere and Ocean and the Question of an Increase of Atmospheric CO_2 during the Past Decades

By ROGER REVELLE and HANS E. SUESS, Scripps Institution of Oceanography, University of California, La Jolla, California

(Manuscript received September 4, 1956)

Abstract

From a comparison of C^{14}/C^{12} and C^{13}/C^{12} ratios in wood and in marine material and from a slight decrease of the C^{14} concentration in terrestrial plants over the past 50 years it can be concluded that the average lifetime of a CO_2 molecule in the atmosphere before it is dissolved into the sea is of the order of 10 years. This means that most of the CO_2 released by artificial fuel combustion since the beginning of the industrial revolution must have been absorbed by the oceans. The increase of atmospheric CO_2 from this cause is at present small but may become significant during future decades if industrial fuel combustion continues to rise exponentially.

Present data on the total amount of CO_2 in the atmosphere, on the rates and mechanisms of exchange, and on possible fluctuations in terrestrial and marine organic carbon, are inadequate for accurate measurement of future changes in atmospheric CO_2. An opportunity exists during the International Geophysical Year to obtain much of the necessary information.

Introduction

In the middle of the 19th century appreciable amounts of carbon dioxide began to be added to the atmosphere through the combustion of fossil fuels. The rate of combustion has continually increased so that at the present time the annual increment from this source is nearly 0.4 % of the total atmospheric carbon dioxide. By 1960 the amount added during the past century will be more than 15 %.

CALLENDAR (1938, 1940, 1949) believed that nearly all the carbon dioxide produced by fossil fuel combustion has remained in the atmosphere, and he suggested that the increase in atmospheric carbon dioxide may account for the observed slight rise of average temperature in northern latitudes during recent decades. He thus revived the hypothesis of T. C. CHAMBERLIN (1899) and S. ARRHENIUS (1903) that climatic changes may be related to fluctuations in the carbon dioxide content of the air. These authors supposed that an increase of carbon dioxide in the upper atmosphere would lower the mean level of back radiation in the infrared and thereby increase the average temperature near the earth's surface.

Subsequently, other authors have questioned Callendar's conclusions on two grounds. First, comparison of measurements made in the 19th century and in recent years do not demonstrate that there has been a significant increase in

Contribution from the Scripps Institution of Oceanography, New Series, No. 900. This paper represents in part results of research carried out by the University of California under contract with the Office of Naval Research.

O Aumento de CO_2 na Atmosfera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By ROGER REVELLE and HANS E. SUESS, Scripps Institution of Oceanography, University of California, La Jolla, California

Aumento do CO_2 na atmosfera, causado pela queima de combustível fóssil. Chamberlin e Arrhenius acreditavam que isso poderia levar a um aumento da temperatura na superfície da Terra.

Introduction

In the middle of the 19th century appreciable amounts of carbon dioxide began to be added to the atmosphere through the combustion of fossil fuels. The rate of combustion has continually increased so that at the present time the annual increment from this source is nearly 0.4 % of the total atmospheric carbon dioxide. By 1960 the amount added during the past century will be more than 15 %.

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Abstract

In contemplating the probably large increase in CO_2 production by fossil fuel combustion in coming decades we conclude that a total increase of 20 to 40 % in atmospheric CO_2 can be anticipated. This should certainly be adequate to allow a determination of the effects, if any, of changes in atmospheric carbon dioxide on weather and climate throughout the earth.

O Aumento de CO_2 na Atmosfera

Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica

J. R. Petit*, J. Jouzel†, D. Raynaud*, N. I. Barkov‡, J.-M. Barnola*, I. Basile*, M. Bender§, J. Chappellaz*, M. Davis‖, G. Delaygue†, M. Delmotte*, V. M. Kotlyakov¶, M. Legrand*, V. Y. Lipenkov‡, C. Lorius*, L. Pépin*, C. Ritz*, E. Saltzman‖ & M. Stievenard†

* Laboratoire de Glaciologie et Géophysique de l'Environnement, CNRS, BP96, 38402, Saint Martin d'Hères Cedex, France
† Laboratoire des Sciences du Climat et de l'Environnement (UMR CEA/CNRS 1572), L'Orme des Merisiers, Bât. 709, CEA Saclay, 91191 Gif-sur-Yvette Cedex, France

