PGF-5321
Introdução à Física Atmosférica

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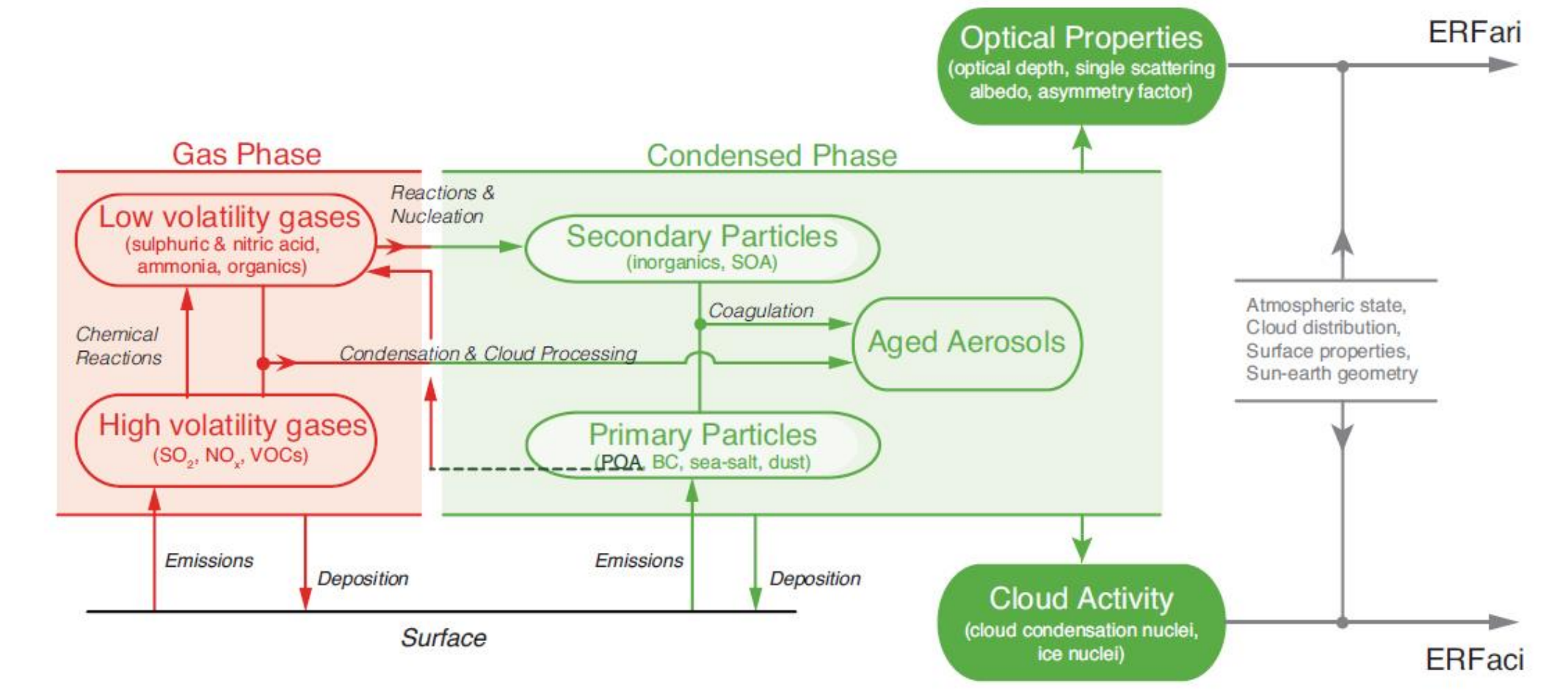
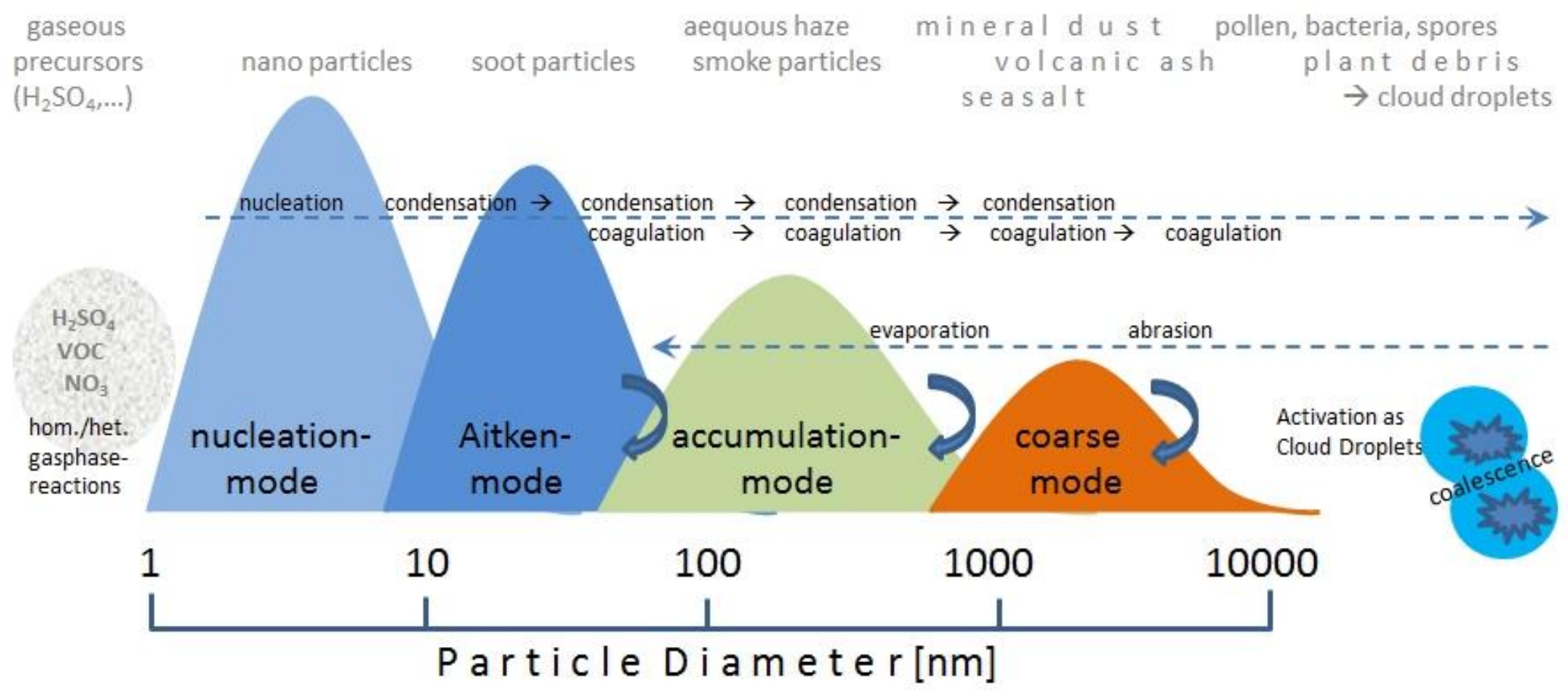
Espalhamento e absorção da radiação solar por partículas de aerossol

Formação de aerossol

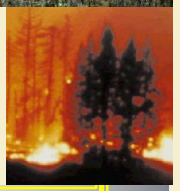


Distribuição de tamanho de partícula



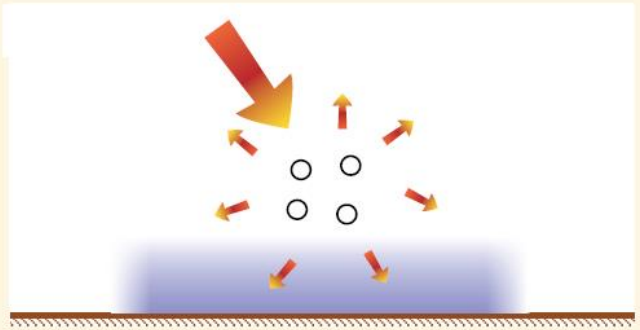
Aerosol, their sources and effects on climate

Properties	Net effect	Aerosol type	Main Source
Reflect Sunlight	Cool the earth reduce evaporation	Desert dust, sulfate smog	deserts industry
Absorb sunlight	Heat the atmosphere increase stability reduce cloudiness or increase precipitation	Black carbon	biomass burning dirty engines
Cloud Condensation Nuclei	brighter clouds less precipitation	sulfate smog smoke	industry fires

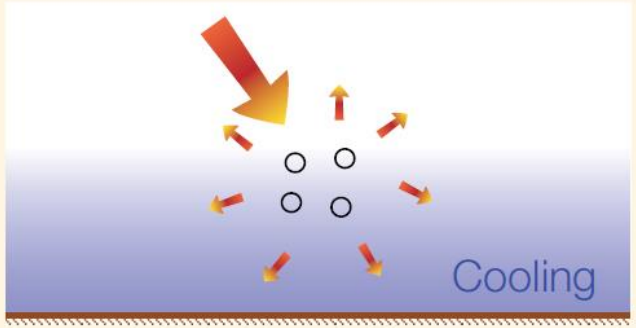


Interações aerossol-radiação

Scattering aerosols

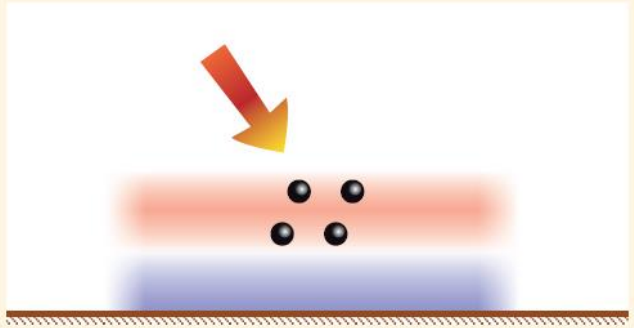


Aerosols scatter solar radiation. Less solar radiation reaches the surface, which leads to a localised cooling.

