

# Fundamentos de Sensoriamento Remoto

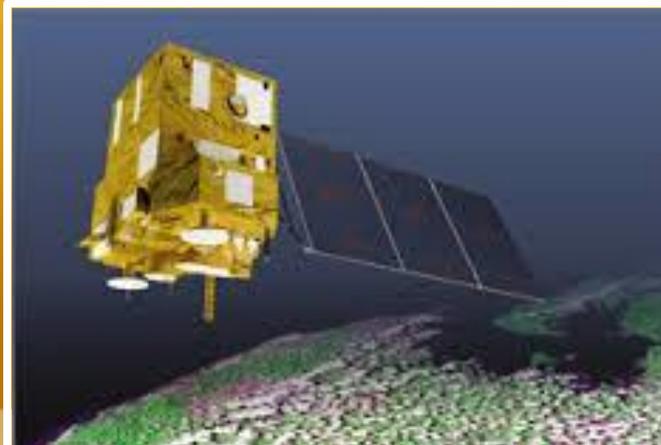


Elisabete Caria Moraes  
bete@dsr.inpe.br

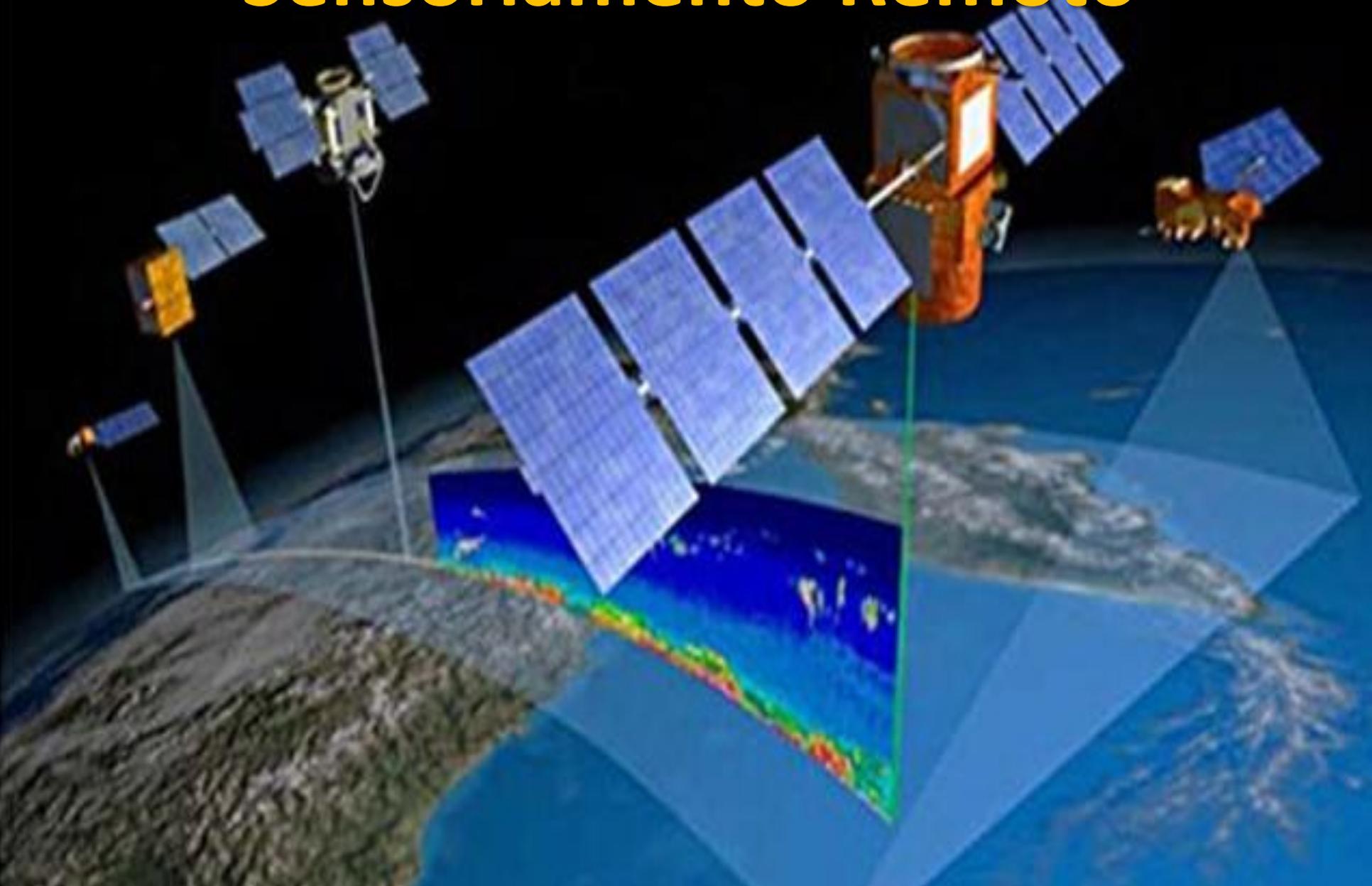
# Sensoriamento Remoto

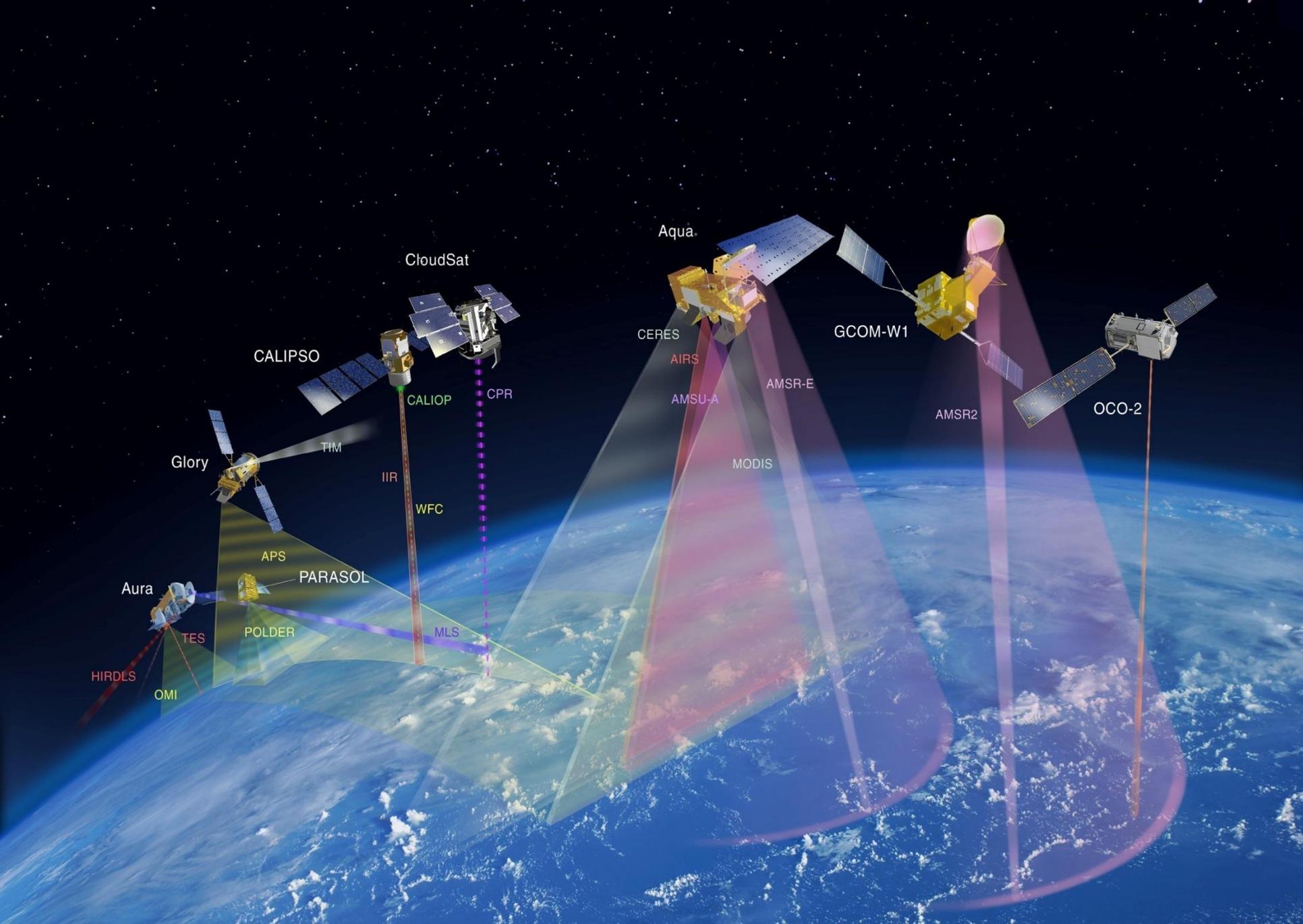


# Origem



# Sensoriamento Remoto





# Monitoramento da

# Atmosfera e dos Recursos Terrestres

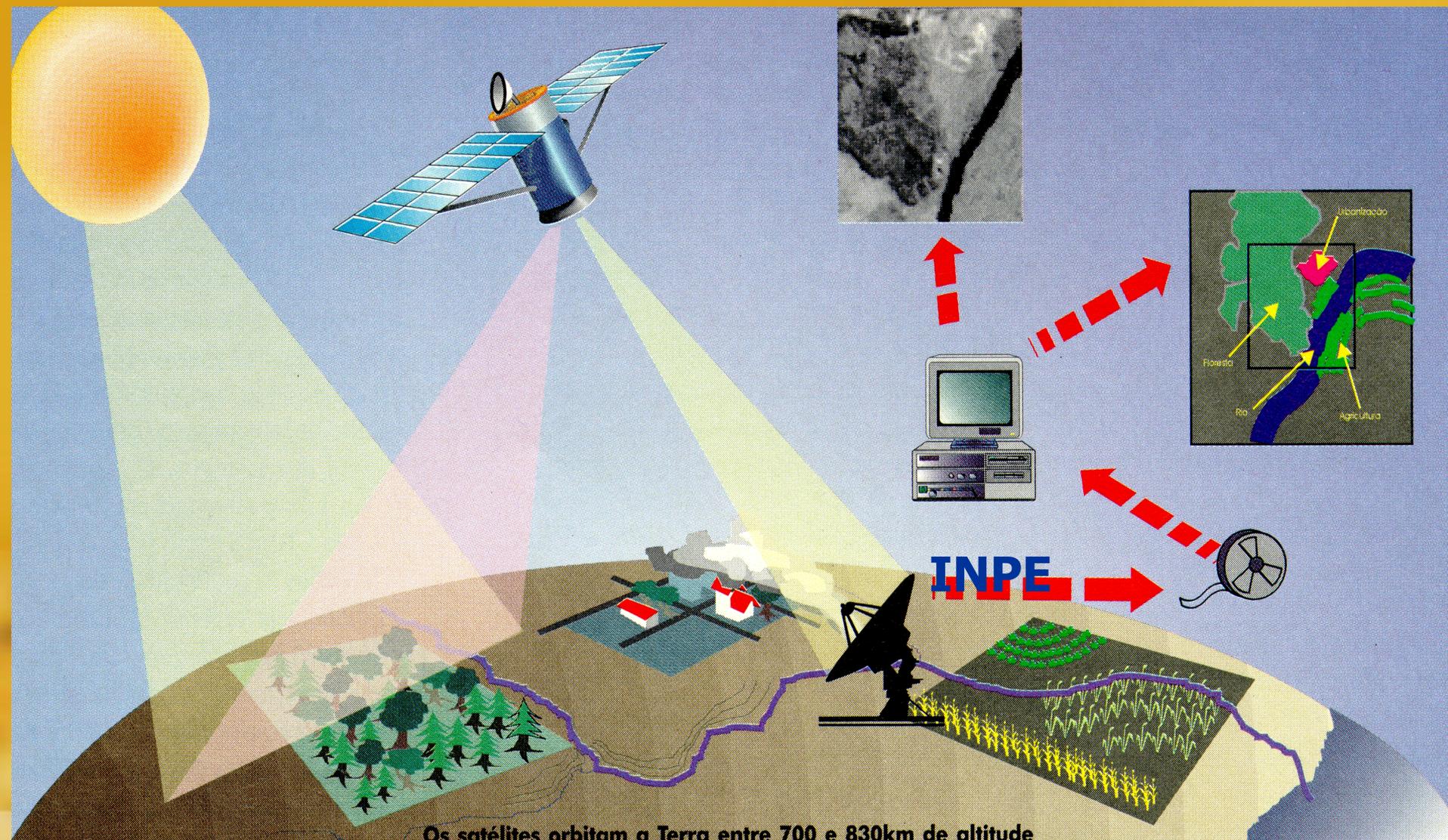






**Curso de Uso Escolar de Sensoriamento Remoto - Inpe**

# Sensoriamento Remoto



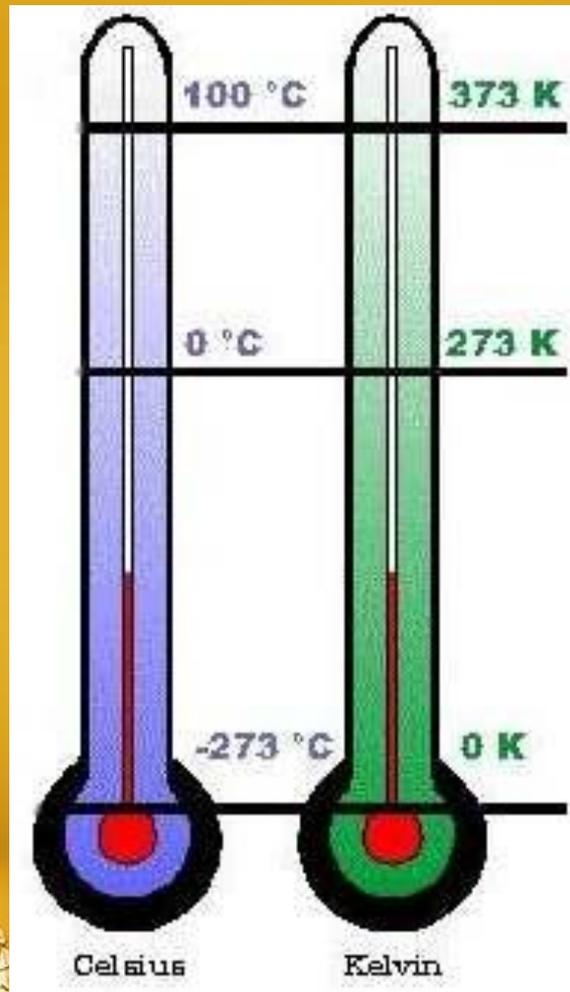
Os satélites orbitam a Terra entre 700 e 830km de altitude

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# Propagação de Energia



# Relação entre as escalas Celsius e Kelvin



$$0 \text{ K} = -273,16^{\circ}\text{C}$$

$$T_{\text{C}} = T_{\text{K}} - 273,16$$

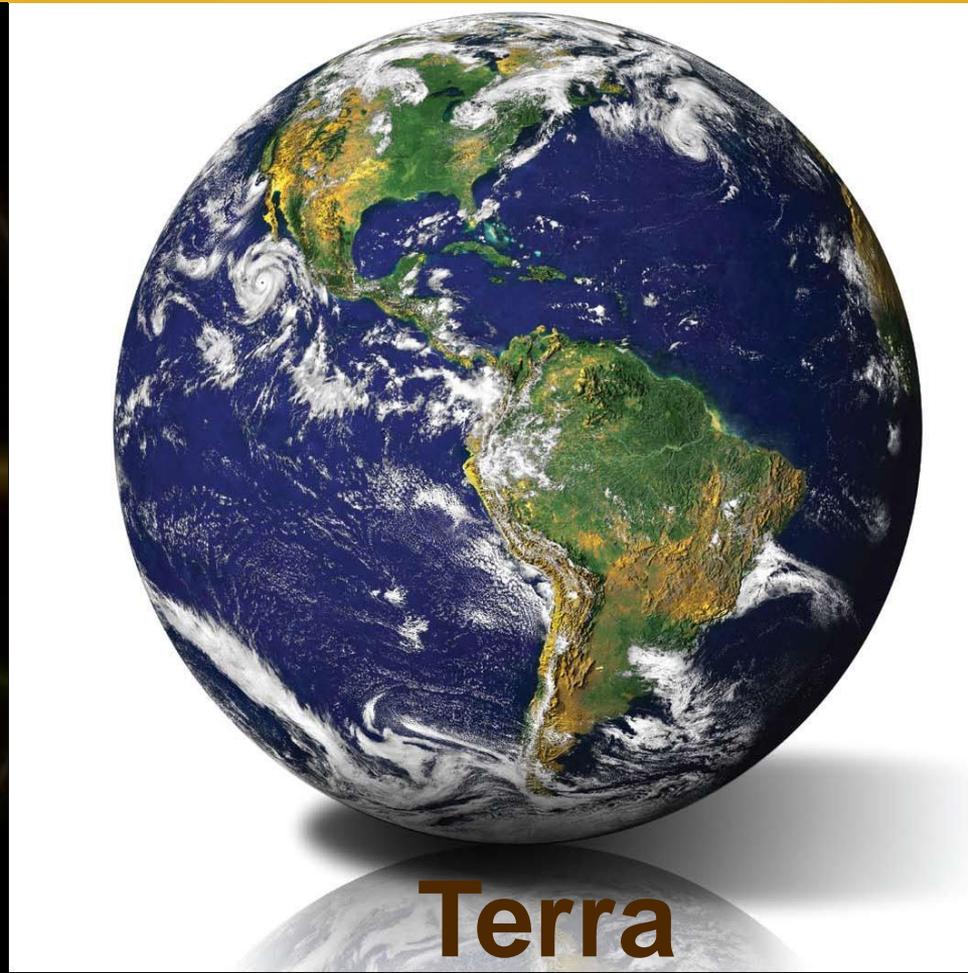
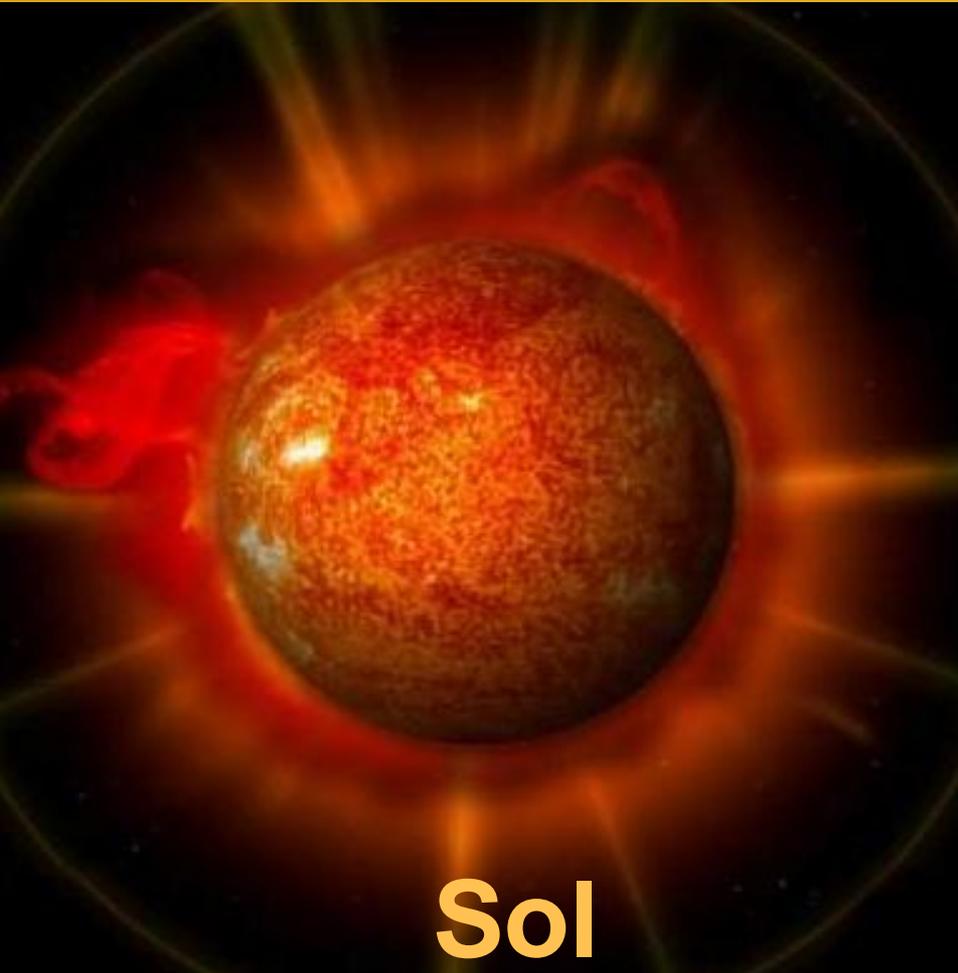
$T_{\text{C}}$  = temperatura Celsius

