



QFL4520 – Química Ambiental II

Parte I – Conceitos sobre o Meio Ambiente

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Parte I - Conceitos sobre o Meio Ambiente

- *A Terra;*
- *Meio Ambiente / Compartimentos Ambientais;*
- *Ciclos Biogeoquímicos;*
- *Compostos de importância ambiental;*
- *Influência Humana sobre o Meio Ambiente (poluição, Química Verde)*



Aula 1:

- *A Terra;*
- *Meio Ambiente / Compartimentos Ambientais;*



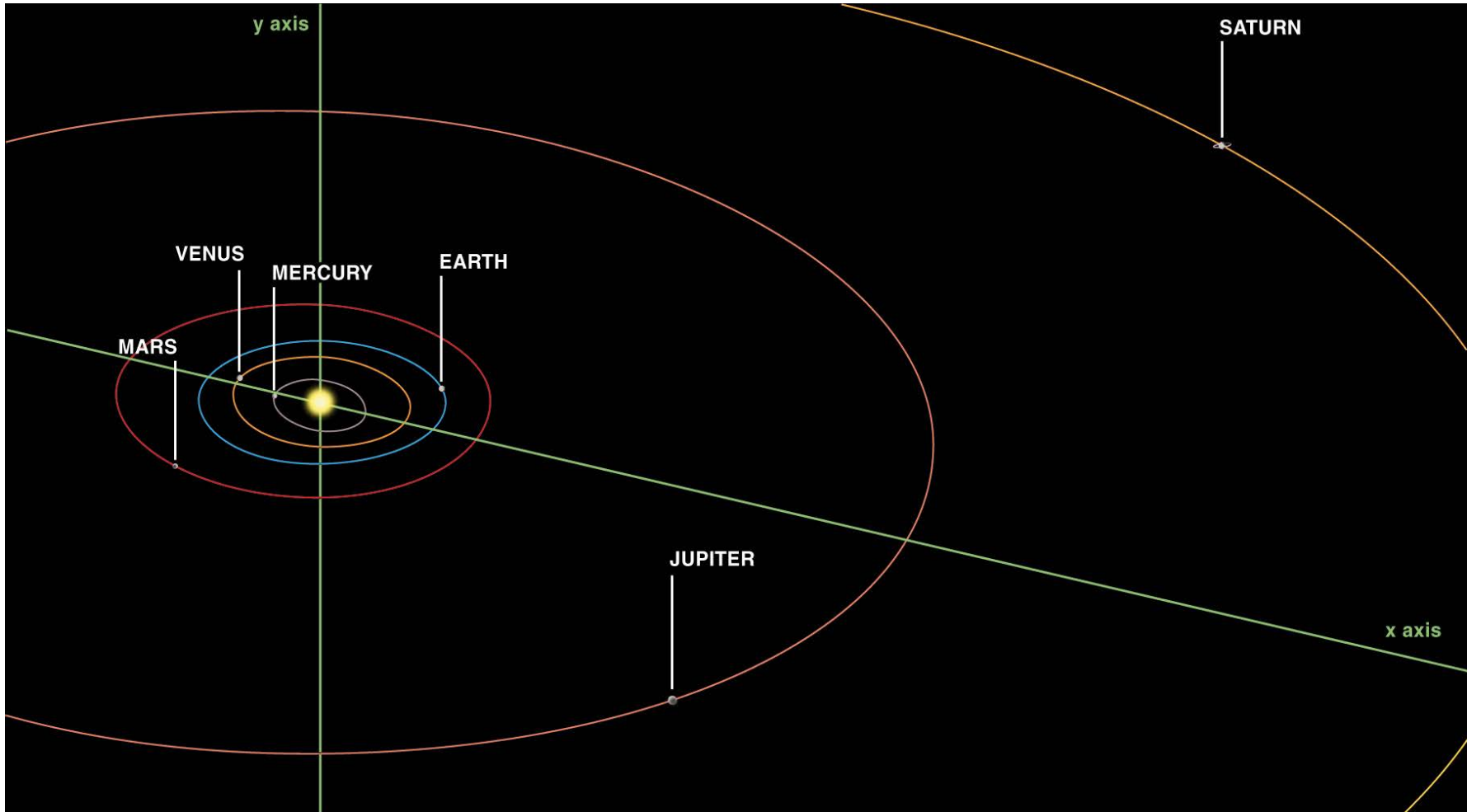
“Química do Meio Ambiente”:
Observa, mede, entende e prevê



A Terra



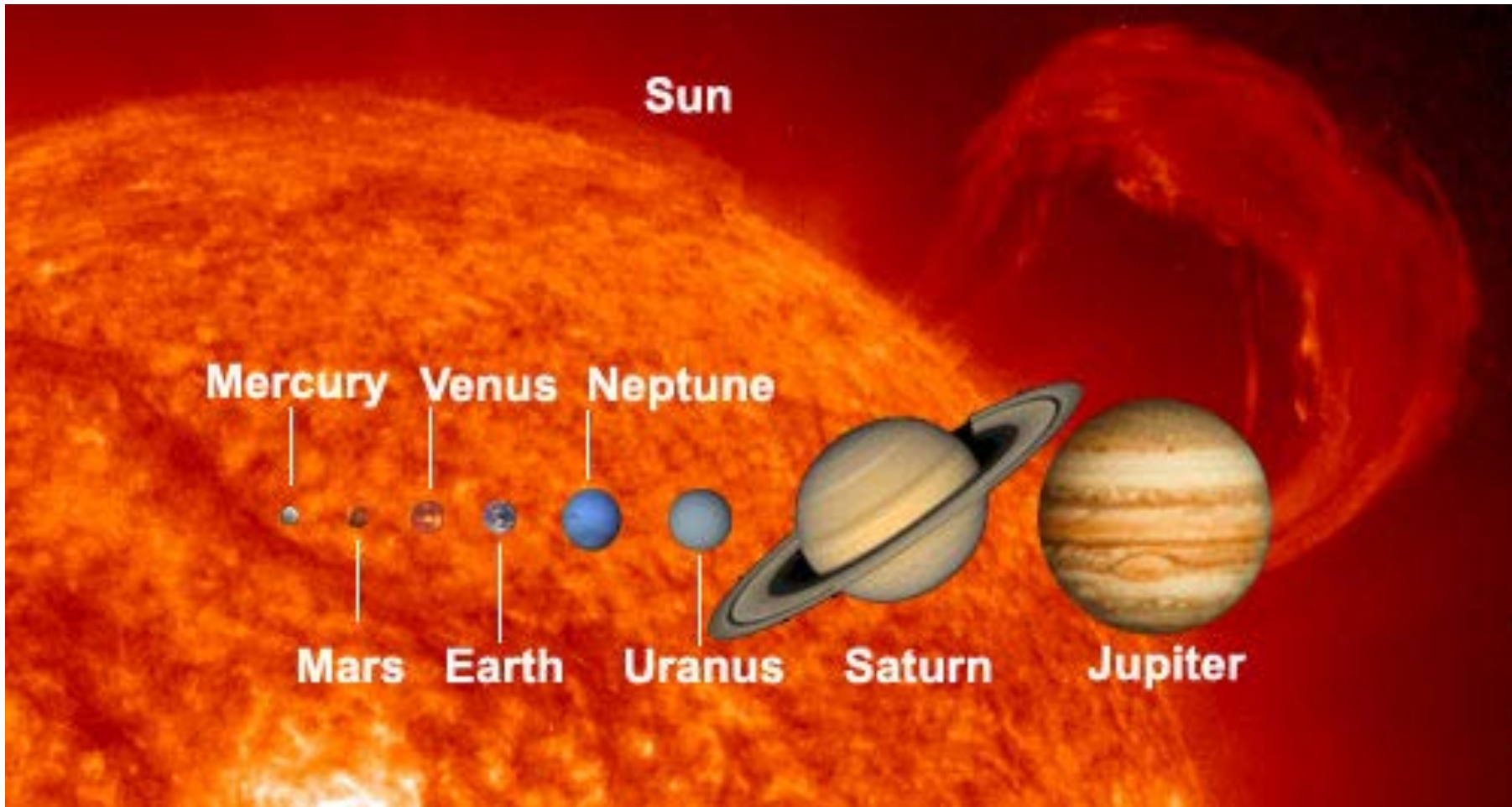
O Sistema Solar



http://solarsystem.nasa.gov/multimedia/gallery/vis_orb.jpg



O Sistema Solar



http://spaceplace.nasa.gov/review/switch-a-roo/sse_planet_sizes.en.jpg



A Terra



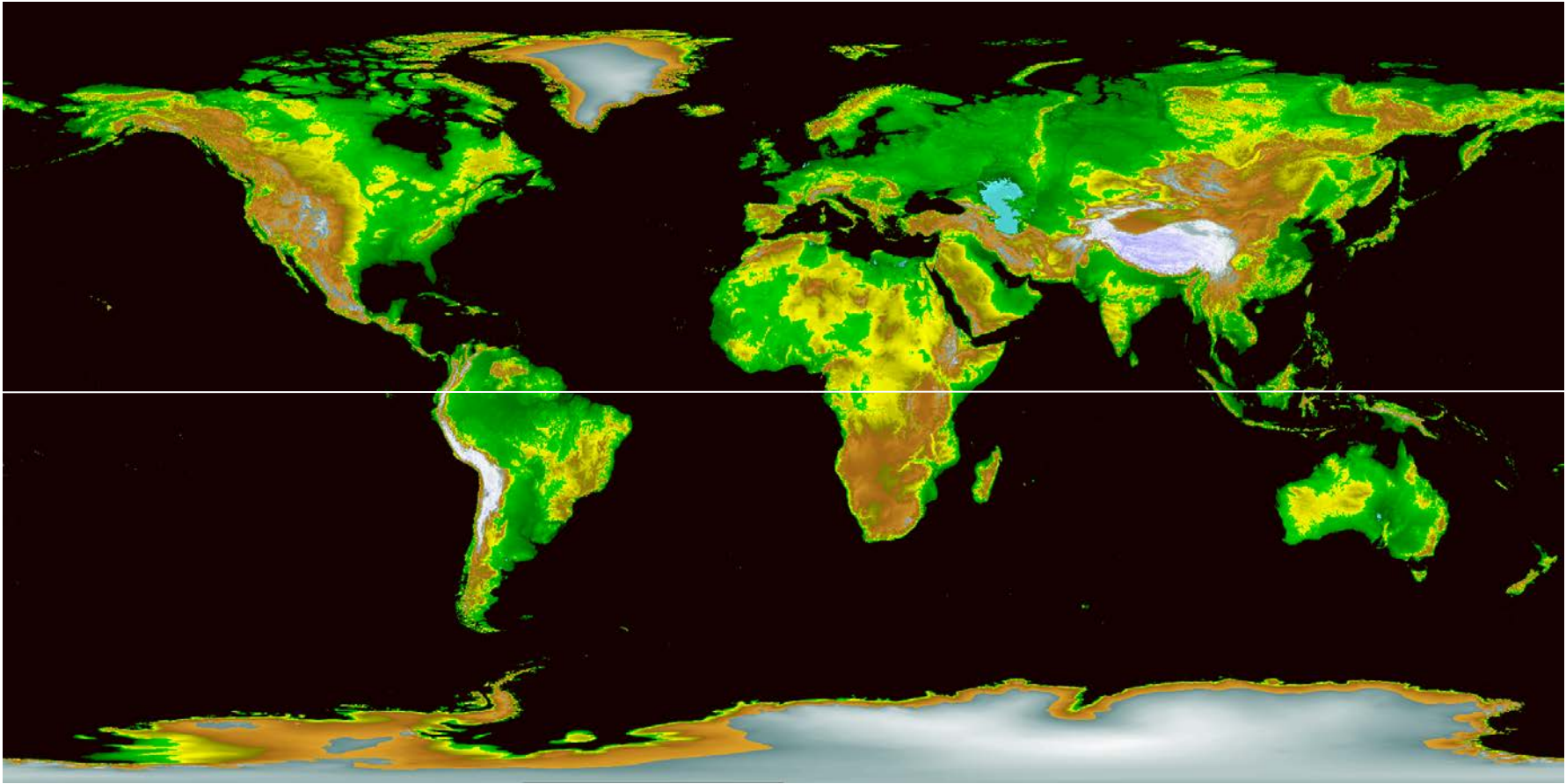
- Raio: 6.378,14 km
- Volume: $1,0832 \times 10^{12} \text{ km}^3$
- Massa: $5,9737 \times 10^{24} \text{ kg}$
- Densidade: 5.515 g/cm^3
- Área Superficial:
 $5,100657 \times 10^8 \text{ km}^2$
- Temperaturas:
-88/58 (min/max) °C

“The Blue Marble” – NASA Apollo 17

<http://solarsystem.nasa.gov/planets/profile.cfm?Object=Earth&Display=Facts&System=Metric>



Terra: Distribuição de áreas de “solo”



<http://www.ngdc.noaa.gov/mgg/topo/img/globeco2.gif>

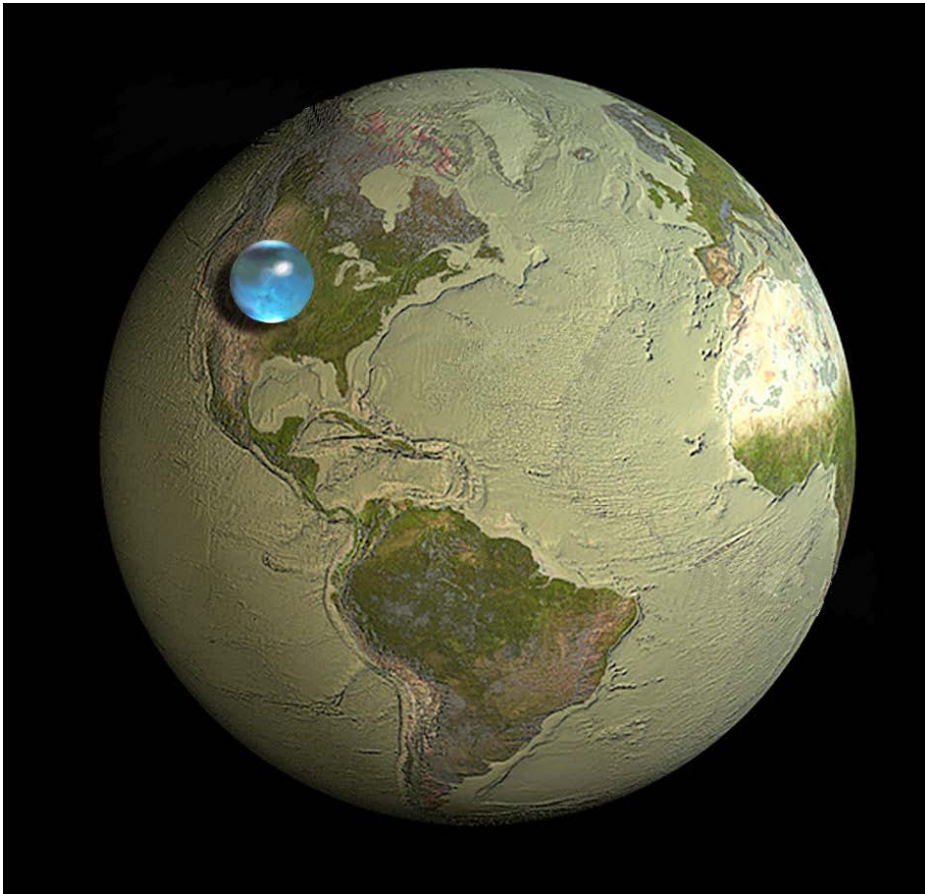
70,8% da área ocupada por água.



Terra: Quantidade de água

Volume = $1,386 \times 10^9 \text{ km}^3$ (ou $1,386 \times 10^{18} \text{ m}^3$)

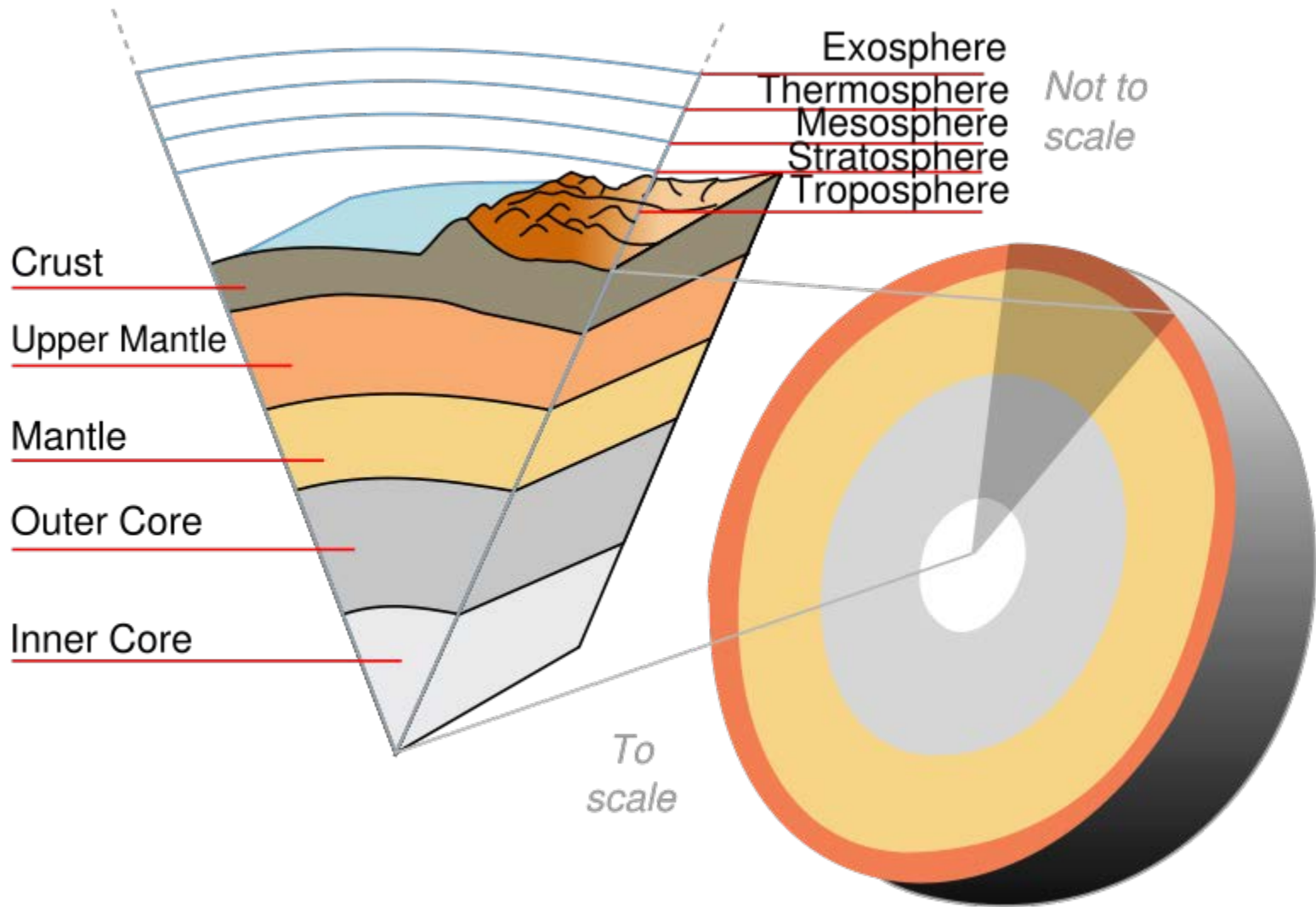
Massa = $1,4 \times 10^{18} \text{ ton}$



<https://water.usgs.gov/edu/gallery/global-water-volume.html>



Terra: Camadas



http://en.wikipedia.org/wiki/Earth#_note-EB1911



Terra: Composição química

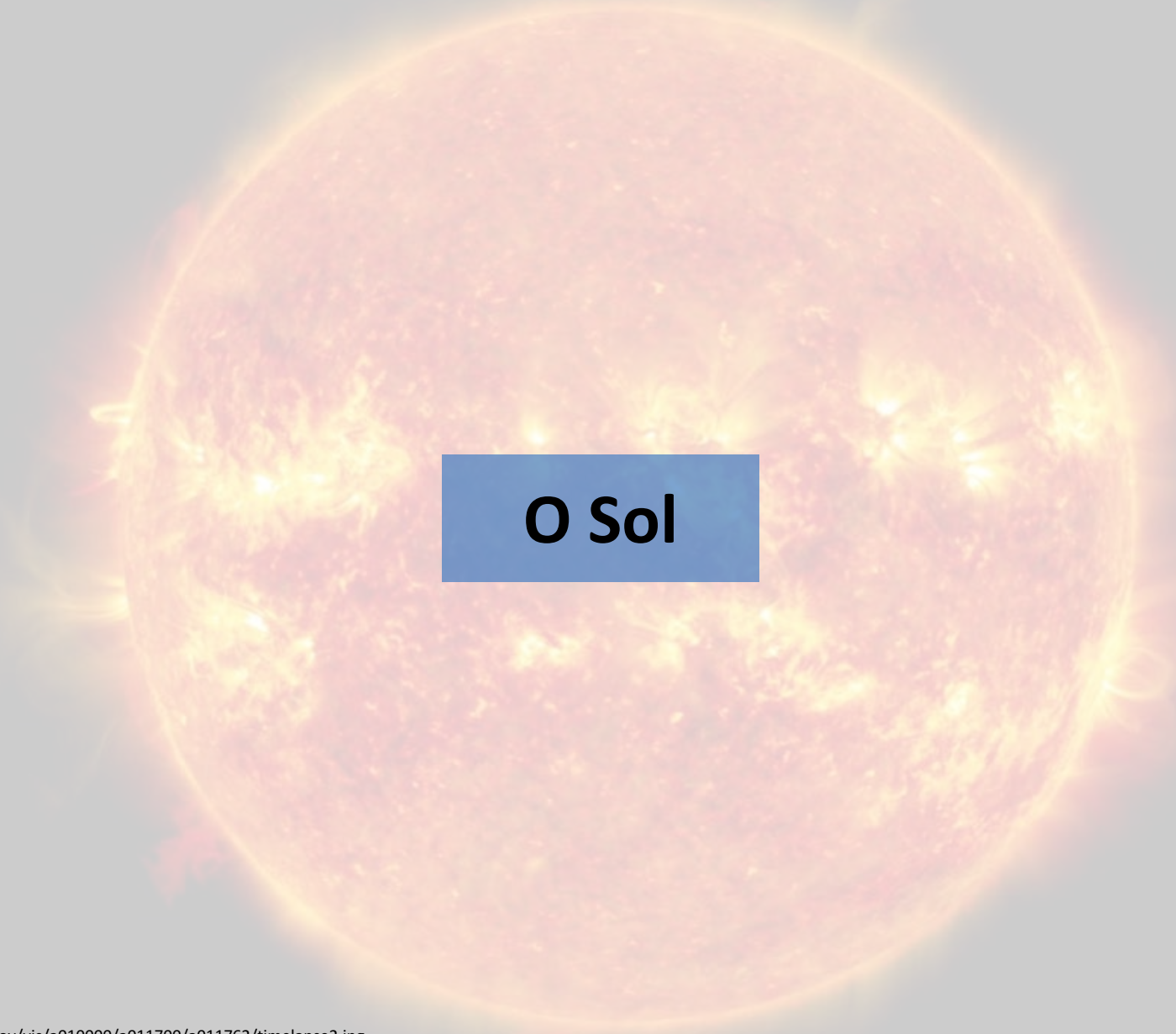
Global:

- Fe 32,1%
- O 30,1%
- Si 15,1%
- Mg 13,9%
- S 2,9%
- Ni 1,8%
- Ca 1,5%
- Al 1,4%
- Outros 1,2%

Crosta:

F. W. Clarke's Table of Crust Oxides		
Compound	Formula	Composition
silica	SiO ₂	59.71%
Alumina	Al ₂ O ₃	15.41%
Lime	CaO	4.90%
Magnesia	MgO	4.36%
Sodium oxide	Na ₂ O	3.55%
Iron (II) oxide	FeO	3.52%
Potassium oxide	K ₂ O	2.80%
Iron (III) oxide	Fe ₂ O ₃	2.63%
Water	H ₂ O	1.52%
Titanium dioxide	TiO ₂	0.60%
Phosphorous pentoxide	P ₂ O ₅	0.22%
Total		99.22%