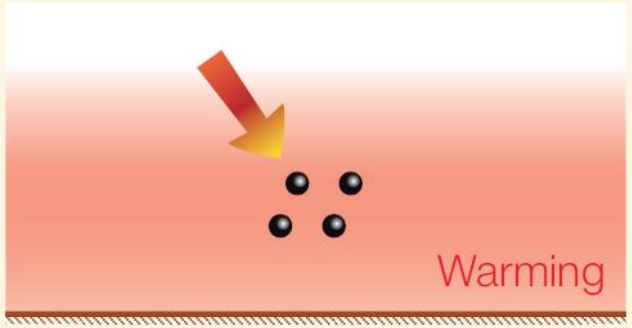


The atmospheric circulation and mixing processes spread the cooling regionally and in the vertical.

Absorbing aerosols



Aerosols absorb solar radiation. This heats the aerosol layer but the surface, which receives less solar radiation, can cool locally.



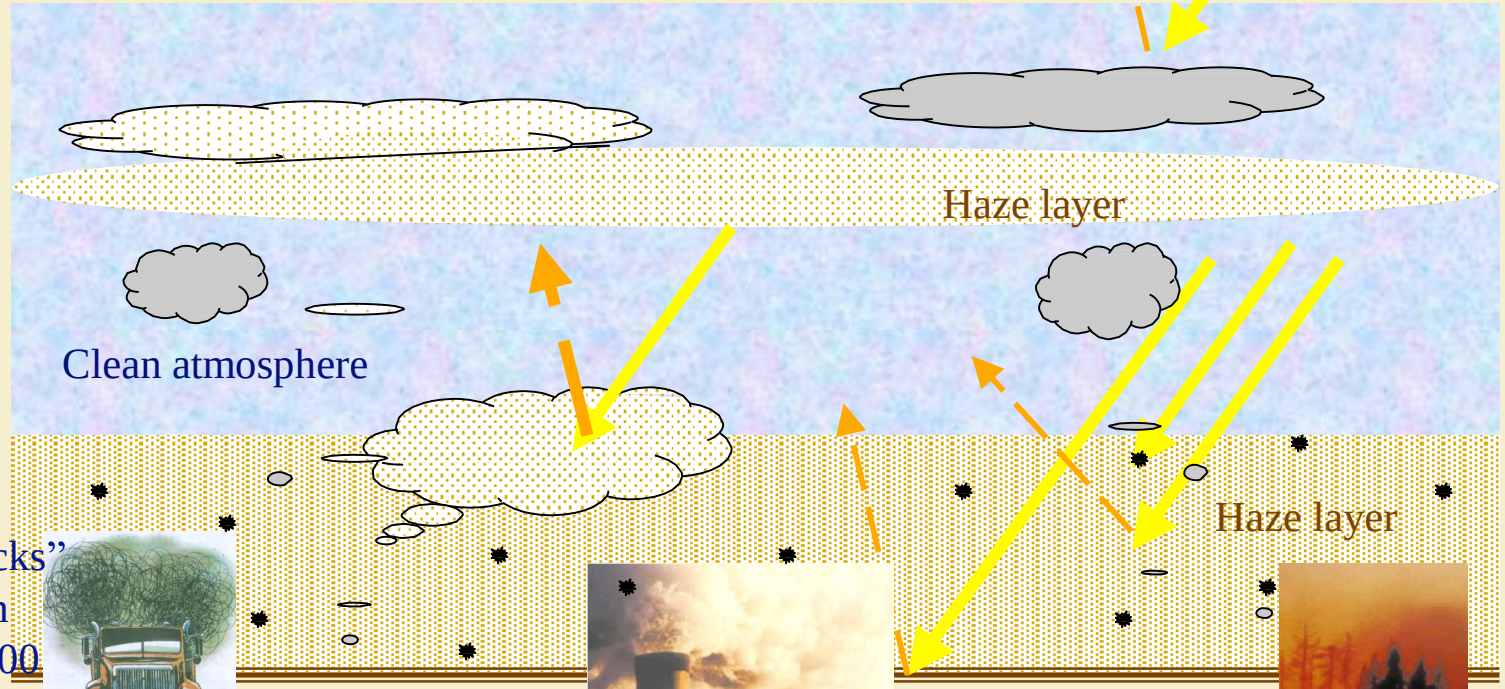
At the larger scale there is a net warming of the surface and atmosphere because the atmospheric circulation and mixing processes redistribute the thermal energy.

Aerosol effect on radiation and clouds:

- Reflects / absorbs sunlight
- changes cloud reflectance
- changes cloud lifetime
- less energy to the surface

- Reduces cloud droplet size

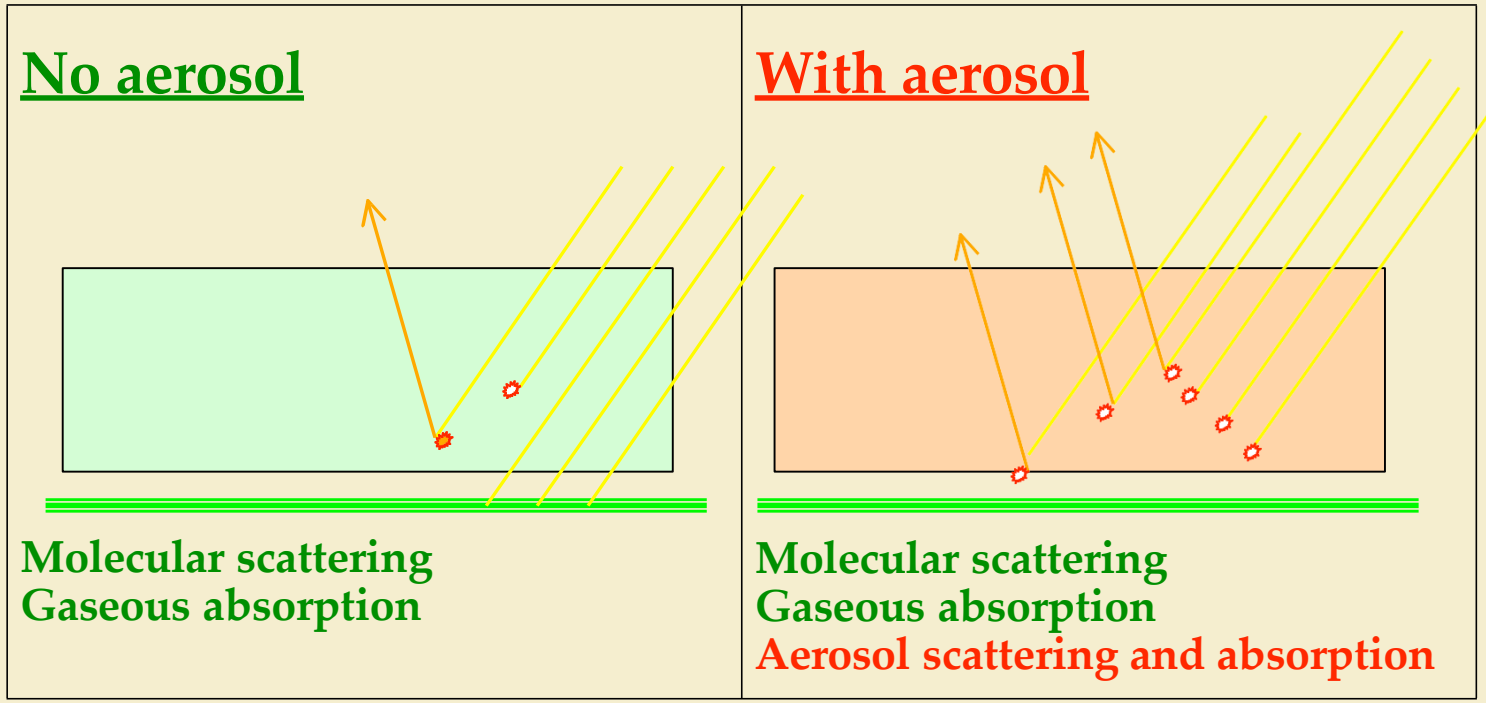
-heats the lower atmosphere
-changes precipitation