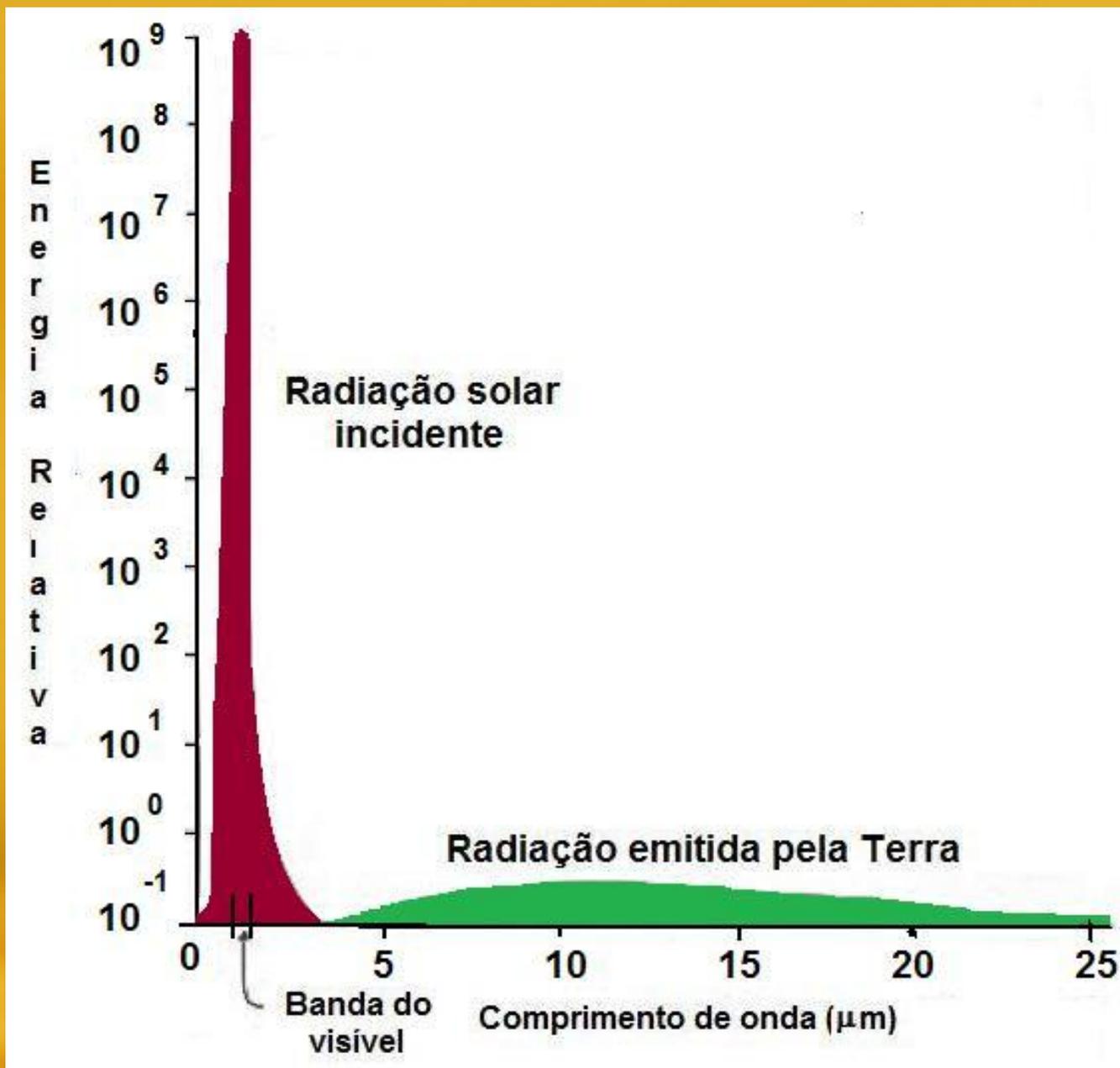
$T_{\text{K}}$  = temperatura Kelvin

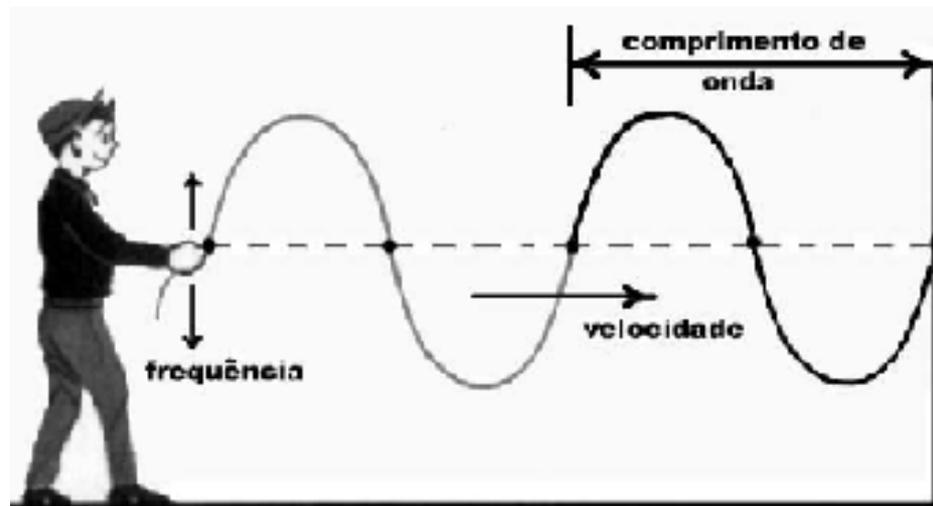
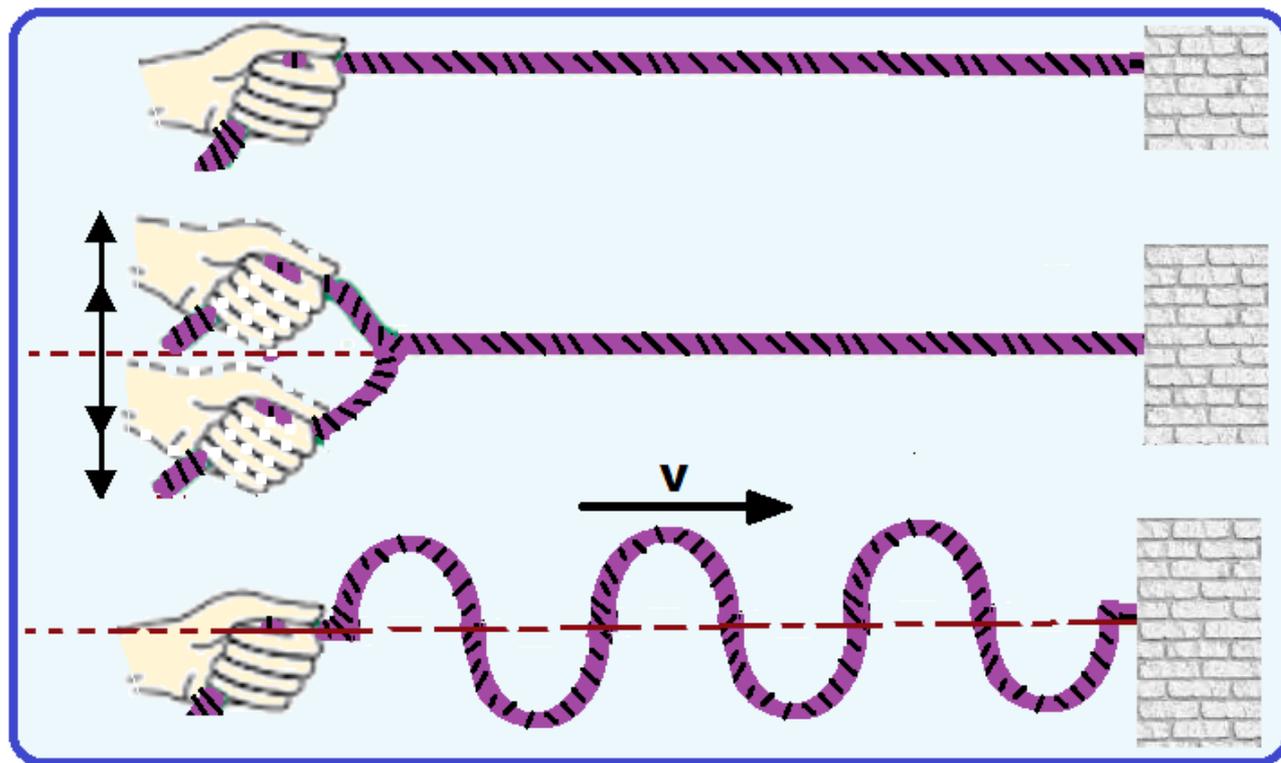


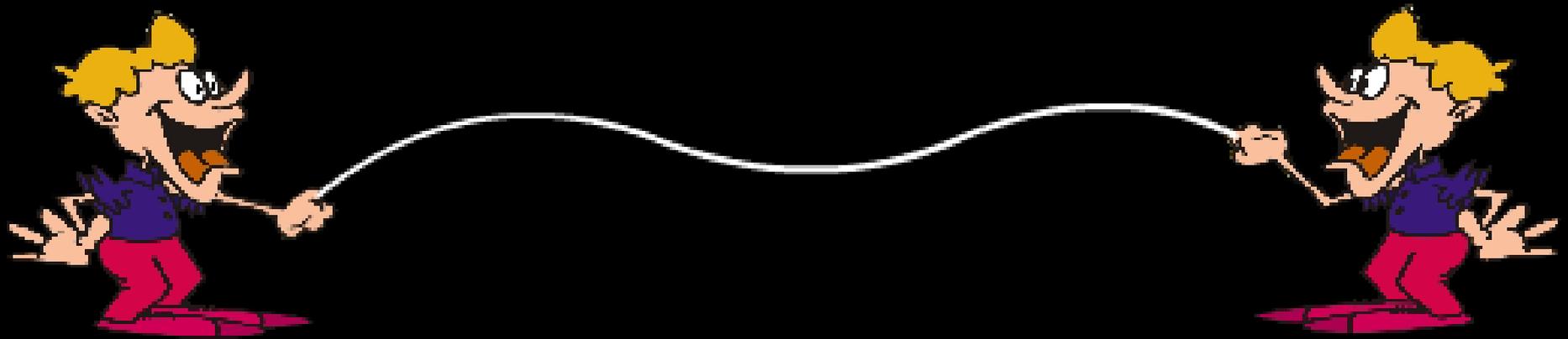
# Principais Fontes de Energia

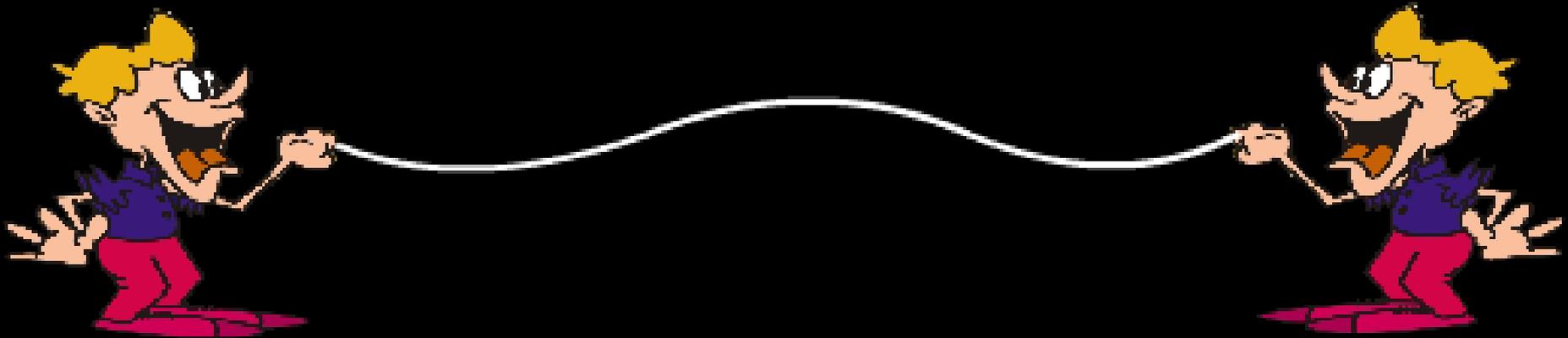
Todo corpo com temperatura acima de zero absoluto (0 K) emite energia eletromagnética