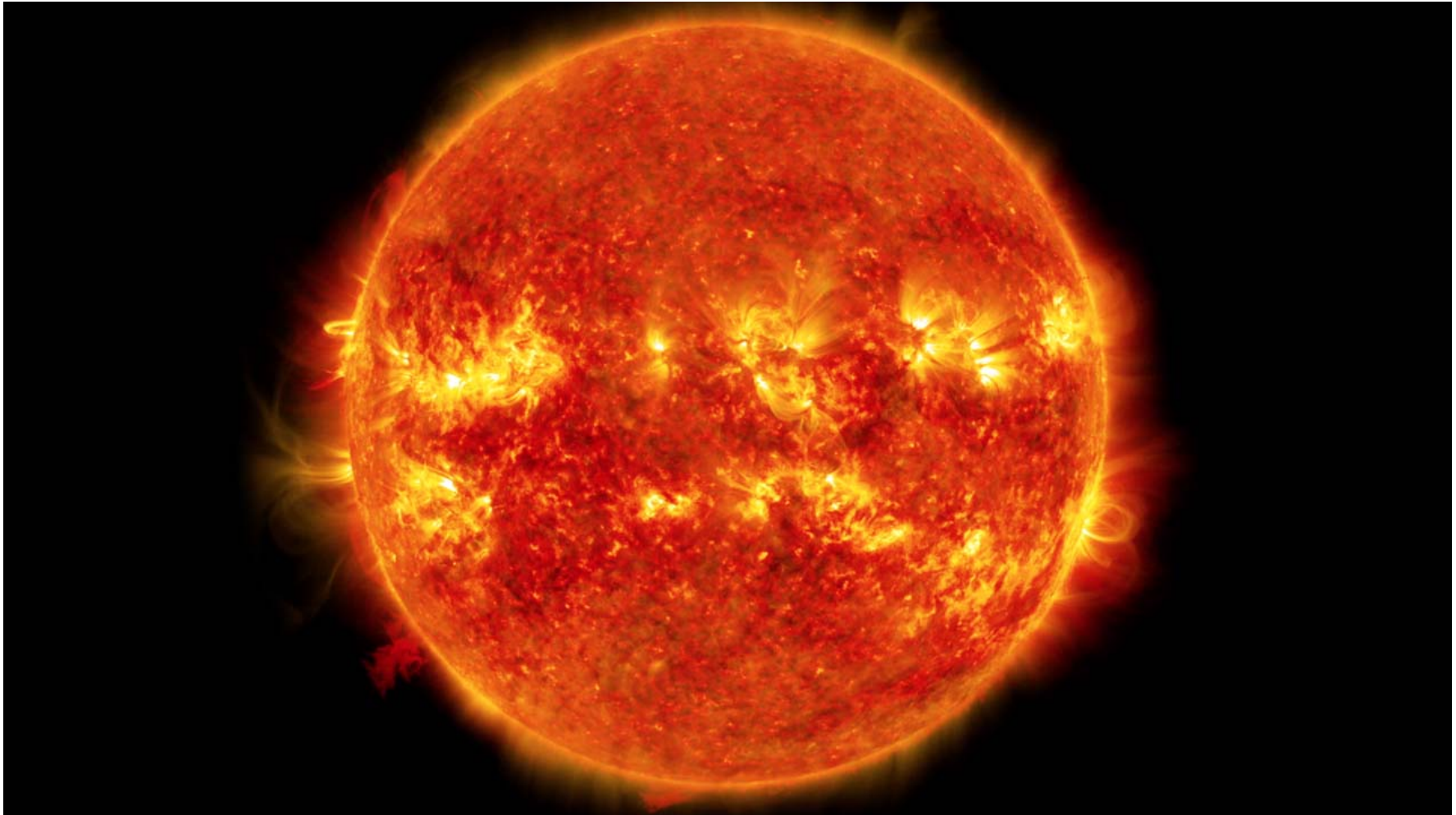
http://en.wikipedia.org/wiki/Earth#_note-EB1911



O Sol



O Sol



<http://svs.gsfc.nasa.gov/vis/a010000/a011700/a011762/timelapse2.jpg>

Vídeo "5 anos SDO" neste link: <https://svs.gsfc.nasa.gov/11742>



Terra vs. Sol

	Sol	Terra	Razão S/T
Massa (kg)	2×10^{30}	6×10^{24}	333.000
Raio (km)	695.700	6.378	109
Volume (km ³)	$1,41 \times 10^{18}$	$1,08 \times 10^{12}$	1.300.000
Densidade Média (g/cm ³)	1,41	5,52	0,255
Temperatura	Centro $1,6 \times 10^7$ K Fotosfera 5.772 K Corona 5×10^6 K	Média 288 K	
Composição Aproximada	74% H 25% He 1% Outros	32,1% Fe 30,1% O 15,1% Si 13,9% Mg 2,9% S 5,9% Outros	

Dados da Wikipedia



Terra: Fontes de Energia

SOL

- Irradia $1,17 \times 10^{31}$ kJ/ano !!!
- Terra intercepta pequena fração: $54,4 \times 10^{20}$ kJ/ano

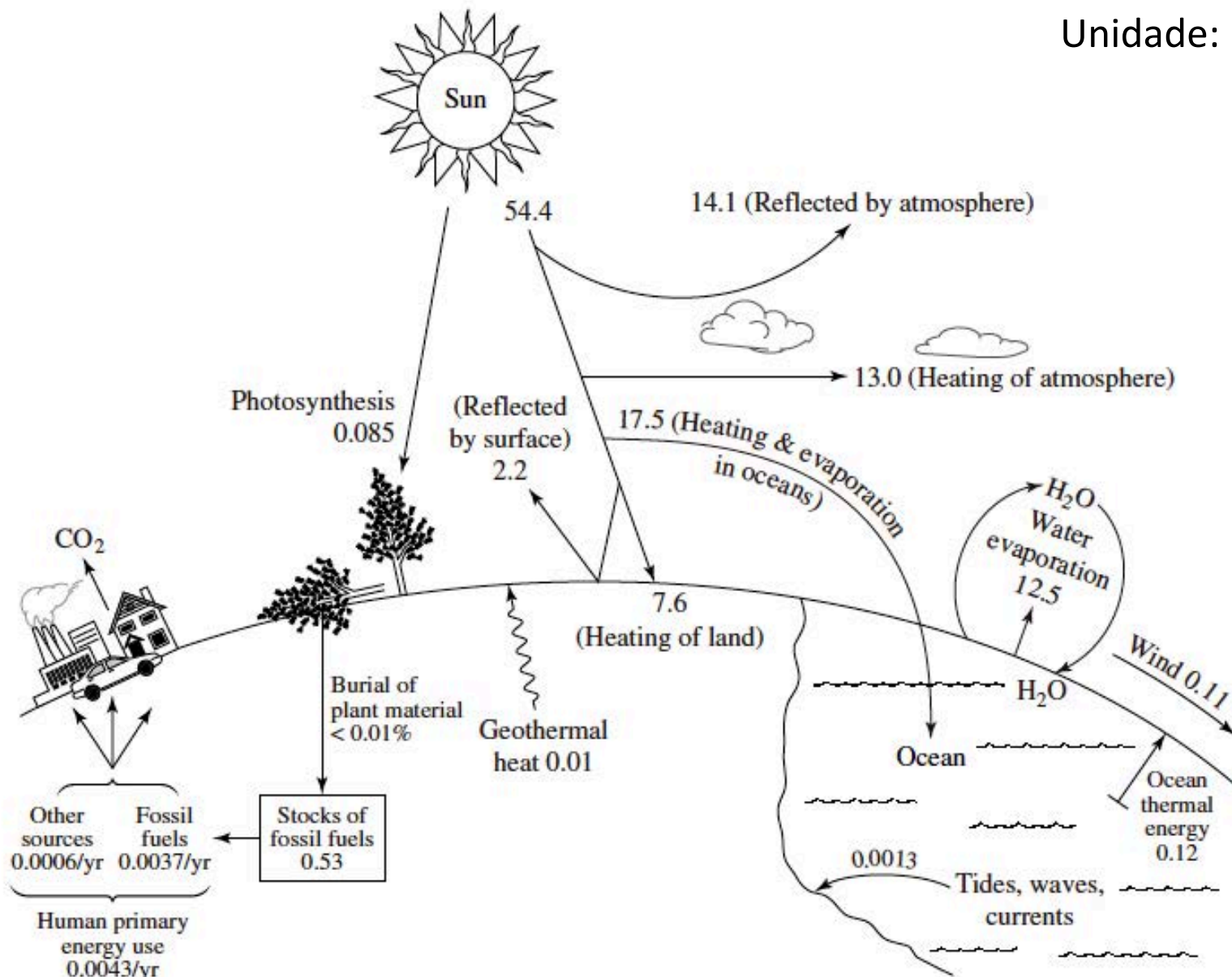
Outras Fontes

- Marés (atração gravitacional): $0,0013 \times 10^{20}$ kJ/ano
- Calor geotérmico (núcleo da Terra): $0,01 \times 10^{20}$ kJ/ano
- Energia nuclear



Terra: Fluxo de Energia

Unidade: 10^{20} kJ/ano



Spiro & Stigliani, *Chemistry of the Environment*, 2nd ed., 2002.



Terra: Fluxo de Energia

- 30% refletida (albedo – 24% atmosfera e 4% superfície).

Convertido em calor e irradiado de volta para o espaço:

- 24% absorvida pela atmosfera;
- 14% absorvida pela superfície terrestre;
- 32% absorvida pelos oceanos.

Da energia absorvida:

- 50% "circula" pelo ciclo hidrológico;
- Calor de vaporização H₂O (a 15°C) – 2,46 kJ/g;
- Mesmo chuvas fracas envolvem uma enorme quantidade de energia!

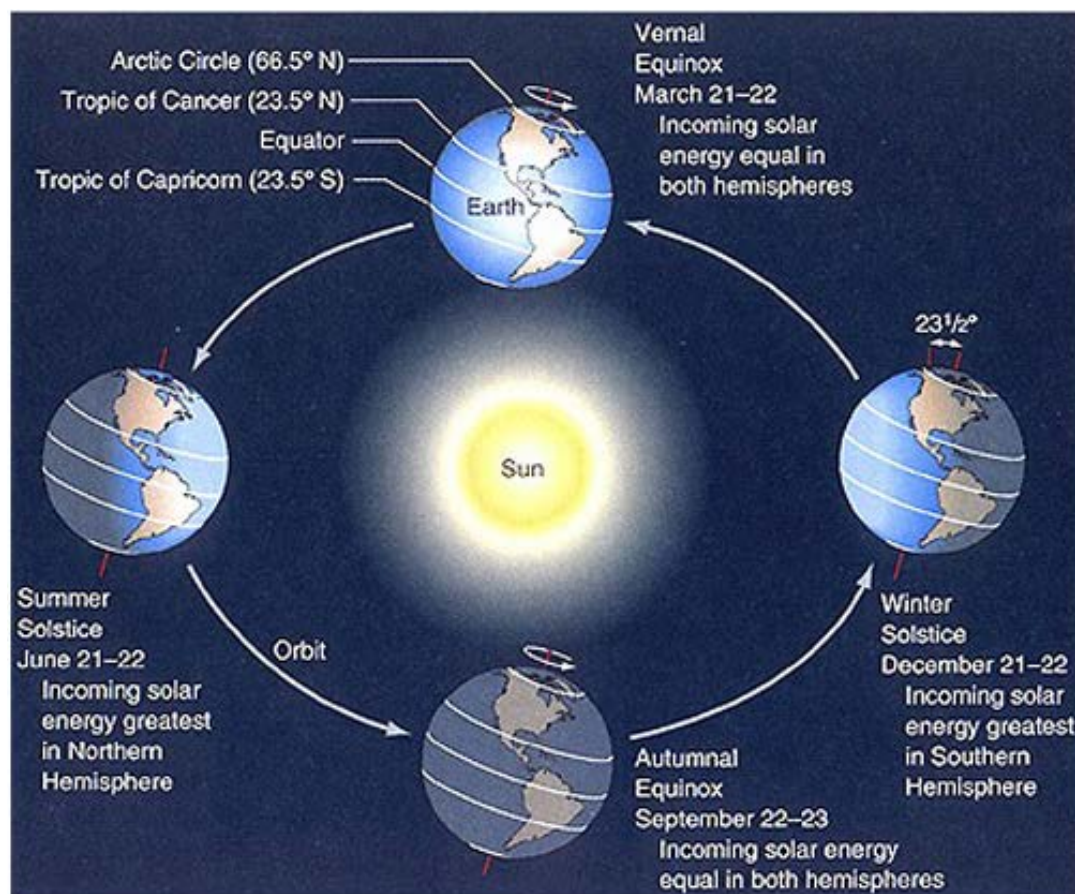


Terra: Estações do Ano

Distância da Terra ao Sol?

- Periélio (~147 milhões de km) – 3 de janeiro;
- Afélio (~152 milhões de km) – 4 de julho

Eixo de “precessão”?



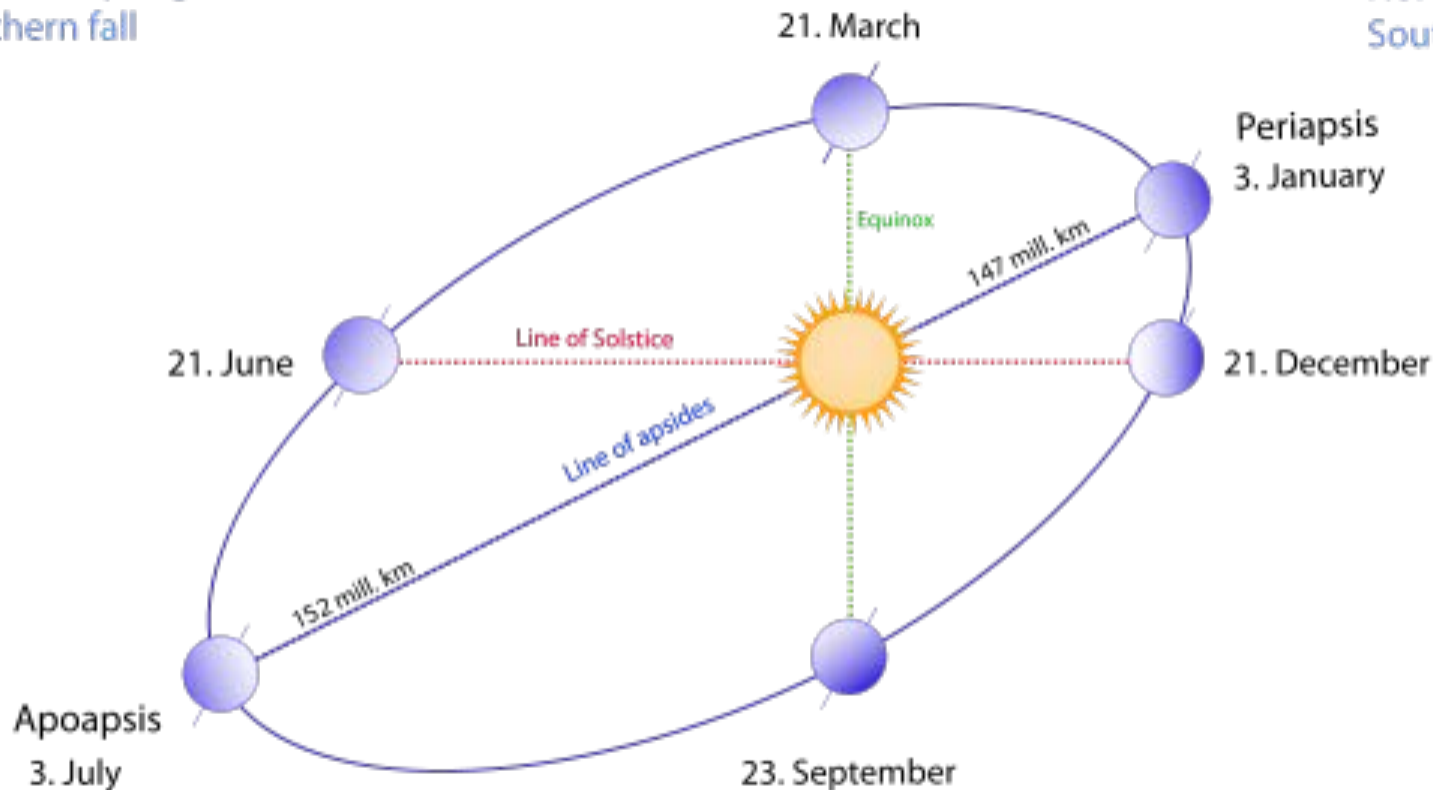
http://solarsystem.nasa.gov/multimedia/gallery/Solstice_Equinox-732X520.jpg



Terra: Estações do Ano

Northern spring/
Southern fall

Northern winter/
Southern summer



Northern summer/
Southern winter

Northern fall/
Southern spring

http://en.wikipedia.org/wiki/Earth's_orbit



Terra: Estações do Ano



Imagens obtidas pelo Satélite Geoestacionário Meteosat-9 (usando o SEVIRI - Spinning Enhanced Visible and Infrared Imager), às 6:12 da manhã dos dias 21/12/2010, 20/03/2010, 21/06/2010 e 20/09/2010.



Terra: Radiação Solar

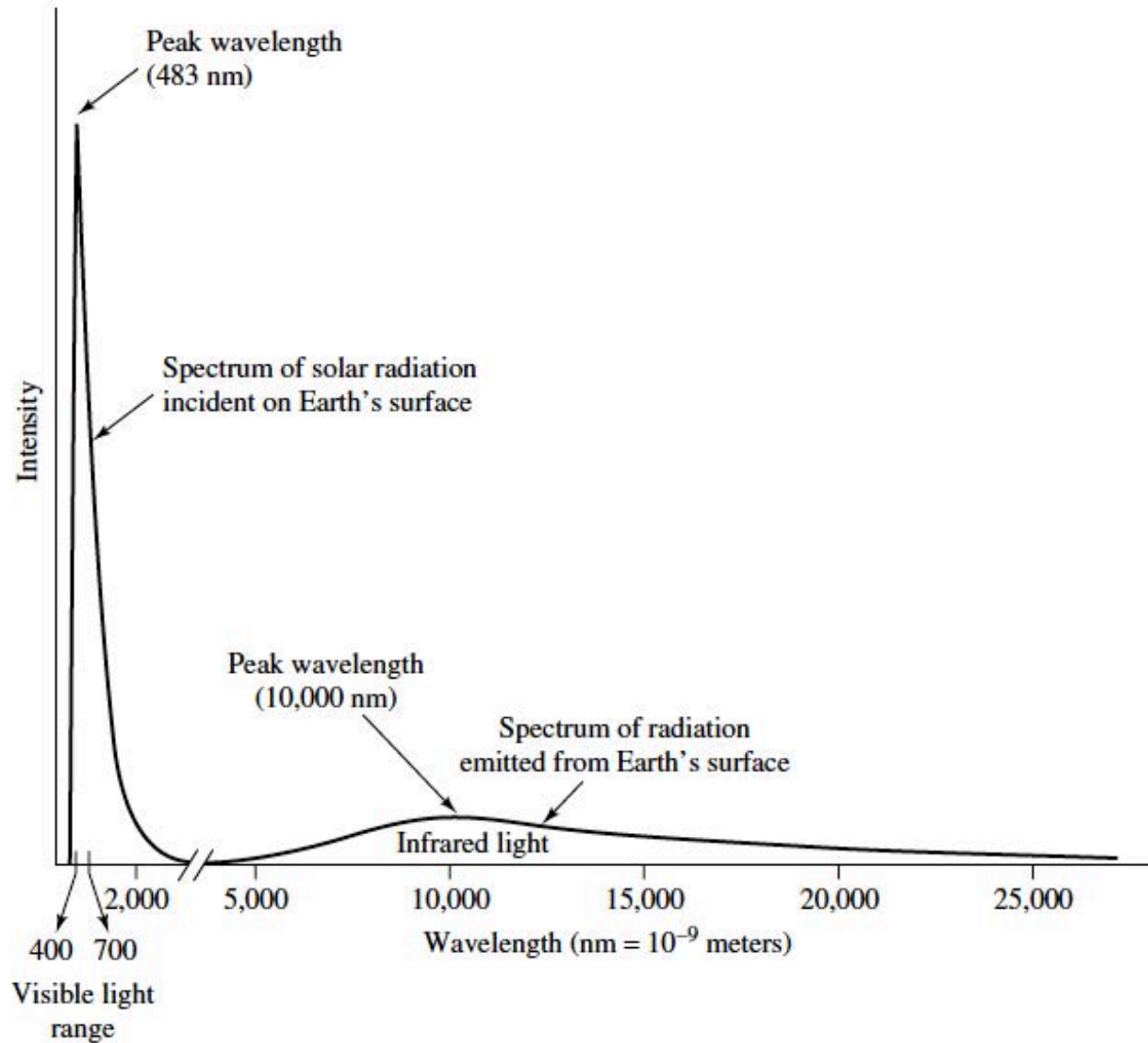


Figure 6.1 Spectral distribution of solar and terrestrial radiation.

Spiro & Stigliani, Chemistry of the Environment, 2nd ed., 2002.



Terra: Balanço Energético

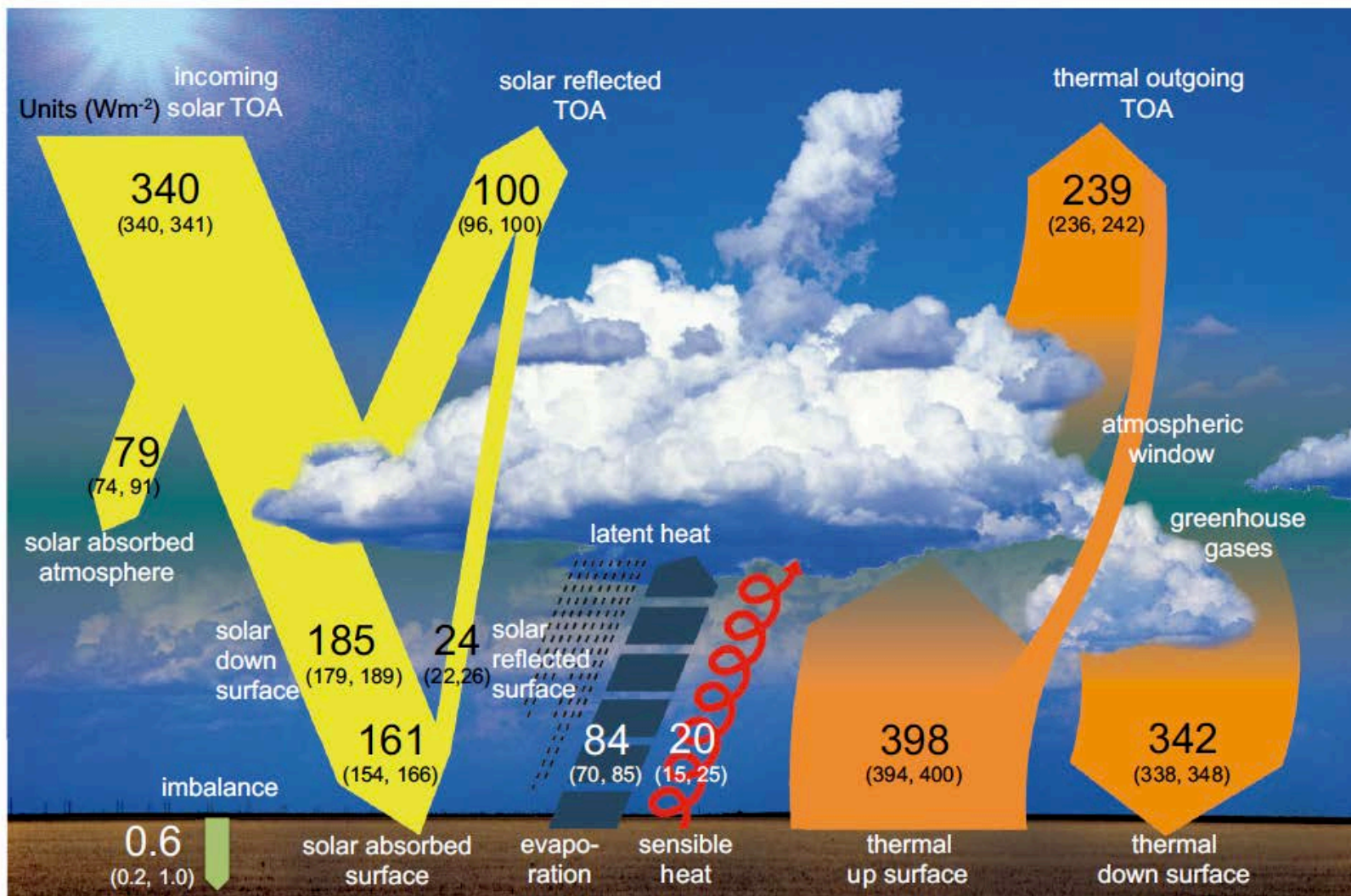


Figure 2.11: | Global mean energy budget under present-day climate conditions. Numbers state magnitudes of the individual energy fluxes in $W m^{-2}$, adjusted within their uncertainty ranges to close the energy budgets. Numbers in parentheses attached to the energy fluxes cover the range of values in line with observational constraints. (Adapted from Wild et al., 2013.)