The recent completion of drilling at Vostok station in East Antarctica has allowed the extension of the ice record of atmospheric composition and climate to the past four glacial–interglacial cycles. The succession of changes through each climate cycle and termination was similar, and atmospheric and climate properties oscillated between stable bounds. Interglacial periods differed in temporal evolution and duration. Atmospheric concentrations of carbon dioxide and methane correlate well with Antarctic air-temperature throughout the record. Present-day atmospheric burdens of these two important greenhouse gases seem to have been unprecedented during the past 420,000 years.

changes are documented by complementary climate records[1,2] largely derived from deep sea sediments, continental deposits of flora, fauna and loess, and ice cores. These studies have documented the wide range of climate variability on Earth. They have shown that much

in order to avoid any risk that drilling fluid would contaminate the lake water. Preliminary data[17] indicated that the Vostok ice-core record extended through four climate cycles, with ice slightly older than 400 kyr at a depth of 3,310 m, thus spanning a period

As concentrações atmosféricas de dióxido de carbono e metano estão correlacionadas com a temperatura do ar da Antártida de acordo com os registros.

Níveis atuais desses dois importantes gases de efeito estufa parecem ter atingido níveis sem precedentes nos últimos 420 mil anos.

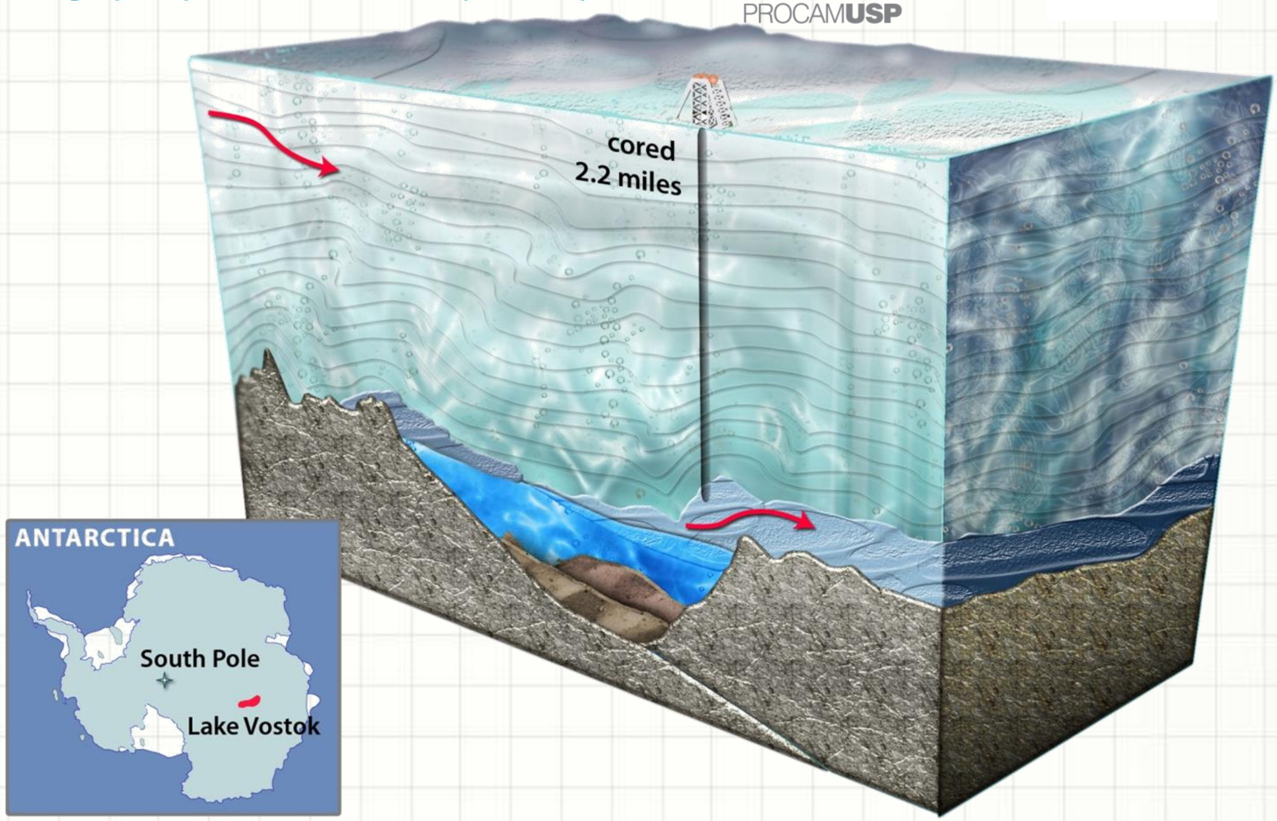
circulation. There is a close correlation between Antarctic temperature and atmospheric concentrations of CO_2 and CH_4 (refs 5, 9). This discovery suggests that greenhouse gases are important as amplifiers of the initial orbital forcing and may have significantly contributed to the glacial–interglacial changes[14–16]. The Vostok ice cores were also used to infer an empirical estimate of the sensitivity of global climate to future anthropogenic increases of greenhouse-gas concentrations[15].