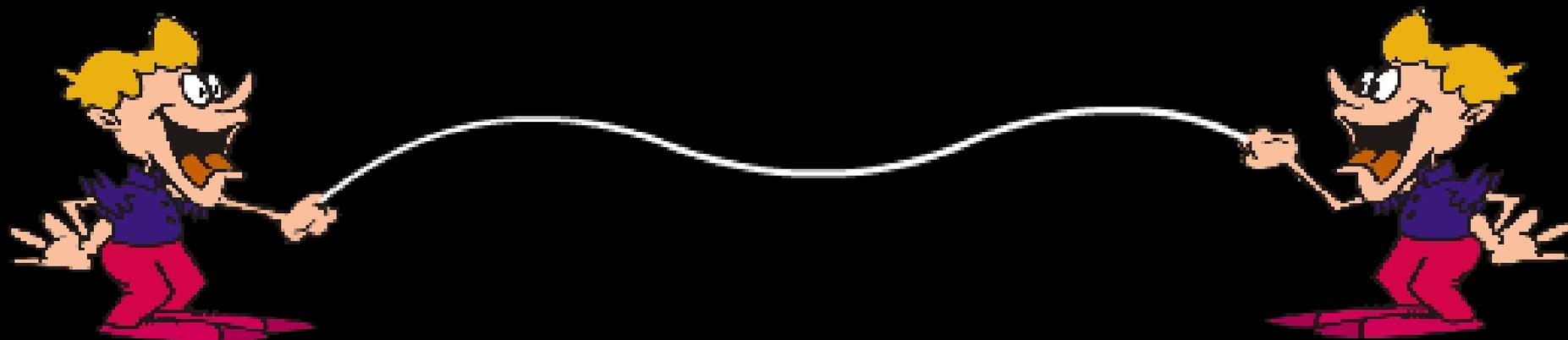




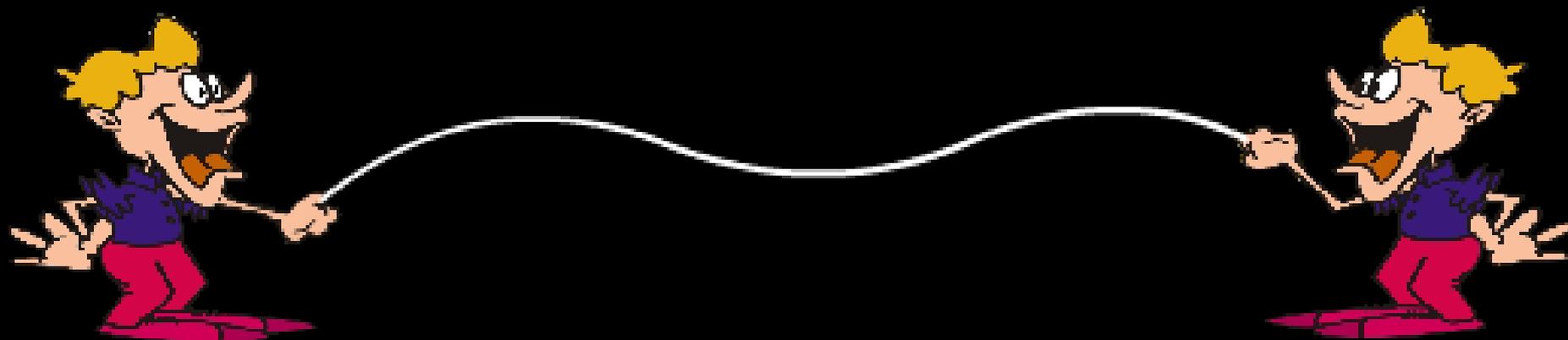


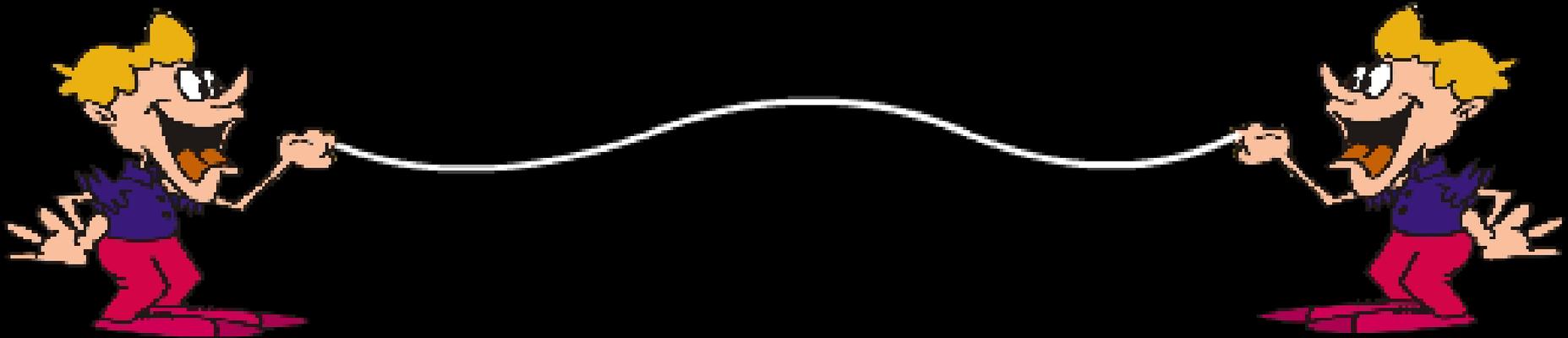


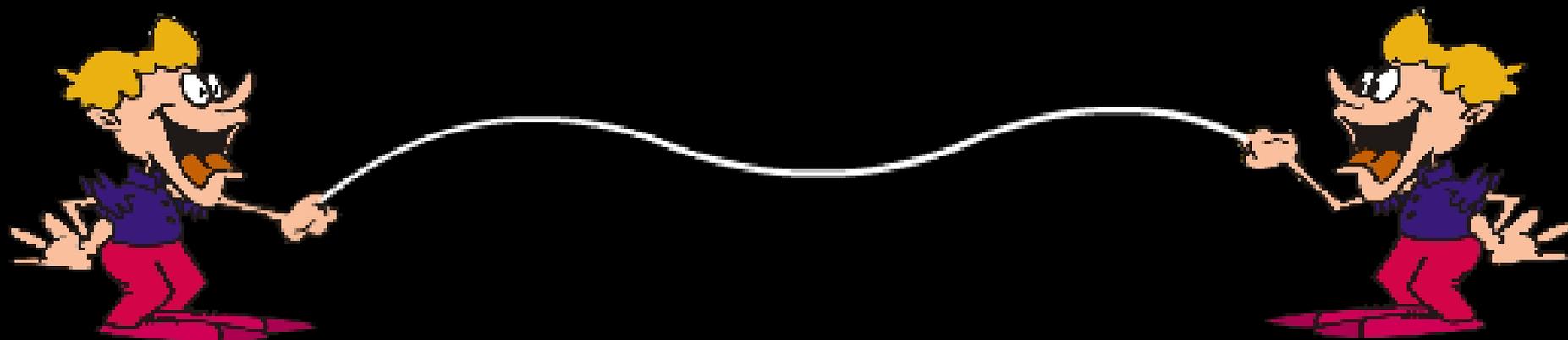


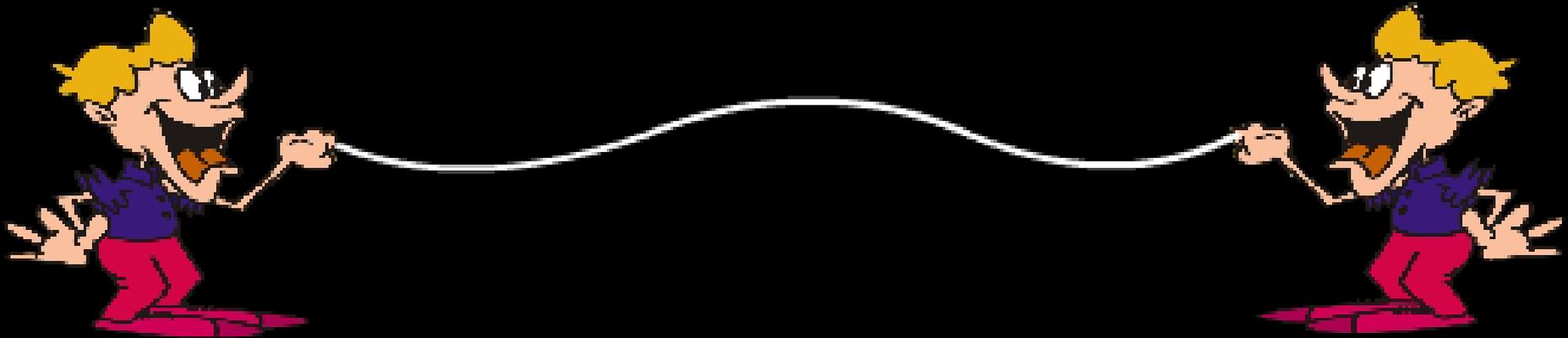








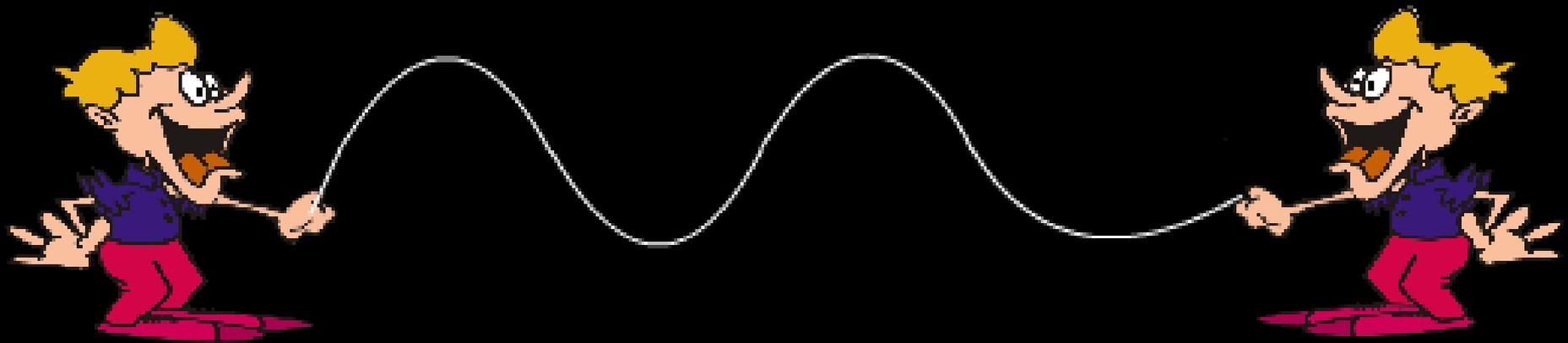


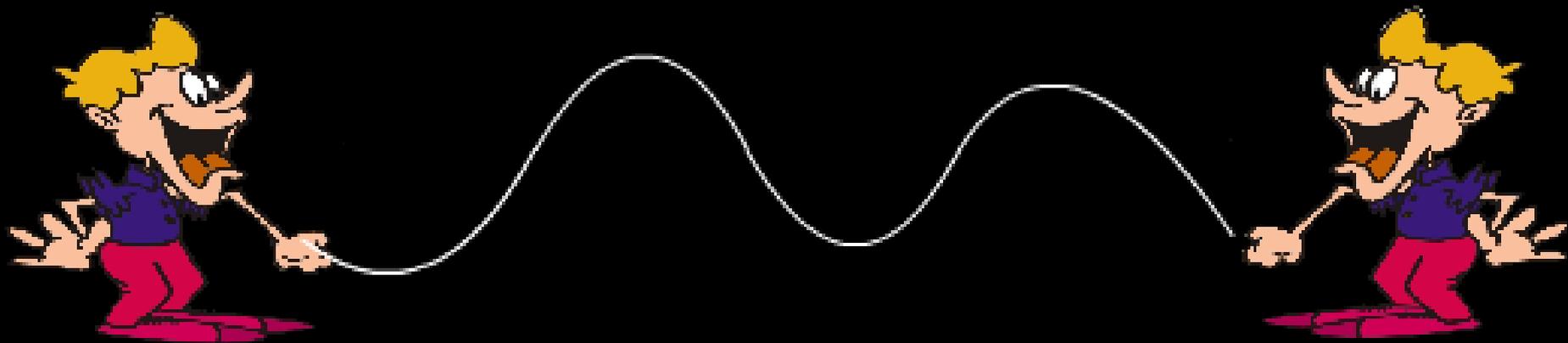


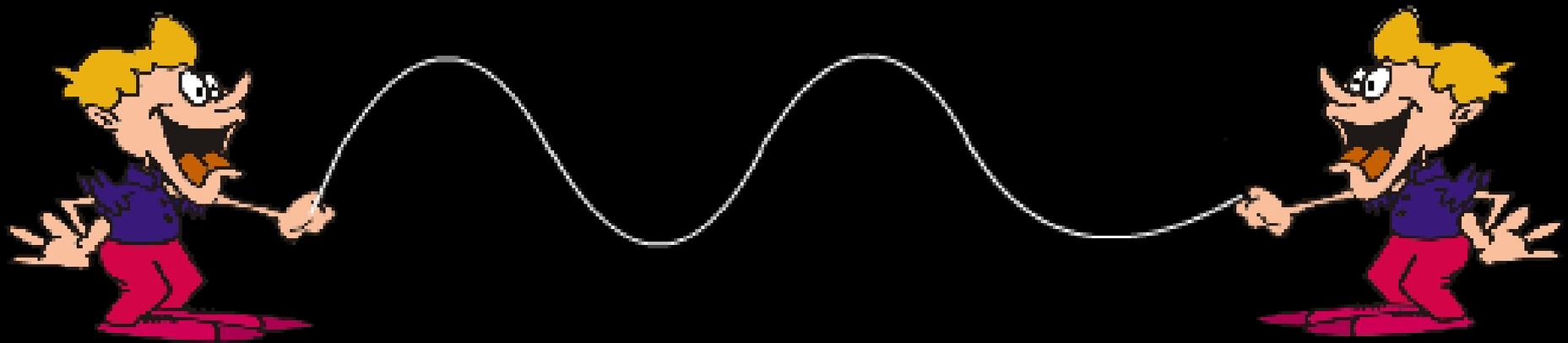
# **AUMENTANDO A ENERGIA NA CORDA**

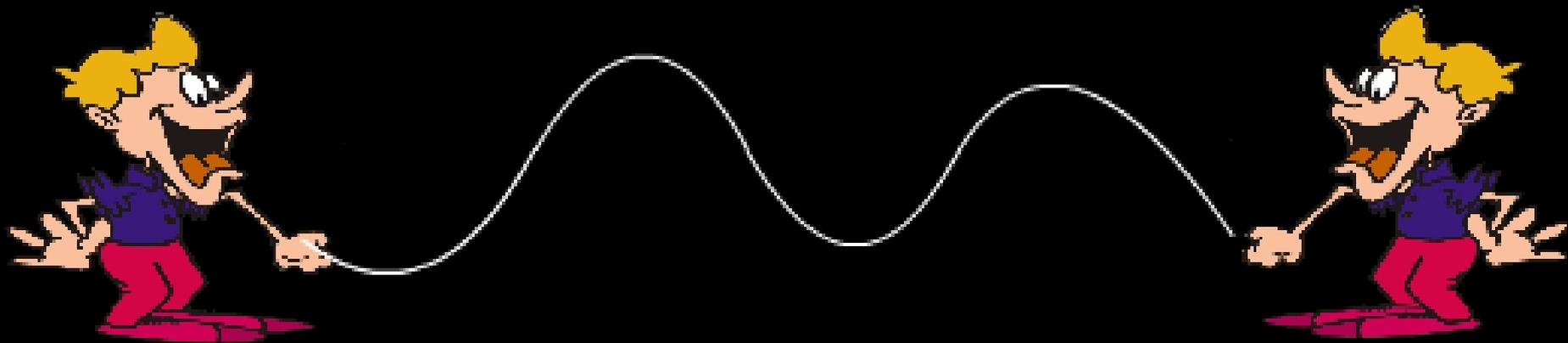
**O QUE SE OBSERVA?**

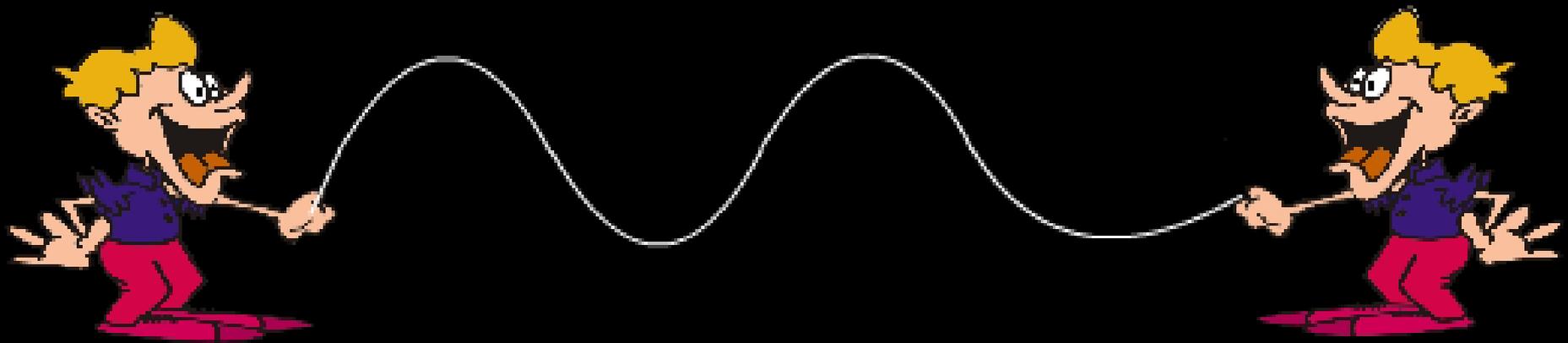


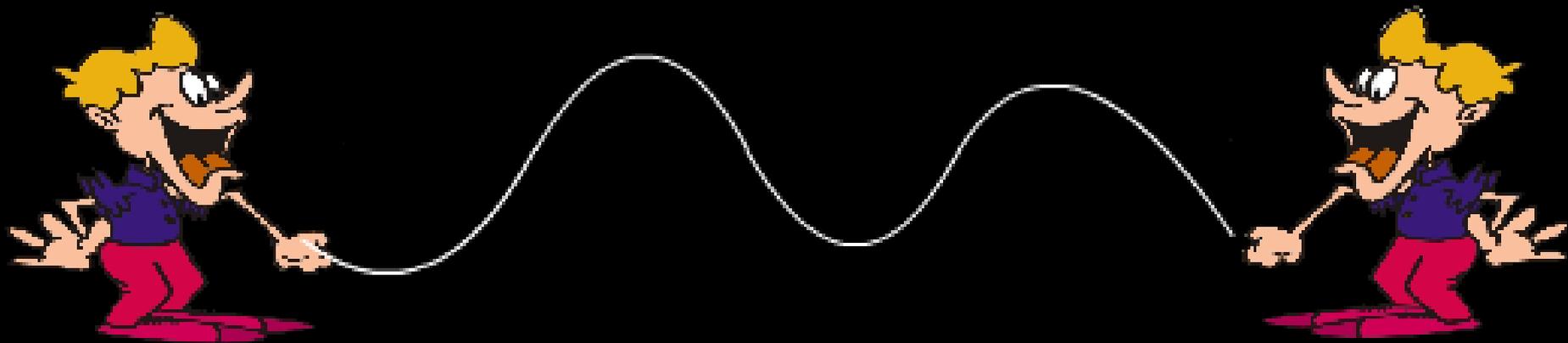


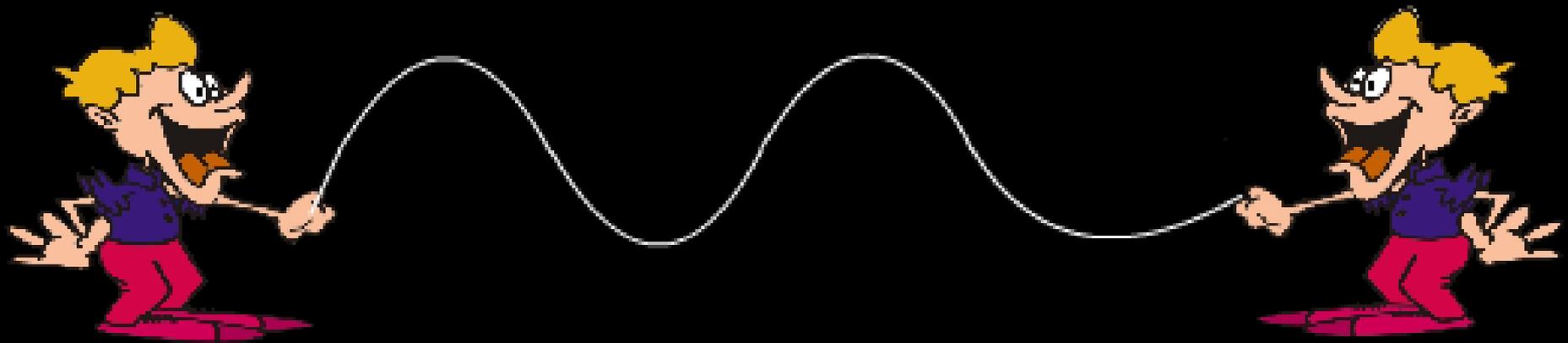


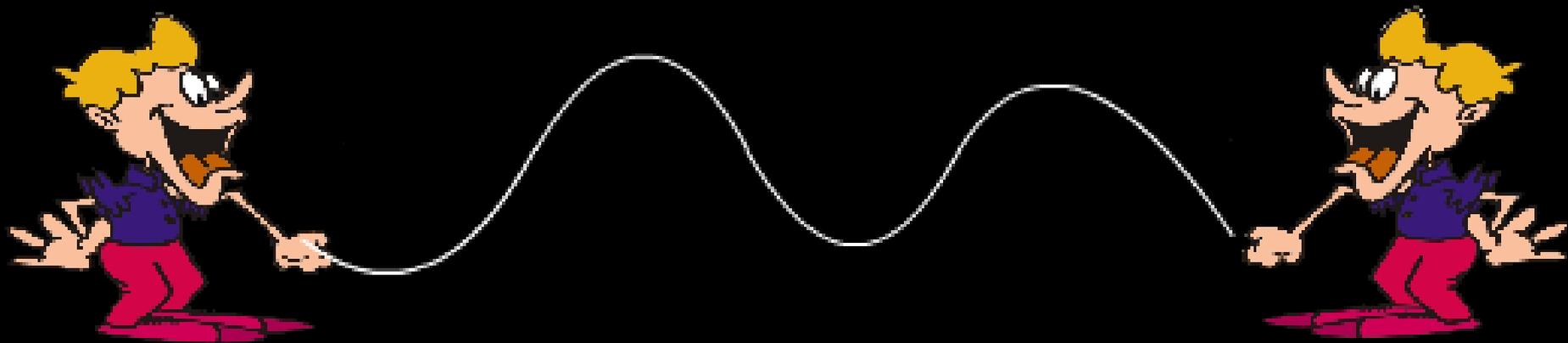


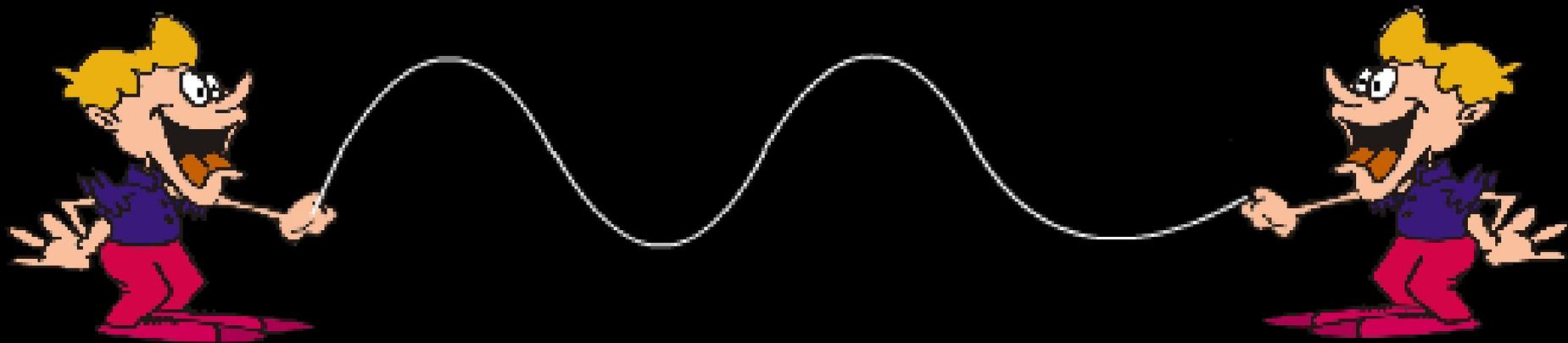


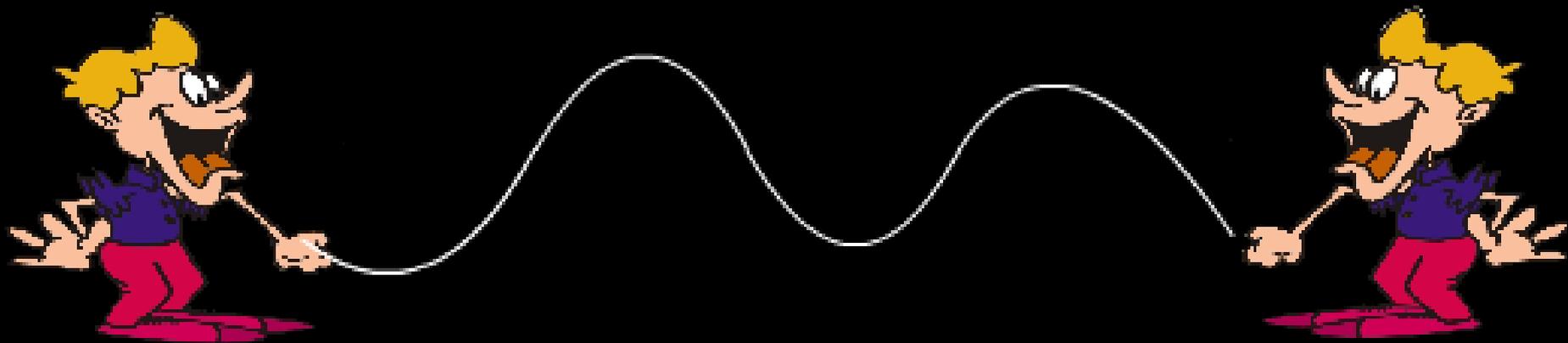


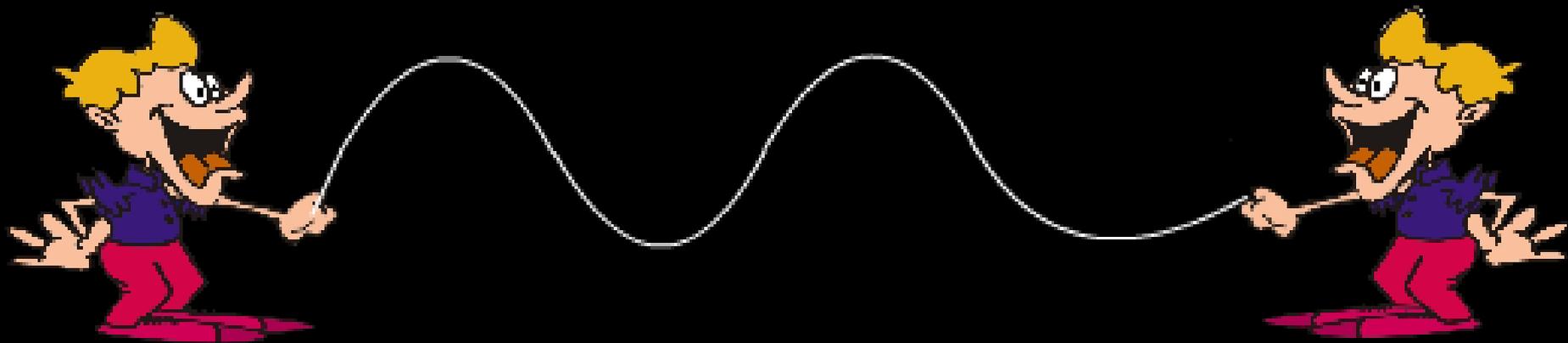


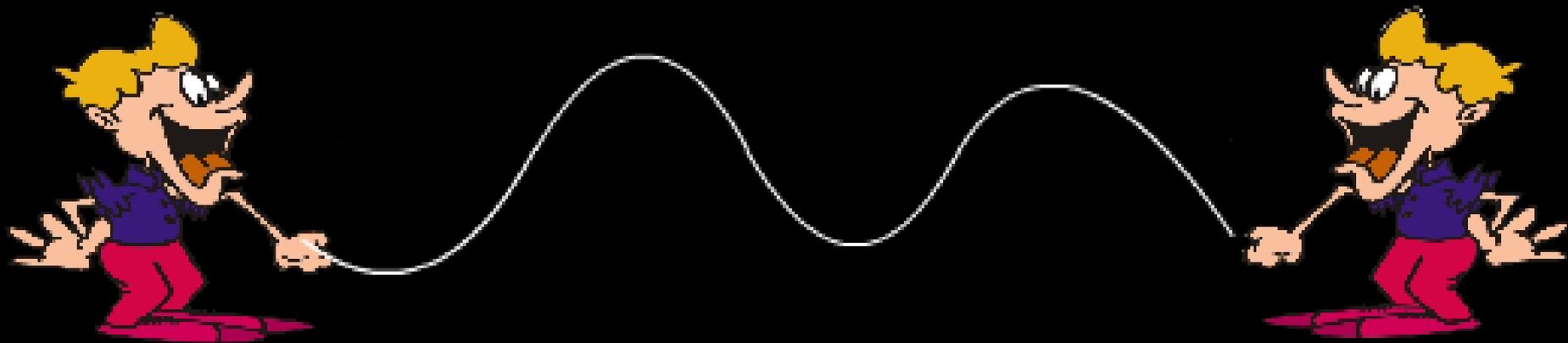












Qual a relação entre  
energia e frequência (f)?

$$E \propto f$$



Qual a relação entre  
energia e comprimento  
de onda ( $\lambda$ ) ?

$$E \propto 1/\lambda$$



Qual a relação entre  
frequência e comprimento  
de onda ( $\lambda$ )?

$$f = c / \lambda$$

ou

$$c = f \cdot \lambda$$



# Energia da Onda Eletromagnética



$$E = cte . f$$

ou

$$E = cte.c / \lambda$$

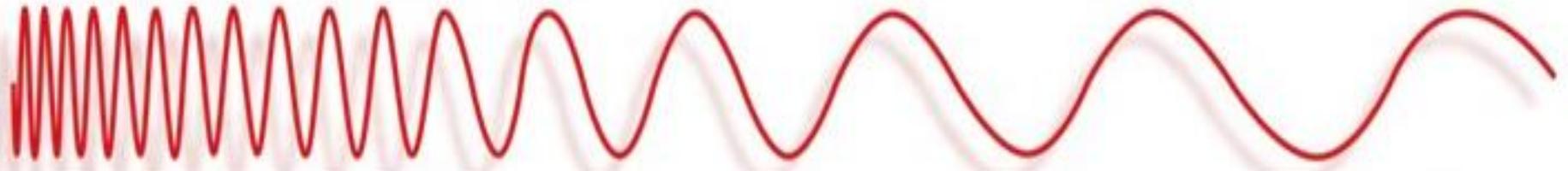
medida da capacidade da radiação de realizar trabalho físico, de aquecer um objeto ou causar mudança de estado da matéria



# Espectro Eletromagnético

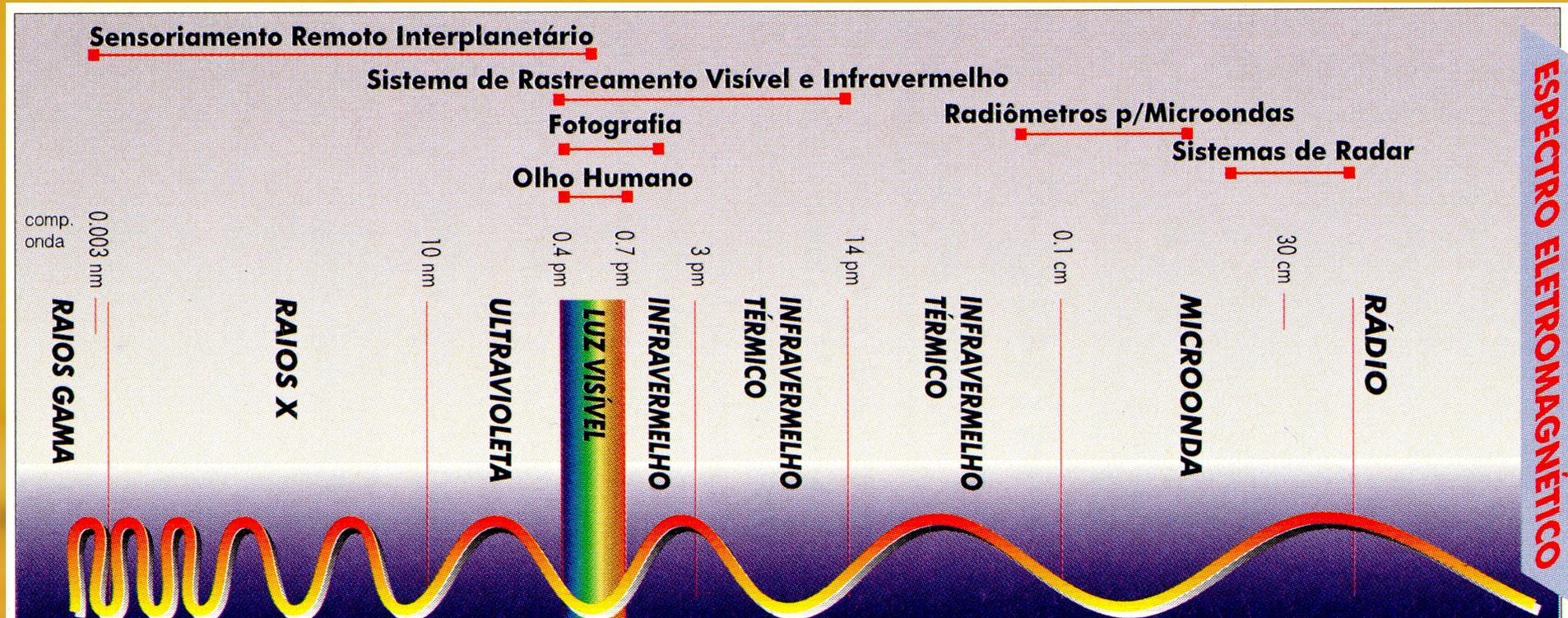
Ordenação contínua da energia eletromagnética em função do comprimento de onda ou da frequência

Raios Gama    Raios X    Ultra-Violeta    Visível    Infravermelho    Microondas    Rádio



# Espectro Eletromagnético

Regiões espectrais de interesse do Sensoriamento Remoto:  
Ótico e Microondas



ESPECTRO ELETROMAGNÉTICO

# Espectro Eletromagnético



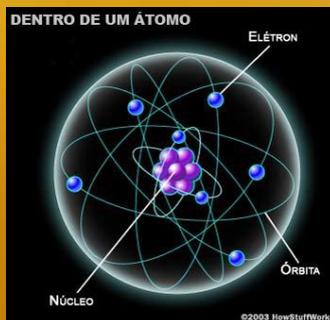
# O que é 1 micrometro?

- $1/1\text{milhão} = 1/1.000.000 = 0,000001$  metros
  - $1\text{ milhão} = 1000 \times 1000 = 1.000.000$
- Logo,  $1\text{micrometro} = 0,000001\text{ m}$



# O que é 1 nanômetro?

- $1/1\text{bilhão} = 1/1.000.000.000 = 0,000000001$  metros
- $1\text{ bilhão} = 1000 \times 1000 \times 1000 = 1.000.000.000$
- Logo,  $1\text{ nanômetro} = 0,000000001\text{ m}$



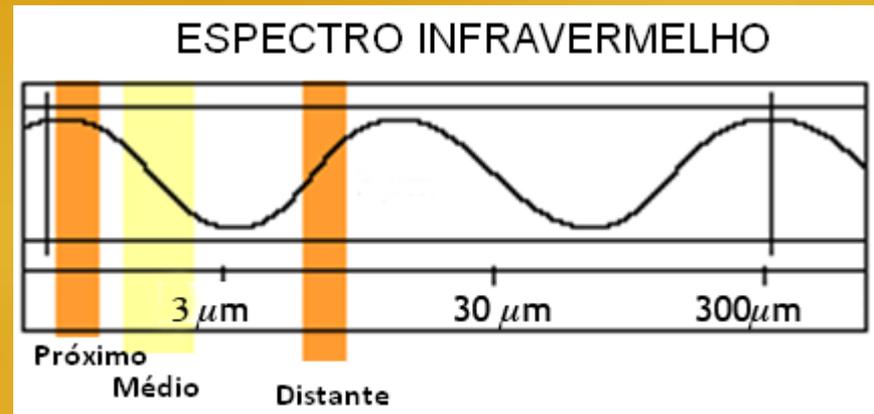
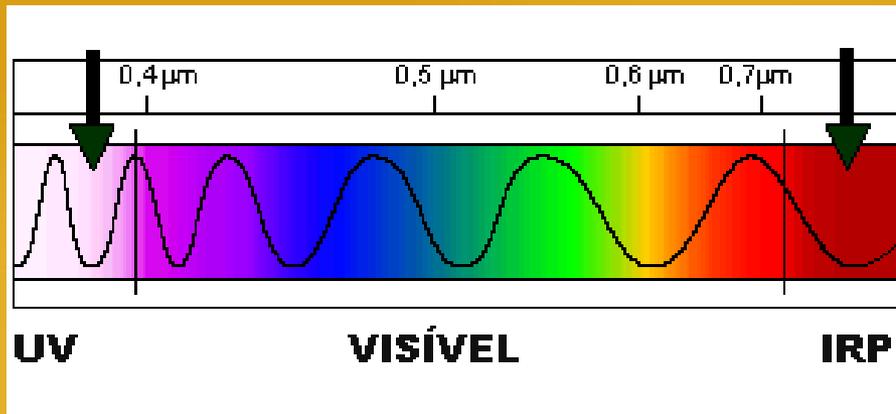
# Faixas espectrais importantes para o SR

Denominação	Comprimento de onda ( $\mu\text{m}$ )
SR Óptico	0,30 – 14,0
Refletido	0,40 – 4,00
Visível	0,40 – 0,70
Infravermelho próximo	0,70 – 1,10
Infravermelho Médio	1,10 – 4,00
Infravermelho distante (Termal, Emitido)	8,00 – 12,0
Microondas	1 mm a 1m

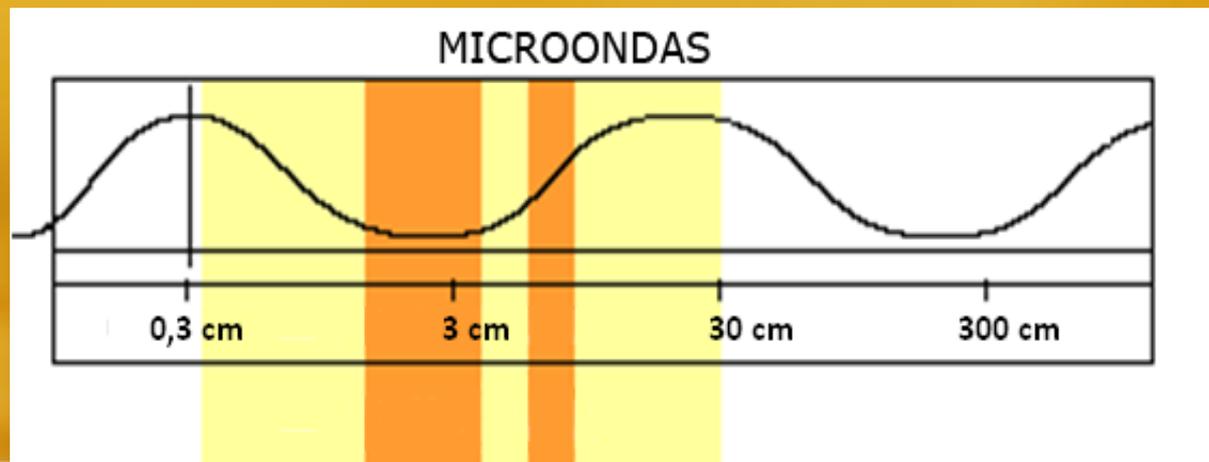


# Regiões Espectrais

## SENSORIAMENTO REMOTO PASSIVO

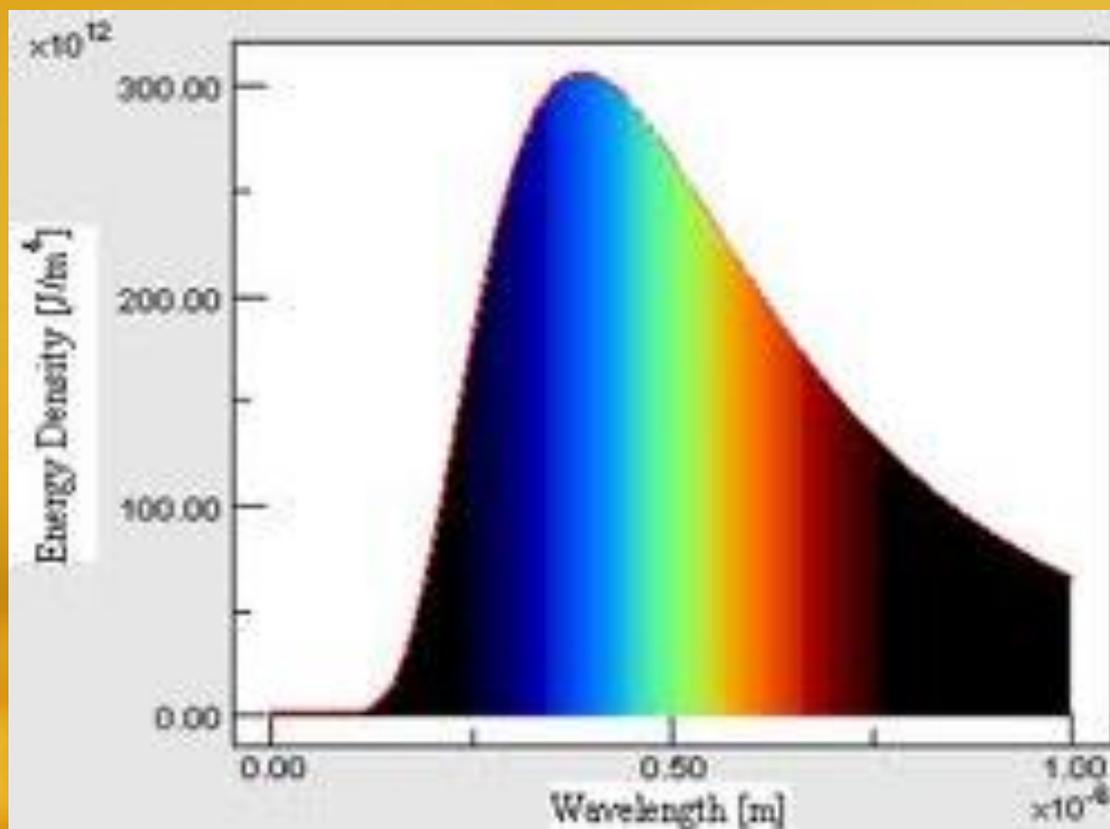


## SENSORIAMENTO REMOTO ATIVO



# Visível

- Energia que sensibiliza o olho humano.
- A radiação visível é emitida por muitas coisas, p. ex. fogo, lâmpadas e estrelas.