Terra: "Janela Atmosférica"

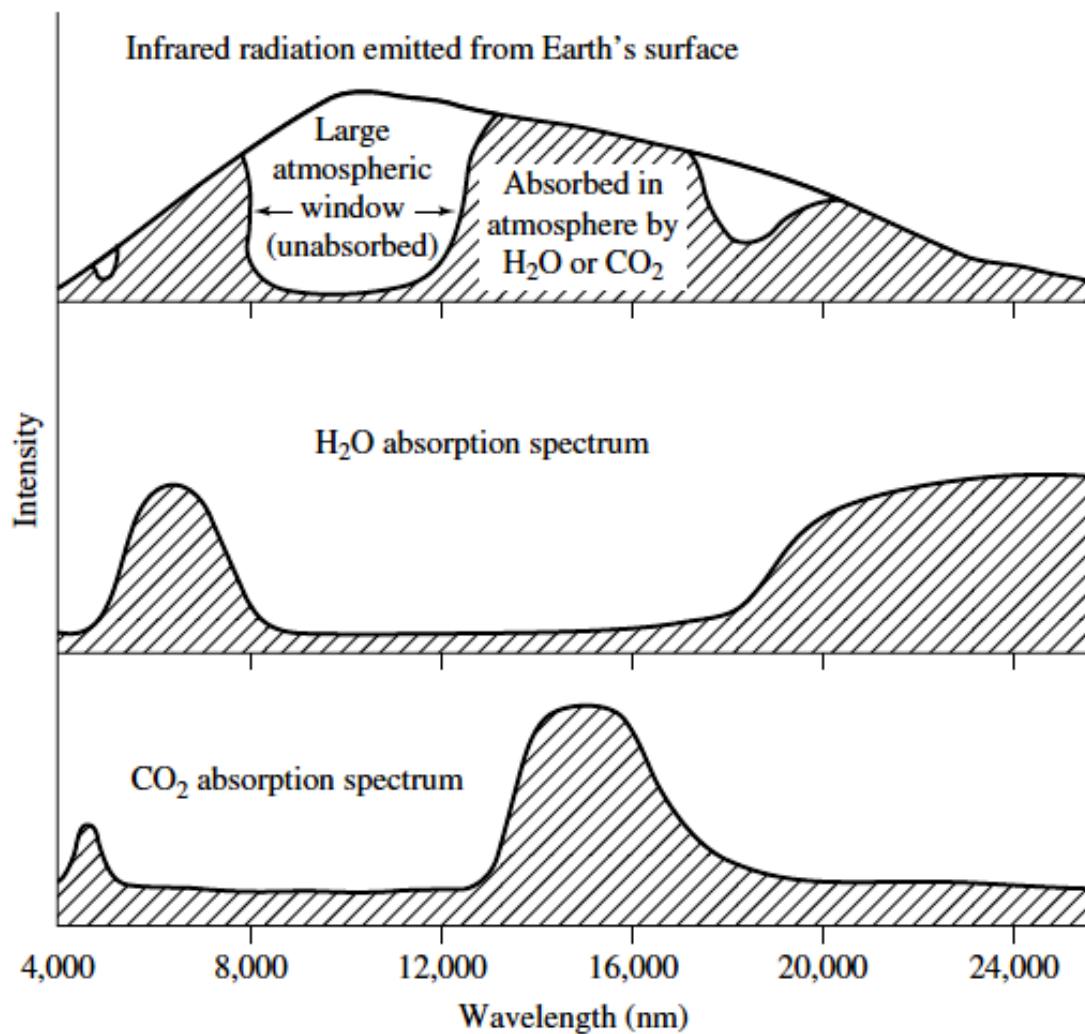


Figure 6.14 Absorption of terrestrial radiation by water and carbon dioxide.



Terra: "Janela Atmosférica"

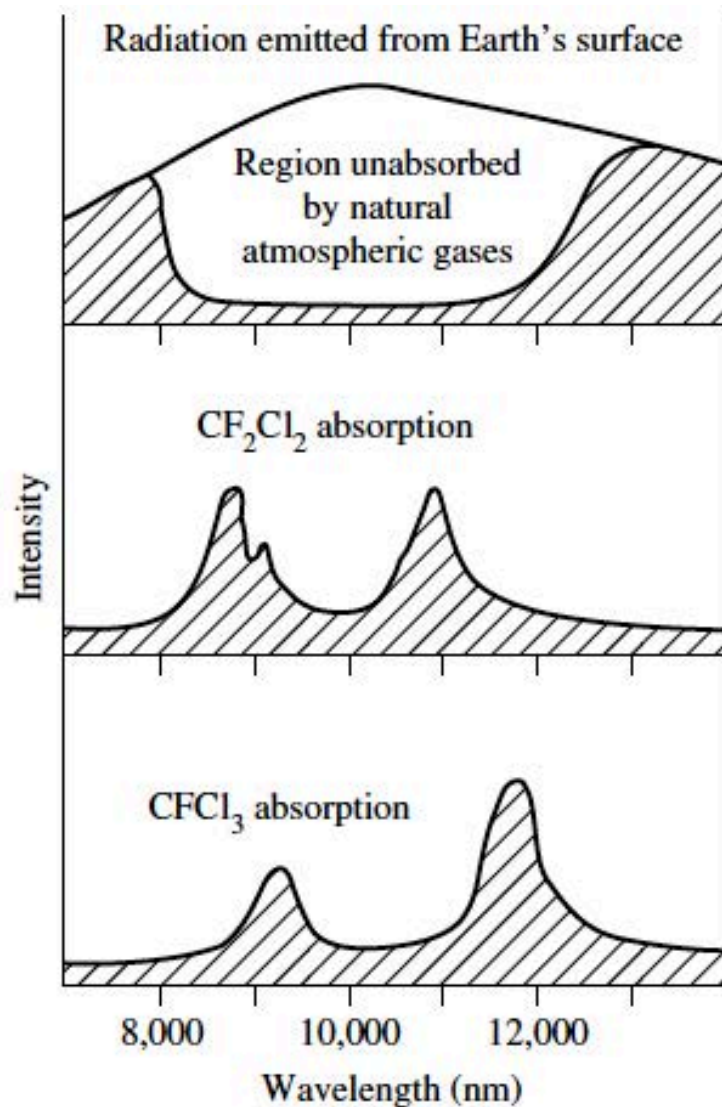


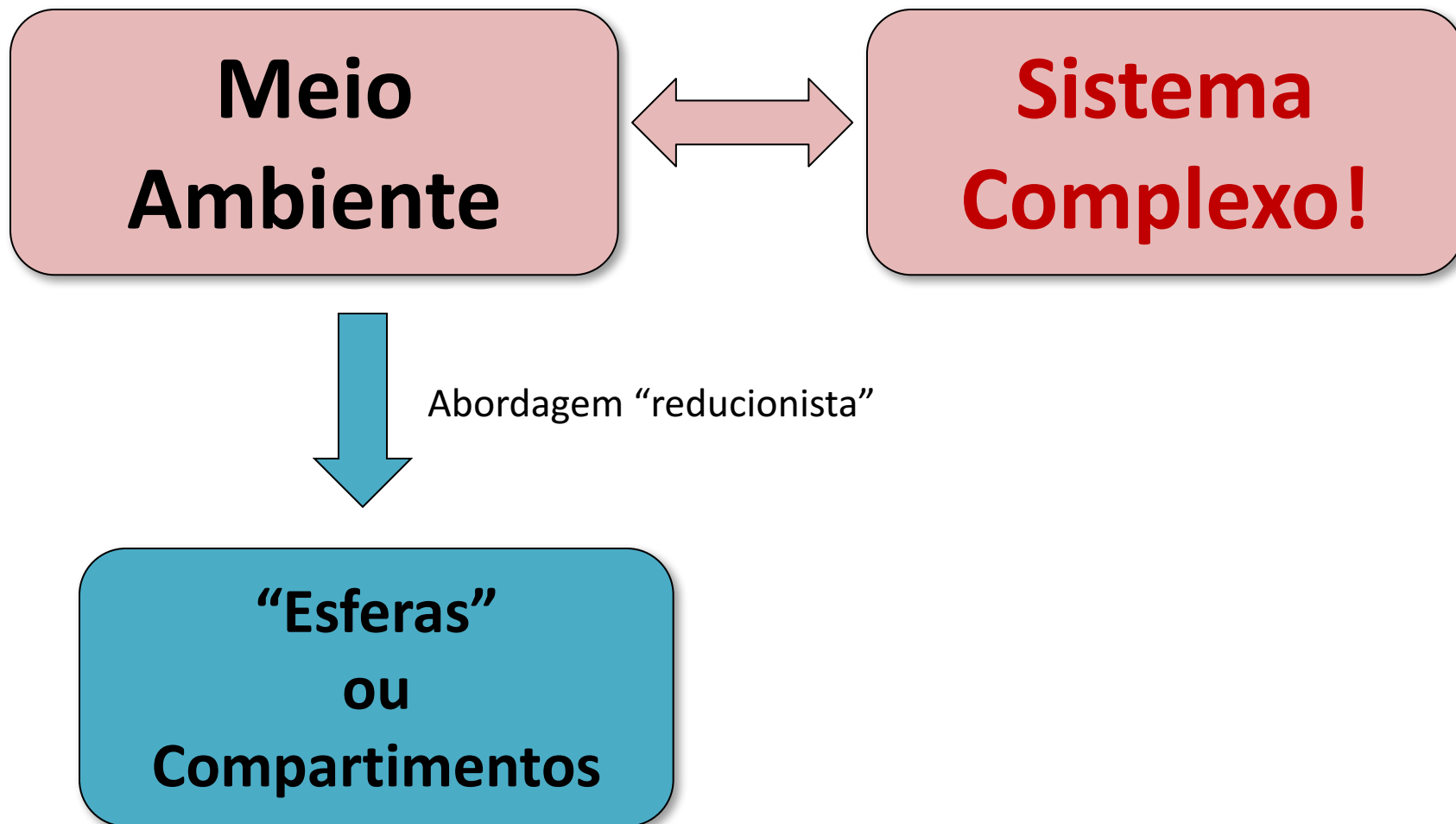
Figure 6.15 Absorption spectra of chlorofluoromethanes (CF₂Cl₂ and CFC₁₃) and their coincidence with the atmospheric window (8,000 to 13,000 nm).



O Meio Ambiente

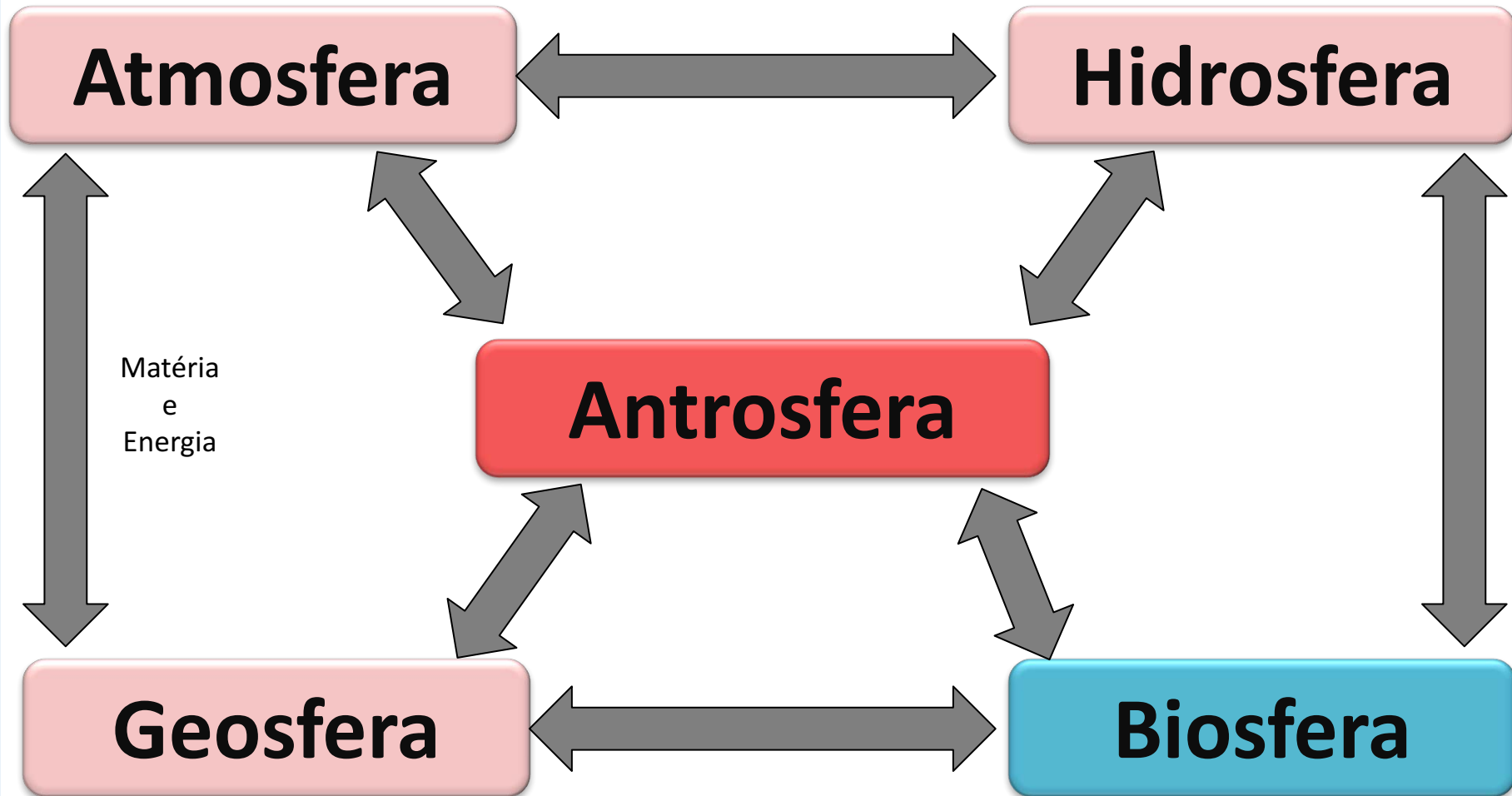


O Meio Ambiente





Compartimentos Ambientais





A Atmosfera



A Atmosfera



http://www.allsciencesites.com/news/gallery/science/earth_atmosphere.jpg

“Envelope” gasoso que circunda a Terra, composto de uma mistura de gases e líquidos/sólidos suspensos (aerossóis)



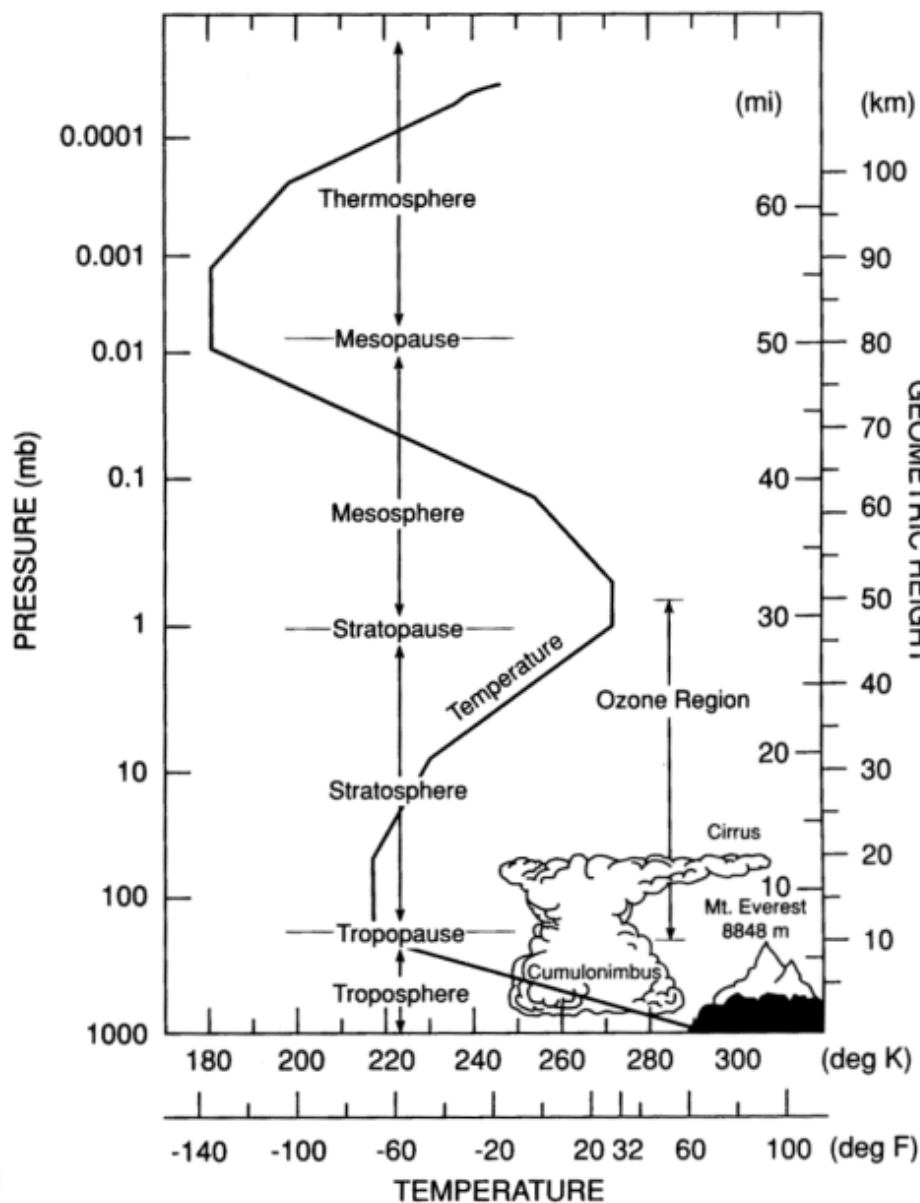
Atmosfera: Composição

Constituinte	Massa Molar (g/mol)	Razão de Mistura (mol/mol)
Nitrogênio (N ₂)	28,016	0,7808
Oxigênio (O ₂)	32,00	0,2095
Argônio (Ar)	39,94	0,0093
Vapor de água (H ₂ O)	18,02	0 – 0,04
Dióxido de Carbono (CO ₂)	44,01	365 x 10 ⁻⁶
Neônio (Ne)	20,18	18 x 10 ⁻⁶
Hélio (He)	4,00	5,2 x 10 ⁻⁶
Metano (CH ₄)	16,04	1,7 x 10 ⁻⁶
Criptônio (Kr)	83,7	1,1 x 10 ⁻⁶
Hidrogênio (H ₂)	2,02	0,50 x 10 ⁻⁶
Ozônio (O ₃)	48,00	0 - 12 x 10 ⁻⁶
Óxido Nitroso (N ₂ O)	44,01	0,32 x 10 ⁻⁶

$$MM_{ar} = C_{N_2} MM_{N_2} + C_{O_2} MM_{O_2} + C_{Ar} MM_{Ar} = 28,96 \times 10^{-3} \text{ kg / mol}$$



Atmosfera: Camadas



- Definidas pelo gradiente de temperatura;
- “pausas” = regiões intermediárias (“fronteiras”)

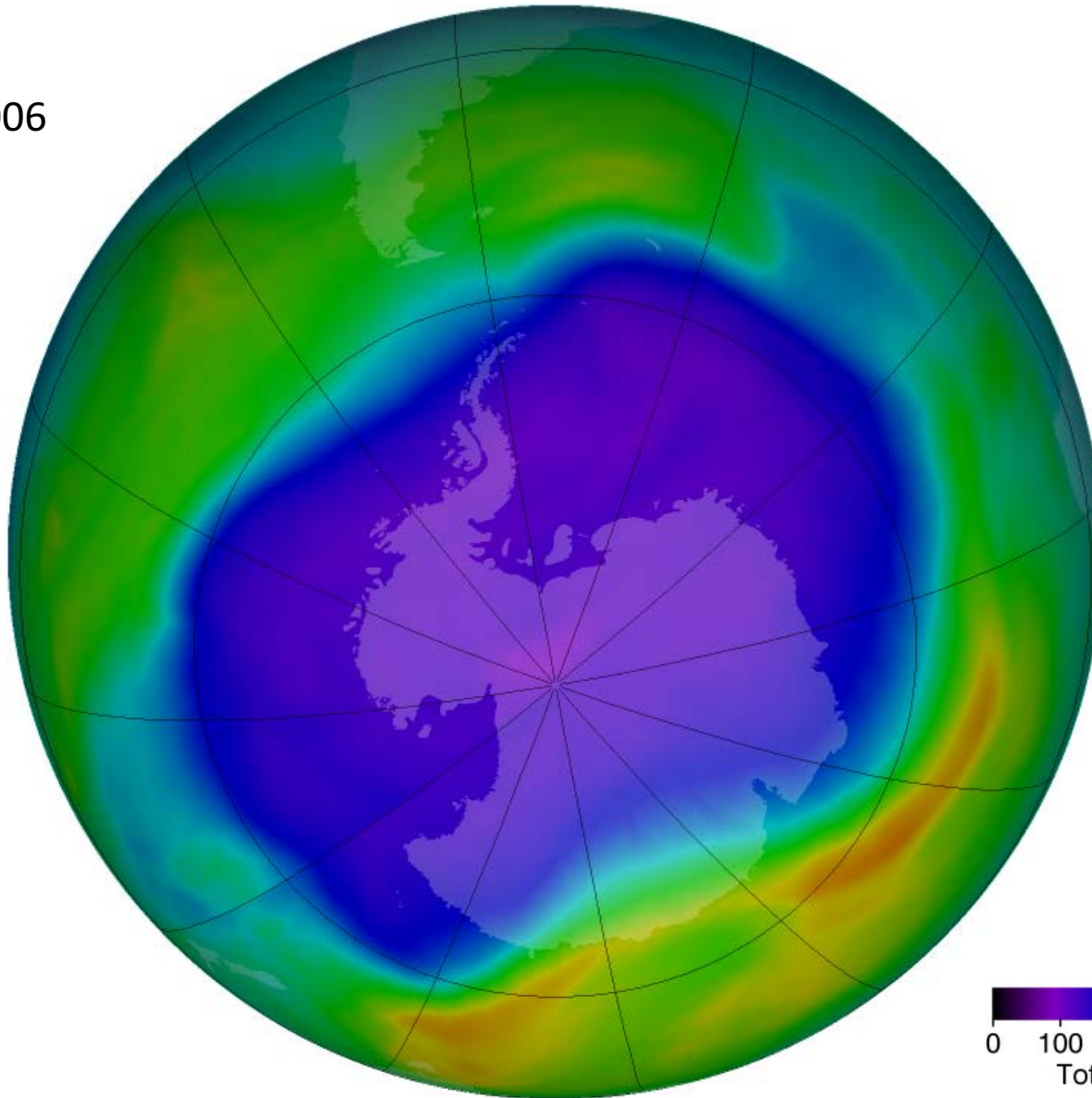


”Buraco” na Camada de Ozônio

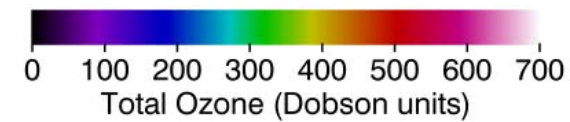


Buraco na Camada de Ozônio

Recorde:
24/09/2006



Calculado usando o
limite de 220 DU



http://ozonewatch.gsfc.nasa.gov/Scripts/big_image.php?date=2006-09-24&hem=S

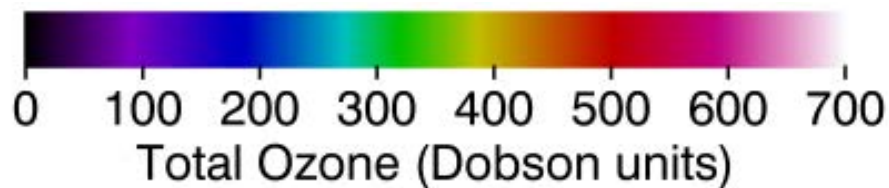


Unidades Dobson: densidade de coluna

1 Unidade Dobson = espessura que o ozônio iria ocupar se fosse comprimido a uma densidade uniforme, $T= 273,15\text{K}$ e $P= 1\text{ atm}$, em unidades de 10^{-3} cm .

$$1\text{ Dobson} = 446,2\ \mu\text{mol}/\text{m}^2 = 21,4\ \text{mg}/\text{m}^2\ \text{de ozônio.}$$

O valor médio típico é ao redor de 300 DU

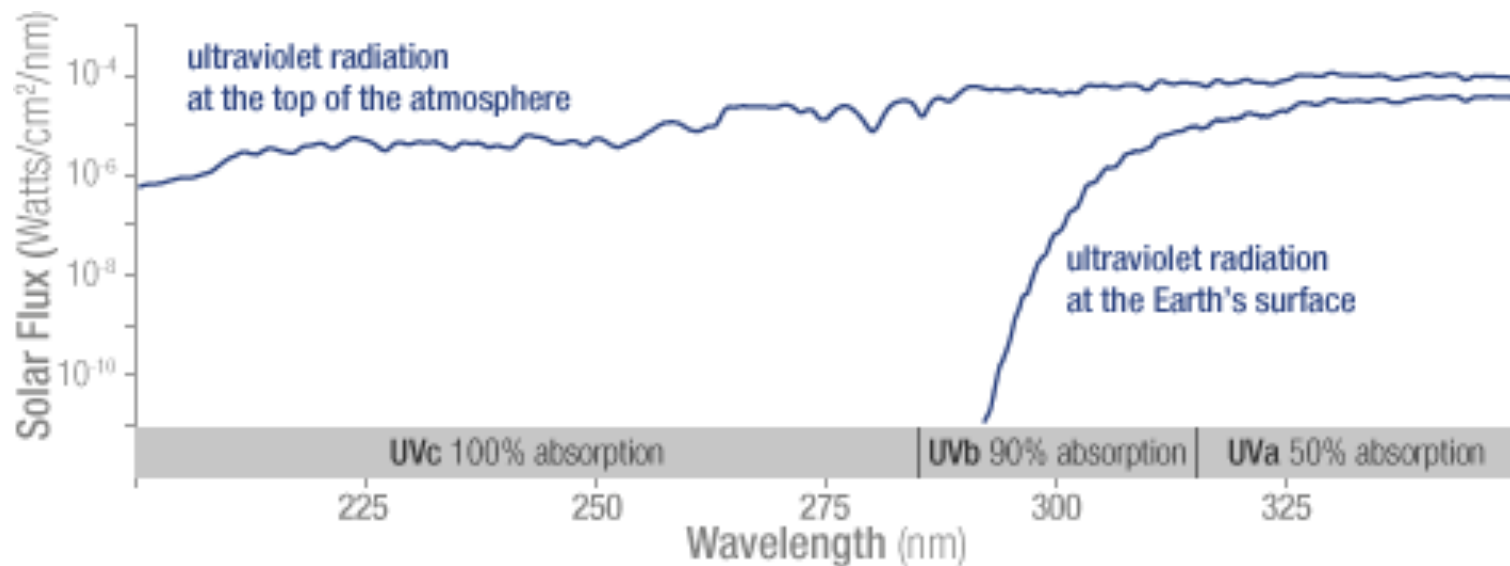


IUPAC: S. E. Schwartz; P. Warneck (1995). "Units for use in atmospheric chemistry". Pure Appl. Chem. 67, p.1377–1406 (1995)



Por quê é um problema?