The recent completion of the ice-core drilling at Vostok allows us to considerably extend the ice-core record of climate properties at this site. In January 1998, the Vostok project yielded the deepest ice

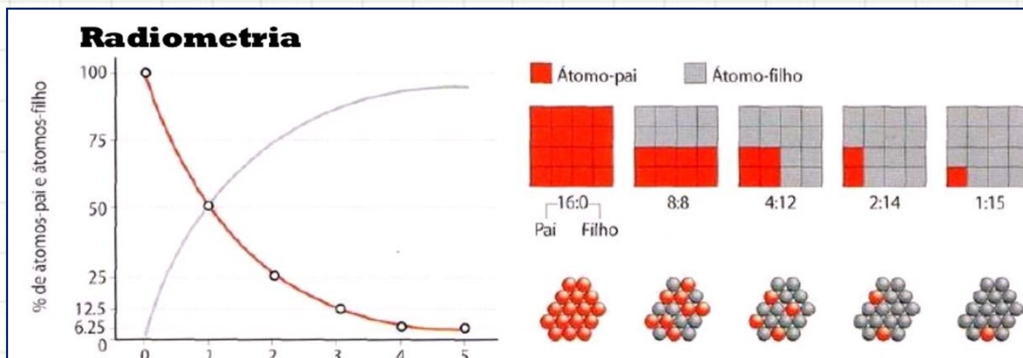
aerosol), and from the entrapped air the greenhouse gases CO_2 and CH_4, and the $\delta^{18}O$ of O_2 (hereafter $\delta^{18}O_{atm}$) which reflects changes in global ice volume and in the hydrological cycle[19]. (δD and $\delta^{18}O$ are defined in the legends to Figs 1 and 2, respectively.) All these measurements have been performed using methods previously described except for slight modifications (see figure legends).

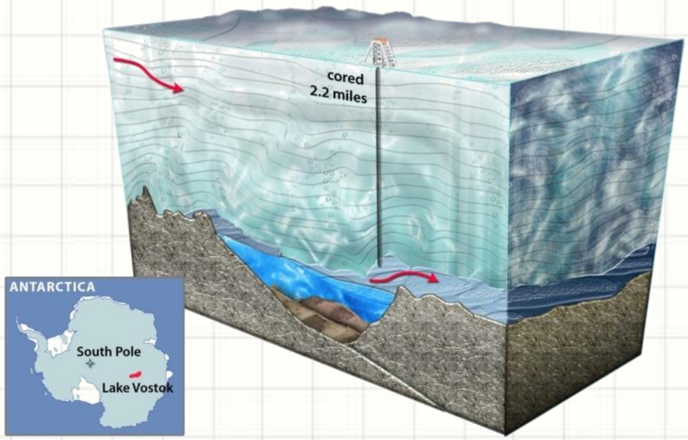
The detailed record of δD_{ice} (Fig. 1) confirms the main features of the third and fourth climate cycles previously illustrated by the coarse-resolution record[17]. However, a sudden decrease from interglacial-like to glacial-like values, rapidly followed by an abrupt return to interglacial-like values, occurs between 3,320 and 3,330 m.

O Aumento de CO_2 na Atmosfera



A razão O^{18}/O^{16} permite um registro preciso da temperatura da água contida no gelo dos glaciares.





Elementos como **Na (sódio)** têm sua concentração aumentada na geleira sobre o Lago Vostok durante os períodos mais quentes. Devido ao maior degelo, o vento marinho forma uma espécie de aerossol com sal marinho que se dispersa sobre o gelo.