# Espectro Visível

- violeta: 400 a 455 nm
- azul: 455 a 492 nm
- verde: 492 a 577 nm
- amarelo: 577 a 597 nm
- laranja: 597 a 622 nm
- vermelho: 622 a 700 nm



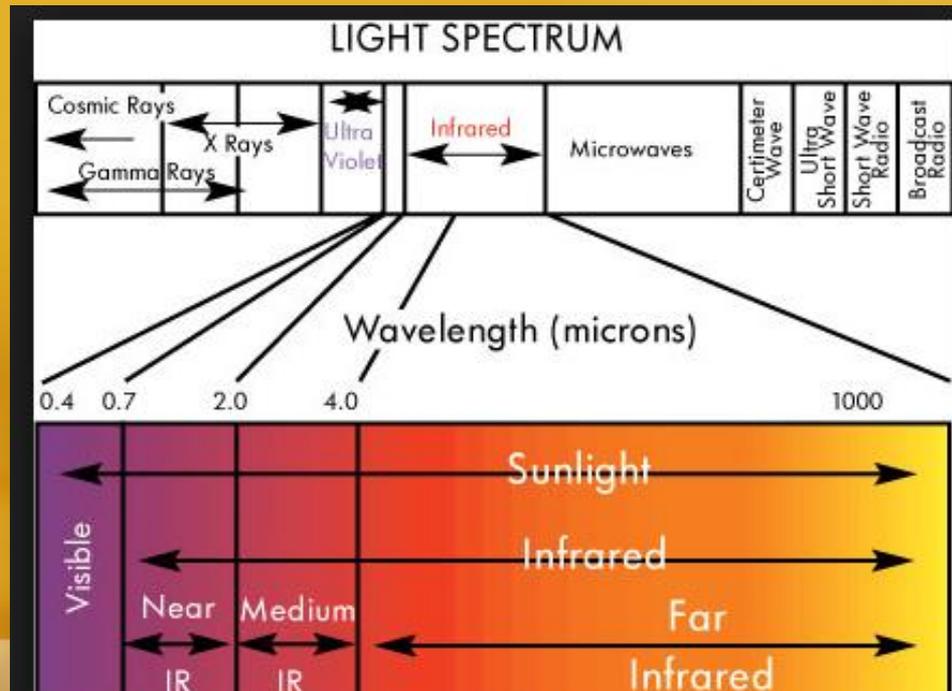
# Infravermelho

**NIR** - “Near Infrared”

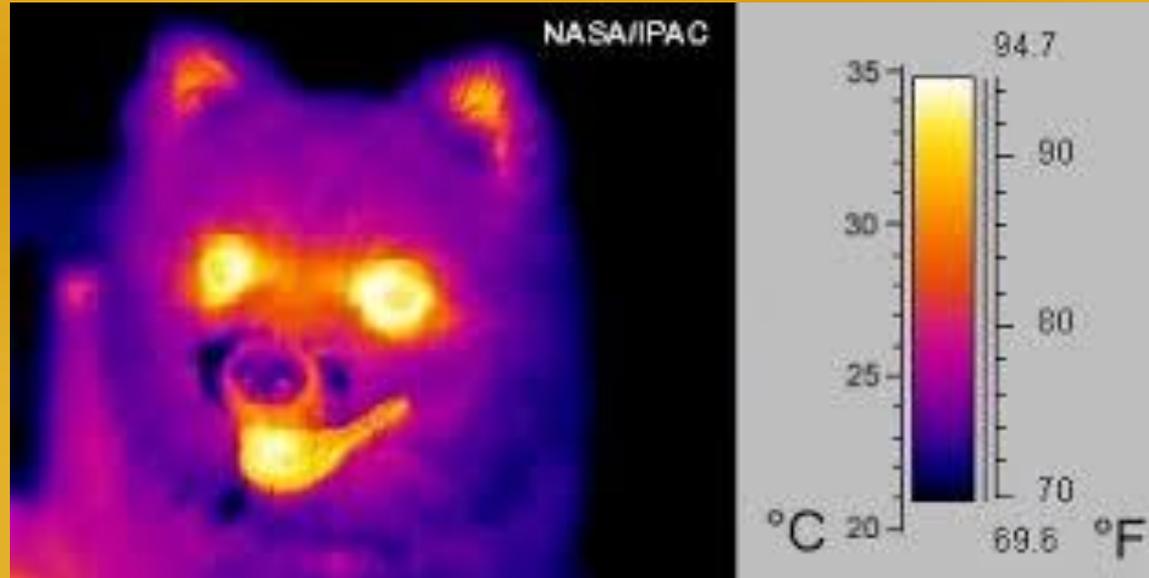
**SWIR** - “Short Wavelength Infrared”

**MWIR** - “Middle Wavelength Infrared”

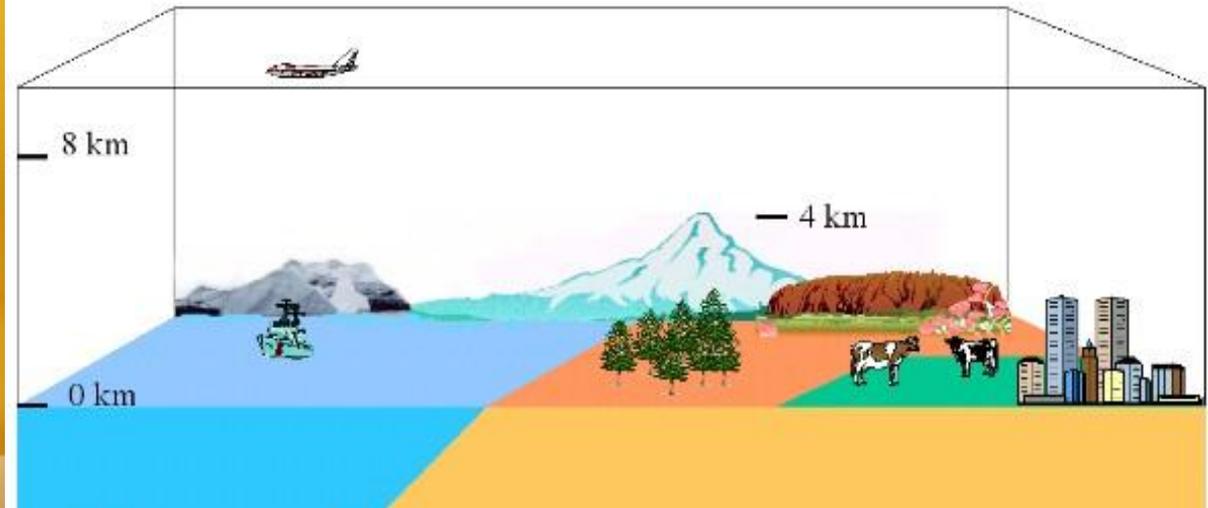
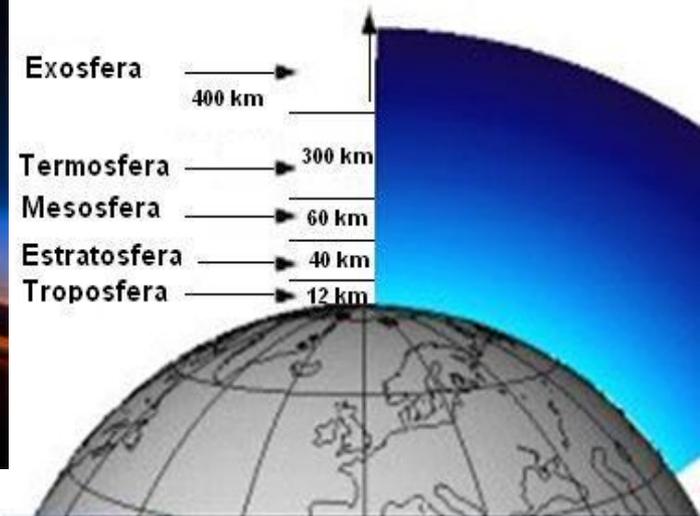
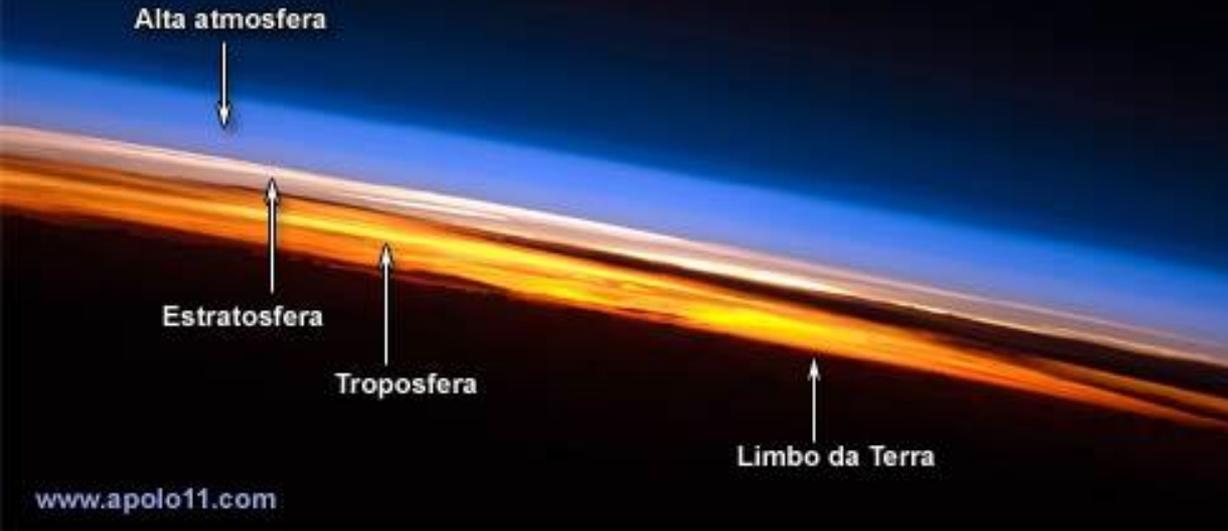
**LWIR** - “Long Wavelength Infrared”



# Infravermelho distante



Espaço Profundo



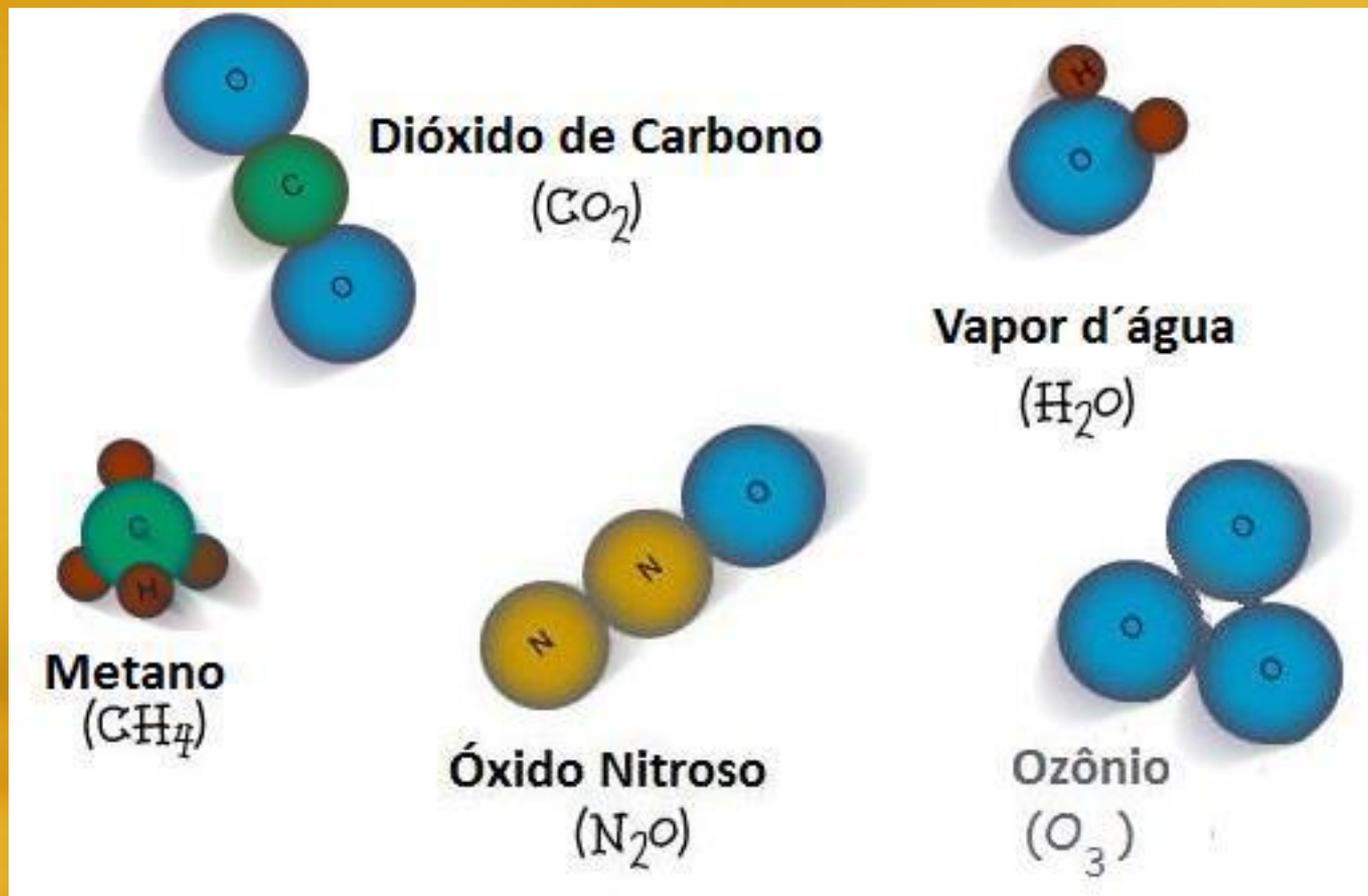
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# Interação da Radiação Solar com a Atmosfera

- A energia eletromagnética ao atravessar a atmosfera é absorvida, refletida e espalhada pelos gases nela presentes

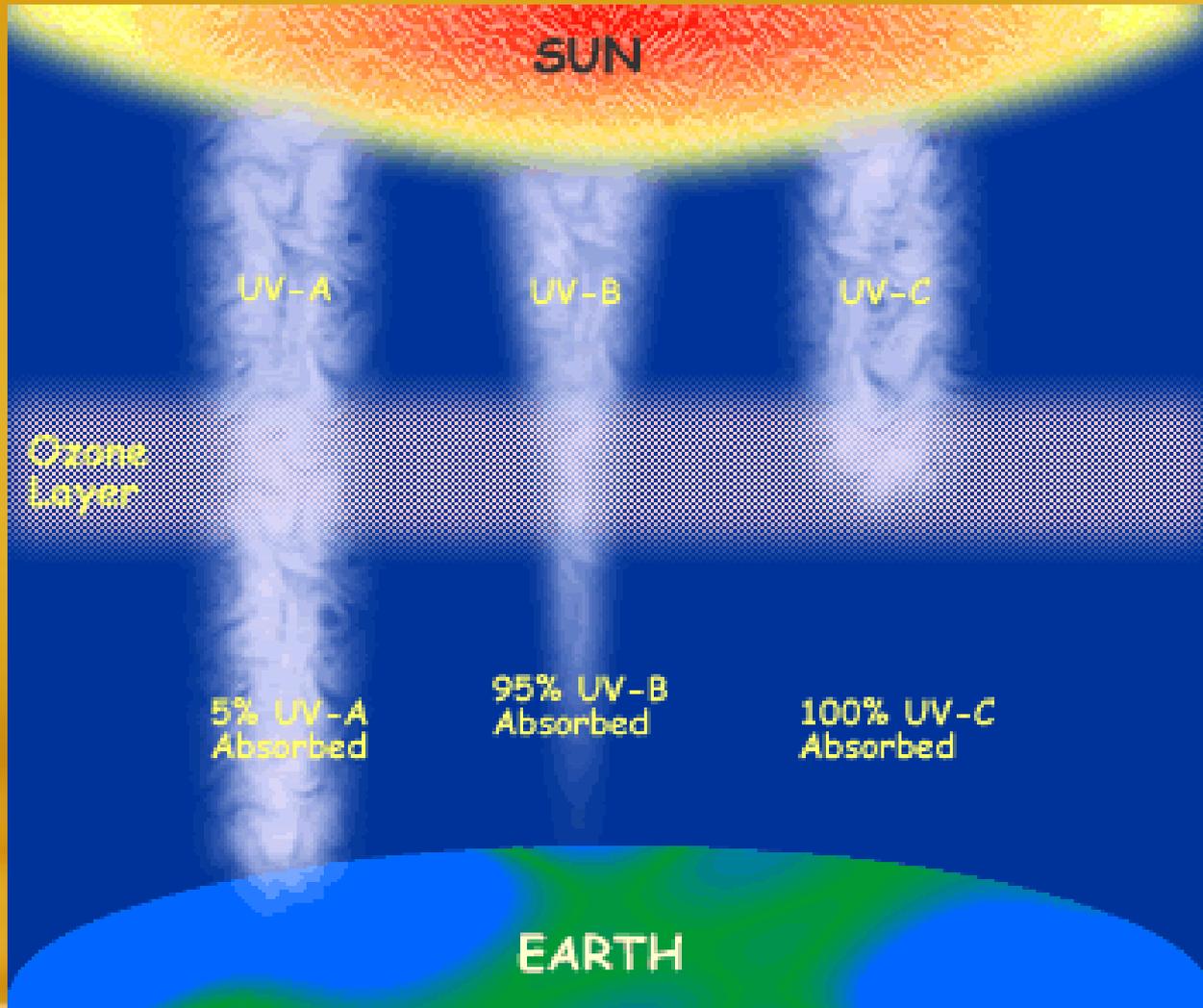


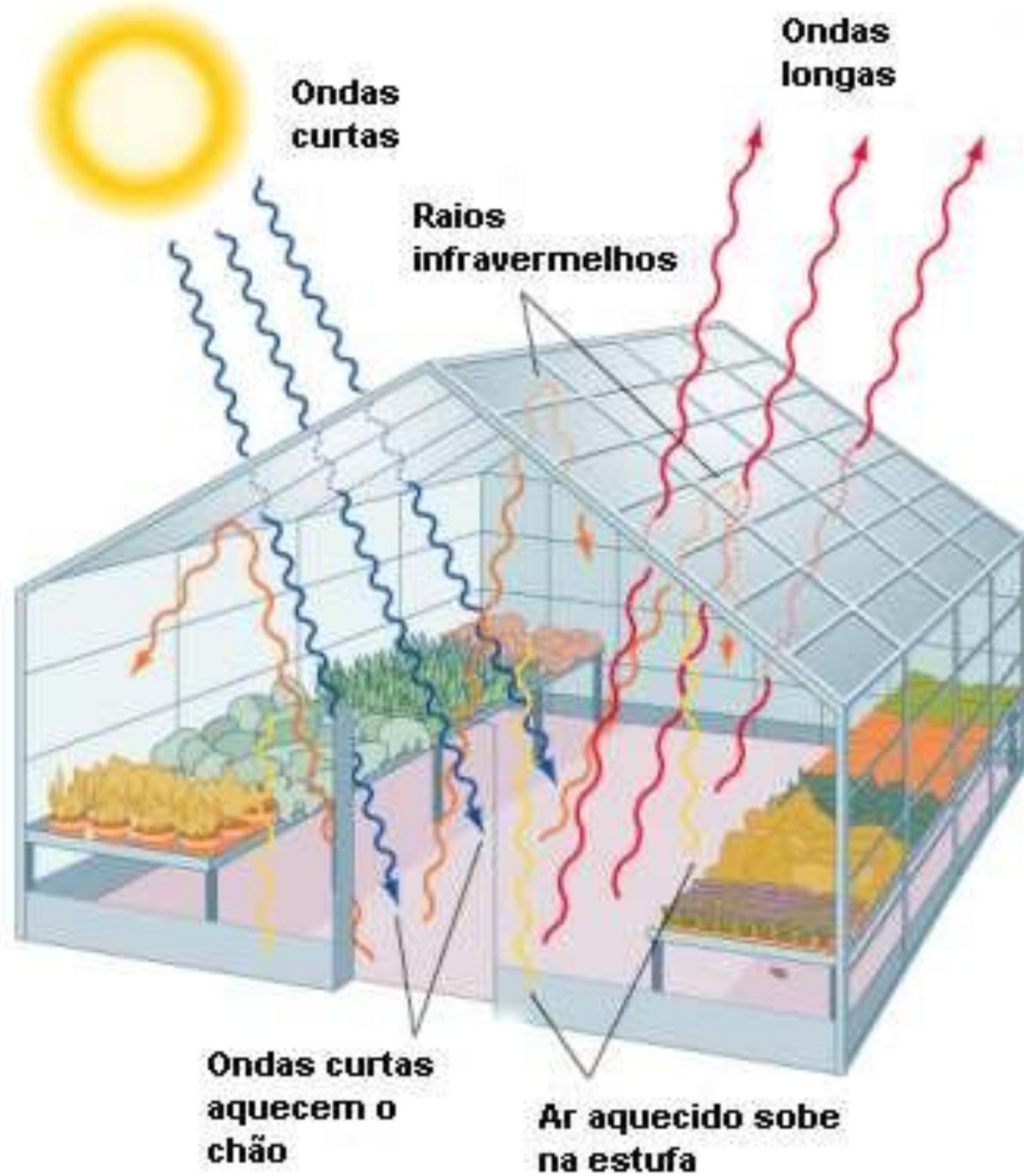
# Principais Gases da Atmosfera que Interagem com a Radiação Solar e Terrestre