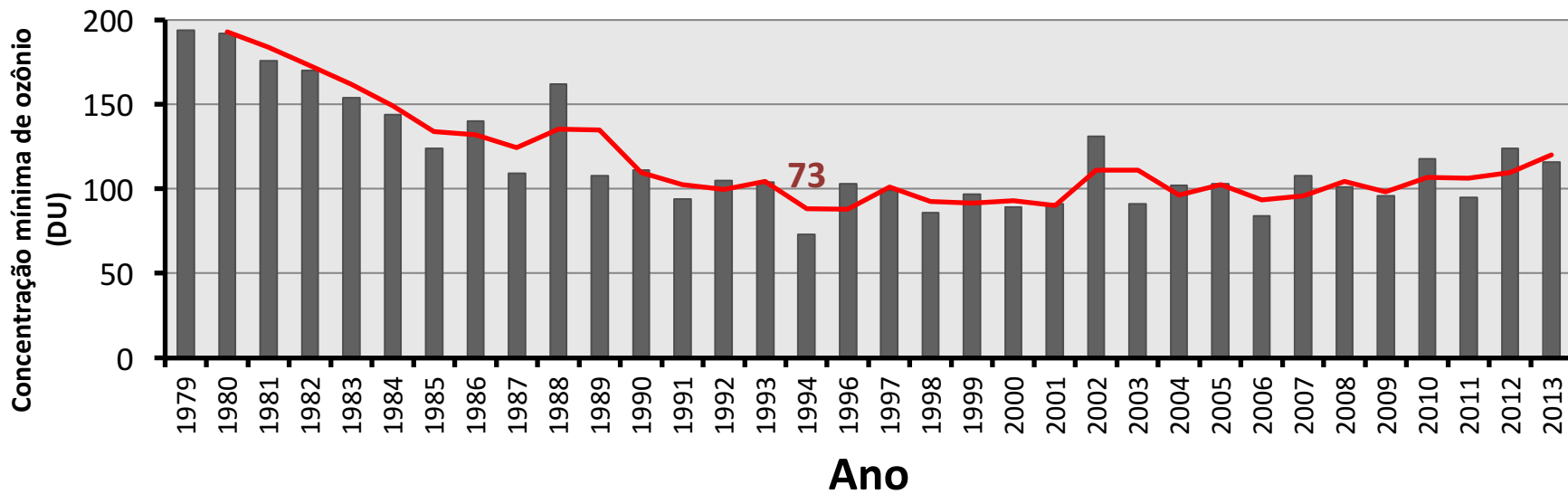
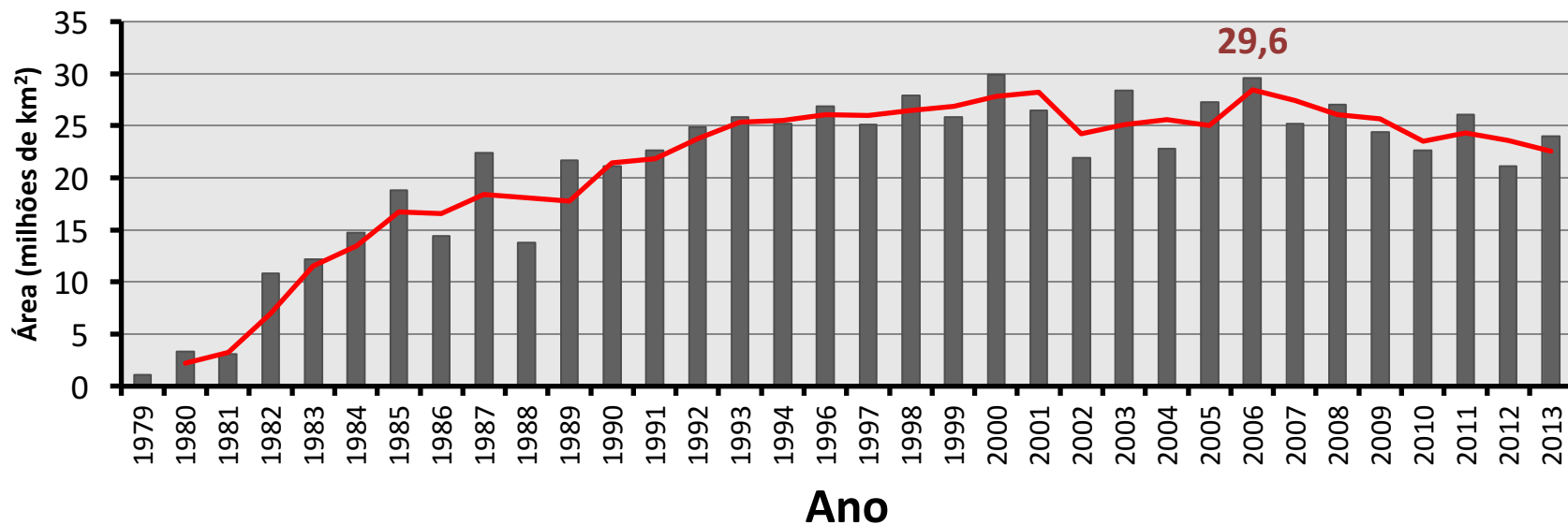
Fluxo de radiação solar



http://ozonewatch.gsfc.nasa.gov/facts/images/uv_flux_graph.gif



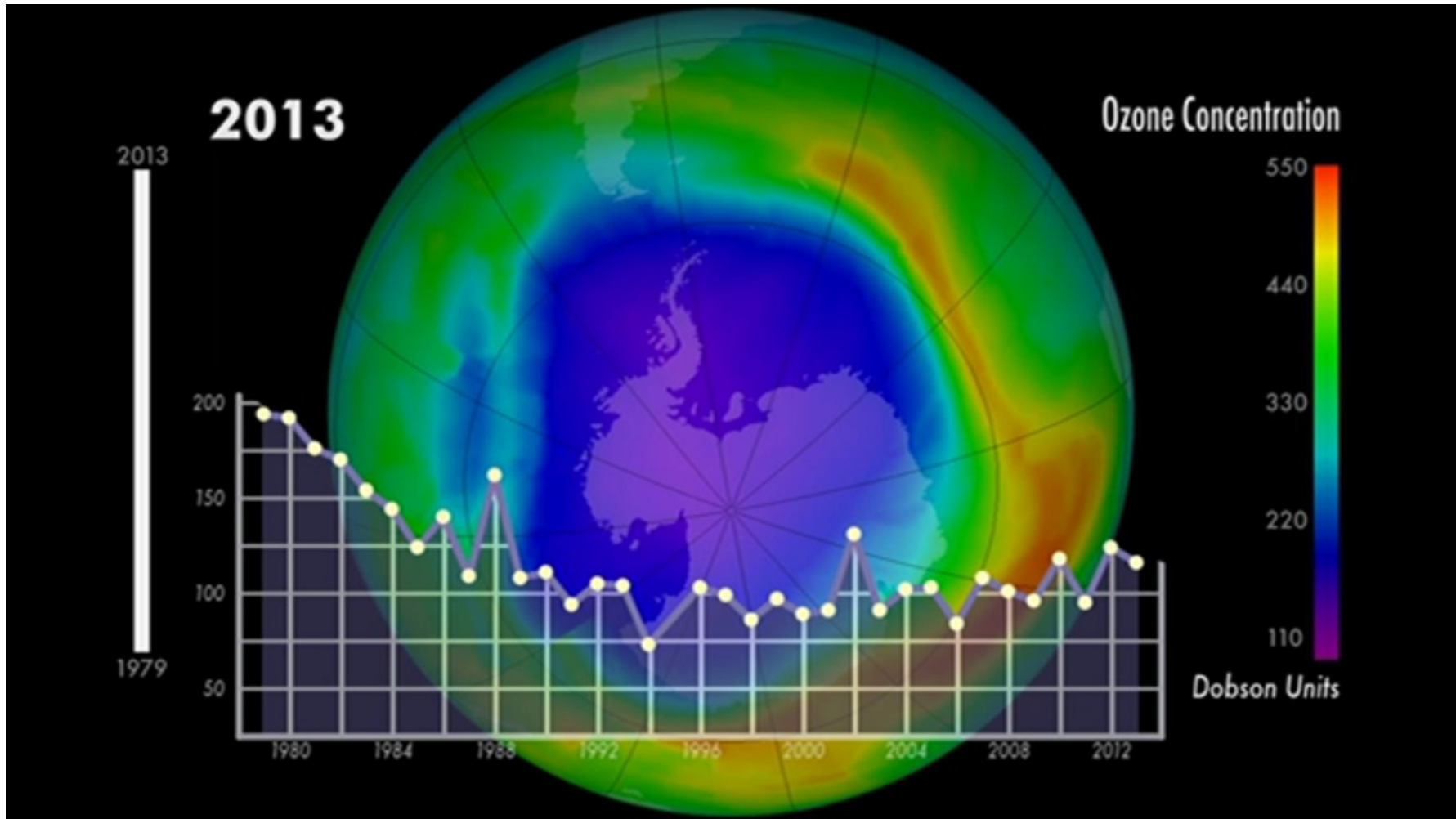
Buraco na Camada de Ozônio



http://ozonewatch.gsfc.nasa.gov/meteorology/ytd_data.txt



Buraco na Camada de Ozônio

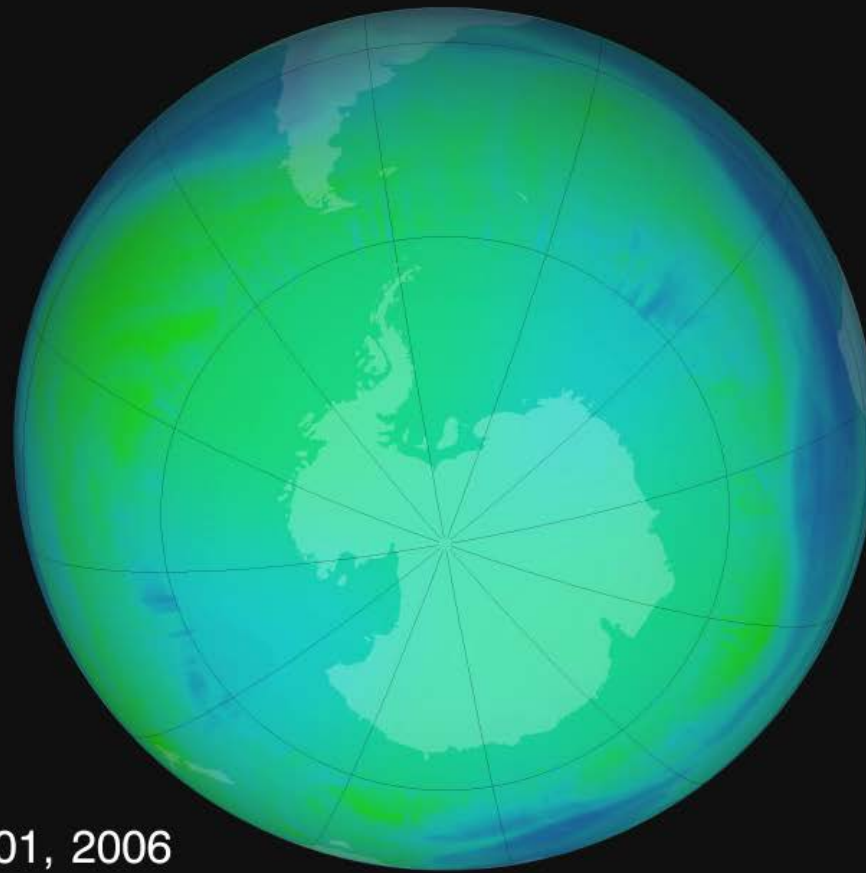


<http://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=11648>

Vídeo em: http://svs.gsfc.nasa.gov//vis/a010000/a011600/a011648/Ozone_minimums_with_graph_ipod_lg.m4v



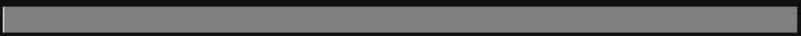
Buraco na Camada de Ozônio: Sazonal



Jul 01, 2006

Jul 01

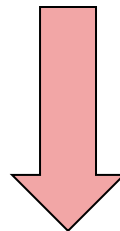
Dec 31





Origem do Problema

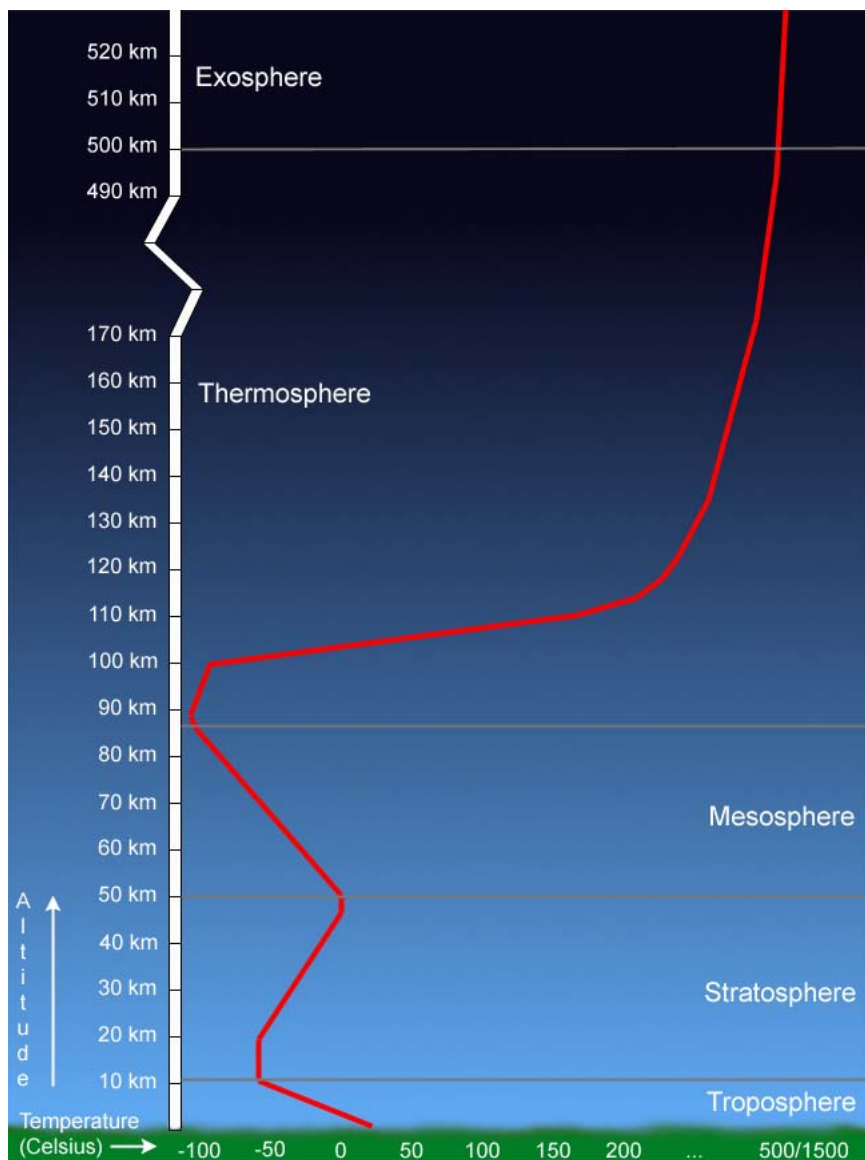
CFCs + $h\nu$



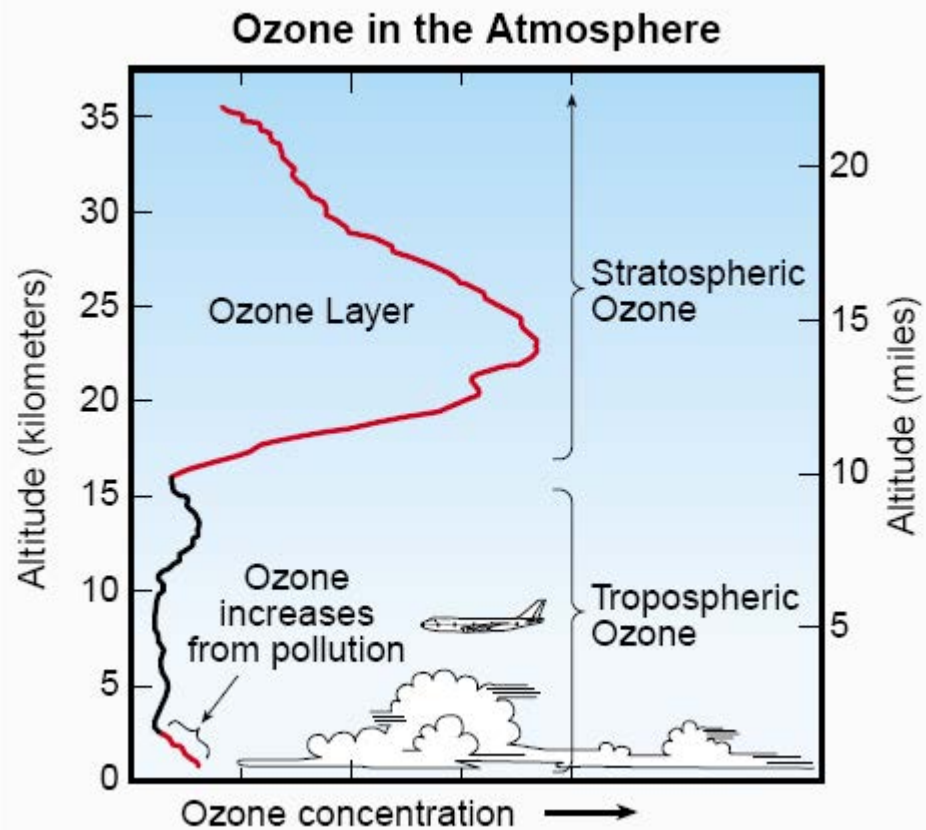
**Destruição do
Ozônio**



Ozônio Estratosférico



<http://www.windows2universe.org/earth/images/profile.jpg>

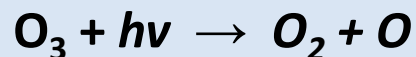
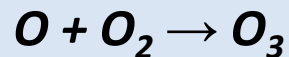
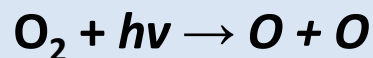


http://www2.sunysuffolk.edu/mandias/global_warming/images/ozone_atmosphere.gif

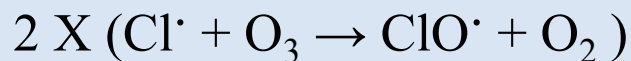
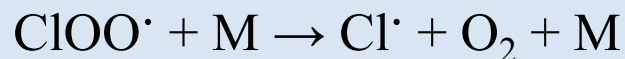
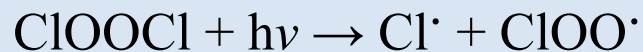


A Química do Ozônio Estratosférico

Ciclo Natural:



Destruição:





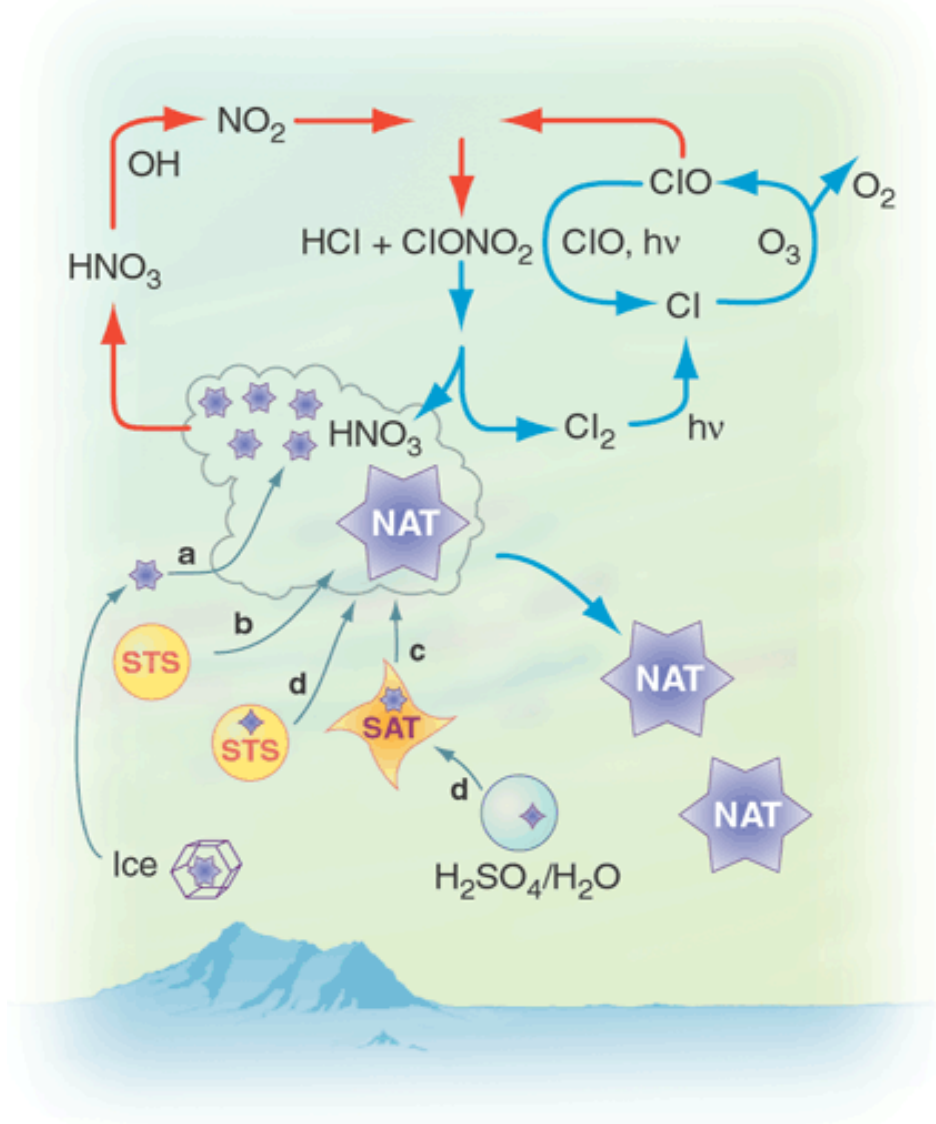
Ciclo da destruição do Ozônio

Espécies inativas de Cloro
("Reservatórios"):

ClONO_2 e HCl

Espécies ativas de Cloro

ClO^\bullet e Cl^\bullet



Solving the PSC Mystery
Science 6 April 2001:
vol. 292 no. 5514 61-63



Nuvens Polares Estratosféricas (PSC)

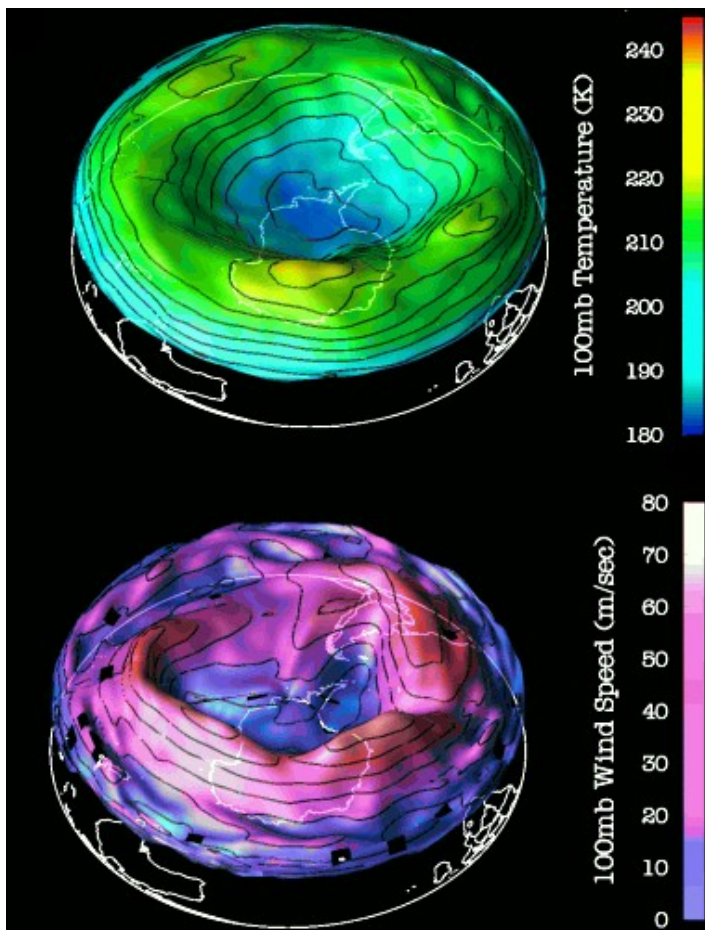


http://ozonewatch.gsfc.nasa.gov/facts/images/polar_stratospheric_cloud.jpg



Por quê é sazonal?