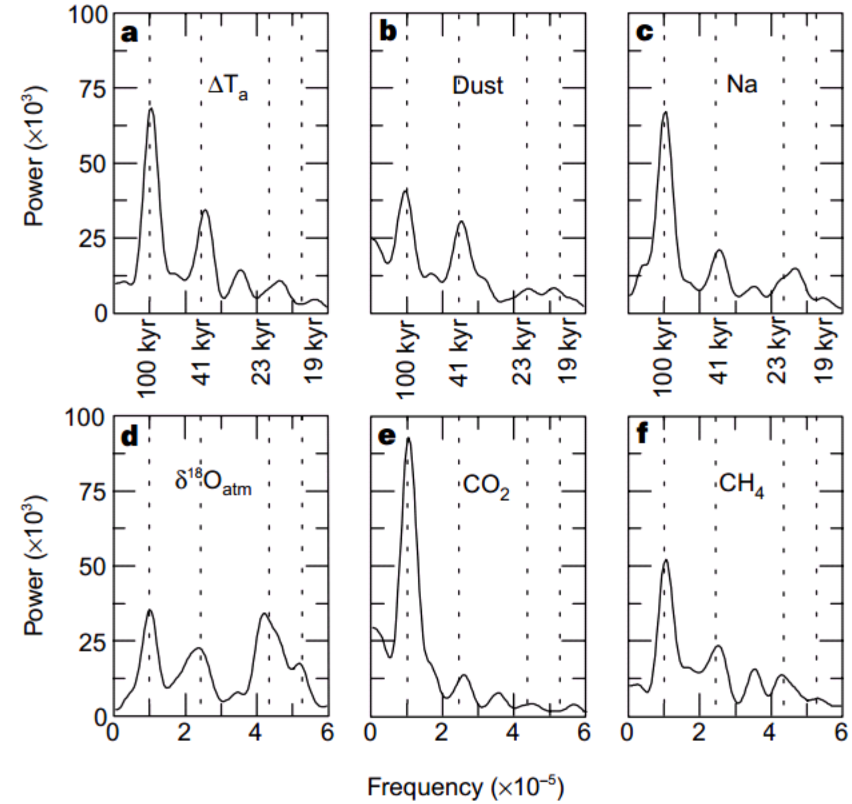
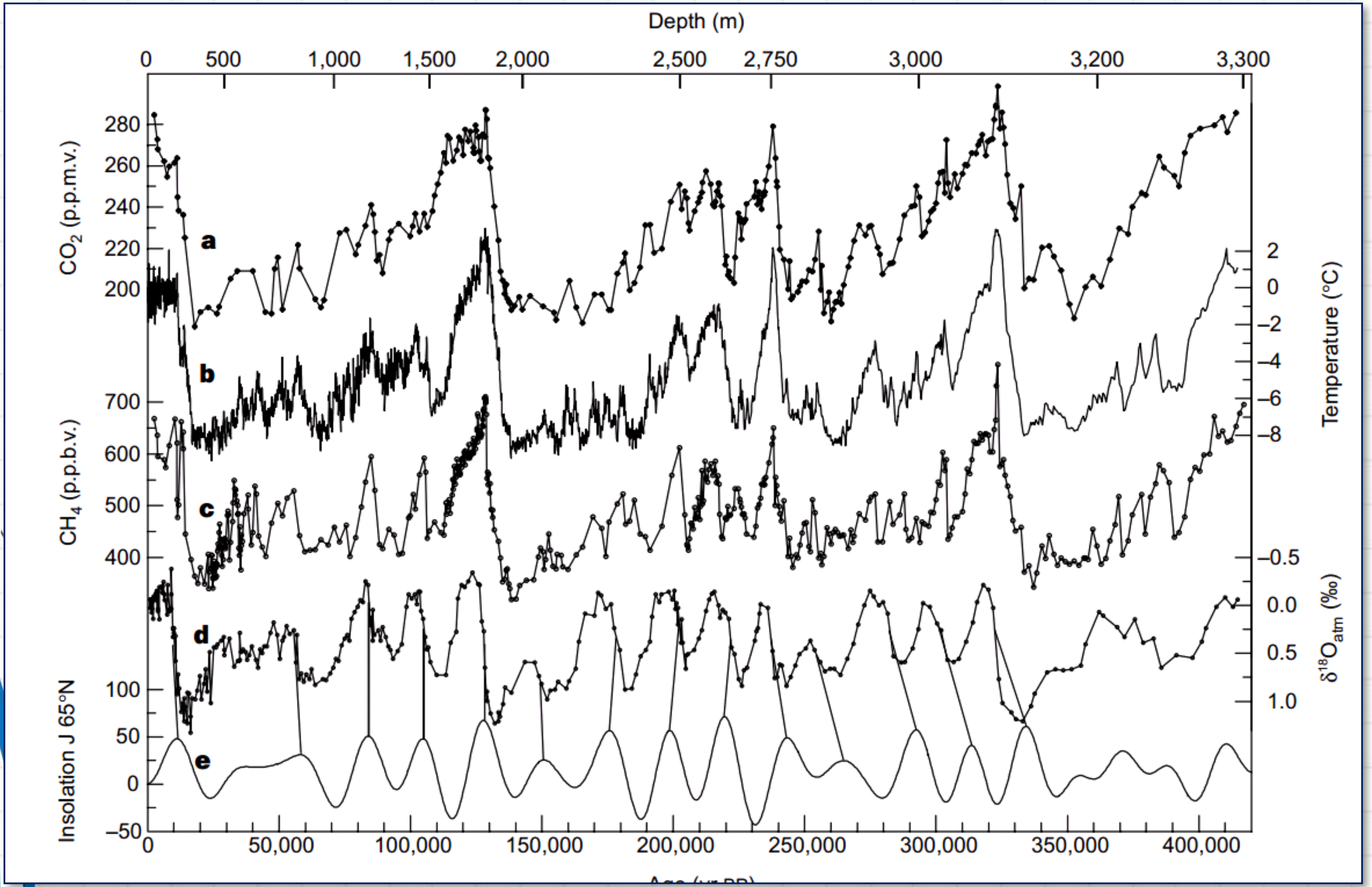