”Toxic trucks” Washington Post 11/19/00

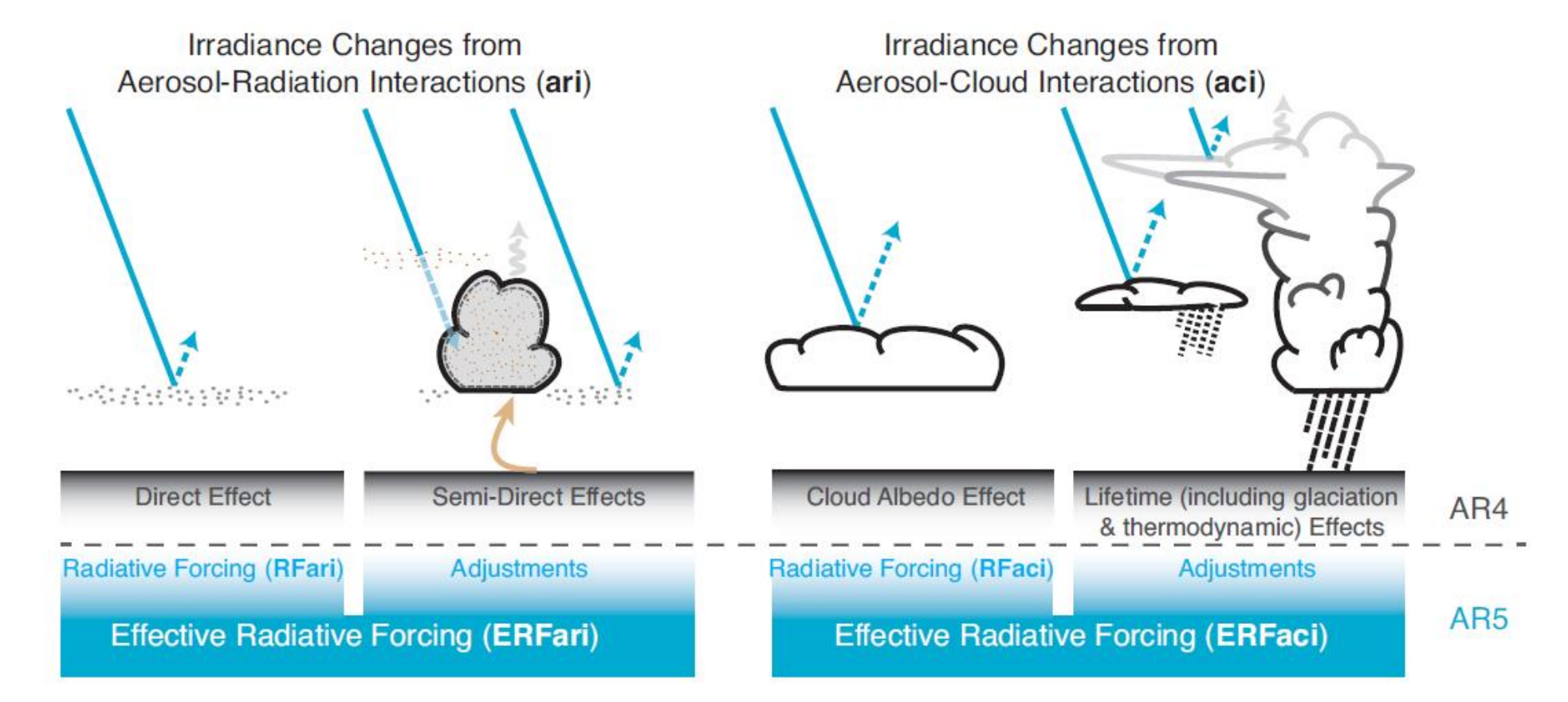
“Trouble in the greenhouse” Nature, Sept., 2000

What is radiative forcing of aerosol?



- Aerosol increases atmospheric scattering and absorption
- Aerosol increases reflection of sunlight to space and reduces sunlight reaching the surface
- Aerosol absorption changes the temperature profile in the atmosphere

Forçante Radiativa Efetiva (terminologia)



Fontes de aerossol

Aerosol Species	Size Distribution	Main Sources	Main Sinks	Tropospheric Lifetime	Key Climate Relevant Properties
Sulphate	Primary: Aitken, accumulation and coarse modes Secondary: Nucleation, Aitken, and accumulation modes	Primary: marine and volcanic emissions. Secondary: oxidation of SO_2 and other S gases from natural and anthropogenic sources	Wet deposition Dry deposition	~ 1 week	Light scattering. Very hygroscopic. Enhances absorption when deposited as a coating on black carbon. Cloud condensation nuclei (CCN) active.
Nitrate	Accumulation and coarse modes	Oxidation of NO_x	Wet deposition Dry deposition	~ 1 week	Light scattering. Hygroscopic. CCN active.
Black carbon	Freshly emitted: <100 nm Aged: accumulation mode	Combustion of fossil fuels, biofuels and biomass	Wet deposition Dry deposition	1 week to 10 days	Large mass absorption efficiency in the shortwave. CCN active when coated. May be ice nuclei (IN) active.
Organic aerosol	POA: Aitken and accumulation modes. SOA: nucleation, Aitken and mostly accumulation modes. Aged OA: accumulation mode	Combustion of fossil fuel, biofuel and biomass. Continental and marine ecosystems. Some anthropogenic and biogenic non-combustion sources	Wet deposition Dry deposition	~ 1 week	Light scattering. Enhances absorption when deposited as a coating on black carbon. CCN active (depending on aging time and size).
... of which brown carbon	Freshly emitted: 100–400 nm Aged: accumulation mode	Combustion of biofuels and biomass. Natural humic-like substances from the biosphere	Wet deposition Dry deposition	~ 1 week	Medium mass absorption efficiency in the UV and visible. Light scattering.
... of which terrestrial PBAP	Mostly coarse mode	Terrestrial ecosystems	Sedimentation Wet deposition Dry deposition	1 day to 1 week depending on size	May be IN active. May form giant CCN
Mineral dust	Coarse and super-coarse modes, with a small accumulation mode	Wind erosion, soil resuspension. Some agricultural practices and industrial activities (cement)	Sedimentation Dry deposition Wet deposition	1 day to 1 week depending on size	IN active. Light scattering and absorption. Greenhouse effect.
Sea spray	Coarse and accumulation modes	Breaking of air bubbles induced e.g., by wave breaking. Wind erosion.	Sedimentation Wet deposition Dry deposition	1 day to 1 week depending on size	Light scattering. Very hygroscopic. CCN active. Can include primary organic compounds in smaller size range
... of which marine POA	Preferentially Aitken and accumulation modes	Emitted with sea spray in biologically active oceanic regions	Sedimentation Wet deposition Dry deposition	~ 1 week	CCN active.

Black Carbon e Brown Carbon

Entre os aerossóis carbonáceos, duas componentes se destacam:

O *"black carbon"* (BC) que consiste em partículas emitidas em processos de combustão em alta temperatura e alta eficiência.

O *"brown carbon"* (BrC) que consiste em partículas emitidas em processos de combustão em baixa temperatura e lenta e geradas em processos químicos atmosféricos.