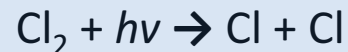
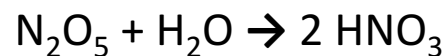
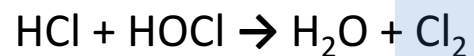
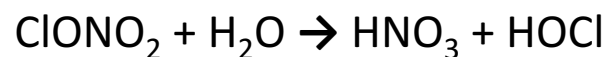
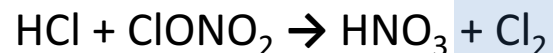
Vórtex Polar



“Ativação” do Cloro:

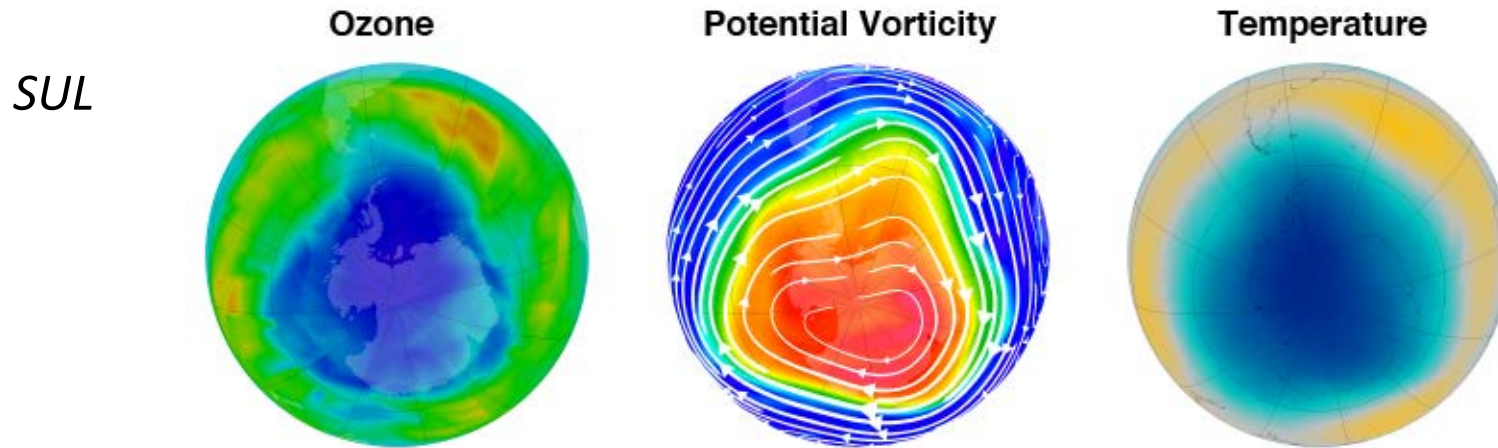
Conversão de espécies de cloro inativas em ativas

Reação em Fase heterogênea nas Nuvens Polares Estratosféricas

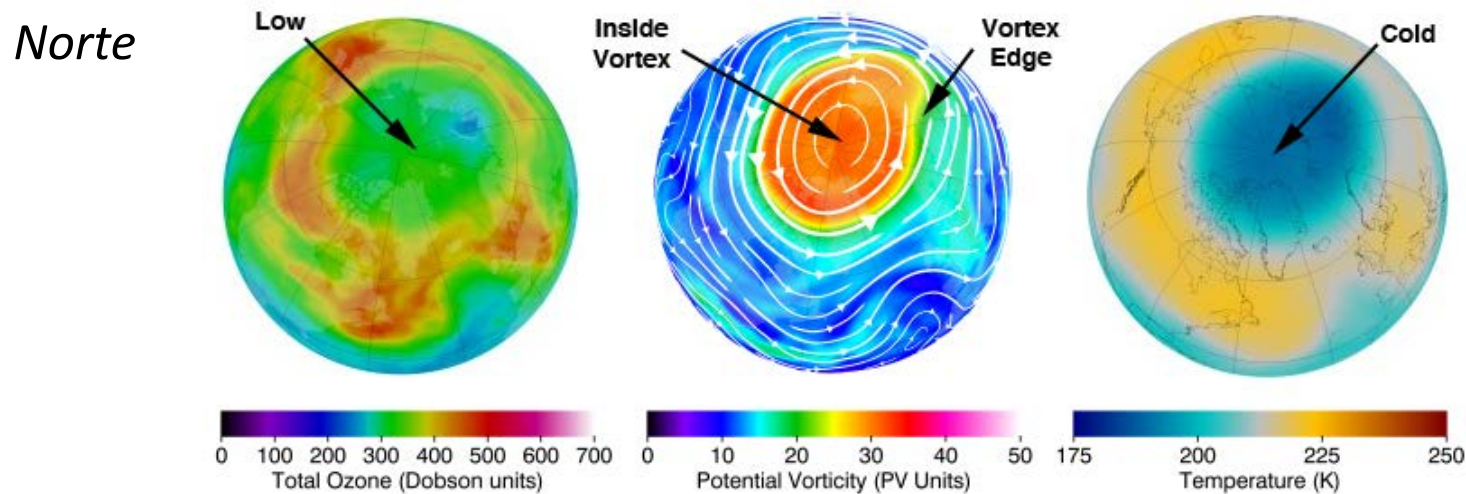




Pólo Sul vs. Pólo Norte



http://ozonewatch.gsfc.nasa.gov/facts/images/2011-08-22_LSH.png



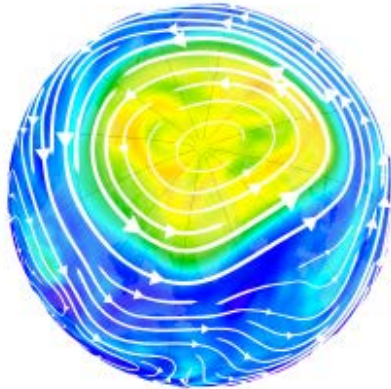
http://ozonewatch.gsfc.nasa.gov/facts/images/2011-02-22_LNH.png



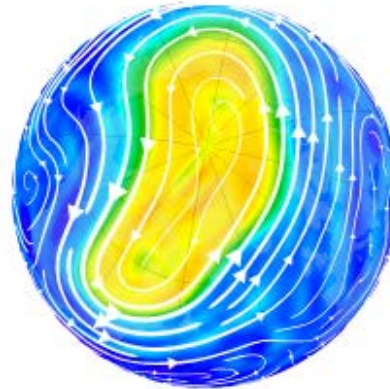
Vórtex Polar: Inverno Polar

Hemisfério Norte

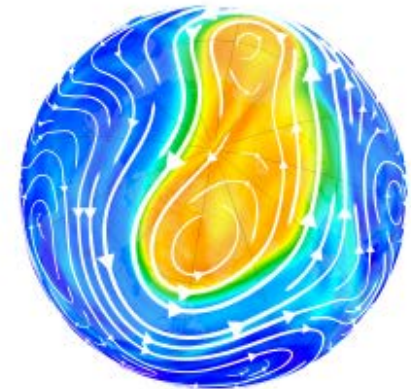
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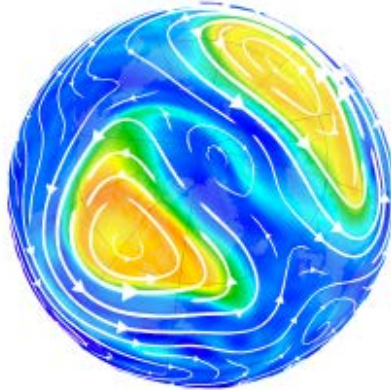
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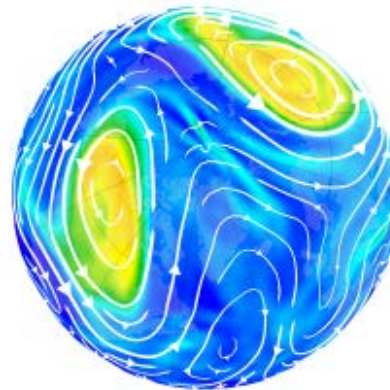
2009-01-22



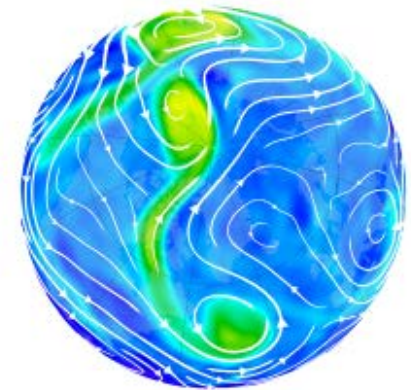
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2009-02-05



2009-02-12

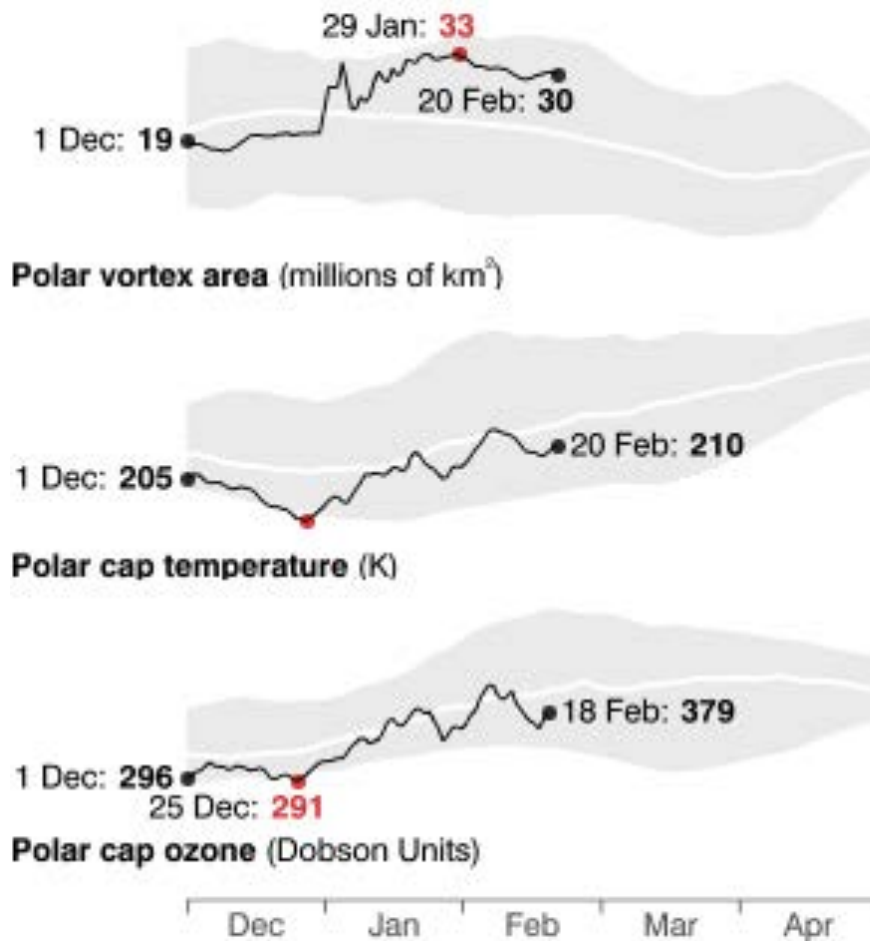


http://ozonewatch.gsfc.nasa.gov/facts/images/breakup_LNH.png



Ozônio Estratosférico: Hemisfério Norte

2013-2014



http://ozonewatch.gsfc.nasa.gov/statistics/meteorology_ytd_nh.png



“Smog” Fotoquímico



Ozônio Troposférico

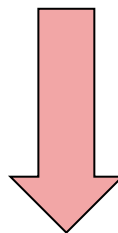


http://magazine.ucla.edu/exclusives/air-pollution_cholesterol2.jpg



Ozônio Troposérico: Smog Fotoquímico

VOCs + NO_x + hν

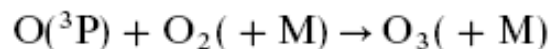
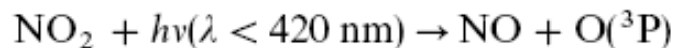
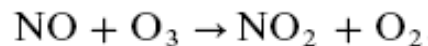


**Ozônio
Troposférico**

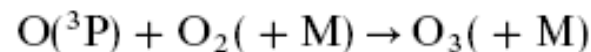
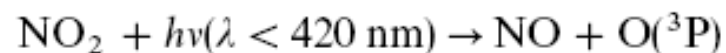
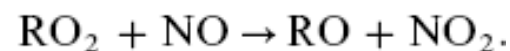
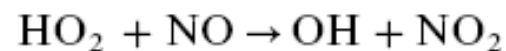


A Química do Ozônio Estratosférico

Na ausência de VOCs:

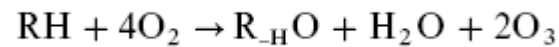
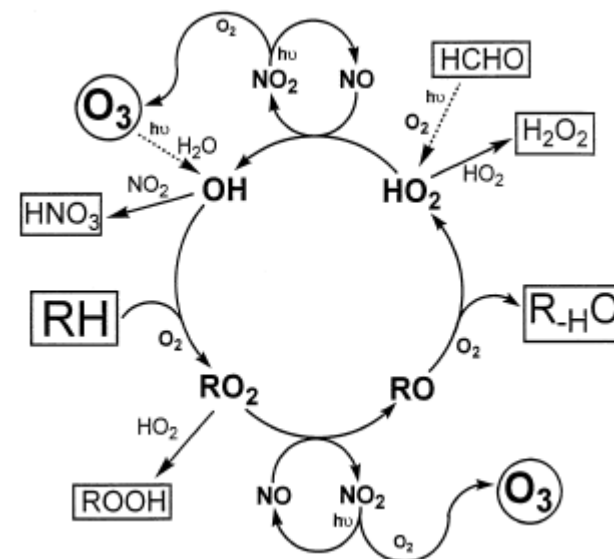
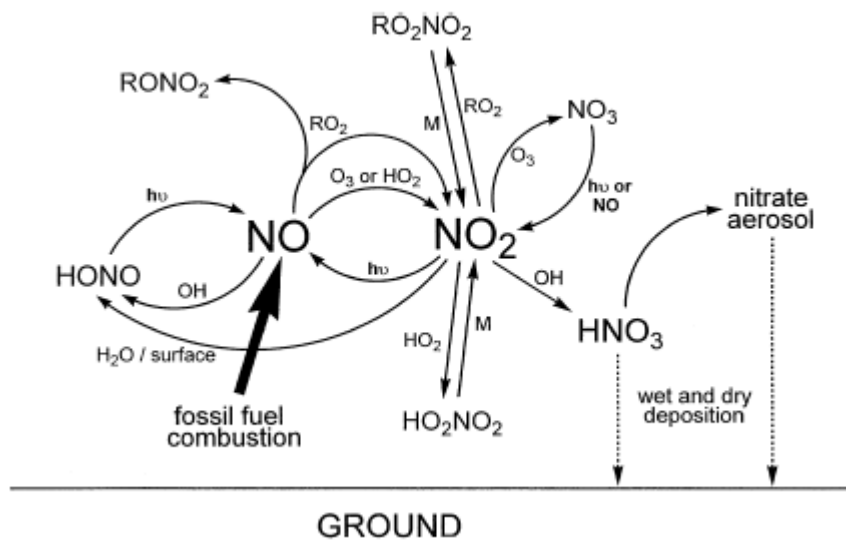


Na presença de VOCs:





A Química do Ozônio Estratosférico



M.E. Jenkin, K.C. Clemmshaw / Atmospheric Environment 34 (2000) 2499–2527



Cid.Universitária-USP-Ipen - 31/01/2014

Hora	NO2 µg/m ³		CO ppm			O3 µg/m ³			MP2.5 µg/m ³		
	Média Horária	Índice / Qualidade	Média horária	Média 8 h	Índice / Qualidade	Média horária	Média 8 h	Índice / Qualidade	Média horária	Média 24 h	Índice / Qualidade
01:00	--	--	2.3	2.2	10	2	70	28	33	18	28
02:00	83	17	2.3	2.2	10	1	44	18	22	18	28
03:00	77	15	2.3	2.2	10	1	27	11	9	17	27
04:00	70	14	2.2	2.2	10	6	16	6	24	17	27
05:00	75	15	--	2.2	10	1	9	4	22	17	27
06:00	68	14	0.6	2.0	9	1	5	2	23	17	27
07:00	72	14	0.6	1.8	8	1	2	1	34	17	27
08:00	72	14	1.1	1.6	7	3	2	1	33	18	28
09:00	109	22	2.9	1.7	8	7	3	1	44	20	31
10:00	105	21	2.6	1.8	8	26	6	2	44	21	33
11:00	29	6	2.0	1.7	8	76	15	6	17	21	33
12:00	26	5	2.0	1.7	8	107	28	11	3	20	31
13:00	20	4	1.9	1.7	8	156	47	19	12	20	31
14:00	19	4	2.0	1.9	8	188	70	28	19	21	33
15:00	21	4	2.0	2.1	9	234	100	40	26	21	33
16:00	31	6	2.1	2.2	10	284	135	87	19	22	35
17:00	30	6	2.0	2.1	9	234	163	126	23	22	35
18:00	26	5	2.0	2.0	9	170	181	162	18	22	35
19:00	27	5	2.0	2.0	9	128	188	175	13	23	36
20:00	36	7	2.0	2.0	9	116	189	177	12	23	36
21:00	55	11	2.1	2.0	9	78	179	158	18	24	38
22:00	66	13	2.2	2.1	9	51	162	124	15	24	36
23:00	53	11	2.2	2.1	9	53	139	92	0	22	35
24:00	62	12	2.3	2.1	9	45	109	52	9	21	33

http://sistemasinter.cetesb.sp.gov.br/Ar/php/ar_dados_horarios_resultado.php



Aquecimento Global



Aquecimento Global

Figure 13: A Photo showing comparison of the area covered by ice cap (snow) at Mt. Kilimanjaro between February, 1993 and February 2000



http://www.worldculturepictorial.com/images/content_2/kilimanjaro-icecap-1993-vs-2000.jpg



Mudanças Climáticas

Atmosphere

Stratosphere

Cooling Stratospheric temperature (Chapter 2.4).

Changes in winter polar vortex strength (Chapter 2.7).

Troposphere

Warming from the surface through much of the troposphere (Chapter 2.4).

Long-term changes in the large-scale atmospheric circulation, including a poleward shift of jet streams (Chapter 2.7).

Increasing concentration of CO₂ and other greenhouse gases from human activities (Chapter 2.2).

Changes in cloud cover (Chapter 2.5).

Increasing tropospheric water vapour (Chapter 2.5).

Changes in aerosole burden and ozone concentrations (Chapter 2.2)

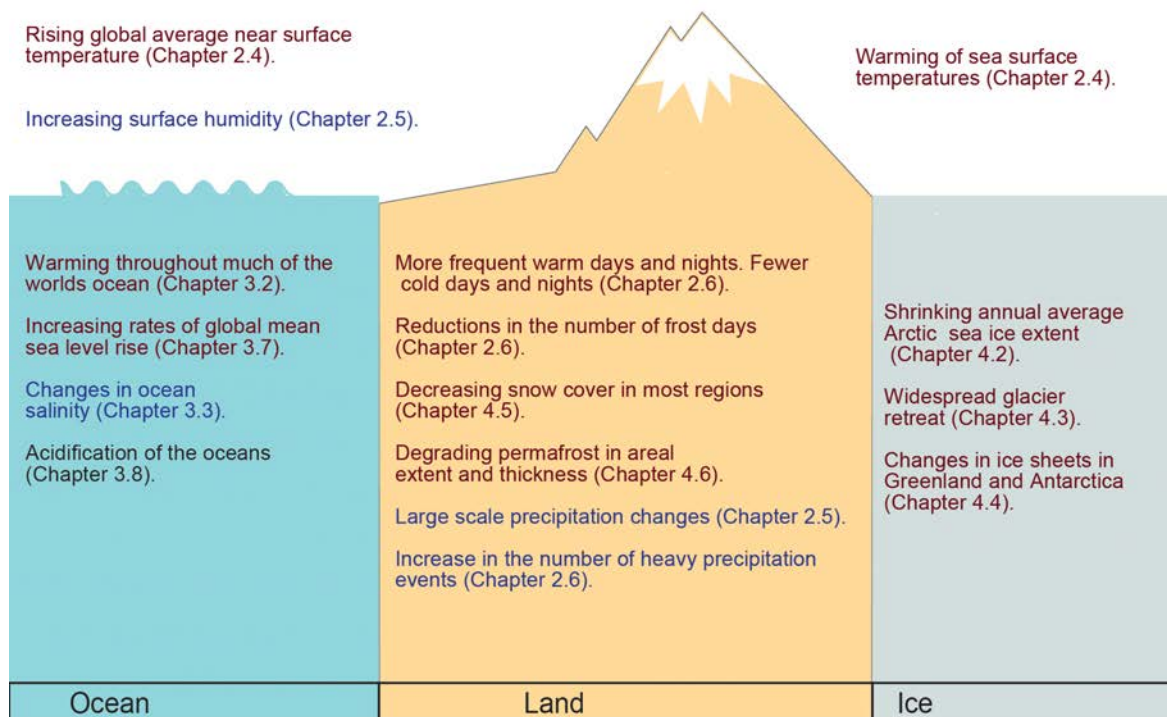
Observations of Climate Changes from AR4 (points to AR5)

Near Surface

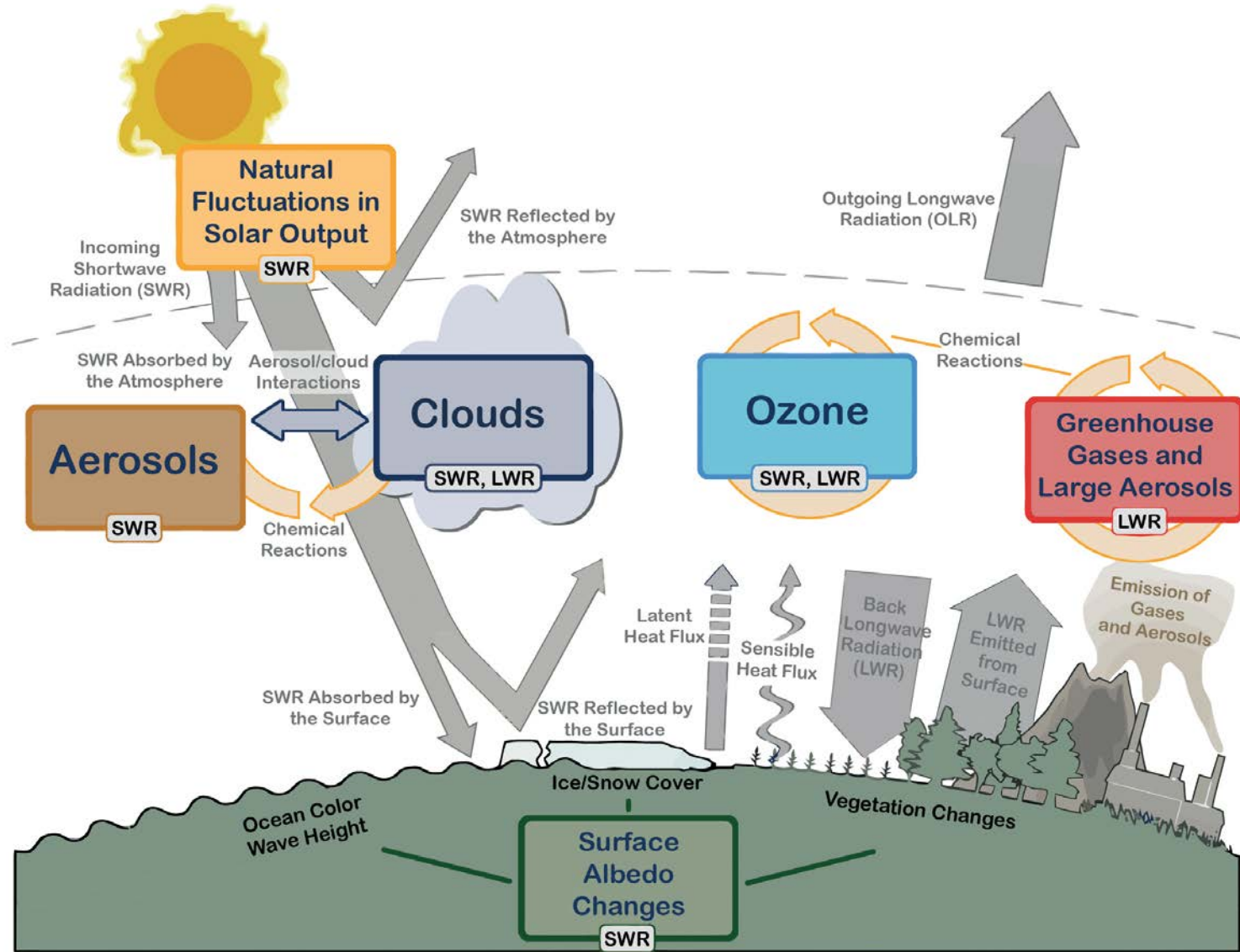
Rising global average near surface temperature (Chapter 2.4).