# Ultravioleta

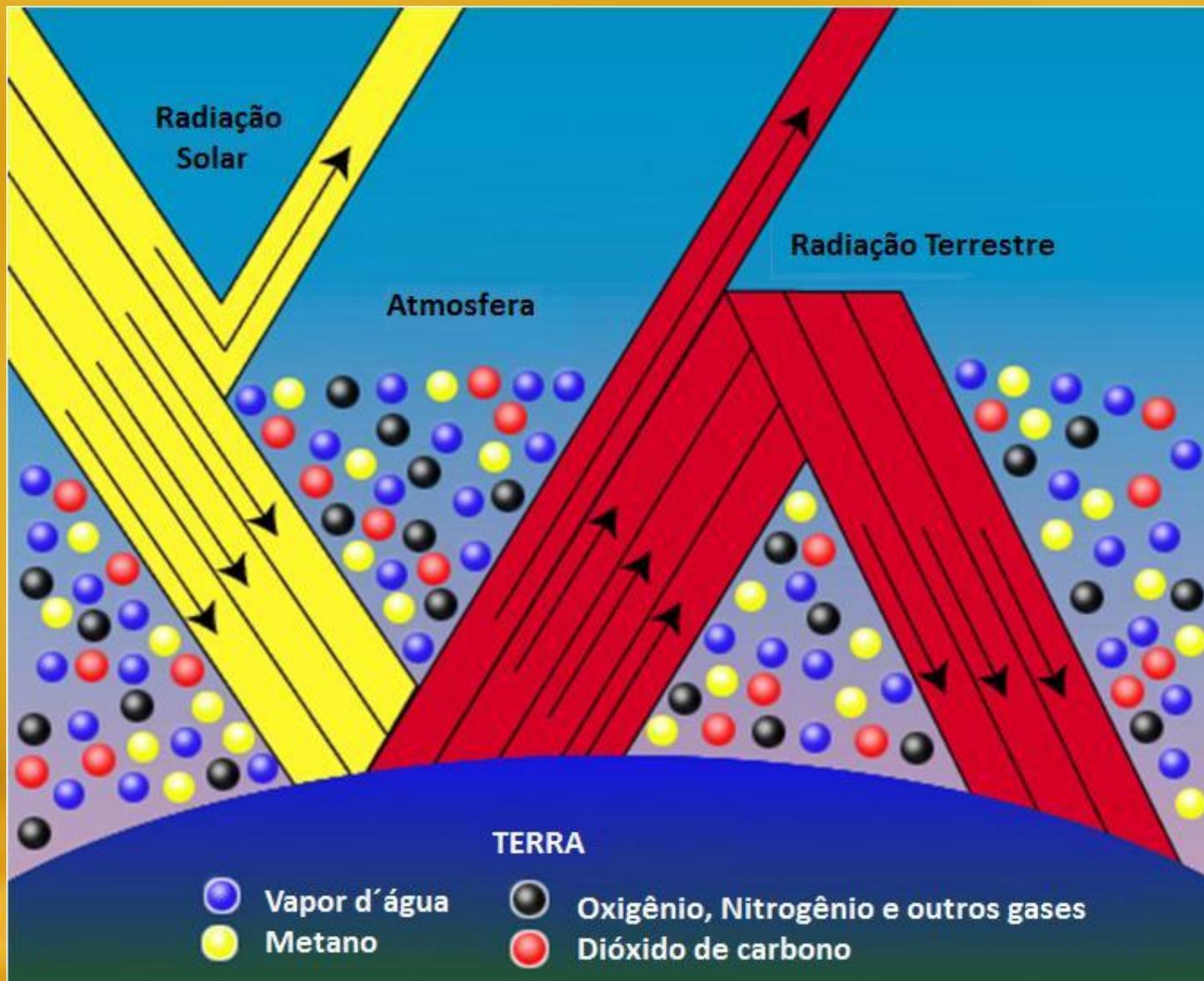
Estrelas e outros objetos quentes emitem energia em UV



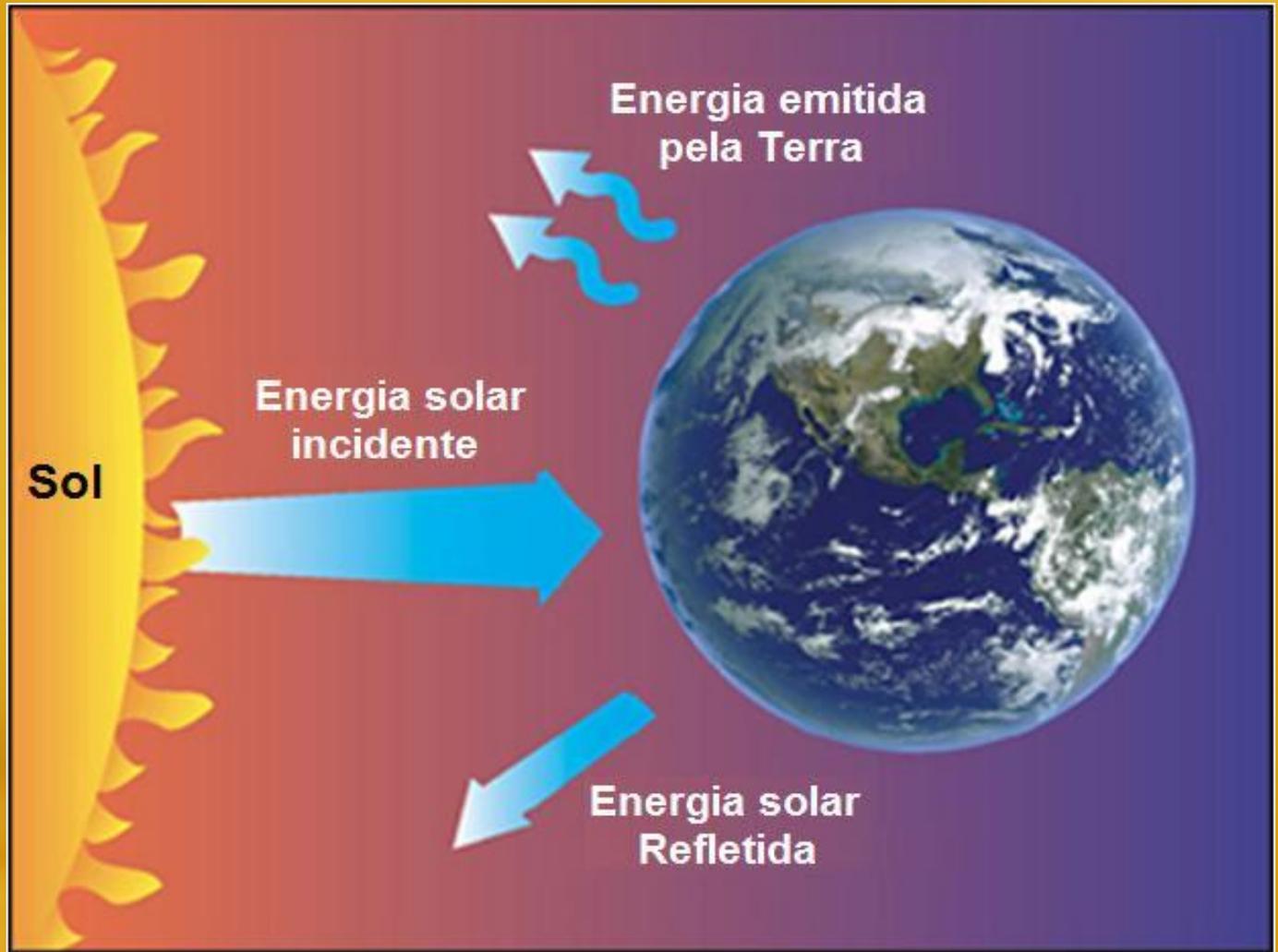


**Ondas curtas aquecem o chão**

**Ar aquecido sobe na estufa**



# Balanço de Radiação



**Mars**  
Thin atmosphere  
(Almost all CO<sub>2</sub> in ground)



**Earth**  
0,03% of CO<sub>2</sub> in the atmosphere



**Venus**  
Thick atmosphere  
containing 96% of CO<sub>2</sub>

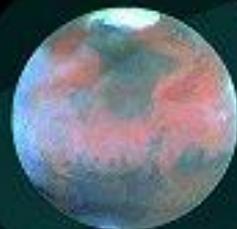


## Mars

Thin atmosphere

(Almost all CO<sub>2</sub> in ground)

Average temperature : - 50°C



## Earth

0,03% of CO<sub>2</sub> in the atmosphere

Average temperature : + 15°C



## Venus

Thick atmosphere

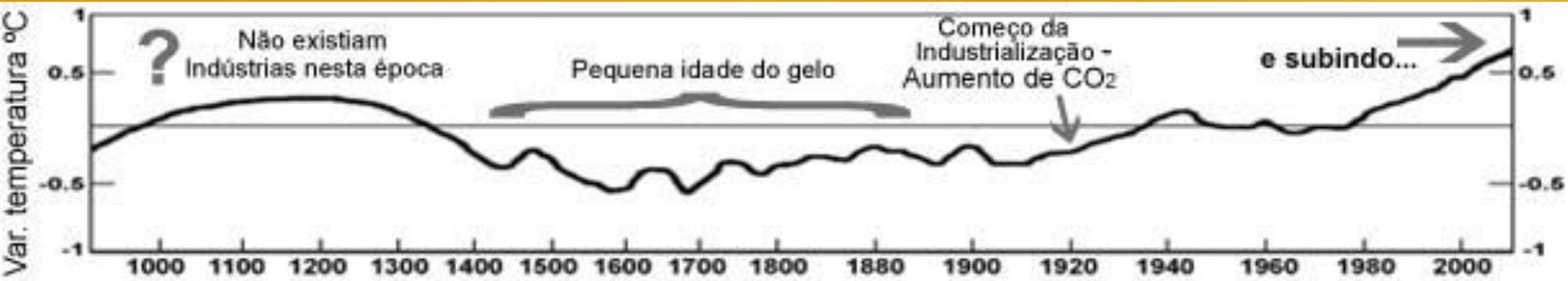
containing 96% of CO<sub>2</sub>

Average temperature : + 420°C

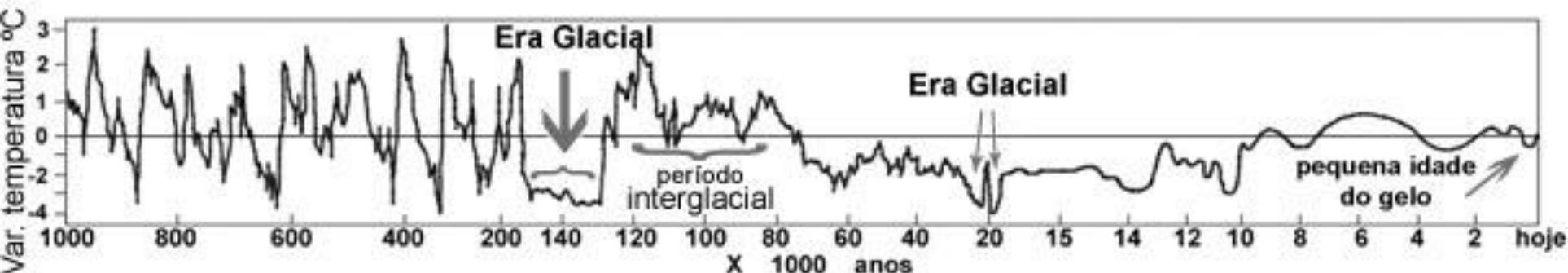


# Variação da Temperatura

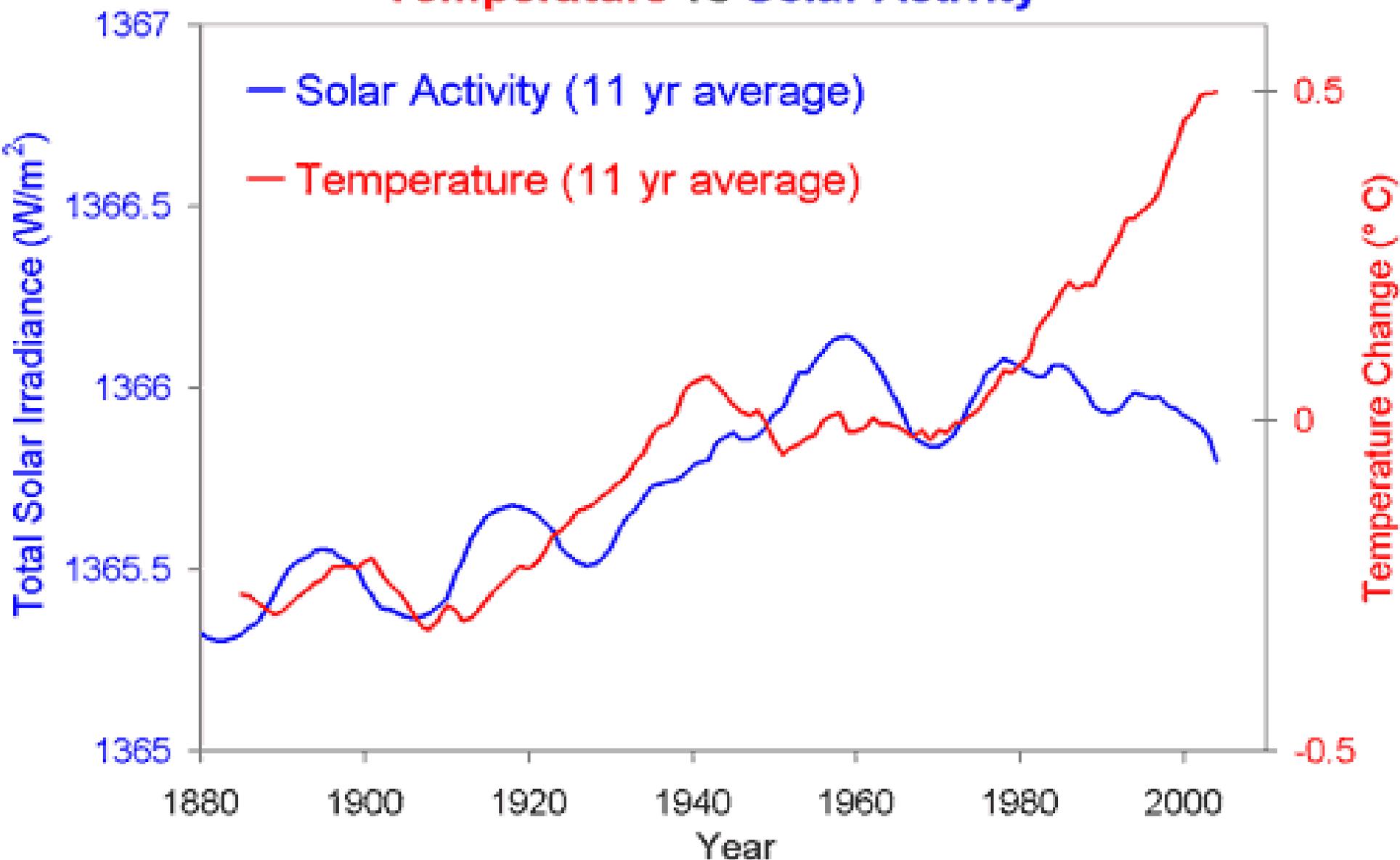
- Último mil ano

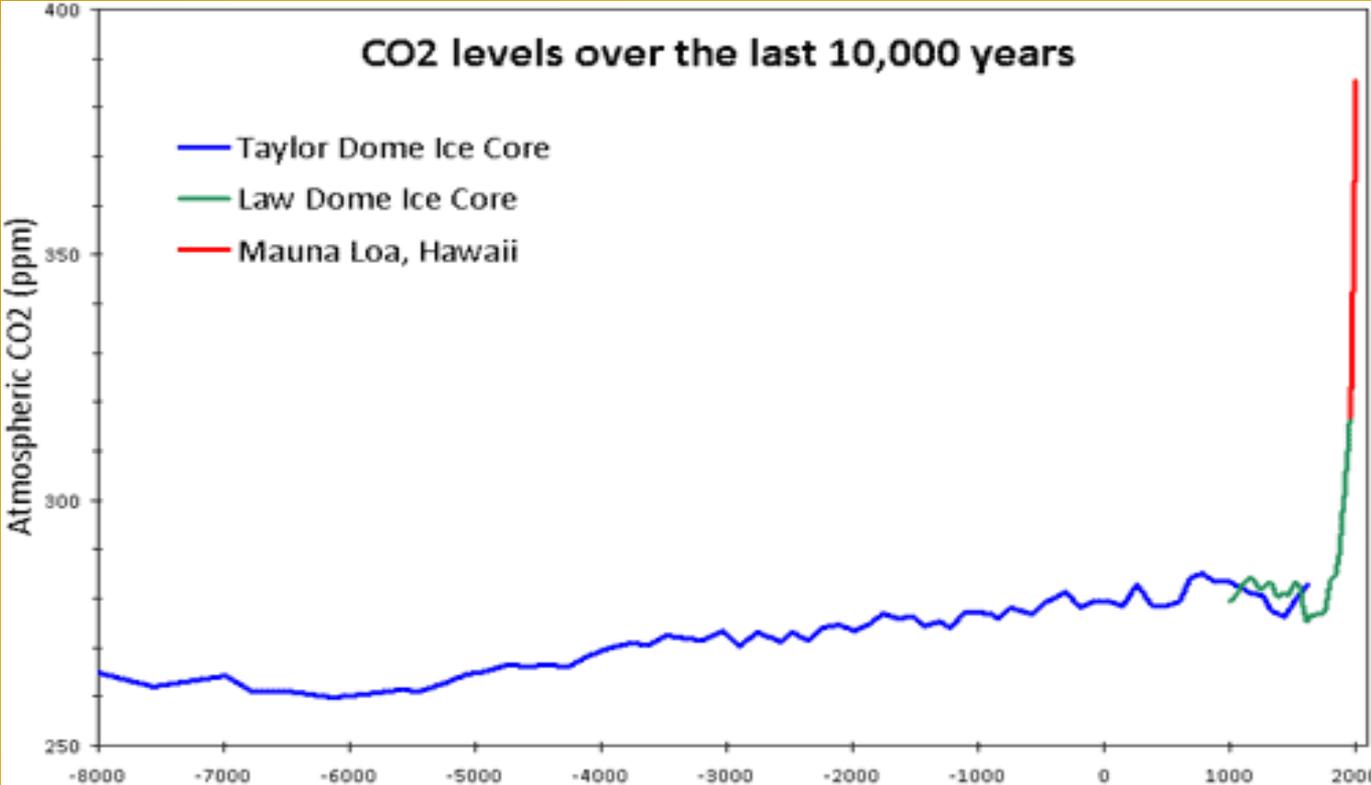


- Último Milhão de ano



## Temperature vs Solar Activity

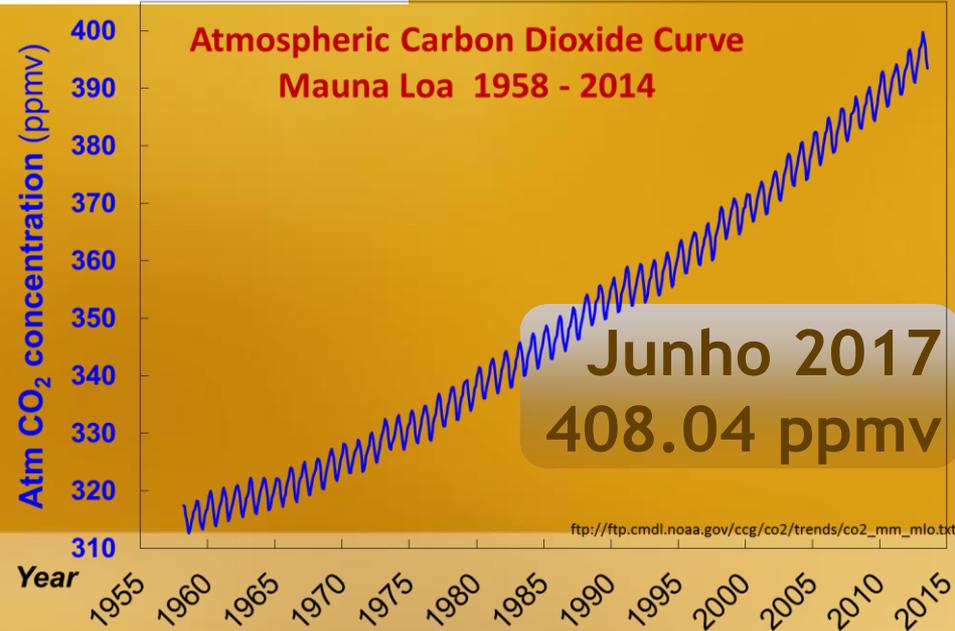




**Anos**

[https://globalchange.umich.edu/globalchange1/current/lectures/king/carbon\\_cycle/carbon\\_cycle.html](https://globalchange.umich.edu/globalchange1/current/lectures/king/carbon_cycle/carbon_cycle.html)

<https://www.co2.earth/daily-co2>



# Emissão Territorial (MtCO<sub>2</sub>)

## Territorial (MtCO<sub>2</sub>)

Rank	Country	MtCO <sub>2</sub>
1	China	9680
2	United States of America	5561
3	India	2597
4	Russian Federation	1595
5	Japan	1232
6	Germany	789
7	Indonesia	641
8	Iran	616
9	Saudi Arabia	602
10	South Korea	599
11	Canada	558
12	Brazil	507
13	South Africa	457
14	Mexico	457
15	United Kingdom	428
16	Australia	428
17	Turkey	382
18	Thailand	373
19	France	331
20	Italy	327
21	Poland	310
22	Taiwan	260
23	Malaysia	253

Rank	Country	MtCO <sub>2</sub>
1	United States of America	5561
2	Canada	558
3	Brazil	507
4	Mexico	457
5	Venezuela	207
6	Argentina	202
7	Chile	82
8	Colombia	81
9	Peru	59
10	Trinidad and Tobago	47
11	Ecuador	41
12	Cuba	37
13	Dominican Republic	23
14	Bolivia	18
15	Guatemala	11
16	Panama	9.8
17	Honduras	8.5
18	Costa Rica	7.8
19	Uruguay	7.8
20	Jamaica	7.8
21	Netherlands Antilles	7.0
22	El Salvador	6.7
23	Paraguay	5.3

FONTE: <http://www.statista.com/>



PORTAGE GLACIER AK, 1914 • NOAA



Vista do Glaciar Upsala,  
Argentina



PORTAGE GLACIER AK  
© 2004 GARY BRAASCH  
(AERIAL ESTIMATION OF 1914)



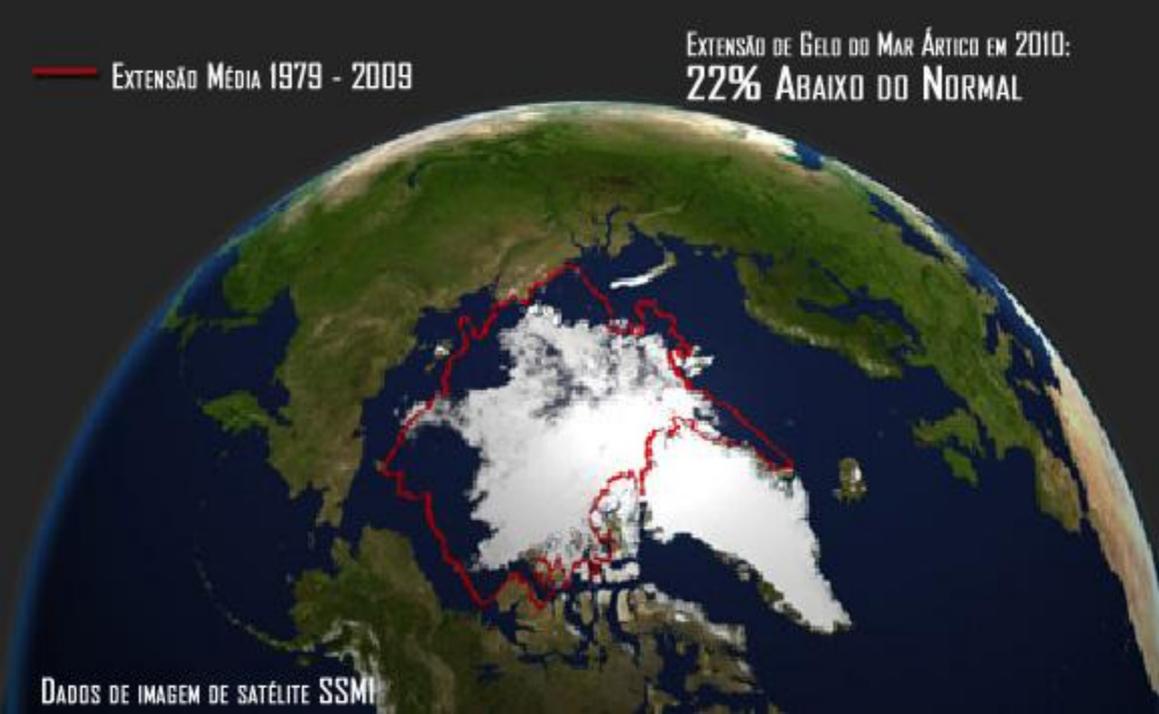
Payachatas na Bolívia



Ártico e a região do Permafrost

# Permafrost começou a descongelar

- 850 bilhões de toneladas de carbono armazenado no solo congelado do Ártico poderia ser liberado na atmosfera



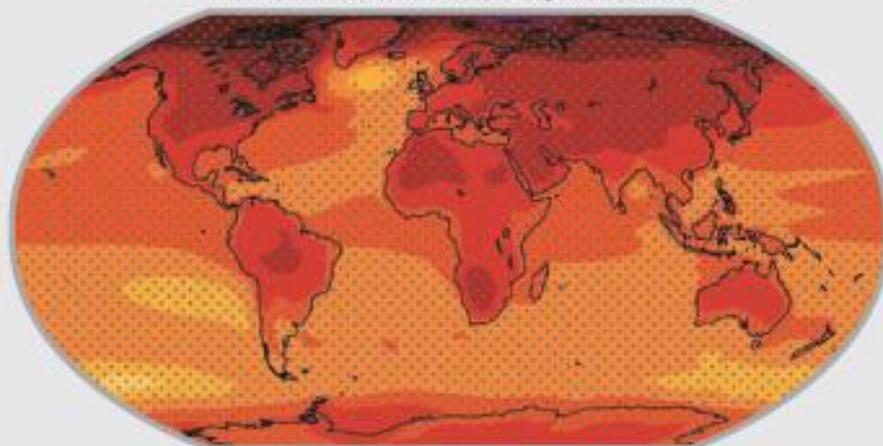
- *Uma grande reserva de metano, gás estufa 30 vezes mais potente que o dióxido de carbono está se abrindo.*