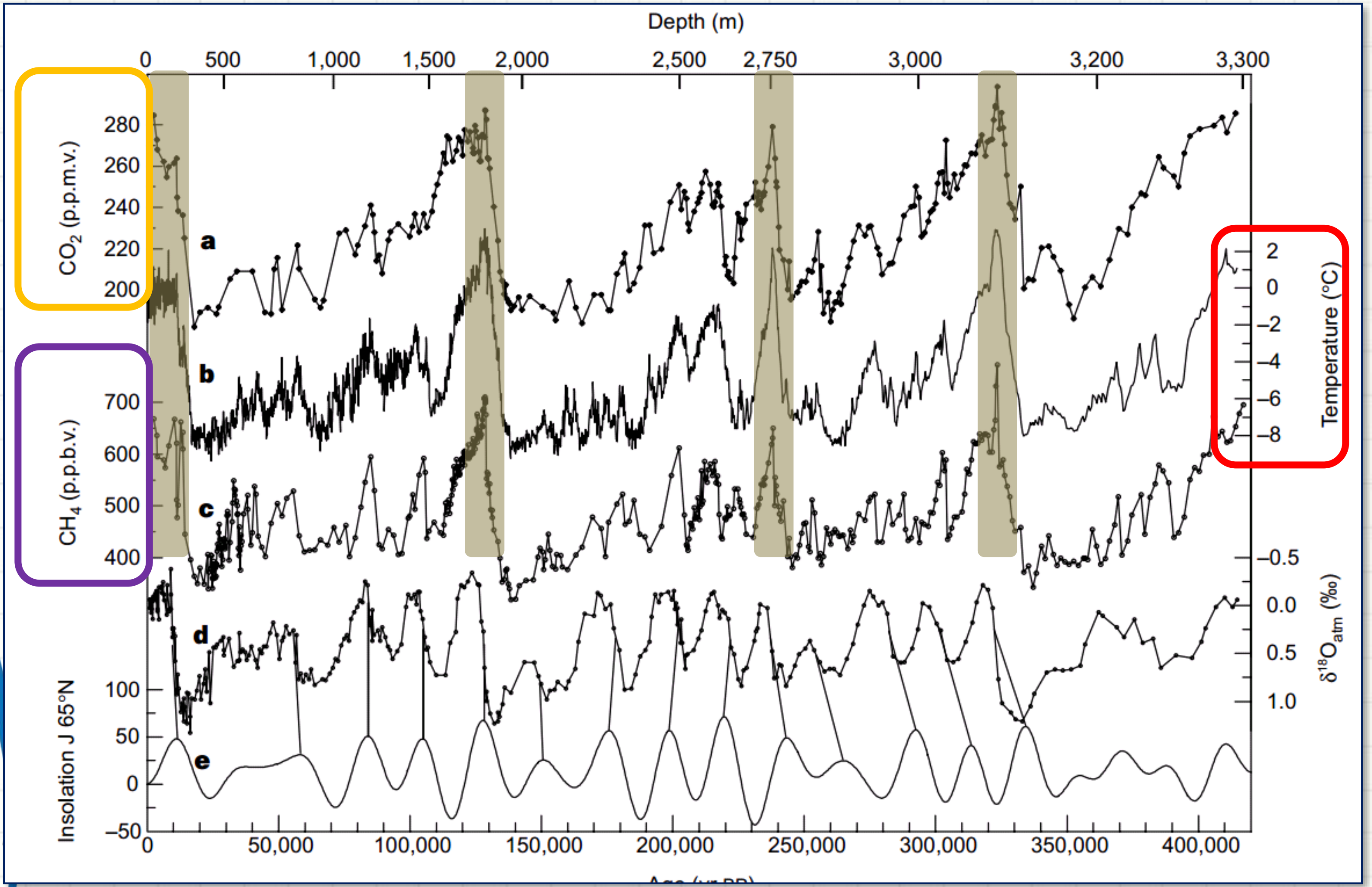
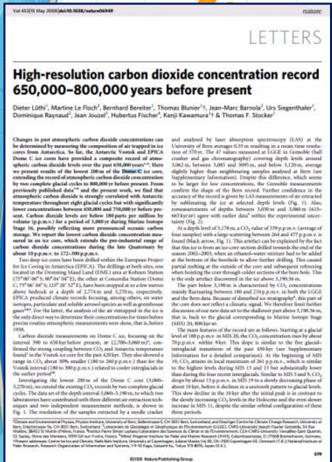