Increasing surface humidity (Chapter 2.5).

Warming of sea surface temperatures (Chapter 2.4).

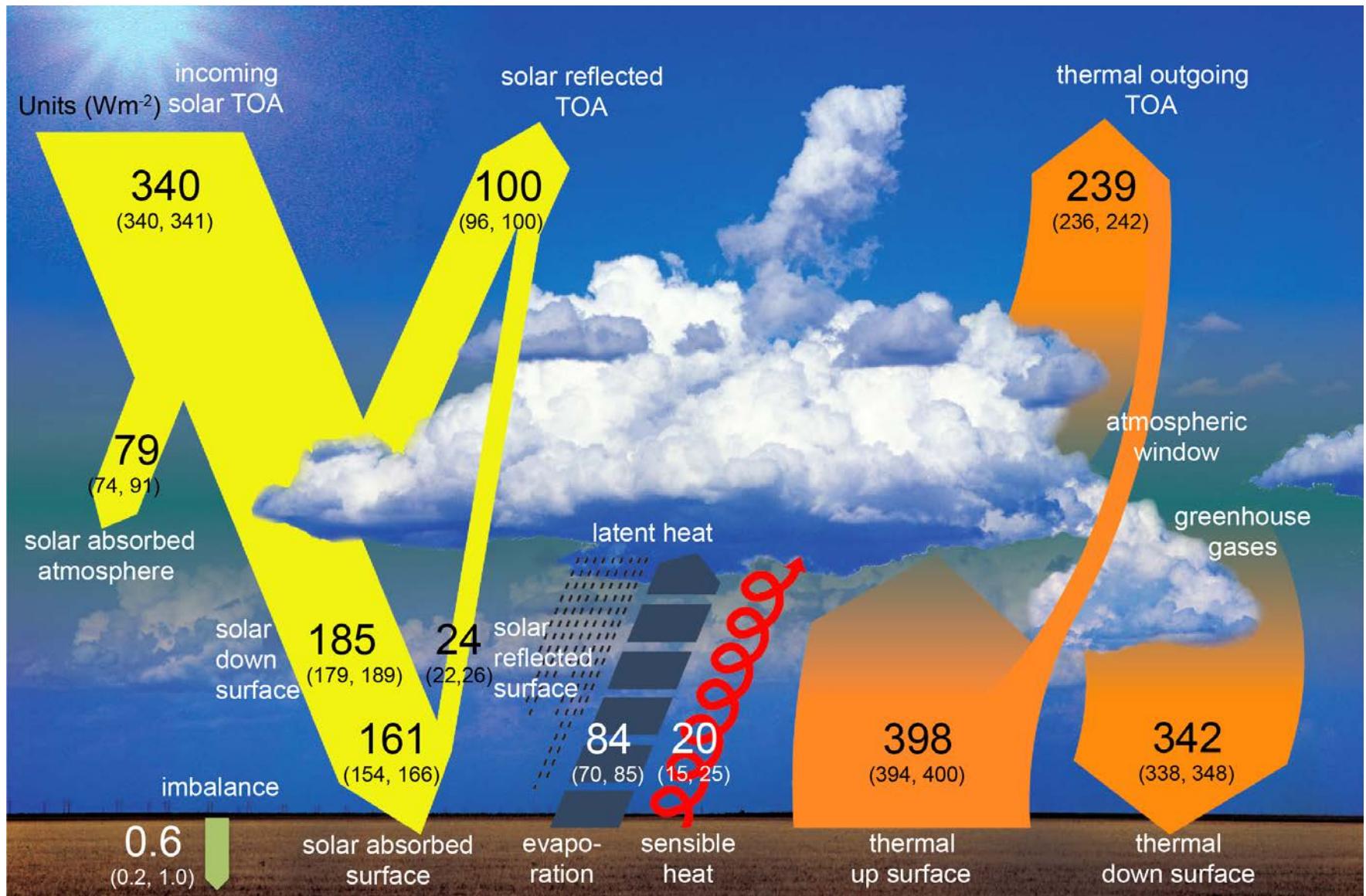


Fatores que afetam o balanço energético



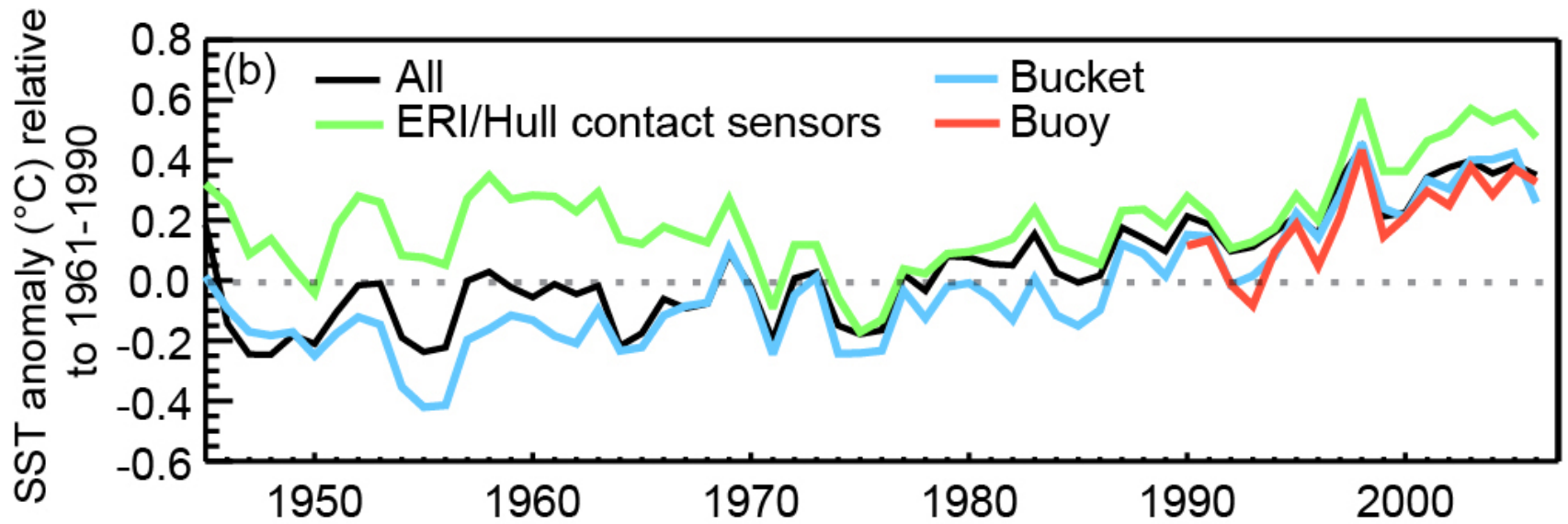
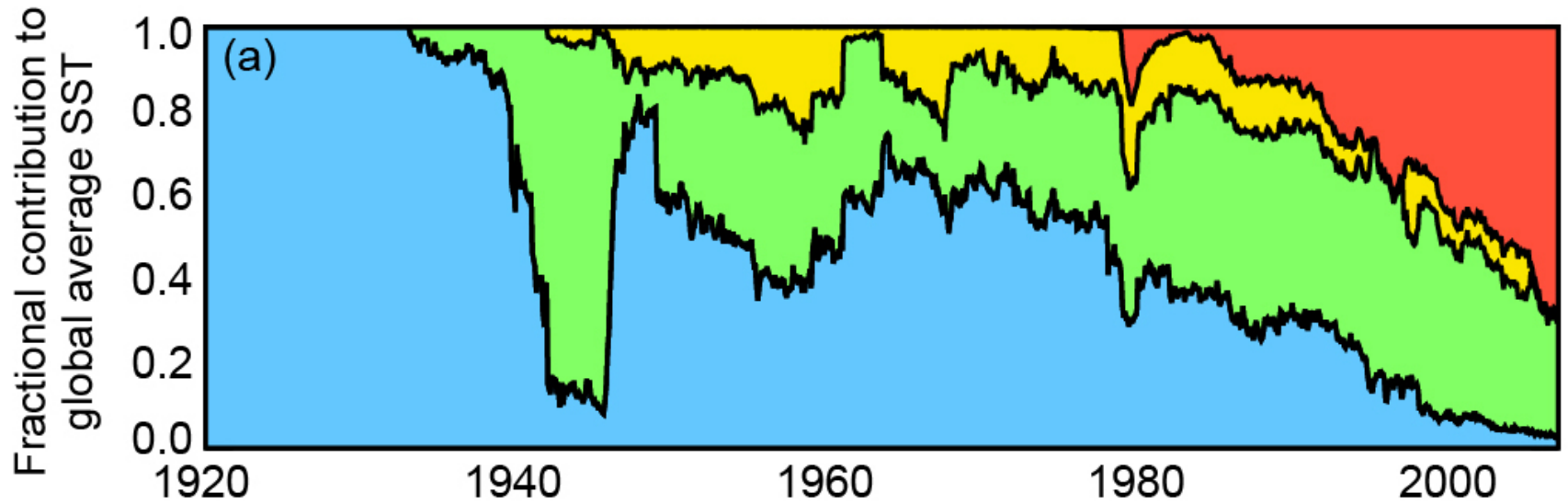