## Variação da média da temperatura à superfície 1986-2005 a 2081-2100

Melhor dos cenários  
Referentes à libertação de CO<sub>2</sub>



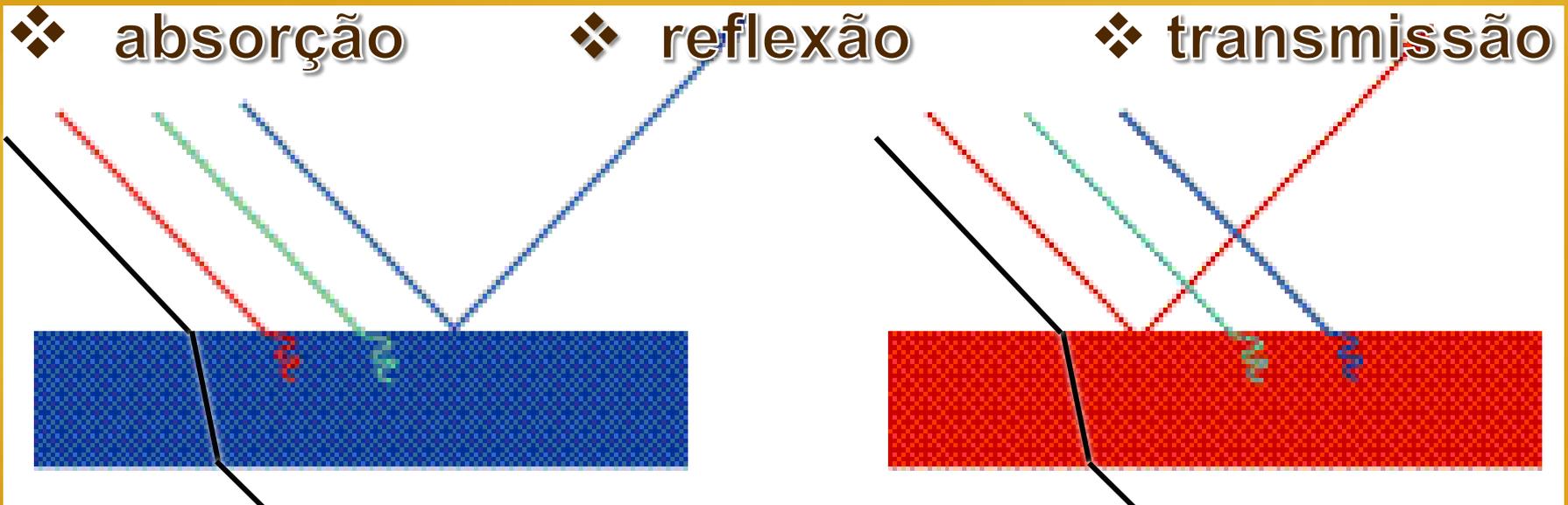
Pior dos cenários  
Referentes à libertação de CO<sub>2</sub>

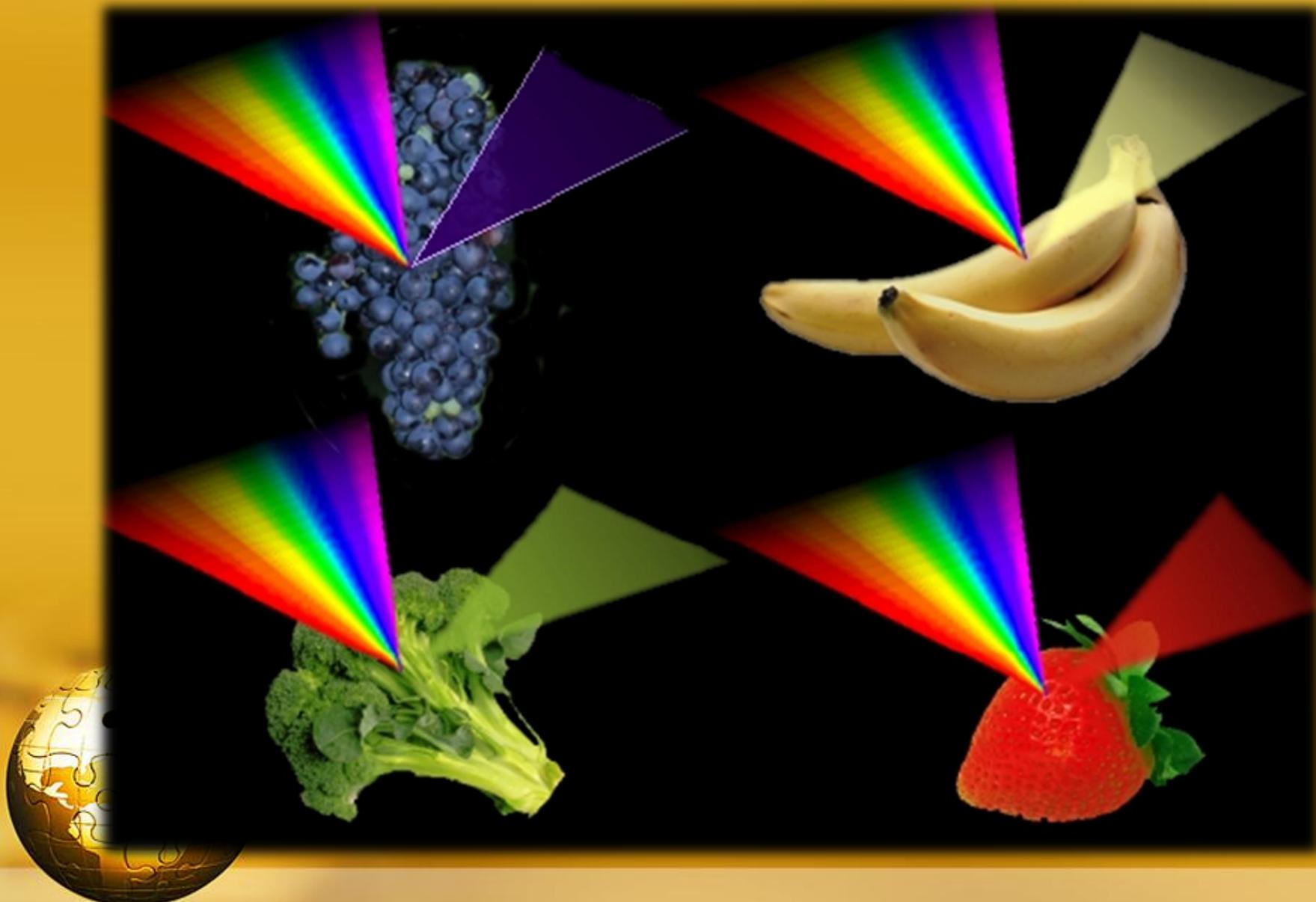


(°C)



# Interação Energia Eletromagnética x Objeto



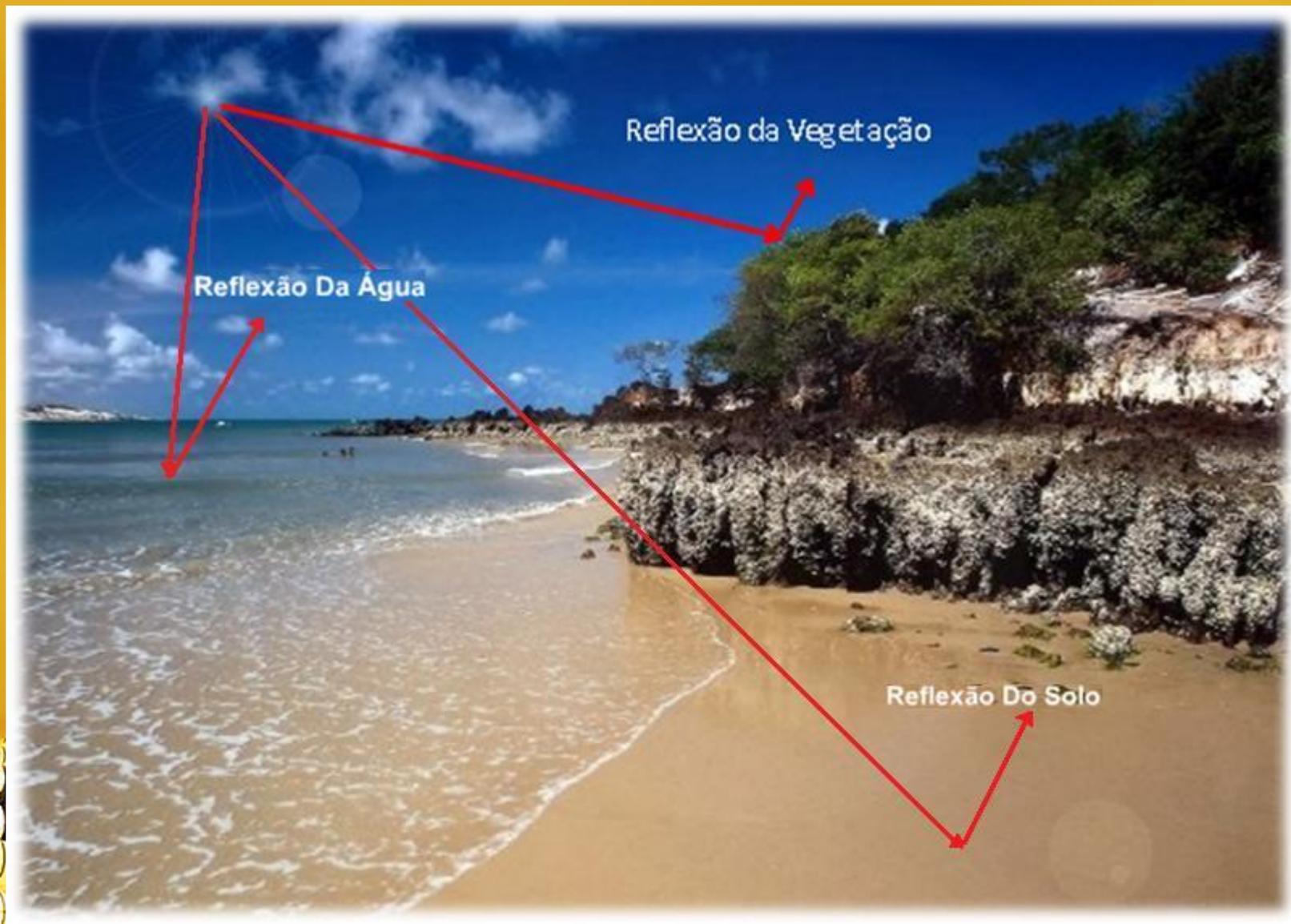


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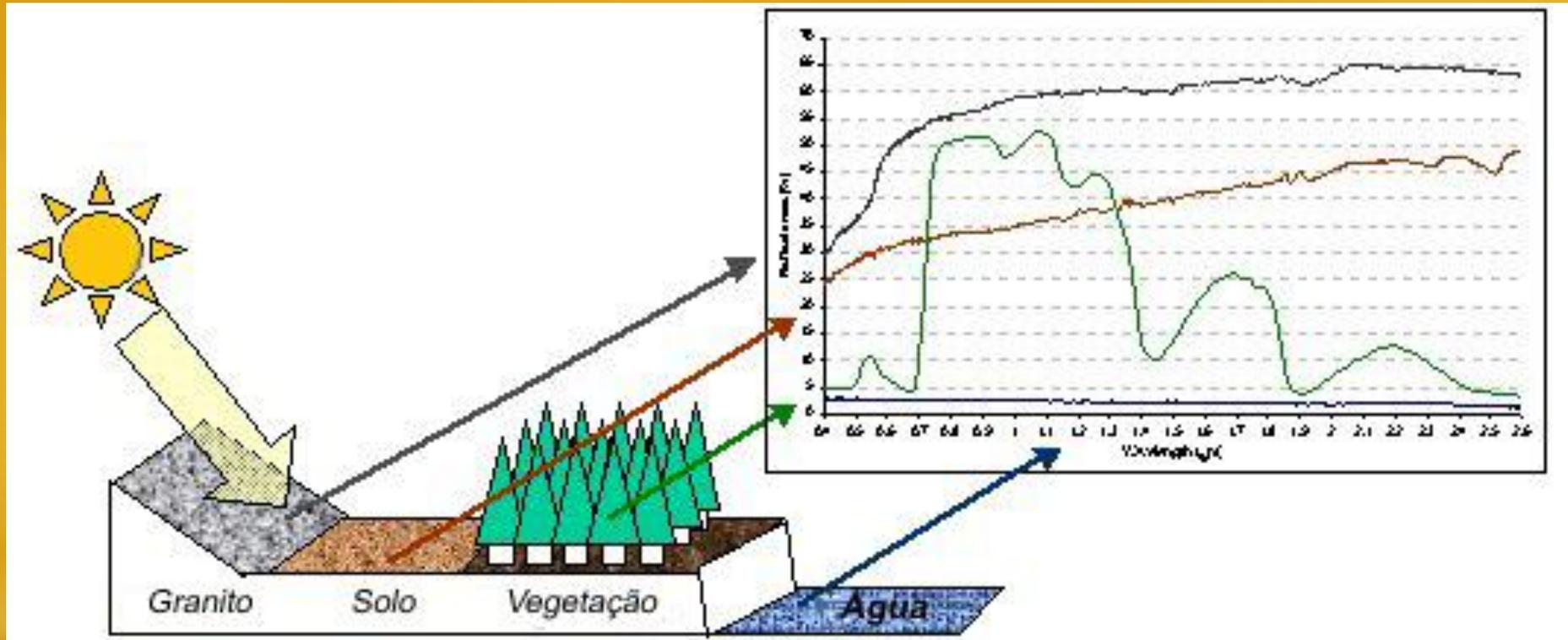




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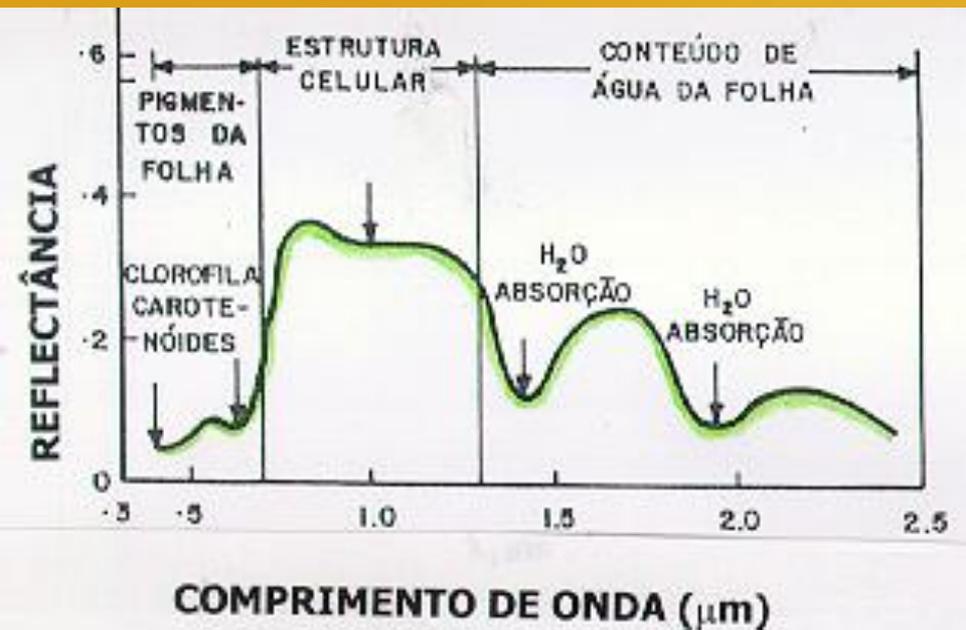


# Comportamento Espectral

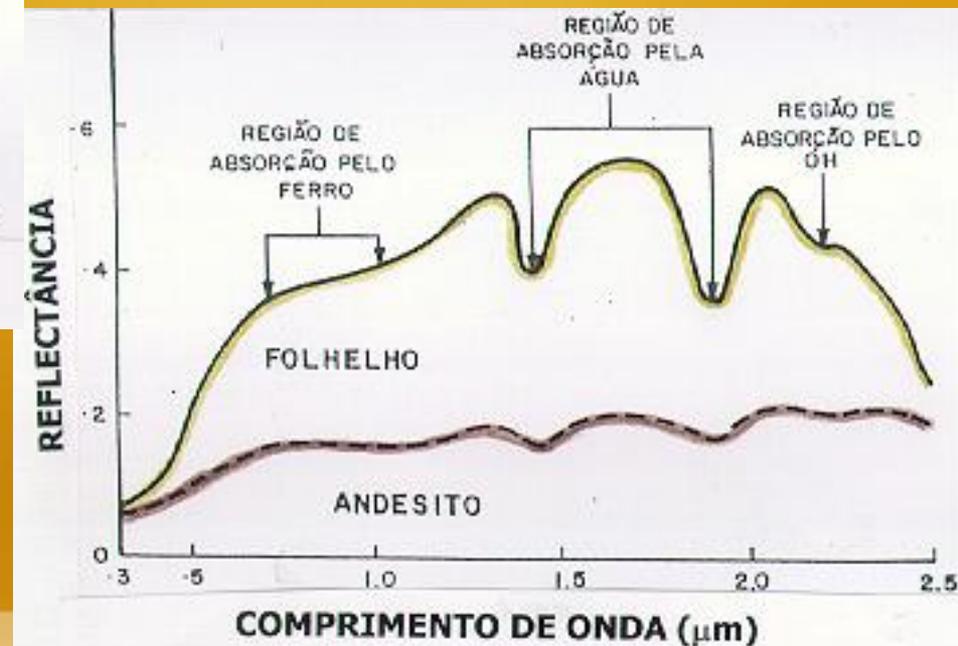


# Comportamento Espectral

## Vegetação sadia

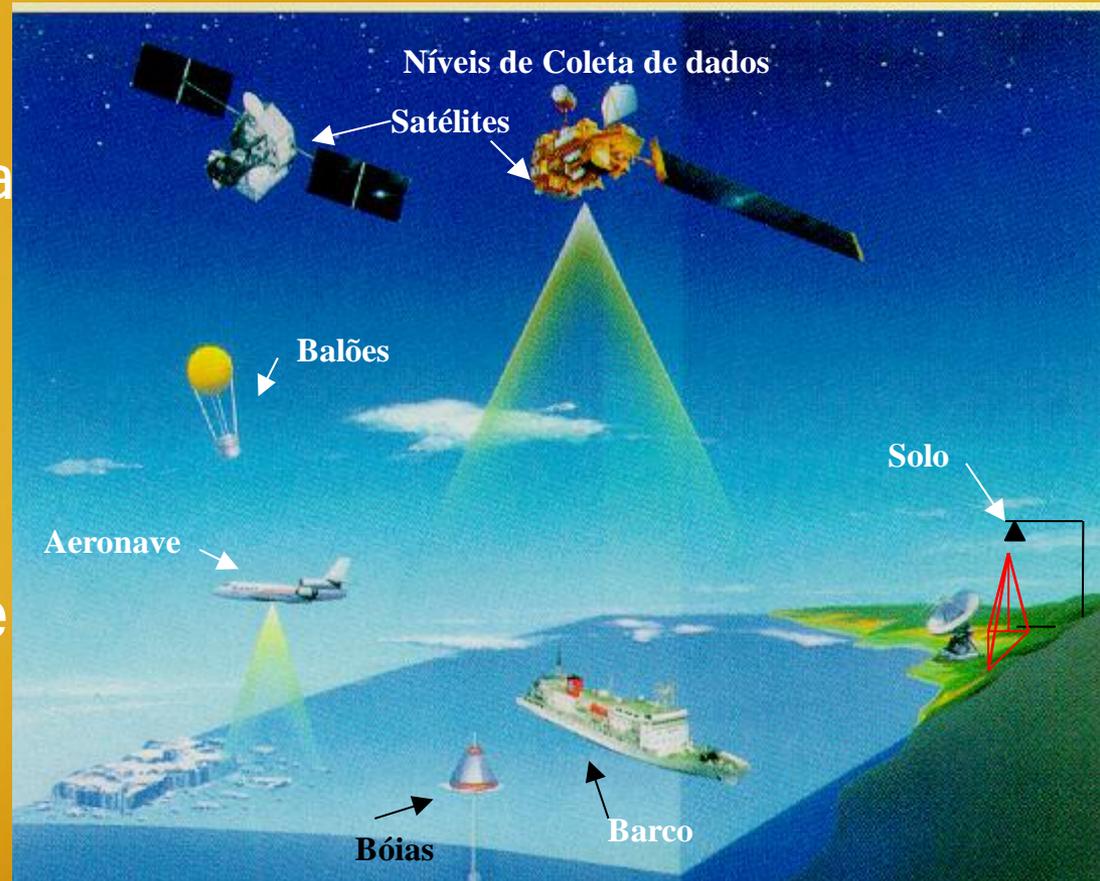


## Rochas



# Níveis de Coleta de Dados

- **Nível orbital ou plataforma espacial**
- **Nível suborbital**
  - ❖ plataforma aérea
  - ❖ plataforma terrestre
    - campo
    - laboratório

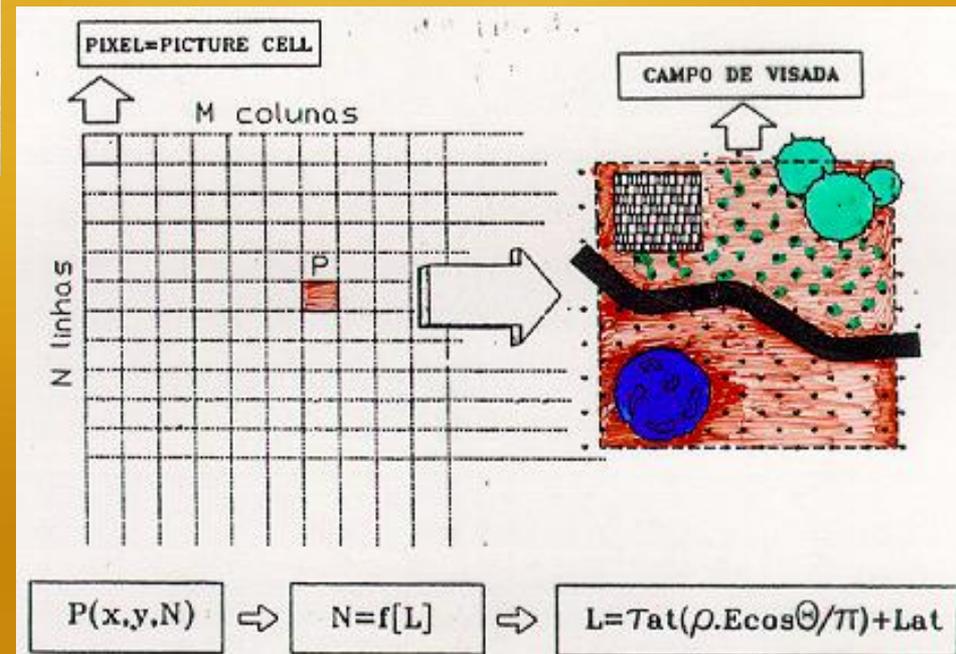
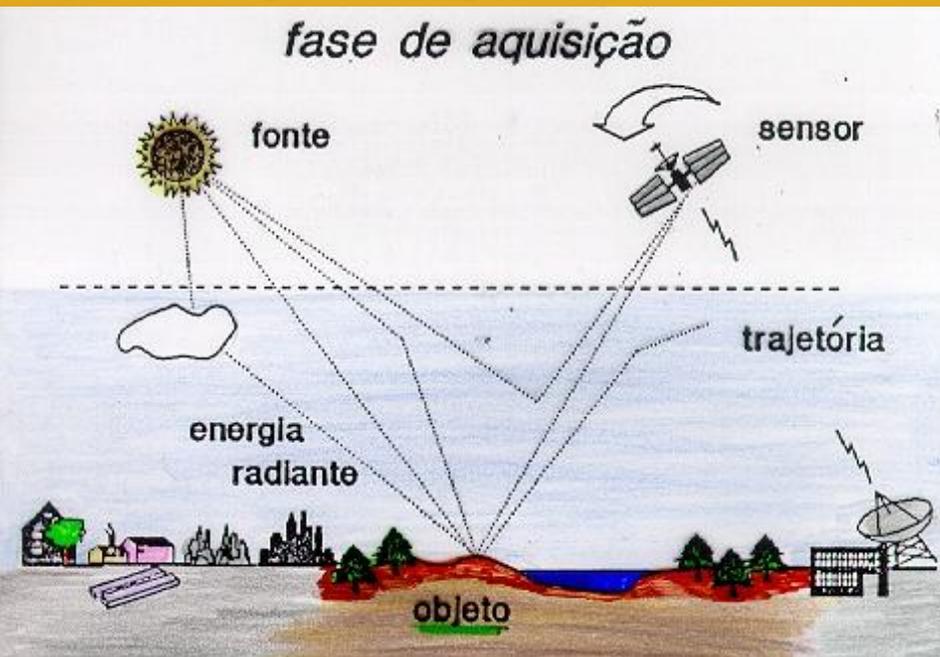