Black Carbon (BC)

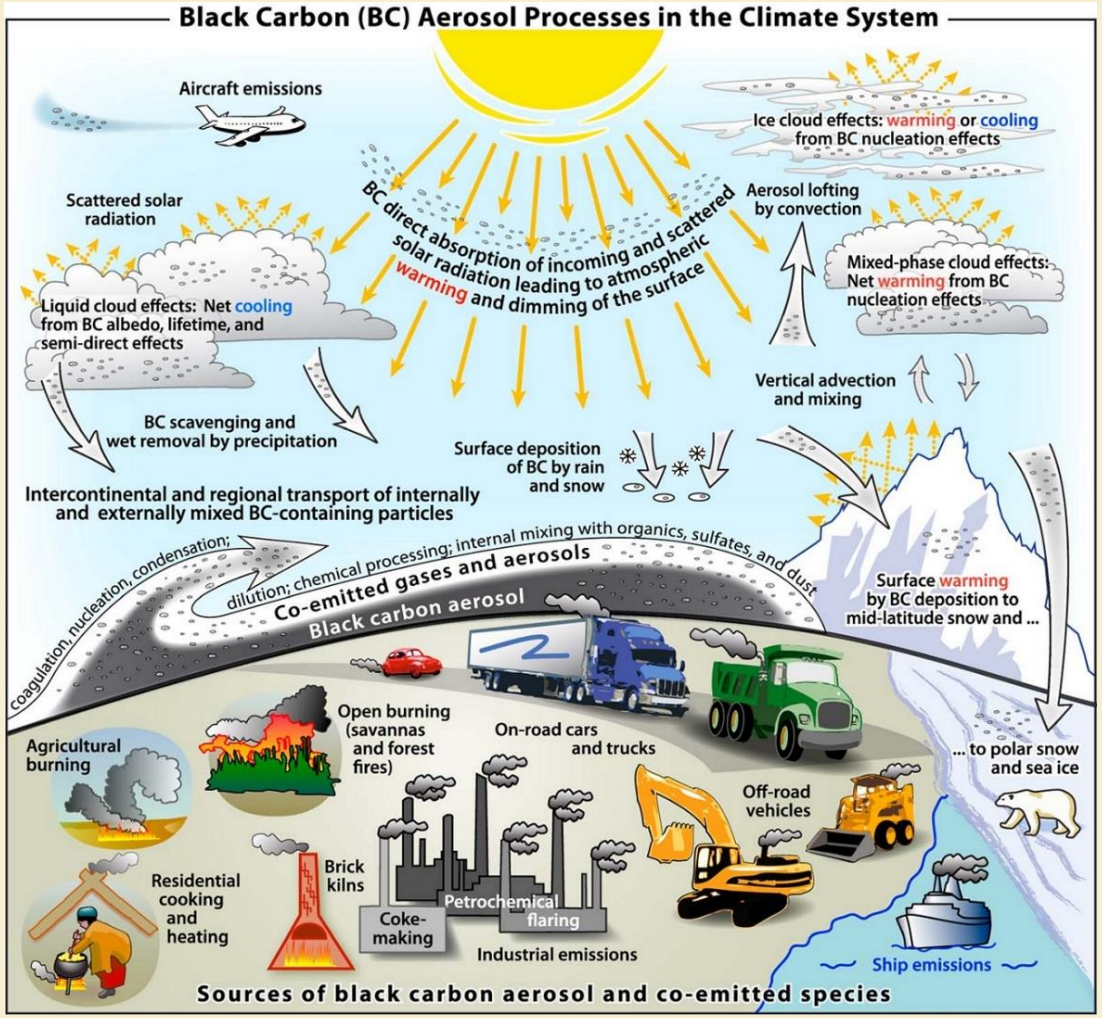
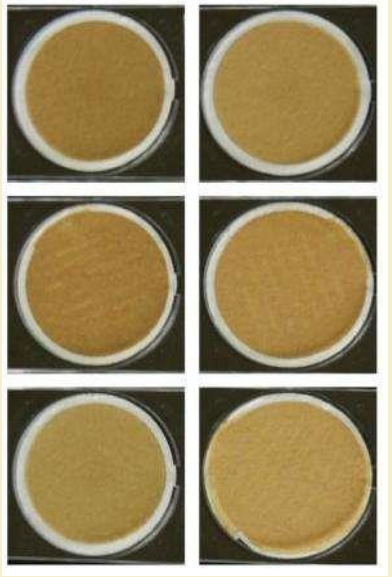


Figura ilustrando a produção transformação e deposição de BC na atmosfera terrestre (Bond et al., 2013). A ilustração mostra o complexo comportamento do BC na atmosfera, com emissões industriais, queimadas, transporte e outras. A deposição em neve é importante na alteração do albedo terrestre. Também é ilustrado seu papel no desenvolvimento de nuvens.

Brown Carbon

- Brown Carbon (BrC), consiste em partículas de carbono orgânico com propriedades de absorção de radiação visível e ultravioleta.
- É conhecido pela sua cor amarronzada clara, absorve fortemente nos comprimentos de onda próximos do ultravioleta.
- Exemplos: Alcatrão produzido por combustão lenta e de baixa temperatura, produtos de degradação a partir da queima de biomassa, misturas de compostos orgânicos emitidos a partir do solo, e compostos orgânicos voláteis emitidos pela vegetação após serem oxidados na atmosfera.



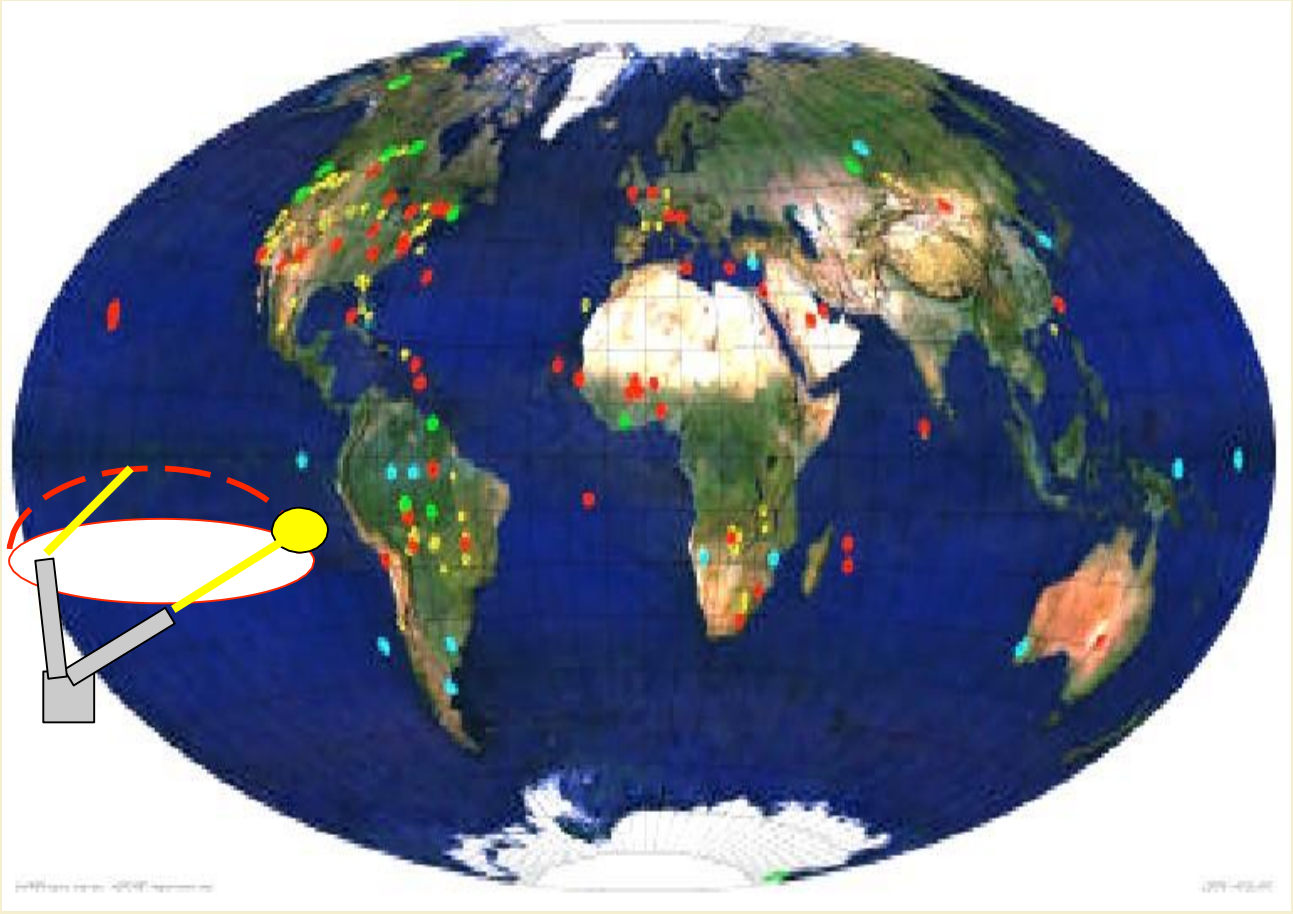
Amostras de BrC obtidas durante o período de 6 horas próximo a uma pira funerária queimando na Índia, **Rajan K. Chakrabarty, 2014.**