Balanço Energético da Terra



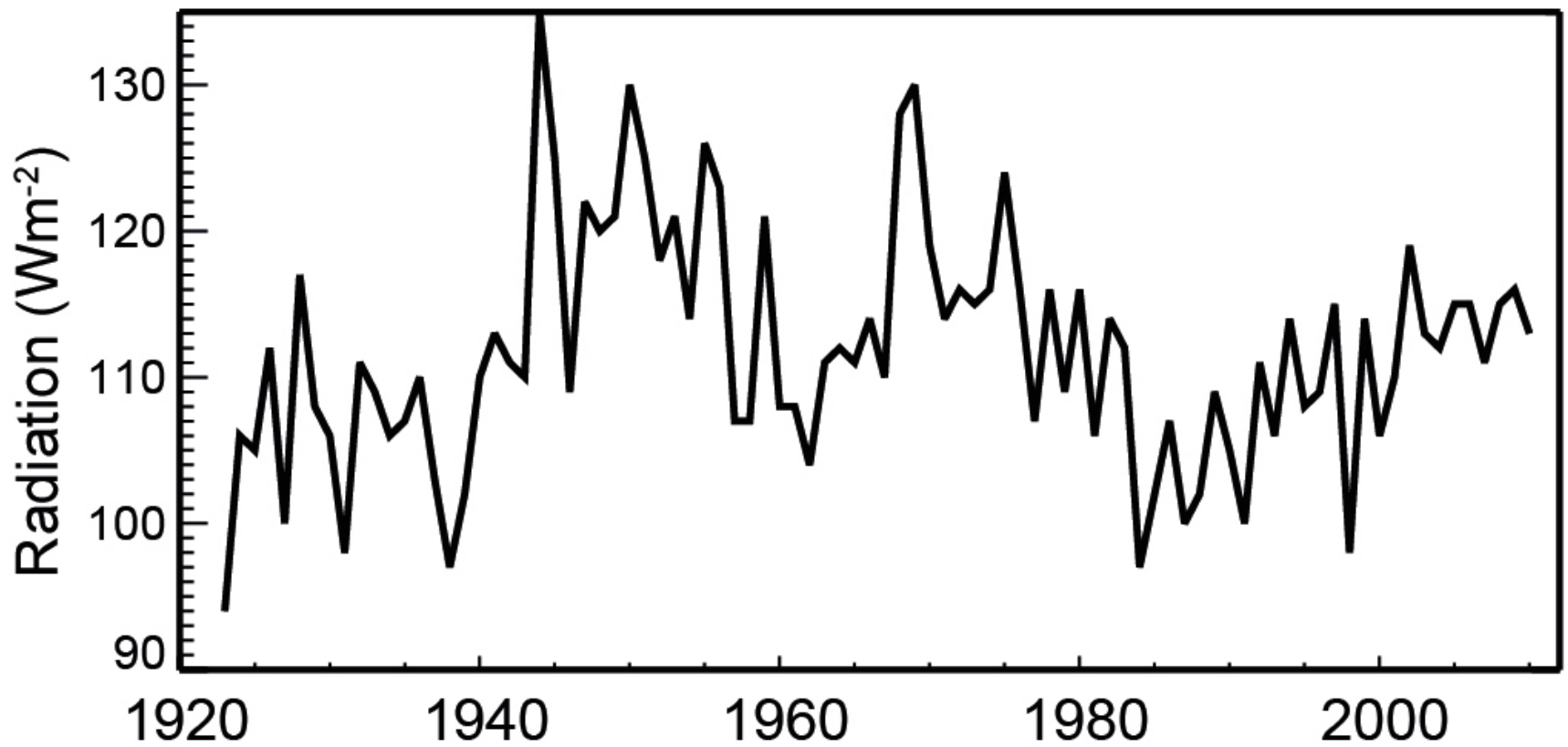


Anomalias de Temperatura



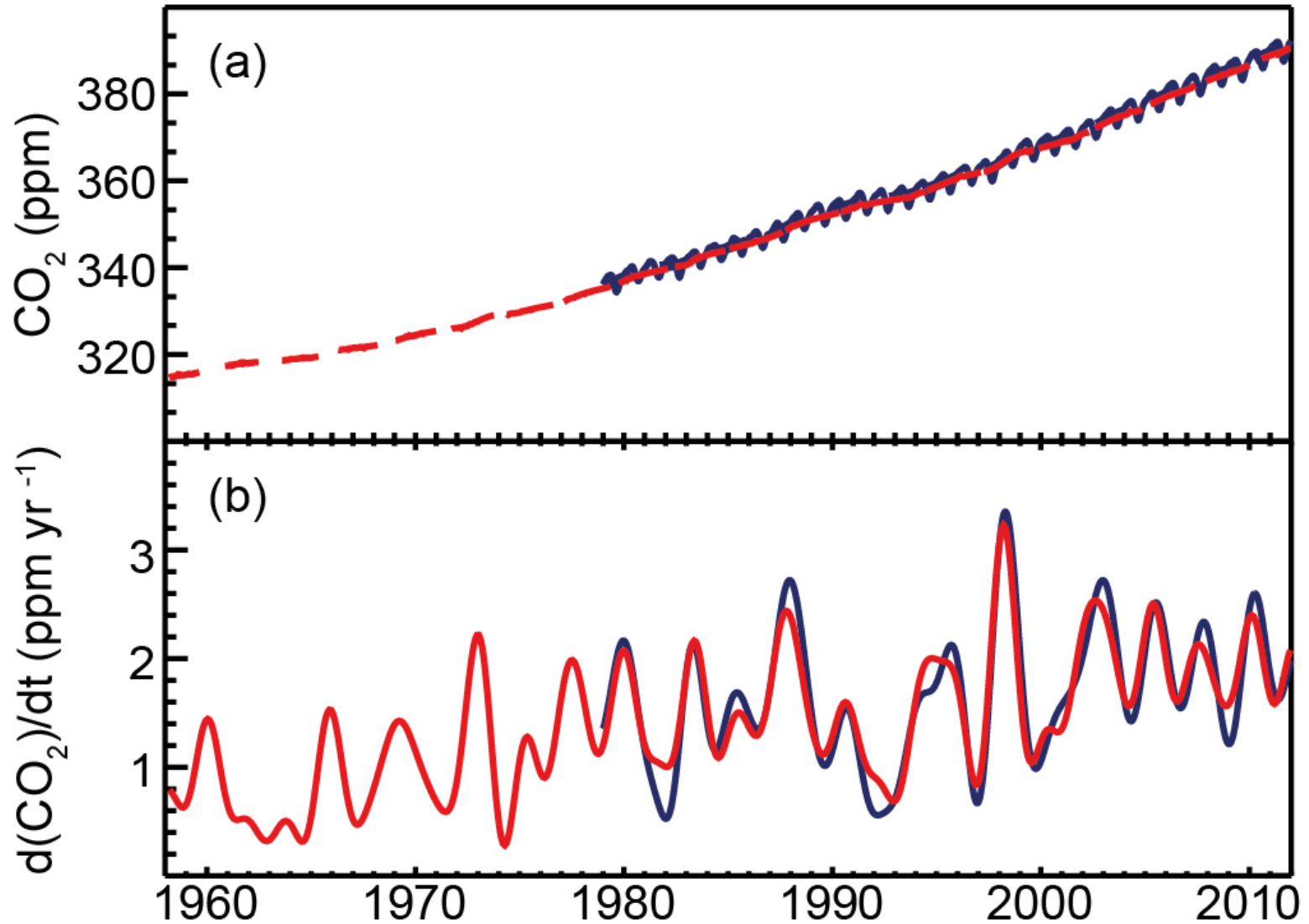


Radiação Solar



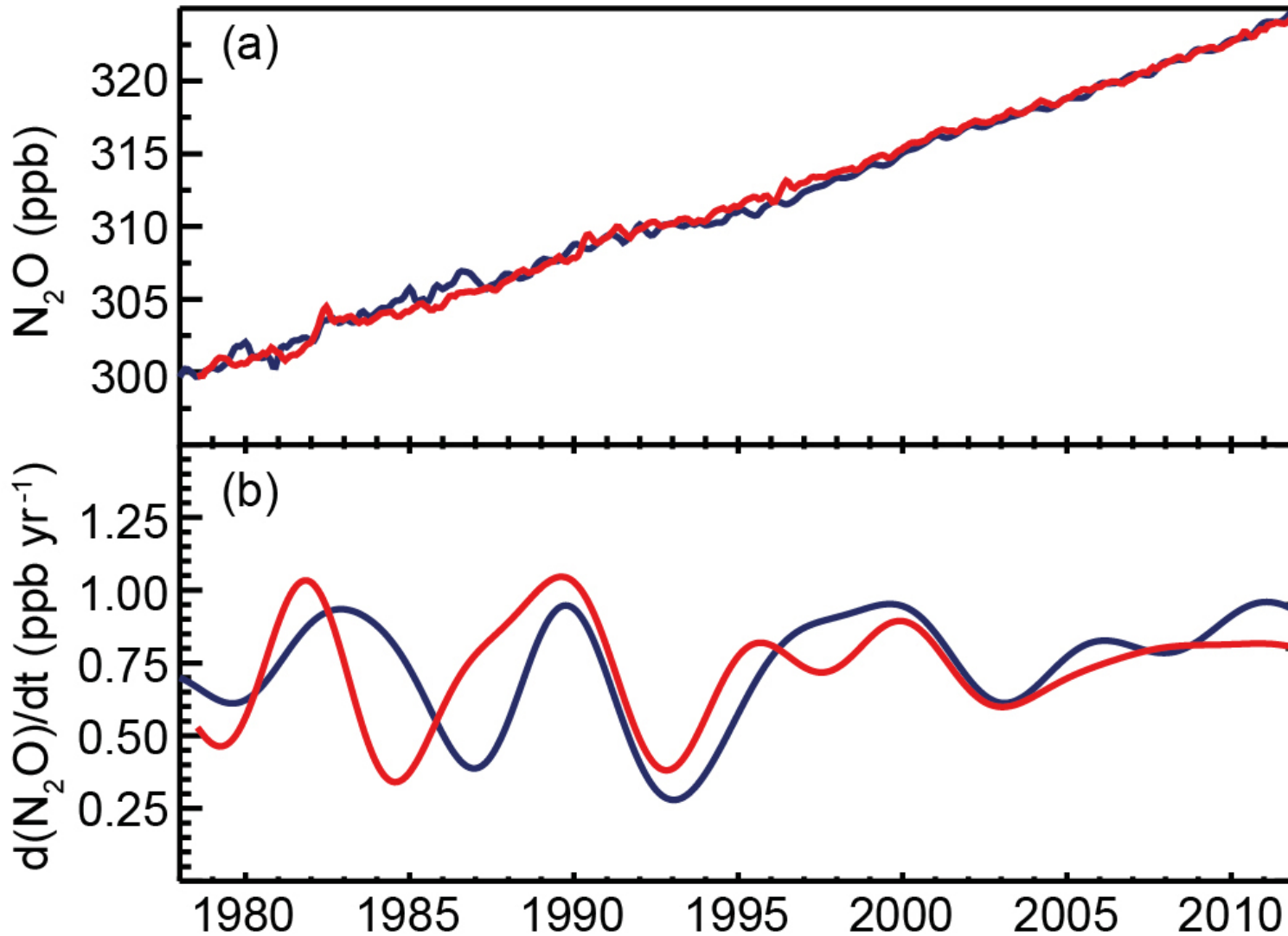


Emissões de CO₂



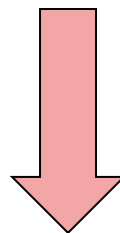


Emissões de N₂O





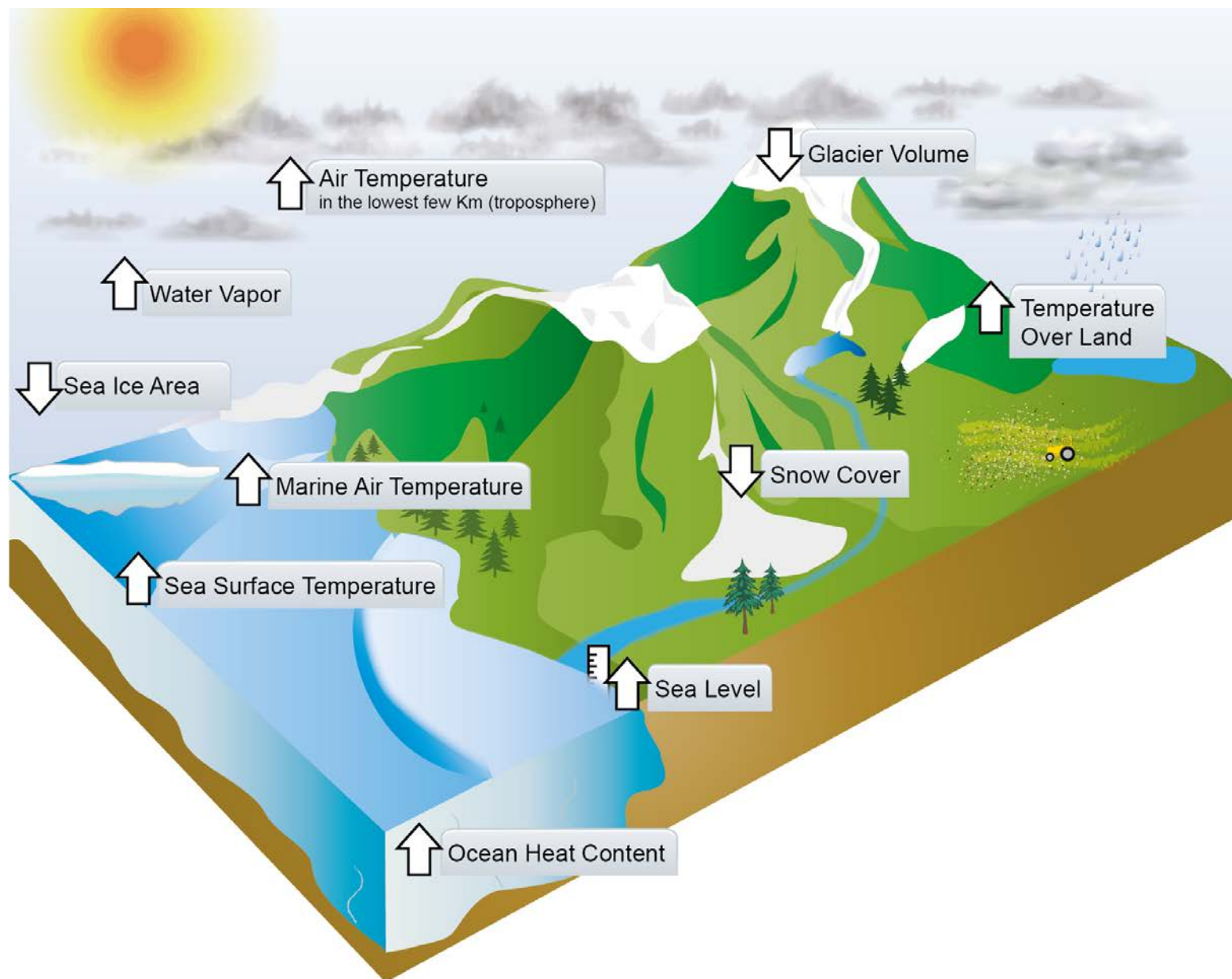
Emissão de gases estufa



**Aumento da
temperatura global**

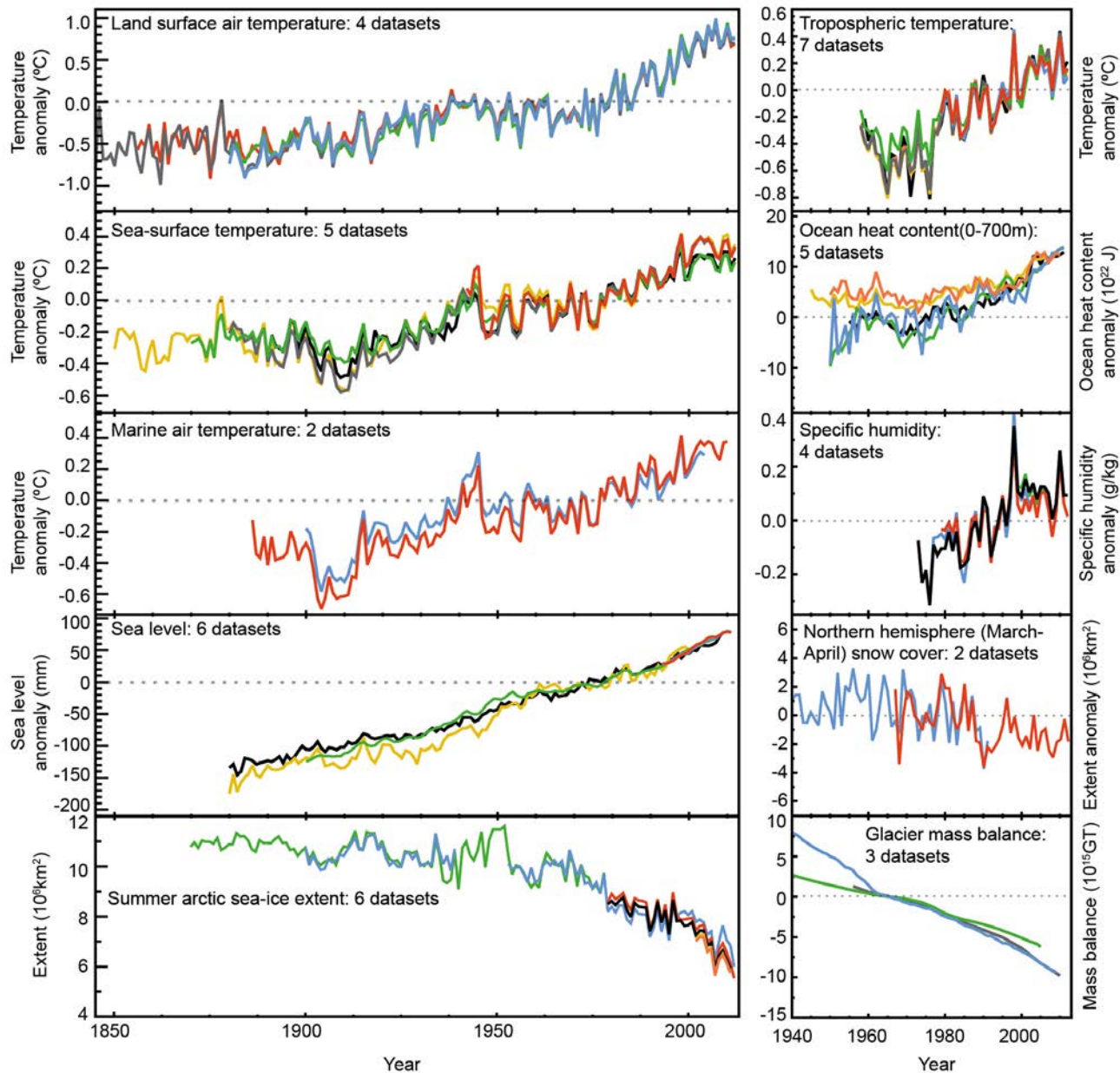


Efeitos



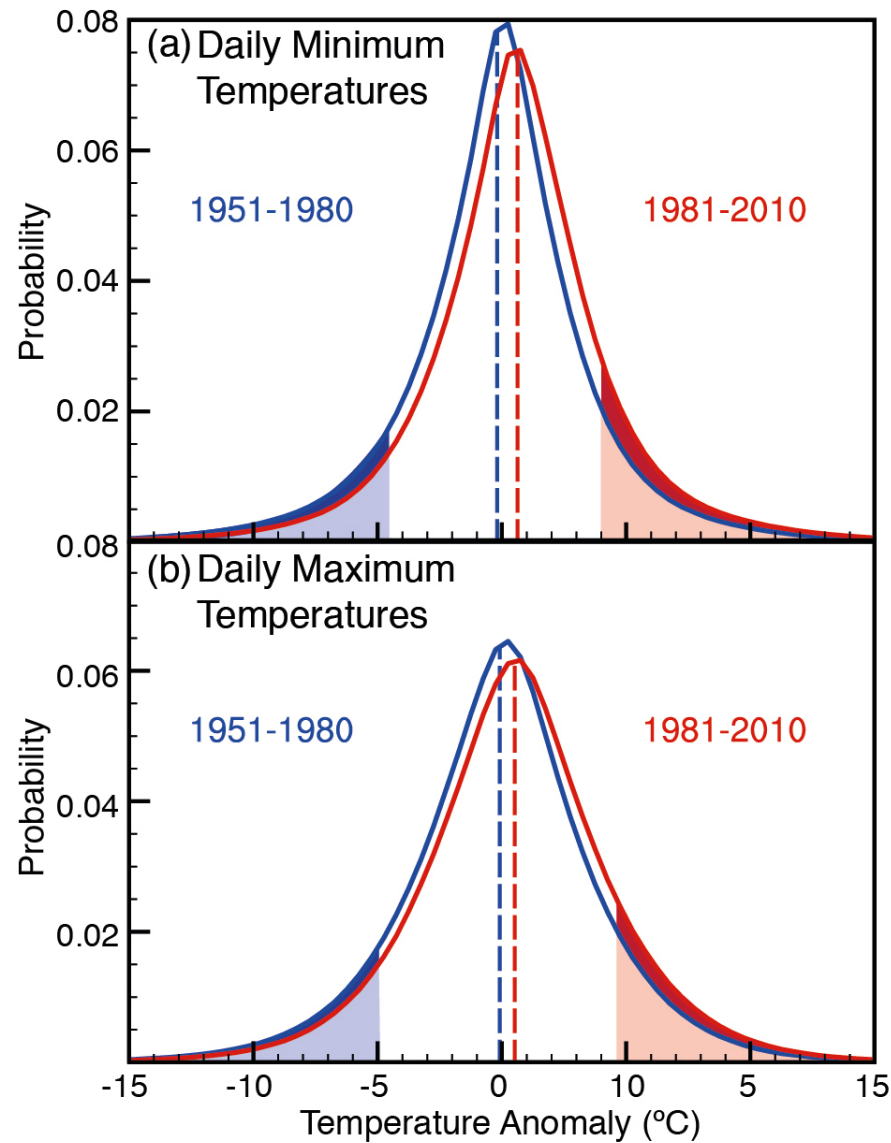


Alguns Dados



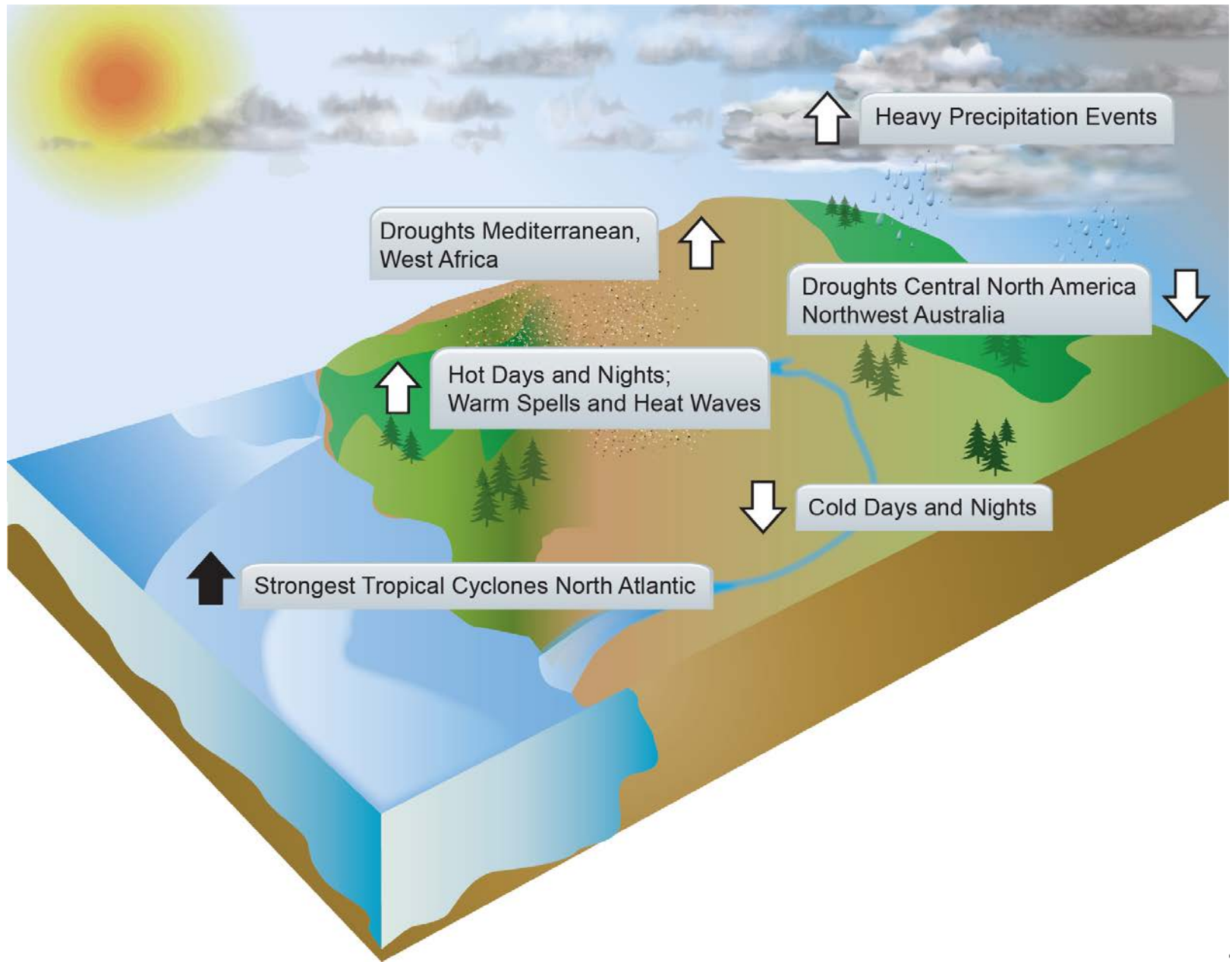


Alguns dados de Temperatura





Efeitos





Hidrosfera e Geosfera



A Hidrosfera e a Geosfera (ou Litosfera)

Rio Amazonas (confluência dos Rios Negro e Solimões)



<https://earthobservatory.nasa.gov/IOTD//view.php?id=5254>

Hidrosfera: toda a água encontrada na, sob ou sobre a superfície da Terra.

Geosfera/Litosfera: crosta e porção "sólida" do Manto Superior da Terra



A Hidrosfera e a Geosfera (ou Litosfera)

Delta do Rio Amarelo (China) ao longo do tempo



https://earthobservatory.nasa.gov/Features/WorldOfChange/yellow_river.php?all=y



Água: Distribuição na Terra

Fonte	Volume de Água (Km ³)	Porcentagem da água fresca	Porcentagem da água total
Oceanos, Mares e Baías	1,338,000,000	--	96.5
Neve de montanhas, glaciares e neve permanente	24,064,000	68.7	1.74
Água Subterrânea	23,400,000	--	1.69
Doce	10,530,000	30.1	0.76
Salgada	12,870,000	--	0.93
Umidade do solo	16,500	0.05	0.001
Solo congelado e Permafrost	300,000	0.86	0.022
Lagos	176,400	--	0.013
Doce	91,000	0.26	0.007
Salgados	85,400	--	0.006
Atmosfera	12,900	0.04	0.001
Água de pântanos	11,470	0.03	0.0008
Rios	2,120	0.006	0.0002
Água biológica	1,120	0.003	0.0001

Fonte: Igor Shiklomanov's chapter "World fresh water resources" in Peter H. Gleick (editor), 1993, Water in Crisis: A Guide to the World's Fresh Water Resources (Oxford University Press, New York).

Porcentagens arredondadas, por isso não somam 100%



Água: Distribuição na Terra

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Doce	10,530,000	30.1	0.76
Salgada	12,870,000	--	0.93
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Salgados	85,400	--	0.006
Atmosfera	12,900	0.04	0.001
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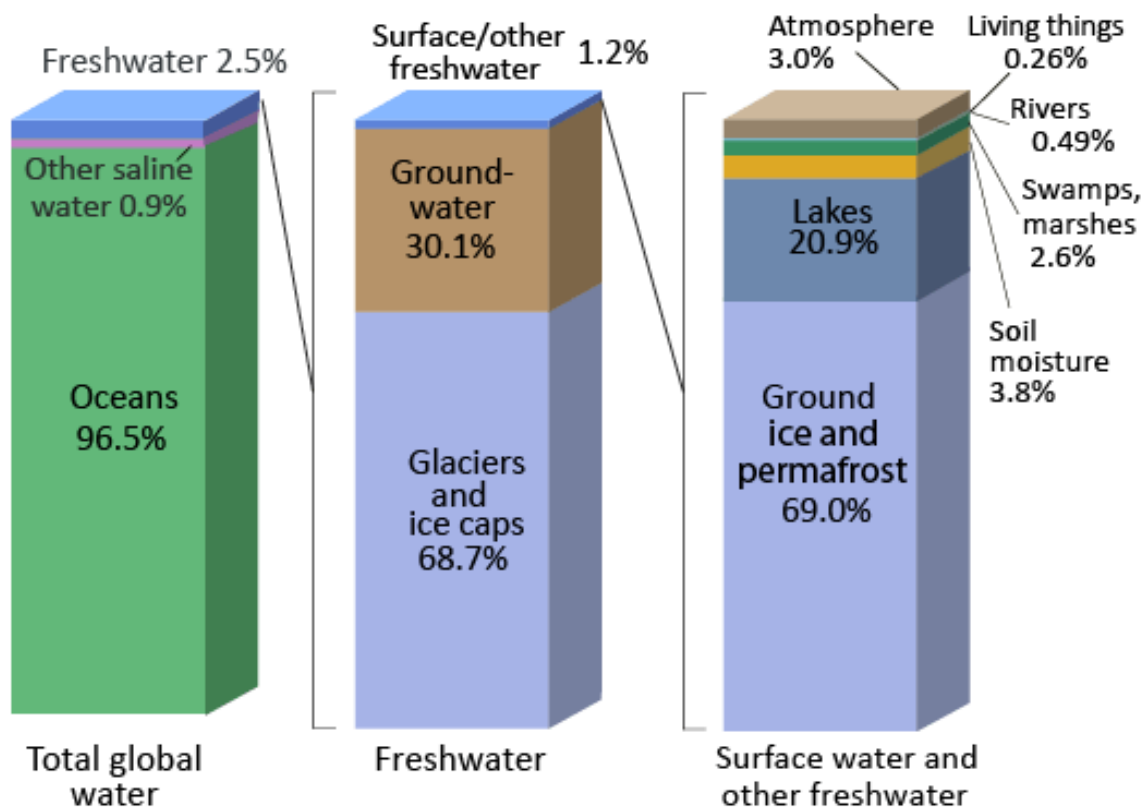
Fonte: Igor Shiklomanov's chapter "World fresh water resources" in Peter H. Gleick (editor), 1993, Water in Crisis: A Guide to the World's Fresh Water Resources (Oxford University Press, New York).

Água salgada 97,5%
Água doce 2,5%



Água: Distribuição na Terra

Where is Earth's Water?



Source: Igor Shiklomanov's chapter "World fresh water resources" in Peter H. Gleick (editor), 1993, *Water in Crisis: A Guide to the World's Fresh Water Resources*.

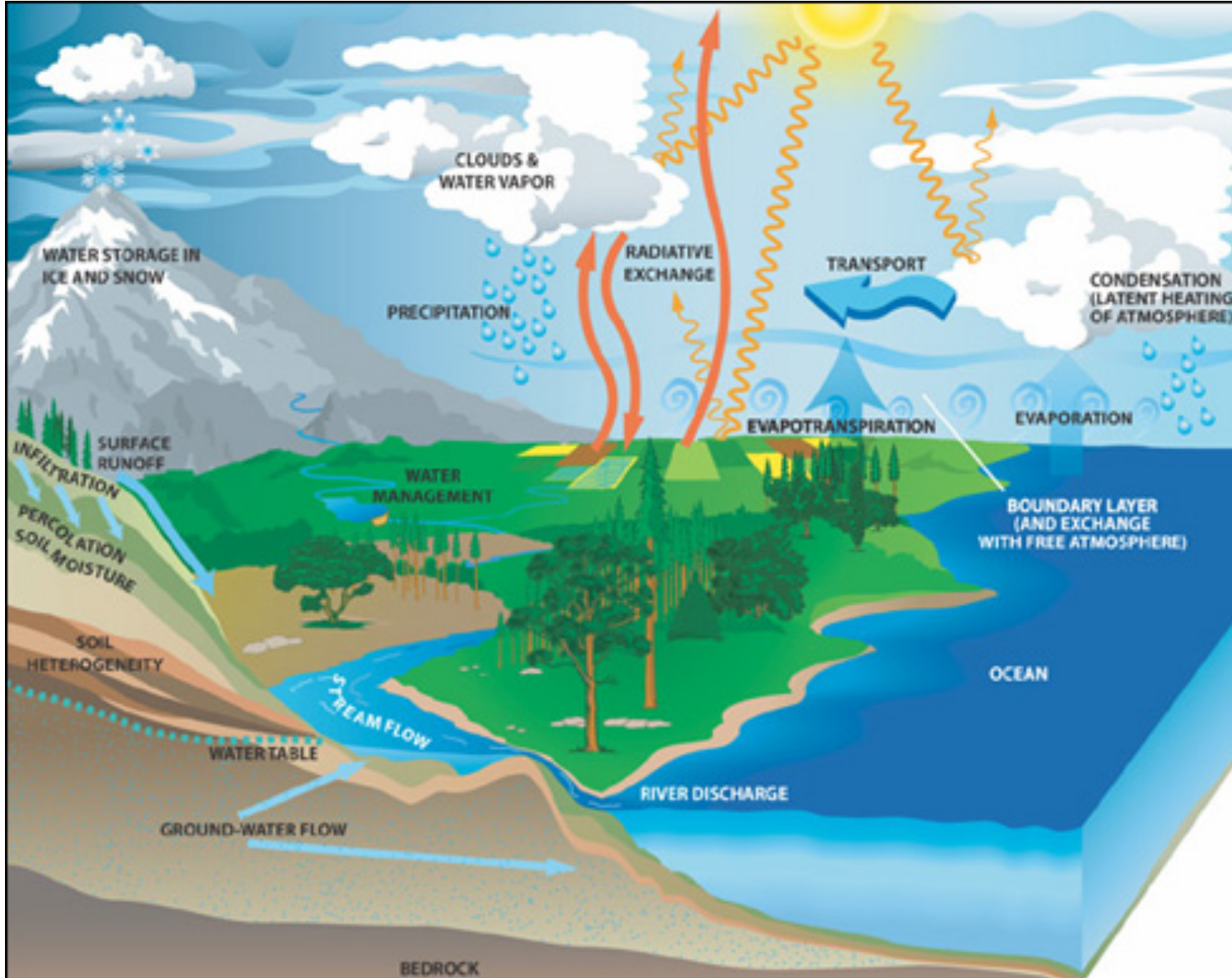
NOTE: Numbers are rounded, so percent summations may not add to 100.

(porcentagens arredondadas, por isso não somam 100%)



Ciclo Hidrológico

~ 50% da energia solar absorvida pela Terra



https://disc.gsfc.nasa.gov/images/water_cycle_nasa_earth.jpg



Ciclo Hidrológico

~ 50% da energia solar absorvida pela Terra

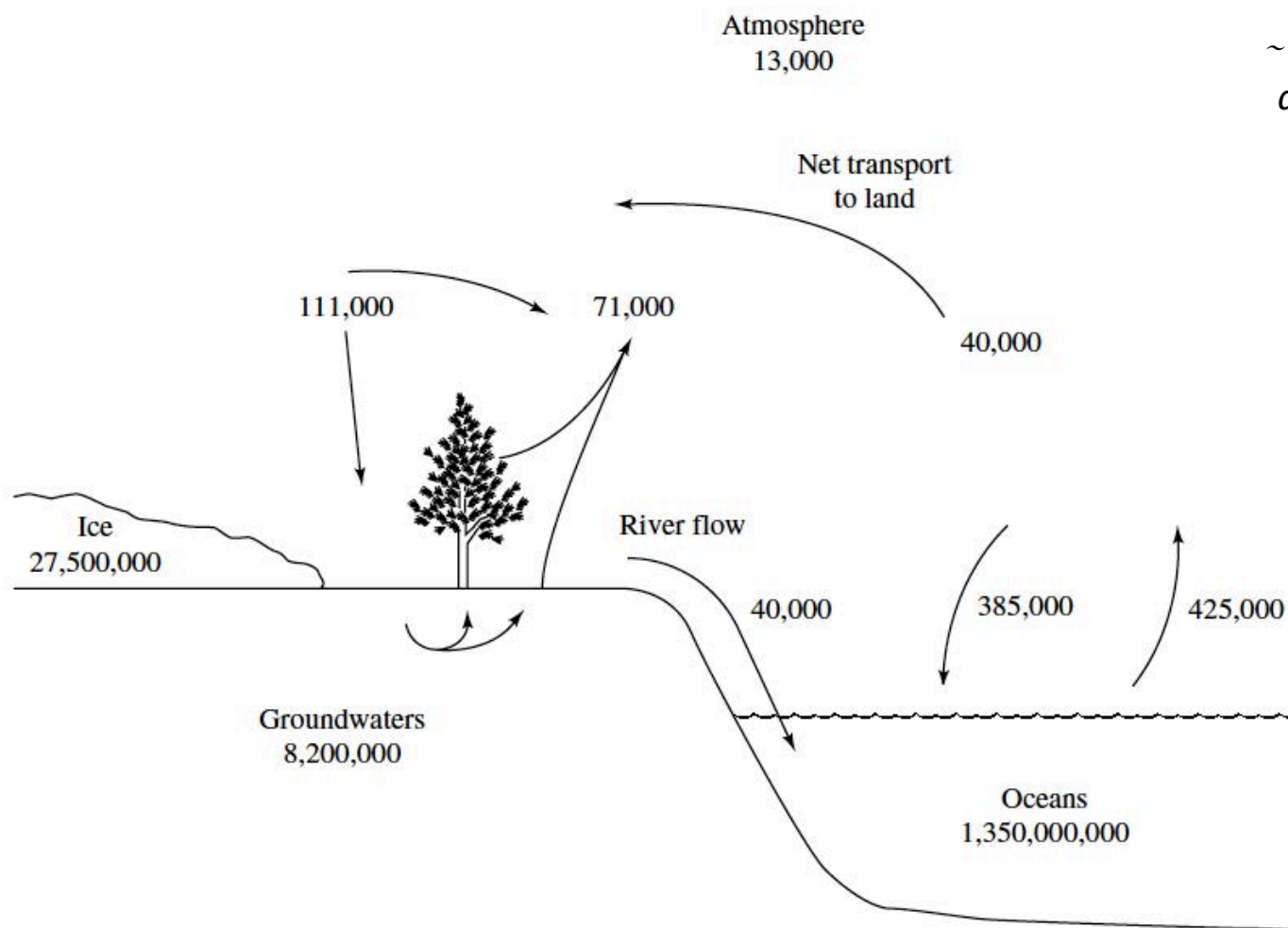


Figure 10.1 The global water cycle. The numbers are in km³ for the water reservoirs, and km³/yr for the flows. Figure from “The Global Water Cycle” in *Biogeochemistry: An Analysis of Global Change* by William H. Schlesinger. Copyright © 1991 by Academic Press. Reproduced by permission of the publisher.