Importância da plataforma terrestre

- ➔ verdade terrestre para as outras plataformas
- ➔ eliminação da atmosfera terrestre



# Aquisição das imagens



145	128	143	195	241
182	98	98	191	212
163	221	154	159	117
172	155	138	87	68
153	121	127	75	12

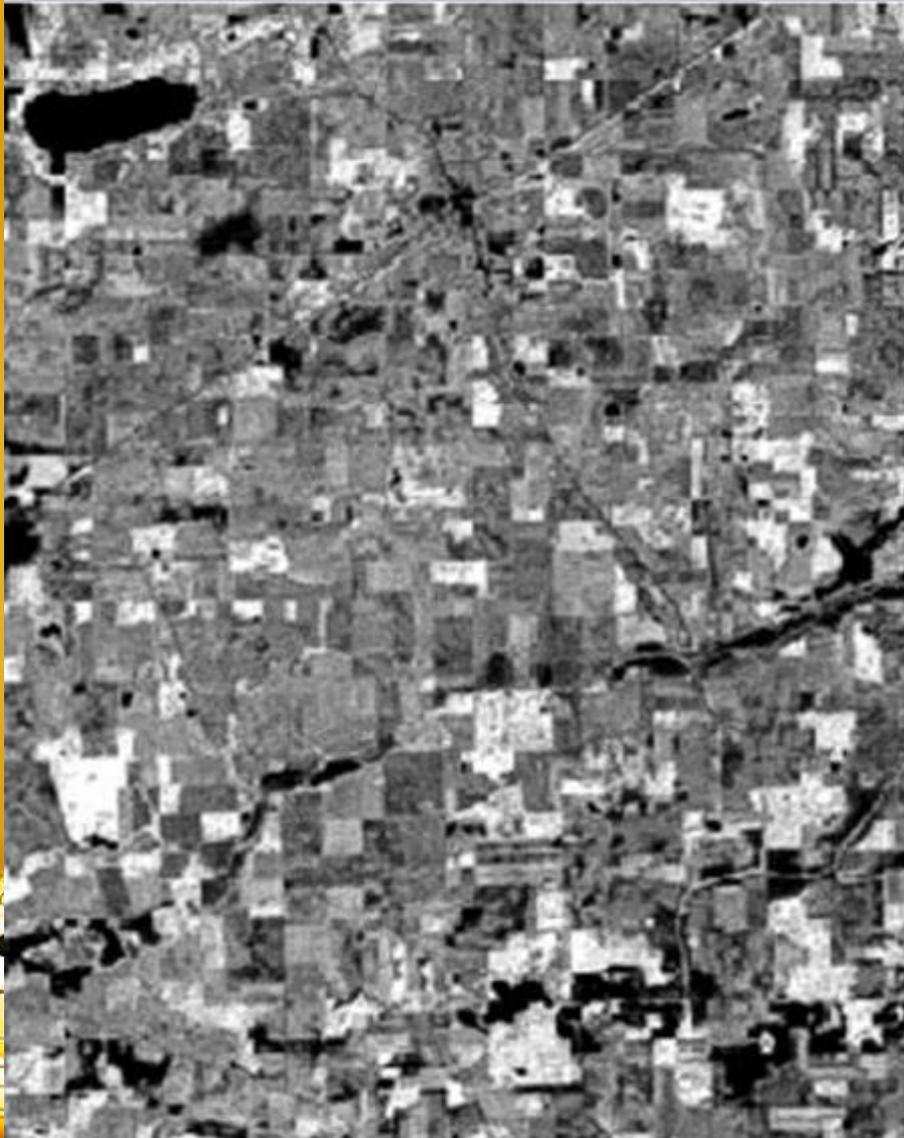


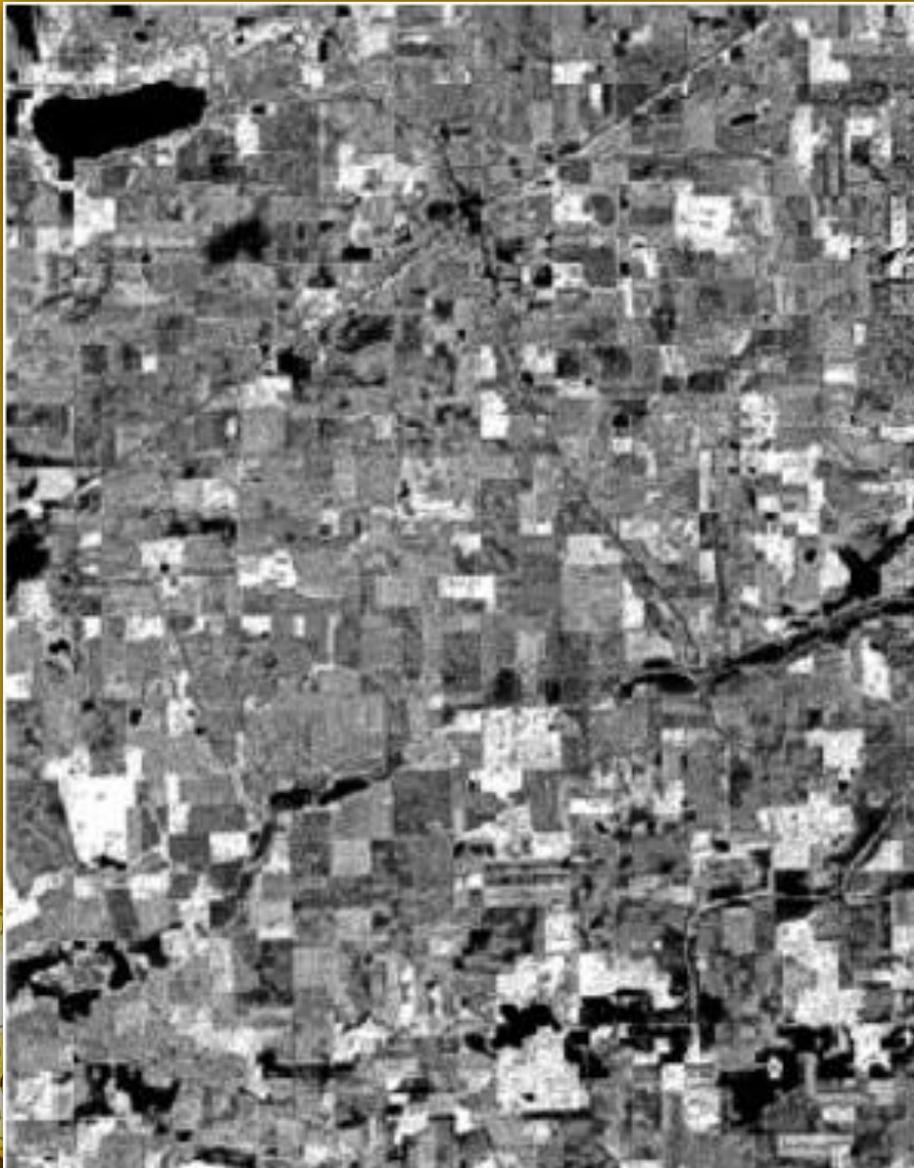
0

255



Reflexão  
no  
Infravermelho  
Próximo



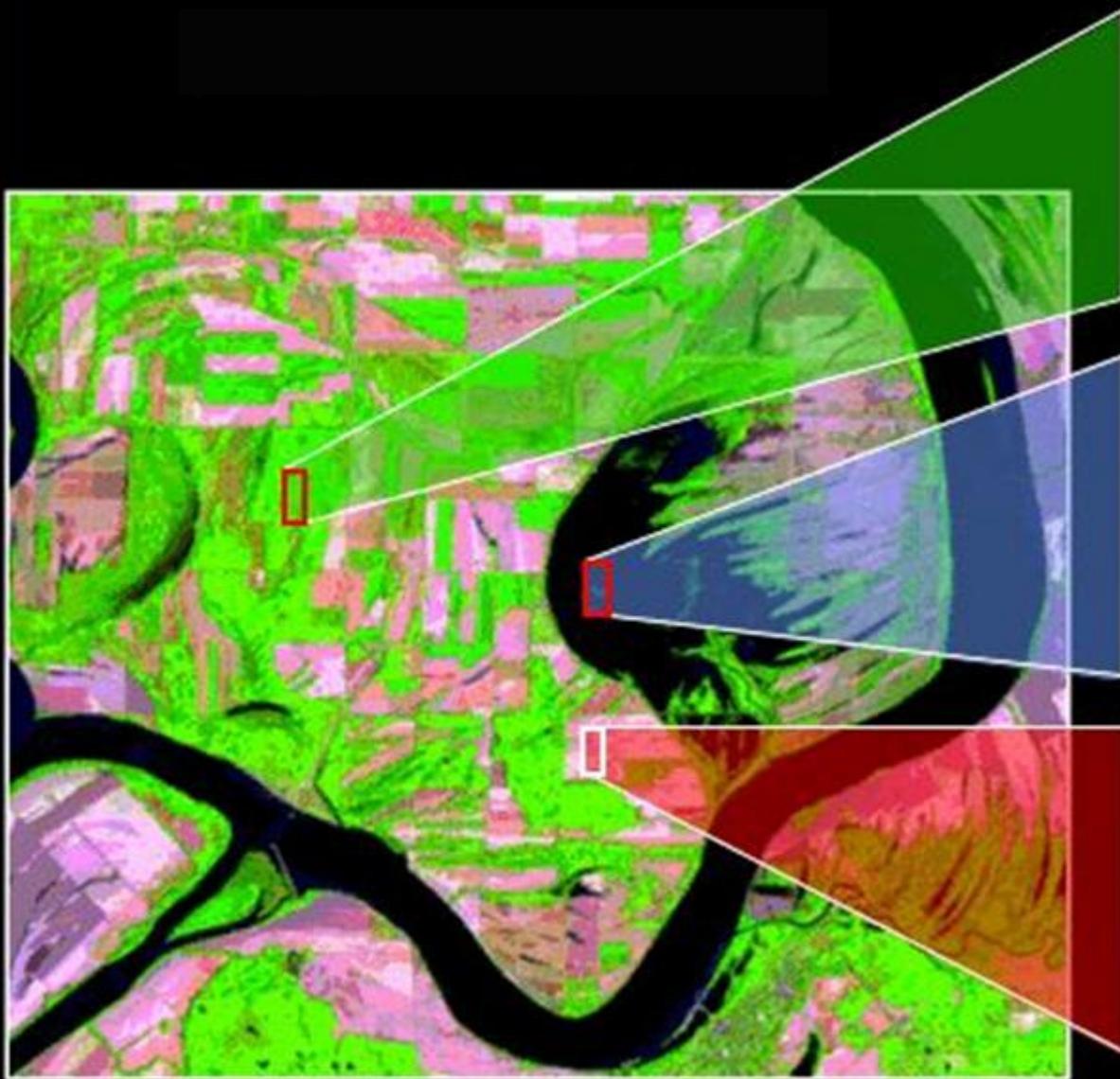


## Reflexão no Infravermelho

### Próximo



# Respostas espectrais nas bandas do verde, vermelho, IRP e IRM



## Respostas Espectrais



Valores de ND

Verde Verm. IVP IVM



# Respostas Espectrais



Valores de ND

Verde Verm. IVP IVM

# Respostas Espectrais



Valores de ND

Verde Verm. IVP IVM

# Respostas Espectrais



Valores de ND



Verde Verm. IVP IVM

Valores de ND

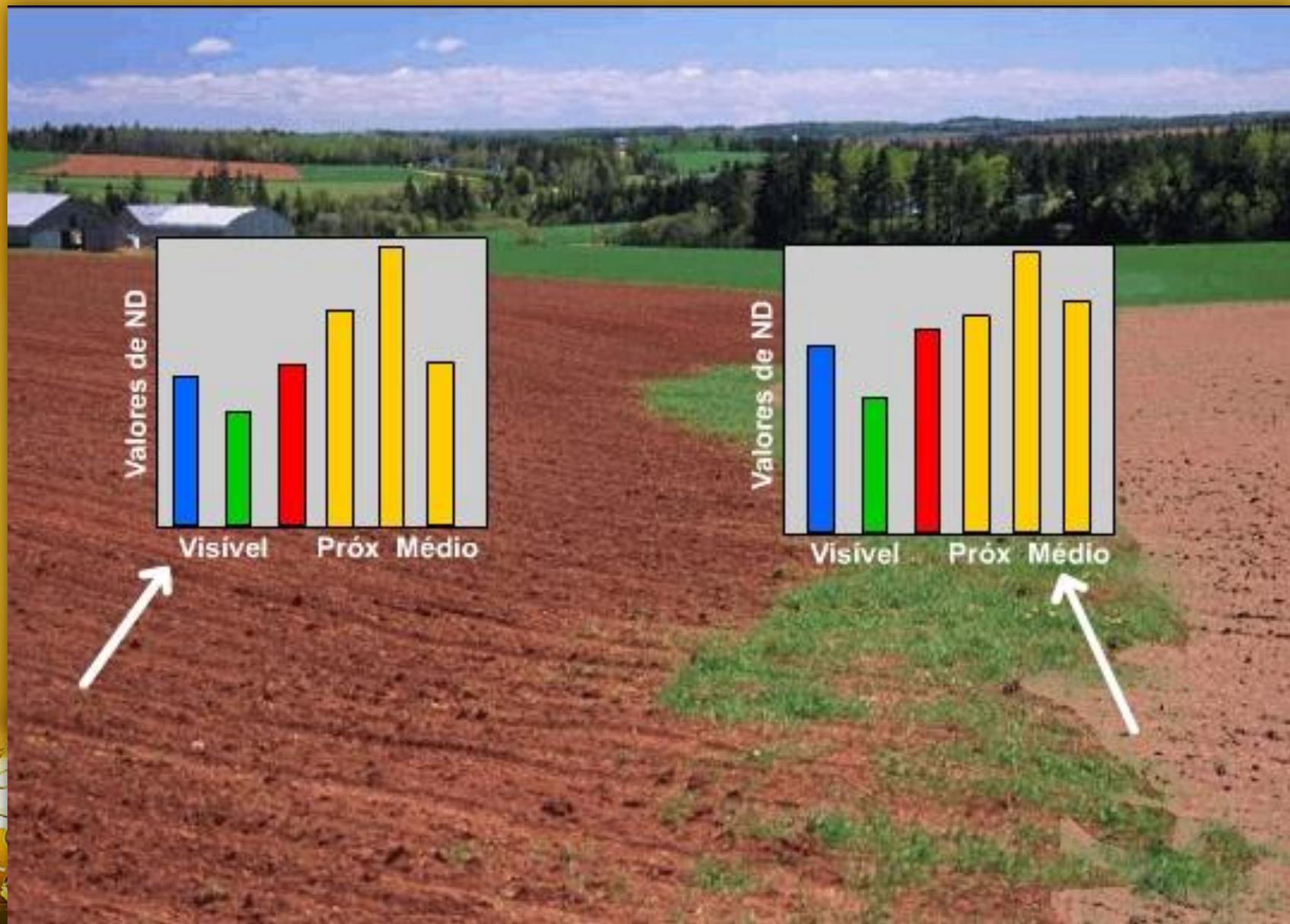


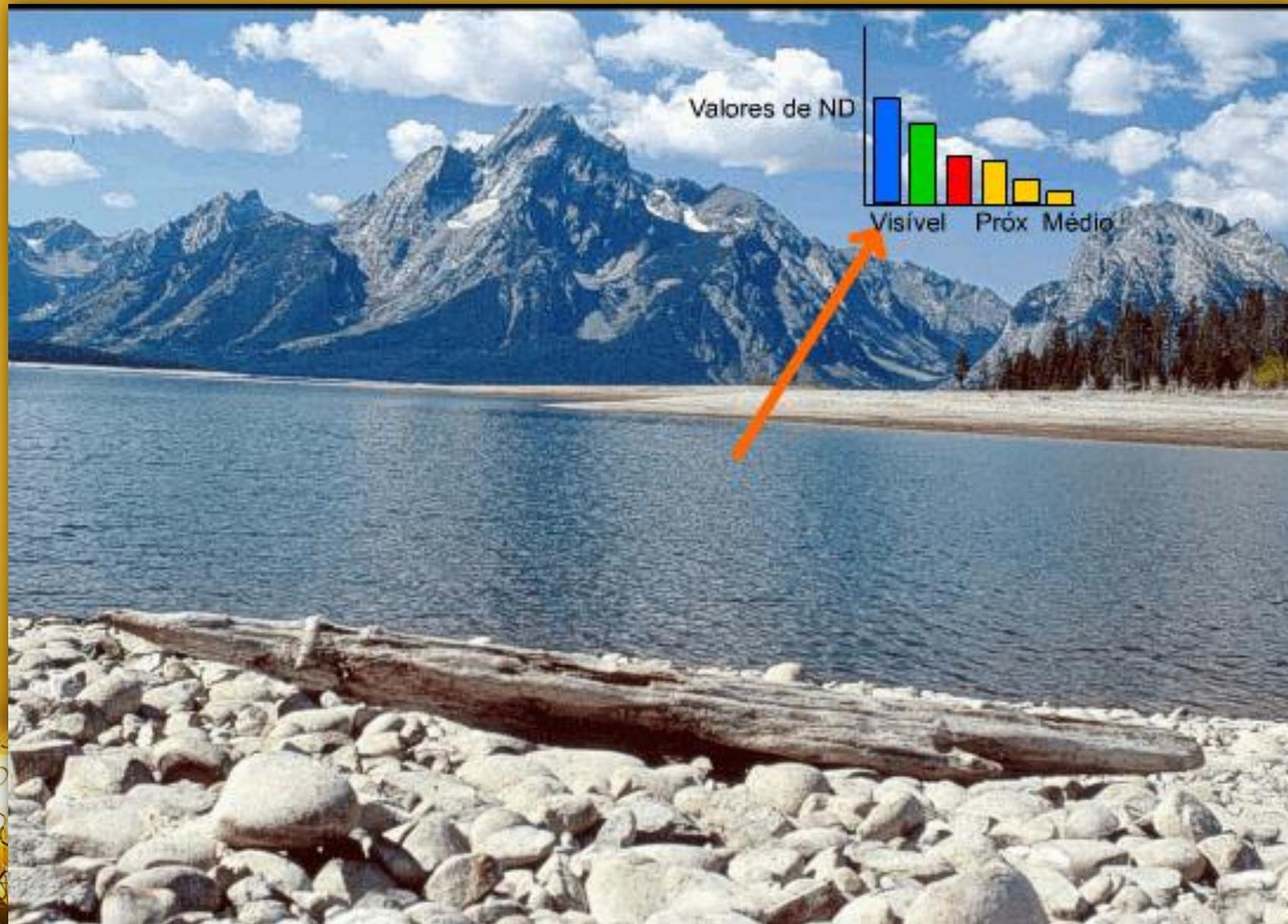
Verde Verm. IVP IVM

Valores de ND



Verde Verm. IVP IVM





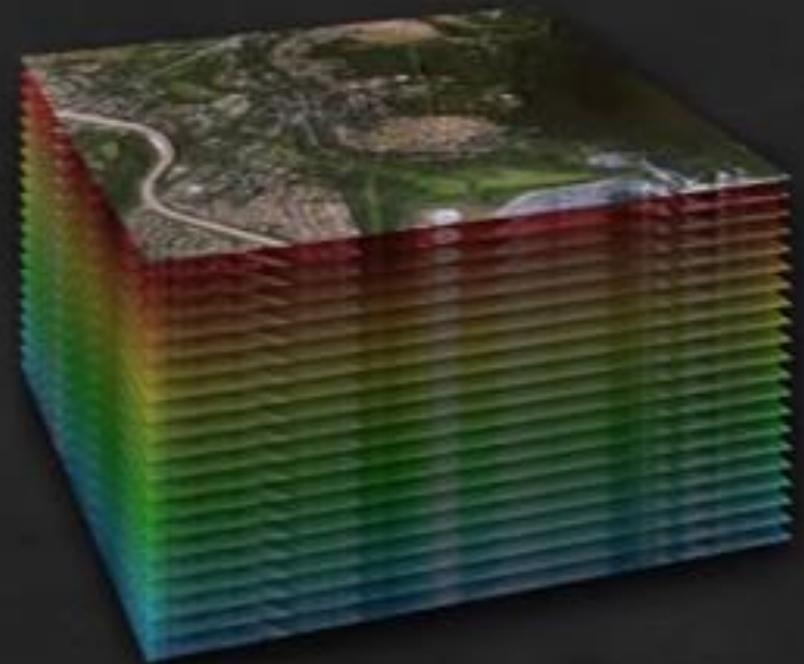
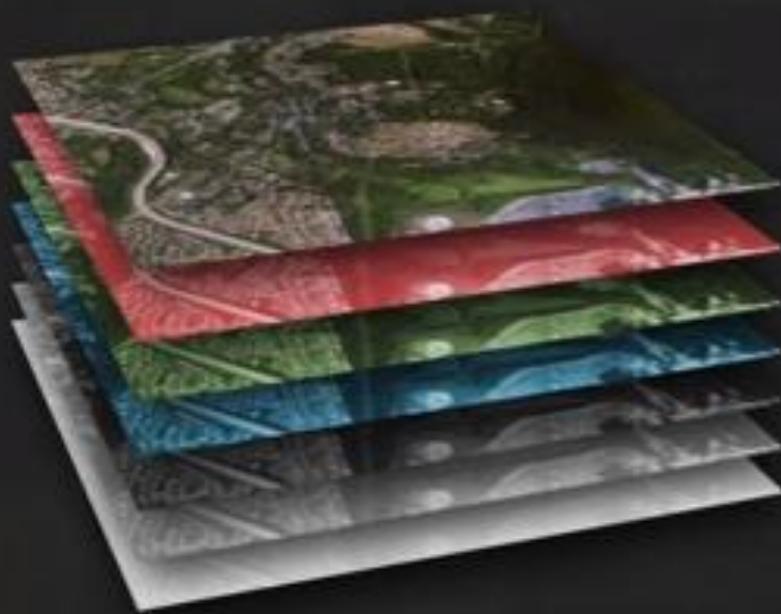
# Imageamento

## Multiespectral

- Algumas bandas (ex: 36)