Aerosol Robotic NETwork – AERONET

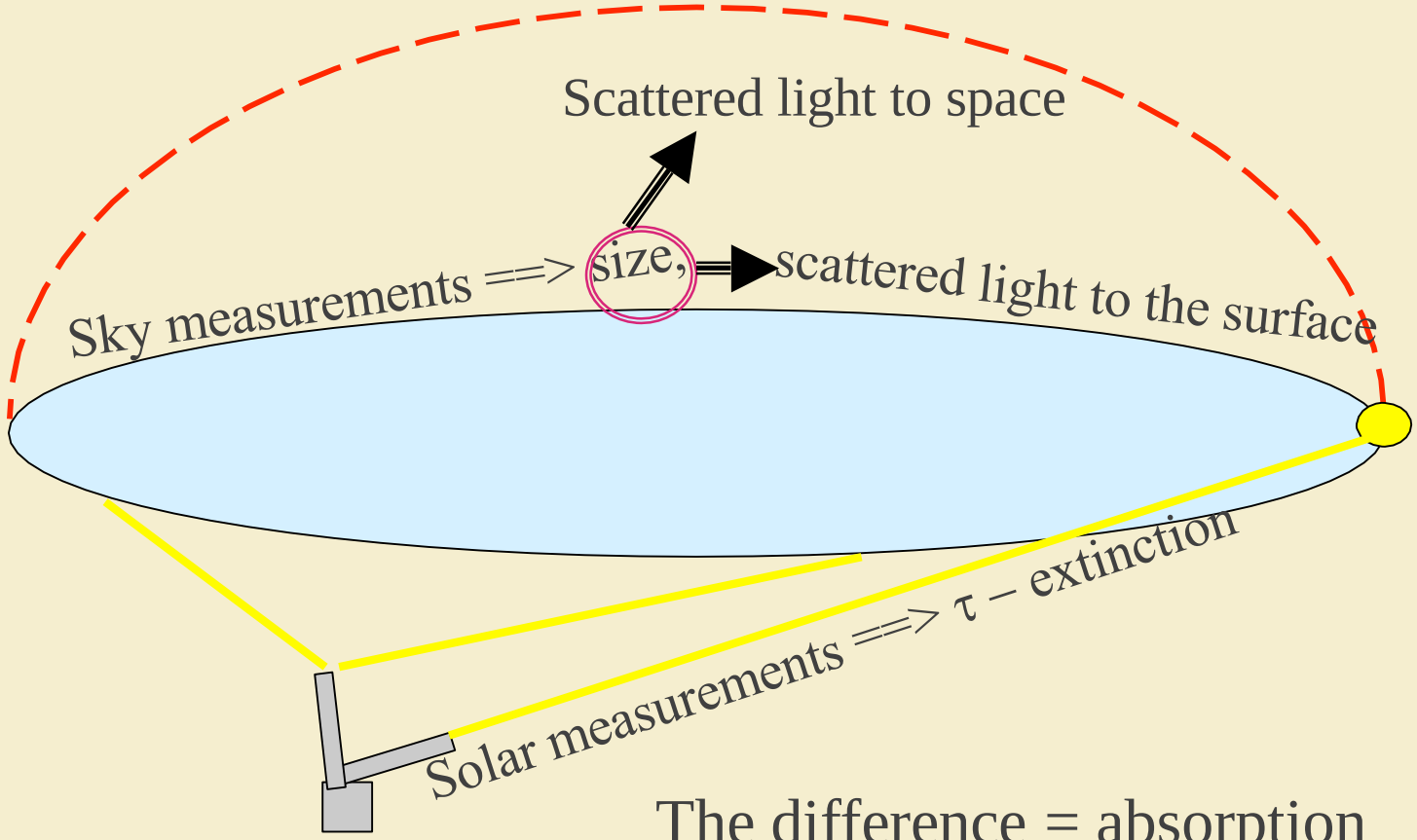
A network of ground based sun/sky radiometers to observe:

Sun: Spectral optical thickness, Total precipitable water vapor

Sky: Aerosol size distribution (0.05 15 μm), Single scattering albedo ($\otimes\omega_o$=±0.04),



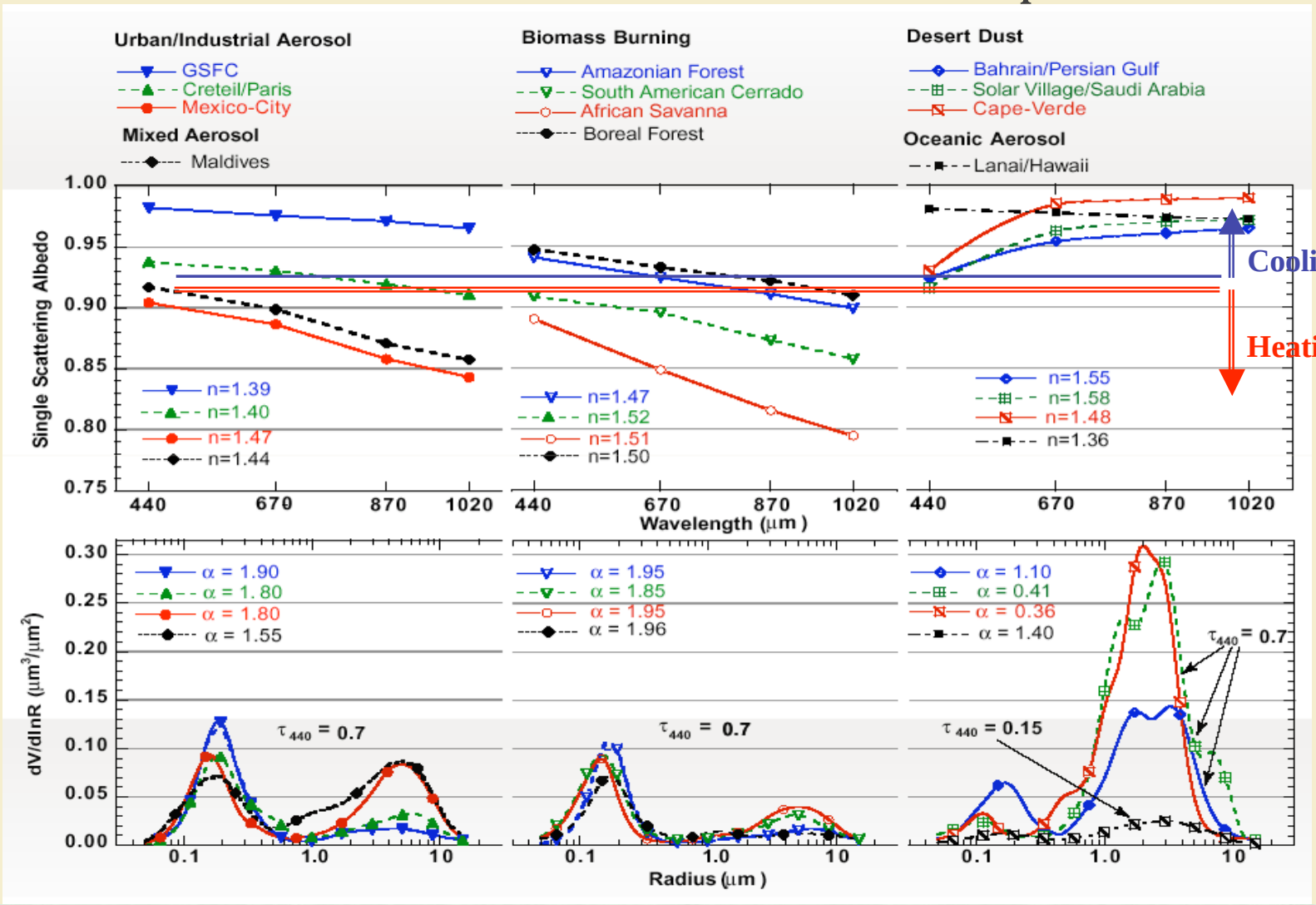
Dust absorption derived from AERONET sky measurements



The difference = absorption

Aerosol climatology from AERONET (Dubovik et al. 2002)