Figure 4 Spectral properties of the Vostok time series. Frequency distribution (in cycles yr^{-1}) of the normalized variance power spectrum (arbitrary units). Spectral analysis was done using the Blackman-Tukey method (calculations were performed with the Analyseries software[47]): **a**, isotopic temperature; **b**, dust; **c**, sodium; **d**, $\delta^{18}O_{atm}$; **e**, CO_2; and **f**, CH_4. Vertical lines correspond to periodicities of 100, 41, 23 and 19 kyr.


Depth (m)
0
500
1,000
1,500
2,000
2,500
2,750
3,000
3,200
3,300
CO2 (p.p.m.v.)
280
260
240
220
200
a
b
c
d
e
Temperature (°C)
2
0
−2
−4
−6
−8
CH4 (p.p.b.v.)
700
600
500
400
−0.5
0.0
0.5
1.0
δ18Oatm (‰)
Insolation J 65°N
100
50
0
−50
0
50,000
100,000
150,000
200,000
250,000
300,000
350,000
400,000


Depth (m)
0
500
1,000
1,500
2,000
2,500
2,750
3,000
3,200
3,300
CO_2 (p.p.m.v.)
280
260
240
220
200
a
b
c
d
e
CH_4 (p.p.b.v.)
700
600
500
400
Temperature (°C)
2
0
−2
−4
−6
−8
−0.5
0.0
0.5
1.0
$\delta^{18}O_{atm}$ (‰)
Insolation J 65°N
100
50
0
−50
0
50,000
100,000
150,000
200,000
250,000
300,000
350,000
400,000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LETTERS

High-resolution carbon dioxide concentration record 650,000–800,000 years before present

Dieter Lüthi[1], Martine Le Floch[2], Bernhard Bereiter[1], Thomas Blunier[1]†, Jean-Marc Barnola[2], Urs Siegenthaler[1], Dominique Raynaud[2], Jean Jouzel[3], Hubertus Fischer[4], Kenji Kawamura[1]† & Thomas F. Stocker[1]