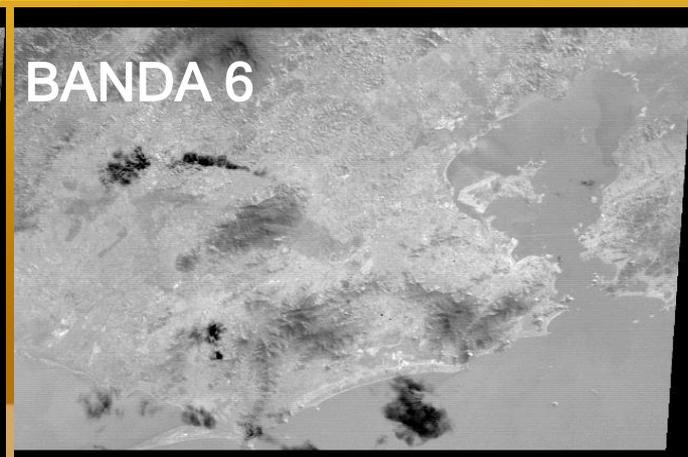
## Hiperespectral

- Acima de 100 bandas

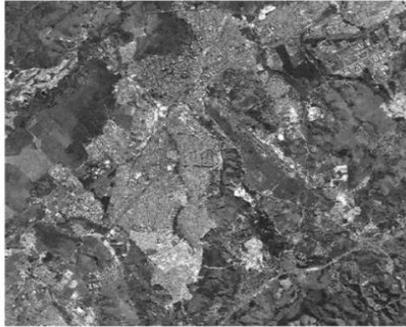




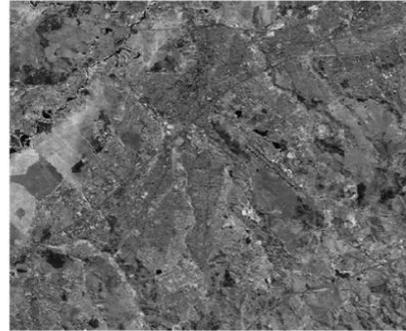
# RIO DE JANEIRO



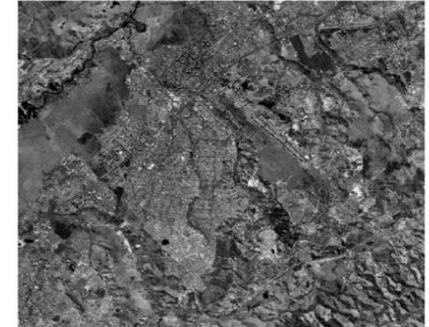
Banda 3  
Visível



Banda 4  
Infravermelho



Banda 5  
Infravermelho



Filtro Azul



Filtro Verde



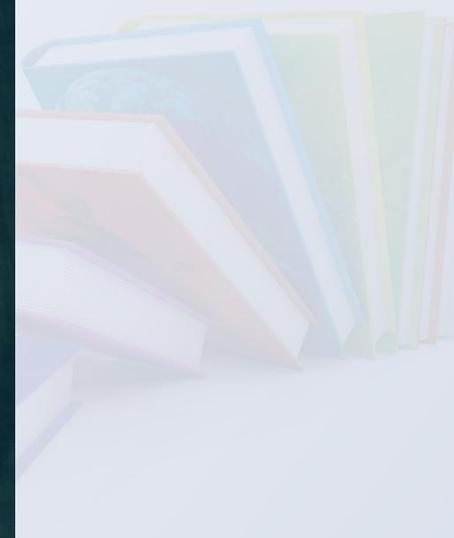
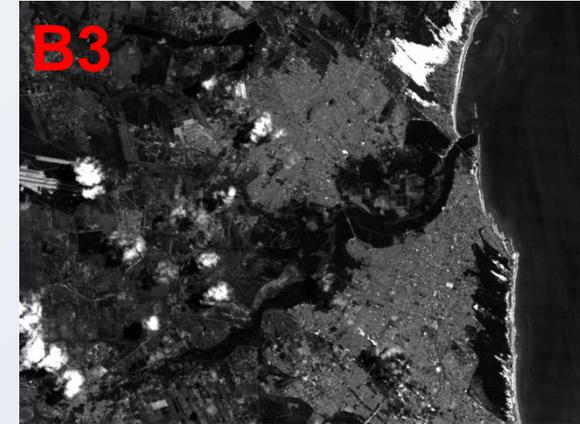
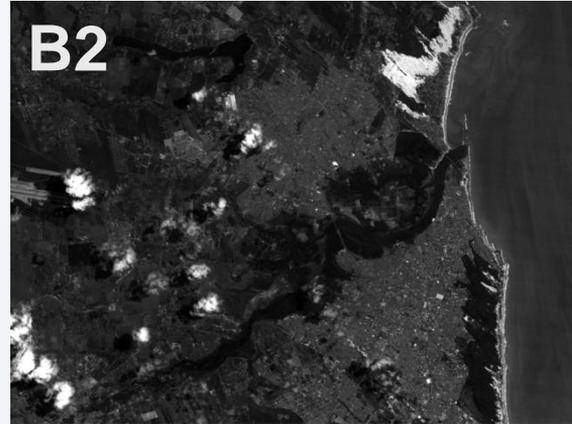
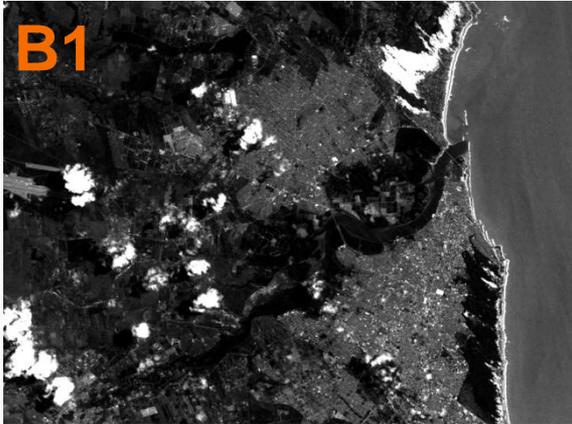
Filtro Vermelho

Banda 3,4 e 5

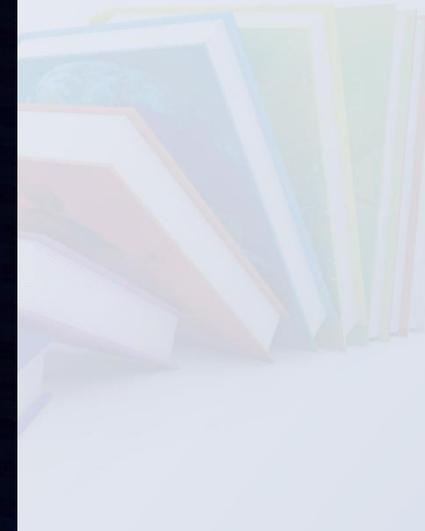
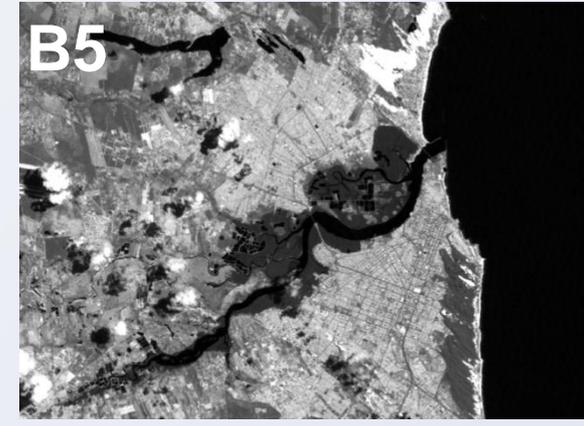
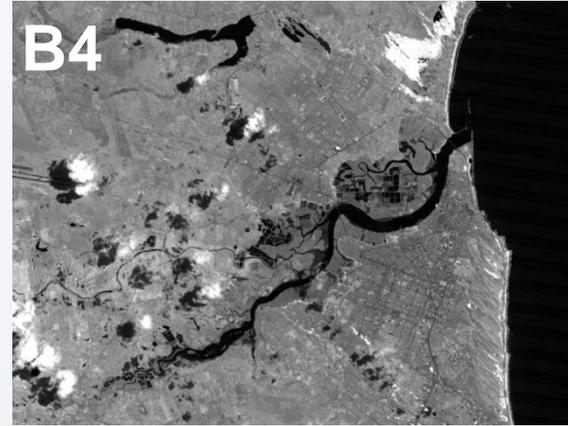
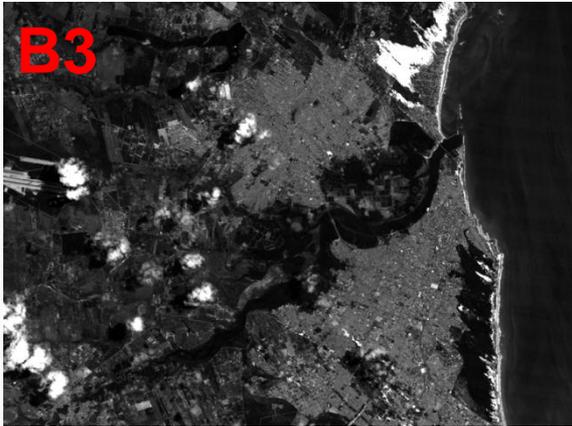


Colorida

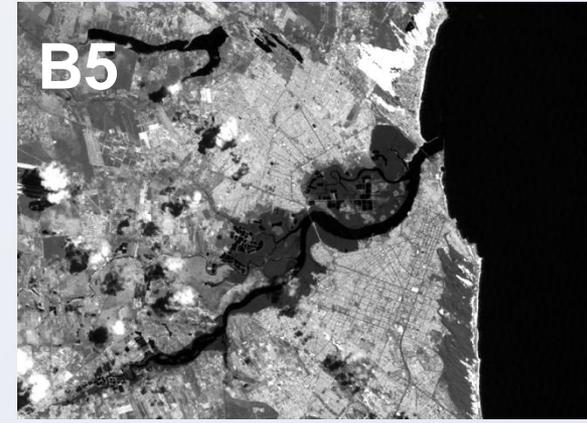
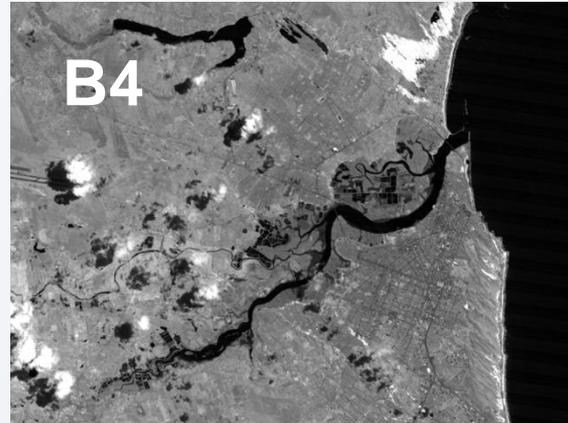
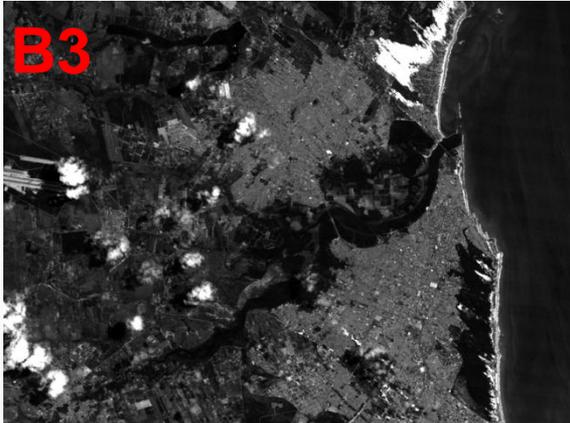
# Composição Colorida



# Composição Colorida



# Composição Colorida





<b>Bandas Landsat-8</b>		<b>Comprimento de onda (micrometros)</b>	<b>Resolução (metros)</b>
<b>OLI</b>	Banda 1 – Aerossol Costeiro	0,43 – 0,45	30
	Banda 2 – Azul	0,45 – 0,51	30
	Banda 3 – Verde	0,53 – 0,59	30
	Banda 4 – Vermelha	0,64 – 0,67	30
	Banda 5 – Infravermelho Próximo (NIR)	0,85 – 0,88	30
	Banda 6 – SWIR <sub>1</sub>	1,57 – 1,65	30
	Banda 7 – SWIR <sub>2</sub>	2,11 – 2,29	30
	Banda 8 – Pancromático	0,50 – 0,68	15
	Banda 9 – Cirrus	1,36 – 1,38	30
<b>TIRS</b>	Banda 10 – Infravermelho Termal (TIRS) <sub>1</sub>	10,60 – 11,19	100
	Banda 11 - Infravermelho Termal (TIRS) <sub>2</sub>	11,50 – 12,51	100

# Combinação de bandas 2, 3, 4 – cor verdadeira (**azul**, **verde**, **vermelho**)



**Fort Collins, Colorado, USA**

Realça informações sobre: Corpos de água (regiões de águas rasas; turbidez; correntes; e sedimentos em suspensão), Áreas Urbanas e Vegetação



# Combinação de bandas 3(verde), 5(NIR), 7(SWIR) (azul, verde, vermelho)



**Fort Collins, Colorado, USA**

Combinação de duas bandas no IR possibilita uma maior diferenciação entre solo e água; Tipos e condições de vegetações; Áreas urbanas e Solos expostos.

Curso de Uso Escolar de Sensoriamento Remoto - Inpe



# Landsat 8

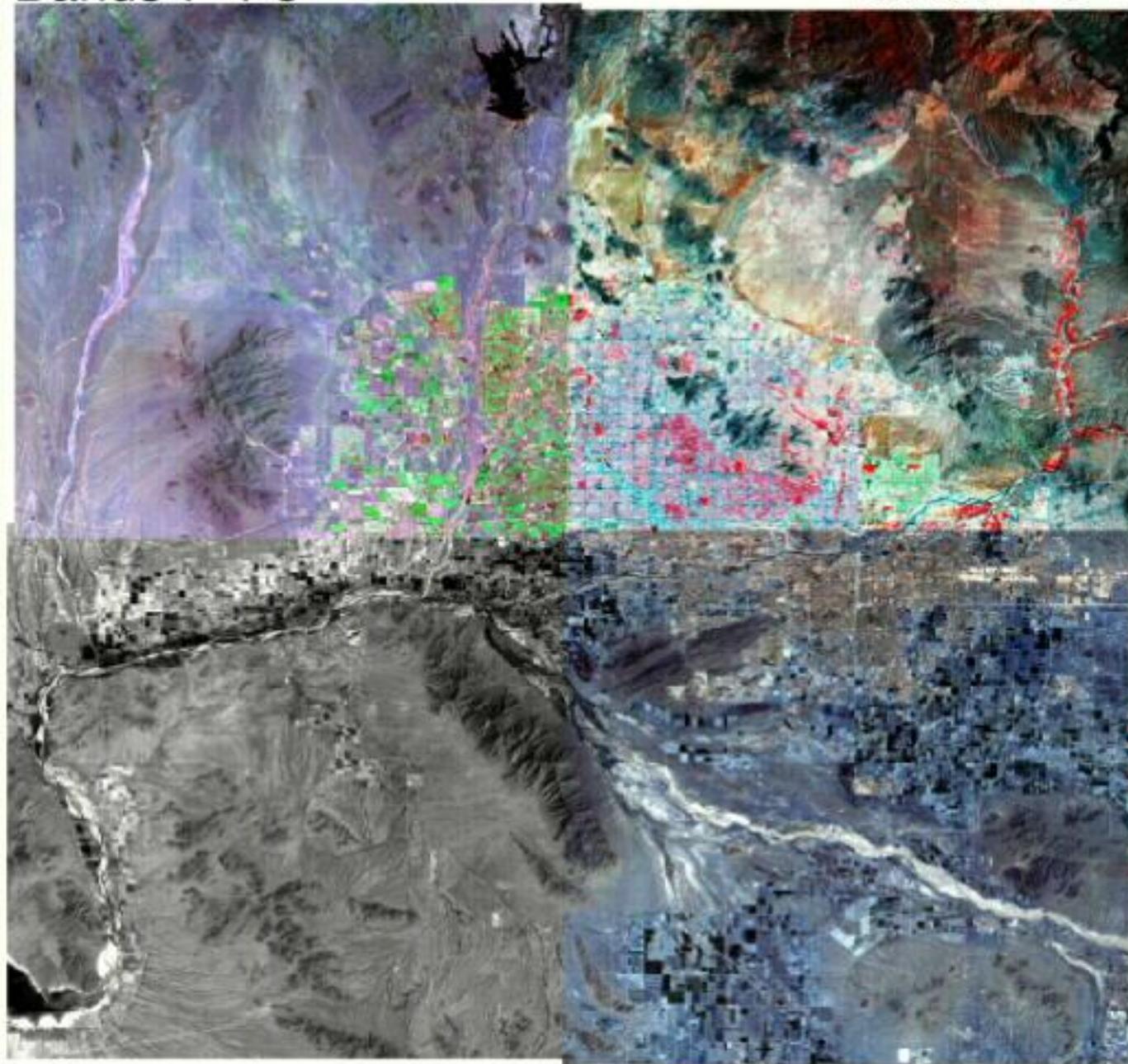
## OLI



Aplicações	Bandas B G R
Cor Verdadeira	4 3 2
Falsa Cor (urbano)	7 6 4
Cor Infravermelha (vegetação)	5 4 3
Agricultura	6 5 2
Penetração Atmosférica	7 6 5
Vegetação Saudável	5 6 2
Solo/água	5 6 4
Natural com Remoção Atmosférica	7 5 3
Infravermelho Solar	7 5 4
Análise da Vegetação	6 5 4

Bands 7-4-5

Bands 4-3-2



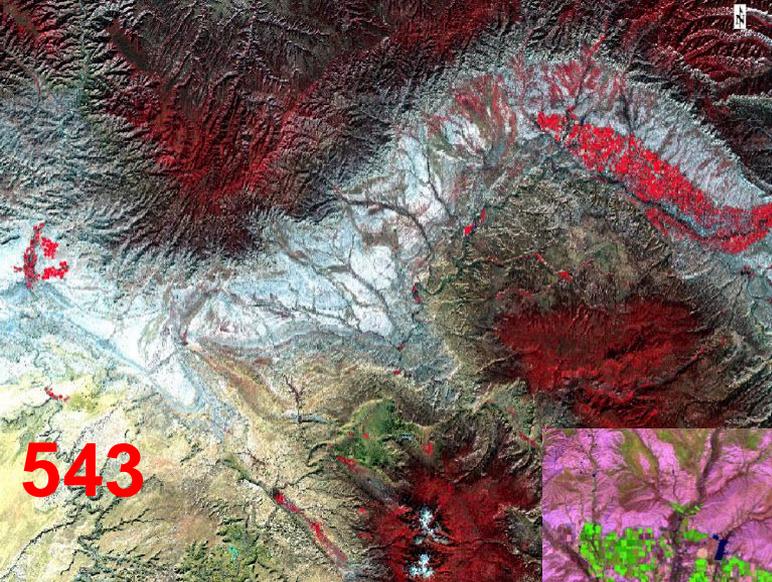
# Landsat 8 Sensor OLI



Bands 7-5-3

Landsat Band 1

Bands 3-2-1



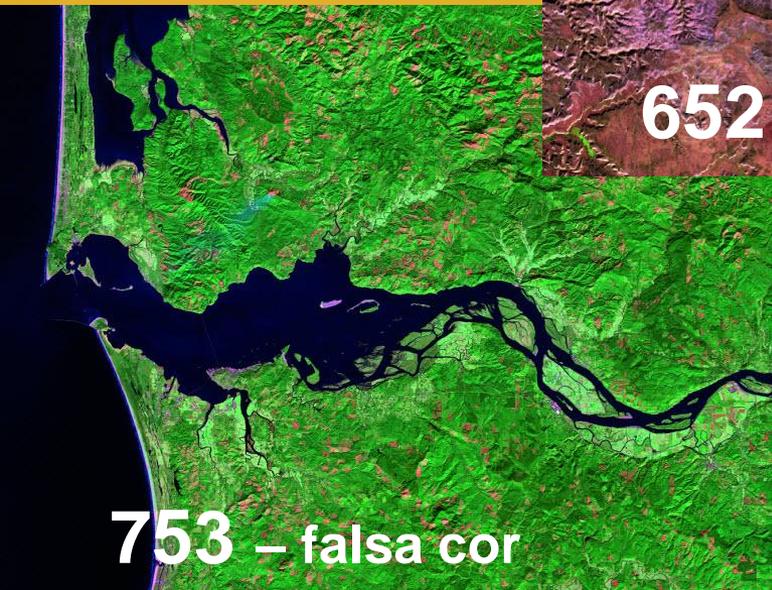
**543**



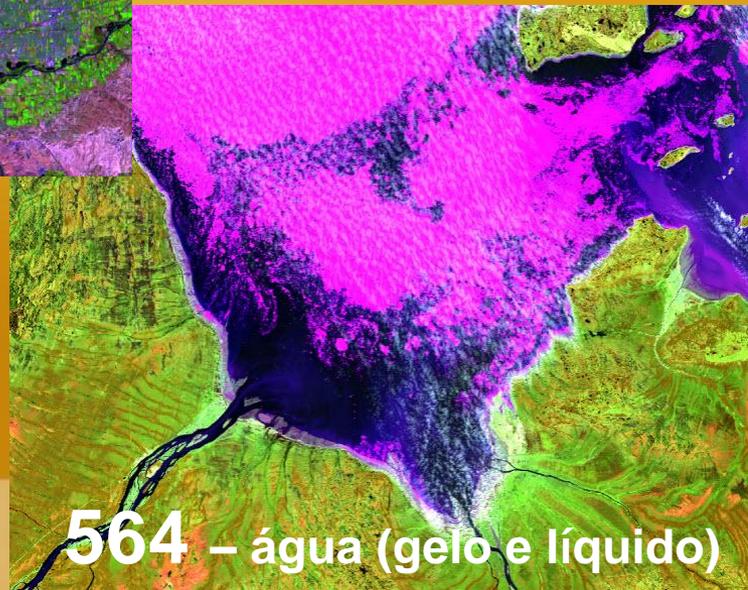
**764 – urbana**



**652 – agricultura**

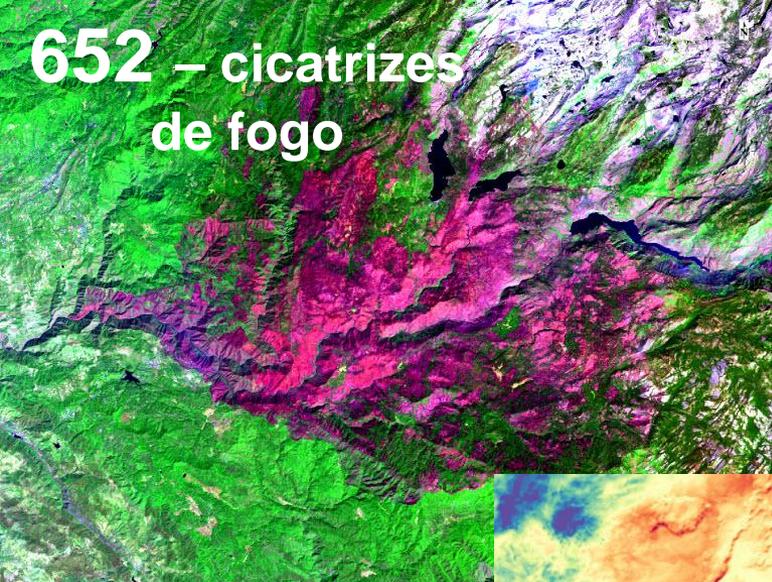


**753 – falsa cor**



**564 – água (gelo e líquido)**

**652** – cicatrizes  
de fogo



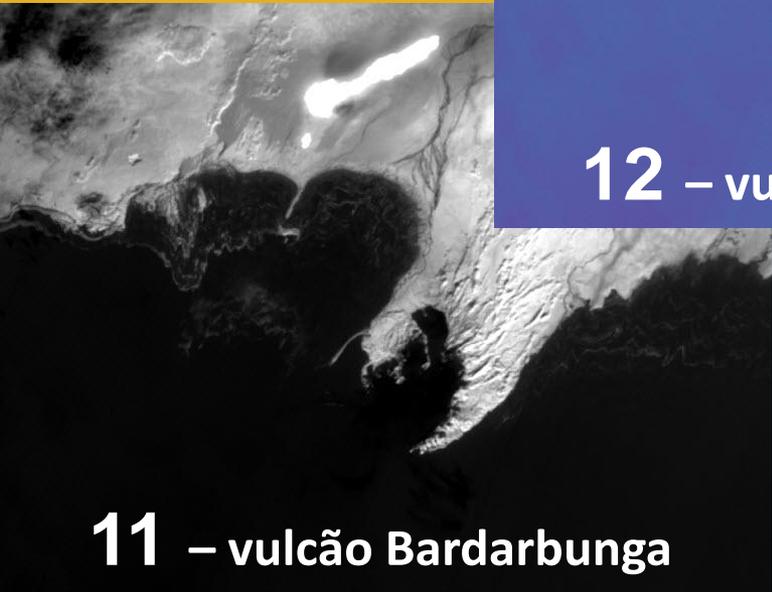
**571** – qualidade de água e  
aerossóis



**12** – vulcão Bardarbunga



**11** – vulcão Bardarbunga



**632** – geologia



# Sugestões de sites

[https://www.youtube.com/watch?v=Ftbx4\\_kYRUg](https://www.youtube.com/watch?v=Ftbx4_kYRUg)

[https://youtu.be/Ftbx4\\_kYRUg](https://youtu.be/Ftbx4_kYRUg)

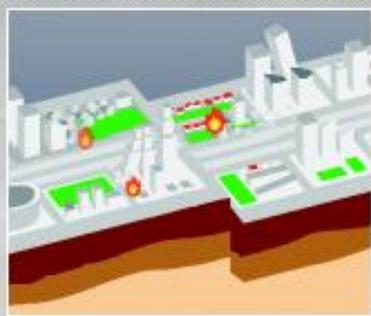
<https://www.youtube.com/watch?v=eGIDxp4TNWk>



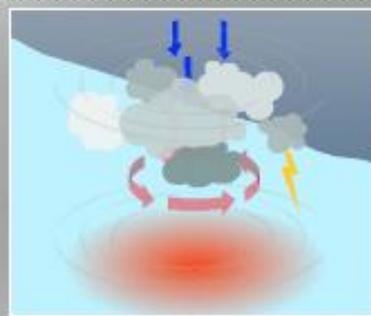
# ESPECIAL ON-LINE desastres naturais

veja.com

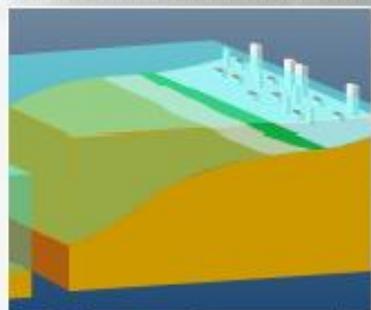
## Terremotos



## Furacões



## Tsunamis



## Outros fenômenos



▪ Vulcões, enchentes, secas e ondas de calor, nevascas e avalanches

## Contexto



▪ Homem x natureza: as tragédias na história e como elas mudam tudo

## Cronologia (1900 - 2008)

MORTOS	ANO
8 mil	1900 Galveston (EUA), furacão
38 mil	1902 Martinica, vulcão Pelée
3 mil	1906 San Francisco (EUA), terremoto com incêndios
20 mil	1906 Chile, terremoto
70 mil	1908 Messina (Itália), terremoto
200 mil	1920 Gansu (China), terremoto
143 mil	1923 Yokohama (Japão), terremoto
200 mil	1927 Nanshan (China), terremoto
1,8 mil	1928 Flórida (EUA), furacão

SAIBA MAIS

SAIBA MAIS

## Outras tragédias (1500 - 1900)

[clique aqui](#)



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