Hundreds - thousands of measurements per site

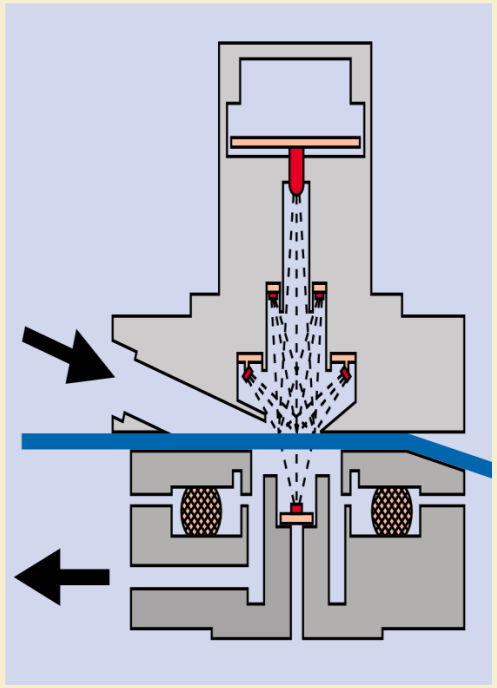


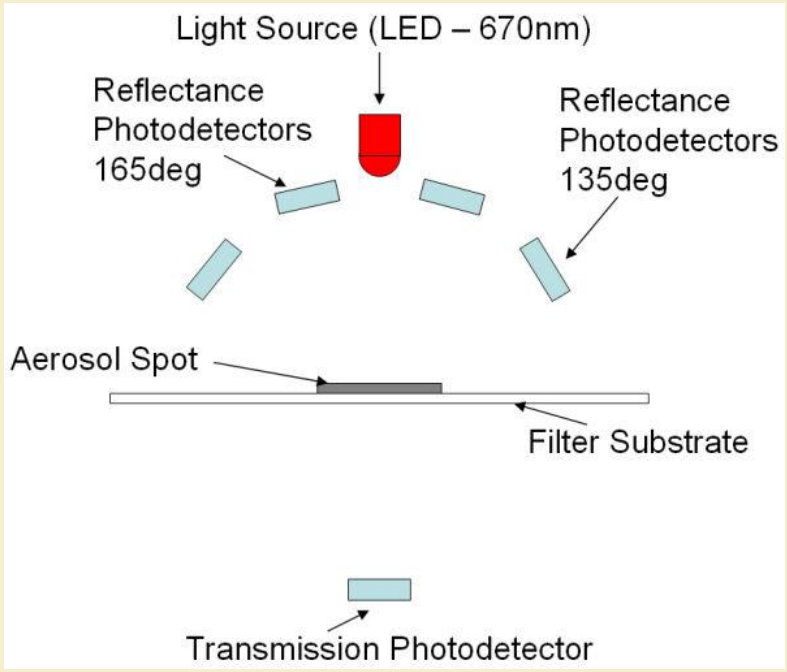
MAAP (Multiangle Aerosol Absorption Photometer)

Instrumento que mede em tempo real a concentração de *black carbon (BC).*

A determinação da concentração de BC é por meio da medida da atenuação de um feixe de luz transmitido através de um filtro de partículas.

O LED do instrumento tem um comprimento de onda de 670nm.





Properties of MAAP:

- Scattering artifacts are reduced.
- Method is based on the solution of a radiative transfer problem.
- Calculation of the absorption coefficient requires a rather complex algorithm (not explained here).
- The MAAP overcomes most problems, which occur for Aethalometer.
- It is less sensitive to particle scattering.
- Excellent agreement with other methods (difference of extinction and scattering)

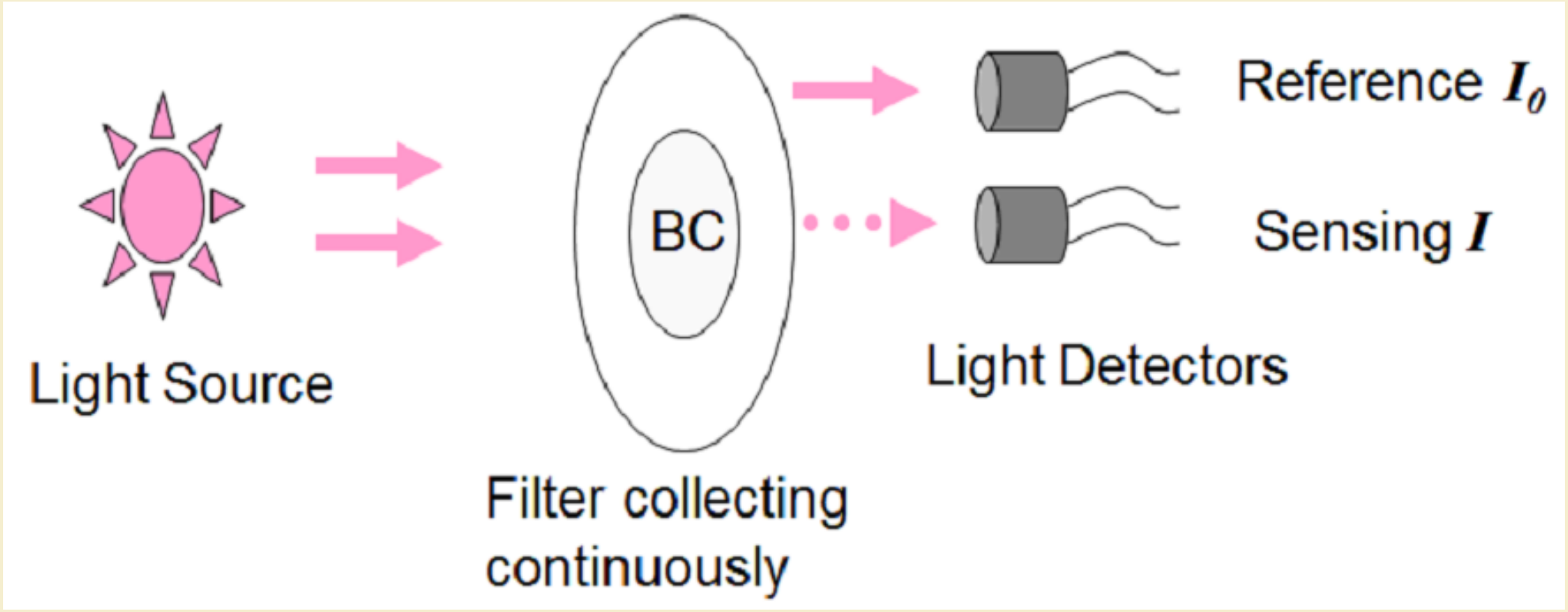
AETALÔMETRO AE33

O Aetalômetro mede a atenuação de um feixe de luz transmitida por um filtro que está continuamente coletando partículas.

O aumento da atenuação óptica de um período para outro é devido ao incremento de BC e BrC coletado pelo fluxo de ar que passa pelo filtro neste período de tempo. Dividindo este incremento de partículas pelo volume de ar amostrado, calcula-se a concentração do BC.

A fonte de luz no modelo AE-33 consiste em LEDs de alta intensidade que emite radiação em sete comprimentos de onda (370nm ~ 950nm).

AETALÔMETRO AE33



Aethalometer

- The Aethalometer of the AE3-series measures the absorption coefficient at 7 wavelengths (0.37, 0.47, 0.52, 0.59, 0.66, 0.88, and 0.95 μm).
- The calibration use an other filter tape.
- Weingartner (2003) e.g. presented a calibration for the Aethalometer.