Distribuição de água é desigual!

TABLE 10.1 ANNUAL WATER SUPPLY AND WITHDRAWAL FOR CONTINENTS AND VARIOUS COUNTRIES

Continents/ countries	Water supply			Water withdrawal		Per capita use/supply ratio (%)	Status [†]
	Total (km ³)	Per km ² (m ³)	Per capita (m ³)	Total* (km ³)	Per capita (m ³)		
World	41,022	314,386	6,761.5	3,240.0	534.0	7.9	Potential problems
Africa	3,996	134,842	4,995.0	145.1	181.4	3.6	Potential problems
Kenya	20	35,492	665.8	2.1	67.6	10.1	Scarcity
Congo, D.R.	935	412,430	17,992.9	0.4	6.9	0.0	Surplus
North America [‡]	6,365	302,698	14,373.2	608.4	1,373.9	9.6	Surplus
Mexico	357	187,249	3,586.9	77.6	779.0	21.7	Potential problems
Canada	2,850	309,024	92,624.5	45.1	1,466.0	1.6	Surplus
South America	9,526	543,435	27,628.7	106.2	308.0	1.1	Surplus
Peru	40	31,250	1,474.1	6.1	224.8	15.3	Stress
Brazil	5,190	613,728	30,508.8	36.5	214.4	0.7	Surplus
Asia	13,207	428,038	3,584.4	1,633.9	443.4	12.4	Potential problems
China	2,800	301,367	2,214.3	460.0	363.8	16.4	Potential problems
Indonesia	2,530	1,396,579	11,922.3	16.6	78.2	0.7	Surplus
Europe	6,235	275,826	8,570.3	455.3	625.9	7.3	Potential problems
Poland	49	162,276	1,278.2	12.3	317.7	24.9	Stress
Russia	4,313	255,363	29,695.5	77.1	530.9	1.3	Surplus
Oceania	1,614	190,105	52,072.6	16.7	539.7	1.0	Surplus
Australia	343	44,648	17,864.6	14.6	760.4	4.3	Surplus
Papua New Guinea	801	1,768,759	166,528.1	0.1	20.8	0.0	Surplus

*Total water withdrawals are for various years ranging from 1980 to 1995 as provided in WRI (1999).

[†]Refers to per capita water supply:

Water surplus: >10,000 m³/capita

Potential water management problems: >2,000 m³/capita <10,000 m³ capita

Water stress: >1,000 m³/capita <2,000 m³ capita

[‡]Includes Central America

Sources: Population data is for mid-2000, as reported in the Population Reference Bureau (2000), *2000 World Population Data Sheet*, Washington, DC.

Other data from the World Resources Institute (in collaboration with the United Nations Environment Programme and the United Nations Development Programme) (1999). *World Resources 1998-1999* (Oxford, UK: University Press).

Spiro & Stigliani, Chemistry of the Environment, 2nd ed., 2002.



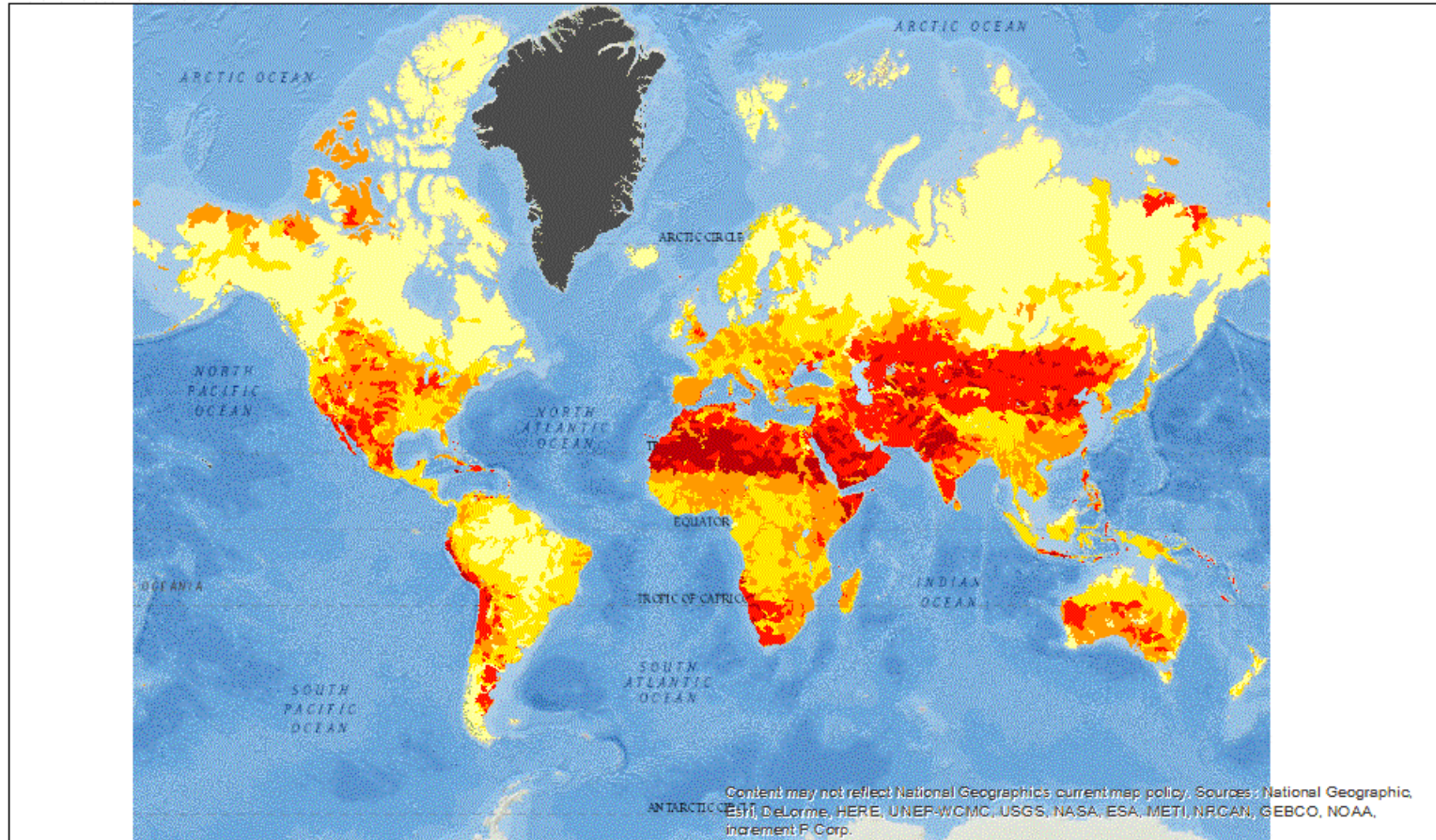
Risco Hídrico



Risco Hídrico

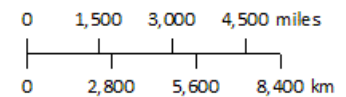
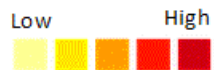
 **AQUEDUCT**

Wednesday, August 9, 2017



Overall Water Risk

Legend:



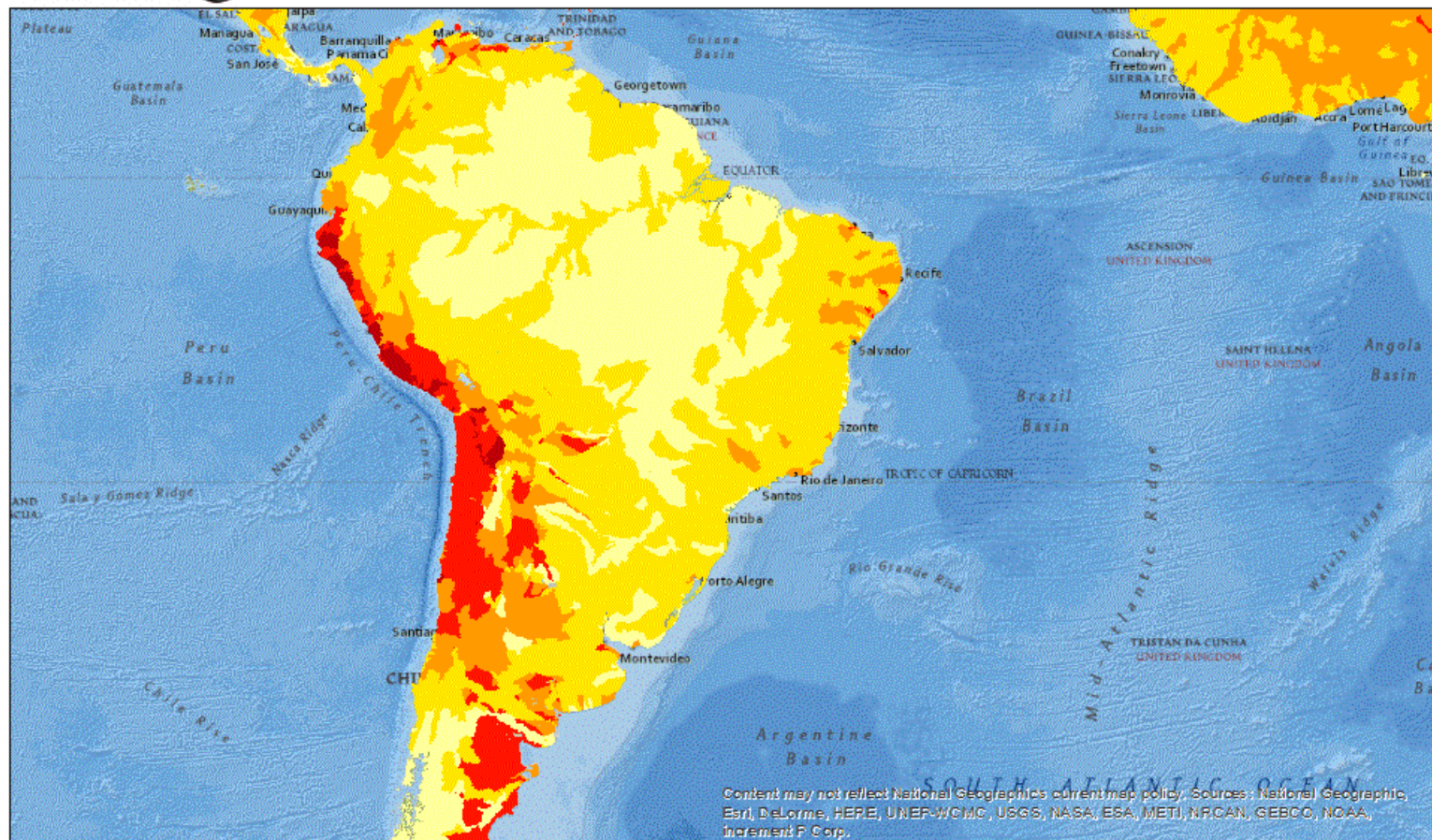
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Risco Hídrico

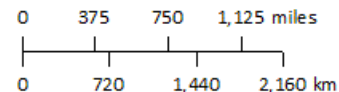
 **AQUEDUCT**

Wednesday, August 9, 2017



Overall Water Risk

Legend:



<http://www.wri.org/our-work/project/aqueduct/aqueduct-atlas>

Uso de água

TABLE 10.2 USES OF WATER FOR CONTINENTS AND COUNTRIES

Continents/countries	Domestic (%)	Industry/power (%)	Agriculture (%)
World	8	23	69
Africa	7	5	88
Kenya	20	4	76
Congo, D.R.	61	16	23
North America*	12	41	47
Mexico [†]	6	8	86
Canada [†]	18	70	12
South America	18	23	59
Peru [†]	19	9	72
Brazil [†]	22	19	59
Asia	6	9	85
China [†]	6	7	87
Indonesia [†]	13	11	76
Europe	14	55	31
Poland [†]	13	76	11
Russia	19	62	20
Oceania	64	2	34
Australia [†]	65	2	33
Papua New Guinea [†]	29	22	49

*Includes Central America

[†]Sectoral withdrawal estimates are for 1987

Source: World Resources Institute (in collaboration with the United Nations Environment Programme and the United Nations Development Programme) (1999). *World Resources 1998–1999* (Oxford, UK: University Press).

Spiro & Stigliani, Chemistry of the Environment, 2nd ed., 2002.



Uso de água

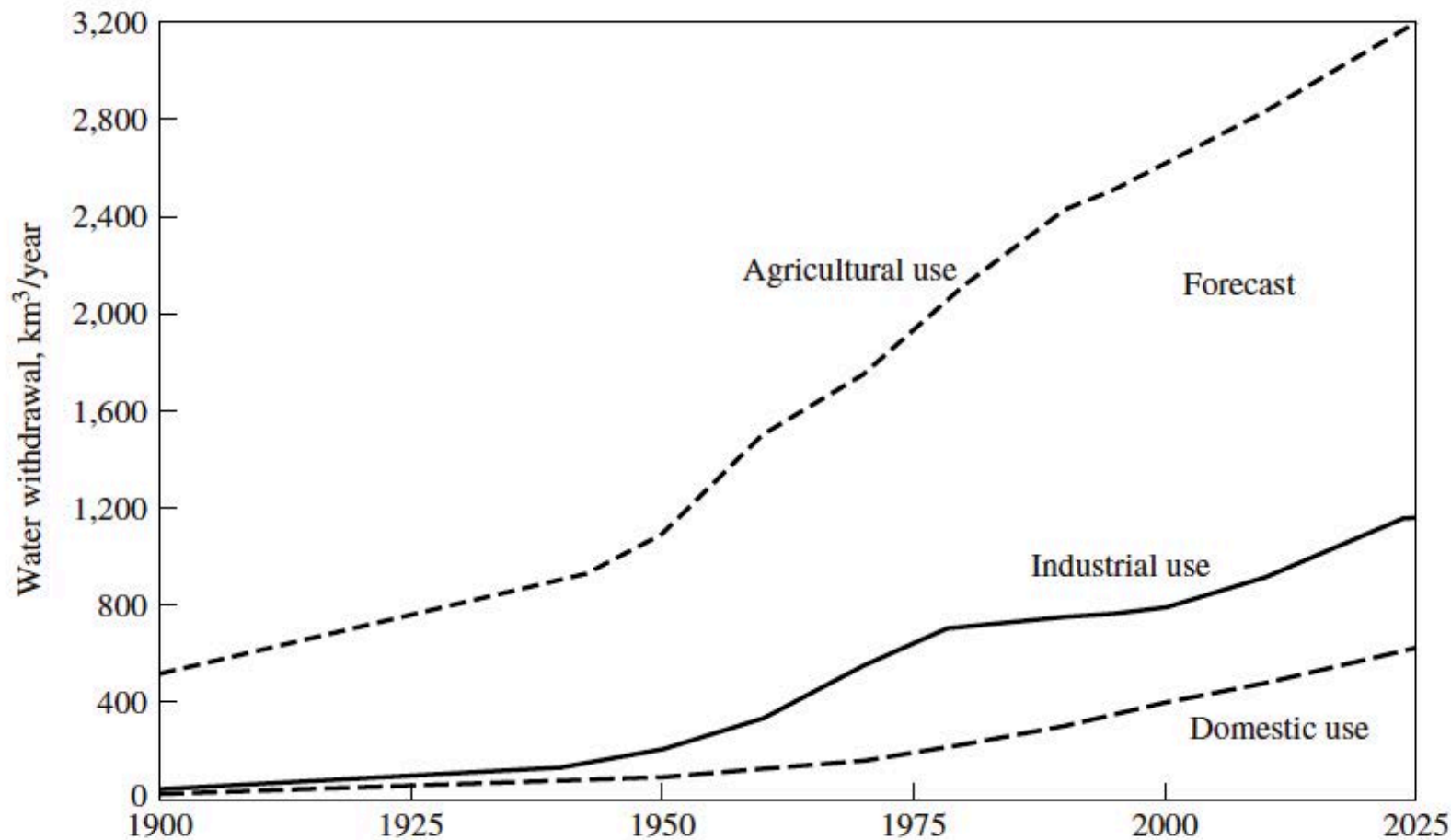


Figure 10.2 Global water use, 1900 to 2025. *Source:* I. A. Shiklomanov (ed.) (1999). *World Water Resources at the Beginning of the 21st Century* (St. Petersburg, Russia: State Hydrological Institute/UNESCO).

Spiro & Stigliani, Chemistry of the Environment, 2nd ed., 2002.



Uso de água: Agricultura

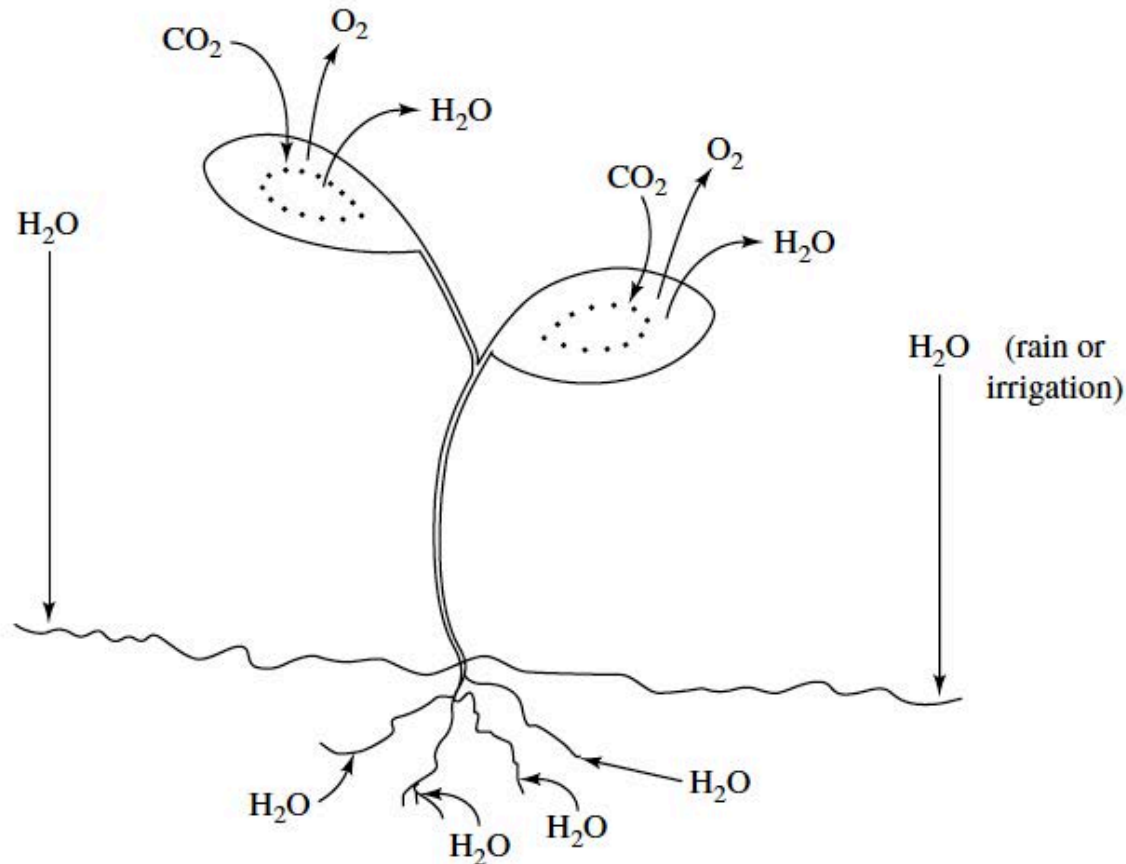


Figure 10.3 Exchange of gases on the stomata of leaves, and loss of water through transpiration.

Perde-se ao redor de 60% da água de irrigação antes de atingir a planta

Spiro & Stigliani, Chemistry of the Environment, 2nd ed., 2002.



Contaminação / Erosão





Erosão



http://s.glbimg.com/jo/g1/f/original/2012/01/26/img_1999.jpg



Contaminação

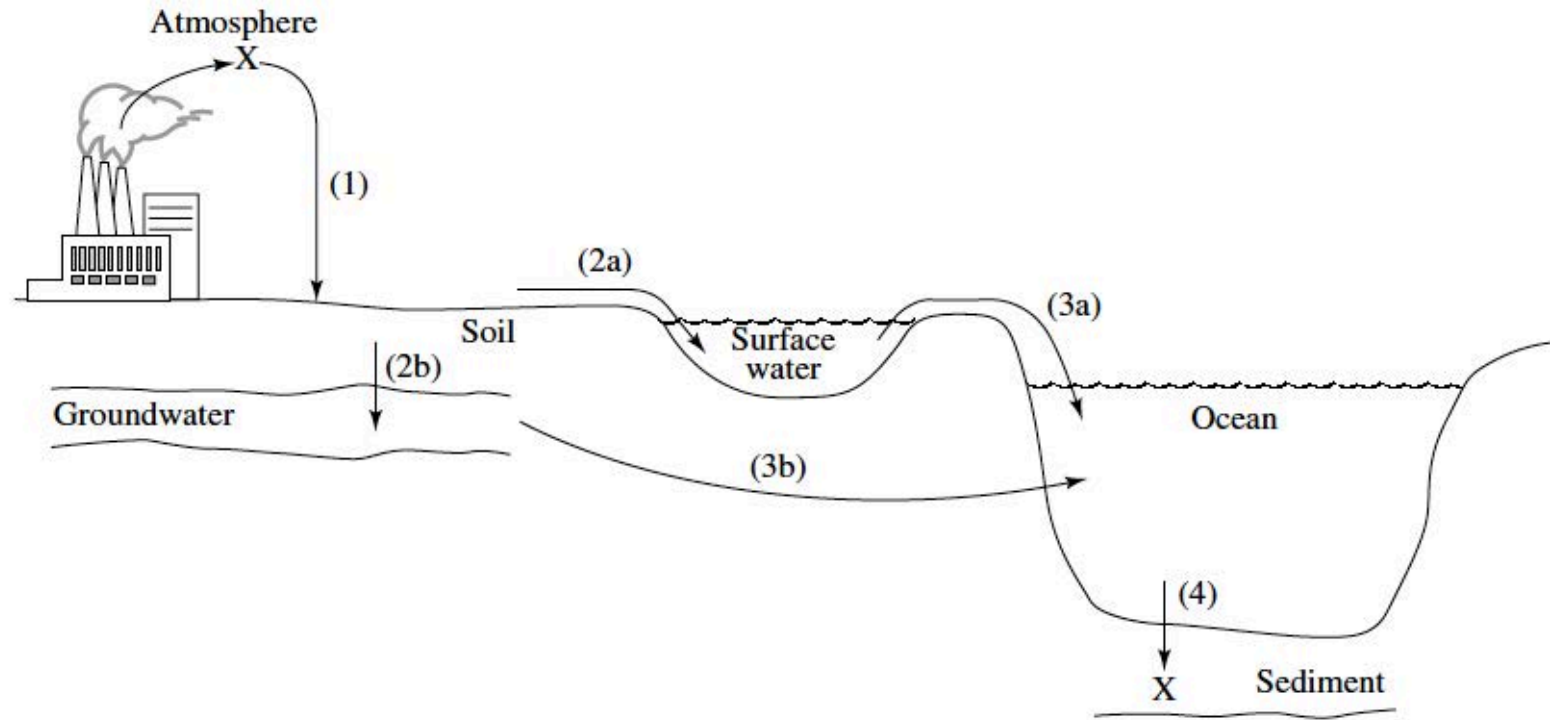


Figure 12.10 Flow of pollutant X from sources to sinks.

Spiro & Stigliani, Chemistry of the Environment, 2nd ed., 2002.



Ozônio:

- World Meteorological Organization (WMO), Scientific Assessment of Ozone Depletion: 2014, World Meteorological Organization, Global Ozone Research and Monitoring Project - Report No. 55, 416 pp., Geneva, Switzerland, 2014.
- “Solving the PSC Mystery”, Margaret A. Tolbert and Owen B. Toon, *Science* 2001: 292 (5514), 61-63. [DOI:10.1126/science.1060083].
- “Heterogeneous chlorine activation on stratospheric aerosols and clouds in the Arctic polar vortex”. T. Wegner, J.-U. Grooß, M. von Hobe, F. Stroh, O. Suminska-Ebersoldt, C. M. Volk, E. Hösen, V. Mitev, G. Shur, and R. Müller. *Atmos. Chem. Phys.* 2012: 12 p.11095–11106 . [doi:10.5194/acp-12-11095-2012].



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