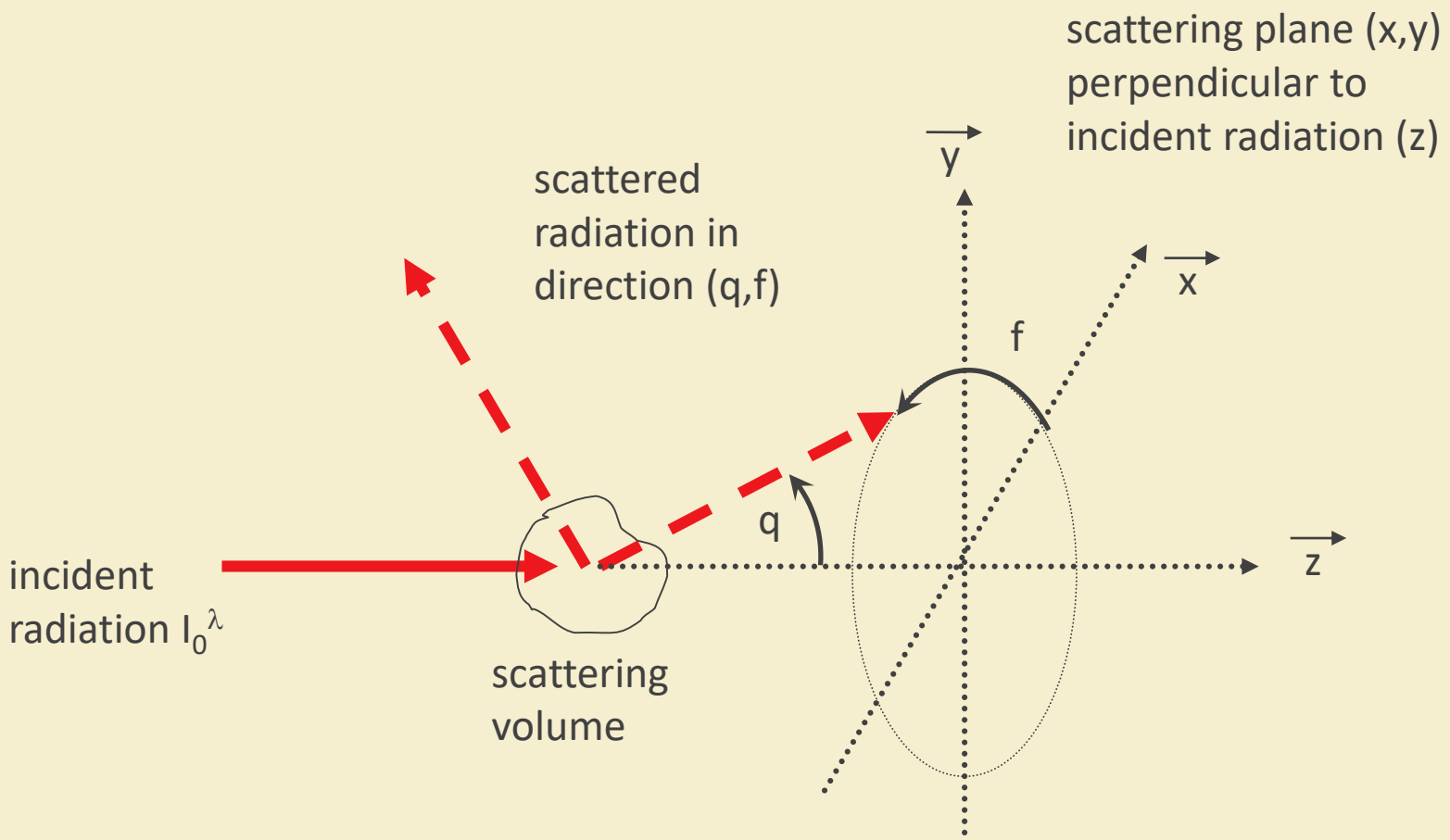
$$\sigma_{abs} \approx \frac{\sigma_{apparent}}{2.14}$$

- The calibration constant depends on the filter loading, the wavelength, and on the type of aerosol.
- There is no established method yet to correct for particle scattering.

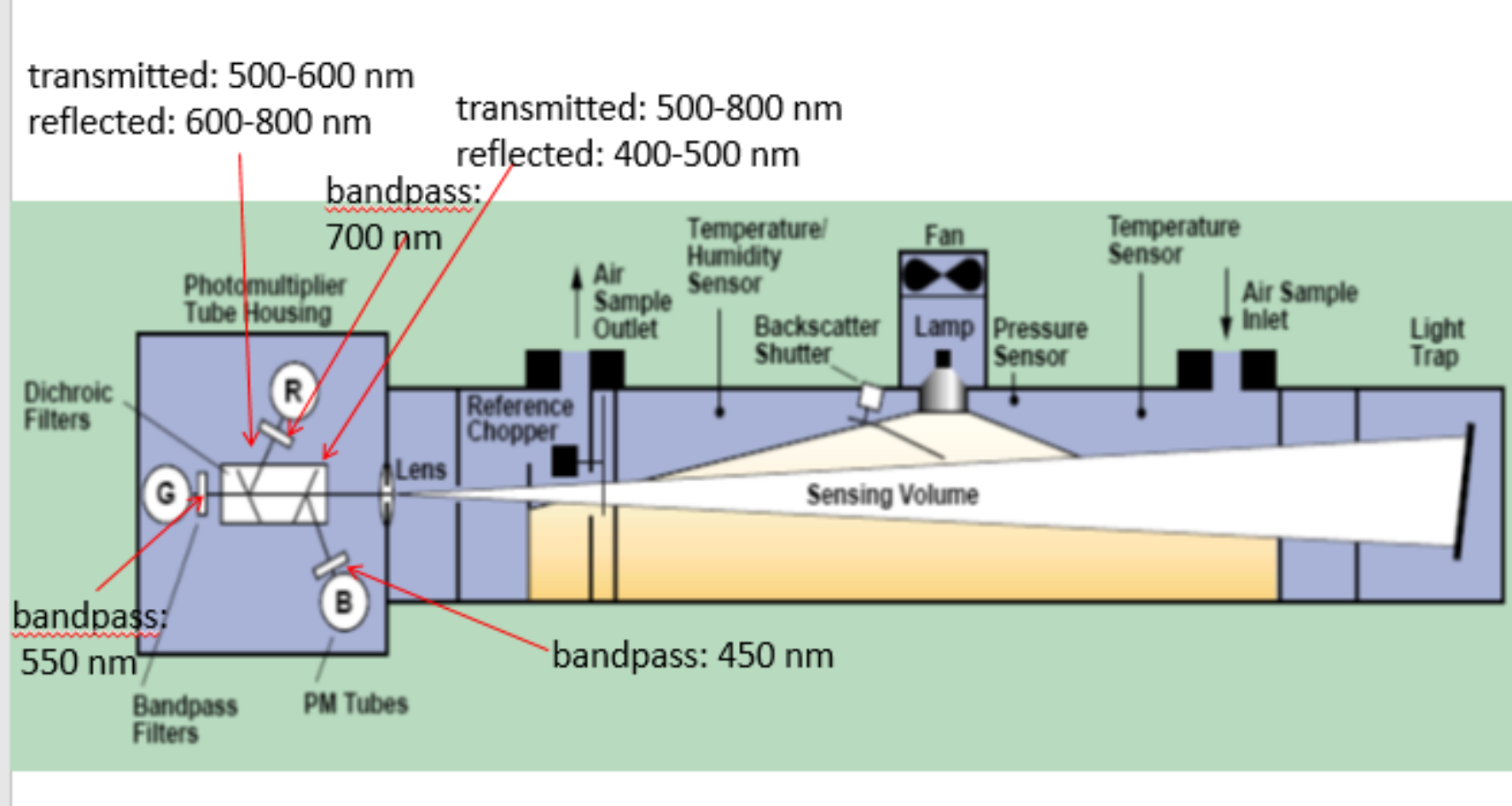
Integrating Nephelometer TSI 3563

- The original application of the instrument was for estimating the horizontal visibility at night for wartime military operations (Beuttel and Brewer, 1949)
- Since that time, numerous other applications of the integrating nephelometer have been found
- Integrating nephelometers produz um sinal que está intimamente relacionado com o coeficiente de espalhamento espectral

Principle Light Scattering



Integrating Nephelometer TSI 3563



Ångström Exponent

Spectral behavior of particle scattering often is described by the Ångström exponent

$$\frac{\sigma_s^{\lambda_1}}{\sigma_s^{\lambda_2}} = \left(\frac{\lambda_1}{\lambda_2}\right)^{-\alpha}$$

The Ångström exponent depends on particle size distribution (aerosol type)

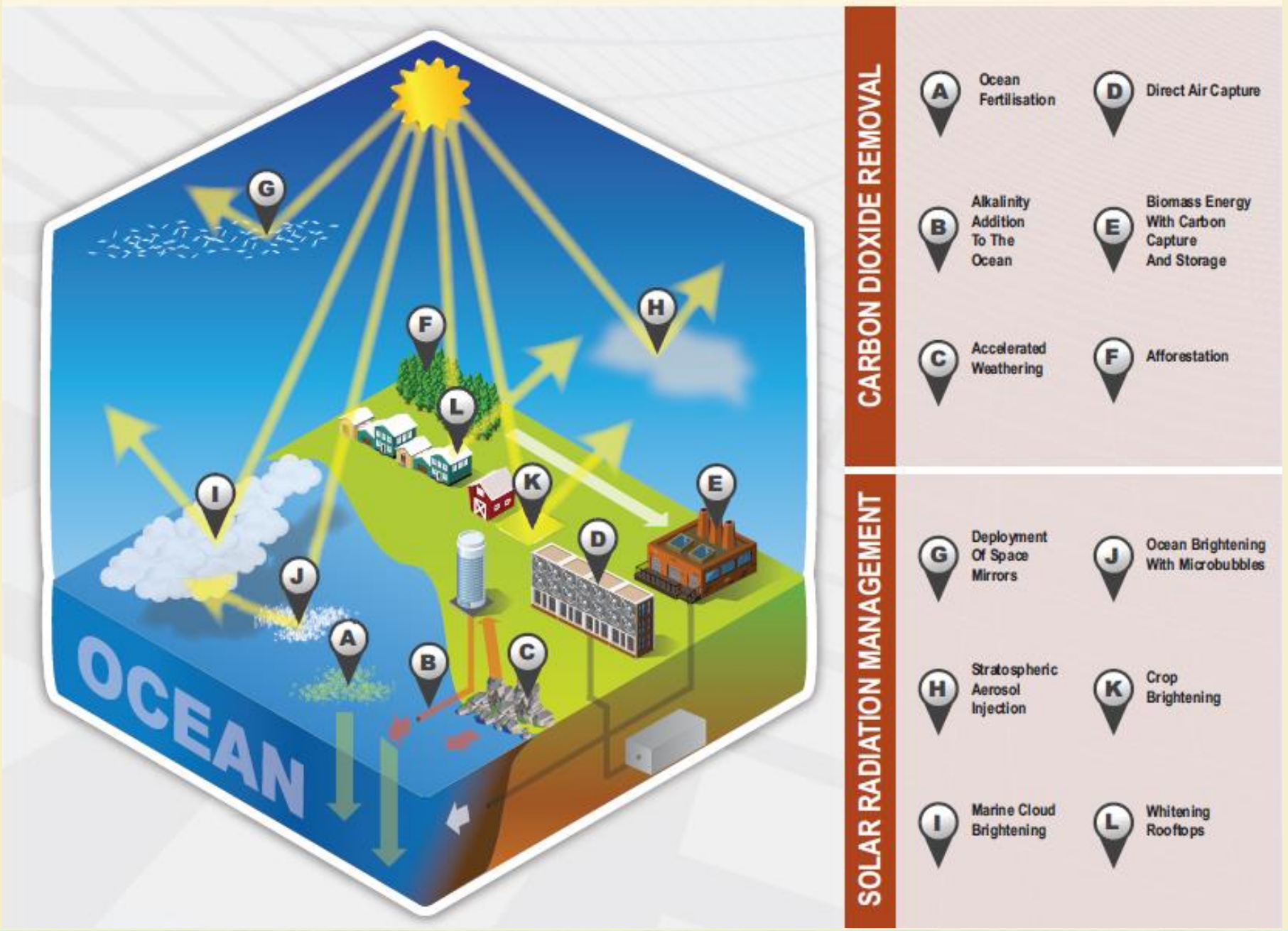
- urban aerosol: $1.5 < \alpha < 2.5$
- rural aerosol: $1.0 < \alpha < 1.5$
- mineral dust : $-0.1 < \alpha < 0.5$
- marine aerosol : $0.2 < \alpha < 0.5$

Geoengenharia

Definido como um amplo conjunto de métodos e tecnologias que visam alterar deliberadamente o sistema climático, a fim de aliviar os impactos das mudanças climáticas.

Remoção do dióxido de carbono

Gerenciamento da Radiação Solar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CARBON DIOXIDE REMOVAL
A Ocean Fertilisation
D Direct Air Capture
B Alkalinity Addition To The Ocean
E Biomass Energy With Carbon Capture And Storage
C Accelerated Weathering
F Afforestation
SOLAR RADIATION MANAGEMENT
G Deployment Of Space Mirrors
J Ocean Brightening With Microbubbles
H Stratospheric Aerosol Injection
K Crop Brightening
I Marine Cloud Brightening
L Whitening Rooftops

Conclusões

1) Como os aerossóis afetam o clima e as mudanças climáticas?

Os aerossóis atmosféricos são compostos de pequenas partículas líquidas ou sólidas suspensas na atmosfera, além de nuvens maiores e partículas de precipitação. Provenientes de fontes naturais e antropogênicas, e podem afetar o clima de formas complexas através de suas interações com radiação e nuvens.

Em geral, modelos e observações indicam que aerossóis antropogênicos exerceram uma influência de resfriamento na Terra desde a era pré-industrial, a qual tem ocultado alguns dos efeitos do aquecimento global de gases de efeito estufa que teriam ocorrido na sua ausência.

A projeção da diminuição das emissões antropogênicas de aerossóis no futuro, em resposta a políticas de qualidade do ar, acabariam por desmascarar esse aquecimento.

Conclusões

2) A Geoengenharia poderia neutralizar as mudanças climáticas?

Os modelos sugerem que o método de Gerenciamento de Radiação Solar é menos efetivo para conter as mudanças climáticas. Além disso, não combate todos os efeitos das mudanças climáticas. Todos os métodos de geoengenharia recomendados também trazem riscos e efeitos colaterais.

Consequências adicionais ainda não podem ser antecipadas, já que o nível de compreensão científica sobre Gerenciamento de radiação solar e Remoção de dióxido de Carbono é baixo. Há também muitas questões (políticas, éticas e práticas) que envolvem a geoengenharia.

3) O relatório do IPCC AR5 tentou mostrar quais são as questões científicas que precisam ser resolvidas para saber como o clima realmente funciona e assim decidir quais as direções assumir em relação as mudanças climáticas.

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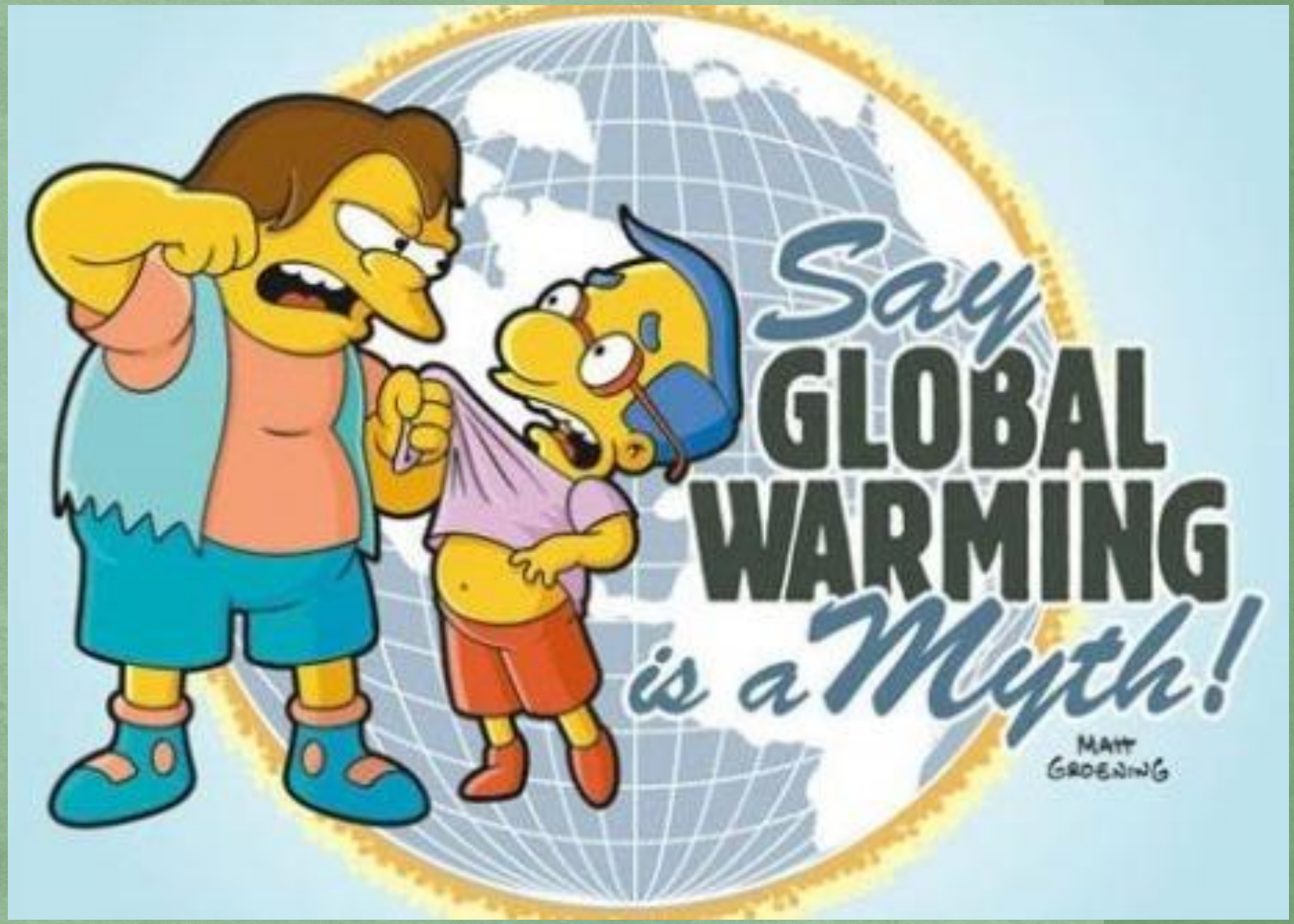
- Kaufman Lectures – Atmospheric aerosol – chemistry, physics and effect on climate



Obrigado pela Atenção